Electron and Ion Transmission of GEM-based Detectors

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ALICE GEM-TPC Upgrade

- High rate capability
  - Target: 2MHz in p-p and 50kHz in Pb-Pb collisions

- Plan for the ALICE-TPC upgrade
  - No gating grid and continuous readout
  - MWPC readout will be replaced with GEM

- Major issues for the GEM-TPC upgrade

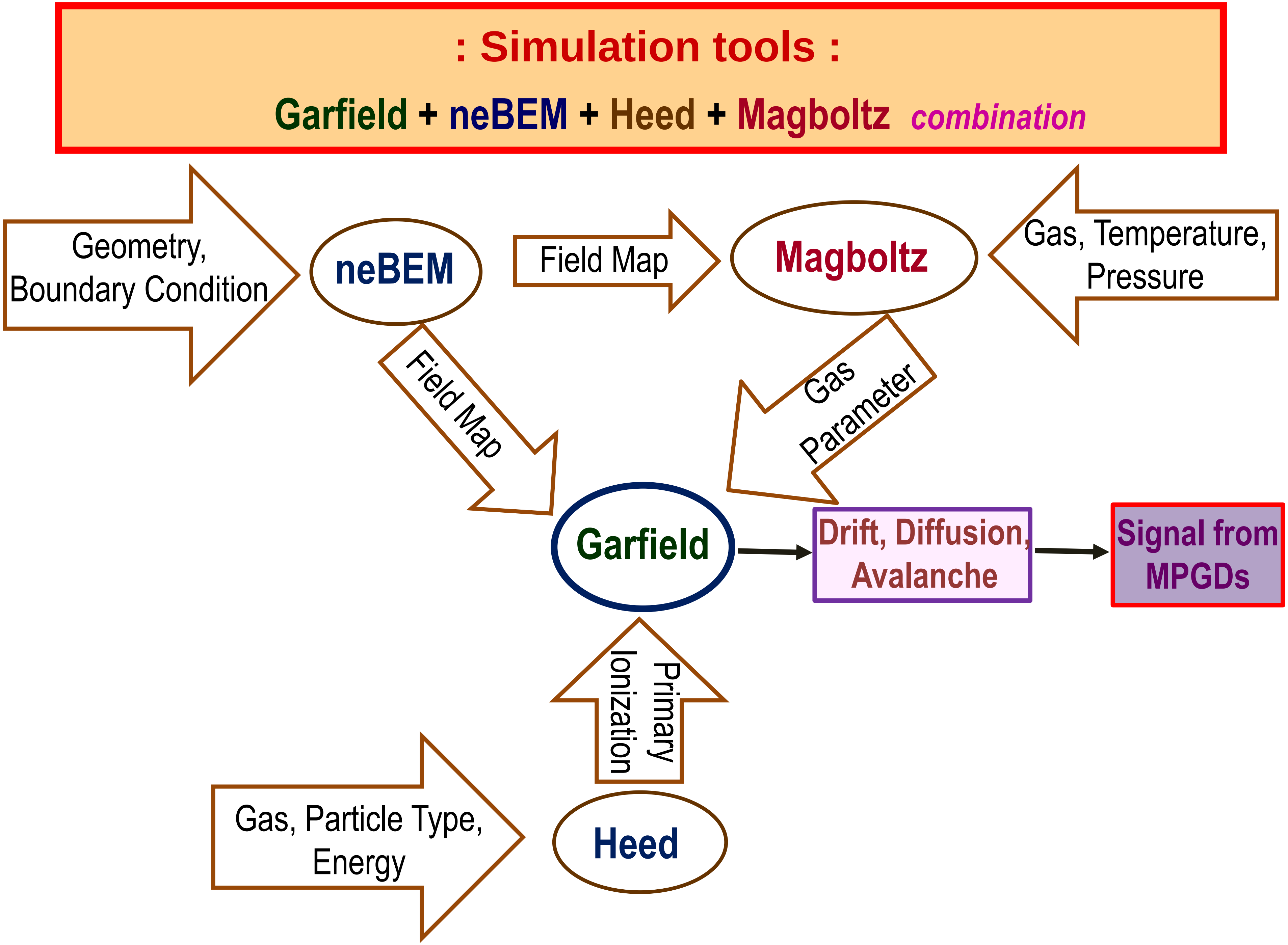
- < 0.25% Ion back flow to avoid space charge distortion

- Better electron transmission -- dE/dx resolution for the particle identification

- Stability of GEM (gain, charge up, discharge, P/T)

These parameters are known to depend on geometry of the detector, electrostatic configuration within the detector, gas composition, pressure …

Motivation -- Electron Transmission, Ion Backflow for GEM-based detectors



: Simulation tools :
Garfield + neBEM + Heed + Magboltz combination
Geometry, Boundary Condition
neBEM
Field Map
Magboltz
Gas, Temperature, Pressure
Field Map
Gas Parameter
Garfield
Drift, Diffusion, Avalanche
Signal from MPGDs
Primary Ionization
Gas, Particle Type, Energy
Heed

Current Design of GEM detectors for ALICE

- Quadruple GEM detectors
- Two foils, outer hole diameter of 70 μm and pitch of 140 μm (denoted as S i.e standard)
- Two foils, outer hole diameter of 70 μm and pitch of 280 μm (denoted as LP i.e Large Pitch)
- Gas mixture: Ne/ CO_2/ N_2 90/10/5

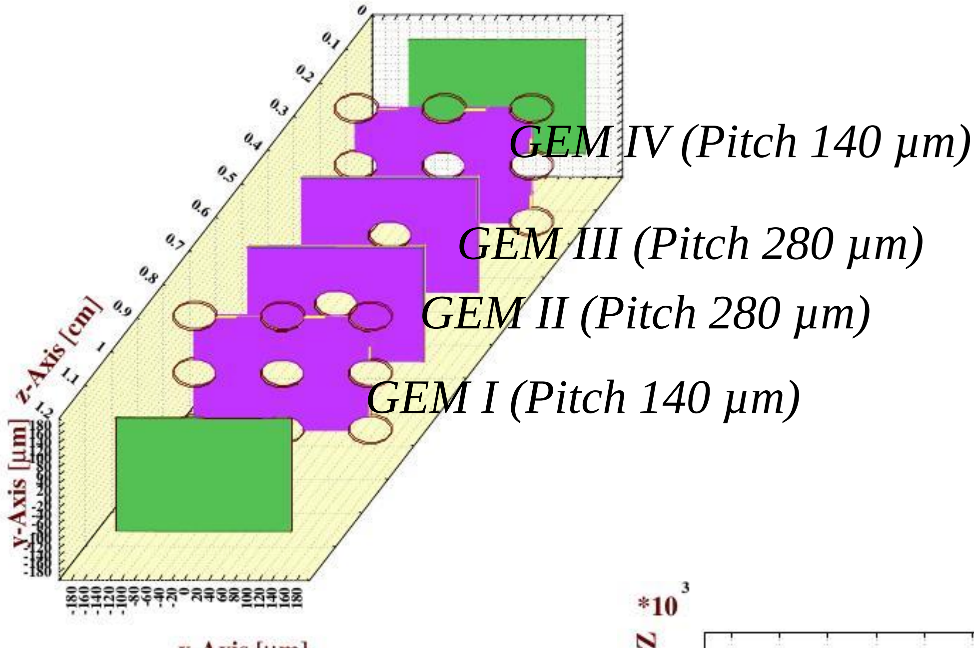
Earlier Results from single simulation:

- Higher electron transmission and lower backflow fraction can be obtained with higher V_{GEM}, lower E_{Drift}, higher $E_{Induction}$
- GEM foil with standard hole pitch is better in terms of higher electron transmission and less backflow fraction
- No significant effect of 0.5 T magnetic field has been observed

Today's Discussion:

- Quadruple GEM detector: Electron and Ion Transmission for different geometry, field configuration, with and without magnetic field
- Triple GEM detector having a configuration of LP-S-SP (SP stands for smaller pitch of 80 μm)

Quadruple GEM Detector (S-LP-LP-S)



Drift Field: 400 V/cm

V_{GEMI}: 275 V

Transfer Field I: 4000 V/cm

V_{GEMII}: 235 V

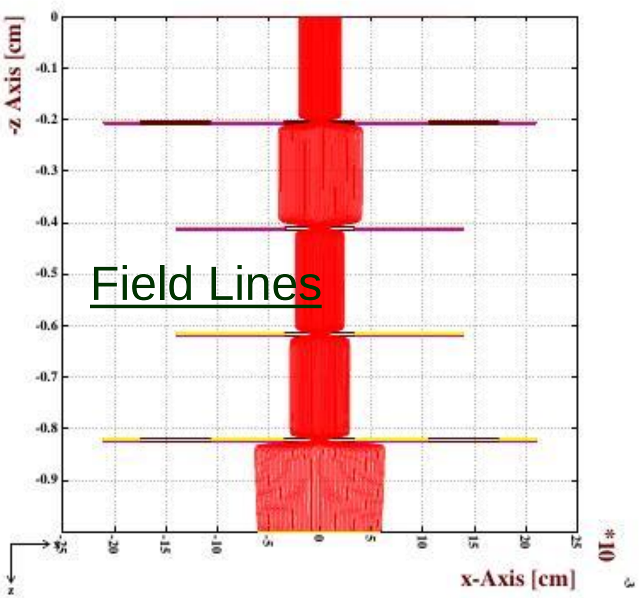
Transfer Field II: 2000 V/cm

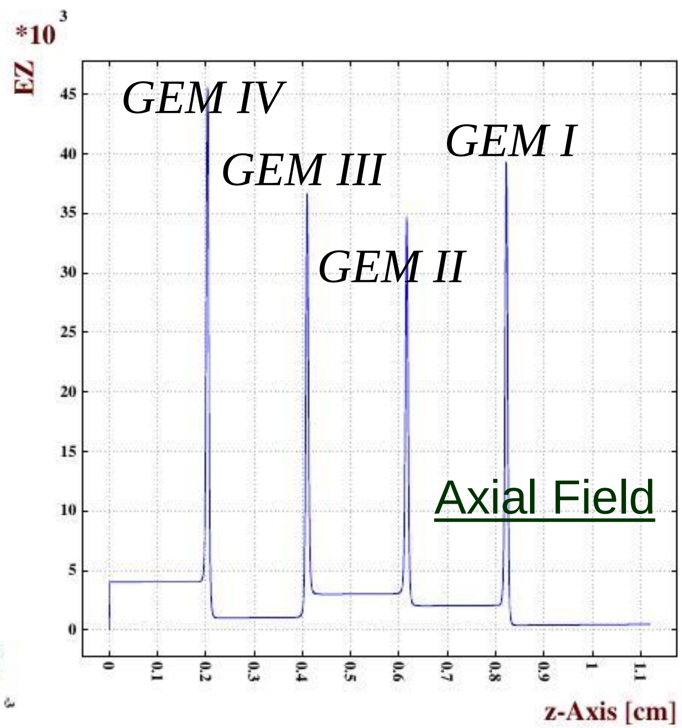
V_{GEMIII}: 284 V

Transfer Field III: 100 V/cm

V_{GEMIV}: 345 V

Induction Field: 4000 kV/cm





Electron Transmission

- Microscopic drift method
- 10000 5.9 keV photon track are considered in the drift volume for primary ionization
- Gas mixture: Ne/ CO_2 / N_2 (90/ 10/ 5)

$$\varepsilon_{tot} = \frac{N_{anode}}{N_{drift}} = \varepsilon_{coll} \times \varepsilon_{ext}$$

$$\varepsilon_{coll} = \frac{N_{GEM}}{N_{drift}}$$

$$\varepsilon_{ext} = \frac{N_{anode}}{N_{GEM}}$$

$$\varepsilon_{tot} = \varepsilon_{coll1} \times \varepsilon_{ext1} \times \varepsilon_{coll2} \times \varepsilon_{ext2} \times \varepsilon_{coll3} \times \varepsilon_{ext3} \times \varepsilon_{coll4} \times \varepsilon_{ext4}$$

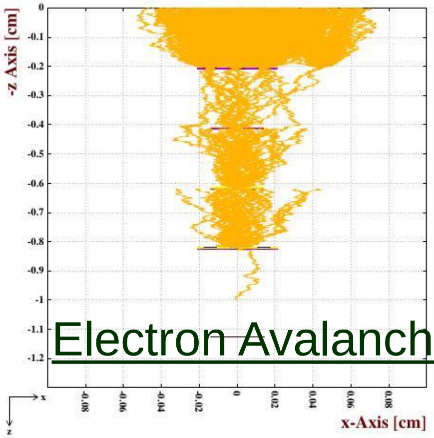
Individual efficiencies of GEM foils:

Magnetic Field	GEM I		GEM II		GEM III		GEM IV	
	ε_{coll}	ε_{extr}	ε_{coll}	ε_{extr}	ε_{coll}	ε_{extr}	ε_{coll}	ε_{extr}
B = 0T	98.9%	34.9%	6.7%	31.0%	15.1%	13.5%	92.9%	37.2%
B = 0.5T	99.3%	35.4%	7.1%	30.5%	14.2%	13.0%	93.0%	37.4%

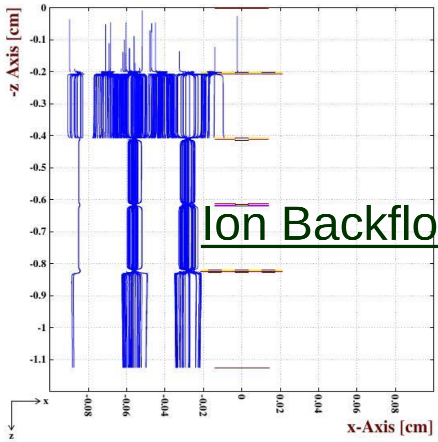
- ✓ No significant of magnetic field of 0.5 T has been observed on ε_{tot}
- ✓ Increase of Transfer field II improves the ε_{ext} of GEM II, but affects ε_{coll} of GEM III
- ✓ Increase of Transfer field III affects ε_{coll} of GEM IV

} No effect on ε_{tot}

Ion Backflow



Electron Avalanche



Ion Backflow

Simulation (Monte Carlo Method):

1) drifting of initial electron from specified point

2) creation of secondary electrons for each step according to Townsend and attachment coefficient

3) Ion drift lines are followed and fraction calculated as N_b/N_T

Gain ~ 1950 in Ne/ CO_2/ N_2 (90/10/5) considering Penning transfer rate of 65%

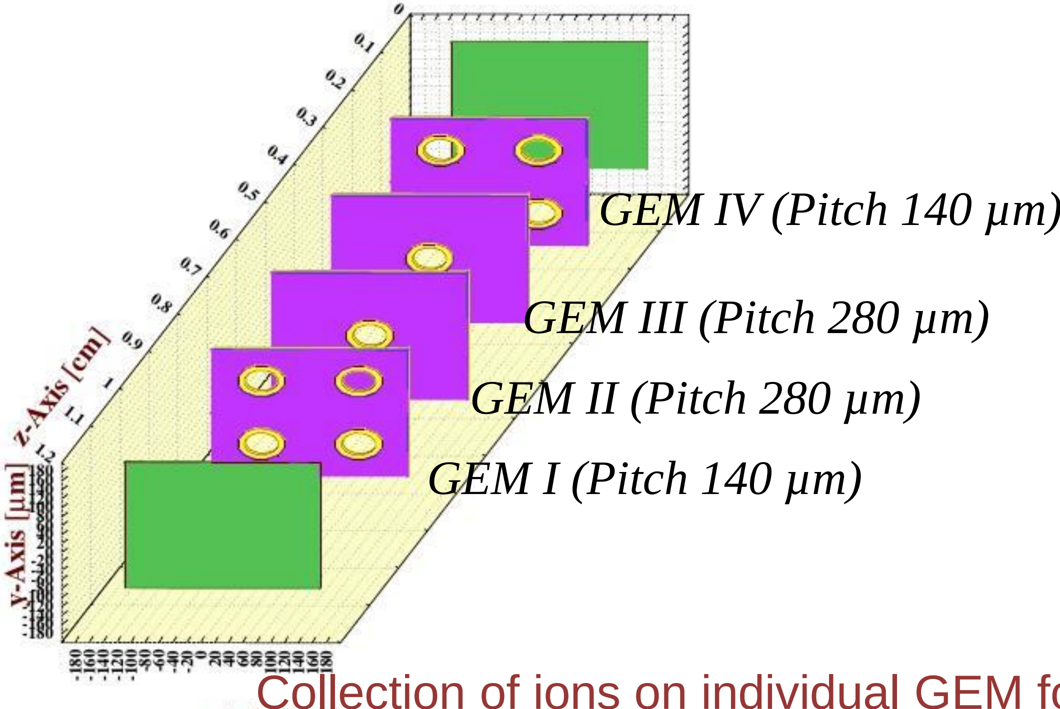
Collection of ions on individual GEM foils:

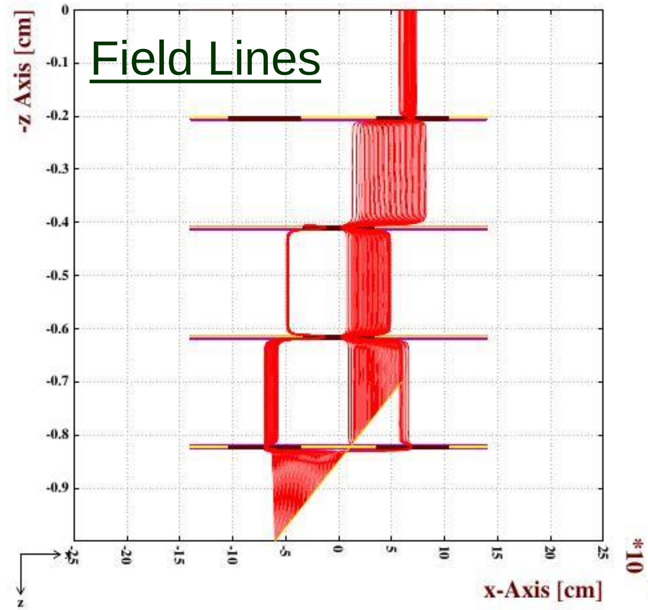
Magnetic Field	GEM I	GEM II	GEM III	GEM IV
B = 0T	2.5%	0.4%	1.3%	93.2%
B = 0.5T	2.3%	0.4%	1.3%	93.0%

- Most of the ions are collected on the IV[th] GEM foil.
- Only 2.64% of ions are able to drift back to the drift volume
- No significant effect of 0.5T magnetic field has been observed on backflow fraction
- Increase of Transfer field II improves backflow fraction ~ 15%

Quadruple GEM Detector (S-LP-LP-S)

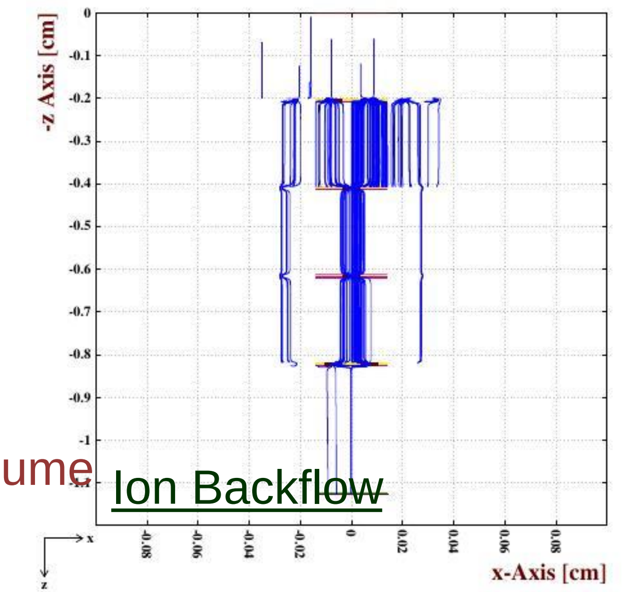
(Another Geometry, Different Placement of Holes, Same Voltage Configuration)





Collection of ions on individual GEM foils:

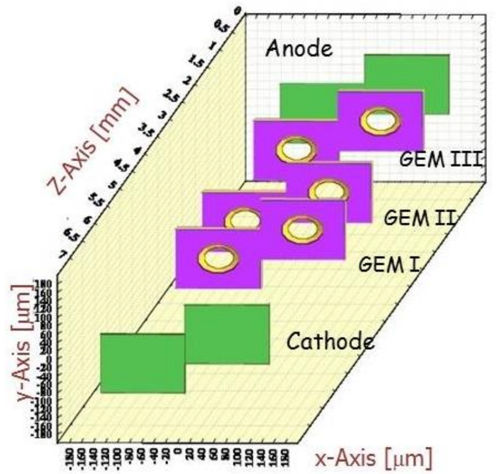
Magnetic Field	GEM I	GEM II	GEM III	GEM IV
B = 0.5T	6.02%	0.49%	1.26%	92.10%



- ❖ Ions collected on the Ist GEM foil increases.
- ❖ Only 0.14% of ions are able to drift back to the drift volume
- ❖ Gain reduced to ~ 1300

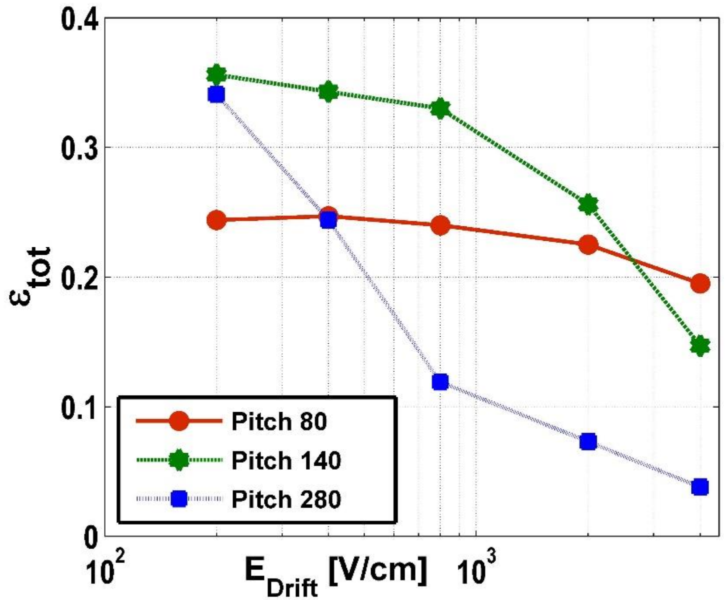
Another Geometry -- Triple GEM Detector (LP-S-SP)

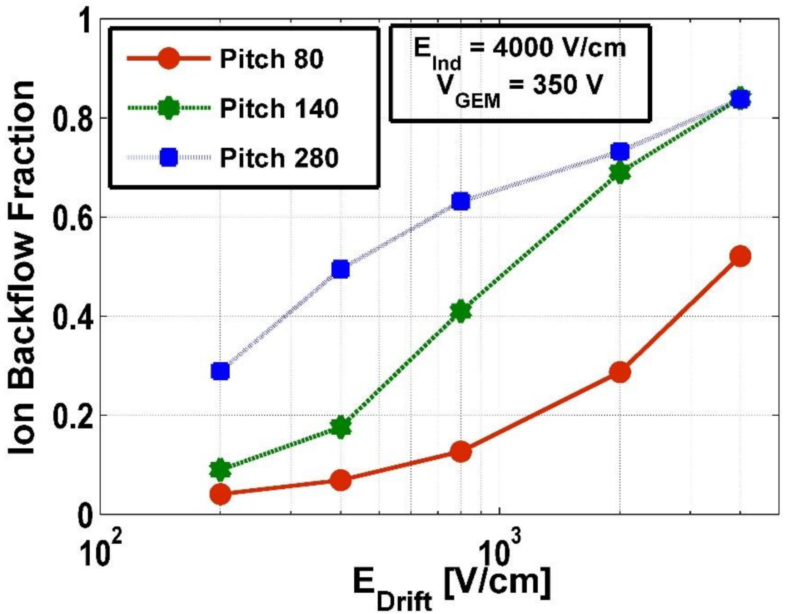
- Triple GEM systems using standard foils of 140 μm; Ion backflow values ~ 4.7% which exceeds the specifications based on the maximum tolerable drift field distortions. Electron transmission ~ 0.16%

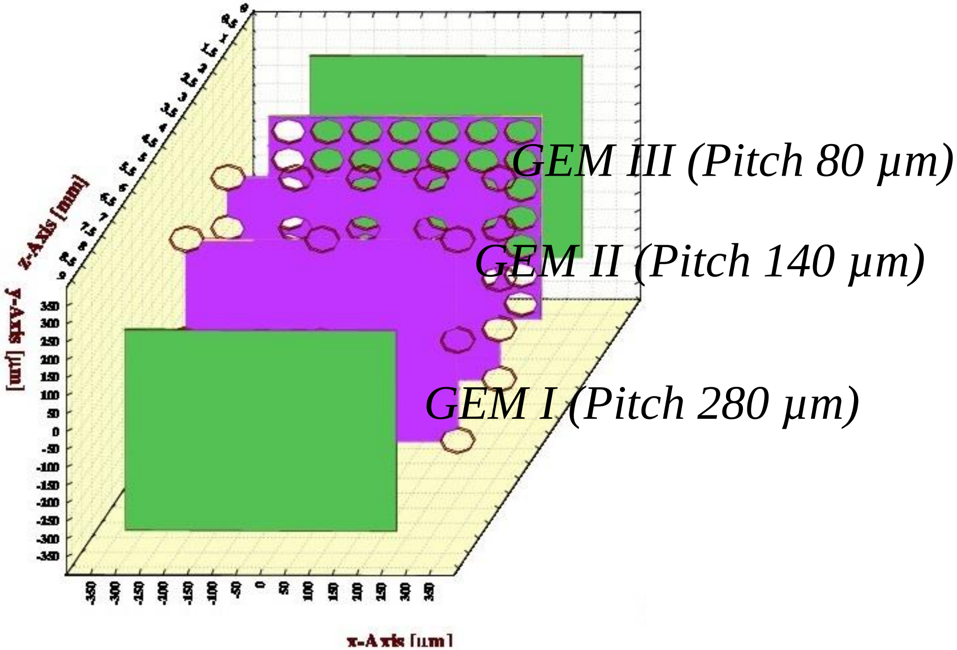


- A new proposal from ALICE group from Sao Paulo, Brazil -- Use of triple GEM detector having a configuration of LP-S-SP from top to bottom direction (here SP is the smaller pitch of 80 μm)

- Numerical simulation has been initiated -- Study of single GEM foil shows that SP is better in terms of lower backflow fraction though for lower drift field, electron transmission is less in comparison to standard pitch.







Drift Field: 400 V/cm

V_{GEMI}: 255 V

Transfer Field I: 1750 V/cm

V_{GEMII}: 275 V

Transfer Field II: 3600 V/cm

V_{GEMIII}: 345 V

Induction Field: 4000 kV/cm

ε_{coll} and ε_{ext} of individual GEM foils:

GEM I		GEM II		GEM III	
ε_{coll}	ε_{extr}	ε_{coll}	ε_{extr}	ε_{coll}	ε_{extr}
20.05%	29.53%	63.96%	38.23%	89.36%	24.33%

Collection of ions on individual GEM foils:

GEM I	GEM II	GEM III
8.96%	12.82%	77.37%

- Gain ~ 1850.
- Electron transmission ~ 0.31%,
- Ion backflow ~ 0.2%

Summary:

1) Numerical simulation to estimate electron transmission, energy resolution and ion backflow have been performed.

2) Multi-GEM device is suitable in terms of less backflow fraction but it affects electron transmission adversely. Numerical simulation for a quadruple GEM detector has been performed with different voltage configuration, geometry configuration has been performed in presence and absence of magnetic field.

3) Investigation of a triple GEM detector having configuration of LP-S-SP has been initiated to achieve a better backflow fraction.

Future Plan:

1. Energy resolution will be estimated.
2. Space charge effect will be considered.
3. The behaviour of electron and ion transmission on detector edge will be also simulated.
4. Effect of geometrical inhomogeneity on these characteristics will be evaluated.
5. In addition to the further improvement in the numerical work, development of a setup for measuring the backflow fraction has been planned.

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