Update on the US program in the post-P5 era

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114th Plenary ECFA Meeting
July 2024

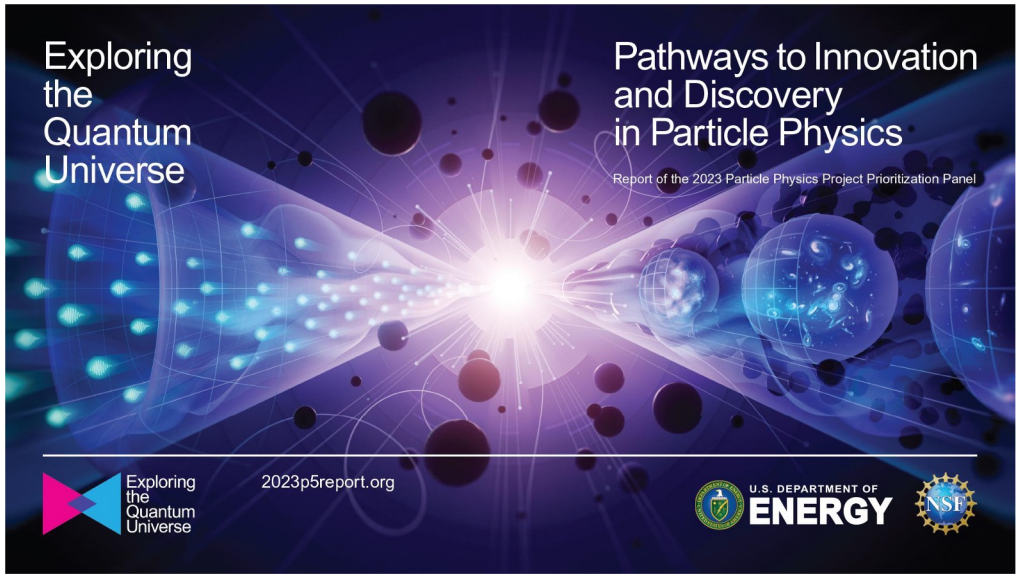
Outline

- P5 process and recommendations
- DOE and NSF responses, and other developments since P5 Report publication
- Where we (think we) stand

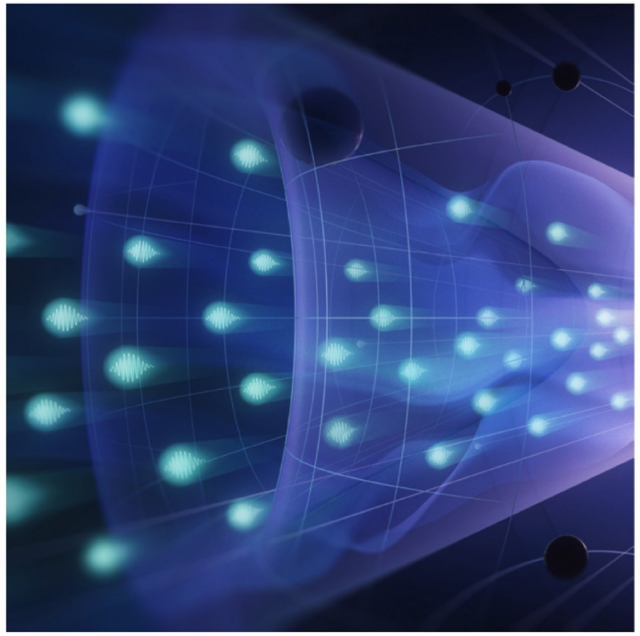
This presentation is focused mainly on the Higgs (HET) Factory

The 2023 P5

- A full-year process following the 2-year long Snowmass community study.
- 4 Town Hall meetings (LBNL, FNAL/Argonne, SLAC, BNL) and 2 virtual ones (one for ECRs).
- Input from DOE & NSF.
- Report writing August-December 2023
- 30-member panel: PP, Accelerators, Cosmology; Theory & Experiment; 5 non-US members; wide career-point span.
- Report presented & accepted by HEPAP last December.



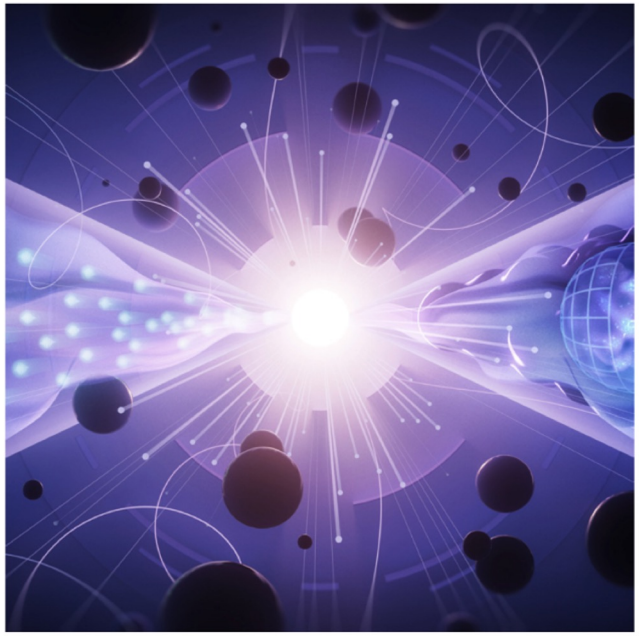
Three science themes and six drivers



Decipher the Quantum Realm

Elucidate the Mysteries of Neutrinos

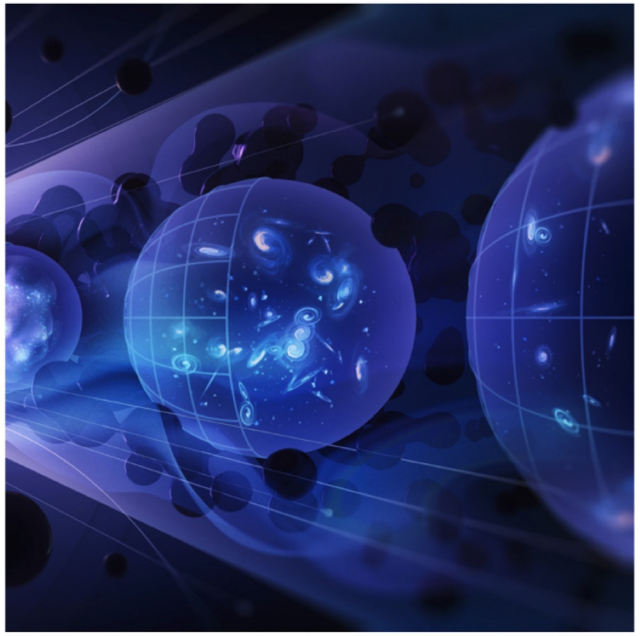
Reveal the Secrets of the Higgs Boson



Explore New Paradigms in Physics

Search for Direct Evidence of New Particles

Pursue Quantum Imprints of New Phenomena

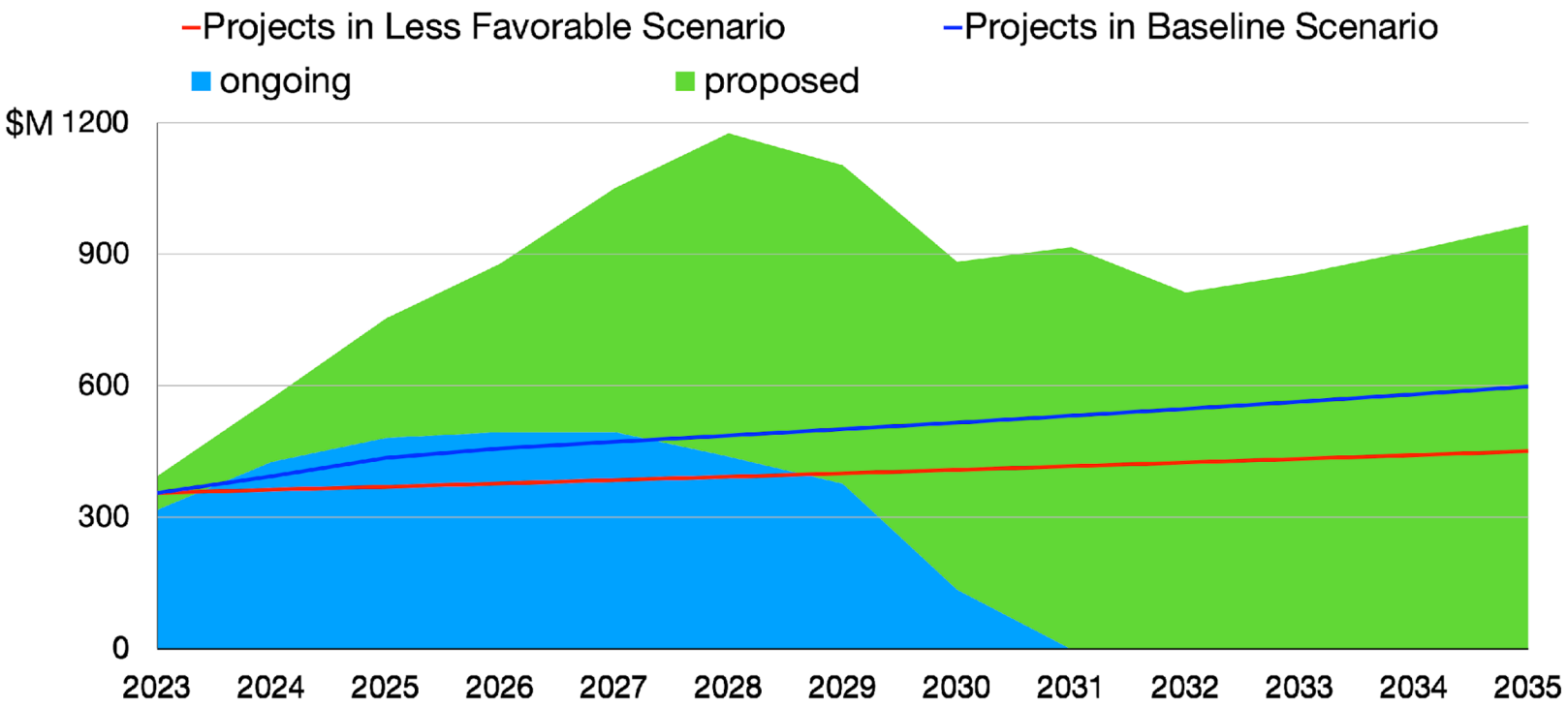


Illuminate the Hidden Universe

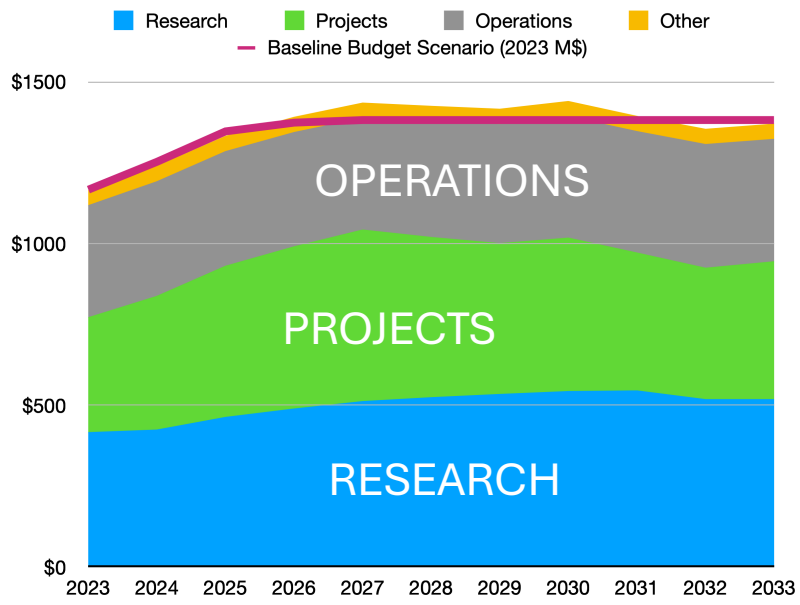
Determine the Nature of Dark Matter

Understand What Drives Cosmic Evolution

Funding scenarios (DOE only)



not including on-shore Higgs factory



DOE only

Project funds only, P5 INPUT

Total US HEP budget,

P5 recommendations

Costs and Risks consideration

- Funding agencies are very sensitive to cost and time overruns.
- The "factor π" problem.
- P5 set up a dedicated Cost, Risks and Schedule sub-panel who provided three cost ranges and advice on construction timeline for all proposed large projects.
- Their input allowed us to check compatibility of our recommendations with the funding envelopes.

Not Rank-Ordered

Recommendation 1

As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science. We reaffirm the previous P5 recommendations on major initiatives:

a. **HL-LHC** (including ATLAS and CMS detectors, as well as Accelerator Upgrade Project) to start addressing why the Higgs boson condensed in the universe (reveal the secrets of the Higgs boson, section 3.2), to search for direct evidence for new particles (section 5.1), to pursue quantum imprints of new phenomena (section 5.2), and to determine the nature of dark matter (section 4.1).

b. **The first phase of DUNE and PIP-II** to determine the mass ordering among neutrinos, a fundamental property and a crucial input to cosmology and nuclear science (elucidate the mysteries of neutrinos, section 3.1).

c. **The Vera C. Rubin Observatory** to carry out the LSST, and the LSST Dark Energy Science Collaboration, to understand what drives cosmic evolution (section 4.2).

Rank-Ordered

Recommendation 2

a. **CMB-S4**, which looks back at the earliest moments of the universe to probe physics at the highest energy scales. It is critical to install telescopes at and observe from both the South Pole and Chile sites to achieve the science goals (section 4.2).

b. **Re-envisioned second phase of DUNE** with an early implementation of an enhanced 2.1 MW beam—ACE-MIRT—a third far detector, and an upgraded near-detector complex as the definitive long-baseline neutrino oscillation experiment of its kind (section 3.1).

c. **An off-shore Higgs factory**, realized in collaboration with **international partners**, in order to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should actively engage in feasibility and design studies. Once a specific project is deemed feasible and well-defined (see also Recommendation 6), the US should aim for a contribution at funding levels commensurate to that of the US involvement in the LHC and HL-LHC, while maintaining a healthy US on-shore program in particle physics (section 3.2).

d. **An ultimate Generation 3 (G3) dark matter direct detection experiment** reaching the neutrino fog, in coordination with international partners and preferably sited in the US (section 4.1).

e. **IceCube-Gen2** for study of neutrino properties using non-beam neutrinos complementary to DUNE and for indirect detection of dark matter covering higher mass ranges using neutrinos as a tool (section 4.1).

Recommendation 4

targeted R&D for future colliders > 10xLHC, such as muon collider

> Although we do not know if a muon collider is ultimately feasible, the road toward it leads from current Fermilab strengths and capabilities to a series of proton beam improvements and neutrino beam facilities, each producing world-class science while performing critical R&D toward a muon collider. At the end of the path is an unparalleled global facility on US soil. This is our Muon Shot.

targeted areas of research (theory, instrumentation, computing, accelerator technology)

capitalizing on national initiatives (QIS, AI/ML, microelectronics)

developing technology for specific projects (Higgs factory detectors, Spec-S5, DUNE FD4, Mu2e-II, Advanced Muon Facility, and line intensity mapping)

Recommendation 6

Convene a targeted panel with broad membership across particle physics later this decade that makes decisions on the US accelerator-based program at the time when major decisions concerning an off-shore Higgs factory are expected, and/or significant adjustments within the accelerator-based R&D portfolio are likely to be needed. A plan for the Fermilab accelerator complex consistent with the long-term vision in this report should also be reviewed.

The panel would consider the following:

1. The level and nature of **US contribution in a specific Higgs factory** including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.

2. Mid- and large-scale **test and demonstrator facilities** in the accelerator and collider R&D portfolios.

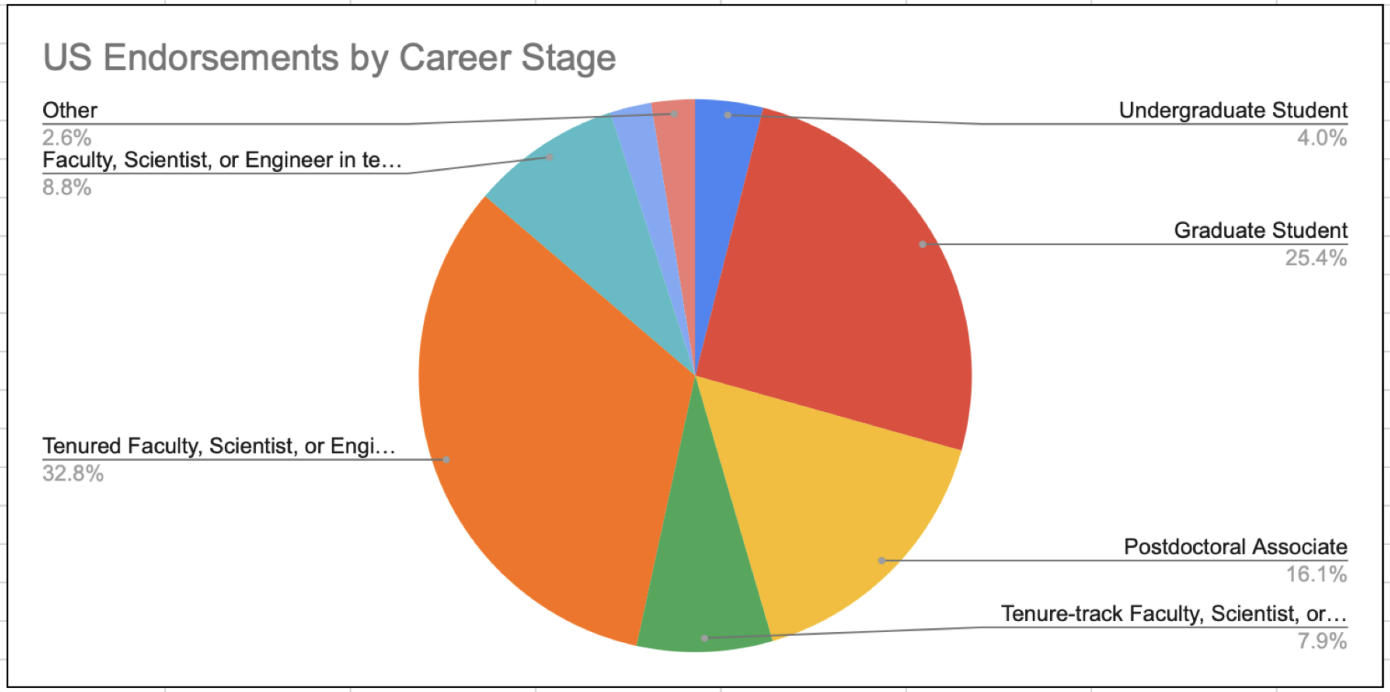
3. A plan for the evolution of the **Fermilab accelerator complex** consistent with the longterm vision in this report, which may commence construction in the event of a more favorable budget situation.

Post-P5

- P5 Report presented to HEPAP on Dec. 7-8 2023.
- Many events and contacts to Congress and government
- DOE & NSF presented their “perspectives on the P5 report” at the HEPAP meeting on May 9-10 2024.
- FCC Week, San Francisco, 10-14 June 2024. ~450 participants!

Support the 2023 P5 Report : Statistics

Number of Endorsements (Total)	Number of Endorsements (US)
3523	3157



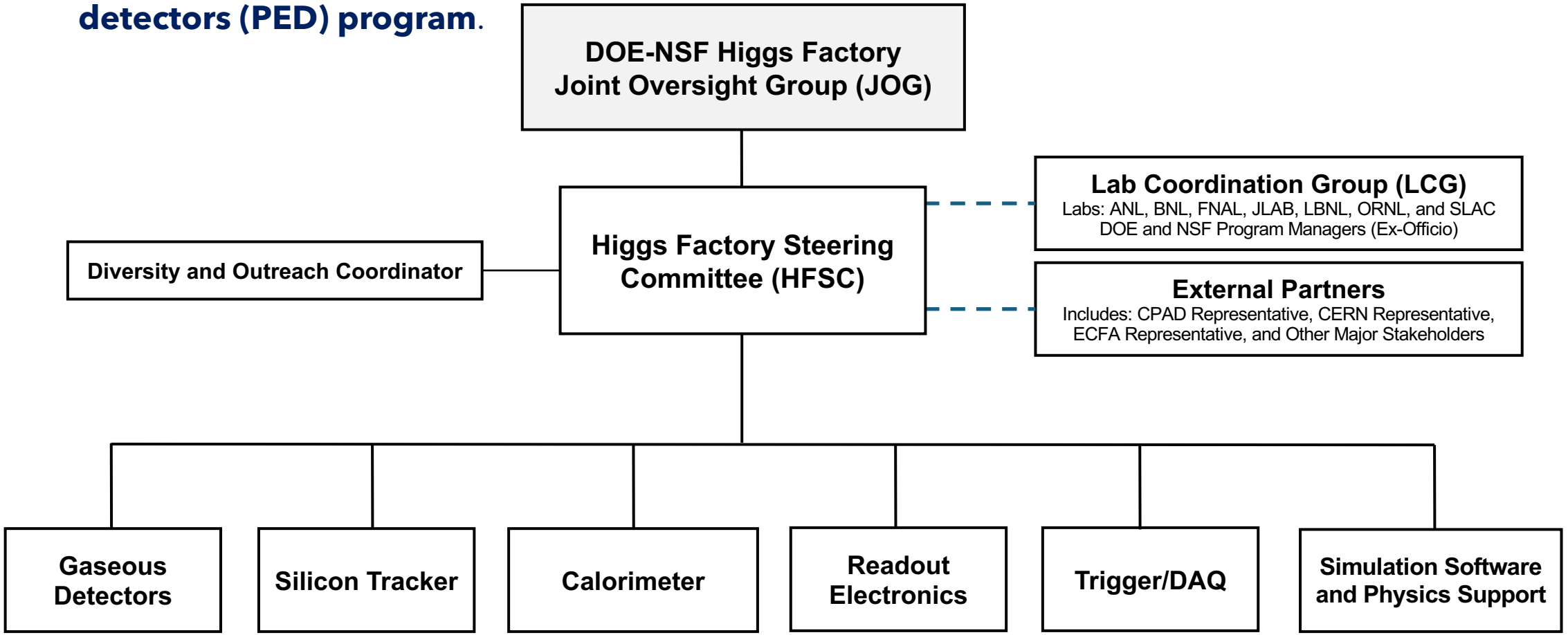
DOE response to P5: US-CERN Statement of Intent

Shown by Gina Rameika, DOE OS Associate Director for HEP:

- Text available at: U.S. Department of State Remarks & Releases site
- Among the topics in the Statement,
  - Expresses intentions by the U.S. and CERN to continue collaborating in the FCC Higgs Factory feasibility study
  - Subject to appropriate processes, the intention for the U.S. to collaborate on the FCC-ee, should the CERN Member States determine the FCC-ee is likely to be CERN's next research facility following the HL-LHC
- Statement aligned with P5: should FCC-ee receive a "green-light" following the next update of the European Strategy, U.S. intends to collaborate; and nature of the contributions to be discussed by the panel prescribed in 6.1.

US Organisation for Higgs Factory Development - PED

- DOE and NSF have jointly issued a charge that forms a ***nationally coordinated* U.S. Higgs Factory Coordination Consortium (HFCC)** for developing the **physics, experiments, and detectors (PED) program**.



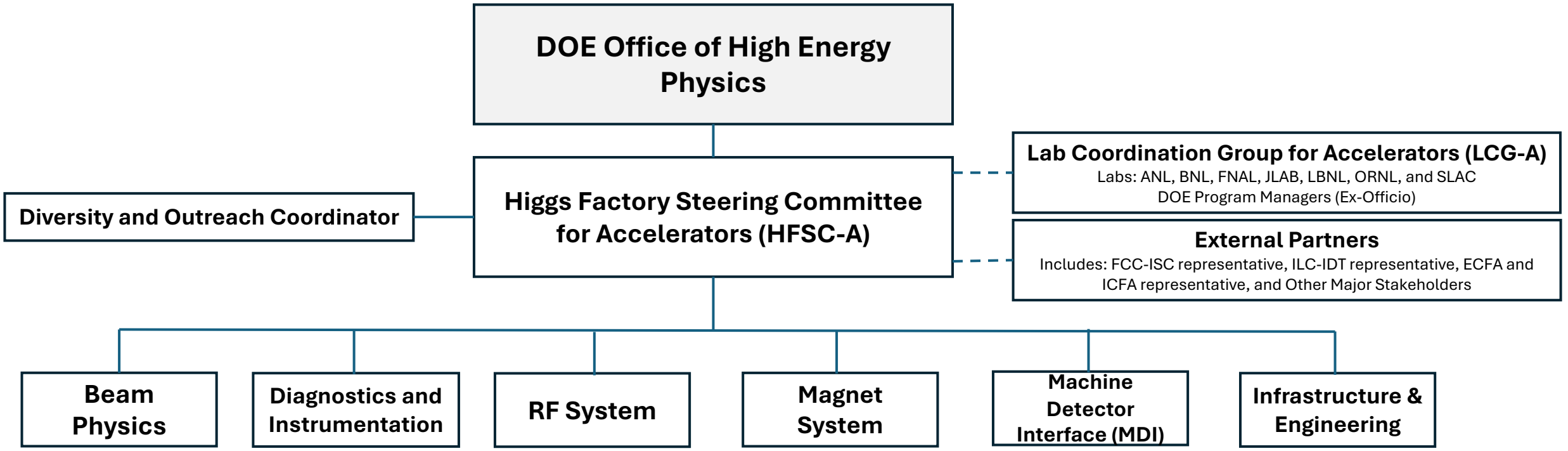
U.S. Higgs Factory Development – PED

(slide: G. Rameika)

- The U.S. HFCC includes:
  1) Higgs Factory Steering Committee (HFSC)
  2) Lab Coordination Group (LCG), which is integral to the U.S. Higgs factory coordination
  3) Detector systems that report to the HFSC and naturally map onto CERN's DRD structure
- The Consortium is to ensure that collaborations by the U.S. with our international partners are cost-effectively carried out for the Higgs factory initiatives
- The LCG will include representatives from each of our DOE labs:
  - ANL, BNL, FNAL, JLAB, LBNL, ORNL, and SLAC
  - A representative from each lab is to be selected by the respective lab's management
- Representatives in this Consortium also include external partners such as those from the APS/DPF's Coordinating Panel for Advanced Detectors (CPAD) in the U.S. and the CERN-hosted Detector R&D (DRD) initiative
- PED leadership:
  - Srini Rajagopalan (*Chair*), Sarah Eno
  - Ritchie Patterson (*Deputy Chair*), Marcel Demarteau

U.S. Organization for Higgs Factory Development – Accelerators

Composition and leadership to be announced in the very near future



US-CERN Partnership, by G. Rameika

- The U.S. collaborative partnership with CERN is long standing and very strong
- We appreciate the willingness of the CERN management and the Member States to accept our collaboration on the projects that are addressing the most fundamental questions in particle physics
  - The plan is to complete the construction of the High-Luminosity LHC, and we are committed to supporting the subsequent operations and exploitation of the data that it will bring
- We greatly appreciate the investment and collaboration that CERN is making in the neutrino program hosted in the United States
- We look forward to carrying this partnership far into the future
- We also look forward to continuing our discussions with CERN to advance the development and realization of the future Higgs factory

US response to P5, continuation

- KEK has requested US support for ILC through the ITN.
  - DOE decided to be observers and continue some R&D effort under existing HEP cooperation scheme.

- P5 recommended one committee in ~5 years from now to review:
  - Higgs Factory participation
  - Accelerator R&D and demonstration facilities
  - The evolution of the Fermilab accelerator complex
- DOE response: will work with NSF, National Labs and the community to convene three separate panels.

Response to other P5 recommendations

- P5 rec. 2: CMB-S4 highest priority with both Chile and South Pole sites.
  - NSF: decided not to move it to Design Stage. Prioritising Antarctic infrastructure.
  - DOE: “working with Project and NSF to develop alternatives”
  - P5: letter to Congress to support replacement of special transport planes
- Dark Matter G3 (XLZD, ARGO):
  - P5 recommended 1 in the US, DOE prefers development of off-shore concepts
- ASTAE scheme (agile projects) recommended by P5:
  - DOE will start by funding 1-3DMNI projects (ADMX-EFR, DM-Radio, LDMX, OSCURA)

Closing comments

- P5 Report well received by the US community, generated a lot of concrete actions in the areas relevant to the ECFA scope.
- Higgs Factory organisation and participation a clear sign.
- Many messages about US-CERN collaboration.
- Voices of realism: ”Which is best? Whichever one we can get built”, JoAnne Hewett, BNL Director on “e+e- machines comparison”.
- Muon Collider community also getting organized, P5 Report clarified that it is not a Higgs Factory competitor at the same timescale, but a 10 GeV pcm option for the second half of the century.
- Are we on the Baseline (higher) or Less Favorable funding scenario?
  - Can’t tell for the decade but we are not on the Baseline for next couple of years.