A GEM-TPC for the CBELSA/TAPS experiment

The present detector setup at CBELSA/TAPS in Bonn, Germany, is dedicated to the observation of baryonic resonances with neutral final states, e.g. \( \gamma p \rightarrow p^0 \gamma, \gamma p \rightarrow p^+ \gamma, \gamma p \rightarrow p^0 \gamma' \). The TPC-upgrade will significantly increase statistics by granting access to charged states in addition: e.g. \( \gamma n \rightarrow n \pi^+ \pi^- \), \( BR = 8.25 \% \) and \( \gamma n \rightarrow n \pi^+ \pi^- \pi^0 \), \( BR = 89.2 \% \). Furthermore isospin separation can be performed (\( \gamma p \rightarrow n^+ p^0 \)) and strangeness production (\( K^0 \rightarrow \pi^+ \pi^- \)) can be observed.

Upgrade of the CBELSA/TAPS experiment

The CBELSA/TAPS experimental area: An electron beam is supplied by the Electron Stretcher facility with energies and currents up to 3.5 GeV and 200 mA. It produces a photon beam off a Bremsstrahlung-target, hitting a polarised target in the center of the main detector, the Crystal Barrel (CB).

CB setup: 1320 CsI(Tl)-crystals surrounding the polarised target. Polar angle coverage 30° to 156°. Charged reactions are identified by an inner detector of scintillating fibers (red).

The TPC prototype[2]

- Single-sided readout (forward boost)
- Drift length: 727.8 mm
- Inner diameter: 104.0 mm
- Outer diameter: 308.0 mm
- Wall thickness: 4.0 mm
- Material budget < 1% \( X_0 \) (Kapton/Rohacell sandwich)
- Gaseous amplification based on Gas Electron Multipliers (GEM) [1] allows for a continuous readout
- >10000 pads read out by 168 × T2K AFTER chips

Optimisation of the GEM-stage


Collection efficiency:

\[ \eta_{\text{Coll}} = \frac{N_{\text{primary}}}{N_{\text{primary}} - N_{\text{coll}}} \]

Extraction efficiency:

\[ \eta_{\text{Extr}} = \frac{N_{\text{transfer}}}{N_{\text{transfer}} + N_{\text{bottom}}} \]

Garfield++ simulation of single electron avalanche: Electron paths (green), ion paths (red), creation points (black dots).

Electron collection efficiency from Garfield++ simulation for different GEM geometries.

Electron extraction efficiency from Garfield++ simulation for different GEM geometries.

Results

- The TPC prototype was operated at the FOPI spectrometer at GSI, Germany
- Reactions created by 1.7 GeV/c pions impinging on a carbon target were observed
- The measurement of the specific energy loss shows clear bands for pions, kaons, protons, and deuterons
- Vertex resolution:
- Energy resolution:

The design of the fieldcage is to be revised:
- Improved homogeneity of driftfield
- Implementation of a removable cathode
- Adapt for geometric constraints from existing setup (new target, maximum polar angle coverage)
- The composition of the GEM stack will be optimised with respect to ion backflow and energy resolution, considering
- different GEM geometries
- 4 GEMs instead of 3 GEMs
- the electrostatic setup of the amplification system
- Upgrade of the frontend electronics (e.g. SAMPA)
- A photoelectric-effect-based field calibration system is foreseen to take into account distortions of the drift field (see poster 44 by D. Schaab)

Outlook

- The present detector setup at CBELSA/TAPS in Bonn, Germany, is dedicated to the observation of baryonic resonances with neutral final states, e.g. \( \gamma p \rightarrow p^0 \gamma, \gamma p \rightarrow p^+ \gamma, \gamma p \rightarrow p^0 \gamma' \). The TPC-upgrade will significantly increase statistics by granting access to charged states in addition: e.g. \( \gamma n \rightarrow n \pi^+ \pi^- \), \( BR = 8.25 \% \) and \( \gamma n \rightarrow n \pi^+ \pi^- \pi^0 \), \( BR = 89.2 \% \). Furthermore isospin separation can be performed (\( \gamma p \rightarrow n^+ p^0 \)) and strangeness production (\( K^0 \rightarrow \pi^+ \pi^- \)) can be observed.

Jonathan Ottnd, M. Ball, R. Beck, V. Ratza, D. Schaab, R. Schmitz, and B. Ketzer for the CBELSA/TAPS collaboration