

Toward Strengthening U. S. Academic Accelerator Science  
Request for Information  
August 25, 2015

*Catalog of Responses*

<b>Respondent</b>		<b>Page</b>
<i>DOE Request for Information</i>		2
Phil Burrows	6/5/2015	5
(TIARA report)	6/5/2015	6
Richard Temkin	6/9/2015	68
John Madey	6/11/2015	72
Justin Schwartz	6/12/2015	75
Jean Delayen	6/17/2015	77
Vladimir Shiltsev	6/17/2015	87
Swapan Chattopadhyay	6/18/2015	109
Paul Gueye	6/18/2015	114
Thomas Glasmacher	6/18/2015	119
Sarah Cousineau	6/18/2015	126
Geoff Krafft	6/18/2015	127
Sergei Nagaitzev	6/18/2015	132
Zhirong Huang	6/18/2015	137
Blaine Norum	6/18/2015	145
Stephen Milton	6/18/2015	147
John Fox	6/18/2015	159
Martin Berz	6/18/2015	163
Bob Zwaska	6/18/2015	166
Jay Hirshfield	6/19/2015	168
Ritchie Patterson	6/22/2015	173
Ilan Ben-Zvi	7/17/2015	178
Dave Sutter	8/25/2015	180

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contained in OSD Administrative Instruction 81; 32 CFR part 311; or may be obtained from the system manager.

**RECORD SOURCE CATEGORIES:**

Individual, industrial facilities cleared by the Personnel Security Management Office for Industry (PSMO-I), and DoD Component fingerprint capture devices.

**EXEMPTIONS CLAIMED BY THE SYSTEM:**

None.

[FR Doc. 2015-11606 Filed 5-13-15; 8:45 am]

BILLING CODE 5001-06-P

**DEPARTMENT OF DEFENSE**

**Department of the Navy**

**Extension of Public Comment Period for the Draft Environmental Impact Statement/Overseas Environmental Impact Statement for Commonwealth of the Northern Mariana Islands Joint Military Training**

**AGENCY:** Department of the Navy, Department of Defense.

**ACTION:** Notice.

**SUMMARY:** On April 03, 2015, the Department of Navy (DoN) published a Notice of Availability and Notice of Public Meetings for the Draft Environmental Impact Statement/Overseas Environmental Impact Statement for Commonwealth of the Northern Mariana Islands Joint Military Training (80 FR 18385, April 03, 2015). The purpose of this notice is to announce an extension of the 60-day public comment period. The public comment period will be extended by 60 days to end on August 3, 2015 Eastern Daylight Time (E.D.T.) [August 4, 2015, Chamorro Standard Time (ChST)].

**DATES:** The extended 120-day public comment period for the Draft EIS began on April 3, 2015, EDT [April 04, 2015, ChST] with the publication of the Notice of Availability in the **Federal Register** by the U.S. Environmental Protection Agency, and with this extension, will end on August 3, 2015, EDT [August 4, 2015, ChST]. Mailed comments should be postmarked no later than August 3, 2015, EDT [August 4, 2015, ChST] to ensure they are considered.

**ADDRESSES:** The public may provide comments through the project Web site at [www.CNMIJointMilitaryTrainingEIS.com](http://www.CNMIJointMilitaryTrainingEIS.com), or by mail at: Naval Facilities Engineering Command, Pacific, Attn: 09PA, Public Affairs Office, 258 Makalapa Drive, Suite 100, JBPHH, HI 96860-3134.

The Draft EIS/OEIS was distributed to federal and local agencies, elected officials, and other interested individuals and organizations. The Draft EIS/OEIS is available for public review at [www.CNMIJointMilitaryTrainingEIS.com](http://www.CNMIJointMilitaryTrainingEIS.com), and at the following libraries:

(1) Joeten Kiyu Public Library, Saipan; (2) Northern Marianas College Olympio T. Borja Memorial Library, Saipan; (3) Tinian Public Library, Tinian; (4) Antonio C. Atalig Memorial Rota Public Library, Rota; (5) University of Guam Robert F. Kennedy Memorial Library, Guam; (6) Nieves M. Flores Memorial Library, Guam.

**SUPPLEMENTARY INFORMATION:** The DoN's proposed action is to establish live-fire Range Training Areas (RTAs) within the CNMI to address the U.S. Pacific Command Service Components' unfilled unit level and combined level training requirements in the Western Pacific. The DoN recognizes that public comments are an essential part of the National Environmental Policy Act (NEPA) process. Accordingly, the DoN established a 60-day public comment period in lieu of the minimum 45-day period required by NEPA implementing regulations. In response to requests by CNMI officials, Federal resource agencies, and the public, the DoN has extended the Draft EIS 60-day public comment period by a heretofore additional 60 days to August 3, 2015, EDT [August 4, 2015, ChST].

**FOR FURTHER INFORMATION CONTACT:** CNMI Joint Military Training EIS/OEIS Project Manager by email via the project Web site ([www.CNMIJointMilitaryTrainingEIS.com](http://www.CNMIJointMilitaryTrainingEIS.com)).

Dated: May 11, 2015.

**N.A. Hagerty-Ford**

*Commander, Judge Advocate General's Corps, U.S. Navy, Federal Register Liaison Officer.*

[FR Doc. 2015-11674 Filed 5-13-15; 8:45 am]

BILLING CODE 3810-FF-P

**DEPARTMENT OF ENERGY**

**Strengthening U.S. Academic Programs in Accelerator Science**

**AGENCY:** Office of High Energy Physics, Department of Energy.

**ACTION:** Notice of request for information (RFI).

**SUMMARY:** The Office of High Energy Physics (HEP), as the Department of Energy's (DOE or Department) lead office for long-term accelerator research and development (R&D), invites interested parties to provide comments on proposed policies, practices and mechanisms which DOE-HEP may

implement to foster robust academic R&D and workforce development in this vitally important high technology area.

**DATES:** Written comments and information are requested on or before June 18, 2015.

**ADDRESSES:** Interested persons may submit comments only by email. Comments must be addressed to [AcademicAcceleratorScienceRFI@science.doe.gov](mailto:AcademicAcceleratorScienceRFI@science.doe.gov), with the subject line "Academic Accelerator Science RFI Comments".

**FOR FURTHER INFORMATION CONTACT:** Dr. Bruce P. Strauss, (301) 903-3705, [AcademicAcceleratorScienceRFI@science.doe.gov](mailto:AcademicAcceleratorScienceRFI@science.doe.gov).

**SUPPLEMENTARY INFORMATION:**

**The Challenge**

Accelerators play a key role in the discovery sciences, including High Energy Physics, Nuclear Physics, and Basic Energy Sciences. Modern discovery science accelerators are high technology instruments of remarkable complexity, having advanced over eight orders of magnitude in energy since their invention. Aggressive reinvention of the underlying technology has driven improvements in this science, and has required sustained investment in accelerator science R&D that advances the methods, materials, and understanding of accelerator science.

Accelerator Science is an interdisciplinary field that encompasses the design and improvement of particle accelerators, the development of new methods of charged particle production and manipulation, and the development of unique supporting technologies needed for accelerators. Significant career specialization has evolved as the demand for ever greater performance has required reaching deep into mathematics, computation, materials science, plasma science, radio frequency technology, superconducting materials, laser engineering, and a variety of other disciplines. The accelerator science workforce must be capable of spanning both the breadth and depth of the subject matter needed to build discovery science accelerators. It must also possess the range of skills and proficiency levels needed to support operating accelerators for science, medicine, industry, security, defense, and energy & environmental applications.

National laboratories, academia, and industry each play vital, mutually reinforcing roles in the success of the accelerator-based discovery sciences, and in providing the scientific and technological advances necessary to sustain U.S. leadership in this area.

With an estimated 30,000 particle accelerators operating worldwide, there is a significant—and growing—need<sup>1</sup> for a technically competent workforce that can design, install, operate, upgrade, and repair accelerators.

A High Energy Physics Advisory Panel subcommittee, in 2014, identified the present deficit in the accelerator science workforce as an area of special concern, both for its impact on the Office of Science mission, and for its broader consequences.<sup>2,3</sup> Approximately 10–12 accelerator science Ph.D.s graduate each year in the U.S., nearly an order of magnitude less than Europe. This is traceable to the small number of U.S. universities that have accelerator faculty and offer instruction in accelerator science.

### The Response

The Department, acting through the Office of High Energy Physics in the Office of Science, is considering funding practices and mechanisms which DOE–HEP could implement to help ensure continued world-class accelerator R&D and the training of a world-class accelerator workforce.

*Request for information:* The objective of this RFI is to gather information about the current state of academic practice and policy surrounding accelerator science (as defined above), and to elucidate potential mechanisms to strengthen academic programs in accelerator science at U.S. institutions of higher education. Please note that this is not a request for information about specific scientific research topics. Submissions arguing the merits of specific lines of scientific research will be disregarded as unresponsive.

The questions below are intended to assist in the formulation of comments, and should not be considered as a limitation on either the number or the issues that may be addressed in such comments. The Department will make all comments available to the general public.

The DOE Office of High Energy Physics is specifically interested in receiving comments pertaining to any of the following questions:

<sup>1</sup> “Accelerators for America’s Future”, workshop report, <http://science.energy.gov/~media/hep/pdf/accelerator-rd-stewardship/Report.pdf>, (2009).

<sup>2</sup> “OHEP Workforce Development”, Report presented to HEPAP May 22, 2014, [http://science.energy.gov/~media/hep/hepap/pdf/May%202014/Patterson\\_HEPAP\\_DOEWorkforce\\_v1-1.pdf](http://science.energy.gov/~media/hep/hepap/pdf/May%202014/Patterson_HEPAP_DOEWorkforce_v1-1.pdf).

<sup>3</sup> “HEP Workforce Development Needs”, report of the HEPAP subcommittee, June 30, 2014, [http://science.energy.gov/~media/hep/hepap/pdf/Reports/OHEP\\_Workforce\\_Letter\\_Report.pdf](http://science.energy.gov/~media/hep/hepap/pdf/Reports/OHEP_Workforce_Letter_Report.pdf).

### Increasing the Recognition of Accelerator Science in Academia

1. Does your institution regard accelerator science as an academic discipline? Why or why not?
2. If your institution offers graduate training in accelerator science:
  - a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)
  - b. How often do students change fields to study accelerator science? From which fields do these students typically come?
  - c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments?
  - d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?
  - e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?
  - f. How often do collaborations occur between accelerator science and other programs at the university?
  - g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program?
3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?
4. What funding sources for accelerator science are you aware of?

### Integrating the Roles of the Universities and the U.S. National Laboratories

5. How can the national laboratory system be best utilized by the university accelerator science community?
6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?
7. Does your university accept accelerator course credits from other institutions?
8. Do accelerator science students at your institution routinely take courses and training elsewhere?
9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?
10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with

national laboratories? Could these mechanisms be extended to accelerator science?

### Contemporary Models of University Accelerator Science

11. What examples exist of thriving academic accelerator science programs?
  - a. Are there policies at your university specific to the accelerator science program that are essential to its success?
  - b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?
  - c. Are there barriers to having accelerator scientists serve as PI or Co-PI on proposals?
  - d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded?
  - e. Are there specific attributes of the institution’s culture that contribute to the success of the accelerator science program?
  - f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?
12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)–(f) above).
13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)–(f) above).

### Possible Mechanisms To Encourage Academic Accelerator Science

14. What specific, cost-effective actions could be taken to:
  - a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.
  - b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.
  - c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master’s degree, or grants to develop instructional materials.

d. Increase the enrollment in education opportunities at the baccalaureate and master's level?

e. Increase the availability of hands-on training opportunities in accelerator technology?

#### Other Factors

15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?

16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?

This RFI is issued to gather information that may be used to help formulate DOE-HEP funding practices and grant mechanisms to strengthen academic accelerator science.

Issued in Washington, DC, on April 30, 2015.

**James Siegrist,**

*Associate Director, Office of High Energy Physics.*

[FR Doc. 2015-11664 Filed 5-13-15; 8:45 am]

BILLING CODE 6450-01-P

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## DEPARTMENT OF ENERGY

### Office of Energy Efficiency & Renewable Energy

[Docket Number EERE-2015-BT-BC-0001]

#### Request for Information: Updating and Improving the DOE Methodology for Assessing the Cost-Effectiveness of Building Energy Codes

**AGENCY:** Office of Energy Efficiency and Renewable Energy, Department of Energy.

**ACTION:** Extension of public comment period.

**SUMMARY:** This notice announces an extension of the time period for submitting comments on the request for information on the DOE Methodology for Assessing the Cost-effectiveness of Building Energy Codes, which was originally published in the **Federal Register** on April 14, 2015 (80 FR 19974). The comment period is extended to June 3, 2015.

**DATES:** Comments on the RFI must be received no later than June 3, 2015.

**ADDRESSES:** *Instructions:* Comments must identify the docket number EERE-2015-BT-BC-0001 and may be submitted using any of the following methods:

1. *Regulations.gov:* <http://www.regulations.gov/>

*#!docketDetail;D=EERE-2015-BT-BC-0001.* Follow the instructions for submitting comments.

2. *Email:*

*BCMMethodology2015BC0001@ee.doe.gov.* Include docket number EERE-2015-BT-BC-0001 in the subject line of the message.

3. *Postal Mail:* Ms. Brenda Edwards; U.S. Department of Energy, Building Technologies Office EE-5B, 1000 Independence Avenue SW., Washington, DC 20585; Phone: (202) 586-2945. Please submit one signed paper original.

Further instructions, including the use of topic identifiers, are provided in the original notice. Comments submitted in response to the notice will become a matter of public records and will be made publicly available.

*Public Docket:* The docket, which includes notices published in the **Federal Register** and public comments received, is available for review at [Regulations.gov](http://www.regulations.gov). All documents in the docket are listed in the [Regulations.gov](http://www.regulations.gov) index. However, some documents listed in the index, such as those containing information exempt from public disclosure, may not be publicly available. A link to the docket Web page can be found under Public Participation at: <http://www.energycodes.gov/events>. This Web page will also contain a link to the docket for this notice on [Regulations.gov](http://www.regulations.gov). The [Regulations.gov](http://www.regulations.gov) site will contain instructions on how to access all documents, including public comments, in the docket.

For further information on how to submit a comment, review comments received, or otherwise participate in the public comment process, contact Ms. Brenda Edwards by phone at (202) 586-2945 or email: [Brenda.Edwards@ee.doe.gov](mailto:Brenda.Edwards@ee.doe.gov).

**FOR FURTHER INFORMATION CONTACT:** Mr. Jeremiah Williams; U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office EE-5B, 1000 Independence Avenue SW., Washington, DC 20585; Phone: (202) 287-1941, Email: [jeremiah.williams@ee.doe.gov](mailto:jeremiah.williams@ee.doe.gov).

For legal matters, contact: Kavita Vaidyanathan; U.S. Department of Energy, Office of the General Counsel, Forrestal Building, Mailstop GC-33, 1000 Independence Ave SW., Washington, DC 20585; Phone: (202) 586-0669, Email: [kavita.vaidyanathan@hq.doe.gov](mailto:kavita.vaidyanathan@hq.doe.gov).

**SUPPLEMENTARY INFORMATION:** On April 14, 2015, the U.S. Department of Energy (DOE or the Department) published a

request for information (RFI) in the **Federal Register** (80 FR 19974) to request information on how the Department may update and improve the methodology it intends to use for assessing cost effectiveness (which includes an energy savings assessment) of building energy codes. The RFI provided for the submission of comments by May 14, 2015. One commenter requested an extension of the comment period in order to sufficiently study and understand the proposed changes and their impacts. It was also noted that many interested stakeholders might also be participating in code development hearings held by the International Code Council (ICC) through April 30th. DOE has concluded that an extension of the comment period is warranted based on the timing of the ICC code development hearings, and is hereby extending the public comment period through June 3, 2015.

Issued in Washington, DC, on May 8, 2015.

**Roland Risser,**

*Director, Building Technologies Office, Energy Efficiency and Renewable Energy.*

[FR Doc. 2015-11662 Filed 5-13-15; 8:45 am]

BILLING CODE 6450-01-P

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## DEPARTMENT OF ENERGY

### Federal Energy Regulatory Commission

[Docket No. CP15-272-000]

#### Regency Field Services, LLC; Notice of Application

Take notice that on April 27, 2015, Regency Field Services, LLC (RFS), 2001 Bryan St., Suite 3700, Dallas, Texas 75201, filed with the Federal Energy Regulatory Commission (Commission) an application pursuant to section 7(c) of the Natural Gas Act (NGA) and Part 157 of the Commission's regulations requesting: (i) A certificate of public convenience and necessity authorizing RFS to own, operate and maintain its 8 mile 20-inch diameter Coyanosa Residue Line, located in Pecos County, Texas, for the purpose of transporting its own natural gas; (ii) a blanket certificate, pursuant to Part 157, Subpart F, of the Commission's regulations; (iii) waivers of certain regulatory requirements; and (iv) confirmation that the Commission's assertion of jurisdiction over the Coyanosa Residue Line will not jeopardize the non-jurisdictional status of RFS's otherwise non-jurisdictional gathering and processing facilities and operations, all as more fully set forth in the application which is on file with the Commission

## Colby, Eric

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**From:** Philip Burrows <Philip.Burrows@physics.ox.ac.uk>  
**Sent:** Friday, June 05, 2015 4:28 AM  
**To:** Strauss, Bruce  
**Cc:** Ritchie Patterson  
**Subject:** data on accelerator PhDs in Europe  
**Attachments:** TIARA-REP-WP5-2012-006.pdf

Hi Bruce,

Andrei forwarded to me a query from you concerning numbers of PhDs in accelerator science in Europe. Apologies for attaching a long report, but I led a major study on accelerator training in Europe (TIARA, WP5) and we worked quite hard over 4 years to collect a load of data that is summarised in several reports. I can send you the others if you're interested.

The quick answer to your question can be found in figure 4.1 of report 2012-006: the 2011 snapshot shows about 200 PhDs receiving formal training in accelerator science in the countries surveyed (this will be a small underestimate as not ALL countries in Europe participated, but it's probably >95% of the true total students).

Now, what does this 200 mean?!

Dividing by 3 or 4 years, the typical length of a European PhD, gets you a lower limit of 50-70 per year on average. However, most people do formal training only during the first 1-2 years of the PhD. So if you say the 200 number represents 2 year-cohorts of students, you get about 100 per year, which I'd take as sensible estimate.

So:  
Minimum bound: 50 per year.  
Absolute upper limit: 200 per year  
Best estimate: 100 per year.

Feel free to reference the above report, and don't hesitate to get in touch if I can help further. I did field similar questions last year from Ritchie Patterson, whom I copy also for information.

Best wishes,  
Phil



Test Infrastructure and Accelerator Research Area

## Status Report

# Education and Training Survey Report

Kircher, F. (CEA, France) *et al*

23 April 2012

The research leading to these results has received funding from the European Commission under the FP7-INFRASTRUCTURES-2010-1/INFRA-2010-2.2.11 project TIARA (CNI-PP). Grant agreement no 261905.

This work is part of TIARA Work Package **5: Education and Training**.

The electronic version of this TIARA Publication is available via the *TIARA web site* at <http://www.eu-tiara.eu/database> or on the *CERN Document Server* at the following URL: <http://cdsweb.cern.ch/search?p=TIARA-REP-WP5-2012-006>



## Test Infrastructure and Accelerator Research Area

# TIARA WP5 Deliverable 5.1 - ETR Education and Training Survey Report

25 June 2012

*François Kircher, Phu-Anh-Phi Nghiem, CEA, France*

*Roger Bailey, Louis Rinolfi, CERN, Switzerland*

*M. Luisa Marco Arboli (WP Deputy), Susana Falcon, Diego Obradors, CIEMAT, Spain*

*Catherine Clerc, Alex C. Mueller (WP Deputy), CNRS/IN2P3/LLR, France*

*Leonid Rivkin, EPFL, Switzerland*

*Sabrina Appel, Oliver Boine-Frankenheim, GSI, Germany*

*Francesca Galluccio, Vittorio Vaccaro, INFN-Napoli, Italy*

*Piotr Malecki, Institute of Nuclear Physics, Polish Academy of Sciences, Poland*

*Søren Pape Møller, ISA, Aarhus University, Denmark*

*Philip Burrows (WP leader), Max Bradbury, John Adams Institute, University of Oxford,  
United Kingdom*

*Pauli Heikkinen, University of Jyväskylä, Finland*

*Ole Petter Nordahl, Steinar Stapnes, University of Oslo, Norway*

The research leading to these results has received funding from the European Commission under the FP7-INFRASTRUCTURES-2010-1/INFRA-2010-2.2.11 project TIARA (CNI-PP). Grant agreement no 261905.

# Content

EXECUTIVE SUMMARY	3
1. INTRODUCTION	4
2. INSTITUTES AND PERSONNEL	5
3. INSTITUTES' PROVISION OF TRAINING	7
4. TRAINEE NUMBERS	9
5. FORMAL TRAINING TIME	14
6. TRAINING SUBJECTS	19
7. ACCELERATOR SCHOOLS AND THE CERN DOCTORAL STUDENT PROGRAMME	22
8. TRAINING MATERIALS AND USE OF FACILITIES	25
9. CAREER DESTINATIONS	28
10. SUMMARY OF MAIN FINDINGS	30
11. OUTLOOK	31
<i>APPENDIX 1: RESPONDING INSTITUTES AND CONTACT PERSONS</i>	32
<i>APPENDIX 2: SURVEY</i>	36
<i>APPENDIX 3: COUNTRY-SPECIFIC ANALYSIS</i>	40
<i>APPENDIX 4: CAS STATISTICS</i>	54
<i>APPENDIX 5: JUAS STATISTICS</i>	57
<i>APPENDIX 6: NATIONAL AND INTERNATIONAL FACILITIES</i>	59



## EXECUTIVE SUMMARY

- 88 institutes from Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland and the United Kingdom completed the TIARA survey on education and training in accelerator science. A total of 3060 personnel at these institutes are engaged in accelerator science activities.
- 75 institutes (85%) provide training of some kind in some aspects of accelerator science to their own students or staff. 195 personnel are involved in providing training. 49% of institutes provide training to undergraduates, 64% to master's students, 70% to PhD students; 44% to postdoctoral fellows, and 24% to staff.
- 83 institutes (94%) send people for training to accelerator schools and workshops, and 30 institutes (34%) have staff members who provide training at the schools and workshops.
- 1371 people per annum currently receive training, which comprises: 34% undergraduates, 26% master's students, 14% PhD students, 7% postdoctoral fellows and 17% staff.
- 55 institutes reported the number of formal training hours provided per annum. Currently a total of 62,777 training hours per annum are given: 46% to master's students, 27% to undergraduates, 13% to PhD students, 10% to staff and 3% to postdoctoral fellows.
- Accelerator science typically represents a small fraction (below 30%) of total formal training time for undergraduate, master's and PhD students, and typically a larger fraction for postdoctoral fellows and staff. There are only a handful of dedicated full-time formal training programmes in accelerator science.
- The majority of trainees receive training in five main areas: particle sources, accelerating structures, magnets, beam dynamics, instrumentation and controls. More than 50% of institutes offer training in one or more of these areas.
- 53% of institutes that provide formal training to undergraduates offer examinations on accelerator science coursework; the corresponding figure for master's students is 55%, and for PhD students it is 45%.
- 35% of institutes that train undergraduates participate in ECTS; the corresponding figure for master's students is 46%.
- More than 339 people each year receive training by attending international and/or national accelerator schools. The most attended international schools are the CERN Accelerator Schools (CAS), the Joint Universities Accelerator School (JUAS), the U.S. particle accelerator Schools (USPAS) and the Linear Collider School.
- For the available dataset, although a majority of each category of trainee goes on to pursue work in the academic/research sector, 28% of the undergraduates, 31% of the master's students, 34% of the PhD students, and 38% of the postdoctoral fellows go on to find employment in the manufacturing, medical, financial and services sectors.

# 1. INTRODUCTION

A survey of the provision of training in accelerator science was performed between September 2011 and January 2012. Approximately 100 institutes were contacted in the TIARA member states: Denmark, Finland, France, Germany, Italy, Norway, Poland, Spain, Sweden, Switzerland and the United Kingdom. In addition to those from the TIARA member states responses were received from several institutes in Greece and the Netherlands. A total of 88 institutes provided data for the survey; the institutes and respective contact-persons are listed in Appendix 1.

A web-based survey was conducted. A representative of each institute contacted was requested to provide responses to straightforward questions concerning training in accelerator science at her/his institute. Information was requested about the institute and its staff, whether training is provided, and if so the type of training and the recipients of the training. A text version of the survey is given in Appendix 2.

In each country the survey was targeted primarily at those institutes known to be engaged in accelerator science activities, but an attempt was made also to advertise the survey more widely so as to allow the potential for capturing a more complete picture. Given the very high response rate, and the fact that in each country essentially all institutes known to be engaged in accelerator science responded, we believe that we have captured a comprehensive and almost ‘complete’ dataset on education and training in accelerator science among the countries surveyed.

## 2. INSTITUTES AND PERSONNEL

The number of personnel (defined as physicists and engineers) engaged in accelerator science activities, summed over the responding institutes, is shown by country in Figure 2.1. Several countries have large national accelerator-related laboratories, most notably France, Germany and Switzerland (which, for these purposes is defined to include CERN). A total of 3060 personnel are engaged in accelerator science activities, of which 195 are involved in providing training.

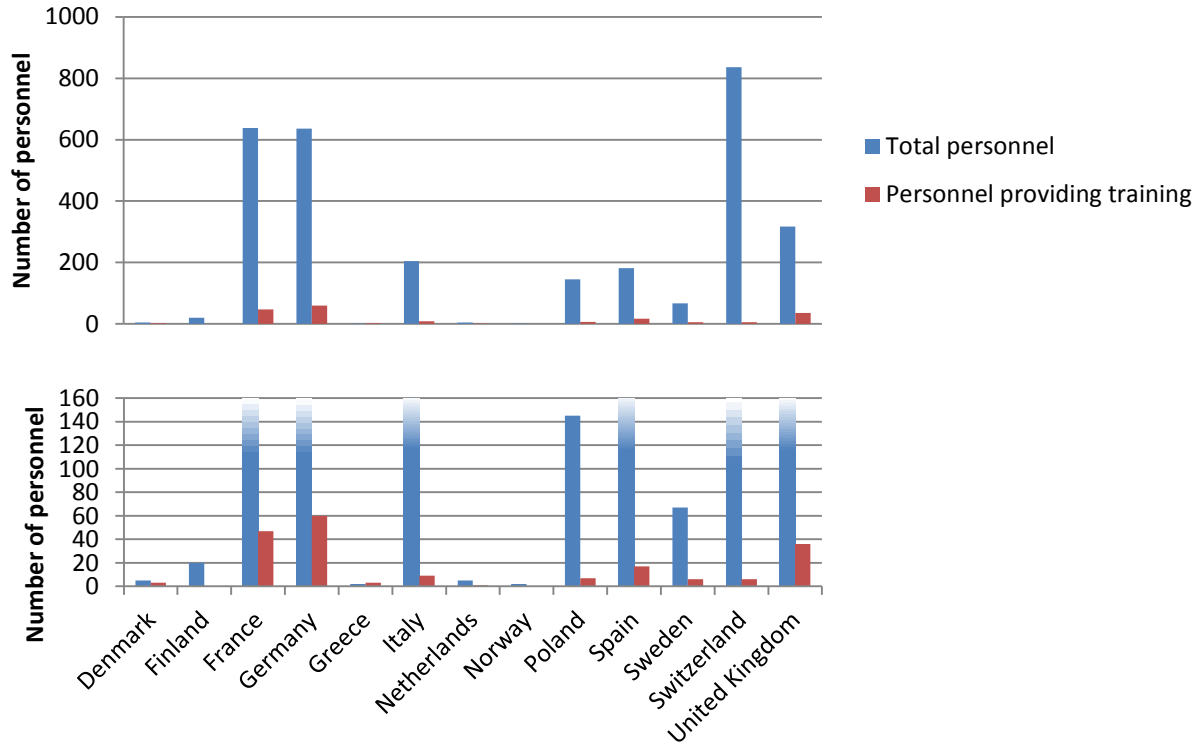


Figure 2.1: Top: total number (blue) of personnel (physicists and engineers) engaged in accelerator science activities by country. For each country the number of personnel engaged in training in accelerator science is also shown (red). Bottom: a ‘zoom’ into the region below 160 personnel per country.

The distribution of the number of accelerator science personnel per institute is shown in Figure 2.2. A typical institute has fewer than 20 such personnel, but the number of personnel ranges from a handful (typically universities) to several hundred (the large national/international laboratories).

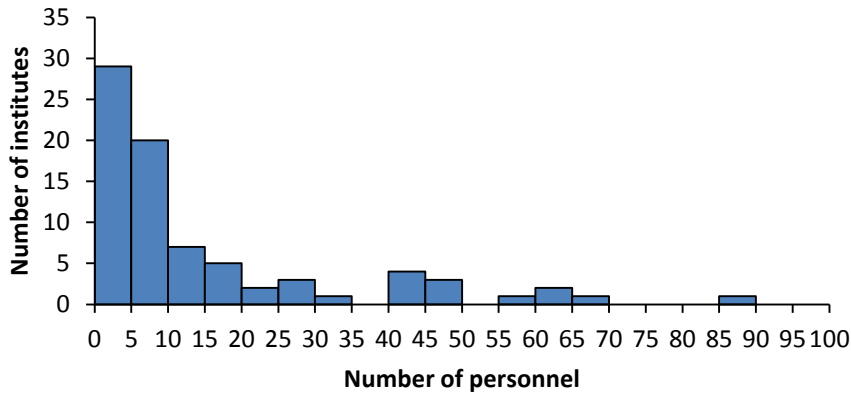
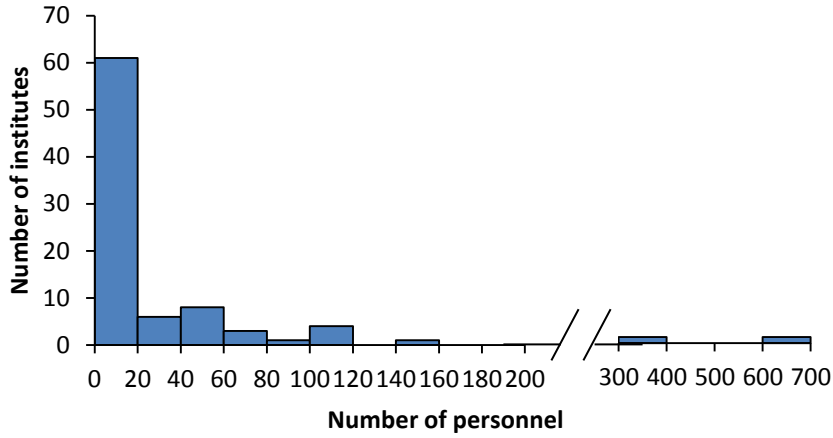


Figure 2.2: Top: distribution of the total number of accelerator science personnel per institute. Note the break in scale at 200 personnel. Bottom: a 'zoom' into the distribution for those institutes with fewer than 100 personnel.

### 3. INSTITUTES' PROVISION OF TRAINING

Of the 88 responding institutes, 75 replied affirmatively that they provide training of some kind in some aspects of accelerator science. This should therefore be regarded as a firm lower bound on the number of institutes engaged actively in providing training in this discipline among the countries surveyed. The number per country is shown in Figure 3.1. Of the thirteen institutes that do not currently offer training, three indicated plans to do so in future, and nine of the remaining ten indicated a desire to do so in future. Also, all of these thirteen institutes do send people for training at accelerator schools and workshops, which are a key vehicle for provision of 'centralised' training to people drawn from many institutes. For example, in 2011 a total of 83 institutes (94%) sent people for training to accelerator schools and workshops, and 30 institutes (34%) have staff members who *provide* training at the accelerator schools. The percentages of institutes participating in, and providing training at, schools and workshops are shown by country in Figure 3.2. Accelerator schools will be discussed further in Section 7.

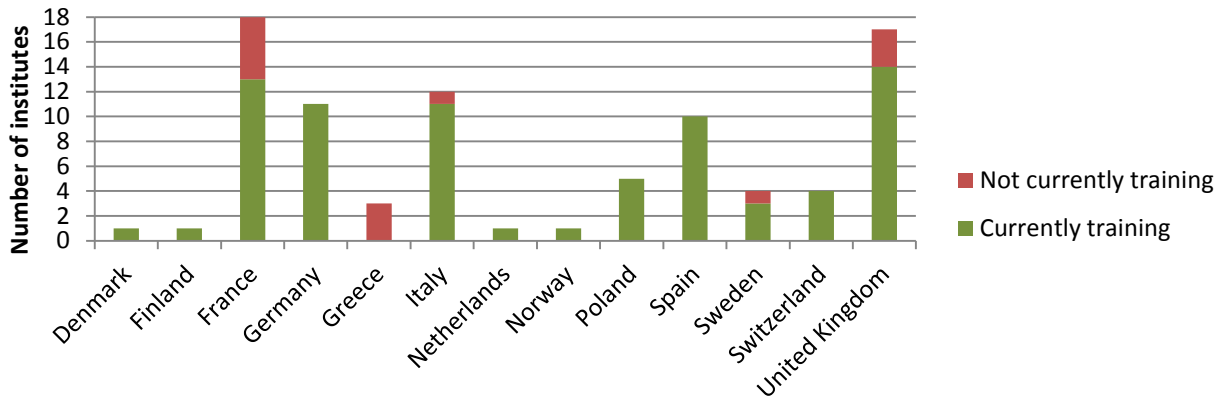


Figure 3.1: The number of institutes per country that responded to the survey. Those institutes that currently offer training in accelerator science are represented in green, and those that do not are represented in red.

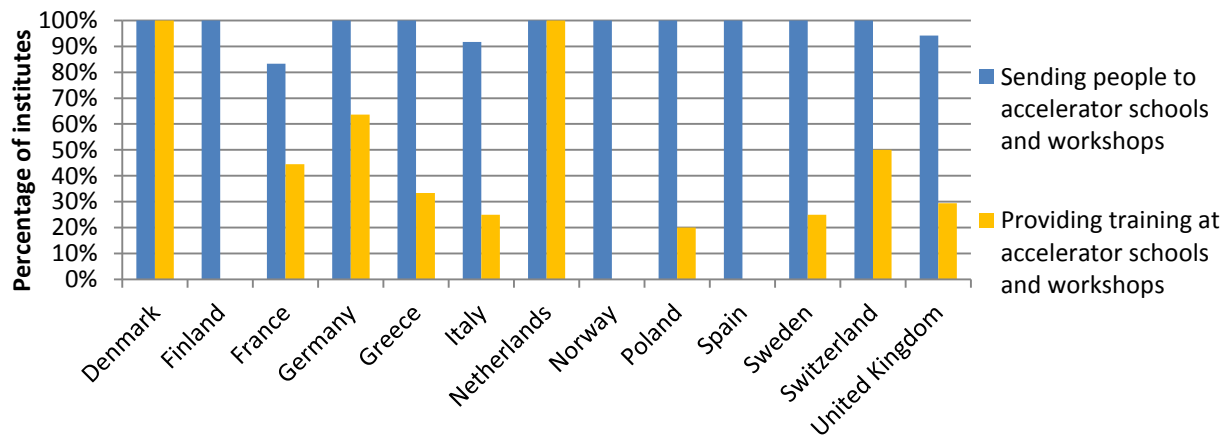


Figure 3.2: The percentage of responding institutes in each country that send people for training to accelerator schools and workshops (blue), and that provide training at accelerator schools and workshops (orange).

The percentage of responding institutes that currently offer training to each category of trainee (undergraduate, master’s, PhD, postdoctoral fellow, staff) is shown by country in Figure 3.3. Provision of training is most common at the master’s and PhD level, though many institutes provide training at the undergraduate level, as well as to postdoctoral fellows and staff. Overall, 49% of institutes provide training to undergraduates, 64% to master’s students, 70% to PhD students; 44% to postdoctoral fellows, and 24% to staff.

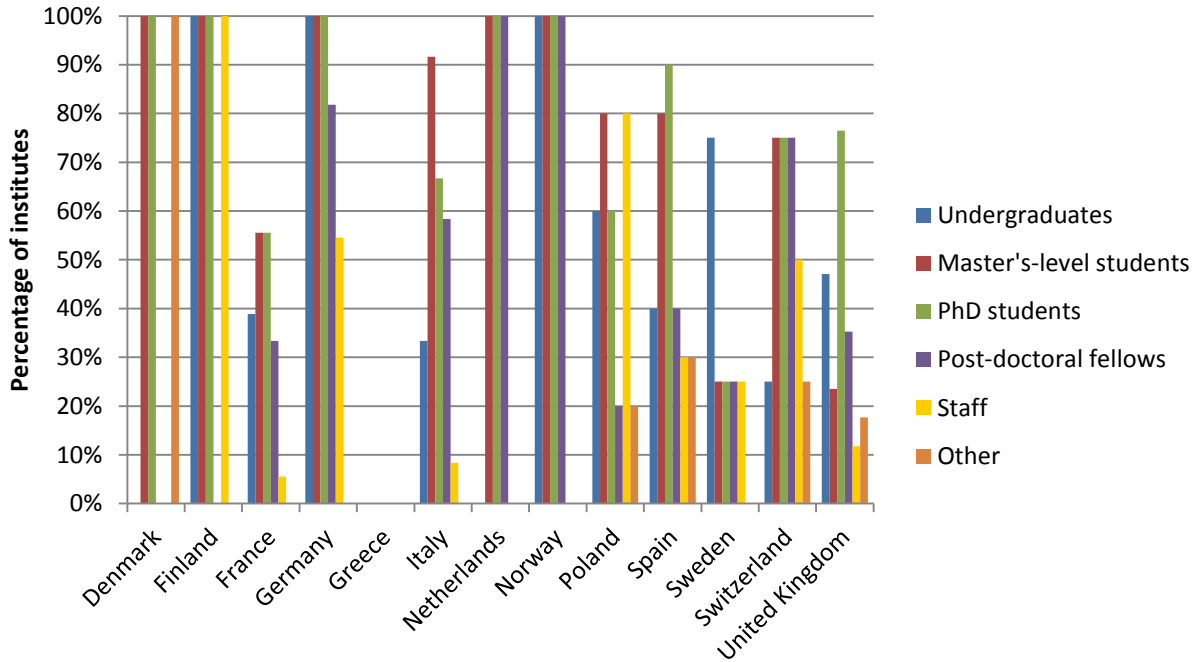
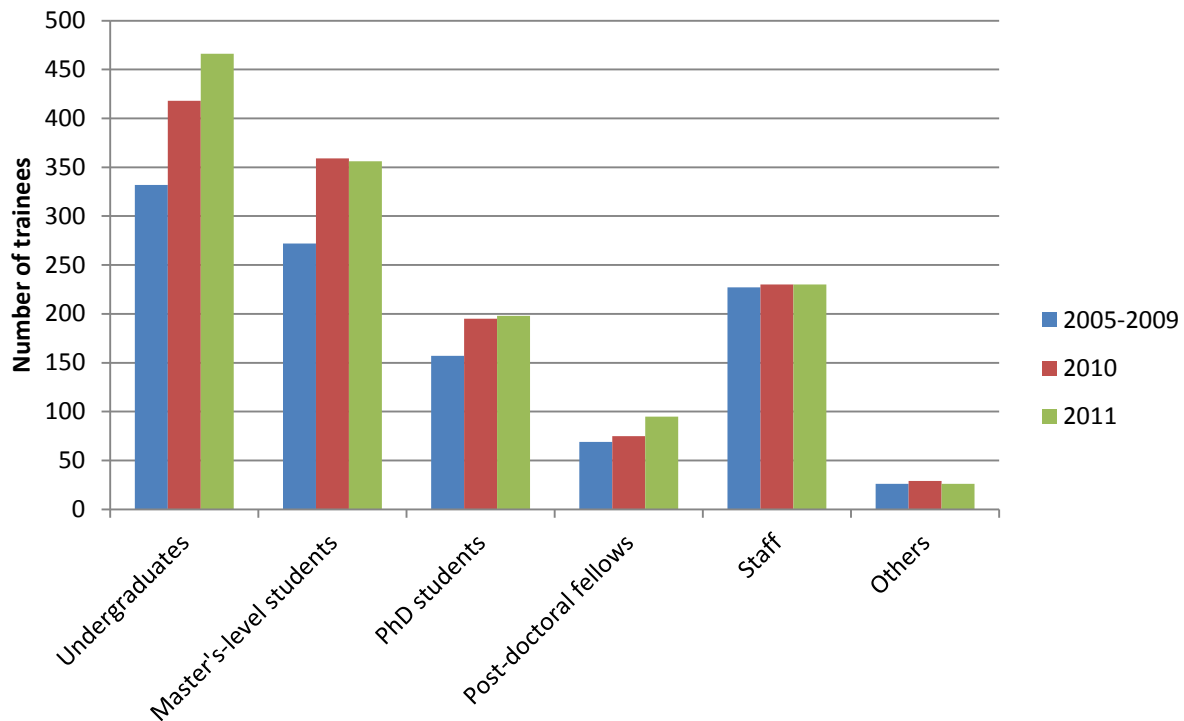


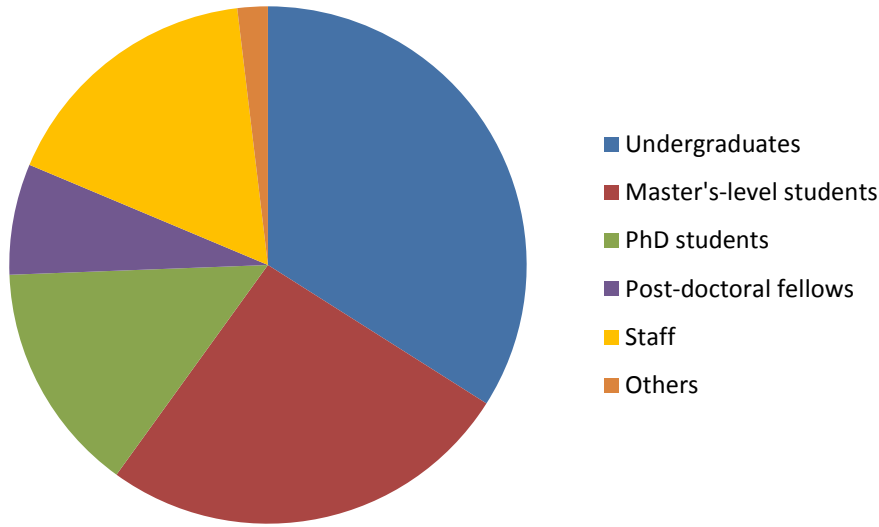
Figure 3.3: The percentage of responding institutes in each country that currently offer training to each category of trainee.

## 4. TRAINEE NUMBERS

Integrated over all institutions, the number of people receiving any training in accelerator science is shown, by trainee type, in Figure 4.1. For example, in 2011, 1371 people received training, which comprised: 466 undergraduates (34%), 356 master's students (26%), 198 PhD students (14%), 95 postdoctoral fellows (7%), 230 staff (17%) and 26 others (2%); these data are represented in Figure 4.2. The category 'others' includes, for example, visiting overseas students and industry employees. The numbers did not change dramatically during the period 2005–2011, though there is evidence of a modest increase in the numbers of undergraduates (+40%), master's students (+31%), PhD students (+26%) and post-doctoral fellows (+38%) that were trained between 2005 and 2011.



*Figure 4.1: The total number of accelerator science trainees, by trainee type. Data are shown for the academic year 2011 (green), 2010 (red) and the average over the 5 years 2005-2009 (blue).*



*Figure 4.2: The relative proportions of trainee types in academic year 2011.*

The total number of trainees in each country is shown in Figure 4.3. Clearly there is a large spread in numbers between countries that partly reflects the spread in populations. In order to account for the population differences, the number of trainees for the year 2011 was normalised by the population of each country; this is shown in Figure 4.4. With this normalisation, the spread in accelerator science student numbers between countries is much reduced, though there are still large differences between the relative populations being trained in different countries. An alternative normalisation, by the total number of accelerator science personnel in each country (Figure 2.1), is shown in Figure 4.5. This normalisation tends to enhance the visibility of countries with smaller staff numbers. An analysis of the situation in each country is provided in Appendix 3.



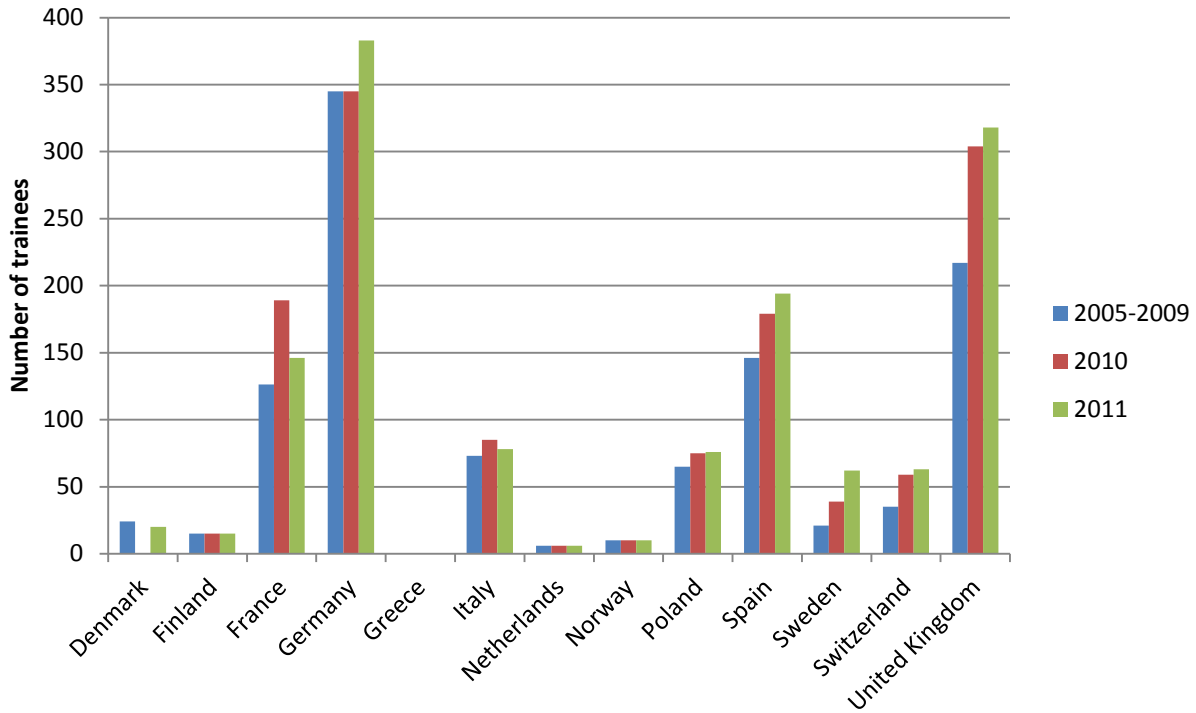


Figure 4.3: The total number of trainees in each country. Data are shown for the academic year 2011 (green), 2010 (red) and the average per year over the 5 years 2005-2009 (blue).

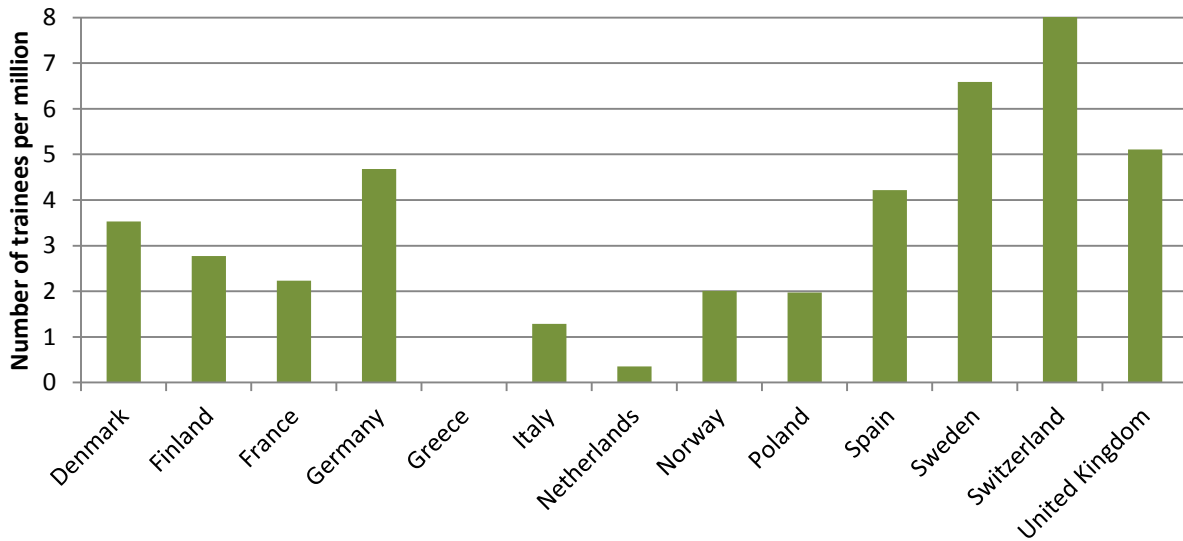


Figure 4.4: The total number of trainees in each country (for academic year 2011) normalised by the population of that country, expressed in trainees per million.

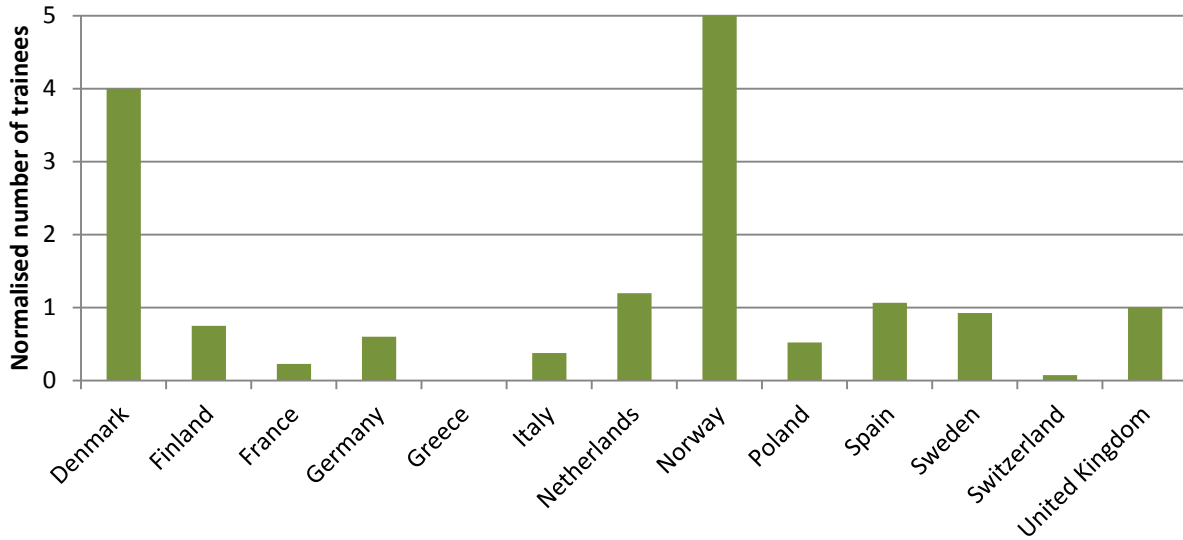


Figure 4.5: The total number of trainees in each country (for academic year 2011) normalised by the respective number of accelerator science personnel.

For each country, the percentage of the accelerator science population of each trainee type (for academic year 2011 as an example) is represented in Figure 4.6. A comparison between countries of the six different trainee types is shown in figure 4.7. Because the situation is different in each country, a brief discussion of student numbers and country-specific issues is given in Appendix 3.

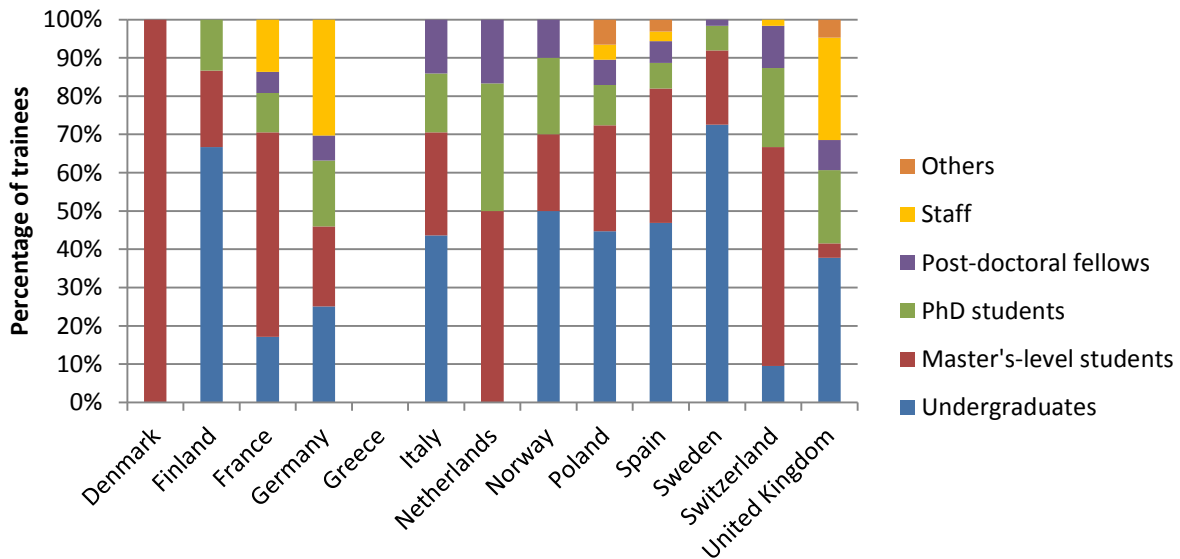


Figure 4.6: Representation of the percentage of trainees in each country (for academic year 2011) that is of each type.

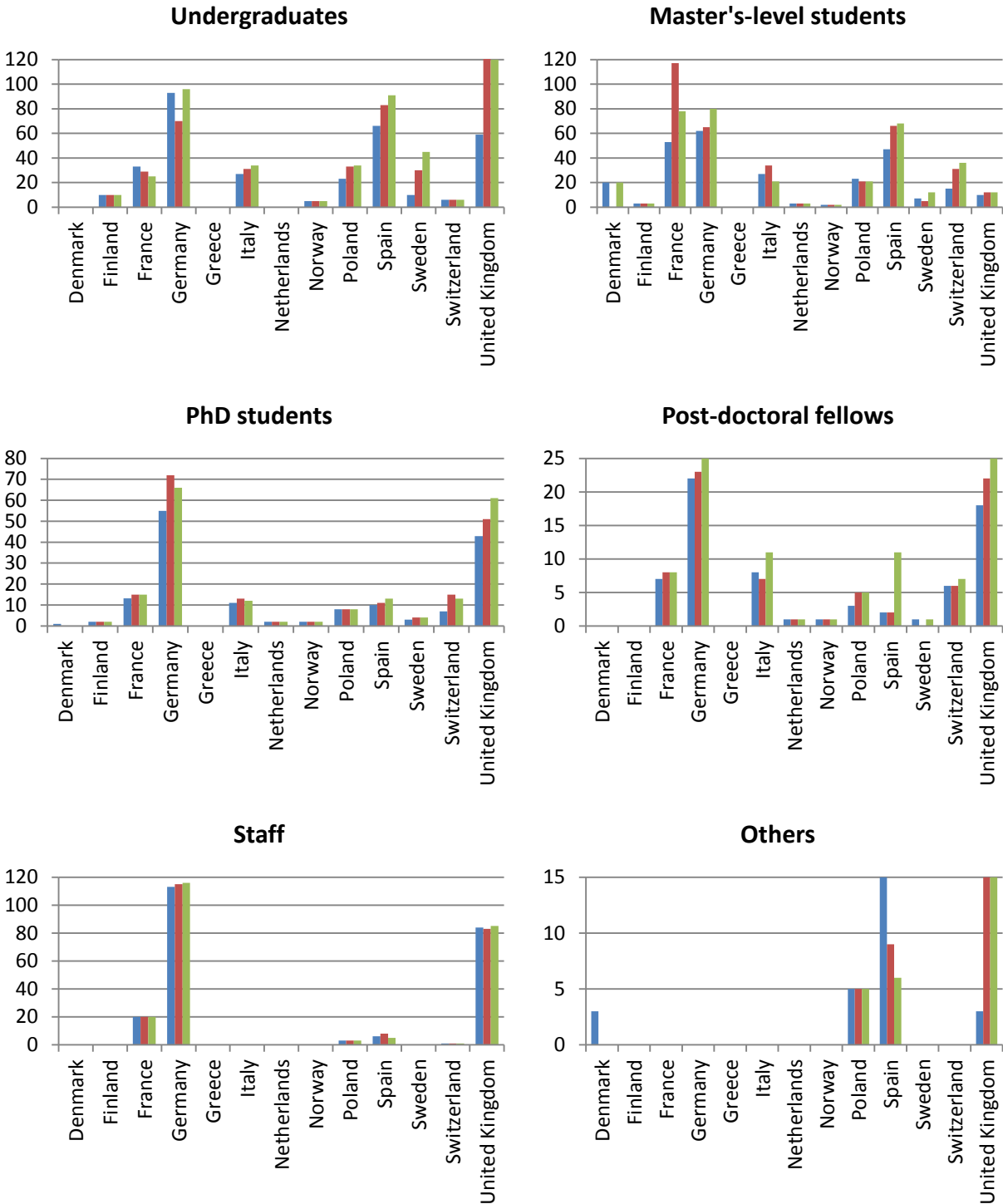


Figure 4.7: For each country, the total number of trainees in each category. Data are shown for the academic year 2011 (green), 2010 (red) and the average per year over the 5 years 2005-2009 (blue). (a) Undergraduates; (b) master's students; (c) PhD students; (d) postdoctoral fellows; (e) staff; (f) others.

## 5. FORMAL TRAINING TIME

55 of the 75 institutes that provide training reported the number of formal training hours provided. Formal training is defined to be instructive training provided in a lecture, class or tutorial environment. The distribution of the number of formal training hours is shown in Figure 5.1; training hours are shown separately for the different categories of students. For any student type the amount of training varies considerably, from between a few hours to hundreds of hours, though the majority of institutions provide of order a few tens of hours of such training. 11 institutes provide more than 100 hours of training to master's students:

1. University of Manchester
2. Universitat Aut3noma de Barcelona
3. IKP, TU Darmstadt
4. Institut f3ur Kernphysik der Johannes Gutenberg-Universit3t Mainz
5. University Paris-Sud
6. IKP, FZ J3ulich
7. DELTA, TU Dortmund
8. INFN - Milano & Universit3 degli Studi di Milano
9. EPFL: Swiss Institute of Technology Lausanne
10. Universit3 di Roma "La Sapienza"
11. Hamburg University

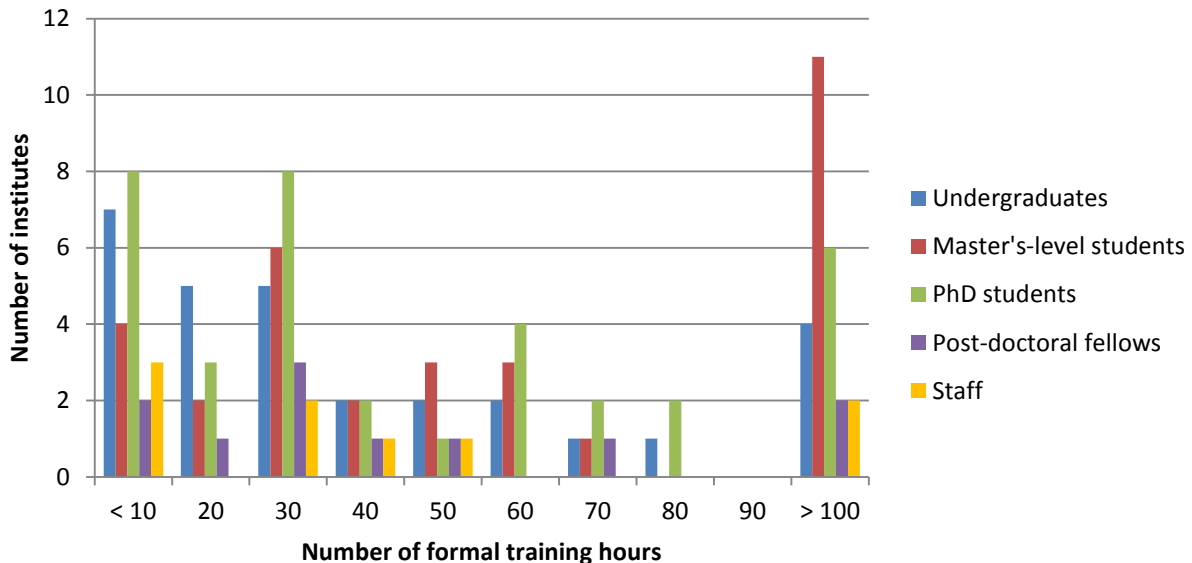


Figure 5.1: Distribution of the number of formal training hours provided. Data are shown for separate categories of trainee. Zeroes have not been displayed. The bin width is 10 hours.

The total number of trainees (for academic year 2011 as an example) vs. number of formal training hours is shown in Figure 5.2; 1177 students received any formal training, of which 412 (35%) were undergraduates, 324 (28%) were master’s students, 151 (13%) were PhD students, 50 (4%) were post-doctoral fellows and 218 (19%) were staff members. 841 (181) students received more than 10 (100) hours of formal training, respectively. The number receiving more than 10 hours of training is shown by trainee type and academic year in Figure 5.3.

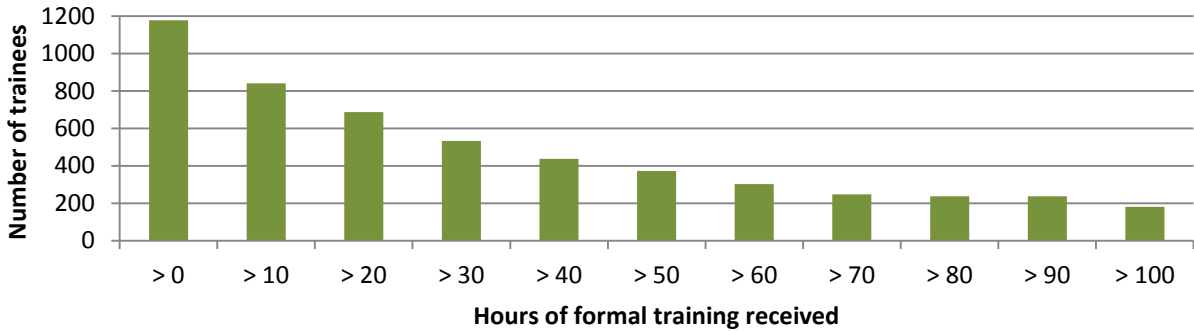


Figure 5.2: Number of trainees (academic year 2011) vs. hours of formal training in accelerator science.

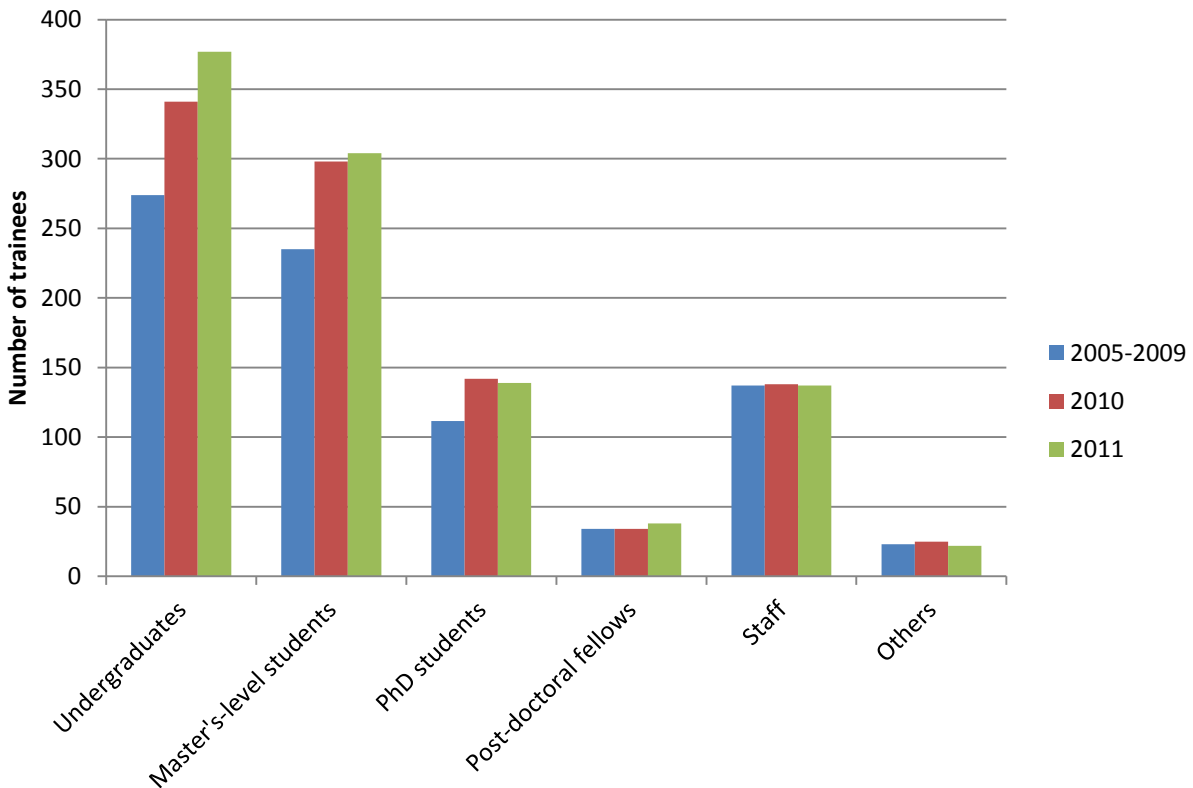


Figure 5.3: The total number of trainees who received at least 10 hours of formal training in accelerator science, by trainee type. Data are shown for the academic year 2011 (green), 2010 (red) and the average per year over the 5 years 2005-2009 (blue).

The total number of reported formal training hours per annum currently provided is shown by country in Figure 5.4. Note that, since 20 institutes did not provide data on the number of hours, these numbers represent lower bounds, and the real totals will be larger. In some countries (France, Germany, Italy, Spain, Switzerland) the dominant number of training hours is provided to master's students; in the UK the largest number of hours is provided to PhD students. The total number of reported training hours by country is shown in Figure 5.5, and by category of trainee in Figure 5.6. Overall, of the 62,777 total reported training hours provided per annum, 46% are currently given to master's students, 27% to undergraduates, 13% to PhD students, 10% to staff and 3% to post-doctoral fellows.

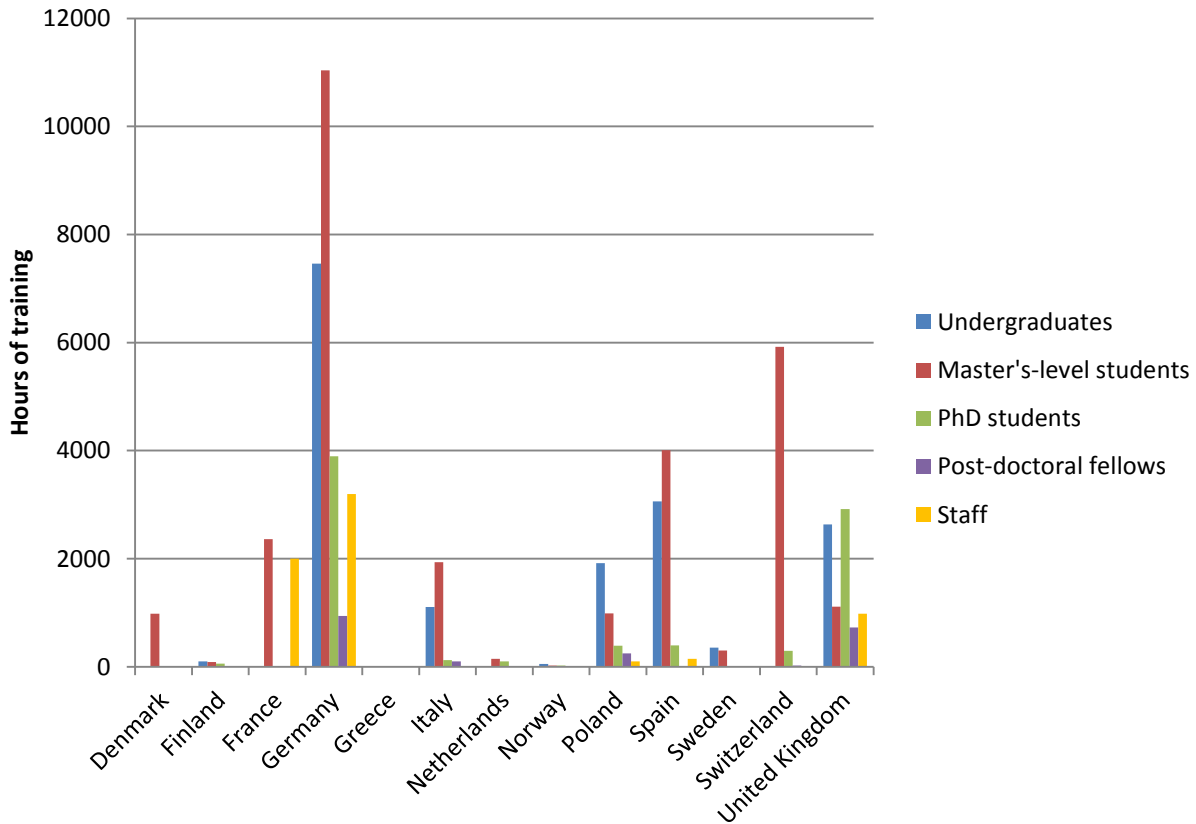


Figure 5.4: The total number of accelerator science formal training hours reported by institutes that offer training to each category of trainee, by country.

The distribution of the percentage of formal training time that is spent on accelerator science is shown by category of trainee in Figure 5.7. Accelerator science typically represents a small fraction (below 30%) of total training time, which reflects the fact that it is often a small component of a more general training in physics and/or engineering disciplines. This is particularly evident for undergraduate, master's and PhD students. For postdoctoral fellows and staff a noticeably higher fraction of their total training time is spent on accelerator science, reflecting the fact that they are professionals in this discipline.

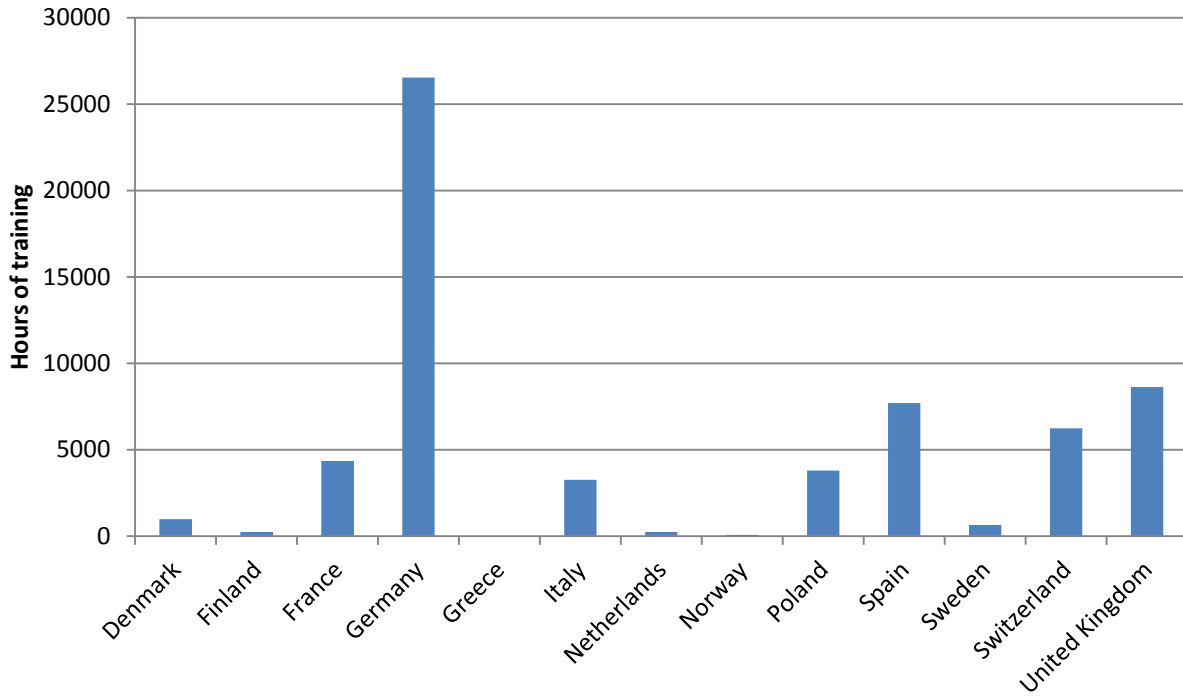


Figure 5.5: Total reported formal training hours spent on accelerator science per country.

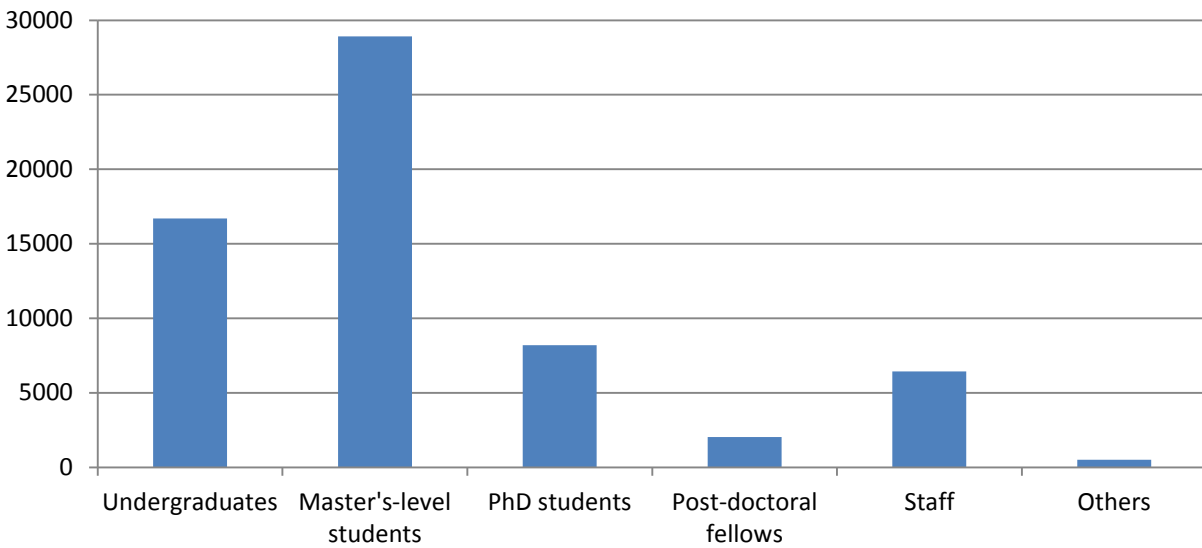


Figure 5.6: Total reported formal training hours spent on accelerator science by category of trainee.

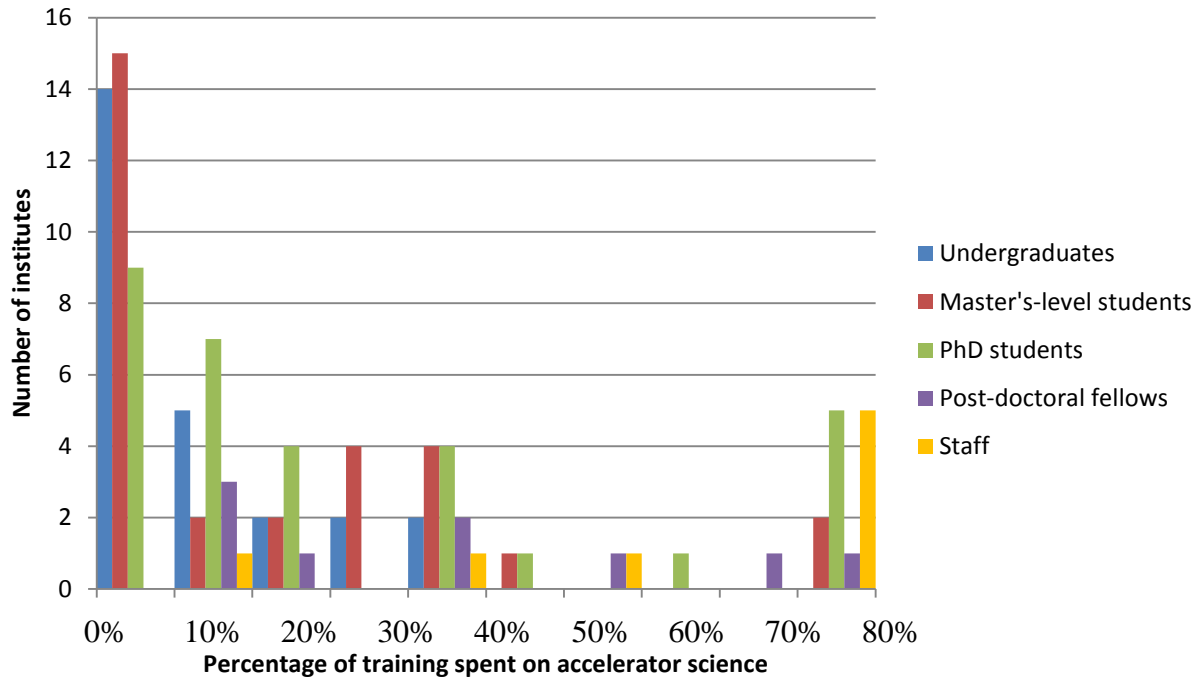


Figure 5.7: Distribution of the percentage of formal training time that is spent on accelerator science, reported by institutes that offer formal training to each category of trainee.



## 6. TRAINING SUBJECTS

For the 72 institutes that reported on training areas provided, the number of trainees by subject area is shown in Figure 6.1. The majority of trainees receive training in the five areas:

- particle sources
- accelerating structures
- magnets
- beam dynamics
- instrumentation and controls

Figure 6.2 shows the percentage of institutes that offer training in each subject area; more than 50% of institutes offer training in one or more the five main areas listed above. In addition, a significant fraction of institutes offer training in laser systems and cryogenics for accelerators.

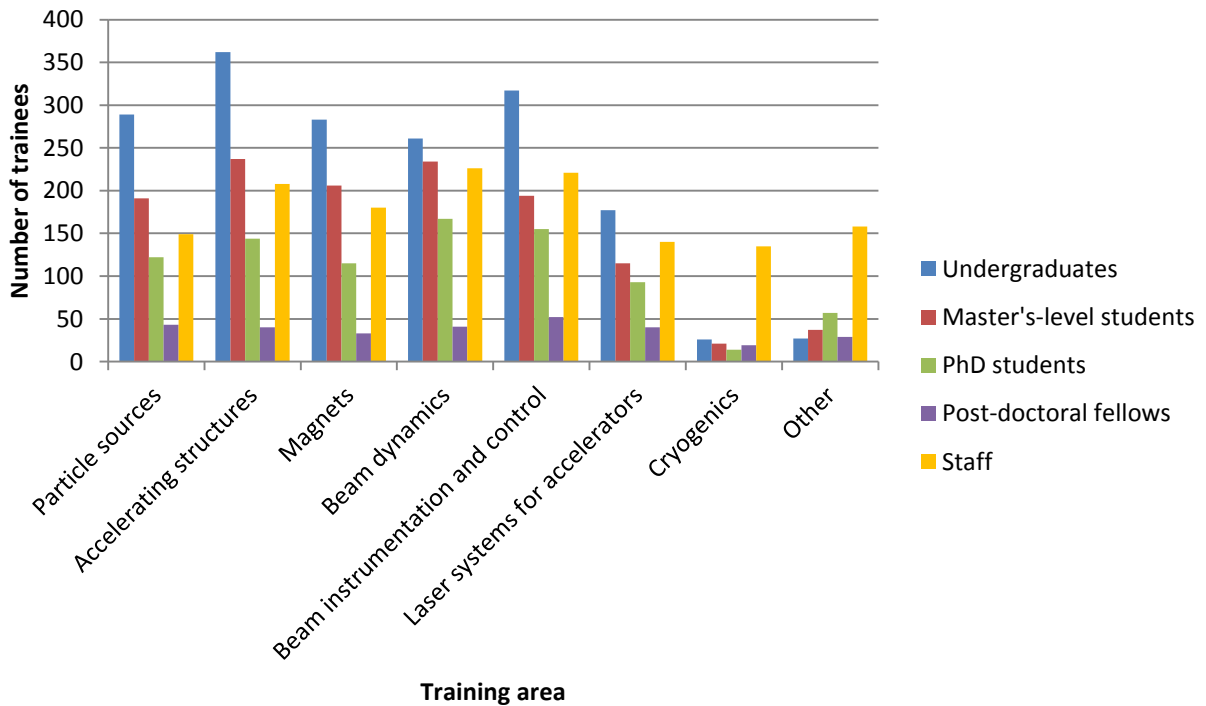


Figure 6.1: Number of trainees versus training area and by category of trainee.

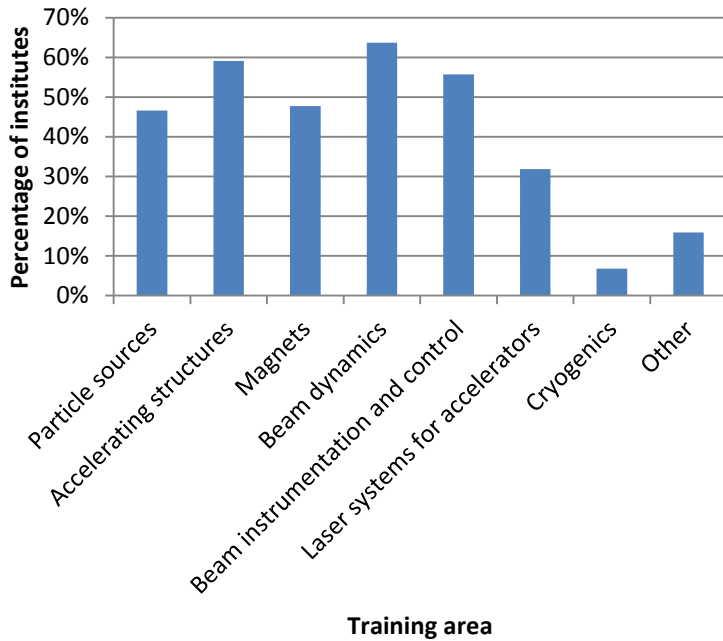


Figure 6.2: Percentage of institutes that offer training in each area.

The percentage of institutes that reported offering formal examinations on accelerator science coursework is shown by country and student type in Figure 6.3. In total, 53% of institutes that train undergraduates offer formal examinations; the corresponding figure for master’s students is 55%, and for PhD students is 45%. Participation in the European Credit Transfer Scheme (ECTS) is shown in Figure 6.4. In total, 35% of institutes that train undergraduates participate in ECTS; the corresponding figure for master’s students is 46%.

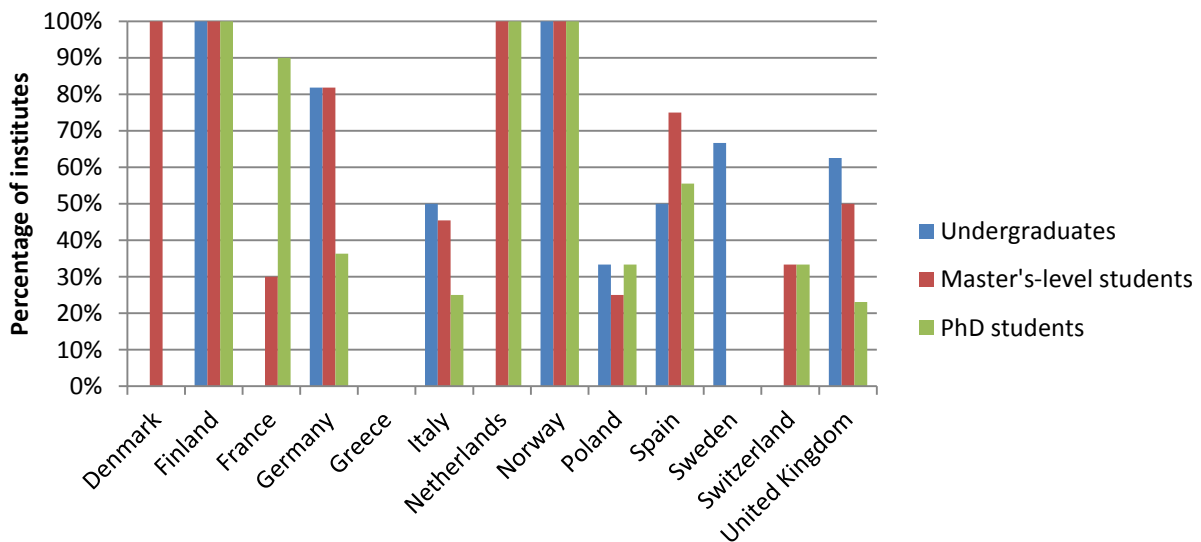


Figure 6.3: Percentage of institutes that offer formal examinations, by country.

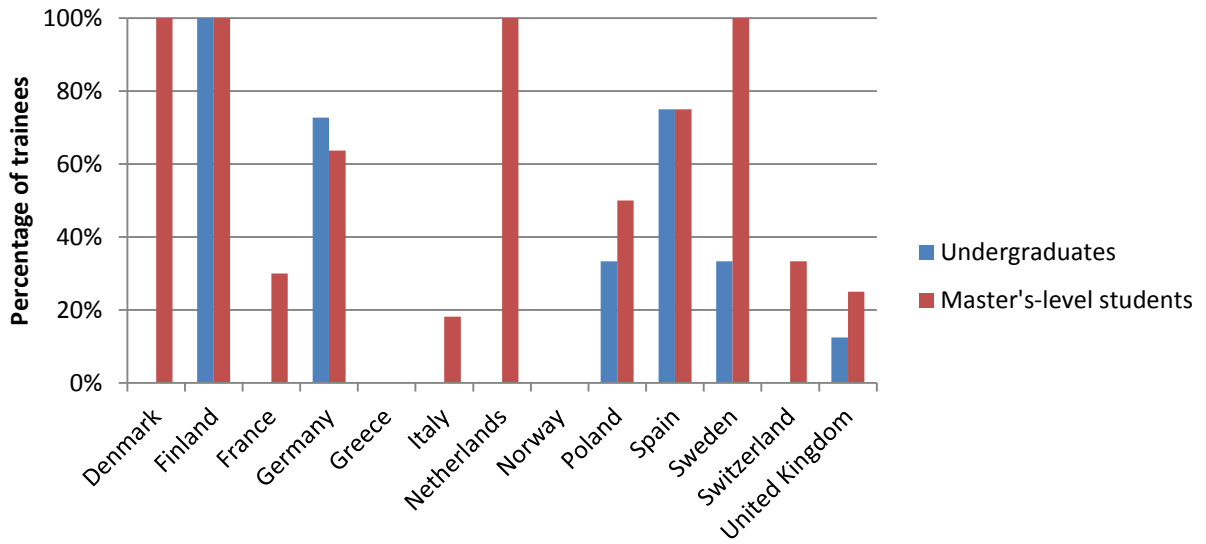


Figure 6.4: Percentage of institutes that report participation in the ECTS scheme, by country: undergraduate training (blue) and master's level training (red).

## 7. ACCELERATOR SCHOOLS AND THE CERN DOCTORAL STUDENT PROGRAMME

Accelerator schools represent an important training mechanism. In 2011 institutes reported sending 339 people to attend international and/or national accelerator schools. The number of attendees by country is shown in Figure 7.1. The most attended international schools are the CERN Accelerator Schools (CAS), the Joint Universities Accelerator School (JUAS), the U.S. Particle Accelerator Schools (USPAS) and the Linear Collider School. CERN sends a significant number for training to the CAS. Poland sends a significant number for training at its WILGA school.

The CAS and USPAS are organized as intensive residential schools, held twice per year and typically of two weeks duration. Each school provides some 50 hours of teaching. The Linear Collider School is similar, but shorter and held yearly. The JUAS provides 2 courses of 110 hours of teaching each, supplemented by several days of practical work and visits to various experimental facilities (CERN, ESRF, PSI, Geneva hospital), over a period of ten weeks. Additional statistics on CAS and JUAS are shown in Appendices 4 and 5 respectively. The total number of trainees per country attending schools, normalised by population, is shown in Figure 7.2.

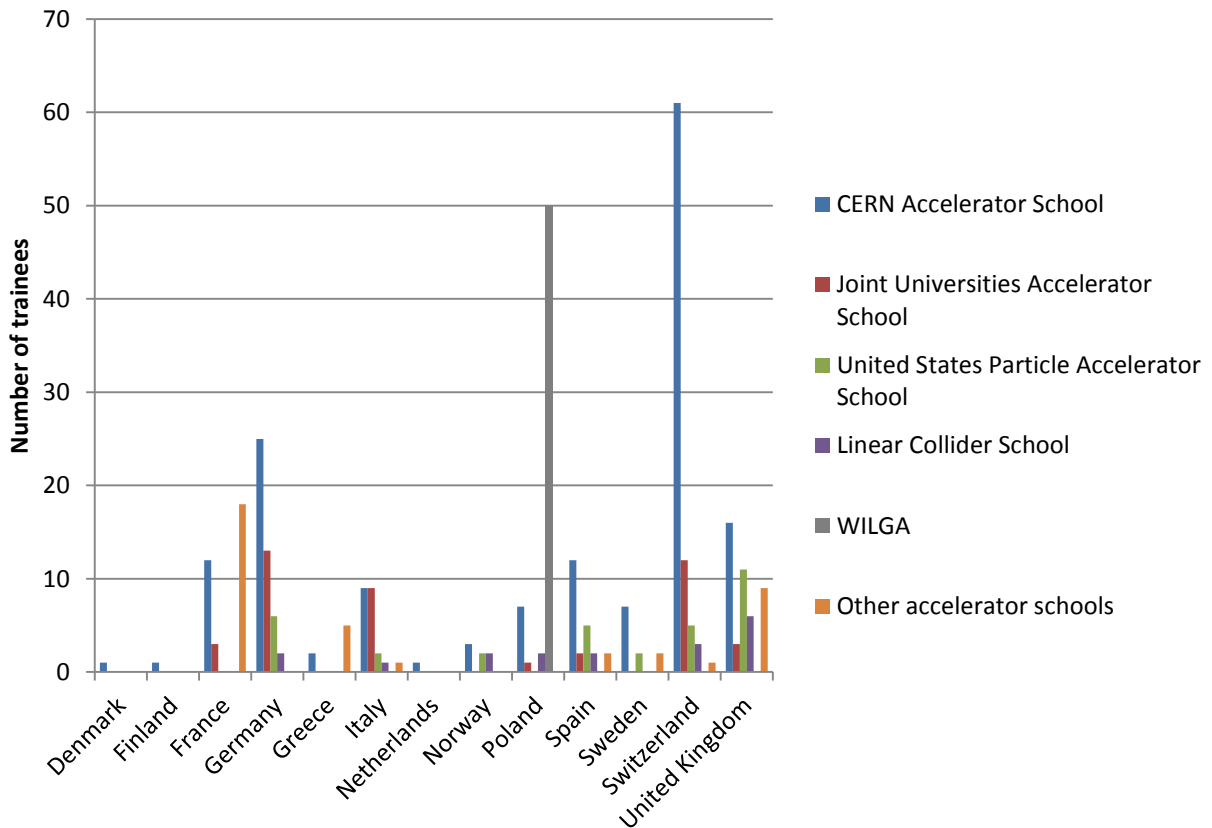


Figure 7.1: Number of trainees attending international and national accelerator schools, by country.

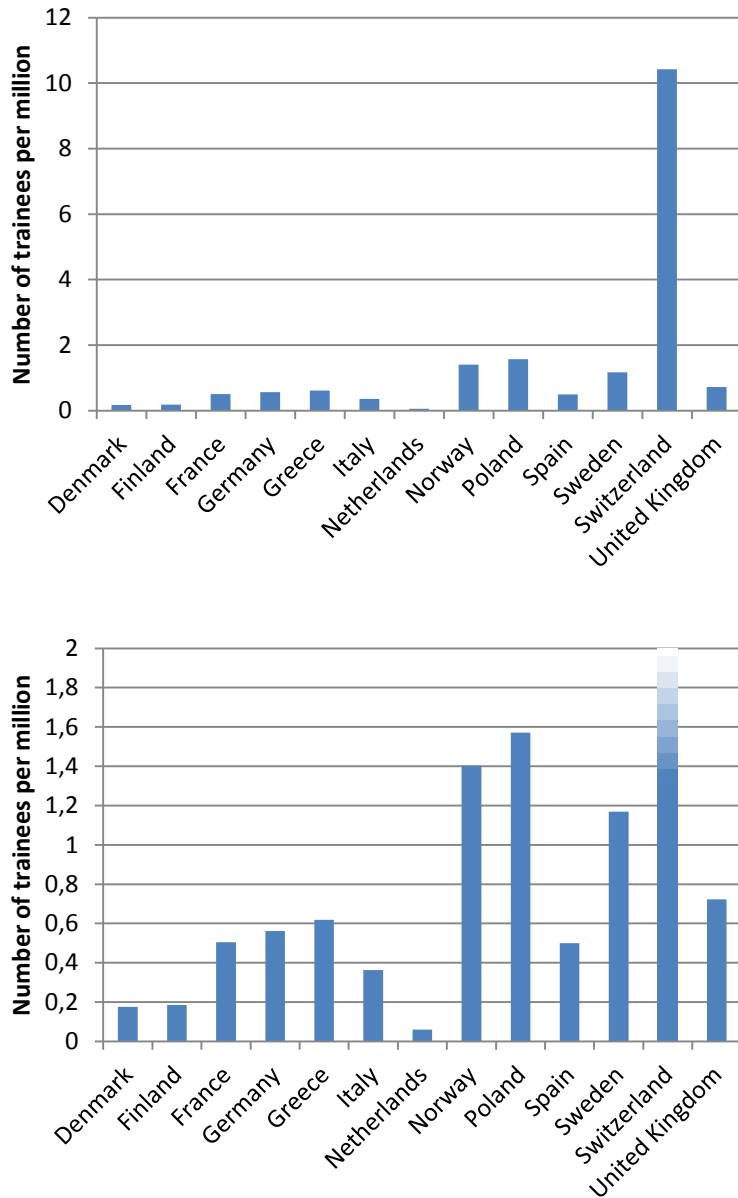


Figure 7.2: Top: number of trainees per million sent to accelerator schools. Bottom: a 'zoom into the region below 2 students/million.

In addition, the CERN Doctoral Student Programme (DSP) provides an important mechanism for the hands-on training of PhD students in accelerator science at CERN. Figure 7.3 shows participation in the DSP by country. In 2011, for example, 19 people from the responding institutes commenced training in the DSP.

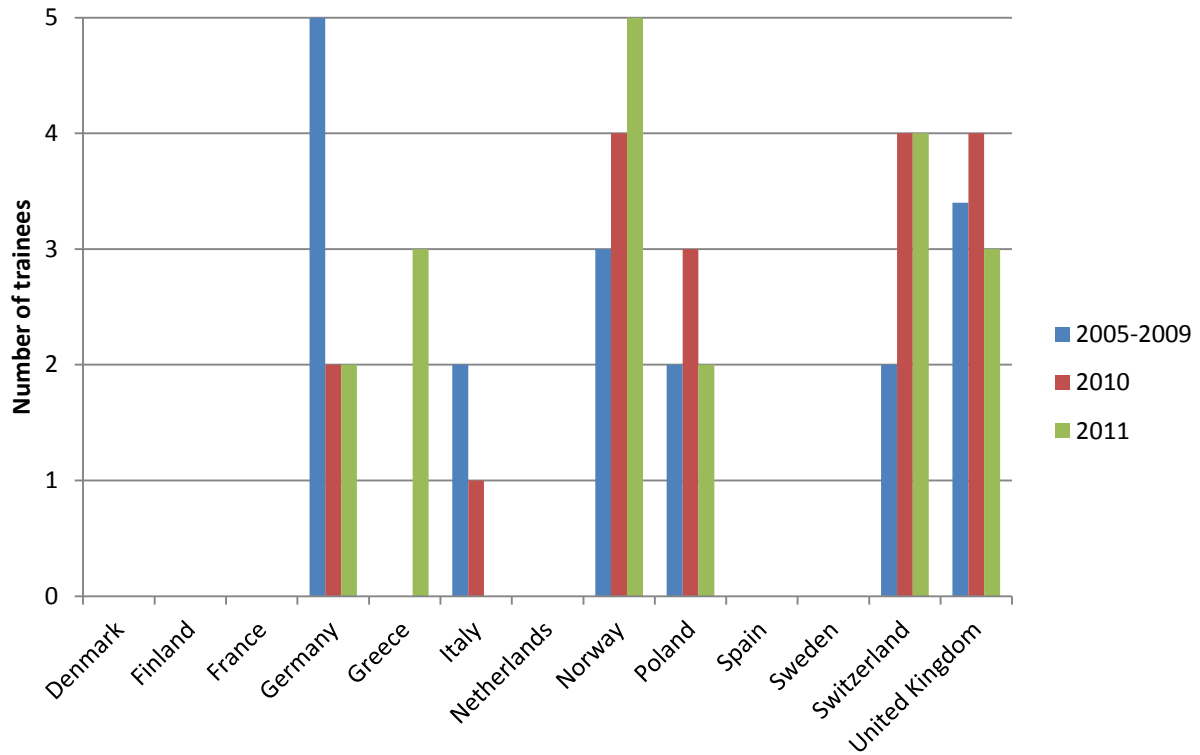


Figure 7.3: Numbers of trainees reported as participating in the CERN Doctoral Student Programme, by country. Data are shown for trainees commencing in the academic year 2011 (green), 2010 (red) and the average commencing per year over the 5 years 2005-2009 (blue).

## 8. TRAINING MATERIALS AND USE OF FACILITIES

A number of standard text books are used in accelerator science training:

- An Introduction to Particle Accelerators (E. Wilson)
- An Introduction to the Physics of High Energy Accelerators (D.A. Edwards and M.J. Syphers)
- Beam instrumentation and diagnostics (P. Strehl)
- Fundamentals of Beam Physics (J. Rosenzweig)
- Handbook of Accelerator Physics and Engineering (A.W. Chao and M. Tigner)
- Measurement and control of charged particle beams (M.G. Minty and F. Zimmermann)
- Particle Accelerator Physics (H. Wiedemann)
- The Physics of Particle Accelerators (F. Hinterberger)
- The Physics of Particle Accelerators: an Introduction (K. Wille)

The number of institutes using each text book is shown by category of student in Figure 8.1. The books are widely used for training all categories of trainee. Additional books and materials that were reported include:

- R.F. Superconductivity (H. Padamsee)
- High Voltage Vacuum Insulation (R.V. Latham)
- The Physics and Technology of Ion Sources (Ian Brown)
- CAS Proceedings
- Biomedical particle accelerators (W. Scharf)
- Principles of Particle Accelerators (W.A. Benjamin)

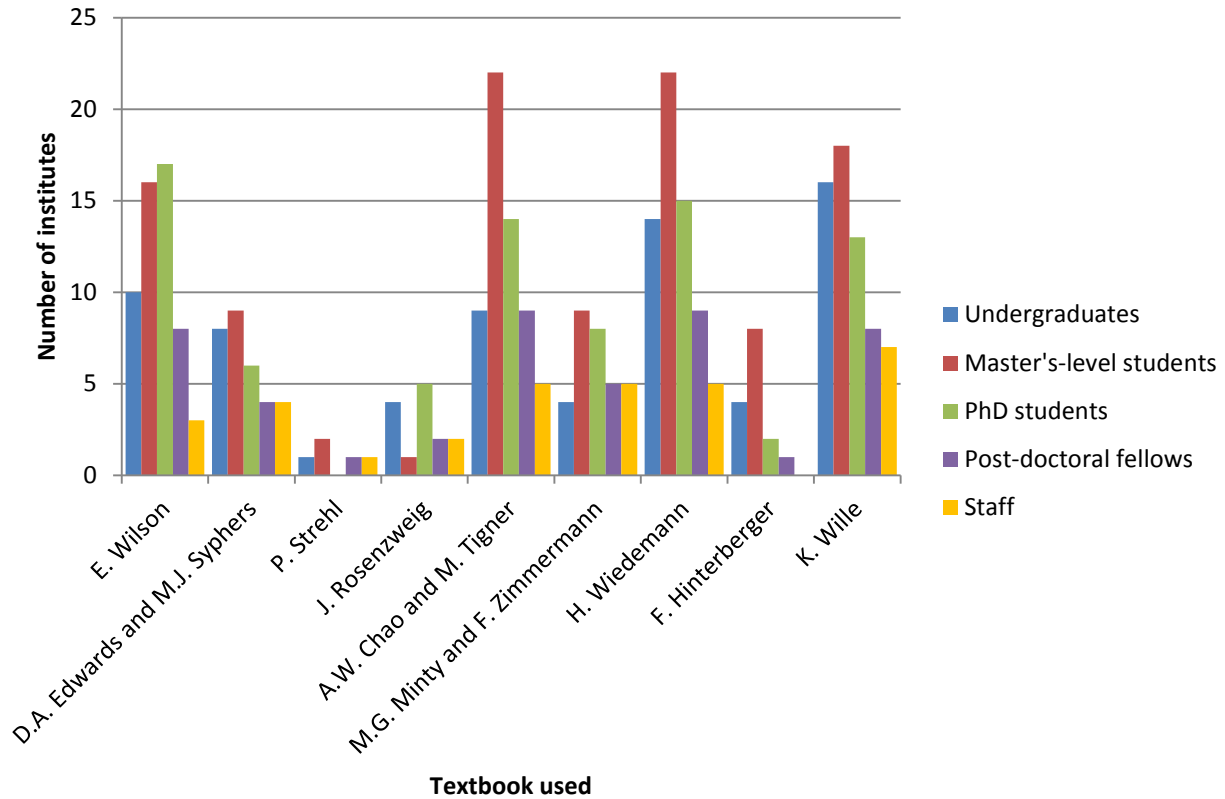


Figure 8.1: Number of institutes using well known accelerator text books for training, by category of trainee.

59 institutes reported on their use of national and/or international laboratories and facilities as part of their training programmes. A total of 51 such facilities were reported; these are listed in Appendix 6. Those facilities being used by at least two institutes are represented in Figure 8.2. CERN is the most-used facility, with major national laboratories being reported by users in each respective country.



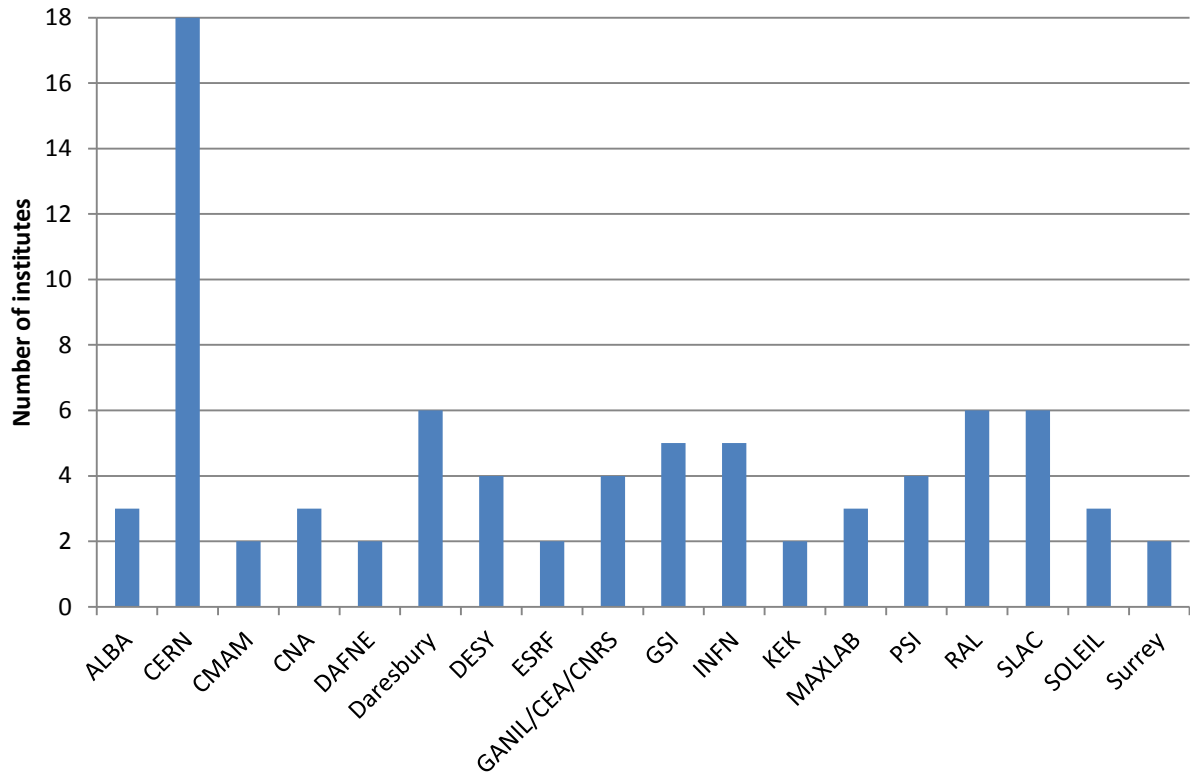


Figure 8.2: Number of institutes using the listed international and national facilities for training in accelerator science.

## 9. CAREER DESTINATIONS

41 institutes provided information on career destinations for the different categories of accelerator science trainee. The percentages of each population moving into:

- postgraduate studies (relevant for undergraduates and master's students)
- employment in the university sector
- employment at national or international laboratories
- employment in the medical sector
- employment in the manufacturing sector
- employment in the financial sector (e.g. banking)
- employment in the services sector (e.g. information technology)

are shown in Figure 9.1. For example, 64% of the undergraduates, and 59% of the master's students, go on to pursue postgraduate training. 66% of the PhD students, and 63% of the postdoctoral fellows, go on to find employment at universities and national or international laboratories. For each category of trainee, significant numbers go on to find employment outside the academic research sector: 28% of the undergraduates, 31% of the master's students, 34% of the PhD students, and 38% of the postdoctoral fellows, go on to find employment in the manufacturing, medical, financial and services sectors.

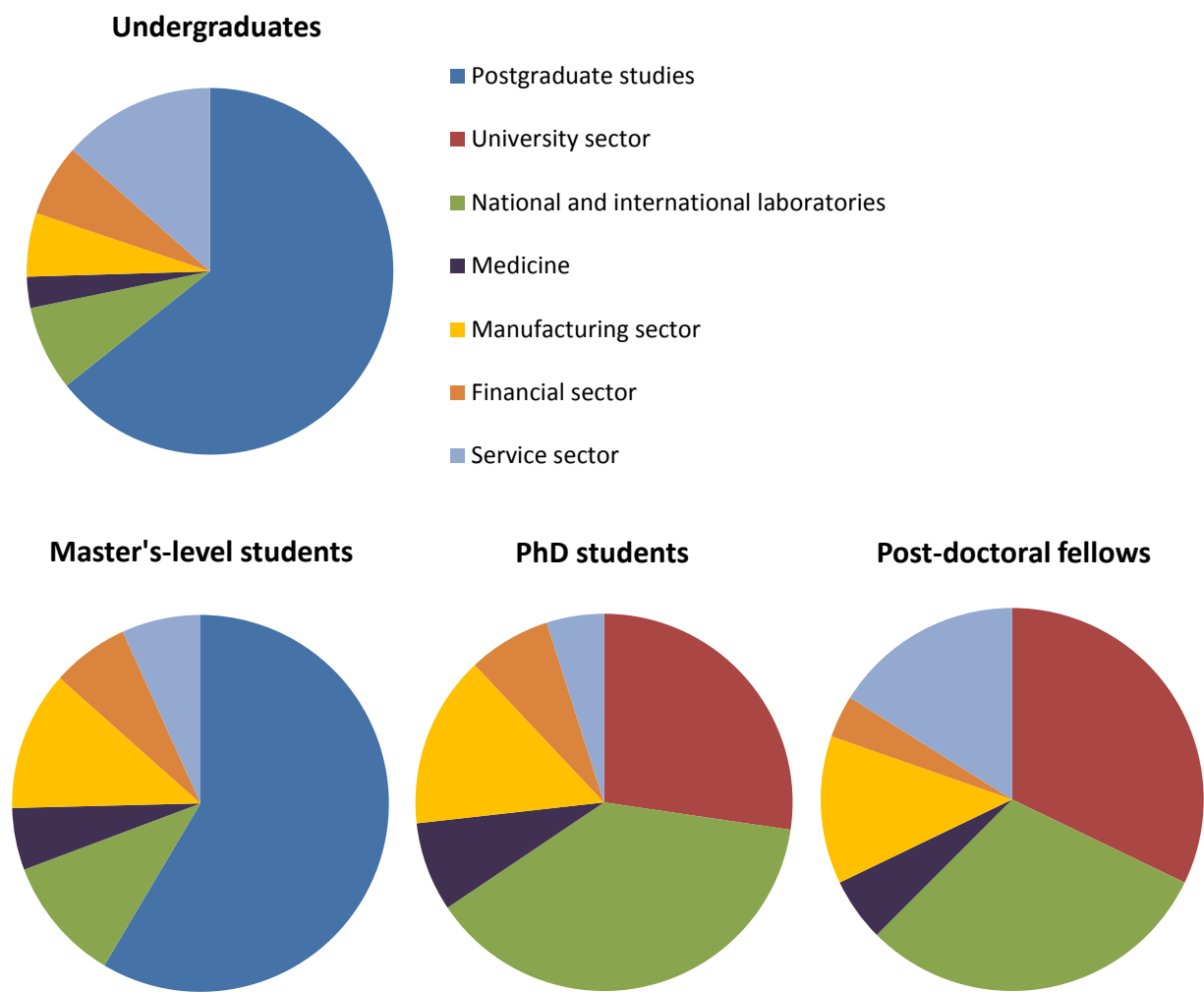


Figure 9.1: Percentage of trainees by career destination for each category of trainee.

## 10. SUMMARY OF MAIN FINDINGS

- 88 institutes from Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland and the United Kingdom completed the TIARA survey on education and training in accelerator science.
- A total of 3060 personnel at these institutes are engaged in accelerator science activities, of which 195 are involved in providing training.
- 75 institutes (85%) provide training of some kind in some aspects of accelerator science to their own students or staff. Of the 13 institutes that do not currently offer such training, 3 indicated that they have plans to do so in future, and 9 of the remaining 10 indicated a desire to do so in future.
- 83 institutes (94%) send people for training to accelerator schools and workshops, and 30 institutes (34%) have staff members who *provide* training at the accelerator schools and workshops.
- 49% of institutes provide training to undergraduates, 64% to master's students, 70% to PhD students; 44% to postdoctoral fellows, and 24% to staff.
- 1371 people per annum currently receive training, which comprises: 34% undergraduates, 26% master's students, 14% PhD students, 7% postdoctoral fellows and 17% staff.
- 55 institutes reported the number of training hours provided per annum. Currently a total of 62,777 training hours per annum are given: 46% to master's students, 27% to undergraduates, 13% to PhD students, 10% to staff and 3% to postdoctoral fellows.
- Accelerator science typically represents a small fraction (below 30%) of total formal training time for undergraduate, master's and PhD students, and typically a larger fraction for postdoctoral fellows and staff. There are only a handful of dedicated full-time formal training programmes in accelerator science.
- The majority of trainees receive training in five main areas: particle sources, accelerating structures, magnets, beam dynamics, instrumentation and controls. More than 50% of institutes offer training in one or more of these areas.
- 53% of institutes that provide formal training to undergraduates offer examinations on accelerator science coursework; the corresponding figure for master's students is 55%, and for PhD students it is 45%.
- 35% of institutes that train undergraduates participate in ECTS; the corresponding figure for master's students is 46%.
- More than 339 people each year receive training by attending international and/or national accelerator schools. The most attended international schools are the CERN Accelerator Schools (CAS), the Joint Universities Accelerator School (JUAS), the U.S. particle accelerator Schools (USPAS) and the Linear Collider School.

- In 2011, the responding institutes reported that 19 PhD students joined the CERN Doctoral Training Scheme for hands-on training in accelerator science at CERN.
- For the available dataset, although a majority of each category of trainee goes on to pursue work in the academic/research sector, 28% of the undergraduates, 31% of the master's students, 34% of the PhD students, and 38% of the postdoctoral fellows go on to find employment in the manufacturing, medical, financial and services sectors.

## 11. OUTLOOK

The survey has provided a remarkable 'snapshot' of training provision in accelerator science within the participating European states. The response rate has been extremely high. However, it cannot be excluded that additional training is being provided at institutes that did not respond to the survey; the statistics presented here should therefore be considered as a firm 'lower bound' on the amount and type of training. Furthermore, it is possible that training provision in accelerator science is considered desirable additionally at institutes that were not surveyed. It could well be appropriate to repeat the survey periodically in the future, in which case an attempt could be made to gather data on these points.

## **APPENDIX 1: RESPONDING INSTITUTES AND CONTACT PERSONS**

### **Denmark**

ISA, Aarhus University, Søren Pape Møller

### **Finland**

Department of Physics, University of Jyväskylä, Pauli Heikkinen

### **France**

C2RMF, Claire Pacheco

CEA/INAC/SBT, Alain Girard

CEA/DSM/IRFU/SACM, P.A. Phi Nghiem

CNRS/IN2P3/CENBG, Laurent Serani

CNRS/IN2P3/CSNSM, Cyril Bachelet

CNRS/IN2P3/IPN, Patrick Ausset

CNRS/IN2P3/IPNL, Marcel Bajard

CNRS/IN2P3/LAL, Alessandro Variola

CNRS/IN2P3/LAPP-Universite de Savoie, Andrea Jeremie

CNRS/IN2P3/LLR, Catherine Clerc

CNRS/IN2P3/LPSC, Maud Baylac

CNRS-LPGP, Brigitte Cros

ESRF, Jean-luc Revol

GANIL/CEA/CNRS, Frederic Chautard

SOLEIL, Jean-Claude Denard

Université et Ecole des Mines de Nantes/CNRS/IN2P3/SUBATECH, Freddy Poirier

Université Paris 11, Costel Petrache

Université Paris 11/Paris 6/Paris 7/INSTN, Alessandro Variola

### **Germany**

DELTA, TU Dortmund, Thomas Weis

DESY, Alexander Gamp

Goethe-Universität Frankfurt,

GSI Helmholtzzentrum für Schwerionenforschung GmbH, Oliver Kester

Hamburg University, Joerg Rossbach

Helmholtz-Zentrum Berlin, Andreas Jankowiak

Institut für Kernphysik der Johannes Gutenberg-Universität Mainz, Kurt Aulenbacher

Institut für Kernphysik, FZ Jülich, Andreas Lehrach

Institut für Kernphysik, TU Darmstadt, Ralf Eichhorn

TEMF, TU Darmstadt, Thomas Weiland

University of Wuppertal, Günter Müller

## **Greece**

Aristotle University of Thessaloniki, Petridou Charikleia

Inst. of Nuclear Physics, National Center for Research 'Demokritos', Petros Rapidis

University of Crete, Giorgos Tsironis

## **Italy**

ENEA, Luigi Picardi

Fondazione CNAO, Marco Pullia

INFN - Laboratori Nazionali del Sud, Luciano Calabretta

INFN - Laboratori Nazionali di Frascati, Andrea Ghigo, Maria Enrica Biagini, Caterina Biscari, Massimo Ferrario

INFN - Laboratori Nazionali di Legnaro, Andrea Pisent

INFN - MILANO & Università degli Studi di Milano, Paolo Pierini, Angelo Bosotti, Dario Giove, Giovanni Volpini

INFN - NAPOLI & Università degli Studi di Napoli Federico II, Maria Rosaria Masullo

INFN - PISA & Università degli Studi di Pisa, Franco Cervelli, Danilo Giulietti

Sincrotrone Trieste, Gerardo D'Auria

Università degli Studi di Torino, Mauro Gallio

Università di Bologna, Giorgio Turchetti

Università di Roma "La Sapienza", Luigi Palumbo

## **Netherlands**

Kernfysisch Versneller Instituut, University of Groningen, Sytze Brandenburg

## **Norway**

University of Oslo, Steinar Stapnes

## **Poland**

Cracow University of Technology/ Faculty of Mechanical Engineering, Blazej Skoczen

Institute of Nuclear Physics, Polish Academy of Sciences, Piotr Malecki

National Centre for Nuclear Research, Slawomir Wronka

Technical University of Lodz, Department of Microelectronics and Computer Science, Dariusz Makowski

Warsaw University of Technology, Ryszard S. Romaniuk

## **Spain**

ALBA CELLS, Gaston Garcia

Centro Nacional de Aceleradores, CNA, Joquin Gomez Camacho

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas, CIEMAT, Marisa Marco

European Spallation Source of Bilbao, FJ Bermejo

Instituto de Física Corpuscular, Angeles Faus-Golfe

Technical University of Catalonia (Universitat Politecnica de Catalunya), Yuri Kubyshin

Universidad Autónoma de Barcelona, Manel Sabés

Universidad Autónoma de Madrid, Angel Munoz-Martin

Universidad de Huelva, Ismael Martel

Universidad Nacional de Educación a Distancia, UNED. (ETS Ingenieros Industriales), Javier Sanz Gozalo

## **Sweden**

European Spallation Source ESS AB, Håkan Danared

Lund University/MAX-lab, Sverker Werin



Stockholm University, Ansgar Simonsson

The Svedberg Laboratory, Uppsala University, Björn Gålnander

## **Switzerland**

CERN, Roger Bailey

EPFL: Swiss Institute of Technology Lausanne, Lenny Rivkin

LHEP, Uni-Bern, Antonio Ereditato

Paul Scherrer Institut, Terence Garvey

United Kingdom

Brunel University, Akram Khan

Diamond Light Source, Riccardo Bartolini

Dundee University, Allan Gillespie

Glasgow University, Paul Soler

Huddersfield University, Roger Barlow

Imperial College London, Juergen Pozimski

John Adams Institute, University of Oxford, Riccardo Bartolini

John Adams Institute, Royal Holloway, University of London, Pavel Karataev

Lancaster University, Amos Dexter

Liverpool University, Andy Wolski

Manchester University, Roger Jones

Science and Technology Facilities Council, Greg Diakun

Sheffield University, Chris Booth

Strathclyde University, Alan Phelps

Surrey University, Karen Kirkby

Warwick University, Paul Harrison

University College London, Matthew Wing

## **APPENDIX 2: Survey**

The web survey can be found at:

[tiara.physics.ox.ac.uk/tiara-survey/](http://tiara.physics.ox.ac.uk/tiara-survey/)

A text version of the survey is given below.

### **TIARA Survey**

#### ***You & Your Institution***

Your Name

Your Email

Your institution

Type of institution (University/National Laboratory/Other)

Address

City

Postcode

Country

How many staff (i.e. physicists and engineers) at your institution are engaged in accelerator science activities?

Does your institution currently offer training in any aspect of accelerator science? (*Yes/No*)

(if “No” to above)

Have you offered training in accelerator science in the past? (*Yes/No*)

Do you plan to offer training in the future? (*Yes/No*)

(if “No” to above)

Would it be desirable to offer such training? (*Yes/No*)

Even if your institution does not provide training in accelerator science, do any of your faculty members provide training in accelerator science at other institutions or workshops? (*Yes/No*)

Do you send any people to accelerator schools and workshops? (*Yes/No*)

## ***Training***

To which groups do you offer training? (Undergraduates/Master's-level students/PhD students/Post-doctoral fellows (not permanent appointments/Staff (permanent appointments)/Others)

***Students*** (this section is repeated for each of the student types selected above)

In which areas do you provide training? (Particle sources/Accelerating structures/Magnets/Beam dynamics/Beam instrumentation and control/Laser systems for accelerators/Cryogenics)

Other training areas (please specify)

Names of training programmes

How many students received training in academic year 2010/11?

How many students will receive training in academic year 2011/12?

Approximately how many students PER YEAR received training, averaged over the 5 years 2005-2009?

## ***Teaching***

How many hours of lectures or other formal training (in accelerator science) did the students receive in 2010/11? (e.g. 100)

What is the total number of hours of instruction (in all subjects) during the academic year? (e.g. 500)

Do you participate in the European Credit Transfer and Accumulation System scheme? (Yes/No/Don't know)

If applicable, how many ECTS credits does your accelerator training amount to?

Are there formal examinations in accelerator science? (Yes/No)

Which books do you use for teaching?

- An Introduction to Particle Accelerators (E. Wilson)
- An Introduction to the Physics of High Energy Accelerators (D.A. Edwards and M.J. Syphers)
- Beam instrumentation and diagnostics (P. Strehl)
- Fundamentals of Beam Physics (J. Rosenzweig)
- Handbook of Accelerator Physics and Engineering (A.W. Chao and M. Tigner)
- Measurement and control of charged particle beams (M.G. Minty and F. Zimmermann)

- Particle Accelerator Physics (H. Wiedemann)
- Physik der Teilchenbeschleuniger (F. Hinterberger)
- The Physics of Particle Accelerators: an Introduction (K. Wille)

Other books (please specify)

Do you use local, national or international accelerator facilities for 'hands-on' training? (*Yes/No*)

(if “Yes” above)

Which facilities?

### ***Faculty***

How many faculty members provide formal training in accelerator science?

Do your faculty members provide accelerator training at other institutions? (e.g. national laboratories or other universities) (*Yes/No*)

(if “Yes” above)

Which other institutions?

Do your faculty members provide training at any accelerator schools? (*Yes/No*)

(if “Yes” above)

Which accelerator schools?

### ***Accelerator Schools***

How many people do you send to the following accelerator schools?

CERN Accelerator School

Joint Universities Accelerator School

United States Particle Accelerator School

Linear Collider School

Other accelerator schools

(If “Other accelerator schools” is completed above)

Which other accelerator schools?

## ***Meetings and Workshops***

Which meetings, workshops or similar educational events do you send people to?

## ***Doctoral Training Programmes***

Do you participate in any doctoral training programmes? (*Yes/No*)

(if “Yes” above)

### **CERN Doctoral Training Programme**

How many students joined the programme in academic year 2010/11?

How many students do you expect to join in academic year 2011/12?

How many students joined per year, averaged over the 5 years 2005-2009? (approximate)

### **Other Doctoral Training Programmes (if applicable)**

Please specify

## ***Career Destinations***

Please provide information on the career destinations of your leavers in the following categories, averaged over the 5 years 2005-2009 (if known).

(repeated for each student type)

### **Postgraduate studies** (or “University sector” for postgraduate alumni)

National and international laboratories

(if “National and international laboratories” completed)

Which?

Medicine

Manufacturing sector

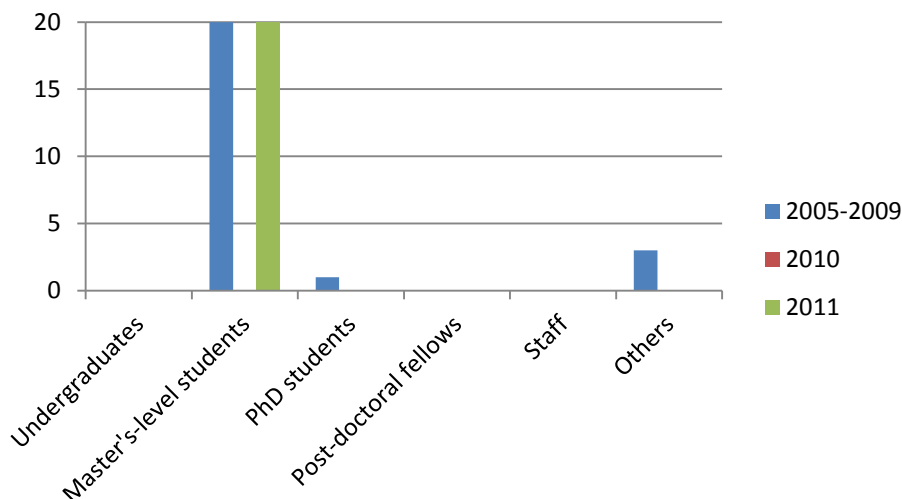
Financial sector (e.g. banks)

Service sector (e.g. IT)

### ***Comments*** - Comments (if any)

## APPENDIX 3: country-specific analysis

### Denmark



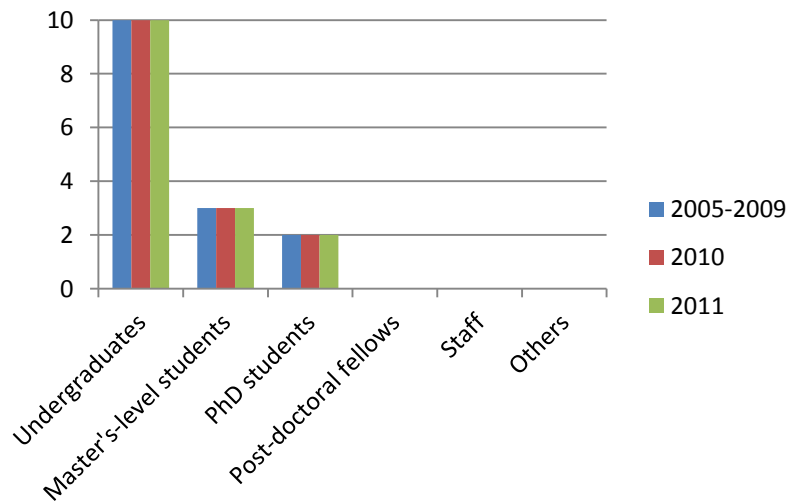
Denmark is a minor player in the accelerator world, in particular due to the size of the country.

The only university where accelerator research and training is going on, is Aarhus University. Previously some activity also existed at Copenhagen University, but accelerator research and development proper is not existing, only use of accelerators like at CERN, DESY and many other places. At Aarhus University, several smaller accelerators have existed for many years, and in 1990 the ASTRID storage ring, with its associated injectors, initially provided research with ion beams and in the last 10 years only with synchrotron radiation. The first electrostatic storage ring was invented and built at AU more than 10 years ago, and new electrostatic storage rings are being built. Finally a new low-emittance synchrotron radiation source, ASTRID2, is presently being constructed and starting commissioning in 2012. Aarhus University has also been and is involved in several external accelerator projects including ANKA in Karlsruhe, the Canadian Light Source, the Australian Light Source, the Particle Therapy machines at Siemens and lately the European Spallation Source in Lund.

Two well-known companies are engaged in designing and building accelerator components and complete accelerators (DANFYSIK and SIEMENS). Finally, we should mention the hospitals in Denmark which have a large staff of medical physicists for both cancer treatment and diagnostics etc. These physicists, including accelerator physicists, are partly trained at the universities partly during courses abroad at foreign companies and hospitals.

Aarhus University is the only University in Denmark giving formal training in accelerator science. Every second year, a 6 ECTS course in accelerator physics is filled with the available 20 places for students. In addition over the last years, around 5 students have obtained their PhD degree in accelerator science, two as industrial PhDs.

## Finland



The only laboratory in Finland with major activities in accelerator physics and training is at the University of Jyväskylä. The facility is based on a cyclotron used very actively in nuclear physics. The first cyclotron, MC20, at the Department of Physics (JYFL) was installed in the mid-1970s. It served the laboratory until 1992. A heavy-ion cyclotron, K130, was installed 1990-1991. It was partly designed by JYFL and manufactured by Scanditronix AB. The cyclotron is a multi-particle, variable energy machine. It is used for nuclear physics research and for applications, such as isotope production, space electronics radiation damage tests and some other commercial applications. Since 1996 the cyclotron has been used for 6000–7500 hours/year.

A new 30 MeV negative ion cyclotron for protons and deuterons was installed in 2008-2009. The cyclotron (MCC30/15) will be used for nuclear physics experiments and isotope production.

In addition to two operating cyclotrons the laboratory houses also a 1.7 MV Pelletron accelerator (tandem). It is used for materials physics research and applications, such as fabrication and modification of nanoscale materials, elemental profiling of thin films and different materials, experimental characterization of fundamental ion-matter interaction processes in nanometric materials and proton lithography.

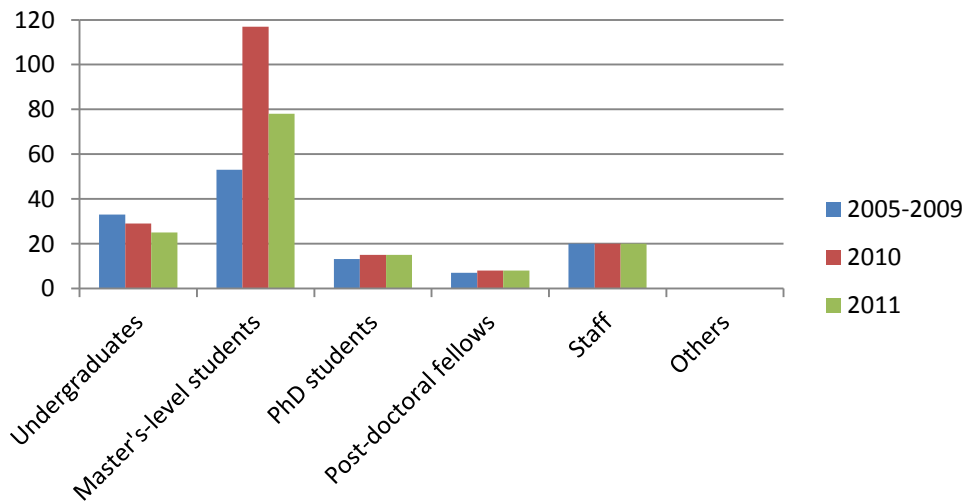
There are two different levels of accelerator-oriented training. The cyclotrons are operated by three permanently employed operators and by student operators. Annually, some ten students are trained as operators. The training consists of about 10 hours of theoretical training and practical training with the cyclotron. Until now, about 100 students have been trained as student operators for the K130 cyclotron.

In addition to the operator training there are three different accelerator physics and accelerator techniques courses (Accelerator Physics, Cyclotron Physics and Accelerator Techniques). All these courses are worth 5 credit points (30–32 hours of lectures and 16 hours of exercises). The Accelerator Physics course is based on the CERN Accelerator Physics course, Cyclotron Physics and Accelerator Techniques courses have been composed to meet the requirements of the JYFL Accelerator Laboratory. Normally one of the three courses is offered every second year. If there

are enough requests the courses are provided more often. If there is at least one student who cannot follow the course in Finnish the courses are provided in English.

The laboratory has a very active ion source group. Several Masters theses and PhD theses have been completed related to light ion sources and ECR ion sources. Until now, no special ion source courses have been offered.

## France



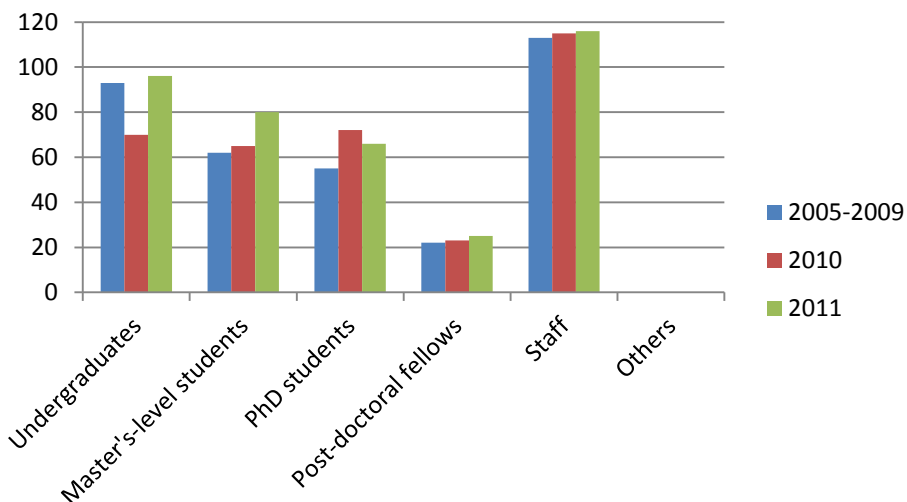
In France, two types of institutions are involved in training in accelerator fields; "Universities" and "National Laboratories", which are administratively independent.

Formal training and formal examination are given only at the level of a Master's Degree. This is done in Universities in specific structures and organisations as is the case for every Master's-level student. The lecturing faculty and other teachers are provided by the National Laboratories working in accelerators. For these Master's-level students, lectures on accelerators are only a part of all the given lectures. Due to the decreasing number of students interested in accelerator fields, the proportion of accelerator-related lectures is also decreasing.

On their side, accelerator laboratories offer internships at Undergraduate and Master levels (mandatory in these curricula), as well as PhD and Post-doc positions. These laboratories also organise regular or unique training sessions for their members, on specific accelerator topics.



## Germany



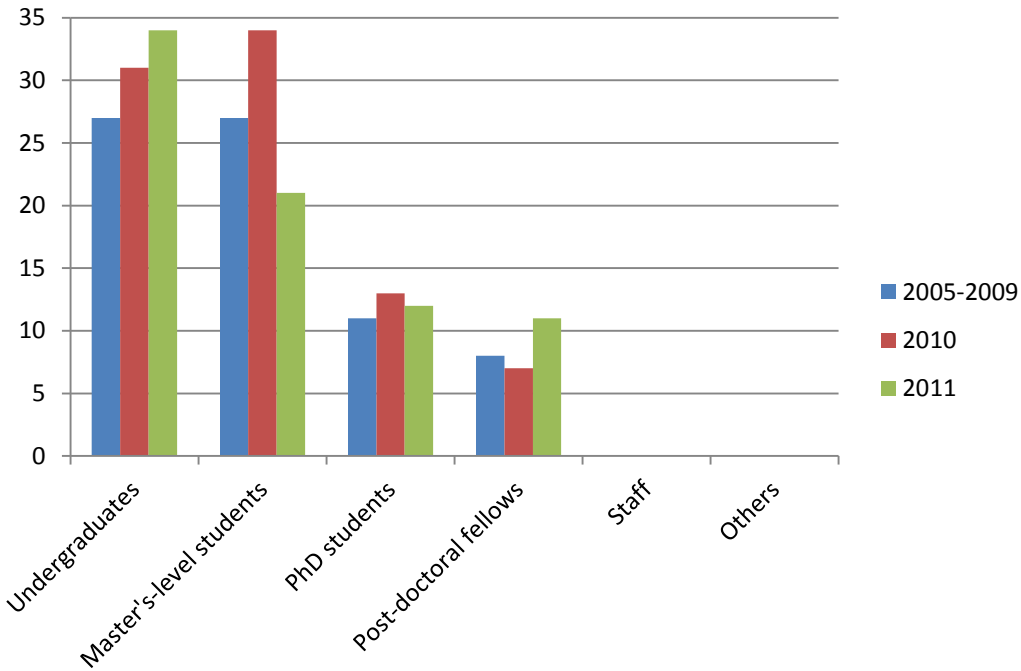
The numbers shown in Figure 2.1 included national accelerator laboratories (labs) and universities. Only universities contribute to the official education for bachelor and master students and only the universities can award bachelor, master's and PhD degrees. In recent years, most of the German universities have changed from the diploma system to the bachelor and master's systems, however some students will still obtain a diploma degree. At some of the German technical universities (TUs) the diploma degree can again be obtained. For the education in accelerator physics the universities have close collaborations with nearby labs or they have their own accelerator facilities on site. University professors, and in some cases scientists from the labs, hold lectures in accelerator physics at the universities for undergraduates and master's-level students. The labs offer practical training in terms of student trainees for bachelor and master's students. In addition the students can perform their bachelor, master's or PhD work in the labs' departments, guided by a university professor and a local supervisor. The duration of a master's thesis is between half and one year and between 3-5 years for a PhD thesis.

The labs and the universities both train their technical staff that operates their accelerators. In Germany 636 staff members (Figures 2.2 and 3.1) are engaged in accelerator science activities. 300 physicist and engineers working in accelerator physics and technology are employed at DESY, 120 at GSI, 50 at the IKP (FZ Jülich) and 166 at the universities. German professors and lab scientists participate in the training at universities and in the international schools (CAS, JUAS). Figure 4.1 shows a smaller number of PhD students compared to the number of master's students, which can be explained by the excellent job market in Germany for physicists and engineers with a master's degree.

Figure 5.1 includes the numbers for students (~210 per year) and technical staff (~120 per year). Most of the lectures are for undergraduates (~80 per year) and master's students (~75 per year). PhD students (~65 per year) use most of their time to work on their research project and spend much less time in training programmes. To support a more structured PhD education, in particular for research projects associated with the labs, graduate schools were established at some universities. They provide mandatory training in the form of block seminars (one block of up to one week). The PhD students receive training in accelerator physics, related physics fields

and soft skills organized by the graduate schools (typically 2-3 seminars per year, ~20 people). In addition the German universities and the labs send their PhD students and postdocs to the international accelerator schools.

## Italy



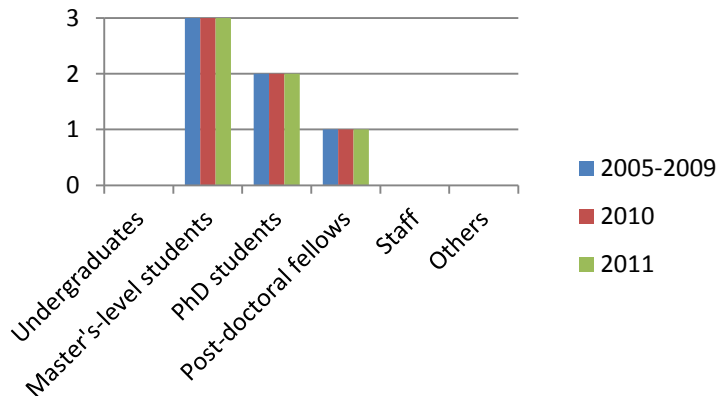
In contrast with the trend of other countries (Fig. 4.3), the number of Italian undergraduate students trained in accelerator physics exhibits a remarkable increase between 2005 and 2011.

On the other hand it should be noticed that no staff were trained in the surveyed period, in striking contrast to what happens in other countries like France or Germany, and in contrast with the average of 6% of scientific staff being trained every year. This is partially due to the ageing of the personnel. In recent years, due to a generalized recruitment freeze, in Italy very few people were hired.

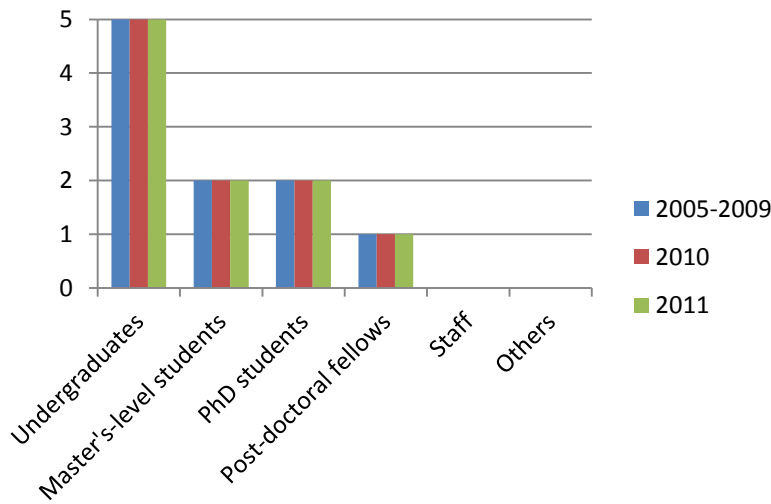
It is difficult for Italian students to profit from the CERN doctoral program. In Italy, the access to the doctoral program and its structure is such that in most cases it has little compatibility with the CERN doctoral program.

Furthermore, most of the Italian universities do not participate in the ECTS scheme, to the detriment of the internationalization of education.

## Netherlands



## Norway



In Norway, only one university—the University of Oslo—is offering education within the field of accelerator science.

At Master's-level, this teaching is limited to parts of a course and only technical students at CERN spend any extended time on accelerator science issues. Also, at PhD level, the activities are linked to CERN where some students carry out their projects there, following courses in Norway. The total number of students and faculty within this field is low, with about 5 new students at master level and 2 new students at doctoral level every year.

A dedicated faculty position will be opened in 2013 for an accelerator physicist, opening for an improved accelerator science programme.

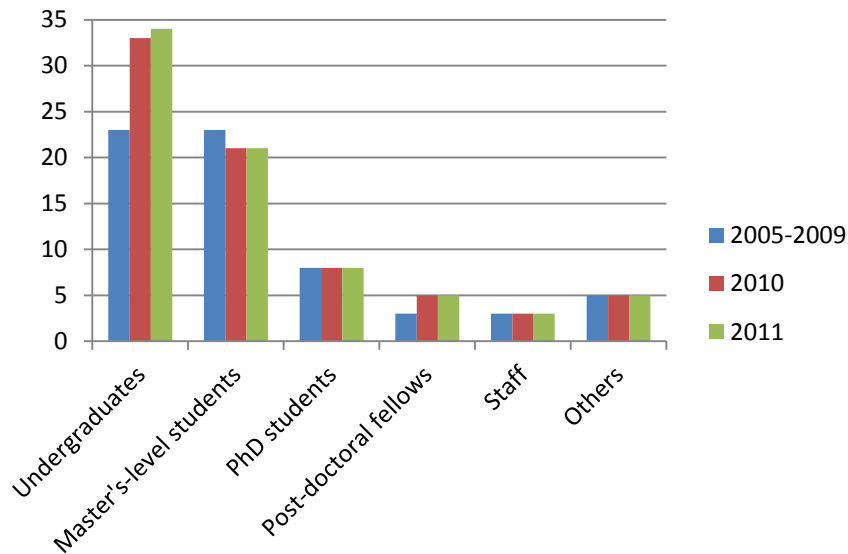
The accelerator infrastructure at the University is limited with only one cyclotron. The Oslo Cyclotron Laboratory (OCL) houses the only accelerator in Norway. The laboratory serves as an experimental centre for various fields of research and applications. The main field of research is

within nuclear physics and nuclear chemistry. In addition, isotopes are produced for nuclear medicine. Accelerator physics projects are generally not carried out there.

Since the infrastructure at the university is limited most of the doctoral students and faculty works on projects related to CERN or other accelerators outside Norway.

There are no companies in Norway which specialise in delivering accelerator components.

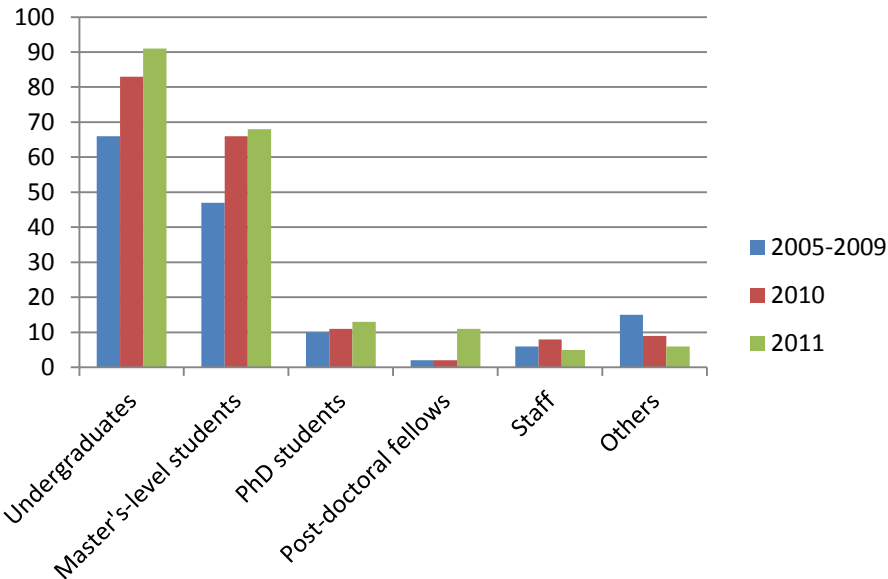
## Poland



Looking at the WP5 survey results for Poland, one can formulate the following brief remarks:

1. There are almost no regular university courses on accelerator physics.
2. There is considerable engagement of technical universities and research institutes in acceleration techniques (mechanical constructions, control systems, cryogenics).
3. Accelerator schools play a fundamental role, particularly CAS.
4. There are large groups of engineers and technicians with long-term experience in accelerator maintenance and R&D (in INP Krakow, UST Krakow, NCBJ).
5. Local schools and workshops play a considerable role— oriented on accelerator techniques rather than on accelerator physics itself.

## Spain



### Introduction

From an historical point of view, academic education at University level was built in the 1970's around the main branches of Theoretical Physics, Applied Physics, and other derived fields, such as Meteorology, Electronics & Computing, and Material Science, which have evolved into their own disciplines.

These subjects subsequently evolved, and have given rise to various specialized Degrees in Physics and Engineering. They now provide an excellent base for education in Accelerator Physics.

### Physics Accelerator Infrastructures

The Spanish commitment to the field and its development has been an intense and lengthy effort in the past decade. It has culminated on the current on-line facilities of ALBA CELLS (third generation Synchrotron Light Facility, 3GeV), CMAM (Tandem 5MV, Crockcroft-walton), CNA (Tandem 3MV Peletron, and 1MV Crockcoft-Walton). Much effort has been focused into various projects, to develop and construct two superconducting Linacs in Bilbao and Huelva, a superconducting cyclotron at CIEMAT, and an electron race-track microtron (6, 8, 10, 12 MeV) at UPC.



Figure 1: Accelerator infrastructure in Spain

### Framework for Higher Education Qualifications

Spanish Universities have recently had to adapt to the EU agreement regarding the framework of qualifications for European Higher Education, as outlined in the Bergen Declaration of 2005. Under such provisions, the Degrees in Physics have been adapted to three cycles of higher education qualification. These are defined in terms of qualifications and European Credit Transfer and Accumulation System (ECTS) credits:

- 1<sup>st</sup> cycle: Bachelor in Science (B.Sc.) 4 years, generic approach
- 2<sup>nd</sup> cycle: Master in Science (M.Sc.) 1/2 years, specialized
- 3<sup>rd</sup> cycle: Doctor of Philosophy in Science, 3 /4 years.

#### First cycle qualification: Bachelor in Science

As the B.Sc. Degree is based on a generic approach, students are encouraged to enter the field via summer schools, etc... In some Universities, an effort is made to introduce Accelerator Physics at the B. Sc. level, providing students with a choice of subjects, such as “Synchrotron Engineering” (UPC) and “Applied Techniques of Particle Accelerators” (UPC), within the engineering field.

Degree students have the option to enroll in European summer schools at CERN, DESY, GSI, etc. They can also take part in Erasmus intensive programs, in order to get hands-on experience in IBA, photon and hyperfine techniques.

In addition to Bachelor Degrees, some Spanish institutions offer training with the possibility of writing a Bachelor thesis.

### **Second cycle qualification: Master in Science**

There is only one Master's degree in Spain devoted entirely to accelerator physics:

**Master:** "Synchrotron Radiation and particles accelerators"

**Offered by:** Universidad Autónoma de Barcelona (UAB), Universidad Politécnica de Cataluña (UPC), ALBA CELLS.

**Duration:** 60 ECTS.

Along with Degree level syllabuses, several Masters contain subjects which familiarize students with problems and methodologies related to accelerators and other similar installations.

**Master:** "R&D of industrial technology"

**Offered by:** Universidad Nacional de Educación a Distancia (UNED)

**Subjects:**

- *Safety and environment impact of nuclear fusion facilities:* Research on irradiation sources for material development and production, especially those with low activation levels. Within this context the IFMIF facility is presented, its goals and the foundations laid by IFMIF on both Security and Radiation Protection studies.
- *Technologies for nuclear waste managements and disposal:* Study on the technology of transmutation systems using accelerators is emphasized. In this subject students are introduced to accelerators as main components of these systems, their function within and the computational tools created to describe both interaction and transport of particles and the intended transmutation.

**Master:** "Nuclear engineering"

**Offered by:** Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Universidad Autónoma de Madrid.

**Subjects:**

- Technology of particle accelerators

**Master:** "Technology and nuclear instrumentation"

**Offered by:** Universidad de Huelva (HU).

**Subjects:**

- Technology of particle accelerators
- Control and instrumentation

**Master:** “Physics engineering” (next year)

**Offered by:** Universidad del Pais Vasco/Euskal Herriko Uniberstsitea (UPC/EHU), European Spallation Source of Bilbao (ESS- Bilbao)

Subjects:

- Control and instrumentation for particle accelerators
- Components and power systems for particle accelerators.
- Neutron techniques
- Industrial, medical and research facilities.
- Radiation protection in particle accelerators.

### **Third cycle qualification: Philosophical Doctor of Science**

Some Spanish research institutes offer PhD training: ALBA CELLS, Universidad Nacional de Educación a Distancia (UNED), Universidad Politécnica de Cataluña (UPC), Universidad de Valencia (UV, Instituto de Física Corpuscular, IFIC), European Spallation Source of Bilbao (ESS-Bilbao), Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT).

### **Other accelerator training**

Further specialization is provided thanks to the enormous effort of the Spanish government financing scholarships to do training in some interesting accelerator physics topics on the framework of the program of specialization on scientific facilities and international organism. Some examples are shown in the next table.

International Institute	Project
CERN	Cryogenics for linear research facility of Huelva
CERN	ECR ion source for linear research facility of Huelva
CERN	Beam dynamics and magnet design.
CERN	Beam dynamics for linear research facility of Huelva
ESRF	Control systems for light synchrotron light
ESRF	Scientific instrumentation in the field of synchrotron radiation
ITER	Integration and development of diagnostics systems
ILL	Design of Neutron beam-lines infrastructures

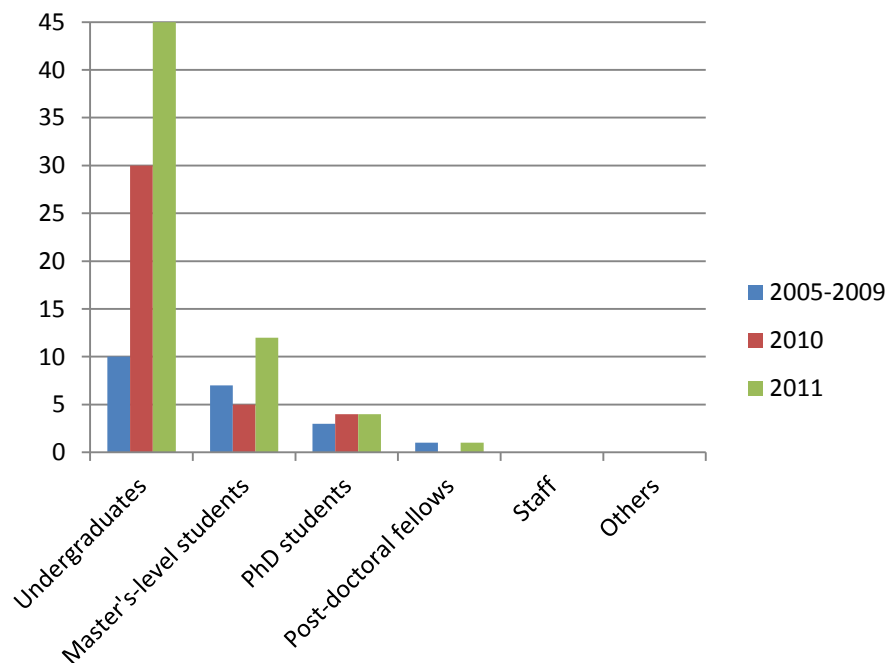
Contribution of Spanish universities, UPC, UV and UAB to Joint Universities Accelerator School, JUAS.

ALBA CELLS has activities of training and transfer of knowledge between research centres, mainly in these 3 areas:

- Accelerators
- Lines/experiments of synchrotron light
- Other tasks, like computing



## Sweden



Accelerator research and training in Sweden has taken and is taking place in several places including the Universities in Stockholm, Uppsala and Lund and additionally at Royal Institute of Technology. Two very major accelerator laboratories are presently being built in Sweden, both in Lund; namely the world's most intense neutron source, the European Spallation Source, and the world's brightest synchrotron radiation light source, the MAX IV project.

At Stockholm University, the accelerator scientists originate mainly from the former National Laboratory "Manne Siegbahn Laboratory", where an ion storage ring for atomic physics, CRYRING, was operated for many years; this machine will now be included in the FAIR project at GSI. A new cryogenic storage ring, DESIREE, is presently close to completion. The accelerator physicists count up to around 10 people.

At Uppsala University, the accelerator scientists originate mainly from the former The Svedberg Laboratory, which is now closed. A cyclotron facility is still operating, to be closed down when the proton therapy facility becomes operational. A tandem accelerator is also still operating. In addition, Uppsala University has invested in RF test facilities for the European Spallation Source in Lund. Around 10 accelerator physicists and engineers are working at the university. A course in Accelerator physics is regularly given on under graduate level and PhD students study Accelerator physics.

At Lund University, several electron accelerators have been built over the years at the so called MAX IV laboratory (former MAX-lab). Formal training and teaching has been ongoing for many years in accelerator physics and technology. A large number of students have been trained and obtained their degrees at all levels. Recently a new set of educations have started: a Bachelor program in "Science with photons and neutrons", a Master program in "Synchrotron radiation based sciences" and a specialization at the Lund Institute of Technology (LTH) in "Accelerators

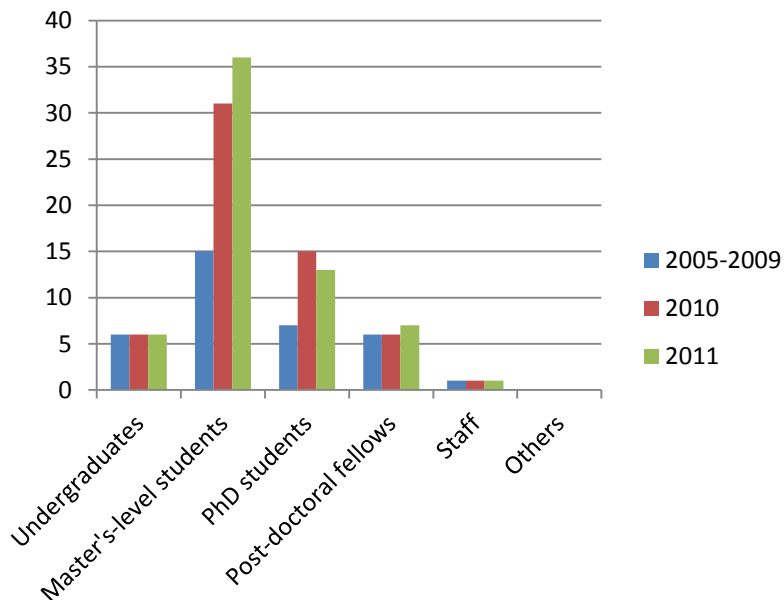
- physics and technology”. In 2011 the construction of the MAX IV project started. At present 10 PhDs in accelerator physics are working at the laboratory. In addition there are around 5 PhD students and more than 10 scientists and engineers working closely with accelerator technology. These numbers include the staff at Lund University. The design team for the Polish light source, SOLARIS, has placed five accelerator scientists at the MAX laboratory.

Recently, it was decided to locate the European Spallation Source, a very major accelerator facility, in Lund in Sweden. Already now more than 100 persons are employed, to increase to maybe 400 in a few years. A significant fraction of these will be accelerator physicists, at present maybe 20 increasing to maybe 40 in the next years.

The Royal Institute of Technology in Stockholm had for many years their own accelerators including staffs for research and development. These facilities have now closed down, but basic training is apparently still taking place, although this was not included in the present survey.

Finally, we mention a couple of companies delivering accelerator products exist in Sweden, namely Scanditronix Magnets and ScandiNova.

## Switzerland

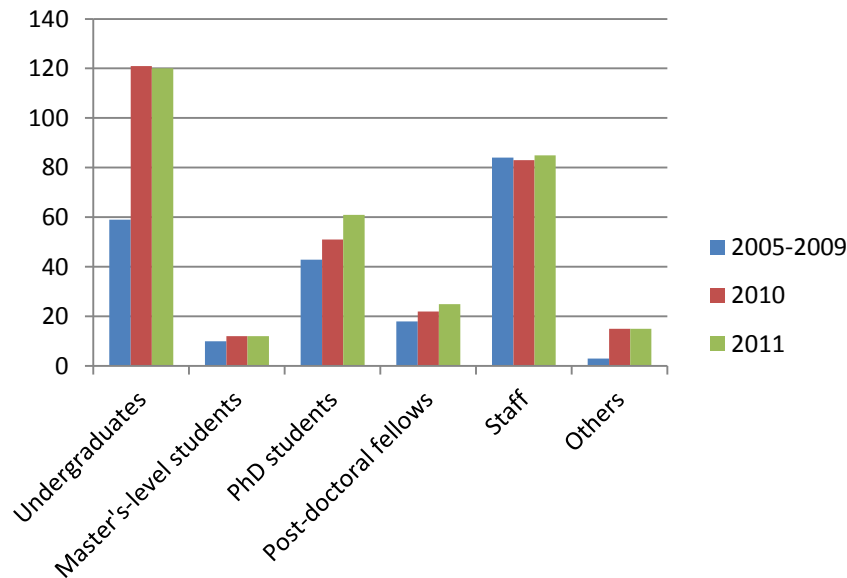


Accelerator science teaching and training in Switzerland is concentrated around the two large centres, CERN and PSI.

In 2004, the Swiss Federal Institute of Technology in Lausanne (EPFL) and Paul Scherrer Institute (PSI) jointly created a chair for accelerator physics. The Particle Accelerator Physics Laboratory (LPAP) offers courses on accelerator physics at Master and Doctoral level. Master students are given an opportunity to have practical training and Master’s thesis projects based at CERN and PSI.

CERN Doctoral Students program is a very important resource supporting PhD study, working closely with European universities, and in particular, with EPFL.

## United Kingdom



The United Kingdom operates large accelerator facilities at the Rutherford Appleton Laboratory and Daresbury Laboratory sites. The largest of the facilities are the ISIS spallation neutron source and the Diamond Light Source. Several universities also have local accelerator R&D facilities.

A major new initiative in accelerator science was launched approximately 10 years ago with two main aims: 1) investment in R&D in accelerator science in key areas of interest to the UK community; 2) regeneration of accelerator science as an academic training discipline in the UK.

Two new university-based institutes, the John Adams Institute (Oxford University and Royal Holloway, University of London) and the Cockcroft Institute (Lancaster, Liverpool and Manchester Universities) were formed with the explicit task of rejuvenating formal training in accelerator science. Both institutes have set up training programmes at the undergraduate, master's and PhD levels. In addition, a number of other universities (see Appendix 1) have started their own academic training programmes. This national initiative, combined with the funding of R&D programmes that provide opportunities for PhD students and post-doctoral fellows to work on research projects, accounts for the increase in the numbers of UK trainees during the survey period.

## ***APPENDIX 4: CAS statistics***

The CERN Accelerator School holds training courses for physicists and engineers twice per year. The courses take place in conference centres in different member states of CERN and consist of a programme of lectures and tutorials spread over a period of two weeks. Participants are welcome from member states of CERN and other countries world-wide.

The present pattern is to hold a course in the spring on a specialist topic, and a course on general accelerator physics in the autumn. The general course is at an introductory level in even years and at an advanced level in odd years. Average attendance at a school is around 100 students; in some schools the participation has to be limited. Each school provides some 50 hours of teaching.

More details can be found at <https://cas.web.cern.ch/cas/>

A summary of the CAS student institute national affiliations, and student nationalities, is given in the tables below for schools between 2006 and 2010.

Student Home Institute Country at CERN Accelerator Schools 2006 to 2010													
	Total	%	Average/yr	Poland06	Spain06	UK07	Sweden07	Italy07	France08	Germany09	Belgium09	Bulgaria 10	Denmark10
	952												
SWITZERLAND	320	33.6	64	44	22	29	29	51	24	26	16	42	37
GERMANY	190	20.0	38	14	20	14	27	14	19	16	14	35	17
UNITED KINGDOM	101	10.6	20.2	22	3	11	4	14	10	13	13	3	8
FRANCE	72	7.6	14.4	12	4	7	3	6	16	2	7	6	9
ITALY	59	6.2	11.8	3	7	6	11	8	3	4	7	6	4
SPAIN	44	4.6	8.8	4	13	5	1	6	7	0	3	1	4
UNITED STATES	18	1.9	3.6	1	8	0	1	0	3	0	3	1	1
POLAND	14	1.5	2.8	4	1	0	3	0	1	0	0	2	3
DENMARK	13	1.4	2.6	4	1	0	2	2	2	0	2	0	0
SWEDEN	13	1.4	2.6	0	5	0	1	0	0	0	1	4	2
RUSSIA	12	1.3	2.4	2	1	0	3	0	3	2	0	0	1
CANADA	10	1.1	2	1	1	0	0	1	2	1	0	1	3
AUSTRALIA	8	0.8	1.6	0	0	0	0	2	3	0	0	1	2
BELGIUM	8	0.8	1.6	0	0	0	0	1	1	1	3	2	0
TAIWAN	7	0.7	1.4	0	2	0	3	0	0	0	2	0	0
TURKEY	6	0.6	1.2	1	0	1	0	2	1	0	0	1	0
INDIA	6	0.6	1.2	1	1	0	0	0	1	0	2	0	1
SLOVENIA	6	0.6	1.2	1	0	0	2	0	1	0	0	0	2
CZECH REPUBLIC	4	0.4	0.8	0	0	1	2	0	1	0	0	0	0
NETHERLANDS	4	0.4	0.8	0	0	0	2	1	1	0	0	0	0
AUSTRIA	4	0.4	0.8	0	0	0	0	1	1	0	2	0	0
PORTUGAL	3	0.3	0.6	0	1	0	0	2	0	0	0	0	0
BULGARIA	3	0.3	0.6	0	0	1	0	0	0	0	0	2	0
IRAN	3	0.3	0.6	0	0	3	0	0	0	0	0	0	0
JAPAN	3	0.3	0.6	0	0	0	1	0	1	0	0	0	1
UKRAINE	2	0.2	0.4	1	0	0	0	0	0	0	0	1	0
FINLAND	2	0.2	0.4	0	0	2	0	0	0	0	0	0	0
KOREA	2	0.2	0.4	0	0	0	0	0	0	0	0	0	2
GREECE	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
HUNGARY	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
JORDAN	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
BRAZIL	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0
SOUTH AFRICA	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0
LITHUANIA	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
ARMENIA	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
CHINA	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
UZBEKISTAN	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0
SUDAN	1	0.1	0.2	0	0	0	0	0	1	0	0	0	0
NORWAY	1	0.1	0.2	0	0	0	0	0	1	0	0	0	0
MEXICO	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0
MALAYSIA	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0
VIETNAM	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0
KENYA	1	0.1	0.2	0	0	0	0	0	0	0	0	0	1
43	952	100	190.4										

Student Nationality Distribution at CERN Accelerator Schools 2006 to 2010														
	Total	%	average/yr	Poland06	Spain06	UK07	Sweden07	Italy07	France08	Germany09	Belgium09	Bulgaria10	Denmark10	
	930													
German	169	18.2	33.8	14	18	11	20	16	19	17	14	22	18	
French	122	13.1	24.4	21	13	10	13	10	18	5	7	10	15	
Italian	120	12.9	24	10	10	15	12	19	8	6	11	16	13	
British	77	8.3	15.4	16	3	5	4	17	6	8	10	3	5	
Spanish	72	7.7	14.4	8	14	6	4	8	11	3	5	6	7	
Polish	33	3.5	6.6	6	1	0	9	4	3	2	1	4	3	
Swiss	30	3.2	6	2	1	3	5	5	4	0	1	4	5	
Austrian	26	2.8	5.2	5	0	4	1	2	3	4	2	2	3	
Belgian	26	2.8	5.2	3	4	3	0	4	3	1	5	3	0	
Russian	22	2.4	4.4	4	2	2	4	2	3	2	0	1	2	
Danish	14	1.5	2.8	3	1	0	2	2	2	1	2	1	0	
American	14	1.5	2.8	1	5	0	2	0	3	0	3	0	0	
Swedish	14	1.5	2.8	1	5	0	2	0	0	0	2	1	3	
Canadian	13	1.4	2.6	2	1	1	0	1	2	1	1	2	2	
Dutch	13	1.4	2.6	2	2	0	4	0	2	0	3	0	0	
Indian	12	1.3	2.4	1	1	1	0	0	2	0	2	2	3	
Chinese	12	1.3	2.4	1	1	0	0	2	0	3	0	2	3	
Greek	11	1.2	2.2	3	1	1	0	2	0	2	0	0	2	
Portuguese	9	1.0	1.8	3	2	0	0	3	0	0	1	0	0	
Turkish	9	1.0	1.8	1	0	1	1	2	2	1	0	1	0	
Australian	9	1.0	1.8	0	0	1	0	2	2	1	0	1	2	
Ukrainian	7	0.8	1.4	1	1	0	0	1	0	0	0	3	1	
Taiwan	7	0.8	1.4	0	2	0	3	0	0	0	2	0	0	
Iranian	7	0.8	1.4	0	0	3	0	0	0	0	1	2	1	
Romanian	7	0.8	1.4	1	0	1	0	0	1	0	0	2	2	
Czech	6	0.6	1.2	0	0	1	3	0	1	0	0	1	0	
Bulgarian	5	0.5	1	1	0	1	0	0	0	0	1	2	0	
Norwegian	5	0.5	1	0	0	1	0	1	1	1	0	1	0	
Japanese	5	0.5	1	0	0	0	1	0	1	0	1	1	1	
Slovenian	4	0.4	0.8	1	0	0	1	0	0	0	0	0	2	
Hungarian	4	0.4	0.8	1	1	1	0	0	0	0	0	0	1	
Irish	4	0.4	0.8	1	0	1	1	0	0	0	0	1	0	
Slovak	3	0.3	0.6	1	0	0	0	0	1	0	0	1	0	
New Zealand	3	0.3	0.6	0	0	2	0	0	1	0	0	0	0	
Finnish	3	0.3	0.6	0	0	2	0	1	0	0	0	0	0	
Armenian	3	0.3	0.6	0	0	1	0	1	0	1	0	0	0	
South Korean	3	0.3	0.6	0	0	0	0	0	0	0	0	1	2	
Pakistani	2	0.2	0.4	0	0	1	0	0	0	0	0	1	0	
Thai	2	0.2	0.4	0	0	0	0	2	0	0	0	0	0	
Cypriot	2	0.2	0.4	0	0	0	0	0	0	1	0	1	0	
Mexican	2	0.2	0.4	0	0	0	0	0	0	1	0	1	0	
Macedonian	1	0.1	0.2	1	0	0	0	0	0	0	0	0	0	
Jordanian	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0	
Brazilian	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0	
Moroccan	1	0.1	0.2	0	1	0	0	0	0	0	0	0	0	
Singapore	1	0.1	0.2	0	0	1	0	0	0	0	0	0	0	
Paruvian	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0	
Argentinian	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0	
South African	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0	
Serbian	1	0.1	0.2	0	0	0	1	0	0	0	0	0	0	
Lithuanian	1	0.1	0.2	0	0	0	0	1	0	0	0	0	0	
Sudanese	1	0.1	0.2	0	0	0	0	0	1	0	0	0	0	
Malaysian	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0	
Nigerian	1	0.1	0.2	0	0	0	0	0	0	1	0	0	0	
Vietnam	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0	
Colombian	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0	
Filipino	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0	
Lebanese	1	0.1	0.2	0	0	0	0	0	0	0	0	1	0	
Kenyan	1	0.1	0.2	0	0	0	0	0	0	0	0	0	1	
Tunisian	1	0.1	0.2	0	0	0	0	0	0	0	0	0	1	
	60	930	100	186	115	92	80	96	108	100	63	75	103	98

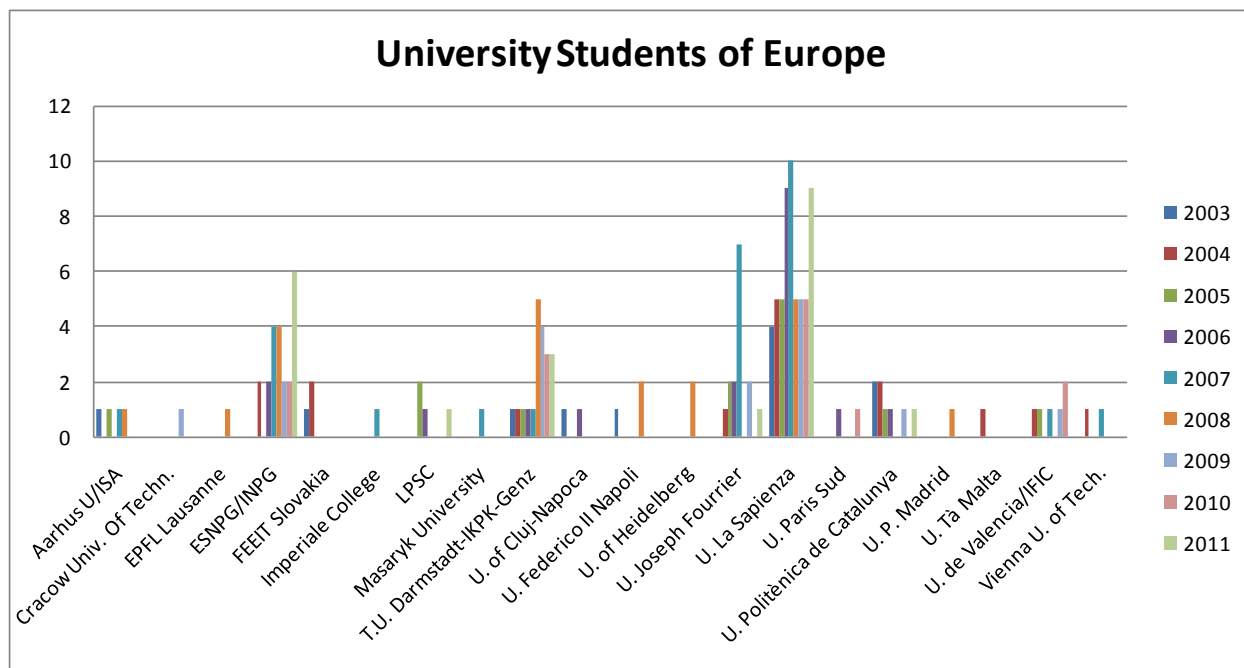
## APPENDIX 5: JUAS statistics

The Joint Universities Accelerator School holds training courses for Master’s students, PhD students and engineers once per year. The courses take place in the “Centre Universitaire”-Archamps (Haute-Savoie) in France, 15km from CERN. They consist of a programme of lectures and tutorials spread over a period of 10 weeks. Participants are welcome from European universities, European Institutes and other countries world-wide.

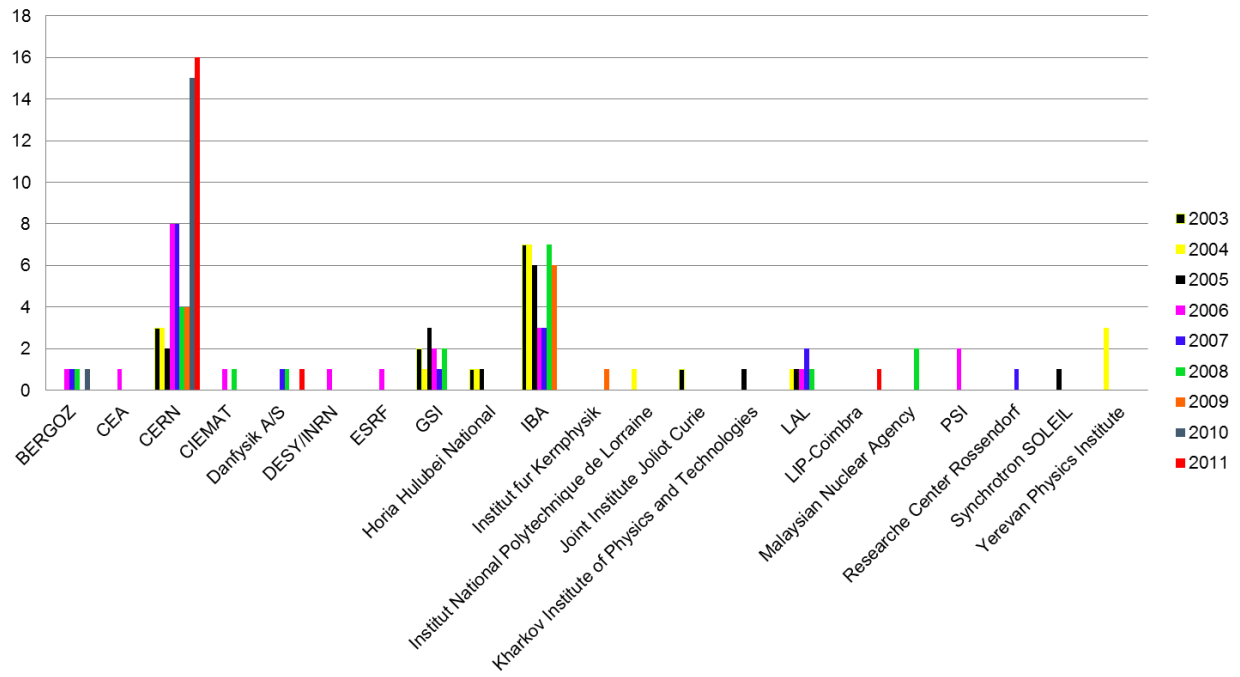
The first course “Sciences & Physics of Particle Accelerators” runs, each year, at the beginning of January followed by the second one “Technology & Applications of Particle Accelerators”. Students could present examinations at the end of each course and could obtain a total of 20 ECTS (European Credit Transfer System) credits, recognised by the 14 European university partners of JUAS.

The first figure below shows universities students who have followed JUAS courses between 2003 and 2011; the second figure shows the number of students coming from the various European laboratories and institutes for the same period. In 2012, there were 60 students coming from 22 different countries world-wide. Presently more than 800 students have followed JUAS courses since 1994.

The JUAS web site at <http://cern.ch/juas> provides more details.



## Students of Europe





## **APPENDIX 6: NATIONAL AND INTERNATIONAL FACILITIES**

The following facilities were reported as being used for provision of training. Where they were identified in the survey, specific projects at the respective facility are listed in brackets.

### **Finland**

Jyvaskyla University

### **France**

CEA/DSM/IRFU/SACM

CNRS/IN2P3/LPSC

ESRF

GANIL/CEA/CNRS

### **Germany**

DESY (FLASH, PETRA III, DORIS III)

GSI (UNILAC, SIS, ESR)

FZ Jülich (COSY)

Helmholtz-Zentrum Berlin (BESSY-II, HoBiCaT, MLS)

TU Darmstadt (S-DALINAC)

TU Dortmund (DELTA)

Universität Mainz (MAMI-C)

### **Italy**

CNAO (hadron therapy facility)

ENEA (proton and electron linacs)

INFN-LNF (DAFNE, SPARC, BTF)

INFN-LNS (Tandem Van der Graaf, superconducting cyclotron, ECR ion sources)

Università di Napoli (Tandem)

## **Japan**

J-PARC

KEK

UVSOR

## **Poland**

IPJ

Warsaw Heavy Ion Cyclotron

## **Spain**

ALBA

## **Sweden**

Lund (MAX-lab)

## **Switzerland**

CERN

PSI

## **United Kingdom**

Daresbury Laboratory (ALICE, EMMA)

RAL (Diamond, FETS, ISIS, MICE)

Strathclyde University

Surrey Ion Beam Centre

## **United States**

ANL

FNAL

SLAC (FACET, LCLS)

UCLA

## **Increasing the Recognition of Accelerator Science in Academia**

**Comments Submitted by Richard Temkin, MIT**

**Senior Scientist, Dept. of Physics**

**Associate Director, Plasma Science and Fusion Center**

**June, 2015**

1. Does your institution regard accelerator science as an academic discipline? Why or why not?

**Accelerator physics research is conducted by specific individual research groups. Graduate and undergraduate students play an important role in this research.**

2. If your institution offers graduate training in accelerator science:

a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)

**Our graduate students take graduate courses in plasma physics and in nuclear physics. They supplement their university course work by attending the US Particle Accelerator School (USPAS). Students usually attend USPAS two times in order to take a wide range of courses in accelerator physics. USPAS is an excellent substitute for the lack of on-campus courses in accelerator physics.**

b. How often do students change fields to study accelerator science? From which fields do these students typically come?

c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments?

**Most students are from the Physics Department or the Nuclear Science and Engineering Dept.**

d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?

e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?

**There is an on-campus accelerator dedicated to accelerator R&D supported by DOE HEP. We also collaborate with US national laboratories, including SLAC and LANL.**

f. How often do collaborations occur between accelerator science and other programs at the university?

g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program?

**There is no corporate sponsorship but there is corporate recruitment.**

3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?

4. What funding sources for accelerator science are you aware of?

**Only DOE HEP**

### **Integrating the Roles of the Universities and the U.S. National Laboratories**

5. How can the national laboratory system be best utilized by the university accelerator science community?

**The national labs can provide time on their unique accelerator test and research facilities for students to conduct accelerator physics experiments.**

6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?

**Barriers are a major issue. One obstacle is that many students do not want to relocate to a national lab for an extended time period. They like the intellectual and social atmosphere on campus. Another issue is the cost and time for travel. The integration of the national lab and campus research is another barrier, especially in terms of safety concerns. One very positive aspect is that the national labs appreciate having the student visitors.**

7. Does your university accept accelerator course credits from other institutions?

8. Do accelerator science students at your institution routinely take courses and training elsewhere?

**The US Particle Accelerator School (USPAS) has been an enormous asset in training students in accelerator physics. Our students benefit greatly from the courses and have fun attending USPAS. Most students attend two times to take a variety of courses. USPAS has been extremely helpful in training students in accelerator physics and should be supported very strongly.**

9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?

10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?

### **Contemporary Models of University Accelerator Science**

11. What examples exist of thriving academic accelerator science programs?

a. Are there policies at your university specific to the accelerator science program that are essential to its success?

**Our university has made available high quality laboratory space for our accelerator laboratory. Because of the need for shielding, space is a major issue in siting an accelerator laboratory. Without a space capable of holding the required three feet of concrete shielding and an overhead crane, we would not have an accelerator laboratory.**

b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?

c. Are there barriers to having accelerator scientists serve as PI or Co-I on proposals?

d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded?

e. Are there specific attributes of the institution's culture that contribute to the success of the accelerator science program?

f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?

12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)-(f) above).

13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)-(f) above).

### **Possible Mechanisms To Encourage Academic Accelerator Science**

14. What specific, cost-effective actions could be taken to:

a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.

b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.

c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials.

**The US has to take the lead role in building a new, large scale accelerator, such as an ILC. Otherwise, top students in the US will not be inspired to choose a career in accelerator science. Top students do not want to enter a field in which the leadership role will always be in Europe or Asia.**

d. Increase the enrollment in education opportunities at the baccalaureate and master's level?

e. Increase the availability of hands-on training opportunities in accelerator technology?

### **Other Factors**

15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?

16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?

## Colby, Eric

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**From:** John Madey <kingcrab@hawaii.rr.com>  
**Sent:** Thursday, June 11, 2015 6:02 AM  
**To:** Academic Accelerator Science RFI  
**Subject:** Academic Accelerator Science RFI Comments

This is to respond to the DoE's request for comments of 05/14/2015 regarding academic R&D and workforce training in accelerator science.

My responses are organized to match the numbering system employed in the DoE's email of 05/14/2015.

1. Recognition of Accelerator Science as an Academic Discipline:  
although no undergraduate or graduate degrees are issued at UH under this category, students receiving training in accelerator science and technology are eligible for degrees issued by the Physics and/or Electrical Engineering Departments
2. a. the core curriculum includes undergraduate and graduate electrodynamics, advanced calculus including differential and integral equations and numerical methods, and laboratory research training in accelerator systems design and operation and radiation safety.
2. b. not aware of any students changing fields, although the lack of funding for training in accelerator science and technology has surely discouraged a number of students from entering this field
2. c. primary affiliation: physics department
2. d. evidence of DoE interest in supporting the research and training in accelerator R&D provided by the Department's existing faculty
2. e. yes. An advanced, high brightness, high peak current 45 MeV electron linac system
2. f. there are frequent opportunities for collaboration, particularly in the areas of remote sensing and instrumentation for advanced HEP experimental programs
2. g. Although a number of our graduates have ended up working for private companies with interests in accelerator R&D, this has not been an area specifically supported by UH
3. Program has not been terminated to date, though it certainly seems threatened by the inexplicable absence of recognition or support from the DoE. The conclusion here is that the DoE's expressions of support for academic training in accelerator science and technology are simply empty posturing without any real commitment to support our efforts here in Hawaii
4. The primary opportunities for funding in accelerator science and technology are through programs seeking research in the applications of accelerator-based science and technology
5. We have proposed to set up visiting appointments by some of the leading researchers at the national labs here in the US, in Europe and Asia to provide our students with first hand accounts of the research underway at these locations, but our proposals for this effort were dismissed by the reviewers of our proposals without comment.
6. Absence of recognition by the national labs of our contributions to



accelerator science and technology, and to workforce training. It would appear in general; that our relationship is more nearly adversarial than supportive.

7. Probably. Never had the need to check

8. No, as noted above, our efforts to secure the funds needed for such training were dismissed without comment by the reviewers of our proposals to the DoE.

9. Encourage exchange of information along the lines we have proposed for improved communications between the national labs in the US, Europe and Asia and our students here at UH

10. The programmatic opportunities would be primarily through the graduate research training programs already authorized by UH

11. a. no

11. b. no

11. c. no

11. d. not an issue

11. e. not particularly

11. f. none in accelerator-related fields

12. The Physics Department already has a very strong DoE supported effort in High Energy Physics Research. It would be natural to expand this program to include a component relevant to the underlying accelerator science and technology for this effort.

13. Don't know

14. a. it would appear that one of the most effective steps that could be taken - other than actually making good on the DoE's so far empty promises of support for accelerator R&D - would be to establish a graduate fellowship program for students undertaking a course of study resulting in a degree relevant to accelerator science and technology

14. b. the only business related issue of interest to UH would be the actual availability of DoE funding for accelerator-related R&D as opposed to the current tradition of empty promises

14. c. likewise, the only step that could be taken by the DoE to increase student participation would be to make funding available for academic training in this area

14. d. Same as (c) above

14. e. Same as 5 and 14. c above

15. non-communicative or evasive behaviour on the part of the DoE's relevant program officers

16. There is simply not any compelling evidence that the DoE is seriously interested in extending the opportunities for accelerator-related R&D or training at institutions like UH despite our past transformative contributions to the field and present research capabilities. This is all most frustrating to our faculty and students.

If there is a "club" of institutions recognized by the DoE as contributing to their efforts in these fields, we are surely not members of that club nor have we ever been invited to join despite applying to do so.

At least part of the problem of which we are aware is the inbred nature of the DoE's review and advisory panels. If those panels are always staffed by representatives of the DoE's existing programs, there is obviously little chance of recognition of the programs operated by institutions who are "outside the club."

This is, of course, a problem common to many of the United States funding agencies which has, over the years, resulted in increasing levels of parochial focus in the programs funded by these agencies.

The only natural way to overcome this problem that I can identify is to increase the funding available for graduate study in accelerator science and technology with funding available directly to students at the institutions at which they choose to study. Let the students make the choice of the programs and institutions which they have concluded would best serve their long term career goals. I suspect that their choices would be far less inbred than the choices recommended by the DoE's present professional advisory panels.

Sincerely,

John M. J. Madey  
Professor of Physics and Technology

## Colby, Eric

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**From:** Justin Schwartz <Justin\_Schwartz@ncsu.edu>  
**Sent:** Friday, June 12, 2015 10:22 PM  
**To:** Academic Accelerator Science RFI  
**Subject:** Academic Accelerator Science RFI Comments

1. No -- our disciplines are the traditional ones in science & engineering. But within them our research programs overlap many of those which directly affect accelerator sci&tech.
  4. DoE HEP university program and SBIR/STTR programs (with small business partners).
  5. The DoE needs to encourage and value this from both sides (national lab and university). Are the national labs rewarded for partnering with universities? At present there are programs for national labs to house graduate students for short or long term visits, but that only helps more advanced students (post-classes) and doesn't necessarily engage the university faculty.
  6. There are no funding mechanisms to motivate it. The NSF has a GOALI program to encourage universities to work with industry. Why not create a similar mechanism to fund universities but only if there is a real national lab collaboration involved.
  7. Yes - case by case basis. It's a decision for the individual academic department.
  8. Yes - summer schools.
  10. We have a strong relationship with ORNL because we are one of the managing universities.
  12. When I was in graduate school I was supported by a DoE Fellowship to support students pursuing research related to fusion. This gave me full support (but I was at my university) and also required a 3-month practicum at a national lab. Why not create an Accelerator Science & Technology Graduate Fellowship program? You'd need to include some M&S support (helium is expensive). Some grad student conference travel support would be good too.
  14. a- yes to all examples. b - this sounds like STTR. c - yes to examples and aforementioned fellowship program.
  15. funding really is the driver.
  16. The larger national and international programs/projects (MICE, EUCARD, EUCARD2, etc.) are often "where the action is" but universities are not readily incorporated into these. Why not fund US universities to collaborate with these larger projects? The US programs often appear to be national-lab "welfare" that exclude universities, even though universities are significantly more cost-effective and are the training ground for the next generation of scientists and engineers.
- Make sure anything new that is done does not become a rich-get-richer outcome for the few well-funded universities in accel sci&tech.

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esse quam videri

*For the strength of the Pack is the Wolf, and the strength of the Wolf is the Pack.*  
--- Rudyard Kipling

**Response by Old Dominion University, Center for Accelerator Science  
to  
Notice of Request for Information (RFI)  
Office of High Energy Physics, U. S. Department of Energy  
Strengthening U. S. Academic Programs in Accelerator Science**

## **Introduction**

The Center for Accelerator Science (CAS) at Old Dominion University (ODU) was created with the support of the Thomas Jefferson National Accelerator Facility (JLab) specifically to address the lack of opportunities for education and training in the disciplines of accelerator science.

About 10 years ago JLab and ODU entered into an agreement whereby 3 senior accelerator physicists could dedicate approximately 1/3 of their time in academic activities at ODU. These include teaching, mentoring, and supervising students. These “Jefferson Lab” professors have the same rights and privileges as other professors in the Physics Department; in particular they can submit proposals to various funding agencies and supervise graduate students in their doctoral research.

Subsequently, the ODU Center for Accelerator Science was created in 2009, again with the strong support of JLab. While ODU CAS resides in the Physics Department, it is intended to be a multi-disciplinary enterprise and includes faculty from the Computer Science and Engineering Departments.

A number of new accelerator science-related courses at the undergraduate and graduate levels have been established. New ones will be created and taught in the next academic year.

So far ODU/CAS has attracted in excess of \$6M of funding from DOE (HEP and NP), NSF, and small businesses (STTRs and SBIRs). And 3 new faculty in accelerator science have been created in the Physics Department.

## **Increasing the Roles of the Universities and the U. S. National Laboratories**

### **1. Does your institution regard accelerator science as an academic discipline? Why or why not?**

In the ODU physics department accelerator science is on an equal footing with other subfields, such as nuclear or atomic physics. Since accelerator science is very interdisciplinary, it involves faculty in computer science and engineering as well as physics. Our view at ODU is that

accelerator science is an academic discipline, in the sense that it is a subfield and we offer students a PhD in physics or engineering for pursuing projects in that area.

We are in the process of creating a Masters in Accelerator Science in partnership with the US Particle Accelerator School (USPAS). Later on ODU plans on creating a PhD in Accelerator Science, again in partnership with USPAS.

**2. If your institution offers graduate training in accelerator science:**

**a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)**

At present the core curriculum is identical for all the physics students (classical mechanics and electromagnetism, quantum mechanics, statistical mechanics). Specialization in accelerator science is in the choice of elective courses (accelerator physics, classical mechanics and electromagnetism for accelerators, low temperature physics). New electives are being established and students can also use some of the courses taught at USPAS as acceptable electives.

Students in the Engineering or Computer Science Departments follow the core curriculums of those departments.

**b. How often do students change fields to study accelerator science? From which fields do these students typically come?**

Since accelerator science is not, at present a separate department but has found a place in several departments, students have not formally changed field of study. What has happened, at least in the physics department, is that some graduate students came to ODU specifically to study accelerator science, while others came without a particular field of study in mind but opted for accelerator physics at the end of their first year. Some students have switched from other areas of physics to accelerator science.

**c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments?**

It is primarily located in the physics department but some faculty and students are in the computer science and engineering departments.

**d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?**

Since the creation of CAS, ODU has hired 3 accelerator-related faculty in the physics department:

Professor and CAS director: Linear SRF accelerator physics and technology

Professor: SRF theory and material science

Assistant Professor: Accelerator physics, computer simulations.

Creation of new positions and hiring of additional faculty will, of course, be strongly dependent on the success of CAS. The main measures of success are the amount of funding received and the number of PhD students produced by the program. What would be greatly beneficial is the constant lobbying by the national laboratories and DOE stating the urgent need for expanding academic programs in accelerator science. One hurdle we have faced in starting the Center is that equipment money is difficult to come by as part of DOE or NSF grants.

**e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?**

ODU does not have a particle accelerator on site. We have designed a small light source based on inverse Compton scattering and would like to build it. So far BES has not been very receptive to the idea.

We have access to the JLab facilities and accelerator, and our students spend a significant amount of their time at JLab.

One of our students will be going to the Materials Science Department at ANL this summer to perform measurements on small samples of advanced superconductors for accelerator applications.

**f. How often do collaborations occur between accelerator science and other programs at the university?**

Our accelerator science program is multi-disciplinary and includes faculty from several departments who work on joint projects.

**g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program?**

About 1/3 of all the funding that ODU CAS has received since its creation has been from private companies through STTRs, SBIRs, or contracts. We have not sought corporate sponsorship that is not tied to a specific project.

**3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?**

NA

**4. What funding sources for accelerator science are you aware of?**

We have received funding from:

DOE HEP  
DOE NP  
NSF  
Small businesses  
We have applied to  
DOD  
NNSA

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

### **5. How can the national laboratory system be best utilized by the university accelerator science community?**

The national laboratory system itself is organized to provide access to scientists to facilities generally beyond the reach of individual universities. This feature can be their main benefit to university programs in accelerators generally: access to fore-front equipment and facilities. In order for this access to be achieved, suitable arrangements must be found to support students at the national lab during their research.

Proximity of a national lab to the university is a big advantage, but definitely not sufficient. The national labs must be encouraged and given recognition for collaborating with universities in fostering accelerator science education. The collaboration must include access to the expertise of the scientists and engineers and to the facilities that are not normally available at the universities. For example, it would be helpful if national lab staff with technical expertise could help students without concern about what project code that time should be charged to. It would be helpful if “educating students” were considered a valid project.

### **6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?**

Given the present funding models of national laboratories where every activity has to be assigned to a project and every work with or for an outside entity has to be done through a Work-for-Others or a CRADA, collaboration with a national laboratory has become extremely difficult, expensive, and time-wasting. Universities are treated in a similar way as private businesses with respect to access of facilities or personnel.

For example, it has taken several months for ODU to send a few thousand dollars from grants from DOE-HEP and DOE- NP through Work-for-Others to Jefferson lab and Fermilab for a fairly simple activity. Not only did it cost time and money to the university but the cost to the national lab in paper work probably exceeded the sums involved.



There are also instances where there is an overlap of skill and/or interest between university faculty and national laboratory staff. In a climate of tight funding there can also be reluctance on the part of the national labs to give up resources to the universities in cases where lab-internal resources can complete the sub-project without assistance. Essentially there is a danger that lab staff view academic institutions as competitors.

**7. Does your university accept accelerator course credits from other institutions?**

The case has not arisen with other universities but we give credit to some courses taken at USPAS. Several of the USPAS courses are listed in the ODU catalog.

**8. Do accelerator science students at your institution routinely take courses and training elsewhere?**

Our students routinely take courses at USPAS and ODU has hosted 2 of the USPAS sessions. ODU faculty also routinely teach at USPAS.

**9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?**

Support of academic institutions by providing access to facilities and staff should be a stated mission of the national laboratories. This would require a commitment by DOE to allocate a portion of the national laboratory resources, both intellectual and facilities, (taking into account the mission-critical operations of the laboratory), at no or low cost to supporting the activities of the students and faculty of U.S. universities.

**10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?**

JLab is presently supporting six “Jefferson Lab Professors” at ODU. They are fully supported by JLab but spend ~1/3 of their time on ODU activities.

- Three in experimental nuclear physics
- Three in accelerator science

JLab is also supporting seven joint appointments with ODU physics faculty. JLab provides half of their salary during the academic year.

- Six in theoretical nuclear physics
- One in accelerator science (CAS director)

Increasing the number of joint appointments in accelerator science would be greatly beneficial. In the area of nuclear physics, ODU faculty collaborate closely with scientific staff at Jefferson Lab. Lab staff often collaborate with university faculty on experiments and on equipment proposals (NSF MRI for example) to agencies.

## Contemporary Models of University Accelerator Science

### 11. What examples exist of thriving academic accelerator science programs?

#### a. Are there policies at your university specific to the accelerator science program that are essential to its success?

Accelerator science is considered a regular subfield of physics so no special rules are necessary, which is probably essential to its success. We are struggling now with how the Center for Accelerator Science (CAS) should be funded. There are several models and it is not clear that we have organized it in an optimal way yet at ODU. However, CAS is successful because the faculty in it are successful, which is primarily because many of those faculty have a home in physics.

#### b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?

No

#### c. Are there barriers to having accelerator scientists serve as PI or Co-I on proposals?

Accelerator scientists from Jefferson Lab can easily be appointed adjunct professors and can be Co-PI on proposals to the funding agencies. In some cases adjuncts can be PI with special permission.

All Jefferson Lab professors have the same rights and privileges as regular faculty (except that they cannot vote on tenure and promotion) and can be PI on proposals.

#### d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded?

Full faculty are only hired following an open search, so there is no process by which someone can simply “convert” to a regular faculty position. We have hired Jefferson Lab scientists into a regular tenure/tenure-track faculty position following an open search.

#### e. Are there specific attributes of the institution’s culture that contribute to the success of the accelerator science program?

ODU is somewhat entrepreneurial and can respond quickly to opportunities when they present themselves. Given the strong support by Jefferson Lab and our long-standing partnership with the lab in nuclear physics, it was natural to expand into accelerator science. That allowed us to

start CAS without too many administrative hassles. Absolutely critical to the ODU CAS was the support and encouragement of Jefferson Lab management, who see it as very important to the lab to foster a strong academic accelerator program nearby. It is important for the Lab workforce, both current and future. The Jefferson Lab accelerator division has had a strong focus on the value of education, which we hope will continue.

**f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?**

JLab is supporting seven joint appointments with ODU physics faculty. JLab provides half of their salary during the academic year.

Six in theoretical nuclear physics

One in accelerator science (CAS director)

**12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)–(f) above).**

**13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)–(f) above).**

There are two successful academic accelerator science programs in the UK.

The Cockcroft Institute is a joint venture of Lancaster University, the University of Liverpool, the University of Manchester, the Science and Technology Facilities Council, and the Northwest Regional Development Agency. It is located at Daresbury Laboratory.

The John Adams Institute of Accelerator Science is a joint venture of the University of Oxford, the Royal Holloway University of London, and the Imperial College of London.

## **Possible Mechanisms to Encourage Academic Accelerator Science**

**14. What specific, cost-effective actions could be taken to:**

**a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.**

Having grant money available for basic, curiosity-driven research that is not tied to a specific operational objective is helpful. The fact that such a program has been started at NSF is a big boost. It is not clear how much money is or will be available in this category at DOE.

Having an endowed chair in accelerator science would be great, but it is not apparent how the funding agencies can help make this happen.

It is imperative that DOE and NSF include accelerator science students, postdocs, and faculty in the eligibility requirements for prestigious awards. For example, post-doctoral fellows are not, at present, eligible for early career awards. Since faculty positions in this field are limited, including post-docs would raise the status of accelerator science.

It is also important that existing accelerator scientists publish in top, refereed physics journals. This has never been a priority in national laboratories; it is sometimes discouraged as a “waste of time”.

**b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.**

Certainly increasing grants for accelerator science faculty is very good for the bottom line and would make these faculty attractive hires. Perhaps DOE could give small starter grants to new faculty at universities with a significantly higher success rate than regular grants.

Also, our university is very interested in having more M.S. students. These students tend to be profitable for the university because they often do not get tuition waivers (whereas Ph.D. students do) and often do not require too many extra resources to educate, at least if the master's degree is mainly coursework. Certainly having industry involved and perhaps funding scholarships for students and providing internships would be a huge plus. It would also be helpful if the national labs could allow staff time away from their duties to pursue an advanced degree. One concern with the MS in accelerator science that we are pursuing in partnership with USPAS is that it is difficult for someone with a full time job at a national lab to have four weeks off per year (two USPAS schools at two weeks each) to complete the course work.

**c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials.**

Having funding available for master's and Ph.D. students to pursue advanced degrees is very important. Internships and the connection to industry are also very useful. Students are very concerned about what types of careers they can pursue with their degree. It would be helpful to have resources on this topic accessible somewhere on the web. For example, going to the AIP website and look at career options, it is hard to find something which specifically mentions accelerators.

**d. Increase the enrollment in education opportunities at the baccalaureate and master's level?**

Continuing support for USPAS is critical, even to maintain the current educational opportunities. One possibility for expanding opportunity is for USPAS to offer a semester long course that is delivered on-line. Encouraging faculty to include undergraduate research funding as part of their DOE grants is another way to encourage undergraduates.

**e. Increase the availability of hands-on training opportunities in accelerator technology?**

USPAS offers hands on training when it is taking place near a national lab. These courses are very popular and extremely valuable to the participants. Offering these courses costs real money for the national lab and it is important that this activity be preserved.

## **Other Factors**

**15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?**

As the major funder of accelerator science research, DOE should make sure that education of graduate and undergraduate students is a well thought out component of awarded grants. Another issue that may be relevant is research projects for master's students. In most fields of physics one would not use grant money to support a master's level project. It might be that in accelerator science, such support from DOE would be extremely important to increasing the attractiveness of doing a two-year master's thesis. Such students would be very valuable and do not necessarily need a Ph.D.

It is often stated that, of the approximately 30,000 particle accelerators in operation worldwide, only approximately 5% are used for research in high-energy or nuclear physics. Therefore, academic programs in accelerator science, and the support they receive from funding agencies, have to reflect this breadth of applications. If DOE, and in particular DOE-HEP, is to take the lead in supporting broad academic programs in accelerator science, it will have to be less DOE-HEP-centric that it has been in the past, at the expense of DOE-NP, DOE-BES, and all the other beneficiaries (governmental, public, and commercial) of advances in accelerator science.

**16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?**

The USPAS is absolutely critical to the ability of almost any university to offer a meaningful accelerator science program. In our case, even with three regular faculty and the Jefferson Lab professors, we cannot always offer even one course per semester that is related to accelerators. Continuing to support and strengthen USPAS is one of the most important things that DOE can do.

However, the proposed changes for the structure, operation, and funding of USPAS are quite worrisome and risk endangering what has been a successful academic program. Treating USPAS as a DOE-HEP lab entity and project will reinforce the HEP-centric vision of accelerator science and will reduce its effectiveness as one of the main means of educating the next generation of accelerator scientists and engineers. Again, accelerator science is much broader than high energy physics, and, more generally, the applications of accelerators outside the scientific establishment will probably grow more than within. Elevating USPAS as a DOE-OS level entity, with strong involvement of and participation from other agencies (NSF, NNSA, DOD, etc) would strengthen academic accelerator science. Alternatively, if the goal really is to have a strong U. S. academic accelerator science program, USPAS could be a university-based NSF funded program with support from other agencies.

June 18, 2015

## **Fermilab Programs in Accelerator Training and Education**

*Prepared in response to DOE/OHEP RFI on*

*“Strengthening U.S. Academic Programs in Accelerator Science”*

DOE national labs are America’s steward for accelerators in knowledge, skills, abilities, facilities, infrastructure and equipment. Having highly trained accelerator personnel is essential for DOE labs to create the workforce they need to accomplish their missions. High-energy, high-intensity/luminosity accelerators require a good understanding of underlying beam physics and, consequently, talented accelerator scientists.

U.S. academic programs in accelerator science and technology are of critical importance for Fermilab, as the national lab with the largest accelerator staff. Fermilab’s Accelerator and Technical divisions total about 650 members. About half of them are accelerator scientists, engineering physicists and engineers that usually come from either other labs and abroad, another third come from U.S. universities and the rest are home-grown via programs such as the USPAS and others (see below)<sup>1</sup>.

It is generally recognized that over the past decades it has become more and more difficult to get good accelerator physicists into the lab and, in general, to attract the best students in the field of high-energy particle accelerators. While development of Fermilab’s accelerator workforce strongly relies on the U.S. academic programs, there several lab-supported accelerator training and education programs that have established to address the need. All of them are closely coordinated via Fermilab/AD’s Accelerator Physics Center<sup>2</sup>, which states in its mission that it is to “...train accelerator scientists and engineers.” Below are brief descriptions of the efforts:

### **1. Joint University-Fermilab Doctoral Program in Accelerator Physics and Technology**

The Joint University-Fermilab Doctoral Program<sup>3</sup> was established in 1985 as a way to encourage students to pursue a career in accelerator physics and technology by providing research opportunities using facilities and expertise available at Fermilab. The Ph.D. program works in a

<sup>1</sup> T.Myers, presentation to the HEPAP USPAS Review committee, March 2015

<sup>2</sup> <http://apc.fnal.gov/>

<sup>3</sup> [http://apc.fnal.gov/programs2/joint\\_university.shtml](http://apc.fnal.gov/programs2/joint_university.shtml)

joint agreement with universities. Fermilab reimburses the university for the student's salary, provides the research project and provides supervisors. The student maintains a relationship with the home institution's advisers, who oversee the student's progress toward a Ph.D. degree from the university. Typically, between six and eight Ph.D. students carry out research in Fermilab Accelerator, Technical and Scientific Computing divisions every year. The average duration of the support is about three years. The Ph.D. program committee (currently chaired by Dr. Vyatcheslav Yakovlev of the Technical Division) not only selects the participants but also regularly assesses the status of the research at the monthly Budker Seminar series and at the regular meetings with the student's mentors and supervisors. Usually, Ph.D. students are deeply involved either Fermilab accelerator R&D programs (see Appendix 1), employing R&D and test facilities, including Fermilab Accelerator Science and Technology (FAST) Facility, the Mucool Test Area (MTA), High-Brightness Electron Source Lab (HBESL), superconducting RF and superconducting magnet and material test facilities in the Technical Division, or carrying out research at the operational machines (currently the Proton Source, Booster, Recycler, Main Injector) or in the beam physics and technology research groups in AD, TD and SCD. The full list of the Ph.D. program graduates since the programs' beginning (48) is given in Appendix 2. Many Ph.D. students carry out accelerator research at Fermilab without direct support from the lab (i.e., being supported by their universities directly). See Appendix 3 for the last decade's graduates.

## **2. Fermilab Hosts the US Particle Accelerator School (USPAS)**

The US Particle Accelerator School<sup>4</sup> is a national graduate program that provides graduate-level educational programs in the science of particle beams and their associated accelerator technologies that are not otherwise available to the scientific and engineering communities. It also promotes the development and publication of advanced technology textbooks. USPAS conducts graduate and undergraduate level courses at U.S. universities, holding two such programs per year, one in June and one in January. Average attendance is about 300 per year. These courses, which are two weeks in duration, take place at leading universities across the United States. By successfully completing the two-week course requirements, which include 45 contact hours as well as daily problems and examinations, students earn three semester hours of university credit.

The USPAS was recently (2015) reviewed by HEPAP, and detailed information can be found in *Report of the HEPAP Subcommittee for Review of the United States Particle Accelerator School* (May 2015)<sup>5</sup>.

<sup>4</sup> <http://uspas.fnal.gov/index.shtml>

<sup>5</sup> [http://science.energy.gov/~media/hep/hepap/pdf/Reports/HEPAP\\_USPAS\\_Subcommittee\\_Final\\_Report.pdf](http://science.energy.gov/~media/hep/hepap/pdf/Reports/HEPAP_USPAS_Subcommittee_Final_Report.pdf)



### **3. Lee Teng Internship (joint with Argonne National Laboratory)**

The Lee Teng undergraduate internship program<sup>6</sup> provides a unique summer research experience for undergraduate students at the college junior level in the area of accelerator science and technology. The program was established in 2008 and is carried out jointly by Argonne National Laboratory, Fermi National Accelerator Laboratory and the US Particle Accelerator School (USPAS). At present (2015), Dr. Eric Prebys of Fermilab chairs the Lee Teng Internship Committee. Undergraduate students from any university in the United States (required), preferably those finishing their junior year in either physics, engineering or computer science, are eligible to apply. Approximately 10 students are selected from the applicant pool each year. These students are given a mentored research project at either Argonne or Fermilab in equal numbers – i.e., five at Fermilab and five at Argonne – which they carry out during their 10-week summer residency. The Lee Teng internship provides an integrated approach to accelerator science and technology by including exposure to the field beyond the individual research projects. The Lee Teng students attend the US Particle Accelerator School (USPAS) for two weeks out of the 10-week period. Here they get the equivalent of a semester course in accelerator physics, receiving credit from the host university. Attendance at USPAS gives an academic grounding in the subject. There are several activities common to the Argonne and Fermilab interns that take place during the summer. Besides the two weeks together at the USPAS, there is a one-day tour of Fermilab and a one-day tour of Argonne lab.

### **4. PARTI International Summer Internship**

Since 1999, Fermilab's Physics of Accelerators and Related Technology for International Students (PARTI) program<sup>7</sup> offers 10-week summer internships to students from universities in the Former Soviet Union majoring in physics and engineering. These internships offer a chance for students to work with Fermilab scientists and engineers at the frontier of scientific research in the physics and technology of particle accelerators. The interns are assigned only to projects associated either with accelerator physics or accelerator-related technology in AD, TD and/or SCD. The range of topics is wide, from tuning an accelerator to upgrading a beam simulation program to improving radio-frequency cavities or accelerator magnets. The interns use a wide range of skills (performing experiments, data analysis, programming, etc.) and knowledge of physics (electrodynamics, solid state physics, etc.), at the end of the session they prepare and present oral reports, which are later published on the Web. The PARTI program committee, currently chaired by Dr. Alexander Valishev, selects on average 10 students annually. Many

<sup>6</sup> [http://www.illinoisacceleratorinstitute.org/lee\\_teng\\_internship.html](http://www.illinoisacceleratorinstitute.org/lee_teng_internship.html)

<sup>7</sup> <http://apc.fnal.gov/parti>

and <http://ed.fnal.gov/interns/programs/parti/>

students (~1/6) later enroll in the M.S./Ph.D. programs in accelerator science and technology in U.S. universities

## **5. Italian Engineering Graduate Student Internships and Laurea Thesis Program**

Jointly with several Italian universities and funding agencies, Fermilab annually supports some 20 nine-week summer internships to outstanding graduate engineering students. In this comprehensive program, interns work with scientists or engineers on projects related to Fermilab's research program. They also attend career planning and numerous training/informational sessions. The program is led by Dr. Emanuela Barzi of the Fermilab Technical Division.

These collaborative activities started in 1984, when Italian Istituto Nazionale di Fisica Nucleare created a summer students program to support four physics students from University of Pisa at Fermilab. Since 2004 there has been official support from the U.S. Department of Energy. Agreement between Fermilab and Scuola Superiore Sant'Anna (Pisa) was signed in 2007 to jointly support of four SSSA students each year. In 2010 the Italian Scientists and Scholars in North America Foundation (ISSNAF) started fundraising for a similar program in several science institutions in the U.S., including Fermilab.

The Italian Summer Internship program<sup>8</sup> lasts from the end of July to the end of September. Each student is assigned to a mentor (Fermilab employee) responsible for the training program and, with a supervisor, for overseeing the student's work on a daily basis. Students also attend seminars and introductory courses on high-energy physics and advanced technologies.

Students submit a written report to Fermilab at the end of the program. Students majoring physics and engineering come from University of Pisa, Roma, Padova, Siena, Trieste, Trento, Bologna, Torino, Naples, Sant'Anna Engineering School of Pisa, Polytechnic of Turin, Polytechnic of Milan, and Order of the Engineers of the Italian Provinces

Jointly with Italian Universities, Fermilab also supports *Laurea* (Master's) degree research of one to two Italian students annually primarily in Fermilab's Technical Division. See the list of 23 graduates since 1999 in Appendix 4. Five of the graduates are currently employed as scientific staff at the Fermilab. The program is also coordinated by Dr. Emanuela Barzi.

## **6. Fellowships (Peoples, Bardeen, Wilson, Toohig)**

Fermilab supports several fellowship programs for outstanding young researchers in the field of accelerator science and technology: the Peoples Fellowship<sup>9</sup> (2000-present), the Bardeen

<sup>8</sup> <http://ed.fnal.gov/interns/programs/ital-sssa/index.shtml>

<sup>9</sup> [http://fnal.gov/pub/forphysicists/fellowships/john\\_peoples/index.html](http://fnal.gov/pub/forphysicists/fellowships/john_peoples/index.html)

Fellowship<sup>10</sup> (2005-present), the US LARP Toohig Fellowship<sup>11</sup> (2006-present) and, in the past, the Wilson Fellowship (1988-1998). All past and current fellows, total of six, 14, 11 and five, correspondingly, are listed in Appendix 5.

The Peoples Fellowship was created at Fermilab with the goal of attracting outstanding accelerator scientists early in their careers, both to enhance Fermilab's capabilities in accelerator science and related technologies and to train and develop the accelerator scientists and technologists who will carry our field forward in the future. The Peoples Fellows program targets entry-level accelerator physicists, specialists in accelerator technologies and high-energy physics postdoctoral researchers who wish to embark on a new career in accelerator physics or technology. Peoples Fellows have extraordinary latitude in choosing their research activities and are provided with significant research support. Current areas of research that are of interest at Fermilab include (but are not limited to): stochastic and electron cooling, high-intensity proton beams, high-intensity neutrino sources, muon storage rings, superconducting magnets, superconducting RF, linear colliders, high-luminosity hadron colliders, beam-beam effects and their compensation, accelerator controls and feedback, and computational physics and modeling.

Fermilab seeks Peoples Fellows candidates with outstanding credentials who have the potential to be leaders of the field. There are two options for eligibility. 1) Candidates must have received within the prior three years a Ph.D. in accelerator physics or accelerator-related technology, in which case postdoctoral experience is not required, or 2) they must have received within the prior five years a Ph.D. in high-energy physics or a related field, in which case they are typically expected to have at least three years of postdoctoral experience in high-energy physics or a related field. The initial term of the fellowship for candidates with less than two years of postdoc experience is an initial four-year appointment, eligible to be considered for a second three-year term. For candidates with two or more years of postdoc experience, the term is an initial three-year appointment, eligible to be considered for a second two-year term. At present, Prof. Swapan Chattopadhyay of Northern Illinois University and the Accelerator Division chairs the Peoples Fellowship committee.

The John Bardeen Engineering Leadership Program (Fellowship) is designed to provide full-time entry-level opportunities for outstanding engineering graduates who are interested in working in a cutting-edge research environment. Fermilab provides opportunities in the fields of electrical, electronics, radio-frequency systems, power distribution, magnets, RF cavities, mechanical, materials science and cryogenic engineering. The program honors John Bardeen's revolutionary achievements as both a physicist and engineer. Applicants must be recipients of a Master or Doctoral degree in engineering from an accredited institution and apply within three years of graduation or completion of a first postdoctoral position. A thesis consisting of independent study must have been a significant part of the graduate degree. Degrees consisting of only classroom work do not qualify. Candidates who rank in the top quarter of their graduating class

<sup>10</sup> [http://www.fnal.gov/pub/forphysicists/fellowships/john\\_bardeen/index.html](http://www.fnal.gov/pub/forphysicists/fellowships/john_bardeen/index.html)

<sup>11</sup> <http://www.interactions.org/toohig/index.html>

are considered favorably. This program provides successful candidates full-time employment without term limit.

The Toohig Fellowships in Accelerator Science at the LHC were established in 2006 with support from the US LHC Accelerator Research Program (LARP). LARP is a collaborative initiative of the U.S. DOE Office of Science, Division of High Energy Physics and DOE Office of Science laboratories, with Fermilab playing a key role. The Toohig Fellow postdoctoral positions are for recent Ph.D. scientists or engineers and support research activities related to CERN's Large Hadron Collider and the LHC High-Luminosity program. Currently, Dr. John Fox of SLAC chairs the Toohig Fellowship Committee. The term of the fellowship is two years, extendable to three with mutual interest. Fellows are hosted by one the U.S. DOE laboratories involved in the LARP collaboration, with opportunities for CERN-based research as part of experimental efforts, commissioning of LARP-developed equipment, and for collaborative projects with CERN related to the HL-LHC program. Out of a total 11 fellows, three were hosted by Fermilab. See Appendix 5.

## **7. Joint Appointments and Adjunct/Visiting Professorships**

Academic appointments prove a powerful recruitment tool for the world's leading scientists. At present, there are four joint appointees pursue pioneering collaborative accelerator research at Fermilab and local universities:

- Prof. Swapan Chattopadhyay (NIU)
- Prof. Philippe Piot (NIU)
- Prof. Young-Min Shin (NIU)
- Prof. Pavel Snopok (IIT)

These appointments enrich research programs at the lab and the universities, playing a major role in the recruitment of top scientific talent in the Chicago region and advancing technology and discovery throughout the United States. Fermilab greatly benefits from the appointee's scientific and technical contributions, the influx of the student they supervise and additional support of the accelerator research at the lab that the appointees bring in form of research grants.

These appointments are joint tenure or tenure track position in accelerator physics at the level of Full, Associate or Assistant Professor, they are funded 50 percent by Fermilab and 50 percent by the university, with a commensurate reduction in the teaching load. They offer unique opportunities to carry out accelerator physics-related research in both national laboratory and university settings.

To further strengthen academic collaborations in accelerator science with Chicagoland universities, two Fermilab leading accelerator scientists have been recently appointed part-time/adjunct professors:

Dr. Sergei Nagaitsev – Professor Part-time, University of Chicago, Department of Physics;  
Dr. Vladimir Shiltsev – Adjunct Professor, Northern Illinois University, Department of Physics.

## **8. U.S. and Foreign Universities in Fermilab’s Accelerator Programs**

Fermilab offers access to its many R&D and operational accelerator facilities to many U.S. and foreign universities. A recent review of these activities was presented by Dr. Sarah Cousineau (U.Tennessee/ORNL) at the HEPAP GARD Subpanel meeting at Fermilab in August 2014<sup>12</sup>. See summary table in Appendix 6. Many foreign universities are actively involved, too, including Imperial College London, University of Mexico, IAP Frankfurt and Oxford.

<sup>12</sup> <https://indico.fnal.gov/conferenceDisplay.py?confId=8832>

***Below are Fermilab's responses to the RFI specific questions:***

**Increasing the Recognition of Accelerator Science in Academia**

1. Does your institution regard accelerator science as an academic discipline? Why or why not?

*Yes, Fermilab regards accelerator science as academic discipline of key importance for the laboratory as it directly affects the performance of the current accelerator complex and its future development. Some 40 peer-reviewed publications in leading high-impact US and international journals are published annually by Fermilab accelerator staff and our collaborators.*

2. If your institution offers graduate training in accelerator science (several questions):

*Yes, Fermilab offers Joint University-Fermilab Accelerator Ph.D. program (see above). Some six to eight students are supported annually.*

3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?

*n/a*

4. What funding sources for accelerator science are you aware of?

*DOE OHEP, BES, ASCR, and NP, NSF, national laboratories (e.g., Fermilab)*

**Integrating the Roles of the Universities and the U.S. National Laboratories**

5. How can the national laboratory system be best utilized by the university accelerator science community?

*Boost the research via free access of the university faculty and students to operational accelerators and beam R&D facilities – e.g., Fermilab Accelerator Science and Technology (FAST) facility - that might have particularly high impact for small minority-serving institutions and historical black colleges and universities, which now have a hard time participating in and contributing to lab accelerator programs because of a lack of basic infrastructure and training at their home institutions; expanded possibilities to attract lab's scientists for the collaborative work and supervision of university students; expand the number of joint appointments between labs and universities and number of adjunct professorship positions for lab scientists in the U.S. universities.*

6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?

*Many universities do not have strong faculty in accelerator and beam science; some universities do not consider the accelerators as priority for their scientific activities.*

7. Does your university accept accelerator course credits from other institutions?

*n/a*

8. Do accelerator science students at your institution routinely take courses and training elsewhere?

*Yes, usually at the USPAS (see above).*

9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?

*Expand the number of joint appointments between labs and universities and number of adjunct professorship positions for lab scientists in the U.S. universities.*

10. Considering disciplines other than accelerator science what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?

*See above 8 activities in accelerator science training and education supported by Fermilab.*

### **Contemporary Models of University Accelerator Science**

11. What examples exist of thriving academic accelerator science programs?

f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?

*Yes, three with NIU and 1 with IIT – see above*

12. Are there successful examples of academic programs from other technologically oriented disciplines that you believe are relevant to the establishment or improvement of an accelerator science program? What key attributes make the program successful?

*n/a*

13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful?

*There are two examples of successful programs in accelerator science overseas: 1) at CERN, there are many (dozens to hundreds) positions for Ph.D. students and fellows from all over Europe that come to do either graduate of limited-term postgraduate research and development; they participate in the accelerator complex operations and accelerator R&D and make very valuable contributions to the lab, and, at the same time, allow to attract the best accelerator talent to the organization; 2) in Russia, most of the Ph.D. research work is done at research (not educational) institutions and the Ph.D. degrees are granted by them as well (not by universities). In both cases, very high-class research and many talented young scientists are produced because of several factors: easy access to the world leading accelerator facilities, everyday work with and supervision by world leading “practical” accelerator scientists and engineers, and sustainable support of these activities or programs over many years.*

### **Possible Mechanisms To Encourage Academic Accelerator Science**

14. What specific, cost-effective actions could be taken to:

a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.

*Yes (agree)*

b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.

*Yes (agree); Illinois Accelerator Research Center (IARC) <sup>13</sup> at Fermilab can be instrumental for that*

c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master’s degree, or grants to develop instructional materials.

*Yes (agree)*

d. Increase the enrollment in education opportunities at the baccalaureate and master’s level?

*Offer more opportunities for the master thesis work at the near-by national accelerator labs*

<sup>13</sup> <http://iarc.fnal.gov/>



e. Increase the availability of hands on training opportunities in accelerator technology?

*Offer one to two weeks of hand-on classes a la USPAS at the technology development facilities at large national labs (e.g., at Fermilab's IARC/FAST or at Argonne).*

### **Other Factors**

15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?

*Strategic planning toward, e.g., more effective use of the unique accelerator facilities and infrastructure at the national labs and balanced approach to prioritization of the accelerator R&D programs supported by DOE and NSF to reflect the long-term aspirations of HEP, BES and NP should be publicly announced by the funding agencies and can help to properly orient university based accelerator science programs.*

16. Are there other factors not addressed by the questions above that contribute to the strength or weakness of U.S. academic accelerator science?

*In the part in which the U.S. academic accelerator science programs depend on support from federal funding agencies, they are subject to the annual budget cycle uncertainties and risks and greatly affected by the level of bureaucracy in the grant competition and reporting processes*

Sincerely,

A handwritten signature in black ink, appearing to read "V. Shiltsev (V.S.)".

Vladimir Shiltsev  
Director, Accelerator Physics Center/AD  
Fermilab

## Appendix 1: Fermilab Accelerator R&D Programs

	<b>Coordinator</b>	<b>Collaboration</b>
<b>Fermilab Accelerator Science and Technology facility (FAST)</b>	Shiltsev	ANL, Berkeley, BNL, Budker Institute of Nuclear Physics, CERN, Chicago, Colorado State, Fermilab, IAP Frankfurt, JINR Dubna, Kansas, LANL, LBNL, Maryland, Michigan State, Northern Illinois, ORNL, Oxford, RadiaBeam Technologies, RadiaSoft LLC, Tech-X, Tennessee, Vanderbilt
<b>High Power Beam Targetry</b>	Hurh	ANL, BNL, CERN, CIEMAT, ESS, Fermilab, KEK, Michigan State, LANL, ORNL, Oxford, PNNL, PSI, STFC
<b>Muon Accelerator Program (MAP)</b>	Palmer	ANL, BNL, Cornell, Fermilab, IIT, ICL, JLab, LBNL, Mississippi, Muons Inc, Particle Beam Lasers, Princeton, SLAC, SUNY Stony Brook, UC/Berkeley, UCLA, UC/Riverside, Virginia Tech
<b>Muon Ionization Cooling Experiment (MICE)</b>	Long / Bross	Belgrade, BNL, Brunel, CERN, Cockcroft, Daresbury, Fermilab, DPNC Geneva, Glasgow, Harbin, IIT, ICL, Iowa, JLab, Kyoto, LBNL, Liverpool, Milano, Mississippi, Napoli, New Hampshire, NIKHEF, Osaka, Oxford, Pavia, RAL, Roma III, Sheffield, Sichuan, Sofia, Strathclyde, UC/Riverside, Warwick
<b>LHC Accelerator Research Program (LARP)</b>	Apollinari	BNL, CERN, Fermilab, LBNL, SLAC, JLab, Old Dominion
<b>Superconducting RF</b>	Romanenko	ANL, CERN, Cornell, DESY, ESS, Fermilab, India (RRCAT, BARC, UECC, IUAC), IHEP/Beijing, INFN, JLab, KEK, Korea (RISP), MSU(FRIB), Northern Illinois, Northwestern, SLAC, TRIUMF, NHMFL
<b>High-Field Superconducting Magnets and Materials</b>	Zlobin	BNL, CERN, Fermilab, Florida State/NHMFL, LBNL, KEK/NIMS, Ohio State

## **Appendix 2: Joint Fermilab-University Accelerator PhD Program graduates (1987-2014)**

Mike Syphers 1987 University of Illinois-Chicago  
*An Improved 8-GeV Beam Transport System for the Fermi National Accelerator Laboratory*

Nikolitsa Merminga 1989 University of Michigan  
*A Study of Nonlinear Dynamics in the Fermilab Tevatron*

Leonid Sagalofsky 1989 University of Illinois  
*Third-order Charged Particle Beam Optics*

Mark Stahl 1990 Northwestern University  
*Beam Dynamics in the Fermilab Booster in the Presence of Space Charge*

Peilei Zhang 1991 University of Houston  
*A Study of Tunes Near Integer Values in Hadron Colliders*

Xiao-qing Wang 1991 Illinois Institute of Technology  
*A Study of Longitudinal Coherent Effects of Unbunched Beams Near Transition in the Fermilab Accumulator.*

John Palkovic 1991 University of Wisconsin  
*Gabor Lens Focusing and Emittance Growth in a Low-Energy Proton Beam*  
**1993 APS DPB Outstanding Doctoral Thesis Research in Beam Physics Award Recipient**

Todd Satogata 1993 Northwestern University  
*Nonlinear Resonance Islands and Modulational Effects in a Proton Synchrotron*

Ping Zhou 1993 Northwestern University  
*A Study of Ion Trapping and Instability in the Fermilab Anti-proton Accumulator*

Kathy Harkay 1993 Purdue University  
*A Study of Longitudinal Instabilities and Emittance Growth in the Fermilab Booster Synchrotron*

Bill Graves 1994 University of Wisconsin  
*Measurement of Transverse Emittance in the Fermilab Booster*

Xianping Lu 1994 University of Colorado  
*Study of a Longitudinal Coupled Bunch Instability in the Fermilab Main Ring*

Donna Siergiej 1995 University of New Mexico  
Beam-beam Interaction Effects in the Fermilab Collider

Ping Jung Chou 1995 Northwestern University  
The Nature of Transverse Beam Instabilities at Injection in the Fermilab Main Ring

David Olivieri 1996 Massachusetts University  
*A Dynamic Momentum Compaction Factor Lattice for Improvements to Stochastic Cooling in Storage Rings*

Linda Spentzouris 1996 Northwestern University  
*Coherent Nonlinear Longitudinal Phenomena in Unbunched Synchrotron Beams*  
**1997 APS DPB Outstanding Doctoral Thesis Research in Beam Physics Award Recipient**

Eric Colby 1997 UCLA  
*Design, Construction, and Testing of a Radiofrequency Electron Photoinjector for the Next Generation Linear Collider*

Katya Langen 1997 University of Wisconsin  
*Microdosimetric Investigation at the Fast Neutron Therapy Facility at Fermilab*

Oleg Krivosheev 1998 Tomsk Polytechnic  
*University Object Oriented integrated System for Beam Included Energy Deposition Simulations for Tevatron and Upgrades*

Michael Fitch 2000 University of Rochester  
*Electrooptic Sampling of Transient Electric Fields from Charged Particle Beams*

Jean-Paul Carneiro 2001 Paris XI  
*Etude Experimentale du Photo-injecteur de Fermilab*

Vadim Kashikhin 2001 Efremov Institute  
*Design and Optimization of Superconducting Accelerator Magnets*

Vincent Wu 2002 Cincinnati University  
*Design and Testing of a High Gradient Radio Frequency Cavity for the Muon Collider*

Linda Imbasciati 2003 TU-Vienna

*Studies of Quench Protection in Nb<sub>3</sub>Sn Superconducting Magnets for Future Particle Accelerators*

Mohammad Alsharoa 2004 Illinois Institute of Technology  
*Electromagnetic and Mechanical Design of Gridded Radio-frequency Cavity Windows*

Kip Bishofberger 2005 UCLA  
*Tevatron Beam-Beam Compensation*

Ludovic Nicolas 2005 Glasgow  
*Radiation environment simulations at the Tevatron, studies of the beam profile and measurement of the Bc meson mass*

Sergei Seletskiy 2005 Rochester University  
*Attainment of Electron Beam Suitable for Medium Energy Electron Cooling*

Robert Zwaska 2005 Texas University  
*Accelerator systems and instrumentation for the NuMI neutrino beam*

Xiaobiao Huang 2005 Indiana University  
*Beam Diagnosis and Lattice Modeling of the Fermilab Booster*

Bernardo Bordini 2006 Pisa  
*Thermo-magnetic instabilities in Nb<sub>3</sub>Sn superconducting accelerator magnets*

Pavel Snopok 2007 Michigan State  
*Capture of a Large Phase Space Beam*

Phil Yoon 2007 University of Rochester  
*Error-Induced Beam Degradation in Fermilab's Accelerators*

Alexei Poklonsky 2008 Michigan State University  
*Optimization and Control of Tevatron Parameters*

Ryoichi Miyamoto 2008 University of Texas, Austin  
*AC Dipole Diagnostics of Fermilab's Tevatron*  
**2010 APS/DPB Outstanding Doctoral Thesis Research in Beam Physics Award Recipient**

Timothy Koeth 2009 Rutgers University  
*The first observation of a Transverse to Longitudinal Emittance Exchange*

U.Mavric 2009 University of Ljubljana

*The LLRF control system for the international linear collider main LINACs*

W.M.Tam 2010 Indiana University  
*HINS H- source and beam diagnostics*

Dan McCarron 2010 IIT  
*Measurement and Simulations of intensity Dependent Effects in the Fermilab Booster Synchrotron*

A.Saini 2012 University of Delhi  
*Study of the beam dynamics in the International Linear Collider and in the Project X linac*

T.Maxwell 2012 NIU  
*Measurement of sub-picosecond electron bunches via electro-optic sampling of coherent transition radiation*

Alexey Petrenko 2012 Budker Institute of Nuclear Physics  
*Model-independent analysis of the Fermilab Tevatron turn-by-turn beam position monitor measurements.*

Denise Ford 2013 Northwestern University  
*Insights to Superconducting Radio-Frequency Cavity Processing from First Principles Calculations and Spectroscopic Techniques*

Meghan McAteer 2014 University of Texas - Austin  
*Linear optics measurements in the FNAL Booster and in the CERN PS Booster*

Timofey Zolkin 2014 University of Chicago  
*Beam Dynamics (Fermilab Boost); Non-linear integrable accelerators*

Gene Kafka 2014 Illinois Institute of Technology  
*Lattice Design of the Integrable Optics Test Accelerator and Optical Stochastic Cooling Experiment at Fermilab*

Yulia Trenikhina 2014 Illinois Institute of Technology  
*Investigation of Nb surface structure and composition for improvement of superconducting radio-frequency cavities*

Ao Liu 2014 Indiana University  
*Design and simulation of the nuSTORM facility*

### **Appendix 3: Accelerator PhDs granted on base of research done at Fermilab (2004-2014)**

Matthew Thomson 2004 UCLA

*Plasma Density Transition Trapping of Plasma Electrons  
in a Plasma Wake Field Accelerator*

Yin-e Sun 2005 University of Chicago

*Round-to-Flat beam transformation at A0 Photoinjector*

Rodion Tikhoplav 2006 Rochester University

*“Laser Acceleration in Vacuum at A0 Photoinjector”*

Jian-Jian Li 2008 IIT

*“SC RF Cryomodule Couplers”*

Chris Prokop 2014 NIU

*Advanced Phase Space Manipulations at the Fermilab's Advanced Superconducting Test  
Accelerator*

Francois Lemery 2015 NIU

*Beam Acceleration and Manipulation Using Dielectric Linear Waveguides*

## Appendix 4: Italian Laurea graduates on base of research done at Fermilab (1999-2014)

1. Cristian Boffo – Mechanical Eng., University of Udine, 1999: *Magnetization Measurements at 4.2K of Multifilamentary Superconducting Strand*, Prof. G. Pauletta, E. Barzi Advisors – TD (hired at FNAL)
2. Michela Fratini – Nuclear Eng., Pisa University, 2002: *A Device to Test Critical Current Sensitivity of Nb<sub>3</sub>Sn Cables to Transverse Pressure*, Prof. C. Angelini, Prof. F. Fineschi, E. Barzi Advisors – TD (hired at CEA/Saclay)
3. Sara Mattafirri – Nuclear Eng., Pisa University, 2002: *Kinetics of Phase Growth during the Cu-Sn Diffusion Process and the Nb<sub>3</sub>Sn Formation. Optimization of Superconducting Properties*, Prof. C. Angelini, Prof. F. Fineschi, Prof. S. Lanza, E. Barzi, J.M. Rey Advisors – TD (hired at LBNL)
4. Licia Del Frate – Nuclear Eng., Pisa University, 2004: *Design of a Low Resistance Sample Holder for Instability Studies of Superconducting Wire*, Prof. C. Angelini, Prof. F. Fineschi, Prof. S. Lanza, E. Barzi Advisors – TD (hired at INFN)
5. Vito Lombardo – Computing/Automation Eng., Sant’Anna School (Pisa), 2007: *Automation of Short Sample Facility for Critical Current and Low Field Instability Measurements of Superconducting Strands at Cryogenic Temperatures*, Prof. M. Innocenti, Prof. L. Pollini, E. Barzi, D. Turrioni Advisors – TD (hired at FNAL)
6. Marco Danuso – Mechanical Eng., Sant’Anna School (Pisa), 2008: *Parametric Analysis of Forces and Stresses in Superconducting Magnets Windings*, Prof. M. Beghini, E. Barzi, A. Zlobin Advisors - TD
7. Gabriella Norcia – Mechanical Eng., Pisa University, 2009: *Design of Modular Test Facility for HTS Insert Coils*, Prof. M. Beghini, E. Barzi Advisors – TD (hired at Ansaldo)
8. Giuseppe Gallo – Mechanical Eng., Pisa University, 2010: *Mechanical Modeling of Superconducting Rutherford-type Cable Fabrication*, Prof. M. Beghini, Prof. L. Bertini, E. Barzi Advisors – TD (hired at FNAL)
9. Antonio Bartalesi – Mechanical Eng., Pisa University, 2010: *Design of High Field Solenoids made of High Temperature Superconductors*, Prof. M. Beghini, E. Barzi Advisors – TD (at CERN)
10. Alessandro Quadrelli – Electrical Eng., Pisa University, 2010: *Automated Control of the Tuning of Superconducting RF Cavities*, Mirko Marracci, Franco Bedeschi Advisors (Warren Schappert supervisor) - TD
11. Matteo Scorrano – Electronic Eng., Pisa University, 2010: *Development of a Control System for Superconducting Cavities with Fast Tuners*, Giovanni Pennelli, Franco Bedeschi Advisors (Youri Pischnikov supervisor) – TD
12. Simone Moio – Physics Eng., Turin Polytechnics, 2011: *Effect of Subelement Size, RRR and Strand Size on Stability of RRP Nb<sub>3</sub>Sn Strands*, Prof. R. Gonnelli, E. Barzi Advisors – TD (hired at Magneti Marelli)



13. Donato Passarelli – Mechanical Eng., Pisa University, 2011: *Analysis of the mechanical behavior of the Superconducting Single Spoke Resonator type 1 in tests at cryogenic temperature*, Prof. M. Beghini, L. Ristori Advisors – TD (hired at FNAL)
14. Federico Puccinelli – Mechanical Eng., Pisa University, 2011: *Detector support structure and installation system for the Mu2e experiment*, Prof. Marco Beghini, Sandor Feher, Rodger Bossert Advisors - TD
15. Paolo Berrutti – Physics Eng., Turin Polytechnics, 2011: *Radio frequency design and optimization of the low-medium-beta section for a 3 GeV linear particle accelerator*, Prof. Gianni Coppa, Slava Yakovlev Advisors – TD (hired at FNAL)
16. Andrea Pisoni – Physics Eng., Milan Polytechnics, 2012: *Implementation of Nano Scale Formations in A15 Brittle Superconductors*, Prof. R. Bertacco, E. Barzi, T. Rajh Advisors – TD (PhD at University of Lausanne)
17. Giulia Collura – Electronic Eng., Turin Polytechnics, 2012: *Beam Test of a High Pressure RF Cavity for the Muon Collider*, Prof. Felice Iazzi Advisor (Alvin Tollestrup Supervisor) - APC
18. Pietro Giannelli – Electronic Eng., Turin Polytechnics, 2012: *Design of a Signal Conditioner for the Fermilab Magnet Test Facility*, Prof. Marco Parvis Advisor (Darryl Orris Supervisor) - TD
19. Vincenzo Li Vigni – Electronic Eng., Palermo University, 2012: *Design and testing of a digital regulator for Fermilab magnet power systems*, Prof. Giuseppe Capponi, Valeria Boscaino, Andrzej Makulski Advisors - TD
20. Silvia Zorzetti – Electronic Eng., Pisa University, 2013: *Development of the world's first digital direct-current current transformer (DCCT) to measure particle beam intensities*, Prof. Luca Fanucci, Manfred Wendt Advisors – AD (at CERN)
21. Federico Reginato – Physics Eng., Milan Polytechnics, 2014: *Electrochemical Synthesis of Nb-Sn Coatings for High Field Accelerator Magnets*, Prof. Silvia Franz, E. Barzi Advisors - TD
22. Matteo Grandini – Mechanical Eng., Pisa University, 2014: *Design of a liquid helium transfer line support system*, Prof. Bernardo Disma Monelli, Thomas Page Advisors - TD
23. Andrea Palagi – Mechanical Eng., Pisa University, 2014: *ASME Verification and Pressure Sensitivity optimization of the Cryostat of the 1.3 GHz Cavity*, Prof. Marco Beghini, Prof. Leonardo Bertini, Allan Rowe Advisors - TD

**Appendix 5: Fermilab Fellowships in Accelerators: Wilson Fellows (1988-1998), Peoples Fellows (2000-2015), Bardeen Fellows (2009-2014), Toohig Fellows (2006-2015)**

*Wilson Fellows*

		<i>now at:</i>
James Rosenzweig	1988	UCLA
Gerald Jackson	1988	Hbar Technologies
Andrei Gerasimov	1991	Liberty Power (finance)
Vladimir Shiltsev	1996	Fermilab
Sergei Nagaitsev	1998	Fermilab

*Peoples Fellows*

		<i>now at:</i>
Pierre Bauer		European Fusion Development Agreement (ITER)
Markus Huening		DESY
Andreas Jansson		ESS
Andrea Latina		CERN
Philippe Piot		Northern Illinois University
Lionel Prost		Fermilab
Alex Romanenko		Fermilab
Yin-e Sun		Argonne Nat'l Lab
Katsuya Yonehara		Fermilab
Robert Zwaska		Fermilab
Tengmin Shen		Fermilab
Charles Thangaraj		Fermilab
Anna Grasselino		current Fellow, since 2013
Daniel Bowring		current Fellow, since 2013

*Bardeen Fellows*

		<i>now at:</i>
Julien Branlard	2005	DESY
Nandhini Dhanaraj	2006	TD/Superconducting RF Cavity Department
Torben Grumstrup	2007	Colorado State
Vito Lombardo	2007	TD/Superconducting RF Cavity Department
Mohamed Hassan	2010	TD/Superconducting and RF Development
Kevin Ammigan	2012	AD/Targetry Department

*Toohig Fellows*

Rama Calaga	2006-08 (BNL)	<i>now at:</i> CERN
Helene Felice	2007-09 (LBNL)	LBNL
Darius Boscian	2008-11 (FNAL)	INP, Poland
Ryoichi Miyamoto	2008-11 (FNAL)	ESS
Ricardo de Maria	2010-11 (FNAL)	CERN
Themis Masteridis	2010-11 (SLAC)	California Polytech
Valentina Previtali	2011-13 (FNAL)	Geneva
Simon White	2010-13 (BNL)	ESRF
John Caseratto	2011-14 (SLAC)	Philips
Ian Pong	2013-now (LBNL)	
Silvia Verdu-Andes	2013-now (BNL)	

## Appendix 6: US Universities carrying out accelerator R&D at Fermilab (2014)

(from S.Cousineau (U.Tennessee/ORNL), presentation to the HEPAP GARD Subpanel meeting, FNAL, August 2014)

University	Primary Topic(s)	Funding agency
IIT	SRF technology; machine concepts; novel accelerator technologies	DOE-HEP grant, NSF
U. of Chicago	Beam dynamics (IOTA)	Fermilab, NSF, U.of Chi
NIU	SRF technology; beam dynamics (IOTA); accelerator technology	DOE-HEP grant, NSF, DOD, NIU
IU	Beam dynamics; machine concepts	DOE-HEP grant
U. of MD	Beam dynamics	DOE-HEP grant, NSF, ONR
U. Tenn.	Accelerator technology; beam dynamics	DOE-HEP grant
U. Wisc.	SRF technology	DOE-HEP grant
MSU	SRF technology; beam dynamics; machine concepts	DOE-HEP grant; NSF
U. Colorado	Beam dynamics; accelerator technology	DOE-SBIR
Colorado State Univ.	SRF technology	ONR, High-Energy Laser Joint Tech Office
Cornell	SRF technology	DOE; NSF
MIT	Machine concepts	NSF

## **RESPONSE**

**TO:** DoE RFI on “STRENGTHENING U.S. ACADEMIC PROGRAMS IN ACCELERATOR SCIENCE”, Office of High Energy Physics, Department of Energy

**FROM:** Northern Illinois University (NIU)

### **Policies, practices, and mechanisms to foster robust academic R&D and workforce development in accelerator science.**

#### **General Comments:**

Northern Illinois University considers accelerators science a full academic discipline and supports the program accordingly with personnel and resources as a Center of Research Excellence. The existing program of three accelerator physicists in the academic faculty has been in place for ten years and has recently been enhanced by the addition of a fourth senior accelerator scientist at the full professor level. Three of these four are joint appointees with Fermilab and a fourth one joint appointee with ANL. The faculty is currently being augmented with two (and possibly three) additional joint hires – for an eventual total of six (and possibly seven) faculty in accelerator science. The University’s willingness to pursue the program was facilitated by the long and close association with FNAL and ANL and existence of strong synergistic groups of experimental high energy and condensed matter physicists at NIU working with FNAL and ANL. The laboratories have historically shared resources and leveraged facilities with NIU.

University support would be further solidified by clear federal policies and practices supporting and promoting laboratory – university relationships for joint research and joint positions. Such policies would demonstrate to all universities that new programs would not require the enormous capital investments associated with such a technological dependent discipline and that the risks of new programs would be shared. Of course, significant peer-reviewed grant funding from across the Federal government would ensure the longevity of accelerator science.

Finally, incentives promoting the interdisciplinary nature of accelerator science would be extremely helpful in terms of accessing all of the academic disciplines in science and engineering necessary for accelerator science. Such centers would also promote crucial campus wide support. An ideal initiative for a Federal program would be sponsorship of laboratory-campus interdisciplinary centers in accelerator science.

#### **Answers to Specific Questions:**

- 1) Yes, because of benefits afforded by close association with local laboratories and constant education of the administration by faculty. The peer reviewed

publications in refereed journals add considerable academic esteem factor to the university's profile.

- 2) NIU offers several courses in accelerator science, all at the graduate level:
  - (a) All graduate students doing PhD in accelerator science must have taken from a series of courses in Beam Physics at an advanced seminar level, in addition to all the required basic courses for a PhD in Physics at NIU: the courses Beam Physics I and II (respectively PHYS673 and PHYS 683) introduce the basics of Beam Physics. In addition we regularly offer advanced classes in Accelerator Science and Technology as part of our PHYS799 course "Special Topics in Physics". A recent example of such a specialized class includes "beam-wave interaction". The classes related to accelerator science are generally attended by ~6 to 10 students (a significant number given the small size of our department). All these classes are within the elective-course requirement for the PhD program;
  - (b) Students decide to study accelerator physics based primarily on original intentions. Many students switch from particle physics and some in the past have switched from condensed matter/nanoscience. In a given year we have about 10 students within the PhD or master program carrying out researches in Accelerator Science. This corresponds to 20-25% of the student population in the department of Physics. All the student are from Physics. Occasionally we see some students transiting from engineering;
  - (c) Yes, currently the NIU accelerator science program is exclusively in the Physics Department, but strong research collaboration exists with NIU's School of Engineering, which is growing, with joint grant applications etc. There are no barriers to joint appointments between physics and engineering. There was an attempt 5 years ago to implement a master in RF engineering within the electrical engineering department and we are considering re-establishing such a program;
  - (d) As described above, NIU is already in the process of strengthening its Accelerator science faculty by its commitment to create a Cluster of Research Excellence in accelerator science, raising the level of faculty from current 4 to 6 (7) eventually;
  - (e) NIU faculty makes heavy use of accelerator test facilities at Fermilab and ANL. At Fermilab, NIU faculty was instrumental in creating the High Brightness Electron Source Laboratory (HBESL) using advanced lasers and photocathode guns and is primarily responsible for operating it. In addition NIU faculty plans to use the IOTA ring and the 300 MeV Superconducting linear accelerator within its FAST facility. At ANL, NIU faculty uses the AWA facility and also the Argonne nano-lab. Within the NIU physics department, there is an underground laboratory housing a

S-band RF klystron and associated RF structures, with the goal of creating an advanced low-power high precision RF laboratory for novel RF structure studies; we are setting a small-scale facility that could be used to train students, but as explained above, our university currently makes extensive use of facility located at the two neighborhood laboratories. At Fermilab, our group operates the HBESL facility (formerly known as the A0 photoinjector) and this has been an excellent platform for training students in all aspects of Accelerator Science and Technology. Likewise we are using the AWA facility located in Argonne in support of one of our current DOE proposal;

- (f) There is already collaboration between NIU accelerator science and High Energy Physics via the NICADD affiliation. There is also existing collaboration with condensed matter and nano-science group in Physics and Engineering but this collaboration could be strengthened. There are regular attempts to write joint proposals with faculty in electrical engineering and chemical sciences but to date we have not been able to sustain these venture due to lack of funding;
  - (g) Industrial collaboration exists in connection with DOE SBIR and potential collaboration with DoD, DNDO and Air Force Research but no industrial sponsorship has been sought to date. There is some interaction with many small to medium sized accelerator industries, both hardware and software and incentives are growing with the increased collaboration between Fermilab IARC facility and NIU. In particular the HBESL is planned for relocation in the IARC Building.
- 3) Not applicable.
  - 4) NIU has been awarded funding by DOE, DOD and Air Force and has not yet received funding from NSF, though active grant application to NSF continues in the second year of NSF accelerator science program.
  - 5) Primarily as a partner to provide capital investment in accelerators and accelerator technology and to provide a base for and support of academic research.
  - 6) Lack of explicit funding for laboratory-university academic programs and the famously bureaucratic difficulty the labs have entering into agreements.
  - 7) Yes, classes in accelerator Physics from other universities can be transferred. As an example we are transferring classes taken by our students at USPAS and mapping them to our beam-physics classes or our special-topics classes (see 3a/). NIU also has mechanism and willingness to accept accelerator course credits from other institutions as well as the willingness to offer

credits against USPAS courses, should NIU be asked to do so. Discussions to offer credit to USPAS students have already taken place within NIU.

- 8) Yes at other labs, universities, and USPAS.
- 9) Funding incentives and flexibility on the part of the labs into entering agreements. The labs also need the autonomy to enter into workforce training agreements.
- 10) Primarily joint positions and it is in effect and fully operational already between NIU and Fermilab and NIU and ANL.
- 11) The NIU program, comprised of a mix of joint and university positions, has been successful in educating graduate students. Although there have been no Fellowships, funds are now being set aside explicitly for graduate assistantships. NIU has a long history of collaborating with the labs and this built a solid basis for our Center of Research Excellence. Thriving models exist in UK at present e.g. the Cockcroft Institute Education and Training program in Accelerator Science and Technology (<http://www.cockcroft.ac.uk>) and the John Adams Institute Education and Training program (<http://www.jai.ox.ac.uk>). In addition there is the Joint Universities Accelerator School (JUAS) in Europe.
  - (a) Yes the policy to encourage and support the formation of the Cluster of research Excellence in Accelerator Science;
  - (b) Accelerator science is a NIU presidential initiative in the context of the cluster of research excellence with commitment of cluster start-up funds;
  - (c) There are no perceived barriers at NIU;
  - (d) At NIU, the transition from research to full faculty is possible. Two out of four accelerator faculty are tenured full professors; one a tenured Associate Professor; a fourth a tenure-track Assistant professor;
  - (e) NIU has a strong experimental particle physics group and experimental condensed matter group, collaborating strongly with Fermilab, ANL and CERN. These are strong motivating factors for accelerator science;
  - (f) Yes there are three joint appointments in accelerator science with FNAL and one in accelerator science with ANL.
- 12) Not aware of any.
- 13) Yes, as mentioned above the Cockcroft Institute and John Adams Institute in UK and the Joint Universities Accelerator School in Europe. Success is due to



'directed' and targeted consolidated grants to the institutes, a substantial fraction of which is dedicated to education and training in accelerators. Also nationally developed and planned accelerator science masterclasses and particle physics masterclasses in UK. Both institutes have strong collaboration research universities such as Universities of Liverpool, Manchester, Lancaster, Oxford, Imperial College and Royal Holloway and together have about 40 PhD students at any particular time and 20 post-doctoral fellows. Some of our faculty have been involved and collaborated with several institution and one of the programs that stands out in our opinion is also the program that surrounds DESY in Germany. In a given years, DESY has about 30 students and 10-20 postdoctoral engaged in accelerator research. This is partially due to the different mode of funding but also the strong symbiosis between the DESY national laboratory and local universities (e.g. U. Hamburg). This strong integration of university with a national lab is also facilitated by a long-term programmatic than ensure enough stability to confidently engage students on a 3-5 year period. This kind of stability is missing around US national laboratory.

- 14) To raise the status, DOE and NSF should publicly and visibly announce a collaborative effort to build the funding basis for accelerator science as a discipline. A solicitation for initiation of programs based on a five year grant in collaboration with a sponsoring laboratory would be very effective. Also providing competitive scholarships at the undergraduate level and summer research would be extremely effective in promoting student interest.
- 15 and 16) The mission driven characteristic of the laboratories does not lend itself to an academic discipline. On the other hand, only the laboratories have the resources to support the technological base. Thus, to support the academic discipline the laboratories must support a visible and steady stream of curiosity driven accelerator science.

# Increasing the Recognition of Accelerator Science in Academia

1. Does your institution regard accelerator science as an academic discipline? Why or why not?

**Yes. There is an effort to create an accelerator physics track in collaboration with the nearby Jefferson Lab lab.**

2. If your institution offers graduate training in accelerator science:

**No**

a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)

**N/A**

b. How often do students change fields to study accelerator science? From which fields do these students typically come?

**N/A**

c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments?

**N/A. Although the effort mentioned above is under the Physics Department**

d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?

- **Faculty support as a joint position with a national facility to offset cost**
- **Dedicated scholarships for students**
- **Establish annual on-campus workshops/schools on accelerator science and related applications**

e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?

- **A gun was loaned by Jefferson lab but is not yet operational.**
- **Yes faculty are using accelerator facilities at U.S. national laboratories (Fermilab, Jefferson Lab) for their work**

f. How often do collaborations occur between accelerator science and other programs at the university?

**There have been and are ongoing routine discussions/collaboration between the planned accelerator science program and other programs (within and outside the School of Science). Some of the collaboration is through students and faculty research that are linked to applications of accelerators (nuclear physics, beam studies, laser, radiation biology, building design, EH&S, chemistry, business, medical physics to name a few).**

g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program?

**Yes: there are discussions with companies (Radiabeam Technologies, Thales Laser, Muons Inc.) to involve them in the accelerator science program**

**There is no current recruitment of students, although proposals to support students have been submitted jointly between my institution and some companies focusing on accelerator science technologies**

3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?

N/A

4. What funding sources for accelerator science are you aware of?
- NSF: Accelerator Science, Major Research Instrumentation and other accelerator science applied programs
  - DoE Office of Science programs for faculty and students
  - Corporate funding

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

5. How can the national laboratory system be best utilized by the university accelerator science community?
- **Increasing diversity (e.g., Minority Serving Institutions) at national facilities through dedicated (named)**
    - o Joint appointments between Accelerator Physics Divisions and University faculty
    - o Joint appointments between Accelerator Physics Divisions staff scientists and University
    - o Postdoc positions
    - o Scholarships for students
  - Increase budget and staff for Diversity Offices
  - Dedicated joint University/Laboratory programs for K-12 and undergraduate/graduate students outreach (ex: programs similar to PING [[www.nsbping.org](http://www.nsbping.org)], HUGS [[www.jlab.org/hugs](http://www.jlab.org/hugs)])
  - More collaboration with organizations targeting under-represented groups such as National Society of Black Physicists (NSBP), National Society of Hispanic Physicists (NSHP), Society for the Advancement of Hispanics/Chicanos and Native Americans in Science (SACNAS), National Society of Black Engineers (NASBE) and others focusing on women and people with disabilities
    - o Work with the Accelerator Physics Sections of these organizations
    - o Participate in annual meetings with scientific sessions on accelerator science
    - o Annual financial support for joint students/faculty programs (including workshops) with these organizations
  - Develop collaboration/consortium of MSI universities to work on accelerator science similar to the NSCL/MONA collaboration (<http://persweb.wabash.edu/facstaff/brownj/mona/index.html>)
6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?
- Many faculty and students are not aware of the opportunities at national facilities
  - Need dedicated programs located at both the laboratories and universities to facilitate more exposure at universities: laboratory scientists involvement at universities through lectures, teaching courses, on-campus small scale research ...
  - Teaching load and manpower are critical factors
  - University Administration/Laboratory exchange program: create an exchange program that will bring staff scientists to teach courses during one semester and send an administrator (preferentially at the Provost level) to spend 2-3 days monthly at the national facility during that period to establish a bridge to understand each environment and increase efficiency for collaboration/partnership.

7. Does your university accept accelerator course credits from other institutions?

N/A

8. Do accelerator science students at your institution routinely take courses and training elsewhere?

N/A

9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?

- **Faculty (and students) must first be more engaged in national laboratory accelerator science through**
  - o **Dedicated small scale but high impact research projects: building of prototype detectors for FRIB or other facilities, involvement in materials and optical sciences (dominant at MSIs) ...**
  - o **Infrastructure at small institutions must be improved through the partnership/collaboration with national laboratories**
- **Create a dedicated small scale facility to address DoE science mission that benefits the laboratories but also provide a training environment for targeted communities**
- **Expand the US Particle Accelerator School**
  - o **Provide more funding to USPAS to expand their reach into University settings**
  - o **Needed to provide an understanding of accelerator science**
- **Create new user friendly tools for teaching accelerator physics**
  - o **One effort by Muons Inc. using an updated version of their G4beamline tool**
- **Expand/duplicate the NSCL/MONA Consortium**
  - o **Create a consortium of HBCU physics departments (as the lead) to work as a group with national laboratories**
- **Leverage the INCREASE Consortium**
  - o **Provide more funding for their workshops**
- **Annual strong (financial and collaboration) support of professional organizations that focuses on minorities**
  - o **Required to maintain a sustainable effort to reach out to students and faculty and inform them/engage them into national laboratories**

10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?

- **Existing MOU between university and national lab with the Nuclear Physics Division**
  - o **Support faculty, postdoc and students**
  - o **Joint faculty appointments (for both university faculty and laboratory staff scientists)**
- **Can be expanded to accelerator science (has been done at my institution)**

## Contemporary Models of University Accelerator Science

## 11. What examples exist of thriving academic accelerator science programs?

a. Are there policies at your university specific to the accelerator science program that are essential to its success?

**N/A**

b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?

**N/A**

c. Are there barriers to having accelerator scientists serve as PI or Co-I on proposals?

**No.**

d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded?

- **Conversion is possible**
- **One faculty member is in the process of converting**

e. Are there specific attributes of the institution's culture that contribute to the success of the accelerator science program?

**N/A**

f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?

**No**

12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)-(f) above).

- **Establishment: joint appointments, support for postdocs and students have strengthen our nuclear physics program**
- **Improvement: establish similar programs in accelerator science, include engineering department**

13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)-(f) above).

**Not familiar enough.**

## **Possible Mechanisms To Encourage Academic Accelerator Science**

14. What specific, cost-effective actions could be taken to:

**All of the suggestions listed below (a-e) plus**

- **MOUs between Accelerator Division and universities that will provide joint appointments from university faculty and**

<https://www.federalregister.gov/articles/2015/05/14/2015-11664/strengthening-us-academic-programs-in-accelerator-science>

Page 4 of 7

**staff scientists**

- **On-campus mini-series workshops**
- **Develop dedicated K-12 outreach programs in accelerator science (especially at middle/high school level)**
- **University credit courses in accelerator science at the high-school level**
- **USPAS-style hybrid (online/in-class) credit courses for small institutions but stretched over a semester**
- **Awards in Accelerator Science similar to the APS Bouchet Award for women and minorities**
- **Institutional award for advancing accelerator science for and at MSIs**
- **Establish a low energy accelerator facility to address specific science topics aligned with faculty expertise at MSIs that will also provide a framework to increase diversity in workforce development**
- **Support professional organizations that foster accelerator science**

- a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.
- b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.
- c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials.
- d. Increase the enrollment in education opportunities at the baccalaureate and master's level?
- e. Increase the availability of hands-on training opportunities in accelerator technology?

## Other Factors

15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?

- **Inclusion of MSIs during discussions for the upgrade or establishment of new facilities to align/include faculty expertise**
- **Visits/discussion forum between DoE and MSIs on science and education programs located at DoE (headquarters or national facilities) and on MSI campuses.**

16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?

- **Strength: national laboratories environment is extremely powerful and unique to advance accelerator science R&D and programs by nature of their organization, role and function.**
- **Weakness: not enough inclusion of minorities (Hispanic, African-Americans) to tap on a pool of talented scientists. The creation of a small-scale facility as a consortium of MSIs could address this issue, along with involving faculty, postdocs and students in ongoing research to expose them to DoE lab opportunities**

# Request for Information -- Strengthening U.S. Academic Programs in Accelerator Science

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## *Response from Michigan State University*

College of Engineering  
College of Natural Science  
Facility for Rare Isotope Beams

The discussion of academic accelerator science in the U.S. is a timely one, especially for Michigan State University (MSU). At MSU the NSF-supported nuclear science national user facility at the National Superconducting Cyclotron Laboratory (NSCL) is presently an operating accelerator facility, while Facility for Rare Isotope Beams (FRIB) project is under construction. FRIB will be a DOE-SC scientific user facility based on a new superconducting linear accelerator capable of accelerating all ions to 200 MeV/nucleon with 400 kW of beam power. FRIB will allow the nation to maintain leadership in rare isotope science and will allow MSU to maintain a world-class accelerator for years to come. The nearly \$1B FRIB project, funded by the U.S. Department of Energy through a cooperative agreement with Michigan State University, has led to a recent increase in the laboratory's staff from roughly 300 to over 600 employees (both NSCL and FRIB) during the past five years including a rise in the number of accelerator science faculty and graduate students performing accelerator research on campus.

With FRIB comes the continuous need for a well-trained staff of technicians, engineers and scientists to deliver the high-power rare isotope beams to the user community. The NSCL/FRIB staff presently includes approximately 50 PhD physicists engaged in accelerator or beam-related activities, 50 accelerator engineers, and 100 non-PhD engineering physicists/technicians working on accelerator or beam-related efforts. FRIB is expected to increase its staff even further by the time it becomes operational, with a greater percentage of these employees being accelerator professionals relative to the present NSCL. With this opportunity, comes the increased importance for a reassessment of MSU's academic program in accelerator science.

Traditionally, over the past 50 years, roughly 2-3 faculty members at MSU have had research interests in accelerator science at any one time; today, with FRIB comes an increased academic presence. Over the past 5 years the number of accelerator faculty members at MSU has grown to 12, distributed between the Department of Physics and Astronomy (2), FRIB/NSCL (8, including 5 with joint appointments in

the Physics department), and the College of Engineering (2). The current number of PhD students enrolled in these departments working with an accelerator science emphasis is approximately 18 (12 in Physics and 6 in Engineering). Numerous undergraduate students are also hired from physics and engineering for specific accelerator-related projects. Many of these become motivated to pursue graduate training in the field, thereby providing valuable future talent to accelerator science.

The accelerator research at FRIB/NSCL has traditionally been in areas such as cyclotrons, beam transport, beam instrumentation, space charge effects, heavy ion acceleration, with more recent (past 15 years) emphasis in the areas of superconducting radio frequency cavities and systems, ion source R&D, and computational accelerator physics. In the Department of Physics and Astronomy the Center for Beam Theory carries out research in computational and mathematical physics related to the design and modeling of beams and accelerators. Also within this department is a very strong group developing next generation ultrafast electron microscopes, and the Center for Beam Theory is contributing to the design and simulation effort for this project. In the College of Engineering, within the Department of Electrical and Computer Engineering, a research group concentrates on plasma physics and related accelerator R&D. MSU has also formed a new computational sciences department that is expected to have an accelerator-linked component, and also has a well-developed High Performance Computer Center (HPCC) with significant freely available parallel computer resources for faculty projects. While student research may be concentrated in accelerator science, the graduates of these programs at MSU acquire MS and PhD degrees in Physics or in Engineering.

## **Increasing the Recognition of Accelerator Science in Academia**

The curriculum at MSU offers several courses for students that wish to specialize in accelerator science: approximately 8 in physics and 3 in engineering. In particular, courses in introductory beam physics, nonlinear beam dynamics, particle accelerators, electrodynamics of plasmas, numerical modeling of plasmas, and "advanced topics" courses that vary from semester to semester. Additionally, MSU offers a course, PHY 963 -- "USPAS Courses", through which credits can be readily obtained by students that attend the U.S. Particle Accelerator School, held twice each year (see [uspas.fnal.gov](http://uspas.fnal.gov)).

The typical graduate student in physics or engineering specializing in beam and accelerator physics typically takes an introductory course (either given at MSU or through the USPAS), 1-2 other courses at MSU (plasma or nonlinear dynamics courses) and usually 2-3 USPAS courses. All of these courses are in addition to the core-curriculum required of any PhD in Physics (classical mechanics,



electrodynamics, quantum mechanics, statistical mechanics, for example) or Engineering.

MSU is also home to the online VUBeam program for Master's and PhD studies, which allows various online courses along with MSU physics department courses and USPAS courses to meet degree requirements in accelerator physics. This ongoing program has been in place for over 15 years. Having the professors running the VUBeam program "in-house" opens significant additional benefit for local MSU students in accelerator science.

The USPAS plays an important role for the MSU accelerator science program. Students take good advantage of the USPAS, with course credits directly transferring to MSU through the special course provided in the MSU curriculum. Even with the vibrant ongoing project at FRIB, it is unusual to have more than 2-3 new students at MSU ready for advanced topics accelerator courses at any specific time. This results in severe issues both in scheduling and justifying preparation time for faculty to teach. Conversely, through the USPAS, students have access to specialized accelerator courses twice each year (an intensive format held between terms to minimize conflicts). This helps MSU offer adequate specialized training. Several MSU faculty also actively participate in the USPAS teaching both accelerator fundamentals and advanced topics courses. Better support for these activities would be most welcome and fit realistic constraints. It should also be noted that class sizes are typically larger in the USPAS helping justify substantial faculty time to prepare advanced topic lectures. Students also benefit from lectures delivered by recognized leading experts in relevant topical areas in the USPAS program.

Students at MSU have traditionally come into the field of accelerator science from disciplines such as nuclear or high-energy physics, condensed matter physics, or from various engineering disciplines. More recently there have been students applying to MSU that want to study accelerator science and technology from the outset. This number has increased in the past 1-2 years, no doubt stimulated by the unique situation of having the high-profile FRIB project being built directly on campus.

Funding for accelerator research at MSU comes from a variety of sources, including grants from the Department of Energy and from the National Science Foundation, as well as direct MSU support. Work for other DOE national laboratories is sometimes performed through contracts. Improved funding for the field could stimulate further growth in the accelerator program at MSU. Due to the FRIB project needs and good support from the university, there will be an additional professor hire linked to accelerator physics and FRIB in the near future. Enhanced funding both for academic projects and student support is needed.

FRIB and the NSCL are located in the middle of the MSU campus, right next door to the Physics and Astronomy Department and close to the engineering complex. While the FRIB laboratory is university-based it is similar in scale to national lab

infrastructure creating a rather unique situation for student training: laboratory research and class work can be undertaken by students simultaneously to enhance training. Often it is the case that students must stop traditional student activities to join laboratory research groups in accelerator physics at a national laboratory. This is not the case at MSU. As a result of this proximity of academic and laboratory resources and the vibrant FRIB project, MSU is well situated for an active future role in the development of our accelerator workforce. Additional funding to exploit this via academic grants, students scholarships, etc. would be most welcome and could be effectively exploited at MSU to enhance opportunities for academic training.

In terms of business contacts, MSU has numerous contracts with industry associated with the purchasing of accelerator hardware associated with ongoing construction of FRIB. Unfortunately, it is difficult to mix such industrial contracts with academic training needs due to the necessity to segregate funding. One exception to this is the Small Business Innovative Research program (SBIR), which has stimulated various long-range accelerator research projects. Such programs can easily accommodate student labor for training.

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

The national laboratories provide rich environments for the development of graduate students in accelerator science. Whether the students, upon graduation, move into the national laboratory realm, remain in academia, or go into industry, experience gained through visits and/or work performed at large accelerator laboratories generally are quite transformative. MSU has often sent students to visit a national laboratory for short periods. In a few cases of late, students have received funding from a laboratory for a summer visit or for a meeting. In the past, MSU students have participated in the Joint University-Fermilab Doctoral Program in Accelerator Physics and Technology, which sponsors students for extended stays to perform PhD research at the accelerator lab.

A primary barrier that exists between further student involvements at national laboratories is financial. The high cost of FTEs at DOE laboratories is a major impediment. If overhead could be reduced for external collaborations, this could stimulate use of unique national lab capabilities. Additionally, the overhead required for a university student to participate effectively in research at a national lab includes substantial time spent at the lab and travel/housing costs, etc. The DOE has instituted its Office of Science Graduate Student Research (SCGSR) Program to help in this regard, but the program is limited to U.S. citizens (many of our graduate students are not), and the time frame is limited to 3 to 12 months. While this is often adequate for someone who is performing a user experiment at a DOE lab and requires beam time, for example, it can be too limited for full participation in accelerator projects or development studies.

A more extensive program to support graduate students in much the same fashion as in the Fermilab doctoral program -- where the student is supported at the national lab for a number of years, and housing, tuition, graduate stipend, etc., are covered -- would be very attractive. With such a program, graduate students can become involved in new accelerator initiatives and extensive accelerator improvement projects at the labs.

## Contemporary Models of University Accelerator Science

MSU continues to be one of the top producers of PhD and MS graduates in the sub-field of accelerator science. A typical academic year produces 2-3 PhDs and 2-3 MS graduates from MSU. The VUBeam online program within the Center for Beam Physics at MSU is unique in that it attracts students from all over the world. The Center for Beam Physics has often taken good advantage of opportunities provided at the national labs for student involvement and training. The interaction of the USPAS with MSU also provides a model for how to integrate the community's investment in the USPAS (developed to provide advanced training in accelerator physics) into a university's academic program.

MSU support for accelerator physics has been very good. This support is derived from MSU's desire to remain the premier university-based facility for nuclear physics in the U.S. Accelerator physics is seen as essential to secure this role via FRIB. Support from the MSU president and Michigan state legislature has been excellent and has made a positive difference in both the highly competitive proposal process to secure funding and in project reviews.

While funding for faculty is derived from the FRIB project, an NSF grant supporting the operation of NSCL, support through MSU funds, and through separately funded DOE and NSF grants, there are no endowed chairs or other awards or positions that give special recognition to accelerator science. Providing funding for such would enhance both the academic prestige and standing of accelerator physics within the university. Due to the primarily applied and support nature of accelerator physics, there is not recognition of the technical creativity within accelerator physics commensurate with developments made.

It should be emphasized that practically all of the accelerator science faculty at MSU have made the transition from research faculty positions, most having previously been employed at national laboratories. While there are no joint appointments with any other national laboratories or private companies, numerous national lab and company scientists are involved in the FRIB project.

Much of accelerator physics is practical and hence advances in materials can have strong impact in improved performance of accelerator systems. Improved superconductors, better understanding of superconductor properties for magnetic optics and SRF cavities, and permanent magnets are good examples. Academic programs in materials science are therefore successful examples from other technologically oriented disciplines that are relevant to the establishment or improvement of a strong accelerator science program.

## **Possible Mechanisms to Encourage Academic Accelerator Science**

Below is a list of cost-effective actions that could be taken to better foster academic programs in accelerator science.

1. Improve funding at universities for accelerator projects with relevance to accelerators at scientific user facilities.
2. Support 6-8 graduate/post-doctoral training programs at leading academic accelerator institutions, each sponsoring 10-12 graduate students/post-docs per year
3. Increase student and postdoctoral support of university campus-based facilities such as FRIB. This allows intermixing of academic studies and project training while not precluding student life.
4. Reduce national lab overhead rates for university linked accelerator projects and longer-term student support so unique capabilities can be better exploited for academic projects.
5. Encourage university linkages in SBIR funding related to accelerator science. This would also help ensure that advances are disseminated and retained.
6. Undergraduate students can often be employed in support work when projects (such as FRIB) are located on university campuses. This can both provide valuable training and motivate the students to continue on to a graduate level in the field. Funding to support this should help recruit quality students to the field.

## **Other Factors**

Linkages to the US Particle Accelerator School should be fostered further. It is not practical to have enough students at universities to regularly instruct specific specialized topics relevant to the field. The USPAS allows this to happen with focused, high quality instruction. It is a good system. A recent question on whether the DOE could continue support of the USPAS due to unfortunate language in congressional guidance was alarming. Pulling support for the USPAS would severely damage accelerator science. Programs also need proper continuity to

remain viable and meet the national needs to remain on the forefront of accelerator science and technology.

## **Final Remarks**

The recognition by the DOE of the important long term needs to strengthen the US program in accelerator science and technology is very encouraging. The field is a critical driver for many technical topics vital to our nation. It requires proper continuity of support and funding for us to remain world leaders. MSU is well situated to take an active role in meeting this need. The vibrant FRIB project integrated into a research university, together with a large and growing staff with a significant number of professors, online offerings and linked USPAS offerings, and programs in physics, engineering, and computational sciences creates a unique situation to help address academic program needs. MSU looks forward to working with the DOE to address strengthening of the US academic program in the field.

## **JFI Response from University of Tennessee**

The University of Tennessee Department of Physics and Astronomy has a recognized graduate program in Accelerator Physics, which was initiated about one decade ago. The program relies on a few UT/ORNL Joint Faculty Appointments with physicists at the Spallation Neutron Source accelerator. This is a particularly effective arrangement in the field of accelerator science, where the primary scientific technology is typically located at a DOE facility, and the university partnership capitalizes on these resources for educational purposes. While a conversion from a Joint Faculty appointment to a full faculty position at UT is possible in principle, it is not necessary to accomplish the educational mission in accelerator science.

The accelerator physics graduate students take the same core graduate coursework as the other doctoral students, but rely on the USPAS to fulfill their field specialty courses. All of the UT accelerator physics graduate students conduct their graduate research at the SNS accelerator. The doctoral program does not seek out corporate sponsorship, and instead relies on funding through ORNL and through grants from DOE or NSF acquired by Joint Faculty members.

To increase activity in accelerator science educational programs, a few suggested actions are:

- 1) Revise the eligibility requirements for the graduate fellowship in accelerator science. Currently, the fellowship program requires that students have completed their coursework in order to apply for the fellowship. However, at UT and most universities, graduate student recruiting occurs after the doctoral qualifier exam but before the completion of coursework. If the eligibility requirement were revised to require only the successful completion of the qualifier exam, the fellowship could be more broadly used as a recruiting tool.
- 2) Establish a small, competitive fund to support equipment for graduate doctoral projects. Due to restricted budgets across the laboratories, there is a deficit of good “hands-on” projects for graduate students. A competitive fund requiring a small proposal would give graduate students an opportunity to gain experience with grant writing, and to secure funding for a equipment to be used in their doctoral research in a timely fashion. This would broaden the number and variety of available graduate research projects.
- 3) Establish a postdoctoral fellowship program similar to the Jansky Fellowship program in astronomy. In the case of accelerator science, senior graduate students would write proposals to work on a particular topic in accelerator science at a qualifying university of their choice. The fellowship would include 2-3 years of postdoctoral funding and a small equipment budget. Though the graduate student would write the proposal, letters of support would be required from the university committing to hosting the student as a postdoctoral scientist if the award is made.

## Jefferson Lab Response to the Accelerator Science

### Request for Information

This document summarizes the response of the senior leadership of Jefferson Laboratory's Accelerator and Engineering Divisions to the Request for Information (RFI) entitled "**Strengthening U.S. Academic Programs in Accelerator Science**".

The document is structured into the following sections: Jefferson Lab's mission, operating accelerators, and training needs are briefly described, including some information on current staff. Jefferson Lab's past and current education efforts in the fields of accelerator physics and technology are then briefly reviewed. Finally, the specific questions in the RFI addressed mainly to University-National Lab interactions (Questions 5-10) will be addressed directly. As discussed below, Jefferson Lab has a formal agreement with Old Dominion University (ODU) regarding training in Accelerator Physics and Technology. This document has been coordinated with those individuals from ODU preparing their input.

Jefferson Laboratory is a DOE nuclear physics laboratory organized so that world-leading electron scattering experiments can be performed allowing detailed study of the theory of strong interactions, QCD. The center-piece of this experimental program is the superconducting CEBAF accelerator, recently upgraded to 12 GeV beam energy, and a variety of detectors located in four experimental halls. Jefferson Lab is a world leader in Superconducting Radio Frequency (SRF) beam acceleration, and has hosted a smaller, high current energy recovered linac accelerator which has been used to drive a high average power free electron laser.

Currently, approximately 250-300 staff members at the lab are engaged in accelerator related activity: operating and maintaining the accelerator systems; further developing the lab's core high intensity, long life time polarized electron source and SRF accelerator technology R&D; and designing and planning accelerators for future experimental programs at the lab. An important part of our future activity will be to build about half of the superconducting linac for the new LCLS II project at SLAC National Accelerator Laboratory.

In the past and up until the last decade, most of the accelerator physics and engineering staff at Jefferson Lab have been trained in the relevant technology through a combination of "on-the-job" training and by attending job-related courses presented by the United States Particle Accelerator School (USPAS). This situation is largely the result of realities within the academic system in the United States being addressed by this RFI: general lack of regular presentation of accelerator courses in university curricula, difficulties in creating new programs and disciplines within universities, especially of a cross-discipline nature, and a general lack of funding support for accelerator physics as an academic discipline within university physics and engineering departments. As the opportunities for participating in accelerator projects have resided mainly within the national lab system, it is quite natural that accelerator training has been forced to reside there, even though the sporadic nature of this kind of approach is not very efficient.

In response to the dearth of possibilities in accelerator physics in academia, approximately 10 years ago, Jefferson Lab and Old Dominion University (ODU) entered into an agreement

whereby several senior accelerator physicists from the Center for Advanced Studies of Accelerators (CASA) could engage in university activity up to a set fraction of their time. The overall goal and idea was that a university-based training center for accelerators and accelerator physics be created. Presently, ODU's Center for Accelerator Science (CAS) is an on-going enterprise that has attracted approximately \$6M of external funding from a variety of sources. Regular accelerator physics courses have been established at the senior undergraduate/beginning graduate level, a new course at the graduate level will be presented for the first time in Fall 2015, and the center has allowed ODU to initiate materials science studies supporting the future development of advanced SRF accelerators. Please refer to the document from ODU for more information.

The rest of the document provides our responses, from the perspective of a national lab, to questions 5-10.

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

5. How can the national laboratory system be best utilized by the university accelerator science community?

*The national laboratory system itself is organized to provide access to scientists to facilities generally beyond the reach of individual universities. This feature can be their main benefit to university programs in accelerators generally: access to fore-front equipment and facilities. In order for this access to be achieved, suitable arrangements must be found to support students at the national lab during their research.*

*The national labs often have challenging problems and needs for forefront R&D that could be ideal training opportunities for students and provide stepping stones into future career paths.*

*Proximity of a national lab to the university is a big advantage, but definitely not sufficient. The national labs must be encouraged and given recognition for collaborating with universities in fostering accelerator science education. The collaboration must include access to the expertise of the scientists and engineers and to the facilities which are not normally available at the universities.*

6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?

*Other than the fact that the capabilities of the Jefferson Lab accelerators are perhaps not so widely known and generally accessible to interested outside parties as at other national laboratories, we believe that there are relatively few technical barriers to prevent close collaboration between Jefferson Lab scientists and university researchers. In fact, mainly in experimental nuclear physics here, it is routine for university scientists to participate fully in developing and providing experimental equipment, executing experiments, and publishing Jefferson Lab experimental results within the context of the collaborations present at the lab.*



*This means the technical mechanisms to solve many of the problems of collaborating with university scientists have been established already.*

*On the other hand there are indeed significant operational and economic barriers present that make such collaboration more difficult in accelerator physics and technology. Within the current funding model, Jefferson Lab's Accelerator Division operating funding is primarily directed towards delivering beam for physics users, developing technology for future experiments at the lab, and supporting work-for-others activities for clients outside the lab. Presently, the largest example of work in the latter category is our participation and major contribution to the LCLS II project mentioned previously. As is true with any large project, funding tends to follow pre-planned smaller sub-projects with specific project deliverables. Usually it is difficult for University-based efforts to have specific competences in particle accelerators that would allow them to be considered as possible sub-contractors on the sub-projects, especially if there is no track record of accomplishment at the University. There can also be reluctance on the part of the national labs to give up resources to the universities in cases where lab-internal resources can complete the sub-project without assistance. However in cases where suitable lab-internal resources are lacking, the national labs will very often be quite happy to participate with external experts, perhaps at a university, to solve specific problems within a project or sub-project.*

*Partly this problem is one of scale; the scale of the accelerator projects is so large. But with forethought, proper planning, and intent, it should be possible to break up large accelerator projects into packages suitable for university participation, as has become routine in high energy and nuclear physics experiments.*

*Another possible barrier is the limited availability of suitable and experienced mentors within the labs to host and guide students. In practice at Jefferson lab there are many such qualified individuals willing to perform this role, however the dedicated time required to engage in such activity is not always available because of other demands. A lack of specific funding for this purpose and/or dedicated financial support for the students or their projects can likewise hinder significant utilization of lab scientists in mentoring activity.*

*Finally, access to facilities and the costs that the universities have to pay for the access and overheads is an economic burden that a university department cannot always afford.*

7. Does your university accept accelerator course credits from other institutions?

*Jefferson Lab does not face this problem. We routinely utilize courses at ODU and other universities as part of staff training. We encourage our staff to attend the USPAS. We have not had any problems with the ODU program accepting USPAS credit, especially since many of the relevant USPAS courses are listed in the ODU course catalogue because ODU has organized two USPAS sessions. In principle, the university will accept accelerator course credits subject to the usual evaluation by the department.*

8. Do accelerator science students at your institution routinely take courses and training elsewhere?

*All Jefferson lab students, including those from universities other than ODU, take advantage of the courses offered by USPAS, which is an invaluable resource in promoting accelerator science in the US. Many students take training in the use of SRF equipment, in addition to safety training required of all workers at Jefferson Lab. We have not had the need or occasion to send students performing research at Jefferson Lab to courses in departments outside their home university department, by in large. We have had occasions when we needed to send students to businesses or universities to perform measurements on specialized equipment that they possessed, or for specific software training.*

*In the short term, we anticipate continuing need for USPAS courses to meet Jefferson Lab training needs. The course structure, content, duration, and frequency of presentation are quite well suited to our demand; indeed Jefferson Lab staff assist in developing the curricula for the school. Therefore we do not expect or anticipate many changes in these areas.*

*On the other hand, we are aware of the discussions surrounding future funding of the USPAS. Because the activities in the field of particle accelerators has broadened beyond its original HEP base, adopting a model where the US Particle Accelerator School is funded as a separate line item by DOE-OS or as a university collaboration by NSF might have very beneficial effects. The former model may enhance the support of and the standing of the large amount of accelerator work outside of the traditional DOE-HEP home of such funding (e.g., DOE-NP or DOE-BES programs), and the latter approach is sure to enhance the possibility of accelerator physics and development activities at universities.*

9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?

*A commitment by DOE to allocate the national laboratory resources both intellectual and facilities, (taking into account the mission-critical operations of the laboratory), at no or low cost in fostering the education of accelerator scientists will be highly beneficial.*

*Another idea that has been successful in creating and strengthening a strong Jefferson Lab-university relationship in nuclear physics studies, is the use of joint positions and bridge positions at the universities. In a typical example the university and Jefferson Lab agree to fund a set fraction of a university position, with the understanding that the faculty member works on Jefferson Lab-related physics. For the bridge positions the support from Jefferson Lab has a finite duration. Presently there are 18 joint faculty members in 7 universities and 6 bridge positions in another 6 universities working on theoretical and experimental studies of Jefferson Lab nuclear physics topics. There is only one such joint position in accelerator physics at present; this position is held by the director at ODU's accelerator center. Given support, it is possible to imagine expanding the joint faculty programs to include Jefferson Lab accelerator physics studies. If several universities could be persuaded and supported to establish joint positions, this could go a long way towards expanding course possibilities and graduate student training in accelerator physics at universities, and enhancing the field of particle accelerator physics within universities generally.*

*One should also be cognizant of the need to attract engineering students into the field of particle accelerators by providing academic opportunities to work on accelerator technology development interesting to the national labs. Various accelerator technologies have a strong engineering component to their development. For example, superconducting magnets, superconducting beam acceleration, both in its science and engineering aspects, the cryogenic systems to keep the superconductors cold, RF power and low level RF control, beam instrumentation and beam feedback control, and many other topics have a very strong engineering flavor but no “academic” home in this country. The strongest programs are within the national lab system. In order to facilitate entry of engineering talent into these fields it may be very advantageous to establish “Centers of Excellence” partnerships between the leading national lab programs and interested academic engineering programs, analogous to the CASA/CAS model. Projects and funding in the field would be directed into the Center for development with the idea that an appropriate mix of national lab and university talent (and funding!) would be directed towards individual projects. In the beginning, the national lab fraction of the funding would perhaps be the larger fraction; the longer term goal, e.g., after 5 years to a decade, would be to evolve to a more equitable mix. Possibilities of joint appointments of lab engineers in engineering departments of the center participants would be appropriate and it is important that the university faculty involved in the center have a strong interest in developing engineering talent specifically for future accelerators.*

10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?

*Jefferson Lab has MOUs with ODU that allow faculty to hold joint and bridge positions. ODU invites and encourages Jefferson Lab scientists to be adjunct faculty and has established special professorship categories which allow the scientists to have full faculty privileges. These have been extended to both nuclear physics and accelerator science staff at Jefferson Lab. As is obvious from our response in questions 6 and 9, we would welcome extending the scope of present agreements with universities to include accelerator physics and engineering if there is mutual benefit to do so. Going in this direction would to some extent build on the model that we have pursued with ODU, which we would like to expand if possible. On the other hand, until there are more faculty members participating in accelerator activity in academia, there may be a “chicken-and-egg” problem in finding suitably accomplished accelerator practitioners to form collaborations and MOUs with.*

## RESPONSE

**TO:** DoE RFI on “STRENGTHENING U.S. ACADEMIC PROGRAMS IN ACCELERATOR SCIENCE”, Office of High Energy Physics, Department of Energy

**FROM:** The University of Chicago, Prof. Young-Kee Kim, Prof. Kwang-Je Kim, and Prof. Sergei Nagaitsev

### **Increasing the Recognition of Accelerator Science in Academia**

**1. Does your institution regard accelerator science as an academic discipline? Why or why not?**

Yes, accelerator science research topics are regarded as a suitable thesis topic for PhD. The accelerator research is active and will hopefully be more active with the “return” of YKK from FNAL and with the appointment of a new part-time professor (SN)

**2. If your institution offers graduate training in accelerator science:**

Yes, limited. Practical training is available at partner labs, ANL and Fermilab.

a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)

All PhD students, including those pursuing accelerator research, need either take the minimum courses (analytical mechanics, E&M, Quantum mechanics, experimental physics,..), or must prove her/his proficiency in those areas by passing a qualifying exam.

b. How often do students change fields to study accelerator science? From which fields do these students typically come?

There have been four accelerator PhD degrees conferred since 1998. (two by KJK, two by YKK). One student was from elementary particle theory (KJK). The other three were all interested in accelerator physics from the beginning. At present, there are two graduate students enrolled in a Joint University-Fermilab PhD program.

c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments?

The Department of Physics; the University of Chicago does not have applied physics or engineering department.

d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?

The most compelling driver is the accelerator science itself. The University of Chicago is a relative new-comer in this area of science. Establishing a world-class program will require additional funding opportunities.

e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?

No accelerator on campus. Students use facilities at Argonne, Fermilab, and LBNL.

f. How often do collaborations occur between accelerator science and other programs at the university?

Collaborations occur fairly regularly.

g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program?

No.

3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?

N/A

4. What funding sources for accelerator science are you aware of?

DOE, NSF, DND, and Keck Foundation

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

5. How can the national laboratory system be best utilized by the university accelerator science community?

The Joint Universities-Fermilab PhD program in accelerator science is an excellent example of how the national laboratory system can be utilized.

6. What are the current barriers (*e.g.* technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?

Scarcity of part-time or visiting professors from national laboratories, in sufficient funding for providing student research fellowships.

7. Does your university accept accelerator course credits from other institutions?

Yes

8. Do accelerator science students at your institution routinely take courses and training elsewhere?

They normally attend the USPAS

9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?

Identify common areas of expertise between the research areas of faculties and accelerator labs, such as detector technology

10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?

Some U of C condensed matter physicists are studying the problem of improving superconducting RF cavity performance (higher Q, higher accelerating gradient,..) by surface treatment.

## Contemporary Models of University Accelerator Science

11. What examples exist of thriving academic accelerator science programs?

a. Are there policies at your university specific to the accelerator science program that are essential to its success?

No

b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?

No. It would be nice to have those!

c. Are there barriers to having accelerator scientists serve as PI or Co-I on proposals?

No

d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded?

Nearly impossible. However, U of C is open to hire high profile accelerator scientists as faculty.

e. Are there specific attributes of the institution's culture that contribute to the success of the accelerator science program?

f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?

U of C has two part-time professors as joint appointment, KJK from Argonne and S. Nagaitsev from FNAL. The status of the part-time professors is higher than adjunct professor—they can be PI, can vote for promotions and hiring (except for full professors).

12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)-(f) above).

13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)-(f) above).

There are several academic institutions in foreign countries that produce qualified accelerator physicists, such as Budker Institute of Nuclear Physics, Accelerator physics group at Peking U, Accelerator physics department in Tsinghua U, etc. Collaboration with these institute can lead to enticing bright students in accelerator physics.

## Possible Mechanisms To Encourage Academic Accelerator Science

14. What specific, cost-effective actions could be taken to:

a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.

Universities typically provide start-up funding to new faculty members, especially to junior faculties, to buy lab equipment, get students, etc, before they can get their own funding. It would be nice to have a similar funding opportunity to the part-time professors of U of C to be able to offer research fellowships for part-time summer students or for PhD program. Sometimes we encounter students wishing to pursue accelerator physics research but have to turn them back due to lack of funding. It takes too long to apply for funding after finding students. It could be more cost effective than a named faculty position.

b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.

c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials.

See the response above, 14a

d. Increase the enrollment in education opportunities at the baccalaureate and master's level?

This is also a good point. Students from abroad who majored in accelerator physics have difficult time to be admitted to the U of C physics PHD program since they have not taken sufficient core physics course. The U of Chicago used to have (and may be they still do) a university master's program which are designed for such students. Students successfully completing the master's program are usually admitted to the regular graduate PhD program. We need, of course, funding for student stipendium.

e. Increase the availability of hands-on training opportunities in accelerator technology?

## Other Factors

15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?

See 14a

16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?

See 14a



# Response to the DOE/HEP Request for Information on Strengthening U.S. Academic Programs in Accelerator Science<sup>†</sup>

(<sup>†</sup>Federal Register / Vol. 80, No. 93 / Thursday, May 14, 2015 / Notices)

Submitted by: P. Bucksbaum, R. Hettel, Z. Huang, D. MacFarlane, L. Merminga, N. Phinney, D. Reis, R. Ruth, J. Seeman, S. Tantawi, V. Yakimenko

SLAC and Stanford University

June 18, 2015

## Increasing the Recognition of Accelerator Science in Academia

### 1. Does your institution regard accelerator science as an academic discipline? Why or why not?

*Stanford considers SLAC as a school of the University as well as a National Laboratory. Stanford currently has seven accelerator faculty members at SLAC, some with courtesy joint appointments at the other Stanford schools. Several other faculty members of Stanford actively conduct research in fields broadly related to accelerator sciences. Both Physics and Applied Physics give prospective students the choice to select accelerator physics and related fields as an academic interest on their applications.*

### 2. If your institution offers graduate training in accelerator science:

#### a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)

*The following courses are offered by the Stanford Applied Physics Department and are taught by SLAC accelerator and Stanford Applied Physics faculty:*

- *Electrons and Photons (AP201)*
- *Applied Electrodynamics (AP220)*
- *Nonlinear Dynamics: This side of Chaos (AP223B)*
- *From Atom Smashers to X-ray Lasers (AP240)*
- *Introduction to accelerator physics (AP324)*
- *X-rays: past, present and future (AP325)*
- *Synchrotron radiation and FELs (AP453A)*

*“Electrons and Photons” is part of the core curriculum for Applied Physics students and is cross-listed as a SLAC Photon Science course. The others are typically taken as well by students of accelerator physics or the subfields of physics, chemistry, and materials science that use these sources.*

*In addition, SLAC offers a one-week summer seminar (school) on Electron and Photon Beams to introduce senior undergraduate and graduate students to accelerator research (<https://conf-slac.stanford.edu/sssepb-2015/home>).*

#### b. How often do students change fields to study accelerator science? From which fields do these students typically come?

SLAC currently has about 15 Stanford graduate students in accelerator science from physics, applied physics and engineering departments. Some of them have switched from particle physics, nuclear physics, engineering or X-ray sciences.

- c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments?**

SLAC is considered a school of Stanford University and is the primary home to the accelerator science program. The Stanford Applied Physics recognizes its stewardship responsibility for the academic program (see their website <http://web.stanford.edu/dept/app-physics/>). There are also faculty members in the Stanford Applied Physics and Engineering departments that participate in accelerator research and education.

- d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?**

The departments of Photon Science and Particle Physics and Astrophysics at SLAC have faculty development plans that explicitly include future hires in accelerator science associated with new opportunities such as advanced materials, RF technology and laser applications in accelerators. In order to realize these new hires, we will need additional funding to conduct independent accelerator research, including the hiring of graduate students and post docs.

An added boost would come by providing named accelerator science faculty positions, supported by university patrons that would allow an academic department, such as EE or (Applied) Physics, to host such a discipline. This is more likely to happen if the benefits of accelerator science and technology are exposed to a wider field of applications. DOE can encourage this.

- e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?**

All accelerator test facilities and all experimental accelerator R&D facilities are on the SLAC National Accelerator Laboratory site. This does not include potentially related research on low energy laser electron acceleration or electron nanotips on Stanford campus.

- f. How often do collaborations occur between accelerator science and other programs at the university?**

Ongoing collaborations occur quite often between accelerator science and other science and engineering disciplines, especially related to laser applications in accelerators (Applied Physics Department), accelerator technology for medical applications (Stanford Medical School), ultrafast electron diffraction and microscopy (Materials Science, Chemistry and Biology Departments), and accelerator instrumentation, controls and feedback systems (Electrical Engineering Department).

- g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program?**

SLAC has relations with several Silicon Valley companies, most notably CPI, Varian Medical, and L3 Communications. SLAC also has constant contacts with SRI and other companies. These institutions consult and work with SLAC on a variety of accelerator

*technology issues and recruit SLAC graduate students and post docs at times. While they do not presently sponsor academic work at SLAC, it is a possibility worth exploring.*

**3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?**

*Stanford currently offers graduate training in accelerator science.*

**4. What funding sources for accelerator science are you aware of?**

*Funding sources for SLAC accelerator science and technology programs include DOE/HEP, DOE/BES, DOE/NP, NSF, NIH, DARPA, Accelerator Stewardship program and some work for others funded by various national and international institutions.*

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

**5. How can the national laboratory system be best utilized by the university accelerator science community?**

*U.S. national laboratories can provide access to accelerator user and test facilities for education and training. They can provide opportunities for participation in design, operation and R&D programs for these facilities, and immersion in the professional accelerator science and technology community. They can teach specialty classes and summer schools for graduate students. They can offer summer internships for undergraduates.*

*DOE can establish graduate fellowships to encourage students to work in US national labs specifically for accelerator science. This can be similar to the DOE graduate program, and indeed we have one UCLA student working on his Ph.D. on accelerator physics at SLAC supported by DOE Office of Science Graduate Student Research (SCGSR) Program.*

**6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?**

*Technical:*

- The lack of small training facilities at national labs where students can gain hands-on experience deters many collaborative opportunities with universities.*
- Activities at most national labs must align with laboratory missions, preventing a broader range of research from being pursued with universities.*

*Operational:*

- See next "Economic" section for comments on the cost of doing business at SLAC.*

*Economic:*

- University researchers planning experiments at the SLAC accelerator test facilities require substantial support from the SLAC staff. This can be prohibitively expensive unless supported by operations funding for the facilities. While there have been examples of seed money from the laboratory, long term viability requires appropriate operations funding to support university researchers.*
- The ability of the DOE labs to accept or take advantage of other non-DOE funding sources with limits on application of overheads remains a significant barrier to alternative funding, for example from Stanford University or NSF. A mechanism to allow offset of overhead costs in these cases would open up many new education and research opportunities.*

**7. Does your university accept accelerator course credits from other institutions?**

*Stanford accepts course credits from other universities provided that there is a faculty member that teaches a similar course that is willing to certify that the content of the course in question is adequate.*

**8. Do accelerator science students at your institution routinely take courses and training elsewhere?**

*Students routinely take classes at the US Particle Accelerator School and occasionally at the Linear Collider and CERN Accelerator Schools.*

**9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?**

*Develop funding programs that are specifically aimed at small-scale research and education (graduate and postdoctoral fellowships) at the National Labs that are targeted at fostering University-Laboratory collaboration. DOE and the national labs should work together to create a suitable structure for these programs.*

**10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?**

*The Stanford PULSE Institute is a Stanford Independent laboratory that exists in order to facilitate cooperative and/or collaborative research between Stanford faculty and SLAC in the area of ultrafast science. PULSE has been a primary mechanism for collaboration between campus faculty and accelerator research at SLAC. Examples of the services provided by PULSE are appointment of students and postdocs who work with SLAC scientists and faculty; hosting cross-school proposals for interdisciplinary research involving the accelerator faculty and staff; organizing an international Ultrafast X-ray Summer Institute to expose grad students and postdocs to x-ray laser research opportunities.*

## **Contemporary Models of University Accelerator Science**

**11. What examples exist of thriving academic accelerator science programs?**

*Accelerator science programs in the US exist at the following universities:*

- *Colorado State University*
- *Cornell University*
- *Indiana University*
- *Michigan State University*
- *Northern Illinois University*
- *Old Dominion University*
- *SLAC/Stanford University*
- *SUNY Stony Brook*
- *UCLA*
- *University of Chicago*
- *University of Maryland*
- *University of Texas*

*SLAC/Stanford University has a strong program with dedicated faculty members that teach and give PhD degrees in accelerator science and technology. Cornell University also has a strong program with its ERL R&D, CESR collider and CHESS light source. A key advantage*

of the Cornell program is that the accelerator physics is embedded in the Physics Department. This gives their faculty full access to both undergraduate and graduate students.

Other universities, having reasonably good connections to more remote national labs, can still have strong academic programs in accelerator physics with dedicated faculty members (e.g. UCLA). Still other universities have programs in accelerator physics simply because of a faculty member or two that have interest in the subject. In some cases the programs are linked to the interests of a particular individual faculty member and can disappear as those faculty retire or shift interest.

**a. Are there policies at your university specific to the accelerator science program that are essential to its success?**

*The accelerator science program at Stanford adheres to the same policies as the other programs of study in Humanities and Sciences, and in Engineering.*

*The success of cooperation between SLAC and its sister Stanford schools depends on faculty members sharing common research interests and goals rather than having a policy that dictates this cooperation.*

**b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?**

*While there are no endowed chairs for accelerator faculty members at Stanford, there are about 5-7 billets for accelerator faculty members at the SLAC school. In addition, SLAC/Stanford offers the Robert Siemann Graduate Fellowship for accelerator students and Panofsky Fellowships for post-graduate young investigators in multiple disciplines, including accelerator science.*

**c. Are there barriers to having accelerator scientists serve as PI or Co-PI on proposals?**

*Traditionally, only faculty members in the Stanford community had PI privileges, but waivers to this rule were available on a case-by-case basis for SLAC Staff Scientists. However, three years ago the Stanford Academic Council approved a trial program to allow any non-faculty physicist at SLAC with a title "senior scientist" or "distinguished scientist" to have an automatic waiver to obtain faculty PI privileges.*

**d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded?**

*The conversion from research faculty to full faculty in accelerator science is possible but very difficult, similar to other academic disciplines at Stanford. We are not aware of such an attempted transition at SLAC/Stanford.*

**e. Are there specific attributes of the institution's culture that contribute to the success of the accelerator science program?**

*Stanford has a long tradition of pioneering accelerator research. Its connection to accelerator science & technology dates back to the days of the Hansen Experimental Physics Lab (HEPL) and the microwave research. The list includes the invention of the world's first high power klystron, the development of SRF, one of the first ERL demonstrations, and the invention of FEL by Madey. The long and continuing tradition of pioneering accelerator research at Stanford bred a deep culture that regards accelerator science as an integral part of the university's scientific agenda.*

*The most important attribute is the recognition by the Stanford academic community that accelerator science is a unique discipline with the need for dedicated faculty members. The discipline is also supported by being recognized as a core competency at SLAC playing a major role in the lab's mission and vision.*

- f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?**

*SLAC accelerator faculty members are joined to Stanford University by virtue of SLAC being a school in the university, there are presently no joint appointments.*

*Several SLAC accelerator faculty members are founders of spin-off companies. There are also others that serve on the boards of several Silicon Valley companies.*

- 12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)–(f) above).**

*Research activities that serve more than one discipline and are nurtured by interdisciplinary collaborative efforts can invoke interest and legitimacy. One example is nanofabrication technology, housed at Stanford which has a host of applications in other disciplines, including accelerator high gradient and ultra-compact technology. Another example is laser technology which has a myriad of cross-cutting applications, including accelerator technology.*

- 13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)–(f) above).**

*One example is Germany, which has thriving accelerator research and development programs in both universities and national labs, with “non-stovepiped” funding for cross-cutting accelerator R&D that benefits several science thrusts, unlike the funding from the US DOE. For example, the Accelerator Research and Development (ARD) program for the Helmholtz Association of German Research Centers is under Matter and Technology, not under Matter and the Universe (equivalent to OHEP in DOE). Therefore, the ARD program can be at the cutting edge without serving a single primary customer. The ties between DESY and University of Hamburg are also very strong, particularly in accelerator science through faculty and students.*

## **Possible Mechanisms To Encourage Academic Accelerator Science**

- 14. What specific, cost-effective actions could be taken to:**

- a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.**

- *For the training of accelerator scientists to be effective, there needs to be opportunities for non-programmatic accelerator research funding that is forward looking. Graduate students are attracted to exciting frontier research opportunities, which typically cannot be supported through programmatic funding sources. These opportunities should also extend through the postdoctoral training period. Finally, there needs to be recognition and funding of early career opportunities for new faculty or staff so a longer-term attractive career path is apparent.*

- *It is important to establish accelerator science faculty with named faculty positions because it helps academic departments such as EE and (Applied) Physics to host such disciplines. See 2d above.*
- *Furthermore, since most accelerator research activities occur at or in institutions near or associated to a national lab or facility, removing barriers for student recruiting and hiring would help a lot. For example the overhead charged to student tuition at the DOE national labs prevents many agencies such as NSF, or Stanford Graduate Fellowships from Provost's office, from funding accelerator students. This also applies to accepting grants from named foundations that typically demand reduced overhead rates or tuition waivers.*

**b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.**

- *The best improvement for the accelerator science business case would be to have more open healthy funding opportunities from DOE that allow researchers with innovative ideas to pursue them. The industry connection would then naturally follow. Trying to tailor these relations early on will only limit initiatives.*
- *This business-oriented environment naturally occurs in the university setting, especially in places like Stanford. If anything, the flexibility of the lab's business system to allow such collaboration with industry is one of the key conditions necessary for success. This spirit of business flexibility should be encouraged in national labs.*

**c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials.**

- *Encouraging interdisciplinary activities related to accelerator science and technology will have the strongest impact on attracting students to the field.*
- *While grants to young faculty members would certainly help, grants supporting multi-disciplinary applications of accelerator science and technology would boost the accelerator science case dramatically.*
- *The recent stewardship program initiated by DoE-HEP can be considered a beginning for such an initiative but it needs to be better funded and more open and diverse beyond the narrowly focused areas addressed so far in order to offer more educational opportunities.*
- *We agree that Stanford could offer a co-terminal master's degree (i.e. 1-year program for undergraduate students in the last year of their B.S. degrees) in accelerator science or technology that would boost the chance of a student choosing a career in that field.*
- *Offering beginning accelerator courses for undergraduate courses helps expose accelerator science to students early on.*

**d. Increase the enrollment in education opportunities at the baccalaureate and master's level?**

*A co-terminal masters program would be a good starting point to penetrate beyond traditional PhD level of accelerator training.*

**e. Increase the availability of hands-on training opportunities in accelerator technology?**

*Summer science and other internship programs at SLAC enable students to receive hands-on training in accelerator science and technology. Providing similar programs during the school year might be beneficial.*

**Other Factors**

**15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?**

*As already mentioned in 13, the “stove-piping” of accelerator R&D funding within different DOE divisions (HEP, BES, NP) limits funds available for cross-cutting R&D that could benefit all of those divisions.*

**16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?**

*HEP has traditionally and will continue to play the leading role in developing accelerator science for the nation and the world. We hope to see further strengthening in this area through investment to the US academic accelerator science program.*



## Strengthening U.S. Academic Programs in Accelerator Science

### Increasing the Recognition of Accelerator Science in Academia:

The issue of recognition by the university has not arisen in our case. We have had three graduate students in the last several years receive PhD's in accelerator science with degrees awarded through the Engineering Physics Program which is administered jointly by the Physics Department and the School of Engineering but resides in the Department of Material Science and Engineering. The research upon which these degrees were awarded was carried out in conjunction with accelerator physicists from Jefferson Lab with programmatic oversight by members of the university faculty. As such, we do not have a formal accelerator physics program. We currently have no graduate working in the accelerator field as funding for the students became unavailable. I would note that the students from our program have done well. One is a Peoples Fellow at FNAL, one is at Oxford University, and one is employed at a company working in the accelerator field.

When we did offer opportunities in this field the program of formal study consisted of an introductory course in accelerator physics, core physics courses, and engineering courses selected on the basis of the proposed area of research. There are currently no faculty working full-time in the field of accelerator science and there is no evident interest in initiating a program with this focus. We are, however, in the process of attempting to start a program of work in the field in conjunction with Jefferson Lab by connecting Jefferson Laboratory accelerator physicists with faculty at the university having relevant expertise: material science, surface science, rf and terahertz engineering, systems engineering, condensed matter physics, radiation physics, etc. We have initiated such discussions and invariably found that faculty members are interested in problems brought to their attention.

### Integrating the Roles of the Universities and the U.S. National Laboratories:

In the absence of an accelerator suitable for research on campus, it is natural to utilize the accelerator(s) at a national laboratory within a reasonable distance. Based on our admittedly limited experience we feel that the principal impediments to increased collaboration are distance and the lack of awareness by faculty members of the interesting problems in the accelerator field. While nothing can be done about geography, more effort could be expended in making faculty members aware of the potential for interesting work on accelerator-related issues. This would not necessitate their identifying as "accelerator physicists," at least initially, perhaps never. When we did have accelerator physics students, we handled the related academic issues of specialized courses and credits for them on an ad hoc basis. Courses at other institutions and the national particle accelerator school were accepted for graduate credit.

## Contemporary Models of University Accelerator Science:

The schools with successful accelerator physics programs that come immediately to mind are those with accelerator facilities on site, schools such as Cornell, Stanford, Michigan State, Duke, and Texas A&M, for examples. The underexploited resources in this regard are schools that are within reasonable travelling distances of a national laboratory. It is at these schools that the potential exists for the largest increase in faculty and student involvement.

## Possible Mechanisms to Encourage Academic Accelerator Science

The two main requirements are increased awareness of the opportunities to study interesting problems and the availability of resources to carry out the studies. At the present time I think that the most efficient way to proceed is to address these two issues and not to focus on getting accelerator physics identified as a separate field per se. As more university faculty become involved and develop productive research programs, recognition will follow. The most direct way to expand the participation of faculty is to make available funding for joint university-national laboratory research efforts on questions of relevance to accelerator science. By initially focusing on getting faculty with expertise and ongoing research efforts (including, in many cases, existing infrastructure) in relevant areas to enter into collaborations with accelerator scientists at national laboratories there exists a real opportunity to leverage previous investments and grow the field in a cost-effective manner.

**Colby, Eric**

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**From:** milton@rams.colostate.edu on behalf of Stephen Milton <milton@enr.colostate.edu>  
**Sent:** Thursday, June 18, 2015 5:36 PM  
**To:** Academic Accelerator Science RFI  
**Subject:** "Academic Accelerator Science RFI Comments"  
**Attachments:** CSU\_RFI\_Response-FINAL.pdf

Attached are comments and replies generated by myself and colleagues at Colorado State University, as such these represent our collective thoughts regarding the RFI, but in no means constitutes the final opinion of the University.

Regards,  
Stephen Milton  
Professor  
Dept. of Electrical and Computer Engineering  
Colorado State University

RFI Response - Colorado State University – These are responses that were collected from researcher inputs across the University and should not be considered a direct view of the University.

## **Increasing the Recognition of Accelerator Science in Academia**

### ***1. Does your institution regard accelerator science as an academic discipline? Why or why not?***

Two faculty members of the Electrical and Computer Engineering Department with expertise in accelerator science have been hired. These faculty have spearheaded an effort to establish accelerator science at CSU. We are trying to gain traction to establish an interdisciplinary program in particle accelerators and peripherals that will include participants from three colleges. External support to convince the colleges and university of its importance is critical.

### ***2. If your institution offers graduate training in accelerator science:***

#### ***a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)***

The current efforts in graduate student training in accelerator science at CSU include:

For the graduate level:

- External
  - At least two USPAS courses (Students are able to transfer up to 6 credit hours from the external USPAS to CSU)
- Courses taught and in process of being integrated into the ECE curriculum
  - Accelerator Engineering
  - Advanced Accelerator Engineering
  - Pulsed Power
  - Microwave Measurements and Beam Instrumentation Laboratory
  - Synchrotron Radiation, Free-Electron Lasers, and Hard X-ray Optics
  - Other courses needed or at the discretion of the student's advisor and dependent upon the student's eventual principle area of research. These have included classes in the Physics, Mathematic, Computer Science, and Environmental and Radiological Health Sciences Departments.

#### ***b. How often do students change fields to study accelerator science? From which fields do these students typically come?***

- An undergraduate joined the Biedron/Milton group as a graduate student (he had previously wanted to continue in integrated circuit design). He is about to graduate with his Master's and will work for industry in electromagnets.

- One graduate student came in from a physics undergraduate originally wanting to be in the cosmic frontier. He graduated with expertise in microwave measurements with a Master's.
- Two graduate students came from undersea warfare (a US Navy laboratory). One graduated with a Ph.D. in accelerators with a concentration in RF devices and simulation and one is about to graduate with a Ph.D. in the area of controls.
- One graduate student came from industry (medical devices) and will graduate with a Ph.D. in accelerators in the area of coherent light sources and Low-Level RF (LLRF) in about a year.

***c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of these departments?***

The accelerator science "program" (activities) is primarily located in the Electrical and Computer Engineering Department. Students can take classes in the Physics, Mathematics, Computer Science, and Environmental and Radiological Health Sciences Departments and we involve faculty in these departments as well as on the clinical radiation side (Vet School) in our activities and research.

***d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?***

Adequate external funding would potentially catalyze full 9-month support for the existing faculty and provide additional potential for the hiring of new faculty. With such external funding from DOE in the area of accelerator science we will negotiate with the CSU administration for new faculty positions and other support of accelerator science and technology.

***e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?***

There is an on-campus particle accelerator that was donated to the Department of Electrical and Computer Engineering. It is awaiting some additional funds to be turned on (all systems are tested). The accelerator is housed in a dedicated building, The Advanced Beam Laboratory. We have access to the Vet School linac for radiation hardness and related tests. We also make use of collaborations at US and international laboratories to have access to facilities of all types (not just defined facilities, but also peripheral labs and equipment). Examples of collaborations include FNAL, ANL, JLAB, LANL, SLAC, Sincrotrone Trieste, SPARC at INFN, and we hope soon ELI.

***f. How often do collaborations occur between accelerator science and other programs at the university?***

CSU has a number of schools with an interest in accelerator science and its technology spin offs. These include the College of Engineering, the College of Natural

Science, and the Veterinarian School. With such a broad base there are many opportunities for collaboration and we have strived to maintain communication and collaboration across the campus. Unfortunately, due to the existing funding climate research activities are funding limited and this has limited our ability to leverage the many talents and interests across campus. If funding were available to start a pilot program for cross-disciplinary accelerator science, the accelerator science team would absolutely be a key participant. Nevertheless, and despite the funding climate, we have worked hard to do things together in the spirit of collaboration such as helping each other with calculations, participation of all accelerator-related persons across campus to host and teach at a USPAS, sitting on one another's students committees, et cetera.

***g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program?***

Yes, we actively seek out corporate sponsorship for the accelerator science activities. We have been successful in receiving equipment donations from industry as well as small contracts for deliverables. We are also trying to transfer technology in accelerators to industry.

Yes, private companies actively recruit students from our accelerator science activities.

***3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?***

NOT APPLICABLE

***4. What funding sources for accelerator science are you aware of?***

DOE, NSF (recent), DHS (DNDO), DARPA was funding, ONR was funding until 2014, Pentagon's HEL-JTO was funding until 2015, private industry if you can find a niche.

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

***5. How can the national laboratory system be best utilized by the university accelerator science community?***

National laboratories cannot provide advanced degrees, but they require individuals with education in accelerator science and technology. There could be a much more synergistic relationship between the national laboratories and the universities. National laboratories could provide the facilities and infrastructure for some university research and some for the final education stage of the students.

One thing to point out is that it is not simply enough to have a dedicated accelerator user facility at one or more national laboratories. It is not just beam that university researchers and students require. There is much more infrastructure required for

research and training. It is incomplete to think that all that is required is access to a dedicated accelerator user facility. For instance, test beds for electronics, borrowing oscilloscopes and network analyzers, or other specialized costly equipment for research or teaching, controls labs, powerful computing resources, high power source, liquid helium sources, and controlled radiation enclosures are some of the few items that come immediately to mind.

And one person states: "...having more of a partnership relationship, rather than just a user relationship (is useful). A partnership with shared research goals can leverage the funding for devices at the lab with students who can do work from universities. This is much less costly for a university group (compared to producing their own experiment), and is more productive for the lab group. Additionally, students would better acquire the practical skills required by laboratory jobs."

***6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?***

There must be a true partnership established between national laboratories and universities working in accelerator science and peripherals that creates trust. Right now, in most cases, there is a huge abyss.

Operationally, not every facility or infrastructure on a national lab's site falls into a "dedicated DOE user facility." The point is not to change every facility or infrastructure into such a "dedicated facility." They need not be marked or categorized in such a manner. Agreements between universities and national laboratories to integrate the university research and map it into the needs of the laboratories need to be made.

Universities tend to be more cost-effective in terms of labor rates and indirect cost rates. This makes university researchers and students attractive in terms of cost for helping on projects, technical issues, etc. at the laboratory. It is challenging to establish contracts for such research or technical assistance with the national laboratories. This is sometimes caused by the laboratory money being labeled as labor and not for M&S that is required to make a sub-contract with a university.

Some universities cannot perform research that will be limited in publication, i.e. For Official Use Only or classified research. This is not the case for our university, but has been for many universities, making universities a challenge to work with.

Also, university researchers in the area of accelerator science and technology tend to be viewed as outsiders to national laboratories. This is ordinary and fine if you are truly a user at a user facility, but most accelerator laboratories are not structured as user facilities for accelerator science and engineering, thus the above noted perception. A potential way to rectify this is to establish more joint positions in the laboratories. This would break down many barriers and provide opportunities advantageous to both laboratory and university.

***7. Does your university accept accelerator course credits from other institutions?***

Yes, we will accept in the CSU Department of Electrical and Computer Engineering up to six course credits from other institutions. In the framework of the USPAS, this effectively means two full USPAS courses.

***8. Do accelerator science students at your institution routinely take courses and training elsewhere?***

Yes, USPAS. Each student has taken at least two courses. We cannot provide what the USPAS provides. Furthermore, students in ECE can take graduate level courses from any department at CSU, and from other universities with the approval of the advisor; however, external to CSU the students are still limited to a maximum of 6 credit hours transferred.

***9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?***

University professors working in accelerator science and technology should be recruited to participate at several levels in the operation and improvement of the national resources of accelerators at the laboratories. University professors have skills in management, leadership, systems engineering, and namely accelerator science and technology. University professors are also training the next generation of students who will transfer into these facilities. Why not better couple them? Quarter time or half-time appointments at a national laboratory as well as associated “Apprenticeships” or “journeyman/woman-ships” for graduate students at an advanced stage at a national lab would give the laboratory better synergy with the universities. Yes, legally the national laboratories should not be doing training, but the point is that in engineering in particular the research has fairly hard deliverables. Having a sub-contract with a university for deliverables at a reasonable price that also results in a Master’s or Ph.D. (and a potential employee) seems like low-hanging fruit. The same is not completely true for the physics side.

***10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?***

We do not have a complete picture of all established relationships between our university and the various national laboratories. We do, however, see the relationship between our university and national laboratories with major accelerators. The largest community in this category comes from the physics department, specifically high-energy physics. Here the relationship is classical/conventional. Members of the physics department are members of the existing major HEP collaborations. Such a relationship could also work for accelerator science and technology if the universities were allowed to directly participate on major accelerator projects or upgrades.



Some input collected across the university is summarized here “All the relationships with national labs in our group are informal, and have little if no formal documentation. In fact, the relationships were driven by individual researchers with a desire to work together in spite of (rather than caused by) laboratory management. Informal arrangements work well, but make funding for projects almost impossible. The use of Laboratory facilities can be difficult if they are fee for use, and generally the Lab persons have to find funding to pay for any of the projects from their own budget. The costs can be appalling, as the Lab charges full overhead for the use of the facility AND the labor. Labor costs can exceed several hundred dollars per hour, and thus, we tend to try to “piggyback” on other projects. In short, I am personally aware of no mechanism (outside of some joint grant that funds both lab and university) that encourages joint research. In fact, at this point, I would say that the lab infrastructure restricts any collaboration with universities, and that research is done in spite of the current in place programs.”

Another comment is “We (one group at the university, namely HEP) have had contracts with the labs on a range of activities from research, engineering services, prototype design and equipment production. The Office of Sponsored Programs has been very good with processing/managing these contracts (which have different indirect cost rates).”

Another comment “Traditionally, accelerator science arose from HEP experimenters who considered the accelerator to be part of their instrument. Thus, there should be some scope to attach to experiment with a university’s contribution being on the accelerator side of the house.”

As for accelerator science, we have MOUs with two national laboratories and one international laboratory. So these have been extended to include accelerator science. The scope of the collaboration is what requires more strategizing and more developed agreements. One concern that the labs have is only including US citizen graduate students to avoid export control issues with foreign students from sensitive countries. We agree with this and therefore there might need to be a mechanism for encouraging US citizens to study.

One person says “I think a university accelerator program could train graduate students in 1-2 years of course work and then have them work on accelerator problems at a National Lab. This would be similar to the model of how HEP research works. We have grads students that take about 1.5 years of course work and then they work on a large particle physics experimental collaboration for ~3 years to finish with their Ph.D. In the last 3 years they work in a large collaboration working with many people from other universities and labs. In accelerator programs, you might send a student to FNAL or other national labs to work on an accelerator project.

## **Contemporary Models of University Accelerator Science**

**11. What examples exist of thriving academic accelerator science programs?**

Our program is four years old and was started with a very limited investment and with half-time faculty. It is far from thriving despite the fact that we have granted three Master's degrees and one Ph.D. and have several Ph.D.s in the queue. Further, of ten students either graduated or presently in the program, only two are non-US citizens and they are from a non-sensitive country. That said, we wish we could point to an example of a thriving program, but many programs are currently suffering or folding due to the budget situation. A couple of examples that could be better explored are the folding of the Indiana program and the atrophy of the Cornell program.

**a. Are there policies at your university specific to the accelerator science program that are essential to its success?**

No.

**b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?**

No, not at our institution.

**c. Are there barriers to having accelerator scientists serve as PI or Co-PI on proposals?**

No.

**d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded?**

Yes.

None have attempted.

**e. Are there specific attributes of the institution's culture that contribute to the success of the accelerator science program?**

The culture of the university was to take the risk of starting a small program with two half time (4.5 month paid) professors. It is not a successful program as of yet. One challenge is that accelerator science sits between physics and engineering and also has aspects of mechanical engineering, materials, and chemistry at times. This is hard to explain to more "standard" activities in a say mechanical engineering department.

Once the local accelerator is stood up, there will be a dedicated facility for research combining lasers and accelerators - at the frontiers of accelerator science.

**f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D?**

No. There is no appropriate nearby national laboratory or company. We have collaborations with national laboratories and companies but no join-appointment per-se.

***How many?***

Zero.

**12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)-(f) above).**

Lasers and Optics and Systems Engineering programs have been successful, as they tend to have significant investments from industry as well as having investment from government in the past.

**13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)-(f) above).**

One example is accelerator physics program at Lund University. They have a national lab connected with the University so the accelerator science is given a very high level of regard. Also, the engineers and physicists that work there can work toward a degree, whether they come in as a student or not.

## **Possible Mechanisms To Encourage Academic Accelerator Science**

***14. What specific, cost-effective actions could be taken to:***

***a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships.***

- Visits by DOE and NSF to academic institutions working in these areas to express the need for this inter-disciplinary field of science and technology to the campus management; stress the differences of how accelerator science and technology differs from other disciplines to the campus management and why training in this area is relevant.
- Grants or contracts to help launch new programs with a long-term commitment (i.e. 5 year or more commitment).
- Named faculty positions.
- Joint positions with national laboratories or industry.
- Funding multi-disciplinary areas – with lasers/medical/physics/engineering on a specific campus.
- Encourage and fund research associate positions or visiting faculty positions at the universities for those national laboratory scientists and engineers wishing to work directly in a university environment. The individual would

most likely sit on a thesis or dissertation committee and also have access to the university resources.

- Provisions for students to perform work on accelerators at national labs on an as available basis, without paying the high overhead and prohibitively costly operational overhead. Lab staff should be rewarded for taking on students and mentoring them, not just in lip service, but perhaps offering fellowships or at least summer internships to students under willing mentors. Lab mentors should be allowed to work with university faculty without incurring gross operational costs that would stop collaborations. University faculty should be supported for training and mentoring such students as well.

**b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.**

- Have a program where there could be cost matching of a contract from industry by DOE or a national lab for a university.
- Have a DOE award for technology transfer of accelerator technology and peripherals yearly. The award could be ~100k for future research.
- Joint grants/contracts for industry and universities.

**c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials.**

- Having a grant for developing a couple of cross campus courses related to accelerators. A course development grant that emphasizes the multi-disciplinary nature of accelerators would be ideal. A class covering basic accelerator design, shielding, and applications, from material processing to high energy physics and cancer treatment is needed. The class would target third and fourth year undergraduates, meeting science elective requirements, and introduce them to accelerators, as well as serving as a means to identify and recruit the best students.
- A targeted outreach program, involving high schools as well as combining with the medical use accelerator would bring more attention to the science, and also attract more students.
- Having an accelerator locally has already shown to attract high-school students, undergraduates and graduate students to our program; however, here is no current funding mechanism to be able to maintain this successful program.
- It is not just early career faculty that need assistance, starting a new program in accelerator science at any career level requires assistance.
- Grants to develop course materials for on-line classes.
- Have a grant that encourages US citizens to work with a faculty member for a Master's or PhD that would be linked to the last two years at a national

laboratory and would transition into a third year of a post-doc at the same university. The long-term goal would be hiring that individual at the national laboratory after these three years of already-proven service and performance. What students want to see is long term job prospects.

**d. Increase the enrollment in education opportunities at the baccalaureate and master's level?**

- We have demonstrated that having accelerator equipment at a university attracts all levels, including the undergraduates through to graduates. Hardware helps and we imagine that operational hardware would attract even more students for hands-on class-work.
- Have sponsored joint university-lab internships in the summer for actual required tasks at national labs – a true deliverable needed by an operational facility. A few weeks shadowing at a lab with a faculty member or graduate students of a faculty member at a lab and then working at the university the remainder of the summer on one or two related tasks. This is a lower level of journeyman-ship.
- Have several university accelerator scientists each year be DOE paid at say the 10-20% level to go around and give lectures on accelerators and peripheral equipment at universities not connected with accelerators. The individuals can then discuss the internship opportunities for undergraduates as well as the graduate schools that offer classes as well as the USPAS opportunities. This small investment could go a long way. A sort-of Distinguished lectureship.

**e. Increase the availability of hands on training opportunities in accelerator technology?**

- We have demonstrated that having accelerator equipment at a university attracts all levels, including the undergraduates through to graduates. Hardware helps and we imagine that operational hardware would attract even more students for hands-on class-work.
- Better connection between universities and laboratories for hands on opportunities for more advanced students.
- University professors working in accelerator science and technology should be recruited to participate at several levels in the operation and improvement of the national resources of accelerators at the laboratories. University professors have skills in management, leadership, systems engineering, and namely accelerator science and technology. University professors are also training the next generation of students who will transfer into these facilities. Why not better couple them? Quarter time or half-time appointments at a national laboratory as well as associated “journeyman-ships” for graduate students at an advanced stage at a national lab would give the laboratory better synergy with the universities. Yes, legally the national laboratories should not be doing training, but the point is that in engineering in particular the research has fairly hard deliverables. Having a

sub-contract with a university for deliverables at a reasonable price that also results in a Master's or Ph.D. (and a potential employee) seems like low-hanging fruit.

## Other Factors

### **15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program?**

- A funding agent recently requested work be kept going and then did not pay the invoices despite a grant in place and acknowledging receipt of the work. This was at the couple hundred thousand dollar level. This negatively impacted the accelerator and peripherals program.
- Get funding to academia on time. The University allows spending before the grant is fully executed; however, give the current funding climate this puts both the University and researcher at risk as there have been instances of grants being cancelled prior to completion. In such instances where there is no overhead available for bridge funding, again a “modern feature” of the funding of education, the university can choose to make choices with regards to paying salaries of researchers in light of their current work loads that result in very awkward positions.
- It is by law that grant PIs need only report quarterly. Some funding agents ask for weekly and monthly reports that are counter to law. This stresses relationships. (Contracts are different, but some agencies are used to contracts and expect grantees to perform the same.)
- The funding agents should not require participation at multiple events when funding has not been provided yet for that fiscal year. The universities refuse to pay and the faculty is left paying for his/her own travel expenses.
- Although we understand limited funds are available for programs, consider discussing with faculty reductions in funding if cuts are made, rather than completely cutting funding.

### **16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?**

The perception is that accelerator science is akin to other academic areas, but in fact it is not. It is very collaborative due to many levels of engineering, fabrication, testing, and operation. It has a different publishing history for papers. It requires a much broader skill set that transcends multiple disciplines. It needs to be communicated that this academic discipline is different. It is not clear that it is a respected discipline and needs to be highlighted perhaps by DOE as an important discipline.

18 June 2015

**RE: RFI STRENGTHENING U.S. ACADEMIC PROGRAMS IN ACCELERATOR SCIENCE**

Dear Dr. Siegrist, Dr. Strauss and the Office of High Energy Physics:

I want to offer some ideas for your RFI. I know that my SLAC colleagues Ron Ruth, Sami Tantawi, Zhirong Huang and others have drafted a formal letter which addresses some specific questions from the RFI. I agree with their letter, but I want to add some of my own ideas, which are based on my experience spanning both the National Lab and University environments. I have had a significant involvement with teaching at both undergraduate and graduate levels, over the years I supervised 4 Ph.D. students from the Applied Physics and Electrical Engineering departments who did their Thesis work in areas focused on accelerator physics and technology ( two of these students won the DPB Thesis prize), and I was the research supervisor for over 12 Master's students who went on to careers in industry and national labs.

My efforts in education have included developing and teaching 3 new courses at the USPAS, and teaching graduate and undergraduate courses in Physics and Applied Physics at Stanford. At Stanford, I was honored with the Dean's Award for Distinguished Teaching. I feel this experience, with more than 25 years of accelerator physics research with graduate and postdoctoral students allows me to comment on your RFI questions.

**Theme #1) Numbers of students doing Ph.D. level work in Accelerators and Accelerator technology, and what factors influence students to pursue study in an area involving accelerators?**

I think that one important factor in graduate study is the pipeline from undergraduate institutions. Very few undergrads know much of the accelerator field or the opportunities. Very few faculty at undergrad institutions who advise advanced undergraduates have detailed or up to date experience with the University programs in accelerator science and technology. Similarly, not many undergraduate faculty have close ties with a national lab where students might go to do summer research or school year projects.

My experience at Stanford, and the Applied Physics department, suggests that the majority of students arrive with a well-formed idea for an area of advanced study, often have arranged a research assistantship the summer before their arrival on campus. Despite Stanford's supported rotation system, where first-year grad students can try out possible research areas, most students apply with a field pre-selected. And if Accelerator Science isn't visible at the undergraduate

stage, the possible numbers of new young researchers and engineers interested in accelerators is going to be very small.

**A Suggestion** – develop high quality exciting undergraduate seminar talks on accelerators, send speakers out each year to undergrad physics and engineering institutions to offer seminars and undergraduate colloquia. Do not view this as “recruiting” for a particular university program, make it very broad to highlight opportunities, and make sure many programs in the US are mentioned as examples. Present the science and opportunities in the accelerator field at an advanced undergraduate level, show the new ideas and new facilities that might be something a young person could work on in graduate school. The purpose is to bring visibility of the science and opportunities for graduate study to an audience that might not even consider applying to the few dedicated programs, and to bring awareness of the field and opportunities to the faculty at schools that have excellent science and engineering programs, but very little contact with the national lab and accelerator community.

This idea needs specific funding to run such an undergraduate outreach program, and a small committee of enthusiastic and exciting lecturers drawing from several labs who could develop a general set of talks which an individual speaker could customize with examples from their own work. The funding should support time to develop these materials as well as travel support to go visit with the undergrad institutions and give the colloquia.

The goal of this outreach would be to increase the number of students potentially interested in the existing University accelerator programs, highlight awareness of the USPAS courses, summer research options at labs, etc.

**Theme #2) – Are accelerator research opportunities, and work environments, experienced by grad students and postdocs competitive with other scientific and technical fields?**

Beyond the issue of invisibility for potential graduate students, students at highly-competitive universities have many choices of Ph.D. research areas. In essence research in Accelerator Science and technology is competing with areas such as lasers and nonlinear optics, nanoscience and quantum engineering, biophysics, condensed matter physics and a host of areas. Students are drawn to opportunities with intellectual challenge, available and inspiring thesis supervisors, adequate support, modern facilities, exciting research group co-workers, and future job prospects.

In the historical past, accelerator physics and technology could compete on a level playing field. In my opinion, the restrictions on funding of the recent years, and the increasing burden of travel restrictions, stovepiped and project designated funding, emphasis on large construction projects, reduction in research support for new or unproven ideas not directly tied to a “deliverable”, etc. have made an environment where it is much more difficult to attract the highest quality students. For grad students and postdocs thinking of starting a career, the current environment for accelerator science and technology is seen



by prospective students in an less-favorable light compared to opportunities in growing fields.

To improve the situation, I think more attention to the scale and availability of research funding, and expansion of opportunities for intellectually significant contributions from Ph.D. students, postdoctoral researchers and young scientists is needed. “More Funding” is only a part of the problem, the value of existing funding is unfortunately reduced with the growth of overhead and hierarchal management layers, and the micro-management of research organizations. An environment where there are restricted opportunities to travel to workshops and professional meetings, where opportunities to develop collegial relationships with other researchers at national labs and universities around the world is constrained, where there is no budget to update and modernize research instruments and facilities, much less keep existing lab equipment in working order, is very discouraging to new scientists and engineers. They have exciting alternatives without these headaches.

## **Theme #2) Integrating the Roles of the Universities and the National Laboratories**

I think there are great strengths in both the University and National Lab environments, and building ties between them is vital. But simply teaching courses specific to accelerator physics at a university might be much less useful in the big picture than teaching courses that are central in a larger academic department and have intellectual content that is important for many fields in addition to Accelerator Science.

Our experience bringing SLAC faculty to teach in the Stanford Applied Physics department showed there is great interest in material that is relevant to multiple disciplines. For example, Ron Ruth’s class “Nonlinear Dynamics – This Side of Chaos” had applications of nonlinear dynamics and methods to lasers, accelerators, condensed matter physics and biophysics. As such, it attracted a good enrollment, and increased the visibility of the accelerator science to a larger pool of students. Similarly, Sami Tantawi taught an “Applied Electrodynamics” class, with the E&M formalism applied to microwave engineering, geophysics, optical devices, accelerators, antennas and plasma physics. My Laboratory Electronics courses have large enrollments, I use examples from accelerators but also from radio astronomy, low temperature physics, biophysics, chemistry, etc. and serve many students beyond those in the accelerator field. While specific courses for accelerators and accelerator technology are taught, we have discovered that we reach a bigger audience of potential accelerator researchers through courses that serve many sub-disciplines and are seen as real contributions to the intellectual mission of the department. These courses increase the visibility of accelerator faculty, and can interest students in accelerator research though the content, which might use accelerator science as a part of larger academic discipline. Several of our current graduate students came to meet us, and became interested in our research areas, from these broadly themed graduate courses.

This participation in the academic mission is important to provide visibility of the accelerator field and to build collegial awareness of accelerator science as an intellectual sub-field. If national lab staff and faculty do not participate actively in a host university department, attend colloquia, serve on department committees, serve the larger mission of the University – they are essentially “invisible” in the University setting even if they teach a class with accelerator science themes. If accelerator-specific courses are offered, but only serve a small portion of the host department students, and the accelerator faculty do not interact or share research interests with the host department, the impact of the teaching role is limited. And the intellectual contribution of Accelerator Science faculty to the broader University mission is not felt by the larger University faculty.

**A Suggestion** – provide a funding source to allow career development or mid-career sabbaticals so that a national lab scientist or faculty could be resident at a host university or college, teach courses, participate in research etc. for a year. Make this bi-directional, so that someone at an undergrad or graduate institution could be resident at a national lab, too. Programs of this sort need to be encouraged, funded, and valued so that someone who wants to do this isn't punished or penalized at the host institution.

I hope these suggestions are helpful to you. My perspective is certainly colored by my experience specific to SLAC and Stanford, but I think all of these ideas are applicable to the general goal of strengthening the academic programs in accelerator science. If I can expand or clarify on these suggestions do not hesitate to call or email.

Sincerely,

John D. Fox

Senior Scientist ( SLAC)

Consulting Professor, Stanford Applied Physics

## Colby, Eric

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**From:** Martin Berz <berz@msu.edu>  
**Sent:** Thursday, June 18, 2015 11:26 PM  
**To:** Academic Accelerator Science RFI  
**Subject:** Academic Accelerator Science RFI

Comments on various aspects of the RFI on Strengthening US Academic Programs

Martin Berz  
Department of Physics and Astronomy  
Michigan State University

Below are comments on specific aspects of this RFI. There is a separate submission from MSU originating in NSCL/FRIB which broadly describes various activities at MSU. I will not repeat these matters but focus on some additional aspects I personally consider important, and attempt to tie these to the specific numbering used by DOE.

I believe this RFI is a very worthwhile step towards putting accelerator science where it should be on the science landscape, and I am happy to see these specific activities. Much more can be said and the information below can be elaborated significantly. Please do not hesitate to contact me with any specific or generic additional information you may be interested in.

### Comments on Discussion Points in RFI.

1. Accelerator Science is embedded in activities at the NSCL/FRIB lab, the Physics Dept, and the College of Engineering. It is not considered a separate discipline.

2. Various courses, including the DOE-funded Physics courses PHY861 (Intro Acc Phys), PHY961 (Nonlinear Beam Dynamics), PHY962 Parts 1 and 2 (Accelerators of the World), PHY963 (US Particle Accelerator School credit for approved classes), PHY964 (Research Topics in Beam Physics) are offered. In addition there are various Engineering courses with overlap/emphasis in beam physics and occasional other courses.

a) There is no formal core curriculum, although most students go through above courses and repeatedly attend USPAS.

b) About 50% of our students are directly recruited into our accelerator physics research group, others transition from HEP, Nuclear, Engineering, Math.

c) Dept. of Physics

d) 1) Better funding prospects. In the last years, the success rate in the DOE Accelerator Stewardship program is much too low to make a good faith effort to try to recruit faculty, as their need for tenure and academic advancement hinges on external grant funding. 2) A clear understanding of the difference between accelerator research, and project work necessary for a local accelerator, which hinders the academic publication activity necessary for success in an academic department such as MSU Physics.

e) There are on-campus accelerators (NSCL and FRIB), but they are not dedicated to accelerator R&D. They are nuclear physics machines, and any pure accelerator R&D has to be carried out parasitically to not interfere with planned experiments, and must be separately funded since the FRIB mission does not support generic accelerator R&D. Interactions exist with various test facilities at national labs for specific research questions, in our case for example the earlier muon cooling activities.

- f) In our specific case, rather frequently: Math, Engineering.
- g) The university has generally not actively sought out companies, but companies recruit some of our graduates.
4. The typical: DOE Stewardship, NSF, and application-related activities connected to DOE HEP, DOE BES. Limited support through companies and SBIR.
5. Provide research projects suitable for students; provide funding mechanisms for work with sufficient overlap with their main mission.
6. For our specific case, in the past there were very few barriers, but recently there is a significant drought in accelerator physics student support at the places we have worked with earlier.
7. Yes, after review of appropriateness; either as part of PHY963 above, or as transfer credits.
8. Yes, at USPAS and occasionally at short courses in Nat Labs.
9. Mostly: restore earlier funding mechanisms, or in my opinion, even greatly increase funding opportunities for students wishing to work at Nat Labs. These student positions are significantly less expensive than other man power at these labs, in particular if a funding flow-through is put in place that capitalizes on the usually lesser overhead and fringe rates at Universities.
10. Many research groups carry out experiments at national labs (HEP, some Nuclear, some CMP). But these are usually within the specific primary mission of the laboratory, while accelerator science often more plays the role of a fringe benefit that is less clearly recognized.
- 11 a. A general openness, as long as funding can be obtained. A general sense that it is useful for the two labs on campus, but in reality their needs are very project driven and they do not benefit directly from fundamental accelerator R&D of the kind that would be typical for other academic disciplines.
- b. No, rather to the contrary. It is exceedingly difficult to succeed in the traditional tenure-based system if one has to satisfy the common departmental standards for tenure, promotion, ranking in the department, etc. Synchronizing these requirements with the programmatic needs of the two MSU labs is nearly impossible. This is the main reason why there is only a single tenured accelerator faculty in Physics and none at NSCL/FRIB, where all positions designated as “faculty” are fixed term, and because of tight embedding into programmatic development and construction needs, allow little freedom for genuine accelerator research. There are some tenure track faculty positions in Engineering with overlap to accelerator science, but these are not part of the programmatic NSCL/FRIB effort.
- c. Yes, as some RFPs are open only to tenure stream faculty. Furthermore because emphasis on what would be needed for accelerator research takes time away from the programmatic needs of the labs, which are very strained as it is.
- d. It is basically not possible, in the 25 years I have been here it has never happened.
- f. There are about 3-4 adjunct appointments with national laboratories, but no joint appointments in the spirit of shared salary commitment. This is partly because of geographic distance, which makes something like this much harder than for example at partnerships of FNAL with NIU and IIT. All NSCL/FRIB faculty are fully paid from their operation funds.
12. There are various such activities in Engineering, where such methods are long-established. But a fundamental prerequisite of this is an established mechanism how to “value” such activities in the respective departments and academic units, which is a culture not very highly developed in Physics.

14. a. Availability of sufficient funding is absolutely critical, and the current status in the DOE accelerator stewardship program and the new NSF program is, in my opinion, far from sufficient to achieving this worthwhile goal by providing the needed resources.

b. Again availability of funding is critical, combined with the ability to perform publishable research and give talks at meetings, which are the far dominating criteria for success in a university setting.

c. Here too, funding for students and young faculty is the main limitation as far as I can see.

d. At the undergraduate level, this would involve development of some more courses. At the Master's level the situation is already fairly good because of the wide online reach of our courses.

e. This would be very useful, and would be optimally achieved if most of the US labs were to offer such opportunities, and students would be able to participate in several during their education.

15. Over the last few years, I am getting the impression that desirable research topics as advertised by DOE, and to a lesser extent NSF, are getting a bit too much compartmentalized and need-driven. Genuine academic research needs freedom to attack the issues the faculty consider most fruitful, even if they are not of very immediate benefit to specific ongoing development projects at national labs.

**Robert Zwaska**  
Target Systems Department  
MS 341

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June 18, 2015

Dear Colleagues,

I wish to relate to you some of my personal concerns regarding your RFI on “Strengthening U.S. Academic Programs in Accelerator Science”.

Accelerator Science is a vital tool in the major scientific facilities of today and the foreseeable future. It has unique theories, approaches, and experimental techniques, yet it receives negligible support from academia. This is a conundrum that is a threat to our nation’s major scientific facilities, but which can be countered by some select actions of the Department of Energy.

The academic deficit in accelerator physics is twofold: (1) a lack of accelerator researchers or practitioners in the professor ranks, (2) a shortage in the production of accelerator Ph.D.s to support the need of major science facilities. The shortage of students of particularly vexing, compared to the academic overproduction that is common in most areas of science. Accelerator facilities have almost no rigorously trained students at all from the United States. Most facilities fill their needs by importing Ph.D. from overseas or converting graduates from other disciplines. The result is a lack of a cohesive academic community within the United States. The converts from other disciplines are often sufficiently competent to contribute to the operations of a system or facility, but generally lack the deep knowledge necessary to advance the theories and techniques of the fields, or conceive of truly novel facilities.

Historically, we can observe that accelerator physics grew out of the nuclear and particle physics communities where accelerators were novel apparatus that enabled their experiments. The accelerators of today are still fundamentally enabling for the nuclear and particle physics, but also have broader applications to the whole of the physical sciences, and many other areas. It is therefore proper that accelerator physics has emerged as its own discipline, yet regrettable that it nearly absent from universities.

A possible comparison is to certain specialties of high-energy physics (HEP). Within HEP experimentalists, there are specialists in various detector technologies such as calorimetry, silicon vertex detectors, electronics, gaseous detectors, and others. There are numerous programs across the country in these areas. These groups usually comprise multiple professors, postdocs, numerous graduate students, and technical facilities and support staff. They make up an efficient pipeline of students that emerge well trained. In fact, the volume of students produced by these programs cannot nearly be absorbed into the national HEP enterprise. The discipline of accelerator physics could be vastly aided with only a dozen such groups, and still avoid the problems of overproduction.

This comparison to HEP groups further suggest a model for the support of accelerator faculty by DOE. Many HEP students are supported through continuing university grants to reside at national laboratories and participate in research there. This arrangement provides stability for the involved parties (university, faculty member, student, national lab). The university, faculty, and student gain access to the resources and facilities of a national lab. The lab gains researchers without the need to educate the students, grant degrees (generally impossible), or provide monetary support. The advantages would be even greater for accelerator physics than HEP. For accelerator researchers, students could directly take part in the operation and research at the accelerators, as HEP students do on detectors. The labs would be further

advantaged by the presence of the students and faculty members as the academic partners are more prone to document advancements through publication. Often there are advanced and novel techniques that are under-documented at the national labs, particularly in peer-reviewed literature. The pressure of results and operation, combined with a reward structure biased away from publication, contribute to the lower rate of publishing.

Academics are also best positioned to anthologize the advances of science into textbooks, monographs, and review articles. Who will write the next great textbook in accelerator physics? The pressures of a lab physicist generally preclude such activities. Accelerator physics could greatly gain from the depth of academic involvement.

DOE is best positioned to foster the development of academic accelerator physics programs. Research universities are responsive to the intentions of the funding agencies. Universities will make faculty positions available if DOE were to make clear that it intends to support university groups in accelerator physics like it does in HEP and other disciplines. The NSF has similar capacity. Piecemeal grants are insufficient to maintain faculty lines. Furthermore, small grants in accelerator physics to potential crossovers are also generally ineffective as those faculty will always be dabbling accelerator physics and not develop the depth that is required to properly train students.

In short, our nation needs trained accelerator physicists. Our universities are not producing them, and do not hire them. DOE, and other funding agencies, have the capacity to instigate action in these directions and develop a strong academic community in the United States.

Sincerely,

A handwritten signature in black ink, appearing to read 'Robert Zwaska', written in a cursive style.

Robert Zwaska  
Target Systems Department, Head  
Fermi National Accelerator Laboratory

Responses below originated from Jay L. Hirshfield, professor adjunct of physics at Yale University. But, so as to best reflect an institutional response, his comments were passed to his Department chairman, Professor Paul Tipton; and to the Director of the Wright Laboratory at Yale, Professor Karsten Heeger. It is within Professor Heeger's campus domain that the Yale Beam Physics Lab resides. Their comments have been integrated into the responses sent here.

## **Increasing the Recognition of Accelerator Science in Academia**

1. Does your institution regard accelerator science as an academic discipline? Why or why not? Yes, as evidenced by appointment to the faculty in the Department of Physics of two Research Scientists and one Professor Adjunct—the latter most recently for a term of five years; and for the provision of a ~3000 sq ft laboratory space for accelerator-related experiments.

2. If your institution offers graduate training in accelerator science: Graduate students have obtained Yale Ph.D's in accelerator physics, but not recently—principally because of funding restraints. But no serious institutional barriers should prevent this in future. In fact, a research proposal from Yale pending with NSF lists a budget item to support a graduate student in accelerator science.

a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?) Aside from the standard course work for all physics Ph.D candidates, an introductory one-term course in accelerator science was offered in the past, but recent coursework for interested students and postdocs has been adequately offered by the US Particle Accelerator School.

b. How often do students change fields to study accelerator science? From which fields do these students typically come? The only recent transition from one field into accelerator science at Yale was for a newly-minted Ph.D in atomic and molecular physics who joined our group; he has matured into an exceptional research scientist in accelerator science.

c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments? It is only in the Department of Physics at Yale.

d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty? Incremental ladder faculty additions would probably require funding to cover remuneration and research support for at least one senior and one junior full-time teaching faculty members for at least three years, plus a widely publicized statement announcing this initiative to be part of a National program with long-term DoE commitment, identifying Yale as one of the institutions so selected.

e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories? A wide range of laboratory facilities for accelerator R&D are available and in use in the Yale Beam Physics Lab.



f. How often do collaborations occur between accelerator science and other programs at the university? Not infrequently. One two-year collaboration, recently ended, involved a search for light neutral bosons, including axions. A second collaboration, now under discussion, is aimed towards experiments to measure end-point energies for electrons near the end point in beta decay, in an attempt at determining anti-electron neutrino mass. These are on-campus collaborations.

g. Does your institution actively seek out corporate sponsorship for an accelerator science program? Do private companies actively recruit students from your accelerator science program? Yale has received grant support from Omega-P, Inc. in recent years. One very bright Ph.D. graduate from our group was recruited by a private company where she went to work—as a computer programmer! Another went into academia.

3. If your institution no longer offers graduate training in accelerator science, why was the program terminated? Terminated would be an incorrect label; how about delayed?

4. What funding sources for accelerator science are you aware of? DoE HEP, NP, and BES; plus NSF.

## **Integrating the Roles of the Universities and the U.S. National Laboratories**

5. How can the national laboratory system be best utilized by the university accelerator science community? Good question!! As we have had less-than-stellar experiences at BNL-ATF, ANL, and at SLAC, others may be better positioned to comment. Issues involved low priority for our project, long delays in getting required unionized installers, uncertainties in who on the lab side can be available to lend a hand, and when. These experiences have led us to try to devise, build and conduct relevant experiments on campus, where we can better control all the logistics.

6. What are the current barriers (*e.g.* technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories? Poor past experiences.

7. Does your university accept accelerator course credits from other institutions? Haven't raised this question, since no such situation has arisen.

8. Do accelerator science students at your institution routinely take courses and training elsewhere? USPAS, as stated above.

9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators? Establish formal couplings, including necessary funding, for on-campus pursuit of basic research topics that can support the National Lab goals, but that rigid schedules and personnel interests at the Lab may be less suited to, than would be the case at a university. This could also establish a natural supply mechanism for graduate students to transition into the Lab after finishing their degrees. [This is purported to be an intent of the SBIR program, but it might be more cost effective and intellectually more easily tied in with the Lab interests if it could occur between academia and a Lab.]

10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science? [Don't know why not.](#)

## Contemporary Models of University Accelerator Science

11. What examples exist of thriving academic accelerator science programs? [UCLA and Cornell \(at least historically\) come to mind as the best examples. \[I don't count Stanford, since most activity is really an extension of SLAC.\]](#)

a. Are there policies at your university specific to the accelerator science program that are essential to its success? [If support described so far \(research faculty appointments, lab space, open-ness to collaborations with other faculty's research\) can be considered "policy," then yes these are essential to whatever success it can achieve. But stronger policy to incorporate accelerator science into the "mainstream" Department of Physics program would add greatly. This idea was floated recently before a departmental committee on future priorities, but appears to have sunk deeply below the surface.](#)

b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science? [No.](#)

c. Are there barriers to having accelerator scientists serve as PI or Co-I on proposals? [Yes, but these can evidently be overcome with approval by the Provost.](#)

d. Is conversion from research faculty to full faculty in accelerator science possible? How many faculty members have attempted the transition, and how many have succeeded? [I don't believe that such a transition would be impossible, but would be unlikely under the prevailing priorities. None, to my knowledge have tried with the past two decades, so none succeeding is the correct answer.](#)

e. Are there specific attributes of the institution's culture that contribute to the success of the accelerator science program? [Many physicists evidently trust that accelerators for discovery science have emerged, and will continue to emerge, at National Laboratories through some process that need not involve R&D at a fundamental level. This fundamental inquiry can emerge when bright grad students are given latitude to explore what is not the flavor-of-the-day approach, but is truly "out of the box." Such a culture will only exist in an un-inhibiting university environment. So until an elite institution's culture shifts to accept some responsibility to train the physicists who in future can continue to find ways to make future accelerators meet physics demands within budgetary limits, we shouldn't expect much in the way of brilliant discoveries to allow paradigm shifts to emerge.](#)

f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many? [Two out of the three Yale appointees also are employed by Omega-P, Inc.](#)

12. Are there successful examples of academic programs from other technologically-oriented disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)-(f) above). [None come to mind.](#)

13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)-(f) above). [Labs in Europe \(especially CERN\), in Japan, in Korea, and in Russia \(historically\) have tight connections with universities that seem to be more effective than what exists in accelerator science in the US.](#)

## **Possible Mechanisms To Encourage Academic Accelerator Science**

14. What specific, cost-effective actions could be taken to:

a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships. [Provided added to those would be a reliable source of continued funding for on-campus activities.](#)

b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry. [Coupling between a university with an industrial enterprise with deep enough pockets to provide grants to the university is done at Yale, principally in biomedical fields. But this needs very careful guidelines to be set up through a separate university cooperative research office.](#)

c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials. [Sure, provided the young faculty person is already on board, under terms discussed above.](#)

d. Increase the enrollment in education opportunities at the baccalaureate and master's level? [Graduate work at Yale is normally only towards the Ph.D.](#)

e. Increase the availability of hands-on training opportunities in accelerator technology? [Not so sure that this should be a university activity. There are some small companies that might be better venues for this sort of training.](#)

## **Other Factors**

15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program? [Without the money, it's hard to imagine much change. With money, recruitment needs to be inspired—both for the faculty and for the grad students. This will take some PR, to be sure.](#)

16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science? [None come to mind.](#)

This RFI is issued to gather information that may be used to help formulate DOE-HEP funding practices and grant mechanisms to strengthen academic accelerator science.

## Strengthening U.S. Academic Programs in Accelerator Science

*Response from Cornell University, June 2015*

AGENCY: Office of High Energy Physics, DOE.

1. Does your institution regard accelerator science as an academic discipline? Why or why not?

Yes. The Cornell Department of Physics has five full faculty members who specialize in accelerator science. This program has been in place for many decades and has led to innovations in storage rings, superconducting RF cavities, photoemission electron sources and other areas. The department and university recognize the field's importance

as a discovery science, and as a supportive partner for other disciplines.

2. If your institution offers graduate training in accelerator science:

a. What is the core curriculum shared by all accelerator students, regardless of specialization? (e.g. What is the common coursework taken by all accelerator students?)

As part of the physics graduate program, students take at minimum E&M, quantum mechanics, statistical mechanics, and an advanced lab course. In addition, we offer two courses in accelerator science, though they are typically offered only every few years. Accelerator science students also take two or three USPAS courses.

b. How often do students change fields to study accelerator science? From which fields do these students typically come?

It is common for physics graduate students to explore options in several fields before settling down, and some students drift into accelerator science as part of that process. Perhaps half of our accelerator graduate students have had prior exposure to accelerator

science as undergraduates and came to Cornell with that field in mind.

c. Is your accelerator science program primarily located in the physics, applied physics, or engineering department, or in a combination of two or more of those departments?  
Physics.

d. What incentives would increase the likelihood that your institution would hire additional accelerator science faculty?

An on-campus accelerator that would directly benefit the research of other faculty on campus is a powerful motivation for hiring. The impetus is most immediate if the research of other members of the Physics department will benefit.

e. Is there an on-campus particle accelerator that is dedicated to accelerator science R&D? If not, do you make use of accelerator test facilities at U.S. national laboratories?  
CESR operates mostly as an X-ray user facility and part time for accelerator R&D and is critical to our program in accelerator science. A high-brightness photoinjector is the basis

of research for other faculty.

We do not make regular use of accelerator test facilities at the national labs, but from time to time we use them to test a device that we've developed (eg, undulator, polarized positron source, kickers).

f. How often do collaborations occur between accelerator science and other programs at the university?

We currently have collaborations with applied physics and materials science on photocathodes, with condensed matter physics on SRF cavities and storage ring beam

dynamics, and with particle physics on algorithm development.

g. Does your institution actively seek out corporate sponsorship for an accelerator science

program? Do private companies actively recruit students from your accelerator science program?

Currently, some of our work is motivated and sponsored by the company ASML. We also participate in SBIR and STTR programs with several companies. About one-third of our PhD's end up in positions in industry.

3. If your institution no longer offers graduate training in accelerator science, why was the program terminated?

N/A

4. What funding sources for accelerator science are you aware of?

Most of our funding comes from NSF and DOE. In addition to research funding, we partner with national labs on projects, as in MAP, ILC and LCLS-II. At times, we have had support from other sources such as DOD.

### **Integrating the Roles of the Universities and the U.S. National Laboratories**

5. How can the national laboratory system be best utilized by the university accelerator science community?

Production accelerators such as APS could be made available for experiments. This would supplement the limited number of test accelerators, such as FACET and ATF, and

would support university research on topics relevant for larger accelerators.

6. What are the current barriers (e.g. technical, operational, and economic) that prevent closer collaboration between universities and the national laboratories?

The grading system for the national labs, which focuses solely on production (eg user days or integrated luminosity), is an obstacle.

Also, while our recent contracts with national labs have been straight-forward, we have had past experiences in which we faced sizeable bureaucratic hurdles. For example, one

national lab required a subcontracting plan with detailed diversity information for our suppliers that had to be updated for each addition of funds.

7. Does your university accept accelerator course credits from other institutions?

Our university doesn't track course credit for graduate students. For undergraduates, the

decision to accept course credit from other universities is made on a case-by-case basis by our Director of Undergraduate Studies.

8. Do accelerator science students at your institution routinely take courses and training elsewhere?

Yes, at USPAS.

9. What could be done to strengthen the participation of academia in the operation and improvement of existing national laboratory accelerators?

National labs have adopted mature technologies developed at Cornell, including SRF cavities for NSLS-II, a photoemission gun at BNL, and vacuum chamber treatments to protect against electron cloud at KEK-B. However, labs are often not receptive to partnering with universities during the R&D phase. One disincentive to disbursing R&D funds to universities is the interest of the national lab in sustaining and strengthening

their own R&D groups.

Cornell and other universities have expertise in many areas of accelerator physics and beam instrumentation and can contribute directly to operation and improvement of national lab accelerators by providing talent and equipment. For example, Cornell is developing fast kickers, as well as contributing to the design of beam optics, for the g-2 experiment at Fermilab. The national labs could reach out to academia for more direct contributions.

10. Considering disciplines, other than Accelerator Science, what mechanisms are in place at your university for collaboration with national laboratories? Could these mechanisms be extended to accelerator science?

PREP at Fermilab makes equipment available to university groups for its HEP experiments (so I understand). It would be helpful if the national labs made resources available to university groups for accelerator science. This could be on a fee-for-service basis, and it could include engineering, design and drafting, technical shops and access to equipment. Availability should not be limited to national lab projects.

### **Contemporary Models of University Accelerator Science**

11. What examples exist of thriving academic accelerator science programs?

We have five tenure-track faculty, which makes us one of the largest programs in the country. However, our research program depends on a constellation of funding sources, and the continuation of funding for operating accelerators, which is essential, is constantly at risk.

Other thriving programs include UCLA and MSU. A handful of other universities have smaller programs, and some of these are growing or hope to do so.

a. Are there policies at your university specific to the accelerator science program that are essential to its success?

Our accelerator program has direct access to the Vice Provost for Research. This is tremendously important. The overhead policy, which excludes overhead on capital equipment, is also beneficial.

b. Are there scholarships, endowed chairs, or other awards and positions that give special recognition to accelerator science?

About fourteen years ago, a chair in accelerator science was established.

c. Are there barriers to having accelerator scientists serve as PI or Co-PI on proposals? Every proposal has a faculty PI.

d. Is conversion from research faculty to full faculty in accelerator science possible? How

many faculty members have attempted the transition, and how many have succeeded? The only example of this was decades ago. There are a few examples of SRA's who earned appointments as Adjunct Professors.

e. Are there specific attributes of the institution's culture that contribute to the success of the accelerator science program?

We have a strong emphasis on team science – our faculty collaborate to tackle big projects. This culture of cohesiveness has been essential for establishing the research

infrastructure and operating accelerators that allow our program to succeed.

It is also important that our program is based on a large number of tenured or tenure-track

faculty members (five) who lead the program. This structure is enabled by the highly supportive attitude of both the department and the university.

f. Are there joint appointments with a nearby national laboratory or a private company engaged in accelerator R&D? How many?

No.

12. Are there successful examples of academic programs from other technologically oriented

disciplines that you believe are relevant to establishment or improvement of an accelerator science program? What key attributes make the program successful? (See 11(a)–(f) above).

None come to mind.

13. Are there successful examples of academic accelerator science programs from other countries that you believe are relevant to the U.S. system? What key attributes make the programs successful? (See 11(a)–(f) above).

### **Possible Mechanisms To Encourage Academic Accelerator Science**

14. What specific, cost-effective actions could be taken to:

a. Raise the academic status of accelerator science? Examples in this category might include: Funding named accelerator science faculty positions or named scholarships. Prizes; Early career awards; More research funding.

b. Improve the business case for accelerator science in a university setting? Examples in this category might include grants and practices designed to increase interactions with private industry.

c. Encourage students to choose a career in accelerator science and technology? Examples in this category might include a grant for young faculty to conduct R&D in accelerator science, a tuition stipend for a co-terminal master's degree, or grants to develop instructional materials.

The best way to encourage undergraduates to choose a career in accelerator physics is to

get them involved in accelerator research. At Cornell, we involve 40 undergraduates in our accelerator science research each year. This figure includes 12 REU students drawn

from colleges and universities across the country.

d. Increase the enrollment in education opportunities at the baccalaureate and master's level?

Our REU program in accelerator science gets over 200 applicants each year for 12 spots.

Our requests for funding to increase the number of students to 15 have been denied.

e. Increase the availability of hands-on training opportunities in accelerator technology? Additional research funding will provide more projects for students to work on.

### **Other Factors**



15. Other than the actual award of funding, is there any specific funding agency behavior that impacts positively or negatively on the success of an accelerator science program? Structured calls for proposals, with proposal deadlines, and clear review processes lead to the most effective use of funds. (This is already the norm at NSF and in OHEP.) In addition, more stable, longer term funding would allow us to make the best use of the resources.

16. Are there other factors, not addressed by the questions above, which contribute to the strength or weakness of U.S. academic accelerator science?

In funding decisions, when a university is pitted against a lab for a particular project, the lab tends to win because of the DOE priority on lab stewardship. If the university program is to succeed, DOE needs to relax this priority, and recognize that healthy universities are essential to the long-term success of the national labs.

This RFI is issued to gather information that may be used to help formulate DOE–HEP funding practices and grant mechanisms to strengthen academic accelerator science.

# Academic Accelerator Science RFI

## Comments

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*Ilan Ben-Zvi,*

*Collider-Accelerator Department, Brookhaven National Laboratory*

My comments are based on my 27 years experience at Brookhaven National Laboratory (BNL), serving in various departments (NSLS, Physics, Collider-Accelerator) on a variety of subjects spanning the Office of Science programs of BES, HEP and NP. I am serving now as Associate Chair and Division Head for Accelerator R&D at the Collider-Accelerator Department and as the Scientific Program Director of the BNL Accelerator Test Facility, an Office of Science Users Facility for accelerator science and technology funded under the Accelerator Stewardship program. I am also a BNL Professor of Physics at Stony Brook University.

BNL regards accelerator science as an academic discipline, as evidenced by a uniform ranking scheme for accelerator scientists as other sciences, including granting tenure.

BNL supports graduate training in accelerator science through the support of graduate students from many universities, mostly from Stony Brook University. I have been (or still am) the adviser of fourteen graduate students. A couple of my students changed direction (one from experimental High Energy Physics, the other from theoretical Nuclear Physics) to get a PhD degree in accelerator physics. My students come primarily from the Physics and Astronomy department at Stony Brook.

All my students but two used accelerator facilities at BNL for their thesis research. The BNL Accelerator Test Facility is dedicated to accelerator science R&D, and is an excellent facility for training graduate students, approaching now the 40 student mark from nearly twenty universities. Last year the ATF provided a hands-on graduate level course in accelerator science. The ATF maintains a thriving academic accelerator science program, and is very effective in supporting accelerator science education for a very large number of US and international universities, enabling professors to provide advanced, sophisticated equipment for thesis research free of charge. Clearly a national users' facility in accelerator science is an outstanding tool to promote graduate and postgraduate education in accelerator science. There are no barriers for this utilization other than availability of grant money to the university educators.

BNL's institutional culture, which is based on full recognition of accelerator science as a core program, is a key contributor to the success of the accelerator science program at the ATF and other BNL accelerator groups.

Other than the actual award of funding, specific funding-agency behavior that can positively impact the success of accelerator science programs is the recognition at the Office of Science level of accelerator physics as a scientific discipline. This has been a recommendation of the 2006 Marx Advanced Accelerator R&D HEPAP subpanel. To quote from the Executive Summary:

“For decades, OHEP has had a historical stewardship of accelerator science and technology, which has resulted in substantial benefits to science and the nation. The subpanel endorses the importance of this stewardship responsibility and recommends that the mission statement of OHEP should be modified to include the following: *“The Office of High Energy Physics (OHEP) provides program planning, oversight and funding for research in fundamental accelerator science and technology.*

The NSF Particle Physics Program provides significant support for accelerator science and R&D at two user facilities (Cornell and Michigan State University) and several universities. The proposed new Accelerator Physics and Physics Instrumentation (APPI) program will provide additional funding for grant-based accelerator science and be a major step towards recognition of the importance of accelerator science. *The subpanel recommends that APPI should be established and funded.”*

Of these two quoted recommendations, the first led eventually (but indirectly) to the establishment of the Accelerator Stewardship program, and the second one was adopted by the NSF under a different name.

What is still missing is a DOE mission of fundamental accelerator science and technology. This would impact positively on the success of accelerator science programs.

## **Response to the DOE Office of High Energy Physics, U.S. Department of Energy, May 15, 2015 Request for Information**

Dr. David F. Sutter  
Senior Scientist,  
Institute for Research in Electronics and Applied Physics (IREAP)  
University of Maryland  
College Park, Maryland

**The Question:** The DoE Office of High Energy Physics invites interested parties to provide comments on proposed policies, practices, mechanisms which the DoE might implement to foster robust academic R&D and workforce development in this vitally important high technology area.

### **Response:**

A caveat: I have been a senior guest scientist at the University of Maryland, Institute for Research in Electronics and Applied Physics (IREAP) for 10 years and am not a member of the faculty or the University management. I have had ample opportunity to observe and participate in discussions at an informal level concerning accelerator physics and engineering activities at the University, and I have known all of the active principal investigators in accelerator physics and engineering, present and past, for many years. Consequently, the views expressed below are strictly my own and do not represent the official views of the University staff, faculty or management.

### **Increasing Recognition of Accelerator Science in Academia**

There are many issues involved in increasing the recognition and importance in accelerator science in a University. I am in a very unique position with respect to this subject because of the 30 years spent in the Office of High Energy Physics pushing exactly this issue and the 10 years that I have now observed the issue from the university side. It has been a very interesting and educational 10 years.

The University of Maryland has a long record of supporting accelerator science as an academic discipline. The beginning of the University's commitment was in the cyclotron facility that was part of the Physics Department in the fifties and sixties and funded by the forerunner of the current DoE Office of Nuclear Physics. Graduate programs in accelerator science and engineering at the University of Maryland, as at most Universities, center around research groups led by a very senior scientist, usually but not always tenured. This graduate education effort at Maryland has been historically centered in four groups, Professor Martin Reiser's in the area of space charge dominated beam physics utilizing the UMER ring, Professor Victor Granatstein's in high powered microwave power sources, Professor Howard Milchberg's in laser plasma acceleration physics and professor Alex Dragt's in the theory of non linear systems in charged particle beam optics. Only two of these remain, the Martin Reiser group now led by Dr. Rami Kishek and Professor Milchberg's. There has been recent funding through the DOD for R&D on a

new approach to higher powered microwave source led by Professor Thomas Antonsen, but it is not clear that this is a long term research activity – i.e. a long term R&D group. Professor Antonsen, who has an established record of research in support of plasma based accelerators, has drawn on staff and students from the UMER group and from the former Granatstein group. Professor Reiser passed away four years ago and Professor Dragt retired fully from all University activities about three years ago. Professor Granatstein has not been active in actual research for several years. There has been no move by the University to replace these researchers in either the Physics or Electrical Engineering Departments. Professor Pat O’Shea, who was PI for the Reiser group for a number of years, has been promoted to Vice President for Research at the University, and there has been no effort to replace him. Recently, the current Physics department Chair expressed an interest in recruiting a person in accelerator physics, but nothing has progressed. So The University of Maryland is now down to what I call two and a half groups, and between the impact of fewer groups and reduced funding due to sequestration, the number of PhD students enrolled in accelerator physics and technology is reduced and will remain so for the foreseeable future. This local example is not unique to Maryland.

I believe that there three principal factors driving this decline, the focus of Physics and Electrical Engineering on current hot research topics that are perceived to be academically forefront (e.g. string theory and nanotechnology), the financial stress of reduced state funding in a major state university (a national problem) coupled with the increasing pressure to hold tuitions down in the face of rising costs, and the severe recent reduction in Federally available research funding. All of these impact the issue of hiring new tenured faculty.

Funding for R&D in accelerator sciences and technology at the University of Maryland is primarily from three sources, the DoE Office of High Energy Physics, the DoD and the National Science Foundation. Of the three primary government sources, the DoE Office of High Energy Physics has provided the longest running and most steadfast support. The DoD funding was very important until about 3 or 4 years ago when a combination of funding shortfalls and a change in DoD R&D policy, particularly in the Navy, to focus only on short term, high pay off technology development dried up most of the DOD funding in accelerator physics and technology. The NSF program in advanced accelerator R&D, started by Denise Caldwell, Head of the NSF Physics Directorate, is now beginning its third funding cycle. It is very much University oriented, but the funds are limited and there is strong competition for the grants. The major problem is that the NSF philosophy is to only provide enough funding for a PI and a couple of graduate students, which is sufficient for theoretical or other paper based R&D, but is inadequate for a viable program in experimental science unless running in concert with an existing program. This is partly due to the ground rules chosen initially for the program, driven by the limited amount of start up funds. Even so, the new NSF program is very important for University based physics, and it is an excellent example of how to set up and structure an R&D program for stimulating University R&D in accelerator physics and technology! I personally expect the NSF program to grow, but I do not know by how much. I should also note the continuing support of the NSF for the Cornell program in accelerator physics, which is very much bigger.

Other than some limited collaborations with SBIR/STTR industrial grantees, there is essentially no funding from industry or any evident interest by industry that I am aware of related to R&D in accelerator physics and engineering at Maryland. I must note that these small SBIR/STTR collaborations have importantly helped our research staff in IREAP survive recent funding stresses. While the University does have programs encouraging academic R&D collaboration with and sponsorship by industry, I am not aware that any of these have addressed the area of accelerator science and engineering. Moreover, there has been essentially no effort by U.S. industry to hire Maryland graduate students into accelerator engineering or technology roles. This is certainly influenced by the circumstance that there are only a small handful of U.S. companies that formally work in accelerator science and technology on a broad scale. I would note that this state of affairs is consistent with the most common U.S. corporate business model.

We have had no trouble finding talented graduate students at the University of Maryland interested in accelerator science and engineering, and historically, the University has in fact produced more PhD graduates in these fields than any other U.S. University. We are now primarily limited in the funding needed to support the student's research and the ability to replace or acquire tenured faculty. In the last 10 years most of the graduate students have matriculated in the Physics or Electrical Engineering Departments. Since the departmental location of plasma scientists has been a little dispersed (it now seems to be solidly in Physics), I am not sure from which Departments Professor Milchberg has drawn his students, but I believe that it is also principally from Physics and Electrical Engineering.

There are no Applied Physics, Engineering Physics or Engineering Science Departments at the University of Maryland.

All of the students complete graduate level foundation courses in mechanics, electricity and magnetism, quantum mechanics and mathematics. There are also a number of special courses that they may take in plasma physics and electrical engineering depending on which department they are in and their research interests. At Maryland, as at most U.S. universities, there is a real difficulty in providing specialty courses in beam optics or physics because these are considered specialty topics and the University requires preregistration of at least 6 students before it will schedule such a course. This has proven very difficult to do, and the course in space charge dominated beams, for example, that was given in the past every other year, has not been given in four years. As a result, we are very, very dependent on the U.S. Particle Accelerator School for the special training. Each of our UMER graduate students has taken 3 to 4 USPAS courses for credit. Without USPAS our graduate program in accelerator science would be badly crippled! The University of Maryland is not unique in this issue, as DoE/OHEP is very much aware!

There are two major accelerator physics R&D centers at the university, both located in IREAP, the University of Maryland Electron Ring (UMER) and Howard Milchberg's laser plasma acceleration facility. IREAP is an independent institute devoted to providing larger experimental facilities to a variety of academic Departments, not just Physics and

Electrical Engineering. It serves a broader function than Cornell's Wilson lab or MIT's Bates but is similar in its focus on research and not on broader academics issues. The two accelerator R&D centers are both unique and give students 24/7 access to their experiments. The good news is that the research environment is excellent. The bad news is that the research is off in a far corner of the campus and not under the day-to-day visibility of a broad spectrum of faculty; the result: a lack of broader awareness and recognition in Physics and Electrical Engineering. This reflects in sensitivity to the need for additional faculty in this area.

The renewal or expansion of the faculty in accelerator science and engineering is of great concern. I don't think that the general issue is unique to Maryland, but of course the particulars are different at each University. There is need for tenured faculty because that is the magic title in a university for recognition, prestige and priorities and with the funding agencies, particularly in recent limited budget times. UMER represents a not uncommon problem in Universities. All of its current scientific research staff are non tenured. They have a job as long as there is research funding. An attempt was made several years ago to get one of our longest resident research staff tenure, but it failed. It is the only attempt that I am aware of in at least 10 years. Creating tenured faculty positions in a state university is a problem because of the long term financial burden the position represents and state support for higher education is shrinking – everywhere, not just at Maryland. Moreover, priority is given to the areas of hot research topics. The physics Department wants to hire string theorists or nanotechnology specialists with first priority because they are more likely to bring prestige and money. These are part of the issues that OHEP has to recognize and address in order to make headway in getting more University centers of excellence in accelerator science.

### **Integrating the Role of Universities and U.S. National Laboratories.**

Establishing a strong, mutually beneficial interaction between National Laboratories and University programs in accelerator physics engineering and technology by personnel exchanges and collaborations was a strong recommendation of the 1980 Tigner sub panel of HEPAP and has been endorsed by every relevant review panel of which I am aware since– to little avail! There is a strong message here, and I think it is that the parties are not that enthusiastic about such collaborations. This is based in part on the very different missions and culture of the two institutions. But the situation has improved somewhat in the 35 years since the Tigner Panel report. The best measure of success has been the introduction of formal User Facilities in accelerator physics, particularly FACET at SLAC and the ATF at BNL. These do provide capabilities not available elsewhere. I think that FACET is especially important first because it has seriously facilitated research collaboration between university and lab scientists and second because it represents a significant shift in management philosophy at SLAC. BNL's ATF has been successful also and may be more so in its new role as part of the Stewardship program. The small wake field accelerator facility at ANL and the New Muon facility at Fermilab are also of importance in the future and need to be adequately supported and encouraged to broaden their respective programs, which does require more funding. The issues at Fermilab of getting the IOTA project operating and the rest of the facility fully operational need to be

given priority. The unique major University facilities that deserve preservation, at least in the short term, include the labs at UCLA (Neptune and Rosenzweig's separate FEL work); the laser acceleration facility at University of Texas, Austin; Milchberg's laser acceleration laboratory; and UMER. Note that I do not include Cornell's Wilson Lab or the MSU Superconducting Cyclotron Lab. These are in effect national laboratories whose primary mission is not accelerator science, although they do make important contributions to the field.

I am very concerned at the recent OHEP efforts to force all University experimental R&D into a national laboratory user facility at the expense of unique university facilities - a policy based, I believe, more on the need to reduce expenditures, the belief that you can do the same science more economically and effectively and some historical funding agency policies, particularly the Nuclear Physics strategy in the 1950's and 60's of closing many small university based accelerators in favor of a few national user facilities. This by the way was a very different circumstance than that in High Energy Particle Physics where the size of the accelerators forced the research into a national laboratory type structure. I note that three questions are provided by OHEP in this section on how to "strengthen national laboratory ties, having to do with the means, methods of strengthening, and models from other disciplines. The best strategy that I know derives from the lessons of technology transfer: when there is market pull there is common motive and success; when there is market push (like from Federal agencies) there is a lot of money spent and little accomplished. So the strategy should be to very gently encourage but don't push. I think that given the progress that I have cited above and some enlightened self interest sure to develop on the part of the national labs in the next 10 years, that we will see more Lab - University collaboration than ever before. All the DoE/OHEP needs to do is supply the funds and some very subtle positive approval. In summary, DoE/OHEP should quit trying to force the issue; they should lead from behind - a strategy that Bill Wallenmeyer used with very great effectiveness, and that I have given the briefest view of above.

### **Contemporary Models, Possible Mechanisms and Other Factors.**

I am going to try and answer the questions more directly in the last sections because I think that there is some redundancy and because I have already addressed some of them in part above.

Examples of successful university accelerator physics programs exist at Cornell, University of Maryland, UCLA, Northern Illinois University, Stanford/SLAC, and University of Texas, Austin among others. The university policies making these effective vary widely from no particular, formal university policy - U. of Maryland - to formal centers for accelerator physics at UCLA and at Northern Illinois.

There are no barriers at any university that I know of impeding a tenured or tenure track faculty member from being a PI or Co-PI on a research proposal or grant. There are issues for non tenured research scientists and guest scientists at most universities. At



Maryland if the employment tenure and official University status are high enough, then the employee can be a PI or Co-Pi. By and large the impediments are overcome.

There can certainly be attributes of a Universities culture that contribute to the success of a University accelerator science program. I would cite first and foremost Cornell. At Maryland the very long history of successful, outstanding, talented faculty with real passion for Research and the approval of it in the Departments of Physics and Electrical Engineering, as well as at higher levels (we have in the past had two accelerator physicists at the highest levels of University management, and the current University Vice President for Research was the UMER PI for many years) has created a culture of general support within the academic hierarchy that has endured for a long time.

At Maryland we have no nearby national laboratories, like Stanford with SLAC and the State University of New York at Stony Brook with BNL. We do have current joint appointments with the Naval Research Laboratory that are very beneficial to both parties. Geographic accessibility is a great facilitator! I spoke above to the lack of connections with U.S. industry. This is largely fallout from the U.S. corporate business model of doing no mid term or long term R&D, and even the DoE/OHEP Stewardship program is not going to have much luck with this one.

We do not have any university based scholarships, endowed chairs, or other awards or positions that give special recognition to accelerator science at Maryland, nor am I aware of any at other universities. There may be some nationally, but they are few. There are some at national labs that are important, Fermilab's Peoples and Wilson fellowships come to mind.

I think that there are a number of actions that could substantially encourage academic science. There are two aspects of this: First, proselytizing a culture of strong academic desire for and support of programs in accelerator science is essentially impossible for an outside organization to do successfully - it corresponds to the push of the push - pull analogy to technology transfer - and is not an approach that is likely to be productive or cost - effective. Second, the most important thing to recognize is that a modern university is foremost a business organization - certainly evident these days at the University of Maryland, Stanford, and other major universities. So if you want programs in accelerator science you have to wisely fund them. All of the suggestions raised in the questions are good ones: fund named faculty positions, fund named scholarships (more on this later), fund outstanding senior investigators for five years, as an alternative to funding research projects (there has been a very successful NIH program to do this which was recommended to the recent HEPAP subpanel and strongly rejected out of hand - mistakenly I believe), fund five year grants for big programs instead of the present canonical three (OHEP used to do this), fund young faculty to conduct start up research in accelerator physics or engineering, and fund grants to develop instructional materials, particularly the writing of text books (OHEP has also done this in the past with success). One approach that might help, but is costly, is to follow a strategy used by NSF in fields important to its mission: set up a competition for a center of excellence (or two or three) in accelerator science or engineering at universities and provide guaranteed funding for at

least 5 years of at least one million dollars per year, with possibility of renewal if the results of the program are outstanding and needs warrant. As far as I know The DoE Office of Science has never done this, but it is the time to consider trying new approaches.

I am not that familiar with foreign university programs in accelerator physics. I am also very skeptical of the claim that Europe is producing around a hundred PhD's in accelerator science per year. This might be true world wide. There is an important activity where Europe has taken leadership and that is in publication of the lecture notes from the CERN Accelerator Physics School. USPAS used to support the publication of texts based on the schools lectures in the Wiley series that are still popular, but there hasn't been any from recent schools - like in more than 10 years. There are essentially no texts in the area of plasma acceleration, but both an introductory and mid level text would be most welcome.

The way the funding agency approaches the oversight and funding of the university program in accelerator research is of fundamental importance. So about accelerator science, engineering and technology, there are a number of factors. Realize practically that the development of technology is primarily a national laboratory activity. In spite of expressions of a need to change academic standards, technology development is not generally seen as an attractive PhD topic in most academic departments. With the continuing attrition of supporting university shop facilities this is becoming ever more difficult. I think there is in DoE/OHEP an under appreciation of the fact that advanced accelerator R&D is frequently a long term activity, not easy to complete in one three year grant. The outstanding example of this is plasma accelerators which after 30 some years are just now coming to the point where in the next 5 to 10 years, depending on funding, they will be ready to provide a good practical demonstration. There has been and still exists, as near as I can tell, a policy of funding only what is of direct programmatic need for HEP research. In the field of advanced R&D, the focus appropriately of much university based accelerator R&D, there is no sure way of telling whether a project is going to meet a particular DoE program's needs. I spent 30 years learning this lesson and there is no one that I know of who is smart enough to reliably make these restrictive choices – not on staff, on comparative review committees or on HEPAP subpanels. As one famous west coast leader once said, “You must let a thousand flowers bloom.” The place to start requiring mission relevance is in midterm R&D and more so in short term R&D, even when not so clearly relevant to a construction prospective project. U.S. HEP really has only one prospective accelerator project, the high intensity linac for the proposed Fermilab upgrade. That is a pretty narrow area of relevance, important as it is!

I recently participated in the modern version of the Outstanding Junior Investigator program award selection committee review process. I quickly became convinced that the present Office of Science wide, front Office managed version of this is absolutely not giving the agency or the individual OSC programs what they need. From my recent experience compared with what I observed in OHEP before the present change in approach, these special awards need to be administered by the programs managing that area of research. Otherwise one gets into an apples and oranges competition that becomes silly in the lack of Committee wisdom exhibited in making final choices.

In summary, the DoE/OHEP has had a strong and enduring record of outstanding management of long range accelerator R&D, starting with Bill Wallenmeyer. Times have indeed changed, and new and creative approaches are essential. But at the same time there are some lessons that always apply: know the field and its needs – through reviews and advisory panels, of course, but also by getting program managers into the field often for informal visits and getting them to as many conferences and workshops as often as possible to carry on personal dialogs and continuing self development. Creativity, an essential, valued feature of university research, requires the broadest and most patient oversight by the research program’s funding Office. The concept of a “field run” program, which is what leading from behind is all about, is probably the most effective programmatic leadership there is.