COLLIMATION IN THE SNS LINAC AND HEBT*

Dong-o Jeon#, SNS, ORNL, Oak Ridge, TN 37831, U.S.A.
Jingyu Tang, Xiyin Zhang, IHEP, CAS, Beijing 100049, P R China

Abstract

A pair of horizontal MEBT collimators at the chopper target was proposed by [D. Jeon *et al.*, PRST-AB 5, 094201 (2002)] based on the findings of the halo mechanism driven by a large ratio of x and y beam size in the MEBT. Recently the MEBT collimators were installed and prove very effective in reducing beam loss throughout the linac, HEBT and IDump. The HEBT collimation system is a combination of stripping foil for H- beam and collimators. A benchmarking study of the HEBT collimation system is conducted with beam experiment and multiparticle tracking. We measure the efficiency of the HEBT collimators using beam loss monitors and compare with the model. Experiment and simulation show a reasonable agreement.

INTRODUCTION

With a high intensity linac such as the Spallation Neutron Source (SNS) linac [1], a primary concern is a potential damage and radio-activation of accelerator components resulting from uncontrolled beam losses. A major source of beam losses consists of halo that is intercepted outside the bore radius.

To understand halo formation and beam loss, extensive studies of halo formation mechanisms have been conducted. Most recently Jeon *et al.* discovered the $4\sigma=360°$ resonance for high intensity linear accelerators [2] (equivalent of the $4\nu=1$ resonance of circular accelerators) and this linac resonance was experimentally verified [3]. This finding bridges a gap between the linac and ring beam dynamics.

Halo particles can be removed by the use of collimators to reduce beam loss and subsequent activation. Collimation in the field of high intensity linac is one of challenging topics. For the SNS linac, Jeon *et al.* found a halo mechanism driven by a large ratio of x and y beam size in the MEBT (Medium Energy Beam Transport) and proposed a halo mitigation plan including a pair of horizontal collimators at the chopper target [4]. The MEBT collimators were recently installed and beam operation has proven that the MEBT collimation is very effective in reducing beam loss across the linac, HEBT (High Energy Beam Transport) and IDump (Injection Dump). The HEBT collimation system was installed in order to intercept halo particles, which is a combination of thin stripping foils (called scrapers) and collimators for H^- beam [5]. In this paper we present the results of experiment and simulation of the MEBT collimation and the HEBT collimation system benchmarking study.

* SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.
#jeond@ornl.gov

MEBT COLLIMATION

To facilitate beam chopping, beam is squeezed vertically in the middle of the MEBT (see "1.6-m long chopper section" in Fig. 1) where the chopper target is placed. The beam size plot is shown in Fig. 1 obtained from the Trace3D [6] for the nominal MEBT optics.

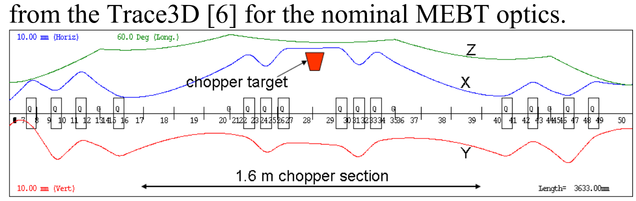

Figure 1: Plot of Trace3D output for the MEBT. 1.6 m chopper section is indicated and x beam size is about two times bigger than y beam size for chopping. Beam travels from left to right.

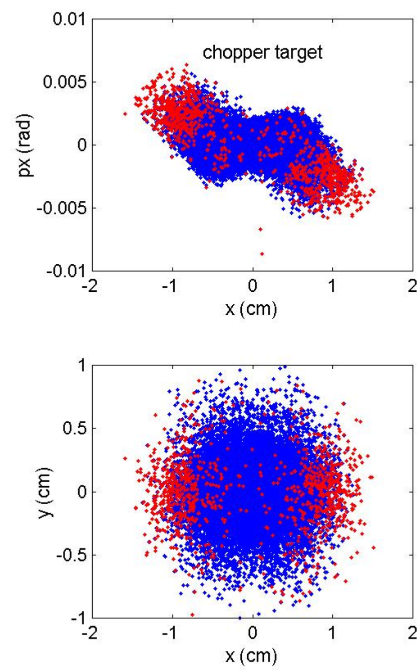

Figure 2: Plots of beam distribution at the position of the MEBT chopper target where horizontal collimators are installed. The particles in red are ones that are potential halo particles to be lost in downstream linac.

It was discovered that a large ratio of x and y beam size drives halo formation through space charge mainly in the horizontal plane [4]. This study showed that when beam is at the chopper target, potential halo particles (depicted as red particles) that can be lost in the downstream linac are populated mostly at both ends of x beam distribution as shown in Fig. 2, especially in the bottom plot. This finding led to the proposal of a pair of horizontal collimators to intercept these halo particles to be installed where the chopper target is.

Simulations suggest that clear reduction in the beam loss should be observed with the MEBT collimation in the downstream linac. We measure the beam loss using beam loss monitors and neutron detectors along the linac, HEBT and IDump with and without MEBT collimation. Figure 3 shows the beam loss comparison in the CCL (Coupled Cavity Linac) and the SCL (Superconducting Linac) with and without MEBT collimation, and Fig. 4 beam loss comparison in the HEBT and IDump. Figures 3 and 4 clearly show that MEBT collimation reduces beam loss significantly across the linac, the HEBT and IDump. For the measurement 4.5 µC beam is used.

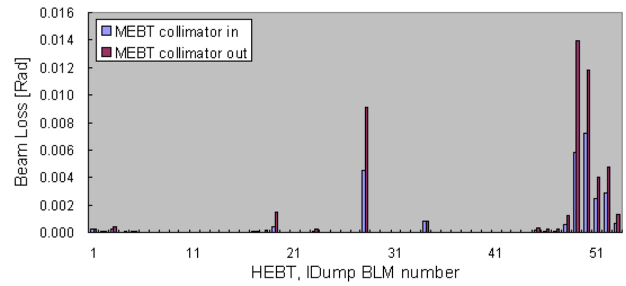

Figure 4: Plot of measured beam loss along the HEBT and IDump (Injection Dump) with the MEBT collimator in and out. Data shows significant reduction in beam loss in the HEBT and IDump with the MEBT collimation. Horizontal axis is BLM (Beam Loss Monitor) number. (1-45) of the x-axis is the HEBT and (46-53) is the IDump.

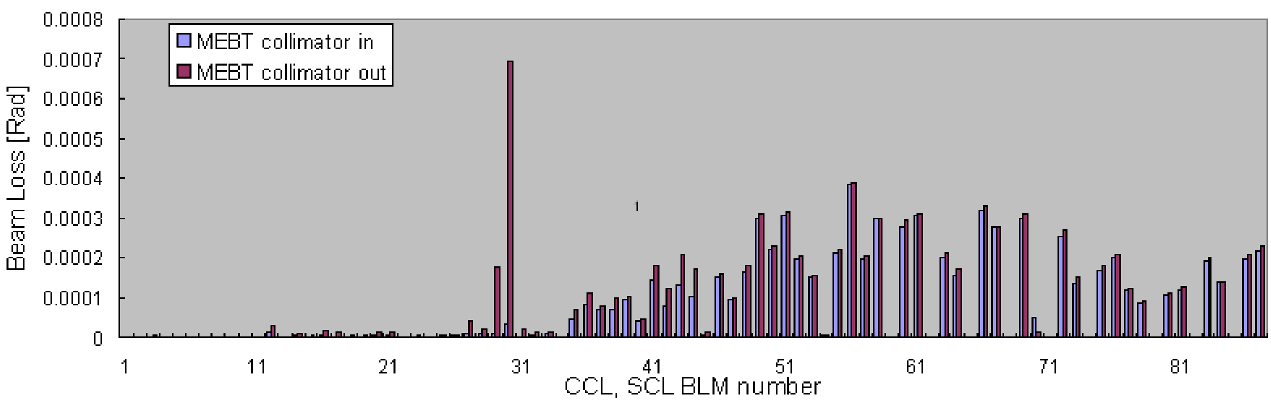

Figure 3: Plot of measured beam loss along the CCL and SCL with the MEBT collimators in and out. Data show clear reduction in beam loss by the MEBT collimation. Vertical axis is the beam loss per pulse in log scale and horizontal axis is BLM (Beam Loss Monitor) number. (1-29) of the x-axis is the CCL and (30-88) is the SCL.

BENCHMARKING STUDY OF THE HEBT COLLIMATION SYSTEM

The SNS HEBT collimation system is a combination of thin stripping foils (called scrapers) and collimators for H^- beam as shown in Fig. 5 [5]. Scrapers are installed just upstream of a quadrupole in the focusing plane, converting H^- beam into H^+ beam. The scraped H^+ beam is defocused by the following quadrupole, facilitating collimation by downstream collimators. Scrapers 01L,R refer to scrapers, 01 Left and 01 Right. QH (QV) refers to horizontal (vertical) focusing quadrupoles. When electrons of H^- beam are stripped by scrapers, thus formed H^+ beam is either collimated by collimators (collimated H^+ beam) or propagates to the first dipole (scraped but uncollimated H^+ beam). Figure 6 shows the schematic plot of the HEBT line with the BLM (Beam Loss Monitor) used for the experiment. This particular BLM is for measuring the activation by the H^+ beam.

Systematic beam studies have been conducted for the benchmarking of experiment and simulation for the HEBT collimation. Scraper position (or insertion depth) determines the ratio of scraped-and-collimated H^+ beam and scraped-but-uncollimated H^+ beam. In the dipole, uncollimated H^+ beam is bent in the opposite direction of H^- beam and irradiates the BLM in Fig. 6. The purpose of simulations is to calculate the amount of scraped-but-uncollimated H^+ beam irradiating the BLM, for the BLM reading is proportional to the amount of H^+ beam irradiating the BLM. This requires information of the amount of H^- beam scraped by a scraper (measured in experiment) and the fraction of scraped-but-uncollimated H^+ beam as a function of scraper position (obtained by simulation).

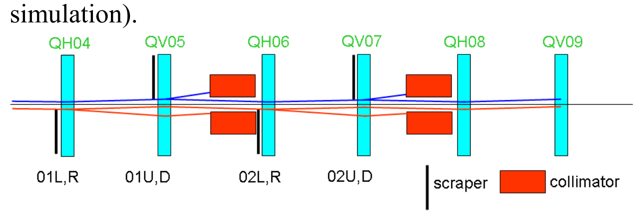

Figure 5: Schematic plot of the SNS HEBT collimation system.

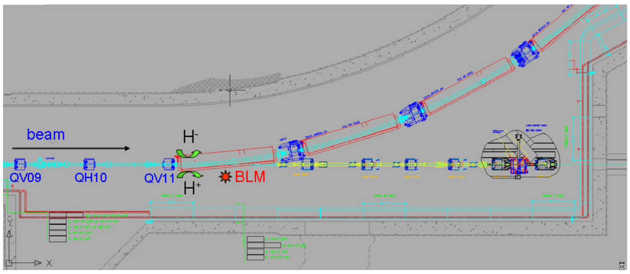

Figure 6: Schematic plot of the HEBT line and the BLM (Beam Loss Monitor) used for the study. H^- beam moves along the HEBT line through the bending magnet depicted as red rectangles, while H^+ beam is bent opposite direction and irradiates the BLM marked on the plot.

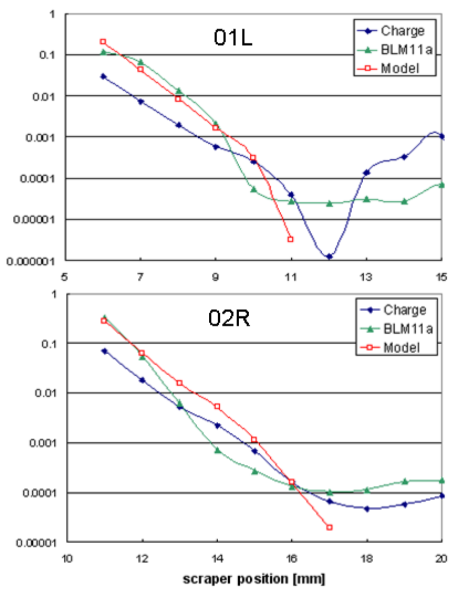

Figure 7: Plots of the HEBT collimation benchmarking study. The "Charge" line represents the charge collected by each scraper [μC], the "BLM11a" line represents the BLM reading [Rad] by H^+ beam, and the "Model" line the simulated BLM reading [Rad]. Reasonable agreement between actual BLM reading and model prediction is observed. The plots show the data for the scraper 01L and 02R. Vertical axis is in log scale. It is interesting to note that beam tail shows exponential decrease.

Figure 7 shows the benchmarking results of experiment and simulation for scrapers that affect the BLM reading. The experimentally measured beam loss data are in green triangle line labeled as "BLM11a" [Rad] and the model prediction in red square line labeled as "Model" [Rad]. The "Charge" line in blue represents the charge collected by each scraper [μC]. We observe a reasonable agreement between the measured BLM reading and the model prediction over a wide range of reading (note that vertical axis of plots is in log scale) for scrapers 01L, 01D, 02R, 02D, and 02L. The other three scrapers do not show changes in the reading of the BLM of Fig. 7, mainly because the impact parameter of the scrapers is too large (in other words, all the scraped H^+ beam is collimated). It is worthwhile to mention the overall effectiveness of the HEBT collimation system. At the time of measurement, only scrapers 01U and 02U reduce beam loss at a few BLMs downstream of the HEBT 90° bending section, while the rest scrapers do not induce any beam loss reduction. Figure 10 shows the plots of beam losses at a few BLMs vs. position of the scraper 01U and 02U. The top plot shows that the scraper 01U reduces beam loss at the HEBT BLM Mov03 and modest beam loss reduction for the IDump BLM 01b and 01c. The bottom plot shows that the scraper 02U reduces beam loss at the IDump BLM 01b and modest beam loss reduction for the IDump BLM 01c and HEBT BLM Mov03.

CONCLUSIONS

The MEBT collimation at the chopper target proposed in the previous study [4] proves very effective in reducing beam loss across the entire linac, HEBT and IDump. This is consistent with results of previous study, which predicts substantial reduction in halo in the linac because of the MEBT collimation. The MEBT collimators are very simple and inexpensive but quite effective in reducing beam loss. Benchmarking study of the HEBT collimation system shows a reasonable agreement between the actual beam loss measurement and its model prediction. It is demonstrated that profiles of low intensity beam halo can be measured using the HEBT scrapers.

REFERENCES

[1] J. Wei et al., Proc. of the 2001 Part. Accel. Conf. (Chicago, 2001), p. 319.

[2] D. Jeon, L. Groening, G. Franchetti, Phys. Rev. ST Accel. Beams **12**, 054204 (2009).

[3] L. Groening, W. Barth, W. Bayer, G. Clemente, L. Dahl, P. Forck, P. Gerhard, I. Hofmann, M.S. Kaiser, M. Maier, S. Mickat, T. Milosic, D. Jeon, D. Uriot, Phys. Rev. Lett. **102**, 234801 (2009).

[4] D. Jeon, J. Stovall, A. Aleksandrov, J. Wei, J. Staples, R. Keller, L. Young, H. Takeda, S. Nath, Phys. Rev. ST Accel. Beams **5**, 094201 (2002).

[5] N. Simos, H. Ludewig, D. Raparia, N. Catalan-Lasheras, J. Brodowski, A. Korostyshevsky, S. Crivello, Proc. of the 2002 European Part. Accel. Conf. (Paris, 2002), p. 1055.

[6] K. Crandall and D. Rusthoi, *An Interactive Beam-Transport Code*, Los Alamos National Laboratory report LA-10235-MS (January 1985): the Trace3D code.