GAS-RELATED STUDIES ON TRIPLE-GEM DETECTORS

EP-DT-FS
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GEM DETECTORS AT LHC

- GEMs: Gaseous Electron Multiplier detectors used in the muon systems of CMS and LHCb as well as in ALICE TPC.
- LHCb GEM operated with Ar/CO2/CF4 45/15/40 in gas recirculation (now dismounted)
- CMS GEM operated with Ar/CO2 70/30 in open mode
- ALICE TPC is changing MWPC with GEM detectors and operation will be in gas recirculation
- It is important to provide a stable and correct gas mixture to all LHC gas detectors
- We want to test effects of gas mixture variation and creation of impurities in GEM gas systems

GEM working principle:
- Charged particle passes through → ionizes molecules along its path
- Free electron drifts down due to applied electric field and multiplies in areas of high field density (inside holes)
- With 3 foils & an applied voltage of ~400V to each foil → ~$10^4$ total gain

In this work, I focused on the gas mixture: Ar/CO2/CF4 45/15/40
EXPERIMENTAL SETUP

- GEM pulse signal is shaped in Pre-Amplifier and amplified again in Amplifier
- Height of pulse signal and detector current are both measures of gain
GEM GAS COMPOSITION STUDIES

Experimental:
- Test GEM gain response to signal from $^{55}$Fe source under varying gas compositions
- Tests: Constant CO2, Constant Ar, Constant Ar/CO2 ratio

Simulation:
- ANSYS models field inside GEM and Garfield++ computes electron avalanche process
- Output is properties of electrons formed in avalanche

<table>
<thead>
<tr>
<th>Component</th>
<th>Role</th>
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<tbody>
<tr>
<td>Ar</td>
<td>Primary ionization</td>
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<tr>
<td>CO2</td>
<td>Limits avalanche spread by absorbing photons</td>
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<tr>
<td>CF4</td>
<td>Improves time resolution</td>
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Sample statistics from avalanche
Gain trends experimental vs simulation
- Decreasing CO2 → smaller gain suggests CF4 effect dominates over CO2 effect

Rate trend experimental only
- Decreasing gain does not imply a change in rate
- Argon being held constant so rate is approximately constant as well

Fixed Argon Gain Trend at 4650V

Fixed Ar Rate at 4650V

χ² / ndf 1.133 / 5
p0 0.9851 ± 0.08679
p1 0.000615 ± 0.002159
CONSTANT AR/CO2 RATIO TEST

- Two objectives: to test gas mixture variation effects on gain/rate and to compare detector sensitivities to changes in CF4

Gain trends GEM vs SWPC
- GEM trend has steeper slope suggesting a higher sensitivity to changes in CF4 - possibly due to 3 stages of multiplication vs 1 stage in SWPC

Rate trends GEM vs SWPC
- Nearly identical slopes suggesting comparable sensitivity but SWPC is slightly steeper - maybe due to higher chance of primary electron absorption in drift volume
F⁻ ACCUMULATION

- CF₄ can break down during irradiated GEM operation into CF₃ and F⁻
- F⁻ can react with H₂O in detector to form HF which damages detector foils
- Objective: Expose triple-GEM detectors to radiation at GIF++ facility to test (using Ion Selective Electrodes) for production of F⁻
- ISE electrode: sensor that converts activity of an ion dissolved in a solution into an electric potential
  - 2 different electrodes used: Separated (Hanna) and Combined (ThermoFisher Scientific)
ISE ELECTRODE MEASUREMENT CHARACTERIZATION

- Triple-GEM output gas bubbles into a solution in jar outside detector
- Electrodes tested solution for concentrations of $\text{F}^-$
- Measurements performed first in lab with small $\text{Fe}^{55}$ sources and then at GIF++ for time periods of one hour
- Switched to overnight measurements so GEM & source left on for 10-15 hours

Standard deviation in measurements of ppm/min vs time accumulating
NEXT STEPS

- More ISE measurements using procedure characterized this summer
- Effect of applied voltage to the GEM on rate of CF4 breakage
- Effect of gas flow
- Effect of irradiation level

WHAT I LEARNED

- Working principles of gaseous detectors
- How to operate GEM detectors
- Characterization and high voltage scans
- Software: ROOT
- How to operate ISE Electrodes
- A little bit of Italian
- How to drive manual (poorly)
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