Systematic Errors on the Emittance Calculation

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MICE VC 199

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Contents

Introduction

The main focus is for the Emittance Measurement Paper - The 07469 dataset.

We have a good measurement of emittance with mature beam selection and reconstruction routines, however there is still some unknown systematic error on the final emittance measurement.

Experience and testing has implied that this is primarily due to the field within the tracking volume - we currently assume a perfect uniform solenoid.

Using a combination of Data, MC and Reconstructed MC we can model this effect in simulation and estimate variations in the emittance calculation.

The Method

1. Take the best measurements from data to develop an initial MC model
   e.g. alignment, field maps, PRY, etc.

2. Tweak the initial model to try and reproduce the measurements and reconstruction seen in data,

3. Build some estimate of "trust" in that model
   e.g. measurement errors, field map variation, etc.

4. Use the measure of "trust" to vary the model and examine the resulting change in the emittance reconstruction,

5. Use the variation in emittance reconstruction as an estimate of the systematic error.

Analysis Method

The current analysis scheme:

1. Produce a vast amount of MC data,
2. Perform multiple reconstructions on unique subsamples of the whole dataset,
3. Use the variation in the subsamples to predict the systematic effect.

This is very similar to the approach used to estimate the momentum binning error and has proven quite robust.

Field Alignment

I have developed a field alignment measurement based on fitting straight lines to low-pt tracks. (See CM49 - Magnet-Tracker Alignment).

Works well with some interesting systematic effects - however these can be assumed to cancel out to first order for this analysis.

(The systematics are still to be fully understood, but do not prevent us from continuing.)

Field Alignment

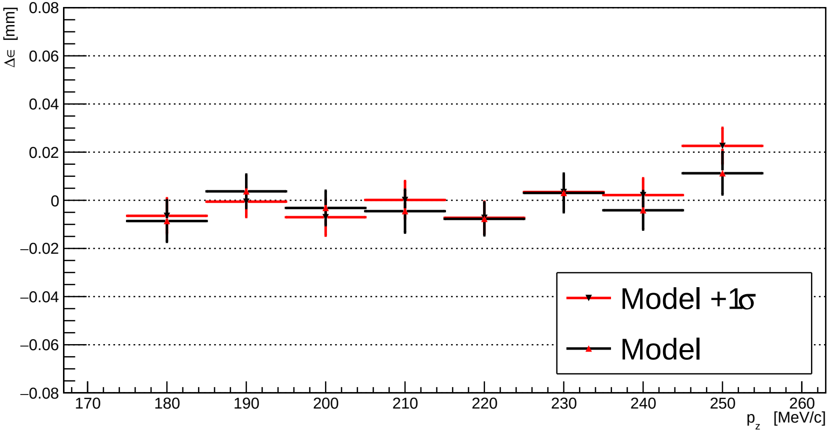
1. Start with a CDB geometry, the Comsol Field map and the alignment using 07469 data,
2. Make a new CDB geometry where we rotate the Comsol field map such that the alignment calculation in reconstructed MC returns the same values as in Data,
3. Use the errors from the 07469 data alignment as our measure of trust and vary the new geometry by 1σ,
4. Perform a full MC reconstruction and examine how the emittance changes.

Field Alignment

Alignment Numbers

Geometry	ϕ_x [mrad]	ϕ_y [mrad]
CDB Official	-1.125 $\pm$ 0.030	-2.314 $\pm$ 0.030
07469 Data	0.288 $\pm$ 0.097	-1.466 $\pm$ 0.093
07469 Model	0.191 $\pm$ 0.030	-1.480 $\pm$ 0.030
07469 Model $+1\sigma$	0.371 $\pm$ 0.030	-1.582 $\pm$ 0.030

Field Alignment



Error bars are underestimated at present.

Field Uniformity

This is fundamentally more difficult to parameterize as "uniformity" is not necessarily quantitative.

However the proceedure is largely similar, as long as we can choose some definition for the level of "trust"...

Field Uniformity

1. Start with a CDB geometry and the Comsol Field map,
2. Make some test geometries to examine the sensitivity of the reconstruction on the uniformity,
3. Produce some field maps that represent the level to which the field may be expected to vary,

- or -

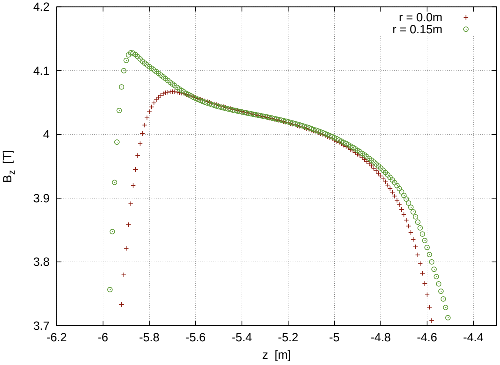
4. Produce some field maps that represent the variation from a perfect field that could cause systematic effects.

Currently looking at No. 4

Field Uniformity

The three primary differences between the Comsol field map and a perfect solenoid can be considered to be;

1. On-axis B_z is not flat,
2. Off-axis B_z is not flat (fringe fields),
3. There is some variation due to iron, etc, represented to some degree in the field map.



Standard Comsol Field Map

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Field Uniformity

Currently looking at three field maps:

1. Perfect solenoid with B_z gradient that agrees with Comsol ("Linear"),
2. On axis field, with no radius dependence ("Fringeless"),
3. Full Comsol field map.

4. On-axis field with a first order approximation to the off-axis components, to satisfy Maxwell's equations. - *Still to come*

Field Uniformity

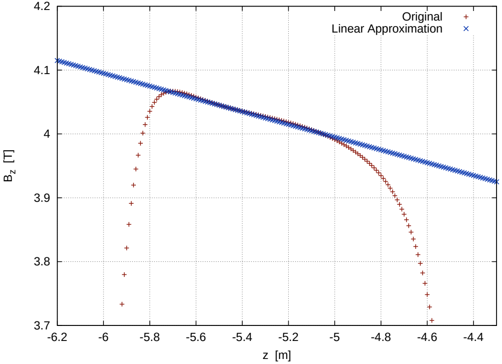
Disclaimer

The current iteration is using Field maps where we are knowingly violating Maxwell's Equations.

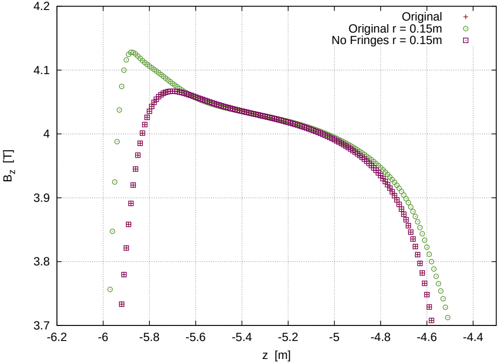
To first order we don't actually care.
This will have some funky effect in the optics, etc, but we are only interested in perturbing the reconstruction resolutions.

If we include first order corrections that may be a better model to use to create an error bar, however I wanted to start by calculating the upper limit, so that we understand the scale of the effect.

Field Uniformity



Linear Field Map



Fringeless Field Map

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Field Uniformity

Analysis is unfortunately currently ongoing - need a lot of MC data!

Still need to include the measured data alignment for the final pass.

Current Activity

Currently trying to close the loops in both fronts.

Victoria and I both have unique analyses desgined to estimate reconstruction resolutions using simulated data. We are fixing bugs and (hopefully) converging on the same estimate for emittance residuals.

I had an unexpected issue last week so there was a little delay, but we are seeing reasonable systematic errors in the alignment analysis.

Once we have confidence in that, we can rinse and repeat on the uniformity analysis.

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Conclusions

- General process is well understood and reliable,
- Alignment analysis indicates no correction needed,
- Two distinct analysis chains to validate results,
- MC data for all models is being/has been produced,
- Only some small subtleties remain in how we turn emittance residual distributions into systematic error bars,
- Additional field maps for uniformity analysis may be required.