LOW AND MEDIUM ENERGY BEAM TRANSPORT UPGRADE AT BNL 200 MEV LINAC*

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Abstract

The BNL 200 MeV linac has been under operation since 1972 and gone through several changes during its 38 year lifetime. The latest reconfiguration in low and medium energy (35 and 750 keV) beam transport lines results in about a factor of 2 reduction in the transverse emittance for the accelerated polarized proton beam, and for the un-polarized high current H^- beam a several-fold reduction in the radiation levels due to beam losses throughout the linac and isotope production facility complex, with more beam current on the isotope production target. These improvements are achieved by proper matching into the linac in longitudinal as well as transverse phase spaces [1].

INTRODUCTION

The Brookhaven National Laboratory (BNL) 200 MeV drift tube linac (DTL) provides H- beam at 6.67 Hz, 200 MeV for the polarized proton program at Relativistic Heavy Ion Collider (RHIC) and 116 MeV for Brookhaven Linac Isotope Production (BLIP). The RHIC program needs 2 pulses every AGS cycle (~4 sec), one for injection into Booster and the other for polarization measurement in the 200 MeV polarimeter located in the high energy transport line (HEBT). The rest of the pulses go to BLIP. The requirements for these programs are quite different and are the following. (1) RHIC: 200 MeV, 200 μA beam current, up 400 μs pulse length, polarization as high as possible and emittance as low as possible, (2) BLIP: 116 MeV, 450 μs pulse length, current as high as possible (~40 mA), uniform beam distribution at the target, and losses as low as possible. Prior to the upgrade, transmission efficiencies from source to the linac exit were about 35% for the high current and 50% for the polarized beams, and emittance growth several fold for both beams. The emittance is one of the most fundamental parameters for any accelerator and in particular for colliders. To reduce the emittance growth in the linac, in 2008 the low energy and medium energy transport lines were reconfigured as proposed in 2004 [2] and results were reported in PAC09 [1]

MODIFICATION FOR 2010 RUN

Modification in Low Energy Beam Transport for High Intensity

After the reconfiguration in 2008, the low energy beam transport (LEBT) for the high intensity H^- was 4 meters long as shown in Figure 1. Transmission through RFQ was rather low due to beam instability in the LEBT. In 2009, the high intensity source was moved upstream with a bend angle of 45 degrees as shown in Figure 2. The new length of the LEBT is now 2 meters and has two solenoids, two quadrupoles, and two steerers in each plane, a chopper and one 45 degree dipole. Figure 3 shows the TRACE2D output. The transmission through linac was increased by 30%. Average beam current on the BLIP target was increased to 110 μA in 2010 from 72 μA in 2009. Radiation in the BLIP transport line was further reduced. Table 1 shows the linac performance for high intensity for the last three years.

Table1: BNL Linac Performance for High Intensity H^-

Parameters	***2008***	***2009***	***2010***
Average Current within 2" target	71μA	72μA	110μA
Beam outside 2"	8%	0%	0%
Collimator temp.	160°C	70°C	65 °C
Radiation	Normal	Low	Lower

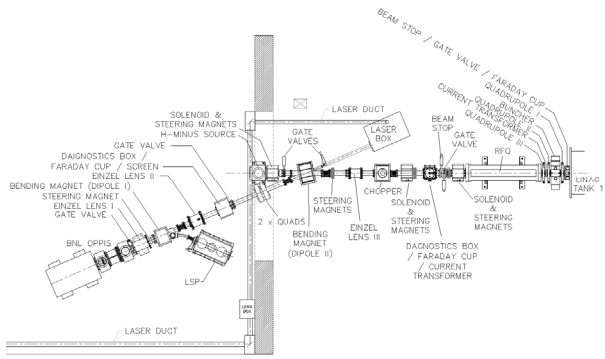

Figure 1: Layout of LEBT and MEBT in 2008.

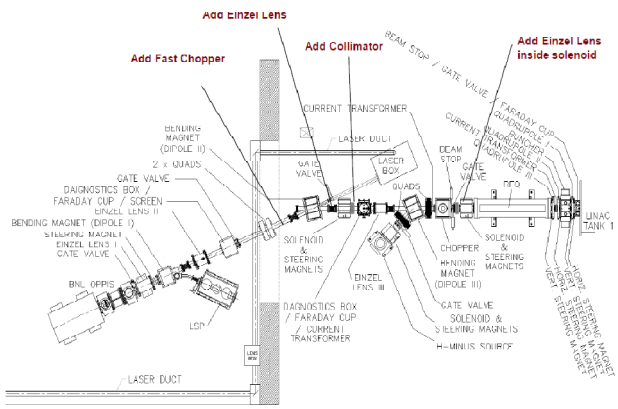

Figure 2: Layout of LEBT and MEBT in 2009.

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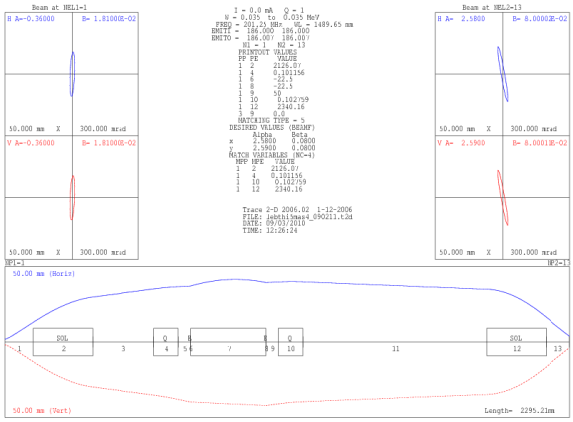


Figure 3: Beam envelope (TRACE2D) through the LEBT.

Modification in Low Energy Beam Transport for Polarized Protons

Table 2 shows the polarization of H- beams for last few years. It seems that the polarization was lower in 2009. The beam coming from OPPIS has some ions with 33.5 keV energy, which are un-polarized and cause reduction in net polarization of H^- beam. To suppress, these ions a lens system was design with two einzel lenses put together in de-acceleration mode, as shown in Figure 4. The first lens has more than 34 kV potential , therefore stopping all the ions less than 34 kV, while ions with 35 kV will go through this potential barrier but are very sharply focused, The second lens in the system then makes the beam parallel, as shown in Figure 5.

Table 2: H^- Polarization for Past Few Years Measured at 200 MeV

Year	Polarization
Run 2006	83 -85 %
Run 2007	85-89 %
Run 2008 before LEBT/MEBT upgrade	80-82 %
Run 2009 after new LEBT (less spin precession)	78-80%
Run 2010, double –einzel lens	80-83 %
Run 2011, solenoid replaced with einzel lens	Expected 82-85%

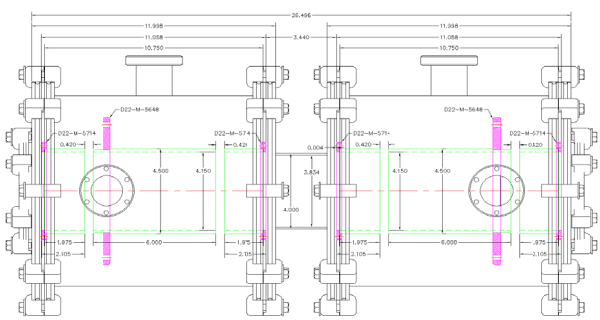
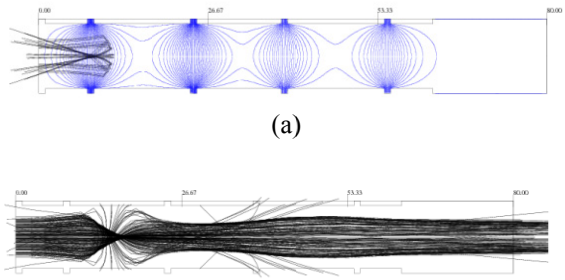


Figure 4: Design of double–einzel lens to reduce molecular component of the 35 keV polarized beam.



(a)

(b)

Figure 5: Ray traces showing that 33.5 keV ions will not go through the lens system (a), while 35.0 keV ions make through the lens system with parallel beam out (b).

Figure 6 shows the measurement results at the end of the linac at 200 MeV as the extraction voltage of OPPIS was varied from 32 kV to 34 kV.

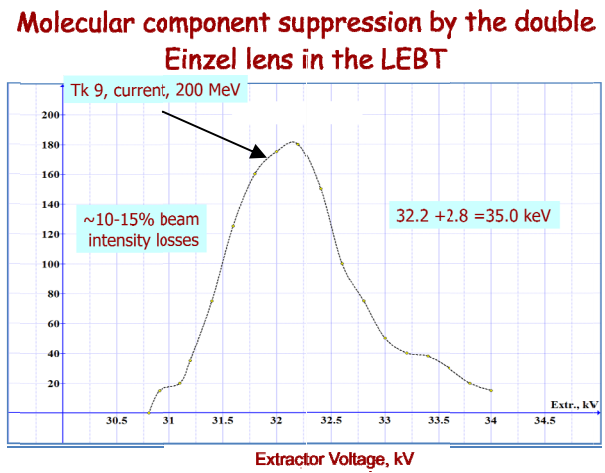


Figure 6: Polarized H^- beam current at 200 MeV as function of extraction voltage of OPPIS source, showing that the molecular component (33.5 keV) in the ion beam is suppressed by the double-einzel lens system.

The H^- ions emerge from OPPIS with longitudinal polarization, and the 23.7 degree bend rotates polarization to the vertical direction. The present LEBT configuration for polarized protons has two solenoids. One in front of RFQ is used to focus beam into the RFQ, but it also precesses the spin direction. To make this polarization vertical, a second solenoid is used in LEBT. This double-solenoid configuration causes un-necessary precession of polarization by more than 360 degrees. It is believed that due to this extra precession beam polarization is lowered.

Early this summer, the solenoid in front of the RFQ was replaced by an einzel lens, and the polarization measured at 200 MeV. There was an indication from this that there might have been an improvement in the polarization.

MODIFICATION FOR 2011 RUN

Modification in Low Energy Beam Transport

As discussed in the previous section, to reduce extra precession, we will be installing solenoid-einzel lens in front of the RFQ. einzel lens and solenoid will be pulsed devices and polarized beam will uses einzel lens and high intensity will see only solenoid filed. The Figure 7 depicts design of this solenoid-einzel combine lens system.

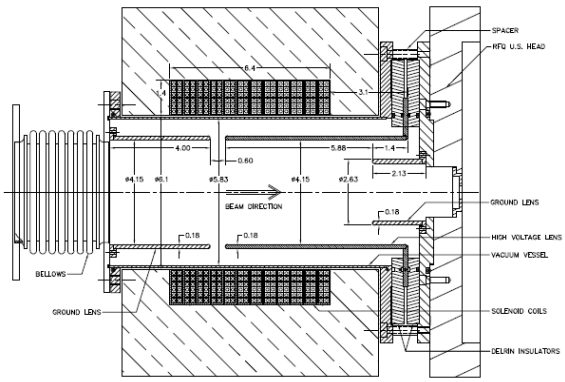


Figure 7: Design of the new solenoid-einzel lens system for front of RFQ.

Modification in Medium Energy Beam Transport

As reported in 2009, the buncher performance in the MEBT is limited by the available rf power [2]. For the upcoming run we are installing a new buncher with 10 time higher Q value, shown in Figure 8. This buncher was made from solid aluminium by a 5 axis machine. The model buncher was tested up to 5 kW of power. We will need to operate at about 3.5 kW [3].

At present we using quadrupoles in the MEBT from the LEDA project, which have solid core and therefore we are unable to pulse them for different beams. We are in the processes of making new quadrupoles with laminations. We will be able to install these for the 2012 run [3].

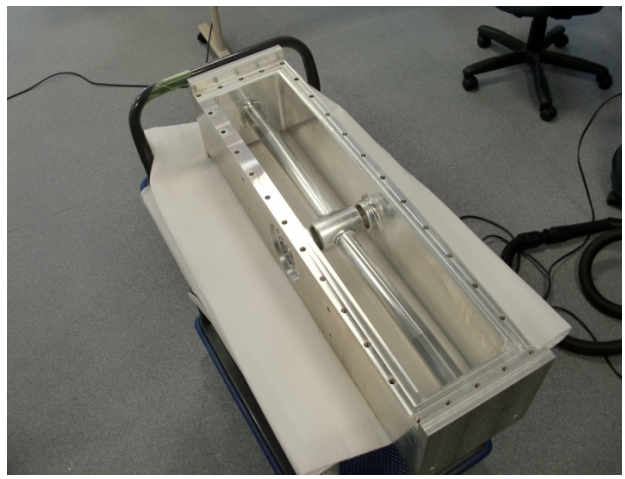


Figure 8: New 201.25 MHz buncher for the MEBT.

CONCLUSIONS

We have increased the average current on the BLIP target by 30%, to 110 μA, by shortening the LEBT line. We have also increased polarization by a couple of percent by the use of the double-einzel lens in the 2010 run. This year further improvement in high intensity beam is expected due to new buncher in the MEBT and further increase in the polarization is expected due to solenoid-einzel lens system in front of the RFQ.

REFERENCES

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[3] M. Okamura, *et. al.,* "A New Medium Energy Beam Transport Line for the Proton Injector of AGS-RHIC", this conference.