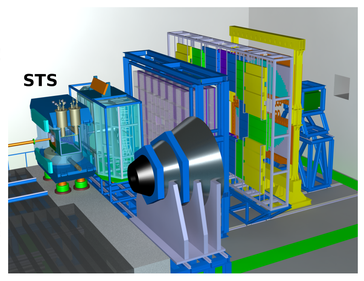
Realistic Hit Reconstruction in the CBM Silicon Tracking System

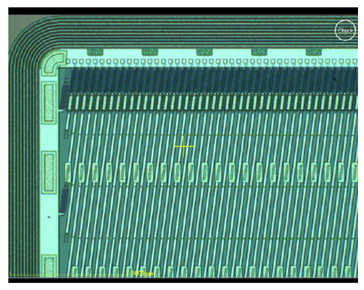
Hanna Malygina[1,2,4], Volker Friese[2], Maksym Zyzak[2,3]
[1]Goethe University, Frankfurt; [2]GSI, Darmstadt; [3]FIAS, Frankfurt; [4]KINR, Kyiv

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



STS design:
- 8 tracking stations in 1 T field;
- double-sided micro-strip Si sensors: $\sim$ 300 μm thick, 58 μm strip pitch;
- 7.5° stereo-angle between front and back side strips;
- fast self-triggered ro electronics.

Detector response model

- non-uniform energy loss of a 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 with time due to **thermal** diffusion;
- cross-talk — a charge redistribution over the read-out channels due to **interstrip** 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:

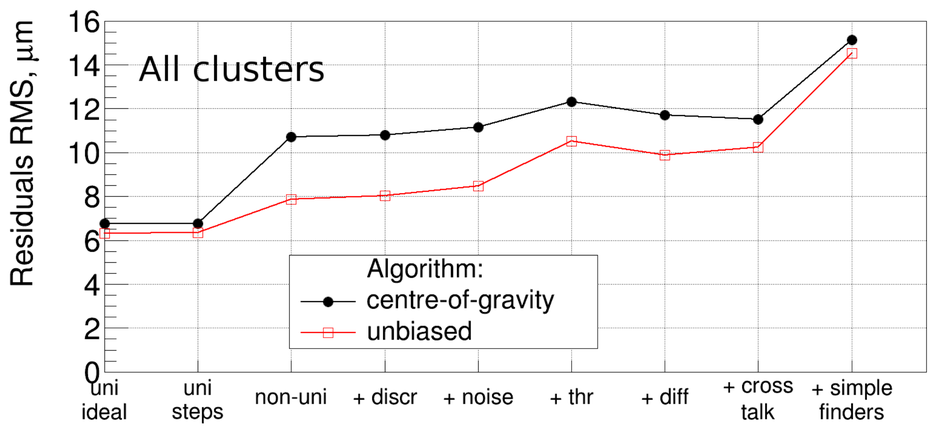
$$x_{rec} = p\frac{\Sigma x_i q_i}{\Sigma q_i}$$

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

The unbiased algorithm:

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 taking into account different physical processes one-by-one for all cluster sizes.

Unbiased *vs* Center-Of-Gravity:
- performance of both algorithms are comparable;
- unbiased algorithm is faster and simplifies position error estimation.

Position error estimation

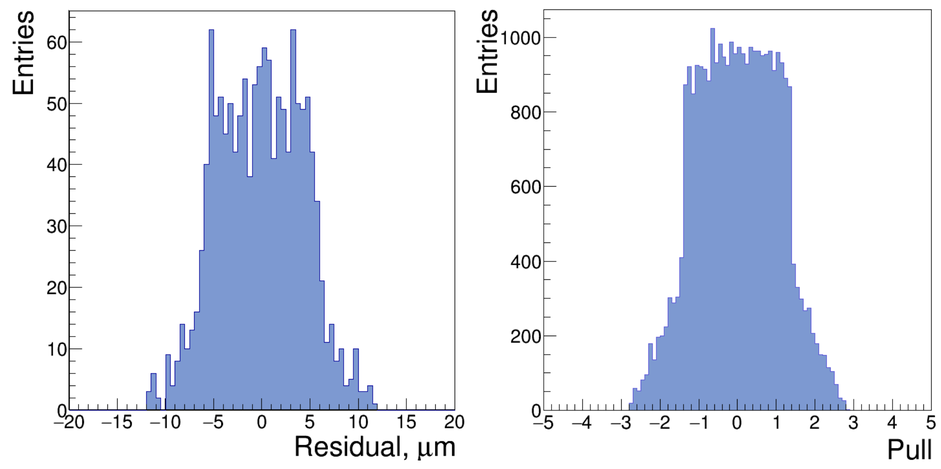
- $\sigma^2 = \sigma^2_{algorithm} + \sum_{strips}\left(\frac{\partial x_{rec}}{\partial q_i}\right)^2 \sum_{components} \sigma_j^2$;
- Considered contributions of error:
  - unbiased algorithm:
    $\sigma_{1\text{-strip}} = \frac{p}{\sqrt{24}}$, $\sigma_{2\text{-strip}} = \frac{p}{\sqrt{72}}\left(\frac{q_2 - q_1}{\max(q_1, q_2)}\right)$, $\sigma_{n\text{-strip}} = 0$;
  - noise: σ_{noise} = equivalent noise charge;
  - 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.

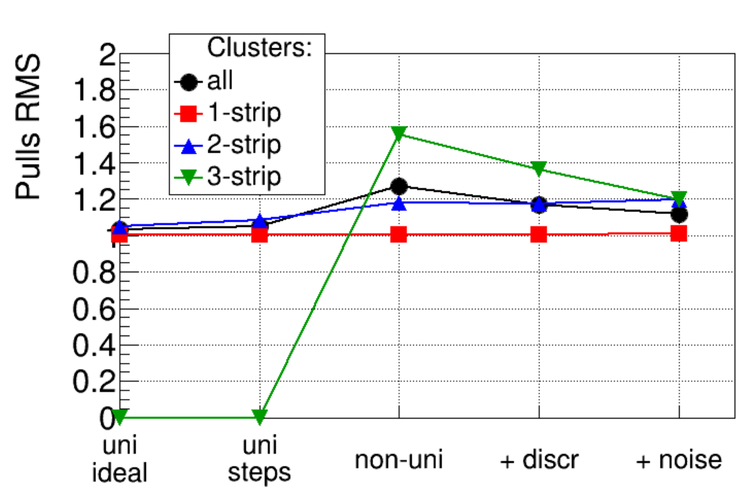
Error verification

- **pull distribution**: $\text{pull} = \frac{\text{residual}}{\text{error}}$:
  - its shape must reproduce the shape of residuals;



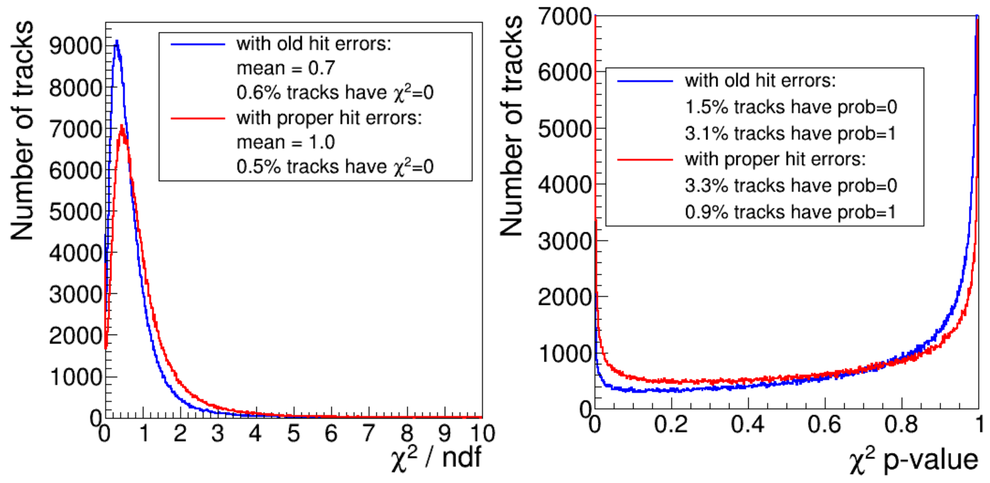
Residuals (left) and pulls (right) for 2-strip clusters at fixed q_1 and q_2.

  - its width must be ≈ 1.



Pull width when taking into account different physical processes.

- χ^2 **distribution** for tracks:
  - mean value must be ≈ 1;
  - prob = 1 - CDF (cumulative distribution function) — must be flat.



χ^2-distribution (left) and prob of it (right) using the described method of error estimation (red) and the old simplified one (blue).

Summary

- Implemented unbiased cluster **position finding algorithm**:
  - has residuals $\leqslant$ the Center-Of-Gravity residuals;
  - considerably simplifies error estimation.
- Developed **position error estimation** method:
  - gives expected width and shape of pull distribution;
  - yields χ^2 distribution and its probs.

Contact

Hanna Malygina: h.malygina@gsi.de