THE SNS RING TO TARGET BEAM TRANSPORT LINE

D. Raparia, J. Alessi, Y.Y. Lee, and W.T. Weng
AGS Department, Brookhaven National Laboratory, Upton, NY 11973.

Abstract

The Ring to Target Beam Transport (RTBT) line connects the Spallation Neutron Source (SNS) accumulator ring to the target, with the required footprint for the accelerator complex. This line also provides four sets of beta collimators to clean any beam halo. This 160 meter long transport line consists of eleven 90 degree FODO cells, beam extraction and a beam spreader system, in addition to a ring extraction dump line.

1 INTRODUCTION

In the 1 MW SNS [1], the Ring to Target Beam Transport line (RTBT) connects the 1 GeV accumulator ring [2] to the target. A major requirement of all parts of this accelerator is to have low uncontrolled beam losses (≤ 1 nA/m), to allow hands on maintenance. The RTBT is equipped with four sets of beam halo scrapers, and the ratio of aperture to rms beam size is kept greater than 3.5 up until the beam spreader section. Fig. 1 shows the RTBT line.

The beam requirements at the target are given in Table 1.

Table 2 gives the Twiss parameters at the beginning of the extraction kicker magnet and at the target.

Table 1 Beam requirements at the target.

Beam width	200 mm
Beam height	70 mm
Time average current density, over beam footprint	≤ 0.091 A/m^2
Beam power within target and outside nominal footprint	< 5%
Peak time-average beam current density, over 1 cm^2	≤ 0.182 A/m^2
Peak 1-pulse density,over 1cm^2	1.89×10^{16} protons/m^2

Table 2 Twiss Parameters at the Entrance and Exit of the RTBT for a 1 MW beam.

Twiss parameters	Entrance	Exit	Units
α_X	0.00	-2.1	
β_X	4.15	17.4	mm/mrad
ε_X(unnorm., 100%)	120	120.0	π mm mrad
α_Y	0.00	0.7	
β_Y	1.97	4.2	mm/mrad
ε_Y(unnorm., 100%)	120	120.0	π mm mrad

2 FUNCTIONS OF THE RTBT LINE

The RTBT uses a FODO lattice up to the beam spreading section. The 90°/cell phase advance and length of 11.6 m/cell matches very closely the ring lattice. The line has following elements: (a) extraction, (b) beam dump, (c) halo collimation, (d) beam spreader, and (e) diagnostics. The first four functions have essentially been decoupled in the RTBT. The extraction system starts in the ring with a kicker magnet and continues through four cells in the RTBT. Following the extraction system, the beam can be dumped straight through a 15.5° dipole magnet. After this 15.5° bend, two cells are used for the halo collimation. Following another 4 cells of transport, the last five quadrupoles in the line are used for final beam spreading to produce the beam size required at the target. Every other two quadrupoles in the RTBT are followed by small dipole corrector magnets for steering of the beam in the quadrupole focusing plane. To reduce the probability of uncontrolled beam losses and define the beam size precisely on the target, RTBT is equipped with four transverse beam halo scrapers and several types of diagnostic devices. Table 3 shows the magnet requirements for the RTBT.

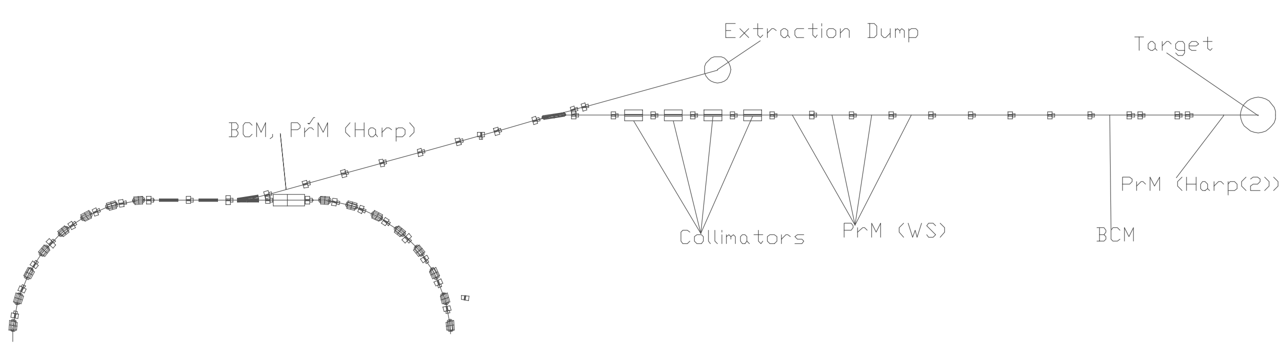

Fig 1. Layout and diagnostics location of the RTBT.

Table 3 Magnet requirement for the RTBT

Type	Number	Field (T)	Aperture (cm)	Length (m)
		Dipoles		
15.5°	1	0.71	17 x 45	3.1
Correctors	12	0.02	20 x 20	0.3
Correctors	5	0.02	36 x 36	0.3
Corrector (V)	1	0.13	20 x 45	1.4
		Quadrupoles		
QH/QV	23	3.4 T/m	20 ϕ	0.5
Spreader	5	3.0T/m	36 ϕ	0.8

Fig. 2 shows the amplitude functions (β_X, β_Y) and the dispersion function (η) along the RTBT. This line is designed such that it can accommodate the beam current required for the upgrade to 2 MW.

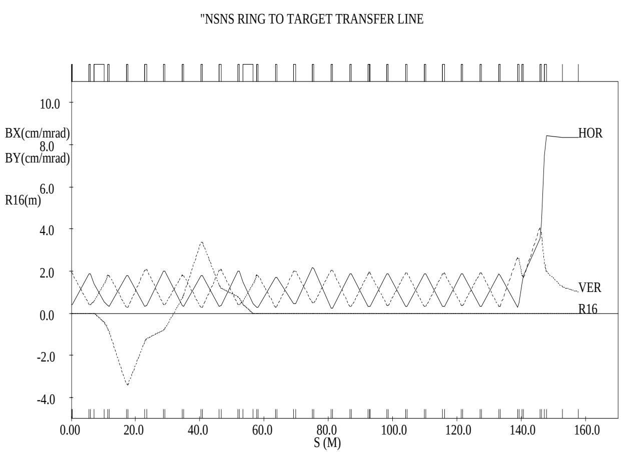

Fig 2. The amplitude function (β_X,β_y) and the dispersion function (η) along the RTBT.

Extraction

The extraction of the beam is done in a single turn with full aperture at a pulse repetition frequency of 60 Hz. The extraction system consists of a full-aperture kicker and a Lambertson magnet septum and dipole magnet. The kick will be in the vertical direction. The Lambertson septum magnet (90° phase advance from kicker) will receive the vertically kicked beam and will provide large deflection (15.5°) to enable ejection horizontally from the accumulator ring. A dipole, which is 360° phase advance away from the Lambertson magnet, bends the beam horizontally in the opposite direction by 15.5°, making the extraction system achromatic. At end of extraction the horizontal dispersion and its derivative are zero (see figure 2). A magnet to bend the beam vertically downward by 32.3 mrad (opposite direction to the kicker magnet) is located about 9.3 meter away from the kicker magnet, providing a ≈ 30 cm difference vertically between the ring and the target planes.

Extraction dump

Following the extraction section, the beam dump is in a line straight through the 15.5º dipole magnet. This dump can handle up to 200 kW beam power and will be used for accumulator tuning purposes. This line is 28 m long and the optics of this line is shown in Fig. 3.

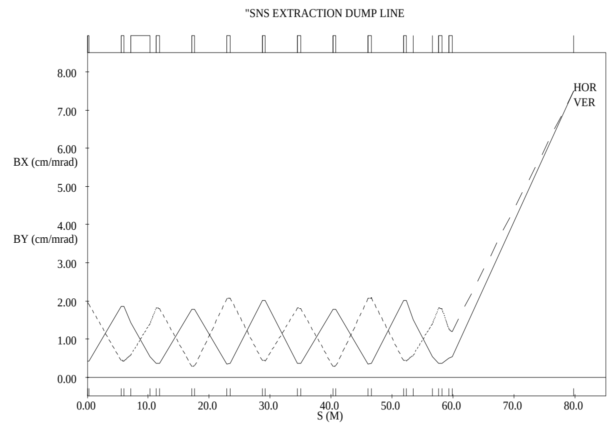

Fig 3. TRANSPORT output showing beam optics to the ring extraction dump.

Beam spreader

The beam spreader consists of five quadrupoles near the end of the RTBT. These five 32 cm diameter aperture quadrupoles provide the desired beam size at the target, as given in Table 1. Due to thermal considerations of the target, the beam current density on target must remain below the limits shown in the table. This requirment results in an non-Gaussian beam distribution in space (with rms emittance of 36 π mm mrad). The required current density distribution can be obtained using the injection painting scheme described elsewhere [3]. Fig. 4 shows the current density distribution at the target using such a scheme. Scattering effects of a 4 mm thick inconel window, 2 meters from the target, were included.

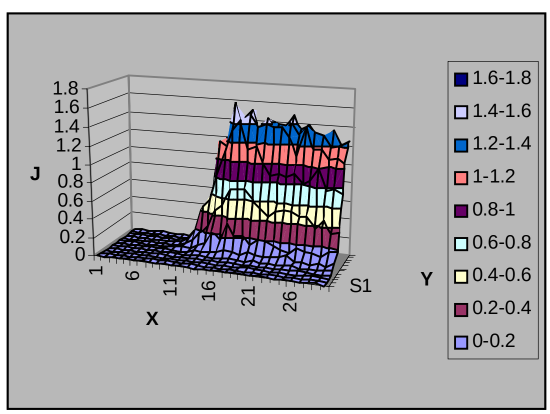

Fig 4. Current density distribution at the target in units of 10 A/m^2. Only one quadrant of the beam foot print is shown.

Diagnostics

There must be enough diagnostic devices in the RTBT line to determine beam quality and beam losses in the line, as well as to determine the beam profile as close as possible to the target. There is one beam loss monitor per quadrupoles and one per dipole, with 17 units left for additional (still to be determined) critical locations. Horizontal and vertical beam position monitors are located near every other pair of quadrupoles. Current toroids will allow continuous monitoring of beam current near the beginning and end of the transport line. Using profiles from four crawling-wire profile monitors located between four consecutive quadrupole magnets in the line, one will be able to infer the beam emittance in the line. These units will have 4 wires, taking profile measurements in four projections - 0º (horizontal), 30º, 60º, and 90º (vertical). From these projections, we will use an algebraic reconstruction technique[4], to get a detailed 2-dimensional density distribution of the beam. Finally, there will be one harp located near the ring extraction and a pair of harps ~2 m in front of the target. The lifetime of the harps should not be a problem, since the current density at the RTBT harps will be lower than in the HEBT line, and the power deposited in the wires will be less than that in harps used in the BNL Booster injection line. Since the harp in front of the target is important for guaranteeing beam flatness, there will be two units for redundancy. An excursion from the target requirements given in Table 1, as inferred by the harp measurements, will trigger a fast beam inhibit. A list of the diagnostic devices is given in Table 4, and the locations are shown in Fig. 1.

Table 4 Diagnostic devices in the RTBT

Device	Number
Beam loss Monitor (BLM)	50
Beam Current Monitor (BCM)	2
Beam Position Monitor (BPM)	16
HARP(PrM)	3
Crawling Wire Scanner (PrM(WS))	4

Beam collimation

To scrape any beam halo produced in the ring, there are four collimators in the RTBT line. These collimators are located just after the last 15.5º bend in the line spread over two cells defining full emittance ellipse, and each is designed to handle up to 1 kW of beam power[5]. There is a three meter long collimator just before the target window to prevent beam from hitting outside of the target area.

3 REFERENCES

[1] B. Appleton, “The NSNS Project”, Proc. 1997 Particle Accelerator Conference, p. 20.

[2] W. T. Weng, *et al.*, “Accumulator Ring Design for the NSNS Project”, Proc. 1997 Particle Accelerator Conference, p. 970.

[3] J. Beebe-Wang and Y.Y. Lee, “Transverse Phase Space Painting for SNS Accumulator Ring Injection”, these proceedings.

[4] D. Raparia, *et al*, “The Algebraic Reconstruction Technique”, Proc. 1997 Particle Accelerator Conference, p. 2023.

[5] H. Ludewig, *et al*, “Collimator Design for the NSNS Accumulator Ring”, to be published in ANS Winter Conf., Albuquerque, New Mexico, Nov. 1997.