



U.S. DEPARTMENT OF
ENERGY

Office of
Science

DOE High Energy Physics Program

*High Energy Physics Advisory Panel (HEPAP) Teleconference
September 26, 2017*

Jim Siegrist

**Associate Director for High Energy Physics
Office of Science, U.S. Department of Energy**

U.S. Department of Energy: Mission

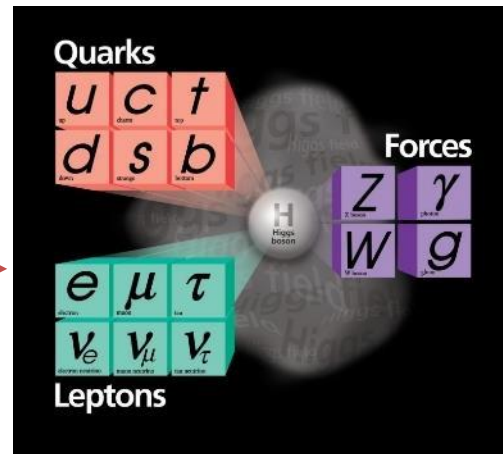
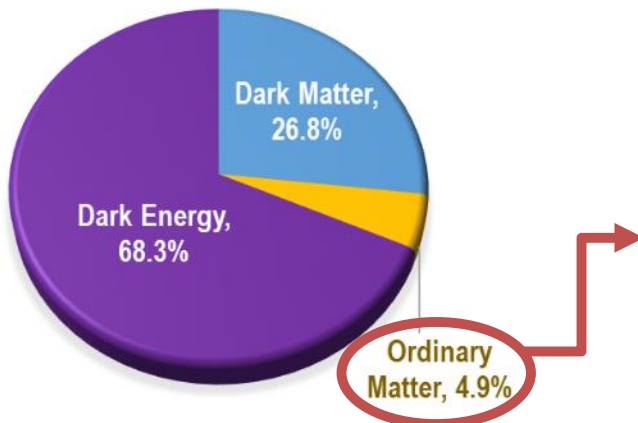
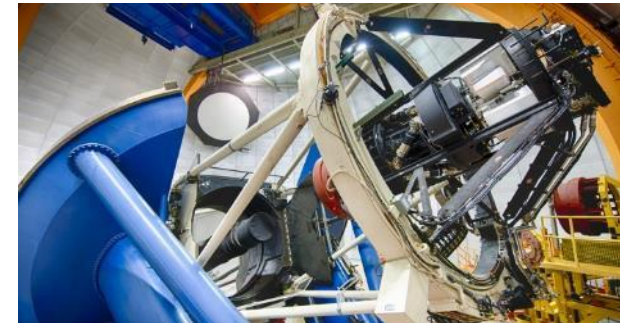
The Mission of the U.S. Department of Energy is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.

DOE/HEP 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 DOE Office of High Energy Physics fulfills its mission by:

- Building **projects** that enable discovery science
- Operating **facilities** that provide the capability for discoveries
- Supporting a **research** program that produces discovery science

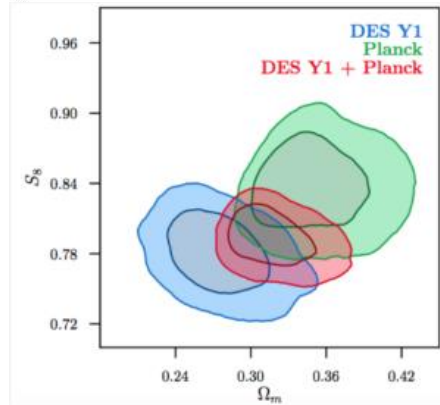
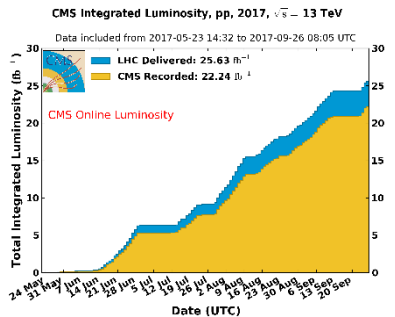
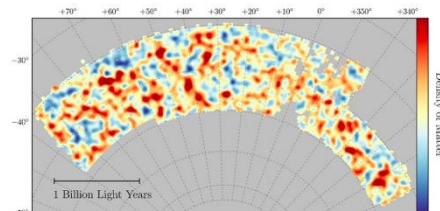
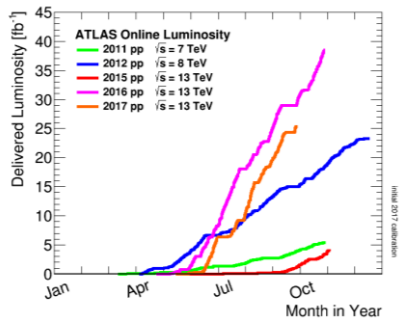




**DOE HIGH ENERGY PHYSICS
PROGRAM**

Discovery Science

- The particle physics community continues to produce many exciting science results!
 - LHC continues excellent performance, enabling many science results
 - DES produced excellent dark energy science results from Y1 data
 - Neutrino experiments, large and small, are creating exciting news



Energy Frontier: LHC, ATLAS, and CMS

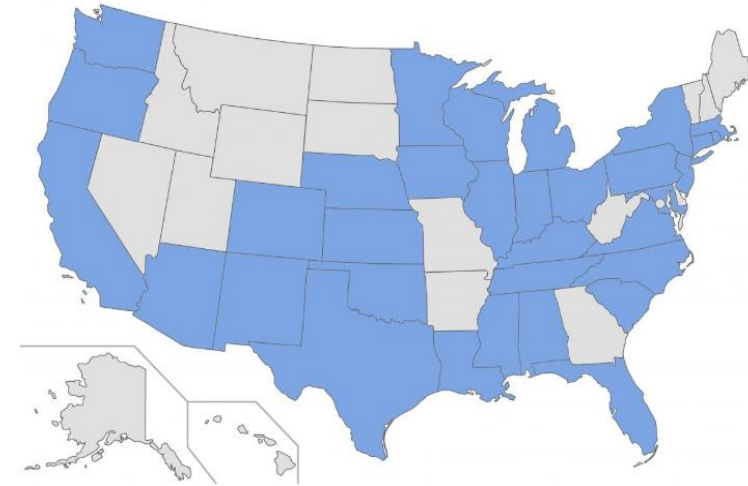
The Large Hadron Collider at CERN is the centerpiece of the U.S. Energy Frontier program and an integral component of the DOE HEP program

- **U.S. ATLAS represents ~20% of the international ATLAS Collaboration**

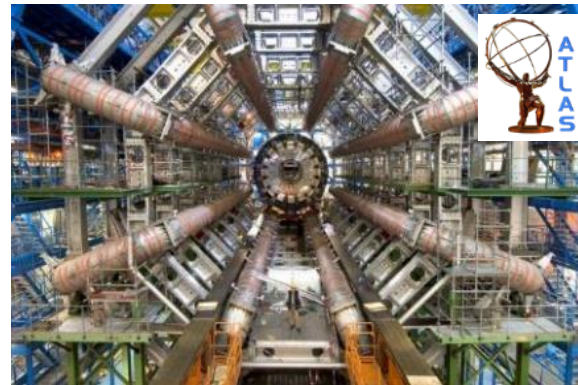
- 41 universities, 4 national labs
(Argonne, Brookhaven, Lawrence Berkeley, SLAC)
- Brookhaven National Lab is host lab for U.S. ATLAS

- **U.S. CMS represents ~27% of the international CMS Collaboration**

- 48 universities, 1 national lab
- Fermilab is the host lab for U.S. CMS



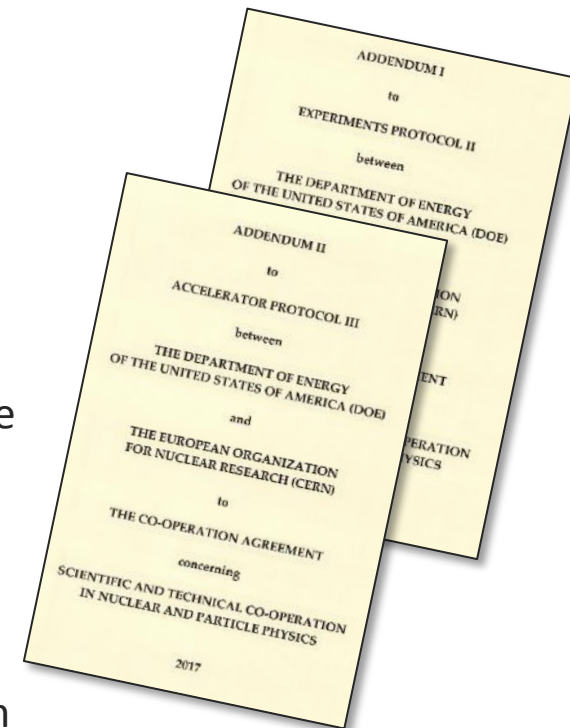
States hosting members of the U.S. LHC experimental program



Future of the Energy Frontier

Energy Frontier program continues to build on the *bilateral U.S.-CERN Agreement and Protocols*, signed in 2015

- Renew cooperation on the CERN-hosted LHC and the U.S.-hosted neutrino programs
- **Signed May 2017: DOE-CERN addenda to the Protocols**
 - HL-LHC accelerator, experiments; and neutrinos
- **P5 report identified HL-LHC upgrades as highest priority near-term large project**
 - Extends discovery potential by increasing LHC collision rate, enabling detectors to collect a factor of ten more data over another decade
- **U.S. leadership in superconducting magnet technology, and with Nb₃Sn in particular, is essential to the success of the HL-LHC program**
 - HL-LHC Accelerator Upgrade Project uses this expertise to serve HEP community needs
- **U.S. laboratories and institutions will develop and build major subsystems for the HL-LHC ATLAS and CMS detector upgrades**
 - Detector expertise and support provides foundation for continued U.S. leadership in HL-LHC scientific research program



HL-LHC Accelerator Upgrades: Enabling U.S. Science Participation



2

CIVIL ENGINEERING

2 new 300-metre service tunnels and 2 shafts near to ATLAS and CMS.



3

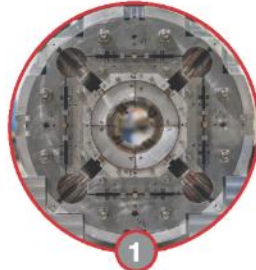
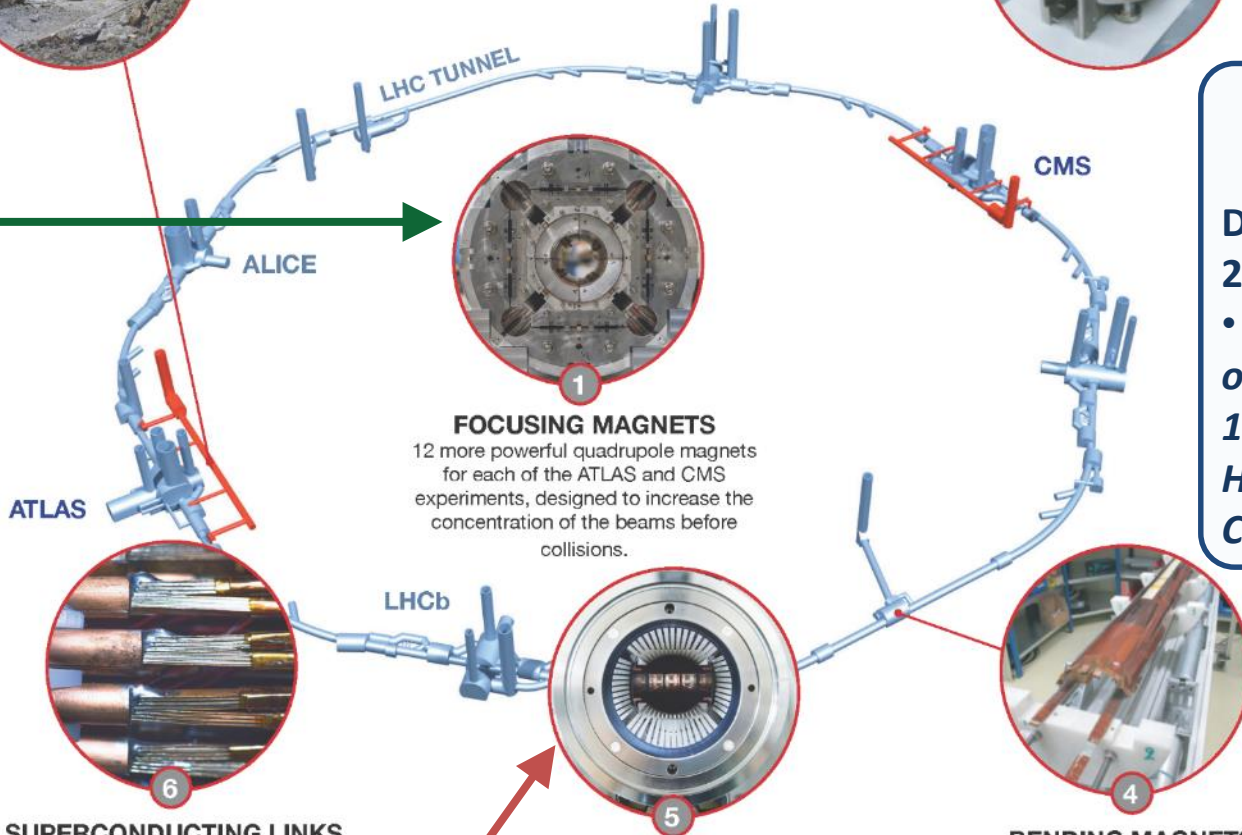
"CRAB" CAVITIES

16 superconducting "crab" cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.



DOE contribution:
10 cold mass
(Nb₃Sn) assemblies

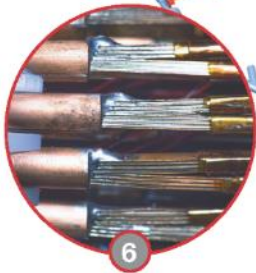
- 4 each for ATLAS & CMS interaction regions
- 2 spares



1

FOCUSING MAGNETS

12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.



6

SUPERCONDUCTING LINKS

Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service tunnels near ATLAS and CMS.



4

BENDING MAGNETS

4 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.



5

COLLIMATORS

15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.



DOE contribution:
20 Crab Cavities
• 16 + 4 spares
or:
10 Crab cavities &
Hollow e-Lens
Components



DOE contribution:

Hollow e-Lens Components (under discussion)

CMS HL-LHC Upgrade

- DOE and U.S. National Science Foundation coordinating U.S. contributions with CERN and international partners on CMS
- Scope of the U.S. deliverables leverages expertise by U.S. scientists

DOE

Trigger/HLT/DAQ

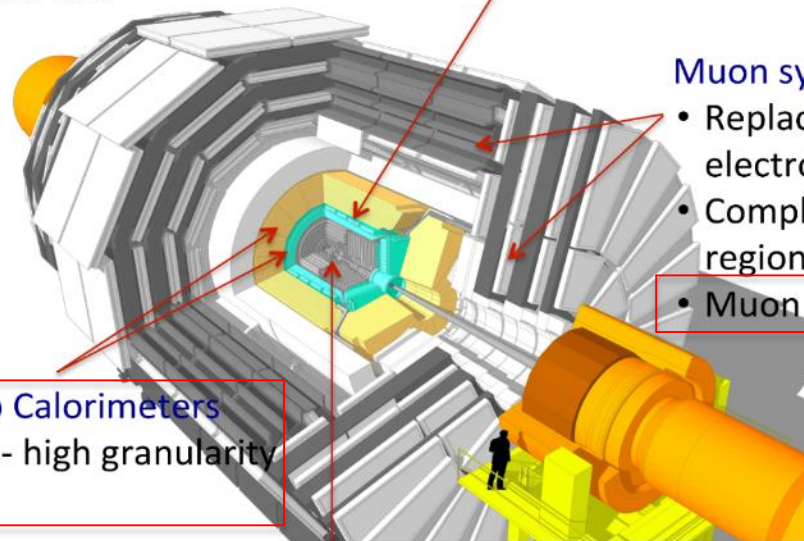
- Track information at L1-Trigger
- L1-Trigger: 12.5 μ s latency - output 750 kHz
- HLT output \approx 7.5 kHz

NSF

Barrel EM calorimeter

- Replace FE/BE electronics
- Lower operating temperature (8 $^{\circ}$)

NSF



Muon systems

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

NSF

DOE

DOE

*Replace Endcap Calorimeters

- Rad. tolerant - high granularity
- 3D capability

Replace Tracker *

- Rad. tolerant - high granularity - significantly less material
- 40 MHz selective readout ($P_t \geq 2$ GeV) in Outer Tracker for L1-Trigger
- Extend coverage to $\eta = 3.8$

DOE

NSF

 = Significant U.S. contributions



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ATLAS HL-LHC Upgrade

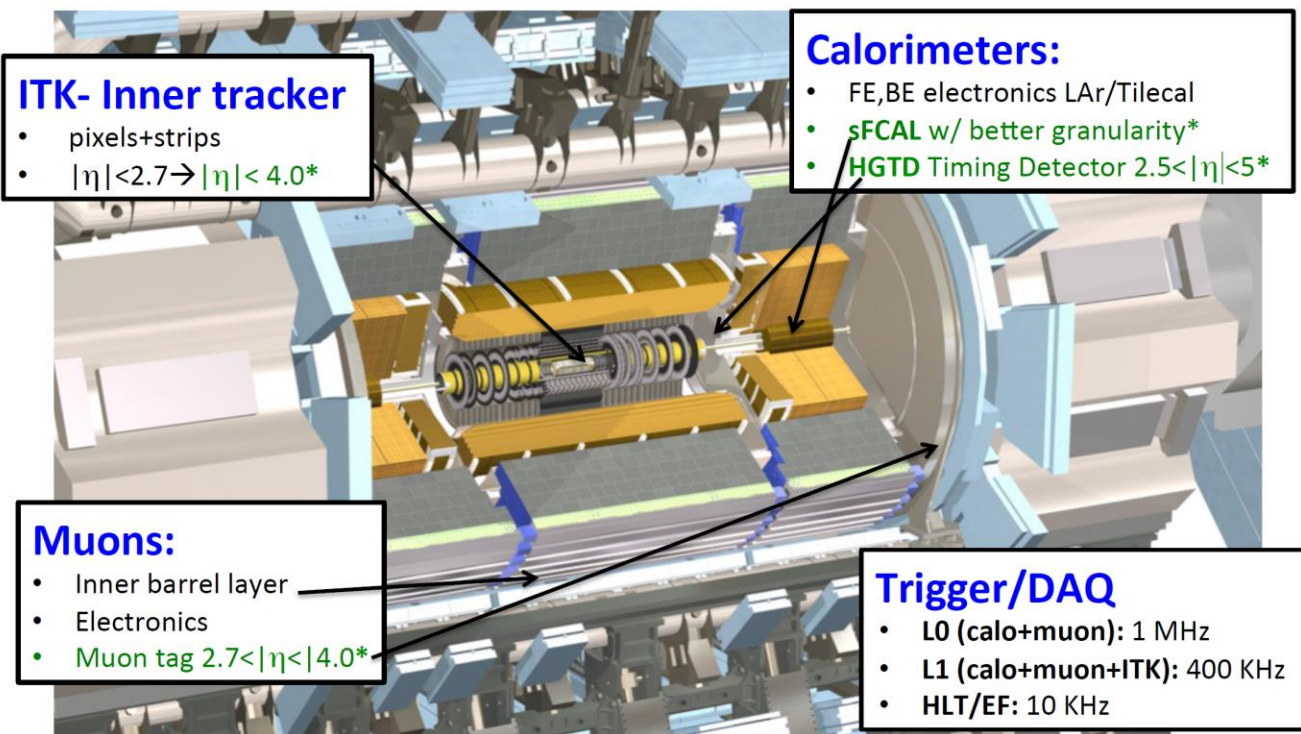
- Similarly, U.S. ATLAS is defining the scope of its contributions to HL-LHC by leveraging interests and experience of U.S. groups, coordinating with international ATLAS

- **DOE Scope:**

- Barrel Inner Tracker (pixel & strip detector)
- LAr Calorimeter front-end analog chip development
- DAQ hardware (data flow elements)

- **NSF Scope:**

- ‘Triggering’ at high luminosities
- Readout electronics for LAr, Tile, Muons



** Large forward rapidities, as described in the 2015 ATLAS HL-LHC scoping document (for the reference 275 MCHF CORE total cost scenario)*

NSF & DOE Partnership

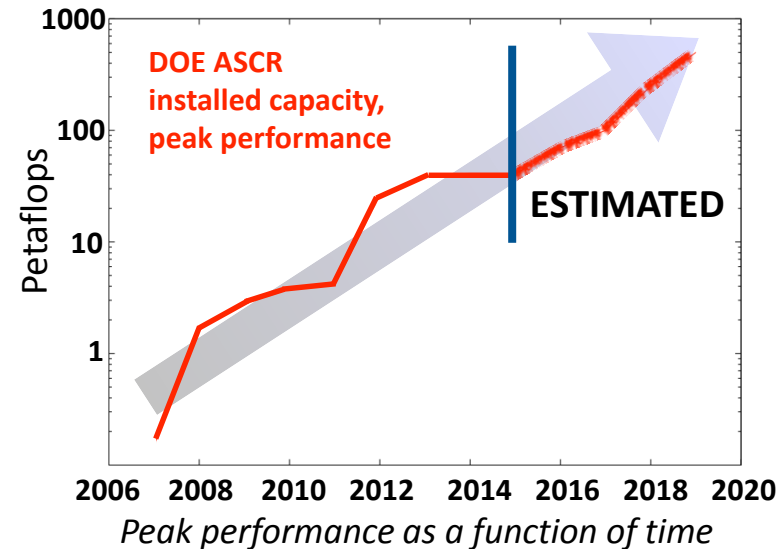
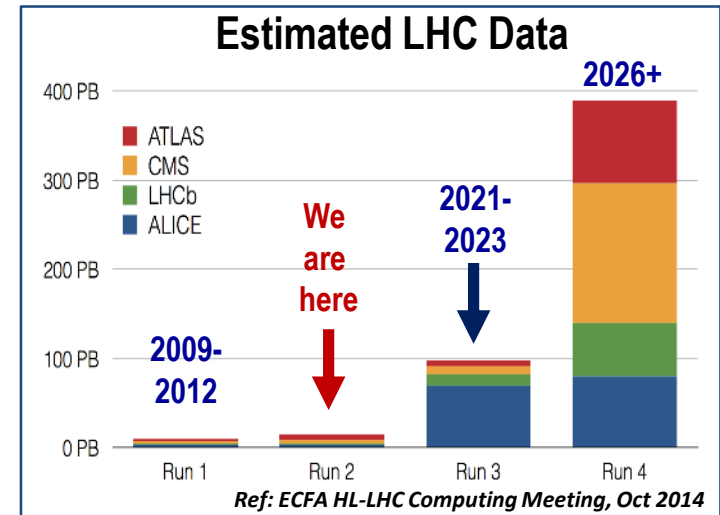
- **In addition to the partnership with CERN, the U.S. HL-LHC ATLAS and CMS Detector Upgrade Projects are a partnership between NSF and DOE**
- **Each detector upgrade is managed as a single project**
 - A single resource loaded schedule
 - A single Earned Value Management System with agency specific financial reporting to measure performance and progress
 - Integrated project controls team
- **Partitioning of scope and deliverables to the maximum extent as possible in order to minimize dependencies**
 - Maintaining oversight and coordination through the DOE-NSF U.S. LHC Joint Oversight Group (JOG)
- **Both DOE and NSF have long and successful experience with this single project management model**
 - Agency processes for approval are distinct (DOE Critical Decision, NSF MREFC), but agencies and Administration (OMB, OSTP) are experienced at managing these differences

DOE HL-LHC Project Schedules

- **HL-LHC Accelerator Upgrade Project**
 - DOE CD-1/CD-3a (Long-lead Procurement) Reviews held in August 2017 went well; DOE decision for CD-1/CD-3a approval planned for fall 2017
 - Project is advanced technically and management team is transitioning well from the LARP R&D mode to DOE project execution with a strong project office at Fermilab
 - Project likely to go for CD-2 (Project Baseline) in the second half of 2018
- **HL-LHC ATLAS and CMS Detector Upgrade Projects**
 - Finalizing resource-loaded schedules, including scope contributions and contingency estimations
 - DOE working with U.S. ATLAS (BNL) and U.S. CMS (Fermilab) project offices to understand funding profiles in preparation for next milestone (DOE CD-1), which is planned for spring 2018

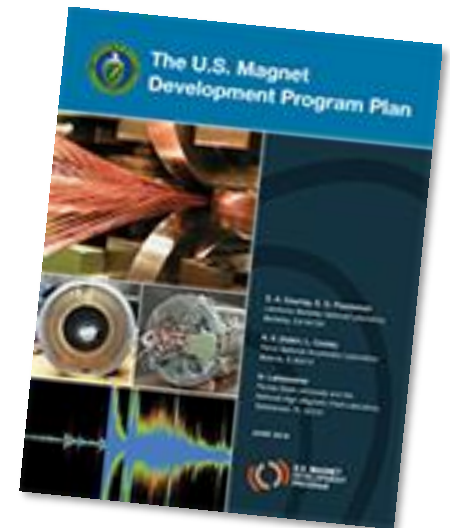
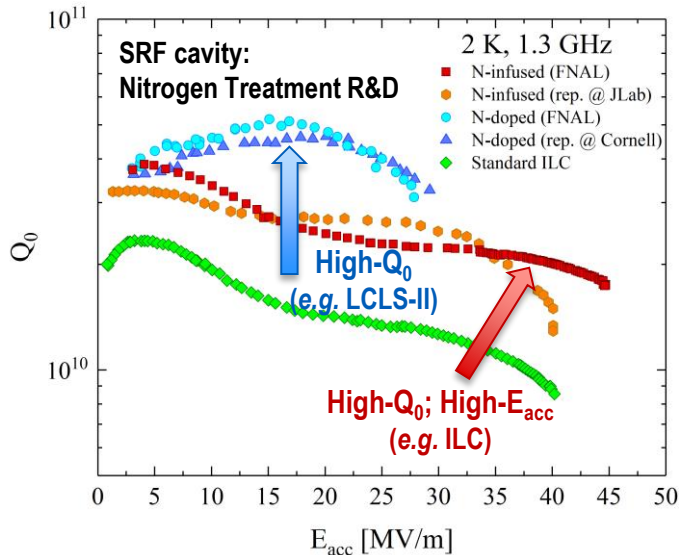
U.S. LHC Computing

- We recognize the challenges faced by the experiments in Runs 3 and 4
- A central element in our strategy is leveraging DOE High Performance Computing (HPC) resources in the Office of Advanced Scientific Computing Research
 - ATLAS and CMS leveraging HPCs during Run 2
 - U.S. LHC Operations Program is working with DOE for seeking multi-year HPC allocations, which are useful for planning
 - DOE coordinating with U.S. ATLAS/CMS to utilize HPCs during the HL-LHC running period
 - The Exascale Computing Project plans to increase HPC capacity even faster than the LHC luminosity
 - We are supporting efforts at our labs and universities along this direction
- Data curation, handling and distribution is equally important
- We would like to foster partnerships throughout the global HEP community to prepare for the future computing landscape



Future Colliders

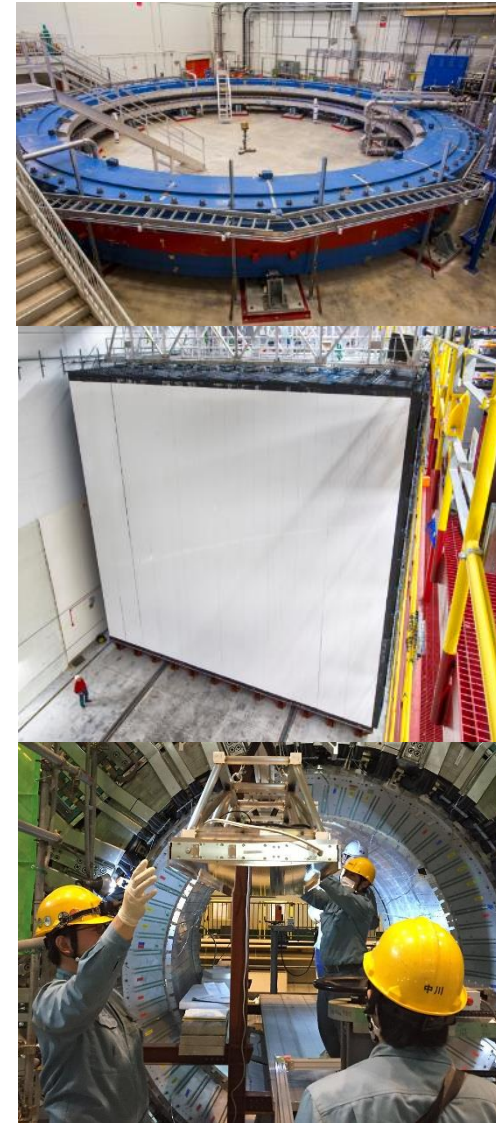
- DOE has been coordinating with the international community towards the development of the next collider program
- Interest from HEP community to pursue R&D studies for future collider options (e.g., Europe/CERN Future Circular Collider or Japan-proposed ILC)
 - Current DOE efforts focused on next generation high-field magnet technology to enable higher energy future circular collider
 - For ILC, current DOE efforts focused on cost reduction R&D—for e.g., nitrogen treatment in SRF accelerator cavity technology: potential for up to 10% cost reductions in 3-5 years, up to 15% in 5-10 years
- **Given tight fiscal budgets in the Energy Frontier program, near-term priorities will aim to support the LHC program as well as R&D for the HL-LHC upgrades**
 - Very modest R&D towards these future collider initiatives may continue, as funding allows



Intensity Frontier Program

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

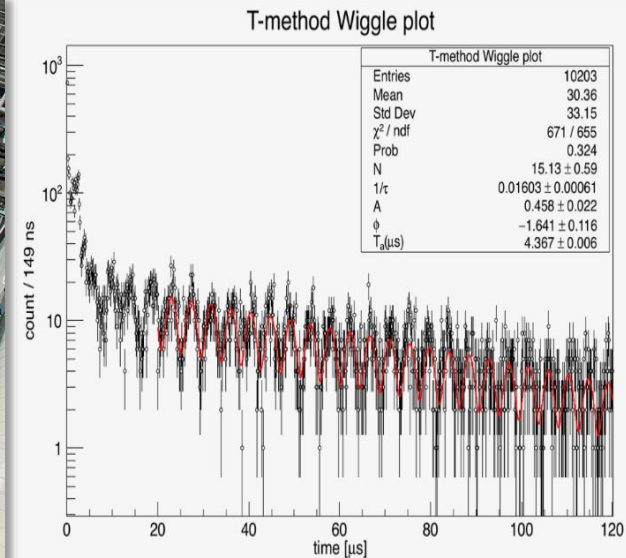
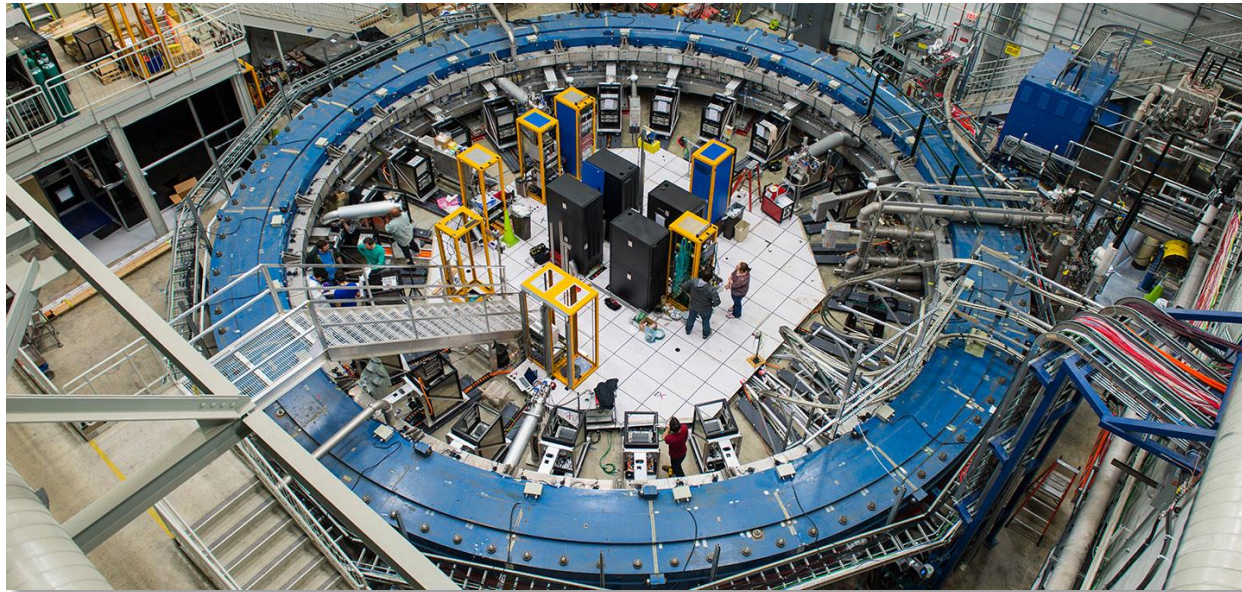
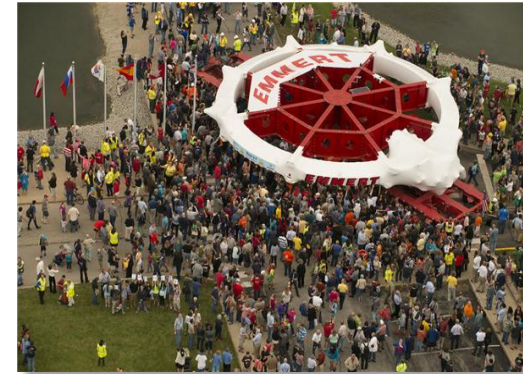
- Exploring the unknown through precision measurements:
 - *Muon g-2, Mu2e, Belle II, KOTO*
- Identify the new physics of dark matter:
 - *Heavy Photon Search*
- Pursuing the physics associated with neutrino mass:
 - *NOvA, Daya Bay, MINERvA, Super-K, T2K* ongoing
 - Fermilab Short-Baseline Neutrino Program (*MicroBooNE, SBND, ICARUS*)
 - Preparing to host world-leading neutrino program with the Long-Baseline Neutrino Facility and Deep Underground Neutrino Experiment (*LBNF/DUNE*)



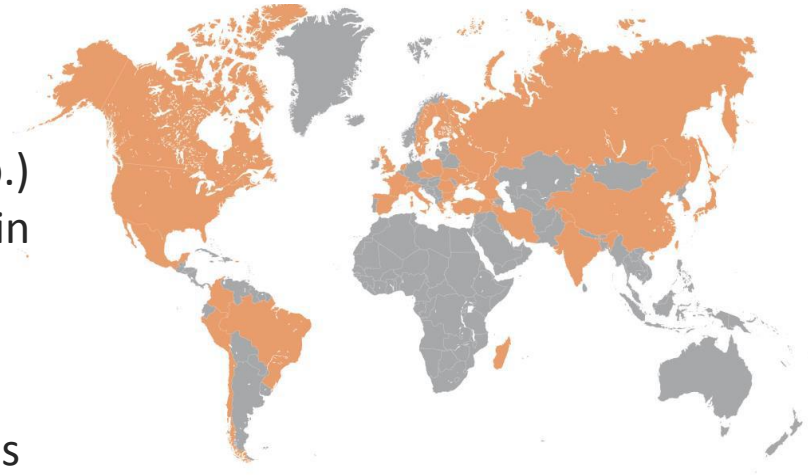
Fermilab Muon $g-2$ MIE Near Completion

Muon Storage Ring from BNL relocated to Fermilab in 2013 for the Muon $g-2$ Experiment

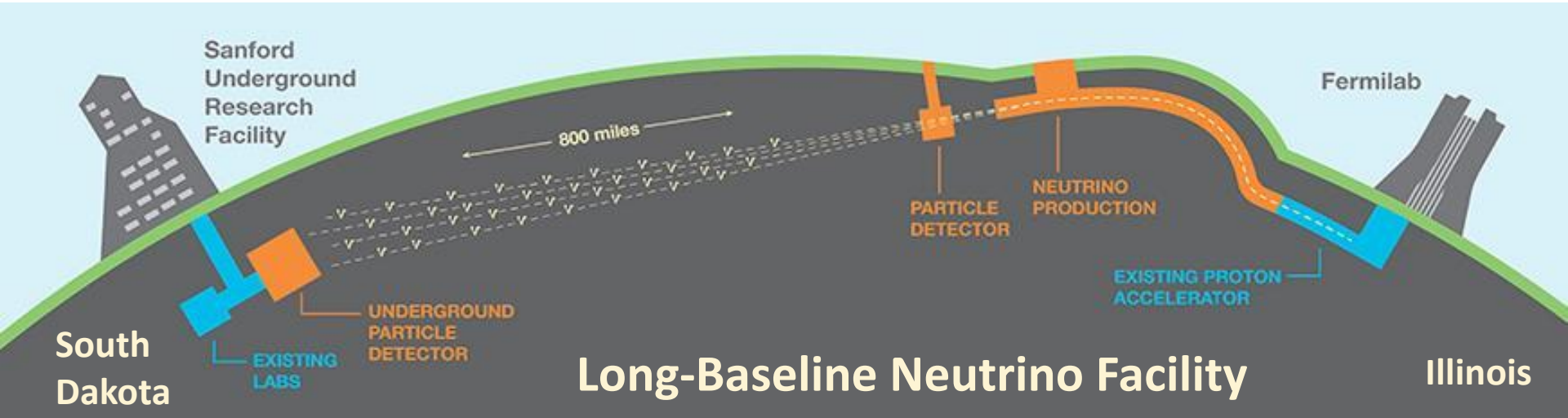
- New beam and detectors at the Fermilab Muon Campus
- DOE/NSF Equipment Project is 99% complete
- DOE CD-4 project completion planned for December 2017
- 190 collaborators from 35 institutions in 8 countries



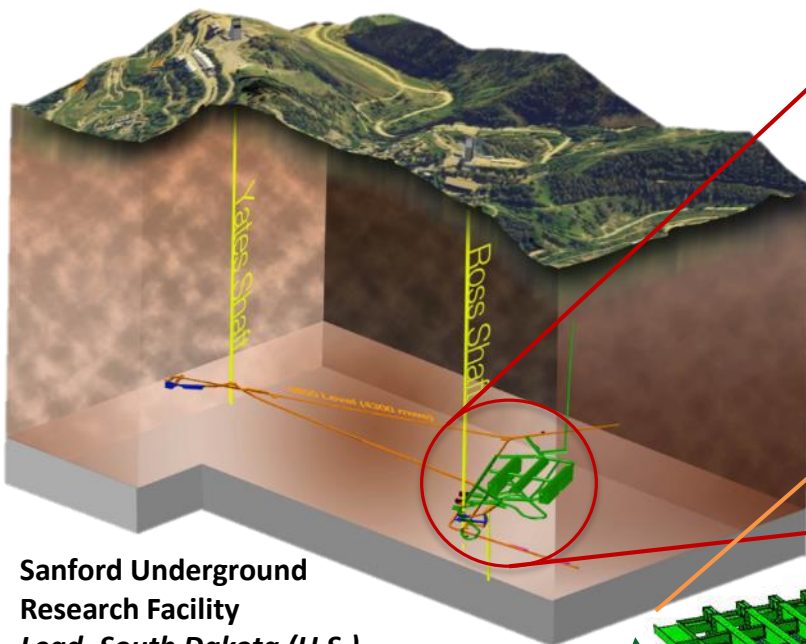
LBNF/DUNE



- **P5 recommended Long-Baseline Neutrino Facility (LBNF) as the centerpiece of a U.S.-hosted world-leading neutrino program**
 - LBNF will produce the world’s most intense neutrino beam, send it 800 miles through the earth to DUNE (Deep Underground Neutrino Exp.)
 - “Mega-science” facility with strong support within the U.S. Government
 - Many potential global partners are interested
- **International DUNE collaboration includes:**
 - **1,021** collaborators, **174** institutions, **30** countries

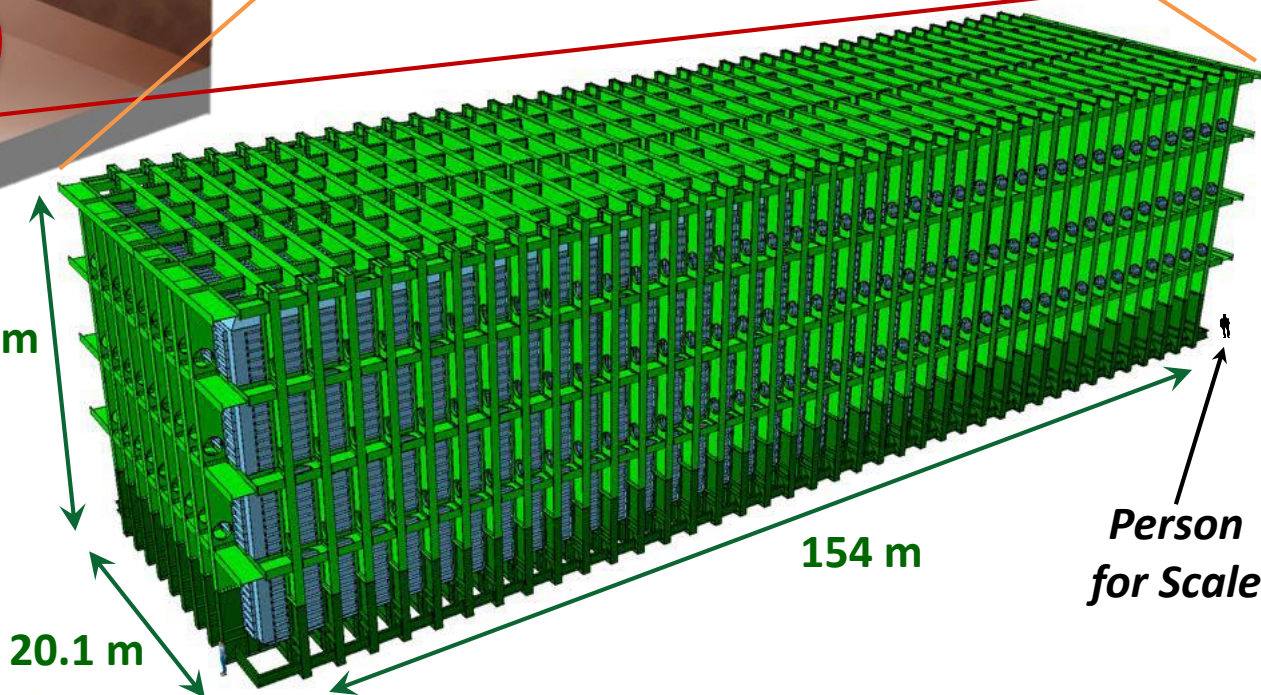
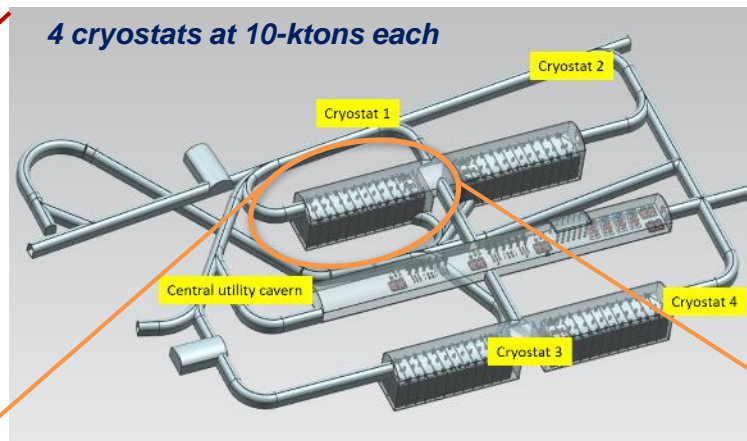


LBNF/DUNE in South Dakota



Sanford Underground
Research Facility
Lead, South Dakota (U.S.)

Large-scale
cryogenic vessel
will house state-of-
the-art neutrino
detector 1.6 km
(1 mile) underground



LBNF/DUNE Project Groundbreaking

21 July 2017 – Lead, South Dakota (United States)

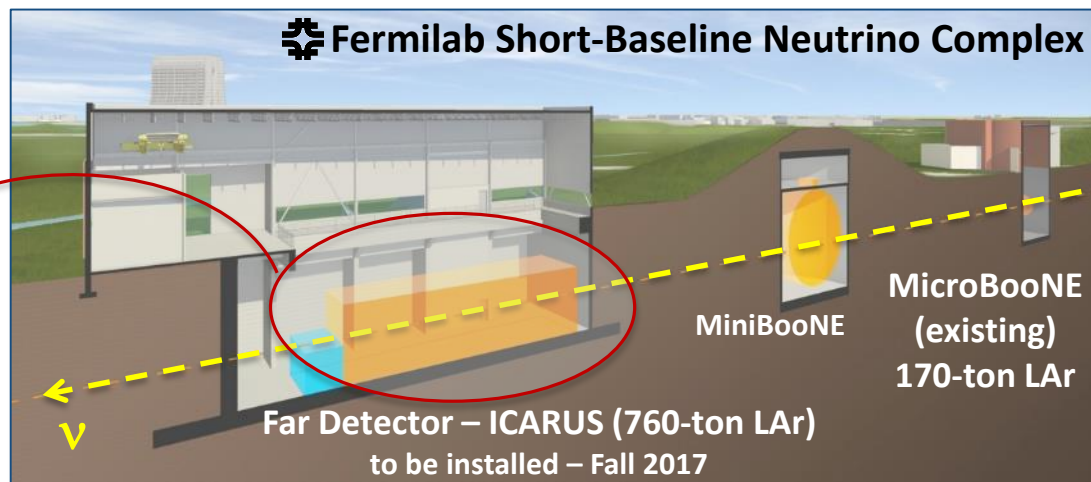


From Left: Fermilab Director N. Lockyer; Exec. Director of Programs G. Blair, STFC U.K.; Prof. S. Bertolucci, INFN Italy; Director for International Relations C. Warakaulle, CERN; Rep. R. Hultgren, Illinois; Rep. K. Noem, South Dakota; Senator M. Rounds, South Dakota; Senator J. Thune, South Dakota; Assoc. Director for HEP J. Siegrist, U.S. DOE; Deputy Assistant to the President and Deputy U.S. Chief Technology Officer M. Kratsios; South Dakota Governor D. Daugaard; Project Manager S. Lundgren, Kiewit/Alberici; Exec. Director M. Headley, SURF; and Chair of the Board C. Peterson, South Dakota Science and Technology Authority. Photo Courtesy: Reidar Hahn, Fermilab.

“Today's groundbreaking ... serves as a model for what the future of mega-science research looks like: an intensely collaborative effort between state, local and federal governments, international partners, and enterprising corporate and philanthropic pioneers whose combined efforts will significantly increase our understanding of the universe.” — Deputy Assistant to the President and Deputy U.S. Chief Technology Officer Michael Kratsios, White House Office of Science and Technology Policy

Advancing Technology Towards LBNF/DUNE

- **Fermilab Short-Baseline Neutrino Program**
 - Resolve experimental anomalies in measured ν -spectrum, including search for sterile neutrino
 - Demonstrate the detector technology for DUNE
- **The largest liquid argon neutrino detector in the world, ICARUS, was transported this summer from Europe (CERN) to the U.S. (Fermilab in Illinois)**
 - First major item of equipment to ship for the international neutrino program



#IcarusTrip

Fermilab's new home for refurbished ICARUS

ICARUS arrives at Fermilab
July 26, 2017

17 June 2017

On Barge near
Mainz, Germany

Transatlantic Voyage

via Big Rig from
Indiana to Fermilab
24-26 July 2017

Great Lakes Cargo Vessel

6 July 2017

12 June 2017

Leaving CERN in
Geneva, Switzerland



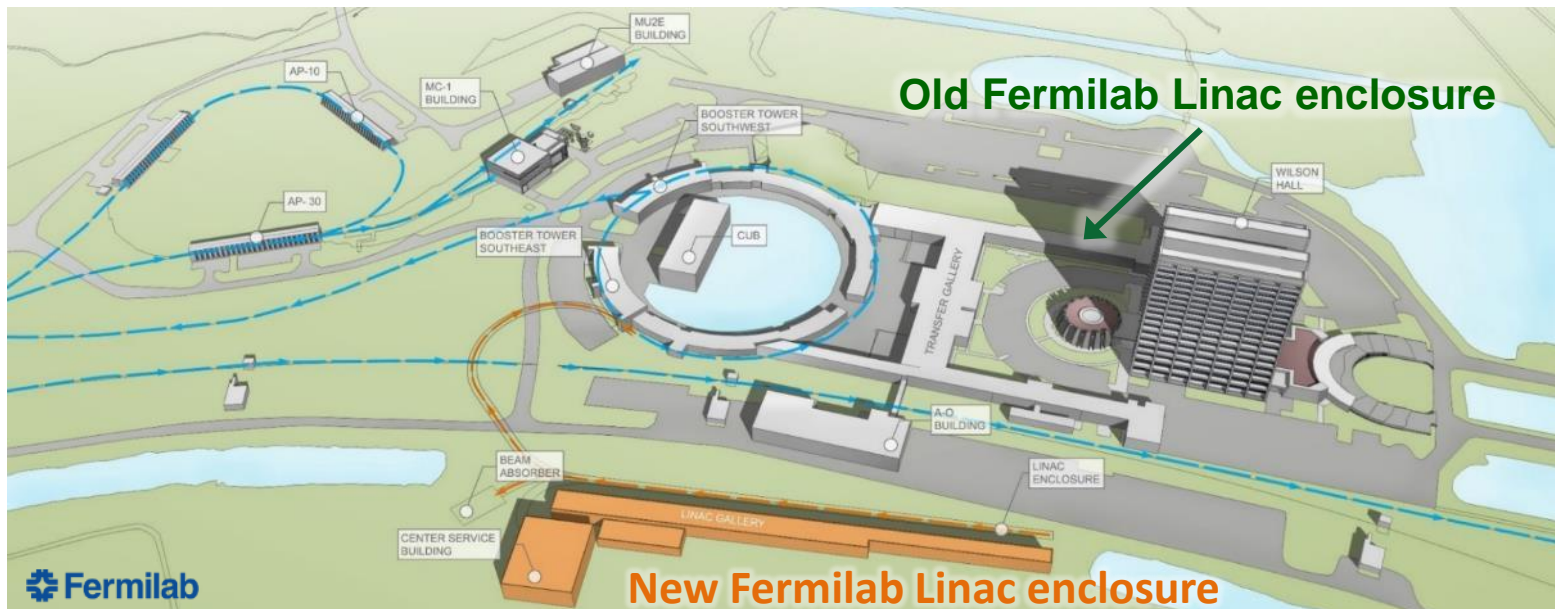
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Proton Improvement Plan II (PIP-II)

The P5 report recommended that PIP-II proceed immediately in order to provide increased proton beam intensity (of > 1 megawatt) for LBNF

- Replace the existing 50 year old linear accelerator with a higher power, modern one powered by superconducting radiofrequency cavities
- Supports longer-term physics research goals by providing increased beam power and high reliability for future experiments at Fermilab, including LBNF/DUNE

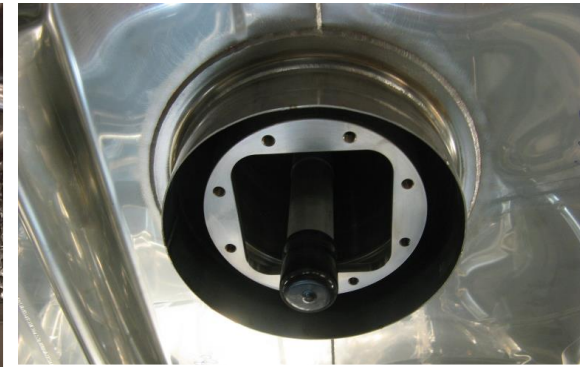
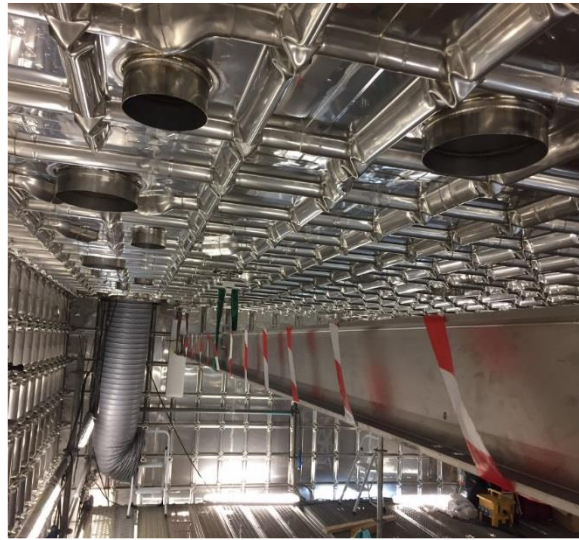


DUNE Far Detector Consortia



- **DUNE Collaboration underwent a major reorganization, moving from far detector working groups to consortia of institutions that will take responsibility for detector sub-systems**
 - Similar to the LHC experiments, this organization will allow institutions to take responsibility for concrete deliverables
 - Consortia will have responsibility to prepare technical proposals, TDRs, and will help to establish the required funding matrix
- **Nine international consortia groups include:**
 - **Joint Single-Phase/Dual-Phase detector:** High Voltage, Data Acquisition, Slow controls and cryogenic instrumentation
 - **Single-Phase detector:** Anode Plane Assembly, Photon Detection, TPC Electronics
 - **Dual-Phase detector:** Charge Readout Plane, Photon Detection, TPC Electronics

Technical Progress Towards DUNE: protoDUNE



International Partnerships for U.S.-hosted Neutrino Program

- **International partnerships for LBNF/DUNE and/or PIP-II continue to grow**
 - CERN is an important partner and is meeting commitments according to the signed DOE-CERN Protocol and Addendum; planning to begin cryostat procurement
 - DOE looks forward to completing U.S.-India Project Annex II
 - Discussions continue with Italy, Brazil, and other Latin American nations
- **Institutions from several countries have signed international Cooperative R&D Agreements with Fermilab to work on LBNF/DUNE development**
 - Including Australia, France, Germany, Mexico, and Brazil
- **Recently, UK-U.S. Science and Technology Agreement signed 20 September 2017**
 - By UK Science Minister Jo Johnson and U.S. Acting Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs Judith Garber
 - The first major project under this agreement is UK investment of £65 million (\$88 million) in LBNF/DUNE



Cosmic Frontier Program

Dark energy program through suite of complementary surveys, in partnership with NSF

- **Fast sky scanning surveys catch dynamic events, like supernovae:** *Dark Energy Survey (DES) operating, Large Synoptic Survey Telescope (LSST) camera in fabrication*
- **Deep, high accuracy surveys study dim, more distant objects:** *BOSS completed; eBOSS operating, Dark Energy Spectroscopic Instrument (DESI) in fabrication*

Dark matter searches through direct detection experiments with multiple technologies, in partnership with NSF

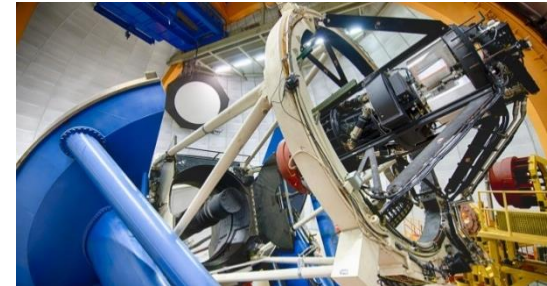
- **First-gen. experiments produced world's most sensitive searches**
- **Progressing toward next generation experiments:** *ADMX-G2 operating, LZ in fabrication, SuperCDMS-SNOLAB*

Study high-energy particles produced from cosmos, in partnership with NSF, NASA

- **Cosmic- and gamma-ray detectors on Earth and in space:** *Fermi/GLAST, AMS, and HAWC*

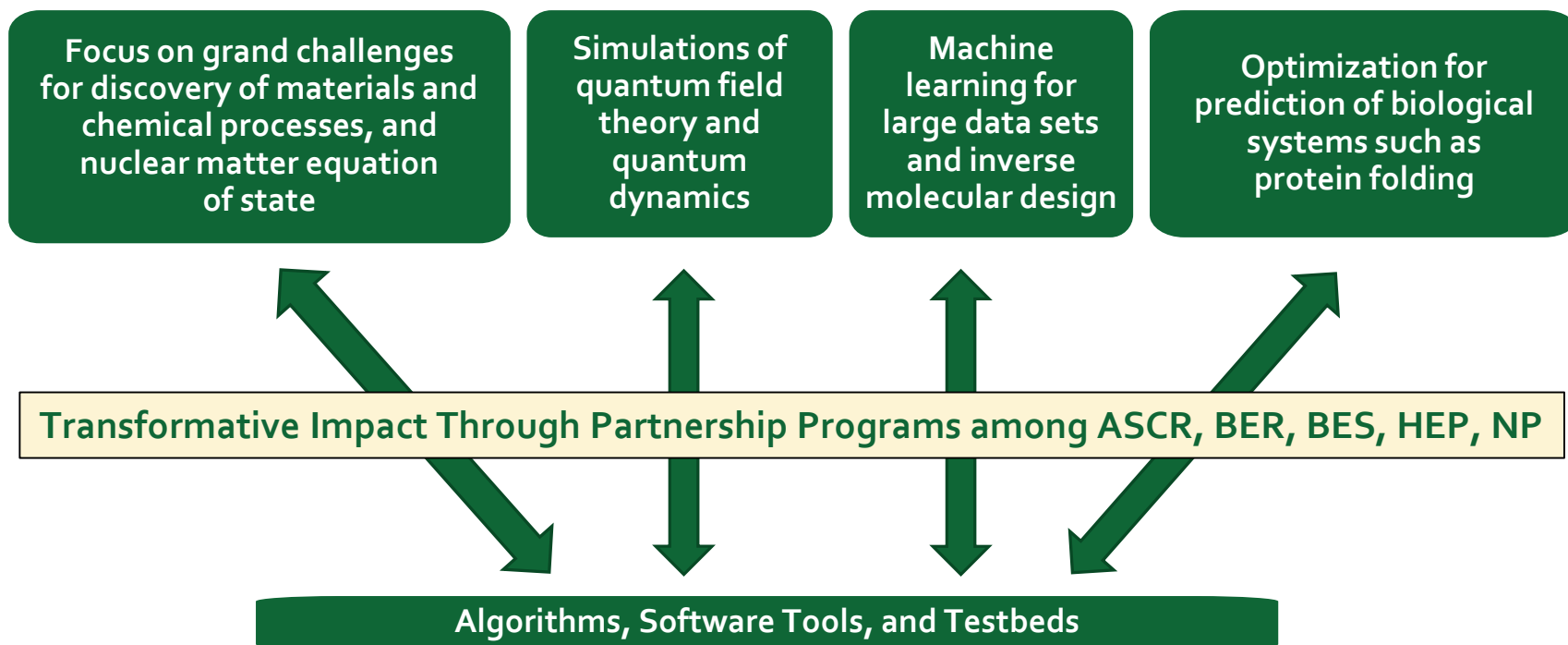
Study cosmic acceleration imprint on cosmic microwave background (CMB), in partnership with NSF, NASA

- **New generation now operating:** *SPT-3G*



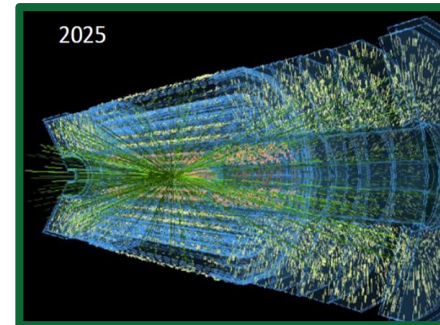
Quantum Information Science (QIS) across SC

- HEP is playing a major role in a broader DOE Office of Science (SC) initiative on QIS, building on HEP's three years of strong engagement in this topic via roundtables, workshops, reports, and Federal interagency cooperation



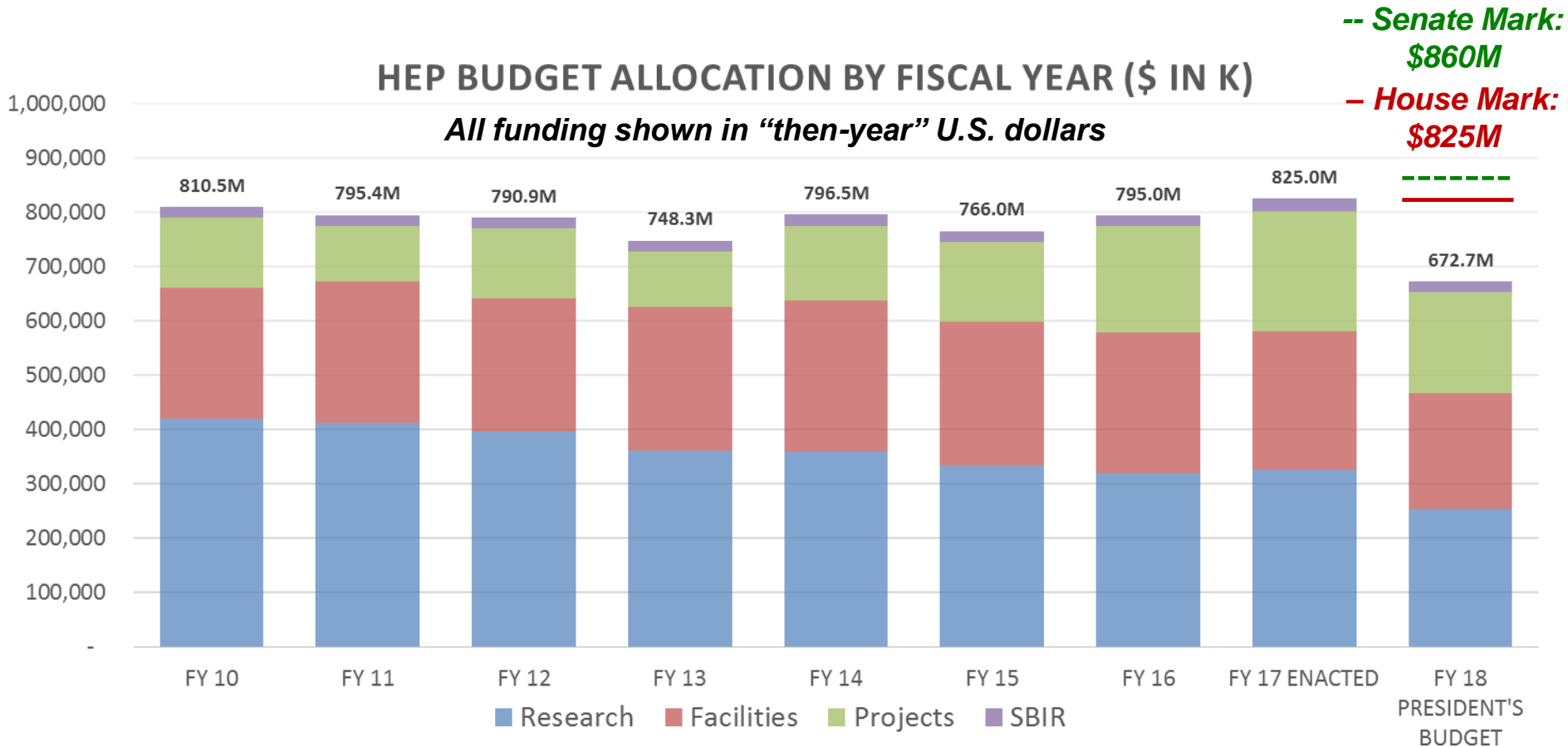
Quantum Information Science - HEP update

- Emphasis is on HEP mission, science drivers, and advancement of QIS in the context of the broader SC initiative
- Program Manager for QIS at HEP: Lali Chatterjee
- **FY 2018: Total of ~\$15M for QIS, prioritized as:**
 - Fundamental HEP and QIS research
 - Foundational concepts of quantum information
 - Field theory and analog simulations
 - Experiments and emulators
 - Supporting technology for HEP
 - Quantum computing
 - Quantum controls and sensors
- **Funding Opportunity Announcement (FOA) and Lab Program Announcement**
 - in development for potential release after appropriations
- **Potential SBIR topics are being developed to support and complement HEP QIS activities**
- **Community input needed! Request For Information expected to be posted by HEP soon**



Overall HEP Budget Trend

- P5 strategy continues to define investments in future of the field
- Current draft of U.S. House of Representatives FY 2018 appropriations bill is flat with respect to FY 2017, while the U.S. Senate draft bill is slightly up



Status of FY 2018 Appropriations

- **U.S. House of Representatives released draft language for the FY 2018 budget in June 2017; U.S. Senate in mid-July 2017**
 - Language in both chambers of U.S. Congress supportive of HL-LHC Accelerator Project, HL-LHC ATLAS and CMS Upgrade projects, LBNF/DUNE, and Cosmic Frontier projects
 - Research funding will by necessity continue to be constrained, but efforts critical to executing the P5 recommendations remain a priority
- **DOE is also working with Fermilab and SBN managements to develop FY 2018 operations schedule for the SBN complex, including ICARUS**
- **Funding level is set once the Congressional appropriation bill has passed**

- **Fiscal Year 2018 begins on October 1, 2017, with a Continuing Resolution (CR) through December 8, 2017**
 - CR passed by U.S. Congress and has been signed by the President

HEP Office Comings & Goings

- **Incoming:**
 - Altaf (Tof) Carim (from BES) [HEP International, QIS](#)
 - Michael Harrison (Detaillee) [PIP-II](#)
 - Thomas LeCompte (Detaillee) [Energy Frontier, Computing](#)
 - Brian Morsony (AAAS S&T Policy Fellow) [Big Data, Computing](#)
 - Andrea Peterson (AAAS S&T Policy Fellow) [Communications](#)
- **Outgoing:**
 - Anwar Bhatti (IPA) [Cosmic Frontier](#)
- **“Hiring freeze” has lifted but no DOE Fed positions open at this time**
- **We are actively pursuing additional IPAs/Detailees to assist with critical tasks in Cosmic and Intensity Frontier subprograms**
 - Interested parties should contact HEP Management

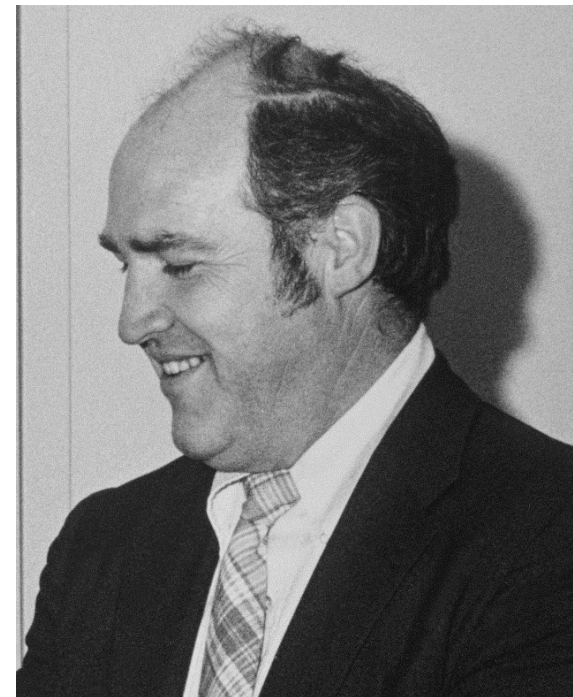
In Memory of Bill Wallenmeyer

The Office of High Energy Physics was saddened to hear that Bill Wallenmeyer passed away on August 25, 2017.

Bill served as the Director of the Office of High Energy Physics of the Office of Science of the Department of Energy for 23 years from 1964 to 1987.

Bill led the Office of High Energy Physics through an active and challenging period which saw the construction, commissioning and operation of the Fermi National Accelerator Laboratory and the evolution of the four other national labs with large HEP programs, Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory and the Stanford Linear Accelerator Center. He oversaw the preparation of the proposal for the Superconducting Super Collider. He also guided the Universities Research programs and was instrumental in formulating and achieving several international agreements and cooperative programs including bilateral agreements with the Peoples Republic of China, Japan, U.S.S.R, and the European community.

His Celebration of Life will be held at Cedar Lane Unitarian Church in Bethesda, Maryland on Sunday, November 5, 2017 at 3 pm. Expressions of sympathy may be made to The Rockville Nursing Home in Rockville, Maryland and The American Rhododendron Society - Potomac Valley Chapter.



Closing Remarks

- **In the immediate future:**
 - Keep “Building for Discovery!” and producing great science!
 - Communicate any of your concerns to us
- **In the coming months:**
 - Keep producing great science!
 - We will begin the next fiscal year (FY 2018) on October 1, 2017 under a continuing resolution (CR), currently through December 8, 2017
 - HEP is working with laboratory management on program plans under the CR as well as developing plans for an eventual appropriation
 - HEP is also working with Project Managers on plans while waiting for the final appropriation





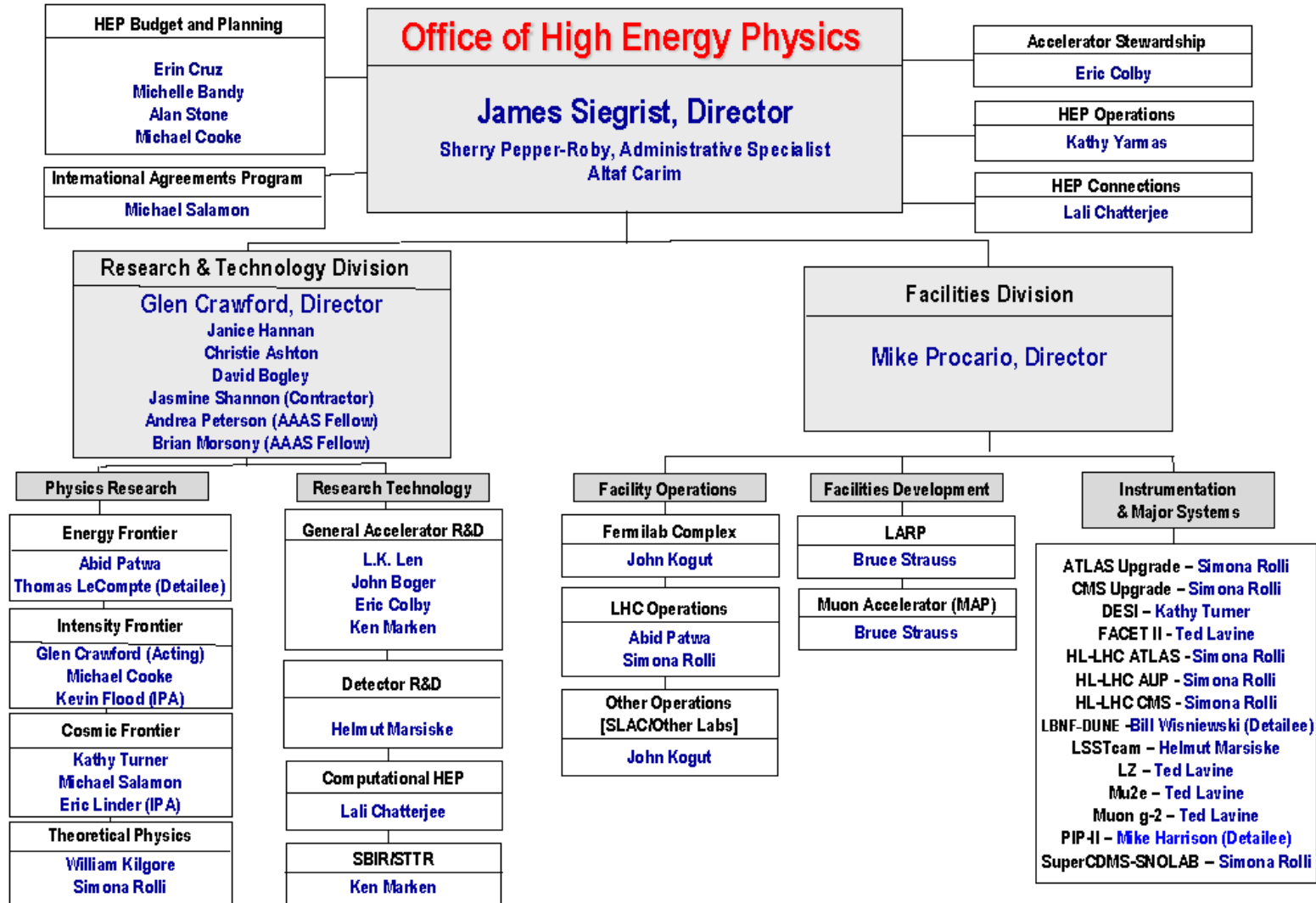
U.S. DEPARTMENT OF
ENERGY

Office of
Science

HEP MIE Project Status

| Subprogram | TPC (\$M) | CD Status | CD Date |
|--|---------------|-----------|-------------------|
| INTENSITY FRONTIER | | | |
| Long Baseline Neutrino Facility / Deep Underground Neutrino Experiment (LBNF/DUNE) | 1,300 – 1,900 | CD-3A | September 1, 2016 |
| Proton Improvement Project (PIP-II) | 465-650 | CD-0 | November 12, 2015 |
| Muon g-2 | 46.4 | CD-3 | August 20, 2015 |
| Muon-to-Electron Conversion Experiment (Mu2e) | 273.677 | CD-3 | July 14, 2016 |
| ENERGY FRONTIER | | | |
| LHC ATLAS Detector Upgrade | 33 | CD-3 | November 12, 2014 |
| LHC CMS Detector Upgrade | 33 | CD-3 | November 12, 2014 |
| High-Luminosity LHC (HL-LHC) Accelerator Upgrade | 180-250 | CD-0 | April 13, 2016 |
| High-Luminosity LHC (HL-LHC) ATLAS Detector Upgrade | 125-155 | CD-0 | April 13, 2016 |
| High-Luminosity LHC (HL-LHC) CMS Detector Upgrade | 125-155 | CD-0 | April 13, 2016 |
| COSMIC FRONTIER | | | |
| LUX-ZEPLIN (LZ) | 55.5 | CD-3 | February 9, 2017 |
| Super Cryogenic Dark Matter Search - SNOLAB (SuperCDMS-SNOLAB) | 16-21 | CD-1 | December 21, 2015 |
| Dark Energy Spectroscopic Instrument (DESI) | 56.328 | CD-3 | June 22, 2016 |
| 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) | 46-60 | CD-1 | December 21, 2015 |

DOE Office of High Energy Physics



HEP underpins and advances the DOE missions and objectives through a balance portfolio of scientific **research**, facilities' **operations** and **projects**, and by the development of **key technologies** and **trained person-power** needed to work at the cutting edge of science.

HEP Budget vs. P5 Funding Scenarios

- P5 was charged to consider three 10-year budget scenarios for HEP within the context of a 20-year vision for the global field
 - Scenario A was the lowest constrained budget scenario
 - Scenario B was a slightly higher constrained budget scenario
 - Scenario C was “unconstrained,” but not considered unlimited
- FY 2018 appropriations process is progressing
 - President’s Budget Request released May 23; House/Senate Marks in June/July
 - Congressional Appropriations Committees are drafting legislation
 - Final language of appropriations bill (and report) impact how funding is directed

HEP BUDGET SCENARIOS

