



Collimation in the HEBT

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Introduction

The 2 MW SNS machine consists of 1 GeV linac, an accumulator ring [1], and two transfer lines: (a) High Energy Beam Transfer line (HEBT)[2], and (b) Ring to Target Beam Transfer line (RTBT)[3]. The main feature of this accelerator is the low uncontrolled beam losses (w/m) to allow hands on maintenance. To achieve such low beam losses, the beam is prepared very carefully before injecting in to the accumulator. The HEBT not only matches the beam into accumulator but also determines the beam quality before injection. To reduce the probability of uncontrolled beam losses, HEBT is equipped with five sets of beam halo scrapers. The ratio of aperture to RMS beam size is kept greater than 10. The maximum magnetic field in dipoles and quadrupoles is less than 3 kG to keep the H^- stripping losses under control. Another key feature of this line (to reduce the uncontrolled beam loss) is very tight tolerances on elements. The Figure 1 shows the HEBT.

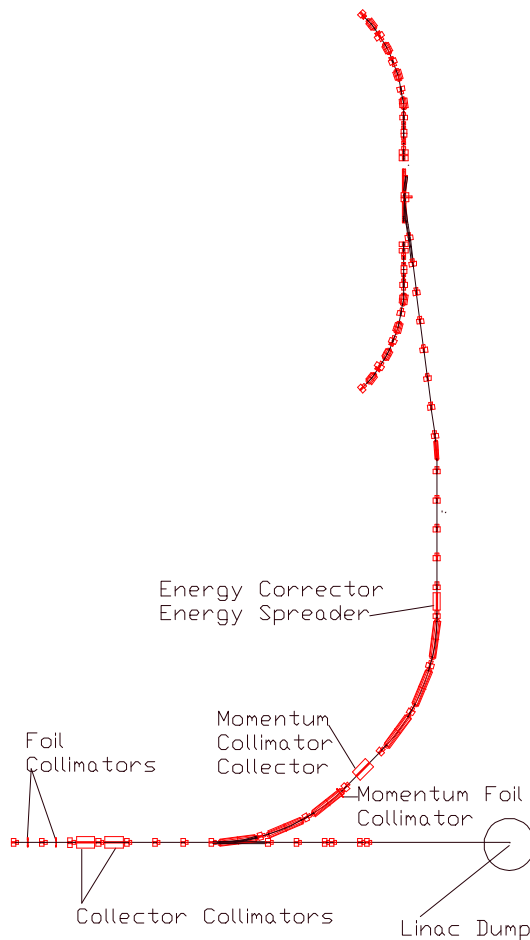


Figure 1: Layout of the HEBT line.

Table 1 shows beam sizes and the apertures in the HEBT.

Table 1: Apertures in the HEBT.

Location	β_{MAX} (m)	η (m)	RMS Beam Size (diameter) (mm)	Available Aperture (mm)	Ratio Aper./RMS beam size
LAMS	23.5	0	5.13	110	21
Achromat	23.5	8.4	5.13,13.33(V,H)	70,180(V,H)	14,14(V,H)
Phase Rotator Cavity	13.0	0	3.8	48	13
ARMS	25.0	1	5.29, 10.63(V,H)	70,110	13,10

There are a total of five collimators in the HEBT, one for momentum collimation and four for transverse collimation. Each collimator is designed to handle 10^{-2} of the beam, but we expect any one to intercept less than 10^{-4} . The collimator radius is chosen such that it protect the RF cavity against beam loss in it. Table 2 shows locations and radii of the collimators. Collimator locations are chosen such that they provide approximately full collimation of the phase space.

Table 2 Collimator Location and Radii

Collimator	Location Quad No	β_x, β_y (m)	η (m)	σ (Deg.)	Radius (mm)
H1,V1	Q1	6.08,6.08	0	0	10
H2,V2	Q2	6.08,6.08	0	45	10
H3,V3	Q3	6.08,6.08	0	90	15
H4,V4	Q4	6.08,6.08	0	135	15
P1	DD3	19.84,5.72	7.4	408	15

Beta Collimation

Four transverse collimators (2 each in x and y) are located just after the linac in the 1st half cell through the 4th half cell. Out of these four collimators, the first two horizontal collimator are movable foils, which strip the H⁻ to H⁺, which is then dumped in the collector collimators in 3rd and 4th half cells. This reduces costs, and has the added advantage of being adjustable in both planes. Details of the collimators are given elsewhere [4], and the configuration for these collimators is shown schematically in figure 2.

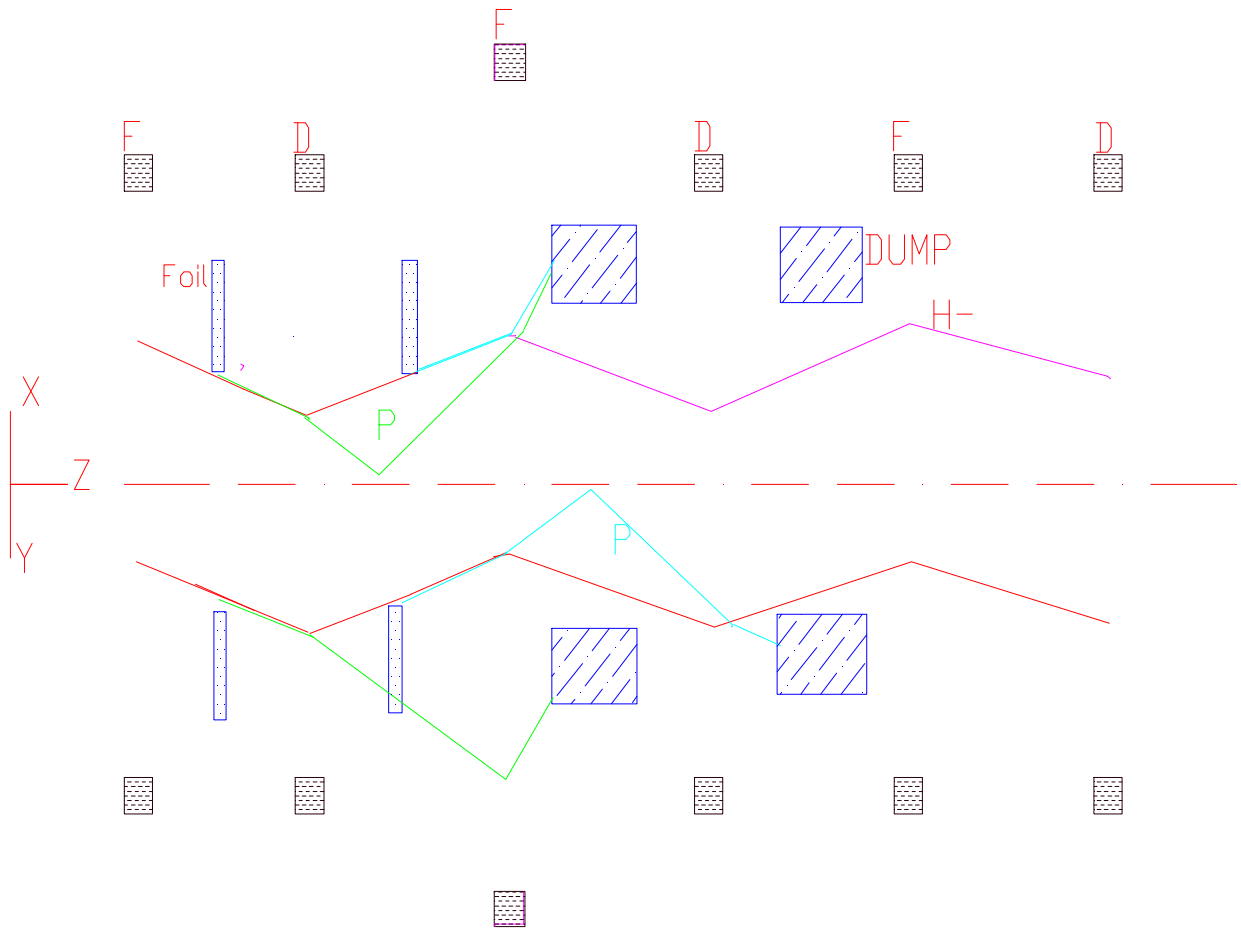


Figure 2: Schematic of the HEBT Collimator configuration.

The 3rd quadrupole has a bigger aperture (20 cm diameter) to allow protons, which are converted from H⁻ by the first movable foil, to expand before beam dump into the collector collimator (dump). Red lines represent the beam envelop for H⁻. Protons are shown in green and cyan colors.

The PARMILA input deck for LAMS are given in appendix A. Figure 3a to 3f shows the phase space distribution after each transport element. Red particles are representing the protons and blue particles are lost in the collector collimators.

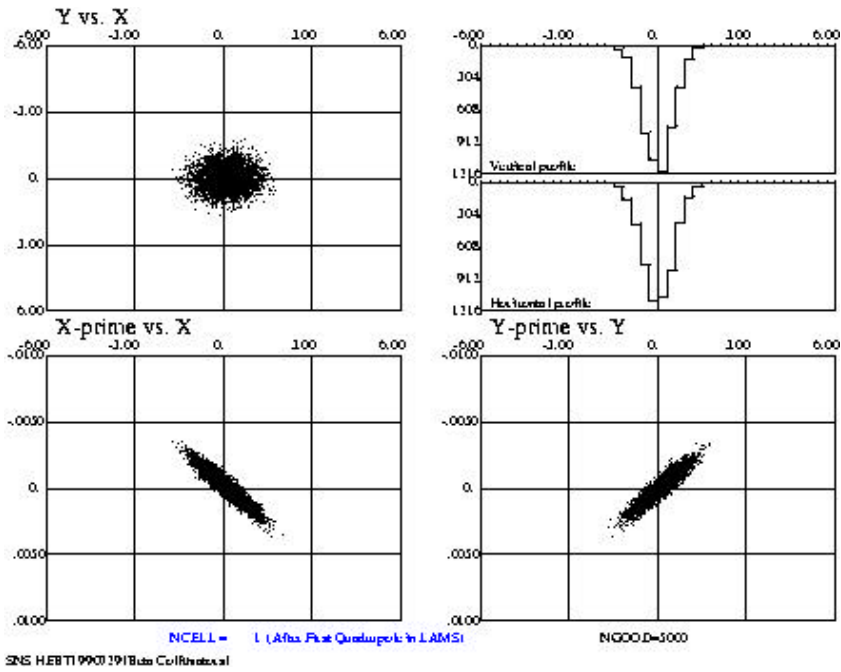


Figure 3a: Phase spaces at the middle of the first quadrupole in LAMS.

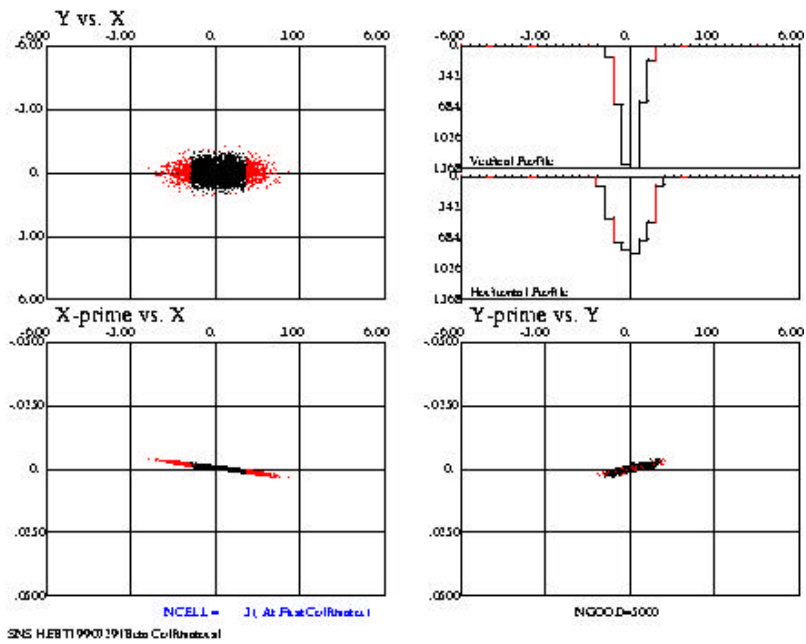


Figure 3b: Phase spaces at the first movable collimator, red particles represent protons.

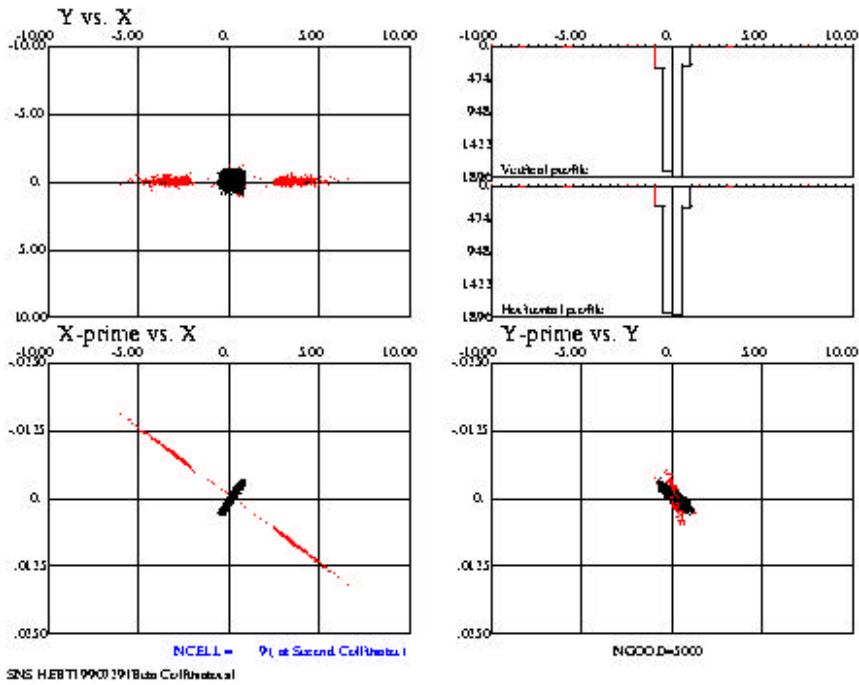


Figure 3c: Phase spaces at the second movable collimator, red particles represent protons.

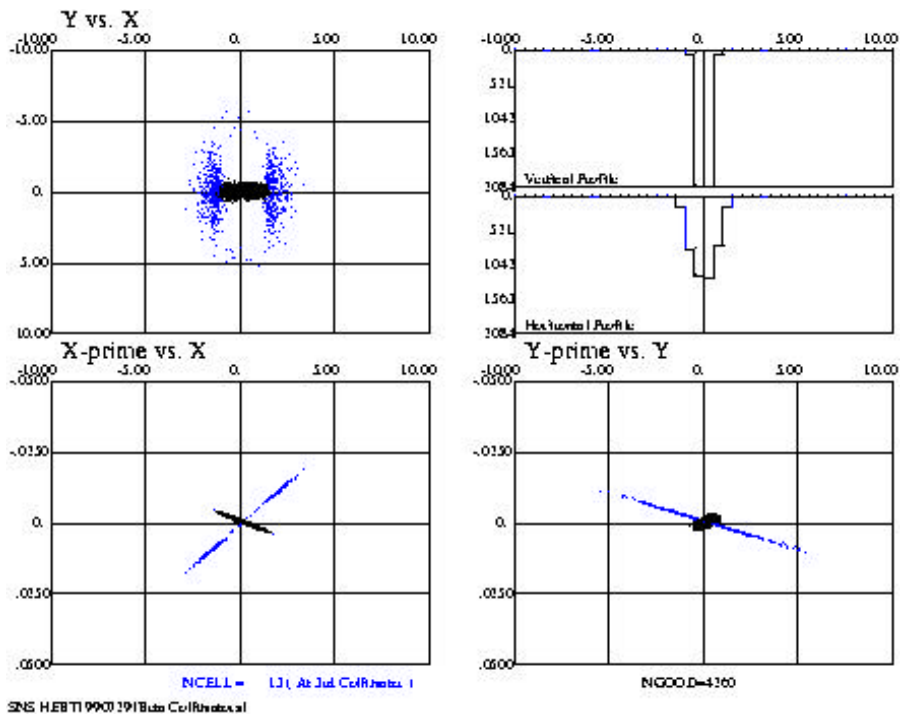


Figure 3d: Phase spaces at the 3rd collimator (collector), blue particles represent lost particles (either proton or H⁻) in the collector collimators.

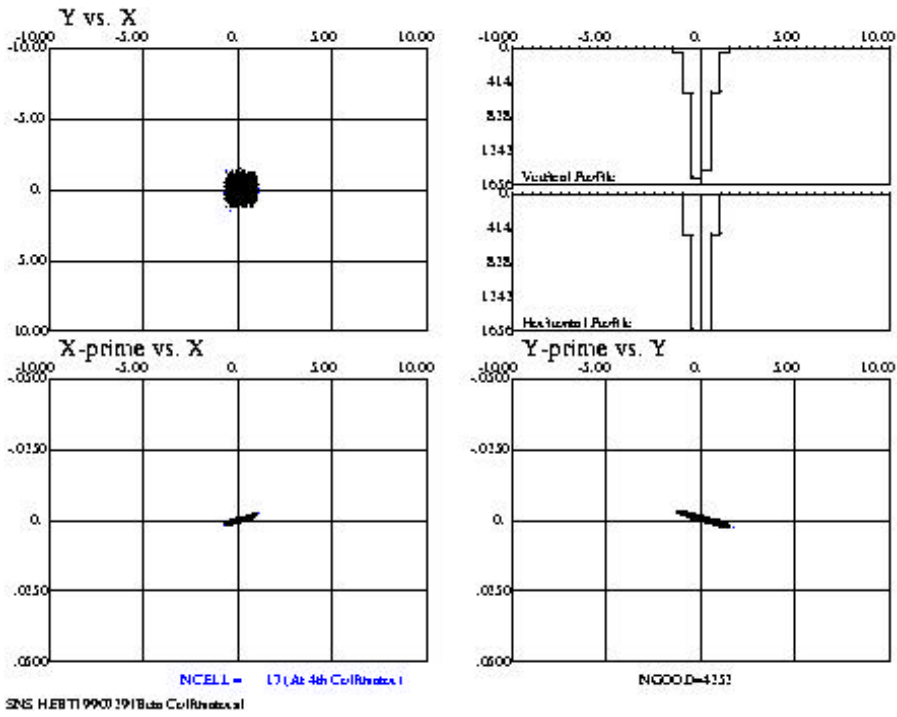


Figure 3e: Phase spaces at the 4th collimator (collector), blue particles represent lost particles (either proton or H⁻) in the collector collimators.

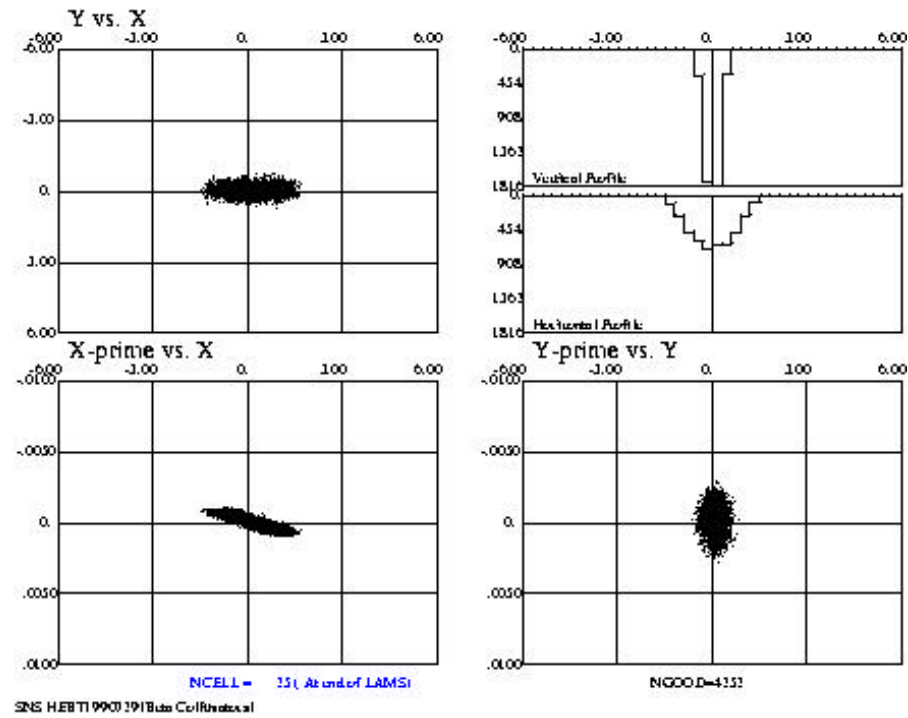


Figure 3f: Phase spaces at end of LAMS (middle of the 8th quadrupole).

Momentum Collimation

The achromat providing energy resolution ~ 5 mm/MeV and resolving power R

$$R = \frac{R_{16}}{2 \times X_0} = \frac{7.1}{2 \times \sqrt{19 \times 1.4 \times 10^{-6}}} \cong 700$$

The momentum acceptance of the achromat is $\pm 1.2\%$. The momentum collimator is located at the maximum dispersion point in the achromat. This scraper is pair of movable striping foils 33.3 cm before the exit of the 3rd dipole magnet (DD3), followed by an off line beam dump for oppositely bent protons. Protons will come out of this magnet about 2 degrees from the H, the beam dump is located 25 cm down from the 11th quadrupole magnet.

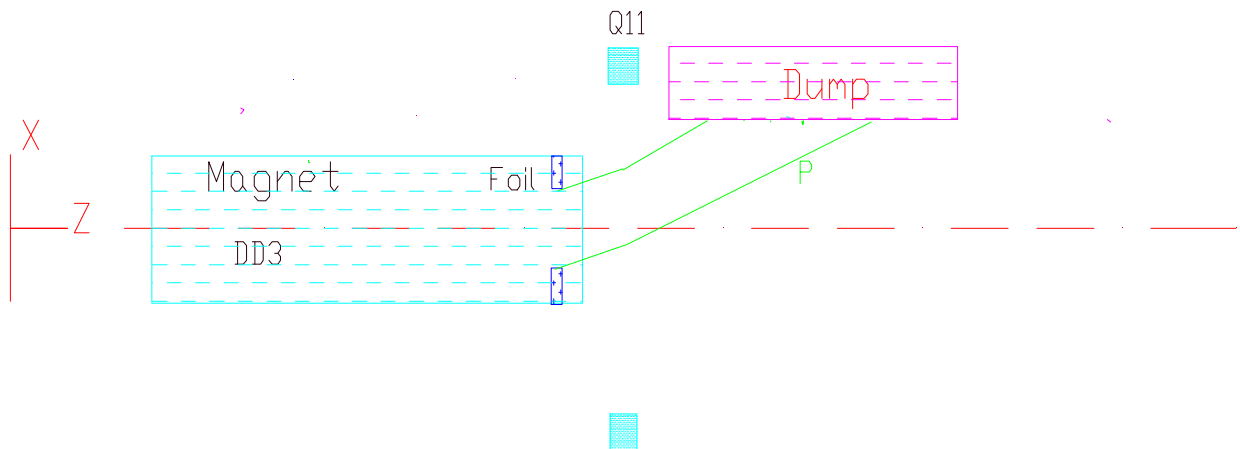


Figure 4: Schematic of the momentum collimator.

Figure 4 shows the schematic of the momentum collimator and collector. Proton trajectories are shown in green color. The PARMILA input deck are given in appendix B and figure 5a-5e shows the phase space in the momentum collimator region. The red particles represent protons and blue particles are lost particles on the collector.

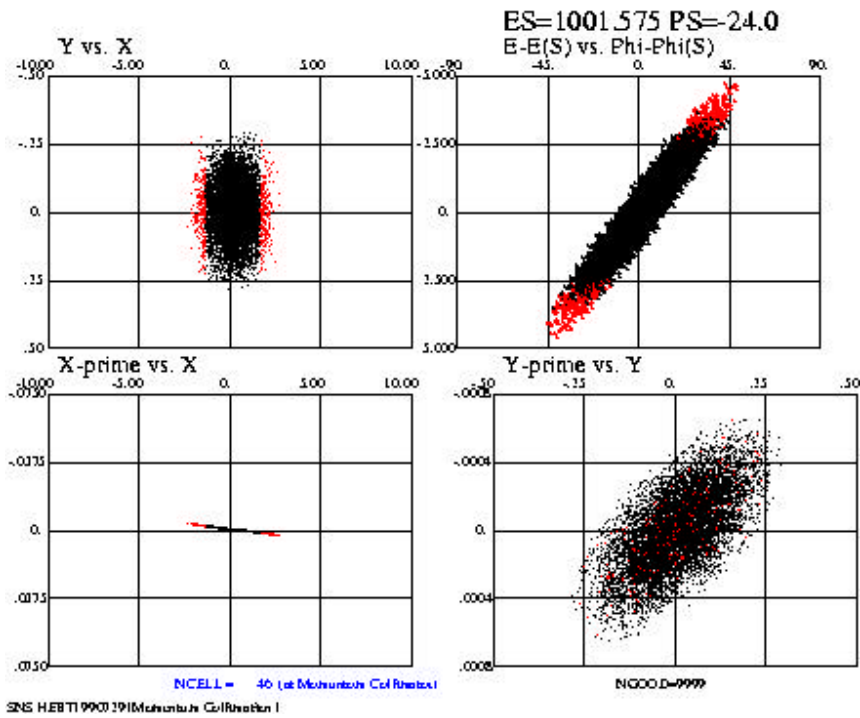


Figure 5a: Phase space at the momentum collimator, red particles representing protons.

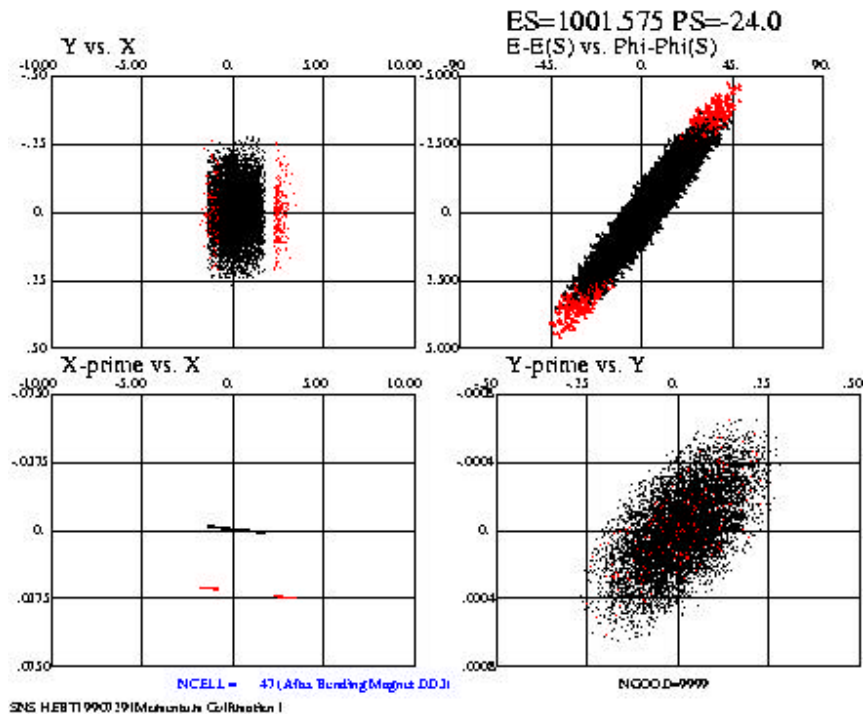


Figure 5b: Phase space after the 3rd dipole (DD3) magnet.

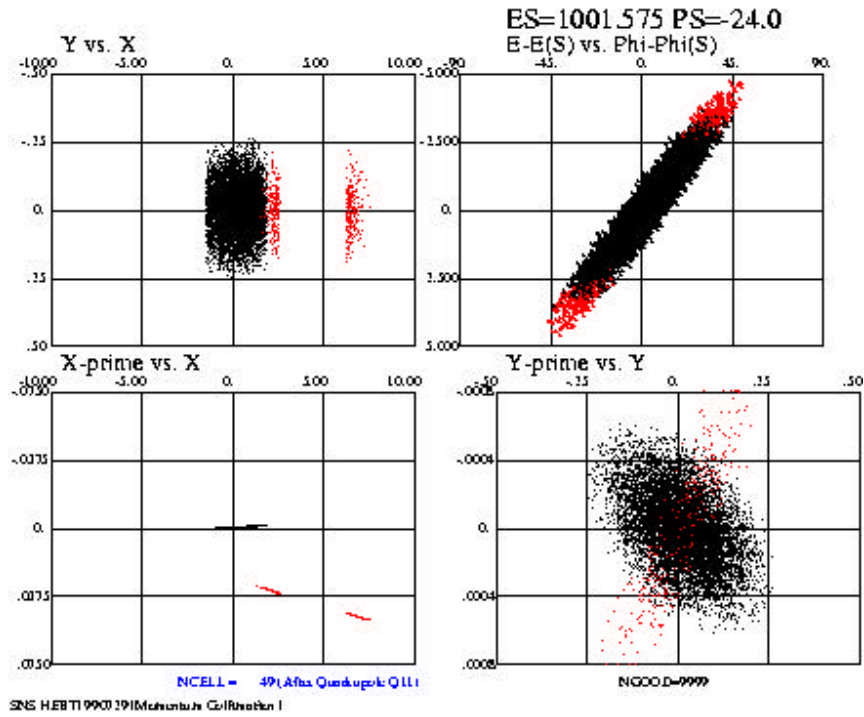


Figure 5c: Phase space after the quadrupole (11th).

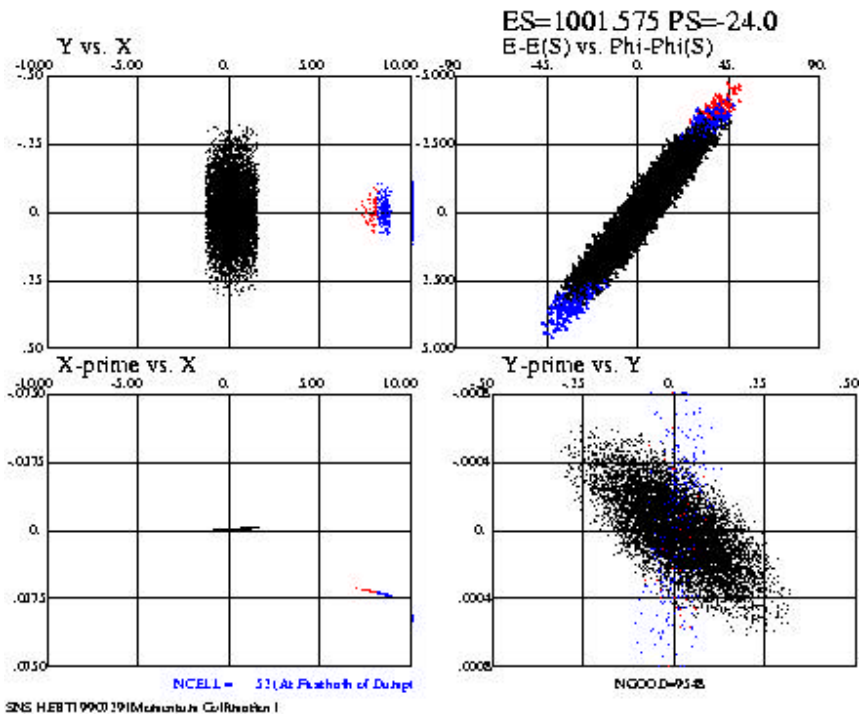


Figure 5d: Phase space at first half of collector, red particles representing proton and blue particles lost particle in the collector.

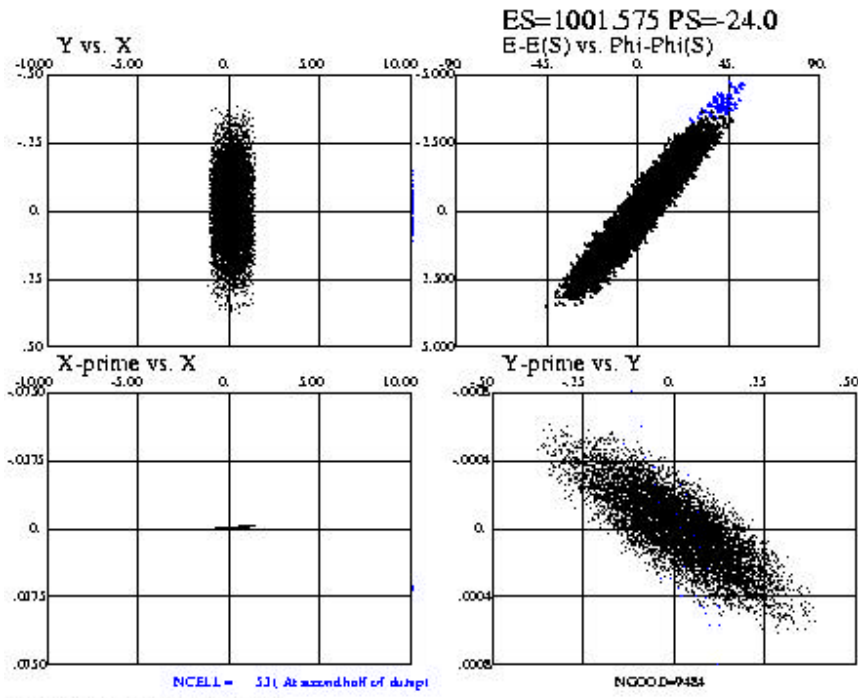


Figure 5e: Phase spaces at second half of collector, blue particles lost particle in the collector.

References

[1] W. T. Weng, et al, “ Accumulator Ring Design for the SNS Project”, Proceedings of the 1997 Particle Accelerator Conference, 1997, p970

[2] D. Raparia, et al, “The SNS High Energy Beam Transport Line” , Proceedings of the 1997 Particle Accelerator Conference, 1997, p970

[3] D. Raparia, et al, “ The SNS ring to Target Beam Transport Line” to be published in the Proceedings of the 1999 Particle Accelerator Conference.

[4] H. Ludewig, et al, “Collimator Design for the SNS Accumulator Ring”, to be published in ANS Winter Conference , Albuquerque, New Mexico, 1997.

APPENDIX A

PARMILA input deck for LAMS

```
RUN 1 1
LINAC 1 1000.0 805.000 1.001089
CHARGE -1
TANK 1 1005.0 -0.0 0.046 0.00 0.046 0.0 0.0 3.0 -3.0
      3.8 1 2 11 0 0.5 0.0 0.0 1.0 0 0 0 0 0 1.0
INPUT -48 -5000 0.0 1345.1 0.003 0.0 1345.1 0.003
      -3.221215 6987.836 0.000015338 0.0 0.0 0.0 0.0 0.0 0.0
OUTPUT 3 1 0 0 0 0 1
OUTPUT 2 1 0 0 0 0 1 300 1
OUTPUT 1 1 1 0 0 0 1 200
OUTPUT 1 1
ELIMIT 5
SCHEFF 0.0 0.3 0.1 20 40 0 0 3 1 3
TRANS1 1 3 417.887 25 06 0. 1 1 7 1 01
TRANS1 2 1 175.00000 15.0 06 0. 1 1 7 1
TRANS1 3 7 1.0 1.0 00 0 1 1 7 1
TRANS1 4 1 175.00000 15.0 06 0. 1 1 7 1
TRANS1 5 3 -417.887000 50.0 06 0. 1 1 7 1 02
TRANS1 6 1 25.00000 15.0 06 0. 1 1 7 1
TRANS1 7 1 150.00000 15.0 10 0. 1 1 7 1
TRANS1 8 1 000.00000 15.0 10 0. 1 1 7 1
TRANS1 9 7 1.0 1.0 00 0 1 1 7 1
TRANS1 10 1 175.00000 15.0 10 0. 1 1 7 1
TRANS1 11 3 417.887 50 10 0. 1 1 7 1 03
TRANS1 12 1 25.00000 2. 10 0. 1 1 7 1
TRANS1 13 1 300.00000 15.0 1.50 0. 1 1 7 1
TRANS1 14 1 25.00000 15.0 06 0. 1 1 7 1
TRANS1 15 3 -417.887000 50.0 06 0. 1 1 7 1 04
TRANS1 16 1 25.00000 15.0 06 0. 1 1 7 1
TRANS1 17 1 300.00000 15.0 1.50 0. 1 1 7 1
TRANS1 18 1 25.00000 15.0 06 0. 1 1 7 1
TRANS1 19 3 417.887 50 06 0. 1 1 7 1 05
TRANS1 20 1 350.00000 15.0 06 0. 1 1 7 1
TRANS1 21 3 -417.887000 50.0 06 0. 1 1 7 1 06
TRANS1 22 1 350.00000 15.0 06 0. 1 1 7 1
TRANS1 23 3 417.887 50 06 0. 1 1 7 1 07
TRANS1 24 1 350.00000 15.0 06 0. 1 1 7 1
TRANS1 25 3 -417.887000 25.0 06 0. 1 1 7 1 08
START 0
STOP 0
TITLE
      SNS HEBT| 990729 |Beta Collimators |
BEGIN
END 1.0 1.0
END
```

APPENDIX B

PARMILA input deck for HEBT

```

RUN 1 1
LINAC 1 1001.57520 805.000 1.001089
CHARGE -1
TANK 1 1005.0 -24.0 0.046 0.00 0.046 0.0 0.0 3.0 -3.0
      3.8 1 2 11 0 0.5 0.0 0.0 0.0 1.0 0 0 0 0 0 1.0
INPUT -38 -9999 0.000537 1541.610 0.0001383 0.00248 304.668 0.0001383
      0.0 540.0264 0.0031298 0.0 0.0 0.0 0.0 0.0 0.0
SCHEFF 0.0 0.3 0.1 20 40 0 0 3 1 3
OUTPUT 3 1 0 0 0 0 1
OUTPUT 2 1 0 0 0 0 1 300 1
OUTPUT 1 1 1 0 0 0 1 200
OUTPUT 1 0
ELIMIT 5
TRANS1 1 1 00.00000 1.0 06 0. 1 1 7 1
TRANS1 2 3 -429.773000 25.0 06 1. 1 1 7 1 1
TRANS1 3 12 000.00 20.0 -00.000 20. 1 1 7 1
TRANS1 4 1 155.00000 03.0 06 0. 1 1 7 1
TRANS1 5 7 1.0 1.0 20 0 1 1 7 1
TRANS1 6 1 175.00000 03.0 06 0. 1 1 7 1
TRANS1 7 3 417.88700 50.0 06 1. 1 1 7 1 2
TRANS1 8 12 000.00 20.0 000. 20. 1 1 7 1
TRANS1 9 1 155.00000 03.0 06 0. 1 1 7 1
TRANS1 10 7 1.0 1.0 20 0 1 1 7 1
TRANS1 11 1 175.00000 03.0 06 0. 1 1 7 1
TRANS1 12 3 -417.88700 50.0 20 1. 1 1 7 1 3
TRANS1 13 19 0 0 0 0 1 1 7 1
TRANS1 14 1 025.00000 01.0 06 0. 1 1 7 1
TRANS1 15 1 300.00000 05.0 1.5 0. 1 1 7 1
TRANS1 16 1 025.00000 01.0 06 0. 1 1 7 1
TRANS1 17 3 417.88700 50.0 06 1. 1 1 7 1 4
TRANS1 18 19 0 0 0 0 1 1 7 1
TRANS1 19 1 025.00000 01.0 06 0. 1 1 7 1
TRANS1 20 1 300.00000 05.0 1.5 0. 1 1 7 1
TRANS1 21 1 025.00000 01.0 06 0. 1 1 7 1
TRANS1 22 3 -355.55000 50.0 06 1. 1 1 7 1 5
TRANS1 23 12 000.00 20.0 -00000 20. 1 1 7 1
TRANS1 24 1 330.00000 07.0 06 0. 1 1 7 1
TRANS1 25 3 313.56800 50.0 06 1. 1 1 7 1 6
TRANS1 26 12 000.00 20.0 0000. 20. 1 1 7 1
TRANS1 27 1 330.00000 07.0 06 0. 1 1 7 1
TRANS1 28 3 -302.58500 50.0 06 1. 1 1 7 1 7
TRANS1 29 19 0 0 0 0 1 1 7 1
TRANS1 30 1 350.00000 07.0 06 0. 1 1 7 1
TRANS1 31 3 251.59350 50.0 06 1. 1 1 7 1 8
TRANS1 32 19 0 0 0 0 1 1 7 1
TRANS1 33 1 100.00000 2.0 06 0. 1 1 7 1
TRANS1 34 13 4.00000 0.45 2.8 1001.575 0 1 7 1
TRANS1 35 4 15.000 -1909.9 0 0. 0 1 2 1
TRANS1 36 1 50.00000 01.0 10 0. 1 1 7 1
TRANS1 37 3 -219.45300 50.0 10 1. 1 1 7 1 9
TRANS1 38 12 000.00 20.0 000.0 20. 1 1 7 1
TRANS1 39 1 080.00000 2.0 10 0. 1 1 7 1
TRANS1 40 4 15.000 -1909.9 0 0. 0 1 2 1
TRANS1 41 1 50.00000 01.0 10 0. 1 1 7 1
TRANS1 42 3 217.25400 50.0 10 1. 1 1 7 1 10
TRANS1 43 12 000.00 20.0 000. 20. 1 1 7 1
TRANS1 44 1 080.00000 2.0 10 0. 1 1 7 1
TRANS1 45 4 14.00 -1909.9 0 0. 0 0 0 1
TRANS1 46 7 1.5 1.5 0 0 1 1 7 1
TRANS1 47 4 01.000 -1909.9 0 0. 0 0 0 1
TRANS1 48 1 50.00000 01.0 10. 0. 1 1 7 1
TRANS1 49 3 -232.26000 50.0 10. 1. 1 1 7 1 11
TRANS1 50 19 0 0 0 0 1 1 7 1
TRANS1 51 1 25.00000 1.0 10 0. 1 1 7 1
TRANS1 52 1 150.00000 3.0 8 0. 1 1 7 1

```

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TRANS1	59	1	100.00000	2.0	10	0.	1	1	7	1	
TRANS1	60	4	15.00000	-1909.9	0	0.	0	1	2	1	
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TRANS1	64	1	080.00000	2.0	10	0.	1	1	7	1	
TRANS1	65	4	15.00000	-1909.9	0	0.	0	1	2	1	
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TRANS1	68	12	000.00	20.0	000.	20.	1	1	7	1	
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TRANS1	76	2	0.300000	-90.0	1	6	1	1	7	1	
TRANS1	77	1	43.442967	1.0	2.4	0.	1	1	7	1	
TRANS1	78	2	0.300000	-90.0	1	6	1	1	7	1	
TRANS1	79	1	43.442967	1.0	2.4	0.	1	1	7	1	
TRANS1	80	2	0.300000	-90.0	1	6	1	1	7	1	
TRANS1	81	1	43.442967	1.0	2.4	0.	1	1	7	1	
TRANS1	82	2	0.300000	-90.0	1	6	1	1	7	1	
TRANS1	83	1	43.442967	1.0	2.4	0.	1	1	7	1	
TRANS1	84	2	0.300000	-90.0	1	6	1	1	7	1	
TRANS1	85	1	43.442967	1.0	2.4	0.	1	1	7	1	
TRANS1	86	2	0.300000	-90.0	1	6	1	1	7	1	
TRANS1	87	1	21.721483	1.0	2.4	0.	1	1	7	1	
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TRANS1	92	1	350.00000	07.0	6.	0.	1	1	7	1	
TRANS1	93	3	-288.64985	50.0	6.	1.	1	1	7	1	17
TRANS1	94	12	-00.00	20.0	000.	20.	1	1	7	1	
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TRANS1	96	3	317.31661	50.0	6.	1.	1	1	7	1	18
TRANS1	97	12	000.00	20.0	000.	20.	1	1	7	1	
TRANS1	98	1	330.00000	07.0	6.	0.	1	1	7	1	
TRANS1	99	3	-405.11928	50.0	6.	1.	1	1	7	1	19
TRANS1	100	19	0	0	0	0	1	1	7	1	
TRANS1	101	1	350.00000	07.0	6.	0.	1	1	7	1	
TRANS1	102	3	310.00000	50.0	6.	1.	1	1	7	1	20
TRANS1	103	19	0	0	0	0	1	1	7	1	
TRANS1	105	1	50.00000	1.0	6.	0.	1	1	7	1	
TRANS1	106	4	7.50000	-1909.9	0.	0.	0	1	2	1	
TRANS1	107	1	50.00000	1.0	6	0.	1	1	7	1	
TRANS1	108	3	-410.00000	50.0	6	1.	1	1	7	1	21
TRANS1	109	12	000.00	20.0	-000	20.	1	1	7	1	
TRANS1	110	1	330.00000	07.0	6	0.	1	1	7	1	
TRANS1	111	3	300.00000	50.0	6.	1.	1	1	7	1	22
TRANS1	112	12	000.00	20.0	000.	20.	1	1	7	1	
TRANS1	113	1	330.00000	07.0	6	0.	1	1	7	1	
TRANS1	114	3	-410.00000	50.0	6	1.	1	1	7	1	23
TRANS1	115	19	0	0	0	0	1	1	7	1	
TRANS1	116	1	350.00000	07.0	6	0.	1	1	7	1	
TRANS1	117	3	300.00000	50.0	6.	1.	1	1	7	1	24
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TRANS1	121	12	-000.0	20.0	000.000	20.	1	1	7	1	
TRANS1	122	1	330.00000	07.0	6	0.	1	1	7	1	
TRANS1	123	3	300.00000	50.0	6.	1.	1	1	7	1	26
TRANS1	124	12	-000.00	20.0	-31.9	20.	1	1	7	1	

TRANS1	125	1	330.00000	07.0	6	0.	1	1	7	1	
TRANS1	126	3	-410.00000	50.0	6	1.	1	1	7	1	27
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TRANS1	130	1	50.00000	1.0	6	0.	1	1	7	1	
TRANS1	131	3	300.00000	50.0	6.	1.	1	1	7	1	28
TRANS1	132	19	0	0	0	0	1	1	7	1	
TRANS1	133	1	50.000000	1.0	6	0.	1	1	7	1	
TRANS1	134	4	-7.5974204	1927.7	0.	0.	0	1	2	1	
TRANS1	135	1	33.89000	1.0	6	0.	1	1	7	1	
TRANS1	136	4	-1.88861980	1885.8	0	0.	0	1	2	1	
TRANS1	137	1	0.0000000	1.0	6	0.	1	1	7	1	

START 0
 STOP 0
 TITLE
 SNS HEBT| 990729 |Momentum Collimation |
 BEGIN
 END 1.0 1.0
 END