CERN SUMMER STUDENT PROGRAMME 2013

PROJECT REPORT

3-Dimensional Charge Collection Efficiency

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1. Abstract

In this project, we designed a simulation program to create the efficiency map of a 3 dimensional rectangular detector. Efficiency is calculated by observing the collected charge at the output. Using this simulation program, one can observe the inefficient regions at not only on the surface of detector but at the depths of detector.

2. Introduction

At the beginning of the project, we did a preliminary work for the new innermost detector of ATLAS Experiment: Insertable b-layer (IBL).

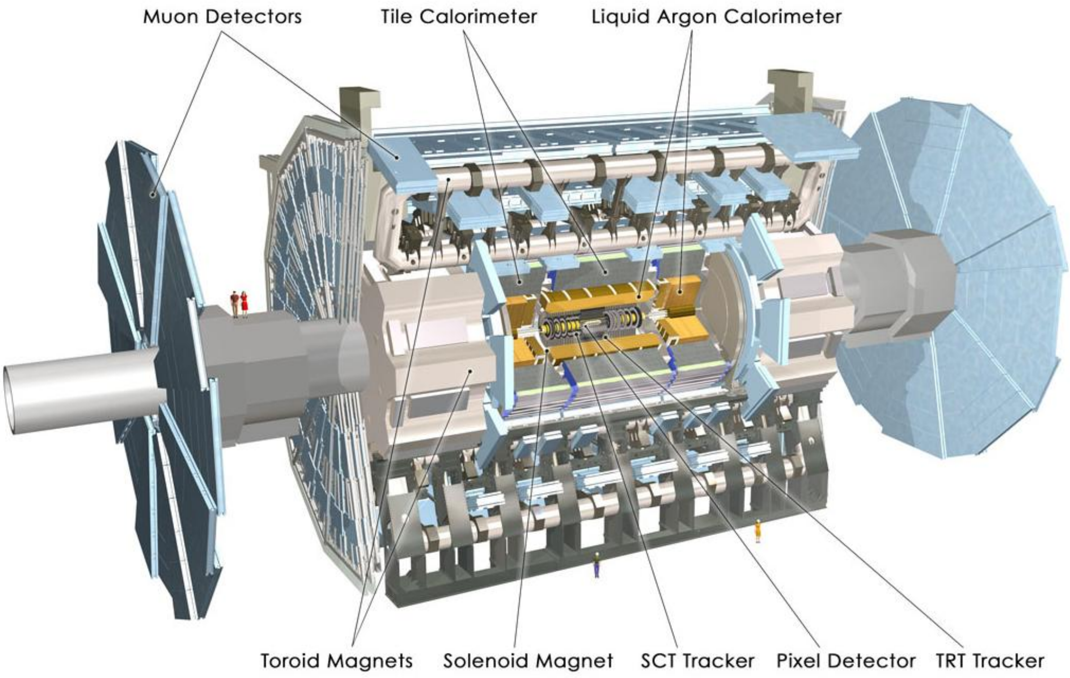

Figure 1: ATLAS Experiment

First of all, we understood how minimum ionizing particles are generated in IBL sensors. In LHC, protons collide at enormous amount of energies, therefore the particles which are generated by the collisions have kinetic energy that is greater than their rest mass energy. These particles are called minimum ionizing particles. MIP's ionize the silicon atoms inside the sensor and create electrons and holes. These electrons and holes are collected by the analog amplifier and amplified with high gain. Then using the discriminator circuit, the analog signal is converted into a digital pulse. Second of all, we understood that the collected charge at the output is directly proportional to the distance travelled by beam. Therefore, we need to calculate the travelled distance inside the 3-dimensional object.

3. Calculation of Distance in 3D

In order to calculate the distance travelled by beam in 3D, we started from the simplest cases which is 1D and 2D at different rotation angles. On the paper, using trigonometric identities, it can be calculated easily. However, in 3D, it is not as straigthforward as 1D and 2D. For 3D, we developed 2 methods however we abandoned one of them because of its inflexibility.

For the calculation of the distance at different rotation angles of the rectangular prism and different positions and angles of the beam, we created four classes: Vecteur, Matrice33, Plan, Rectangle. The coordinate system, rotation angles and lengths of the rectangular prism is given in Figure 2.

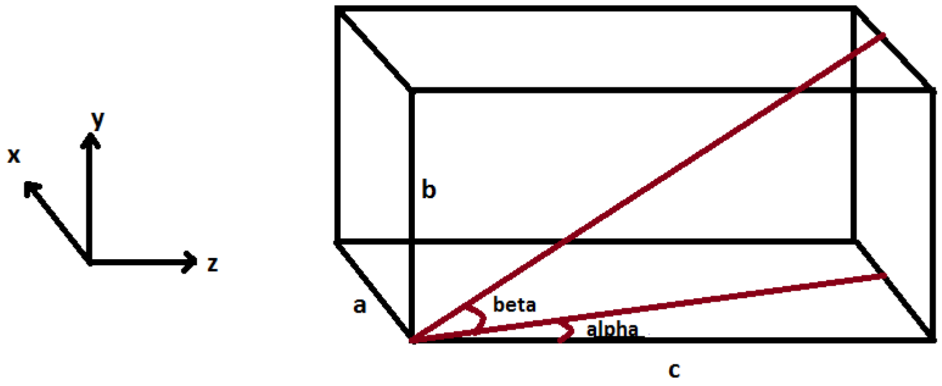

Figure 2: Coordinate system, lengths and rotation angles of the rectangular prism

We created a 2D histogram which scans two rotation angles of the rectangular prism from 0 to 180. The lengths of rectangular prism are a=1, b=1 and c=1 for simplicity. As it can be seen in Figure 3, we have 4 peaks that correspond to the diagonals of the cube. The diagonal distance is √3 which is approximately 1.73. It can be observed at the histogram roughly.

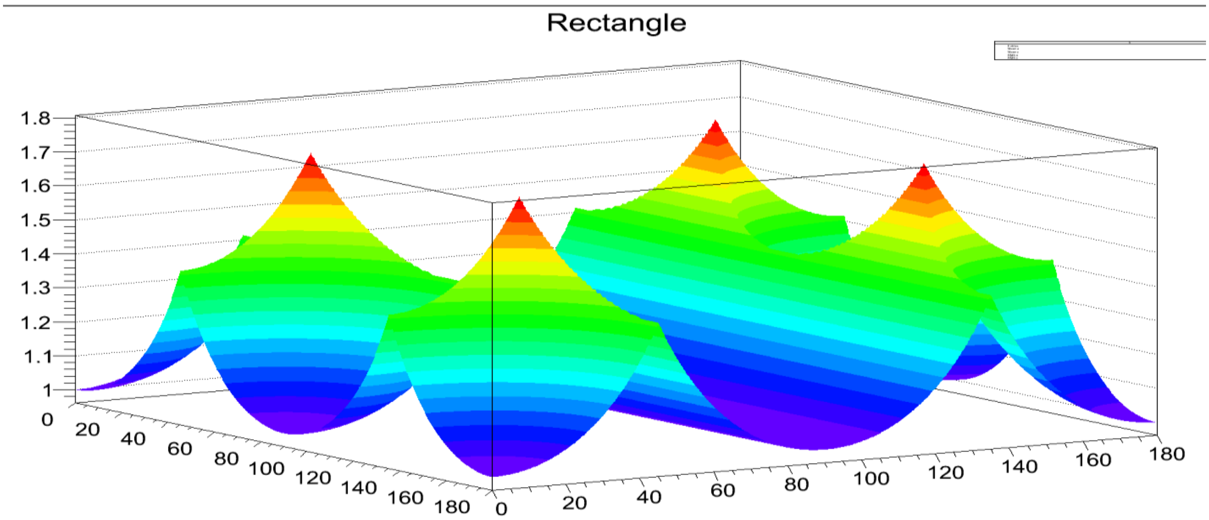

Figure 3: 2D distance histogram for unit cube.

4. Sinograms, Back Projections, Reconstructions and Filters

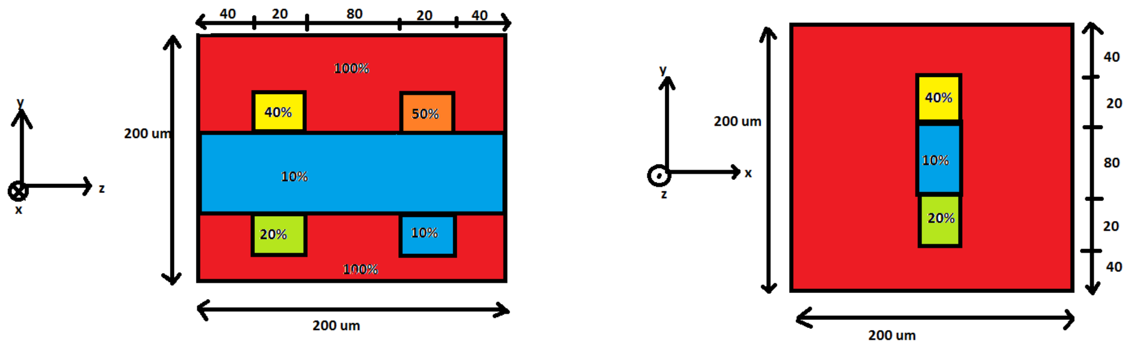

Figure 4: Example used for creating sinograms

After the distance calcualtion algorithm is finished, we combined the works with my officemate who studied the Langau distributions. To be able to obtain the 3D tomography of the detector we create a sinogram in the following way. First of all, in Figure 4, we created an example detector which has a volume of 200x200x200 μm^3 with different efficiencies. We used this example detector to create sinograms and back projections and reconstructions. We kept one of the rotation angles of the rectangular prism fixed and rotated the other one for one beam position. We did this rotation for each beam position and obtained the sinogram for 1 slice with axes: beam position versus angle.

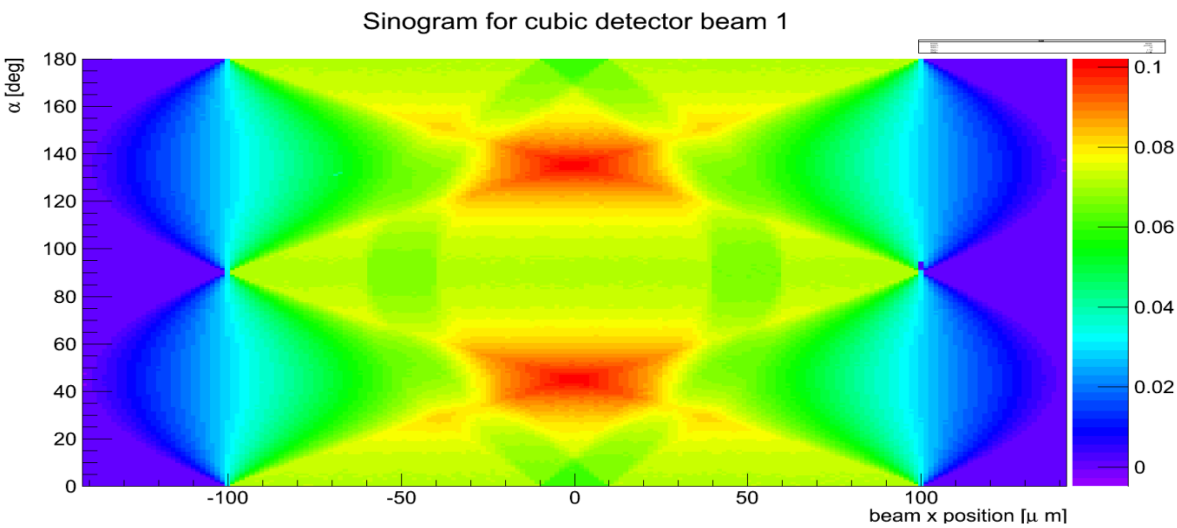

Figure 5: Sinogram for cubic detector

The cubic detector is rotated around y-axis by 180 degrees and beam position is determined by calculating the diagonal distance of the cubic detector (in this case it is +- $100\sqrt{2}$ = +-142 micrometers).

According to the obtained sinogram, we need to reconstruct our detector by taking slices from sinogram and back project it. In order to achieve that, we started from the simplest case which is taking only 1 slice at a certain angle and back project it on an empty canvas. If we do that for every slice at different angles, we expect to see the reconstructed version of our detector. However, to obtain a better image of detector, we must use a high pass filter so that we can sharpen the edges of the detector and eliminate the blurrings. By this way, the final reconstructed version of our detector is obtained as it can be seen in Figure 6.

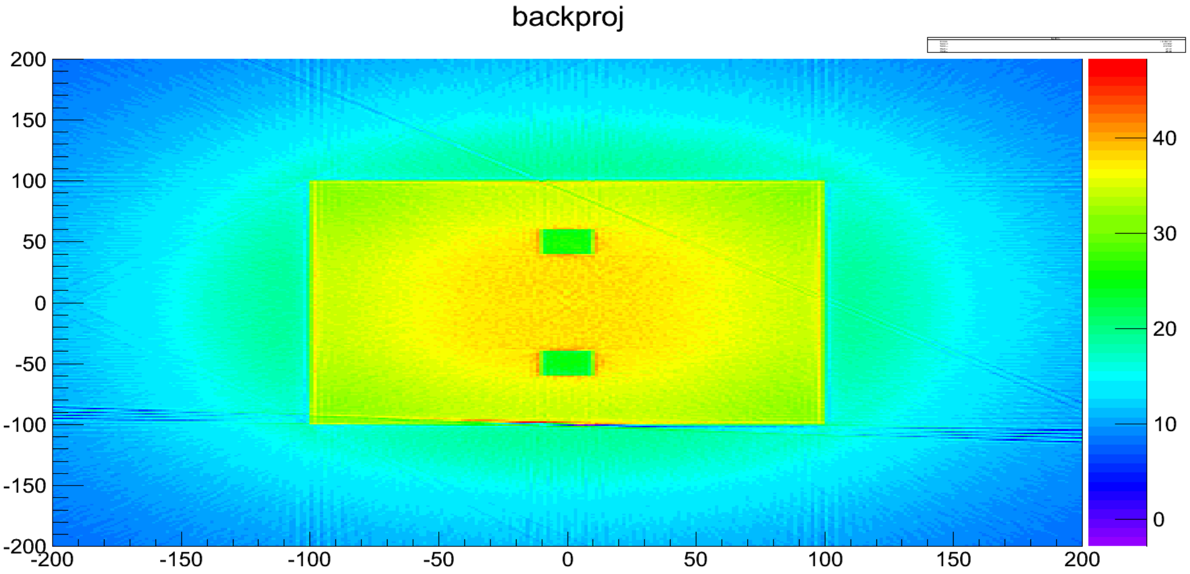

Figure 6: Filtered reconstruction of the detector

5. Conclusion

The distance calculation was done by creating several classes. Combining distance calculations with the langau distributions, we obtained sinograms, back projections and reconstructed versions of our detector.

We learned lots of things about programming and physics when we do our project. This was very fun and enjoyable. CERN Summer School gave me the opportunity to enhance my skills and it was an invaluable experience for me.

6. References

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