U.S. DEPARTMENT OF ENERGY | Office of Science

Status of the DOE High Energy Physics Program

HEPAP Meeting
December 9, 2015

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

Executing the P5 Strategy to Enable Discovery

- The Particle Physics Project Prioritization Panel (P5) report sets a clear long-term vision for U.S. particle physics within the global context
  - Report is the culmination of years of effort by the U.S. particle physics community
  - Strong U.S. particle physics community support
- DOE HEP is implementing the discovery-driven strategic plan set within a global vision for particle physics as presented in the P5 report

International Partnerships

Successful partnerships key to implementing U.S. long-term strategy

New Bilateral U.S.-CERN Agreement – May 7, 2015

DOE-Italy Agreement on High Energy, Astroparticle and Nuclear Physics Research – July 17, 2015

DOE-MEXT Project Arrangement – Oct. 6, 2015

U.S.-CERN Agreement Annexes

- New bilateral DOE-NSF-CERN International Co-operation Agreement was signed at the White House Eisenhower Executive Office Building on the 7th of May 2015
  - Highlights important future international scientific and technological collaborations between the U.S. and CERN
- Protocols (annexes) to the Cooperation Agreement are now under negotiation with CERN and are expected to be completed soon
  - Accelerator Protocol (III)
    - LHC Accelerator Research Program (LARP)
    - U.S. Contributions to the HL-LHC Accelerator Upgrades
    - Future Circular Collider initiatives with CERN (as an Addendum)
  - Experiments Protocol (II)
    - U.S. and CERN responsibilities for HL-LHC ATLAS and CMS detector upgrades
    - U.S. contributions towards the HL-LHC ATLAS and CMS detector upgrades
    - Framework of ATLAS and CMS Experiments' National Contact Physicists, LHC Resources Review Boards (RRBs), and U.S. contributions to Common Funds
  - Neutrino Protocol (I)
    - CERN contributions to U.S.-hosted international neutrino program, including the Fermilab Short-Baseline Neutrino Program and LBNF/DUNE
    - Framework of Fermilab LBNF/DUNE RRBs and CERN contributions to Common Funds
- Protocols do not include detailed cost and scope, which will be specified through MOUs (non-binding) and/or Addenda (binding)

Other International Agreements

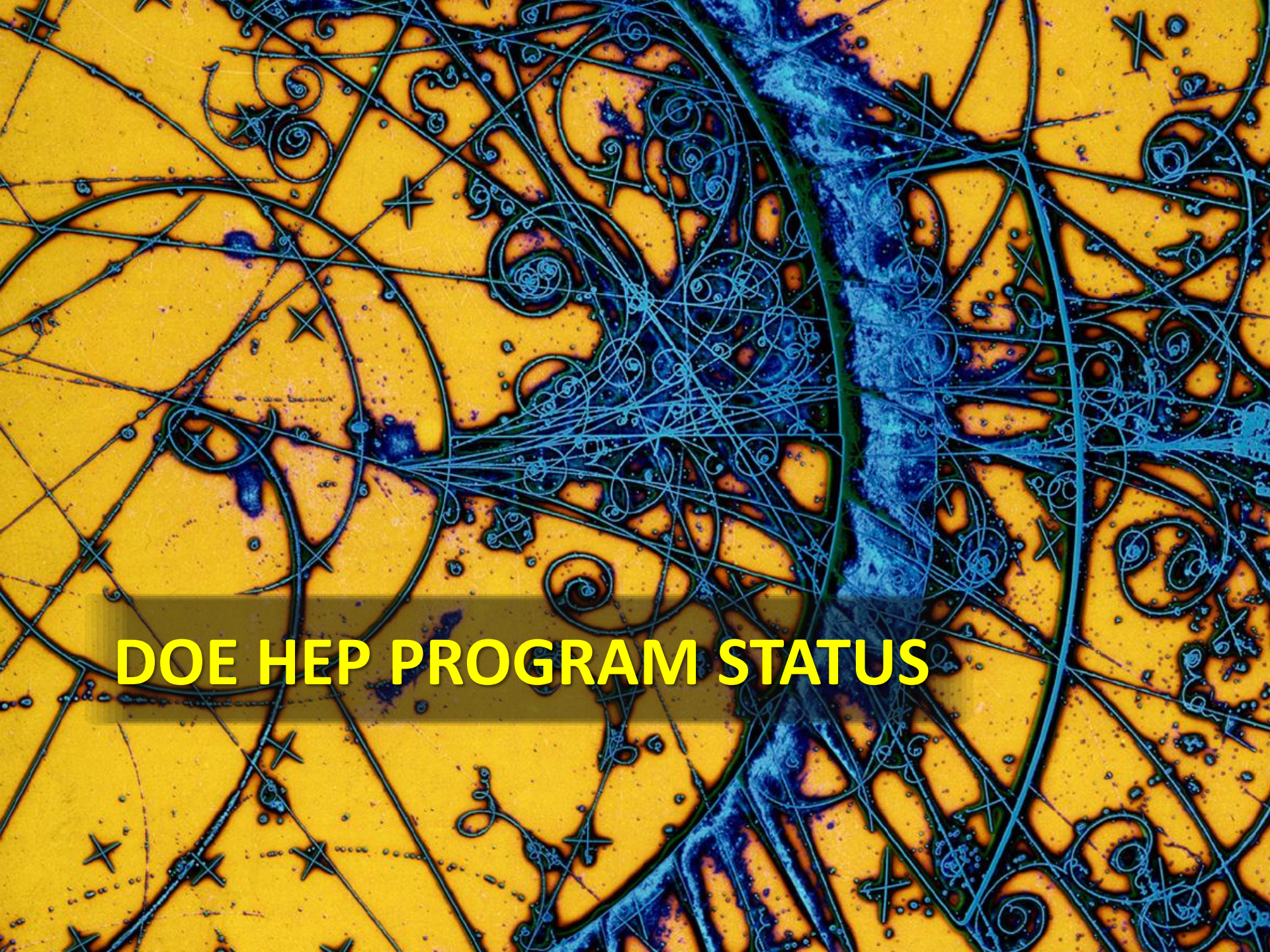
- **India**
  - An Implementing Agreement exists between DOE and the Indian Department of Atomic Energy (DAE) for Cooperation in the Area of Accelerator and Particle Detector R&D for Discovery Science
  - Under this Agreement with India are two DOE-DAE Project Annexes:
    - An Annex I agreement has been signed whose primary focus is on R&D and construction of high-intensity SRF linear proton accelerators (HISPA)
    - An Annex II agreement, on cooperation in scientific activities that are enabled by HISPA, is being negotiated
- **Italy**
  - An Implementing Arrangement was signed this July by DOE and the Italian Ministry of Education, Universities and Research for Cooperation in High Energy, Astroparticle and Nuclear Physics Research
  - A Project Annex to this Agreement was signed concurrently for cooperation in neutrino physics projects

Other International Agreements

- **Japan**
  - A Project Arrangement (Annex) for cooperation in HEP under an existing Implementing Arrangement was signed on October 6, 2015
- **France**
  - An Agreement exists between DOE and CNRS for cooperation in energy sciences
  - Following discussions at the U.S.-France Joint Commission Meeting this March, a Project Annex for cooperation in HEP is being considered
- **Brazil**
  - Following this May's U.S.-Brazil Joint Commission Meeting, a statement of intent to collaborate in neutrino physics was signed by DOE and the Brazilian Ministry of Science, Technology and Innovation
  - Potential agreements that would support DOE-Brazil cooperative activities in HEP are under discussion
- **UK and Canada**
  - Nation-to-Nation Science & Technology Agreements, under whose aegis lesser agreements obtain legal standing, do not exist for the UK or Canada
  - Other options for legal agreements are currently being pursued

Maintaining Visibility of the P5 Report

- **Successful implementation of the P5 strategy requires a coherent effort by members of the U.S. particle physics community**
- **A community-wide strategy that will enable the particle physics community to support the continued implementation of the plan needs to be developed**
  1. Build and maintain community consensus in the vision for the field
     - HEP aims to provide a forum to facilitate continued conversations by hosting annual PI meetings
  2. Develop a clear message supported by the community
     - Steve Ritz is leading this effort (see his HEPAP talk on Dec. 11)
  3. Share the message broadly
     - Steve Ritz has expressed interest in coordinating some of these activities
  4. Reinforce the message through media engagement
     - HEP will invite spokespersons to a teleconference to discuss this issue
  5. Leverage support from industry partners
     - Laboratories, universities, and experiments can all contribute


DOE HEP PROGRAM STATUS

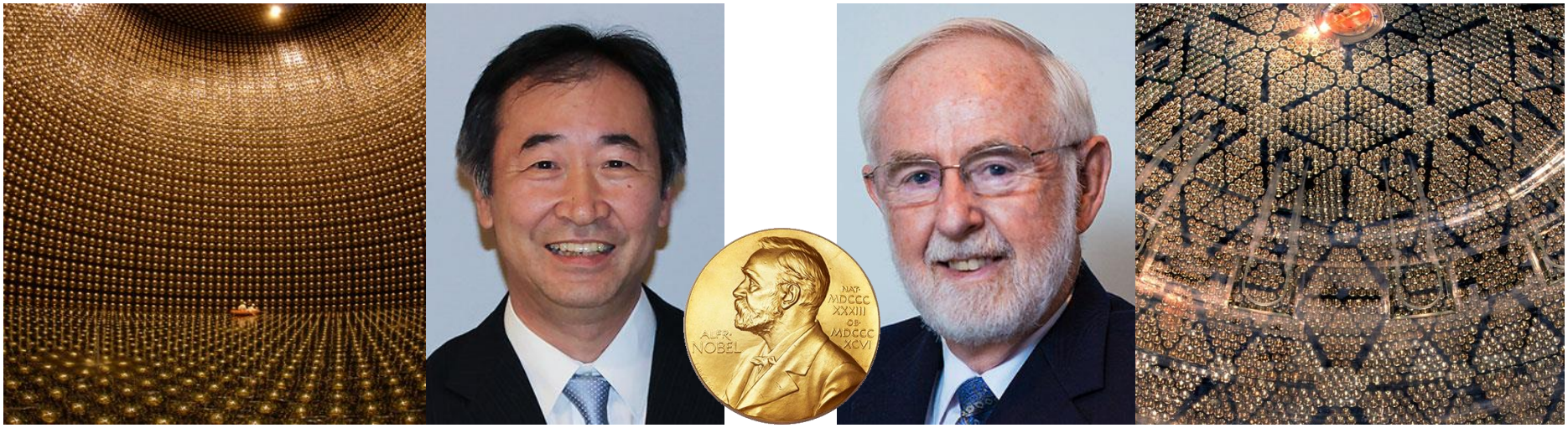
Enabling the Next Discovery

Science drivers identify the scientific motivation while the Research Frontiers provide a useful categorization of experimental techniques

	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

2015 Nobel Prize in Physics

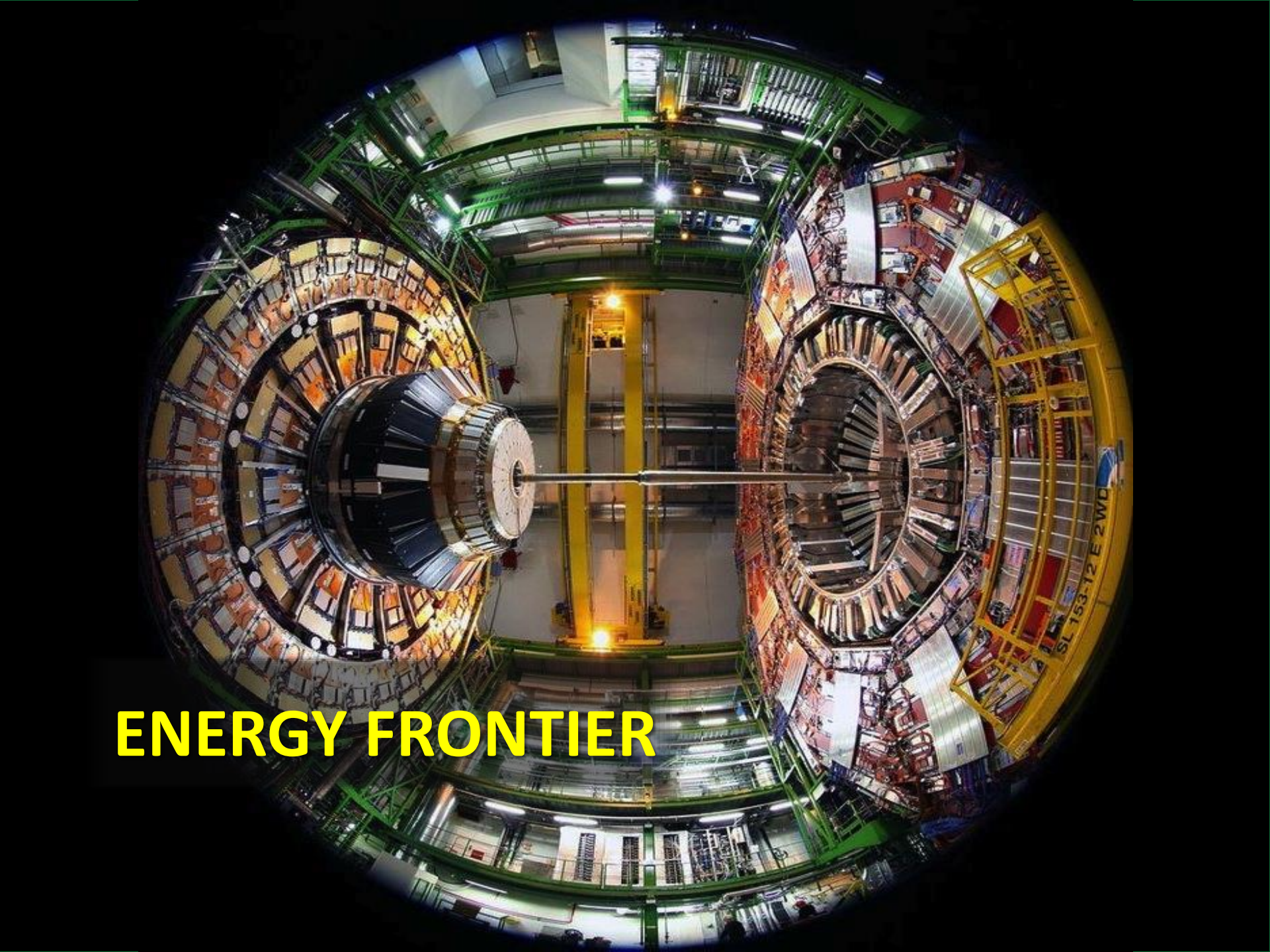
The Nobel Prize in Physics for 2015 was awarded to Takaaki Kajita and Arthur B. McDonald for the discovery of neutrino oscillations, which shows that neutrinos have mass



- The DOE Office of Science helped enable the discovery of neutrino oscillation by providing substantial support to the construction, operation, and research efforts of the Super-Kamiokande experiment in Japan and the Sudbury Neutrino Observatory in Canada
- The DOE High Energy Physics program is actively pursing the physics associated with neutrino mass through the Cosmic Frontier (DESI, LSST, CMB-S4) and the Intensity Frontier (a coherent set of U.S.-hosted, international short- and long-baseline neutrino experiments)

Neutrino Oscillations win Breakthrough Prize

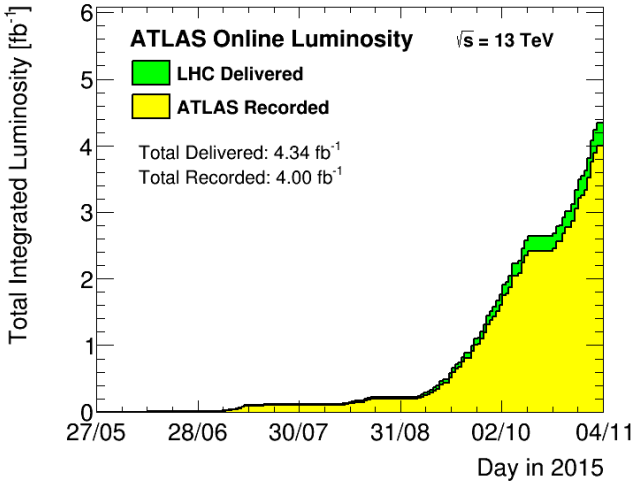
- **The 2016 Breakthrough Prize in Fundamental Physics was awarded to five experiments investigating neutrino oscillations that all received support from DOE HEP:**
  - **Daya Bay (China); KamLAND (Japan); K2K / T2K (Japan); Sudbury Neutrino Observatory (Canada); and Super-Kamiokande (Japan)**


ENERGY FRONTIER

Energy Frontier Highlight:

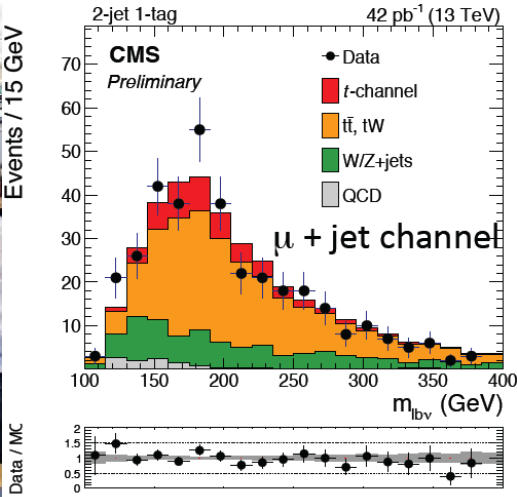
LHC Run II Provides Proton Collisions at a New Energy Frontier

- **LHC Run II in 2015 provided 13 TeV pp collisions from June 3 to Nov. 4**
  - **Over 4 fb^{-1} of integrated luminosity delivered to the experiments!**



ATLAS Run II integrated luminosity plot

Start of Run II!



CMS Run II single top analysis

- **Higher energy collisions increases the reach into search for new physics in high-impact topics:**
  - **SUSY, dark matter, extra dimensions, …**
- **DOE looks forward to Run II physics 'Results End-of-Year' event at CERN on December 15, 2015 (next week)**

LHC Strategy

- **P5 report identified LHC upgrades as the highest priority near-term large project and specifically recommends:**
  - **Complete "Phase-1" (2019) upgrades of ATLAS and CMS experiments**
  - **Continue collaborations with the "Phase-2" (High-Luminosity LHC, 2024-26) upgrades of the accelerator and the ATLAS and CMS experiments to extend discovery potential**
- **The next important step for HL-LHC is *finalizing* the international scope of accelerator and detector upgrades and determining the U.S. contributions**
  - **CERN's approval at October 2015 LHC RRB for ATLAS and CMS to proceed in developing subsystem-specific TDRs for upgrades**
  - **NSF will be an important partner in realizing the continued success of the U.S. LHC program through the HL-LHC upgrades**
  - **We are actively coordinating with NSF and the experiments the HL-LHC detector upgrade schedule and plans**

HL-LHC Detector Upgrade Status

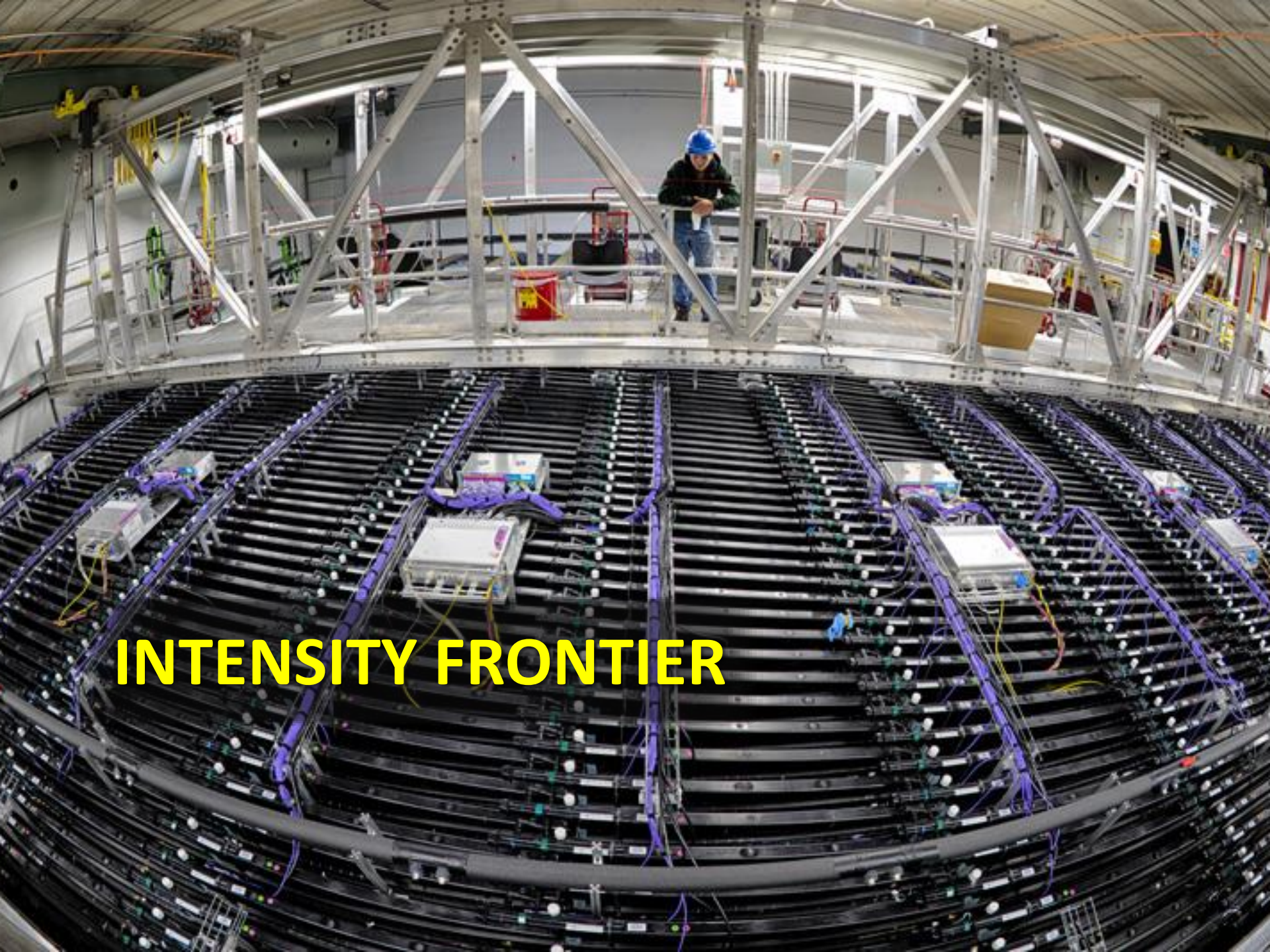
- **DOE plans for HL-LHC detector upgrades have progressed in conjunction with NSF, CERN, international funding agencies, and U.S. ATLAS and U.S. CMS**
  - Late-2014: at request of funding agencies, CERN directed CMS and ATLAS to develop performance optimization proposals under 3 "core" cost scenarios for each experiment:
  - Sep. 2015: Scoping Documents sent to CERN LHCC & Upgrade Cost Group for review
  - Oct. 2015: Discussion at LHC Resources Review Boards (RRB)
    - Proceed to baseline projects at a core cost-level between 235 MCHF and the Reference costs outlined in Scoping Documents (271.1/265 MCHF for ATLAS/CMS)
- **DOE provided preliminary budget guidance for HL-LHC ATLAS & CMS Upgrade projects of $150 M total per exp. (U.S. accounting) between FY 2017–2025**
  - Preliminary scope and schedule presented at Sep. 2015 U.S. LHC DOE-NSF JOG meeting
  - U.S. ATLAS/CMS HL-LHC project managements continue to develop DOE project scope
- **DOE project scope and schedule being coordinated with NSF MREFC scope**
  - Construction schedule largely driven by date of LHC shutdown (2024–26)
  - Discussions with U.S. ATLAS and U.S. CMS and indicate DOE scope will include Inner Tracker for ATLAS and CMS and High-Granular (silicon-based) Calorimeter for CMS
    - DOE scope driven by long-lead procurement items (e.g., silicon sensors)
    - DOE now preparing CD-0 (mission need), aiming for approval by ~Jan. 2016
  - NSF guidance: any appropriations for MREFC funding not likely before FY 2020

International Linear Collider Strategy

- **P5 noted the strong scientific importance of the ILC global project:**
  - **Recommended modest and appropriate levels of ILC accelerator and detector design in areas where the U.S. can contribute critical expertise**
  - **Report emphasized that support for these efforts would ensure a strong position for the U.S. within the ILC global project**
- **DOE is maintaining modest investments in ILC R&D efforts during the Japanese decision making process**
  - **An interim report of the ILC Advisory Panel to the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) recommends monitoring LHC Run II results closely for potential impact on the science achievable with the ILC**
    - **This establishes a time scale for a decision on ILC by Japan**

Global Coordination of Future Energy Frontier Machine Planning

- P5 reported that particle physics is a global field for discovery and why
  - "The United States and major players in other regions can together address the full breadth of the field's most urgent scientific questions if each hosts a world-class facility at home and partners in high-priority facilities hosted elsewhere."
    - "Hosting world-class facilities and joining partnerships in facilities hosted elsewhere are both essential components of a global vision."
- China & Europe are studying and initiating R&D for future circular colliders
  - P5 said that U.S. should be counted among the potential host nations
- There is a pressing need for a global discussion among regions regarding the Energy Frontier program to follow the HL-LHC
  - Regional and national planning needs global coherence
  - Labs and agencies need a coordinated discussion in order that the formal planning process does not slow the scientific community
  - Funding Agencies for Large Colliders (FALC), coordinated with major partner institutions, may become a forum for this discussion among agencies
- Current priority in the General Accelerator R&D portfolio is investment in the enabling technologies for future machines
  - E.g., high-field magnets


INTENSITY FRONTIER

Intensity Frontier Highlight:

Fermilab Muon g-2 Magnet Successfully Cooled and Activated

- Two years ago, the 17-ton electromagnet successfully traveled 3,200 miles over land and sea from BNL to Fermilab
- Now magnet has been successfully cooled to operating temperature and activated using 5,300 amps of current
- Next step is shimming the magnetic field while muon beamline is constructed, with first muons scheduled for 2017

Intensity Frontier Strategy

- The P5 report recommended completing the Muon g-2 and Muon-to-electron Conversion (Mu2e) experiments at Fermilab, which provide complementary ways of exploring the unknown for signs of new particles and interactions
- P5 recommended substantial investments in the U.S. neutrino program in order to develop, with international partners, a coherent short- and long-baseline neutrino program hosted at Fermilab
  - The swift establishment of the international Deep Underground Neutrino Experiment (DUNE) is a strong indication of the high level of interest from the neutrino community in achieving this global vision
  - The Fermilab Proton Improvement Plan II (PIP-II) program of updates to the accelerator complex will provide proton beams with power >1 MW by the time of first operation of DUNE
  - A coordinated set of short-baseline neutrino experiments will address the observed anomalies in current neutrino experiments while advancing the R&D necessary for LBNF and DUNE

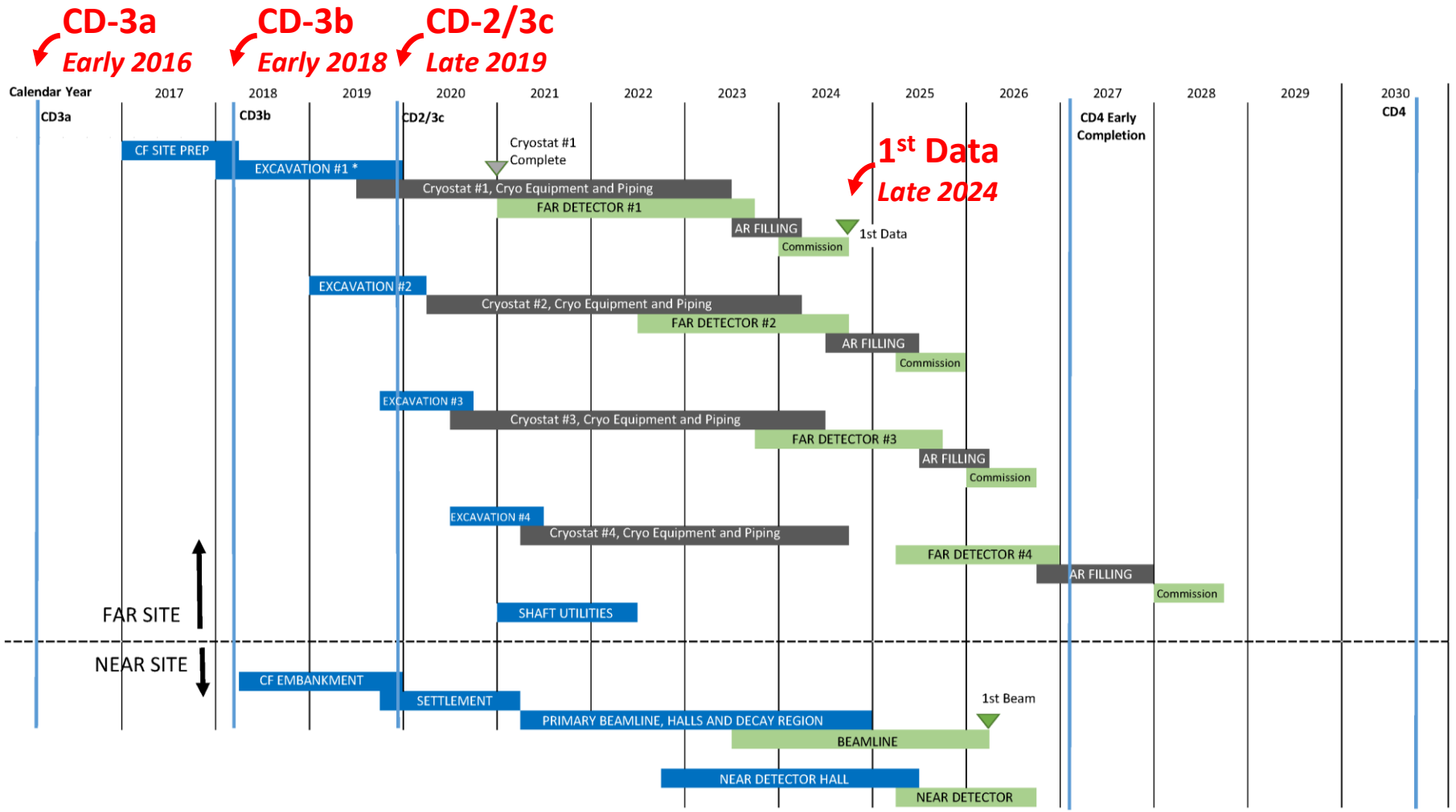
LBNF/DUNE Strategy

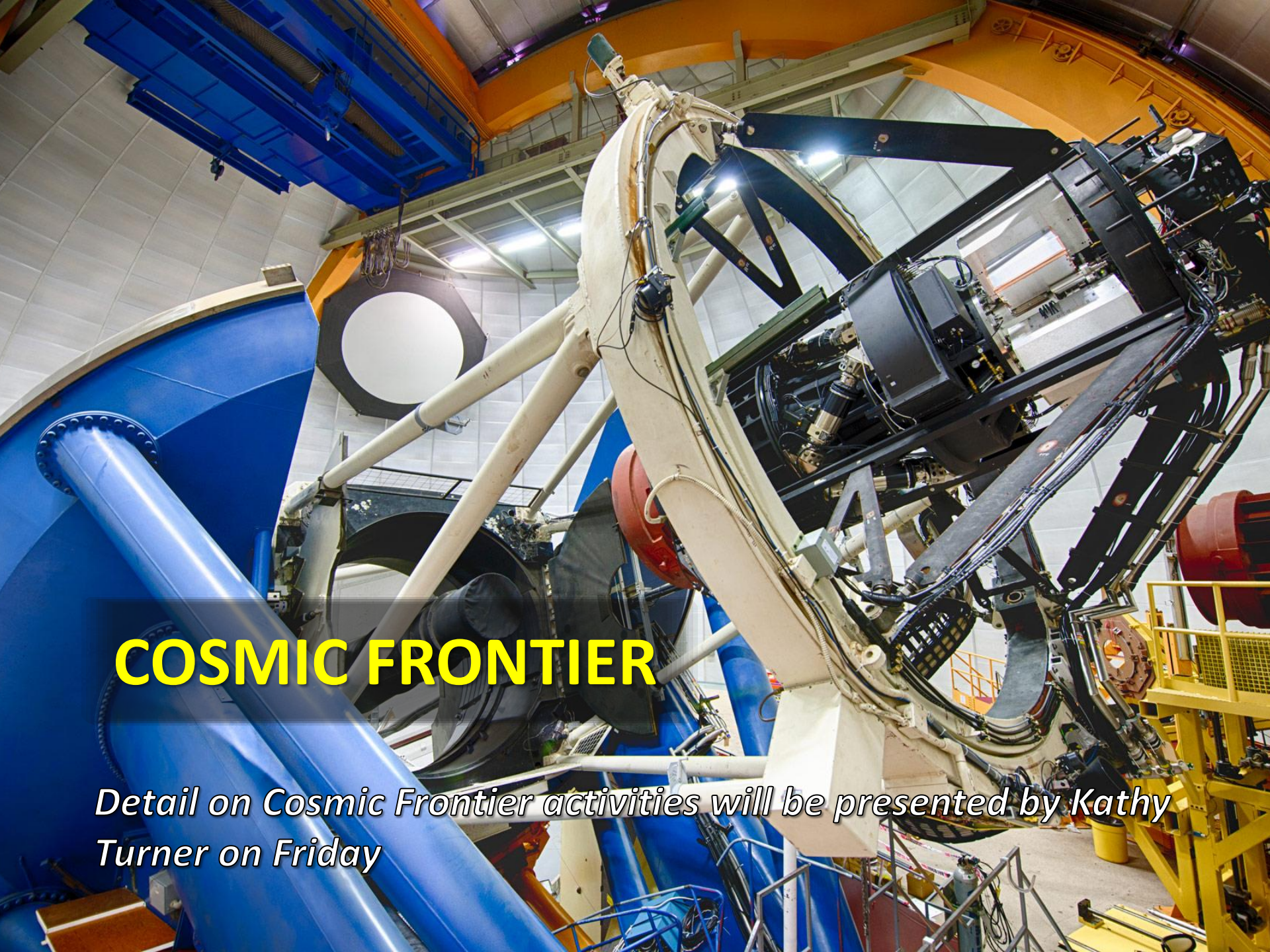
- **LBNF/DUNE is a key element of the global vision presented in the P5 report, and a major domestic milestone as the first international science facility hosted in the U.S.**
  - **DUNE now includes 770 scientists from 150 institutions across 25 countries in Asia, Europe, and North and South America**
  - **DOE and Fermilab have worked with International LBNF/DUNE to develop the organizational structure, based on the successful LHC model**
    - **International Neutrino Council, LBNF/DUNE RRB, Finance Board, etc.**
- **Rapid progress has attracted significant attention from interested international partners and has seeded discussion of formal participation agreements**
  - **The currently proposed schedule, which puts detector construction ahead of beamline construction, is favored by the global neutrino community because it advances science output to 2025**
  - **This is a crucial time for solidifying the international partnerships that will make LBNF/DUNE possible**

LBNF/DUNE Progress

- **Progress has been extremely rapid since the P5 report was released:**
  - ✓ Framework for internationalization of LBNF/DUNE established
  - ✓ DUNE Spokespersons and Technical & Resources Coordinators appointed
  - ✓ DUNE Executive Committee in-place
  - ✓ DUNE Institutional Board Chair elected
  - ✓ Experiment-Facility Interface Group (EFIG) established
  - ✓ U.S.-CERN Bilateral Cooperation Agreement Signed
  - ✓ Deputy Director for LBNF appointed
  - ✓ DOE CD-1 Refresh Review held and DOE-agency approval
  - ✓ DOE CD-3a (long-lead procurement) Review held
- **Next steps:**
  - ❑ Approval of Protocols to the U.S.-CERN Bilateral Cooperation Agreement
  - ❑ Continue negotiations of other International Agreements
  - ❑ Establish Common Projects and Common Funds for international DUNE
  - ❑ CD-3a Review DOE-agency Approval
  - ❑ FY 2017 Budget Request
  - ❑ CD-2 (baseline) Review & DOE-agency Approval

LBNF/DUNE Construction Schedule





COSMIC FRONTIER

Detail on Cosmic Frontier activities will be presented by Kathy Turner on Friday

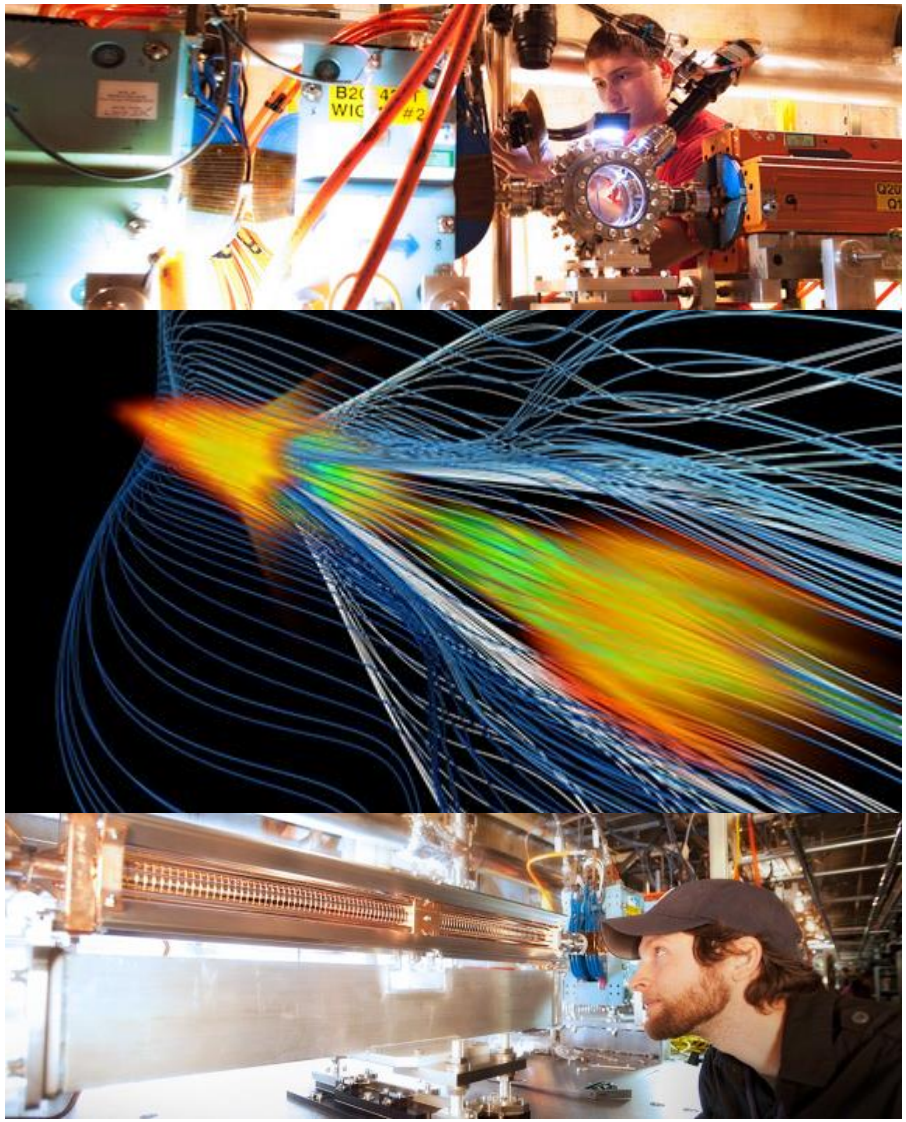
ADVANCED TECHNOLOGY R&D

More detail on Accelerator R&D and Accelerator Stewardship will be presented by Glen Crawford on Thursday

Advanced Technology R&D Highlight:

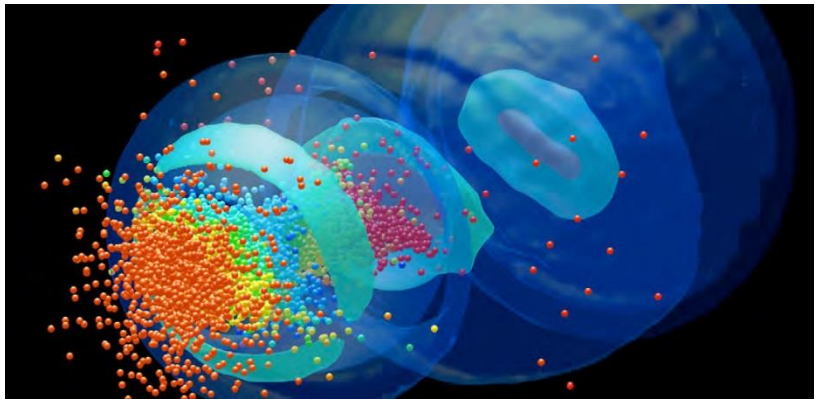
FACET Demonstrates Positron Plasma Wakefield Acceleration

- Beam driven plasma acceleration of positrons, the antimatter opposites of electrons, was successfully demonstrated at FACET
  - Research performed by team from SLAC National Accelerator Laboratory and UCLA
  - Electron acceleration has been previously demonstrated at FACET using two beam pulses
    - Drive bunch generates plasma wake
    - Trailing bunch accelerated by wake
  - New technique used to accelerate positions uses a single pulse of particles
    - Front of particle bunch generates a plasma wake that accelerates and focuses the trailing end
- This advanced acceleration technique may help boost the energy and shrink the size of future linear particle colliders

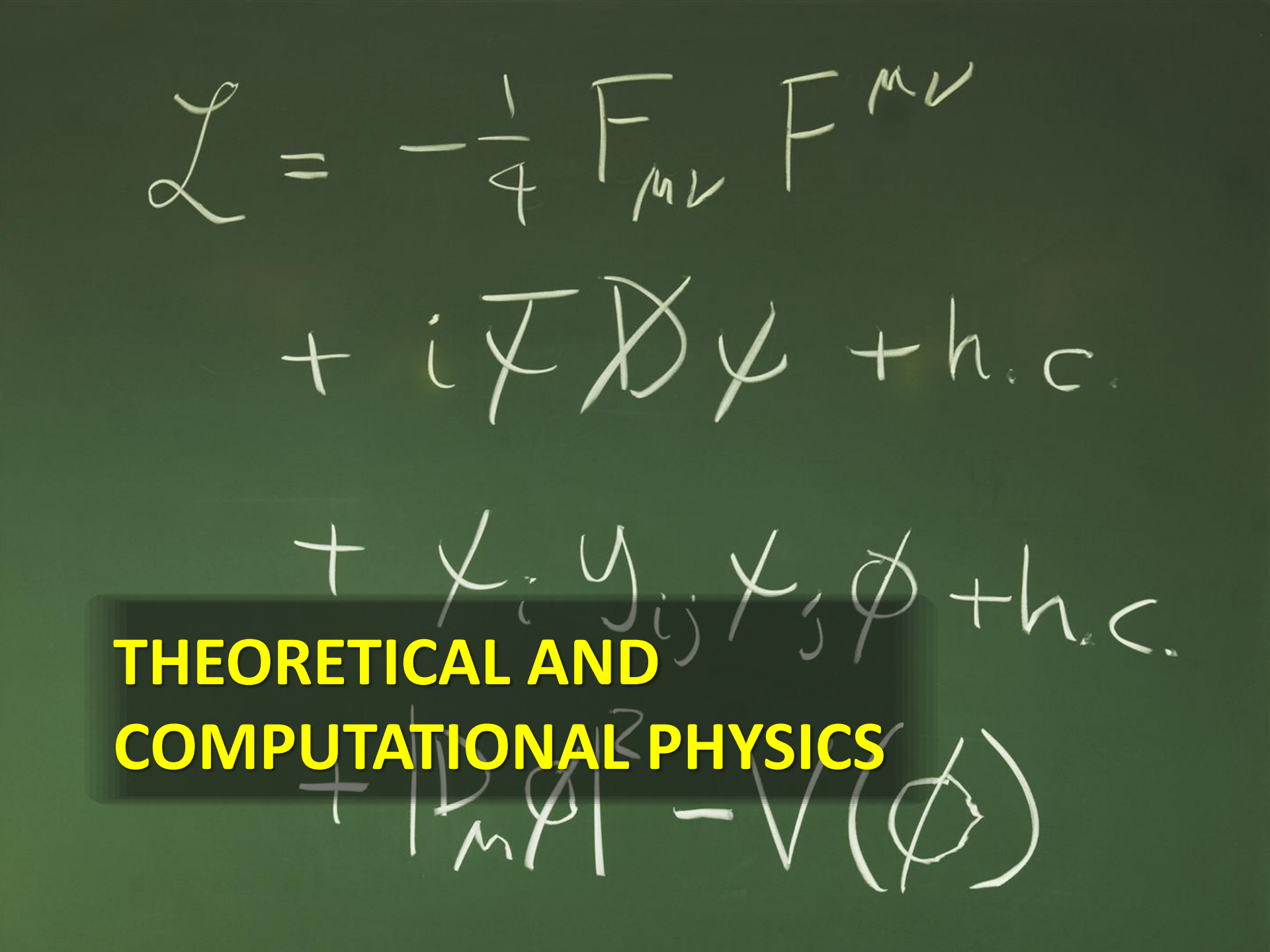


Accelerator R&D Strategy: FACET II

- **FACET-II is recognized as a DOE Office of Science priority**
  - It will be the only facility that enables R&D in the promising area of beam-driven plasma wakefield acceleration
  - It will sustain the momentum of excellent achievements in the program and maintain U.S. leadership globally in this area
  - It could enable technology that broadly benefits the Office of Science program
- **We recognize that the Accelerator R&D Subpanel (ARDS) report recommended investing in FACET-II under "Scenario C" level funding for the General Accelerator R&D (GARD) program**
  - Current GARD funding is not at this level of support
- **FACET-II received CD-0 approval September 18, 2015**
  - The LCLS-II construction schedule drives the timeline for FACET-II
  - Early approval necessary to open the window for FACET-II installation
    - **Installation of FACET-II would need to occur before LCLS-II begins commissioning in April 2019**

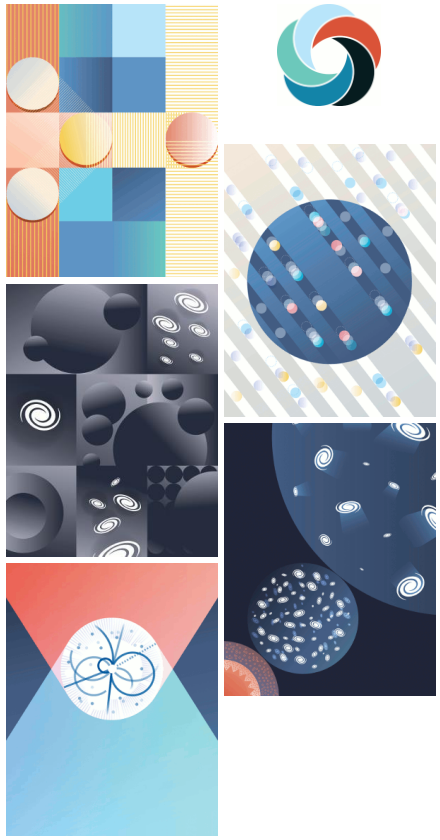


Simulation of a beam-driven plasma wake field accelerator, where electrons (dots) drive and "surf" on waves of plasma (blue surfaces), accelerating very quickly over a very short distance.


THEORETICAL AND
COMPUTATIONAL PHYSICS

Theoretical and Computational Physics

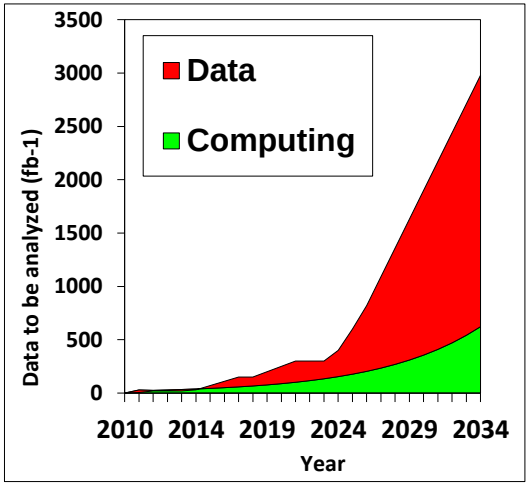
- **Provides the mathematical, phenomenological, and computational framework to understand and extend our knowledge of the dynamics of particles and forces, and the nature of space and time**
  - Theoretical research essential for proper interpretation and understanding of the experimental research activities in other HEP subprograms
  - Advanced computing tools necessary for designing, operating, and interpreting experiments and scientific simulations that enable experimental discovery research
- **The P5 report recognized the importance of theory and computing:**
  - "The U.S. has leadership in diverse areas of theoretical research in particle physics. A thriving theory program is essential for both identifying new directions for the field and supporting the current experimental program."
  - Recommended strengthening global cooperation among laboratories and universities to address computing and scientific software needs and provide efficient training in next-generation hardware and data-science software relevant to particle physics



Computational Physics Strategy

- Implementing P5 strategy requires advancing computing infrastructure to handle the exponentially increasing data and computing needs
- HEP works to address computing issues through:
  - Multifaceted partnerships with Advanced Scientific Computing Research (ASCR) for algorithms, data, network and high performance computing needs
  - A new Forum for Computational Excellence (FCE)
  - Community workshops and planning meetings
- HEP and the Exascale Ecosystem
  - ASCR is leading the Exascale Initiative for SC and working towards establishing exascale-class computing facilities in the early 2020s
  - Office of Science Exascale Requirements Reviews began with HEP-ASCR on June 10–13, 2015, where talks emphasized:
    - Need to recognize future HEP computing as an integrated "ecosystem" that includes data, software, and networking
    - Stronger partnerships with ASCR necessary to address the challenges and design issues of exascale systems

HEP computing needs by 2025 anticipated to be ~10-100x current HEP infrastructure



Estimated ATLAS Computing Requirements

The green assumes 15% growth per year from Run 1, and that Run 1 had exactly enough capacity.

HEP Connections and Partnerships

- HEP Connections Activities reach out to SC programs and beyond to strengthen our position in the National Science and Technology enterprise as users and contributors
  - Tools, Techniques and Technology Connections Report (2014)
    - Identifies potential opportunities for advancing scientific discovery and accelerating the pace of innovation in an effective manner by taking advantage of science and technology connections
- Through HEP Connections, HEP has partnered with other SC programs to encourage joint study groups and round tables to identify science and technology grand challenges at their interfaces
  - HEP-ASCR Quantum Information Systems (QIS) Study Group Meeting (December 2014)
    - Report identified Grand Challenges at the intersection of Particle Physics, Computing, and QIS
    - Potential for new windows to HEP Discoveries and Tools
    - QIS report has been instrumental in HEP engagement with ASCR in post-Moore explorations
  - HEP-BES Round Table (February 2015)
    - Report identifies relevant Grand Challenges
- HEP Connections Reports available at:
  - ***http://science.energy.gov/hep/news-and-resources/reports/***

HEP BUDGET AND ISSUES

DOE Budget Formulation and Execution

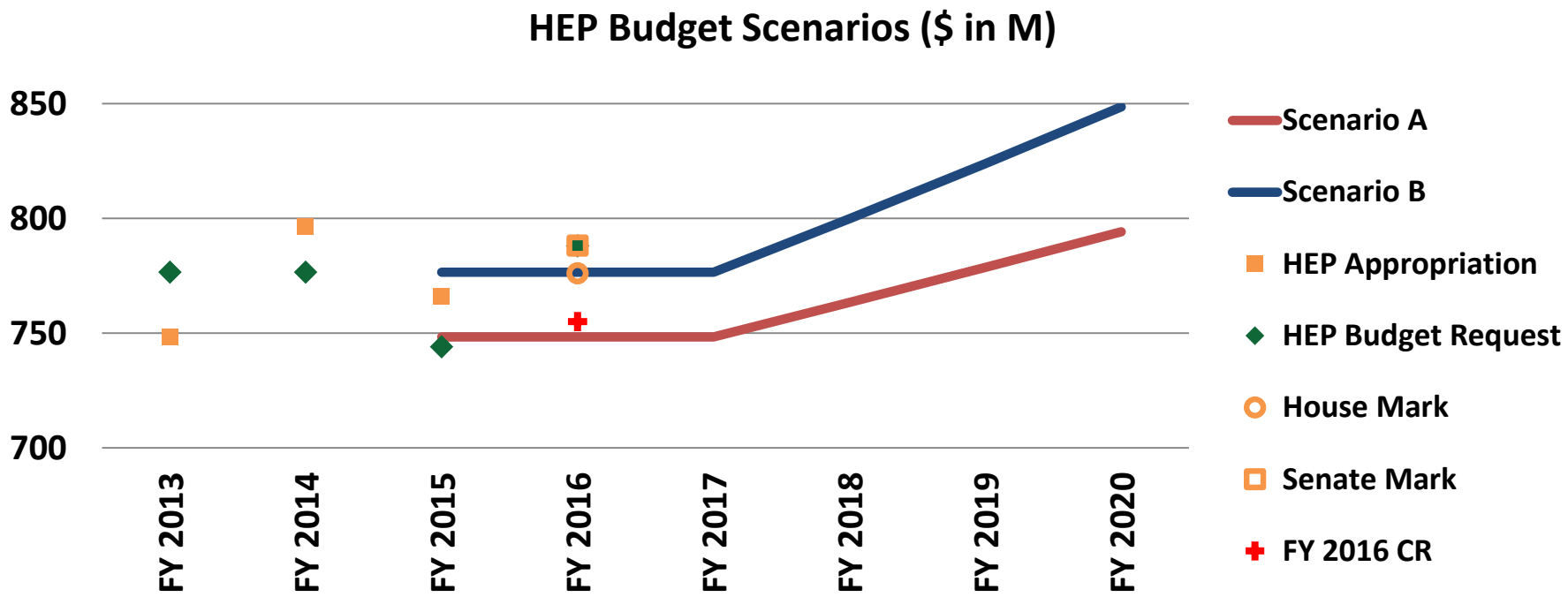
- A Fiscal Year in the U.S. runs from Oct. 1, 201*X* – Sept. 30, 201(*X+1*)
- U.S. Federal budget is planned and executed over a three-year cycle, with activity occurring simultaneously for three fiscal years
  - Presidential budget formulation **(2 years ahead)**
    - Agencies are currently formulating plans for FY 2017
  - Congressional budget resolution **(1 year ahead)**
    - U.S. Congress is now considering the U.S. President's request for FY 2016
  - Appropriated budget execution **(current year)**
    - Agencies are now beginning to execute programs for FY 2016
- The U.S. President's Budget Request for FY 2016 is the first budget formulation influenced by the P5 report strategy
  - Large project construction funding requires line-item approval by Congress in a budget appropriation

FY 2016 HEP Budget: Congressional Marks

- FY 2016 Request for HEP is $788 M, a ~2.9% increase compared to FY 2015
- The House released its FY 2016 Markup of the Energy and Water Appropriation at $776 M, which overall is slightly below the FY 2016 Request, but above FY 2015 (by ~1.3%)
  - The mark is aligned with "Scenario B" of the P5 strategic report and notes: "The Committee strongly supports the Department's efforts to advance the recommendations of [P5] and urges the Department to maintain a careful balance among competing priorities and among small, medium, and large scale projects."
  - Construction Line-item is increased by $2 M for the Long-Baseline Neutrino Facility
  - Accelerator Stewardship is marked at "not less than $5 M" compared to $14 M in the Request
  - Energy Frontier is marked at the FY 2016 requested level and includes LHC Experimental Research, Operations, and initial [Phase-1] ATLAS and CMS Detector Upgrades
- The Senate released its FY 2016 Markup of the Energy and Water Appropriation at $788.1 M, overall near the level of the FY 2016 Request
- The current Continuing Resolution (CR) has designated ~$150 M for Oct. 1, 2015, through Dec. 11, 2015, equivalent to $754.9 M to HEP if translated into a full year

Context: P5 HEP Budget 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



*Budget Request and Appropriations include SBIR/STTR

FY 2016 Budget Impact

- **In the President's Request for FY 2016, total HEP funding is near the P5 "Scenario B" level**
  - **Research funding is very similar to the actual research funding in FY 2015**
  - **Most of the additional funding requested in FY 2016 is dedicated to supporting active projects, particularly *LSSTcam* and *Mu2e***
- **While the House and Senate Marks are near the President's Request, the current CR for FY 2016 is near the "Scenario A" level**
  - **Project support is being maintained through the CR as we await an appropriation**
  - **Funding active projects puts significant pressure on research funding**
- **The actual funding level and language of an appropriation for FY 2016 will affect our ability to maintain balance between research and projects envisioned by P5**

Research and Project Funding

- **P5 recommended increasing the project budget fraction to 20%–25% for renewed investment in projects while recommending that research reductions be "planned with care"**
  - We recognize that the P5 plan suggests only a few years of flat research budgets before restoring research funding
  - It is vital to the long-term success of the strategy that project support increases in the early years
- **University research is a crucial element to achieving our mission**
  - Necessary to deliver the full science output of ongoing experiments while shaping and supporting future projects
  - The comparative review process has been important in maintaining a healthy University research program during tight budgets
- **Most of the redirection from research to projects is occurring within Laboratory funding**
  - Inflation of the overhead rates at Laboratories appears on track to outpace increases in funding, causing effective loss of support
  - We have asked Laboratories to create 7-year plans that account for this in order to identify potential issues and ways to mitigate them

OFFICE NEWS AND MISCELLANY

Progress Reports & Demographic Data

- **Annual Progress Reports will now be submitted online via the Portfolio Analysis and Management System (PAMS)**
  - Key feature of new format requires PIs inputting their progress, accomplishments, and plans in subject-related text-boxes in PAMS
  - PIs on active grants with next budget period beginning April 1, 2016 should have already received an email with the request to submit their report for 2015; reports due 90-days prior to next budget period
    - PIs with active grants who did not receive email should contact their Grant Monitor
    - Progress report format (RPPR) has been provided to PIs via email
- **As part of the progress report, all people supported on the grant have the opportunity to voluntarily provide demographic information regarding their gender, race, and ethnicity**
  - The DOE does not use this information as the basis for any funding decisions
  - Providing this information would make it possible for the DOE to examine the distribution of awards across various demographic categories
- **A high response rate from the community would be valuable in helping identify and address diversity issues in our field**

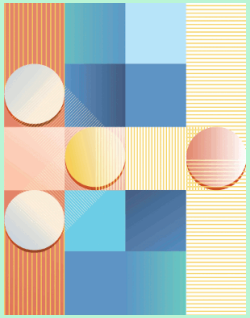
HEP Program Status Updates

- **Comings and Goings**
  - Tina Kaarsberg (detailee) returned to DOE/EERE Nov 2015
  - Eric Colby now permanent Science Advisor/PM for Accelerator Stewardship and Technology R&D
  - Helmut Marsiske now permanent PM for Detector R&D
  - Michael Cooke now permanent PM for Strategic Planning and Communications
  - Simona Rolli moving to Facilities Division to take on Projects (vice Helmut)
  - Simona Rolli will lead the LHC Phase-2 detector upgrade Projects, Abid Patwa will coordinate LHC Phase-2 with Research and Operations
  - New detailee for Accelerator R&D (Uli Wienands) starting Jan 2016
  - In discussions with new IPA candidates for Accelerator Stewardship and Intensity Frontier
  - In discussions with new PM candidate for Intensity Frontier

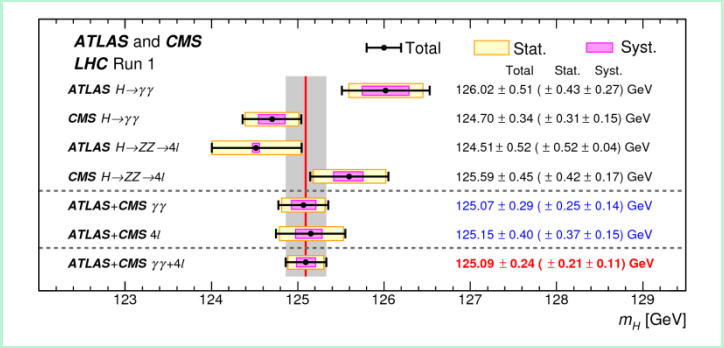
- **New Assignments and Opportunities**
  - New permanent position for Theory PM (vice Simona) planned in 2016
  - Interested in new IPA/detailee for Energy Frontier starting ~Summer/Fall 2016
  - ***Interested parties should contact HEP management!***

Addressing Compelling Questions in HEP:

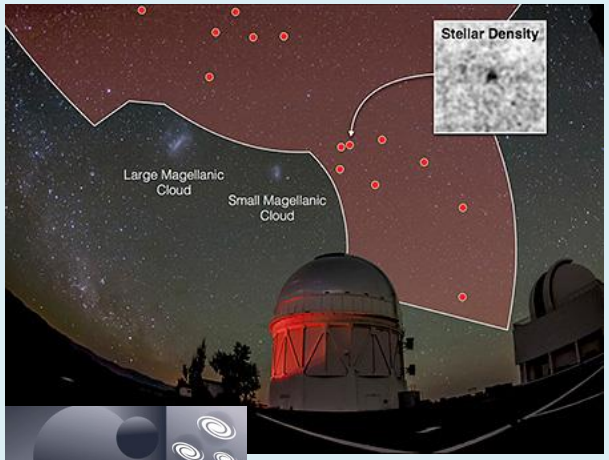
Science Highlights from the Past Year

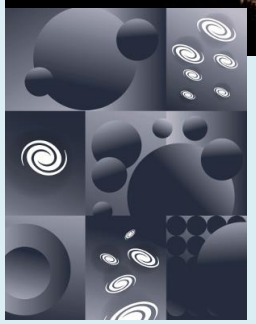


Higgs boson



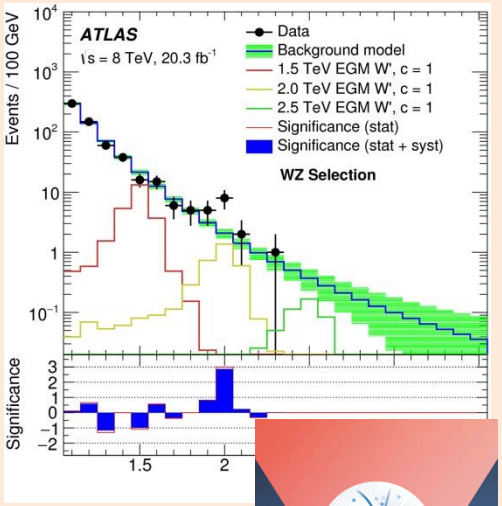
ATLAS and CMS Higgs boson mass combination (0.19% precision!):
m_H = 125.09 ± 0.21 (stat.) ± 0.11 (syst.) GeV



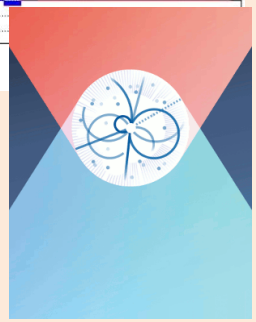


DES discovered 17 dwarf galaxy candidates during 2015, providing excellent laboratories to study properties of dark matter

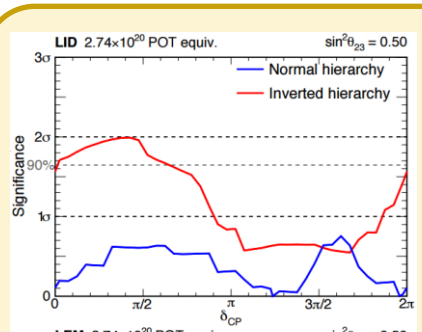
Dark matter



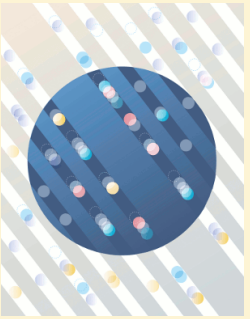
ATLAS beyond the Standard Model searches show a slight excess for 2 TeV *W-prime* bosons decaying to *WZ*



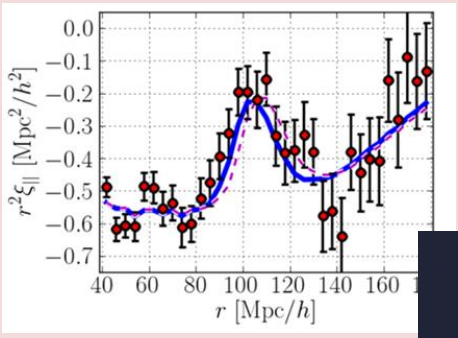
Explore the Unknown



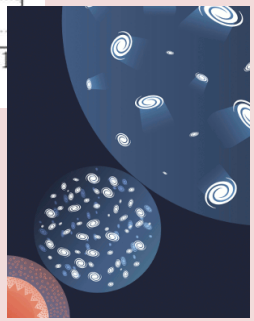
NOvA results using the first 7.6% of the total planned neutrino beam exposure slightly favor the Normal Mass Hierarchy



Neutrino Mass



BOSS measured the expansion rate in the young Universe with an unprecedented 2% precision



Cosmic acceleration

Fulfilling the HEP Mission: Enabling Discovery

- Pursue the most important science opportunities wherever they are: on- and off-shore
- Time-phased project execution
- Projects of different scales
- Balanced across Frontiers

- Continuous physics output
  - Any science driver across the Frontiers could lead to discovery
  - Historic opportunities await us!

Green: Physics Blue: Approximate Construction

Future of the HEP Program

- HEP is implementing the strategic plan presented in the P5 report in the context of a global vision for particle physics
  - P5 recognized that the scientific program required to address all of the most compelling questions of the field is beyond the finances and the technical expertise of any one nation or region
- Particle physics has a long history of leading successful efforts to "internationalize" science
  - We are working with international partners to implement the P5 vision
- New bilateral U.S.-CERN Agreement intertwines the future international science programs based both at CERN and in the U.S.
  - The LHC will provide exciting science for the next two decades
    - U.S. expertise and investments are critical to fully exploit the discovery opportunities at the LHC
  - Bilateral cooperation will be crucial in establishing the first U.S.-hosted international science facility, the Long-Baseline Neutrino Facility
    - Successful collaborative model of the LHC at CERN serves as an example for large international collaboration at LBNF


BACKUP

DOE Project Management

- Construction projects and fabrication of large pieces of experimental equipment costing over $10M are managed through a series of "Critical Decision" (CD) milestones (per DOE Order 413.3b)
  - CD-0: Approve Mission Need
    - Identifies there is a need that can only be met through material means
  - CD-1: Approve Alternative Selection and Cost Range
    - Ensures the selected alternative and approach is the optimum solution
  - CD-2: Approve Performance Baseline
    - Definitive cost, scope, and schedule baselines have been developed
  - CD-3: Approve Start of Construction
    - Project has demonstrated technical readiness for implementation
    - CD-3a may be granted prior to CD-2 approval to support long-lead procurement
  - CD-4: Approve Start of Operations
    - Project is completed and ready for turnover or transition to operations
- 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 the White House Office of Management and Budget must support them during budget formulation and Congress must appropriate funds before they can begin

Achieving a CD Milestone

- **Achieving a CD Milestone (*e.g.,* reaching "CD-2") in the DOE Office of Science (SC) begins with a DOE Office of Project Assessment (OPA) "Lehman" Review**
  - **OPA conducts independent technical, cost, schedule, and management reviews of construction projects, experimental equipment, and facilities**
  - **Comments, Findings and Recommendations are presented immediately to Project Management in the Review Closeout Presentation**
- **Approval of a CD Milestone is granted by SC management through the Energy Systems Acquisition Advisory Board (ESAAB)**
  - **This process typically occurs a month after the OPA Review**
  - **There is time before the ESAAB decision is made to receive feedback from Project Management regarding OPA Comments, Findings and Recommendations**

HEP Project Status

Subprogram	TPC ($M)	CD Status	CD Date
INTENSITY FRONTIER			
Long Baseline Neutrino Facility (LBNF) / Deep Underground Neutrino Experiment (DUNE)	TBD	CD-1	December 10, 2012
Muon g-2	46	CD-2/3	August 20, 2015
Mu2e	273	CD-2/3	March 4, 2015
Next Generation B-Factory Detector Systems (BELLE-II)	15	CD-2/3	April 23, 2014
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
COSMIC FRONTIER			
LZ	50	CD-1/3A	April 28, 2015
SuperCDMS-SNOlab	14	CD-0	September 18, 2012
Dark Energy Spectroscopic Instrument (DESI)	56	CD-2	September 18, 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-0	September 18, 2015

Energy Frontier Status

LHC is planned to be central component of the U.S. Energy Frontier program for next ~20 years

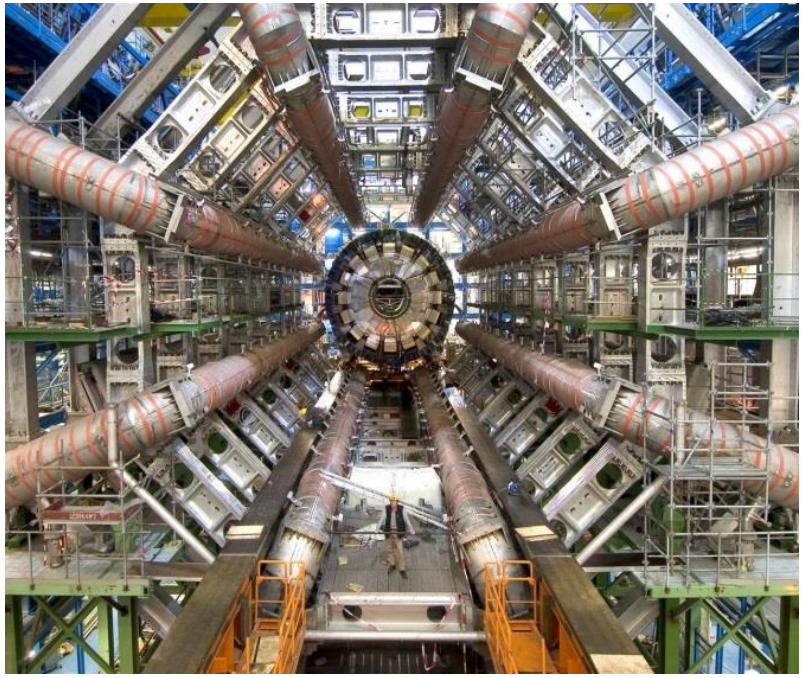
- **U.S. investments enable leading roles in the *global* LHC physics collaborations**

Current program

- **450+ LHC Run I papers submitted by *each* of the ATLAS and CMS Collaborations with continued and key participation by U.S. collaborators**
  - **~100 more publications per experiment in the pipeline (1,000+ Run 1 papers!)**
- **Run II data-taking & operations activities on ATLAS and CMS progressing at a new energy regime**
- **U.S. active in executing initial [Phase-1] upgrades**
  - **CMS and ATLAS CD-2/3 [baseline & construction start] approved for both detectors on Nov. 12, 2014**
  - **MIE fabrication start in FY 2015 appropriations**

Planned program

- **Launching the high luminosity upgrades to LHC for running beyond 2026 to extend discovery potential**
  - **Increase LHC luminosity by a factor of 10 beyond its design value to explore new physics and new dynamics for W/Z, top, and Higgs at TeV energies**
  - **HEP actively working with U.S.-CMS/ATLAS to begin the HL-LHC detector upgrade projects and proceed to subsystem TDRs**
- **Modest investments in R&D for future options:**
  - **Lepton colliders**
  - **Very high energy hadron colliders**



Intensity Frontier Status

Exploring the unknown through precision measurements

- Development of muon-beam based program at Fermilab continues:
  - *Muon g-2*: Successfully tested SC magnet and held CD-2 review in June 2015
  - *Mu2e*: Reached CD-2/3 on March 4, 2015
- Collaborating with Japan on *K* meson, *c/b* quark, and *τ* lepton precision studies:
  - *Belle II:* reached CD-3 in April 2014
  - *K0TO* (J-PARC) physics data taking in Spring and Fall 2015

Identify the physics of dark matter

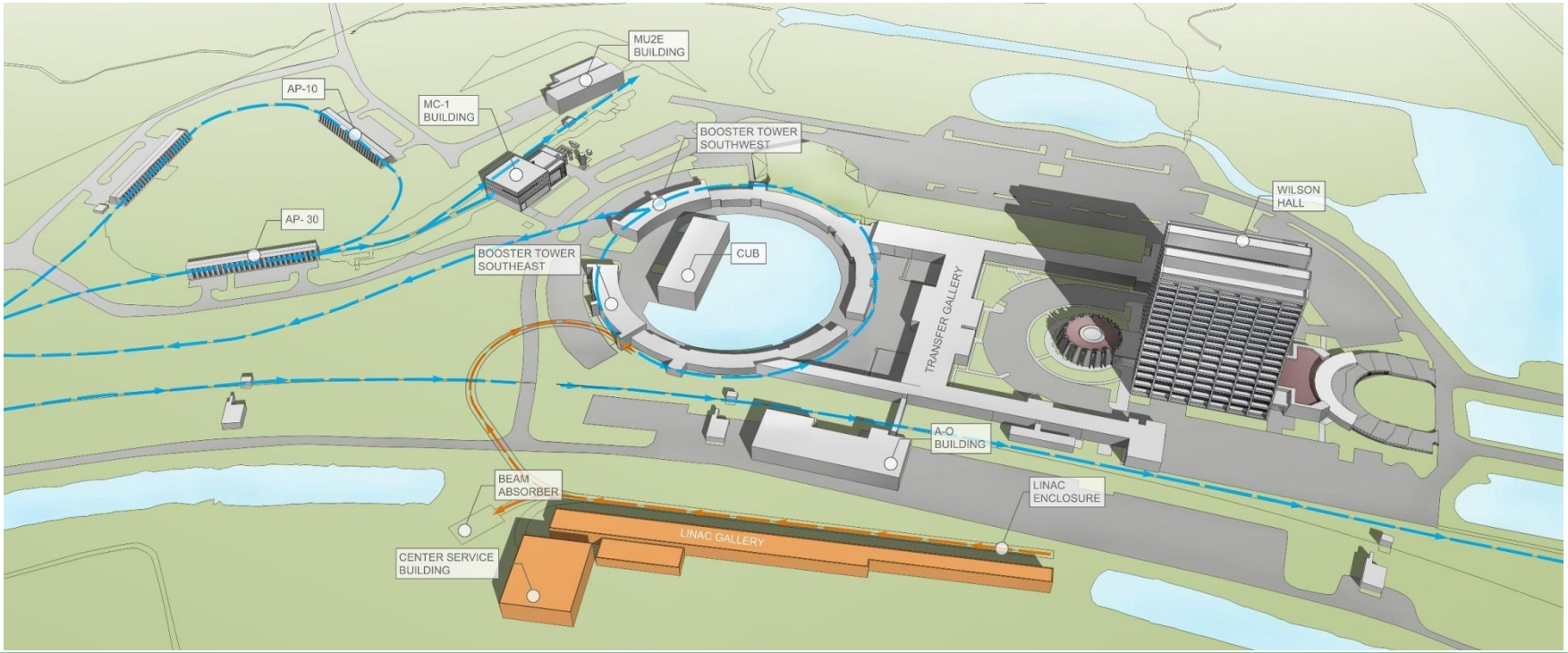
- *APEX* and *Heavy Photon Search* performing particle beam based searches for DM
  - *Heavy Photon Search (HPS)* recorded initial data in Jefferson Lab Hall B; physics to follow

Pursuing the physics associated with neutrino mass

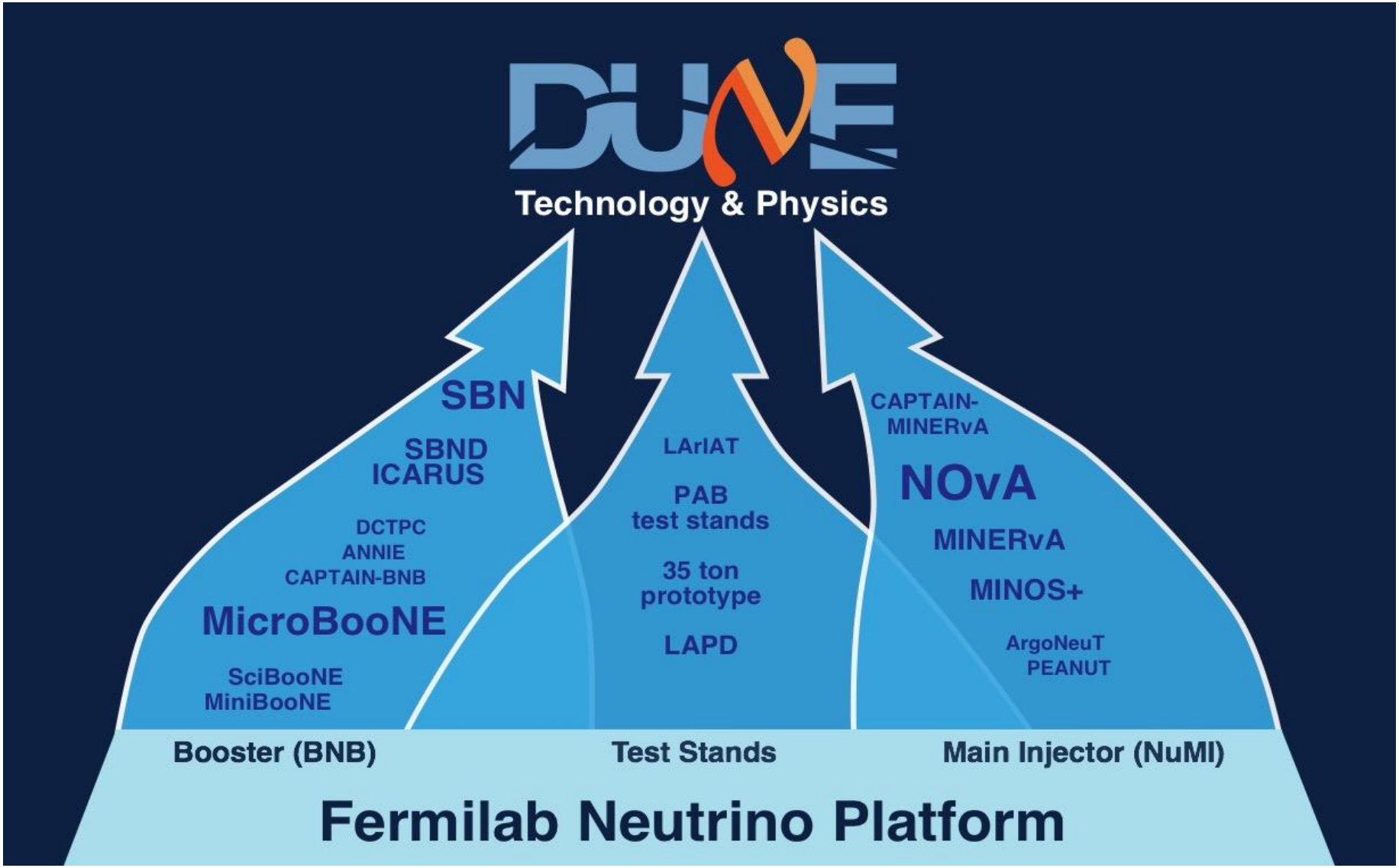
- Mass hierarchy & *ν* properties studied at Fermilab, Japan, China, and underground:
  - *Daya Bay, MicroBooNE, MINERvA, MINOS+, NOvA, Super-K, T2K*
- Sterile neutrino search and neutrino CP violation program continues to evolve:
  - Fermilab short-baseline neutrino (SBN) program will complement *MicroBooNE* with *ICARUS* arrival in 2017, *SBND* installation in 2018
  - Workshop on Intermediate Neutrino Program (WINP) at BNL in Feb. 2015 provided useful input for taking the next step in the non-FNAL neutrino program
  - *DUNE* established as international long-baseline neutrino experiment

Proton Improvement Plan II (PIP-II)

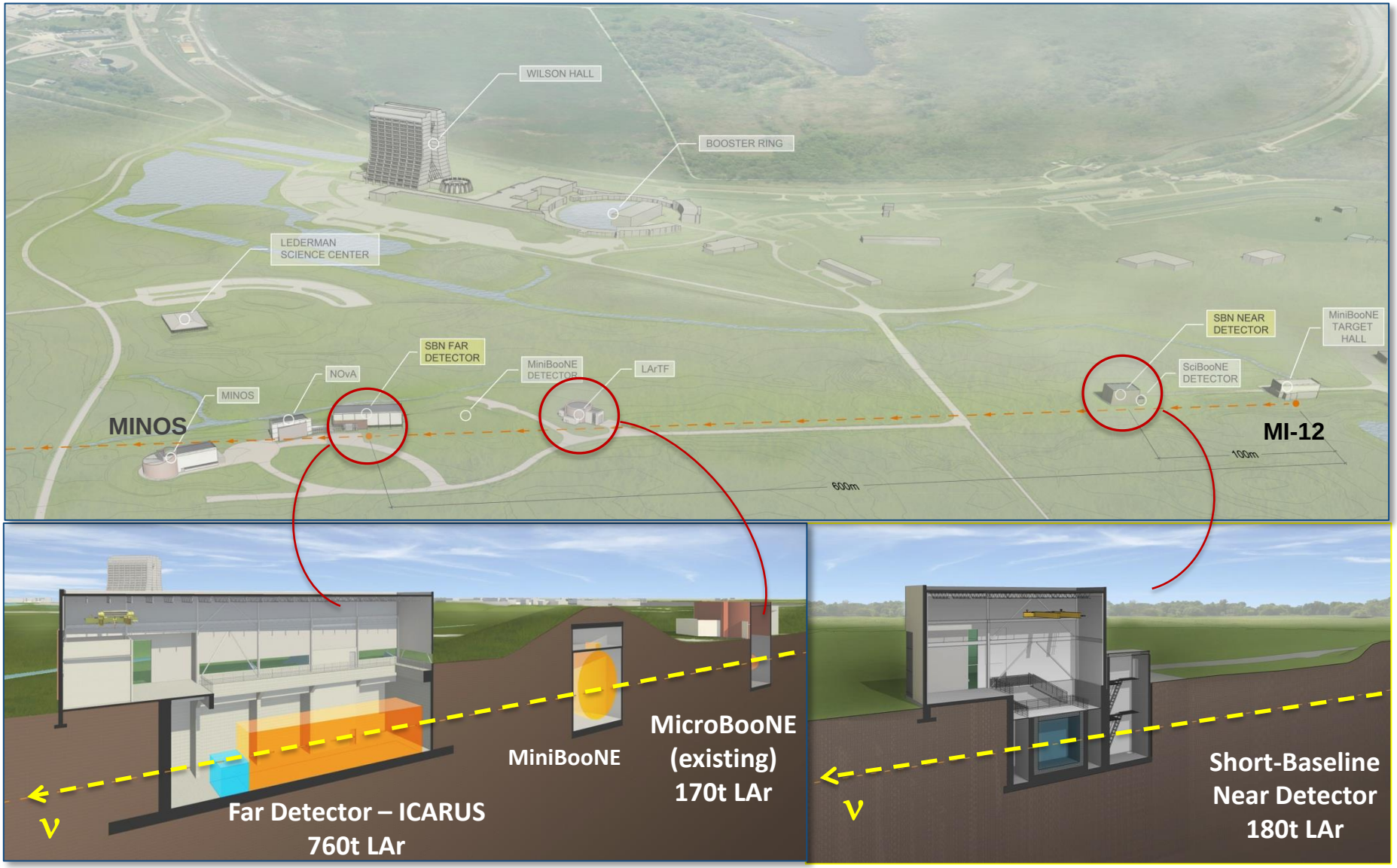
- PIP-II supports longer term physics research goals by providing increased beam power to LBNF while providing a platform for the future
- Infrastructure and workforce development due to LCLS-II work at Fermilab will be leveraged in support of PIP-II, further advancing SRF capabilities



Fermilab Neutrino Platform



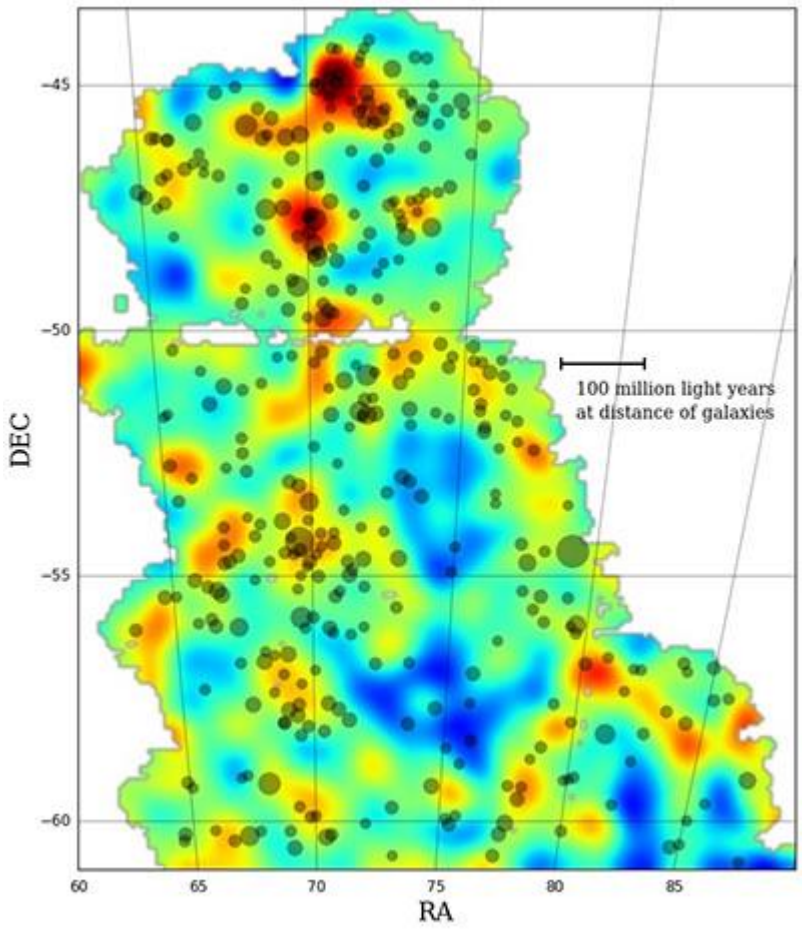
FNAL Short Baseline Neutrino Program



Cosmic Frontier Highlight:

DES Releases its First Map of Dark Matter

- The Dark Energy Survey and the 570-megapixel DECam continue to move science forward
  - Partnership with NSF
  - DECam mounted on the 4-meter Victor Blanco Telescope in the Chilean Andes
- Scientists on the Dark Energy Survey have released the first in a series of dark matter maps of the cosmos
  - Weak lensing mass map based on galaxy shape measurements in the 139 deg^2 SPT-E field from the Dark Energy Survey Science Verification data
  - Map covers only about 3% of the sky area DES will document over its five-year mission
  - Cross-correlation of DES galaxies with CMB lensing data allows tests of the growth of cosmic structure from z=0.2-1.2



http://www.fnal.gov/pub/presspass/press_releases/2015/Mapping-The-Cosmos-20150413.html

Cosmic Frontier Status

Dark Energy

- *BOSS* and *DES* anticipate releasing new results soon!
- *Large Synoptic Survey Telescope (LSST)* received CD-3a in June 2014, CD-2 in Jan. 2015
  - CD-3 review occurred August 4-6, 2015
- *Dark Energy Spectroscopic Instrument (DESI)* received CD-1 in March 2015
  - CD-2 review occurred July 28-30, 2015; received Congressional "MIE start" in FY 2015
  - Finalizing MOA with NSF to transition Mayall telescope operations costs to DOE in FY2016 – FY2019

Dark Matter (direct detection)

- Progress continues on DM-G2 experiments: *ADMX-G2, LZ, SuperCDMS-SNOLab*
  - *LZ* & *SuperCDMS-SNOLab* projects received Congressional "MIE starts" in FY 2015
  - *LZ* held CD-1 review in March 2015, *SuperCDMS-SNOLab* held CD-1 review in October 2015

Cosmic-ray, Gamma-ray

- *Fermi/GLAST, AMS,* and *HAWC* continue operations
  - *HAWC* gamma-ray observatory began taking data in late November 2014
- DOE operations efforts will complete in FY 2016 for *VERITAS* and *Auger*

Cosmic Microwave Background (CMB)

- *South Pole Telescope polarization (SPTpol)* continues operations
- *SPT-3G* had successful review of DOE roles/responsibilities in September 2014
  - Fabrication funding approved for FY 2015 – 16
- Community planning continues for a CMB Stage IV experiment

Cosmic Frontier Strategy

- **P5 recommended proceeding immediately with a broad second-generation (G2) dark matter direct detection program and R&D towards third generation experiments**
  - Three G2 experiments jointly selected by DOE and NSF in July 2014
    - ADMX-G2, LZ, and SuperCDMS-SNOLab
  - LZ and SuperCDMS-SNOLab expected to begin fabrication in FY 2016

- **P5 supported advancing the dark energy program from current generation of experiments to the Large Synoptic Survey Telescope (LSST) and the Dark Energy Spectroscopic Instrument (DESI)**
  - LSST baseline was approved in January 2015
  - DESI is approved for fabrication start in 2015
  - Ramping up as rapidly as possible within constraints of FY 2015 funding

- **P5 recommended an advanced cosmic microwave background (CMB) experiment sensitive to the early expansion phase of the universe**
  - Community planning towards a "Stage 4" CMB experiment continues

FY 2016 HEP Budget Request Summary

- **HEP is implementing the strategy detailed in the May 2014 report of the Particle Physics Project Prioritization Panel (P5), formulated in the context of a global vision for the field**
  - HEP addresses the five compelling science drivers with research in three frontiers and related efforts in theory, computing and advanced technology R&D
  - Increasing emphasis on international partnerships (such as LHC) to achieve critical physics goals
- **Energy Frontier: Continue LHC program with higher collision energy (13+ TeV)**
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis and the initial upgrades to the ATLAS and CMS detectors
- **Intensity Frontier: Develop a world-class U.S.-hosted Long Baseline Neutrino Facility**
  - Continue the design process for an internationalized LBNF and development of a Short-Baseline Neutrino Program that will support the science and R&D required to ensure LBNF success
  - Fermilab will continue to send world's highest intensity neutrino beam to NOvA, 500 miles away to Ash River, MN
- **Cosmic Frontier: Advance our understanding of dark matter and dark energy**
  - Immediate development of new capabilities in dark matter detection by continuing development of 2nd generation experiments; and in dark energy exploration with baselining of DESI and fabrication of LSST camera

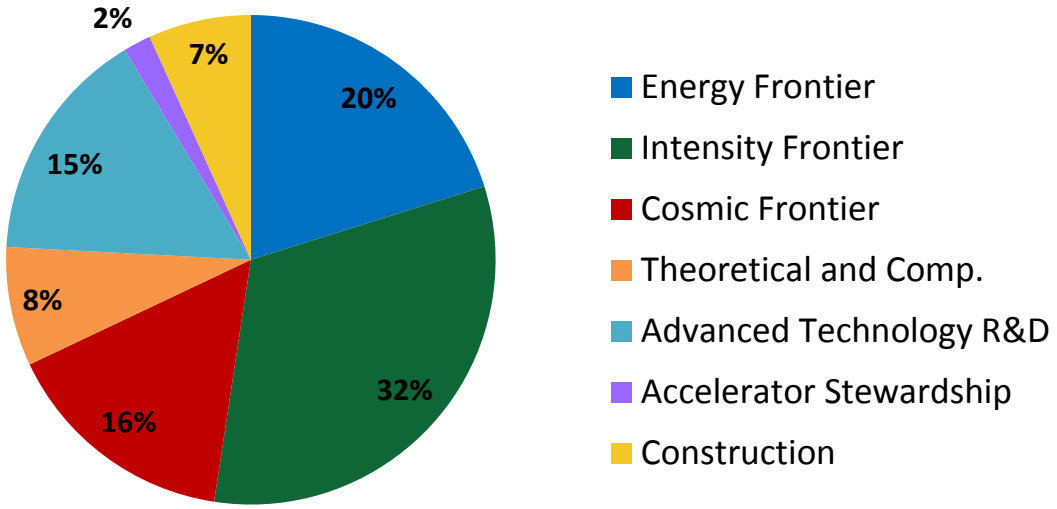
FY 2016 HEP Funding by Activity

HEP Funding Category ($ in K)	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	Explanation of Changes (FY16 vs. FY15)
Research	373,932	337,383	334,703	*Research reductions support project investments*
Facilities	278,683	265,125	262,658	*Maintain efficient operations of facilities and ongoing experiments*
Projects	71,305	105,698	113,401	
Energy Frontier Projects	*0*	*15,000*	*19,000*	*Ramp up in LHC detector upgrades fabrication*
Intensity Frontier Projects	*37,400*	*43,970*	*33,700*	*Continue g-2 and FNAL acc. upgrade profiles; some LBNE efforts move to construction*
Cosmic Frontier Projects	*30,705*	*45,728*	*58,701*	*Increase supports LSSTcam, DESI and second generation dark matter experiments*
Other Projects	*3,200*	*1,000*	*2,000*	*Planned Lattice QCD hardware acquisition*
Construction (Line Item)	51,000	37,000	56,100	*Planned profile for Mu2e; engineering and design for LBNE*
SBIR/STTR	21,601*	20,794	21,138	
Total	**796,521***	**766,000**	**788,000**	***House mark: $776 M; Senate mark: $788.1 M***

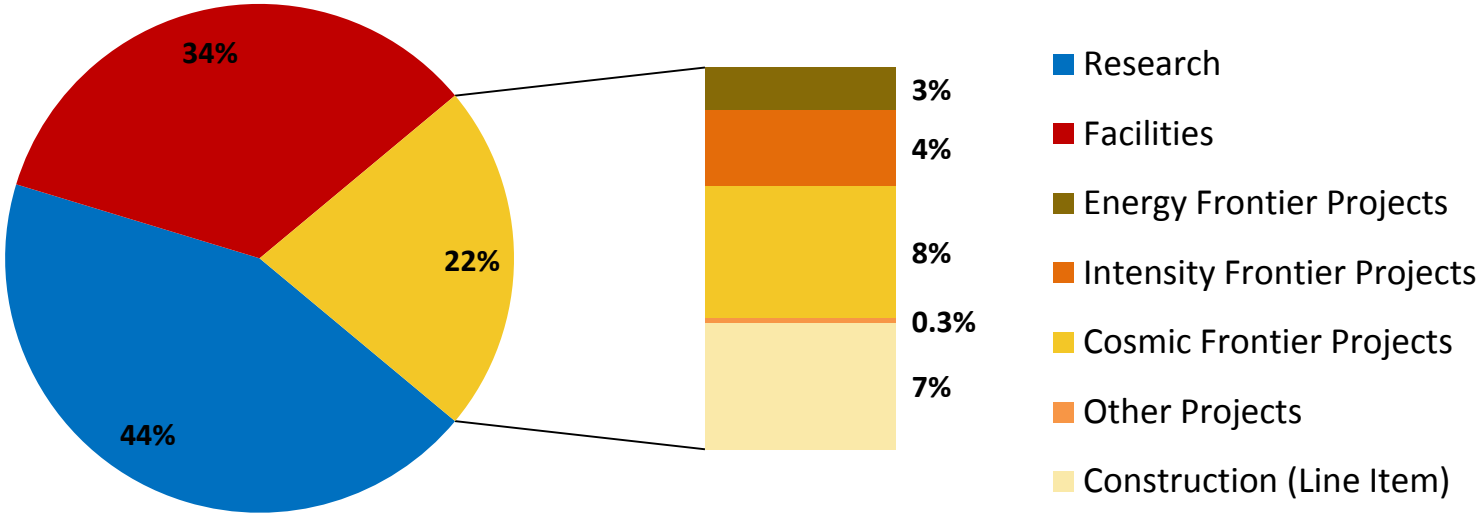
**** SBIR/STTR added to FY 2014 for comparison to FY 2015/2016***

FY 2016 HEP Budget Request Overview

HEP FY 2016 Request Funding by Subprogram

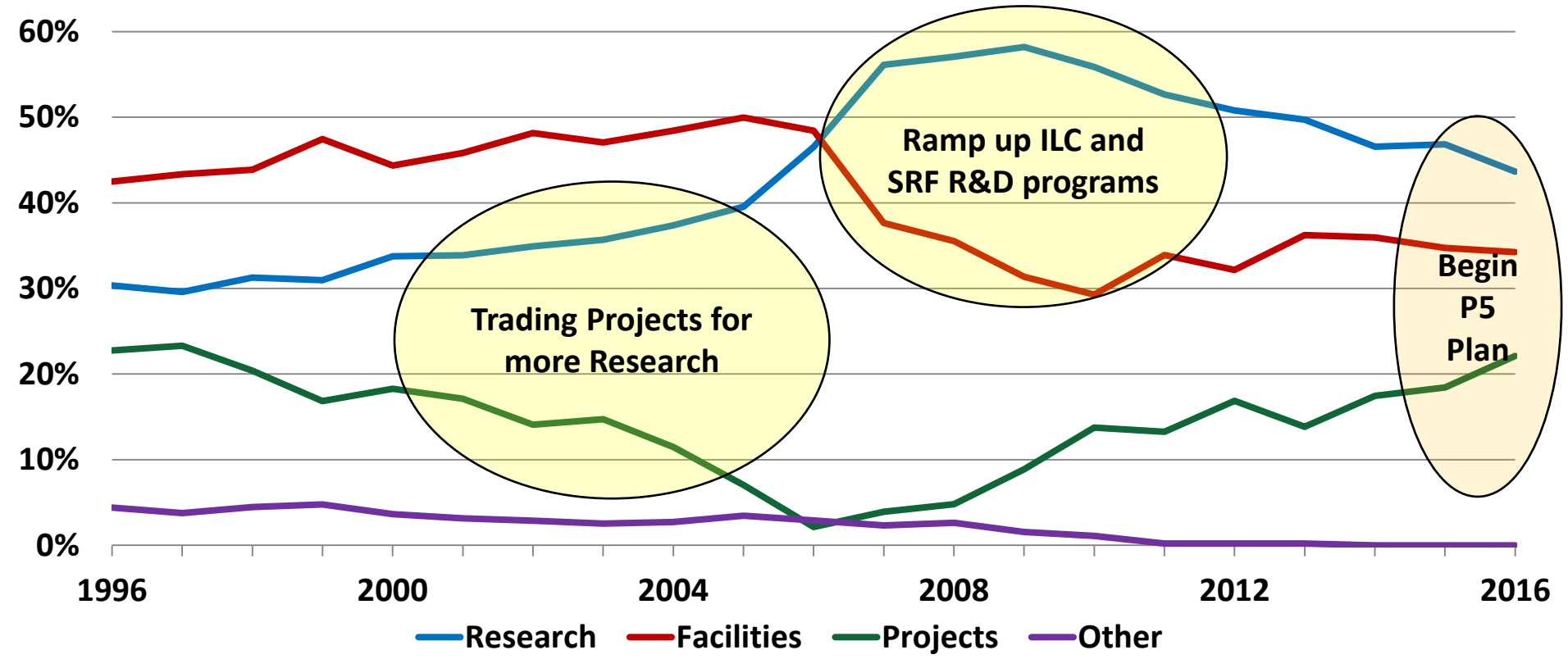


HEP FY 2016 Request Funding by Activity



Funding Trends by Fiscal Year

(FY 2016 shows President's Request)



- **P5 report recommendation suggests increasing the project budget fraction to 20%–25%**
  - "Addressing the [science] Drivers in the coming and subsequent decades requires renewed investment in projects."
- **Maintaining balance between research and projects as envisioned by P5 presents a challenge, given the fiscal budget constraints**