Upgrading the Linac 400MeV Switchyard

Charles M. Ankenbrandt, David Harding,
James Lackey, Elliott McCrory, Milorad Popovic,
Fermi National Accelerator Laboratory

Daniel Kaplan, Katsuya Yonehara,
Illinois Institute of Technology

Robert E. Hartline, and Rolland P. Johnson
Muons, Inc.

May13, 2004

This note describes changes in the 400 MeV beam transfer system from the Linac to improve the quality of the beam delivered to the Booster and to add the capability to direct beam to the MuCool Test Area (MTA). The new configuration has two pairs of pulsed dipole magnets on each side of the 400MeV electrostatic Chopper. The smaller pair deflects vertically to replace the kick of the Chopper to send the beam to the Booster while the larger pair deflects horizontally to transfer the beam to the MTA. In this new scheme, the Chopper is uncharged while the beam is injected into the Booster such that the injection position does not rely on Chopper power supply regulation as it does now. A feature of the proposed upgrade is that no changes in the lattice functions are required in the lines to the Booster or to the Dump and switching between the old and new operating modes can be done from upstairs.

Introduction

Historically, the Chopper selected the part of the Linac pulse to be sent to the Booster. With both of the Chopper's horizontal plates charged to 56 kV, the front portion of the beam pulse passed straight through them to the Linac Dump. Then one plate was discharged causing a vertical deflection of the middle portion of the beam toward the Booster. Once the desired number of Booster turns was injected, the second plate was discharged to allow the rest of beam to go straight to the dump. Thus the amount of beam discarded from the first part of the Linac pulse and the number of Booster turns were simply determined by the timing of the discharging of the Chopper electrodes. Since the discharge of the electrodes is fast, little beam is lost during transitions.

Present and Proposed Operation

After the 400MeV upgrade, the time in the Linac cycle that the first electrode discharged was fixed so that a feed forward system could be implemented in the upgraded debuncher cavity. Also, to lower the Chopper voltage required for the higher energy extraction, a defocusing quad (Q2) was introduced. Then, in early 2000, the 750keV Chopper became the method to control the beam pulse duration and consequently the number of Booster turns, such that there is no longer any tail portion of the 400 MeV Linac pulse to be discarded.

In the proposed scheme, two small dipole magnets on each side of the Chopper replace it to provide the needed vertical deflection for transfer to the Booster. For straight-ahead transfer to the Dump, the Chopper is on and deflects downward to cancel the upward bend of the two small dipoles. Thus the Chopper will start out with only one plate charged as the unwanted initial Linac beam is directed to the Dump and then it will quickly discharge to switch to the Booster beam line.

Figure 1 shows a Trace3D diagram of the present configuration used to transfer beam to the Booster. After Q1, the Chopper deflects the beam upward through Q2, which produces an additional upward kick. In this and subsequent diagrams the vertical position of the beam centroid is shown as a bold line.

Figure 2 shows a Trace3D diagram of the proposed configuration to transfer beam to the Booster. The Chopper is grounded. Two small dipole magnets on each side of the Chopper effectively replace it to deflect beam upward through Q2, as before.

Figure 3 shows a Trace3D diagram of the present configuration used to transfer beam to the Dump. Both Chopper plates are at the same voltage, providing no deflection. The beam ends in the Linac Dump after the Spectrometer magnet.

Figure 4 shows a Trace3D diagram of the proposed configuration to transfer beam to the Dump. In this case, the Chopper bends the beam downward to counter the upward bends from the two small dipoles on each side of the Chopper to send the front portion to the dump. The discharge of the Chopper causes a fast switch from the Dump to the Booster.

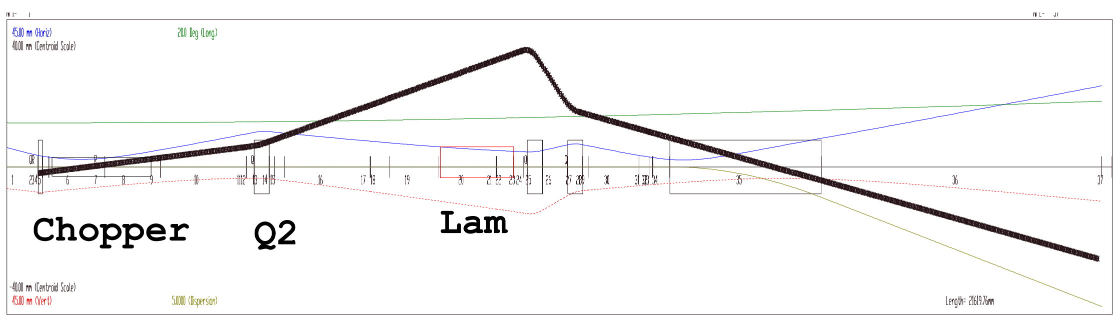


Figure 1. Trace3D elevation diagram of the present 400 MeV transfer system from the Linac to the line down to the Booster. The position of the beam centroid is shown as a bold line. For beam to be injected into the Booster, the Chopper must provide a vertical deflection that is amplified by the defocusing quad, Q2.

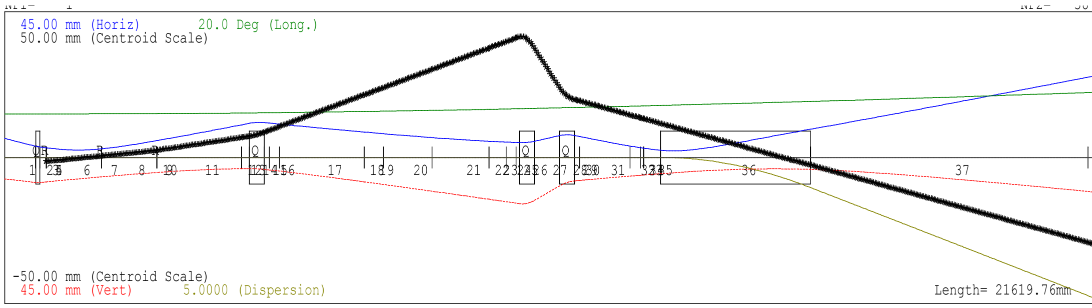


Figure 2. Trace3D elevation diagram of the proposed 400 MeV transfer system from the Linac to the line down to the Booster. The position of the beam centroid is shown as a bold line. For beam to be injected into the Booster, the Chopper is grounded and two small dipole magnets, one on each side of the Chopper, provide the vertical deflection that is amplified by the defocusing quad, Q2. The dipole magnets are window-frame magnets, which are also used to provide the horizontal deflection of beam to the MTA.

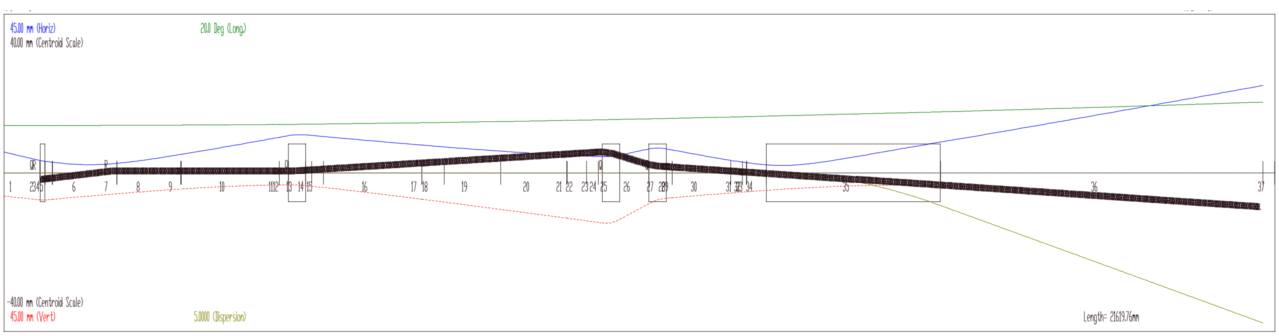


Figure 3. Trace3D elevation diagram of the present 400 MeV transfer system from the Linac to the line to the Dump. The Chopper provides no deflection for the unwanted initial portion of the beam to be dumped.

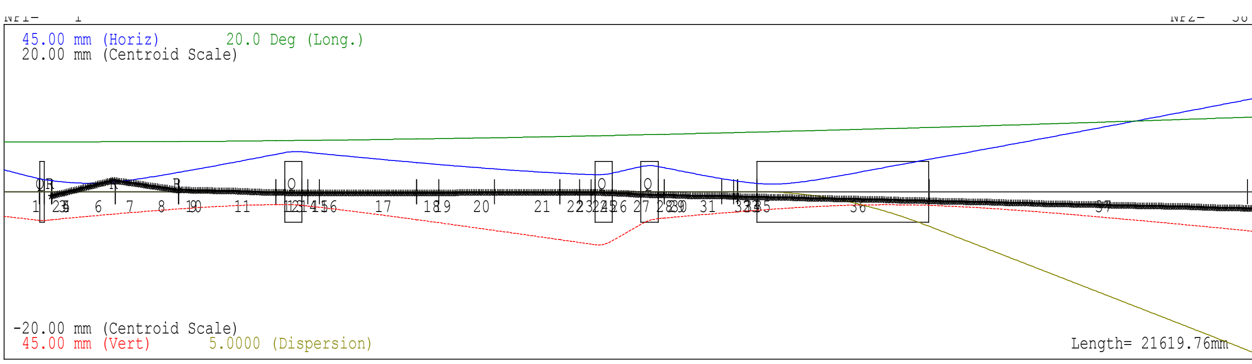


Figure 4. Trace3D elevation diagram of the proposed 400 MeV transfer system from the Linac to the line to the Dump. Here the Chopper deflects the beam downward to compensate the upward bend of the new dipoles on each side of the Chopper.

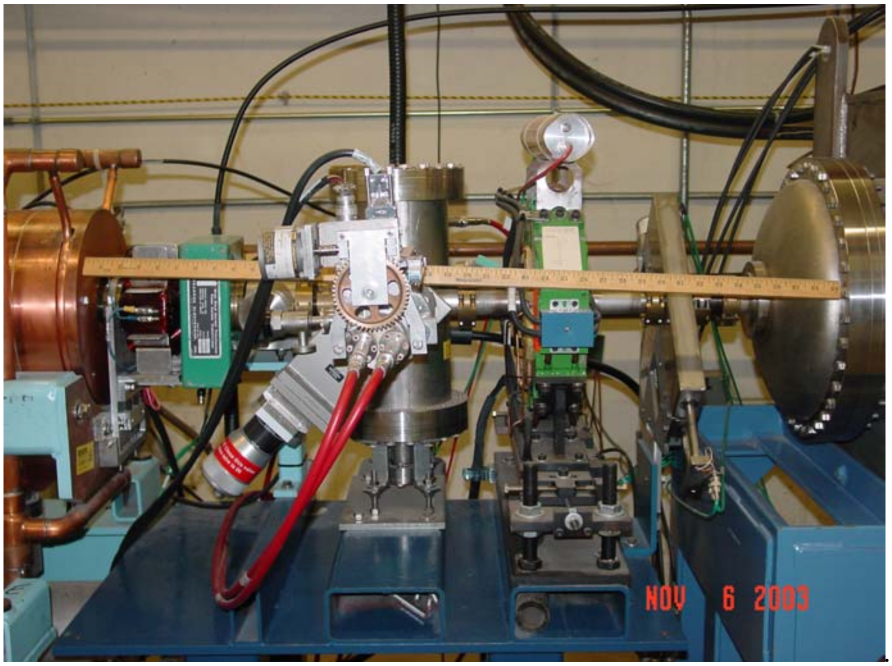


Figure 5. The region between the end of the 400 MeV Linac and the Chopper. A horizontal pulsed dipole magnet will replace the bunch length monitor at the center of the photo. A smaller vertical pulsed dipole will be placed near the Chopper.

Figure 6. The downstream end of the Chopper. A small wide-aperture vertical pulsed dipole will be placed just after the Chopper, followed by a horizontal pulsed dipole. A new arrangement of the wire scanner, Pierson transformer and Griffin monitor will provide the needed space.

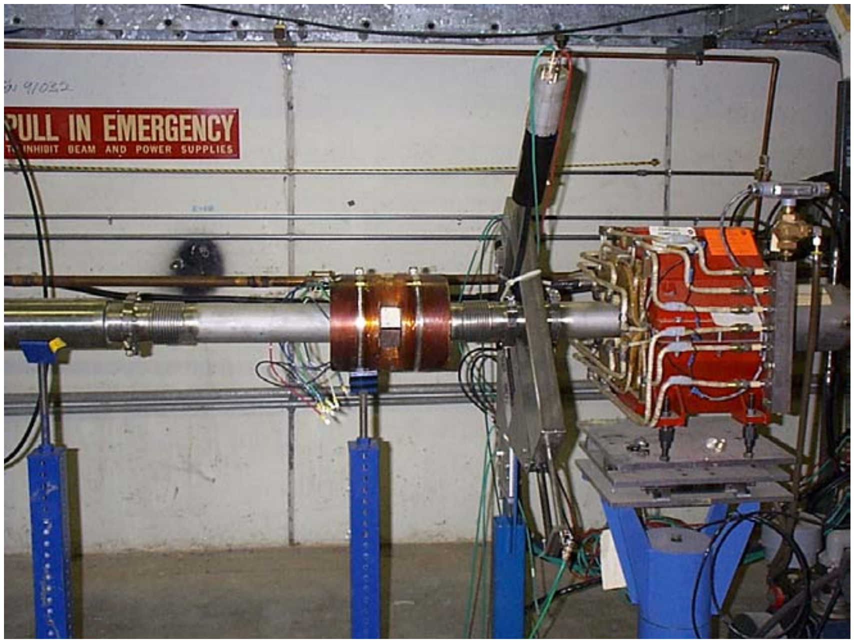


Figure 7. Continuation of figure 6, showing Q2.

Magnets and Parameters

The description of the MTA beam line is contained in MuCool Note 287 (MUC-NOTE-COOL_EXP-287). The horizontal pulsed dipoles can be made as shown in Figure 8, below, where the straight-ahead Linac beam (circle) and the MTA beam (ellipse) positions are indicated in the magnet downstream of the Chopper. The vertical pulsed dipole immediately following the Chopper must have sufficient horizontal aperture to accommodate both the straight ahead and MTA beams.

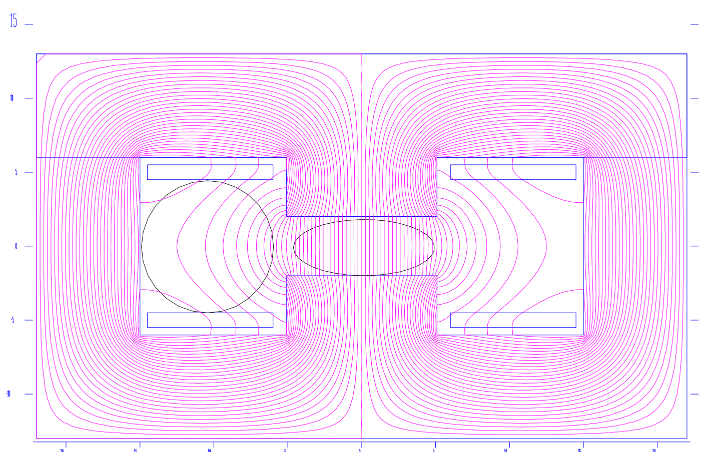


Figure 8. IDH dipole (Main Injector horizontal trim) profile showing field calculation. In the case of the second, downstream pulsed magnet, the straight-ahead Linac beam pipe passes through the magnet between the coils as shown by the circle in the figure.

Initial Test

An initial test can be performed by adding a new dipole corrector between Q74 and the wire-scanner in front of the Chopper or by moving the exiting corrector from the end of the Linac to this location. The first Chopper plate has to discharge before the beam comes and the second plate at the time that beam has to be sent to the Booster.

Here is beam to the dump,

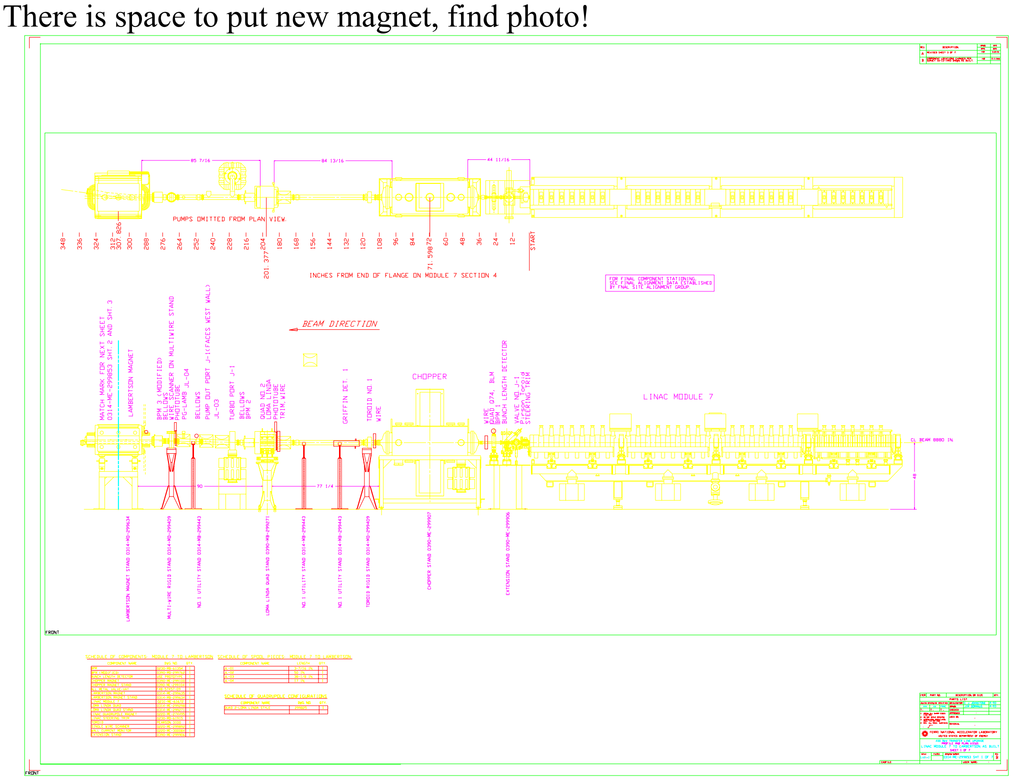
Note chance in the scale for centroiod, here is 20 mm, below 50mm. Three bump angle are –0.1, 1.16, -0.05 and –0.1, 0.0, -0.05

==

My Notes, Ignore them.

- Magnet scaling from 40degree, 300cm, 7.5kGauss, not to strip H-. So 1degree, 7.5cm, 7.5kG, then 0.1 degree, 0.75kG and from formula, NI=2.02*B(Gauss)*h(inches), NI=325Amp-turns. Looks like 7.5cm long, 2.54cm gap dipole with 325Amp-Turms will make 0.1 degree deflection.
- There is H/V dipole corrector right after the linac and it can be used for initial tests. This magnet is window frame type, it is 3.9in long, with aperture of 1.75in. It has 941 turns and 5kG-inch intergraded field at 10Amps. (Elliott)
- Here is Poisson run, looks simple magnet to build.

- From Jim, Chopper kick is 5mrad@57kV= 100gauss 0.3metar magnet. Chopper plates are 1 inch apart.
- There is space to put new magnet, find photo!



- Jim Lackey has suggested that additional trim is put after Chopper to avoid possible scraping in the Chopper. It makes sense, let me see, he has also numbers for trim.

Here is Jim's three bump version

Note chance in the scale for centroiod, here is 20 mm, below 50mm. Three bump angle are –0.1, 1.16, -0.05 and –0.1, 0.0, -0.05