3D FEA Computation of the CLIC Machine Detector Interface Magnets

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Abstract

A critical aspect of the Compact Linear Collider (CLIC) design is represented by the Accelerator/Experiment interface (called Machine Detector Interface or MDI). In the 3 TeV CLIC layout, the final focus QD0 quadrupole will be located inside the end-cap of the detector itself. This complex MDI scenario required to be simulated with a full 3D-FE analysis. This study was critical to check and control the magnetic cross-talk between the detector solenoid and the final focus magnet and therefore to optimize the design of an "antisolenoids" system needed to shield the QD0 and the e^-/e^+ beams from the detector magnetic field. In this paper the development and evolution of the computational FE model is presented together with the results obtained and their implication on the CLIC MDI design.

The CLIC SiD

One of the challenges related to the design of the compact Silicon Detector CLIC SiD, comes from the parameter L^*, which represents the distance between the Interaction Point (IP) and the last magnet of the Beam Delivery System. With a baseline L^* value of 3.5 m, the final focus magnet QD0 must be placed *inside* the detector, precisely within the limits of the yoke end-cap, as shown in figures 1 and 2.

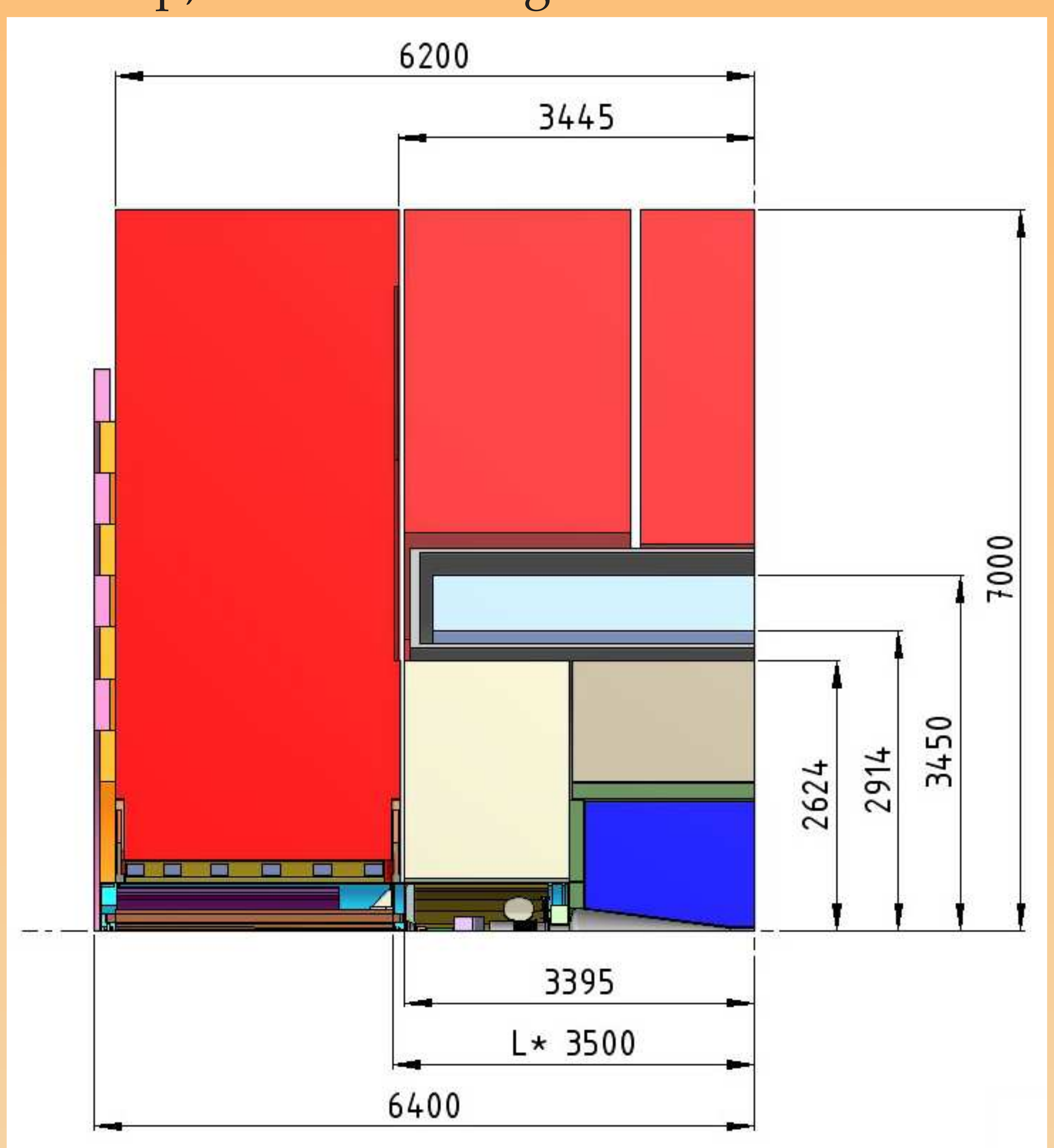

Figure 1 : The CLIC SiD dimensions

There are many different components in the CLIC SiD MDI region, but only a few need to be included in the magnetic simulations.

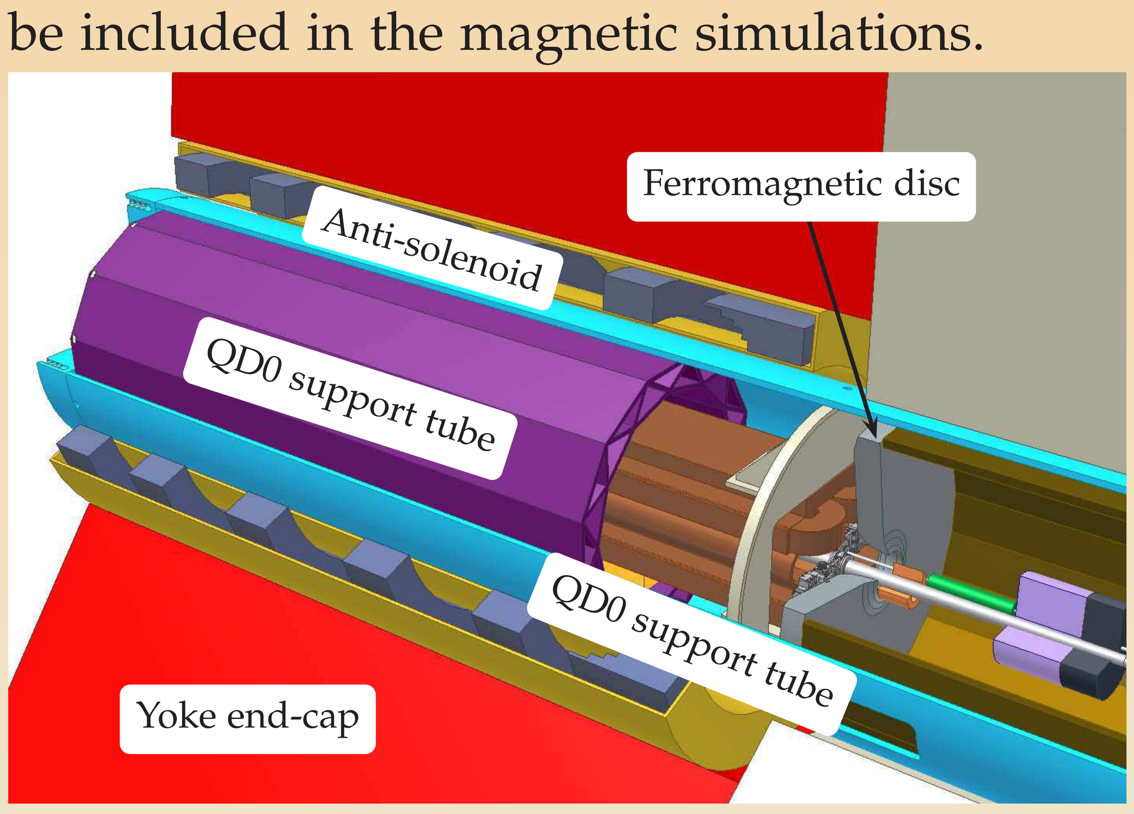

Figure 2 : The CLIC MDI region

A single 3D model: the detector *and* the final focus

Since QD0 is a *ferromagnetic* quadrupole which also contains permanent magnets, an active shielding (provided by an "anti-solenoid") is necessary to limit the interaction with the detector main solenoid field, as this could lead to a degradation of the quadrupole performance in terms of gradient and to an increase of the magnetic forces on QD0.

A 3D model of the MDI region (represented in figures 3 and 4) was proposed, to correctly simulate all the magnets and ferromagnetic parts influencing this region. The aim of this model is to help in the correct dimensioning and integration of the anti-solenoid system, by investigating its magnetic relations with the main solenoid, the detector and the QD0, as well as its impact on the beam dynamic and on the supporting structure, in terms of both magnetic field and forces.

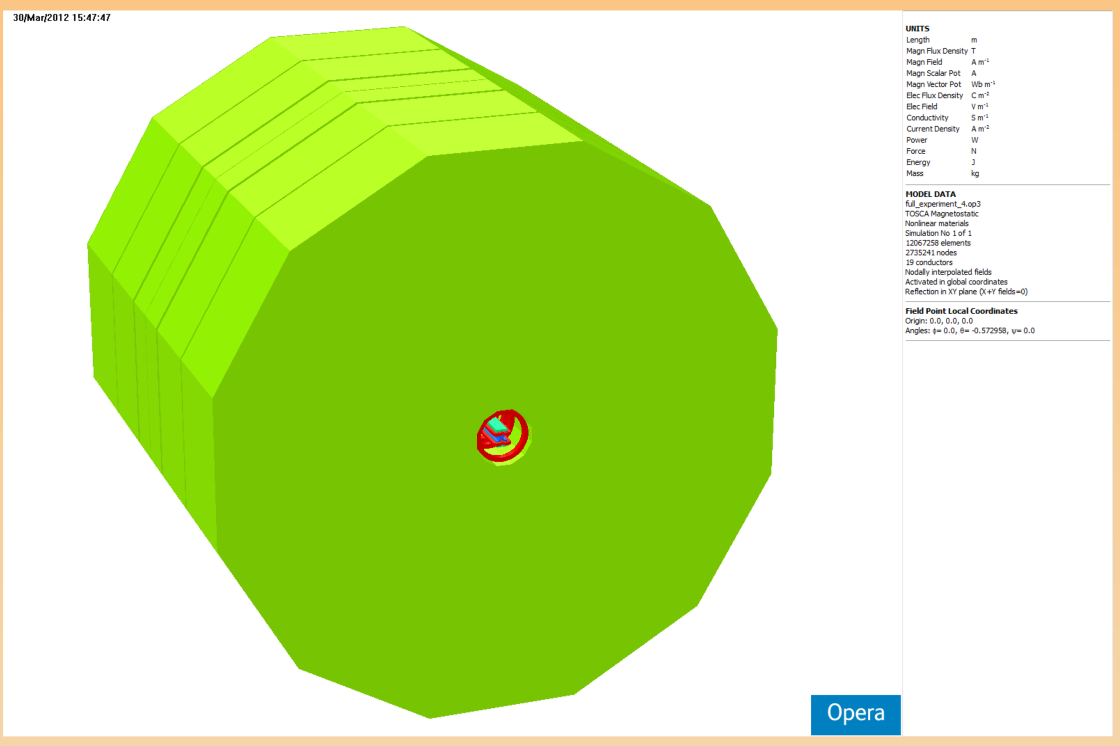

Figure 3: The whole detector model

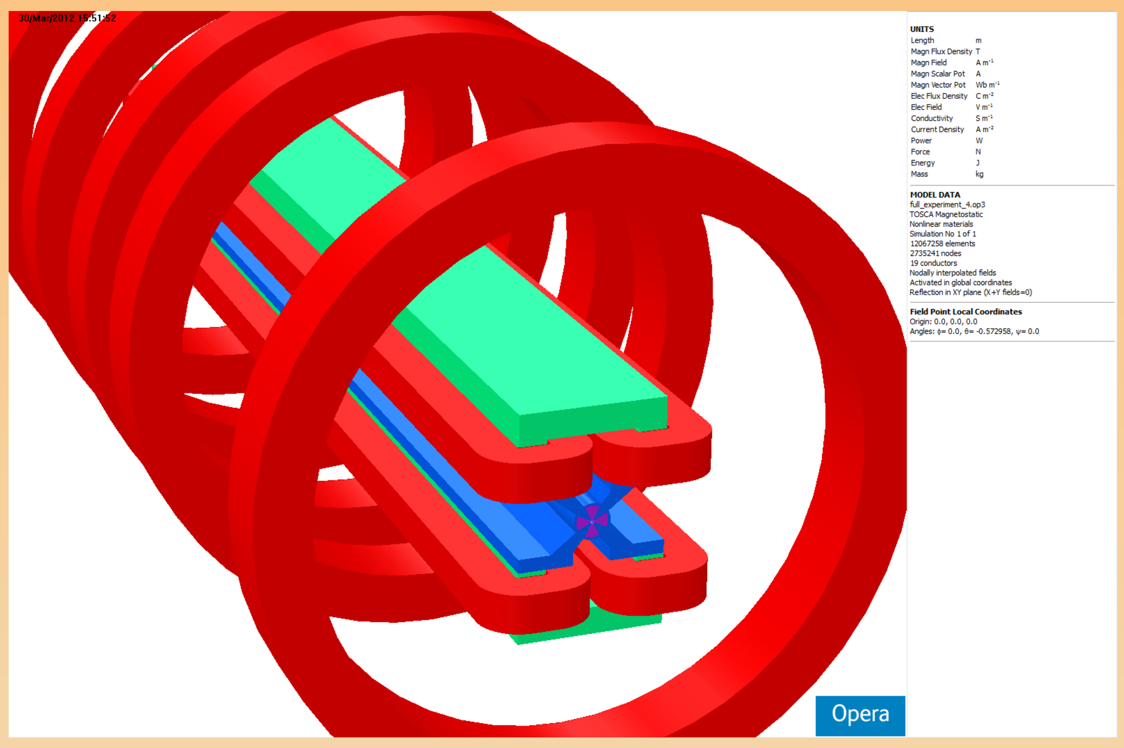

Figure 4: A zoom in the QD0 region

The software chosen for the simulation is Opera3D™. The model to be evaluated is made of a half of the detector yoke, plus one of the two QD0 held in the experiment. The most challenging aspect of such model is the scale difference: in the same simulation coexist in fact objects as big as the iron yoke, which has a "radius" of 7 m and a half-length of 6.2 m, and QD0, which has an aperture radius of just 4.125 mm. Moreover, the field in the QD0 aperture is the most relevant quantity, but due to meshing convergence problems, and to computation time, the precision of the results is lower than the one achievable by models representing the single magnet only.

Finally, due to the *hybrid* design of QD0 [1], permanent magnets, soft ferromagnetic region, normal conducting racetrack coils and super-conducting solenoids have to be included all at once in the same simulation.

Resulting magnetic field on the beam axis

In terms of field on the beam axis, the resulting component B_z is plotted in figure 5, and B_r is shown in figure 6. The effect of QD0 on the beam axis is beneficial, since its ferromagnetic structure *shields* the beam from the surrounding fields. Such results are visibly affected by a numeric error due to the element size, so they were interpolated before being used for beam dynamics simulations. This smoothing may appear unjustified, but it was necessary, considering the nature of the problem and the FE model features.

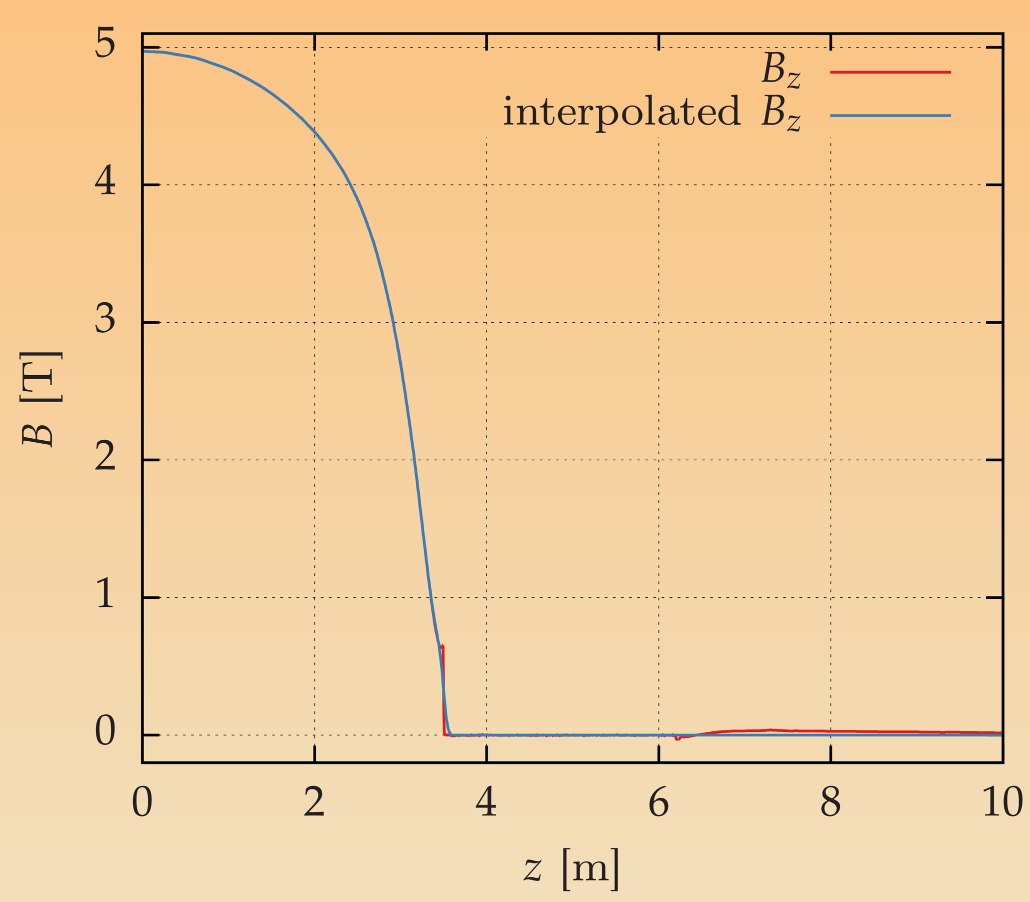

Figure 5: Resulting B_z on the beam axis

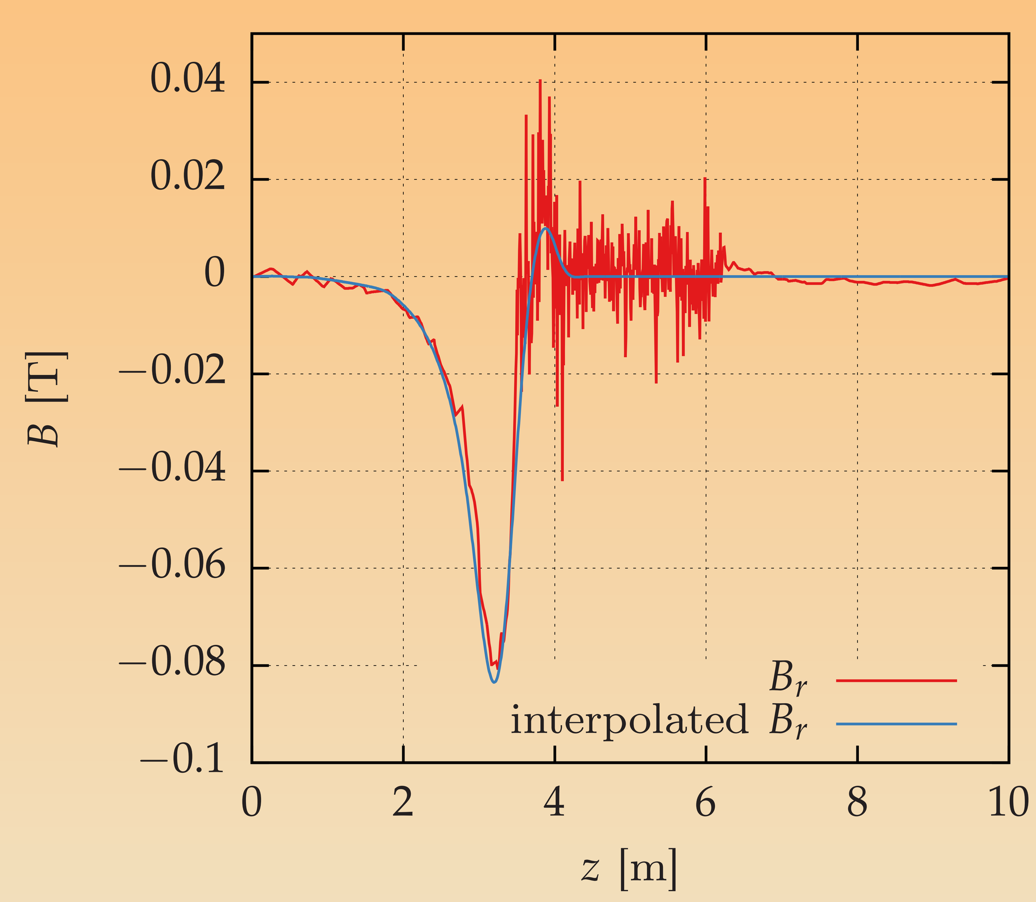

Figure 6: Resulting B_r on the beam axis

The luminosity loss due to the new field maps is $\simeq$14%, which is compatible with any other previous CLIC SiD design simulated so far, as presented in [2].

Forces on the anti-solenoid