Physics Advisory Committee

March 29-31, 2007

Comments and Recommendations

Neutrino Physics Program

US Long Baseline Neutrino Study

The Committee heard presentations on the US Long Baseline Neutrino Study, which is exploring the optimum strategy for accelerator-based neutrino experiments beyond NOνA. The Committee greatly appreciates the very considerable, interesting, and illuminating work of the members of the Long Baseline Study. Their results will be very helpful to the planning of the future neutrino program.

The experiments beyond NOνA would enhance our sensitivity to CP violation in the leptonic sector, to the sign of the neutrino mass hierarchy, and to the crucial small mixing angle θ_{13}. The Study is focusing on two approaches: 1) Add detector mass at a location along the existing NuMI beamline, for example at the site of NOνA; 2) Construct at Fermilab a new wideband neutrino beam pointed at a very large detector over 1000 km away, possibly in a Deep Underground Science and Engineering Laboratory (DUSEL). Approach (1) would put the new detector mass at the earth's surface, so that it would require detector technology capable of the needed high background rejection. To this end, liquid argon technology is being studied. Approach (2) could use either a water Cherenkov detector, whose capabilities are already established and appear adequate, or a liquid argon detector. A very large water Cherenkov detector would have to be placed deep underground, so a suitable large deep underground cavern in which to place it would be essential. An underground very large neutrino detector, either water or liquid argon, would also permit searches for proton decay with greater sensitivity than in the past.

Approach (1) would have the advantage of capitalizing on the considerable investment in the NuMI beamline, and the advantage of being incremental. For given "exposure" (detector mass times beam power times running time), approach (2) has greater sensitivity to CP violation unless the exposure is large, and to the sign of the mass ordering for any exposure. Approach (1) depends on detector technology yet to be developed, while approach (2), if utilizing an underground site for its detector, depends on the existence of a suitable site.

The physics to be explored with the neutrino experiments beyond NOνA is compelling. The optimum strategy for these experiments will depend on the value of θ_{13}. If $\sin^2 2\theta_{13}$ proves to be not too much smaller than the present bound, a lot could be learned through approach (1). If $\sin^2 2\theta_{13}$ is smaller, but not below 0.01, approach (2)

would be an excellent strategy. If $\sin^2 2\theta_{13} < 0.01$, technology such as a neutrino factory or a beta beam will be necessary to probe CP violation.

For $\sin^2 2\theta_{13} > 0.01$, the optimum strategy will also depend on what is learned from R&D on the different approaches. The Committee encourages this R&D, and looks forward to its results.

MiniBooNE

MiniBooNE presented preliminary results based on anti-neutrino data collected since January 2006. Event distributions are in good agreement with expectations. The Committee eagerly awaits the 11 April 2007 report on the results from the neutrino oscillation analysis.

MINERνA

The MINERνA physics goals of measuring low-energy neutrino cross-sections are unique and important, both in their own right and for their impact on other experiments. The Committee is pleased with the technical progress in the development of the detector. Good progress is also being made with the approval process, and the funding seems to be secured.

NOνA

The Committee remains convinced that the physics case for NOνA is compelling. Therefore, it expresses some concerns about the changes in scope and schedule associated with budgetary restrictions and funding profile. The Committee believes that the size of the building should enable increasing the detector mass. Significant progress has been made on the detector R&D. The Committee encourages the collaboration to build and test a full-length prototype detector module filled with scintillator. The Committee also encourages continuation of the efforts to obtain international collaborators.

Physics Program at Colliders

CDF and D0

The Committee heard reports from both CDF and D0. Both detectors are performing well and the collaborations are focused on extracting the maximum amount of physics from their data. This has clearly been a banner year for physics, with the measurements of B_s mixing, single top production, WZ and ZZ production, the discovery of new baryon states, and precision measurements of M_t and M_W, among many other

results. The collaborations are to be congratulated on the large number of new and important physics results. One of the key ingredients enabling this success was the continuously improving Tevatron luminosity, which has reached a record peak luminosity of $2.92\times10^{32}\text{cm}^{-2}\text{s}^{-1}$. It appears likely that the Tevatron will deliver between 6 and 7 fb^{-1} by the end of 2009. The Committee commends the Laboratory, the accelerator team, and the collaborations for the quality of the science and the ingenuity in operating this flagship energy frontier facility.

The collaborations have turned their focus to improving the analysis techniques and triggers in order to gain physics sensitivity at a significantly faster pace than the canonical square root of luminosity. The Committee is pleased to see the aggressive plans of both collaborations to systematically reorganize resources and identify a wide range of possible analysis improvements. The Committee commends these efforts and wishes them success!

The search for the Higgs boson is a major focus of both collaborations. One standard-model Higgs discovery channel at the Tevatron is associated production with a W or Z boson, followed by Higgs decay to bottom quarks. This provides a measurement of the coupling of the Higgs boson to vector bosons, which is an important test of the nature of the Higgs boson. This channel is not accessible at the LHC in the first few years of running, and is difficult even with a large amount of data.

The Committee is also pleased to see the increasing effort in expediting the analysis output as the experiments become more mature. The first result with 2 fb^{-1} of data from D0, the search for $B_s\rightarrow\mu\mu$, typifies this effort. The Committee is looking forward to more results with 2 fb^{-1} and beyond.

D0 has successfully installed and commissioned upgrades to the tracking and Level-1 Trigger in order to deal with high luminosity. CDF is commissioning further trigger upgrades for the tracking and calorimeter and increased the DAQ bandwidth for high luminosity running. The Committee encourages continued strong efforts in detector improvements to optimize the physics throughput. The Committee is looking forward to the creative solutions along this path to deal with the additional challenges for high luminosity, such as the D0 tracker-occupancy issue.

Both CDF and D0 face significant resource challenges as collaborators transition to the LHC in the coming years. The efficient deployment of analysis and reconstruction efforts to a wide range of analyses is encouraging. The collaborations have made serious attempts to plan to overcome the resource challenges. The Committee encourages the Laboratory to continue to explore creative and flexible solutions to help supply the required manpower.

The date of the final turn-off of the Tevatron will be addressed by P5 in June of this year. The Committee encourages the Laboratory to develop a strategy for determining the optimal date for the end of the Tevatron program.

The successful operation of the Tevatron, CDF, and D0 should remain the top priority of the Laboratory.

CMS

The Committee heard a status report on the activities of CMS and the progress on detector installation and the preparation for physics. Progress on the installation of this enormous detector is inspiring, and the Committee looks forward to the beginning of the LHC era in the near future.

At Fermilab, the CMS efforts have been joined into a "CMS Center", which includes the LHC Physics Center (LPC), the Remote Operations Center (ROC), the Tier 1 Computing and Analysis Facility (LPC-CAF), and the research program management and program office. The CMS Center pulls the Fermilab research effort on CMS under a single umbrella. The Committee was impressed by its tour of the ROC, and encourages the further development of the CMS Center in order to enhance remote participation of physicists in CMS activities.

With detector commissioning and initial operations beginning soon, the Committee encourages the Laboratory to think about the optimal deployment of post-docs between Fermilab and CERN in order to maximize their potential scientific impact and career opportunities.

Particle Astrophysics Program

Cryogenic Dark Matter Search (CDMS)

The Cryogenic Dark Matter Search (CDMS) experiment continues to progress well. It has already produced the best cross-section limits for WIMPs. It has collected sufficient data to improve its published results by a factor of three in sensitivity, and is on track to improve by another factor of three in the next year. The SuperCDMS 25 kg experiment targets another factor of 15 improvement. The Committee endorses Fermilab's commitment to these efforts, and to the SuperCDMS 25 kg experiment, in particular. Furthermore, given the level of the Laboratory's commitment to the experiment, the fairly large cost of the experiment, the support for dark matter searches by P5 and DM SAG, and lastly the synergy of the experiment with the COUPP project, the Committee encourages submission of an updated proposal for Stage I approval of a SuperCDMS 25 kg project at Fermilab.

Dark Energy Survey (DES)

The Dark Energy Survey (DES) is a near-term dark energy experiment that combines four complementary methods (cluster survey, supernova survey, weak lensing survey, and measurements of baryon acoustic oscillations) to significantly improve

understanding of dark energy. In its October 2006 Particle Physics Roadmap, the HEPAP P5 subpanel recommended for DES "that the agencies proceed with funding this project".

The Committee is pleased to see that the DES collaboration has made significant progress on R&D of its prime focus camera (DECam) and that it has grown into a strong multi-institutional collaboration including participants from Brazil, Spain and the UK. Fermilab is the leading institution for the DECam project and provides project management.

A joint NSF-DOE review (CD-1 review) is scheduled in May and the PAC is looking forward to a successful completion of the review. The Committee also encourages the collaboration to work closely with the Laboratory to assess the impact on the schedule of the funding profile recently given by DOE for DECam, and to optimize the project planning.

Center for Particle Astrophysics (CPA)

The creation of the Center for Particle Astrophysics has enabled the disparate groups engaged in particle astrophysics research at Fermilab to come together in a common environment and a common organization. The new Center, like the Particle Physics and Computing Divisions and the CMS Center, report directly to the Associate Director for Research. This is appropriate recognition of the leading role Fermilab has played since the early 1980's in fostering the field of particle astrophysics as a major component of high energy physics research. The present mix of particle astrophysics projects in the Center is diverse and comprises most of the exciting new directions for this field. The Committee was impressed with the enhanced level of interaction that has resulted from the new organization, and with the degree to which it has eased the transition for traditional particle physicists now entering particle astrophysics projects. The Committee also applauds the long-range planning that was undertaken as part of the proposal preparation by the Fermi Research Alliance. Fermilab has benefited substantially in this field from its close association with the University of Chicago, and this provides a model for strengthening Fermilab-UC collaborations in other research areas. It is important, however, for the particle astrophysics programs to continue to provide and foster opportunities for user involvement by a wide range of universities, as is the case for the accelerator-based programs at the Laboratory.