Time Projection Chamber with Triple GEM and Pixel Readout

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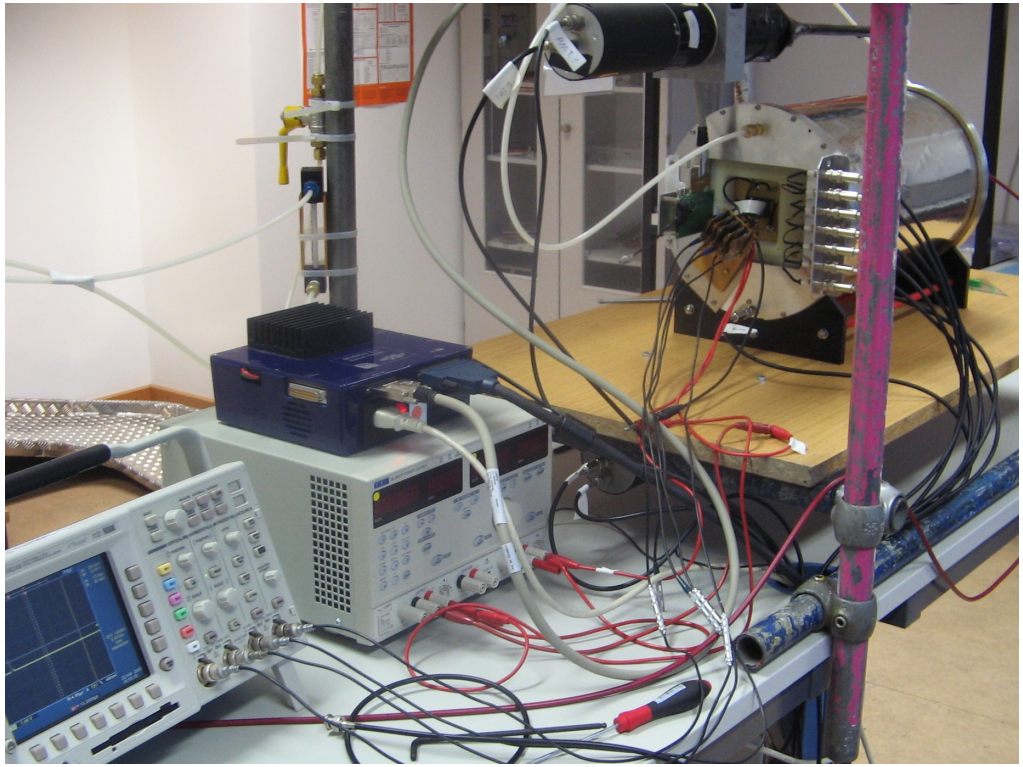
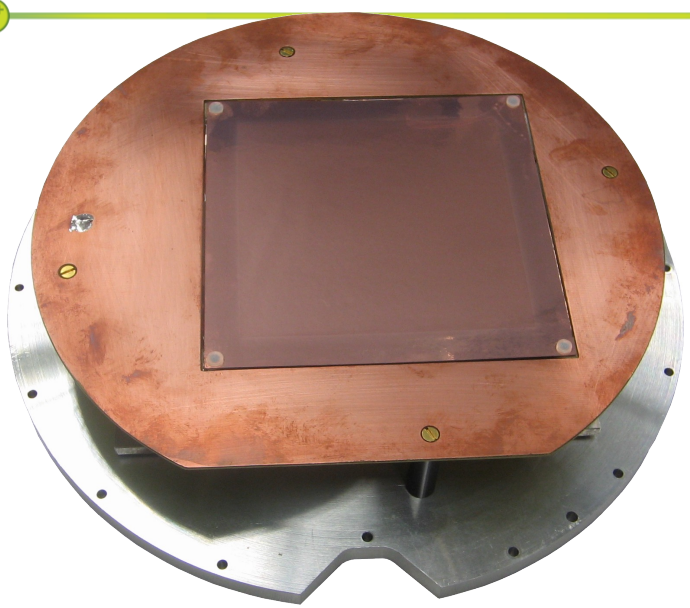
TPC Test Setup

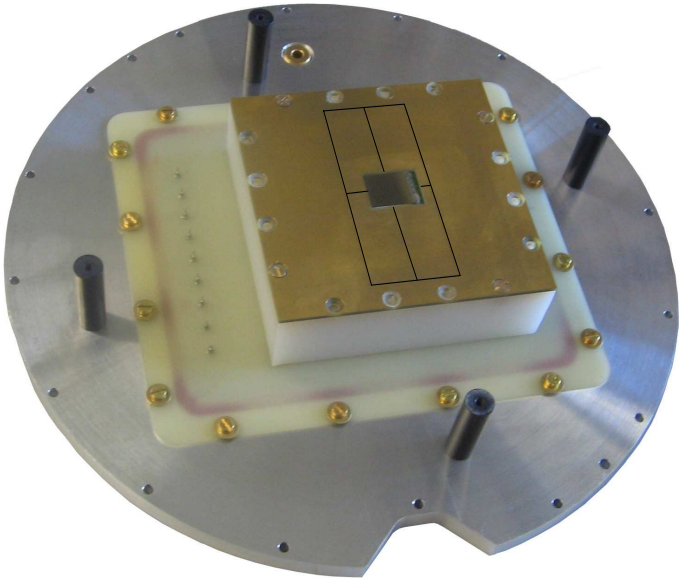


- Field cage designed and produced in Aachen
  - 26 cm diameter
  - 26 cm drift distance
  - Low material budget: 1 % X_0
  - Drift field up to 1 kV/cm
  - Fits into 5 T magnet at DESY
- Trigger for cosmic muons: Scintillators above and below the chamber
  - Veto circuit: Only one shutter window per recorded frame
- TimePix readout with Muros and PixelMan

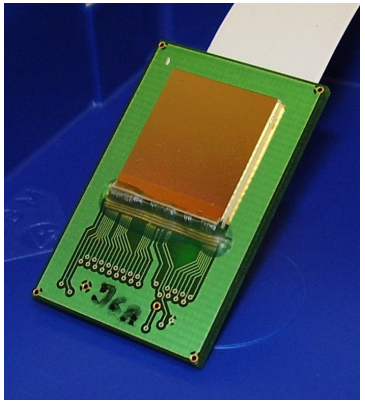
Gas Amplification and Readout



- Triple-GEM stack
- 1 mm transfer gaps and induction gap
- 390 V across each GEM
- Transfer field 2500 V/cm
- Induction field 3000 V/cm



- TimePix
  - 256×256 Pixel^2
  - 55×55 µm^2 pixel size
  - Active area 14×14 mm^2
- Set readout mode for each pixel individually
  - Time Over Threshold
  - Time
  - Hit counting
  - Hit yes/no
- 4 large pads, connected to preamps and oscilloscope



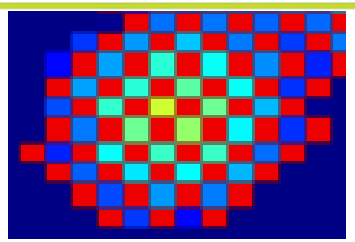
Modified Freiburg design to glue board into readout plane from the back

Measurements

40,000 cosmics tracks
40,000 test beam tracks

TimePix operated in "Mixed Mode": Chequerboard pattern with pixels alternating in

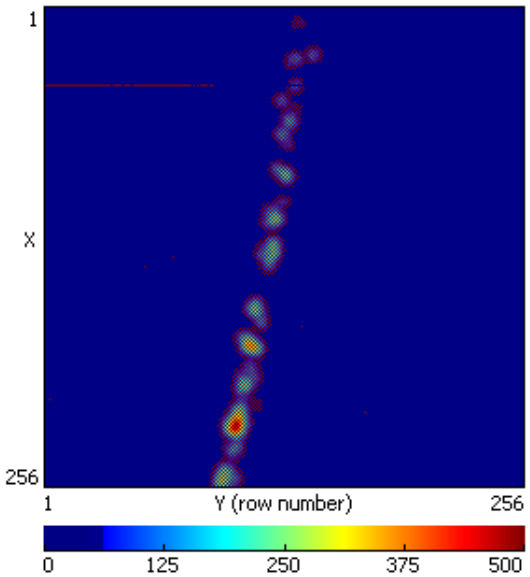
- Time Mode
- Time-Over-Threshold Mode
  proportional to charge



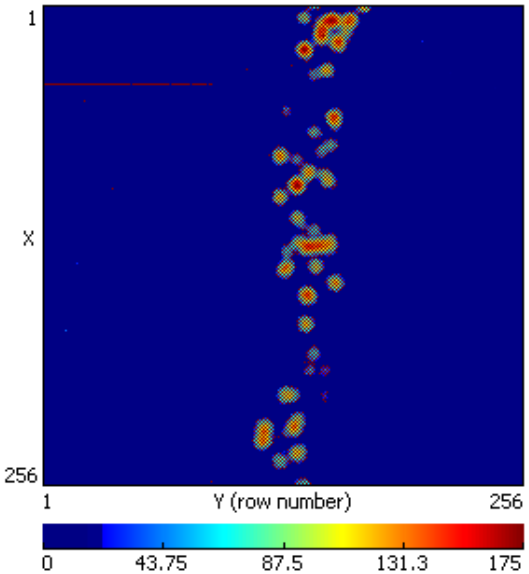
Cluster recorded in mixed mode

- Red: Time
- Blue to green: Charge

- Gas: Ar/CO_2 70/30
- Drift field: 500 V/cm
- GEM voltages: 390 V
- Transfer fields: 2500 V/cm
- Induction field: 3000 V/cm



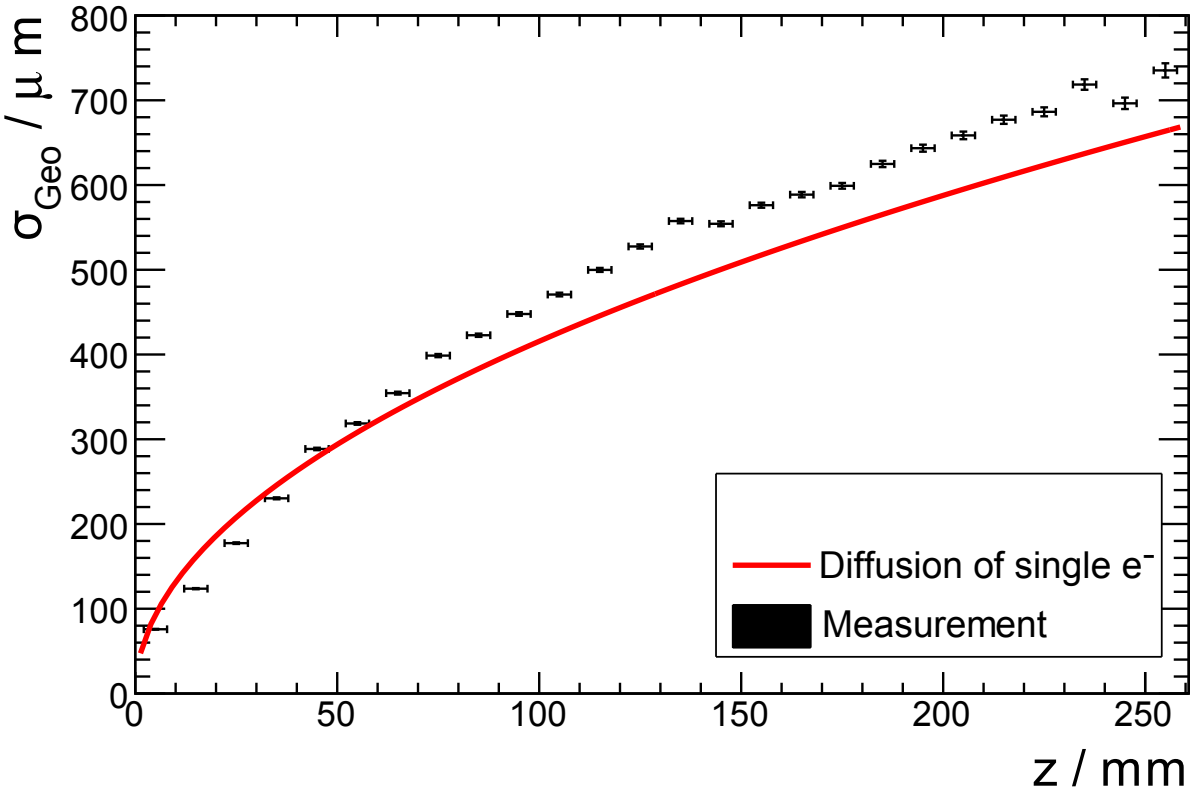
short drift distance



long drift distance

PixelMan Event Display

Spatial Resolution



Current interpretation:

- Short drift distances: Multi-electron clusters
- Long drift distances: Single-electron clusters?

Spatial Resolution

Single electrons

$$\sigma = \sqrt{D_t^2 z}$$

$$D_t = \text{Transverse diffusion in } \mu\text{m}/\sqrt{\text{cm}}$$

More realistic assumption

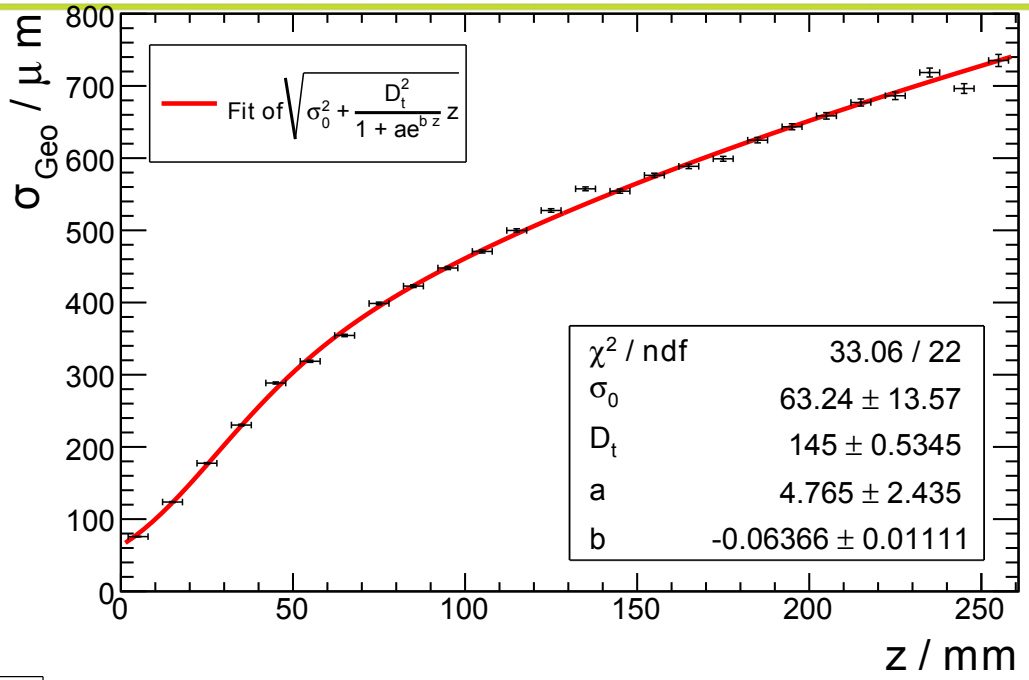
$$\sigma = \sqrt{\sigma_0^2 + \frac{D_t^2}{n_{ele}} z}$$

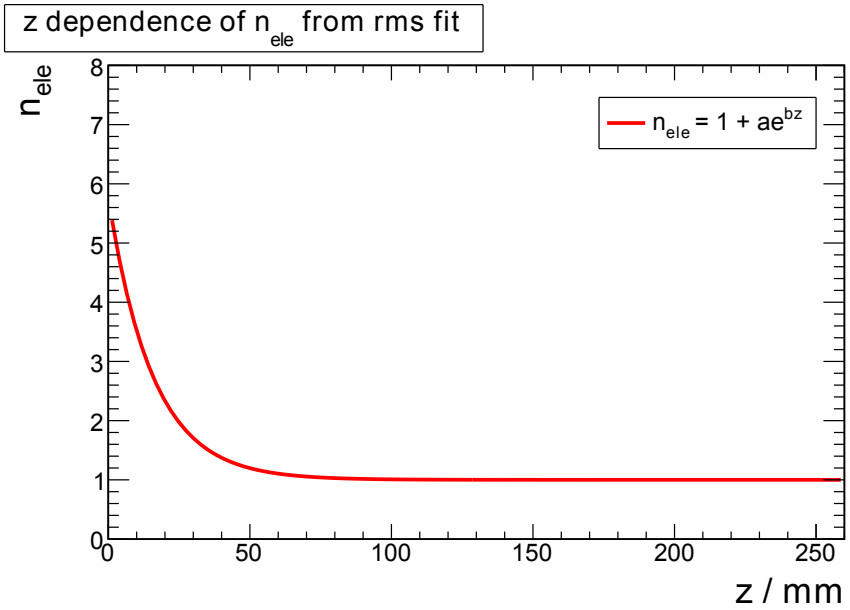
$$\sigma_0 = \text{Intrinsic detector resolution}$$

$$n_{ele} = 1 + a\, e^{-bz}$$

$$= \text{Number of primary electrons contributing to recorded cluster}$$

Spatial Resolution

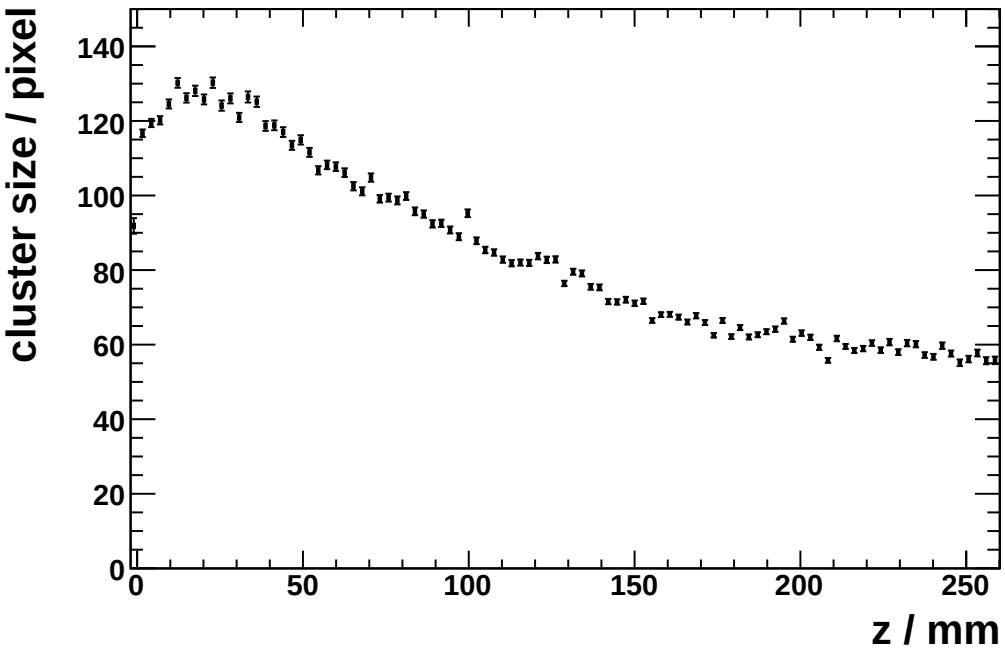


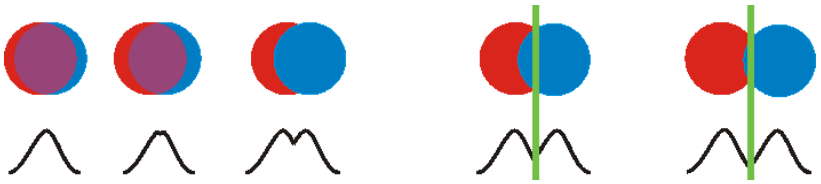


- $n_{\text{ele,max}} = 5.7$
- $\bar{n}_{\text{primary}} \approx 3$

$\Rightarrow$ 1.9 *primary ionisation clusters* in one *recorded cluster*

Cluster Size





Statistical process

Declustering

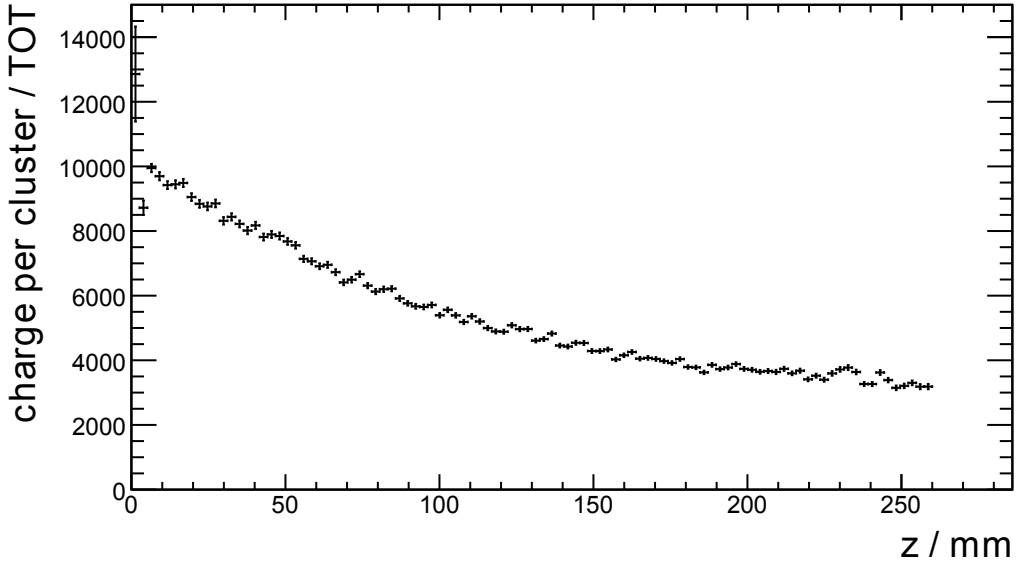
Small drift distances

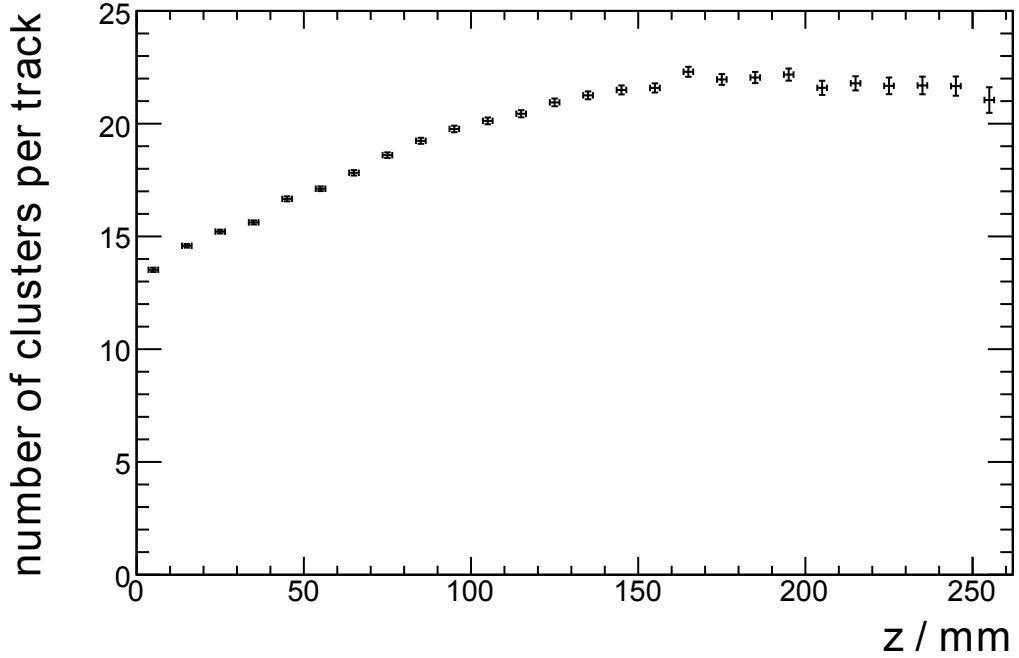
- Cluster size increases with z
- Multi-electron clusters become wider

Large drift distances

- Cluster size decreases with z
- More and more individual electrons become separable

Cluster Charge / Number of Hits



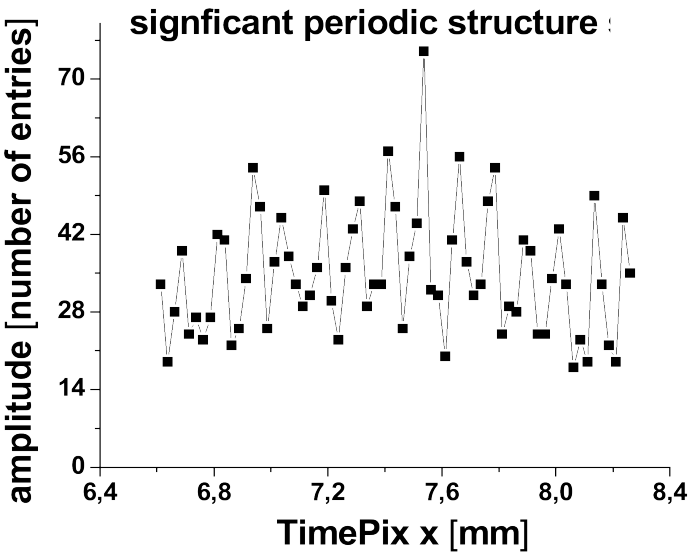


- Charge per cluster decreases with z
- Consistent with declustering, less electrons per cluster

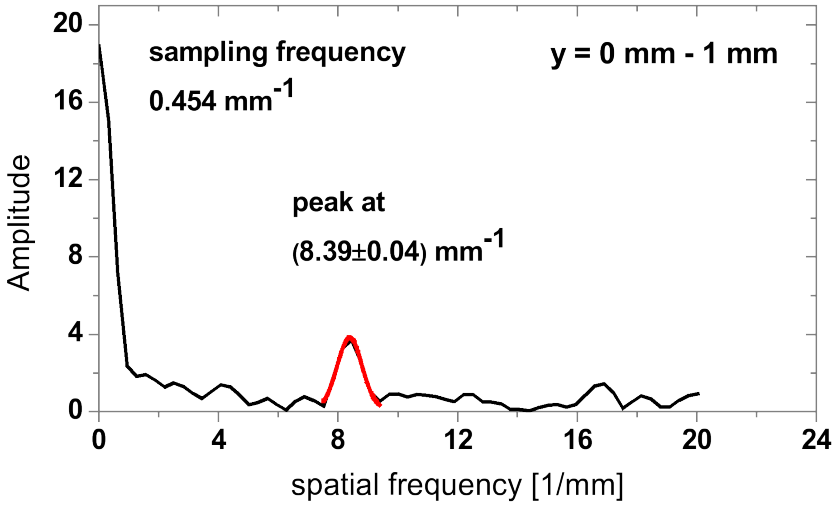
- Number of clusters is increasing with z
- Consistent with declustering, more and more individual electrons can be resolved

Results from Freiburg Test Beam

GEM structure shows up in reconstructed data



Fourier analysis



- Fourier transform: Period is 119 ± 6 µm (GEM pitch in x-projection is 120 µm)
- Signal only shows up in first millimetre
- For larger drift distances signal is smeared out due to diffusion

- Drift gap 6 mm
- Transfer gaps 2 mm each
- Induction gap 1 mm

GEM structure measured in Bonn

- Dedicated high statistics run with ^{90}Sr source untriggered, no z information available
- Long drift distance ≈25 cm
- GEM spacing: 1 mm transfer gaps and induction gap

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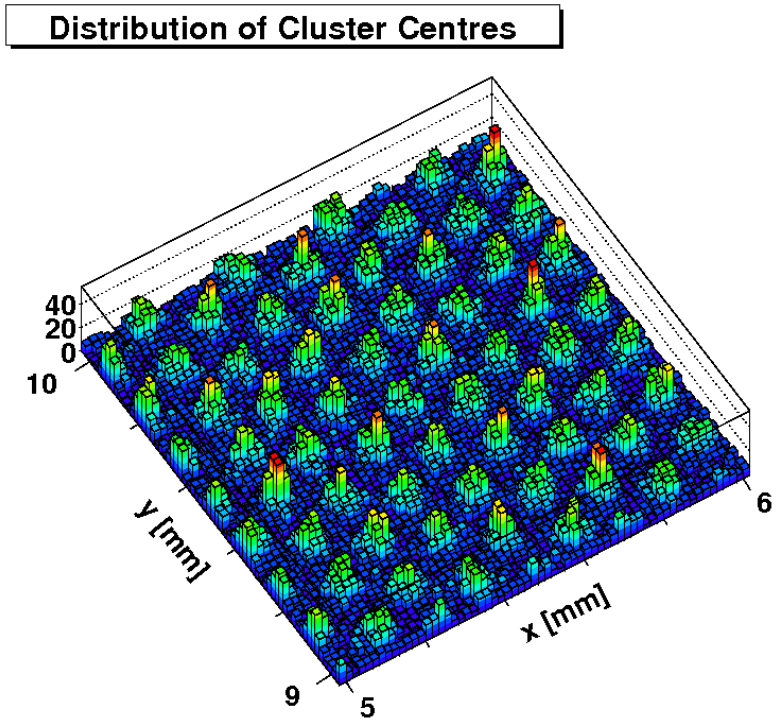
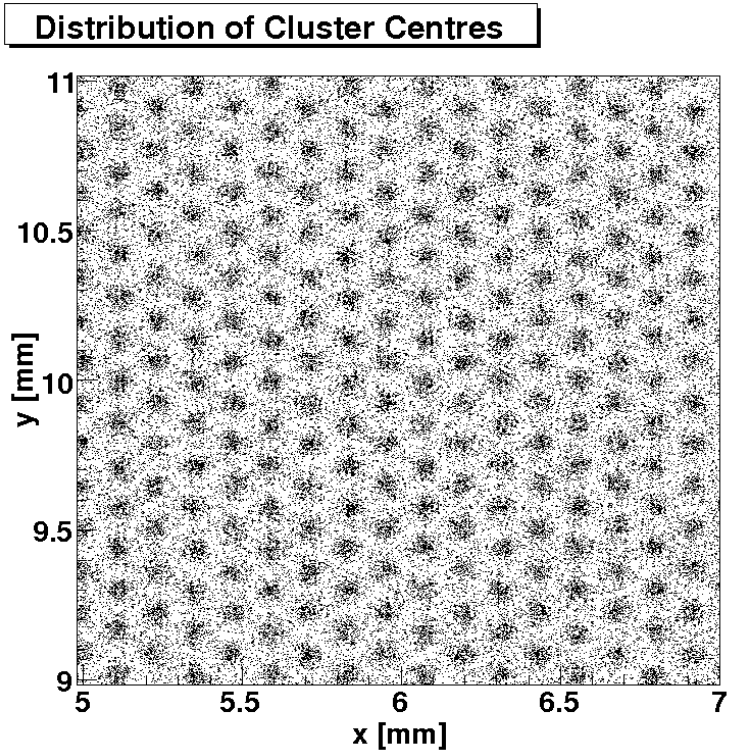
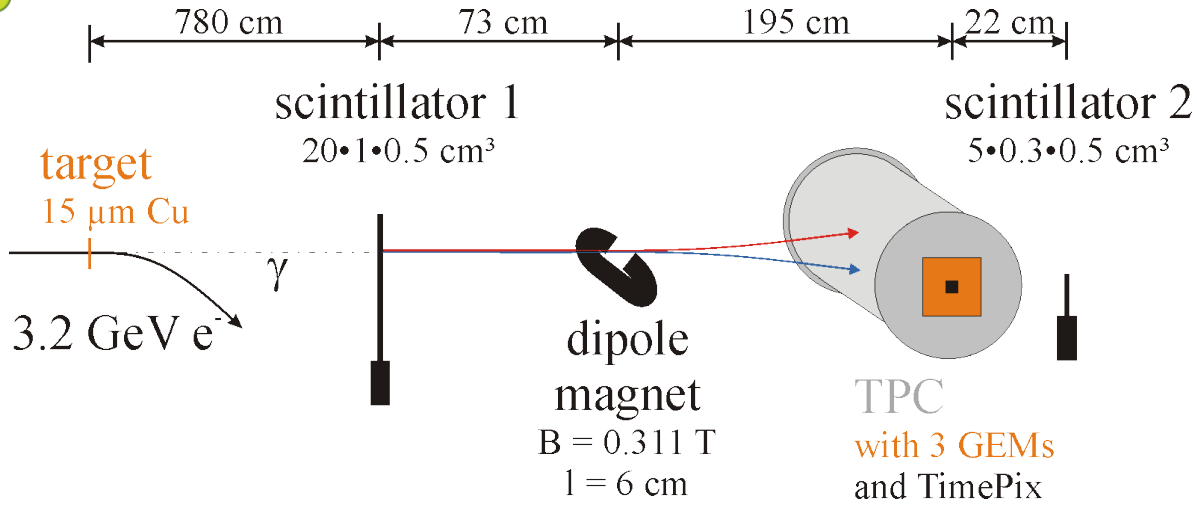


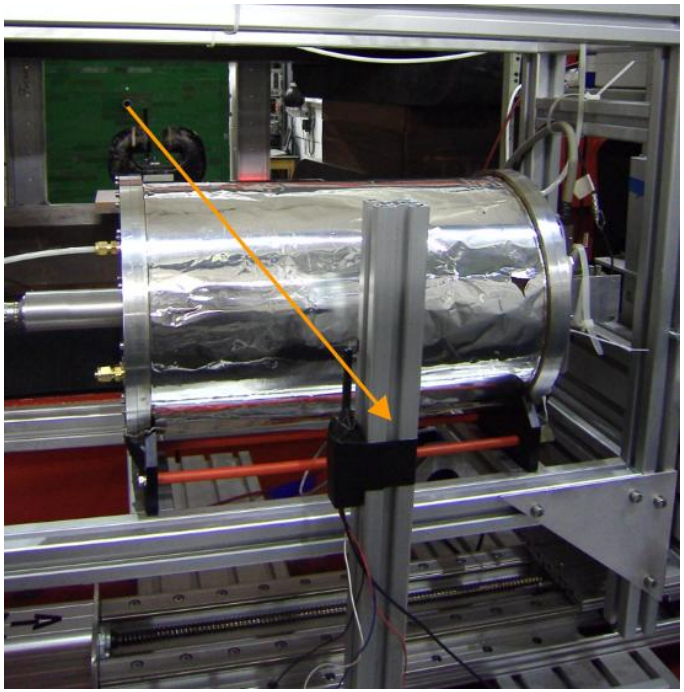


We can see every single GEM hole!

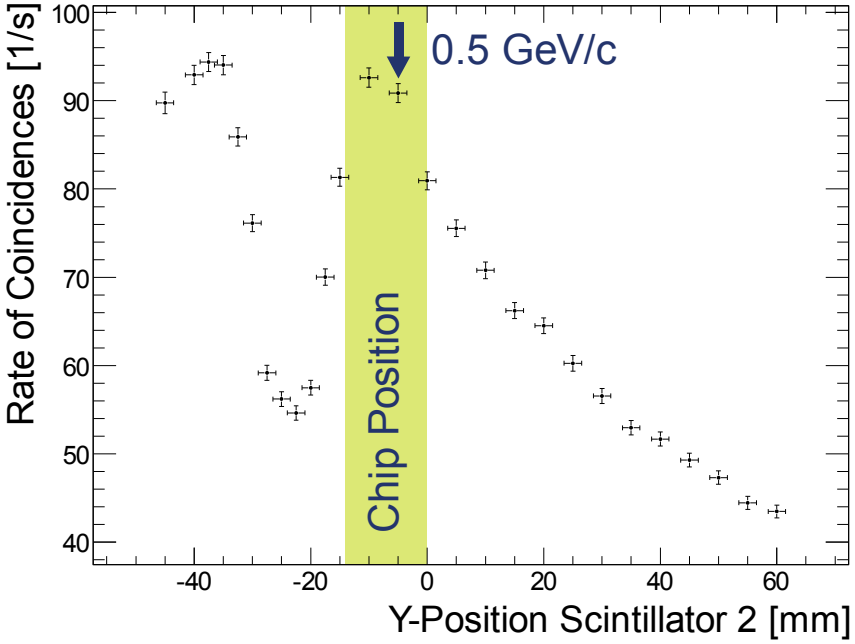
Test Beam Setup



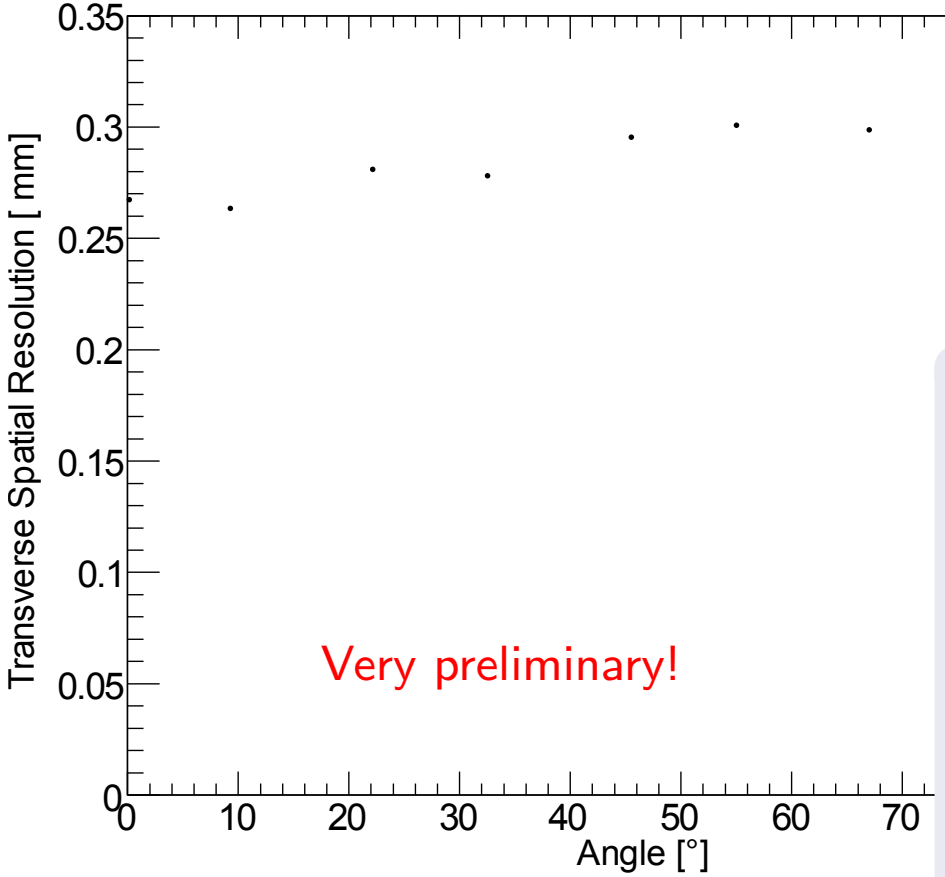
- γ were created at target
- primary e^- were dumped
- photons converted in scintillator 1
- dipole separated e^+ and e^-
- coincidence of both scintillators as trigger



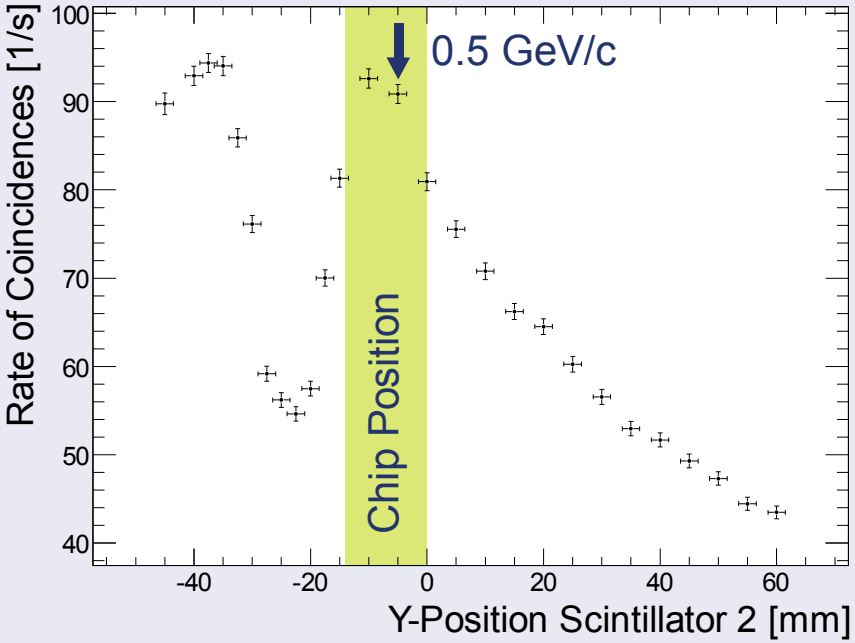
Beam Profile in y



Resolution vs. Track Inclination



Quasi flat over 90°



Rotation shifted chip position in beam
⇒ Energy changed

Summary

Setup

- 26 cm TPC with single TimePix + 3GEM
- 40.000 cosmics tracks
- 40.000 test beam tracks

Results

- Declustering studies in detail
- Indications that we see single electron clusters
- Resolution limited by GEMs + diffusion
- Test beam data show weak dependency on track inclination

Modern Particle Identification