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Magnetic field compensation for E-Linac

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Abstract: The 4-wire scheme of creating a region of relatively uniform magnetic field is applied to that required to compensate the ambient field as measured after demagnetizing the floor.

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1 Fields required

Refer to Fig. 1. The installed steering correctors will be able to compensate up to $\pm 500\,\mathrm{mG}$ [Chao]. Thus, we ignore the horizontal component and compensate only the vertical component with coil pairs that are in horizontal planes; $h/2$ above and $h/2$ below the median plane of the beam. We can stay within the $\pm 500\,\mathrm{mG}$ with as few as two coil pairs; one at 3000 mG and the other at 2250 mG.

The egun cathode is 7.5 m from the crossover point, which is 0 in the figure. The injector cryomodule begins 2 m from the cathode, so on the figure, from -7.5 to -5.5 m we need 3000 mG. We call this the “small coil”. From there on, through the region of the crossover to the end of the e-hall before the doghouse, we need a compensation of 2250 mG; this is the “large coil”. The large coil could of course for practical reasons be split into as many shorter coils as desired. The splits can occur anywhere, since the resulting currents across the beam axis will cancel each other and cause negligible fields. The preferred configuration for the split is with beam crossing sections overlapping each other in vertical plane. This yields smaller field distortion compared to alternative option with coils placed at the same elevation.

The small coil needs to extend past the egun (on the negative side in the figure) to accommodate the tank. Refer to my first note TRI-BN-10-03 for the math. If I recast the formula into dependence on width (horizontal separation of the wires) w and recalling that the vertical separation is $h = w/\sqrt{3}$, then

$$I = \left(\frac{B}{12\,\mathrm{mG}}\right)\left(\frac{w}{1\,\mathrm{metre}}\right)\ \mathrm{Amps} \qquad (1)$$

Example: Choose $w = 2\,\mathrm{m}$; then $I = 500$ Amps for the small coil and $I = 375$ Amps for the large coil.

The two coils need not have the same width. Coil width-to-height ratio requirement is a soft one. Deviations of up to 20% are allowed if space constraints due to interferences with beam line components are hard to satisfy.

Reminder: This I is total current; one is free to divide this among as many turns as desired. For example, 500 Amps could be a 10 by 10 turn coil running 5 Amps.

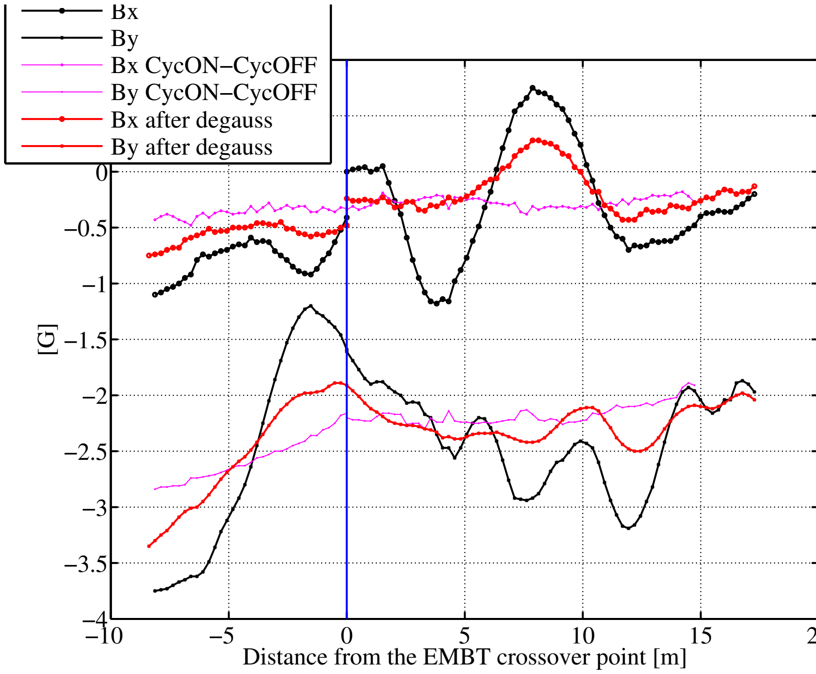

Figure 1: Measurements, before (black) and after (red) demagnetizing.

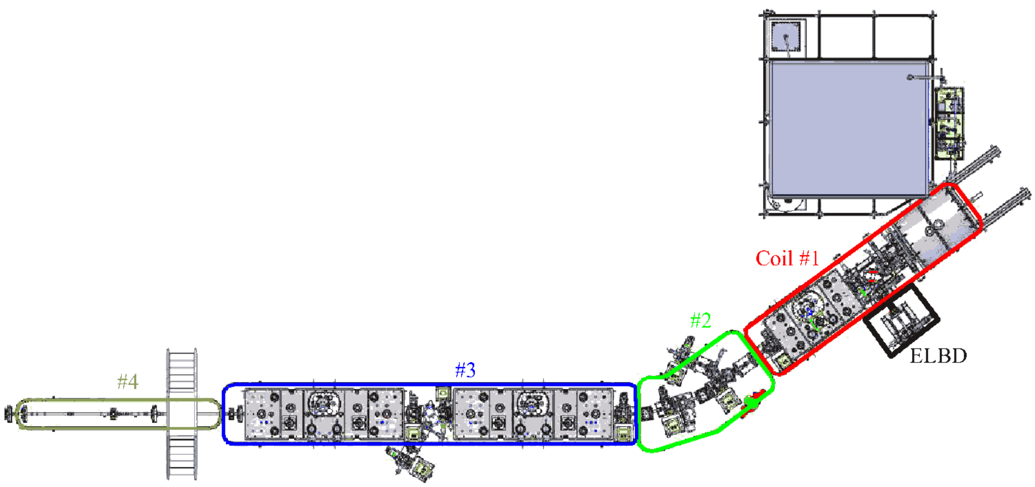

Figure 2: Layout of the 4 coils. Egun is on the right.

2 Detailed Compensation

It has been decided for various practical reasons to segment the coils into 4: see fig. 2. From the gun cathode downstream, they are shown as resp. red, green, blue, olive. The coils extend around the cryomodules, but these have their own shielding so the beam inside the cryomodules needs not be considered. We assume EACB is not installed.

Referred to the stray field graph of Fig 1, the relevant sections are as in the following table, along with the fields they would ideally be required to compensate. These have been found by averaging over the relevant ranges of z. As well, a horizontal component can be compensated by (slightly) tilting the coils.

The angles given in the table are the optimum tilts. The sign of these angles is as follows. Looking downstream in the beam direction, a positive angle is a counter-clockwise rotation of the coils about the beam axis. They are all positive because B_x is mostly negative, and this arises because the electron beam plane is below the cyclotron's median plane.

Coil #	z range(s)	Avg. field (G)			Angle
		B_x	B_y	$\|B\|$	
1	−7.2m to −5.0m, −3.0m to −2.4m	−0.55	−2.95	3.0	11°
2	−2.4m to +1.0m	−0.4	−1.95	2.0	11°
3	1.1m to 1.6m, 5.5m to 11.1m	0.0	−2.25	2.2	0°
4	11.1m to 15.8m	−0.3	−2.25	2.3	8°

Table 1: Optimized Settings of the 4 coils

2.1 ELBD

During commissioning, there was no Helmholtz coil to cover the ELBD analysis leg. To mitigate the field, μ-metal shielding was wrapped around the narrower portions. This proved to be insufficient as the beam was poorly centred and under some conditions was intercepted by the beam pipe in the constricted region of the RF deflector.

It has therefore been decided to add a coil to cover the ELBD region. The field measurements indicated that the difference of ambient field between the Coil #1 region and the ELBD is not significant. For this reason, the additional coil to cover the ELBD needs not have its own power supply but can be in series with the Coil #1.

Moreover, the coil that had been used for the VECC installation was already the correct width, so this new coil could re-use the curved end pieces of the VECC coil. The result would like like the black coil drawn around the ELBD in Figure 2. From perspective of the power supply, this lengthens the Coil #1 effectively by a factor of about 4/3, so the voltage would increase by this same factor. Curremtly, operating at 30 Amps, the voltage is 26 Volts [Marco Marchetto]. This voltage would rise to 35 Volts. This is well within the capability of the current power supply, which is 40 Amps, 60 Volts.

During commissioning, it was also established that the Coil #1 current needed to minimize steering in the ELBT wih the cyclotron ON, is 24 Amps. This is somewhat lower than the 30 Amps expected. This experience thus reduces the upper bound requirement on Coil #1 current from 36 Amps to 30 Amps, which still gives a 20% contingency over and above the operating current of 24 Amps.