Fermilab Accelerator Advisory Committee

Initial Meeting

November 8-9, 1999

Committee Report

The first meeting of the Fermilab Accelerator Advisory Committee took place on November 8 and 9, 1999. The Committee consisted of V. Balakin, J.-P. Delahaye, G. Dugan (Chair), M. Harrison, C. Leeman, T. Shintake, J. Seeman, R. Siemann, F. Willeke, and J. Wurtele. Four of the members of this committee (G. Dugan, M. Harrison, J. Seeman, and R. Siemann) had been members of a previous Fermilab advisory committee (the Fermilab III Technical Advisory Committee). The charge to the Committee for this meeting, and the agenda for the meeting, are included as appendices to this report.

At the outset, the Committee wishes to commend the Beams Division and the Laboratory on the excellent job that has been done in commissioning the Main Injector. This major element of Fermilab's upgraded accelerator complex constitutes a firm base upon which to build. The Committee recognizes that, during the next year, an enormous amount of work will be required to commission all the other pieces of the Tevatron Collider complex. This first meeting of the AAC focused on this commissioning work, and on plans to push beyond the initial goals.

Charge Item #1:

Comment on the status of preparations for re-commissioning the Tevatron collider, starting in the spring of 2000 with particular attention to items that could impact the achievement of stated luminosity goals.

The re-commissioning of the Tevatron as a Collider will be a major effort, since a great number of changes have been made since the last run, the Main Injector being the most notable example. The laboratory is to be commended for setting aside a significant period for commissioning work. The Main Injector has been operating very effectively for fixed target physics for the past several months and the Committee believes that Main Injector performance will not be an issue during commissioning of the Collider operation. Areas that the Committee feels will need special attention are:

- The long-term solution to the mismatch in circumference between the Accumulator and the Recycler needs to be identified. If this solution requires hardware changes then it may be necessary to complete these modifications in a timely fashion.
- It is planned to operate the machine at beam energy of 1 TeV. In addition, the 36 bunch scenario will raise the overall machine intensity significantly from the last run, and antiproton recycling requires the removal of protons using collimation, which will add to the beam loss mechanisms. It remained unclear to the Committee, whether the potential increase of beam energy deposition due to increased beam intensity and larger beam energy will reduce the available quench safety margin. The anticipated beam losses, especially at high field, should be analyzed.

- A significant fraction of the anticipated luminosity increase in Run II is due to the recycling of antiprotons. The Committee notes that not much has been accomplished to date in the areas of deceleration and proton removal. Both of these operations are necessary to exploit the Recycler. The Committee encourages timely machine experiments to explore these issues.
- The Recycler commissioning is proceeding but much work remains to be done. The ring has had initial success but is still on zeroth order problems. It has a very long way to go before it is a useful storage ring for collider operations. The Committee considers magnetic coupling between the Main Injector and the Recycler to be possibly a serious issue. Achieving the required high vacuum in the machine will be a challenge. More effort than is currently expected may be needed to get the ring fully commissioned. In view of this, the Committee suggests that the implications of having to continue to commission the machine during Run II Collider operation be considered.

Charge Item #2:

What would the committee regard as a reasonable expectation for collider performance during the 2000 commissioning runs?

The Tevatron Collider will be re-commissioned in an engineering run in the summer and fall of 2000, and will start up in March 2001 for Run II. Even with the Main Injector, and after improvements of the antiproton production complex, the luminosity of in the Tevatron Collider is governed by the total number of antiprotons which can be produced, stacked and cooled per unit time in the injector complex. The performance goals for the upcoming Tevatron Collider run are to achieve initially a luminosity of more than 10^{31} $cm^{-2}\ s^{-1}$, at a beam energy of 1 TeV, and to reach a peak luminosity of about $9x10^{31}$ $cm^{-2}s^{-1}$ before the end of 2002. In this period, an integrated luminosity of 2 fb^{-1} is supposed to be delivered. To achieve this, the Tevatron Collider will be operated with 36 x 36 bunches, which is to be compared with the 6 x 6 bunches in the previous run. This step appears to be carefully prepared and thought through, and it may be considered as a reasonable and calculable upgrade compared to previous performance.

The main improvement for the performance of Run II will come from the Main Injector beam intensity. Approximately 60% of the design intensity has been achieved in one year of commissioning. This is a good basis for achieving the full intensity within the run II operation. The committee is not aware of any obstacles or problems, which stand in the way of achieving high intensity. A further ingredient in higher luminosity is improved coalescing of proton bunches, which has already been successfully demonstrated. It is expected that the antiproton transfer efficiency from the source to the Tevatron will improve from 60% to 80%, which appears to be a reasonable extrapolation, given the substantial improvements in the injector complex.

The Committee considers the time allocated for re-commissioning the Tevatron Collider complex to be sufficient, and the plan for re-commissioning to be coherent. However, there does not appear to be a great deal of excess time, and it will be important to be as efficient as possible. In view of this, the benefit for CDF of rolling in the detector twice, the first time in the middle of re-commissioning, should be re-assessed. In conclusion, the performance goal for the Tevatron Collider commissioning run (>10^{31} cm^{-2} s^{-1}) appears to be reasonable and the failure risk appears to be low.

Charge Item #3:

Comment on outstanding physics and technology R&D issues that need to be addressed in order to implement 132 ns bunch spacing.

At luminosities in excess of $1.5x10^{32}$ $cm^{-2}s^{-1}$, with 36x36 bunches, the number of interactions per crossing becomes large enough (<n> > 4) to present significant difficulties to the collider detectors. This problem can be eliminated by operating with a larger number of bunches. The bunch spacing would go down from 396 ns to 132 ns, corresponding to an increase in the number of bunches from 36x36 to 140x121 bunches.

There are a number of important accelerator physics issues associated with this mode of operation. There will be many more long-range collisions around the ring. A relatively large crossing angle (192 μrad) is required to provide sufficient clearance for the near-miss collisions closest to the IP. With this crossing angle, the ratio of bunch length times crossing angle to beam size is in the range of 1-2, which implies a substantial (>50%) loss of peak luminosity, and possibly increased sensitivity to synchrobetatron resonances. In addition, the beams will be 8 mm off-axis at β_{max} in the IR quads, which will result in increased sensitivity to harmonic errors in these quads. Eight more separators must be built and introduced into the ring, increasing the complexity and impedance of the separator system. A short batch proton kicker with a 132 ns rise time will be needed. The beam collimation system may need to be redesigned.

There is a reasonable expectation that a luminosity in excess of $1.5x10^{32}$ $cm^{-2}s^{-1}$ could be achieved in the next two years. Given the amount of work needed to implement 132 ns bunch spacing, the Committee feels that much more effort must be applied to this task than has been the case in the past. Considerable design work and calculation, and a very considerable amount of machine experiment time, will be needed. Studies should be pursued as soon as possible to explore operation with large crossing angles and off-axis transit through the low-β quadrupoles. The lab might also consider asking A. Piwinski (DESY) to run his synchrobetatron coupling code for the Tevatron collider parameters.

As noted above, this scheme involves an inevitable loss of peak luminosity from the large crossing angle. Thus, the overall advantage, in terms of physics output from the experiments, depends in detail on a complex mix of the antiproton production rate, the recycling efficiency, the mean store length, the tune spread with different numbers of bunches, and the efficiency of the collider detectors as a function of the number of interactions per crossing. The Committee was not convinced that this complex situation was well understood. For example, the optimum situation may correspond to an intermediate bunch spacing (between 396 and 132 ns). The Committee encourages efforts to arrive at a clearer understanding of the precise benefits and optimum parameters of any scheme involving reduced bunch spacing. Such efforts must involve close collaboration between accelerator physicists and detector physicists.

Charge Item #4:

Comment on the status of preparations for the electron beam compensation experiment and the potential impact on collider performance.

This work has two different objectives:

- Use of an electron beam with a radius large compared to the antiproton beam to compensate the bunch-by- bunch tune differences produced by different patterns of parasitic crossings, and
- Use of an electron beam with a radius comparable to the antiproton beam size to compensate beam-beam tune spread within the an antiproton bunch.

Work has concentrated on the first objective where a prototype lens has been demonstrated and a solenoid has been specified and ordered. There are issues that need to be addressed before this can become an operational device. These include

- Developing a modulator with adequate power, bandwidth, and regulation to compensate individual bunches without emittance blow-up. The implications of 132 ns spacing should be understood during the engineering design.
- Nuances of operation need to be included in the discussion. These include the role and importance of electron compensation during injection, ramping, lattice changes for beta-squeeze, etc.

Work on the second objective is calculation and simulation, and, appropriately, it is taking a back seat to the design for compensation of the bunch-by-bunch tune differences.

The potential of this technique for improving Tevatron luminosity is not clear. Evaluating it depends on details of the beam-beam footprints including bunch-by-bunch tune differences and beam-beam tune spread. The one example we were shown had a footprint that was already contained within the usual value of tolerable tune spread for hadron colliders, $\Delta Q = 0.02$, without any beam-beam compensation. The specific goals of each objective (the linear and the non-linear compensation), in terms of enhanced luminosity performance, should be clearly defined.

Finally, one member of the Committee had a question about the linearity of the forces arising from a uniform current distribution. The Committee encourages more careful study of this issue.

Charge Item #5

The committee is invited to explore any other avenues it considers relevant to Tevatron Collider performance. Comments and/or recommendations are welcome.

Several members of the Committee noted that there does not seem to be a coherent plan to get the luminosity above about 1-2x10^{32} $cm^{-2}s^{-1}$, with specific parameters identified and the needed improvements spelled out. Rather, a list of possible improvements has been identified, many of which could play a role in achieving higher luminosities. This approach has the virtue of flexibility, and considering the large number of changes to the Tevatron collider complex which are about to be commissioned, reserving judgement on the exact direction to pursue for medium-term improvements is not unreasonable. However, the window of opportunity to implement plans for luminosities in excess of a 1-2x10^{32} $cm^{-2}s^{-1}$ will close in a few years.

Charge Item #6

A second focus of the meeting will be the advanced accelerator R&D program based on the 15 MeV photoinjector facility at A-0. The AAC is asked to provide its opinion on the uniqueness and utility of this facility within the world-wide R&D effort on fundamental new acceleration processes.

The Committee was impressed by the quality and the quantity of the work done for the past seven years on the A0 photoinjector, especially considering the small amount of resources allocated to the development of the facility (5 FTE, $150K/yr).

The photoinjector facility has been built in collaboration with a large number of institutes (INFN Milano, Cornell University, DESY, University of Rochester, UCLA, ORSAY, among others). It is now complete and commissioned with beam, and has reached an excellent level of performance. Although it is a duplicate of the TTF injector at DESY, there are not many similar facilities in the world (UCLA, BNL, CLIC Test Facility at CERN). The facility is also extremely useful in providing the opportunity for Fermilab to develop expertise in advanced technologies, such as lasers and photocathodes, high gradient normal conducting rf, superconducting rf, and space-charge dominated electron beams.

Nevertheless, the facility is presently operated mainly by students (doctoral and post-doctoral), with a rapid turn-over. Only a few permanent Fermilab staff members are involved and acquiring knowledge and experience. With the imminent departure of the students, there will be a lack of support starting early next year, especially in the critical area of the laser.

Moreover, although a number of possible studies were mentioned (crystal polarization, channeling radiation, plasma source acceleration and focusing, development of a polarized electron source), no coherent scientific program was presented. The present level of support (budget and manpower) is obviously under the critical level required for a competitive, state-of-the-art facility for advanced accelerator development.

The Committee recommends that the facility establish a coherent and well-focused experimental program. Preferably, this program will have a strong connection to a major initiative of the lab, such as NLC R&D. It is also possible that such a program could be justified by compelling advanced accelerator experiments. If a coherent program can be established, the Committee then recommends the appointment of a full-time Fermilab staff scientist to run the facility, and recommends raising to an adequate level the support for the facility.

The Committee concurs in the judgement that the development of expertise in the area of superconducting rf technology is of potential importance to the laboratory and should be considered separately from the A0 laboratory. The Committee encourages Fermilab to develop expertise in superconducting rf technology.

Long-range Accelerator R&D

The Committee heard presentations on superconducting magnet R&D, a discussion of the ongoing neutrino source study and related muon collider R&D, and a report on Fermilab's efforts in support of NLC R&D. Although the Committee was not asked specifically for comments in these areas, we nevertheless offer the following brief remarks on these subjects.

The superconducting magnet R&D is focused on low field and high field magnet development, with applications to future very large hadron colliders and/or muon colliders. This effort is a natural continuation and preservation of one of the major technical strengths of Fermilab. The Committee supports this effort.

The detailed site-specific study of a neutrino source was recently initiated and is expected to be complete in six months. In addition to having a potentially strong physics justification in its own right, the neutrino source would address some of the major technical challenges for a high energy muon collider. It would provide a good opportunity to find practical solutions to those challenges. The Committee feels that this study is a reasonable path to take, and encourages it.

Fermilab's effort in collaboration with SLAC in support of NLC R&D was described to the Committee. The Committee supports Fermilab's effort in this area. The Committee encourages Fermilab both to contribute to the NLC project in areas that will benefit from the lab's expertise, and to strive to develop general expertise in the area of linear colliders. Some members of the Committee felt that, if it developed sufficient expertise, Fermilab could provide significant input to the question of what overall technology should be used in a future linear collider. Other members felt that this may not be possible, given the limited amount of resources which could be applied to developing expertise.

Appendix 1:

Charge (Draft #2)

With the completion of the Main Injector Project preparations are now underway for the initiation of Tevatron collider operations in the spring of 2000. The upgraded accelerator complex is expected to support Tevatron collider operations with a luminosity of at least $8x10^{31}$ $cm^{-2}sec^{-1}$ during the first few years of this program. As Fermilab looks beyond we see the need to maximize the integrated luminosity in the pre-LHC era while developing the technologies that will provide the foundation of the Fermilab research program after the LHC becomes operational.

The initial meeting of the Fermilab Accelerator Advisory Committee (AAC) will focus on the preparations for the upcoming collider run and on planning for pushing the performance beyond the initially established goals. The AAC is asked to review the status of these preparations and plans, to comment on their appropriateness, and to recommend the next steps, if any, in the development of these activities. More specifically, the committee is asked to comment on:

- The status of preparations for re-commissioning the Tevatron collider, starting in the spring of 2000 with particular attention to items that could impact the achievement of stated luminosity goals.
- What would the committee regard as a reasonable expectation for collider performance during the 2000 commissioning runs?
- Outstanding physics and technology R&D issues that need to be addressed in order to implement 132 ns bunch spacing.
- The status of preparations for the electron beam compensation experiment and the potential impact on collider performance.
- The committee is invited to explore any other avenues it considers relevant to Tevatron Collider performance. Comments and/or recommendations are welcome.

A second focus of the meeting will be the advanced accelerator R&D program based on the 15 MeV photoinjector facility at A-0. The AAC is asked to provide its opinion on the uniqueness and utility of this facility within the world-wide R&D effort on fundamental new acceleration processes.

Finally, Fermilab will present to the AAC a summary of the status and plans for accelerator R&D aimed at new facilities that could provide the basis for the future research program beyond the LHC. These presentations will primarily be introductory and are seen as laying the basis for subsequent meetings. As such no specific comments are solicited at this time. However, any comments the committee might wish to make are welcome.

It is requested that a concise report responsive to this charge be forwarded to the Fermilab Director by January 3, 2000.

Appendix 2:

Accelerator Advisory Committee

November 8-9 Meeting Agenda

Comitium

Monday Morning, Nov 8

9:00 Executive session

9:15 Welcome (Witherall/5 min)

9:20 Overview - (Holmes/30 min)

10:00 Break

10:30 Recycler status & plans (Jackson/25 min)

11:00 Electron Cooling (Nagaitsev/45 min)

12:00 Lunch

Monday Afternoon, Nov 8

1:30 Run II Engineering & Commissioning Runs: Plans and Issues (Church/25 min)

2:00 Plans for 132 nsec bunch spacing (Sen/25 min)

2:30 Beam-Beam Effect Compensation (Shiltsev/30 min)

3:10 Break

3:30 SC Magnet R&D: Overview (Limon/10 min)

3:45 High-Field SC Magnets (Zlobin/30 min)

4:25 Low-Field SC Magnets (Foster/20 min)

7:00 Dinner

Tuesday Morning, Nov 9

9:00 Neutrino Source Study & Muon Collider R&D (Holtkamp/45 min)

9:55 NLC R&D (Dombeck/25 min)

10:30 Break

11:00 A0 beam: Present capabilities and possible upgrades (Edwards/30 min)

11:40 Discussion

12:00 Lunch

Tuesday Afternoon, Nov 9

1:30 Executive Session

3:00 Closeout