CHANGES IN LEBT/MEBT AT THE BNL 200 MEV LINAC*

D. Raparia, J. Alessi, J. Fite, O. Gould, V. LoDestro, M. Okamura, J. Ritter, A. Zelenski
Brookhaven National Laboratory, Upton, NY, U.S.A.

Abstract

After reconfiguration of the low energy (35 keV) and the medium energy (750 keV) transport lines in 2009-10, the Brookhaven linac is now delivering the highest intensity beam since it was built in 1970 (~120 μA average current of H^- to the Brookhaven Linac Isotope Producer). It is also now delivering lower emittance polarized H- ion beam for the polarized program at RHIC. To increase the intensity further, we are replacing the buncher in the 750 keV line with one with higher Q value, to allow operation at higher power. Also, to improve polarization, we are replacing the magnetic solenoid before the RFQ in the 35 keV line by a solenoid-einzel lens combination. The paper will report on the results of these changes.

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 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, Linac transmission efficiencies from source to tank 9 were about 35% for the high current and 50% for the polarized beams and emittance growth several folds for the both beams. The emittance is one of the most fundamental parameters for any accelerator and in particular for the colliders. To reduce the emittance growth in the linac, low energy and medium energy transport lines were reconfigured as proposed in 2004 [1] in 2008 and results were reported in PAC09 and LINAC 2010 [2,3]

CHANGES FOR 2011 RUN

Changes in Low Energy Beam Transport

The H- ion emerges OPPIS with longitudinal polarization, the 23.7 degree bend rotate polarization in the vertical direction. Present LEBT configuration for polarized proton has two solenoids. One in front of RFQ is used to focus beam into the RFQ but it also processes the polarization. To make this polarization vertical LEBT uses 2nd solenoid. This causes un-necessary precession of polarization by more than 360 degrees. It is believed that due to this extra precession beam polarization is lowered.

To reduce extra precession, we have installed solenoid-Einzel lens in front of the RFQ. Einzel lens and solenoid is pulsed devices and polarized beam uses Einzel lens and high intensity sees only solenoid filed. The Figure 1 depicts design of this solenoid-Einzel combine lens system.

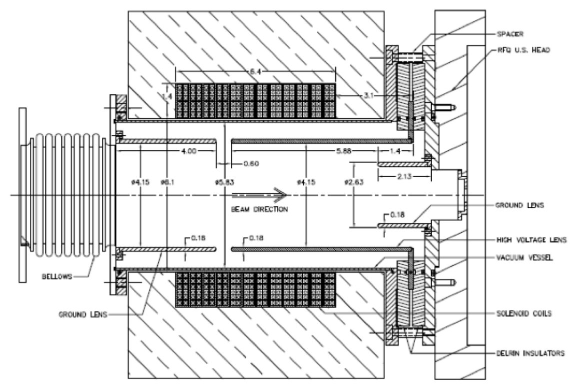

Figure 1: Design of the new solenoid-Einzel lens system for front of RFQ. The distance between RFQ and solenoid is increased by 1.5 inches

To accommodate high voltage feed through, the distance between RFQ and solenoid is increased by 1.5 inches, resulting about 10% lower transmission for the high intensity beam. The polarization did not improve. Table 1 show the polarization measured at 200 MeV for last few years.

Table 1: H^- Polarization for Past Few Years Measured at 200 MeV

Year polarization	Polarization
Run 2006	83 -85 %
Run 2007	85-89 %
Run 2008 before LEBT/MEBT upgrade	80-82 %
Run 2009 new LEBT (less spin precession)	78-80%
Run 2010, double –Einzel lens	80-83 %
Run 2011,solenoid replace with Einzel lens	80-81%

Changes in Medium Energy Beam Transport

As reported in 2009 that buncher performance in the MEBT is limited by the available power [2]. For upcoming run we are installing new buncher with 10 time higher Q value shown in Figure 2.

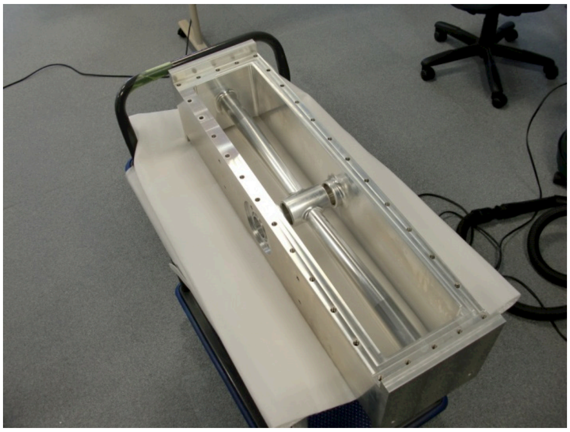

Figure 2: New 201.25 MHz buncher for the MEBT

Figure 3: (a) Tuning blocks to adjust the frequency shift due to grids (b) Grid install in the both side of drift tubes.

Buncher was made solid Aluminium by 5d machine. The model buncher was tested up to 5 kW of power.[4].

The transmission was much lower than expected. Lower transmission was due to drift tube diameter which was 4.3 cm instead of 3.2 cm. This reduces the effective bunching voltage as seen by the beam. To increase the effective voltage we decided to install the four grids in the drift tubes as shown in figure 3. Figure 4 shows compare the bead pull measurements with and without the grids. After installing the grids transmission through linac has increased up 80%.

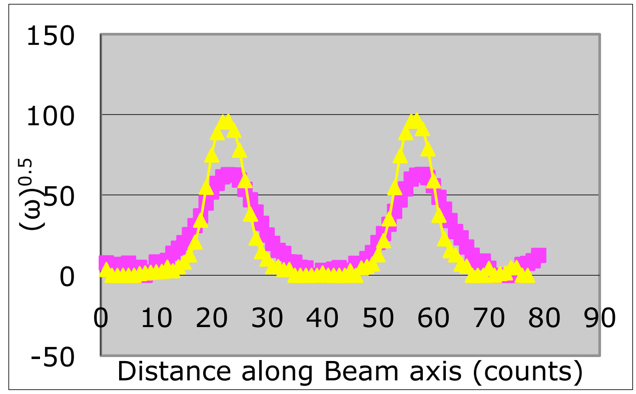

Figure 4:. Comparison of bead pull through the buncher with (yellow) and without (pink) grids.

We have installed four steers, two in x plane and two in y plane [5]. At present we using quadrupoles in the MEBT from the LEDA project, which has solid core therefore we unable to pulse them for different beam. We are in the processes to make new quadrupole with laminations. We will be able to install them for the run1012 [4].

Changes in High Energy Beam Transport

In the high energy transport line after tank 9, we have installed a laser profile monitor which also measures the beam energy by measuring energy of stripped electrons. We not only able measure the energy of the pulse but also energy variation within pulse (450 micro-second) and energy spread of the bunch [6]

RESULTS

Polarized H⁻

For polarized H$^-$, over all transmission from source to 200 MeV is increased to ~65% from ~50%, this improvement mainly comes from the new buncher and steers in the MEBT.

High intensity H⁻

The average intensity for BLIP remains about same as 2010. We lost about 10% RFQ transmission due to increased distance between RFQ and solenoid and reduced aperture 3 inches from 4 inches ant end of the Einzel lens. But we gain in the linac transmission about 14%. Table 2 show the comparison for transmission for last two years.

Table 2: Transmission Efficiencies for High Intensity H$^-$

Parameters	***2010***	***2011***
	current (trans)	current (trans)
LEBT	70 mA	70 mA
MEBT	57 mA (81%)	50 mA (71%)
BLIP target	39 mA (68%)	41 mA (82%)
Ave. Cur.	120 µA	125µA

We are running buncher at 5 kW which is the limit for the RF power source. The linac transmission increases with power, no sign of saturation (figure 5)

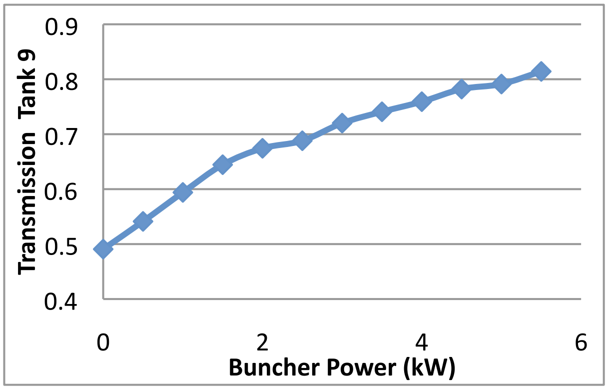

Figure 5: Transmission through tank 9 as function of buncher power in MEBT.

We planning install new buncher with 3.2 cm of drift tube diameter and made of copper to increase the transmission further. Table 3 summarizes the linac performance for last 4 years.

Table 3: BNL Linac Performance for High Intensity H^-

Parameters	***2008***	***2009***	***2010***	***2011***
Ave. Cur. within 2" target	71μA	72μA	120 μA	125μA
Beam outside 2"	8%	0%	0%	0%
Collimator temp.	160°C	70°C	65 °C	62°C
Radiation	Normal	Low	Lower	Lowest

REFERENCES

[1] D. Raparia, *et. al.,* "Results of LEBT/MEBT Reconfiguration at BNL 200 MeV Linac*",* Proceedings of PAC09, Vancouver, Canada.

[2] D. Raparia, *et. al.,* "Proposal for Reduction of Transverse Emittance of BNL 200 MeV linac", Proceedings of Linac 2004, Lubeck, Germany, 2004

[3] D. Raparia, *et. al.*, Low and Medium Energy Beam Transport Upgrade at BNL 200 MeV Linac", Proceeding of Linac 2010, Tsukuba, Japan

[4] M. Okamura, *et. al.,* "A New Medium Energy Beam Transport Line for the Proton Injector of AGS-RHIC", Proceeding of Linac 2010, Tsukuba, Japan

[5] M. Okamura, *et al*, "Steering magnet design for limited space", Proceedings of PAC09, Vancouver, Canada.PAC2009, Vancouver, Canada

[6] R. Connolly, *et. al.*, "A Laser-Wire Beam-Enrtgy and Beam-Profile Monitor at the BNL Linac", this conference.