DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, March 8, 1993

Note: **L-6**

DAΦNE STAY-CLEAR APERTURES

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The apertures of the main ring are computed for structures D13 and D14* (see Appendix). **The allowance for residual closed orbit (C.O.) is not included**. A_x (A_y) means half horizontal (vertical) aperture.

HORIZONTAL APERTURES

In DAΦNE beam lifetime is mostly limited by Touschek effect. The rf acceptance is of the order of 2%, while the maximum momentum acceptance for a particle Touschek scattered in the most critical point of the lattice (horizontal betatron function $\beta_x \sim 15$ m and dispersion $D_x \sim 1$ m) is**:

$$\Delta p/p \sim 0.1\ A_x$$

(with A_x in m). For typical values of A_x, it is much smaller than rf acceptance: this means that most of the Touschek losses are due to particles exceeding the horizontal acceptance. If the horizontal vacuum chamber size were constant with an aperture A_x = 4cm, the maximum allowed amplitude would correspond to ~10 σ_x and to a Touschek lifetime of about 400 min. Since this is a reasonably good lifetime value, to preserve it we will compute the aperture of the whole ring with 10 σ_x scaling.

Since injection is performed in the horizontal plane also injection requirements have been considered.

- The injected beam emittance is $\varepsilon_x \sim 3\ 10^{-7}$ m rad.
- The horizontal betatron function @ injection is ~ 7 m.
- The injection septum is 4.2 mm thick and is placed at 4 times the stored beam rms width.

The maximum residual oscillation is:

$$A_{inj} = 4\sigma_{xstored} + D_{sept} + 2\,(3\sigma_{xinjected}) \sim 25 \text{ mm} \sim 9.5\ \sigma_{xstored}$$

($\sigma_{xinjected}$ has been computed using β_{in} = 10 m; if β_{in} = 5 m =>A_{inj} = 8.3 $\sigma_{xstored}$

Our 10 σ_x assumption accommodates injection requirements.

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* DAΦNE Lattice group - Structures D13...D15 - in preparation

** Bassetti et al. : Main rings optic updating - 3rd Machine Review - July 1992.

VERTICAL APERTURES

The vertical aperture determines the gas scattering lifetime τ_{sc}; τ_{sc} has been computed as a function of the aperture in units of σ_y in full coupling (f.c.). (σ_y @ f.c. = 7 σ_y @1%); as horizontal limitation A_x = 40 mm at the maximum beta (β_x = 16 m) position has been assumed, corresponding to 10 σ_x. As already pointed out the total lifetime is mainly limited by the Touschek effect.

In Fig. 1 the total lifetime τ_t, given as:

$$1/\tau_t = 1/\tau_{tou} + 1/\tau_{sc}$$

is represented (all the other contributions to beam lifetime have been here neglected). With τ_{tou} = 400 min a minimum aperture of ~ 10σ_y is necessary for not further reducing the beam lifetime. So, we take a minimum vertical aperture of 10 σ_y with a vertical emittance of 5 10^{-7} m rad.

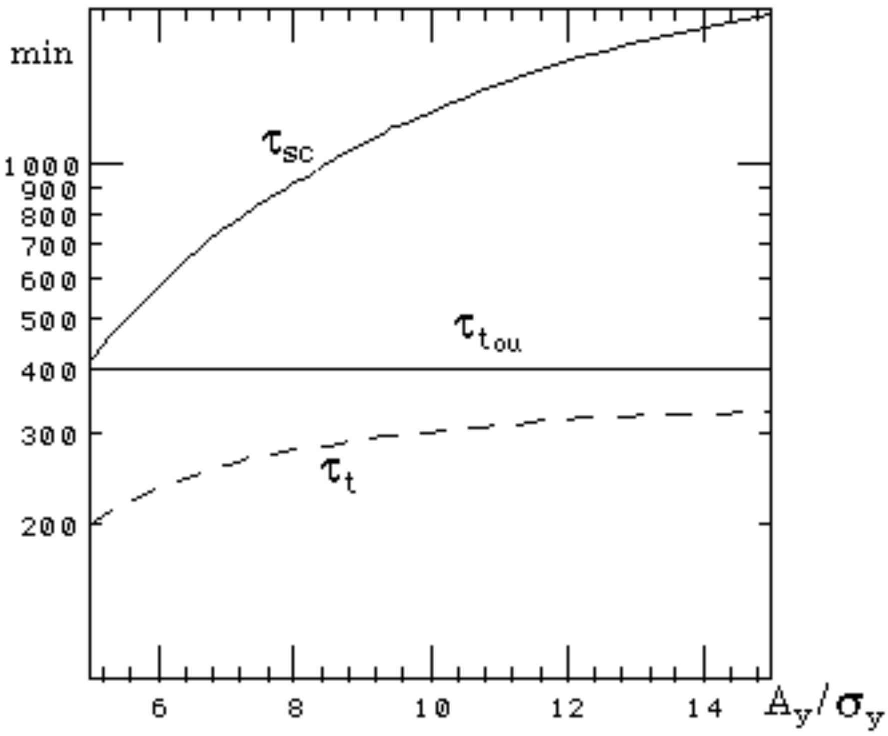

Fig. 1 - Beam lifetime computed with the only contribution of Touschek effect and gas scattering.

INTERACTION REGIONS

Three different Interaction Regions are foreseen:

a) Day-one : triplet of conventional quadrupoles on each side of the IP.

b) KLOE : detector solenoid containing the permanent magnet quadrupole triplet plus one compensator solenoid.

c) FI.NU.DA. : detector solenoid containing two permanent magnet quadrupoles(?), one conventional quadrupole and the compensator solenoid.

- The maximum horizontal crossing angle is ± 15 mrad.
- A vertical separation Yo = ± 2.5 mm @I.P (corresponding to a total separation between the two beam centers of 2.35 σ_x) is obtained with three correctors on each side, originating a vertical bump starting near the bending magnet through the following three quadrupoles, the splitter and the interaction region. (see Figure 2).

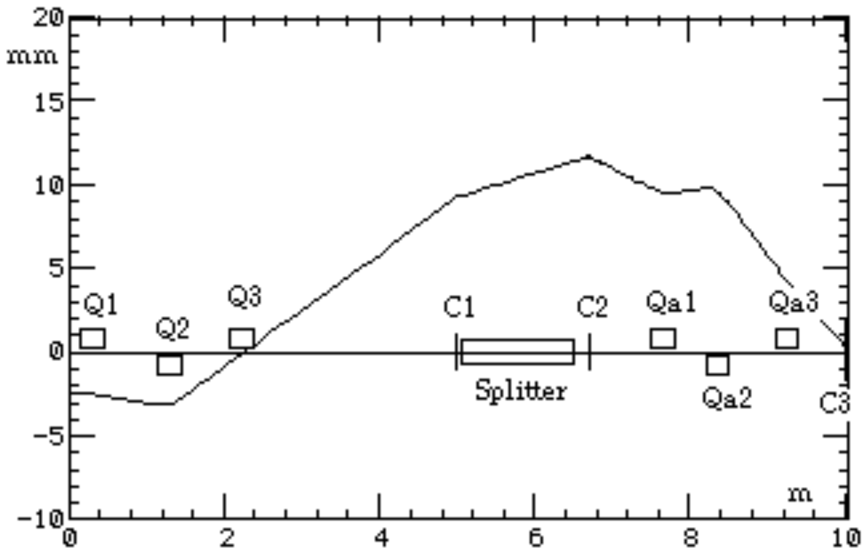

Fig. 2 - Example of bump in the Interaction Region with the commissioning optics.

The values of the three bump correctors are slightly different in the "short" and in the "long" ring sections because the arc quadrupole fields are not symmetric with respect to the I.P. The first corrector is placed 5 cm before the splitter and due to the lack of space its maximum kick is 2 mrad; the 2nd corrector is 20 cm after the splitter and the 3rd 15 cm before the first dipole. Any change in the optics will of course lead to changes in the corrector settings and in the bump amplitude. To take this possible variation into account an additional ±2.5 mm should be added to the vertical aperture of the splitter, of the crossing angle corrector and of the three quadrupoles between the splitter and the first dipole, i.e. where the bump passes. A VAX code is available to compute the corrector settings in any configuration.

To compute the apertures in the three Interaction Regions the following assumptions have been made.

In absence of solenoidal fields and for rectangular (or ellipsoidal or any shape discriminating between horizontal and vertical dimensions) vacuum chamber, the maximum horizontal aperture is given by (see Fig. 3).

$$Apx = \Delta x + S_x$$

± Δx being the total separation between the two beam trajectories crossing at ± 15 mrad, and $S_x = 10\ \sigma_x$.

The maximum vertical aperture is:

$$Apy = \Delta y + S_y$$

where Δy is the bump amplitude and $S_y = 10\ \sigma_y$.

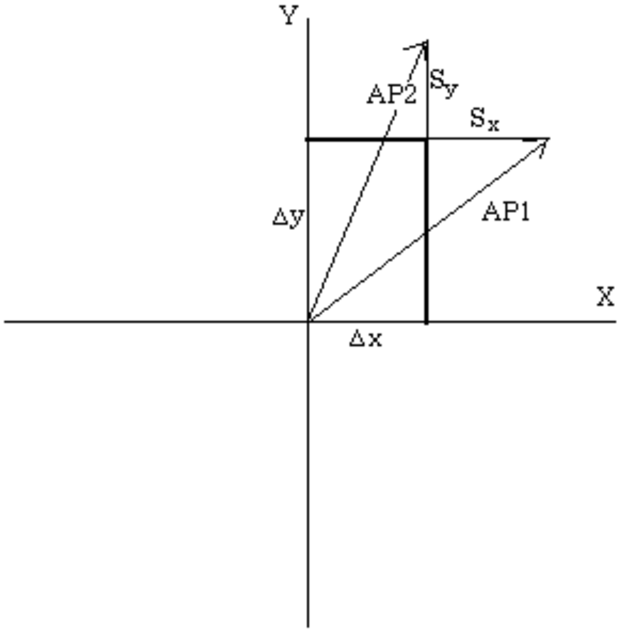

Fig. 3 - Apertures in absence of solenoidal fields.

It has to be noticed that the maximum horizontal aperture is necessary not only at y = 0, but within ± Δy , and the maximum vertical aperture within ± Δx.

For a circular vacuum chamber, the radius is APmax, which is the maximum between AP1 and AP2, being:

$$AP1^2 = Apx^2 + \Delta y^2$$
$$AP2^2 = Apy^2 + \Delta x^2$$

In presence of solenoidal fields the rotation of the transverse plane is taken into account. The absolute values of the separation, of the bump and of the beam dimensions in the two perpendicular planes have been computed in the rotating frame (x_r, y_r) (see Fig. 4).

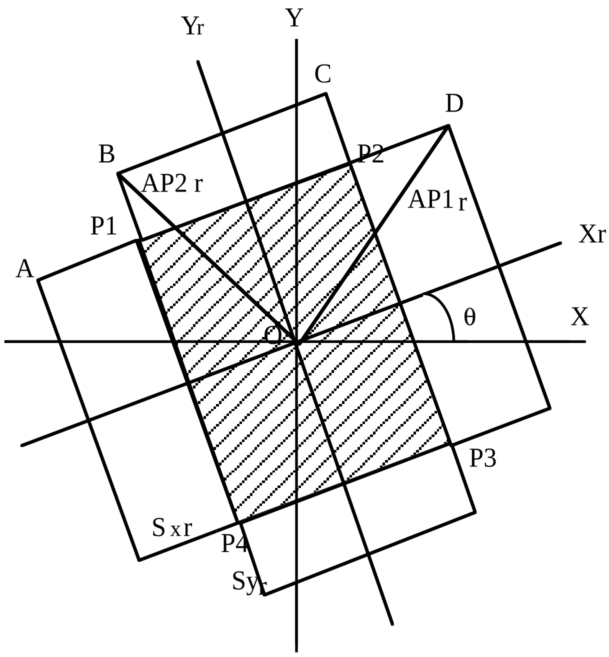

Fig. 4 - Apertures in presence of solenoidal fields.

Figure 4 shows schematically the maximum beam displacements at a given position inside the interaction region. θ is the rotation angle due to the solenoidal field. The position of the beam center, depending on the crossing angle and on the vertical separation, is within the rectangle (P1 P2 P3 P4). The four outer rectangles account for the contribution of S_{xr} and S_{xr}. Apx_r and Apy_r are the apertures in the rotating frame:

$$Apx_r = \Delta x_r + S_{xr}$$
$$Apy_r = \Delta y_r + S_{yr}$$

where the symbols have the same meaning as before but in the rotating frame.

For a circular vacuum chamber, AP1r and AP2r are computed and the larger is the necessary aperture, APmax.

If the vacuum chamber is not circular the horizontal aperture Px is the maximum between the projections on the horizontal axis of OA and OB, while the vertical aperture Py is the maximum between the projections on the vertical axis of OC and OD.

DAY-ONE INTERACTION REGION

In Table 1 and in Figs. 5 the characteristics of the Interaction region and of the arc up to the first dipole are listed. For the arc apertures up to the dipole the same assumptions as for the Interaction Region have been done. Both the short arc and the long arc are given.

Table 1a - Day-one Interaction Region and adjacent arc for the short part. Apertures are given in mm

El	z	x	ap1	apx	y	ap2	apy	apmax	angle
Q1	0.150	2.3	23.6	23.5	2.5	8.0	7.7	23.6	0.00
	0.450	6.6	27.1	27.0	2.6	19.2	18.1	27.1	0.00
Q2	1.160	16.3	33.2	33.1	3.1	47.2	44.3	47.2	0.00
	1.460	24.2	43.3	43.2	2.7	51.8	45.8	51.8	0.00
Q3	2.080	49.5	81.0	81.0	0.6	57.3	28.8	81.0	0.00
	2.380	56.5	90.9	90.9	0.4	61.4	24.1	90.9	0.00
C1	5.000	70.2	101.8	101.3	9.3	72.2	16.9	101.8	0.00
Spl	5.050	70.5	102.0	101.5	9.4	72.5	16.8	102.0	0.00
	6.500	0.0	32.0	29.8	11.4	21.6	21.6	32.0	0.00
C2	6.700	0.0	31.9	29.7	11.7	23.1	23.1	31.9	0.00
Ch	6.875	0.0	31.7	29.6	11.3	23.7	23.7	31.7	0.00
	7.125	0.0	31.3	29.5	10.6	24.6	24.6	31.3	0.00
Qa1	7.500	0.0	30.9	29.3	9.7	26.2	26.2	30.9	0.00
	7.800	0.0	29.0	27.4	9.6	29.2	29.2	29.2	0.00
Qa2	8.200	0.0	24.7	22.5	10.2	35.6	35.6	35.6	0.00
	8.500	0.0	23.6	21.7	9.4	35.9	35.9	35.9	0.00
Qa3	9.100	0.0	26.3	25.7	5.3	27.3	27.3	27.3	0.00
	9.400	0.0	26.8	26.6	3.5	24.3	24.3	26.8	0.00
C3	10.050	0.0	26.2	26.2	0.0	20.3	20.3	26.2	0.00

Table 1b - Day-one Interaction Region and adjacent arc for the long part

El	z	x	ap1	apx	y	ap2	apy	apmax	angle
Q1	0.150	2.3	23.6	23.5	2.5	8.0	7.7	23.6	0.00
	0.450	6.6	27.1	27.0	2.6	19.2	18.1	27.1	0.00
Q2	1.160	16.3	33.2	33.1	3.1	47.2	44.3	47.2	0.00
	1.460	24.2	43.3	43.2	2.7	51.8	45.8	51.8	0.00
Q3	2.080	49.5	81.0	81.0	0.6	57.3	28.8	81.0	0.00
	2.380	56.5	90.9	90.9	0.4	61.4	24.1	90.9	0.00
C1	5.000	70.2	101.8	101.3	9.3	72.2	16.9	101.8	0.00
Spl	5.050	70.5	102.0	101.5	9.4	72.5	16.8	102.0	0.00
	6.500	0.0	32.0	29.8	11.4	21.6	21.6	32.0	0.00
C2	6.700	0.0	31.9	29.7	11.7	23.1	23.1	31.9	0.00
Ch	6.875	0.0	31.7	29.6	11.3	23.7	23.7	31.7	0.00
	7.125	0.0	31.3	29.5	10.7	24.7	24.7	31.3	0.00
Qa1	7.500	0.0	30.9	29.3	9.8	26.3	26.3	30.9	0.00
	7.800	0.0	29.5	27.9	9.5	28.8	28.8	29.5	0.00
Qa2	8.200	0.0	26.2	24.4	9.8	34.0	34.0	34.0	0.00
	8.500	0.0	26.0	24.4	8.9	34.1	34.1	34.1	0.00
Qa3	9.100	0.0	30.3	29.8	5.1	26.9	26.9	30.3	0.00
	9.400	0.0	31.7	31.5	3.4	24.3	24.3	31.7	0.00
C3	10.050	0.0	32.7	32.7	0.0	20.7	20.7	32.7	0.00

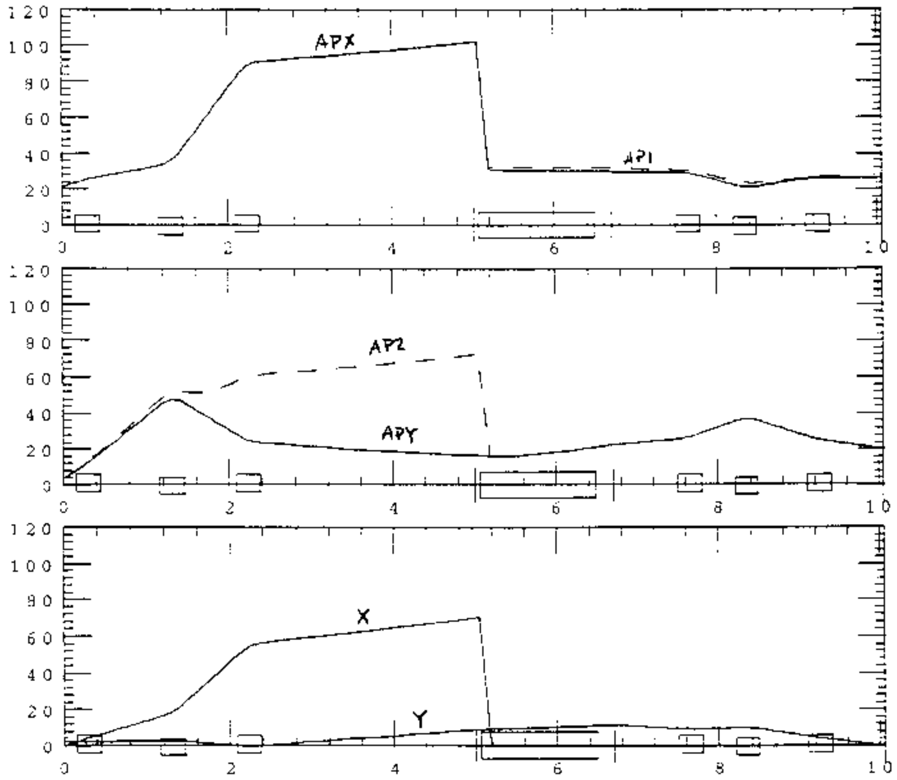

Fig. 5a - Day-one Interaction Region and adjacent arc for the short part

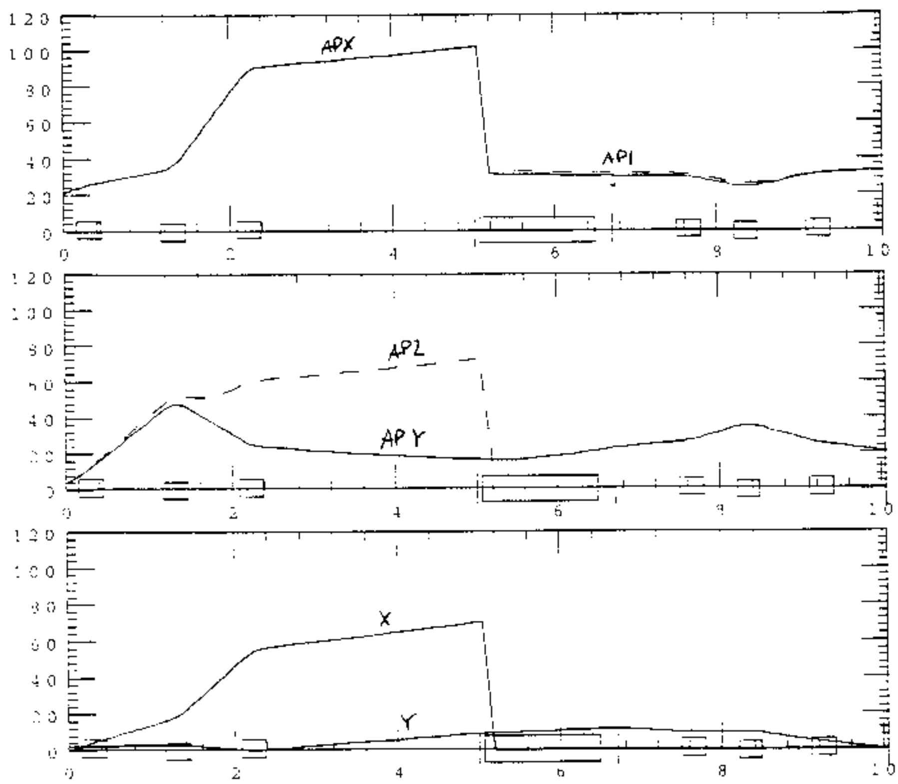

Fig. 5b - Day-one Interaction Region and adjacent arc for the long part

In Table 2 the characteristics of the low beta triplet are given. Apmax is the maximum value along the quadrupole.

Table 2 - Day One Quadrupole Triplet

Quad	z (m)	L (m)	K (m-2)	G (T/m)	Apmax (mm)	Apx (mm)	Apy (mm)
Q1	0.15	0.30	0.9724	1.65	28	27	19
Q2	1.16	0.30	-4.6001	7.83	52	44	46
Q3	2.08	0.30	2.1961	3.74	91	91	29

KLOE

In Table 3 and Figs. 6 the characteristics of KLOE Interaction Region and adjacent arc are given.

Table 3a - KLOE Interaction Region and adjacent arc for the short part. Apertures are given in mm

El	z	x	ap1	px	y	ap2	py	apmax	angle
Q1	0.460	6.9	28.3	28.3	2.5	19.2	18.4	28.3	4.65
	0.660	9.3	29.3	29.3	2.7	27.5	26.8	29.3	6.67
Q2	0.830	10.9	28.5	28.4	3.0	35.8	35.3	35.8	8.39
	1.180	18.8	37.7	37.3	2.4	41.4	40.0	41.4	11.92
Q3	1.330	24.5	46.8	45.9	1.8	40.3	36.8	46.8	13.44
	1.600	31.8	57.5	55.4	0.7	41.4	34.3	57.5	16.17
	1.950	36.7	63.2	59.6	0.4	43.9	35.1	63.2	19.70
	2.250	40.8	68.0	63.9	1.5	47.1	36.7	68.0	21.22
Comp	3.455	57.4	87.7	83.6	5.6	61.0	40.2	87.7	21.22
	3.755	61.3	92.5	90.0	6.6	64.6	37.7	92.5	17.43
	4.295	66.5	98.3	98.2	8.2	69.1	23.2	98.3	3.79
	4.595	68.2	99.7	99.3	8.9	70.5	18.0	99.7	0.00
C1	5.000	70.3	101.5	101.0	9.9	72.3	17.2	101.5	0.00
Spl	5.050	70.5	101.7	101.2	9.9	72.6	17.1	101.7	0.00
	6.500	0.0	31.3	29.5	10.5	21.0	21.0	31.3	0.00
C2	6.700	0.0	31.2	29.3	10.6	22.3	22.3	31.2	0.00
CH	6.875	0.0	30.9	29.2	10.2	23.0	23.0	30.9	0.00
	7.125	0.0	30.6	29.1	9.6	24.0	24.0	30.6	0.00
Qa1	7.500	0.0	30.2	28.9	8.7	25.7	25.7	30.2	0.00
	7.800	0.0	28.2	26.9	8.5	28.9	28.9	28.9	0.00
Qa2	8.200	0.0	23.6	21.8	9.1	35.6	35.6	35.6	0.00
	8.500	0.0	22.3	20.7	8.4	36.2	36.2	36.2	0.00
Qa3	9.100	0.0	24.4	24.0	4.8	28.1	28.1	28.1	0.00
	9.400	0.0	25.0	24.8	3.2	25.2	25.2	25.2	0.00
C3	10.050	0.0	24.7	24.7	0.0	21.1	21.1	24.7	0.00

Table 3b - KLOE Interaction Region and adjacent arc for the long part

El	z	x	ap1	px	y	ap2	py	apmax	angle
Q1	0.460	6.9	28.3	28.3	2.5	19.2	18.4	28.3	4.65
	0.660	9.3	29.3	29.3	2.7	27.5	26.8	29.3	6.67
Q2	0.830	10.9	28.5	28.4	3.0	35.8	35.3	35.8	8.39
	1.180	18.8	37.7	37.3	2.4	41.4	40.0	41.4	11.92
Q3	1.330	24.5	46.8	45.9	1.8	40.3	36.8	46.8	13.44
	1.600	31.8	57.5	55.4	0.7	41.4	34.3	57.5	16.17
	1.950	36.7	63.2	59.6	0.4	43.9	35.1	63.2	19.70
	2.250	40.8	68.0	63.9	1.5	47.1	36.7	68.0	21.22
Comp	3.455	57.4	87.7	83.6	5.6	61.0	40.2	87.7	21.22
	3.755	61.3	92.5	90.0	6.6	64.6	37.7	92.5	17.43
	4.295	66.5	98.3	98.2	8.2	69.1	23.2	98.3	3.79
	4.595	68.2	99.7	99.3	8.9	70.5	18.0	99.7	0.00
C1	5.000	70.3	101.5	101.0	9.9	72.3	17.2	101.5	0.00
Spl	5.050	70.5	101.7	101.2	9.9	72.6	17.1	101.7	0.00
	6.500	0.0	31.3	29.5	10.5	21.0	21.0	31.3	0.00
C2	6.700	0.0	31.2	29.3	10.6	22.3	22.3	31.2	0.00
Ch	6.875	0.0	31.0	29.2	10.3	23.1	23.1	31.0	0.00
	7.125	0.0	30.7	29.1	9.9	24.4	24.4	30.7	0.00
Qa1	7.500	0.0	30.4	28.9	9.3	26.3	26.3	30.4	0.00
	7.800	0.0	29.5	28.0	9.1	28.7	28.7	29.5	0.00
Qa2	8.200	0.0	27.3	25.8	9.2	33.1	33.1	33.1	0.00
	8.500	0.0	28.0	26.8	8.3	32.9	32.9	32.9	0.00
Qa3	9.100	0.0	34.8	34.4	4.7	25.5	25.5	34.8	0.00
	9.400	0.0	36.8	36.7	3.1	23.0	23.0	36.8	0.00
C3	10.050	0.0	38.0	38.0	0.0	20.0	20.0	38.0	0.00

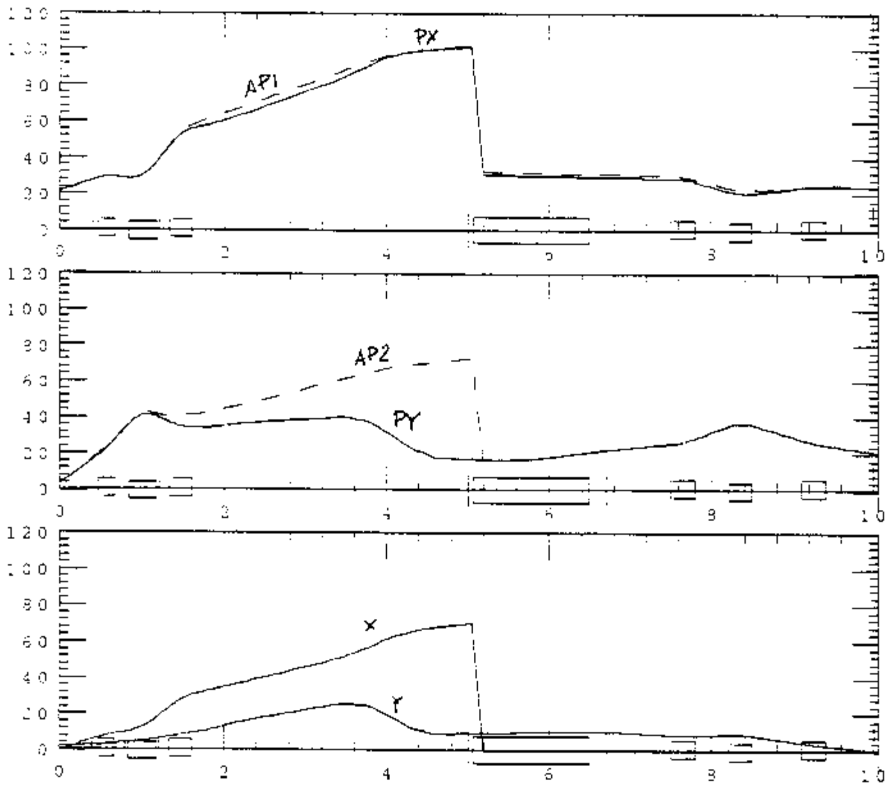

Fig. 6a - KLOE Interaction Region and adjacent arc for the short part

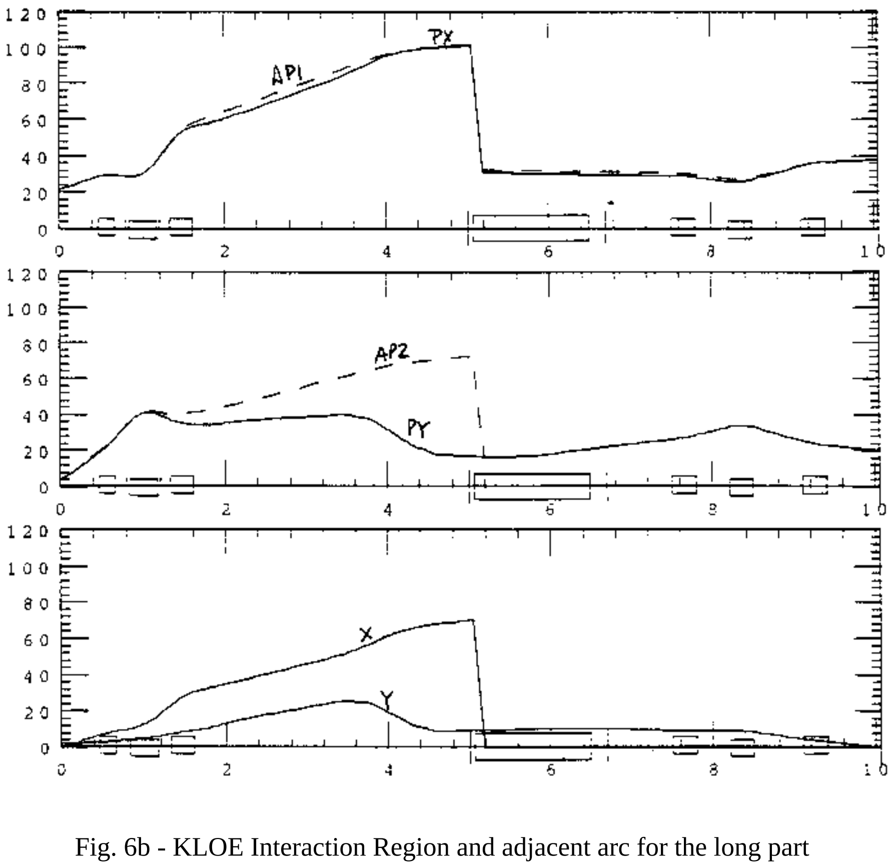

Fig. 6b - KLOE Interaction Region and adjacent arc for the long part

The three quadrupoles inside the detector are permanent magnets. The inner radius r_1 and the outer dimension R_2 in a permanent magnet quadrupole are related by:

$$G = \frac{1.82}{r_1} - \frac{2.16}{R_2} \qquad \text{(Cattoni: M3)}$$

In the quadrupole region the vacuum chamber should be circular, so the necessary aperture is Apmax; r1 is obtained as:

$$r_1 = \text{Apmax} + 12 \text{ mm}$$

R_2 is obtained with the above formula and compared to the maximum available space, which is given by:

$$R_{max} = Z \tan(9°)$$

The value of R_2 is always smaller than R_{max} ; In Fig. 7 the Interaction Region details are given: Apmax, R_2 an R_{max} are plotted. In Table 4 the characteristics of the three quadrupoles are summarized; R_2 is the maximum along each quadrupole.

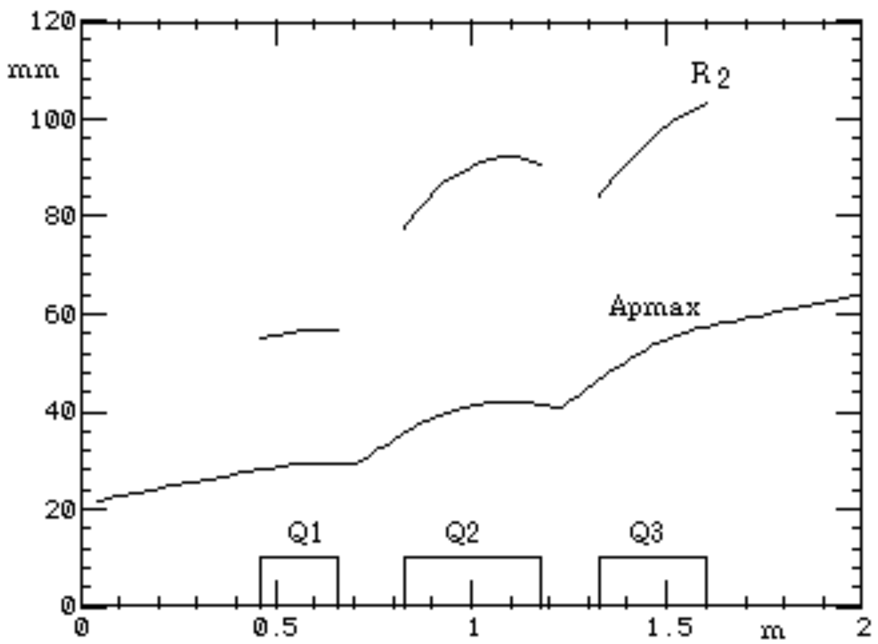

Fig. 7 - KLOE Interaction Region

Table 4 - KLOE TRIPLET

Quad	z (m)	L (m)	K (m-2)	G (T/m)	Apmax (mm)	r1 (mm)	R2 (mm)	Rmax (mm)
Q1	0.46	0.20	3.4840	5.93	30	42	57	73
Q2	0.83	0.35	-6.0493	10.29	42	54	93	131
Q3	1.33	0.27	3.1011	5.28	58	70	104	211

FI.NU.DA.

In Table 5 and Figs. 8 the characteristics of FI.NU.DA. Interaction Region and adjacent arc are given.

Table 5a - FI.NU.DA. Interaction Region and adjacent arc for the short part. Apertures are given in mm

El	z	x	ap1	px	y	ap2	py	apmax	angle
Q1	0.460	6.9	27.9	27.7	2.4	19.0	18.8	27.9	11.62
	0.660	9.4	29.0	28.4	2.5	26.8	26.8	29.0	16.67
Q2	0.850	11.3	28.5	27.4	2.7	35.0	35.0	35.0	21.47
	1.150	17.7	35.8	33.2	2.2	39.7	39.7	39.7	25.26
Q3	1.424	27.4	50.6	46.2	1.1	39.5	37.4	50.6	25.26
	1.624	32.5	57.9	52.5	0.4	41.0	36.5	57.9	25.26
Comp	2.953	52.9	82.8	76.6	4.2	57.4	42.7	82.8	25.26
	3.253	57.4	88.4	84.0	5.3	61.4	41.4	88.4	21.47
	3.949	64.6	96.6	96.6	7.3	67.6	24.3	96.6	3.79
	4.249	66.3	98.1	97.8	8.1	69.0	18.9	98.1	0.00
C1	5.000	70.2	101.3	100.8	9.9	72.2	17.1	101.3	0.00
Spl	5.050	70.4	101.5	101.1	9.9	72.5	17.0	101.5	0.00
	6.500	0.0	31.2	29.4	10.5	21.2	21.2	31.2	0.00
C2	6.700	0.0	31.1	29.3	10.6	22.5	22.5	31.1	0.00
Ch	6.875	0.0	30.9	29.1	10.2	23.2	23.2	30.9	0.00
	7.125	0.0	30.6	29.0	9.6	24.3	24.3	30.6	0.00
Qa1	7.500	0.0	30.1	28.9	8.7	25.9	25.9	30.1	0.00
	7.800	0.0	28.2	26.9	8.5	29.2	29.2	29.2	0.00
Qa2	8.200	0.0	23.6	21.8	9.1	36.0	36.0	36.0	0.00
	8.500	0.0	22.3	20.7	8.4	36.5	36.5	36.5	0.00
Qa3	9.100	0.0	24.4	23.9	4.8	28.4	28.4	28.4	0.00
	9.400	0.0	25.0	24.8	3.2	25.5	25.5	25.5	0.00
C3	10.050	0.0	24.7	24.7	0.0	21.3	21.3	24.7	0.00

Table 5b - FI.NU.DA. Interaction Region and adjacent arc for the long part

El	z	x	ap1	px	y	ap2	py	apmax	angle
Q1	0.460	6.9	27.9	27.7	2.4	19.0	18.8	27.9	11.62
	0.660	9.4	29.0	28.4	2.5	26.8	26.8	29.0	16.67
Q2	0.850	11.3	28.5	27.4	2.7	35.0	35.0	35.0	21.47
	1.150	17.7	35.8	33.2	2.2	39.7	39.7	39.7	25.26
Q3	1.424	27.4	50.6	46.2	1.1	39.5	37.4	50.6	25.26
	1.624	32.5	57.9	52.5	0.4	41.0	36.5	57.9	25.26
Comp	2.953	52.9	82.8	76.6	4.2	57.4	42.7	82.8	25.26
	3.253	57.4	88.4	84.0	5.3	61.4	41.4	88.4	21.47
	3.949	64.6	96.6	96.6	7.3	67.6	24.3	96.6	3.79
	4.249	66.3	98.1	97.8	8.1	69.0	18.9	98.1	0.00
C1	5.000	70.2	101.3	100.8	9.9	72.2	17.1	101.3	0.00
Spl	5.050	70.4	101.5	101.1	9.9	72.5	17.0	101.5	0.00
	6.500	0.0	31.2	29.4	10.5	21.2	21.2	31.2	0.00
C2	6.700	0.0	31.1	29.3	10.6	22.5	22.5	31.1	0.00
Ch	6.875	0.0	30.9	29.1	10.2	23.2	23.2	30.9	0.00
	7.125	0.0	30.6	29.0	9.6	24.3	24.3	30.6	0.00
Qa1	7.500	0.0	30.2	28.9	8.8	26.1	26.1	30.2	0.00
	7.800	0.0	28.8	27.5	8.5	28.7	28.7	28.8	0.00
Qa2	8.200	0.0	25.5	24.0	8.6	34.0	34.0	34.0	0.00
	8.500	0.0	25.2	23.9	7.9	34.4	34.4	34.4	0.00
Qa3	9.100	0.0	29.3	28.9	4.6	27.9	27.9	29.3	0.00
	9.400	0.0	30.8	30.6	3.1	25.5	25.5	30.8	0.00
C3	10.050	0.0	32.5	32.5	0.0	21.9	21.9	32.5	0.00

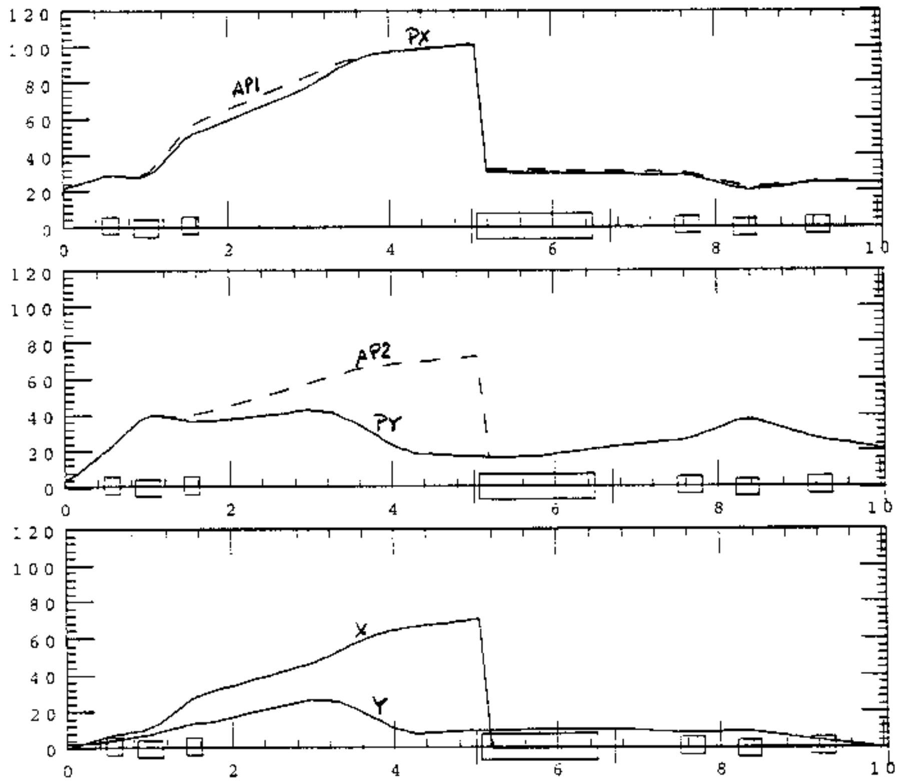

Fig. 8a - FI.NU.DA. Interaction Region and adjacent arc for the short part

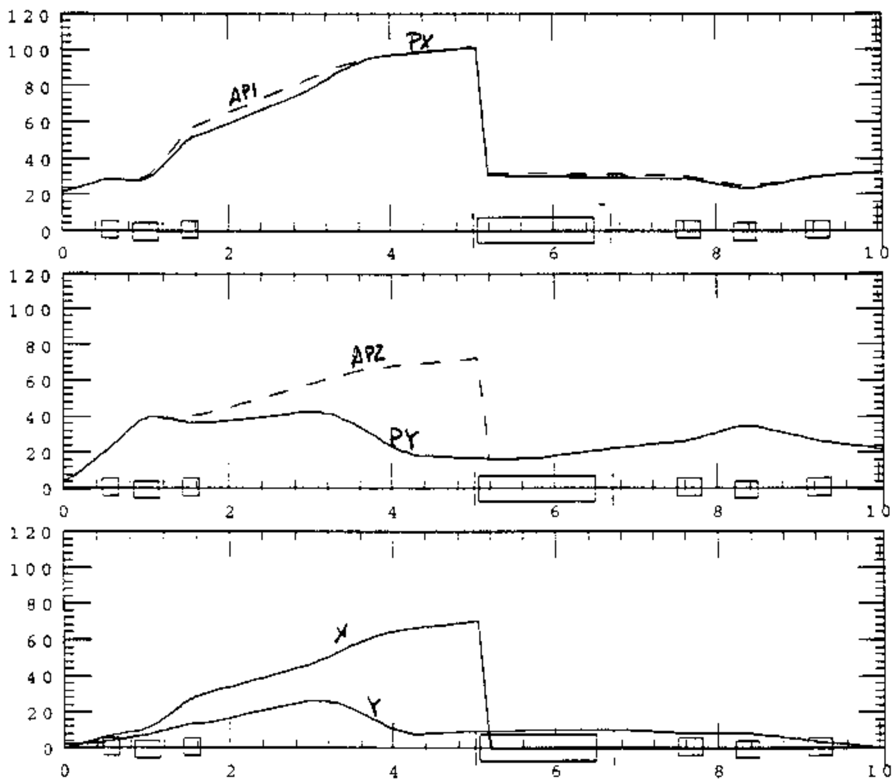

Fig. 8b - FI.NU.DA. Interaction Region and adjacent arc for the long part

The characteristics of the quadrupole triplet are summarized in Table 6.

Table 6 - FI.NU.DA. TRIPLET

Quad	z (m)	L (m)	K (m-2)	G (T/m)	Apmax (mm)	Px (mm)	Py (mm)
Q1	0.46	0.20	2.5653	4.36	29	29	27
Q2	0.85	0.30	-6.1900	10.53	40	34	40
Q3	1.424	0.20	3.3020	5.62	58	53	38

SPLITTER and CORRECTOR

Nominal values of the splitter correspond to ±12.5 mrad crossing angle. They are the same for the three different interaction region configurations. The crossing angle goes from ± 10 to ±15 mrad changing the splitter field and switching on the corrector.

Crossing angle (mrad)	± 12.5	± 15	± 10
Splitter			
Horizontal separation(mm)	58.75	70.50	47.00
Trajectory angle (mrad)	4.375	5.25	3.5
Arc length (m)	1.4500	1.4493	1.4508
Bending angle (mrad)	152.7046	141.7751	163.6179
Magnetic field (T)	0.1792	0.1664	0.1919
Bending radius (m)	9.4955	10.2224	8.8668
Corrector			
Arc length (m)	0.25	0.2498	0.2502
Bending angle (mrad)	0.	10.0545	-10.0383

In the splitter the maximum vertical half aperture is 21.2 mm + 2.5 mm (accounting for bump dimension changes), i.e. 24 mm.

The horizontal apertures must take into account the inner trajectory, corresponding to ± 10 mrad crossing angle, and the outer one, corresponding to ± 15 mrad. In Fig. 9 the necessary total horizontal aperture without c.o. is sketched.

At the splitter input the trajectories corresponding to ±10 and to ±15 mrad are separated by a distance Δx_{tr} = 23.5 mm and at the output they are 9.6 mm apart. So the total aperture at the input is:

$$2A_x = 2\,Px + \Delta x_{tr} = 87\text{ mm}$$

and at the output:

$$2A_x = 2\,Px + \Delta x_{tr} = 74\text{mm}$$ in the hypothesis of circular vacuum chamber.

At the splitter input the distance between the splitter center and the vacuum chamber is 15 mm.

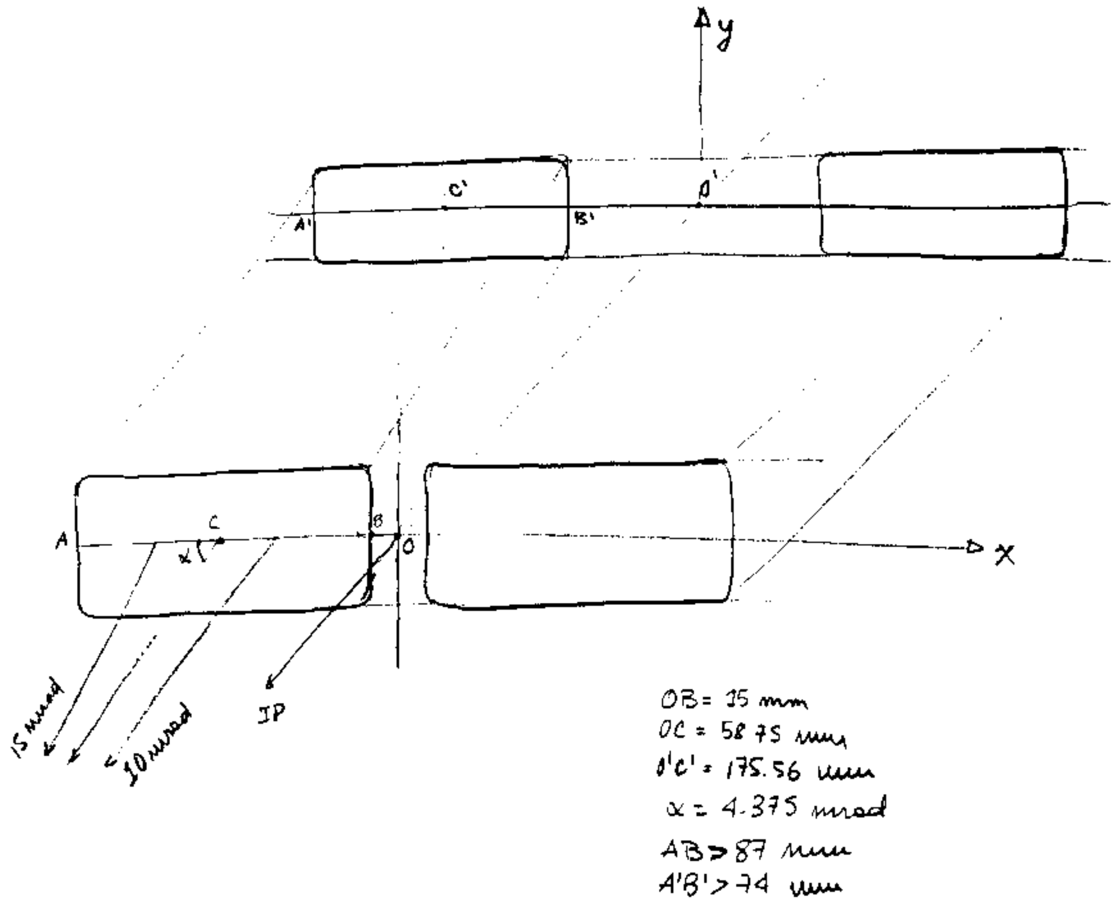

Fig. 9 - Splitter

ARCS

The optical functions of the main ring lattice for which the apertures have been computed are represented in Figs. 10 and 11 for the short and the long part respectively from the splitter output to the center of the straight sections. Since the optics is not completely frozen, we point out the limits on the maximum beam sizes fitting the requested apertures according to our hypothesis. The arcs have been divided in three parts: a) the section between the splitter and the first dipole, b)the zone between the two dipoles, and c) the straight sections.

<u>*Section a*)</u>

For the section a) the apertures have been calculated together with the interaction regions specifications, as can be seen in previous tables. If the vacuum chamber is circular a minimum radius of 40 mm is needed, so that possible variations of the betatron functions up to a maximum of 16 m in the horizontal plane and 18 m in the vertical plane can be accepted. If the vacuum chamber is rectangular ±40 mm in the horizontal direction are needed, while in the vertical ±30 mm are sufficient apart from the central quadrupole where the bump dimension is higher and a minimum aperture of ±40 mm is necessary.

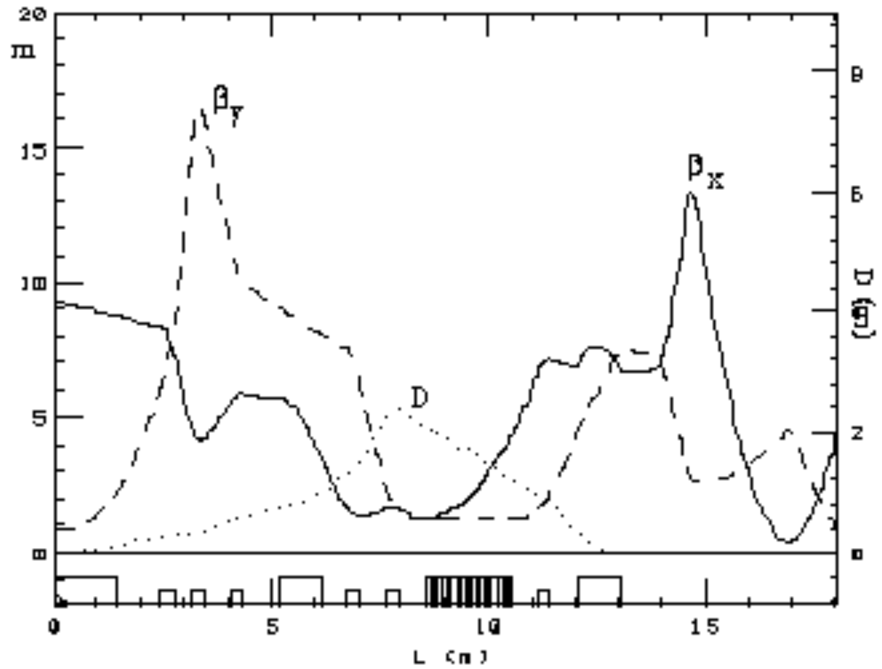

Fig. 10 - Optical functions in the short part

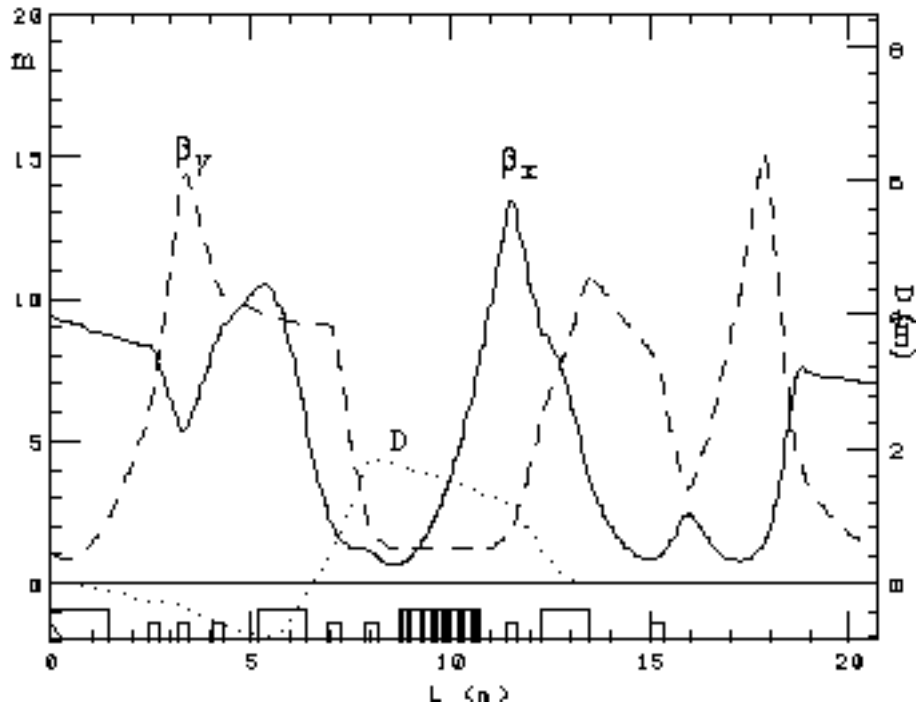

Fig. 11 - Optical functions in the long part

Section b)

Dipole characteristic are listed in the table below. The apertures correspond to a maximum horizontal betatron function of 12 m and the same for the vertical one.

DIPOLES

Type	Arc length (m)	α (°)	ρ (m)	B (T)	$2A_x$ (mm)	$2A_y$ (mm)
Long sector	1.210	49.50	1.40056	1.2146	74	49
Long rect	1.210	49.50	1.40056	1.2146	74	49
Short sector	0.990	40.50	1.40056	1.2146	74	49
Short rect	0.990	40.50	1.40056	1.2146	74	49
					(+ C.O)	(+ C.O)

In the **wiggler** the vertical beam dimension is small; the necessary aperture is $2\ A_y = 16$ + C.O. (β_y = 1.2 m).

In the horizontal plane the central trajectory is not centered around the magnetic axis of the other elements (see Fig. 12), so that the necessary horizontal aperture is larger on the outer part of the machine.

$$2\ A_x = 100 + \text{C.O.} \quad \text{(centered around } x = 12 \text{ mm).}$$

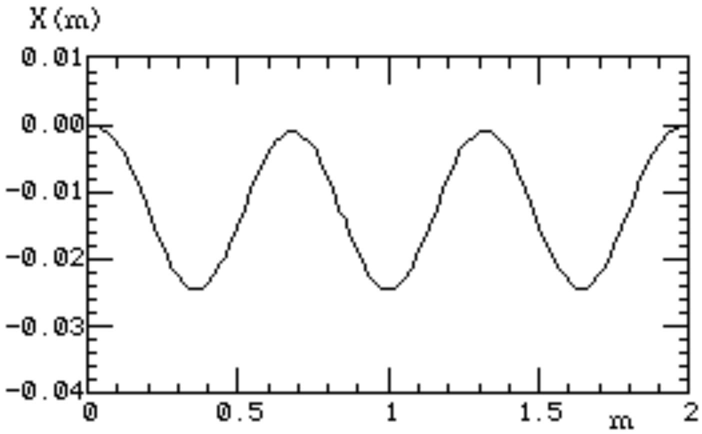

Fig. 12 - Central trajectory inside the wiggler

The vacuum chamber between dipoles and wiggler should be:

$$A_x > 40 \text{ mm}$$
$$A_y > 21 \text{ mm}$$

Section c)

The maximum considered betatron function values are β_x = 16 m ; β_y = 18 m corresponding to A_x > 40 mm - A_y > 30 mm.

APPENDIX

The lattice characteristics and the optical functions of the structure D14* are listed in the following from the splitter input to the center of the straight sections for the short and the long part.

SHORT ARC

I	TY	LENGTH	DL	STRENGTH	ANGLE
8	4	1.450	1.450	0.000000	0.152705
9	1	1.825	0.375	0.000000	0.000000
10	1	1.825	0.000	0.000000	0.000000
11	1	2.075	0.250	0.000000	0.000000
12	1	2.075	0.000	0.000000	0.000000
13	1	2.450	0.375	0.000000	0.000000
14	2	2.750	0.300	1.506706	0.000000
15	1	3.150	0.400	0.000000	0.000000
16	3	3.450	0.300	-2.748434	0.000000
17	1	3.650	0.200	0.000000	0.000000
18	1	3.850	0.200	0.000000	0.000000
19	1	4.050	0.200	0.000000	0.000000
20	2	4.350	0.300	0.848674	0.000000
21	1	5.150	0.800	0.000000	0.000000
22	4	6.140	0.990	0.000000	0.706858
23	1	6.740	0.600	0.000000	0.000000
24	3	7.040	0.300	-1.885094	0.000000
25	1	7.340	0.300	0.000000	0.000000
26	1	7.340	0.000	0.000000	0.000000
27	1	7.640	0.300	0.000000	0.000000
28	2	7.940	0.300	2.348985	0.000000
29	1	8.540	0.600	0.000000	0.000000
30	3	8.540	0.000	-0.011250	0.000000
31	4	8.620	0.080	0.000000	0.042495
32	3	8.620	0.000	-0.011250	0.000000
33	3	8.620	0.000	-0.022501	0.000000
34	4	8.660	0.040	0.000000	0.042495
35	3	8.660	0.000	-0.022501	0.000000
36	3	8.660	0.000	-0.011250	0.000000
37	4	8.741	0.080	0.000000	0.042495
38	3	8.741	0.000	-0.011250	0.000000
39	3	8.741	0.000	-0.011250	0.000000
40	4	8.821	0.080	0.000000	-0.042495
41	3	8.821	0.000	-0.011250	0.000000
42	3	8.821	0.000	-0.090206	0.000000
43	4	8.981	0.161	0.000000	-0.169979
44	3	8.981	0.000	-0.090206	0.000000
45	3	8.981	0.000	-0.011250	0.000000
46	4	9.062	0.080	0.000000	-0.042495
47	3	9.062	0.000	-0.011250	0.000000
48	3	9.062	0.000	-0.011250	0.000000
49	4	9.142	0.080	0.000000	0.042495
50	3	9.142	0.000	-0.011250	0.000000
51	3	9.142	0.000	-0.090206	0.000000
52	4	9.303	0.161	0.000000	0.169979
53	3	9.303	0.000	-0.090206	0.000000
54	3	9.303	0.000	-0.011250	0.000000
55	4	9.383	0.080	0.000000	0.042495
56	3	9.383	0.000	-0.011250	0.000000
57	3	9.383	0.000	-0.011250	0.000000
58	4	9.463	0.080	0.000000	-0.042495
59	3	9.463	0.000	-0.011250	0.000000
60	3	9.463	0.000	-0.090206	0.000000

61	4	9.543	0.080	0.000000	-0.084989
62	4	9.624	0.080	0.000000	-0.084989
63	3	9.624	0.000	-0.090206	0.000000
64	3	9.624	0.000	-0.011250	0.000000
65	4	9.704	0.080	0.000000	-0.042495
66	3	9.704	0.000	-0.011250	0.000000
67	3	9.704	0.000	-0.011250	0.000000
68	4	9.784	0.080	0.000000	0.042495
69	3	9.784	0.000	-0.011250	0.000000
70	3	9.784	0.000	-0.090206	0.000000
71	4	9.945	0.161	0.000000	0.169979
72	3	9.945	0.000	-0.090206	0.000000
73	3	9.945	0.000	-0.011250	0.000000
74	4	10.025	0.080	0.000000	0.042495
75	3	10.025	0.000	-0.011250	0.000000
76	3	10.025	0.000	-0.011250	0.000000
77	4	10.105	0.080	0.000000	-0.042495
78	3	10.105	0.000	-0.011250	0.000000
79	3	10.105	0.000	-0.090206	0.000000
80	4	10.266	0.161	0.000000	-0.169979
81	3	10.266	0.000	-0.090206	0.000000
82	3	10.266	0.000	-0.011250	0.000000
83	4	10.346	0.080	0.000000	-0.042495
84	3	10.346	0.000	-0.011250	0.000000
85	3	10.346	0.000	-0.011250	0.000000
86	4	10.426	0.080	0.000000	0.042495
87	3	10.426	0.000	-0.011250	0.000000
88	3	10.426	0.000	-0.022501	0.000000
89	4	10.466	0.040	0.000000	0.042495
90	3	10.466	0.000	-0.022501	0.000000
91	3	10.466	0.000	-0.011250	0.000000
92	4	10.547	0.080	0.000000	0.042495
93	3	10.547	0.000	-0.011250	0.000000
94	1	10.847	0.300	0.000000	0.000000
95	1	10.847	0.000	0.000000	0.000000
96	1	11.147	0.300	0.000000	0.000000
97	2	11.447	0.300	1.155657	0.000000
98	1	12.047	0.600	0.000000	0.000000
99	3	12.047	0.000	-0.263408	0.000000
100	4	13.037	0.990	0.000000	0.706858
101	3	13.037	0.000	-0.263408	0.000000
102	1	13.337	0.300	0.000000	0.000000
103	1	13.537	0.200	0.000000	0.000000
104	1	13.837	0.300	0.000000	0.000000
105	3	14.137	0.300	-2.031072	0.000000
106	1	14.537	0.400	0.000000	0.000000
107	2	14.837	0.300	3.062147	0.000000
108	1	16.857	2.020	0.000000	0.000000
109	3	17.157	0.300	-2.791873	0.000000
110	1	17.921	0.764	0.000000	0.000000
111	2	18.071	0.150	5.639400	0.000000

EL.	TIP	BETX	ALFX	BETY	ALFY	DX	DPX	QX	QY	dy	
0	0	9.3852	0.2560	1.0000	0.3738	0.000000	0.000000	0.000000	0.000000	0.000000	0.
8	4	8.6740	0.2307	2.3123	-1.2788	0.110496	0.152112	0.025588	0.201308	0.000000	0.
9	1	8.5181	0.1851	3.4316	-1.7062	0.167538	0.152112	0.032534	0.222559	0.000000	0.
10	1	8.5181	0.1851	3.4316	-1.7062	0.167538	0.152112	0.032534	0.222559	0.000000	0.
11	1	8.4331	0.1548	4.3560	-1.9911	0.205566	0.152112	0.037229	0.232858	0.000000	0.
12	1	8.4331	0.1548	4.3560	-1.9911	0.205566	0.152112	0.037229	0.232858	0.000000	0.
13	1	8.3341	0.1093	6.0096	-2.4185	0.262608	0.152112	0.044351	0.244533	0.000000	0.
14	2	7.2048	3.4834	8.5552	-6.4470	0.289612	0.025877	0.050376	0.251346	0.000000	0.
15	1	4.7097	2.7542	14.5089	-8.4371	0.299963	0.025877	0.061313	0.257061	0.000000	0.
16	3	4.2132	-0.9649	15.8862	4.2311	0.345920	0.286796	0.072488	0.260078	0.000000	0.
17	1	4.6175	-1.0566	14.2413	3.9931	0.403280	0.286796	0.079707	0.262194	0.000000	0.
18	1	5.0585	-1.1482	12.6917	3.7552	0.460639	0.286796	0.086295	0.264562	0.000000	0.
19	1	5.5361	-1.2399	11.2372	3.5172	0.517998	0.286796	0.092312	0.267228	0.000000	0.
20	2	5.8708	0.1529	10.0080	0.6839	0.583289	0.145702	0.100584	0.271788	0.000000	0.
21	1	5.7376	0.0135	9.0076	0.5666	0.69985J	0.145702	0.122592	0.285214	0.000000	0.
22	4	3.4432	1.9047	8.0294	0.4214	1.000266	0.435717	0.155394	0.303783	0.000000	0.
23	1	1.6414	1.0982	7.5765	0.3334	1.261696	0.435717	0.196002	0.316039	0.000000	0.
24	3	1.3279	0.0052	6.1964	4.0036	1.504689	1.207076	0.229511	0.322814	0.000000	0.
25	1	1.3926	-0.2208	4.0416	3.1792	1.866812	1.207076	0.264913	0.332361	0.000000	0.
26	1	1.3926	-0.2208	4.0416	3.1792	1.866812	1.207076	0.264913	0.332361	0.000000	0.
27	1	1.5928	-0.4467	2.3814	2.3547	2.228935	1.207076	0.297192	0.347775	0.000000	0.
28	2	1.5741	0.5047	1.5661	0.5519	2.346947	-0.434244	0.326459	0.373491	0.000000	0.
29	1	1.2554	0.0264	1.2037	0.0521	2.086400	-0.434244	0.396641	0.445470	0.000000	0.
30	3	1.2554	0.0123	1.2037	0.0656	2.086400	-0.410771	0.396641	0.445470	0.000000	0.

31	4	1.2563	-0.0234	1.1985	-0.0013	2.053260	-0.414842	0.406817	0.456114	0.000000	0.
32	3	1.2563	-0.0375	1.1985	0.0121	2.053260	-0.391743	0.406817	0.456114	0.000000	0.
33	3	1.2563	-0.0658	1.1985	0.0391	2.053260	-0.345543	0.406817	0.456114	0.000000	0.
34	4	1.2606	-0.0412	1.1968	0.0056	2.038396	-0.395107	0.411892	0.461448	0.000000	0.
35	3	1.2606	-0.0695	1.1968	0.0325	2.038396	-0.349242	0.411892	0.461448	0.000000	0.
36	3	1.2606	-0.0837	1.1968	0.0460	2.038396	-0.326309	0.411892	0.461448	0.000000	0.
37	4	1.2769	-0.1191	1.1948	-0.0212	2.012077	-0.329377	0.421964	0.472140	0.000000	0.
38	3	1.2769	-0.1335	1.1948	-0.0078	2.012077	-0.306741	0.421964	0.472140	0.000000	0.
39	3	1.2769	-0.1478	1.1948	0.0056	2.012077	-0.284104	0.421964	0.472140	0.000000	0.
40	4	1.3035	-0.1828	1.1993	-0.0615	1.985757	-0.371582	0.431870	0.482820	0.000000	0.
41	3	1.3035	-0.1974	1.1993	-0.0481	1.985757	-0.349242	0.431870	0.482820	0.000000	0.
42	3	1.3035	-0.3150	1.1993	0.0601	1.985757	-0.170114	0.431870	0.482820	0.000000	0.
43	4	1.3869	-0.1997	1.2015	-0.0742	1.916351	-0.692497	0.450826	0.504169	0.000000	0.
44	3	1.3869	-0.3248	1.2015	0.0342	1.916351	-0.519631	0.450826	0.504169	0.000000	0.
45	3	1.3869	-0.3404	1.2015	0.0477	1.916351	-0.498071	0.450826	0.504169	0.000000	0.
46	4	1.4442	-0.3725	1.1992	-0.0193	1.872949	-0.583203	0.459855	0.514819	0.000000	0.
47	3	1.4442	-0.3887	1.1992	-0.0058	1.872949	-0.562132	0.459855	0.514819	0.000000	0.
48	3	1.4442	-0.4050	1.1992	0.0077	1.872949	-0.541060	0.459855	0.514819	0.000000	0.
49	4	1.5117	-0.4357	1.2034	-0.0592	1.829547	-0.540214	0.468502	0.525462	0.000000	0.
50	3	1.5117	-0.4527	1.2034	-0.0457	1.829547	-0.519631	0.468502	0.525462	0.000000	0.
51	3	1.5117	-0.5891	1.2034	0.0629	1.829547	-0.354594	0.468502	0.525462	0.000000	0.
52	4	1.6767	-0.4288	1.2047	-0.0711	1.760140	-0.508017	0.484501	0.546745	0.000000	0.
53	3	1.6767	-0.5801	1.2047	0.0376	1.760140	-0.349242	0.484501	0.546745	0.000000	0.
54	3	1.6767	-0.5989	1.2047	0.0512	1.760140	-0.329440	0.484501	0.546745	0.000000	0.
55	4	1.7749	-0.6240	1.2018	-0.0156	1.733821	-0.326247	0.491906	0.557370	0.000000	0.
56	3	1.7749	-0.6440	1.2018	-0.0021	1.733821	-0.306741	0.491906	0.557370	0.000000	0.
57	3	1.7749	-0.6640	1.2018	0.0114	1.733821	-0.287235	0.491906	0.557370	0.000000	0.
58	4	1.8834	-0.6868	1.2054	-0.0554	1.707502	-0.368452	0.498894	0.567992	0.000000	0.
59	3	1.8834	-0.7080	1.2054	-0.0418	1.707502	-0.349242	0.498894	0.567992	0.000000	0.
60	3	1.8834	-0.8779	1.2054	0.0669	1.707502	-0.195214	0.498894	0.567992	0.000000	0.
61	4	2.0161	-0.7716	1.2000	0.0000	1.682279	-0.432868	0.505444	0.578622	0.000000	0.
62	4	2.1300	-0.6432	1.2054	-0.0669	1.638095	-0.667397	0.511602	0.589252	0.000000	0.
63	3	2.1300	-0.8353	1.2054	0.0418	1.638095	-0.519631	0.511602	0.589252	0.000000	0.
64	3	2.1300	-0.8593	1.2054	0.0554	1.638095	-0.501202	0.511602	0.589252	0.000000	0.
65	4	2.2691	-0.8738	1.2018	-0.0114	1.594693	-0.580072	0.517413	0.599874	0.000000	0.
66	3	2.2691	-0.8993	1.2018	0.0021	1.594693	-0.562132	0.517413	0.599874	0.000000	0.
67	3	2.2691	-0.9248	1.2018	0.0156	1.594693	-0.544191	0.517413	0.599874	0.000000	0.
68	4	2.4186	-0.9360	1.2047	-0.0512	1.551291	-0.537083	0.522865	0.610499	0.000000	0.
69	3	2.4186	-0.9632	1.2047	-0.0376	1.551291	-0.519631	0.522865	0.610499	0.000000	0.
70	3	2.4186	-1.1814	1.2047	0.0711	1.551291	-0.379695	0.522865	0.610499	0.000000	0.
71	4	2.7467	-0.8428	1.2034	-0.0629	1.481884	-0.482917	0.532737	0.631782	0.000000	0.
72	3	2.7467	-1.0906	1.2034	0.0457	1.481884	-0.349242	0.532737	0.631782	0.000000	0.
73	3	2.7467	-1.1215	1.2034	0.0592	1.481884	-0.332570	0.532737	0.631782	0.000000	0.
74	4	2.9269	-1.1216	1.1992	-0.0077	1.455565	-0.323116	0.537242	0.642425	0.000000	0.
75	3	2.9269	-1.1546	1.1992	0.0058	1.455565	-0.306741	0.537242	0.642425	0.000000	0.
76	3	2.9269	-1.1875	1.1992	0.0193	1.455565	-0.290365	0.537242	0.642425	0.000000	0.
77	4	3.1173	-1.1834	1.2015	-0.0477	1.429246	-0.365321	0.541470	0.653075	0.000000	0.
78	3	3.1173	-1.2185	1.2015	-0.0342	1.429246	-0.349242	0.541470	0.653075	0.000000	0.
79	3	3.1173	-1.4997	1.2015	0.0742	1.429246	-0.220315	0.541470	0.653075	0.000000	0.
80	4	3.5270	-1.0277	1.1993	-0.0601	1.359839	-0.642296	0.549142	0.674424	0.000000	0.
81	3	3.5270	-1.3459	1.1993	0.0481	1.359839	-0.519631	0.549142	0.674424	0.000000	0.
82	3	3.5270	-1.3855	1.1993	0.0615	1.359839	-0.504332	0.549142	0.674424	0.000000	0.
83	4	3.7481	-1.3677	1.1948	-0.0056	1.316437	-0.576942	0.552654	0.685104	0.000000	0.
84	3	3.7481	-1.4098	1.1948	0.0078	1.316437	-0.562132	0.552654	0.685104	0.000000	0.
85	3	3.7481	-1.4520	1.1948	0.0212	1.316437	-0.547321	0.552654	0.685104	0.000000	0.
86	4	3.9795	-1.4290	1.1968	-0.0460	1.273035	-0.533953	0.555962	0.695796	0.000000	0.
87	3	3.9795	-1.4738	1.1968	-0.0325	1.273035	-0.519631	0.555962	0.695796	0.000000	0.
88	3	3.9795	-1.5633	1.1968	-0.0056	1.273035	-0.490987	0.555962	0.695796	0.000000	0.
89	4	4.0991	-1.4135	1.1985	-0.0391	1.253039	-0.505324	0.557543	0.701130	0.000000	0.
90	3	4.0991	-1.5058	1.1985	-0.0121	1.253039	-0.477130	0.557543	0.701130	0.000000	0.
91	3	4.0991	-1.5519	1.1985	0.0013	1.253039	-0.463033	0.557543	0.701130	0.000000	0.
92	4	4.3458	-1.5208	1.2037	-0.0656	1.216458	-0.448314	0.560569	0.711774	0.000000	0.
93	3	4.3458	-1.5697	1.2037	-0.0521	1.216458	-0.434629	0.560569	0.711774	0.000000	0.
94	1	5.3594	-1.8088	1.3099	-0.3020	1.086069	-0.434629	0.570468	0.750169	0.000000	0.
95	1	5.3594	-1.8088	1.3099	-0.3020	1.086069	-0.434629	0.570468	0.750169	0.000000	0.
96	1	6.5165	-2.0480	1.5661	-0.5519	0.955681	-0.434629	0.578551	0.783753	0.000000	0.
97	2	7.0765	0.2464	2.1669	-1.5198	0.778270	-0.737839	0.585463	0.810246	0.000000	0.
98	1	6.8348	0.1565	4.5405	-2.4362	0.335567	-0.737839	0.599211	0.840878	0.000000	0.
99	3	6.8348	-1.6439	4.5405	-1.2402	0.335567	-0.649448	0.599211	0.840878	0.000000	0.
100	4	6.6741	1.7781	7.5439	-1.7936	0.000000	0.000000	0.620711	0.867931	0.000000	0.
101	3	6.6741	0.0201	7.5439	0.1936	0.000000	0.000000	0.620711	0.867931	0.000000	0.
102	1	6.6756	-0.0248	7.4401	0.1523	0.000000	0.000000	0.627867	0.874305	0.000000	0.
103	1	6.6915	-0.0548	7.3847	0.1248	0.000000	0.000000	0.632630	0.878600	0.000000	0.
104	1	6.7379	-0.0998	7.3222	0.0835	0.000000	0.000000	0.639743	0.885095	0.000000	0.
105	3	8.1282	-4.8137	6.0307	3.9558	0.000000	0.000000	0.646395	0.892066	0.000000	0.
106	1	12.4550	-6.0032	3.3078	2.8516	0.000000	0.000000	0.652724	0.906338	0.000000	0.
107	2	12.5460	5.7280	2.5353	-0.0444	0.000000	0.000000	0.656371	0.923628	0.000000	0.
108	1	0.4011	0.2843	4.3273	-0.8427	0.000000	0.000000	0.834776	1.028014	0.000000	0.
109	3	0.5735	-0.9064	3.7858	2.4938	0.000000	0.000000	0.947824	1.039333	0.000000	0.
110	1	3.8137	-3.3337	1.0879	1.0366	0.000000	0.000000	1.034251	1.100779	0.000000	0.
111	2	4.3361	0.0000	0.9387	0.0000	0.000000	0.000000	1.040000	1.125000	0.000000	0.

LONG ARC

I	TY	LENGTH	DL	STRENGTH	ANGLE
8	4	1.450	1.450	0.000000	-0.152705
9	1	1.825	0.375	0.000000	0.000000
10	1	1.825	0.000	0.000000	0.000000
11	1	2.075	0.250	0.000000	0.000000
12	1	2.075	0.000	0.000000	0.000000
13	1	2.450	0.375	0.000000	0.000000
14	2	2.750	0.300	1.023086	0.000000
15	1	3.150	0.400	0.000000	0.000000
16	3	3.450	0.300	-2.316216	0.000000
17	1	3.650	0.200	0.000000	0.000000
18	1	3.850	0.200	0.000000	0.000000
19	1	4.050	0.200	0.000000	0.000000
20	2	4.350	0.300	0.659662	0.000000
21	1	5.150	0.800	0.000000	0.000000
22	4	6.360	1.210	0.000000	0.863938
23	1	6.960	0.600	0.000000	0.000000
24	3	7.260	0.300	-2.171706	0.000000
25	1	7.560	0.300	0.000000	0.000000
26	1	7.560	0.000	0.000000	0.000000
27	1	7.860	0.300	0.000000	0.000000
28	2	8.160	0.300	3.056279	0.000000
29	1	8.760	0.600	0.000000	0.000000
30	3	8.760	0.000	-0.011250	0.000000
31	4	8.840	0.080	0.000000	0.042495
32	3	8.840	0.000	-0.011250	0.000000
33	3	8.840	0.000	-0.022501	0.000000
34	4	8.880	0.040	0.000000	0.042495
35	3	8.880	0.000	-0.022501	0.000000
36	3	8.880	0.000	-0.011250	0.000000
37	4	8.961	0.080	0.000000	0.042495
38	3	8.961	0.000	-0.011250	0.000000
39	3	8.961	0.000	-0.011250	0.000000
40	4	9.041	0.080	0.000000	-0.042495
41	3	9.041	0.000	-0.011250	0.000000
42	3	9.041	0.000	-0.090206	0.000000
43	4	9.201	0.161	0.000000	-0.169979
44	3	9.201	0.000	-0.090206	0.000000
45	3	9.201	0.000	-0.011250	0.000000
46	4	9.282	0.080	0.000000	-0.042495
47	3	9.282	0.000	-0.011250	0.000000
48	3	9.282	0.000	-0.011250	0.000000
49	4	9.362	0.080	0.000000	0.042495
50	3	9.362	0.000	-0.011250	0.000000
51	3	9.362	0.000	-0.090206	0.000000
52	4	9.523	0.161	0.000000	0.169979
53	3	9.523	0.000	-0.090206	0.000000
54	3	9.523	0.000	-0.011250	0.000000
55	4	9.603	0.080	0.000000	0.042495
56	3	9.603	0.000	-0.011250	0.000000
57	3	9.603	0.000	-0.011250	0.000000
58	4	9.683	0.080	0.000000	-0.042495
59	3	9.683	0.000	-0.011250	0.000000
60	3	9.683	0.000	-0.090206	0.000000
61	4	9.763	0.080	0.000000	-0.084989
62	4	9.844	0.080	0.000000	-0.084989
63	3	9.844	0.000	-0.090206	0.000000
64	3	9.844	0.000	-0.011250	0.000000
65	4	9.924	0.080	0.000000	-0.042495
66	3	9.924	0.000	-0.011250	0.000000
67	3	9.924	0.000	-0.011250	0.000000
68	4	10.004	0.080	0.000000	0.042495
69	3	10.004	0.000	-0.011250	0.000000
70	3	10.004	0.000	-0.090206	0.000000
71	4	10.165	0.161	0.000000	0.169979
72	3	10.165	0.000	-0.090206	0.000000
73	3	10.165	0.000	-0.011250	0.000000
74	4	10.245	0.080	0.000000	0.042495
75	3	10.245	0.000	-0.011250	0.000000
76	3	10.245	0.000	-0.011250	0.000000
77	4	10.325	0.080	0.000000	-0.042495
78	3	10.325	0.000	-0.011250	0.000000
79	3	10.325	0.000	-0.090206	0.000000
80	4	10.486	0.161	0.000000	-0.169979
81	3	10.486	0.000	-0.090206	0.000000
82	3	10.486	0.000	-0.011250	0.000000

83	4	10.566	0.080	0.000000	-0.042495
84	3	10.566	0.000	-0.011250	0.000000
85	3	10.566	0.000	-0.011250	0.000000
86	4	10.646	0.080	0.000000	0.042495
87	3	10.646	0.000	-0.011250	0.000000
88	3	10.646	0.000	-0.022501	0.000000
89	4	10.686	0.040	0.000000	0.042495
90	3	10.686	0.000	-0.022501	0.000000
91	3	10.686	0.000	-0.011250	0.000000
92	4	10.767	0.080	0.000000	0.042495
93	3	10.767	0.000	-0.011250	0.000000
94	1	11.067	0.300	0.000000	0.000000
95	1	11.067	0.000	0.000000	0.000000
96	1	11.367	0.300	0.000000	0.000000
97	2	11.667	0.300	2.091142	0.000000
98	1	12.267	0.600	0.000000	0.000000
99	3	12.267	0.000	-0.329158	0.000000
100	4	13.477	1.210	0.000000	0.863938
101	3	13.477	0.000	-0.329158	0.000000
102	1	14.177	0.700	0.000000	0.000000
103	1	14.477	0.300	0.000000	0.000000
104	1	15.027	0.550	0.000000	0.000000
105	3	15.327	0.300	-1.392419	0.000000
106	1	15.807	0.480	0.000000	0.000000
107	2	16.107	0.300	4.371567	0.000000
108	1	17.747	1.640	0.000000	0.000000
109	3	18.047	0.300	-3.307238	0.000000
110	1	18.497	0.450	0.000000	0.000000
111	2	18.797	0.300	2.822939	0.000000
112	1	20.674	1.878	0.000000	0.000000

EL.	TIP	BETX	ALFX	BETY	ALFY	DX	DPX	QX	QY	dy	
0	0	9.3852	0.2560	1.0000	0.3738	0.000000	0.000000	0.000000	0.000000	0.000000	0.
8	4	8.6740	0.2307	2.3123	-1.2788	-0.110496	-0.152112	0.025588	0.201308	0.000000	0.
9	1	8.5181	0.1851	3.4316	-1.7062	-0.167538	-0.152112	0.032534	0.222559	0.000000	0.
10	1	8.5181	0.1851	3.4316	-1.7062	-0.167538	-0.152112	0.032534	0.222559	0.000000	0.
11	1	8.4331	0.1548	4.3560	-1.9911	-0.205566	-0.152112	0.037229	0.232858	0.000000	0.
12	1	8.4331	0.1548	4.3560	-1.9911	-0.205566	-0.152112	0.037229	0.232858	0.000000	0.
13	1	8.3341	0.1093	6.0096	-2.4185	-0.262608	-0.152112	0.044351	0.244533	0.000000	0.
14	2	7.5389	2.4593	8.2277	-5.2009	-0.295547	-0.065792	0.050284	0.251430	0.000000	0.
15	1	5.7211	2.0853	12.9339	-6.5645	-0.321864	-0.065792	0.059983	0.257603	0.000000	0.
16	3	5.6566	-1.8556	14.1197	2.8904	-0.376429	-0.304273	0.068675	0.261015	0.000000	0.
17	1	6.4302	-2.0127	12.9901	2.7579	-0.437283	-0.304273	0.073954	0.263365	0.000000	0.
18	1	7.2667	-2.1698	11.9134	2.6254	-0.498138	-0.304273	0.078611	0.265924	0.000000	0.
19	1	8.1661	-2.3269	10.8898	2.4929	-0.558993	-0.304273	0.082744	0.268719	0.000000	0.
20	2	9.1016	-0.7296	10.0544	0.3467	-0.632863	-0.185753	0.088229	0.273328	0.000000	0.
21	1	10.3767	-0.8643	9.5710	0.2575	-0.781465	-0.185753	0.101345	0.286322	0.000000	0.
22	4	5.7632	3.6776	9.1109	0.1227	-0.214377	1.064049	0.123333	0.307002	0.000000	0.
23	1	2.2574	2.1655	9.0037	0.0559	0.424052	1:064049	0.149932	0.317554	0.000000	0.
24	3	1.4948	0.5401	7.3357	5.1372	0.795888	1.455103	0.176908	0.323240	0.000000	0.
25	1	1.2485	0.2808	4.5894	4.0170	1.232419	1.455103	0.212146	0.331473	0.000000	0.
26	1	1.2485	0.2808	4.5894	4.0170	1.232419	1.455103	0.212146	0.331473	0.000000	0.
27	1	1.1578	0.0216	2.5153	2.8969	1.668949	1.455103	0.252283	0.345544	0.000000	0.
28	2	0.9277	0.6739	1.5661	0.5519	1.861420	-0.201515	0.296851	0.370825	0.000000	0.
29	1	0.6833	-0.2666	1.2037	0.0521	1.740511	-0.201515	0.432692	0.442805	0.000000	0.
30	3	0.6833	-0.2743	1.2037	0.0656	1.740511	-0.181934	0.432692	0.442805	0.000000	0.
31	4	0.7362	-0.3841	1.1985	-0.0013	1.726046	-0.178432	0.450737	0.453449	0.000000	0.
32	3	0.7362	-0.3924	1.1985	0.0121	1.726046	-0.159014	0.450737	0.453449	0.000000	0.
33	3	0.7362	-0.4090	1.1985	0.0391	1.726046	-0.120177	0.450737	0.453449	0.000000	0.
34	4	0.7702	-0.4380	1.1968	0.0056	1.720519	-0.155226	0.459221	0.458783	0.000000	0.
35	3	0.7702	-0.4553	1.1968	0.0325	1.720519	-0.116513	0.459221	0.458783	0.000000	0.
36	3	0.7702	-0.4639	1.1968	0.0460	1.720519	-0.097156	0.459221	0.458783	0.000000	0.
37	4	0.8534	-0.5715	1.1948	-0.0212	1.712874	-0.093282	0.474999	0.469474	0.000000	0.
38	3	0.8534	-0.5811	1.1948	-0.0078	1.712874	-0.074012	0.474999	0.469474	0.000000	0.
39	3	0.8534	-0.5907	1.1948	0.0056	1.712874	-0.054741	0.474999	0.469474	0.000000	0.
40	4	0.9567	-0.6961	1.1993	-0.0615	1.705230	-0.135697	0.489151	0.480155	0.000000	0.
41	3	0.9567	-0.7068	1.1993	-0.0481	1.705230	-0.116513	0.489151	0.480155	0.000000	0.
42	3	0.9567	-0.7931	1.1993	0.0601	1.705230	0.037309	0.489151	0.480155	0.000000	0.
43	4	1.2226	-0.8470	1.2015	-0.0742	1.673005	-0.437817	0.512748	0.501504	0.000000	0.
44	3	1.2226	-0.9573	1.2015	0.0342	1.673005	-0.286902	0.512748	0.501504	0.000000	0.
45	3	1.2226	-0.9710	1.2015	0.0477	1.673005	-0.268080	0.512748	0.501504	0.000000	0.
46	4	1.3863	-1.0674	1.1992	-0.0193	1.648278	-0.347946	0.522564	0.512154	0.000000	0.
47	3	1.3863	-1.0830	1.1992	-0.0058	1.648278	-0.329403	0.522564	0.512154	0.000000	0.
48	3	1.3863	-1.0986	1.1992	0.0077	1.648278	-0.310859	0.522564	0.512154	0.000000	0.
49	4	1.5702	-1.1911	1.2034	-0.0592	1.623551	-0.305167	0.531225	0.522796	0.000000	0.
50	3	1.5702	-1.2088	1.2034	-0.0457	1.623551	-0.286902	0.531225	0.522796	0.000000	0.
51	3	1.5702	-1.3505	1.2034	0.0629	1.623551	-0.140448	0.531225	0.522796	0.000000	0.
52	4	1.9965	-1.2791	1.2047	-0.0711	1.591325	-0.260060	0.545605	0.544080	0.000000	0.

53	3	1.9965	-1.4592	1.2047	0.0376	1.591325	-0.116513	0.545605	0.544080	0.000000	0.
54	3	1.9965	-1.4817	1.2047	0.0512	1.591325	-0.098610	0.545605	0.544080	0.000000	0.
55	4	2.2407	-1.5598	1.2018	-0.0156	1.583681	-0.091829	0.551645	0.554705	0.000000	0.
56	3	2.2407	-1.5850	1.2018	-0.0021	1.583681	-0.074012	0.551645	0.554705	0.000000	0.
57	3	2.2407	-1.6102	1.2018	0.0114	1.583681	-0.056195	0.551645	0.554705	0.000000	0.
58	4	2.5052	-1.6826	1.2054	-0.0554	1.576037	-0.134244	0.557036	0.565327	0.000000	0.
59	3	2.5052	-1.7108	1.2054	-0.0418	1.576037	-0.116513	0.557036	0.565327	0.000000	0.
60	3	2.5052	-1.9368	1.2054	0.0669	1.576037	0.025655	0.557036	0.565327	0.000000	0.
61	4	2.8088	-1.8360	1.2000	0.0000	1.568996	-0.200979	0.561847	0.575957	0.000000	0.
62	4	3.0919	-1.6823	1.2054	-0.0669	1.543812	-0.426163	0.566177	0.586587	0.000000	0.
63	3	3.0919	-1.9612	1.2054	0.0418	1.543812	-0.286902	0.566177	0.586587	0.000000	0.
64	3	3.0919	-1.9960	1.2054	0.0554	1.543812	-0.269533	0.566177	0.586587	0.000000	0.
65	4	3.4167	-2.0485	1.2018	-0.0114	1.519084	-0.346493	0.570107	0.597209	0.000000	0.
66	3	3.4167	-2.0870	1.2018	0.0021	1.519084	-0.329403	0.570107	0.597209	0.000000	0.
67	3	3.4167	-2.1254	1.2018	0.0156	1.519084	-0.312313	0.570107	0.597209	0.000000	0.
68	4	3.7617	-2.1704	1.2047	-0.0512	1.494357	-0.303714	0.573670	0.607833	0.000000	0.
69	3	3.7617	-2.2128	1.2047	-0.0376	1.494357	-0.286902	0.573670	0.607833	0.000000	0.
70	3	3.7617	-2.5521	1.2047	0.0711	1.494357	-0.152102	0.573670	0.607833	0.000000	0.
71	4	4.5088	-2.0565	1.2034	-0.0629	1.462132	-0.248406	0.579845	0.629117	0.000000	0.
72	3	4.5088	-2.4632	1.2034	0.0457	1.462132	-0.116513	0.579845	0.629117	0.000000	0.
73	3	4.5088	-2.5139	1.2034	0.0592	1.462132	-0.100063	0.579845	0.629117	0.000000	0.
74	4	4.9142	-2.5337	1.1992	-0.0077	1.454488	-0.090375	0.582559	0.639759	0.000000	0.
75	3	4.9142	-2.5890	1.1992	0.0058	1.454488	-0.074012	0.582559	0.639759	0.000000	0.
76	3	4.9142	-2.6442	1.1992	0.0193	1.454488	-0.057648	0.582559	0.639759	0.000000	0.
77	4	5.3398	-2.6547	1.2015	-0.0477	1.446844	-0.132790	0.585052	0.650410	0.000000	0.
78	3	5.3398	-2.7147	1.2015	-0.0342	1.446844	-0.116513	0.585052	0.650410	0.000000	0.
79	3	5.3398	-3.1964	1.2015	0.0742	1.446844	0.014001	0.585052	0.650410	0.000000	0.
80	4	6.2472	-2.4016	1.1993	-0.0601	1.414618	-0.414509	0.589455	0.671759	0.000000	0.
81	3	6.2472	-2.9652	1.1993	0.0481	1.414618	-0.286902	0.589455	0.671759	0.000000	0.
82	3	6.2472	-3.0354	1.1993	0.0615	1.414618	-0.270987	0.589455	0.671759	0.000000	0.
83	4	6.7332	-3.0152	1.1948	-0.0056	1.389891	-0.345040	0.591424	0.682439	0.000000	0.
84	3	6.7332	-3.0909	1.1948	0.0078	1.389891	-0.329403	0.591424	0.682439	0.000000	0.
85	3	6.7332	-3.1667	1.1948	0.0212	1.389891	-0.313766	0.591424	0.682439	0.000000	0.
86	4	7.2393	-3.1353	1.1968	-0.0460	1.365164	-0.302260	0.593253	0.693131	0.000000	0.
87	3	7.2393	-3.2167	1.1968	-0.0325	1.365164	-0.286902	0.593253	0.693131	0.000000	0.
88	3	7.2393	-3.3796	1.1968	-0.0056	1.365164	-0.256185	0.593253	0.693131	0.000000	0.
89	4	7.4999	-3.1108	1.1985	-0.0391	1.354506	-0.274878	0.594120	0.698465	0.000000	0.
90	3	7.4999	-3.2796	1.1985	-0.0121	1.354506	-0.244401	0.594120	0.698465	0.000000	0.
91	3	7.4999	-3.3640	1.1985	0.0013	1.354506	-0.229162	0.594120	0.698465	0.000000	0.
92	4	8.0364	-3.3150	1.2037	-0.0656	1.336599	-0.216937	0.595765	0.709109	0.000000	0.
93	3	8.0364	-3.4054	1.2037	-0.0521	1.336599	-0.201900	0.595765	0.709109	0.000000	0.
94	1	10.2207	-3.8756	1.3099	-0.3020	1.276029	-0.201900	0.601034	0.747504	0.000000	0.
95	1	10.2207	-3.8756	1.3099	-0.3020	1.276029	-0.201900	0.601034	0.747504	0.000000	0.
96	1	12.6871	-4.3459	1.5661	-0.5519	1.215459	-0.201900	0.605228	0.781088	0.000000	0.
97	2	12.8703	3.7739	2.3339	-2.1660	1.044178	-0.922013	0.608848	0.806967	0.000000	0.
98	1	8.7680	3.0633	5.8109	-3.6291	0.490970	-0.922013	0.617842	0.833013	0.000000	0.
99	3	8.7680	0.1773	5.8109	-1.7164	0.490970	-0.760406	0.617842	0.833013	0.000000	0.
100	4	3.5864	2.9825	10.9588	-2.5381	0.000000	0.000000	0.648254	0.857239	0.000000	0.
101	3	3.5864	1.8020	10.9588	1.0691	0.000000	0.000000	0.648254	0.857239	0.000000	0.
102	1	1.6438	0.9730	9.5579	0.9322	0.000000	0.000000	0.694799	0.868133	0.000000	0.
103	1	1.1666	0.6177	9.0161	0.8736	0.000000	0.000000	0.729553	0.873278	0.000000	0.
104	1	0.8453	-0.0336	8.1143	0.7660	0.000000	0.000000	0.822974	0.883519	0.000000	0.
105	3	1.0888	-0.8115	6.7340	3.6414	0.000000	0.000000	0.874694	0.889846	0.000000	0.
106	1	2.2188	-1.5427	3.7261	2.6250	0.000000	0.000000	0.924662	0.905120	0.000000	0.
107	2	2.2758	1.3784	3.5898	-2.1126	0.000000	0.000000	0.944596	0.919066	0.000000	0.
108	1	1.1819	-0.7115	14.6125	-4.6085	0.000000	0.000000	1.193129	0.955420	0.000000	0.
109	3	2.2134	-3.0612	13.0499	9.2898	0.000000	0.000000	1.224334	0.958709	0.000000	0.
110	1	5.9173	-5.1697	6.0438	6.2794	0.000000	0.000000	1.244176	0.966776	0.000000	0.
111	2	7.5267	0.2673	3.9296	1.3548	0.000000	0.000000	1.251033	0.977001	0.000000	0.
112	1	7.0249	0.0000	1.3859	0.0000	0.000000	0.000000	1.292600	1.125800	0.000000	0.