# Office of High Energy Physics

## *Report to the Board of Physics and Astronomy*

***April 24, 2009***

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**Office of Science, U.S. Department of Energy**

# DOE Office of Science (SC)
# Office of High Energy Physics (OHEP)

**High Energy Physics attempts to understand how our universe works at its most fundamental level by:**

- discovering the most elementary constituents of matter and energy
- probing the interactions between them,
- exploring the basic nature of space and time itself.

**DOE SC OHEP Program is the U.S. Federal Steward of HEP research**

- **providing over 90 % of federal support to**
  - design, construct and operate the research facilities needed to advance our knowledge
  - support the researchers at universities and laboratories to carry out the research
  - develop the advanced technologies and next generation scientific/technical workforce

**The Scientific community identifies the scientific opportunities and their priorities**

- **defines the scientific field and future direction**
  - DOE/NSF chartered High Energy Physics Advisory Panel (HEPAP) Reports
  - Other scientific reports (National Academy, AAAC, OECD GSF, etc.)
  - Facility PACs, DOE Reviews, etc.

**OHEP Mission is to maintain the Nation's competency/leadership in HEP research**

- **with responsibilities to**
  - establish a strategic plan that address the identified scientific opportunities
  - formulate, justify and defend Budget Requests to implement that plan
  - effectively manage the funding obtained to deliver significant outcomes

# Overview

# The U.S. HEP Program
# Some Perspective

- **Historically the U.S. has been the leader in HEP research**
  - Most major discoveries (many recognized by Nobel Prizes) were made in the U.S.
  - Made possible by a continuous implementation of forefront accelerator facilities

- **At beginning of this decade the U.S. HEP program remained the leader**
  - The Fermilab Tevatron was the Energy Frontier facility
  - The SLAC B-Factory was an Intensity Frontier facility
  - U.S. HEP physicists were playing important roles at the Cosmic Frontier

- **The U.S. HEP program's long range strategy was**
  - To participate at CERN Large Hadron Collider (LHC) when it became the Energy Frontier program
  - To start construction of a next-generation lepton collider soon after the time LHC came into operations

- **Over the decade DOE OHEP started to implement this strategy**
  - Resources went into LHC program (accelerator & detectors) to allow US participation
  - The number of U.S. HEP accelerator user facilities were reduced to one (Fermilab Tevatron/NuMi)
  - Ramped up funding for R&D to position the U.S. to host the International Linear Collider (ILC)

- **Then the estimated cost of ILC increased and planned start of construction slipped**

# DOE SC HEP
# Report last year

- **Current circumstances for the U.S. program are challenging !**
  - **Reductions in FY 2008 DOE HEP funding (-8.4 %) resulted in loss of**
    - HEP's scientific productivity and workforce
    - Momentum on planned activities (NOvA, SRF infrastructure, ILC R&D)
    - U.S. credibility as an interagency/international collaborator (BaBar, ILC)
  - **No realistic strategic plan that has dealt with**
    - the increase in cost and the delay in possible start of an ILC
    - energy frontier moving to Europe in FY 2009
    - closure of B-Factory and imminent closure of Tevatron
    - Fermilab's role in the future
  - **Competition for federal funding is fierce**
    - HEP is not a priority of the Administration or Congress
    - HEP funding has eroded over the last decade
    - "Why does the U.S. have to be a leader in HEP (particle physics)?

# DOE SC HEP
# Report this year

- **Dealt with FY 2008 funding reduction**
  - Most serious impacts were mitigated
  - Protected core activities and delivered science
  - Supplemental funding at end of year – mitigated impact of 6-month Continuing Resolution

- **Developed (DOE/NSF with the scientific community) a new strategic plan for U.S. HEP**
  - Particle physics at three scientific frontiers
  - A U.S. role that will deliver significant outcomes
  - Realistic and robust with respect to funding scenarios and scientific discoveries

- **DOE HEP funding in FY 2009 supports the implementation of the plan**
  - FY 2009 Appropriation restores program to FY 2007 level
  - Recovery Act funding accelerates / enhances research / infrastructure projects

# DOE SC HEP Budget
# FY 2008 Program

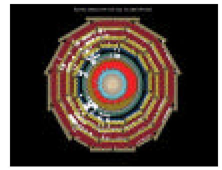
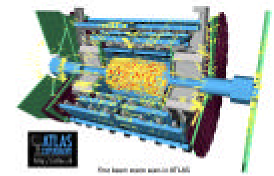
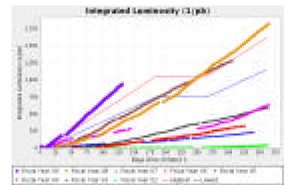
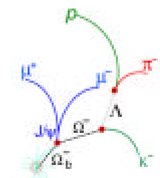
- **FY 2008 Appropriations ($689M → 8.4% reduction compared to FY 2007)**
  - **A productive program**
    - Tevatron ran well – CDF/D0, MINOS, MiniBooNE
    - B-Factory completed a successful four month run
    - LHC circulated beam and ATLAS/CMS ready for beam
    - FGTS (GLAST) launched and collecting data

    - Many projects underway: Minerva, T2K, Daya Bay, EXO, DES, CDMS
    - DOE/NASA/NSF planning for joint projects
  - **There were significant impacts**
    - Staff reductions at SLAC (76+100) and Fermilab (110)
    - B-Factory schedule was reduced from 10 months to 4 months
    - Work on NOvA stopped
    - ILC & SRF R&D supported at a minimal level
- **FY 2008 Supplemental**
  - $32M for HEP ($29.5M for Fermilab, $2.5M for SLAC)

# DOE SC HEP
# FY 2008 Science Highlights

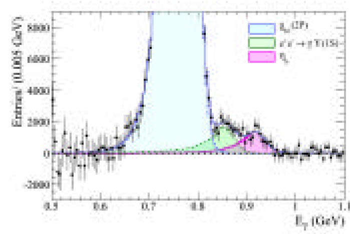
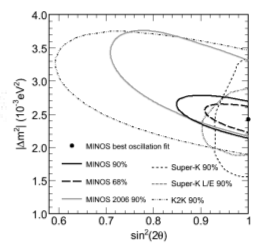
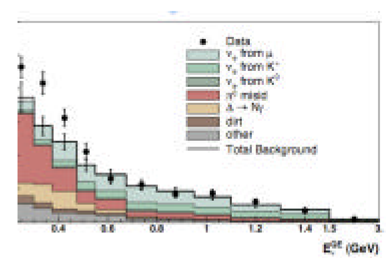
## Energy Frontier

- Operation of LHC
  (AIP Top Ten Story)
- Tevatron (Performance/Experimental Results)
  (AIP Top Ten Story)

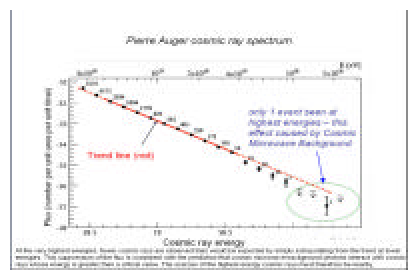
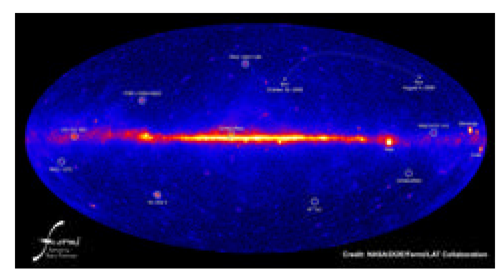
## Intensity Frontier

- BaBar discovery of bottomonium ground state
  (AIP Top Ten Story)
- Results from MiniBooNE and MINOS

## Cosmic Frontier

- Pierre Auger
  (AIP Top Ten Story)
- Fermi (GLAST)

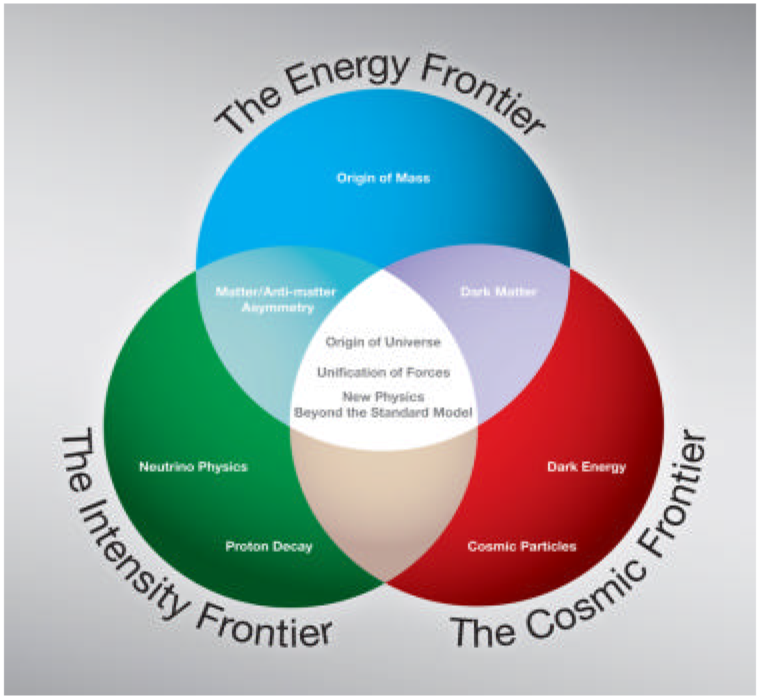



# HEPAP Report
# Guidance for a U.S. HEP Strategic Plan

- **HEPAP (Particle Physics Project Prioritization Panel (P5)) seriously addressed the charge given by DOE/NSF:**
  - to examine the scientific opportunities and options
  - for mounting a world class particle physics program
  - at different funding levels

- **Grappled with the issue of how to mount a world-class program that addresses the highest priority scientific opportunities identified with the funding available**

- **The result is a realistic vision whose priorities are consistent with the major findings that is robust and that should produce outcomes that justify the investment**




- **Lays out what the nation will get with different investments**
  - Scenario A (FY 2008 Approp + COL) – unable to mount productive, world-class programs at all three frontiers
  - Scenario B (FY 2007 Approp + COL) – productive programs at all three frontiers
  - Scenario C (FY 2007 ACI level) – leadership programs – partner in TeV-scale facility
  - Scenario D (additional above C) – the funding to host next TeV-scale facility

Report submitted 2 June 2008, www.science.doe.gov/hep/files/pdfs/P5_Report%2006022008.pdf

# HEPAP (P5) Report
# The Guidance

**Progress in achieving the goals of particle physics requires advancements at the**
- **Energy, Intensity and Cosmic Frontiers.**
- **Each provides a unique window for insight about the fundamental forces and particles of nature**
- **The U.S. should have a strong, integrated research program at all three frontiers**

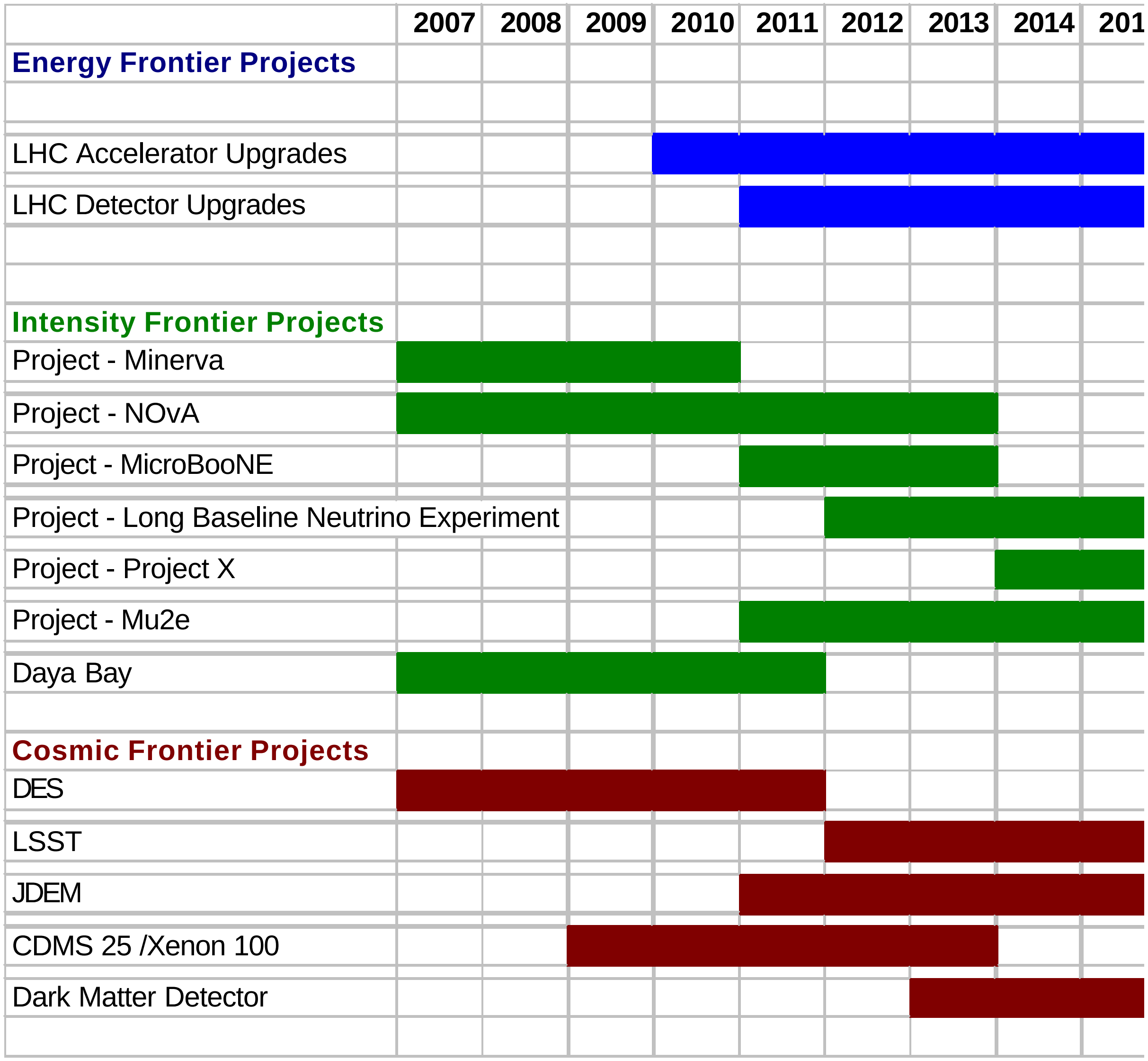
**Energy Frontier**
- Continued support for the Tevatron Collider program for next 1-2 years
- LHC program has the highest priority, including US involvement in planned upgrades
- Accelerator and detector R&D program for next generation lepton collider

**Intensity Frontier**
- Recommends a world class neutrino program as core component
- Long term vision includes a large detector at DUSEL and high-intensity neutrino source at Fermilab.
- Program of rare decays (e.g.: muon to electron conversion – Mu2e)

**Cosmic Frontier with an emphasis on dark energy and matter**
- Joint Dark Energy Mission (JDEM) in collaboration with NASA
- Large Synoptic Survey Telescope (LSST) in collaboration with NSF
- Direct dark matter search experiments

**HEP at its core is an accelerator based experimental science.**
- Support accelerator R&D to develop technologies
    - that are needed by the field
    - The benefit the nation

# It is a Plan that will deliver significant science




**<u>Position U.S. with capabilities to:</u>**

**To be major player in discoveries at LHC**

**Important neutrino-nucleus cross sections**

**Important information on neutrino parameters**

**LAr expertise for next generation detector**

**CP and proton decay discoveries**

**Needed to nail CP measurement**

**Important rare decay measurement**

**Measurement of q13**

**Stage III Dark Energy Measurement**

**Stage IV Dark Energy measurement**

**Stage IV space-based DE measurement**

**Intermediate Dark Matter Experiments**

**Large Volume Dark Matter Experiment**

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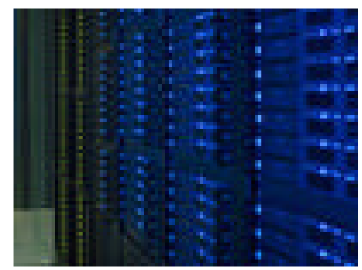
# A Plan that will deliver new technologies for the Nation

**The accelerator and detector technologies developed for high energy physics research in the past have had important impacts on the Nation's economy, security, and society. (See** http://www.science.doe.gov/hep/benefits/index.shtml **)**

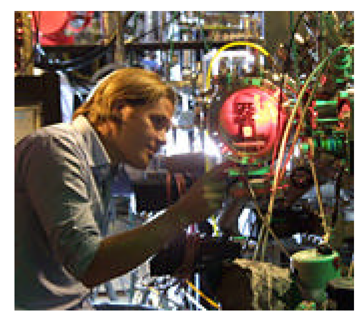
- Medicine: Accelerators and detector technologies first developed for particle physics are now used throughout the nation to treat and diagnose patients
- Homeland security Similarly, detector technologies have found uses in cargo scanning and monitoring of nuclear waste and proliferation
- Computing: To record and analyze the unprecedented volumes of data generated in particle collisions, particle physicists have developed cutting-edge computing technologies, including the www and grid strategies
- Sciences: Many of the tools developed for particle physics have led to important scientific innovations, such as the synchrotron light source, that benefit other areas of science.



**Looking to the future**

- OHEP's ongoing and future development of accelerator, detector, electronics and magnet technologies is anticipated to continue to have significant impact in medical treatment and diagnosis, homeland and national security, industry, the internet grid, and other scientific fields.

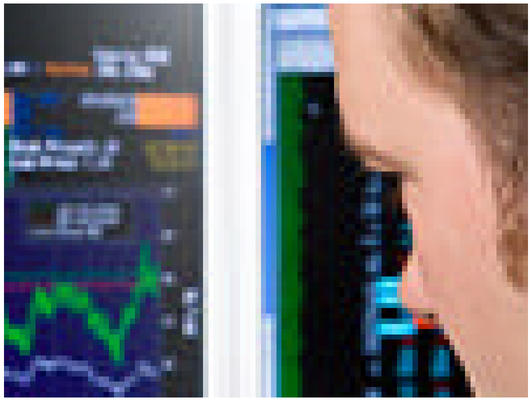
- OHEP will be sponsoring an Accelerator R&D Workshop in 2009 to make a more direct connection between fundamental accelerator technology and applications and obtain guidance on the needs of federal programs and the private sector



U.S. DEPARTMENT OF ENERGY

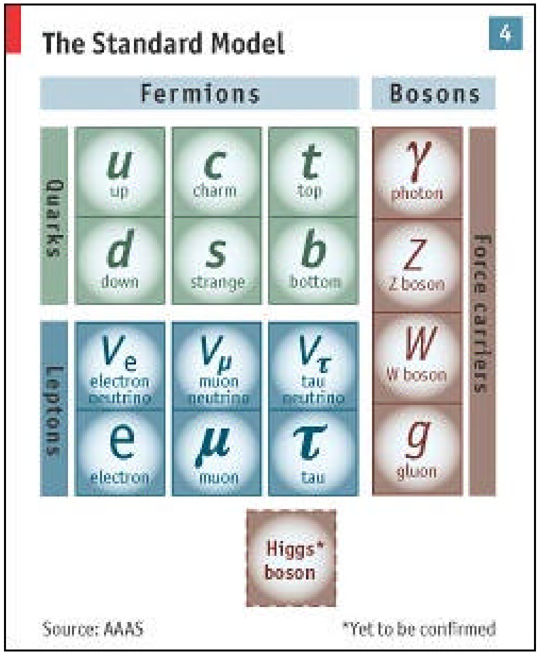
# A Plan that will deliver scientists to the Nation's Workforce

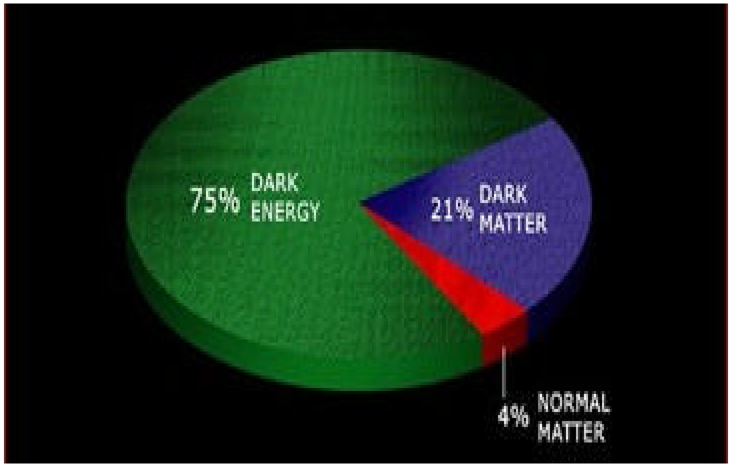
- **An important benefit to the Nation provided by the OHEP program is the recruitment and training of a highly motivated, highly trained scientific and technical work force.**
  - About 80% of those completing doctoral degrees in particle physics or accelerator science ultimately pursue careers in outside high energy physics research: i.e.;
    - industry, national defense, information technology, medical instrumentation, electronics, communications, biophysics, etc.
  - These scientists are highly valued in employment where the workforce requires
    - highly developed analytical and technical skills,
    - the ability to work in large teams on complex projects
    - the ability to think creatively to solve unique problems



# Particle Physics Today in an exciting period

- **Studies over the last decade and recent discoveries have revealed the Standard Model of particle physics to be highly successful, but incomplete -- the model**
  - Does not predict all the properties of the known particles
  - Fails at extremely high energies
  - Describes only a small fraction of the matter and energy filling the universe
- **The field is on the verge of significant discoveries and probably paradigm changes but needs critical experimental results and observations!**
  - The Standard Model **will** break at ***O***(1 TeV)…but how?
  - Measuring the small neutrino mixing angle will determine how rich this sector is: can we see CP Violation in leptons?
  - Dark matter just "around the corner" of direct detection?
  - The elephant in the room: Dark Energy. What is it?
- **However, additional results will be needed**
  - Requires results from all three scientific frontiers
  - Requires significant resources
    - International / interagency
    - Coordination / collaboration



# U.S. HEP program at a crossroad

**U.S. has not made investments in onshore HEP research capabilities**

- Number of U.S. accelerator user facilities has been reduced to one
- Investments have not implemented a sustainable U.S. program
  - Major investment over last decade has been offshore (LHC)
  - Proposed onshore initiatives have not materialized (BTeV, ILC,….)

**Foreign nations have made (are planning to make) investments in HEP research capabilities**

| | | |
|---|---|---|
| Europe | → CERN/LHC (Phase I &II) | Energy Frontier |
| Japan | → J-PARC / S- BELLE | neutrinos /rare decay/ $e^+$-$e^-$ collider |
| China | → BES-II / Daya Bay | electron beams / neutrinos |
| Italy | → (Super-B) | $e^+$-$e^-$ collider |

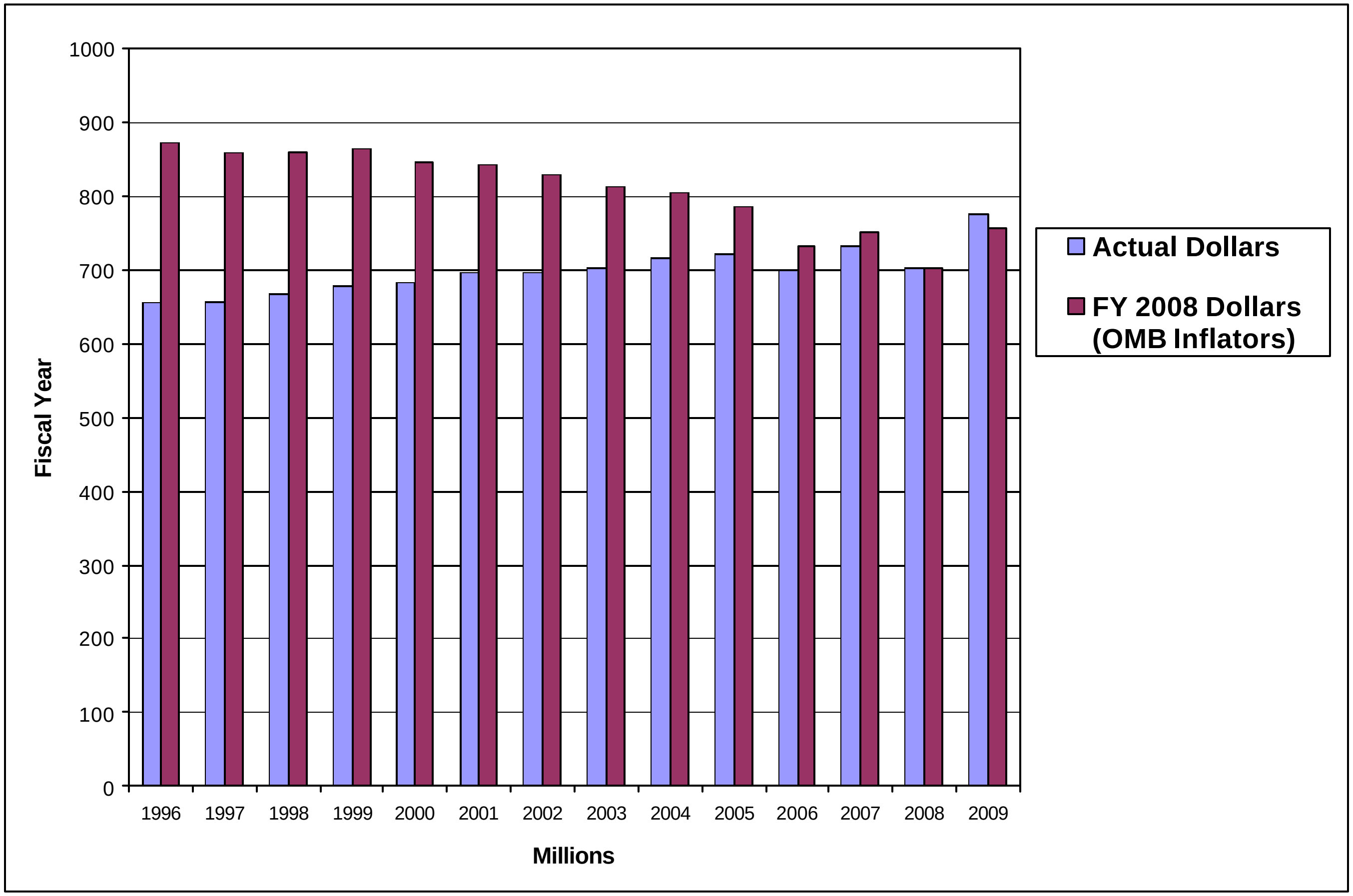
**If the U.S. wants to remain among the leaders investments need to be made**

- **A realistic strategic plan has been developed that will position the U.S. to play a leadership role**
  - Develop research infrastructure in the U.S. that produces outstanding science and a technology foundation
  - Provides a role for U.S. scientists in campaigns at all three scientific frontiers
  - Positions the U.S. for a productive, sustainable program in the future
- **Leadership in HEP is important to the Nation**
  - Delivers new knowledge/discoveries about the world we live in - that have significant impact on other scientific fields
  - Attracts and trains a next generation of scientists for the Nation's scientific workforce
  - Develops advanced technologies that are important for the Nation's security and competitiveness

# FY 2009 funding is (hopefully) a reversal of recent DOE HEP funding trend

- **HEP funding has been eroded by inflation: FY 2008 / FY 1996 ~ 20 % (OMB COL)**
- **HEP FY 2008 funding was a -8.4 % reduction from FY 2007 (mitigated by supplement of $32M)**

- **HEP FY 2009 funding is +10 % compared to FY 2008 and above Cost-of-Living (COL) from FY 2007**
- **HEP to receive >$200 million in Recovery Act funding**

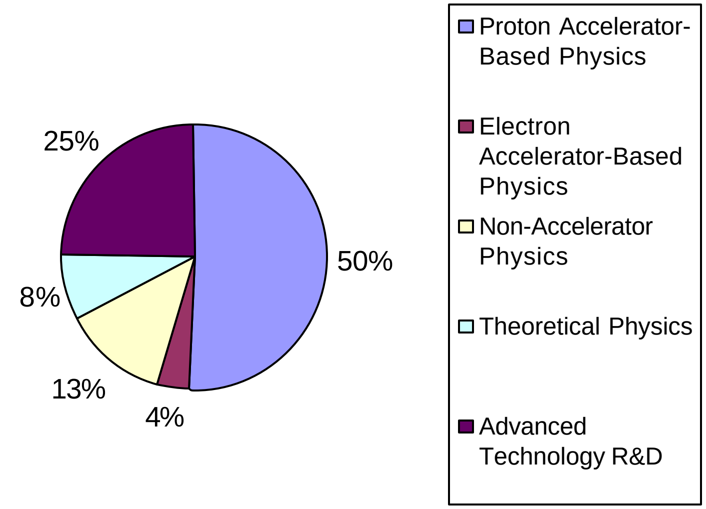


# FY 2009 Program

# U.S. DOE HEP Program Overview

## FIVE Subprograms

| Budget Categories | (millions) FY 2009 |
| --- | --- |
| Proton Accelerator-Based Physics | 402.5 |
| Electron Accelerator-Based Physics | 31.0 |
| Non-Accelerator Physics | 100.9 |
| Theoretical Physics | 64.8 |
| Advanced Technology R&D | 196.6 |
| High Energy Physics Total | 795.7 |




| Research Statistics | FY 2009 estimate |
| --- | --- |
| # University Grants | 200 |
| # Laboratory Groups | 45 |
| # Permanent Ph.D.'s (FTEs) | 1,135 |
| # Postdoctoral Associates (FTEs) | 550 |
| # Graduate Students (FTEs) | 595 |
| # Ph.D.'s awarded | 110 |

# HEP
# Budget Overview

| HEP Budget Categories | FY 2007 | FY 2008 | vs FY08 | FY 2009 | vs FY08 | vs FY07 |
|---|---|---|---|---|---|---|
| Proton Accelerator-Based Research | 110.0 | 122.9 | 2.9 | 125.7 | 2.3% | 14.3% |
| Proton Accelerator-Based Facilities | 233.6 | 248.8 | 27.9 | 276.7 | 11.2% | 18.5% |
| **Proton Accelerator-Based Physics** | **343.6** | **371.7** | 30.8 | **402.5** | 8.3% | 17.1% |
| Electron Accelerator-Based Research | 22.3 | 20.7 | -4.2 | 16.5 | -20.3% | -26.0% |
| Electron Accelerator-Based Facilities | 79.0 | 36.5 | -22.0 | 14.5 | -60.3% | -81.7% |
| **Electron Accelerator-Based Physics** | **101.3** | **57.2** | -26.2 | **31.0** | -45.8% | -69.4% |
| **Non-Accelerator Physics** | **60.7** | **75.8** | 25.1 | **100.9** | 33.1% | 66.3% |
| **Theoretical Physics** | **59.1** | **60.0** | 4.8 | **64.8** | 7.9% | 9.6% |
| Accel Science | 37.4 | 45.1 | 8.1 | 53.2 | 18.1% | 42.2% |
| Accelerator Development | 98.6 | 70.2 | 28.3 | 98.5 | 40.4% | 0.0% |
| Detector Development | 31.7 | 22.9 | 1.6 | 24.5 | 6.8% | -22.9% |
| **Advanced Technology R&D** | **167.7** | **138.1** | 38.1 | **176.2** | 27.5% | 5.1% |
| SBIR/STTR (2.8% of ops) | 19.4 | 18.5 | 1.9 | 20.4 | 10.3% | 5.4% |
| **Advanced Technology R&D** | **187.1** | **156.6** | 40.0 | **196.6** | 25.5% | 5.1% |
| **High Energy Physics Total** | **751.8** | **721.3** | 74.4 | **795.7** | 10.3% | 5.8% |

# DOE SC HEP
# Budget Overview

| HEP Functional Categories | FY 2007 | FY 2008 | vs FY08 | FY 2009 | vs FY08 | vs FY07 |
|---|---|---|---|---|---|---|
| Fermilab Accelerator Complex Operations | 145.1 | 151.0 | 6.6 | 157.7 | 4.4% | 8.7% |
| LHC Detector Support/Operations | 56.8 | 65.6 | 6.4 | 71.9 | 9.7% | 26.6% |
| SLAC Accelerator Complex Operations | 79.0 | 36.5 | -22.0 | 14.5 | -60.3% | -81.7% |
| **Facility Operations** | **280.9** | **253.1** | -9.0 | **244.1** | -3.6% | -13.1% |
| | | | | | | |
| EPP Research | 249.1 | 264.5 | 19.7 | 284.2 | 7.5% | 14.1% |
| Advanced Technology R&D | 167.7 | 138.1 | 30.1 | 168.2 | 21.8% | 0.3% |
| **Core Research** | **416.8** | **402.6** | 49.8 | **452.4** | 12.4% | 8.5% |
| | | | | | | |
| Project - NOvA | 12.5 | 12.0 | 15.7 | 27.8 | | |
| Project - Minerva | 4.0 | 7.2 | -2.3 | 4.9 | | |
| Project - T2K | 0.6 | 2.5 | -1.5 | 1.0 | | |
| Daya Bay | 1.0 | 6.9 | 6.1 | 13.0 | | |
| LHC Detectors | 3.2 | 0.0 | 0.0 | 0.0 | | |
| LHC Accelerator Upgrade Phase I | 0.0 | 0.0 | 2.5 | 2.5 | | |
| DES | 1.4 | 5.5 | 3.2 | 8.7 | | |
| CDMS 25 MIE | 0.0 | 0.0 | 1.0 | 1.0 | | |
| FACET | 0.0 | 0.0 | 0.0 | 0.0 | | |
| BELLA | 0.0 | 0.0 | 8.0 | 8.0 | | |
| **Projects** | **22.6** | **34.1** | 32.7 | **66.9** | 96.0% | 195.5% |
| | | | | | | |
| **Other (GPP/GPE/SBIR/STTR)** | **31.5** | **31.5** | 0.9 | **32.4** | 2.7% | 2.9% |
| | | | | | | |
| **High Energy Physics** | **751.8** | **721.3** | 74.4 | **795.7** | 10.3% | 5.8% |

# Proton Accelerator Based Physics

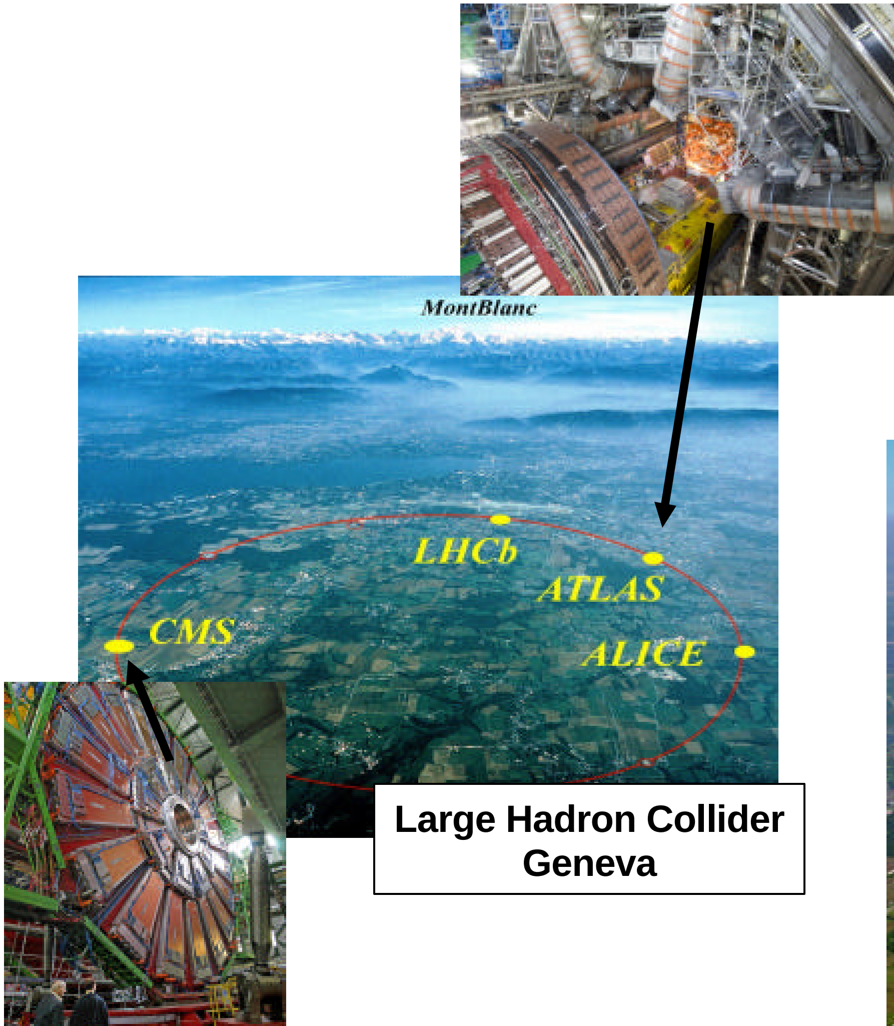
**The Proton Accelerator Based Physics subprogram support research / facility operations at the Energy and Intensity Frontiers that utilize / provide proton beams**

- **Research program supports:**
  - Groups at 75 universities and 5 national labs
  - Approximately 940 FTEs (= 700 university + 240 lab) at Energy Frontier (775) and Intensity Frontier (165)

- **Facility Operations supports:**
  - Fermilab Accelerator Complex Operations and Development
  - LHC Experimental Operations and Support (Phase I accelerator upgrade MIE)
  - Ongoing Facility Projects (Minerva and NOvA)
  - Future Projects R&D (MicroBooNE, Mu2e, LBNE, Project X)

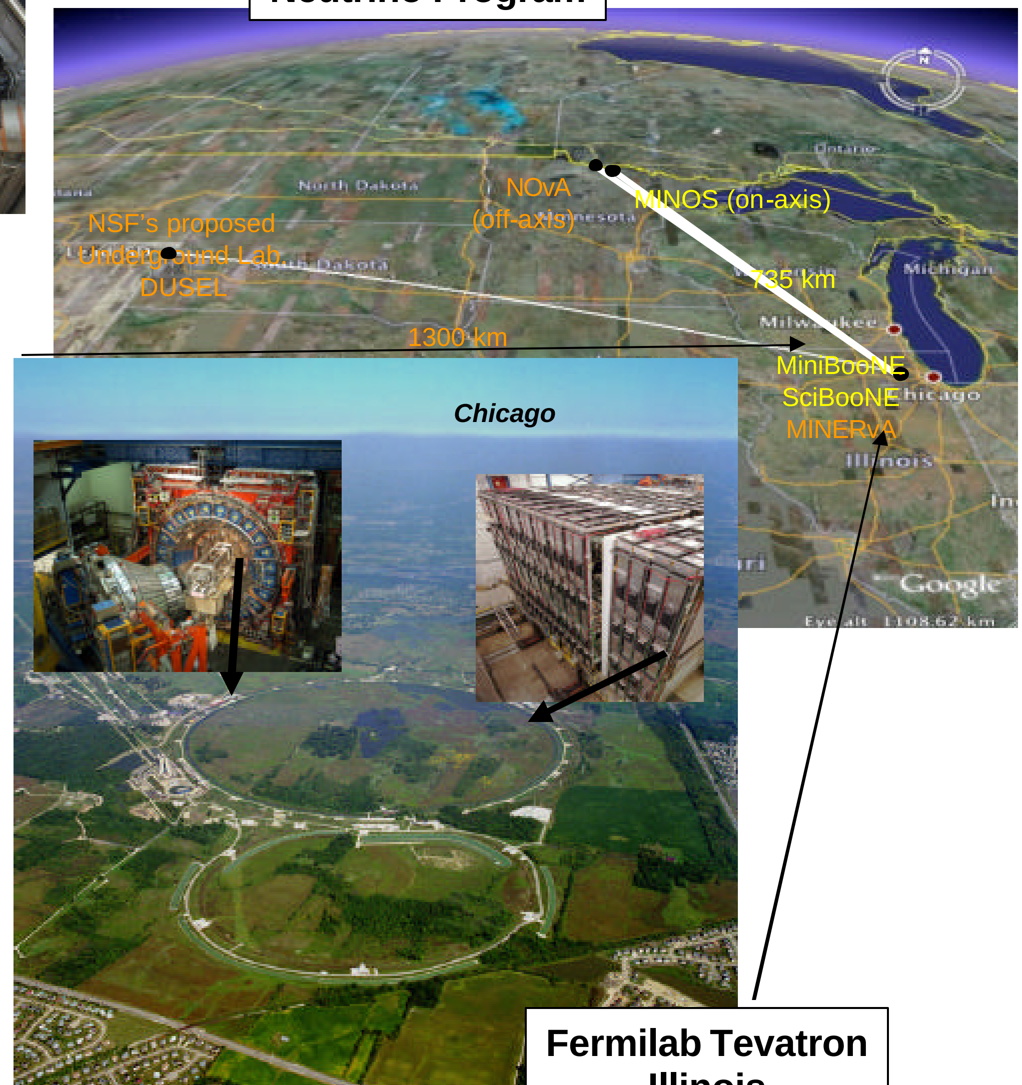
- **Priorities:**
  - Discover evidence of physics beyond the Standard Model at Tevatron (D0/CDF) and/or LHC (ATLAS/CMS)
  - Improve knowledge about neutrino properties (Minerva, MINOS and NOvA)
  - Implement capabilities to measure CP violation and proton decay (LBNE)
    - positions US with infrastructure to regain Energy Frontier (muon collider)

# Proton Facilities




Large Hadron Collider
Geneva

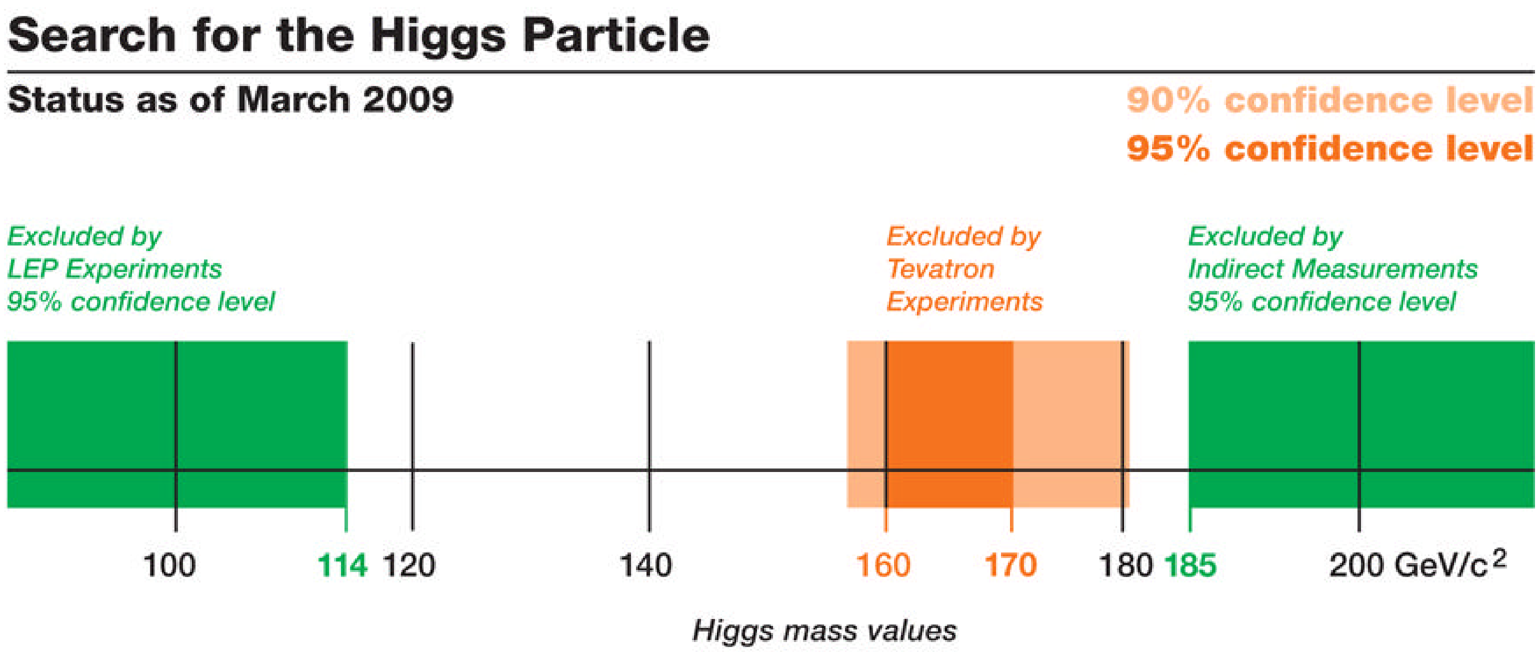
Neutrino Program



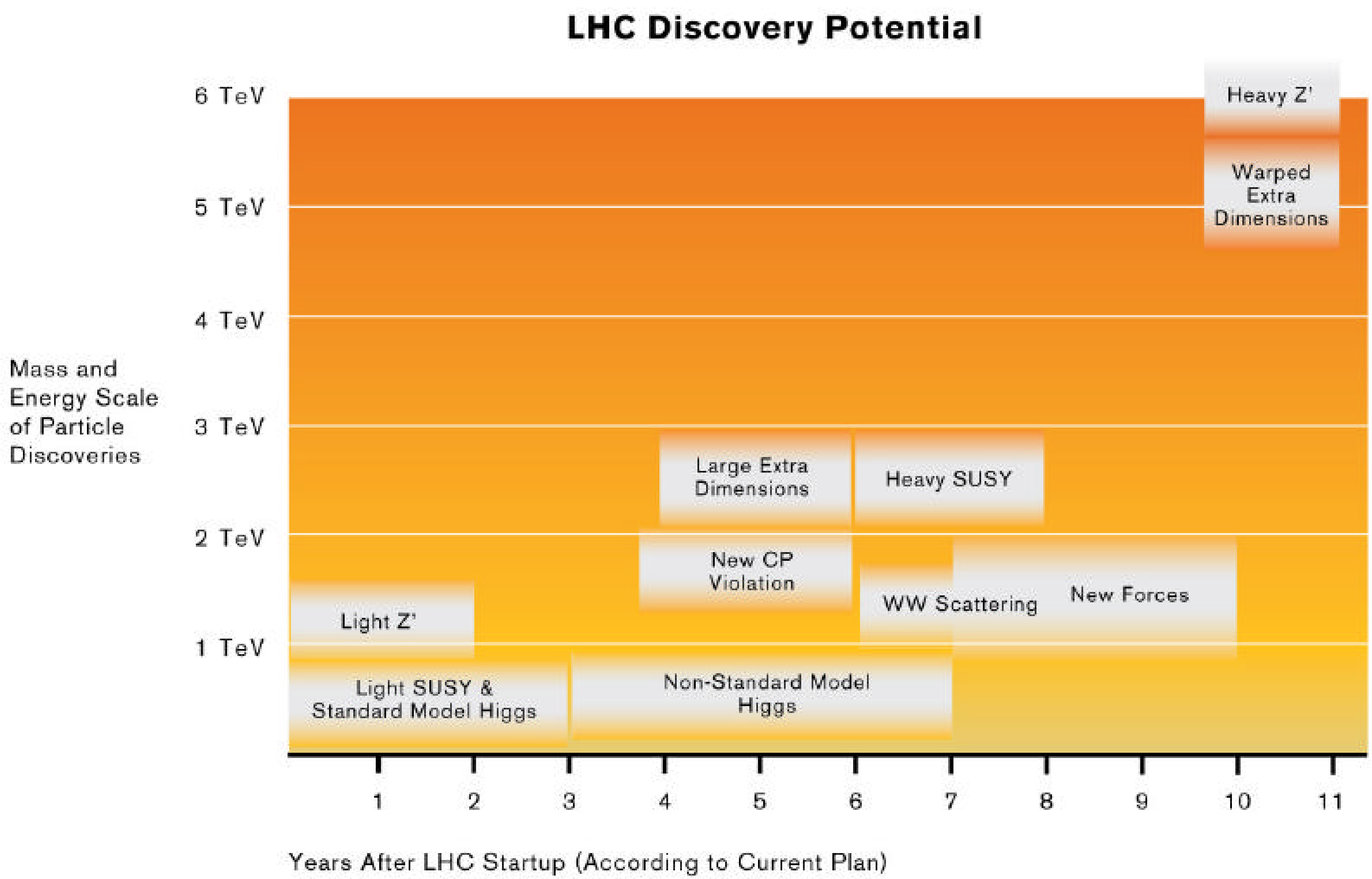

Fermilab Tevatron
Illinois

# Energy Frontier
# The Tevatron Opportunity

- Entering unexplored territory: First direct limits on Higgs Boson since 2000 (LEP2)
- As more data is collected, either the exclusion region will expand or first hints of the Higgs boson will appear
- Real competition with LHC for first Higgs observation
- Many new results: resonances, W mass, single-top, Higgs constraints



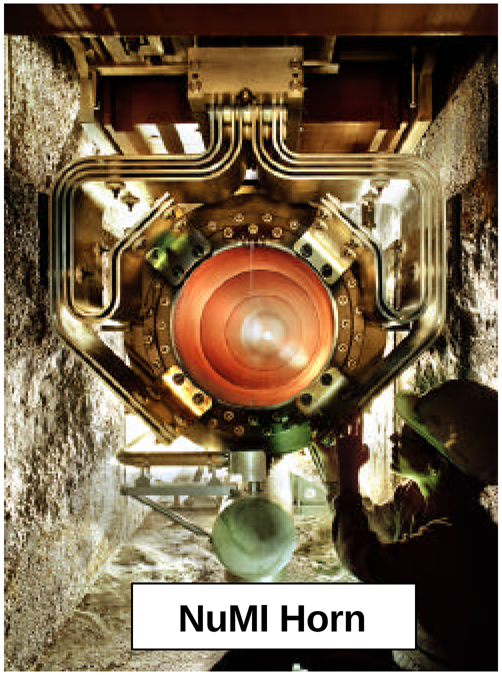
# Near term Energy Frontier Campaign is rich in potential discoveries



# Intensity Frontier
# Neutrino Physics

- **Goals for the next phases of the experimental program in neutrino oscillations:**
  - The mixing angles
  - The ordering of the neutrino mass states.
  - The extent of CP violation in neutrino sector.

- **There is worldwide effort to address these questions**




**DOE Program:**

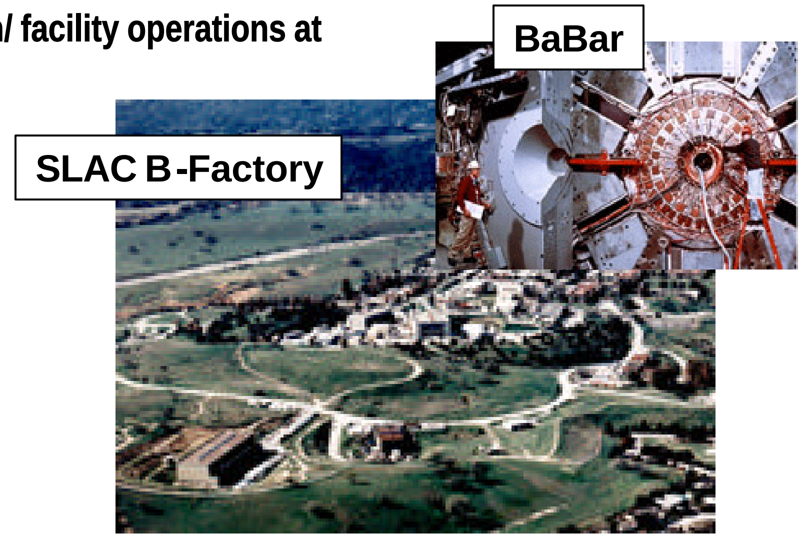
- **Fermilab: Accelerator-based Neutrino Oscillations**
  - Running: MiniBooNe, Minos
  - Under construction: Minerva, Nova
  - In planning stages: Long Baseline Neutrino Exp. (LBNE)
  - Supported by a series of phased beam upgrades

- **Elsewhere:**
  - Daya Bay Reactor Neutrino Detector (China) - reactor neutrino oscillation
  - Double Chooz (France) - reactor neutrino oscillation
  - Tokai-to-Kamioka (T2K/Japan) - accelerator neutrino oscillation
  - Enriched Xenon experiment (EXO/U.S.) - double beta decay

# Intensity Frontier
# Fermilab Neutrino Program

# Electron Accelerator Based Physics

**The Electron Accelerator Based Physics subprogram support research/ facility operations at the Intensity Frontier that utilize / provide electron beams**




- **Research program supports:**
  - Groups at 34 universities and 3 national labs
  - Approximately 105 FTEs (= 75 university + 30 lab), focused on Intensity Frontier

- **Facility Operations supports:**
  - Computing infrastructure to complete analysis of BaBAR data
  - Decommissioning and Decontamination (D&D) of the BaBAR and PEP II ring

- **Priorities:**
  - Discover evidence of physics beyond the Standard Model in the BaBAR data
  - Complete D&D of BaBAR and PEP II in a timely and cost-effective manner
  - If Italians pursue "SuperB" project – the transfer of PEP II components to SuperB will
    - Save D&D costs for US DOE HEP programs
    - Science opportunity with ~100 greater intensity than B-Factory

# Non-Accelerator Physics

**The Non Accelerator Physics subprogram support research/ facility operations for measurements of radiation or particles from non particle accelerator sources (e.g.; reactors, naturally occurring (beta decay, proton decay), and astrophysical phenomena)**

- **Research program supports:**
  - Groups at 35 universities and 5 national labs
  - Approximately 300 FTEs (= 180 university + 120 lab) at Cosmic (200) and Intensity (100) Frontiers
  - Operations of ongoing experiments (SSDS, Veritas, Auger, BOSS, LUX, EXO, etc.)
  - Ongoing Projects (DES, and Daya Bay) and future projects R&D (JDEM, LSST, dark matter, DBD)

- **Priorities:**
  - To obtain insight into nature of Dark Energy from Stage III & planned Stage IV Dark Energy searches
  - To measure "small" neutrino mixing angle ($T_{13}$) in the Daya Bay Reactor Experiment
  - To push the sensitivity of direct Dark Matter measurements by a factor 1000
  - To gather support for an international effort for a proton decay measurement as part of LBNE

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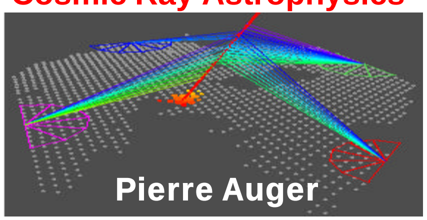
# Cosmic Frontier Projects

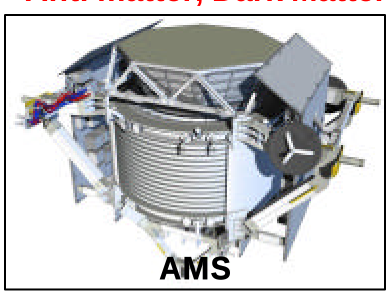
**Gamma-ray Astrophysics**



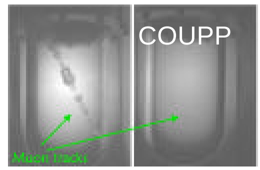
**Cosmic Ray Astrophysics**

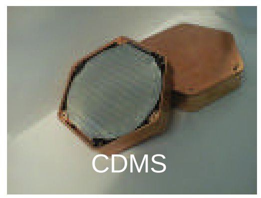



**Anti-matter, Dark Matter**



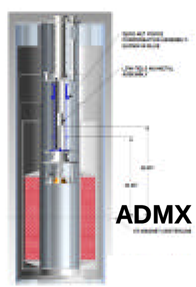

**Dark Matter (WIMPs)**



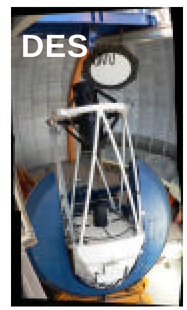




LUX

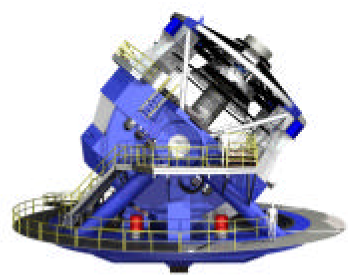
**Dark Matter (axions)**



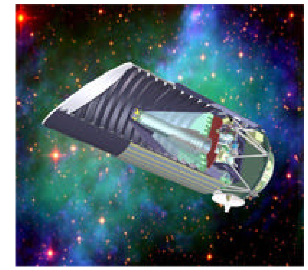

**Dark Energy (ground-based)**


**LSST - proposed**



**Dark Energy (space-based)**



**JDEM - proposed**

# Theoretical Physics

**The Theoretical Physics subprogram provides the vision and mathematical framework for understanding and extending the knowledge of particles, forces, space-time, and the universe.**

- **Research program supports:**
  - Groups at 70 universities and 6 national labs
  - Approximately 550 FTEs (= 440 university + 110 lab), across all three Frontiers
  - Computational physics (SciDAC, LQCD, etc.) are supported by this subprogram
  - Stewardship and education/outreach activities (Particle Data Group, QuarkNet, etc.)

- **Priorities:**
  - Support Tevatron and LHC experiments: improve calculations of background events, interpret data, suggest useful measurements for testing new ideas/models.
    - In particular, increase support for graduate students
  - Implement the planned upgrade of computer capabilities for the PDG
  - Improve precision of lattice computations with dedicated hardware and software

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# Advanced Technology R&D

**The Advanced Technology R&D subprogram fosters world-leading research in the physics of particle beams, accelerator research and development, and particle detection - all necessary for continued progress in high energy physics.**

- **Research program supports:**
  - Groups at ~75 universities and 5 laboratories
  - Approximately 610 FTEs (160 at universities and 450 at laboratories), supports all three Frontiers
  - Accelerator science at universities and laboratories
    - Fundamental physics of beams
    - High-risk, high reward future concepts: muon accelerators, plasma-based accelerators
  - Accelerator development at laboratories
    - Technology: superconducting magnets, radiofrequency systems, instrumentation, beam dynamics
    - Superconducting radio frequency (SRF) infrastructure for the next generation of accelerators
    - International Linear Collider R&D
  - Detector development at universities and laboratories

- **Priorities:**
  - Develop the theoretical and technological basis to improve the operation of current accelerators and detectors
  - Explore concepts for future energy and intensity frontier accelerators, and detectors for all HEP applications
  - Build the infrastructure for development of future SRF-based accelerators
  - Complete R&D for the ILC on a timely basis in cooperation with international community.
  - Provide stewardship on the national level for accelerator R&D.

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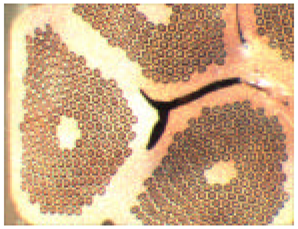
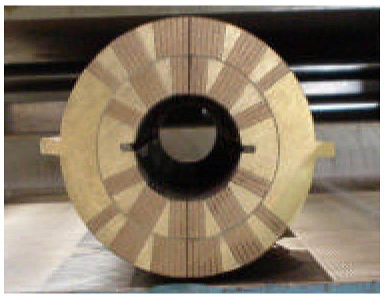
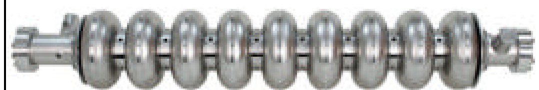
# Advanced Technology

## Superconducting Cable & High Field Magnets

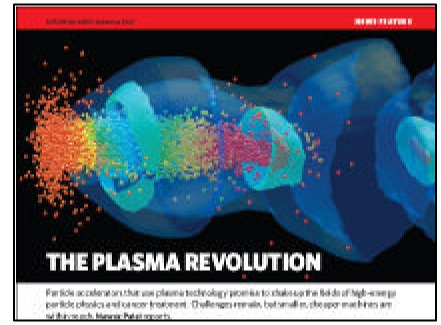


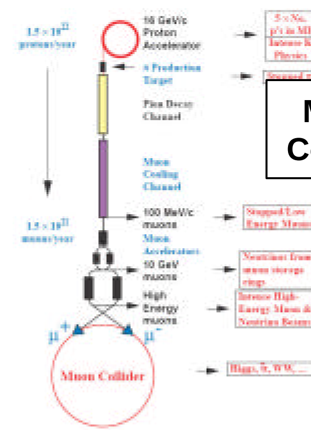


## Superconducting Cavity Technology



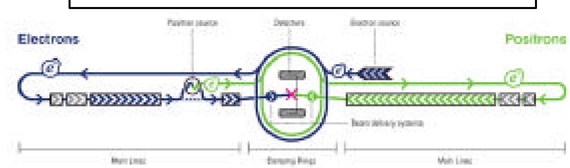
## Accelerators



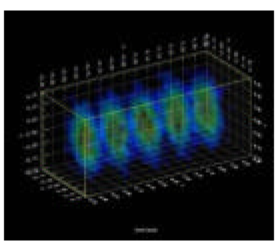



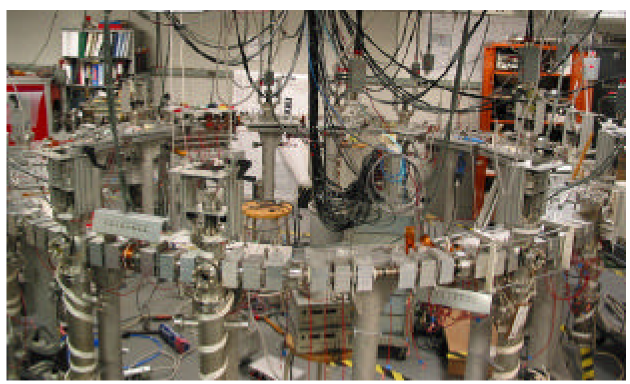

**Muon Collider**

**International Linear Collider**




## Accelerator Science





# Advanced Technology R&D
# Significant activities and issues

**U.S. leadership in Accelerator R&D**

- **Historically the U.S. has been a leader in the development of advanced accelerators**

- **The developments have been largely driven by the HEP program, and supported by the DOE OHEP, in the quest for higher energies and intensities and more demanding beam properties.**

- **U.S. leadership in this area is being challenged by efforts in other regions and countries**
  - Investments have been made and are being made in new forefront HEP accelerator facilities
  - There appears to be recognition by governments of the importance of accelerator competency and infrastructure
  - Industrial capabilities have been nurtured in Europe/Japan and are now preferred vendors for specialized accelerator components

- **OHEP has begun to address this technology gap**
  - Started in FY 2007 to nurture the development critical accelerator capabilities (e.g.; SRF cavities) in the U.S.
  - Participating in the international ILC and muon collider effort R&D effort
  - Significant Recovery Act funding is being directed towards accelerator R&D and in particular industrialization

- **OHEP will be sponsoring an Accelerator R&D Workshop in 2009**
  - to make a more direct connection between fundamental accelerator technology and applications
  - To obtain guidance on the needs of federal programs and the private sector