MPGD based tracking and PID detectors

Prakhar Garg
Department of Physics and Astronomy
Stony Brok University, NY, USA

DAE-BRNS HIGH ENERGY PHYSICS SYMPOSIUM 2020
Accelerator Based High Energy Experiments

Heavy-Ion Collisions

High Energy Particle Physics

Scattering Experiments

Deep Inelastic Scattering
Typical Requirements for Detectors

- Large Kinematic Acceptance
- Low Material (low radiation length)
- Fast Detection (High Rate)
- Magnetic Field Compatibility
- Eco Friendly Gases (for gaseous detectors)
- Good Particle Identification Capabilities (over a wide range of momentum)
- Good Resolution (Position, Momentum, Energy etc.)
MPGD’s: Versatile Technology

- Single Stage
- Multi Stage
- Hybrids (different MPGD)
- Thin Drift
- Large Drift
- Pads
- ZigZags
- Strips
- Conversion outside the gas
- Conversion in gas

- Pure Noble Gas
- Pure Quencher
- Very High Gain
- Low Gain
- No Gain
- Radio-Pure
- Low Material Budget
- Charge readout
- Light readout
- Low Fields
- High Fields
- High Rate
- Low Rate
- Self Triggering

- Charged Particles
- Photons
- Neutrons
- Calorimeter
- Tracking
- TPC
- Small
- Large
- Planar
- Spherical
- Semi-Cylindrical
- Cylindrical

- High Pressure
- Ambient Pressure
- Low Pressure
- Low Fields
- High Fields
- Low Material Budget
- High Fields
- Low Fields
- Self Triggering
- Radio-Pure
Gas Electron Multiplier (GEM)

F. Sauli, Nucl. Instr. and Meth. A386(1997) 531

“STANDARD” GEM

DOUBLE CONICAL “HOURGLASS”

IN MULTI-GEMS, THE CHARGE SPREADS BY DIFFUSION OVER MANY HOLES!
Micromegas (Micro MEsh Gaseous Structure) Detector


Involvement in different Experiments:

- COMPASS, Hybrid Pixel Micromegas @CERN, SPS
- CLAS12 projects (barrel, forward tracker, forward tagger) @JLAB, Hall B
- ASACUSA cylindrical tracker @CERN, AD
- LDRD Zigzag / EIC @BNL
- New Small Wheel for @CERN, ATLAS
- T2K, CAST, NBLM, FCC, ILC ...

High Rate Environment is challenging!!
Micromegas + GEM hybrid

Discharge Probability vs GAIN

VGEM = 280 V

Interesting for TPC IBF
**μRWELL Detector**

G. Bencivenni et al., 2015_JINST_10_P02008

The **μ-RWELL_PCB**, the core of the detector, is realized by coupling:

- “WELL patterned kapton foil” as “amplification stage”
- “resistive sheet” for the discharge suppression & current evacuation
- “Single resistive layer” (SL) < 100 kHz/cm²: resistivity ~100 MΩ/☐ (CMS-phase2 upgrade; SHIP)
- “Double resistive layer” (DL) > 1 MHz/cm²: A standard readout PCB

✓ gas gain ~104
✓ Intrinsically spark protected
✓ Rate capability ~1 MHz/cm² for m.i.p(with HR scheme)
✓ Space resolution < 60µm

High Rate Environment is challenging!!
## Comparison

<table>
<thead>
<tr>
<th></th>
<th>GEM</th>
<th>Micromegas</th>
<th>uRWELL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resol. &lt; 100 μm</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Low mass</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Large size capability</td>
<td>Yes, but Require spacers in active area</td>
<td>Yes, but Require pillars in active area</td>
<td>Yes, No need for pillars or spacers</td>
</tr>
<tr>
<td>Challenges for cylindrical device</td>
<td>Very high</td>
<td>high</td>
<td>minimal</td>
</tr>
<tr>
<td>Detector stability</td>
<td>Strong</td>
<td>strong</td>
<td>Strong</td>
</tr>
<tr>
<td>Production cost</td>
<td>high</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Proven technology? i.e. operated in HEP/NP</td>
<td>Yes</td>
<td>Yes</td>
<td>requires more R&amp;D</td>
</tr>
</tbody>
</table>
Particle Identification (PID) ~ Velocity

\[ p = m \gamma \beta \quad E = m \gamma \text{velocity(} \beta \text{)} \] measurement yields mass.

Direct measurement:
- Record signal time at multiple locations, calculate \( v \).
- “Fast” detector = low transit time spread (most easily achieved at small transit time)

Velocity-dependent interaction(s) with detector:
- Specific Ionization \( \frac{dE}{dx} \)
- Cherenkov Radiation: \( \cos \theta_c = 1/n\beta \)
  \( \theta_c \) measured wrt. track direction.
  Thus dependent upon deliverables from tracking

Transition Radiation and Bremsstrahlung: eID mechanisms

Prakhar Garg, 14 Dec 2020  
MPGD based tracking and PID Detectors
Roundup and reconstruct the trajectories of charged particles.

- High magnetic field parallel to the electric field is used to "bend" the trajectory of the particle on a spiral track due to the Lorenz force.

- Calculate the momentum of the particle from the knowledge of the curvature and the B-field.

TPC as an Example:
**ALICE TPC Upgrade at LHC**

**Old TPC: Wire chamber end plates**
- pT Resolution: $s/p < 3.5\%$ at $p = 50\text{GeV}/c$ and below $1\%$ at $p = 1\text{GeV}/c$.
- $dE/dx$ resolution: 5% (p-p) – 6.5% (central Pb-Pb) (158 max. samples)
- Event rate: 1 kHz Pb-Pb minimum bias

- Want to be able to record 50 kHz Pb-Pb collision rate and maintain the current performance

**BUT**

- Drift time for ionization electrons from central electrode to end plate is $O(100\ \mu s)$ Drift time for ions from end plate to central electrode is $O(160\ \text{ms})$

- Build up of positive ions in the drift volume $\rightarrow$ electric field distortion $\rightarrow$ distortion of the ionization electron tracks as they drift to the end plates

- Ions produced by charged particles traversing the detector are unavoidable – this is the signal

- Ions from the gain structure - typically a few thousand times the initial ionization - must be prevented from getting to main drift volume
sPHENIX TPC @ RHIC

Same as ALICE GEM scheme
Exploits ZigZag Pads for Readout

Unique Zig-Zag shape
Hadron Blind Detector @PHENIX

- PHENIX HBD optimized for 1e-vs-2e separation.
- 20 photoelectrons vs 40 photoelectrons
- Non-zero hadron response.

Limited by 1st Gap
Quintuple GEM based RICH

- Tested a Ring-Imaging Cherenkov detector prototype with:
  - CsI Photocathode on top GEM
  - Mirror in deep UV -> MgF2 coating
  - Single Photon Capability -> quintuple GEM stack
  - Radiator choice: CF4

- The windowless technology + wave-length-tuned mirror: Minimize the loss of photons

- Small Ref. Index: Particle identification (PID) reaching out to high momenta

Ref: IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 62, NO. 6, DECEMBER 2015
Electron Ion Collider @ RHIC

Exciting Time for MPGD community as well

More Details:
PLENARY-VII (16:40 to 19:20) Future facilities
Abhay Deshpande (18:00 to 18:40)
Interaction Region @EIC

RHIC yellow ring: EIC hadron ring
Add electron storage ring in existing tunnel
Possible IR location: IP6

+/- 4.5 meters for detectors
# Yellow Report Initiative for EIC

<table>
<thead>
<tr>
<th>η</th>
<th>ϒ</th>
<th>Nomenclature</th>
<th>Tracking</th>
<th>Electrons and Photons</th>
<th>n/p/p</th>
<th>HCAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Forward Detector</td>
<td>low Q2 tagger</td>
<td>Reduced Performance</td>
<td>50%/4/10%</td>
<td>0.5-100MeV</td>
</tr>
<tr>
<td>-0.5 to 0.5</td>
<td>0.5 to 1.0</td>
<td>Central Detector</td>
<td>Barrel</td>
<td>-0.4 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-1.0 to -0.5</td>
<td>0.0 to 0.5</td>
<td>Central Detector</td>
<td>Backward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-1.5 to -1.0</td>
<td>1.0 to 1.5</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-2.0 to -1.5</td>
<td>1.5 to 2.0</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-2.5 to -2.0</td>
<td>2.0 to 2.5</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-3.0 to -2.5</td>
<td>2.5 to 3.0</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-3.5 to -3.0</td>
<td>3.0 to 3.5</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-4.0 to -3.5</td>
<td>3.5 to 4.0</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>-4.5 to -4.0</td>
<td>4.0 to 4.5</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
<tr>
<td>&gt; 4.6</td>
<td>4.6</td>
<td>Forward Detector</td>
<td>Forward Detector</td>
<td>0.0 to 0.1</td>
<td>100 MeV</td>
<td>100% E/10% - 500 MeV</td>
</tr>
</tbody>
</table>

---

Prakhar Garg, 14 Dec 2020

MPGD based tracking and PID Detectors
MPGD’s are potential candidates in various region of EIC Detector

A lot of upcoming proposals like ILC, FCC may have place for MPGD’S

Still a lot to uncover in MPGD’S R&D: Active community in RD51 and ERD6

Thanks for your Patience