BEAM DUMP OPTICS FOR THE SPALLATION NEUTRON SOURCE *

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Abstract

The Spallation Neutron Source accelerator complex will have three beam dumps for beam tuning and for the collection of controlled losses. The linac and extraction beam dumps will be used for beam tuning purposes and are designed for 7.5 kW of beam power. The optics issues for these dumps are i) the beam size at the vacuum window which is near the last quardrupole and ii) guaranteeing the beam size at the dump due to multiple scattering in the presence of potentially large variations in the linac and accumulator ring emittances. The injection dump will collect the partially stripped H^0 ions as well as H^- ions which have miss the foil and is designed to absorb up to 200 kW of beam power. The closed orbit for these ions are much different in the injection area and have to be collected in the injection beam dump with a certain beam size.

INTRODUCTION

For Spallation Neutron Source (SNS) accelerator complex [1], a major requirement of all parts of this accelerator is to have low uncontrolled beam losses ($\leq$ 1 Watt/m), to allow hands on maintenance. There will have three beam dumps for beam tuning and for the collection of controlled losses. The linac and extraction beam dumps will be used for beam tuning purposes and are designed to absorb 7.5 kW of beam power. The injection dump will collect the partially stripped H^0 ions as well as H^- ions which have miss the foil and is designed to absorb up to 200 kW of beam power. Figure 1 shows these all three dumps.
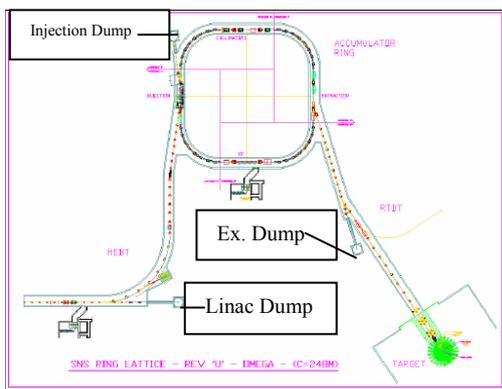

Figure 1: Layout of beam dumps.

LINAC BEAM DUMP

Linac beam dump is located after linac to achromat matching section of the High Energy Beam Transport

(HEBT) [2], this dump will be used for linac beam characterization of the linac beam from 200 MeV to 1.3 GeV and for collecting singly stripped H^0 particle from the linac. This line is about 35 meters long and has six quadrupoles and one vacuum window. Vacuum window is located just after the last quadrupole. This window is made of Inconel and 2 mm thick. The advantage of the window at this location is that it guarantees the beam size at the dump. The requirement for the dump is that beam size should be 60 mm in radius and beam power outside 8 inch diameter circle should be less than 750 watts.

As H^- traverse through the window [3], it deposited two electrons and some energy due to straggling and suffer from multiple and nuclear scattering. The average energy deposited by H^- ions due to two electrons is 1.12 MeV at 1000 MeV and 0.22 MeV at 200 MeV in relatively short distance in the window. Figure 2 shows the rms multiple scattering angles as function of energy and Figure 3 shows the energy loss per proton as function of energy for 2 mm of Be, Al, and Inconel.
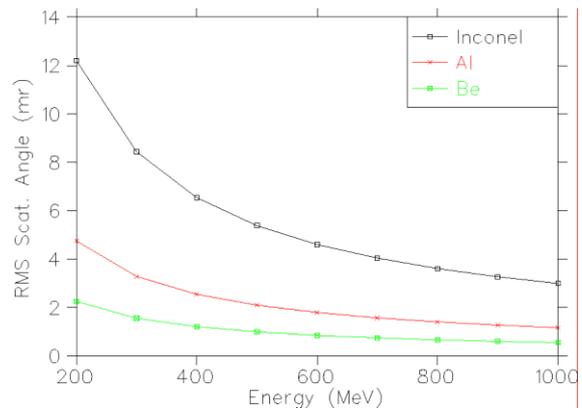

Figure 2: RMS multiple scattering angle as function of the proton energy for 2.0 mm thick window for Be, Al, and Inconel.
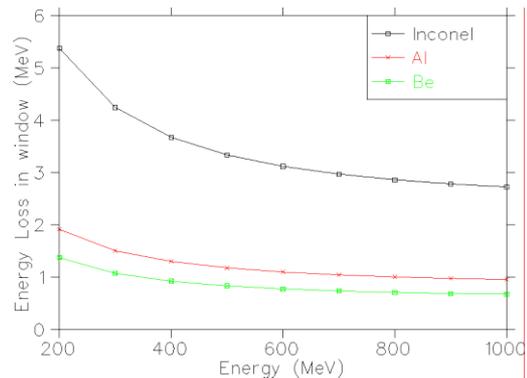

Figure 3: Average energy loss in window per proton in 2 mm thick window as function of proton energy.

To minimize the temperature in the window the beam size is kept 30 mm in diameter for 95% of beam for all the energies and various emittances. Figure 4 shows the TRANSPORT out put for the 200 MeV and Figure 5 shows the TRANSPORT out put for the 1000 MeV.
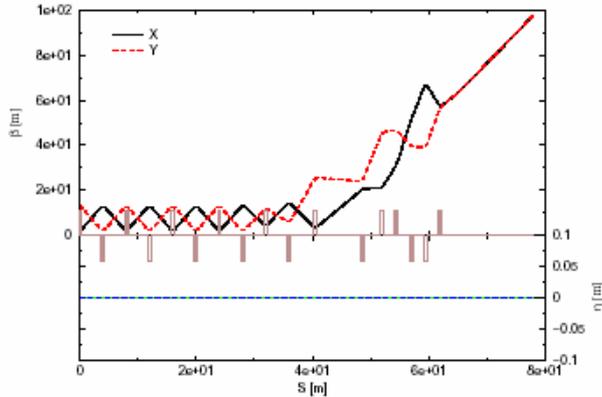

Figure 4: Beta function along linac dump for thick window (2.0 mm of Inconel) at 200 MeV.
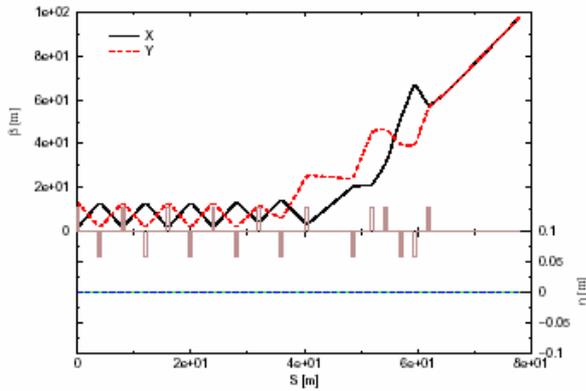

Figure 5: Beta function along the linac dump for 2.0 mm Inconel vacuum window and four times normal emittance at 1000 MeV.

As shown in Figure 2, at lower energies the rms scattering angle is higher therefore more particles will be outside 8 inches diameter circle. Linac has to operate at lower power at the time of commissioning for lower energies. PARMILA (which was modified for multiple and nuclear scattering) simulations show losses in the flight tube and dump. Table I shows the require operating power for different energies.

Table I: Maximum power for different energies.

E, GeV	0.2	0.4	0.6	0.8	1.0
β	0.56	0.71	0.79	0.84	0.87
Υ	1.21	1.43	1.64	1.85	2.06
$\beta\Upsilon$	0.69	1.02	1.30	1.56	1.81
Loss in FT, %	40	7.6	3.3	2.6	2.3
$P_{outside\,8''}$, %	39.0	39.0	21.1	10.9	5.9
Max. P, kW	1.92	1.92	3.55	6.88	7.5

INJECTION BEAM DUMP

Injection beam dump is designed to absorb 200 kW of beam power and requires that 99% of the beam should lie in 200 mm diameter circle. It will collect unstripped H^- and partially stripped H^0 ions. Figure 6 shows the layout of the injection region.
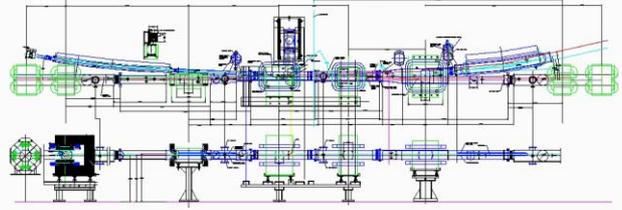

Figure 6: Layout of the injection region.

H^- ions which have missed the foil will emerge from the injection bump magnet # 2 as 2.1 mrad toward left, H^0 will go straight and proton will bend 2.1 mrad right. The injection bump magnet # 3 will bend further H^- ions by 42 mrad while H^0 ions will go straight. There will be a thick foil before the injection bump magnet #4, which will convert H^- and H^0 ions to proton by stripping two and one electrons respectively. After injection bump magnet #4 both trajectory goes through an injection dump gradient magnet and finally though an x-defocusing quadrupole magnet. The optics is such that that the both trajectories coincide at the injection dump. Figure 7 shows the H^0 centroid displacement with respect to the close orbit. H^- trajectory will be just mirror of the H^0 trajectories in Figure 7.
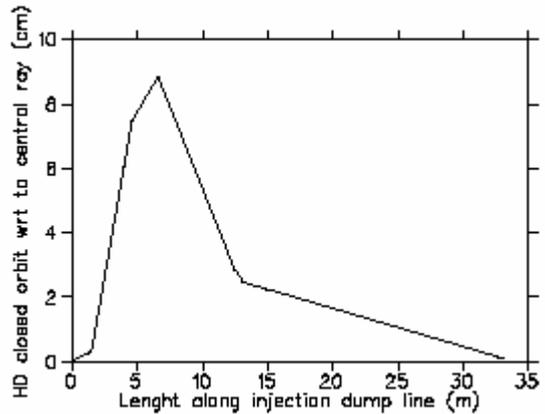

Figure 7: H^0 trajectory displacement with respect to the central closed orbit.

PARMILA was modified to track three species (P, H-, H^0) and included multiple and nuclear scattering. Figure 8 shows the all three species after the foil. Foil will be carbon about 300 µg/cm^2, about 2-4 % H^- will be partially stripped and about 1-2% H^- ion will miss the foil. Figure 9 shows the particle distribution at dump, middle particle are the H^0 and outer particle are H^- when they started at

the foil. Figure 10 shows the TRANSPORT out for the injection beam dump beam line.
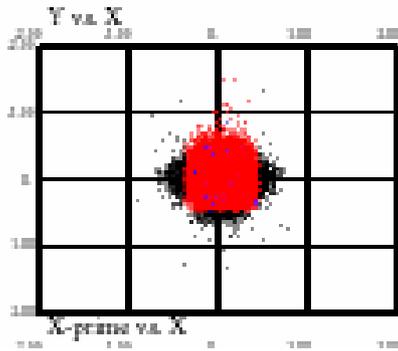

Figure 8: Particle distribution at the foil. **Red** are the fully stripped protons, **black** are the H$^-$ ions, which have missed the foil and **blue** are the partially stripped H^0 ions.
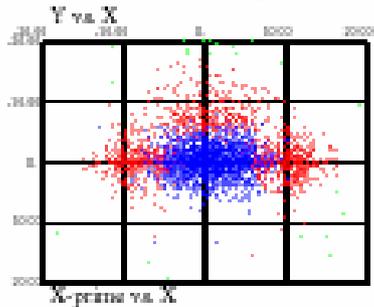

Figure 9: Particle distribution at the injection dump. In the middle (**blue**) are the particles, which started H^0 at the foil. The outer (**red**) are the particles which started as H$^-$ at the foil.
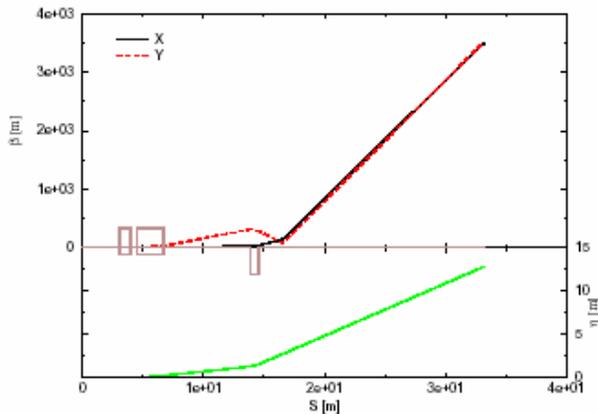

Figure 10: TRANSPORT output for the injection beam dump line.

EXTRACTION BEAM DUMP

The extraction dump will be used for ring tuning purposes and will have the capacity of 7.5 kW. The extraction dump requirement is that 99% beam should be within 8 inch of diameter circle and only 750 Watts of beam can lie out side of this circle. The extraction dump is located after the 16.8 degrees dipole in the Ring Target Beam Transfer (RTBT) [2] line. If the dipole is off beam will get o the dump hence failsafe. There are two quadruples in this line and vacuum window is located just after the last quad in the line. The vacuum window will be 0.5 mm thick of Inconel. The line is designed to accommodate single turn to full 1060 turns injection into the ring. Again like the linac dump line vacuum window guarantee the beam size at the dump. Figure 11 shows the TRANSPORT output for this line.
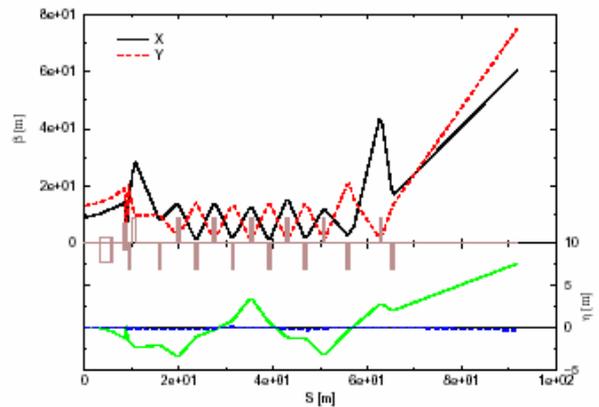

Figure 11: Transport output for extraction dump beam line.

Figure 12 shows the current distribution at the extraction beam dump only ¼ of the beam footprint is shown.
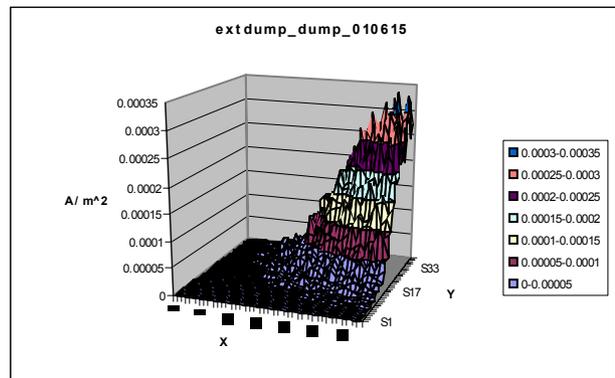

Figure 12: beam current density at the extraction dump, only ¼ of the beam footprint is shown.

REFERENCES

[1] N. Holtkamp, Proc. EPAC 2002, p. 164.

[2] D. Raparia et al., Proc. AIP #642, p. 130.

[3] G. R. Murdoch, SNS-NOTE-ENGR-40, 28 January 2002.