U.S. DEPARTMENT OF ENERGY | Office of Science

High Energy Physics Status Report

HEPAP Meeting
July 9, 2019

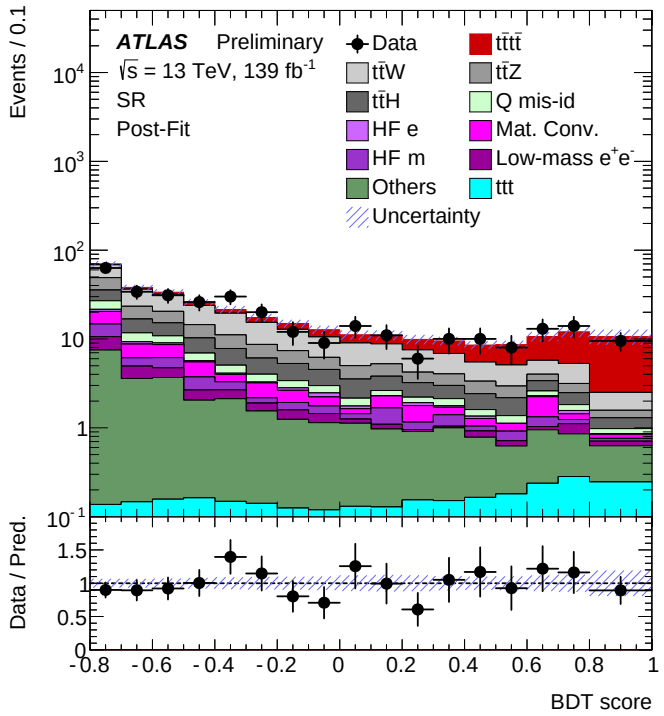
Jim Siegrist
Associate Director for High Energy Physics
Office of Science, U.S. Department of Energy

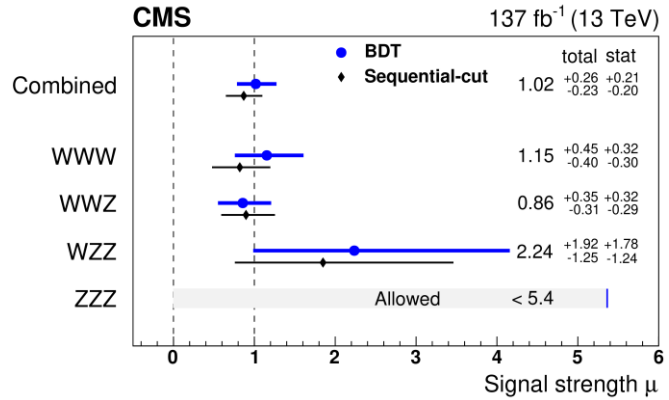
Opening Remarks

- The DOE Office of Science (SC) is fully committed to fostering safe, diverse, equitable, and inclusive work, research, and funding environments that value mutual respect and personal integrity
  - More detail in tomorrow's talk by Julie Carruthers
- The P5 report strategy continues to be successful
  - The HEP community is producing excellent science results
  - Support from the Administration, Congress, and international partners continues to be strong
  - Community engagement remains important as we lay the foundation for the next long-term strategic plan
- COVID-19 pandemic
  - HEP project impacts detailed in talk by Mike Procario
  - HEP continues to be interested in hearing from community, including today's HEPAP discussion

Energy Frontier Highlights: tttt and VVV

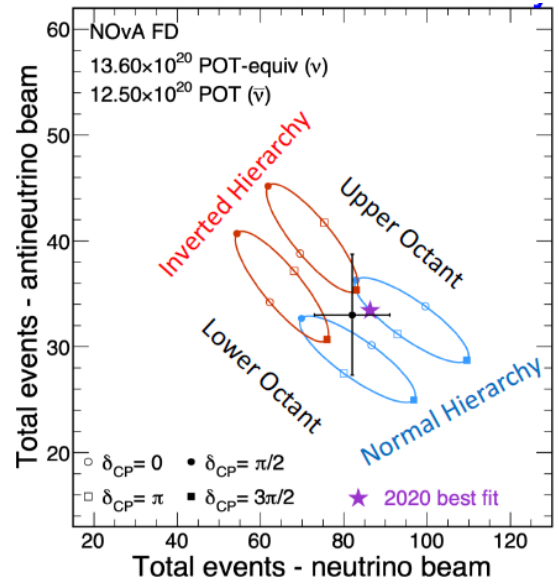
- LHC experiments continue to produce excellent results from LHC Run 1 and Run 2 data
- ATLAS: first strong evidence for 4-top production
  - Heavy final state with ~700 GeV mass
  - Search for final states including two same-sign leptons or 3 leptons
  - Obs. (exp) significance: 4.4σ (2.4σ)
- CMS: first observation for VVV (V=W or Z) production
  - Searches for WWW, WWZ, WZZ, and ZZZ production in final states with 3-6 leptons or 2 same-sign leptons plus 1-2 jets
  - Combined VVV prod. obs. (exp) significance: 5.7σ (5.9σ)

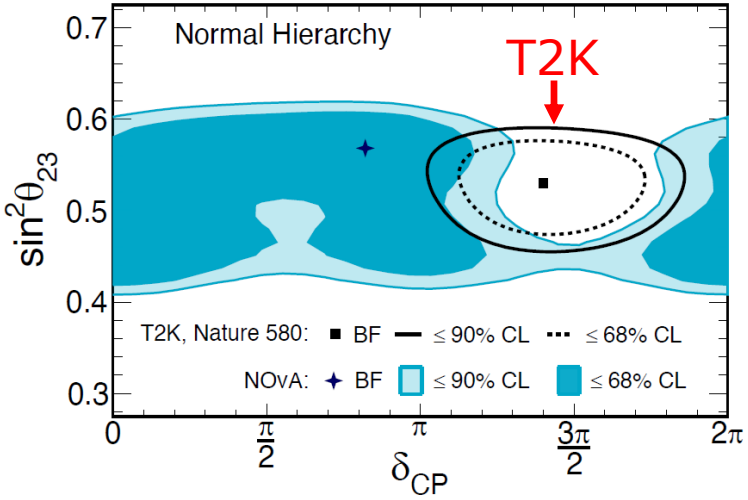




Intensity Frontier Highlight: NOvA Oscillation Fit

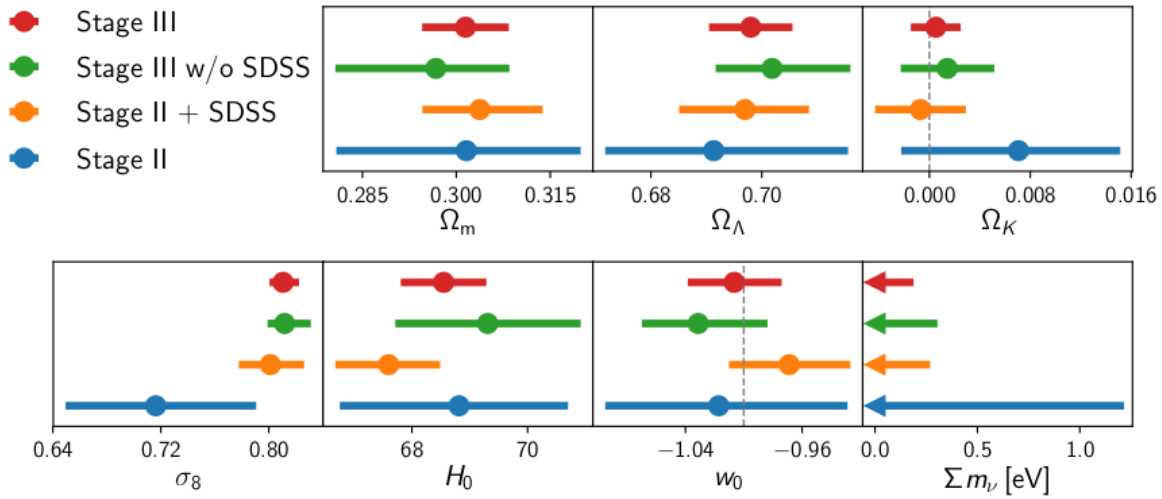
- NOvA presented preliminary results including 2020 data at Neutrino 2020
- Best oscillation fit favors normal hierarchy:
  - $\Delta m^2_{32} = (2.41 \pm 0.07) \times 10^{-3}$ eV^2
  - $\sin 2\theta_{23} = 0.57^{+0.04}_{-0.03}$
  - $\delta_{CP} = 0.82\pi$
- Normal hierarchy result hints to tension with T2K's preferred region
  - Quantifying consistency requires a joint fit of the data from the two experiments, which is already in the works
  - Semi-annual workshops, regular joint group meetings, and a signed joint agreement





Cosmic Frontier Highlight: Extended Baryon Oscillation Spectroscopic Survey (eBOSS)

- Stage 3 Spectroscopic Survey for Dark Energy
  - Survey ran 2014-19, precursor to DESI
  - Component of the Sloan Digital Sky Survey (SDSS-IV) at Apache Point Obs., NM
  - DOE-HEP partnership with Sloan Foundation, U.S. Universities and international institutions

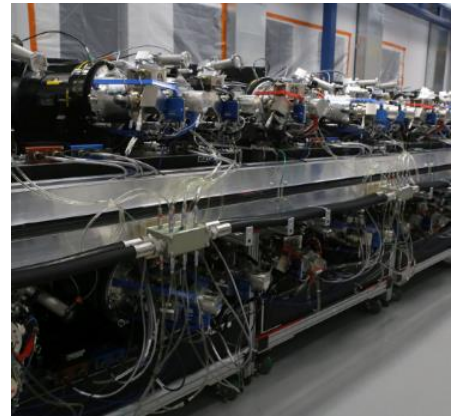


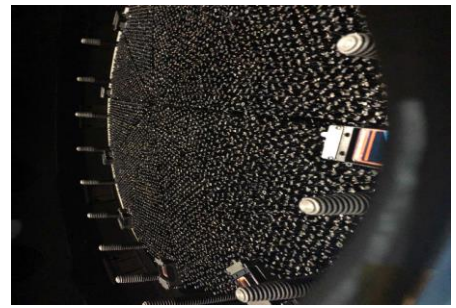
- Major Milestone: Final results and papers in Collaboration review
  - BAO/RSD from objects over 0<z<2; BAO from Lyman-α forest and quasars at z=2.35
  - 20+ papers planned for batch submission in July, with press release and interpretation
- Implications for Cosmology:
  - 50X improvement relative to Stage-II in 5-parameter likelihood
  - Stage-III (Planck, SDSS, Pantheon SNe Ia, DES yr1) is 1000X decrease in likelihood volume

Dark Energy Spectroscopic Instrument (DESI)

DESI is ready to take data!

- Premier multi-object spectrograph and the first Stage IV dark energy project to start operations
- DOE/LBNL-led MIE to fabricate instrumentation & data management system, upgrades of NSF's Mayall telescope
- International collaboration includes ~500 researchers at 75 institutions in 13 nations
  - Partners: STFC, Heising-Simons, Gordon and Betty Moore, France, Mexico, Spain, NSF
  - HEP has MOU w/NSF-AST to "lease" the Mayall telescope





See https://vimeo.com/422889846

March 16, 2020: All Project Deliverables complete, including Commissioning
March 16 - 22, 2020: DESI was closed up and put into safe mode
April 2, 2020: CD-4 review – successful
May 11, 2020: CD-4 approved, fabrication complete, ready to operate

Cosmic Microwave Background Stage 4 CMB-S4

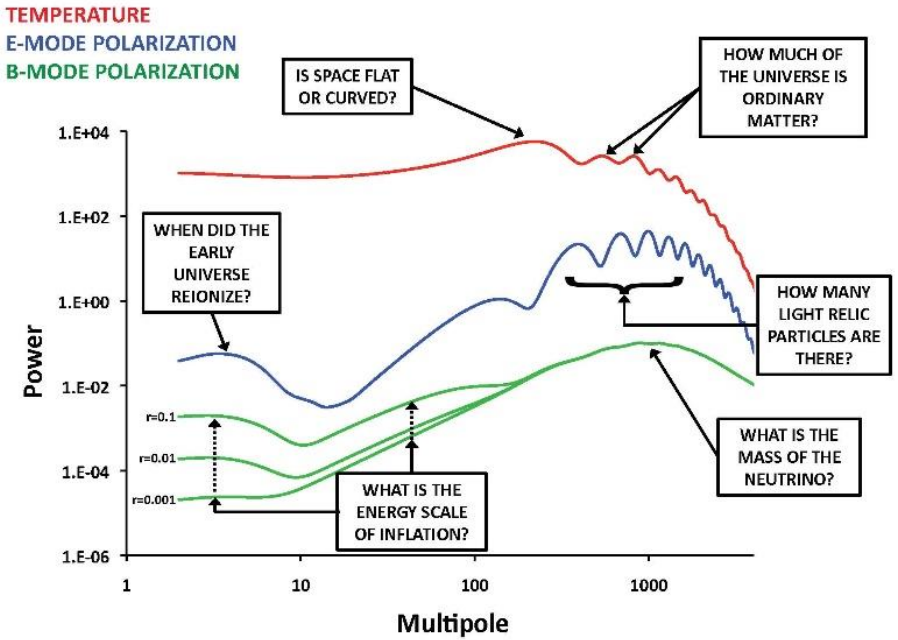
CMB-S4 Goal: cross critical science thresholds

Science	Stage 2	Stage 3	Stage 4	
Inflation "r"	≤0.1	≤0.01	≤0.001	Detect/rule out classes of inflationary models
σ(Neff)	0.14	0.06	0.03	Detector/rule out light relic particles w/ spin
σ(Mν)	0.15eV	0.06eV	0.02eV	3σ detection

Highlights:

- 2 sites: Chile, South Pole
  - Large & small telescopes;
  - 500,000 cryogenic sensors, superconducting readout
- $600M TPC multiagency project
  - Plan HEP (lead) and 3 NSF divisions
  - **DOE approved CD-0 in July 2019**
  - Now completing process to select a lead laboratory

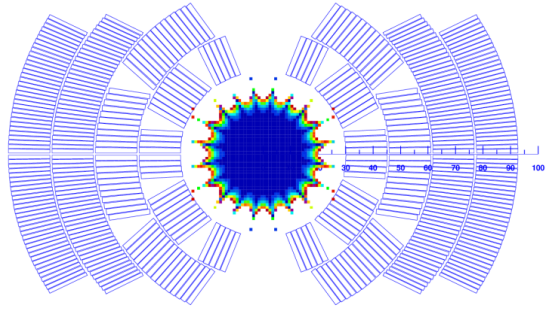
Ultra-precision measurement of CMB power spectrum



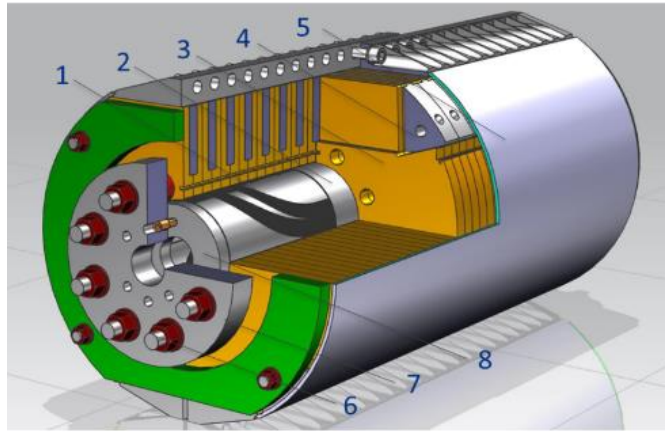
Accelerator R&D Highlight: High-Field Magnets

- U.S. Magnet Development Program is updating its research roadmap
  - MDP activities are synergistic with CERN HF Magnet R&D
  - Discussion for closer collaboration is ongoing
- Current US efforts towards a 15 T Nb_3Sn dipole demonstrator (MDPCT1)
- Magnet design allows for innovative mechanical structure
- First test at Fermilab limited pre-load to achieve 14 T
  - **Record field at 4.5 K!**
- MDPCT1, reassembled with nominal pre-load, is under test to 15 T

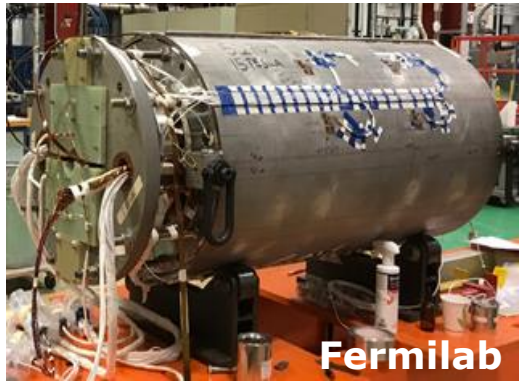
4-Layer Coil



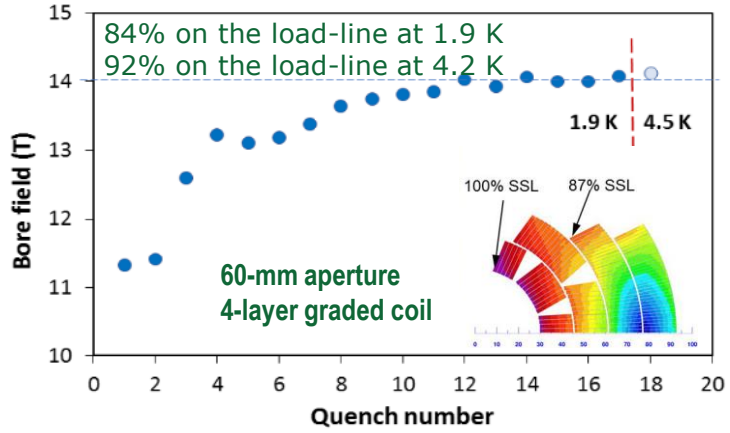
Magnet Cold Mass



Instrumented MDPCT1 Cold Mass



14 T Tested & Achieved at Fermilab



QIS at HEP – Aligned to SC/DOE/National Strategy

- Budgets for HEP-QIS Research Activities derive from SC QIS Budgets
- HEP QIS Core Research supported through Quantum Information Science Enabled Discovery (QuantISED)
  - Emphasizes **HEP for QIS** and **QIS for HEP** (like the SC emphasis, **SC⇔QIS**)
  - Topics are aligned to OSTP QIS categories as identified in the National Strategic Overview for QIS:
    - https://www.whitehouse.gov/wp-content/uploads/2018/09/National-Strategic-Overview-for-Quantum-Information-Science.pdf
  - Some papers:
    - A. Macridin, P. Spentzouris, J. Amundson, R. Harnik PRL 121, 110504 and Phys. Rev. A 98, 042312
    - Jet Clustering Algorithms Wei, Naik, Harrow, Thaler, PRD 2020
    - The ghost in the radiation: encoding the black hole interior I.Kim, E. Tang, J. Preskill, JHEP 2020
    - Three-Dimensional Superconducting Resonators …… A. Romanenko et al PR Applied 2020
    - Disentangling Scrambling & Decoherence via Quantum Teleportation B Yoshida & N Yao PRX 2019

DOE Aligned Computing at HEP

- HEP Computing primarily managed within Frontiers and Lab Ops
- Current and future HEP computing challenges addressed in part
  - Via alignment with DOE Computing
  - Cross cut solutions across HEP as possible
- HEP CCE (Center for Computational Excellence) led by ANL interfaces with ASCR Resources/expertise to advance HEP Computing goals
- SciDAC is an Office of Science program where ASCR and HEP jointly fund HEP computing – currently HEP-ASCR SciDAC 4. Examples:
  - HEP Data Analytics on HPC (FNAL, LBNL, ANL, U Cincinnati, Colorado State U)
  - Inference and Machine Learning at Extreme Scales (ANL, LBNL, LANL, VTech)

HEP Center for Computational Excellence

HEP-CCE

- Bridge between the broader HEP community, HPC-oriented HEP research teams, and ASCR expertise and resources
- Develop and make available selected HPC tools/capabilities to aid HEP science in coordinated work with ASCR
- Current activity focused on projects to study use of ASCR HPC systems, especially near-future exascale resources, for all HEP frontiers
- Primary targets are experiments taking data in 2020+ (ATLAS, CMB-S4, CMS, DESI, DUNE, LSST DESC, –)

Current Activities

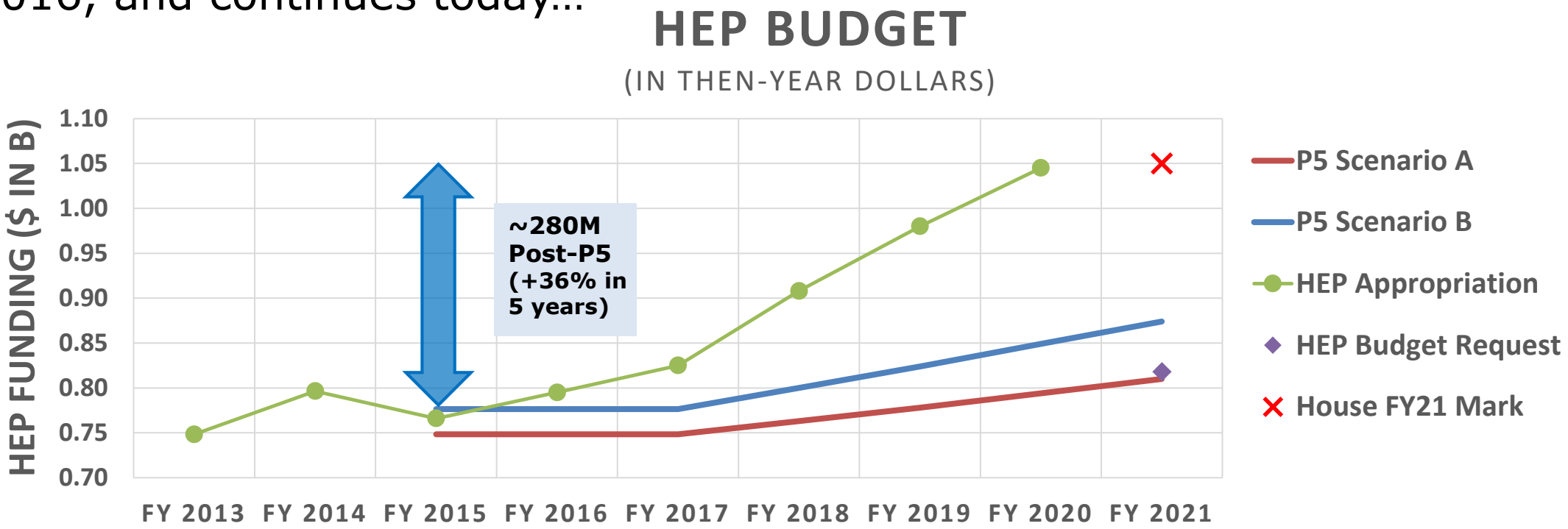
Two projects started in CY20, two will ramp up in FY20-21:

- Portable Parallelization Strategies – investigating software portability solutions (Kokkos, SYCL, Alpaka, OpenMP, –) via a small number of HEP testbeds as example cases for each option
- Fine-grained IO and Storage – data representations tuned for HPC storage systems and optimized for HEP IO patterns; optimization of data reads to algorithm consumption requirements, memory mapping optimizations
- Event Generation and Complex Workflows for FY20 -21

The exascale systems Aurora (Argonne) and Frontier (Oak Ridge) expected in the 2021/22 timeframe; both systems are >1EF, ~10PB system memory, >200PB file systems at ~10TB/s. One cabinet is roughly 10PF; both systems are CPU/GPU (compute dominated by the GPUs)

U.S. Congress Supports P5 Strategy

- U.S. Congress continues to show strong support for executing the P5 strategy, and for accelerating the pace of projects
- When the P5 report was released in May 2014, the FY 2015 budget was already in Congress and the FY 2016 budget was being formulated
- Arguably the first impact (success!) of the P5 report was not seen until FY 2016, and continues today…



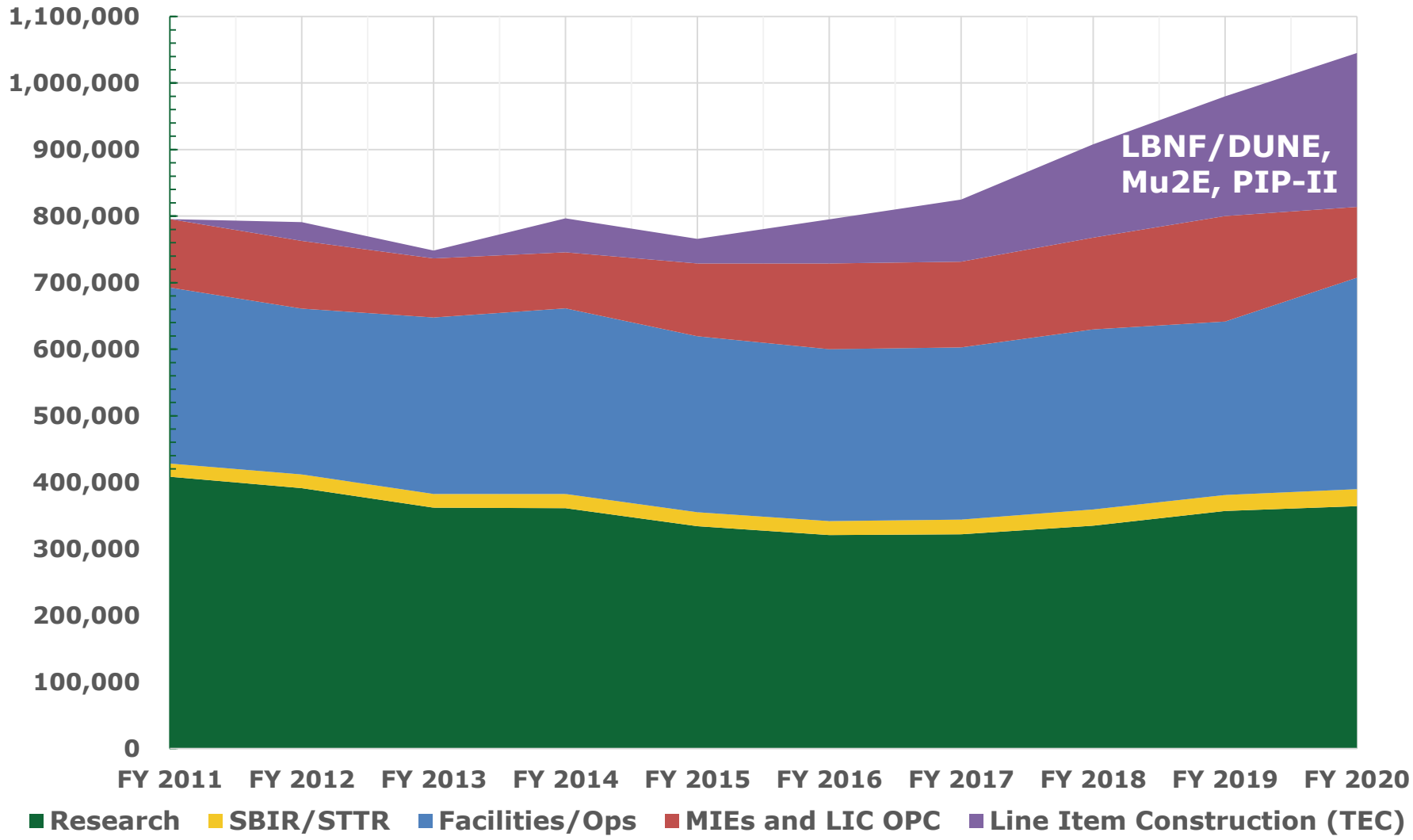
FY 2020 HEP Appropriation

HEP Funding Category ($ in K)	FY 2018 Actual	FY 2019 Actual	FY 2020 Appropriation	FY 2020 Appropriation - FY 2019 Actual
Research	359,177	384,286	389,577	+5,291
Facilities/Operations	270,488	258,364	317,929	+59,565
Projects	278,335	337,350	337,494	+144
Total	**908,000**	**980,000**	**1,045,000**	**+65,000**

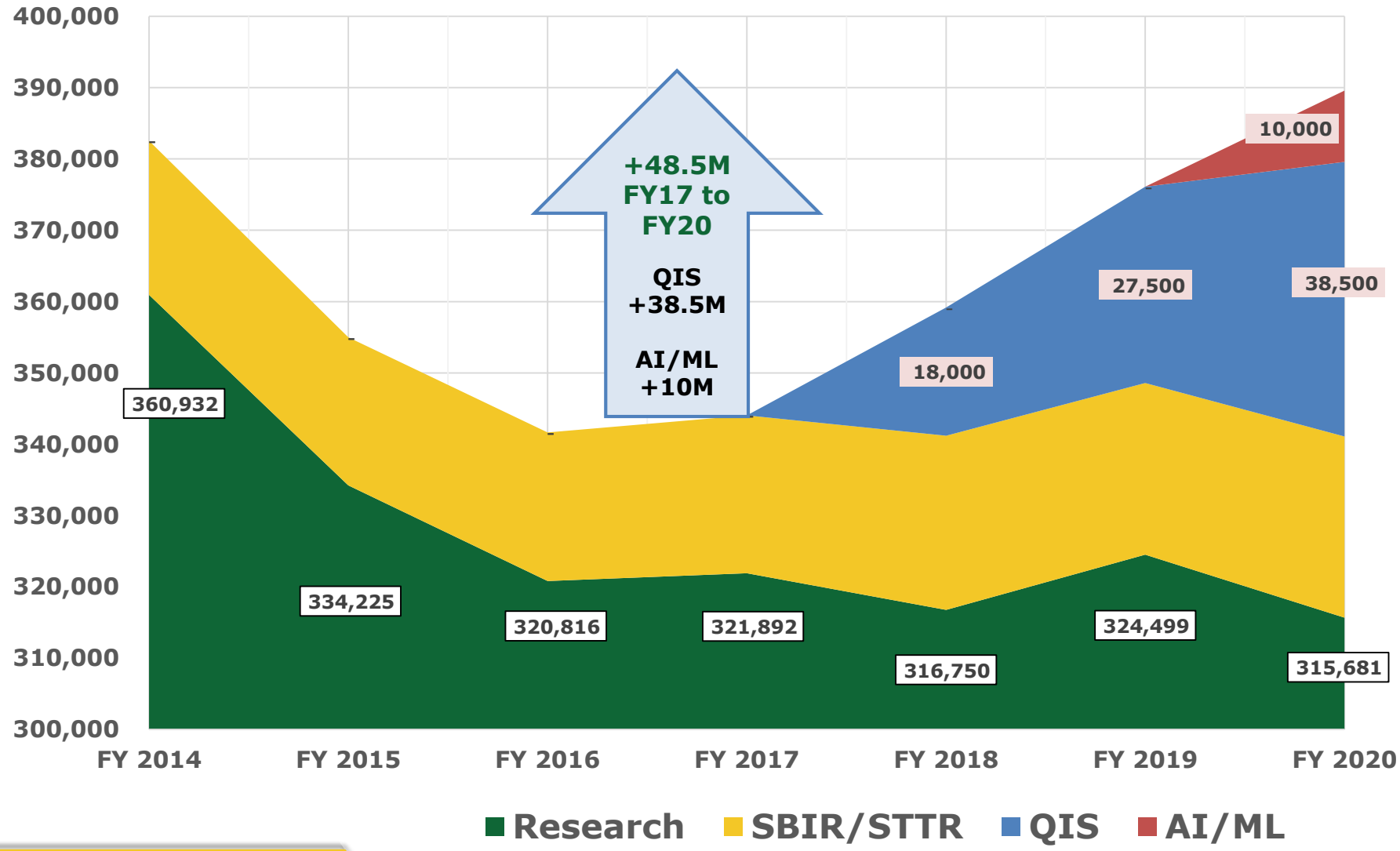
- FY 2020 Appropriations supports the SC and P5 priorities
  - SC: Interagency and international partnerships, national laboratories, R&D initiatives
  - P5: preserve vision, modify execution
- FY 2020 HEP Budget continues support for P5-guided investments in mid- and long-term program
  - "Building for Discovery" by supporting P5 projects to enable future program
  - Research support advances P5 science drivers and world-leading, long-term R&D in Advanced Technology, Accelerator Stewardship, Quantum Information Science, and Artificial Intelligence & Machine Learning
  - Operations support enables world-class research at HEP User Facilities:
    - Fermilab Accelerator Complex, Brookhaven Accelerator Test Facility (ATF), SLAC Facility for Advanced Accelerator Experimental Tests (FACET)

HEP Budget ($k) FY 2011-2020

Research, Operations, Projects: (Construction and MIEs)



HEP Research ($k) FY 2014-2020



FY 2021 HEP Budget Request

HEP Funding Category ($ in K)	FY 2019 Actual	FY 2020 Enacted	FY 2021 Request	FY 2021 vs. FY 2020
Research	372,629	390,077	328,903	-61,171
Facilities/Operations	266,556	316,429	285,725	-30,704
Projects	340,815	338,494	818,131	-134,994
Total	**980,000**	**1,045,000**	**818,131**	**-226,869**

- FY 2021 President's Budget Request is overlay of Administration, SC, P5 priorities
  - SC: interagency partnerships, national laboratories, accelerator R&D, QIS, AI/ML
  - HEP: continue successful P5 execution, advance Administration and DOE/SC initiatives
- FY 2021 HEP Budget continues support for P5-guided investments
  - Research: Continue U.S. leadership in LHC, muon experiments, international neutrino experiments at Fermilab, dark matter, dark energy, and vibrant theory program; QIS; AI/ML; Microelectronics centers (with ASCR, BES, and FES); Strategic Accelerator Technology Initiative; Traineeships in accelerator science
  - Operations: Support HEP user facilities and running P5-recommended experiments
  - Line Item Construction and Projects: HL-LHC Accelerator and ATLAS & CMS Detectors, LBNF/DUNE, PIP-II, new MIE start for CMB-S4

FY 2021 House Marks

- FY 2021 House Mark is $7.05B for DOE SC, $1.050B for HEP
- Additional infrastructure package also under consideration brings:
  - At SC level:
    - $75,000,000 shall be for equipment and infrastructure for the Quantum Information Science Research Centers;
  - At HEP level: (total ~$1,305M)
    - $641,000,000 shall be for Long Baseline Neutrino Facility;
    - $284,380,000 shall be for the Proton Improvement Plan II
    - $200,300,000 shall be for Large Hadron Collider computing and equipment;
    - $100,000,000 shall be for Wilson Hall renovations;
    - $62,000,000 shall be for Cosmic Microwave Background - Stage 4;
    - $9,000,000 shall be for Muon to Electron Conversion Experiment equipment;
    - $6,000,000 shall be for Super Cryogenic Dark Matter Search equipment;
    - $2,100,000 shall be for the Large Synoptic Survey Telescope project;
  - In SLI program, two projects benefit Fermilab: (total $82.5M)
    - $77,000,000 shall be for the Utilities Infrastructure Project;
    - $5,500,000 shall be for the Integrated Engineering Research Center;

Final Appropriation Report Language Matters!

- Congress will usually specify top-line budget for a program and sometimes direct specific project or subprogram budget levels
  - It is up to program management to make things work "within available funds"
- Example: HEP received $1,045M in the FY 2020 Congressional Appropriation, about $277M above the FY 2020 President's Budget Request
  - Congressional "Research" line includes everything other than Line Item Construction, or what HEP traditionally calls Research, Operations, and Projects
  - Congressional direction included specific amounts for Line Item Construction, Projects, Vera C. Rubin Observatory, and SURF; HEP cannot adjust what is spent on those items

High Energy Physics (HEP).—Within available funds, $30,000,000 is for the Sanford Underground Research Facility, $100,000,000 is for the HL–LHC Upgrade Projects, and $15,000,000 is for the Large Synoptic Survey Telescope.

The agreement provides $71,000,000 for Artificial Intelligence and Machine Learning for the six Office of Science programs to apply those capabilities to the Department's mission.

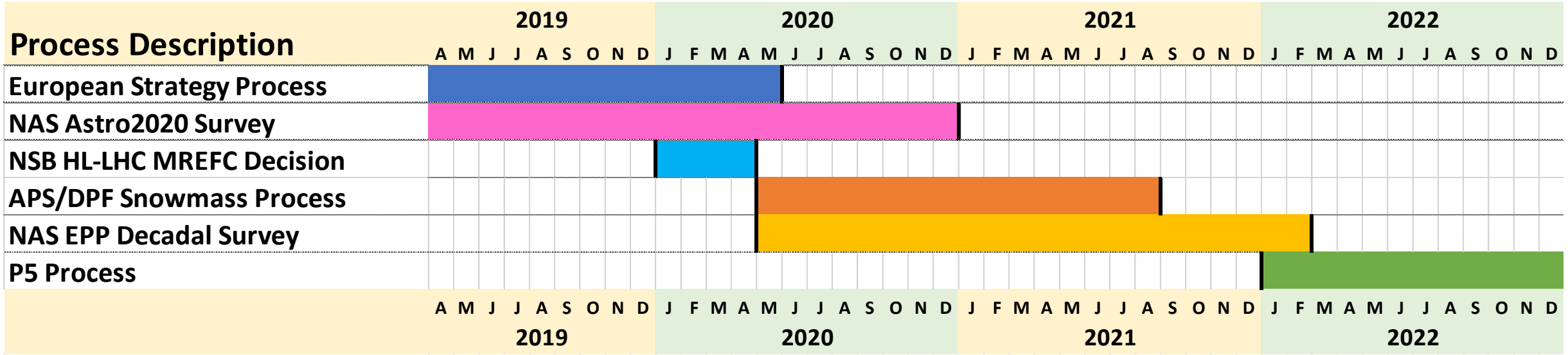
The agreement provides $195,000,000 for Quantum Information Sciences across the Office of Science programs to advance early-stage fundamental research in this field of science, including $120,000,000 to carry out a basic research program on quantum information science and $75,000,000 for the establishment of up to five National Quantum Information Science Research Centers. To the greatest extent practical, this effort shall be undertaken in coordination with the National Science Foundation and the National Institute of Standards and Technology.

DEPARTMENT OF ENERGY
(Amounts in thousands)

	FY 2019 Enacted	FY 2020 Request	Final Bill
High energy physics:			
Research	800,000	648,038	814,000
Construction:			
18-SC-42 Proton Improvement Plan II (PIP-II), FNAL	20,000	20,000	60,000
11-SC-41 Muon to electron conversion experiment, FNAL	30,000	---	---
11-SC-40 Long baseline neutrino facility / deep underground neutrino experiment (LBNF/DUNE), FNAL	130,000	100,000	171,000
Subtotal, Construction	180,000	120,000	231,000
Subtotal, High energy physics	980,000	768,038	1,045,000

Strategic Planning Timeline

- To provide timely input to the FY25 budget formulation, the next P5 report will be required by March 2023
- U.S. Community Snowmass process is underway with major meeting occurring in summer 2021
- Potential timeline for the next NAS EPP Decadal Survey could be mid-2020 through early-2022
  - Overlap with Snowmass could enable synergy with Snowmass processes and delivery of report as P5 process begins



European Strategy Update

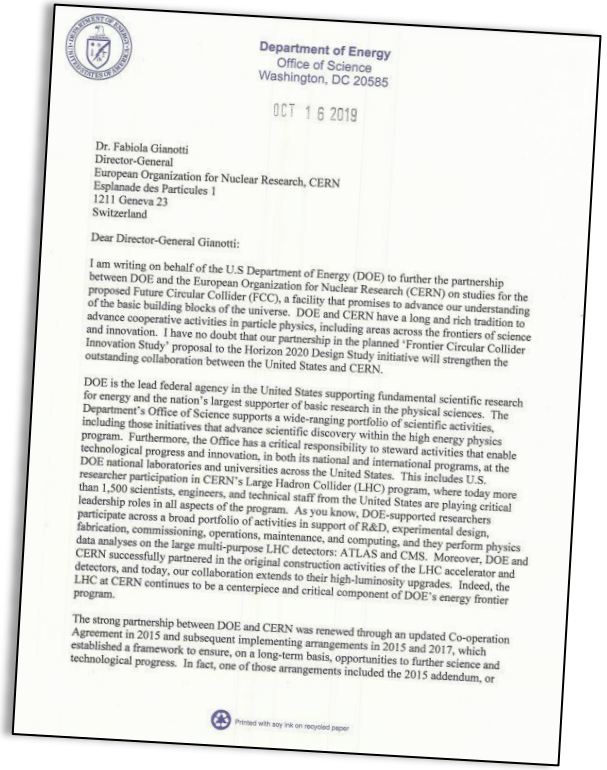
- DOE congratulates CERN, the CERN Member States, and all delegates of the European Strategy for Particle Physics (ESPP) process on successfully preparing and endorsing the 2020 Update of the ESPP
  - More details of the Strategy in tomorrow's HEPAP session

- DOE shares the same views as the ones recently expressed by the CERN Director-General, namely that the Strategy is visionary and ambitious while realistic and prudent
  - Many exciting future initiatives in particle physics are emphasized, and the roadmap to successfully achieve them, in collaboration with global partners including DOE, is most appreciated and welcomed
- We also thank the CERN Council and the Strategy team for facilitating, on behalf of the U.S., the participation of Drs. Marcela Carena, Fermilab, and Abid Patwa, DOE, to the Physics Preparatory Group and European Strategy Group, respectively

FCC Innovation Study: Horizon 2020 Design Study

- DOE has partnered with CERN and national laboratories across Europe on the "FCC Innovation Study" proposal submitted to the European Commission's Horizon 2020 Design Study initiative
- November 2019 proposal's goal includes
  - Technical design study for a 100 km luminosity frontier circular collider infrastructure hosted at CERN
  - Study topics to optimize the particle collider design; planning and necessary investigations for a sustainable civil engineering construction project
- April 2020: European Commission selected CERN's proposal for funding
  - DOE is working with CERN on a Consortium Agreement to facilitate DOE's and U.S. national labs' activities
- DOE's partnership covers participation by the U.S. national laboratories and further advances their ongoing work on FCC-related R&D activities
  - Enables integration and synergies of all partners into the study's network and user community
  - Furthers the cooperative partnership on the FCC study enabled by the DOE-CERN protocol/agreements and topic-specific MOUs signed during 2015-2017

Oct. 2019 Partnership Letter from DOE/HEP J. Siegrist to CERN Director-General F. Gianotti



Department of Energy
Office of Science
Washington, DC 20585

OCT 16 2019

Dr. Fabiola Gianotti
Director-General
European Organization for Nuclear Research, CERN
Esplanade des Particules 1
1211 Geneva 23
Switzerland

Dear Director-General Gianotti:

I am writing on behalf of the U.S Department of Energy (DOE) to further the partnership between DOE and the European Organization for Nuclear Research (CERN) on studies for the proposed Future Circular Collider (FCC), a facility that promises to advance our understanding of the basic building blocks of the universe. DOE and CERN have a long and rich tradition to advance cooperative activities in particle physics, including areas across the frontiers of science and innovation. I have no doubt that our partnership in the planned 'Frontier Circular Collider Innovation Study' proposal to the Horizon 2020 Design Study initiative will strengthen the outstanding collaboration between the United States and CERN.

DOE is the lead federal agency in the United States supporting fundamental scientific research for energy and the nation's largest supporter of basic research in the physical sciences. The Department's Office of Science supports a wide-ranging portfolio of scientific activities, including those initiatives that advance scientific discovery within the high energy physics program. Furthermore, the Office has a critical responsibility to steward activities that enable technological progress and innovation, in both its national and international programs, at the DOE national laboratories and universities across the United States. This includes U.S. researcher participation in CERN's Large Hadron Collider (LHC) program, where today more than 1,500 scientists, engineers, and technical staff from the United States are playing critical leadership roles in all aspects of the program. As you know, DOE-supported researchers participate across a broad portfolio of activities in support of R&D, experimental design, fabrication, commissioning, operations, maintenance, and computing, and they perform physics data analyses on the large multi-purpose LHC detectors: ATLAS and CMS. Moreover, DOE and CERN successfully partnered in the original construction activities of the LHC accelerator and detectors, and today, our collaboration extends to their high-luminosity upgrades. Indeed, the LHC at CERN continues to be a centerpiece and critical component of DOE's energy frontier program.

The strong partnership between DOE and CERN was renewed through an updated Co-operation Agreement in 2015 and subsequent implementing arrangements in 2015 and 2017, which established a framework to ensure, on a long-term basis, opportunities to further science and technological progress. In fact, one of those arrangements included the 2015 addendum, or

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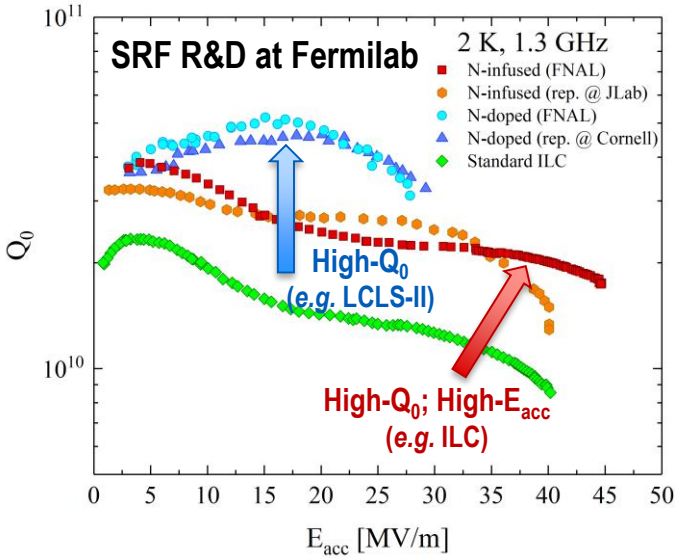
U.S. Efforts Towards the International Linear Collider

- U.S. supports the development and realization of a future Higgs Factory with international participation, taking into consideration the 2014 P5 strategy
  - 2014 P5 recommendation: *"Motivated by the strong scientific importance of the ILC and the recent initiative in Japan to host it, the U.S. should engage in modest and appropriate levels of ILC accelerator and detector design in areas where the U.S. can contribute critical expertise. Consider higher levels of collaboration if the ILC proceeds."*



- Current support from the U.S. to enable Japan move forward with the ILC
  - U.S. R&D efforts focused in cost-reduction for accelerator superconducting radiofrequency (SRF) cavities and modest ILC detector R&D
  - To strengthen the long-standing U.S.-Japan cooperation in science and technology, concerted effort during last 12-15 months by the U.S. Government — DOE, U.S. State Department, The White House Office of Science & Technology Policy, and the National Security Council — to support a Japanese initiative to move forward to the proposed ILC "Pre-Laboratory" phase of the project

Looking Forward

- The P5 strategy continues to receive strong support from the Administration and Congress
- FY 2021 discretionary spending levels have been authorized and we have a House Mark, but there are many uncertainties
  - FY 2021 is an election year: Increased uncertainty
  - COVID-19 Impacts: Escalating costs due to schedule delays, standing army costs
  - Stimulus Funding: Will Congress appropriate funds for SC infrastructure projects?
  - Length and number of Continuing Resolutions
  - Government Shutdown?
- The community is successfully implementing the P5 strategy by executing projects and producing excellent science, even while facing recent challenges
- We will continue to work with the community and our international partners as we begin the next phase of long-term community planning

U.S. DEPARTMENT OF
ENERGY

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FY 2020 Funding by Subprogram

HEP Funding Category ($ in K)	FY 2018 Actual	FY 2019 Actual	FY 2020 Appropriation	FY 2020 Appropriation - FY 2019 Actual
Energy Frontier	183,219	235,403	229,666	-5,737
Intensity Frontier	247,048	247,256	251,666	+4,410
Cosmic Frontier	119,630	105,084	95,858	-9,226
Theoretical, Computational, and Interdisciplinary Physics*	76,176	87,043	112,560	+25,517
Advanced Technology R&D*	125,643	109,190	107,711	-1,479
Accelerator Stewardship*	15,885	16,024	16,539	+515
Construction (Line Item)	140,400	180,000	231,000	+51,000
Total	**908,000**	**980,000**	**1,045,000**	**+65,000**

** Includes reserve funds pending final decision. Funding levels may change.*

- Energy: -5M HL-LHC Projects
- Intensity: -14.5M PIP-II OPC; +3M DUNE OPC; Fermilab Acc Complex ramps up
- Cosmic: -26.35M DESI, LZ, and SuperCDMS-SNOLAB projects; +2M CMB; Operations ramps up +20.4M
- Theory, Computational, and Interdisciplinary: +11M QIS; +10M AI/ML; +2.5M LQCD
- Advanced Technology: -10M FACET-II SLAC; Operations ramps up