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Magnetic field simulation for the 10D37 magnet

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The magnetic field simulation for the 10D37 magnet was provided by the 3D TOSCA code [1]. The magnet dimensions were taken from the SLAC drawings. The views of the magnet model (without screens) are in Fig.1-2. The excitation lines (central field and magnetic field integral) for this magnet are in Fig.3. The required field integral 0.118 T*m can be get at Io=146 A. The effective magnet length is 106.8 cm.

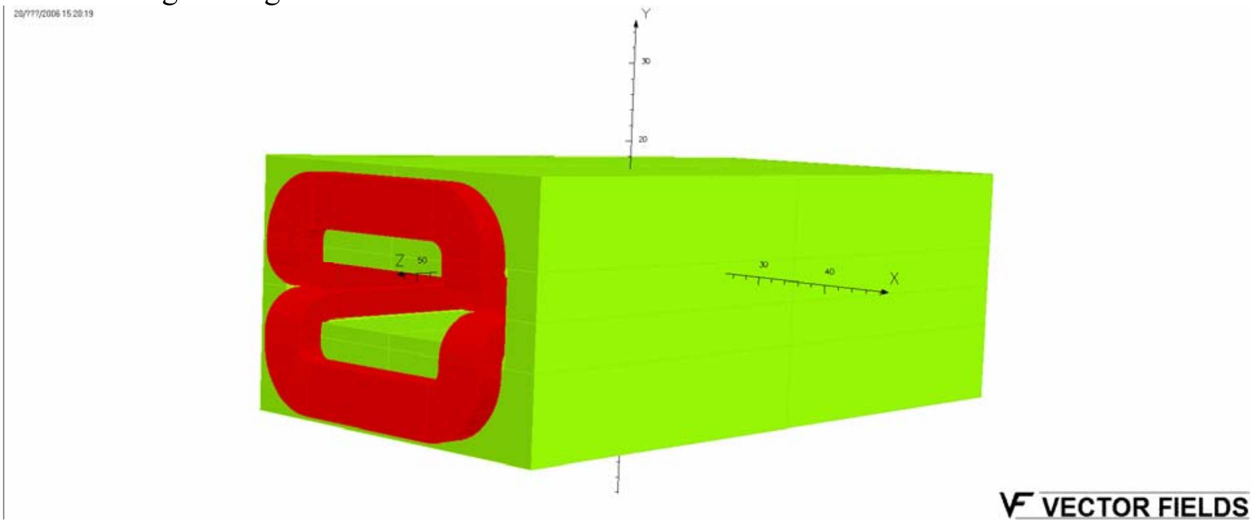

Fig.1. Overall view of the TOSCA model of the 10D37 magnet

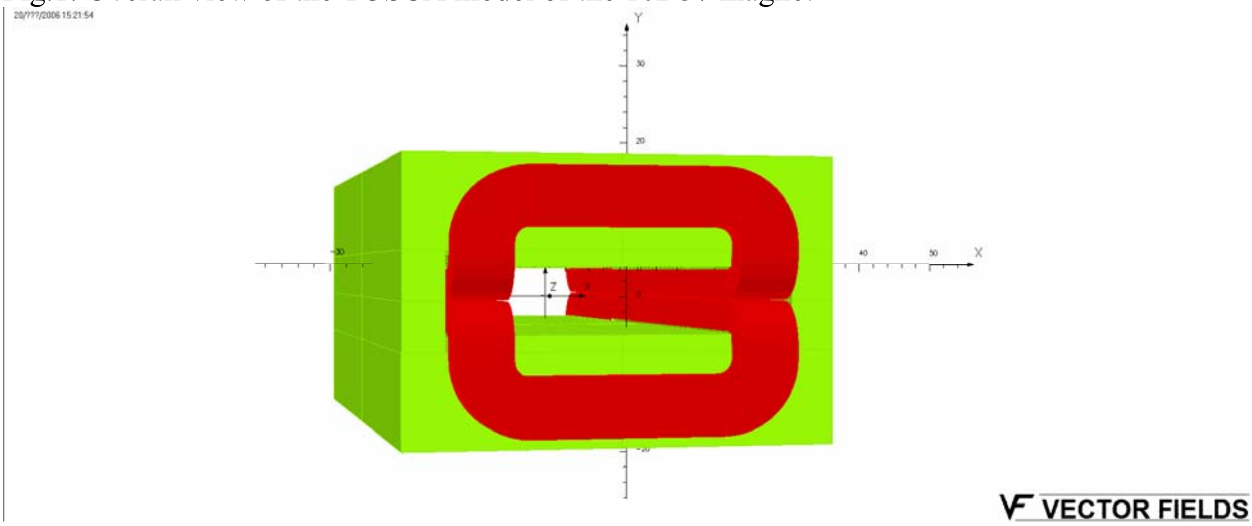

Fig.2. End view of the TOSCA model of the 10D37 magnet

For the nominal magnet excitation current the vertical yoke is very far from the saturation, the induction of the magnetic field is less 0.4 T (Fig.4) and the background field is small enough (Fig.5). Normalized magnetic field for the middle cross section is in Fig.6, magnetic field gradient is in Fig.7. Possible to see that NMR probe can be used up to 7 cm from the magnet center in transverse direction. Normalized magnetic field integral transverse distribution is presented in Fig.8.

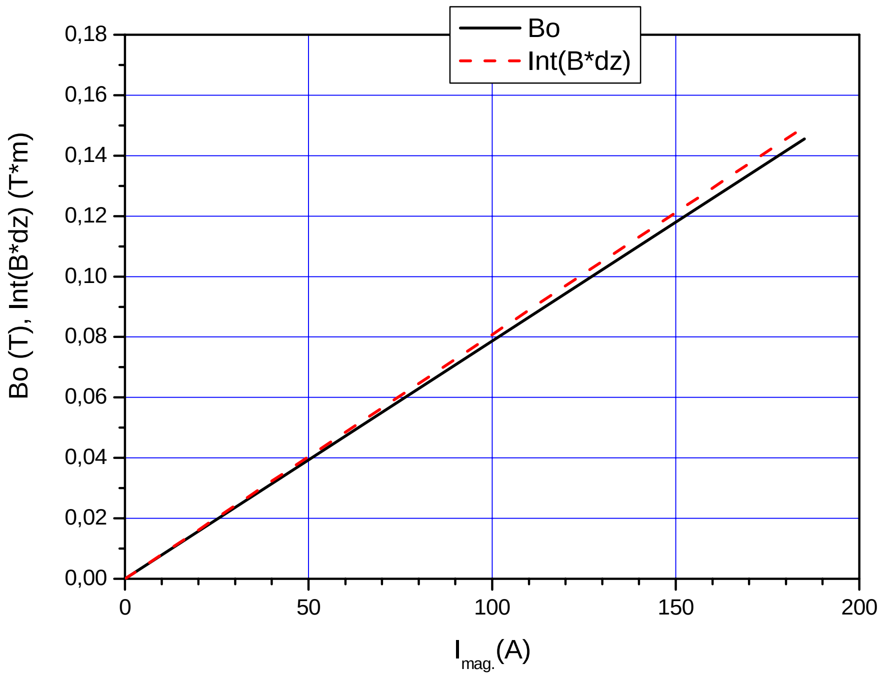

Fig.3. Excitation lines for 10D37 magnet without screens

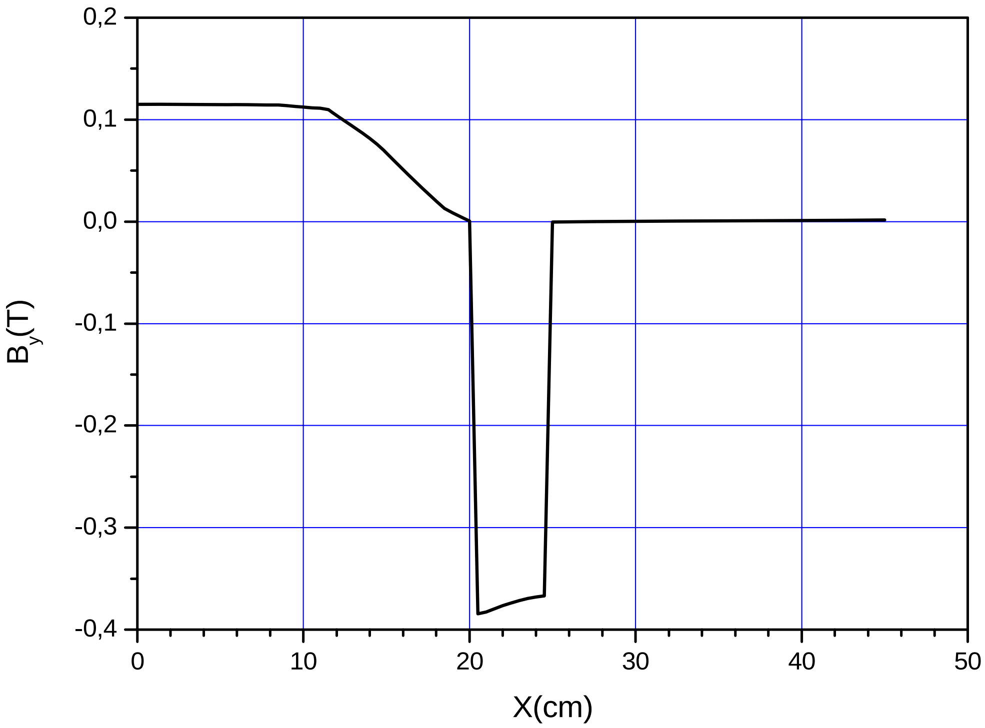

Fig.4. Magnetic field of the magnet in the middle transverse cross section

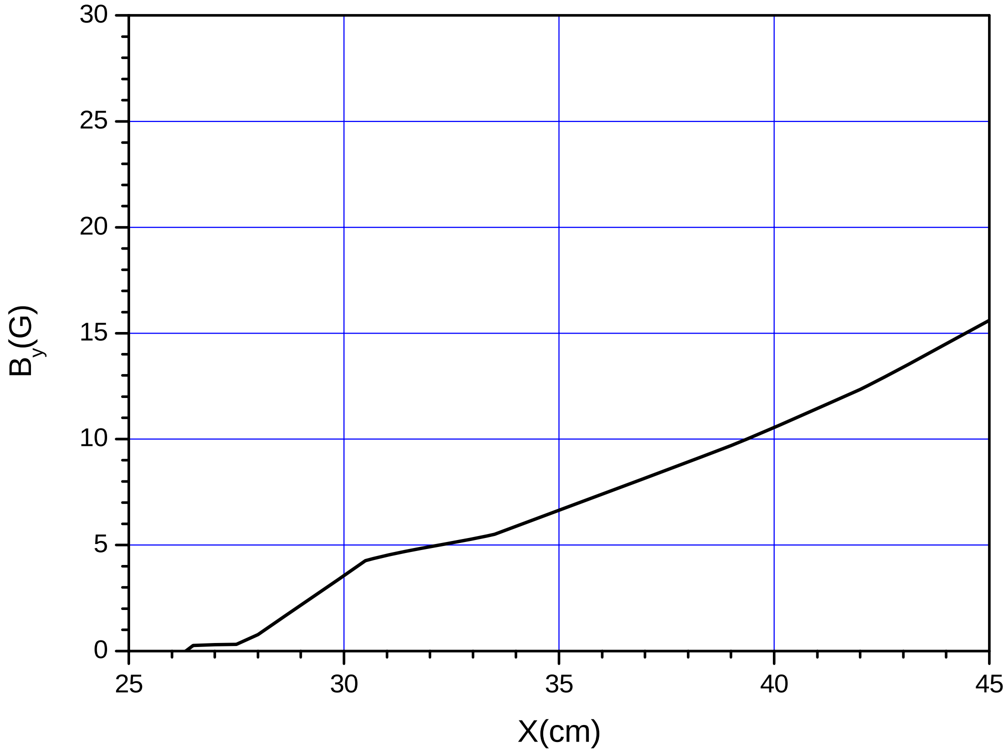

Fig.5. Background magnetic field of the magnet in the middle transverse cross section

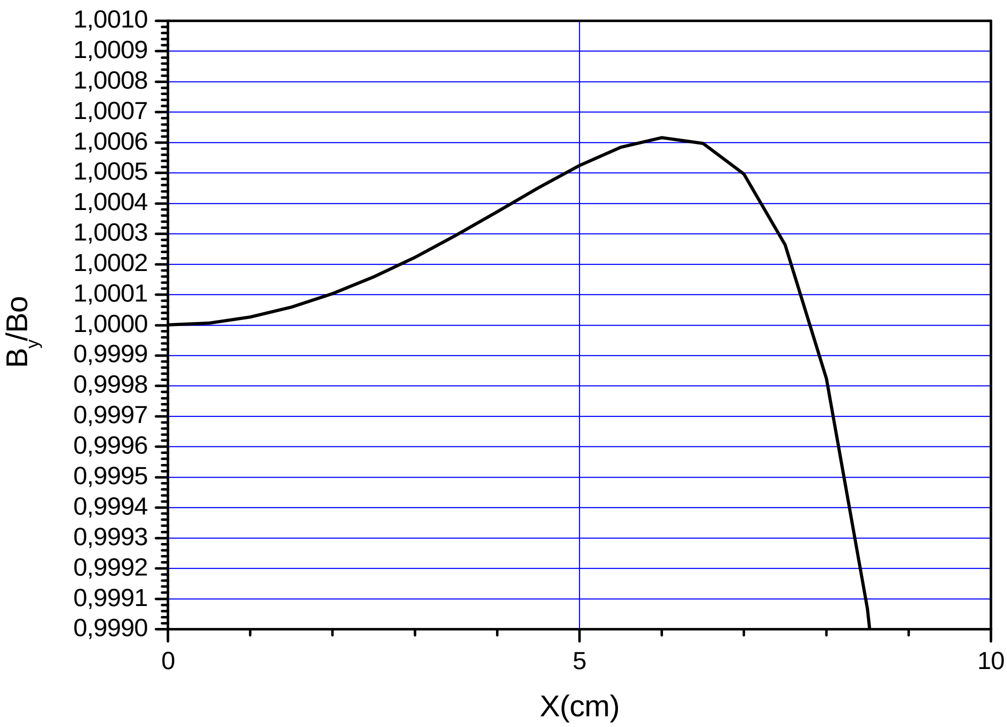

Fig.6. Normalized magnetic field in the middle cross-section of the magnet

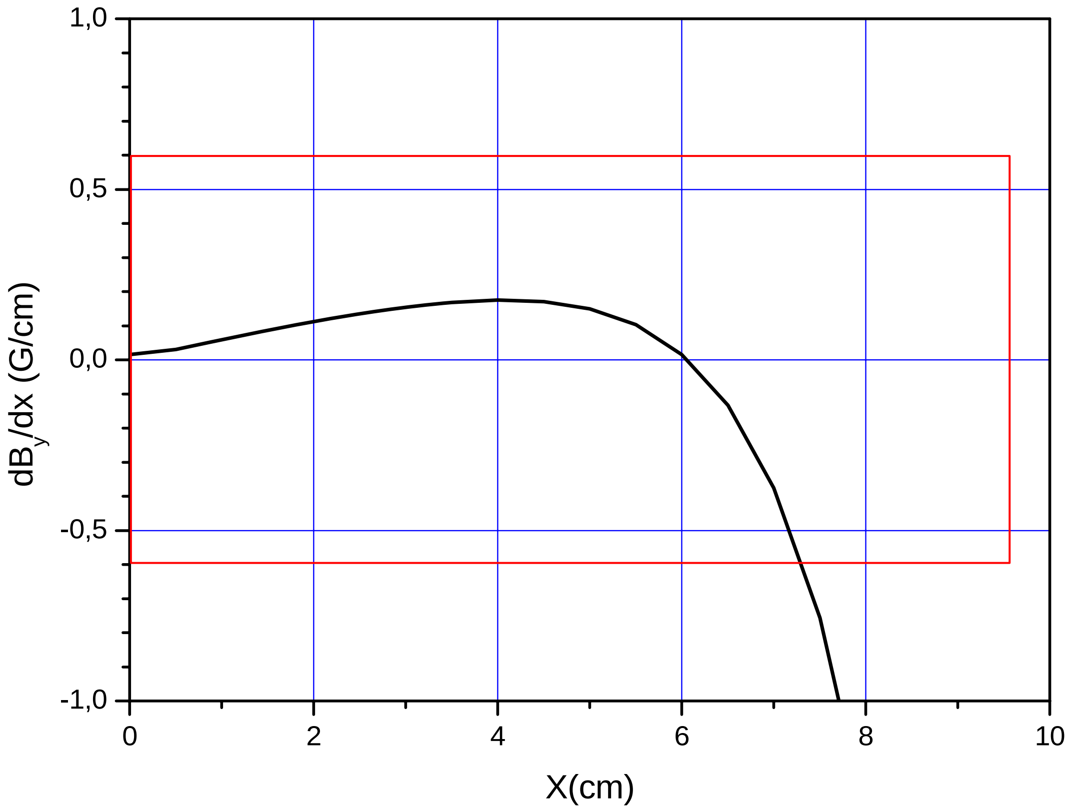

Fig.7. Magnetic field gradient in the middle cross-section of the magnet

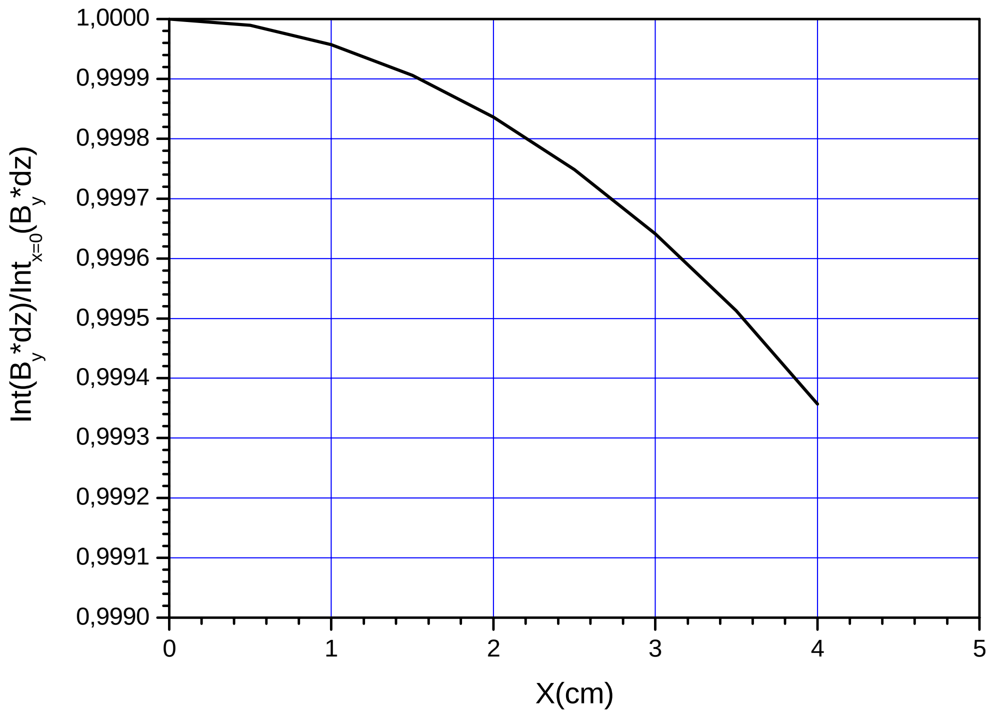

Fig.8. Normalized magnetic field longitudinal integral in the transverse direction of the magnet gap

Magnetic field distribution in the longitudinal direction is shown in Fig.9 and its gradient is in Fig.10. Possible to watch that NMR probe can be used to the distance 40 cm from the magnet center. This region will cover the 78% of the total field integral. The background magnetic field in the longitudinal direction is in Fig.11.

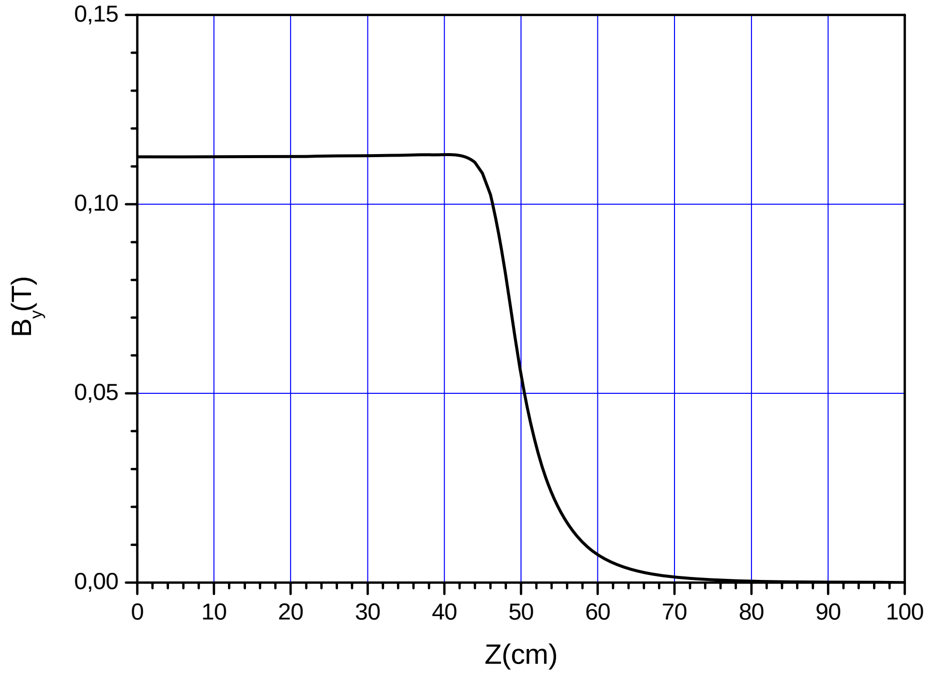

Fig.9. Magnetic field in the longitudinal direction

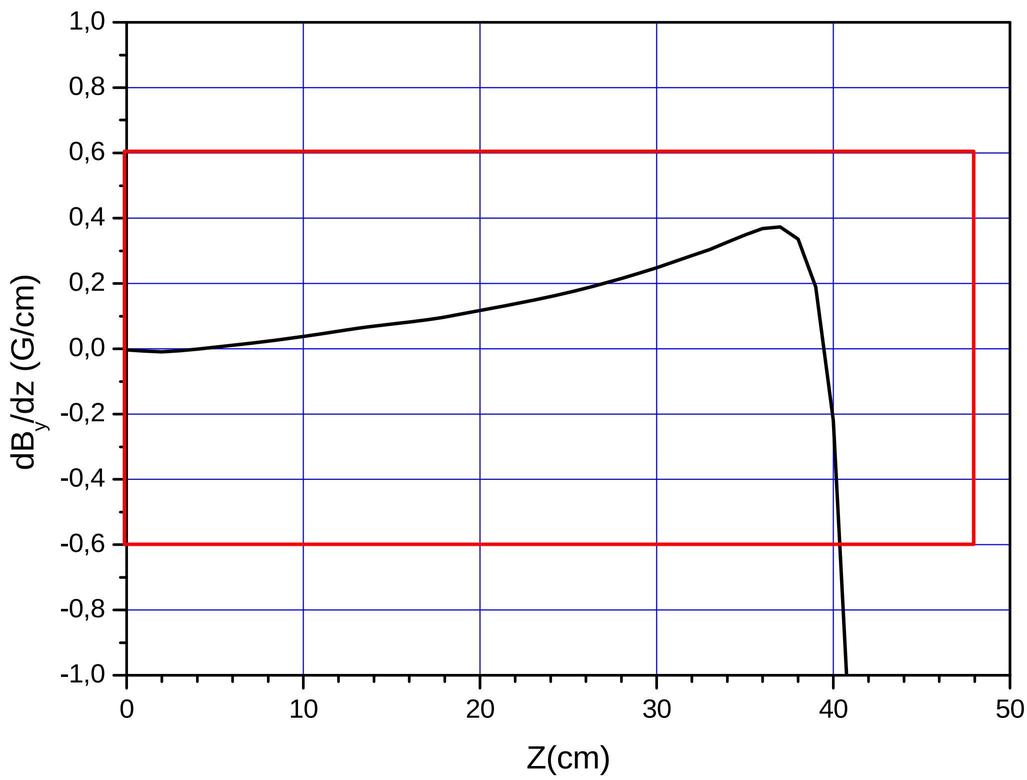

Fig.10. Magnetic field gradient in longitudinal direction

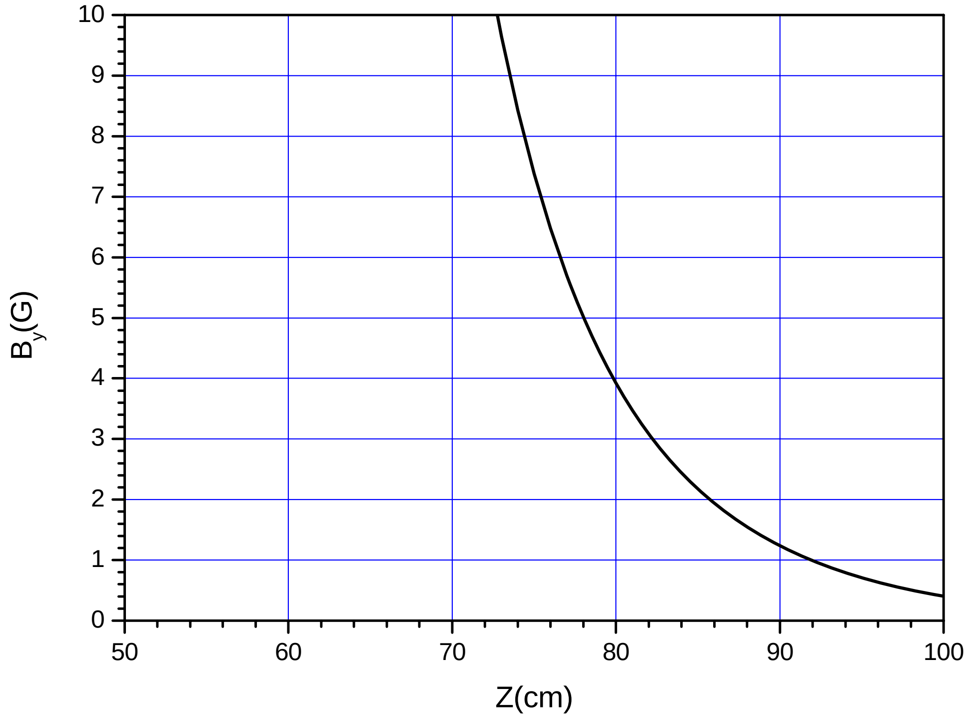

Fig.11. Background magnetic field in the longitudinal direction

The next round of simulation was dialed with magnet screen. From one magnet end the screen was installed at the distance 4.4 cm from the yoke, from the other one is at the distance 7.6 cm (model views are in Fig.12-13). The longitudinal magnetic field distribution for the magnet with screens is shown in Fig.14. The effective magnet length in this case is 98.54 cm and the center of the field integral is shifted by 0.4 cm from the magnet center.

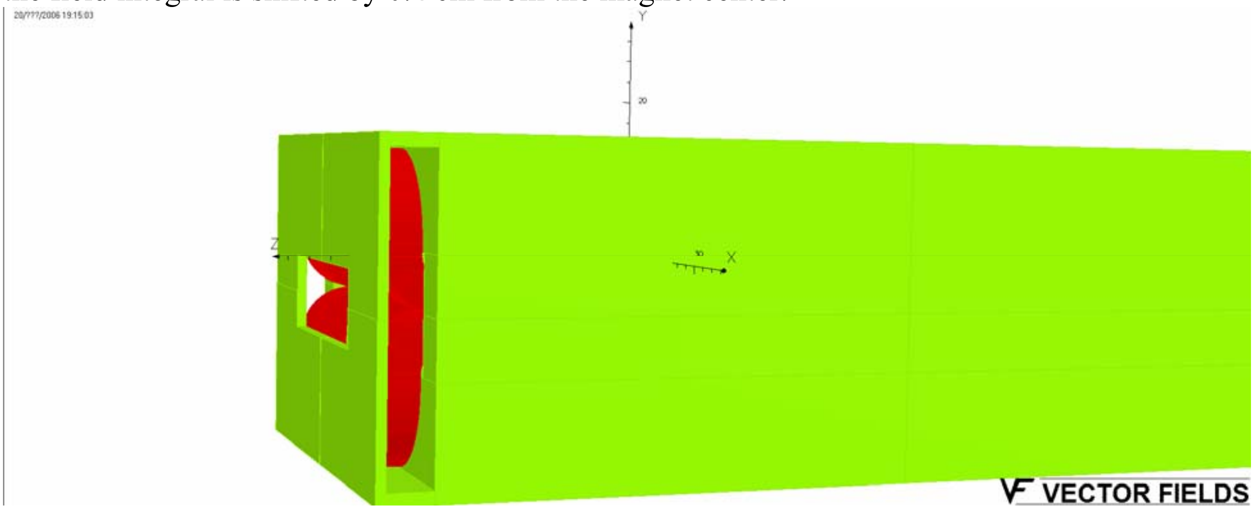

Fig.12. Magnet model with the screen at 4.4 cm

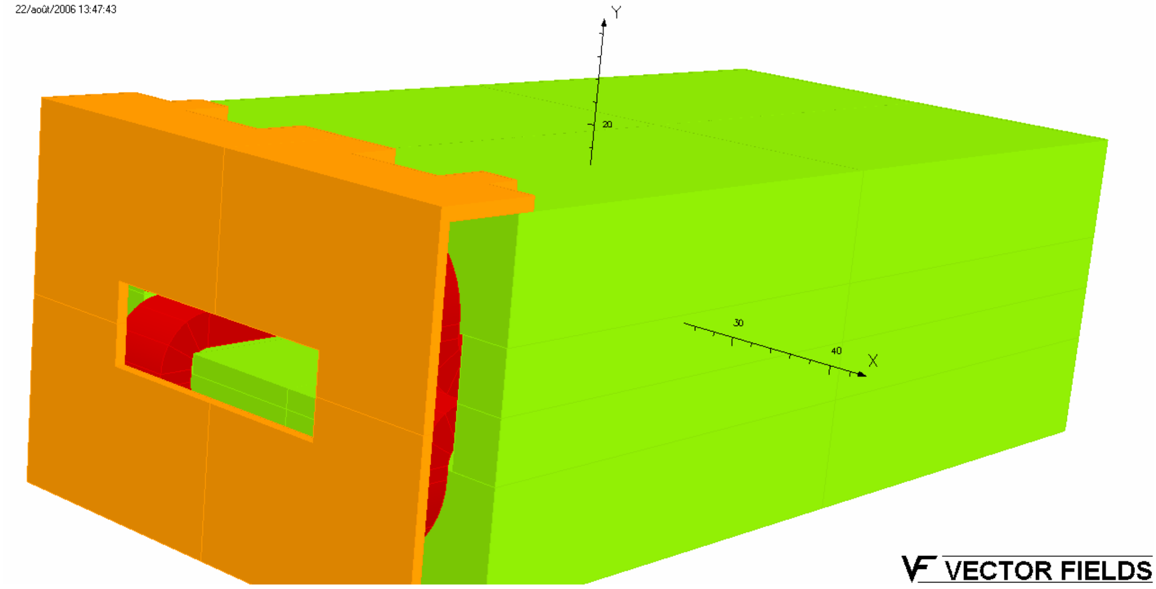

Fig.13. Magnet model with the screen at 7.6 cm

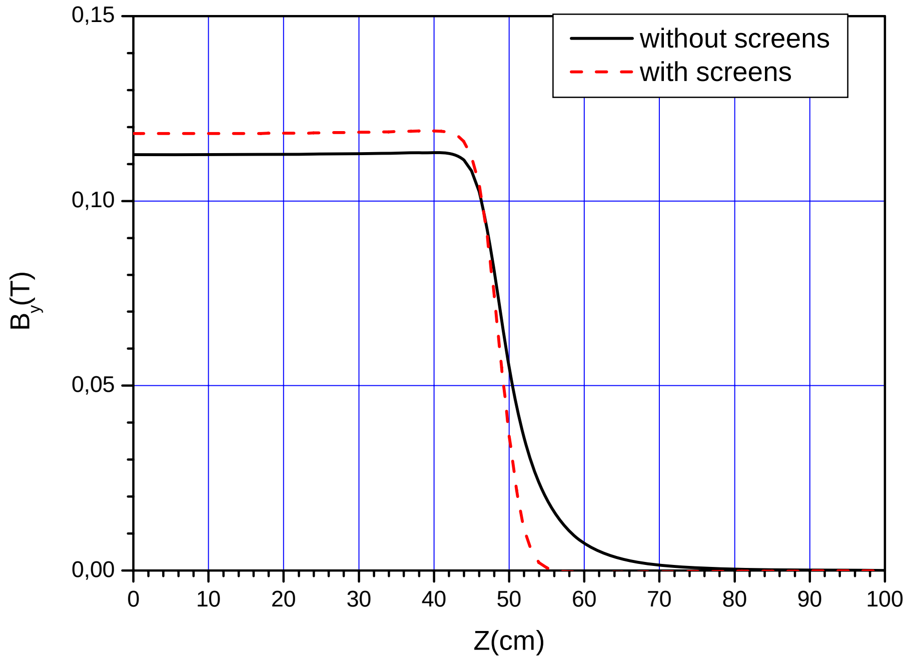

Fig.14. Magnetic field in the longitudinal direction

The background magnetic field in the longitudinal direction is presented in Fig.15. The required tolerance of the field integral measurement leads to finish measurement when the background field falls to the level of the earth field level (~ 0.3-0.5 G). In case of absent of the magnet screens it occurs at the distance 100 cm from the magnet center. In case of screens using the main field is shorter but the background field is 5-1 G and should to be measured at the distance ever more then 100 cm as at 100 cm it is still 1 G. The attempts to change this situation by variation the screen window sizes (Fig.15) has no change the situation principally. The NMR probe region (±40 cm) in case of screens is covering the 82% of the magnetic field integral but in the Hall region the magnetic field gradients are essentially increased this leads to the increase of the field measurement error. So taking into account those points possible to recommend not using the screens for the 10D37 magnet.

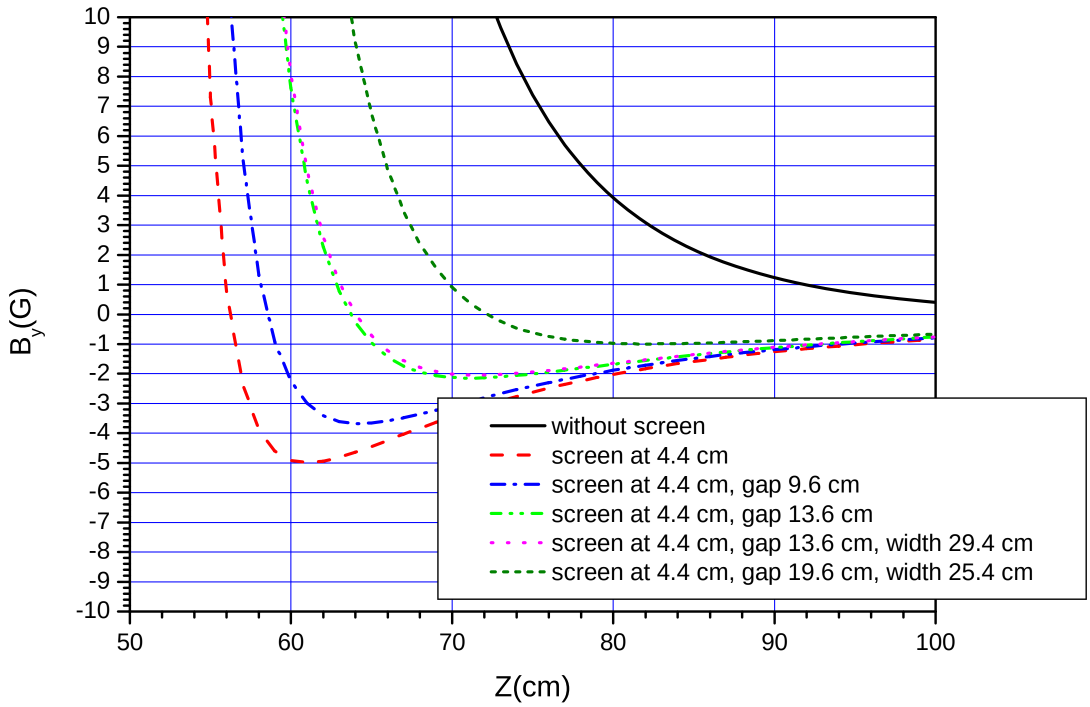

Fig.15. Background magnetic field in the longitudinal direction (different dimensions of the screen window)

The position of the holes at the magnet gives the conclusion of the poor their influence on the magnetic field. It was simulated the influence of the hole for the main magnet bolts. Because of some TOSCA difficulties for real insertion of such elements it was assumed as grooves. The model view with the grooves is shown in Fig.16. The influence of such grooves on the gap field has appeared less 0.1 G.

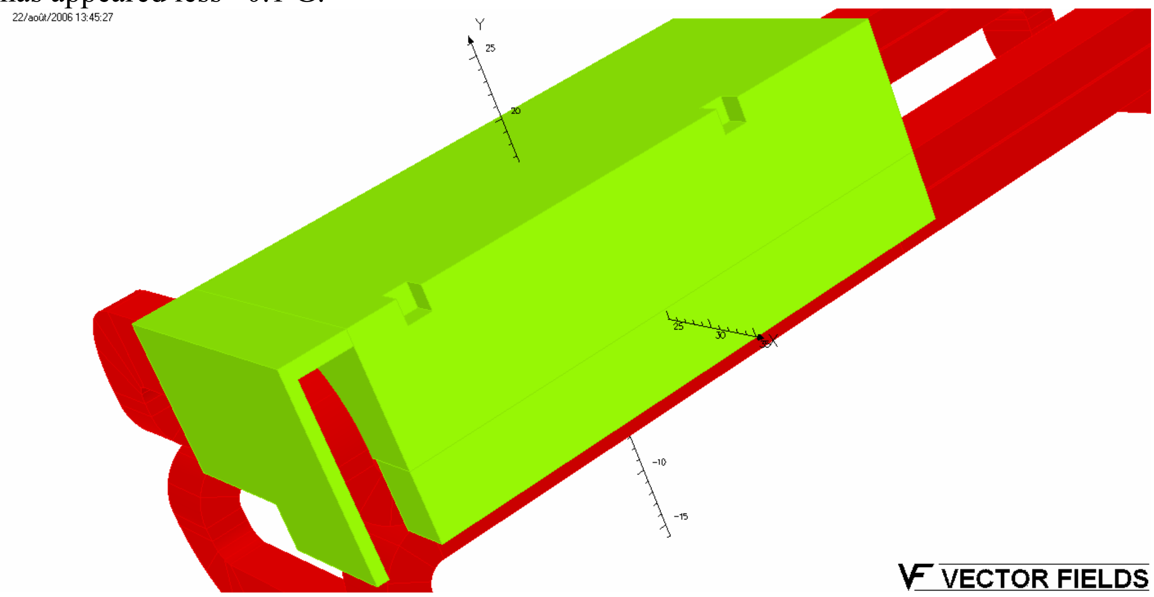

Fig.16. TOSCA model for simulation of the grooves

The last point of simulation was the getting field integral temperature factor. This point was realized into two steps:

1. The model geometry was changed due to the iron expansion temperature coefficient. The estimated factor is 2.7 10^{-5} 1/C^{o}.

2. The magnetization curve was change with the factor $\Delta\mu_{max}$=20 1/C^o. The estimated factor for the field integral is 3.4 10^{-5} 1/C^o.

The summary temperature factor for the magnetic field integral of the 10D37 magnet is 6.1 10^{-5} 1/C^o.

Conclusions

1. Some computer models for the 10D37 magnet were realized by TOSCA code.
2. The expected magnetic field integral 10^{-4} uniformity region is ±15 mm.
3. The region for possible NMR probe use is X*Z= ±7*±40 cm.
4. The screen plates are better not to use due to possible increase of the longitudinal measurement region and measurement error increase by Hall probe in the fringe magnetic field.
5. The relative contribution of the fringe field is 22% to the total field integral.
6. There will not be a problem with the thin return yoke. Maximal level of the magnetic field in it is no more 0.4 T.
7. There will not be a problems with irregularities due to bolts, holes etc.
8. The temperature factor for the magnetic field integral is 6.1 10^{-5} 1/C^o.

References

[1] OPERA 2D and 3D, Vector Fields, UK, www.vectorfields.com