



# **HEP Program and Strategic Planning and Community Process [Snowmass/P5]**

**Snowmass Energy Frontier Workshop  
Seattle, Washington  
June 30 – July 3, 2013**

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# Outline

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- **Energy Frontier Program Status & Issues**
- **Budget and Issues**
- **Strategic Planning and Community Process**
- **Summary**

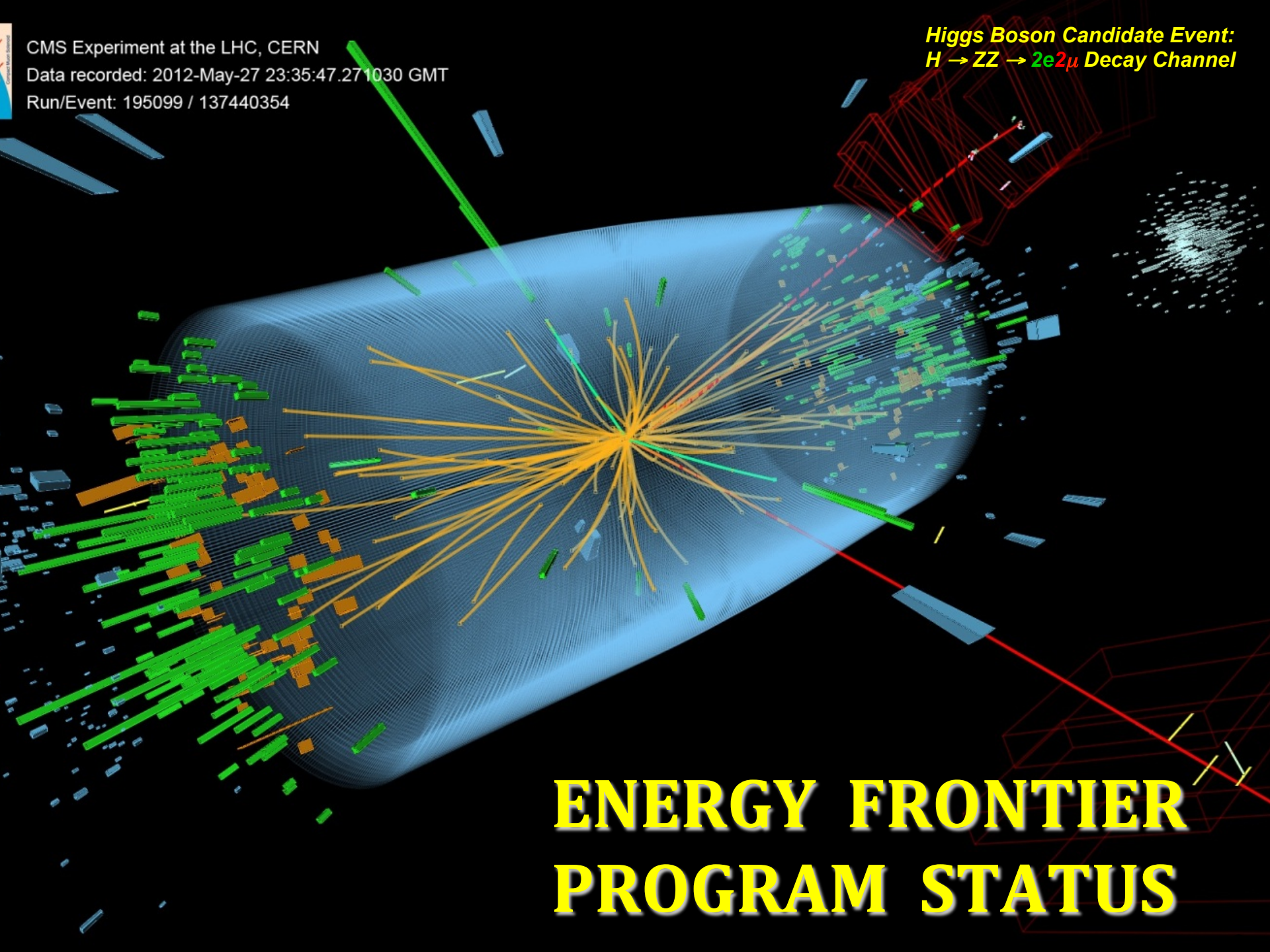


CMS Experiment at the LHC, CERN

Data recorded: 2012-May-27 23:35:47.271030 GMT

Run/Event: 195099 / 137440354

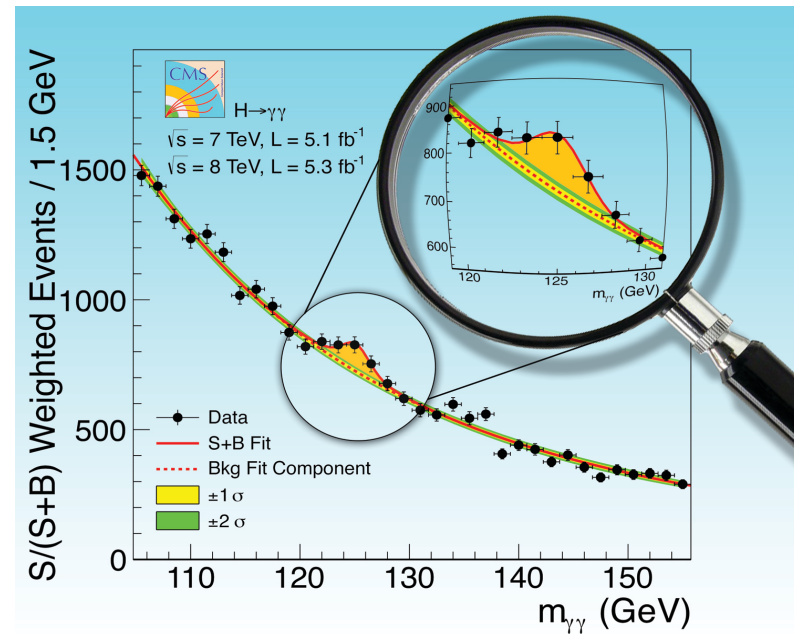
Higgs Boson Candidate Event:  
 $H \rightarrow ZZ \rightarrow 2e2\mu$  Decay Channel



**ENERGY FRONTIER  
PROGRAM STATUS**

# 2012: Particle of the Year

- **July 4, 2012: a particle that looks a lot like the SM Higgs boson has been discovered at CERN**
  - seen by both experiments in multiple decay modes of the Higgs
  - experiments are actively measuring its properties to determine if the particle is consistent with the one predicted in SM
- **In 2012, observation was**
  - TIME Magazine: “Particle of the Year”
  - Science: “Breakthrough of the Year”
  - The Economist: “A giant leap for science”
- **Recently, Moriond 2013 results**
  - Measurements from CMS and ATLAS prefer zero spin and positive parity, strongly indicate consistency with a SM Higgs
  - March 2013: one-page briefing to White House Chief of Staff on Higgs results presented at the Moriond conferences





# HEP Energy Frontier Experiments

Experiment	Location	CM Energy; Status	Description	# Institutions; # Countries	#US Institutions	#US Coll.
DZero	Fermilab Tevatron Collider [Batavia, Illinois, USA]	1.96 TeV; Operations ended: Sept. 30, 2011	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics	74 Institutions; 18 Countries	33 Univ., 1 National Lab	192
CDF (Collider Detector at Fermilab)	Fermilab Tevatron Collider [Batavia, Illinois, USA]	1.96 TeV; Operations ended: Sept. 30, 2011	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics	55 Institutions; 14 Countries	26 Univ., 1 National Lab	224
ATLAS (A Toroidal LHC ApparatuS)	CERN, Large Hadron Collider [Geneva, Switzerland / Meyrin, Switzerland]	7-8 TeV; 13-14 TeV Run 1 ended: Dec. 2012 Run 2 start: 2015	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics, and Heavy-ion	174 Institutions; 38 Countries	40 Univ., 4 National Labs	556
CMS (Compact Muon Solenoid)	CERN, Large Hadron Collider [Geneva, Switzerland / Cessy, France]	7-8 TeV; 13-14 TeV Run 1 ended: Dec. 2012 Run 2 start: 2015	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics, and Heavy-ion	179 Institutions; 41 Countries	46 Univ., 1 National Lab	676

*Collaboration data as of May 2013.*

- **US-ATLAS comprises ~21% of the international ATLAS Collaboration**
- **US-CMS comprises ~33% of the international CMS Collaboration**

# Energy Frontier Status

## Fermilab Tevatron (DØ and CDF)

- Working with DØ and CDF collaborations on orderly completion of **legacy** analyses by the early 2014.

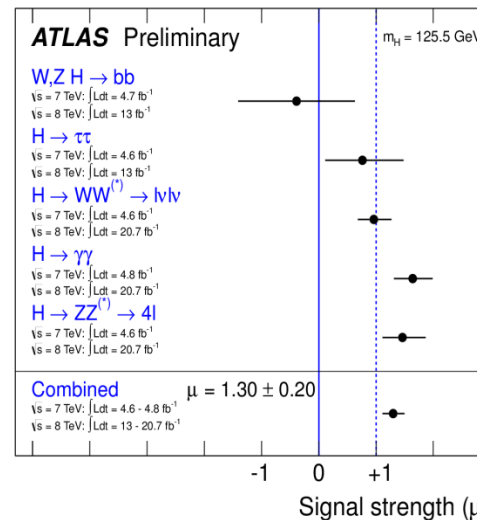
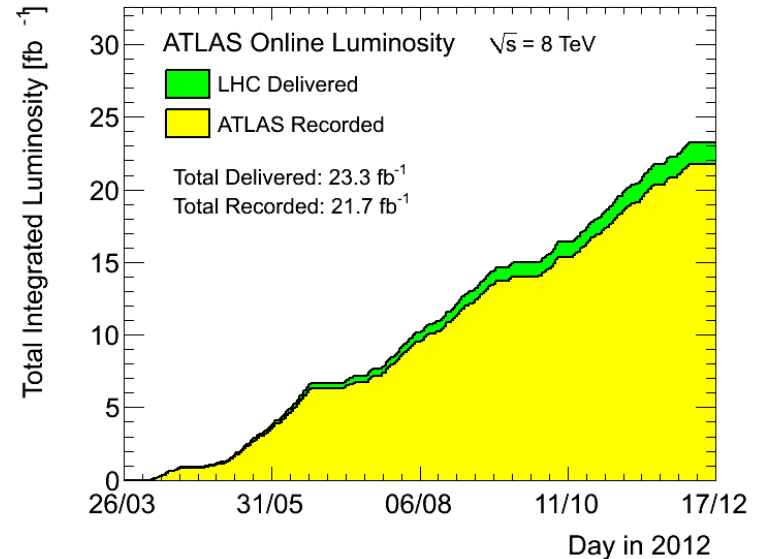
## Large Hadron Collider (LHC) at CERN

- Run I (proton) completed in Dec. 2012**
- Working with experiments to develop plan for contributions to “Phase-I” upgrades
  - CD-0 approval last September 2012 (\$22-34M each experiment: ATLAS and CMS).
  - CD-1 reviews scheduled in August 2013.

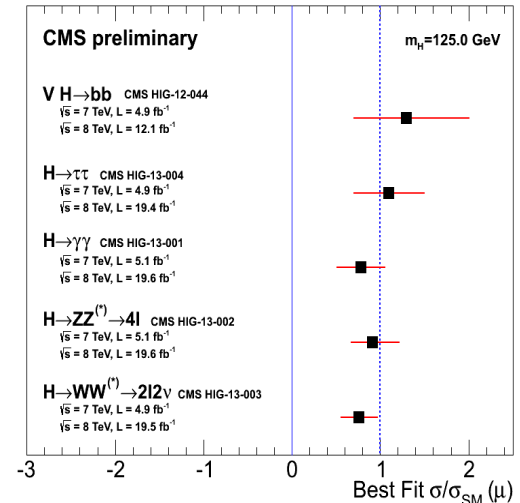
## Current program

- Analyze and publish results from LHC Run I
- 2013-2014 shutdown: repair splices in LHC magnets; detector maintenance and consolidation, upgrades and repairs
- In 2015: resume running at 13~14 TeV
- Still no smoking guns for BSM physics
  - What will 13~14 TeV running tell us?
  - Focus on new physics

Completion of Run I; CMS & ATLAS recorded:  $\sim 22 \text{ fb}^{-1}$



**ATLAS Signal Strength**  
[Moriond 2013]



**CMS Signal Strength**  
[Moriond 2013]

# Energy Frontier Issues

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- **Discussions with CERN about follow-on to LHC Agreement proceeding**
  - Necessary precursor to planning for “Phase-II” upgrades; US scope for “Phase-II” TBD.
- **Energy Frontier science plan will require high-energy, high-luminosity LHC running**
  - What is the real physics of the TeV scale?
    - this will likely take a few years to sort itself out
  - US “Snowmass/P5” process is an important element, along with European and Japanese HEP strategies
- **Significant collaborations with other regions on future colliders will require a high-level approach between governments**
  - Modest ground-level R&D efforts can continue as funding allows
  - We support an international process to discuss future HEP facilities that respects the interests of major national and regional partners as well as realistic schedule and fiscal constraints
  - Once Snowmass/P5 studies and the community input are complete, we will be in a better position to evaluate future US priorities for the HEP program in detail
  - We encourage active engagement by all interested parties



# HEP BUDGET

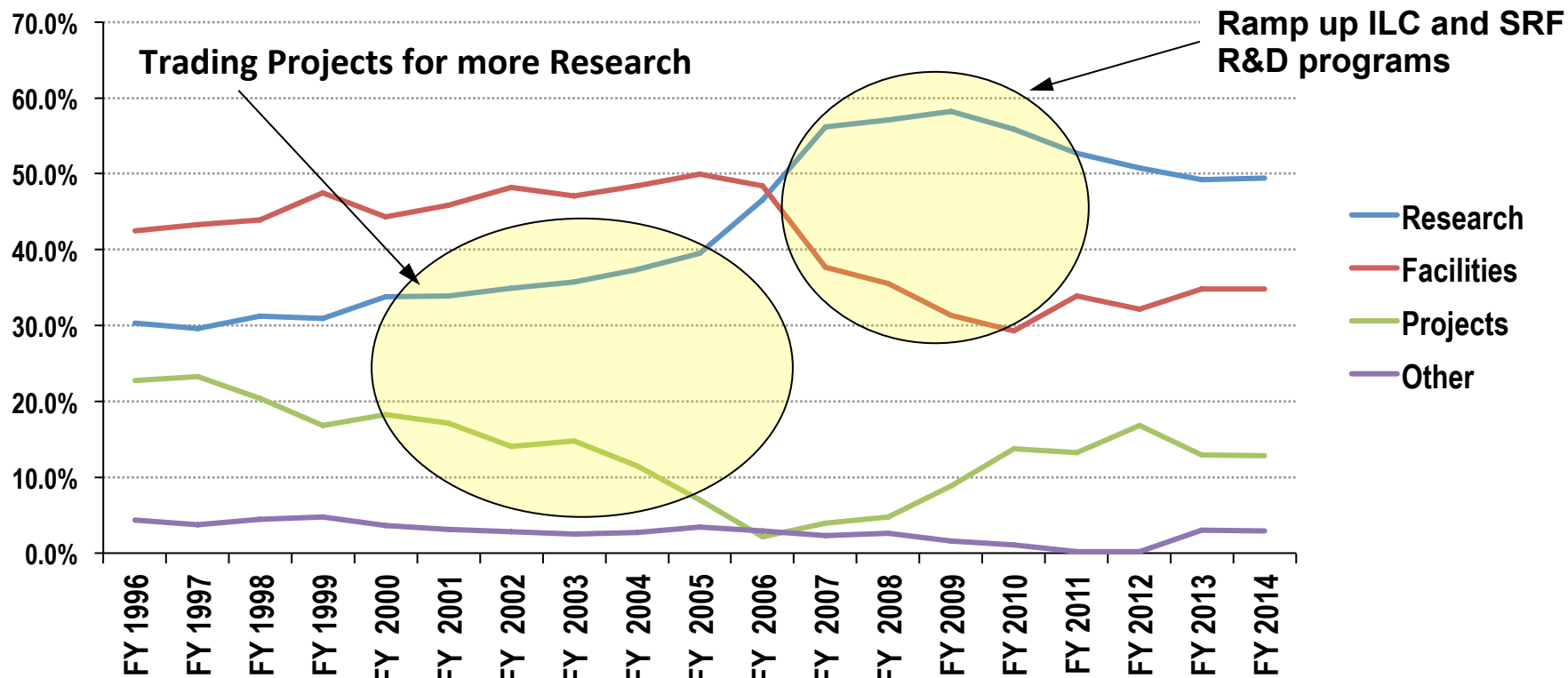


# HEP Budget Overview

- FY2014 budget philosophy was to enable new world-leading HEP capabilities in the U.S. through investments on all three frontiers
  - Accomplished through ramp-down of existing Projects and Research
  - When we were not able to fully implement this approach, converted planned project funds to R&D: Research → ~~Projects~~ → Research
  - Therefore the FY14 Request shows *increases* for Research that are driven by this R&D “bump”, while Construction/MIE funding is only slightly increased
  - Details in following slides
- Impact of these actions:
  - Several new efforts are delayed:
    - LHC detector upgrades, LBNE, 2<sup>nd</sup> Generation Dark Matter detectors
  - US leadership/partnership capabilities will be challenged by others
  - Workforce reductions at universities and labs
- Key areas in FY2014 Request
  - Maintaining forward progress on new projects via Construction and Research funding lines

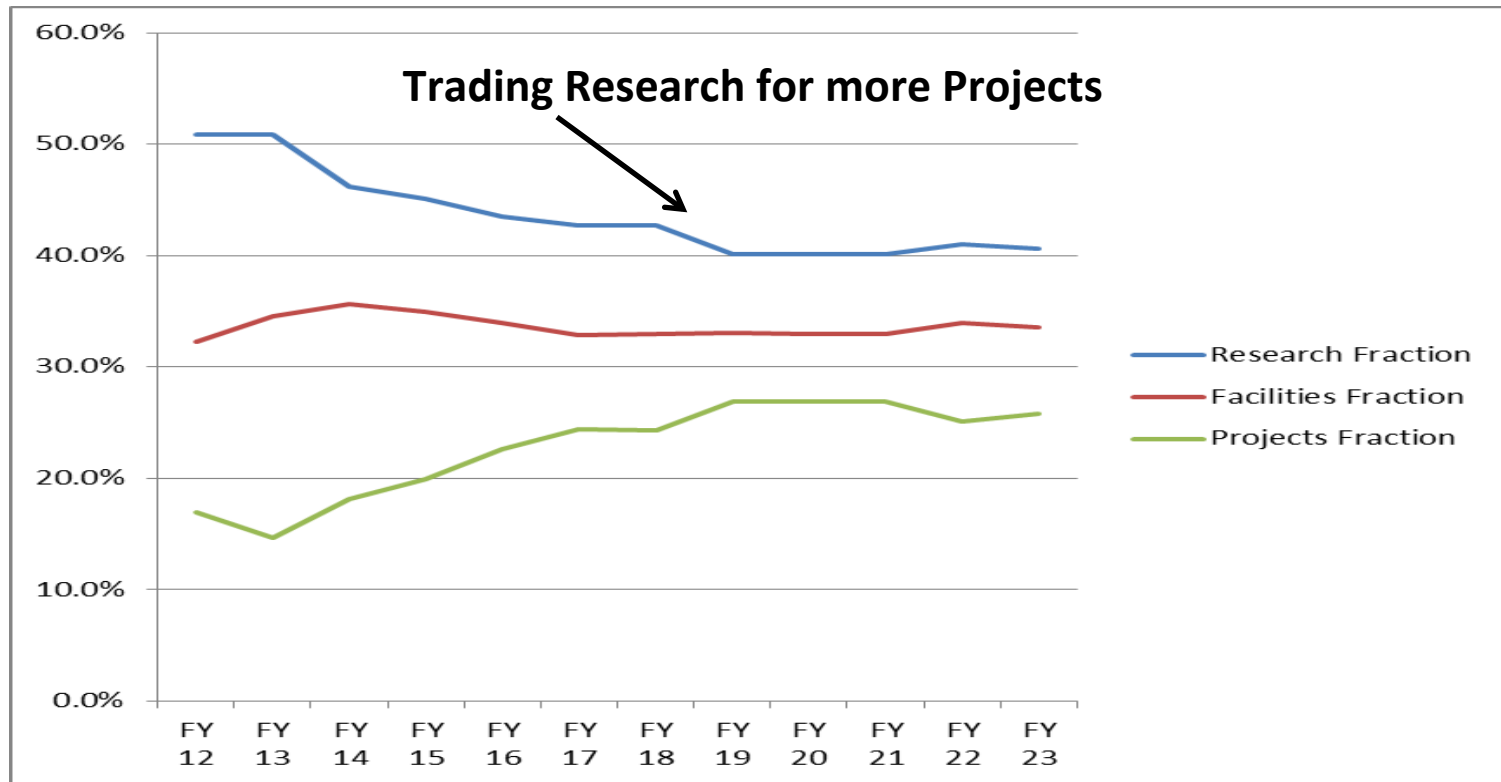


# Recent Funding Trends



- In the late 90's the fraction of the budget devoted to projects was about 20%.
- Progress in many fields require new investments to produce new capabilities.
- The projects started in 2006 are coming to completion.
- New investments are needed to continue US leadership in well defined research areas.
- Possibilities for future funding growth are weak. Must make do with what we have.

# One Possible Future Scenario



- About 20% (relative) reduction in Research fraction over ~5 years
  - *In order to address priorities, this will not be applied equally across Frontiers.*
- This necessarily implies reductions in scientific staffing
  - **Some can migrate to Projects but other transitions are more difficult.**
- We have requested Labs to help manage this transition as gracefully as possible

# FY 2014 High Energy Physics Budget

(Data in new structure, dollars in thousands)

Description	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Explanation of Change
Energy Frontier Exp. Physics	159,997	148,164	154,687	Ramp-down of Tevatron Research
Intensity Frontier Exp. Physics	283,675	287,220	271,043	Completion of NOvA (MIE), partially offset by Fermi Ops
Cosmic Frontier Exp. Physics	71,940	78,943	99,080	Ramp-up of LSST
Theoretical and Computational Physics	66,965	66,398	62,870	Continuing reductions in Research
Advanced Technology R&D	157,106	131,885	122,453	Completion of ILC R&D
Accelerator Stewardship	2,850	3,132	9,931	FY14 includes Stewardship-related Research
SBIR/STTR	0	0	21,457	
Construction (Line Item)	28,000	11,781	35,000	Mostly Mu2e; no LBNE ramp-up
<b>Total, High Energy Physics:</b>	<b>770,533<sup>(a)</sup></b>	<b>727,523<sup>(b,c)</sup></b>	<b>776,521</b>	<b>wrt FY12: Down -2% after SBIR correction wrt FY13: Up +3.6% after SBIR correction</b>
<b>Ref: Office of Science (SC):</b>	<b>4,873,634</b>	<b>4,621,075<sup>(c)</sup></b>	<b>5,152,752</b>	

SBIR = Small Business Innovation Research  
STTR = Small Business Technology Transfer

(a) The FY 2012 Actual is reduced by \$20,327,000 for SBIR/STTR.

(b) The FY 2013 CR Actual is reduced by \$20,791,000 for SBIR/STTR.

(c) Reflects sequestration.



# HEP Energy Frontier

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Comment
Research	91,757	86,172	96,129 <sup>(a)</sup>	Tevatron ramp-down offset by R&D for LHC detector upgrades
Facilities	68,240	61,992	58,558	
<i>LHC Detector Ops</i>	64,846 <sup>(b)</sup>	56,912	56,774	LHC down for maintenance
<i>LHC Upgrade Project</i>	0	3,000	0	LHC detector upgrades (OPC)
<i>Other</i>	3,394	2,080	1,784	IPAs, Detailees, Reviews
<b>TOTAL, Energy Frontier:</b>	<b>159,997</b>	<b>148,164</b>	<b>154,687</b>	

OPC = Other Project Costs

**(a) Includes \$12M (= \$6M CMS + \$6M ATLAS) Phase-1 detector upgrades [R&D];  
Therefore, Energy Frontier Core Research FY14 Request = 84,129k**

**(b) Per interagency MOU, HEP provided LHC Detector Ops funding during FY12 CR  
to offset NSF contributions to Homestake de-watering activities.**

# Current LBNE Strategy

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- We are trying to follow the reconfiguration [phased] plan for LBNE, though it has hit some snags
  - Out-year budgets are challenging
  - Some members of the community objected that the phased LBNE was not what P5 (or they) had in mind
- The plan, as it currently stands:
  - Use time before baselining to recruit partners (international and domestic) that expand scope and science reach
  - Working to get more of the community on board
- It seems clear this is necessary. Will it also be sufficient?
  - Need to get agreement on what is required for success

# Major Item of Equipment (MIE) Issues

- We were not able to implement [most] new MIE starts in the FY14 request
  - Muon g-2 experiment is the only new start in HEP

Brookhaven National Laboratory  
Muon g-2 Ring: On Barge, Departing Southern Long Island  
June 25, 2013



- This upsets at least 2 major features of our budget strategy:
  - Strategic plan: “Trading Research for Projects”
  - Implementation of facilities balanced across Frontiers

# HEP Physics MIE Funding

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Description
<b>MIE's</b>	<b>55,770</b>	<b>45,687</b>	<b>39,000</b>	
<i>Intensity Frontier</i>	41,240	19,480	0	NOvA ramp-down
<i>Intensity Frontier</i>	6,000	5,857	0	MicroBooNE
<i>Intensity Frontier</i>	500	0	0	Reactor Neutrino Detector at Daya Bay
<i>Intensity Frontier</i>	1,030	5,000	8,000	Belle-II
<i>Intensity Frontier</i>	0	5,850	9,000	Muon g-2 Experiment
<i>Cosmic Frontier</i>	1,500	1,500	0	HAWC
<i>Cosmic Frontier</i>	5,500	8,000	22,000	Large Synoptic Survey Telescope (LSST) Camera
<b>TOTAL MIE's</b>	<b>55,770</b>	<b>45,687</b>	<b>39,000</b>	



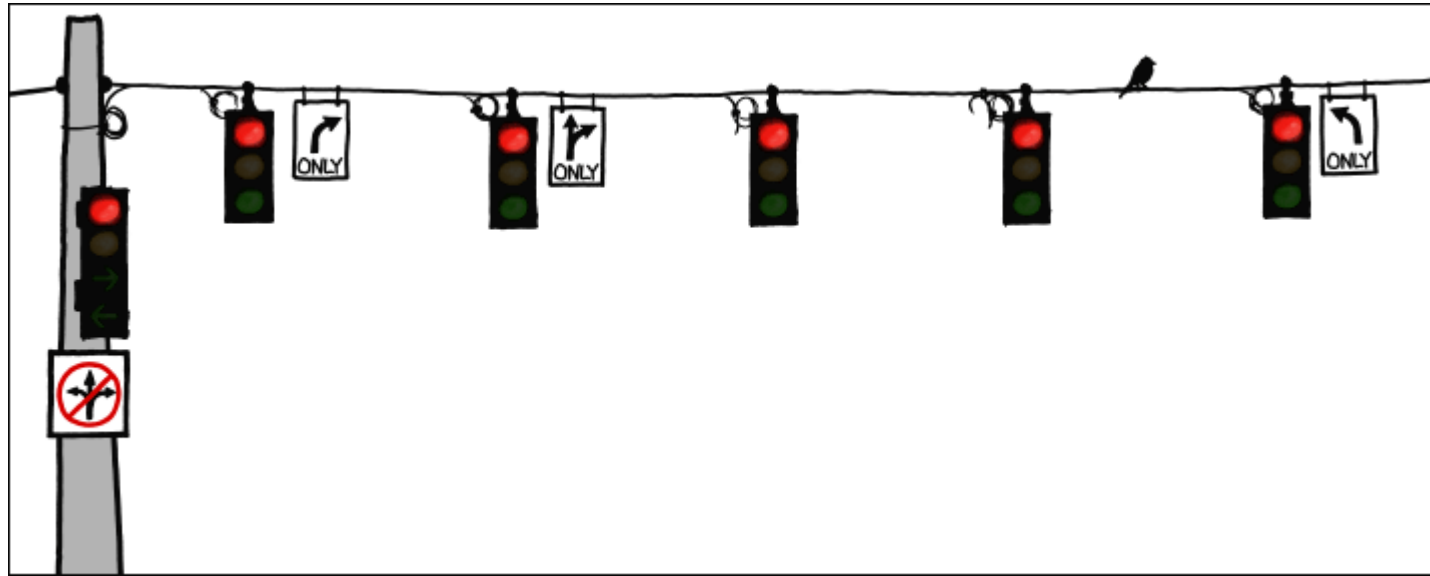
# HEP Physics Construction Funding

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request
<b>Construction - TPC</b>	<b>53,000</b>	<b>28,388</b>	<b>45,000</b>
<b>Long Baseline Neutrino Experiment</b>	<b>21,000</b>	<b>17,888</b>	<b>10,000</b>
<i>TEC</i>	4,000	3,781	0
<i>OPC</i>	17,000	14,107	10,000
<i>TPC</i>	21,000	17,888	10,000
<b>Muon to Electron Conversion Experiment</b>	<b>32,000</b>	<b>10,500</b>	<b>35,000</b>
<i>TEC</i>	24,000	8,000	35,000
<i>OPC</i>	8,000	2,500	0
<i>TPC</i>	32,000	10,500	35,000

TEC = Total Estimated Cost (refers to Capital Equipment expenses)

OPC = Other Project Costs

TPC = Total Project Cost



<http://xkcd.com/1116/>

# STRATEGIC PLANNING AND COMMUNITY PROCESS

# Major Recommendations of 2008 Advisory Panel (P5)

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- The panel recommends that the US maintain a leadership role in world-wide particle physics. The panel recommends a strong, integrated research program at the three frontiers of the field: **the Energy Frontier, the Intensity Frontier, and the Cosmic Frontier.**
- The panel recommends support for the US LHC program, including US involvement in the planned detector and accelerator upgrades. (**highest priority**)
- The panel recommends a world-class neutrino program as a core component of the US program, with the long-term vision of a **large detector in the proposed DUSEL and a high-intensity neutrino source at Fermilab.**
- The panel recommends funding for **measurements of rare processes** to an extent depending on the funding levels available... (Mu2e)
- The panel recommends support for the study of **dark matter and dark energy** as an integral part of the US particle physics program.
- The panel recommends a **broad strategic program in accelerator R&D**, including work ..., along with support of **basic accelerator science.**
- **These are still relevant, and this is still the plan.**

# Strategic Planning

- The HEP budget puts in place a comprehensive program across the three frontiers
  - In five years,
    - The CMS and ATLAS detector upgrades will be installed at CERN.
    - NOvA, Belle-II, Muon g-2 will be running on the Intensity Frontier.
    - Mu2e will be in commissioning preparing for first data.
    - DES will have completed its science program and new mid-scale spectroscopic instrument and DM-G2 should begin operation
    - The two big initiatives, LSST and LBNE, will be well underway.
- Need to start planning now for what comes next
  - Engaging with DPF community planning process that will conclude this summer.
  - Will set up a prioritization process – Particle Physics Project Prioritization Panel – (à la P5) using that input.





# Customized Implementation Strategies

## ■ Energy Frontier

- US has a leading role in LHC physics collaborations but is not the **driver**
  - The issue is the scope and scale of US involvement. Requires US-CERN negotiation
  - Could also be true for Japanese-hosted ILC

## ■ Intensity Frontier

- US is the world leader and needs new facilities and/or upgrades of existing facilities to maintain its position
  - Has the potential to attract new partners to US-led projects
  - Portfolio of experiments and science case is diverse. This complicates the case. The scale of the projected investments is a big challenge

## ■ Cosmic Frontier

- US HEP has a leading role in a competitive, multidisciplinary environment
  - HEP component of the physics case is simple and compelling. Only question is how far one needs to go in precision/setting limits on, e.g., dark matter.
  - DOE is a technology enabler, not a facilities provider (see NSF, NASA)
    - Analogous to LHC but the HEP physics goals are not those of the facility owners
  - DOE supports particle physics goals and HEP-style collaborations
    - Astronomy and astrophysics is not in our mission nor our *modus operandi*

# Joint Agency Letter to the Community

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- **Fundamentally...[planning] is a multi-step process with several important milestones over the coming year, and each step will inform and prepare for the next.**
  - 1. HEP Facilities Subpanel:** Advise DOE/SC mgmt. on the scientific impact and technical maturity of planned and proposed SC Facilities, in order to develop a coherent 10-yr SC facilities plan
    - Subpanel can add or subtract from initial facilities list
    - Does not exclude/pre-empt later additions
  - 2. DPF/CSS2013 “Snowmass”:** community identifies compelling HEP science opportunities over an approximately 20-year time frame.
    - Not a prioritization but can make scientific judgments
  - 3. HEPAP/P5:** Advises agencies on new strategic plan and priorities for US HEP in various funding scenarios, using input from #1 and #2 above (among others)



# Snowmass / P5 Interface

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## What we hope to see from Snowmass:

- What are the most compelling science questions in HEP that can be addressed in the next 10 to 20 years and why?
- What are the primary experimental approaches that can be used to address them? Are they likely to answer the question(s) in a “definitive” manner or will follow-on experiments be needed?
- What are the “hard questions” (science, technical, cost...) that a given experiment or facility needs to answer to respond to perceived limitations in its proposal?

**These topics should be covered in the Snowmass Reports and White Papers. P5 will use these reports and white papers as its starting point.**

- We expect to have the P5 panel selected and a formal charge issued by the time of the September HEPAP meeting

# Goals for the P5 Process

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DOE/NSF met in early May to kickoff P5 process and agree on goals:

- The P5 process takes the science vision of the community and turns it into plan that is feasible and executable over a 10-20 year timescale
- HEP MUST have a planning and prioritization process that the community can stand behind and support once the P5 report is complete.
- We also need a process that repeats at more less regular intervals (5 years?)
  - We also want to allow for less comprehensive updates and modest course corrections to the plan along the way (à la P5 updates in 2009, 2010)
- Key elements envisioned for the P5 process:
  - Revisit the questions we use to describe the field
    - e.g., *Quantum Universe*, updated and corrected
  - Decide on the project priorities within budget guidance
    - in detail for the next 10 years, in broad outline beyond that
  - Propose the best way to describe the *value* of HEP research to society
  - Build on the investment in Snowmass process and outcomes



# What P5 Is (and is Not)

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P5 will prioritize HEP projects over a 10-20 year timeframe within reasonable budget assumptions and position the U.S. to be a leader in some (but not all) areas of HEP.

- This will include an explicit discussion of the necessity (or not) of domestic HEP facilities in order to maintain such a world leadership position.
- Necessarily this will involve consideration of technical feasibility as well as plausible timescales and resources for future projects.
- There will be budget “fixed points” for projects already under construction and other prior commitments

The charge to P5 will NOT include explicit examination of

- Agency review processes
- Roles, responsibilities and funding of Labs vs. Universities
- Relative funding of experimental HEP vs. theory vs. technology R&D



# DRAFT New P5 Process (for discussion)

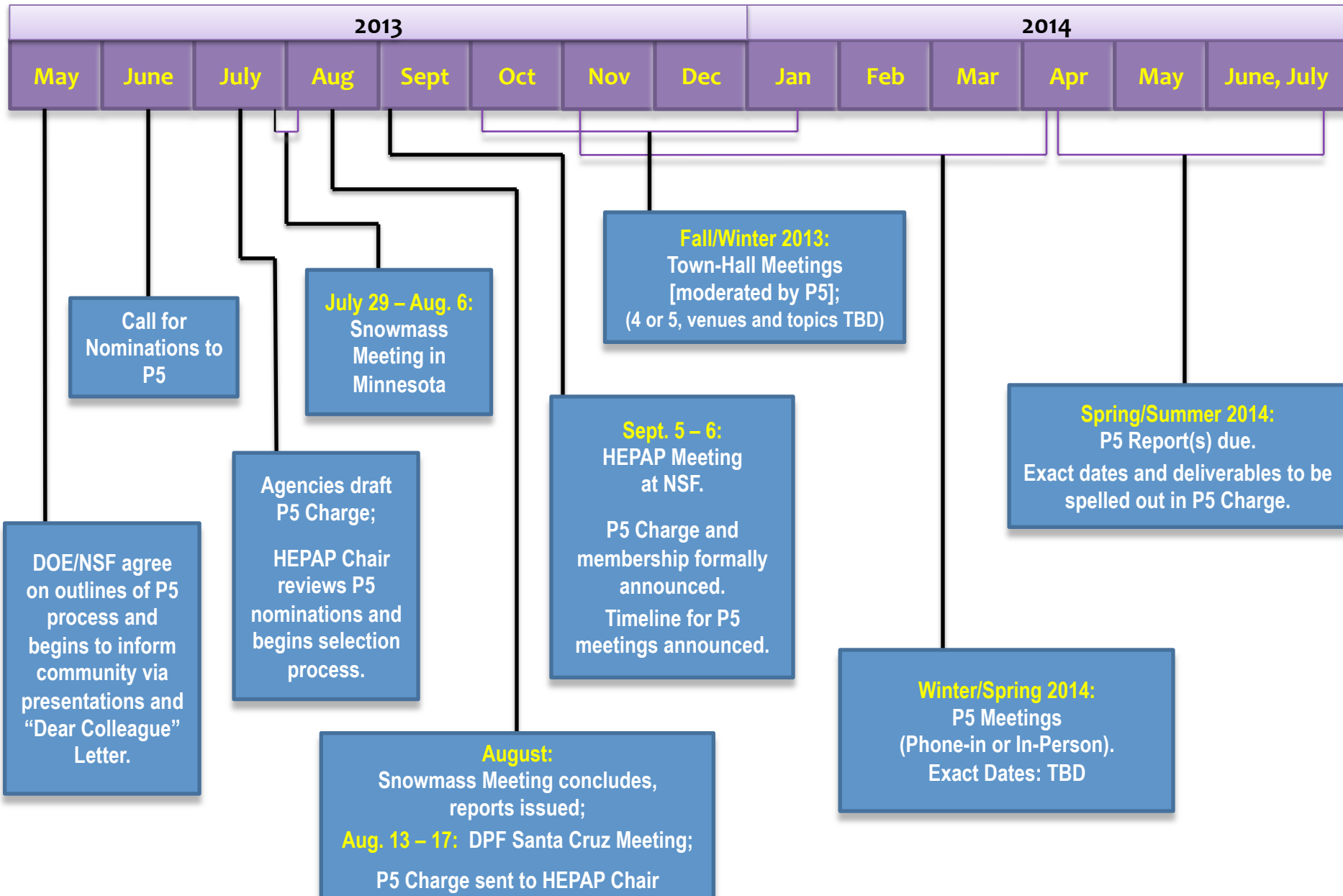
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Based on adopting “best practices” from our colleagues in Nuclear Physics and Astrophysics, we are considering the following enhancements to the P5 process for this iteration:

- **Greatly enlarged P5 panel (~50 members). Previous P5 had 21 members.**
  - Nominations will be sought from HEP and related communities through a ‘Dear Colleague’ letter
  - Snowmass output (reports, white papers) as a starting point, but may solicit additional material on specific projects
- **Several “town meetings” as public forums not only to advocate for particular science opportunities but also to *prioritize***
  - Each sub-group of the community should be able to prioritize the most important science (and projects) within its specialty. P5 will recommend priorities across the entire field.
- **Working subgroup for updating the *Quantum Universe* questions in parallel with science priority discussion**
- **Separate working group elucidating HEP benefits to society**



# DRAFT New P5 Timeline



# Draft: Proposed Town Meetings (1)

- 1<sup>st</sup> meeting on the overall strategy, questions to describe the field, and discussion of how technology development priorities and other crosscutting issues should be covered in the P5 report
  - Start with the current P5 plan and possible alternatives as well as global strategy considerations
    - Need to understand “where we are now” and recognize much has changed since the last P5 – does this also change our strategy? Does this change how we think about the field?
    - Open discussion of issues so the community can better understand the constraints, and hopefully reach broader agreement.
  - Fundamental questions for the field and how to unify/connect the Frontiers framework will also be discussed
    - Input from the Theory community will be especially important in this area
  - Technology support will NOT be a main focus of P5, but the panel will benefit from wisdom in the community in this area
    - e.g., Do we have a coherent technology R&D plan that dovetails with the science opportunities? If not, how do we get there?
    - Note that ‘Accelerator Stewardship’ is an Office of Science wide initiative managed by the HEP office, so should be discussed for information, but will not be modified by P5.





# Draft: Proposed Town Meetings (2)

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- Subsequent meetings will focus on open community discussion of project priorities on each of the frontiers: **Energy**, **Intensity**, and **Cosmic**
  - The process will be moderated by P5 itself, and based on input from Snowmass White Papers and project White Papers updated from the Facility Panel, Snowmass, or just for this purpose.
  - The expected outcome will be advice to P5 on a *prioritized project list* by frontier. Each meeting will focus on one frontier, not flaws in the plan of the other frontiers.
  - The budget guidance to P5 will be public as part of its Charge, so proponents will have a good idea of the total budget envelope that can be considered and can debate what is a “reasonable” budget profile.
  - P5 will see to it that the meetings do not descend into a shouting contest
- Based on the results of the first 4 meetings, we will consider a 5<sup>th</sup> meeting to ‘wrap up’ and discuss any broad matters arising

# Next Steps on Snowmass / P5

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- Agencies welcome input from the community on the shape of the P5 process
- We have until the end of Snowmass to modify our P5 plans
  - the agencies continue to give a series of talks at the Snowmass meetings to solicit further input
  - information on Snowmass/P5 process is also available from DOE OHEP webpage
- Agencies will begin to draft P5 charge
- The agencies expect that our community is capable of professional behavior, and look forward to vigorous and open discussions of our challenges and opportunities
  - encourage active engagement from the entire HEP community in the full process including those from the US that are resident at experiments offshore (*e.g.*, at CERN)



# **SUMMARY**

# HEP Program Planning – Energy Frontier

Issues and questions we will need to deal with when laying out longer term plans – and to be able to execute & defend the program

- Continue to sharpen the science case: What is the physics motivation for the Phase-2 LHC detector upgrades? How best do we exploit the physics opportunities for high luminosity LHC running? What is the physics motivation for future lepton colliders? Do we need more results from the LHC experiments in order to make the case for future machines?
- How far do we need to go in precision measurements and/or setting limits in each respective area of physics research with the current machines?
- What computational resources are needed for future participation in large-scale projects and operations such as the LHC and ILC?
- How do we maintain or enhance the performance of LHC detectors in the challenging accelerator environment of high instantaneous luminosities and high pile-up?
- What is the impact of participation in global projects at a time when the US is trying to advance leadership in a domestic program? Can the impact be quantified?
- Need to promote case for the importance of Energy Frontier with other frontiers and overall HEP community



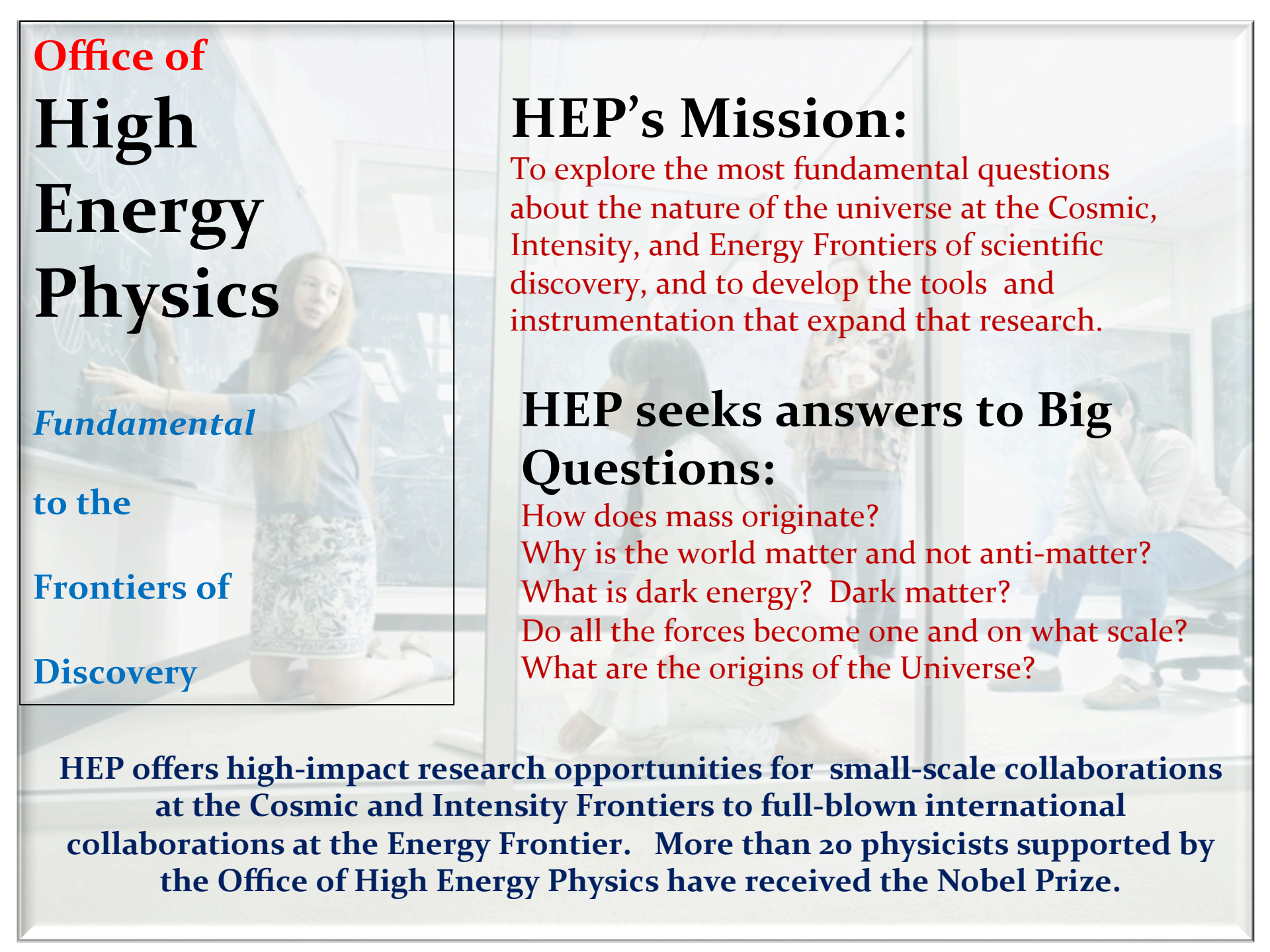
# Take-Away Messages

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- The U.S. HEP program is following the strategic plan laid out by the previous HEPAP/P5 studies
- Though some of the boundary conditions have changed, we are still trying to implement that plan within the current constraints
  - FY 2014 request generally supports this, though funding constraints have led to delays in some key projects
  - Need to maintain progress with projects currently “on the books”
  - Working to attract partnerships that will extend the science impact
- Actively engaged with community in developing new strategic plan
- Our only hope to maintain leadership in the long-term is to out-innovate the competition, and exploit unique capabilities
  - Focus on areas where US can have leadership
  - “High-risk, high-impact” as opposed to incremental advances
  - Note this is not an either/or proposition, we need both with appropriate balance



# **REFERENCE SLIDES**



# Office of High Energy Physics

*Fundamental*  
to the  
*Frontiers of*  
*Discovery*

## HEP's Mission:

To explore the most fundamental questions about the nature of the universe at the Cosmic, Intensity, and Energy Frontiers of scientific discovery, and to develop the tools and instrumentation that expand that research.

## HEP seeks answers to Big Questions:

How does mass originate?

Why is the world matter and not anti-matter?

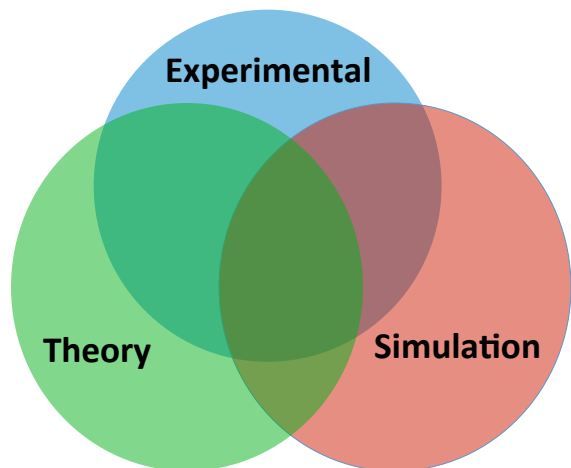
What is dark energy? Dark matter?

Do all the forces become one and on what scale?

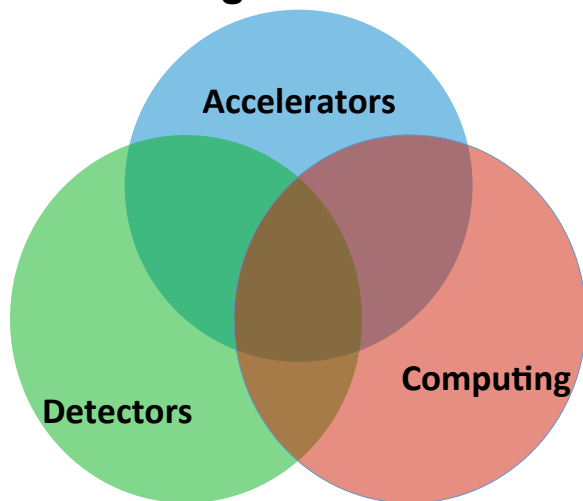
What are the origins of the Universe?

HEP offers high-impact research opportunities for small-scale collaborations at the Cosmic and Intensity Frontiers to full-blown international collaborations at the Energy Frontier. More than 20 physicists supported by the Office of High Energy Physics have received the Nobel Prize.

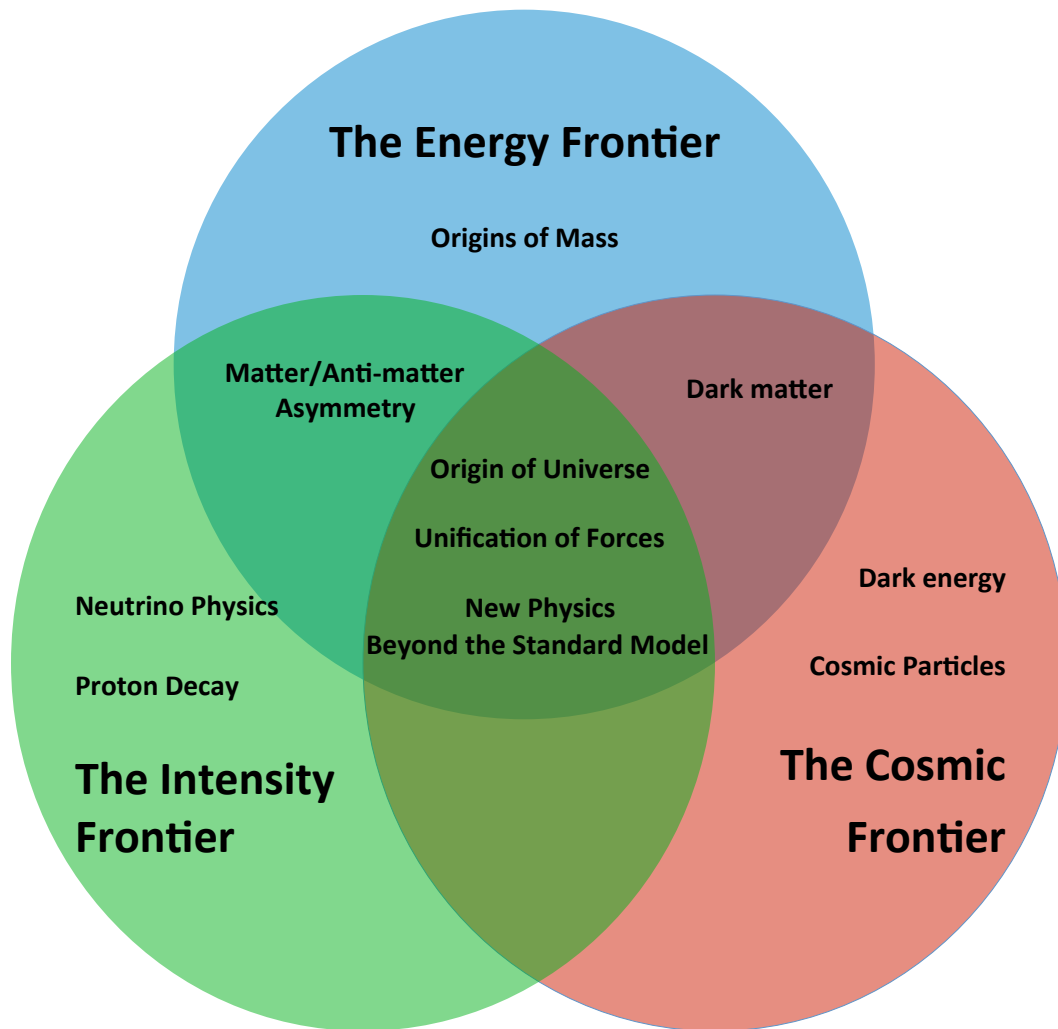
# HEP Physics and Technology



**Along Three Paths**



**Enabled by  
Advanced Technologies**



**Physics Frontiers**



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science



# From Deep Underground to the Tops of Mountains, HEP pushes the Frontiers of Research

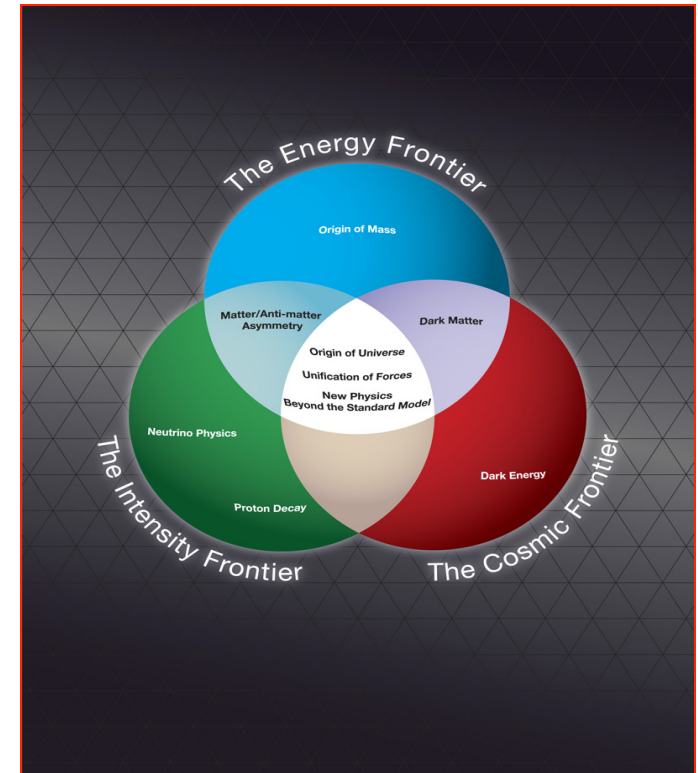
**RESEARCH AT THE ENERGY FRONTIER** — HEP supports research where powerful accelerators such as the LHC are used to create new particles, reveal their interactions, and investigate fundamental forces, and where experiments such as ATLAS and CMS explore these phenomena.

**RESEARCH AT INTENSITY FRONTIER** — Reactor and beam-based neutrino physics experiments such as Daya Bay and LBNE may ultimately answer some of the fundamental questions of our time: why does the Universe seem to be composed of matter and not anti-matter?

**RESEARCH AT THE COSMIC FRONTIER** — Through ground-based telescopes, space missions, and deep underground detectors, research at the cosmic frontier aims to explore dark energy and dark matter, which together comprise approximately 95% of the universe.

**THEORY AND COMPUTATION** — Essential to the lifeblood of High Energy Physics, the interplay between theory, computation, and experiment drive the science forward. Computational sciences and resources enhance both data analysis and model building.

**ACCELERATOR SCIENCE** — New accelerator techniques such as plasma wake-field acceleration, researched at LBL's BELLA and SLACs' FACET facilities, may eventually lead to higher beam energies than ever before, opening up new realms for discovery.



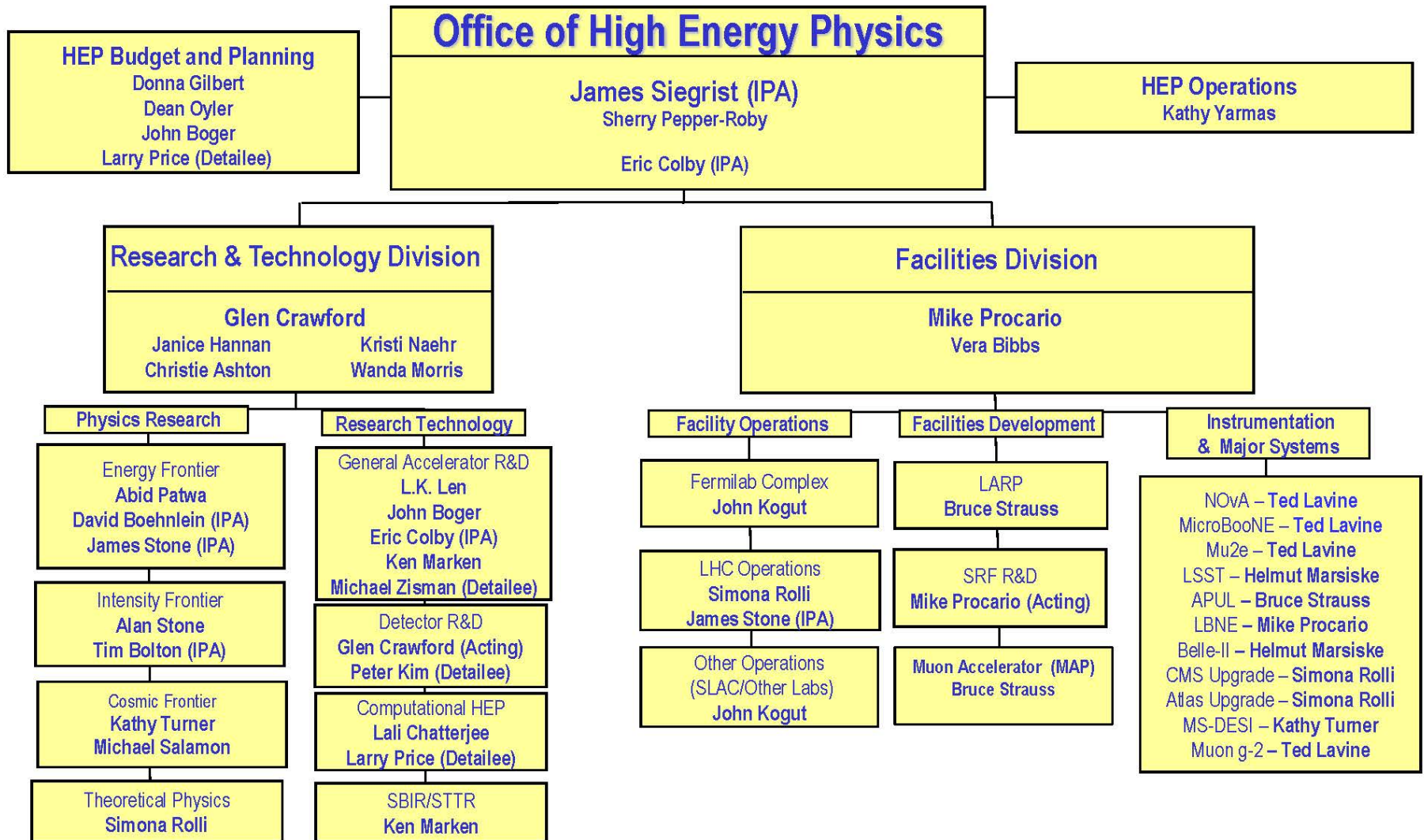
# The Common Goal

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- **A realistic, coherent, shared plan for US HEP**
  - Enabling world-leading facilities and experiments in the US while recognizing the global context and the priorities of other regions
  - Recognizing the centrality of Fermilab while maintaining a healthy US research ecosystem that has essential roles for both universities and multi-purpose labs
  - Articulating both the value of basic research and the broader impacts of HEP
  - Maintaining a balanced and diverse program that can deliver research results consistently

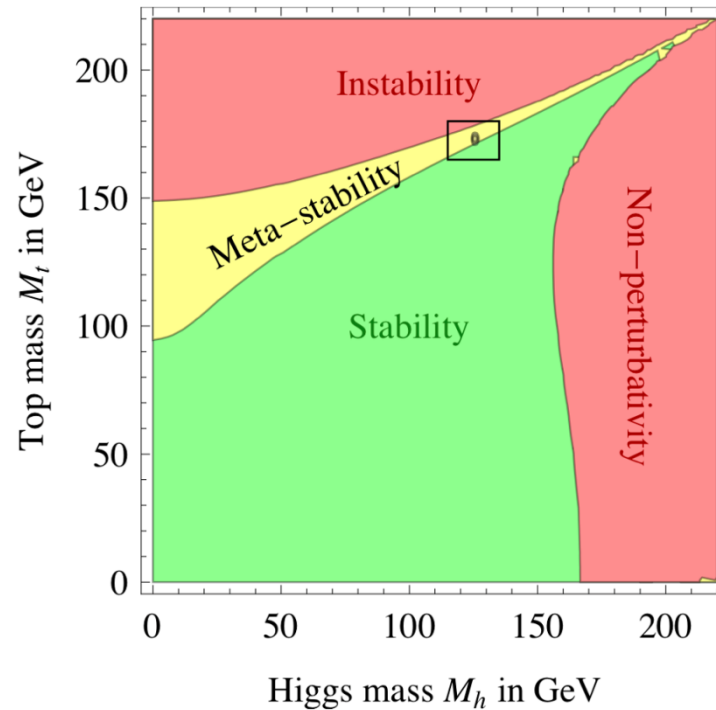


# DOE OHEP Organization



# **ENERGY FRONTIER**

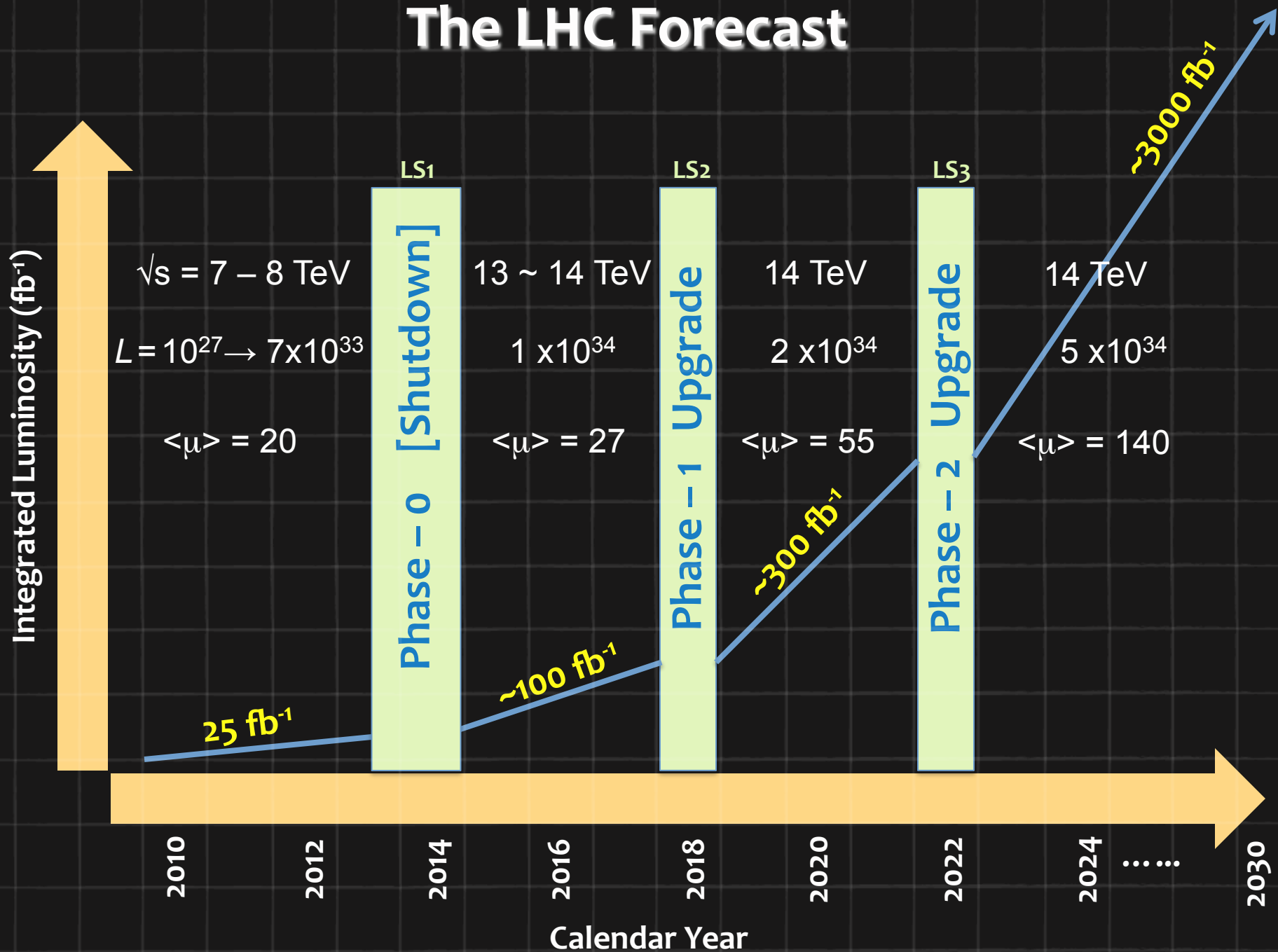
# The Higgs may be telling us something...



*Ref: Joseph Lykken (Fermilab),  
Presentation at DOE OHEP,  
April 1, 2013*

- Motivation for precision measurements of Higgs sector as well as for precision measurements of the top- and W-mass

# The LHC Forecast



# **BROADER IMPACTS OF HEP**

# The Accelerator R&D Stewardship Program

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- The mission of the HEP long-term accelerator R&D stewardship program is to support fundamental accelerator science and technology development of relevance to many fields and to disseminate accelerator knowledge and training to the broad community of accelerator users and providers.
- Strategies:
  - **Improve access to national laboratory accelerator facilities** and resources for industrial and for other U.S. government agency users and developers of accelerators and related technology;
  - Work with accelerator user communities and industrial accelerator providers to **develop innovative solutions to critical problems**, to the mutual benefit of our customers and the DOE discovery science community;
  - Serve as a catalyst to **broaden and strengthen the community of accelerator users and providers**
- Strategic plan sent to Congress in October 2012
- Incorporated into FY2014 Budget Request as new subprogram in HEP



# Connecting Accelerator R&D to Science and to End-User Needs

## Science Goal “Push”

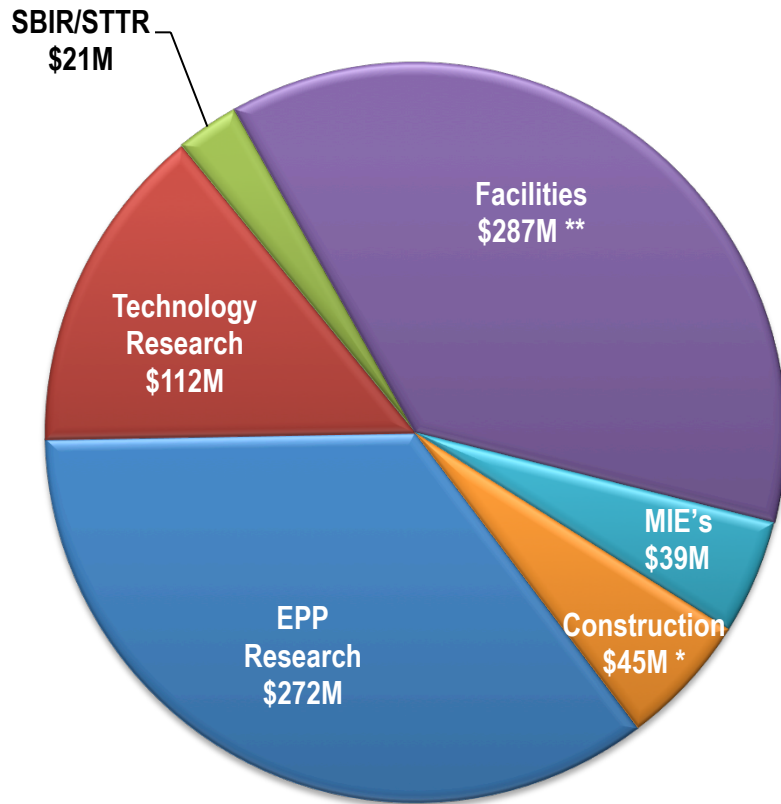
## Application “Pull”

Particle Beam Quality	Photon Beam Quality	Beam Intensity	Compact or High Energy	DOE R&D Program Thrust	Industry	Medicine	Energy and Environment	Defense and Security	Discovery Science
●	●	●	●	Superconducting RF	●		●	●	●
●	●	●	●	Accelerator, Beam, Computation		●	●	●	●
●	●	●	●	Particle Sources	●		●	●	●
		●	●	RF Sources	●		●	●	●
●	●	●	●	Beam Inst. & Controls		●	●	●	●
●	●		●	NC High-gradient Accel. Structures	●	●		●	●
			●	New Accelerator Concepts		●		●	●
●	●	●	●	Superconducting Magnets	●	●			●

**BUDGET BACKUP**

# FY 2014 Request Crosscuts

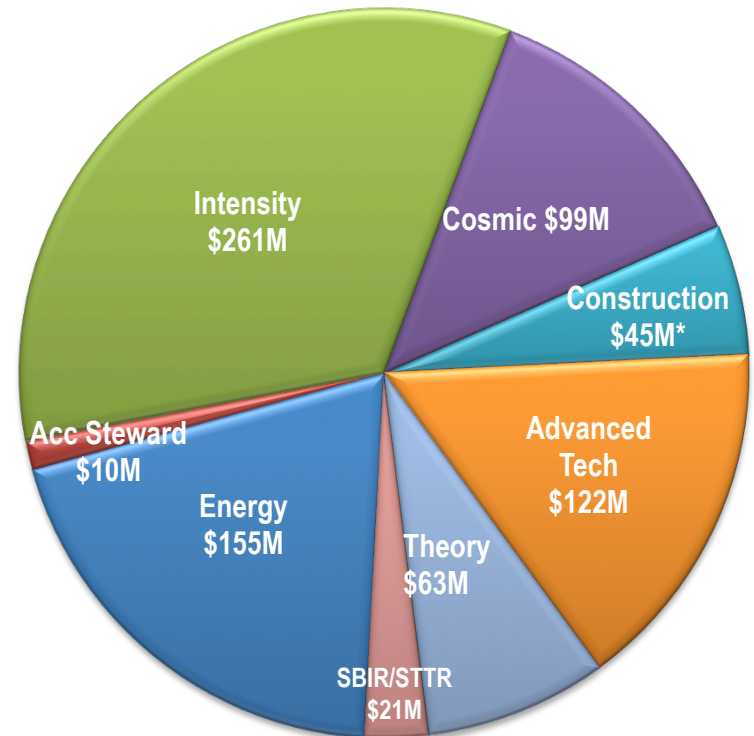
## By Function



\*Includes Other Project Costs (R&D) for LBNE

\*\*Includes \$15.9M Other Facility Support

## By Frontier



\*Includes Other Project Costs (R&D) for LBNE

# HEP Physics Funding by Activity

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Explanation of Change wrt FY12
<b>Research</b>	<b>391,329</b>	<b>362,284</b>	<b>383,609</b>	Reduction mostly ILC R&D
<b>Facility Operations and Exp't Support</b>	<b>249,241</b>	<b>265,305</b>	<b>271,561<sup>(a)</sup></b>	NOvA ops start-up and Infrastructure improvements
<b>Projects</b>	<b>129,963</b>	<b>99,934</b>	<b>99,894</b>	
<i>Energy Frontier</i>	0	3,000	0	Phase-1 LHC detector upgrades
<i>Intensity Frontier</i>	86,570	62,794	37,000	NOvA ramp-down, start Muon g-2
<i>Cosmic Frontier</i>	12,893	19,159	24,694	LSST
<i>Other</i>	2,500	3,200	3,200	LQCD hardware
<i>Construction (Line Item)</i>	28,000	11,781	35,000	Mostly Mu2e; no LBNE ramp-up
<b>SBIR/STTR</b>	<b>0</b>	<b>0</b>	<b>21,457</b>	
<b>TOTAL, HEP</b>	<b>770,533</b>	<b>727,523<sup>(b)</sup></b>	<b>776,521</b>	

<sup>(a)</sup> Includes \$1,563K GPE.

<sup>(b)</sup> Reflects sequestration.

# HEP Intensity Frontier

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Comment
<b>Research</b>	<b>53,261</b>	<b>52,108</b>	<b>53,562</b>	Ramp-down of B-factory research offset by increased support for new initiatives
<b>Facilities</b>	<b>143,844</b>	<b>172,318</b>	<b>180,481</b>	
<i>Expt Ops</i>	6,615	7,354	7,245	Offshore and Offsite Ops
<i>Fermi Ops</i>	119,544	143,128	156,438	Accelerator and Infrastructure improvements
<i>B-factory Ops</i>	10,031	5,654	4,600	Completion of BaBar D&D
<i>Homestake*</i>	5,478	14,000	10,000	
<i>Other</i>	2,176	2,182	2,198	GPE and Waste Mgmt
<b>Projects</b>	<b>86,750</b>	<b>62,794</b>	<b>37,000</b>	
<i>Current</i>	73,770	52,794	27,000	NOvA + MicroBooNE ramp-down
<i>Future R&amp;D</i>	12,880	10,000	10,000	
<b>TOTAL, Intensity Frontier</b>	<b>283,675</b>	<b>287,220</b>	<b>271,043</b>	

\*Per interagency MOU, HEP provided LHC Detector Ops funding during FY12 CR to offset NSF contributions to Homestake dewatering activities.

# HEP Cosmic Frontier

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Comment
<b>Research</b>	<b>47,840</b>	<b>48,836</b>	<b>62,364</b>	R&D for G2 Dark Matter
<b>Facilities</b>	<b>11,207</b>	<b>10,948</b>	<b>12,022</b>	Offshore and offsite Ops
<b>Projects</b>	<b>12,893</b>	<b>19,159</b>	<b>24,694</b>	
<i>Current</i>	9,153	9,500	23,200	LSSTcam fabrication begins
<i>Future R&amp;D</i>	3,380	9,659	1,484	Dark energy and dark matter projects move to conceptual design
<b>TOTAL, Cosmic Frontier</b>	<b>71,940</b>	<b>78,943</b>	<b>99,080</b>	

# HEP Theory and Computation

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Comment
<b>Research</b>	<b>64,465</b>	<b>63,198</b>	<b>59,670</b>	
<i>HEP Theory</i>	55,929	54,621	51,196	Follows programmatic reductions in Research
<i>Computational HEP</i>	8,536	8,577	8,474	
<b>Projects</b>	<b>2,500</b>	<b>3,200</b>	<b>3,200</b>	Lattice QCD hardware
<b>TOTAL, Theory and Comp.</b>	<b>66,965</b>	<b>66,398</b>	<b>62,870</b>	

# HEP Advanced Technology R&D

Funding (in \$K)	FY 2012 Actual	FY 2013 CR Actual	FY 2014 Request	Comment
<b>Research</b>	<b>134,006</b>	<b>111,888</b>	<b>105,303</b>	
<i>General Accel. R&amp;D</i>	59,280	61,791	57,856	Selected long-term R&D moves to Accelerator Stewardship
<i>Directed Accel. R&amp;D</i>	46,587	22,692	23,500	Completion of ILC R&D
<i>Detector R&amp;D</i>	28,139	27,405	23,947	Funding for liquid argon R&D is reduced
<b>Facility Operations</b>	<b>23,100</b>	<b>19,997</b>	<b>17,150</b>	Completing SRF infrastructure at Fermilab
<b>TOTAL, Advanced Technology R&amp;D</b>	<b>157,106</b>	<b>131,885</b>	<b>122,453</b>	



# Accelerator Stewardship

<b>Funding (in \$K)</b>	<b>FY 2012 Actual</b>	<b>FY 2013 CR Actual</b>	<b>FY 2014 Request</b>	<b>Comment</b>
<b>Research</b>	<b>0</b>	<b>82</b>	<b>6,581</b>	Recast of Accelerator R&D activities relevant to broader impacts
<b>Facility Operations</b>	<b>2,850</b>	<b>3,050</b>	<b>3,350</b>	Incremental FACET ops for stewardship research
<b>TOTAL, Accel. Stewardship</b>	<b>2,850</b>	<b>3,132</b>	<b>9,931</b>	

# HEP Project Status

Subprogram	TPC (\$M)	CD Status	CD Date
<b>INTENSITY FRONTIER</b>			
Long Baseline Neutrino Experiment (LBNE)	TBD	CD-1	December 10, 2012
Muon g-2	40	CD-0	September 18, 2012
Mu2e	249	CD-1	July 11, 2012
Next Generation B Factory Detector Systems (BELLE-II)	16	CD-3a	November 8, 2012
NuMI Off-Axis Electron Neutrino Appearance Exp't (NOvA)	278	CD-3b	October 29, 2009
Micro Booster Neutrino Experiment (MicroBooNE)	19.9	CD-3b	March 29, 2012
Main INjector ExpeRiment for $\nu$ -A (MINERvA)	16.8	CD-4	June 28, 2010 [Finished]
Daya Bay Reactor Neutrino Experiment	35.5	CD-4b	August 20, 2012 [Finished]
<b>ENERGY FRONTIER</b>			
LHC ATLAS Detector (Phase-1) Upgrade	TBD	CD-0	September 18, 2012
LHC CMS Detector (Phase-1) Upgrade	TBD	CD-0	September 18, 2012
<b>COSMIC FRONTIER</b>			
Dark Matter (DM-G2)	TBD	CD-0	September 18, 2012
Large Synoptic Survey Telescope (LSST)	173	CD-1	April 12, 2012
Dark Energy Survey (DES)	35.1	CD-4	June 4, 2012 [Finished]
<b>ADVANCED TECHNOLOGY R&amp;D</b>			
Accelerator Project for the Upgrade of the LHC (APUL)	11.5	CD-2/3	July 29, 2011
Berkeley Lab Laser Accelerator (BELLA)	27.2	CD-4	January 17, 2013 [Finished]
Facility for Advanced Accelerator Experimental Tests (FACET)	14.5	CD-4	January 31, 2012 [Finished]

**NEUTRINO BACKUP**

# HEP Intensity Frontier Experiments

Experiment	Location	Status	Description	#US Inst.	#US Coll.
Belle II	KEK, Tsukuba, Japan	Physics run 2016	Heavy flavor physics, CP asymmetries, new matter states	10 Univ., 1 Lab	55
CAPTAIN	Los Alamos, NM, USA	R&D; Neutron run 2015	Cryogenic apparatus for precision tests of argon interactions with neutrinos	5 Univ., 1 Lab	20
Daya Bay	Dapeng Peninsula, China	Running	Precise determination of $\theta_{13}$	13 Univ., 2 Lab	76
Heavy Photon Search	Jefferson Lab, Newport News, VA, USA	Physics run 2015	Search for massive vector gauge bosons which may be evidence of dark matter or explain g-2 anomaly	8 Univ., 2 Lab	47
KOTO	J-PARC, Tokai, Japan	Running	Discover and measure $K_L \rightarrow \pi^0 \nu \bar{\nu}$ to search for CP violation	3 Univ.	12
LArIAT	Fermilab, Batavia, IL	R&D; Phase I 2013	LArTPC in a testbeam; develop particle ID & reconstruction	11 Univ., 3 Lab	38
LBNE	Fermilab, Batavia, IL & Homestake Mine, SD, USA	CD1 Dec 2012; First data 2023	Discover and characterize CP violation in the neutrino sector; comprehensive program to measure neutrino oscillations	48 Univ., 6 Lab	336
MicroBooNE	Fermilab, Batavia, IL, USA	Physics run 2014	Address MiniBooNE low energy excess; measure neutrino cross sections in LArTPC	15 Univ., 2 Lab	101
MINERvA	Fermilab, Batavia, IL, USA	Med. Energy Run 2013	Precise measurements of neutrino-nuclear effects and cross sections at 2-20 GeV	13 Univ., 1 Lab	48
MINOS+	Fermilab, Batavia, IL & Soudan Mine, MN, USA	NuMI start-up 2013	Search for sterile neutrinos, non-standard interactions and exotic phenomena	15 Univ., 3 Lab	53
Mu2e	Fermilab, Batavia, IL, USA	First data 2019	Charged lepton flavor violation search for $\mu N \rightarrow e N$	15 Univ., 4 Lab	106
Muon g-2	Fermilab, Batavia, IL, USA	First data 2016	Definitively measure muon anomalous magnetic moment	13 Univ., 3 Lab, 1 SBIR	75
NOvA	Fermilab, Batavia, IL & Ash River, MN, USA	Physics run 2014	Measure $\nu_\mu \rightarrow \nu_e$ and $\nu_\mu \rightarrow \nu_\tau$ oscillations; resolve the neutrino mass hierarchy; first information about value of $\delta_{cp}$ (with T2K)	18 Univ., 2 Lab	114
ORKA	Fermilab, Batavia, IL, USA	R&D; CD0 2017+	Precision measurement of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ to search for new physics	6 Univ., 2 Lab	26
Super-K	Mozumi Mine, Gifu, Japan	Running	Long-baseline neutrino oscillation with T2K, nucleon decay, supernova neutrinos, atmospheric neutrinos	7 Univ.	29
T2K	J-PARC, Tokai & Mozumi Mine, Gifu, Japan	Running; Linac upgrade 2014	Measure $\nu_\mu \rightarrow \nu_e$ and $\nu_\mu \rightarrow \nu_\tau$ oscillations; resolve the neutrino mass hierarchy; first information about value of $\delta_{cp}$ (with NOvA)	10 Univ.	70
US-NA61	CERN, Geneva, Switzerland	Target runs 2014-15	Measure hadron production cross sections crucial for neutrino beam flux estimations needed for NOvA, LBNE	4 Univ., 1 Lab	15
US Short-Baseline Reactor	Site(s) TBD	R&D; First data 2016	Short-baseline sterile neutrino oscillation search	6 Univ., 5 Lab	28

# Intensity Frontier Status

Current program: MINERvA, NOvA, T2K, MicroBooNE, Daya Bay, EXO-200

- NOvA and MicroBoone will complete construction in FY 2014 (see below + next slide), others taking data

Planned program: 4 projects in design/R&D phase; fabrication not approved yet

- Belle-II
- Mu2e
- LBNE
- Muon g-2

## Physics Status

- Daya Bay, T2K, NOvA, et al. will usher in the era of precision neutrino physics with few % measurements
  - 1<sup>st</sup> steps in a comprehensive program

*MicroBooNE cryostat delivered* →



# The Questions - the Experimental Program

- Key remaining questions:

- Where did all the antimatter go ?
- Why are there so many different types (“flavors”) of neutrinos?
- What is the ordering of neutrino masses?
- Are there hidden phenomena we have not yet discovered ?

	Experiment	AntiMatter	Flavors	Mass Order	Hidden Sector	Technology R&D
<div> <div>reactor</div> <div>high energy <math>\nu</math></div> <div>low energy <math>\nu</math></div> </div>	Daya Bay		***	-	-	*
	MINOS		**	-	*	*
	T2K	*	**	-	*	*
	NO <sub>v</sub> A	**	***	*	**	*
	LBNE	***	*****	***	***	***
	Minerva	--	---	---	*	*
	MicroBooNE	--	--	---	**	**



# Why Study Neutrinos?

- Neutrinos are the least understood and most abundant constituents of matter.
  - They are everywhere, but they hardly interact at all. More than 10 million are inside every person on earth. You don't notice.
  - Neutrinos are very, very, very light.
    - Less than one-millionth the mass of an electron, so light no one has actually been able to measure the mass yet (but we know it's not = 0).
  - Neutrinos come in three “flavors” (types) that can change from one kind to another.
- Neutrinos are also very important to our existence.
  - They are vital to how stars shine and how they produce all the elements beyond hydrogen, including the carbon and oxygen that makes up people.
  - They may play a key role in why there is any matter at all in the universe.
    - The Big Bang should have produced equal amounts of matter and antimatter, which should have annihilated into pure energy. Yet almost all the antimatter seems to have vanished and matter is still here.





# Recent Major Accomplishment

*Daya Bay Reactor Neutrino Experiment makes the first definitive measurement of the remaining unknown neutrino mixing angle.*

In China, the Daya Bay collaboration led by U.S. and Chinese physicists reported a measurement of the mixing angle responsible for changing muon neutrinos to electron neutrinos. This result means that in the current neutrino oscillation model, the possibility of matter-antimatter asymmetry, and a hierarchy of neutrino masses, can be definitively tested with new experiments.



**Daya Bay Far Detector Hall with 4 neutrino detectors**

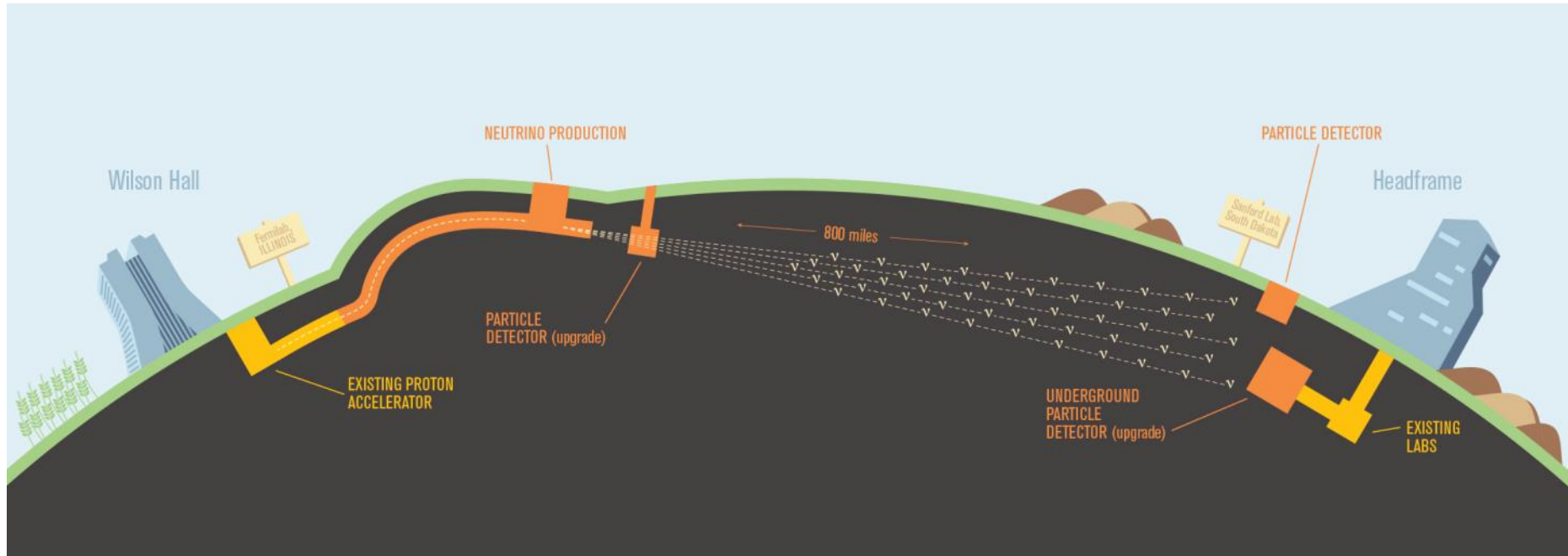


U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science



# The Long Baseline Neutrino Experiment



- Neutrino beam from Fermilab travels ~800 miles to large detector at the Sanford Lab (old Homestake Mine) in Lead, SD. On the way there, some of the neutrinos change type and some interact with matter in the earth. The large detector counts how many neutrinos survive and what type they are. These studies can address many of the key questions about neutrinos.
- LBNE is currently has CD-1 approval and is seeking additional domestic and international partners to enhance the physics reach of its initial configuration

# Current Intensity Frontier R&D Efforts

Experiment	Location	Status	Description	#US Inst.	#US Coll.
CAPTAIN	Los Alamos, NM, USA	R&D; Neutron run 2015	Cryogenic apparatus for precision tests of argon interactions with neutrinos	5 Univ., 1 Lab	20
Heavy Photon Search	Jefferson Lab, Newport News, VA, USA	Physics run 2015	Search for massive vector gauge bosons which may be evidence of dark matter or explain g-2 anomaly	8 Univ., 2 Lab	47
LArIAT	Fermilab, Batavia, IL	R&D; Phase I 2013	LArTPC in a test beam; develop particle ID & reconstruction	11 Univ., 3 Lab	38
ORKA	Fermilab, Batavia, IL, USA	R&D; CD0 2017+	Precision measurement of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ to search for new physics	6 Univ., 2 Lab	26
US-NA61	CERN, Geneva, Switzerland	Target runs 2014-15	Measure hadrons production cross sections crucial for neutrino beam flux estimations needed for NOvA, LBNE	4 Univ., 1 Lab	15
US Short-Baseline Reactor	Site(s) TBD	R&D; First data 2016	Short-baseline sterile neutrino oscillation search	6 Univ., 5 Lab	28

- **Heavy Photon Search: Feb 2013 DOE Briefing; July 11, 2013 DOE Panel Review**
  - Determine whether to fund the design, construction, commissioning, and operation of the first phase of the experiment for the period of FY14-FY16
- **nEXO R&D: Monthly DOE HEP/NP Phone Calls; July 12, 2013 DOE Panel Review**
  - Determine whether to fund the 5 ton LXe TPC R&D program for the period of FY13-FY16
- **US Short-Baseline Reactor: Monthly DOE Phone Calls; Apr 2013 DOE Briefing**
- **LArIAT: Monthly DOE Phone Calls; Apr 2013 DOE Briefing**
- **ORKA: May 2012 DOE Briefing; FNAL Stage 1**
- **CAPTAIN: Feb 2012 LANL Review (DOE Observer); Monthly DOE Phone Calls**
- **nuSTORM: Monthly DOE Phone Calls; Proposal to FNAL PAC in June 2013**
- **US-NA61: ?**

# What Makes HEP Unique?

- **Collaboration/teamwork**
- **Ambition/"big science"**
- **A long-term view**
- **We invent our own tools**

"Americans seem to work very well, only they obviously insist on making everything as big as possible."

—German physicist Franz Simon's impression upon a visit to the US in 1932.



**LBNL Staff in 1939**



# What Are HEP's limitations?

- Middle-aged field
- Technology plateau
  - (At least at Energy Frontier)
- Not a national priority
  - Increased competition for science funding
- Long timescale and high threshold for new experiments
- Over-reach?
- Reliance on international partners

