11/30/2017

Fermilab
Physics Advisory Committee Report
Fermilab, November 16-17, 2017

Executive Summary

The Physics Advisory Committee (PAC) met at Fermilab on November 16 and 17 2017 to consider the progress and strategic development of the Laboratory research program. The PAC also held a very useful preparatory meeting on November 10 with the participation of the Laboratory Management.

The focus-topic of the Fall 2017 PAC at Fermilab was the status and prospects of the LHC program carried out by an impressive team of Fermilab researchers and staff. Fermilab is the hub of the US-LHC activities at the Compact Muon Solenoid. They have a strong tradition of achievement and critical support of the CMS Collaboration in i) Computing & Software (with the Tier 1 as well as software paradigm shifts they introduced which proved timely and critical for the success of the CMS physics program at the LHC startup), ii) detector instrumentation and R&D, (with leadership of the Hadron Calorimeter overall currently and in the past), major contributions in the Phase-I upgrades and critical responsibilities and leadership in the HL-LHC CMS upgrades (on the Outer Tracker, HGC, trigger and DAQ and the fast timing system) and iii) physics research results especially in new physics searches.

The PAC heard presentations from the CMS Fermilab leaders on the general CMS status, the upgrade status, the plans and involvement of the Fermilab CMS group, the physics analysis activities at Fermilab and the critical and unique role of the LHC Physics Center at Fermilab. The PAC also heard the Fermilab CMS group budget analysis, and the envisaged evolution of the Fermilab CMS group.

The PAC was impressed with the efforts of the Fermilab CMS group towards efficiency in resources needed to carry out an extremely impactful and far reaching program upon which rests the entire USCMS commitment to CMS. Fermilab maintains the computing leadership of CMS, supported and leveraged by the Laboratory's efforts, resulting in the high uptime and efficient Tier-1, as well as new efforts on data analysis using advanced machine learning methods. Fermilab's LPC is an incubator of collaboration, new knowledge production, innovation in physics analyses and production of significant physics results. They have positioned themselves strategically in topics of new physics exploration and precision standard model and Higgs physics. The CMS Fermilab group is formally credited with 150 publications/year in the past few years. They plan steady production of physics results in the future. Fermilab's technical infrastructure and focused expertise and engineering resources in silicon and DAQ systems make it ideal for development, testing, assembly and production of major HL-LHC upgrade systems. The success of CMS at the HL-LHC relies on the success of the Fermilab LHC program success. The Fermilab CMS group has core research contributions in the trigger, physics object reconstruction, and analysis of final states and signatures with leptons, jets and b-jets, that offer a broad range of new physics interpretations and standard model measurements. The PAC commends the Fermilab CMS group on their critical roles and productivity and suggests that Laboratory Management requests that the group frames their message of overall impact in a compact and clear quantitative statement presenting their i) added value to USCMS, CMS and Fermilab ii) cost vs. benefit analysis across all areas of involvement and iii) efficiency metrics such as science productivity, impact, optimization of resources, workforce development, leadership and management positions, et cetera – identifying areas in operations, upgrade projects and research. The PAC notes that the Laboratory and the DOE Management be mindful of the fact that the current proposed cuts (most notably affecting the research sector) to the Fermilab/CMS program are not consistent with the science priorities of the HEP program as defined by the P5 report, nor with the commitments that the US has taken on CMS.

In the Fall 2017 meeting the PAC was asked to follow-up on the status of the neutrino program and accelerator scheduling that was reviewed in the Summer 2017 PAC meeting. The PAC was asked to comment on current issues that are important to the success of the ongoing neutrino program and crucial for future planning. In this context the PAC heard an overview and strategy of the expected timeline and results from the NOvA collaboration as a function of beam delivery, both near-term and given PIP-I and beyond, and in comparison with the corresponding projected results from competing ongoing neutrino efforts internationally. The PAC concludes that it is important that the laboratory maximizes the POT for NOvA through an optimization of NuMI beam power, allocated run-time and financial cost, and any risk linked to the accelerator improvement projects. Under the assumption of minimal such risks, ramping the beam power and target capability to 900 kW and minimizing the shutdowns will support optimally the NOvA research program.

The PAC heard on the vital function and impressive results of the Fermilab Test Beam program that serves all HEP frontiers (and beyond) and experiments nationally and internationally. Many examples of the critical impact of the test beam program on current and future HEP projects were presented, including on the upcoming CERN HL-LHC program. The PAC thinks that the very organized and excellently managed operation of the test beam, which effectively mitigates its impact on beam delivery to NOvA, allows this important program to move forward with minimal impact to the NOvA program, and thus recommends sustaining the test beam program at the level requested.

The PAC heard the request for, and implications of, additional physics running for the MINERvA experiment. The collaboration is producing numerous valuable physics results that are unique in their own right and crucial ingredients to the future neutrino research program in term of neutrino interaction models and beam modelling. The PAC is impressed overall with MINERvA's research program and the productivity of the collaboration and suggests that the Laboratory consider positively their request for additional one year run since they would not interfere with the NOvA running plans and would maintain a vital physics results production stream.

The PAC heard the status and progress of MicroBooNE, the first operating experiment of the SBN program, and received a report with detailed answers addressing questions and comments the PAC brought up to MicroBooNE during the Summer 2017 PAC meeting. Significant progress was presented on the November 9 preparatory PAC meeting on understanding detector-related challenges based on the collected data. The PAC learned that the collaboration continues to produce and publish useful detector performance results.

The PAC was informed on the baseline and parallel approaches towards the MicroBooNE reconstruction framework. Associated emerging challenges related to the volume of data as well as the strategy to tune and streamline the computing workflows for expeditious production turnaround – especially of Monte Carlo data – were discussed in detail.

The committee is anticipating precision physics results from MicroBooNE will be produced in time for Neutrino 2018 (specifically, cross section results). Results on track multiplicity are foreseen to be ready earlier, while the hallmark low-energy excess results should be concluded within 2019. The Committee urges the Laboratory Management to assist MIcroBooNE in maintaining, amidst the launch of the SBN era, a vibrant, productive and engaged research workforce so the Collaboration meets their physics research mission. The PAC commends MicroBooNE for their hard work and notes that MicroBooNE is entering a critical year (2018) with a set of well identified challenges and strategies to address them.

In response to the discussion at the Summer 2017 PAC meeting regarding HEP-NP synergy on theoretical neutrino research, the PAC learned about common efforts connected to Fermilab towards improving the understanding and modelling of nuclear physics effects, particularly those effects that are of relevance to the future neutrino oscillation program. The PAC suggests organizing at Fermilab a joint HEP-NP "Basic Research Needs" workshop to fully explore the physics synergies and develop an effective model of cross HEP-NP collaboration that would serve the future neutrino program.

The PAC heard a very informative presentation on LBNF and DUNE progress since the Summer 2017 PAC meeting and in response to the issues raised at that meeting. Major milestones have been met on LBNF construction including a very well attended ground-breaking ceremony and excavation planning for 2018 and 2019. Similarly, DUNE has established a consortium-based, management, organization, and project control framework of the detector and its subsystems. The PAC notes progress with the ProtoDUNE cryostats at CERN and tests of the first Anode Plane Assemblies composed of 3 wire planes and versions of cold electronics. The PAC learned that the LBNC has made significant progress in streamlining and monitoring progress on many of the challenges discussed in the Summer 2017 PAC meeting. The PAC fully supports the October 2017 LBNC recommendations that are based on clear and direct connection between the DUNE science and the technical requirements. The PAC is looking forward to hearing about major technical and engineering DUNE milestones in 2018 including the production and review of the Technical Proposal.

The PAC heard an update on the Resources Review Board (RRB) for LBNF/DUNE. The RRB, which is comprised of the funding agencies that sponsor LBNF and DUNE, last met in November 2017 and received updates on the substantial progress made by both LBNF and DUNE. At the meeting, the RRB also charted a course for its review and, if appropriate, approval of the Technical Design Report for the DUNE Far Detector and the Conceptual Design Report for the Near Detector by the fall of 2019. The RRB will be informed by the Long-Baseline Neutrino Committee and a new Neutrino Cost Group that will be reviewing the TDRs and providing recommendations to the RRB.

An Expression of Interest was presented to the PAC for DarkPhoton, a proton beam dump experiment searching for sub-GeV Dark Matter. This is a unique opportunity for the Fermilab Booster Neutrino Beamline, exploiting the availability of the planned LAr detectors for the SBN program. The PAC finds the proposal highly-aligned with the science mission of the Laboratory and scientifically compelling, tapping into the 2017 "Cosmic Visions" light Dark Matter DOE scope.

A second Expression of Interest was presented for the REDTOP – Rare Eta Decays with a TPC for Optical Photons – experiment. The proposal focuses on generating an η and η' factory using a proton beam of a few GeV on a Be target. The goal of the experiment is ultraprecise C, CP and T tests, down many orders of magnitude below current levels. The scope of the program is aligned with the mission of the laboratory and is scientifically interesting.

The PAC received a follow-up communication from E1039, the polarized target experiment which was discussed in the Summer 2017 PAC. The PAC recognizes the value of the physics goals of E1039 and we are pleased to see the interest and funding commitment from the office of Nuclear Physics. We encourage the Laboratory to assist the collaboration in finalizing a robust cost estimate to install the experiment. The PAC looks forward to a further update on whether the E1039 proposal fits within the NP guideline.

The PAC learned about the formation of the new Fermilab machine intelligence group. The PAC was impressed with the rapid progress and work of the group and supports its dual role in service of the experiments' physics program and Machine Learning research itself.

The PAC discussed the workflow and framework for a computing resource review body to serve the Fermilab experiments that produce significant volumes of data currently and in the future program. A proto-proposal was developed.

The FY 2018 Fermilab Strategic Planning Workshop was held on November 9 and 10 and the PAC members had access to the plenary session that comprised of impressive presentations on a) Strategic Plan and Lab-Wide Workforce Planning b) Quantum Science c) Precision Science d)

Neutrino Science e) LHC Science f) Cosmic Science g) Computation Science h) Building for Science i) Accelerator Science j) Laboratory Directed Research and Development (LDRD plan). Parallel working group sessions on Lab-Wide Workforce Planning challenges, opportunities implementation and optimization were held. Proposed objectives and timelines for the various research programs were also discussed in detail.

The PAC will consider the muon campus research program status and progress, the cosmic program, and the theory program during the Summer 2018 PAC meeting as well as all follow-up issues regarding the overall research program of the Lab and its continuing success.

The Committee thanks all the presenters for committing time to produce excellent reports and interact with the PAC. We are grateful to Steve Geer, Hema Ramamoorthi for their flawless support and organization of the PAC meeting and Kayla Decker for her attention to all the logistic details. We are grateful to Fermilab and its staff for their hospitality and support of this meeting.

Elena Aprile, Florencia Canelli, Andre de Gouvea, Salman Habib, Francis Halzen, Andreas Hoecker, Josh Klein, David MacFarlane, Stefano Miscetti, Alexander Olshevskiy, Silvia Pascoli, Kate Scholberg, Maria Spiropulu (chair), Hirohisa Tanaka, Yifang Wang , David Lee Wark, Stephen Geer (Science Secretary), Hema Ramamoorthi (Office of the Director)

1. LHC/CMS

This is a critical time for developing the roles, plans, and commitments associated with the participation of the Fermilab group in the CMS upgrade. We ask the PAC to comment on these things including (i) the role of Fermilab leadership in the upgrade organization, (ii) the foreseen evolution of the Fermilab group, and (iii) the various budget pressures and their impact. In addition, we ask the committee to comment on the engagement of the Fermilab group in important CMS physics topics.

The PAC heard presentations about the general CMS status, the upgrade status, the plans and involvement of the Fermilab CMS group, the physics analysis activities at Fermilab, the budget situation and the evolution of the Fermilab CMS group. The PAC is impressed with the continuing productivity of the CMS collaboration with 680 papers submitted to date, and recent landmark physics results such as the observation of the Higgs boson decay to tautau, evidence for Higgs decaying to bb, the observation of electroweak same-sign WW production, further strengthened bounds on physics beyond the Standard Model, and the overall diversity of the physics program. The large dataset delivered by the LHC this year, and expected for 2018 and the forthcoming runs promise a continuing strong physics output by CMS extending the boundaries of knowledge at the energy frontier. Challenges for the experiment lie in the parallel construction of the remainder of the Phase-I upgrade and preparations for the HL-LHC upgrade required to meet the extreme running conditions imposed by the high-luminosity LHC (HL-LHC), while maintaining efficient data taking operation under rising pileup conditions.

DOE and NSF HEP-supported scientists constitute 27% of the CMS collaboration authorship. With 5% of the CMS members, the Fermilab group is the largest US group and the second largest group of CMS. Fermilab is the only host lab for CMS in the US. It manages the US CMS operations program and upgrade projects, and hosts and operates the LHC Physics Center (LPC) and Remote CMS Operations Center. The Fermilab CMS group is well represented in the current CMS management up to the highest level (spokesperson). Fermilab's experience and large and diverse infrastructure are key assets to ensure that CMS can successfully pursue and exploit its research program.

Fermilab contributed significantly to the Phase-I upgrade of the experiment and is strongly involved in the HL-LHC upgrade of the CMS detector. Nearly all scientists in Fermilab's CMS group have transitioned to work on the HL-LHC upgrades. The lab contributes to four upgrade projects (outer silicon tracker, endcap calorimeter, trigger and data acquisition, fast timing detector), taking advantage of unique on-site infrastructure such as the silicon detector lab, scintillator fabrication facility and test beam, as well as expertise in ASIC engineering. The projects give Fermilab the opportunity to remain at the forefront of detector development, to offer hardware training to students and postdocs, and allows to support a large fraction of the US community. Fermilab's strong intellectual leadership on hadron collider detector and physics, as well as technical R&D and funding commitments to the CMS upgrade projects enable the CMS Fermilab group to lead and manage these projects in various positions.

Fermilab has a long record of carrying leading roles in almost all aspects of CMS software and computing (for example, the main "CMSSW" software framework was developed and is maintained at Fermilab). The Fermilab Tier-1 center is by far the largest resource outside CERN, delivering almost half of the CMS production and analysis activity in 2017. The unprecedented computing demands of the HL-LHC era require novel approaches for which Fermilab is first ranked and qualified to make major contributions owing to the high efficiency of computing operations and computation science advances. Fermilab excels in a number of software and computing areas including novel software tools, e.g. benefiting from Fermilab's new Machine Intelligence group, hardware technologies and new collaborations, e.g., for cloud computing, and distributed agile networking.

Fermilab scientists significantly and successfully contribute to exploiting the physics opportunities provided by the CMS data with emphasis on searches for new physics such as supersymmetry and dark matter. Advanced techniques developed by Fermilab scientists improve the event reconstruction under high pileup condition and allow CMS to explore physics in new kinematic regimes. The PAC suggests that the group continues to develop a strategic plan for detector, physics object performance, and physics analysis portfolio, taking into account the evolving priorities of the CMS physics program and the lab's unique expertise.

Through its visitor program, training, schools, and computing facilities, the LPC is a hub of support for physics at Fermilab, the US and CMS as a whole. It is a key contributor to many aspects of CMS, especially data analysis. Survey results show that the majority of the US CMS scientists uses the LPC software and hardware resources and benefits from the LPC for developing, advancing and publishing physics analysis. Fermilab's LPC has proved to be a unique and economical asset to the LHC physics community. It is a source of remarkable success for the CMS research program and a paradigm of a very efficient enterprise. It leverages the Laboratory resources and amplifies opportunities for its members beyond their rich physics research activities. For example, the ability of the LPC community to interact rapidly with Fermilab's detector R&D teams, theorists, CMS operations teams, computation teams etc., provides a unique environment to tackle successfully challenges across many areas and develop vision for the program.

Budget provisions exhibit a significant decrease in the proton research funding that would strongly affect the successful LPC visitor program, reduce Fermilab staff for operations support and management at CERN, reduce the visibility of Fermilab scientists and postdocs at HEP conferences and workshops, and, most importantly, the execution of the ambitious HL-LHC upgrade and computing development plan. The Fermilab CMS group has lost key people because of career evolution and retirements. Without replacement, the Laboratory will lose the ability to execute succession planning for its leadership in the HL-LHC upgrades and computing, and put in danger the delivery of committed projects to CMS.

The PAC observes that the proposed cuts to the Fermilab CMS program are not consistent with the science priorities of the US HEP program[1]) and the commitments the US has taken within the international CMS collaboration.

2. NOvA & PIP-I

Given the present expectations for beam delivery and the NOvA Collaborations science strategy, we ask the committee to comment on the expected timeliness of NOvA results with respect to the competition.

The NOvA experiment has been making good progress, with a steady rate of new results and publications. With reasonably optimistic assumptions on exposure and analysis improvements, NOvA is highly competitive with T2K for the milestone of 2 sigma mass ordering determination, and for CP violation sensitivity. NOvA is foreseen to be ahead of JUNO for mass ordering determination.

We encourage the NOvA and T2K collaborations' continued efforts to produce joint results. We expect this to be a multi-year process which will bear long-term scientific benefits for the community by exploiting complementarities. We encourage NOvA generally to explore and develop other means of cooperation and collaboration with T2K.

The PIP program aims at increasing NuMI beam power, and includes multiple accelerator and target improvement projects. The expectation is that ramping to 900 kW will be possible by the 2020 summer shutdown, and there will be attempts to step power up in 2019.

We recommend that the laboratory put priority on optimizing the beam power to NOvA, as this will contribute to potentially high-profile near term physics payoff for the US program, given the competition with T2K. It is important that the laboratory maximize the POT for NOvA, which would mean increasing the beam power as early as possible, minimizing any associated risks and keeping the lengths of the summer shutdowns to a minimum, and carefully managing the proton allocations for the rest of the program.

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[1] according to the Particle Physics Project Prioritization Panel (P5) report , LHC physics is the highest near term HEP priority.

3. Test Beam

Historically, in the period before SeaQuest running, the Test Beam program was allocated 5% of the accelerator timeline. During SeaQuest running, the SY120 program was allocated 10% of the timeline. SeaQuest is not running this FY. The Test Beam coordinator is requesting a continued allocation of 10% of the timeline. We ask the PAC to comment on this request.

The PAC heard on the vital function and impressive results of the Fermilab Test Beam program that serves all HEP frontiers (and beyond) and experiments nationally and internationally. Many examples of the critical impact of the test beam program on current and future HEP projects were presented, including on the upcoming CERN HL-LHC program. The PAC thinks that the very organized and excellently managed operation of the test beam, which effectively mitigates its impact on beam delivery to NOvA, allows this important program to move forward with minimal impact to the NOvA program, and thus recommends sustaining the test beam program at the level requested. The PAC notes that for the years to come, the Fermilab Test Beam with its two beamlines will continue serving the HEP community and provide unique support of the HEP program.

4. MINERvA

In the June 2016 meeting the PAC reiterated its "… support for an anti-neutrino exposure of at least 6E20 POT in the medium energy configuration." By the end of FY18 we anticipate that the experiment will have received an anti-neutrino exposure of about 8E20 POT in this configuration. The MINERvA Collaboration is requesting further running in FY19. We ask the PAC to comment on this request.

The MINERvA experiment was approved for 6e20 POT of antineutrino beam, and should receive 8e20 POT by the summer. They request continued running in FY19 for a total of 12e20 POT.

The MINERvA physics program is very important for interpretation of long-baseline oscillation experiments, as neutrino-interaction and beam uncertainties will limit eventual sensitivity. The collaboration has been very successful so far, with important contributions towards improvement of neutrino-interaction models using their "low energy" (~1-6 GeV) data sets of neutrinos and antineutrinos. The "medium energy" data set (~2-10 GeV) is still under data-taking and analysis. Data in this energy regime probe Deep Inelastic Scattering processes and have good overlap with the DUNE beam range. The PAC notes that antineutrino cross sections are relatively poorly known with respect to neutrino cross sections, so antineutrino data are potentially more valuable to the neutrino community. The PAC also notes that since antineutrino rates are smaller than neutrino rates by about a factor of three, more POT are needed to accumulate an equivalent statistical sample of antineutrino interactions.

The MINERvA collaboration has identified a discrepancy between data and simulation which has delayed the publication of the medium-energy result. The leading hypothesis is that the effect is related to issues with modeling of the NuMI focusing system. It will be valuable for the MINERvA collaboration to resolve this discrepancy both from the point of view of beam modeling for future experiments, as well as for interpretation of medium energy data.

We expect that the neutrino vs antineutrino running mode will be driven by NOvA needs, and continued MINERvA running will not have additional impact on the accelerator resources. A potential concern of a continued MINERvA running is that any maintenance needs of the aging detector could divert resources from new high priority projects such as the SBN program. The PAC expects the MINERvA collaboration to finish analyzing their existing dataset. The additional POT requested would likely require only modest additional resources for data analysis and results publication. The PAC advises the Laboratory to accommodate this request given MINERvA's valuable and unique physics program, so long as major additional resources for detector repair or maintenance are not required.

5. MicroBooNE

The committee is asked to comment on progress towards understanding the ultimate sensitivity of the experiment including (i) the plans for staging physics results, (ii) progress on calibrations, (iii) the impact of the realized detector performance on the ability of the experiment to measure the low-energy excess seen by MiniBooNE.

The PAC was very happy to see the MicroBooNE Collaboration's presentation on the status of their data analysis, and the detailed responses to the PAC's questions from the Summer 2017 PAC meeting. MicroBooNE is planning on providing physics results by the 2018 Summer conferences, with an emphasis on a ν_μ charged-current charged-particle multiplicity measurement and a few possible neutrino interaction cross section measurements. The multiplicity measurement is particularly exciting, as it has never been done in argon, and it leverages the high-resolution capabilities of the LArTPC technology. A stretch goal is a low-energy excess result by Summer 2018, but MicroBooNE pointed out that their nominal timeline for such a result is 2019.

On the basis of their presentation, and the answers to the PAC's questions, it is clear that several challenges need to be addressed in getting to physics results by Summer 2018. One of these discussed with the PAC is the long timescale for new data processing and Monte Carlo production, which currently takes months. As the collaboration pointed out, this is driven by data and MC event I/O, which in turn is dominated by the complete waveforms being written for both. Based on a MicroBooNE task force charged to review this challenge, the collaboration has decided to write out a restricted amount of information for data events. This approach is being internally reviewed also for Monte Carlo events and is expected to reduce the processing time by as much as a factor of three. This will allow faster turn-around time when the simulation model changes (in response to new calibrations, for example) and thus significantly improves the likelihood of physics results by the 2018 Summer conferences.

It is also clear that much important work is still ongoing, including the results of the laser calibration of the detector's electric field (which is affected by space charge) and determination of higher-level uncertainties like those on energy scale and bias. These calibrations and evaluations of systematic uncertainties will be needed for precision physics results from MicroBooNE, and getting all of these done – even with the faster turn-around time on processing with the recent decision on storing reduced event information –will be challenging by Summer 2018.

A result on a low-energy excess by 2019 will be an important milestone for MIcroBooNE. If this result comes later than 2019, MicroBooNE runs the risk that the competition for resources with the SBN program and DUNE will further delay the MicroBooNE physics analysis efforts. Hence there is a premium on getting this analysis done by mid-2019. In addition to the importance of MicroBooNE's low-energy excess results, the development of reconstruction, analysis, and signal-processing techniques are very valuable for the development of the broader LArTPC program, and the PAC looks ahead eagerly to seeing the continued progress in these areas.

6. Neutrino Interaction Theory

We ask the PAC to comment on progress and plans towards improving the understanding and modeling on nuclear physics effects, particularly those effects that are of relevance to the future neutrino oscillation program.

Nuclear physics effects in neutrino interactions are relatively poorly understood theoretically, and understanding will be critical to fully exploit information from long-baseline oscillation experiments. The PAC learned of multiple efforts, many based at or connected to Fermilab, to improve theoretical understanding of neutrino-nucleus interactions, including activities of a new experimental-theoretical working group, formation of the NUSTEC collaboration, and various relevant workshops. We commend these efforts and encourage the neutrino theory community to continue to pursue them.

The PAC also encourages further specific efforts to improve connections with the nuclear physics community. We suggest organizing a "Basic Research Needs" workshop jointly with the theoretical nuclear physics community.

7. LBNF/DUNE

The LBNC reviews progress and gives advice on LBNF and DUNE. We ask the PAC to comment on recent progress.

The PAC congratulates LBNF and DUNE on the impressive progress since the Summer 2017 PAC meeting. LBNF i) has completed a major contract award for the Construction Manager/General Contractor (CM/GC), which positions the project to proceed with the more than $300M in conventional facilities construction authorized at the far site; ii) had a very successful official ground breaking ceremony held on July 21st, with attendance from State, international, and US Federal representation; iii) saw the completion of the Ross shaft steel set refurbishment to the 4850 level; iv) is on track to initiate pre-excavation work in 2018 and major cavern excavation work in 2019; and v) is continuing outreach for non-DOE participation.

The project is being actively managed with robust risk, organizational staffing, and project control systems. Specifically, DUNE i) named its 1000th collaborator; ii) has effectively established consortia, including leadership, for far detector subsystems; iii) has the first significant commitment of funds from outside CERN and the US announced by the UK government; iv) achieved completion of the ProtoDUNE cryostats which have been leak-checked by the Neutrino Platform and GTT; and v) has the first APA plane delivered and tested at CERN, including initial production versions of the cold electronics.

The LBNC has been pursuing the list of issues raised by the PAC at its Summer 2017 meeting, some of which will continue to be followed over the next several reviews. These include:

i) Incorporating lessons learned, including calibration systems and operational experience, from MicroBooNE into the DUNE TPC design and planning. A task force was formed and a report is expected by the next PAC meeting;

ii) Monitoring SBN joint analysis development, including identifying milestones and possible agreements between collaborations towards an SBN unified organization era. A ssummary of the reports from joint working meetings is expected by the next LBNC meeting.
iii) Test plan and scheduling for cryogenic operations and commissioning of ProtoDUNE-SP and ProtoDUNE-DP cryostats. A Plenary talk was provided at the SURF November LBNC review with a follow-up plan expected in 2018.
iv) Comprehensive strategy for SP electronics system, including an extensive system test program**.** A plenary talk was provided at the SURF November LBNC review and a recommendation for follow-up with additional information was made.
v) Progress with consortia formation and leadership. A plenary talk was provided at the SURF November LBNC review.
vi) Update on SBND planning in relation to possible DUNE CE solutions. A plenary talk was provided at SURF, and the option of SBND adopting commercial off-shelf ADC solution was discussed.
vii) LBNC will closely scrutinize the leadership of consortia, the depth and experience of the partners, and their ability to deal with project risks. Monitoring is foreseen through the TP/TDR development and guidance.
viii) Goals for the ProtoDUNE program, including flow-down from physics to specific technical requirements. Follow-up with new recommendations for the TP is expected.

The PAC learned about additional recommendations from the LBNC review in October 2017 and fully supports these actions, including the need to provide clear connection between science and technical requirements. Fermilab and the DUNE RRB have agreed to the formation of a new Neutrino Cost Group (NCG), which will work in close coordination with the LBNC to review and ultimately recommend approval of the DUNE Technical Design Report (TDR) and associated project organization, schedule and cost. Close coordination is planned for the LBNC and NCG, and the PAC agrees that this is essential for an effective and meaningful review of the TDR. The Chair of the RRB provided an update on the Resources Review Board (RRB) for LBNF/DUNE. The RRB, which is comprised of the funding agencies that sponsor LBNF and DUNE, last met in November 2017 and received updates on the substantial progress made by both LBNF and DUNE. At the meeting, the RRB also charted a course for its review and, if appropriate, approval of the Technical Design Report for the DUNE Far Detector and the Conceptual Design Report for the Near Detector by the fall of 2019. The RRB will be informed by the LBNC and the NCG that will be reviewing the TDRs and providing recommendations to the RRB. The LBNC, NCG and RRB have developed a comprehensive plan for approval of the TDR by September 2019 and the PAC agrees that this is an ambitious but well-thought out approach to establishing the DUNE plan for constructing the DUNE far detectors.

8. EOIs (REDTOP and DarkPhoton)

For the two Expressions of Interest, we ask the PAC to comment on whether the science goals are compelling given the likely scopes of the experiments.

The PAC heard about the expression of interest for the REDTOP (Rare Eta Decays with a TPC for Optical Photons) experiment. The proposal requires the production of a very large sample of η (10^{13}) or η' (10^{11}) mesons by the interaction of a few GeV proton beam on a Be target. The goal is to test C, CP and T symmetries at many orders of magnitude below current levels. In particular, four "golden" physics flagship goals were presented: i) a study of the $\eta \rightarrow \pi^+\pi^-\pi^0$ Dalitz plot, ii) CP-violating asymmetry in $\eta \rightarrow \pi^+\pi^- l^+ l^-$, (iii) a search for new "dark-force" mediator (A') on $\eta \rightarrow \gamma e^+e^-$ sample and (iv) a scalar meson search on the $\eta \rightarrow \pi^0 H^0 \rightarrow \pi^0 \mu^+\mu^-$ (e^+e^-) channel.

The REDTOP proposal foresees a 2-3 GeV proton beam, obtained by decelerating the 8 GeV protons produced by the Delivery Ring, that is then transported to the AP50 enclosure where the detector could be located. Some technical concerns and difficulties on the implementation in terms of the accelerator have been expressed. Moreover, the currently proposed start of construction (2021-2022) would have to be coordinated with the Mu2e commissioning.

The detector conceptual layout consists of a multipurpose detector embedded inside a superconducting solenoid and is composed of an optical TPC, a scintillating fiber vertex detector, a high granularity dual-readout calorimeter (ADRIANO-2) with precise timing, and an active muon polarimeter. The optical TPC uses Cherenkov photons to reconstruct the particle momenta; these photons are produced in the aerogel surrounding the OTPC inner ring thus limiting the reconstruction only to fast leptons and pions. The scintillating fiber tracker follows a scheme similar to the one used at LHCb. The high granularity calorimeter has a dual readout (scintillating and Cherenkov light) based on a combination of plastic scintillators and heavy glass. It offers interesting capability of particle ID while reaching energy resolution for the electromagnetic component at the level of $5\%/\sqrt{(E/GeV)}$. The design and the need of the muon polarimeter are still under discussion. A two-level trigger is needed to reduce the 200 MHz inelastic rate (2 Tb/s data throughput) by four orders of magnitude. A processor farm of 2000 CPUs should be needed to handle the 20 kHz of triggered events for a data storage of 200 MB/s, i.e. 2 pB/year.

In this EOI, the estimates of precision for the golden measurements and the achievable sensitivity for discovering an A' have not taken into account the presence of hadronic backgrounds or irreducible η decays, nor have they included any smearing effects due to detector resolutions. No tagging techniques for the η meson were presented. Technical concerns arise from the strong detector irradiation due to the beam halo. Namely, the SiPMs of the OTPC forward plate will be exposed to a neutron fluence of up to 6×10^{12} n/cm^2 and dose up to 300 krad. The optical sensors (SiPM) and the scintillators of the fiber tracker will see similar or larger fluence and dose. The irradiation effect on the detector components should be quantified and mitigations proposed. The addition of a cooling system to lower the running temperature of the irradiated SiPMs between -20, -30 C would likely be needed. Trigger, DAQ and computing requirements seem to be demanding. A study of the tradeoff between the number of produced mesons and achievable precisions could be useful to evaluate irradiation effects, running time as well as trigger, DAQ and computing needs.

The PAC finds that the science goals of the experiment are very interesting. Given the difficulty to implement the deceleration scheme, the need for engineering resources and the Laboratory commitment to already-established high-priority programs, the PAC does not recommend that the Laboratory invest resources into furthering the REDTOP proposal at this time.

The Second Expression of Interest presented to the PAC was for a search for sub-GeV Dark Matter (DM) with a proton beam dump experiment. This is a unique opportunity for the Fermilab Booster Neutrino Beamline, exploiting the availability of the planned LAr detectors for the SBN program. Following the successful experience of the Miniboone-DM run, the EOI envisages a clever leverage of the SBN detectors with modification of the neutrino beam line to obtain an 8 GeV proton beam dump. This will allow to search for DM interactions with world-leading sensitivity, testing the range of parameters required to explain the observed DM relic density for some DM mass regions.

It is the sense of the PAC that a search for light DM is aligned with the Fermilab research strategic program. Dark Matter candicates in the mass range of MeV to GeV are predicted in several theoretical models and many DM portals can be uniquely tested by an experiment at a proton beam. In addition, such a search is timely in view of the recent DOE call for new initiatives in DM searches ("Cosmic Visions" DOE initiative) .

In order to reach the required sensitivity, it is critical to reduce the neutrino-induced backgrounds. Two options for the modification of the beam line have been presented to this end. In addition to a 50 m long iron dump, to further reduce the neutrino-induced background, Option 1 involves replacement of the Be target and horn with a 2 m long instrumented iron absorber. The foreseen cost is of O($1 M). No changes to the SBND detector are required. A total time of 12 months is estimated to achieve 2E20 POT when considering also the switching time with neutrino running mode. Improvements larger than one order of magnitude on the mixing strength of DM relic density with respect to MiniBoone-DM are foreseen.

The Option 2 presented is more complicated, requiring a dedicated kicker magnet to direct the protons onto the dump and has a higher cost ($5 M) and it provides the great advantage to allow an instantaneous switching between beam dump and neutrino/antineutrino mode, without a negative impact on the SBN program. The PAC would like to understand the availability of the SBND detector for this interesting measurement. The PAC finds the EOI to be of the high scientific value and considers it an especially timely opportunity to achieve significant science with a modest cost investment in the next few years.

9. Big Data and Machine Learning Group

We ask the PAC to comment on the plans of the new Machine Learning Group within the Scientific Computing Division.

The PAC heard about the formation of the new Machine Intelligence Group at Fermilab. There are a number of good motivations for having such a dedicated team. Next-generation experiments across all HEP frontiers demand a major jump in computational capability; given budgetary considerations, it is clear that brute-force solutions are largely infeasible. Recent advances in data-driven machine learning holds considerable promise in alleviating several aspects of this urgent problem. HEP scientists are vigorously investigating these techniques using ongoing experiments as well as large datasets from simulations. The expectation is that analysis and simulation tasks (e.g., generative models) can both benefit greatly from breakthroughs in machine learning.

Given this background, organizing a dedicated and future-looking group in this broad area is a welcome development. The PAC supports the idea of the group's planned dual role in service and research and commends the Laboratory for this initiative. Maintaining a strong connection −as a science domain hub − to parallel activities in the individual experiments will be an important role for the group. Aside from relations with industry, the PAC recommends enhanced collaboration with university groups with expertise in machine learning, especially by initiating joint programs involving students and early career scientists. The data and problems Fermilab experiments offer represent interesting challenges for the ML community.

10. Data Scrutiny Group

We ask the committee to comment on the status of, and plans for, the new "Data Scrutiny Group".

Regular and effective computing resource scrutiny is an essential part of Fermilab's resource planning process. The scrutiny of an experiment that consumes resources above some threshold should proceed along a predefined set of questions such as physics motivation, data versus MC needs, lifetime and deletion policy, data compression and reduction, memory and CPU performance, IO and storage requirements, release cycles and software validation, longer-term data and analysis preservation, etc.

In light of the upcoming large computing requests of Fermilab's incoming experiments, significantly exceeding current resources, the PAC proposes to augment the role of the SC-PMT to perform full scrutiny along the lines described above, which may require an expansion of the committee. SC-PMT sub-committees would follow individual experiments. Full scrutiny meetings could occur twice a year to discuss resource usage, needs and upcoming requests.

In this model, the LBNC would do the scrutiny for DUNE and report its recommendations to the SC-PMT.

The SC-PMT reports to a dedicated computing advisory group under the PAC. The role of this data & computing scrutiny group is to help the SC-PMT and Fermilab's management with advice on the overall resource allocations and the setting of priorities.