Fermilab Accelerator Advisory Committee

Report of the Meeting of May 13-15 2002

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Introductory Remark

The Committee enjoyed the interesting and well prepared meeting with excellent presentations and open discussions in plenary and breakout sessions. We would like to thank the Fermilab staff for helping to make our work a pleasant and interesting one.

General Comments

The committee is impressed by the large progress made over the last 6 months. The peak luminosity is now with L=1.92 x $10^{31}cm^{-2}sec^{-1}$ close to the best values achieved before the upgrade and the operational efficiency has improved. The committee recognizes that this progress is mainly due to the hard work of Run II staff on all levels.

The committee also acknowledges that the general support for Run II is improving as the laboratory has started to redirect resources to the beams division to provide stronger support for Run IIa. Such effort naturally aims towards medium term rather than short term improvement. But it sets important immediate signals that Run II is in center of the laboratory´s interest and this has noticeably helped to improve the general spirit and renewed the enthusiasm.

The increase of manpower for the benefit of Run2, however, has not reached yet the desired level for the time being.

The committee however also recognizes that many problems have still to be solved and many improvements have to be made to be able to fully exploit the large investments. The major shortfall is still the antiproton intensity which available for collisions. The overall transfer efficiency from the main injector to the TEVATRON at collision is still only 40% and a lot of work needs to be done to increase the antiproton production rate and beam quality to reach the medium term goals.

Recommendation: The committee suggests continuing the process of reallocating manpower resources for the benefit of Run IIa/b.

The committee acknowledges that the efforts have been concentrating during the last months on increasing the present Run IIa performance. A strategy with milestones has been developed to guide the effort.

The committee considers the focus on RunIIa appropriate considering the state of the accelerators six month ago. The short term goals for integrated luminosity however still appear to be rather ambitious.

Recommendation: The Committee suggest to develop an updated plan in the near future. This plan should go beyond the present goals aiming at medium term milestones including decisive plans for integrating the recycler in the luminosity production at the earliest possible time.

Recommendation: The Committee would also like to see the top level plan for making the transition from RunIIa to RunIIb which could be based on the comprehensive report on RunIIb which has been submitted 6 month ago.

Run II Performance and Strategy

Two clear presentations were made on the Run IIa achievements. The committee acknowledges the positive trend which is accomplished by several improvements (e.g., fixing a subtle problem in the beta squeezing and collision helix procedure) and the committed and excellent work carried out.

Nevertheless, the luminosity remains a factor of two below the intermediate goal and a factor of at least four below the target of Run IIa. The largest adverse phenomenon is shown to arise from a stronger than anticipated effect: the long range beam-beam forces which are suffered by the antiprotons through the whole operation cycle.

In this situation, the committee recommends the highest priority for increasing the antiproton intensity. This includes a top priority for the study and evaluation of the yield expected from the recycler.

In second line, the committee endorses the steps taken to increase the effective beam separation. The most direct is a strict preservation of the normalized emittance at all levels in the chain. In order to accomplish this, an upgrade of instrumentation is probably required such as the possibility of a proper turn-by-turn emittance measurement to prevent blow-up at injections.

The other line is to process specifically the few encounters at the smallest separation such as optimization of helical orbits for protons and antiprotons, changes in the beam optics layout and beam-beam compensation schemes.

The committee heard of several other phenomena such as longitudinal blow-up and weak instabilities, which all contribute at a significant level. While they all look manageable, this most likely raises an issue of availability of experienced accelerator engineers and physicists.

The committee endorses the effort to temporarily focus on Run IIa and the preparation of Run IIb by using all the relevant laboratory resources and by enforcing these by external collaborations.

Recommendation:
The committee recomments to put highest priority on the increase of antiproton intensity.
The committee recommends to better match the milestones to the available resources by taking into account recent experience.

Injector performance

The injector complex provides proton and anti-proton beams to the TEVATRON. For the Run IIa the required bunch parameters at collision are 270 x 10^9 protons/bunch and 33 x 10^9 anti-protons/bunch with transverse and longitudinal emittances of 17.5 π mrad mm and about 2 eVs.

The injector complex is operating very well. The presently achieved bunch parameters in the Main Injector at 150 GeV are 300 x 10^9 protons/bunch and about 25 x 10^9 anti-protons/bunch with about 17 π mrad mm transverse emittance and 4 eVsec longitudinal emittance. For protons the intensity meets the Run IIa requirements, however with little margin. The anti-protons intensity is low by about 30%. In addition, the issues with long range beam-beam effects at injection in the TEVATRON make it necessary to reduce the anti-proton emittance to 10 to 15 π mm mrad. This is a very challenging task.

The antiproton source has operated with a stacking rate of about 10 mA/h and maximum stack of 120 mA. This is adequate for the present run but the horizontal emittance is about twice the required value of about 8 π mm mrad in the Accumulator ring. The large emittance is responsible for the poor transfer efficiencies and the reduced TEVATRON luminosity. We were presented with a report of an excellent study program conducted at the antiproton source that identified intra beam scattering (IBS) and trapped ions to be responsible for 60 % and 40% of the emittance increase, respectively.

The increase of IBS is the result of the new high-stacking-rate Accumulator lattice with larger values of the dispersion function. The committee strongly endorses the very creative proposal to change to the old lattice for core cooling after the stacking is complete. Together with the new high-bandwidth core cooling system, the horizontal emittance should be reduced to about 8 π mm mrad.

Careful analysis of the optics of the transport line from the Accumulator to the Main Injector resulted in significantly improved transport efficiency. Further improvements in the preservation of the anti-proton emittance should be pursued by carefully matching injections into the Main Injector and the TEVATRON using turn-by-turn instrumentation and dampers.

In the Main Injector protons and anti-protons are accelerated with the 53 MHz rf system and then 7 to 11 bunches are coalesced to a single high intensity bunch using the 2.5 MHz RF system. There is little beam loss or transverse emittance growth during acceleration. The longitudinal emittance typically increases from 2 to 4 eVsec per TEVATRON bunch. Most of the increase occurs during bunch coalescing, which should be mitigated by the recently installed feed forward beam loading compensation.

Recommendation: The longitudinal emittance blow-up in the Main Injector should be addressed in a timely fashion. Additional Accelerator Physicist support should be increased in the Main Injector development.

Operational Issues

We note the progress in improving the Run II performance. The presentation showed a good organization with an appropriate balance between flexibility and strict scheduling procedures. The schedule of five machine study shifts per week should allow for the planning experiments, carrying them out, and then, during the time the luminosity is being provided to the detectors, there is time for analysis of the experiments.

The methods and tools for analysis of run performance look promising. We support its development so that important machine data are accessible through a user-friendly interface. We encourage the use of the logged data for obtaining a better understanding of problems affecting machine performance.

Recommendation: A set of significant indicators (figures of merit) from the total of the run data should be extracted and made available. This should show the actually achieved performance relative to the planned performance, along with identification of the critical places where actions could lead to significantly improved performance. This may be beneficial for monitoring progress identifying difficulties at an early stage and putting the optimum priority for taking action on various operational issues.

Instrumentation

The presentations made to the committee demonstrate that a detailed knowledge of beam parameters is essential to the understanding of the beam dynamics and the improvement of machine performance. A compelling case has been presented that some instrumentation upgrades will be essential to some of the plans for the completion of Run II. The very accurate measurement of the beam position in the recycler is vital diagnostic for operation of the machine. Systematic turn-by-turn emittance measurements should allow the prevention of emittance dilution due to mismatch. The measurement of the anti-proton position in the TEVATRON should help understanding long-range beam-beam effects.

We look forward to the implementation of a prioritized plan, with regard to the enhancement of the overall collider performance, for the integration of new and/or improved instrumentation into the collider complex. Finally, the committee acknowledges that some of the new effort in this area, and in the development of tools for data analysis, has come from outside the division. This example of flexibility and willingness to work on Run II problems should be encouraged.

Recommendation: We recommend strong support to the beam instrumentation group to reach these goals.

Recycler Ring

The committee was pleased to hear about the steady progress that has been made with the recycler ring. Studies have included emittance growth at injection, aperture limitations, beam lifetime, studies of beta mismatch etc. There is now initial experience with antiproton injection, stacking and cooling. Present efforts are focused on injection efficiency, and extraction studies are planned.

These studies have led to a planned upgrade of the recycler which will be implemented starting in October 2002 in a long shutdown. These include vacuum upgrades to increase beam lifetime, instrumentation upgrades, injection dampers and beam loading and RF noise reduction.

In all scenarios the committee believes that the recycler ring is critical for the long term success of Run II. We therefore believe it is time to begin to develop a concrete plan for integration of the recycler into the complex, which would include definite milestones for the commissioning team to achieve. However, we also believe that, so far, there is not enough data on ring performance to complete such a plan. This additional data will require improvements in instrumentation and additional experiments.

Perhaps the most critical early test is the stacking and cooling of a high intensity beam in the recycler. This would give early indications on the adequacy of the lifetime and equilibrium emittance of the anitprotons. This test should be done soon well in advance of the scheduled downtime in October.

The present injection efficiency is poor and perhaps can be addressed by increasing a known small aperture in a Main Ring extraction Lambertson and by better matching. However, it is important to get early information to check injection efficiency for the planned mode of operation for the initial integration of the recycler. An early test of the transfer of a 20mA stack from the accumulator would provide a more reliable measure of the operational injection efficiency.

It is critical that the new BPM hardware be made to work. Tune control appears to be critical to maintenance of long lifetime.

We understand that there are issues of frequency matching and momentum offset of the accumulator and the rest of the complex. In order to get experience with the recycler in the mode in which the beam simply passes through the main injector, is appears to be necessary to shift the “8.9 GeV/c” in the accumulator by 40 MeV/c. It might be good to implement this change after the shutdown during commissioning of the new cooling hardware.

Recommendations:
Begin to develop a concrete plan for integration of the recycler into the complex. The plan should consider manpower requirements as well as technical accelerator issues.
Test the stacking and cooling of a high intensity beam in the recycler as soon as possible and well in advance of the scheduled downtime in October.
Study the injection efficiency into the recycler for the planned mode of operation as soon as possible.
The recycler instrumentation issues should have a high priority.

Accelerator physics

At present nearly all of the components for Run IIa are in place and functioning, and many of the impediments to the success of Run IIa are accelerator physics problems. There is an urgent need for help of the Beam Physics Department in solving these problems, in close coordination with the groups responsible for the machines.

The Beam Physics Department has been lending its support in critical areas including effects related to the helices, the beam-beam interaction and parasitic beam-beam interaction, apertures, beam loss, backgrounds, and collimation. The Beam Physics Department is also collaborating with accelerator physics groups from SLAC and LBNL on Run II issues.

There has been increased cooperation and communication between members of the TEVATRON group and the Beam Physics Department as groups have formed around particular accelerator physics issues. The TEVATRON group has made an explicit prioritization of the accelerator physics issues is seeks help with, and several Beam Physics Department members regularly attend the TEVATRON meetings. We strongly support these trends.

We urge that the Beam Physics Department maintain and further develop this communication with the machine groups. Simulation studies (which had been focused on the ultimate parameters of Run II) will be needed for the near-term Run IIa parameters. Attention must be given to Tevatron injection conditions in simulations. Prioritization of accelerator physics issues important for Run IIa must continue to be done by the machine groups and communicated to the Beam Physics Department. Continued collaboration with outside institutions is very desirable and requires regular communication with both the Fermilab machine groups and Beam Physics Department to insure that the effort is directed toward Run II priorities.
We note that in recent years the flow of physicists between the beam physics department and the departments responsible for the machines has ended, and that the beam physics group has been further isolated by being moved from the area of the main control room to the 12th floor. We recommend that steps be taken to reverse this isolation.

Proton Drivers

The Committee received reports on two alternative designs of proton drivers. These studies are responsive to a request by the directorate in early January 2002. The committee is impressed by the quantity and the quality of the work performed in a so short amount of time and congratulates the corresponding study teams.

Two drivers were envisioned, one a synchrotron driver and the other a Super-conducting Linac. Both met the specified challenging performance goal of delivering 3.0 10^{14} protons per second at 8 GeV (corresponding to a beam power of 380 kW). The necessary modifications of the Main Injector to accelerate the corresponding beam of 1.5 10^{14} protons per cycle (corresponding to a beam power of 1.9 MW) were presented. In contrast to the previous study (Proton Driver Study I), which was mainly Neutrino Factory oriented, Proton Driver Study II explores schemes to improve the performance of the FNAL complex and to diversify its research programs. It is strongly supported by the committee as a part of a necessary examination of future options for the Laboratory. Although the study is far from being mature enough to allow for a choice between the two Proton Driver options, it raises clearly the advantages as well as the challenges of each option and provides a first estimation of their cost. Both options fit well on the FNAL site and integrate into the present complex.
The synchrotron based proton drivers provides a 0.5 MW beam power with a design and technology upgraded from the Booster, while the linac-based proton diver takes advantage of

the SNS/TESLA technology developments and provides up to 2 MW of beam power, but with a cost significantly higher. In parallel with feeding the Main Injector for possible Super-Beam experiments, both options allow for very attractive additional operation by providing extra beams during the Main Injector cycle. An upgraded Mini-Boone, for example, could benefit from this. In particular, the high power provided by the linac coupled with its flexibility to provide alternative particles like electrons or ions is specially attractive, and opens interesting possibilities like an X-Ray FEL or a recirculating electron linac. This possible mode of operation calls for a diversification of the FNAL Physics program---a change that would need the support of the Physics community.
At the level of the envisaged beam powers, the committee considers that a key issue, which may even guide the choice between the two options, is primarily the capability to minimize the beam losses and to keep the activation of the equipments at an acceptable level in order to preserve as much as possible a hand-on maintenance of the installations.
In particular, maximum beam loss rates at the level of 1% at extraction from the Synchrotron and at injection in the Main Injector, and 0.5% at extraction from the Main Injector and 10^{-5} of the beam intensity per meter of the linac have been mentioned. These have been presented without detailed arguments and without convincing beam stability studies demonstrating that these levels can be safely guaranteed.

The committee therefore recommends:

- To carefully evaluate the tolerable beam loss rate in the various systems
- To examine the beam stability all along the chain and the actions to e taken in order to guarantee a minimum beam loss rate
- To specially study the beam stability on the flat bottom of the Main Injector during the injection of the synchrotron pulse which appears particularly critical
- To design collimator schemes concentrating the losses in specially equipped area
- To study the feasibility of H- stripping system of the 8 GeV powerful Linac beam at injection into the Main Injector which is specially unusual.
- To launch the R&D of fast ferrite necessary for SC cavity tuning and for particle exchange in the linac

Moreover, the committee recommends launching the R&D of all equipment which would be necessary for the proton driver and which would already reduce the beam losses and/or improve the performance of the present complex during the Tevatron operation. Their construction and implementation will then have to be prioritized according to the improved performance and the available budget:
We note the possibilities in the Booster:

- Modification of the 53 MHz RF cavities
- Space charge study at injection
- Inductive insert
- Measurement of the magnet ac field in E4R
- Improvement of the Linac front-end including an RFQ

And in the Main Injector:

- Fast Gamma-Transition jump
- Collimator system
- Large aperture (4’’) quadrupoles

High Brightness Photo-Injector

The committee was informed that an Expression of Interest (EOI) for a collaboration between seven universities (Chicago, Michigan, NIU, Northwestern, Pennsylvania, Rochester, UCLA) and four laboratories (FNAL, Argonne, LBNL, DESY) about a High Brightness Electron Source has been submitted in February 2002 to FNAL, ANL, LBNL, DOE and NSF. The facility would consist of a Photoinjector followed by one or two TESLA type Superconducting Cryomodules and a Bunch Compressor with 3rd harmonic compensation. it would provide a beam at 5 Hz repetition rate with trains of up to 11500 bunches with charges of 1 to 2.3 nC/b and an energy of 140 to 300 MeV. The facility would be used for fundamental beam and accelerator physics and study the feasibility of injector for Linear Colliders, FEL and synchrotron radiation sources.

The overall budget (M&S) is estimated at 30 M∃ over a 5 years construction period from which 6 M∃ could be provided by the Department of Education (DoEd) and 2.5 M∃ by the Illinois Consortium of Accelerator Research (ICAR). This would bring additional resources to FNAL in budget and in man-power (students) such that the program would barely interfere with the FNAL main work program.

The committee especially welcome the collaboration with Universities and the participation of students as it would provide them with excellent training on Accelerator applications and because they would provide innovative ideas and enthusiasm. The facility would also constitute an excellent opportunity for FNAL to build-up an expertise on Super-Conducting technology in parallel with its participation to the NLC collaboration. That would put FNAL in an ideal position with independent competence on both TESLA and NLC technologies when the choice of technology of a Linear Collider will have to be made in a few years.

But the committees feels that the work program as presented is not convincing enough for such a facility and duplicate with the one of similar existing facilities. It encourages the team to be more ambitious by setting-up a well- focused and challenging Physics program in line with the A0 experiment as well as an R&D in Super-conducting technology with goals complementary to the one of TTF.

APENDIX A: **Charge (Rev. 14-April-2002)**
Fermilab Accelerator Advisory Committee
May 13-15, 2002 Meeting

The May 2002 meeting of the Fermilab Accelerator Advisory Committee (AAC) will focus on the status of Tevatron Collider Run II operations. The committee is asked to review and comment on the initial operational experience with **Run II** with particular emphasis on the following points:

- Assessment of potential impediments to achievement of a luminosity of approximately 5×10^{31} $cm^{-2}sec^{-1}$ in the Tevatron over the next six months.
- Evaluation of the key underlying accelerator physics issues and the adequacy of the calculational support.
- Evaluation of the overall strategic approach to achieving the goal of 8×10^{31} $cm^{-2}sec^{-1}$ in the Tevatron over the coming year.
- Suggestions for overcoming identified impediments to Run II goals.

The committee will also hear presentations on a follow on second generation proton driver study, and Expression of Intent for a high brightness photoinjector, and the status of the Fermilab linear collider R&D program. Specific requests to the committee in these areas include:

- **Proton Driver Study II**. The committee is asked to review and comment on the current Proton Driver Design Study. In particular we would like input with regard to the adequacy of the study in terms of providing a basis for an R&D program, and the critical technical issues that would factor into a decision on a synchrotron vs. linac based implementation.
- **High Brightness Photoinjector**. The committee is asked to comment on how such a facility might fit into the overall picture of future accelerator R&D at the lab, and within the broader U.S. program.

The AAC will also be presented with a short status report on our linear collider R&D program. This presentation is intended to be primarily informative and 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 June 14, 2002.

APENDIX B: AAC Agenda May 13-15, 2002 Revision 12-April-2002

Monday, May 13

8:30 Executive Session – Willeke (20 minutes)

8:50 Welcome and Presentation of Charge – Holmes (10 minutes)

Collider Run II

9:00 Run IIA Overview – Church (20 minutes)

9:30 Antiproton Source Performance and Plans – McGinnis (40 minutes)

10:15 Break

10:35 Main Injector Performance and Plans – Kourbanis (30 minutes)

11:10Tevatron Performance and Plans – Shiltsev (40 minutes)

12:00 Lunch

1:00 Accelerator Physics Issues – Syphers (40 minutes)

1:50 Shot Engineering – Harms (20 minutes)

2:20 Recycler Status and Plans – Mishra (40 Minutes)

3:10 Break

3:30 Run II Instrumentation – TBD (30 minutes)

4:00 Discussion

Linear Collider

4:30 TESLA Engineering/Cost Study – Garbincius (20 minutes)

5:00 Executive Session

Requests for supplementary or breakout presentations on Thursday

Tuesday May 14

Proton Driver

8:30 Synchrotron-based 8 GeV Proton Driver and Main Injector Upgrades–Chou (40 min)

9:10 Proton Driver Lattice – Michelotti (15 minutes)

9:25 Main Injector rf upgrade – Reid (15 minutes)

9:40 Discussion

9:50 Break

10:10 Superconducting 8 GeV Linac – Foster (50 minute)

11:00 Discussion

Linear Collider (continued)

11:15 Linear Collider R&D Program – Finley (30 minutes)

High Brightness Photoinjector

11:45 High Brightness Photoinject EOI – Bohn (35 minutes)

12:20 Discussion

12:30 Lunch

1:30 Supplementary presentations and/or breakout discussions as requested by the committee.

Committee Executive Session

Wednesday, May 15

8:30 Committee Executive Session

10:30 Closeout (60 minutes)