Simulation of the NDB magnets
to be used in the Minerva Tertiary Beam

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I have used the poisson program system that is a part of the Los Alomos Superfish package to simulate the NDB magnets that are to be a part of Minerva tertiary test beam at Mtest. I do not have any information on the detailed composition of the steel used in these magnets, so the default steel available in superfish was used. This will limit the final accuracy of the simulation. Experience has shown that if the steel is accurately known, these simulations can be quite accurate.

Two simulations were done. The first was to simulate a cross section in the horizontal and vertical planes. This simulation accurately portrays the magnet. The magnet quarter model as simulated, with the lines representing field lines, is shown in Figure 1. The simulation is for 4000 A-turns which corresponds to 400 turns and 100 A.

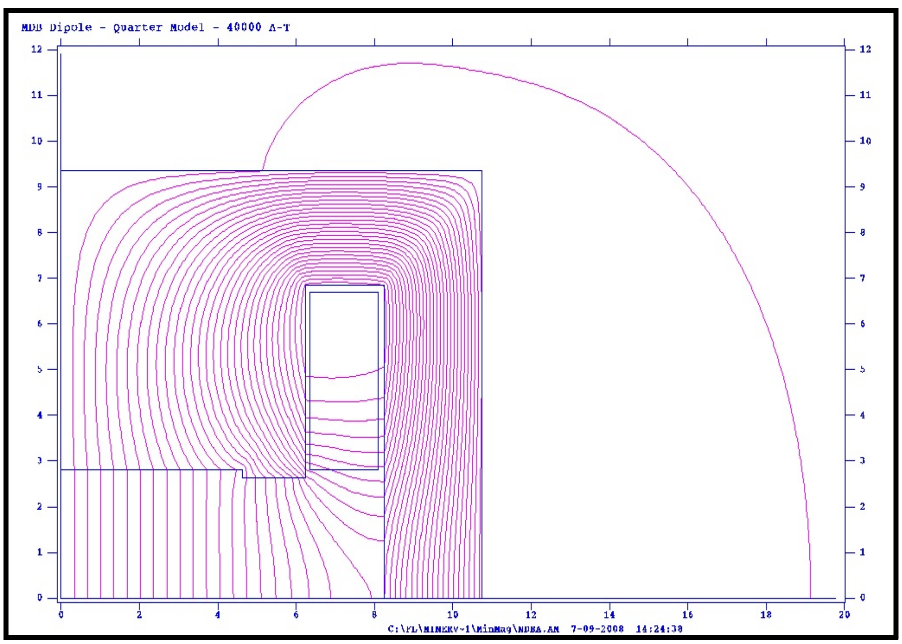

Figure 1 Supefish Plot of the x-y simulation of the NDB magnets. Dimensions in inches. Red lies are field lines

Figure 2 is a plot of the output from the Poisson progra: By as a function of x. The curve with the field increasing with increasing x is the field at y = 2 inches. The next lower plots are for y = 1 and 0 inches respectively. Note that the poles are 6 inches half width.

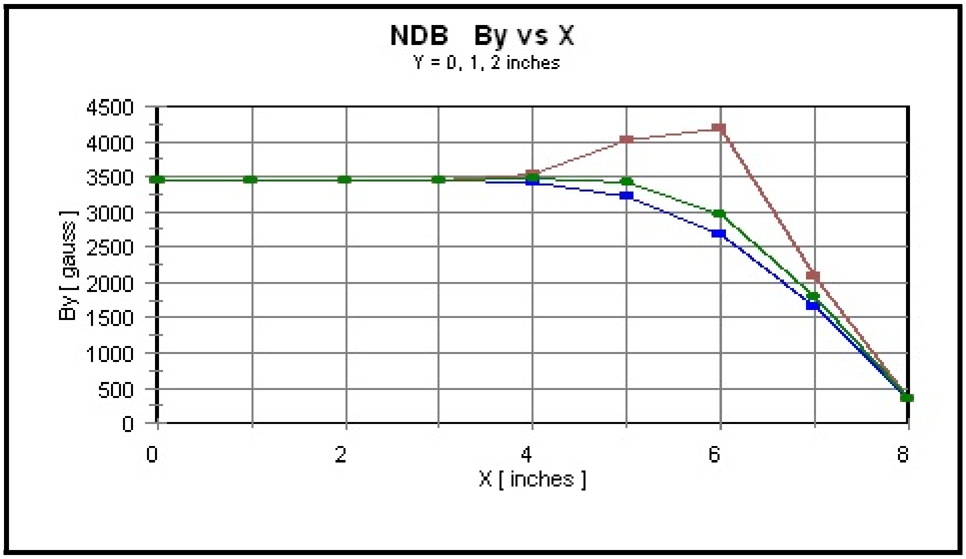

Figure 2 By as a function of x at y = 0, 1, 2 inches Blue is at y=0, green at y=1, brown at y=2.

A second simulation was done to understand of the fringe fields as a function of z (along the beam direction). A 'C' magnet model was used with the pole lengths and coils accurately simulated, but steel added to provide a return path. The reluctance of the magnetic circuit is thus not accurately simulated so that the value of the central field must be scaled to match the central field in the previous simulation. The shape of the fringe field at the end of the magnet in the direction opposite the extra steel should be reasonably accurate. The superfish output from that simulation is shown in Figure 3

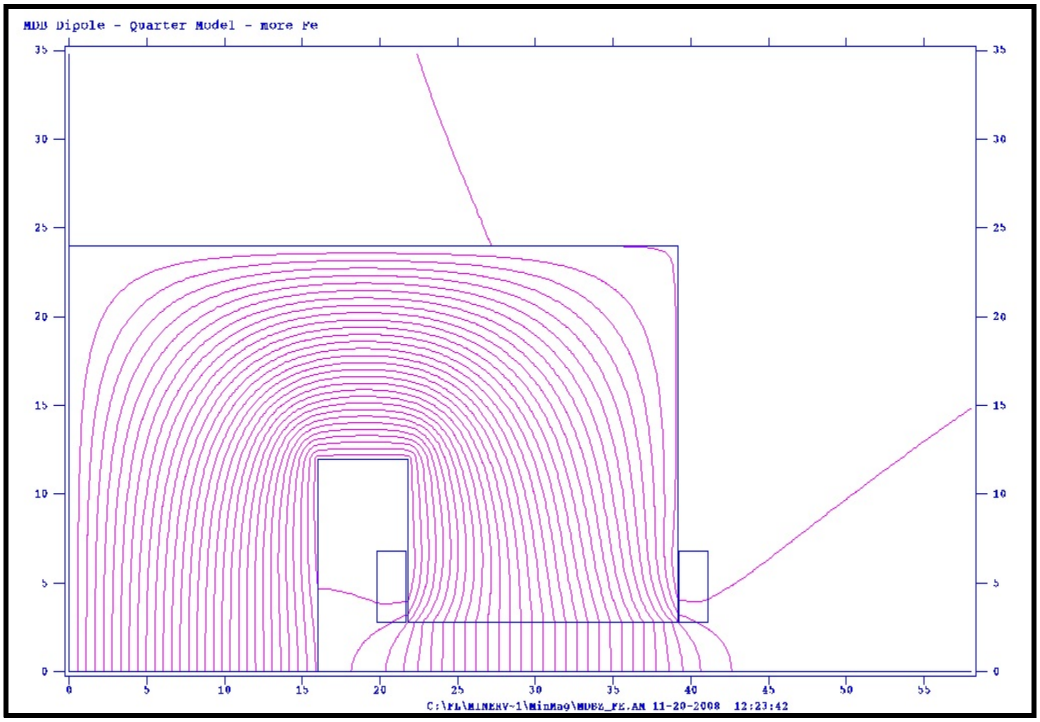

Figure 3 Superfish plot of the geometry and field lines for the y-z simulation of the NDB magnets. The steel on the left side is added as a flux return to simulate the field. The model should be reasonable from the center out to the right.

The results of the simulation in the y-z plane for the model above are shown in Figures 4 and 5. The first plot is on a linear scale and shows the field over the half length of the pole and the fringe field out to 30 inched beyond the center of the magnet (z = 30 is the center of the magnet).

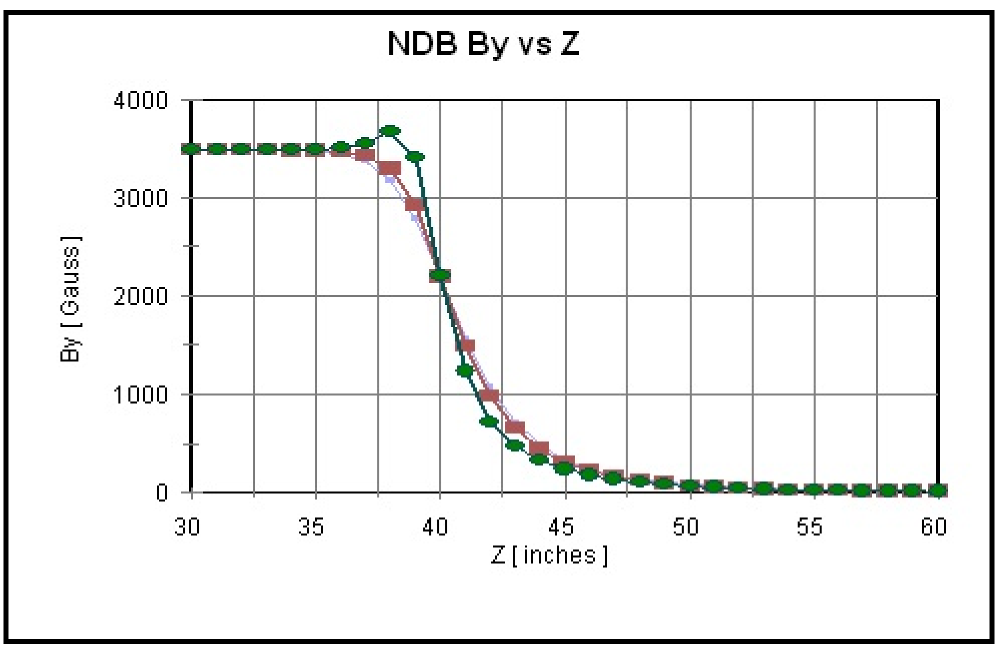

Figure 4 By as a function of z along the axis of the magnet

The field shown Figure 4 has not been rescaled to match the field in the previous simulation The green curve is for y=2, the other two in order are for y=0, 1 inch.

Figure 5 shows the same data with the field rescaled by 0.9466 to match the field in the first simulation. The data is plotted from the center of the pole (set to 30 inches in the simulation geometry) to well outside the magnet. Clearly the log(By) is plotted to better show size of the fringe field.

The effects of the fringe field can be considered to first order by determining the effective length of the magnet. This is done by calculating the field integral and dividing by the central field. This yields an Effective half Length = 11.75 inches. The half length of the steel pole is 9.19 inches. The effective length is close to the length of the iron plus the gap. The field integral for this excitation is 54.5 MeV/c for the half length or 108 MeV/c for the full magnet. This is at a current of 100 amps.

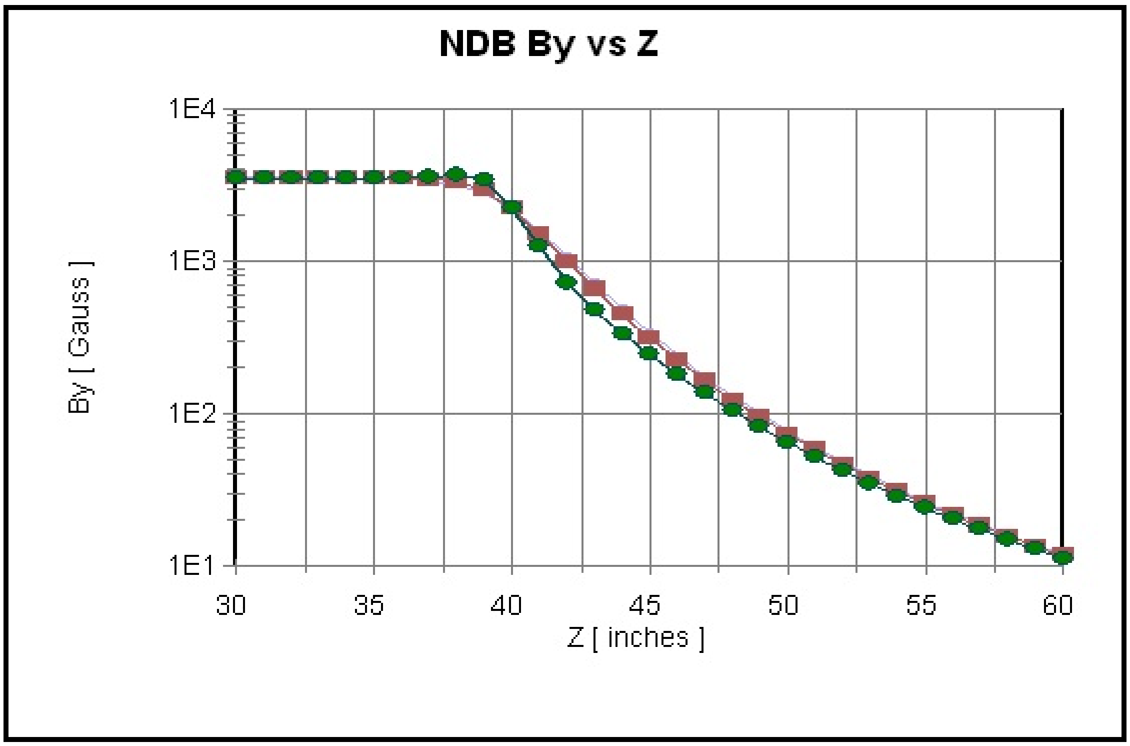

Figure 5 Semilog plot of By vs Z

Excitation

The excitation (B vs I) has also been simulated. The results are shown in Figures 6 and 7.

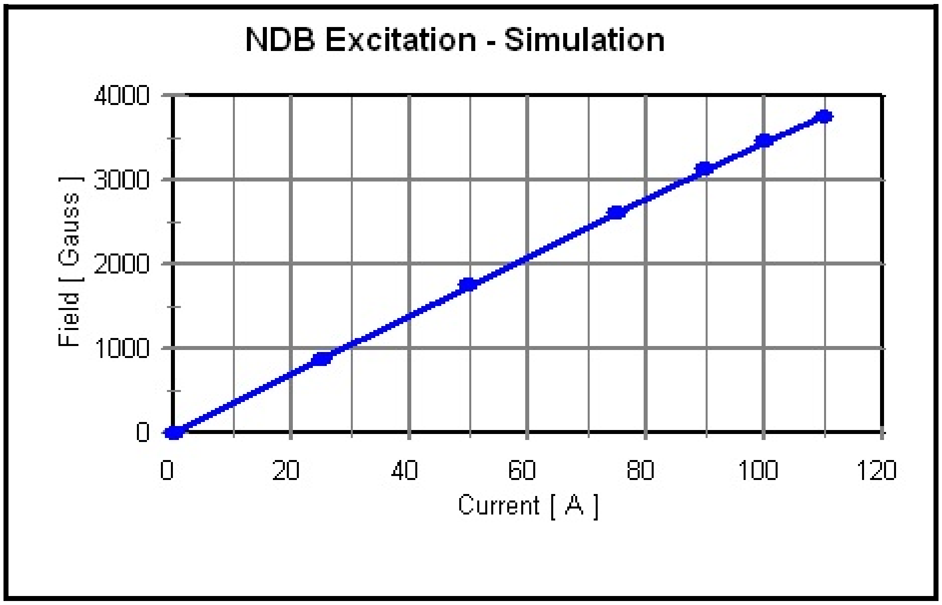

Figure 6 Simulated By vs current

A more sensitive way to look for any saturation effects is to plot the central field divided by the current as a function of current. That plot is shown in Figure 7. There is clearly a small amount of saturation.

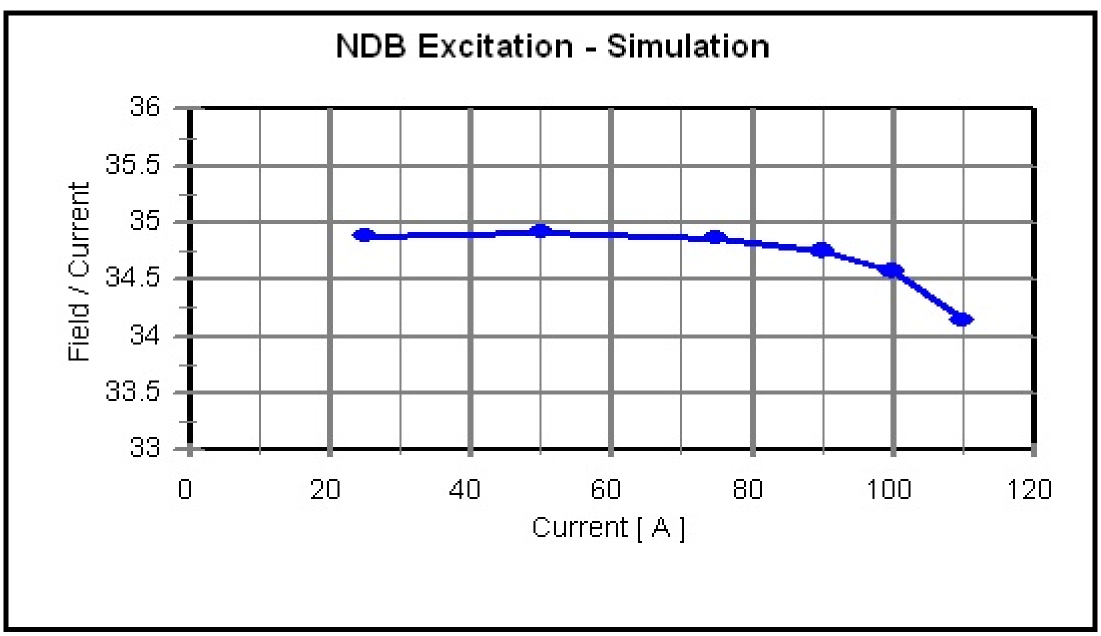

Figure 7 By / I vs I - gauss per amp as a function of the excitation

Before the magnets were mounted on their stands in the experimental area, they were set up in the power supply room and connected in series - the nominal configuration. The excitation of each of the magnets was measured. This was done as a PRELIMINARY study of the magnets. This work will be repeated when the magnets are in their final configuration. The B / I curves for the two magnets are shown below. The top curve is NDB021, the blue curve is for NDB022

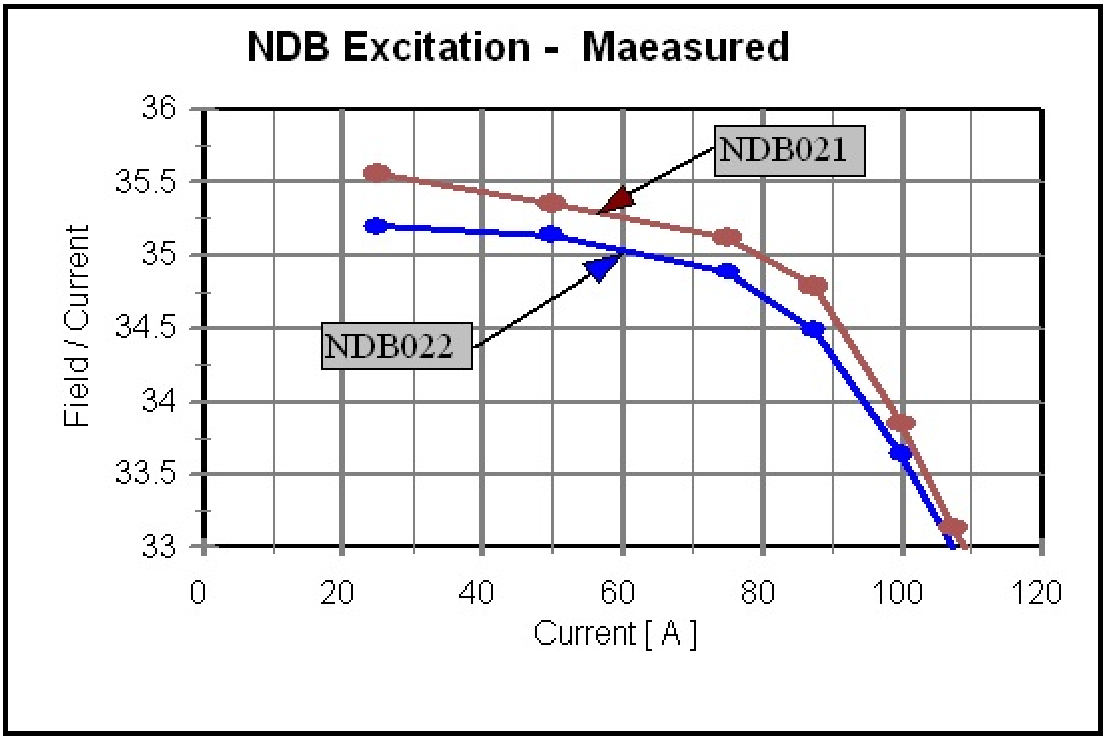

Figure 8 Measured excitation of the two NDB magnets

The vertical scales on the simulated and measured excitation plots are the same, making a direct comparison straightforward.

Clearly the excitation is not accurately reproduced, there being a discrepancy of a few percent. This is not surprising, as, as noted above, the steel is not well defined in the model. The simulation and data both yield about 35 gauss per amp, but the shapes of the excitation differ. I do not understand the small (~< 1%) difference between the excitation curves of the two magnets as measured.