Simulating the prototype for the Future Linear Collider Ecal: the problem of non-active regions.

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1 Introduction

The proposal of the *Calice* collaboration [1] for the electromagnetic calorimeter at the Future Linear Detector is a high granularity tungsten-silicon sampling calorimeter. The sensitive part of the detector is made of silicon PIN diodes matrices, that we will call *wafers* in the following. Each wafer is made of 36 readout pads of 1cm x 1cm. In this note I present some results from a set of simulations performed for a prototype of this detector, which is at the moment under construction at the LLR laboratory [2]. The deterioration of energy reconstruction due to the presence of *non-active regions*, namely the guard-rings which border each wafer and the interspaces between wafers, has been particularly studied.

In the next section I will briefly describe the simulation set-up, pointing out some differences between the simulated detector and the real one.

2 Prototype simulation with Mokka

Mokka[1], a Geant4 based simulation tool for FLC studies accessing detector geometries through a database [3, 4], was used for simulating the events. The geometry used for the detector is described in [5]. For the electromagnetic part (ECAL), it is a quite faithful representation of the real prototype under construction. As shown in figure 1, in the y direction (the direction of the incoming beam) it presents three structures, containing 10 silicon (Si) layers each, which differ in the thikness of the tungsten (W) interspacing layers. In the z direction the Ecal prototype is composed by 3 towers, interspaced with carbon fiber. Half of the W layers are placed whith their long side along the z direction, while the other half, placed with their long side along the x direction, are part of elements called *detector slabs*. One detector slab is built as the superposition of different materials: tungsten in the center and then, on both sides, Si wafers, Al shielding and a "Material Mix" that takes account for the effects of the different materials that complete the slab structure, for the PCB and for the glue. In odd numbered layers, the Si wafers are all shifted by 2.4 mm in the x direction in order to prevent particles passing through the gaps between wafers and escaping detection.

Figure 2 shows the detector as viewed from the incoming beam. Since the geometry model is based on an old project, the size of the simulated detector is not the

[1]Mokka Release mokka02-01.

same as that of the real one, which corresponds to the shaded region in the figure. Morever, to reduce the prototype cost, the real prototype won't be fully equiped; the nine wafers shaded in darker colour correspond to the ones which will be active in reality.

One non trivial discrepancy between real and simulated detector is the different behaviour in the region near the border of the wafers: in order to study the worst possible case, the charge collection in the non-active zones of the Si layer, namely the 1 mm wide region between the border of the wafer and the active zone, including the guard ring (see figure 3), and the 0.1 mm spacing between wafers, is assumed to be exactly zero.

3 Some consequences on energy reconstruction of the presence of non-active regions.

When a particle goes through the gap between two wafers, part of its energy is lost. This becomes serious, as we will see, when the particle direction is perpendicular or nearly perpendicular to the surface, because in that case it can miss a big fraction of the detection layers; it becomes catastrophic when the particle travels along the carbon fiber structure between towers (see figure 1).

In order to test the quality of energy reconstruction near non-active regions, a set of productions was made, in each of which the (x,z) surface of the detector is illuminated with 10 GeV electrons. The position in which the particles reach the detector can be set very precisely by setting two parameters of the simulation, namely the position and the direction of the *gun*. It is therefore possible to shoot the detector in different positions and then compare the reconstructed energies. Two sets of positions, sketched as dotted lines in figure 2, are studied: set A is centered on the interspace between two wafers, set B is centered on the carbon fiber separating two towers. A production of one thousand events was performed for each position. All the tests were repeated for three different inclinations of incoming particles: the beam lays always in the yz plane but its inclination with respect to the z axis is changed between 85, 88 and 90 degrees (see figure 4). This is in accord with what will be performed with the real prototype in beam tests.

Figure 5 shows the superposition of three histograms representing reconstructed energy for each of the three beam inclinations. In each histogram all the events from the 25 productions of set A are plotted. These plots show that an important fraction of the energy is not detected. In figure 6, the reconstructed energy is averaged over all the events in the same production and then plotted against the x position of the target (position 0 corresponds to the boundary between the two wafers). One can now clearly see that the degradation of energy reconstruction is due to energy loss in the non-active region between wafers. The effect is only slightly dependent on beam direction because the chosen directions all lay in the yz plane. Figure 7 shows a zoom of central positions. The asimmetry in the effect is due to the wafer shift in odd numbered layers.

Figure 8 and 9 show the same plots for the 19 productions of set B (position - 6.3 corresponds to carbon fiber). Here the effect is still larger and more dependent on beam direction.

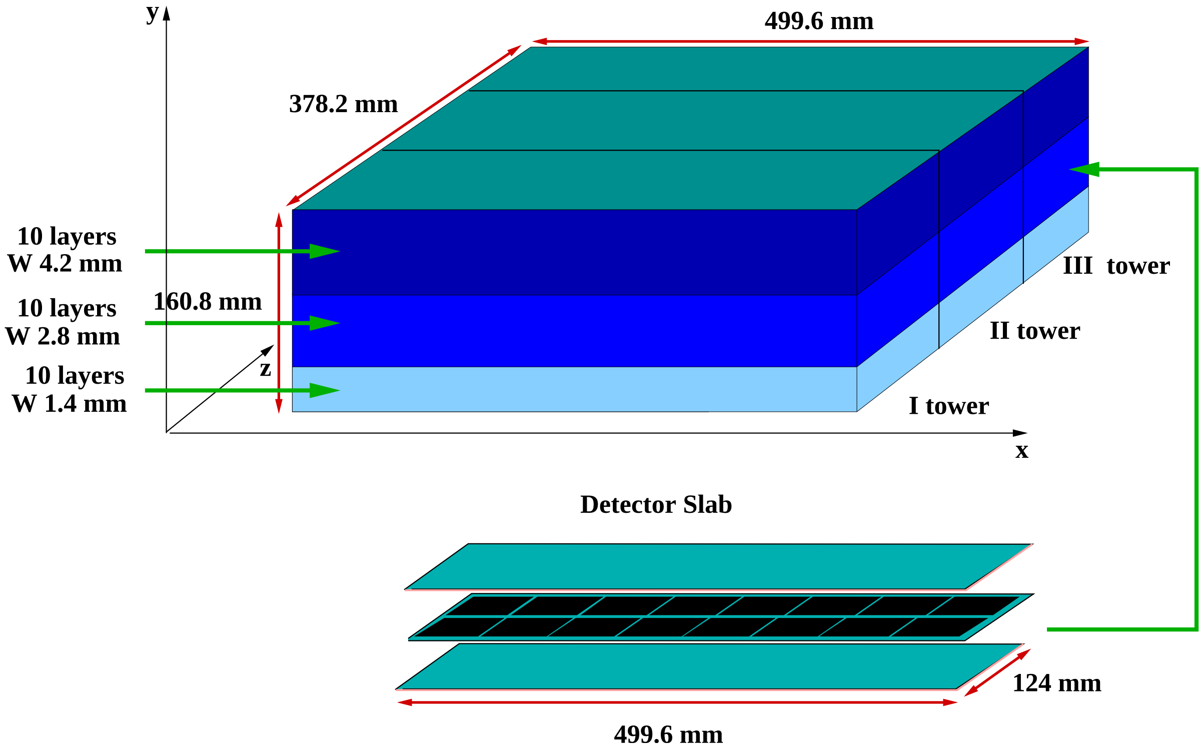

Figure 1: Sketch of the geometry used for the Ecal prototype in the simulation.

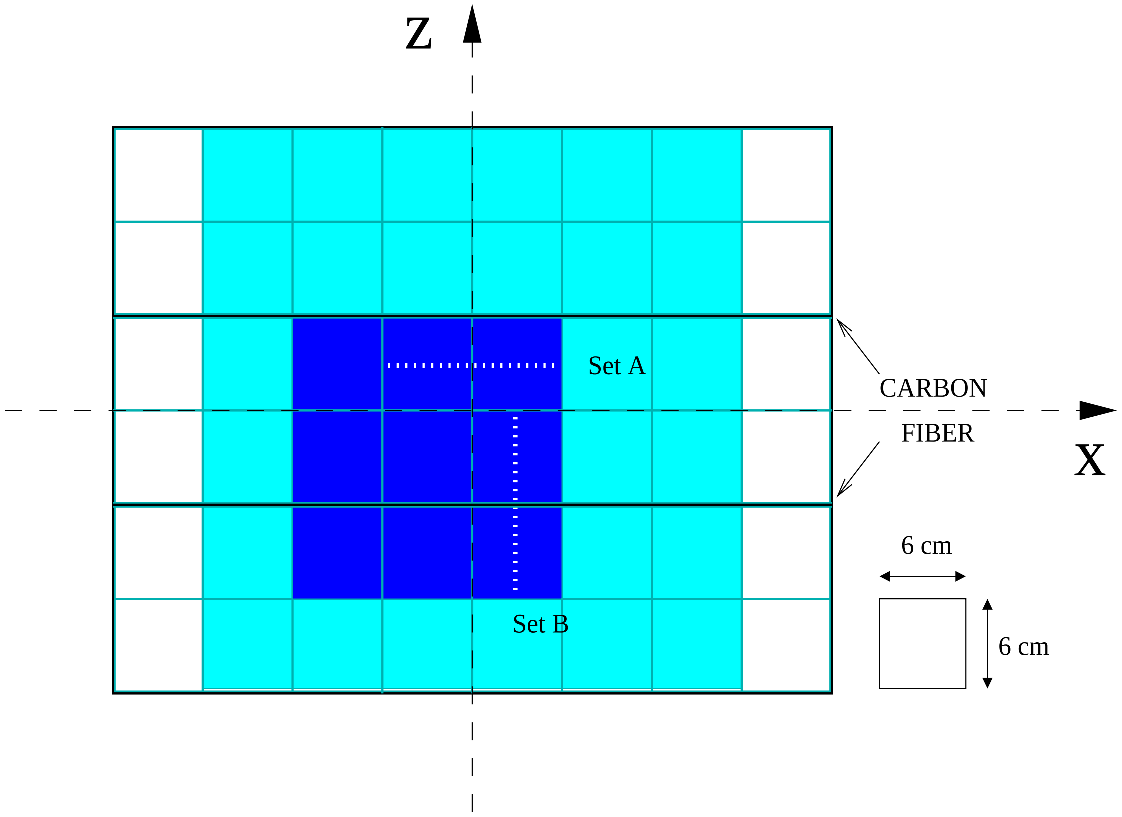

Figure 2: The prototype as viewed from the incoming beam. Dotted lines correspond to target positions used for this study

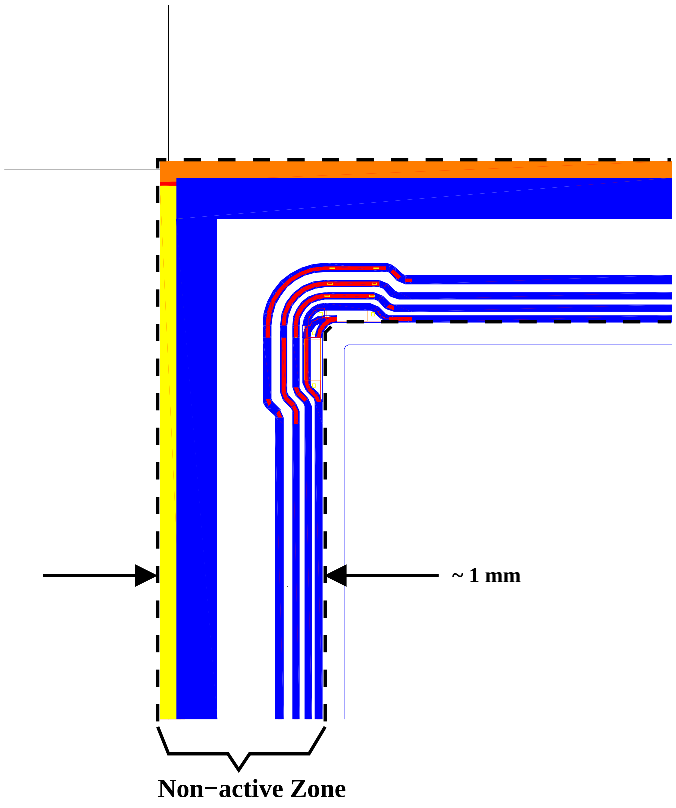

Figure 3: View of the guard ring.

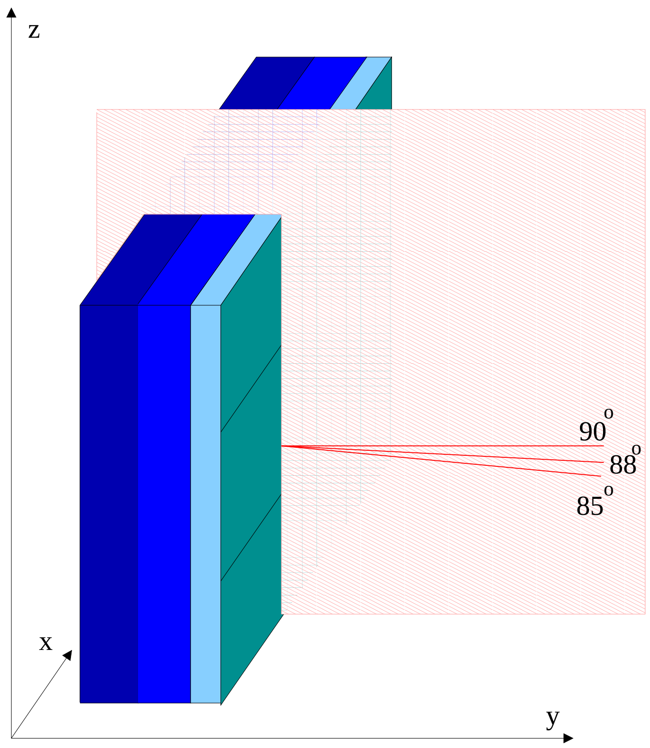

Figure 4: Beam directions for simulated events.

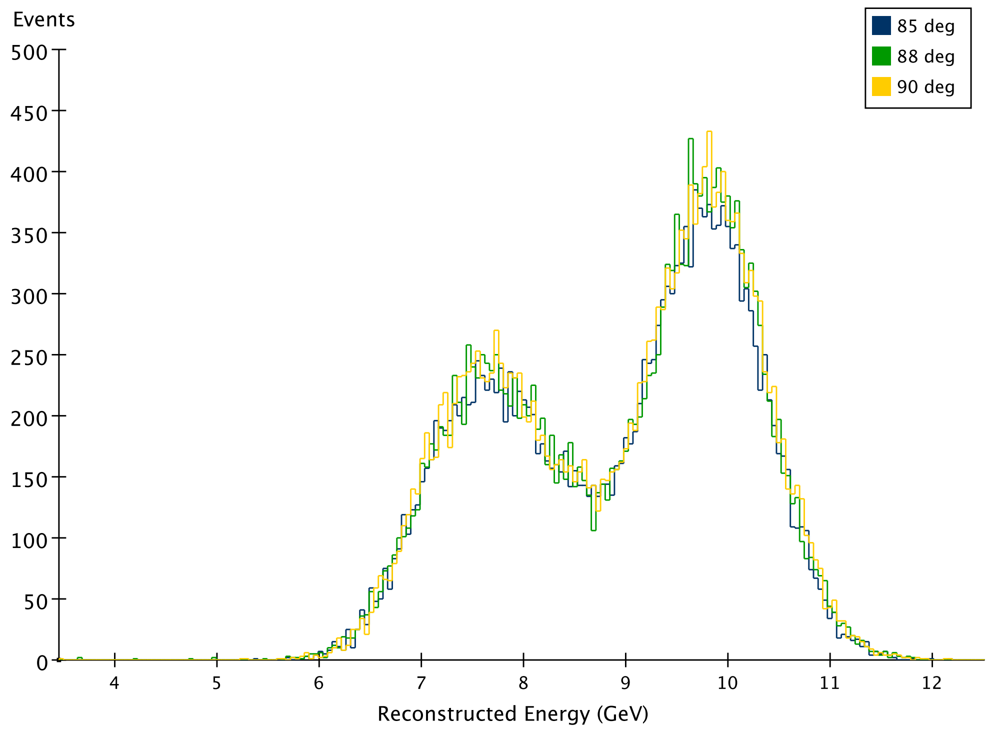

Figure 5: Set A - Reconstructed energy.

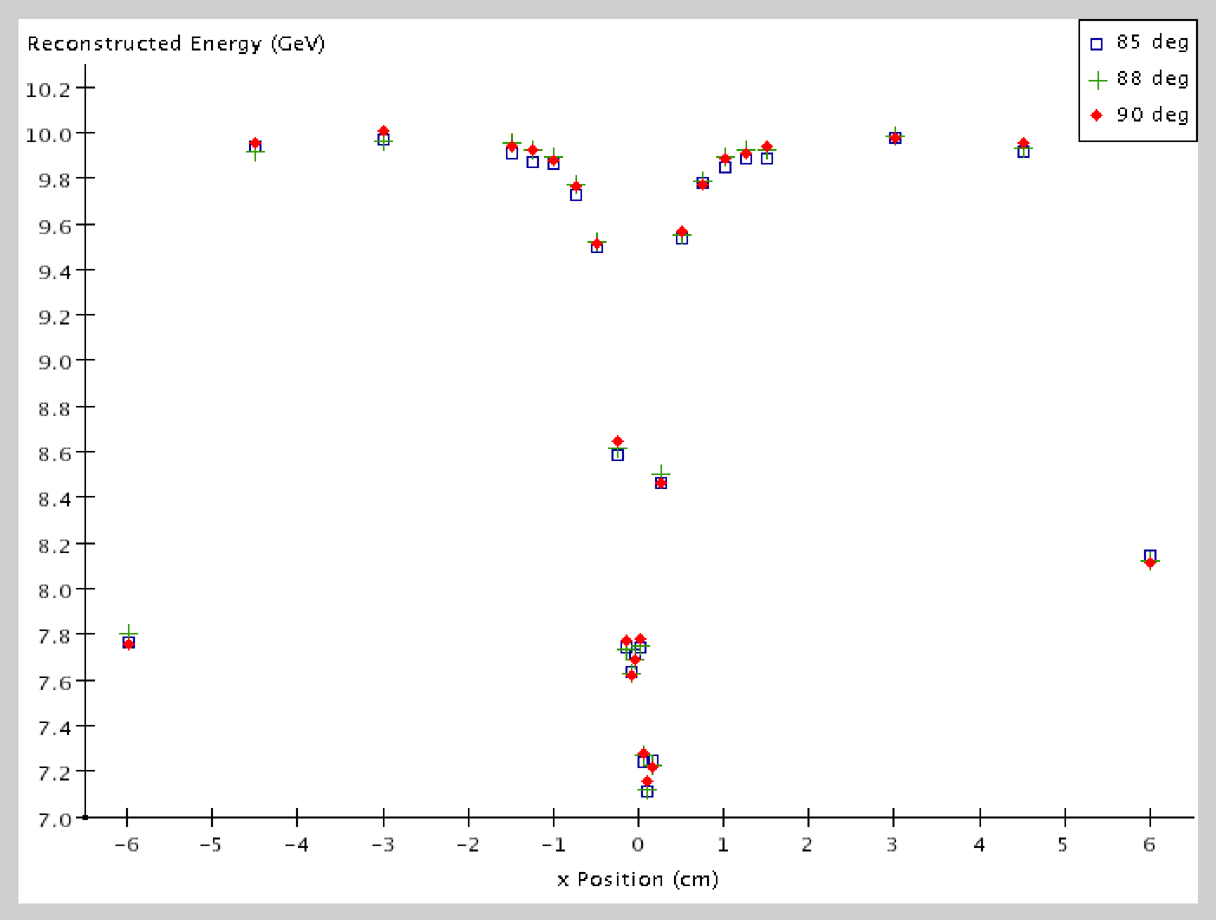

Figure 6: Set A - Reconstructed energy versus x position of target.

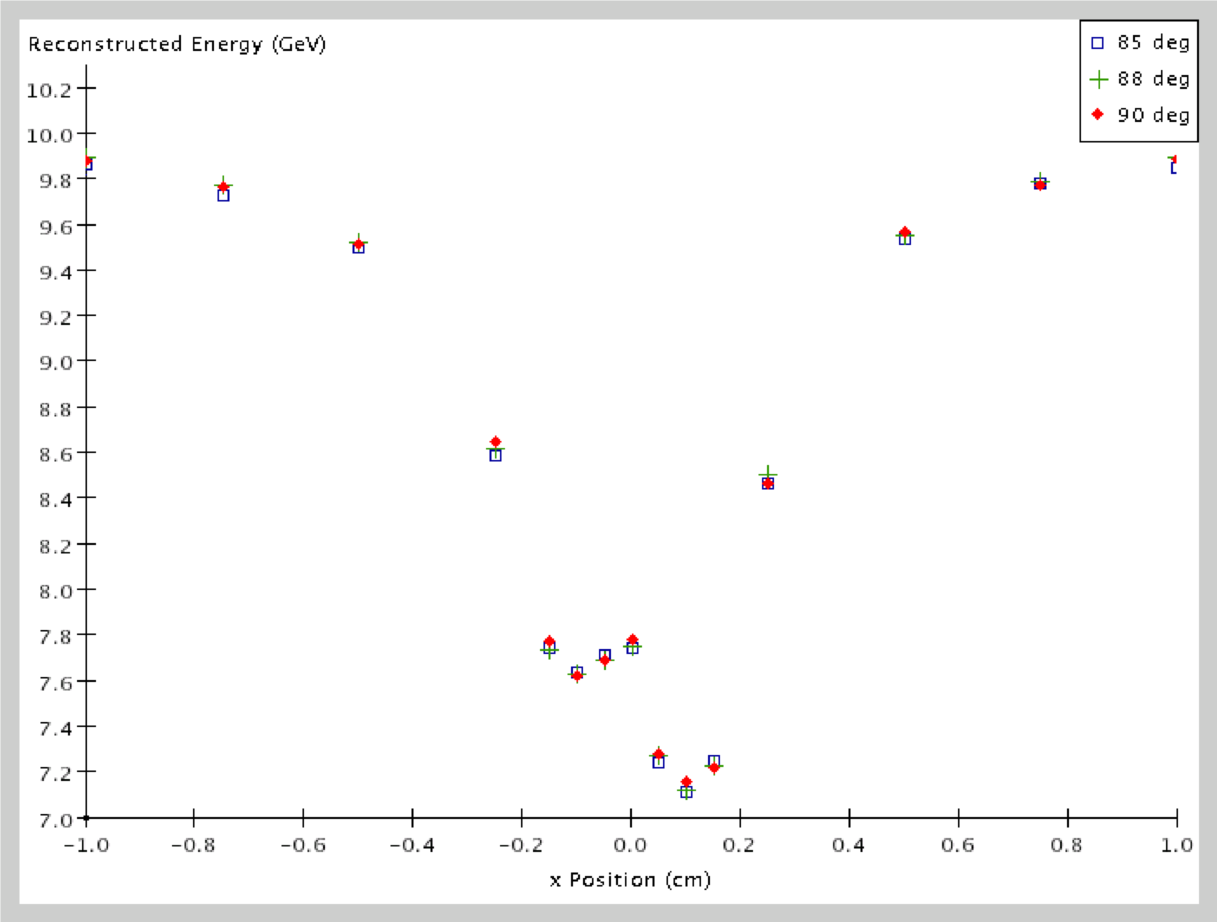

Figure 7: Set A - Reconstructed energy versus x position of target: zoom on central positions.

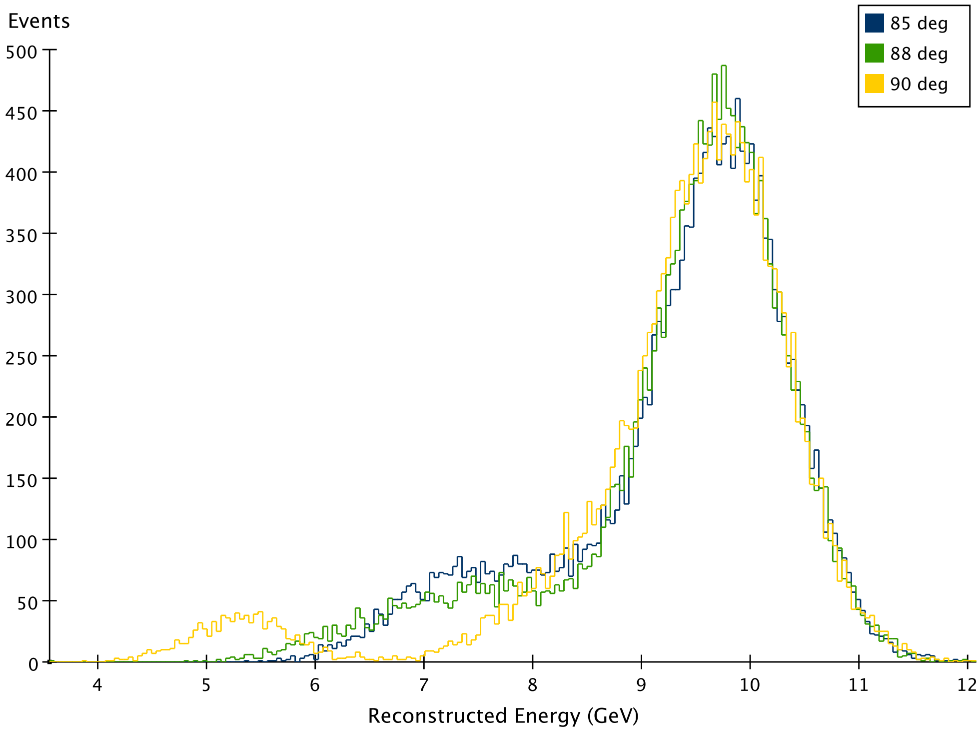

Figure 8: Set B - Reconstructed energy.

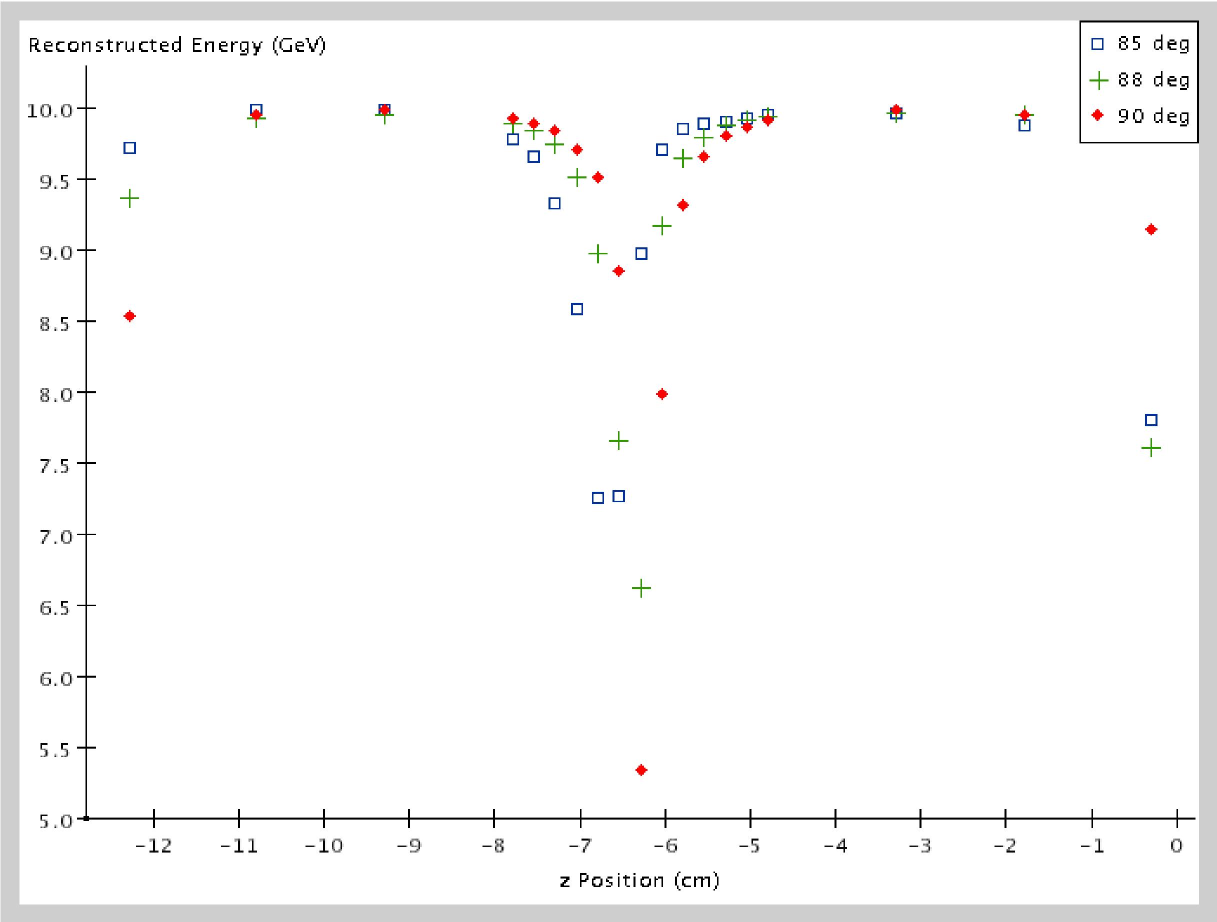

Figure 9: Set B - Reconstructed energy versus z position of target.

4 Conclusion

This study shows that the energy loss due to the presence of non-active regions in the Ecal prototype has a significant impact on energy reconstruction. This information is of capital importance in designing the ultimate geometry for the real prototype under construction: clearly a skilful positioning of the Si wafers is mandatory in order to minimize the effect of particles passing through non-active regions. The energy loss due to the presence of carbon fiber in the prototype structure, which can not be avoided, must be carefully taken into account in reconstruction and analysis, especially for beam directions perpendicular or nearly perpendicular to the surface of the detector.

Simulation is a very effective tool for defining the best geometry but, on the other hand, a better understanding of the behaviour of the guard ring region is necessary to obtain a more faithful simulation of the detector. Such an understanding could be achieved by a measurement of the charge collection with a point-like source whose position is known with very high precision. This measurement is under preparation at the LLR laboratory.

References

[1] Calice Collaboration Home Page, http://polywww.in2p3.fr/flc/calice.html

[2] LLR Laboratory Home Page, http://polywww.in2p3.fr/

[3] Mokka Home Page, http://polype.in2p3.fr/geant4/tesla/www/mokka/mokka.html

[4] P.Mora De Freitas, H.Videau, *Detector Simulation with MOKKA and Geant4: Present and Future*, LC-TOOL-2003-010

[5] Mokka Prototype simulation Home Page, http://polype.in2p3.fr/geant4/tesla/www/mokka/PortoDoc/ProtoMain.html