Physics Advisory Committee Meeting

June 17-20, 2008
Naperville, IL

Comments and Recommendations

Introduction

The June meeting of the Physics Advisory Committee (PAC) occurred soon after the release of the report from the Particle Physics Project Prioritization Panel (P5), which was charged with the task of providing a plan for particle physics in the United States under a variety of budget scenarios. The PAC meeting included an in-depth discussion of the findings of P5 and their potential implications for Fermilab. The P5 report emphasizes three main frontiers for the field: the Energy Frontier, which involves probing fundamental interactions through direct collisions at the Terascale, where new phenomena are expected; the Intensity Frontier, which involves unraveling the nature of neutrinos and studying rare decays through the generation of intense proton and electron beams; and the Cosmic Frontier, which involves studying the nature of dark energy, dark matter, and other phenomena with telescopes and underground detectors. The P5 report outlines an impressive program of opportunities for US particle physics in each of these three areas, with some clearly indicated prioritizations. The PAC concurs with the conclusions of P5, and congratulates that committee on doing an excellent job under difficult circumstances.

As the sole remaining U.S. national laboratory devoted exclusively to particle physics, Fermilab has a special role in shepherding the future of the US program in this field. That role was recognized explicitly by P5, and the future health of Fermilab was a factor in their deliberations. Indeed, the specific P5 recommendations match well to the general directions that the Laboratory has been pursuing. For the Energy Frontier, highest priority was given to the future running of the Tevatron, and the commissioning, operation, physics exploitation, and eventual upgrade of the Large Hadron Collider (LHC) at CERN. As the host laboratory for US participation in the CMS experiment at the LHC, Fermilab is well-positioned to be at the forefront of the energy frontier for many years to come. Fermilab continues to play an important role in the R&D for future lepton colliders that will help explore the physics discovered at the LHC. For the Intensity Frontier, highest priority was given to the eventual development of a long-baseline neutrino oscillation experiment that would involve a 2 MW proton facility at Fermilab, Project X, producing an intense neutrino beam for detection by a 100Kt-scale detector at the Deep Underground Science and Engineering Laboratory (DUSEL) in South Dakota. In addition, P5 gave high priority to a muon-to-electron conversion experiment at Fermilab. For the Cosmic Frontier, P5 re-endorsed the Dark Energy Survey experiment, under development at Fermilab, and the Joint Dark Energy Mission (JDEM), for which one of the candidate concepts, the SuperNova Acceleration Probe (SNAP), has significant Fermilab involvement. Dark matter searches were also given high priority, and this aligns well with Fermilab's involvement in CDMS and COUPP. Implementing the P5 program at Fermilab will be a challenge, and will require the Laboratory to form strong partnerships with universities and other laboratories.

The Committee commends the Laboratory management for taking the initial steps to align with the P5 recommendations. However, there is still a long way to go. Given that P5 has made reasonable choices, and that realizing this program will be a challenge under financial constraints and uncertainties, the Committee encourages the Laboratory to continue to make implementing the P5 plan a top priority. Difficult decisions will have to be made in the allocation of limited personnel and M&S resources, and certain promising R&D areas may have to be curtailed to enable the P5 plan to move forward at Fermilab. It is clear that the program must be more sharply focused, while encouraging creative ideas.

The combination of Project X and DUSEL enables a world-leading program in neutrino physics. The scientific importance of this program and the increased alignment this generates between DOE and NSF priorities enhances the chance of a timely execution of these two programs. However, the required coordination between the agencies can also be challenging, and introduces programmatic vulnerabilities, which need to be mitigated through a tight collaboration. The Laboratory must work closely with both agencies to ensure that this program is successful.

Project X and DUSEL

The Committee commends Fermilab for the steady progress in the development of Project X into a mature world-class endeavor and looks forward to seeing a multi-institutional collaboration take shape in the coming months. The Committee notes that an optimization process aimed at maximizing the potential of Project X while reducing its cost and leading to a realistic schedule is underway, with the goal of reaching a CD-2 approval in FY2011. The initial design appropriately maintains alignment with the ILC design goals, but future evolution may be necessary to avoid compromising the Project X goals. During the next year, the Laboratory should schedule a technical review conducted by an external international committee of accelerator experts to provide an assessment of progress in the design development.

As emphasized by P5, the long-baseline neutrino program at DUSEL should begin with a 700kW neutrino source and a first-stage detector. P5 recommended that this first phase of the long-baseline neutrino program be implemented under any of the funding scenarios considered (i.e., even if the 2MW source must be delayed). The Committee urges Fermilab to intensify activities relevant to R&D and design of the neutrino beamline to DUSEL, with the goal of achieving a final design by 2012. The recently formed DUSEL Beamline Working Group is an excellent start. However, this activity should be significantly strengthened, and should proceed in parallel with Project X R&D with comparable emphasis and visibility.

P-973 Mu2e (Bernstein/Miller)

The Committee is impressed by the very strong physics case for lepton-flavor-violating muon-to-electron conversion at a single event sensitivity of less than 2×10^{-17}, which was presented by the Mu2e collaboration. The proposed experiment probes multi-TeV-scale physics in a wide variety of models. It would become one of the flagship experiments during the pre-Project-X era. An upgraded experiment could have a significant increase in sensitivity with Project-X. This experiment, however, faces quite challenging issues in terms of the accelerator, beamline, and detector. The current design has not progressed significantly since the MECO proposal. To develop the proposal, the Committee recommends that Fermilab provide sufficient technical and engineering resources, in particular for the areas of the interface between the accelerator and the experiment, the optimization of the design of the superconducting solenoid magnets, and other detector issues. The Committee recommends that key members of the physics research and accelerator staffs at the Laboratory get involved in this experiment. The Committee reiterates its March recommendation that the collaboration also needs to be significantly strengthened, with the addition of more institutions experienced in the challenges of rare-decay experiments, in order to successfully mount such a challenging experiment.

Kaon Physics

The Committee discussed possible future plans for kaon decay experiments at Fermilab, and the potential for measuring $K^+ \rightarrow \pi^+\nu\overline{\nu}$ with a sensitivity of about 40 events/year by using the existing BNL E949 detector with modest modifications. The Committee believes that the physics motivation at this sensitivity is not strong enough to pursue at Fermilab. However, the Committee encourages future consideration of a more sensitive kaon program during the Project-X era.

E-929 NOvA (Feldman/Messier)

The Committee reiterates the importance of a timely construction start of NOvA and urges the Laboratory to make every effort to bridge the gap in funding caused by the FY08 budget situation.

P-974 MicroBooNE (Fleming)

The MicroBooNE experiment is a combination of strategic detector R&D with a physics component. The detector R&D focuses the LAr detector development in North America and is one of the intermediate steps required for a possible much larger LAr detector for the long-baseline oscillation program and for a proton decay experiment. Many, but not all, of the issues required for construction and operation of a much larger LAr detector can be addressed with the MicroBooNE detector. The physics program involves the measurement of low-energy neutrino interactions utilizing the unique capabilities of a LAr TPC (including addressing the possible low-energy excess observed by MiniBooNE). The MicroBooNE collaboration brings together strong components of the LAr community from universities and national laboratories. The Committee recommends that P-974 MicroBooNE be granted Stage I approval, and further recommends that the collaboration and Fermilab work together to finalize the size of the experiment so as to optimize the balance between the physics and longer-term LAr detector R&D goals.

P-983 NewBooNE (Louis/Mills)

The Committee heard a presentation of P-983, NewBooNE, an Expression of Interest to perform a search for new particles beyond the Standard Model. NewBooNE is based on the idea that MiniBooNE can be reconfigured as a beam dump experiment by replacing the existing target and focusing horn with a beam dump. This replacement is relatively inexpensive, but the total cost of such an experiment and its impact on other experiments at Fermilab are unclear. While the Committee appreciates the collaboration's efforts to capitalize on the ongoing MiniBooNE detector, the Committee finds that the present physics motivation for NewBooNE is weak.

P-975 NuSOnG (Conrad/Fisher)

The Committee appreciates the collaboration's suggestions for a Tevatron-based neutrino program at Fermilab, which place the NuSOnG proposal into a broader context. The Committee also appreciates the collaboration's comparison between NuSOnG and the SLAC experiment on Moller scattering. The physics that would be explored by NuSOnG is interesting. However, the total cost of mounting the NuSOnG experiment (and possible additional Tevatron-based experiments), including the running of the Tevatron for several years, would be considerable, and the NuSOnG experiment is not well aligned with the long-range physics plan that has been developed by Fermilab, this Committee, and P5. Therefore, the Committee cannot recommend that NuSOnG be encouraged to proceed to a full proposal.

E-954 SciBooNE (Nakaya/Wascko)

The Committee commends the SciBooNE collaboration for its excellent start on data collection and physics analyses. The goal is to measure precision neutrino and antineutrino cross sections on nuclei at low energies, to provide essential input to long-baseline neutrino experiments. The Committee appreciates SciBooNE's comprehensive responses to its questions. The procedure to arrive at absolute charged-current-1π and neutral-current-1π^0 cross sections has been carefully described, and the update to the expected precision has been shown to meet the needs of T2K. The formal procedure for joint SciBooNE-MiniBooNE data analyses and the ongoing joint analyses are an excellent direction for maximizing scientific impact. Further collaboration between the experiments is highly encouraged.

E-944 MiniBooNE (Brice/Van de Water)

The Committee strongly encourages MiniBooNE to expeditiously complete the analysis of its observed low-energy ν_e event-rate excess. Whether this excess is new physics or a background effect is a very interesting question, and understanding the excess will be important to the T2K experiment. The Committee will also be interested to hear what MiniBooNE learns from its antineutrino running, its NuMI data, and the combining of its observations with those of SciBooNE.

E-875 MINOS (Plunkett/Wojcicki)

The Committee congratulates the MINOS collaboration for its continuing successful data-taking. Based on a two-year exposure to muon neutrinos, using 3×10^{20} protons-on-target, the MINOS collaboration determined the atmospheric neutrino oscillation parameters, $|\Delta m^2| = (2.43 \pm 0.13) \times 10^{-3}\ eV^2$, and, at 90% CL, $\sin^2(2\theta) > 0.90$. The $|\Delta m^2|$ measurement is the best in the world. The Committee commends the MINOS collaboration on their accomplishment, and looks forward to even more exciting physics results, including the outcome of a ν_e appearance study, in the future.

P-981 AGE (Kaplan/Phillips)

The Antimatter Gravity Experiment (AGE) proposes to measure the acceleration of antihydrogen in the earth's gravitational field. The technique involves deceleration of antiprotons in the Main Injector, followed by a degrader system to reduce the energy to ~1 MeV. The Committee reviewed the responses from the AGE collaboration to questions raised at the March PAC meeting.

In consultation with theorists, the collaboration reports that there is no existing direct evidence against a 1% effect. Indirect constraints are in principal much lower, but they appear to be based on the assumption that the theory of gravitation is complete. The proposed experiment therefore is effectively a test of gravity, or search for a fifth force, on the size scale of the Earth. In response to the Committee's requests, the collaboration reported on the ongoing progress of their design studies for using antihydrogen, in particular on the antiproton decelerator, degrader and capture efficiency, as well as on the antihydrogen detection, for which several options are being investigated.

The Committee found the potential science of this exploratory experiment to be interesting. The Committee notes, however, that there are substantial costs required for magnets, a new building, and, as yet undecided, antiproton detector.

The Committee has several concerns. There remain unresolved issues in the efficiency for trapping antiprotons that prevent detailed comparisons with other possible antiproton experiments. Furthermore, the collaboration would need to fully demonstrate the interferometer with normal atoms, as requested in the PAC's March report. If such a full-scale test were to be done at Fermilab, the collaboration would first need to identify the resources required, and progress would be subject to Laboratory resource constraints. The Committee also believes a precision significantly better than 1% should be targeted since 99% of the inertial mass of both the proton and antiproton comes from binding energy (the gluon field), which Eotvos experiments have shown obeys the equivalence principle. Finally, it does not seem possible to complete the experiment before the Antiproton Source is terminated with the Tevatron Collider running, even if the run is extended through 2010. The Committee does not recommend that the Laboratory further consider this experiment.

Fermilab Center for Particle Astrophysics

The Fermilab Center for Particle Astrophysics is an important initiative of the Laboratory, well aligned with one of the three frontiers identified by P5. It is important for the Laboratory to be engaged in the exploration of fundamental physics at the Cosmic Frontier and coordinate its program in this area.

The Acting Director of the Center has been very successful in bringing together the experimentalists and the theorists, and generating a vibrant brainstorming atmosphere. The new Director of the Center will have to balance the generation of new ideas, the exploration at the R&D level of the most promising ones, and the convergence on a few critical-mass projects. Such projects will have to be chosen for high scientific impact, competitiveness, and alignment with the priorities of the field, DOE and the vision of Fermilab. Other criteria may include the use of unique Laboratory capabilities, synergy with other Laboratory programs, and the breadth of the collaboration. The Committee further recommends that each project undergo expert external review.

Such a portfolio would presumably include:

a) Dark dnergy with SDSS, DES and SNAP.
b) Dark matter with CDMS, COUPP and likely the development of liquid argon detectors, which are highly synergistic with the developments for neutrino physics.
c) New ideas, such as those discussed in the Center's recent retreat.

The program will have to evolve, as projects are completed, for the research to remain at the leading edge of the Cosmic Frontier and to remain aligned with the mission of the Laboratory.

SNAP/JDEM

Context

The Joint Dark Energy Mission was given the highest priority by BEPAC. It was also strongly supported by P5, as part of the exploration of the Cosmic Frontier. An Announcement of Opportunity is expected to be released soon. DOE is committed to supporting JDEM at a level estimated to be about $200M. SNAP is one of the strong contenders for JDEM, and is the only one with significant DOE participation.

However, a number of uncertainties exist. The JDEM competition is open, and there is no guarantee that, in spite of its strength, SNAP will be the chosen mission. It is also unclear how DOE and NASA will jointly handle the various aspects of the mission, but this should be resolved soon, when the negotiations between the two agencies are completed.

SNAP R&D

SNAP R&D has been progressing well. The CCD packaging is being developed in collaboration with Yale. Other more minor R&D activities seem also to be on track.

Project Definition

SNAP is evolving from the exploration of a concept and R&D to the project definition stage. The role of Fermilab in SNAP is being negotiated within the collaboration, and decisions should occur in the coming weeks.

Fermilab is proposing in particular to take the responsibility for the Science Operations Center. Fermilab is ideally suited for this project, and a Fermilab physicist has already been appointed to lead this effort within the SNAP collaboration. The Laboratory's role in supporting community and guest / virtual observatory programs, and in the data archiving, will need to be defined. If these responsibilities are shared with other institutions, the interface should be specified carefully.

Fermilab is also likely to have the responsibility for the packaging of the LBNL optical CCDs. This would use the experience gained in the production of the Dark Energy Survey focal plane and the R&D on SNAP packaging. Although essential, this is a relatively small involvement for the Laboratory. The Fermilab SNAP team was hoping for a larger hardware role, with the warm electronics, but the SNAP collaboration chose instead another design.

It is essential for Fermilab to further define its scientific foci in the SNAP instrument characterization and data analysis, and to build a strong science team around the selected themes. If the Laboratory is indeed chosen as the Science Operations Center, some high-level responsibilities such as calibration may naturally follow. Another route is for a broader set of Fermilab scientists to get involved in SNAP scientific working groups, and take leadership roles, when appropriate, especially in areas synergistic with other activities in the Center for Particle Astrophysics.

Tevatron Run

The accelerator continues to perform well and the Committee congratulates the Accelerator Division. The experiments continue to produce exciting physics results. The P5 report raises the possibility of running the Tevatron in 2010 under certain funding scenarios.

CMS Center and Upgrades

The Committee discussed the status of the CMS center at Fermilab. The Committee notes the mostly positive review of the LPC by the LPC Advisory Board, and concurs with the judgment of that Board that it is too early to determine if the LPC format will be successful in the era when the LHC is running. The Committee also concurs with the report's emphasis on the importance of the LPC working group leaders interacting regularly with the experiment leadership, and encourages the Laboratory to support the required travel to CERN.

The CMS effort at Fermilab is strong and is making a significant impact within the CMS collaboration.

The Committee heard detailed plans regarding the US contribution to the CMS upgrades. However, not enough information was provided to the Committee for it to understand the Fermilab role in the CMS upgrades. The Committee also did not understand how the Fermilab role in the US portion of the CMS upgrades will be evaluated and decided. The Committee encourages Fermilab to play an active role in the CMS upgrades and to define an appropriate role for Fermilab, perhaps with the help of a Fermilab CMS upgrades manager.

The Committee would like to see a plan for the evolution of the Fermilab contribution to the US CMS effort, including allocation of resources among commissioning, physics analysis and operations, and upgrades.

Computing

The Committee heard presentations both on computing needs for experiments at colliders and neutrino programs, and on the R&D efforts within the Computing Division. The Computing Division has maintained the necessary computing services for all experiments, and for the collider experiments by assuming more responsibilities within the division as support from university collaborators has declined. They also have thorough plans for maintaining these services for as long as the collaborations need them. They have built one of the Tier 1 centers that will provide long-term storage and reprocessing capability for the CMS collaboration, and serve that data to the Tier 2 centers for user access. They have leadership roles in the Open Science Grid (OSG) and its security, and have successfully made their computing resources available on the grid for Fermilab-based experiments, as well as providing opportunistic resources for outside users. The R&D efforts within the Computing Division seem well-aligned with the mission of the Laboratory. The Committee especially was intrigued by the possibility of a program, connected to the pending end of the Tevatron run, in the area of data curation and the development of a software environment that could allow access to this data by the broader community. The Committee commends the Computing Division for their work.

Detector R&D at Fermilab

Progress in experimental particle physics at the Energy frontier, the Intensity Frontier, and particle astrophysics at the Cosmic Frontier all depend critically on the development of new detector technologies. Fermilab plays an essential role, and has had a solid track record in the design and construction of detectors in collaboration with universities. Fermilab's capabilities provide a solid foundation for the future program of detector R&D that is closely aligned with the experimental program. The test beams available at Fermilab are also very valuable to the community.

The Laboratory is currently involved in five main detector R&D efforts: pixel detectors, dark-matter detectors, water cerenkov detectors, liquid-argon neutrino detectors, and multi-pixel photon detectors. These detector technologies address important physics goals and are well-chosen. However, the Committee recommends that the resources devoted to each activity be reviewed and carefully balanced to maximize alignment with the physics priorities of the Laboratory and user community.

Pixel Detectors

Silicon detectors combine excellent position resolution with radiation hardness and have become the technology of choice for vertexing in particle physics experiments at collider facilities. Fermilab has designed a 3D Vertical Integrated Pixel (VIP) chip for an ILC vertex detector through a DARPA-funded run at MIT-LL. Fermilab is also hosting a 3D run with a commercial vendor that will accommodate prototype designs for readout for ILC and SLHC: CMS/ILC (Fermilab), ATLAS/ILC (IN2P3), and Super-B/ILC (INFN). This is an excellent example of generic detector development with an international base that is well-suited to a national laboratory. The Committee supports this general direction of R&D on 3D pixel technology which is likely to be critical to extract physics at future facilities.

Dark-Matter Detectors

The nature of cosmological dark matter is one of the greatest mysteries in physics. These particles may be capable of producing low-energy nuclear recoils in bulk matter, and several experiments have searched for this signature using a variety of techniques. The Laboratory provides support to the CDMS experiment, which looks for recoils in cryogenic Ge and Si. CDMS has been extremely successful, and currently provides the best limit on dark-matter cross sections above 40 GeV WIMP mass. Most of the CDMS detector R&D is conducted at universities.

It is anticipated that larger-scale experiments could be required to produce a measurable event rate. Various alternative technologies for dark-matter searches which might be practical on a ton scale are being pursued in the community. One such alternative is COUPP (Chicagoland Observatory for Underground Particle Physics). This is a WIMP detector based on a heavy-liquid bubble chamber (currently using CF_3I). Excellent progress has been achieved, obtaining competitive limits on spin-dependent couplings by operating a 2-kg chamber in the NuMI tunnel. The Committee congratulates COUPP on this achievement.

Almost all work on COUPP is detector R&D: reducing backgrounds and understanding how to operate, calibrate, and analyze data from this new type of detector. The collaboration is now working with Fermilab to build a 60-kg chamber, which could achieve competitive spin-independent sensitivity and give information on the background rate, as well as experience in background reduction needed to assess scalability to the ton scale. The Committee endorses this approach. COUPP is encouraged to seek additional collaborators, prepare for the future

DMSAG review, further define the potential role at DUSEL, and pursue outside sources of funding in addition to the resources Fermilab can make available.

Water Cerenkov Detectors

The Committee endorses the Laboratory's efforts to support workshops on various technologies for future large neutrino detectors, including water Cerenkov detectors. The Laboratory is still assessing its role in the R&D effort on this technology. The Committee looks forward to hearing about Fermilab's plans to contribute towards water Cerenkov detector development.

LAr Detectors

The Laboratory is commended for conducting a review of LAr TPC R&D towards a 100KT detector. LAr TPCs show promise as scalable devices for large detectors needed for long-baseline neutrino oscillation physics. Over the last several years, a staged approach to developing the technology for larger detectors has been developed. A specific plan with a 200-ton MicroBooNE detector and the 5KTon LAr5 detector as key elements emerged. The Committee recommends that the Laboratory put in place a coordinated strategy that brings together experimentalists, the detector R&D group, engineers and safety experts, and other relevant resources and personnel of Fermilab to facilitate this important program. In addition, the program should have well-defined goals and a schedule of milestones for achieving them. Finally, the Committee notes that important synergies likely exist with dark-matter detectors.

Multi-Pixel Photon Detectors

Pixelated Photon Detectors (PPD) are avalanche photodiodes operating in Geiger-mode. Fermilab is developing tools for complete characterization of the detector response, including developing readout, working with industry on the development of the technology, and studying large scale applications of the technology.

Total absorption calorimetry suitable for future lepton colliders and SLHC offers the potential for extremely good energy resolution. PPDs combined with heavy scintillating crystals now enable the total absorption calorimetry technique to be developed. Specifically, Fermilab is developing a collaborative plan to study the feasibility of dual readout with separate scintillation and Č-light readout with silicon photomultipliers. The Committee believes that this is an interesting direction to pursue.