Extract: Magnetic mapping aims and requirements (WIP, Focus Coil Centric)

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1 Why map the MICE magnets?

There are two main reasons for mapping our magnets,

1. Align the focus coil with the MICE magnetic axis.
2. Understand the magnetic field for simulations and analysis.
   (a) Check the operating fields for hysteresis effects.
   (b) Verify OPERA calculations.
   (c) Determine best coil geometry that reproduces the measured fields
   (d) Determine the effect of iron on the magnetic field and any measurable error fields.
   (e) Check linearity of field with current.

and the better we do (1), the easier it is to do (2) well.

2 Table of Measurements

Need to do all the survey measurements and correction measurements before we take any data. We don't necessarily need to do anything with them on-the-spot, but we will need to do something with them eventually in which case we need that data. A full list of measurements is shown in Table 1, and notes on the different measurements are given below, organised by their ID tags:

Survey** Measure different properties of the mapping machine with respect to the magnet or surveyed co-ordinate system.

Survey03 The aim of this measurement is to track any deviations of the mapper from a straight line as it moves through the magnet.

Survey04 A repeat of Survey01 after the mapper has been moved. We want to check that we reliably return to specific points.

Survey05-07 We are checking that the assumed $5°$ rotation increments of the mapper disc are correct, and also checking for any tilts in the disc by examining the z-component. The Hall probe at 140mm (or 150mm if the Spectrometer Solenoid mapping disc is in use) is chosen since it can be measured at $\phi = 180°$, whereas the outermost one cannot. Combine these measurements with the output of Survey04 for the $\phi = 0°$ measurement.

Data01 The first field map is mostly for checking that we're seeing sensible results. We want to examine this fairly carefully:

1. Plot the field seen by each probe at each rotation and look for anomalies in the flat-field region.
2. For each probe, compare the measurements at $\phi = 0, 90$ and $180°$. They should all be similar, in other words, we shouldn't see any evidence of a B_ϕ component to the field.
3. Make a contour plot of the total field, $|B|$ in the horizontal and vertical plane. They should look similar.
4. Make a first estimate of the magnetic axis and compare the residuals – might we need a finer mapping grid for later measurements?

Data02 A repeat of Data01, we want to see how repeatable our results are. Compare some plots from Data01 with similar ones from Data02. There shouldn't be any large differences.

Data03 The first fine-mesh field map. XYZ needs a bit of study to see what is acceptable when looking at smeared simulation, but is *probably* 1–2cm and $45°$ (depending on available time).

Data04 A quick field map at an intermediate current. The purpose of this is to compare it to the $\phi = 0°$ map from Data01-02 and check that the field scales linearly with current.

Data07 A full ϕ scan is necessary to later locate and correct for any offsets in the hall probe mountings on the cards. It also allows us to normalise the Hall probe outputs. Three z positions may be overkill – it depends on time – but a minimum of one must be done, preferably at full field so the Hall probes are in their element.

Data08 Checking for hysteresis effects. Compare with Data05, where we approached the current from below.

Data12 We can't forget to repeat the other side of the hysteresis check measurement!

Data13 Similar to Data01, except this time in Flip Mode. Of particular interest is how the Hall probes behave as they go through the zero-crossing of the field. Check this region and decide if we need to increase our map mesh from XYZ to something else. Do the same sanity checks as for Data01.

Data17 Make sure there's no hysteresis that strangely only affects Flip Mode.

Data21 Combines with Data17 for hysteresis check.

Tab. 1: A checklist of measurements that need to be made, in the order I believe they need to be taken in. 'Operating Mode' describes how the magnet is powered ('S' = Solenoid Mode, 'F' = Flip Mode) and at which end of it the mapper is placed. Currents A, B, C are in principle $0.3I_D, 0.6I_D, I_D$ respectively, where I_D is the design current, but these need checking to make sure the expected fields are within the range of the Hall probes.

	ID	Operating Mode	I(A)	Measurement Description
☐	Survey01	S, US	0	Measure Hall probe positions on mapper disc face at far upstream end of carriage.
☐	Survey02			Measure Hall probe positions on mapper disc face at far downstream end of carriage.
☐	Survey03			Measure centre Hall probe position on mapper disc face when travelling through the bore of the magnet.
☐	Survey04			Measure Hall probe positions on mapper disc face at far upstream end of carriage (checking repeatability of (x, y, z) positioning, particularly z).
☐	Survey05			Rotate mapper disc to $\phi = 5°$ and measure (x, y, z) position of $r = 140$(150 for SS)mm Hall probe.
☐	Survey06			Rotate mapper disc to $\phi = 45°$ and measure (x, y, z) position $r = 140$(150 for SS)mm Hall probe.
☐	Survey07			Rotate mapper disc to $\phi = 180°$ and measure (x, y, z) position $r = 140$(150 for SS)mm Hall probe.

Tab. 2: Continues from Table 1

	ID	Operating Mode	I(A)	Measurement Description
☐	Data01	S, US	A	Field map the magnet in z = 10cm steps at $\phi = 0, 90, 180$ and 270°.
☐	Data02			Repeat Data01
☐	Data03			Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data04		B	Field map the magnet in z = 10cm steps at $\phi = 0°$.
☐	Data05			Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data06		C	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data07		C	Measure through one full ϕ rotation (*i.e. in* 5° *steps*) of the mapper disc at $z = -100, 0, +100$cm.
☐	Data08		B	Approach this from current C (hysteresis check). Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.

Tab. 3: Continues from Table 2

	ID	Operating Mode	I(A)	Measurement Description
☐	Survey08	S, DS	0	Measure Hall probe positions on mapper disc face at far upstream end of carriage.
☐	Survey09			Measure Hall probe positions on mapper disc face at far downstream end of carriage.

Tab. 4: Continues from Table 3

	ID	Operating Mode	I(A)	Measurement Description
☐	Data09	S, DS	A	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data10		B	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data11		C	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data12		B	Approach this from current C (hysteresis check). Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.

Tab. 5: Continues from Table 4

	ID	Operating Mode	I(A)	Measurement Description
☐	Survey10	F, DS	0	Measure Hall probe positions on mapper disc face at far upstream end of carriage.
☐	Survey11			Measure Hall probe positions on mapper disc face at far downstream end of carriage.

Tab. 6: Continues from Table 5

	ID	Operating Mode	I(A)	Measurement Description
☐	Data13	F, DS	A	Field map the magnet in $z = 10$cm steps at $\phi = 0, 90, 180$ and $270°$.
☐	Data14		A	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data15		B	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data16		C	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data17		B	Approach this from current C (hysteresis check). Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.

Tab. 7: Continues from Table 6

	ID	Operating Mode	I(A)	Measurement Description
☐	Survey12	F, US	0	Measure Hall probe positions on mapper disc face at far upstream end of carriage.
☐	Survey13			Measure Hall probe positions on mapper disc face at far downstream end of carriage.

Tab. 8: Continues from Table 7

	ID	Operating Mode	I(A)	Measurement Description
☐	Data18	F, US	A	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data19		B	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data20		C	Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.
☐	Data21		B	Approach this from current C (hysteresis check). Field map the magnet in $z = XYZ$mm steps at $\phi = XYZ$ intervals.