Numerical Investigation on Triple-GEM Detector

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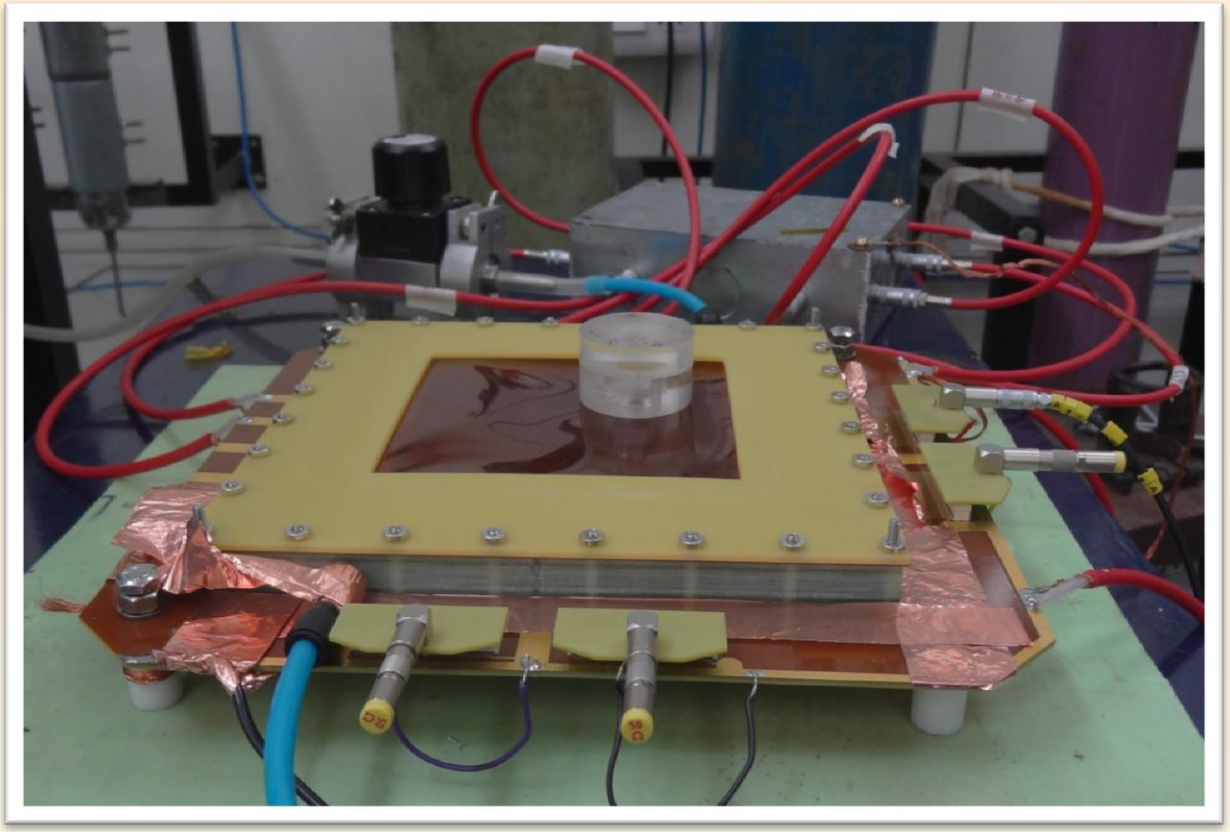
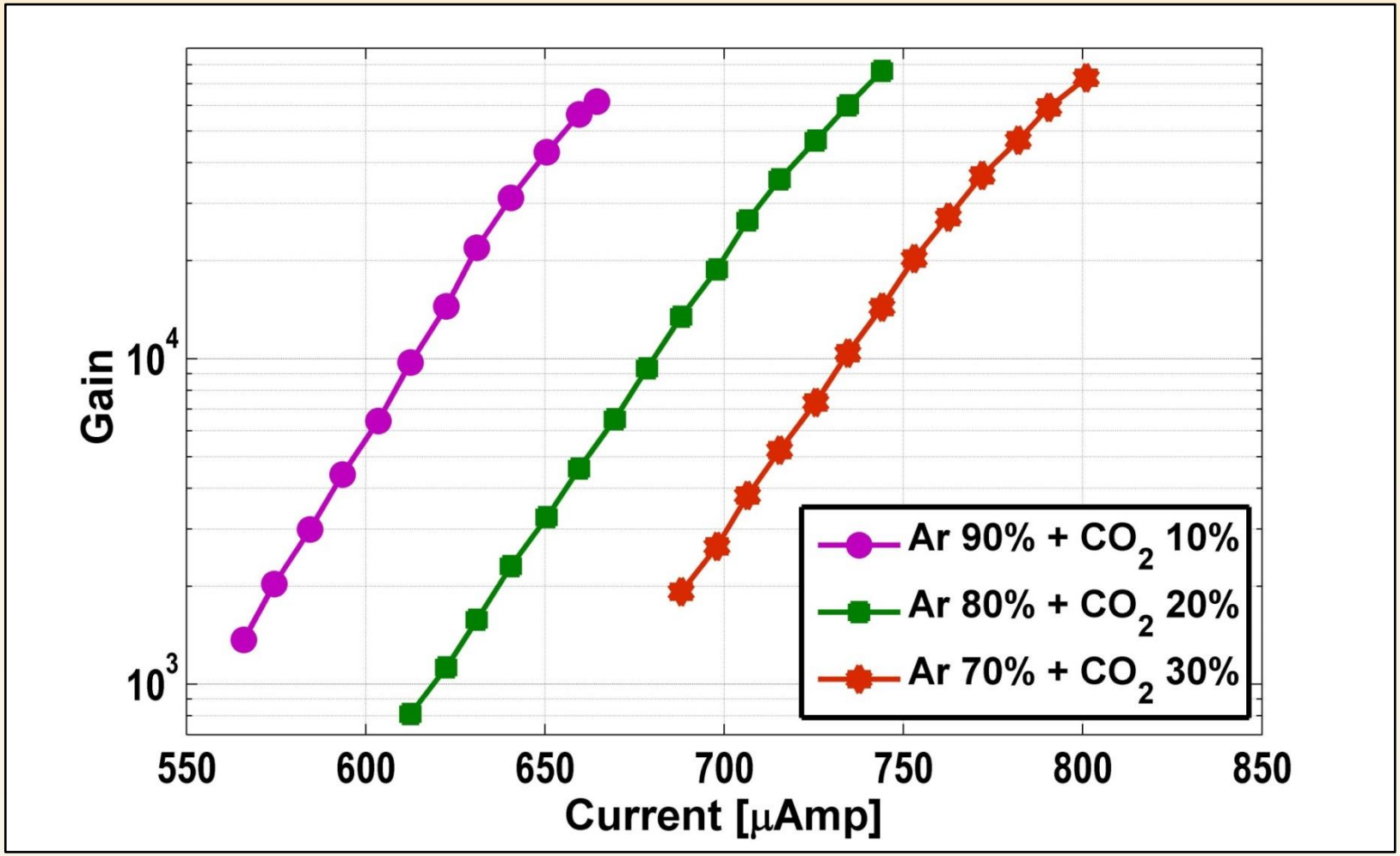
Triple-GEM Test

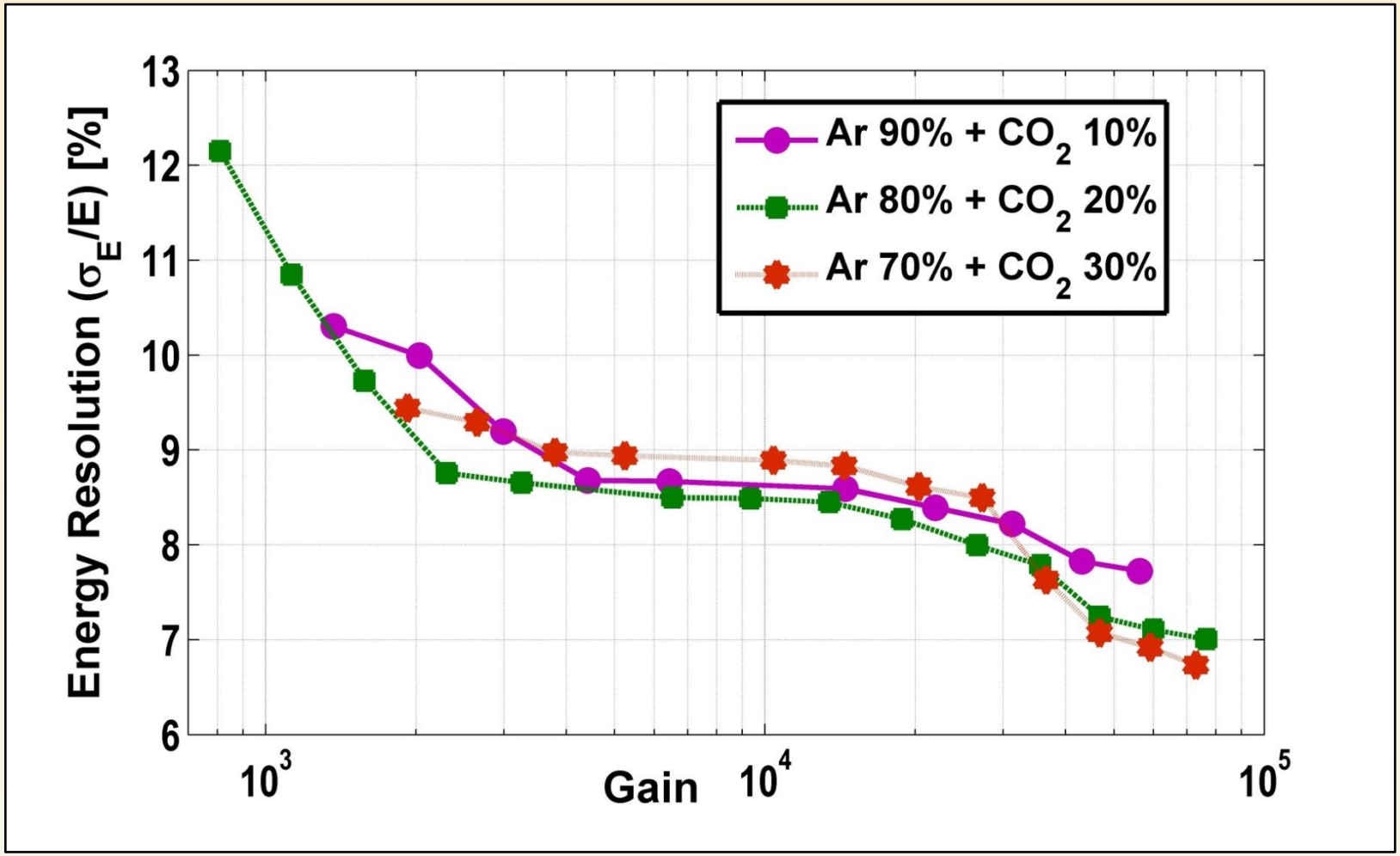


- Test done with ^{55}Fe source
- Gas mixture Ar/CO_2 (70:30/80:20/90:10) at STP

Gain Measurement



Energy Resolution Measurement



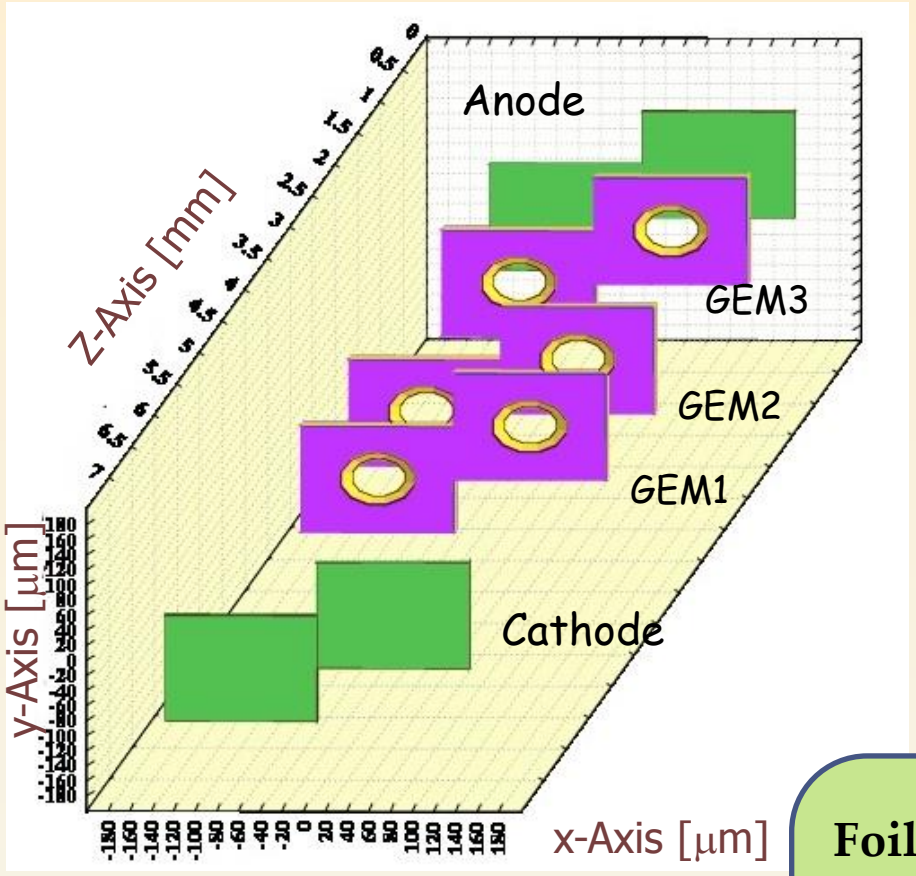
Numerical Simulation

Garfield Simulation Framework

- **(1) Ionization:** energy loss through ionization of a particle crossing the gas and production of clusters – **HEED**
- **(2) Transport and Amplification:** electron drift velocity and the longitudinal and transverse diffusion coefficients – **MAGBOLTZ**
- **(3) Detector Response:** Charge Induction using Reciprocity theorem (Shockley-Ramo's theorem), Particle drift, charge sharing (pad response function - PRF); Charge Collection - **GARFIELD**

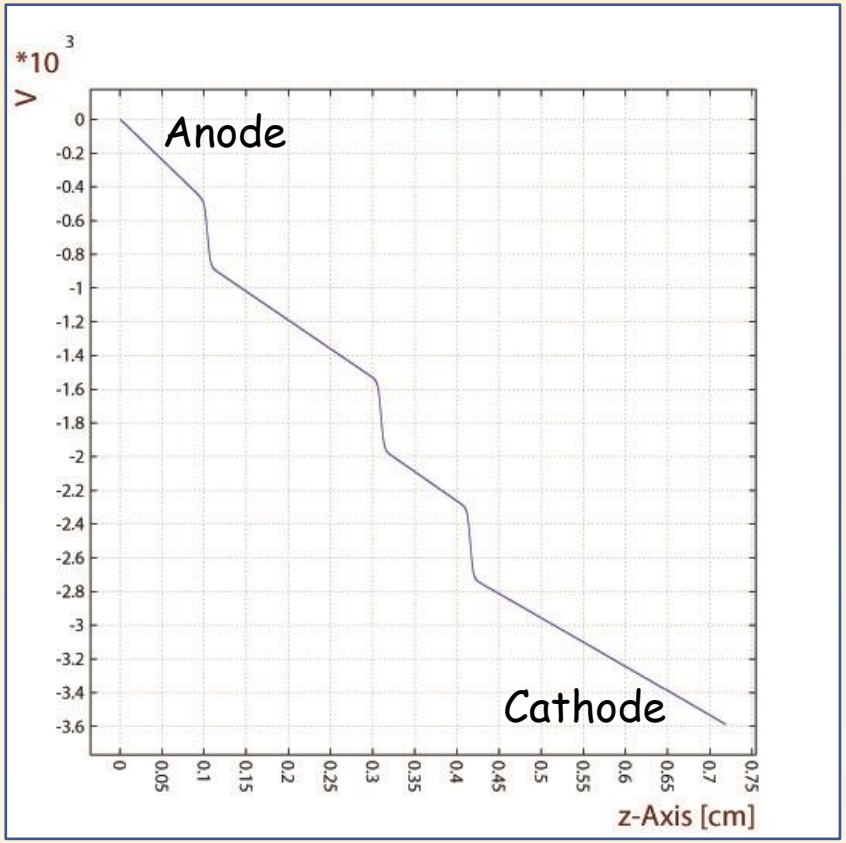
Field Solver: *neBEM* (nearly exact Boundary Element Method):

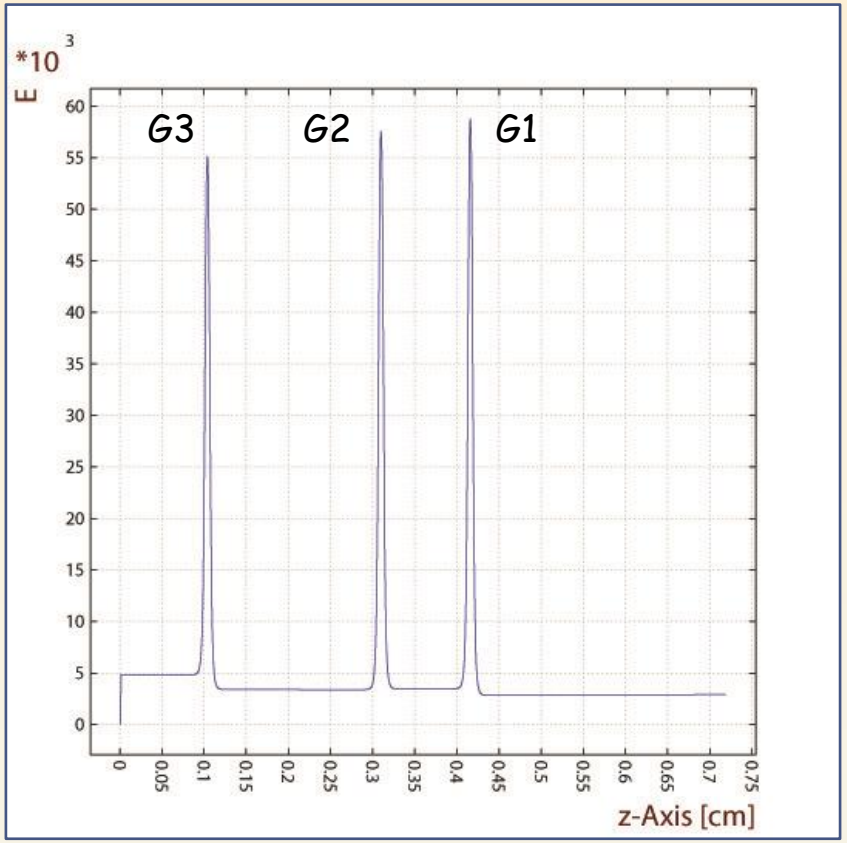
Triple-GEM Model



Foil thickness :	**50 µm**
Copper thickness :	**5 µm**
Hole dia (outer) :	**70 µm**
Hole dia (inner) :	**50 µm**
Hole pitch :	**140 µm (staggered)**
Gap configuration :	**3:1:2:1 (mm)**

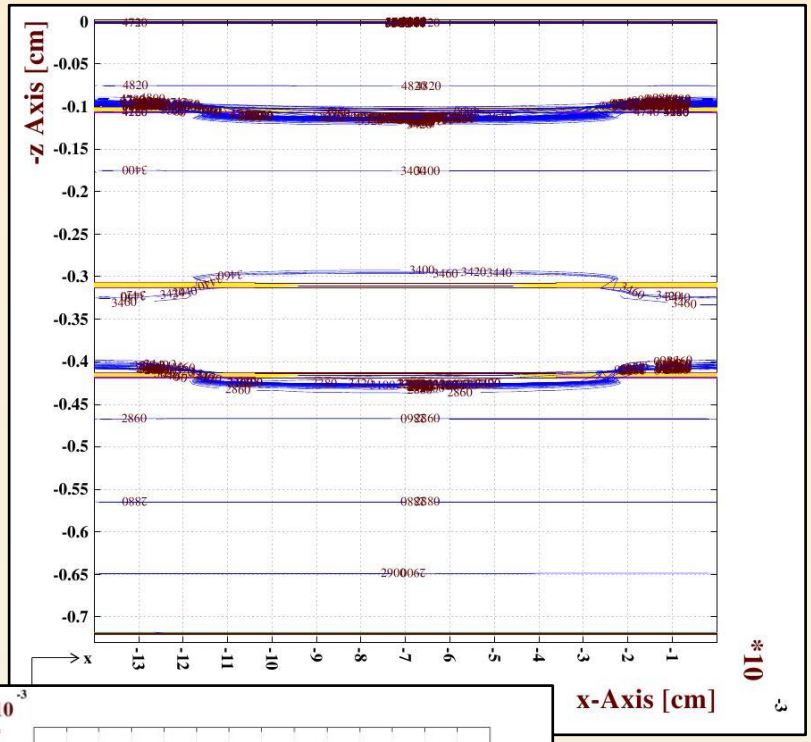
Axial Potential & Field Distributions

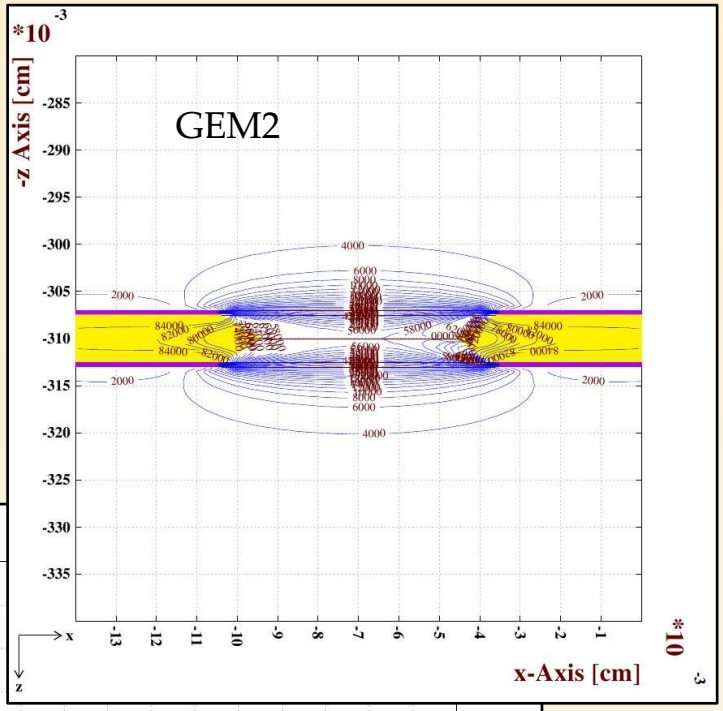


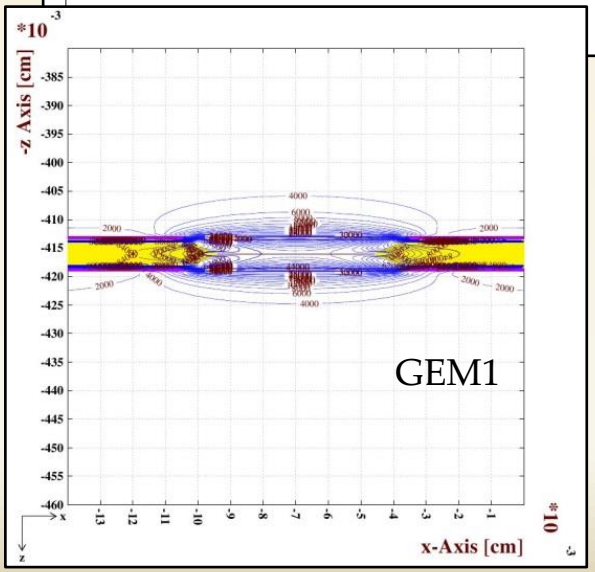


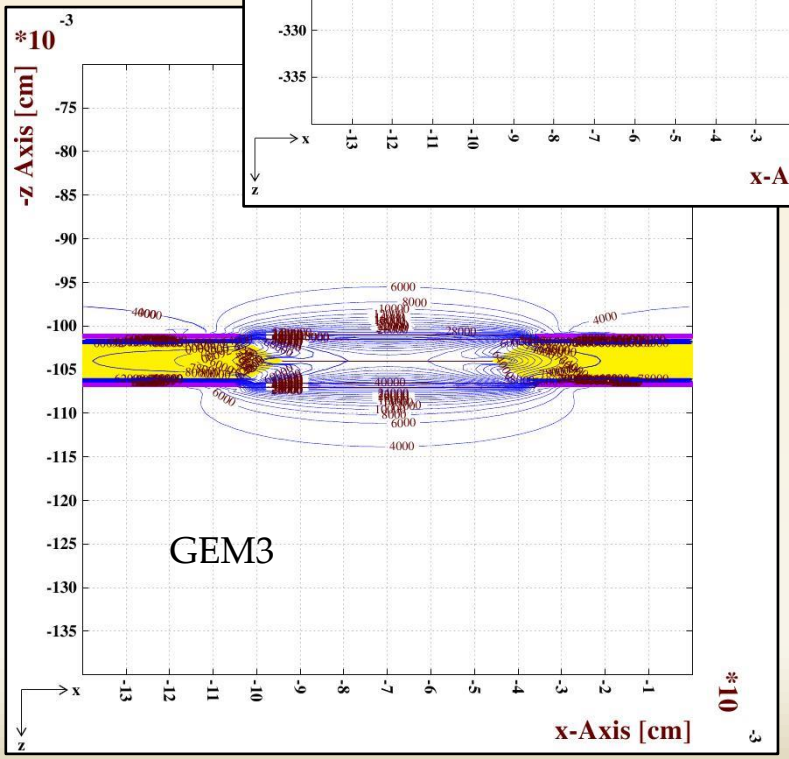
- **High voltage supply is 4.05 kV.**
- **Voltages on different electrodes calculated following CERN voltage divider scheme.**

Field Contours

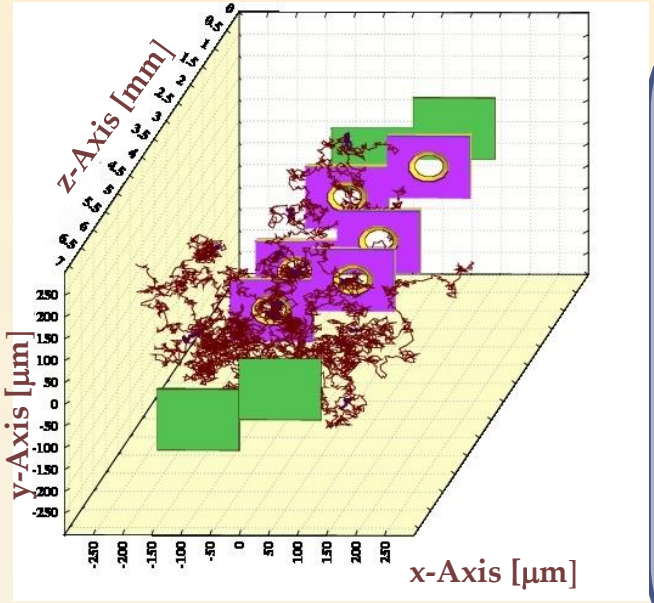








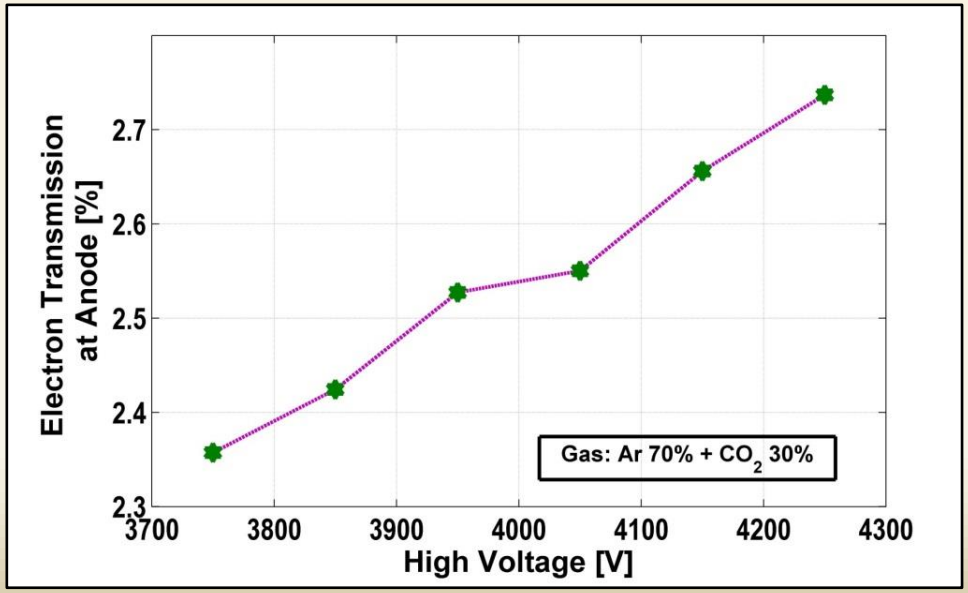
Electron Transmission



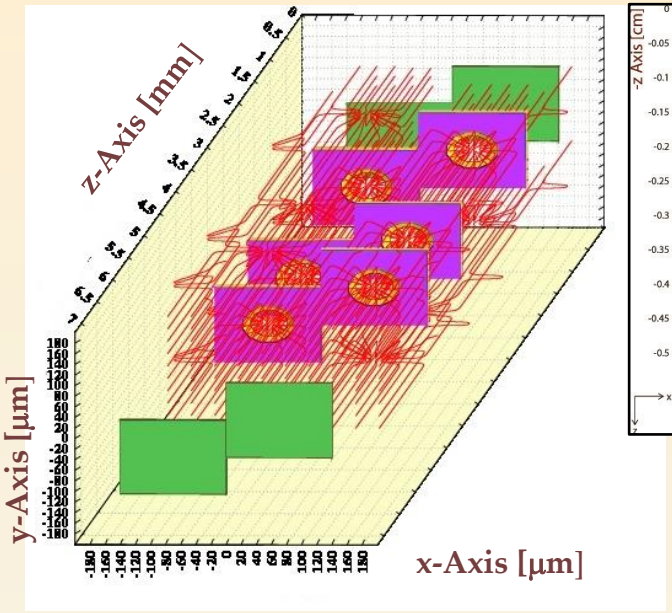
- Electron transmission : $\eta = N_A / N_P$ where N_A: electrons reaching the anode and N_p : primaries generated in drift volume by ^{55}Fe track.
- Microscopic-drift method adopted for the calculation.
- Transmission takes into account Collection and Extraction Efficiency of individual GEMs
- Collection efficiency : $\varepsilon_{coll} = N_M / N_P$ where N_M: electron reaching middle of GEM; Extraction efficiency : $\varepsilon_{extr} = N_E / N_M$ where N_E : electrons getting out of GEM

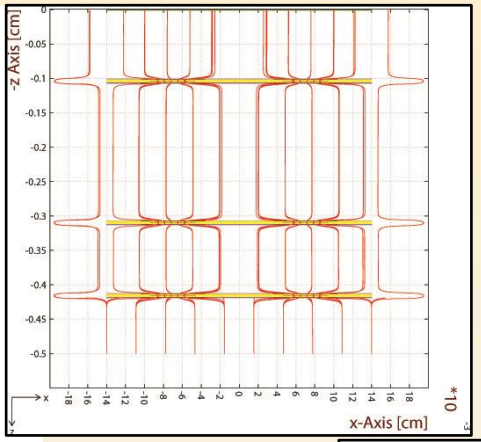
HV : 4.05 kV

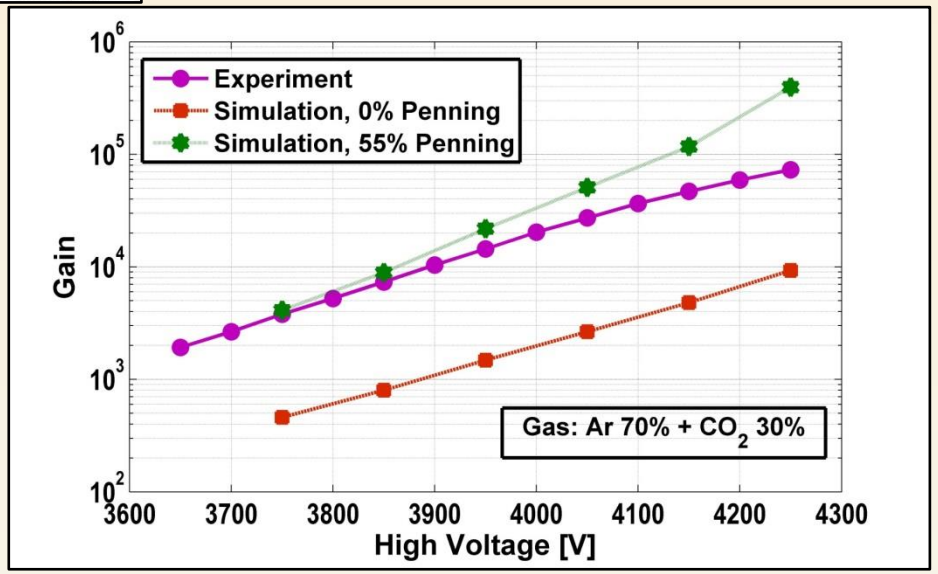
GEM 1		GEM 2		GEM 3	
ε_{coll}	ε_{extr}	ε_{coll}	ε_{extr}	ε_{coll}	ε_{extr}
76%	44%	55%	49%	54%	54%



Electron Gain

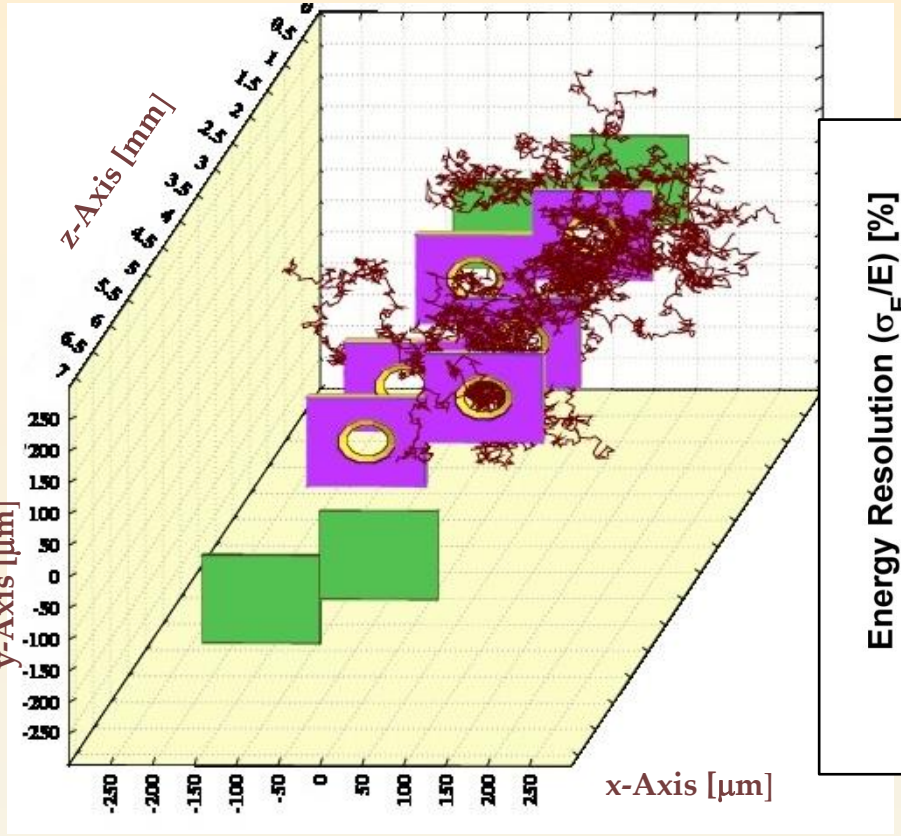


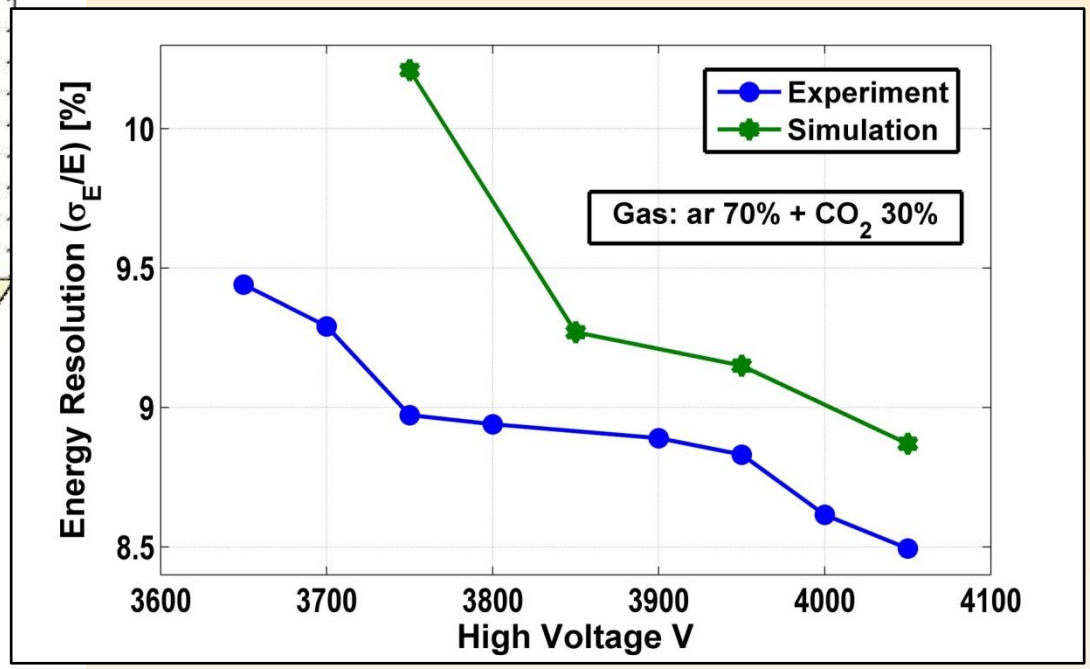




- Electron gain : $G_{eff} = \eta \times G_{mult}$ where η : transmission and G_{mult} : multiplication factor.
- Multiplication factor calculated with Drift-RKF method.

Energy Resolution





- Energy resolution : $\frac{\sigma_E}{E} = \sqrt{\frac{F}{N_p} + \frac{1}{N_p}\left(\frac{\sigma_G}{G}\right)^2}$ where F: Fano factor (~ 0.2), N_p: primaries generated by HEED, σ_G: variance of gain distribution and G: gain
- Gain calculated with MC- avalanche method.

Computation

Efficiency of neBEM-GARFIELD improved with implementation of

- Fast Volume Algorithm
- Reduced Order Modelling
- OMP Threading

Field calculation	RKF-Drift	Microscopic-drift	MC-avalanche (for higher gain)
1 week	15 minutes	1 day (10,000 statistics)	1-2 days (100 statistics)

- Resource used is one DELL Precision T7500 Workstation, 6 threads

Remarks

Summary of Work

- Gain and energy resolution measurements done for 3:1:2:1 prototype with Ar+CO_2 (70:30/80:20/90:10)
- Simulation of gain and energy resolution carried out for Ar+CO_2 (70:30).
- Simulated gain (with 55% penning transfer) compares well with the experimental value in order of magnitude.
- Energy resolution simulation compared to the experiment within 4% at higher voltages.
- The difference in the values of simulation and experiment is under investigation.

Remarks

Future Plan

- Simulation to be carried out for other Ar+CO_2 compositions.
- Gain simulation to be done following other schemes and compared to the present results.
- Simulation to be initiated for Ar+CO_2+CF_4 compositions.
- Time resolution to be computed for each mixture.

Acknowledgements

Group Members:

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Thank You All !!