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TRS/vm

AA INJECTION AND EJECTION BEAM LINES

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Introduction

This note gives a summary of the beam optics calculated for the AA beam lines. A non-standard version of TRANSPORT has been used, but users of the standard CERN version should be able to follow the appended data lists. Appendix I explains the relevant differences as well as giving some correspondences between TRANSPORT and BEATCH data conventions. Data files are stored on the permanent data file base for the CDC-MFB computer under the names AADn, ID = PS 321 TRS.

Names of beam line magnets follow the system described in PS/AA/Mem.79-41 (Blechschmidt, Sherwood, 28.3.79) and differ from those used in previous (informal) notes.

Lists of beam elements are given showing beam size and required currents against apertures and maximum nominal current available. The geometrical layout is given in PS/ML/BS/nc, (Mayoud, Szeless, 25.5.79).

When reading the geometry and beam optic lists, the following points should be noted:

1. Distances are given along the beam axis, whether sloping or horizontal.

2. Magnetic lengths are usually used, but in any case, the centre of the element and the integral of the field or gradient are always well defined.

3. The length of a bending magnet is defined as the arc length of the central trajectory (TRANSPORT convention). For a rectangular magnet block, of length L, oriented symmetrically to the incoming and outgoing beams and which gives a deflection angle θ, we have the related lengths:

   a) arc-length, s, where

   $$s = L\theta/(2 \sin \frac{\theta}{2})$$

   and L', the distance from entry (or exit) to the intersection point of the entering and exiting beams where

   $$L' = (L/2) \sec \frac{\theta}{2}$$

   Usually s, 2L' and L are only slightly different.

4. Tilt angles are defined in the geometry memo. In TRANSPORT a a tilted magnet is treated by rotating the beam reference axis about the beam longitudinal direction so as to align it with the magnet element system. The angle is introduced via a TRANSPORT type 20 element. When the incoming beam X axis is horizontal, tilt and rotation angles are identical. Since beam envelopes are given in the beam reference system, the presence of tilted magnets introduces the discontinuities seen in the graphs. A vertical bending magnet is treated as a tilted magnet with tilt angle 90°.

Beam Envelopes

The injection line is treated in two parts:

a) From the PS to the antiproton production target

and

b) From the target to the end of the injection/ejection straight section.

The ejection line is taken from the start of the ejection straight section to a point just beyond the crossing with TT2.

The interpretation of the accompanying beam envelope and momentum vector graphs differ in these three sections.

Injection line PS to target

A small beam waist is required at the target for 26 GeV/c incident protons. The lower limit to beam size (apart from power density in the target itself) is given by the emittance and momentum spread of the PS beam as well as the apertures in the final vertical bending magnet and pulsed quadrupoles. The momentum vector ($^{\alpha}p$,$^{\alpha}p'$) should be zero at the target in both transverse planes., ($^{\alpha}p'$ does not affect beam size at the target but does use aperture in the upstream magnets). Such solutions were not found, in particular the condition ($^{\alpha'}p$)v was not possible and allowance had to be made for this.

The aperture required to pass this fraction of the beam is then

$$A = 2\left[w^2 + \left(\frac{\Delta p}{p}\,\alpha p\right)^2\right]^{\frac{1}{2}} + 2\,\frac{dp}{p}\,\alpha p$$

where w is the half-width of one component. Values of A_H, A_V are given in the table comparing required aperture with that available. No special allowance has been made for steering errors or poor magnetic field quality regions. In the calculations the starting point has been taken as magnet QD102. The beam parameters at this point were obtained from a BEATCH run for normal operation of TT2 when the beam is going to the ISR.

Injection line - Target to AA ring

The antiproton beam is matched to the AA ring using the lattice parameters given in the 7th edition of the parameter list (Jan. 1979) using an acceptance of 100π mm.mR., a momentum spread of ±0.75%. The septum magnets and the small effect of the kicker on the momentum vector are included.

It is assumed that the antiproton beam is a waist of radius 22 mm at the exit of the magnetic horn. The beam envelope is for $\frac{dp}{p} = 0$ and the required apertures are given by:

$$A = 2(w + \frac{dp}{p}\alpha_p)$$

Even to get $(\alpha p, \alpha p')_H = 0$ requires changing two quadrupoles, QF 107, in the TT2 line to run at currents a little higher than for normal ISR operation.

Solutions are given for the following beam sizes at the centre of the target:

1) horizontal 1.4 mm, vertical 1.5 mm
2) " 2.0 mm, " 2.0 mm
3) " 3.0 mm, " 3.0 mm

Two solutions are given for case 3). Beam envelopes are for zero momentum spread.

PS beam assumptions

The characteristics of the PS beam have been given in PS/DL/Note.78-7 (P. Lefèvre). If the beam is combined into five bunches at 26 GeV/c, we can consider it as a double beam, each component matched to the PS lattice but separated by a distance:

$$\delta x = \alpha_p \frac{dp}{p}$$

Each component is expected to have an emittance of 2π mm.mR and a momentum spread $\frac{\Delta p}{p} = \pm 10^{-3}$ (contains 95% of the beam) but separated in momentum by $\frac{dp}{p} = \pm 2.10^{-3}$.

The envelopes calculated are for a component emittance 2.46 mm mR giving nearer to 97½% of the beam (assuming a Gaussian model).

Ejection Line - AA ring to junction with TTL2

The hande-over point is at the end of EJ 2575(D8 is the TTL2 name). This is the second quadrupole magnet after the ejection line crosses TT2. At this point the matching conditions requested are:

$(\alpha_p)_H = 0$, $(\alpha_p')_H = 0$

$(\alpha_p)_V = -0.508$, $(\alpha_p')_V = -0.0135$

$L_H = 10$ mn , $L_V = 75$ m

$S_H = 0$, $S_V = 0$

The ejected beam is matched to the AA lattice with an initial horizontal momentum vector (-0.0745 m, 0.0039 rad) due to the ejection kicker. The emittances used are 1.4π mn mR for the horizonzal and $1.\pi$ mm mR for the vertical Beam envelopes are for $\frac{dp}{p} = 0$. Required apertures are given by:

$$A = 2\left[\left(w^2 + \left(\frac{dp}{p} = \alpha_p\right)^2\right]^{\frac{1}{2}}\right.$$

using a value of $\frac{dp}{p} = 3 \times 10^{-4}$.

The effect of momentum spread on aperture requirement is small for the above values.

APPENDIX I

Non-Standard TRANSPORT

The beam optic calculations were made using a non-standard version of TRANSPORT. The attached data lists are for this version. They differ from that required for the CERN version of TRANSPORT (CERN 73-16) in format and the presence of both non-standard element types and modified standard types. These differences are noted below. The purpose of these notes is to enable a person familiar with the standard version of TRANSPORT to be able to construct a standard data list.

1. Format. The data is given in a fixed format (1X, A10, 7F 10.5). The first word is any lable (or blank). The rest of the words on each line conform to the data requirement for the element type (word 2).

2. No indicator word is used.

3. Beam momentum (4th word) is entered via the type 16. element, not with a type 1 element.

4. The initial beam description is entered by the combination of the special type 24 emittance element and the modified type 1 element. The type 24 element gives three independent emittances for the horizontal, vertical and longitudinal planes in that order. The following type 1 element gives (in TRANSPORT notation)

$$\sigma_{11}^{\frac{1}{2}}, r_{12}, \sigma_{33}^{\frac{1}{2}}\ r_{34}, \sigma_{55}^{\frac{1}{2}}, r_{56}$$

5. The special type 22 element is used to obtain plots of beam envelopes.

Relations between some BEATCH and TRANSPORT parameters

1. Quadrupole strengths. TRANSPORT expect two parameters (words 4 and 5) viz. field and a radius.

The fields are given in KG and an arbitary radius of 1 cm is used. Consequently word 4 can be interpreted as gradient, G, in KG/am. BEATCH requires the parameter $K(m^{-2})$. G and K are related by

$$K = -\frac{G}{(B\rho)}$$

where G is in T/m , $B\rho$ is in T.m

In TRANSPORT G is positive for a horizontally focussing magnet.

2. Bending magnet lengths. BEATCH uses the straight length of a straight magnet while TRANSPORT uses the arc length of the reference trajectory.

3. BEATCH uses the parameters L, S. TRANSPORT uses the sigma matrix

Horizontal beam size , $\sigma_{11}^{\frac{1}{2}} = \left[(\varepsilon/L_H)\ \ (S_H{}^2 + L_H^2)\right]^{\frac{1}{2}}$

" divergence , $\sigma_{22}^{\frac{1}{2}} = (\varepsilon/L_H)^{\frac{1}{2}}$

Distance to beam waist is $r_{12} \cdot (\sigma_{11}/\sigma_{22})^{\frac{1}{2}} = S_H$

giving $r_{12} = S_H / (L^2 + S^2)^{\frac{1}{2}}$

ε is the emittance (ellipe area / π)

E R R A T U M

Please note that all magnetic elements in the ejection line should have names of the form xyz 25 nn <u>NOT</u> xyz 24 nn as in the data lists and diagrams.

```
D1OMMFILE  START QD102. APH=0 AFTER BTI11. SMALL SPOT ON TARGET 22/05/79  17.47.
SETMOM     16.000000 16.000000 20.000000
EMIT       24.000000   .246000   .246000   .000100  0.000000
BEAM        1.000000   .594620  -.720385   .772111   .009301100.000000  0.000000
PLOT       22.000000   .400000  0.000000200.000000  0.000000  1.000000
INTR2       6.000000  0.000000  2.000000
ALPHAIN    14.00000   1.00000
   1.00000  0.00000   0.00000   0.00000   0.00000   1.56470
ALPHAPIN   14.00000   2.00000
   0.00000  1.00000   0.00000  -0.00000  -0.00000  -1.71600
D0          3.000000  0.000000
QD102       5.000000  1.200000  -.986960  1.000000
D4          3.000000   .700000
ZROT1      20.000000-90.000000
EDG10       2.000000   .050500
VB101       4.000000  2.200030  6.953090  0.000000
EDG10       2.000000   .050500
ZROT1      20.000000 90.000000
D5          3.000000  2.316000
QF103       5.000000  1.200000   .872132  1.000000
D6          3.000000  2.371000
EDGE11      2.000000   .378000
HB102       4.000000  1.850000  6.188000  0.000000
EDG11       2.000000   .378000
D7          3.000000  8.094900
QD104       5.000000  1.200000  -.687576  1.000000
D8          3.000000  8.515000
QF105       5.010000  1.200000   .779320  1.000000
D9          3.000000   .700000
EDG12       2.000000  -.244000
HB103       4.000000  1.400000 -5.286640  0.000000
EDG12       2.000000  -.244000
D10         3.000000  1.553000
ZROT2      20.000000 90.000000
EDG13       2.000000   .050500
VB102       4.000000  2.200030  6.953090  0.000000
EDG13       2.000000   .050500
ZROT2      20.000000-90.000000
D11         3.000000  1.946000
QD106       5.000000  1.200000  -.745900  1.000000
D12         3.000000  7.960000
QF107       5.010000  1.200000   .784521  1.000000
D13         3.000000 13.080000
QD208       5.000000   .820000 -1.019570  1.000000
D14         3.000000  7.940000
QF209       5.000000   .800000  1.006040  1.000000
D15         3.000000  8.430000
QD210       5.000000   .800000 -1.021560  1.000000
D16         3.000000  8.430000
QF211       5.000000   .800000  1.006040  1.000000
D17         3.000000  8.430000
QD212       5.000000   .800000 -1.021560  1.000000
D18         3.000000  8.430000
QF213       5.000000   .800000  1.006040  1.000000
D19         3.000000  8.420000
QD214       5.000000   .820000 -1.019570  1.000000
D20         3.000000  8.420000
QF215       5.000000   .800000  1.006040  1.000000
D21         3.000000   .590000
TLT1       20.000000-14.085600
EDG000      2.000000  1.150000
BTI00       4.000000  2.500200 13.952518  0.000000
EDG000      2.000000  1.150000
D22         3.000000   .750000
EDG001      2.000000  1.150000
BTI01       4.000000  2.500200 13.952518  0.000000
EDG001      2.000000  1.150000
TLBT1      20.000000 14.041900
D23         3.000000  3.229000
QIN05       5.010000   .800000 -1.114766   1.000000
D24         3.000000  1.019000
TLT2       20.000000-14.041900
EDG010      2.000000  1.037000
BTI10       4.000000  1.960100 16.024625  0.000000
EDG010      2.000000  1.037000
D25         3.000000   .633000
EDG011      2.000000  1.037000
BTI11       4.000000  1.960100 16.024625  0.000000
EDG011      2.000000  1.037000
[illegible] 10.000000 13.927800
COND10     10.000000-21.000000  6.000000  0.000000   .001000
COND11     10.000000-22.000000  6.000000  0.000000   .001000
D26         3.000000 11.173840
QIN15       5.010000   .800000  1.226308  1.000000
D27         3.000000  6.906100
QIN30       5.010000   .800000 -1.616533  1.000000
D28         3.000000 21.200000
QIN35       6.010000   .800000  -.030079  1.000000
D29         3.000000   .902840
ZROT       20.000000 90.000000
EDGV01      2.000000  1.062000
BVI40       4.000000  1.960100 16.402290  0.000000
EDGV01      2.000000  1.052000
ZROTR      20.000000-90.000000
D30         3.         3.068
QIN50       5.000000  1.060000  3.122869  1.000000
D31         3.000000   .547500
QIN52       5.010000  1.060000 -5.158794 1.000000
D32         3.000000  1.250000
QIN55       5.020000   .450000  4.165266  1.000000
D33         3.000000   .150000
QIN56       6.620000   .450000  4.165266  1.000000
D34         3.000000  1.760000
COND1      10.000000  1.000000  1.000000   .070000   .001000
COND3      10.000000  3.000000  3.000000   .077000   .000100
COND2      10.000000  2.000000  1.000000  0.000000   .001000
COND4      10.000000  4.000000  3.000000  0.000000   .001000
COND13     10.000000-23.000000  6.000000  0.000000   .001000
 SENTINEL.
```

LIST 1 Data list AAD10. Injection line from TT2 to target.
Beam diameter on target 1.5 mm

```
D11MPFILE  START QD102, APH=0 AFTER BTI11. 2MM SPOT ON TARGET 22/05/79  17.47.
SETMOM       16.000000 16.000000 26.000000
EMIT         24.000000   .246000   .246000   .000100  0.000000
BEAM          1.000000   .594620  -.728385   .772111   .809301100.000000  0.000000
PLOT         22.000000   .400000  0.000000200.000000  0.000000  1.000000
INTR2         6.000000  0.000000  2.000000
ALPHAIN      14.00000    1.00000
   1.00000    0.00000    0.00000   0.00000   0.00000   1.56470
ALPHAPIN     14.00000    2.00000
   0.00000    1.00000    0.00000  -0.00000  -0.00000  -1.71600
D0            3.000000  0.000000
QD102         5.000000  1.200000  -.986960  1.000000
D4            3.000000   .700000
ZROT1        20.000000-90.000000
EDG10         2.000000   .050500
VB101         4.000000  2.200030  6.953090  0.000000
EDG10         2.000000   .050500
ZROT1        20.000000 90.000000
D5            3.000000  2.316000
QF103         5.000000  1.200000   .872132  1.000000
D6            3.000000  2.371000
EDGE11        2.000000   .378000
HB102         4.000000  1.850000  6.188080  0.000000
EDG11         2.000000   .378000
D7            3.000000  8.094960
QD104         5.000000  1.200000  -.687576  1.000000
D8            3.000000  8.515000
QF105         5.010000  1.200000   .780143  1.000000
D9            3.000000   .700000
EDG12         2.000000  -.244000
HB103         4.000000  1.400000 -5.286640  0.000000
EDG12         2.000000  -.244000
D10           3.000000  1.553000
ZROT2        20.000000 90.000000
EDG13         2.000000   .050500
VB102         4.000000  2.200030  6.953090  0.000000
EDG13         2.000000   .050500
ZROT2        20.000000-90.000000
D11           3.000000  1.966000
QD106         5.000000  1.200000  -.745900  1.000000
D12           3.000000  7.966000
QF107         5.010000  1.200000   .784202  1.000000
D13           3.000000 13.680000
QD208         5.000000   .820000 -1.019570  1.000000
D14           3.000000  7.940000
QF209         5.000000   .800000  1.006040  1.000000
D15           3.000000  8.430000
QD210         5.000000   .800000 -1.021560  1.000000
D16           3.000000  8.430000
QF211         5.000000   .800000  1.006040  1.000000
D17           3.000000  8.430000
QD212         5.000000   .800000 -1.021560  1.000000
D18           3.000000  8.430000
QF213         5.000000   .800000  1.006040  1.000000
D19           3.000000  8.420000
QD214         5.000000   .820000 -1.019570  1.000000
D20           3.000000  8.420000
QF215         5.000000   .800000  1.006040  1.000000
D21           3.000000   .590000
TLT1         20.000000-14.085600
EDG000        2.000000  1.150000
BTI00         4.000000  2.500200 13.952518  0.000000
EDG000        2.000000  1.150000
D22           3.000000   .750000
EDG001        2.000000  1.150000
BTI01         4.000000  2.500200 13.952518  0.000000
EDG001        2.000000  1.150000
TLBT1        20.000000 14.041900
D23           3.000000  3.229000
QIN05         5.010000   .800000 -1.101001  1.000000
D24           3.000000  1.019000
TLT2         20.000000-14.041900
EDG010        2.000000  1.037000
BTI10         4.000000  1.960100 10.024625  0.000000
EDG010        2.000000  1.037000
D25           3.000000   .633000
EDG011        2.000000  1.037000
BTI11         4.000000  1.960100 10.024625  0.000000
EDG011        2.000000  1.037000
TILT0L       20.000000 13.523400
COND10       10.000000-21.000000  6.000000  0.000000   .001000
COND11       10.000000-22.000000  6.000000  0.000000   .001000
D26           3.000000 11.170840
QIN15         5.010000   .800000  1.216346  1.000000
D27           3.000000  6.900100
QIN30         5.010000   .800000 -1.531706  1.000000
D28           3.000000 21.200000
QIN35         5.010000   .800000   .699012  1.000000
D29           3.000000   .902840
ZROT         20.000000 90.000000
EDGV01        2.000000  1.062000
BVT40         4.000000  1.960100 10.402290  0.000000
EDGV01        2.000000  1.062000
ZROTB        20.000000-90.000000
D30           3.           3.068
QIN50         5.000000  1.060000  2.096061  1.000000
D31           3.000000   .547500
QIN52         5.010000  1.060000 -4.800000 1.000000
D32           3.000000  1.250000
QIN55         5.020000   .450000  4.880198  1.000000
D33           3.000000   .150000
QIN56         5.020000   .450000  4.880198  1.000000
D34           3.000000  1.760000
COND1        10.000000  1.000000  1.000000   .100000   .001000
COND3        10.000000  3.000000  3.000000   .100000   .000100
COND2        10.000000  2.000000  1.000000  0.000000   .001000
COND4        10.000000  4.000000  3.000000  0.000000   .001000
COND13       10.000000-23.000000  6.000000  0.000000   .001000
 SENTINEL
```

LIST 2 Data list AAD11. Injection line from TT2 to target.
Beam diameter 2 mm on target.

```
D12MMFILE  START QD102..APH=0 AFTER BTI11. 3MM-8 SPOT ON TARGET 22/05/79  17.47.
SETMOM      16.000000 16.000000 20.000000
EMIT        24.000000   .246000   .246000   .000100  0.000000
BEAM         1.000000   .594620  -.728386   .772111   .809301100.000000  0.000000
PLOT        22.000000   .400000  0.000000200.000000  0.000000  1.000000
INTR2        6.000000  0.000000  2.000000
ALPHAIN     14.00000   1.00000
  1.00000    0.00000   0.00000   0.00000   0.00000   1.50470
ALPHAPIN    14.00000   2.00000
  0.00000    1.00000   0.00000   0.00000   0.00000  -1.71600
D0           3.000000  0.000000
QD102        5.000000  1.200000  -.986960  1.000000
D4           3.000000   .700000
ZROT1       20.000000-90.000000
EDG10        2.000000   .050500
VB101        4.000000  2.200030  6.953090  0.000000
EDG10        2.000000   .050500
ZROT1       20.000000 90.000000
D5           3.000000  2.316000
QF103        5.000000  1.200000   .872132  1.000000
D6           3.000000  2.371000
EDGE11       2.000000   .378000
HB102        4.000000  1.850000  6.185080  0.000000
EDG11        2.000000   .378000
D7           3.000000  8.094900
QD104        5.000000  1.200000  -.687576  1.000000
D8           3.000000  8.515000
QF105        5.010000  1.200000   .773379  1.000000
D9           3.000000   .700000
EDG12        2.000000  -.244000
HB103        4.000000  1.400000 -5.286640  0.000000
EDG12        2.000000  -.244000
D10          3.000000  1.553000
ZROT2       20.000000 90.000000
EDG13        2.000000   .050500
VB102        4.000000  2.200030  6.953090  0.000000
EDG13        2.000000   .050500
ZROT2       20.000000-90.000000
D11          3.000000  1.966000
QD106        5.000000  1.200000  -.745900  1.000000
D12          3.000000  7.966000
QF107        5.010000  1.200000   .786792  1.000000
D13          3.000000 13.680000
QD208        5.000000   .820000 -1.019570  1.000000
D14          3.000000  7.940000
QF209        5.000000   .800000  1.006040  1.000000
D15          3.000000  8.430000
QD210        5.000000   .800000 -1.021560  1.000000
D16          3.000000  8.430000
QF211        5.000000   .800000  1.006040  1.000000
D17          3.000000  8.430000
QD212        5.000000   .800000 -1.021560  1.000000
D18          3.000000  8.430000
QF213        5.000000   .800000  1.006040  1.000000
D19          3.000000  8.420000
QD214        5.000000   .820000 -1.019570  1.000000
D20          3.000000  8.420000
QF215        5.000000   .800000  1.006040  1.000000
D21          3.000000   .590000
TLT1        20.000000-14.085600
EDG000       2.000000  1.150000
BTI00        4.000000  2.500200 13.952518  0.000000
EDG000       2.000000  1.150000
D22          3.000000   .750000
EDG001       2.000000  1.150000
BTI01        4.000000  2.500200 13.952518  0.000000
EDG001       2.000000  1.150000
TLOT1       20.000000 14.041900
D23          3.000000  3.229000
QIN05        5.010000   .800000 -1.214061  1.000000
D24          3.000000  1.019000
TLT2        20.000000-14.041900
EDG010       2.000000  1.037000
BTI10        4.000000  1.960100 16.024625  0.000000
EDG010       2.000000  1.037000
D25          3.000000   .633000
EDG011       2.000000  1.037000
BTI11        4.000000  1.960100 16.024625  0.000000
EDG011       2.000000  1.032000
TILT82      20.000000 13.927600
COND10      10.000000-21.000000  6.000000  0.000000   .001000
COND11      10.000000-22.000000  6.000000  0.000000   .001000
D26          3.000000 11.170840
QIN15        5.010000   .800000  1.209183  1.000000
D27          3.000000  6.906100
QIN30        5.010000   .800000 -1.452392  1.000000
D28          3.000000 21.200000
QIN35        5.010000   .800000  1.091484  1.000000
D29          3.000000   .902840
ZROT        20.000000 90.000000
EDGV01       2.000000  1.062000
BVI40        4.000000  1.960100 16.402290  0.000000
EDGV01       2.000000  1.062000
ZROTA       20.000000-90.000000
D30          3.           3.068
QIN50        5.000000  1.060000  0.812070  1.000000
D31          3.000000   .547500
QIN52        5.010000  1.060000 -4.050000 1.000000
D32          3.000000  1.250000
QIN55        5.020000   .450000  4.880198  1.000000
D33          3.000000   .150000
QIN56        5.020000   .450000  4.880198  1.000000
D34          3.000000  1.760000
COND1       10.000000  1.000000  1.000000   .150000   .001000
COND3       10.000000  3.000000  3.000000   .150000   .000100
COND2       10.000000  2.000000  1.000000  0.000000   .001000
COND4       10.000000  4.000000  3.000000  0.000000   .001000
COND13      10.000000-23.000000  6.000000  0.000000   .001000
  SENTINEL
```

LIST 3 Data list AAD12. Injection line from TT2 to target.
Beam diameter on target 3 mm. Solution 1.

```
D3MNFILE  START QD102. APH=0 AFTER BTI11. 3MM SPOT ON TARGET 22/05/79  17.47.52.
SETMOM      16.000000  16.000000  26.000000
EMIT        24.000000    .246000    .246000    .000100   0.000000
BEAM         1.000000    .594620   -.728385    .772111    .009301100.000000   0.000000
PLOT        22.000000    .400000   0.000000200.000000   0.000000   1.000000
INTRO        6.000000   0.000000   2.000000
ALPHAIN     14.00000    1.00000
   1.00000   0.00000    0.00000    0.00000    0.00000    1.56470
ALPH/PIN    14.00000    2.00000
   0.00000  -1.00000    0.00000    0.00000    0.00000   -1.71600
D0           3.000000   0.000000
QD102        5.000000   1.200000   -.986960   1.000000
D4           3.000000    .700000
ZROT1       20.000000 -90.000000
EDG10        2.000000    .050500
VB101        4.000000   2.200030   6.953090   0.000000
EDG10        2.000000    .050500
ZROT1       20.000000  90.000000
D5           3.000000   2.316000
QF103        5.000000   1.200000    .872132   1.000000
D6           3.000000   2.371000
EDGE11       2.000000   -.378000
HB102        4.000000   1.850000   6.188080   0.000000
EDG11        2.000000    .378000
D7           3.000000   8.094900
QD104        5.000000   1.200000   -.687576   1.000000
D8           3.000000   8.515000
QF105        5.010000   1.200000    .848603   1.000000
D9           3.000000    .700000
EDG12        2.000000   -.244000
HB103        4.000000   1.400000  -5.286640   0.000000
EDG12        2.000000   -.244000
D10          3.000000   1.553000
ZROT2       20.000000  90.000000
EDG13        2.000000    .050500
VB102        4.000000   2.200030   6.953090   0.000000
EDG13        2.000000    .050500
ZROT2       20.000000 -90.000000
D11          3.000000   1.960000
QD106        5.000000   1.200000   -.745900   1.000000
D12          3.000000   7.966000
QF107        5.010000   1.200000    .752495   1.000000
D13          3.000000  13.680000
QD208        5.000000    .826000  -1.019570   1.000000
D14          3.000000   7.940000
QF209        5.000000    .806000   1.006040   1.000000
D15          3.000000   8.430000
QD210        5.000000    .806000  -1.021560   1.000000
D16          3.000000   8.430000
QF211        5.000000    .800000   1.006040   1.000000
D17          3.000000   8.430000
QD212        5.000000    .600000  -1.021560   1.000000
D18          3.000000   8.430000
QF213        5.000000    .800000   1.006040   1.000000
D19          3.000000   8.420000
QD214        5.000000    .626000  -1.019570   1.000000
D20          3.000000   8.420000
QF215        5.000000    .800000   1.006040   1.000000
D21          3.000000    .590000
TLT1        20.000000 -14.005600
EDG000       2.000000   1.150000
BTI00        4.000000   2.500200  13.952518   0.000000
EDG000       2.000000   1.150000
D22          3.000000    .750000
EDG001       2.000000   1.150000
BTI01        4.000000   2.500200  13.952518   0.000000
EDG001       2.000000   1.150000
TLBT1       20.000000  14.041900
D23          3.000000   3.229000
QIN05        5.010000    .800000    .051951   1.000000
D24          3.000000   1.019000
TLT2        20.000000 -14.041900
EDG010       2.000000   1.037000
BTI10        4.000000   1.960100  16.024625   0.000000
EDG010       2.000000   1.037000
D25          3.000000    .633000
EDG011       2.000000   1.037000
BTI11        4.000000   1.960100  16.024625   0.000000
EDG011       2.000000   1.037000
TITB1       20.000000  13.917900
COND10      10.000000 -21.000000   6.000000   0.000000    .001000
COND11      10.000000 -22.000000   6.000000   0.000000    .001000
D26          3.000000  11.170840
QIN16        5.010000    .800000    .984065   1.000000
D27          3.000000   6.906100
QIN30        5.010000    .800000   -.991106   1.000000
COND6       10.200000   3.000000   3.000000   2.600000    .001000
D28          3.000000  21.200000
QIN35        5.010000    .800000   1.284056   1.000000
D29          3.000000    .902840
COND5       10.200000   1.000000   1.000000   1.400000    .001000
ZROT        20.000000  90.000000
EDGV01       2.000000   1.062000
BVT40        4.000000   1.960100  16.402290   0.000000
EDGV01       2.000000   1.062000
ZROTB       20.000000 -90.000000
D30          3.000000   3.660000
QIN50        5.000000   1.060000   0.000000   1.000000
D31          3.000000    .547500
QIN52        5.010000   1.060000  -2.97235    1.000000
D32          3.000000   1.250000
QIN55        5.020000    .450000   5.489082   1.000000
D33          3.000000    .150000
QIN56        5.020000    .450000   5.489082   1.000000
D34          3.000000   1.760000
COND1       10.000000   1.000000   1.000000    .150000    .001000
COND3       10.000000   3.000000   3.000000    .150000    .000100
COND2       10.000000   2.000000   1.000000   0.000000    .001000
COND4       10.000000   4.000000   3.000000   0.000000    .001000
COND13      10.000000 -23.000000   6.000000   0.000000    .001000
  SENTINEL
```

LIST 4 Data list AAD3. Injection line from TT2 to target.
Beam diameter on target 3 mm. Solution 2.

```
D1SOL1     AAD1 FINAL VERSION 25/4/79 TARGET TO AA RING         16/05/79  12.21.22.
P           16.000000 16.000000  3.575200
*EMITT*     24.000000 10.000000 10.000000 75.000000  0.000000
*BEAM*       1.000000  2.200000  0.000000  2.200000  0.000000100.000000  0.000000
*SP CH*     ?2.000000   .250000  0.000000200.000000  0.000000  1.000000
*SLIT*       0.000000  0.000000  2.000000
D            3.000000  2.810000
Q60          5.010000  1.160000  -.457392  1.000000
D            3.000000   .340000
Q65          5.010000  1.160000   .440517  1.000000
D            3.000000   .459600
EG           2.000000  2.250000
BHZ70        4.000000  1.140300  8.213910  0.000000
EG           2.000000  2.250000
D            3.000000  7.849600
Q75          5.010000  1.160000  -.234131  1.000000
D            3.000000   .840000
Q80          5.010000  1.160000   .151600  1.000000
D            3.000000  8.100000
Q85          5.010000  1.160000   .127873  1.000000
D            3.000000  3.920000
Q90          5.010000  1.160000  -.203178  1.000000
D            3.000000  3.420000
Q95          5.010000  1.160000   .148980  1.000000
D            3.000000  8.052200
EG           2.000000  6.500000
SMH24        4.000000   .900000  6.820000  0.000000
EG           2.000000 -3.549270
D            3.000000   .575000
EG           2.000000  3.549270
QDW1         4.000000   .750000  2.548112334.312000
EG           2.000000 -2.614410
D            3.000000   .575000
EG           2.000000  2.614410
SMH1         4.000000   .900000  6.820000  0.000000
EG           2.000000   .336000
D            3.000000  3.920500
COND1       10.000000  1.000000  1.000000  4.318970   .001000
COND2       10.000000  2.000000  2.000000  4.050810   .001000
COND3       10.000000  3.000000  3.000000  2.816190   .001000
COND4       10.000000  4.000000  4.000000  3.713300   .001000
COND5       10.000000-21.000000  6.000000   .109000   .001000
COND6       10.000000-22.000000  6.000000   .063000   .001000
  SENTINEL
```

LIST 5 Data list AAD1. Injection line. Target to AA ring

```
D7SOL1                    AA EJECTION-FINAL                                     14/06/79   08.58.16.
P                16.000000 16.000000  3.575200
EMIT             24.000000   .140000   .100000   .000010  0.000000
BEAM              1.000000   .511027  -.820547   .281819  -.294713100.000000   0.000000
PLOT             22.000000   .500000  0.000000200.000000  0.000000   1.000000
INTR2             6.000000  0.000000  2.000000
INTAP            14.00000    1.00000
     1.00000      0.00000    0.00000   0.00000   0.00000   -.07450
INTAPP           14.00000    2.00000
     0.00000      1.00000    0.00000  -0.00000   0.00000    .03890
D0                3.000000  0.000000
D1                3.000000  3.920500
EDG1              2.000000  -.215000
SMH1              4.000000   .900000 -6.824000  0.000000
EDG2              2.000000 -2.736000
D2                3.000000   .575000
EDG3              2.000000  2.736000
QDW1              4.000000   .750000 -2.259410425.200000
EDG4              2.000000 -3.549000
D3                3.000000   .575000
EDG5              2.000000  3.549000
SMH24             4.000000   .900000 -6.824000  0.000000
EDG6              2.000000 -6.500000
D4                3.000000  7.160000
QEJ2410           5.010000   .500000   .831380  1.000000
D5                3.000000  1.700000
QEJ2415           5.010000   .500000  -.908389  1.000000
D6                3.000000   .812900
ROTZ1            20.000000-17.559700
EDG7              2.000000 -6.859600
BTI2420           4.000000  1.964700-14.534070  0.000000
EDG8              2.000000 -6.859600
ROTZ1B           20.000000 17.043200
D7                3.000000 -3.092900
QEJ2430           5.010000   .500000   .951020  1.000000
D8                3.000000  4.090000
QEJ2435           5.010000   .500000  -.886993  1.000000
COND10           10.200000  3.000000  3.000000   .800000   .100000
D9                3.000000  5.300000
QEJ2440           5.010000   .500000   .836143  1.000000
COND9            10.200000  1.000000  1.000000   .750000   .100000
D10               3.000000  3.040000
QEJ2445           5.010000   .500000  -.986792  1.000000
D11               3.000000  5.920000
QEJ2450           5.010000   .500000  1.056610  1.000000
D12               3.000000   .635500
ROTZ2            20.000000-15.316947
EDG9              2.000000  7.580000
BTI2455           4.000000  1.964690 16.056152  0.000000
EDG10             2.000000  7.580000
ROTZ2B           20.000000 15.883200
D13               3.000000   .782700
QEJ2460           5.000000   .500000 -1.050000  1.000000
D14               3.000000  1.713000
QEJ2565           5.010000   .500000   .660174  1.000000
D15               3.000000  6.752200
QEJ2470           5.010000   .500000   .361335  1.000000
D16               3.000000  3.850000
QEJ2475           5.010000   .500000  -.339440  1.000000
COND1            10.000000-21.000000  6.000000  0.000000   .001000
COND2            10.000000-22.000000  6.000000  0.000000   .001000
COND3            10.000000-23.000000  6.000000  -.507626   .001000
COND4            10.000000-24.000000  6.000000  -.134760   .001000
COND5            10.000000  1.000000  1.000000   .374160   .000100
COND6            10.000000  2.000000  1.000000  0.000000   .001000
COND7            10.000000  3.000000  3.000000   .865000   .000100
COND8            10.000000  4.000000  3.000000  0.000000   .001000
DOEND             3.000000  1.000000
 SENTINEL
```

LIST 6 Data list AAD7. Ejection line.

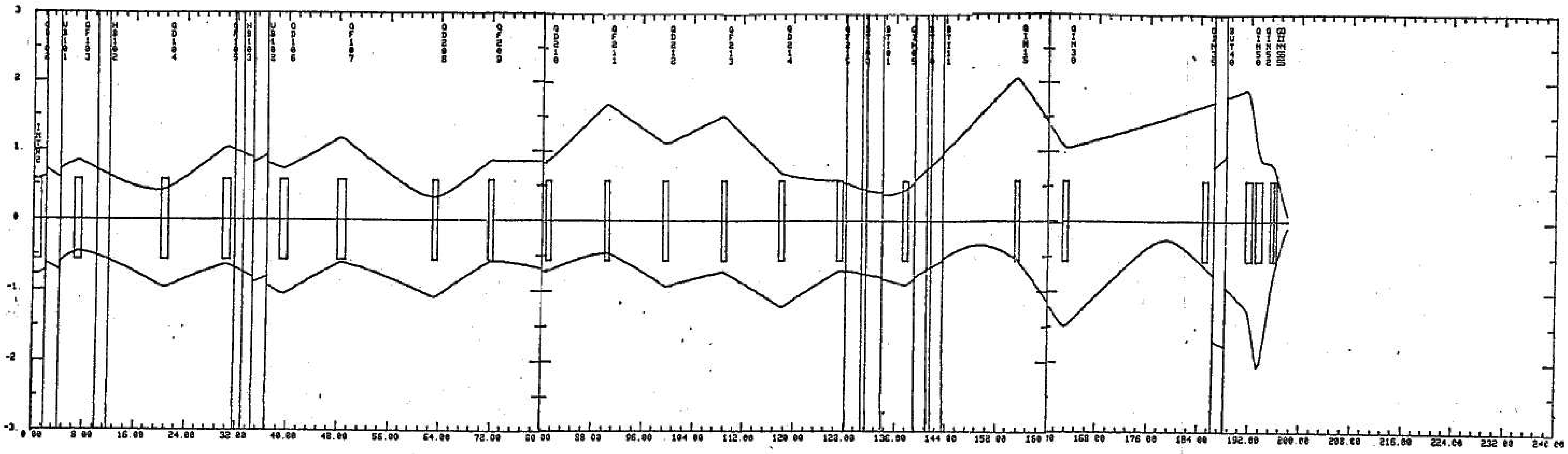

Fig. 1. Beam Envelopes from TT2 to target. Beam diameter on target 1.5 mm LIST 1. Data set AAD10

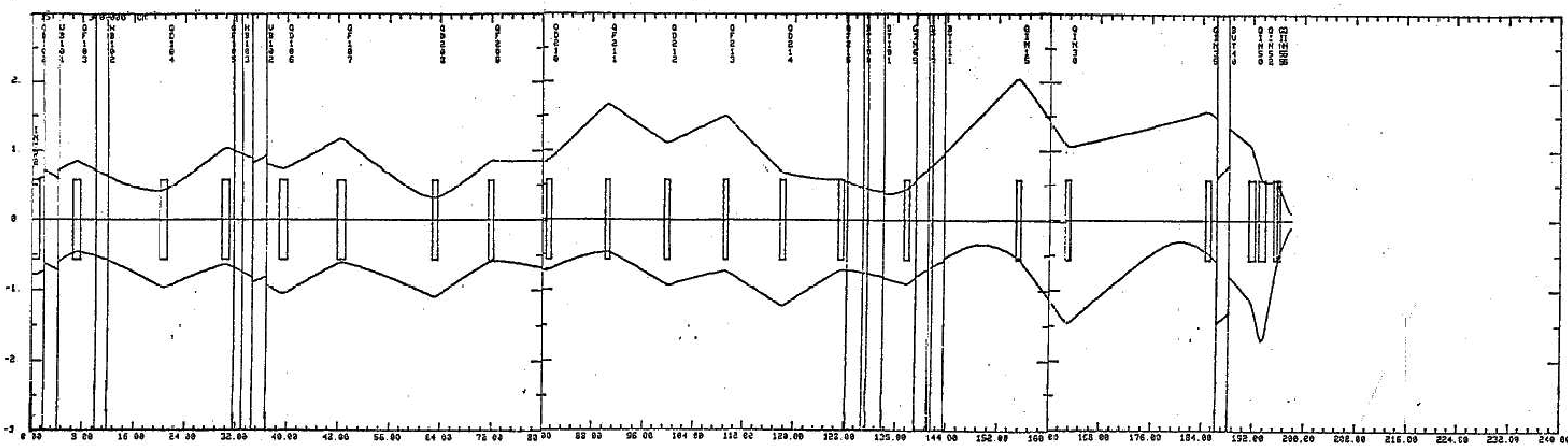

Fig. 2. Beam Envelopes from TT2 to target. Beam diameter on target 2.0 mm LIST 2. Data set AAD11

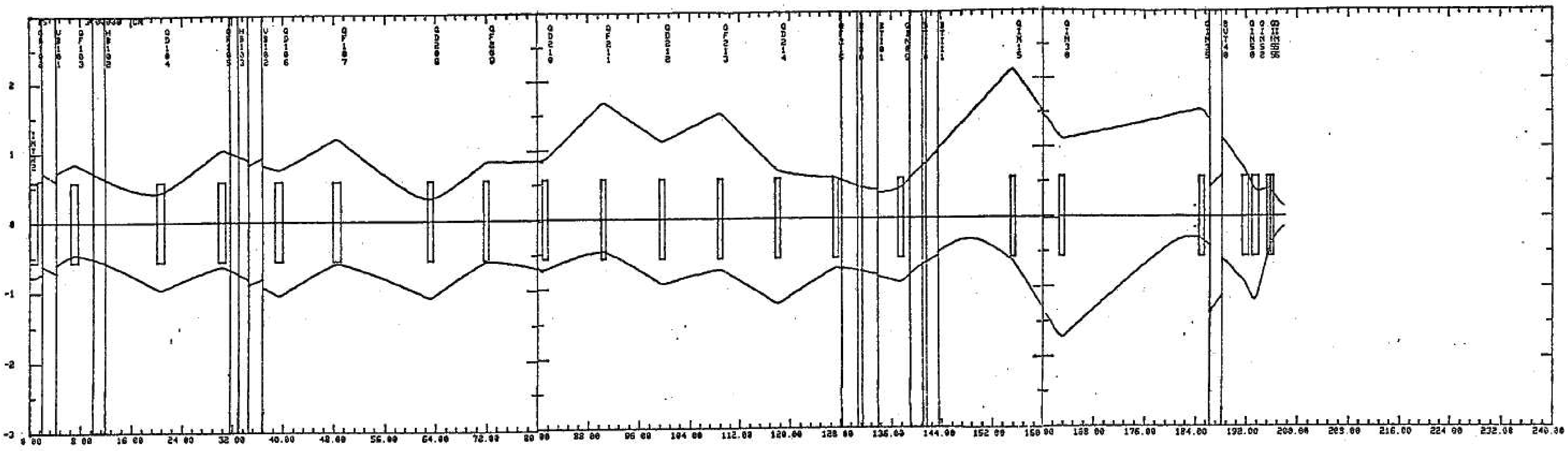

Fig. 3. Beam Envelopes from TT2 to target. Beam diameter on target 3.0 mm LIST 3. Data set ADD12 Solution 1

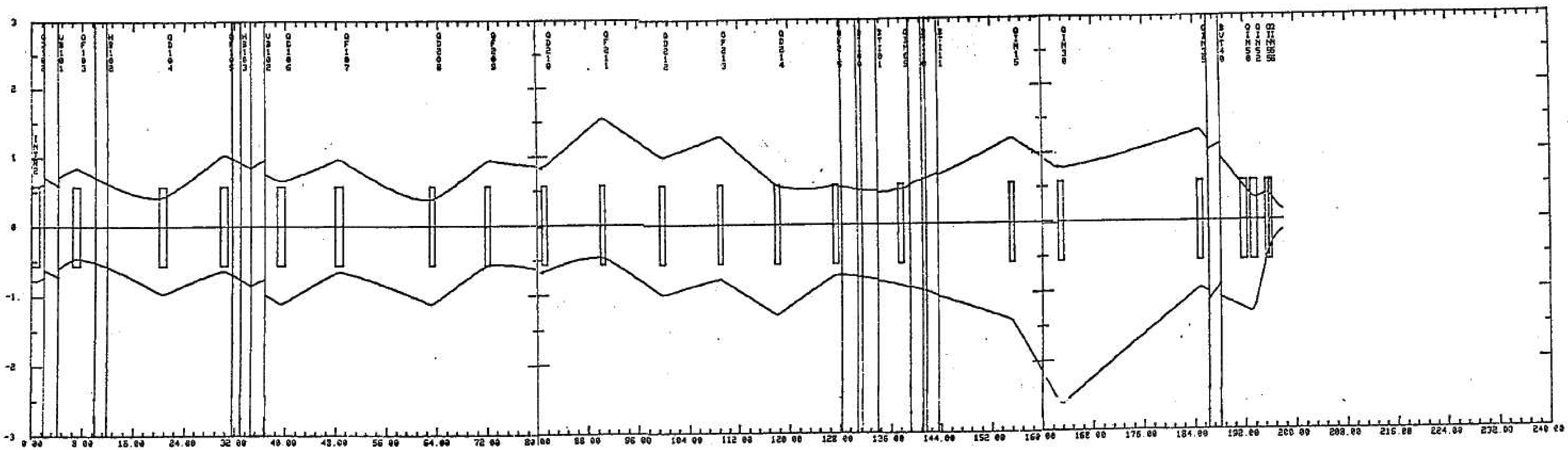

Fig. 4. Beam envelopes from TT2 to target. Beam diameter on target 3.0 mm LIST 4. Data set AAD3 Solution 2

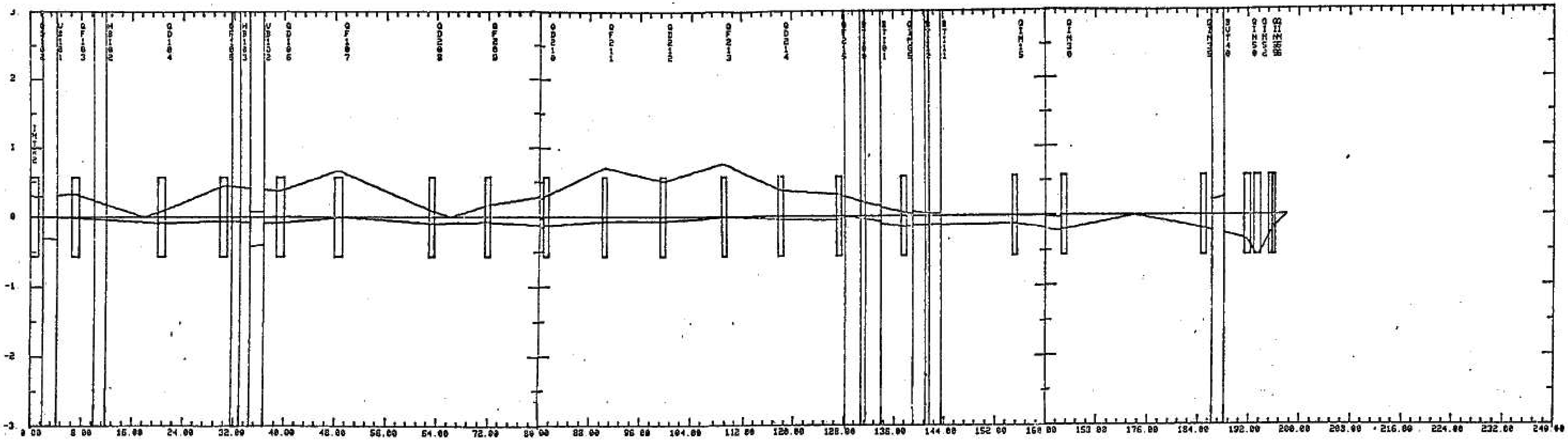

Fig. 7. Momentum Vectors dp/p = 0.2% See Fig. 1

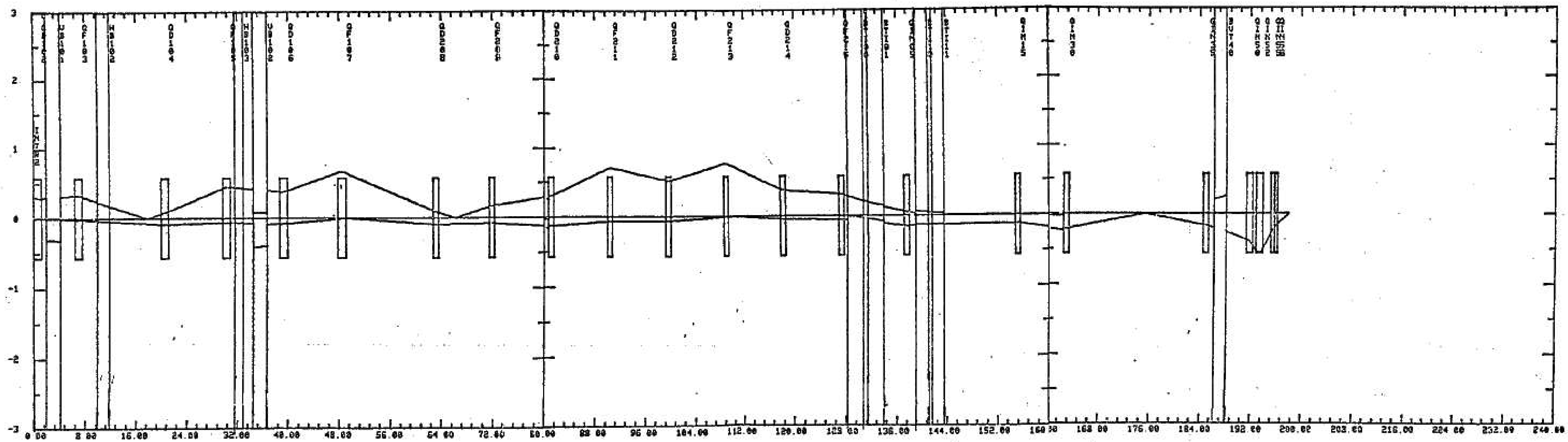

Fig. 8. Momentum Vectors dp/p = 0.2% See Fig. 2

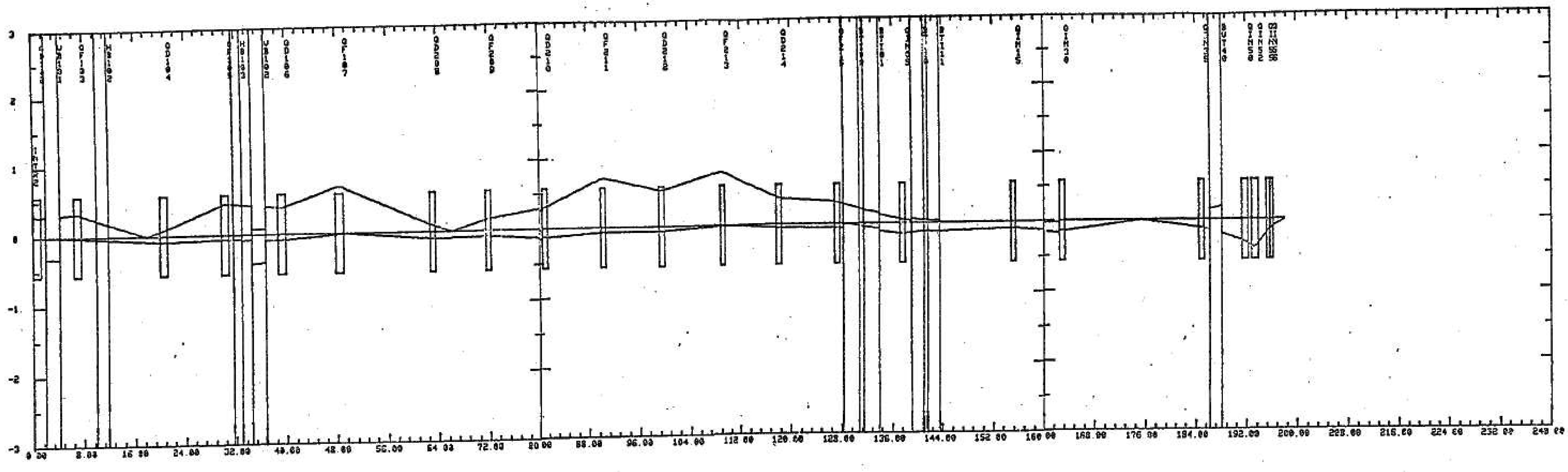

Fig. 9. Momentum Vectors dp/p = 0.2% See Fig. 3

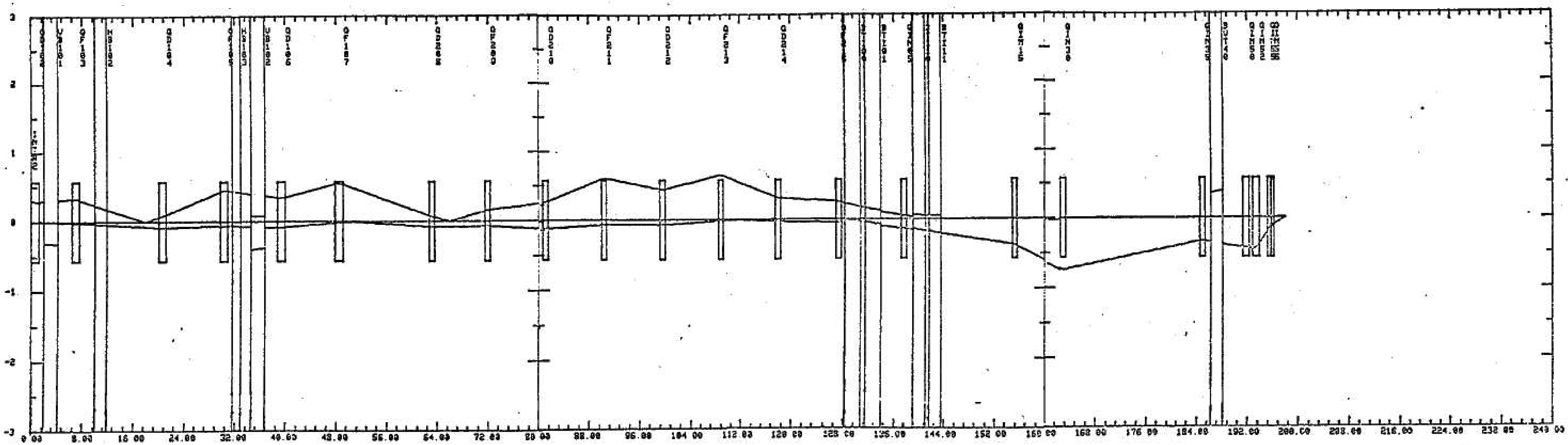

Fig. 10. Momentum Vectors dp/p = 0.2% See Fig. 4

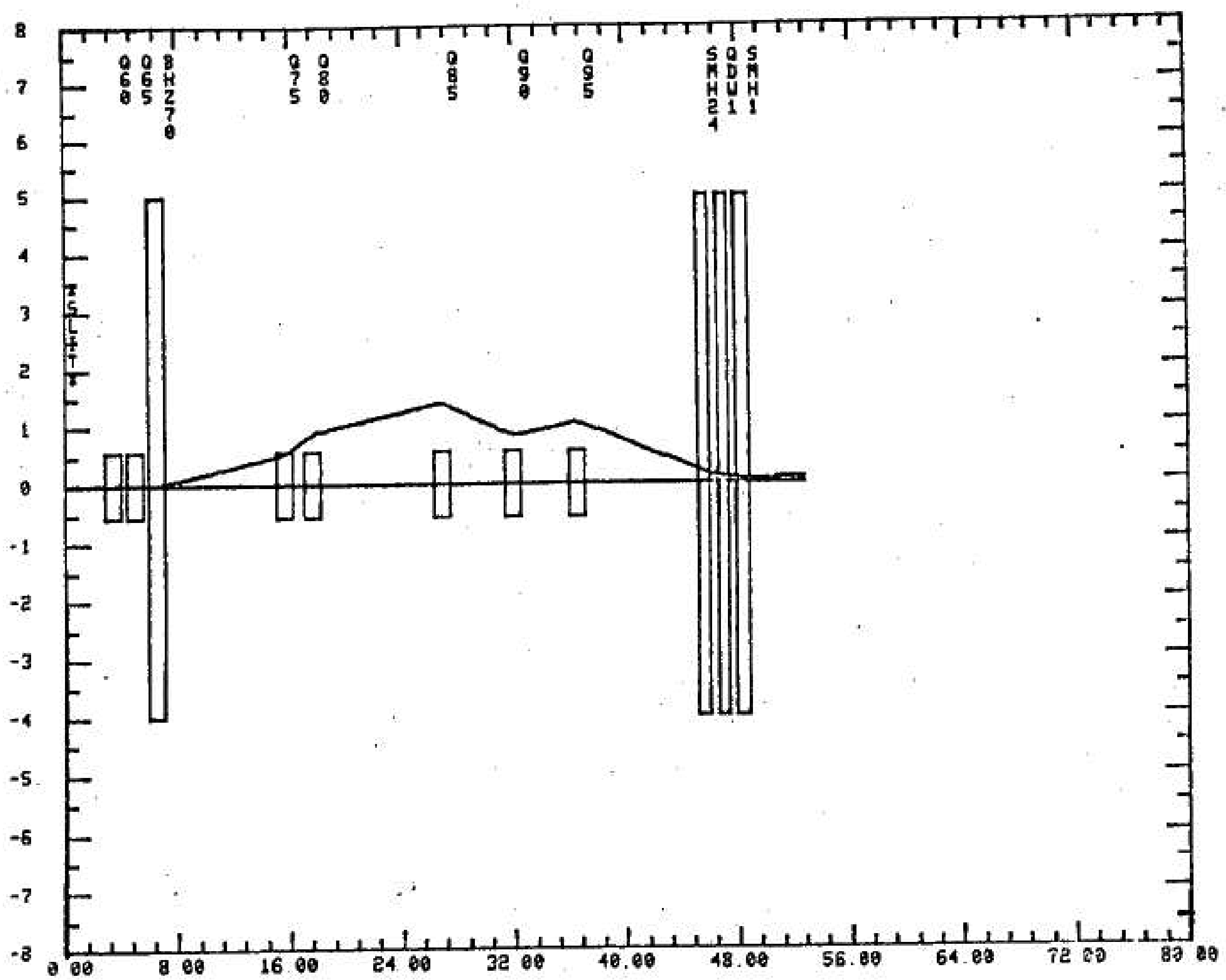

Fig. 11. Momentum Vectors dp/p = 0.75% See Fig. 5

Target → ring

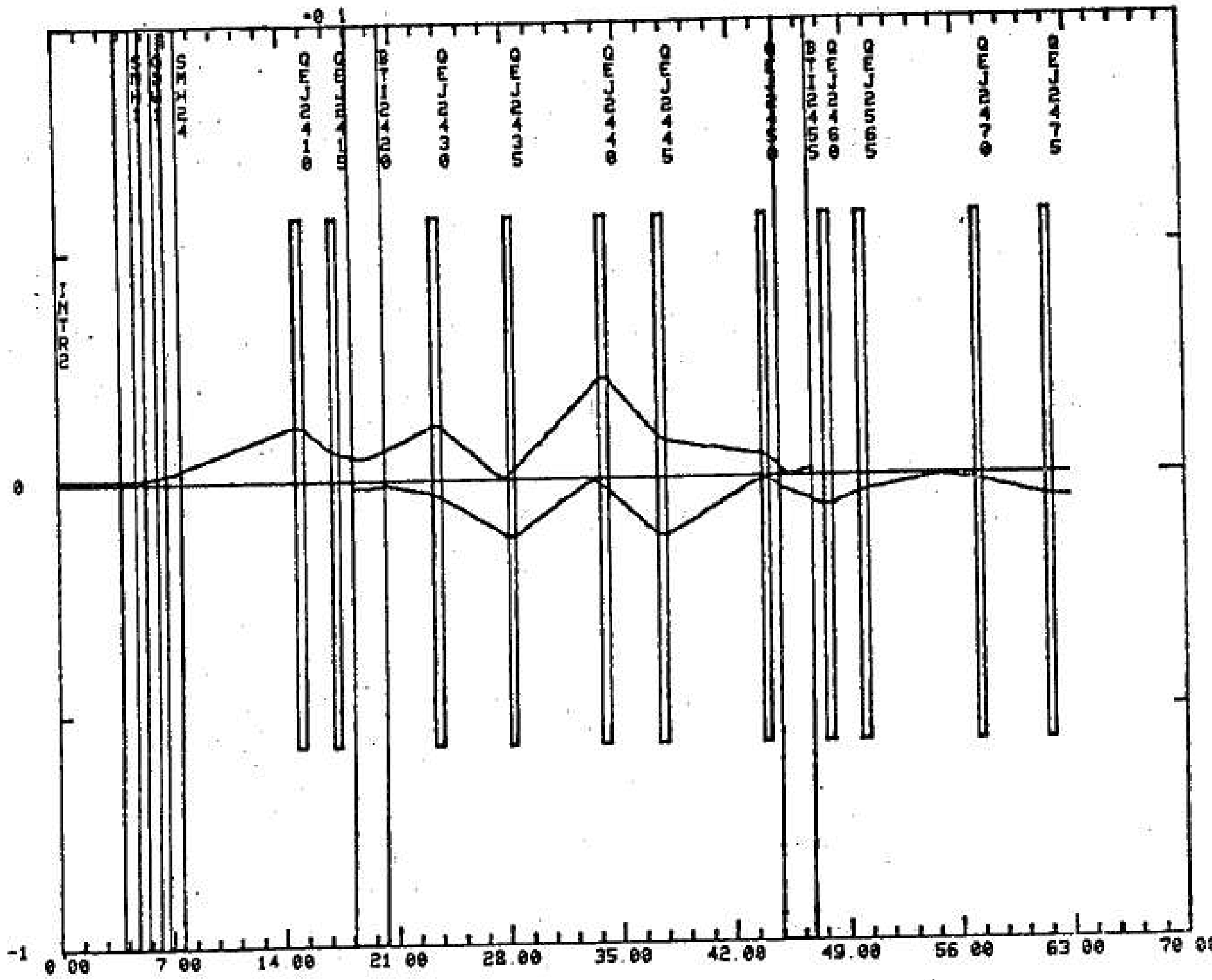

Fig. 12. Momentum Vectors dp/p = 0.1% See Fig. 6

Ej. Line

Name	Type Origin	Pole tip Diameter (mm)	Vacuum tube ID	Plane	Required Aperature		Required Strengths G in KG/cm, K in m^{-2}	Required Current	Available Current
QIN0060	Q100 PS	200	152	H V	72 52	G K	-0.4574 0.3835	230.2	430
QIN0065	Q100 PS	200	152	H V	97 40	G K	0.4405 -0.3694	221.7	430
QIN0075	Q100 PS	200	152	H V	70 137	G K	-0.2341 0.1963	117.8	250
QIN0080	Q100 PS	200	152	H V	104 118	G K	0.1516 -0.1271	76.3	150
QIN0085	Q100 PS	200	152	H V	142 98	G K	0.1279 -0.1072	64.4	150
QIN0090	Q100 PS	200	152	H V	102 142	G K	-0.2032 -0.1704	102.3	150
QIN0095	Q100 PS	200	152	H V	132 82	G K	0.1490 -0.1249	75.0	150

Quadrupole Magnet - Operating Requirements - Injection line Target to AA Ring

Name	Type Origin	Pole tip diameter (mm)	Vacuum tube I.D.	Plane	Required Aperture		Required Strength G in KG/cm, K in m⁻²	* Required Current	Available Current
QEJ2410	Q50 SPS	80	75	H V	13 7	G K	0.8314 -0.6971	80.4	150
QEJ2415	Q50 SPS	80	75	H V	6 13	G K	-0.9084 0.7617	87.9	150
QEJ2430	Q50 SPS	80	75	H V	8 3	G K	0.9510 -0.7974	92.0	150
QEJ2435	Q50 SPS	80	75	H V	4 12	G K	-0.8870 0.7438	85.8	150
QEJ2440	Q50 SPS	80	75	H V	16 3	G K	0.8361 -0.7011	80.9	150
QEJ2445	Q50 SPS	80	75	H V	6 8	G K	-0.9868 0.8274	95.4	150
QEJ2450	Q50 SPS	80	75	H V	8 4	G K	1.0567 -0.8860	102.2	150
QEJ2460	Q50 SPS	80	75	H V	4 11	G K	-1.0500 0.8804	101.5	150
QEJ2465	Q50 SPS	80	75	H V	9 6	G K	0.6602 -0.5536	63.8	150
QEJ2470	Q50 SPS	80	75	H V	13 8	G K	0.3613 -0.3030	34.9	150
QEJ2475	Q50 SPS	80	75	H V	8 18	G K	-0.3394 0.2846	32.8	150

N.B. All references to sector 24 ie. QEJ2470 should be to sector 25 ie. should read QEJ2570.

* to be confirmed from prototype

Quadrupole Magnet Operating Requirements - Ejection line AA Ring to TTL2

Name	Type Origin	Pole tip diameter (mm)	Vacuum tube I.D	Plane	Required Apertures AAD10	AAD11	AAD12	AAD3		Required strengths G in KG/cm, K in m⁻² AAD10	AAD11	AAD12	AAD3	Required Currents (A) AAD10	AAD11	AAD12	AAD3	Available current
QF105	QFL ISR								G 10.K	0.7793 -0.8987	0.7801 -0.8996	0.7734 -0.8919	0.8486 -0.9786	182.3	182.5	180.9	198.5	300
QF107	QFL ISR								G 10.K	0.7845 -0.9047	0.7842 -0.9043	0.7868 -0.9073	0.7525 -0.8678	183.5	183.4	184.7	176.0	300
QIN0005	QD ISR	91	86	H V	11 23	11 21	11 21	12 21	G 10.K	-1.1148 1.2856	-1.1010 1.2697	-1.2141 1.4001	0.0520 -0.0600	250.5	247.4	272.8	11.7	500
QIN0015	QD ISR	91	86	H V	41 15	41 15	43 16	25 38	G 10.K	1.2264 -1.4143	1.2163 -1.4026	1.2092 -1.3944	0.9841 -1.1349	275.6	273.3	271.7	221.2	500
QIN0030	QD ISR	91	86	H V	22 34	23 34	24 37	16 67	G 10.K	-1.6165 1.8641	-1.5317 1.7663	-1.4524 1.6749	-0.9911 1.1429	367.7	346.6	328.1	222.7	500
QIN0035	QD ISR	91	86	H V	34 17	31 14	31 10	27 23	G 10.K	-0.0301 0.0347	0.6990 -0.8061	1.0915 -1.2587	1.2841 -1.4808	6.8	157.1	245.3	288.6	500
QIN0050	L60-1000 EP	60	56	H V	38 43	23 37	15 29	11 36	G 10.K	3.1229 -3.6013	2.0961 -2.4172	0.8121 -0.9365	0.0 0.0	1882.9	1331.9	482.7	0	3500
QIN0052	L60-1000 EP	60	56	H V	25 36	15 44	10 32	8 36	G 10.K	-5.1588 5.9491	-4.800 5.5353	-4.0500 4.6704	-2.9724 3.4277	3713.2	3181.9	2500.9	1790.5	3500
QIN0055	L40-420 EP	40	35	H V	17 23	12 23	8 16	8 17	G 10.K	4.1653 -4.8034	4.8802 -5.6278	4.8802 -5.6278	5.4891 -6.3300	1288.0	1512.4	1512.4	1722.3	3500
QIN0056	L40-420	40	35	H V	15 19	11 16	8 11	8 12	G 10.K	4.1653 -4.8034	4.8802 -5.6278	4.8802 -5.6278	5.4891 -6.3300	1288.0	1512.4	1512.4	1722.3	3500
TARGET BEAM SIZE					1.5	2	3 Sol 1	3 Sol 2		1.5	2	3 Sol 1	3 Sol 2	1.5	2	3 Sol 1	3 Sol 2	

Quadrupole Magnet Operating Requirements - Injection line from TT2 to Antiproton Production Target

Name	Type Origin	Pole gap (mm)	Plane	Available Aperture	Required Apertures AAD10	AAD11	AAD12	AAD3	AAD1	AAD7	Bending Angle (mR)	Tilt Angle (deg)	Required Current	Available Current
BTI0000	HBT	80	H	152	18	18	18	18			40.22	14.09	1466	
	ISR		V	28	16	16	16	16						
BTI0001	HBT	80	H	152	14	14	14	15			40.22	14.07	1466	
	ISR		V	28	18	18	18	18						
BTI0010	B190	52	H	100	16	16	16	14			36.22	14.04	376	400
	SPS		V	48	19	19	19	23						
BTI0011	B190	52	H	100	20	20	21	16			36.22	13.99	376	400
	SPS		V	48	16	16	16	25						
BVT0040	B19	52	H	48	36	30	28	23			37.07	90.00	400	430
	SPS		V	100	25	22	17	31						
BHZ0070	VB3	108	H						93		78.54	0.00	375	500
	ISR		V						88					
BTI2420	B190	52	H							5	239.44	17.56	340	430
	SPS		V							11				
BTI2455	B190	52	H							6	264.52	15.36	376	430
	SPS		V							9				

Bending Magnet Operating Conditions - Injection and Ejection lines