# DOE-HEP response to P5

Regina Rameika
Associate Director of the Office of Science
for High Energy Physics

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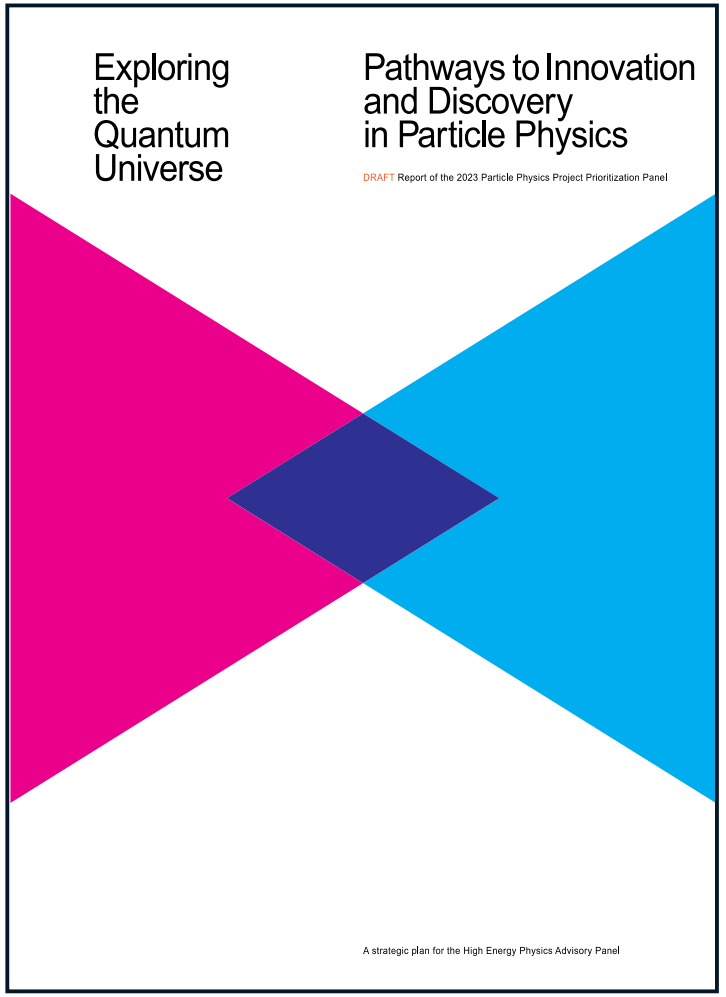
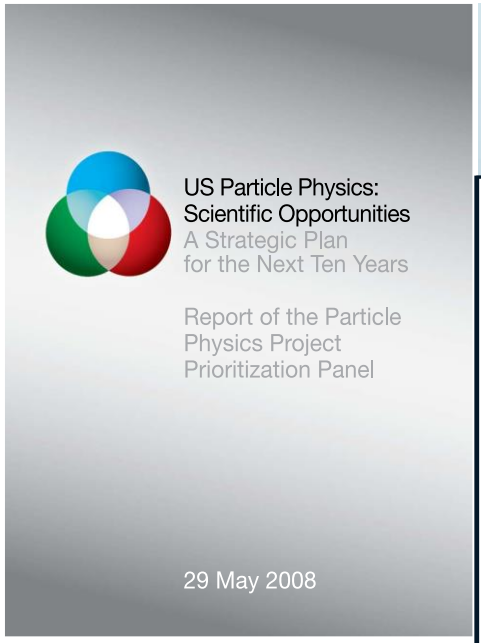
# Outline

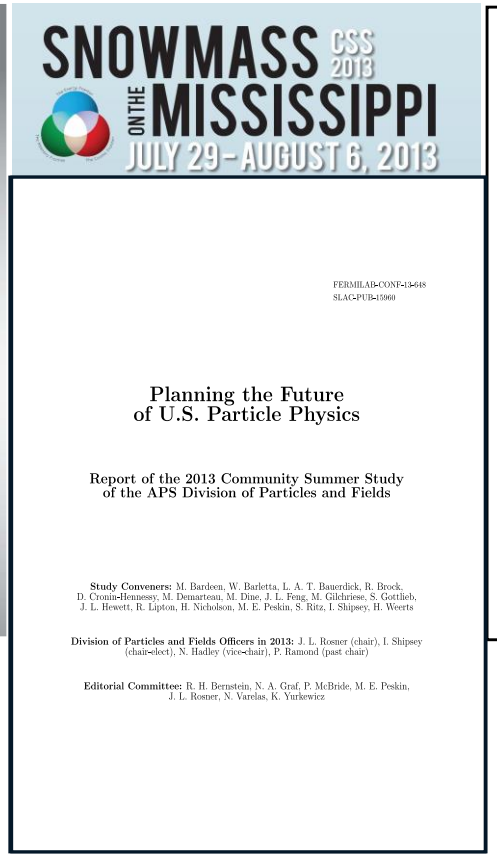
- Introduction
- General response to major recommendations
- Specific comments related to :
  - Off-shore Higgs Factory
  - DUNE Phase II
  - Evolution of the Fermilab Complex
  - ASTAE
  - G-3 Dark Matter
  - CMB-S4
- Assumptions about the budget
- Conclusions

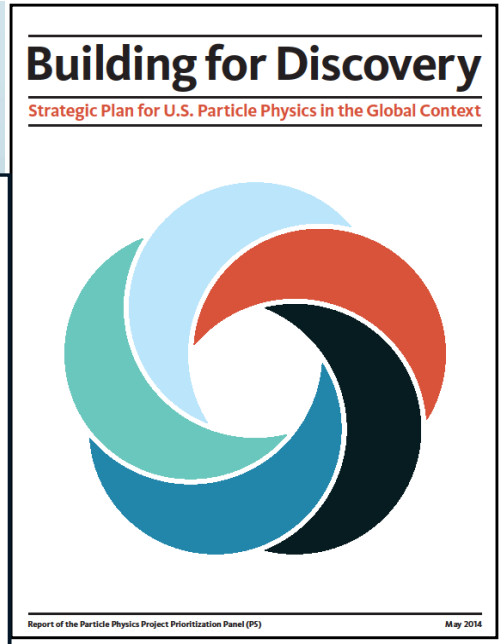


# U.S. Particle Physics Strategic Planning Process

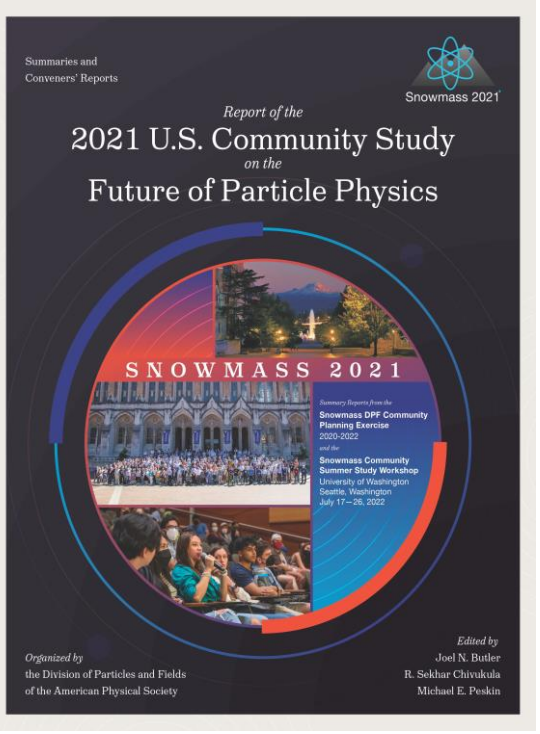
2008 → 2014 → Snowmass 2021 → PPPP → 2023 → Exploring the Quantum Universe

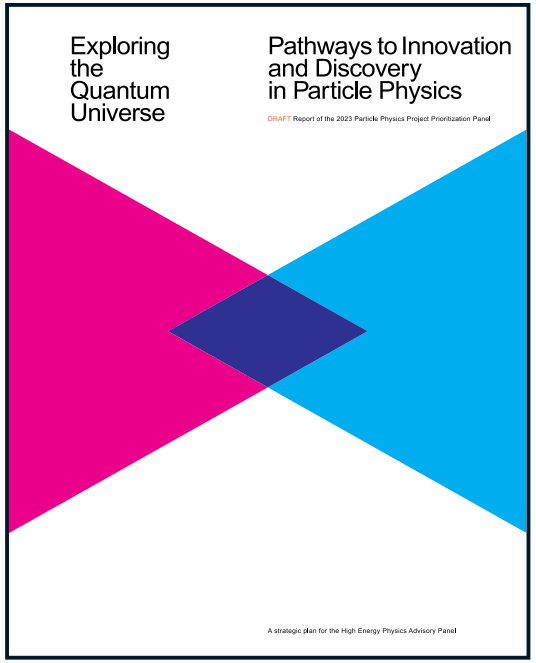


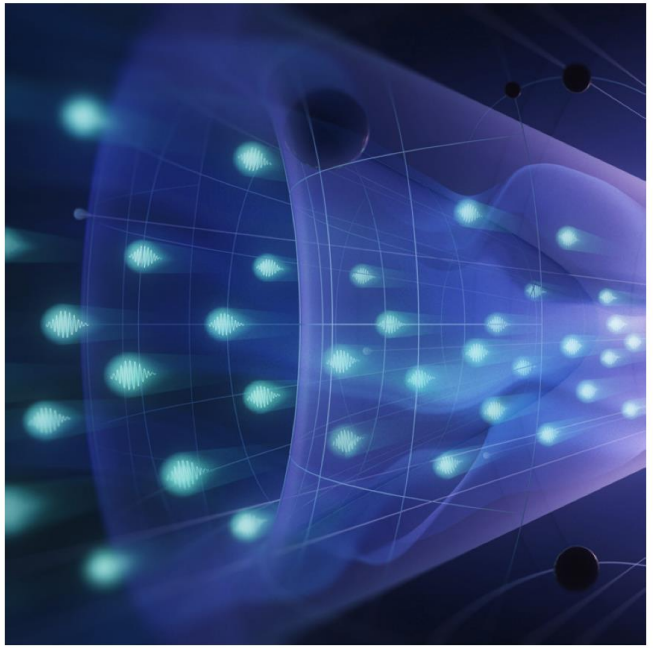







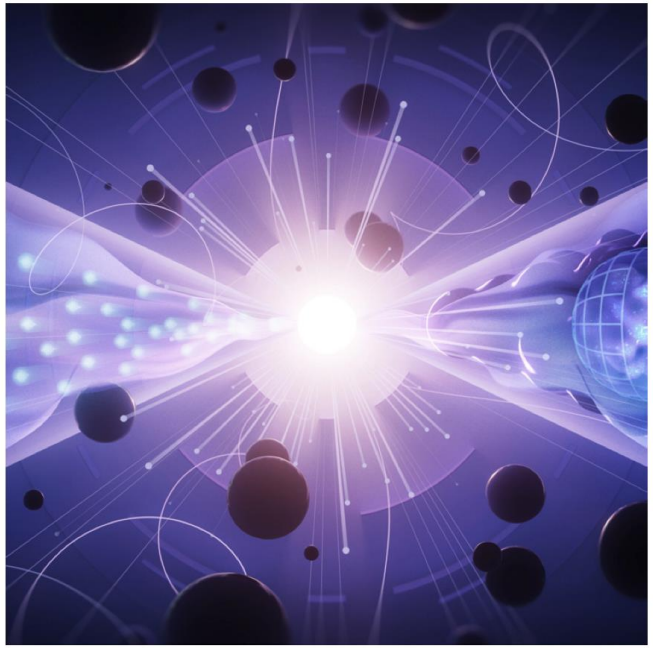
# P5 2023 Science Drivers



## Decipher the Quantum Realm

Elucidate the Mysteries of Neutrinos

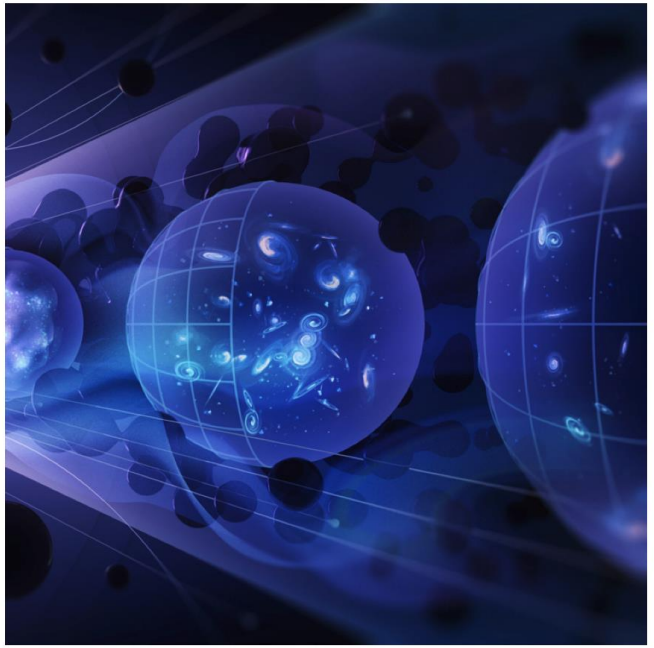
Reveal the Secrets of the Higgs Boson



## Explore New Paradigms in Physics

Search for Direct Evidence of New Particles

Pursue Quantum Imprints of New Phenomena

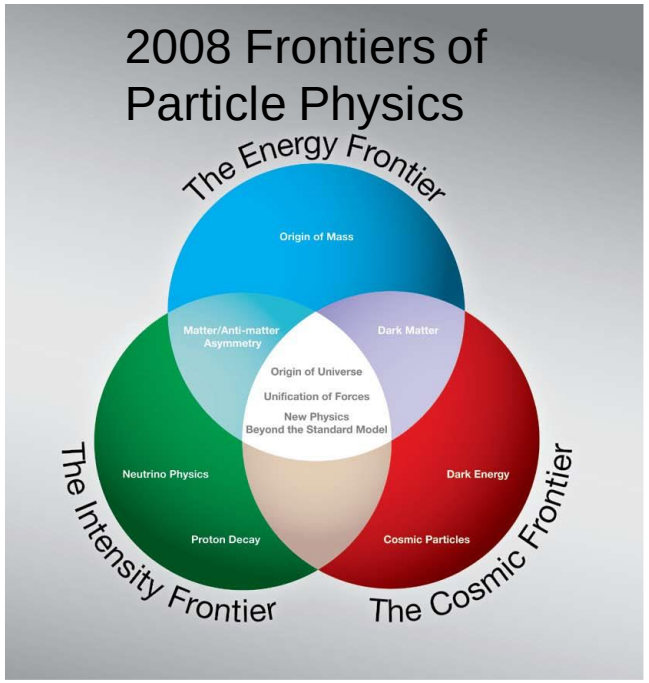


## Illuminate the Hidden Universe

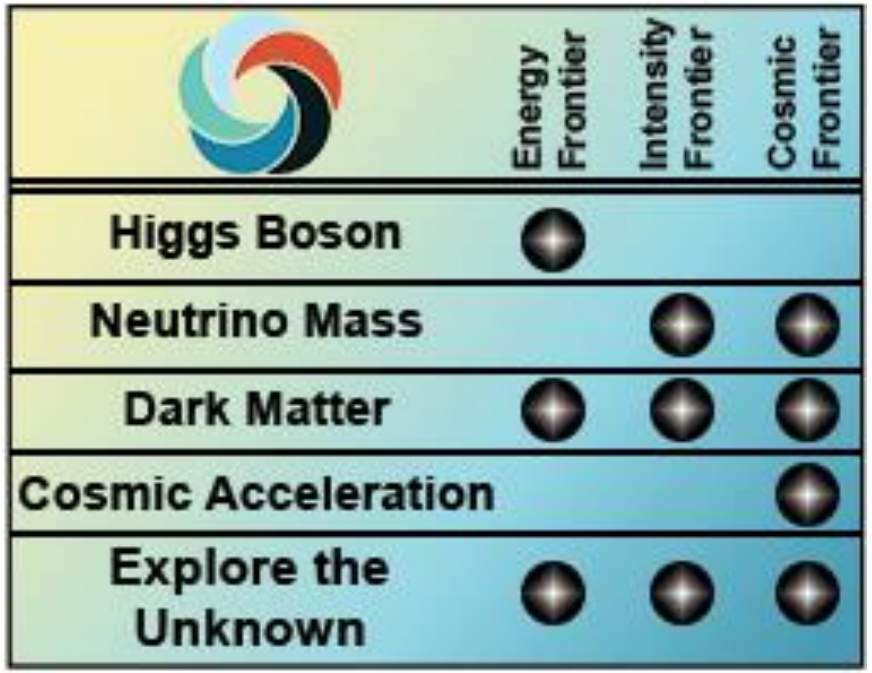
Determine the Nature of Dark Matter

Understand What Drives Cosmic Evolution

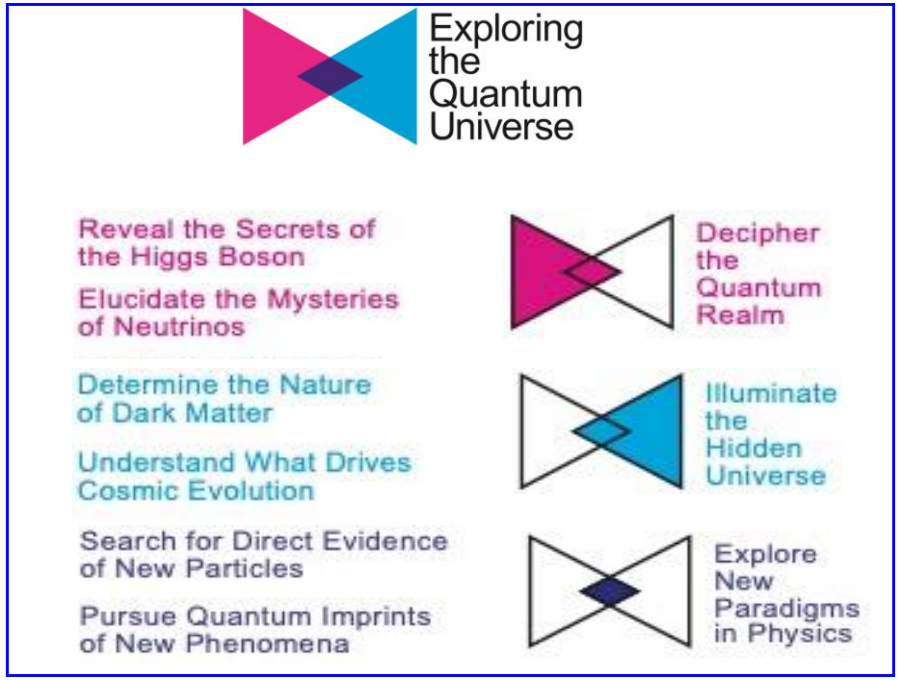
# Evolution of the key questions in particle physics




2014 Science Drivers




2023 Science Drivers



# 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:
  - 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).
  - 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).
  - The Vera C. Rubin Observatory to carry out the **Legacy Survey of Space and Time (LSST)**, and the LSST Dark Energy Science Collaboration, to understand what drives cosmic evolution (section 4.2).
  - In addition, we recommend continued support for the following ongoing experiments at the medium scale (project costs > $50M for DOE and > $4M for NSF), including completion of **construction, operations and research** on :
    - NOvA, SBN, and T2K (elucidate the mysteries of neutrinos, section 3.1).
    - DarkSide-20k, LZ, SuperCDMS, and XENONnT (determine the nature of dark matter, section 4.1).
    - DESI (understand what drives cosmic evolution, section 4.2).
    - Belle II, LHCb, and Mu2e (pursue quantum imprints of new phenomena, section 5.2).

# Recommendation 2

In priority order

- Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future. These projects have the potential to transcend and transform our current paradigms. They inspire collaboration and international cooperation in advancing the frontiers of human knowledge.
  - **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).
  - **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).
  - 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).
  - 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).
  - **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 3

- 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.
  - 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).
  - Continue Mid-Scale Research Infrastructure (MSRI) and Major Research Instrumentation (MRI) programs as a critical component of the NSF research and project portfolio.
  - Support **DESI-II for cosmic evolution**, LHCb upgrade II and Belle II upgrade for quantum imprints, and US contributions to the global Cherenkov Telescope Array (CTA) Observatory for dark matter (sections 4.2, 5.2, and 4.1). **Support for Belle-II includes contribution to SuperKEKB** .
    - DESI*-II
    - *LHCb*
    - Belle-II*, SuperKEKB
    - *CTA*

* Fall into the DOE portfolio

# 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

# 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 and 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

# 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: 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.
  - The panel would consider the following: Mid- and large-scale **test and demonstrator facilities** in the accelerator and collider R&D portfolios.
  - The panel would consider the following: A plan for the **evolution of the Fermilab accelerator complex** consistent with the long-term vision in this report, which may commence construction in the event of a more favorable budget situation.

DOE does not envision a single panel to address this recommendation; rather we will work with NSF, the DOE Laboratories and community at large to convene three separate panels that each will address one of the topics.
*Initial thoughts on the following slides ….*

# DOE's Response to Recommendation 6.1

- The panel prescribed in 6.1 is envisioned to be a separate panel from the ones in 6.2 and 6.3
- We likely will precede this panel with a task force to evaluate the status of activities that have been addressed over the last many years
  - The task force is anticipated to run in-parallel to the next update of the European Strategy for Particle Physics
  - The U.S. community has strong proponents of both circular and linear Higgs factories as well as a vision for a future muon collider that can be potentially hosted in the United States
- We have been asked by KEK (Japan) to support ILC development through the ILC Technology Network (ITN)
  - DOE has decided that we, including our DOE national labs, will be observers and not officially join the ITN
  - Instead, we plan to consider R&D efforts for ILC technologies under our existing U.S.-Japan Cooperation Program
- Regarding FCC-ee, we will continue to support and expand our participation in the feasibility studies, including expanding efforts to work on the 800 MHz SRF accelerator cavities as well as other technical topics and studies as they arise
  - These efforts are aligned with topics contemplated under the 2020 DOE-CERN FCC feasibility study agreement
- Within the U.S. community, we are actively working to bring together the linear and circular collider communities wanting to develop detectors for a future Higgs factory
  - Our goal is to have our community work together, along with the international partners, to converge on an optimum solution to realize a future collider

# Off-shore Higgs Factory

- From P5 Recommendation 2, Priority 3 out of 5: *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 P5 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 response and actions (thus far):
  - In Feb 2024, we presented our approach to MEXT to be observers in the ITN while considering, at some fraction, associated R&D efforts under the existing U.S.-Japan Cooperation Program
  - In Mar 2024, we presented DOE's view on participating in any potential FCC-ee to the CERN Council
  - Through interagency coordination, led by The White House Office of Science and Technology Policy (OSTP) and which included the U.S. Department of State, DOE, NSF, and NASA, a Statement of Intent was signed in Apr 2024 between the U.S. Government and CERN
    - Statement expresses an intent for the U.S. to collaborate on the FCC-ee should the CERN Member States determine it is likely to be CERN's next research facility following the HL-LHC (*more next slide*)
  - Jointly with NSF, we've initiated forming a U.S. based organization for Higgs Factory development efforts for the Physics, Experiment, and Detectors (*more in a couple of slides*)
    - At DOE we are also beginning to develop a similar approach for the accelerator side

# U.S.-CERN Statement of Intent

★ ★ ★

Joint Statement of Intent between The United States of America and The European Organization for Nuclear Research concerning Future Planning for Large Research Infrastructure Facilities, Advanced Scientific Computing, and Open Science

OTHER RELEASE

BUREAU OF OCEANS AND INTERNATIONAL ENVIRONMENTAL AND SCIENTIFIC AFFAIRS

APRIL 26, 2024

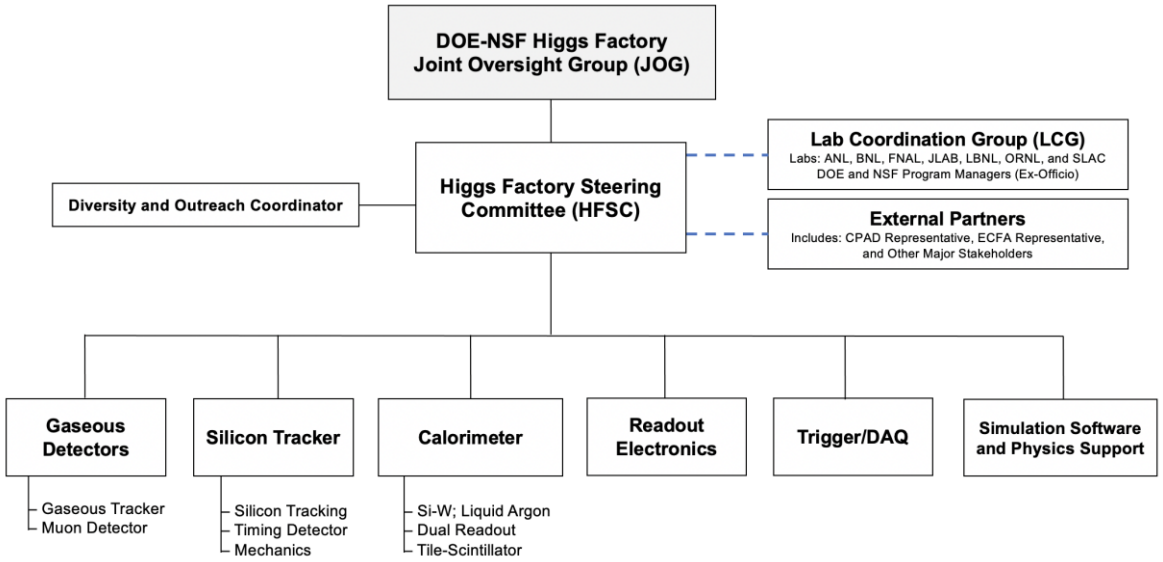
The text of the following statement was released by the Government of the United States of America and the European Organization for Nuclear Research (CERN), an Intergovernmental Organization having its seat at Geneva, Switzerland. White House Office of Science and Technology Policy Principal Deputy 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. Organization for Higgs Factory Development

- Jointly with NSF, we are preparing a charge that forms a ***nationally coordinated*** U.S. Higgs Factory Coordination Consortium (HFCC) for developing the physics, experiment, and detector (PED) program
  - A similar approach by DOE is envisioned for developing the Higgs factory accelerator program
- The proposed U.S. HFCC plans to include 1) Higgs Factory Steering Committee (HFSC); 2) a Lab Coordination Group (LCG); and 3) various detector systems that report to the HFSC & naturally map onto CERN's DRD structure
  - Ensure collaborations by the U.S. with our partners are cost-effectively carried out for Higgs factory initiatives
- The LCG includes reps from: ANL, BNL, FNAL, JLAB, LBNL, ORNL, and SLAC
  - Partners include CPAD in the U.S. and the CERN-hosted Detector R&D (DRD) initiative

- Charge to be available soon; example tasks and goals could include:
  - physics and technical feasibility studies
  - pre-project R&D
  - software and computing framework to advance the physics and R&D

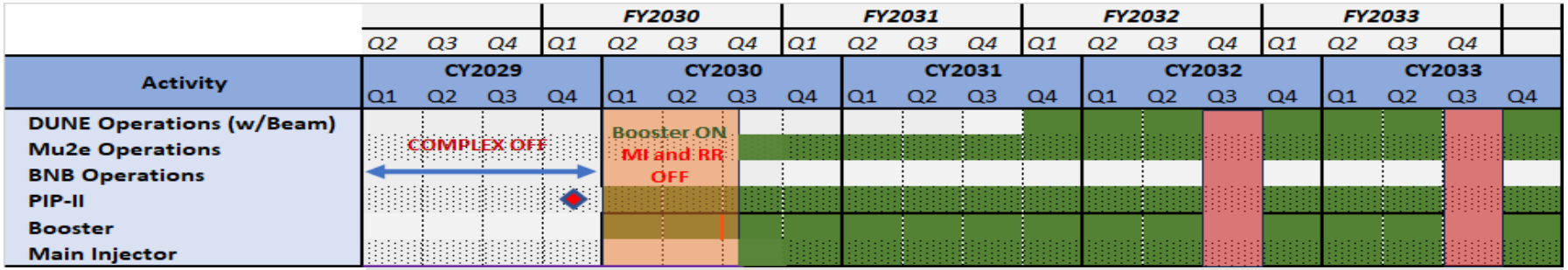


# DUNE Phase-II

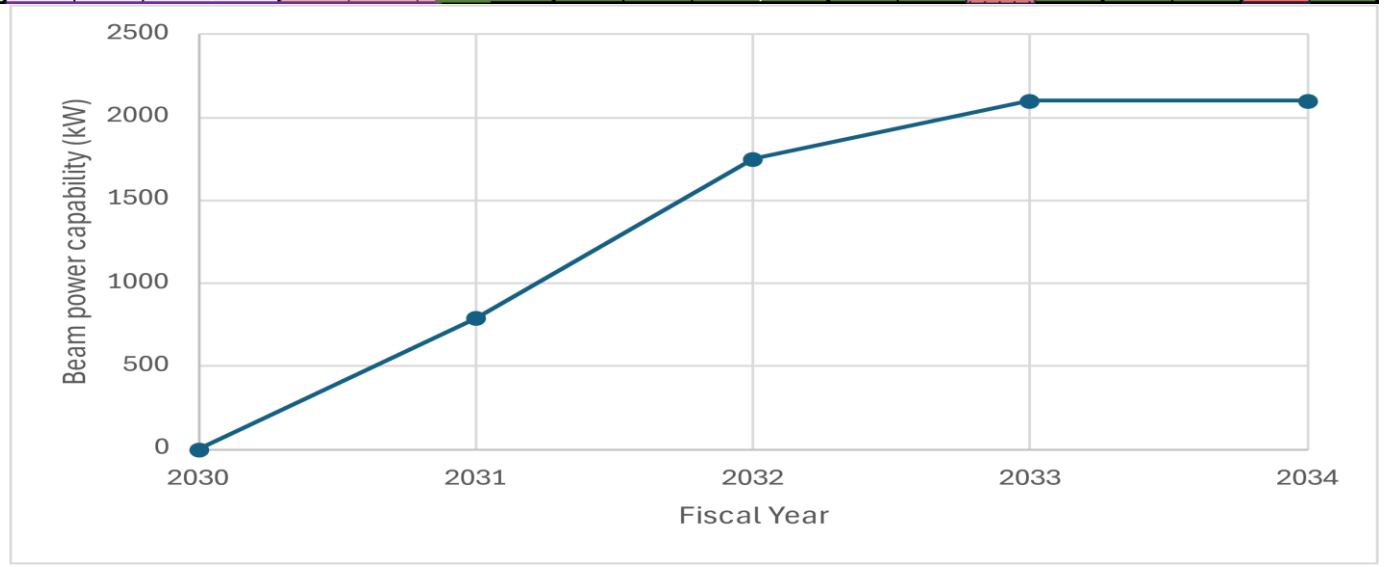
- From P5 Recommendation 2, Priority 2/5 : ***Re-envisioned second phase of DUNE*** *with an early implementation of an enhanced 2.1 MW beam (**ACE-MIRT**), a **third far detector**, and an **upgraded near-detector complex** as the definitive long-baseline neutrino oscillation experiment of its kind (section 3.1).*
- DOE response and actions :
  - ACE-MIRT : one element of the near-term evolution of the Fermilab Complex (see next slide)
  - Far Detector 3: to be planned and proposed by the DUNE Collaboration in consultation and partnership with DOE and international partners; top priority is to secure an understanding of how the cryostat is funded
  - Upgraded near-detector complex (MCND): to be planned and proposed by the DUNE Collaboration in consultation and partnership with DOE and international partners; top priority is to finalize a baseline plan for the Phase 1 Near Detector

# Evolution of the Fermilab Complex – part 1

From Fermilab




- First consider the accelerator capability at completion of PIP-II Project
- A three step path to reach 2.1MW for the early operation of the DUNE experiment :
  - Post-PIP-II instrumentation and booster improvements to handle beam power
  - ACE-MIRT
    - Main Injector upgrade to operate at 0.7 sec cycle time
    - Target to handle 2 MW
  - Booster improvements to insure reliable operation



# ASTAE

- From P5 Report recommendation #3 *: 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).*
- DOE response and actions :
  - DOE will initiate fabrication of 1-3 DMNI projects (5 projects remain under consideration)
  - The key word for new projects is AGILE

P5's call for *agile* implies that we should complete these experiments quickly, and shift course when it comes time to start new ones.

To do this:

- Keep FOA's and # of reviews limited. Select a few (2?) concepts at a time to develop into projects.
- Short R&D/design phase to finalize technology, concept development.
- Keep projects within a set funding envelope and schedule.
- We expect the lead laboratories to develop project execution plans to keep the initiatives on track and within budget

# DMNI Status

| Concept | DM type | Mass range | Lead lab | Orig R&D request ($K) | R&D $K thru FY24 | Est. Fab. cost ($M) |
|---|---|---|---|---|---|---|
| ADMX-EFR | Axions | 9-17 μeV | FNAL | 1,976 | 3,140 | $20 |
| DM-Radio | Axions | <μeV | SLAC | 993 | 1,560 | $24 |
| LDMX | Hidden sector | 10-300 MeV | SLAC | 1,960 | 2,250 | $21 |
| OSCURA | WIMPs | 1MeV-1GeV | FNAL | 3,943 | 3,544 | $15 |
| TESSERACT | WIMPs | >10 MeV | LBNL | 3,975 | 1,815 | <$10 |
| Total | | | | 12,847 | 12,309 | $90 |

- These are the remaining DMNI proposals.
  - CCM at LANL was funded, fabricated and is operating.
- The French have funded a proposal to host TESSERACT.
- DOE has decided to fund TESSERACT starting in FY25 based on its cost effectiveness and the French offer to host.
  - These considerations made it the ideal concept to go next.
- We are still working on the process to select other DMNI proposals.
  - Most likely start will be in FY 26
- HEP will try to select 2 additional DMNI's to move to fabrication, with the rest folded into the ASTAE program competition. This will also allow new dark matter proposals to be considered.

# G3 Dark Matter

- From P5 Recommendation 2, Priority 4 out of 5 :
  - 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 response and actions :
  - At the present time, based on the Snowmass Community Summer Study, there have been two proposals for G3 Dark Matter detectors : XLZD and ARGO
  - Each concept has explored potential sites both within the US and off-shore.
  - At the present time, DOE is supportive of the development of the off-shore concepts.
  - DOE will entertain proposals by U.S. groups for pre-project R&D consistent with experiment deployment at an off-shore site.

# Accelerator Test Facilities

- From P5 Recommendation 6.2 : *The panel would consider the following: Mid- and large-scale **test and demonstrator facilities** in the accelerator and collider R&D portfolios.*
- DOE response and actions :
  - As a first step in developing a response to this recommendation, DOE will be conducting a review of the GARD program this August.
  - This will be followed by an  Accelerator Test Facilities comparative review of existing facilities at ANL, BNL, FNAL, LBNL and SLAC; tentative time frame is Fall 2024; more information will be forthcoming.
  - In 2025 a panel will be convened to develop a roadmap towards a test facility plan that will be well supported and meet the needs of the emerging directions for future colliders and development of the workforce that will be needed over a 20-30 year time frame.

# Evolution of the Fermilab Accelerator Complex – part 2

- From P5 Recommendation 6.3 : *The panel would consider the following: A plan for the evolution of the Fermilab accelerator complex consistent with the long-term vision in this report, which may commence construction in the event of a more favorable budget situation.*
- DOE response and actions :
  - The panel = A Task Force, led by Fermilab, and drawn from the US HEP community and interested international partners
  - The time frame for convening such a Task Force is no sooner than in calendar year 2026 and most likely following the panel initiated to consider the task in Recommendation 6.1
  - This gives priority to detailed planning towards the Fermilab accelerator complex evolution – Part 1
  - Further planning for the complex evolution must include demonstration that the elements of the plan are compatible with the long-term vision towards a 10TeV pCM collider

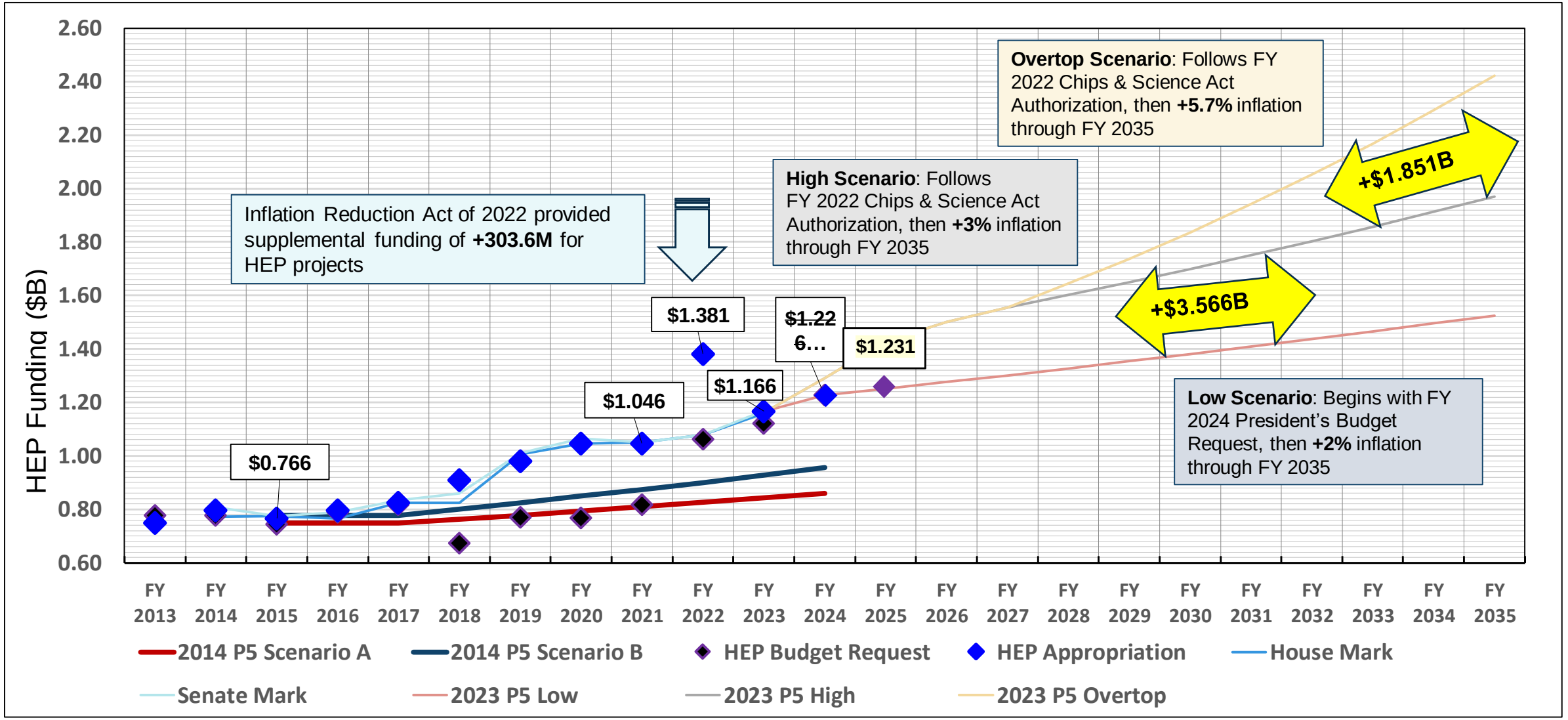
# CMB-S4

- From P5 Recommendation 2, Priority 1 out of 5 : **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)

- Input from the NSF :
  - There is a serious issue with South Pole infrastructure that has led the NSF to a difficult decision (which you will hear about in the next two talks)

- DOE response and actions :
  - We are working with the Project team and the NSF to develop alternatives that achieve the science results that we are seeking.

# 2023 P5 Budget Scenarios



# Prescriptive P5 area recommendations

| P5 recommendation | Funding/year |
|---|---|
| ASTAE | 35 |
| Detector R&D | 4 |
| Theory | 15 |
| GARD | 10 |
| EF Frontier detectors | 20 |
| EF Frontier accelerator | 35 |
| Total | 119 |

| | |
|---|---|
| FY 2024 enacted ($M) | 1,200 |
| FY 2025 PRB ($M) | 1,230 |
| Initiative fraction | **10%** |

- The P5 area recommendations for budgets is 10% of the current budget. At this moment, 10% increases in the budget look very unlikely.
- Our analysis shows the ASTAE funding can support a steady stream of 1 new project starting per year, so it looks quite appropriate.
- The other recommendations have not been fully studied.
- In order, to prevent strain on the core research budget and facility ops we will need to build up to these levels as current projects ramp down.
- We need to emphasize that funding priorities will be towards execution of Recommendation #1

# Conclusion

The 2023 P5 Report :

- Provides a vision of an exciting path into the future for high energy/particle physics
- Provides us with actionable recommendations that will keep us on that path
- The vision is long-term and will take long-term planning

# P5 Area recommendations regarding small projects

- **Area Recommendation 2**: For the ASTAE program to be agile, we recommend a broad, predictable, and recurring (preferably annual) call for proposals. This ensures the flexibility to target emerging opportunities and fields. A program on the scale of $35 million per year in 2023 dollars is needed to ensure a healthy pipeline of projects.
- **Area Recommendation 3**: To preserve the agility of the ASTAE program, project management requirements should be outlined for the portfolio and should be adjusted to be commensurate with the scale of the experiment.
- **Area Recommendation 4**: A successful ASTAE experiment involves 3 phases: design, construction, and operations. A design phase proposal should precede a construction proposal, and construction proposals are considered from projects within the group that have successfully completed their design phase.
- **Area Recommendation 5**: The DMNI projects that have successfully completed their design phase and are ready to be reviewed for construction, should form the first set of construction proposals for ASTAE. The corresponding design phase call would be open to proposals from all areas of particle physics.

→ We have considered these recommendations and how to most effectively carry out an ASTAE program.