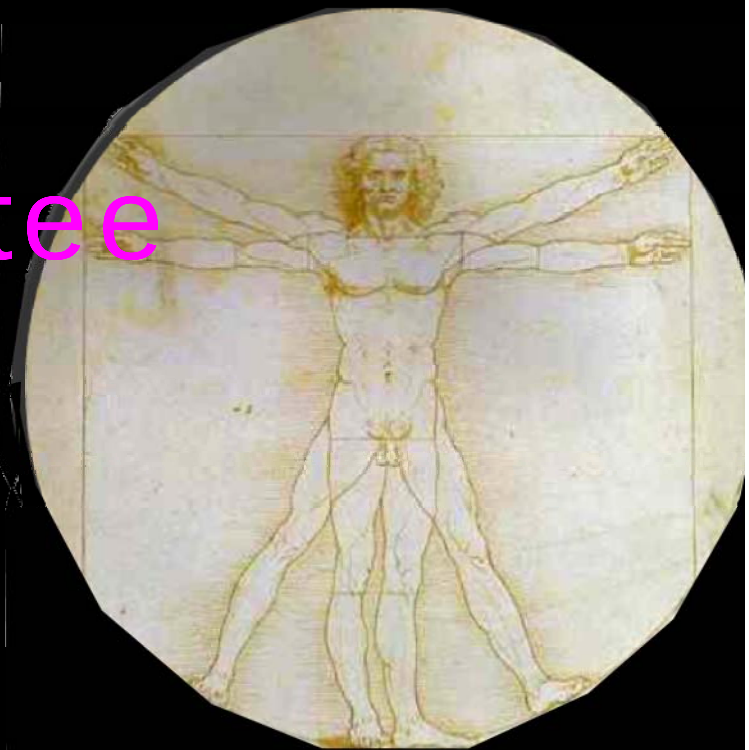
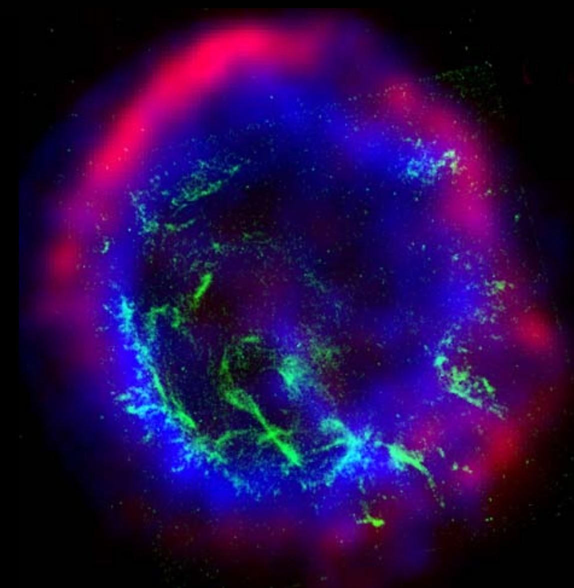
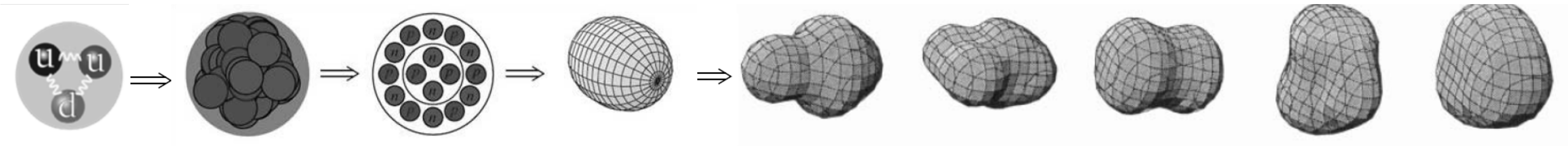
NSAC Subcommittee on **Isotopes**

Charge 1

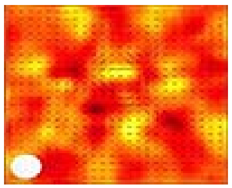
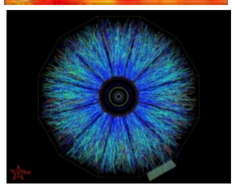


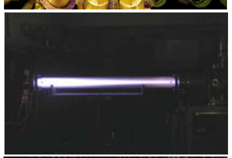
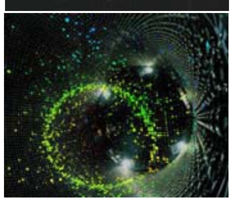
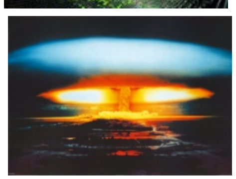


Ani Aprahamian
University of Notre Dame
and
Don Geesaman
Argonne National Laboratory



Science Goals in Nuclear Physics

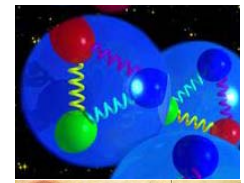
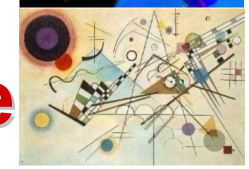
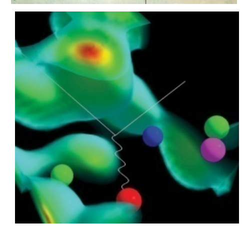
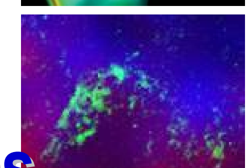
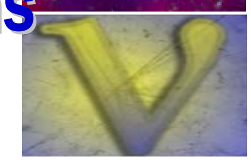
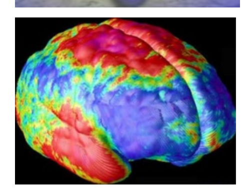
- Quark Structure of Nucleon
- Quark gluon plasma
- Nuclear Structure

} NP Science

- Nuclear Astrophysics
- Fundamental Studies

} NP Implications

- Nuclear Physics Applications
  Nuclear Data, Isotopes.....

OPINION NATURE|Vol 457|29 January 2009

ESSAY

Accelerating production of medical isotopes

The global problem of a safe and reliable supply of radioactive isotopes for use in critical hospital procedures can be solved with accelerators, not nuclear reactors, says **Thomas Ruth**.

February 17, 2009

Mo-99 production resumes at troubled European isotope reactor

DiagnosticImaging.com

NSAC Subcommittee on Isotopes

FY 2009 Budget Request

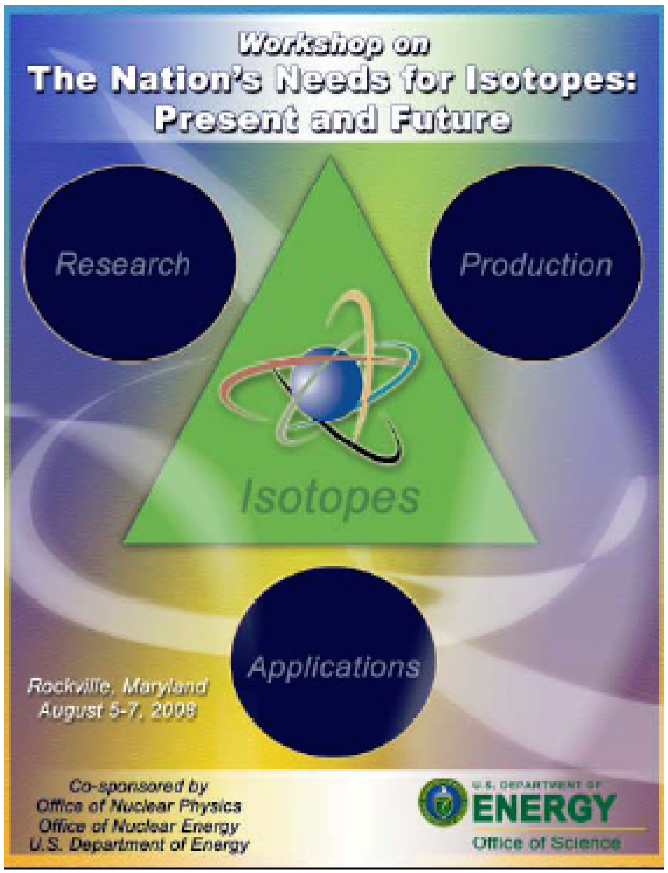
The Fiscal Year (FY) 2009 President's Request Budget proposes to transfer the Isotope Production Program from the Department of Energy (DOE) Office of Nuclear Energy to the Office of Science's Office of Nuclear Physics and rename it the Isotope Production and Applications Program. In preparation for this transfer, NSAC was requested to establish a standing committee, the NSAC Isotope (NSACI) sub-committee, to advise the DOE Office of Nuclear Physics on specific questions concerning the National Isotope Production and Applications (NIPA) Program.

NSACI constituted for a period of two years as a subcommittee of NSAC. It will report to the DOE through NSAC who will consider its recommendations for approval and transmittal to the DOE.

The Subcommittee is asked to establish the priority of research isotope production and development, and to form of a strategic plan for the NIPA Program.

Workshop in August

DOE/SC-0107



Questions Asked

Who uses isotopes and Why?

Who produces them and Where?

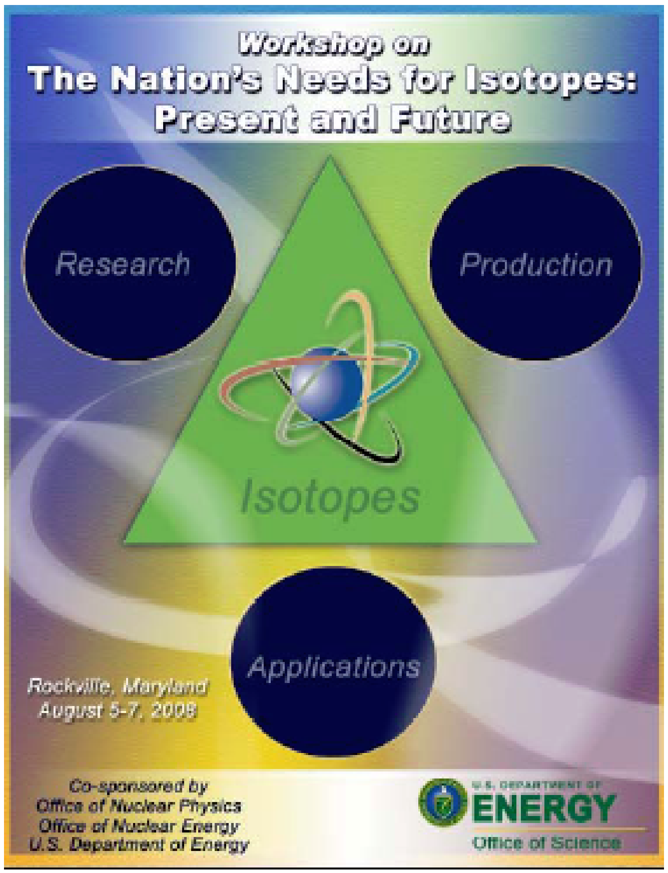
What are the needs today and in the future?

What is the status of the supply/what is missing?

What options for increasing availability /technical hurdles?

Workshop in August

DOE/SC-0107



Findings ....

A reliable program in isotope production at DOE is crucial for the long term health of developments in medicine, basic physical and biological sciences, national security and industry.

Many of isotopes in domestic use are produced only by foreign suppliers

Affordability

The production capability of the NIPA program relies on facilities that are operated by DOE for other primary missions.

There is a pressing need for more training and education programs in nuclear science and radiochemistry to provide the highly skilled work force for isotope application.

NP resources...

Nuclear Science Advisory Subcommittee on Isotopes

Charge 1:

As part of the NIPA Program, the FY 2009 President's Request includes $3,090,000 for the technical development and production of critical isotopes needed by the broad U.S. community for research purposes.

- NSACI is requested to consider broad community input regarding how research isotopes are used and to identify compelling research opportunities using isotopes.

- The subcommittee's response to this charge should include the identification and prioritization of the research opportunities; identification of the stable and radioactive isotopes that are needed to realize these opportunities, including estimated quantity and purity; technical options for producing each isotope; and the research and development efforts associated with the production of the isotope. Timely recommendations from NSACI will be important in order to initiate this program in FY 2009; for this reason an interim report is requested by January 31, 2009, and a final report by April 1, 2009.

NSACI Subcommittee

Ercan Alp Ph.D.
Argonne National Laboratory

Ani Aprahamian Ph.D. (co-chair)
University of Notre Dame

Robert W. Atcher Ph.D.
Los Alamos National Laboratory

Kelly J. Beierschmitt Ph.D.
Oak Ridge National Laboratory

Dennis Bier M.D.
Baylor College of Medicine

Roy W. Brown
Council on Radionuclides and
Radiopharmaceuticals, Inc

Daniel Decman
Lawerence Livermore National Laboratory

Jack Faught
Spectra Gas Inc.

Donald F. Geesaman Ph.D.(co-chair)
Argonne National Laboratory

Kenny Jordan
Association of Energy Service Companies

Thomas H. Jourdan Ph.D.
University of Central Oklahoma

Steven M. Larson M.D.
Memorial Sloan-Kettering Cancer Center

Richard G. Milner Ph.D.
Massachusetts Institute of Technology

Jeffrey P. Norenberg Pharm.D.
University of New Mexico

Eugene J. Peterson Ph.D.
Los Alamos National Laboratory

Lee L. Riedinger Ph.D.
University of Tennessee

Thomas J. Ruth Ph.D.
TRIUMF

Robert Tribble Ph.D. (ex-officio)
Texas A&M University
Susan Seestrom Ph.D. (ex-officio)
LANL

Roberto M. Uribe Ph.D.
Kent State University

Nuclear Science Advisory Subcommittee on Isotopes

Nov. 13-14, 2008	Organizational meeting
	Publicize our charges, seek community input
Dec. 15-16, 2008	Get input from government agencies
Jan. 13-15, 2008	Input from customers,
	Ideas for production research R&D
	Research priorities recommendations
Jan. 31, 2009	First interim report due
Feb. 10-12, 2009	2- day Meeting to hear plans for facility and infrastructure improvements
Mar. 25-27, 2009	3 day meeting
	Finalize report for 1st charge
	Decide on recommendations for Long Range Plan
April 1, 2009	Final report for first charge submitted by NSACI
April 2009	Write report on second charge
June 2009	Meeting to finalize 2nd report
July 31, 2009	Final report for second charge submitted by NSACI

Federal Agencies Contacted

Air Force Office of Scientific Research, Armed Forces Radiobiology Research Institute, Department of Agriculture, Department of Defense, Department of Energy - Fusion Energy Sciences, Department of Energy-National Nuclear Security Administration - Nuclear Non-proliferation, Department of Energy-Basic Energy Sciences, Department of Energy-Biological and Environmental Research, Department of Energy-Nuclear Physics, Department of Homeland Security, Environmental Protection Agency, Federal Bureau of Investigation, National Cancer Institute, National Institute of Allergy and Infectious Disease, National Institute of Biomedical Imaging and Bioengineering, National Institute of Drug Abuse, National Institute of Environmental Health Science, National Institute of General Medical Science, National Institute of Standards and Technology, National Science Foundation - Directorate for Engineering, National Science Foundation - Directorate for Mathematical and Physical Sciences, National Science Foundation- Directorate for Biological Sciences, Office of Naval Research, State Department, U. S. Geologic Survey

DOE-NIH Working Group

Professional Societies Contacted

Academy of Molecular Imaging, Academy of Radiology Imaging, Academy of Radiology Research, Amercan Association of Physicists in Medicine, American Association of Cancer Research, American Chemical Society, American Chemical Society - Division of Nuclear Chemistry and Technology, American College of Nuclear Physicians, American College of Radiology, American Medical Association, American Nuclear Society, American Nuclear Society - Division of Isotopes and Radiation, American Pharmacists Association - Academy of Pharmaceutical Research and Science (APhA-APRS), American Physical Society, American Physical Society - Division of Biological Physics, American Physical Society - Division of Material Physics, American Physical Society - Division of Nuclear Physics, American Society of Clinical Oncology, American Society of Hematology, American Society of Nuclear Cardiology, American Society of Therapeutic Radiation and Oncology, Council on Ionizing Radiation and Standards, Health Physics Society, National Organization of Test, Research and Training Reactors, Radiation Research Society, Radiation Therapy Oncology Group, Radiochemistry Society, Radiological Society of North America, Society of Molecular Imaging, Society of Nuclear Medicine

Trade Groups contacted

Association of Energy Service Companies

Council on Radionuclides and Radiopharmaceuticals

Gamma Industry Processing Alliance

International Source Suppliers and Producers Association

Nuclear Energy Institute

Nuclear Science Advisory Subcommittee on Isotopes

Report Outline

1. General Introduction on the broad use of isotopes

2. Landscape of production
   Common issues to all areas....
   stables/radioactives, nat/int.

3. Medicine, Pharmaceutical and Biology
   Research in Biology/Pharma
   Diagnostic and Therapeutic

4. Basic Physical Science/Engineering Research

5. Security Applications of Nuclear Science
   DHS, NNSA, AFCI, GNEP

6. Summary and Recommendation

Chapter 1: Introduction

Introduction to the use of isotopes

(vital to health of US science &Technology)

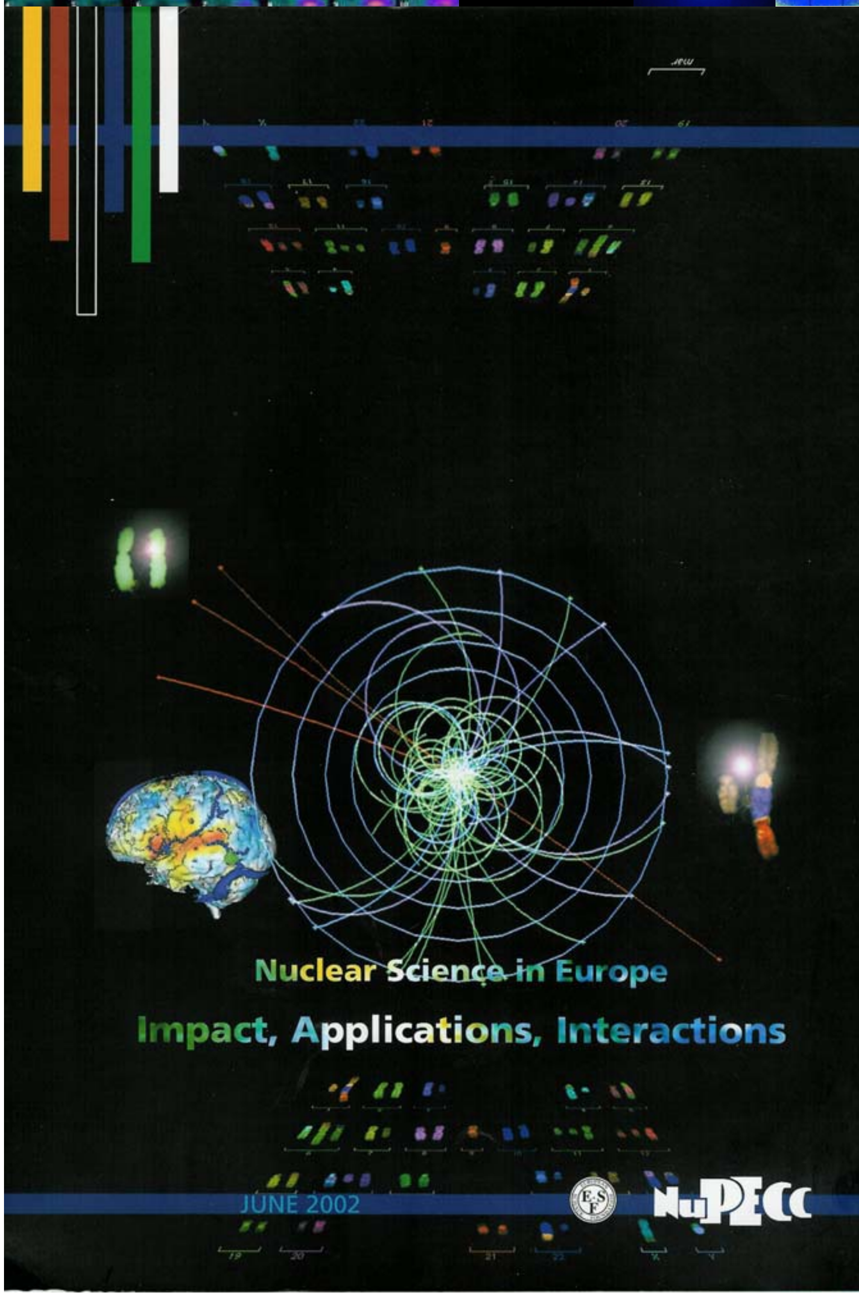
Basic Nuclear Science

Medicine (imagine/therapeutic)

Energy

Security

Forensics



Nuclear Physics Applications

Energy
- ADS systems
- Fusion confinement
- Nuclear Waste
- Nuclear Data

Nuclear Forensics
- Homeland Security
- Risk Assessments
- Nuclear Trafficking
- Proliferation

Life Science
- Medical Diagnostics
- Medical Therapy
- Radiobiology
- Biomedical tracers

Material Analysis
- Ion Implantation
- Material Structure
- Geology & Climate
- Environment
- Art & Archaeology

Nuclear Defense
- Weapon Analysis
- Functionality Simulation
- Long-Term Storage

Nuclear Science Advisory Subcommittee on Isotopes

Chapter 2: Production Landscape

Landscape of Isotope Production at DOE

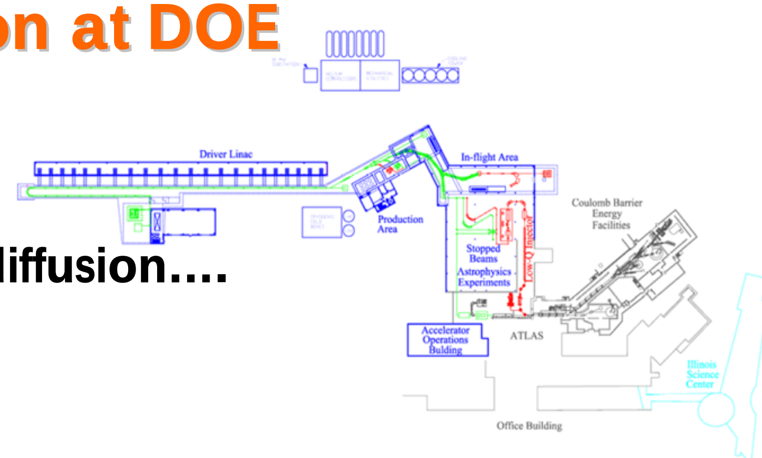
Reactors

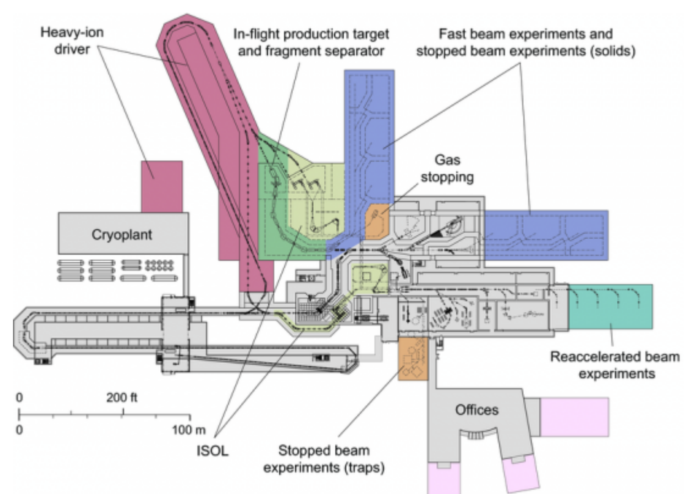
Accelerators

Private sector production:

distillation, chemical exchange, thermal diffusion….

How do we define Research?





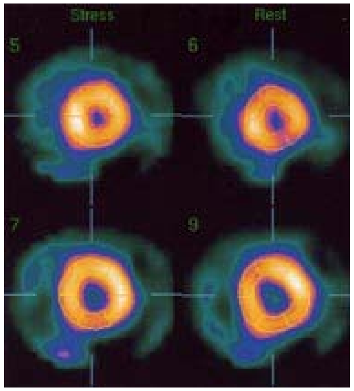
Nuclear Science Advisory Subcommittee on Isotopes

Chapter 3: Biology, Medicine, Pharma

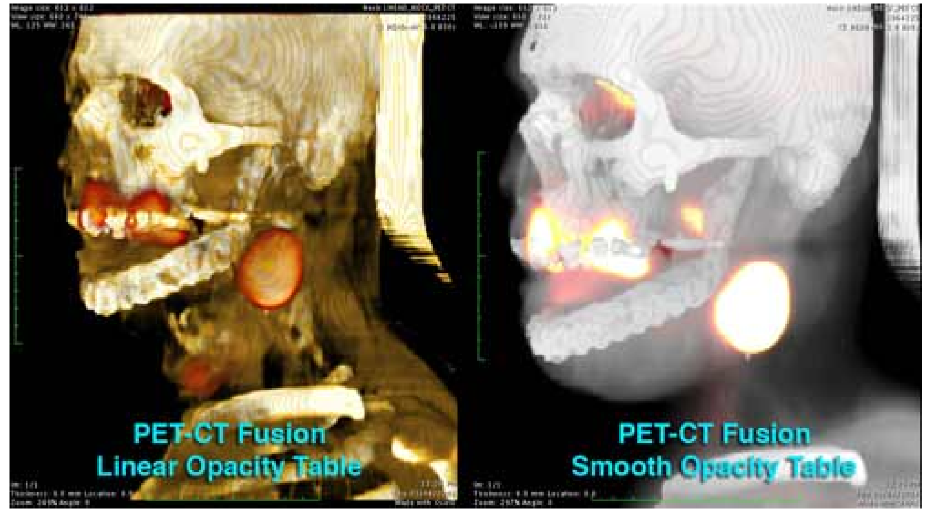
Science and Application

Therapeutic
Imaging
RadioPharma

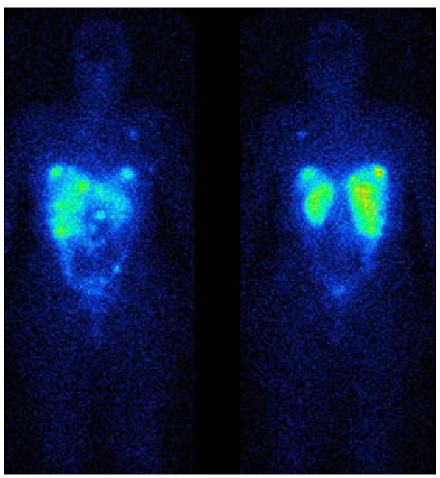
Nuclear Imaging



Blood flow with radiopharmaceuticals



Imaging software and analysis

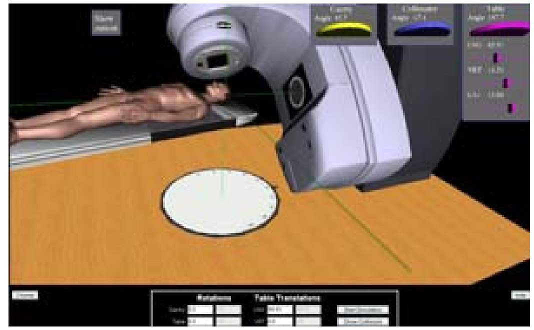


- Gamma Camer
- SPEC & PEP

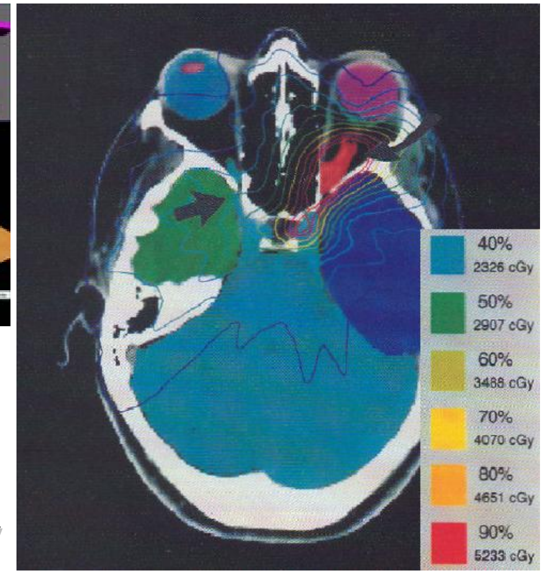
Tumor mapping & visualization by radioactive isotope accumulation.

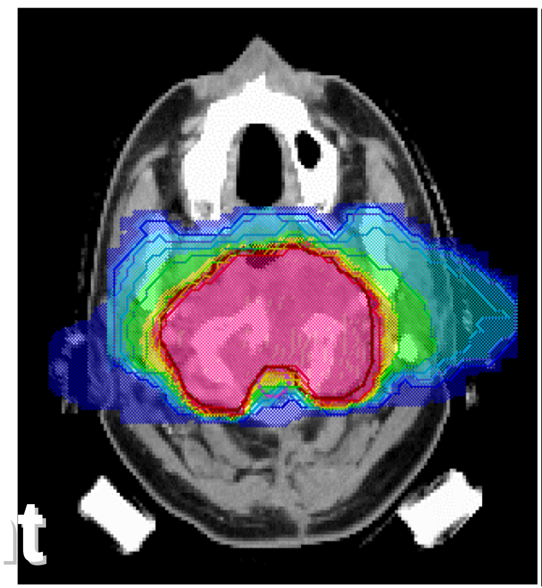
Imaging system development

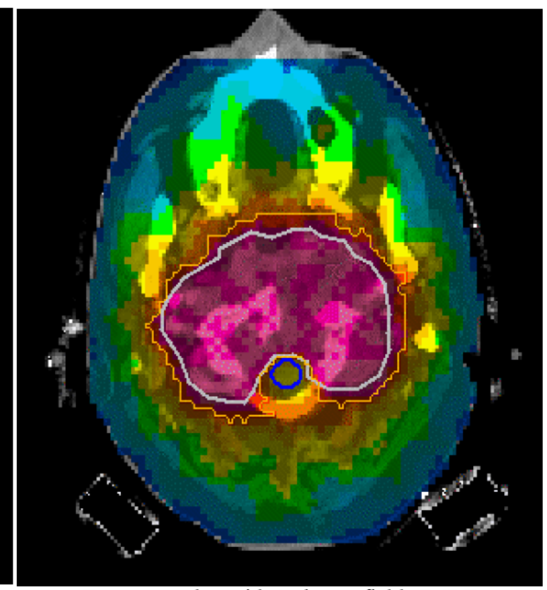
Radiation Treatment



- Brachytherapy
- Gamma therapy
- Neutron therapy
- Heavy ion therapy




Treatment plan with 2 heavy ion fields


Treatment plan with 9 photon fields IMRT

Chapter 3: Biology, Medicine, Pharma

Science opportunities

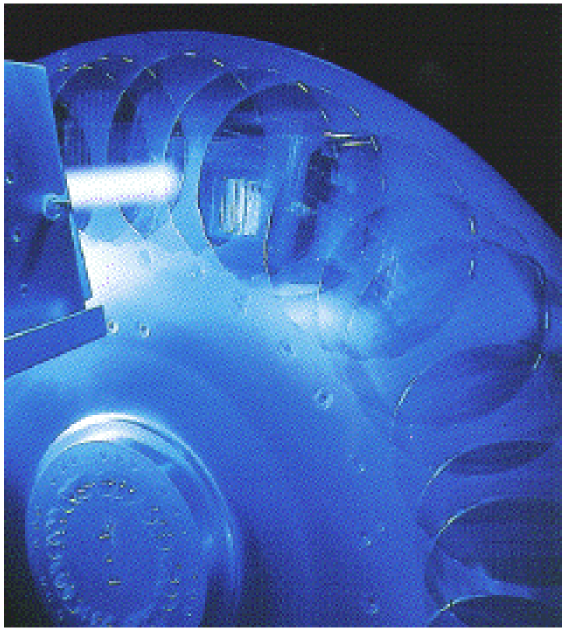
Research activity	Isotope	Issue/Action
Alpha therapy	^{225}Ac ^{211}At ^{212}Pb	extraction of ^{229}Th from ^{233}U cyclotrons capable of ^{4}He acceleration
Diagnostic dosimetry	^{64}Cu ^{86}Y ^{124}I ^{203}Pb	^{67}Cu therapy ^{90}Y therapy ^{131}I therapy ^{212}Pb therapy
Diagnostic tracer	^{89}Zr	stem cell trafficking
Therapeutic	^{67}Cu	high energy production (enriched target)

Nuclear Science Advisory Subcommittee on Isotopes

Chapter 4: Basic Physical Sciences/Engineering

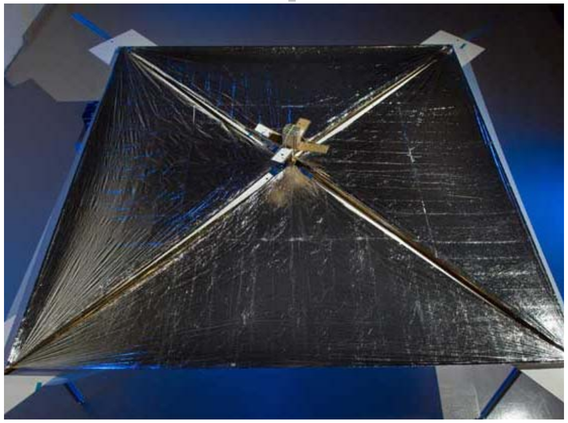
- Nuclear Science-
  - Structure -
  - Fund. Symmetries/Physics Beyond Standard Model
- Energy
- Chemistry
- Environmental
- Materials

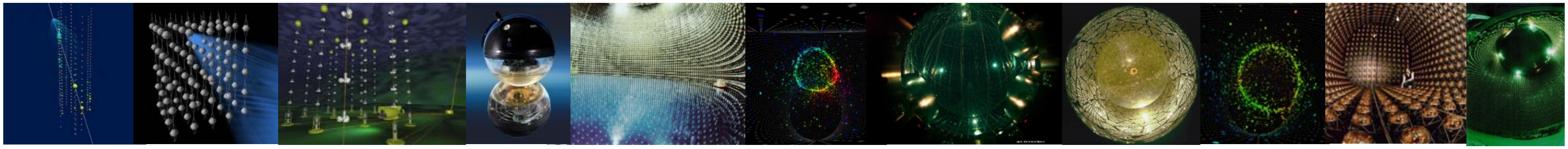
Material Treatment and Analysis of Artifacts



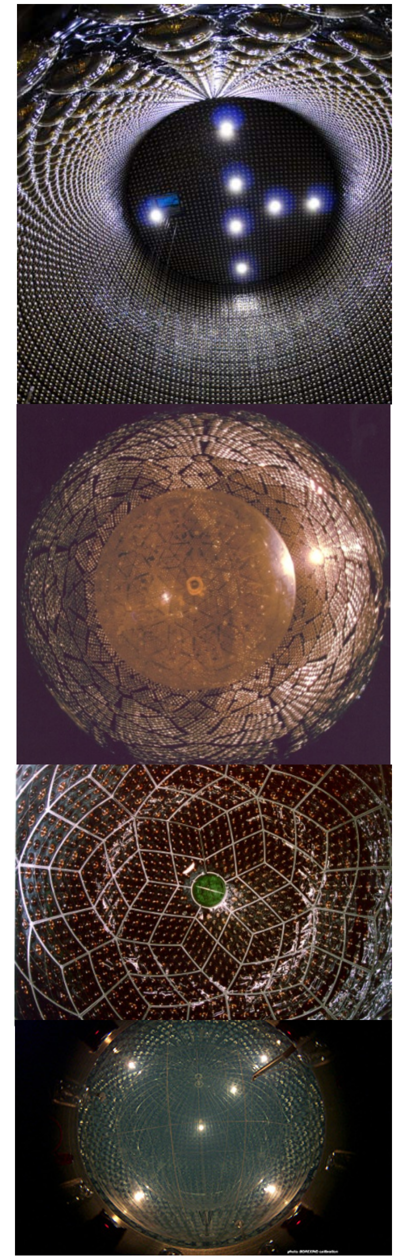
Dating real and false mummies

Implantation and irradiation from silicon chips to solar sails

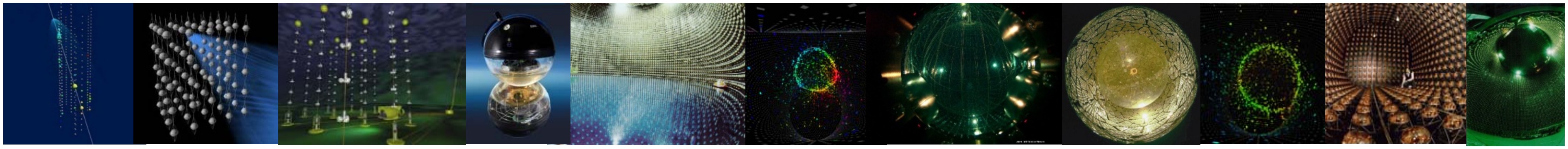




Neutrino Physics –
Particle and Nuclear Physics



Last decade opened new era of nuclear physics,
the study of low energy neutrinos from sun and supernova and in laboratory decay



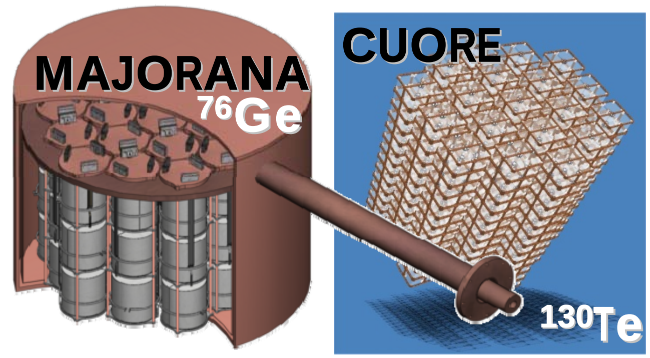
Fundamental Symmetries

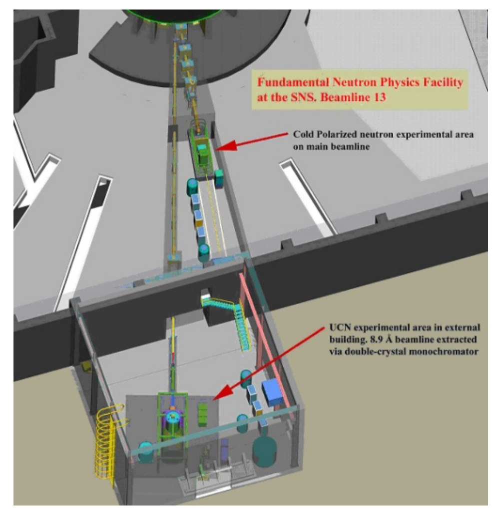
Standard Model Initiative

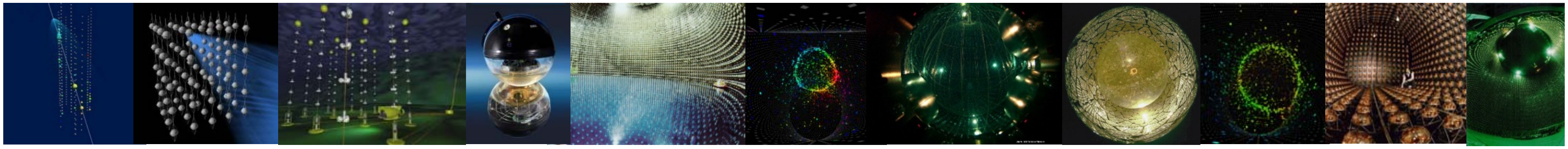
What are the neutrino masses?
Tritium decay measurements with KATRIN

Are neutrinos their own antiparticles?
Neutrino less double beta decay measurements
In background free underground environments
(Gran Sasso, SNO, WIPP, ...)

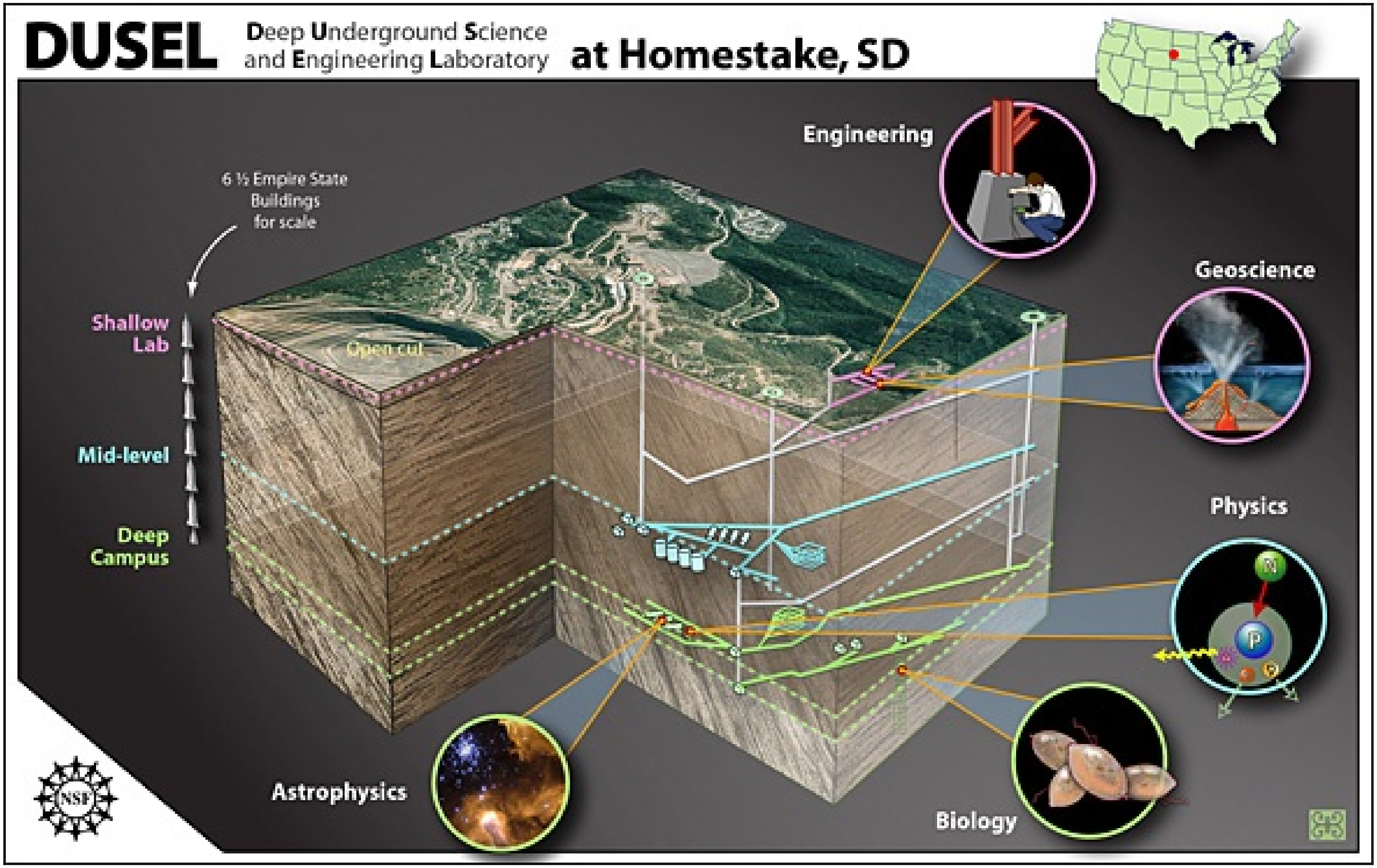
Violation of CP symmetry (matter anti-matter balance) by neutrino oscillation and neutron EDM measurements (ultra-cold neutrons at Los Alamos, SNS, PSI ...



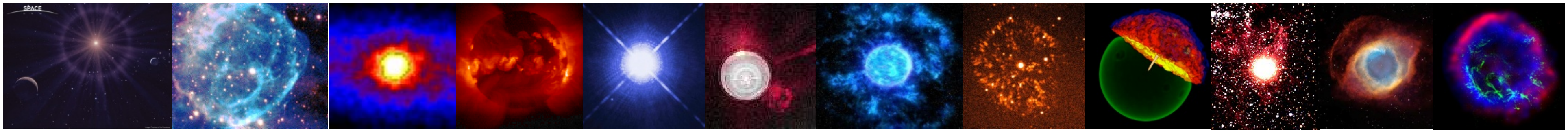




Neutrino Physics Underground



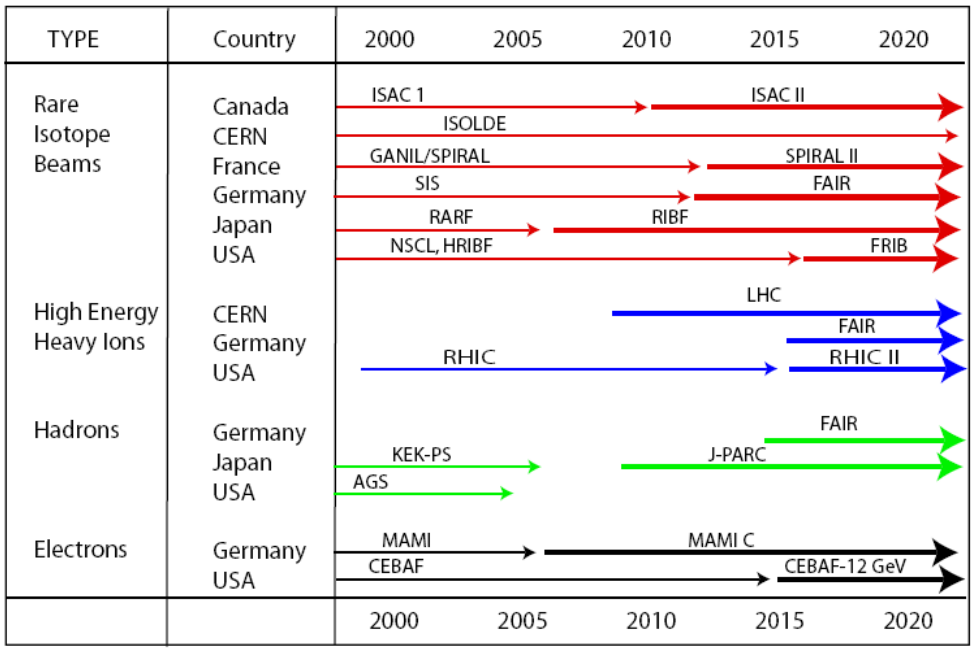
designed for experiments that require extremely low cosmogenic backgrounds: in particular, the search for neutrino-less double beta decay and relic dark matter.



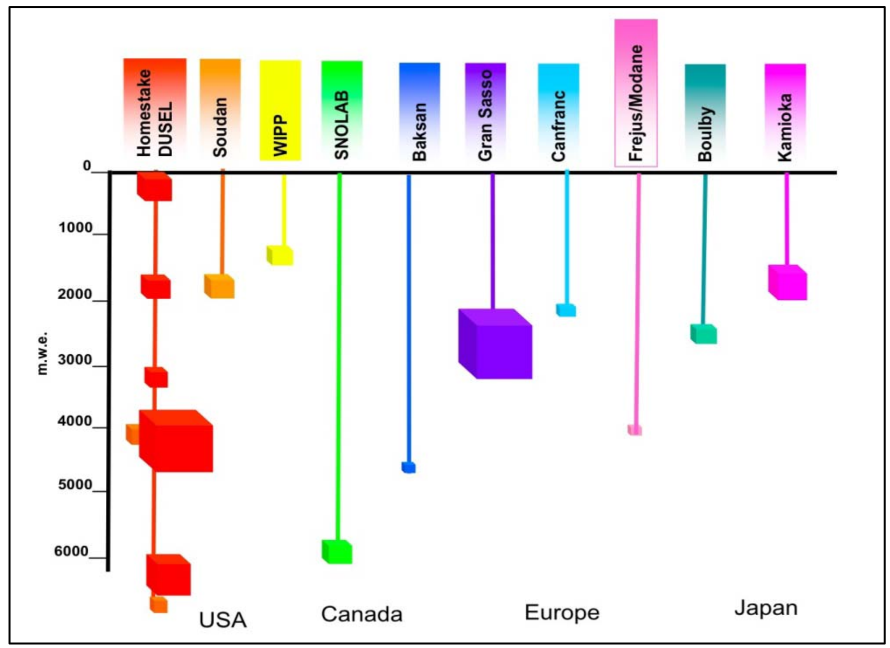
International Situation

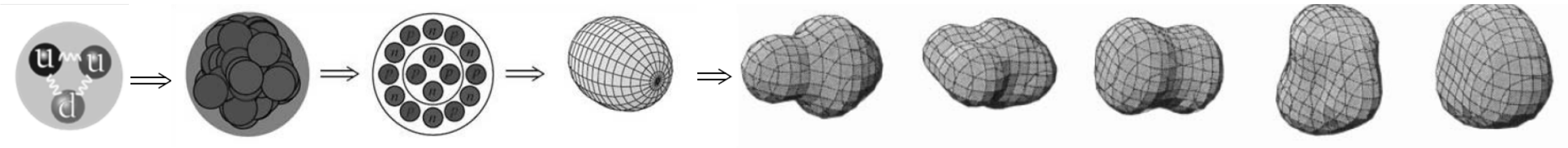
OECD Report: Roadmap for existing and planned underground laboratories with the size of the box corresponding to the relative space for experiments at each depth. These facilities are typically shared or primarily funded by other disciplines such as particle astrophysics.

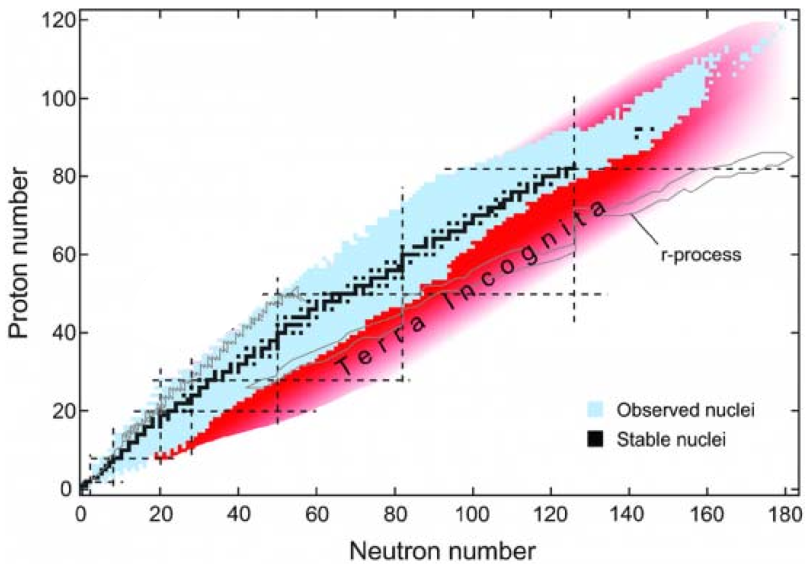
Accelerators



Underground Laboratories

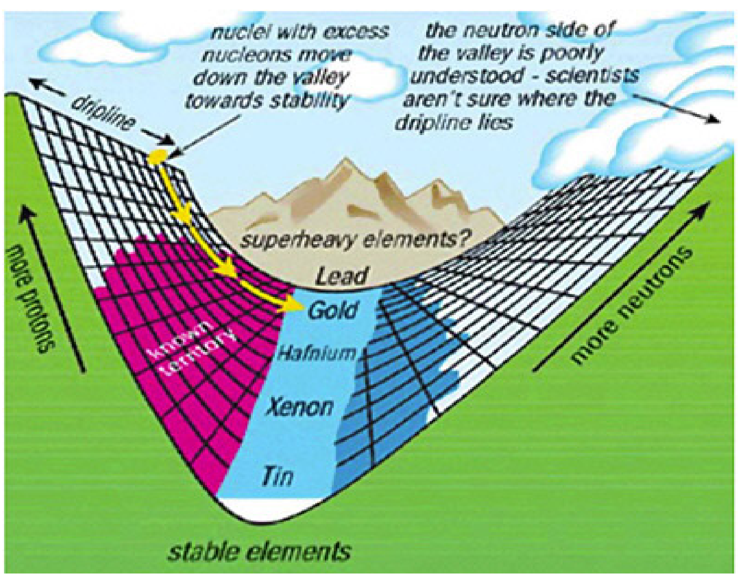


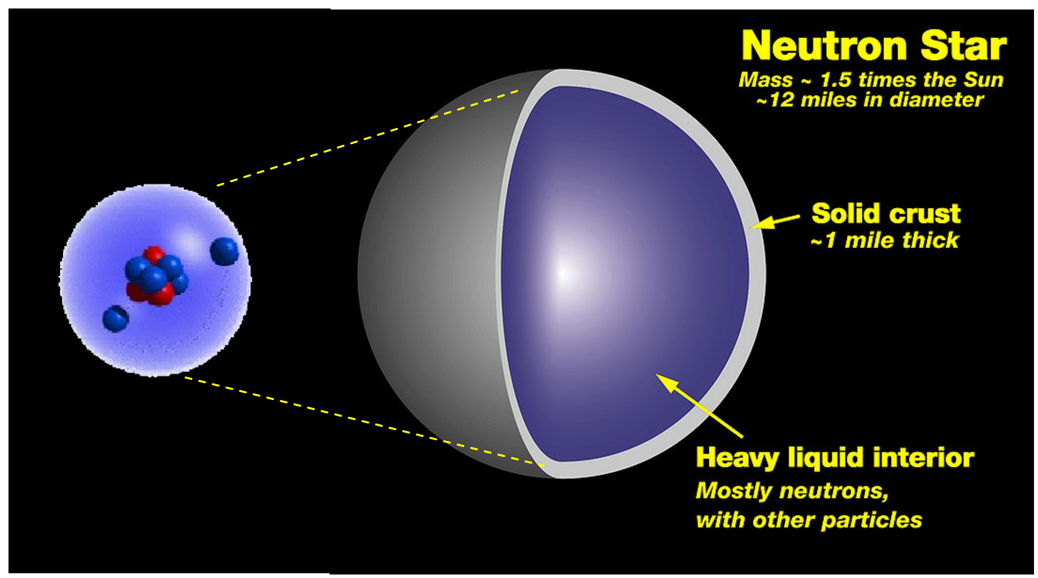




Goals far off Stability

- Nuclear Masses & decay properties
- Neutron halos
- Disappearance of shell structure
- Emergence of new shapes
- New collective modes of excitation
- Mapping the driplines
- Islands of stability





Science Opportunities

Order	Isotope	Use	Supplier	Status	Amount
1	**^{252}Cf (2.6 yr)**	Fission source for CARIBU at ANL	HFIR/ORNL	Possibly available in required form	~1 Ci/3yrs ~$0.5M/Ci
2	**^{225}Ra (15 d)**	EDM expt at ANL	ORNL; ^{233}U/^{229}Th decay	Needs to be extracted and processed	**~5 mCi/2 months** **Need 10mCi/2 mos.**
3	**Various actinides**	Targets for searches for super heavy elements	HFIR/ORNL	Some are available; ^{241}Am, ^{249}Bk, ^{254}Es not available	10 - 100 mg on a regular basis; purity is important
4	**^{28}Si**	Avogadro project - worldwide weight standard based on pure ^{28}Si crystal balls	DOE Russia	Concern about future supply and cost	kilograms
5	^{236}Np, ^{236,244}Pu, ^{243}Am, ^{229}Th	Isotope dilution mass spectrometers	ORNL; Russia?	Most available; high purity ^{236}Np is not	10 - 100 mg on a regular basis; purity is important
6	**^{76}Ge**	Double beta decay expt	Russia	US cannot produce quantity needed	**~ 1000 kg**
7	^{202,203,205}Pb, ^{206}Bi, ^{210}Po	Spikes for mass spectrometers	ORNL Russia	^{202,205}Pb difficult to get in high purity	Grams
8	**^{3}He**	Neutron detectors, EDM, etc	Savannah River Russia	Total demand exceeds that available	
9	**^{147}Pm**	Radioisotope micropower	Not available	Fission product	

Chapter 5: Security and other applications

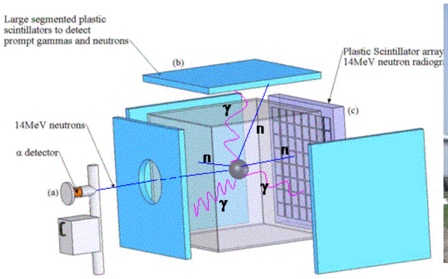
- Detection (^3He…)
- Forensics
- Standards

Nuclear Forensics

Trafficking of nuclear materials & material loss assessments

Border control & radiation exposure (instrumentation)

Provenance of radioactive material by isotope composition or material structure analysis



- Signature identification,
- Detector array development
- Sensitivity analysis

Recommendations for Charge 1

Compelling Research Opportunities Using Isotopes

There are compelling research opportunities using alpha-emitters in medicine. Development and testing of therapies using alpha emitters are very promising for the medical field. NSACI is aware of the research opportunities and the timeliness of the issue since the downbleeding of ^{233}U.

1.Invest in new production approaches of alpha-emitters, ex: ^{225}Ac. Extraction of the thorium parent from ^{233}U is an interim solution that needs to be seriously considered for the short term until other production capacity can become available.

Recommendations for Charge 1

Compelling Research Opportunities Using Isotopes

A unified conclusion of the NSACI panel was to maximize the production and availability of domestic isotopes in the US through investments in research and coordination activities between existing accelerators. The panel felt that such a network could benefit all areas of basic research and applications from security to industry.

2. We recommend investment in coordination of production capabilities and supporting research to facilitate networking among existing accelerators.

This should include R&D to standardize efficient production target technology and chemistry procedures.

Recommendations for Charge 1

Compelling Research Opportunities Using Isotopes

The basic physical sciences and engineering group prioritized the availability of californium, radium and other trans-uranic isotopes as particularly important for research.

3. We recommend the creation of a plan and investment in production to meet these research needs for heavy elements.

Recommendations for Charge 1

Compelling Research Opportunities Using Isotopes

Experts in the nuclear security and applications areas strongly feel the vulnerability of supply from foreign sources. Additionally, the projected demand for ^{3}He by national security agencies far outstrips the supply. This would likely endanger supply for many other areas of basic research. While it is beyond our charge, it would be prudent for DOE and DHS to seriously consider alternative materials or technologies for their neutron detectors to prepare if substantial increases in ^{3}He production capacity cannot be realized.

4. We recommend a focused study and R&D to address new or increased production of ^{3}He

Recommendations for Charge 1

Compelling Research Opportunities Using Isotopes

While no single stable isotope except ^{28}Si (^{3}He is stable but obtained from the beta-decay of ^{3}H, not by isotope separation) reached the level of the highest research priority, the broad needs for a wide range of stable isotopes and the prospect of no domestic supply raised this issue in priority for the subcommittee. NSACI feels that the unavailability of a domestic supply poses a danger to national security. The subcommittee also recommends:

5. Research and Development should be addressed to preparing to re-establish a domestic source of stable research isotopes.

Recommendations for Charge 1

Compelling Research Opportunities Using Isotopes

Vital to the success of all scientific endeavors is the availability of trained workforce. While the scientific opportunities have expanded far beyond the disciplines of radiochemistry and nuclear chemistry, the availability of trained personnel remains critical to the success of research in all frontiers of basic science, homeland security, medicine, and industry.

6. We therefore recommend that a robust investment be made into the education and training of personnel with expertise to develop new methods in the production, purification and use of stable and radio-active isotopes.

Skilled workforce in areas of National Need