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
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 the 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)
NOvA presented preliminary results including 2020 data at Neutrino 2020

Best oscillation fit favors normal hierarchy:
\[ \Delta m^2_{32} = (2.41 \pm 0.07) \times 10^{-3} \text{ eV}^2 \]
\[ \sin^2 \theta_{23} = 0.57^{+0.04}_{-0.03} \]
\[ \delta_{CP} = 0.82\pi \]

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
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

<table>
<thead>
<tr>
<th>Science</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation “r”</td>
<td>≤0.1</td>
<td>≤0.01</td>
<td>≤0.001</td>
</tr>
<tr>
<td>σ(Neff)</td>
<td>0.14</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>σ(Mₙ)</td>
<td>0.15eV</td>
<td>0.06eV</td>
<td>0.02eV</td>
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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

Science

- Inflation “r” ≤0.1 ≤0.01 ≤0.001
- σ(Neff) 0.14 0.06 0.03
- σ(Mₙ) 0.15eV 0.06eV 0.02eV

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(Mₙ) 0.15eV 0.06eV 0.02eV 3σ detection
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$_3$Sn 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
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:
- Some papers:
  - 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)
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).

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
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...

**HEP BUDGET**
(IN THEN-YEAR DOLLARS)

**~280M Post-P5 (+36% in 5 years)**

July 2020

HEP Status Report
FY 2020 HEP Appropriation

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<tr>
<td>Research</td>
<td>359,177</td>
<td>384,286</td>
<td>389,577</td>
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<tr>
<td>Facilities/Operations</td>
<td>270,488</td>
<td>258,364</td>
<td>317,929</td>
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<td>Projects</td>
<td>278,335</td>
<td>337,350</td>
<td>337,494</td>
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<td><strong>Total</strong></td>
<td><strong>908,000</strong></td>
<td><strong>980,000</strong></td>
<td><strong>1,045,000</strong></td>
<td><strong>+65,000</strong></td>
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- 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)

July 2020
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<tr>
<td>Research</td>
<td>SBIR/STTR</td>
<td>Facilities/Ops</td>
<td>MIEs and LIC OPC</td>
<td>Line Item Construction (TEC)</td>
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**HEP Budget ($k) FY 2011-2020**
Research, Operations, Projects: (Construction and MIEs)

**LBNF/DUNE, Mu2E, PIP-II**

July 2020
HEP Research ($k) FY 2014-2020

+48.5M FY17 to FY20
QIS +38.5M
AI/ML +10M

Research | SBIR/STTR | QIS | AI/ML
---|---|---|---
$360,932 | $334,225 | $320,816 | $321,892 |
$320,816 | $316,750 | $324,499 | $315,681 |

July 2020
FY 2021 HEP Budget Request

- 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

### HEP Funding Category ($ in K)

<table>
<thead>
<tr>
<th>HEP Funding Category</th>
<th>FY 2019 Actual</th>
<th>FY 2020 Enacted</th>
<th>FY 2021 Request</th>
<th>FY 2021 vs. FY 2020</th>
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<tbody>
<tr>
<td>Research</td>
<td>372,629</td>
<td>390,077</td>
<td>328,903</td>
<td>-61,171</td>
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<tr>
<td>Facilities/Operations</td>
<td>266,556</td>
<td>316,429</td>
<td>285,725</td>
<td>-30,704</td>
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<tr>
<td>Projects</td>
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<td>338,494</td>
<td>818,131</td>
<td>-134,994</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>980,000</strong></td>
<td><strong>1,045,000</strong></td>
<td><strong>818,131</strong></td>
<td><strong>-226,869</strong></td>
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July 2020

HEP Status Report
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;
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
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
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
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
### FY 2020 Funding by Subprogram

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<tbody>
<tr>
<td>Energy Frontier</td>
<td>183,219</td>
<td>235,403</td>
<td>229,666</td>
<td>-5,737</td>
</tr>
<tr>
<td>Intensity Frontier</td>
<td>247,048</td>
<td>247,256</td>
<td>251,666</td>
<td>+4,410</td>
</tr>
<tr>
<td>Cosmic Frontier</td>
<td>119,630</td>
<td>105,084</td>
<td>95,858</td>
<td>-9,226</td>
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<tr>
<td>Theoretical, Computational, and Interdisciplinary Physics*</td>
<td>76,176</td>
<td>87,043</td>
<td>112,560</td>
<td>+25,517</td>
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<tr>
<td>Advanced Technology R&amp;D*</td>
<td>125,643</td>
<td>109,190</td>
<td>107,711</td>
<td>-1,479</td>
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<tr>
<td>Accelerator Stewardship*</td>
<td>15,885</td>
<td>16,024</td>
<td>16,539</td>
<td>+515</td>
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<tr>
<td>Construction (Line Item)</td>
<td>140,400</td>
<td>180,000</td>
<td>231,000</td>
<td>+51,000</td>
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<tr>
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*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