ELETTRA BOOSTER SYNCHROTRON LATTICE

F. Iazzourene*, M.Bassetti°, O. Ferrando*
* Sincrotrone Trieste SCpA, Trieste, Italy
° on leave from INFN, Rome, Italy

Abstract

The proposed substitution of the present 1 GeV linac injector will be a system composed of a 100 MeV electron linac and a booster synchrotron[1]. The main constraints for the design of the magnet lattice are : the space available in the site, the synchronisation with the storage ring, a final nominal energy of 2.5 GeV, long and low dispersion drift spaces to ease the extraction, the minimization of the aperture requirements to reduce the magnets power consumption, a large enough dynamic aperture and a low enough equilibrium emittance. Different FODO structures have been studied for the booster lattice[2,3]. The selected one is a 2 fold symmetry structure composed of 18 cells among which 2 are without bending magnets and 4 with one missing bending magnet[2].

1 INTRODUCTION

After having examined several possible locations on site, it has been chosen to install the booster and its preinjector inside the empty circular courtyard of the storage ring building. This requires a rather compact booster as the diameter of the effective space is only 46 m. Three types of FODO structures have been studied :

- dispersive lattices of 20, 21 and 24 cells[2]
- 2, 3 and 4 fold symmetry structures with missing magnets to cancel the dispersion in the long straight sections[2]
- a 2 fold symmetry structure where the dispersion is matched to zero using 3 different bending magnets[3].

The 2 fold symmetry structure with missing magnets has been selected for its simplicity and lesser cost while it achieves all the above requirements.

2 BOOSTER LATTICE

The layout of the new injector inside the storage ring is shown in Fig. 1. The magnet lattice has one family of 28 dipoles, one family of 18 focusing quadrupoles and one family of 18 defocusing quadrupoles. The bending magnetic field is 1 T at the maximum energy 2.5 GeV, corresponding to a bending radius of 8.289 m. The circumference of 118.8 m provides 8 long straight sections of about 3 m each. For the RF storage ring frequency 499.654 MHz, the harmonic number is 198, i.e., a ratio of 11/24 of the storage ring one. Enough additional free space is also provided for vacuum components, sextupoles, correctors, diagnostics, etc.

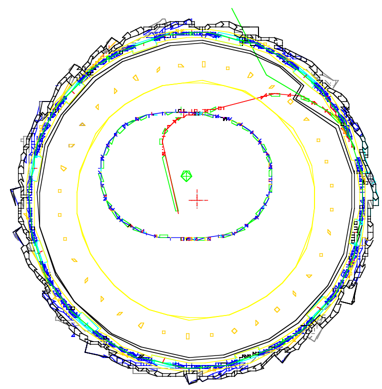

Figure 1: New injector layout

The optic functions for the nominal working point 5.39,3.42 are shown in Fig. 2 along 1/4 of the booster. The dispersion (dashdot line) in the long straight sections stays within a few cm (< 6 cm) while it reaches a maximum value of 1.674 m in the arcs. Going down to tunes like 5.32,3.31, the dispersion in the straights remains still below 7 cm.

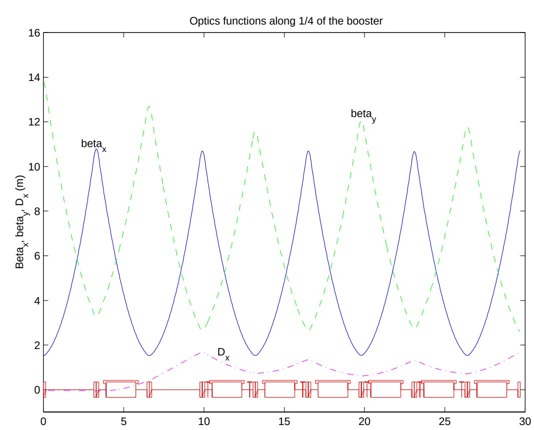

Figure 2 : Optic functions along 1/4 of the booster

The equilibrium emittance at 2.5 GeV is 244 nm.rad. For a quantum lifetime of 60 seconds and a transit time factor of 0.7, the required peak RF voltage is 1.083 MV. There are 12 focusing and 12 defocusing sextupoles for the chromaticity correction. For the closed orbit, there are 20 BPMs for its acquisition and 14 correctors per plane for its correction. The booster main parameters are summarized in table 1.

Table 1 : Booster general parameters

Magnet lattice	2 fold symmetry
Maximum energy	2.5 GeV
Injection energy	100 MeV
RF frequency	499.654 MHz
Circumference	118.8 m
Revolution period	396 ns
Harmonic number	198
Equilibrium emittance @ 2.5 GeV	244 n.m.rad
r.m.s. energy spread @ 2.5 GeV	7.45 10^{-4}
Energy loss per turn @ 2.5 GeV	417 keV
Damping times τ_x,τ_y,τ_z @ 2.5 GeV	4.7,4.8,2.4 ms
Betatron tunes Q_x, Q_y	5.39, 3.42
Natural chromaticity ξ_x, ξ_y	-6.6, -4.7
Momentum compaction factor	0.0439
Maximum β_x, β_y, D_x	10.8,13.8,1.674 m
Peak effective RF voltage (τ ~ 60 s)	1.083 MV
Bending magnets: Bending angle Bending magnetic field @ 2.5 GeV	 12.857° 1 T
Quadrupoles: Magnetic length Max. gradient (+10% margin)	 0.3 m 15 T/m

3 CLOSED ORBIT

Closed orbit errors are mainly introduced by the transverse misalignments of the quadrupoles and by the errors on the magnetic integrated field, longitudinal misalignment and rotation around the longitudinal axis of the bending magnets. Closed orbit distortions have been simulated for 10 machines, each with a different set of random errors distributed according to Gaussians with the r.m.s. field and alignment errors listed in table 2. 20 BPMs are forseen for the acquisition of the closed orbit and 14 correctors per plane for its correction. The largest closed orbit distortions before and after correction, using the Micado method, are listed in table 3. For all ten machines, the maximum corrector strength is below 0.9 mrad for the horizontal plane and 0.7 mrad in the vertical plane. In actual operation, it is forseen to use the SVD method, so that the strengths will be much smaller.

Table 2 : r.m.s. field and alignment errors

Bending magnets : $\Delta(BL)/(BL)_0$ Δs $\Delta\phi_s$	 6 10-4 1 mm 0.5 mrad
Quadrupoles: Δx Δy	 0.2 mm 0.2 mm

Table 3 : largest of maximum and r.m.s. closed orbits

Largest of (mm)	Max_x	rms_x	Max_y	rms_y
Before correction	11	7.6	4	2.8
After correction	3	1.5	0.75	0.46

4 INJECTION AND EXTRACTION

The injection and extraction take place along the two adjacent long straight sections as shown in the layout of Fig.1, for convenience. Injection to the booster is performed on axis by means of a septum of 16° and a fast kicker of 2.78 mrad from the inside of the booster.

For the extraction, the beam is brought close to the extraction septum sheet by 3 slow bumpers which create a bump of 5 mm, then the beam is kicked out by a fast kicker of 1.6 mrad. The kicked beam is then bent away by two septa, similar to the storage ring injection ones, of 6.5° total bending angle. The extraction scheme is shown in Fig. 3.

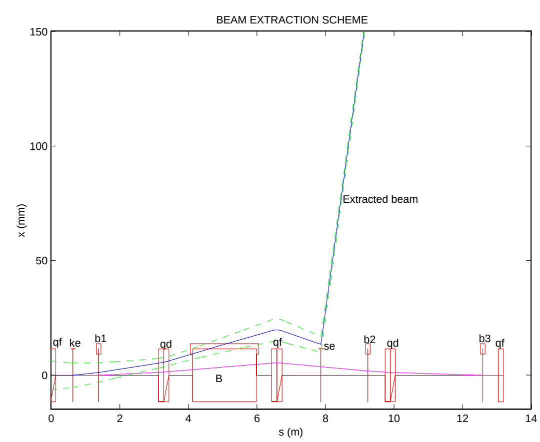

Figure 3: Extraction scheme. Extracted $6\sigma_x$ beam. se and ke are the septa and kicker respectively; b1,b2 and b3 are the 3 slow bumpers.

5 VACUUM CHAMBER APERTURE REQUIREMENTS

To avoid corrugation of the vacuum chamber or the use of ribs, the vacuum chamber thickness has been increased from the widely used 0.2,0.3 mm to 0.7 mm. However, even with this thickness, the vacuum chamber aperture must be small enough. The aperture requirements have been evaluated in each magnet, taking the maximum between :

- $\sigma_{x,y}$_100MeV + max. $\sigma_{x,y}$_u.c.o.
- $3\sigma_{x,y}$_2.5GeV + max. $\sigma_{x,y}$_u.c.o.
- beam displacement at injection and extraction

where max. $\sigma_{x,y}$_u.c.o. is the maximum of the 10 simulated uncorrected r.m.s. closed orbit distortions. Fig. 4 shows $\sigma_{x,y}$_100MeV (in blue) for an emittance of 1 mm.mrad and $\Delta p/p$ = ± 0.5% [4], and $\sigma_{x,y}$_2.5GeV (green) with ε_x = 244 n.m.rad, ε_y = 122 n.m.rad, $\Delta p/p$ = ± 0.0745%. The maximum horizontal size is at the QF quadrupoles of the arcs where the dispersion is the highest. Maximum of σ_x_100MeV is 9 mm and maximum of σ_x_2.5GeV is 2 mm. The vertical size is much smaller with respect to the horizontal size as there is no contribution from the energy spread. The aperture requirements in the injection and extraction regions are by far much larger. For evident simplicity, it has been chosen to built a unique vacuum chamber for the whole booster (a circular 26*26 mm or an elliptical 34*26 mm total), except for the injection and extraction regions, where for the required aperture 43*26 mm total, it is planned to use ribs for the vacuum chamber of the dipoles and to increase the thickness of the vacuum chamber of the quadrupoles.

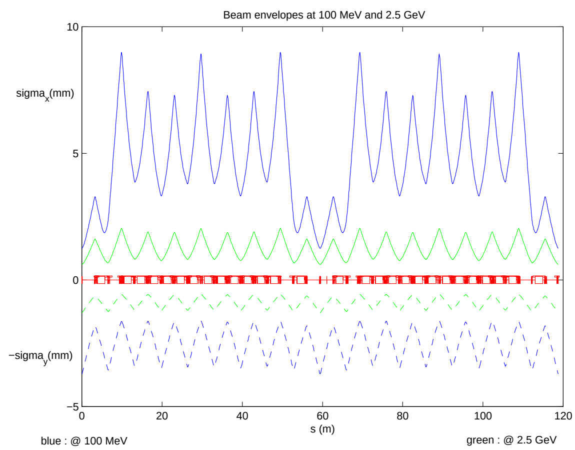

Figure 4: Beam envelopes at 100 MeV and 2.5 GeV

6 EDDY CURRENT EFFECTS

The time variation of the magnetic field induces eddy currents in the stainless steel vacuum chamber of the dipoles, and to a much smaller extent, in the quadrupoles. With a repetition frequency of 3 Hz, a vacuum chamber thickness of 0.7 mm and B_{min}= 0 T, the maximum values of the induced sextupolar component are 1.69 m^{-3} and 1.44 m^{-3} in the circular and elliptical (34*26 mm) vacuum chambers of the bending magnets, respectively. The dynamic aperture at injection with 1.69 m^{-3} is shown in figure 5 for $\Delta p/p$= -0.5%,0,+0.5%.

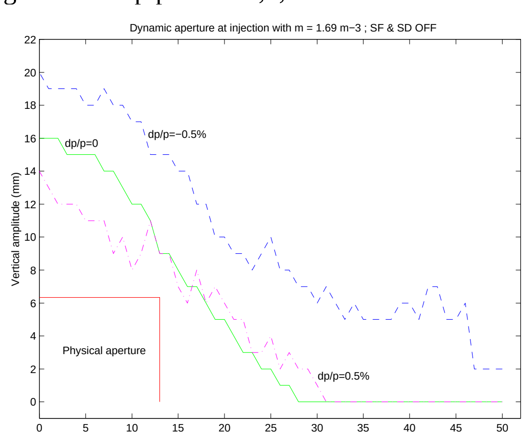

Figure 5 : Dynamic aperture at injection with eddy current sextupole component m_{max} = 1.69 m^{-3}, *uncompensated chromaticity*

The correction of the overall chromaticity using 12 focusing and 12 defocusing sextupoles leads to the much larger dynamic aperture as shown in figure 6.

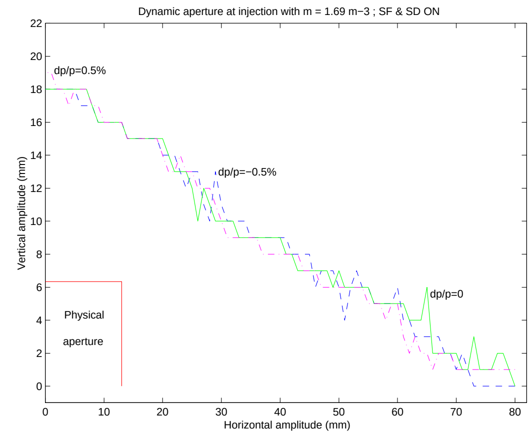

Figure 6: Dynamic aperture at injection with eddy current sextupole component m_{max} = 1.69 m^{-3}, *compensated chromaticity*

7 SYSTEMATIC MULTIPOLE TOLERANCES

Adding to the bending magnets the systematic multipoles $\Delta BL/BL$ b3=10^{-2},b5=10^{-3} and b7=10^{-3} taken at 30 mm, the dynamic aperture without and with compensated chromaticity remains large, as shown in Fig. 7 for the latter.

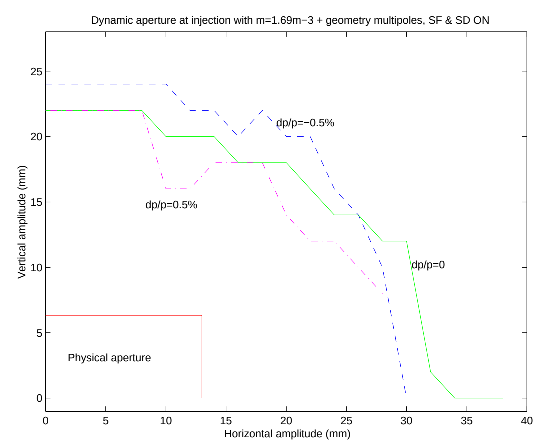

Figure 7: Dynamic aperture at injection with eddy current sextupole component m_{max} = 1.69 m^{-3} & b3 = 10^{-2}, b5=10^{-3},b7=10^{-3}; *compensated chromaticity*

REFERENCES

[1] C.J.Bocchetta, “Elettra Full Energy Injector”, these proceedings

[2] F. Iazzourene, "Studied Lattices for Elettra Booster Synchrotron", To be published, Internal report.

[3] M. Bassetti, O. Ferrando, To be published, Internal report.

[4] G. D'Auria et al,"The Elettra 100 MeV Preinjector Linac for the Proposed Booster", these proceeding