Status of the Aachen LC TPC Efforts

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RWTH AACHEN

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Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

bmb+f Großgeräte der physikalischen Grundlagenforschung

Overview

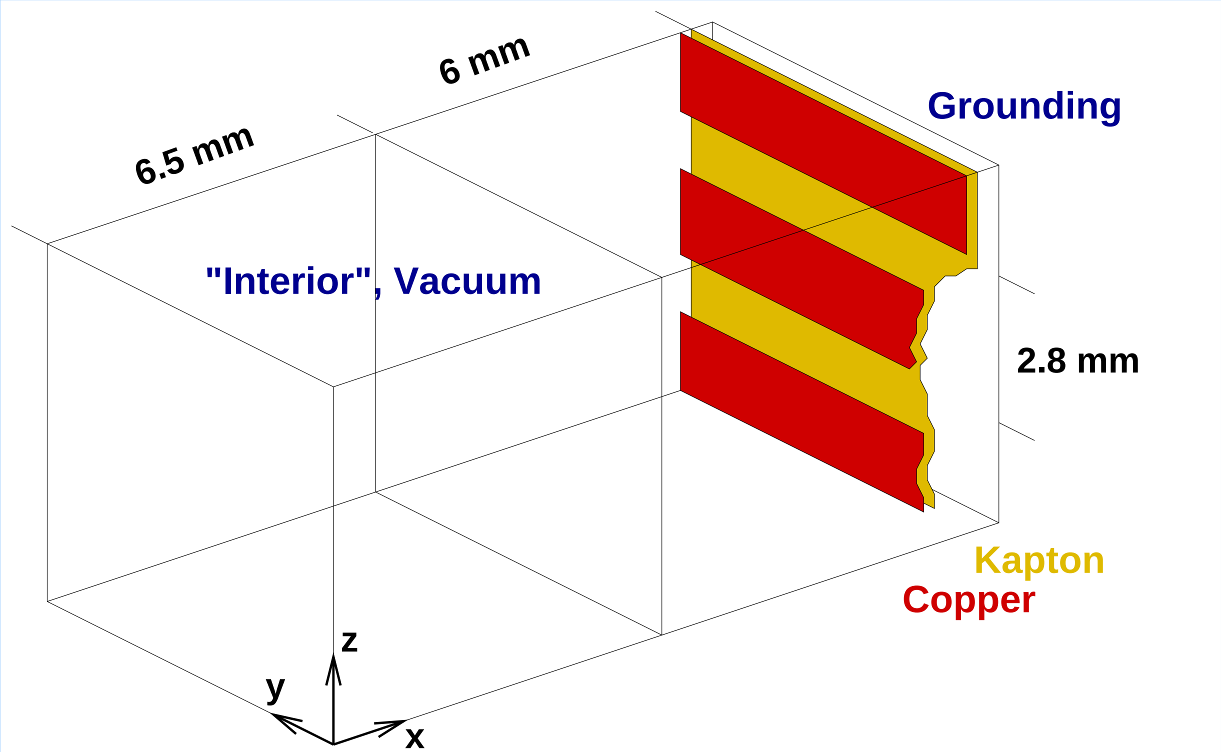
- TPC Prototype
- Hodoscope
- Readout Electronics
- Charge Width
- Ion Backdrift
- Simulations

TPC Prototype: Requirements

- 5T magnet at DESY: 280 mm bore
- SMD resistors as voltage divider
  $\Rightarrow$ minimal pitch = 2.8 mm
- Materials with low density
  (radiation length)
- GEM readout from test TPC
  should be used
- 26 kV for drift field available

TPC Prototype: Simulation

- Optimisation of the field cage
- Simulations of strip geometry with Maxwell 3D:
  copper strips on one or both sides,
  different ratios of strip width and distance with fixed pitch (2.8 mm)



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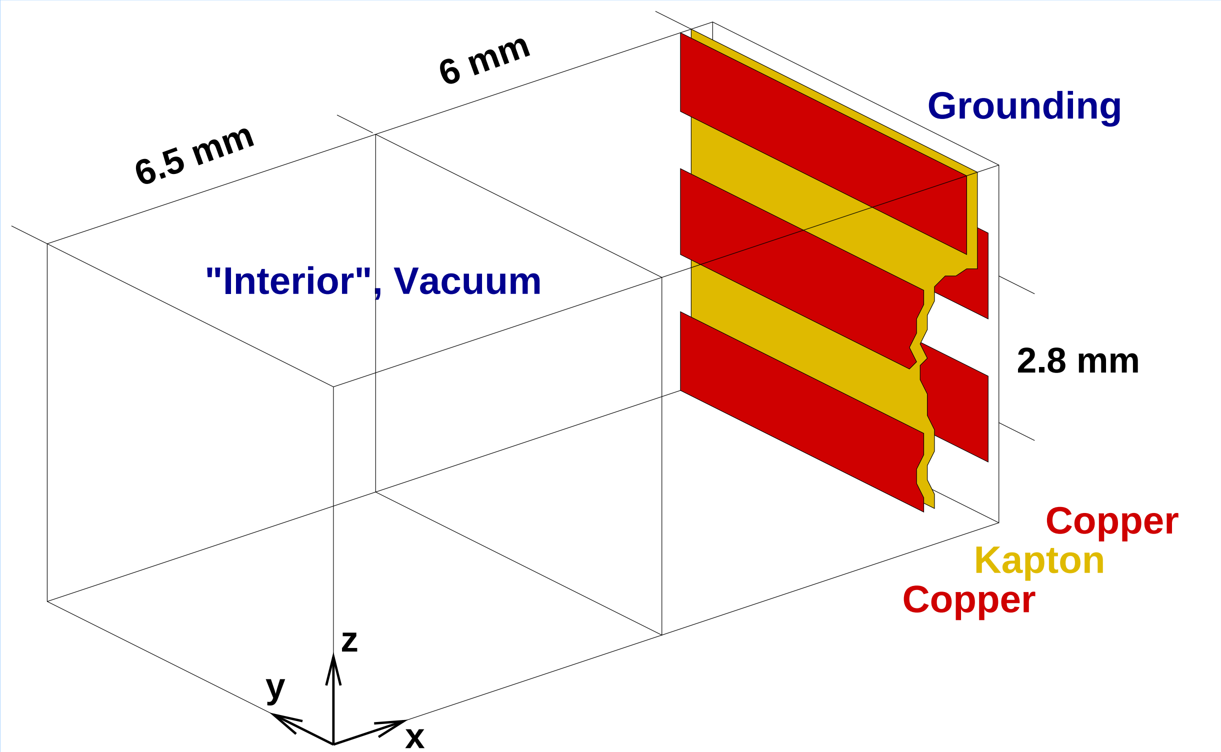
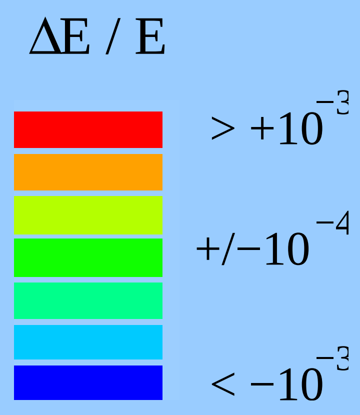
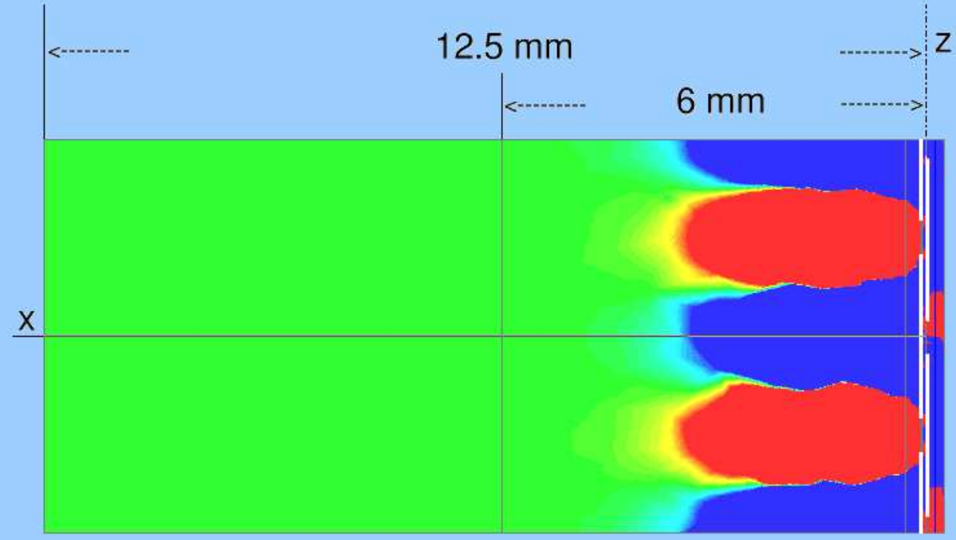


TPC Prototype: Results of the Simulation





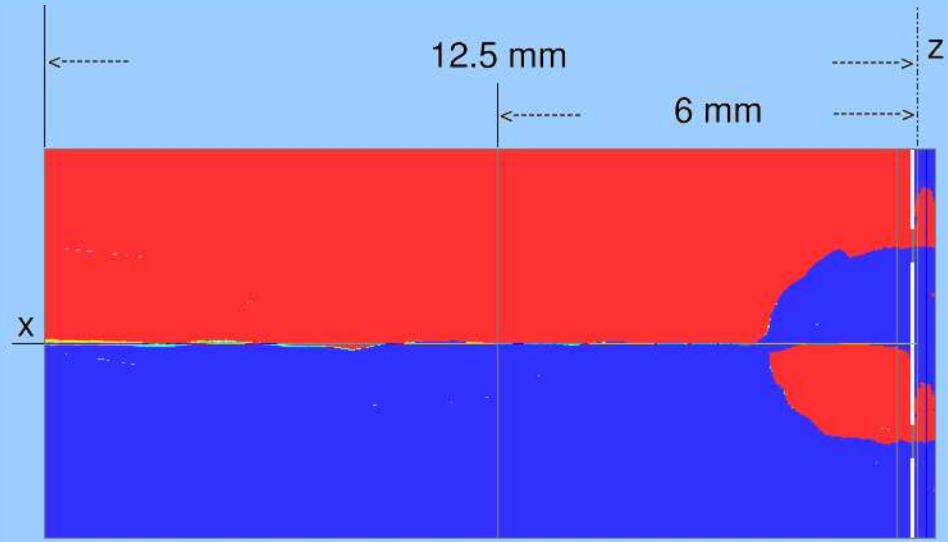
$E_{parallel}$, strips on both sides

Copper strips:

width 2.3 mm

distance 0.5 mm

$\Rightarrow$ field with double-sided strips much better than with one-sided strips



$E_{parallel}$, strips on one side

TPC Prototype: Construction

Ø = 260 mm

pitch = 2.8 mm

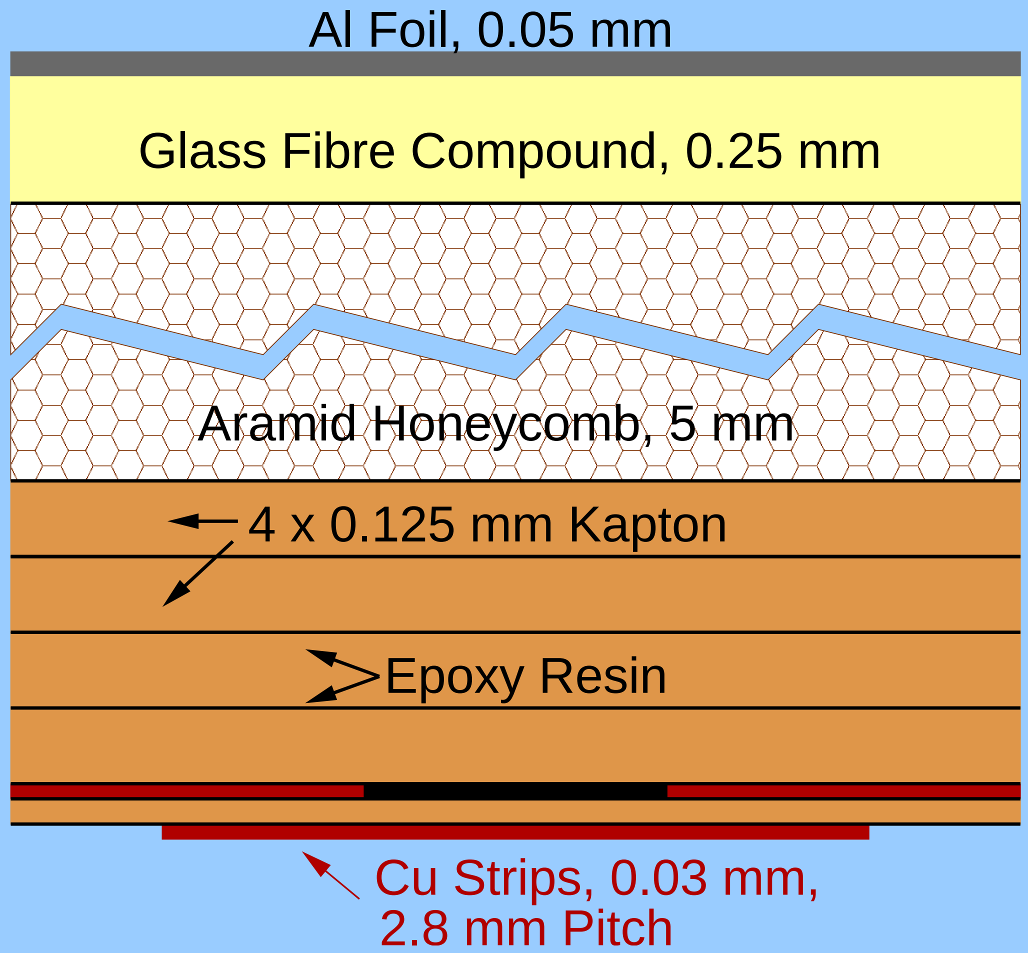
R = 4.7 MΩ (SMD)

U_{max} = 26 kV

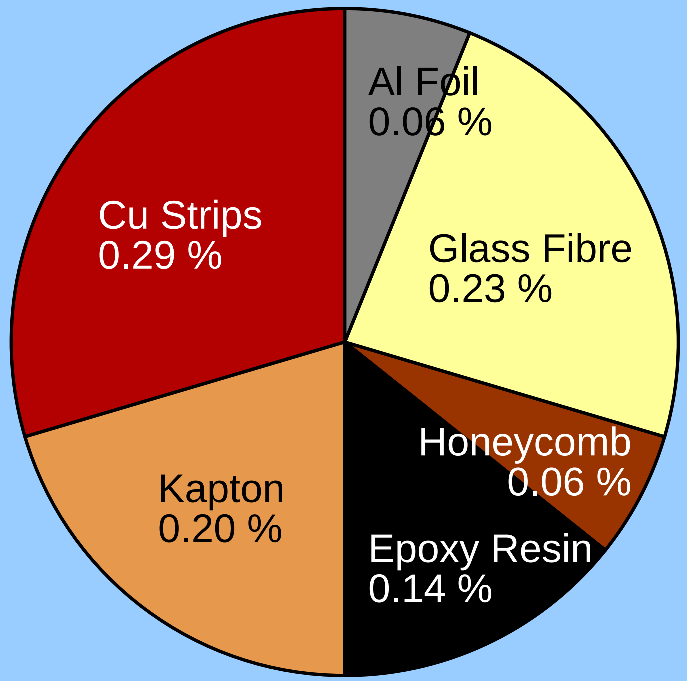
ℓ_{drift} = 26 cm

E_{max} = 1000 V/cm

TPC Prototype: Radiation Length



fraction of radiation length

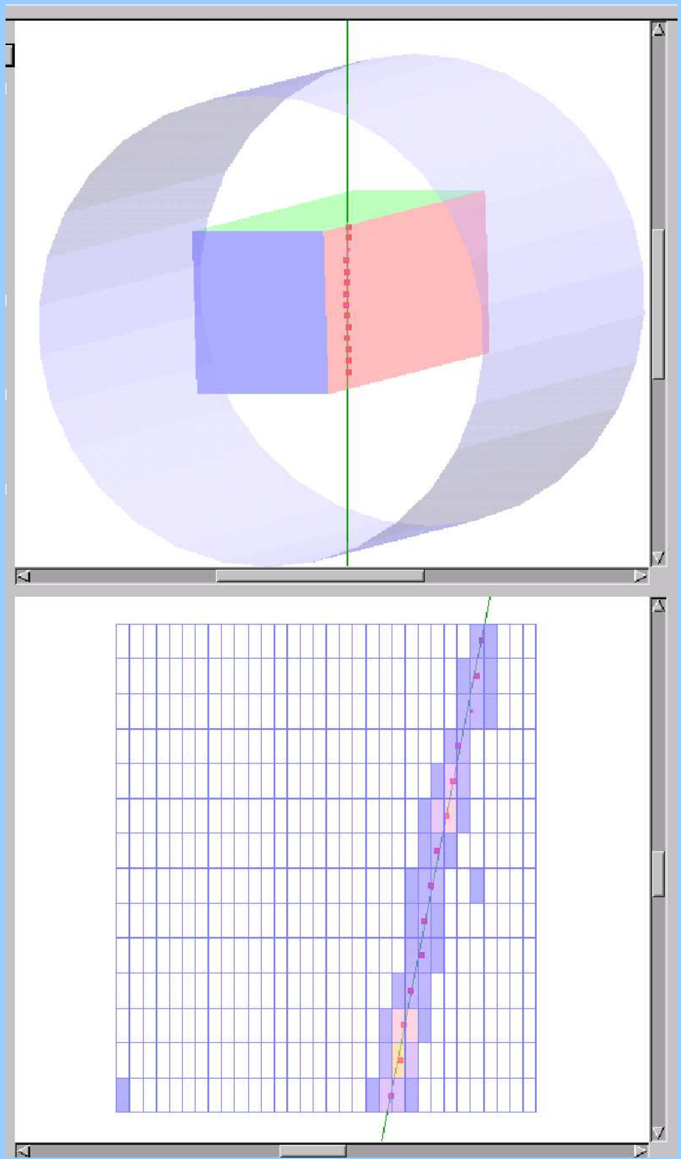


altogether 1% radiation length

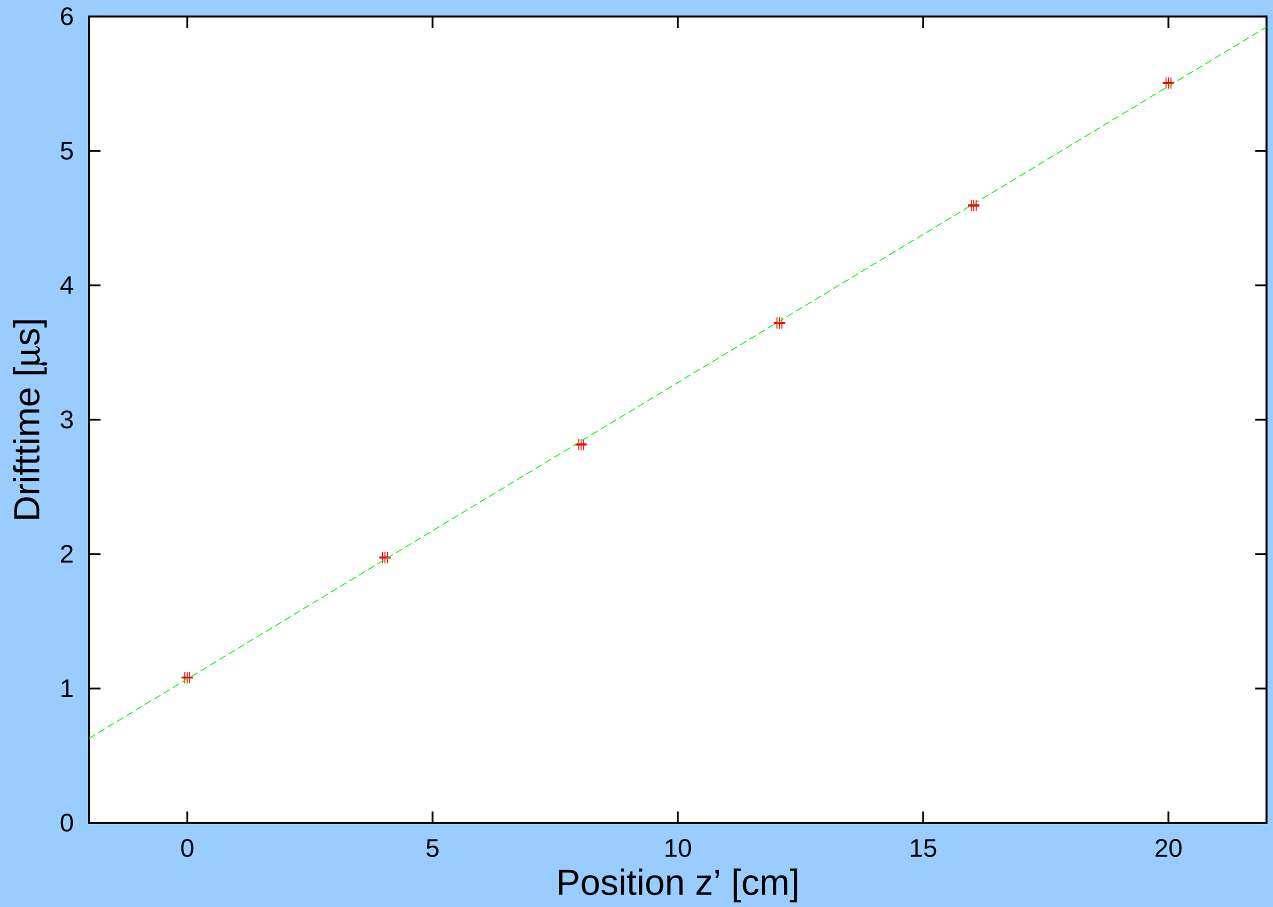
⇒ 3 % radiation length possible (TESLA TDR)

TPC Prototype: First Results

First event



Homogeneous drift velocity

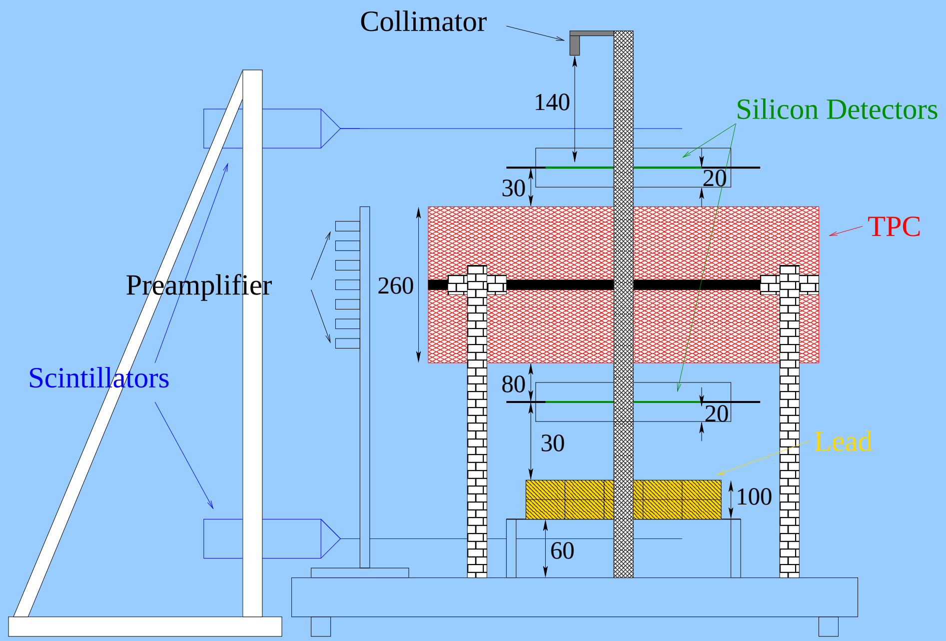


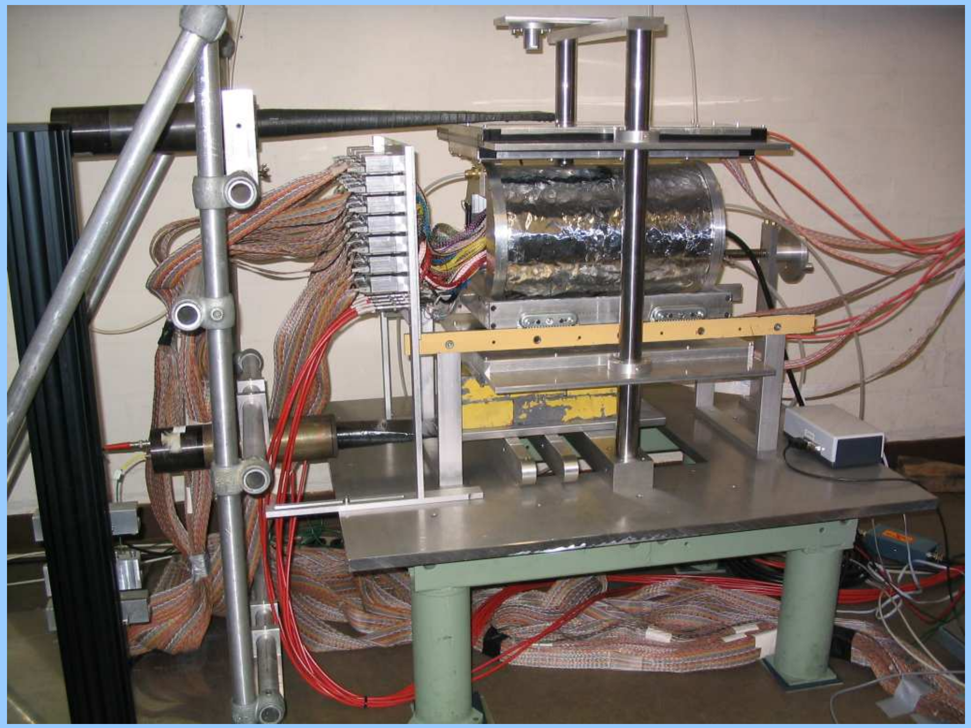
Hodoscope: Task

- Measurement of the drift velocity
- Measurement of the field homogeneity to the order of $\leq 10^{-3}$
- Measurement of the spatial resolution:
  Accuracy in x: $\sim 60\,\mu$m
  Accuracy in z: $\sim 400\,\mu$m

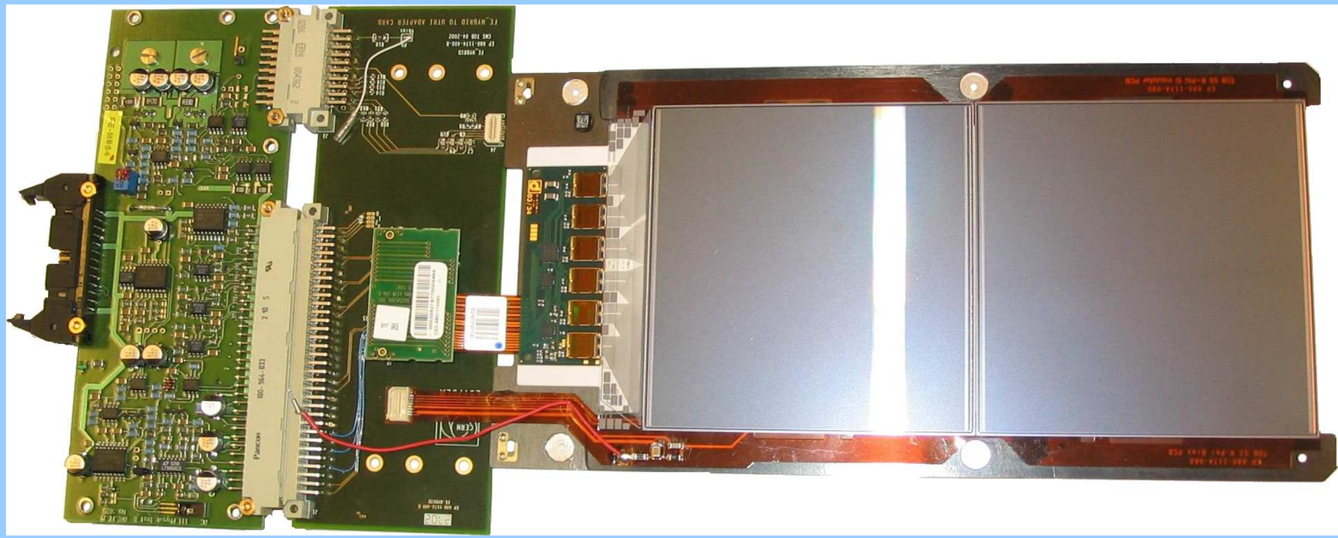
$\Rightarrow$ Goal: Determination of all properties of the TPC,
to know and be able to correct all effects of the chamber
for future measurements (e.g. Test Beam)

Hodoscope: Design



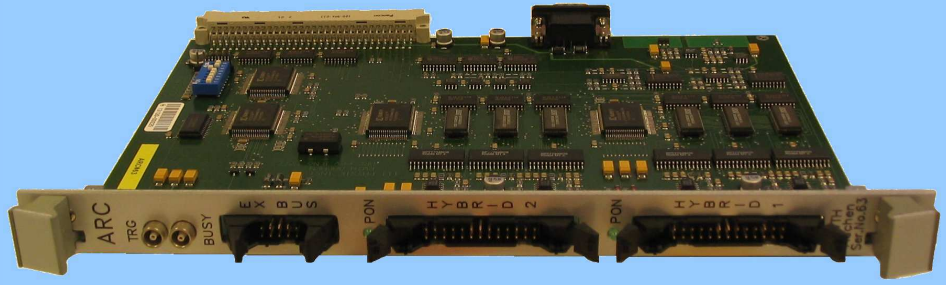


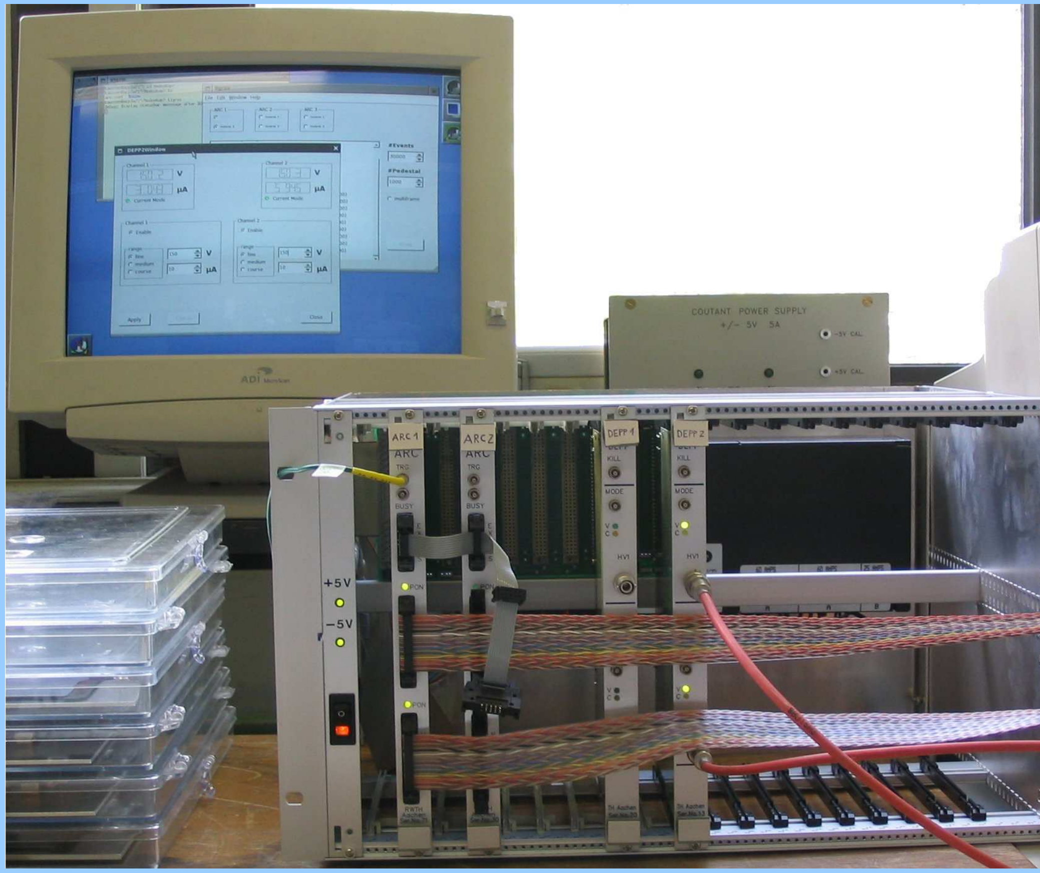
Hodoscope: Silicon Detectors



- CMS TOB module (Tracker Outer Barrel)
- 6 APV-Chips, 768 strips
- Pitch 122 μm
- Active area 93,9 mm x 190,0 mm
- Thickness 500 μm

Hodoscope: Silicon Detector Readout

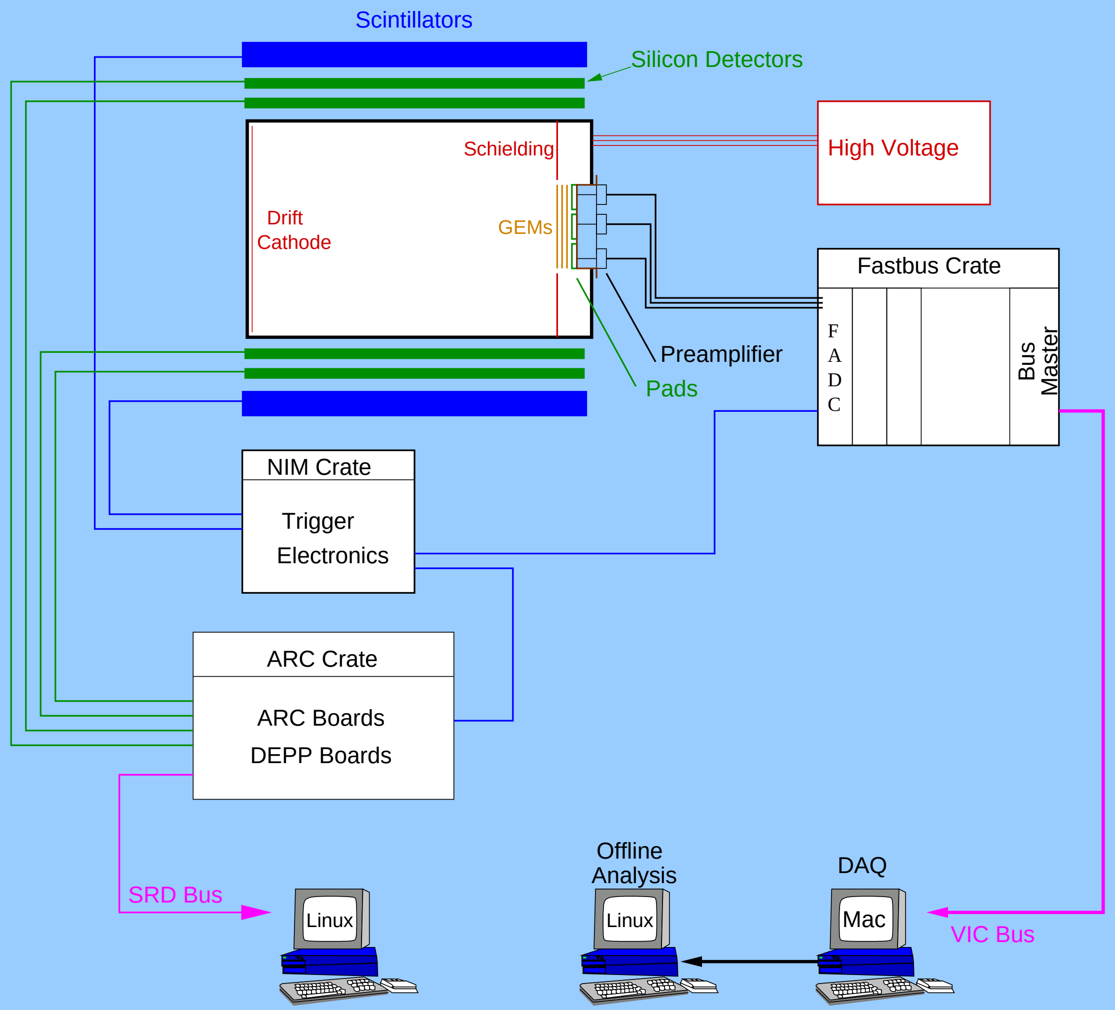


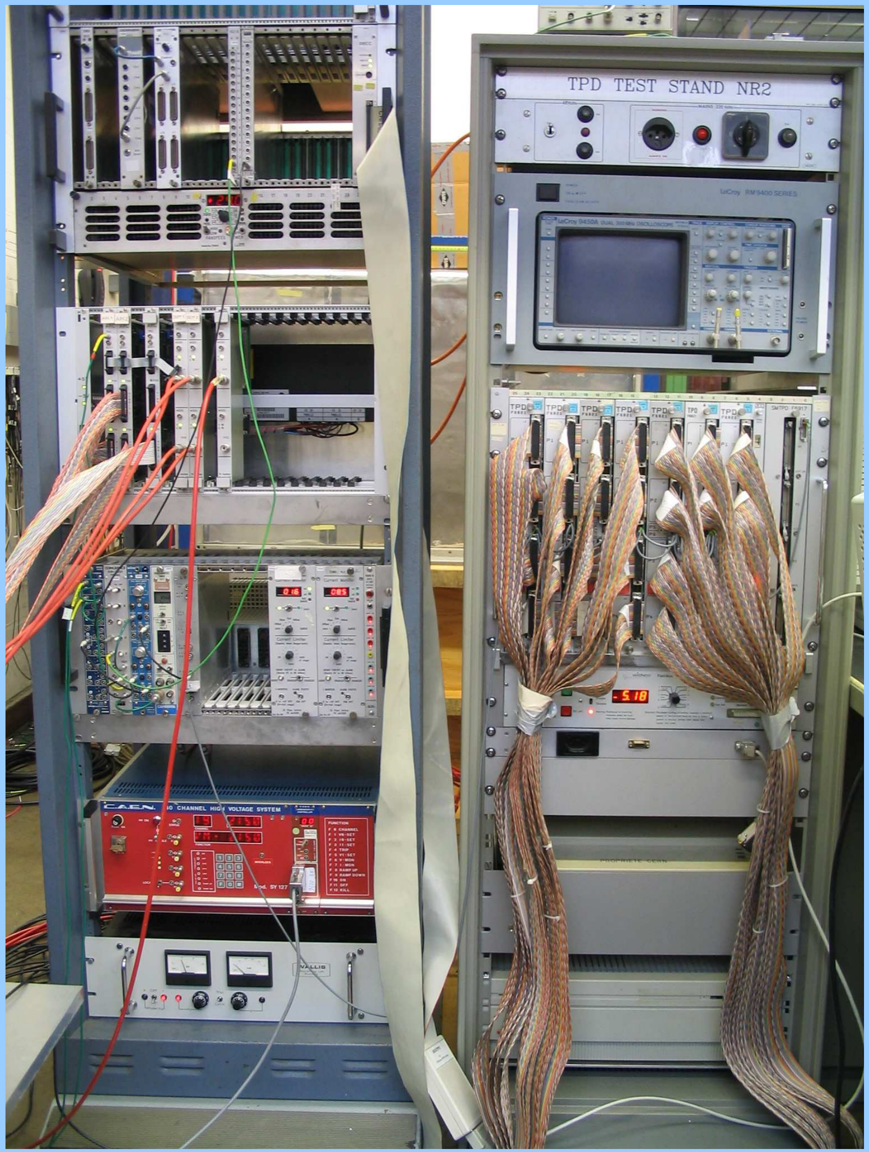


Components:

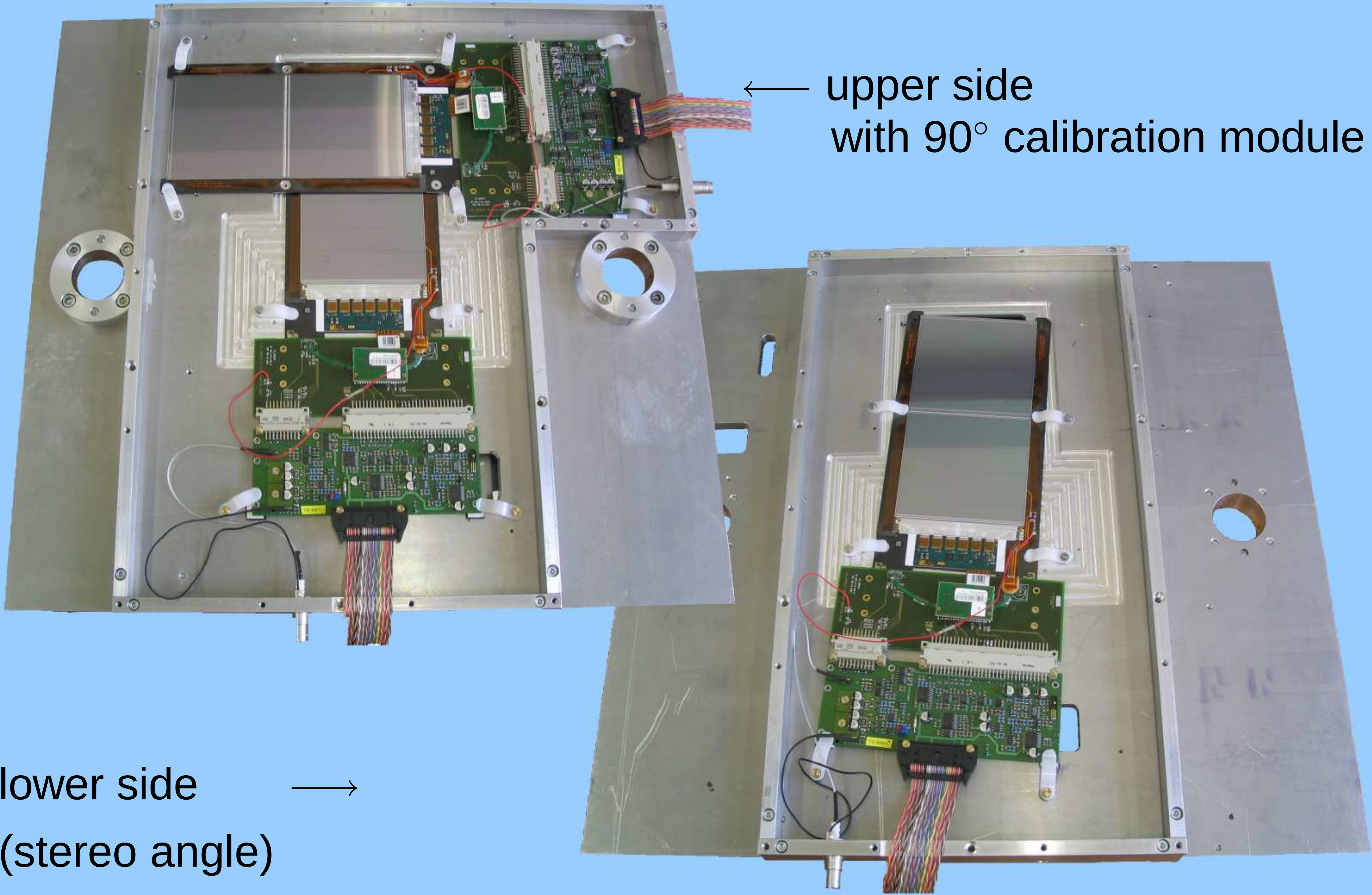
- ARC Board (Readout module)
- DEPP (HV module)

Hodoscope: Electronics





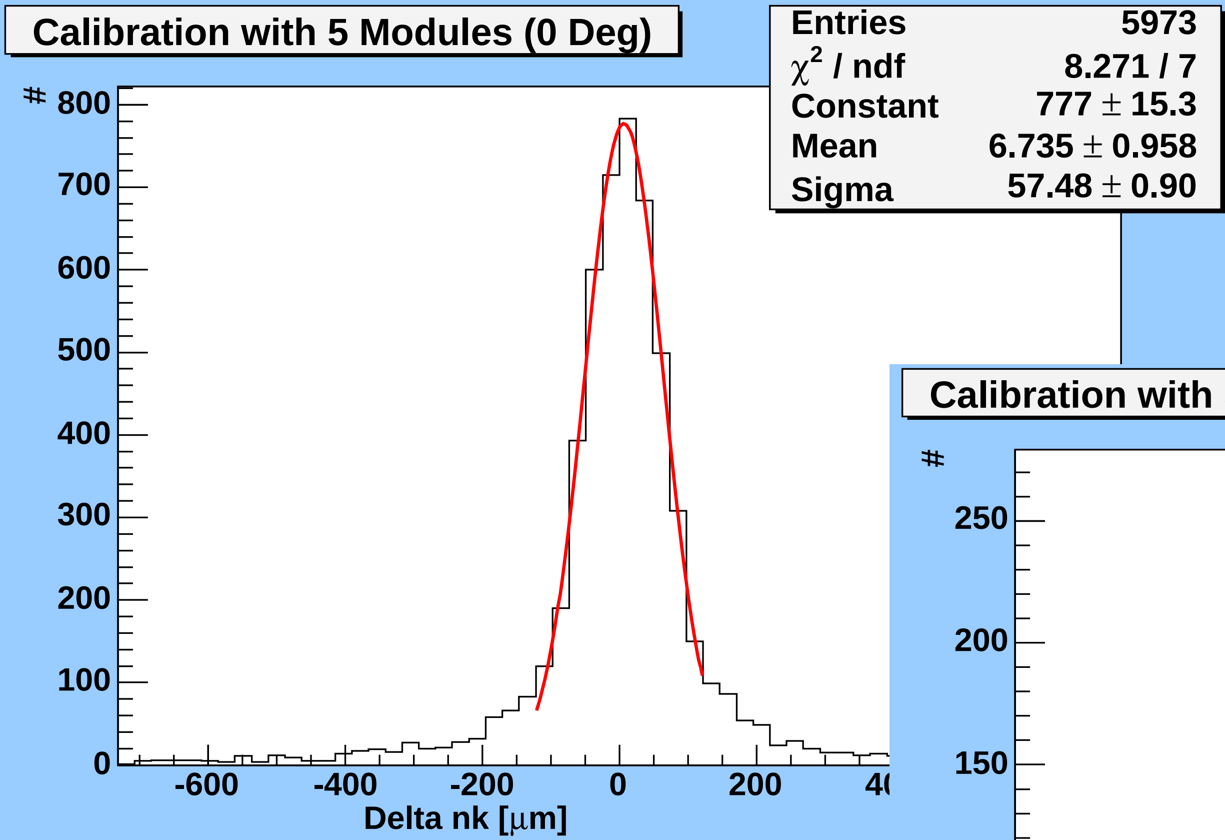
Hodoscope: Application of the Modules



⟵ upper side
with 90° calibration module

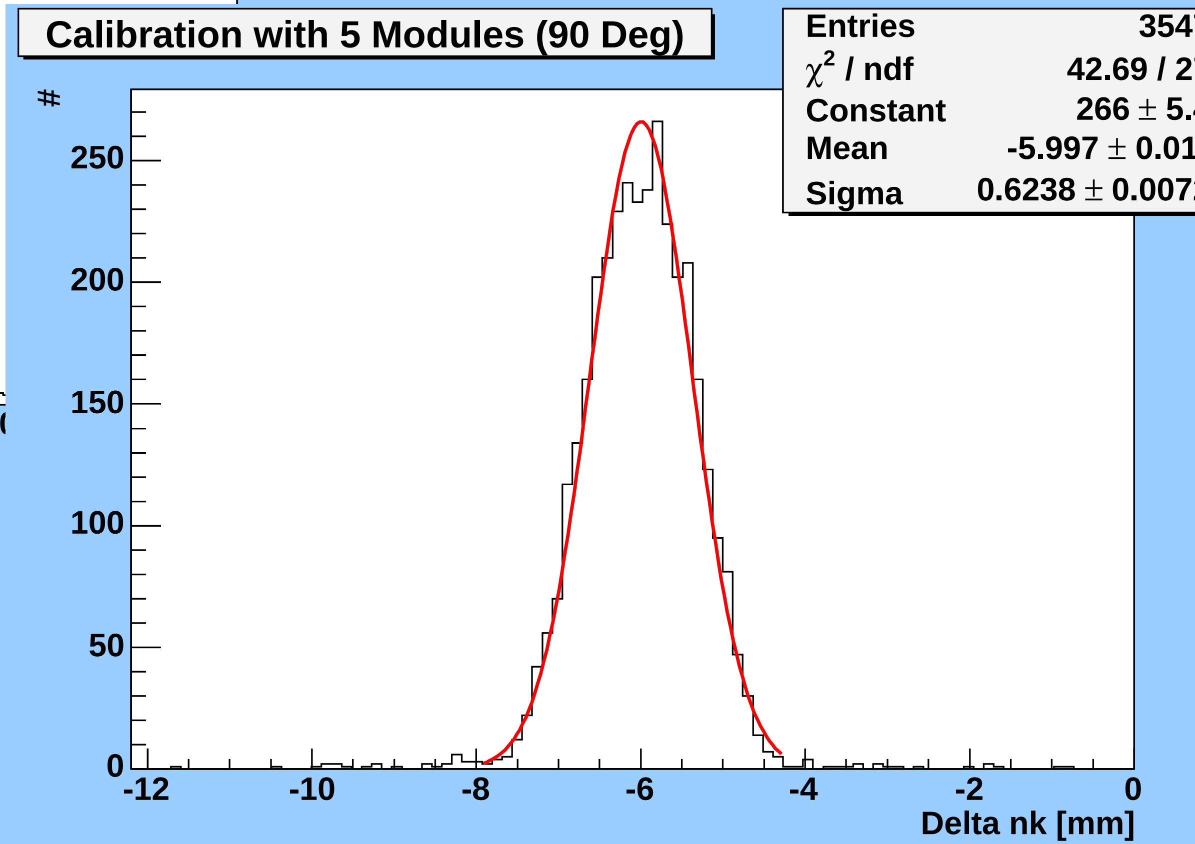
lower side ⟶
(stereo angle)

Hodoscope: Spatial Resolution



x resolution:

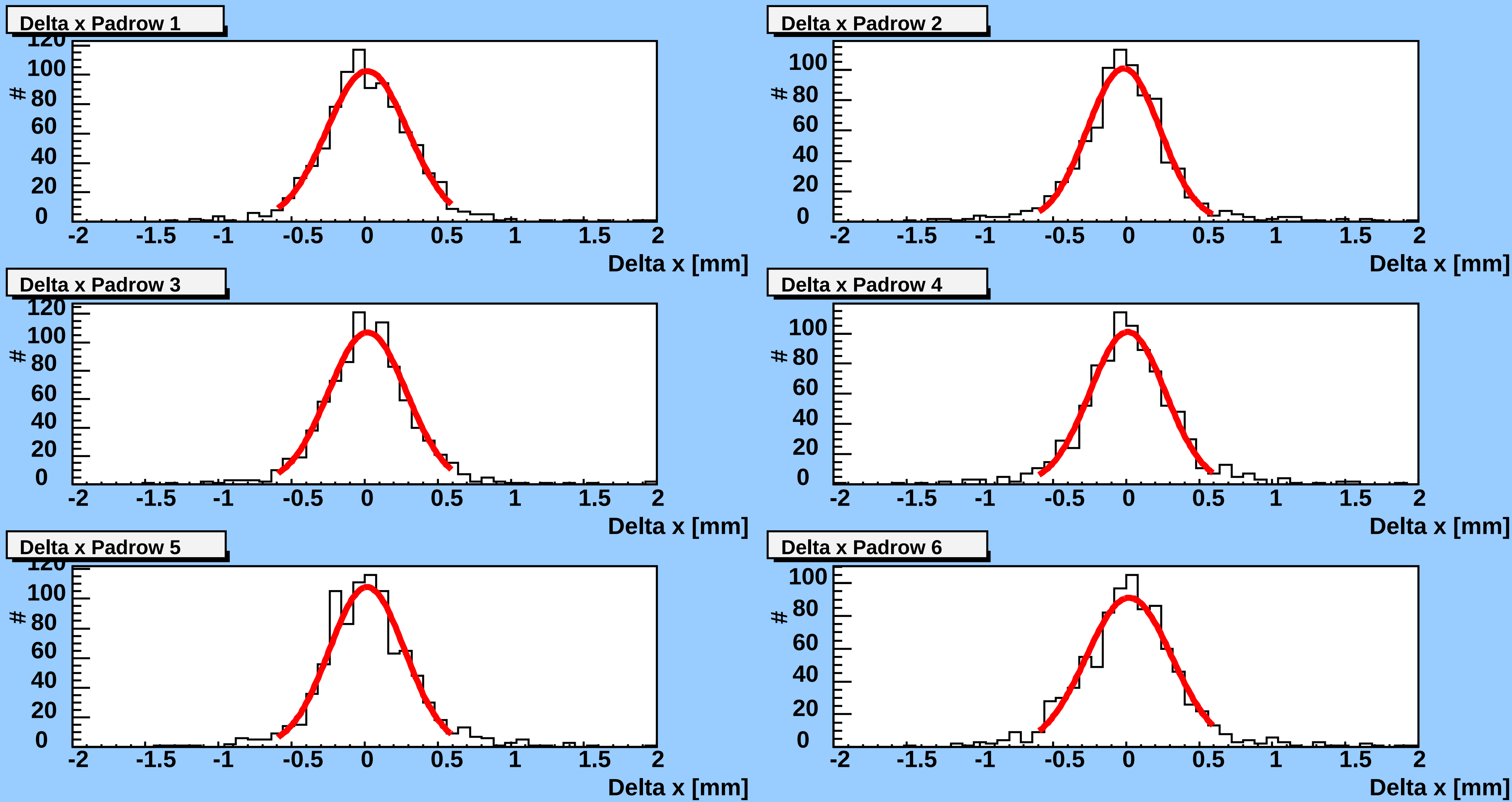
$57{,}5 \pm 0.9\ \mu$m



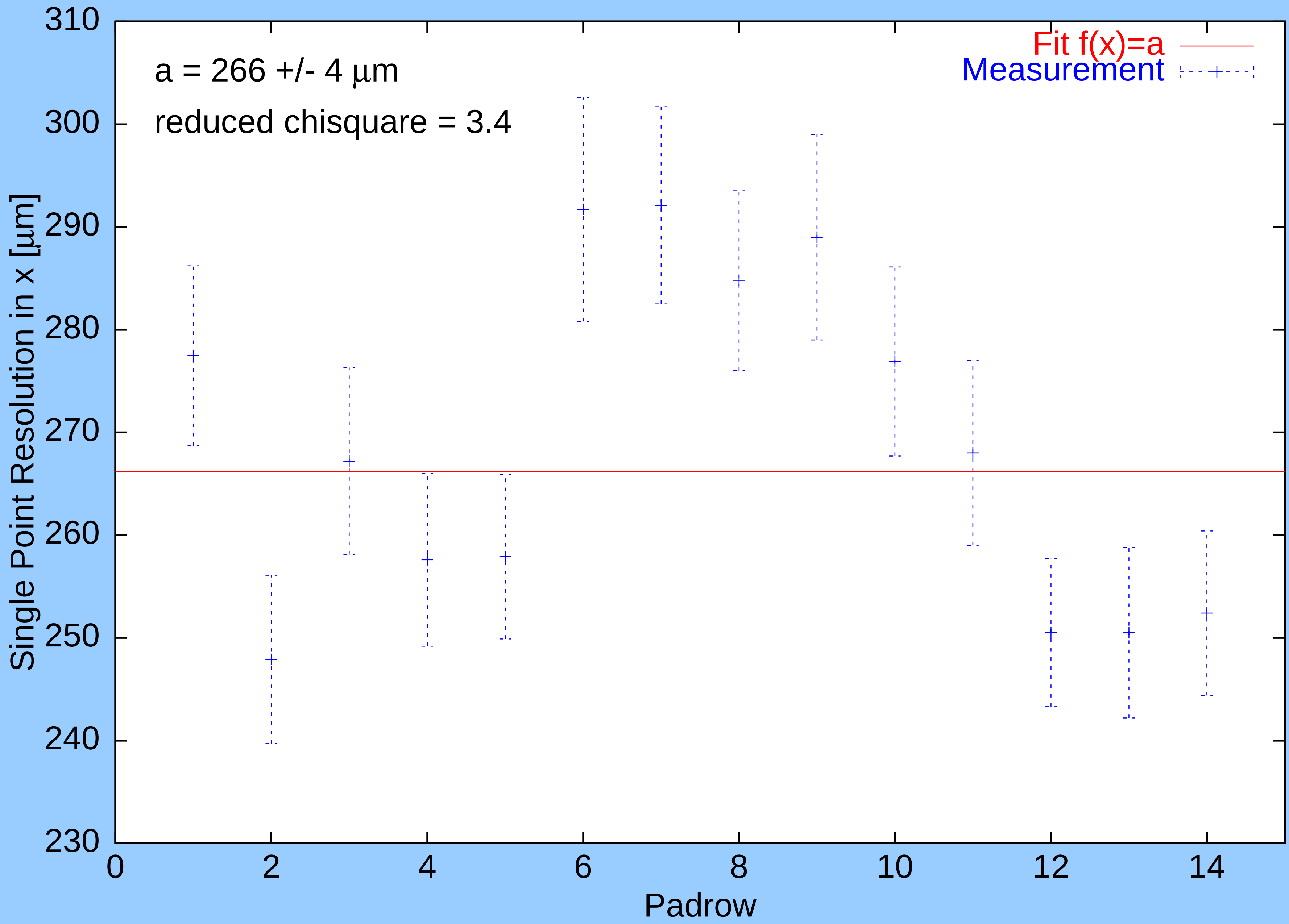
z resolution:

$624 \pm 7\ \mu$m

Hodoscope: Single Point Resolution of the TPC

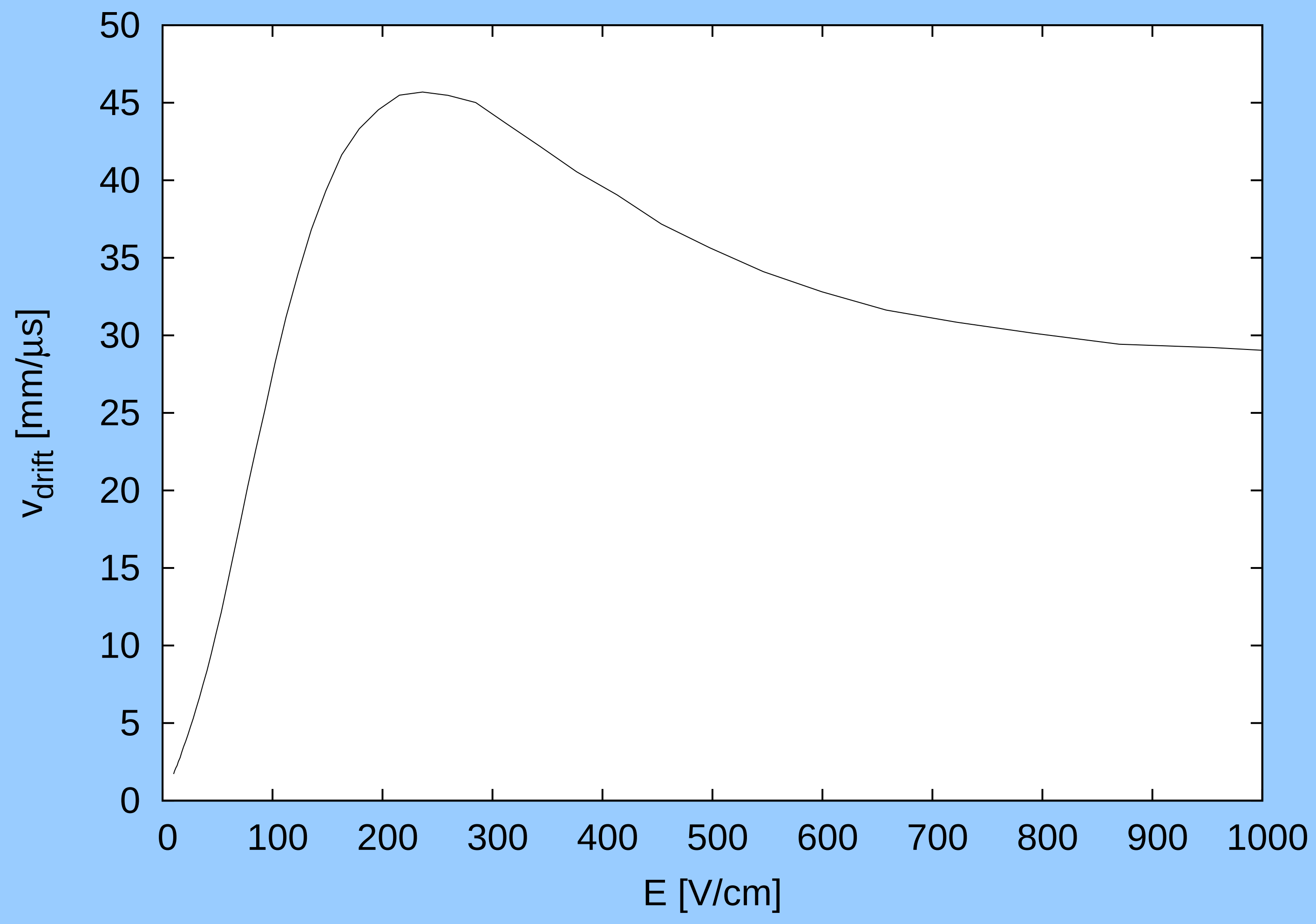


Hodoscope: Single Point Resolution Results



Hodoscope: Field Homogeneity of the TPC

Drift velocity in TDR-gas (Ar-CO_2-CH_4 93-2-5)



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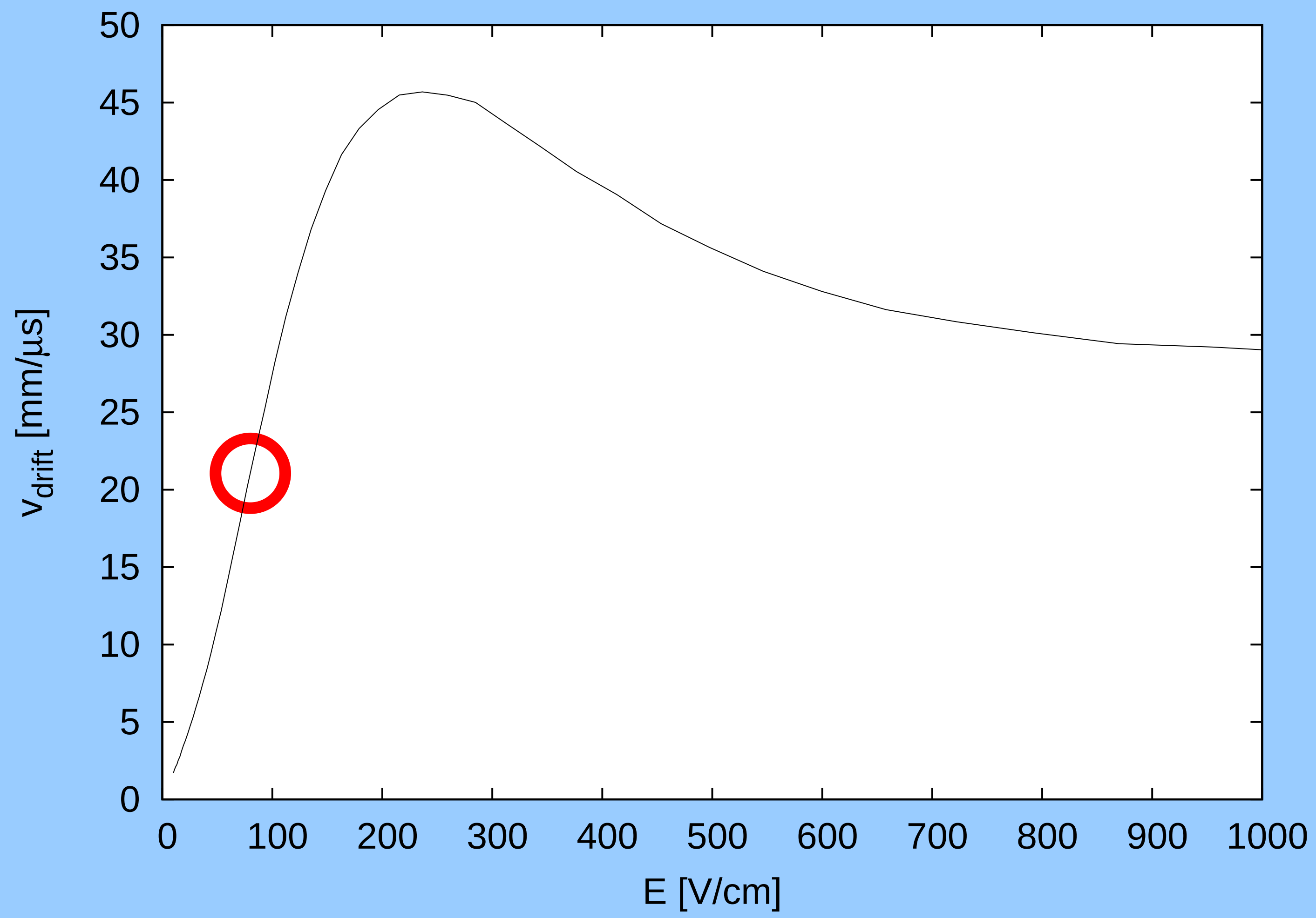
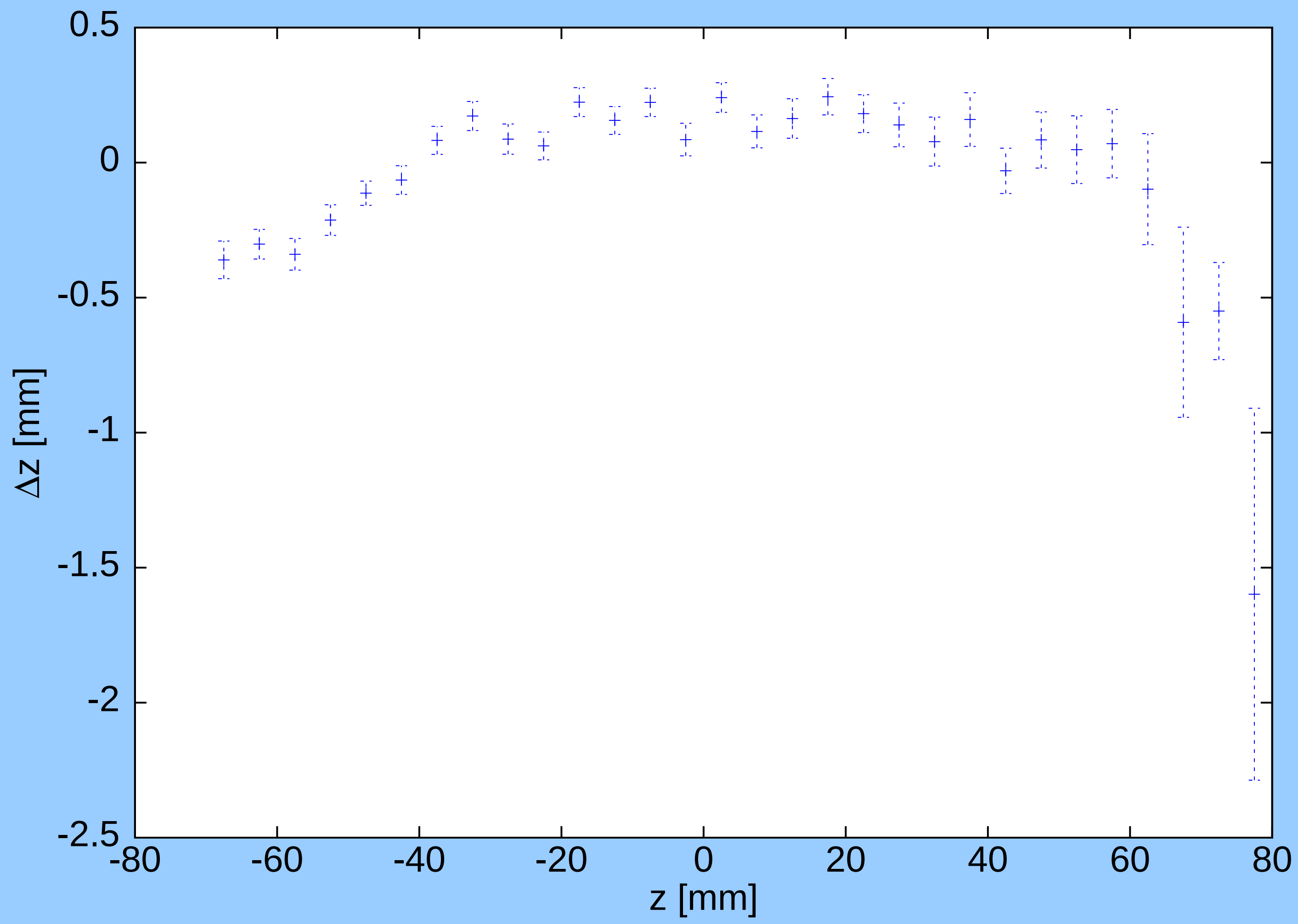


Maximal sensitivity at the steepest position (80 V/cm).

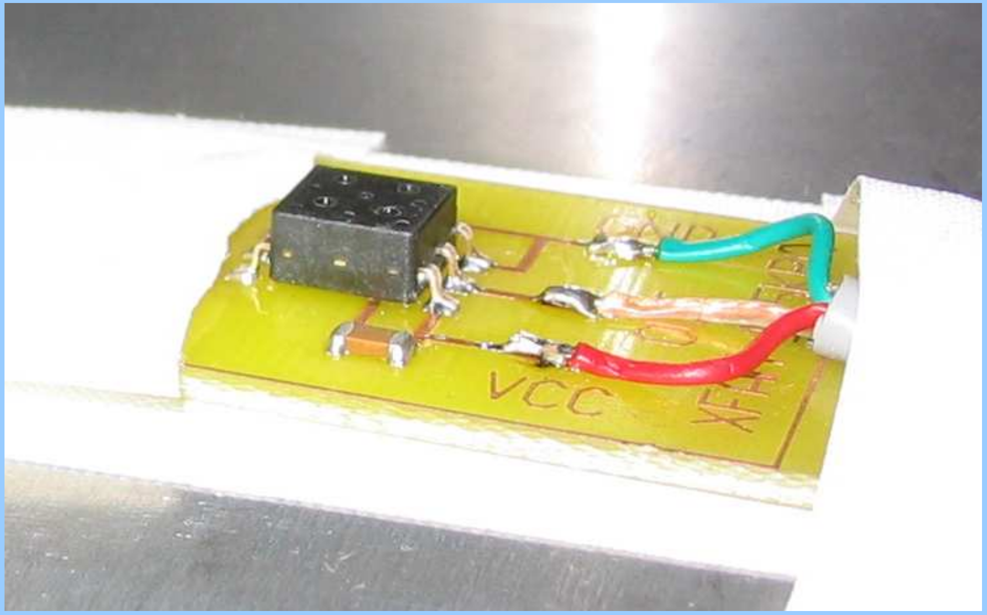
Hodoscope: Deviation of z_{TPC}



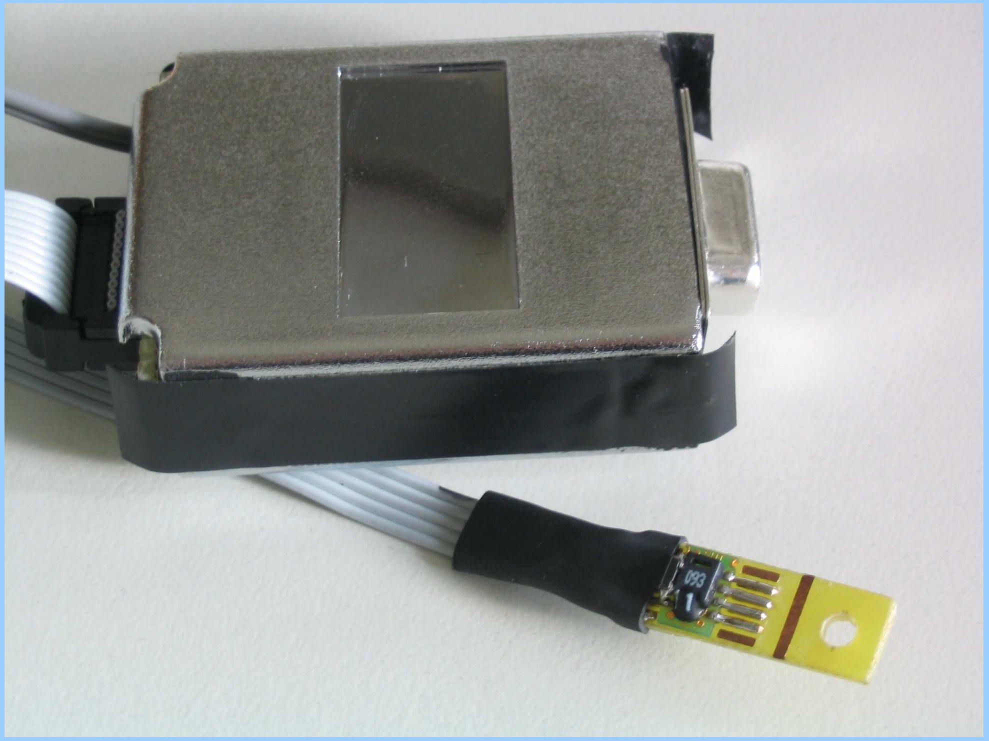
- deviations near the readout
- flat in the middle

Hodoscope: Environmental Monitoring

- Sensors for temperature, humidity and pressure
- Readout via RS232 (microcontroller) and terminal emulation

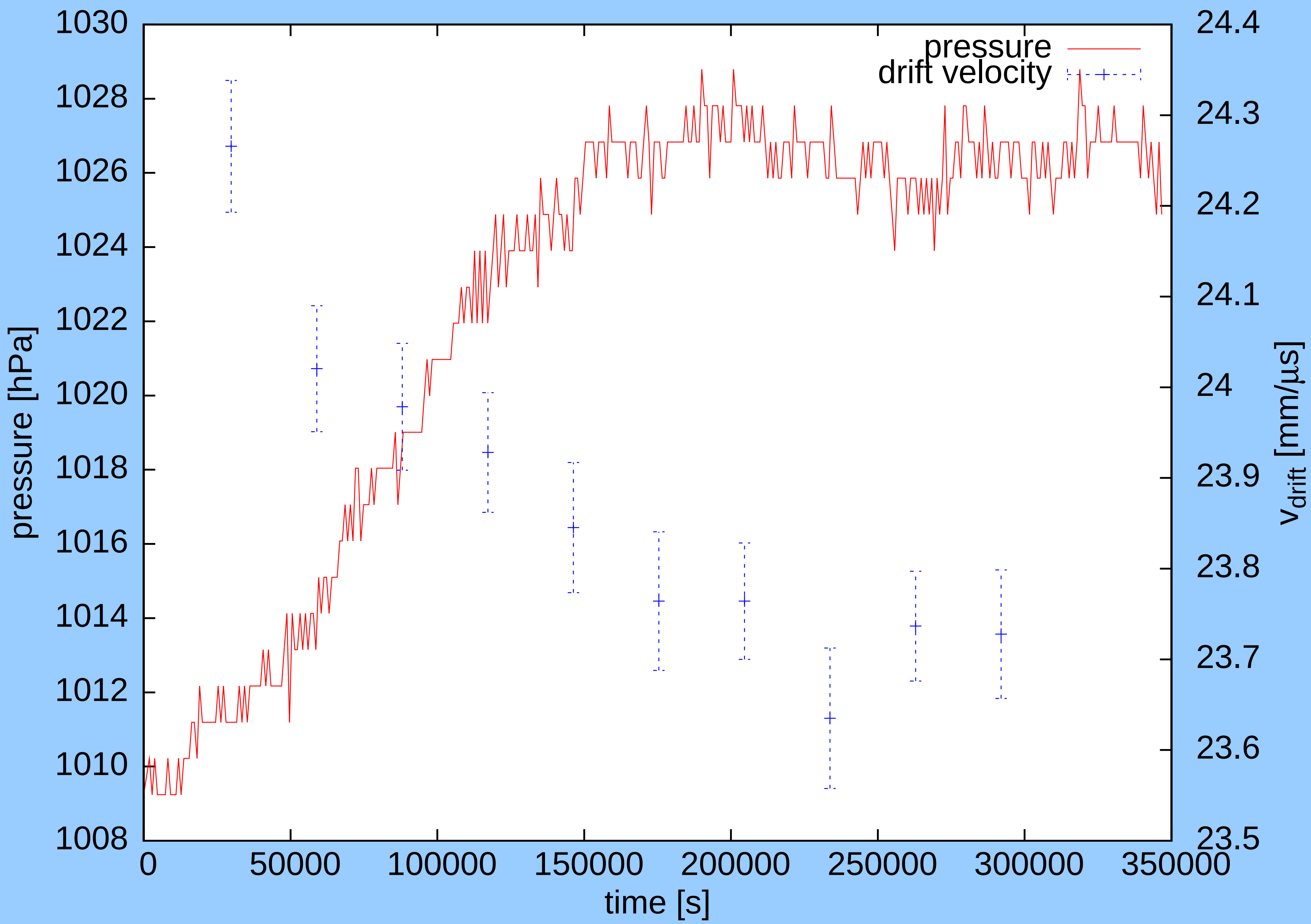


pressure sensor



temperature sensor

Hodoscope: Dependance of v_{drift} on Pressure



Readout Electronics: Goal

Develop a test readout with 512 channels for our TPC

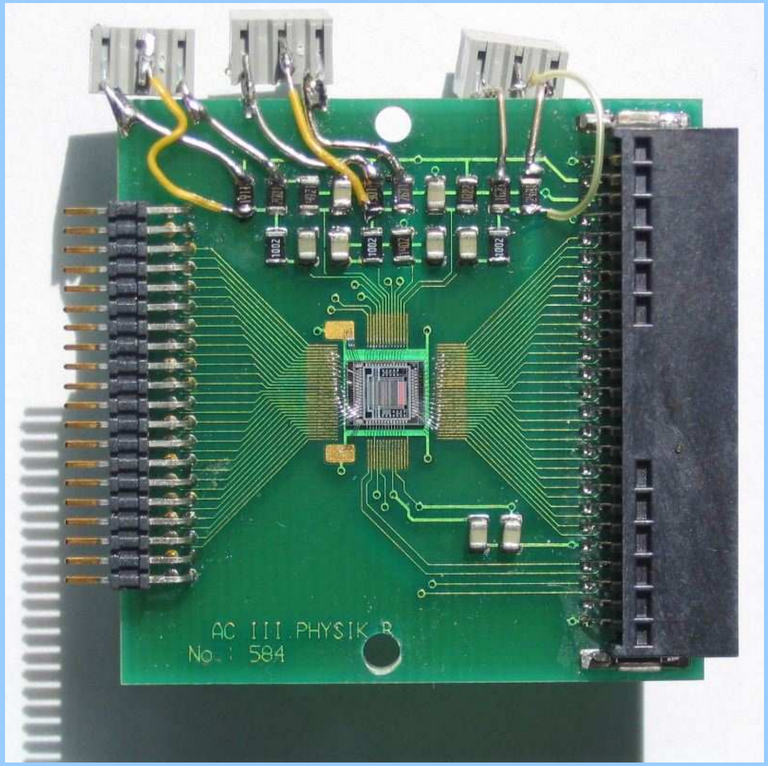
Requirements:

- fast preamplifiers to study time resolution
- small preamplifiers to allow compact readout design with small pads
- fast ADCs to match the preamplifier speed
- fast data aquisition to allow reasonable operation in test beam runs

Readout Electronics: Preamplifier

Preshape 32

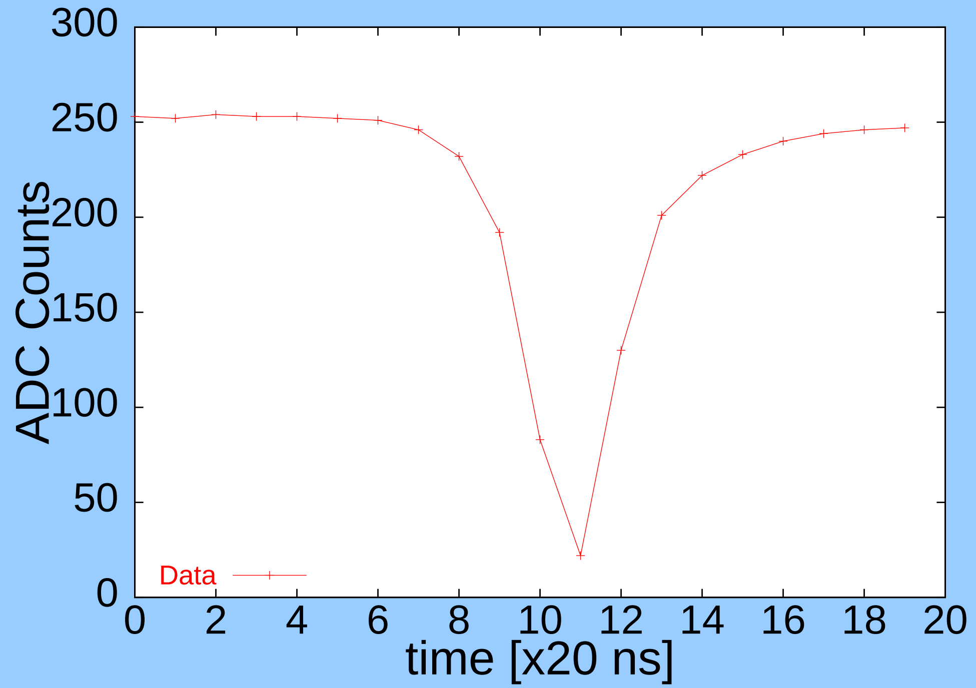
- predecessor of Premux & APV
- 32 channel preamplifier/shaper with parallel In/Out
- nominal peaking time: 45ns
- single ended output
- needs cable driver to get signal to re-asonable distance



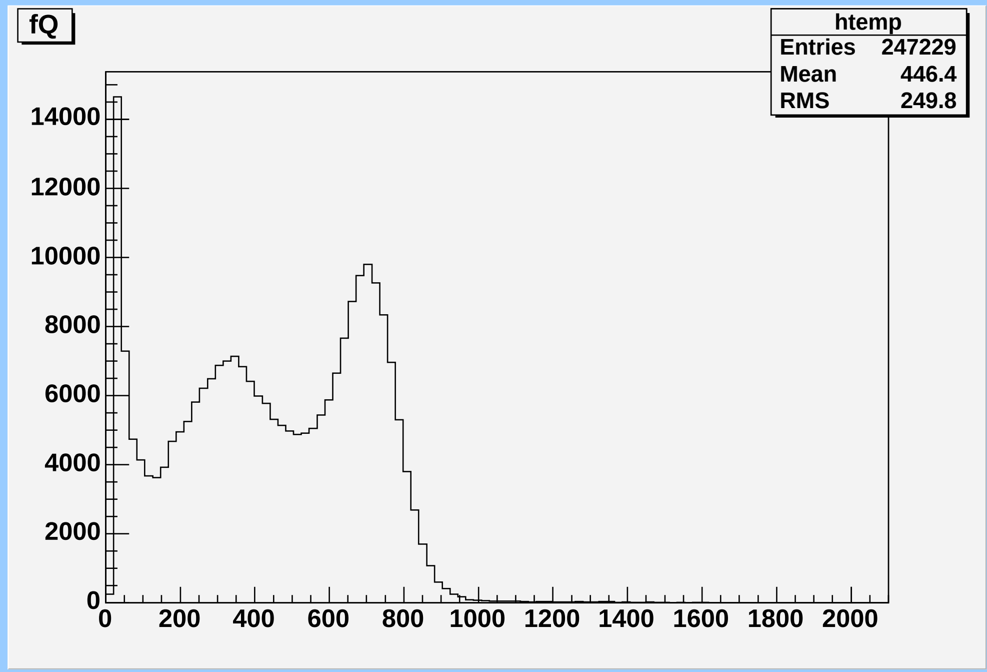
The preshape is bonded on a small board to perform tests.

⇒possibility to reduce size for a readout with small pads.

Electronics: Preamplifier Results



^{55}Fe Puls

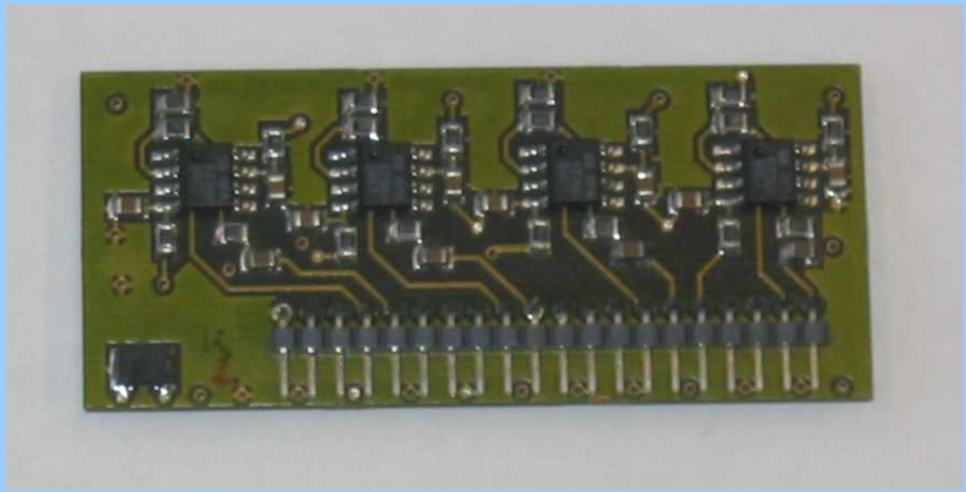


^{55}Fe Spectrum

Electronics: Cable Driver

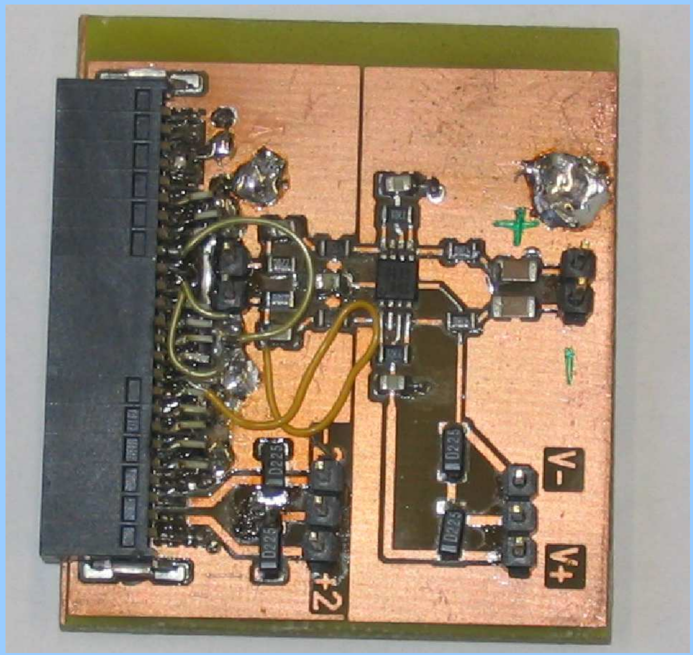
Old 8 channel amplifier cards

- too large
- too hot
- single ended
- not enough in supply



$\Rightarrow$ New design with 32 channels and double ended output.

Testing of prototype with one channel in progress.



Electronics: ADCs

Not enough fast high resolution ADCs available

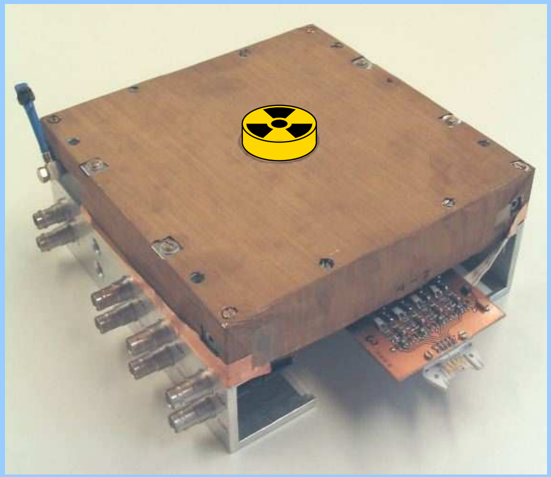
$\Rightarrow$ Take a stepwise approach:

- Use new preamplifiers with ALEPH TPDs (448 Channels)
- Include one of the ADC candidates into this setup
- Compare the candidates to the ALEPH TPDs and to each other
- Choose the best candidate

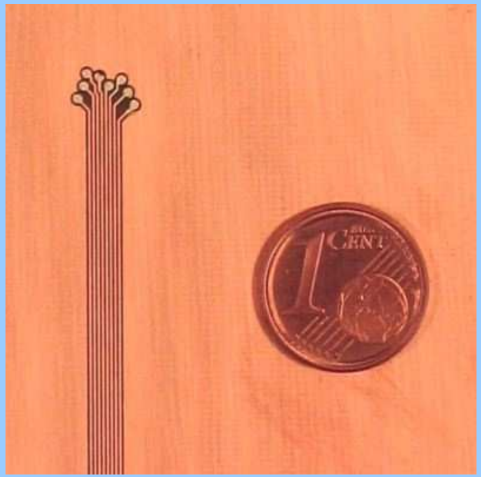
Current challange:

Get the fast preamplifiers to work with the slow ALEPH TPDs.

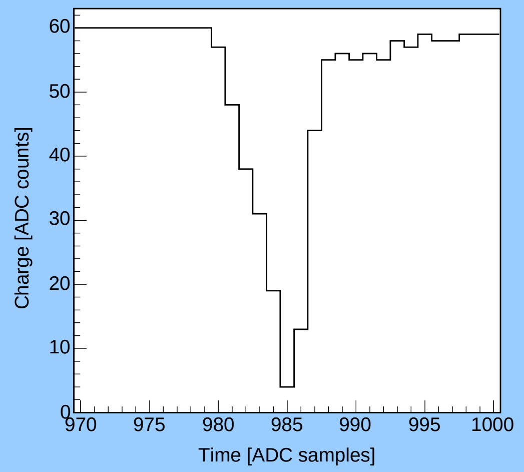
Charge Width: Measurement



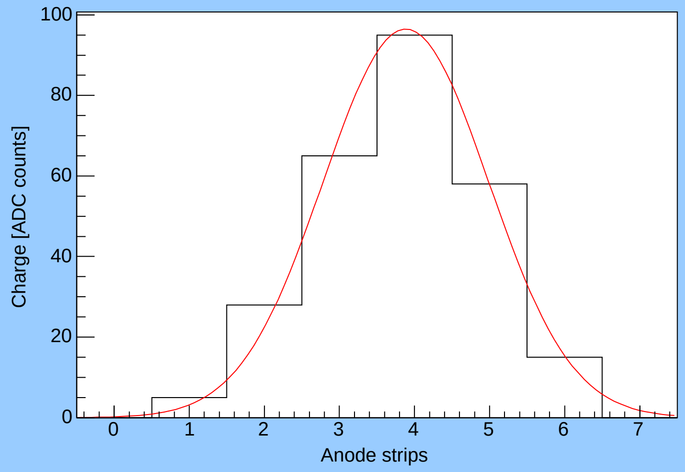
Test chamber, ^{55}Fe source



Anode strips, 300 μm pitch

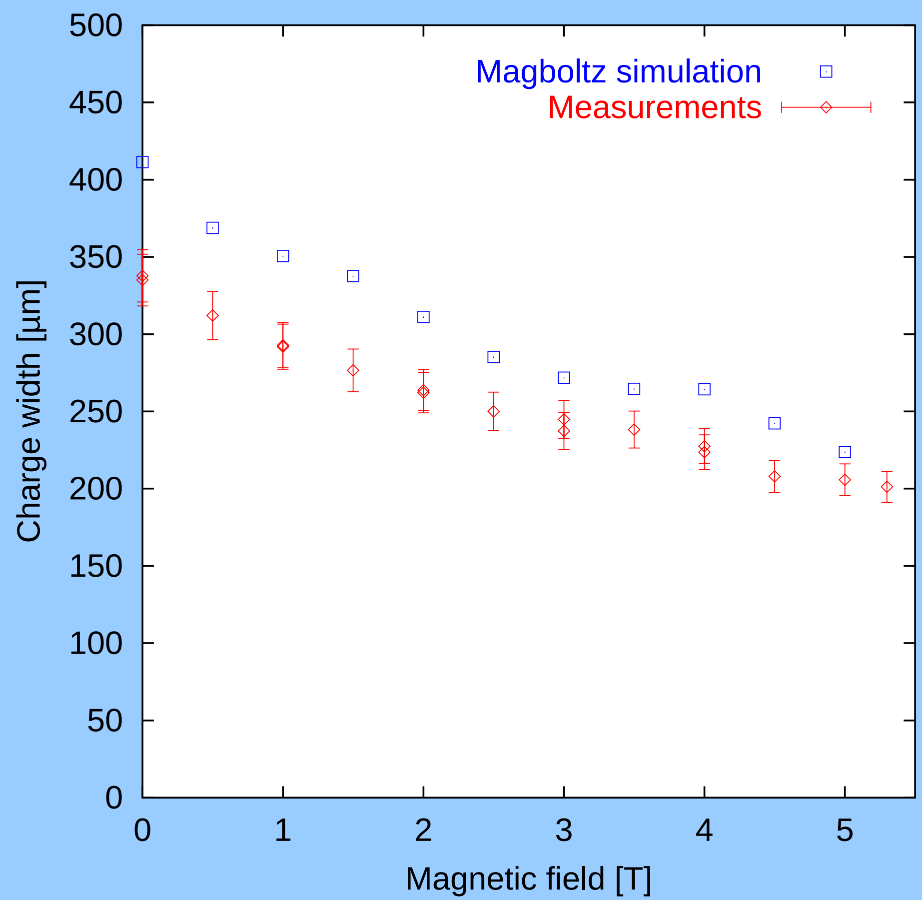


Pulse on one anode strip



Spatial charge distribution

Charge Width: Dependency on B-FIeld



Measured with
5 T magnet at DESY

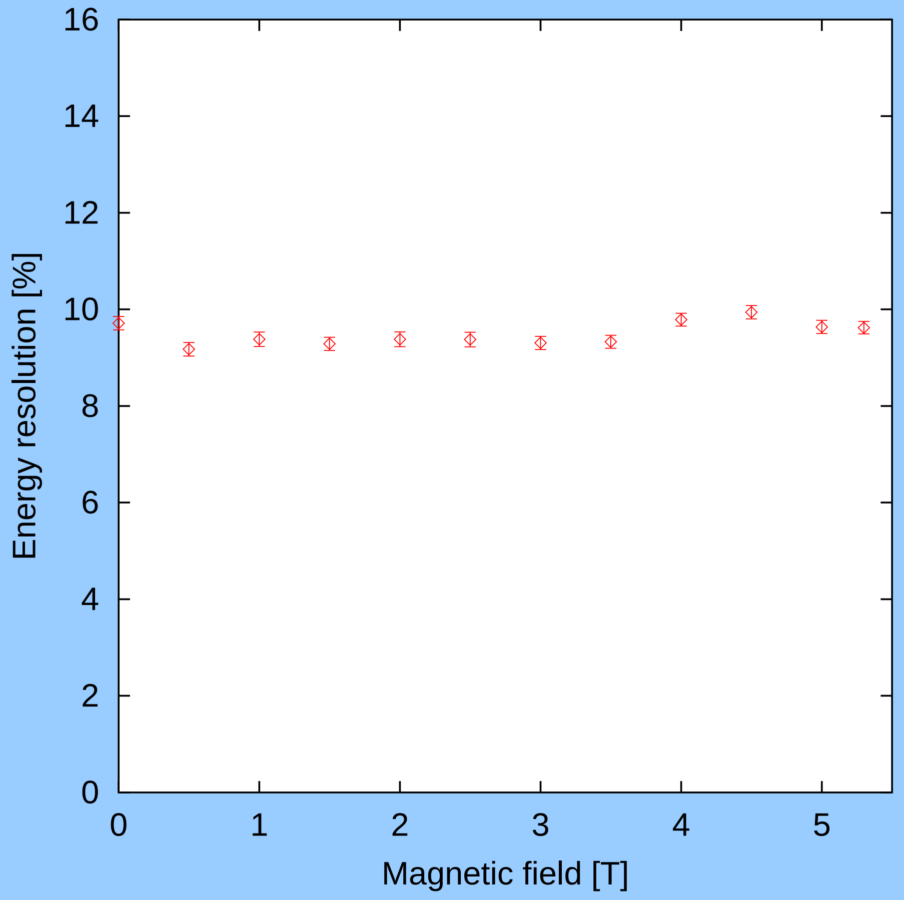
- E- / B-field dependency (caused by diffusion):

$$\sigma_{\text{diff}} \propto \frac{1}{\sqrt{1+\omega^2(B)\tau^2(E)}}$$

- Transverse diffusion is overrated by the used MAGBOLTZ version.
- MAGBOLTZ simulation takes only the fields between the GEMs into account.

$\Rightarrow$ No significant broadening in GEMs!

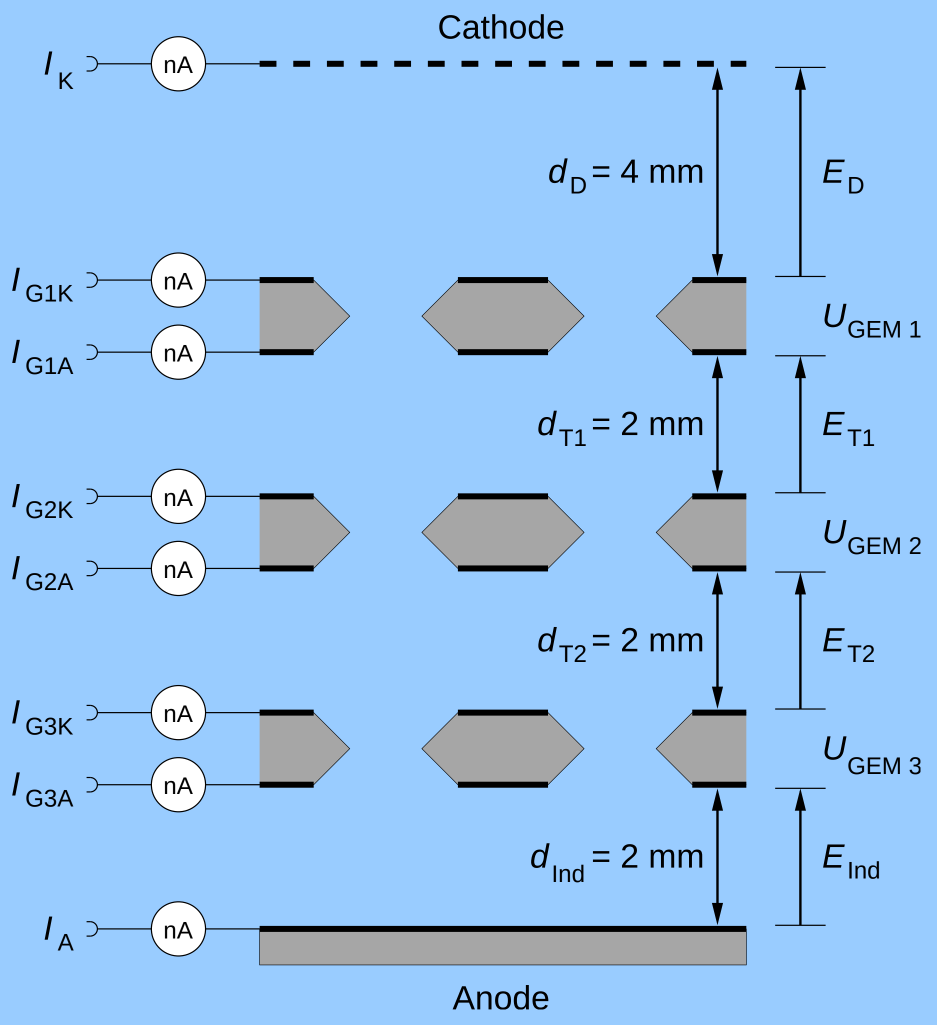
Charge Width: Energy Resolution



Measured with
5 T magnet at DESY

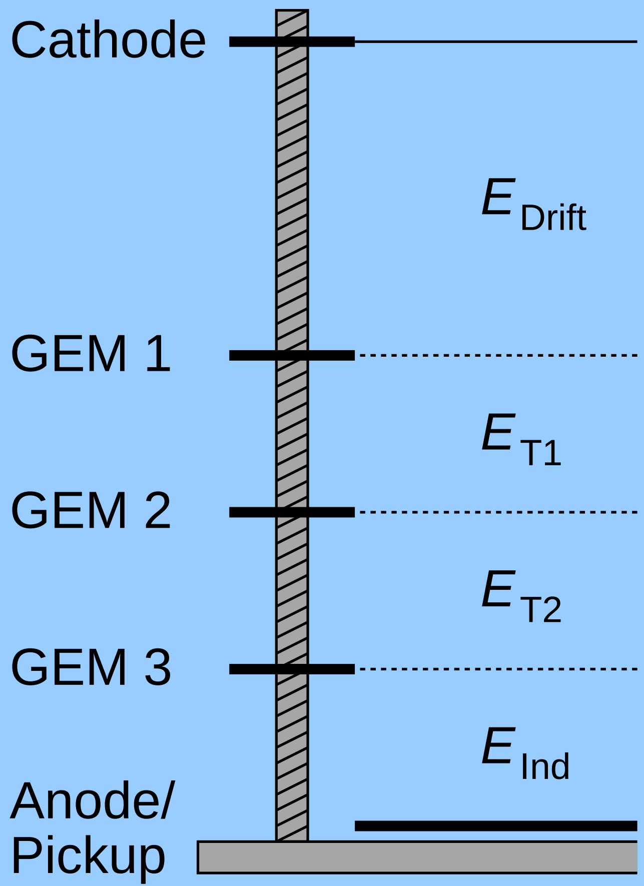
- Determined from photo peak in ^{55}Fe spectrum
- Without B-field: $\sigma_E/E \lesssim 10\,\%$
- No deterioration in high magnetic fields

Ion Backdrift: Setup and Parameters



- Charge transfer determined by 7 chamber parameters (3 GEM voltages, 4 fields)
- Parametrisation of transfer coefficients
- Computation of ion backdrift (IB) and effective gain (G_{eff})
- Optimisation for minimal ion backdrift

Ion Backdrift: Optimisation

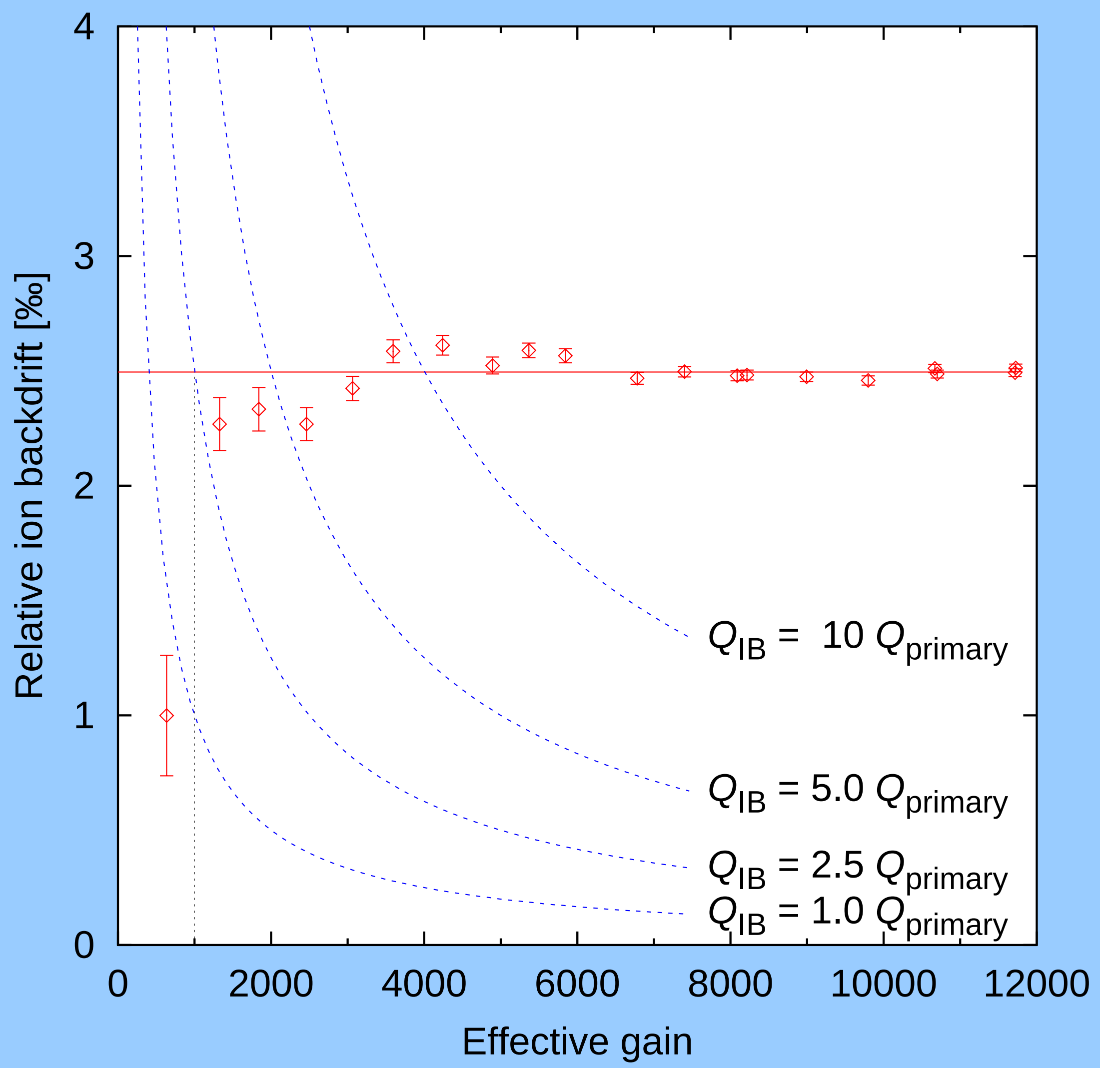


Minimal ion backdrift can be achieved with:

- E_{Drift} ..... fixed at 240 V/cm
- $U_{\mathrm{GEM\,1}}$ .... small influence
- E_{T1} .... maximal
- $U_{\mathrm{GEM\,2}}$ .... small influence
- E_{T2} .... minimal
- $U_{\mathrm{GEM\,3}}$ .... maximal
- E_{Ind} ...... maximal

$U_{\mathrm{GEM\,1}}$ and $U_{\mathrm{GEM\,2}}$ allow variation of effective gain without changing IB.

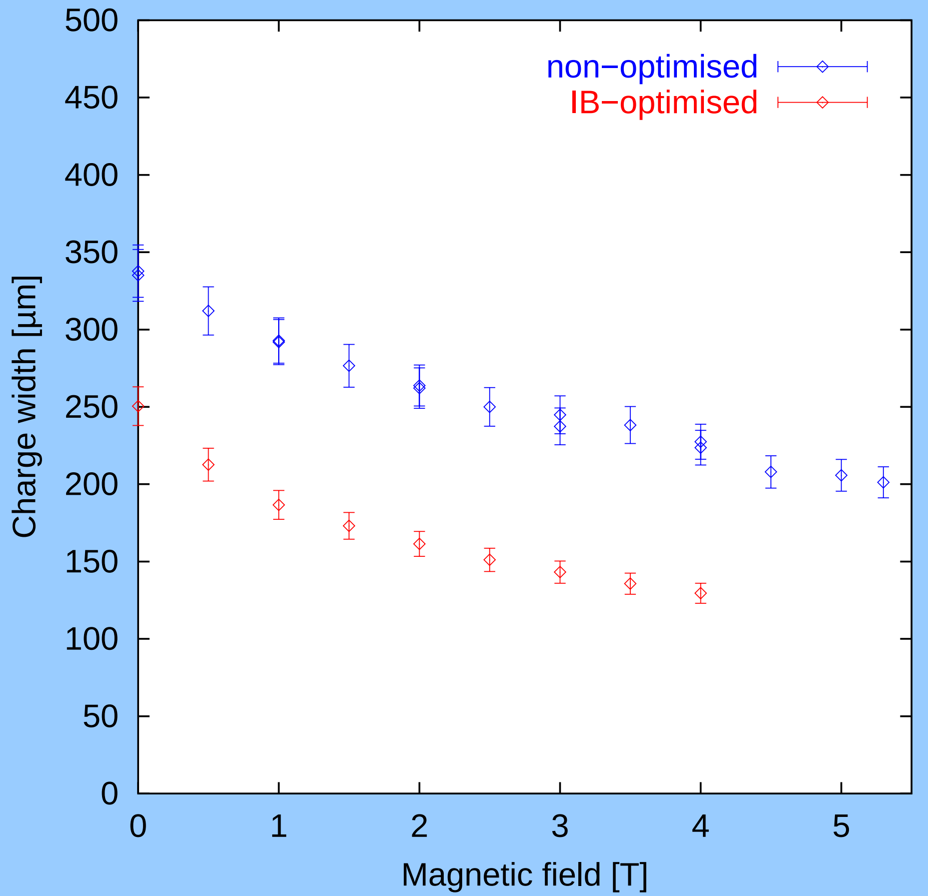
Ion Backdrift: Latest Results



B = 4 T, measured at DESY

- Prediction from parametrisation: IB independent of G_{eff}
- Lower G_{eff} yields lower backdrifting charge Q_{IB}.
- For $G_{\mathrm{eff}} = 1000$: $Q_{\mathrm{IB}} \approx 2.5\, Q_{\mathrm{primary}}$
- Still an open question: How much ion backdrift can be tolerated?

Ion Backdrift: Charge Width

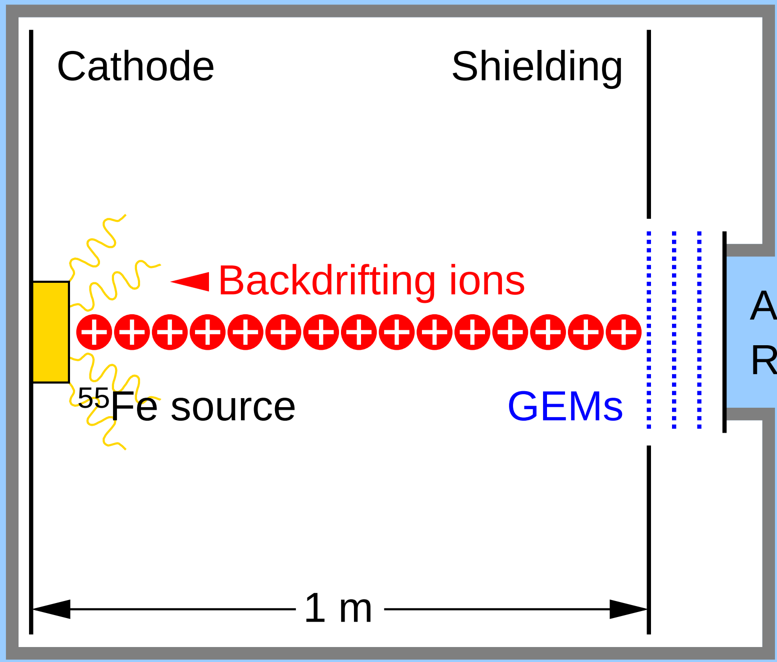


Measured with
5 T magnet at DESY

- Compare IB-optimised settings with non-optimised settings.
- Charge width becomes smaller with IB-optimised settings:
  $230\,\mu\mathrm{m} \rightarrow 130\,\mu\mathrm{m}$ at 4 T
- Energy resolution gets worse with IB-optimised settings:
  $\sigma_E/E \approx 10\,\% \rightarrow 13\,\%$

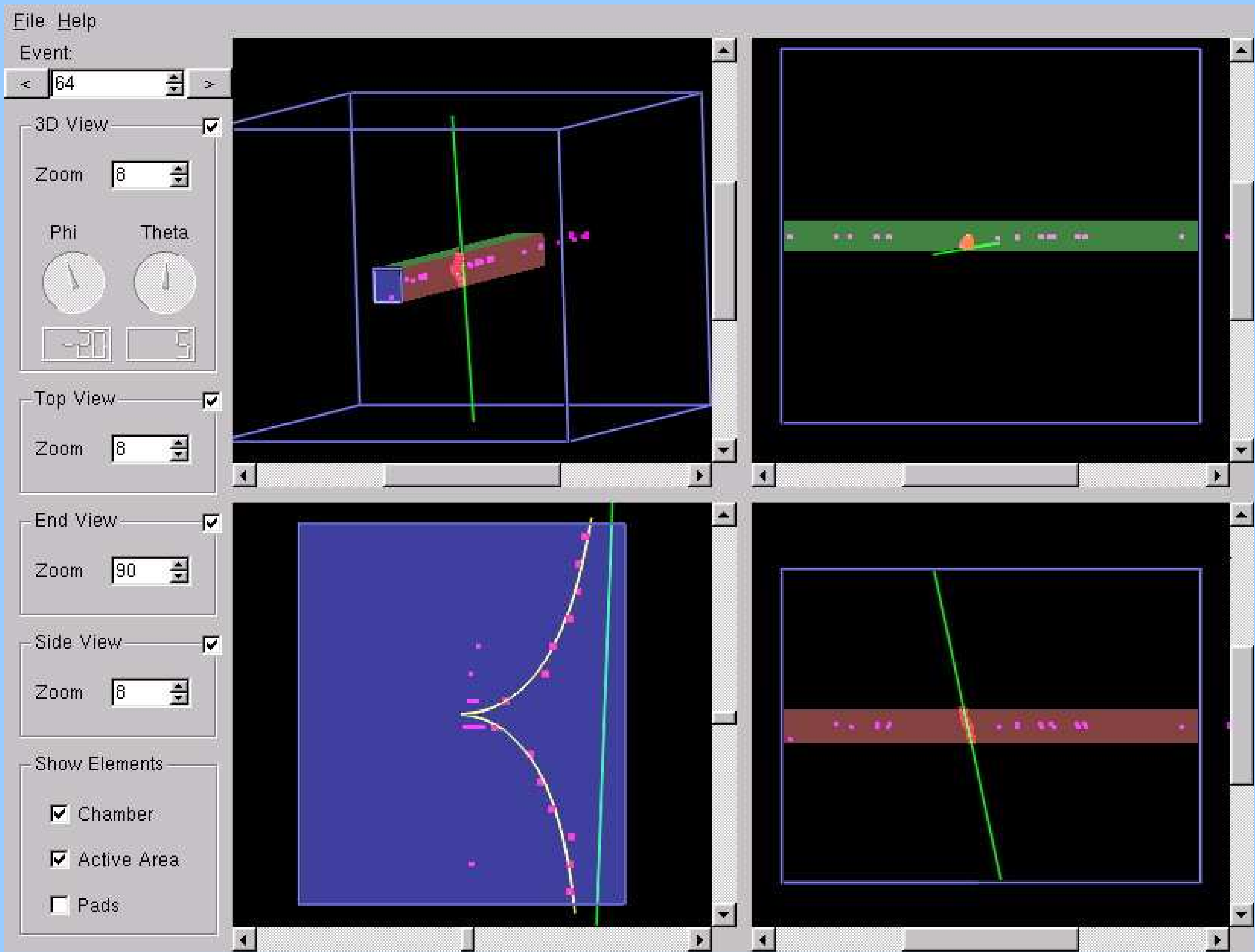
Track Distortions: Setup

Large TPC (1 m^3) with triple-GEM readout

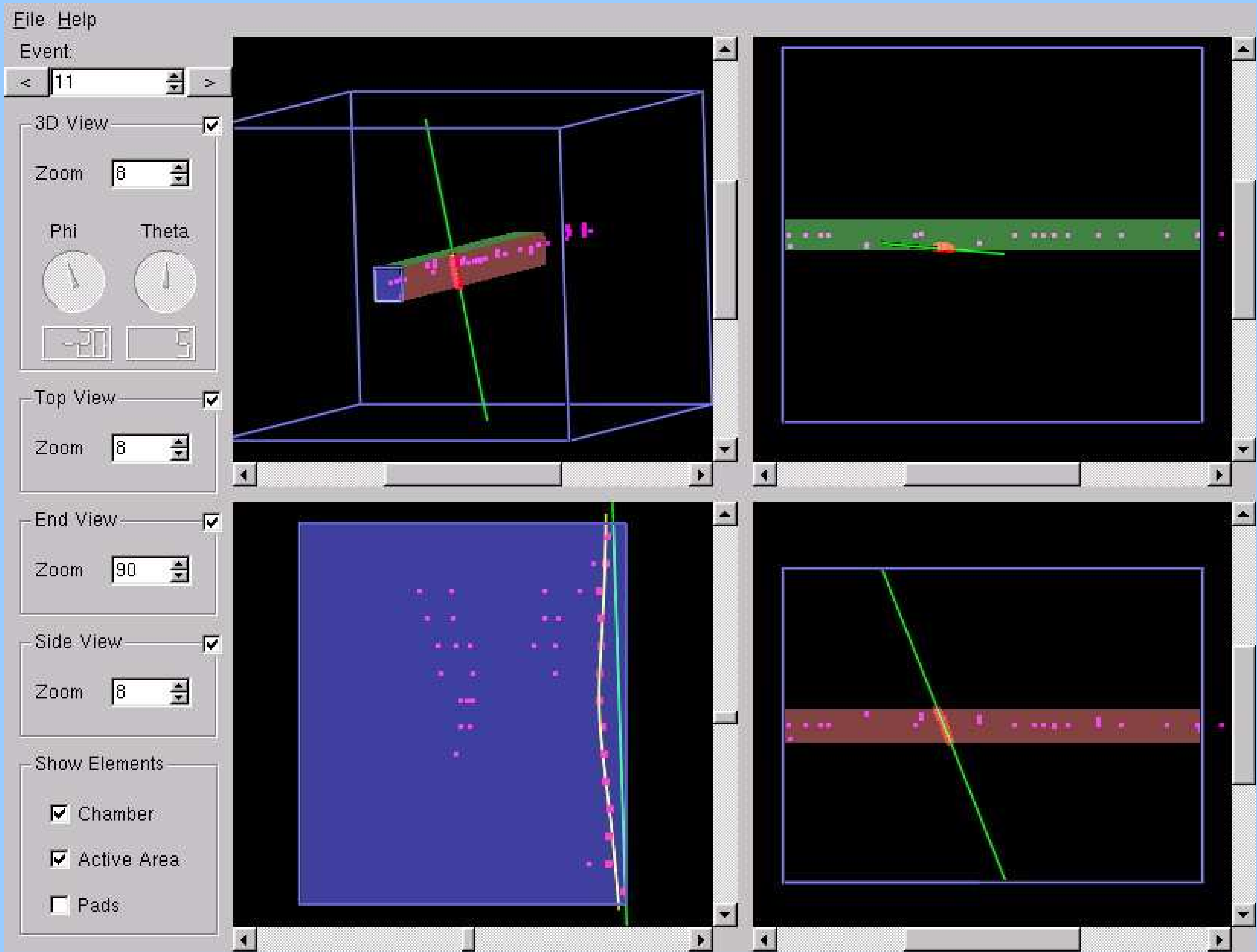


- ^{55}Fe source fixed on cathode
- Continuous intense ionisation
- Formation of ion tube between readout and source

Track Distortions: High Ion Backdrift



Track Distortions: Reduced Ion Backdrift



TPC Simulation: Goals

Simple and efficient tool to simulate a TPC

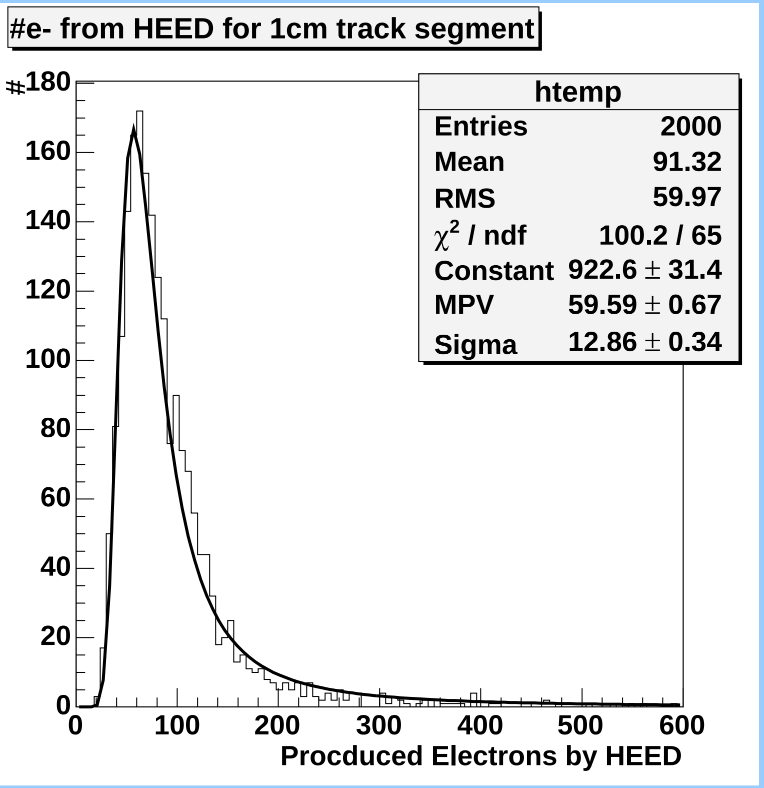
$\Rightarrow$ study specific properties of a TPC, e. g.

- Production and transfer of electric charges
- Influence of electric and magnetic fields
- Amplification in GEM structures
- Ion backdrift
- Pad response
- ...

TPC Simulation: Primary Ionisation

Input:

- Primary particles from generator
- TPC parameters (magnetic field, geometry etc.)

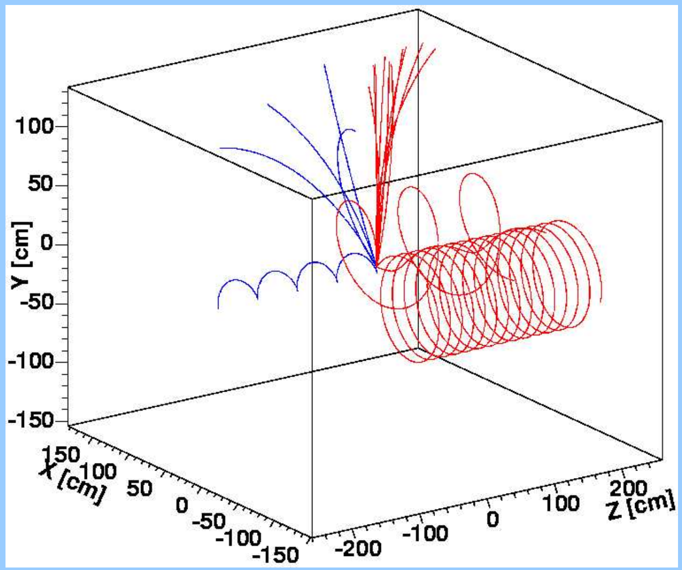


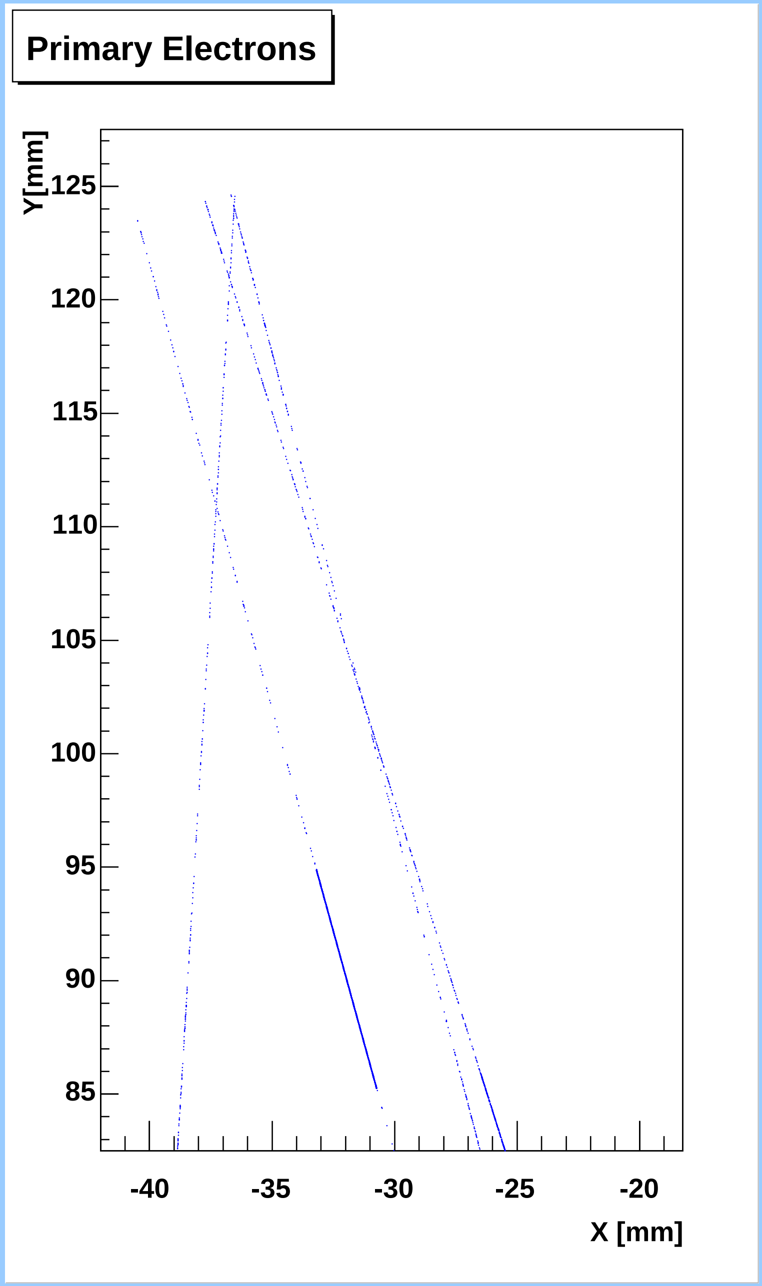
$\Rightarrow$ create number of electrons per track segment randomly according to a parametrisation of HEED results. (Approximated landau distribution.)

Output: coordinates for each produced primary electron

TPC Simulation: Track

- Build track from segments
- Calculate # of e^- for track segment $\rightarrow$ Approximation of clustering
- 3D information possible
- B fields possible



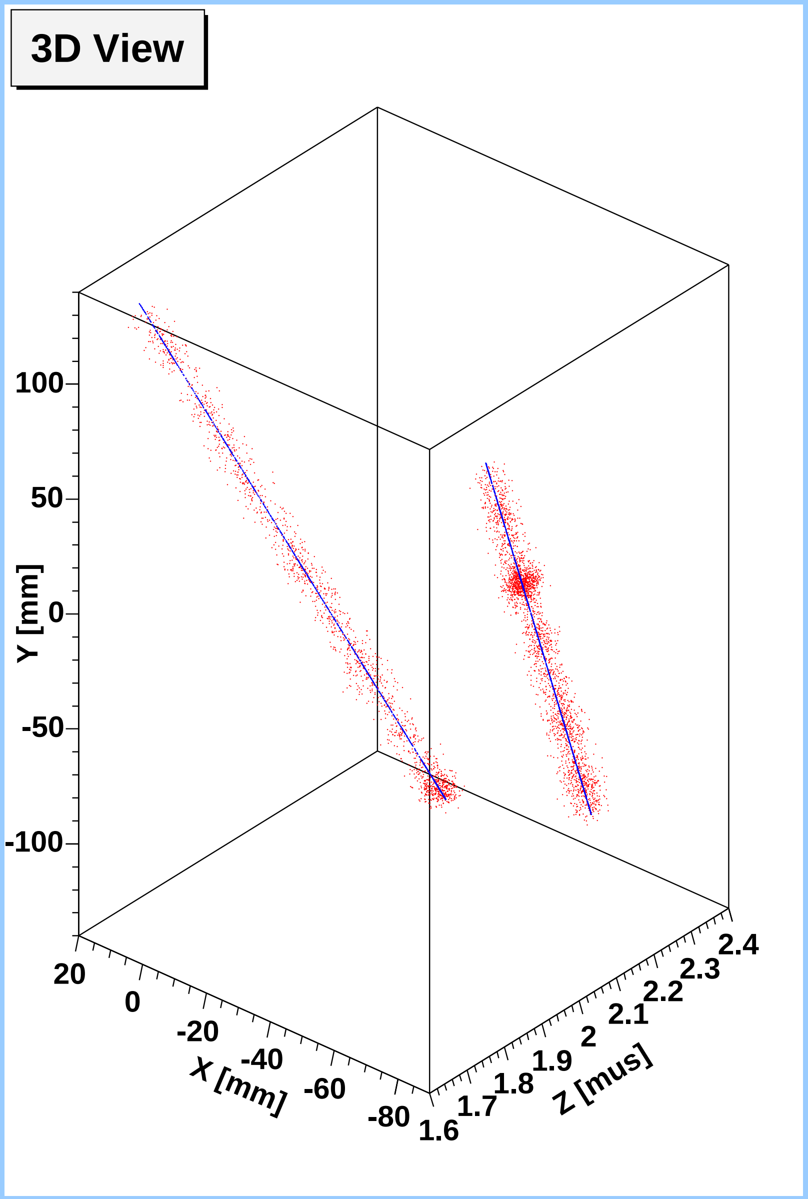


TPC Simulation: Drift

Input:

- Coordinates of primary electrons
- TPC parameters (gas, fields, drift distance etc.)

$\Rightarrow$ Determine position after drift randomly according to MAGBOLTZ gas parametrisation



Output:

Coordinates for each drifted electron.

TPC Simulation: Amplification

Input:

- File with coordinates of drifted electrons
- Pad geometry
- Readout frequency
- Voltages and fields of GEM setting
- Information about charge transfer coefficients

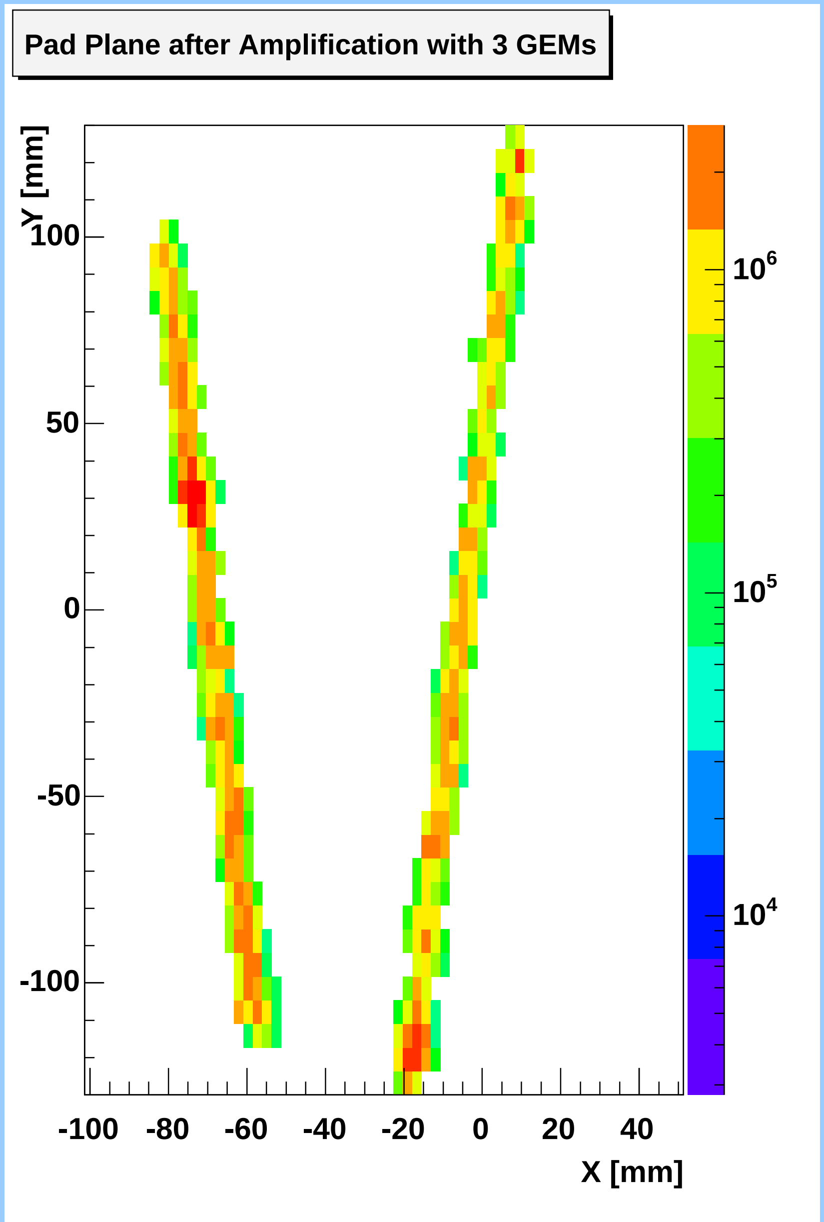
Output:

Charge for each pad and timeslice,

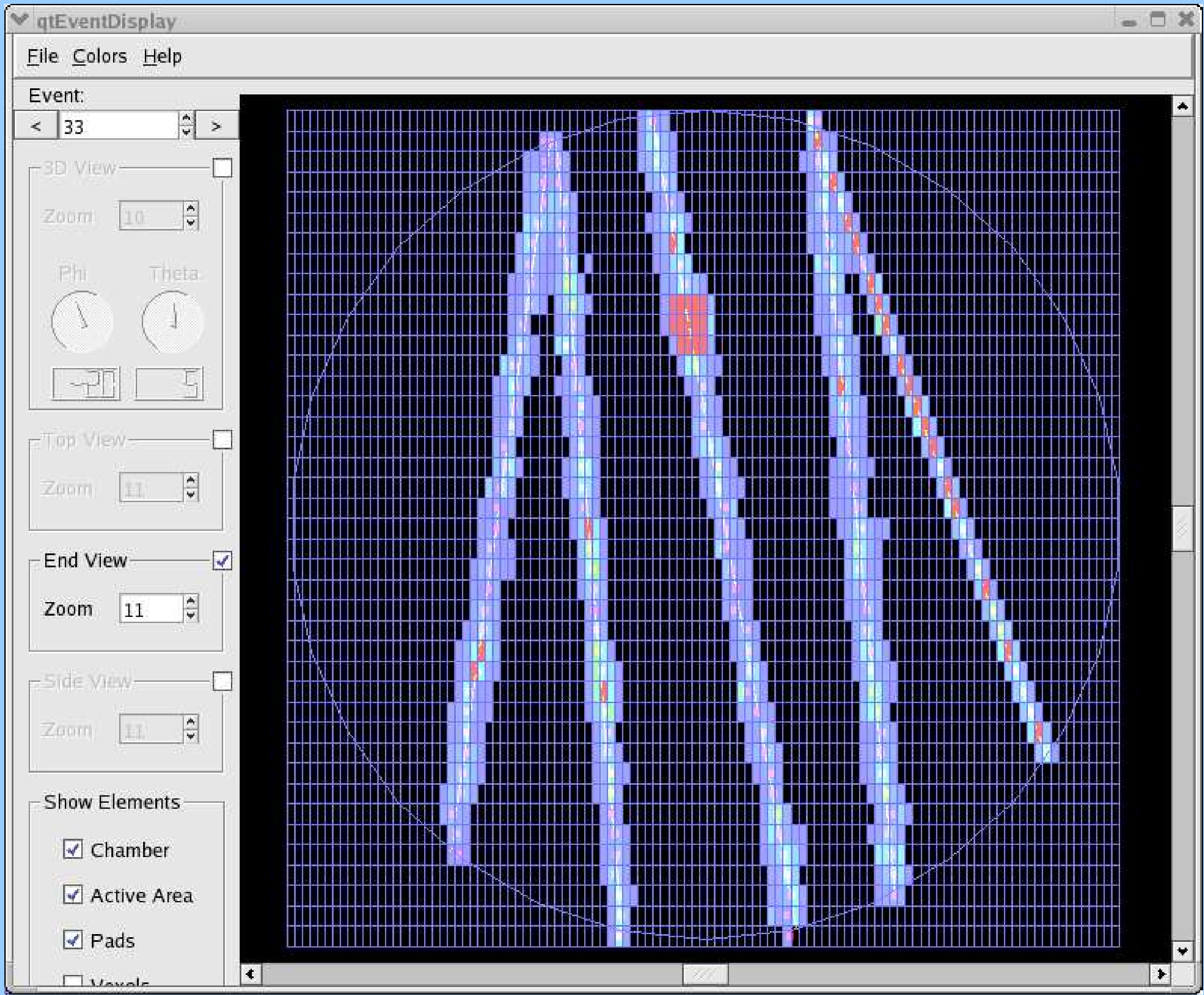
still linked to the particle it was produced from

TPC Simulation: Amplification

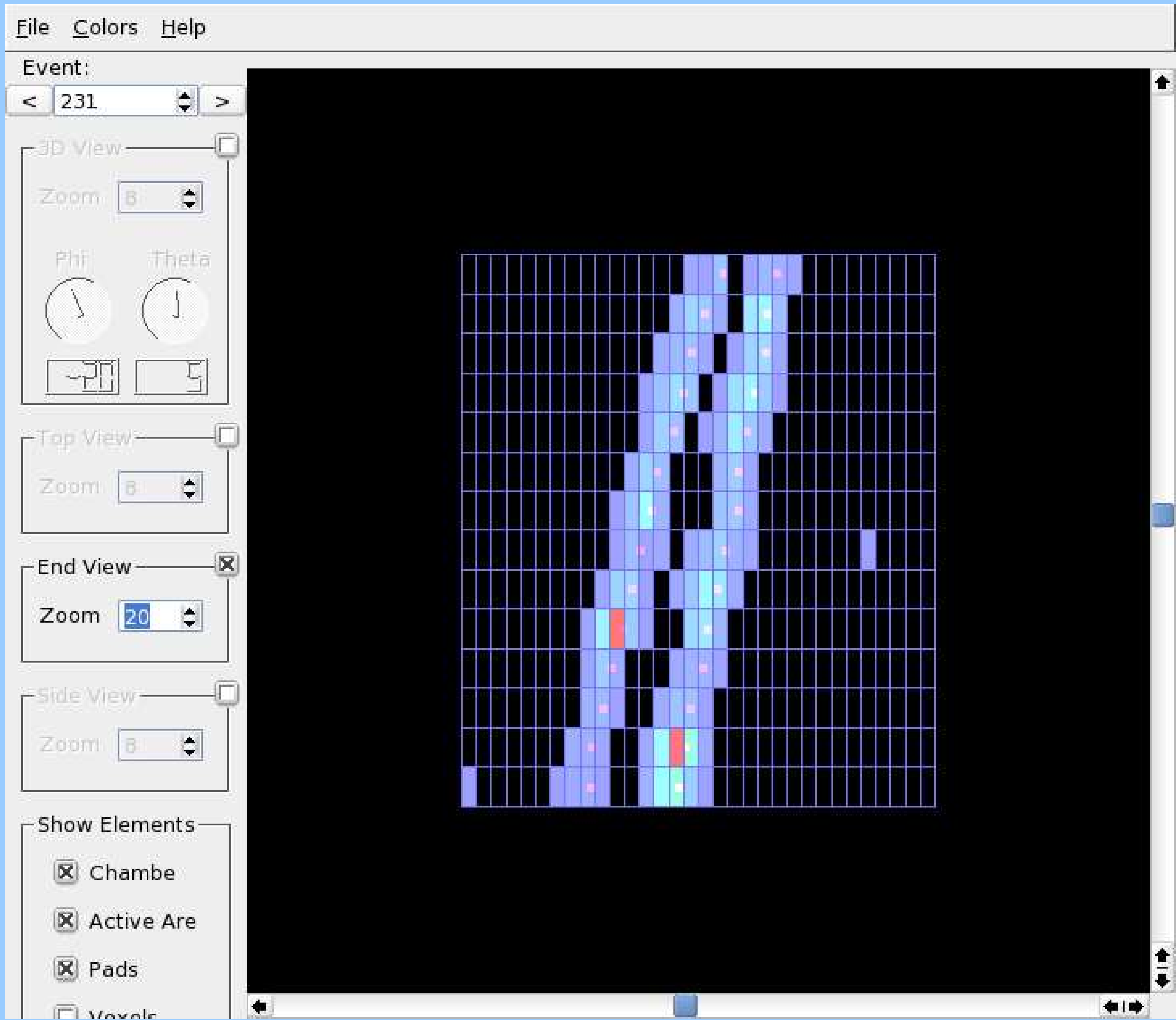
- Calculate number of secondary e^- from parametrised charge transfer combined with binomial statistic
- Integrate over 2D gaussian with sigma of charge cloud to get charge on pads
  $\rightarrow$ voxel information: charge on channel c in timeslice t



TPC Simulation: Event Display



TPC Simulation: Real Event for Comparison



Summary

- Working prototype
- Hodoscope as tool for various measurements
- Preamplifiers for new electronics
- Charge width and ion backdrift is well understood
- Simulation framework

Outlook

- Measurements with new prototype in magnet
- Measurements with prototype and hodoscope in a test beam
- ADCs for new electronics
- Stability studies with reduced IB setting
- Inclusion of IB into the simulations