Field Mapping

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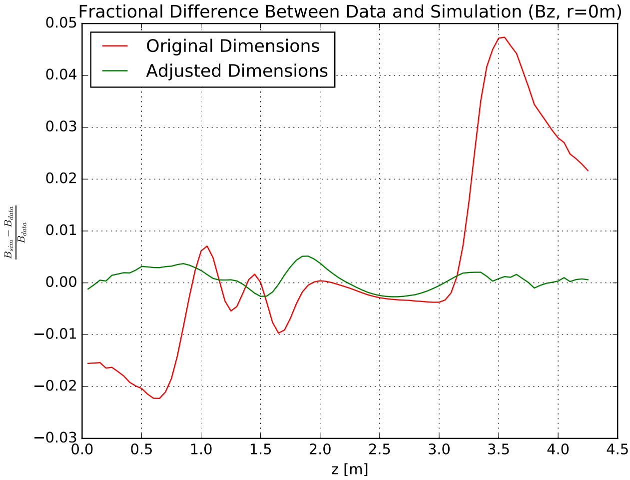
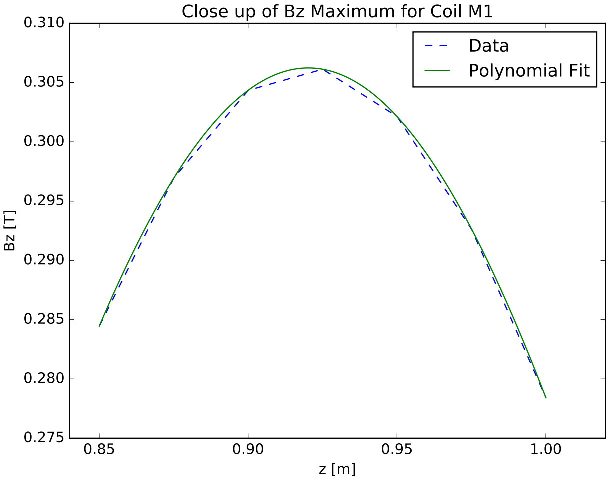
Previously

- Comparing cold and warm dimensions simulations of the SSU field with data from the field mapper.
- Cold dimensions (obviously) agreed more, but improvements could be made by better matching the centre of the coils in the simulations with the coil centre positions in the field map data.
- Used a polynomial fit on field map data where single coils are powered to find the coil centre positions


Fractional Difference Between Data and Simulation (Bz, r=0m)
Original Dimensions
Adjusted Dimensions
$\frac{B_{sim} - B_{data}}{B_{data}}$
z [m]
0.05
0.04
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5


Close up of Bz Maximum for Coil M1
Data
Polynomial Fit
Bz [T]
z [m]
0.310
0.305
0.300
0.295
0.290
0.285
0.280
0.275
0.85
0.90
0.95
1.00

Improvements and Fixes

Recap of the polynomial fit algorithm to find the coil centre positions:

- Find data point where field is maximum
- Take the 4 data points either side
- Fit a fourth order polynomial to these data points
- Differentiate this polynomial
- Use a root finding algorithm to find at what z what the gradient is zero
- This z position should be the centre position of the coil.

I actually use 2 root finding algorithms: Bisector search and Halley's method.

Found and fixed a bug that made Halley's method iterate only once and now centre positions are more accurate.

- I tested this centre finding algorithm by making a 'Toy Coil'
- I made a field map for a single coil with fairly similar dimensions to M1 and added gaussian noise to each data point with $\sigma = 20\,\text{G} = 2\,\text{mT}$.
- This is a figure I have pulled from many past field mapping talks and this is probably larger than the actual Hall probe errors. **This will be investigated.**
- I then randomised the centre position of this coil
- I then used the centre position finding algorithm on the toy coil field map 'data'
- Halley's method agreed to within the millimetre whilst the Bisector search was sometimes off by millimetres

I also implemented the method to find the centre of the centre coil by subtracting the individual E1 and E2 fields from the E1-CC-E2 in series field map... But I lost the plots for these so I remake them and show them in a later talk!

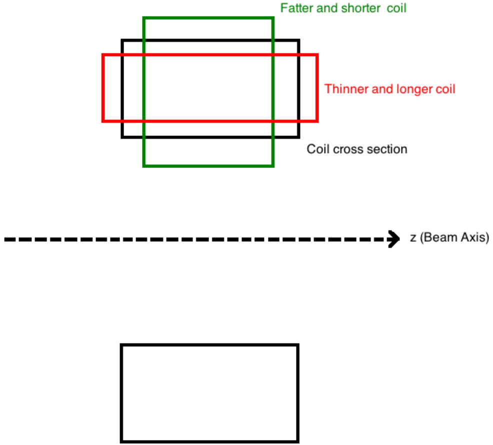
Coil Dimensions

Happy now with the centre positions of the individual coils for the SSU simulations. But what about the dimensions of the coils themselves?

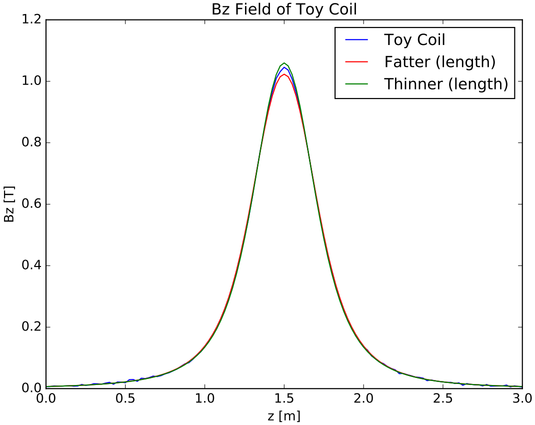
There is a better method than trying to fit a field map to the data by playing with the coil dimensions. Simply put:

- Make a computer model of SSU with slightly fatter and shorted coils.
- Make a computer model of SSU with slightly thinner and longer coils.
- Add these two 'bracketing' fields in proportions (e.g 75:25) and minimise the χ^2 between the added fields and the data by changing the proportions of the bracketing fields using Minuit (and Migrad)

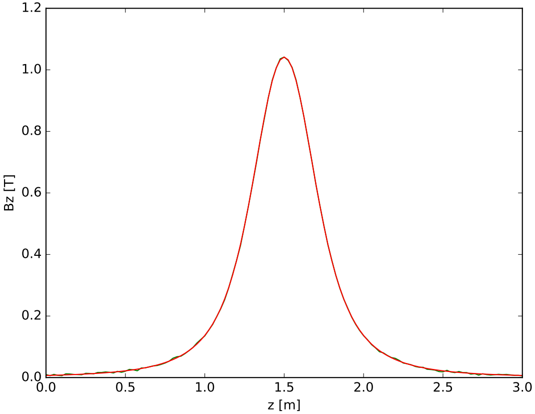
Lets begin with the toy coil mentioned previously.



- I made the toy coil field map with the 2mT noise added.
- I then made a field map in the same centre position (for both r and z) but 10% fatter and 10% shorter dimensions
- I then made a field map but with the coil 10% thinner and 10% longer

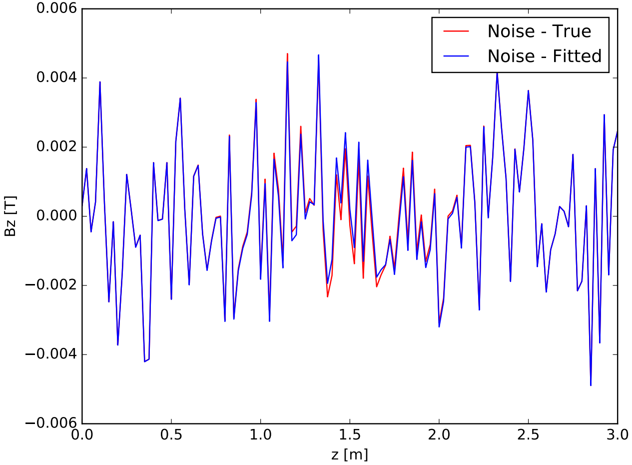


End up with a 50:50 mix of the bracketing fields (not surprising).



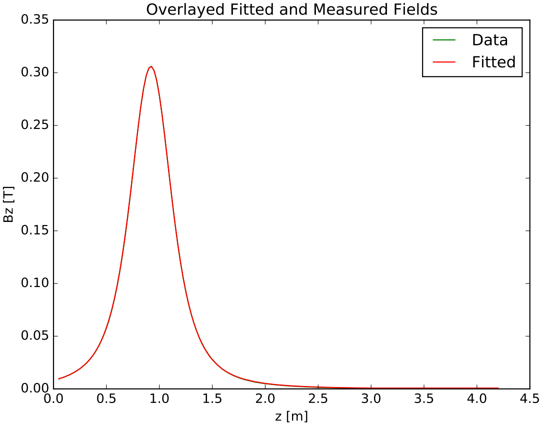
Toy coil field with noise in Green and the resulting field map from the fit given by mixing the two bracketing fields is shown in red.

And the residuals of the toy coil field with noise with the ‘True field’ (The field of the Toy coil without the added noise) and with the fitted field map from the mixing.

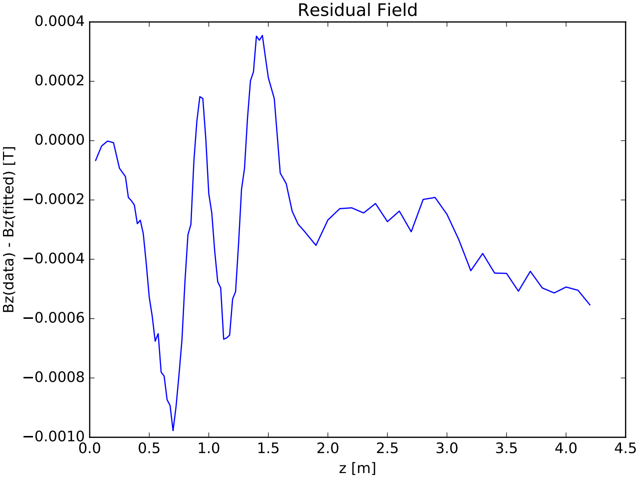


Looks good. Lets try the same method on field map data from an individual coil on SSU – say M1.

Again I take 10% thinner/fatter and longer/shorter around the supposed dimensions of the coil. I get a mixing of $\sim 65 : 35$ Thin : Fat



And the residuals:



Conclusions

This novel method to make field maps using two ‘bracketing fields’ seems to work well on both a Toy Coil and the field map data for M1 coil.

Future work:

- Apply this method to the whole SSU to see if this improves the simulated field map.
- Take into account the tilt of the coils of SSU wrt the field mapper axis.
- Investigate the error on the Hall probes
- Repeat entire process for the other channel magnets.

Halley's Method

$$x_{new} = x_{old} - \frac{2\text{f}(x_{old})\text{f'}(x_{old})}{2(\text{f'}(x_{old}))^2 - \text{f}(x_{old})\text{f''}(x_{old})}$$