

Exploring
the
Quantum
Universe

Pathways to Innovation and Discovery in Particle Physics

Report of the 2023 Particle Physics Project Prioritization Panel

P5 Update



2023p5report.org

Karsten Heeger
On behalf of P5



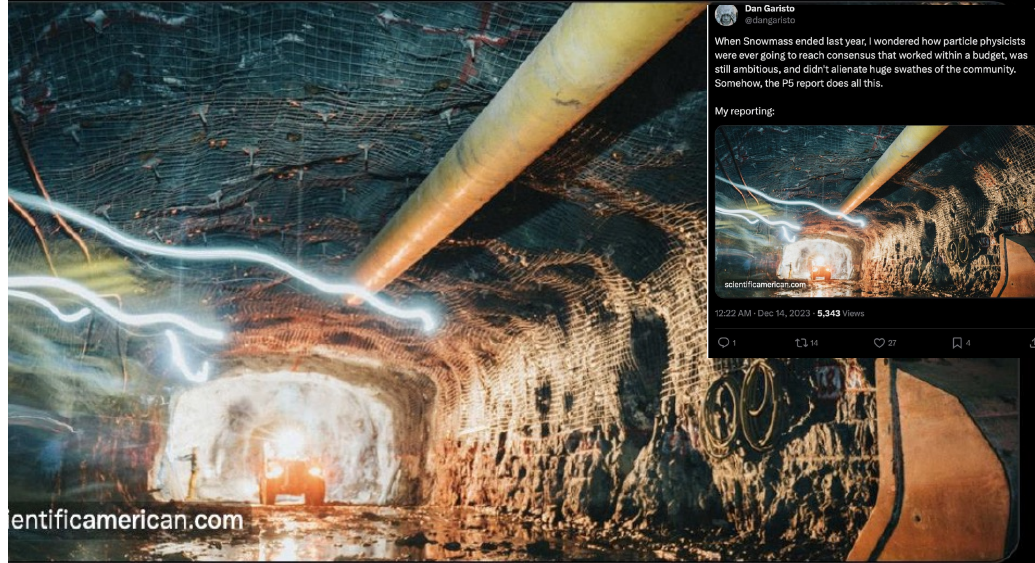
U.S. DEPARTMENT OF
ENERGY



Dan Garisto
@dangaristo

When Snowmass ended last year, I wondered how particle physicists were ever going to reach consensus that worked within a budget, was still ambitious, and didn't alienate huge swathes of the community. Somehow, the P5 report does all this.

My reporting:



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DECEMBER 13, 2023 | 8 MIN READ

Road Map for U.S. Particle Physics Wins Broad Approval

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View from the subterranean excavation for the Deep Underground Neutrino Experiment (DUNE) at the Sanford Underground Research Facility in South Dakota. Credit: Sanford Underground Research Facility



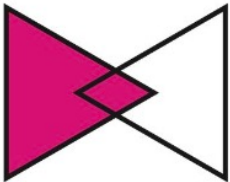
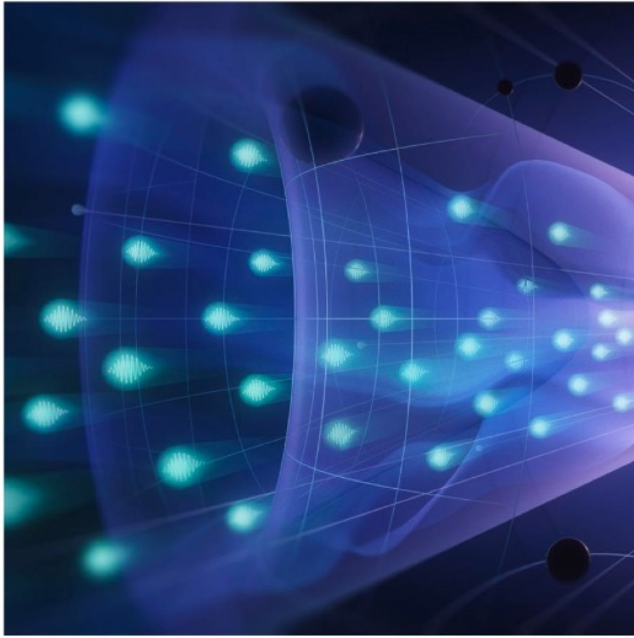
A view from the subterranean excavation for the Deep Underground Neutrino Experiment (DUNE) at the Sanford Underground Research Facility in South Dakota. Credit: Sanford Underground Research Facility

reached out to 532 offices out of 538



Kevin Pedro <pedrok@fnal.gov>

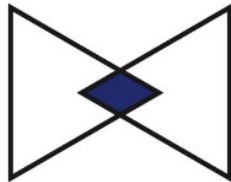




Decipher
the
Quantum
Realm

Elucidate the Mysteries
of Neutrinos

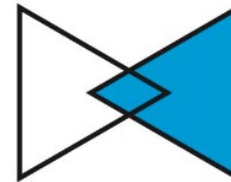
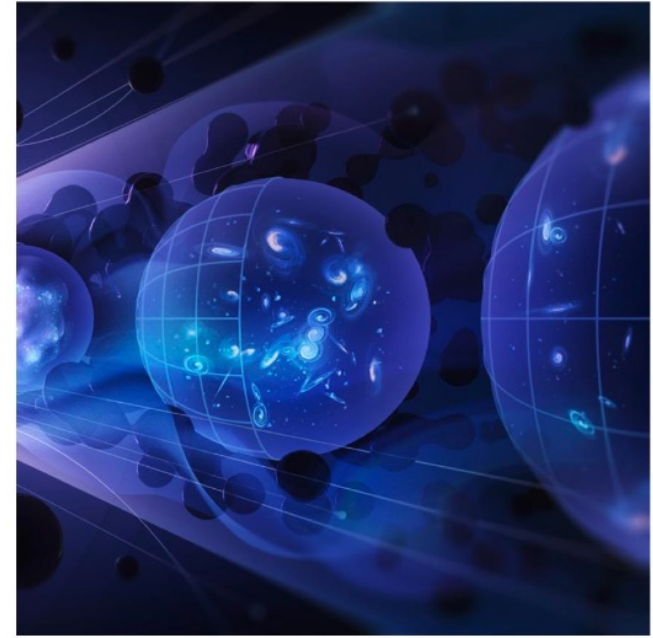
Reveal the Secrets of
the Higgs Boson



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

Recommendation 2

Rank-Ordered

New exciting initiatives

- 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). DOE & NSF AST
- 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). Mostly DOE
- 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). DOE & NSF PHY
- 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). DOE & NSF PHY
- 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). NSF PHY

Recommendation 3

Balanced Portfolio from small to large

Create **an improved balance between small-, medium-, and large-scale projects** to open new scientific opportunities and maximize their results, enhance workforce development, promote creativity, and compete on the world stage.

In order to achieve this balance across all project sizes we recommend the following:

- a. Implement a new small-project portfolio at DOE, **Advancing Science and Technology through Agile Experiments (ASTAE)**, across science themes in particle physics with a competitive program and recurring funding opportunity announcements. This program should start with the construction of experiments from the Dark Matter New Initiatives (DMNI) by DOE-HEP (section 6.2).
- b. Continue Mid-Scale Research Infrastructure (**MSRI**) and Major Research Instrumentation (**MRI**) programs as a critical component of the NSF research and project portfolio.
- c. Support **DESI-II** for cosmic evolution, **LHCb upgrade II** and **Belle II upgrade** for quantum imprints, and **US contributions to the global CTA Observatory** for dark matter (sections 4.2, 5.2, and 4.1).

The Belle II recommendation includes contributions towards the SuperKEKB accelerator.

DOE Response

General response to recommendations 1, 2, and 3

- ◆ Recommendation 1:
 - DOE fully supports this recommendation and puts it as the **highest priority** in planning our allocation of funding.
- ◆ Recommendation 2:
 - DOE forwarded each of the projects listed **in red** on slide 7 to the Facilities sub-panel.
 - These are all large undertakings and will comment on each one separately.
- ◆ Recommendation 3:
 - DOE will implement and execute a plan to address the ASTAE recommendation.
 - DOE will NOT support scope towards the LHCb Upgrade II.
 - DOE will continue to meet its on-going commitments to Belle-II; contributions towards SuperKEKB will be considered in the context of accelerator R&D toward e^+e^- luminosity improvements.
 - DOE will work with the DESI Collaboration to carefully decide a scope, schedule and cost envelope for the DESI-II upgrade.

DOE Response



After 2014, planning began, in coordination with the agencies. The design was revised and developed along the way as it progressed.

2024 May: Due to the need to prioritize the recapitalization of critical Antarctic infrastructure, NSF decided not to move the CMB-S4 project in its current form into the NSF Major Facility Design Stage.

Sept. 2024: DOE/HEP and NSF/MPS charged the CMB-S4 leadership to develop a revised project concept that does not include significant new instrumentation or facilities at the South Pole. The goal is to plan a configuration that is capable of the full set of science goals with reasonable cost, schedule and risk. Set up two study groups:

1. Survey the Landscape: Collect and evaluate information regarding the plans and capabilities of CMB experiments that are expected to take data in the next 10 years, and which contribute to the CMB-S4 science goals, to determine how best to use and expand beyond those capabilities.
 2. Optimize an all-Chile design: Develop the revised design for a Chile-only concept, incorporating the significant design work already done by the CMB-S4 collaboration for both sites, using well-developed scientific, engineering and project planning tools
- Revised concept for the basic design expected by spring 2025
 - Agencies will meet regularly with the team along the way to coordinate and monitor progress.

Recommendation 4

Investment in the future

- a. Support **vigorous R&D toward a cost-effective 10 TeV pCM collider** based on proton, muon, or possible wakefield technologies, including an evaluation of options for US siting of such a machine, with a goal of being ready to build **major test facilities and demonstrator facilities within the next 10 years** (sections 3.2, 5.1, 6.5, and Recommendation 6).
- b. Enhance research in **theory** to propel innovation, maximize scientific impact of investments in experiments, and expand our understanding of the universe (section 6.1).
- c. Expand the **General Accelerator R&D (GARD)** program within HEP, including stewardship (section 6.4).
- d. Invest in R&D in **instrumentation** to develop innovative scientific tools (section 6.3).
- e. Conduct **R&D** efforts to define and enable new projects in the next decade, including detectors for an e^+e^- Higgs factory and 10 TeV pCM collider, Spec-S5, DUNE FD4, Mu2e-II, Advanced Muon Facility, and line intensity mapping (sections 3.1, 3.2, 4.2, 5.1, 5.2, and 6.3).
- f. Support key **cyberinfrastructure** components such as shared software tools and a sustained R&D effort in computing, to fully exploit emerging technologies for projects. Prioritize **computing and novel data analysis techniques** for maximizing science across the entire field (section 6.7).
- g. Develop plans for improving the **Fermilab accelerator complex** that are consistent with the long-term vision of this report, including neutrinos, flavor, and a 10 TeV pCM collider (section 6.6).

We recommend specific budget levels for enhanced support of these efforts and their justifications as **Area Recommendations** in section 6.

DOE Response

Recommendations 4 and 5

- ◆ Recommendation 4 :
 - *Support a comprehensive effort to develop the resources - theoretical, computational and technological - essential to our 20-year vision for the field. This includes an aggressive R&D program that, while technologically challenging, could yield revolutionary accelerator designs that chart a realistic path to a 10 TeV pCM collider.*
- ◆ Recommendation 5 :
 - *Invest in initiatives aimed at developing the workforce, broadening engagement, and supporting ethical conduct in the field. This commitment nurtures an advanced technological workforce not only for particle physics, but the nation as a whole.*

We will incorporate actions to address these recommendations in our on-going planning

DOE Response

AGILE

HEP is developing a plan on how implement ASTAE. Using lessons learned from DMNI. What we have concluded so far.

This requires actions from DOE:

- Limit the number of reviews. Select a just few concepts at a time to develop into projects.
- Tailor the oversight to the size of the project.
- Provide adequate funding to complete the work on a technically limited schedule.
- Protect the budget envelope for the program.

And the community:

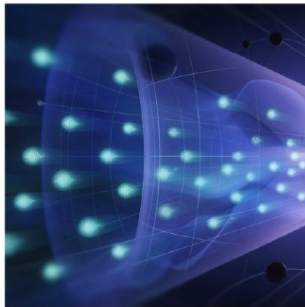
- Concentrate R&D on the critical enabling technology.
- Do the necessary up-front planning
- Arrange for adequate resources be available when needed: engineering, procurement, etc.

DOE Response

HEPAP P5 report (Dec.2023)

Charge: Develop a 10-year strategic plan for US particle physics, in the context of a 20-year global strategy and two constrained budget scenarios (provided by HEP)

- Low scenario FY2024 President's Budget Request **+2%** inflation through FY2023
- High scenario Follows FY 2022 Chips & Science Act Authorization, then **+3%** inflation through FY 2035



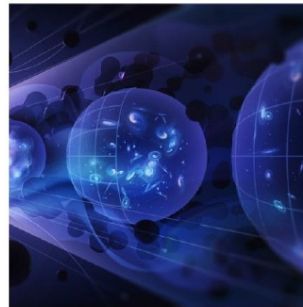
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Search for Direct Evidence
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Determine the Nature
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Understand What Drives
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Report w/6 recommendations:

<https://www.usparticlephysics.org/2023-p5-report/>

**HEP first responses – shown at the May 2024
HEPAP**

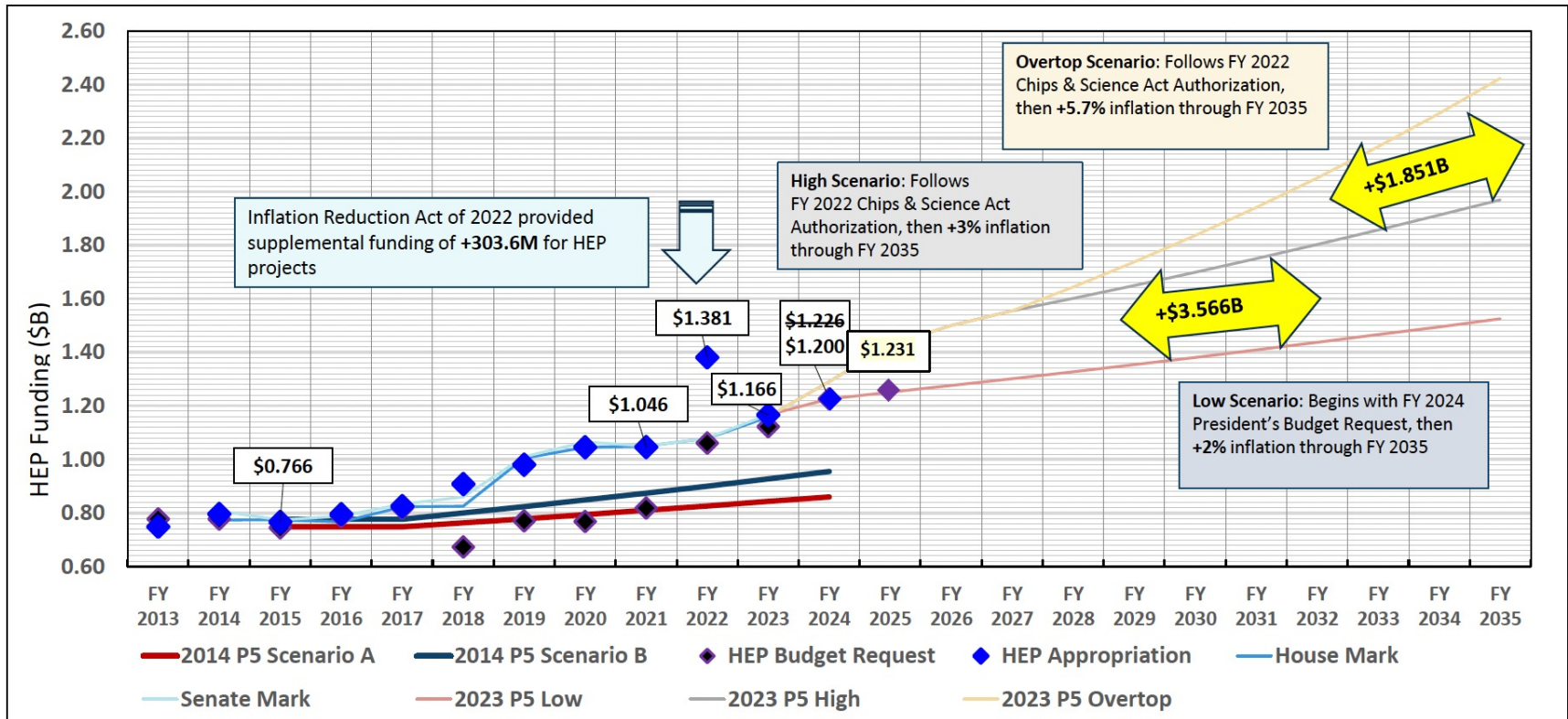
<https://science.osti.gov/hep/hepap/Meetings/202405>

P5 Resources for Outreach:

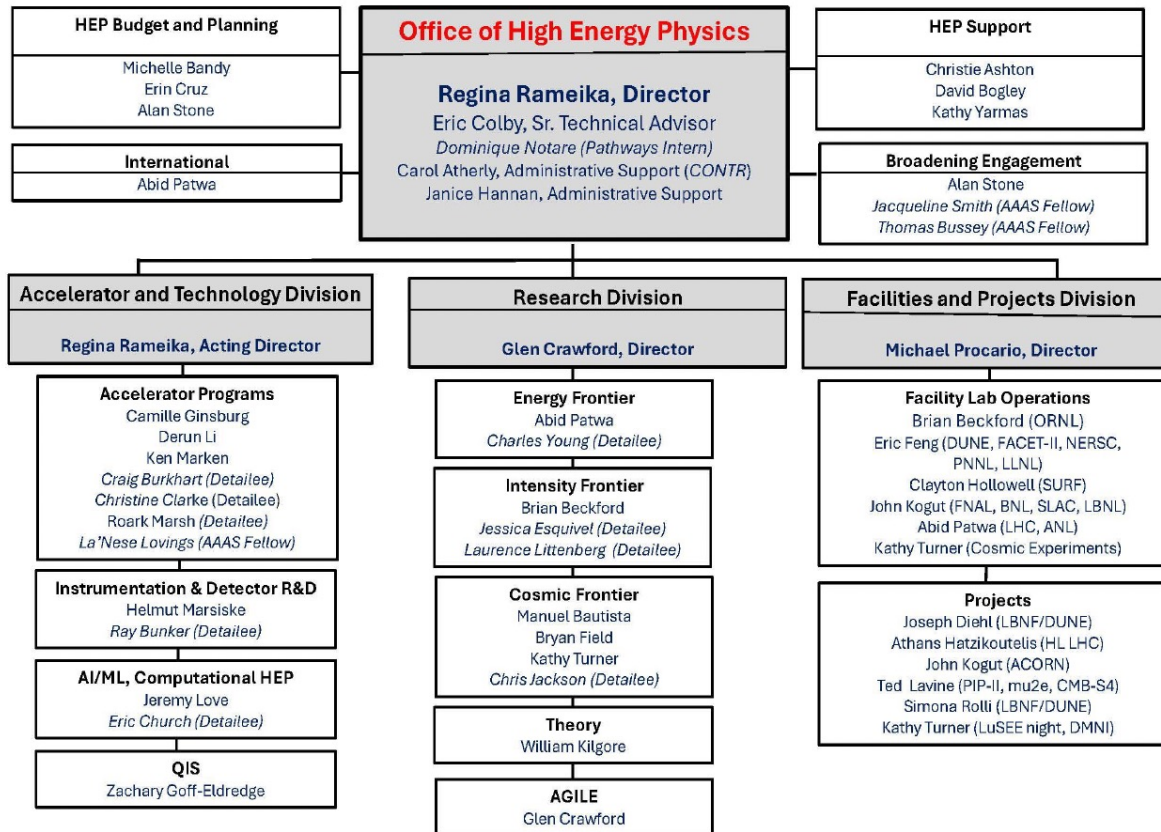
<https://www.usparticlephysics.org/resources/>

DOE Response

2023 P5 Budget Scenarios



HEP Organization (Sept. 2024)



Recommendation 6

Decision without waiting for the next P5

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.

U.S.-CERN Statement of Intent



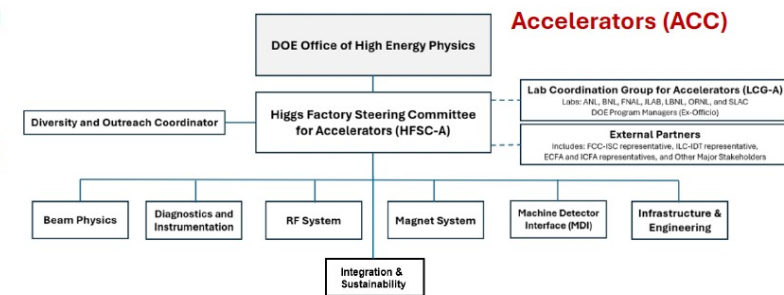
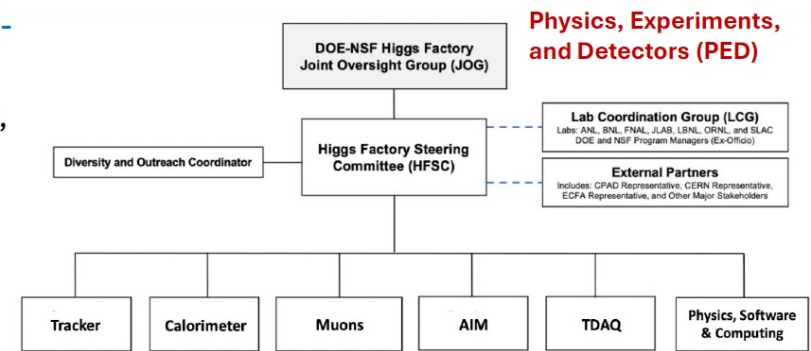
The text of the following statement was released by the Government of the United States of America and the European Organization for Nuclear Research (CERN), an Intergovernmental Organization having its seat at Geneva, Switzerland. White House Office of Science and Technology Policy Principal Deputy U.S. Chief Technology Officer Deirdre Mulligan signed for the United States while Director-General Fabiola Gianotti signed for CERN.

- ◆ 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.

U.S. Higgs Factory Coordination Consortia (HFCC)

- Earlier this year, formed two consortia for the US community to engage and advance the development of a potential future off-shore Higgs factory
 - May 2024: Charge by DOE & NSF to form US HFCC for Physics, Experiments, and Detectors (PED)
 - Aug 2024: Charge by DOE to form US HFCC for Accelerators (ACC)
- Over the last few months, various L2 and L3 subsystem roles filled by experts for each US HFCC – PED and ACC
- Other related efforts since the release of 2023 P5 report:
 - Joint US-CERN Statement of Intent for the US to collaborate at a future FCC-ee should the project receive a green-light (*discussed at the last May 2024 HEPAP meeting*)
 - Requested above US HFCC to prepare input to the now ongoing update of European Strategy for Particle Physics
- As P5 report has now been formulated and delivered, above initiatives are part of the agencies' implementation process... more details in a dedicated talk later today



HF Steering Committee (HFSC) Composition

HFSC-ACC

Tor Raubenheimer (chair)
Steve Gourlay (deputy)
Matthias Liepe
Jean-Luc Vay

HFSC-PED

Srini Rajagopalan (chair)
Ritchie Patterson (deputy)
Marcel Demarteau
Sarah Eno

HFSC-PED reports to JOG (DOE+NSF)
HFSC-ACC reports to DOE

Initial thoughts on U.S. strategic input

Our input should:

- Be consistent with the P5 report
- Seek to engage the broad US HEP community.
- Emphasize P5 statement on current program priorities at CERN:
 - “As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing [HL-LHC] experiments and research to enable maximum science.” **Re-emphasize this message.**
- Emphasize P5 statement on the need to maintain a vibrant domestic program:
 - Other P5 priorities include DUNE (incl. Phase 2), CMB-S4
 - Support “aggressive R&D program” for a 10 TeV pCM collider
 - “Targeted panel to assess the level and nature of U.S. contribution to specific Higgs Factory”.

European Strategy for Particle Physics

ESPP (I): launch of next (current) update

- In March 2024 CERN Council launched the new ESPP process:

- Timeline:





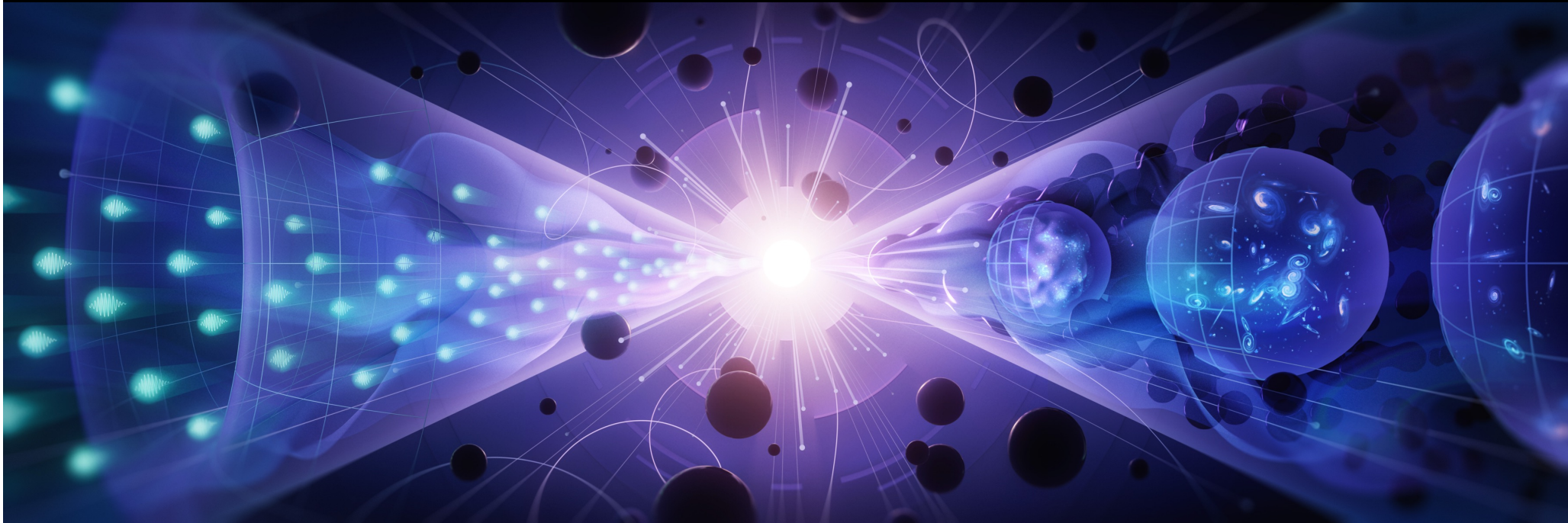
U.S. Particle Physics

Communication Materials

[About Particle Physics](#) [Particle Physics in the U.S.](#) [Resources for Physicists](#) [2023 P5 Report](#)



Exploring the Quantum Universe



*We continue to work on the realization of
the P5 plan!*