Racetrack Accumulator Lattice *a_dec*

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Abstract

This report describes the study of a new KAON racetrack Accumulator lattice *a_dec*. Choice of a longer arc cell and modulation of the initially regular distribution of the lattice dipoles help to solve the two main problems: 1) arranging the Accumulator ring diameter[1] to be equal to the Booster diameter and 2) lack of flexibility in the normalized dispersion at the injection point. This lattice is the best Accumulator option so far found for matching to the Standard Booster lattice. Good shape compatibility is also found with some of the alternative racetrack Booster lattices which are currently under consideration.

1 Requirements on KAON racetrack Accumulator lattices and a brief history

A racetrack Accumulator lattice must satisfy the conditions:

1. A and B ring diameters to be exactly equal (long straight sections placed exactly above one another);
2. transverse separation of the A- and B-ring arcs to be less than 1 m.

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[1] For a racetrack we shall call "ring diameter" the distance between the two end points of the arc as well as the line connecting these two points.

The latest requirements [2], [3] for the H^- injection region are:

1. mean value of the normalized dispersion $\overline{\eta}_n = 1.7$ at the injection point;
2. tuning interval for η_n: 1.7 ± 0.25 is highly desirable;
3. about 2 m or more free space in the H^- injection cell between the soft dipole and the closest quadrupole [3]. We denote this drift as *fc2* (see Fig.2 below).

It was found quite difficult to meet all these conditions in one lattice. Several different attempts were made in 1993.

Splitting the central F-quadrupole in each superperiod of the Standard Booster lattice while keeping the other cells almost unchanged, mentioned for first time by A. Iliev [1] gives too low value for η_n for either normal or reversed quadrupole polarities.

The studies reported in [1] were focused on a search for an Accumulator ring compatible in shape with the Standard Booster. Rejecting the option of injecting into a long straight section, only two of the lattices considered there remain (doublet and triplet).. Both of these lattices have η_n lower than required and little possibility for varying it without changing the ring diameter.

The Accumulator lattice *a_nov* , suggested by R. Servranckx for a Booster having 10-regular arc cells (Fig. 1) makes use of the modified H^- injection scheme proposed by G.Rees [3]. The lattice dipoles (3.27 kG) in the third and eighth arc cells are replaced by the "soft" (1.78 kG) dipoles required for H^- injection. Thus the arc shape becomes automatically very close to a half-circle (all FODO cells are full with dipoles), which is advantageous for shape compatibility requirement. The optical functions are more regular and with some adjustment of the parameters the first four requirements can be met.

Only the last requirement for a 2-m long free space in the H^- injection cell between the soft dipole and the quadrupole cannot be satisfied in *a_nov.* This is because the length of the H^- injection cell cannot be increased without a significant increase in the arc length and the ring diameter.

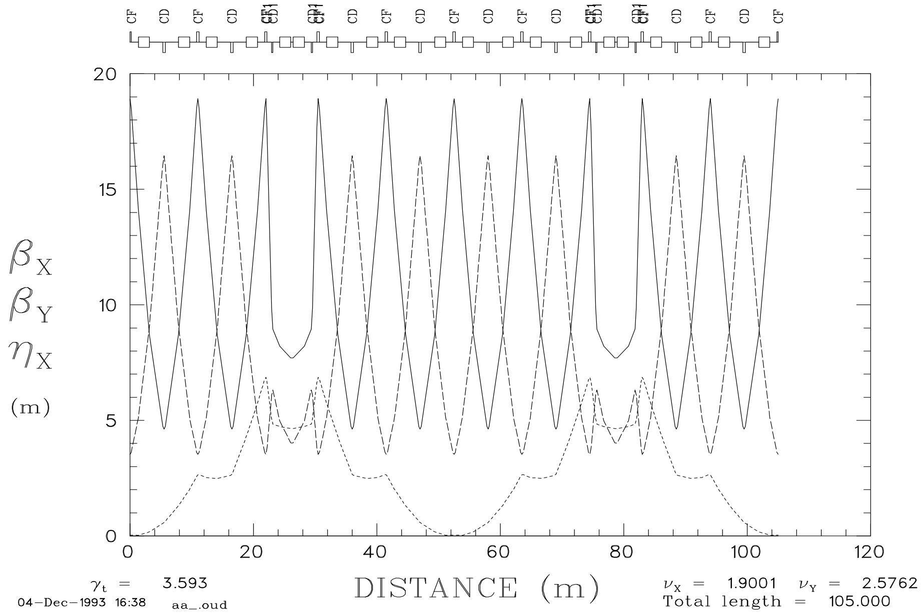

Figure 1: Lattice functions of the Accumulator *a_nov* (R.Servranckx)

2 The Accumulator lattice *a_dec* adapted to the shape of the Standard Booster

Formally the lattice *a_dec* (Fig. 2), is a simple modification of *a_nov* with the two halfcells at the ends of each superperiod removed. This increases the length of the H^- injection cell (and the length of all FBDB cells correspondingly) while keeping the arc length the same. The beta-functions are about 2 m higher and the A-ring shape differs a little more from a circle than in *a_nov*. The longer bending cell allows the lattice dipoles to be shifted, thus varying the mean normalized dispersion within quite a wide interval, as will be seen below. The number of quadrupole families in the arc is four. With all lattice dipoles placed exactly in the middle of every half-cell the mean normalized dispersion is $\overline{\eta}_n = 2$.

To explain how $\overline{\eta}_n$ can be decreased to 1.7 and how the ring diameter is adjusted, we consider the three lattice dipoles in a half superperiod (Fig. 2). A shift of the first dipole (at the end of the superperiod) away from the centre of the superperiod leads to an increase in the ring diameter. We denote the magnitude of the shift by x_1. Shifts of the other two dipoles (x_2 and $-x_2$) towards the middle of the FBDB cell suppress the dispersion and decrease $\overline{\eta}_n$.

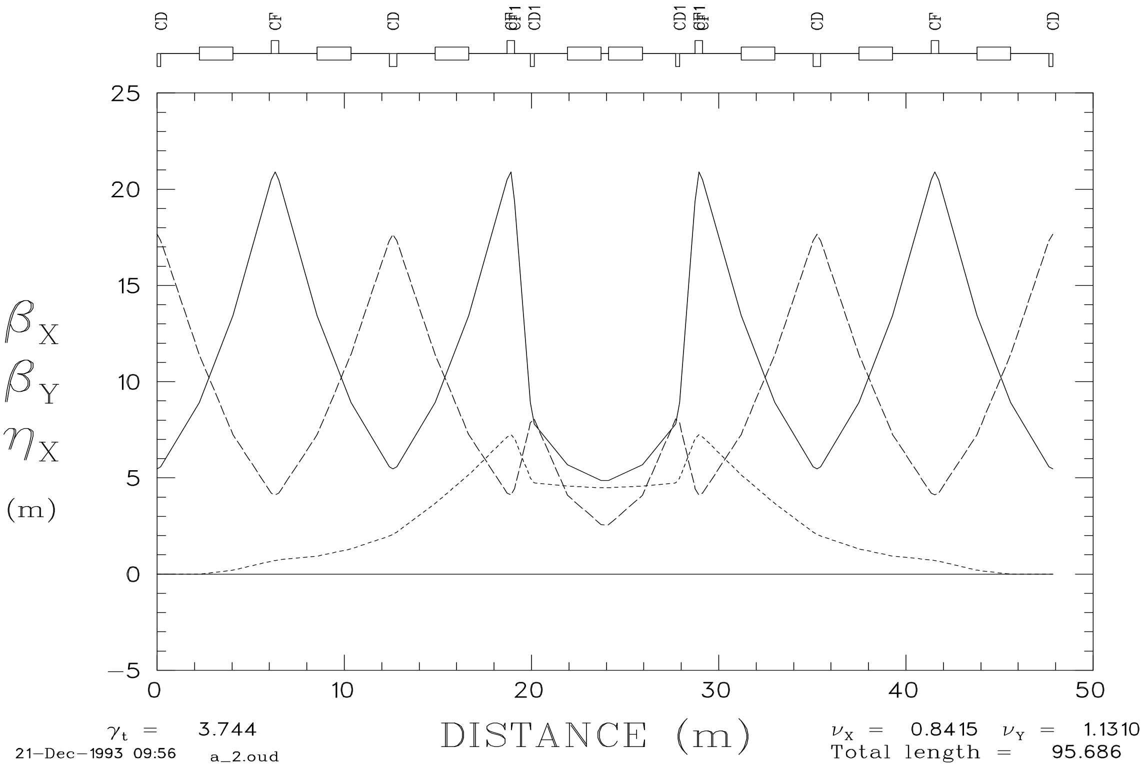

Figure 2: The Accumulator lattice *a_dec* adapted to the shape of the Standard Booster lattice. One of the two arc superperiods is shown. The H^- injection cell (in the middle) has a structure FODOB'B'ODOF. We denote by B' the low-field (soft) dipole for H^- injection and by B – a lattice dipole. The drift space between each of the two soft dipoles B' and the closest defocusing quadrupole must be at least 2 m. Without shifting the lattice dipoles the momentum resolution is $\overline{\eta}_n = 2$.

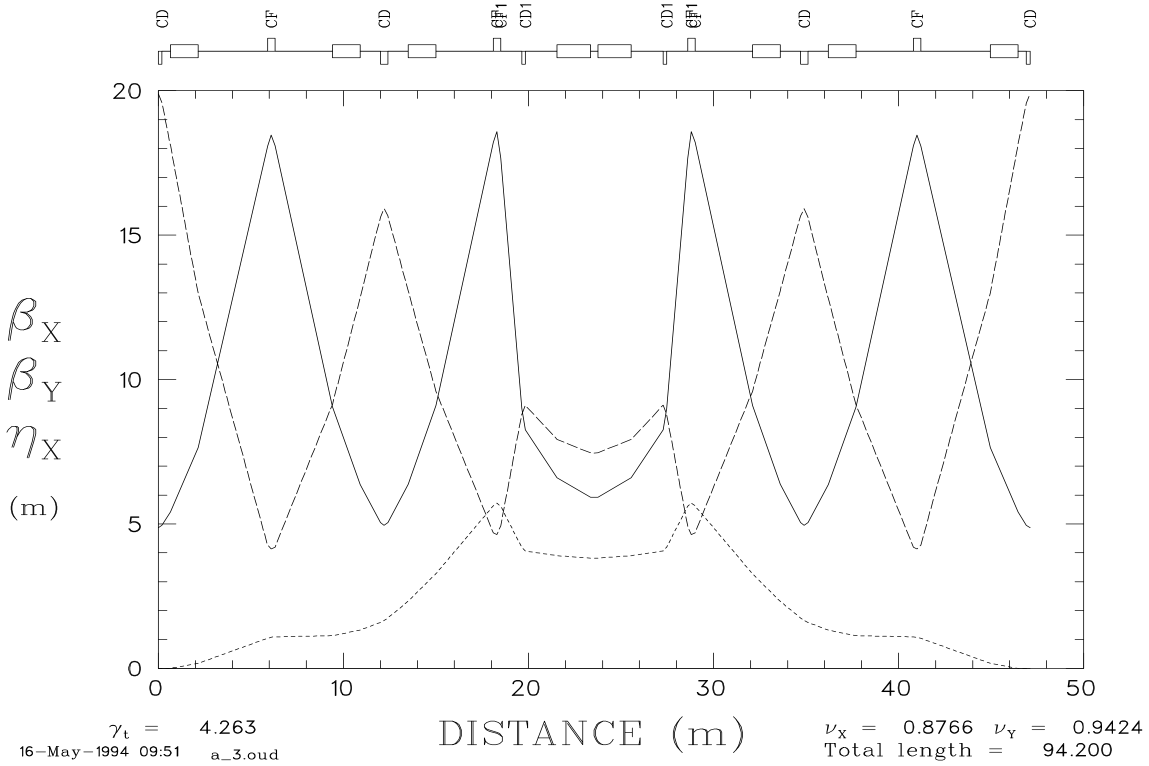

Figure 3: The arc superperiod after shifting the dipoles in order to get $\overline{\eta}_n = 1.7$, while keeping the ring diameter equal to that of the Booster.

The new lattice functions of the arc are shown in Fig. 3.

Summarizing, the variable lattice parameters are:
1) the length of the FBDB cell;
2) the length of the H^- injection cell (within a narrow range where matching of the beta-function and the dispersion function is possible);
3) x_1;
4) x_2.

The goals are :
1) $\eta_n = 1.7$;
2) diameter of A ring = diameter of the B ring;
3) maximum beta function ≤ 23 m;
4) 2 m long drift in the H^- injection cell.

The scheme of shifting the dipoles preserves the following properties of the lattice:
- the arc superperiodicity of 2;
- the mirror symmetry of each superperiod;
- the length of the drift *fc2* in the H^- injection cell is 1.8 m;
- the ring diameters are kept exactly equal;
- the maximum A-ring beta-functions in the arc are less than 22 m (with mismatch);
- the minimum distance between quadrupoles and dipoles in the lattice is 45 cm.

The lengths of both types of arc cells are varied independently in order to adjust the ring diameter and to match the optical functions. Therefore the Accumulator arc length obtained is different from that of the Booster. Since both rings have equal overall length, the footprint of the shorter arc in the survey plots shown below must be shifted in a positive z-direction (the A-ring arc in Fig. 4). The magnitude of this shift is

$$dz_A = (length\ arc_B \ - \ length\ arc_A)/2 \ = \ 0.743m. \tag{1}$$

The middle of the diameter of the longer arc (which is not shifted) is used as an origin to introduce pair of polar coordinates (r, α). The azimuthal dependence of the radial displacement between the Accumulator and the Booster arcs $r_A - r_B$ is shown in Figure 5.

The shift dz_A coincides with the transverse shift between the rings at the symmetry point:

$$dz_A \ = \ (r_A - r_B) \mid \ _{\alpha=90^o}, \tag{2}$$

because the A- and B-ring diameters are equal and the arc of any lattice considered here has mirror symmetry.

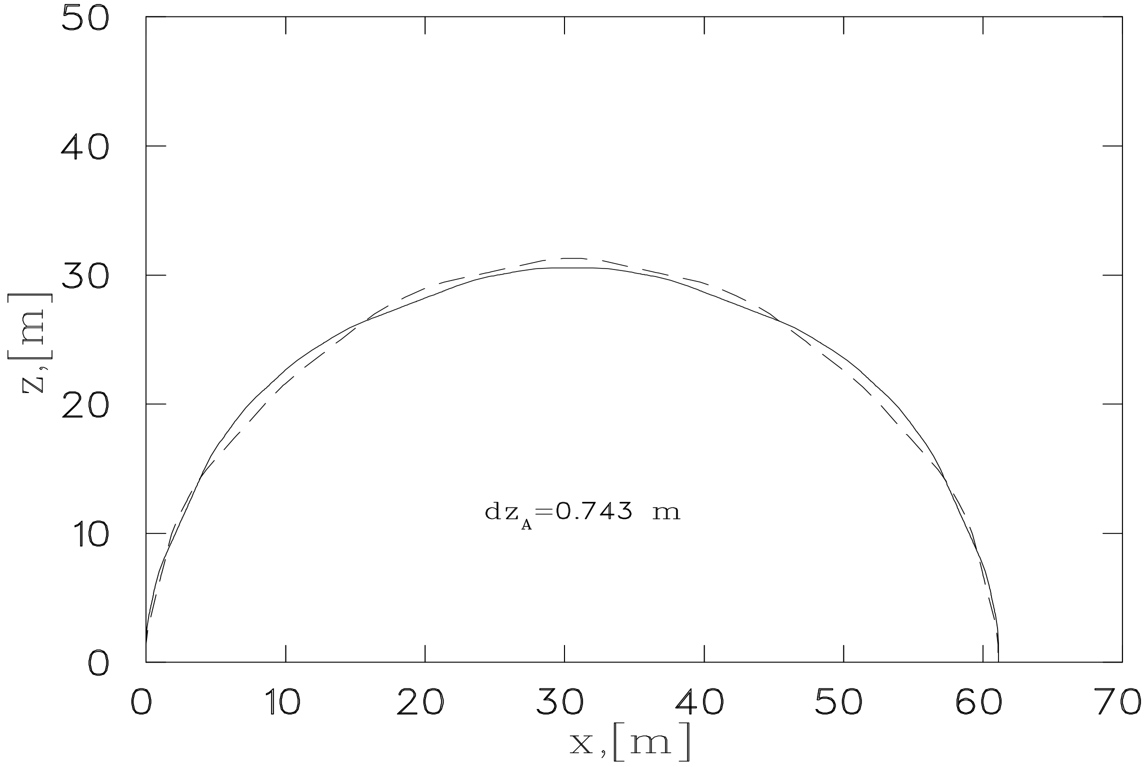

Figure 4: Layout of the arcs of A (dashed line) and B rings – the Standard lattice case.

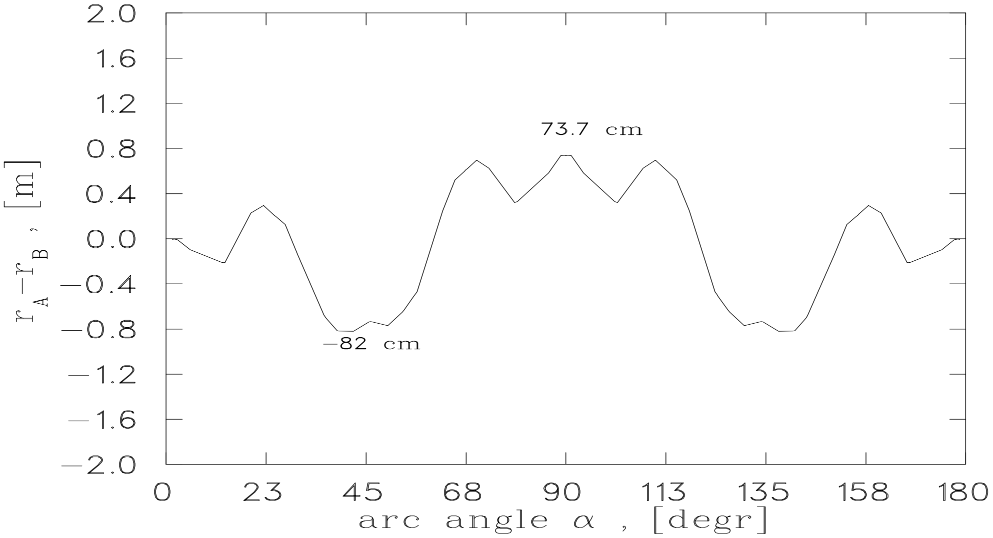

Figure 5: Radial displacement between A and B rings – the Standard lattice case.

3 Flexibility of the *a_dec* parameters. Shape compatibility with alternative racetrack Booster lattices.

The procedure described above was used repeatedly to adjust the *a_dec* parameters to each of the alternative Booster lattices *b_nov* , *NEWBR* and *b_feb10*. The *a_dec* parameters thus obtained are shown in Table 1. Although various combinations are possible between cell lengths and dipole shifts, good matching of the optical functions was found only if the parameters were not far from those in Table 1. Table 1 suggests that the curved cell length and the drift length *fc2* are roughly proportional to the square and to the cube of the ring diameter respectively.

Booster lattice	A- and B-ring diameter m	length of FBDB cell m	length H^- inj. cell m	x_1 m	x_2 m	β_{max} hor./vert. m	*fc2* drift m
b_nov	54	11	9.3	0.3	1.5	17/21	1.3
Stand.latt.	61.09	11.3	10	-1.65	1	19/21	1.8
NEWBR	63.17	12.6	10.9	-1.6	1.2	20/23.5	2.2
	65	13.1	11	-1.8	1.5	20/24	2.38
b_feb10	67.4	13.6	11.2	-2.1	1.8	20.5/22.7	2.48

Table 1: Parameters of the lattice *a_dec* adjusted to get η_n=1.7 at the injection point depending on the kind of Booster lattice.

The A- and B-ring layout and radial shift computed using the parameters of Table 1 are shown in Figures 6–11. These show that dz_A is always less than the maximum transverse shift between the rings. An exception is the case when the arc of one of the lattices A or B starts with an empty halfcell (*NEWBR*). In this case dz_A is quite large (2 m) and thus determines the maximum transverse shift between the rings. The conclusion is that the shape of *a_dec* lattice is not well adapted to *NEWBR*.

For the case of the Booster lattice *b_nov* the maximum length of *fc2* so far obtained giving good matching of the lattice functions is 1.3 m.

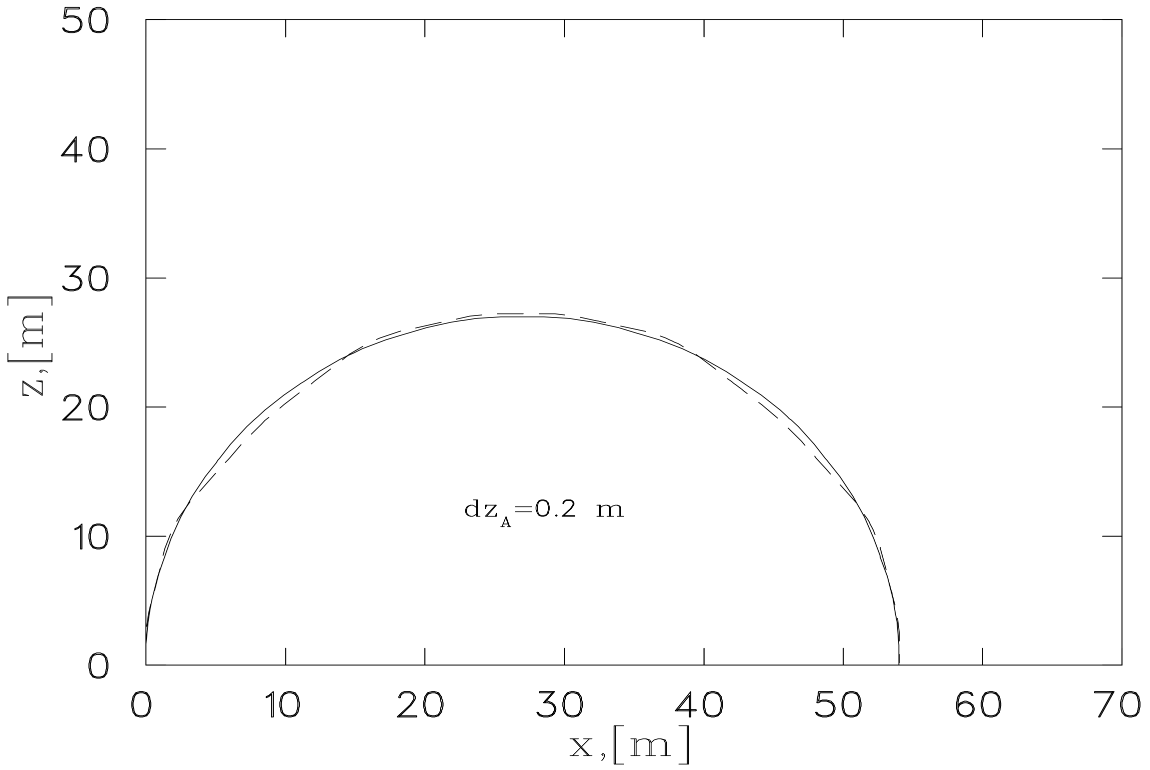

Figure 6: Layout of the arcs of the A (dashed line) and B rings – the case *b_nov* .

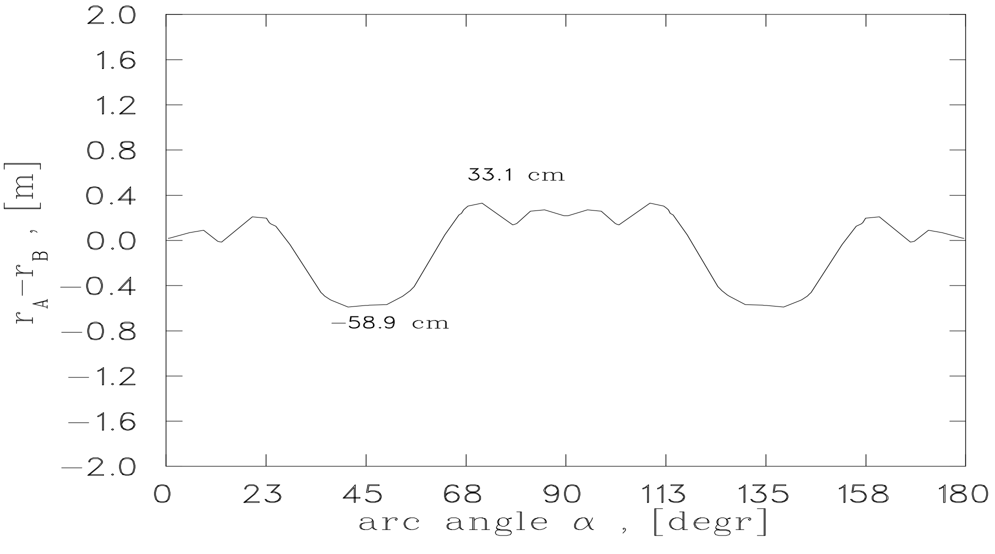

Figure 7: Radial displacement between A and B rings – the case *b_nov* .

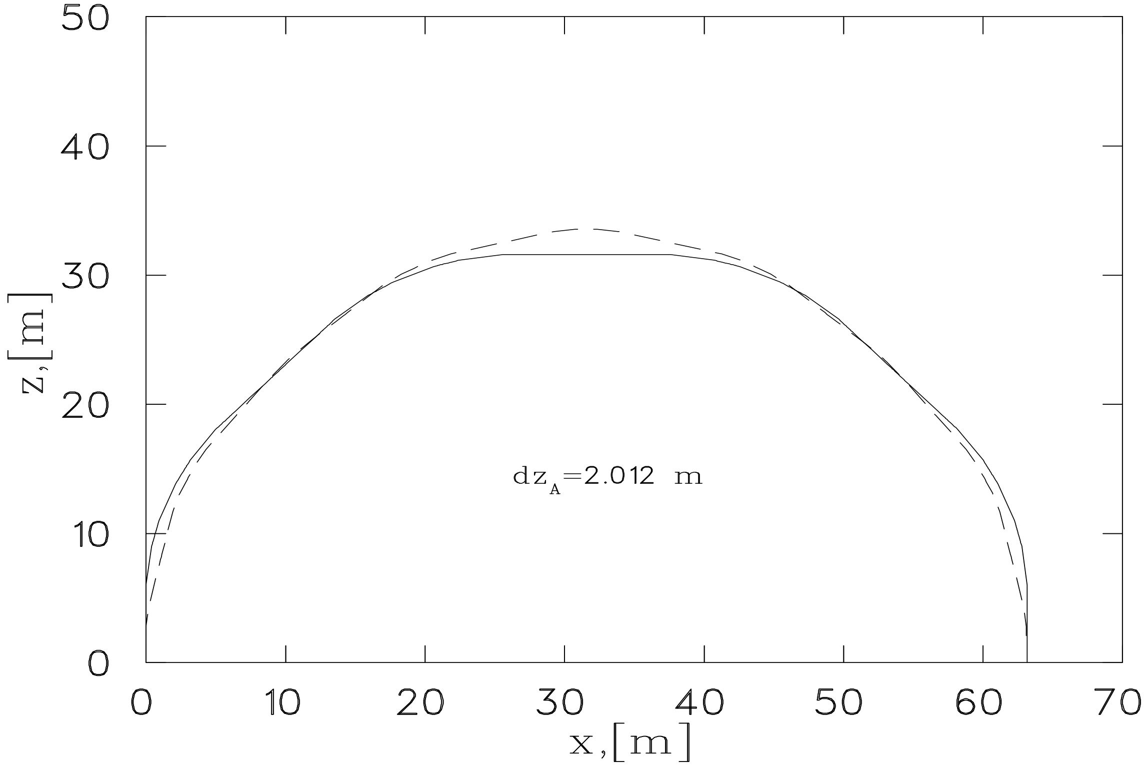

Figure 8: Layout of the arcs of A (dashed line) and B rings – the case *NEWBR*.

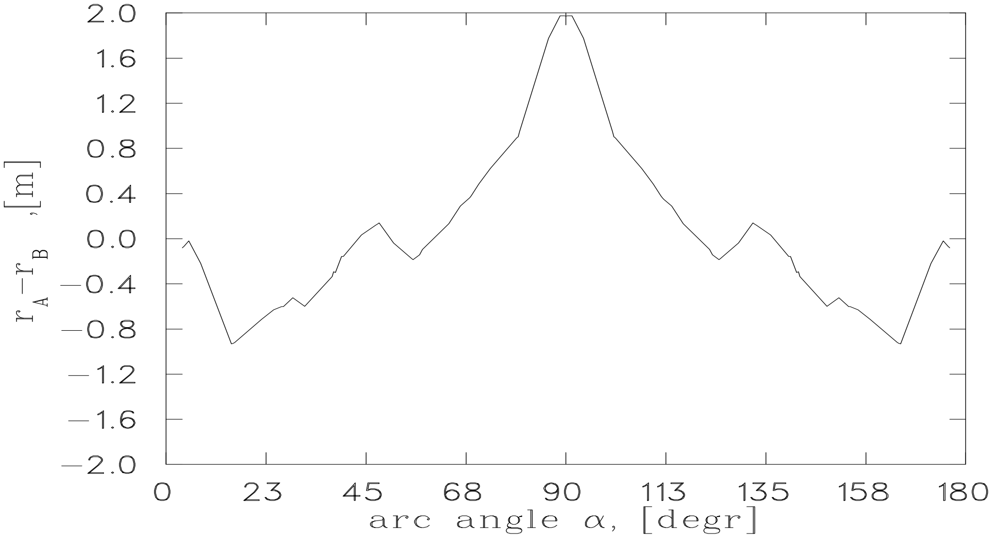

Figure 9: Radial displacement between A and B rings – the case *NEWBR*.

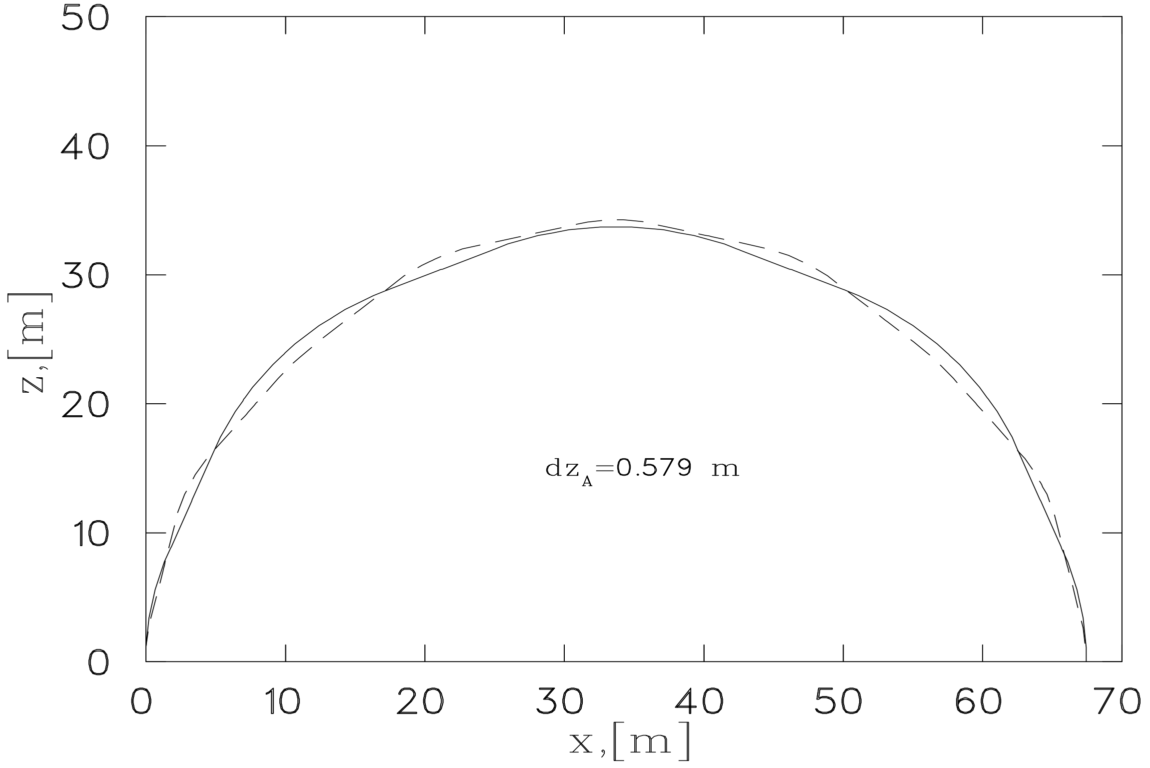

Figure 10: Layout of the arcs of A (dashed line) and B rings – the case *b_feb10*.

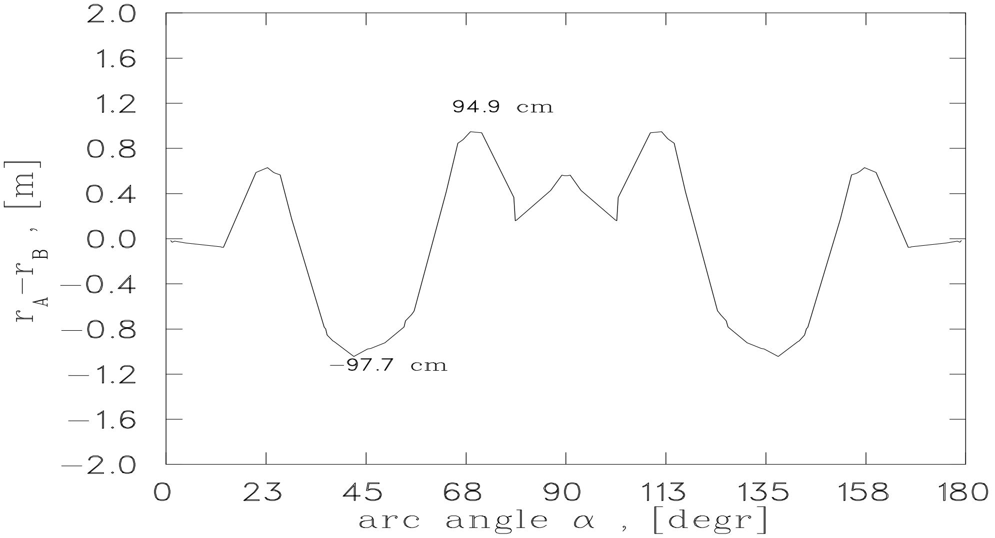

Figure 11: Radial displacement between A and B rings – the case *b_feb10*.

4 Tuneability of the momentum resolution.

By changing the horizontal arc tune the momentum resolution at the foil can be varied within the required interval 1.7 ± 0.25. Sample results for the case of the Standard Booster is shown in Table 2. The mismatched horizontal beta function is kept below 22 m.

$\nu_x^{c.cell}$	η_n	ν_x^{arc}	$max.\beta_x$	$max.\beta_y$
0.24	1.47	1.83	18.5	19.6
0.23	1.52	1.79	18.5	18.20
0.2	1.71	1.67	19	19
0.185	1.83		19.6	20.322
0.175	1.92	1.57	20.2	19.46
0.17	1.96	1.55	21.7	19.12

Table 2: The dependence of the *a_dec* arc parameters on the phase advance of the curved cell ($\nu_x^{c.cell}$). The length of the drift between the soft dipole and the first quadrupole is 1.8 m. Here $\nu_y^{c.cell} = 0.23$.

5 The Perfect Pair Problem

We define a "Perfect Pair" as Accumulator and Booster lattices satisfying all their separate requirements and compatible in shape (less that 1 m transverse shift).

Conclusions on possible perfect pairs:

- The *a_dec* parameters can be successfully adjusted to all Booster lattices having diameters between those of the Standard lattice (61 m) and the lattice *b_feb10* (67.4 m). Any variant of the Standard lattice having longer empty arc cells (dispersive straight sections) in order to accommodate a longitudinal collimator would have a ring diameter somewhere within this interval. This makes it possible to state that at least one set of "perfect pair" lattices exists. One such choice is the Standard Booster lattice with some increase of the length the dispersive straight section.
- The lattice *b_nov* has the best shape compatibility with *a_dec* because of its compact arc. However here the drift length *fc2* is obtained shorter than 2 m. It is possible that some different scheme of shifting the dipoles could be found, which would allow the length of this drift to be increased if necessary.

Conclusions on impossible pairs:

- The lattice *NEWBR* cannot be combined with *a_dec*.
- The lattice *a_nov* (the prototype of lattice *a_dec*) would in principle give a better shape compatibility than *a_dec* with any Booster lattice. However it is impossible to achieve the required length of the drift *fc2*.

References

[1] A. Iliev and R. Servranckx, "Lattice Studies for the Accumulator Ring," TRI-DN-93-K229, TRIUMF, 1993

[2] R.Baartman (private communication).

[3] G.Rees, Sept. 1993 Lattice Workshop (private communication).

[4] U.Wienands (private communication).