Ion Backflow in Bulk Micromegas Detectors

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Current Activities at SINP

Study of Micro-Pattern Gas Detectors

- *Investigation of above features due to change in various physical dimensions of detector*

- *Estimation of different detector characteristics **detector gain, transparency, efficiency, energy resolution, ion backflow etc.***

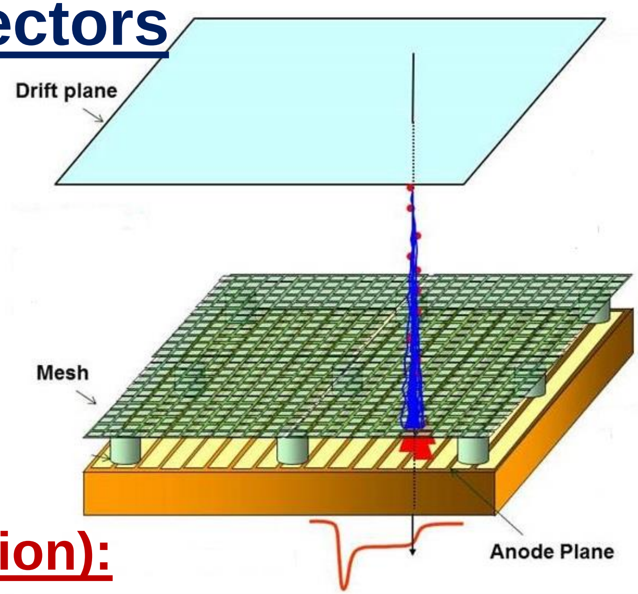
- *Comparison of present numerical estimates (**Garfield** + **neBEM** + **Magboltz** + **Heed**) with experimental results*

Detectors Studied: 1) Gas Electron Multiplier (GEM),

2) Micro Mesh Gaseous Structure (Micromegas)

3) Micro Hole and Strip Plate Detectors (MHSP)

Characterization of bulk Micromegas detectors



Specifications of tested detectors:

- Active area: 15x15 cm^2
- Amplification gap: 64 /128 / 192 μm
- SS wire diameter: 18 μm, pitch 63 / 78 μm
- Spacer diameter: 350 μm, pitch 2 mm

Work done so far (In context of RD51 Collaboration):

Bulk Micromegas →

Performance Parameters of Detectors

Spatial resolution ~ 60 - 100 μm (RMS)
Energy Resolution
Temporal Resolution ~ 10 nsec (RMS)
High Gain ~ 10^4
High Rate Capability
Low Ion backflow

Studied so far

Electric Field, Electron Transmission, Gain, Energy Resolution, Temporal Resolution, Ion Backflow, Signal Generation, Geometrical Inhomogeneity

Studies needed

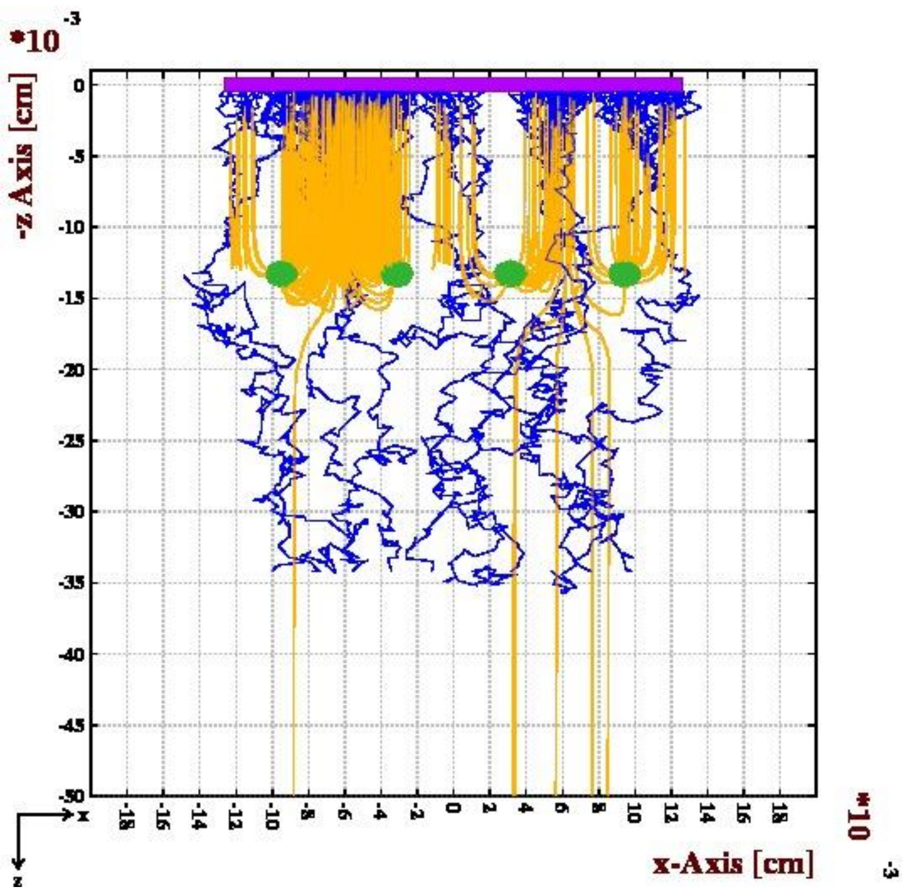
Spatial Resolution, Charge Sharing, Space Charge Effect

Topic of Today's Presentation: ***Ion backflow of bulk Micromegas detector***

Ion Backflow

- Secondary ions from amplification region drift to drift region
- Distortion of electric field; degrades stable operation of detector
- Micromegas micromesh stops a large fraction of these ions

- Backflow fraction: N_b/N_t,
  where $N_b \rightarrow$ backflowing ions
  $N_t \rightarrow$ total ions
- Theoretical formula (2D assumption):
  $N_b/N_t \propto (1/FR)(p/\sigma_t)^2$,
  where, $FR \rightarrow$ field ratio,
  $p \rightarrow$ pitch of the mesh,
  $\sigma_t \rightarrow$ transverse diffusion



Experiment:

Ion back flow : $$\mathbf{BF} = \frac{N_b}{N_t} = \frac{I_C}{(I_M + I_C)}$$

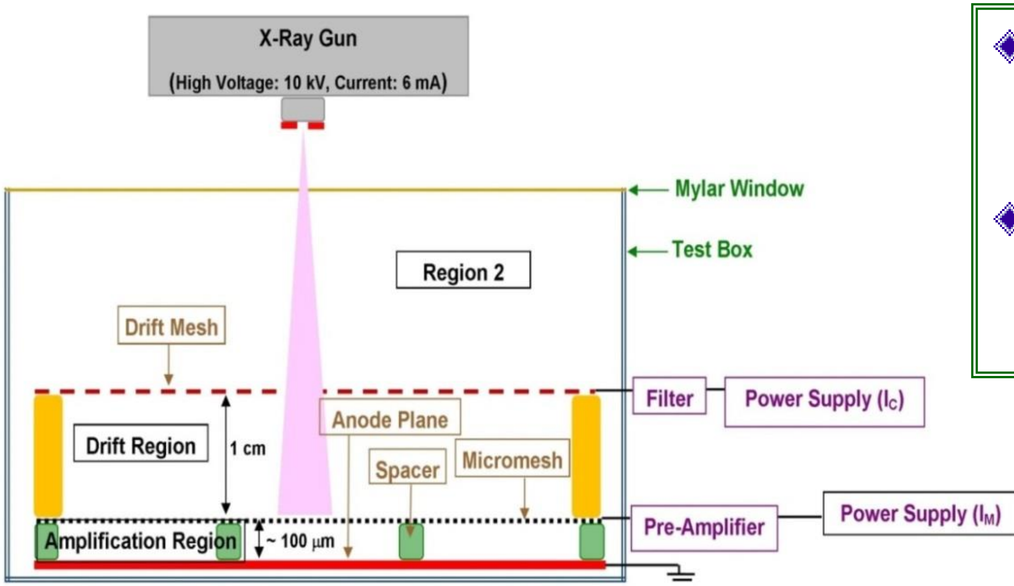
where I_C: current on drift cathode
I_M: current on micromesh

Simulation:

Ion back flow : $$\mathbf{BF} = \frac{N_b}{N_t}$$

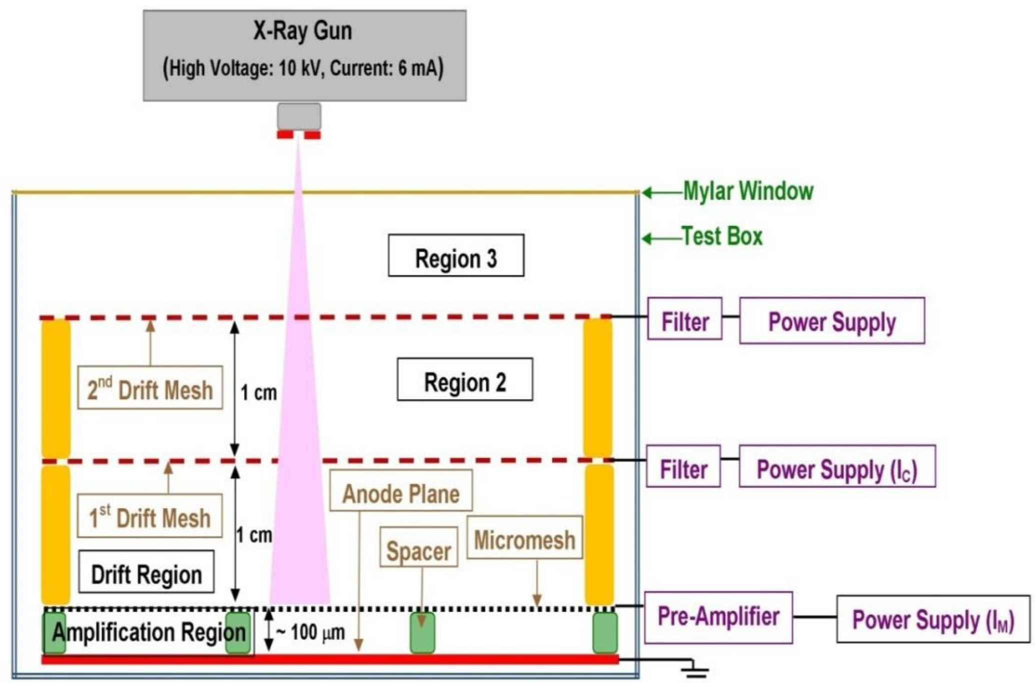
Ref: NIMA 535 (2004) 226

Setup at Saclay (2013)

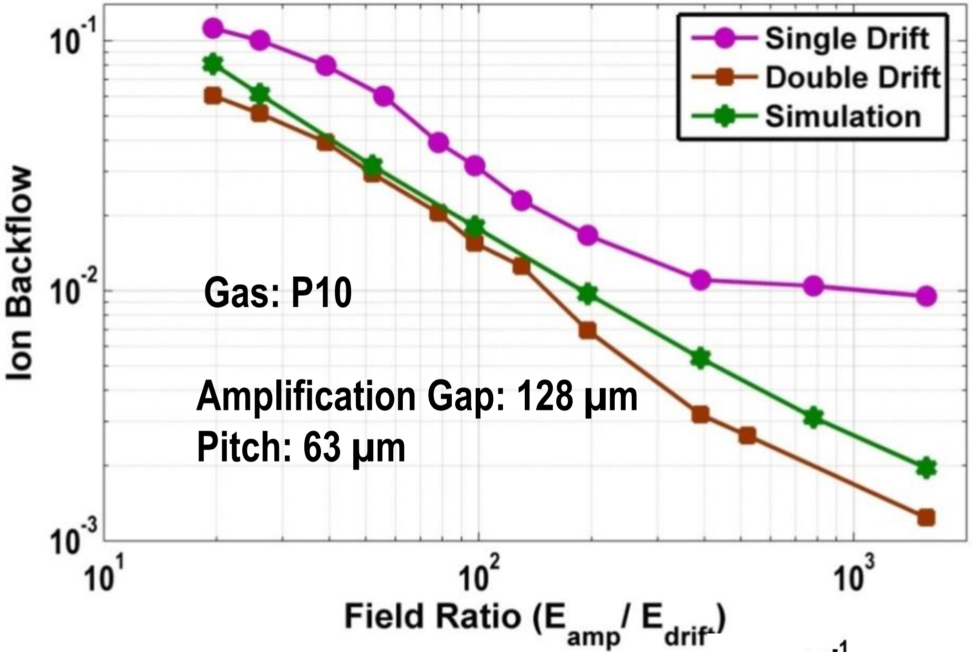


- Radiation source: X-Ray gun, high voltage: 10 kV, current: 6 mA
- Currents on drift and mesh plane measured from HV power supply (CAEN N471A)

- Besides the contribution of ions from avalanche, additional contribution from ions between drift plane and test box window affect the data – placement of 2nd drift plane

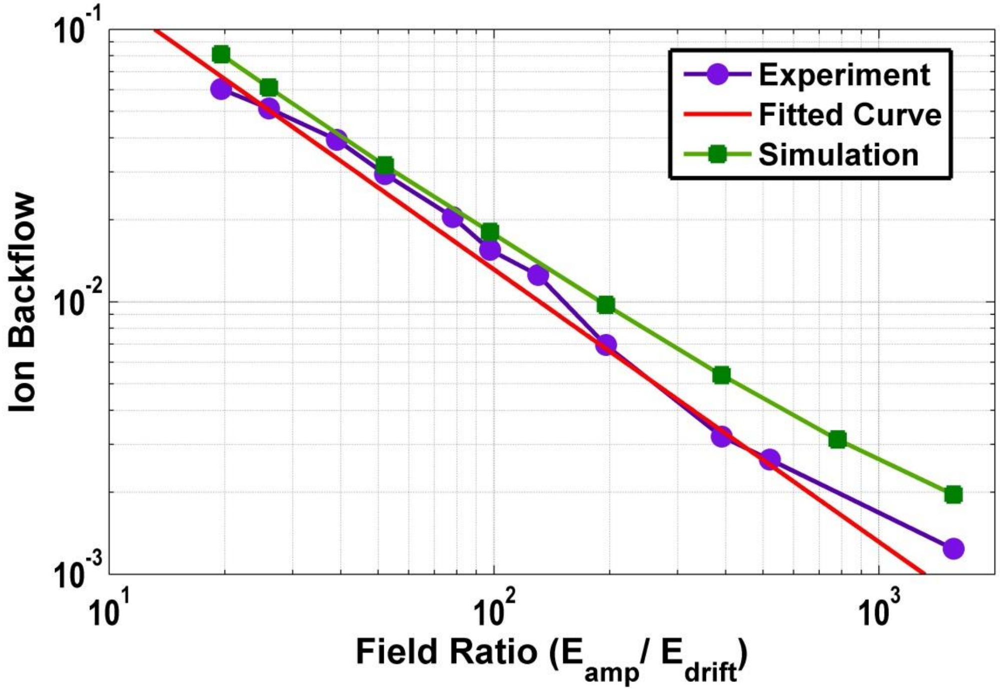


Results

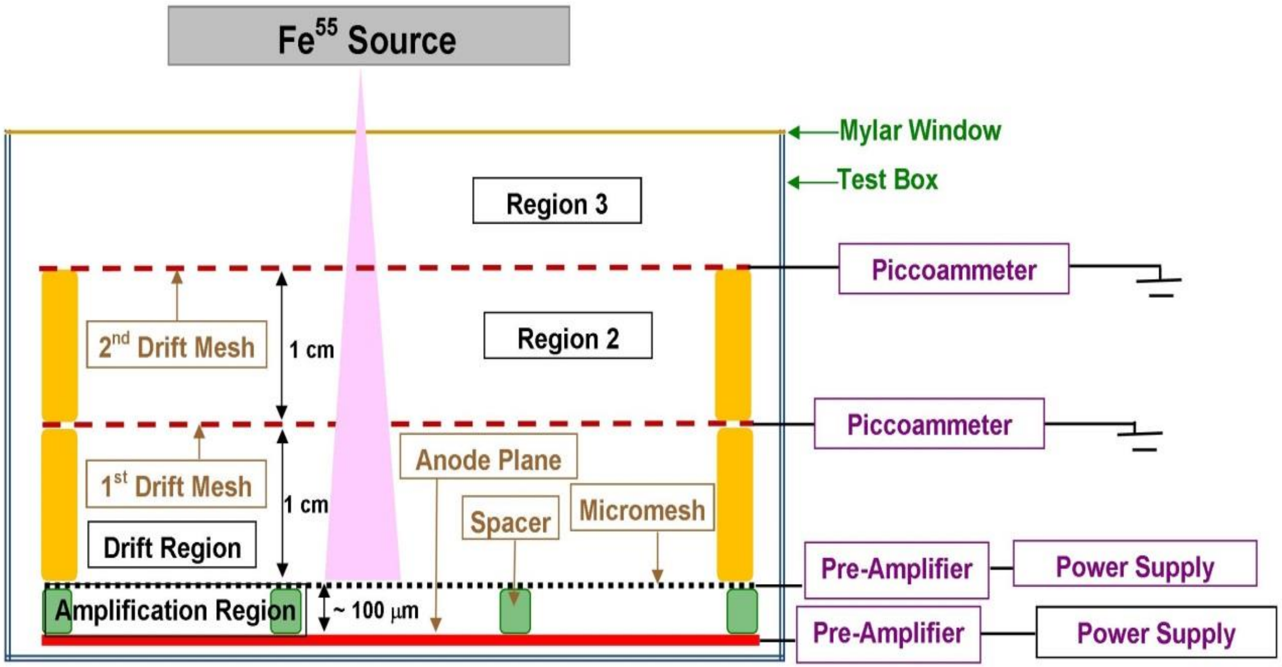


Variation with Drift Field at a fixed Amplification Field

Comparison with Theoretical Expression

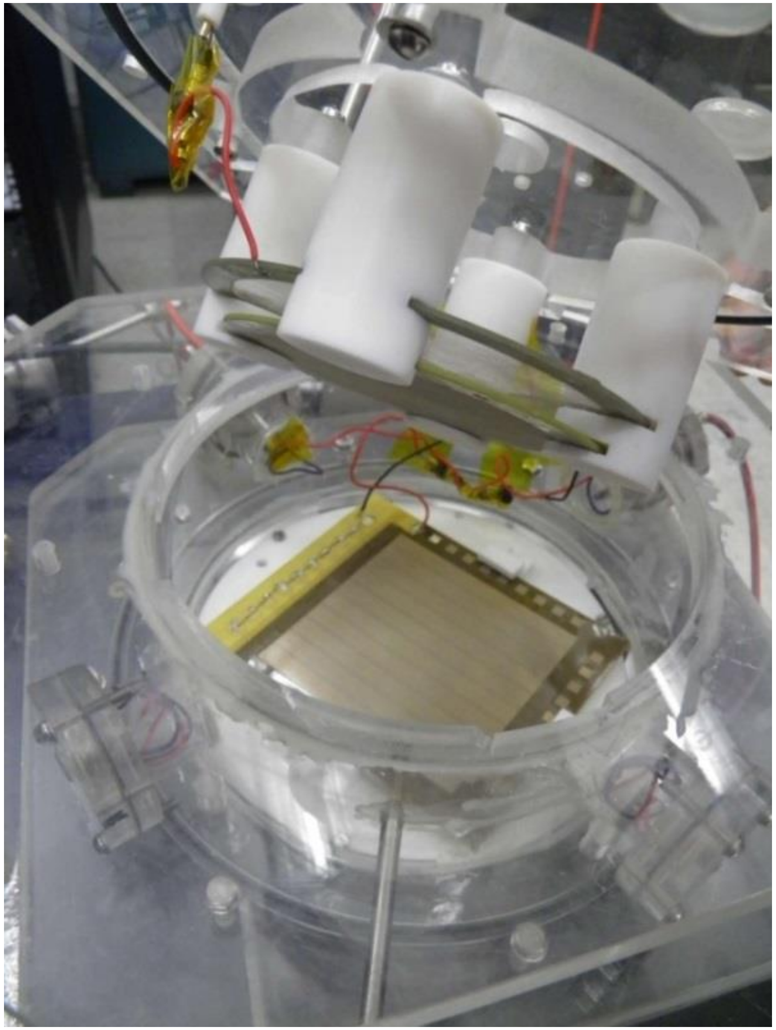


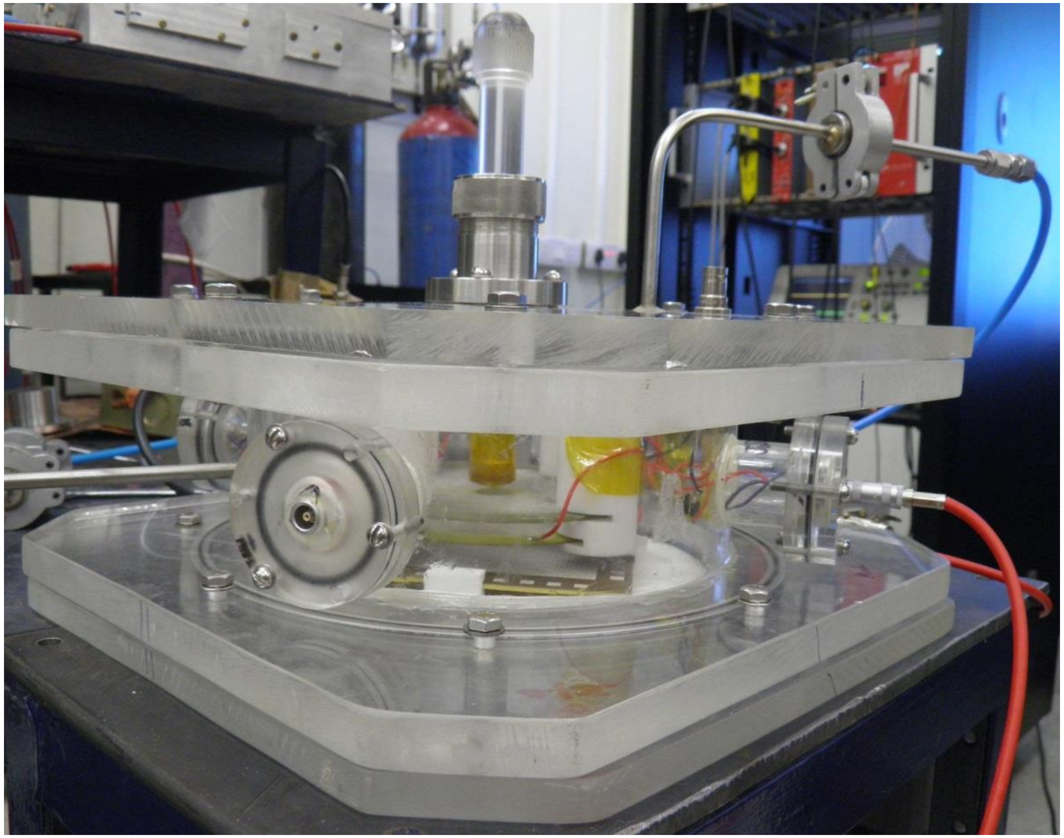
Setup at SINP (2014)



- Radiation source: ^{55}Fe (Activity: 185 MBq in November 2012, ϕ ~ 12.5 mm x 3 mm)
- Implementation of 2nd drift mesh
- Currents are measured using Pico ammeter (CAEN AH401D, Danfysik Current Integrator 554)
- Electrode from which current is measured, is grounded
- Potential of other electrodes are adjusted to maintain the correct field configuration

Test Box





Specification of Pico Ammeter (Model: CAEN AH401D):

- ✓ Current measurements from 50 pA (with a resolution of 50 aA) up to 2.0 µA (with a resolution of 2.0 pA), with integration times ranging from 1 msec up to 1 sec.

Specification of Danfysik Current Integrator 554:

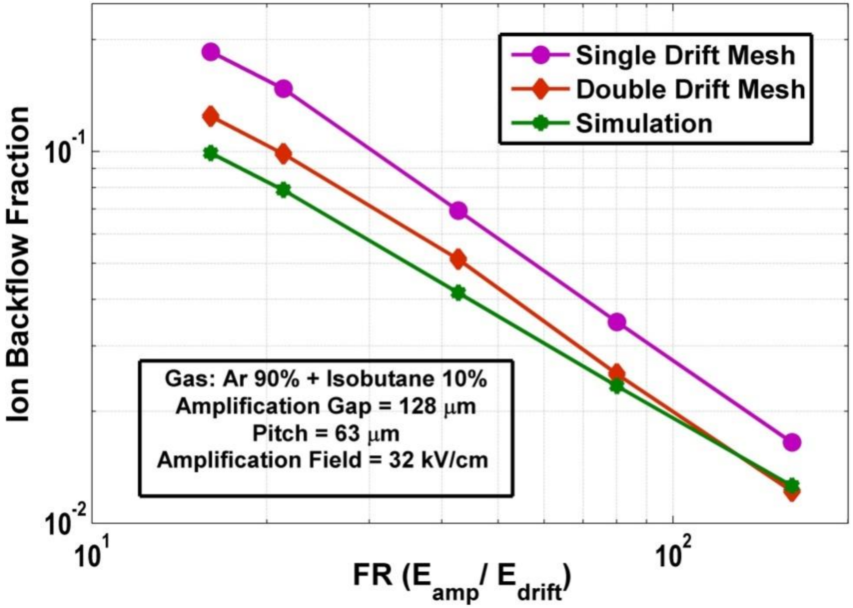
- ✓ Current measurements from 10^{-9} Ampere full scale to 10^{-3} Ampere in thirteen 1x and 3x ranges with an accuracy of ~ 1% of full scale

Current in a Typical Case (Ar Isobutane 90:10, Gap = 128 µm, Pitch = 63 µm, E_{amp} = 32 kV/cm)

Drift Field (V/cm)	Mesh Current (nAmp)	Drift Current (nAmp)
100	17.274	0.093
200	18.208	0.216
300	18.395	0.342
400	18.467	0.495
500	18.411	0.627
750	17.392	0.910
1000	15.615	1.175
1250	14.027	1.262
1500	12.729	1.515
2000	10.757	1.650

Variation with Drift Field

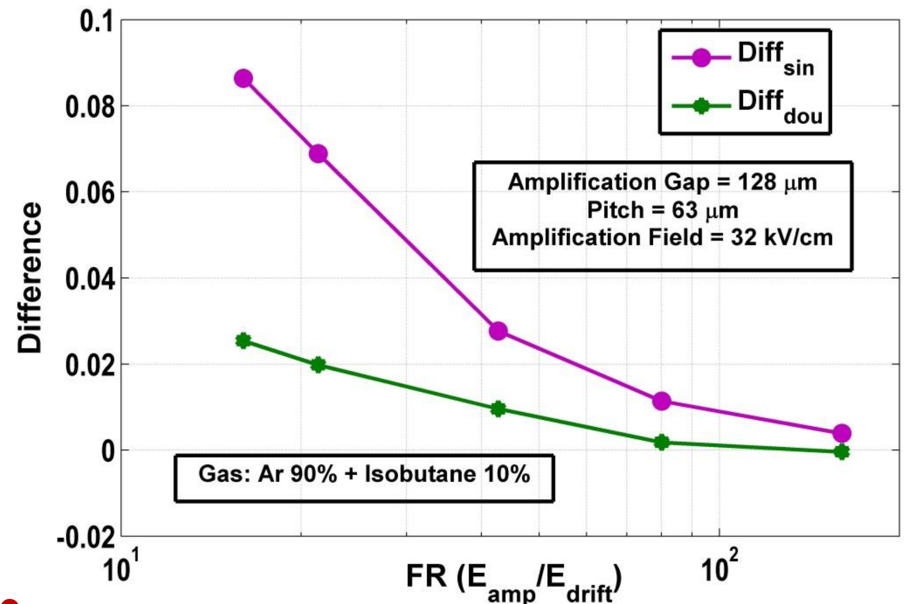
Gas: Argon - Isobutane Mixture (90:10)



- *Lower drift field – less number of field lines get out of holes – less backflow fraction!!*

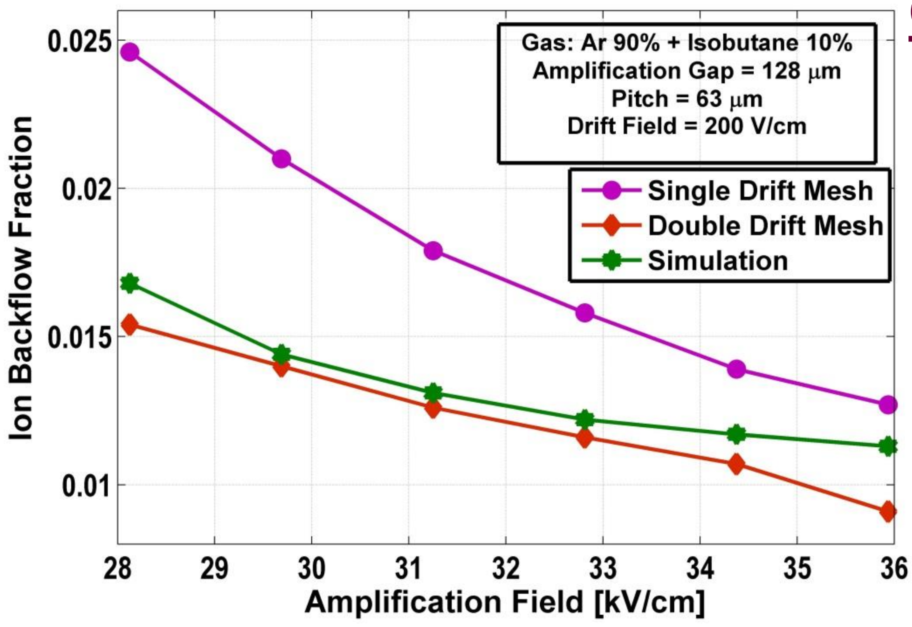
$$Diff_{\sin} = y_{sim} - y_{\sin}$$

$$Diff_{dou} = y_{sim} - y_{dou}$$



Use of double drift improves the estimates of IBF !!

Variation with Amplification Field

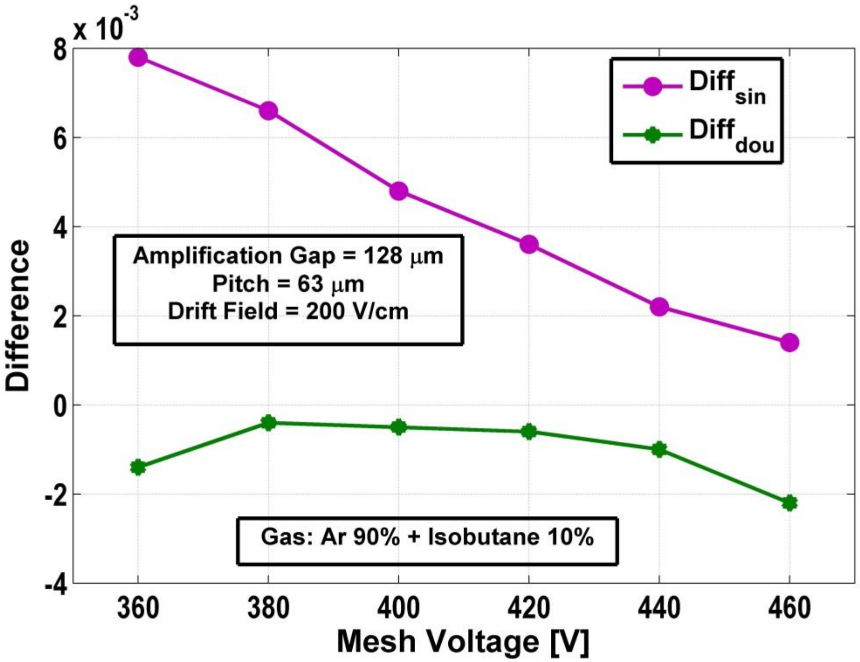


Gas: Argon - Isobutane Mixture (90:10)

- ***Higher amplification field – higher field ratio responsible for lower backflow***

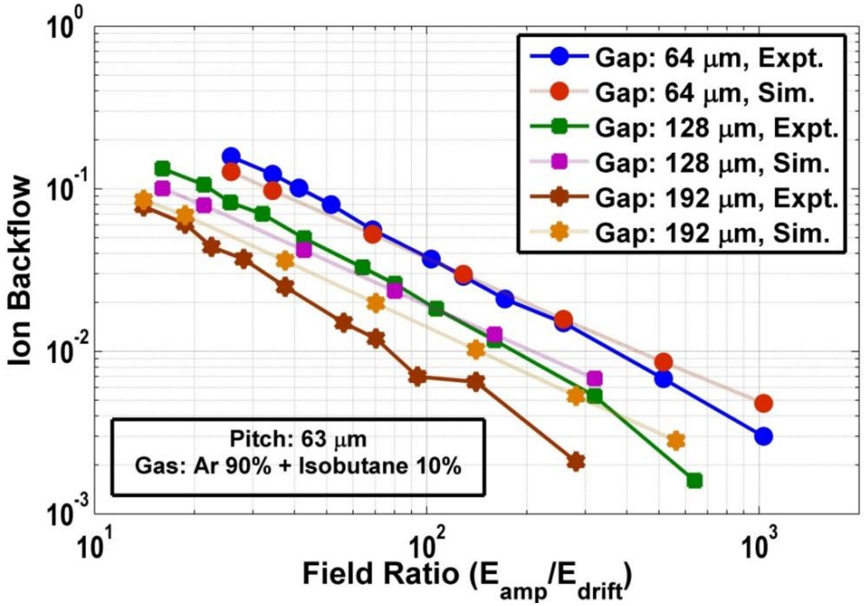
$$Diff_{\sin} = y_{sim} - y_{\sin}$$

$$Diff_{dou} = y_{sim} - y_{dou}$$



Higher amplification field show less backflow fraction!!

Dependence on Detector Geometry

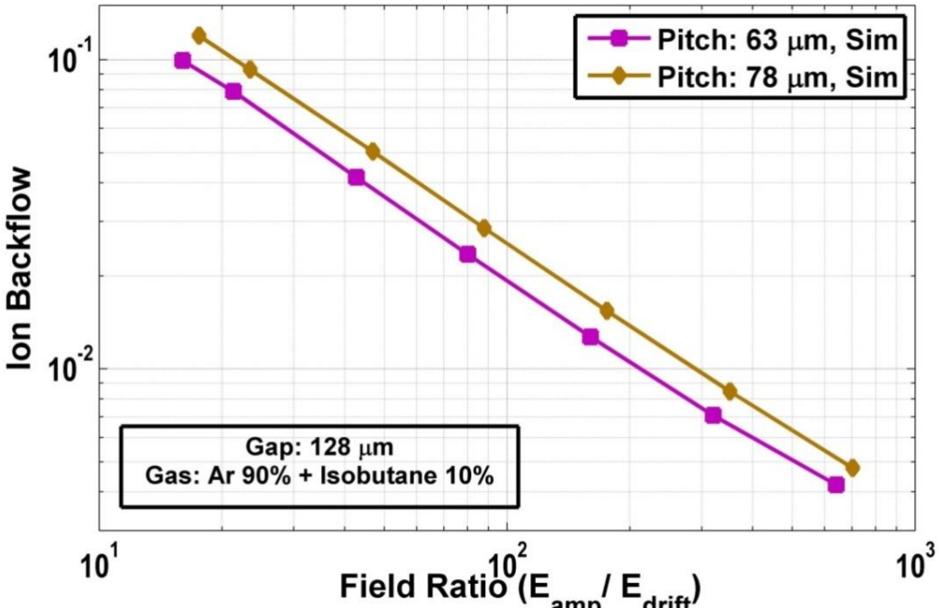


Variation with Amplification Gap

- *Larger amplification gap - Smaller amplification field – Larger transverse diffusion - Lower backflow*

Variation with Mesh Hole Pitch

- *Larger opening - Higher backflow*

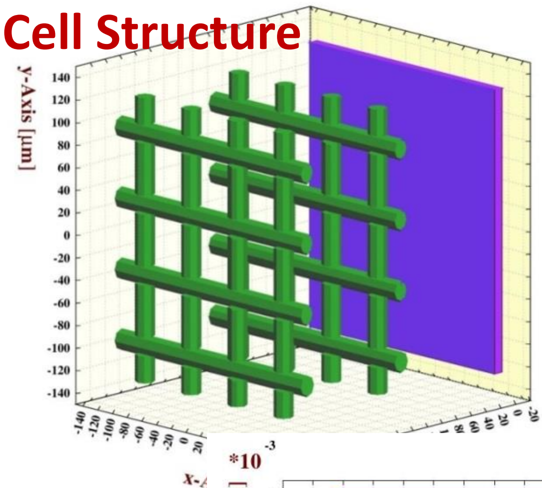


Larger amplification gap and smaller pitch show less backflow fraction!!

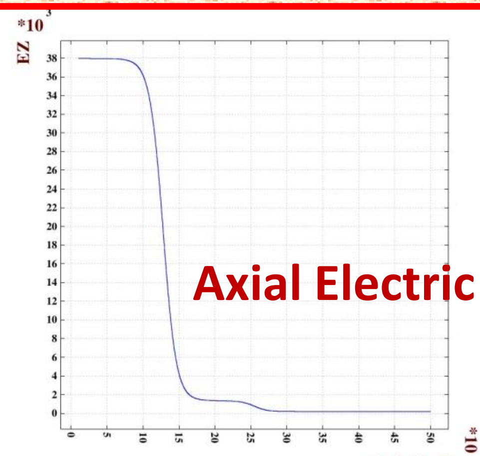
Implementation of Double Micromesh to Reduce IBF – Numerical Study

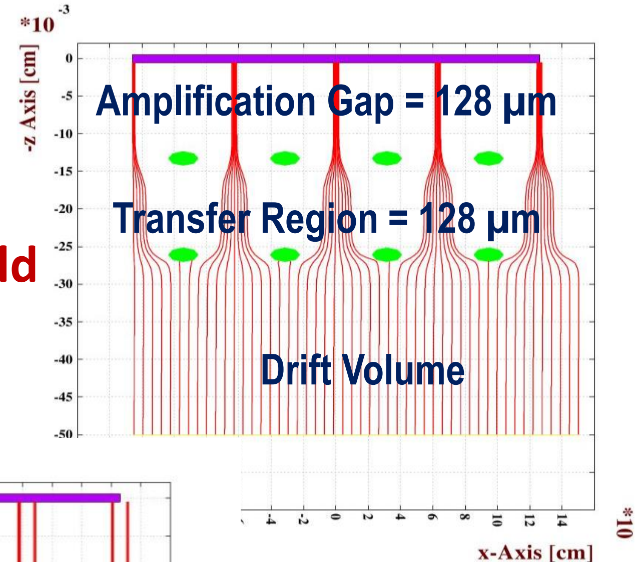
- *Placement of second micromesh above usual mesh*
- *Holes are aligned perfectly and are shifted w.r.t one another*
- *The field between two mesh planes are adjusted for electron drift only*

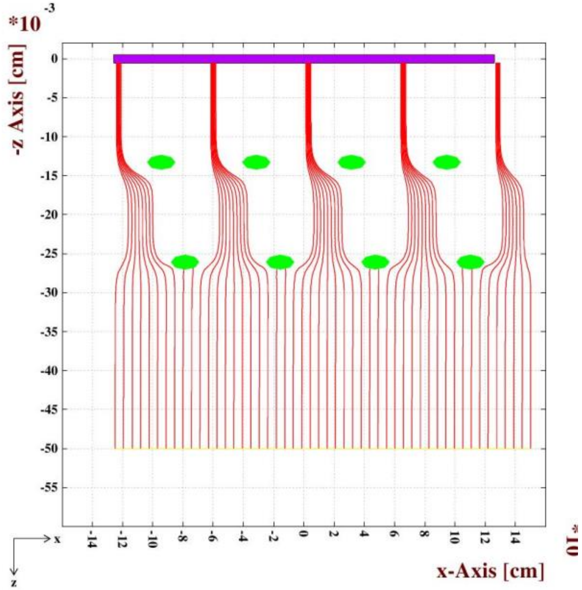
Cell Structure

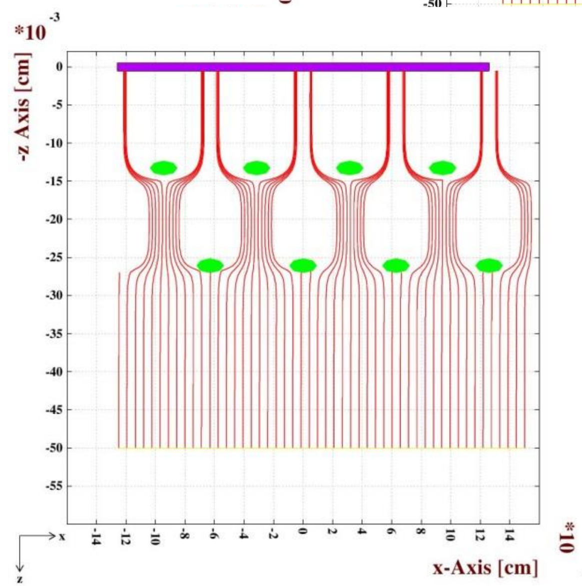


Axial Electric Field





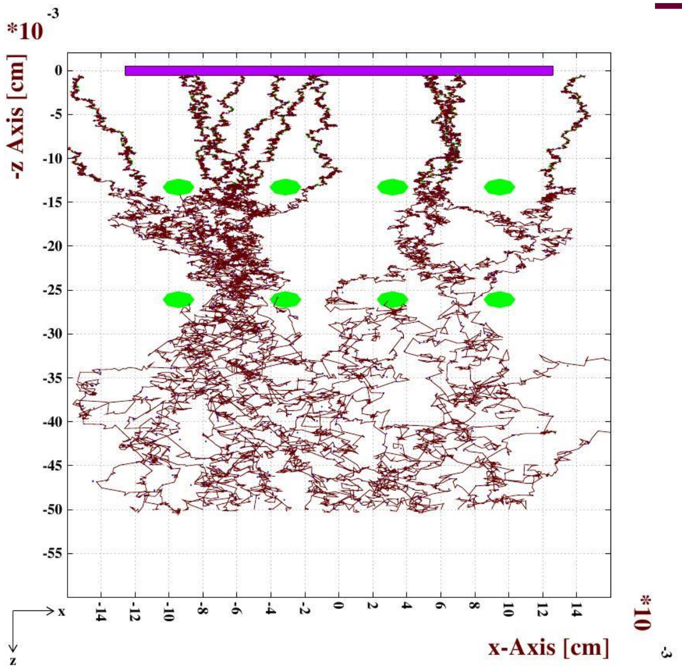


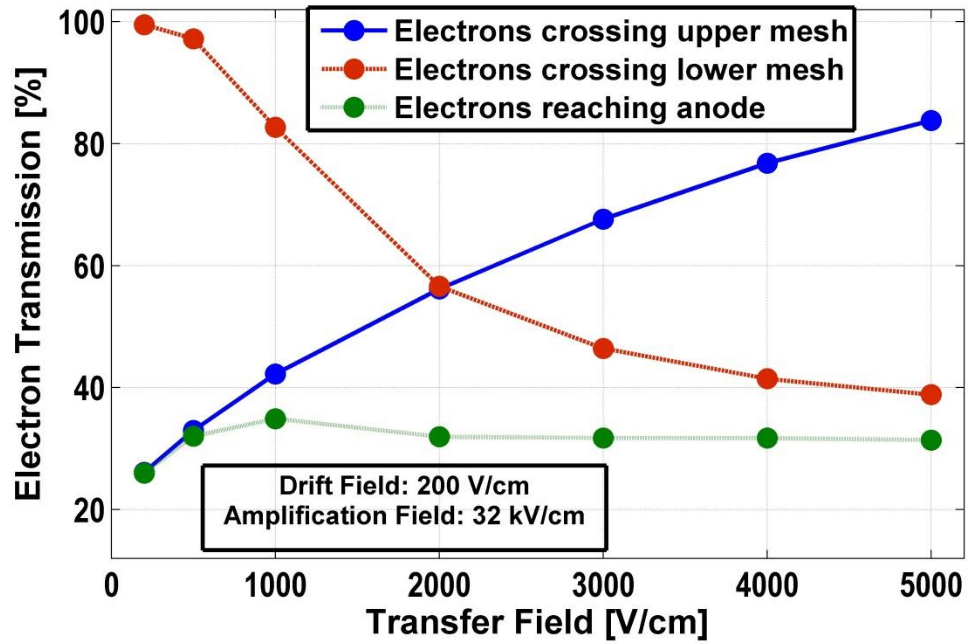


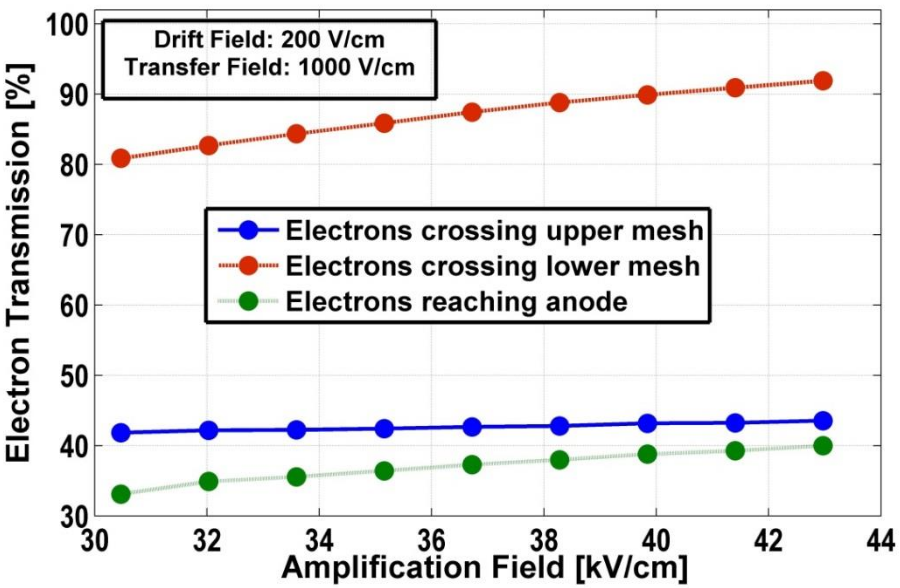
Electron Drift Lines

Electron Transmission

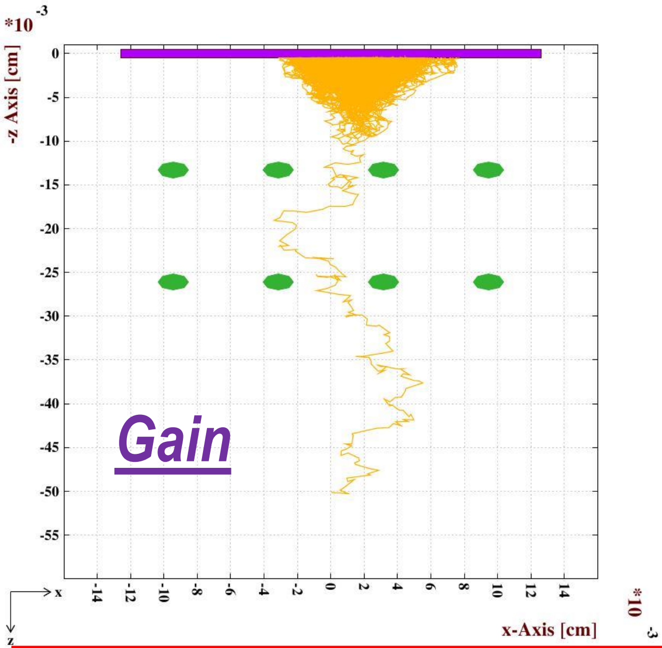
An estimate in Argon - Isobutane Mixture (90:10)

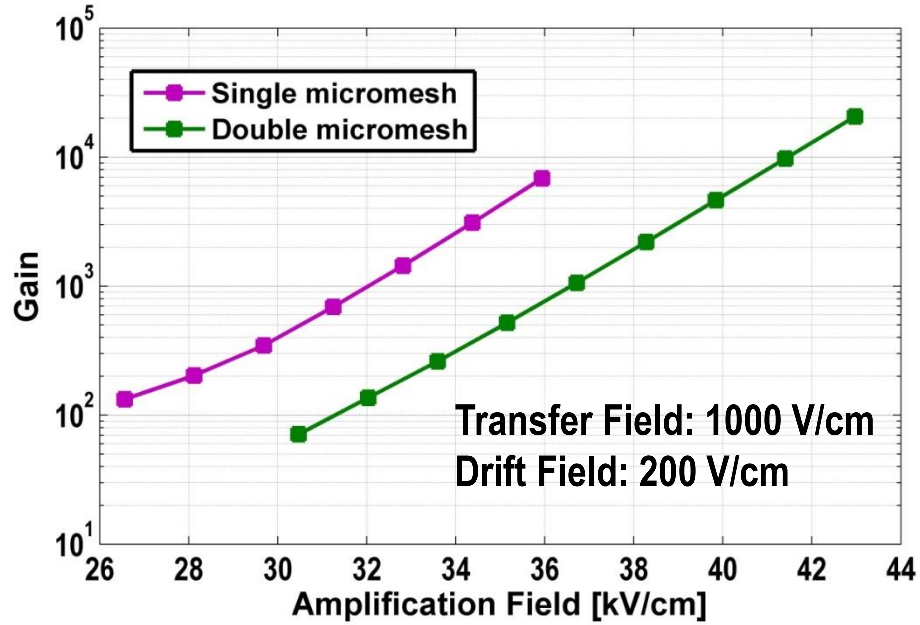




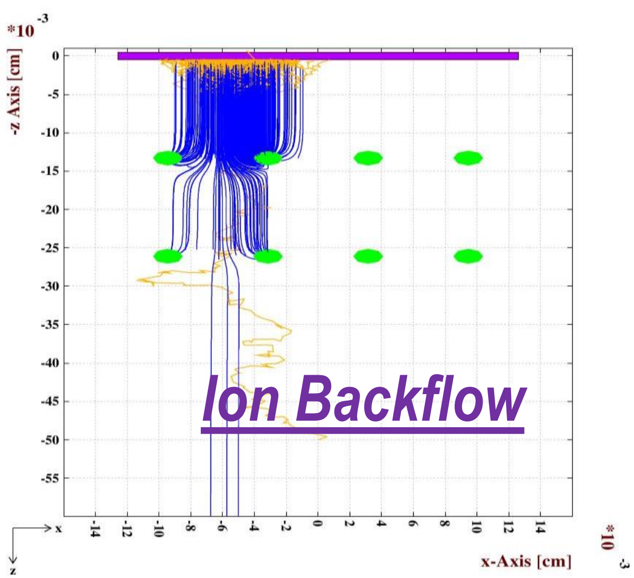


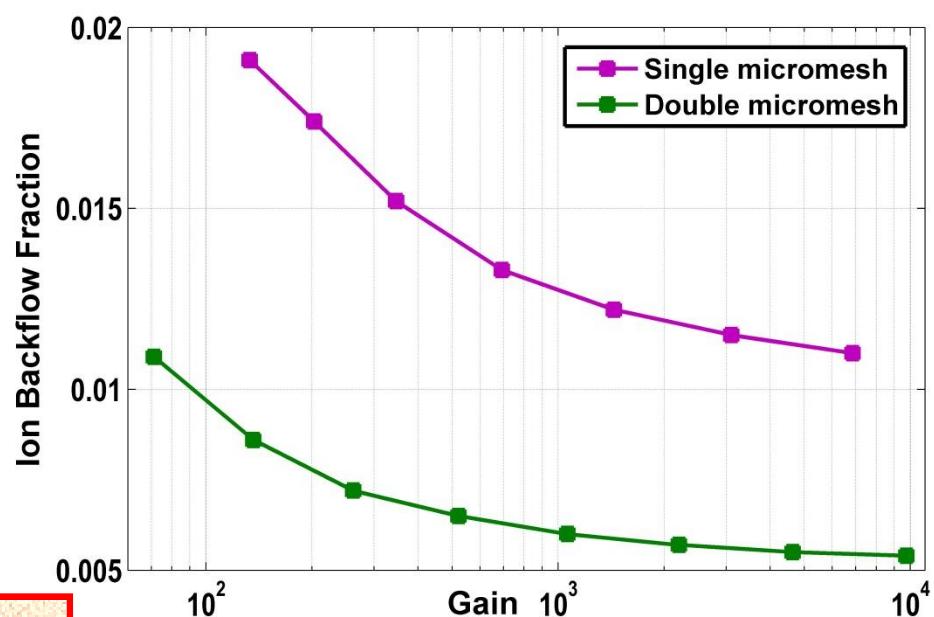
- *Fraction of electrons arrives in the amplification region from drift volume*
- *Optimum condition can be reached depending on the drift field, transfer field and amplification field*
- *Affect electron transmission considerably*





Affect detector gain, needs higher amplification field to allow same value of gain





Reduce ion backflow fraction by a factor of 2

An estimate in Ar-Isobutane Mixture (90:10):

Comparison between Single and Double Micromesh

Number of Micromesh	Drift Field (V/cm)	Transfer Field (V/cm)	Amplification Field (kV/cm)	Transmission (%)	Gain	IBF
Single	200		32	99.8	~ 1400	0.0112
Double	200	1000	37	36.7	~ 1100	0.006

Comparison between Three Different Placements of Holes

Shift between holes	Drift Field (V/cm)	Transfer Field (V/cm)	Lower Mesh Voltage (V)	Transmission (%)	Gain	IBF
0 μm	200	1000	- 470	36.7	1046	0.006
16 μm	200	1000	- 470	38.9	1139	0.0077
31 μm	200	1000	- 470	39.3	1207	0.0082

Summary:

1) Experimental and numerical studies illustrating the effect of different geometrical and electrical parameters on the ion backflow fraction.

2) New experimental setup for measuring the ion backflow fraction using Fe55 source.

3) A systematic comparison between experimental and numerical results has been carried out. These observations have helped us to understand the detector physics and guide our choice to optimal detector geometry for a given gas mixture.

4) Numerical studies to explore the effects of double micromesh to reduce ion backflow fraction.

5) The use of double micromesh lowers the backflow fraction but affects the electron transmission and gain adversely. The energy resolution is also likely to be affected.

6) A comparison between different placements of two micromesh reveals that for misalignment of holes, though the electron transmission and gain increase slightly, the backflow fraction is also larger.

On-going Work:

1) Measurement of backflow fraction in other Argon-based gas mixtures

2) Optimization of the gap and voltage difference between the two drift planes

3) Numerical studies on the space charge effect

Group Members:

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