GEM Simulation Studies

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Overview of activities

- Hole asymmetry or double-mask vs. single-mask foils
  - Gain study of different hole geometry (data and simulation)

- Variation of electric fields
  - Drift, transfer, induction fields

- Long standing issue of lower gain in simulation
  - Investigations on microscopic simulation step

→ Discuss studies with a broader audience
CMS GEM foil design

- Kapton foil as bulk material (50 um)
- Copper cladded on both sides (5 um)
- Foil perforated with hexagonal pattern of holes (pitch of 140 um)
- Double semi-conical holes: standard dimensions 70/50/70 um (depends on etching procedure)

Taken from F. Sauli, “GEM: A new concept for electron amplification in gas detectors”
Triple-GEM simulation

- Triple-GEM detector
- Spacing of 3/1/2/1 mm
- Gas mixture: Ar/CO2 (70/30)
- Nominal voltages for CMS GE1/1 configuration shown

- Electron avalanche in triple-GEM detector
- Effective gas gain defined as factor between P+S electrons and electrons reaching the readout

Taken from CERN-LHCC-2015-012
Simulation workflow

Geometry, materials, voltages

Ansys 16.1 (mesh of nodes with electric field)

MagBoltz (electron transport) \[\rightarrow\] Garfield++ \[\rightarrow\] HEED (ionization of incident particles)

Result
Hole asymmetry studies or double-mask vs. single-mask

- Hole asymmetry can be introduced by different etching procedures (DM/SM)
- Typical hole geometries
  - SM Orientation A
  - SM Orientation B
  - DM: 70/50/70 µm
- What is influence on effective gas gain?

Taken from CERN-THESIS-2016-041 (J. Merlin)
Hole asymmetry studies or double-mask vs. single-mask

- Studies performed by Jeremie M. et al.
- **Outcome:** higher gain for single-mask compared to double-mask
- Not compatible with simulation results

Taken from CERN-THESIS-2016-041 (J. Merlin)
Hole asymmetry studies or double-mask vs. single-mask

- Studies of influence of hole asymmetry on gas gain ongoing in CMS GEM group
- Provide simulations and measurements
Gas gain measurements

• Experience with gas gain measurements
  • GE1/1 mass production, prototypes, 10x10 chambers
• We have ordered 3 sets of GEM foils for our 10x10 chamber from TECHTRA (specs of 3 um on hole dimensions)
  • SM with 70/53/85 um
  • DM with 70/50/70 um
  • DM with 70/50/85 um
Discrepancy between gain in simulation and measurements

- Well-known feature that simulations give less gas gain than observed in measurements.
- Investigating microscopic simulation step
Time Step in Garfield

Initial point: $t_0, x_0$

$\Delta t$ step is diced according to collision rate

End point: $t_1, x_1$

<table>
<thead>
<tr>
<th>Parameter of simulation step</th>
<th>Typical values</th>
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<tbody>
<tr>
<td>Time step $\Delta t$</td>
<td>10 ps</td>
</tr>
<tr>
<td>Distance step ($v_D = 5 \text{ cm/\mu s}$)</td>
<td>5 nm</td>
</tr>
<tr>
<td>Variation of E-Field on that scale (in GEM hole)</td>
<td>5 V/cm (very small)</td>
</tr>
</tbody>
</table>

Note: values are typical for drift fields, not for higher electric fields (in GEM hole)
Time Step in Garfield

Initial point: $t_0, x_0$

$\Delta t$ step is diced according to collision rate

End point: $t_1, x_1$

Energy is calculated based on E-Field at initial point

Conclusions:

• Distance step in simulation $\ll$ mean free path
• In code, E-Field is constant for one simulation step
  • Good approximation even inside GEM hole (large variations on small scale)
• Is it good enough though? $\sim 5\%$ error propagates exponentially to absolute gas gain value

Energy is calculated based on E-Field at initial point
Distribution of time step in Garfield

Time step “manually” scaled with factor 0.5
Influence of time step on gas gain

- Smaller time step -> lower gain; larger time step -> higher gain
- First and preliminary comparison of absolute numbers, dependency (slope of exponential) on HV not really matching, more investigations needed…
Summary

• Gained experience of Garfield++ simulations with single-GEM and triple-GEM configurations
• Studies on hole asymmetry ongoing, results will be ready soon, comparison with lab measurements
• Microscopic simulation step investigated
  • Large dependence of gain on time step observed
Backup
Results from other studies

Variations of VDrift

- Triple-layer GEM simulation

Comparison: Lab vs. Garfield

- Compare measurements with simulations
- In best case, both sides can benefit
- First study: Comparison of gas gain for different Ar/CO2 mixtures as a function of HV

Points: Data taken with CMS GenV prototype GEM detector
Lines: Exponential fit of Garfield simulations
Details on time step variations

Scale time step with factors [0.9,1.0,1.1,1.2] here

• Source code Garfield+++
  • Class: AvalancheMicroscopic
  • Function: TransportElectron()