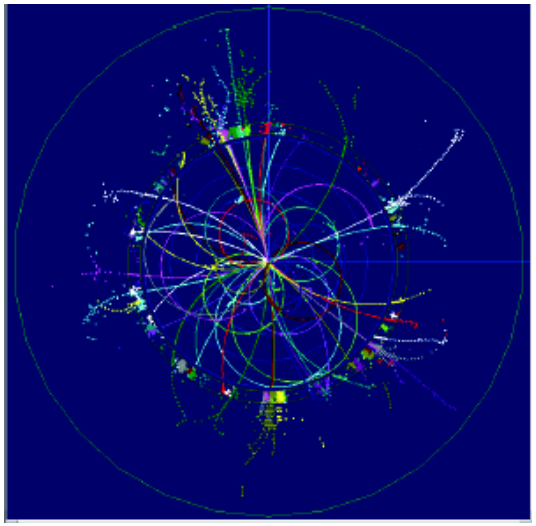
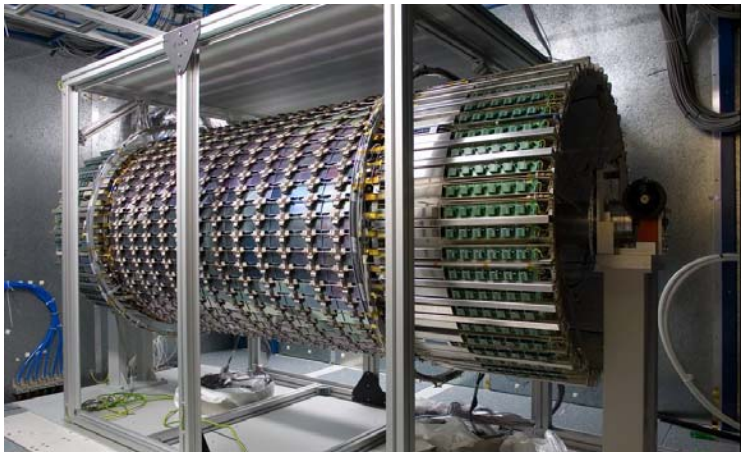
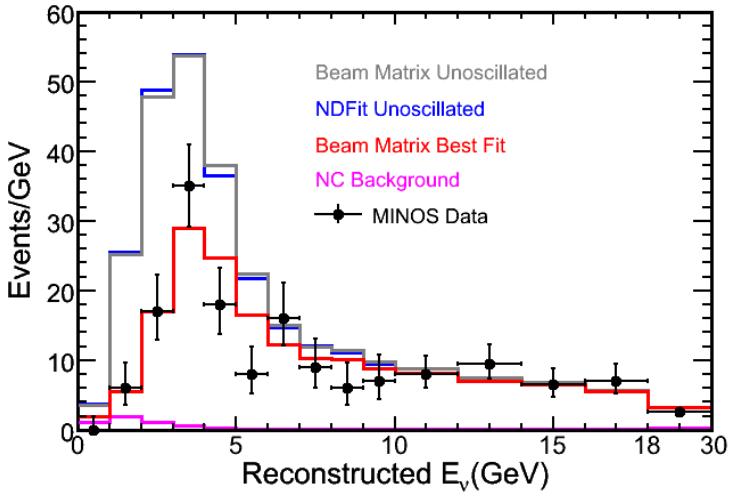
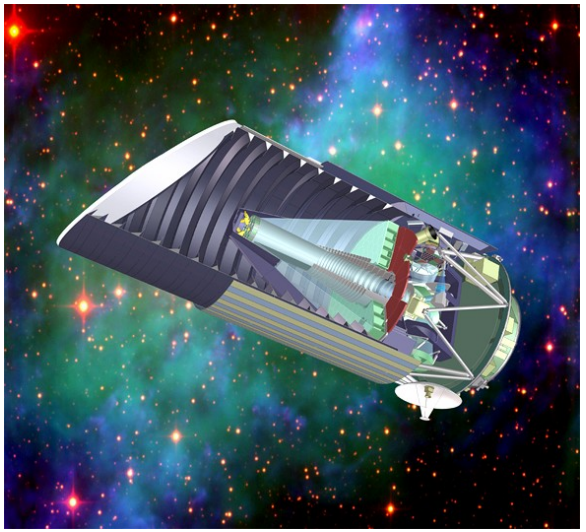
# P5 Status Report 2007: The Particle Physics Roadmap







# P5 Members

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# Status Report to HEPAP

- Includes a recapitulation of the science questions that led to the 2006 Roadmap. However, won't repeat the extensive science discussion in the 2006 Roadmap document.
- Status report on projects recommended for construction in 2006 Roadmap.
- Status report on projects recommended for significant R&D, leading eventually to construction, subject to budget constraints, evolution of the science, technical progress, and interagency or international agreements.
- Recommendations in three areas where we have new developments since the 2006 Roadmap. These are meant for HEPAP to consider for endorsement.
- We note that the DPF has recommended that P5 present a yearly progress report to HEPAP. This is meant to comply with this request. This status report is based on a two day meeting at Fermilab on September 24 and 25.

# Agenda: Meeting Sept. 24 and 25, 2007

**Monday, September 24:**

| | |
|---|---|
| **9:00 – 9:30** | **Pier Oddone, Tevatron and Fermilab Planning** |
| **9:30 – 10:15** | **D0 Presentation, Tevatron Running Past FY09** |
| **10:15 – 11:00** | **CDF Presentation, Tevatron Running Past FY09** |
| **1:30 – 2:00** | **Pier Oddone, Longterm Planning** |
| **2:00 – 3:00** | **Y.Y. Kim, Steering Committee Report** |
| **3:00 – 3:45** | **John Corlett, Accelerator Advisory Committee** |
| **4:15 – 5:00** | **Mike Witherell, Beyond Einstein NRC Report** |
| **5:00 – 5:30** | **Glen Crawford, Budget Projections** |

**Tuesday, September 25:**

| | |
|---|---|
| **8:30 – 9:15** | **Barry Barish, Report from GDE** |
| **9:15 - 9:45** | **Jon Kotcher, DUSEL Status** |
| **9:45 – 10:15** | **Jim Whitmore, Dark Matter Program** |
| **10:15 – 10:45** | **Giorgio Gratta, EXO Status Report** |
| **11:00 – 11:30** | **Jim Whitmore, Base Grant Status at NSF** |
| **11:30 – 12:00** | **P.K. Williams, University Base Grants and Projects** |

# 2006 Roadmap: Science Questions

- The question of mass:
  How do elementary particles acquire their mass?
  How is the electroweak symmetry broken?
  Does the Higgs boson – postulated within the Standard Model – exist?
- The question of undiscovered principles of nature:
  Are there new quantum dimensions corresponding to Supersymmetry?
  Are there hidden additional dimensions of space and time?
  Are there new forces of nature?
- The question of the dark universe:
  What is the dark matter in the universe?
  What is the nature of dark energy?
- The question of unification:
  Is there a universal interaction from which all known fundamental forces, including gravity, can be derived?
- The question of flavor:
  Why are there three families of matter?
  Why are the neutrino masses so small?
  What is the origin of CP violation?

# 2006 Roadmap: Science Opportunities

We have grouped the major science opportunities into five categories:

1) The energy frontier projects: LHC-ILC.
2) A program to study Dark Matter. This is complementary to the work in astrophysics.
3) A program to study the nature of Dark Energy. This is collaborative with the work in astrophysics.
4) A number of projects in neutrino science.
5) Precision measurements involving charged leptons or quarks.

# Recap. of Budget Assumptions

To arrive at a roadmap we need to make assumptions about budgets. In the case of the DOE, a five year funding profile in the document called "Office of Science 5-year Budget Plan: FY2007-FY2011" submitted by the DOE to Congress in early March of 2006 as part of the FY07 budget submission gave us a concrete budget plan to work with. The numbers in this plan were as follows (called our base budget plan):

| FY07 | FY08 | FY09 | FY10 | FY11 |
|---|---|---|---|---|
| $775M | $785M | $810M | $890M | $975M |

We've also assumed the completion of PEPII running in FY08 and the Tevatron running in FY09 for purposes of planning. These assumptions are the fiscal basis of our roadmap.

An alternative budget we looked at assumes a 7% annual increase, resulting in a doubling of the HEP budget over 10 years. The numbers in such a plan were:

| | | | | |
|---|---|---|---|---|
| $775M | $829M | $877M | $950M | $1016M |

These numbers are about $50 M/ per year larger than the base budget plan.

We used these numbers to examine what might be possible in a plan that doubles funding over a 10 year period, as might be appropriate for a renewed emphasis on the physical sciences and their importance to the country's economic health. Will refer to this later.

# Recommended Construction or R&D within the Base Budget Plan (in Priority Order)

1. The highest priority group involves the investigations at the energy frontier. These are the full range of activities for the LHC program and the R&D for the ILC.
2. The second group includes the near-term program in dark matter and dark energy, as well as measurement of the third neutrino-mixing angle. This grouping includes the three small experiments: DES, the 25 kg CDMS experiment, and the Daya Bay reactor experiment. Also in this group is the support for the LSST and SNAP, to bring these to the "Preliminary Design Review Stage" in the case of the NSF and "CD2 Stage" in the case of the DOE over a two to three year time frame. We recommend that the DOE work with NASA to ensure that a dark energy space mission can be carried out and that the three potential approaches to the mission have been properly evaluated. The final item in this group is the R&D funding for DUSEL, along with support by the NSF and the DOE for R&D for both a large dark matter and neutrino-less double beta decay experiment.
3. The next item is the construction of the NO$\nu$A experiment at Fermilab along with a program of modest machine improvements.

# Recap. of Recommendations for Reviews

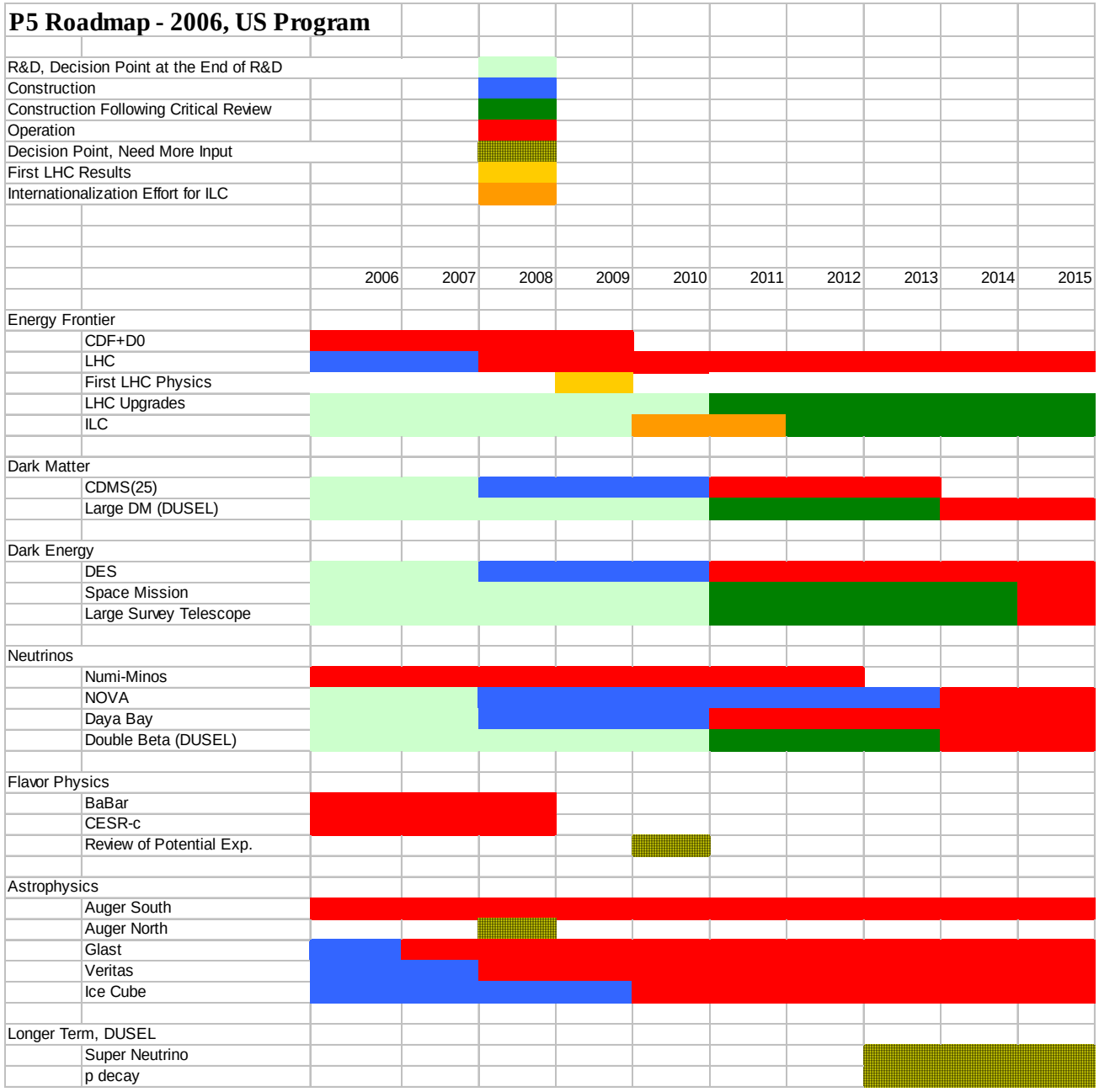
We recommend a review by P5 toward the end of this decade to look at projects that could start construction early in the next decade. The base budget plan would allow a significant number of these to move forward to construction. The review should take into account new physics results, especially those from the LHC, results on R&D for new projects, budget and cost projections at the time, and the status of interagency agreements and MREFC plans. We list some of the areas to be examined.

1. The ILC, including a possible U.S. bid to host, and the steps needed at the governmental level for internationalization.
2. The LHC Upgrades, required for an order of magnitude luminosity increase at the LHC.
3. DUSEL and the large experiments to search for dark matter and neutrino-less double beta decay.
4. The Stage IV dark energy experiments, a large survey telescope and a dark energy space mission. Interagency agreements are crucial to these projects, which could start construction soon after review.
5. An evaluation of the status of flavor physics and the importance of further experiments across a number of possibilities such as the muon g-2, μ to e conversion, a very high luminosity B experiment, and rare K decays.

# Recap. of Recommendations for Reviews

We anticipate that a separate review by P5 will be required to look at the best directions for further experiments in neutrino physics. Much work is ongoing internationally in this area with an optimum program dependent on measurements to be made by the next generation of neutrino experiments as well as results from ongoing R&D. A second important physics area that might be included in this review would be an ambitious proton decay experiment. These two projects could be the major second phase of experiments for DUSEL. The physics results over the next five to ten years will determine the best date and best set of areas to look at in such a review.

# P5 Roadmap - 2006, US Program



# Progress Report: Construction

Of the projects recommended for construction, the DES, Daya Bay, and NO$\nu$A experiments are all moving ahead. Work on developing the experimental equipment is progressing, as are the various international aspects. All three projects have had their CD-1 reviews in 2007. NO$\nu$A has successfully completed the CD-2 process and the other two experiments expect to have their CD-2 reviews within the next few months. Significant data collection for these experiments can be expected to start in the FY2011 to 2012 timeframe.

# Progress Report: Dark Matter

Significant progress is being made on a broad dark matter search program that simultaneously explores many techniques. The CDMS experiment continues to collect data in the Soudan mine. The 25kg SuperCDMS, an upgrade of the present experiment, would consist of seven supertowers of cryogenic detectors. There is now an agreement to move ahead with 2 of the 7 super-towers needed for the experiment. Noble gas experiments are building larger detectors and also presenting interesting results from prototype detectors. These experiments are now exploring a very interesting regime of cross-sections sensitive to models of Supersymmetry. The direct search for axions is continuing and the GLAST satellite will soon be launched and will further the search for signals of dark matter annihilation.

# Progress Report: Double Beta Decay

Another category of projects that have to be placed underground, besides the direct dark matter detection experiments, are neutrino-less double beta decay experiments. This summer the Enriched Xenon Observatory (EXO) installed a 200 kg chamber, associated clean rooms and cryogenics underground in WIPP. Still to be installed in 2008 is the TPC detector and other elements of the detection system. It is important that EXO be funded to complete their detector and start a physics run for the next few years, initiating this promising approach. The science team will simultaneously continue their R&D on Barium tagging, required to make more sensitive measurements with a larger volume of Xenon.

# Potential Longer-Term Projects

The ILC Engineering Design remains on track with an expected completion date of 2010. A Research Director for the ILC detector program, S. Yamada, has recently been chosen. A call for Letters of Intent by groups wishing to prepare detailed designs for detectors by 2010/2011 has been issued.

R&D for the LHC Luminosity Upgrade is moving ahead internationally. A construction plan is likely in the 2011 – 2012 timeframe, with extra support for developing this plan coming from the European Union. A detailed plan for the U.S. contributions, discussed in our 2006 Roadmap, is needed on the same time-scale.

# Potential Longer-Term Projects

Planning for DUSEL is moving ahead on schedule with the Homestake mine chosen as the site. A possible start date is 2011, but this is dependent on a number of factors, among them the NSF MREFC process. An early small-scale experimental program can be launched in FY2009, given special funding from the state of South Dakota and private sources.

JDEM (Joint Dark Energy Mission, a DOE-NASA partnership) has been recommended for NASA priority by an NRC committee, which will hopefully clear the way for rapid progress on this project. It could start construction in the 2009-2010 timeframe but will require a selection of the final concept for the mission (more on this later).

LSST has just completed its NSF Conceptual Design Review and has been recommended to proceed to a Preliminary Design Review next. LSST is likely to be recommended by the NSF to be advanced to the Readiness Stage by Spring 08. Considerable work has been done by the project to find additional resources, both from international science funding agencies and private foundations.

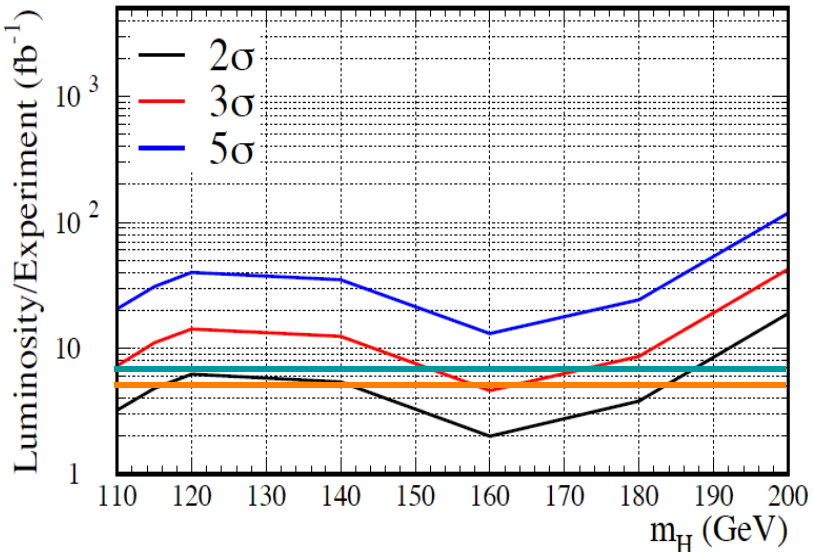
# Issues Arising since the 2006 Roadmap

We provide recommendations on three topics that have arisen since the Roadmap. The first concerns the criteria that might lead to additional Tevatron running beyond FY09. The budget on which the 2006 Roadmap is based assumes that the funding from the shutdown of the Tevatron will be used for new projects, therefore additional running has budget implications. However, the potential for discovery at the Tevatron remains high and we therefore need to balance this against the need to move on to urgent new discovery physics in a number of areas. The second topic concerns JDEM where an NRC committee (the Beyond Einstein Assessment Committee) has recently made a recommendation that JDEM be the first priority for a construction project in the Beyond Einstein NASA program area. The last topic concerns the University program. A HEPAP subpanel (the University Grants Program Subpanel) made recommendations regarding the University program that were accepted by HEPAP in the summer of 2007. We need to include these recommendations into our P5 budget planning for the field.

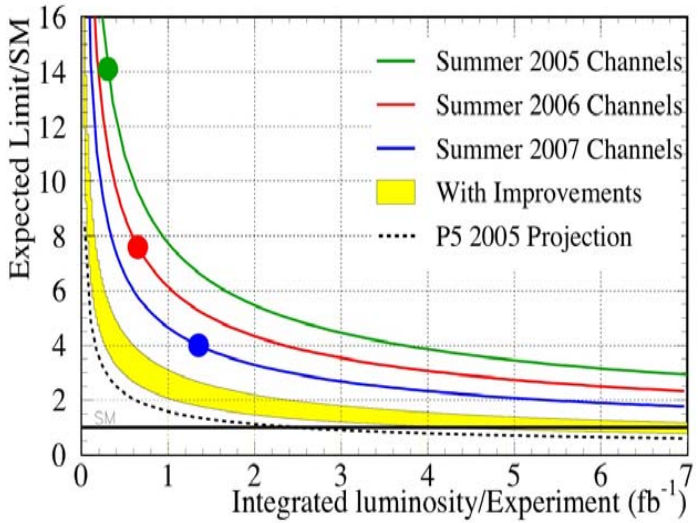
# Tevatron Running in FY2010

The Tevatron continues to be the leading accelerator collecting data at the Energy Frontier. This motivated our recommendation that the Tevatron continue running in 2009. At our meeting at Fermilab in September, we discussed the criteria for extending the Tevatron running beyond 2009. In this case an additional element in the discussion was the impact of additional data when a large amount of data had already been collected at the Tevatron. The experiments indicated that they had made significant improvements in triggering and analysis and that this trend would continue. This would give significant added value to additional data collected. The added data could be expected to allow further progress on the search for the Higgs boson, extending information over a larger mass range in the case of the simplest Higgs scenario, and providing further limits, or discovery, in the case of other models such as Supersymmetry.

# Tevatron Projections




**Projected Tevatron Higgs mass reach. Bottom (orange) line: 5.5 fb-1; top (green) line 7.0 fb-1. Three curves show best estimate of luminosity required for exclusion at 2, 3, or 5 standard deviations as a function of Higgs mass**




**Expected 95% Confidence Limit on the Higgs production cross-section, in units of the SM cross-section, as a function of integrated luminosity for a Higgs mass of 115 GeV. The expectation is shown using the 2005, 2006, and 2007 analysis techniques. The yellow band shows the expectation using further improvements that are foreseen. The dashed line shows the expectation including all hoped-for improvements as presented to our committee in 2005.**

# Tevatron Running in 2010

Many of the improvements to the new physics searches would be best demonstrated in the Fall of 2008 after additional analysis has been completed on a larger data set. We therefore recommend that the option of continued running past 2009 be held open as a possibility and that the Fermilab management work with DOE on the implications of additional running. We recommend that funding for any additional running not come at the expense of the two highest priority areas on the Roadmap (the LHC program and ILC R&D, the program in Dark Matter and Dark Energy research, and the Daya Bay neutrino experiment) and that Fermilab in about a year carefully evaluate both the physics potential and manpower situation, which is likely very dependent on the LHC schedule, before requesting a final decision.

# Joint Particle Physics - Astrophysics Science

For over two decades the DOE and the NSF have fostered research at the intersection of particle physics, astrophysics, and cosmology. The results from particle physics have often been complementary to the information resulting from astrophysical observations, as in the case of the present direct dark matter detection program, but some of the effort is also collaborative between these fields. This is particularly the case for research that has to be done using either large telescopes or in space. In the case of the DOE this research area has been supported through a very small fraction of the HEP program budget. These DOE and NSF programs have produced very important physics, as exemplified by the sharing of the 2006 Nobel Prize in Physics by George Smoot, whose work on a NASA mission (COBE) was supported by the DOE.

# Joint Particle Physics – Astrophysics Science

The NASA-DOE Joint Dark Energy Mission (JDEM) is an important part of our Roadmap. It has recently been recommended to NASA as the number one priority for a construction start around FY09 by a National Research Council committee that was tasked to choose the top priority mission from a number of potential space missions in the NASA "Beyond Einstein Program." This selection demonstrates the importance of JDEM to the Astrophysics community and removes one of the major elements of uncertainty in moving ahead with JDEM.

# Joint Particle Physics – Astrophysics Science

JDEM will be a very large step in scale for DOE investment at the intersection of particle physics, astrophysics and cosmology, since the cost to DOE could be comparable to that of a major accelerator and detector construction project (for example the B factory and BaBar at SLAC). The science is very compelling and we recommend that the DOE try to secure the larger of the budget projections that we looked at while formulating our Roadmap. We quote from our FY06 Roadmap regarding this budget: "The budget that would double support over a decade would have a very significant science impact by allowing added support for the Stage IV dark energy experiments." Given the NRC Panel recommendation, the chance for such a major impact appears to be at hand if the additional funding can be secured. We recommend that the DOE continue to work intensively with NASA toward an early realization of JDEM.

# University Base Grants

The University Grants Program Subpanel has provided a comprehensive evaluation of the status of the university program and its critical role for the future of the field. They note the much greater diversity than in the past of the science program and its associated experimental techniques, as is in fact evident from our Roadmap. The university community will need to strongly participate in innovation for the field and in creating novel science opportunities for this scientific program to prosper. Given the importance of international participation in this program, costs for travel are expected to continue to increase. These elements are being recognized internationally. As an example Germany has recently instituted a new program involving 17 universities and two laboratories to better exploit the LHC and ILC opportunities at the energy frontier. This program is funded at a level of about 5 million euros per year for five years.

# University Base Grants

More broadly, we note that the field's contributions to the training of scientific personnel for the long term economic health of our country lie foremost with the universities and are based on participation in the major science opportunities available. The importance of increasing such contributions has been given special recognition in major policy documents such as the Augustine report and the EPP2010 report and form a major part of the case made to the U.S. Congress for increased funding for research in the physical sciences. We quote from the EPP2010 report "*The success and vitality of the scientific enterprise depend on a distinctive set of institutional arrangements for training new scientists. The committee views the current role of university-based students, postdoctoral researchers, and faculty as a critical component of the particle physics enterprise that strengthens national capabilities in both education and science.*"

# University Base Grants: NSF

The Experimental Particle Physics (EPP) and Particle and Nuclear Astrophysics (PNA) portfolios of the NSF continue to be impressively diverse and cover most of the key science areas of our field. Most of these projects are carried out in a successful collaboration with the DOE. Many are small and therefore have not explicitly appeared in our P5 Roadmap, which includes only larger projects.

The NSF is continuing on a trajectory to double funding over a ten-year period. We quote from the House Appropriations committee regarding this year's NSF budget proposal: "*This level of funding will support the doubling of the NSF budget in 10 years as part of a long-term, sustained commitment to investment in basic research and development, which provides the foundation for innovation and future technologies.*" Combined with the NSF's strong commitment to base grants, these sentiments bode well for our communities continued contributions to science and society.

# Recommendations on University Base Grants

In this regard the situation at DOE HEP gives cause for concern. Despite annual increases in the HEP budget, the university grants program remains essentially flat. As a result immediate needs related to the LHC (especially student travel) as well as the longer-term goals outlined for the field are under unreasonable pressure.

Given the evolution of the field and its science agenda we recommend that the DOE work toward an increase in base grants by an amount of at least 9%, as is consistent with the University Grants Subpanel recommendations. This should be among the highest priorities for the field. We hope that such an increase in investment can be the initial part of a sustained commitment to investment in basic research and development through the DOE supported university base grants program, which like the NSF program provides a significant foundation for innovation and future technologies.

# Recommendation for Next Broad Review

Our original Roadmap did not consider such university issues. A concrete funding plan should now be made. We therefore recommend that P5 look at a possible phasing and make specific recommendations early next year regarding the increase in base grant support. At that time it will be appropriate to also evaluate new ideas from Fermilab regarding a high intensity proton machine (called Project X) and also a plan for future activities being generated at SLAC, in order to understand how these can be harmonized with the Roadmap plan. We anticipate that next year updated profiles for the new construction projects DES, Daya Bay, and NOνA should be available, as well as further plans for JDEM. These should all go into a new evaluation given funding projections.