High Energy Physics Program Status

High Energy Physics Advisory Panel

November 2021

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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.
  - *Julie Carruthers* will provide more information tomorrow at HEPAP.

- 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 impacts.
  - *Glen Crawford* will discuss research program impacts later today at HEPAP.
  - *Mike Procario* will detail project impacts tomorrow at HEPAP.
Science Highlight: Muon g-2 Result

- The first results released April 2021
- The result of Muon g-2 confirmed previous result from Brookhaven experiment

- Four simultaneous publications submitted
  - PRL (g-2), PRD (muon precession frequency), PRA (magnetic field), and PR-AB (beam dynamics)

- The announcement has had a wide reach including 448 citations so far, and an invited lecture by the Nobel Committee for Physics
Muon g-2 Results and Broader Context

- Fermilab’s Muon g-2 experiment measures to 460 ppb released April 2021
  - Combined results from Fermilab and Brookhaven show a difference with theory at **4.2 sigma**
  - Results reported are from 6% (Run-1) of total planned data

- Shaping up as the Century of Quantum in physical sciences!
  - Emerging ability to probe and manipulate basic systems “as they are”
  - Muon g-2 is outstanding example of probing the quantum properties of “empty space”

- Ability to **probe** quantum systems at their most fundamental level goes hand in hand with advancing our ability to **manipulate** quantum systems – in this sense Muon g-2 and QIS are two sides of the same coin

- Future of ultra-high sensitivity laboratory measurements like Muon g-2 has very large overlap with advances in quantum technology
  - Next-generation electric dipole moment experiments (a currently unobserved relative of the magnetic moment), and a variety of experiments looking for wavelike dark matter

- Challenges of following up emerging discovery from Muon g-2 will lead to new HEP experiments, which will act as powerful drivers of quantum and other technology advances

November 2021
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...

**HEP BUDGET**

(IN THEN-YEAR DOLLARS)

~280M

Post-P5

(+36% in 6 years)
HEP Research ($k) FY 2014-2021

Research Growth: Driven by QIS and AI/ML

- **QIS** +43.5M FY17 to FY21
- **AI/ML** +32.3M

FY 2014: 320,816
FY 2015: 321,892
FY 2016: 316,750
FY 2017: 324,499
FY 2018: 315,681
FY 2019: 322,666
FY 2020: 327,500
FY 2021: 38,500

Research SBIR/STTR

- **Research**
- **SBIR/STTR**
FY 2022 HEP Budget Request

- FY 2022 President’s Budget Request is overlay of Administration, SC, P5 priorities
  - SC: interagency partnerships, national laboratories, accelerator R&D, QIS, AI/ML, microelectronics
  - HEP: continue successful P5 execution, advance Administration and DOE/SC initiatives

- FY 2022 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 (with ASCR, BES, and FES); Accelerator Science and Technology Initiative; Traineeships in accelerator science, instrumentation, high-performance scientific computing
  - Operations: Support HEP user facilities and running P5-recommended experiments
  - Projects and Line Item Construction: Project support for HL-LHC Accelerator and ATLAS & CMS Detectors, CMB-S4, and ACORN (new start); LIC support for LBNF/DUNE, PIP-II, and Mu2e

### HEP Funding Category

<table>
<thead>
<tr>
<th>HEP Funding Category</th>
<th>FY 2020 Actual ($ in K)</th>
<th>FY 2021 Enacted ($ in K)</th>
<th>FY 2022 Request ($ in K)</th>
<th>FY 2022 vs. FY 2021</th>
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</thead>
<tbody>
<tr>
<td>Research</td>
<td>389,646</td>
<td>398,203</td>
<td>419,605</td>
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<tr>
<td>Facilities/Operations</td>
<td>317,310</td>
<td>314,297</td>
<td>309,395</td>
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<td>Projects</td>
<td>338,044</td>
<td>333,500</td>
<td>332,000</td>
<td>-1,500</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1,045,000</strong></td>
<td><strong>1,046,000</strong></td>
<td><strong>1,061,000</strong></td>
<td><strong>+15,000</strong></td>
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November 2021  
HEP Program Overview  
7
Some Challenges

- The FY 2022 President’s Request Budget for DOE/HEP is down $1.5 million for projects compared to the FY 2021 Appropriation
  - PIP-II accelerator project request is below the approved baseline
  - LBNF/DUNE is below the planned level
  - HL-LHC projects took larger cuts on a percentage basis

- We remain committed to the P5 strategy and its priorities
  - Talking to CERN management about our ongoing commitment to and priority for HL-LHC
  - Discussing with international partners about plans for LBNF/DUNE and PIP-II
  - Responding to questions from U.S. Congress on impacts

- Congressional marks are slightly above the FY 2022 budget request for HEP, but final budget language will impact the allocation of any additional resources
  - HEP request: $1.061B
  - House mark $1.078B (+1.6%), Senate mark $1.079B (+1.7%)
Completed HEP Projects

- Facility for Advanced Accelerator Experimental Tests II (FACET-II)
- Rubin Observatory Legacy Survey of Space and Time Camera (LSSTCam)
- Dark Energy Spectroscopic Instrument (DESI)
- LUX-ZEPLIN (LZ) Dark Matter Experiment

More details in Mike Procario’s HEPAP presentation...
Advanced Microelectronics

- In FY 2022, ASCR, BES, FES, HEP, and NP will expand coordinated support for multi-disciplinary research to accelerate the advancement of microelectronic technologies in a co-design innovation ecosystem.

- Emphasis will be on basic research to advance:
  - New materials, chemistry, synthesis, and fabrication
  - New computing paradigms and architectures
  - Integrated sensing, edge computing, and communications
  - Microelectronics resilience in high radiation or cryogenic environments

- Microelectronics are:
  - Critical for clean energy generation and efficient energy use
  - Key to domestic manufacturing goals
  - An opportunity to expand the research community at underserved institutions and communities
The President has placed a high priority on American leadership in the Industries of the Future (IOTF):
- artificial intelligence (AI), quantum information science (QIS), advanced manufacturing, biotechnology, and 5G/advanced wireless technologies

As part of the AI initiative, FY21 appropriation includes $100M in AI funding for SC, including $32M for HEP
- SC has prioritized investments in AI/ML for user facilities focusing on accelerator optimization, control, prognostics, and data analysis

In 2021, HEP AI/ML funding contributed to:
- Awards from dedicated FOAs ("Data, AI, and Machine Learning at DOE Scientific User Facilities")
- New and ongoing Early Career Research Awards
- Ongoing Laboratory research programs
- New and renewal applications under standard HEP FOAs (including "Comparative Review")

HEP will continue to support dedicated new AI/ML efforts while enhancing support for existing AI/ML embedded in the ongoing research program
QIS is a National and DOE Priority

“Quantum Information Science represents a foundational shift in our understanding of physics and information science, with the potential for dramatic technology impact.”

– Dr. Charles Tahan, Assistant Director for QIS, Office of Science and Technology Policy

QIS is an all-of-government effort, coordinated across agencies

- Quantum Sensing and Metrology
- Quantum Computing
- Quantum Networks and Communications
- Foundational Quantum Information Science Advances
- Supporting Technology
- Future Applications
- Risk Mitigation
- NQIA (National Quantum Initiative Act) Crosscut

SC core and Centers span most of the above

See also: https://www.quantum.gov/

Major Milestones

- 2018: National Quantum Initiative Act Passed by Congress
- 2018: DOE Office of Science Quantum Initiative & Core programs
- 2020: National QIS Research Centers established by DOE
International Cooperation Agreements

- Efforts actively continue at DOE to advance international cooperation with global partners to the HEP programs
  - Include the preparation and signing of DOE agency-level international agreements and MOUs

- DOE agency-level International Agreements
  - Nine agreements are currently in various preparation or active discussion phases, including substantial progress for those with India, Italy, France, and Spain

- Memoranda of Understanding
  - DOE MOU Working Group – chaired by Abid Patwa with membership from GC, SC, and Fermi Site Office – coordinating with Fermilab in developing multi-institutional MOUs for global HEP activities
  - PIP-II Project Planning Documents: signed by Fermilab with UKRI-STFC and Italy-INFN; awaiting signatures with Poland’s Wroclaw University of Science and Technology; in-progress with India-DAE and France-CEA
  - Short-Baseline Neutrino program multi-institutional MOU: signed by Fermilab with CERN, INFN, and Switzerland-Bern; awaiting signatures with the UK and Brazil
  - DUNE program multi-institutional MOU: currently for DUNE’s Far Detector #1, under discussions with Brazil, Canada, CERN, Czech Republic, Italy, Spain, Switzerland, and the UK
  - HL-LHC accelerator upgrade MOU: signed by Fermilab and CERN, March 2021
DOE/HEP briefed The White House Office of Science and Technology Policy in August 2021 on the currently proposed future colliders

For the FCC, DOE and CERN signed an agreement in December 2020 for DOE and the national labs to engage in the global FCC Feasibility Study

- DOE continues to work with CERN on identifying R&D areas for FCC
- DOE participating in the FCC International Collaboration Board
- Tor Raubenheimer (SLAC) appointed FCC Accelerator Coordinator

For the ILC, DOE has been coordinating efforts with ICFA’s ILC International Development Team (IDT)

- Multilateral meeting held in October 2021 by MEXT (Japan) with funding authorities from France, Germany, UK, and the U.S. (DOE) to exchange opinions on the ILC
- DOE encouraged MEXT to move forward to the pre-lab process
- MEXT plans to continue discussions after a MEXT Advisory Panel completes its review of IDT’s pre-lab proposal (~March 2022)
HEP community-wide “Snowmass” study process organized by the Division of Particles and Fields (DPF) of the American Physical Society (APS) has restarted ([https://snowmass21.org/start](https://snowmass21.org/start))

- Snowmass process was paused/slowed down due to the COVID; resumed full activities as of September 2021
- “Community Summer Study” will take place July 17–27, 2022 at UW-Seattle (in-person)
- Full Snowmass reports will be available by the end of October 2022

New National Academy of Sciences (NAS) Elementary Particle Physics (EPP) Decadal Survey will run concurrently with and complement the community-driven Snowmass process

Next P5 process to begin after Snowmass and NAS Decadal Survey, circa late 2022: P5 report by May 2023 will inform FY 2024 Congressional actions & FY 2025 U.S. budget formulation

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<tr>
<th>Process Description</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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<tr>
<td>NSB HL-LHC MREFC Decision</td>
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<td>European Strategy Process</td>
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<td>NAS Astro2020 Survey</td>
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<td>APS/DPF Snowmass Process</td>
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<td>NAS EPP Decadal Survey</td>
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<td>P5 Process</td>
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HEP Staffing Changes

Outgoing:
- Drew Baden (IPA) returned to U. Maryland at end of August.
- John Boger retired at end of September.
- Eric Colby now full-time Associate Director for Accelerator R&D and Production (ARDAP).

Incoming:
- Derun Li (Detailee, part-time) now assisting with Accelerator R&D
- Jeremy Love new Fed program manager for AI/ML and Computational HEP
- Crystal Yeh (Presidential Management Fellow) new lead for HEP Communications

Job Opportunities
- Program Manager for Projects. To be re-advertised, see next slide
- Program Manager for Cosmic Frontier. Expect announcement soon. Short application window.
- We have an approved HEP staffing plan with 5 vacancies identified (including 2 positions above but not including recent staff departures).

Help Wanted
- COV report reiterates request for HEP Theory IPA. Technology R&D is also short-staffed.
- Also identified other areas (project oversight, operations) that will likely need additional help as large P5 projects ramp-up and come on-line
We are looking for a new program manager to oversee projects to build new equipment and facilities.

Open to engineers and physicists with experience in project management.

HEP projects build highly technical systems and can cost from $10 million to several billion dollars.

Relevant experience:
- Acted as a project manager or project director for an Office of Science project.
- Worked as a lower-level manager (L2, L3) on an Office of Science project.
- Had a managerial role that involved oversight of an Office of Science project.
- Served on an OPA review committee or a director’s review committee.
- Similar experience on a large technical project with an NSF or NASA project.

Job Announcement will go public in several weeks.
- You can contact Mike Procario for more details.
Looking Forward

- The P5 strategy continues to receive strong support from the Administration and Congress.
- The FY 2022 budget process is ongoing, but not yet complete.
- 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.
International Cooperation Agreements (I)

- Efforts actively continue at DOE to advance international cooperation with global partners to HEP programs
  - Include the preparation and signing of MOUs and DOE agency-level international agreements

**MOUs**

- **DOE MOU Working Group (WG)** — chaired by Abid Patwa and comprised of officials from DOE General Counsel, Office of Science, and Fermi Site Office — have been coordinating with Fermilab the development of multi-institutional MOUs for global HEP activities

- **Project Planning Documents ("MOUs") for the Fermilab-hosted PIP-II project**
  - Memorializes cooperation between Fermilab and global partners on PIP-II while also specifying details of project scope and partners’ deliverables that are needed for DOE project reviews
    - Signed by Fermilab with UKRI-STFC and Italy-INFN
    - Fermilab now coordinating signatures with Poland’s Wrocław University of Science and Technology
    - Currently discussing drafts with India-DAE and France-CEA

- **Multi-institutional MOU for collaboration in the Short-Baseline Neutrino program**
  - Signed by Fermilab with CERN, INFN, Switzerland-Bern; now coordinating signatures with the UK and Brazil

- **Multi-institutional MOU for collaboration in the DUNE program**
  - Currently being reviewed by and discussed with global partners to DUNE’s Far Detector #1 (Brazil, Canada, CERN, Czech Republic, Italy, Spain, Switzerland, and the UK)

- **MOU between Fermilab and CERN for U.S. contributions to HL-LHC accelerator upgrade signed March 2021**
Various agreements are at different stages of development and/or are nearing signature:

**India**
- Amendments to existing Project Annex agreements with India’s Department of Atomic Energy (DAE) for PIP-II and DUNE to align each cooperation with project-specific processes such as equipment transfer procedures and the use of subsidiary MOUs
  - Drafts negotiated, now being processed at DOE to authorize signature
  - Anticipate to sign with DAE by end of calendar year 2021

**Italy**
- Two agreements in-progress with Italy’s Ministry of Universities and Research:
  1) Discussing with INFN draft Project Annex for cooperation on DUNE, includes Italy’s in-kind contributions to the DUNE detector
  2) Discussing with INFN draft Project Annex for a Fermilab–INFN partnership to advance software and computing efforts for HEP programs
  - Anticipate to sign by end-2021 or early-2022

**France**
- Three agreements in-progress:
  1) Discussing an Implementing Arrangement draft with CEA for cooperation to PIP-II
  2) Project Annex draft with CNRS for PIP-II and DUNE, currently under DOE review
  3) Project Annex draft with CNRS for cooperation, including data access, on the Vera C. Rubin Observatory program is being prepared at DOE in- coordination with SLAC
  - Anticipate to sign each with CEA and/or CNRS in 2022

**Spain**
- Two agreements in-progress with Spain’s Ministry of Science and Innovation:
  1) Office of Science (SC)-wide Implementing Arrangement for cooperation in SC programs, currently under review and awaiting C-175 authorization by the U.S. State Department
  2) HEP-specific Project Annex for cooperation on DUNE, currently under an initial review by DOE General Counsel
  - Anticipate to sign each in early-2022

Other written instruments in the pipeline include preparing an agreement with the UK for cooperation in the Rubin Observatory program, and with CERN for CERN’s cooperative support for the 2nd LBNF cryostat