

Charge Broadening and Ion Backdrift in a Triple-GEM Readout for a TPC

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Overview



- Measurement of charge width caused by a triple-GEM structure
- Dependency of charge width on magnetic field

- Parametrisation of charge transfer in a GEM structure
- Minimisation of ion backdrift

- Intense ionisation from an ⁵⁵Fe source in our large TPC
- Track distortions caused by ion backdrift

Charge Width: Measurement





Test chamber, ⁵⁵Fe source





Anode strips, 300 μ m pitch



Pulse on one anode strip

Spatial charge distribution

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Charge Width: Dependency on B-Field



Measured with 5 T magnet at DESY

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

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

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

Charge Width: Energy Resolution



Measured with 5 T magnet at DESY

- Determined from photo peak in ⁵⁵Fe spectrum
- Without B-field: $\sigma_E/E \lesssim 10\%$
- No deterioration in high magnetic fields
- Constrained by low primary electron statistics



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
- $U_{\text{GEM 1}}$ small influence
- E_{T1} maximal
- $U_{\text{GEM 2}}$ small influence
- E_{T2} minimal
- $U_{\text{GEM 3}} \dots$ maximal
- E_{Ind} maximal

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

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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 $G_{\text{eff}} = 1000$: $Q_{\text{IB}} \approx 2.5 \, Q_{\text{primary}}$
- Still an open question:
 How much ion backdrift can be tolerated?

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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: $230 \,\mu m \rightarrow 130 \,\mu m$ at 4 T
- Energy resolution gets worse with IB-optimised settings:

 $\sigma_E/E \approx 10\% \rightarrow 13\%$

Effective Gain: Cross-Check

TESIA



B = 4 T, measured at DESY

- Variation of second transfer field E_{T2}
- G_{eff} determined from
 ⁵⁵Fe photo peak
- G_{eff} calculated from parametrisation
- Relative values, normalised at $E_{T2} = 60 \text{ V/cm}$
- Both data sets show a similar trend

Track Distortions: Setup



Large TPC (1 m³) with triple-GEM readout



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

Track Distortions: High Ion Backdrift



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Track Distortions: Reduced Ion Backdrift



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- Charge broadening is dominated by diffusion between GEMs.
- Charge width decreases in high B-fields (200 µm and less) without loss of energy resolution.

- Influences of voltages and fields in a triple-GEM structure are well understood and can be optimised.
- Moderate effective gains allow $Q_{IB} = \mathcal{O}(Q_{primary})$.

- Measurements with intense ionisation in a TPC
- Distortions of observed tracks depend on ion backdrift.