Hit Reconstruction in the CBM Silicon Tracking System

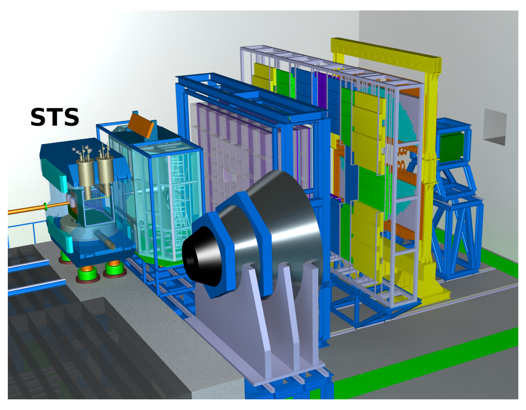
Hanna Malygina[1,2,4], Volker Friese[2], Maksym Zyzak[2,3] for the CBM Collaboration

[1]Goethe University, Frankfurt; [2]GSI, Darmstadt; [3]FIAS, Frankfurt; [4]KINR, Kyiv

The Compressed Baryonic Matter experiment and its Silicon Tracking System

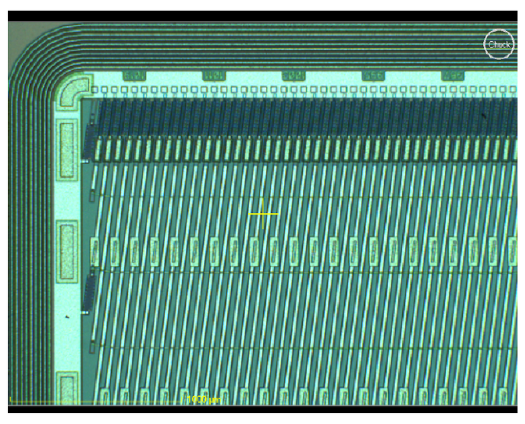
CBM experiment:

- 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 requirements:

- momentum resolution $\lesssim 1.5\,\%$;
- high reconstruction efficiency;
- fast: hit rates up to 20 MHz/cm^2;
- radiation hard: 10^{14} 1 MeV n_{eq}/cm^2;
- low material budget $\sim 1\,\%\,X_0$/station.



STS design:

- 8 tracking stations in 1 T field;
- double-sided micro-strip Si sensors: $\sim 300\,\mu$m thick, 58 μm strip pitch;
- 7.5° stereo-angle between front and back side strips;
- fast free-streaming r/o electronics.

Detector response model

- non-uniform energy loss of incident particle modelled with **Urban method** on discretised trajectory;
- drift of created e-h pairs in **planar** E-field and **Lorentz-shift** in B-field;
- spread out of the charge carriers cloud due to **thermal** diffusion;
- cross-talk — charge redistribution over the read-out channels due to **inter-strip** capacitance;
- read-out electronics modelling: Gaussian noise, threshold $= 3\sigma$ of noise, dead time and time resolution, charge discretisation.

Cluster position x_{rec} finding algorithms

Center-Of-Gravity algorithm:

$$x_{rec} = p\frac{\Sigma x_i q_i}{\Sigma q_i}$$

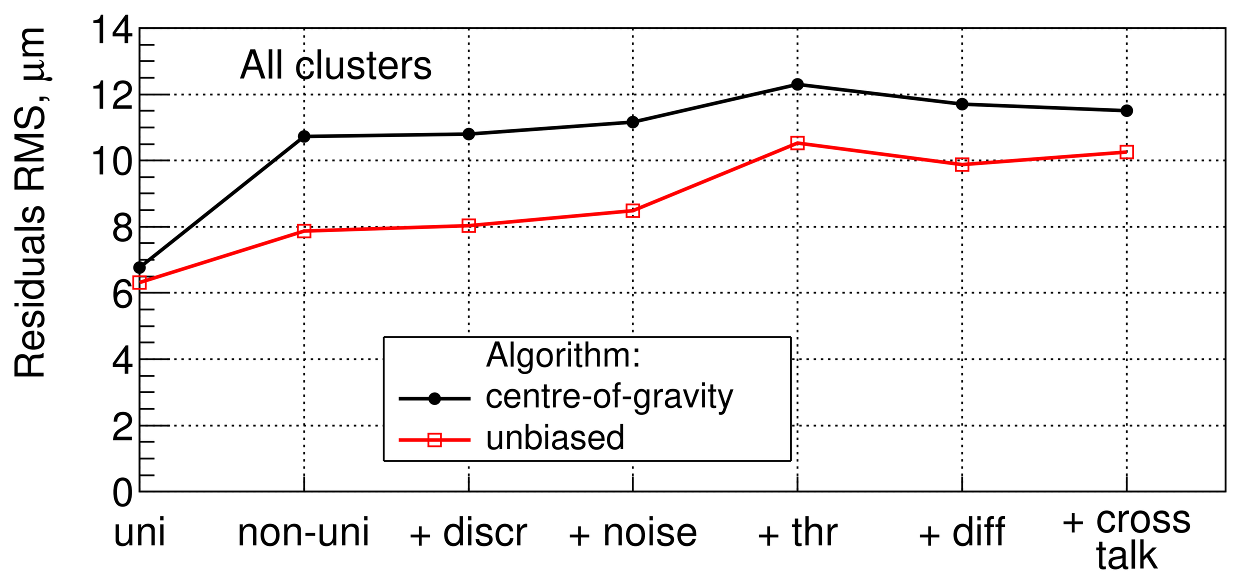
The unbiased algorithm:

$i = 1..n$
n – cluster size
p – strip pitch
x_i – position of strip i
q_i – charge on strip i

2-strip: $$x_{rec} = \frac{p}{2}(x_1 + x_2) + \frac{p}{3}\frac{q_2 - q_1}{\max(q_1, q_2)}$$

n-strip: $$x_{rec} = \frac{p}{2}(x_1 + x_n) + \frac{p}{2}\frac{\min(q_n, q) - \min(q_1, q)}{q}$$

R. Turchetta, 1993.



Simulation of cluster position residuals with ideal cluster finder taking into account different physical processes one-by-one for all cluster sizes. 1000 mbias Au+Au @ 10 AGeV

Unbiased *vs* Center-Of-Gravity:

- residuals obtained from both algorithms are comparable;
- unbiased algorithm is faster and simplifies position error estimation.

Position error estimation

- $\sigma^2 = \sigma^2_{\text{algorithm}} + \sum_{\text{strips}} \left(\frac{\partial x_{rec}}{\partial q_i}\right)^2 \sum_{\text{components}} \sigma_j^2$;
- Considered contributions:

– unbiased algorithm:

$$\sigma_{1\text{-strip}} = \frac{p}{\sqrt{24}},\ \sigma_{2\text{-strip}} = \frac{p}{\sqrt{72}}\left(\frac{|q_2 - q_1|}{\max(q_1, q_2)}\right),\ \sigma_{n\text{-strip}} = 0;$$

– noise: σ_{noise} = equivalent noise charge;

– charge discretisation: $\sigma_{discr} = \frac{\text{dynamic range}}{\sqrt{12}\ \text{number of ADC}}$;

– diffusion: negligible;

– non-uniform energy loss: needs assumptions:

∗ registered charge corresponds to the MPV of the energy loss;

∗ incident particle is ultrarelativistic.

$$\text{MPV} = \xi[\text{eV}] \times \left(\ln\left(1.057 \times 10^6 \xi[\text{eV}]\right) + 0.2\right) \Rightarrow \sigma_{non} = 4.018\xi/2.$$

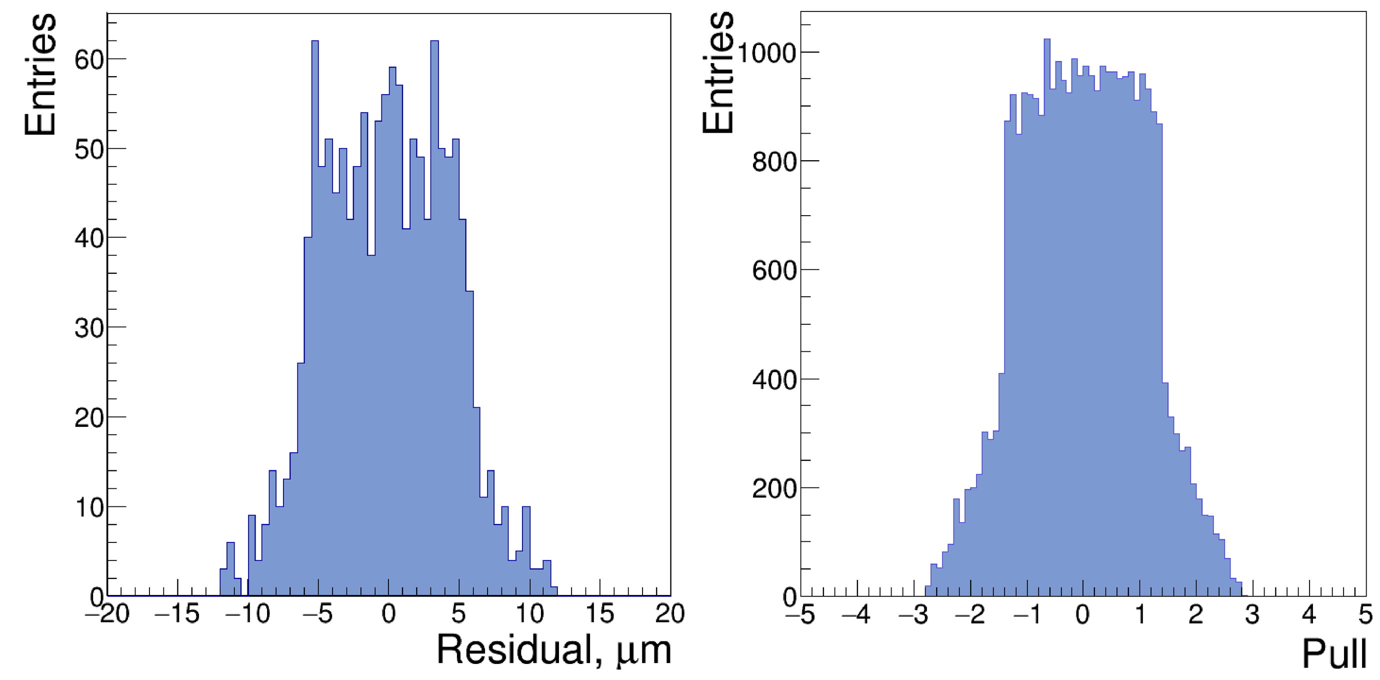
S. Meroli, D. Passeri, and L. Servoli, 2011.

- Contributions TBA: Lorentz shift, threshold, cross-talk.

Hit position error verification

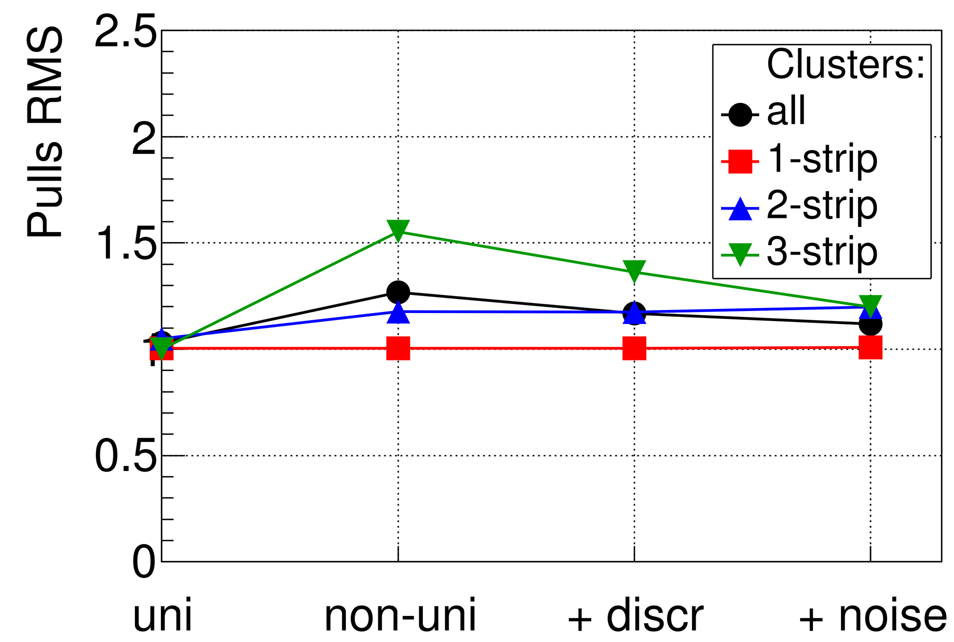
- hit **pull distribution**: pull $= \frac{\text{residual}}{\text{error}}$;

– its shape must reproduce the shape of residuals;



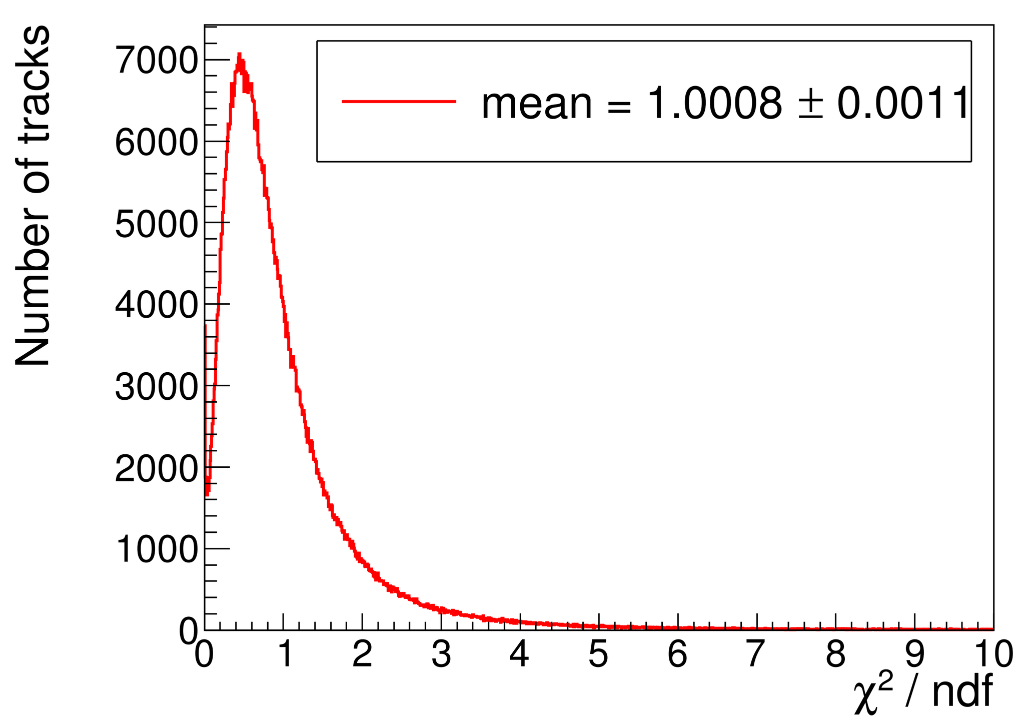
Residuals (left) and pulls (right) for 2-strip clusters at fixed q_1 and q_2 simulated with ideal detector.

– its width must be ≈ 1.



Pull width change with different physical processes taken into account. 1000 mbias Au+Au @ 10 AGeV

- χ^2 **distribution** for tracks: mean value must be ≈ 1;



χ^2-distribution with the described method of error estimation. 20 000 mbias Au+Au @ 10 AGeV

Summary

- Implemented unbiased cluster **position finding algorithm**:

– has residuals ⩽ the Center-Of-Gravity residuals;

– considerably simplifies position error estimation.

- Developed **position error estimation** method is verified by:

– width and shape of the hit pull distribution;

– track χ^2 distribution.

Contact

Hanna Malygina: h.malygina@gsi.de