CERN
PHYSICS DIVISION

SUMMER STUDENT REPORT: SHORT VERSION

Simulation tool for 3D charge collection efficiency tomography

Operating principle of the program

Thibaud Humair

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Supervised by Jennifer Jentzsch and Dr. Daniel Dobos
The simulation tool was developed in collaboration with Umut Kodak

1 Introduction

This document describes a computing tool that has been developed to simulate the whole process of 3D tomography for silicon detectors. Tomography techniques are used in the Atlas experiment to precisely characterise the pixel detector by obtaining a 3D image of its charge collection efficiency. Such a simulation tool can corroborate the experimental measurements and help optimising some parameters of the experiments. Computer programs designed to simulate tomography have already been developed in the past, but the present program has been especially developed to simulate the tomography of very thin silicon detectors with highly energetic charged particle beams.

2 What the program simulates

This section is a quick description of what the program is able to simulate. More precisions about tomography can be found in [1]. We consider the following experiment:

A silicon detector is characterised by a charge (or energy) collection efficiency which is not constant, but space-dependant. To obtain an image of this efficiency, the detector is placed in a beam of charged particles. These particles will go through the detector and deposit some energy, which is recorded. Then, the detector is rotated and translated along the x direction (see part 1 of Fig.1). For each angle α and scanning parameter x, the energy is reported in a 2D histogram, referred to as a sinogram (see part 2 of Fig.1). Then, each slice of constant α on the sinogram is filtered (see part 3 of Fig.1) by a high-pass filter, which stresses the boundaries between two regions of constant efficiency. By back-projecting the filtered sinogram, this process allows for a reconstruction of the image of the efficiency of the detector (see part 4 of Fig.1). For a complete 3D image of the detector, this experiment has to be repeated after having translated the detector along the y axis.

In the case of the Atlas experiment, the beam is actually a beam of 120 GeV pions, the passage of which is recorded by telescopes. The program has been especially tested for that kind of highly-energetic beam. In the program, all the different components of the experiment are implemented as `c++` classes.

This simulation tool is based on the langau distribution, which describes the energy deposited by a particle going through a thin layer of silicon. This distribution is shown in Fig.2. Such distributions are generated in each voxel, and then convoluted between them (using either a numerical or analytical method) to obtain the total energy deposit distribution for the whole detector.

3 Selected results of the simulation

This section contains some examples of results of simulations performed by the program.

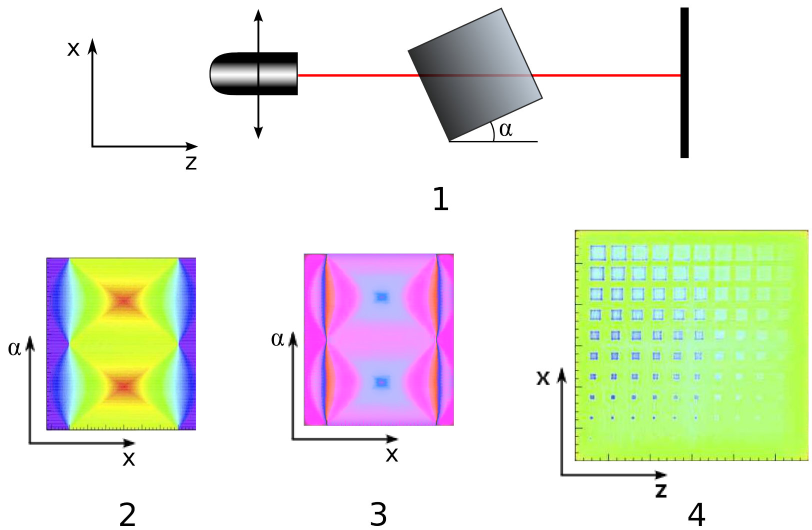


Figure 1: This picture summarises the process of tomography of a detector: experiment (1), extraction of the sinogram (2), filtering (3) and back-projection (4).

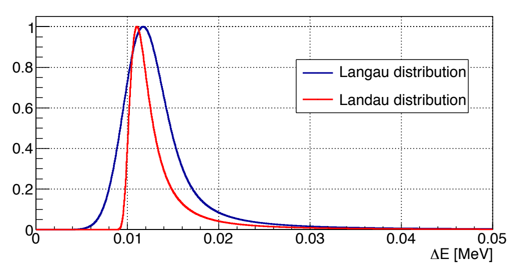


Figure 2: Distribution functions for the energy deposited by 120 GeV pions going through 20 μm of silicon. Both the Landau and langau approximations are represented.

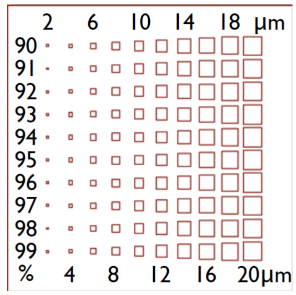


Figure 3: Scheme of the detector being considered in the simulations. The detector is squared, its edges measure 300 μm

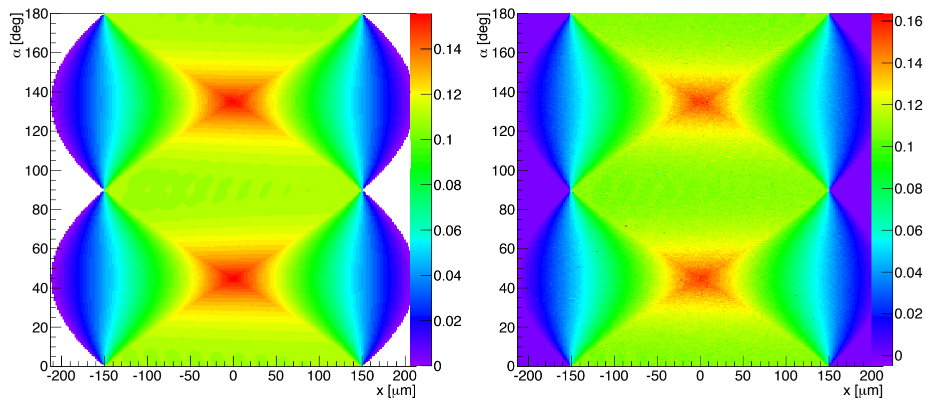
The detector that has been considered for these simulations is the one schematised on Fig.3. It is a bulk piece of silicon with 100% efficiency containing 100 voxels of variable size (ranging from 2 to 20 μm) and variable efficiency (ranging from 90% to 99%), useful to test the precision of the reconstruction. Such a detector was already analysed in a previous study with a simpler program that does not take the landau distribution into account (see [1]).

For this detector, sinograms have been generated for a variable number of events. For every simulation, the angle α scans the interval $[0, 180]$ by steps of 0.5 deg and x was variated between -213 μm and 213 μm by steps of 2 μm. Two sinograms are shown on Fig.4: the left one was obtained by using a fully analytical method, and the right one was obtained by considering 100 events in for each bin.

Two reconstructed images of the detector are shown in Fig.5 for 500 and 10000 events per bin in the sinogram. This image shows that to probe a detector of the form of the detector studied here, a number of events of the order of 10000 is necessary.

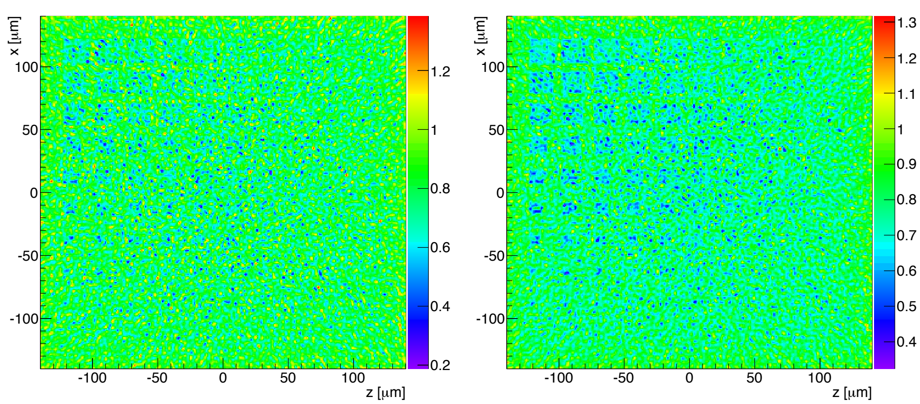
4 Conclusion

Even if the program still remains to be improved and tested, it promises to be useful for future experiments about 3D charge collection efficiency imaging of detectors. Moreover the results it already produced have some implications on the way in which the experiments about detector tomography must be carried out.



(a) Analytical (b) 100 events

Figure 4: Sinograms obtained, for the detector shown on Fig.3 by using the fully analytical method or by generating 100 events.



(a) 500 events (b) 1000 events

Figure 5: Detector reconstructed with different number of random events.

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