Effect of Compensating Iron Ring on the Forces from the Detector Shield on the Hall-B Solenoid Magnet

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Introduction

This document is based on the calculations done for compensating the forces due to detector shields in the Hall-B solenoid magnet. All the calculations presented in this report are based on VF-Cobham software. The Hall-B solenoid magnet has detectors fitted around it. There are 3 types of detector around the magnet.

a. CTOF (Central time of flight)
b. CND (Central Neutron Detector)
c. HTCC (High Threshold Cherenkov counter)

These detectors are sensitive to magnetic field and need shielding from the magnetic field, but these shields will also have an effect on the magnetic field of the solenoid and will exert force on the coils. The CTOF shields have 3 layer of shielding material, there are total 96 (24+24+48) CTOF shields. The CND detector shield is around the upstream CTOF shields and there are total 144 CND shields. Fig. 1 shows the solenoid coils and actual shields. As shown in Fig.1 that the HTCC detectors shields are beyond the shield coil and in much lower fields, forces from these shields on the coils are much less compare to CTOF and CND shield, therefore HTCC shields are not included in further studies.

The CTOF shields exert a net force of about 5kN on the coils. Fig.2 shows the CTOF shield detail. This shield has 3 layers of material. Fig. 3 shows the CTOF shield fitted around the solenoid coils. The magnet vendor (ETI) was given the detail of CTOF shields only and has designed the z-restraints for 5 kN force [1]. The CND shields exert a net force of about 400 N. Fig. 4 shows the CND shields fitted around the coils. The other components are the Hall structure and tubes in MVT and SVT area. The forces on the coils due to the Hall structure depends on the magnet position [2], in the operational position coil forces are about 500 N. Most of the material in MVT and SVT area will be non-magnetic.

This report doesn't take any installation asymmetry into consideration. Though the individual CTOF shielding will be installed within 5 mm of the nominal location, but this is a random error per shield and the whole assembly will average out to be in the nominal position. Therefore, installation asymmetries are not studied for these shields.

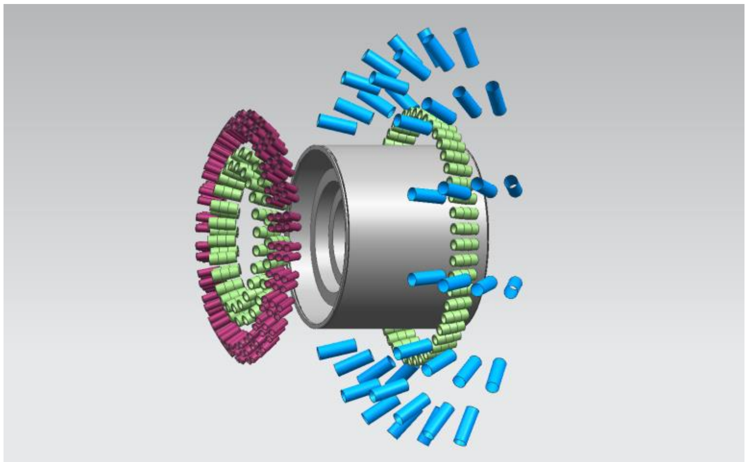

Fig.1: Solenoid coil with CTOF, CND, and HTCC shields

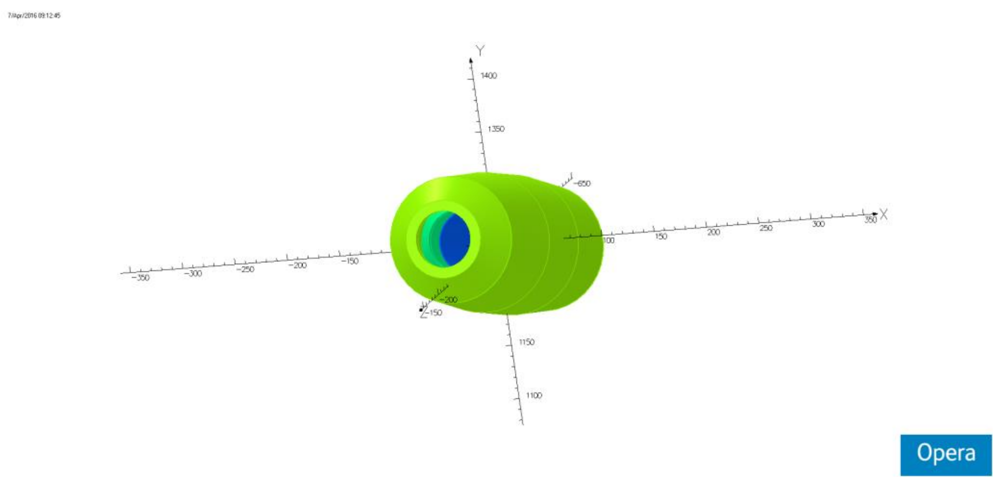

Fig. 2: Details of CTOF shield (3 layers)

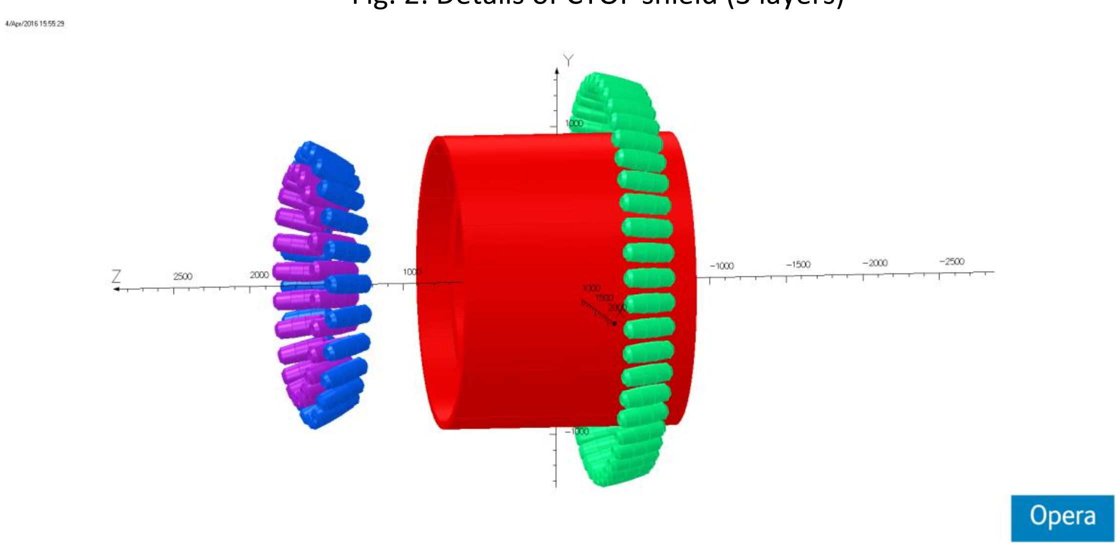

Fig.3: Position of the CTOF detector around the solenoid magnet

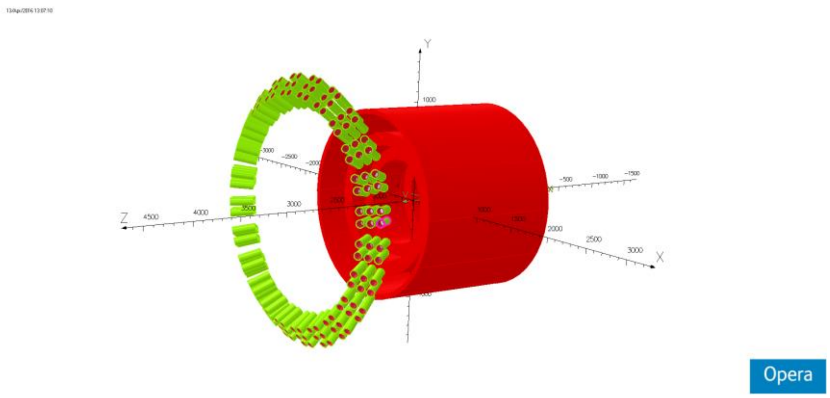

Fig.4: Position of the CND detector around the solenoid magnet

In order to calculate the coil forces from the CTOF shield, all three layers of CTOF shields with their respective BH curves are modeled in VF-Cobham software and forces on the coils are calculated. The forces in the Z-direction from the CTOF shield ate approximately 5 kN (4884 N). The CND shields are modeled independently and the forces in the Z-direction from the CND shield are around 400 N (414 N). To counteract the 5 kN force from the detector shielding, an iron compensating ring is proposed. This ring is mounted on the downstream end of the vacuum vessel. The outer diameter of the ring is 78.2 inch and thickness of the ring is 0.75 in. Three different sizes of the rings are modeled with varying height as 125 mm, 136 mm and 147 mm. Fig. 5 shows the position of the compensating ring and Fig. 6 shows the solenoid coils, CTOF shield and compensating ring as modeled. Table 2 shows the coil forces with different height compensating ring. The default BH curve is used to model the iron ring represents good quality magnet steel. Table 3 shows the coil forces, central field and field homogeneity with and without (136 mm height) ring.

Ring Height (mm)	Axial Force on the coils (N)
125	1314
136	1239
147	1308

Table 2: Effect of ring height on the coil forces

Details of the model	Coil Only	Coil + CTOF shield	Coil + CND shield	Coil+ Compensating ring	Coil + CTOF shield+ Compensating ring
Central field (T)	5.0003	5.0014	5.0005	5.0002	5.0013
Field homogeneity in 25 mm x 40 mm (ppm)	108	115	109	108	113
Axial Forces on the coil (N)	0	4884	414	-3527	1239

Table 3: Coil forces, central field and field homogeneity with and without (136 mm height) ring

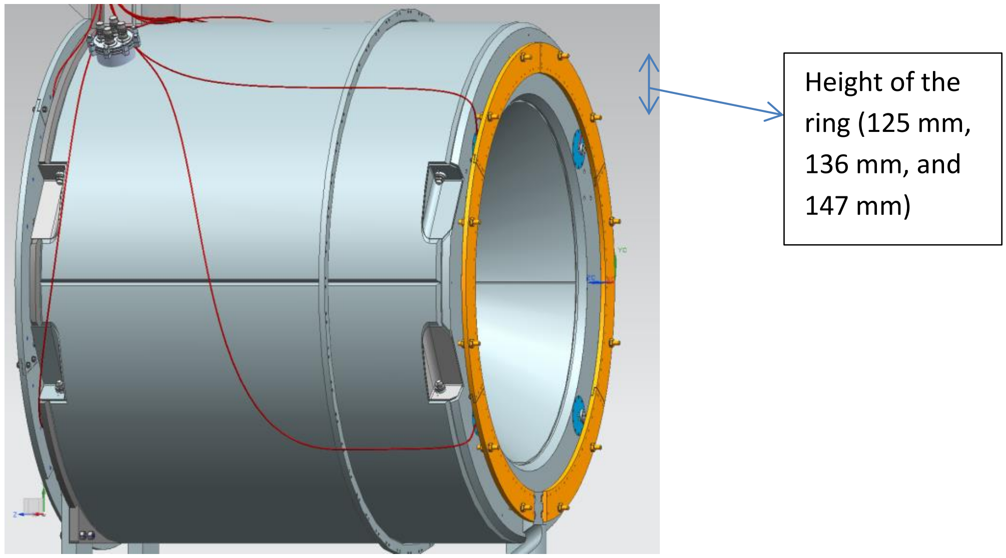

Fig. 5: Position of the compensation ring

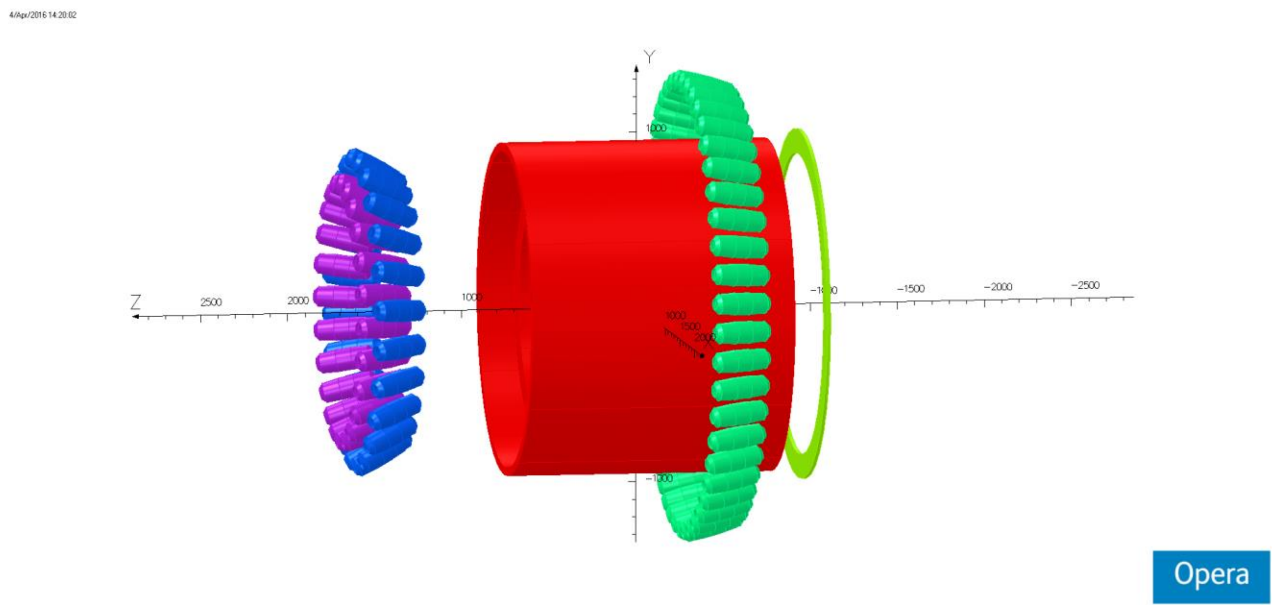

Fig. 6: Solenoid coils with CTOF detector shields and compensating ring

It is clear from the Table 2 that there is a slight effect of changing the ring height on the coil forces. The ring with height 136 mm compensates the maximum forces and results in lowest forces on the coils. It can be concluded from table 3 that the compensating ring significantly reduces the coil forces due to CTOF shield. The magnet vendor (ETI) has designed the z-restraints for 5 kN force. These Z-restraints will have no margin considering all the forces without this compensating ring. The compensating ring reduces the coil force drastically; with this compensating ring z-restraints will have enough margins.

Conclusion

In this technical note effect of compensating ring on the Hall B solenoid to compensate the forces on the coils from the detector shields has been studied. The effect on the magnetic field, field homogeneity, and forces is calculated. Following conclusions can be drawn based on the above study:

- Field homogeneity gets slightly worse with detector shields and improves a little bit with compensating ring.
- The net force on the magnet due to CTOF, and CND detector shield is approximately 5.3 kN (4884+414 N).
- There is some iron in the Hall-B structure and the force on the solenoid due to that structure is around 500 N in the operational position.
- There are some other SS tubes inside the bore of the magnet; they will be made with non-magnetic SS.
- The compensating ring brings the force down by about 3.5 kN from approximately 4.8 kN (with CTOF shield only) to 1.2 kN (with CTOF shield and compensating ring).
- The net force on the coils will be approximately 2.2 kN (including CTOF shield, CND shield, Hall structure and compensating rings). The axial supports are designed for 5 kN.
- Among the 3 ring heights studied here, the ring with 136 mm height is most effective.

References:

[1]. Pre-FDR Section 03 - Magnetic Analysis-JLab_CLAS12_magnetic_modelling_1 August 2013, Fred Goldie, ETI

[2]. Effect of Hall B iron Structure on the Solenoid magnet_Rev 1, Renuka Rajput-Ghoshal, August 6th 2013; Revision-1 Report Number: CLAS12-JLS_0008