Design of A Magnetic Shield for the Polarized Target

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One of important parametres of the gas polarized ^{3}He Target is an ability to hold polarization – relaxation rate. The relaxation rate of spins due to field inhomogeneities is presented ([a] [b] [c]) by:

$$\frac{1}{T_1} = D\frac{|\vec{\nabla}B_x|^2 + |\vec{\nabla}B_y|^2}{B_0^2} \qquad (1)$$

Here D, the diffusion constant for the polarized spins, is inversely proportional to the gas pressure. The mean magnetic field is assumed to lie along the z-axis and have a magnitude B_0.
For our case $D \sim 0.2\frac{cm^2}{s}$ and $B_0 \sim 20G$

In Hall A the Helmholtz coils for $^3\vec{\mathrm{H}}$e target used in the transversity experiment provide holding field with inhomogeneities

$$\left[|\vec{\nabla}B_x|^2 + |\vec{\nabla}B_z|^2\right]^{\frac{1}{2}} \sim 9\frac{\mathrm{mG}}{\mathrm{cm}}$$

A recommended value should be $\leq 10\frac{\mathrm{mG}}{\mathrm{cm}}$.

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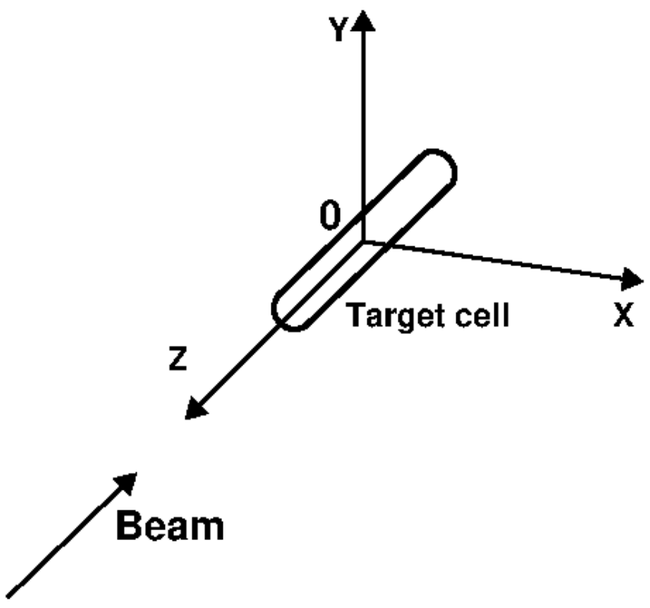
[a] R.L.Gamblin and T.R.Carver Phys.Rev. v.138,946(1965)
[b] L.D.Schearer and G.K.Walkers Phys.Rev. v.139,1398(1965)
[c] G.D.Cates, S.R.Schaefer, and W.Happer Phys.Rev. A37,2877(1988)

1 Magnetic Fields from SBS and BigBite magnets

The G_E^n experiment will be conducting with a longer ^{3}He target chamber and longer transport tubes for circulating gas through the target chamber. The length of the target chamber will be of 60 cm. The inhomogeneities of holding field within the target volume has to be minimized. The holding magnetic field in the target will be formed by two Helmholtz coils early used in the Transversity Experiment. The stray field from BigBite and SBS magnets simulated by TOSCA is shown on the next slides.

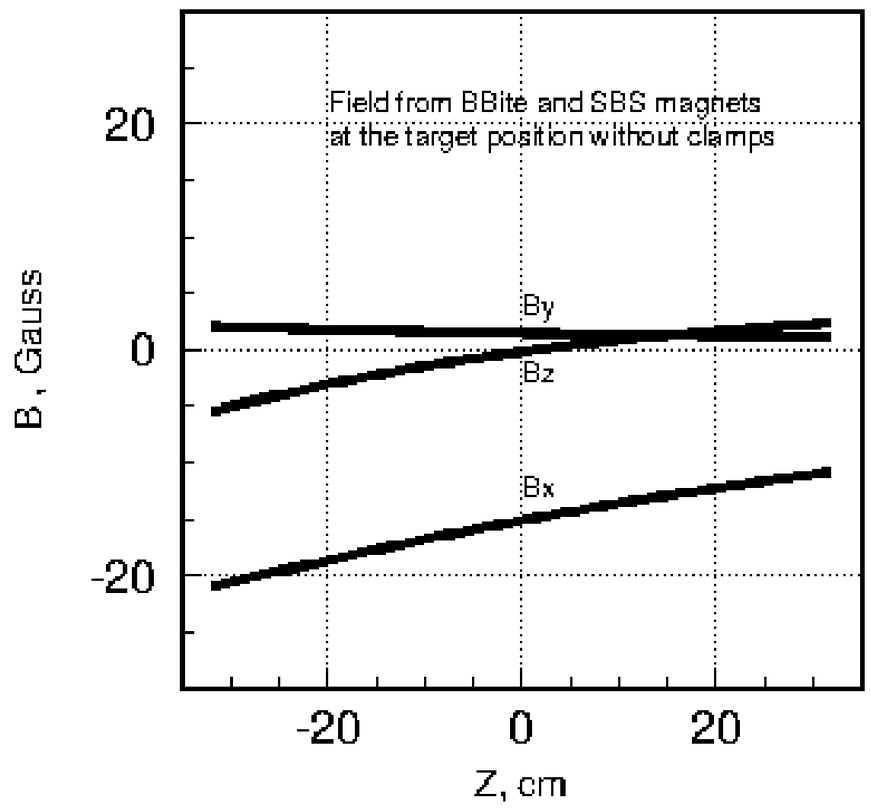
In following plots the system coordinates is shown on Fig.1:

Figure 1: Coordinate system used in calculations of magnetic fields.



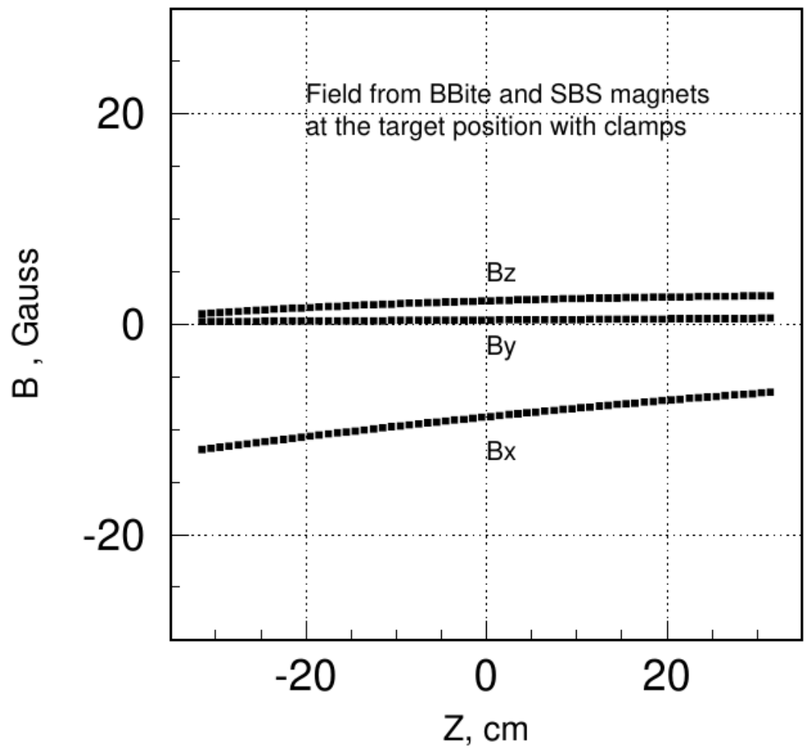
An expected stray field along beam line at the target position without any magnetic shields and clamps is shown on Fig.2:

Figure 2: Components of the B vector along the beam in place of the target cell.



With the clamps in front of BigBite and SBS magnets the stray field is reducing insufficiently.

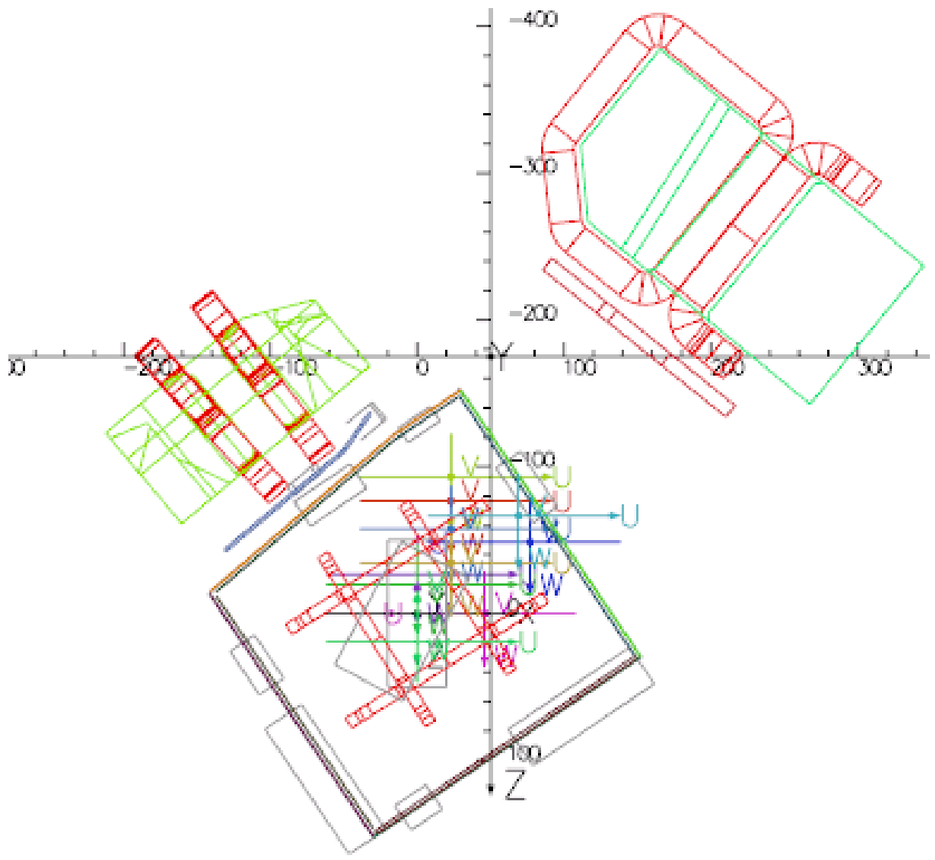
Figure 3: Components of the field vector along the beam line with the clamps in front of BigBite and SBS. Axis Z is directed upstream to the beam.



2 Design of the magnetic shield box

It is proposed to build an iron box surrounding the target and Helmholtz coils. The internal volume of the box has to reserve enough room for installing Helmholtz coils and for personnel to mount the target. The box has area $2.20 \times 2.20\ m^2$ with height of $2.50\ m$. A view from top of the magnetic shield box (MSB) together with SBS and BigBite magnet is shown on Fig.4:

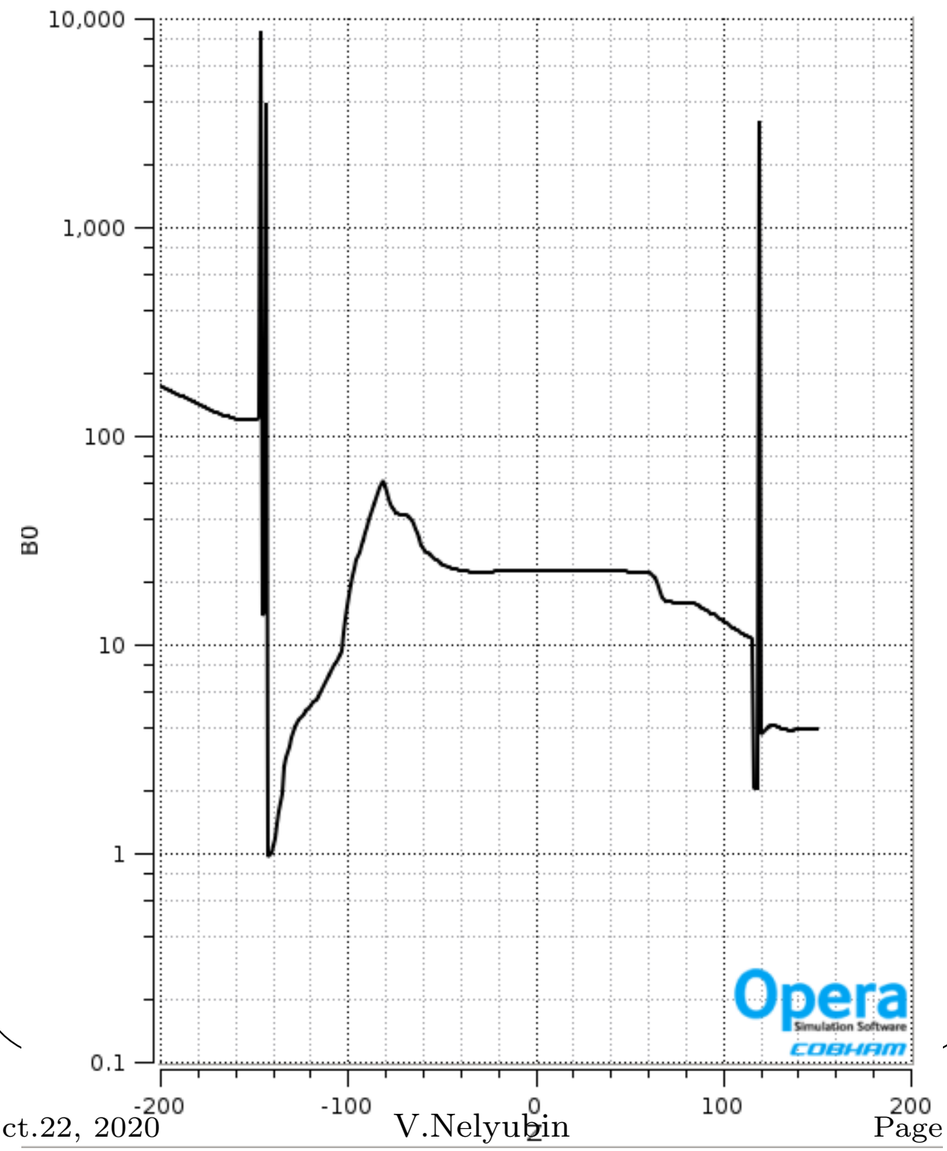
Figure 4: TOSCA model of Bigbite and SBS magnets and a magnetic shield box (MSB). Inside MSB are placed the Helmholtz coils. Doors and windows are shown by empty rectangular boxes on the walls.



3 Stray Field inside MSB

The thickness of double walls of 0.635 cm and 0.317 cm with 2.54 cm gap between are enough to avoid magnetic saturation in the iron of wall and Fig. 5 shows values of field in the box walls near beam line.

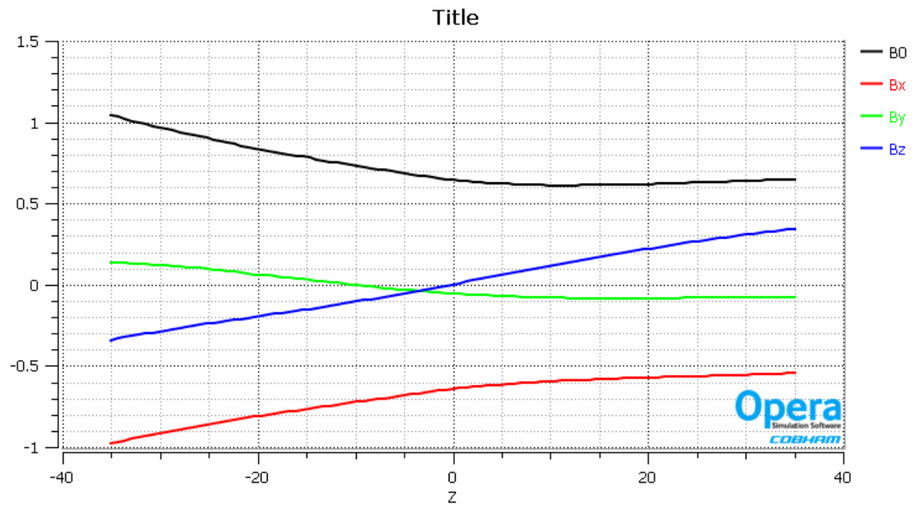
Figure 5: Plot of the B-field along a line parallel to beam on the side near to SBS. Peaks of magnetization are below saturation. Units of field are Gauss and coordinates are centimeters



We made doors from nonmagnetic material to avoid changing magnetic fields inside MSB by opening or closing doors during work with target. The important issue is the residual magnetization of iron around the target after turning on and off BigBite and SBS. These residual fields can impact on the holding field. How strong is difficult to estimate. In the experiment is suggested to measure the field after each changing external field before start data taking. Our Magnetic Field Scanner (MFS) allows do it.

A residual field at location of the cell target from SBS and BigBite magnets is shown on Fig.6. There are total B_0 with components B_x, B_y,andB_z in Gauss vs coordinate along the target (cm).

Figure 6: Stray field along the target cell.



The residual field on the line between the target and pumping cells (along direction of transport tube) is shown on Fig.7. There are total B_0 and components B_x, B_y,andB_z in Gauss vs coordinate along the target (cm).

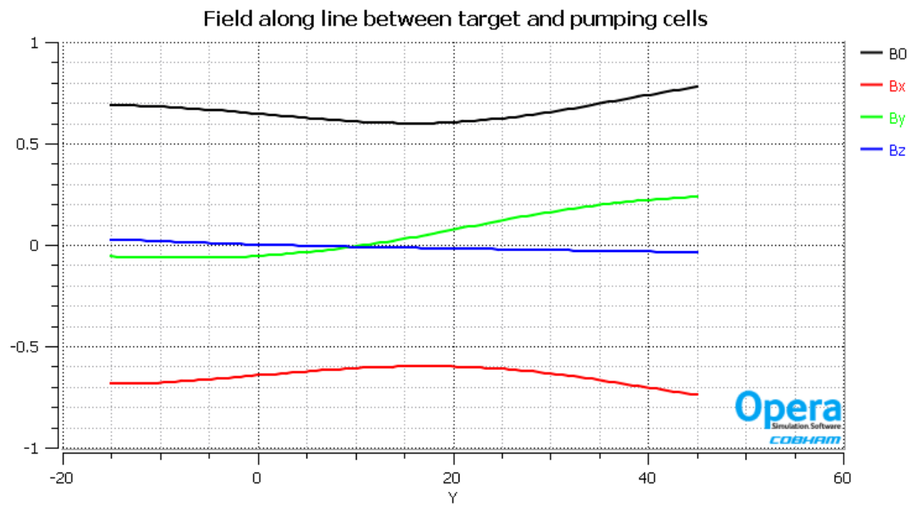
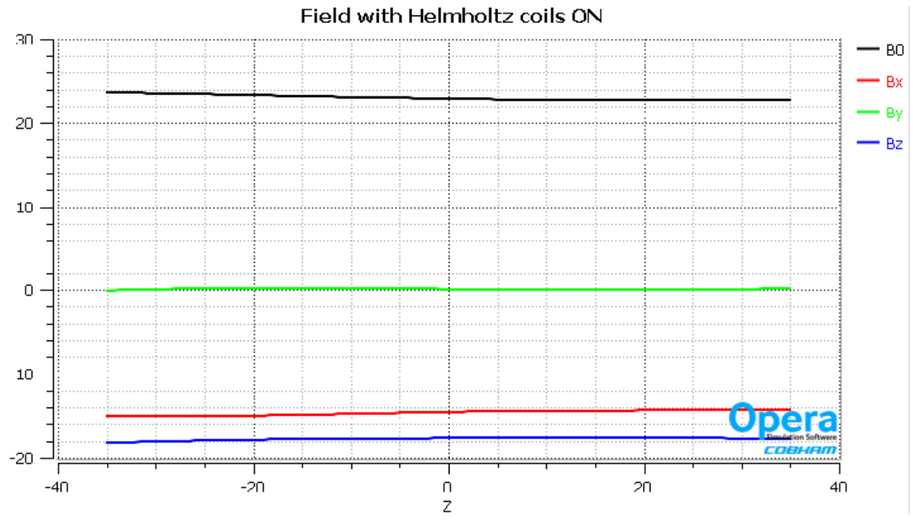


Figure 7: Stray field along line between pumping and target cell.

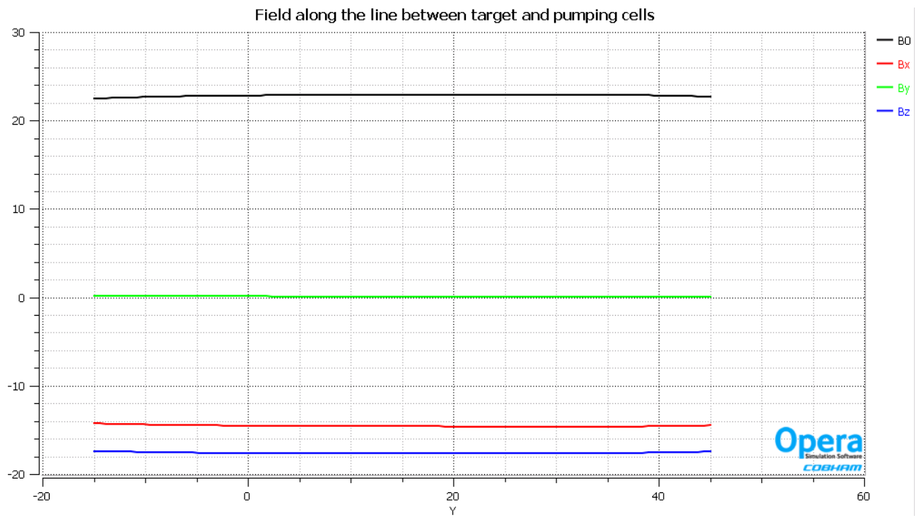
With Helmholtz coils ON the holding field in the MSB is shown on Fig.8. There are total B_0 and components B_x, B_y,andB_z in Gauss vs coordinate in the target (cm).

Figure 8: The holding field along the target cell.



The holding field along the line between the target and pumping cells is shown on Fig.9. There are total B_0 and components B_x, B_y,andB_z in Gauss vs coordinate Y along the transport tube (cm).

Figure 9: The holding field along transport tube between the pumping and target cells.



4 Maxwell Stress

The TOSCA software calculates a load of magnetic forces on the walls of the box. The Maxwell Stress has been calculated by using B and H values in planes closely to surface of the iron walls . These planes are naming Patches in TOSCA. The sistem of units was taken SI and Maxwell Stress was calculating in Pascal(Pa). Two dimensional plots of the Maxwell Stress were built for walls on the side of the BigBite and SBS magnets. Values of the stress are shown in color and for convinience we plot the curves of stress along horizontal and vertical lines going through maxima in 2d plots.

Figure 10: Map of the Maxwell Stress contours in the Patche closed to the box wall onlooking to BigBite side. There on left side is pointed out the hole for beam line. Large rectangular shows the aperture to BigBite. Units are in SI: meters and Pascales.

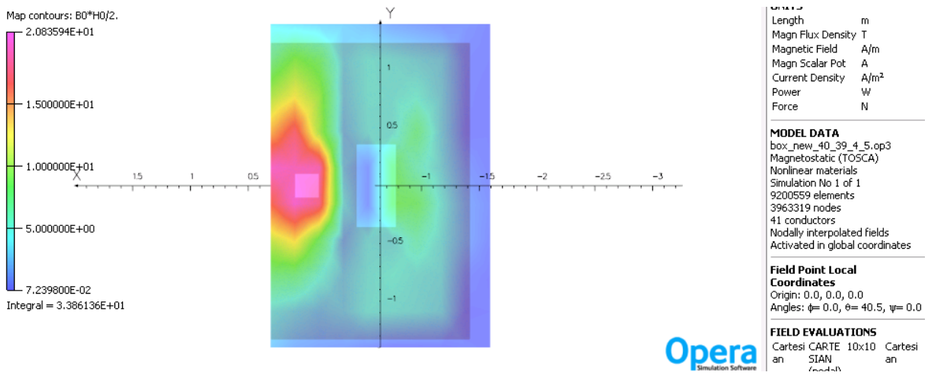


Figure 11: Plot of the Maxwell Stress along middle line closed to the box wall onlooking to BigBite side. There on right part we have maxima around the hole for beam. Units are in SI: meters and Pascales.

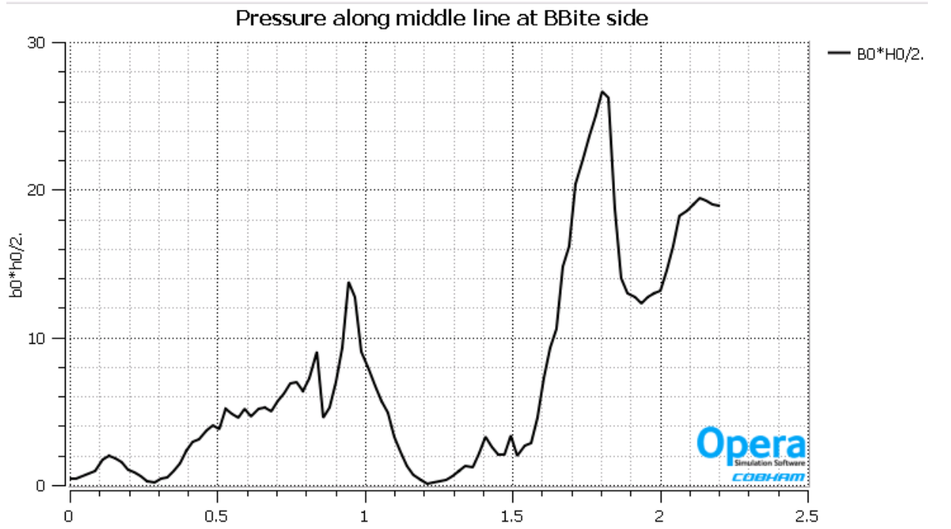


Figure 12: Map of the Maxwell Stress contours in the Patche closed to the box wall onlooking to SBS side. Large rectangular shows the aperture to SBS magnet. Units are in SI: meters and Pascales.

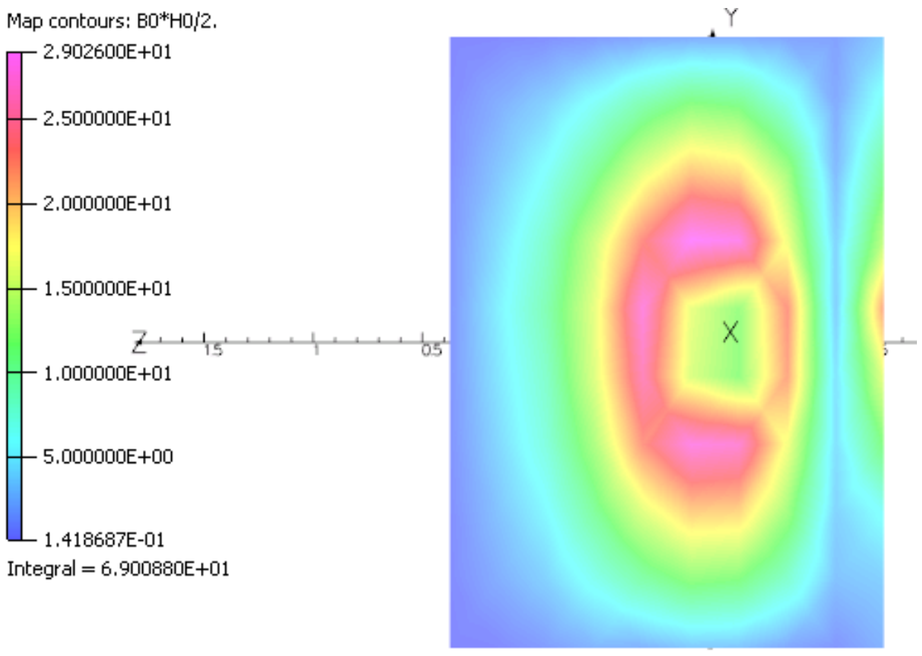


Figure 13: Plot of the Maxwell Stress along middle horizontal line located close to the box wall onlooking to SBS. Here we see maxima of stress around the aperture to SBS magnet. Units are in SI: meters and Pascales.

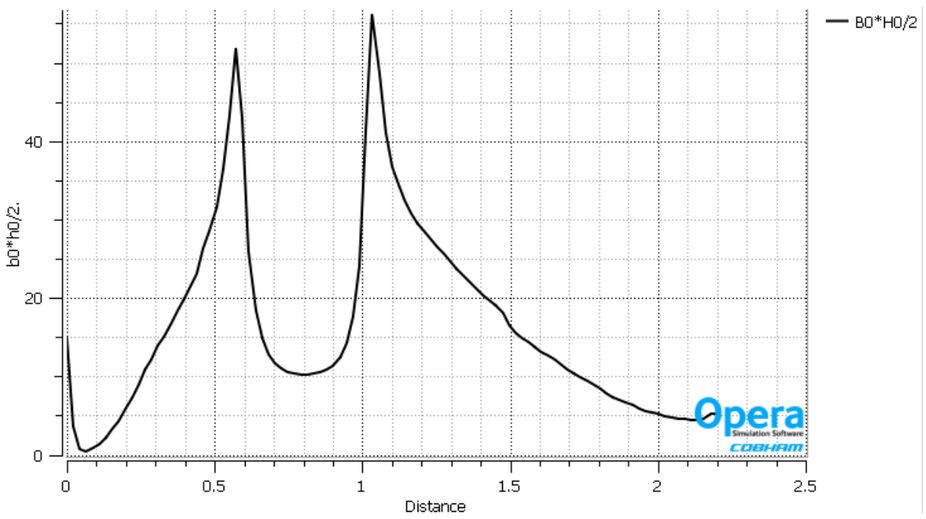
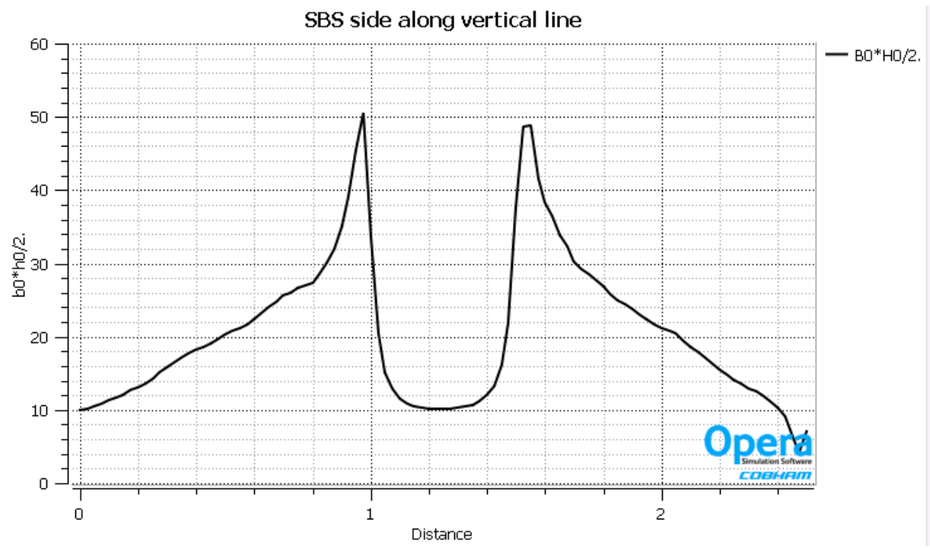


Figure 14: Plot of the Maxwell Stress along vertical line line crossing aperture to SBS magnet located close to the box wall onlooking to SBS. Here we see maxima of stress around the aperture to SBS magnet. Units are in SI: meters and Pascales.



5 Summary

Proposed design of magnetic shield for the polarized ^{3}He target for G_E^n Experiment in Hall A is adequate to technical requirements of coming experiment.