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The NSNS Ring to Target Beam Transport Line

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U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

THE NSNS RING TO TARGET BEAM TRANSPORT LINE

BNL/NSNS TECHNICAL NOTE

NO. 006

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The NSNS Ring to Target Beam Transport Line

Abstract

This 129.12 meter long transport line connects the ring to target and provides the desired foot-print. This line consists of ten 90° FODO cells, and beam extraction system, beam dump switching system, beam spreader, and enough diagnostic devices to determine the beam quality before sending it to the target. To reduce the uncontrolled beam losses this line has two beam halo scrapers and very tight tolerances.

1 Introduction

The 1 MW NSNS machine consists of 1 GeV linac, an accumulator ring, and two transfer lines: (a) High Energy Beam Transfer line (HEBT), and (b) Ring to Target Beam Transfer line (RTBT). The main feature of this accelerator is the low uncontrolled beam losses (nA/m) to allow hands on maintenance. In the RTBT, one prepares and measures the beam for the target. To reduce the probability of uncontrolled beam losses and define the beam size precisely on the target, RTBT is equipped with two sets of beam halo scrapers. The ratio of aperture to rms beam size is kept more than 10. Another key feature of this line (to reduce the uncontrolled beam loss) is very tight tolerances on elements. Figure 1 shows the RTBT. Table 1 shows the Twiss parameters at the entrance and exit of the RTBT. Table 2 shows the component specifications for the RTBT.

2 Functions

The RTBT has following functions: (a) extraction, (b) beam dump, (c) beam spreader, (d) diagnostics, and (e) halo and collimation.

We have tried to decouple these functions in the RTBT. The extraction system start in the ring with a kicker magnet and continues through four cells in the RTBT. Following the extraction system, two cells are used for the beam dump and halo collimation. The beam is dumped vertically down. The last four cell are used for final beam

Table 1: Twiss parameters at the entrance and exit of the RTBT.

At Entrance, Before the Kicker Magnet

α_x	-0.002	
β_x	24.742	mm/mrad
$\pi\epsilon_x$	120.0	π mm mrad
α_y	0.037	
β_y	1.899	mm/mrad
$\pi\epsilon_y$	120	π mm mrad

At Exit, At the Target

α_x	0.0	
β_x	83.0	mm/mrad
$\pi\epsilon_x$	120.0	π mm mrad
α_y	0.0	
β_y	10.2	mm/mrad
$\pi\epsilon_y$	120	π mm mrad

Table 2: Component Specifications for the RTBT.

Type	Quantity	Field	Aperture (dia)	Length
		Dipole		
5.73°	3	0.3 T	14 x 20 cm x cm	2.0 m
Kicker Magnet	1	0.06 T	20 x 14 cm x cm	2.0 m
Lambertson Magnet	1	0.3 T	20 x 14 cm x cm	2.0 m
Switch Magnet (15°)	1	0.9874 T	19.5 x 50 cm x cm	1.5 m
Correctors	22	0.02 T	24 x 24 cm x cm	0.3 m
		Quadrupole		
QF/QD	18	4 T/m	20 cm	0.5 m
Special Quad	4	4 T/m	36 cm	0.8 m

spreading to fulfill the beam size requirements. The collimators are located at the end of the extraction system and before of the beam spreader (see figure 1). Every quadrupole in the RTBT is followed by a steering magnet to steer the beam in the quadrupole focusing plane. Figure 2 shows amplitude functions (β_x, β_y) and the dispersion function (η_x) along the RTBT. Figure 3 shows the TRACE3D output for this line. This line is designed such that it can accomodate the beam current upgrade for 2 MW.

2.1 Extraction

The extraction of the beam is done in a single turn with full aperture at a pulse repetition frequency of 60 Hertz. The extraction system consists of a full-aperture kicker and a Lambertson magnet septum and dipole magnet. Figure 4 shows the ring extraction system. The kick will be in the vertical direction. The Lambertson septum magnet (60° phase advance from kicker) will receive the vertically kicked beam and will provide large deflection 100 mrad (5.73°) to enable eject ion horizontally from the accumulator ring. A dipole, which is 360° away from the Lambertson magnet, bend the beam in the opposite direction by 100 mrad, making the extraction system achromatic. At end of extraction the dispersion and its derivative are zero (see figure 2). Figure 5 shows the TRACE3D output for this extraction system.

2.1.1 Kicker and Lambertson Magnet

The parameters which dictate the kicker design are (a) the large aperture (H x V) 200 mm x 140 mm, (b) the large required deflection, and (c) the relatively fast rise time of 200 nsec.

High frequency ferrite will be used for the kicker magnet's core so that it can reach full field in 200 nsec. The ferrite saturates at 3.0 kG which is well above the 0.6 kG design field. The ferrite has high enough resistance so that the bas bar will not have to be insulated from the core. A window frame core design will be used. Flat eddy current damping sheets will be used at the core midplane to prevent the kicker magnet from being excited by the beam current. The kicker magnet will be located inside the vacuum system and will be designed to be backeable to 250° C minimum. Magnets of this type, size, and materil have been built and installed in the AGS Booster and operate in the 10^{-11} Torr vacuum.

A single turn of copper sheet will be used to carry the required current. In order to keep the high voltage on the magnet at reasonable values, the kicker magnet will be constructed of a number of section, typically four. Electrically, the magnet energy will be supplied by pulse forming networks (PFN's). The PFN's will be lumped parameter, multi-section type and the stored energy will be discharged by hydrogen thyratrons. To reduce the stray series inductance, the PFN's will be mounted close to the magnet straight section. A common DC power supply (PS) will be used to charge all the kicker PFN sections to the same voltage. The PS and electronics will be located in the nearby equipment house. The thyratrions will be triggered by an rf synchronized pulse and through adjustable delays to eliminate any variation in delay between multiple sections. The kicker rise time will be phased with the 280 nsec gap in the circulating beam. Other controls, interlocks and monitoring will be covered by a programmable logic controller (PLC). This will interface to the control computer for remote control.

The Lambertson magnet will use normal, water-cooled copper coils and the core will be machined to the proper Lambertson angle. The field in the upper chamber of the Lambertson magnet will be induced by five turn water cooled saddle coil powered by DC current PS. The lower chamber will be shielded from the field by magnetic septem between the chambers. Field studies of the septum design will determine the optimum shape of the septem for the minimum fringe field in the lower chamber and minimum field destortion in the upper chamber. The magnet core will be solid steel. The vacuum chambers will be joined at the upstream end by a common flange in the accumulator ring vacuume system. The upper chamber will then curve outward from the ring and feed a separate flange for the extraction beam line. The circulating beam chamber will be straight and will be flanged into the accumulator ring on the downstrem end. The magnet will be designed to be backeable to meet the vacuum system requirments. The magnet coils will be insulated and cooling water will be run through the coils during bakeout to prevent damage. This system is presently used in the RHIC injection Lambertson magnet.

The PS will be a DC multi-phase, thyristor controlled rectifier type. A PLC will be incorporated into the power supply design and will also act as the interface to the remote control computers. The digital-to-analog and analog-to-digital converters will be incorporated into the PS. Figure 6 shows the kicker and Lambertson magnet. Table 3 show the specification for kicker and the Lambertson magnet .

2.2 Beam Dump

Following the extraction section, in the 6th cell there is a switching magnet for the beam dump. This switching magnet is similar to the ring dipole magnets and bends the beam vertically down by 15°.

2.3 Beam Spreader

The Beam spreader consists of four cells. The first two cells form a 11.4° achromat to avoid direct neutrons from the target. The

Table 3: Specification for Kicker and the Lambertson Magnet

Kicker Magnet

β_k(Vert.)	10.0	m
β_k(Horiz.)	20.0	m
Bending angle	21.5	mrad
Field	600.0	Gauss
Aperture(H x V)	200 x 140	mm x mm
No Section	4	
Core Length/Section	0.5	m
Core Total Length	2.0	m
Core Material	Ferrite	
Peak Current	8600	A
Pulse Rep. Rate.	16.67	msec
Rise Time	200	nsec
Pulse Length	1000	nsec
Voltage/Section	24	kV
No. PFN's	4	
No. DC PS's	1	

Lambertson Magnet

β_L(Vert.)	10.0	m
β_L(Horiz.)	20.0	m
Bending Angle	100.0	mrad
Field	3.00	kG
Length	2.00	m
Aperture (H x V)	200 x 140	mm x mm
Septum Thickness	25.00	mm

later two cells provide the desired beam size at the target with the help of four special (big aperture) quadrupoles. Figure 7 shows the TRACE3D output for the beam spreader.

2.3.1 Window Effects

The spreader will has a window to separate vacuum from atmosphere. This window will be presently as specified by Oak Ridges is made of 6 mm steel and located about 2 meter up-stream of the target. The root mean square projected angle θ_s due to multiple Coulomb scattering in a window is given by

$$\theta_s = \frac{13.6MeV}{\beta_r cp} Z_{inc} \sqrt{\frac{L}{L_{RAD}}} \left(1 + \frac{1}{9} Log_{10} \frac{L}{L_{RAD}}\right) [radian],$$

where Z_{inc} is particle charge in units of electron charge, p is the particle momentum in MeV/c, $\beta_r = v/c$, L is the thickness of window and L_{RAD} is radiation length of material of the window. The emittance growth due to the window for a uniform distribution, is given by

$$\Delta\epsilon_{x,y} = \frac{1}{2}\beta_{x,y}\theta_s^2.$$

For 6mm of steel, θ_s is about 3 mrad and Twiss parameter at the window are $\beta_x = 81.5$ and $\beta_y = 12.7$ mm/mrad. This gives emittance growth in the x and y plane of 366 and 57 mm mrad respectively.

Figures 8 and 9 shows the PARMILA output (x-xp, y-yp and x-y plane and horizontal and vertical profiles) at the window and target location when multiple scattering is off. Figures 10 and 11 show the PARMILA output at the same location with multiple scattering on. Table 4 shows the Twiss parameters for these two cases.

2.4 Diagnostics

There are enough diagnostic devices to determine beam quality and beam losses. These devices are spread over the entire RTBT and a list of the devices are shown in Table 5.

There are 4 beam loss monitors per quadrupole and 4 per dipole plus 24 beam loss monitors are left movable for special use. Beam position monitors are located in each quadrupole. The rest of the diagnostics are shown in figure 12.

Table 4: Twiss Parameters at the Window and the Target with and without scattering

	α(x,y)	β(x,y) mm/mrad	ϵ_{rms}(x,y) π cm mrad	$\epsilon_{90\%}$(x,y) π cm mrad	$\epsilon_{100\%}$(x,y) π mm mrad
			At the Window		
OFF	0.149, 0.374	7.203, 1.207	4.46, 4.16	18.14, 16.86	29.21, 22.79
0N	-0.013, 0.095	1.398, 0.485	22.72, 9.15	93.80, 40.11	203.23, 75.74
			Target		
OFF	0.078, -0.098	7.090, 1.069	4.46, 4.16	18.14, 16.86	29.21, 22.79
0N	-0.156, -0.321	1.432, 0.530	22.72, 9.15	93.74, 40.08	203.23, 75.70

Table 5: Diagnostic Devices in the RTBT

Device	Number
Beam Loss Monitor	120
Current Toroid	2
Beam Position Monitor	20
Wall Current Monitor	1
Harp	2
Profile by Moments	4 (2x,2y)

Table 6: Lattice Functions and Beam Sizes at the Collimator Locations.

	σ (deg)	β_x m	β_y m	$\sqrt{\epsilon\beta_x}$ mm	$\sqrt{\epsilon\beta_y}$ mm
		Transverse			
b1	0	22.2	2.02	51.6	15.5
b2	270	2.02	23.8	15.5	52.0

2.5 Halo and Collimation

To define the beam size at the target, there are two β collimators in the RTBT. One beta collimator is located just after the extraction system and the other one just before the spreader. The lattice functions and the beam size at the collimator locations are shown in Table 6.

3 Space Charge

In the linear approximation, the electric field components that are due to a uniformly charged ellipsoid, are given by

$$E_x = \frac{1}{4\pi\epsilon_0}\frac{3I\lambda}{c\gamma^2}\frac{(1-f)}{r_x(r_x+r_y)r_z}x$$

$$E_y = \frac{1}{4\pi\epsilon_0}\frac{3I\lambda}{c\gamma^2}\frac{(1-f)}{r_y(r_x+r_y)r_z}y$$

and

$$E_z = \frac{1}{4\pi\epsilon_0}\frac{3I\lambda}{c}\frac{f}{r_xr_yr_z}z$$

where r_x,r_y and r_z are the semi-axis of the ellipsoid, I is the electrical current averaged over rf period, λ is the free-space wavelength of the ring rf, c is the velocity of light, and ϵ_0 is the permittivity of free space. The form factor f is a function of p=$\frac{\gamma r_z}{\sqrt{r_xr_y}}$. The change in the normalized momentum components due to these electric fields during the time interval required for the beam to move a distance Δ s is

$$\Delta(\beta\gamma) = \frac{qE_u\Delta s}{m_0 c^2 \beta},$$

where u represents x, y, or z. This momentum change can be translated to the tune of the line. The tune depression is defined by $\mu = \frac{\sigma}{\sigma_0}$, where σ and σ_0 are the tune with and without the space charge.

The revolution frequency of the ring is 1.258 MHz and revolution period is 795 ns. The extracted pulse length is 515.03 ns and number of proton per pulse are 1.042 . 10^{14}. The average current over the one RF period is

$$I = \frac{1.042x10^{14}X1.6021x10^{-19}}{79510^{-9}} = 21A$$

The tune depression μ for 21 A is 0.985 . To simulate space charge effects we have used TRACE3D and PARMILA programs.

4 Tolerances

Since this machine should have very low losses, this translates to tight tolerances. The RTBT consists of quadrupoles and dipoles. The quadrupole alignments erors can be simulated by PARTRACE. Figures 13, 14 show the probability distribution of the beam centroid, and the maximum radius for 4 and 10 mils quadrupole alignment errors. Figures 15 and 16 shows the probability distribution of the maximum radius and transverse emittance for 0.01, 0.02 and 0.05 degrees of quadrupole rotation errors. Figures 17, 18 and 19 show the probability distribution of the beam centroid, maximum radius and transverse emittance for 10 mil quadrupole alignment and 0.05 degrees quadrupole roll errors.

5 Simulations

We have used following programs to simulate RTBT (a) TRANSPORT, (b) TRACE3D, (c) PARMILA, and (d) PARTRACE.

TRANSPORT code is used to design the line to satisfy certain conditions to be fulfilled by the beam. This code does not include the space charge effects. This simulation starts at beginning of the extraction system.

TRACE3D is used to optimized the lattice with space charge effects. It does include the space charge effects in the linear approximation.

PARMILA is used to simulate the line with full space charge. We have used the transport line option of PARMILA to simulate RTBT. Figure 20 shows the x, $\Delta\phi$, and ΔW profile of the RTBT for the 1 MW case.

PARTRACE is used to estimate the effects of quadrupole alignment errors. The code generates 100 different lines with random errors in the quadrupoles, calculate the beam parameters in the each case, and then the arrangs beam parameters in the ascending order.

6 Figures

Figure 01: RTBT layout.

Figure 02: TRANSPORT output for amplitude functions (β_x, β_y) and dispersion function (η_x) along the RTBT.

Figure 03: TRACE3D output for the RTBT.

Figure 04: The geometrical layout of the ring extraction system in the RTBT.

Figure 05: TRACE3D output for the extraction system.

Figure 06: Kicker and Lambertson magnet.

Figure 07: TRACE3D output for beam spreader.

Figure 08: PARMILA output (x-xp, y-yp and x-y plane and horizontal and vertical profiles) at the window when multiple scattering is off.

Figure 09: PARMILA output (x-xp, y-yp and x-y plane and horizontal and vertical profiles) at the target when multiple scattering is off.

Figure 10: PARMILA output (x-xp, y-yp and x-y plane and horizontal and vertical profiles) at the window when multiple scattering is on.

Figure 11: PARMILA output (x-xp, y-yp and x-y plane and horizontal and vertical profiles) at the target when multiple scattering is on.

Figure 12: The diagnostics distribution in the RTBT.

Figure 13: The probability distribution of beam centroid for 4 and 10 mil quadrupole alignment errors.

Figure 14: The probability distribution of maximum beam radius for 4 and 10 mil quadrupole alignment errors.

Figure 15: The probability distribution of maximum beam radius for 0.01, 0.02 and 0.05 degrees quadrupole rotational errors.

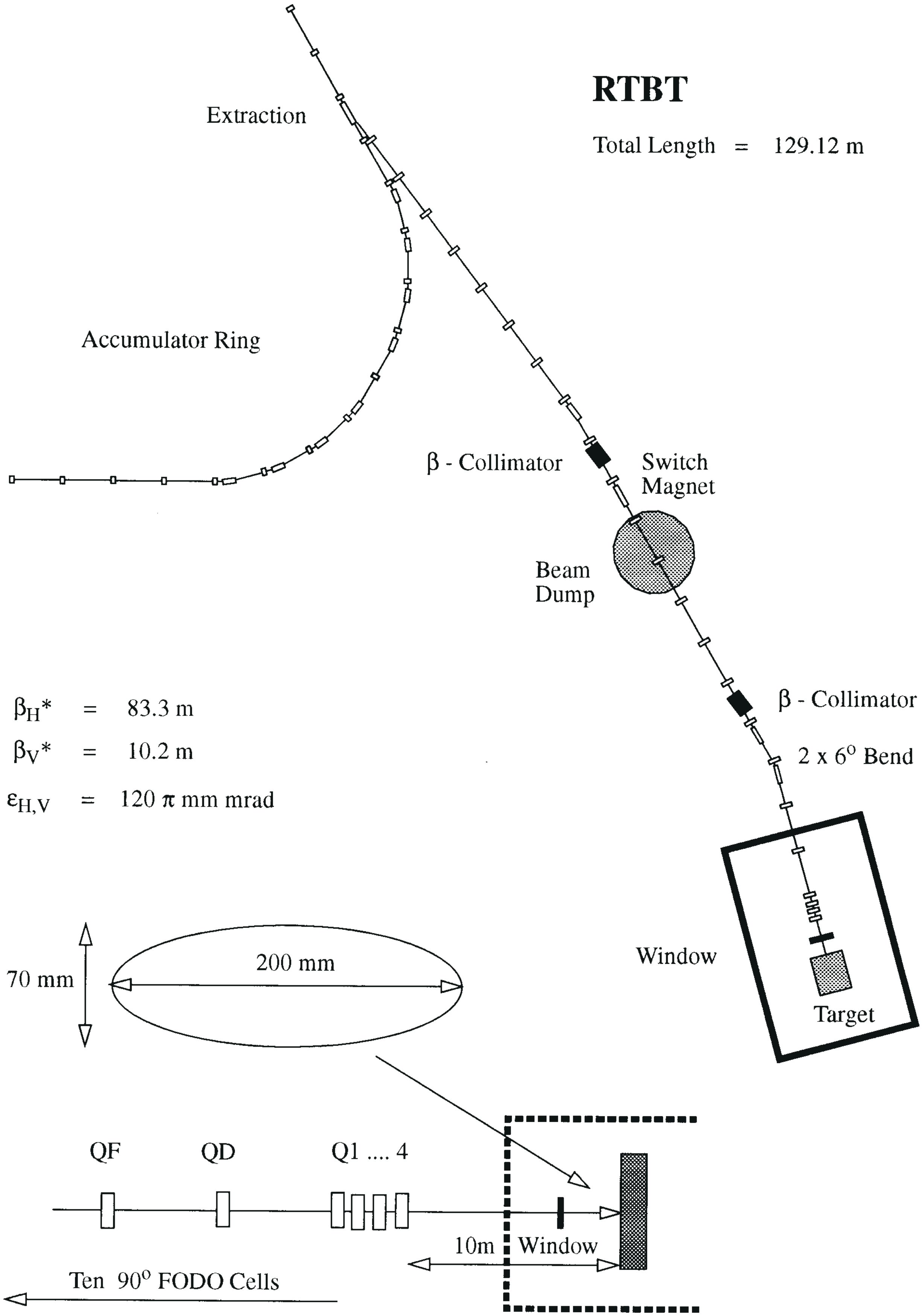
Figure 16: The probability distribution of transverse emittance for 0.01, 0.02 and 0.05 degrees quadrupole rotational errors.

Figure 17: The probability distribution of beam centroid for 10 mil alignment and 0.05 degrees rotational errors in the quadrupole.

Figure 18: The probability distribution of maximum beam radius for 10 mil alignment and 0.05 degrees rotational errors in the quadrupole.

Figure 19: The probability distribution of transverse emittance for 10 mil alignment and 0.05 degrees rotational errors in the quadrupole.

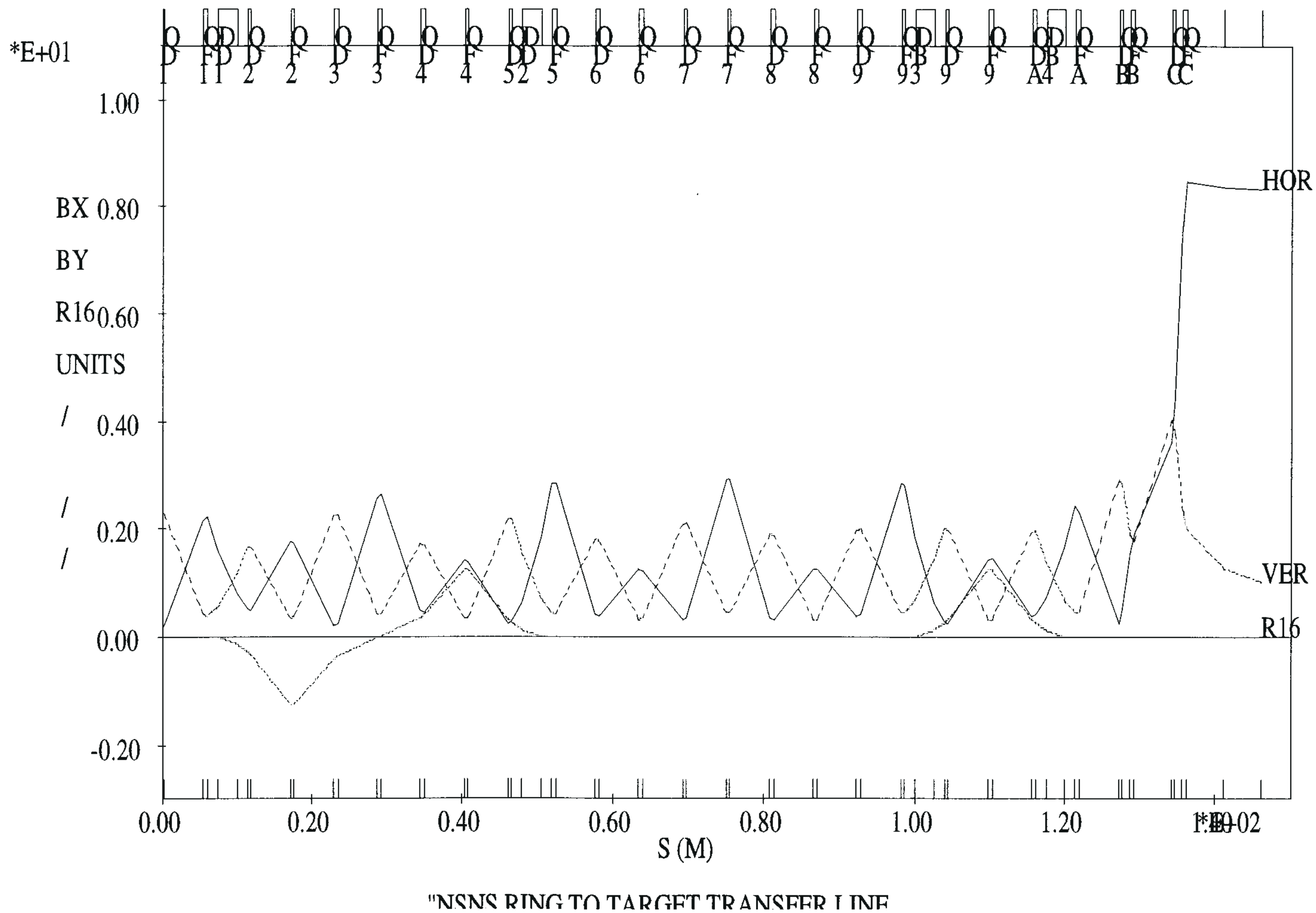
Figure 20: x, $\Delta\phi$, and ΔW profile of the RTBT.



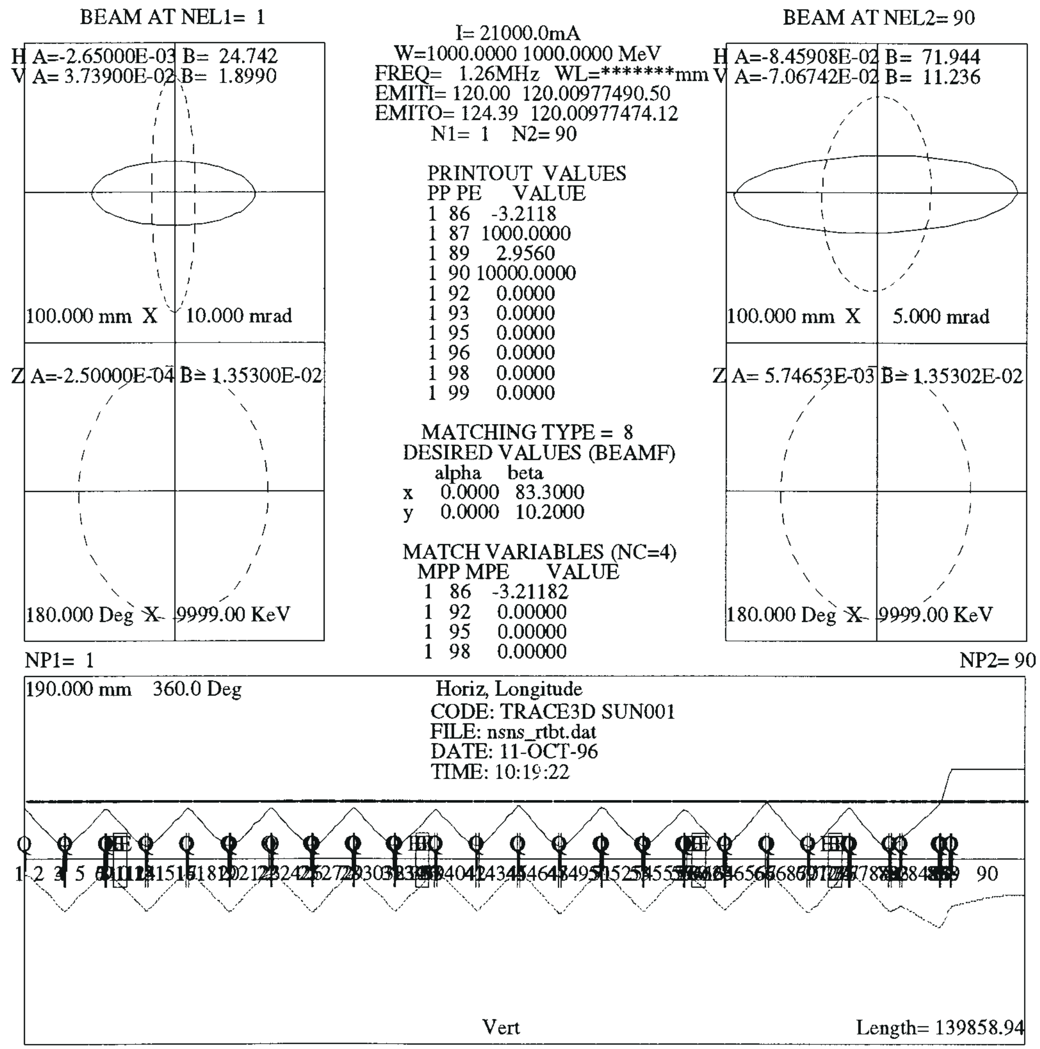
RTBT
Total Length = 129.12 m
Extraction
Accumulator Ring
β - Collimator
Switch Magnet
Beam Dump
β - Collimator
2 x 6° Bend
β_H^* = 83.3 m
β_V^* = 10.2 m
$\varepsilon_{H,V}$ = 120 π mm mrad
Window
Target
70 mm
200 mm
QF
QD
Q1 4
10m
Window
Ten 90° FODO Cells

Figure 1

Figure 2



*E+01
BX
BY
R16
UNITS
HOR
VER
R16
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
0.00
0.20
0.40
0.60
0.80
1.00
1.20
*E+02
S (M)
"NSNS RING TO TARGET TRANSFER LINE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V A= 3.73900E-02 B= 1.8990
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Z A=-2.50000E-04 B= 1.35300E-02
180.000 Deg X 9999.00 KeV
I= 21000.0mA
W=1000.0000 1000.0000 MeV
FREQ= 1.26MHz WL=*******mm
EMITI= 120.00 120.00977490.50
EMITO= 124.39 120.00977474.12
N1= 1 N2= 90
PRINTOUT VALUES
PP PE VALUE
1 86 -3.2118
1 87 1000.0000
1 89 2.9560
1 90 10000.0000
1 92 0.0000
1 93 0.0000
1 95 0.0000
1 96 0.0000
1 98 0.0000
1 99 0.0000
MATCHING TYPE = 8
DESIRED VALUES (BEAMF)
alpha beta
x 0.0000 83.3000
y 0.0000 10.2000
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 86 -3.21182
1 92 0.00000
1 95 0.00000
1 98 0.00000
BEAM AT NEL2= 90
H A=-8.45908E-02 B= 71.944
V A=-7.06742E-02 B= 11.236
100.000 mm X 5.000 mrad
Z A= 5.74653E-03 B= 1.35302E-02
180.000 Deg X 9999.00 KeV
NP1= 1
NP2= 90
190.000 mm 360.0 Deg
Horiz, Longitude
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TIME: 10:19:22
Vert
Length= 139858.94

Figure 3

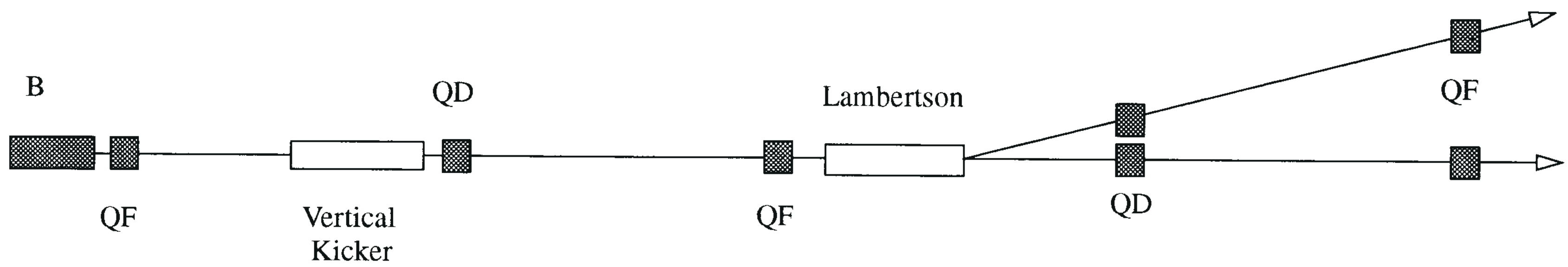
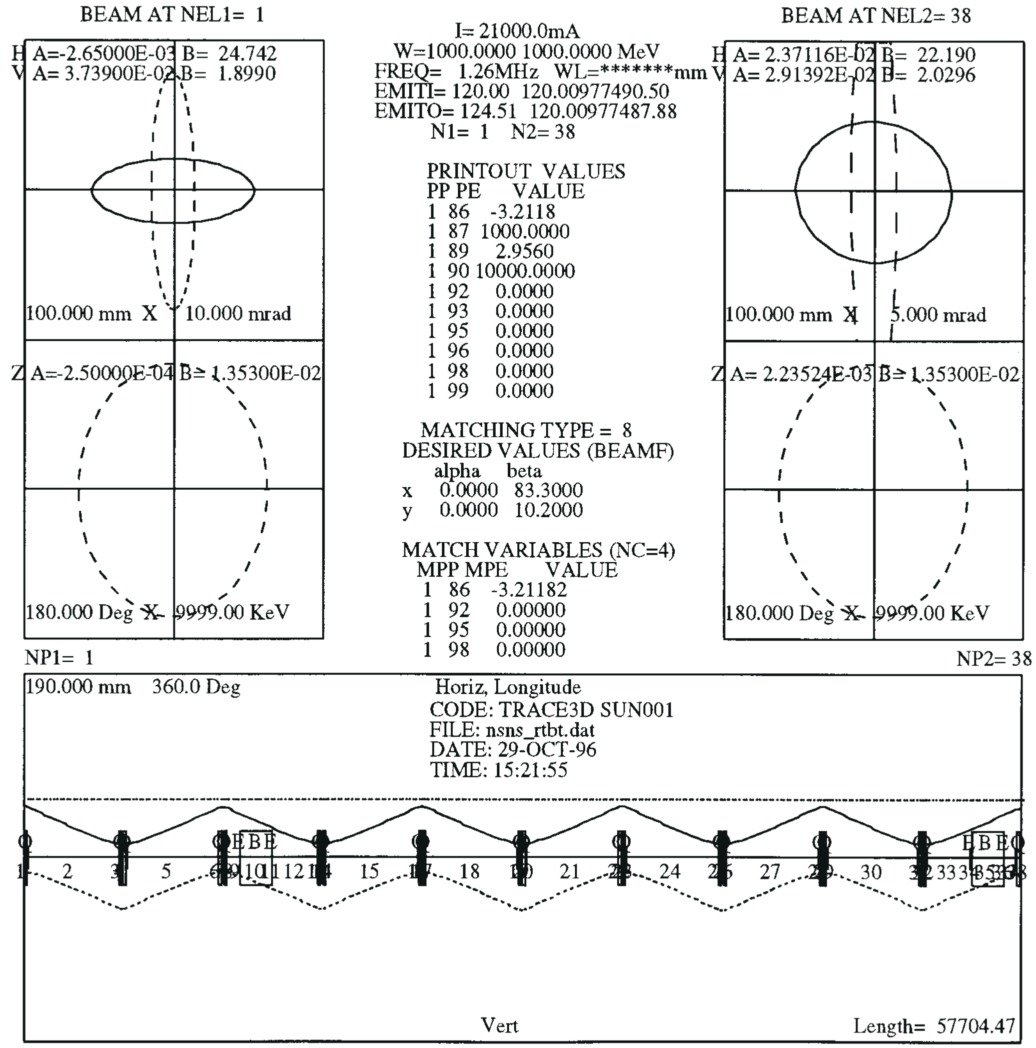


Figure 4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V A= 3.73900E-02 B= 1.8990
100.000 mm X 10.000 mrad
Z A=-2.50000E-04 B= 1.35300E-02
180.000 Deg X 9999.00 KeV
NP1= 1
I= 21000.0mA
W=1000.0000 1000.0000 MeV
FREQ= 1.26MHz WL=*******mm
EMITI= 120.00 120.00977490.50
EMITO= 124.51 120.00977487.88
N1= 1 N2= 38
PRINTOUT VALUES
PP PE VALUE
1 86 -3.2118
1 87 1000.0000
1 89 2.9560
1 90 10000.0000
1 92 0.0000
1 93 0.0000
1 95 0.0000
1 96 0.0000
1 98 0.0000
1 99 0.0000
MATCHING TYPE = 8
DESIRED VALUES (BEAMF)
alpha beta
x 0.0000 83.3000
y 0.0000 10.2000
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 86 -3.21182
1 92 0.00000
1 95 0.00000
1 98 0.00000
BEAM AT NEL2= 38
H A= 2.37116E-02 B= 22.190
V A= 2.91392E-02 B= 2.0296
100.000 mm X 5.000 mrad
Z A= 2.23524E-03 B= 1.35300E-02
180.000 Deg X 9999.00 KeV
NP2= 38
190.000 mm 360.0 Deg
Horiz, Longitude
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Vert
Length= 57704.47

Figure 5

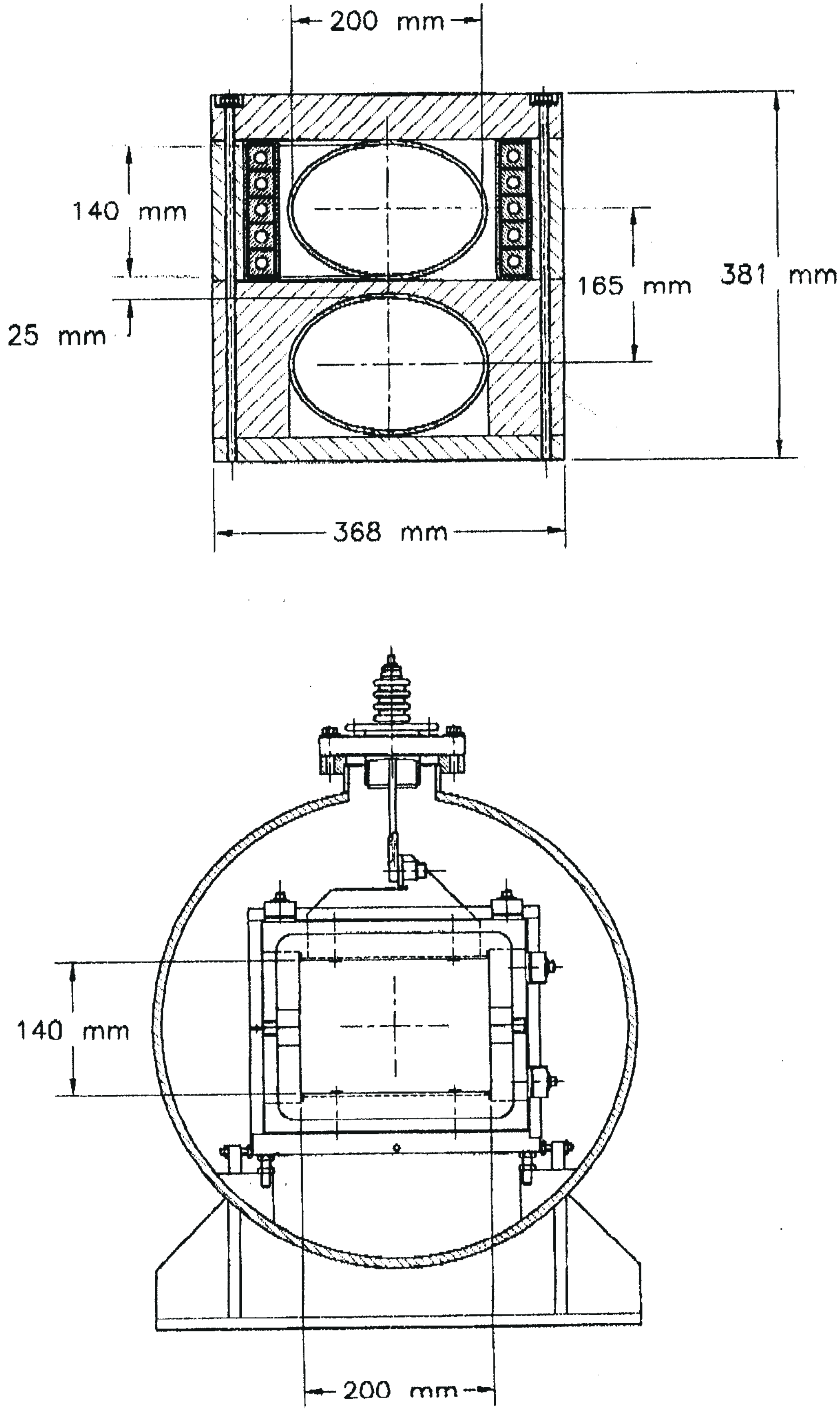
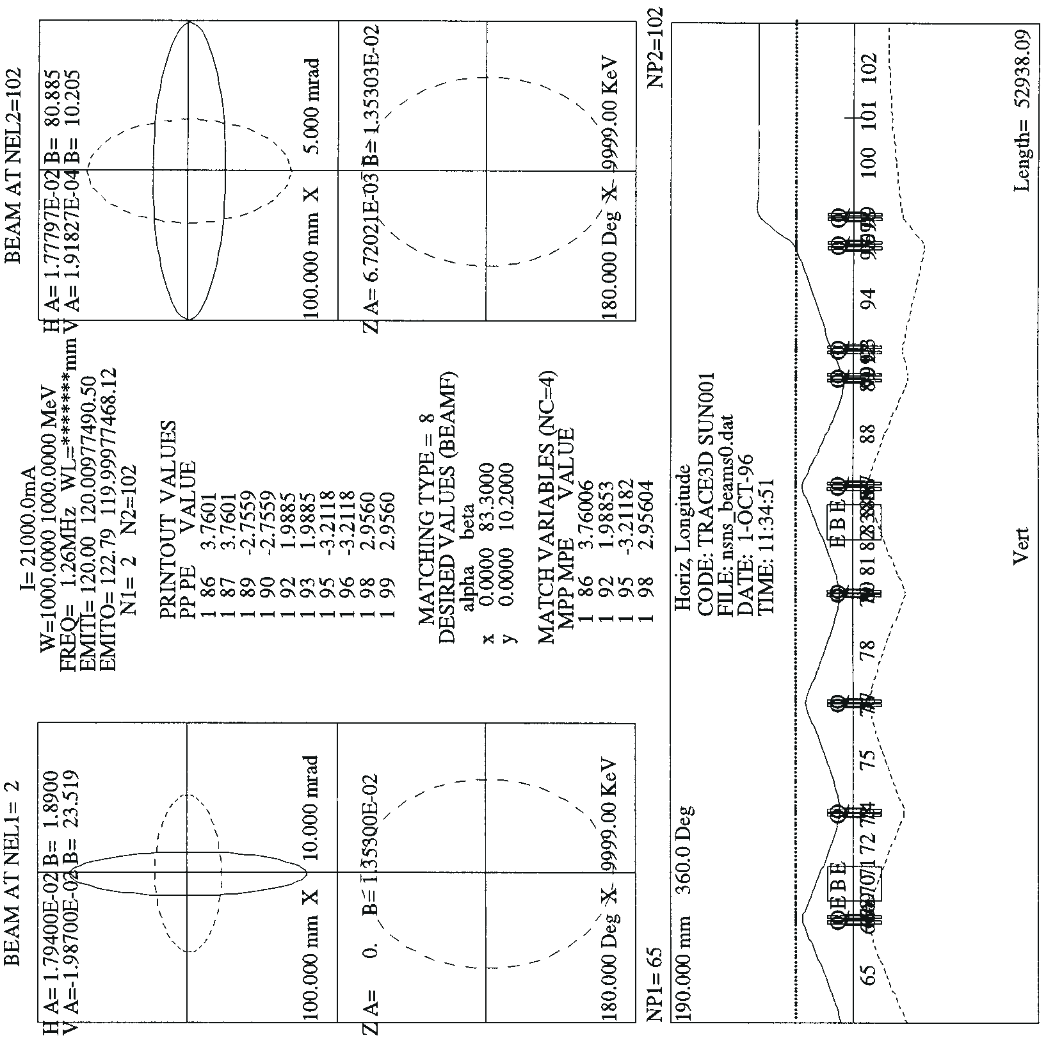


Figure 6
Lambertson & Kicker Magnet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180.000 Deg X 9999.00 KeV
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W=1000.0000 1000.0000 MeV
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EMITI= 120.00 120.00 97490.50
EMITO= 122.79 119.99 97468.12
N1= 2 N2=102
PRINTOUT VALUES
PP PE VALUE
1 86 3.7601
1 87 3.7601
1 89 -2.7559
1 90 -2.7559
1 92 1.9885
1 93 1.9885
1 95 -3.2118
1 96 -3.2118
1 98 2.9560
1 99 2.9560
MATCHING TYPE = 8
DESIRED VALUES (BEAMF)
alpha beta
x 0.0000 83.3000
y 0.0000 10.2000
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 86 3.76006
1 92 1.98853
1 95 -3.21182
1 98 2.95604
BEAM AT NEL2=102
H A= 1.77797E-02 B= 80.885
V A= 1.91827E-04 B= 10.205
100.000 mm X 5.000 mrad
Z A= 6.72021E-03 B= 1.35303E-02
180.000 Deg X 9999.00 KeV
NP2=102
190.000 mm 360.0 Deg
Horiz, Longitude
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DATE: 1-OCT-96
TIME: 11:34:51
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Vert
Length= 52938.09

Figure 7

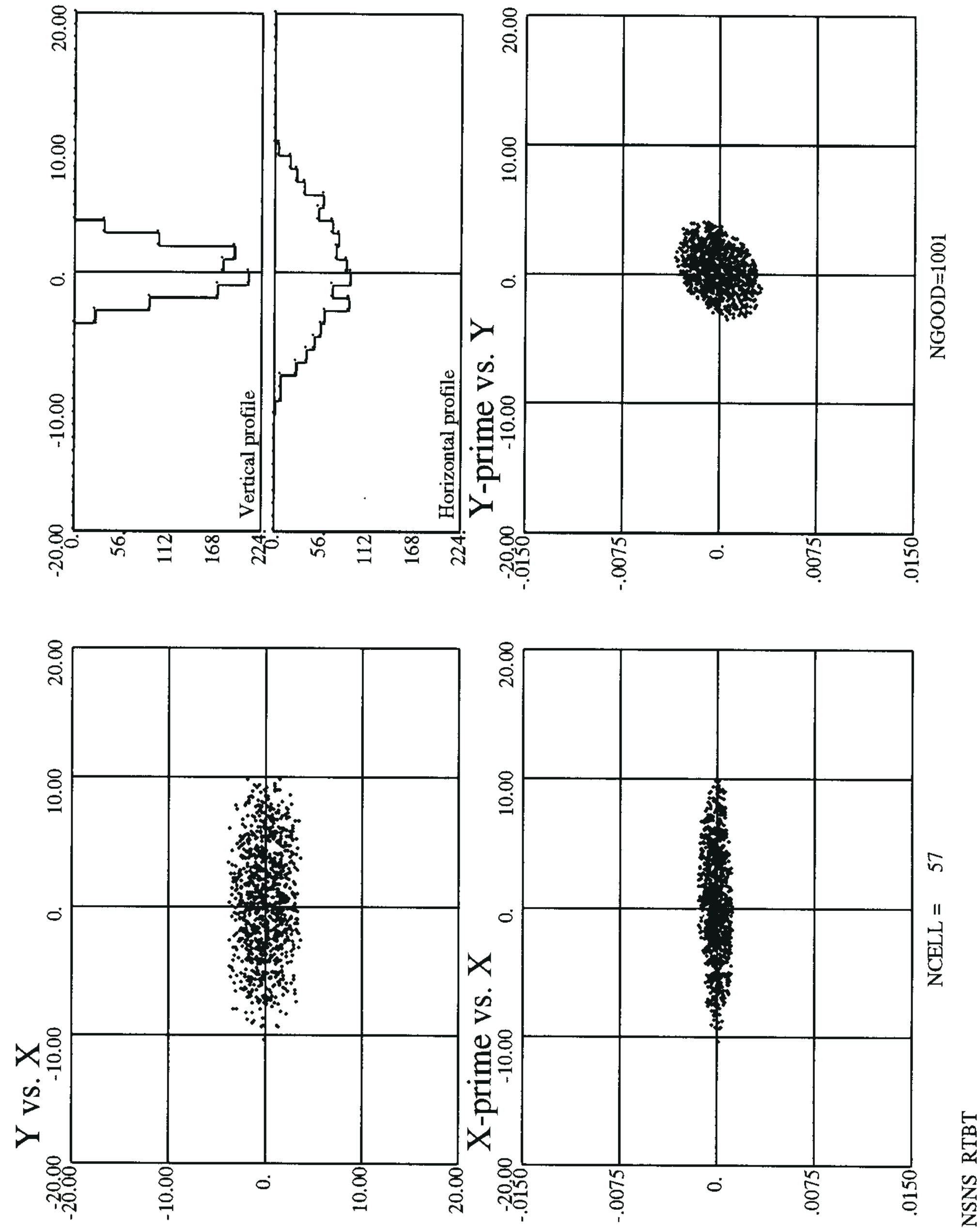

Y vs. X
X-prime vs. X
Vertical profile
Horizontal profile
Y-prime vs. Y
NCELL = 57
NGOOD=1001
NSNS RTBT

Figure 8

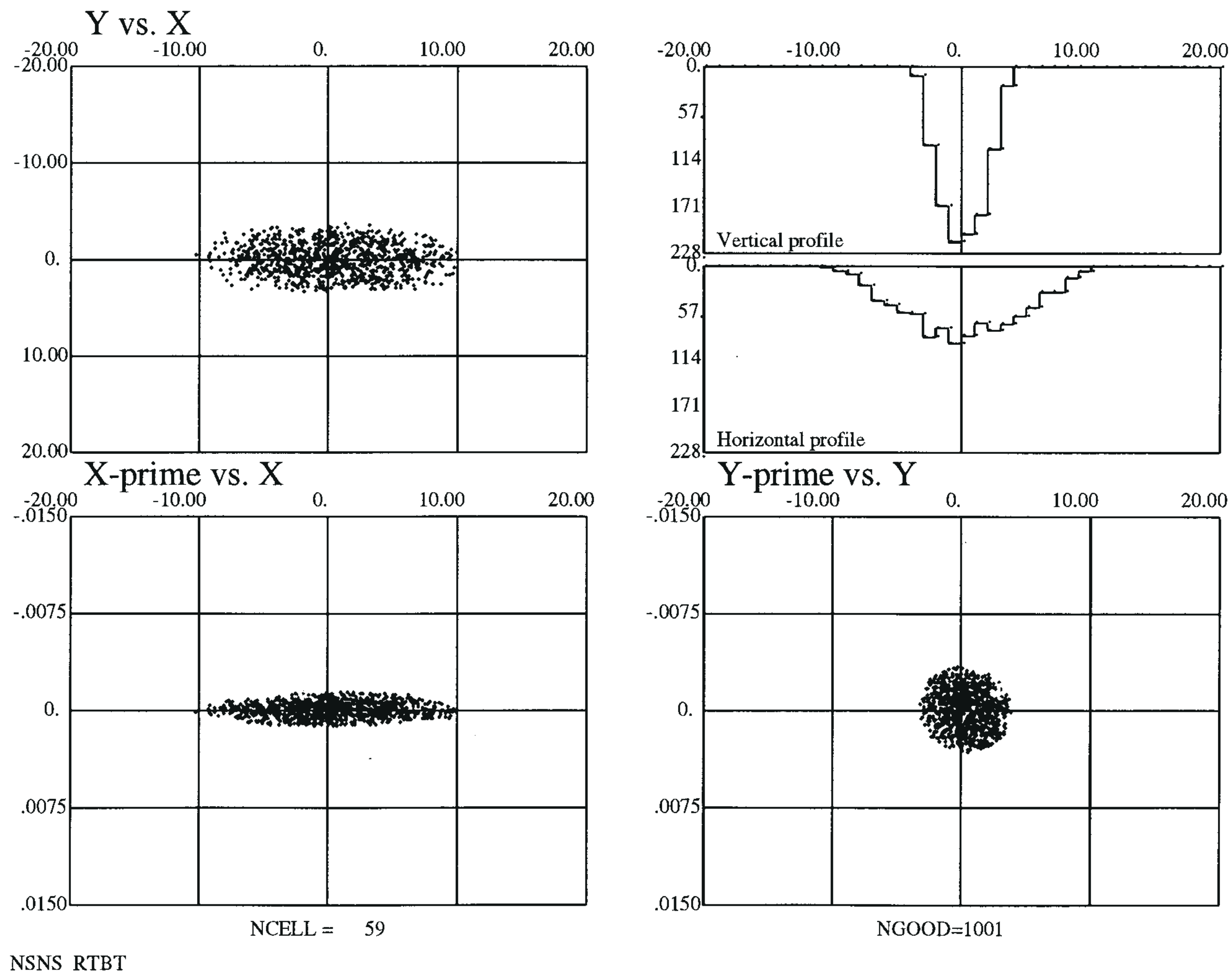
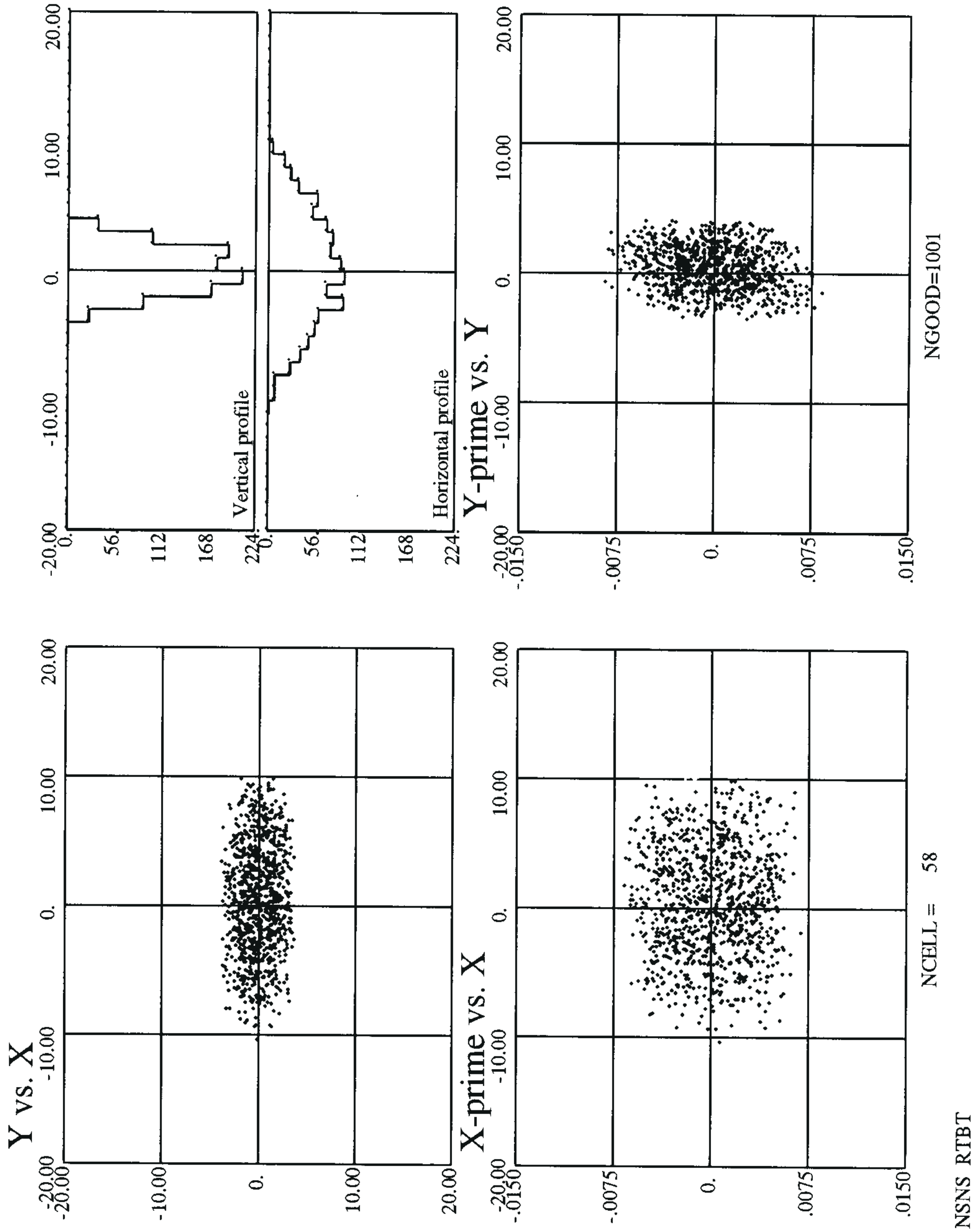
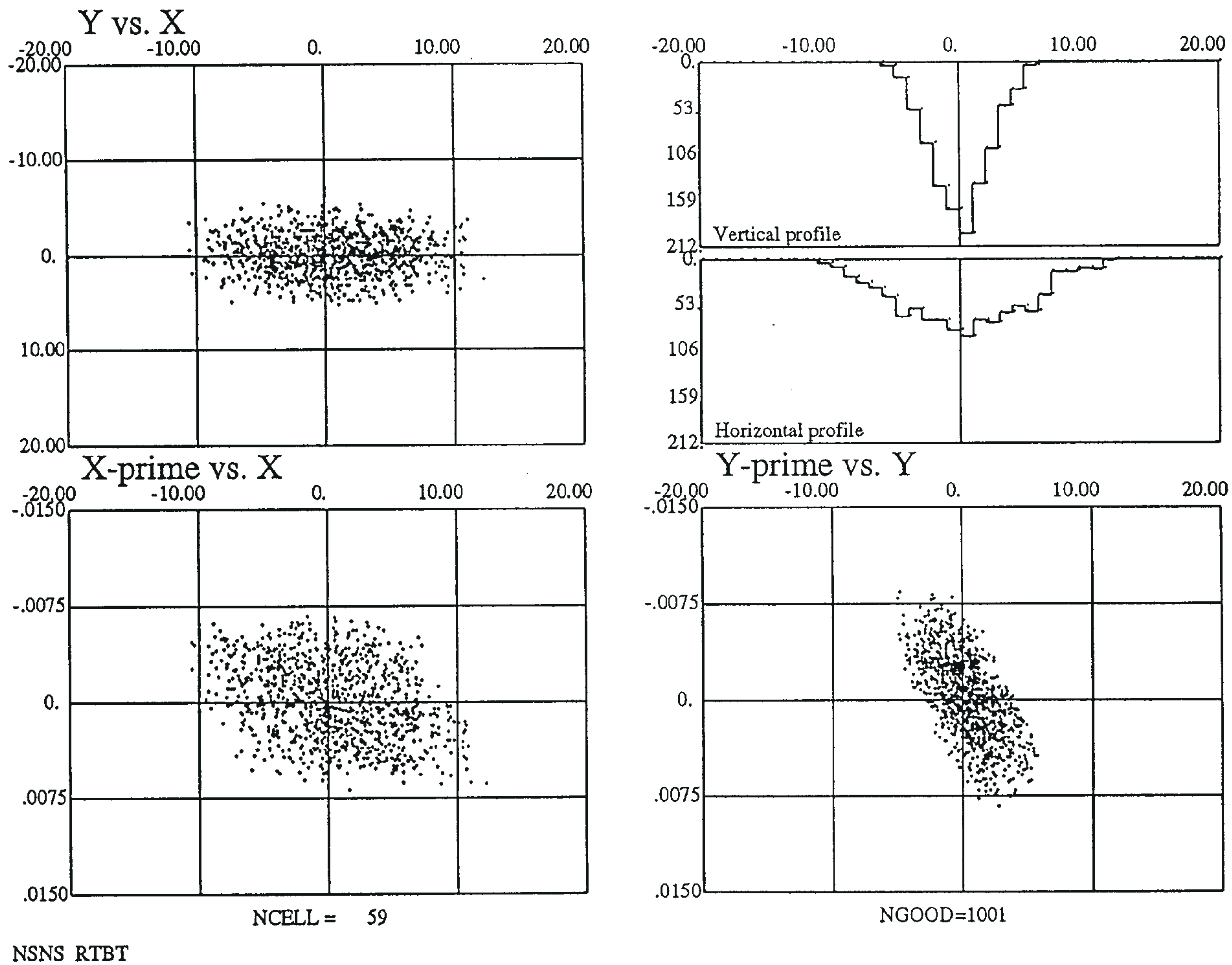

Y vs. X
-20.00
-10.00
0.
10.00
20.00
Vertical profile
Horizontal profile
0.
57.
114
171
228
X-prime vs. X
Y-prime vs. Y
-.0150
-.0075
.0075
.0150
NCELL = 59
NGOOD=1001
NSNS RTBT

Figure 9



Y vs. X
X-prime vs. X
Y-prime vs. Y
Vertical profile
Horizontal profile
NCELL = 58
NGOOD=1001
NSNS RTBT

Figure 10



Y vs. X
-20.00
-10.00
0.
10.00
20.00
Vertical profile
Horizontal profile
53
106
159
212
X-prime vs. X
Y-prime vs. Y
-.0150
-.0075
.0075
.0150
NCELL = 59
NGOOD=1001
NSNS RTBT

Figure 11

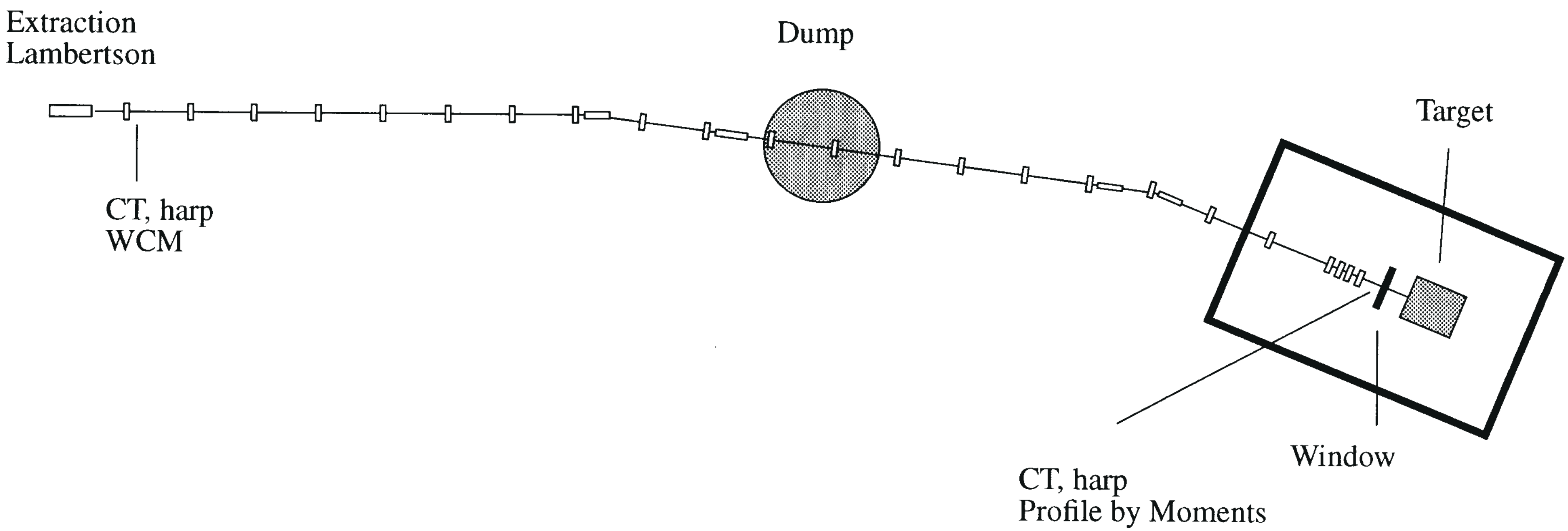

Extraction
Lambertson
CT, harp
WCM
Dump
Target
Window
CT, harp
Profile by Moments

Figure 12

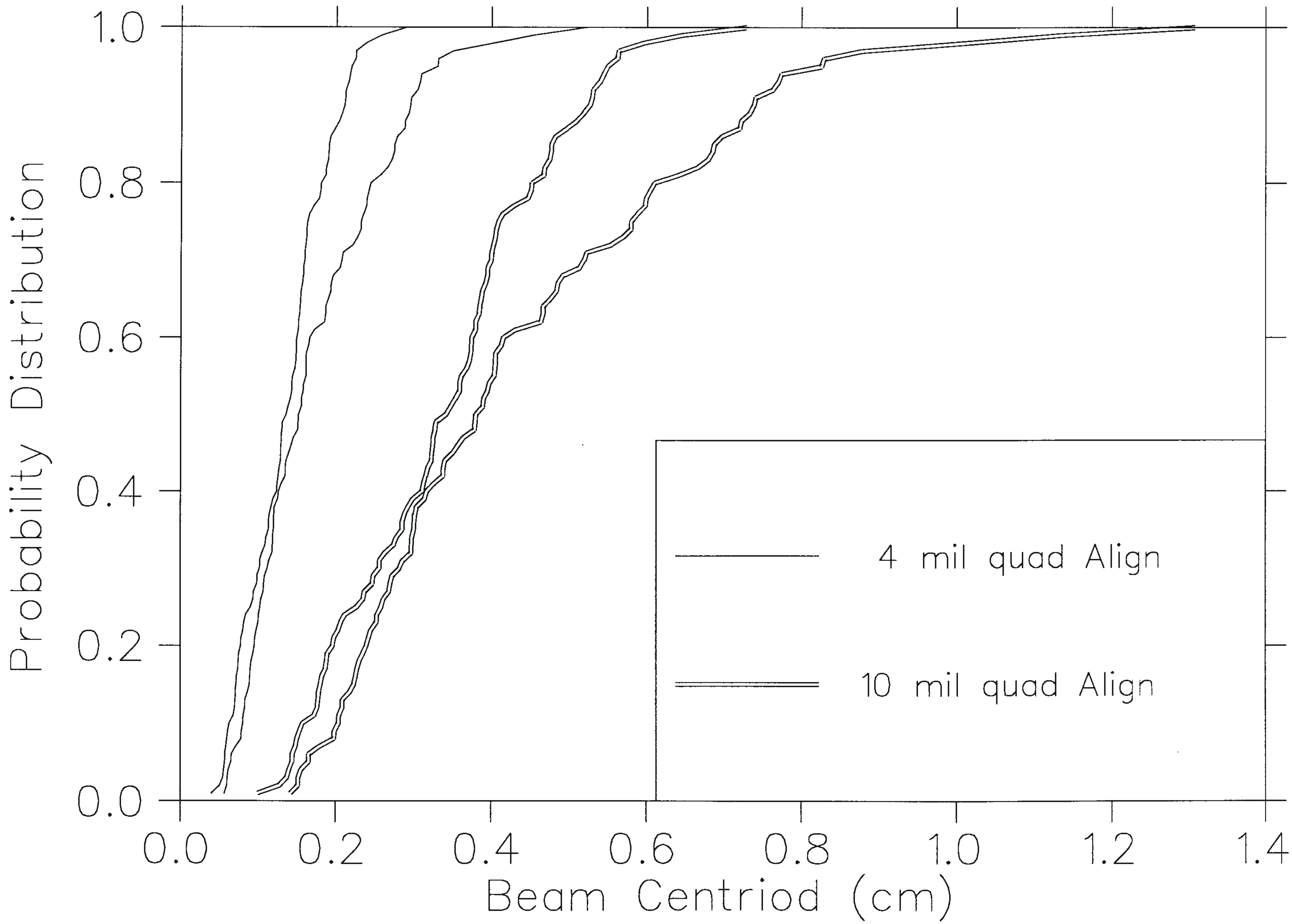

1.0
0.8
0.6
0.4
0.2
0.0
Probability Distribution
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Beam Centriod (cm)
4 mil quad Align
10 mil quad Align

Figure 13

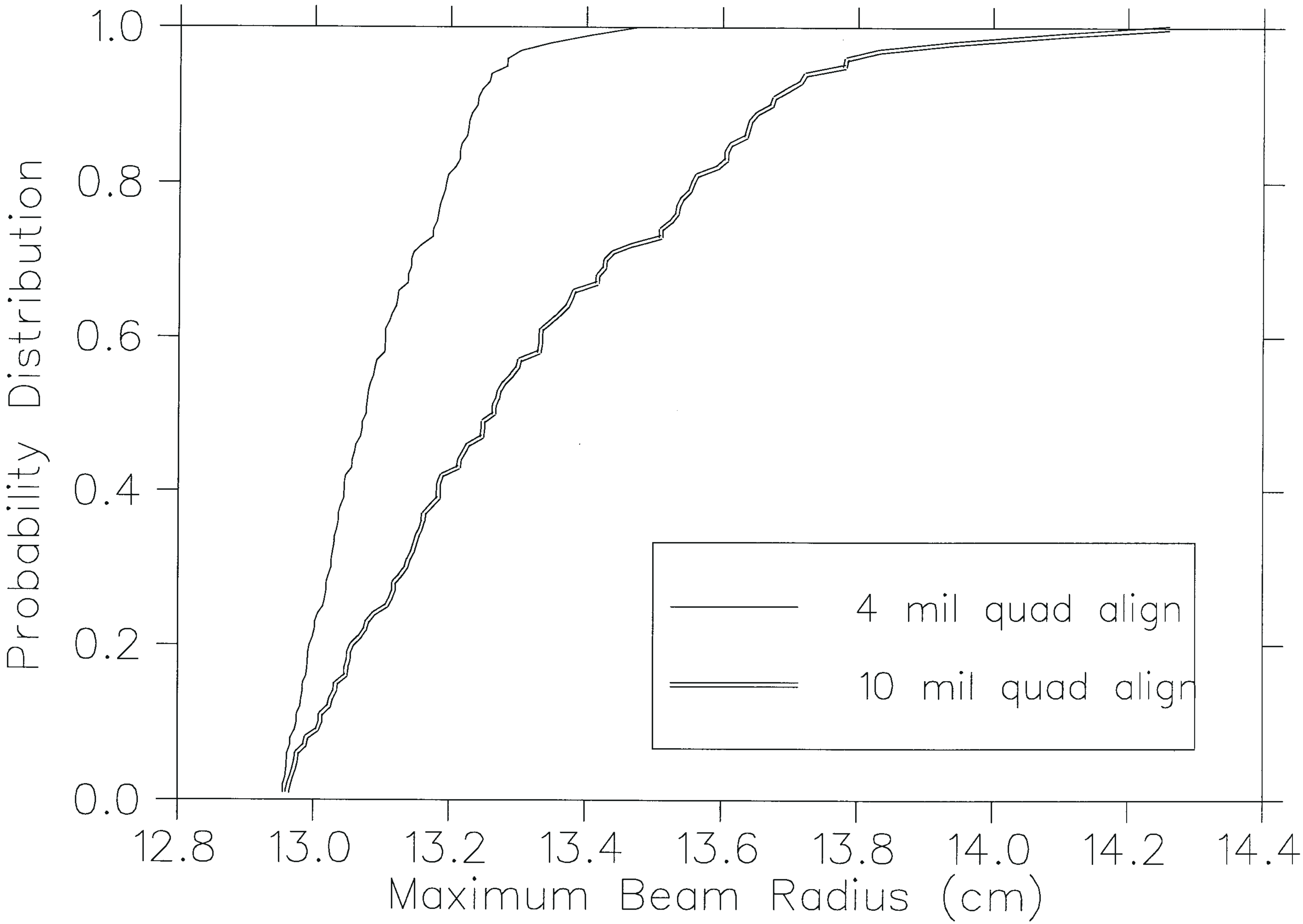

Probability Distribution
1.0
0.8
0.6
0.4
0.2
0.0
12.8
13.0
13.2
13.4
13.6
13.8
14.0
14.2
14.4
Maximum Beam Radius (cm)
4 mil quad align
10 mil quad align

Figure 14

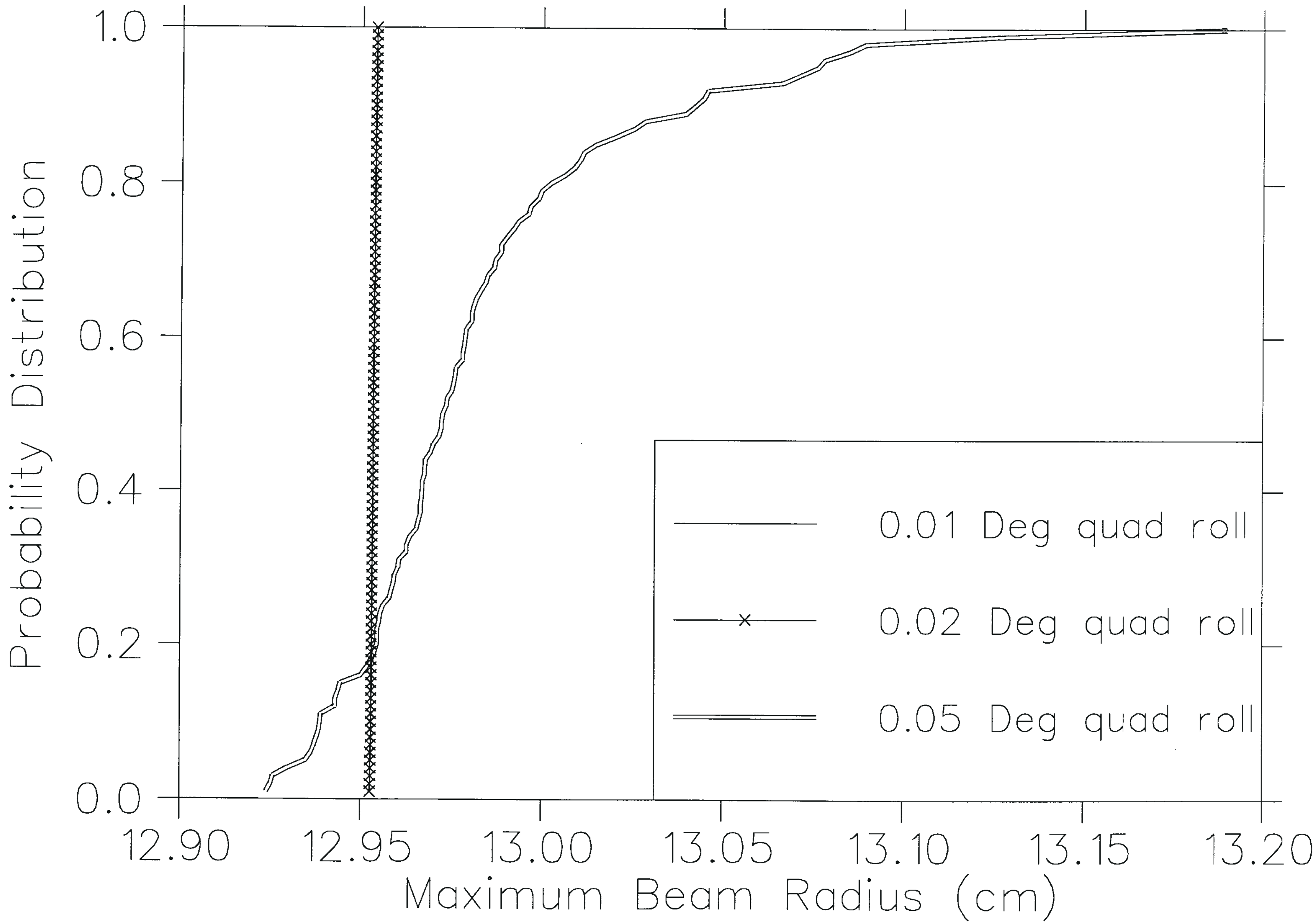

1.0
0.8
0.6
0.4
0.2
0.0
Probability Distribution
12.90
12.95
13.00
13.05
13.10
13.15
13.20
Maximum Beam Radius (cm)
0.01 Deg quad roll
0.02 Deg quad roll
0.05 Deg quad roll

Figure 15

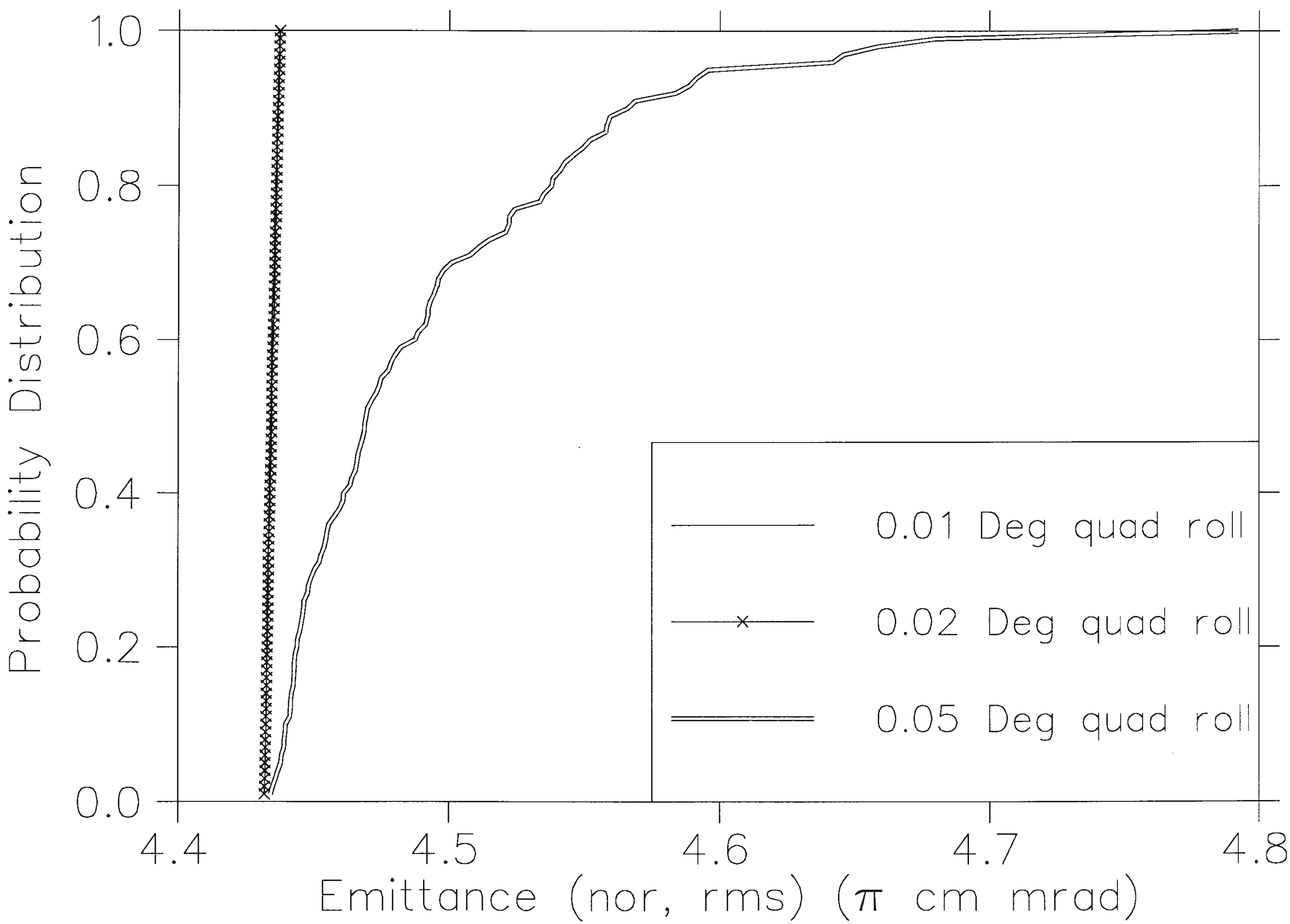

1.0
0.8
0.6
0.4
0.2
0.0
Probability Distribution
4.4
4.5
4.6
4.7
4.8
Emittance (nor, rms) (π cm mrad)
0.01 Deg quad roll
0.02 Deg quad roll
0.05 Deg quad roll

Figure 16

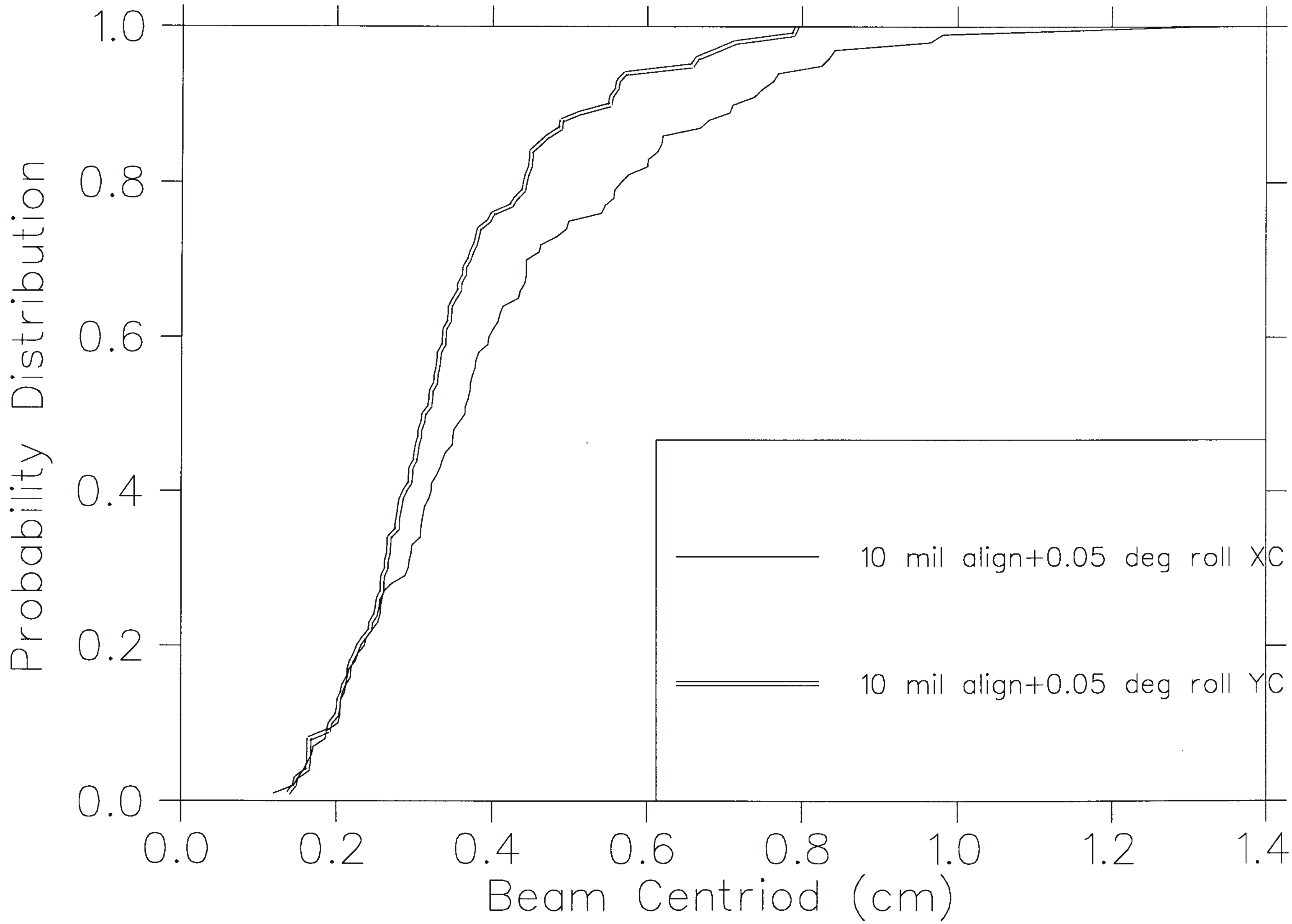

1.0
0.8
0.6
0.4
0.2
0.0
Probability Distribution
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Beam Centriod (cm)
10 mil align+0.05 deg roll XC
10 mil align+0.05 deg roll YC

Figure 17

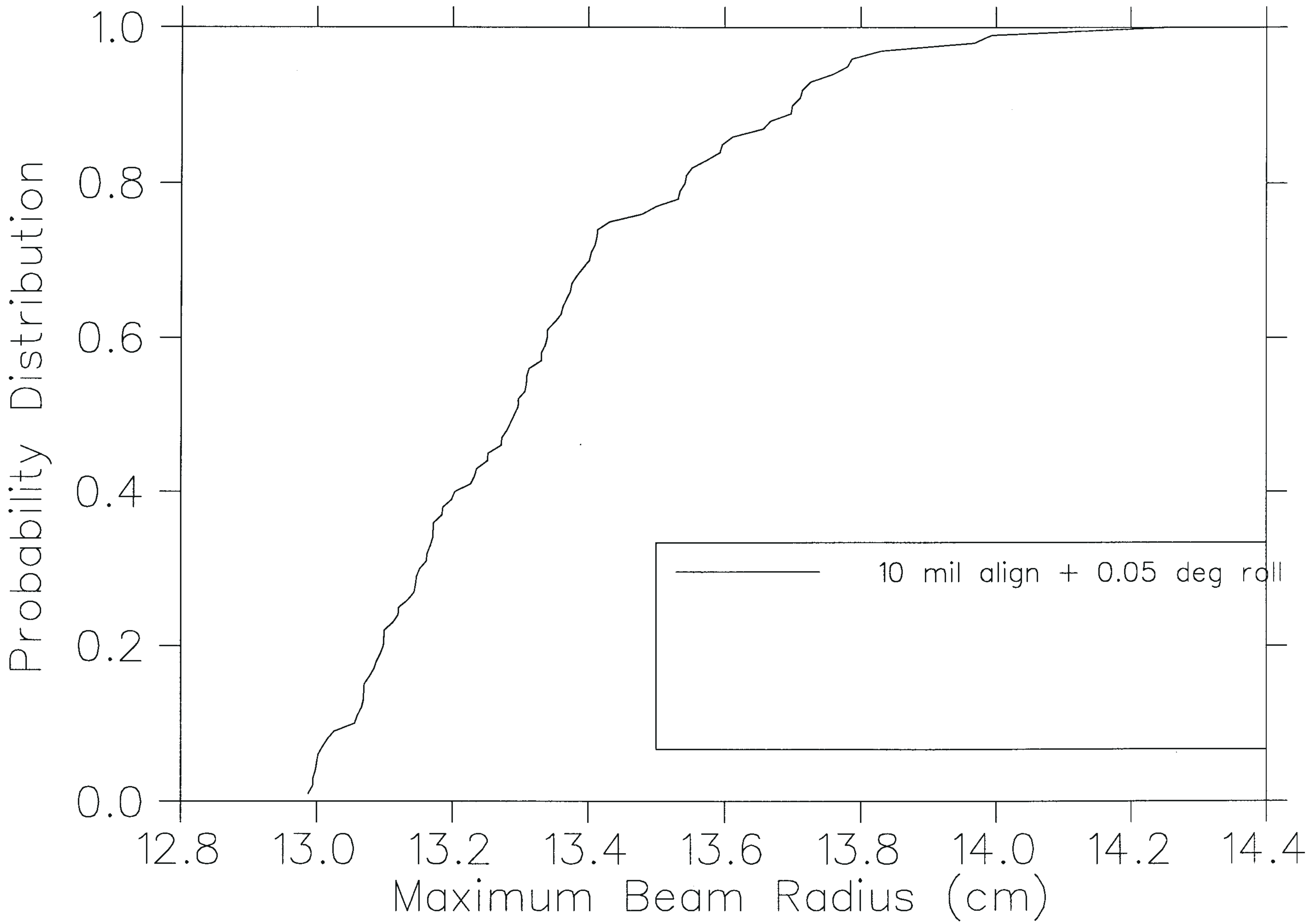

1.0
0.8
0.6
0.4
0.2
0.0
Probability Distribution
10 mil align + 0.05 deg roll
12.8
13.0
13.2
13.4
13.6
13.8
14.0
14.2
14.4
Maximum Beam Radius (cm)

Figure 18

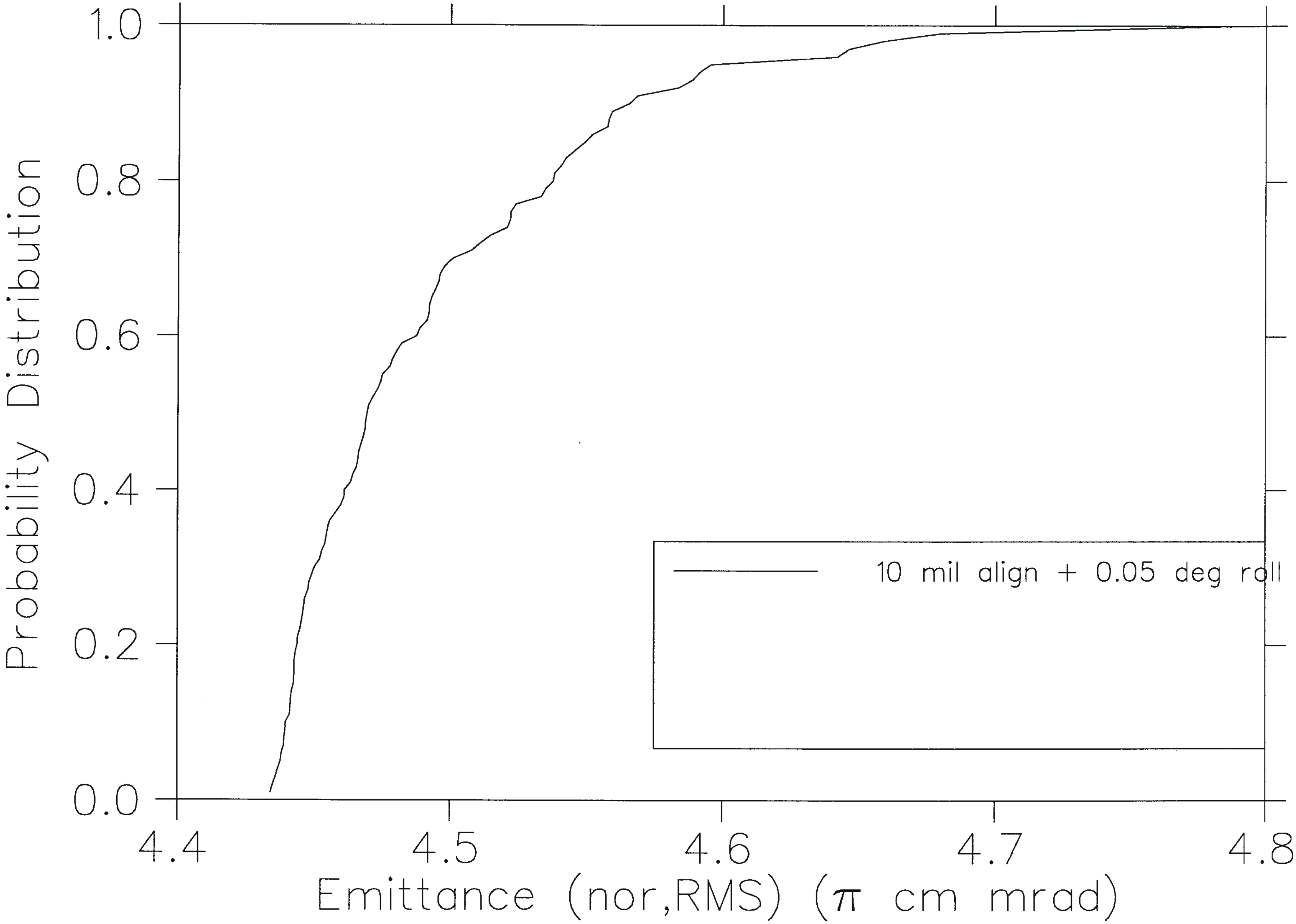

1.0
0.8
0.6
0.4
0.2
0.0
Probability Distribution
4.4
4.5
4.6
4.7
4.8
Emittance (nor,RMS) (π cm mrad)
10 mil align + 0.05 deg roll

Figure 19

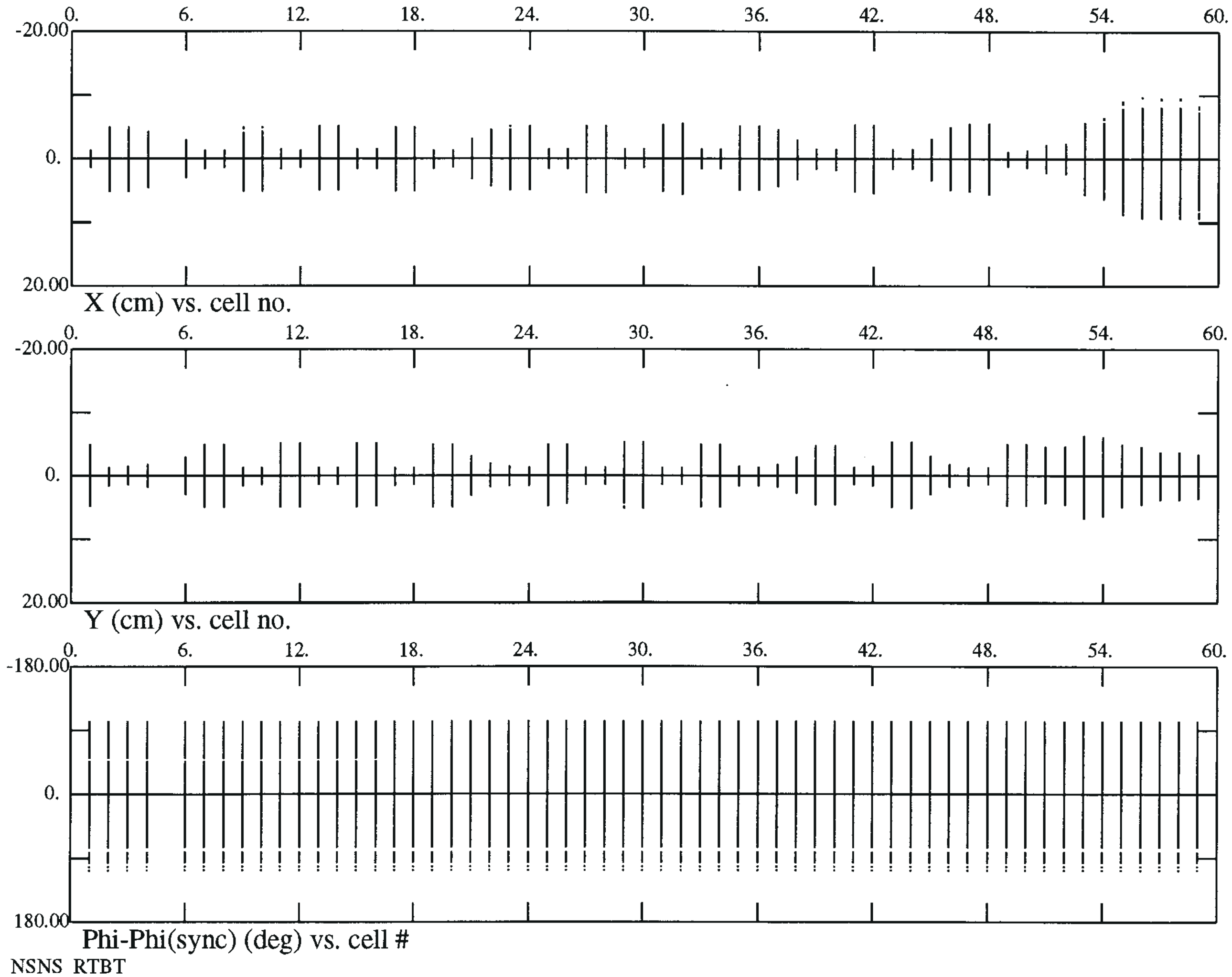


Figure 20

Appendices

A Input file for TRANSPORT

```
" NSNS RING TO TARGET TRANSFER LINE"
    0 ;
    PRINT, REFER ;
    PRINT, BEAM, ON ;
    PRINT, TRANS, ON ;
    PRINT, ACCEL, ON ;
    PRINT, ONELINE ;
    BM:BEAM.0000,BETAX=0.188997,ALPHAX=0.01794,BETAY=2.351945,ALPHAY=-0.01987,P0=1.6960 ;
    QF:=2.79666 ;
    QD:=-2.61145 ;
    QL1:=0.2500 ;
    QL2:=0.5000 ;
    QAR:=10.00 ;
    QD1: QUAD.00, L=QL1, B=QD, APER=QAR ;
    LL1: DRIFT, L=5.2932734 ;
    QF1: QUAD.00, L=QL2, B=QF, APER=QAR;
    LL2: DRIFT, L=1.3966367 ;
    DR1: ROTAT, ANGLE=0.0 ;
    DD1: BEND, L=2.500, ANGLE=-5.7297795 ;
    DR2: ROTAT, ANGLE=0.0 ;
    LL3: DRIFT, L=1.3966367;
    QD2: QUAD.00, L=QL2, B=-2.61145 , APER=QAR ;
    LL4: DRIFT, L=5.2932734;
    QF2: QUAD.00, L=QL2, B=2.79666, APER=QAR ;
    LL5: DRIFT, L=5.2932734 ;
    QD3: QUAD.00, L=QL2, B=-2.61145 , APER=QAR ;
    LL6: DRIFT, L=5.2932723,
    QF3: QUAD.00, L=QL2, B=2.79666, APER=QAR ;
    LL7: DRIFT, L=5.2932734 ;
    QD4: QUAD.00, L=QL2, B=-2.61145, APER=QAR ;
    LL8: DRIFT, L=5.2932734 ;
    QF4: QUAD.00, L=QL2, B=2.79666, APER=QAR ;
    LL9: DRIFT, L=5.2932734 ;
    QD5: QUAD.00, L=QL2, B=-2.61145, APER=QAR ;
    LLA: DRIFT, L=1.3966367;
    DR3: ROTAT, ANGLE=0.0 ;
    DD2: BEND, L=2.500, ANGLE=5.7297795 ;
    DR4: ROTAT, ANGLE=0.0 ;
    LLB: DRIFT, L=1.3966367,
    QF5: QUAD.00, L=QL2, B=QF, APER=QAR ;
    LLC: DRIFT, L=5.2932734 ;
    QD6: QUAD.00 L=QL2, B=QD, APER=QAR ;
    LLD: DRIFT, L=5.2932734 ;
    QF6: QUAD.00, L=QL2, B=QF, APER=QAR ;
    LLE: DRIFT, L=5.2932734 ;
    QD7: QUAD.00 L=QL2,B=QD, APER=QAR ;
    LLF: DRIFT, L=5.2932734 ;
    QF7: QUAD.00, L=QL2, B=QF, APER=QAR ;
    LLG: DRIFT, L=5.2932734 ;
    QD8: QUAD.00 L=QL2,B=QD, APER=QAR ;
    LLH: DRIFT, L=5.2932734 ;
    QF8: QUAD.00, L=QL2, B=QF, APER=QAR ;
    LLI: DRIFT, L=5.2932734 ;
    QD9: QUAD.00 L=QL2,B=QD, APER=QAR ;
    LLJ: DRIFT, L=5.2932734 ;
    QF9: QUAD.00, L=QL2, B=QF, APER=QAR ;
    LLK: DRIFT, L=1.3966367 ;
    DR5: ROTAT, ANGLE=0.0 ;
    DB3: BEND, L=2.5, ANGLE=5.7297795;
    DR6: ROTAT, ANGLE=0.0 ;
    LLL: DRIFT, L=1.3966367 ;
    QD9: QUAD.00 L=QL2,B=-2.61043, APER=QAR ;
    LLM: DRIFT, L=5.2932734 ;
    QF9: QUAD.00, L=QL2, B=2.92239, APER=QAR ;
    LLN: DRIFT, L=5.2932734 ;
    QDA: QUAD.00 L=QL2,B=-2.61043, APER=QAR ;
    LLO: DRIFT, L=1.3966367 ;
    DR7: ROTAT, ANGLE=0.0 ;
    DB4: BEND, L=2.5, ANGLE=5.7297795;
    DR8: ROTAT, ANGLE=0.0 ;
    LLP: DRIFT, L=1.3966367 ;
    QFA: QUAD.01, L=QL2, B=3.73958, APER=QAR ;
    LLQ: DRIFT, L=5.2932734 ;
    QDB: QUAD.01 L=QL2,B=-3.20893, APER=QAR ;
    LLR: DRIFT, L=1.000000 ;
```

```
QFB: QUAD.01, L=QL2, B=3.44683, APER=QAR ;
LLQ: DRIFT, L=5.000000 ;
QDC: QUAD.01 L=QL2,B=-2.94088, APER=QAR ;
LLR: DRIFT, L=1.000000 ;
QFC: QUAD.01, L=QL2, B=2.46113, APER=QAR ;
LLS: DRIFT, L=5.000000 ;
LLT: DRIFT, L=5.000000 ;
FPBT: FIT, BETAX=8.33000,TOLER=0.001 ;
FPB1: FIT, ALPHAX=0.000, TOLER=0.001 ;
FPB2: FIT, BETAY=1.02000,TOLER=0.001 ;
FPB3: FIT, ALPHAY=0.0000,TOLER=0.001 ;
SENTINEL
SENTINEL
```

B Input file for TRACE

```
$DATA
     ER= 939.29000, Q= 1., W= 1000.00000, XI= 21000.000,
     EMITI(1)= 120.000450, 119.998379, 977490.470943,
     BEAMI(1)= -0.00265, 24.74225, 0.03739, 1.89904, -0.00025, 0.01353,
     FREQ= 1.258, PQEXT= 2.50, ICHROM= 0,
     XM= 200.0000, XPM= 15.0000, YM= 190.00, DPM= 125.00, DWM= 800.00, DPP= 360.00,
     XMI= 100.0000, XPMI= 10.0000, XMF= 100.0000, XPMF= 5.0000,
     DPMI= 180.0000, DPMF= 180.0000, DWMI=9999.0000, DWMF=9999.0000,
     N1= 1, N2= 90, SMAX= 200.0, PQSMAX= 2.5, NEL1= 1, NEL2= 90, NP1= 1, NP2= 90,
     NPRIN=10,
     IJPRIN=1, 86,1, 87,1, 89,1, 90,1, 92,1, 93,1, 95,1, 96,1, 98,1, 99,
     BEAMF(1)= 0.00000, 83.30000, 0.00000, 10.20000, 24.59752, 16.24767,
     MT= 8,NC= 4,MP=1, 86 , 1, 92 , 1, 95 , 1, 98 , 0, 0 , 0, 0 ,
     MVC=1, 87, 1 , 1, 93, 1 , 1, 96, 1 , 1, 99, 1 , 0, 0, 0 , 0, 0, 0 ,
     IJM=2,6, 3,3, 0,0, 0,0, 0,0, 0,0,
     VAL= 0.0000000, 35.0000000, 0.0000000, 0.0000000, 0.0000000, 0.0000000,
     ISECURE=0,
     CMT( 1)=' ' NT( 1)= 3, A(1, 1)= 3.4684100 , 250.00000 ,
     CMT( 2)=' ' NT( 2)= 1, A(1, 2)= 5293.2734 ,
     CMT( 3)=' QD1 ' NT( 3)= 3, A(1, 3)=-3.4684100 , 250.00000 ,
     CMT( 4)=' ' NT( 4)= 3, A(1, 4)=-3.4684100 , 250.00000 ,
     CMT( 5)=' L ' NT( 5)= 1, A(1, 5)= 5293.2734 ,
     CMT( 6)=' QF1 ' NT( 6)= 3, A(1, 6)= 3.4684100 , 250.00000 ,
     CMT( 7)=' QF ' NT( 7)= 3, A(1, 7)= 3.4684100 , 250.00000 ,
     CMT( 8)=' ' NT( 8)= 1, A(1, 8)= 720.00000 ,
     CMT( 9)=' ' NT( 9)= 9, A(1, 9)=0.00000000E+00,-18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
     CMT( 10)=' ' NT( 10)= 8, A(1, 10)=-5.7297795 ,-18858.000 ,0.00000000E+00,
     CMT( 11)=' ' NT( 11)= 9, A(1, 11)=0.00000000E+00,-18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
     CMT( 12)=' L ' NT( 12)= 1, A(1, 12)= 2573.2734 ,
     CMT( 13)=' QD2 ' NT( 13)= 3, A(1, 13)=-3.4684100 , 250.00000 ,
     CMT( 14)=' ' NT( 14)= 3, A(1, 14)=-3.4684100 , 250.00000 ,
     CMT( 15)=' L ' NT( 15)= 1, A(1, 15)= 5293.2734 ,
     CMT( 16)=' QF2 ' NT( 16)= 3, A(1, 16)= 3.4684100 , 250.00000 ,
     CMT( 17)=' QF ' NT( 17)= 3, A(1, 17)= 3.4684100 , 250.00000 ,
     CMT( 18)=' L ' NT( 18)= 1, A(1, 18)= 5293.2734 ,
     CMT( 19)=' QD3 ' NT( 19)= 3, A(1, 19)=-3.4684100 , 250.00000 ,
     CMT( 20)=' ' NT( 20)= 3, A(1, 20)=-3.4684100 , 250.00000 ,
     CMT( 21)=' L ' NT( 21)= 1, A(1, 21)= 5293.2734 ,
     CMT( 22)=' QF3 ' NT( 22)= 3, A(1, 22)= 3.4684000 , 250.00000 ,
     CMT( 23)=' QF ' NT( 23)= 3, A(1, 23)= 3.4684000 , 250.00000 ,
     CMT( 24)=' L ' NT( 24)= 1, A(1, 24)= 5293.2734 ,
     CMT( 25)=' QD4 ' NT( 25)= 3, A(1, 25)=-3.4684100 , 250.00000 ,
     CMT( 26)=' ' NT( 26)= 3, A(1, 26)=-3.4684100 , 250.00000 ,
     CMT( 27)=' L ' NT( 27)= 1, A(1, 27)= 5293.2734 ,
     CMT( 28)=' QF4 ' NT( 28)= 3, A(1, 28)= 3.4684100 , 250.00000 ,
     CMT( 29)=' QF ' NT( 29)= 3, A(1, 29)= 3.4684100 , 250.00000 ,
     CMT( 30)=' L ' NT( 30)= 1, A(1, 30)= 5293.2734 ,
     CMT( 31)=' QD5 ' NT( 31)= 3, A(1, 31)=-3.4684100 , 250.00000 ,
     CMT( 32)=' ' NT( 32)= 3, A(1, 32)=-3.4684100 , 250.00000 ,
     CMT( 33)=' ' NT( 33)= 1, A(1, 33)= 2573.2734 ,
     CMT( 34)=' ' NT( 34)= 9, A(1, 34)=0.00000000E+00, 18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
     CMT( 35)=' ' NT( 35)= 8, A(1, 35)= 5.7297795 , 18858.000 ,0.00000000E+00,
     CMT( 36)=' ' NT( 36)= 9, A(1, 36)=0.00000000E+00, 18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
     CMT( 37)=' L ' NT( 37)= 1, A(1, 37)= 720.00000 ,
     CMT( 38)=' QF5 ' NT( 38)= 3, A(1, 38)= 3.4684100 , 250.00000 ,
     CMT( 39)=' QF ' NT( 39)= 3, A(1, 39)= 3.4684100 , 250.00000 ,
     CMT( 40)=' L ' NT( 40)= 1, A(1, 40)= 5293.2734 ,
     CMT( 41)=' QD6 ' NT( 41)= 3, A(1, 41)=-3.4684100 , 250.00000 ,
     CMT( 42)=' ' NT( 42)= 3, A(1, 42)=-3.4684100 , 250.00000 ,
     CMT( 43)=' L ' NT( 43)= 1, A(1, 43)= 5293.2734 ,
     CMT( 44)=' QF6 ' NT( 44)= 3, A(1, 44)= 3.4684100 , 250.00000 ,
     CMT( 45)=' QF6 ' NT( 45)= 3, A(1, 45)= 3.4684100 , 250.00000 ,
     CMT( 46)=' L ' NT( 46)= 1, A(1, 46)= 5293.2734 ,
     CMT( 47)=' QD7 ' NT( 47)= 3, A(1, 47)=-3.4684100 , 250.00000 ,
     CMT( 48)=' ' NT( 48)= 3, A(1, 48)=-3.4684100 , 250.00000 ,
     CMT( 49)=' L ' NT( 49)= 1, A(1, 49)= 5293.2734 ,
     CMT( 50)=' QF7 ' NT( 50)= 3, A(1, 50)= 3.4684100 , 250.00000 ,
     CMT( 51)=' QF ' NT( 51)= 3, A(1, 51)= 3.4684100 , 250.00000 ,
     CMT( 52)=' L ' NT( 52)= 1, A(1, 52)= 5293.2734 ,
     CMT( 53)=' QD8 ' NT( 53)= 3, A(1, 53)=-3.4684100 , 250.00000 ,
     CMT( 54)=' ' NT( 54)= 3, A(1, 54)=-3.4684100 , 250.00000 ,
     CMT( 55)=' L ' NT( 55)= 1, A(1, 55)= 5293.2734 ,
     CMT( 56)=' QF8 ' NT( 56)= 3, A(1, 56)= 3.4684100 , 250.00000 ,
     CMT( 57)=' QF ' NT( 57)= 3, A(1, 57)= 3.4684100 , 250.00000 ,
     CMT( 58)=' L ' NT( 58)= 1, A(1, 58)= 720.00000 ,
     CMT( 59)=' ' NT( 59)= 9, A(1, 59)=0.00000000E+00, 18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
     CMT( 60)=' ' NT( 60)= 8, A(1, 60)= 5.7297795 , 18858.000 ,0.00000000E+00,
     CMT( 61)=' L ' NT( 61)= 9, A(1, 61)=0.00000000E+00, 18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
     CMT( 62)=' ' NT( 62)= 1, A(1, 62)= 2573.2734 ,
     CMT( 63)=' QD9 ' NT( 63)= 3, A(1, 63)=-3.4684100 , 250.00000 ,
     CMT( 64)=' L ' NT( 64)= 3, A(1, 64)=-3.4684100 , 250.00000 ,
     CMT( 65)=' ' NT( 65)= 1, A(1, 65)= 5293.2734 ,
     CMT( 66)=' QF9 ' NT( 66)= 3, A(1, 66)= 3.4872970 , 250.00000 ,
```

```
CMT( 67)=' L ' NT( 67)= 3, A(1, 67)= 3.4872970 , 250.00000 ,
CMT( 68)=' ' NT( 68)= 1, A(1, 68)= 5293.2734 ,
CMT( 69)=' QDA ' NT( 69)= 3, A(1, 69)=-3.4684100 , 250.00000 ,
CMT( 70)=' ' NT( 70)= 3, A(1, 70)=-3.4684100 , 250.00000 ,
CMT( 71)=' ' NT( 71)= 1, A(1, 71)= 2573.2734 ,
CMT( 72)=' ' NT( 72)= 9, A(1, 72)=0.00000000E+00, 18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
CMT( 73)=' ' NT( 73)= 8, A(1, 73)= 5.7297795 , 18858.000 ,0.00000000E+00,
CMT( 74)=' L ' NT( 74)= 9, A(1, 74)=0.00000000E+00, 18858.000 ,0.00000000E+00,0.00000000E+00,0.00000000E+00,
CMT( 75)=' ' NT( 75)= 1, A(1, 75)= 720.00000 ,
CMT( 76)=' QFA ' NT( 76)= 3, A(1, 76)= 3.7600620 , 250.00000 ,
CMT( 77)=' ' NT( 77)= 3, A(1, 77)= 3.7600620 , 250.00000 ,
CMT( 78)=' ' NT( 78)= 1, A(1, 78)= 5200.0000 ,
CMT( 79)=' QDB ' NT( 79)= 3, A(1, 79)=-2.7559005 , 250.00000 ,
CMT( 80)=' ' NT( 80)= 3, A(1, 80)=-2.7559005 , 250.00000 ,
CMT( 81)=' ' NT( 81)= 1, A(1, 81)= 1000.0000 ,
CMT( 82)=' QFB ' NT( 82)= 3, A(1, 82)= 1.9885338 , 250.00000 ,
CMT( 83)=' ' NT( 83)= 3, A(1, 83)= 1.9885338 , 250.00000 ,
CMT( 84)=' ' NT( 84)= 1, A(1, 84)= 5000.0000 ,
CMT( 85)=' QDC ' NT( 85)= 3, A(1, 85)=-3.2118232 , 250.00000 ,
CMT( 86)=' ' NT( 86)= 3, A(1, 86)=-3.2118232 , 250.00000 ,
CMT( 87)=' ' NT( 87)= 1, A(1, 87)= 1000.0000 ,
CMT( 88)=' QFC ' NT( 88)= 3, A(1, 88)= 2.9560388 , 250.00000 ,
CMT( 89)=' ' NT( 89)= 3, A(1, 89)= 2.9560388 , 250.00000 ,
CMT( 90)=' L ' NT( 90)= 1, A(1, 90)= 10000.000 ,
$END
```

C Input file for PARMILA

```
RUN 1
    TITLE
    NSNS RTBT
    CHARGE 1
    LINAC 1 1000.00 1.258 1.001089
    TANK 1 1005.0 -30.0 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 8 -1001 0.018 188.997 0.0120 -0.0199 2351.945 0.0120 115.0 8.5
    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
    ELIMIT 5
    SCHEFF 0.00 0.5 0.5 20 40 0 0 3 1 3
    TRANS1 1 3 -346.84100 25.0 10. 0. 1 1 7 1
    TRANS1 2 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 3 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 4 1 72.00000 7.0 10. 0. 1 1 7 1
    TRANS1 5 13 12.00000 0.0 0 1000 0
    TRANS1 6 4 -5.72978 -1885.8 0 0. 0 1 7 1
    TRANS1 7 1 257.32734 20.0 20. 0. 1 1 7 1
    TRANS1 8 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 9 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 10 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 11 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 12 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 13 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 14 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 15 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 16 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 17 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 18 3 346.32734 50.0 10. 0. 1 1 7 1
    TRANS1 19 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 20 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 21 1 257.32734 20.0 10. 0. 1 1 7 1
    TRANS1 22 4 5.72978 1885.8 0 0. 0 1 7 1
    TRANS1 23 1 72.00000 7.0 10. 0. 1 1 7 1
    TRANS1 24 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 25 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 26 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 27 1 529.84100 20.0 10. 0. 1 1 7 1
    TRANS1 28 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 29 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 30 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 31 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 32 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 33 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 34 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 35 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 36 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 37 1 72.00000 7.0 10. 0. 1 1 7 1
    TRANS1 38 4 5.72978 1885.8 0 0. 0 1 7 1
    TRANS1 39 1 257.32734 7.0 10. 0. 1 1 7 1
    TRANS1 40 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 41 1 529.32734 27.0 10. 0. 1 1 7 1
    TRANS1 42 3 346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 43 1 529.32734 50.0 10. 0. 1 1 7 1
    TRANS1 44 3 -346.84100 50.0 10. 0. 1 1 7 1
    TRANS1 45 1 257.27340 50.0 10. 0. 1 1 7 1
    TRANS1 46 4 5.72978 1885.8 0 0. 0 1 7 1
    TRANS1 47 1 72.00000 7.0 10. 0. 1 1 7 1
    TRANS1 48 3 376.00620 50.0 10. 0. 1 1 7 1
    TRANS1 49 1 520.00000 50.0 20. 0. 1 1 7 1
    TRANS1 50 3 -275.59005 50.0 20. 0. 1 1 7 1
    TRANS1 51 1 100.00000 20.0 20. 0. 1 1 7 1
    TRANS1 52 3 198.85338 50.0 20. 0. 1 1 7 1
    TRANS1 53 1 500.00000 50.0 20. 0. 1 1 7 1
    TRANS1 54 3 -321.18232 50.0 20. 0. 1 1 7 1
    TRANS1 55 1 100.00000 50.0 20. 0. 1 1 7 1
    TRANS1 56 3 295.60388 50.0 20. 0. 1 1 7 1
    TRANS1 57 1 800.00000 50.0 20. 0. 1 1 7 1
    TRANS1 58 17 3.00000 00.0 20. 0. 1 1 7 1
    TRANS1 59 1 200.00000 50.0 20. 0. 1 1 7 1
    START
    STOP 0
    BEGIN
    END 1 0
```

D Input file for PARTRACE

```
run 1 1
    title
    NSNS RTBT
    charge 1
    linac 1 1000.00 1.258 1.001089
    tank 1 1005.0 -30.0 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 3 0.018 188.997 0.0120 -0.0199 2351.945 0.0120 115.0 8.5 0.0
    error 10. 0. 10. 0. 0. 0. 0. 0.000 0.05
    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
    optcon 3 3
    elimit 5
    scheff 0.00 0.5 0.5 20 40 0 0 3 1 3
    transl 1 3 -346.84100 25.0 10. 1. 1 1 7 1
    transl 2 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 3 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 4 1 72.00000 7.0 10. 0. 1 1 7 1
    transl 5 13 12.00000 0.0 0 1000 0
    transl 6 4 -5.72978 -1885.8 0 0. 0 1 7 1
    transl 7 1 257.32734 20.0 20. 0. 1 1 7 1
    transl 8 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 9 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 10 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 11 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 12 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 13 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 14 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 15 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 16 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 17 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 18 3 346.32734 50.0 10. 1. 1 1 7 1
    transl 19 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 20 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 21 1 257.32734 20.0 10. 0. 1 1 7 1
    transl 22 4 5.72978 1885.8 0 0. 0 1 7 1
    transl 23 1 72.00000 7.0 10. 0. 1 1 7 1
    transl 24 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 25 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 26 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 27 1 529.84100 20.0 10. 0. 1 1 7 1
    transl 28 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 29 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 30 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 31 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 32 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 33 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 34 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 35 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 36 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 37 1 72.00000 7.0 10. 0. 1 1 7 1
    transl 38 4 5.72978 1885.8 0 0. 0 1 7 1
    transl 39 1 257.32734 7.0 10. 0. 1 1 7 1
    transl 40 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 41 1 529.32734 27.0 10. 0. 1 1 7 1
    transl 42 3 346.84100 50.0 10. 1. 1 1 7 1
    transl 43 1 529.32734 50.0 10. 0. 1 1 7 1
    transl 44 3 -346.84100 50.0 10. 1. 1 1 7 1
    transl 45 1 257.27340 50.0 10. 0. 1 1 7 1
    transl 46 4 5.72978 1885.8 0 0. 0 1 7 1
    transl 47 1 72.00000 7.0 10. 0. 1 1 7 1
    transl 48 3 376.00620 50.0 10. 1. 1 1 7 1
    transl 49 1 520.00000 50.0 20. 0. 1 1 7 1
    transl 50 3 -275.59005 50.0 20. 1. 1 1 7 1
    transl 51 1 100.00000 20.0 20. 0. 1 1 7 1
    transl 52 3 198.85338 50.0 20. 1. 1 1 7 1
    transl 53 1 500.00000 50.0 20. 0. 1 1 7 1
    transl 54 3 -321.18232 50.0 20. 1. 1 1 7 1
    transl 55 1 100.00000 50.0 20. 0. 1 1 7 1
    transl 56 3 295.60388 50.0 20. 1. 1 1 7 1
    transl 57 1 500.00000 50.0 20. 0. 1 1 7 1
    transl 58 17 3.00000 00.0 20. 0. 1 1 7 1
    transl 59 1 500.00000 50.0 20. 0. 1 1 7 1
    start 0
    stop 0
    begin 100
    end 1 0
```