3.2.2 Magnets

The characteristics for the two types of combined function magnets,BD and BF, are listed in table t322_a. Their cross-sections are shown, together with the vacuum chamber, in Figure f322_a. These magnets are very compact and have modest fields to avoid saturation and to keep the power consumption low. The field profiles and the field deviations from an ideal linear field are shown in Figures f322_b and f322_c. As mentioned the BF magnet is actually a half-quad, with the corresponding excellent field quality. The width of the good field region should be 30*20mm^2 for BF, corresponding to the inner dimensions of the vacuum pipe, and about 24*20mm^2 for the BD magnet, assuming a curved magnet without sagitta.

The booster magnets are ramped. It is therefore important to have a good field quality for both, low and high field levels. The optimal pole profiles for BD and BF were calculated by minimizing the deviations from an ideal vector potential, giving equal weight at low and high excitation. The reference values for the vector potential were defined on the ellipse defining the good field region.

For the coils we want a low number of turns, in order to have a low inductance and thus a low induced AC voltage. By choosing for a BD-coil 8 turns and for the BF-coil 2 turns one could find a solution with identical currents in both magnets. At the maximum current of 840A, corresponding to the reference energy of 2.4GeV, the average current density is about 5A/mm^2, for the chosen coil dimension of 15*8mm^2.

A small aperture radius of 18mm in the quadrupoles and the tuning sextupoles gives a very economic design with a maximum power consumption of 300W resp. 20W. Water cooling is thus not required for the sextupoles. Figure f322_d shows a cross-section of the quadrupole and sextupole.

For closed orbit corrections we will use identical but separate correctors for the horizontal and vertical direction with a compact design.

The properties of the quadrupoles, sextupoles and correctors are listed in tables t322_b,_c and _d.

All booster magnets will be splittable in the medium plane, allowing easy installation of the vacuum chamber. The magnets will be mounted with support brackets on the inner wall of the storage ring tunnel as shown in Figure f322_e.

Eddy current losses in the two coils of a BD dipole are less than 10W at 3Hz, and the hysteresis losses in the iron are only a few Watts as well.

In the case of **top-up injection** one has to consider the influence of the time dependent **stray fields** on the stored beam, since the storage ring is only about 2.5m away from the booster. As a first measure to reduce these stray fields all booster magnets were designed with closed yokes; e.g. the correctors will be built as H-magnets.
A second step is to keep the magnetic field in all parts of the booster magnets below 1T in order to avoid saturation effects. This ensures that the stray field from the iron is below 1μT at the storage ring.

Three-dimensional calculations indicate that the stray field from the coil ends can be of the order of about 5µT. This can give time dependent deflections of the stored beam in the region of a few µrad. This is small compared with the beam divergence of about 50µrad and thus tolerable.

Dipoles (comb. function)	**BD**	**BF**
Total number	48	45
magnetic length	1.26 m	1.0 m
Bend angle	6.441 ^{0}	1.1296 ^{0}
Bend radius	11.21 m	50.72 m
gap at beam center	23.3 mm	26.45 mm
maximum field at 2.4 GeV	0.714 T	0.158 T
maximum gradient	-3.09 T/m	4.66 T/m
max. sext. gradient B_0/a^2	-10 T/m^2	7 T/m^2
turns/pole	8	2
maximum current	840A	840A
average power	2.2 kW	0.6 kW
weight	300 kg	160 kg

power supply: all dipoles in series

total resistance	0.6 Ω
total inductance	80mH
max. voltage	± 1000 V (middle on earth)
max. stored energy	28 kJ
max. average power	160 kW
wave form	programmable up to 3Hz

Table t322_a: Booster Dipoles

Booster Quads type	long	short
number of quads	6	12
magnetic length	0.4 m	0.22 m
iron length	0.38 m	0.2 m
aperture radius a	18 mm	18 mm
max. gradient at 2.4 GeV	16 T/m	16 T/m
max. poletip field	0.29 T	0.29 T
number of turns/pole	15	15
resistance	65 mΩ	40 mΩ
inductance	5 mH	3 mH
max. current	140 A	140 A
max. voltage	15 V	10 V
max. average power	0.5 kW	0.3 kW
weight	130 kg	70 kg

total of 18 Quads in 3 families:

QF: 6 long Quads in series

QD: 6 short Quads in series

QE: 6 short Quads in series (,40A)

Table t322_b: Booster Quadrupoles

number of sextupoles	18
magnetic length	0.2 m
aperture radius a	18 mm
max. $B_0/a^2 = 0.5\cdot B''$	200 T/m^2
max. poletip field B_0	0.063 T
Ampturns/pole	300
number of turns/pole	50
resistance	1.0 Ω
inductance	40 mH
max. current SF/SD	6 A / 4 A
max. voltage SF/SD	8 V/ 5 V
max. average power	ca. 20 W
weight	30 kg

total 18 sextupoles in 2 families:

SF: 6 Sextupoles in series (48 V)

SD: 12 Sextupoles in series (60 V)

Table 322_c: Booster sextupoles

number of correctors	2·54 = 108
separate for x and y	
overall length	0.13 m
magnetic length	0.10 m
pole length	0.07 m
magnet aperture	35 mm
max. field	0.032 T
max. deflection at 2.4 GeV	0.4 mrad
Ampturns/pole	470
coil	174turns·2.7A
total resistance	1.5 Ω
total inductance	40 mH
max. voltage	5 V
max. average power	4 W
weight	12 kg

Table t322_d: Correctors in booster

max. field	0.5 mT
max. deflection at 2.4 GeV	0.06 mrad
Ampturns/pole	5
coil	2 turns · 5A
resistance (45 BF's)	2.3 Ω
total resistance with leads	5 Ω
max. voltage	15V DC+15V AC

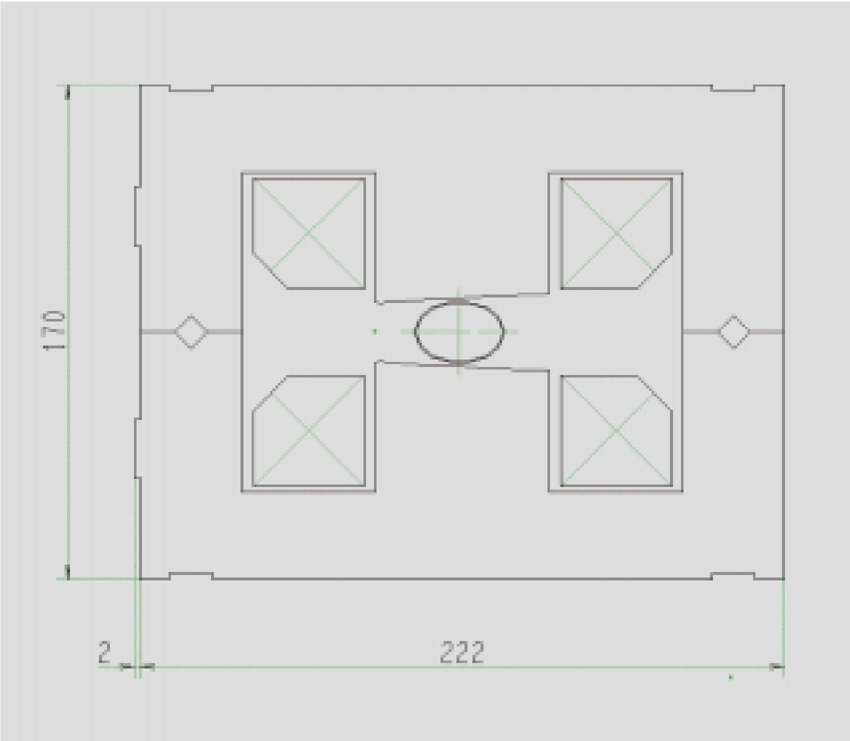
Table t322_e: Corrector BFC for BF in booster

237 Magnets
- 93 Dipoles
- 18 Quadrupoles
- 18 Sextupoles
- 108 Correctors

2 Kickers
2 Septa
1 RF cavity
67 Vacuum Chamber Sections
97 Ion Sputter Pumps

54 Beam Position Monitors (BPM)
3 Synchrotron Radiation Monitors
5 Optical Transition Radiation Screens

Table t322_f: List of Booster Components



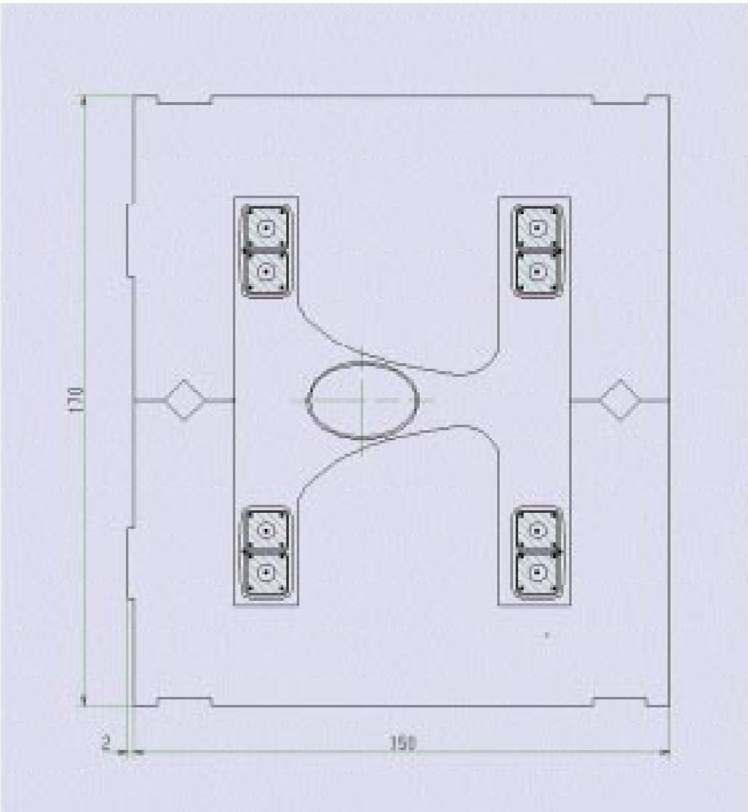


Figure f322_a: Cross-section of Booster dipoles BD (top) and BF (bottom). BF is actually a Halfquad with a mirror plate on the left side. The inner dimensions of the elliptical vacuum chamber are 30*20mm.

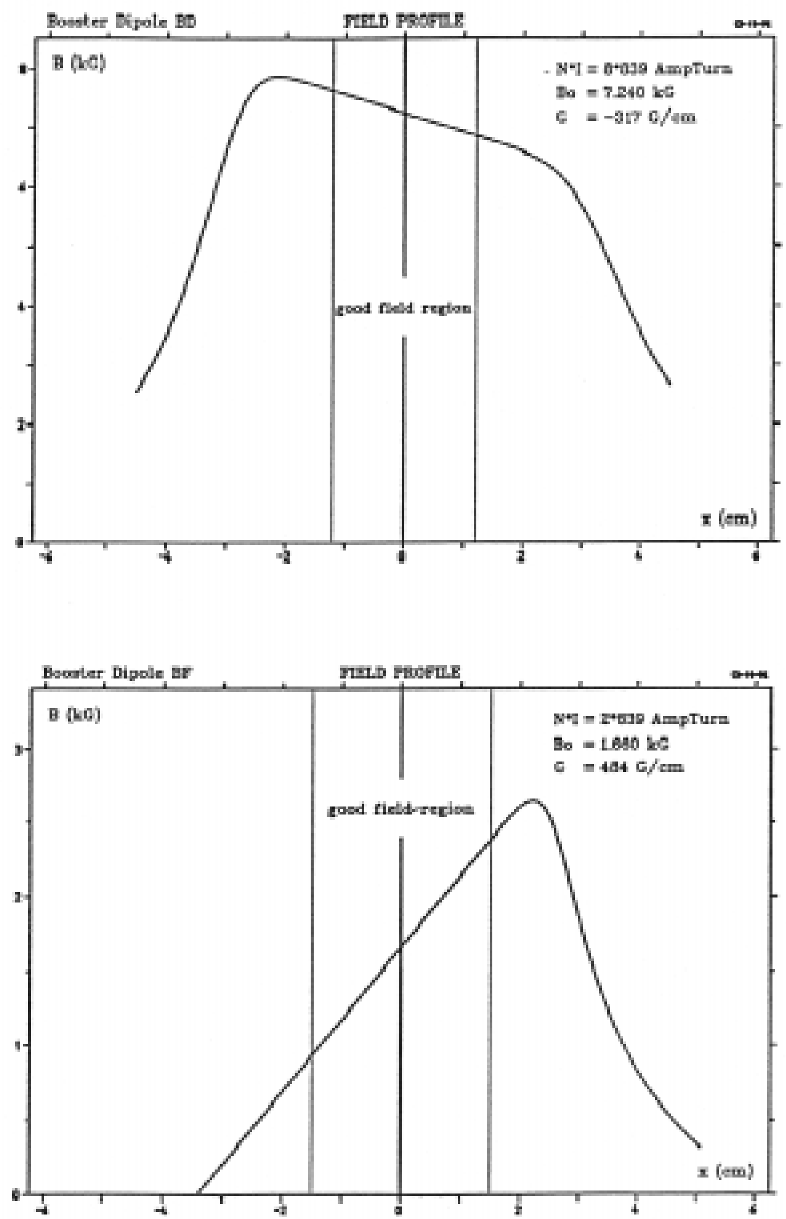


Figure f322_b: Field profiles of the booster dipoles BD and BF at the maximum energy of 2.4 GeV. Both magnets share the same powersupply with a maximum current of 839A. The vastly different field levels are obtained with turn numbers of 8 resp. 2 per coil.

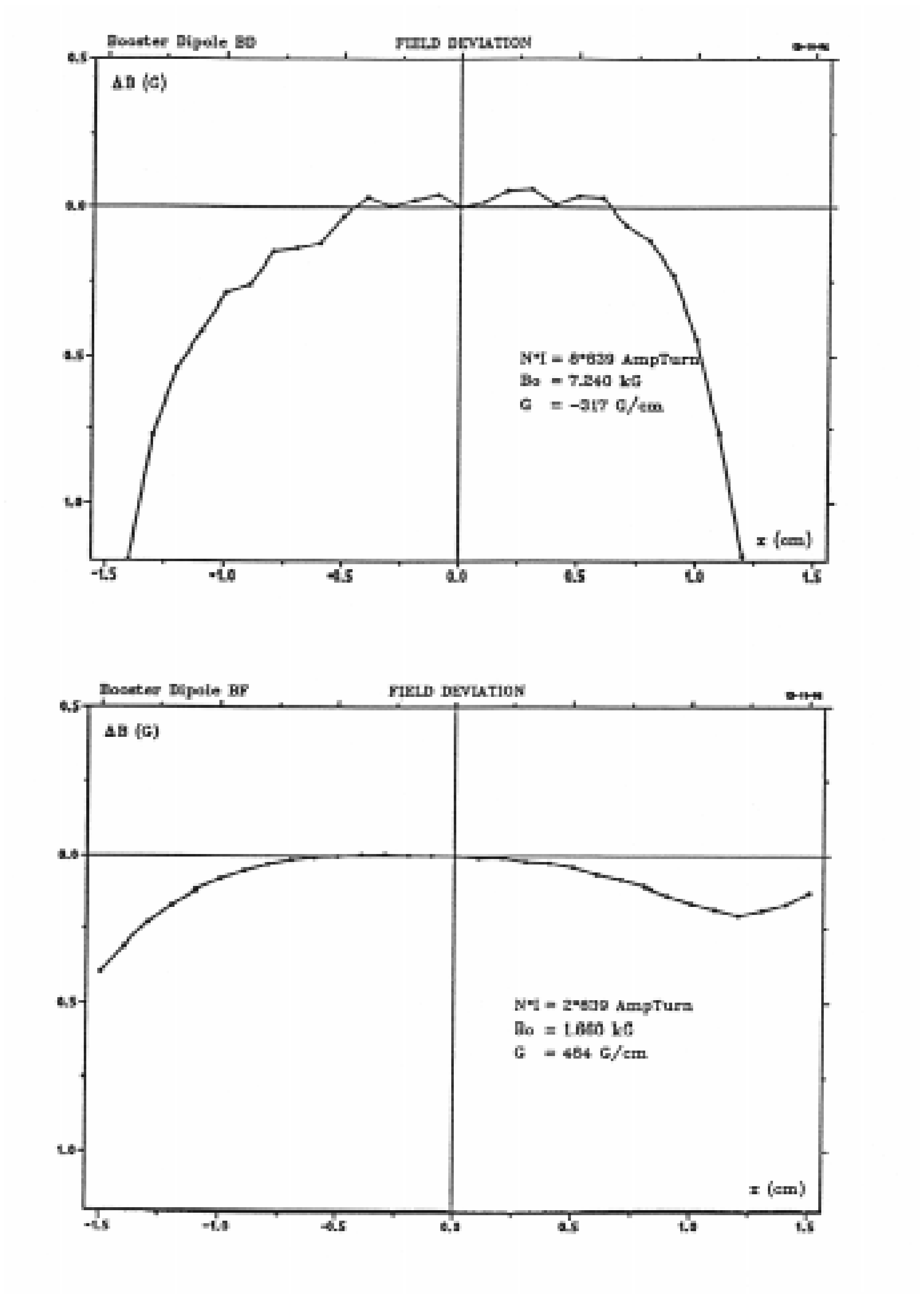
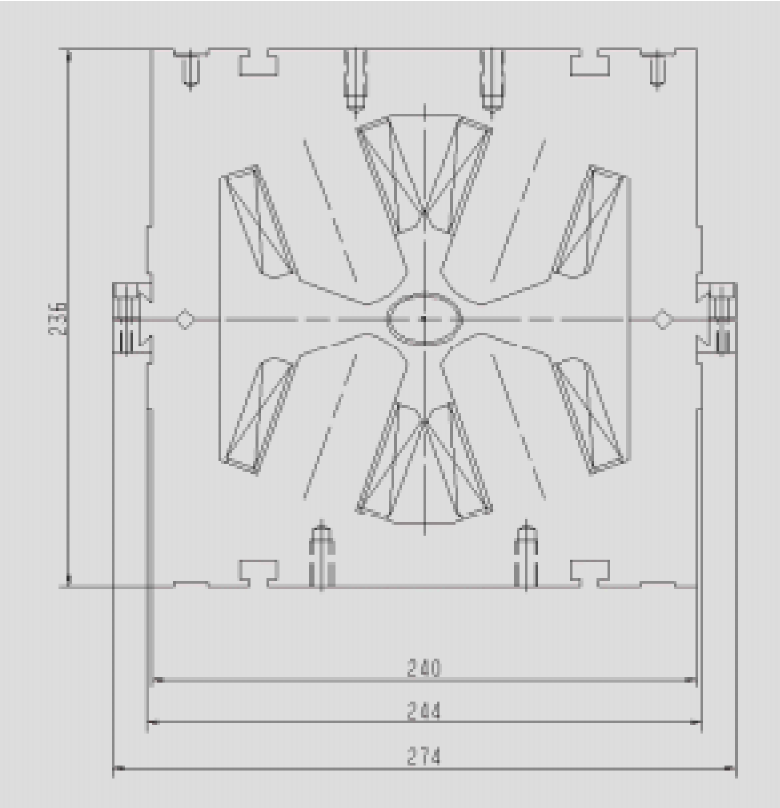


Figure f322_c: Absolute deviations from an ideal linear field for the two dipoles BD and BF after shimming the pole profile.



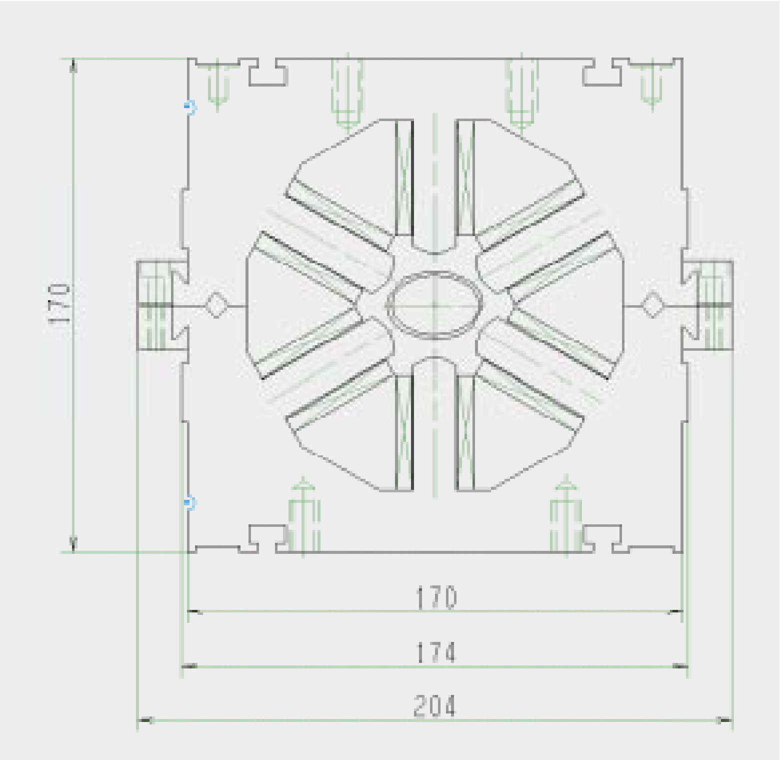
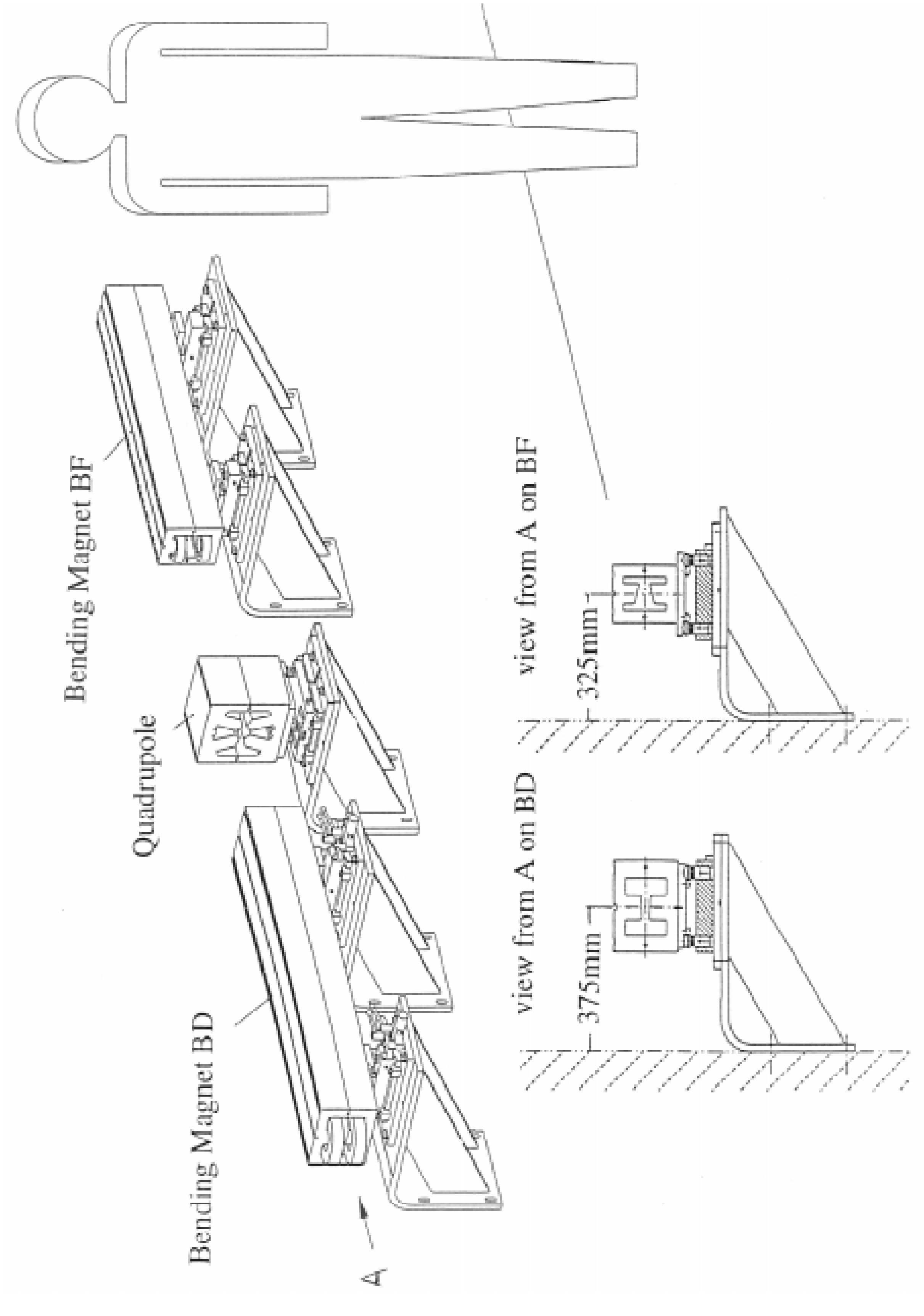


Figure 322_d: cross-section of booster quadrupole and tuning sextupole



<u>Figure 322_e:</u> support structures for booster magnets on the tunnel wall