Studies for a Crystal Ball TPC

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Outline

Introduction

Time Projection Chambers

Studies
  The Karlsruhe Prototype
  Simulation Studies

Conclusion and Outlook
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Conclusion and Outlook
Current Setup at A2 (Inner detectors)

**Crystal Ball**

**PID**
- Particle Identification Detector
  - plastic scintillator
  - 24 strips each covering 15°
  - energy loss based particle identification

**MWPCs**
- 2 hits per track
- Spatial resolution $\sim O(mm)$

**Target**

**Beam**

**MWPC: Multi Wire Proportional Chamber**
Photon Induced Meson Production

For $\eta'$ production we need

- high photon energy
- high event rates
Photon Induced Meson Production

For $\eta'$ production we need

- high photon energy
- high event rates

Problem
MWPCs cannot handle the event rates needed!

A possible solution
Replace current track detection by a GEM driven TPC.
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Gaseous TPC

How to get 3D information

- Charged Particles cause ionisation.
- Primary charge drifts in homogenic electric field.
- $x$ and $y$ coordinates: position on readout plane.
- By measuring the drift time we get the $z$ coordinate.
Gaseous TPC

Limiting factors

▶ Diffusion limits the spatial resolution.
▶ Drift velocity and diffusion depends on gas mixture.
▶ Ionisation rate for MIPs is $\sim 10 \frac{e^{-}}{mm}$, Gas amplification is needed.
Gas Electron Multiplier

- Kapton foil with conducting layers (Cu) on top and bottom.
- Strong electric field $\sim 10^5 \frac{V}{cm}$ within holes yields gas amplification.
Gas Electron Multiplier

- Field geometry suppresses ion drift back.
- Gas gain $\sim 10 - 100$ per foil.
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The Karlsruhe Prototype

Test with cosmics for:
- Resolution studies
- Develop and test reconstruction software
- Gaining experience
Measurements: Test runs with Cosmics

Cluster charge vs. Charge [ADC Counts]
Measurements: Test runs with Cosmics
Measurements: Test runs with Cosmics

Trackfinder: Calculates the principal axes of inertia.
A Problem (to be) solved?
A Problem (to be) solved?

Cluster counts

PMT test

[Graph showing cluster counts over time]
A Problem (to be) solved?
A Problem (to be) solved?
Parameter Driven Fast Simulation

Purpose

- Flexible simulation for fast estimation of resolutions depending on different pad geometries
- Test and develop reconstruction software with simulated signals

The spatial resolution depends on

- Length of drift volume and gas within the chamber: longitudinal and transversal diffusion
- Geometry of pad planes for $x$ and $y$ direction
- Readout electronics: sampling rate, signal response, etc.
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Gas

- Gas mixture: Drift velocity and diffusion via MAGBOLZ

Parameters

- Drift velocity
- Transverse diffusion
- Longitudinal diffusion

Gas mixture: Drift velocity and diffusion via MAGBOLZ
Parameters

Gas

- Gas mixture: Drift velocity and diffusion via MAGBOLZ
- Ionisation rate $n_T$ for MIPs
- Probability for cluster sizes
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Geometry
- Drift length, active volume defined via pad plane
- GEMS: Position and amplification
- Track parameters

Voltages
Working Principle

- Generate primary electrons
- Calculate $\sigma_T, \sigma_L$ from $z$-positions
  \[ \sigma_{T,L} = D_{T,L}(E) \sqrt{z} \]
- Recursively generate electrons and diffuse within and between GEMS
- Time binning depending on sampling frequency
The Crystal Ball TPC

Possible layouts for drift volumes
Results: Typical track in Crystal Ball

Simulation:

- 3 GEMs with gas gain
  \( G \sim 5800 \)
- \( r_{in} = 66 \text{ mm}, \)
  \( r_{out} = 145 \text{ mm} \)
- \( l_{drift} = 400 \text{ mm} \)

- Binned in a radial symmetric readout plane with 12 tracks
- 2094 pads with an area of \( 25 \text{ mm}^2 \) per pad
- Time integrated signal
Results: Typical track in Crystal Ball

**CB TPC**

- Simulation:
  - 3 GEMs with gas gain $G \sim 5800$
  - $r_{in} = 66$ mm, $r_{out} = 145$ mm
  - $l_{drift} = 400$ mm
  - Binned in a radial symmetric readout plane with 12 tracks
  - 2094 pads with an area of $25 \text{ mm}^2$ per pad
  - Time integrated signal
Results: Broadening due to Diffusion

Transversal Diffusion

Track: $z = 200\text{mm}$ length = 79 mm

Gaussian fit: $\sigma = (1.8983 \pm 0.0005) \text{mm}$
Results: Time binning

Sampling frequency: 19.66 MHz
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A GEM driven TPC within the Crystal Ball Detector yields:

▶ A reliable track detection system at high event rates.
▶ More Points along the tracks $\implies$ better track reconstruction.
▶ To be studied: Contribution to PID via $\frac{dE}{dx}$?
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(STAR-Experiment)
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Outlook
There is still work to be done...

▶ More accurate simulation for GEM contribution.
▶ Include Signal response in the simulation.
▶ Compare different Pad Geometries concerning resolutions
▶ Develop new readout system for CB TPC.
▶ Track finder for high event rate.
▶ Build new chamber.
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Thank you for your attention!