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LS Schaile • Chair of Experimental Particle Physics •
Bernhard Flierl

Improvement of Spatial Resolution by Full Muon Track Reconstruction in Gaseous Detectors

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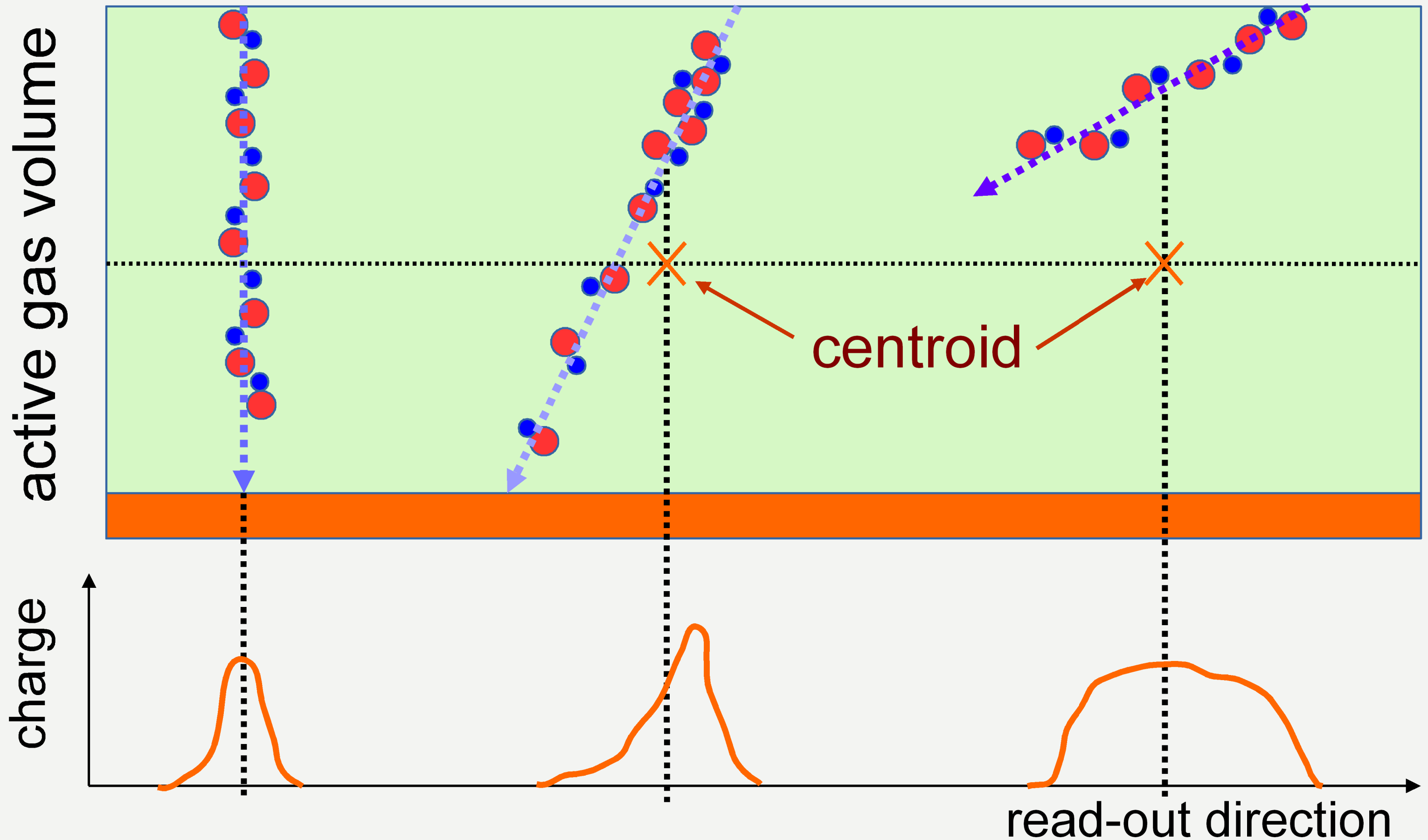
Motivation

Tracks from ionizing particles



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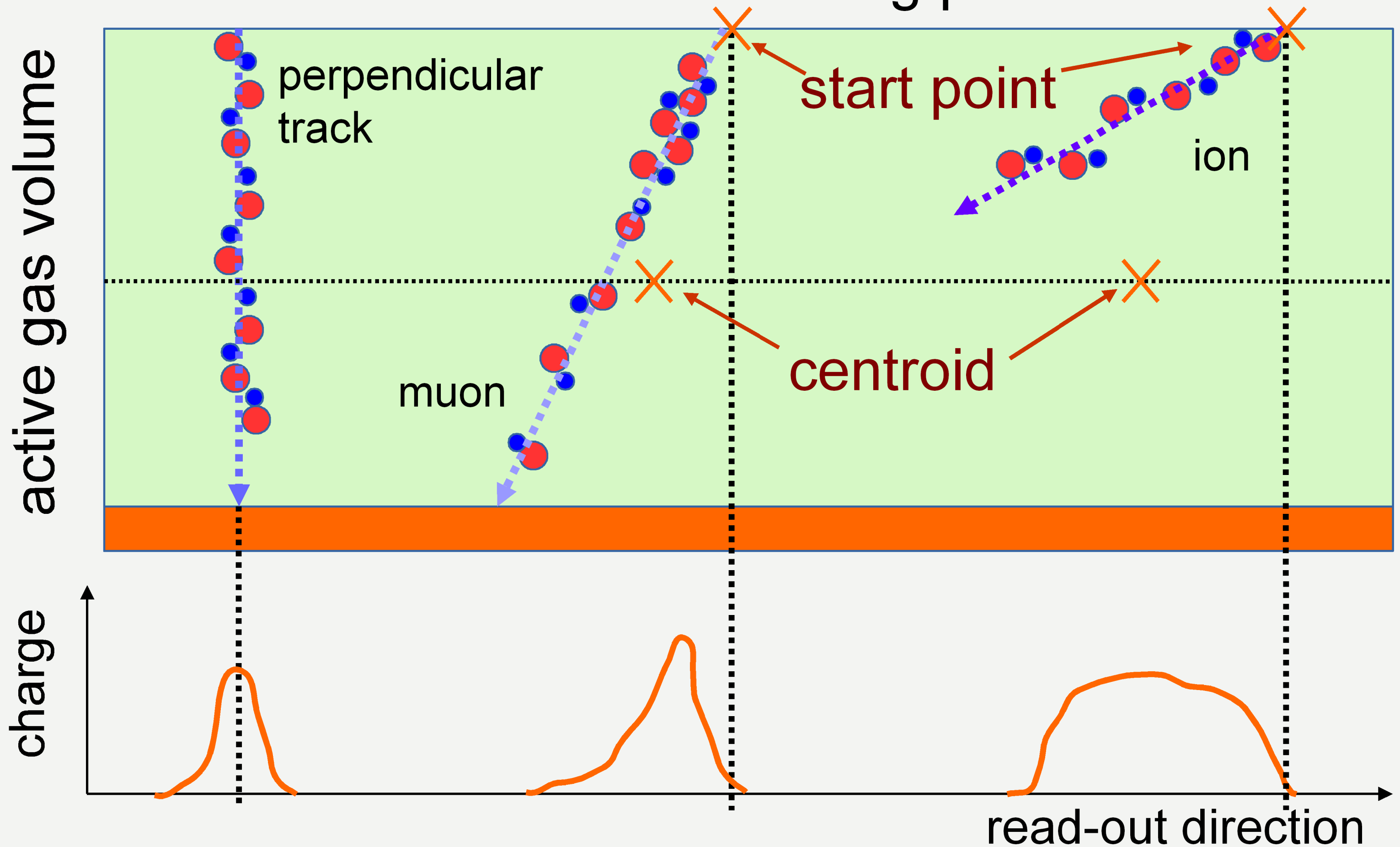
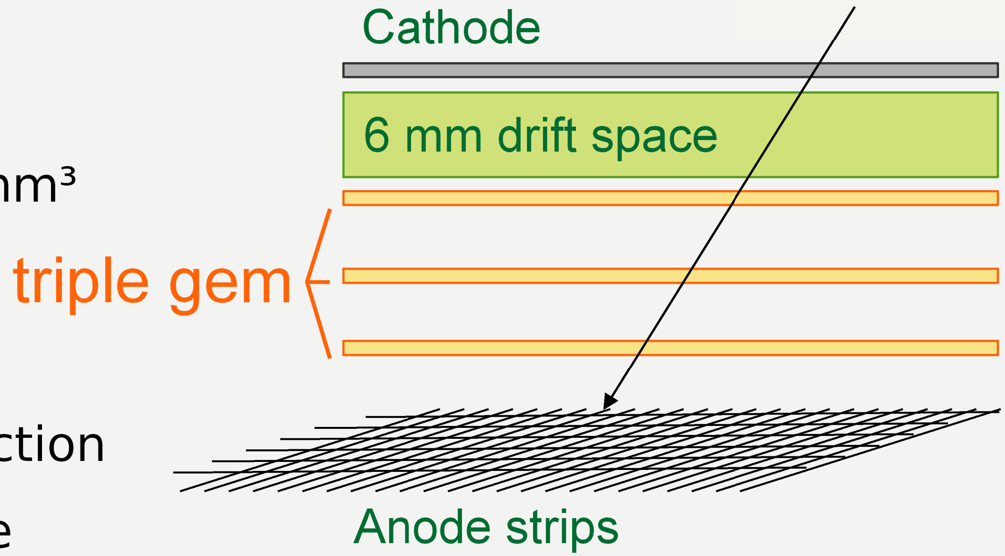
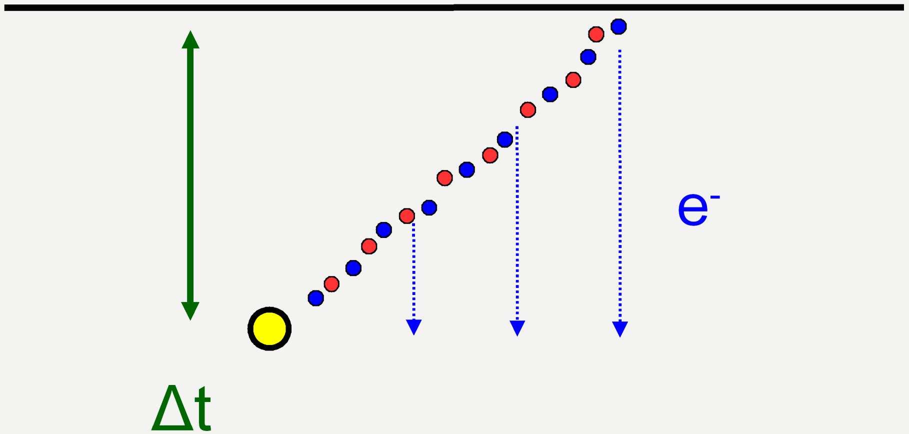
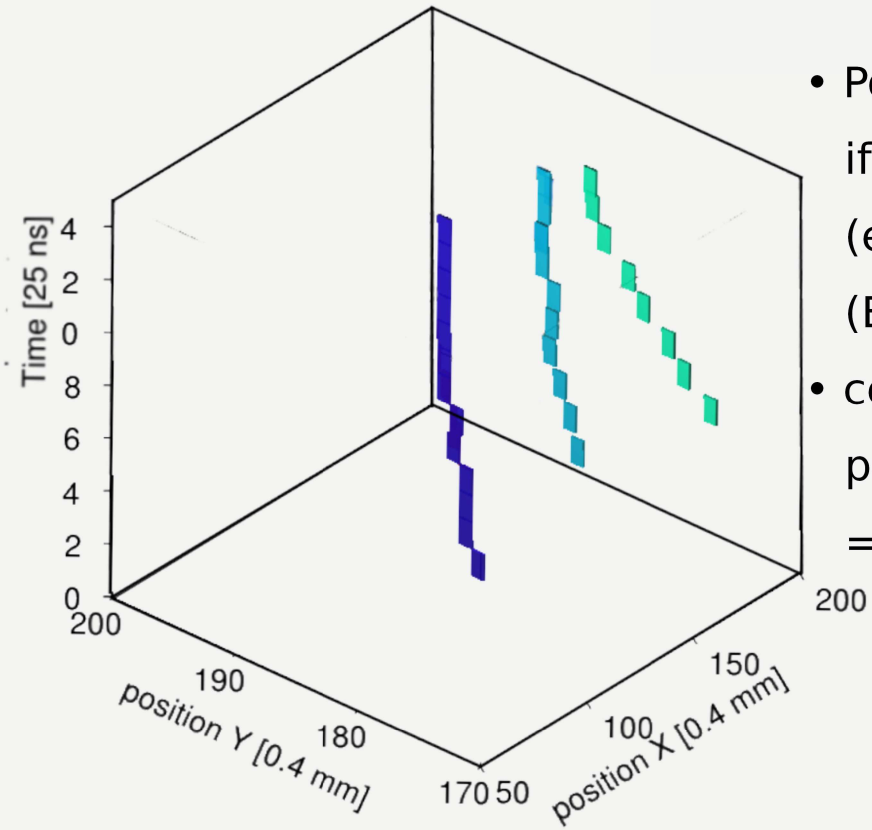


GEM-detector

- triple GEM detector 100x100x6 mm^3 active volume
- used as Time-Projection chamber
- crossed read-out strips in X-Y direction
- APV25 based time resolving single strip read-out

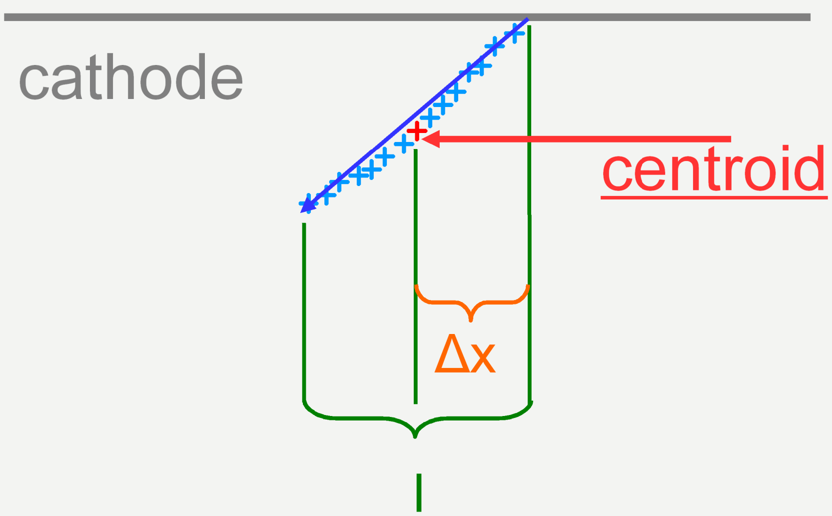






reconstructed events

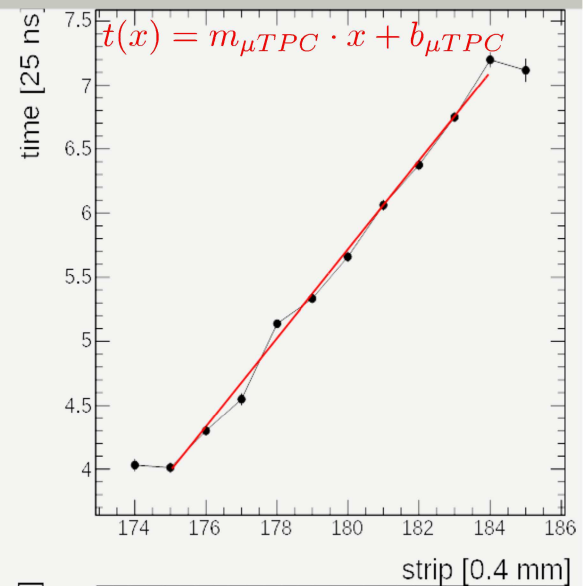
- Point of interaction in cathode plane wanted if secondary particle created in conversion layer (e.g photo-electrons, spallation fragments (B+n→ Li+He))
- centroid measurement distorts point of interaction by ~ 0.5 track length => reconstruction of start position necessary



Origin-Reconstruction

- Track inclination measured by arrival time of electrons

$$\tan\theta_{\mu TPC} = \frac{1}{m_{\mu TPC} \cdot v_{drift}}$$



- Charge distribution on strips measured

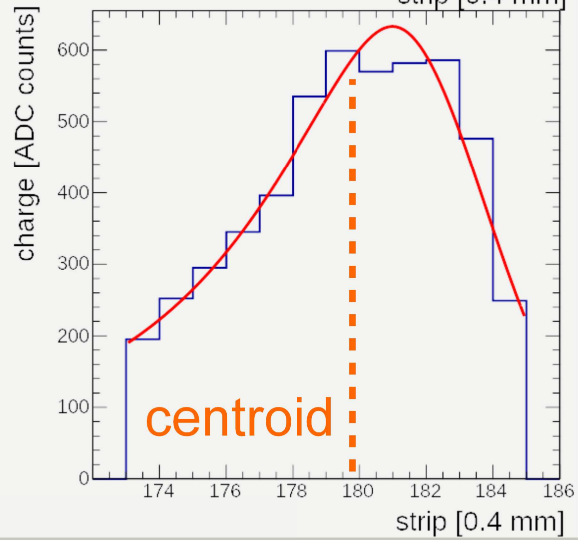
  => centroid, track length, charge per strip

  & charge skewness (projected in readout directions)

- Reconstruction of track projection in both read-out directions separately

  → reconstruction of two angles and one point

  → Full track Reconstruction



Origin-Reconstruction

$$\Delta x = sign(\theta)\left(a \cdot \sqrt{\left(\frac{l}{\Delta l}\right)^2 + l_0^2} + b \cdot \sqrt{\epsilon - \epsilon_0} + c \cdot m_{\mu TPC} + d\right)$$

θ = reconstructed track inclination angle

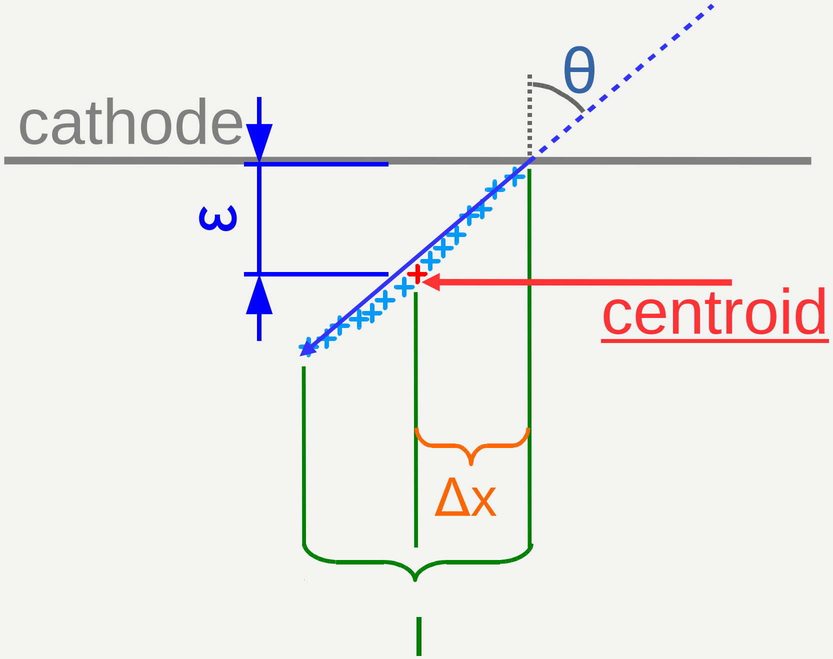
l = projected track length

Δl = mean projected distance from centroid to origin

l_0 = minimal projected cluster size

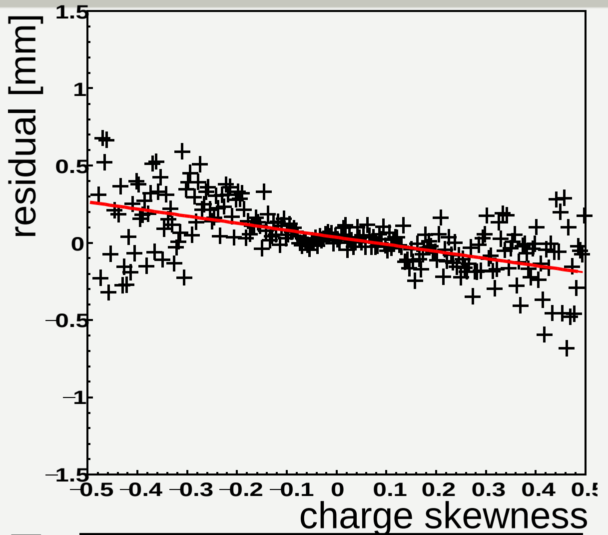
ε and ε_0 = skewness and mean skewness of charge distribution

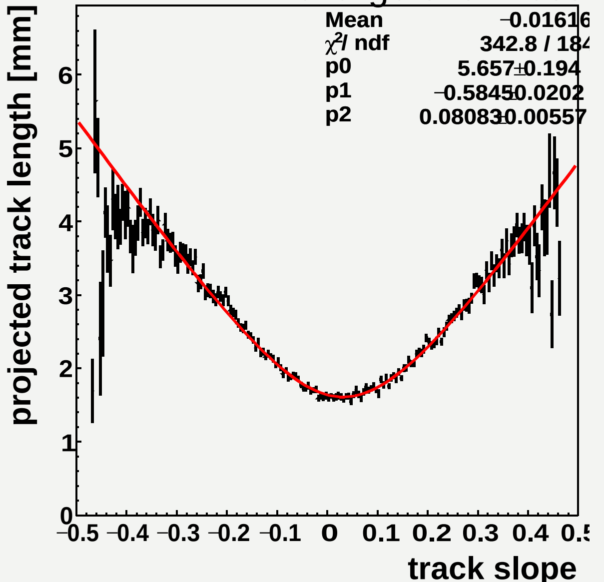
$m_{\mu TPC}$ = reconstructed track inclination



Origin-Reconstruction

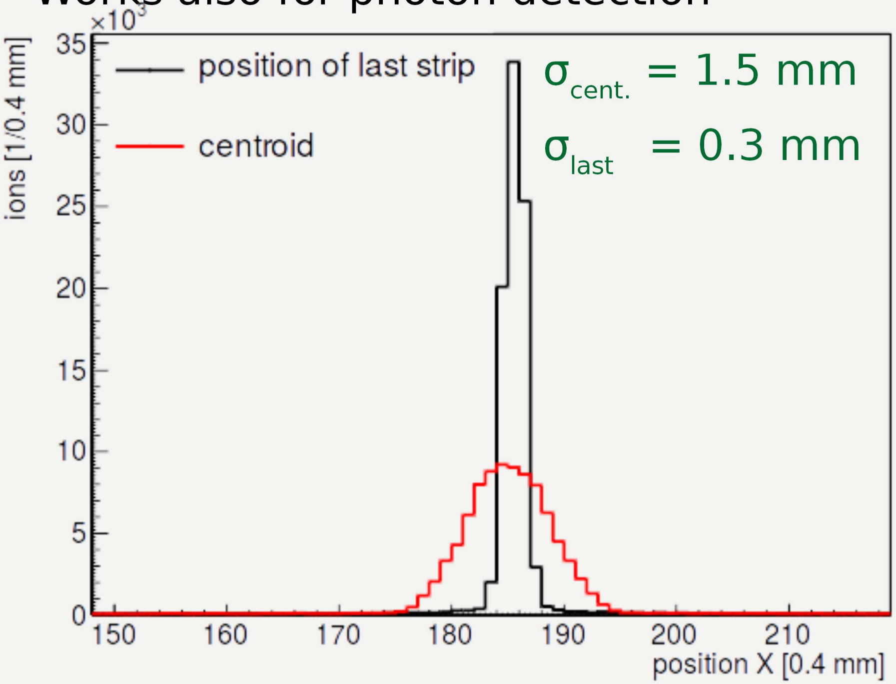
- Origin reconstruction by application of correction to centroid position
- Parameters obtained from detector geometry and fits to:
  - Projected track length vs. inclination
  - Charge skewness
- (linear) dependence of measured correllations has to be considered

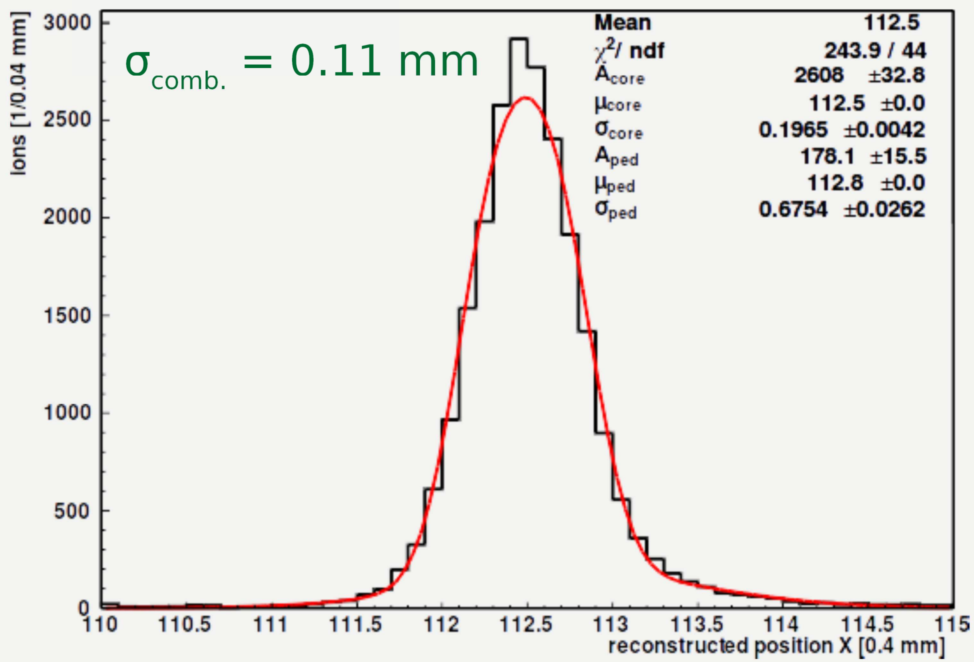




Origin Reconstruction

- Reconstruction method tested with collimated thermal neutron beam
- Improved spatial resolution from $\sigma_{cent.}$=1.5 mm to $\sigma_{comb.}$=0.11mm
- Combined method more accurate than using the last strip info
- Works also for photon detection

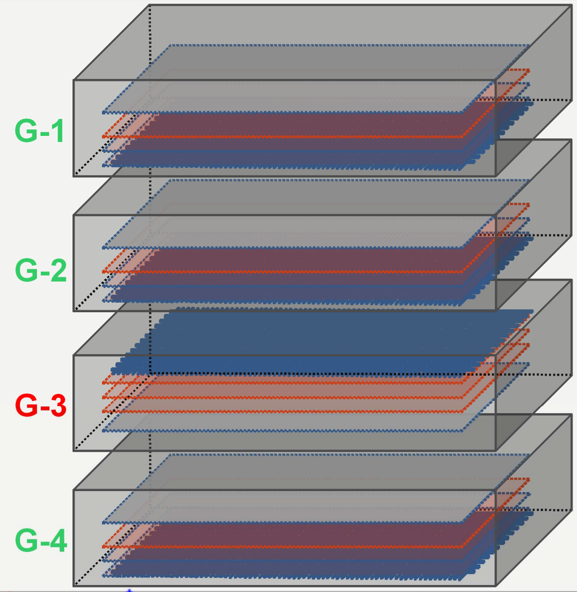


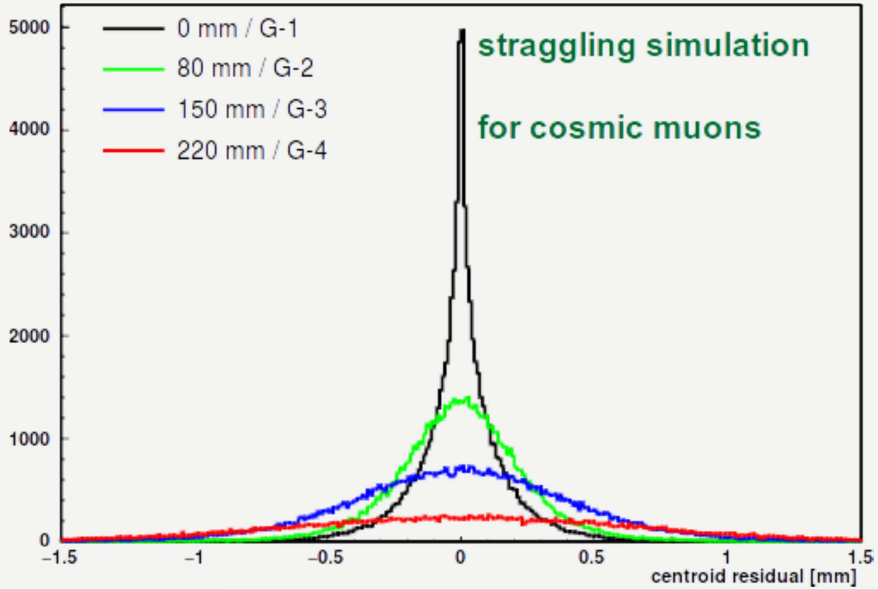


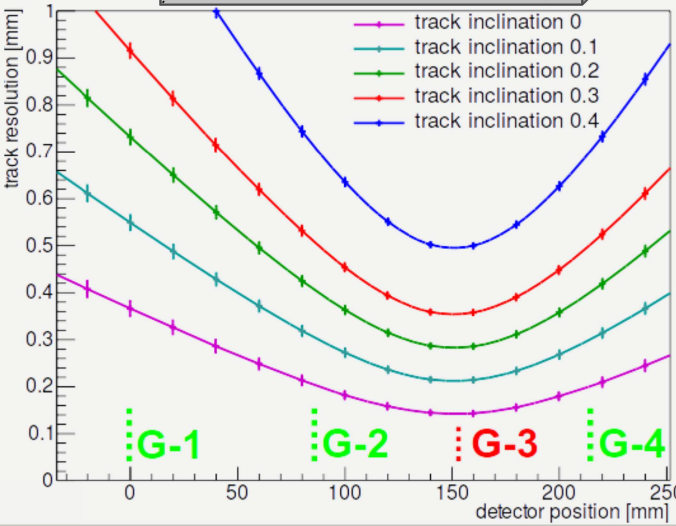
Works also for muon detection?

Setup

- System consists of 4-triple GEM detectors with 2D-strip read-out (pitch 0.4 mm)
- Filled with Ar:CO_2 93:7 Vol.% or He-CO_2 90:10 Vol.%
- Trigger by coincident signal on G-1/G-2 & G-4 GEM-foil
- measurement with cosmic muons (acceptance ± 25°)
- G-3 tested by reference track from G-1/G-2 & G-4

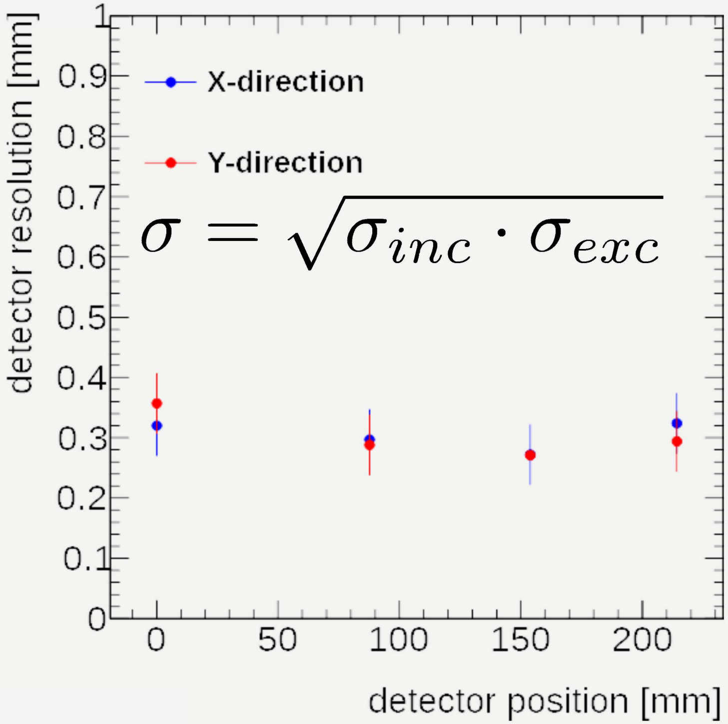




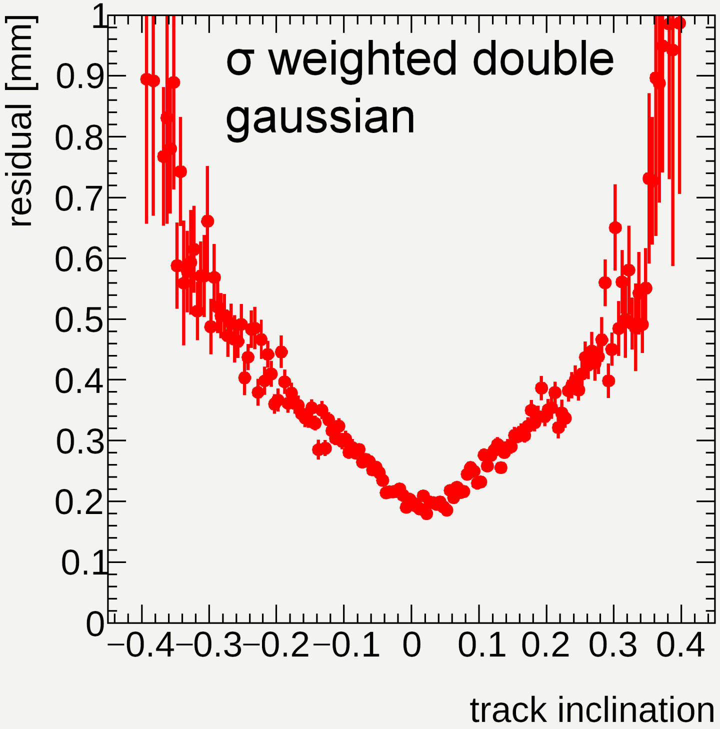


Track Resolution

- overall centroid detector resolution σ<0.35 mm (integrated over all track inclinations)
  - homogeneous for all detectors
  - homogeneous for both strip orientations
- centroid resolution inclination dependent, resolution worsens from 0.2 mm to 0.8 mm



$$\sigma = \sqrt{\sigma_{inc} \cdot \sigma_{exc}}$$



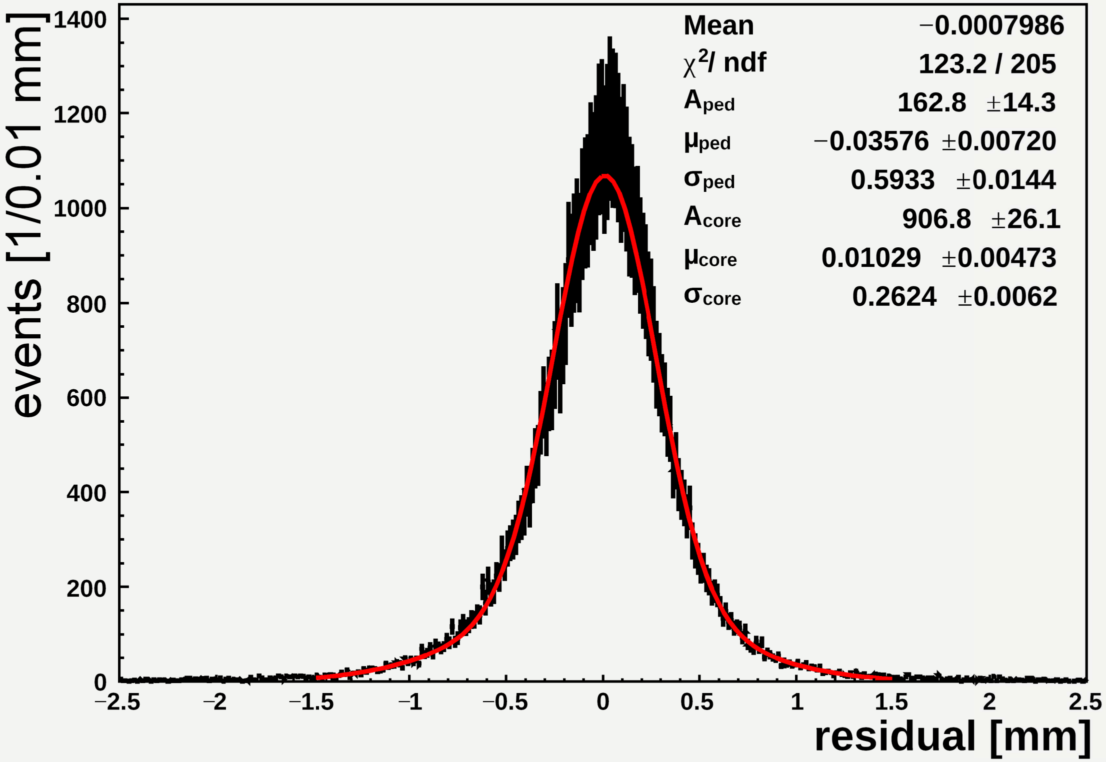
Reconstruction Resolution

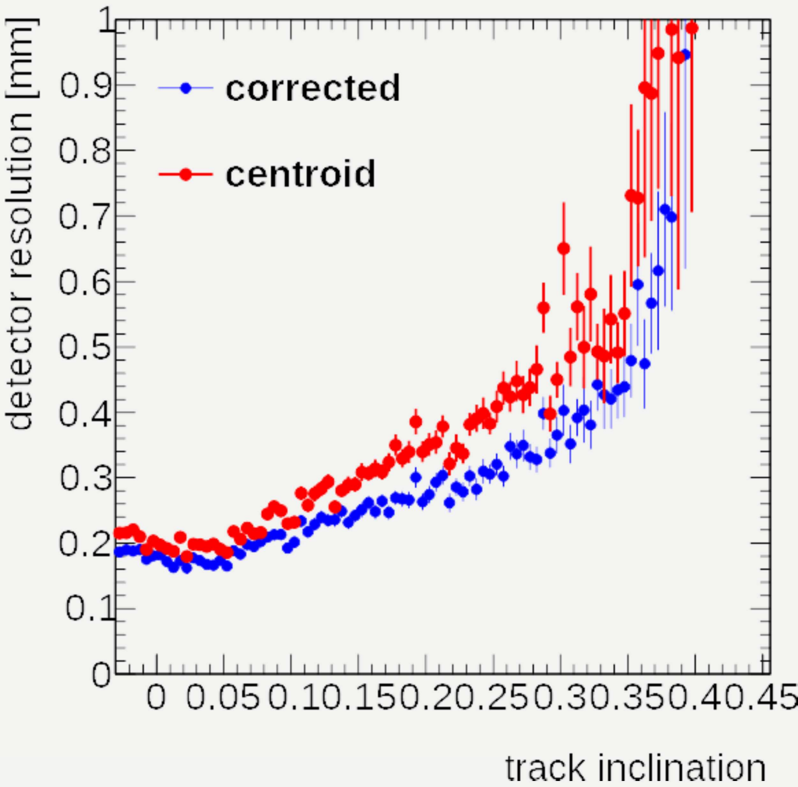
- correction improves overall spatial resolution from

  σ=0.29 to σ=0.22 mm

- resolution less affected by inclination

- skewness and inclination dependence can be compensated

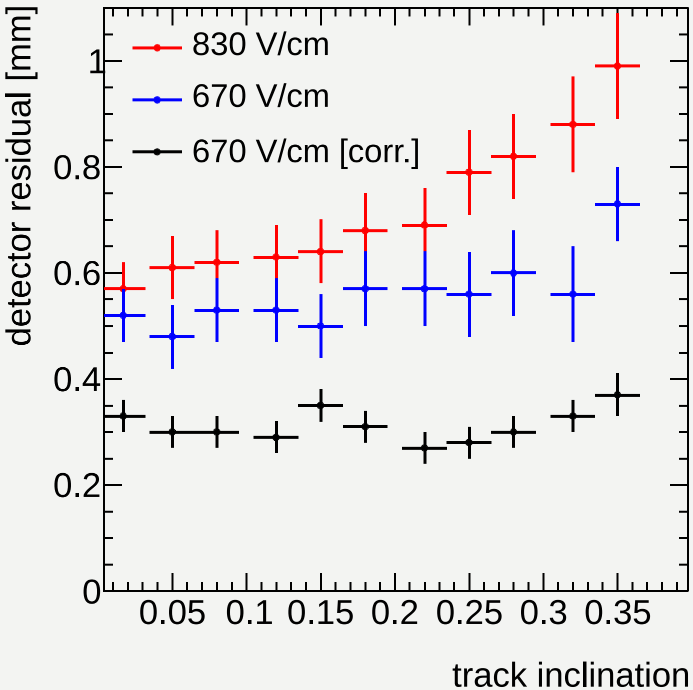


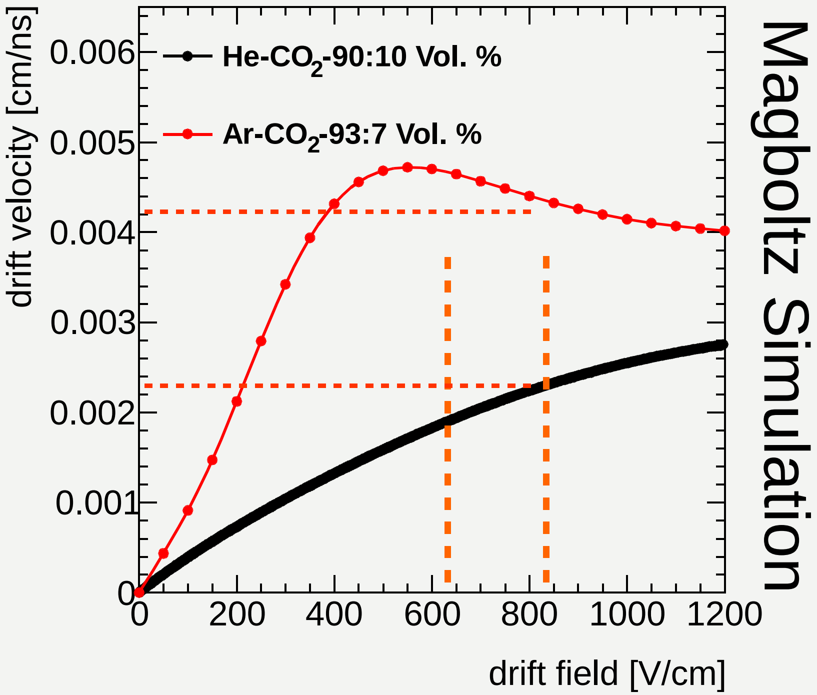


Track Reconstruction Resolution in He

- Lower drift fields improve spatial resolution for centroid method
- Better angular resolution → corrected reconstruction improves
- He:CO_2: v_{drift}~ 0.5 of Ar:CO_2 93:7 Vol. %
- Combined method in He-CO_2 90:10 Vol.%:

  → improves resolution and eliminates inclination dependence





Conclusion

- Full-Tracking of particles, which are created in a converter layer in the detector improves spatial resolution

- Combination of track information with centroid delivers better spatial resolution for non-homogenously ionizing particles

- Method allows better full track reconstruction with a single detector plane without the need of external timing information

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Thank you!

Backup

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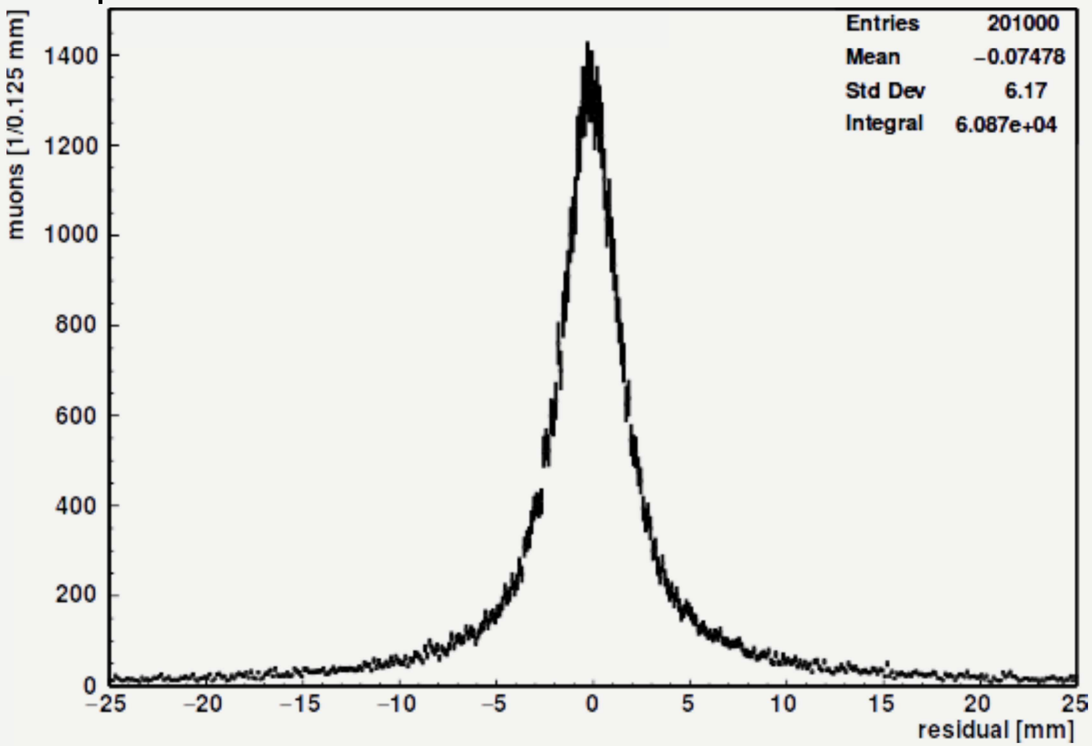
- pure µTPC spatial resolution very poor in this setup
  - -no absolute timing information (trigger jitter > 50 ns)
  - -clustering distorts timing & start/end of track
  - -angle acceptance of telescope not optimal for µTPC
- mean of µTPC position can still be used for calibration



Angular Resolution

- µTPC angle reconstruction not meaningfull below ~ 10°
- drift field dependency
  - smallest reconstructable angle
  - angular resolution
- improvement of both with lower drift field