Magnetic fields for the HD cell transfer

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Abstract

We summarize in this note the study of the magnetic fields present in the IBC during a cell transfer.

1 Introduction

To insure that the HD target cell does not depolarize when transferred to the IBC, the cell has to always be under a large magnetic field ($\gtrsim$100 Gauss). Three magnets are present along the transfer axis to provide such fields:

1. A transverse field Halbach dipole in which the cell is transported.
2. The main IBC solenoid that provides the magnetic field during in-beam target operation.
3. A transfer magnet to provide a field between the two magnets above.

2 Frame of reference

In the note below, the $z-$axis refers to the transfer axis. It is the same as the beam axis when the IBC is in place in CLAS. Positive z is pointing downstream the beam. x and y are transverse directions. The origin $z = 0$ of the frame is set to coincide with the upstream edge of the main IBC solenoid.

3 Magnets

3.1 Halbach Dipole.

The field in the Halbach dipole is transverse and ideally homogeneous. A field map of the dipole was provided by Xiangdong Wei. The field map gives only $B_x(z)$ at $x = y = 0$ over the range -9.5cm$< z <$+7cm. We had to extrapolate the field map up to $+10.5$ cm in order to obtain the field up to a z where the field becomes negligible (we used the $-z$ part of the map for the extrapolation). The position, in our frame, of the center of the magnet is $z = -88.93$ cm. The $z-$size of the dipole is 14.4 cm. The field map is provided on Fig. 1 and 2.

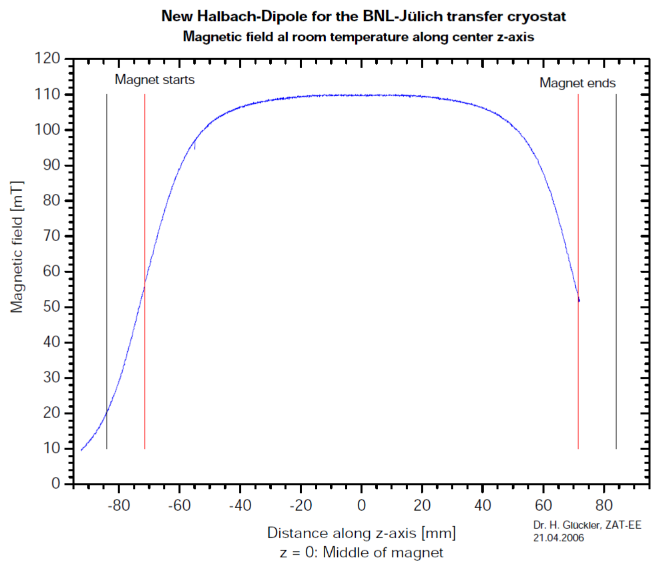


Figure 1:
Magnetic field $B_x(z)$ map of the Halbach dipole.

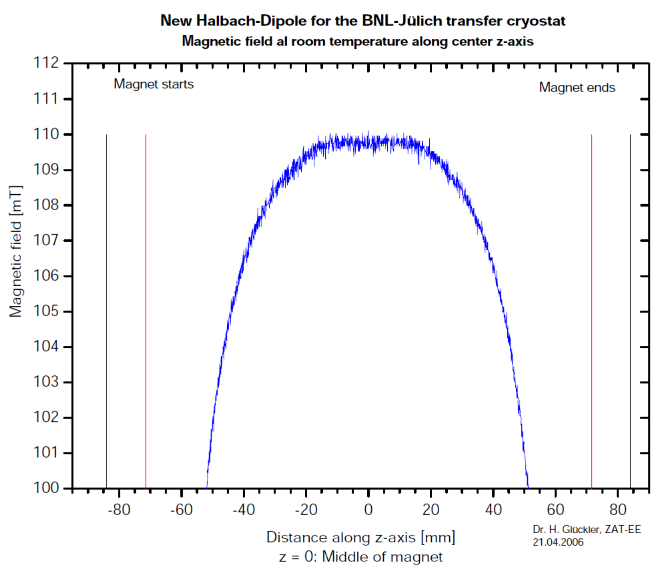


Figure 2:
Magnetic field $B_x(z)$ map of the Halbach dipole. (Zoom on the central homogeneous region.)

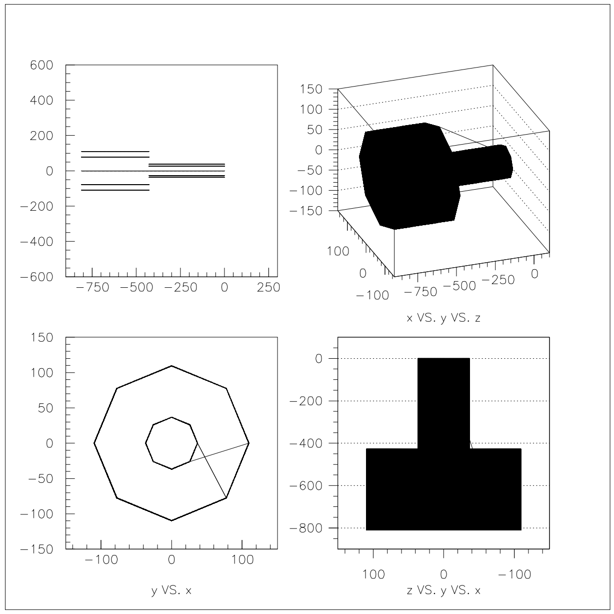


Figure 3: Model for the transfer magnet. Top left plot shows a projection in the xz plane (on the plot, x is the vertical scale and z the horizontal one). The line at x=0 is immaterial. The ref. frame used is the one described in this report. Top right: model in 3d xyz. Bottom left, cross section in the yx plane. Bottom right, cross section in the zx plane (z: vertical scale). Distances are in mm. For plotting purpose, only 8 segments have been used to approximate circles. In the field simulation, 20 segments are used.

3.2 Transfer magnet

The transfer magnet provides a B_z field. The magnet is made of 2 layers of supraconducting wires (expected to be Supracon 54S43 wires). Its total length is 81.04 cm. The first 38.26 cm has a 10.95 cm inside radius and consists of 2152 spires. The last 42.78 cm has an inside radius of 3.67 cm and consists of 2406 spires. We assume that a 16 A current is used to generate the field. We modeled this solenoid and simulated the field using the Biot-Savart law. Each circular spire was approximated with 20-segments polygons. The model is shown on Fig. 3. Field maps for the transfer magnet are given in Fig. 4. Similar fields were obtained when computed off z-axis (9 mm offset).

3.3 Main IBC solenoid

We used an obsolete design of the solenoid (10 layer of thin Supracon 54S43 wires, with the 10th layer having gaps to minimize field gradient). The present design is using only 4 layers of thicker Supracon T48B-M wires with two incomplete layers. These details only affect the field at a 10^{-3} to 10^{-4} level and

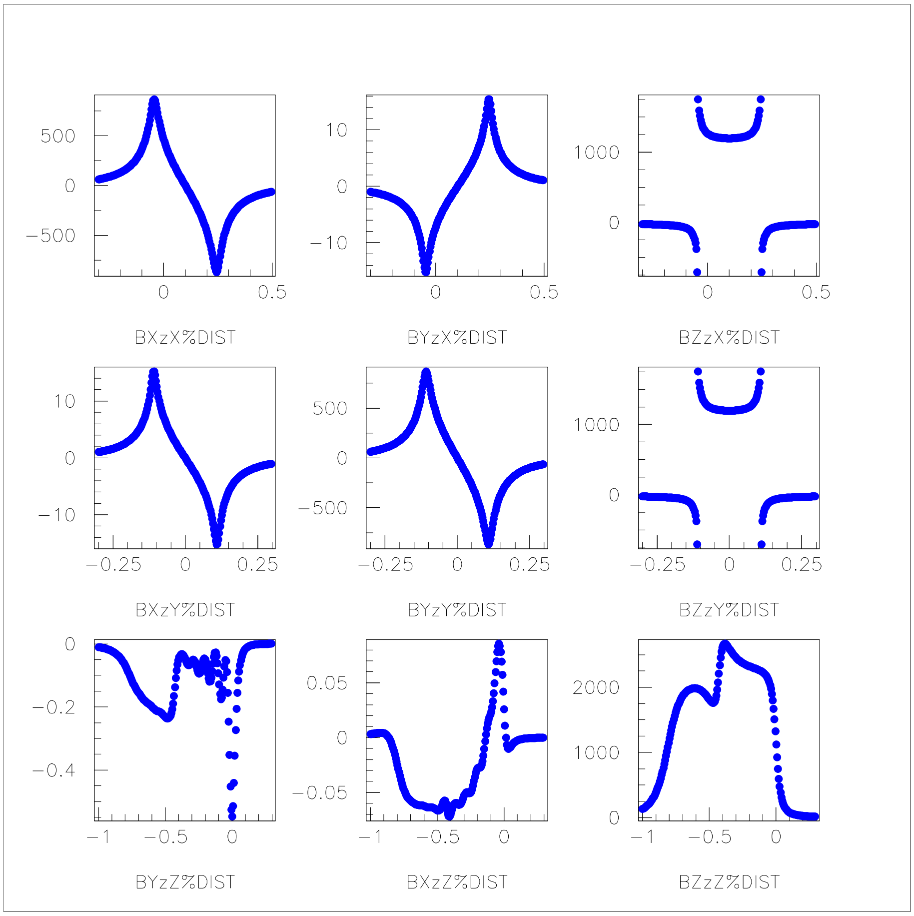


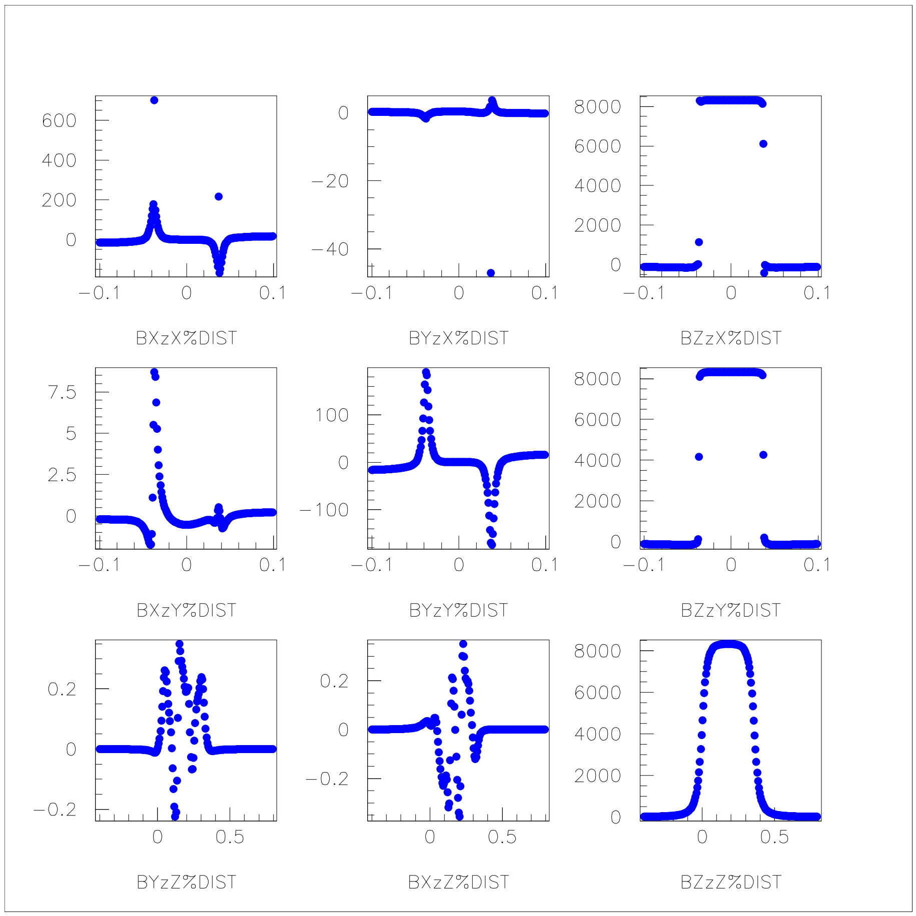
Figure 4:
Fields from the transfer magnet model. Fields are in Gauss and distances are in meter. We assume a 16 A current in the coil. Top row, from left to right: $B_x(x)$, $B_y(x)$ and $B_z(x)$ measured for $y = 0$ and $z = -80$ cm. Middle row, from left to right: $B_x(y)$, $B_y(y)$ and $B_z(y)$ measured for $x = 0$ and $z = -80$ cm. Bottom row, from left to right: $B_x(z)$, $B_y(z)$ and $B_z(z)$ measured for $x = y = 0$.

are thus unimportant in our context. The solenoid is 40 cm long with its origin at $z = 0$. Its internal radius is 3.64 cm. Figure 5 displays field maps for the main IBC solenoid. Similar fields were obtained when computed off z-axis (9 mm offset).

4 Results and conclusion

The results of the simulation are displayed in Fig. 6 (field components measured in function of z for $x = y = 0$) and 7 (field components measured in function of z for $x = 9$ mm, except for the Halbach dipole). We also did a sanity checked for $x = -9$ mm and found similar results as in Fig. 7, except that the signs for the transfer magnet and main IBC magnet B_x and B_y field components are reversed, as expected. It can be seen on Figs. 6 and 7 that there is a good overlap of the fields and consequently the target cell will always see a field magnitude greater or equal to about $\sqrt{0.1^2 + 0.08^2} = 0.13$ Tesla during its transfer from the Halbach magnet to the main solenoid, ***if the transfer magnet and main IBC solenoid have the same polarity***. The only possible caveat in this conclusion is that for the $x = \pm 9$ mm result, the Halbach magnet field was assumed to be the same as for $x = 0$. Although it would be safer to get a map of the Halbach field on the edge of this magnet, our assumption is probably fine since we expect the Halbach magnet field to be homogeneous.

Figure 5:



Fields from the main IBC magnet. Fields are in Gauss and distances are in meter. Top row, from left to right: $B_x(x)$, $B_y(x)$ and $B_z(x)$ measured for $y = 0$ and $z = 20$ cm (20 cm = middle of the solenoid). Middle row, from left to right: $B_x(y)$, $B_y(y)$ and $B_z(y)$ measured for $x = 0$ and $z = 20$ cm. Bottom row, from left to right: $B_x(z)$, $B_y(z)$ and $B_z(z)$ measured for $x = y = 0$.

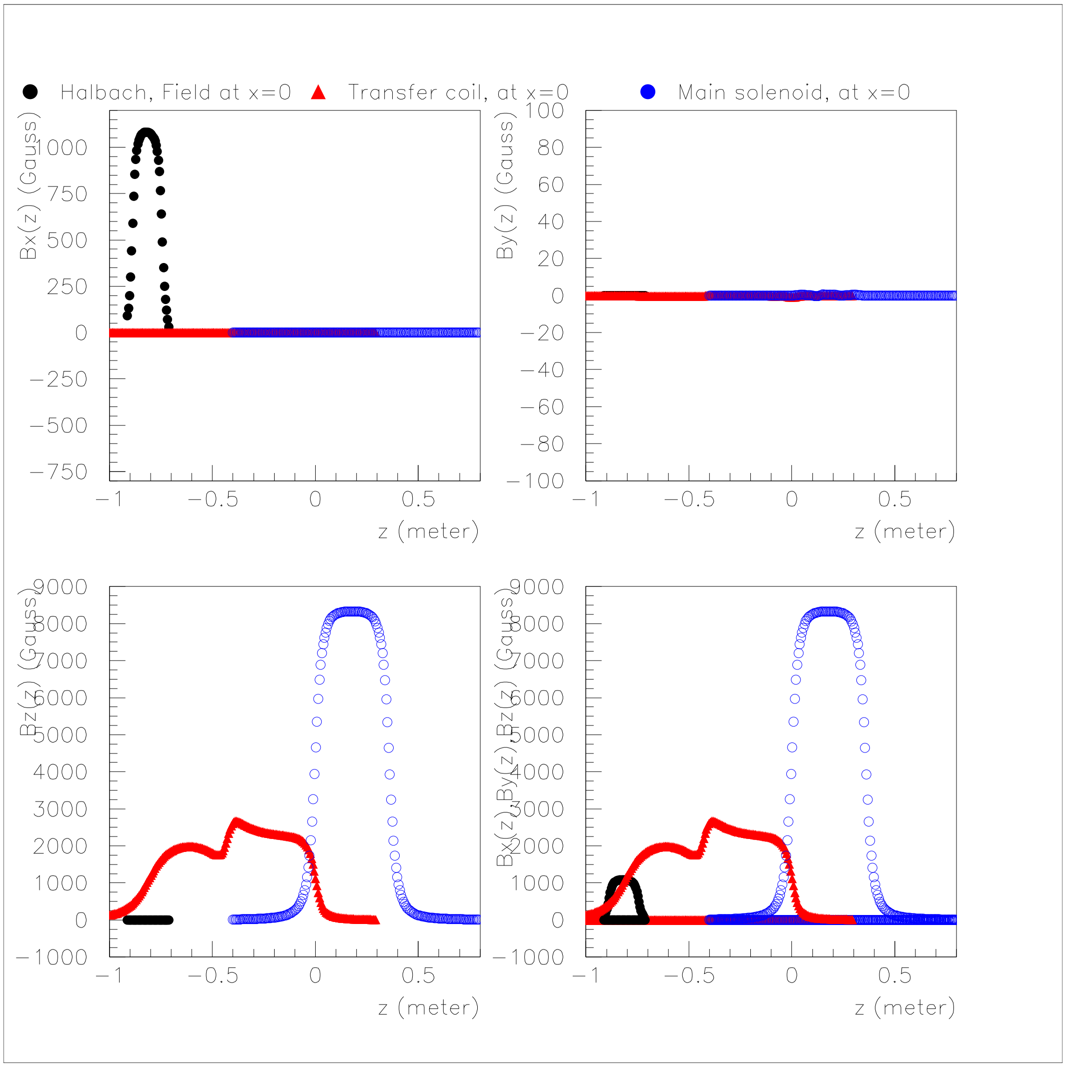


Figure 6:
Fields along the z direction and for $x = y = 0$ from the 3 magnets . Black is for the Halbach dipole, red for the transfer magnet and blue for the main IBC solenoid. The top left plot is for $B_x(z)$, the top right for $B_y(z)$, the bottom left is for $B_z(z)$. The bottom right panel displays all the field components on the same scale (fields components are not added).

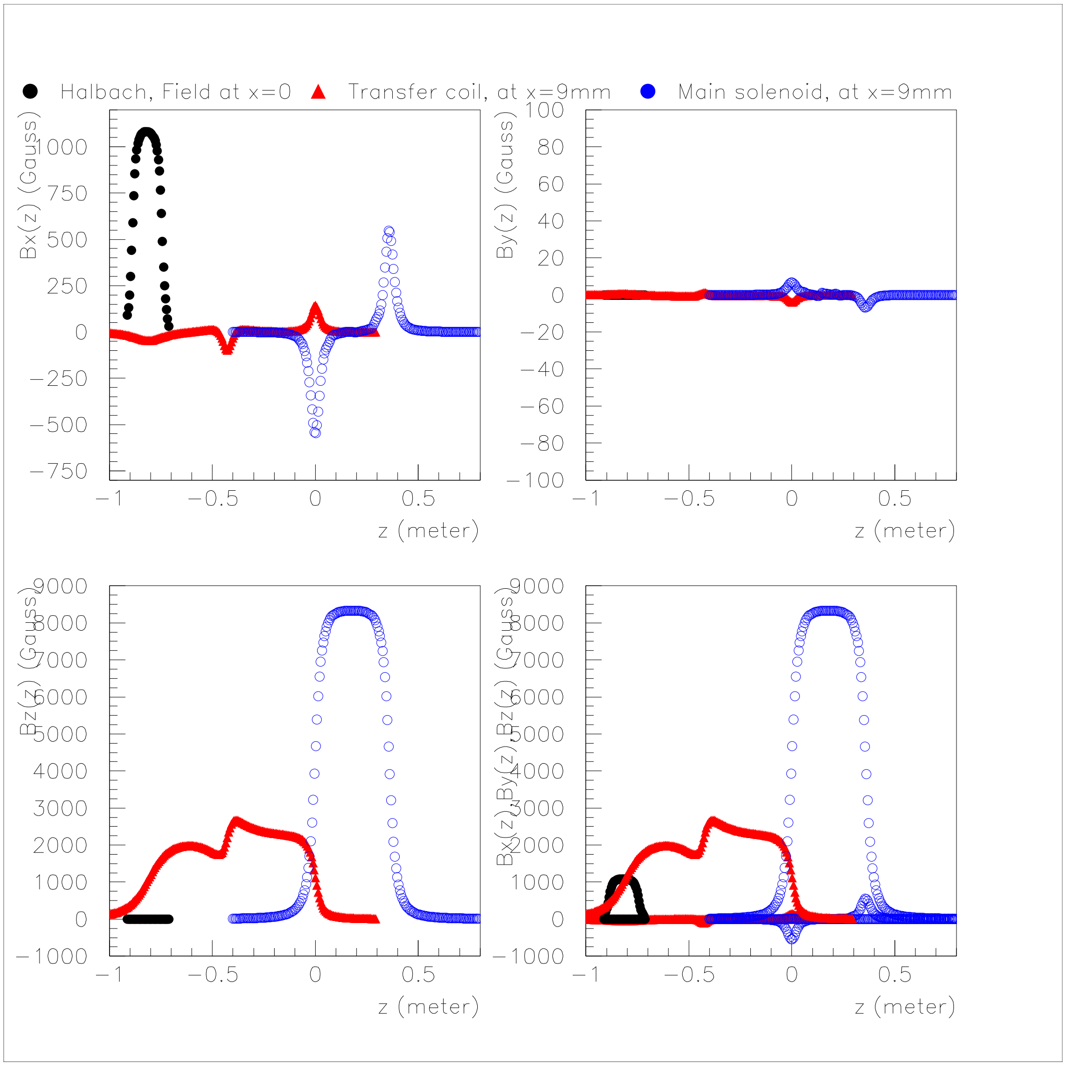


Figure 7:
Same as Fig. 6 except $x = 9$ mm for the transfer magnet and main IBC solenoid. The Halbach field map is still at $x = y = 0$.