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SIMULATION OF SILICON DETECTORS FOR THE ALICE EXPERIMENT AT LHC

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1 Introduction

Simulation of silicon detectors has been addressed in many papers for the last several years. Different aspects of the problem were investigated. All of them imply using a detailed "microsimulation" to describe relevant physical processes in details. This, in turn, can cause some difficulties when silicon detectors are considered as a part of a large detector.

In this paper we present a silicon simulation program written as a part of the "global" Monte Carlo of the ALICE experiment. We tried to reproduce the detector response with sufficient accuracy in order to create a useful tool for studies of tracking, pattern recognition and physics in ALICE.

2 General approach to silicon detector simulation within the GEANT3 frame

GEANT3 [1] has shown to be a powerful tool serving as a framework for a global Monte Carlo. But it may need some tuning for any given detector. For silicon detectors it means that physical processes of the scale of the strip pitch or pixel size should be reproduced. It means, in turn, that the tracking precision of particles has to be smaller than the strip pitch or pixel size. Within the GEANT framework it can be accomplished by ajusting cut-off energies of particles and step size of tracking [2-4]. It is necessary also to include other important processes such as diffusion of charge carriers and their deflection in the magnetic field.

The global Monte Carlo program should produce sets of raw data for further analysis. For events with high multiplicity (heavy ion collisions) it may create significant difficulties due to large amount of generated data. This problem can be handled by different methods (see for instance ref. [4]). We have chosen a more general way to do that within the standard "GEANT hit" approach. The scheme we have implemented is as follows. At the tracking stage information for each charged track is stored as a "one-track" cluster. At the digitization stage all "one-track" clusters are looked through and if overlapping clusters are found they are merged together to form "real" clusters. Then noise can be added and zero suppression performed.

3 Detector geometry and GEANT parameters

Description of the silicon tracker geometry of the ALICE detector can be found in ref. [5]. It includes five layers of silicon with the innermost layer being a pixel detector, next 3 layers being silicon drift detectors and the outermost one being a double - sided microstrip detector. The pixel detector has a pixel size of 75 μm in r-ϕ and 270 μm in z-direction, the silicon drift detector has the anode pitch of 250 μm (in r-ϕ) and the drift direction along the beam line, the double - sided microstrip detector has the strip pitch of 100 μm and a stereo angle of 30 mrad. For simplicity all layers are described as cylinders inside the GLHID package [6]. At present, a

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GEANT description of a passive material of the silicon tracker including support structure and cooling system from [7] is also available but has not been considered in this paper. We take all detectors to be analog devices, i.e. pulse height information was used in further analysis. Charge collected on anodes of the silicon drift detector is digitized every 25 ns. Parameters of the silicon are as follows:

• electron Hall effect mobility	0.165 T^{-1}	[8]
• hole Hall effect mobility	0.031 T^{-1}	[8]
• electron and hole diffusion coefficient (for pixel and microstrip detectors)	0.00433 cm/$\sqrt{cm}$	[8]
• electron diffusion coefficient (for drift detector)	30 cm^2/s	[8]
• electron drift velocity	6×10^{-4} cm/ns	[5]

It should be noted that we have disregarded processes affecting electrons in SDDs on their way from their origin in silicon to the drift plane and from the drift plane to the anode. However, this simplification affects results only for tracks passing near anodes.

We used GEANT version 3.15 and took 75 keV as a cut-off energy for particles corresponding to a δ-ray range of 25 microns and a maximum step size of 20 microns (GEANT parameter AUTO was set to 0 to disable automatic calculation of tracking parameters).

We described two sets of GEANT detectors for each active silicon side: the first one included some fixed length information for a track and the second one included charges from strips or pixels. Correspondingly, if a track "fired" a large number of strips or pixels several GEANT hits of the second type were stored for that track.

4 Some results of the simulation

In this section we present some results of the simulation of single track events to demonstrate the program performance. To produce them we used an obvious algorithm of cluster finding in silicon detectors, i.e a cluster was defined as any continuous group of charges exceeding some threshold value. We took the threshold to be equal to 0 for the case without noise added and $4\times\sigma_{noise}$ otherwise, where σ_{noise} is a standard deviation of the gaussian noise distribution equal to 500 electrons for the pixel and SDDs and 1240e^- for the microstrip (400e^- and 600e^- in LoI [5]).

Fig.1 shows a distribution of energy losses in the silicon detectors for muons with momentum of 5 GeV/c with normal incidence (without noise added). As can be seen the mean value of energy losses in silicon is close to the table one [9].

Distributions of x_{gen}-x_{reco} and z_{gen}-z_{reco}, where x_{gen}-x_{reco} and z_{gen}-z_{reco} are the differences of generated and reconstructed coordinates in azimuthal and along the beam line directions, are shown in figs. 2 and 3, respectively. These distributions were produced for muons with momenta of $6\div10$ GeV/c randomly distributed in angular intervals of $-180°\div180°$ in ϕ and $85°\div95°$ in θ. Reconstructed coordinate was found as a center of gravity of a charge distribution in a cluster. It can be seen that our results on resolution reproduce ones from the LoI [5] except maybe for the SDDs for the case with noise. Effect of the noise is significant for the SDDs due to the fact that we added uncorrelated noise contribution to each time/space bin. The time correlation for the electronics noise should be taken into account [10] and it will be the subject of our future study.

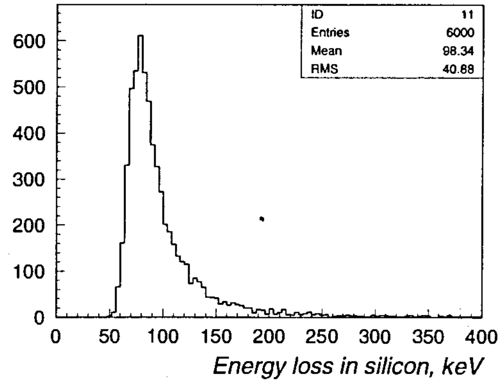

Figure 1: Distribution of ionization losses in the silicon detector for 5 GeV/c muons with normal angle of incidence.

Average cluster size values are shown in table 1 for the case with noise added.

Effect of long-range δ-electrons can be seen in fig.4 which shows coordinate difference versus number of strips in a cluster for the microstrip. Large clusters give "outsiders" and this fact has to be taken into account in order to introduce correct errors for track reconstruction and fitting.

Table 1: Average cluster size values for the silicon detectors (with noise added)

Detector	Cluster size	
	r-ϕ-coordinate	z-coordinate
pixel	1.2 (pixels)	1.1 (pixels)
SDD	1.9 (anode pads)	2.9 (FADC bins)
microstrip	1.1 (strips)	-

The centroid algorithm gives biased coordinate estimates for 2-strip clusters due to the fact that charge distribution has width much smaller than the strip pitch (in absence of δ-electrons charge released by a track has RMS of about 8 μm for the pixel and microstrip detectors). In ref. [11] an experimental procedure is described which improves the resolution for 2-strip clusters by taking into account the ratio of the charges from the strips. We achieved the same improvement using the ratio of the charges within a simple "theoretical" model of gaussian charge diffusion with known RMS. The improved result is shown in fig.5. It can be seen that

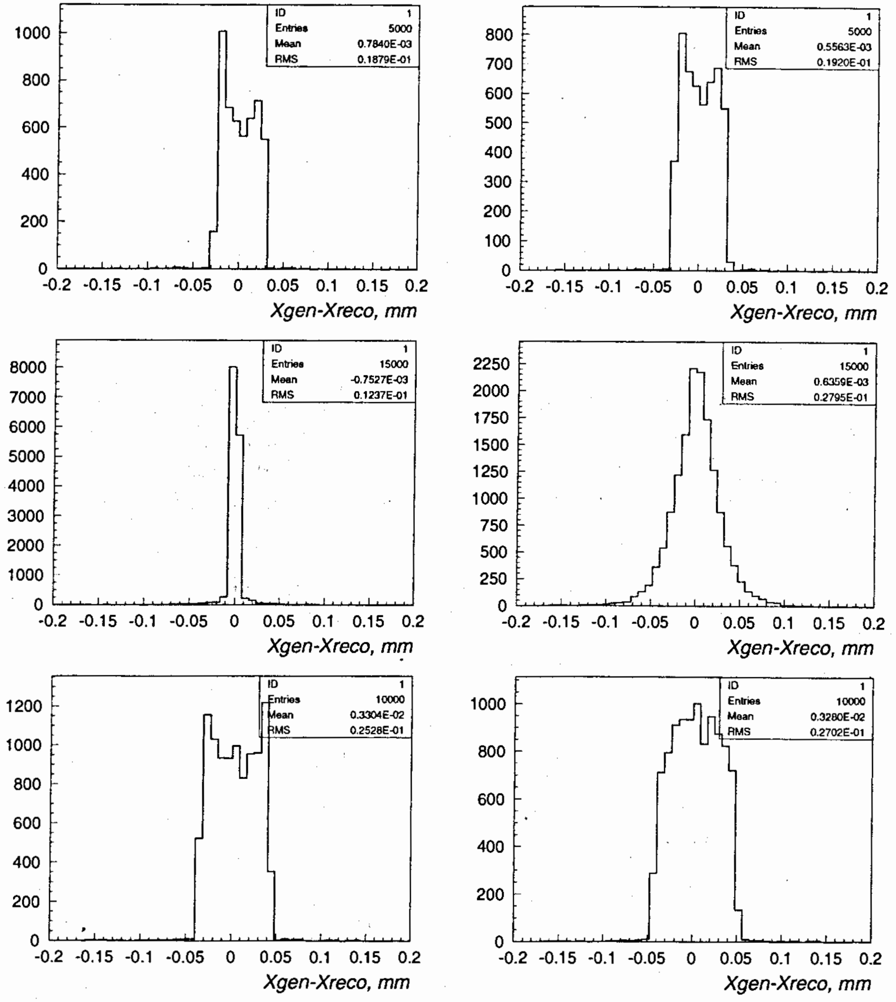

Figure 2: "x_{gen}-x_{reco}"-distribution for the silicon detectors: upper row - pixel, middle - SDDs, lower - microstrip; left column - without noise added, right - with noise.

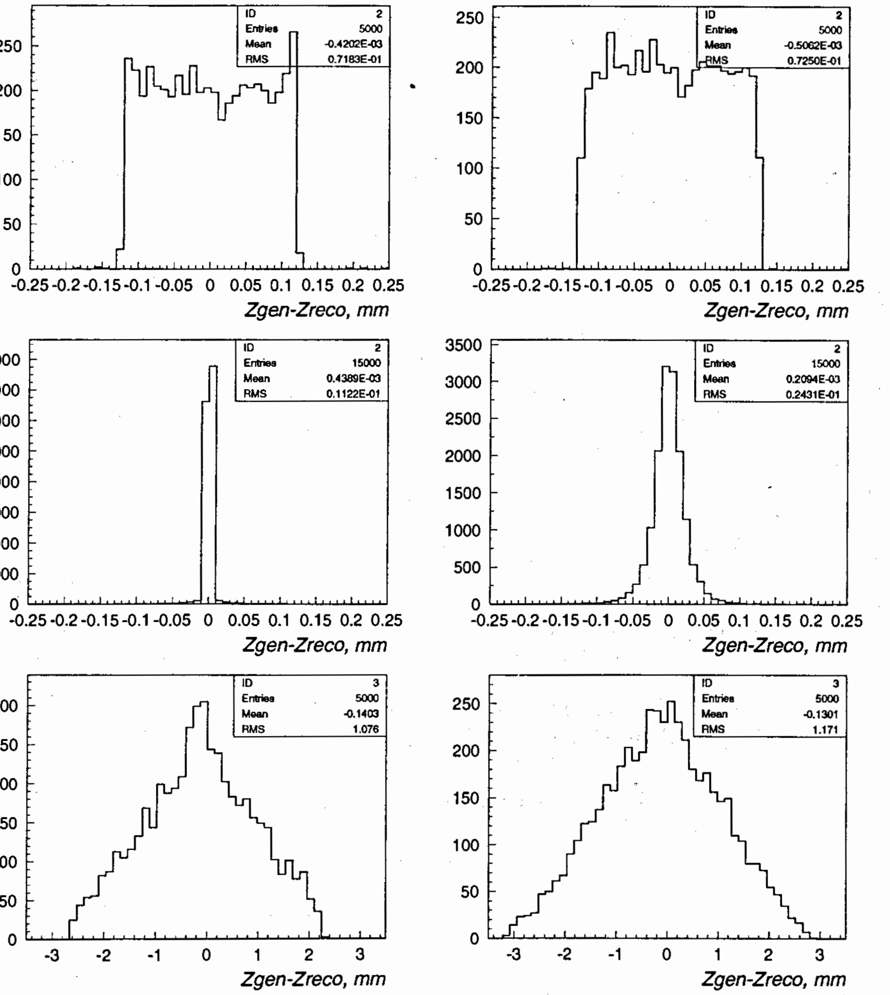

Figure 3: "z_{gen}-z_{reco}"-distribution for the silicon detectors: upper row - pixel, middle - SDDs, lower - microstrip; left column - without noise added, right - with noise.

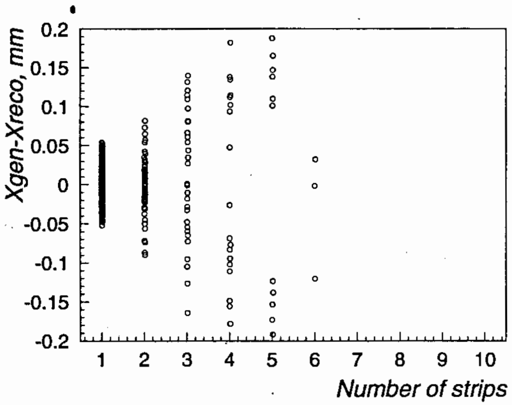

Figure 4: "x_{gen}-x_{reco}" as a function of the number of strips in a cluster for the microstrip detector

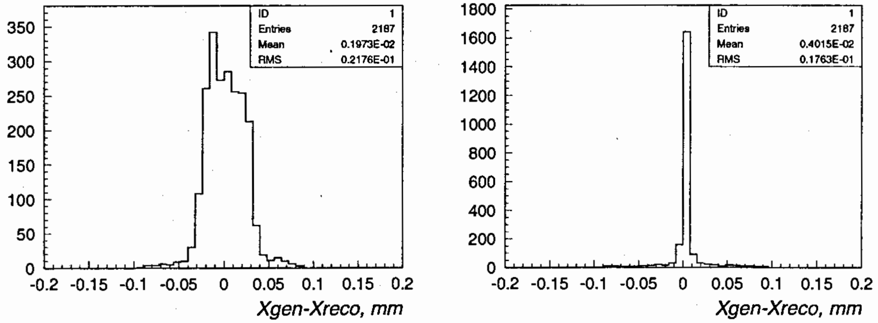

Figure 5: "x_{gen}-x_{reco}"-distribution for 2-strip clusters in the microstrip: left plot - centroid of a cluster, right - "gaussian" coordinate.

this simple correction gives significant improvement in resolution for 2-strip clusters.

5 Conclusion

The results presented in this paper show that the program of the silicon detector simulation described gives reasonable output. They also indicate some problems which should be taken care of at first stages of tracking.

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