

Fermilab Physics Advisory Committee Fall 2025

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Executive Summary

During the introductory executive session, the FNAL Interim Director, Young-Kee Kim, presented a report on the status of research at the lab as well as plans for the future. The PAC was impressed to hear that in the fiscal year 2025 the accelerator complex delivered a record number of protons on target to the Booster Neutrino Beam (BNB). The PAC commended the lab for publishing the final results of the muon $g-2$ value with record precision, which challenges the developments in theory. The PAC was pleased to hear that the Directorate established an AI/ML coordination office to oversee and facilitate the relevant activities in the lab and to identify the most innovative and promising avenues of research in this field. The LBNF/DUNE project remains the highest priority project at the lab and drives the development of the accelerator complex, with PIP-II on track to be completed at the end of CY2029.

The lab continues to contribute to the search for dark matter in a broad range of masses, with emphasis on developing new quantum sensing technologies. This profits from the impressive developments in the quantum computing and quantum sensing programs. The theory groups at the laboratory provide tools for, and motivate, the experimental program while pursuing novel and innovative developments, e.g., in algorithms for quantum computers.

Progress has been achieved in the construction and assembly of the Mu2e project, with a realistic window of opportunity to collect a significant amount of data before the long shutdown. The need to repair and maintain the aging infrastructure of the present accelerator complex remains a worry. As for the long-term plans, the lab is engaging in the muon collider project in alignment with the recommendations of P5 and the National Academies Report. The PAC was particularly pleased to hear the actions taken to facilitate access to the lab to visitors is bearing fruit.

The new chair of the LBNC, Prof. Brigitte Vachon, summarized for the PAC the latest findings of the committee, confirming substantial progress on many fronts of the US LBNF/DUNE project, previously mentioned in the Director's report. DUNE is advancing all aspects of operational preparedness in parallel with US LBNF/DUNE project execution, which serves to minimize any future potential delays to science. The collaboration is transitioning into the construction phase of the far detectors. The review of LBNF beamline TDR was completed and the final report submitted to Fermilab Directorate. The near detector is progressing through the preliminary design phase and preparation of the relevant report. Strategic planning is ongoing to develop far detector modules 3 and 4 and a more capable near detector for Phase-II.

The PAC heard the report on the status and plans for the Fermilab accelerator complex. In addition to the highlights on the great performance of the BNB and the initial commissioning of the Mu2e beamline, the PAC was told that the main injector (MI) will remain off until the power transformer situation is resolved, with expected restart in the fall of 2026 at reduced power. Further maintenance work will include the repair of heat exchangers and replacement of MI dipole magnets, which suffered from water leaks. The steps necessary to increase the MI beam power to 1.2 MW were described, as well as different aspects of the Accelerator Complex Evolution (ACE) program, with a focus on the PIP-II program. Finally, the baseline accelerator operations program was shown, including the LBNF/DUNE ramp-up schedule, which shows first-beam to LBNF/DUNE at the start of FY33.

More details on the progress in the Mu2e project was presented during a dedicated executive session. Significant progress on the detector construction, beamline integration and accelerator was reported. The detector solenoid is still under construction and constitutes the critical path item for data taking, as it is expected to take more than one year from delivery to commissioning. Given the tight schedule, contingency plans were evaluated and performance compared to the nominal plan. The favored option consists of two months of operation with 50% beam intensity, partial shielding and veto coverage, and with 100% uptime is expected to achieve a 50-fold improvement over the Sindrum-II results.

The PAC heard presentations on the status and plans of two centers, the LHC Physics Center (LPC) and the Neutrino Physics Center (NPC). The LPC was established more than 20 years ago with four primary goals: maximizing impact in operation, community engagement (with regular events), training and education (CMS Data Analysis School, tutorials, workshops) and providing resources (Remote Operations Center, Tier 1, Tier 3 for analysis). It also acts as an intellectual center for those participating in the CMS detector upgrade program. The success of the LPC may be appreciated by the fact that,

in the last seven years, more than 25% of the CMS publications included significant involvement from the center and that more than 40% of junior researchers hosted by the center secured tenure-track positions. The LPC budget is primarily used to support people, including Distinguished Researchers (DRs), guests and visitors, and Narain graduate scholars. The cut to the research budget of about 50% since 2019 results in fewer DRs, particularly at the senior level, and burdens the LPC residents, who are asked to volunteer in support of the LPC activities. This creates a situation that is not sustainable in the long term.

The Neutrino Physics Center (NPC) was founded in 2016, inspired by the success of the LPC. It operates on three pillars: advancing research, building community and knowledge exchange, and education/training. After strong initial funding from 2016–2018, NPC has faced significant funding challenges. In the period 2019–2024, there was a 3 year funding gap and a year with funding reduced to 30% of previous levels, and there was no new funding this past year. The PAC recognizes the importance of the NPC for hosting the global neutrino community and commended the NPC for being inclusive of smaller experiments and theory alongside DUNE and for their plan to broaden the scope. However, lack of funding threatens the future of the NPC. The PAC recognizes the need to develop a sustainable funding model. As for future plans, a vision was presented mainly for the era of preparation for DUNE running (2026–2030) where the center would remain as a hub for DUNE construction, commissioning and operations, a training center for the next generation of neutrino physicists, and a space for software development, reconstruction and analysis. As for the period of DUNE science, beyond 2030, the PAC thought that the LPC model for the NPC may have to be further developed to take into account the fact that Fermilab will be the DUNE hosting lab. The PAC would thus like to hear a plan that incorporates the DUNE as well as the broader international perspectives.

The muon $g-2$ experiment, after reaching their final measurement of the $g-2$ value with a precision surpassing the original TDR goal, is now embarking on analyzing the collected data to achieve unprecedented sensitivity on the muon EDM and to search for muonphilic DM. The PAC endorsed these plans, especially since the needed computing resources are modest.

The Theory Division has a history of impactful activities and high productivity. It engages in activities that are well-integrated into the experimental efforts at the lab, including contributions to DUNE, LHC, small scale experiments, and future colliders, as well as quantum sensing. It successfully trains a diverse group of postdocs and students and provides a hub for the US particle physics community through leadership of networks (e.g., USQCD, neutrino theory network, etc), a visitor program, and organization and

hosting of summer schools. The PAC commended the theory group for a successful visitor program. Leveraging limited funding through joint RA appointments with universities could bring added value. The PAC also encouraged the division to develop a strategy to enhance AI/ML research integration in HEP theory.

National initiatives in Quantum, AI/ML, and Microelectronics remain key priorities for the lab's program. The PAC was presented with the status and future plans of quantum science at Fermilab, based on the activities of the SQMS center and the Emerging Technologies Division. The PAC was pleased to hear that SQMS and ETD have improved the coordination of their goals and efforts. During the first four years of the SQMS center, 500 individuals were trained, ranging from undergraduates to post-docs and including collaborators hired by partner institutions. Academic partners are in the process of accrediting the courses taught at SQMS center as part of their programs. The statistics on SQMS publications demonstrate FNAL leadership in a large fraction of papers. The SQMS center submitted a proposal for another 5 years of funding, with three large focus efforts, identified as Qubit Coherence, 100-Qudit Facility, and Quantum Data Center prototype with a scalable multi-Qudit platform. The ETD operates a unique suite of quantum testing facilities - LOUD (surface), QUIET (underground), and NEXUS (underground with neutron source and additional shielding) - to study the impact of environmental radiation on quantum devices. A user base for these facilities has been built and is being expanded. ETD has obtained funding for an exciting portfolio of efforts in QIS-for-HEP and HEP-for-QIS via QuantISED 1.0 and 2.0 and funding of the MAGIS-100 project. A base program in QIS-for-HEP is expected to begin in FY2026. The laboratory is actively working on a "quantum strategy" to make optimal use of this funding, as well as of the SQMS developments.

As mentioned in the Director's report, the AI/ML efforts have been reorganized under a single AI Coordination office. Fermilab is active in several areas in which there are unique capabilities or demands in HEP (sensing, low-latency applications, AlaaS/SONIC, HLS4ML, enhanced robustness). Fermilab has also identified opportunities for the use of AI/ML tools in accelerator operations (e.g., READS, APOLLO) and business operations for improving efficiency. Fermilab is responsible for several deliverables of the most recent HEP AI/ML call, which highlights curation of data for AI/ML and industrial partnerships. The ability of the AI Coordination office and AI/ML efforts at Fermilab to respond to the rapidly evolving funding landscape is commendable and reflects the advantage of having a single group under which these efforts are organized.

The executive session dedicated to the review of the Fermilab long-range planning process started with a summary of the NAS report. The NAS report presents a 40-year

vision for Elementary Particle Physics in the unconstrained funding scenario. The highest level recommendation stated that the US should host the world's highest-energy elementary particle collider around the middle of the century, with the muon collider specifically mentioned in this regard. Fermilab established a long range planning (LRP) committee last May, comprising two subgroups: one focused on science and another on business and operations. The PAC was informed about the work of the science subgroup. Significant effort has gone into ascertaining the needs for ongoing science and upgrade projects. A conclusion on this study is expected soon. The activities of the US Muon Collider Collaboration (USMCC) were reported to the PAC. The core activities include preparation for a mid-term P5 review, conceptual design of a US-based ionization cooling demonstrator, and a long-term plan for FNAL. In parallel, the lab leadership established an external expert study group to review the accelerator development needs for a Muon Collider. The group will build on existing USMCC and International Muon Collider Collaboration (IMCC) R&D planning documents, critically evaluating them to identify areas of alignment, overlap, and gaps that require further attention. It is expected to prepare a report for the FNAL director in view of the mid-term P5 review. The PAC endorsed the presented unprioritized draft recommendations and believes it is critical to strengthen research, prepare for a muon collider demonstrator, and modernize laboratory infrastructure (including a new test beam facility) and its systems. The ionization cooling demonstrator was highlighted as a major milestone towards the Muon Collider. A sustained expansion and training of the expert accelerator workforce is a prerequisite for realizing the demonstrator and, ultimately, the collider.

Status and plans for the Fermilab's accelerator complex

Charge: We ask the committee to review the status of Fermilab's accelerator complex, with particular emphasis on progress with delivering 1.2 MW of beam to DUNE(ACE1.2).

Findings:

- The Booster neutrino beam (BNB) ran well in FY2025, with a record number of protons delivered on target.
- The commissioning of the beamline for Mu2e proceeded well.
- The Main Injector (MI) beamline remained off and will remain so until the power transformer situation is resolved. The expected restart is in the fall of 2026 (at reduced power).
- Further maintenance work carried out included the repair of heat exchangers and replacement of MI dipole magnets, which suffered from water leaks.
- The steps necessary to increase the MI beam power to 1.2 MW were described and key instrument challenges were pointed out.

- The different aspects of the ACE (accelerator complex evolution) program were presented with a focus on the PIP-II program. The funding levels expected for different parts of the upgrade program were shown.
- Finally, the baseline accelerator operations program was shown. The schedule for beam delivery shows a restart of MI beams in the fall of 2026. The schedule included the LBNF/DUNE ramp-up schedule, which shows first beam to LBNF/DUNE at the start of FY33. In the introduction from the FNAL Director, the possibility was mentioned of an earlier start of beam delivery.

Comments:

- The PAC commends the accelerator group for the excellent operation of the BNB as well as the successful first steps in the commissioning of the Mu2e beamline.
- The PAC acknowledges the detailed planning that has gone into the beam power upgrade plan. Some elements in the report elicited worries, such as the advanced age of the Booster magnets. However, it was understood through discussion that the elements highlighted for upgrades were the result of detailed reviews including external accelerator experts.
- The PAC requests that summary reports from such expert review committees be presented at future meetings to aid in judging the status and plans of the accelerator complex.
- The emphasis was on preparations for the PIP-II beam, but the status of PIP-II itself was not presented. The PAC would be interested in hearing a more complete presentation of the preparations for the future complex including the status of PIP-II and Accelerator Controls Operations Research Network (ACORN) projects.
- The commissioning of the LBNF beam up to 1.2 MW is based on conservative estimates from previous experience. The PAC encourages the team to consider ways in which to shorten this period since 1.2 MW is essential for early DUNE physics.

Recommendations:

- A coherent schedule for advanced startup of LBNF/DUNE including the near and far DUNE detectors together with the accelerator schedule should be produced and presented at the next PAC meeting.
 - The accelerator operations, optimization and monitoring has high potential for modernization by AI. The PAC requests a presentation about on-going and planned work in this area.
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Report from g-2

Charge: We ask the committee to review the status and future plans for the g-2 physics datasets, as well as assess the corresponding support needs from the computing.

Findings:

- The Muon g-2 experiment reached a precision of 127 ppb for their final measurement of muon g-2, surpassing the precision goal stated in the TDR. The experimental measurements have captured the world's attention.
- Additional data and improvements in Run 4/5/6 were reported to enable this precision.
- Attention now turns to the muon EDM. An analysis of the Run 2&3 data is close to final. With the full data, they expect to improve the sensitivity by two orders of magnitude, reaching 10^{-21} ecm.
- In addition, the data sets are being analyzed to search for Lorentz violation and for scalar and pseudoscalar (axion) dark matter over a range of masses.
- The experiment requests priority on 2,000 CPU cores (grid slots) in FY26 and 1,000 in FY27.

Comments:

- The PAC congratulates the Muon g-2 experiment and the lab for the achieved precision, which will not be matched for years to come and provides a crucial test of the SM.
- The four-fold uncertainty reduction on the experimental measurement has inspired a large theoretical effort to match the experimental precision, which is continuing.
- The requested computing resources are modest and will predominantly be used for the EDM analysis. Lab leadership has confirmed that the necessary resources will be provided.
- Analysis teams have been identified for the ongoing EDM analyses and dark matter searches, and a plan for review by the collaboration is in place.
- The Muon g-2 experiment is particularly sensitive to muonphilic DM, and the searches are expected to improve bounds from SN cooling for some cases.
- The Muon g-2 data sets are stored on the Fermilab tape system to provide long-term preservation of them.

Recommendations:

- The PAC endorses the plans of the Muon g-2 experiment to leverage the existing data sets and pursue improved sensitivity to the muon EDM and searches for DM.
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Report from the Neutrino Physics Center

Charge: We ask the committee to review the status and future plans of the Fermilab Neutrino Physics Center (NPC)

Findings:

- The Neutrino Physics Center (NPC) was founded in 2016, inspired by the success of the LHC Physics Center (LPC). It operates on three pillars: advancing research, building community and knowledge exchange, and education/training.
- After strong initial funding from 2016-2018, NPC has faced significant funding challenges. In the period 2019-2024, there was a 3 year funding gap and a year with funding reduced to 30% of previous levels, and there was no new funding this past year.
- Using residual funds, the NPC was able to host 16 visiting scholars this year with a mix of international and domestic participants, albeit at limited funding levels.
- The NPC also runs education programs and community-building activities, such as the Neutrino University and seminar series as well as the very successful Neutrino Summer School, which hosted 100 participants this past summer.
- A vision was presented for the DUNE era (2026++) where the center would serve as an intellectual home base for neutrino scientists, a hub for DUNE construction, commissioning and operations, a training center for the next generation of neutrino physicists, and a space for software development, reconstruction and analysis.
- Physical space has been identified for NPC meeting and social areas.

Comments:

- The PAC recognizes the importance of the NPC for hosting the global neutrino community, including a program of fellowships, training, intellectual exchange, and community-building activities.
- The PAC commends the NPC for being inclusive of smaller experiments and theory alongside DUNE and their plan to broaden the scope.
- Lack of a funding model threatens the future of the NPC. The PAC recognizes the need to develop a sustainable funding model.
- The NPC's role in the so-called DUNE era has two distinct phases: preparing for DUNE running (2026–2030) and DUNE science (2030–onward). Plans presented were appropriate for the first phase.
- Long-baseline experiments face the challenge of multiple sites, and the NPC has the potential to alleviate this by leading activities at both sites.
- The PAC would be interested in hearing from DUNE on their interaction with and expectations for the NPC.

Recommendations:

- The PAC encourages the laboratory to identify a sustainable funding model that maintains the intellectual breadth of the NPC and also has a path for growth into the DUNE era.
 - A plan for the evolution of the NPC from the pre-DUNE era into the DUNE science era, incorporating the DUNE perspective, should be presented.
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Report from the LHC Physics Center

Charge: We ask the committee to review the status and future plans of the Fermilab LHC Physics Center (LPC)

Findings:

- The LHC Physics Center (LPC) was established more than 20 years ago with the goal of having a critical mass of physicists actively engaged in the CMS experiment physically at the same location on this side of the Atlantic.
- It has 4 primary goals: maximizing US impact in CMS physics, operations, and upgrades, community engagement (with regular events), training and education (CMS Data Analysis School, tutorials, workshops), and providing resources (ROC, Tier 1, Tier 3 for analysis).
- Metrics to quantify the center's success have been established in the past and include the number of publications with contributions from LPC authors, which show that they were main contributors to 25% of the CMS publications in the last seven years. Other measures of success include the number of events and workshops hosted at the LPC and the high rate (42%) of LPC junior DRs securing tenure-track positions.
- The number of shifts (tracker, trigger and DQM) taken at the Fermilab Remote Operation Center (ROC) has increased and now includes DAQ shifts scheduled primarily during the CERN night, an indication of the robustness of the Fermilab ROC.
- The LPC budget is primarily used to support people, including Distinguished Researchers (DRs), guests and visitors, and Narain graduate scholars. The reduced research funding — 50% compared to pre-pandemic levels — primarily affects the number of DRs who can be supported and significantly restricts the number of senior DRs.

Comments:

- The PAC recognizes the unique role the LPC plays for CMS and commends the center leadership for their continued success. The LPC has become a model for other centers, including the NPC or the ROCs in other CMS Institutions.
- The large number of Distinguished Researcher (DR) applications in 2025 compared to the previous years is a measure of the revival of the center post-pandemic.

- The PAC notes that the cut on research budget by about 50% since 2019 results in fewer DRs and burdens the LPC residents who are asked to volunteer in support of the LPC activities. This is not sustainable in the long term.
- The improved site access had a beneficial impact on the center, but some challenges still remain, especially related to onsite housing.
- The PAC notes the plans to keep the center active during the LHC long shutdown 3, e.g., with activities on detector commissioning and Run 3 data analysis.

Recommendations:

- None
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Report from the Theory Division

Charge: We ask the PAC to review the status and future plans for the theory group at the laboratory. The PAC is also asked to review the status of open recommendations from the previous reviews:

1. The Theory Division should develop metrics to quantify the value added of the Division's programs to the larger community. Some possible examples include a running count of papers that use Division-produced software or the number of papers produced jointly with visiting scientists.
2. The PAC recommends that the Directorate and the Theory Division engage with DOE HEP to identify a long term model to support the successful Quantum Theory Department.

Findings:

- The Theory Division comprises 17 staff scientists, 12 postdocs, and 5 JRAs (joint postdocs). It has a history of impactful work and high productivity: every year the division publishes ~130 papers. A sizable number of these papers are coauthored with Fermilab visitors (~50 papers).
- All three departments of the Theory Division engage in activities that are well-integrated into the experimental efforts, including contributions to DUNE, LPC, small scale experiments, and the future colliders group.
- The Theory Division successfully trains a diverse group of postdocs and students. Many past postdocs have moved on to faculty and/or research positions.
- The Theory Division aims to provide a hub for the US particle physics community through leadership of networks (e.g., USQCD, neutrino theory network), a visitor program, and organization and hosting of summer schools.
- Metrics have been developed to quantify the value added by the theory department, as well as its visitor program.
- The Quantum Department successfully secured funding for the next phase following the initial seven years since its establishment. In addition, starting in FY26, the DOE QuantISED program will provide support for "Theory for Quantum

Sensing” via FWP. The new grants and the base FWP support 3.2 staff and 4 postdocs.

- Increasing the fraction of joint RA appointments is being considered as an idea that can help with stretched budgets.

Comments:

- Site access is important to realize the goals of the Theory Division as a hub for US particle physics and recent improvements are appreciated.
- We commend the theory group for a successful visitor program. Expanding the program could bring added value since only a small fraction of the visitors are supported directly by Fermilab.
- We commend the Quantum Theory Department for successfully obtaining funding for the QuantISED 2.0 program.
- We commend the Theory Division for engaging with the DOE HEP theory and QuantISED program managers with the goal of transitioning the Quantum Theory Department from proposal-based support to base funding.
- In addition to helping with budgetary issues, increasing the fraction of joint RA appointments can help both the Theory division itself as well as the particle theory community by guaranteeing the regular presence of the new postdocs at both institutions.
- Since it is a service to the community, it would be useful to assess the extent to which the software developed by the division is adopted within the community and use it to guide future work.

Recommendations:

- We endorse the plan of increasing RA appointments that are joint with universities. We recommend a more structured and strategic plan to pursue such opportunities, including an open call to search for university partners.
- We encourage the Theory Division to develop a strategy to enhance AI/ML research integration in HEP theory.

Quantum Efforts at Fermilab

Charge: We ask the PAC to review the status and future plans of the Fermilab quantum efforts within SQMS Center and ETD.

- The SQMS Center (SQMS 1.0) was funded 5 years ago as part of the National Quantum Initiative Act. A proposal for another 5 years was submitted (SQMS 2.0), and the outcome is expected to be announced soon.
- Close to 500 individuals were trained during SQMS 1.0, ranging from undergraduates to post-docs and including collaborators hired by partner institutions.

- Academic partners are in the process of having the courses taught at SQMS accredited as part of their programs.
- The SQMS 1.0 Center has achieved several of its scientific goals, including realizing SRF cavities with coherence times $>1s$ in the quantum regime, demonstrating coupled qubits controlling up to 20 photons, developing several proposals and experiments leveraging SRF cavities for sensing, and establishing an advanced superconducting materials characterization pipeline for improving superconducting qubits, realizing state of the art coherence times ($>500\mu s$), among others
- Statistics on SQMS 1.0 publications were provided, indicating FNAL leadership of a large fraction of papers.
- The renewal solicitation required the identification of no more than 3 large focus efforts. SQMS 2.0 has identified Qubit Coherence, 100-Qudit Facility, and Quantum Data Center prototype as the 3 focus areas, with a scalable multi-Qudit platform considered the core effort. All three efforts rely on the SRF cavity platform developed as part of SQMS 1.0.
- During year 4 of its previous funding cycle, the center had incurred higher than anticipated expenses, which resulted in funds being redirected to the highest priority initiatives, including reallocating some funds from external partners to internal projects.
- SQMS 2.0 was set up as a tiered partnership structure including 42 partners, ranked from Core to Contributing to Associate. SQMS 2.0 expects to keep about 75-80% of the funds at Fermilab (as opposed to the 50% budgeted in SQMS 1.0).
- ETD has obtained funding for an exciting portfolio of efforts in QIS-for-HEP and HEP-for-QIS via QuantISED 1.0 and 2.0 and funding of the MAGIS-100 project.
- A base program in QIS-for-HEP is expected to begin in FY2026.
- Quantum Testing Facilities: ETD operates a unique suite of facilities — LOUD (surface), QUIET (underground), and NEXUS (underground with neutron source and additional shielding) — to study the impact of environmental radiation on quantum devices. A user base for these facilities has been built and is being expanded.
- The open-source QICK platform (both hardware and software) is the most used quantum control system worldwide with 500+ users.
- The Microelectronics Division has ongoing collaborations on cryoelectronics with a number of quantum industry partners, which build on and/or make use of FNAL/HEP expertise.

Comments

- The laboratory is actively working on a “quantum strategy” to make optimal use of this base funding, the incoming QuantISED 2.0 funding, and SQMS developments.
- SQMS and ETD have improved the coordination of their goals and efforts in the past year, which is to be commended.
- SQMS was established to take advantage of Fermilab’s unique accelerator expertise and intends to continue to play a role in bridging QIS and HEP. The

addition of DESY as one of the new partners will be beneficial for this effort. Particle physicists bring important tools that are being used for data analysis and optimization of R&D experiments.

- SQMS is studying multiple related architectures in order to identify which one to pursue for scaling to 100 qudits. They expect to commit to one choice by year 3. The PAC would appreciate future updates on the progress and decision process.
- The PAC commends the recognition by SQMS leadership that clear communication between SQMS and funded partners about deliverables is key to maintaining healthy collaborative relationships.
- The broader scientific context and competitive environment for both ETD's and SQMS's efforts was not provided.
 - For ETD, it was not clear how the current areas of scientific focus were chosen, whereas the areas of technical focus seem readily connected to historical FNAL expertise.
 - The broader context for SQMS's SRF/qudit approach was not provided — e.g. other approaches being pursued, advantages of this particular approach, applications for which this approach is optimal, etc.
- Both ETD and SQMS have successfully involved specific external partners (international, industry, and academic). However, these partnerships appear to be primarily oriented toward FNAL-originated concepts. It is not yet clear how ETD and SQMS will interface broadly to their external communities.
- Statistics on the impact (e.g., citation rate) of both SQMS and ETD research were not provided.
- The transition process from concept/R&D to funded DOE experiment is not clear. In the case of MAGIS-100, serendipitous availability of external resources facilitated the transition to project funding by DOE HEP. Such external resources may not be available in all cases.
- ETD could play an organizing role for the community in pressing for the realization of the ASTAE program, which is the likely path for ETD and SQMS developments to be used to undertake HEP science.
- Quantum at FNAL could help to organize community input on QIS-for-HEP and HEP-for-QIS for the next Snowmass process, which is still some years off but could be seeded with the right workshops.

Recommendations

- The PAC encourages ETD and SQMS to continue to develop a common long-term strategy. Examples of their coordination and its impact should be presented at a future PAC meeting.
- The PAC encourages the lab to explore ways to involve potential partners and user communities in ETD and SQMS activities. Three potential ways include: prioritizing areas of work; identifying applications and uses of their developments and facilities (such as SQMS's 100-qudit SRF facility, QUIET/LOUD, microelectronics); and, user-facility-style access to these developments and facilities where appropriate.

- In terms of demonstrating impact, both ETD and SQMS should: compile and present statistics on the impact of their work, e.g., citation of papers, number of papers in top-tier journals, etc.; and, collect quantitative data on the outcomes and career choices of trainees.
- The lab should apportion ETD base program resources to provide sustained technical support for developments already made available to users, such as QICK.