END-TO-END SIMULATION OF THE SNS LINAC USING TRACK*

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Abstract

To simulate the SNS linac using the beam dynamics code TRACK and to benchmark the results against the recent commissioning data, we have updated TRACK to support SNS-type elements such as DTL's and CCL's. After successfully implementing and simulating the DTL section of the SNS linac, we have implemented the CCL section and the high energy superconducting (SCL) section up to 1 GeV. Results from end-to-end TRACK simulations of the SNS linac including the RFQ will be presented and discussed.

INTRODUCTION

In an effort to benchmark the beam dynamics code TRACK [1] againt experimental data from existing linacs, such as the SNS linac, we have updated the code to support new elements such as DTLs and CCLs. We previously reported the results of TRACK simulations for the SNS MEBT and DTL [2]. Recently, we implemented a new subroutine for the simulation of CCL tanks. After building the CCL, SCL and HEBT lattices, we were able to perform end-to-end simulations from the RFQ to the HEBT right before the stripping foil.

After briefly describing the SNS linac lattice, results of the RFQ simulations using TRACK are presented and compared to simulations using the RFQ design code Parmteq [3]. The method of implementing CCL tanks is then presented followed by results of end-to-end simulations of the linac from the MEBT to the HEBT. Possible future developments are discussed at the end.

THE SNS LINAC

The SNS accelerator facility [4] is designed to provide a 1 GeV, 1.4 MW proton beam to a liquid mercury target for neutron production. The accelerator complex consists of a H− injector capable of producing 38 mA peak current, a 1 GeV linac, an accumulator ring and associated beam transport lines to experimental areas. The linac consists of a 2.5 MeV, 38mA H− front-end injector, a six-tank 402.5 MHz DTL to accelerate the beam to 87 MeV, a four-module 805 MHz Coupled Cavity Linac (CCL) to accelerate the beam to 187 MeV, and a superconducting linac (SCL) to accelerate the beam to 1 GeV. Figure 1 shows a schematic layout of the SNS linac.

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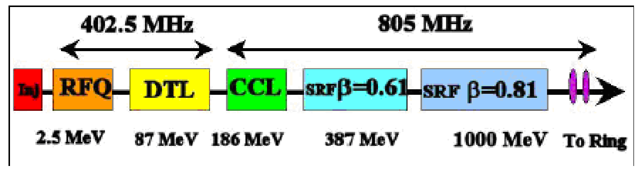

Figure 1: Schematic layout of the SNS linac.

SIMULATIONS OF THE RFQ

The design parameters of the SNS RFQ [5] are summarized in Table 1. According to these parameters the RFQ lattice was generated using Parmteq from which the TRACK lattice was derived. The simulations were performed using both Parmteq and TRACK. Table 2 compares the calculated transmissions for a 0 mA beam and the actual operating current of 32 mA [6]. We notice differences between TRACK and Parmteq that should be further investigated. However, the two codes agree reasonably well on the output beam parameters. Figure 2 compares the phase space plots at the end of the RFQ and Table 3 compares the values of the normalized rms emittances.

Table 1: Design parameters of the SNS RFQ.

Type	4 vane
RF Frequency	402.5 MHz
Voltage	83 kV
N. Of Cells	448
Length	3.723 m
Beam	H-
Input Energy	65 keV
Output Energy	2.5 MeV
Peak Output Current	52 mA
Long. Emittance	103 deg-keV
Trans. Emittance: N-RMS	0.21 mm-mrad
Design Transmission	> 90 %

Table 2: RFQ transmission for different beam currents calculated using both Parmteq and TRACK.

Current	Parmteq	TRACK
0 mA	99.4 %	98.5 %
32 mA	97.3 %	91.4 %

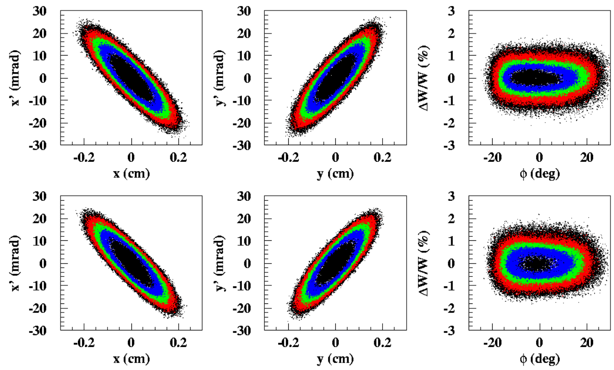

Figure 3: Phase space plots for a 32 mA H- beam at the end of the RFQ. The top three plots are the results of Parmteq and the bottom ones are obtained from TRACK.

Table 3: Normalized RMS beam emittances at the end of the RFQ from both Parmteq and TRACK for 32 mA .

Emittance: N. RMS	Parmteq	TRACK
ε_x (mm-mrad)	0.213	0.204
ε_y (mm-mrad)	0.211	0.203
ε_z (deg-keV)	99.63	105.86

We have also simulated the RFQ with three different beam currents: 0 mA, 32 mA and 60 mA. The results are shown in Fig. 4. We clearly notice the compression of the longitudinal phase space with increasing beam current. The beam envelopes and emittances along the RFQ are shown in Fig. 5 for a 32 mA H- beam.

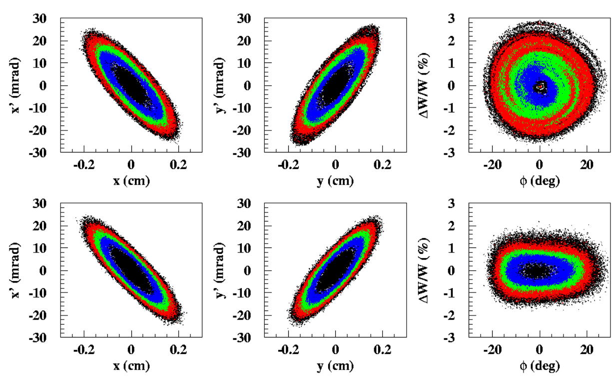

Figure 4: Phase space plots at the end of the RFQ for different beam currents: 0 mA (top) and 32 mA (bottom).

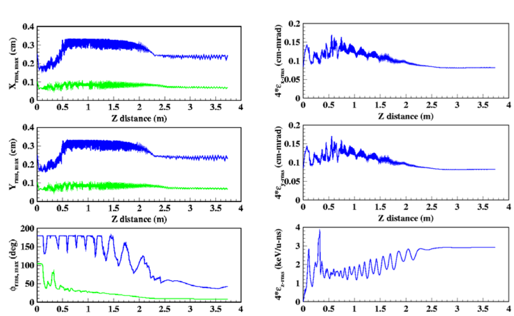

Figure 5: Envelopes and emittances along the SNS RFQ for a 32 mA H- beam.

IMPLEMENTATION OF THE CCL

As was done for the DTL [2], a new TRACK subroutine was developed for particle tracking in a CCL tank. Unlike a DTL, a CCL has external focusing and several CCL tanks are usually powered by a single Klystron. A special attention should be paid to the phasing of the CCL tanks. Every CCL tank has two input files, one for the cells data and one for the field data. The fields are 2D tables calculated using Superfish [7].

END-TO-END SIMULATIONS OF THE LINAC

After building the lattices for the CCL, SCL and HEBT we performed end-to-end simulations of the linac from the MEBT to the HEBT right before the stripping foil. Figure 6 shows the envelopes and emittances along the linac for a 32 mA H- beam while Fig. 7 shows the phase space plots at the exit of the linac. We notice how the phase width of the beam expands for injection into the accumulator ring operating at a lower frequency.

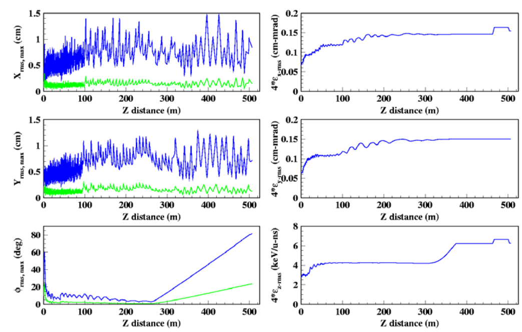

Figure 6: Envelopes and emittances along the SNS linac for a 32 mA H- beam.

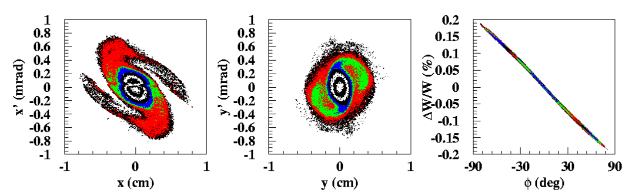

Figure 7: Phase space plots at the exit of the SNS linac; end of HEBT right before the stripping foil. The beam is a 32 mA H- beam.

SUMMARY AND FUTURE WORK

We have successfully implemented and simulated all the sections of the SNS linac, from the RFQ to the HEBT, using the beam dynamics code TRACK. Future work will focus on end-to-end simulations including machine errors and beam loss analysis in order to compare the results with the experimental data. This is an important step towards the realization of the concept of model driven accelerator.

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