cc: Sr. Mgmnt Group
Div. Heads

Department of Energy
Office of Science
Washington, DC 20585

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Dr. Pier Oddone
Director
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P.O. Box 5000
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Dear Dr. ~~Oddone:~~ Pier:

This letter serves to report the findings from the annual program review of Fermi National Accelerator Laboratory (Fermilab) held on May 15-18, 2006, and to provide guidance to the laboratory on the direction of its research program. The annual review serves as our primary peer review of the performance, management, and planning of the laboratory's research program. It is used both to validate the quality of the research performed by Fermilab and to identify any areas in need of improvement. The report is largely based on the peer review letters written by the consultants who participated in the review as well as the results from other DOE reviews and input from OHEP program managers.

I thank you and your staff for your hospitality during our visit and their efforts to make the review successful. Overall the review went well, but we did have difficulty keeping some of the breakout sessions on schedule. I believe that we can avoid this problem next year with a little more consideration of allocating adequate time for questions & answers and having up front understanding of which presentations might be subjects for truncation in case time does not permit.

Overall it has been a very productive year for the laboratory with the Tevatron and NuMI performing well, and interesting physics results coming from CDF, D-Zero, and MINOS. The LHC accelerator and CMS projects are nearly complete, and the groups are moving to commissioning and research activities. I would like to express our appreciation for successfully handling the mitigation of tritium detected in the local surface water. While this was not part of the review, the topic did come up and our consultants found that the laboratory handled the situation very openly and professionally.

Run II

The Tevatron continues to run at the world's premier energy frontier, setting record luminosities and providing world-class data to the experiments. Both CDF and D-Zero have collected over 1 fb^{-1} of data and produced an impressive set of results. The initial observation of B_s mixing generated a fair amount of excitement. The new results on the mass of the top quark and the W boson and the stronger constraints on searches for new physics will continue to be very important. The collaborations have improved their analyses techniques and understanding of backgrounds in many areas, so that the experiments are now more sensitive to various physics processes than was expected at the beginning of Run II.

The detector upgrades are nearly complete on time and under budget, with most components from the CDF upgrade already in operation, while the new D-Zero layer-0 silicon detectors was just being installed during the review. The consultants expect CDF to make use of the upgrades immediately, while the more complex D-Zero upgrade will take some time to be integrated into routine operations.

The overall size of the Fermilab staff and their responsibilities on the Run II experiments are appropriate for the host lab, and individual Fermilab physicists have taken on leadership roles in both the physics analyses and the operations of the detectors.

It was good to see that the personnel required to operate both experiments will likely be available through FY 2007. Please continue your effort with the collaborations to ensure that the experiments will be adequately staffed through the final years of Run II operation and physics analysis.

Compact Muon Solenoid (CMS)

Fermilab serves as the host laboratory for the US CMS collaboration, fulfilling a variety of important roles in project management, detector fabrication, software and computing, physics analysis center, and the commissioning and operation of the detector. This year, the fabrication of many CMS subsystems is nearing completion on time and on budget, including the forward muon system, hadronic calorimeter, electromagnetic calorimeter, and the silicon tracker outer barrel. Installing and commissioning these systems will be the main tasks of the US CMS collaboration for the next year or two, with the forward pixel system (FPix) still needing considerable attention. Significant Fermilab expertise was added to the FPix when much of the former BTeV group chose to join CMS, and has helped progress.

The deployment of the CMS Tier 1 computing center at Fermilab is on schedule. The software framework was redesigned after weaknesses were identified in the data challenges. The US CMS collaboration has taken on significant responsibilities for the framework, which is a critical part of the software system that must be ready before the detector starts to take data. Concerns were raised in FY 2005 about the connectivity of the CMS Tier 1 center at Fermilab, ESnet, and LHCnet. They have been addressed through collaborative solutions put together by FNAL, ESNet, local partners (eg. ANL and Universities), and DOE headquarters. FNAL CMS Tier 1 computing center personnel are currently addressing in detail connectivity with European Tier 2 centers and validating bandwidth requirements being used to plan US and EU network provisioning. US CMS collaboration has carried out its responsibilities very effectively.

The concept of an LHC Physics Center (LPC) is quite appealing, but it may prove challenging to make it successful. The goal of the LPC is to make it possible for physicists located at Fermilab to be as productive as those located at CERN. The challenge will be more sociological than technical, and it will require combined effort from the management of CERN, CMS, and Fermilab to ensure that the distributed model of detector operation, calibration, reconstruction, and data analysis succeeds.

Neutrinos

The Fermilab neutrino program continues to grow with the new initiatives, such as MINERνA, SciBooNE, and NOνA joining the running experiments, MINOS and MiniBooNE. This reflects the unique capabilities of the NuMI and Booster neutrino beams. Fermilab staff plays large and highly visible roles on these neutrino experiments.

The consultants found the MiniBooNE presentations enlightening, and they expect MiniBooNE to converge on their main neutrino oscillation result soon. There was some surprise at how poorly understood the optical model and the low-energy cross-sections were last year, but they now seem to be under control. We appreciate the difficulties in completing this analysis and are looking forward to an unambiguous result based on a through and careful work; even it might take some additional time.

MINOS showed their first accelerator results on ν_μ disappearance, and they were up to expectations. We look forward to further improvements as more data is collected. There was a discussion of the search for ν_e appearance. Although the MINOS detector is not optimized for detecting electrons, it would be worthwhile for MINOS to invest some effort to make the first observation of oscillations to $\nu_{e,}$ since they will be the only player in this area of physics for several years,.

MINERνA and SciBooNE are both small experiments which are designed to provide improved measurements of low-energy neutrino cross-sections. The measurements from these experiments will benefit the physics programs at MINOS, NOνA, and T2K. The two experiments are optimized to help different oscillation experiments with SciBooNE being better suited to help T2K while MINERνA will be of more benefit to MINOS and NOνA. Although the proponents of these experiments may find standalone physics goals appealing, it is quite clear that the benefits to the neutrino oscillation experiments are the strongest justification for mounting such experiments, and therefore the proponents should sharpen their explanation of those benefits.

NOνA will study two very important topics as part of its program, the appearance of electron neutrinos and the mass hierarchy. There will be some competition with T2K, but it is very important that the competition be kept in perspective and that we use all sources of information when evaluating the competitiveness of T2K. While the consultants were concerned about both the schedule relative to T2K and the reduced size of the detector, I believe that both OHEP and the laboratory understand how realistic the public statements on the T2K schedule have been. I expect NOνA go forward in a manner that allows it to be successful part of a robust and diverse HEP program.

Particle-Astrophysics

The experimental particle-astrophysics program features a mix of projects utilizing optical astronomy techniques and more traditional particle physics techniques. In the first class are the Sloan Digital Sky Survey (SDSS), Dark Energy Survey (DES), and SuperNova Acceleration Project (SNAP). SDSS has clearly been a scientific success. The experiment has produced a rich dataset that has been extensively studied by both the Sloan collaboration and others, producing important results in cosmology and other topics. There were some concerns expressed that Fermilab has not fully reaped the benefits of the SDSS data, and that others with stronger astronomy backgrounds have benefited more. The interest of the HEP program and Fermilab in the telescope-based experiments is scientifically sensible, since they do cast light on prominent problems of space, time, and energy; however the techniques are not a natural fit to Fermilab's experience. Care must be taken to develop the expertise needed to exploit these experiments while not straying from Fermilab's mission. The decision to not pursue SDSS-III which will search for extra-solar planets is consistent with this goal.

The Auger Project nears completion and has begun producing interesting physics. The project appears to be capable of dominating the study of high energy cosmic rays. Preliminary results presented appear to be very interesting and we look forward to a definitive statement on the GZK cutoff. Completing the detector will clearly benefit this very important measurement and its science results will dictate the future of the proposal for a northern Auger since a compelling result from the Argentinean array will be required to justify an initiative in such scale.

The CDMS II experiment is currently the world leader in dark matter searches. The technology has matured, so the collaboration should be working hard to exploit that advantage now, by operating the detector, improving the analyses, and doing those small incremental upgrades that do not significantly disrupt data-taking. How much this technology can scale to larger future detectors is yet to be demonstrated, but we expect the Dark Matter SAG as well as a planned R&D program will be addressing this question.

Detector R&D

Detector R&D at Fermilab is concentrated on the detectors needed for the ILC and future neutrino experiments. The involvement in ILC detector R&D was found to be somewhat diffuse with Fermilab working on many systems, and the progress over the last year was not as pronounced as it was at last year's review. Fermilab's plan to improve its test beam to better support current detector R&D was applauded by the committee. Liquid argon TPC R&D was briefly covered in the presentations, but it is still a very early effort.

Theory

Fermilab has strong particle theory and particle-astrophysics theory groups. The individuals within the groups are the leaders in the field and the groups work cohesively to reinforce their strengths. Both groups are well aligned with national priorities. The particle theory group works on the topics which are beyond the standard model physics and is closely aligned with Run II, the LHC, and the ILC. In addition there are strong contributions to neutrino physics. The particle-astrophysics theory group concentrates on topics that use astrophysics to probe beyond the standard model.

The departure of Rocky Kolb from the laboratory does leave a significant hole in the particle-astrophysics theory group, since it is not a large group, it might be necessary to replace him. The group retains enough senior leadership that the choice of either senior or junior hires might be appropriate.

There were several issues raised by the consultants which I would like to just make you aware of, although I believe that decisions of how to handle them are best made by lab management. The consultants advise us that the theory group can contribute to the success of the LHC Physics Center, but the group currently feels that they do not have strong connections with the activities at LPC. The consultants also endorsed the high priority that the theory group puts on its visitor program, since it both strengthens the group and serves the community, and that training students can enhance the theory group. Lastly, the theory group has not felt that they had adequate access to you.

ILC and Superconducting RF R&D

The Fermilab ILC R&D was not specifically covered in the annual review as the full US ILC program was reviewed on April 4-6, 2006. Fermilab's work on lattices for the main linac, beam optics code development and beam position monitor instrumentation has been an important contribution to ILC design. Fermilab has the lead role in cryomodule design, and has important efforts in magnet design, beam delivery system collimation, and machine protection systems in support of the Reference Design Report (RDR). The work toward characterizing the US sample site for the RDR is led by laboratory staff, and the international ILC costing for the RDR is led by a Fermilab physicist. The April ILC review found the Fermilab choice of projects, and progress to date, to be excellent.

The most important ILC effort that Fermilab has taken on is the task of refining the process of fabricating superconducting radiofrequency (SCRF) accelerating cavities so that high gradients can be reliably produced. At the current time only a few such cavities have been built while the ILC will need tens of thousands of them. It will be necessary to master the processes to reliably build high gradient cavities and then transfer the technology to industry.

This work requires a significant investment in infrastructure, from materials handling equipment like clean rooms, ovens, and polishing equipment to the cryogenic systems and RF power to test the fabricated devices. Since SCRF technology has emerged as a very important technology for a variety of future accelerators, a significant fraction of the presentations and discussion was concerned with Fermilab's plans to be able to support an SCRF research program and the infrastructure needed to carry out that program for the ILC or other applications.

While no DOE HEP laboratory currently has a strong SCRF program, Fermilab has reached out and developed collaborations with many of the world's leaders in SCRF technology, such as DESY, JLab, and Cornell. This leveraging of existing world wide infrastructure is a very sensible starting point for the laboratory to develop its in-house expertise and its continued use should be examined while Fermilab builds up its own facilities.

Learning to produce SCRF cavities with a gradient in the range of 30-35 MV/m with high yield will be critical to building the ILC. Fermilab plans are to bring all of the processing into a close proximity to minimize time needed for a complete cycle and the possibility of contamination or damage between steps. This should allow detailed studies of processing to find the variables that affect the maximum achievable gradient. The consultants believe that this approach is sensible, but are concerned that it may not be enough to meet the goals of Fermilab and the ILC. The laboratory should be open to new ideas and should now be concentrating on improving both cavity performance and yields. The SCRF R&D program will be expensive so it must be carefully managed with care and thought put into each major spending decision, but at the same it must retain flexibility.

The consultants strongly endorsed the need for a HEP based SCRF research program. Other US labs and foreign labs that have been helping so far have projects of their own that will soon fully occupy their facilities. Since the expected cost of developing the infrastructure is high, the infrastructure will be under significant scrutiny within DOE. Careful coordination with OHEP will be required to ensure that the infrastructure supports the R&D needed for the ILC, is cost-effective, and is planned, funded, and built in manner consistent with DOE budget and procurement procedures. We are already planning to have a dedicated review of the SCRF work at the laboratory.

High Intensity Neutrino Source

The laboratory's proposal for a high intensity proton source is also based on a SCRF linac. The R&D plan for that linac currently concentrates on the low-energy end of it, since it is assumed that the high energy portion will benefit from R&D for the ILC. The design features a transition from warm to cold accelerating structures that occurs at a lower energy, 10 MeV, than at the Spallation Neutron Source, and a power distribution scheme that drives many cavities from a single klystron. This last feature could provide significant savings to any superconducting RF accelerator including the ILC. On the other hand, powering both the room temperature and the superconducting sections from the same klystron might be an unnecessary complication that would be of little benefit for the 8 GeV machine. Since the ILC and a superconducting RF proton linac share a technology there could be competition for resources during their R&D phases. I expect that the laboratory will intelligently manage any such competition consistent with the priorities of the HEP program.

LARP and Superconducting Magnet R&D

This was a transition year for the superconducting magnet group, as production on the LHC final-focus quadrupoles ended, and participation in the LHC Accelerator Research Program (LARP) heightened. The group has launched a new initiative under LARP to develop Nb_3Sn quadrupoles suitable for a major luminosity upgrade of the LHC. In addition the laboratory plans to help CERN with the commissioning of hardware as well as beam commissioning. With more than two decades experience with the Tevatron and strong expertise in superconducting magnet technology, collider operation, and instrumentation, Fermilab is in a unique position to support progress at the LHC. LARP provides an appropriate organizational structure for these contributions.

Other Accelerator R&D

A muon storage ring or a neutrino factory is unlikely to be built in the near future, but the advantages of such an accelerator justify a long term R&D program at a modest level of support. Fermilab's contributions were found to be excellent and that there is good coordination between the MUCool program, the MICE experiment at Rutherford-Appleton Laboratory, and the MERIT target experiment at CERN.

The advanced accelerator R&D program at the FNAL-NICADD Photo-injector Laboratory studies flat beams, plasma-wakefield effects, polarized RF guns, and other topics. This is also a modest size program that has the potential to make long term contributions to accelerator physics.

Conclusion

The overall conclusion of the review was that Fermilab has an outstanding physics program that is well aligned with national priorities. The transition to the LHC, the development of the ILC, and the growth of the neutrino program are all creating new demands on the laboratory, while Run II continues the high priority exploration of the energy frontier. As the sole DOE laboratory dedicated to high energy physics, we expect that Fermilab will continue playing vital roles in these areas.

Sincerely,

Robin Staffin,
Associate Director
Office of Science