Gain measurements of Chromium GEM foils

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Introduction

- **MESA (Mainz Energy-recovering Superconducting Accelerator):**
  - New linear polarized electron accelerator being built at the Institute for Nuclear Physics in Mainz, Germany
  - Up to 105 MeV @ 1 mA (ERL mode)

- **MAGIX (MESA Gas Internal target eXperiment)**
  - High precision physics including:
    - Search for the dark photon
    - Measurement of the proton radius
  - Internal windows-less gas target
  - Luminosity of $10^{34}$ cm$^{-2}$ s$^{-1}$
  - Magnet spectrometers to identify scattered particles
  - Focal plane detectors: GEMs
Our interest in Chromium GEMs

• Characterized Chromium GEMs to evaluate feasibility of GEM detectors in hodoscope mode for the MAGIX spectrometers

• Tested 10x10 cm² Chromium GEM foils
  • Conductive layer of 100 nm Cr (instead of 5 μm Cu)
  • Produced by CERN
  • Full Cr-GEMs and single sided Cr-GEMs with a regular copper side
GEM detector setup

- Triple GEM setup
- Default GEM voltage: 370 V
- Transfer fields: 200 V/mm
- Induction field: 400 V/mm
- Ionization gap: 5 mm
- Drift field: 100 V/mm
- Counting gas: 70% Ar, 30% CO₂
- Signal from GEM1 anode current
Measurement setup

- $^{55}$Fe source with photo energy of 5.9 keV in the center
- G1-current amplified and shaped, Trigger signal from oscilloscope
- Digitization of the signal with a peak sensitive ADC
- In addition: Signal from readout plane measured with APVs
$^{55}$Fe-spectra from the ADC

- Clear energy spectra
  - Photo peak at 5.9 keV
    - Energy resolution $\approx$ 14%
  - Escape peak at 3.2 keV

- **Effective Gain:**
  - $Q_{\text{GEM1}}/Q_{\text{ionization}}$
  - Setup calibrated with a test pulse generator

- Default setup (All GEMs @ 370 V):
  - Effective Gain $\approx$ 6840

```
ADCrun1680 entries: 117627
```

```
Counts
```

```
ADC Value
```

```
0  200  400  600  800  1000  1200  1400
```

```
Counts
```

```
ADC Value
```

```
0  200  400  600  800  1000  1200  1400
```
Gain curve of copper GEMs (ADC)

- Acquired gain curve by variation of GEM3 voltage from 300 to 420 V
  - GEM1 and GEM2 constant at 370V
- Exponential rise
  - Eff. gain from ≈ 2000 – 10000

\[
\text{Fit: } a \times \exp(b \times x) + c
\]

- \(a = 2.06889472564 \pm 0.121960568659\)
- \(b = 0.019969052557 \pm 0.000137589358987\)
- \(c = 719.011286018 \pm 23.2337221129\)
Gain comparison for Cr GEMs (ADC)

- Cr-GEMs on G3 position
- Two types of chromium GEMs used
  - “One-sided” Cr-GEMs with one side made from copper (red)
  - Full Cr-GEM foil (green)
  - Cu-GEM gain in comparison (blue)
- Noticeable increase in gain over Cu-GEMs
- Stronger effect in Full Cr-GEM
Confirmation from APV spectra

- Confirmed higher gain with measurements of the readout charge with APV-cards
- Only done for one-sided Cr GEM foils
Relative Gain Cr vs Copper (ADC)

- Ratio of Cr-GEM to Cu-GEM gain
- Local maximum, lower for high voltages
- APV results from a different setup
  - Match the order of magnitude
Conclusion

- Recorded spectra of $^{55}$Fe to measure GEM detector gain
- Relevant increase of gain for single sided Cr GEM foils
- Double sided Cr GEM foil even higher than single sided Cr GEM
- Gain curves measured with the APV-cards from the readout plane confirmed these observations
Outlook

• Continue systematic scanning for different positions of the Cr-GEM

• Compare multiple positions and different foils

• Redo the APV measurements
  • Check the relative gain curve
  • Check homogeneity
  • Compare GEM foil and readout signals

• Possible explanations for the higher gain?
  • Different charge up effects then in copper
  • Geometrical effects
  • Edge effects
An open question: Peak broadening at ADC spectra

- Charge up effects deform the Gaussian over time (~hours)
- Independent of GEM material
- Prevents us from analyzing the energy resolution from the ADC spectra
Charge up

- 10 hours at constant GEM voltages (370 V)
- No significant shift in peak position
  - No influence in gain curves
THANK YOU FOR YOUR ATTENTION!

http://magix.kph.uni-mainz.de
• **Energy resolution**: Ratio of photo peak width to mean

• APV measurements showed a better energy resolution for Cr GEM beyond the Cu-gain-range

• Peak broadening prevented us from further investigation