Physics Advisory Committee Meeting

June 18-21, 2007
Aspen, CO

Comments and Recommendations

During this somewhat abbreviated Aspen session, the Committee was concerned mainly with issues related to long-term planning. Such planning is particularly important, given the absence of definite plans to run the Tevatron Collider beyond the end of FY2009 and the uncertainties surrounding the schedule for the construction of the International Linear Collider (ILC). Fermilab's central role in the US high energy physics program further heightens the importance of this exercise.

A long-term planning process, which is being carried out by a special "Steering Group" chaired by Fermilab's Deputy Director, is ongoing, and has not yet led to firm conclusions. Nonetheless, the Steering Group is well along in its work, and the Committee appreciates the opportunity to comment on the Steering Group's activities at this stage.

The Committee was also asked to comment on a few specific issues related to the Laboratory's near-to-mid-term operations. In particular, the Committee was asked to comment on the progress of the NOνA experiment as it passes through the various stages of formal project approval, and it was asked to consider Stage I approval for the SuperCDMS 25 kg experiment. In addition, the Committee was invited to comment on several other issues involving the current operation of the Laboratory (e.g., the Accelerator Physics Center and Laboratory plans for Detector R&D and Computing) as well as longer-term physics involvements (e.g., upgrades at CMS and ILC detector development work).

During the first two days of the meeting, the Committee heard presentations made mainly by Laboratory management regarding the various issues outlined above. The presentations were typically accompanied by questions and informal discussion. The remaining two days of the meeting were devoted to further discussion of the issues and drafting of the report that follows.

The Committee is pleased to see that the Laboratory continues to thrive scientifically and to embody the highest standards of excellence in its technical undertakings. The Committee also commends the Laboratory on approaching its planning exercise in a way that incorporates a wide range of input from both its national and international partners.

Strategic Planning and Steering Group

The Committee heard from Fermilab's Deputy Director and Chair of the Steering Group on the work of the new Group. The Laboratory management is committed to the realization of the International Linear Collider (ILC), and is planning to make a bid to be the host laboratory for the ILC. The Laboratory Director discussed the steps that need to occur before construction on this major new facility could start. The Global Design Effort (GDE) for the ILC has estimated that the engineering design work could be finished in time to allow a 2012 construction start. Start of construction also requires agreements between the funding agencies of Europe, Asia, and the Americas, and a site to be selected. Results from the Tevatron and LHC could also give input to the decision process. Construction in the United States may require a Presidential initiative.

The purpose of the Steering Group is to develop a roadmap that will allow the Laboratory to maximize the accelerator-based physics output in high-energy physics considering a 2012, 2014, or 2017 construction start for the ILC, and to allow the Laboratory to develop the infrastructure and technical capacities necessary for ILC construction. Any proposal the Steering Group develops will go to DOE for review.

The Committee was informed about the structure of the Steering Group, which meets weekly, and includes subcommittees on neutrinos, flavor physics, accelerator facilities, coordination with national priorities, and high-energy colliders beyond the ILC. It also includes various ex-officio members, such as the ILC GDE leaders, the chair of HEPAP, and the chairs of the SLAC and Fermilab user organizations. The existence of the Steering Group has been well-advertised to the US HEP community.

The Steering Group charge was presented to the PAC. That charge specified that the Steering Group will build the roadmap based on the existing recommendations of the EPP2010 National Academy report and the recommendations of the P5 subpanel of HEPAP, and that it should consider the Fermilab-based facilities in the context of the global particle physics program. The roadmap should support the international R&D and engineering design for as early a start of construction of the ILC as possible, and support the development of Fermilab as a potential host site for the ILC. It should develop options for an accelerator-based high energy physics program in the event the start of the ILC construction is slower than the technically-driven schedule. It should include the steps necessary to explore higher-energy colliders that might follow the ILC, or be needed should the results from LHC point toward a higher energy than that planned for the ILC.

The Steering Group's work is based on input from its own subcommittees and letters and proposals from the US community (20 proposals of various lengths and stages of development received to date). Potential programs are required to satisfy the following criteria: they should be important in a global context; they can be done uniquely or substantially better at Fermilab; and they should be unique in their physics reach. The Steering Group is considering two options, among others, of interim physics programs during the transition period that have been discussed as part of the on-going work.

Option 1 includes sNuMI, which uses momentum stacking in the accumulator and box-car stacking in the Recycler Ring to improve the power (>=1.0 MW at 120 GeV) delivered to the neutrino programs, and augments this by using the Debuncher as an 8 GeV slow-spill device and the Tevatron as a 120 GeV slow-spill device. Such a complex can deliver, for example, a 120 GeV fast spill at 19×10^{16} protons/hour, an 8 GeV slow and fast spill at 4.6×10^{16} protons/hour, and a 120 GeV slow spill at 5.4×10^{15} protons/hour.

Option 2, which is synergistic with ILC needs, expands this to include a 2 GeV proton linac, a 6 GeV linac built from ILC components and capable of accelerating electrons or H^- ions, and uses the Recycler to produce an 8 GeV beam at 200 kW and the Main Injector to produce a 120 GeV beam at 2.3 MW.

Since both Option 1 and Option 2 require significant upgrades to the Main Injector RF systems, an early implementation of such upgrades would provide additional flexibility in terms of the decisions on which option will be pursued, an additional year of flexibility for changes based on later decisions and developments.

Option 2 would allow testing of an ILC linac. Option 2 has similarities to the Proton Driver project. However, since the Recycler is used, the linac would be aligned with the ILC requirements. The GDE has stated in its S2 task force report that at least 1 to 2 RF units should be built immediately, and that a larger test facility is believed to be useful at a later date. The exact size of this larger facility was not specified, but is envisioned to be similar to Option 2. Option 2 would allow a more extensive test of system integration ideas, and would allow US industry to get involved in the construction of the components (industrialization). The construction would build the international and industrial team needed for eventual ILC construction, and develop the needed working relationships.

Experiments that could benefit from these programs include those aimed at improved reach for the physics of neutrino oscillations, and other sensitive probes of possible new physics such as muon to electron conversions, precision measurements of rare kaon decays such as $K \rightarrow \pi\nu\bar{\nu}$, and high-statistics measurements of neutrino-electron scattering. These experiments provide complementary probes in the flavor sector to new physics probed at energy-frontier and other HEP facilities.

The Committee believes that making concrete, practical plans for different options is absolutely necessary, and commends the Laboratory for taking this step. The Laboratory must continue the great work that has already been done to make sure that the planning process receives information from the entire global HEP community, and is well advertised. If Option 2 develops favorably, it needs to be integrated into the GDE plans.

As the roadmap from the Steering Group develops, the Laboratory should continue to pay attention to the needed manpower, both for accelerator R&D and construction, and for the associated experiments, and the impact of this experimental program on ILC work and other Laboratory priorities. The Laboratory will obviously need to forge collaborations with other US and foreign laboratories, if the roadmap is eventually recommended by the funding agencies. Furthermore, the Laboratory should work to ensure adequate manpower, avoid any delay to the ILC construction start, and enhance the possibility of an early ILC construction start.

The Committee also heard from the Deputy Director on resource planning at the Laboratory. The shutdown of the Tevatron at the end of the decade will have a substantial impact on the human resource needs. In order to retain and retrain the employees during this transition, the Laboratory has surveyed and categorized the current skills of all employees. The

Committee believes this is a sensible and necessary step to ensure that the Laboratory's manpower is retained and optimally used before, during, and after the coming transition.

P-947 SuperCDMS 25 Kg (Bauer/Cabrera)

The Cryogenic Dark Matter Search (CDMS) has pioneered the development of low-temperature, phonon-mediated devices for the detection of WIMP scattering off nuclei. The combined use of the ratio of ionization-to-phonon signal and the event rise-time leads to excellent discrimination of nuclear recoil events from gamma and beta backgrounds. The CDMS II experiment, containing five towers, each with six individual cryogenic detectors, is currently in operation in the Soudan mine. Data from initial runs of this experiment, employing two of the five towers, have yielded the tightest published upper limits yet on the spin-independent cross-sections for WIMP-nucleon interactions as a function of WIMP mass. Analysis of the full five-tower runs of CDMS II will improve the sensitivity by a factor ~ 8, achieving a cross-section sensitivity of 2.4×10^{-44} cm^2 at a WIMP mass of 60 GeV/c^2.

The SuperCDMS project involves the construction of additional "SuperTowers" for implementation in the Soudan facility. The SuperCDMS detectors are 2.5 times thicker than the CDMS II detectors, have increased phonon sensor coverage, and incorporate an improved hydrogen-passivated electrode design, as well as improved surface preparation to reduce beta-isotope contamination. These advances should provide another factor of ~3 improvement in sensitivity for the Soudan implementation of SuperCDMS in the years 2008-09, leading to a total sensitivity a factor of ~20 better than currently published upper limits.

The SuperCDMS 25-kg experiment will involve the implementation of seven SuperCDMS towers at SNOLAB, where the cosmogenic neutron background is appreciably lower. When fully operational, SuperCDMS 25-kg will achieve a cross-section sensitivity of 1.3×10^{-45} cm^2 at 60 GeV/c^2, roughly 120 times lower than current limits. That level of sensitivity probes deeply into the parameter space predicted by existing theoretical models; including MSSM, split-supersymmetry, and some extra-dimension models. As such, it will provide a very important advance for this field.

The Fermilab CDMS group has been playing a major role in the highly successful CDMS II experiment. It has provided project management and technical expertise on cryogenics, electronics, data acquisition, and computing. It has also led the operations at Soudan. These contributions have been essential to the success of the CDMS program so far. The group is proposing to continue to play a leading role in SuperCDMS, both at Soudan and at SNOLAB. For the Soudan phase, Fermilab will maintain the responsibility for project management, cryogenics, electronics, data acquisition, and computing. For the SNOLAB phase, in addition to project management, Fermilab will lead the effort to develop the new cryogenic system, the shielding and veto system, and data acquisition. The group is also hoping to ramp up its data analysis effort by hiring an additional postdoc. The Committee believes that Fermilab's strong commitment is key to the success of the SuperCDMS experiment, both at Soudan and SNOLAB. The Committee endorses the science case for SuperCDMS 25-kg, and the proposed Fermilab roles in the project. The Committee, therefore, recommends Stage I approval for the participation of the Fermilab CDMS group in the SuperCDMS 25-kg project.

SuperCDMS uses one of several candidate technologies that are under consideration for a ton-scale dark matter direct-detection experiment. This field has been highlighted by the EPP2010 and P5 committees as a very exciting area for future scientific discovery. The Committee advises Fermilab management to keep abreast of competing technologies.

Neutrino Physics Program

Neutrino Beam Delivery

The Committee congratulates the Accelerator Division on the excellent performance of the accelerator complex in delivering neutrino beams of impressive and growing intensity. Over 10^{20} protons on target have been delivered to the Booster neutrino beamline so far in FY2007. Moreover, in excess of 2×10^{20} protons on target have been delivered to the NuMI beamline since June, 2006. There has been considerable progress in slip stacking, and, with further progress, it is expected that the NuMI beam intensity will be increased to 3.6×10^{20} protons on target per year, in agreement with the goals of the Proton Plan.

E-929 NOνA (Feldman/Messier)

The NOνA experiment is the only one on the near horizon with sensitivity to the ordering of the states in the neutrino mass spectrum. The degree of sensitivity will depend on the value of the small leptonic mixing angle θ_{13}. The ordering of the states will discriminate among theoretical models of neutrino mass, and will be important in the effort to determine whether CP symmetry is violated in neutrino oscillation. Thus, the Committee finds the scientific case for NOνA to be strong. However, the Committee is concerned that, owing to recent increases in the estimated costs of some aspects of the experiment, the detector mass is now likely to be about 15 ktons, rather than the 30 ktons originally proposed. Analyses presented to the Committee show that, even with a 15 kton detector, the experiment still has significant physics reach. Nevertheless, the loss in sensitivity due to the decrease in detector mass is regrettable. It is also unfortunate that construction of NOνA cannot proceed more quickly. In addition to its unique ability to study the mass ordering, NOνA can also probe the value of θ_{13}. Faster construction would make NOνA more competitive in the international effort to determine this parameter.

The Committee urges the collaboration, the Laboratory, and the funding agencies to take all possible steps to maintain, and if practicable increase, the physics reach of NOνA.

E-898 MiniBooNE (Conrad/Louis)

The Committee congratulates the MiniBooNE collaboration on producing their important physics result refuting the simplest oscillation interpretation of the LSND measurements. The Committee encourages the collaboration to make every effort to understand their observed anomalous low-energy event rate. This should be facilitated by the availability of SciBooNE data in the near future.

E-954 SciBooNE (Nakaya/Wascko)

SciBooNE is an experiment to measure interesting cross sections for low-energy neutrinos that are important for the T2K experiment, as well as for MiniBooNE. The SciBooNE detector has recently been successfully installed in the newly constructed enclosure 100m from the Booster Neutrino Beam target. Commissioning of the detector with antineutrinos has begun, and physics production running is expected to start soon. The Committee commends the Laboratory and the collaboration on this timely implementation of the SciBooNE experiment, and looks forward to physics results in the near future.

E-938 MINERνA (McFarland/Morfin)

The MINERνA experiment plans to study neutrino and antineutrino scattering from a variety of nuclear targets in the broad energy range 1-20 GeV. Following successful CD-1/2/3a approval early this year, the collaboration has recently had a Director's Review in preparation for a DOE CD-3b Review this summer. This can lead to authority to commit funds for construction of the full experiment. Detector construction is scheduled to take about two years, with initial running to begin in late 2009. The Committee is pleased to see the substantial progress towards the realization of this experiment.

Physics Program at the Tevatron Collider

The Run II Tevatron Collider program has been extremely successful. Among the important results coming from the CDF and DZero experiments in the past year are the discovery of several bottom-flavored baryons; increasingly precise measurements of the top-quark and W-boson masses as well as the W-boson width; the first measurements of the B_s meson oscillation frequency, the cross sections for WZ and ZZ production, and the cross section for electroweak top-quark production which yields the first direct measurement of the CKM matrix element V_{tb}. There has also been impressive progress on the search for Higgs bosons, both in the standard model and in its supersymmetric extension. The accelerator has been running extremely well, having achieved a peak luminosity of 2.92×10^{32} cm^2/s, and has now delivered 3 fb^{-1} of integrated luminosity to the experiments. This is significantly better than the baseline projection formulated in 2003, and is a great achievement.

It now appears likely that the accelerator will deliver between 6 and 7 fb^{-1} of integrated luminosity by the end of FY2009. This will be enough for the experiments to meet or exceed the physics goals formulated in their Run IIb Technical Design Reports, which were based on 15 fb^{-1}. The Committee notes that the search for Higgs bosons and physics beyond the standard model would still greatly benefit from additional integrated luminosity.

The Tevatron will remain at the discovery frontier until it is surpassed by the LHC. When that will happen is difficult to predict due to uncertainties in the LHC schedule and how long it will take to commission the accelerator and experiments.

The Committee considered the issue of running the Tevatron beyond FY2009. It is projected that each additional year of run time could deliver about 2 fb^{-1} of integrated luminosity to the experiments. Thus, running in FY2010 would increase the integrated luminosity by about 30%. This would extend the discovery reach for Higgs bosons and physics beyond the standard model.

The Committee felt that it is now premature to make a recommendation on running the Tevatron Collider in FY2010, but that such a recommendation, if desired, must be made by spring 2008 at the latest, in order to accommodate the funding cycle. Results presented by the CDF and DZero experiments between now and then will help inform that recommendation. It is vital that the experiments optimize their analysis techniques in time for this decision. Tremendous progress has been made along these lines in the past year, but not all the planned optimization strategies have been completed yet. In addition, better knowledge of the LHC schedule will be available in spring 2008.

The Committee also discussed the possibility of running the Tevatron beyond FY2010. While it is too soon to make definite plans, it is worthwhile to consider a possible physics case for such an extension. Running for three years beyond FY2009 could potentially double the integrated luminosity, increasing the discovery potential of the experiments. As an example, it might be possible to observe (at the 3 sigma level) a standard model Higgs boson decaying to $b\bar{b}$ in the range $m_h = 115 – 130$ GeV where $b\bar{b}$ is the dominant decay mode. This range is indicated by precision electroweak experiments as well as supersymmetric models. It will be challenging for the LHC experiments to observe this decay mode of the Higgs boson. So, a Tevatron measurement could be complementary to the LHC.

In addition to the development of a physics case, there are some questions that must be addressed before it would be possible to endorse running in FY2010 or beyond:

- Would the detectors, in particular the silicon vertex detectors, still be performing acceptably?

- What would be the impact of running the Tevatron Collider in 2010 or beyond on the rest of the Laboratory's plan and the national roadmap?

- Would there be sufficient human resources to operate the experiments and carry out the most important analyses?

ILC Detector/Physics Efforts

The Committee heard a presentation on the activities at Fermilab on ILC physics initiatives and ILC detector R&D. The Committee appreciates this comprehensive summary which not only contains the traditional discussion of detector R&D issues, but also the broader perspective on the major strategic issue of Fermilab as the host laboratory for the ILC. The formation of the ILC Physics Coordination Team is a very positive step towards this important strategic goal. The Committee commends the continued progress in the engagement in detector R&D, as well as the important increase of effort in hosting many ILC-related events ranging from collaborative work on detector R&D and test beam facilities, to the physics case and general outreach to establish a leadership role for Fermilab in the ILC enterprise.

An important issue is the scope of Fermilab's effort in physics and detector R&D. How should this effort be carried out commensurate with Fermilab's desire to be the host ILC laboratory? The major questions related to this issue include the level of 'vertical' collaboration within a specific detector concept versus involvement in common 'horizontal' efforts across the various detector concepts. With the inevitable evolution of the effort of the detector collaborations toward detailed engineering designs, as a host laboratory, the uniform support for different detector concepts also emerges as a particularly important issue. The Committee observes that there is a significant mismatch of the desired level of involvement from Fermilab to accomplish this host laboratory role as the top priority for the future and the current level of funding for the ILC physics and detector R&D. The Committee recognizes that Fermilab has improved several aspects of the infrastructure, such as the test beam and SiDet facilities, in order to facilitate ILC detector R&D. However, the Committee was disappointed to hear that the Laboratory was unable to fully fund the M&S requests made from its scientists for detector R&D. In order to achieve the goal as a host laboratory, a significant increase of resources for the ILC physics and detector R&D effort is important.

The Committee notes that the current detector R&D projects are now well focused on some of the key areas of detector design, and are good matches to Fermilab's core competencies. While much of the effort was done in association with the SiD concept, many aspects of this work have also been kept in a general horizontal collaboration across the detector concepts. It is important for Fermilab, as a potential host laboratory for the ILC, to maintain impartiality toward the different detector concepts. Given the current limitation on resources to grow Fermilab effort on all concepts at an equal level immediately, the Committee recommends that the Laboratory strengthen horizontal collaboration whenever possible. The Laboratory should also consider appropriate ways to increase its support for other concepts beyond SiD.

The Committee finds the proposal to engage in Particle Flow Algorithm (PFA) and general calorimetry studies through test beam measurements attractive. Calorimetry is a major focal area to grow the Fermilab involvement. Besides the central importance of the PFA concept to the ILC detector design, this proposal can naturally pull together work on detector design, physics studies, related software, and the test beam facility in a coherent manner. Calorimetry studies also have significant potential for horizontal collaboration with, e.g., CALICE, and would allow Fermilab to evaluate the possible direction of growth into the critical area of ILC calorimetery.

Another important topic is the software infrastructure for ILC physics and detector design studies. The current directions of software development elsewhere are rather divergent, and present some obstacle to coherently facilitating detector design studies in a consistent and easy manner. Steps to improve the current situation are important for the timely convergence of detector design studies. The Committee was encouraged to see initial efforts begun to create tools to serve a wide range of needs. This is a critical area of need where Fermilab can utilize its expertise and potentially play a leadership role.

The Committee would like to applaud the initiative from the Fermilab team to improve the test beam facilities for ILC detector R&D. These improvements will benefit the HEP community as a whole.

The Committee appreciates the initiative to bring young people into the ILC physics and detector effort. An increase of funding to open more opportunity for detector R&D would be an important factor which could help in this area. Establishing fellowships and other positions is also an important tactic to encourage involvement from young people. It is important for the field as a whole to seek a means to provide viable career paths for young people who work on this long-term initiative.

LHC Experiment Upgrades

Although the LHC will begin operation during the next year, plans are already being formulated to enable higher luminosity running during the next decade. This plan, known as SuperLHC (SLHC), will require upgrades to the detectors to accommodate higher luminosity running. CMS has recently submitted an EOI to CERN regarding participation in SLHC and associated upgrades of CMS.

The CMS upgrade will involve improvements to the tracker, trigger, calorimeter, and muon systems. For the tracker, there are two phases. The short-term phase involves new pixel layers, and would be followed by a full tracker replacement in a later phase. The total US CMS upgrade cost is currently estimated at about $150M.

Fermilab is the host laboratory for US CMS. Therefore, it would be natural for Fermilab to play a substantial role in the proposed CMS upgrade. At present, the approval process for such an upgrade is not clear. In view of the substantial Laboratory resources that would be involved, it seems appropriate that a presentation from US CMS regarding the EOI and plans for US participation be scheduled for the fall 2007 PAC meeting.

Detector and Computing R&D

The Committee heard presentations covering a broad spectrum of detector and computing R&D activities. Detector R&D activities include ILC detector R&D, the CMS upgrade, neutrino physics (NOνA, MINERνA, LAr TPC), dark matter direct detection (COUPP, SuperCDMS), and astro-particle physics (DES/DECam, SNAP). Computing R&D activities include accelerator modeling, facilities for lattice QCD calculations, GRID scalability and security issues, wide-area networking, and tools for computational cosmology; some of these attract external funding, for example, from the SciDAC program.

The Committee commends the Laboratory for fostering such a lively and diversified program of R&D projects, for its engagement in crucial and cutting-edge technology developments related to the principal themes of world-wide research in particle and astro-particle physics, for its efforts to foster synergies among projects so as to optimize the scientific output for a given financial investment, and for its intense and healthy collaboration with universities and other labs.

Should opportunities for expanding the scope of Fermilab R&D activities emerge in the future (noble liquid detectors for Dark Matter searches and water Cerenkov detectors for long-baseline neutrino experiments are among the various possibilities), they should be evaluated in the context of the overall national scientific strategy and funding constraints, taking into account the following criteria:

1. Scientific and technical excellence;

2. The uniqueness and impact of the Fermilab contribution, given its existing infrastructure and technical expertise; and

3. The interest among Laboratory personnel in collaborating on the project. Ideally, Laboratory management would help external proponents to identify relevant personnel who might be available to participate.

Accelerator Physics Center

The Committee heard an engaging presentation on Accelerator Physics R&D at Fermilab and the recently formed Accelerator Physics Center (APC). Although the APC is primarily intended to engage in advanced projects, a sizable fraction of its personnel are in fact currently devoted to nearer-term projects.

The Laboratory plays a vitally important role in providing the basis for future accelerator-based research both in the US and internationally. Addressing these long-term needs, while simultaneously providing leadership in the development of technology needed for the ILC and possible other projects, will present a significant challenge to the Laboratory. It will require careful planning of the redeployment of the resources that become available as Tevatron operations come to a close.

The Committee agrees that the APC will be of value in meeting these challenges. In particular, attracting students to accelerator research is clearly important to the long-term health of the field and the APC provides a way to engage students and other university-based researchers in the sort of cutting-edge research that they are likely to find attractive. The APC also provides a framework for Laboratory accelerator physicists who are largely involved in day-to-day operations to get involved in advanced projects on a part-time basis.