High Energy Physics Program

Presentation to Board on Physics and Astronomy

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Dr. Jim Siegrist, Associate Director
Office of High Energy Physics
Office of Science, U.S. Department of Energy
HEP PLANS AND PRIORITIES
High Energy Physics

Understanding how the universe works at its most fundamental level

The Scientific Challenges:
- Determine the origins of mass in terms of the fundamental particles and their properties
- Exploit the unique properties of neutrinos to discover new ways to explain the diversity of particles
- Discover new principles of nature, such as new symmetries, new physical laws, or unseen extra dimensions of space-time
- Explore the “dark” sector that is 95% of the Universe (Dark Matter and Dark Energy)
- Invent better and cheaper accelerator and detector technologies to extend the frontiers of science and benefit society

FY 2013 Highlights:
- Support for U.S. researchers at the LHC
- Research, design, and construction for NOvA, LBNE, and Mu2e experiments as part of a program of high energy physics at the intensity frontier
- Research in accelerator technologies including superconducting radio frequency and plasma wakefield acceleration.
- U.S. participation in international collaborations pursuing dark matter, dark energy and neutrino physics; the Reactor Neutrino Experiment in China and the Dark Energy Survey in Chile begin operations in FY 2012
HEP Strategic Plan

Plan is based on High Energy Physics Advisory Panel “P5” report

This is still the plan.

Implementation at the Energy and Cosmic Frontiers is clear

– End of Tevatron
– LHC (+upgrades)
– Dark Matter + Dark Energy

Implementation at the Intensity Frontier has been more challenging

– Funding levels at lower end of P5 Scenarios
– CR uncertainties + “no new starts”
– DUSEL difficulties
Vision for Program Development

- Our domestic program is the world leader in ‘Intensity Frontier’ area, and we need to increase investments there, while keeping a balance with the other frontiers.

- Community is engaged on further developing the science case on all 3 frontiers – we need a healthy portfolio of construction ideas supported by compelling science drivers at achievable budget levels.

- Our program will deliver science now, in the near term, and in the long term on all 3 frontiers.
HEP Priorities for the Next 12 Months

- Develop Mission Need statement for US participation in LHC detector upgrades
- Make critical decisions on Long Baseline Neutrino Experiment
- Issue solicitation for R&D leading to Next Generation Dark Matter Experiments and make selections
- Develop strategic plans for Intensity Frontier and Accelerator R&D programs
Energy Frontier

• Near-term Science goal:
  – Discover the Higgs or whatever takes its place. Is there just one?

• Recent results
  – LHC + Tevatron have ruled out most of the interesting Higgs mass range
  – Tevatron run is completed, final data analyses are underway
  – LHC will run thru 2012, then shutdown to achieve full energy (14 TeV)

• No new facilities under construction at this time
  – Program is centered in Europe (CERN) for the next 10+ years

• Planned program of major projects:
  – LHC Upgrades Phase I: (2017-2018) to cope with increased data rates
  – LHC Upgrades Phase II: (2021+) factor of 10 increased luminosity
  – Future evolution (>2025) will depend on results in the next few years:
    • If New Physics can be accessed at ~TeV energy, e+e- or mu+mu- collider (?)
    • If not, long program of LHC exploitation (+ LHC energy upgrade?)
Physics 2012: The Terascale
Priorities: Developing a Mission Need Statement

• HEP will work with the collaborations and CERN to understand the impact of the CERN LHC upgrades on detectors:
  – What are the critical needs for detector upgrades?
  – What responsibilities does CERN want the US to take on?
  – In what technical areas does the US possess leading or unique capabilities?

• Analyze the schedule needed to deliver upgraded detector components.
• Develop a cost estimate and plan to have the funding available in the HEP budget.
• Goal is to complete a Mission Need Statement in FY 2012 for the near-term upgrades that keep the detectors running smoothly
• Near-term Science goals:
  – Implement comprehensive program to understand neutrino mixing
  – Deliver much improved limits (measurements?) of charged lepton mixing and hidden sector phenomena

• Recent results (see following slide)
  – Daya Bay discovers third kind of neutrino mixing (and its large!)
  – Various “hints” of additional neutrino species, anomalous interactions?
  – Faster-than-light neutrinos?!

• New facilities under construction:
  – NuMI upgrade + NOvA; reactor experiments commissioning

• Planned program of major projects:
  – Mu2e to explore charged lepton mixing (2018-2022)
  – LBNE to make definitive measurements of neutrino properties (2021+)

• Must upgrade domestic facilities to maintain US leadership
Current Intensity Frontier Facilities

NSF’s proposed Underground Lab.

DUSEL

NOvA (off-axis)

MINOS (on-axis)

1300 km

735 km

MiniBooNE
SciBooNE
MINERvA
The Neutrino Physics Program

- **Neutrinos from the Main Injector (NuMI)** is the most intense neutrino beamline in the world.
- Experiments using this beamline use a detector near the neutrino source at Fermilab and also a far detector, hundreds of kilometers away.
- Key experiments:
  - **MINOS** – This experiment has produced the most precise measurement of one of the neutrino mass differences. Operations continue to collect data for initial measurements of neutrino and antineutrino behavior.
  - **NuMI Off-Axis Electron Neutrino Experiment (NOvA)** – NOvA will provide precision measurements of neutrino mixing and will determine the relative masses of neutrinos. Operations are planned to begin in 2013.
  - **Long Baseline Neutrino Experiment (LBNE)** – Like NOvA, the specific design will be determined by the results of currently active experiments. LBNE should be sensitive to differences between neutrinos and antineutrinos to test our assumptions about the symmetries between matter and antimatter and will deliver more precise measurements of neutrino mixing.
Reactor Neutrino Detector at Daya Bay

Excellent overburden to reduce cosmogenic background

Powerful $\bar{\nu}_e$ source:
Current: $11.6 \text{ GW}_{th}$
2011: $17.4 \text{ GW}_{th}$
Priorities: LBNE Decisions

- The Office of Science charged a review to examine cost-effective options to do underground science.
- Report was delivered in June 2011. Main findings relative to LBNE:
  - Cost estimates need more work.
  - Making a technology choice should be done soon to reduce costs of developing two technologies.
- Project team was charged to develop a technology choice and refine the cost estimates.
  - The project team has recommended a technology.
  - Fermilab and DOE concurred with that recommendation.
- Currently asking Fermilab to examine phased/staged options
  - Explore alternatives to achieve a significant fraction of the science goals of LBNE in a different configuration with significantly reduced cost.
  - Still plan on CD-1 in 2012
Overview of Common Recycler Upgrades

Extraction kicker required by Mu2e and g-2 – Significantly cheaper due to relaxed requirements associated with fewer Booster Batches.

Extension of existing building at MI-52 for extraction kicker power supplies.

Recycler Ring to P1 connection in existing enclosure

New 2.5 MHz RF system using recycled MI RF. Required by Mu2e and g-2.
Overview of Common Debuncher Upgrades: Debuncher AIP

Increase magnet apertures to improve beam transfer efficiency and reduce losses.

Abort magnet and dump

Remove Collider equipment

Beam line instrumentation

Debuncher Injection System
MC-1 design evolved to meet g-2 & Mu2e needs

- Medium bay area 50’ x 70’
  - power supplies for upstream g-2 & Mu2e beamline elements
  - power supply for Mu2e AC dipole
- Low bay area 50’ x 50’
  - houses cryo plant for both experiments
  - saves $ to add onto MC-1 versus stand-alone facility
- All 3 bays built as one $9.0M GPP (proposing FY13 construction)
Near-term Science goals:
- Discover (or rule out) the particle(s) that make up Dark Matter
- Advance understanding of Dark Energy

Recent results:
- Various controversial evidence for Dark Matter from both direct and indirect searches
- Demonstration and prototyping of several Dark Energy measurements

New facilities under construction:
- Dark Energy Survey commissioning

Planned program of major projects:
- Large Synoptic Survey Telescope (2018-2023+) will make definitive ground-based Dark Energy measurements using “weak lensing”
- 3rd-Generation (ton-scale) Dark Matter experiments (2021?) to reach ultimate background limits
70% of the photons in the high-energy $\gamma$-ray sky are diffuse radiation from the Milky Way; remainder are localized sources or extragalactic “diffuse” radiation.
AMS: HEP in Space
Priorities: Develop Cosmic Program Plans

• Dark Matter:
  – **Funding Opportunity for R&D on 2nd Generation direct detection experiments:**
    [https://www.fedconnect.net/FedConnect/?doc=DE-FOA-0000597&agency=DOE](https://www.fedconnect.net/FedConnect/?doc=DE-FOA-0000597&agency=DOE)
  – Aug 2012 – community workshop to get input on strategy for dark matter research, particularly coordination and complementarity of different methods (e.g. direct detection vs. indirect gamma-ray searches vs. LHC)

• Dark Energy:
  – Pro-actively developing a balanced, robust dark energy program in HEP – our own independent plan
    • With near term and low cost options
    • Using multiple methods
  – What facilities are required and how do we obtain access to do our experiments?
  – Plan HEP community workshop this summer, then broaden the discussion

• Computing
  – What do Cosmic Frontier experiments actually need? How well integrated are they with emerging national Computational Cosmology collaboration?
    • Planning meeting with all parties this summer
### Major Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Now</th>
<th>2005</th>
<th>2010</th>
<th>2015+</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are neutrinos telling us?</td>
<td>MiniBooNE</td>
<td>MINOS</td>
<td>v SuperBeam</td>
<td>Double Beta Decay Reactor</td>
</tr>
<tr>
<td>How did the universe come to be?</td>
<td>LHC</td>
<td></td>
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<tr>
<td>Why so many particles?</td>
<td>Tevatron/B-factor</td>
<td>Lattice QCD</td>
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<td></td>
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<tr>
<td>What happened to the antimatter?</td>
<td>B-factor</td>
<td>??</td>
<td>v SuperBeam</td>
<td></td>
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**Legend:**
- Blue = In operation
- Orange = Approved
- Purple = Proposed

**Office of Science**
FY 2013 HEP BUDGET
Leading HEP Budget Issues

- **ILC R&D efforts zeroed out**
  - 5 year R&D plan successfully completed; no project on near horizon
  - Plan to continue involvement with international planning at very low level
    - Physics case needs to be re-examined in light of LHC results
    - Be prepared if foreign gov’t comes with high-level request for partnership
  - Working with HEP labs to minimize damage to accelerator core competencies

- **LBNE construction not included**
  - Revised project plan not ready in time for FY2013 Budget
  - Finish developing LBNE case with the Administration
  - Homestake dewatering effort maintained at reduced scope

- **Lack of new facilities for science threatens the future of the program**
  - To exert leadership we need not only to fully exploit current research infrastructure but also to develop new facilities and infrastructure.
  - Current scientific landscape indicates the ripe opportunities are at the Intensity and Cosmic Frontiers:
    - Mu2e, LBNE, BELLE-II
    - LSSTcam, dark matter detection
# FY 2013 High Energy Physics Budget Request

<table>
<thead>
<tr>
<th>(Dollars In Thousands)</th>
<th>FY 2012</th>
<th>FY 2013 Request</th>
<th>FY 2013 vs. FY 2012</th>
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<tbody>
<tr>
<td>Proton Accelerator-Based Physics</td>
<td>421,594</td>
<td>411,532</td>
<td>-10,062</td>
</tr>
<tr>
<td>Electron Accelerator-Based Physics</td>
<td>23,025</td>
<td>29,146</td>
<td>+6,121</td>
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<tr>
<td>Non-Accelerator Physics</td>
<td>84,062</td>
<td>97,425</td>
<td>+13,363</td>
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<tr>
<td>Theoretical Physics</td>
<td>66,850</td>
<td>68,522</td>
<td>+1,672</td>
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<tr>
<td>Advanced Technology R&amp;D</td>
<td>167,329</td>
<td>149,896</td>
<td>-17,433</td>
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<tr>
<td>Subtotal, Research and Operations</td>
<td>762,860</td>
<td>756,521</td>
<td>-6,339</td>
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<tr>
<td>Construction</td>
<td>28,000</td>
<td>20,000</td>
<td>-8,000</td>
</tr>
<tr>
<td>Total, High Energy Physics</td>
<td>790,860*</td>
<td>776,521</td>
<td>-14,339</td>
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*The FY 2012 appropriation is reduced by $840,000 for the High Energy Physics share of the DOE-wide $73,300,000 rescission for contractor pay freeze savings. The FY 2013 budget request reflects the FY 2013 impact of the contractor pay freeze.*
FY 2013 Request Crosscuts

By Function

- Facilities: $255M**
- Technology Research: $129M
- EPP Research: $294M
- MIE: $43M
- Construction: $35M* SBIR/STTR: $21M

By Frontier

- Intensity: $274M
- Energy: $157M
- Advanced Tech: $162M
- Cosmic: $79M
- Theory: $69M
- Construction: $35M*

*Includes Other Project Costs (R&D) for LBNE and Mu2e
**Includes $17.6M Other Facility Support

*Includes Other Project Costs (R&D) for LBNE and Mu2e
TECHNOLOGY STEWARDSHIP
The FY2012 Senate report specifies that

“The Committee directs the Department to submit a 10-year strategic plan by June 1, 2012 for accelerator technology research and development to advance accelerator applications in energy and the environment, medicine, industry, national security, and discovery science.”

HEP has charged a community task force to provide input on promising R&D areas, pros and cons of current technology transfer models, and potential challenges of implementation

- Report from task force to DOE SC February 13. N. Holtkamp talk at this mtg.

This will be significant effort to implement and is not without risk. We have positive feedback from other SC offices and other agencies. Industry has given many constructive suggestions

- HEP is not expecting any immediate changes associated with this, just some modest redirection and stability for our support to accelerator science

- Community report will form the basis of the strategic plan and inform FY2014 formulation. We are working on a reorganization of our accelerator R&D efforts aligned with the strategic plan
HEP Technology Today
The Facility for Advanced aCcelerator Experimental Tests (FACET) at SLAC received CD-4 in January 2012.

FACET will operate as a national user facility for accelerator R&D with open access based upon peer review.

It will use the front end of the SLAC linac to supply electron beams with high energy (20 GeV) and short length bunch lengths.

Plasma wakefield experiments will be in the first run.

HEP is supporting this facility as part of its accelerator R&D stewardship initiative.
How HEP Benefits Society

• High Energy Physics invents new particle accelerator and detector technologies to solve problems at the scientific frontiers.
• Because they offer innovative or more effective solutions to challenges in probing or imaging inside opaque or tiny objects, these technologies are then adopted by other sciences, industry, medical diagnostics, homeland security
  ➢ Original HEP “application” →
• The Computational HEP program has similar but smaller impact
  ➢ Data intensive computing, widely distributed systems
First proton radiotherapy machine (1980s) was built by Fermilab for Loma Linda University. Very large footprint, and expensive.

More recently, very high field superconducting magnets were developed for HEP accelerators

- This led to a (small) market for high current superconducting wires, which eventually grew into a large market for superconducting MRI magnets.

MIT physicists and Still River Systems further developed this technology for compact proton radiotherapy accelerators – devices currently in use.

First delivery to Barnes Jewish in 2011; around 5 under construction, around 17 ordered.

If proton machines cost the same as x-ray machines, all radiation therapy would use protons.

- Relatively compact, and more affordable systems.
Conclusion

• Exciting program pushing ahead all three frontiers
• Current focus on transition of FNAL facilities to expanded role on the Intensity Frontier
• Cosmic frontier in close collaboration with NSF Astronomy, NASA; regular input from AAAC
• US-CERN relation to be ‘regularized’ before 2017 to support Energy Frontier
• New role in accelerator stewardship under exploration