A Practical Method to Estimate the Spatial Resolution of GEM Detector

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Outline:

• Introduction
• Method description
• Experimental results
• Near future plans
• Summary
Brief introduction to GEM detector

- HV

- Cathode

- Drift /Sensitive (~1-3 kv/cm)

- GEM1 (300v-500v)

- Transfer (~1-3 kv/cm)

- GEM2 (300v-500v)

- Induction (~1-3 kv/cm)

~2-30 mm

~1-2 mm

~1-6 mm

Anode/Readout strip
Introduction to the set up

- **Readout strip**: 1-D, width=200um, 400um; 2-D, width=400um
- **Preamplifier**: Charge-sensitive, 16 channels
- **DAQ**: Based on VME-Bus, peak sensitive ADC
**General performance**

**Event Display**

\[ \chi^2 / \text{ndf} = 8.36 \times 10^4 / 13 \]
- Constant: \( 2494 \pm 62.07 \)
- Mean: \( 7.912 \pm 0.0396 \)
- Sigma: \( 1.344 \pm 0.0366 \)

**The Total Energy for clear Events**

- Entries: 87732
- Mean: 7393
- RMS: 2199

**GEM(Ar-CO2): Gain-Main VS Voltage**

**GEM(Ar-CO2): Resolution-Escape VS Voltage**
Method description
Conventional methods for spatial resolution

Method I:
- Radiation
- Collimator
- Readout strip
- Base board

Method II:
- Cosmic ray or Beam
- Telescope
- Undetermined

Method III:
- Collimated X-ray
- Sharp edge absorber

Ref:
### Comparison of different methods

<table>
<thead>
<tr>
<th>#Method</th>
<th>$\sigma_0 /\mu m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1 (slit width=200 $\mu m$)</td>
<td>1314.9</td>
</tr>
<tr>
<td>No deconvolution</td>
<td></td>
</tr>
<tr>
<td>Method 1 (slit width=200 $\mu m$)</td>
<td>65.0</td>
</tr>
<tr>
<td>With deconvolution</td>
<td></td>
</tr>
<tr>
<td>Method 1 (slit width ~10 $\mu m$)</td>
<td>59.9</td>
</tr>
<tr>
<td>Method 3</td>
<td>71.3</td>
</tr>
<tr>
<td>Method 3 (with improved data processing)</td>
<td>63.3</td>
</tr>
</tbody>
</table>

**Difficulties:**

- **Method 1:** Precise slit fabrication and alignment in the radiation; or intense radioactive source;
- **Method 2:** Complex auxiliary equipment;
- **Method 3:** Precise edge fabrication and collimated X-ray source needed;

*Ref: Chinese Physics C, Vol. 36, No. 3, Page 228-234*
But, what we have:

1. A slit with adjustable width, but the width can NOT be measured precisely.

2. A $^{55}$Fe with low Activity ($5 \times 10^4$ Bq), Surface source, $s \sim 0.78$cm$^2$

3. Very limited in electronics (16 channels);

It is natural to use method 1. But...
A practical method

But, the slit width can NOT be measured precisely.

Luckily:

\[
\sigma_{tot}^2 = \sigma_{GEM}^2 + c_1 \sigma_{Geometry}^2
\]

when \( w \sim \sigma_{GEM} \)

\[
\sigma_{Geometry} = c_2 w
\]

\[
\sigma_{tot}^2 = \sigma_{GEM}^2 + c_0 w^2
\]
A practical method (Continue)

$^{55}\text{Fe (Surface source)}$

Collimator

Readout strip

Base board

$n = c_2 w^2$

therein, $n$ means the counting rate

$\sigma_{tot}^2 = \sigma_{GEM}^2 + c_0 n$
Simulation Results (1-D)

Simulation conditions:
GEM spatial resolution: 70μm;
Slit thickness (mm): 3, 4, 5, 6, 7;
Slit width (μm): 20, 30... 100;
The angle (slit with readout strip, deg): 1.0, 0.5, 0.25, 0.125;
Experimental result

- 1-Dimension Readout
- Readout strip: D=200um 400um;
1, (a): get the events from main peak (mean $\pm 2\sigma$), covered with the red line;
2, (b): calculate the position by the centre-of-gravity method; subtract the background (under the blue dotted line), then fit it with gaus-func;
3, $\text{ratio} = \frac{S}{T}$, Therein: $S$-the area of main peak; $T$-the testing time
The Test result (1-D, 200μm readout strip)

(1), When \( w \approx 40, 50, 60, 70, 80 \, \mu \text{m} \), with the ratio as the x axis, with the \( \sigma^2_{\text{tot}} \) as the y axis.

(2), Fit the graph with line-func, we can get

\[
\sigma^2_{\text{tot}} = 3.0 \times 10^3 + 5.0 \times 10^2 n
\]

\[\Delta n = \sqrt{\frac{n}{T}};\]

\[
\Delta(\sigma^2_{\text{tot}}) = \Delta(\sigma^2_{\text{fit}}) + \Delta(\sigma^2_{\text{non-parallel}})
\]

\[\sigma_{\text{GEM}} = 56 \pm 15 \, \mu \text{m}\]
The Test result (1-D, 400μm readout strip)

\[ k = (5.9 \pm 0.7) \times 10^2 \]
\[ \sigma_g^2 = (1.7 \pm 6.5) \times 10^3 \]

\[ \sigma_{GEM} = 41 \pm 79\mu m \]
Cluster size of signal of main peak

<table>
<thead>
<tr>
<th>Ar</th>
<th>75</th>
<th>80</th>
<th>85</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compare of cluster of different strips</th>
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<th>Compare of cluster of different strips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries: 775584</td>
<td>Entries: 103592</td>
<td>Entries: 103213</td>
</tr>
<tr>
<td>Mean: 5.441</td>
<td>Mean: 2.59</td>
<td>Mean: 2.87</td>
</tr>
<tr>
<td>RMS: 0.539</td>
<td>RMS: 0.5139</td>
<td>RMS: 0.4511</td>
</tr>
</tbody>
</table>

Legend: 400 um, 200 um
Near Future Plans

- Further test:
  - Position resolution for 2-D detector;
  - Simulation with Garfield;
  - Time resolution;

- A prototype for SoLID

- APV electronics (1024)
  Asic-based electronics

- Develop the new DAQ
Summary

◆ GEM-Detector prototype test is ongoing in our lab;
◆ A new method to evaluate the GEM spatial resolution:
  1) For 1-D and $W_{\text{readout}}=200\mu m$, $\sigma_{\text{gem}}=56\pm15\mu m(1\sigma)$;
  2) Global performance tested for the prototype;
     Consistent with literature report
◆ Next step is to build a prototype for SoLID with new electronics and DAQ;

Looking forward to the arrival of the GEM foil and the APV electronics

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Thanks!