CCD digitization

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Plan

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Motivation

- Two reason to try full simulation of CCD response:
  - There is multidimensional space of CCD tracking characteristics , not just spatial resolution. To test limits on detector capabilities for doing physics, we need take into account all of them.
  - Full simulation is needed to optimize CCD design, as it reveals dependence of performance on design parameters.

Model

- It was discussed earlier: SD tracking meeting 6/6/2003
- Simulated effects: charge spread due to diffusion, contribution from δ-electrons, electronics noise

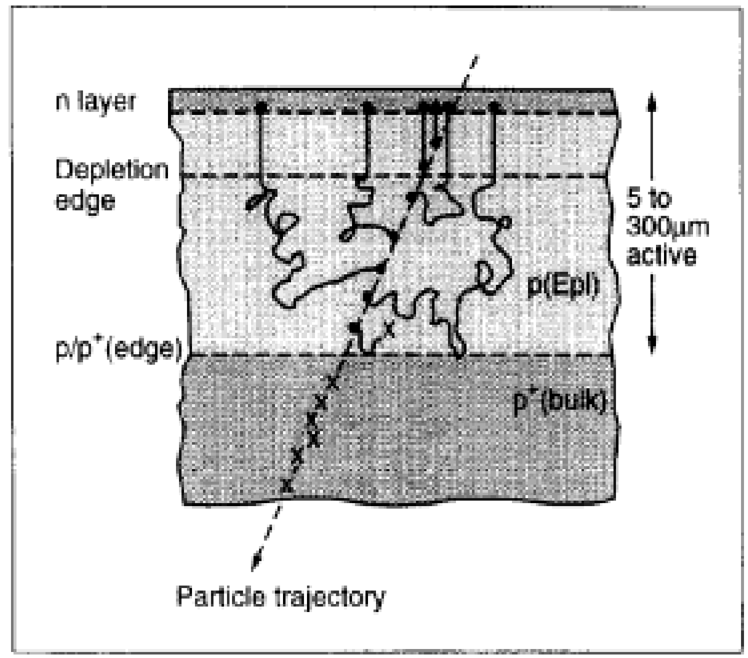


Fig. 24 Charge collection from a silicon structure as used in some pixel devices.

Implementation - mechanism

- Use pre-generated tables of the probability for the electron, generated at given point inside CCD active layer to be collected by given pixel.
- Simulate Landau distribution for total charge deposit, uniformly spread it along track length for small deposits, and generate single δ-electron if deposit exceeds preset threshold. δ-electron position on the track is random, and all ionization deposit from it to be in one point

Implementation - programming

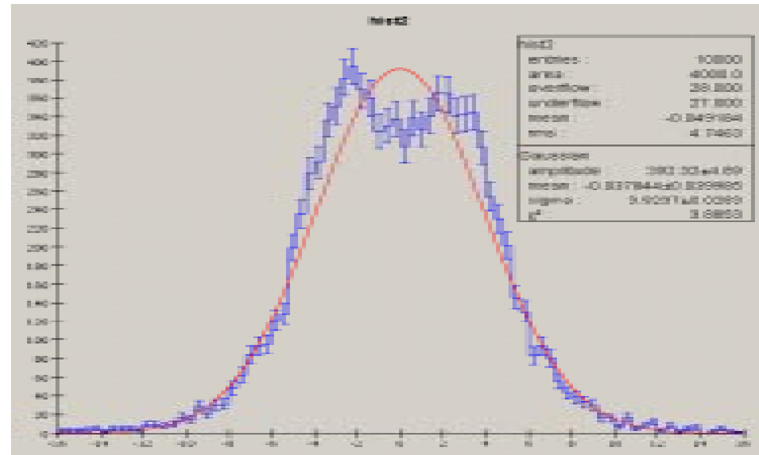
- Stand alone Java program and JAS event generation task.
- Parameters – user level, like: depletion depth, epitaxial depth, pixel size, noise level, ADC scale and model level, like: diffusion distribution parameters, δ-electron generation threshold.

Clustering and center finding algorithm

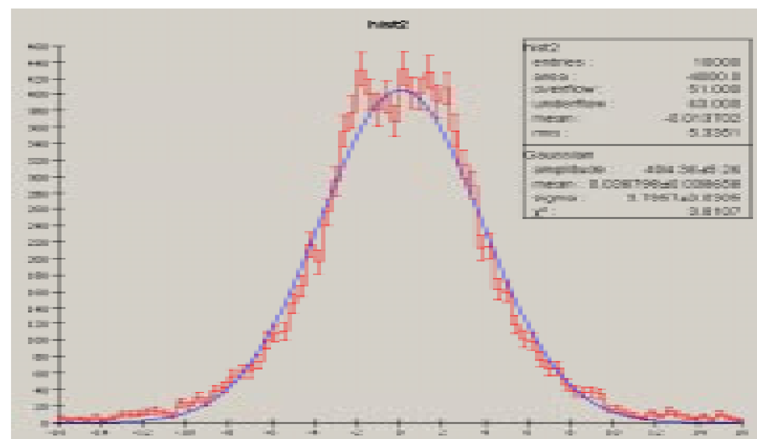
- So far, now cluster splitting algorithm has been implemented. Any continuous blob of pixels is considered one cluster. Pixel and cluster thresholds are applied.
- Center finding requires more discussion – see next slides

Center finding

- Simplest – center of gravity. SLD tried to improve it by reducing largest signal weight. The plots show difference in residual distributions (using described here simulation). CCD parameters and electronics noise were chosen close to VXD3 detector.



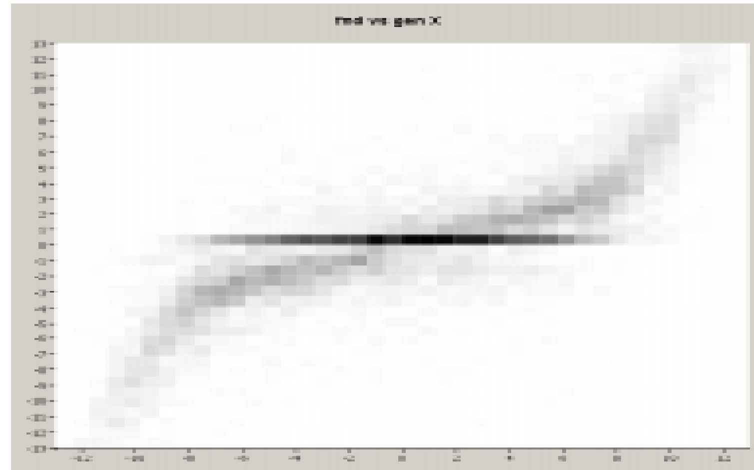
Just center of gravity. σ = 3.92μm



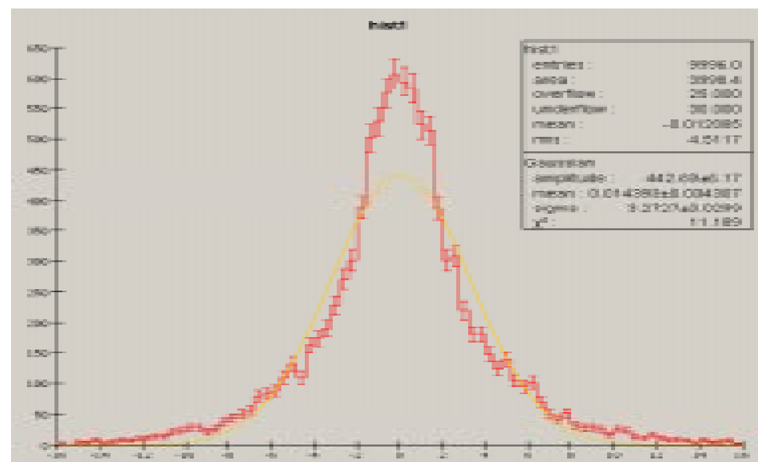
SLD method. σ = 3.79μm

Center finding - more

- We can use more sophisticated method: we can calibrate response function (found vs generated center coordinates dependent on position relative to pixel center)



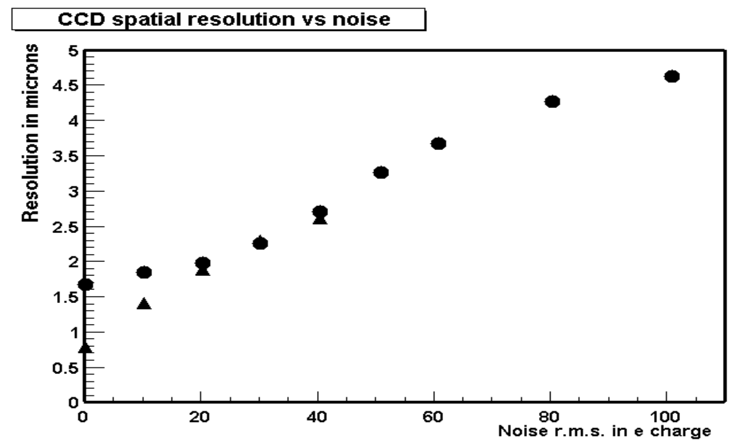
Found vs generated track coordinate

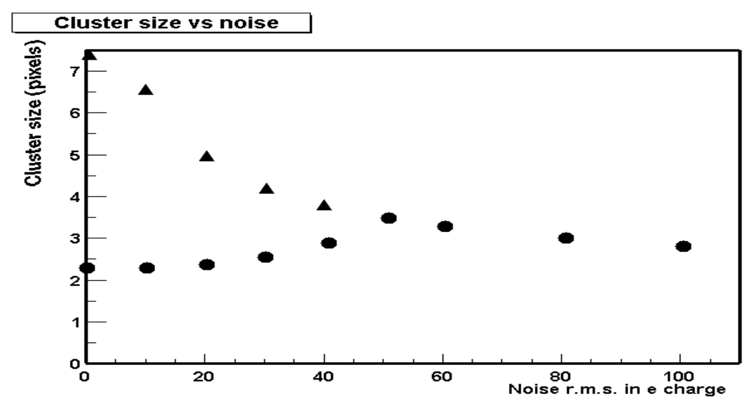


Residuals distribution for response calibration method. σ = 3.27μm

Some examples – noise dependence of spatial resolution

- CCD spatial resolution as function of electronics noise:
  - a) keeping same cluster size by having same pixel threshold for low noise level (circles)
  - b) adjusting pixel threshold to 1.5 of noise level (triangles)





If we want better resolution

- As seen from previous page – we need better signal/noise ratio. To increase signal – increase epitaxial layer thickness, reduce output node capacitance. To reduce noise – better electronics or slower readout. Because readout speed depends on number of pixels in CCD and number of output channels per CCD, reduction of pixel size does not improve resolution, if we do not increase number of output channels. See table on next page

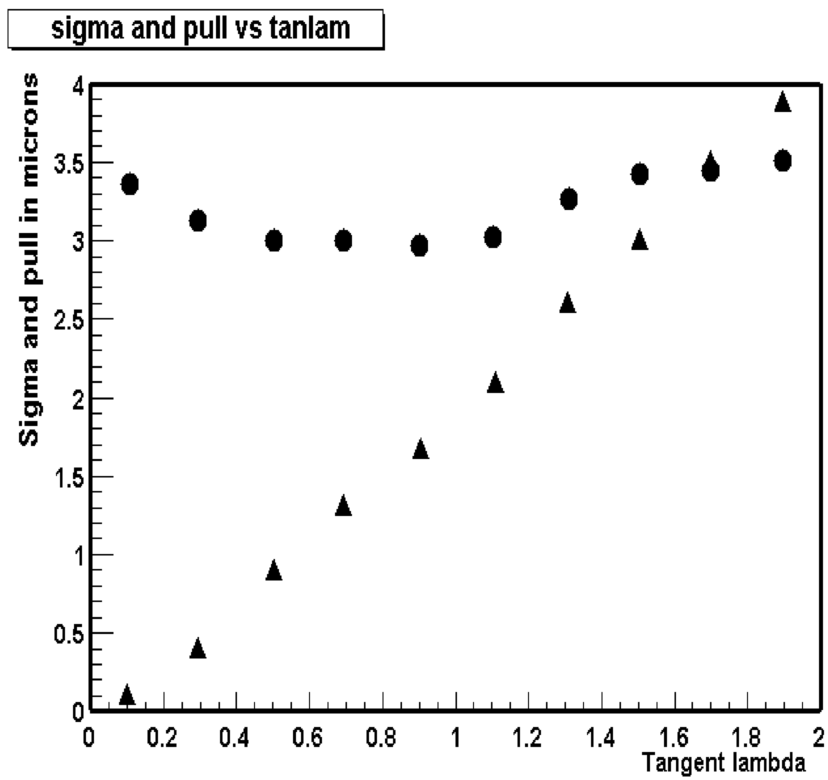
Example – pixel size dependence

Pixel size	Noise level	Resolution
10 μ	30 e	1.54 μ
20 μ	15 e	1.48 μ
30 μ	10 e	1.38 μ
40 μ	7.5 e	1.65 μ

- Increasing pixel size leads to slower readout, so smaller noise.

Example – angle dependence

- Large angle tracks have systematic error in their CCD cluster center position (pull – triangles on the plot) due to different diffusion from different parts of track. Statistical error estimated as sigma of fitting gaussian does not tell the whole story, because at large angles there are increased long tails, which are not affecting fit too much.



Future plans

- Standalone simulation gives us tool to optimize detector performance to achieve desired parameters. It does not provide means to test physics impact of such parameters. So, including CCD digitization into full JAS based simulation is the goal. It requires some changes in the event simulation output – for example, not only hit positions, but track angle relative to CCD surface need to be stored.