3D FEA Computation of the CLIC Machine Detector Interface Magnets

IPAC'12
International Particle Accelerator Conference 2012

Antonio Bartalesi, Michele Modena
antonio.bartalesi@cern.ch, michele.modena@cern.ch

QD0 in the MDI environment

Using the anti-solenoid design defined by the previous 2D simulations, the innermost area of QD0 could not be able to develop the required gradient. The 3D model permitted to improve the anti-solenoid design previously established, by adjusting its coils current and placements in order to balance the higher field attracted by the QD0 in the yoke end-cap region.

This adjustment consisted in an iterative process in which new coil dimensions and currents of the anti-solenoid were proposed, simulated and then evaluated by comparing the performance of QD0 in the different cases. During such procedure it was noticed that without making any change in the overall layout, the innermost area of QD0 could be unable to develop the required gradient. Figure 7 shows the axial field (up to 3 T) attracted by the QD0 in case of an anti-solenoid layout compatible with the CLIC baseline. Figure 8 shows the gradient developed by QD0 along four lines parallel to the beam axis, placed at a distance of 1 mm from it either in the $\pm x$ or the $\pm y$ directions. Such results are not compatible with the correct functioning of the magnet, so a solution is being proposed.

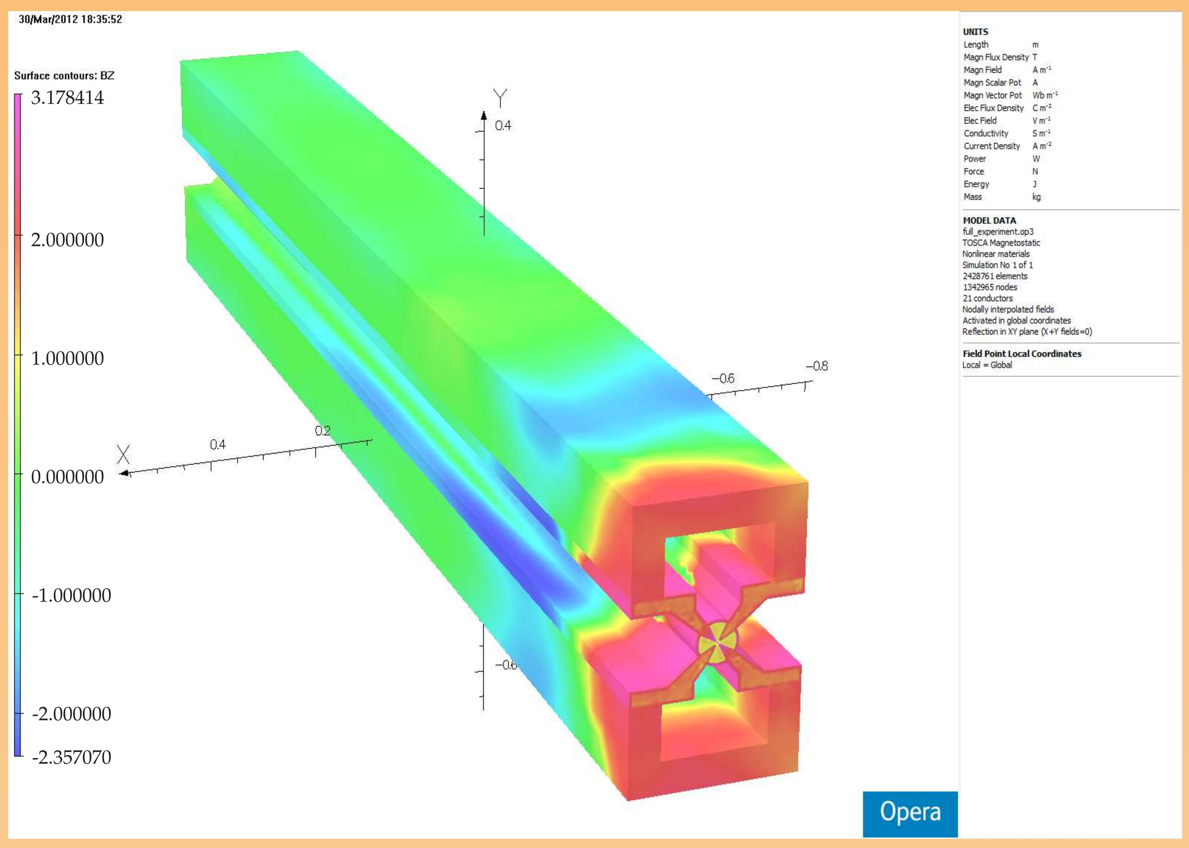

Figure 7: axial field B_z [T] attracted by QD0

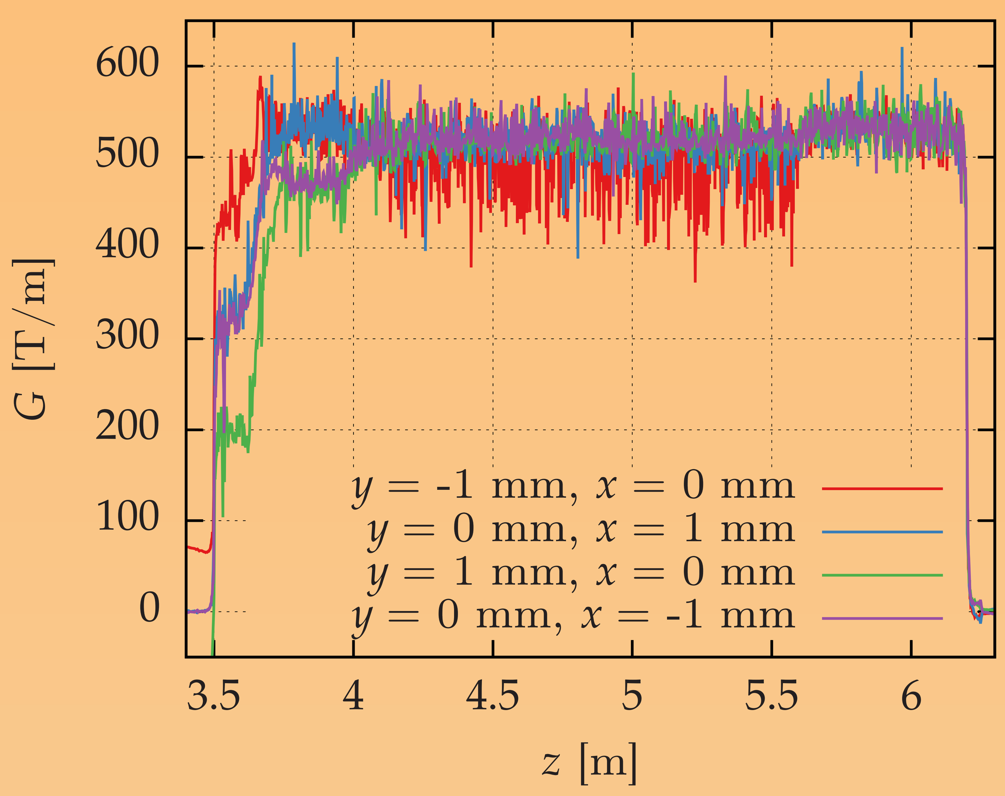

Figure 8: Gradient developed by QD0

A better QD0 performance was achieved by moving the anti-solenoid towards the IP and adjusting its coil shapes and currents [3]. Figure 9 shows the field attracted by QD0 in this solution, while the gradient it developed across its length is plotted in figure 10. A slight decrease of the gradient in the innermost region of the magnet is still visible, but the integrated gradient differed by less than 5% from the requirements, which is acceptable given the R&D status of the detector study.

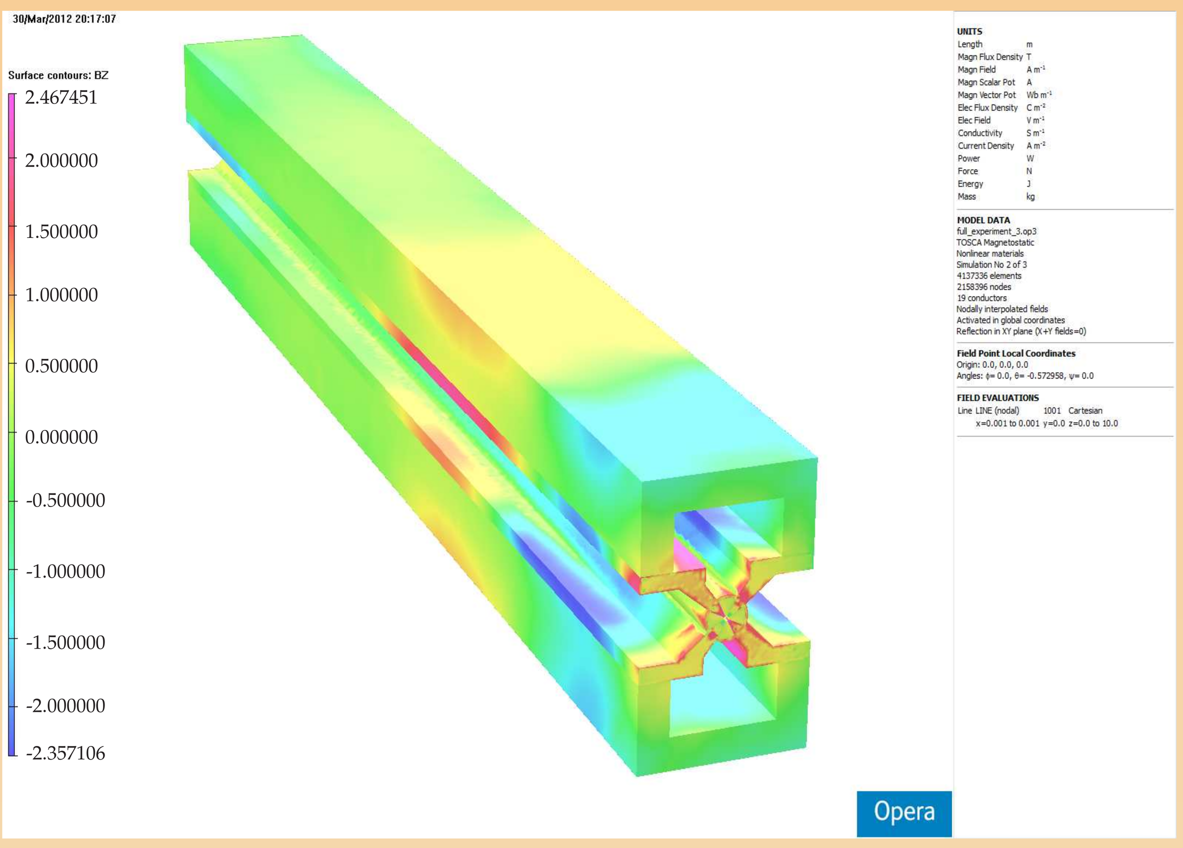

Figure 9: B_z [T] attracted by QD0, with the new anti-solenoid from the 3D model

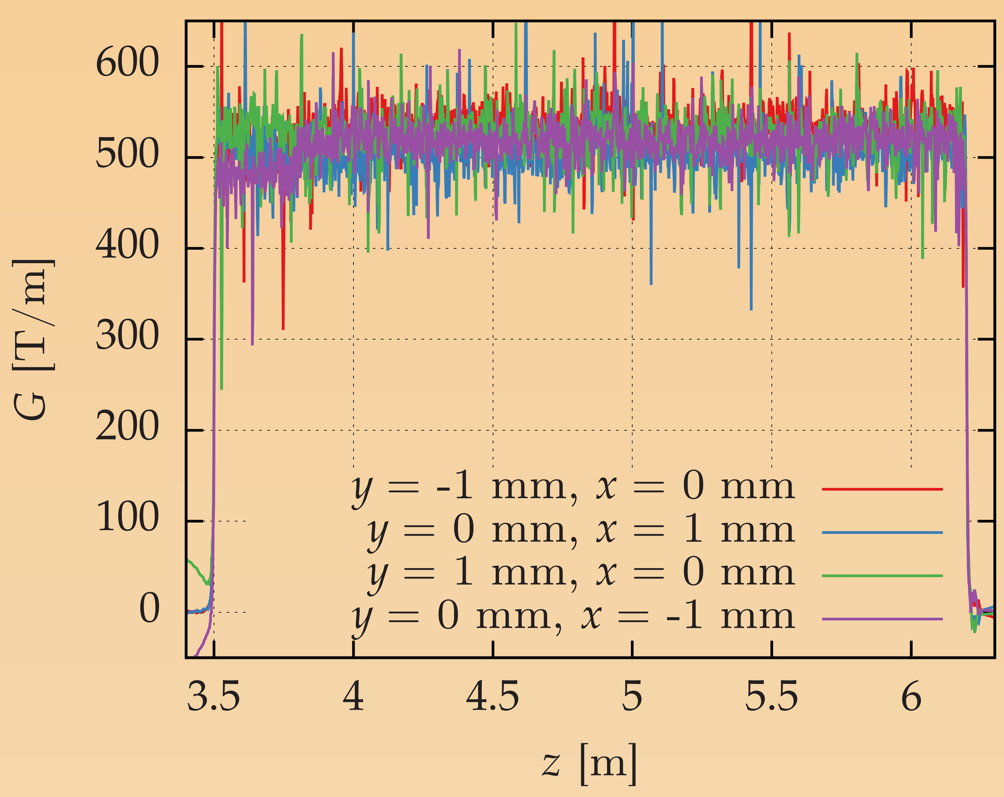

Figure 10: QD0 gradient, with the new anti-solenoid from the 3D model

Finally, to demonstrate the efficiency of the anti-solenoid solution, a last configuration was investigated, not intended to be compliant with the CLIC beam delivery system baseline, as it is based on an L^* increased by 0.3 m (from 3.5 m to 3.8 m). The QD0 gradient obtained is plotted in figure 12, and its integral differs by less than 1% to the specifications, which is less than the accuracy of the model itself.

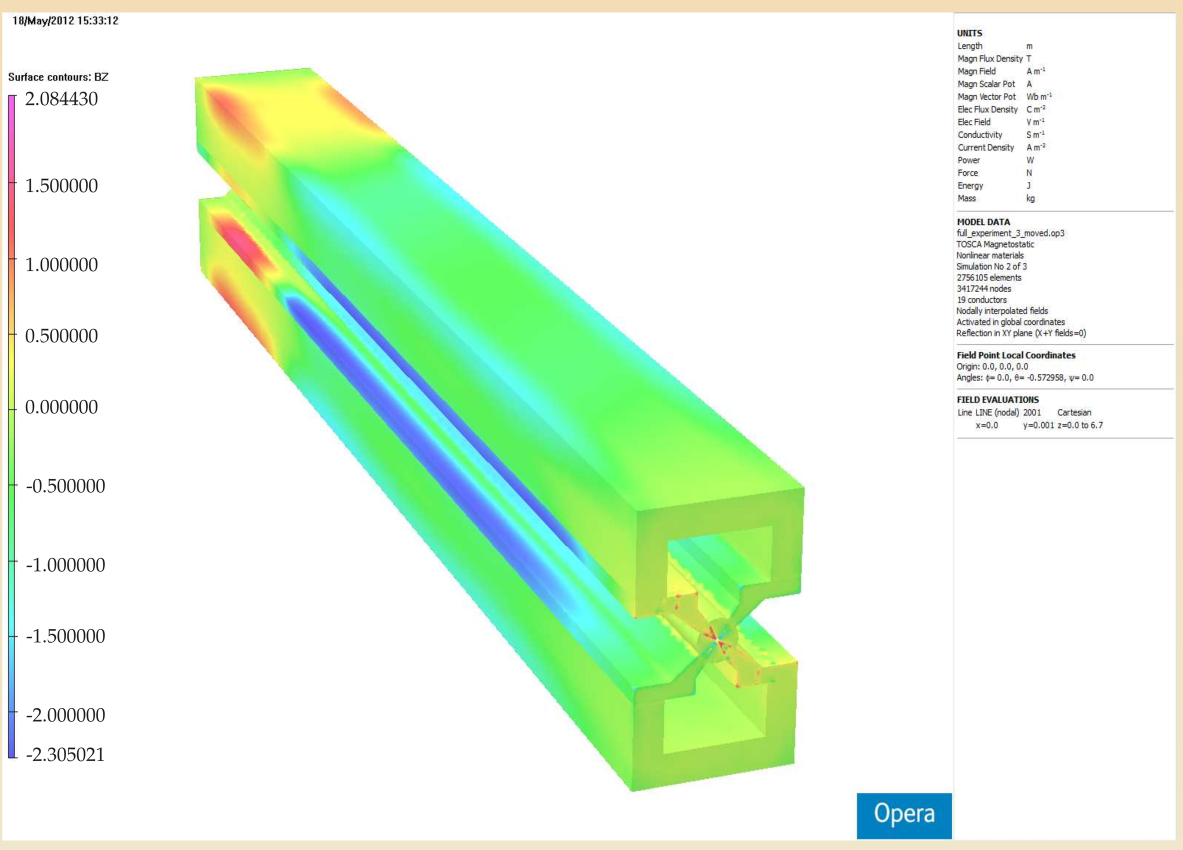

Figure 11: B_z [T] attracted by QD0, $L^* = 3.8$ m

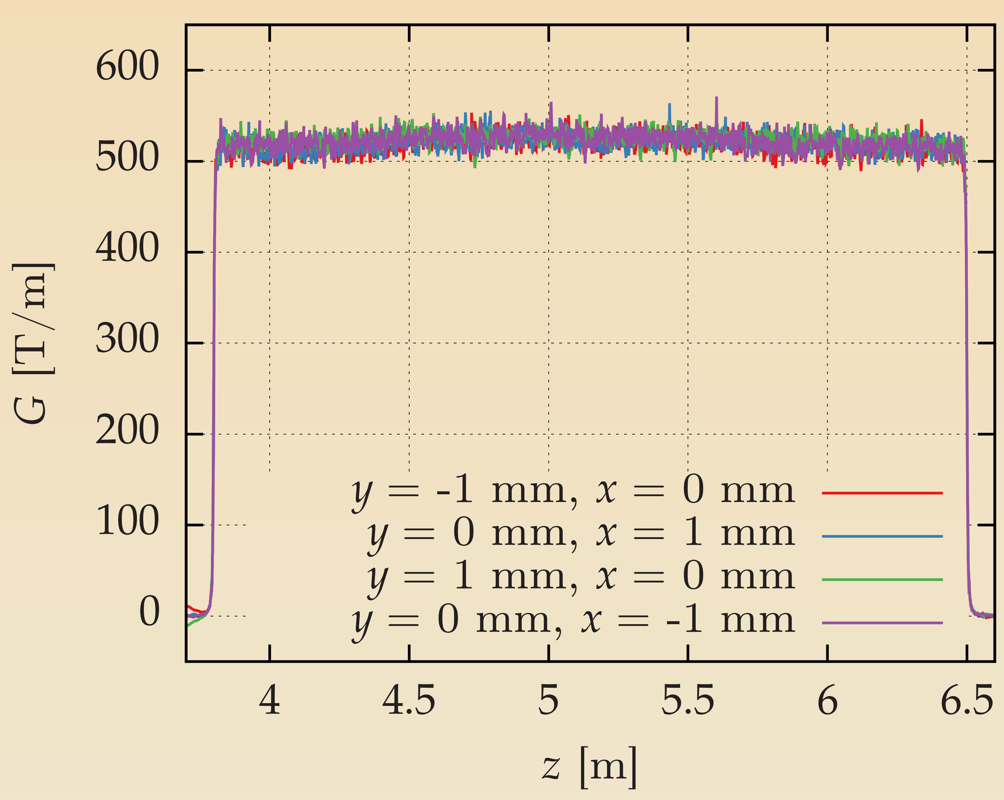

Figure 12: QD0 gradient, $L^* = 3.8$ m

Forces on QD0

The case shown in figures 9 and 10 was also studied by the mechanical point of view, and the magnetic forces acting on QD0 are estimated as $F_z \simeq -5.7$ kN, $F_x \simeq 8.3$ kN and $T_y \simeq 5.6 \cdot 10^3$ Nm. A sign change with respect to the previous case can be noticed in the force in the z direction, meaning that by modifying the anti-solenoid it is possible to cancel the axial force acting on the magnet. This is not true in the case of F_x and T_y, which are forces generated by the fact that QD0 axis is not the same as the anti-solenoid (because of the crossing angle of the beam lines), and therefore there will always be a force pushing the magnet to align its own axis with the one of the anti-solenoid.

Conclusions

The most important achievement of this study was that with an appropriate shielding (i.e. the anti-solenoid) the QD0 *can* work as specifications, even if placed very close to the strong detector magnetic field. On the other hand, to obtain such performances an adequate space allocation is necessary, as the one defined in the conceptual design phase appears to be not sufficient.

A proper shielding of the QD0 can also reduce the forces acting on this hybrid electromagnet, with remarkable benefits on the mechanical stabilization of the final focus system.

Finally, regarding the impact of such systems on the incoming beam, it can be noticed that the luminosity loss is *coherent* with all the previous designs and it is mainly related to the radial component of the field in the region between QD0 and the IP. Considering the relatively small volumes affected, a local solution (at the level of the beam pipe) is proposed to be investigated in order to increase the luminosity, as using the anti-solenoid to obtain a better field map in terms of beam dynamics will lead to an unoptimized solution with respect to the QD0 shielding.

Acknowledgements

Sincere thanks go to the whole MDI working group, especially to Lau Gatignon, to the detector team, represented by Andrea Gaddi and Hubert Gerwig and also to the beam dynamic team, represented by Barbara Dalena.

This work could never have been completed without all the comments and the inputs received at the CLIC MDI meetings.

References

[1] M. Modena et al., "Design, Assembly and First Measurements of a Short Model for CLIC Final Focus Hybrid Quadrupole QD0", this conference.

[2] B. Dalena, "CLIC main detector solenoid and anti-solenoid impact" Presented at the CERN CLIC Collaboration Working Meeting, 10 May 2012.

[3] A. Bartalesi and M. Modena, "Design of an Anti-Solenoid System for the CLIC SiD Experiment" CERN TE-MSC Internal Note 2012-11, EDMS Nr. 1214775.