Minutes of the Solenoid Meeting on November 5, '97

November 21, 1997

1 Agenda

1. Putting Solenoid Info on the Web	G. Fisk
2. Optical Survey of the Field Mapper	R. Yamada
3. Axis of Mapper wrt Field Axis	M. Mostafa
4. Other Business	all

Attendees: Gene Fisk, Dan Markley, Dan Miksa, Miguel Mostafa, Rich Smith, Ryuji Yamada

2 Putting Solenoid Info on the Web - G. Fisk

There is no easy way for our collaborators to get information about the solenoid and distributing documents among the magnet group members is sometimes not very easy. To improve the situation we will begin to put magnet related documents on the Web: http://www-d0.fnal.gov/hardware/upgrade/upgrade.html
As of Nov. 21 the links to Miguel's area: http://www-d0.fnal.gov/ mostafa/solenoid/ were not yet set-up. Miguel and Gene will be responsible for maintaining the solenoid Web information. However, they will need to be made aware of the sources. In other words it is your job to get us the information initially.

The list of potentially interesting information is:

- Conceptual Design (VMS archived and will have to be retrieved. Rich Smith is pursuing this);
- Calculated Field Plot;
- Coil geometry - as built - probably a drawing;
- Plots such as short sample, coil stress, cooling scheme, etc.;
- Table of Radiation Lengths X_o;

- Links to existing Web info: Hance, Markley, etc.;
- Minutes of solenoid meetings;
- List of solenoid publications;
- Plots of Toshiba field maps;
- Field map from future measurements;
- Final design document;
- List of personnel and E-mail addresses.

3 Survey of the Field Mapper - R. Yamada

Ryuji presented the draft plan for doing an optical survey of the field mapper in Lab 6. The steps involved follow:

1. Level the beam of the dummy solenoid;

2. Measure the pitching motion of the carriage by using a small mirror mounted vertically on the arm of the carriage:
   Desired accuracy = 0.1 mr.
   Measure at $\phi = 0^o, 90^o, 180^o, 270^o$ with 10 cm Z steps.
   This measurement will be used to extract the B_z contribution to B_r probe;

3. Measure the X, Y, Z coordinates of the probe:
   Using a glass prism target mounted near the end of the arm measure the X, Y, Z coordinates of the target in 10 cm Z steps.
   Desired accuracy = 0.1 mm.
   Measure at $\phi = 0^o, 90^o, 180^o, 270^o$ with 10 cm Z steps.
   From these measurements we expect to get the Z scale, backlash in Z, vertical sag, droop of the measuring arm, etc.

4. Measure the Z coordinates of the probe using the DØ Assembly Hall setup.
   This setup will differ from the previous measurements due to the more distant location (about 10m away) of the coordinate measuring machine.
   Using the glass prism target mounted near the end of the arm measure the X, Y, Z coordinates of the target in 10 cm Z steps.
   Measure at $\phi = 0^o, 90^o, 180^o, 270^o$ with 10 cm Z steps.
   Desired accuracy = 0.1 mm if possible; otherwise establish the achievable accuracy.
   We also need to understand the range of azimuthal,ϕ, angles that can be measured with this setup.

5. Measure the ϕ coordinates of the probe by measuring its X, Y, Z position at three Z locations: near, intermediate and far in $\Delta\phi = 20^o$.
   Desired accuracy is 0.1 mm on X, Y, Z.

6. Check Z-coordinates of Arm during rotation.
   There is a possibility the z-position of the arm is changes slightly during phi rataion.
   With the transit set perpendicular to the square beam axis, we need to check the Z-coordinate of the target during rotation.
   Desired accuracy is 0.1 mm.
   Check in the clockwise and counter-clockwise rotational directions in $\Delta\phi$ steps of 20^o.

7. Check Perpendicularity of Arm to Beam axis.
   The arm relative to the square beam should be perpendicular. This means the machined vertical plane of the arm should be perpendicular to the beam axis. This can be measured by sliding a target up and down and check it with a transit as set up in the previous measurement.
   Desired accuracy is 0.1 mm.
   Check in the clockwise and counter-clockwise rotational directions in $\Delta\phi$ steps of 20^o in ϕ regions that are visible to the transit.

4 Axis of Mapper wrt Field Axis: M. Mostafa

The field measurements themselves can be used to measure the offset of the field mapper's measuring probe relative to the field. The idea is to use the radial field difference when the probe is oriented up/down and right/left. From field calculations we know

$$\frac{\partial B_r}{\partial r} = 80G/mm$$

in the region where the radial probes are near the physical ends of the coil. Thus for example a 10 G difference between left and right values of B_r implies the field mapper is is shifted left-to-right 0.13 mm. Such a shift in opposite directions at each end of the mapper corresponds to a misalignment of $\sim 0.1\ mr$.

We can do a little better than this up/down left/right argument if we assume cylindrical symmetry and examine the radial field the probe (at radius r_o) sees when it is rotating about a new origin displaced by a small distance $\vec{\Delta r} = (\Delta r, \phi_o)$ from the cylindrically symmetric point:

$$B_r(r,\phi) = B_r(r_o) + \frac{\partial B_r}{\partial r} \mid r - r_o \mid \qquad (1)$$

with:

$$\begin{aligned} \mid r - r_o \mid &= r_o \left\{ \left[1 + \left(\frac{\Delta r}{r_o}\right)^2 - 2\left(\frac{\Delta r}{r_o}\right)\cos(\phi - \phi_o) \right]^{\frac{1}{2}} - 1 \right\} \\ &\doteq \Delta r \cos(\phi - \phi_o) \end{aligned}$$

Using this result in equation 1 gives:

$$B_r(r,\phi) = B_r(r_o) + \frac{\partial B_r}{\partial r}\Delta r\cos(\phi-\phi_o) \tag{2}$$

We can then fit the measured radial field data to a function of the form:

$$B_r(r_o,\phi) = \chi_2 + \chi_1 cos(\phi - \chi_o). \tag{3}$$

Then the fitted values are:

$$\begin{aligned}\chi_o &= \phi_o, \\ \chi_1 &= \left\langle \frac{\partial B_r}{\partial r}\Delta r \right\rangle and \\ \chi_2 &= \langle B_r(r=r_o)\rangle.\end{aligned}$$

The value of Δr is determined by dividing χ_1 by

$$\left\langle \frac{\partial B_r}{\partial r} \right\rangle.$$

Selected data and the results of fitting them to the parameters in equation 2 are shown in Figures 1 and 2. From these plots it is clear the data are reasonably well fitted to the hypothesis given by equation 2. However, there appear to be systematic effects at the level of 20 G that remain to be explained. The data used to derive the parameters in equation 2 are not corrected for systematic errors such as probe misalignment. An example is the addition of B_z flux to the radial flux probe that occurs if the radial probe is not exactly perpendicular to a cylindrically symmetric radius vector passing through the point $r = 0$. Such a misalignment of the Hall probe, expected to be $\sim 1mr$, would lead to a constant offset in B_r of approximately $\Delta B_r = 1\ mr \times B_z$. The values of ϕ_o and the constant in front of the $\cos(\phi-\phi_o)$ term in equation 2, as determined by analysis of the data in Figures 1 and 2 will not be affected by this error. But, the value of the radial derivative of B_r, which is used to determine Δr, would be affected by unequal misalignments of the two radial flux Hall probes. Results from fitting the data in the two figures and additional ϕ sweep measurements are shown in the two tables that follow, Tables 1 and 2.

The value of $\frac{\partial B_r}{\partial r}$ is obtained from:

$$\frac{\partial B_r}{\partial r} \approx \frac{\Delta B_r}{\Delta r} \equiv \frac{B_r(r=52.25) - B_r(r=51.7)}{52.25-51.7}. \tag{4}$$

Dividing the fitted values in the third columns of Tables 1 and 2 by the radial gradient from equation 4 gives the values for Δr that are shown in Table 3. The values in Tables 2 and 3 in red, derived from negative current data are not consistent with the positive current data. The cause for this inconsistency may be a transitory offset in the readout electronics for the 51.7 cm radius Hall

Table 1: Probe Alignment - Positive Current

$(z,r) cm$	$\langle B_r \rangle$ G	$\left\langle \frac{\partial B_r}{\partial r} \Delta r \right\rangle$ G	$\langle \phi_o \rangle$
$(37.25, 52.25)$	-9226	-111.4	40^o
$(37.25, 51.7)$	-8818	-105.3	40^o
$(290.75, 52.25)$	9349	76.4	56^o
$(290.75, 51.7)$	8909	70.9	56^o

Table 2: Probe Alignment - Negative Current

$(z,r) cm$	$\langle B_r \rangle$ G	$\left\langle \frac{\partial B_r}{\partial r} \Delta r \right\rangle$ G	$\langle \phi_o \rangle$
$(37.25, 52.25)$	9188	111.9	39^o
$(37.25, 51.7)$	9071	106.4	40^o
$(290.75, 52.25)$	-9352	-77.1	55^o
$(290.75, 51.7)$	-8748	-72.0	56^o

probe. In Table 3 we show in blue results derived using the radial gradient from the positive current data. These results show the probe as centered on the cryostat end flanges is aligned with the magnetic field to about 1 mm over its 2.8 m length.

Table 3: Summary of Probe Offsets

Current	$z\ cm$	$\left\langle \frac{\partial B_r}{\partial r} \right\rangle$ G/cm	$\langle \Delta r \rangle$ cm	$\langle \phi_o \rangle$
Positive	37.25	-742.0	0.146	40^o
Positive	290.75	800.0	0.092	56^o
Negative	37.25	212.7	0.51	39^o
Negative	290.75	-1098.0	0.070	56^o
Negative*	37.25	742.0	0.147	39.5^o
Negative*	290.75	-800.0	0.093	55.5^o

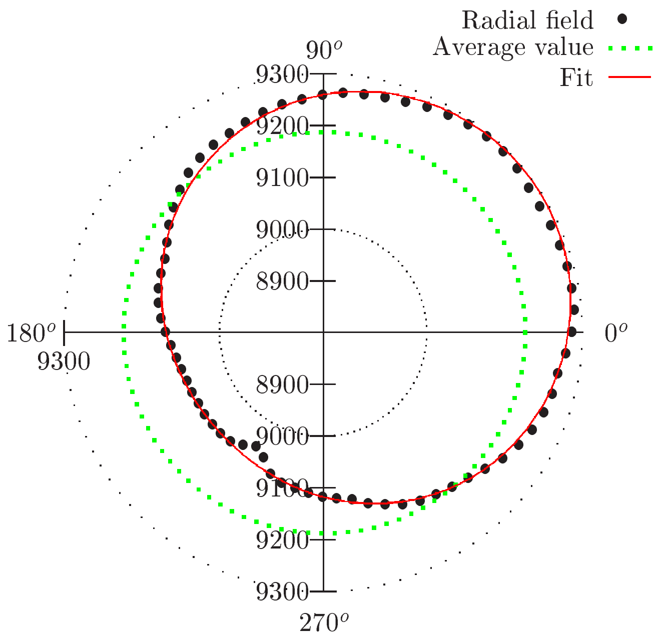

Figure 1: Azimuthal distribution of the radial field component B_r, near the inner surface of the cryostat ($r = 52.25\ cm$), approximately at the south end of the magnet coil ($z = 37.25\ cm$), for a reversed current run. The average value of the field is $9188\ G$ and the fitted field function is $9188 + 111.9\ \cos(\phi - 39^o)$.

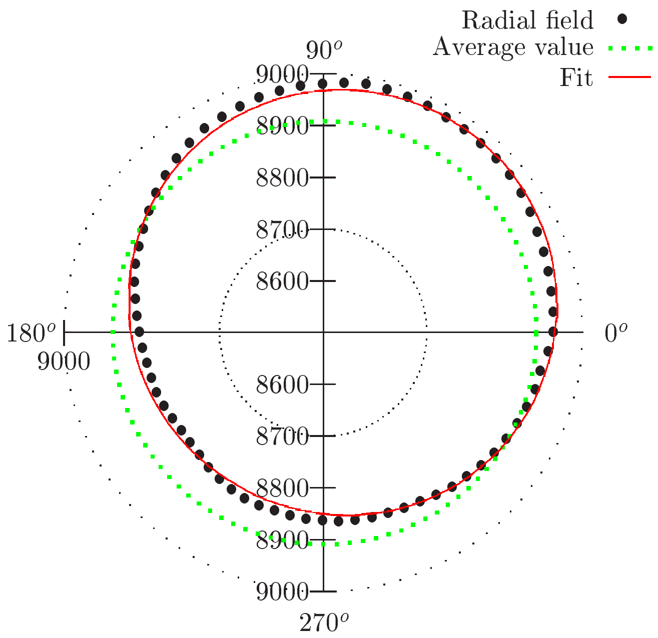

Figure 2: Azimuthal distribution of the radial field component B_r, near the inner surface of the cryostat ($r = 51.7\ cm$), approximately at the north end of the magnet coil ($z = 290.75\ cm$). The average value of the field is 8909 G and the fitted field function is $8909 + 71\ \cos(\phi - 56^o)$.