U.S. DEPARTMENT OF ENERGY | Office of Science

DOE Office of HEP Report

2016 U.S. LHC Users Association Annual Meeting
Lawrence Berkeley National Laboratory
November 4, 2016

Anwar Bhatti
Office of High Energy Physics
Office of Science, U.S. Department of Energy

Outline

- HEP Mission
- Energy Frontier Program Overview
- Intensity Frontier Program
- Cosmic Frontier Program
- HEP Program Planning and Budgets
- Closing Remarks

This talk will describe HEP program with emphasis on Energy Frontier research at the LHC and future particle colliders — within the broader context of the overall HEP program

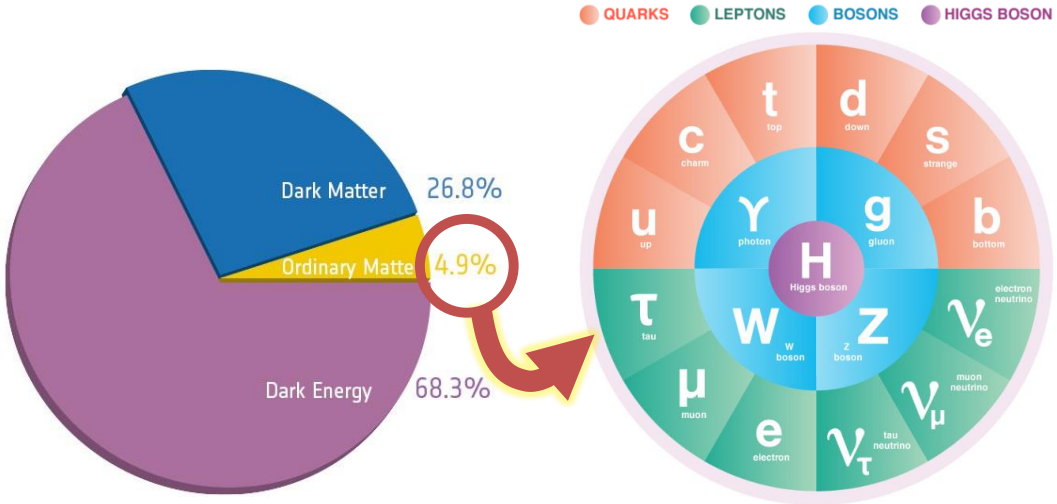
The High Energy Physics Program Mission

…is to understand how the universe works at its most fundamental level:

- Discover the elementary constituents of matter and energy
- Probe the interactions between them
- Explore the basic nature of space and time

The Office of High Energy Physics fulfills its mission by:

- Building projects that enable discovery science
- Operating facilities that provide the capability to perform discovery science
- Supporting a research program that produces discovery science



The Science Drivers of Particle Physics

The Particle Physics Project Prioritization Panel (P5) report identified five intertwined science drivers, compelling lines of inquiry that show great promise for discovery:

- Use the Higgs boson as a new tool for discovery *2013
- Pursue the physics associated with neutrino mass *2015
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation *2011
- Explore the unknown: new particles, interactions, and physical principles

** Since 2011, three of the five science drivers have been lines of inquiry recognized with Nobel Prizes*

HEP Research Subprograms

- **Energy Frontier** researchers accelerate particles to the highest-energies ever made by humanity and collide them to produce and study the fundamental constituents of matter and the architecture of the universe

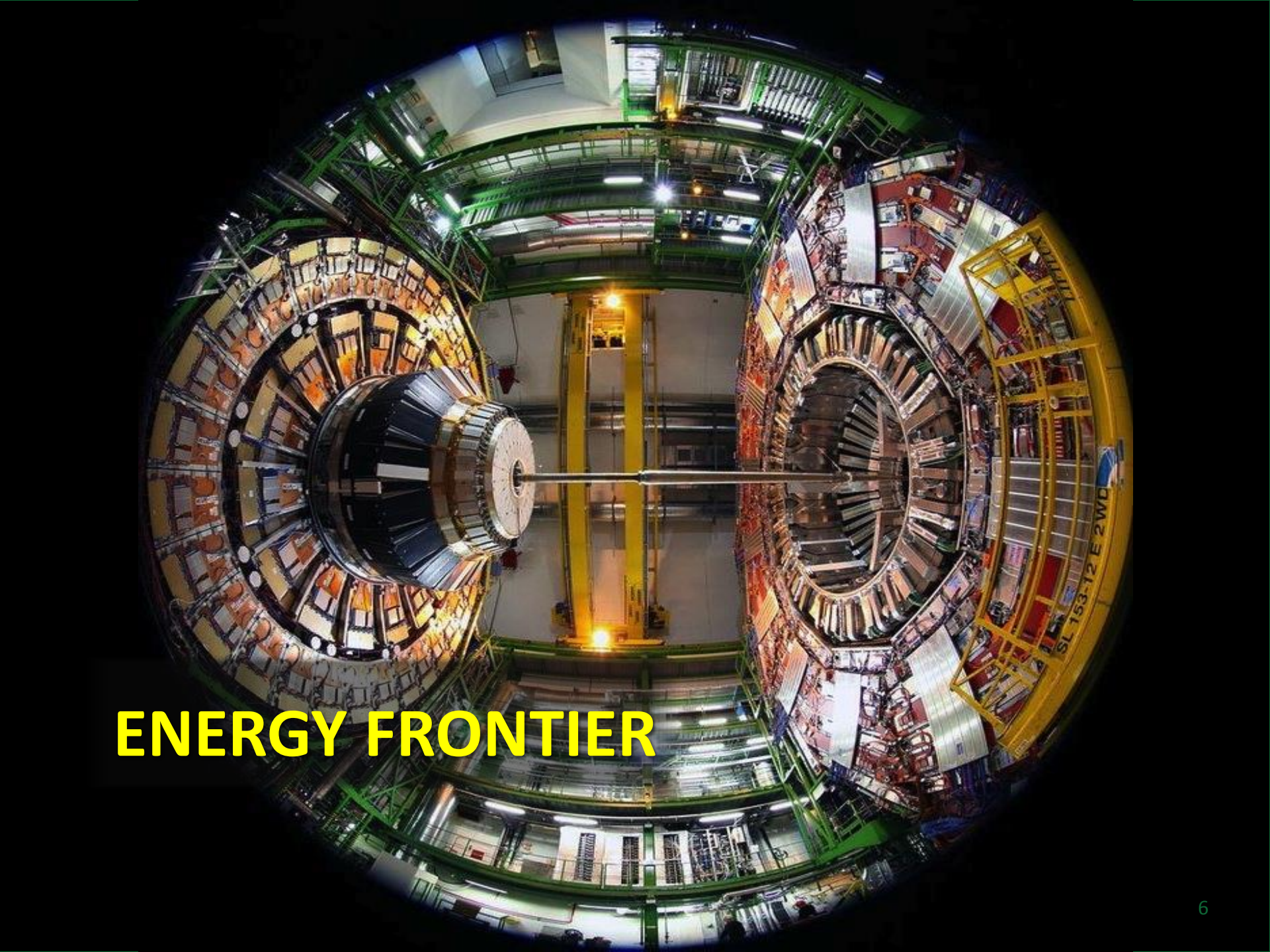
- **Intensity Frontier** researchers use a combination of intense particle beams and highly sensitive detectors to make extremely precise measurements of particle properties, study rare particle interactions, and search for new physics

- **Cosmic Frontier** researchers seek to reveal the nature of dark matter and dark energy by using particles from space to explore new phenomena

- **Theoretical and Computational Physics** provide the framework to explain experimental observations and gain a deeper understanding of nature

- **Advanced Technology R&D** fosters fundamental research into particle acceleration and detection techniques and instrumentation

- **Accelerator Stewardship** coordinates with accelerator user communities and industry to develop innovative solutions to critical problems, benefitting the broader user communities and the discovery science


ENERGY FRONTIER

HEP Energy Frontier Experiments

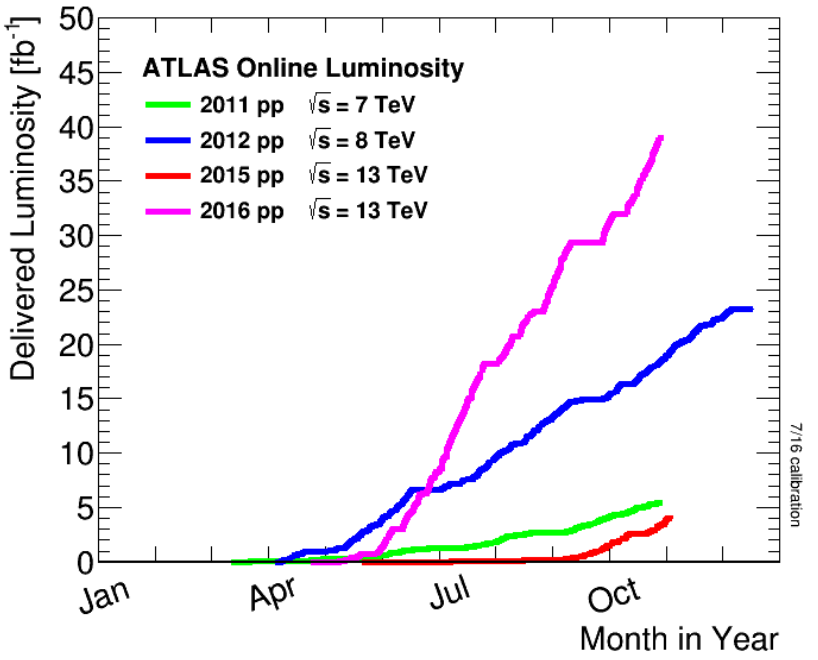
Experiment	Location	Center-of-Mass Energy; Status	Description of Science	# Institutions; # Countries	#U.S. Institutions	#U.S. Coll.
DØ (DZero)	Fermilab Tevatron Collider [Batavia, Illinois, USA]	1.96 TeV; Operations ended: Sept. 30, 2011	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics	74 Institutions; 18 Countries	31 Univ., 1 National Lab	187
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	54 Institutions; 14 Countries	26 Univ., 1 National Lab	194
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 started: May 2015	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics	180 Institutions; 38 Countries	41 Univ., 4 National Labs	629
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 started: May 2015	Higgs, Top, Electroweak, SUSY, New Physics, QCD, B-physics	209 Institutions; 45 Countries	48 Univ., 1 National Lab [+1 National Lab as sub-institute]	670

Tevatron data as of October 2014; LHC data as of July 2016

- **One main scientific thrust – LHC at CERN (pp collider): CMS and ATLAS Collaborations**
- **Modest support for two additional thrusts:**
  - **Tevatron research at Fermilab ($p\bar{p}$ collider): DØ and CDF Collaborations**
  - **Future collider initiatives (mainly ~2-3 FTEs on ILC detector R&D) to universities and laboratories**
- **U.S. is the single largest collaborating nation in both the ATLAS and CMS experiments at LHC**
  - **US-ATLAS: ~22% of the international ATLAS Collaboration**
    - **~200 U.S. graduate students**
  - **US-CMS: ~27% of the international CMS Collaboration**
    - **~250 U.S. graduate students**

Excellent LHC Performance and Near-term Challenges

- LHC continues to set new performance records
  - Unprecedented peak instantaneous luminosity ~1.4 x 10^{34} $cm^{-1}s^{-1}$ exceeds design luminosity by ~40%!
  - Data accumulation ~60% beyond the goal of 25 fb^{-1} for 2016!
- Congratulations to the CERN accelerator team for the hard work in operating the LHC, and to the experiments for the high performance efficiency in acquiring data!



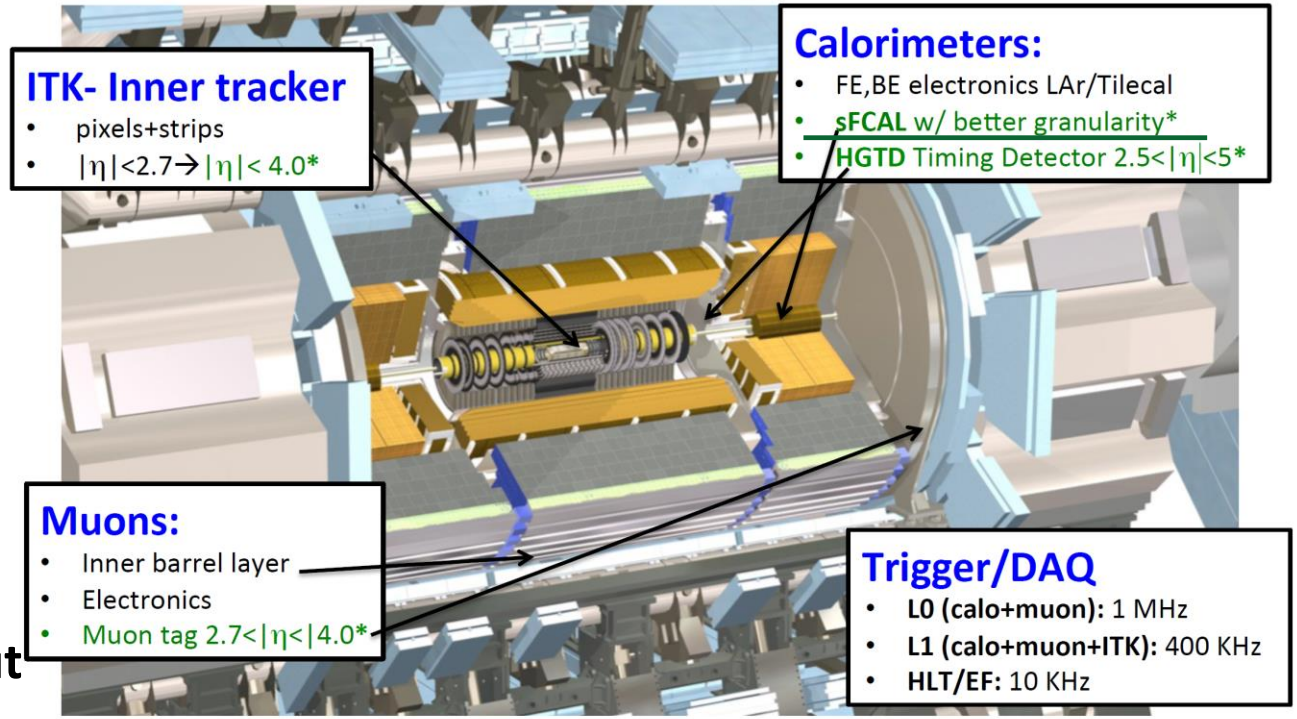
- LHC performance has immediate challenges in computing resources that are needed to support operations and analysis efforts as a result of the increased amount of data generated by ATLAS and CMS by 20-40% in Run 2
  - Increases anticipated need for additional CPU, Disk, and Tape resources by ~20% in FY 2017
- This presents a challenge in the anticipated flat budget, but DOE will continue to coordinate with the experiments, CERN, and its partners through the international process to address these issues

U.S. Contributions to the LHC

- **The LHC and its upgrades are a core part of the U.S. program**
  - **DOE participated in the design, construction, and operation of the LHC and its detectors since the original 1997 International Cooperation Agreement between CERN, DOE, and NSF**
  - **The unique scientific capabilities of the LHC promise compelling science for decades to come**
- **DOE contributions to the HL-LHC accelerator and detector upgrades will leverage our areas of technical expertise and capitalize on previous investments, for example**
  - **Long-term investments in the U.S. LHC Accelerator Research Program (LARP) enables accelerator contributions that will be key to the HL-LHC program**
  - **Long-term investments in silicon-based detector R&D enable U.S. leadership in the ATLAS and CMS inner trackers and the CMS high-granularity calorimeter**

ATLAS HL-LHC Upgrade

- **U.S. ATLAS has defined the scope of its potential contributions to the HL-LHC upgrades**
  - Driven by future science discovery potential while leveraging the interests and experience of U.S. groups
  - Active coordination with international ATLAS — at all levels
- **DOE Scope:**
  - Barrel ITK (pixel & strip detector)
  - DAQ hardware (data flow elements)
  - LAr front end analog chip development
- **NSF Scope:**
  - Trigger and readout electronics for LAr, Tile, Muons



** Large eta scenarios, as described in the 2015 scoping document for the reference 275 MCHF CORE cost scenario*

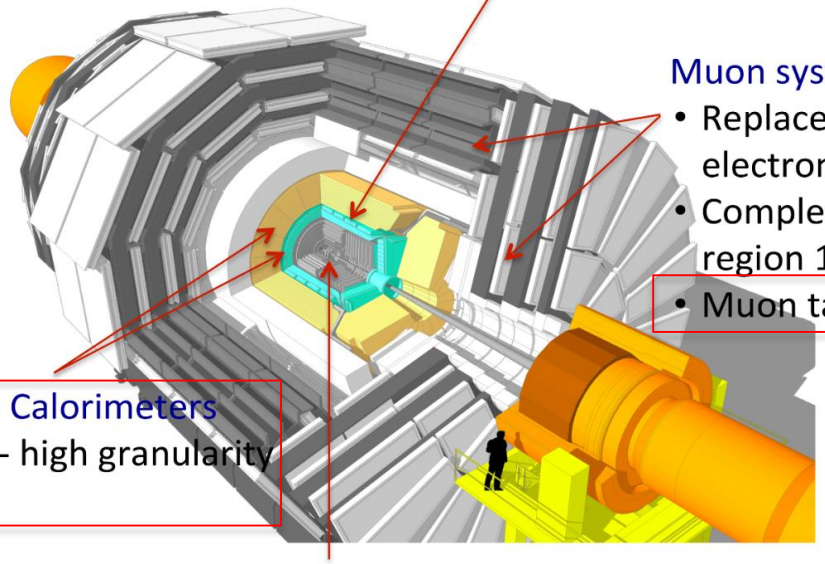
CMS HL-LHC Upgrade

- **U.S. HL-LHC CMS upgrade scope driven by future science opportunities, expertise by U.S. scientists, and coordination with international CMS**

DOE
NSF

Trigger/HLT/DAQ
- Track information at L1-Trigger
- L1-Trigger: 12.5 μs latency - output 750 kHz
- HLT output ≈7.5 kHz

Barrel EM calorimeter NSF
- Replace FE/BE electronics
- Lower operating temperature (8◦)



Muon systems
- Replace DT & CSC FE/BE electronics NSF
- Complete RPC coverage in region $1.5 < \eta < 2.4$
- Muon tagging $2.4 < \eta < 3$ NSF

DOE

***Replace Endcap Calorimeters**
- Rad. tolerant - high granularity
- 3D capability

Replace Tracker *
- Rad. tolerant - high granularity - significantly less material
- 40 MHz selective readout (Pt≥2 GeV) in Outer Tracker for L1-Trigger DOE
- Extend coverage to $\eta = 3.8$ NSF

HL-LHC Detector Upgrades Budget

- U.S. ATLAS and U.S. CMS are planning towards NSF MREFC contributions not to exceed $75M (in U.S. accounting) for each experiment
- Profile DOE used for planning now needs to be fine-tuned and optimized to ensure U.S. "fair-share" commitments to the HL-LHC Detector Upgrades are met
  - Plan at CD-0 targeted U.S. scope for each upgrade as a fair-share of ~235 MCHF CORE cost
    - *i.e.*, CD-0 Total Project Cost in U.S. accounting: $155M (DOE) + $75M (NSF) per experiment
  - October 2015 RRB approved "scale of funds between 235 – 275 MHCF CORE cost," DOE plans to adjust contributions to target total fair-share for U.S. near midpoint of range
    - Working with the U.S. project teams, experiments, & CERN to update profile prior to CD-1
- FY17 President's request includes $1.25M for each DOE ATLAS/CMS HL-LHC project
  - U.S. responsibilities will be finalized after TDRs are complete in 2017
  - Remaining R&D support required for TDRs provided via redirections from LHC Ops funds
    - U.S. LHC Operations already contained the R&D component for HL-LHC prior to CD-0

CD-0 Funding Profile: HL-LHC Detector Upgrade Projects (AY $M; in U.S. accounting)

Fiscal Year	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
ATLAS TPC	1.5*	5.0*	14.0	31.5	42.3	26.1	20.1	10.0	4.5	**155.0**
CMS TPC	1.5*	5.0*	14.0	31.5	42.3	26.1	20.1	10.0	4.5	**155.0**

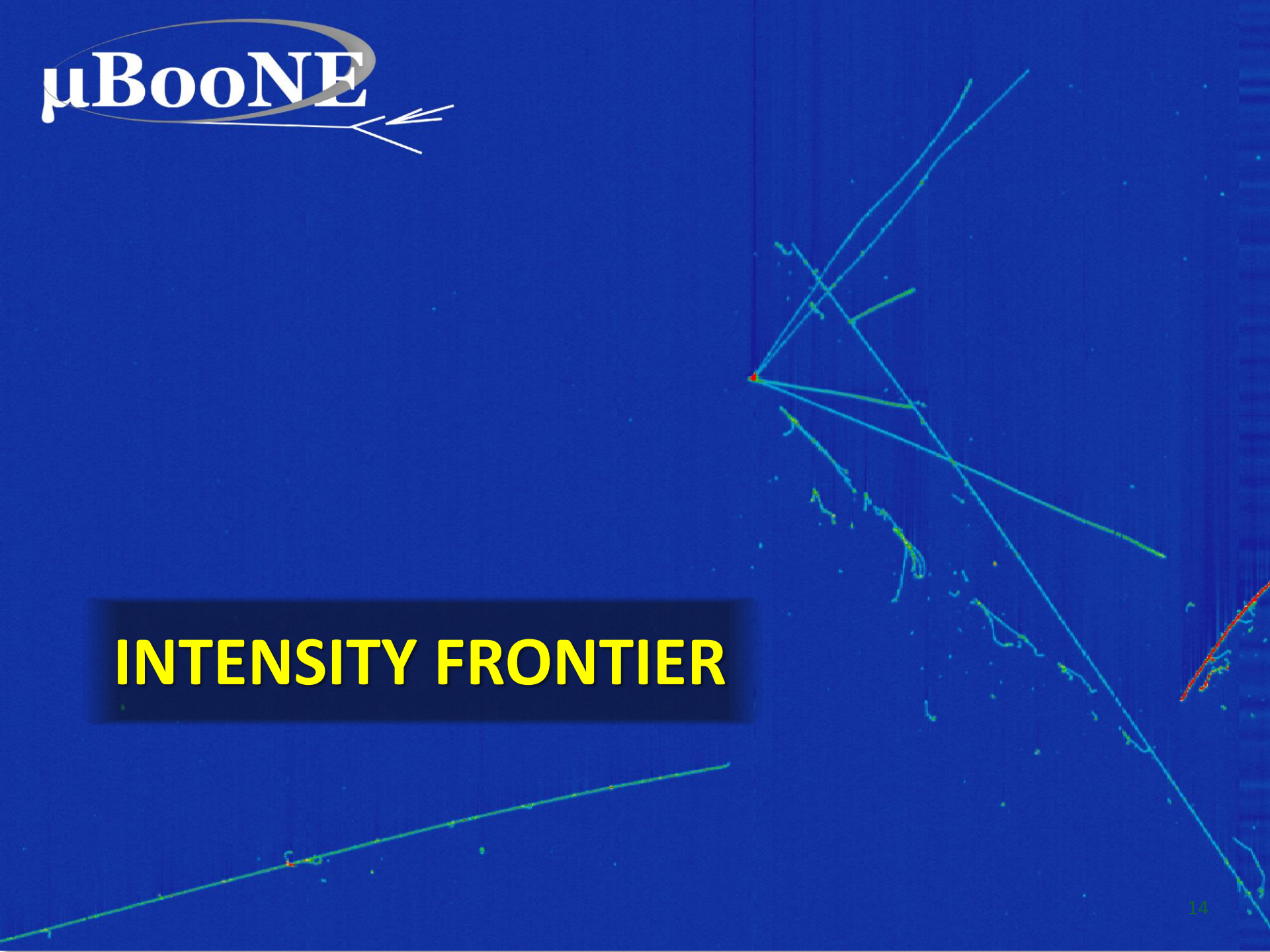
** Upper limits, based on redirection of funds from U.S. LHC Operations R&D line-item to Other Project Costs (OPC)*

Laboratory Comparative Review

- All Laboratory Research Groups (experimental frontiers, Theory, and Detector R&D) have been undergoing Comparative Review since 2008.
- Panels evaluate all laboratory research groups at once and make recommendations on how to best allocate resources to labs, indicating areas of weakness and strength
- Energy Frontier Lab Research groups were reviewed in July 2015, report issued this year
- The recommendations of the Review Panel are forwarded to lab management for implementation, and the DOE-HEP budget line is adjusted accordingly

From review report:

"The overall impact of these laboratories in the field is truly significant and highly competitive, at an international level. This is achieved thanks to excellent infrastructure at the laboratories and thanks to excellent staff often carrying clear leadership roles in the most important international research endeavors (in particular the ATLAS and CMS experiments at CERN's LHC)."


μBooNE
INTENSITY FRONTIER

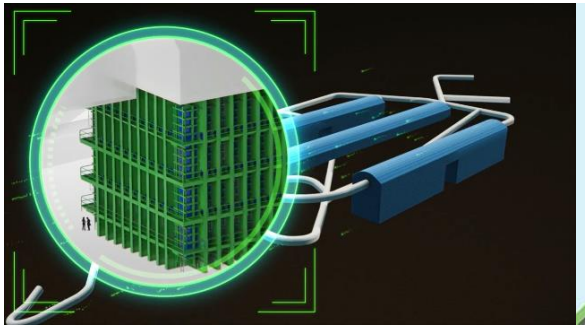
Intensity Frontier

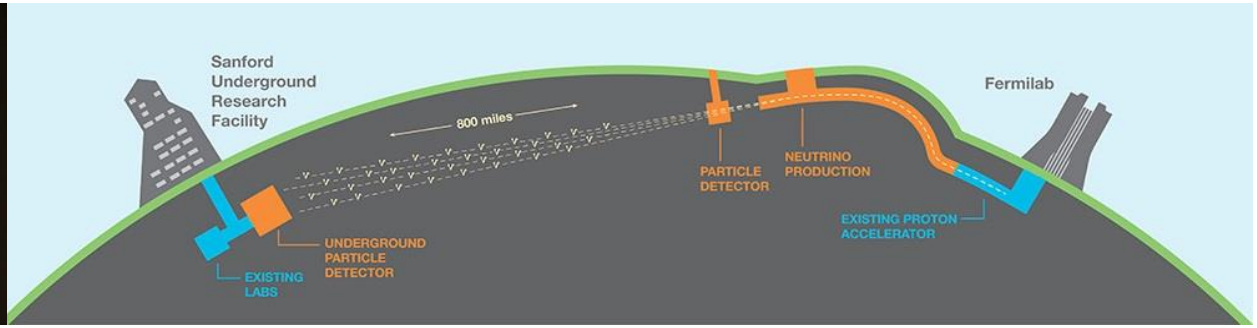
Intensity Frontier experiments address the P5 Science Drivers through intense beams and sensitive detectors

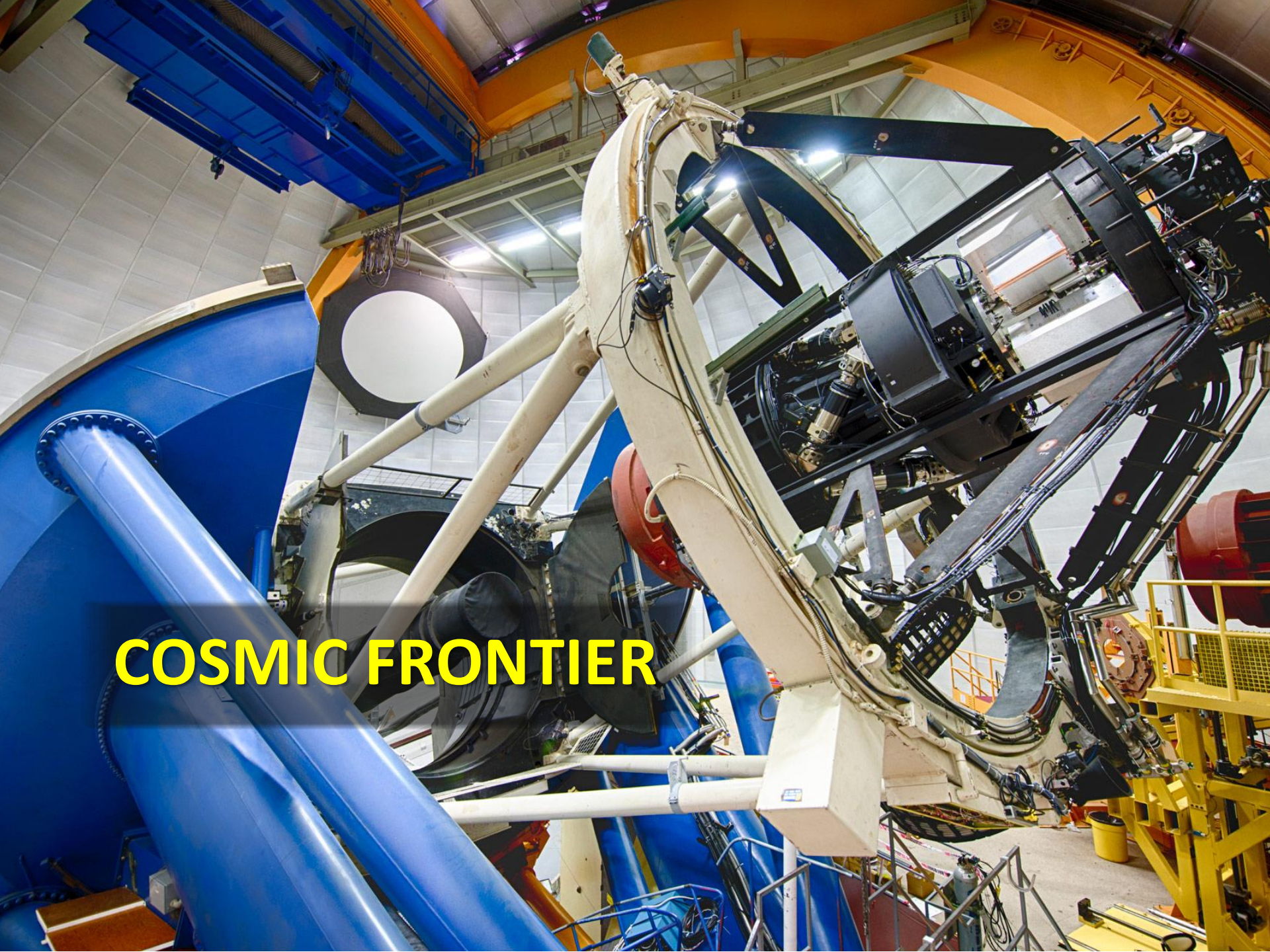
- **Exploring the unknown through precision measurements:** *Muon g-2, Mu2e, Belle II, K0TO*
- **Identify the new physics of dark matter:** *APEX* and *Heavy Photon Search*
- **Pursuing the physics associated with neutrino mass:** *NOvA*, *Daya Bay*, *MINERvA*, *Super-K*, *T2K* ongoing; ramping up Fermilab Short-Baseline Neutrino Program (*MicroBooNE*, *SBND*, *ICARUS*)

P5 recommended *Long Baseline Neutrino Facility (LBNF)* as the centerpiece of a U.S.-hosted world-leading neutrino program, recognizing it as the highest-priority large project in its timeframe

- **Given the compelling discovery potential, Fermilab is working closely with CERN and other global partners to establish a truly international "mega-science" facility with first physics in the mid-2020s**
- ***LBNF* will produce the world's most intense neutrino beam and send it 800 miles through the earth**
- **The *Deep Underground Neutrino Experiment (DUNE)* will be a large (40 kiloton) liquid argon neutrino detector located nearly 1 mile underground at the Sanford Underground Research Facility**
- ***LBNF/DUNE* project received CD-3A (early far-site construction) approval in September 2016**
  - **FY17 investments in site preparation and cavern excavation aim to solidify international partnerships**






COSMIC FRONTIER

Cosmic Frontier

Dark Energy: Staged program of complementary suite of imaging and spectroscopic surveys

- Imaging: *Dark Energy Survey (DES)* continues operations, *Large Synoptic Survey Telescope (LSST)* received CD-3 in August 2015
- Spectroscopic: *BOSS* final results out soon; *eBOSS* continues operations, *Dark Energy Spectroscopic Instrument (DESI)* received CD-3 in June 2016
- Have agreements with NSF-AST for *LSST* partnership & *DESI* cooperation

Dark Matter (direct detection): Staged program of current (G1) and next-generation (G2) experiments with multiple technologies

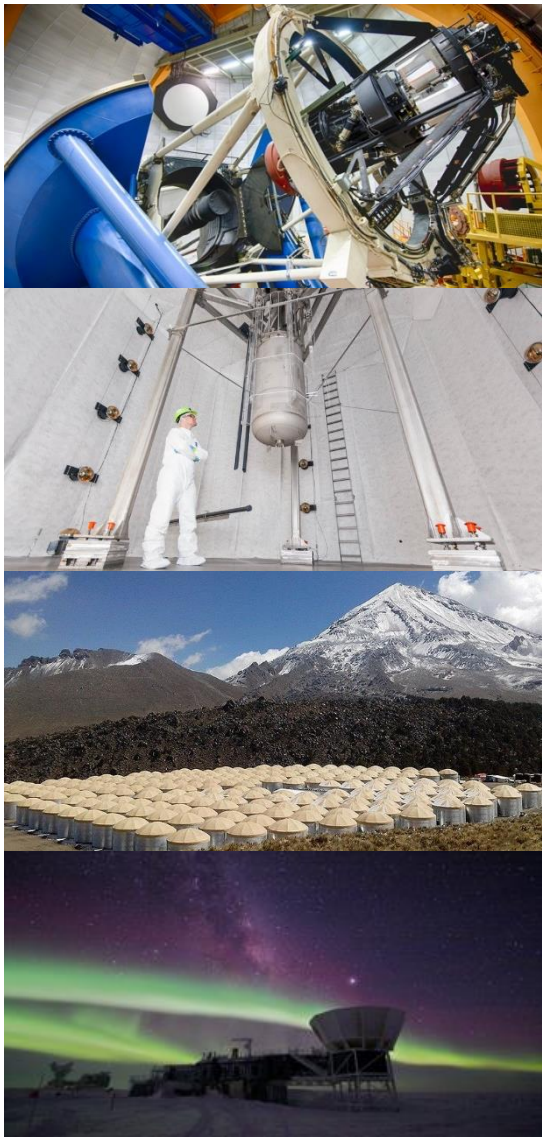
- Completed operations of DM-G1 experiments in FY 2016
- Progress continues towards DM-G2: *ADMX-G2, LZ, SuperCDMS-SNOLAB*
  - *LZ* received CD-2A/3B in August 2016
  - *SuperCDMS-SNOLAB* received CD-1 December 2015

Cosmic-ray, Gamma-ray

- *Fermi/GLAST*, *AMS*, and *HAWC* continue operations

Cosmic Microwave Background (CMB)

- *South Pole Telescope polarization (SPTpol)* continues operations
- *SPT-3G* begins operations in December 2016; partnership with NSF
- Community planning proceeding for CMB-S4 experiment



HEP FY 2017 BUDGET

HEP FY 2017 Budget Overview

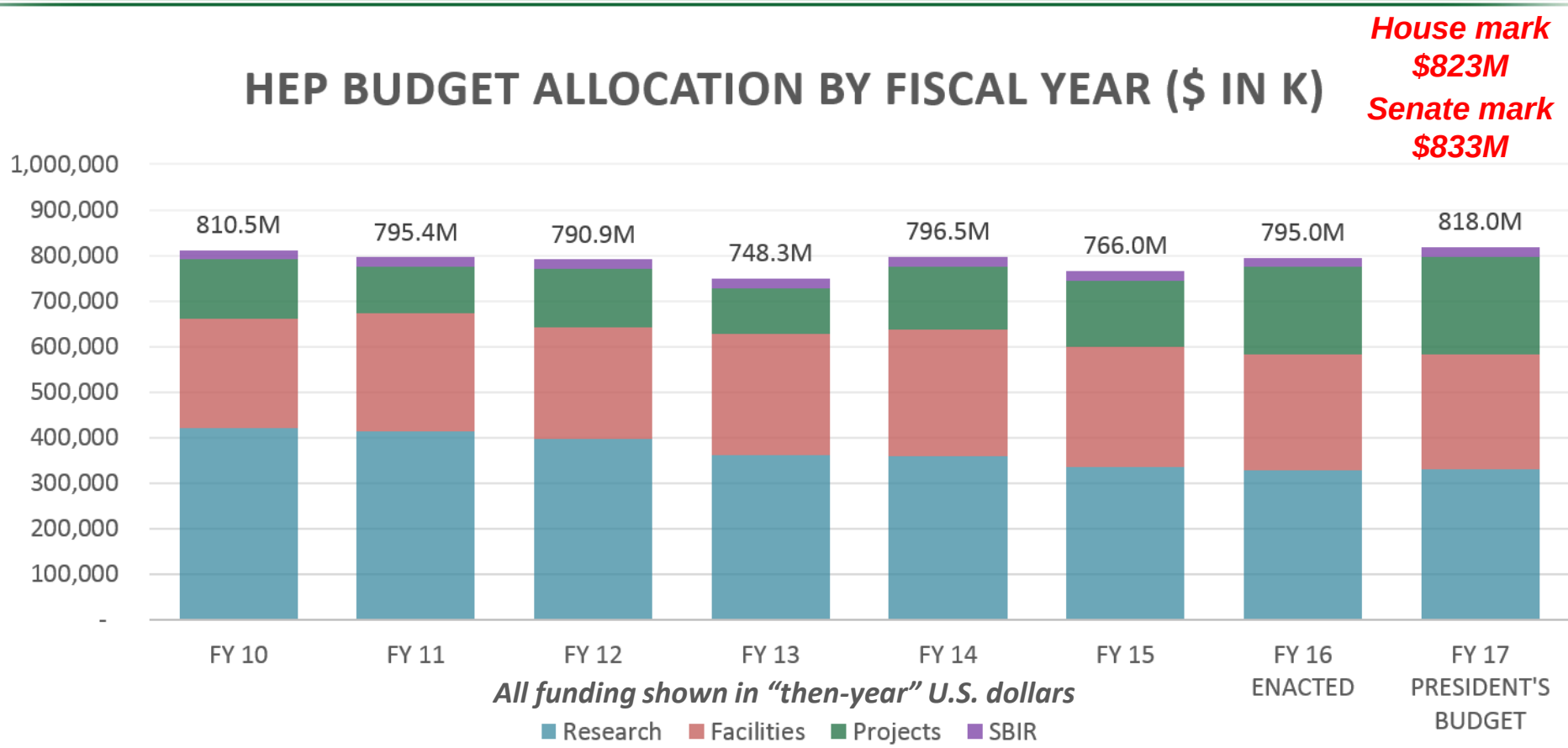
- **Energy Frontier: Continue to support leadership roles in highly successful LHC program**
  - Initial LHC detector upgrade project funding ends in FY 2017
  - Scope being determined for High Luminosity (HL)-LHC, P5's highest priority near-term project; CD-0 in 2016
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis
- **Intensity Frontier: Solidify international partnerships for U.S.-hosted LBNF/DUNE**
  - Rapid progress on LBNF/DUNE has attracted attention from interested international partners and FY 2017 investments in site preparation and cavern excavation aim to solidify international partnerships
  - Fermilab will continue improvements to accelerator complex while serving high-intensity neutrino beams to short-and long-baseline experiments, enabling full utilization of the FNAL facilities
- **Cosmic Frontier: Advance our understanding of dark matter and dark energy**
  - Fabrication funding ramp up in FY 17 supports key P5 recommended Cosmic Frontier projects to study dark matter and dark energy: LSSTcam, DESI, SuperCDMS-SNOLab, LZ

FY 2017 HEP Funding by Activity

HEP Funding Category ($ in K)	FY 2015 Current	FY 2016 Enacted	FY 2017 Request	Explanation of Changes (FY17 vs. FY16)
Research	334,225	327,389	331,123	Sustain support for research program
Facilities	264,634	254,979	252,037	Overall operations support reductions due to scheduled completion of projects
Projects	99,373	107,620	108,516	**Other Project Costs (OPC) includes CDR, project-specific R&D, prototyping and testing, installation and commissioning/pre-operations before CD-4*
Energy Frontier Projects	*15,000*	*19,000*	*18,967*	*Initial ATLAS/CMS upgrades complete in FY17; OPC* begins for HL-LHC detector upgrades*
Intensity Frontier Projects	*48,170*	*17,685*	*9,349*	*Reduction from ramp down of g-2 & end of LBNF/DUNE OPC*; SBN Program increases*
Cosmic Frontier Projects	*45,203*	*66,835*	*70,200*	*Planned ramp up supports fabrication of LSSTcam, DESI, SuperCDMS-SNOLab, LZ*
Other Projects	*1,000*	*4,100*	*10,000*	*Increase to support the FACET-II project*
Construction (Line Item)	37,000	84,115	103,741	Request engineering design, site preparation and long-lead procurement for the LBNF/DUNE; planned profile for Mu2e
SBIR/STTR	20,768*	20,897	22,580	
Total	**766,000***	**795,000**	**817,997**	***House mark $823M; Senate mark $833M***

**** SBIR/STTR added to FY 2015 for comparison to FY 2016/2017***

Overall HEP Budget Trend



- Significant dip in FY 2013 from Congressional sequestration
- FY 2015 request developed prior to P5 report release
- FY 2017 Continuing Resolution (CR) through December 9, 2016
  - Funding through December 9 is equivalent to $791M level of funding, if extrapolated to full FY

Messages for the U.S. LHC Community

- The lion's share of current DOE HEP investment remains the LHC program and will be for many more years
- Our traditional partnership with CERN has been strong and we look forward to continuing it through the U.S.-CERN Agreement and Protocols signed in 2015
- We realize that with the initial (Phase-1) and HL-LHC upgrades, as well as ongoing LHC Operations, resources are quite stretched
  - We are actively taking steps to address this in FY17-18 as the HL-LHC upgrade projects ramp-up and Phase-1 projects ramp-down
  - As a first step, we have added resources to the HL-LHC upgrade projects, for the accelerator, ATLAS R&D, and CMS R&D
  - DOE is leveraging its expertise in high-field magnets and silicon-based detectors to help enable the strong scientific and technological performance of the LHC

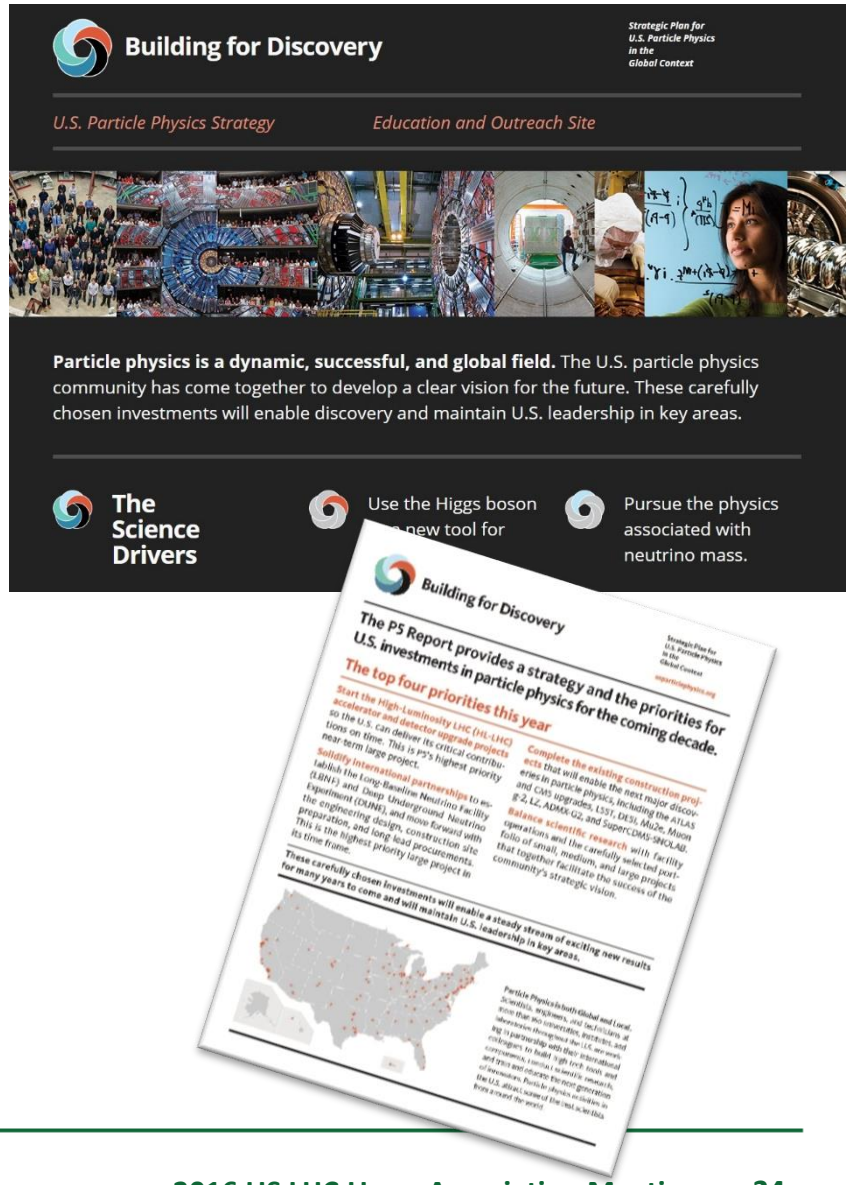
- P5 recognized that a compelling and comprehensive LHC program is a core part of U.S. particle physics, and DOE intends to support key leadership roles in all areas of the ATLAS and CMS experiments
  - U.S. participation is enabled by leveraging U.S. expertise in accelerator science and technology to exploit future opportunities at the LHC

Messages for U.S. Neutrino Community

- As part of the P5 global vision, DOE is working to establish a U.S.-hosted world-leading neutrino physics program with LBNF as its centerpiece
  - This major U.S. initiative in the global program must succeed to balance U.S. participation in science facilities hosted elsewhere, including the LHC
  - Given the compelling scientific discovery potential of LBNF/DUNE, Fermilab is working closely with its global partners to establish a truly international "mega-science" facility with first physics in mid-2020s
  - International partners are beginning to come aboard with contributions; more are expected…
    - CERN will be a major partner through the agreements signed last year
- "Scenario B+" strategy aims to accelerate LBNF/DUNE using additional funding while maintaining program balance and supporting priorities of Scenario B
  - Investments in early far-site construction necessary to enable interested international partners to make "in-kind" contributions on schedule
- Completion of ProtoDUNE is an important R&D step towards timely realization of LBNF/DUNE

Community Materials

- Steve Ritz is leading community efforts to produce materials to help maintain the visibility of the P5 report
  - Initial materials are available at: http://www.usparticlephysics.org/
  - Steve plans to continue working with the U.S. particle physics community to update the material as needed
- Users' Groups report that Steve's material was helpful during their March 2016 visit to Washington, DC
- U.S. particle physics community should consider using Steve's messages as part of their communications strategy




BACKUP

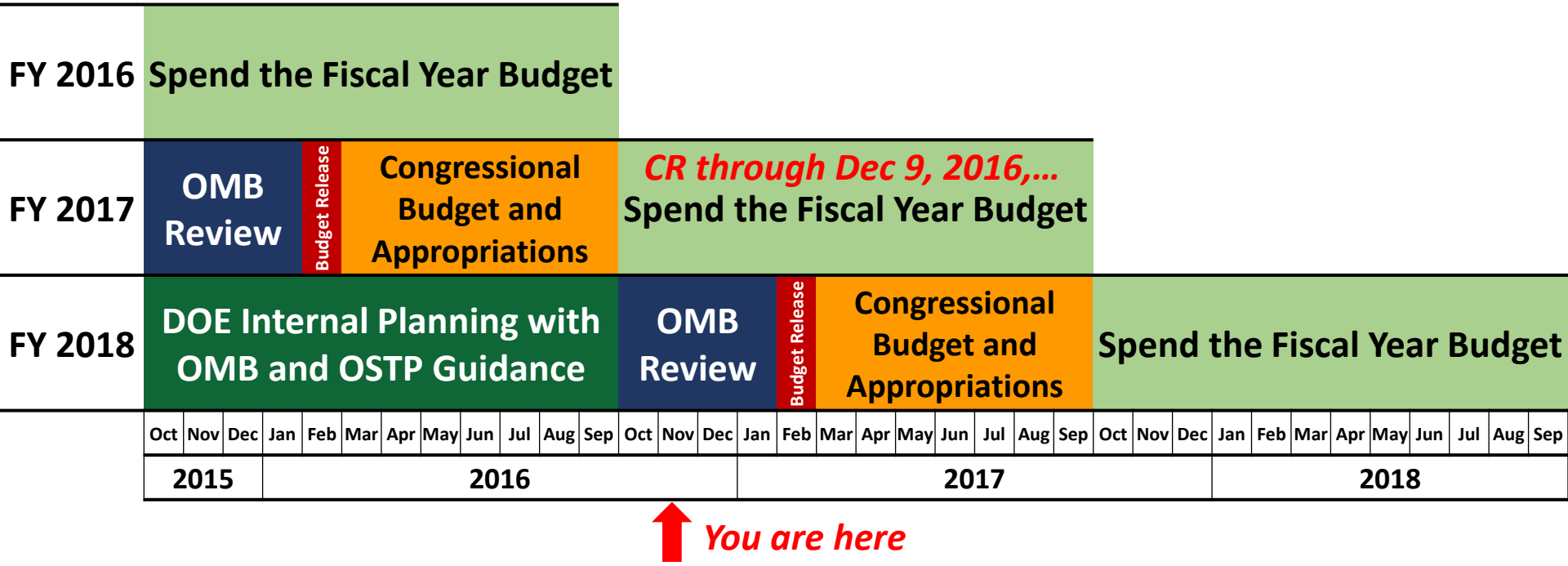
Addressing HL-LHC Concerns from U.S. LHC

- **Recent concerns from the U.S. HL-LHC project managements**
  - Accelerator: long-lead procurement of coil strands for Nb_3Sn magnets to begin fabrication in FY18 and meet scheduled delivery by end of 2023
  - Detector: R&D support necessary for completion of TDRs in 2017 and begin long-lead procurement of silicon-based subsystems
- **Steps are being taken to address immediate FY17 concerns**
  - Accelerator Upgrades: ***Additional $2M in FY17***
    - This is a first step, with funding redirected from lower-priority directed accelerator R&D to LARP for HL-LHC
    - LARP and HL-LHC completely coordinated for U.S. to deliver Nb_3Sn magnets
  - Detector Upgrades: ***Additional $1.25M in FY17 for each of ATLAS/CMS R&D***
    - HEP identified this additional $2.5M total that can be redirected to HL-LHC ATLAS and CMS R&D from lower-priority tasks
    - These funds are in addition to the CD-0 profile shown earlier

In the longer term, we plan to continue working with U.S. HL-LHC projects to optimize HL-LHC project profiles, including adjusting Total Project Cost, as we move toward CD-1 (planned for 2017)

The U.S. Federal Budget Cycle

- **Typically, three budgets are being worked on at any given time**
  - **Executing current Fiscal Year (FY; October 1 – September 30)**
  - **White House Office of Management and Budget (OMB) review and Congressional Appropriation for coming FY**
  - **Agency internal planning for the second FY from now**



Breaking the Cycle: Continuing Resolution

- If the U.S. Congress and the President have not passed all appropriations bills by September 30, a Continuing Resolution (CR) may be passed to avoid a U.S. Government shutdown
  - CRs typically extend the level of funding from the previous year for set amount of time
- A CR may impede the start of new projects
  - Projects with total cost >$10M must be line-items approved by Congress in an appropriations bill before funding can begin
  - It is possible, though not typical, for CRs to include "anomalies" that would allow new starts
- A CR may impact the ramp-up of new projects
  - DOE is committed to the successful execution of projects that have reached CD-2 and aims to provide the baseline funding profile
  - Projects that have not reached CD-2 are most likely to be impacted under a CR
- A CR may also impact future-year planning through such effects…

- Given the current political climate, we expect a CR for at least part of FY 2017 and are planning accordingly
  - DOE has limited flexibility for adjustments under a CR, but will work closely with laboratory and project management to minimize any impacts

Duration of CRs: FY 1998 – FY 2016

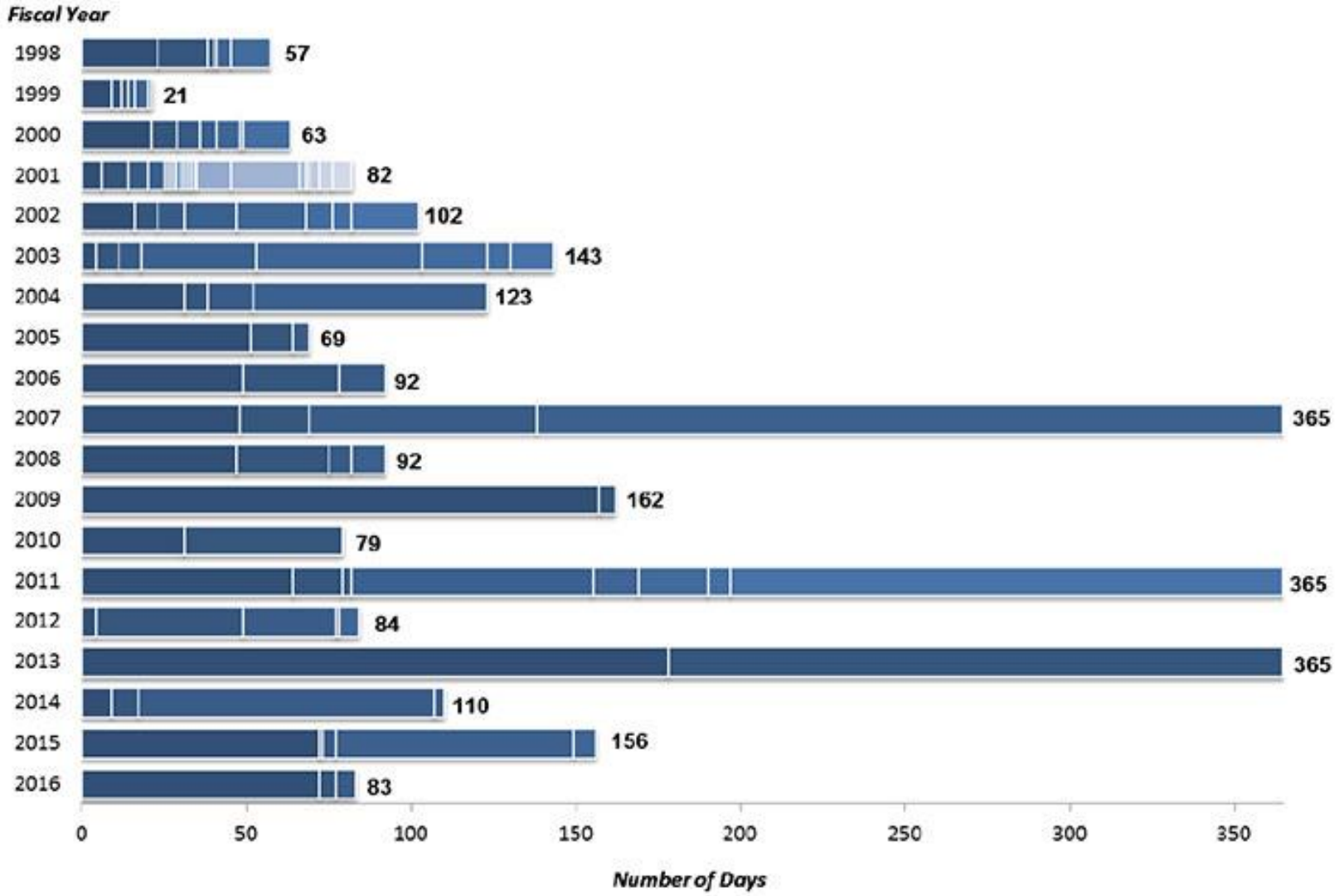
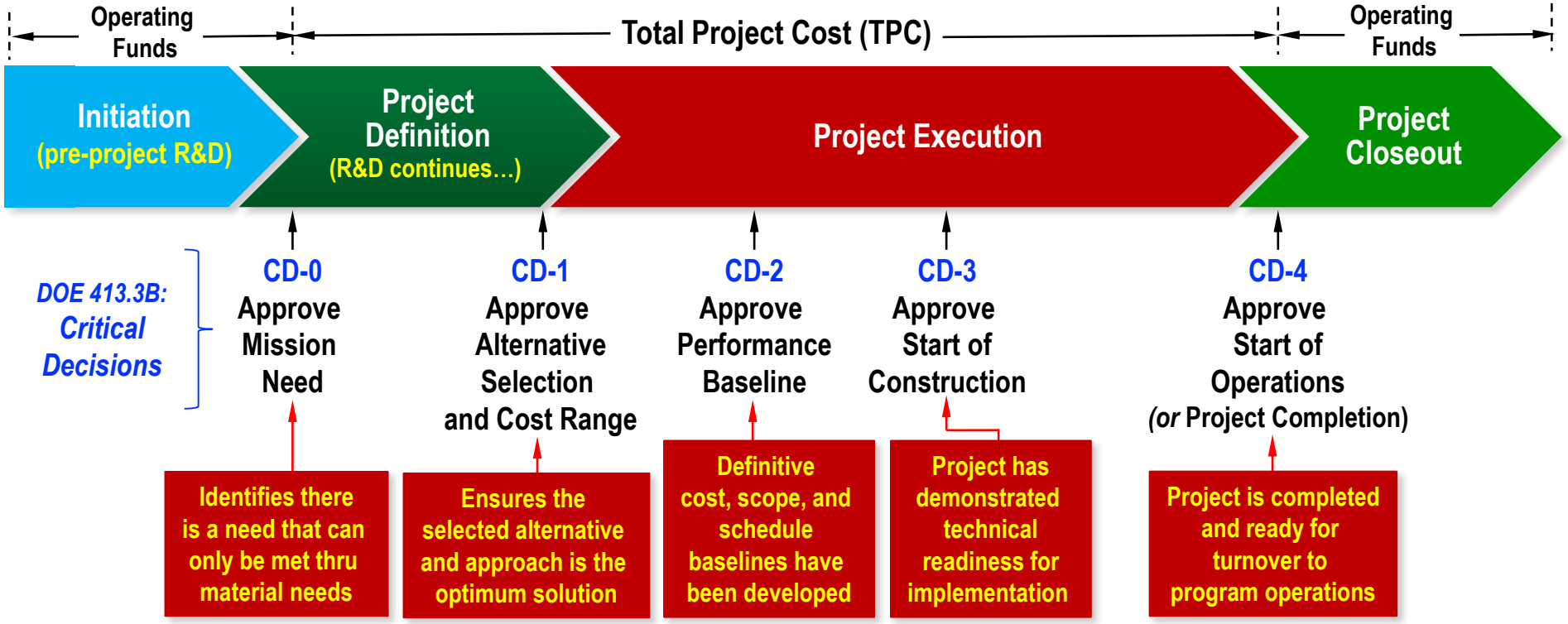


Chart from Congressional Research Service Report R42647, "Continuing Resolutions, Overview of Components and Recent Practices," 2016.

DOE Project Management

- Construction projects and fabrication of large pieces of experimental equipment costing over $5M are managed through a series of "Critical Decision" milestones
- The CD process ensures successful project execution and scientific return on agency investments, but funding must still be appropriated
  - Projects reaching CD-3 may have technical readiness, but they must be supported in the President's Budget Request and receive funding from Congress before they can begin
- U.S. projects require use of U.S. accounting (contingency, labor, etc.) *vs.* CORE (M&S only)



HEP MIE Project Status

Subprogram	TPC ($M)	CD Status	CD Date
INTENSITY FRONTIER			
Long Baseline Neutrino Facility (LBNF) / Deep Underground Neutrino Experiment (DUNE)	1,260 - 1,860	CD-3A	September 1, 2016
Muon g-2	46	CD-2/3	August 20, 2015
Mu2e	273	CD-3	July 14, 2016
ENERGY FRONTIER			
LHC ATLAS Detector (Phase-1) Upgrade	33	CD-2/3	November 12, 2014
LHC CMS Detector (Phase-1) Upgrade	33	CD-2/3	November 12, 2014
HL-LHC ATLAS Detector (Phase-2) Upgrade	155	CD-0	April 14, 2016
HL-LHC CMS Detector (Phase-2) Upgrade	155	CD-0	April 14, 2016
COSMIC FRONTIER			
LZ	46-59	CD-2/3B	August 9, 2016
SuperCDMS-SNOlab	16-21	CD-1	December 21, 2015
Dark Energy Spectroscopic Instrument (DESI)	56	CD-2	September 17, 2015
Large Synoptic Survey Telescope Camera (LSSTcam)	168	CD-3	August 27, 2015
ADVANCED TECHNOLOGY R&D			
Facility for Advanced Accelerator Experimental Tests II (FACET-II)	TBD	CD-1	December 21, 2015
Proton Improvement Project (PIP-II)	TBD	CD-0	November 12, 2015
HL-LHC Accelerator Upgrade	200	CD-0	April 7, 2016

U.S.-CERN International Agreements


CO-OPERATION AGREEMENT
between
THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA
and
THE NATIONAL SCIENCE FOUNDATION OF THE UNITED STATES OF AMERICA
and
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
concerning
Scientific and Technical Co-operation in Nuclear and Particle Physics
2015

International Co-Operation Agreement between the U.S. and CERN concerning Scientific and Technical Co-Operation in Nuclear and Particle Physics

Parties: United States (DOE and NSF), European Organization for Nuclear Research (CERN)
Signed at Washington, D.C. May 7, 2015; Entered into force May 7, 2015. With Annex.
Document: *http://www.state.gov/documents/organization/244968.pdf*


ACCELERATOR PROTOCOL III
between
THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA (DOE)
and
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
to
THE CO-OPERATION AGREEMENT
concerning
SCIENTIFIC AND TECHNICAL CO-OPERATION IN NUCLEAR AND PARTICLE PHYSICS
2015

Accelerator Protocol III between the U.S. and CERN to the Agreement of May 7, 2015 on Scientific and Technical Cooperation

Parties: United States (DOE), European Organization for Nuclear Research (CERN)
Signed at Geneva, Switzerland December 18, 2015; Entered into force December 18, 2015. With Addendum on FCC.
Document: *https://www.state.gov/documents/organization/253295.pdf*


EXPERIMENTS PROTOCOL II
between
THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA (DOE)
and
THE NATIONAL SCIENCE FOUNDATION OF THE UNITED STATES OF AMERICA (NSF)
and
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
to
THE CO-OPERATION AGREEMENT
concerning
SCIENTIFIC AND TECHNICAL CO-OPERATION IN NUCLEAR AND PARTICLE PHYSICS
2015

Experiments Protocol II between the U.S. and CERN to the Agreement of May 7, 2015 on Scientific and Technical Cooperation

Parties: United States (DOE and NSF), European Organization for Nuclear Research (CERN)
Signed at Geneva, Switzerland December 18, 2015; Entered into force December 18, 2015.
Document: *https://www.state.gov/documents/organization/253294.pdf*


NEUTRINO PROTOCOL I
between
THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA (DOE)
and
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
to
THE CO-OPERATION AGREEMENT
concerning
SCIENTIFIC AND TECHNICAL CO-OPERATION IN NUCLEAR AND PARTICLE PHYSICS
2015

Neutrino Protocol I between the U.S. and CERN to the Agreement of May 7, 2015 on Scientific and Technical Cooperation

Parties: United States (DOE), European Organization for Nuclear Research (CERN)
Signed at Geneva, Switzerland December 18, 2015; Entered into force December 18, 2015.
Document: *https://www.state.gov/documents/organization/253290.pdf*