A better understanding of the gas gain in GEM detectors

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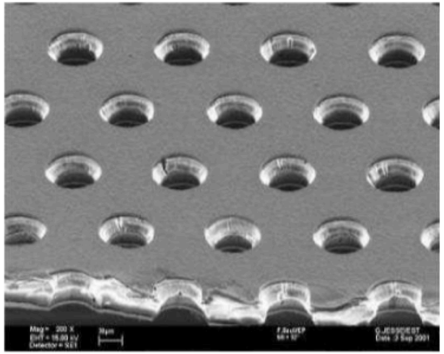
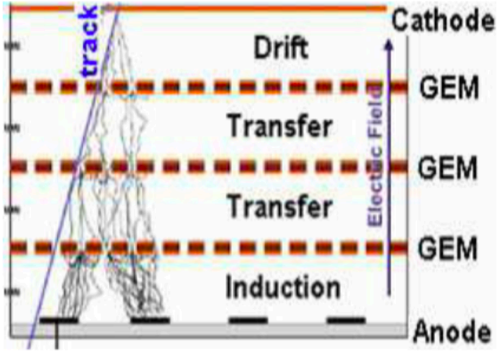
GEM DETECTOS:

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





[1]

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

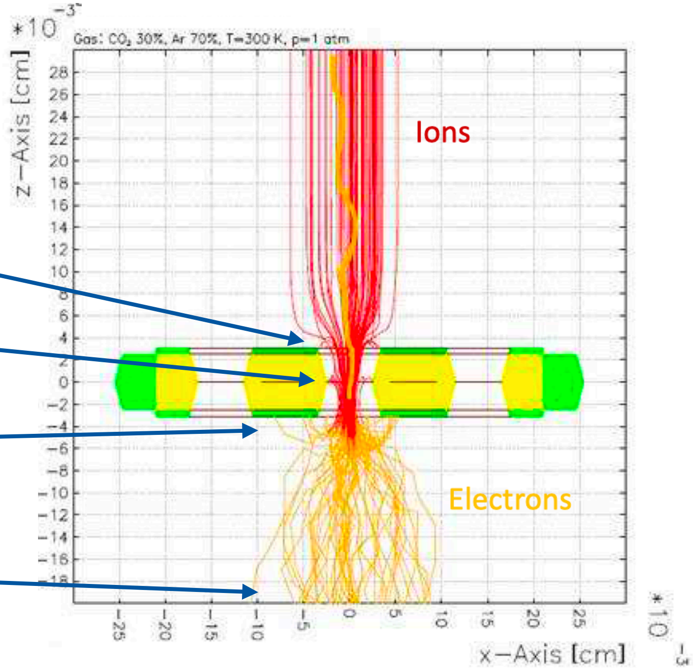
GEM DETECTOS:

Ions on surface of the GEM

Charges on the polyimide

Electrons on the bottom of the GEM

Electrons on the anode



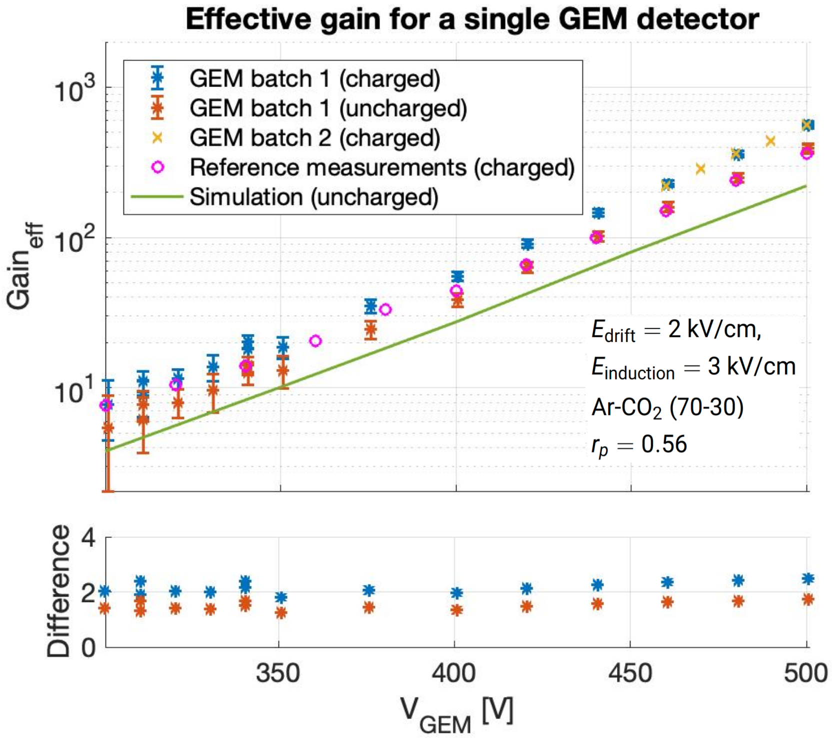
[2]

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

AVENUES OF EXPLORATION:

We have explored this discrepancy between experiment and theory in the following ways:

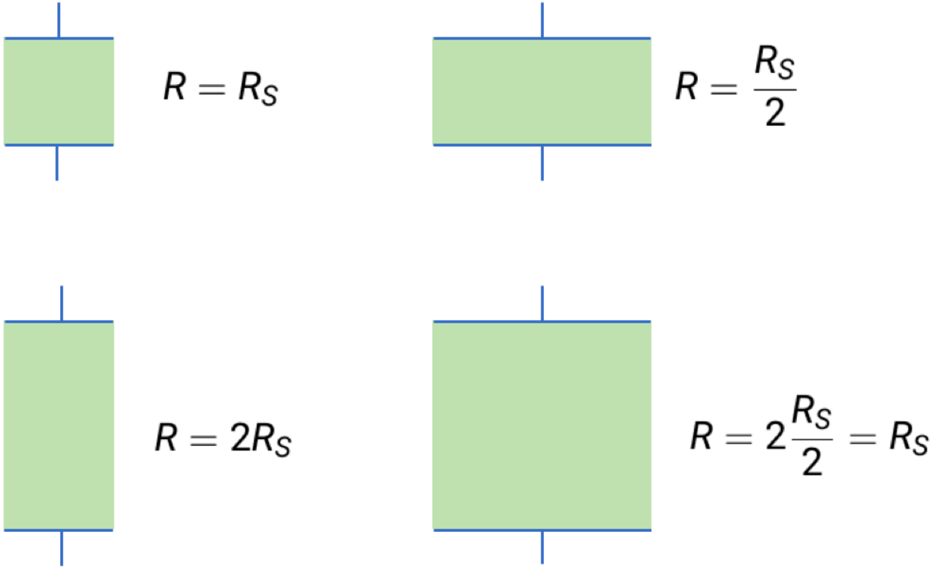
- Surface potential calculations
- Electron transport algorithm
- Secondary electron emission
- Asymmetries in GEM hole geometry



SURFACE POTENTIAL CALCULATIONS:

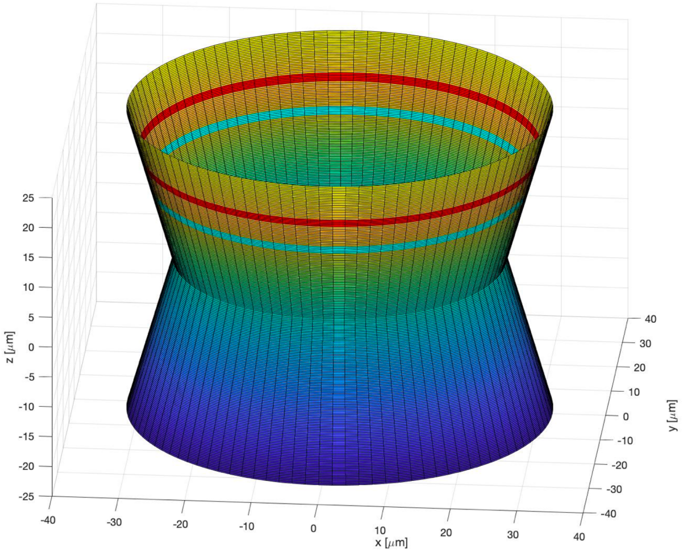
Besides the accumulation of avalanche charge on the GEM we calculate the surface potential using the surface resistivity of polyimide.

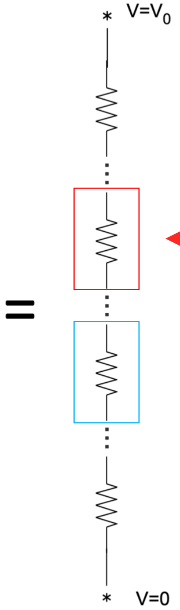
Units: $\Omega/\square$



SURFACE POTENTIAL CALCULATIONS:

Modeling the hole as a double cone and dividing it into strips:

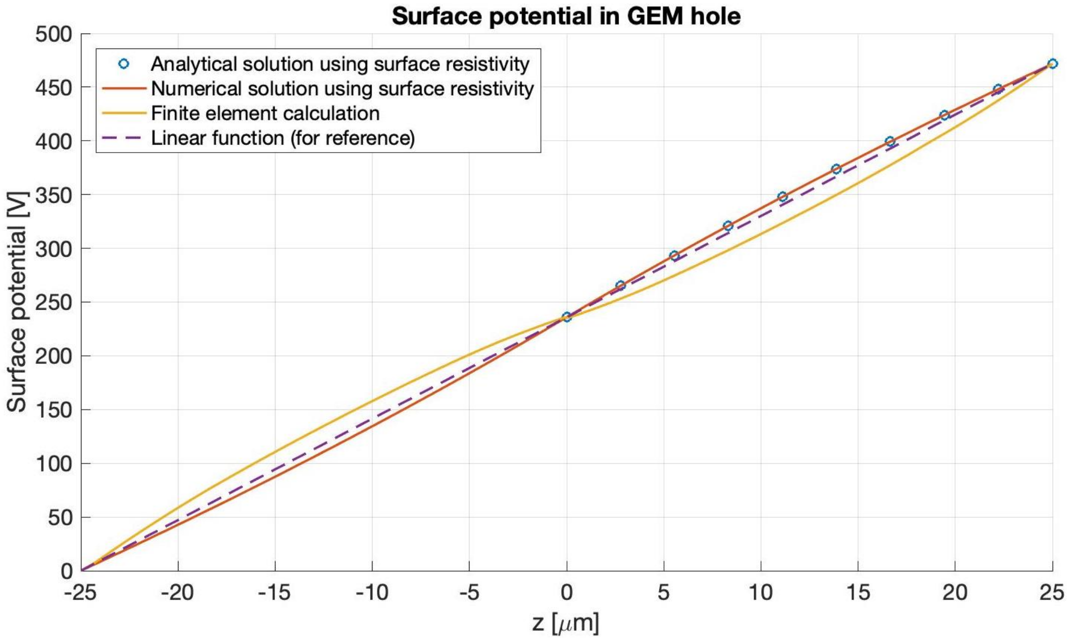




$$R \sim \frac{1}{n}$$

SURFACE POTENTIAL CALCULATIONS:

Taking the width of the strips $\rightarrow$ 0 we get an analytic solution:



ELECTRON TRANSPORT ALGORITHM:

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:

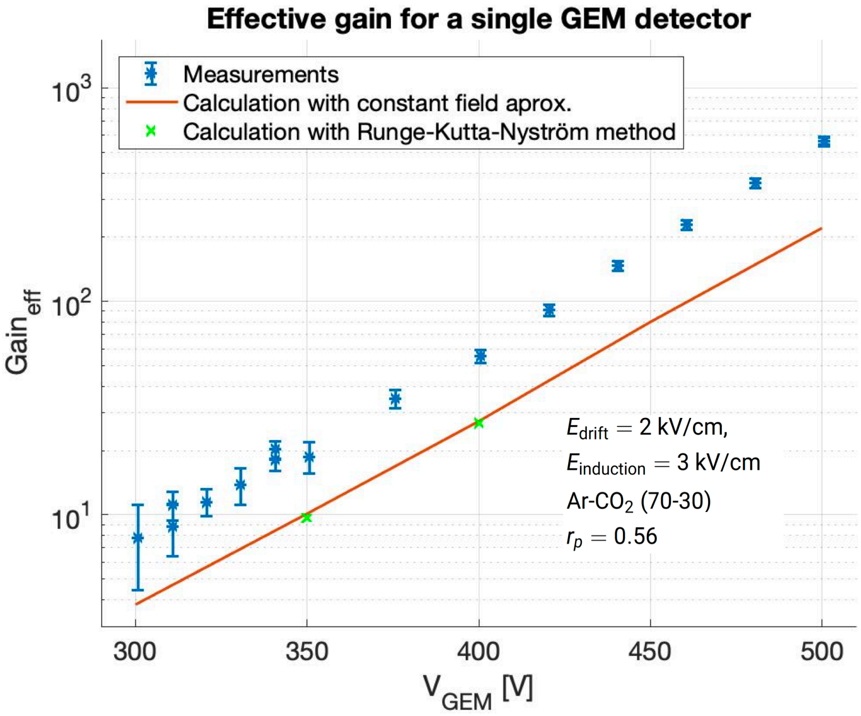
$$\vec{E}(\vec{r},\mathrm{t}) = \vec{E}(\vec{r}_0) = \mathrm{Constant}$$

This local field approximation in addition to the null-collision technique determines collision rate.

ELECTRON TRANSPORT ALGORITHM:

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 atm).

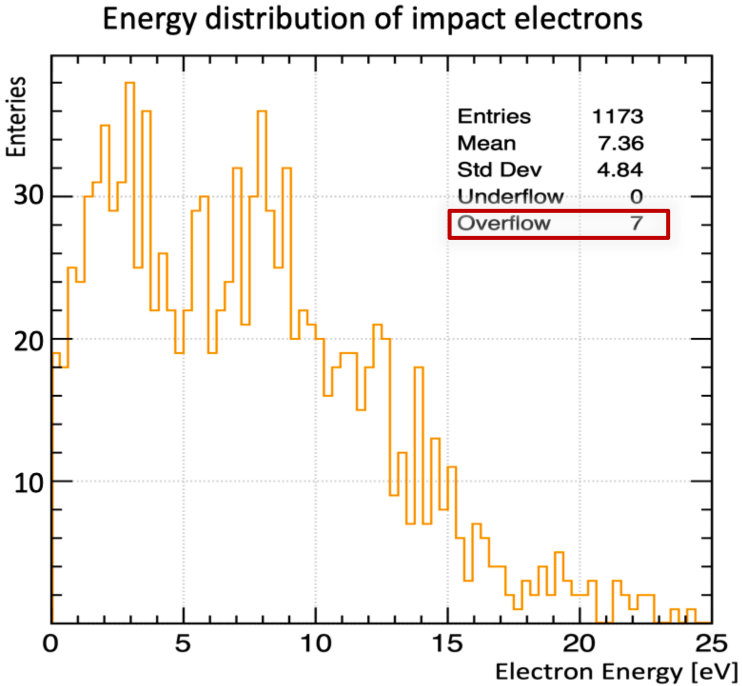


SECUNDARY ELECTRON EMISSION:

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

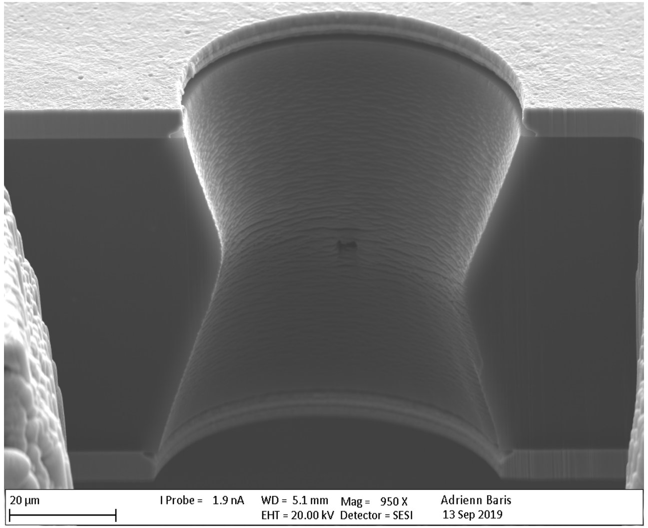
The minimum energy required to release charges from impact is ~ 29 eV.

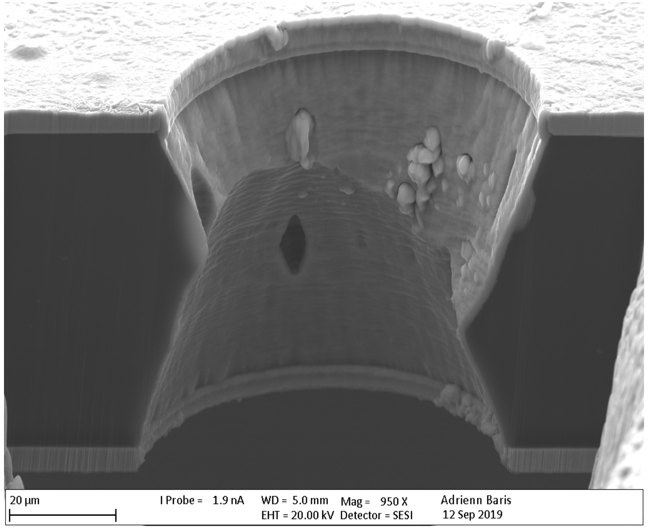
→ Neglectable effect!



EFFECTS OF HOLE GEOMETRY:

Asymmetries in the geometry of a GEM can occur due to the etching processes.



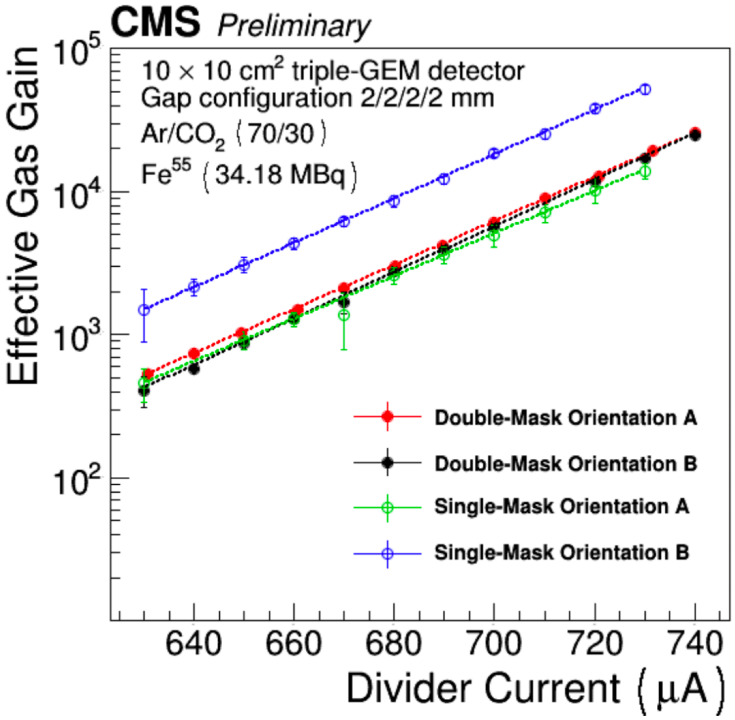


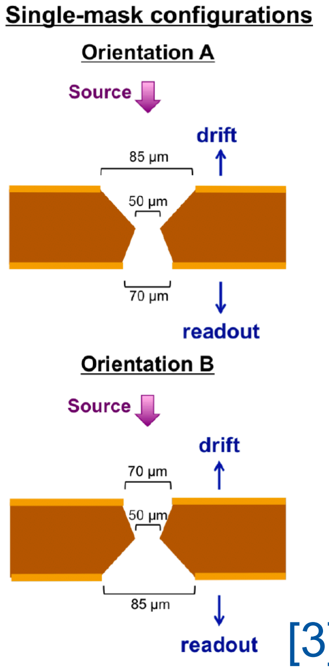
EFFECTS OF HOLE GEOMETRY:

Two main production techniques are used.

- Double mask
- Single mask

The gas gain is dependent on the orientation of the GEM.

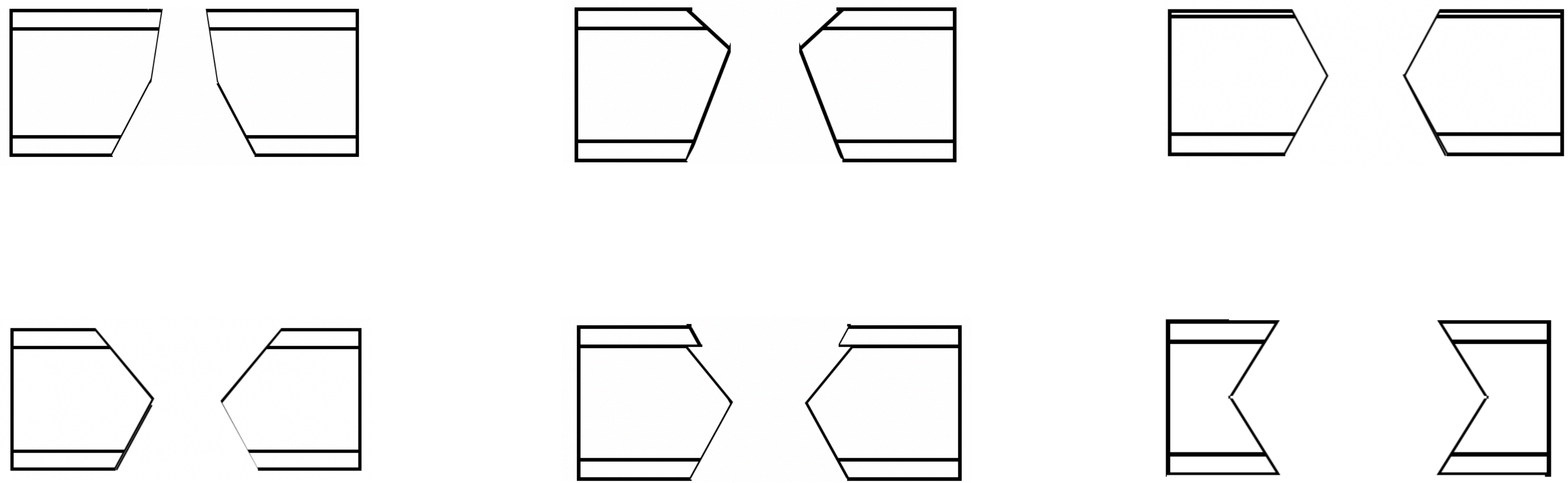




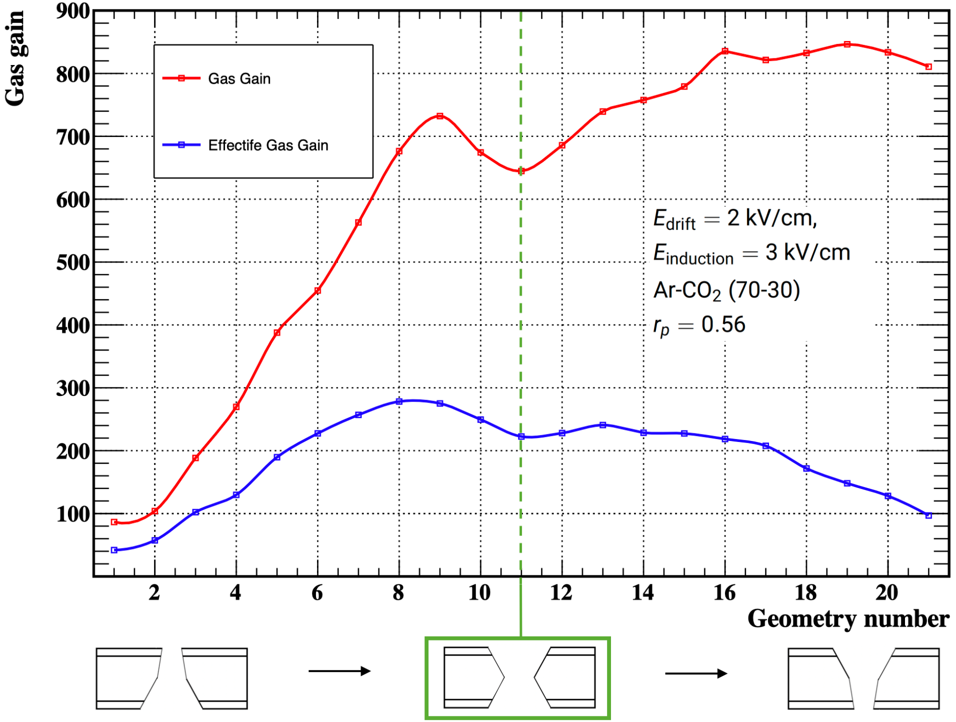
[3]

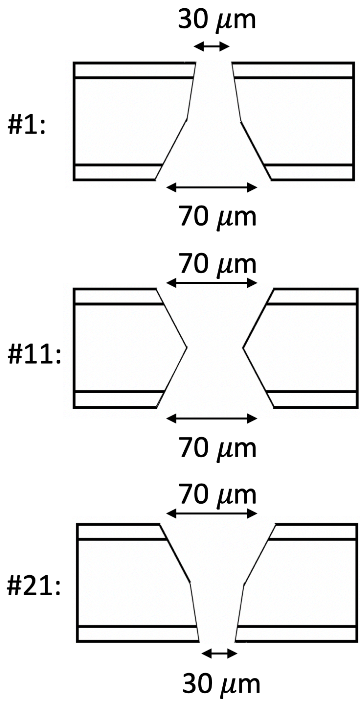
EFFECTS OF HOLE GEOMETRY:

Different types of hole geometries have been studied:

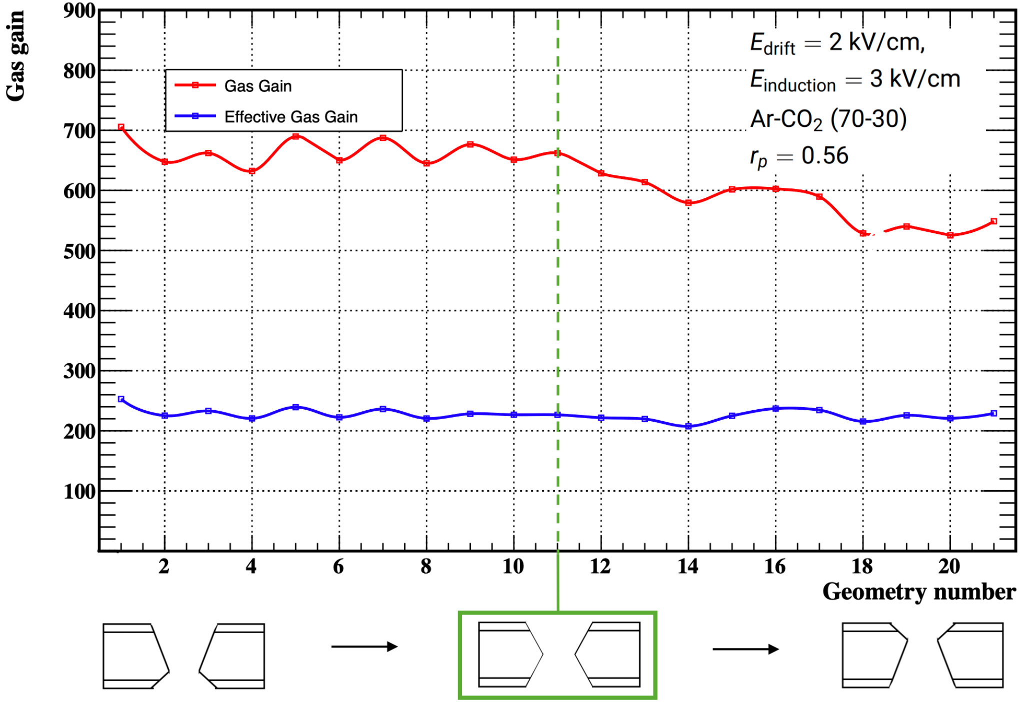


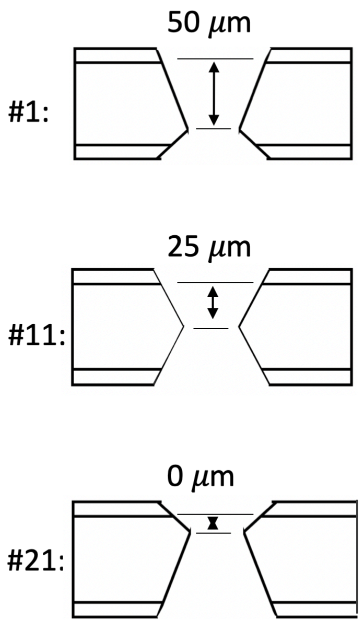
EFFECTS OF HOLE GEOMETRY:





EFFECTS OF HOLE GEOMETRY:





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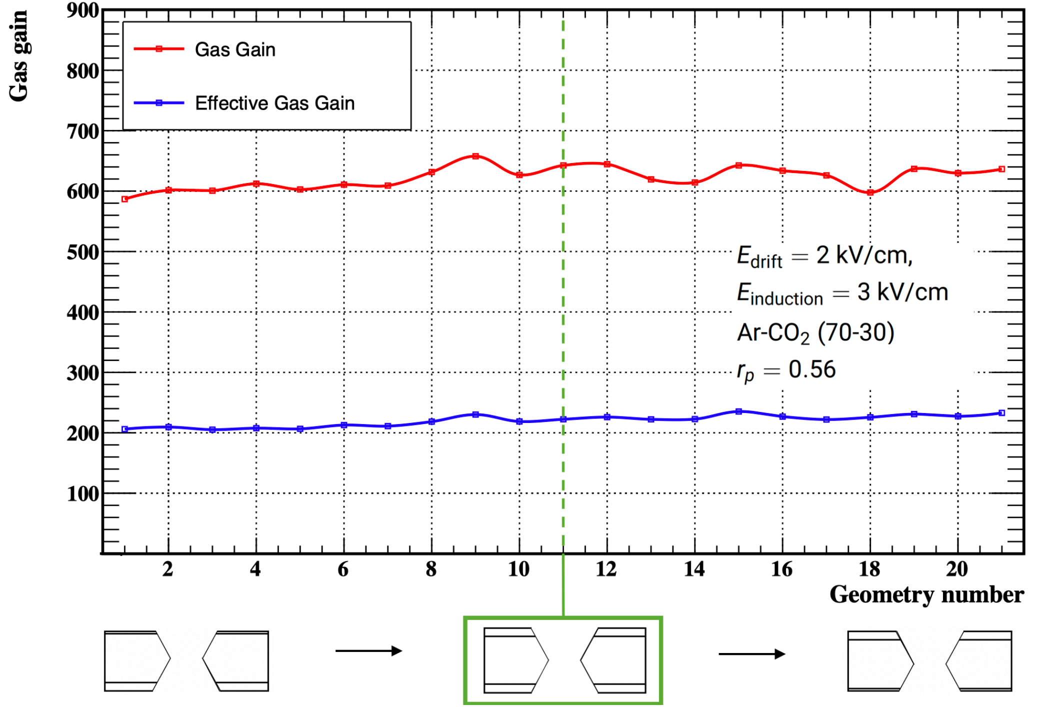

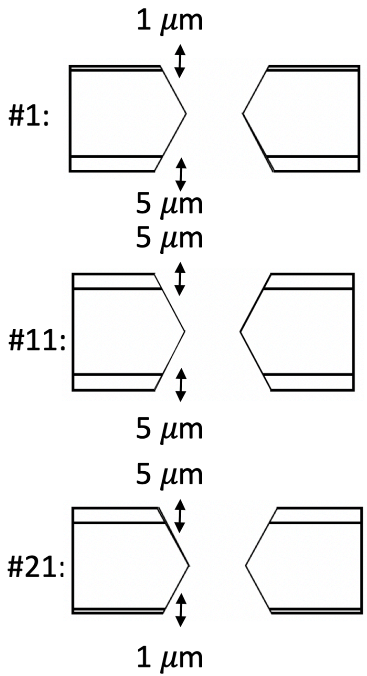

CONCLUSION:

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!

REFRENCES:

Feel free to ask questions!

[1] M. Alfonsi et al., CERN-LHCC-2008-011.

[2] G. Croci, Doctoral Thesis, University of Siena (2010)

[3] J. Merlin, Doctoral Thesis, University of Strasbourg (2016).

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