Track Resolution Measurements for a TPC with GEM Readout

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Dean Karlen$^{1,2}$, P. Poffenberger$^1$, G. Rosenbaum$^1$, R. Carnegie$^3$, M. Dixit$^{3,2}$, H. Mes$^3$, K. Sachs$^3$, J.-P. Martin$^4$

$^1$University of Victoria; $^2$TRIUMF; $^3$Carleton University; $^4$University of Montreal
TPCs with MPGD readout

- MPGDs offer significant advantages for TPC readout
  - Reduced $\mathbf{E} \times \mathbf{B} \Rightarrow$ better resolution
  - Faster signals $\Rightarrow$ better $z$ separation
  - Narrower signals $\Rightarrow$ better $r$-$\phi$ separation
  - Particularly well suited for a LC

- Narrow signals present a new challenge for large scale TPCs:
  - How to accurately determine the centroid of the narrow charge distribution with a reasonable number of channels
TPCs with GEM readout

- GEMs offer a solution:
  - Use gas diffusion between the GEMs to spread the charge over a larger region
    - Since the defocusing occurs during and after the gain stage, the track resolution is not sacrificed
    - For the best two-particle separation, defocus as little as required

```
\begin{center}
\begin{tikzpicture}
\draw[thick,->] (0,0) -- (3,0) node[midway,above] {Drift volume (Low transverse diffusion)};
\draw[thick] (0,0) -- (0,2) node[midway,left] {E \parallel B};
\draw[thick] (0,0) -- (0,-2) node[midway,left] {High trans. diff.};
\draw[thick] (0,0) -- (5,0) node[midway,right] {Pads};
\draw[thick] (0,0) -- (-2,0) node[midway,left] {GEM1};
\draw[thick] (0,0) -- (2,0) node[midway,right] {GEM2};
\draw[thick] (0,0) -- (2.5,0) node[midway,above] {2 mm};
\draw[thick] (0,0) -- (5.5,0) node[midway,above] {2500 mm};
\end{tikzpicture}
\end{center}
```
Example: P5

Transverse Diffusion (cm/\sqrt{cm}) vs. E (kV/cm)

- Drift
  - B=0.05T
  - B=1.0T
  - B=5.0T

- Transfer

- Induction

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Limited defocusing

- Minimum defocusing required to retain track resolution:
  \[ \sigma \approx \frac{1}{4} \text{pad width} \]

- Charge sharing typically over 2 pads:
  - Important to account for non-linear sharing
  - Track fitting is performed by maximum likelihood:
    \[ x_0, \phi_0, \sigma, r^{-1} \]
Demonstrations of defocusing

- Two small TPCs with GEM readout for cosmic ray tests:
  - TPC1 (Carleton University)
    - 15 cm drift
    - Without magnetic field
    - 2mm × 6 mm pads
  - TPC2 (U. Victoria)
    - 30 cm drift
    - With magnetic field
    - 2mm × 7 mm pads
TPC1: no B field, P10 and ArCO₂ (90:10)

- ArCO₂ / short drift distances mimic high magnetic field operation

2mm × 6 mm pads
~ 100 µm resolution

Other results shown in MP2-3
TPC2: First GEM-TPC tracking in B fields

- TRIUMF tests (0 – 0.9 T)
Example events at ~ 25 cm drift

- **Gas: P10**
  - 0 Tesla: $\sigma = 2.3 \text{ mm}$
  - 0.45 Tesla: $\sigma = 1.2 \text{ mm}$
  - 0.9 Tesla: $\sigma = 0.8 \text{ mm}$
Tracking resolution (preliminary)

- Fit track to all but one row:
  - fix $\phi_0$, $1/r$, and $\sigma$, fit to one row alone
  - $x_0$ residual fit to Gaussian

![Resolution vs. Drift Distance](image)

- TDR spec.
  - goal

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Comparison with MC simulation

- Simple simulation of GEM operation
- Good agreement with data
- Preliminary results...
DESY tests (0 – 5.3 T)
Example events at ~ 25 cm drift

- Gas: P5

<table>
<thead>
<tr>
<th>B</th>
<th>0T</th>
<th>0.9T</th>
<th>2.5T</th>
<th>4.5T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
Tracking resolution (preliminary)

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<table>
<thead>
<tr>
<th>Resolution (mm)</th>
<th>Drift Time (50ns time bins)</th>
<th>B = 0</th>
<th>B = 0.9 T</th>
<th>B = 1.5 T</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 cm</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>30 cm</td>
<td></td>
<td></td>
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</tbody>
</table>
Preliminary results

- Tracking resolution $\leq 100 \ \mu m$ for all drift distances for $B \geq 1.5 \ T$
  - Further improvement for higher fields not yet realized...

- Defocusing values larger than expected
  - Maintain $\sigma \approx \frac{1}{4} w$

<table>
<thead>
<tr>
<th>$B(T)$</th>
<th>$\sigma_0$ (mm)</th>
<th>sim $\sigma_0$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.</td>
<td>1.14</td>
<td>0.21</td>
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<tr>
<td>0.9</td>
<td>0.66</td>
<td>0.43</td>
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<tr>
<td>1.5</td>
<td>0.60</td>
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<tr>
<td>2.5</td>
<td>0.52</td>
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<tr>
<td>3.5</td>
<td>0.53</td>
<td>0.38</td>
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<tr>
<td>4.5</td>
<td>0.55</td>
<td>0.36</td>
</tr>
<tr>
<td>5.3</td>
<td>0.51</td>
<td>-</td>
</tr>
</tbody>
</table>
Summary

- MPGD readout for TPCs offers several advantages over wire/pad readout
- Limited defocusing during/after amplification
  \[ \sigma \approx \frac{1}{4} \text{ pad width} \]
  - Achievable with diffusion in GEM gaps
  - Preserves good tracking resolution and two-particle separation
Acknowledgements

- Support staff at Carleton University and University of Victoria
- LBNL – STAR electronics
- TRIUMF laboratory – 1 T magnet setup
- DESY group – 5 T magnet setup and operational support (P. Wienemann, F. Sefkow, T. Lux, ...)