HIGH ENERGY PHYSICS ADVISORY PANEL
to the
U.S. DEPARTMENT OF ENERGY and NATIONAL SCIENCE FOUNDATION

PUBLIC MEETING MINUTES

December 7-8, 2023

HIGH ENERGY PHYSICS ADVISORY PANEL
SUMMARY OF MEETING

The U.S. Department of Energy (DOE) and National Science Foundation (NSF) High Energy Physics Advisory Panel (HEPAP) hybrid in-person and virtual conference was convened via Zoom on December 7-8, 2023, by Chair Sally Seidel at the Westin Washington D.C. Downtown. The meeting was open to the public and conducted in accordance with Federal Advisory Committee Act (FACA) requirements. Attendees can visit http://osti.energy.gov/hep/hepap for more information about HEPAP.

Panel members present *(*Foreign representative)*:

Sally Seidel (Chair), in person
Halina Abramowicz*, remote
Luis Anchordoqui, in person
Ayana Arce, in person
Kenneth Bloom, in person
R. Sekhar Chivukula (*ex-officio*), in person
Sarah Cousineau, remote
Brenna Flaugher, in person
Thomas Giblin, in person
Sudhir Malik, in person
Reina Maruyama, in person
Yasuhiro Okada*, in person
Mayly Sanchez, in person
Heidi Schellman, in person
Monika Schleier-Smith, remote
Marcelle Soares-Santos, in person
Philip Tanedo, in person
Jesse Thaler, in person
Natalia Toro, in person

HEPAP Designated Federal Officer:

John Kogut, DOE, Office of Science (SC), Office of High Energy Physics (HEP), in person

Speakers:

Asmeret Berhe, DOE SC, Director, remote
Regina Rameika, DOE SC HEP, Associate Director of Science, in person
C. Denise Caldwell, NSF, Mathematical and Physical Sciences, Acting Assistant Director, remote
Michael Procario, DOE, in person
Joel Butler, Fermi National Accelerator Laboratory (Fermilab), in person
Hitoshi Murayama, University of California, Berkeley, in person
Karsten Heeger, Yale University, in person
Sally Seidel, University of New Mexico, in person
Sekhar Chivukula, University of California, San Diego, in person

Particle Physics Project Prioritization Panel (P5) members present:

Amalia Ballarino, European Council for Nuclear Research (CERN), remote
Tulika Bose, University of Wisconsin-Madison, in person
Kyle Cranmer, University of Wisconsin-Madison, remote
Francis-Yan Cyr-Racine, University of New Mexico, remote
Sarah Demers, Yale University, in person
Cameron Geddes, Lawrence Berkeley National Laboratory (LBNL), in person
Yuri Gershtein, Rutgers University, in person
Karsten Heeger, Yale University, in person
Beate Heinemann, German Electron Synchrotron (DESY), remote

Kendall Mahn, Michigan State University, remote
Rachel Mandelbaum, Carnegie Mellon University, remote
Jelena Maricic, University of Hawaii at Manoa, in person
Petra Merkel, Fermilab, in person
Christopher Monahan, William & Mary, remote
Hitoshi Murayama, University of California, Berkeley, in person
Peter Onyisi, University of Texas at Austin, in person
Mark Palmer, Brookhaven National Laboratory (BNL), in person
Tor Raubenheimer, Stanford Linear Accelerator Center (SLAC), remote
Mayly Sanchez, Florida State University, in person
Richard Schnee, South Dakota School of Mines & Technology, remote
Sally Seidel, University of New Mexico, *ex officio*, in person
Seon-Hee (Sunny) Seo, Fermilab, remote
Jesse Thaler, Massachusetts Institute of Technology (MIT), in person
Christos Touramanis, University of Liverpool, in person
Abigail Vieregg, University of Chicago, remote
Amanda Weinstein, Iowa State University, in person
Lindley Winslow, MIT, remote
Tien-Tien Yu, University of Oregon, remote
Robert Zwaska, Fermilab, in person

Approximately 90 other in-person attendees were present for all or part of the meeting, including:

Dan Akerib, SLAC
Mary Bishai, BNL
Jodi Cooley, SNOLAB
Marcel Demarteau, Oak Ridge National Laboratory (ORNL)
Dmitri Denisov, BNL
Jonathan Feng, University of California, Irvine
JoAnne Hewett, BNL
Kevin Pedro, Fermilab

Approximately 930 and 310 other remote attendees were present for all or part of the meeting on December 7 and 8, respectively, including:

Giorgio Apollinari, Fermilab
Jonathan Bagger, American Physical Society (APS)
Pushpa Bhat, Fermilab
Julian Borrill, LBNL
Marcela Carena, Fermilab
Philip Chang, University of Florida
Chris Damerell, Rutherford Appleton Laboratory
Angelo Dragone, SLAC
Jessica Esquivel, Fermilab
Corrado Gatto, Instituto Nazionale di Fisica Nucleare (INFN)
Steven Gottlieb, Indiana University (emeritus)
Erin Hansen, University of California, Berkeley
John Hauptman, Iowa State University
Keisho Hidaka (Tokyo Gakugei University)
Tova Holmes, University of Tennessee
David Jaffe, BNL
Bryce Littlejohn, Illinois Institute of Technology
William Morse, BNL
Harvey Newman, California Institute of Technology/ US Large Hadron Collider Users Association (US LUA), Chair
Brendan O'Shea, SLAC
Sergey Pereverzev, Lawrence Livermore National Laboratory (LLNL)
Soren Prestemon, LBNL

Breese Quinn, University of Mississippi
Jennifer Raaf, Fermilab
Natalie Roe, LBNL
Frank Schroeder, University of Delaware
Wei Shi, Stony Brook University
Ruth Van de Water, BNL
Andrew White, University of Texas-Arlington
Katherine Wright, APS

Recordings are available at the links below:
December 7, 2023: https://vimeo.com/892582512/3532e7f287
December 8, 2023: https://vimeo.com/892765632/576ddd6f54

Thursday, December 7, 2023

WELCOME AND INTRODUCTION

Seidel, HEPAP Chair, called the meeting to order at 9:00 a.m. Eastern Time and welcomed attendees. Appreciation was extended to several HEPAP members for whom this is the final meeting.

REPORT FROM THE DOE, Regina Rameika

HEP's fiscal year 2023 (FY23) enacted budget of ~$1.17B is split among facility operations (29.7%), projects (30.4%), and research (39.8%). Since the last Particle Physics Project Prioritization Panel (P5) long-range plan was released in 2014, the percent of HEP's overall budget allocated to projects has increased; from FY96-FY15, HEP funded ~$2.0B in projects at ~14% of the total budget, and from FY16-FY20, HEP funded ~$1.4B in projects at ~30% of the total budget, with a total of 61 projects supported over the entire timeframe. The Inflation Reduction Act (IRA) conferred additional project support of ~$304M in FY22. Core research has seen funding infusions from DOE SC-wide initiatives in Quantum Information Science (QIS) and Artificial Intelligence and Machine Learning (AI/ ML), Reaching a New Energy Sciences Workforce (RENEW), and Funding for Accelerated, Inclusive Research (FAIR). At present, HEP is operating under a continuing resolution (CR). The FY25 budget request is under review with the White House Office of Management and Budget (OMB).

At the Energy Frontier, the A Toroidal LHC ApparatuS (ATLAS) and Compact Muon Solenoid (CMS) collaborations continue to lead HEP with physics results, with >2,480 publications in peer-reviewed journals since data-taking began at the Large Hadron Collider (LHC) in 2009. Highlights include the initial Run 3 results of the Higgs boson from ATLAS; signed amendments to the 2017 DOE-CERN Addendum agreements for DOE's contributions to the High Luminosity (HL)-LHC accelerator and detector upgrades; and shipping of the HL-LHC Accelerator Upgrade Project's (AUP's) first cryo-assembly to CERN. The HL-LHC AUP was re-baselined in March 2023, and the total project cost (TPC) increased from $242M to $266M. The HL-LHC Phase-II detector upgrade projects were baselined at Critical Decision-2 (CD-2) by DOE in January 2023 (ATLAS) and March 2023 (CMS) at a TPC of $200M each. The three US HL-LHC projects are at or approaching the fabrication stage.

At the Intensity Frontier, the Short Baseline Neutrino program (SBN) is addressing experimental hints of physics beyond the three-neutrino program. The Micro Booster Neutrino Experiment (MicroBooNE) produced scientific results from 2015-2021; Imaging Cosmic And Rare Underground Signals (ICARUS) operations began in spring 2022; and the Short Baseline Near Detector (SBND) will begin operations in spring 2024. The Long-Baseline Neutrino Facility and Deep Underground Neutrino Experiment (LBNF/ DUNE), the largest domestic SC project, has a TPC of $3.2B and is being delivered at the Far and Near Sites through a total of five subprojects. Far Site excavation is approaching 90% completion. A Memorandum of Understanding (MOU) between Fermilab (the host lab for DUNE) and international partners collaborating on the experiment was signed in November 2023. The Muon-to-Electron experiment (Mu2e) is fully funded, and the project is 90% complete; Run 1 is scheduled for mid 2026. Civil construction for the Proton Improvement Plan-II (PIP-II) was halted in May 2023 due to a serious accident. Schedule recovery and improvement plans will be implemented following the conclusion of accident investigations and the improvement of safety protocols.

Cosmic Frontier experiments address four of the five 2014 P5 science drivers with projects and experiments realized through partnerships with NSF and the National Aeronautics and Space Administration (NASA). Select highlights from Dark Matter-Generation 2 (DM-G2) experiments featured the complementary LUX-ZEPLIN (LZ) and Super Cryogenic Dark Matter Search (SuperCDMS) searches for weakly-interacting massive particles (WIMPs). Axion Dark Matter Experiment-Generation 2 (ADMX-G2) is searching for axions. HEP is supporting five concepts for Dark Matter New Initiatives (DMNIs) for investigation of WIMPs, axion searches, and accelerator searches. Further DMNI advances will progress through the CD process. Dark matter searches are also leveraging the LHC and gamma-ray and imaging surveys. Science highlights in Cosmic Acceleration featured a Stage 3 and 4 imaging and spectroscopic surveys for Dark Energy: the DOE-NASA Lunar Surface Electromagnetics Experiment-Night (LuSEE-Night) project and Cosmic Microwave Background-Stage 4 (CMB-S4).

SC-wide research initiatives in HEP include QIS, AI/ ML, Microelectronics, and Advanced Computing Accelerator Science and Technology (ACCELERATE). Notably, AI/ ML is deeply embedded in HEP's core research and accelerator technology, with a new thrust in proposal-driven cross-cutting research and development (R&D); the balance between leveraging AI/ ML tools for HEP science and using HEP data to drive AI/ ML development will be reassessed. Science highlights featured the Superconducting Quantum Materials and Systems Center (SQMS), the largest DOE-supported QIS Research Center hosted by Fermilab.

The 2023 P5 report will be presented today. The planning process took several reports into account: the 2020 Update of the European Strategy for Particle Physics; the 2020 National Academies of Sciences (NAS) astronomy and astrophysics decadal survey, the 2021-2022 community Snowmass process; the new NAS decadal survey in elementary particle physics; and the HEPAP report on international benchmarking.

DOE SC has charged each FACA panel in SC to complete a report on desired future facilities for the next 10 years.

DISCUSSION

Thaler requested more information about the CD process for DMNI projects. **Rameika** said HEP plans to generate a single CD-0 package for all projects; there is a single mission need for dark matter experiments and more than one experiment can rely on a mission need. HEP is focused on generating a generic CD-0 this year. Attaining subsequent CD levels should follow the same process although the 413B Order does allow tailoring. Depending on the quality of the plan and needed oversight, smaller projects may be delegated to a lab. Current reviews indicate projects are not large, but this could change between CD-0 and CD-1, and the budget will be tailored as needed. **Procario** noted LZ and SuperCDMS shared a common CD-0.

Pedro asked about future funding for AI research. **Rameika** stated no specifics are available now and envisions the total amount of funding remaining relatively steady. There are currently no plans to make changes.

REPORT FROM THE NSF, Denise Caldwell

Caldwell reviewed senior staff changes in the Directorate for Mathematical and Physical Sciences (MPS) and noted the ongoing search for a new assistant director.

Two of the three 2023 Nobel Prize awardees in Chemistry received NSF funding. One of the Physics awardees also received NSF funding.

The NSF Strategic Plan 2022-2026 guides budget requests. The NSF FY24 budget request for MPS was ~$1.8B. NSF is currently operating under a CR, and FY23 expenditures are not yet available.

The NAS Astro2020 consensus study identified six new medium and large initiatives that should be supported: the U.S. Extremely Large Telescope Program (US-ELT); the next generation Very Large Array (ngVLA); CMB-S4; the augmentation of the Mid-scale program; technology development for Laser Interferometer Gravitational-Wave Observatory (LIGO) upgrades and future observatories; and IceCube Generation 2 (IceCube-Gen2). Within this context, the MPS Major Facilities Portfolio includes facilities which are due for upgrades. Prioritization considers project phase (conceptual design, preliminary design, and final design). Of note, entry into the Design Stage does not imply a commitment to fund construction. A subcommittee report on the best ways to address prioritization across divisions is expected soon.

The Expanding Capacity in Quantum Information Science and Engineering program (ExpandQISE) made a total of 22 awards supported by $38M. The goal of ExpandQISE is to broaden participation of principal investigators (PIs), students, and universities who are not engaged in the QIS endeavor. All leads are at non-R1 universities, including six historically black colleges and universities (HBCUs), three Hispanic-serving institutions (HSIs), and five institutions from Established Program to Stimulate Competitive Research (EPSCoR) states.

Quantum Sensing Challenges for Transformational Advances in Quantum Systems (QuSeC-TAQS) awards are small and focused on new sensor technologies. This round, $29M is supporting 18 awards, including four HSIs and three institutions from EPSCoR states. The National Quantum Initiative (NQI) Reauthorization Act awaits Congressional action. The Act authorizes creation of a coordination hub to generate workforce pipelines within the quantum industry ecosystem; to develop new quantum testbeds through the Technology, Innovation, and Partnerships Directorate (TIP); and to strengthen student traineeship, fellowship, and workforce programs at NSF.

The National Quantum Virtual Laboratory (NQVL) is a new shared infrastructure designed to facilitate the translation of basic science and engineering to technology through a co-design approach that will bring together discoverers, developers, builders, and end users with contributions across diverse NSF networks like the Quantum Leap Challenge Institutes (QLCIs) and ExpandQISE.

MPS Artificial Intelligence Institutes (AI Institutes) are soliciting applications for AI for Astronomical Sciences in FY24 and AI for Discovery in Materials Research in FY25.

MPS activities related to the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act include the creation of a sustainable chemistry program, the ongoing Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT) program, and a collaborative award to University of Colorado, Boulder and Rochester Institute of Technology to perform a study of QIS national workforce activity. NSF will work to increase integration of QISE into STEM curriculum at all levels.

MPS broadening participation programs include Mathematical and Physical Sciences Ascending Postdoctoral Research Fellowships (MPS-Ascend) which made 29 awards in FY23, including 24 to members of underrepresented groups; Launching Early-Career Academic Pathways in the Mathematical and Physical Sciences (LEAPS-MPS) which presented 64 awards in FY23, including to 53 Emerging Research Institutions and 22 minority-serving institutions (MSIs); and a new program, Mathematical and Physical Sciences Ascending Faculty Catalyst Awards (MPS-AFCA), which will support MPS-Ascending postdoctoral research fellows who

transition into tenure-track faculty positions. Finally, several MPS Partnership programs supporting partnerships between MSIs and MPS centers, institutes, and facilities. A new partnership granted 11 supplemental awards to existing awardees of NSF's Research Traineeship program (NRT) and Partnerships for Research and Education in Materials program (PREM).

Science highlights featured the first evidence of low-frequency gravitational waves permeating the universe from the NSF North American Nanohertz Observatory for Gravitational Waves (NANOGrav) Physics Frontiers Center; IceCube's first image of the Milky Way in neutrinos; and the opening of the NSF Zettawatt Equivalent Ultrashort pulse laser System (ZEUS) Laser User Facility at the University of Michigan in October.

DISCUSSION

Schellman appreciated outreach to universities that are not typical recipients of NSF awards. Single investigators, especially those not familiar with NSF programs, may need more support to complete applications. **Caldwell** observed webinars seem effective in raising program awareness. Program managers are also eager to assist with questions. All suggestions for improving communications are welcome. **An attendee** shared program managers have been very helpful in the past.

Sanchez asked about the timeframe for the QIS workforce study and how the integration of QIS into curricula will be supported. **Caldwell** believed preliminary study results will be available in a year. Regarding incorporation of QIS into curricula, ExpandQISE offers two funding tracks: one for institutions that do not have a strong research focus and another for larger institutions to build up a QIS program. Every proposal must be based on a scientific project and will be reviewed based on the science. However, proposals must also contain efforts to attract, develop, and prepare students for the QIS workforce. This workforce component is important.

Seidel dismissed the meeting for a break and reconvened at 10:30 a.m.

A COMMITTEE OF VISITORS (COV) FOR THE HEP FACILITIES DIVISION, Michael Procario

DOE SC has issued two new charges to HEPAP: 1) Facility Construction Projects which will be used to develop SC-wide prioritization and 2) Creation of a COV for the HEP Facilities Division.

The SC-wide facility prioritization was issued to all SC federal advisory committees on December 1, 2023 as a follow-up to processes conducted in 2003 and 2013. HEP was not a strong player on the 2003 list. In 2013, criteria for prioritization were the ability to contribute to world-leading science and readiness for construction. The HEPAP report is available online, but no SC-wide report was issued.

The current charge criteria are similar to those of 2013: potential to contribute to world-leading science in the next decade and readiness for construction. Only projects > $100M should be included in a report supplied by a subpanel of HEPAP, and relevant strategic planning documents and decadal studies should be referenced. The report, in the form of a letter, is due May 2024. This short deadline suggests relying on the P5 Report as much as possible. Facilities should be ranked on scientific impact and readiness.

HEP will provide a preliminary list of projects broken into near-, mid-, and far-term. Projects past CD-3 or <$100M are not included, but other appropriate projects can be added. Near-term projects include LBNF/ DUNE and CMB-S4. LBNF/ DUNE North Cavern

excavation was just completed; far detector and cryogenics just had a CD-2 review. CMB-S4 is at CD-0.

Mid-term projects listed are Accelerator Complex Enhancement-Main Injector + Target (ACE-MI+T); Advanced Accelerator Test Facilities; and DUNE High Power Far Detector Upgrade. Advanced Accelerator Test Facilities provide venues to test newly developed advanced accelerator approaches supported by the General Accelerator R&D program (GARD) but is ranked third in this phase based on current understanding and rate of progress and is non-specific without further community advice.

Far-term projects include the Future Energy Frontier Collider; DUNE High Power Near Detector Upgrade; Stage 5 Spectroscopic Survey Instrument; and Accelerator Complex Enhancement-Booster Replacement (ACE-BR). The Future Energy Frontier Collider is envisioned as a contribution to an offshore collider; an onshore collider is likely outside the timeframe for this exercise.

A charge to create a COV to review the Facilities Division is overdue and is in the process of being signed. Professor Young-Kee Kim, University of Chicago, was selected to chair this COV. Committee members include U.S. and international lab and university affiliates. COV members will meet in Maryland from March 11-13, 2024 and via Zoom in the interim. All projects from 2017-2023 are included; nine each completed and active. The COV may focus on several projects or treat them all equally. Also under examination are a handful of operations programs.

DISCUSSION

Chivukula was curious about the outcome of the 2013 Brinkman process and community input opportunities for once the report is at the SC stage. **Procario** noted the charge does not call out a process for community input, but in this case, the P5 report is likely a good indicator. The 2013 Brinkman process did not release a formal report but was used as internal guidance.

Flaugher asked how this charge differs from the P5 prioritization process. **Procario** explained the charge is designed to allow SC to more easily decide importance across programs, using high level summaries and assessments of importance and readiness. The original 2003 Orbach documents were important, but not exclusive, and many projects completed were smaller. HEP completed more expensive, unlisted projects and projects <$100M. The P5 report can supply needed project details.

Toro observed the time frames, especially "far term," seem oddly defined when the time under examination is a decade. **Seo** (chat) asked for definitions of near-, mid-, and far-terms and timelines for project completion. **Procario** acknowledged the terms were not well defined and estimates can be moved by the panel. The intention is not to focus only on projects that can be finished in 10 years. **Rameika** added these are projects that could start construction in the next 10 years and ultimately generate world-leading science, but the science itself does not have to be done within the next 10 years.

Anchordoqui inquired about the timeline for the report. **Procario** reiterated the due date of May 2024.

Akerib noted the absence of a third generation (G3) dark matter facility. **Procario** said this came to mind during the presentation and could be added based on its treatment in P5.

Demarteau brought up facilities operated by other offices that can be used by HEP. **Procario** stated individual FACA panels would need to reach out across fields if a given facility

could benefit others. Each FACA panel is asked to discuss the facilities proposed by their particular office.

Bloom mused the charge could instead be a "mega subpanel" across all SC areas. **Procario** noted that would be a big lift and evaluation would be done internally at SC.

Chivukula sought confirmation that the COV focus is on managerial and programmatic issues, not on science. **Procario** confirmed the goal of the Facilities Division is to enable science, not decide what science to pursue.

Thaler wondered if there was a plan to have COV foci—facilities and research and technology—alternate every 3-5 years and if there was concern about the risks of long gaps. **Procario** estimated the next COV for research and technology would be in 2025 but was not aware of concerns. FACAs are in charge of tracking COVs and encouraging performance. **An attendee** added other SC offices do similar rotations. There can be up to 10 years between COV reviews. Input on an appropriate timeline is welcome taking into consideration the state of the field and outstanding recommendations from the previous COV.

Tanedo asked if national site access was part of the charge or within the purview of the committee. **Procario** noted this was not mentioned in the charge, but access is a concern at multiple levels at DOE.

Bishai observed the list of facilities is not in a priority order. **Procario** agreed this is a piece of input for management, not a rule.

Hauptman (chat) asked is there any SC requirement or suggestion that physicists in administrative roles at DOE and NSF spend a fraction of their time in the halls of Congress talking with aides and congressional members.

Hidaka (chat) wondered if future accelerator projects such as Higgs factories and muon colliders were mentioned.

A COORDINATING PANEL FOR SOFTWARE AND COMPUTING, Joel Butler, Fermilab, representing APS Division of Particles and Fields (DPF) Executive Committee

The Snowmass 2021 Computational Frontier (CompF) recommended the development of a standing Coordinating Panel for Software and Computing (CPSC, a working name) under the auspices of APS DPF. CompF noted four key areas of need where investment would enhance the output of the U.S. high energy physics community: 1) long-term development, maintenance, and user support of essential software; 2) support for R&D efforts cutting across projects or discipline boundaries; 3) support for computing professionals for effective use of heterogeneous resources; and 4) strong investment in career development for researchers. CPSC's purpose would be to "Promote, coordinate, and assist the HEP community on Software and Computing, working with stakeholders to address the experimental, observational, and theoretical aspects of HEP programs." There are many comparisons between the proposed CPSC and the Coordinating Panel for Advanced Detectors (CPAD) formed in 2012.

The DPF Executive Committee (EC) agreed to create CPSC post Snowmass in 2023. An exploratory group was convened, and together with EC, agreed that a Formation Task Force (FTF) should be created to produce a report defining the governance structure and goals of the CPSC. The FTF will act as an *ad hoc* subcommittee to EC while CPSC, to be subsequently formed, will respond to requests from DPF, HEPAP or funding agencies.

A nomination period for the FTF ran from September 9-30, 2023 with a total of 61 unique names submitted. Among these individuals, ~15-20 will be selected to serve on the FTF. Selections will consider representation across experimental size and research frontier along with

theory, quantum computing, and AI/ ML. A balance of participants considering gender, national laboratories, career status and engagement in existing software and computing projects will also be sought. Ian Fisk of the Flatiron Institute/ Simons Foundation has been selected as FTF chairperson.

Once the FTF's report is approved by EC, EC will begin the process of establishing CPSC as a standing body of DPF.

DISCUSSION

Toro found the underrepresentation of small experiments in the nominations interesting, positing it was reflective of the challenges of communicating with leaders of smaller experiments and that there is probably not one person who is totally devoted to computing in each of these. Given these systemic challenges, it is hoped the FTF can include small experiment needs. **Butler** acknowledged this was very important and raised during Snowmass; small experiment workshop participants served as points of contact to collect more specific input. There may be a slight over-representation relative to the number nominated, although that number was low. Ultimately, a strong panel with good representation of all experiment sizes is desired.

Abramowicz wondered about including an international representative, perhaps from the HEP Software Foundation, to explore common computing software practices. **Butler** clarified there was a representative from a software foundation, noting additionally it was hard to get a balance within the U.S. Fully extending the effort internationally would have been beyond the FTF scope. Many people invited have prominent positions in international collaborations, and the chair's work has a multidisciplinary facet. Others can be invited as advisors.

Denisov observed the absence of BNL in the slides. Is there a possibility of other panels in the future? **Butler** felt panels were appropriate for certain types of problems; in this case, the community is very active with many large projects, but enhanced communication seems lacking. CompF specifically requested this effort.

Seidel dismissed the meeting for lunch and reconvened at 12:35 p.m.

REMARKS BY THE DIRECTOR OF THE OFFICE OF SCIENCE, Asmeret Berhe

Berhe recognized Seidel and Hewett for their service to HEPAP, offered special thanks to Murayama and Heeger for work with P5, and appreciated the contributions of HEPAP. The U.S. physics community is central to global physics efforts, and members are highly valued collaborators. Big transnational science projects and productive collaborations are important to the field, and everyone is eager to hear the recommendations from P5.

The project prioritization charge from SC will examine 20 unique, world-class U.S. facilities that are core to the DOE mission and part of the contribution to the nation's scientific strength. An advisory committee will be asked to identify what new and upgraded facilities will best serve the HEP community's needs in the next ten years. Justification for the assessment is critical, however, members are not asked to rank the facilities nor to consider expected funding levels. The final report will be used to strategically position SC and will allow stakeholders to understand the level of support needed and why it is needed.

The field has advanced several notable experiments with a high level of engagement from students and international collaborators; the Fermilab Muon g-2 experiment and preparation for Mu2e may yield results that further challenge understanding of the Standard Model.

SC is gratified to see equity front and center in the P5 Report. Efforts related to the physics workforce and broadening participation in physics are critical. The U.S. must build a scientific workforce that welcomes and includes everyone, allowing broad benefits from the research and science performed on behalf of the American people.

DISCUSSION

None.

INTRODUCTION OF P5 PROCESS, Sally Seidel

An overview of the P5 charge and process was provided.

PRESENTATION OF THE P5 REPORT, Hitoshi Murayama and Karsten Heeger

SC issued the P5 charge in November 2022. The P5 panel, 30 members with broad expertise from institutions across the U.S. and overseas, was formed by the end of January 2023. The panel used reports generated by the Snowmass process and community engagement through hybrid, in-person, and virtual town hall meetings at labs and universities. Notable features included an exclusive session for early-career members and live captioning and American Sign Language (ASL) interpreters to assist with accessibility. Community engagement and information sessions were also held throughout the year at conferences or workshops. Updates were made available on the U.S. Particle Physics website.

During the deliberation phase, four in-person closed meetings and meetings by working groups with additional input from agencies, government, and the community were held. All decisions were made by consensus, and conflicts of interest (COIs) were recorded and stated during discussions. Those with a COI were allowed to make factual statements but not express opinions during deliberations. Preliminary recommendations were presented to agencies in September and agencies were briefed in November. Peer reviewers provided invaluable comments that helped improve the clarity of recommendations but did not change content. If accepted by HEPAP at this meeting, community discussion and rollout of the report will follow.

The P5 panel created a Subcommittee on Costs/ Risks/ Schedule for the evaluation of projects with a high cost (>$250M in FY23$). This subcommittee convened in March 2023 and provided a report to the panel at the end of June addressing the uncertainty ranges for projects within the assumed budgetary constraints. The provided budget scenarios were “baseline” (CHIPS and Science Act increase + 3% increase/ year) and “less favorable” (CHIPS and Science Act increase + 2% increase/ year). In both scenarios, the continuing costs of current projects will consume available funds for several years. Adding all new, proposed projects on top exceeds available funds for the next decade, creating a challenging problem for prioritization.

Prioritization principles noted the overall program should enable U.S. leadership in core areas of particle physics; leverage unique U.S. facilities and capabilities; engage with core national initiatives to develop key technologies; develop a skilled workforce for the future that draws on U.S. talent; and consider effective engagement and leadership in international endeavors. Scientific opportunities, budgetary realism, and a balanced portfolio were major decision drivers. Also considered were uncertainties in costs, risks, and schedule and prioritized project portfolios were chosen to fit within the budget scenarios and ensure a reasonable outlook

for continuation. Other balancing factors included size and time scale, onshore versus offshore, project versus research, and current versus future investments.

Large projects (>$250M) were required to have paradigm-changing discovery potential and be unique in the world and world-leading. Medium projects ($50M-$250M) embodied excellent discovery potential or development of major tools and were world-class and competitive. Small projects (<$50M) had discovery potential, well-defined measurements, or outstanding technology development, were world-class, and offered excellent training grounds.

The 2023 P5 report is titled *Exploring the Quantum Universe: Pathways to Innovation and Discovery in Particle Physics.* Three overarching science themes were identified with two science drivers in each theme: 1) "Deciphering the quantum realm" includes the Higgs Boson and Neutrino drivers; 2) "Illuminating the hidden universe" encompasses the Dark Matter and Cosmic Evolution drivers; and 3) "Exploring new paradigms in physics" involves the New Particles and Quantum Imprints drivers.

The report's recommendations (Recs.) are in Section (§) 2.2. Twenty more specific recommendations, called Area Recommendations (Area Recs.), appear in §6. Sections 3-5 discuss science themes and drivers, §7 focuses on workforce considerations, and §8 examines budgetary considerations and outlines the hard choices that had to be made.

Rec. 1 is not rank ordered and reaffirms the previous P5 recommendations on major initiatives: HL-LHC, first phase of DUNE and PIP-II; and the Vera C. Rubin Observatory to carry out the Legacy Survey of Space and Time (LSST). Continued support is recommended for ongoing experiments at the medium scale (>$50M for DOE and >$4M for NSF). Agencies should carefully manage the costs and schedule of major initiatives to ensure a broad and balanced portfolio.

Rec. 2 calls for the construction of a portfolio of major projects and is the only recommendation that has rank-order priority: 1) CMB-S4; 2) Re-envisioned second phase of DUNE; 3) Offshore Higgs factory, in collaboration with international partners; 4) Ultimate G3 dark matter direct detection experiment; and 5) IceCube-Gen2, which has a strong science case in multi-messenger astrophysics (MMA) and gravitational wave observation.

Rec. 3, not rank ordered, seeks to improve the balance among small-, medium-, and large-scale projects. These include a new small-project portfolio at DOE, Advancing Science and Technology through Agile Experiments (ASTAE), which should begin with the construction of DMNI experiments. Mid-Scale Research Infrastructure (MSRI) and Major Research Instrumentation (MRI) programs must be continued. The Dark Energy Spectroscopic Instrument-II (DESI-II), Large Hadron Collider beauty (LHCb) upgrade II, and Belle II upgrade (including contributions toward the SuperKEKB accelerator) also require support.

Rec. 4 describes areas, not rank ordered, in which investments are needed to develop theoretical, computational, and technological resources essential to a 20-year vision for the field, with an emphasis on R&D. Experiments and timelines under a baseline budget scenario can be seen in Figure (Fig.) 1 (report p. 28).

Rec. 5 includes five actionable items, not rank ordered, aimed at developing the workforce, broadening engagement, and supporting ethical conduct in the field.

Rec. 6 calls for the convening of a targeted panel to make decisions on the U.S. accelerator-based program. Specific concerns are considering the U.S. contribution in a specific

Higgs factory; mid- and large-scale test and demonstrator facilities; and planning for the evolution of the Fermilab accelerator complex.

In addition to the Recs., a long-term vision for the field was outlined in three areas: §2.3 The Path to 10 TeV parton center-of-momentum (pCM); §2.4 Stewardship of Key Infrastructure and Expertise; and §2.5 International and Inter-Agency Partnerships.

In a less favorable budget scenario, maintaining ongoing projects in Rec. 1 is of highest priority, but some of the major initiatives in Rec. 2 would have reduced scope. Accelerator Complex Evolution-Reduce Main Injector Ramp Time and Target (ACE-MIRT) and the More Capable Near Detector (MCND) would be deferred; contribution to an offshore Higgs factory would be reduced and delayed; and participation in an offshore G3 dark matter experiment would be reduced, and the Sanford Underground Research Facility (SURF) would not be expanded. CMB-S4 and IceCube-Gen2 would continue without reduction in scope. Recs. 3 and 4 would receive proportionate reductions in scope; Rec. 5 is a high priority and supported; and Rec. 6 applies in all scenarios. This would lead to a loss of U.S. leadership in many areas and make it difficult to maintain U.S. competitiveness as a partner in accelerator technology.

A budget scenario more favorable than the baseline would allow for the support of additional opportunities in R&D and projects of all sizes. Figure 2 (p. 29) provides an overview of recommended construction in various budget scenarios. The project wish list from the community guided the recommendations which were closely examined to see what could be done under various budget scenarios. In the budget exercise, the panel attempted to create a more balanced portfolio by FY33 compared with that of FY23.

Twenty Area Recs. were made to highlight theoretical, computational, and technological areas where sustained investments can advance the future of science and technology. Increases in annual funding needed to achieve the field's 20-year goals are explicitly indicated. These increases should be achieved through ~5-year ramp-ups to reach new funding levels. Broad categories include theory, ASTAE, instrumentation, general accelerator R&D, collider R&D, facilities and infrastructure, software, computing, cyberinfrastructure, and sustainability.

All who assisted with P5 are thanked.

Seidel dismissed the meeting for a break and reconvened at 2:30 p.m.

DISCUSSION

CHARGE, APPENDIX, AND §1

Chivukula acknowledged the hard work contributed by the panel and community.

SECTIONS 1 AND 2

Anchordoqui was surprised at the disparity between the emphasis on cosmic neutrinos versus collider neutrinos (e.g., ATLAS or CMS neutrinos). **Murayama** explained these were below the budget cutoff used in the report, and that is the only reason they were not included.

Feng requested details on the apparent recommendation that the Forward Physics Facility (FPF) not be constructed in any budget scenario, per Fig. 2. To justify building a facility, potential experiments must be considered as a package. CERN is unlikely to build a new facility

without experiments that will use it. **Murayama** pointed to §8 for the rationale behind hard choices. FPF, with some tweaking, is recommended to be funded as part of ASTAE. Further discussions with the international community are anticipated. ASTAE is expected to fund well-defined DMNI projects in early years with room for additional projects in about five years.

Morse asked why no additional storage ring electric dipole moment (srEDM) experiments were funded. **Murayama** noted EDM searches are well represented in other DOE programs, and HEP's case needs to mature before funding.

Newman offered compliments to the committee and shared a statement as chair of US LUA. Research is the lifeblood and a priority of the community, and the P5 Report should support community efforts in advocacy to Congress. Pressure is placed on the workforce and other program areas due to adoption of AI and quantum information, but this is reaching a limit, and a study of workforce obligations should be done. **Murayama** was aware of community sentiments. Rec. 4 seeks to reinvigorate research in four targeted areas beyond current levels, but not at the expense of other research, which would maintain inflation-adjusted support. A bottom-up approach identified what was needed to maintain competitiveness in each of the four areas. If this recommendation is followed, research will comprise ~40% of the total budget in 10 years. **Bloom** wondered if the only way to build out was to do additional research in the four listed areas. **Murayama** stated an increase in funding for these areas was the only way to increase the budget in this scenario.

Damerell asked why the Cool Copper Collider (C^3) proposal for a demonstrator was not mentioned. **Murayama** indicated support through GARD. **Geddes** confirmed, referencing §6.4.

Soares-Santos was concerned that the change in language from "cosmic acceleration" to "cosmic evolution" in the science drivers could be seen as a confusing expansion on scope. **Murayama** directed attention to §4.2 and noted a broader term is needed to encompass the desire to embrace astrophysical probes for dark matter as part of the portfolio.

Bhat asked if funding for the C^3 demonstrator comes out of GARD and whether the funding for collider R&D was accounted for in budget scenarios. **Murayama** elucidated a two-track approach that supports involvement with an offshore Higgs factory and domestic 10-TeV-pCM collider construction. C^3 technology research is still ongoing and will continue.

RECOMMENDATION 1

No discussion.

RECOMMENDATION 2

Flaugher wondered about confidence in the numbers provided by the cost subcommittee. **Murayama** explained a range of three different costs was determined for each project. Projects that looked more secure or had a certain level of maturity were chosen. Similar analyses with third-party estimates were conducted by the Astro2020 and Astro2010 decadal surveys.

Chivukula pointed out CMB-S4 and IceCube-Gen2 rely on availability at the South Pole and science station support. **Murayama** acknowledged the risk that new projects cannot be supported at this time, but NSF is engaged in a planning process over the next two years for South Pole infrastructure needs. **Chang** (chat) wondered how South Pole availability would affect the Rec. 2 cost estimate. **Murayama** clarified infrastructure costs are borne by the NSF

Office of Polar Programs and are outside the scope of P5. Standing personnel would have to be paid, but that would not significantly affect the budget.

Borrill (chat) asked why CMB-S4 is not called out as an MMA facility alongside IceCube-Gen2. **Murayama** referenced Fig. 1 in which Astronomy & Astrophysics is noted as a primary science driver of CMB-S4. This could be added to the narrative text in Rec. 2.

Tanedo was concerned about the included construction budget for the South Pole as many outside factors could potentially prevent construction. **Murayama** recognized the South Pole as an important component, but similar goals could be achieved in Chile, although larger detectors and more time would be needed to gather data.

White requested an explanation of the budget scenario for an offshore Higgs factory. **Murayama** stated the U.S. must be a strong partner providing proportionate support for an offshore Higgs factory, but this must be balanced with a healthy onshore program, which creates an upper bound on how much can be contributed. R&D could begin soon, and construction would start in the last two years of the coming decade. This is shown in the Fig. 1 baseline scenario where the color changes from orange to pink.

Pedro observed the U.S. planning process for Higgs factories is out of phase with that of Europe. **Murayama** directed attention to Rec. 6 which calls for the formation of a targeted panel specifically to make timely decisions on the U.S. accelerator-based program.

An attendee requested clarification of the goal in Rec. 1b. **Murayama** explained CP violation is the goal for the entire DUNE program; per DUNE, the goal of phase one will be determination of mass ordering.

Littlejohn inquired how the budget envelope between the most and least favorable budgets compared to the size of the error bars that accompany the large projects described in Rec. 2. **Murayama** answered the difference between the baseline and less favorable scenarios is much bigger than the understood uncertainties which is why funding recommendations are quite different in terms of scope.

Chivukula sought insight into Rec. 1. Were existing funding profiles treated as fixed or was there the possibility to change current operations to optimize science? **Murayama** shared the intent behind the final line in Rec. 1 was that cost overruns on existing projects should not affect funds for other projects in the portfolio.

An attendee was concerned instrumentation and construction success will increase demand for support to do research and has the potential to unbalance the overall funding profiles for projects and research. **Murayama** noted implementation relies on the agencies, and the requested increase in research funds should provide flexibility to allow for re-balancing.

RECOMMENDATION 3

Gatto asked for more details about ASTAE and mid-scale projects. **Murayama** explained ASTAE is meant for relatively small ($10M-$20M) projects and will be run without additional input from P5. G3 Dark Matter is considered mid-scale.

Denisov wondered about projects in Rec. 3. **Murayama** clarified these are independent of one another. ASTAE projects are anticipated to be approximately five-year projects. The panel avoided commenting on the LHCb upgrade as DOE has not committed funds.

Jaffe (chat) asked why the Belle II recommendation concerning SuperKEKB was not explicitly stated in Rec. 3c. **Murayama** noted the list was lengthy, but there was no real reason.

RECOMMENDATION 4

Arce suggested articulating more clearly what is at stake in a constrained budget scenario. Figure 2 provides a nice breakdown, but the Rec. 4 text seems less clear. **Heeger** agreed that R&D, theory, and computation were critically important for the future.

Chivukula expressed concern that as costs for projects or other parts of the budget escalate, research funds would be pressured or even sacrificed. Could language supporting research funding under all circumstances be added? **Murayama** noted the importance of maintaining balance; even in the less favorable budget scenario, research must be maintained at the current level and any reductions should be proportional. **Heeger** reminded all that Rec. 1 encourages agencies to manage the current costs of projects.

Newman queried whether the potentially large adjustments in the research budgets that support a living wage for postdocs were considered. **Heeger** acknowledged these increases could have a large impact on personnel and how research is supported. These issues are under active discussion across the nation and typically handled at the university level. P5 was concerned but did not feel able to include specific factors.

Chivukula noted SC has voiced the intention to have a high level of graduate student support. This is an important budgetary consideration. **Heeger** concurred, pointing out there are real implications for budgets and grants, but the impact on the field and workforce is yet to be seen. This is a challenging issue that is beyond the scope of P5. **Murayama** referred to §7 language on p. 106 regarding living wages and supporting students with caregiver responsibilities, adding the matter was part of discussion and highlighted in the report.

O'Shea (chat) pointed out there is no agreed upon definition for 'living wage.' The amount can vary considerably depending on family composition. Did P5 have a specific/ actionable meaning in mind, and does that specific meaning differ from how DOE currently thinks about wages? University practices vary widely; language in the report requiring a specific wage based on a defined calculation would go a long way to supporting students and early career scientists. **Esquivel** (chat) requested elaboration on why a defined calculation could not be included. **Heeger** reiterated the statement from §7, agreed this is important and P5 is supportive of the effort, but this matter does go beyond the scope of what P5 could address.

RECOMMENDATION 5

Chivukula indicated "accessibility" is an area of concern for the community and is included in the narrative but does not appear directly in any of the recommendations. **Heeger** noted accessibility as important but not spelled out explicitly. **Demers** pointed out dependent care and accessibility were mentioned in Rec. 5b.

Schellman observed the importance of enhancing and preserving pathways into technical careers for non-physicist technical staff at laboratories, particularly at entry-level. **Heeger** remarked this is included in the narrative but is a complex and broad set of issues.

Giblin commented on the strategic academic partnership programs, noting a desire for a specific commitment to support institutions that have not always been represented by DOE funding, like HBCUs or HSIs.

An attendee encouraged including the word "diversity" in the presentation slides. Encouraging a broader set of universities to participate in HEP programs will likely require funding. Current HEP institutions should work with smaller institutions on projects to help create more diversity in the field. **Heeger** indicated Rec. 5b talks about broadening engagement in HEP through partnerships and other new programs with efforts underway to engage a broader set of institutions. P5 endorsed broad engagement and made it part of the Area Rec.

An attendee suggested the creation of new positions to develop high-quality training to assist scientists who support traineeships. QuarkNet as an example of providing such resources. Rethinking the funding model for technical staff is necessary to allow "tinkering" and early-project work for both lab and university personnel. Currently, staff must be funded by existing projects, leaving little flexibility to assist in the development of future research avenues. **Heeger** observed the report tries to make a strong case for investments in technical staff for R&D and research. Rec. 5c points out the importance of professional involvement by non-physicists for work-climate studies. **Sanchez** reminded the group many questions being raised are answered in the text of the report. **Cranmer** agreed and suggested looking at §7.2.

Bagger (chat) advised looking at the Nuclear Science Advisory Committee (NSAC) Long-Range Plan which did a great job of analyzing and discussing workforce development and properly supporting students and postdocs. APS stands ready to partner on workforce issues. **Heeger** acknowledged the comment with thanks.

Hansen (chat) asked why the suggestion to bring on experts, such as organizational psychologists for work-climate studies, was not included verbatim in the recommendations. **Heeger** remarked professional associations should spearhead field-wide work-climate investigations. **Demers** observed that report recommendations require the narrative to support and explain implementation. Snowmass was very helpful with respect to workforce training issues, and P5 was grateful to be able to rely on that work. Attempts were made to calculate living wages but required information the committee did not have. One way to protect workforce development was to make sure project recommendations were done responsibly. **Sanchez** read narrative text from p. 106 on studying the work climate of the field. **Soares-Santos** suggested making explicit reference to narrative sections in the recommendations.

RECOMMENDATION 6

Okada requested additional information about the panel described in Rec. 6. **Murayama** explained the panel would be formed and charged by a funding agency to develop a recommendation for the Higgs factory. The U.S. should engage with Future Circular Collider (FCCee) and International Linear Collider (ILC) design and feasibility studies. Section 6.5 provides more detail.

Holmes wondered when the Rec. 6 panel would convene and about the number of decisions anticipated. **Flaugher** thought a suggestion to form a panel sooner would allow for more informed decision-making and the chance to be proactive. **Murayama** clarified Rec. 6 was formulated to leave details to the funding agency. The agency might decide to use a single panel

for all three points or one panel for each and would have discretion on when to form a panel on which subject. The panel would decide the level of involvement and engagement in a Higgs factory, which would go further than the involvement in a study for an offshore Higgs factory.

Bloom referenced the founding language of P5. Could P5 serve in place of a Rec. 6 panel? **Murayama** noted HEPAP, as a standing committee, is subject to open meeting requirements; this may deter discussion of sensitive issues. Creating a panel for a given investigation allows private discussions. **Schellman** opined the P5 process for long-term plans is truly deliberative, considers many factors, and is coherent and focused. **Murayama** shared P5 began on a more frequent, smaller scale. The first "modern" P5 panel created the three frontiers. The panel in Rec. 6 does not address all three frontiers and is being recommended for a specific purpose.

Toro reflected the elements in Rec. 6 could be relevant on different timescales. **Murayama** revealed the hope all would occur around 2025-27, which is what led to the recommendation for a single panel. If there are delays, a single panel for each element may be more sensible. **Palmer** agreed the timescales are not that far apart as best as can be predicted.

Gottlieb (chat) appreciated that the P5 report recommends support for critical efforts in HEP that do not necessarily qualify as projects, such as computing and theoretical physics.

Soares-Santos was curious if Rec. 4g was meant to be in Rec. 6, noting the wording for the Fermilab accelerator complex improvement planning appears in multiple places. **Murayama** acknowledged a struggle to make the flow clear. The recommendations couple with each other.

Wright (chat) asked if an "offshore" Higgs factory meant on land in another country or situated in the sea. **Cyr-Racine** (chat) clarified it meant situated outside the U.S.

Dragone (chat) sought clarification on the funds in Area Rec. 6, noting a difference between the slides and the report. **Yu** (chat) explained Rec. 6 advises a $4M increase per year for five years, a total of $20M. **Merkel** (chat) responded "the recommendation for detector R&D is to increase the budget to an additional $20M per year, over a period of a few years."

An attendee (chat) pointed out the report consistently states, "All town halls offered live captioning and American Sign Language interpretation." This is not a completely accurate description. In the LBNL town hall, the unqualified interpreter was only on Zoom, so in-person participants with needs did not have equitable access to the town hall compared with other participants. In the SLAC town hall, the captioning was not available for about two hours at the start. Offering access is not the same as ensuring equitable access. Is this phrasing going to be kept like this? **Mahn** (chat) appreciated the comment and added it to the discussion notes to determine the best way to clarify this in the report.

Seidel dismissed the meeting for the day at 4:35 p.m.

Friday, December 8, 2023

Seidel called the meeting to order at 9:00 a.m.

CONTINUED DISCUSSION OF THE P5 REPORT

ALTERNATIVE BUDGET SCENARIOS (§§2 and 8)

Toro requested explanation of the guardrails against erosion of research funding for ASTAE/ smaller scale experiments in the less favorable budget scenario. **Murayama** emphasized that in all cases, research must be supported at the current level. Any reductions should be proportionate. The budget for smaller projects is never dropped to zero. Rec. 1 includes language emphasizing the importance of a broad and balanced portfolio and careful management of costs in major projects. **Palmer** added even the less favorable budget scenario recommends maintaining 60% of ASTAE funding.

Tanedo requested an example of guardrails from agencies and how this might differ from what is currently done. **Murayama** felt this would be better answered by agency personnel. **Procario** referred to LBNF/ DUNE, which was initially treated like a smaller project rather than a major part of the budget for the field. Additional agency personnel were added, increasing the oversight and enabling staff to stay better informed.

Flaugher would have expected a bump in operations costs when LBNF/ DUNE and PIP-II come online. Was there any kind of expert analysis for the operations objectives, and where did operations cost estimates come from? **Murayama** explained before LBNF turns on, NuMI Off-axis ν_e Appearance (NOvA) would turn off, so there would not be a big increase. The costs came from projects as well as the internal cost committee review. **Palmer** noted project proponents provided an incremental cost for an experiment as it began the commissioning and operations phase. These incremental values may help show the overall level and offsetting effects, but all estimates have error bars. The analysis verified the estimates roughly fit.

Bloom sought additional information about incremental values and posited DUNE costs would exceed those of NOvA. **Palmer** explained incremental analyses identified the operational cost differential when, for example, LBNF/ DUNE operations commence versus what was in the operations budget previously. Instead of looking at all Fermilab costs associated with running accelerator experiments, examining incremental operational costs to run, e.g., detectors (such as the actual hardware needed to deliver a particular beamline), is more accurate. These estimates were crosschecked against overall Fermilab costs to prevent major mistakes. Regarding DUNE versus NOvA, accelerator operations dominate detector operations. If one examines the costs to run DUNE versus NOvA detectors, a big ratio results, but there is a large underlying denominator, so transitions are not as noticeable as might be anticipated.

Anchordoqui requested a definition of a favorable budget. The less favorable scenario is very well-defined. Is it possible to put an upper bound on the meaning of "more?" **Murayama** explained the panel was not given a concrete blue sky budget scenario and provided a menu of choices for what can be done with additional resources depending on how much extra money is provided. One billion and beyond was the maximum amount considered for large projects.

Arce wondered if correlation of risks across projects, such as changes in the cost of energy or materials, that might affect many experiments at once were considered. **Murayama** noted the cost committee looked at projects individually and assigned some project-specific risk factors but did not consider correlations among projects.

Newman raised advocacy as an important part of maintaining or increasing budgets. There are larger factors at play affecting the field and workforce. A community-wide strategy is

needed to engage Congress in the spring. **Murayama** said specific dollar figures were included in the Area Recs. to indicate how much money is needed to maintain U.S. leadership. The intent was to be prescriptive and emphasize that research and the size of the community must be maintained. 2023 dollars were used with the assumption that support will increase with inflation with an end goal of more evenly balanced project funding at the end of 10 years.

O'Shea (chat) observed operations costs look flat for the 10-year period and wondered if this was actual or a result of the visualization. **Murayama** said that although all projects discussed in the recommendation should be accounted for, the amount is more or less flat. Many issues discussed would decrease in the less favorable budget scenario, including project budgets.

Cooley asked if SNOLAB was envisioned as an offshore facility. **Murayama** conceded SNOLAB is considered offshore for two reasons: 1) Expansion and outfitting of the caverns in South Dakota will be an expense and the greater cost burden is borne by the country in which a given experiment is located; and 2) Shipping G3 dark matter experiments offshore to Canada would save money and is suggested in the less favorable budget scenario.

Apollinari noted there were few major accelerator projects included in this report. In the less favorable budget scenario, accelerator projects proposals look like they are reduced, severely decreasing potential contributions. An extreme extrapolation might be that accelerator facility leadership will be diminished. Should this be brought up explicitly in §8.3? **Murayama** referenced §6.4-6.5 which address the loss of U.S. competitiveness in accelerators and agreed to see if this would be appropriate to add to §8 as well.

Denisov questioned the lack of specific R&D funding for medium-scale ($50M-$200M) projects in the most favorable budget scenario in Fig. 2. **Murayama** suggested if some projects are eligible for ASTAE funding with a reduced scope, perhaps the letter "N" can be changed to "A" to indicate this. **Heeger** agreed it would be possible to clarify the table but not change the intent. The panel felt the recommendation for a small project portfolio for ASTAE was important enough to not recommend other smaller projects under certain scenarios. **Anchordoqui** agreed and supported clarification.

VISION FOR THE FUTURE (§§3-5)

Toro wondered about the process for DOE projects between the ASTAE cap of $20M and the smallest standalone projects at $60M. **Murayama** explained those projects would have to individually go through the CD process.

Schroeder queried why ultrahigh-energy cosmic rays (UHECR) were not mentioned when the Snowmass Community Frontier 7 (CF7) white paper recommended continuing operation of the current generation of UHECR observatories while doing R&D for the next generation. **Murayama** clarified these were outside the lens of particle physics and what P5 could speak to. DOE does not support this area; NSF does, although this area falls at the border of the field of particle physics.

Shi (chat) observed the report does not specifically mention a possible higher energy neutrino beam dedicated for tau neutrino appearance at the DUNE Far Detector. **Murayama** acknowledged this as an interesting option, but it was not discussed as it was unique to DUNE and not considered to be within the 10-year P5 term. **Mahn** recalled DUNE was mentioned in the 20-year vision section, leaving the door open to explore these capabilities in the future.

Gatto asked why the Rare Eta Decays To Observe new Physics (REDTOP) experiment was not mentioned. **Murayama** explained this was an offshore experiment and not discussed.

Malik raised the issue of risk factors in international collaborations, e.g., the conflict in Ukraine, where the U.S. might have to unexpectedly pick up additional responsibilities. **Murayama** indicated this would be project-specific and was not examined individually.

White wondered if the possibility that linear colliders could go beyond 350GeV earlier was considered. **Murayama** explained P5 tried to remain neutral on the question since beyond 350 GeV is unique to ILC and not possible for FCCee. The panel described in the report would be well-suited to address this and it should not need to wait until the next P5.

VISION FOR SCIENCE & TECHNOLOGY (§6)

Toro queried if ASTAE is rejecting the model of targeted solicitations. If not, perhaps a clarification would be helpful. **Heeger** shared P5 tried to provide a framework for a recurring program with a structure to solicit and evaluate proposals and support initiatives without being too prescriptive. Program implementation is up to DOE; there could be targeted or broad calls. **Sanchez** commented there may be opportunities in the next 10 years that are not evident now. To harness these and allow planning, an open and predictable program is important.

Giblin liked how the report talked about a specific DOE funding recommendation for theory without getting into specifics. Why was there no analogous section for NSF? **Murayama** clarified P5 did not have numbers for the NSF theory budget and did not feel comfortable addressing this. Specific recommendations for theory support were made for universities because there was clear evidence of the need for additional support.

Van de Water (chat) observed much of the computational theory for high energy physics is done at national labs; it would have been nice to see a similar statement about increasing funding for DOE national labs. Maintaining lab theory funding (which is effectively cut every year because of inflation) will not be adequate to support the computational theory needed for the current and planned experimental program. The apparent discrepancy between the lab theory funding information P5 received from DOE and what has been happening in practice would be worth understanding before the report is finalized. **Murayama** noted the plots are all in 2023 dollars, so they do account for inflation; the intent is the level of support will rise along with inflation. University theory groups were specifically mentioned due to a sense of alarm regarding the erosion of funding there. The panel will investigate any apparent discrepancy between the data received and actual practice. **Carena** agreed the erosion of university theory funding has been much higher but emphasized the flat-flat funding (no compensation for inflation) in lab theory over the past ~10 years. It may be helpful to clarify that “constant funding” actually means no increase for inflation and thus a decrease for 10 years. **Heeger** was grateful for the comments and hoped it was clear that the report absolutely supports and sees the value of theory.

Chivukula observed the Area Recs. are quite important and thought they would benefit from an elevated profile and/ or a more impactful name, like “crucial investments.” When advocating for funding, it is important to tie this investment to a return, like investment in the future or expanding the boundaries of knowledge. **Quinn** (chat) suggested "Capability Multiplying Investments." **Heeger** agreed these recommendations address a number of important elements in the field to advance programs and careers and together represent a significant investment. The audience is encouraged to examine this like a package of investments. All are

encouraged to read the narrative to enhance understanding as reading the recommendations on their own does not provide the full context. **Thaler** mentioned the intent of the language in Rec. 4 was to be the high-level recommendation one could take to the broader community. Suggestions to make this more useful for advocacy are welcome. **Murayama** noted length was a consideration for leaving out details.

Bhat asked about the timeline for Area Rec. 10 and whether $20M for collider detector R&D and $35M for collider accelerator R&D were included in the budget scenarios. **Heeger** stated in each Area Rec., target numbers of increases per year were included in the budget profile as well as a built-in ramp-up period, noting the increase to $20M is in $5M increments per year. **Palmer** clarified any number stated was fully included in costing estimates and generally assumed an as early as possible start, with the five-year ramp-up starting as soon as the next round of financial planning. Both the Higgs factory and Multi-TeV R&D are part of the collider R&D package, so the program will need balance among priorities to achieve the goals. **Murayama** indicated some areas must ramp up more quickly than others, referencing Fig. 1.

Bhat requested an explanation of the conditional yes in the test facilities and demonstrators row in Fig. 2. **Heeger** replied R&D is starting, but a panel review is needed before investing in demonstrator facilities. **Palmer** reminded the group there are a number of asks for potential upgrades that all need clearer preparation and clearer decision points. As time passes, information to make well-informed decisions should become available.

Bhat echoed the concern related to high-energy accelerators and the danger of losing a leadership position and competitiveness, with particular interest in Accelerator Complex Enhancement Booster Replacement (ACE-BR) and ACE-MIRT R&D. **Palmer** indicated the accelerator community must undertake a significant investment in preparations and planning to make solid decisions moving forward. Specifically, regarding ACE, the panel was not in a position to make a decision and deliberately put in a later decision point when there should be an updated plan. **Heeger** emphasized targeted R&D increases on the accelerator and collider side and support of the rapid development of ACE-MIRT, as well as the task to develop a plan for the evolution of the Fermilab complex.

Thaler clarified the concern was related to §8.3, the less favorable scenario, not what is being recommended in the baseline scenario. **Heeger** agreed the less favorable scenario was disquieting but noted the long lead time for MIRT allowed for some work.

Malik wondered if costs for future related work could be reduced if accelerator R&D could be expedited. **Heeger** demurred on technical matters. There is currently no design, no scope, and no cost estimate to use as a baseline for a demonstrator and test facility. Workforce limitations regarding feasibility and the rate at which progress can be made on R&D play a role. **Geddes** referenced §§6.4 and 6.5 as pertinent; further term accelerator projects are the biggest lever for colliders at the 10-TeV-pCM scale or at that of other machines. Synergy of general R&D with collider R&D is designed to address this.

Prestemon requested an explanation of the intent behind the Test Facilities portion of the GARD row in the bottom section of Fig. 1. **Geddes** explained this was a way to incorporate multiple components (here, R&D and test facilities) of a portfolio while minimizing the number of lines in the table; details appear in the text. **Palmer** added that the various transitions were incorporated in the budget envelopes.

Bloom questioned why Area Rec. 20 (p. 102) was directed to HEPAP and not an agency, quoting "HEPAP, potentially in collaboration with international partners, should conduct a dedicated study aiming at developing a sustainability strategy for particle physics." **Heeger** responded some groups in Europe are looking at sustainability. This is an opportunity for HEPAP to look at an important area which has not yet seen a U.S. study. **Murayama** noted the community must understand the issue before an agency can take action.

Seidel dismissed the meeting for a break and reconvened at 10:48 a.m.

Roe (chat) wondered why Accelerator Controls Operations Research Network (ACORN) at Fermilab is only briefly mentioned in the report despite having received CD-0 in 2020 and a cost range of $100M-$140M. Was this included in the budget planning? **Murayama** explained, per the charge letter, safety and infrastructure maintenance, like ACORN, were outside of P5 purview. **Thaler** referenced the charge letter and confirmed. **Palmer** noted ACORN was included in the budget analysis.

Holmes noted the color gradation of the timeline for Multi-TeV (Fig. 1) implies there is no investment in the early years. Is there additional guidance for the accelerator portion of the project as there is for detector R&D in Area Rec. 10? **Murayama** indicated all gradations are meant to be gradual, but begin in 2024, so white space may not be indicative of what is described in the text. **Geddes** confirmed the report text does not indicate a specific percentage distribution for accelerators. **Palmer** added there are multiple accelerator options under consideration creating a dynamic situation. Flat splits are inappropriate.

Newman noted the level of detail in Area Recs. seemed more suited for implementation than advocacy; high specificity could limit the effective time of suggested actions. Explicitly indicating this is a snapshot and will require adjustment may be helpful, as could language for support of the whole research enterprise. **Thaler** remarked the charge did not include community advocacy. **Heeger** appreciated the points raised, deferred further discussion to the panel, and affirmed the recommendations. **Chivukula** suggested reworking the first sentence in Rec. 4 and felt advocacy for the field could be woven into the report framework.

Raaf (chat) questioned how the inability of DUNE MCND to make definitive measurements of CP violation for a large fraction of values of DeltaCP in the less favorable budget scenario can be seen as a successful outcome for DUNE overall. It seems inconsistent to cut MCND completely given the statements earlier in the report about how it is critical to DUNE's success; could it be recommended as R&D in Fig. 2 or could a statement be included on the length of any deferral? **Heeger** acknowledged choices had to be made. Not everything could be implemented in the less favorable scenario. In the case of DUNE, the near detector is maintained and other work might be able to be funded in the future.

Pedro asked if detector simulation tools and generators for computational theory were covered by Area Rec. 18 (p. 97) and how the panel saw the $4M in Area Rec. 17 narrative being divided. **Cranmer** responded that a more general statement was agreed on rather than listing specific software or tools. Area Recs. 17 and 18 are meant to be read together: 17 points out the need for software and computing professionals in general, and 18 is more targeted to software

tools and infrastructure. **Heeger** added while individual numbers look small there is a need for balance overall.

Akerib observed development costs do not appear to be explicitly called out for some projects in Fig. 1, i.e., there is white space. **Heeger** explained where no explicit pre-project R&D numbers were provided, they were not shown. **Palmer** further clarified current funding levels for projects remain embedded and only when there was an explicit callout to ramp up were colors added. This could be mentioned in a footnote.

TECHNOLOGICALLY ADVANCED WORKFORCE (§7)

Tanedo thanked the panel and acknowledged DOE and NSF for explicitly including diversity, equity, and inclusion (DEI) in the charge. Calls to reduce barriers to entry and inclusion of social science to inform activities are appreciated.

GENERAL DISCUSSION

Tanedo revisited the suggestion to change the visual language in the Massive Timing Hodoscope for Ultra Stable Neutral Particles (MATHUSLA) and FPF lines in Fig. 2. **Tanedo** said changing the black boxes to gray and replacing "N" with an "A", which will take the place of what is now represented with a hashtag, will make the message of the figure more consistent with the intent of the report.

Toro affirmed an outstanding job by the panel and noted that some copy editing is still needed. **Murayama** clarified the entire document has not been copy edited.

Arce felt the language in §7 related to recognition and accessibility was unclear that the words were being used in a technical sense and it was important to be sure the reading supported the intended meaning. **Heeger** shared the panel will be re-reading those statements to be sure they are properly captured.

Tanedo commented first-time readers might believe there is an implied hierarchy between Recs. and Area Recs. Section 1.6 is good place to include a brief explanation.

Bloom raised implementation of the report's recommendations, perhaps by monitoring through annual reports from agencies and comparing to the Fig. 1 schedule. **Seidel** confirmed this report goes to agencies. HEPAP can request agencies provide annual reports. **An attendee** remarked the agencies ask HEPAP to review progress made on the P5 report every five years. **Thaler** verified a HEPAP meeting occurred in 2019 regarding the 2014 P5 progress, with a report issued in 2020.

Newman referenced a COV report from December 2020 that included a recommendation that the community be involved if there are significant changes to P5. A sub-panel was proposed to make community involvement possible.

Denisov asked when the report will be considered final. **Heeger** noted a town hall discussion will take place at Fermilab on December 11, 2023, and expressed the intention to finalize the report in mid-late December.

Schellman was curious how much open access to, for example, data catalogues, was discussed within the collaboration. **Heeger** cautioned against being too prescriptive about open data while the landscape is rapidly evolving. **Cranmer** observed the international aspect makes this challenging, but now is time to embrace efforts as much as possible. This is easier in some areas, like large collider experiments, than others, like the cosmic frontier, where there is a lack of infrastructure.

Pereverzev (chat) raised the possibility of more focused interactions with other disciplines in resolving the technical problem of excess backgrounds. **Heeger** noted the comment.

Seidel dismissed the meeting for lunch at 11:36 a.m. and reconvened at 1:30 p.m.

PANEL VOTE ON THE P5 REPORT, Sally Seidel

Twelve eligible members of HEPAP voted on the report. The report was approved unanimously and unconditionally.

COMMUNICATIONS WITH THE PARTICLE PHYSICS COMMUNITY, Sekhar Chivukula

The physics community should be proud of its involvement in the P5 planning process and Snowmass events. Several individuals are appreciated for their support of the Community Summer Study; the Snowmass 2021 meeting was held at the University of Washington-Seattle from July 17-26, 2022. Snowmass proceedings are available online: https://www.slac.stanford.edu/econf/C210711/.

Communication during the P5 process was challenging because of the need to reach the entire community, not just APS DPF. DPF worked with P5 leadership to advertise panels, including town halls at LBNL, FNAL/ANL, BNL, SLAC, and virtually. Messages were distributed via APS DPF email announcements, the DPF newsletter, and a Snowmass list serv and Slack channel. An initial message was shared February 8, 2023, and approximately monthly messages from the P5 group were posted.

An informal rollout committee of stakeholders was convened to keep the community engaged and informed. A Dear Colleague Letter sent November 8, 2023, advertised the December 11 town hall and advised that endorsements would be solicited for the letter of support. The APS Media Office helped distribute a media advisory about the HEPAP meeting and provided an embargoed press release drafted and distributed to limited media, labs, and universities. APS News will publish an article as well as an opinion piece.

A hybrid town hall will be held on Monday, December 11 at Fermilab and will include a presentation by Murayama and Heeger, a Q&A with questions gathered pre-meeting, DOE and NSF comments, and an open mic Q&A. At present, >1,200 have registered to attend.

An endorsement letter is being drafted by the rollout committee with a planned release as a Google form by December 15 to collect signatures until January 31, 2024. A virtual town hall will be held in mid-January, and a visit to Capitol Hill is planned for early 2024. An official social media hashtag was not selected in advance.

DISCUSSION

Cranmer (chat) noted #P5report is in use.

GENERAL DISCUSSION

None.

Seidel adjourned the meeting at 1:46 p.m.

Respectfully submitted on January 3, 2024, by Ann B. Gonzalez, JD, MSI,
Science Writer for the Oak Ridge Institute for Science and Education (ORISE)