THE MAGNET DESIGN FOR THE 2.5 GEV ELETTRA BOOSTER

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Abstract

The ELETTRA linear injector that provides a maximum energy of 1.2 GeV will be replaced by a new booster injector with a maximum electron energy of 2.5 GeV and a maximum repetition frequency of 3 Hz [1]. It will be located in the open area on the inside of the ring and will provide full energy top up injection. The paper presents the preliminary design of the booster magnets that will include 28 bending magnets, 36 quadrupole magnets and 22 corrector magnets. The bumper magnets that will be used for the extraction of the electrons from the booster are also presented.

1 INTRODUCTION

The magnet design has been carried out with the help of TOSCA, but some calculations have also been carried out with POISSON and RADIA. The main design parameters of the booster are given in the conceptual design [1].

The magnet design has been carried out in order to minimise the magnet inductance. All the bending magnets will be connected in series and the maximum output voltage should be kept below 1 kV, during ramping at the maximum cycling frequency of 3 Hz [1]. We are also evaluating the possibility to use two power supplies for the dipoles: one for the upper coils and one for the lower coils.

The magnets of each quadrupole family (focusing: QF, defocusing: QD) will be connected in series and powered by only one power supply per family.

2 DIPOLES

Table 1 gives the main parameters for the dipole. It is of the split H type with the core curved to follow the electron beam trajectory. The top and bottom magnet cross section (see fig.1) are symmetrical and designed to allow the installation of the stainless steel vacuum chamber by lifting the upper half of the magnet. It will be fabricated from low carbon laminated sheets (the thickness of the layer has not yet been decided).

The first dipole model studied had a rectangular pole shape with a width of 100 mm. The magnetic field (integral) saturation, calculated by TOSCA, for a current of 2000 A was 25% (27%) with a field of only 1.2 T. As consequence the pole width was increased to 110 mm.

A Rogowski profile has been studied and modelled in TOSCA for the magnet ends [2].

Fig.2 shows the magnetic field at 2.5 GeV (1.3 T and 1850A), with 95% packing factor.

Table 1: Booster Dipole Specifications

Number of magnets	28	in series
Magnetic length	1.431	m
Curvature Angle	12.8571	deg
Gap Height	30	mm
Cross Section	H-type	
Magn.Field (min)	0.052	T
Magn.Field (max)	1.3	T
Turns (total)	18	
Max Curr. (AC+DC)	2000	A

Table 2 lists the results of the magnet design (field, field integral, multipoles, saturation and magnetic length) at four different currents, calculated by TOSCA, with a pessimistic 95% of packing factor for the laminations (reference radius 20 mm). The mechanical length (iron) is 1416 mm.

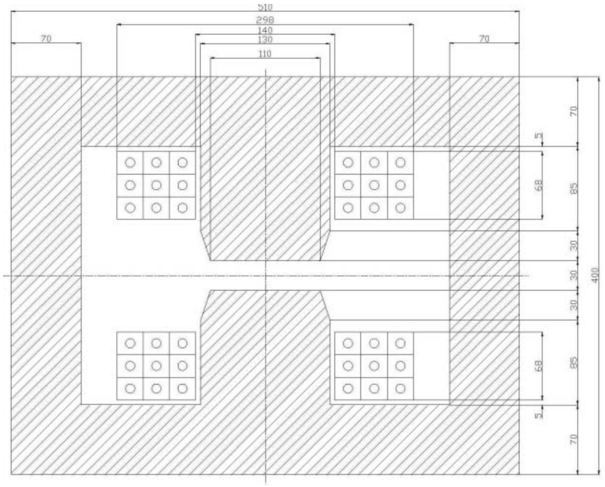

Figure 1: Dipole Cross Section.

Each coil (composed of one pancake) has 9 turns. The copper conductor has a cross section of 18.2x21 mm^2 with a 7.45 mm diameter cooling channel. The average current density is 3.7 A/mm^2 and the estimated inductance is about 3 mH.

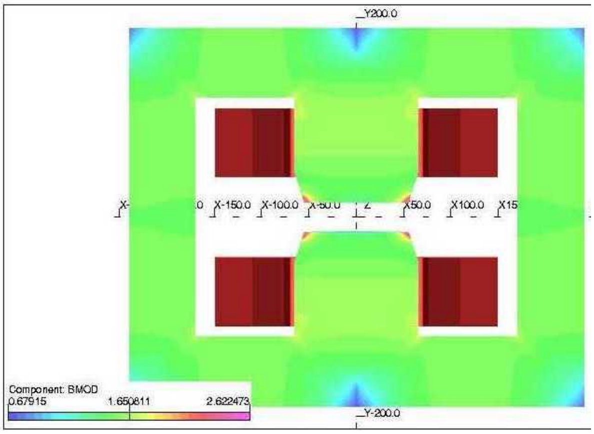

Figure 2: Magnetic Field at 2.5 GeV (1.3 T @ 1850 A)

Table 2: TOSCA results at r=20 mm, packing factor 95%

I(A)	B (T)	n=3 %	n=5 %	ΔB at 20 mm	Sat. %	Mag. L.(m)
80	0.06	0.00	0.00	0.008%	-	
1600	1.178	0.01	0.00	0.021%	1.9	
1850	1.300	0.03	0.01	0.039%	6.7	
2000	1.357	0.04	0.01	0.056%	10.5	
	I(Tm)			ΔI at 20 mm		
80	0.087	0.03	0.00	0.040%	-	1.451
1600	1.695	0.04	0.00	0.054%	2.77	1.439
1850	1.863	0.06	0.01	0.073%	8.10	1.432
2000	1.942	0.07	0.01	0.089%	12.1	1.431

3 QUADRUPOLES

Table 3 shows the main quadrupole parameters. QF and QD will have the same maximum gradient, current and cross section. The yoke is made of four identical quadrants and the pole contour is a hyperbola. Fig.3 shows the magnetic field at 300A (18.5 T/m), calculated by TOSCA. The maximum field in the iron is about 1.5 T. The gradient field integral saturation at I=300 A for the QF (QD) is 1.9% (3%). Table 4 summarises the magnetic design results for QF (yoke length = 220 mm) and QD (yoke length = 155 mm), with a chamfer of 45 deg starting 10 mm from the magnet ends. The systematic components n=10 and n=14 (not shown) are very small (≈ 0.01%).

Table 3: Quadrupole Magnets Parameters

	QF	QD	
Number of magnets	18	18	
Magnetic length	240	175	mm
Bore radius	28	28	mm
Max. gradient	18.5	18.5	T/m
Pole width	60	60	mm
Number of turns	20	20	
Max current (AC+DC)	350	350	A

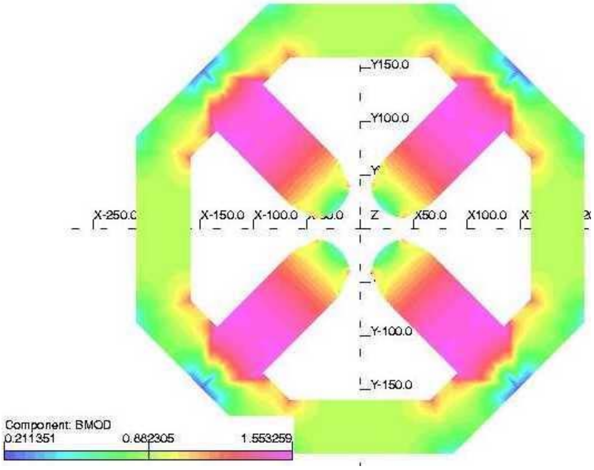

Figure 3: Magnetic field at 300 A.

Table 4: QD and QF magnetic design summary

	I (A)	Grad T/m	∫Gdl (T)	n=6 (%)	L.mag. (mm)
Qd	300	18.8	3.337	0.05	177.08
Qd	8	0.53	0.095	0.03	180.04
QF	300	19.0	4.578	0.04	240.88
QF	8	0.53	0.129	0.01	244.45

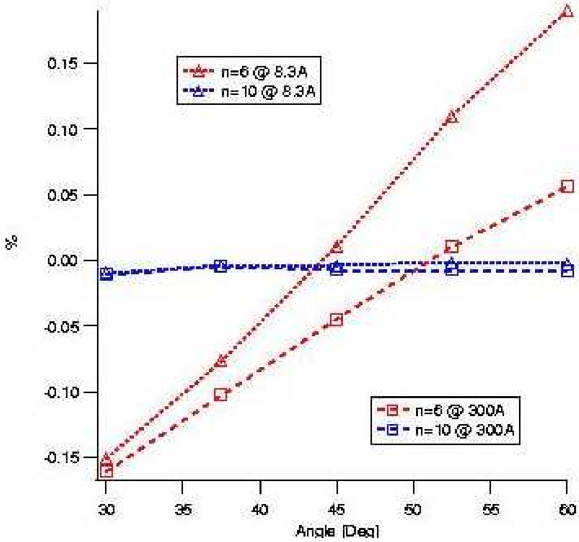

Figure 4 : QF, Field integral N=6, 10 components as a function of the chamfer angle

The nominal field is obtained with a current lower than 300 A.

The effect of the cut angle on the n=6 and n=10 field integral error components (QF) as a function of the angle and current (in percent at r=20 mm) is shown in fig.4. The effect on n=10 is negligible. An angle of 45 deg seems a reasonable compromise.

The estimated inductance of the QF (QD) magnet is about 5 (4) mH. The cross section of the copper conductor is 8x8 mm^2, with a cooling channel diameter of 3 mm.

4 CORRECTORS

The same magnet will be used to correct the horizontal and vertical position of the electron beam, depending on the orientation with respect to the electron beam. Table 4 shows the main corrector magnet parameters.

Table 4: Corrector Magnet Parameters

Number of magnets	10 Hor. + 12 Vert.	
Max. deflection angle (2.5 GeV)	2 (≈0.017)	mRad (Tm)
Pole width	80	mm
Gap height	39	mm
Yoke length	150	mm
Max. current	20	A
Number of turns	160	
Cross section	C - shape	

The magnetic design carried out by TOSCA shows a field (integral) variation at r=20mm of 0.3% (1.2%) at 20 A, with a saturation of about 0.3%. The nominal correction angle is obtained at 17 A.

The central cross section of the corrector is shown in figure 5.

5 BUMPERS

Three bumper magnets in combination with the kicker and septa magnets will be used to extract electrons from the booster [1]. Table 5 summarises the main parameters.

The magnet is made up of 2 air cooled coils (no iron) positioned at a distance of 30 mm (gap), able to generate an integral peak field of about 73 Gm. Each coil has a length of 300 mm and 160 mm wide. The copper wire has a cross section of 4x3 mm^2. A prototype was constructed and measured in September 2001. The measured vertical field integral at 10 A is 16.7 Gm with a magnetic length of 244 mm. The nominal integrated field is obtained with 44 A. Simulations of beam dynamics carried out to check the effects of the measured multipoles on the dynamic aperture show acceptable results [4].

To overcome the inevitable mechanical error in the coil winding, the holder of the bumper coils (under construction) will permit to adjust the single coils independently. An accurate coil alignment will be carried out during magnetic measurements.

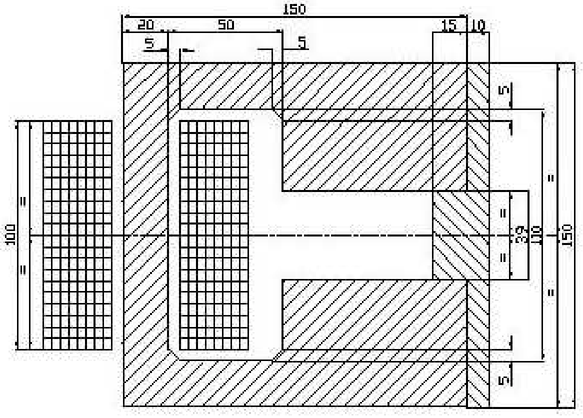

Figure 5: Corrector Cross Section.

Table 5: Bumper Magnet Parameters

Number of magnets	3	
Max. deflection angle (2.5 GeV)	0.87 (≈0.0073)	mRad (Tm)
Gap height	30	mm
Coil length	300	mm
Max. current	50	A
Number of turns	60	

6 REMARKS

The systematic multipolar errors of the presented magnets have been introduced in the booster optics and their effects have already been simulated [4]. Although the new optics [3] requested for a lower emittance will use bending magnets with a magnetic length of 2 m, the present design is still valid. The obtained systematic multipolar components at 1.3 T are much lower at bending fields of 1 T, due to the lower saturation (see table 2). As reported in [3], the correction of the chromaticity is necessary only in the presence of the sextupole component induced by the time variation of the field in vacuum chamber of the bending magnets. The strength of these sextupoles are highest at 200 MeV [3]. The sextupole magnet design is now under development.

The corrector magnets will be slightly modified and shortened due to the reduced space available for the presence of the sextupoles and the lower required strength [3].

7 REFERENCES

[1] Booster Conceptual Design Report, Sincrotrone Trieste, May 2000.
[2] D.Zangrando and M.Zalateu, Design of the Magnets for the ELETTRA Booster, Sincrotrone Trieste Internal Note, ST/M-01/06, November 2001.
[3] F.Iazzourene, Update on the Linear and Nonlinear Optics of the ELETTRA Full Energy Booster Synchrotron, this conference.
[4] F.Iazzourene, private communication.