Time Projection Chamber with Triple GEM and Pixel Readout

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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
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
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/$\mu$s, 0.95 cm/$\mu$s
- diffusion coefficients: 131 $\mu$m/$\sqrt{\text{cm}}$, 129 $\mu$m/$\sqrt{\text{cm}}$

but very different primary ionization: $\sim 90e^-/\text{cm}$, $\sim 15e^-/\text{cm}$

Gas was used from premixed bottles,
oxysorbers were placed directly before the detector.
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

δ-electron

long drift distance

short drift distance
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
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
Track Parameters

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

- **He:CO₂ 70:30**
  - **Inclination in pad plane**
  - **Inclination in drift direction**
  - **Drift distance of hits**
'Electron-tomography' of GEM

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

diffusion of single electrons:
\[ \sigma(z) = \sqrt{D_t^2 z} \]

but: number of electrons per hit
\[ n_{\text{ele}} = 1 + a e^{bz} \]

=> \( \sigma = \sqrt{\sigma_0 + D_t^2 z/(1 + a e^{bz})} \)

He:CO₂ 70:30

Ar:CO₂ 70:30
**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

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**Graphs:**
- **He:CO$_2$ 70:30**
- **Ar:CO$_2$ 70:30**

**Statistical process!**
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?
The argon mixture was operated at a lower gas gain than the helium mixture, resulting in a 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
Test Beam Results

transverse spatial resolution in dependence on track inclination

quasi flat over 90°
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
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

W-boson

Z-boson

\(\sigma\)-particle

Higgs-boson