Accelerator Division's Staged Approach to the Proton Plan

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Warning: All numbers in this note are to be confirmed.

In what follows the Accelerator Division outlines a staged approach to enhance the neutrino physics capabilities at Fermilab over the next decade. The importance of an extended accelerator-based neutrino program in addressing important physics questions is summarized in the report of the APS Multi-Division Study of the Physics of Neutrinos. http://www.aps.org/neutrino

The neutrino program at Fermilab presently consists of two experiments: MiniBooNE, using the 8-GeV proton beam provided by the Booster, and Minos (near and far detectors), using the NuMI 120-GeV beam from the Main Injector.

The discussion is conceptual at this point. The start is defined by the present operational performance of the complex, with a near-term plan to upgrade the accelerators described in the draft Proton Plan as presented to the PAC in Nov 8 2004.
http://www.fnal.gov/directorate/program_planning/Nov2004PACPublic/Draft_Proton_Plan_v2.pdf
At the end point of this discussion the neutrino program is supported by the Proton Driver, http://protondriver.fnal.gov/ which for this purpose is assumed to begin operation on or around 2015.

A program of accelerator improvements is envisaged with the following major phases:

0. The starting point is taken to be summer 2005, at which time the goal (and expectation) is to supply the NuMI beamline with 2.5E13 protons on target (PoT) every 2 seconds (five Booster batches, 5E12 each). MiniBooNE will operate at an annual rate of 1-2E20 PoT.
1. The Proton Plan will be re-scoped due to funding constraints. Nevertheless most of the intensity benefits outlined in the Nov04 draft will be implemented with completion in 2008. The goal for the NuMI beamline will be to deliver 4-5E13 using slip-stacking in the Main Injector. To accomplish this, the cycle time must be increased to about 2.2 seconds. The completion of the Tevatron program near the end of the decade will allow all beam accelerated in the Main Injector to be provided to NuMI, or about 5-6E13 per cycle. If improvements in the radiation levels in the Booster are successful, the annual rate for MiniBooNE will be 2-3E20.
2. On completion of the Tevatron program, the Main Injector and Recycler complex can be devoted to the neutrino program. It is likely that the Recycler can provide a significant benefit providing proton storage for loading the Main Injector. This will allow the cycle time in the Main Injector to be reduced to about 1.5 seconds. The maximum intensity that can be stored and accelerated in this scheme is not yet determined. This scheme will require several improvements to be made, including a new transfer line for protons into the Recycler. The goal would be to commission such a new mode of operation in 2010.
3. Before completion of the Proton Driver, the Main Injector, transfer lines and NuMI beamline and target station must be readied for operation at up to 15E13 PoT every 1.5 seconds. The full scope of this work is not yet determined.

It is believed that these phases can be viewed largely independently, except for the upgrade to the Main Injector RF system. This is the most expensive project in the Proton Plan. There are two steps planned to upgrade the present cavities to allow acceleration (at the present ramp rate) of intensities higher than the present limit of about 3.5E13. These are:

1. **Allow the dissipation of additional power in the MI cavities.** The intensity limit with this step is expected to be around 5E13. If existing ports can be used to make this modification, then the cost scale is $2M and the improvement could be made on a timescale of one year. If significant modifications to the cavities are needed, then the cost and time could be significantly higher.
2. **Double the RF power supplied to the MI cavities.** The cavities themselves were designed to accommodate the addition of a second power amplifier. The cost is dominated by the power amplifiers and modulators. The cost scale is $10-12M (without G&A) and the upgrade would take of order two years. The intensity limit with this upgrade is expected to be above 6E13.

Both of these steps require a prototype phase. The numbers quoted here assume that feedback loops and feed-forward will not allow the beam power accelerated to exceed the power dissipated in the cavities. This is probably pessimistic but the improvement needs to be measured with the present system to project anticipated effect in the upgrade.

The MI RF upgrade needed for the Proton Driver is not yet fully defined, but it is highly probable that these two steps will not be sufficient. The plan with the Proton Driver not only accelerates a higher intensity, but also ramps at 305 GeV/sec rather than the present 200 GeV/sec. The design for this upgrade needs to start soon.

AD will carry out a prototype plan to test step 1 alone, and steps 1 and 2 together, and to determine the effectiveness of feedback and feed-forward loops on the RF performance. It is expected that this effort will be completed by the end of calendar 2005. Additional studies on slip-stacking and barrier bucket stacking for NuMI will proceed during the same period. On completion of the prototype testing a report will be written on expected performance for these upgrades and a technical review held. A decision will be made to proceed with steps 1 and 2 directly or in a phased approach. The needs of the neutrino experimental program and schedule and needs for the Proton Driver will be considered in this decision.

Accelerator Division will develop this program in the following way:

1. The Proton Plan will be re-scoped to meet budget constraints while delivering the maximum PoT rate possible. This work will be planned to be completed in 2008.
2. A study group will be formed to develop the concept for operating NuMI after completion of the Tevatron program when the Main Injector and Recycler can be devoted to this program. This group will write a report on the concept, describing the scale of effort and performance that might be expected, by summer 05.
3. AD will continue to work with TD and the physics community to develop the technology for the Proton Driver, and to develop plans for operating the neutrino program with the Proton Driver, identifying any improvements needed in the existing accelerator complex.