A better understanding of the gas gain in GEM detectors

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For **Gas Electron Multiplier** (GEM) detectors a quantitative understanding of the gas gain is still lacking.

Gas gain = the multiplication factor between initial and final amount of electrons.

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GEM DETECTORS:

Effective gas gain = the multiplication factor between initial and final amount of electrons which reach the anode.

- Ions on surface of the GEM
- Charges on the polyimide
- Electrons on the bottom of the GEM
- Electrons on the anode
We have explored this discrepancy between experiment and theory in the following ways:

• Surface potential calculations
• Electron transport algorithm
• Secondary electron emission
• Asymmetries in GEM hole geometry
Besides the accumulation of avalanche charge on the GEM we calculate the surface potential using the surface resistivity of polyimide.

Units: $\Omega/\square$
Modeling the hole as a double cone and dividing it into strips:

\[ R \sim \frac{1}{n} \]
SURFACE POTENTIAL CALCULATIONS:

Taking the width of the strips → 0 we get an analytic solution:
For each free time electrons are traced on a vacuum trajectory, according to the local $\vec{E}$-field of the initial position of the particle:

$$\vec{E}(\vec{r},t) = \vec{E}(\vec{r}_0) = \text{Constant}$$

This local field approximation in addition to the null-collision technique determines collision rate.
The Runge-Kutta-Nyström method was used to improve the accuracy of the transport algorithm.

This will allow to accurately simulate low pressure gas gain detectors ($P << 1\ \text{atm}$).
SECUNDARY ELECTRON EMISSION:

In the simulations the effect of secondary electron emissions from the polyimide surface has been ignored.

The minimum energy required to release charges from impact is $\sim 29\ eV$.

$\rightarrow$ Neglectable effect!
Asymmetries in the geometry of a GEM can occur due to the etching processes.
EFFECTS OF HOLE GEOMETRY:

Two main production techniques are used.

- Double mask
- Single mask

The gas gain is dependent on the orientation of the GEM.
Different types of hole geometries have been studied:
EFFECTS OF HOLE GEOMETRY:

$E_{\text{drift}} = 2 \text{ kV/cm}$, $E_{\text{induction}} = 3 \text{ kV/cm}$

$\text{Ar-CO}_2 (70-30)$

$r_p = 0.56$
EFFECTS OF HOLE GEOMETRY:

$E_{\text{drift}} = 2 \text{ kV/cm}$,

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Ar-CO$_2$ (70-30)

$r_p = 0.56$

Gas gain

Geometry number

$50 \mu m$

$25 \mu m$

$0 \mu m$
EFFECTS OF HOLE GEOMETRY:

$E_{\text{drift}} = 2 \, \text{kV/cm}$,
$E_{\text{induction}} = 3 \, \text{kV/cm}$
$\text{Ar-CO}_2 (70-30)$
$r_p = 0.56$
During the project the following possibilities have been explored:

• Surface potential calculations
• Electron transport algorithm
• Secondary electron emission
• Asymmetries in GEM hole geometry

→ No solution to the discrepancy has been found!
Feel free to ask questions!


