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Collimation in the HEBT

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Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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August 19, 1999

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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.

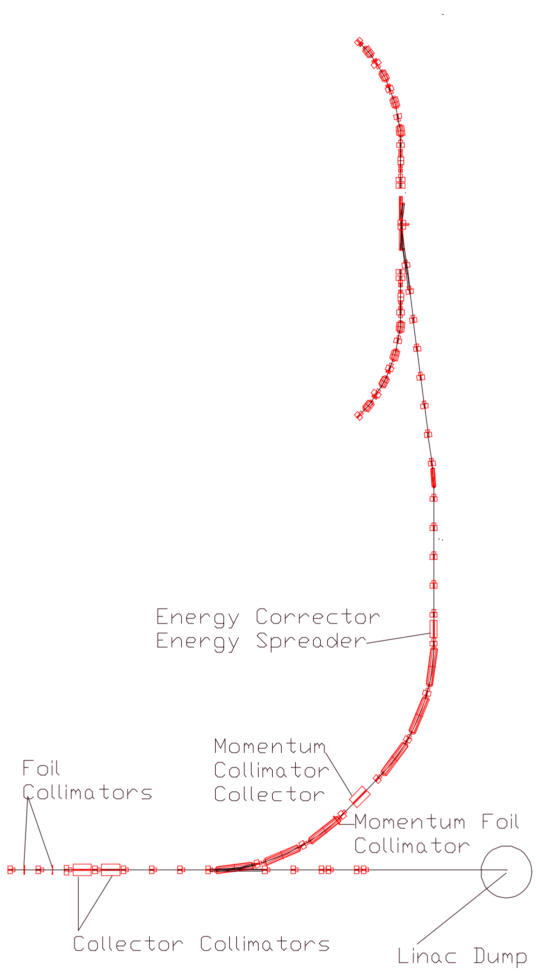

Figure 1: Layout of the HEBT line.

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.

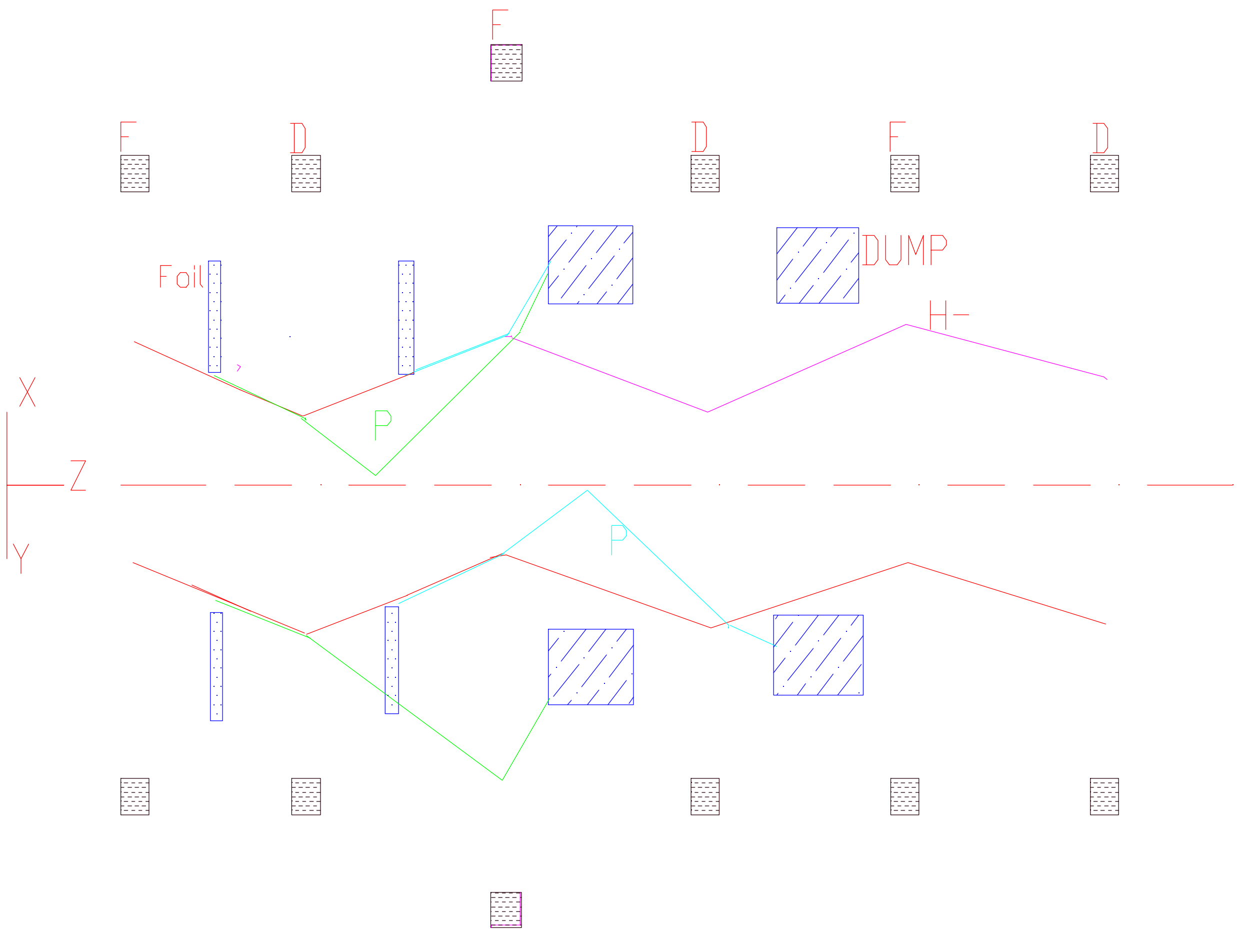

Figure 2: Schematic of the HEBT Collimator configuration.

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.

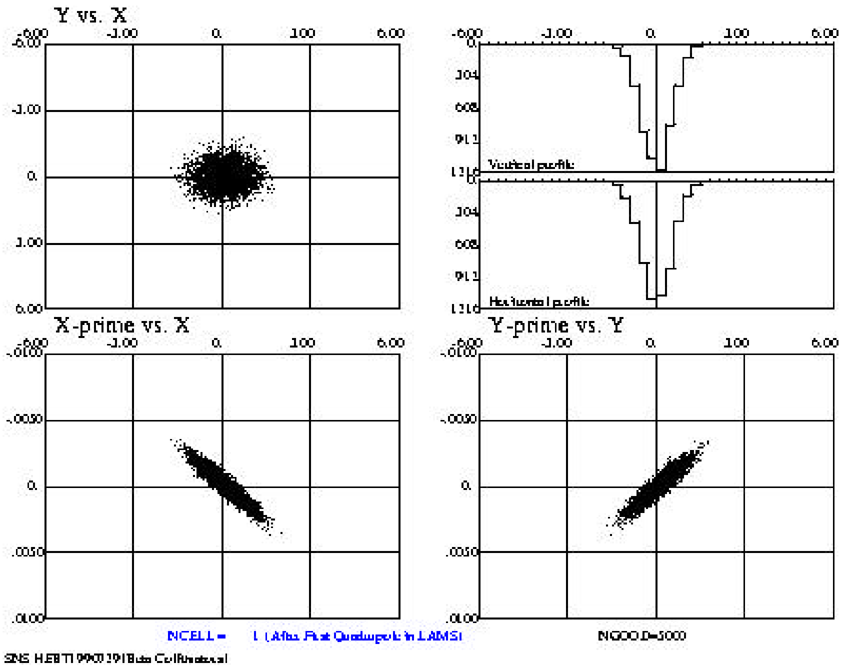

Figure 3a: Phase spaces at the middle of the first quadrupole in LAMS.

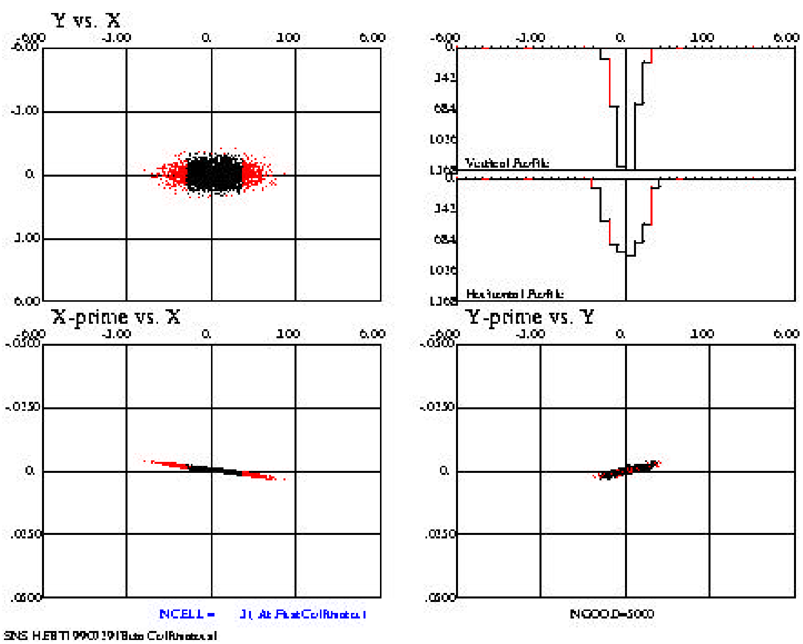

Figure 3b: Phase spaces at the first movable collimator, red particles represent protons.

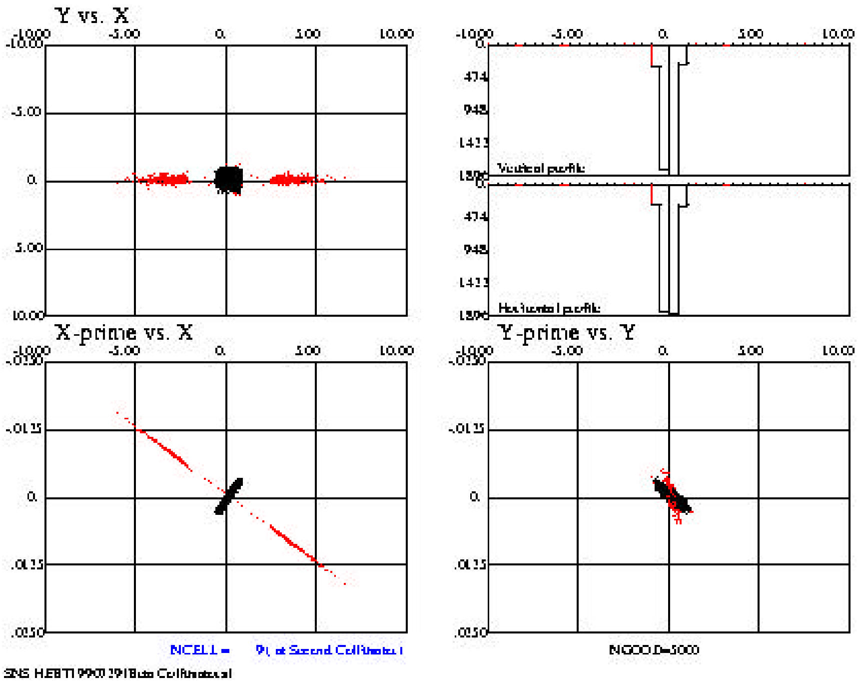

Figure 3c: Phase spaces at the second movable collimator, red particles represent protons.

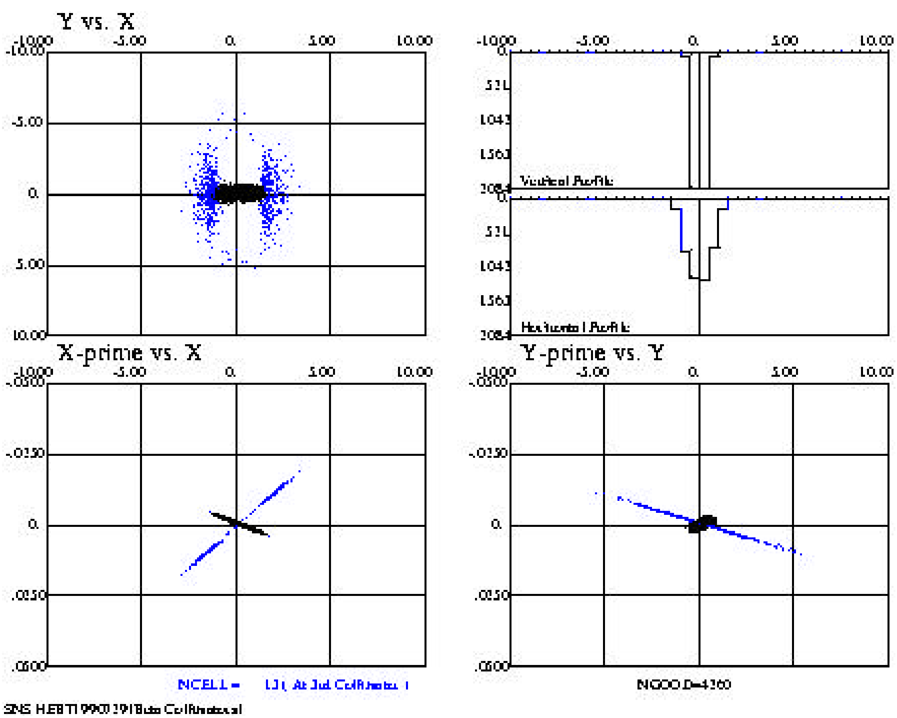

Figure 3d: Phase spaces at the 3rd collimator (collector), blue particles represent lost particles (either proton or H^-)in the collector collimators.

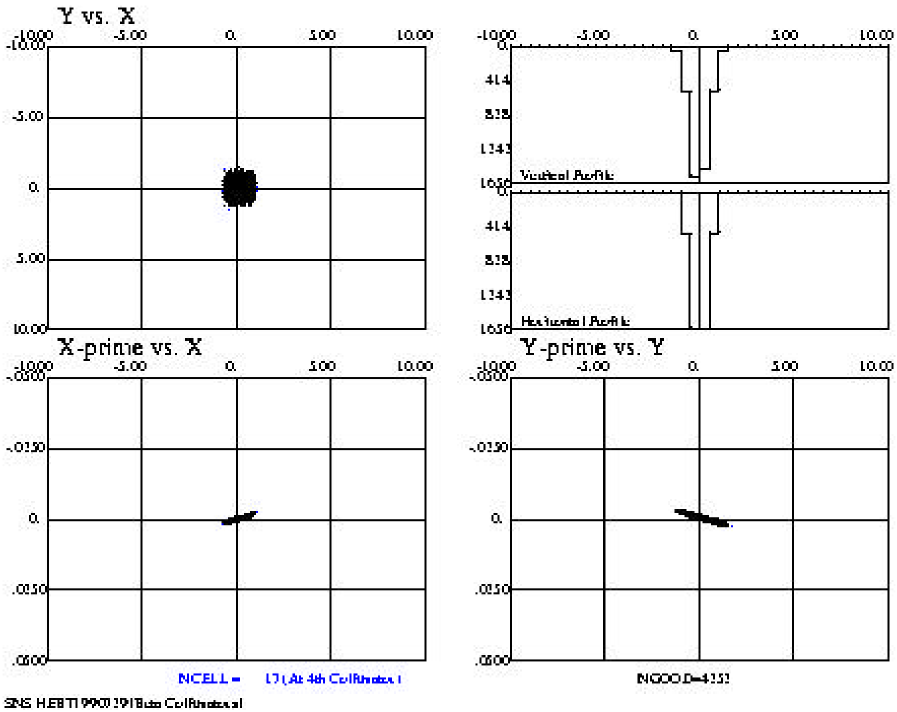

Figure 3e: Phase spaces at the 4th collimator (collector), blue particles represent lost particles (either proton or H^-)in the collector collimators.

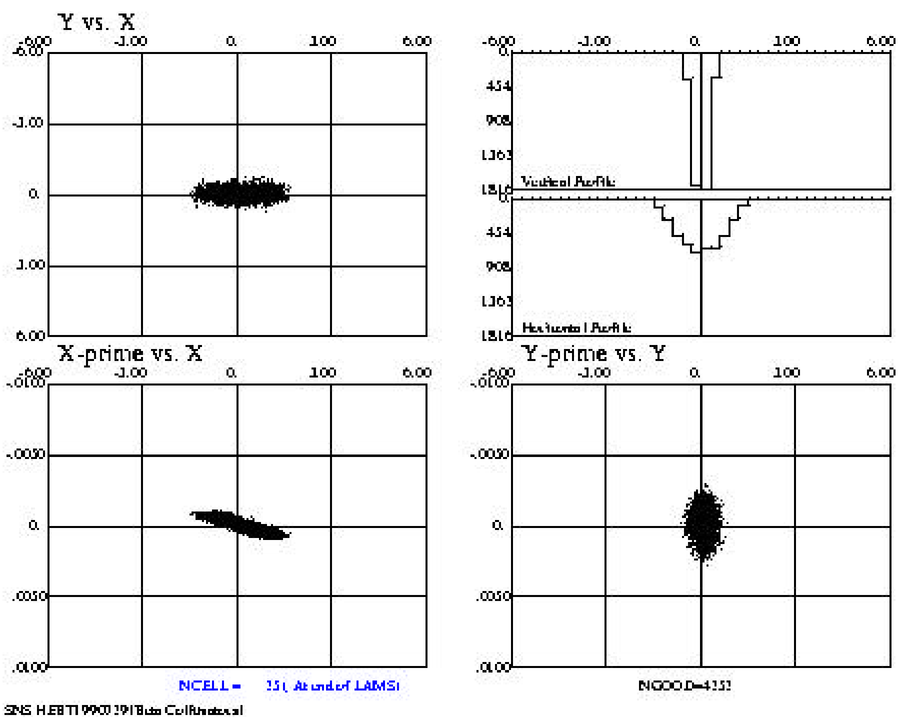

Figure 3f: Phase spaces at end of LAMS (middle of the 8th quadrupole).

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 ± 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.

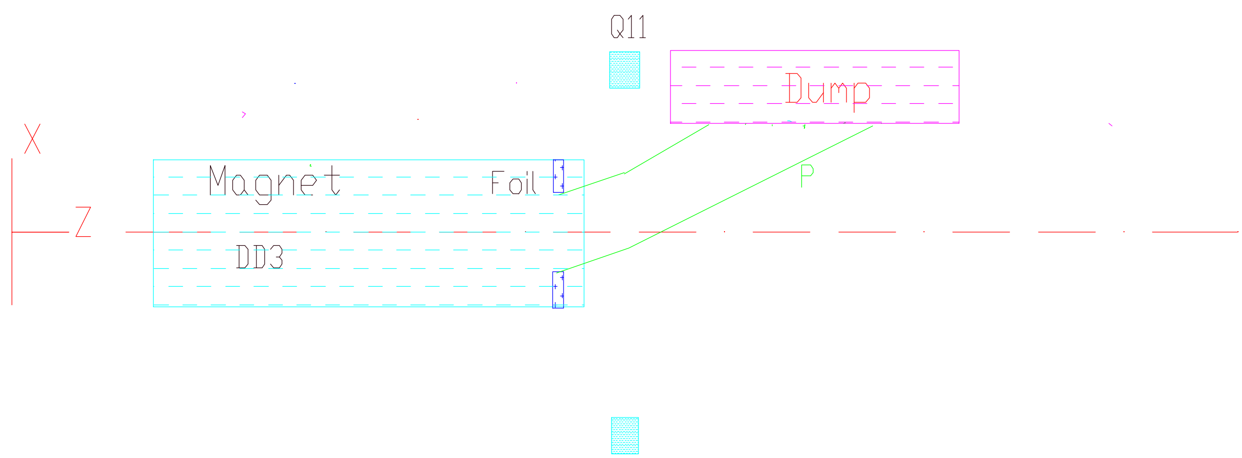

Figure 4: Schematic of the momentum collimator.

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.

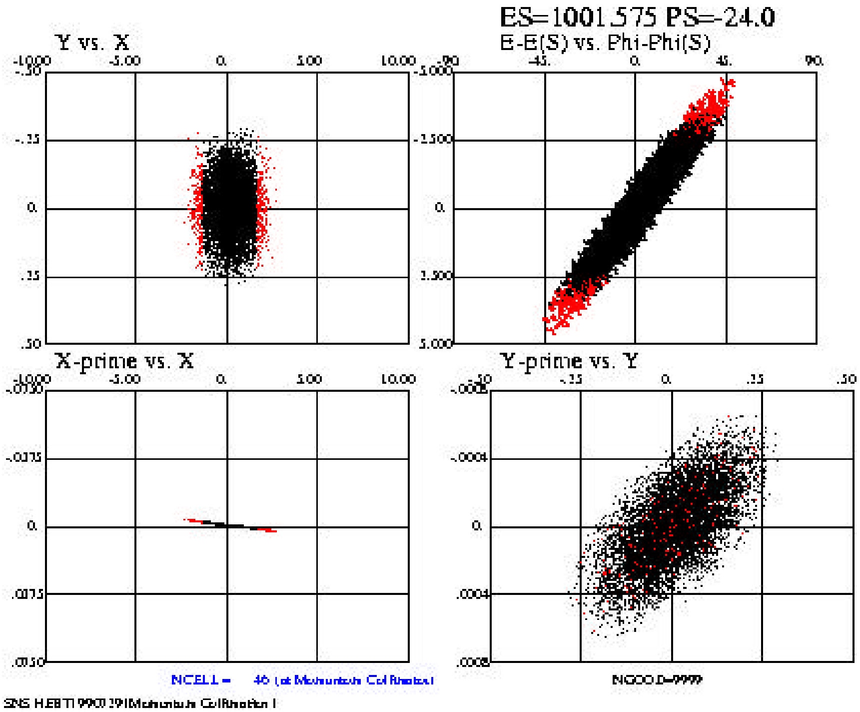

Figure 5a: Phase space at the momentum collimator, red particles representing protons.

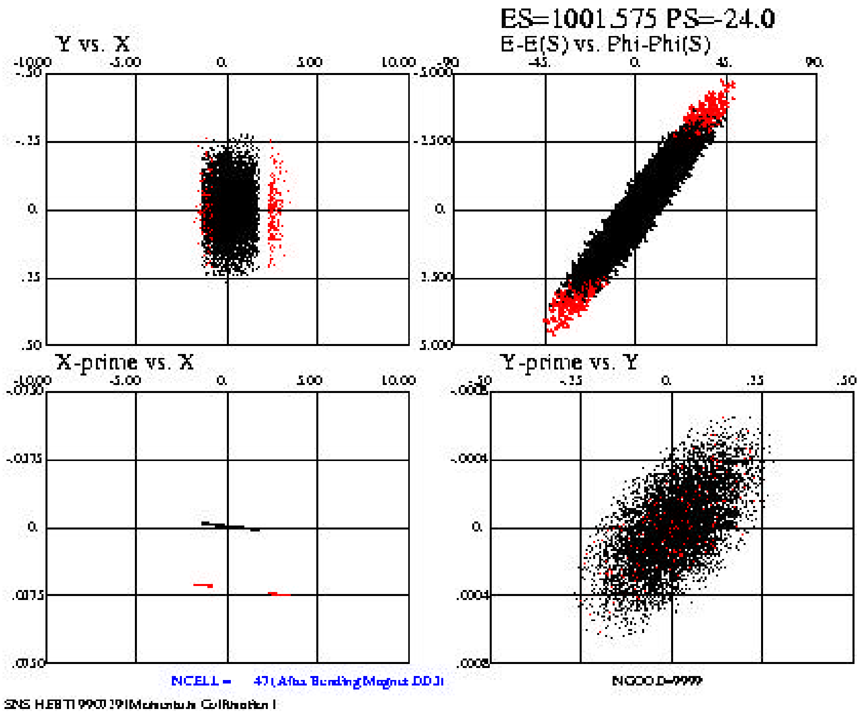

Figure 5b: Phase space after the 3rd dipole (DD3) magnet.

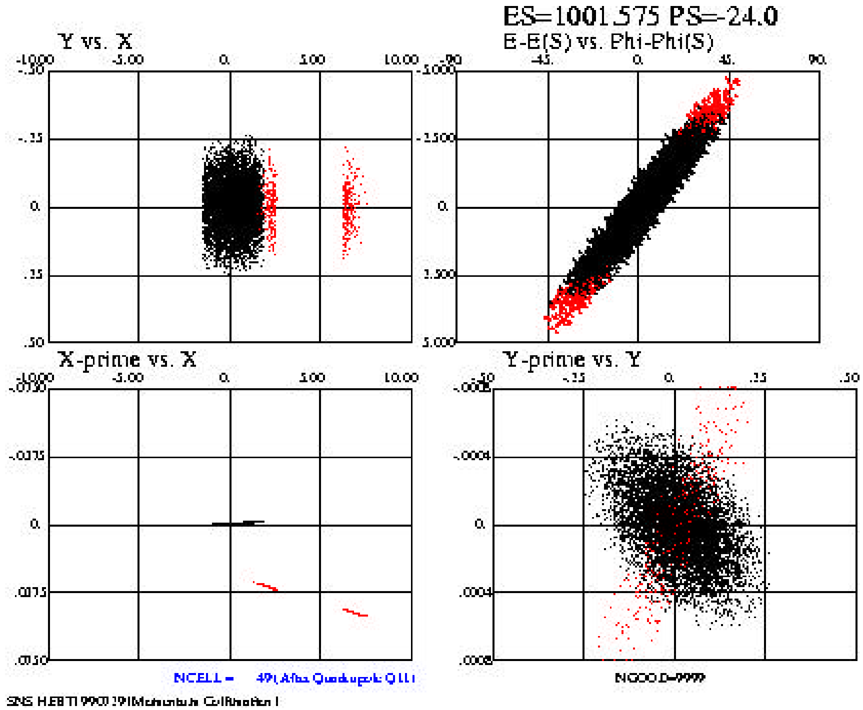

Figure 5c: Phase space after the quadrupole (11th).

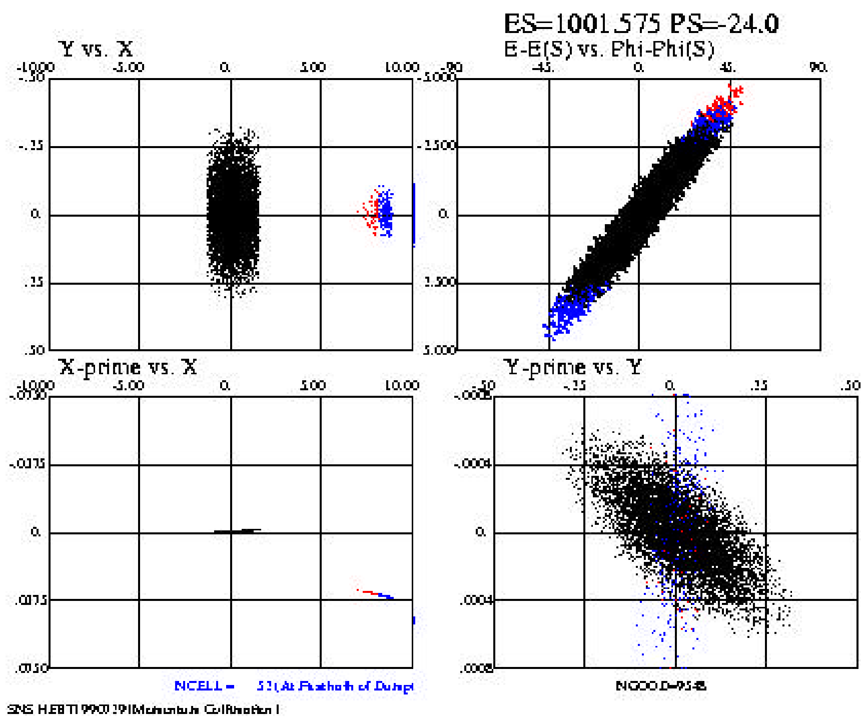

Figure5d: Phase space at first half of collector, red particles representing proton and blue particles lost particle in the collector.

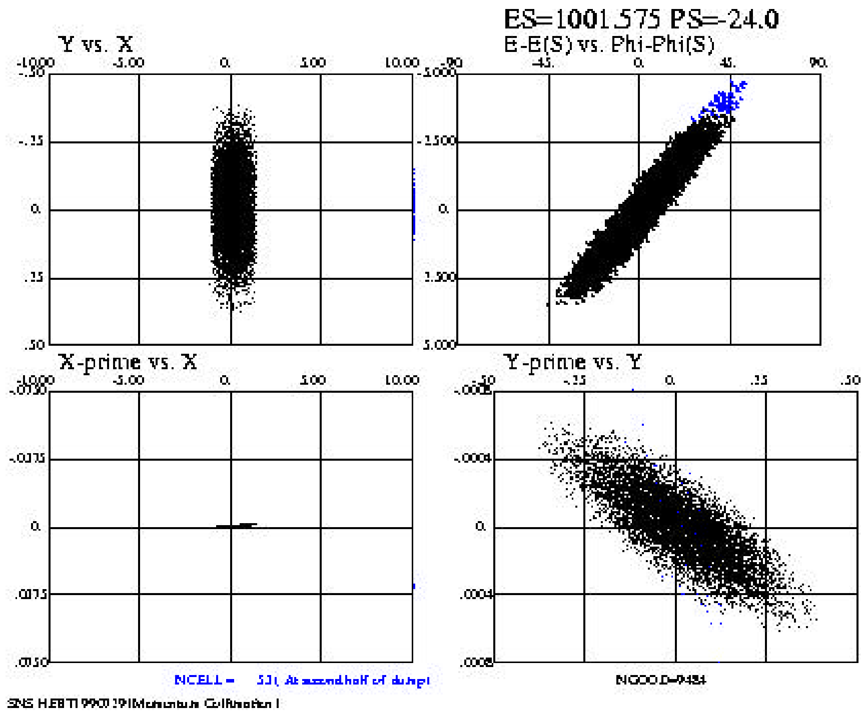

Figure5e: Phase spaces at second half of collector, blue particles lost particle in the collector.

References

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

[2] D. Raparia, et al, "The NSNS 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 NSNS Accumulator Ring", to be published in ANS Winter Conference , Albuquerque, New Maxico, 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 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
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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
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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
```

TRANS1	53	1	150.00000	3.0	8	0.	1	1 7 1	
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TRANS1	62	3	-219.45300	50.0	10	1.	1	1 7 1	13
TRANS1	63	12	000.00	20.0	-00.0	20.	1	1 7 1	
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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	
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TRANS1	85	1	43.442967	1.0	2.4	0.	1	1 7 1	
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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	7.5000	-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
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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
TRANS1	118	19	0	0	0	0	1	1 7 1	
TRANS1	119	1	350.00000	07.0	6	0.	1	1 7 1	
TRANS1	120	3	-447.93200	50.0	6	1.	1	1 7 1	25
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
TRANS1  127     19        0           0         0      0        1  1 7 1
TRANS1  128      1        222.40000   04.00     6      0.       1  1 7 3
TRANS1  129      4        1.9836200  -1885.8    0      0        0  1 2 1
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
```