Outcome of P5 and Implications for PBC Projects

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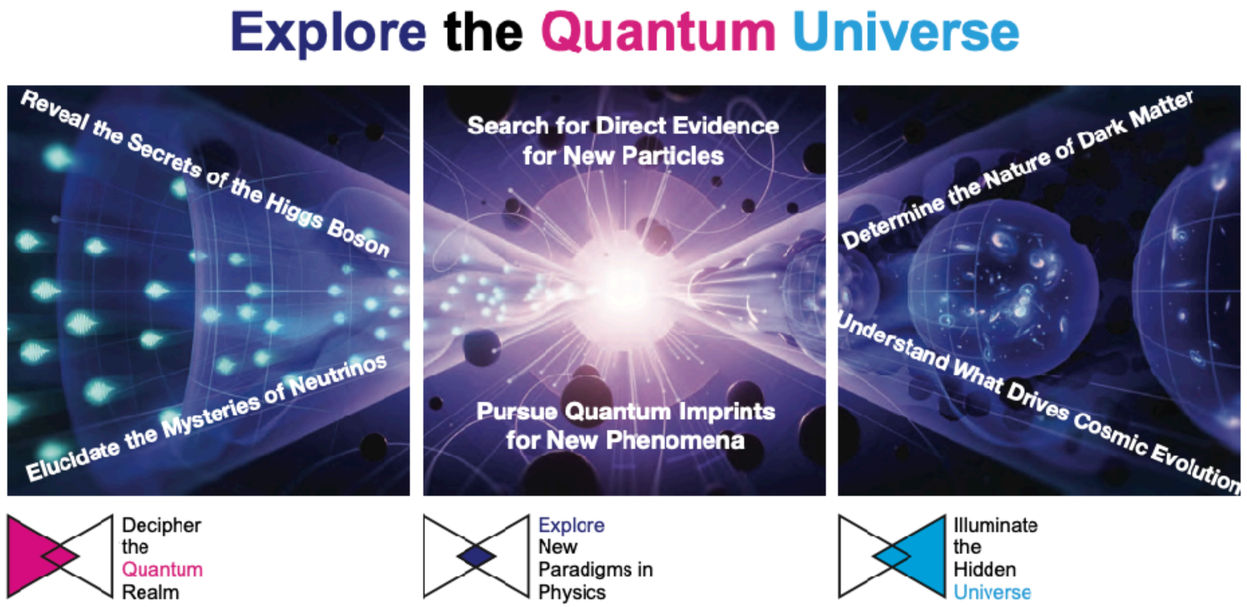
Outline

- High level summary of P5 recommendations
- Comment on recommendations most connected to PBC science and projects
- ASTAE and DMNI science and projects

Most of the material for this summary talk is taken directly from the Dec 7 2023 HEPAP talks by Hitoshi Murayama and Kirsten Seeger (P5 chairs), as well as public DOE summary talks

P5 Process

- Input for Particle Physics Project Prioritization Panel (P5) includes Snowmass reports, open town halls, various community engagement sessions, as well as input from Department of Energy and National Science Foundation agencies.
- Primary work of the panel carried out Feb - Aug 2023, report presented to HEPAP Dec 7, 2023.

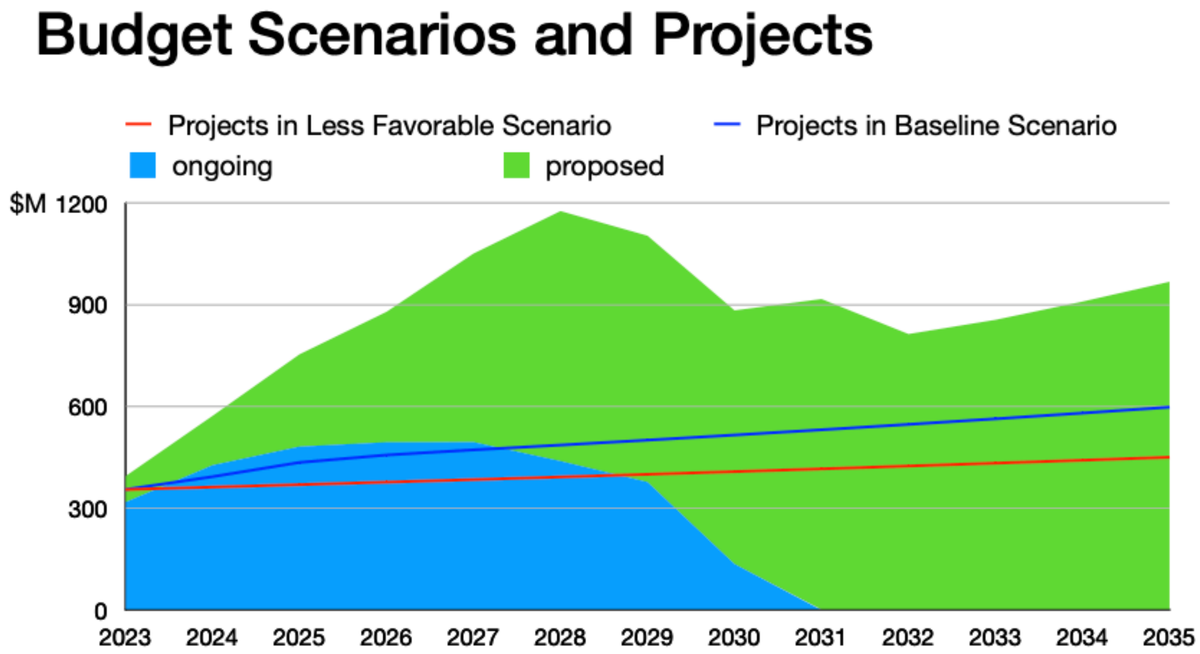


Visit the P5 website for the report and explanations:
https://www.usparticlephysics.org/2023-p5-report/

Budget and timeline context

- Report considers small (<$50M), medium ($50-250M), and large (>$250M) projects in the context of particular budget scenarios over ~10 years

  - Constrained budget vs. ongoing projects in the early years
  - Difficult decisions required with respect to proposed projects vs anticipated DOE funding for late 2020's onward.



From Dec 7 HEPAP presentation

P5 Recommendations At a Glance

(Emphasis is mine)

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…

★ **Recommendation 2:** 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. …

★ **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…

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….

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…

P5 Recommendations 1 & 2

- MATHUSLA & FPF were not endorsed as is by P5 in any budget scenario
- Both projects were flagged as possibilities to consider (with reduced scope) as part of ASTAE

Figure 2 – Construction in Various Budget Scenarios

Index: N: No Y: Yes R&D: Recommend R&D but no funding for project C: Conditional yes based on review P: Primary S: Secondary
Delayed: Recommend construction but delayed to the next decade
Can be considered as part of ASTAE with reduced scope

US Construction Cost >$3B				Science Drivers						
Scenarios	Less	Baseline	More	Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
on-shore Higgs factory	N	N	N		P	S		P	P	
$1–3B										
off-shore Higgs factory	Delayed	Y	Y		P	S		P	P	
ACE-BR	R&D	R&D	C	P				P	P	
$400–1000M										
CMB-S4	Y	Y	Y	S		S	P			P
Spec-S5	R&D	R&D	Y	S		S	P			P
$100–400M										
IceCube-Gen2	Y	Y	Y	P		S				P
G3 Dark Matter 1	Y	Y	Y	S		P				
DUNE FD3	Y	Y	Y	P				S	S	S
test facilities & demonstrator	C	C	C		P	P		P	P	
ACE-MIRT	R&D	Y	Y	P						
DUNE FD4	R&D	R&D	Y	P				S	S	S
G3 Dark Matter 2	N	N	Y	S		P				
Mu2e-II	R&D	R&D	R&D						P	
srEDM	N	N	N						P	
$60–100M										
SURF Expansion	N	Y	Y	P		P				
DUNE MCND	N	Y	Y	P				S	S	
MATHUSLA #	N	N	N			P		P		
FPF #	N	N	N	P		P		P		

P5 Recommendations 3

- Recommendation 3 directly connects to PBC science and projects

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.

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.

P5 ASTAE Area Recommendations

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.

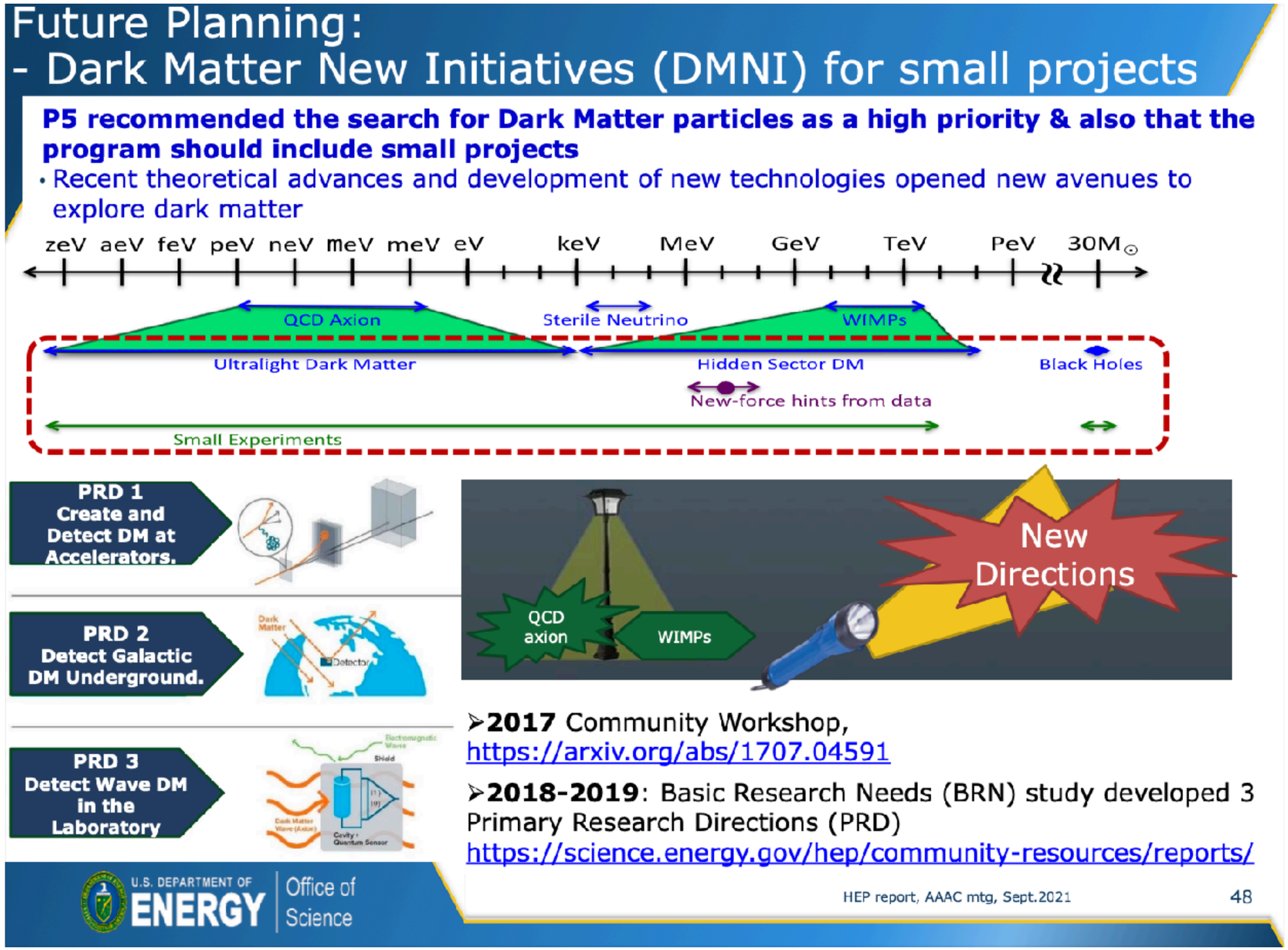
Area Recommendation 4: A successful ASTAE experiment involves 3 phases: design, construction, and operations. A design phase proposal should precede a construction proposal, and construction proposals are considered from projects within the group that have successfully completed their design phase.

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.

Dark Matter New Initiatives (DMNI)

Taken from K. Turner Talk at AAAC in Sept. 2021

- DMNI organized around 3 primary research directions, each with specific goals
- Snowmass-like & P5-like process to establish priorities, defined in Basic Research Needs report in 2019.
- Science goals widely represented in latest Snowmass, and called out in P5 report at a high level.



P5 Support of DMNI science goals

- Strong emphasis placed on small-scale new initiatives to expand the dark matter discovery potential

- Existing DMNI portfolio and strategic science goals called out specifically

4.1.3 – New Initiative: A Portfolio of Agile Projects for Dark Matter

In pursuit of understanding dark matter, a diverse and agile portfolio of ASTAE experiments, as described in Section 6.2, offers the potential for significant discoveries and technological advancements. Small but sensitive detectors are ideal for studying low mass dark matter since the needed size of the detectors scales roughly with the dark matter mass. This strategic approach focuses on two promising areas: hidden sector models and QCD axions, both of which boast high-priority benchmark models that can best be addressed by this scale of experiment.

Accelerator-based searches for the production of hidden sector particles leverage beam dumps at existing beamlines and have sensitivity to thermal benchmark models in the MeV-GeV mass ranges. The direct searches for these hidden sector particles utilize innovative materials and ultra-low noise detectors with the ability to detect down to sub-eV energy depositions to reach the benchmarks. This synergistic combination of approaches is necessary to understand and unlock the secrets of hidden sector dark matter.

The search for axions and ALPs is also well-suited for this agile portfolio. Specific QCD axion models provide definitive benchmarks, and through a series of carefully designed experiments, the parameter space spanning masses from 40 neV to 1 eV can be thoroughly explored. Additionally, these endeavors lay a foundation for even more ambitious projects that target the lightest masses falling within the range of 1 peV to 40 neV.

This multi-faceted approach maximizes the potential for seminal discoveries and pushes the boundaries of what is measurable in the realm of dark matter. Notably, this portfolio has already been set in motion by the Dark Matter New Initiatives (DMNI) experiments, which have completed their design phases and now await construction funding. These initiatives are integral components of the broader portfolio of ASTAE experiments (Recommendation 3a; Section 6.2).

DMNI Project Portfolio and Status

Taken from K. Turner Talk at AAAC in Sept. 2021

- Some DMNI projects are ready for construction now, specifically called out by P5 as forming the first construction projects in ASTAE planning

- Many projects have strong synergy with PBC projects and science goals — e.g. sub-GeV dark matter, axion-like dark matter

Dark Matter New Initiatives (DMNI) – Concept Studies

➢**2019-2020: Funding Opportunity Announcement (FOA); Six proposals aligned with the PRD's selected to develop concept & execution plans for potential small projects to search for dark matter particles in new areas of phase space.**

→Since late 2019, HEP is supporting 6 concept teams to carry out near-term technology R&D and to develop design and execution plans that can be reviewed and considered for advancing to potential small project fabrication phase.

- Most will need to be a Major Item of Equipment (MIE) project, meaning we have to request it in our budget and have it approved by Congress.

Cosmic Frontier:

- **ADMX Extended** (axions 2-4GHz), 9-17 μeV, A. Sonnenschein (FNAL)
- **OSCURA** (low noise "Skipper" CCD detector) 1MeV-1GeV, J. Estrada (FNAL)
- **DM-Radio** (axion search), <μeV, K. Irwin (SLAC)
- **TESSERACT** (Multiple detectors, w/TES readout), >10 MeV, D. McKinsey (LBNL)

Intensity Frontier (accelerator based)

- CCM Beam Dump exp at FNAL, ~1-40 MeV, R. van der Water (LANL)
- Light Dark Matter Experiment (LDMX) ~ 10-300 MeV, T. Nelson (SLAC)

Annual status review of the DMNI concepts held June 2021.

Timeline Expectations Going Forward

- Informal commentary from both OHEP and P5 suggests first ASTAE construction start (from among DMNI portfolio) FY26 or FY27.

- Phasing of new ASTAE projects outside DMNI, and broad vs. targeted selection process, not yet clearly defined.
  - My guess — call for new planning/design proposals no earlier than first DMNI project funding, but may be a few years later.

- Notional (ideal) timescale from selection to project completion: 2-4 years planning (per DMNI) + review + construction time. This has been slower for DMNI due to overall budget limitations

- While budget uncertainties remain, P5 support of DMNI and ASTAE is an exciting development! A mechanism to revitalize small-scale discovery experiments. I think this might have much more impact on the field than most realize.

Thank you!