Silicon micro-strip detector response simulation for the CBM experiment

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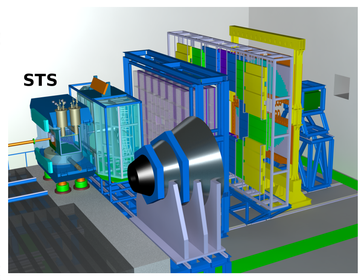
Compressed Baryonic Matter experiment and its Silicon Tracking System

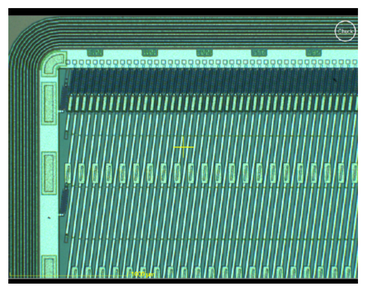
CBM experiment:

- QCD-diagram at moderate temperature and high density;
- Au + Au @ 2-11 AGeV, $10^5 - 10^7$ interactions/s;
- up to 1000 charged particles per central collision.



STS is a main tracking detector:

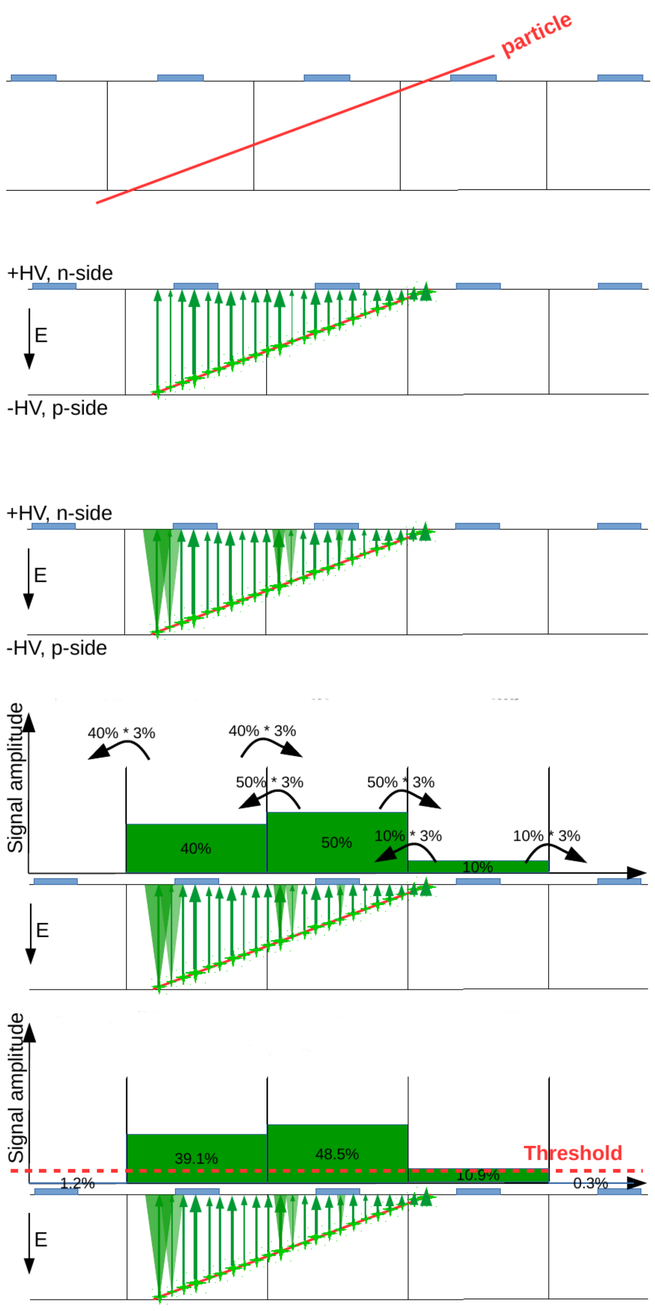
- high efficiency;
- fast: hit rates up to $20\ \mathrm{MHz/cm^2}$;
- radiation hard: $10^{14}\ \mathrm{n_{eq}/cm^2}$;
- low mass: material budget per station $\sim 1\%\ X_0$;



Characteristics:

- double-sided micro-strip Si sensors: $285\ \mu m$ thick, $58\ \mu m$ strip pitch;
- 7.5° stereo-angle between front and back side strips;
- fast self-triggered read-out electronics.

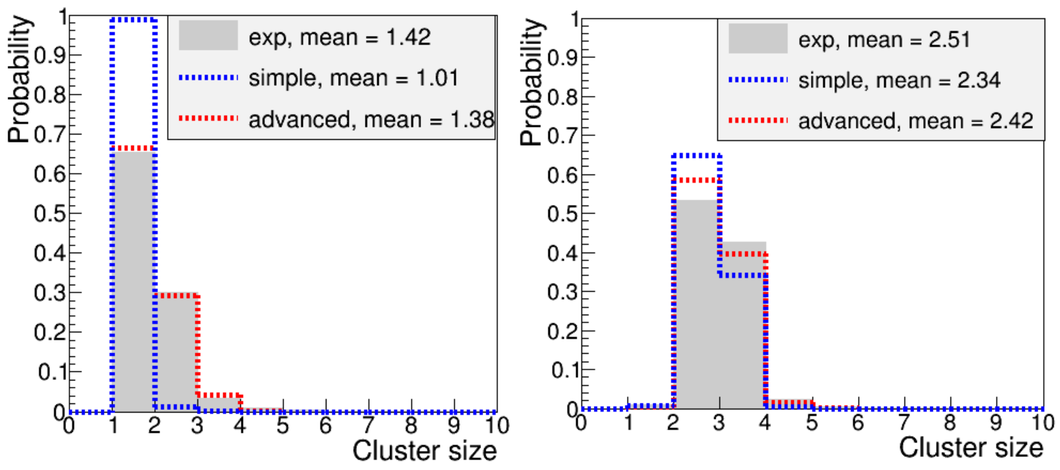
Detector response model



- an incident particle traverses the sensor;
- the particle **non-uniformly** looses its energy creating e-h;
- in each $3\mu m$-layer of trajectory energy loss is modeled with **Urban method**;
- e-h pairs move in **perpendicular direction** due to thermal diffusion;
- non-uniformity in $\vec{E}$ close to strips is neglected;
- cross-talk – a charge redistribution over the read-out channels due to **interstrip** capacitance;
- Gaussian noise model;
- optimal threshold level is 3σ of noise.

Experimental verification

Experiment: 2 GeV protons.
The **advanced** detector response model (presented) agrees better with experimental data than the **simple** model (uniform projection of particle trajectory + noise + threshold).

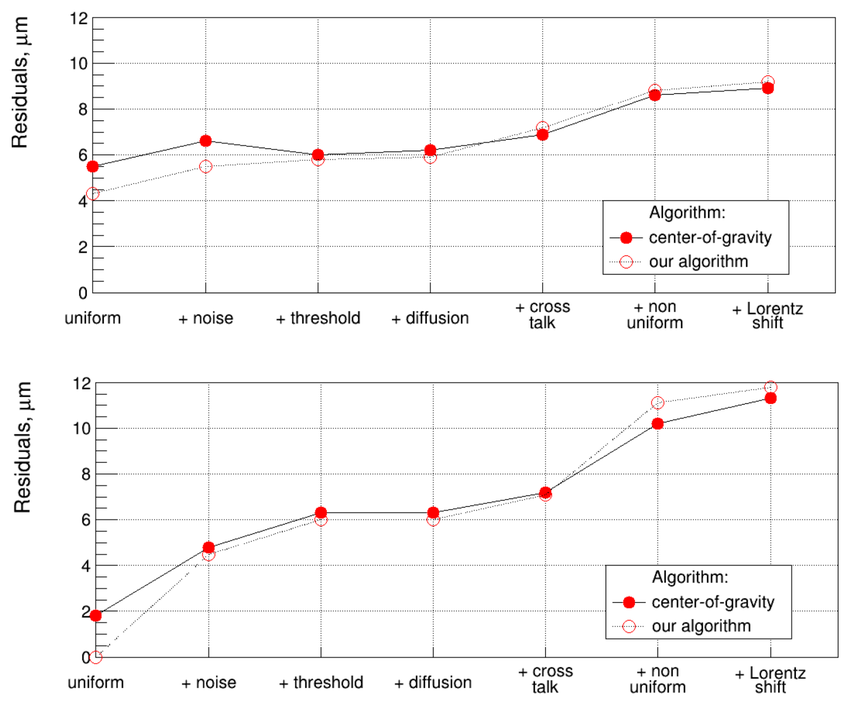


Cluster size distribution for perpendicular tracks (left) and 20°-tracks (right).

Cluster position $\mathrm{x_{rec}}$ finding algorithms

Center-Of-Gravity algorithm: $x_{rec} = p \cdot \frac{\Sigma x_i q_i}{\Sigma q_i}$, $i = 1..n$, n – cluster size, p – strip pitch, x_i – number of ith strip, q_i – charge registered on strip i.
Our algorithm:
for 2-strip clusters: $x_{rec} = \frac{p}{2}(x_1 + x_2) + \frac{p}{3}\frac{q_2 - q_1}{max(q_1, q_2)}$.

for bigger clusters: $x_{rec} = \frac{p}{2}(x_1 + x_n) + \frac{p}{2}\frac{q_n - q_1}{q}$, $q = \frac{1}{n-2}\sum_{i=2}^{n-1} q_i$.



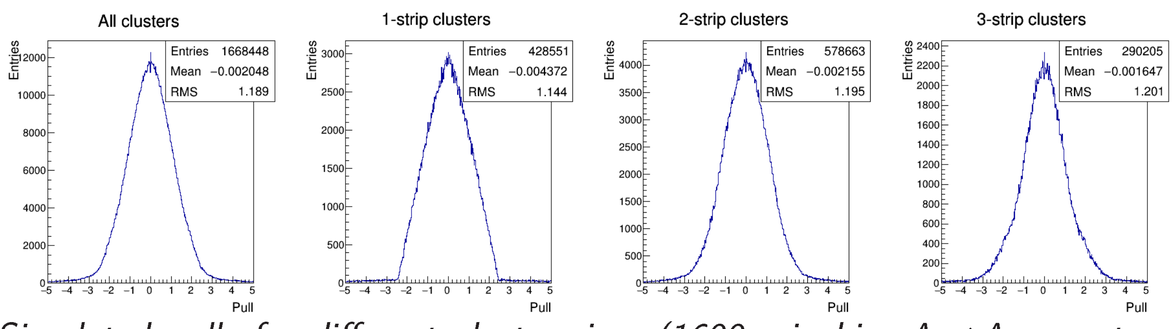
Simulation of cluster position residuals taking into account different physical processes one-by-one for 2-strip (top) and 3-strip (bottom) clusters.

Cluster position error estimation

- $\sigma^2 = \sigma^2_{algorithm} + \sum_{strips}\left(\frac{\partial x_{rec}}{\partial q_i}\right)^2 \sum_{sources} \sigma_j^2$;
- Considered sources of errors: noise, discretization, non-uniform energy loss:
- Sources TBA: diffusion, Lorentz shift, threshold, cross-talk.

To verify errors, pull distribution is used: $\mathrm{pull} = \frac{\mathrm{residual}}{\mathrm{error}}$

- the shape must reproduce shape of residuals;
- the width must be ≈ 1.



Simulated pulls for different cluster sizes (1600 min bias Au+Au events at 10 AGeV).

Summary

- Presented **detector response model** significantly improves the agreement with experimental data.
- Presented cluster **position finding algorithm** has similar residuals as the COG algorithm but considerably simplifies error estimation.
- Developed method of cluster **position error estimation** yields correct pulls (width and shape).