Physics Advisory Committee

October 19-21, 2006

Comments and Recommendations

E-906 (Paul Reimer / Don Geesaman) Drell-Yan

E-906 was granted Stage I approval by the Laboratory in November 2001. The Committee reaffirms the previous PAC judgment that this experiment will yield results of considerable interest. The experiment will continue a very successful series of Fermilab Drell-Yan measurements that have had significant impact.

E-906 will measure Drell-Yan lepton pair production by Main Injector protons incident on proton, deuteron, and heavier nuclear targets. From the proton and deuteron target data, this experiment will determine the antiquark ratio $\bar{d}(x)/\bar{u}(x)$ in the proton in the range $0.1 < x < 0.45$. This determination will probe the origin of the flavor-asymmetric component of the antiquark sea. Measurements will also be made of the valence quark distributions at large values of *x*, where they are poorly known. From the heavy nuclear target data, this experiment will sensitively probe the difference between the antiquark sea of a nucleus and that of an isolated nucleon, addressing fundamental nuclear physics issues such as the meson-exchange picture of nuclear forces. It will also explore the energy lost by partons as they traverse nuclear matter, a basic QCD phenomenon.

Since E-906 received Stage I approval in 2001, there have been no experiments that supercede it, and the physics case for the experiment remains strong. At the time of Stage I approval, two conditions were put in place: the experiment should be scheduled after the end of high-luminosity collider running, and it should be scheduled in parallel with a large fixed-target experiment such as CKM. The Committee feels it is appropriate to modify these conditions. It is now expected that the Tevatron Collider will run until a later date than was anticipated in 2001. If E-906 is ready to take data prior to the end of high-luminosity collider running, then it would be reasonable to consider running the experiment provided that it does not significantly affect the collider luminosity. Although CKM was cancelled, and there are no plans for a comparable fixed-target experiment at this time, the Committee believes that E-906 would be successful, and endorses proceeding with it. This requires finding the appropriate site for the experiment and developing the needed beamline.

Since the original planned site, the Meson East area, is now being used for another purpose, E-906 would have to be mounted elsewhere. This and other changes result in a cost of ~$2M to Fermilab to mount this experiment (a detailed cost estimate from the Laboratory remains to be done). In the present plan, the spectrometer components, including the magnet, will be funded in large part by DOE-NP, with a contribution from the NSF. DOE has requested that Argonne hold a review of the spectrometer cost and schedule.

The collaboration is very experienced and is largely composed of participants in the previous Fermilab Drell-Yan experiments E-772, E-789, and E-866.

The Committee recommends that Fermilab approve the running of this experiment if an acceptable funding plan can be arranged.

E-944 (Steve Brice / Richard Van de Water) MiniBooNE Antineutrino

MiniBooNE has been taking data in antineutrino mode since January 2006, and has collected about 1×10^{20} protons on target. First results show that the observed antineutrino event rates and other event features compare well with expectation.

The MiniBooNE collaboration has requested an extension of the antineutrino run to increase the available data sample, with the main aim of improving the precision of the cross-section measurements in the energy range below ~ 1 GeV, where there is lack of data.

The Committee recommends extension of the MiniBooNE running until the Summer 2007 shutdown. The Committee notes that SciBooNE may wish to commission with neutrinos. The relative priorities between neutrino and antineutrino running should be established by Laboratory management.

Further extensions of MiniBooNE data-taking should be considered on the basis of the neutrino oscillation results.

P-960 (Rajendran Raja) Main Injector Particle Production (MIPP)

The MIPP experiment studies particle production cross sections from beams of protons, antiprotons, $K^{\pm}$, and $\pi^{\pm}$ in the energy range 5-85 GeV. The spectrometer system includes a TPC, ToF detectors, differential Cerenkov, and RICH counters to identify and measure the momenta of the produced particles. The experiment was approved in November 2001 (P-907) and acquired data in a production run during the period January 2005 – March 2006. The collaboration is currently analyzing the 31 million events collected during this run (About 14 million of these triggers were collected in special runs with the analysis magnet off and with no TPC data).

The present apparatus is limited by the TPC electronics to an acquisition rate of about 30 Hz. The present proposal includes upgrading the electronics to enable data acquisition at 3 kHz, which would yield 5 million events per day. Two coils of the Jolly Green Giant TPC magnet failed near the end of the previous run and must be replaced with new coils for further running. The beamline would also be upgraded to allow running at lower momenta down to 1 GeV/c. In addition, the trigger, drift chamber, ToF/CKOV and calorimeter electronics would be upgraded.

The collaboration has proposed using the upgraded spectrometer to perform an expanded program of measurements, collecting 250 million events in a period of 50 days of running. These measurements include production from the NuMI target as well as hydrogen and a variety of nuclear targets. The NuMI target studies are intended to provide data as input to neutrino flux calculations for the MINOS, MINERνA, and NOνA experiments. Other measurements would

provide input data to simulation programs such as those used to design and analyze hadronic calorimeters or to reproduce high-energy cosmic air shower data. A tagged neutral beam capability would enable studies relevant to ILC calorimeter design. In addition, the data could be useful for refining phenomenological QCD models of particle production, and possibly searching for new baryon resonances such as those predicted in flux-tube models of quark interactions.

In general, the Committee believes that the program of studies proposed by the collaboration can be very valuable in providing input to simulation programs and decreasing uncertainties in the neutrino fluxes at NuMI, but the Committee was not convinced that the value of the proposed measurements justifies the upgraded running. The proponents will need to provide more detailed quantitative information about the impact of the proposed measurements. For example, how much would the new data reduce the systematic errors in extracting neutrino oscillation parameters from MINOS and NOνA? What is the sensitivity to new baryon resonances? How would cross section measurements quantitatively impact the performance of simulation programs? Based on the material presented, the Committee judged the "service" measurements to be more compelling than the QCD phenomenology studies.

It would be desirable to see more results from the existing dataset before committing to an upgrade and additional running time. The Committee also has some concerns about the current collaboration's capacity to mount such a substantial hardware upgrade, acquire a much larger dataset, and then analyze such a vast quantity of data.

The Committee recommends that a decision on P-960 be deferred at this time. The collaboration should demonstrate that the existing data can provide high-quality physics results with substantial impact. The case for additional measurements should be developed further to provide more convincing quantitative justification for the proposed program. The collaboration should strengthen their manpower for executing the new program. When these points are addressed, it would be appropriate for the proposal to be reconsidered.

P-961 (Juan Collar) Chicagoland Observatory for Underground Particle Physics (COUPP)

The composition of cosmological dark matter is one of the outstanding mysteries in physics today. Such a particle might produce low-energy nuclear recoils in bulk matter, and several experiments have searched for this signature using a variety of techniques. The Laboratory has provided 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. However, Supersymmetry provides a natural dark matter candidate (the SUSY Lightest Supersymmetric Particle) that could require a ton-scale experiment 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.

The Committee heard a presentation on COUPP (Chicagoland Observatory for Underground Particle Physics). This effort of the University of Chicago and Fermilab, currently working as T-945, together with Indiana University/South Bend, is developing a WIMP detector based on a heavy liquid bubble chamber (currently CF_3I). Excellent progress has been achieved

in the past year. The bubble chamber is inherently insensitive to electrons, and the collaboration has achieved a minimum-ionizing-particle rejection factor of $>10^9$, operating with a 2-kg chamber in the NuMI tunnel. A good effort is underway to reduce the limitations imposed by background radioactivity. The high spatial resolution of this approach is very powerful. This effort is currently focusing on producing competitive sensitivity, especially on spin-dependent couplings, a particular strength of this technique. However, they need, at the same time, to address the needs for the large one-ton chamber to remain competitive with other approaches.

The group has proposed to 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 one ton. Significant resources are requested from the Laboratory to realize this plan. The physics goals are compelling, and the technology looks very promising. The Committee notes that several related efforts are also underway, and are being formally reviewed by the HEPAP Dark Matter Scientific Assessment Group. It is advisable for Fermilab to be cognizant of these other approaches.

The Committee recommends that the Laboratory provide the resources requested for the modest initial phases of this promising effort on WIMP detection. The proposed effort for FY07 is well fleshed out, while the plan for FY08 will need input from the FY07 results. The proponents should be encouraged to report progress as input to decisions about future support from the Laboratory.

Accelerator Operations

The Committee received a summary presentation of the accelerator operations for Run II, NuMI, and MiniBooNE. The Committee is pleased to hear of the ever-increasing luminosity of the Tevatron. The delivered integrated luminosity is approaching 2 fb^{-1}, on track to meet the Run II design luminosity goal. It is now becoming realistic to expect a beam delivery of approximately 8 fb^{-1} through 2009. The Committee congratulates Fermilab on the notable achievement of the record peak luminosity of 2.38×10^{32} $cm^{-2}s^{-1}$, as well as the record anti-proton stacking after the spring shutdown. These record performances were accomplished as a result of the continuing machine improvements by the Accelerator Division. The beam-beam interactions are now under control, and further improvements in Tevatron performance can be expected. The Committee also applauds the stable and increasing proton delivery to the neutrino beamlines for MINOS and MiniBooNE.

Tevatron Experiments

The Committee commends the Laboratory, the machine teams, and the two international collaborations, CDF and DØ, for the quality of the scientific output of this sector of activities at Fermilab. The shutdown activities were a complete success; the impact of the numerous improvements should be observed soon.

The Committee shares the concern of the two experiments about the risk that manpower may decrease too rapidly in the coming years. Both collaborations have taken concrete steps to ameliorate the effects of these decreases. Obviously, they should continue to monitor the

situation, and make appropriate adjustments. Help from both the Laboratory and the funding agencies involved in the project are needed. The two fellowships each allotted to CDF and DØ by Fermilab, and the steps taken to reorganize internally, were noted.

The measurement of ΔM_s by CDF and DØ deserves special mention. It provides one of the most awaited constraints to the CKM model of CP violation. The spectacular analysis progress achieved by these collaborations in the course of a few months is very encouraging. The successful development of aggressive analysis techniques may be a good omen for the Higgs search at the Tevatron, where much significant work is still required to reach the necessary sensitivity. A detailed presentation of the Higgs search potential would be welcome at the next PAC meeting.

The successful operation of the Tevatron, CDF, and DØ should remain the first priority of the Laboratory.

CMS

The Laboratory's contribution to the CMS collaboration is remarkable in all respects: the detector development, construction, installation and commissioning, and the preparation of physics analyses and computing resources devoted to this program. In particular, the Tier-1 center at Fermilab is going to be a key component of the CMS computing structure. The progress on the inter-operability between Open Science Grid (OSG) and LHC Computing Grid (LCG) was noted. The Committee commends the resolute steps taken by Fermilab management to ramp up the Laboratory's commitment to CMS. The recognition of this activity in the management structure, as a CMS center, and the creation of the Remote Operations Center (ROC) and the LHC Physics Center (LPC) are very positive developments. These ambitious initiatives, properly integrated into CMS as an international center, will enable US-based scientists to maximally contribute to the experiment. The Committee would welcome a status report on the Fermilab Tier-1, the ROC, and the LPC at its next meeting.

International Linear Collider (ILC)

The International Linear Collider is the highest priority long-term program for high-energy physics in the United States. As the nation's only laboratory devoted solely to particle physics, Fermilab must play a national, even international, leadership role in shepherding the development of the ILC, both for the accelerator systems and the detectors. To address concerns that the Fermilab physics community has not been sufficiently engaged in the ILC, the Laboratory convened an ILC-HEP Task Force in May 2006, to make recommendations on concrete steps that can be taken now to increase Laboratory particle physicists' involvement in the ILC. A draft report from the task force was delivered on October 18, 2006. The report makes a large number of quite specific recommendations – some of which may have significant financial implications for the Laboratory. While the Committee cannot comment on the practicality of implementing all of these recommendations, it applauds the concrete steps that have been taken so far to meet this challenge, and encourages further discussions in this area.

A significant amount of progress has been achieved in ILC detector studies at the Laboratory. The Committee was intrigued by the presentation on 3D integrated circuits for pixel detectors. This is an exciting new technology that appears quite promising. Laboratory staff have also addressed issues of sensor development, vertex detector mechanical design, and outer tracker sensor and module design, as well as several issues in calorimetry. The Committee was pleased to see a more focused effort in targeted areas that capitalize on the Laboratory's core competencies, rather than subcritical efforts on too broad a range of issues.

The provision of the Meson Test beamline is extremely important for ILC detector R&D, and provides a key resource for both the US and global ILC communities. Fermilab is well poised to continue to play a major leadership role in this arena. Areas of further development should include an enhanced role in ILC software support and data acquisition for the test beam, and strengthening of the ILC simulations group.

E-875 (Stan Wojcicki / Rob Plunkett) MINOS

The MINOS experiment is operating well and is achieving very high data-taking efficiency in both detectors. Based on detailed analyses of a sample of over 10^{20} protons on target, the ν_μ disappearance signal has placed constraints on Δm_{23}^2 and $\sin^2(2\theta_{23})$ that are competitive with those derived by prior experiments. The collaboration is currently conducting a ν_e appearance search as well as a search for other exotic signals. The Committee looks forward to the continued successful running of MINOS and the rich physics results that it will produce.

E-898 (Janet Conrad / William Louis) MiniBooNE Neutrino

The Committee heard a presentation on the status of the ongoing neutrino data analysis by the MiniBooNE collaboration, which is based on a data sample of 7×10^{20} protons on target. The Committee is very pleased to see that substantial progress has been made in understanding the various sources of systematic uncertainties, coming, e.g., from hadron production and neutrino cross-sections, in modelling the detector optical response, and in constraining the backgrounds. Constraining backgrounds is particularly challenging in a neutrino experiment without a near detector, and is based on the use of the data themselves.

The Committee is looking forward to the imminent delivery of the eagerly awaited oscillation results, which will test the LSND observation and will allow the Laboratory to plan for the future of the Booster neutrino beam line.