Time Projection Chamber with Triple GEM and Pixel Readout

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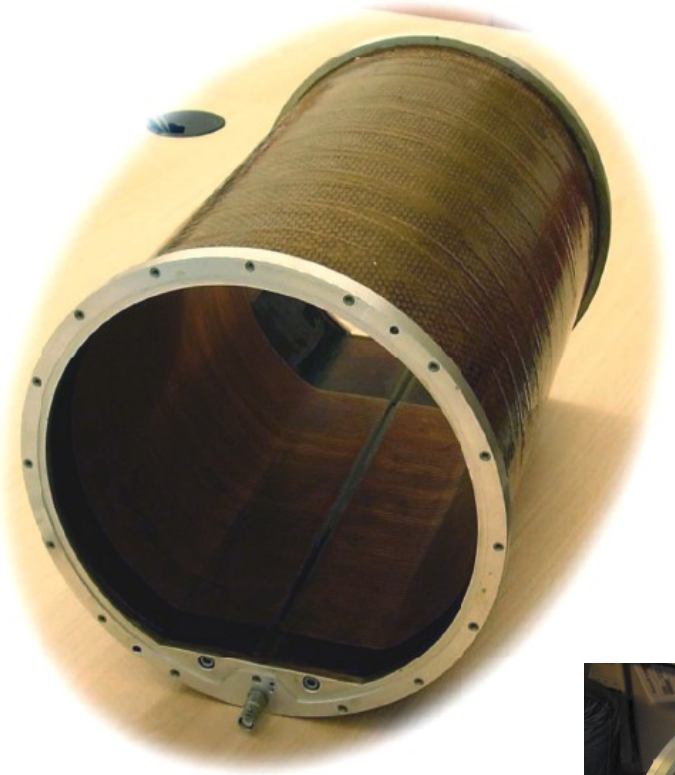
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

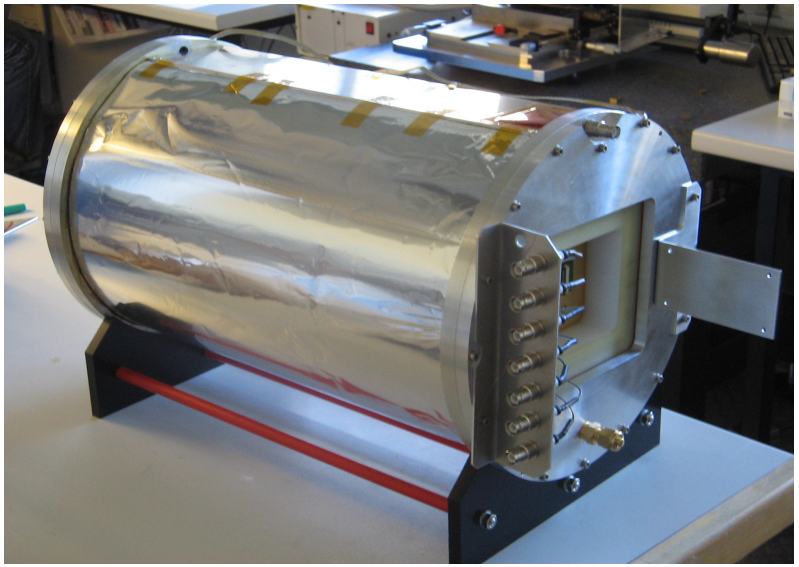
1. Conference on Micro Pattern Gaseous Detectors
Crete, June 12th -15th, 2009

TPC Prototype at Bonn



Field cage / mechanics designed and produced at RWTH Aachen

- drift distance: 26 cm
- inner diameter: 23 cm
- material budget: 1 % X_0
- up to 30 kV => drift field of 1 kV/cm



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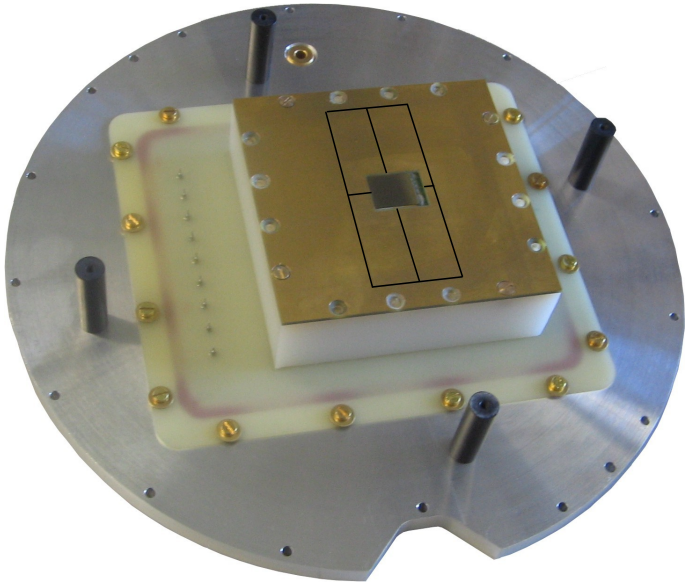
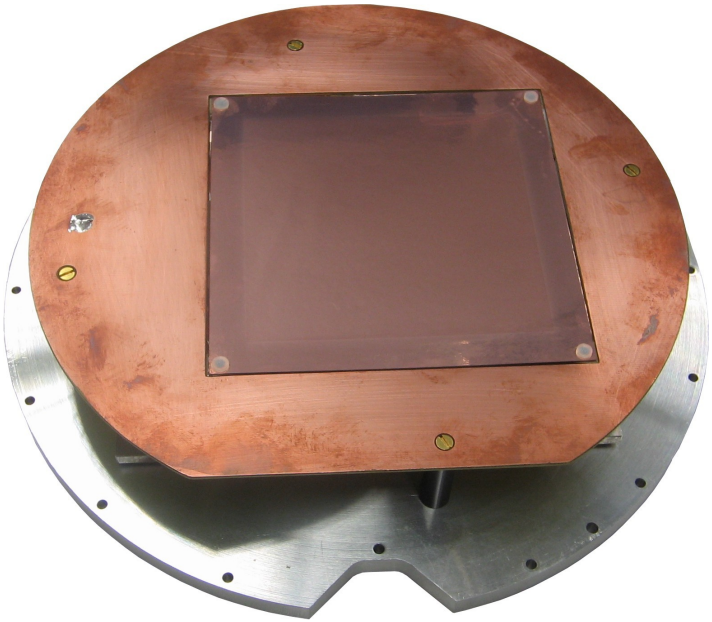
Gas Amplification and Readout





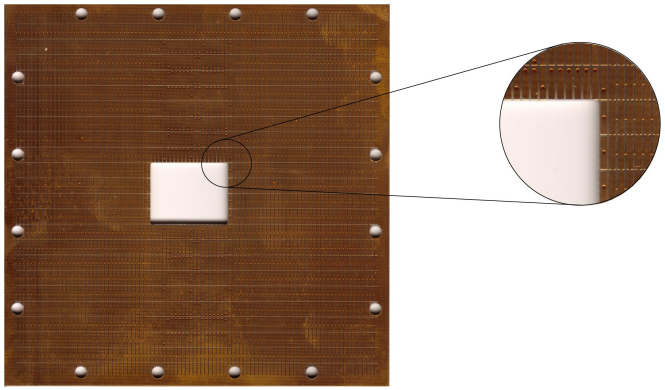
readout:

single Timepix chip

new readout board:

1.1 * 5.6 mm² pads around the Timepix

will be connected to ALTRO-electronics



gas amplification:

3 GEMs 1mm apart

drift field: 500 V/cm

transfer fields: 2.5 kV/cm

induction field: 3 kV/cm

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Gas Mixtures

2 Gas mixtures have been used

$Ar:CO_2$ 70:30

$He:CO_2$ 70:30

Both gas mixtures have similar

drift velocity: 1.2 cm/µs, 0.95 cm/µs

diffusion coefficients: 131 µm/$\sqrt{cm}$, 129 µm/$\sqrt{cm}$

but very different primary ionization: ~90e^-/cm, ~15e^-/cm

Gas was used from premixed bottles,

oxysorbers were placed directly before the detector.

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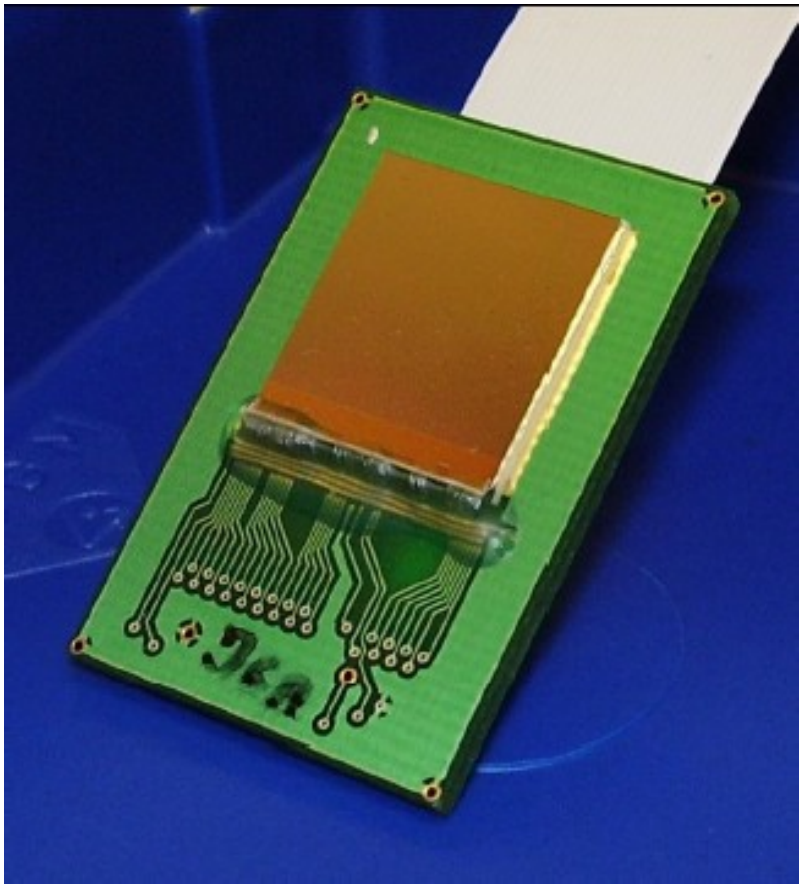
Timepix



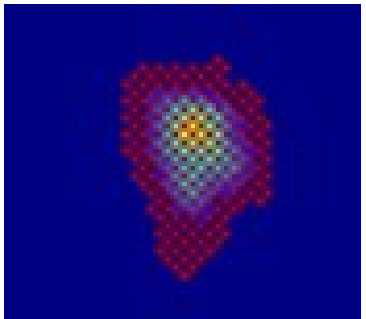
256 * 256 pixel

pixel size: 55 * 55 µm²

chip dimensions: 1.4 * 1.4 cm²

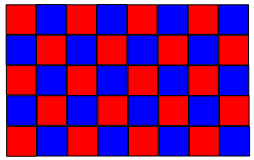
Each pixel can be set to one of these modes:

- hit counting
- TOT = time over threshold
  gives integrated charge
- time between hit and shutter end
- hit/no-hit

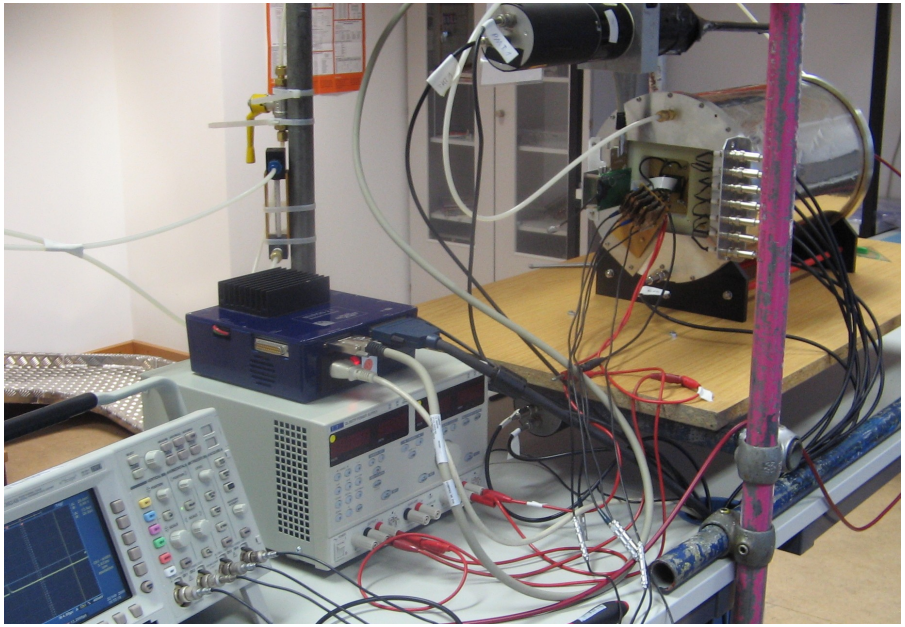


current running condition:

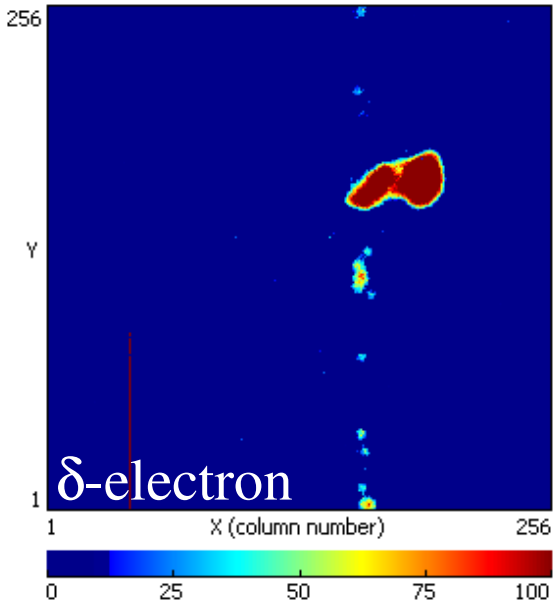
checker-board pattern of TOT and Time

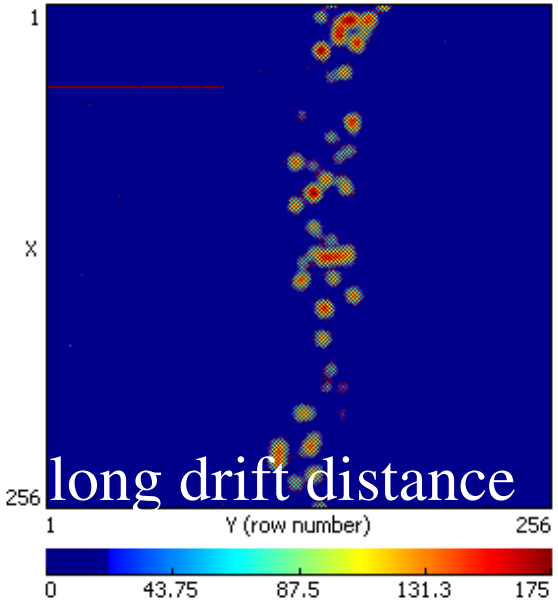


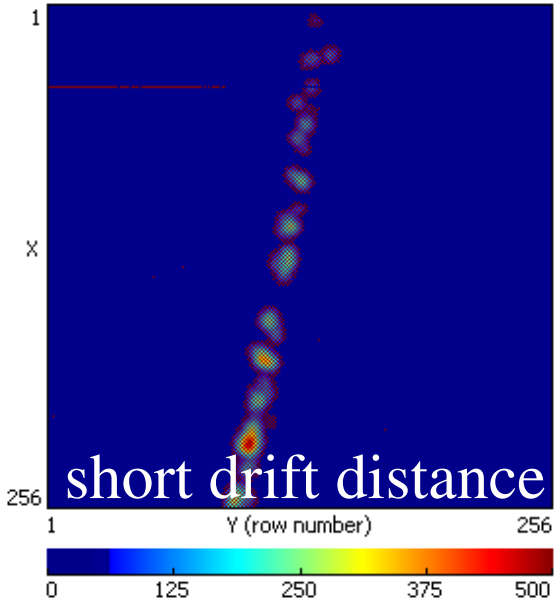
Test Stand with Cosmic Rays



Coincidence of 2 scintillators gives external trigger for TimePix







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Analysis Software – MarlinTPC

The data is analysed within the MARLIN-framework:
Modular Analysis & Reconstruction for the Linear Collider

- Software package for simulation, reconstruction and analysis of various detector data
- Common Data Model for all subdetector systems:
  LCIO: Linear Collider I/O
- very flexible: individual reconstruction/analysis steps (processors) can be easily replaced
- MarlinTPC: Collection of processors for the reconstruction of TPC data

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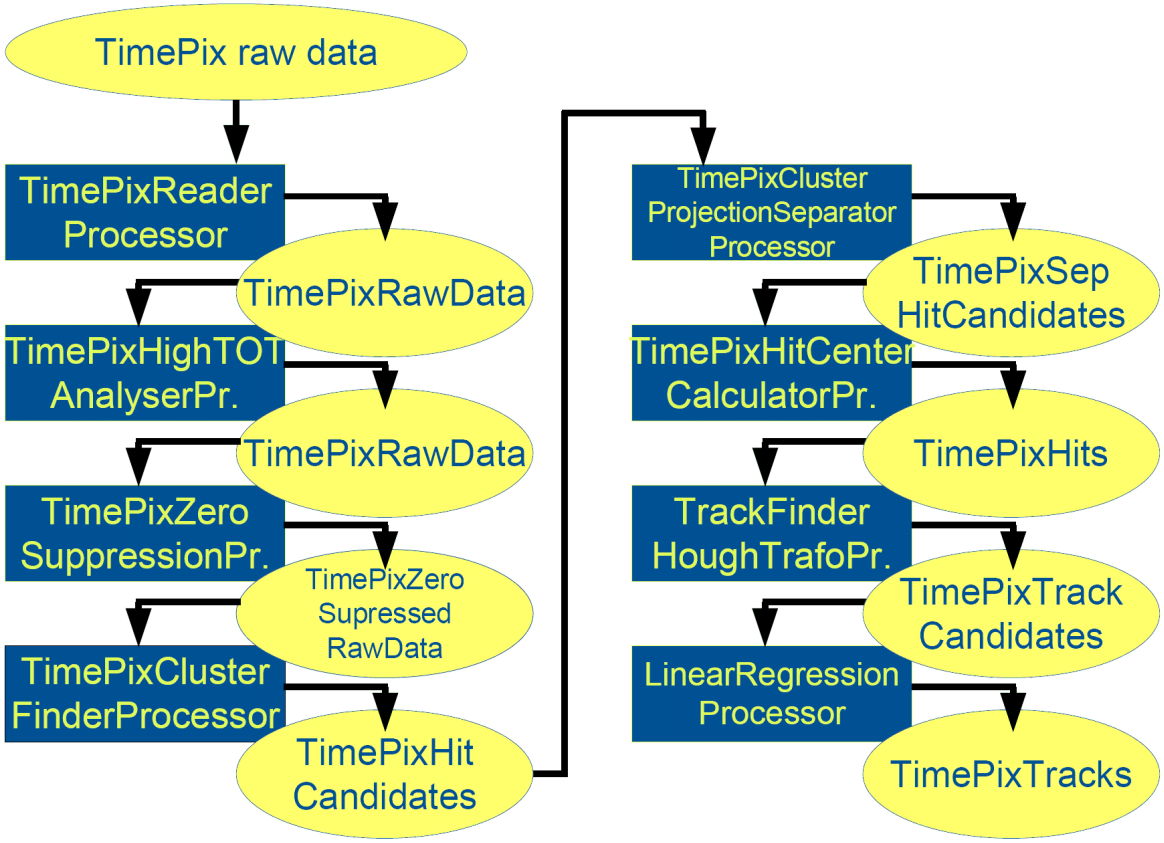
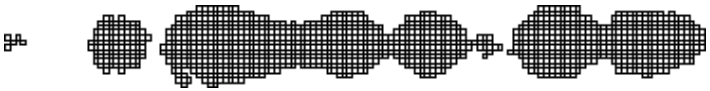
MarlinTPC for TimePix data

Reconstruction and analysis chain for Timepix data has been established and verified



Example:

Cluster separator



clusters defined by combining neighboring pixels

overlapping clusters are separated at local minima

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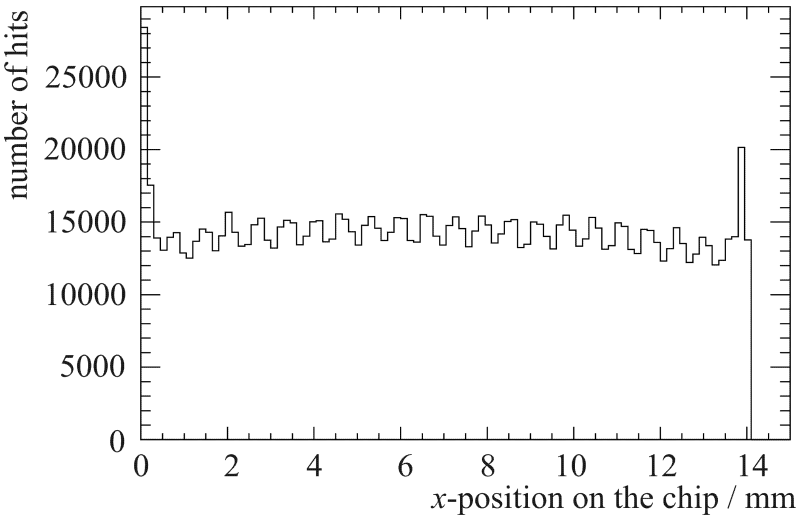
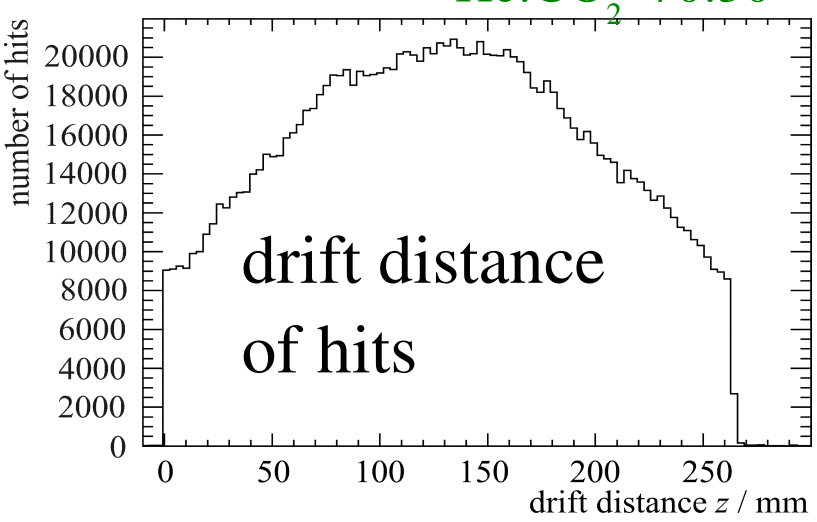
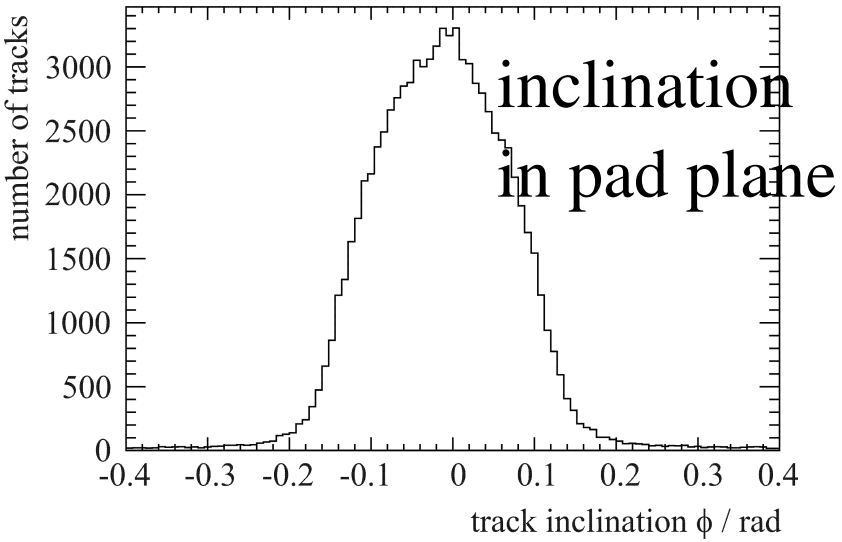
Track Parameters

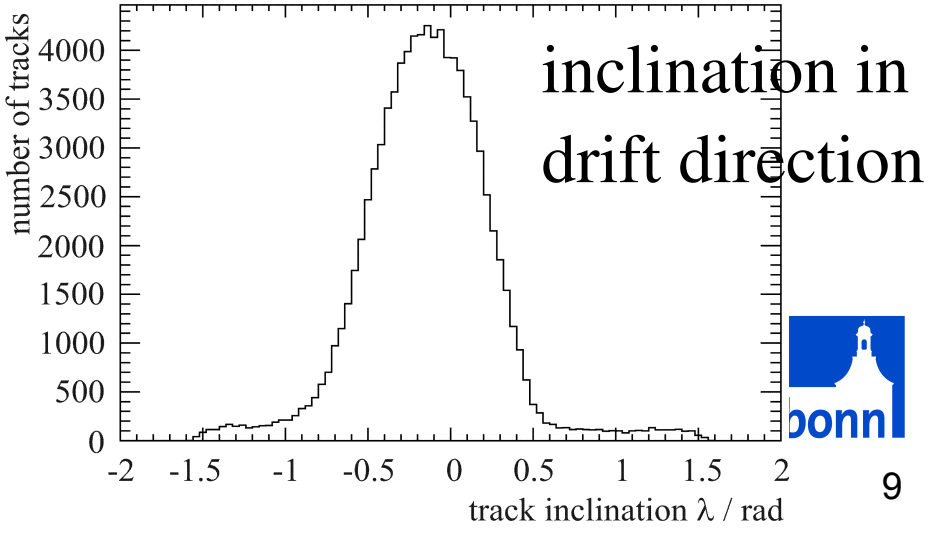
With each gas we took about one month of data, collecting a data sample of 130,000 tracks.

He:CO_2 70:30



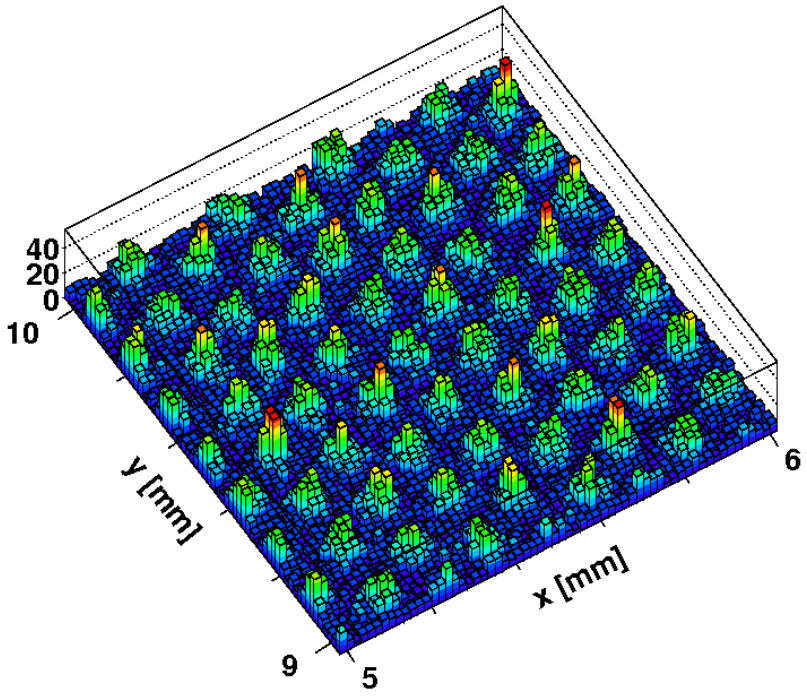


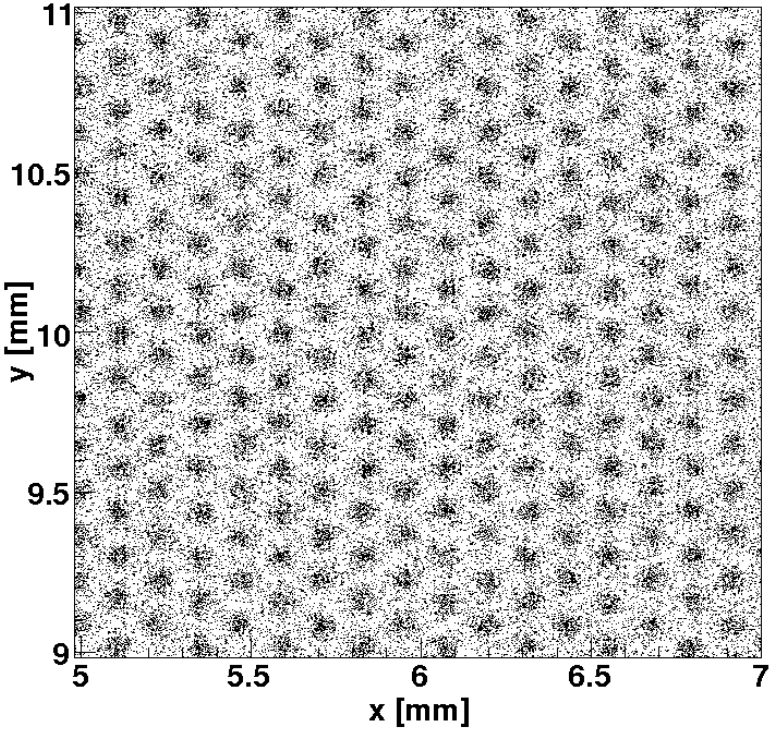




'Electron-tomography' of GEM

- Sr-90 source at a drift distance of about 25 cm
- untriggered mode
- reconstructed position of hits





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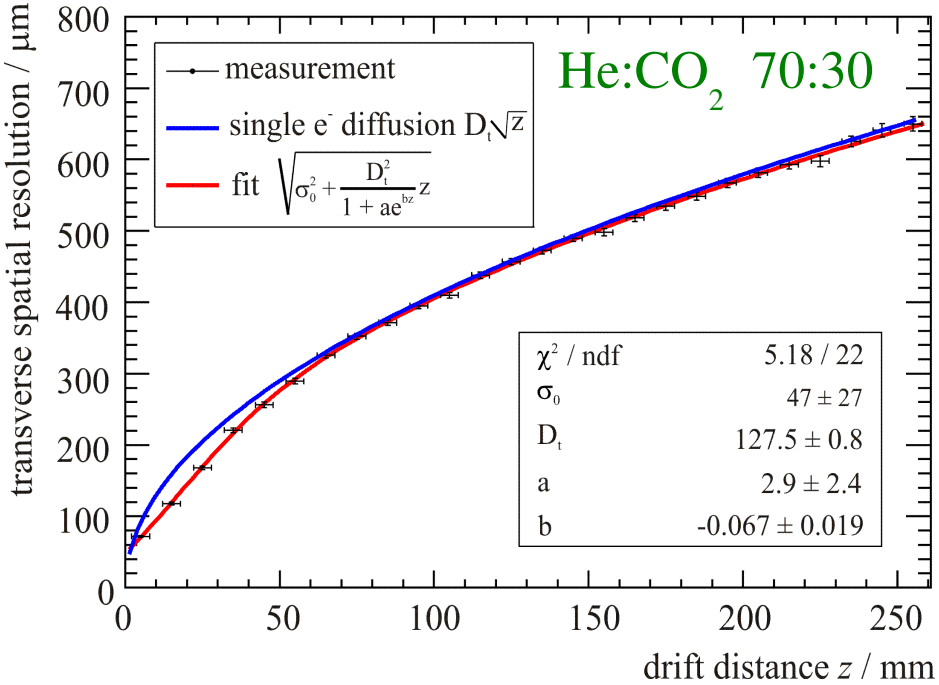
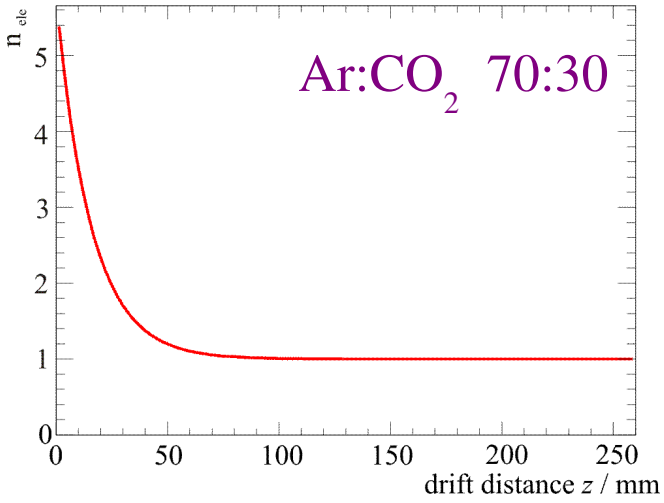
Transverse Spatial Resolution





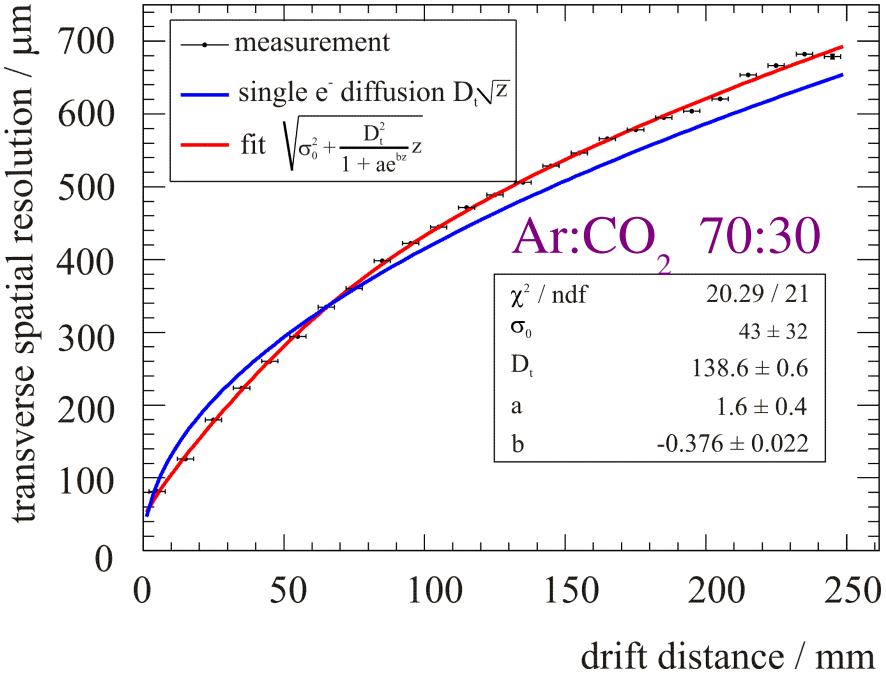
diffusion of single electrons:

$\sigma(z) = \mathrm{sqrt}(D_t^2 z)$

<u>but:</u> number of electrons per hit

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

$\Rightarrow \sigma = \mathrm{sqrt}(\sigma_0 + D_t^2 z/(1 + a\, e^{bz}))$



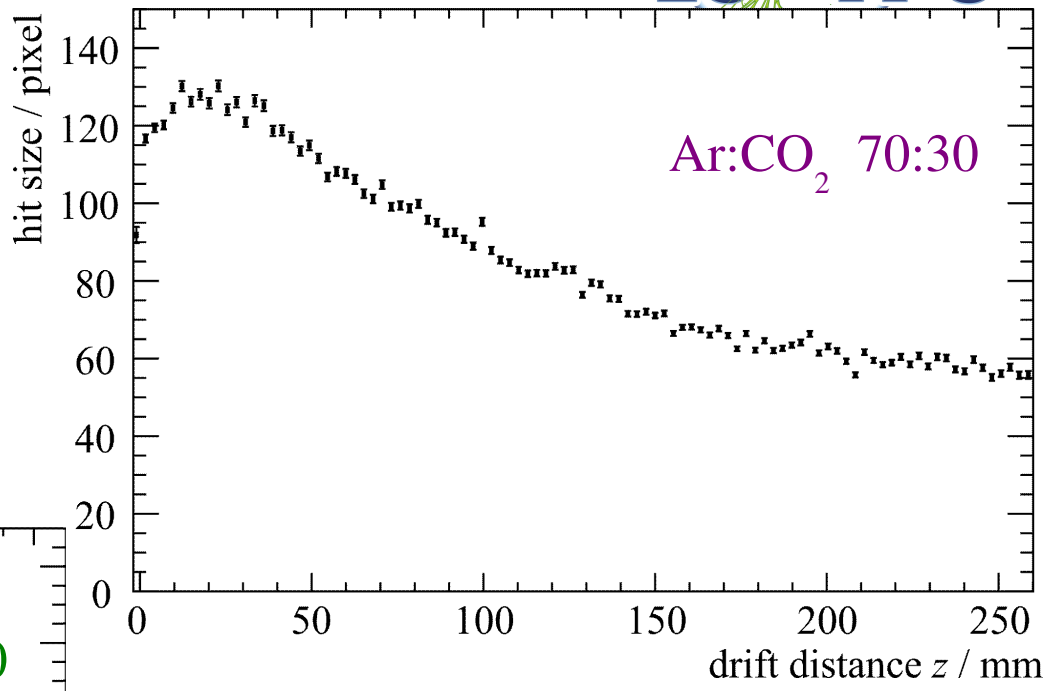
Hit Size

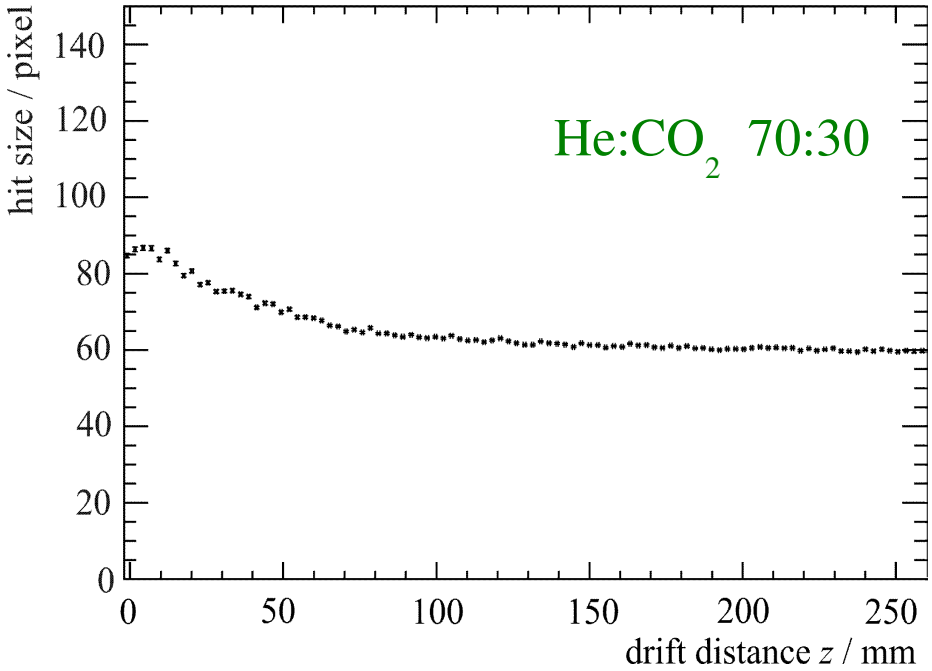
Short drift distances:

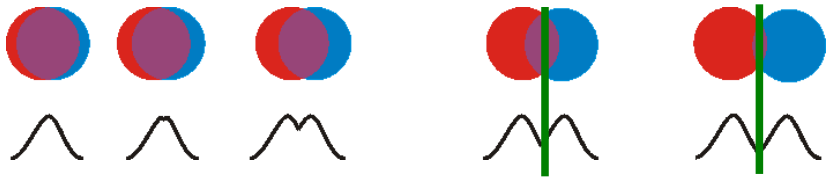
- hit size increases with z
- multi-electron hits become wider

Longer drift distances:

- hit sizes decrease with z
- more and more individual electrons become separable







statistical process !

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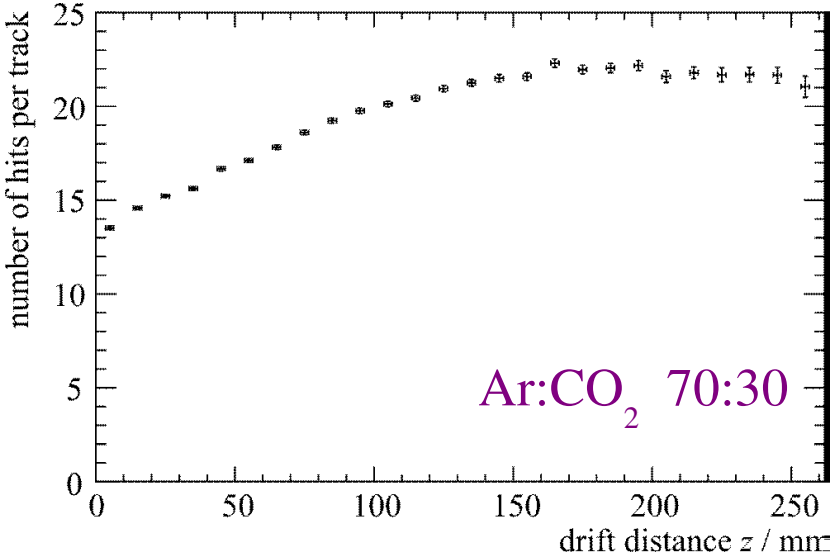
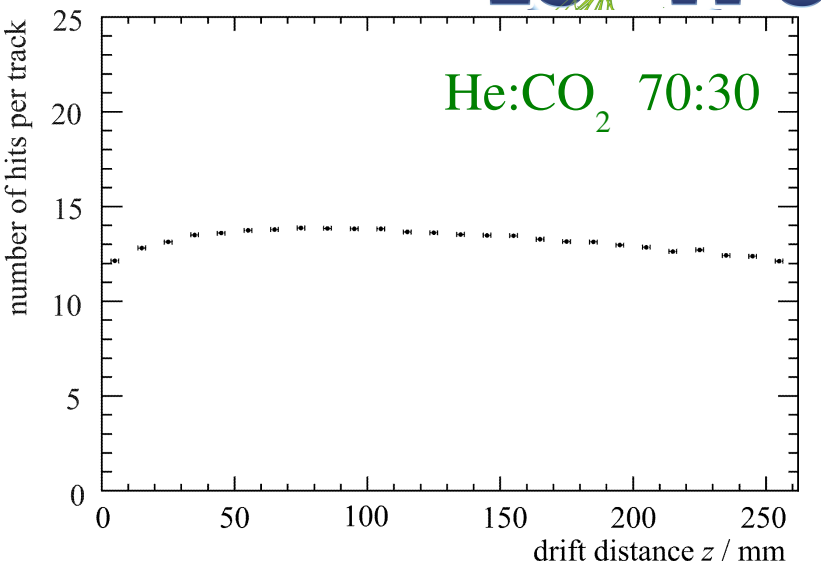
Number of Hits Per Track





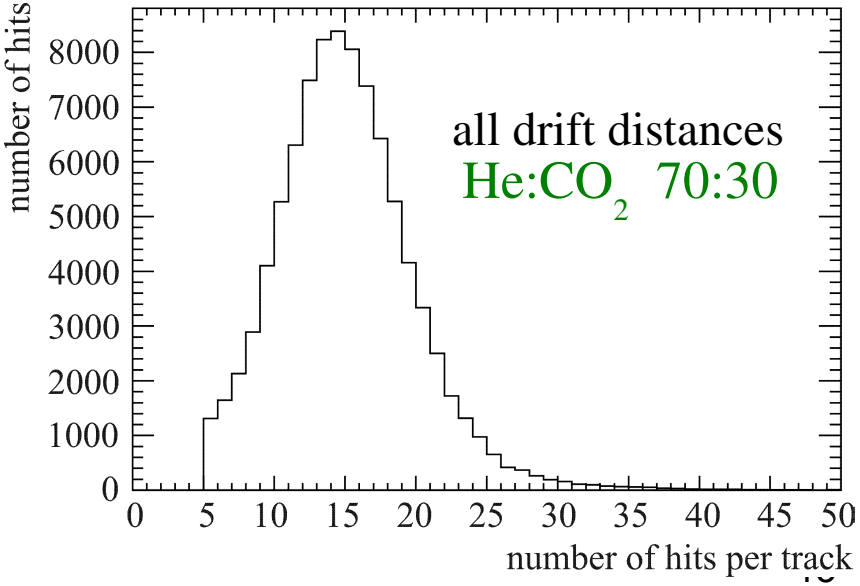
Further evidence for declustering

→ number of hits increase at short drift distances

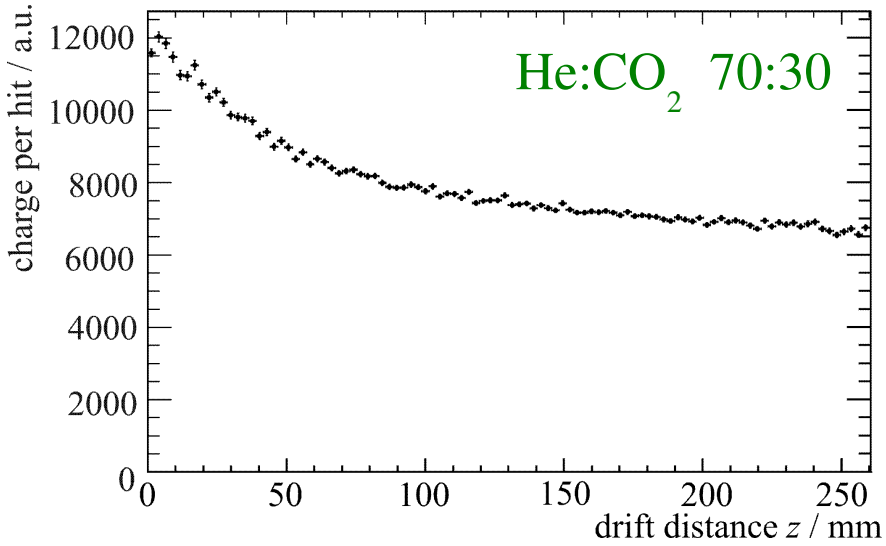
$He:CO_2$: decreases at long drift distances

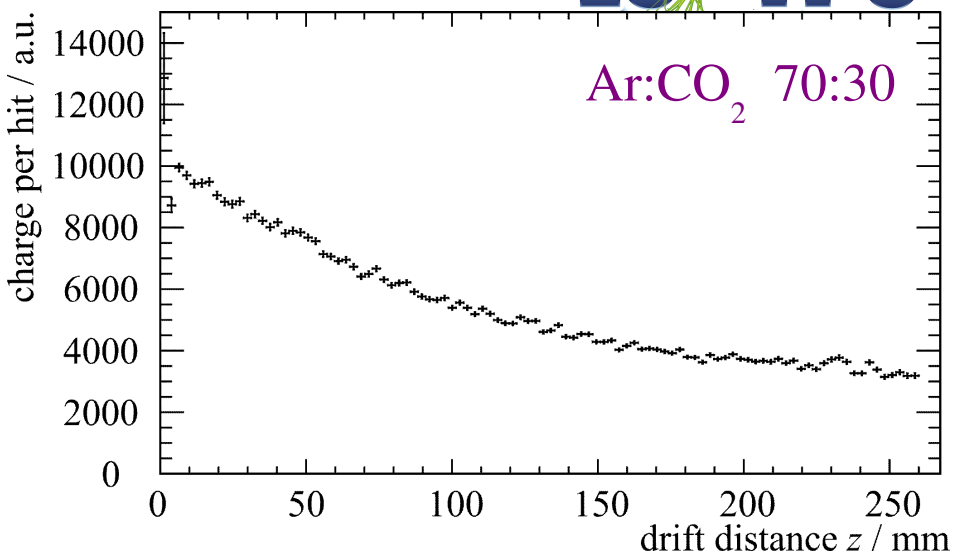
attachment or geometric effect?

$Ar:CO_2$: why so few hits?



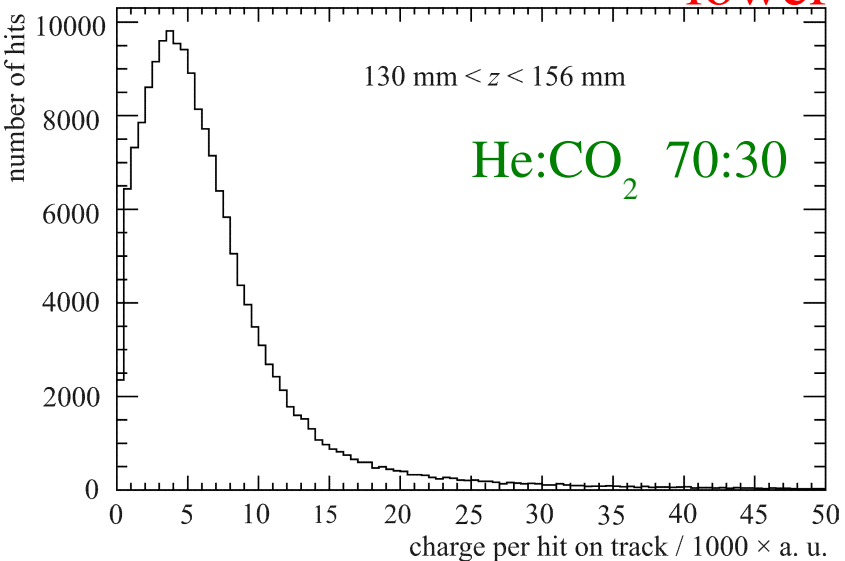
Charge Per Hit

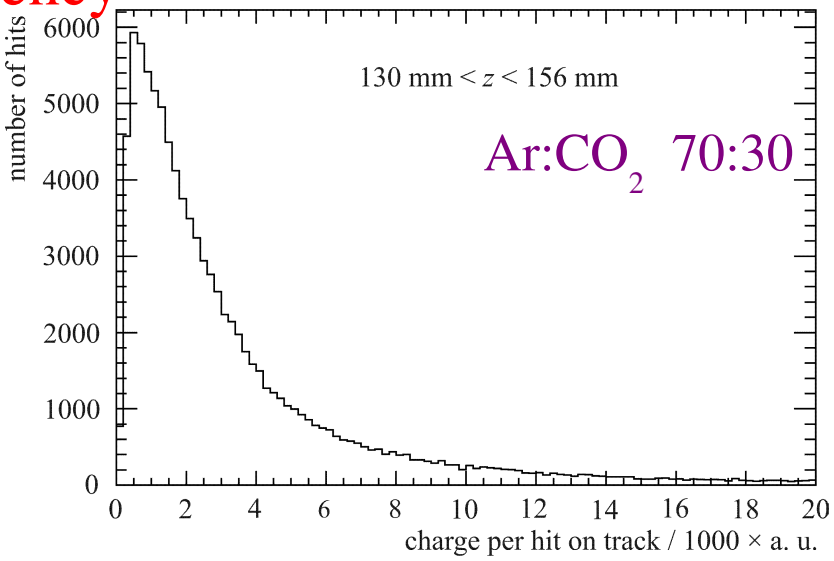




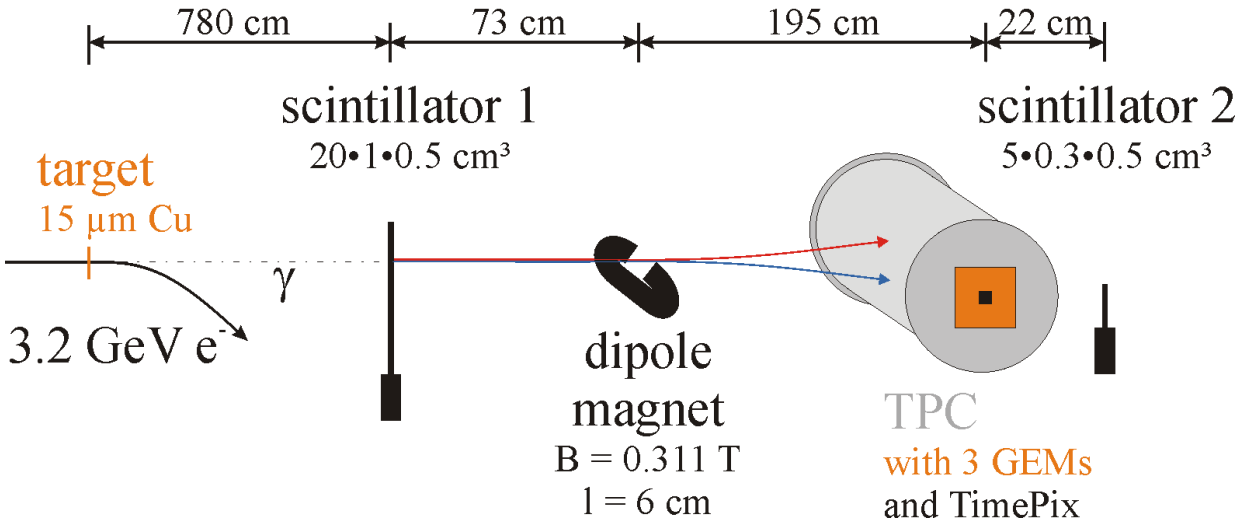
The argon mixture was operated at a lower gas gain than the helium mixture.

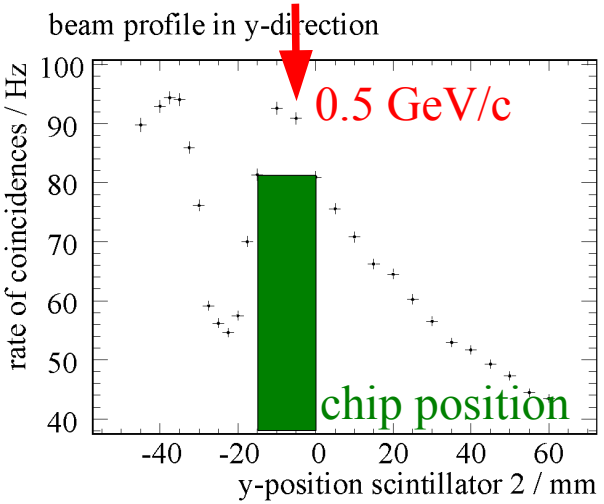
lower efficiency

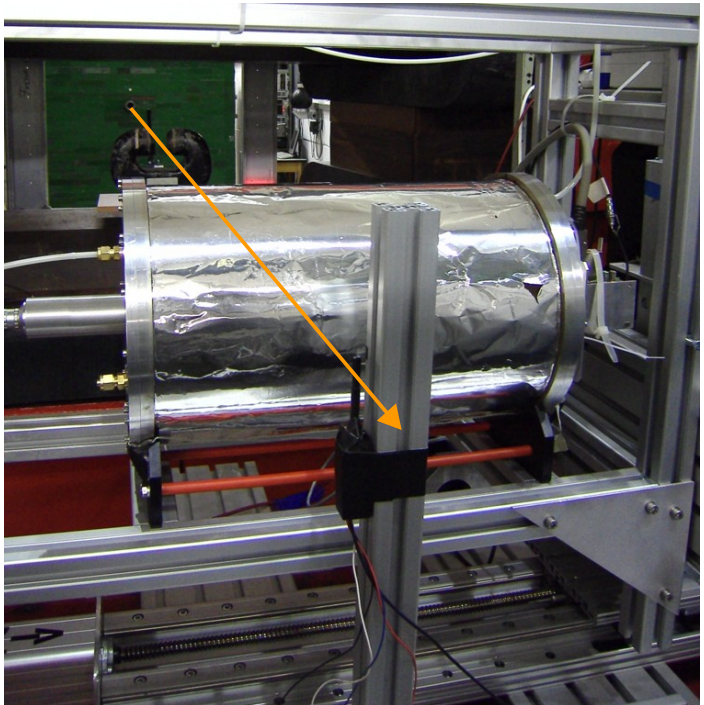




Test Beam Setup at ELSA, Bonn







- γ were created at a target
- primary e^--beam was dumped
- photons converted in scintillator 1
- dipole separated e^+e^-
- coincidence of scinti 1 and 2 select single particle events

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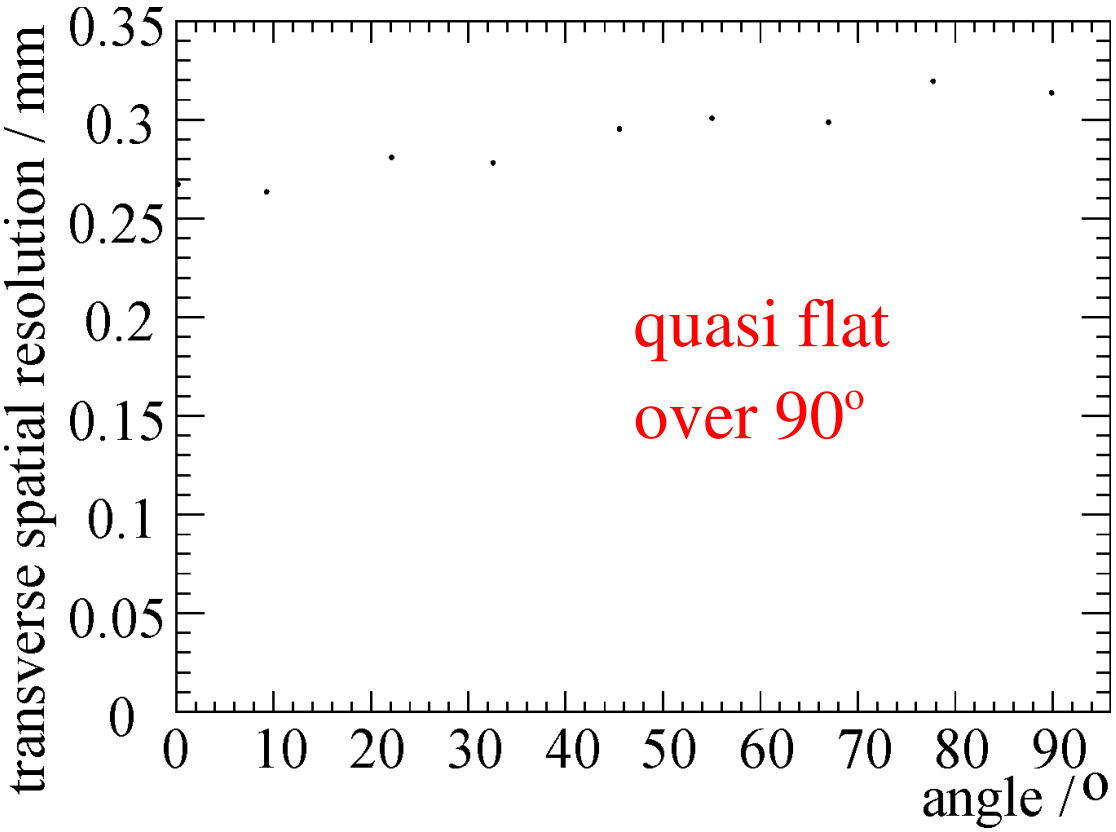
Test Beam Results



transverse spatial resolution in dependence on track inclination

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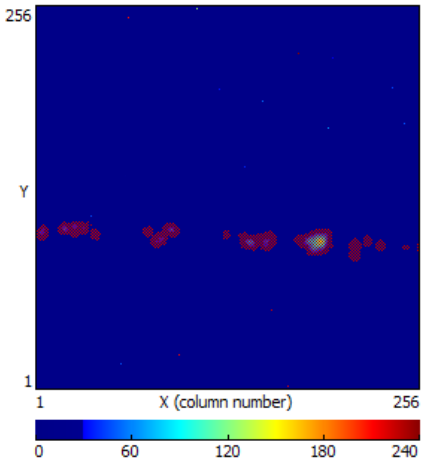
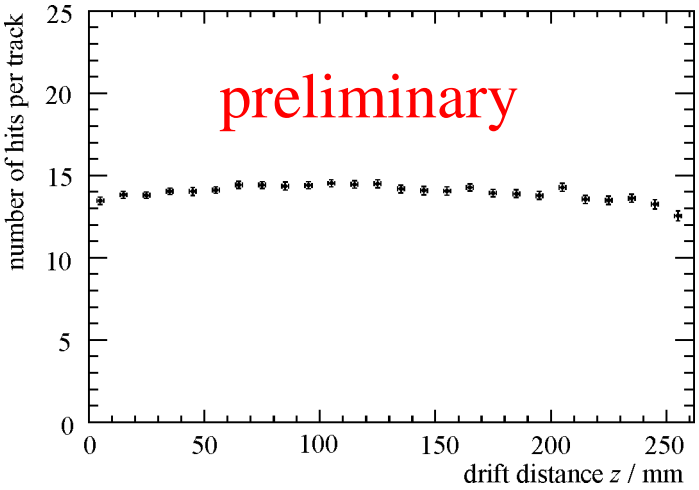
High Magnetic Fields

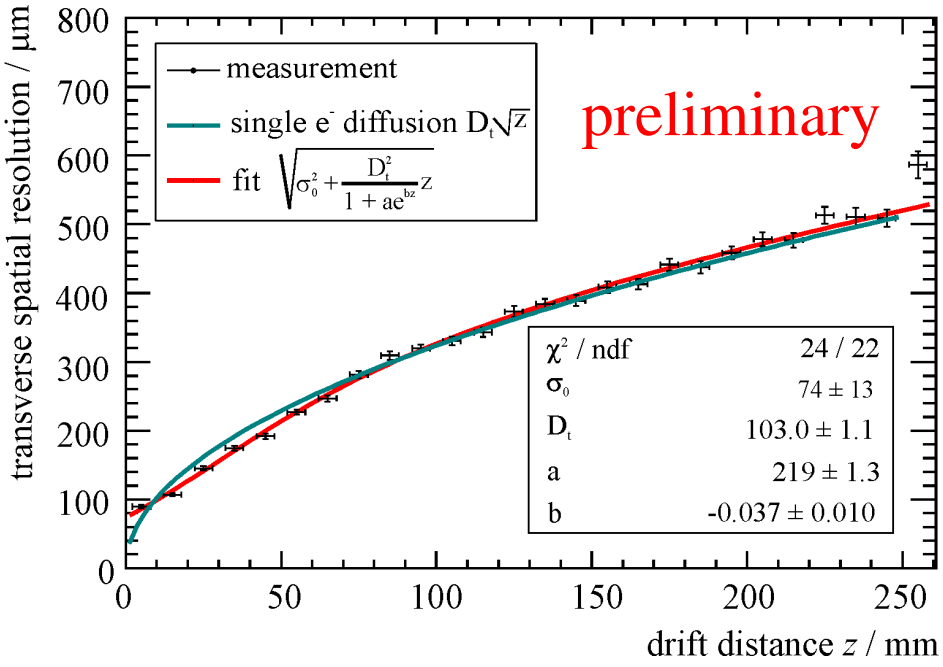
old ZEUS compensation magnet
supraconducting solenoid
reaches up to 5 T

detector is operated in magnet
first results with low statistics



$He:CO_2$ 70:30
at 4T





Large Prototype at DESY

anode plane

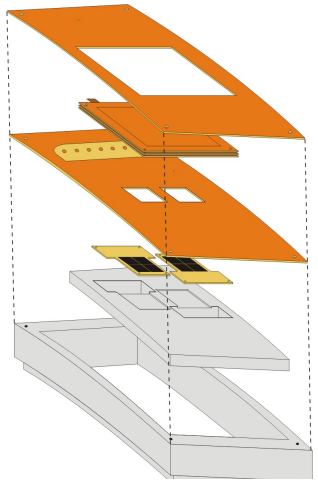
GEMs

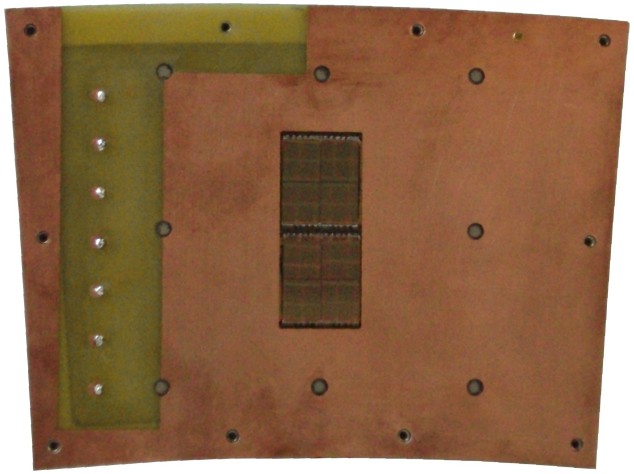
readout plane

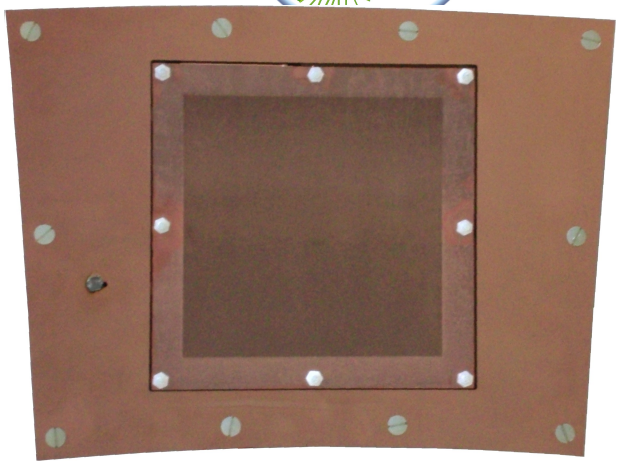
quad-boards

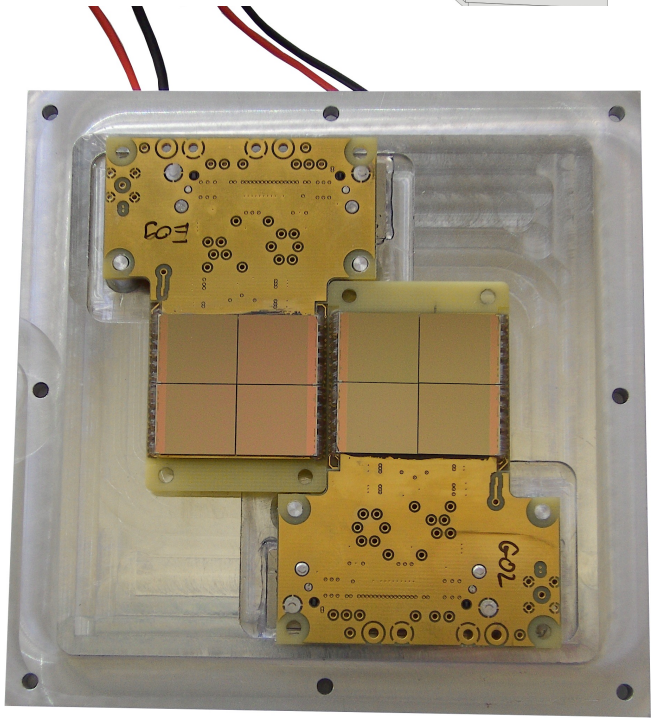
reinforcement of anode plane

redframe



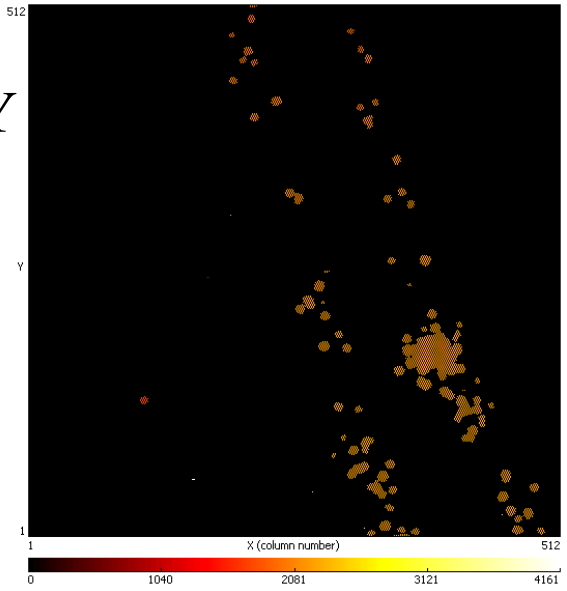






Module has been installed in Large Prototype at DESY (s. talk by T. Matsuda)

First tracks have been seen yesterday.



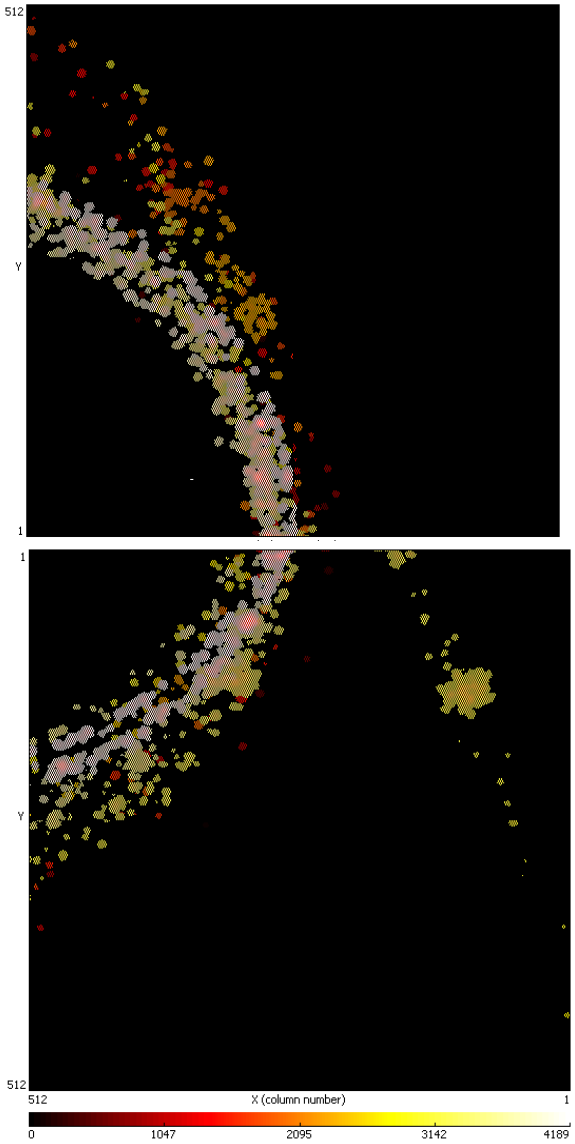
Summary

Detector has performed well with cosmic rays and in an electron test beam.

Declustering has been observed in detail.

Data of test beam show weak dependency on track inclination.

System has been operated in magnetic fields up to 4T



Modern Particle Identification