Design and Construction of a TPC using GEM Foils for Gas Amplification

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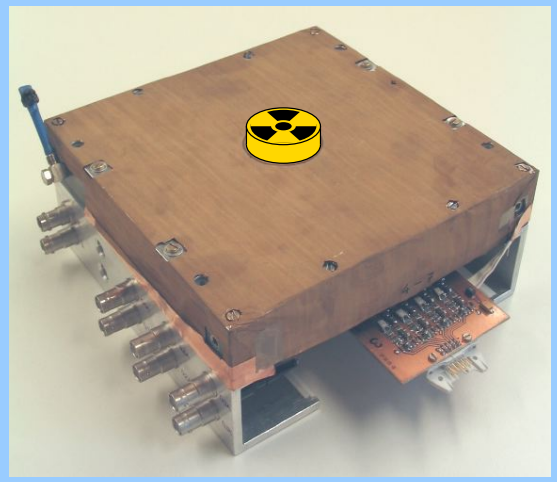
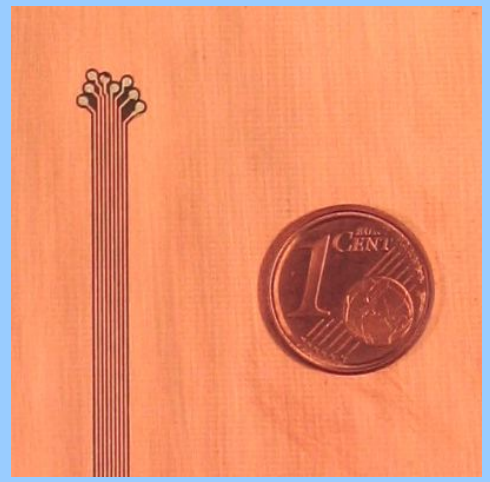
Overview

- Measurement of Charge Width Caused by a Triple-GEM Structure
  - Dependency on Magnetic Field
- Ion Backdrift
  - Parametrisation of Charge Transfer
  - Minimisation
  - Track Distortions
- TPC Prototype
  - Design of the Fieldcage
  - Readout Electronics

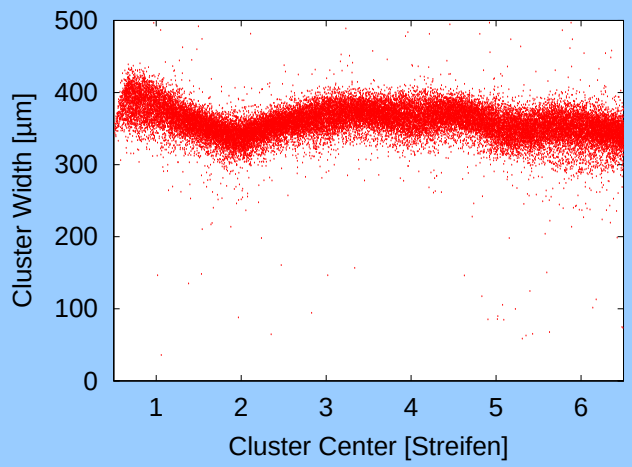
Charge Width: Measurement



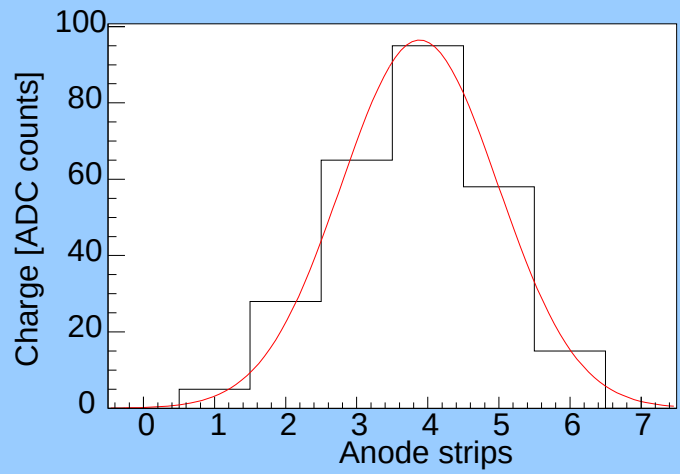
Test chamber, ^{55}Fe source



Anode strips, 300 μm pitch

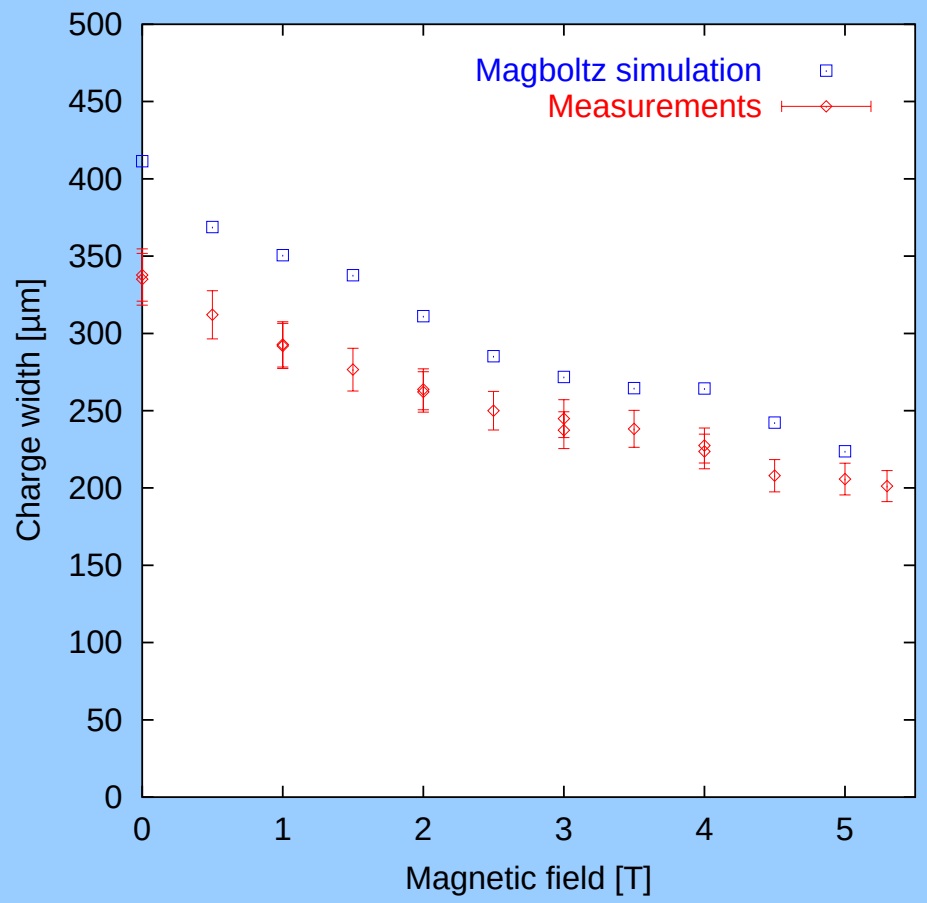


Data points for 30 000 events



Spatial charge distribution

Charge Width: Dependency on B-Field



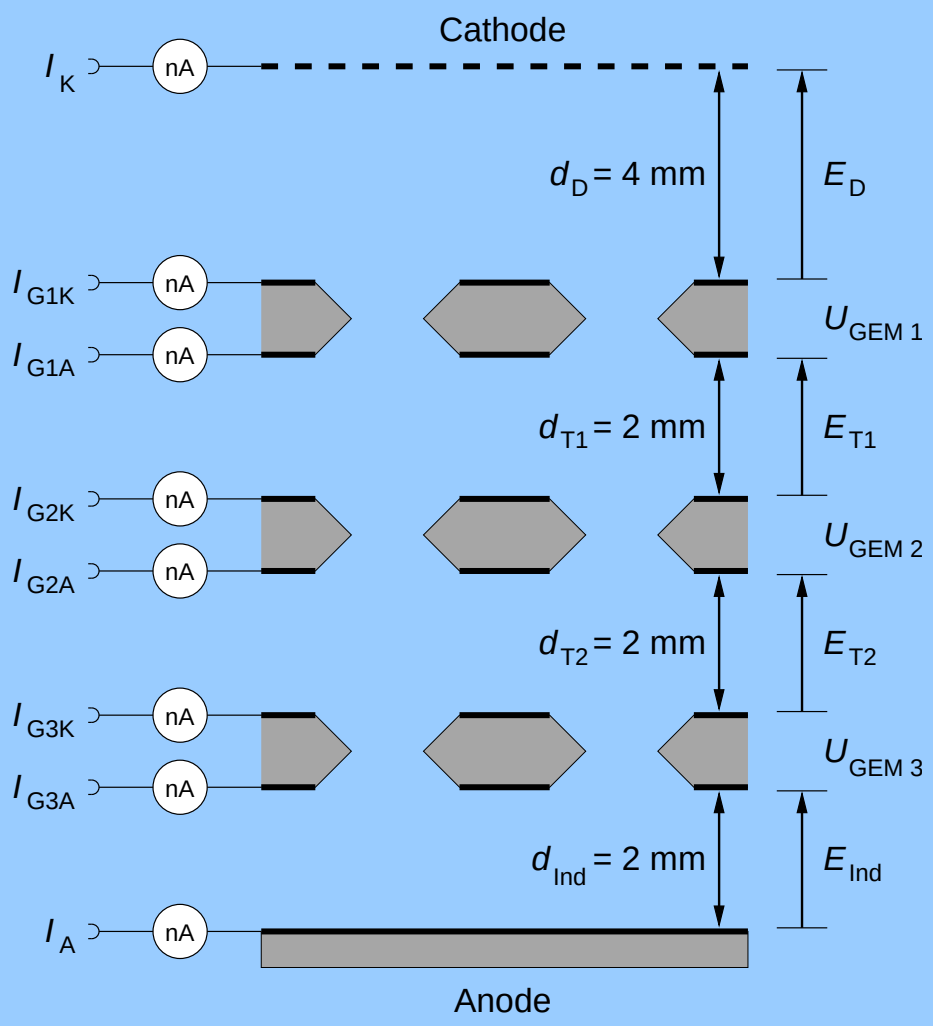
Measured with
5 T magnet at DESY

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

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

- MAGBOLTZ simulation takes different electric fields in GEM structure into account.
- Transverse diffusion is overrated by the used MAGBOLTZ version.
- Charge broadening is dominated by diffusion.

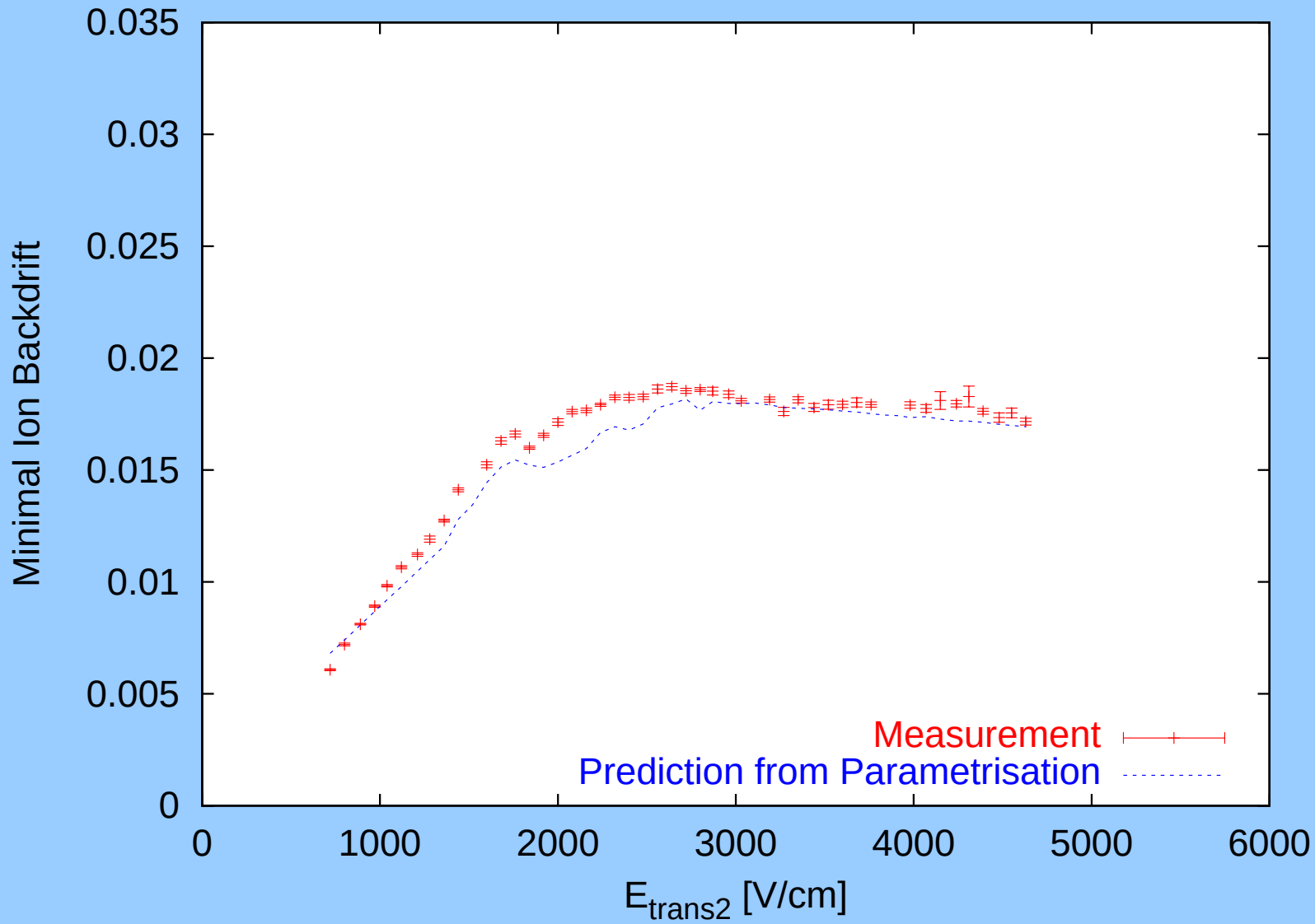
Ion Backdrift: Setup and Parameters



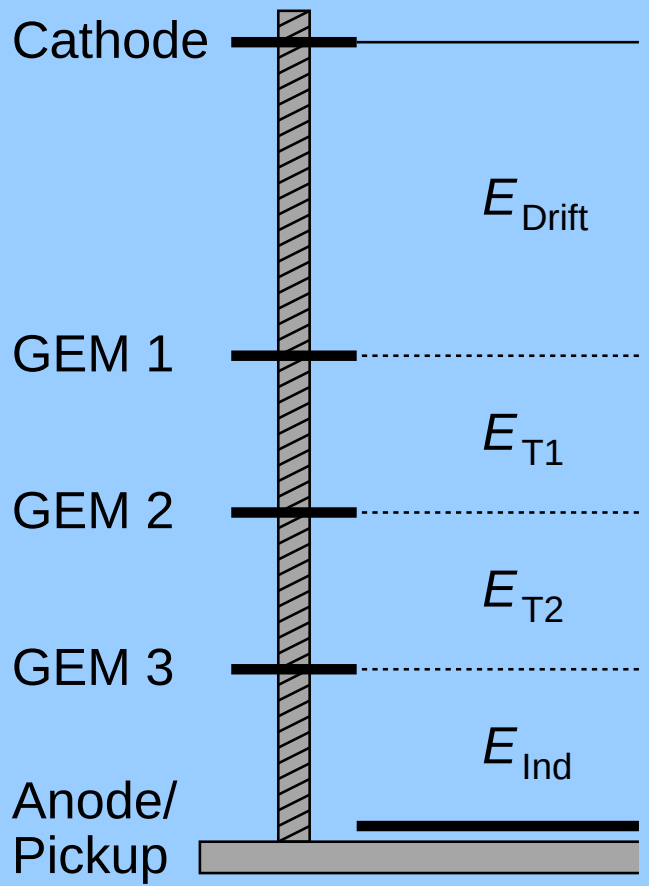
- Charge transfer determined by 7 chamber parameters (3 GEM voltages, 4 fields)
- Parametrisation of transfer coefficients
- Calculation of ion backdrift (IB) and effective gain (G_{eff})
- Optimisation for minimal ion backdrift

Ion Backdrift: Finding Minimum

Example: Minimal ion backdrift is achieved for lowest E_{trans2}



Ion Backdrift: Optimisation

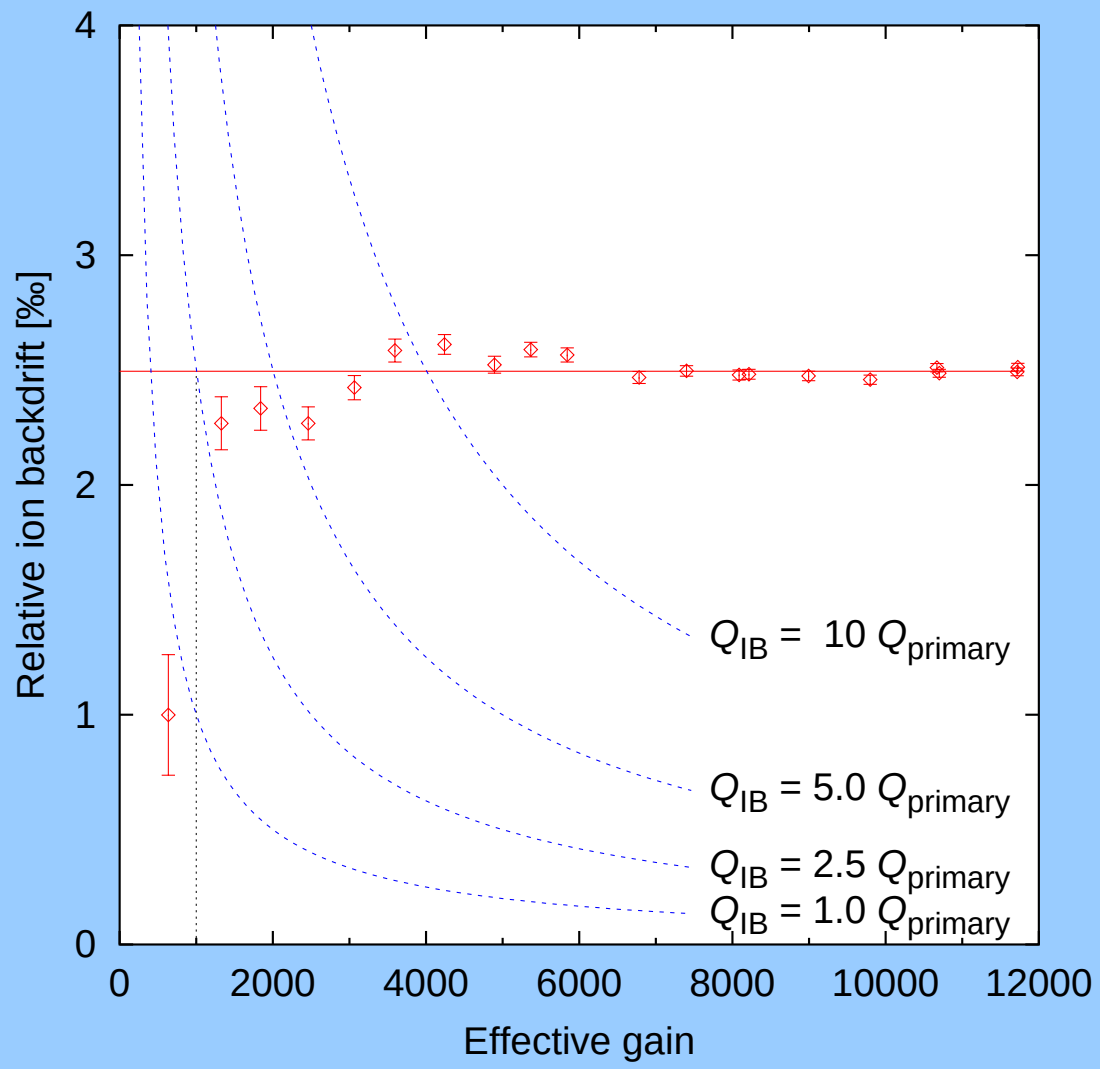


Minimal ion backdrift can be achieved with:

- 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.

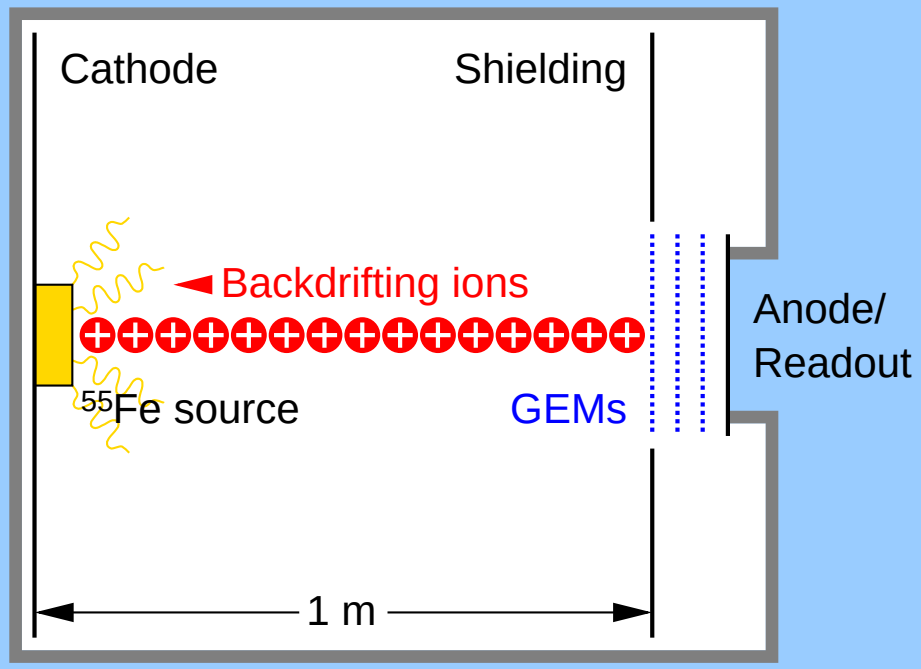
Ion Backdrift: Latest Results



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?

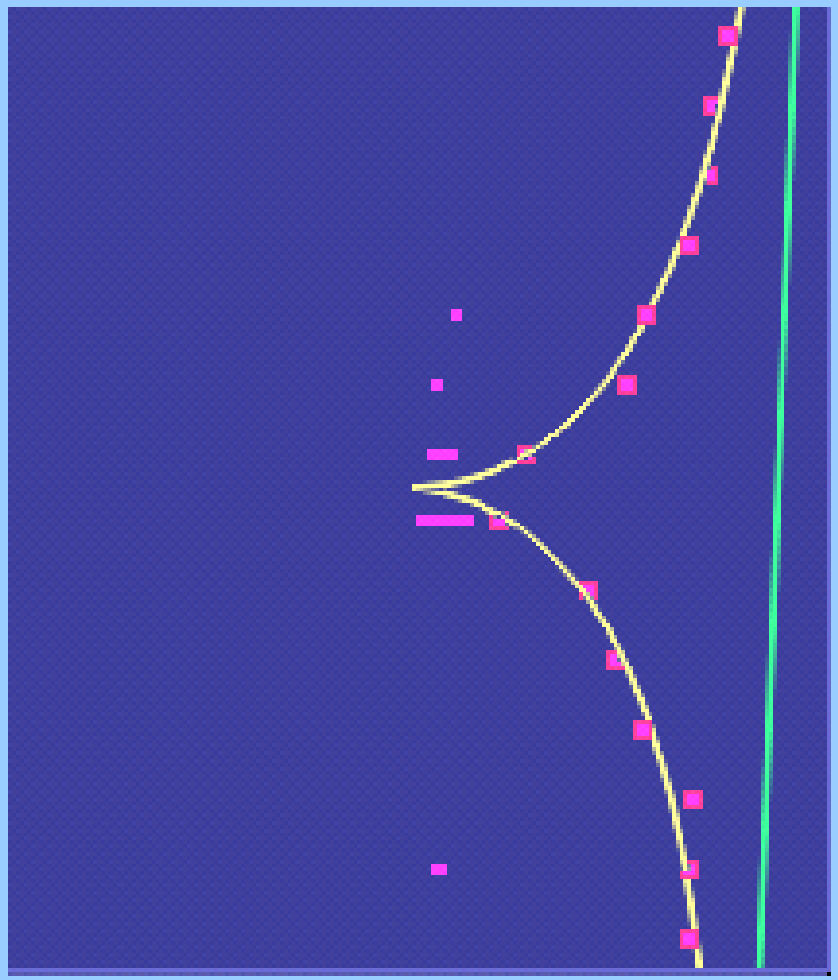
Ion Backdrift: Track Measurements



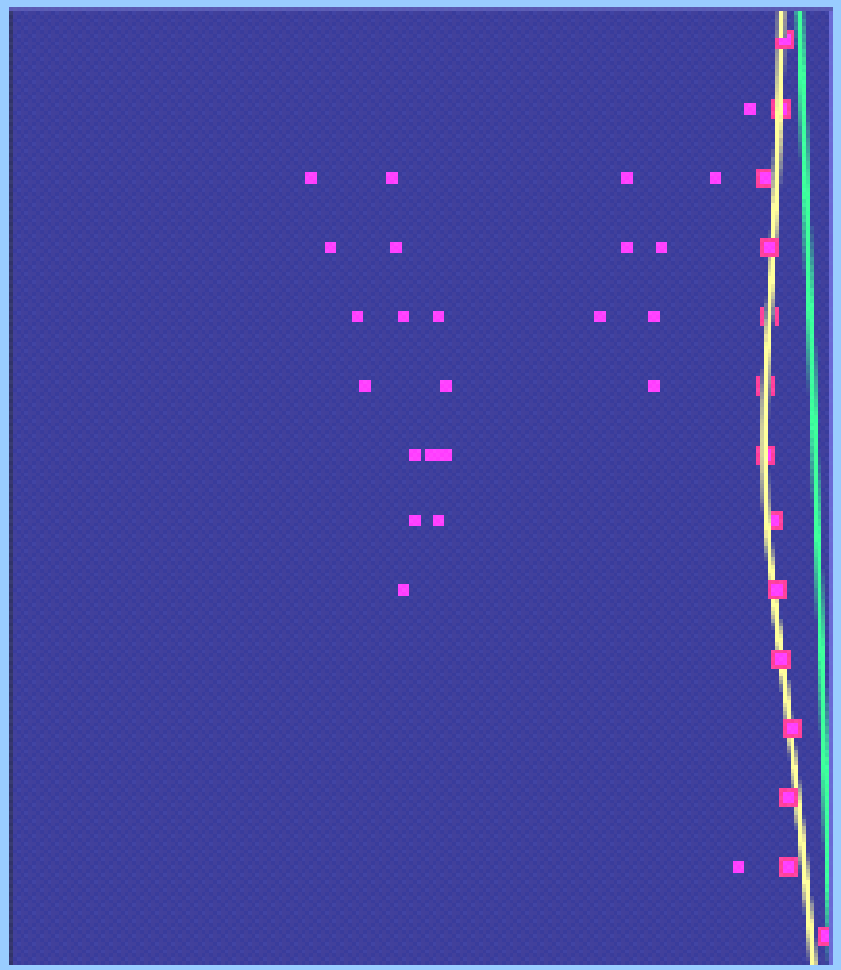
Large TPC (1 m^3) with triple-GEM readout

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

Ion Backdrift: Track Distortions



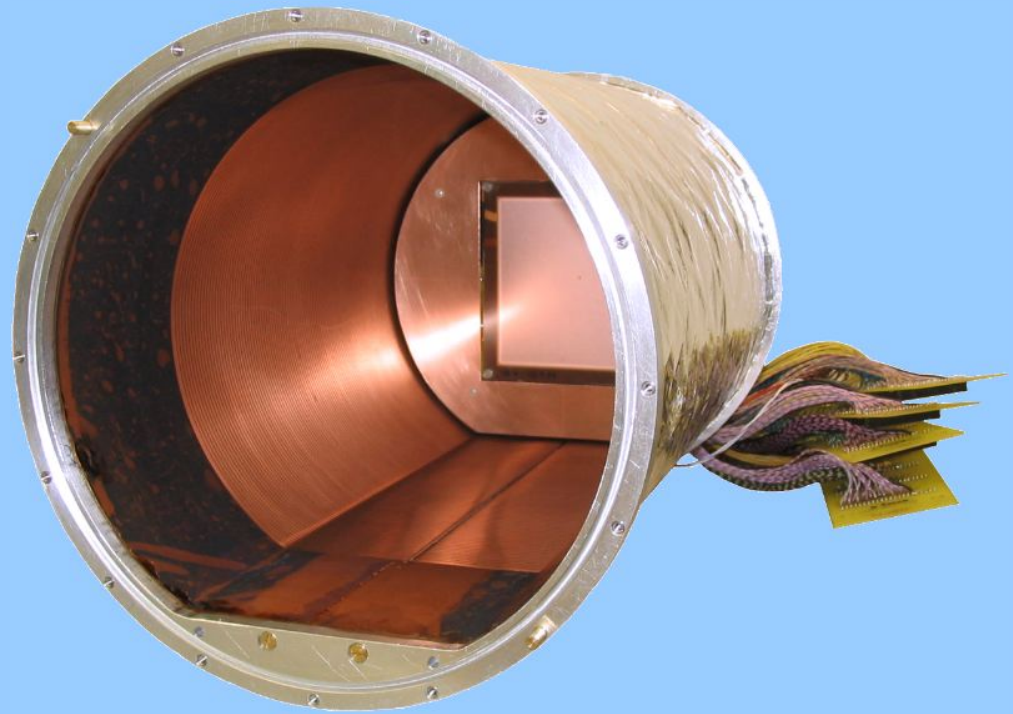
large ion backdrift



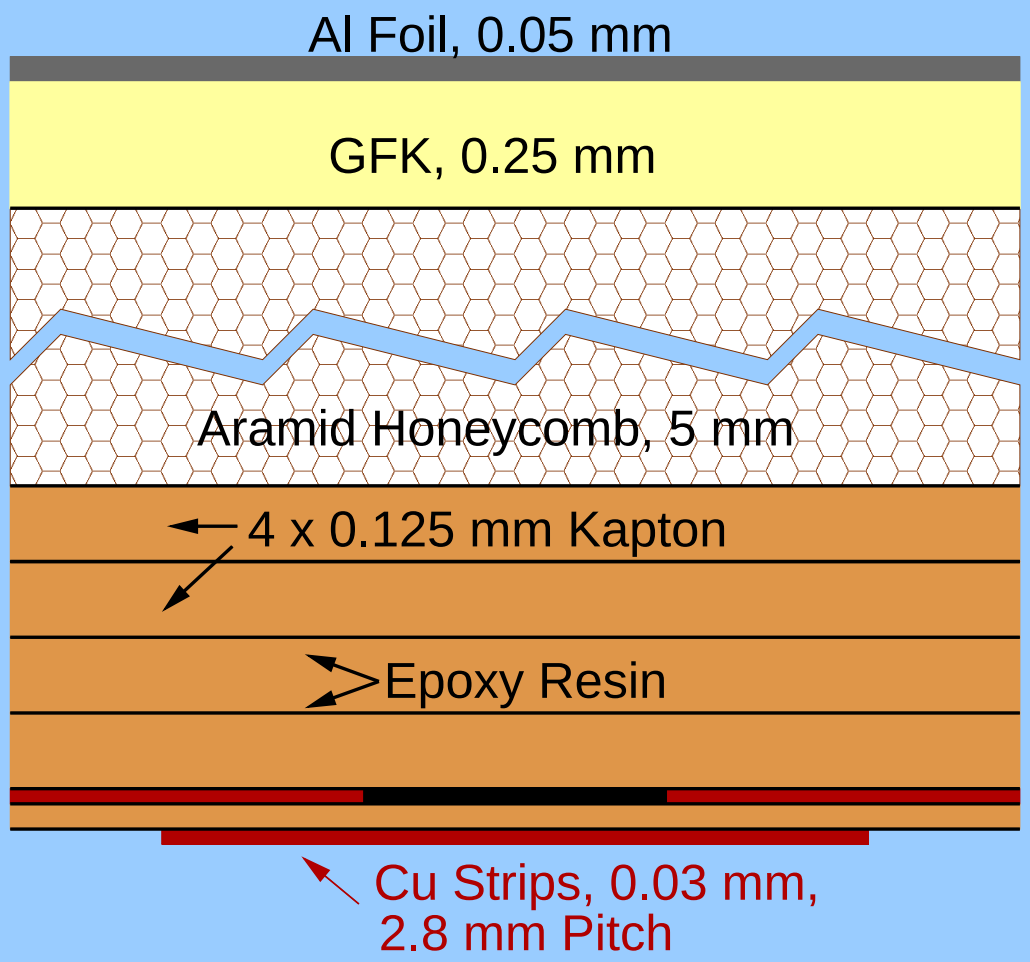
small ion backdrift

TPC Prototype: Construction

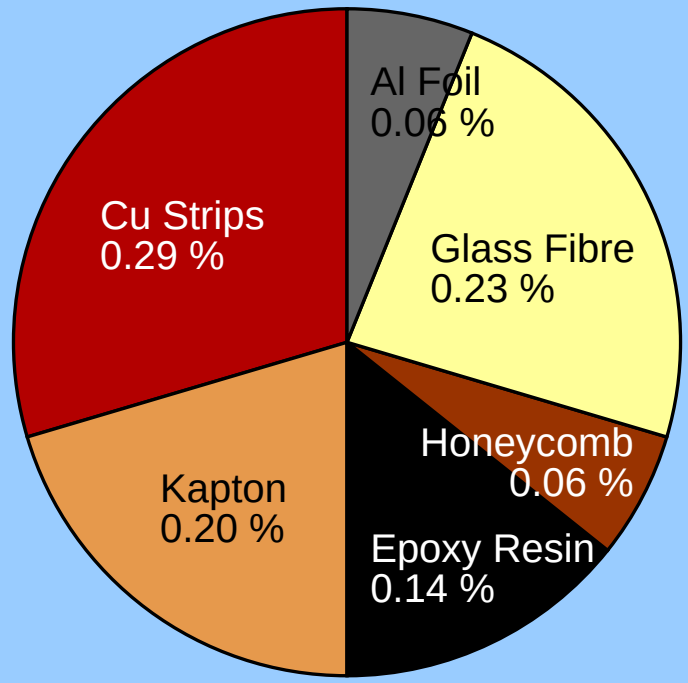
- 5T Magnet at DESY
  $\Rightarrow$ 260 mm chamber diameter
- SMD resistors as voltage divider $\Rightarrow$ pitch = 2.8 mm
- GEM readout from test TPC is used
- drift distance = 26 cm
- maximum drift field = 1000 $\frac{V}{cm}$
- materials with low density



TPC Prototype: Radiation Length



Fraction of Radiation Length

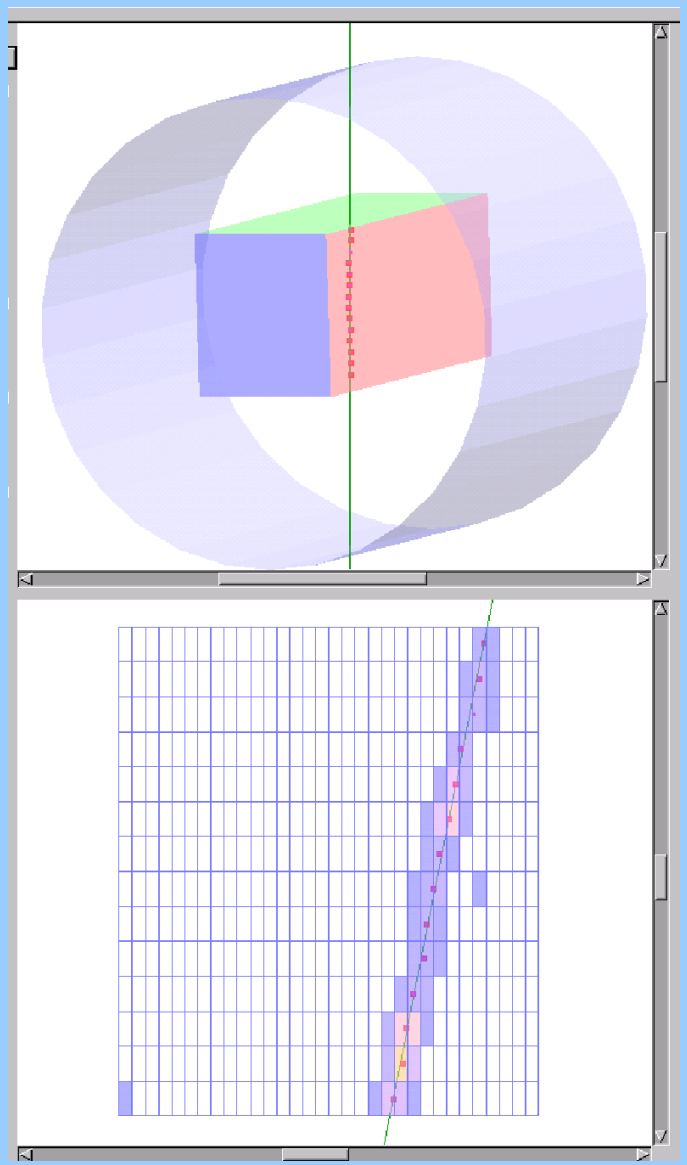


Total 1% of a radiation length

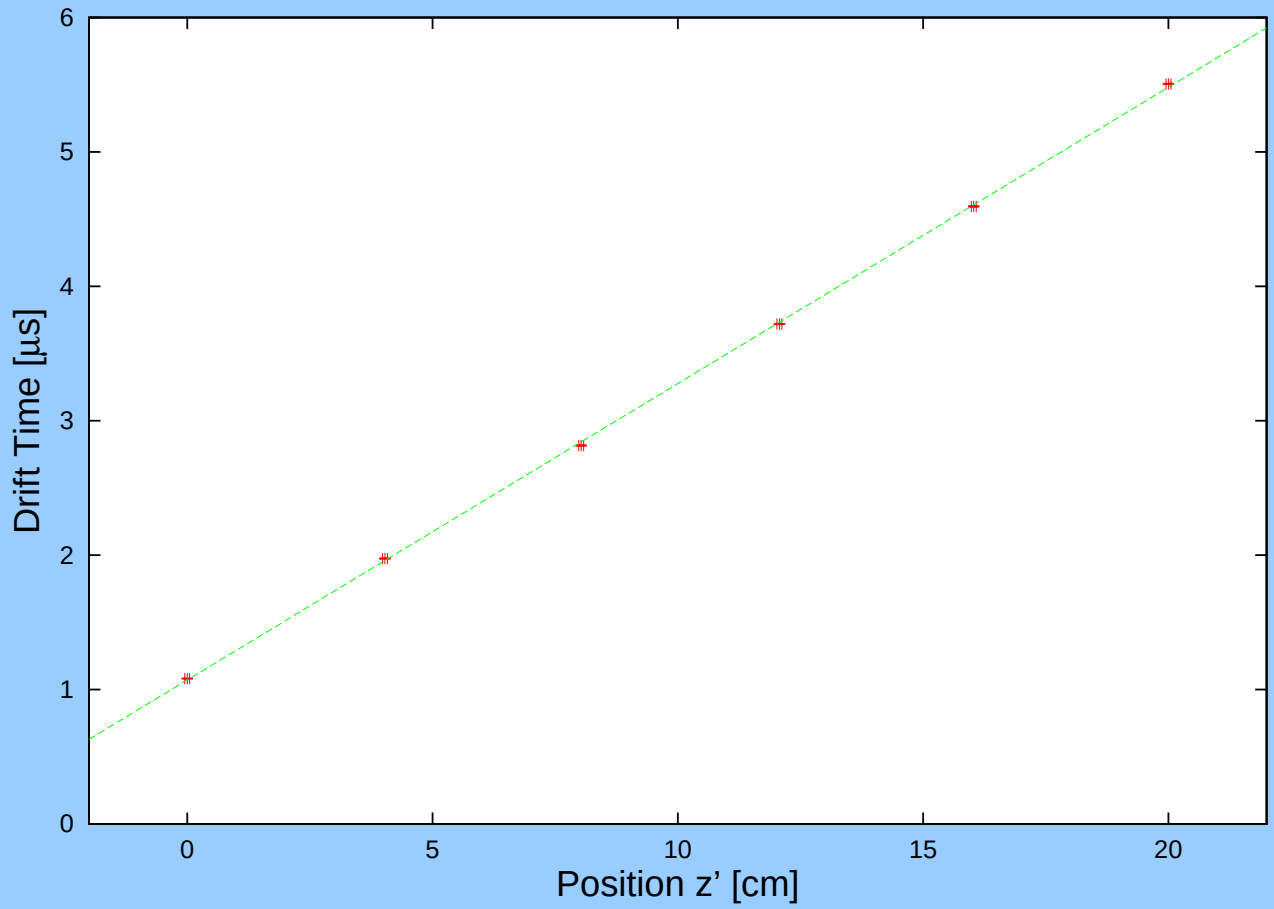
⇒ 3 % of a radiation length possible (TESLA TDR)

TPC Prototype: First Results

First Event



Homogeneous Drift Velocity



TPC Prototype: Readout Electronics

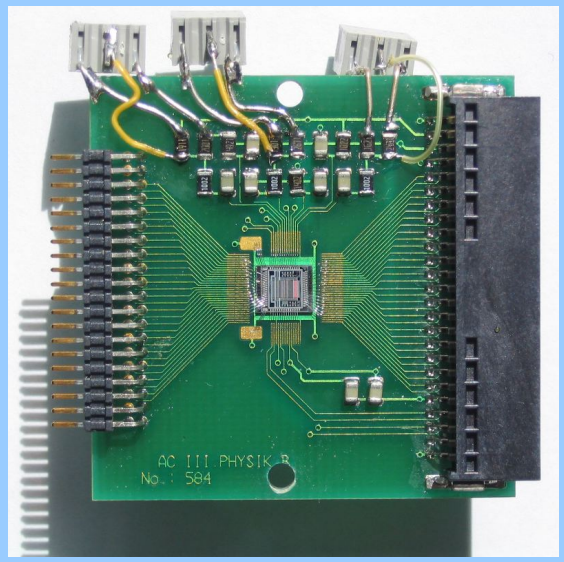
Goal: Develop a test readout with 512 channels for our TPC

Requirements:

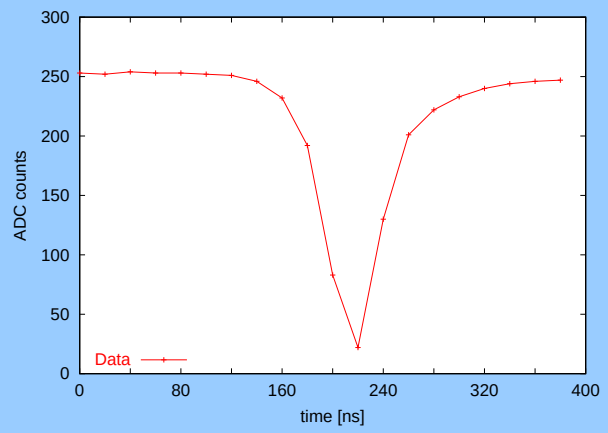
- Fast preamplifiers to study time resolution
- Small preamplifiers to allow compact design
- Fast ADCs
- Data aquisition

Current Status:

- First signals with preamplifiers
- No full ADC instrumentation yet



Preamplifier



Test chamber pulse

Summary

- Charge broadening is dominated by diffusion between GEMs.
- Influences of voltages and fields in a triple-GEM structure are well understood and can be optimised.
- Moderate effective gains allow $Q_{\mathrm{IB}} = \mathcal{O}(Q_{\mathrm{primary}})$.
- Distortions of observed tracks depend on ion backdrift.
- TPC prototype for use in magnet constructed.
- Development of new readout electronics for use in test beam ongoing.