Search for A and B rings lattices

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Abstract

This paper presents results of the search for new lattices for 450 MeV Accumulator and 3 GeV Booster rings for the KAON factory.

Two new approaches proposed in the second half of 1993 are outlined (5-fold lattices and rectangular lattices) and the resultant lattices are described.

1 Introduction

Several problems connected with the *Standard Booster lattice* [1] expected their solution in the second half of 1993:

1. Finding an racetrack Accumulator lattice of compatible shape appeared to be a difficult task [1].
2. The lattice has too big (the maximum allowed by the symmetry) number of quadrupole families: 8 main and 8 trim.
3. There is not enough space in the arc for longitudinal collimator.
4. It is strongly recommended that the loss-collectors (collimators) in the both rings should be well separated from the A-B transfer lines. This means that an ideal lattice should have separate dispersive and nondispersive straight sections of sufficient length for injection, extraction and collimation. This condition is not met in the *Standard lattice*.

[1] Finally, such lattice was found [4].

Later, the *Standard lattice* was modified in order to accommodate the longitudinal collimator. The length of empty DOFO cell in the middle of the arc superperiod (where the dispersion is maximum) was increased at the expense of the straight section.

The variant of *Modified Standard lattice* which uses the maximum length increase compatible with hardware placement requirements in the straight section is described in [3].

Although the *Modified Standard lattice* seems to be the best solution at the moment, the problems of separate long straights and big number of quadrupole families still exist. Given the required tuning range of the Booster the number of quadrupole families could not be decreased even in the case of a regular arc (all cells have equal or almost equal length) ([2].

Another drawback is the extra space lost in the arcs and the straight sections being shortened much more than necessary. This is because all eight empty DOFO cells have to be increased, in order to keep the four-fold symmetry of each arc, although the collimator occupies only one of them.

2 Basic Constraints

The following constraints are presently accepted for the design of the A and B-rings of KAON:

1. γ_t of the Booster must be greater than 9 .
2. The circumference of the rings are 264.57 m.
3. The diameter of the rings must be equal. That means the long straight sections (in the case of the racetrack design and the quadrangle design) must lie exactly one above the other.
4. Where the rings are not identical in shape or position, the transverse shift must be less than 1m.

The following requirements are specific to the H^- injection in the Accumulator ring:

1. The mean value of the normalized dispersion η_n at the injection point must be 1.7 m.

2. η_n must be adjustable in the range 1.7 ± 0.25.

3. A free space greater than 2 m must be provided in the injection cell between the soft dipole and the nearest quadrupole.

This set of constraints is difficult to satisfy. We describe here the latest efforts in finding a pair of lattices that meet these conditions and list some of the acceptable pairs.

We limit our presentation to the new designs that were examined in the last six months, namely the high periodicity lattices suggested by Grahame Rees and the rectangular type suggested by Lee Teng.

3 The γ_t problem and dispersion free sections

One possible way to increase γ_t is to have the dispersion negative in some of the dipoles. This approach however makes the arc one-fold with respect to the dispersion function. An example for such kind of lattice is the lattice *NEWBR* proposed in [3].

With dispersion function everywhere positive, γ_t increases when the dispersion decreases in the dipole magnets. The lattices described bellow use two ways to reduce the dispersion in the dipole magnets:

- The horizontal phase advance between two dipoles is chosen π.
- A periodic FBDB array is set up with high horizontal tune.

The dispersion free zone is automatic in the first case, in the second case, the FBDB array must have a total phase advance of $2k\pi$.

In the second case further increase in γ_t can be obtained by shifting the dipoles towards the defocusing quadrupoles.

4 Basic lattice structures

4.1 High periodicity lattices

This approach was suggested by G.Rees. The lattice is made of 5 superperiods. Each superperiod is made of two dipoles with a π phase shift between them followed by a dispersion free FODO sections which are used for tuning, RF, injection extraction and collimation. Fig.1 illustrates one such superperiod. The γ_t achieved is about 8.

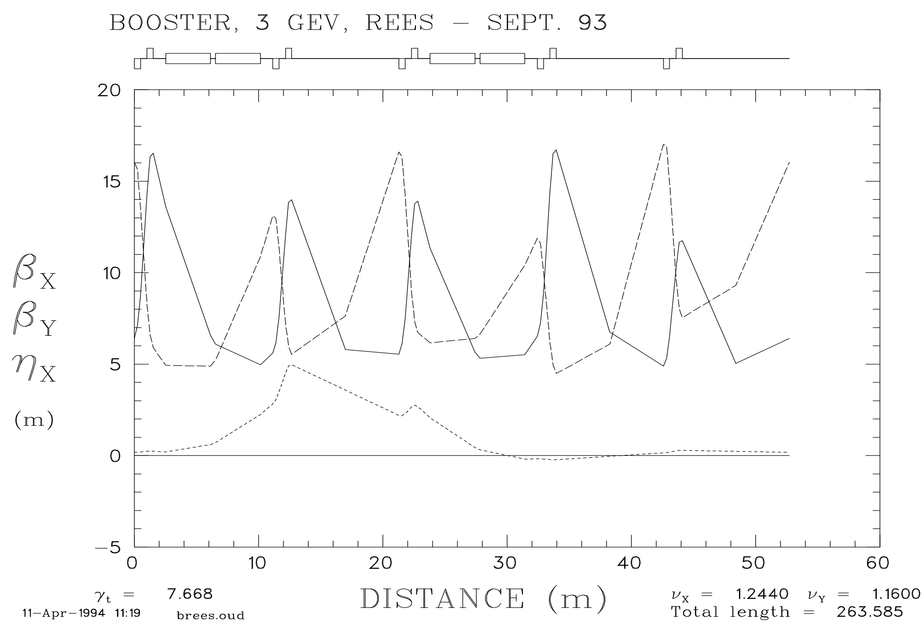

Figure 1: Booster lattice having 5-fold structure proposed by G.Rees

Using the same superperiod structure we considered several lattices having different number of superperiods. Table 4.1 shows some of the basic results obtained for lattices with different periodicity followed by some comments on the relative merit of each case. The bending angle of the dipoles is determined by the periodicity chosen for the complete lattice.

No effort was made to adjust the tune of these lattices to a "reasonable" value.

The conclusion is that to achieve a high enough value of γ_t the periodicity should be at least 10. The free space available in the small straight section between the dipole sections would be too small to accommodate the H^- injection.

Periodicity	γ_t	hor. tune	vert. tune	max η_n ,m	maxβ_x,m	max β_y,m
5	6.5	6.60	6.29	4.13	52.5	13.7
6	6.9	7.08	5.70	2.79	16.2	10.1
8	8.1	9.08	6.4	2.09	23.3	40.1

Table 1:

The 5-fold Accumulator lattice proposed by G. Rees has in principle the same superperiod structure as the Booster, but the quadrupole doublets are replaced by triplets, Fig. 2.

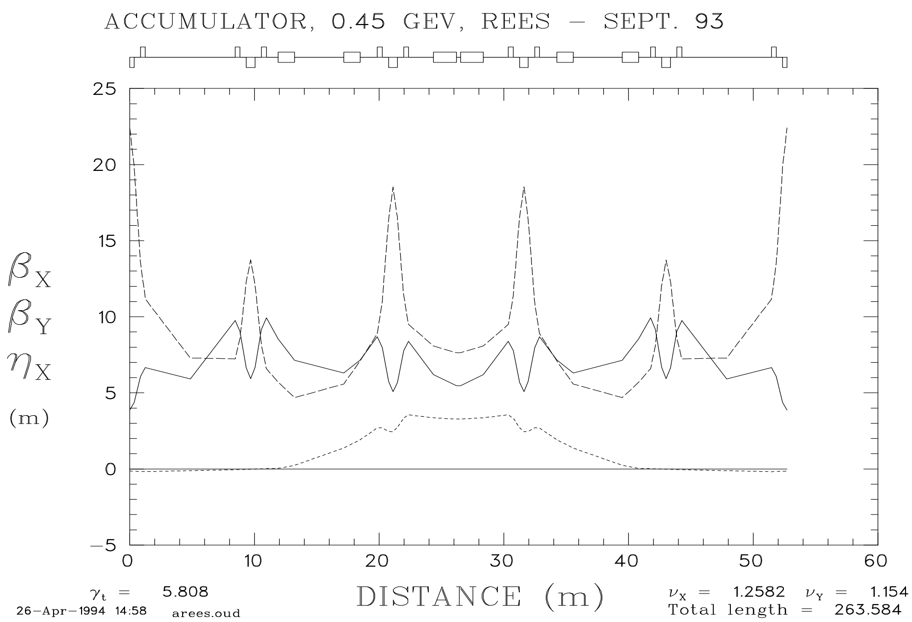

Figure 2: The Accumulator lattice proposed by G.Rees

The region with high dispersion between the pair of dipoles is used as Accumulator H^- –injection cell.

The conditions of shape compatibility, separate long straights and adjustment of η_n are met [5], but there seem to be no way to increase γ_t .

4.2 Racetrack lattice

Consider a racetrack lattice (Fig.3) using an arc with length 84 m consisting of 10 FBDB cells. If each cell has a phase advance of 144 degrees (arc tune = 4) then the γ_t achieved is 8.5.

Shifting the dipoles towards the defocusing quadrupoles increases γ_t to 9.2. In doing this we decrease the minimum distance between quadrupole and dipole to 75 cm. Several lattice elements must be housed in this drift so its length cannot be further diminished, limiting the maximum value of γ_t.

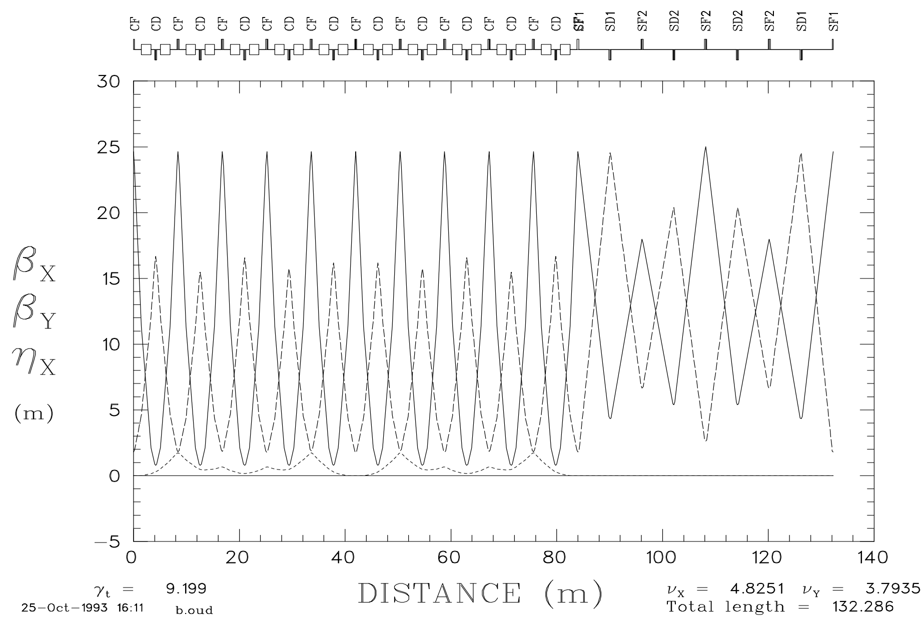

Figure 3: Lattice functions of the Booster

The use of 144-degree arc cells results in higher overall machine tunes than in the previous Booster scenarios (Q_x, Q_y)=(9.65,7.6) and a higher maximum horizontal beta function (about 25 m). The maximum vertical beta function is 16.5 m and the vertical beam size in the dipoles is the same as in the Standard design, so a larger vertical dipole aperture is not needed.

A compatible accumulator ring was found for this Booster lattice, but the corresponding η_n is only 1.4 and cannot be varied much.

The resultant lattice pair satisfies the requirement for high γ_t and the two rings are compatible in shape (transverse shift less than 40 cm). The main drawbacks are the lack of flexibility in η_n and the expected sensitivity to field setting errors due to the very high tune in each curved cell. Still there are no separate long dispersive straights suitable for longitudinal collimator.

4.3 Rectangular lattices

Following the approach suggested by Lee Teng, the rectangular lattice can be obtained as a natural extension of the racetrack lattice. The latter is generally setup so that the straight sections are dispersion-free. Let us suppose that the arc of the racetrack lattice is made up of an even number of identical cells and that the total horizontal phase advance is an odd multiple of 2π. The dispersion function η reaches a maximum at the midpoint of the curved section. Let us now insert at that midpoint a small straight section with a phase advance of 2π. We have now a rectangular lattice in which the long straight sections are dispersion-free and the small straight sections have dispersion which reaches a maximum negative value at the mid point of these sections.

This set up would satisfy relatively easily the constraints related to RF, injection and extraction as well as the H^- injection into the accumulator.

We have tested a few cases of this type of lattice.

An example is a lattice in which the curved section is made of two units each with 6 cells, Fig.4.

We varied the tune shift of these cells to control the value of γ_t. The results are listed in Table 4.3:

hor. tune per cell	γ_t	hor. tune	vert. tune	max η_n ,m	max β_x,m	max β_y,m
0.25	7.6	9.2	10.22	1.8	14.8	16.9
0.41666	11.04	13.2	10.22	0.96	19.5	16.9

Table 2:

These values will vary slightly with different straight section setups.

We have tested a few cases of this type of lattice. The case with 0.41666 phase advance per cell is very promising and was considered for providing space for all the hardware. If, as

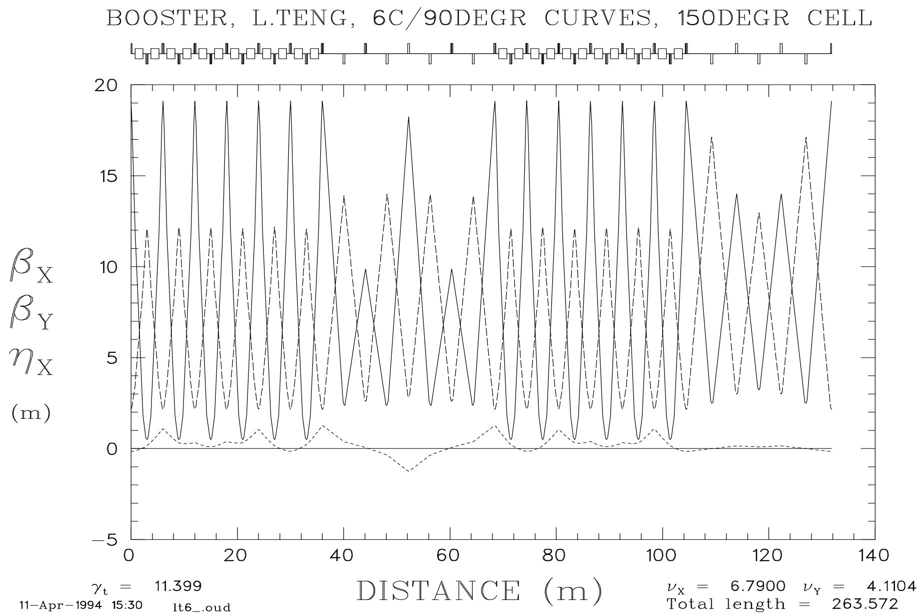

Figure 4: A Booster lattice having rectangular shape, Lee Teng

required, the minimum distance between quadrupole and dipole in the lattice is 75 cm then γ_t is about 10.

Design of the corresponding quadrangle Accumulator ring requires adjusting the A and B straight sections one above another, achieving in the same time the required mean value η_n =1.7 and transverse deviation between the arcs less than 1 m. Prototypes of such a lattice were considered and it was concluded that these problems are solvable.

Such lattice pair satisfies the conditions of high γ_t and separate long straights. As before, a potential problem is the high phase advance per cell in the Booster.

References

[1] U.Wienands et al., "A Racetrack Lattice for the TRIUMF KAON Factory Booster" in proc. of XV-th *Int. Conf. on High Energy Accel.*, Hamburg, 1992, p.1073.

[2] D. Kaltchev, Internal report.

[3] A.Iliev, "Lattice Studies for the Booster", TRI-DN-93-K231, TRIUMF, Sept. 1993.

[4] D. Kaltchev and R. Servranckx, "Racetrack Accumulator Lattice *a_dec*", TRI-DN-94-K244, TRIUMF, 1994

[5] G.Rees, private communication