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SIMULATION OF A CCD OUTPUT FOR A FULL DETECTOR SIMULATION IN THE JAVA ANALYSIS STUDIO

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Description of the code for simulation of CCD signals in the framework of the Java Analysis Studio is presented. This simulation package can give ideas about limits and optimization of a CCD based vertex detector in its spatial resolution, tracks separation, readout speed and other parameters. Along with simulation details, examples of the results obtained with described package are given.

1 Introduction

University of Oregon actively participated in the design and commissioning of the SLAC Large Detector (SLD) vertex detector (VXD3) upgrade [1]. Now we are involved in the R&D on a Charge Coupled Device (CCD) based vertex detector for the Linear Collider project - mainly in the study of radiation hardness of a CCD [2]. Our expertise in the field of CCD operation gives us the basis for realistic simulation of the signals from a CCD based detector. We believe that such a simulation will be essential for the detector design.

2 Simulated Effects

The main process in a CCD which needs to be simulated is the diffusion of the charge from a charged particle track. In a CCD the larger part of an active layer is not depleted, there is no electrical field in that part, and the charge collection occurs because of a slow diffusion of the charge into the CCD channel. In this case transversal diffusion has the same scale as the undepleted layer thickness. To simulate the diffusion, we assumed a Gaussian distribution of the probability of an electron generated at some point deep in the active layer to reach collection point at a certain distance from the projection of generation point. The width of this distribution is proportional to the depth of the generation point. In fact, there are two Gaussians here - one from electrons directly diffused toward the CCD channel, and another - from electrons, reflected at the epitaxial layer - substrate boundary, where there is a potential barrier.

An important role in the performance of a tracking detector is played by the generation of the δ-electrons (large energy transfer by the ionizing particle to a single electron). We simulated this effect by assuming, that the energy

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loss deposition in the Landau distribution "tail" is due to such δ -electrons.

Our simulation package also includes special functions for simulating low-energy electron (for example, Compton electron generated by photon) hits.

Apart from the physics effects in the silicon detector, its performance is affected by noise level of the readout electronics and the parameters of a signal digitization. All these effects have been also simulated.

3 Comparison Of Simulation With VXD3 Data

Cluster size distribution for simulated hits of charged particles and the same distribution from experimental (VXD3) data are shown in fig. 1. Average values agree very well, distribution shape is slightly different. However, we consider agreement sufficient for most applications.

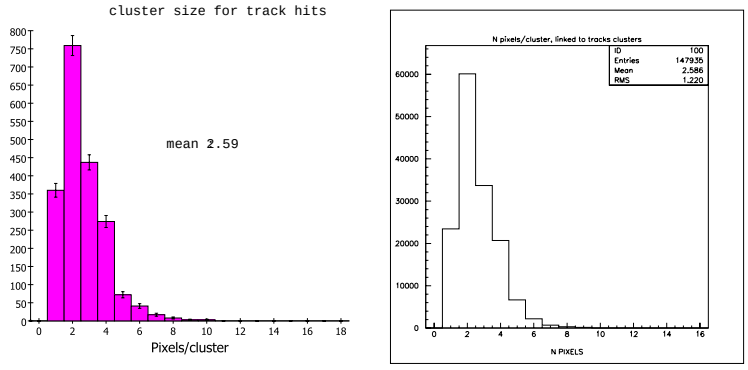

Figure 1: Comparison of cluster size distributions: simulated CCD hits - left and experimental from VXD3 data - right

4 Example of Practical Results

Fig.2 shows the dependence of the CCD spatial resolution for a CCD with 20 micrometer pixel size as a function of noise level. Because an electronics noise amplitude is proportional to a square root of the bandwidth, and readout bandwidth is proportional to number of pixels in a CCD, this simulation shows, that the reduction of pixel size may not improve the spatial resolution.

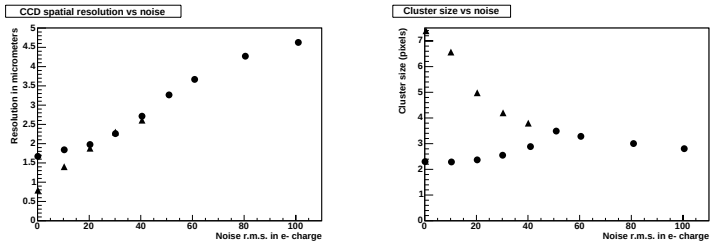

Figure 2: The spatial resolution vs. noise level - left and the cluster size vs. the noise level - right. Triangles are for the case where the pixel registration threshold is adjusted proportional to noise level, circles - when the pixel threshold is fixed

5 Package Use

User needs only to add 2 lines of code into his/her analysis to use it:

FullCCDSimulation fcs = new FullCCDSimulation();

add(fcs);

Of course, there are many access functions which allow user to change simulation parameters, such as the pixel size, the noise level and many, many more.

6 Conclusion

The software package for a full simulation of a CCD signals in the JAS framework is ready for the release.

References

1. SLD collaboration, "Design and performance of the SLD vertex detector, a 307 MPixel tracking system" *Nucl. Instrum. Methods* A**vol.400** (1997) p.287

2. James E. Brau, Olga B. Igonkina, Chris T. Potter, Nikolai B. Sinev "Investigation of Radiation Damage in the SLD CCD Vertex Detector" *IEEE Trans. Nucl. Sci.***vol.NS-51** (2004) p.1742