Report on a test beam with a GEM-TPC at CERN and on a high magnetic field test at DESY

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bmb+f - Förderschwerpunkt
Elementarteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

ICLC
Paris, 21/04/2004

Chamber

<u>dimensions:</u>
length: 25cm
inner diameter: 20cm

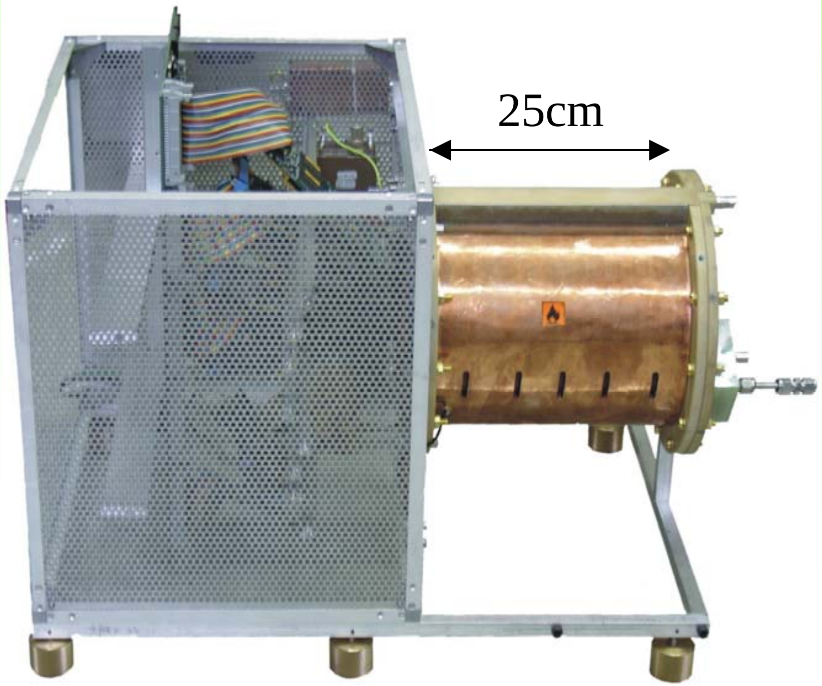
<u>amplification:</u>
GEMs pitch: 140µm
outer diameter holes: 70µm
inner diameter holes: 60µm
transfer gap: 2mm
induction gap: 2mm

transfer field: 2.5kV/cm
induction field: 3.5kV/cm

<u>gas mixture:</u> mostly TDR
$Ar:CH_4:CO_2$ 93-5-2

<u>STAR front-end electronics:</u>
sampling rate: 19.66 MHz
peaking time: 150ns
FWHM of pulse width: 180ns

<u>pads:</u> number of pads: 8*32
size: $1.27*12.5mm^2$



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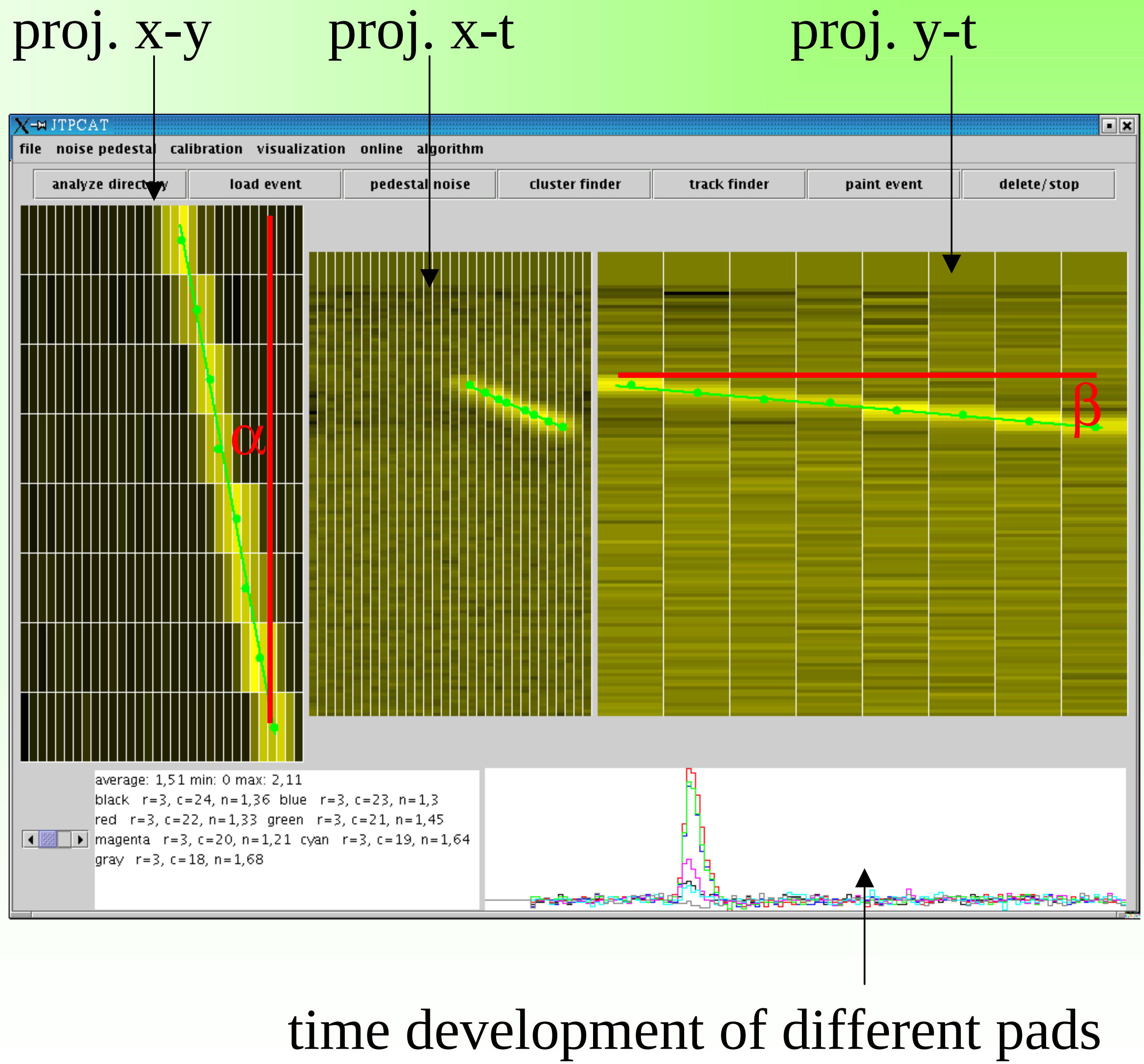
Reconstruction and analysis tool

JAVA program

+ display of signals
+ inversion of signal and pedestal correction
+ reconstruction and analysis of clusters
+ reconstruction and analysis of tracks



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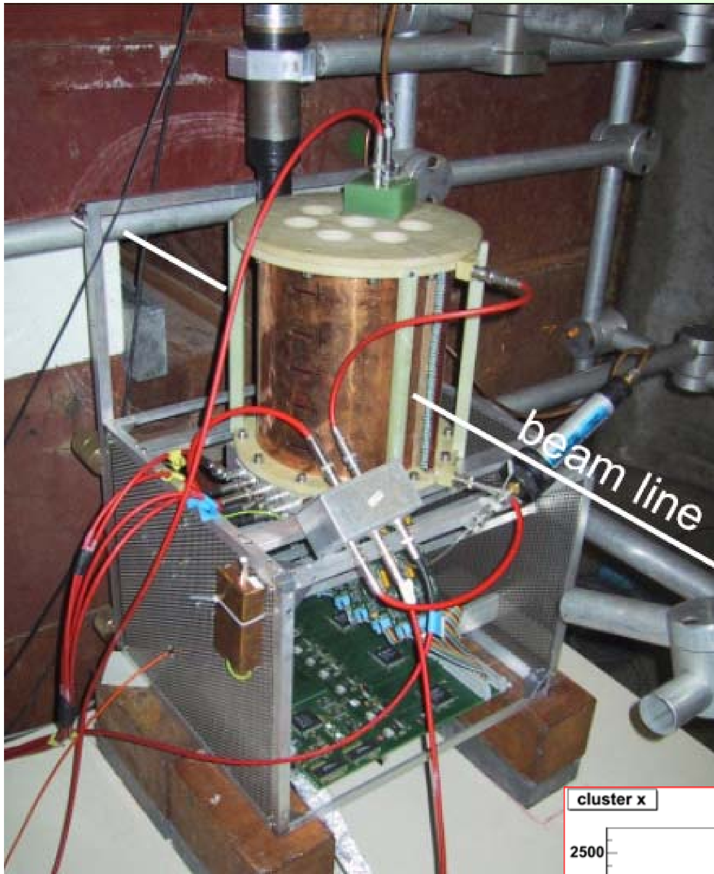
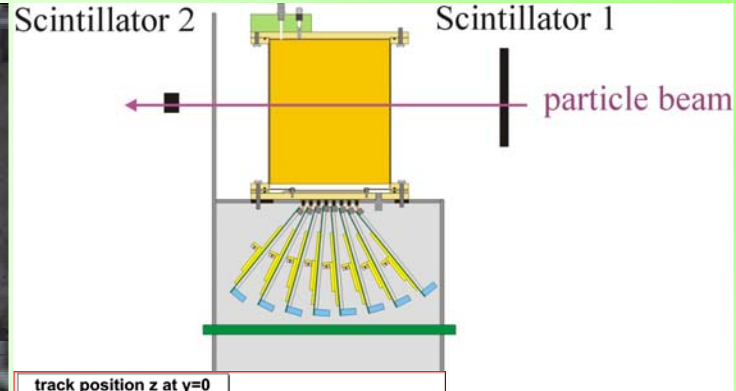
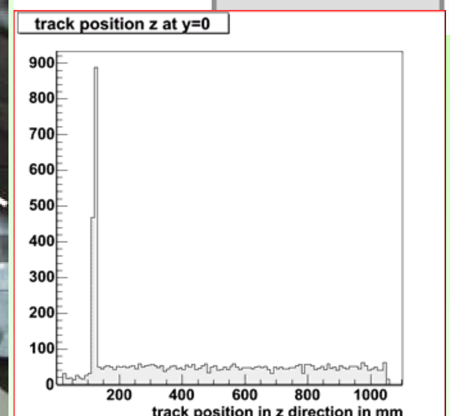
Test beam at CERN's PS-ring (East Hall)





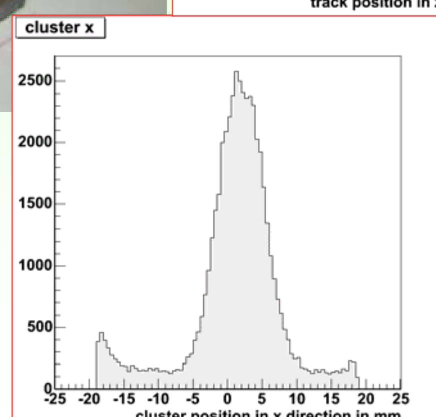
scintillator 1: vertical 4.5*19cm²

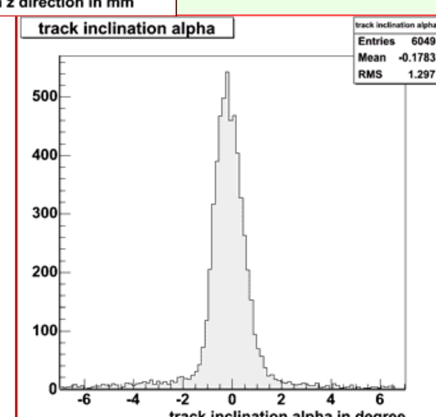
scintillator 2: horizontal 3*7.3cm²

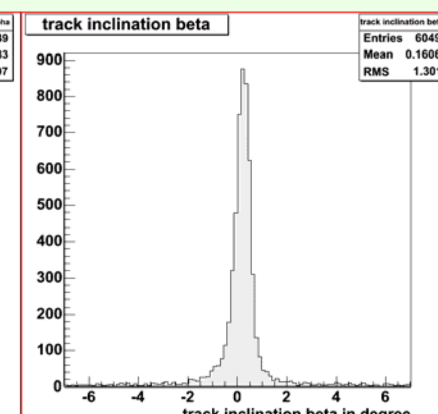


trigger rate: one event per spill but 500 time slices read out, to see more particles

<u>spill length:</u>
550ms







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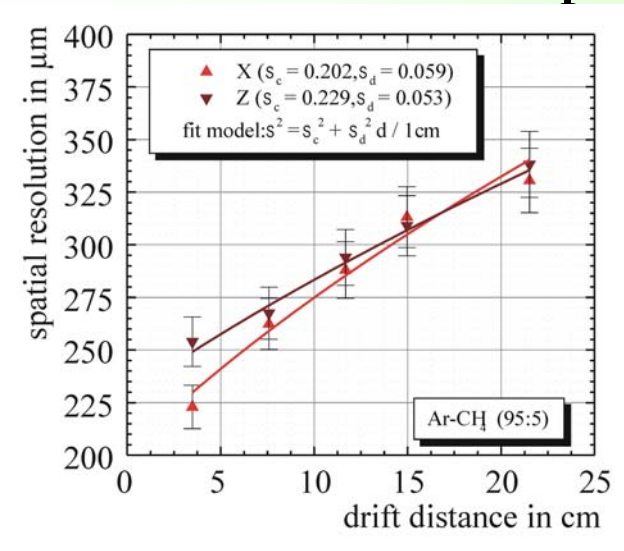
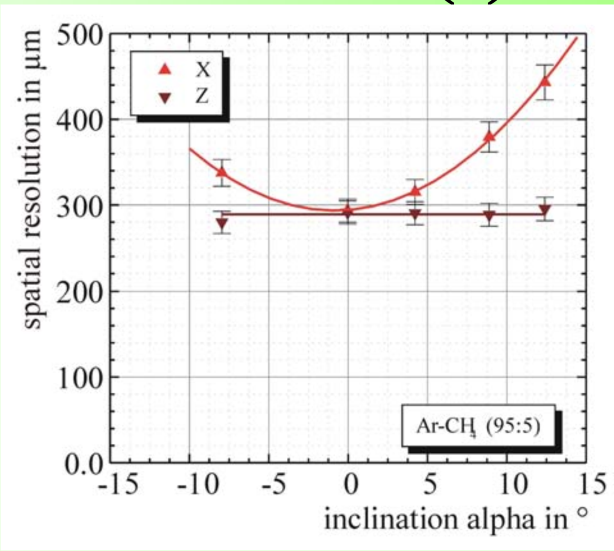
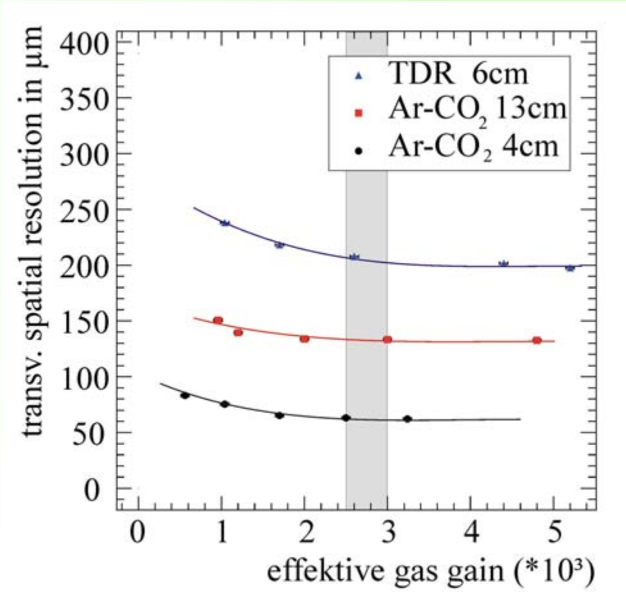
Spatial resolution (I)

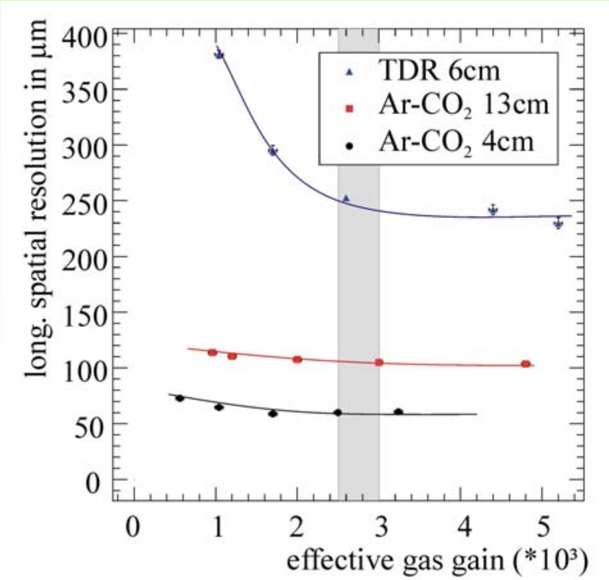




Dependence on drift distance and inclination alpha for $Ar:CH_4$ 95-5

Dependence on gain for different gas mixtures.





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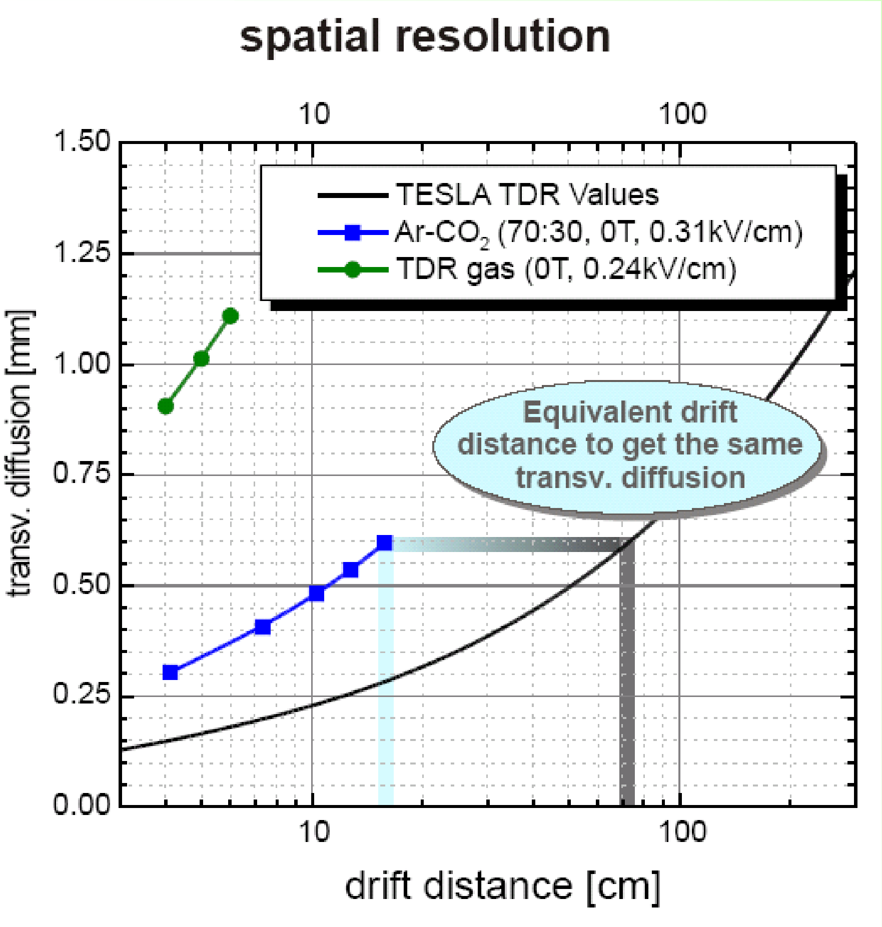
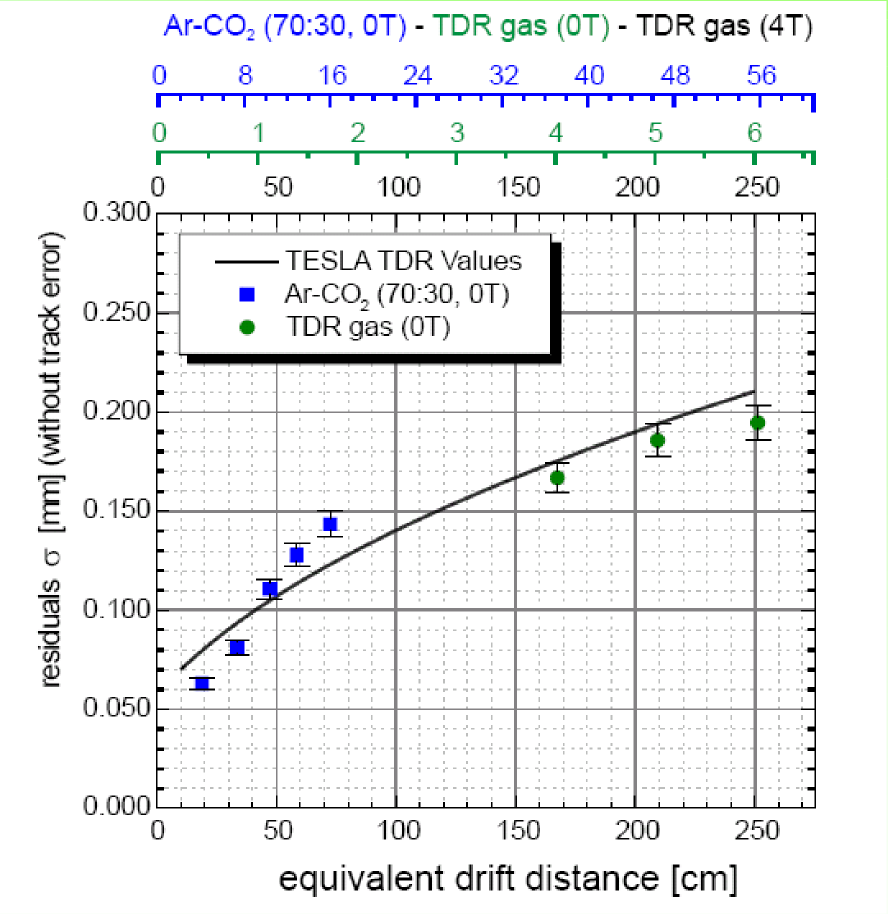
Spatial resolution (II)





$$D_{TDR,4T} \cdot \sqrt{x_{TDR,4T}} = \sigma_{TDR,4T} = \sigma_{gas,0T} = D_{gas,0T} \cdot \sqrt{x_{gas,0T}}$$

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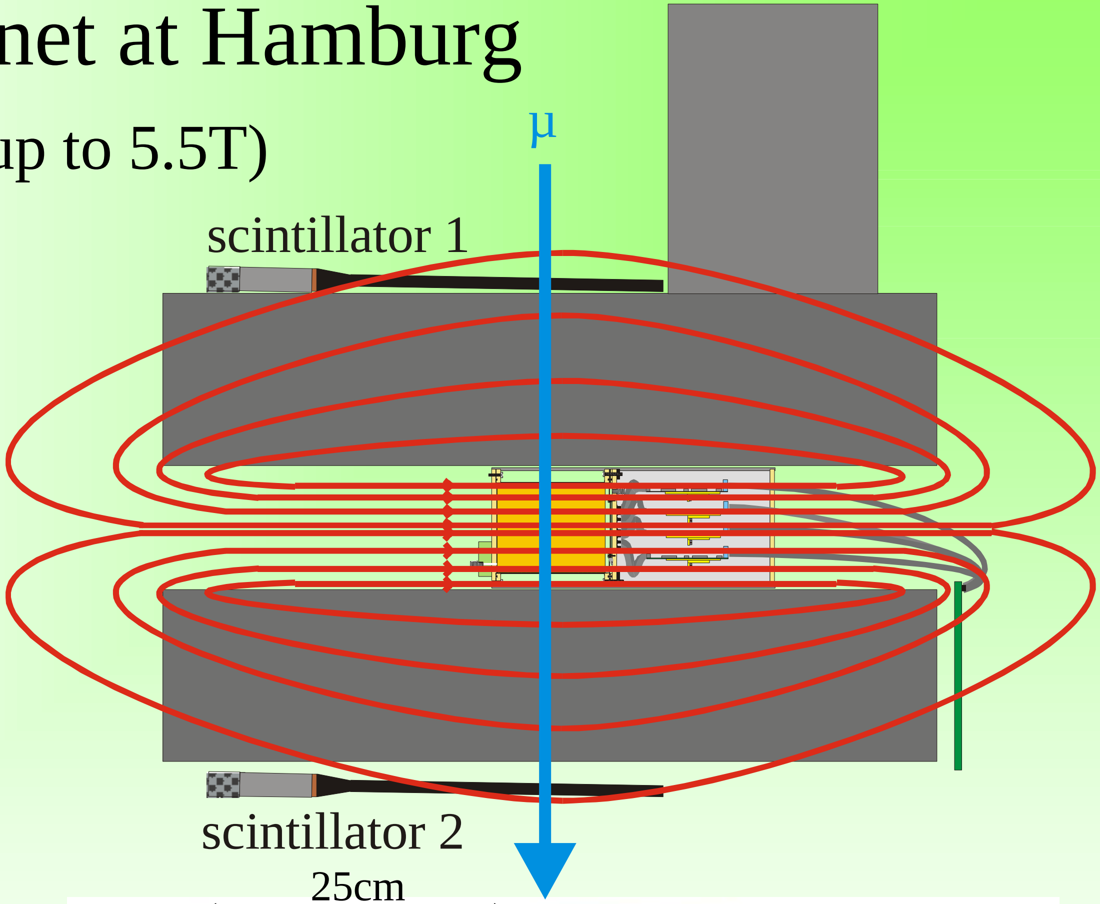
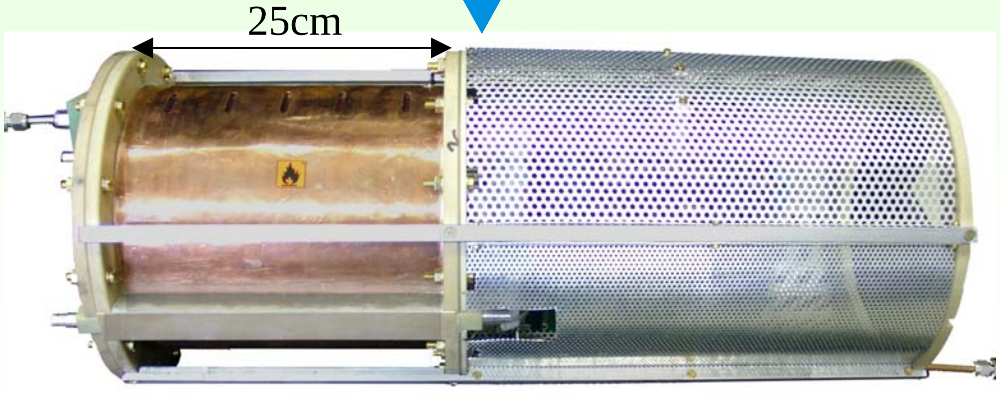
Magnet at Hamburg

super conducting magnet (up to 5.5T)
solenoidal field
diameter of bore: 28cm
length: 186cm





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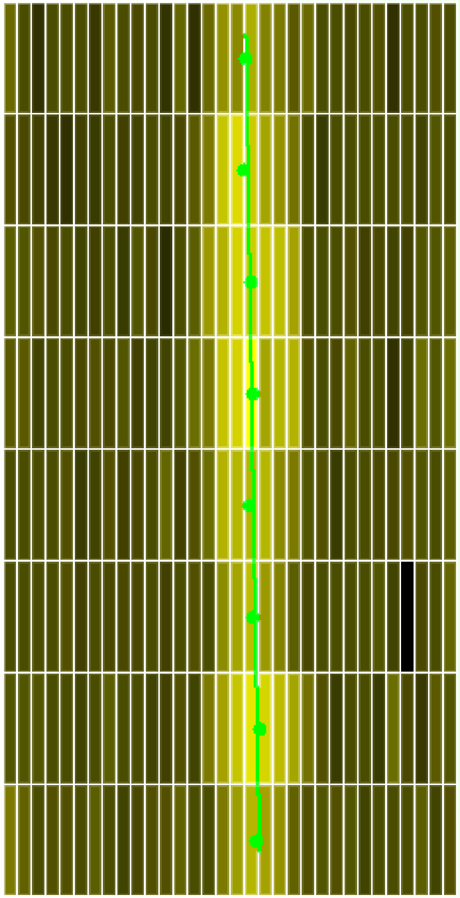
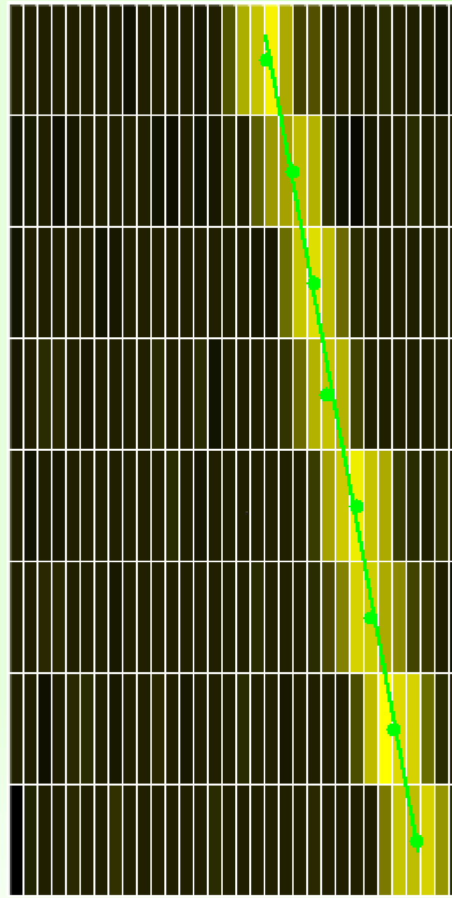
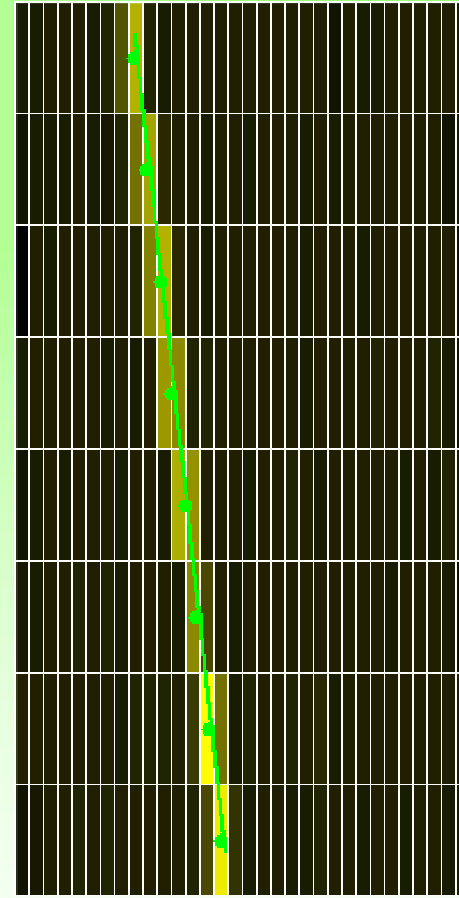
Enlargement of clusters due to diffusion



$Ar : CH_4$ 95-5
$B = 0T \quad E_{drift} = 95 V/cm$
$D_{trans} = 726.0\ \mu m/\sqrt{cm}$



$Ar : CH_4 : CO_2$ 93-5-2
$B = 0T \quad E_{drift} = 240 V/cm$
$D_{trans} = 476.5\ \mu m/\sqrt{cm}$



$Ar : CH_4 : CO_2$ 93-5-2
$B = 5T \quad E_{drift} = 240 V/cm$
$D_{trans} = 72.6\ \mu m/\sqrt{cm}$

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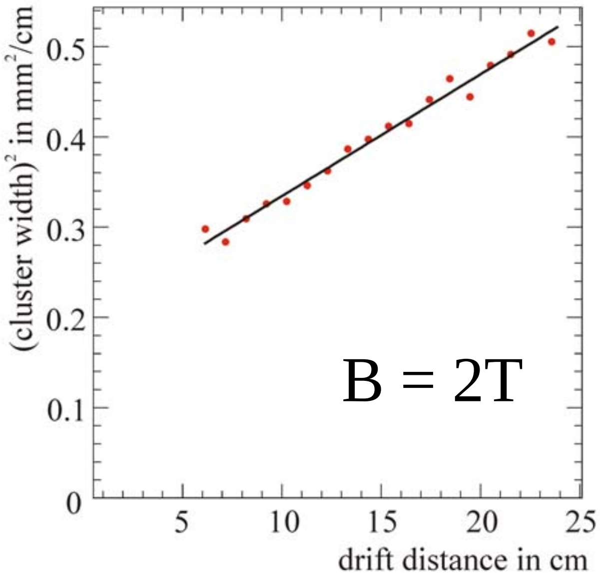
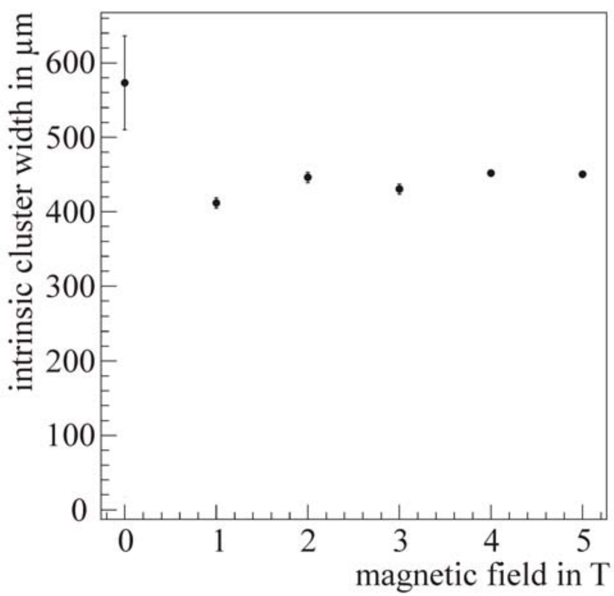
(diffusion coefficients calculated with Magboltz)

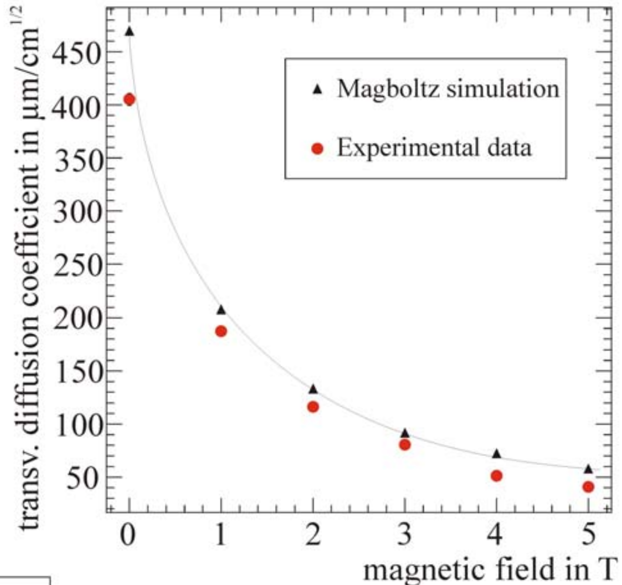
diffusion coefficient in dependence of magnetic field



squared cluster width versus drift distance

Intrinsic enlargement of cluster width by GEMs and transfer/ induction field





Diffusion coefficient in dependence of magnetic field

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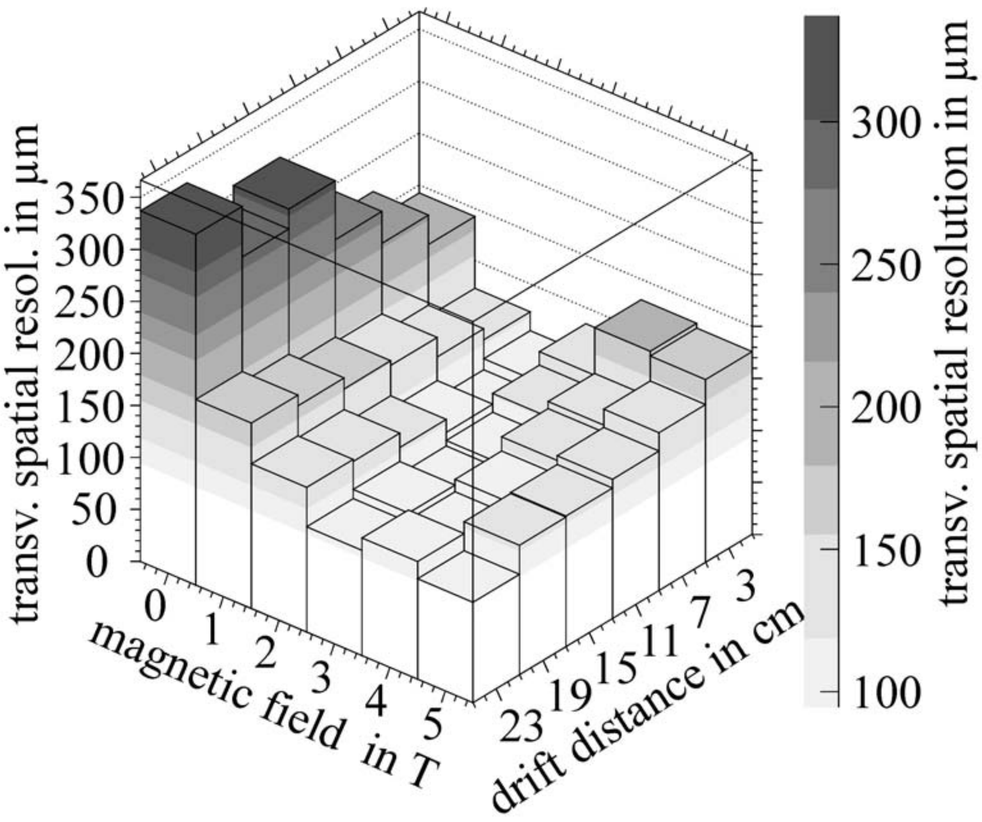
Transversal spatial resolution

Transversal spatial resolution $\sigma_{sp\ res}$ was determined from width of residuals:

$\sigma^2_{res} = \sigma^2_{sp\ res} + \sigma^2_{track}$ => with approximation $\sigma^2_{track} = \sigma^2_{res}/N$



The transv. spatial resolution is limited by diffusion for long drift distances and low magnetic fields.

For short drift distances and high magnetic fields the cluster width becomes so small that the number of pads hit above noise is insufficient for the reconstruction algorithm (COG) and the spatial resolution worsens.

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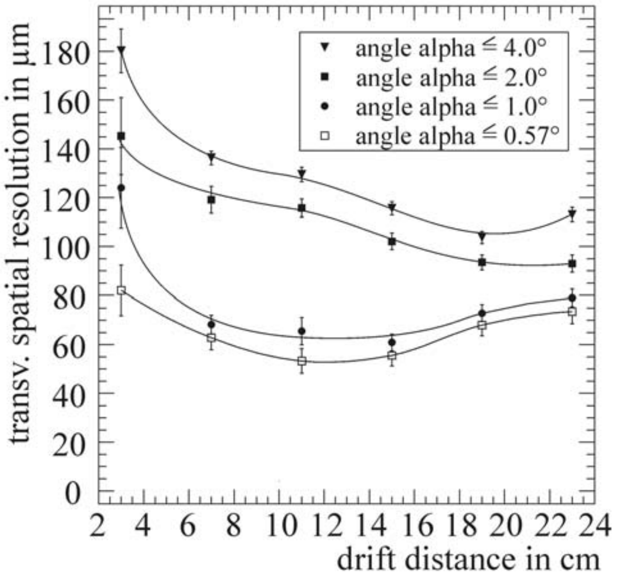
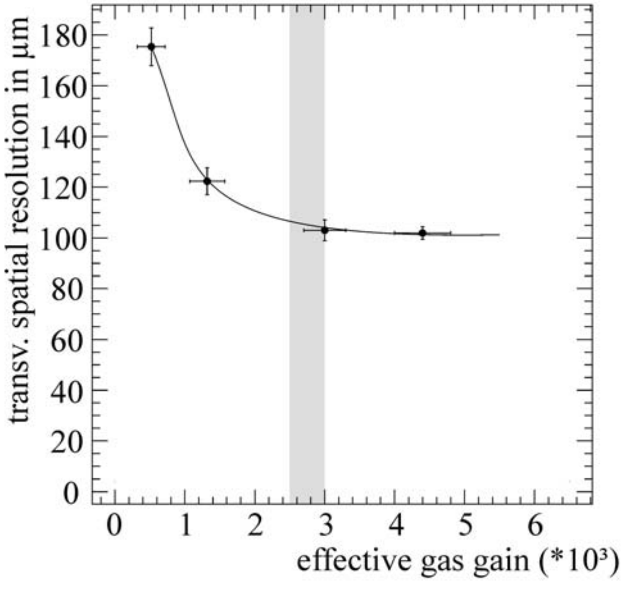
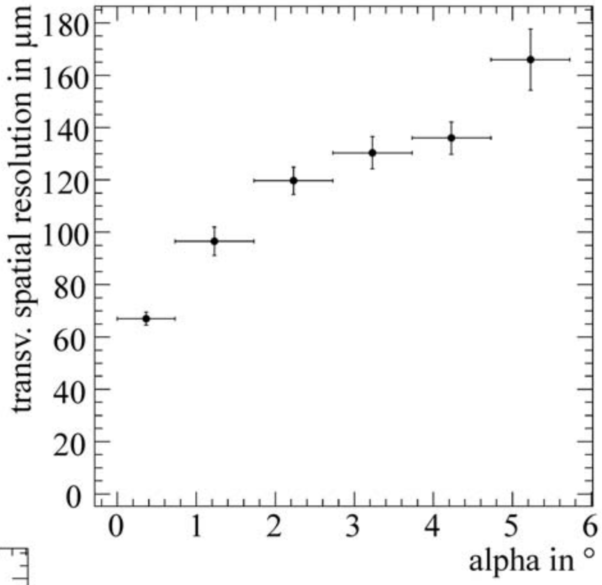
Transversal spatial resolution in dependence of different parameters at B = 4T



transv. spatial resolution versus drift distance and inclination of track

transv. spatial resolution versus effective gas gain





transv. spatial resolution versus inclination of track

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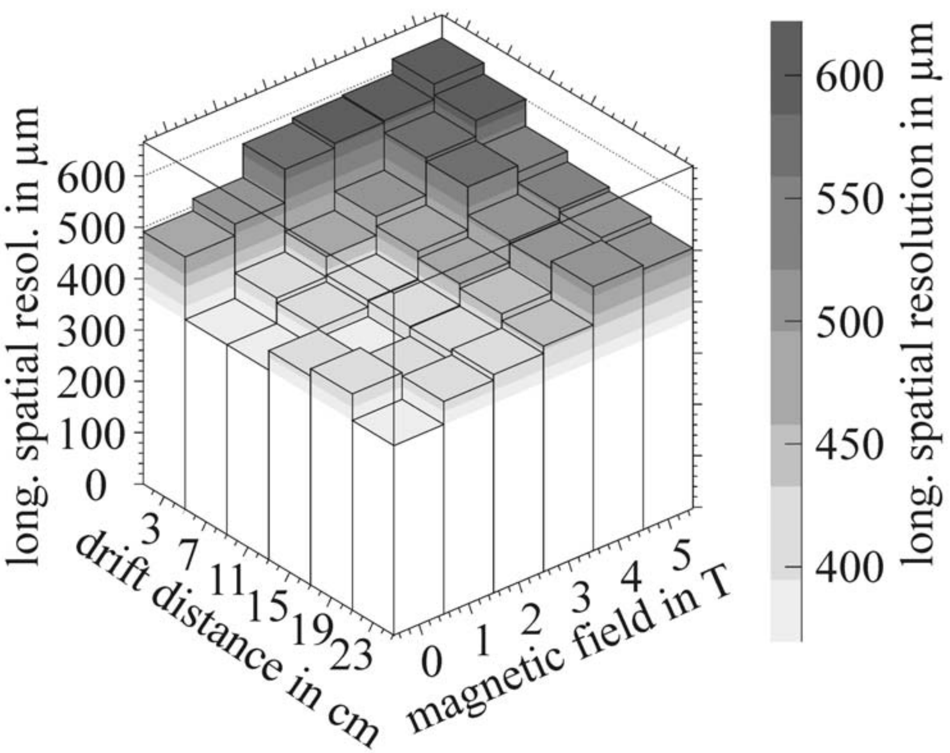
Longitudinal spatial resolution

Calculation of long. spatial resolution analogous to the transv. s. r.



$D_{long} = 297\mu m/\sqrt{cm}$ - Magboltz

At drift distance of 23 cm:

1.42mm = 31.6ns

=> Basically one time slice hit

=> Improvement with longer drift distances

Degradation of spatial resolution with higher magnetic fields: since transversal cluster width decreases and thus the time information of less pads contributes to the cluster reconstruction (COG).

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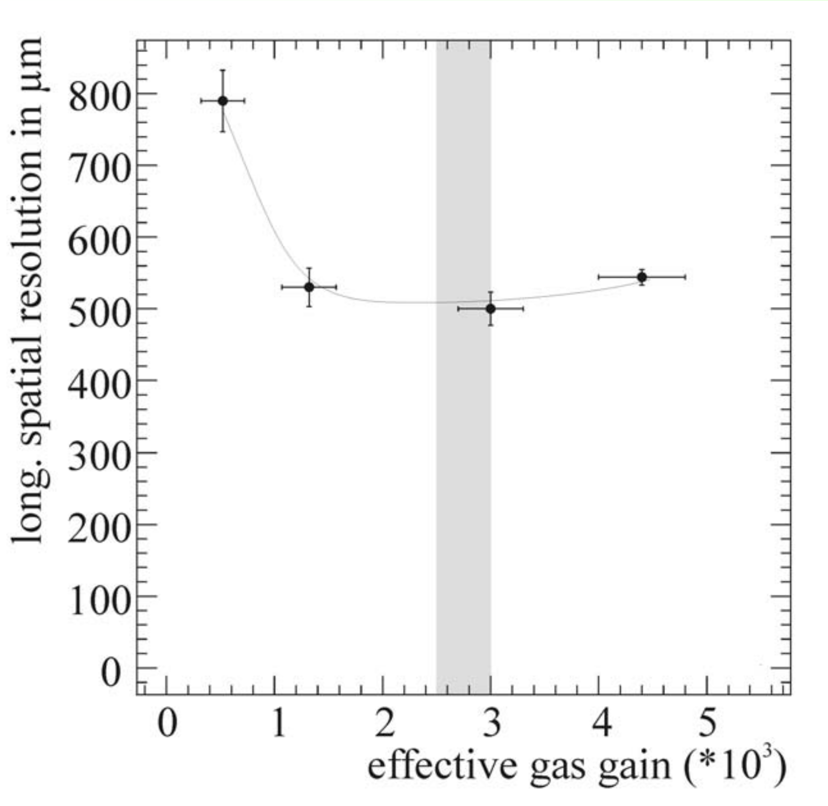
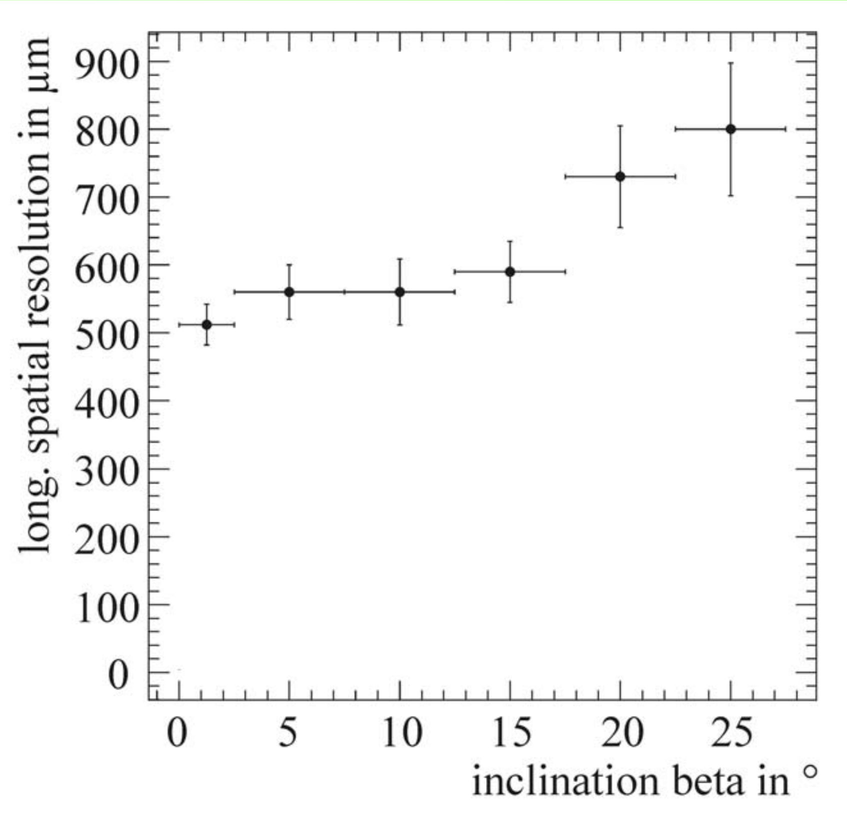
Longitudinal spatial resolution in dependence of different parameters



long. spatial resolution in dependence of gas amplification



long. spatial resolution in dependence of track inclination

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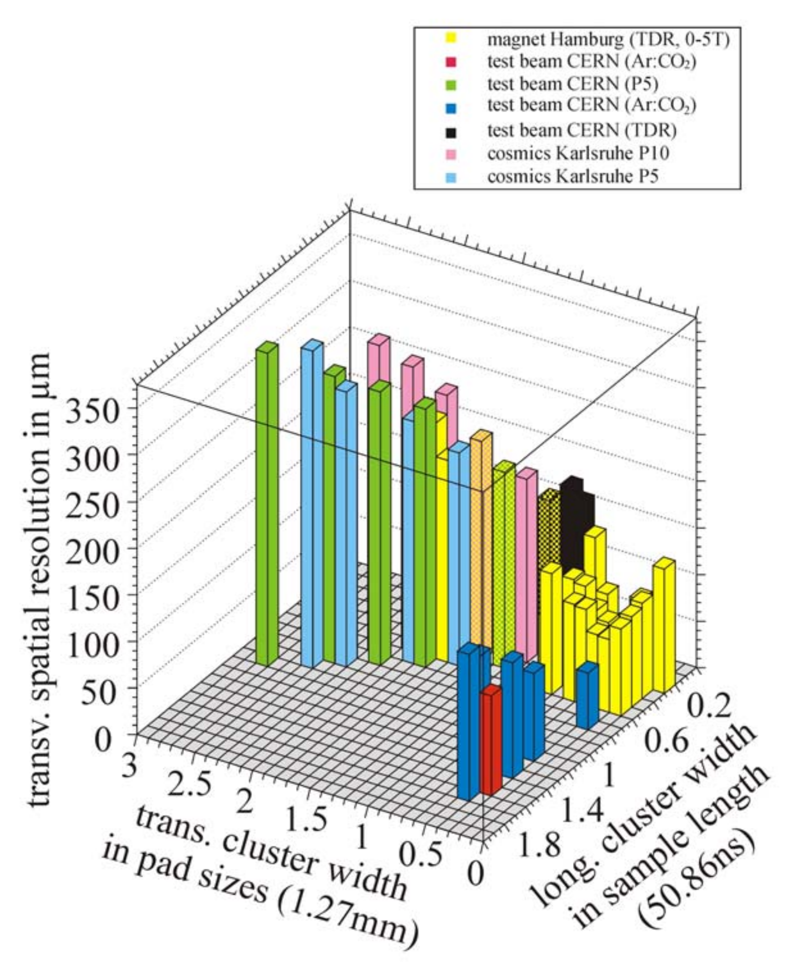
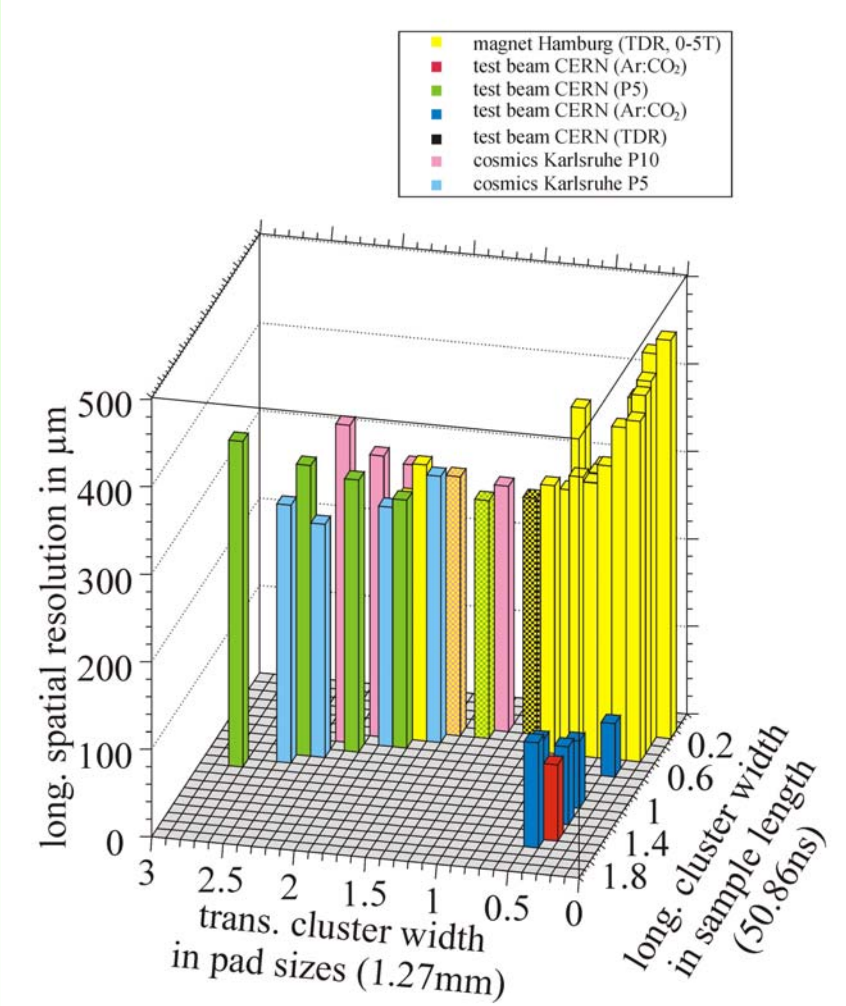
Combined results of spatial resolution study





All cluster sizes are determined by Magboltz diffusion coefficients and actual drift distance.

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Conclusion

Detector was tested in a high rate hadronic beam
and high magnetic fields
=> no problems were observed
Same GEMs are still working after 6 trips of 500 km inside the detector and being operated in 3 different experimental environments.

Transversal and longitudinal spatial resolutions were studied under various conditions. The smallest resolutions reached were:
test beam: 62µm transversally and 59µm longitudinally
- in Ar:CO_2 (4cm drift)
magnetic field: (53 +/- 3)µm transversally (B = 4T, 11cm drift)
and (395 +/- 16)µm longitudinally (B = 0T, 23cm drift) – in TDR.

A combination of all results was done.

Outlook

Further tests at the magnet and the test beam are intended:

- for higher statistics
- test different readout designs
- stability tests

Acknowledgement

The authors would like to thank:

R. Heuer und R. Settles for their support and advice

M. Hauschild (CERN) for discussions and supporting this project

M. Van Stenis (CERN) and T. Barvich (Karlsruhe) for building the detector and parts of the equipment

L. Durieu (CERN) and the CERN PS-Team

The FLC-group at DESY for their help with the magnet