U.S. DEPARTMENT OF ENERGY

Office of Science

Energy Frontier Program

DOE/HEP 2014 • Principal Investigator (PI) Meeting
Rockville, Maryland
June 16 – 17, 2014

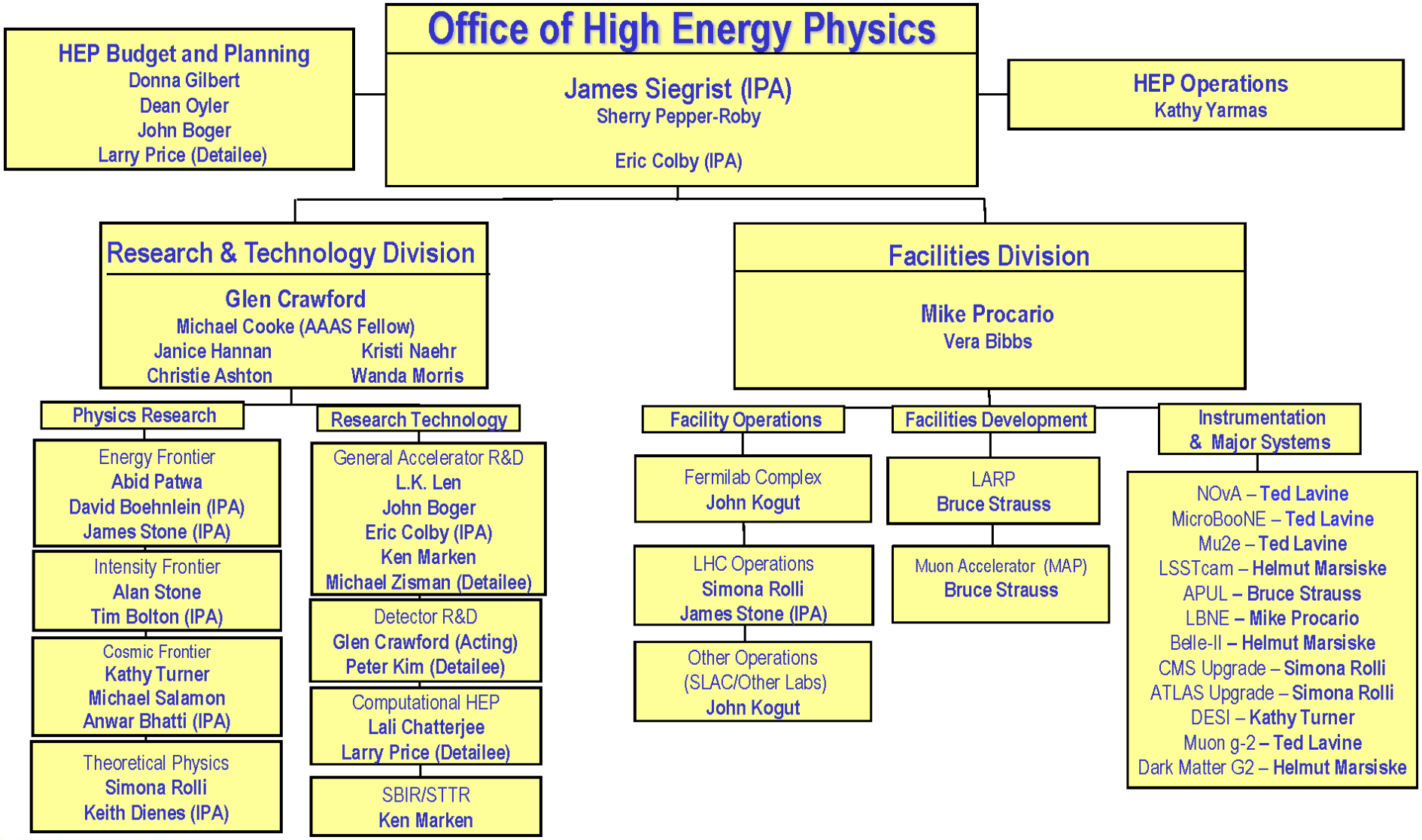
Abid Patwa
Program Manager
Office of High Energy Physics
Office of Science, U.S. Department of Energy

Outline

- Energy Frontier Program & Issues
- HEP Budget and Issues
- A few remarks on Snowmass/P5 and Implementation
- Summary

This talk will focus on the Energy Frontier program — which includes research at Tevatron, LHC, and future lepton colliders — within the broader context of the overall HEP program

DOE Office of HEP Organization



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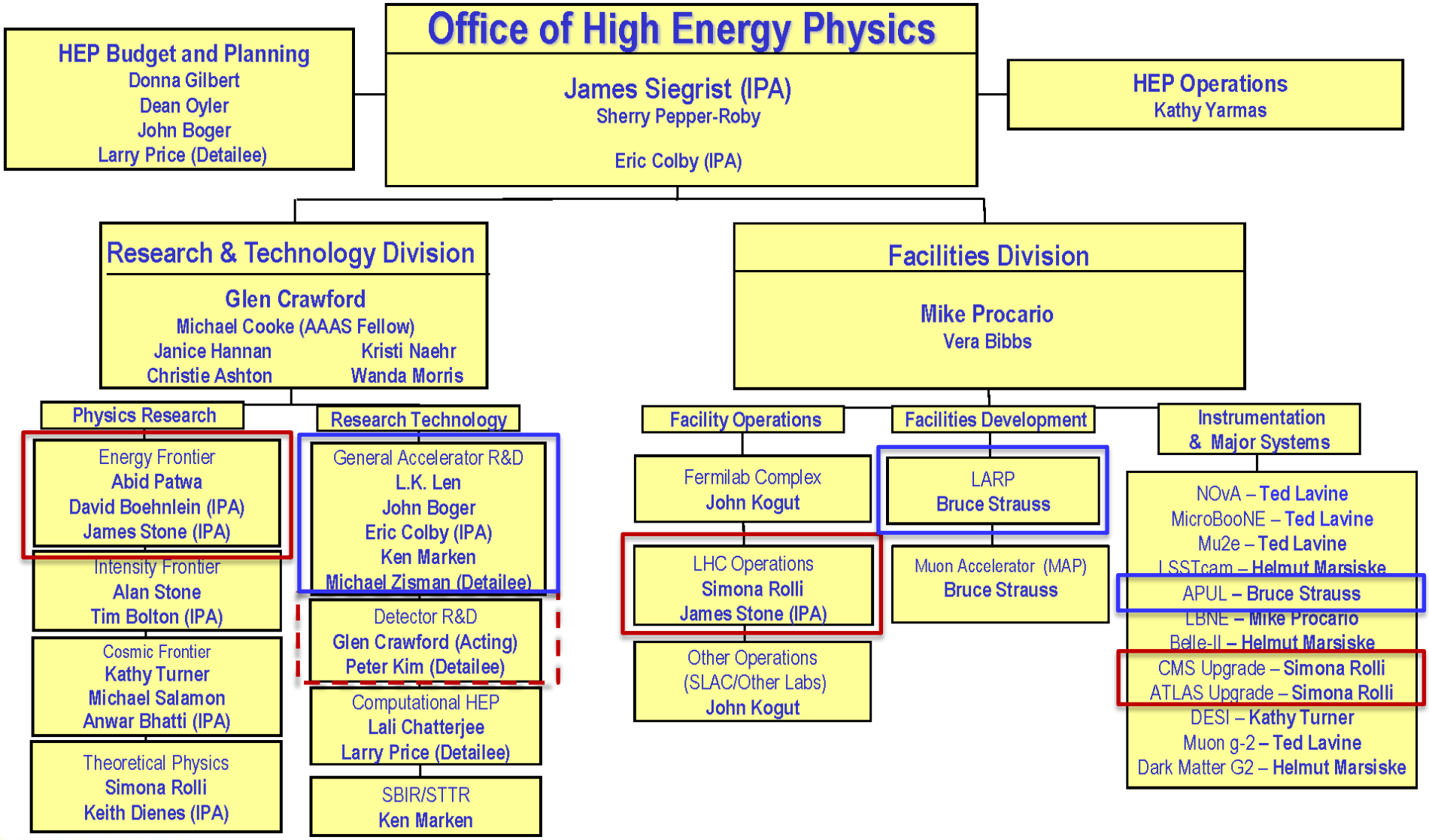

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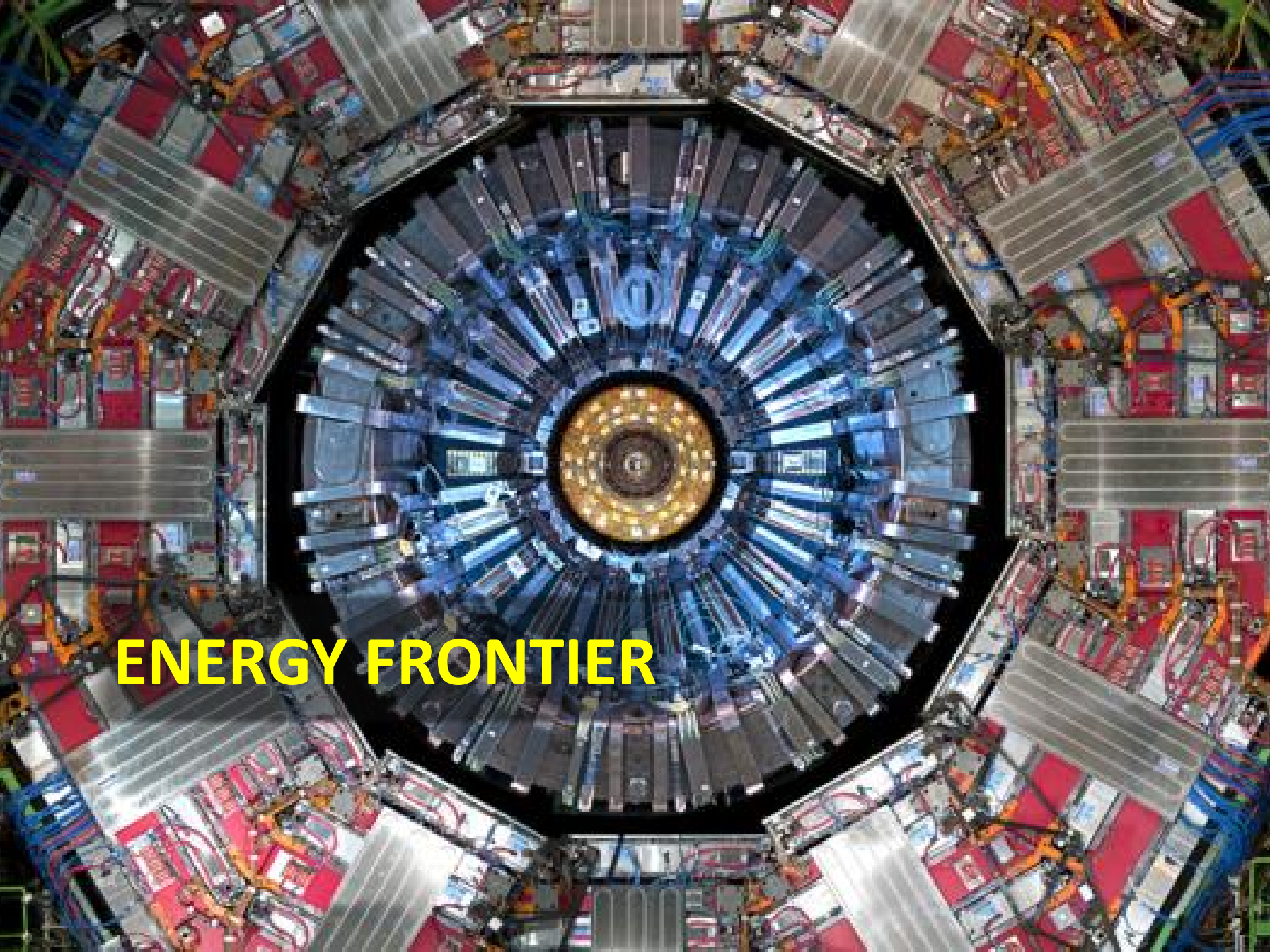
LHC-based areas:

- Experiment Research, Operations, Upgrades (incl. "generic" Detector R&D)
- Accelerator-based efforts


ENERGY FRONTIER

HEP Energy Frontier Experiments

Experiment	Location	CM Energy; Status	Description of Science	# Institutions; # Countries	#U.S. Institutions	#U.S. Coll.
DØ (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 [LHC; 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	177 Institutions; 38 Countries	40 Univ., 4 National Labs	583
CMS (Compact Muon Solenoid)	CERN, Large Hadron Collider [LHC; 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	190 Institutions; 42 Countries	49 Univ., 1 National Lab	680

Tevatron data as of August 2013; LHC data as of December 2013.

- **Main scientific thrusts**
  - **Tevatron at Fermilab ($p\bar{p}$ collider): DØ Collaboration, CDF Collaboration**
  - **LHC at CERN (pp collider): CMS Collaboration, ATLAS Collaboration**
- **U.S. is single biggest collaborator in both ATLAS and CMS experiments at LHC**
  - **US-ATLAS: ~20% of the international ATLAS Collaboration**
  - **US-CMS: ~31% of the international CMS Collaboration**
- **Lepton Collider (mainly ILC): initiated small, direct support (~6 FTE) for detector R&D efforts from Energy Frontier research program**
  - **at universities through DOE grant awards**
  - **at Fermilab, ANL, and plan for FY15, at SLAC**

Energy Frontier Physics Program: Status

Large Hadron Collider (LHC) at CERN

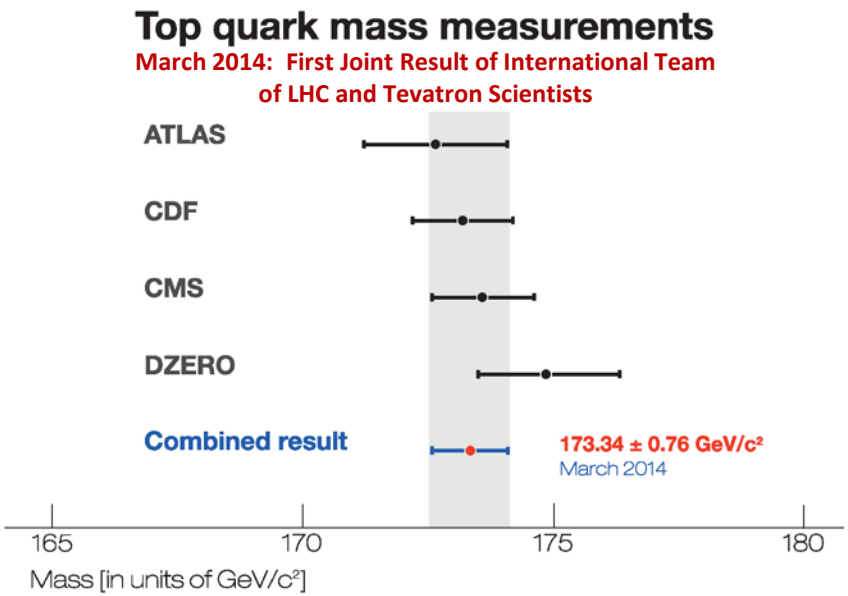
- **Run 1 (proton) completed in Dec. 2012**
- **Working with experiments to execute plan for U.S. contributions to "Phase-1" [2018] upgrades**
  - **CD-0 approval: September 18, 2012**
  - **CD-1 approval: October 17, 2013**
    - CMS: $29.2M – 35.9M
    - ATLAS: $32.2M – 34.5M

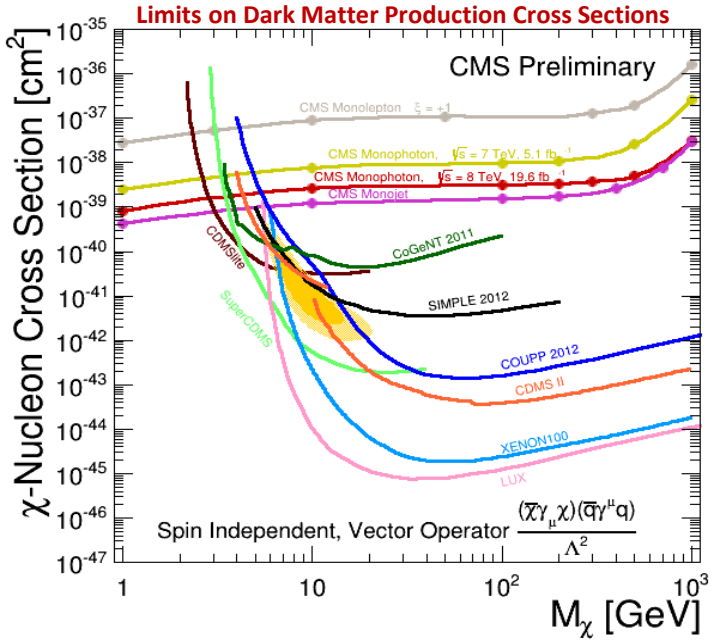
Fermilab Tevatron (DØ and CDF)

- **Working with DØ and CDF collaborations on completion of legacy analyses as part of its ramp-down research program**
  - **most efforts completed in FY13 and FY14**
  - **final papers (*e.g.*, $M_W^{Tevatron}$): FY15**

Current program

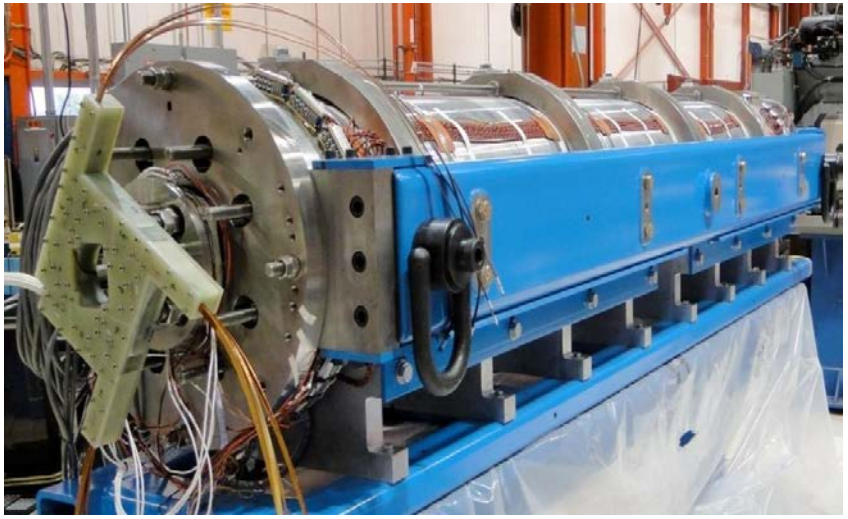
- **Analyze and publish results from LHC Run 1**
- **2013-2014 shutdown:**
  - **splice repairs in LHC magnets (completed March 2014)**
  - **detector maintenance and consolidation**
  - **upgrades and repairs**
- **In 2015: resume [Run 2] at 13~14 TeV: 100 fb^{-1}**
  - **Continue precision Higgs measurements**
  - **Focus on new physics**





Energy Frontier Planning & Issues (I)

- LHC is planned to be central component of the U.S. Energy Frontier program for next ~20 year
  - U.S. investments $\Rightarrow$ leading roles in the [global] LHC physics collaborations
- Considering major update to LHC around 2023 to extend discovery potential
  - high-luminosity LHC program (HL-LHC) to explore new physics and new dynamics for W/Z, top, and Higgs at TeV energies
    - increase LHC luminosity by a factor of 10 beyond its design value
    - ensure U.S. scientists are at the forefront of full physics opportunities offered at the LHC
- U.S. leadership in superconducting magnet technology generally, and now Nb_3Sn in particular, is widely recognized and acknowledged
- U.S. LHC Accelerator Research Program (LARP) aims to leverage this expertise to serve needs of HEP community
  - Consists of four U.S. laboratories: BNL, Fermilab, LBNL, and SLAC
  - Aims to realize the full capability of the LHC and maximize the discovery potential of U.S. investments in the LHC



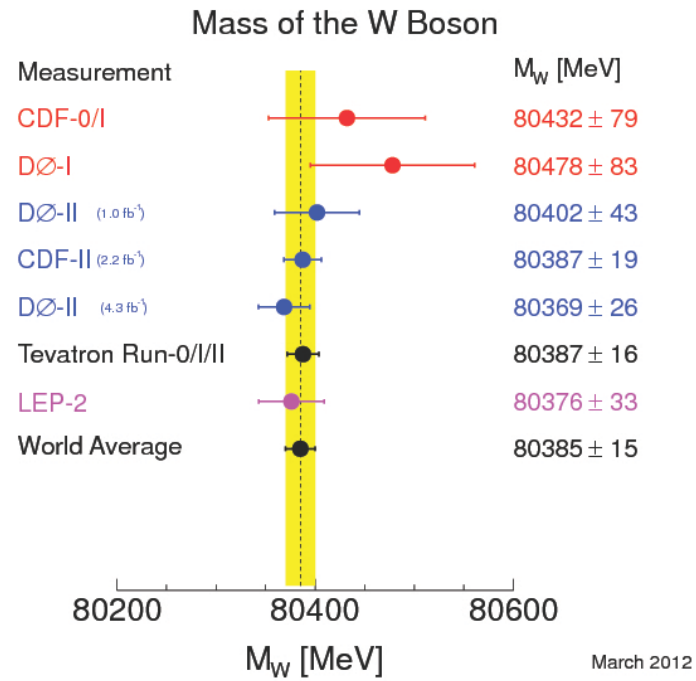
- Discussions with CERN about follow-on to LHC Agreement proceeding
  - Framework of a bilateral agreement currently under review at U.S. Department of State
  - Will be needed to seek approval of DOE CD-0 for the HL-LHC ("Phase-2") upgrade project

Energy Frontier Planning & Issues (II)

- **Significant collaborations with other regions on future colliders will require a high-level approach between governments**
  - **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**
- **Japanese-hosted ILC under consideration**
  - **Preparations for ILC accelerator & experiments have been long in the making, foreseeing a global project**
  - **Modest ground-level R&D efforts can continue as funding allows**
  - ***For e.g.,* through Energy Frontier research program**
    - **physics and detector optimization studies, including detector modeling and simulations**
    - **electron and hadron calorimetry development for SiD and ILD**
    - **technology choice for pixellated vertex detectors**
    - **development of particle flow algorithms**
  - ***For e.g.,* through Accelerator R&D program**
    - **SRF R&D, including high-Q work; cryogenic cooling and engineering studies**
    - **beam dynamic studies**
  - **Coordination and membership roles & responsibilities to ILC-based organizations**
    - **such activities have been enabled through past- and present-DOE funded groups to allow for progress and to achieve key milestones towards global ILC efforts**

Energy Frontier Research:
Next Steps and General Observations (I)

- **Tevatron**
  - **Complete ramp-down of Tevatron research program during next ~ year with final physics results**
    - **Final studies on Higgs with full dataset & analysis improvements** ***(this year)***
    - **Legacy measurements**
      - **W mass ($\delta M_W^{Tevatron} \rightarrow$ 10 MeV) with ~10 fb^{-1}**
      - **Top quark: precision mass, forward-backward asymmetry**
      - **QCD, heavy-flavor physics**

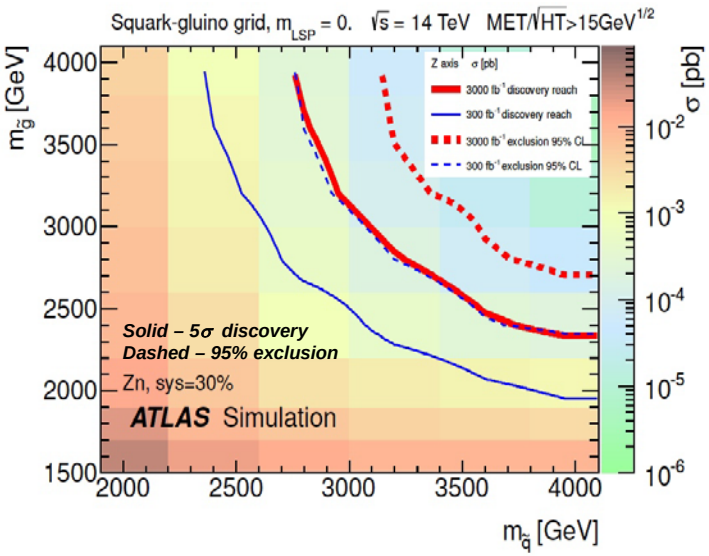


  - **Past years, based on grants funded through DOE/HEP, guidance to institutions was given to complete most Tevatron research by end-FY13**
  - **Going forward, DOE/HEP funding for the Tevatron program through Energy Frontier research expected until end-FY14**

- **During FY15 Comparative Review FOA, primarily due to budgetary factors, will not be directly supporting proposals with Tevatron research scope**

Energy Frontier Research:
Next Steps and General Observations (II)

- **LHC**
  - Discovery of the Higgs boson by CMS and ATLAS
    ⟹ measure properties: couplings, spin/parity
    - Are there multiple Higgs bosons?
  - Publish physics results with $\sqrt{s}$ = 8 TeV data [Run I]
    - Higgs, top, and electroweak measurements
    - Search for new physics BSM: exotic particles, SUSY, …
    - QCD, heavy-flavor physics



- **… and steps in next ~5-10 years**
  - LHC will increase energy ($\sqrt{s}$ = 13~14 TeV), luminosity (L > 10^{34} cm^{-2}s^{-1}) for 2015-2017 Run 2 (~100 fb^{-1}); and post-Phase-1: 2019-2021 Run 3 (~300 fb^{-1}); HL-LHC Phase-2: 2023-2025
    - expand sensitivity reach for new physics
    - Given next Comparative Review application deadline is prior to start of Run 2, proposals should address group's research plans and corresponding timelines during Run 2
  - Phase-1 upgrade *or* Phase-2 R&D activities will mix with physics research-related efforts
    - proposals are encouraged to address a ***balanced*** effort in both with scopes ***aligned*** through the U.S.-CMS and U.S.-ATLAS program

- **Other general observations**
  - Encourage community to exploit and interact with LHC Physics Center (LPC, CMS) or Analysis Support Center (ASC, ATLAS)

Research Scientists (RS)

- Efforts of RS that have support requested in a comparative review proposal is evaluated by the panel
- Guidance to PIs given in Q&A of FAQ…
  - Requests to support RS dedicated full-time (and long-term) to operational and/or project activities for an experiment will not be supported by respective frontier research areas
  - If RS conducting physics research-related activities, requests [scaled to % of time on such efforts] can be included
    - any final support will be based on the merit review process
- Common [past] reviewer comments that result in unfavorable merit reviews:
  - 'RS conducting scope of work typically commensurate at the postdoctoral-level…'
  - 'RS involved in long-term operation/project activities with minimum physics research efforts…'
    - such efforts may review well in a DOE review of the operation/project program but not as well in a review of the experimental research program
- What is "physics research-related activities"?
  - Object reconstruction/algorithm development, performance studies, data taking and analysis, and mentorship of students & postdocs in these areas
  - Scientific activities in support of detector/hardware design and development
- From the research program, cases become an issue when operations/projects become the *dominant* activity long-term
  - A well-balanced portfolio that includes physics research-related activities is encouraged
  - Important to narrate complete plans in 2-page "appendix narrative" outlined this morning…

HEP BUDGET AND ISSUES

HEP Budget Overview

- **Budget philosophy is 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**
- **FY 2015 President's Budget Request for DOE/HEP is down -6.6% relative to FY 2014**
- **Impacts to DOE/HEP:**
  - **Several new efforts may be delayed but efforts underway to minimize impacts**
    - **FY15 request includes two MIEs for ATLAS and CMS detector upgrades (Phase-I), required to leverage discovery opportunities at the LHC**
  - **U.S. leadership/partnership capabilities will be challenged by others**
- **Key areas in FY 2015 President's Budget Request**
  - **Maintaining forward progress on new projects while minimizing the impact of reductions in Research to the extent possible**
  - **The FY 2015 budget request supports:**
    - **Full operation of existing HEP facilities and experiments**
    - **MIEs for the ATLAS and CMS Detector Upgrades (Phase-I)**
    - **Planned construction funding profile for Mu2e**
    - **Capital equipment funding for LSST, Muon *g*-2, and towards Belle-II**
    - **Accelerator Stewardship funding for new research activities in high-impact areas**

High Energy Physics Budget Highlights (I)

- **Research and Facilities Operations:**
  - **Energy Frontier: LHC data taking resumes in 2015**
    - **The U.S. will continue to play a leadership role in LHC discoveries and is actively engaged in executing initial [Phase-1] upgrades to the LHC detectors**
  - **Intensity Frontier: The Fermilab program continues its evolution as the leading accelerator facility on the intensity frontier**
    - **The newly completed NOνA detector begins taking physics data in FY 2015**
    - **Building several new experiments to access new phenomena that cannot directly be observed at the LHC**
      - **such as Mu2e, Muon *g*-2, and the MicroBooNE experiments**
  - **Cosmic Frontier: Advance our understanding of dark matter and dark energy**
    - **The recently-commissioned Dark Energy Survey continues its five-year mission, looking for the subtle effects of dark energy in shaping the evolution of universe**
      - **this search will be significantly extended in the future by the Large Synoptic Survey Telescope (LSST) now under construction**
    - **The search for dark matter will enter new territory with R&D and design of selected next-generation dark matter detector technologies that can advance this field by an order of magnitude in sensitivity**

High Energy Physics Budget Highlights (II)

- **Technology R&D:**
  - A new HEP subprogram that focuses on the broader applications of HEP-developed accelerator technologies known as "Accelerator Stewardship"
    - initiated in FY 2014
    - expected to begin new pilot programs and open new funding opportunities in 2015 to address high-impact R&D topics

- **Construction/Major Items of Equipment [MIEs] – (see also following & back-up slides)**
  - Mu2e will complete its design phase in FY 2015 and move into full construction
  - Long Baseline Neutrino program continues its design phase, which may include enhanced capabilities based on the level of partnership contributions
    - potential international collaborators in Europe, Asia, and South America have expressed interest
  - Funding is provided to initiate fabrication for new MIEs for the LHC Phase-I detector upgrades
  - Continue planned funding profiles of existing MIE projects (*e.g.*, Belle-II and LSST)

FY 2015 High Energy Physics Budget

(dollars in thousands)

Description	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request
Energy Frontier	149,446	154,687	153,639
Intensity Frontier	274,412	275,043	251,245
Cosmic Frontier	80,063	99,080	101,245
Theory and Computation	66,398	62,870	58,850
Advanced Technology R&D	142,291	122,291	114,242
Accelerator Stewardship	3,132	9,931	19,184
SBIR/STTR	0	21,619	20,595
Construction (Line-Item)	11,781	51,000	25,000
Total, DOE High Energy Physics	**727,523 [a,b]**	**796,521**	**744,000**
DOE Office of Science (SC)	**4,681,195**	**5,066,372**	**5,111,155**

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

[a] The FY 2013 Actual is reduced by $20,791,000 for SBIR/STTR.

[b] FY 2013 Actual reflects sequestration.

HEP Physics Funding by Activity

(dollars in thousands)

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request
Research	**361,766**	**370,447**	**352,227**
Facility Operations and Experimental Support	**265,123**	**276,561**	**264,208**
Projects	**100,634**	**127,894**	**106,970**
Energy Frontier	3,000	12,000	15,000
Intensity Frontier	63,494	37,000	24,970
Cosmic Frontier	19,159	24,694	41,000
Theory and Computation	3,200	3,200	1,000
Construction	11,781	51,000	25,000
SBIR/STTR	**0**	**21,619**	**20,595**
Total, DOE High Energy Physics	**727,523 [a,b]**	**796,521**	**744,000**

[a] The FY 2013 Actual is reduced by $20,791,000 for SBIR/STTR.

[b] FY 2013 Actual reflects sequestration [~$748.3M with SBIR/STTR].

HEP Energy Frontier

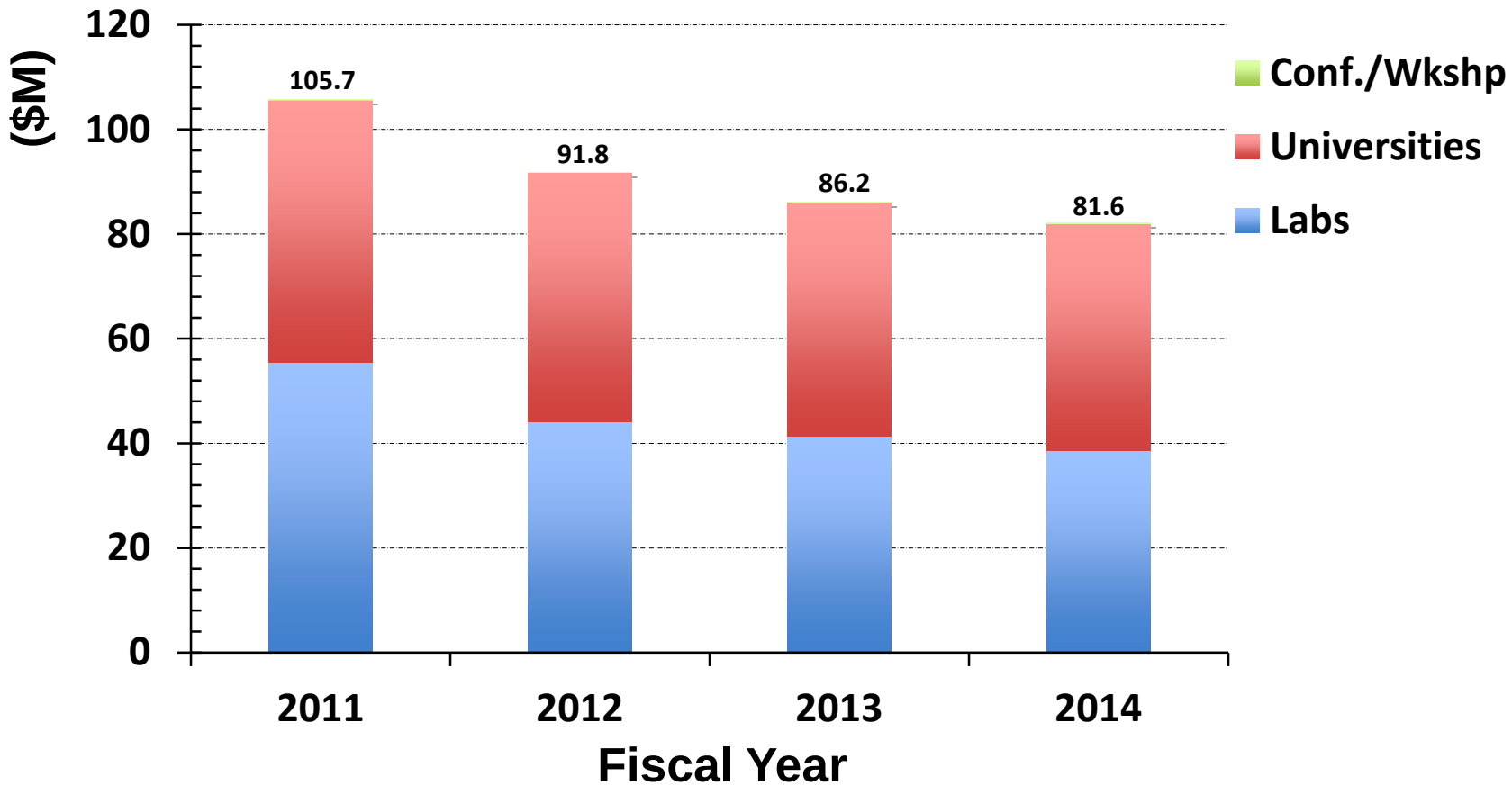
Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request	Comment
1) Research	**86,172**	**81,579**	**79,132**	Redirect research to LHC detector upgrades
2) Facilities	**63,274**	**73,108**	**74,507**	
a) LHC Operations	56,912	56,774	55,522	US-CMS and US-ATLAS Operations Program
b) Projects	3,000 [(a)]	12,000 [(a)]	15,000	CMS and ATLAS Phase-1 Upgrades
CMS Upgrade	1,500	6,000	7,500	*First TEC request in FY15 (non-add)*
ATLAS Upgrade	1,500	6,000	7,500	*First TEC request in FY15 (non-add)*
c) Other	3,362	4,334	3,985	IPAs, Detailees, Reviews
TOTAL: Energy Frontier	**149,446**	**154,687**	**153,639**	

[(a)] In FY13 and FY14 appropriations, support for LHC Phase-I was contained under Energy Frontier Research.

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

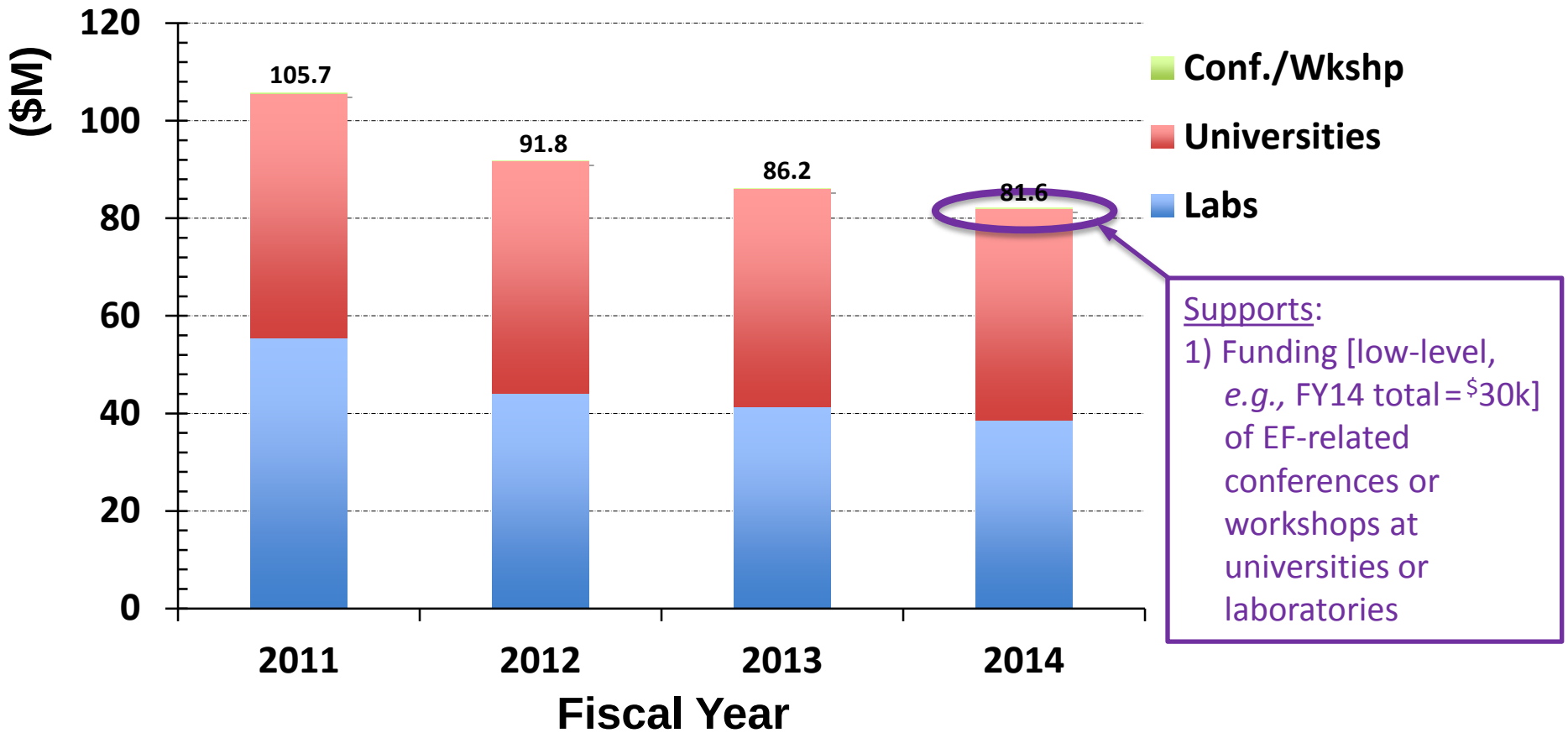
- **Reductions in research funding primarily due to**
  - **Completion of the Fermilab Tevatron research program**
  - **Reductions in research activities to support current and future experimental capabilities**
- **Offset by increase in funding for Phase-1 LHC detector upgrade activities (ATLAS, CMS)**

Energy Frontier Research Budget



- **FY14 core research budget saw reduction of ~5% relative to FY13**
  - driven by end-game [post 2011] of Tevatron physics program + overall programmatic reductions to support future LHC experimental capabilities
  - Reduction at labs (-7%) higher than universities (-3%), and hence, end-FY14 priority given to supplement labs as well as support necessary CMS & ATLAS US leadership roles

Energy Frontier Research Budget



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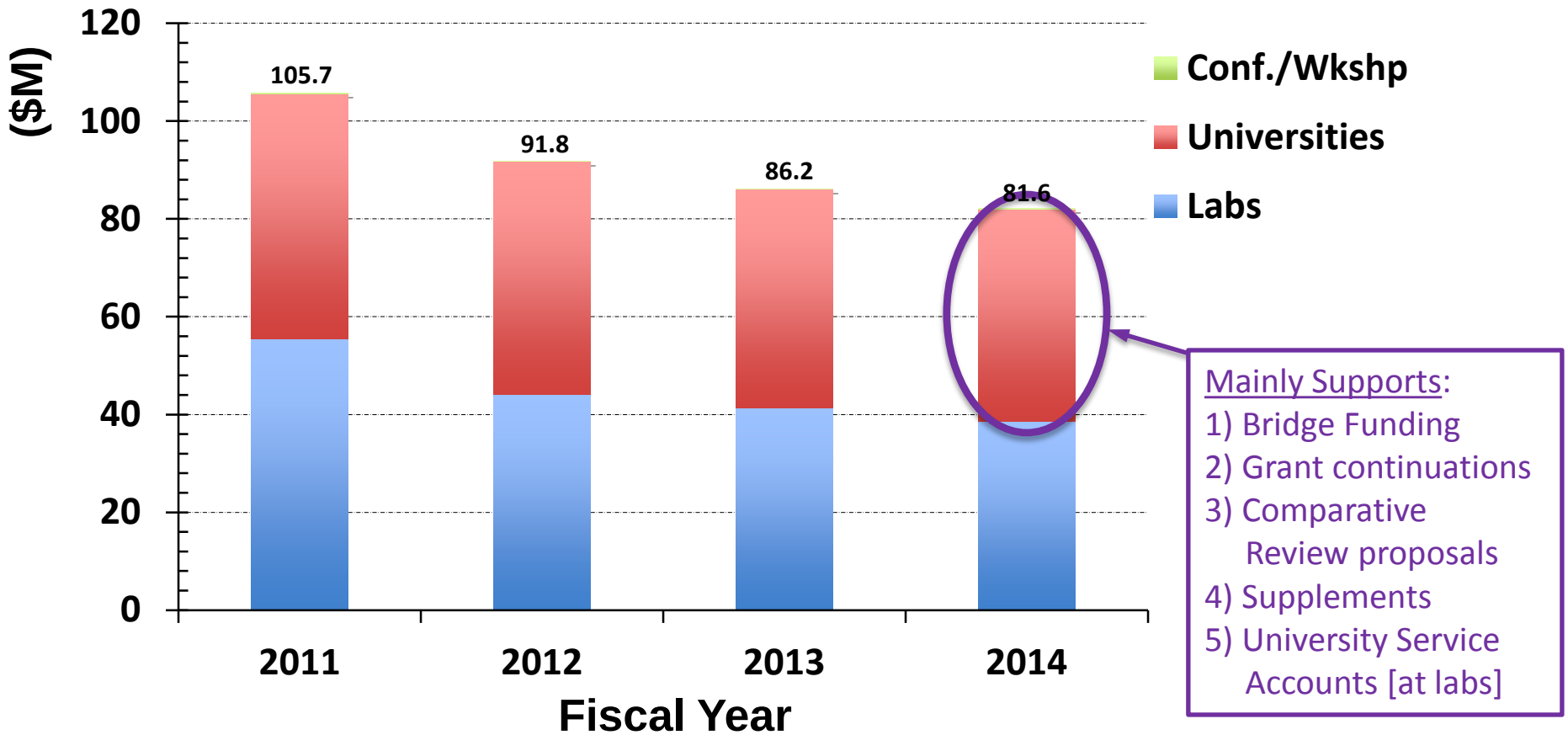
Energy Frontier Research Budget



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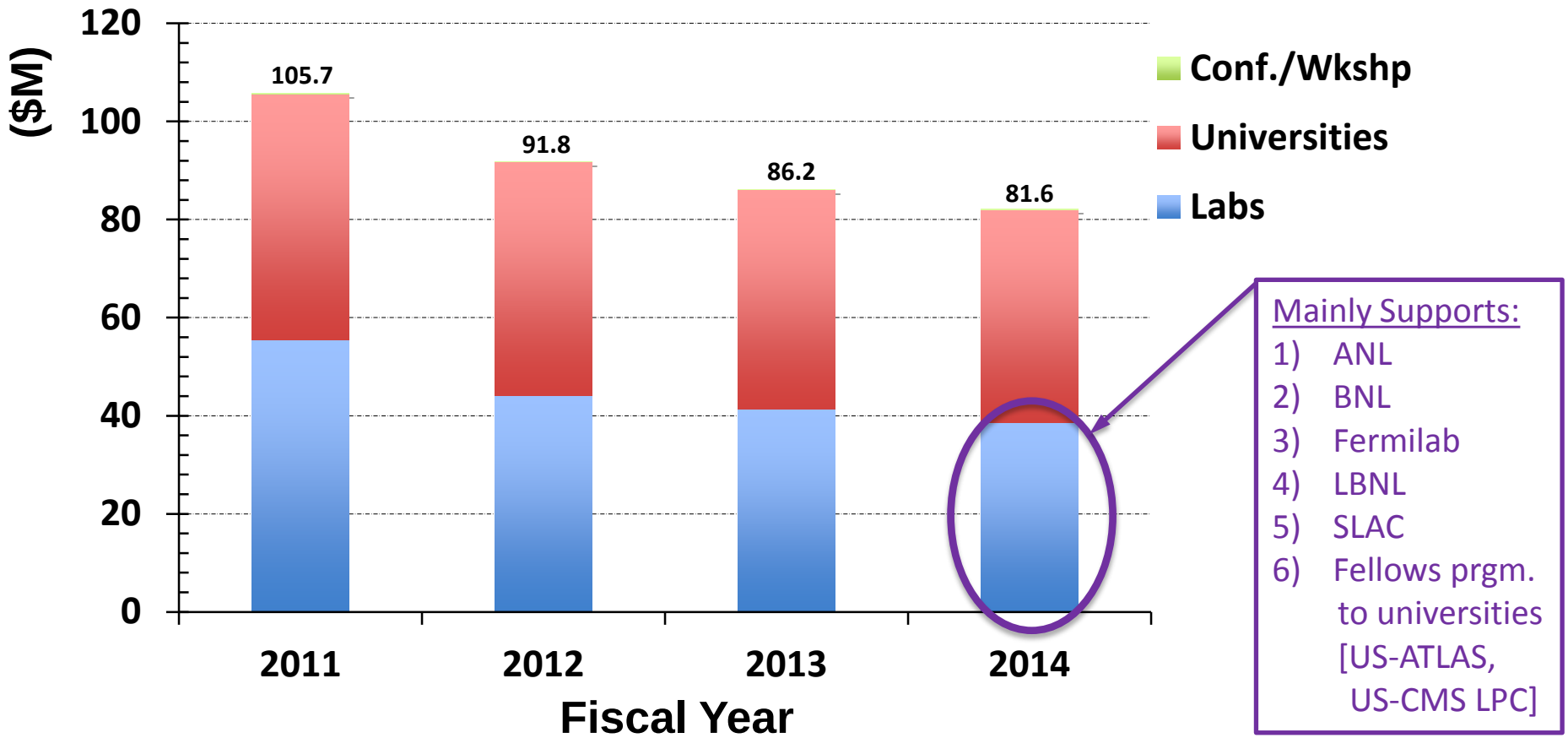
Energy Frontier Research Budget



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HEP Physics MIE Funding

(dollars in thousands)

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request	Description
Energy	1,500*	6,000*	7,500	LHC CMS Detector Upgrades
Energy	1,500*	6,000*	7,500	LHC ATLAS Detector Upgrades
Intensity	19,480	0	0	NOνA ramp-down
Intensity	5,857	0	0	MicroBooNE
Intensity	5,000	8,000	970	Belle-II
Intensity	5,850	9,000	9,000	Muon *g*-2 Experiment
Cosmic	1,500	0	0	HAWC
Cosmic	8,000	22,000	35,000	Large Synoptic Survey Telescope Camera (LSSTcam)
TOTAL MIE's	**48,687**	**51,000**	**59,970**	

*** Other Project Costs (OPC) funding was supplied in FY 2013 and FY 2014. FY 2015 is the first request for TEC funding.**

MIE Issues

- **Only able to implement two new MIE starts in FY15 request**
  - **ATLAS and CMS Phase-I Detector Upgrades**
    - **Performance baseline and start construction for LHC Phase-1 Detector Upgrades: CD-2/3 (DOE Critical Decision) reviews scheduled for end-FY14**
      - **CMS: August 5-7, 2014**
      - **ATLAS: September 15-16, 2014**

- **Other new MIE projects begun in prior years are requesting fabrication funds required to maintain schedule**
  - **Belle-II (Tsukuba, Japan)**
  - **Large Synoptic Survey Telescope (Chile, South America)**
  - **Muon *g*-2 Experiment (Fermilab)**

- **Long-term planning [P5] report will impact prioritization of future MIEs**
  - **2nd Generation Dark Matter (G2DM) detectors**
  - **Dark Energy Spectroscopic Instrument (DESI)**

PARTICLE PHYSICS PROJECT PRIORITIZATION PANEL (P5)

Energy Frontier – Snowmass Vision

- **Driven by the discovery of the Higgs, Snowmass outlined a research program at the Energy Frontier focusing on three fronts**
  - **Determine properties of the Higgs boson as accurately as possible**
  - **Make precision measurements of heavy particles that carry the imprint of the Higgs field, such as W/Z and top**
  - **Search for new particles predicted by models of the Higgs and EWSB**

LHC ↓ HL-LHC

Drives the Energy Frontier program forward for next 15-20 years

- **Precision study of Higgs properties at the few percent level**
- **Search for new particles**
- **Probe for new dynamics of W/Z and Higgs at TeV energies**
- **With ~5 x 10^8 observable $t\bar{t}$ events per experiment, study rare decays for signs of new physics**

ILC

Continue the Energy Frontier program with a lepton collider

- **Sub-percent, model-independent study of Higgs properties**
- **Improved precision in our understanding of W/Z and top to allow discovery of new physics**
- **New particle searches complementary to the LHC**

Energy Frontier – Facilities

Hadron Colliders

- Tevatron operations ended September 30, 2011
- LHC operational since ~2010
  - Phase-I LHC experimental upgrades now being executed
- High Luminosity LHC (HL-LHC) currently in R&D phase with installation ~2023
- More distant options for higher energy being explored
  - *e.g.,* HE-LHC, VLHC

Lepton Colliders

- International Linear Collider (ILC)
  - Initiative from Japan to host
  - 5-volume Technical Design Report (TDR) published June 12, 2013
  - Allows for staged approach to E_{cm}
- More distant options for higher energy being explored
  - *e.g.,* CLIC, μ collider, TLEP

- Other studies initiated for future collider options
  - Future Circular Collider (FCC) — Europe
    - five-year international design study with an emphasis on 100 TeV hadron collider
  - Circular Electron-Positron Collider + Super pp Collider (CEPC + SppC) — China
    - Phase-1: CEPC Higgs factory (240-250 GeV); Phase-2: SppC (50-70 TeV)

P5 Strategic Plan

- HEPAP is DOE's primary panel for providing advice on the status and direction of the field
  - P5, a subpanel of HEPAP, guides our strategic plan
  - Actual implementation of any plan at the agencies is the responsibility of program management

- The P5 report "Strategic Plan for U.S. Particle Physics in the Global Context" represents a consensus vision developed by particle physics to identify the most exciting and productive areas of research and how we pursue them

- P5 recommended that we "pursue the most important opportunities wherever they are", "host unique, world-class facilities that engage the global scientific community" and "pursue a program to address the 5 science Drivers":

Use the Higgs boson as a new tool for discovery

Pursue the physics associated with neutrino mass

Identify the new physics of dark matter

Understand cosmic acceleration: dark energy and inflation

Explore the unknown: new particles, interactions, and physical principles.

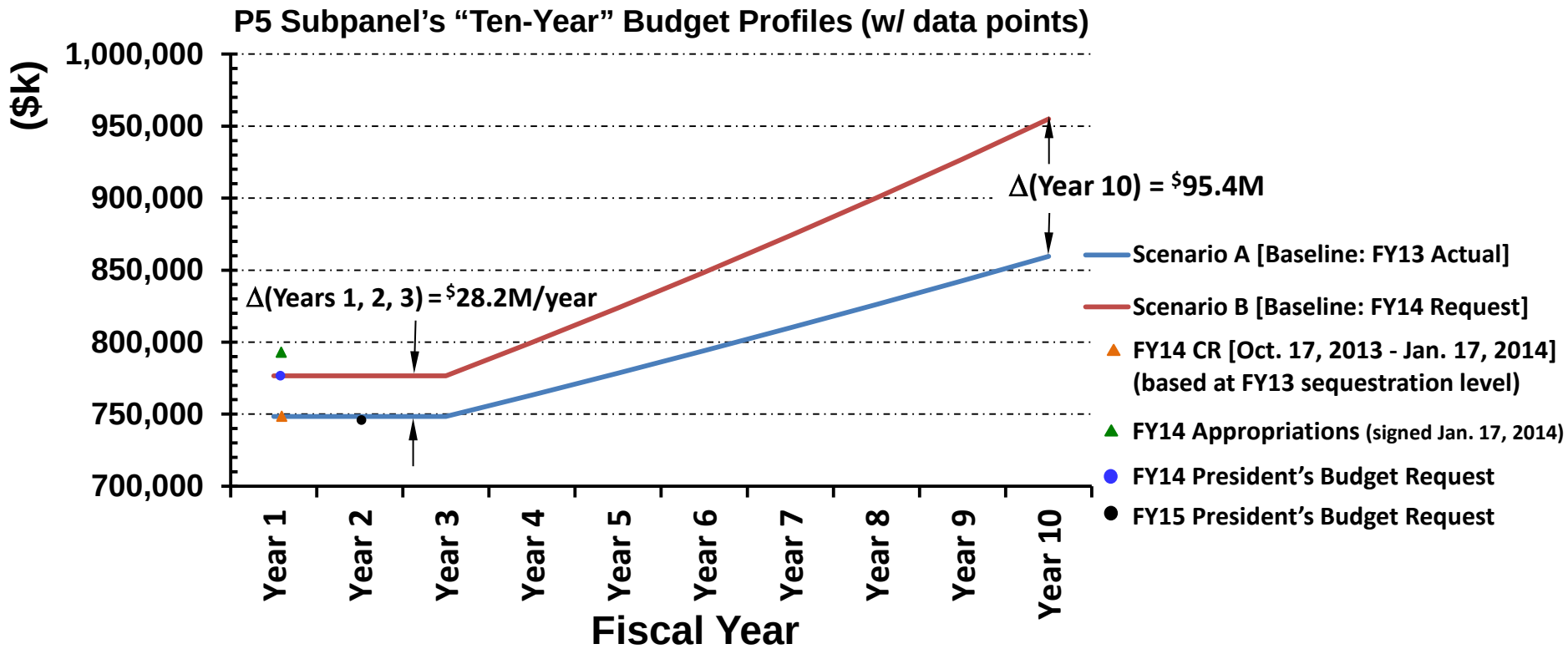
Energy Frontier

Intensity Frontier

Cosmic Frontier

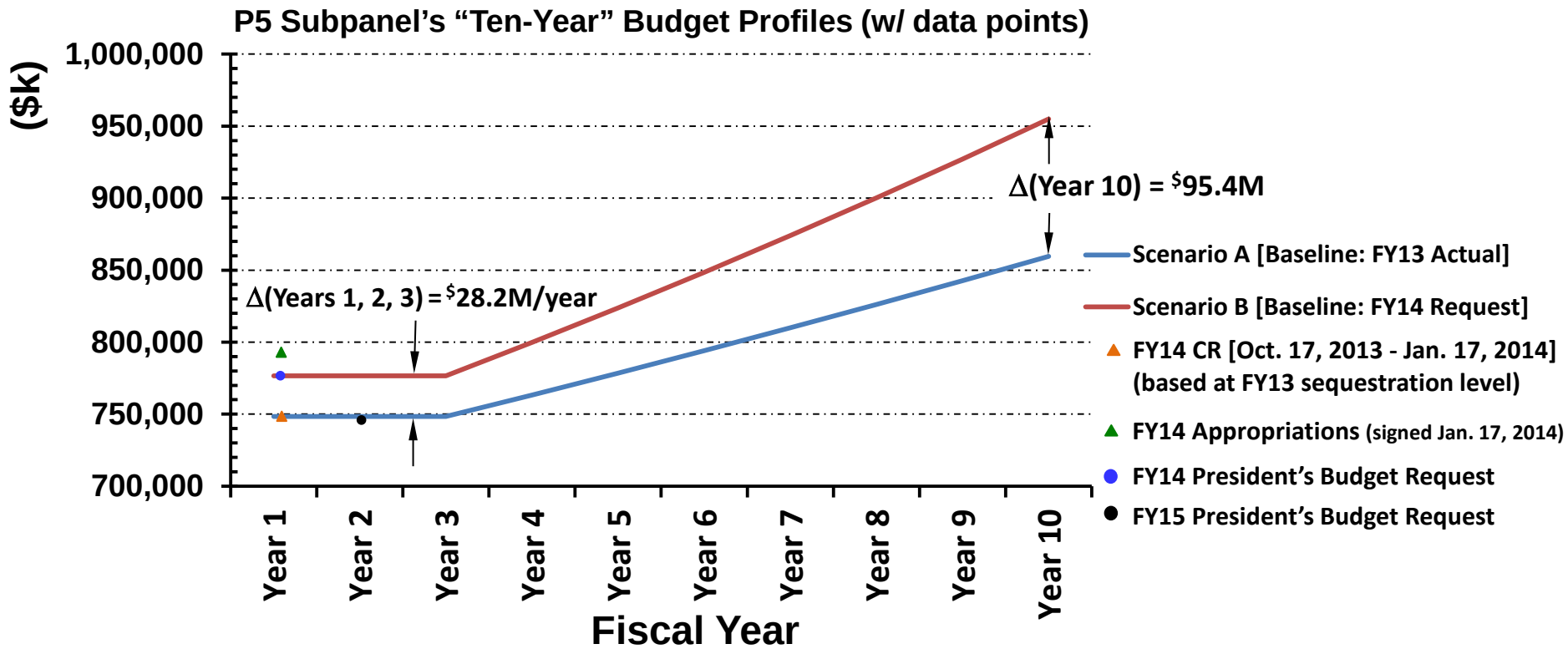
- P5 put forth 29 recommendations to define the global strategic plan for U.S. HEP

P5 Budget Scenarios *vs.* Where we are?



- **Prioritize an optimized HEP program under 10-year HEP budget profiles:**
  - **Scenario A: FY 2013 budget baseline: flat for 3 years, then +2% per year**
  - **Scenario B: FY 2014 President's budget request baseline: flat for 3 years, then +3% per year**
    - **difference between Scenarios A and B integrated over the 10-year period: ~$540M**
  - **Scenario C *(not shown in above plot)*: Unconstrained budget scenario.**
    - **beyond A and B, prioritize specific activities *" … needed to mount a leadership program addressing the scientific opportunities identified by the research community."***

P5 Budget Scenarios *vs.* Where we are?



- **FY15 President's Budget Request (PBR) was developed prior to announcement of P5 plan**
  - **FY15 Request is slightly <u>below</u> Scenario A**
  - **FY14 Appropriations is <u>above</u> Scenario B**
  - **It is difficult to know at this stage exactly which scenario we are working in**
    - **We have communicated adjustments to the FY15 PBR to Congress at their request**
    - **We have also made the arguments for Scenario B funding levels**

P5 Implementation and LHC

- **P5 Recommendation #10 contains three aspects:**
  - **Completing the LHC phase-1 upgrades**
  - **Continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS)**
  - **States that "the LHC upgrades constitute our [P5] highest-priority near-term large project"**
- **As noted earlier, U.S. responsibilities and roles for the Phase-1 CMS and ATLAS detector upgrades are on-track and now being executed; Phase 1 accelerator upgrades underway via LARP.**
- **Phase-2 (2023-2025, Upgrades for HL-LHC):**
  - **DOE/HEP efforts for HL-LHC have begun across three fronts:**
    - **Early discussion stage with CERN, the international funding agencies, and LHC Upgrade Cost Group (UCG) to understand scope and costs of overall upgrades**
      - **Full scope and U.S. share will require iterative process with CERN and UCG "scrutiny" group**
    - **Working with NSF as part of the DOE-NSF interagency partnership, necessary for success**
    - **Discussing with US-ATLAS and US-CMS management to define overall plan for project, including understanding prioritized scope/costs, institutional responsibilities, and timeline**
- **Opportunities for initial R&D activities on Phase-2 are possible through**
  - **U.S. LHC Ops program: in near term, ~$2-3M per experiment for such R&D activities**
  - **A "balanced" research & upgrade proposal submitted through the HEP Comparative Review FOA in the Energy Frontier subprogram**
  - **In either case, institutions will need to *align with prioritized plans* of US-CMS or US-ATLAS**

P5 Implementation and ILC

- **P5 Recommendation #11 states:** ***"Motivated by the strong scientific importance of the ILC and the recent initiative in Japan to host it, the U.S. should engage in modest and appropriate levels of ILC accelerator and detector design in areas where the U.S. can contribute critical expertise. Consider higher levels of collaboration if ILC proceeds."***
- **For "appropriate" levels and plans, currently waiting further discussions with the Japanese government**
- **DOE discussing with the Americas Linear Collider Committee (ALCC) to develop program for future R&D efforts – for both Detector R&D and Accelerator R&D**
  - **Encourage the scope of U.S.-based R&D efforts be coordinated through ALCC**
- **Initially, site-specific accelerator R&D and design will be near-term priority of R&D efforts towards the ILC**
  - **Initially implemented through redirection at the labs**
  - **Labs have been asked to begin planning roles and responsibilities of ILC-based activities**
- **Subsequent plans to integrate ILC Detector R&D activities, where funding allows**
  - **Near-term activities will depend on HEP fiscal budgets and will focus on:**
    - **LHC Detector Upgrades (Phase-2)**
    - **LAr for Long-Baseline Neutrino Facility (LBNF)**
    - **Dark Matter (*e.g.*, G2DM and G1 ops)**

Closing Remarks

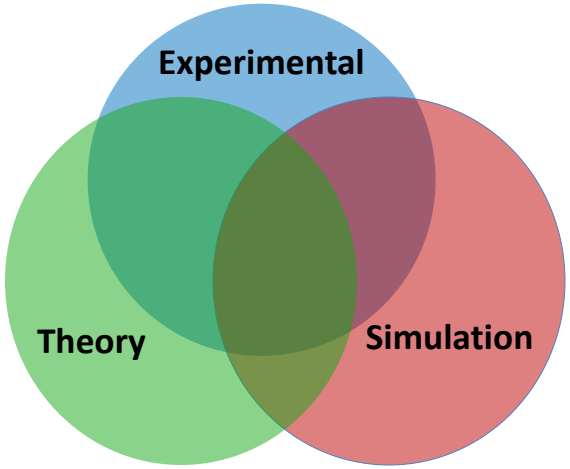
- **Energy Frontier activities primarily focused within two areas:**
  - Efforts at LHC on ATLAS & CMS are now across 5 different fronts
    - complete Run 1 data analyses with ~400 Run 1 publications expected from each experiment
    - preparations for experimental operations during Run 2, which resumes next year
    - execute Phase-1 (2018) detector upgrades
    - initiate R&D for HL-LHC Phase-2 (2023) upgrades
    - early stages of developing U.S. HL-LHC Project
  - Modest R&D investments for future linear colliders as funding allows

- **Budgets**
  - FY14 appropriations has allowed projects — delayed either by extended Continuing Resolutions or by the FY13 sequester — to get moving
  - Near-term appropriations (FY15, FY16) will be very important in setting the future course

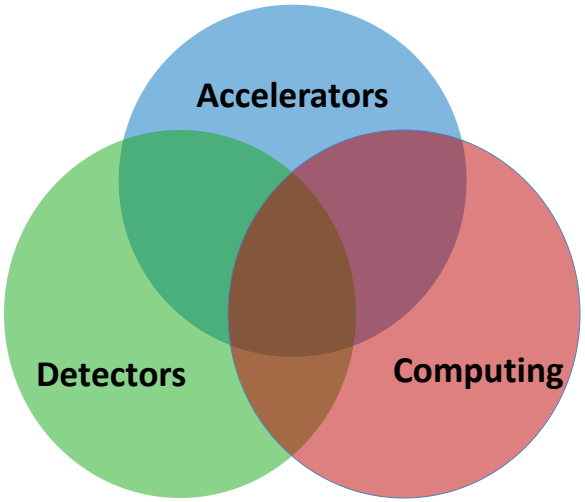
- **Implementation of P5 strategic plan**
  - Agencies working to adapt recommendations as quickly as possible, but certain ones will take time
  - For projects planned within the Energy Frontier portfolio, it is important that U.S. collaborators are aligned to U.S. collaboration's plans to proceed during the coming years
    - DOE will work closely with U.S. collaboration's management (*e.g.*, US-ATLAS, US-CMS, or ALCC for ILC) as well as international partners to define U.S. roles and responsibilities

REFERENCE SLIDES

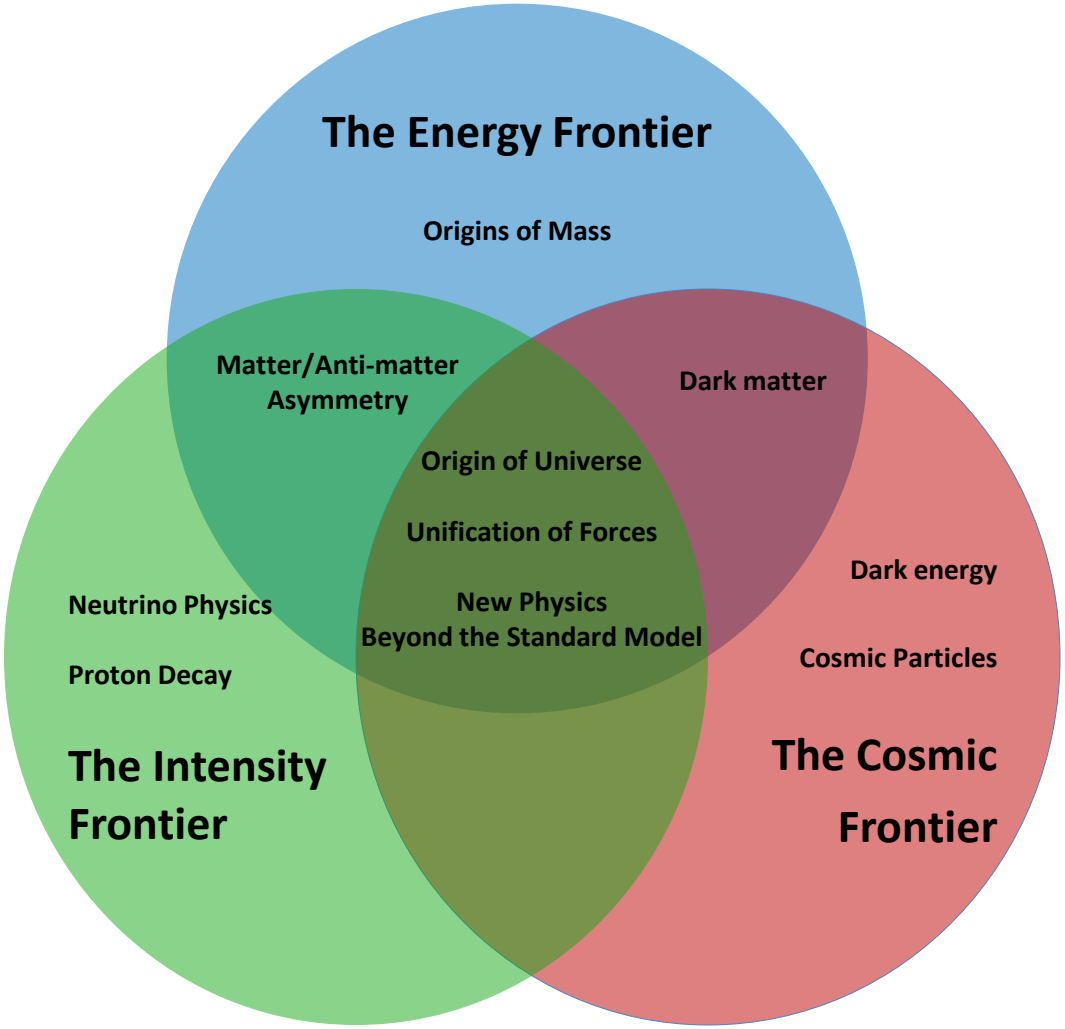
HEP Physics and Technology



Along Three Paths

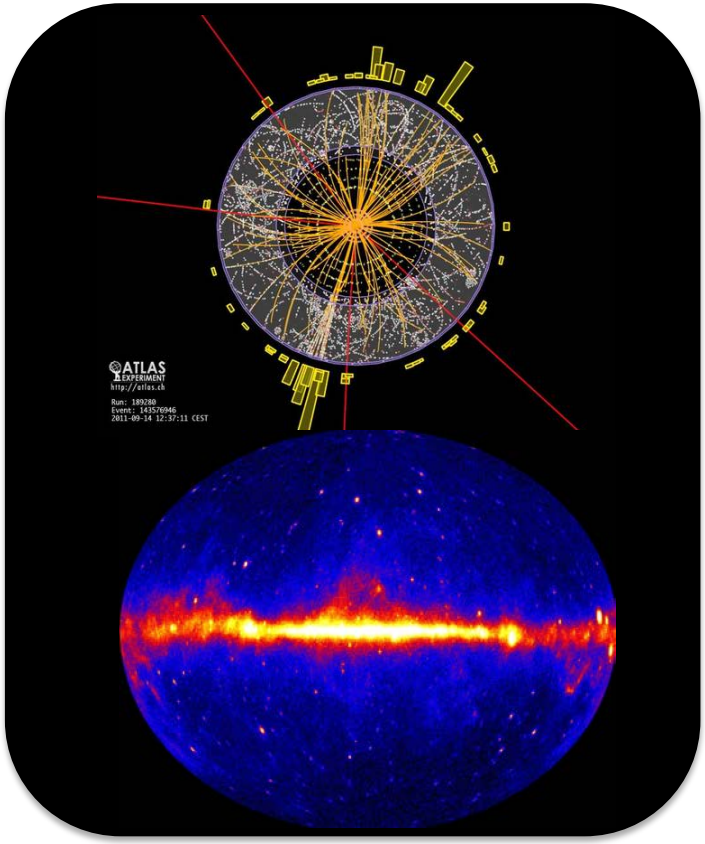


Enabled by
Advanced Technologies



Physics Frontiers

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 the 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 — Supports R&D at national labs and universities in beam physics, novel acceleration concepts, beam instrumentation and control, high gradient research, particle and RF sources, superconducting magnets and materials, and superconducting RF technology.

Detailed LHC schedule — Beyond Long Shutdown 1 (LS1)

Only EYETS (19 weeks) (no Linac4 connection during Run 2)

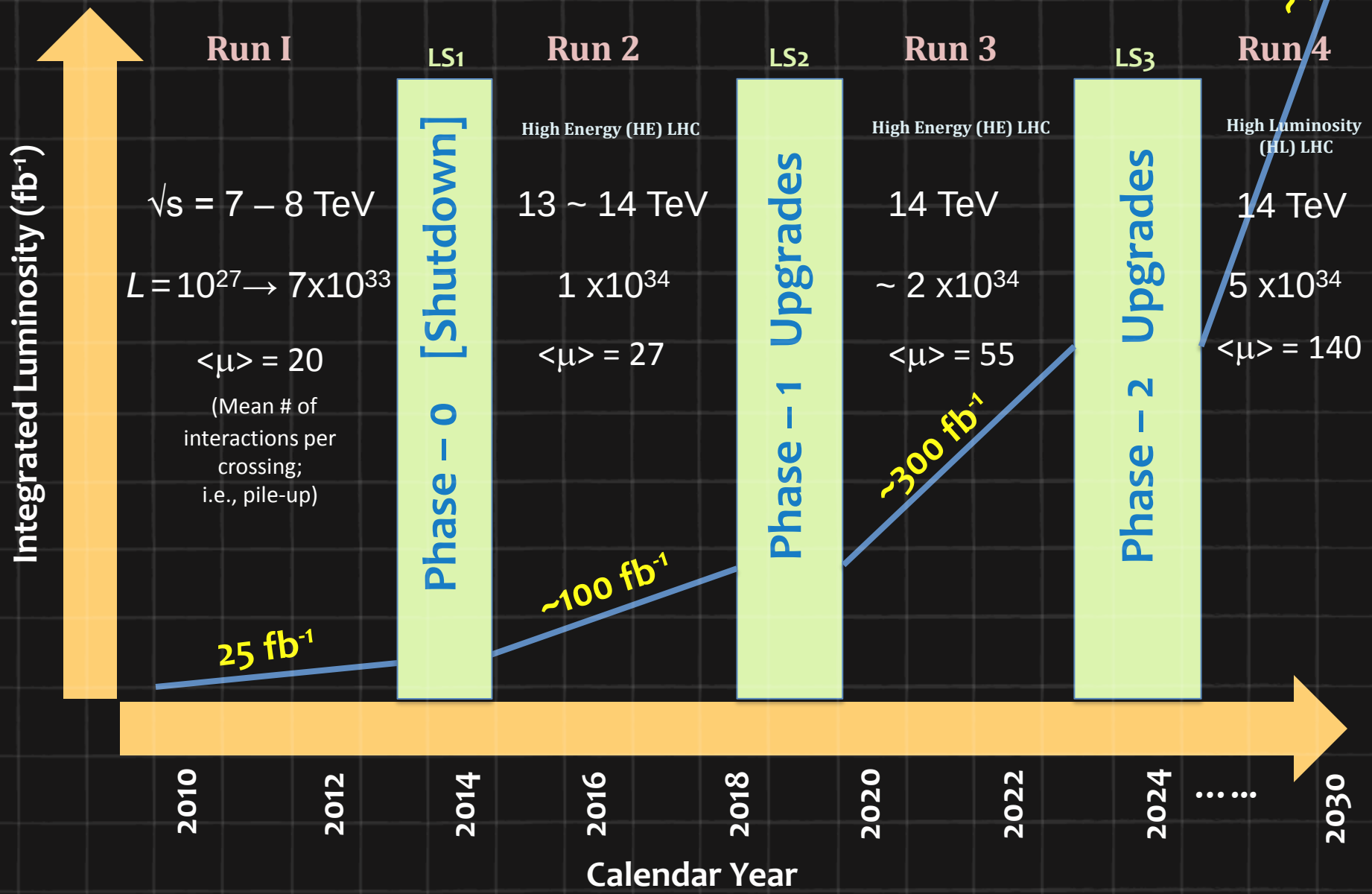
LS2 starting in 2018 (July) ⇒ 18 months + 3 months Beam Commissioning (BC)

LS3 LHC: starting in 2023 ⇒ 30 months + 3 BC

Injectors: in 2024 ⇒ 13 months + 3 BC

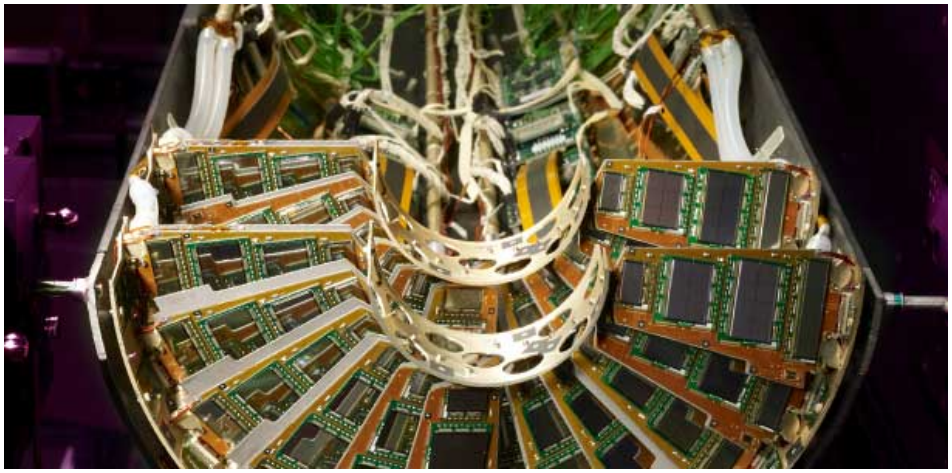
LHC schedule approved by CERN management and LHC experiment's spokespersons and technical coordinators: Monday, 2nd December 2013.

The LHC Forecast: Luminosity *vs.* Year



LHC Phase-1 Detector Upgrades

- CD-0 was approved for upgrades to the ATLAS and CMS detectors on 9/18/2012
- CD-1 was approved for upgrades to the ATLAS and CMS detectors on 10/17/2013
  - Cost: $32.2—34.5M for ATLAS, $29.2—35.9M for CMS
- The upgrades are a joint effort with NSF, which expects to contribute another $10—12 million per project
- The scope in both cases is primarily related to improving the trigger and data acquisition systems to handle larger data rates
  - U.S. CMS is also building replacements for the Endcap Pixel detector



Existing CMS Endcap Pixel Detector

- The U.S. projects are integrated into an international effort to upgrade the detectors.
- There will be a long shutdown of the LHC in 2018 to install the upgrades
- Requesting equipment funds in FY15
  - CD-2/3 reviews for each detector scheduled for end-FY14

Accelerator Project to Upgrade LHC (APUL)

- **Scope:** Two superconducting magnets for CERN's LHC
- **Background:** CERN requested the magnets to increase the reliability of spares
- BNL participated in this type of magnet production for the US-LHC Project

Total Project Cost: $11,440k

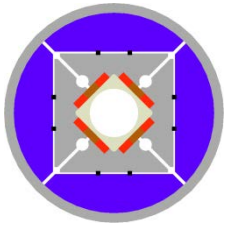
Schedule: CD4 – April 2014

Status

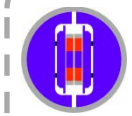
On-track to finish on time, On-budget

Superconducting Magnets

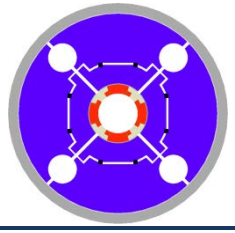
Subscale Quadrupole SQ
0.3 m long
110 mm bore

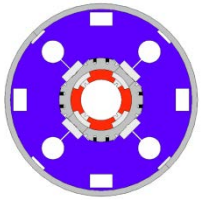


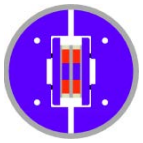
LBNL Subscale Magnet SM
0.3 m long
No bore



Technology Quadrupole TQS - TQC
1 m long
90 mm bore

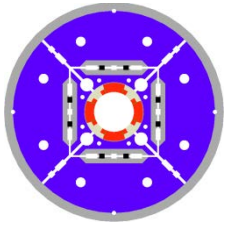




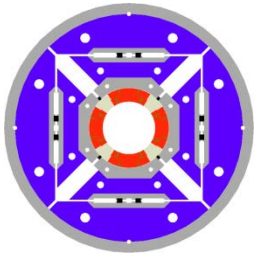


Long Racetrack LRS
3.6 m long
No bore

Long Quadrupole LQS
3.7 m long
90 mm bore

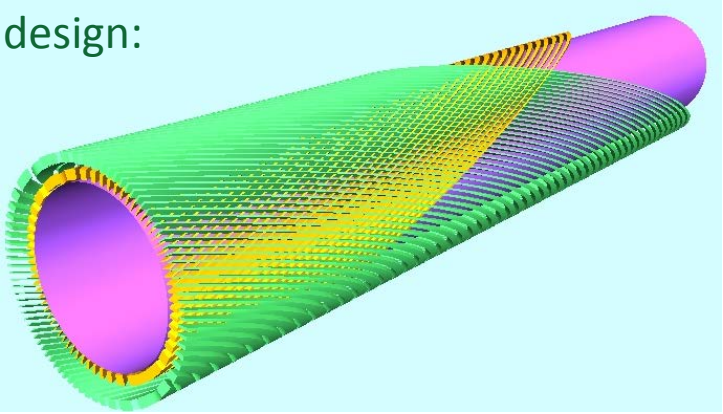


High Field Quadrupole
1 m long
120 mm bore



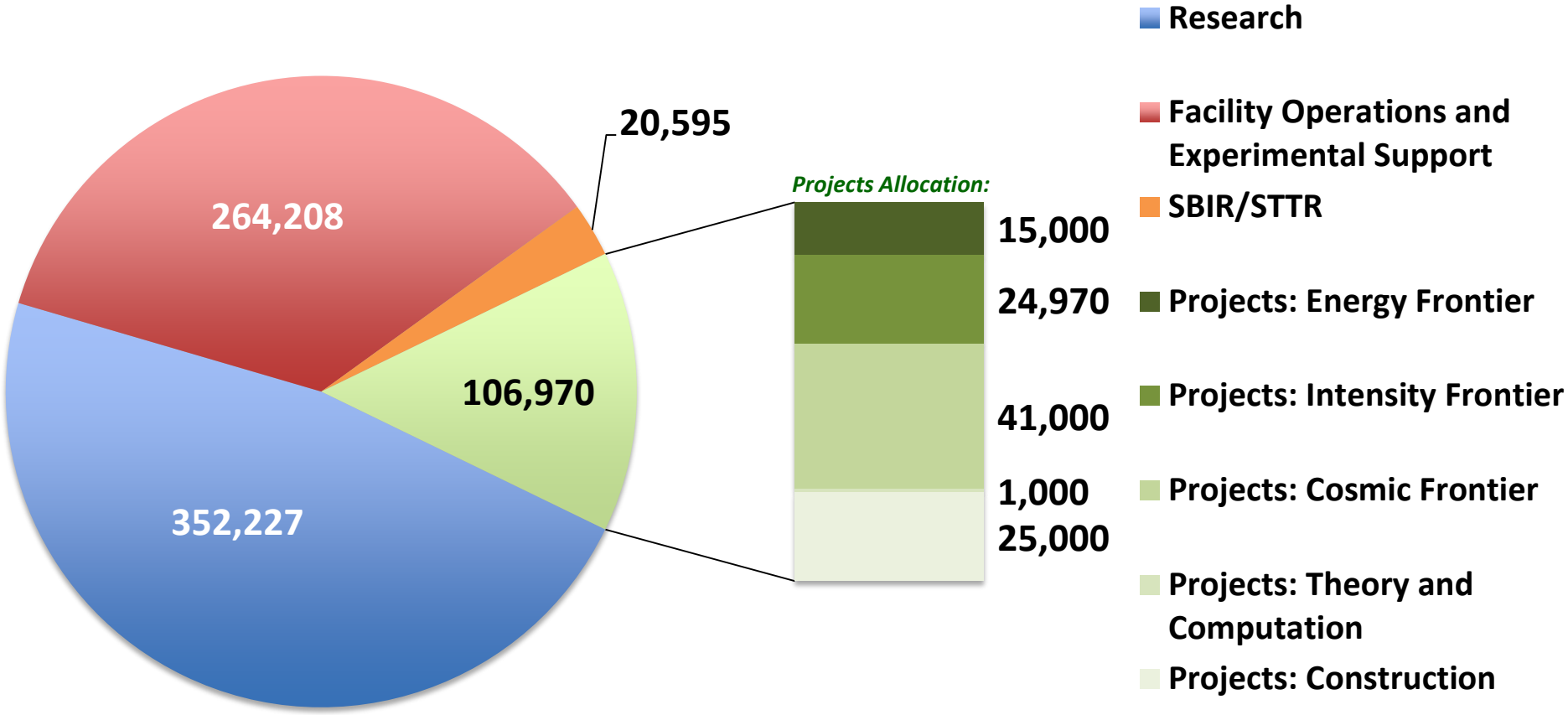
Significant progress made towards building magnets for future LHC upgrades

Continue to innovate in magnet design:



HEP BUDGET REFERENCE SLIDES

FY 2015 HEP Budget Request by Activity
(in $K)



See following budget tables for further details.

HEP Physics Construction Funding

(dollars in thousands)

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request
Construction Total (TEC)	**11,781**	**51,000**	**25,000**
1) Long Baseline Neutrino Experiment (TPC)	**17,888**	**26,000**	**10,000**
Total Estimated Cost (TEC)	3,781	16,000	0
Other Project Costs (OPC)	14,107	10,000	10,000
2) Muon to Electron Conversion Experiment (TPC)	**10,500**	**35,000**	**25,000**
Total Estimated Cost (TEC)	8,000	35,000	25,000
Other Project Costs (OPC)	2,500	0	0

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

- **Funding provided consistent with the planned profile for construction of the Mu2e Experiment**
- **No construction funding provided for LBNE**

HEP Intensity Frontier

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request	Comment
Research	**52,860**	**52,562**	**51,459**	
Facilities	**158,058**	**185,481**	**174,816**	
Expt Ops	7,354	7,245	6,986	Offshore and offsite Ops
Fermi Ops	132,928	156,438	152,096	Full operations for NOνA
B-factory Ops	1,594	4,600	0	End of BaBar disassembly
*Homestake**	14,000	15,000	15,000	
Other	2,182	2,198	734	GPE & waste management
Projects	**63,494**	**37,000**	**24,970**	
Current	52,794	27,000	19,970	Belle-II ramp down
Future R&D	10,700	10,000	5,000	
TOTAL: Intensity Frontier	**274,412**	**275,043**	**251,245**	

- **Reductions dominated by:**
  - Ramp-down of funding associated with current projects (particularly NOvA)
  - SLAC B-factory operations funding eliminated as planned disassembly work completed
- **Partially offset by increase in funding for:**
  - Initial operations of upgraded NuMI beam for NOvA
  - Refurbishment of portions of Fermilab Accel. Complex
  - Support for R&D/fabrication of current/future experiments

HEP Cosmic Frontier

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request
Research	**48,652**	**62,364**	**48,553**
Facilities	**12,252**	**12,022**	**11,692**
Projects	**19,159**	**24,694**	**41,000**
Current	9,500	23,200	41,000
Future R&D	9,659	1,494	0
TOTAL: Cosmic Frontier	**80,063**	**99,080**	**101,245**

- **Funding increases dominated by:**
  - **Ramp-up of the LSSTcam MIE according to planned profile**
- **Funding for research activities decreases**
  - **Redirected to R&D and planning efforts for next generation dark matter and dark energy experiments**

HEP Theory and Computation

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request	Comment
Research	**63,198**	**59,670**	**57,850**	
Theory	54,621	51,196	49,630	Follows programmatic reductions in Research
Computational HEP	8,577	8,474	8,220	As above
Projects	**3,200**	**3,200**	**1,000**	Transition year
TOTAL: Theory and Computation	**66,398**	**62,870**	**58,850**	

- **Funding for theoretical and computational HEP research is reduced to offset increased investments in future facilities**

HEP Advanced Technology R&D

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request	Comment
1) Research	**110,802**	**105,141**	**96,849**	
a) General Accel. R&D	60,705	57,694	47,620	Shift effort to directed R&D
b) Directed Accel. R&D	22,692	23,500	26,000	Need to meet deliverables
c) Detector R&D	27,405	23,947	23,229	"Generic" detector R&D program
2) Facility Operations	**31,489**	**17,150**	**17,393**	
TOTAL: Advanced Technology	**142,291**	**122,291**	**114,242**	

- **Includes General Accelerator R&D (GARD), Directed Accelerator R&D, and Detector R&D**
- **Research activities reduced to offset:**
  - **Increased project funding**
  - **Shift towards more directed R&D activities to develop future experimental capabilities**

Accelerator Stewardship

Funding (in $K)	FY 2013 Actual	FY 2014 Enacted	FY 2015 Request
Research	82	6,581	16,384
Facility Operations	3,050	3,350	2,800
TOTAL: Accelerator Stewardship	3,132	9,931	19,184

- This subprogram focuses on the fundamental physics of charged particle beams and on accelerator technology that can broadly benefit fields both within and outside of HEP
- Additional funding is requested to start new R&D efforts on:
  - Ion beam acceleration for medical use
  - Development of high power/high repetition rate lasers for the manipulation of charged particle beams
  - Higher efficiency RF power sources
- Funding also sought to allow the accelerator industry access to specialized test facilities at the national laboratories