Magnetic Field Mapping

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Curl Corrections

Rotations of the individual Hall probes on the field mapper machine mix components of the field together, distorting the data.
Three (small) rotation angles mixing the three components: $A_{rz}, A_{r\phi}, A_{z\phi}$.
The measured components of the field become:

- $B_{\phi}^{meas} = B_{\phi} + A_{z\phi}B_z - A_{r\phi}B_r$
- $B_z^{meas} = B_z/N_z - A_{zr}B_r\,(+A_{z\phi}B_{\phi})$
- $B_r^{meas} = B_r/N_r + A_{zr}B_z\,(-A_{r\phi}B_{\phi})$

N_z, N_r are normalisation factors. The former can be found from the Fourier-Bessel fit. As B_{phi} is very small, it is a negligible factor when considering B_z^{meas} and B_r^{meas}.
The angles can be found by applying Maxwell's equations to the measured field.

$A_{r\phi}, A_{z\phi}$ are found by considering the integral form of $\nabla \times \mathbf{B} = 0$. (No sources of field within the enclosed area, i.e within our solenoids.

$$\oint \mathbf{B} \cdot \mathrm{d}\mathbf{S} = 0$$

Applying this to the expression for B_{ϕ}^{meas}:

$$\oint B_{\phi}^{meas} \cdot \mathrm{d}S = A_{z\phi} \oint B_z \cdot \mathrm{d}S - A_{r\phi} \oint B_r \cdot \mathrm{d}S$$

Since:

$$\oint B_{\phi} \cdot \mathrm{d}S = 0$$

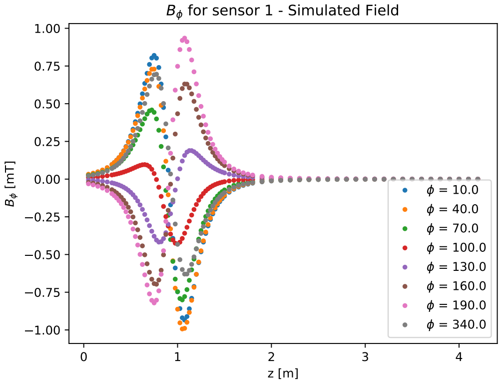
We can then replace the integral with the sum over measured points in ϕ. For B_ϕ, it is sufficient to use $B_{r,z}^{meas} \approx B_{r,z}$.

$$\sum_\phi B_\phi^{meas} = A_{z\phi} \sum_\phi B_z^{meas} - A_{r\phi} \sum_\phi B_r^{meas}$$

Calculate this for all z-steps in the data and then perform a least squares fit.

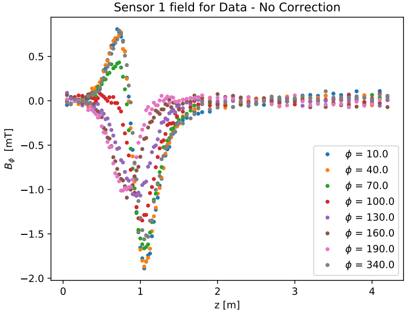
Results

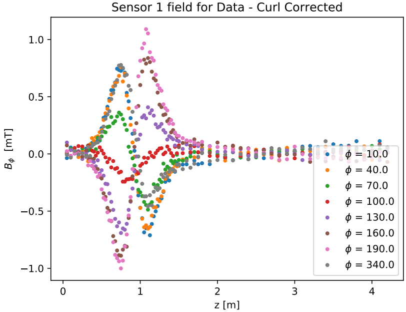
What should B_ϕ look like for a coil rotated wrt to the mapper axis?



B_ϕ at $r = 0.03$m for a simulated SSU M1 coil that is rotated wrt to the mapper axis.

Actual mapper data for SSU M1 before and after corrections.





Obviously we are not too bothered by B_ϕ as it is so small. But for the geometrical fit procedure it helps with finding the rotations since it is very sensitive.

A_{zr} Angle

Working out A_{zr} is more difficult (but arguably more important). It is achieved by considering Gauss's theorem: $\nabla \cdot \mathbf{B} = 0$. In integral form:

$$\int_{surface} \mathbf{B} \cdot \mathrm{d}\mathbf{S} = -\int_{end1} B_z dS + \int_{cylinder} B_r dS + \int_{end2} B_z dS$$

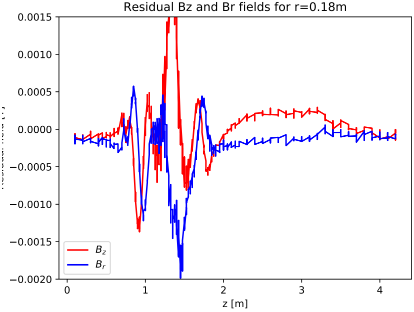
Work has begun on this.

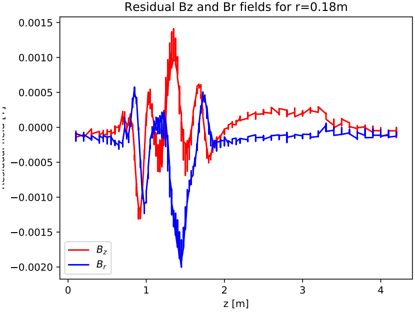
Alternate Geometrical Fit

Chat with Chris Rogers about geometrical fit that calculates field at rotated points and takes actual coil parameters as fitting parameters – current, R_{inner}, R_{outer}, etc...

Now possible to test out now I know how to use parallel processing module without breaking stuff! And it does not take an age to run.

Left – Classic Geometrical fit. Right – New Geometrical fit





Sometimes it is slightly better. However sometimes it is slightly worse. Both need a little more work anyway – Watch this space.