Experimental studies of ion backflow for a bulk micromegas detector using various Argon based gas mixtures

Prasant Kumar Rout[a], Deb Sankar Bhattacharya[b], Purba Bhattacharya[c], Supratik Mukhopadhyay[a] Sudeb Bhattacharya[d], Nayana Majumdar[a], Sandip Sarkar[a], Paul Colas[e], David Attie[e], Serguei Ganjour[e], Aparajita Bhattacharya[f]

[a] Applied Nuclear Physics Division, Saha Institute of Nuclear Physics, Kolkata - 700064, India
[b]Institute Of Physics, Bhubaneswar – 751005 , India
[e]IRFU, CEA, Universit Paris-Saclay, F-91191 Gif sur Yvette, France
[f]Department of Physics, Jadavpur University, Jadavpur, Kolkata - 700032, India
[c]Department of Particle Physics and AstroPhysics, Weizmann Institute of Science, Herzl St. 234, Rehovot - 7610001, Israel
[d]Retired Senior Professor, Applied Nuclear Physics Division, Saha Institute of Nuclear Physics, Kolkata - 700064, India

- **Advanced Detectors for Nuclear, High Energy and Astroparticle Physics Conference, 15-17 February- 2017 , Bose Institute, Kolkata , India**

Outline of the talk

- Introduction
- Motivation: Why ion back flow is important?
- Micromags detector
- Performance of Micromegas
- Ion Backflow of Micromegas detector
- Ion backflow: Experimental measurement
- Ion backflow: Experimental results
- Conclusion

Introduction

- Micro Pattern Gaseous detectors (MPGD) are fast radiation detectors used in many high energy physics experiments for particle tracking and triggering.
- Micromegas and Gas Electron Multiplier(GEM) are two popular kind of MPGDs capable for charged particle tracking at high rate environments.
- These gaseous ionization detectors offer high gain and good position resolution at high luminosity environment.

Motivation: Why ion backflow is important?

- Operation of gaseous detectors is in general often limited by secondary effects, originating from avalanche-induced photons and ions.

- Ion back flow is one of the effects limiting the operation of gas detectors at high particle flux, by giving rise to space charge effects which distorts the local electric field.

- These MPGDs are amplification devices producing large number of electon ion pairs under high electric field.

- The ions drift opposite to the direction of electrons in presence of high electric field. The accumulation of these secondary positive ions often leads to significant space charge in high rate experiments, which distorts the electric field locally.

- It is important to study the IBF characteristics of these gaseous ionization detectors used in many accelerator based experiments.

Micromegas detector

- Micromegas is a parallel plate device and composed of a very thin metallic micro-mesh, which separates the low-field drift region from the high-field amplification region.
- Micromegas works on single stage multiplication.

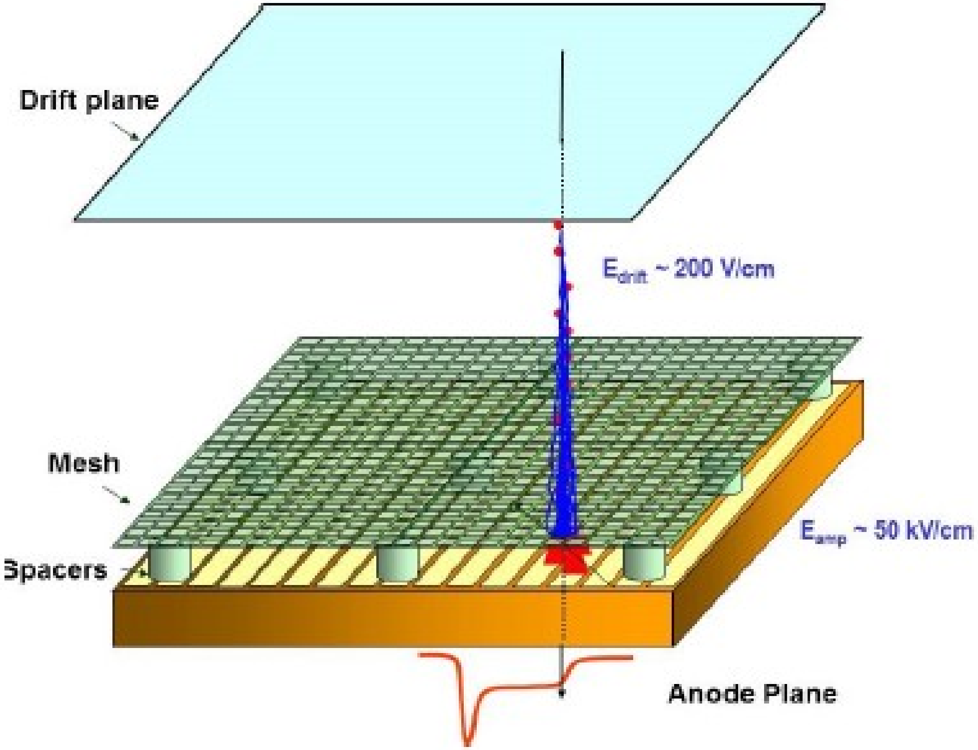


Fig 1 : Schematic diagram for micromegas detector

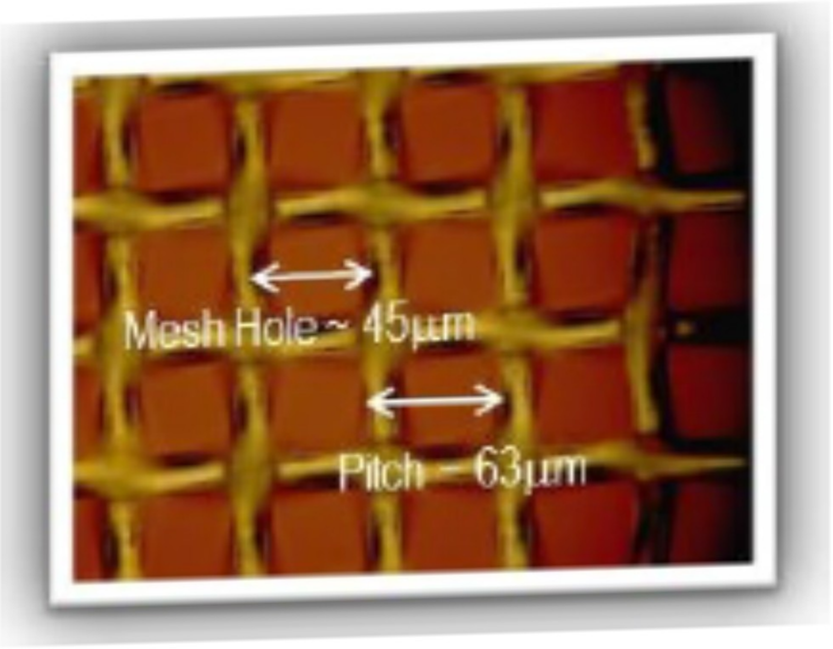
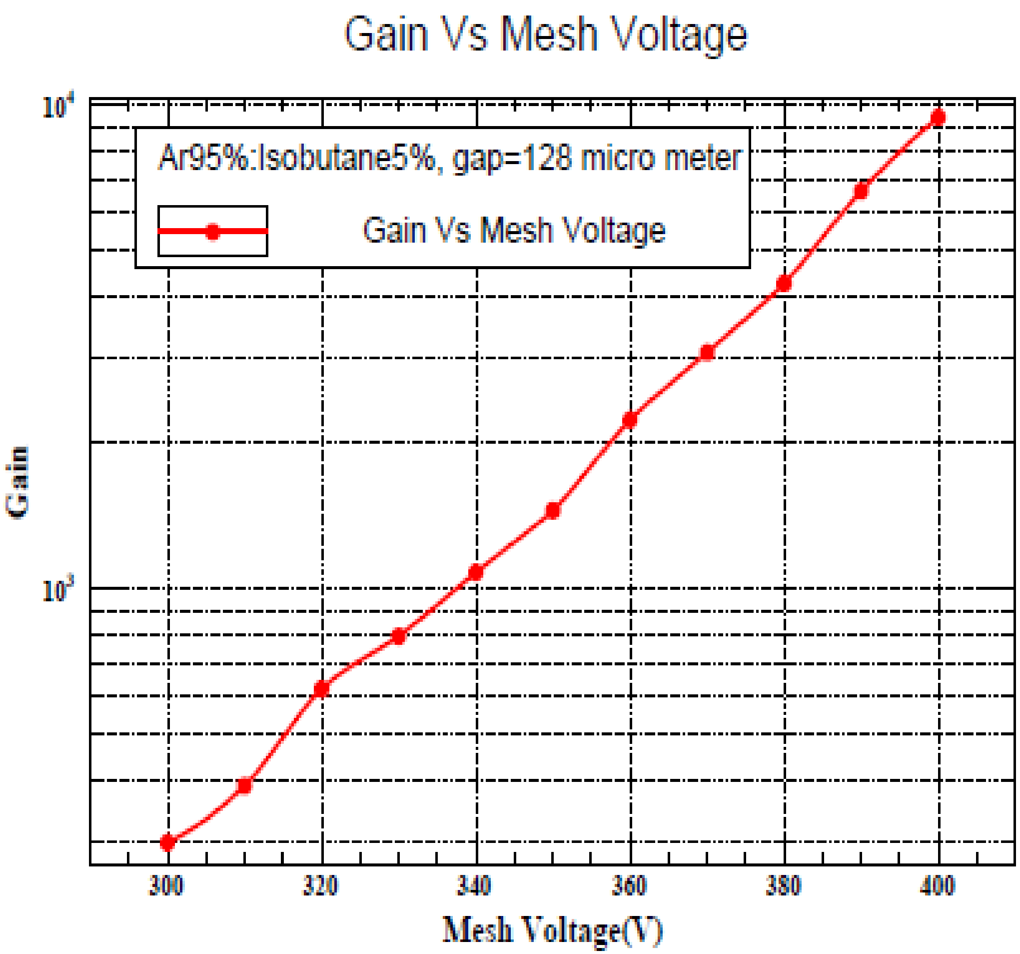
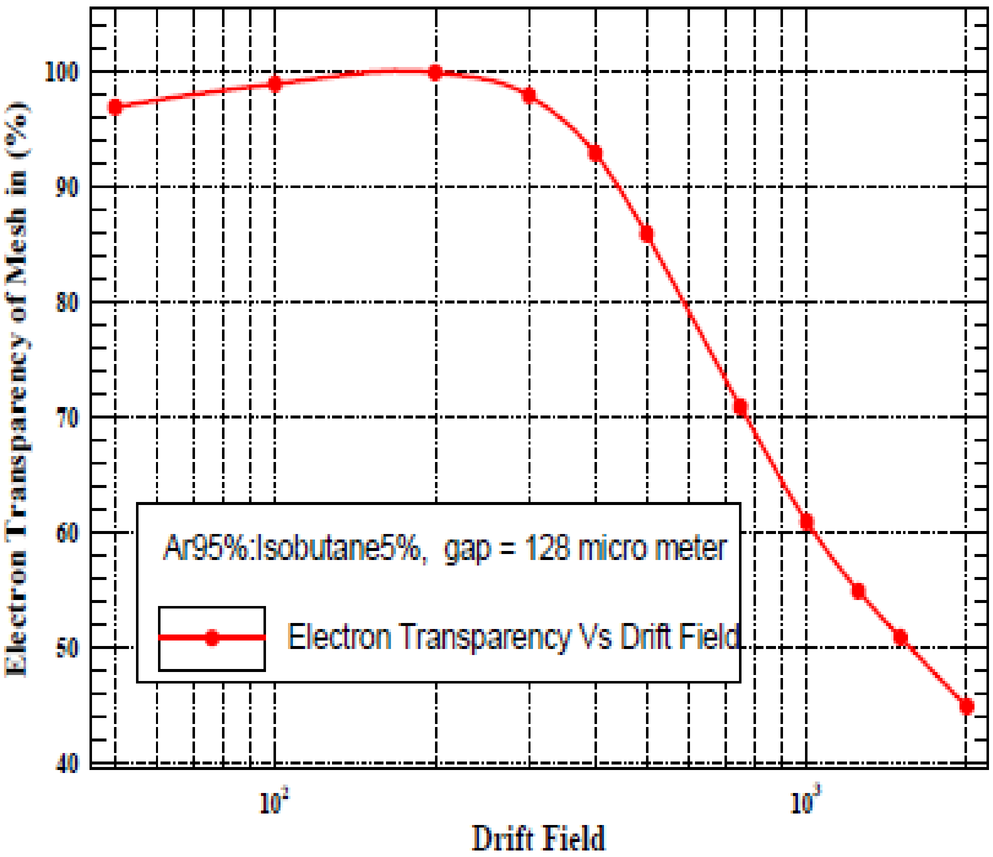


Fig 2 : Microscopic View of micromegas stainless steel wires

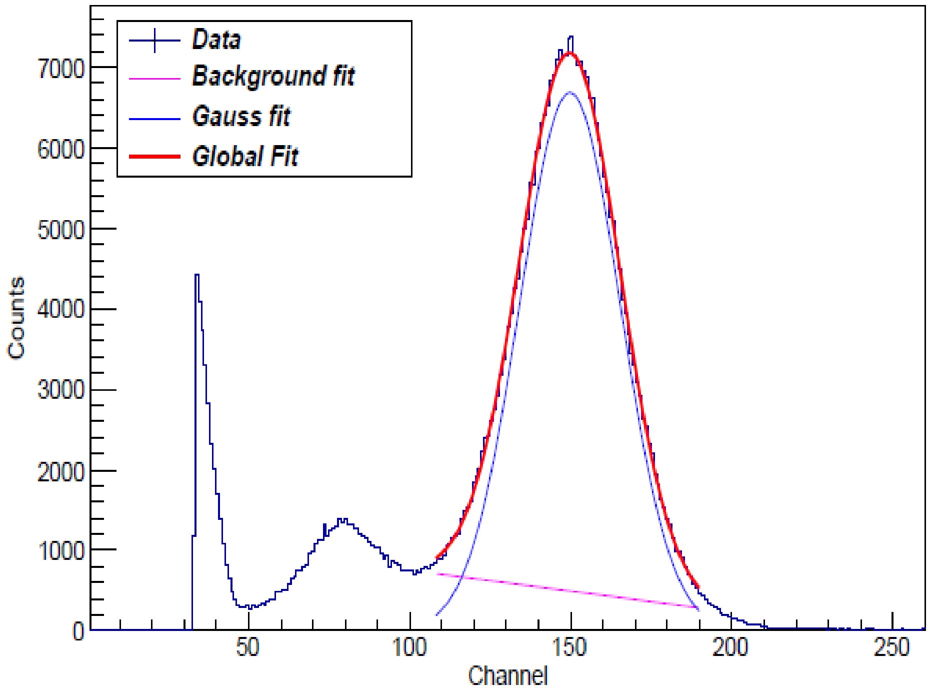
Performance of Micromegas



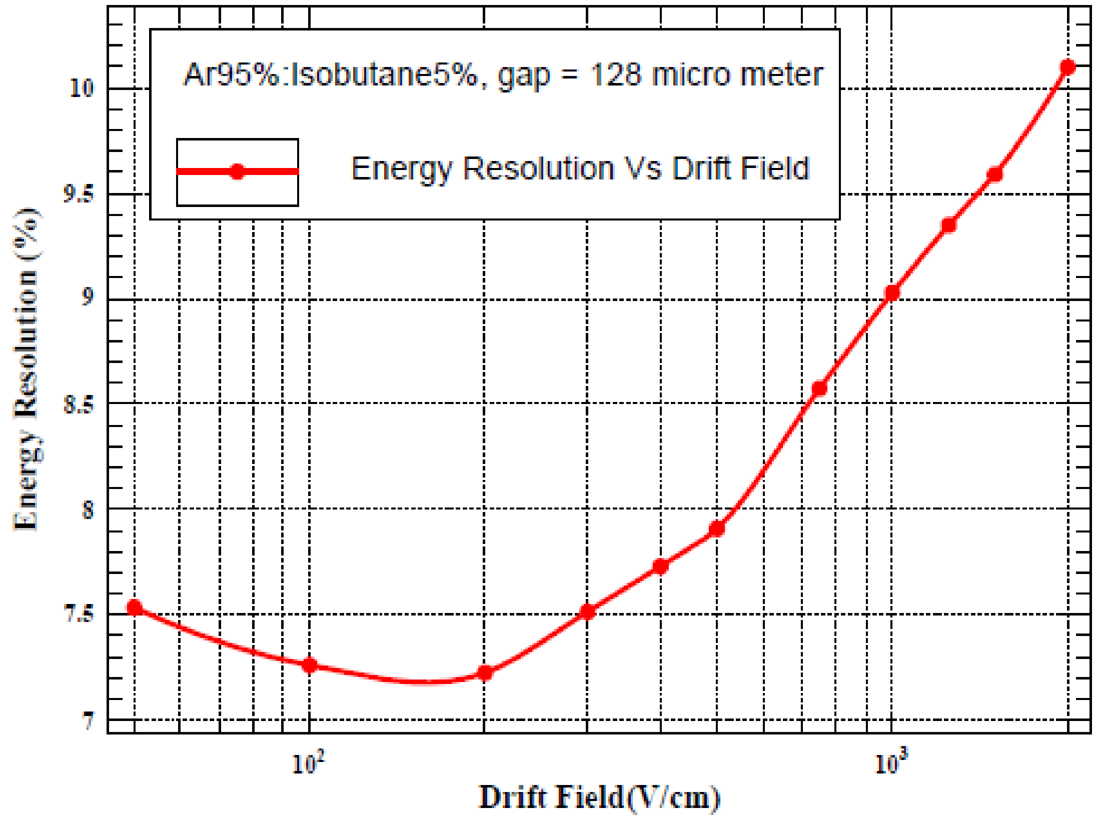
The gain is as high as 10^4.



Transparency is best at around 200 V/cm



MCA spectrum of Fe - 55



Variation of energy resolution with drift field

Ion backflow of Micromegas detector

- Charged particle radiation or neutral radiation creates primary ionizations in the drift volume of the detector.
- An electron approaching the micromesh produces an avalanche inside the funnel creating large number of positive ions and electrons.
- The ions due to their larger mass are not affected much by diffusion and drift along the field lines.
- Most of the ions are collected at the micromesh giving rise to mesh current(Im) and a very small fraction produced drifts back towards the drift volume.
- The ion backflow fraction can be defined as, $IBF = N_b / N_t$

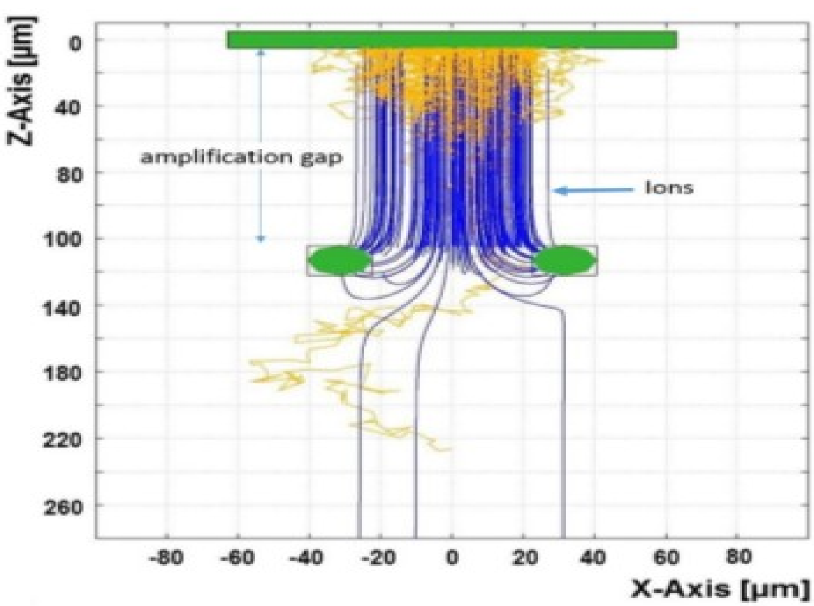


Fig 3 : Electron avalanche and ion drift lines of a micromegas detector

Ion backflow : Experimental Measurement

- Experimentally, ion backflow is estimated using a small TPC like set up.

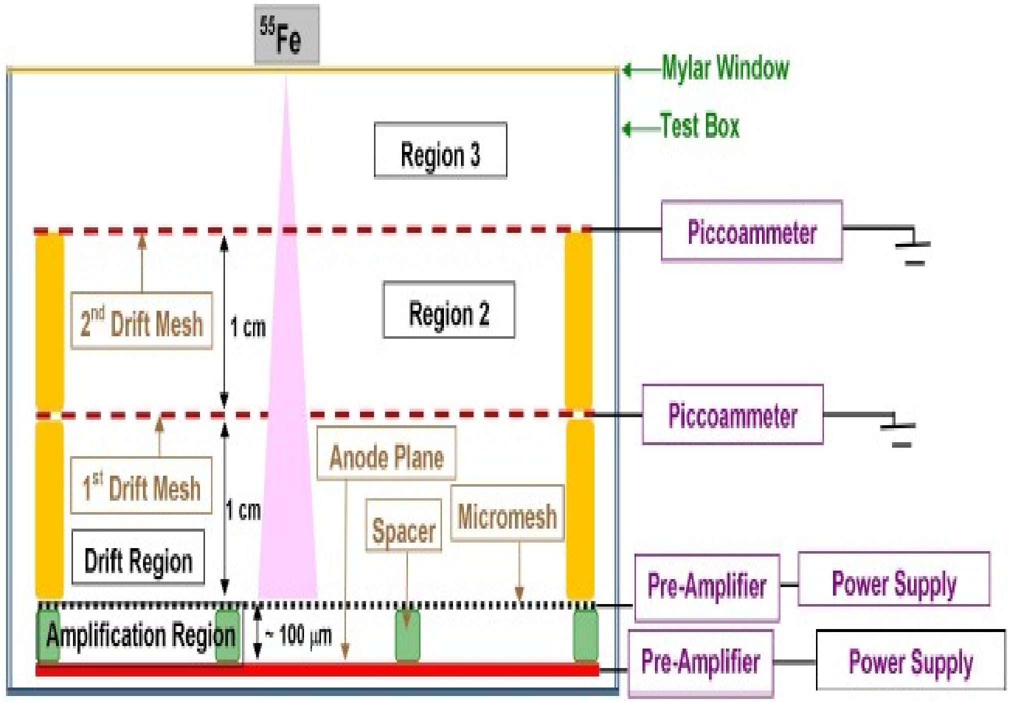


Fig 4: Schematic diagram for experimental Setup for ion backflow measurement

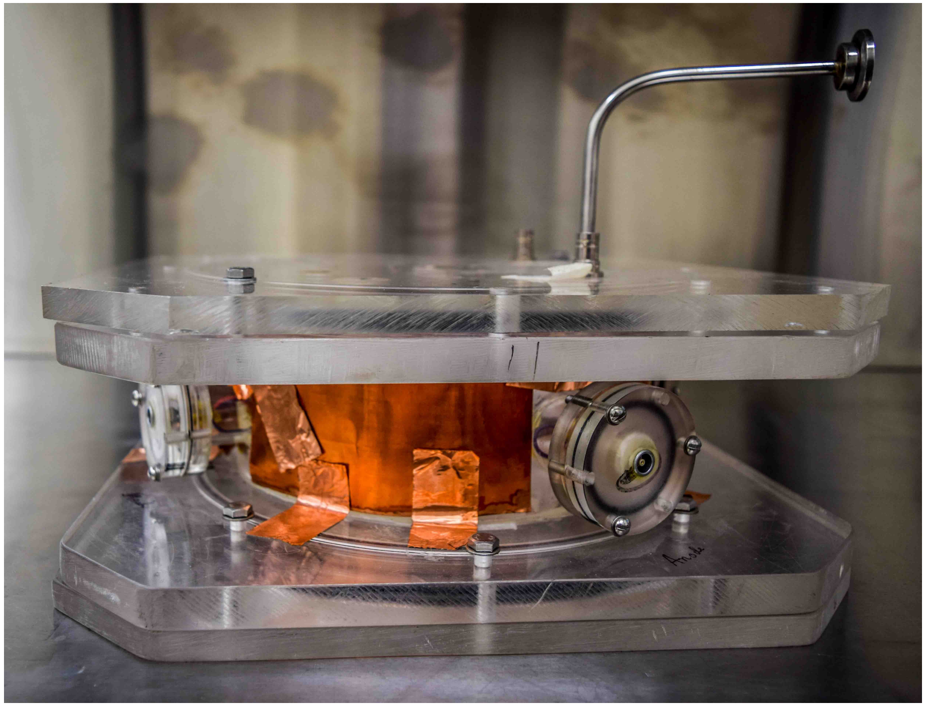


Fig 5: The small TPC setup

Ion backflow : Experimental results

- The experiment has been done with the 128 μm bulk micromegas detector using three different argon based gas mixtures such as Ar + Isobutane (95:5) , Ar + Isobutane + CF_4 (95:2:3) and Ar + CO_2 (80:20) .
- ^{55}Fe has been used as the radiation source which emits 5.91 KeV k_α X-ray photons.
- For the measurements, drift field has been varied, while amplification field remains constant.
- Experimentally ion back flow fraction can be estimated as : $IBF = I_c / (I_c + I_m)$

  Where, I_c = Current measured on the 1st drift mesh and is proportional to the number of ions collected on the drift mesh.

  I_m = Current measured in the micro-mesh and is proportional to the number of ions collected on the mesh.
- The current measurement has been done with two instruments as Danfisique current integrator and a pico-ammeter (CAEN model AH401D) which can measure the current only from the electrode which is at ground potential.
- The micro-mesh has been grounded for mesh-current measurement and lower drift mesh was grounded for drift current measurement.

IBF Measurement for Ar + Isobutane(95:5)

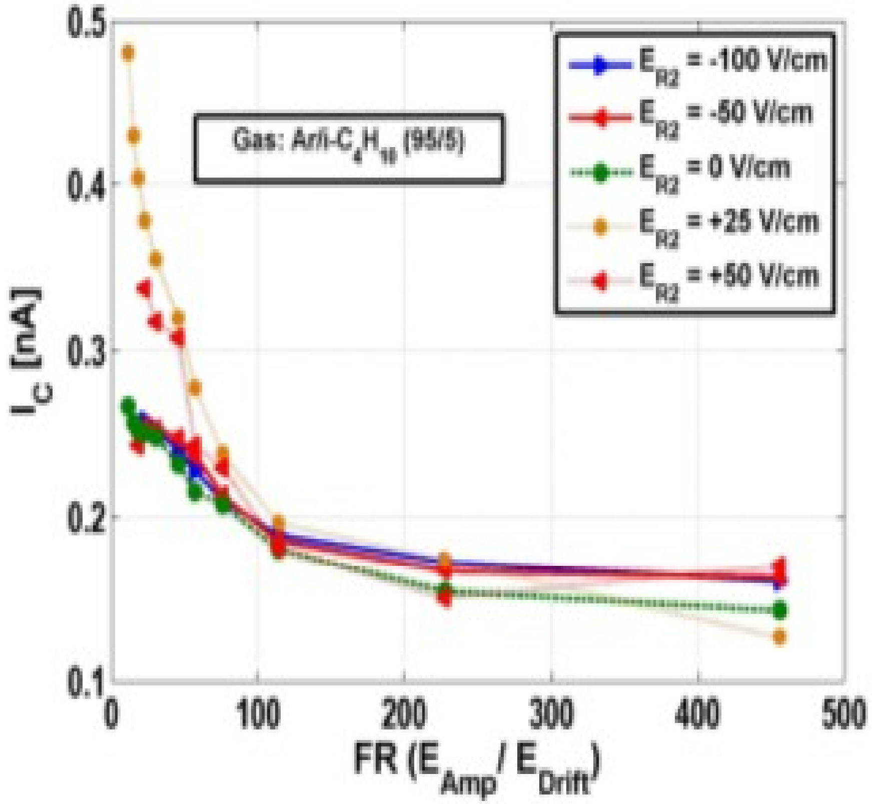


Fig 6 : Variation of I_c with field ratio

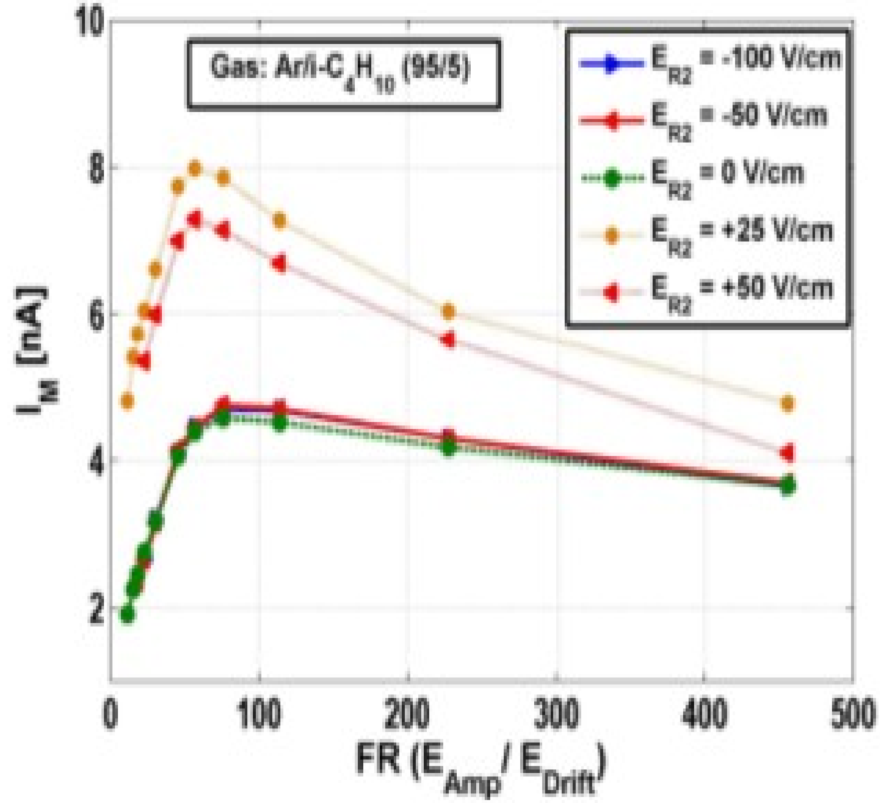


Fig 7 : Variation of I_m with field ratio

Contd.

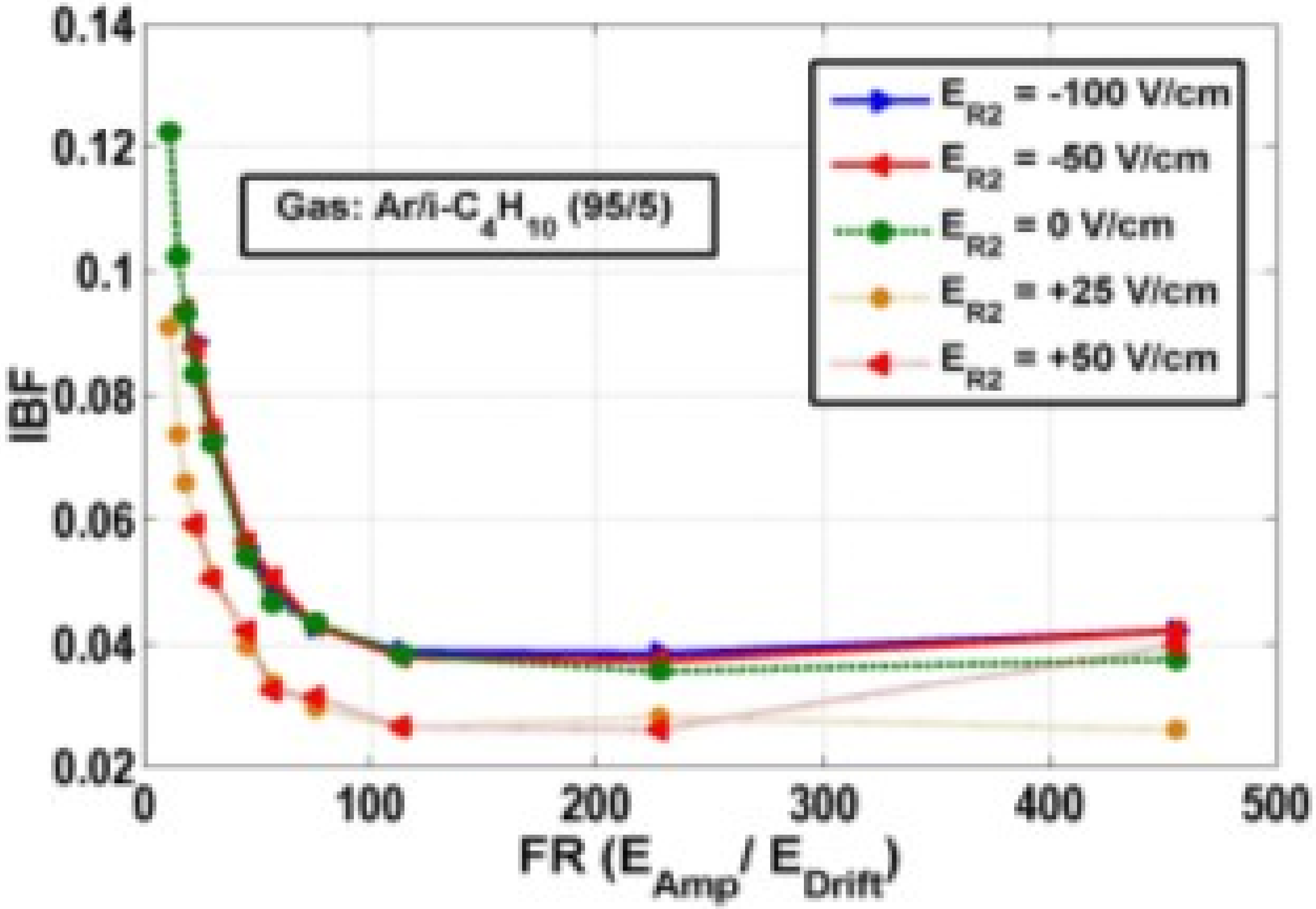


Fig 8 : Variation of IBF with field ratio

IBF Measurement for Ar + Isobutane + CF_4 (95:2:3)

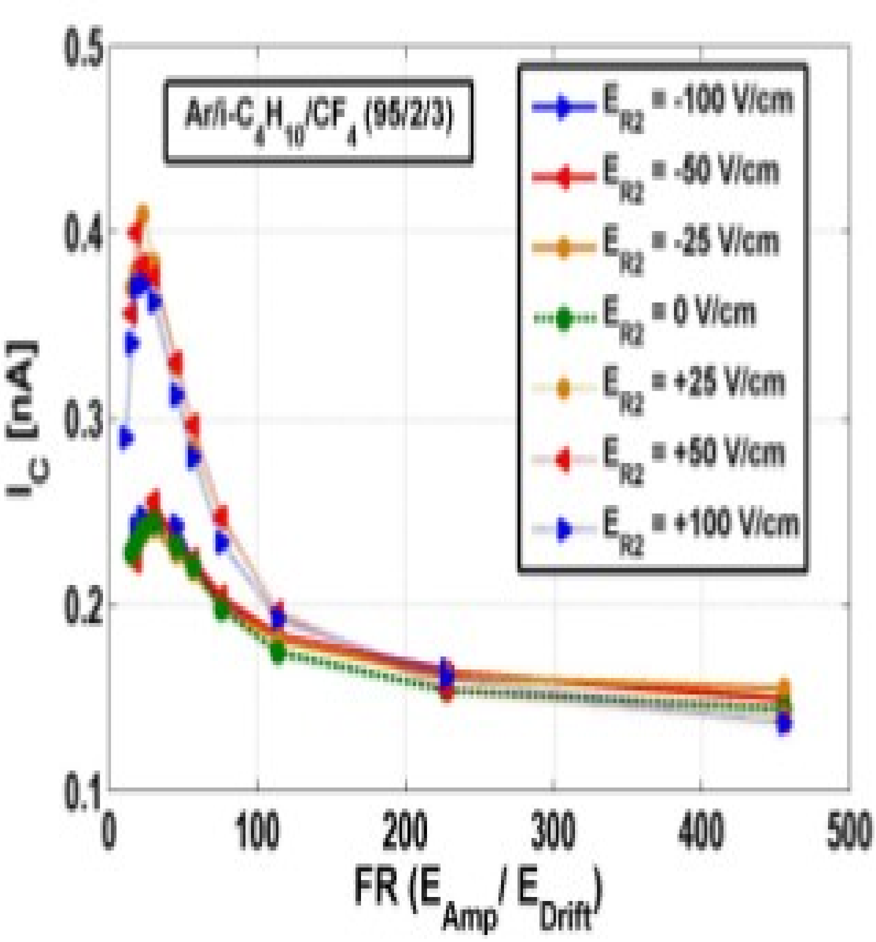


Fig 9 : Variation of I_c with field ratio

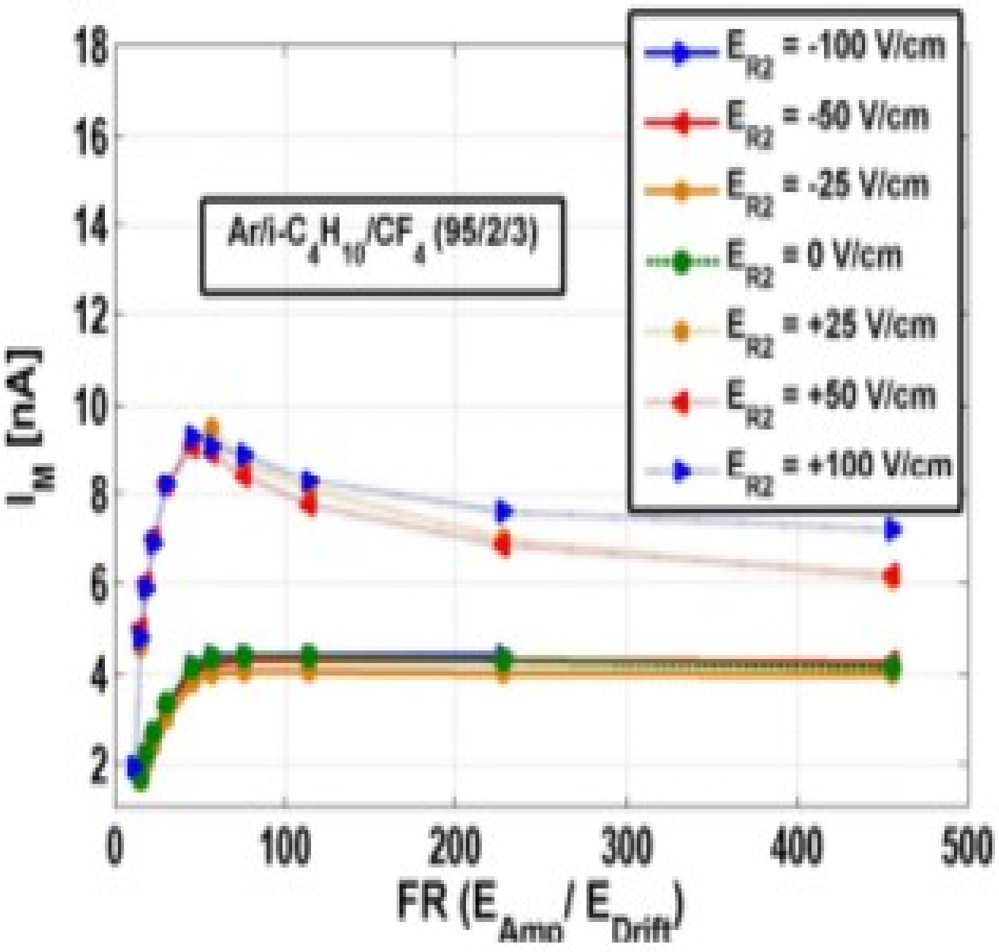


Fig 10 : Variation of I_m with field ratio

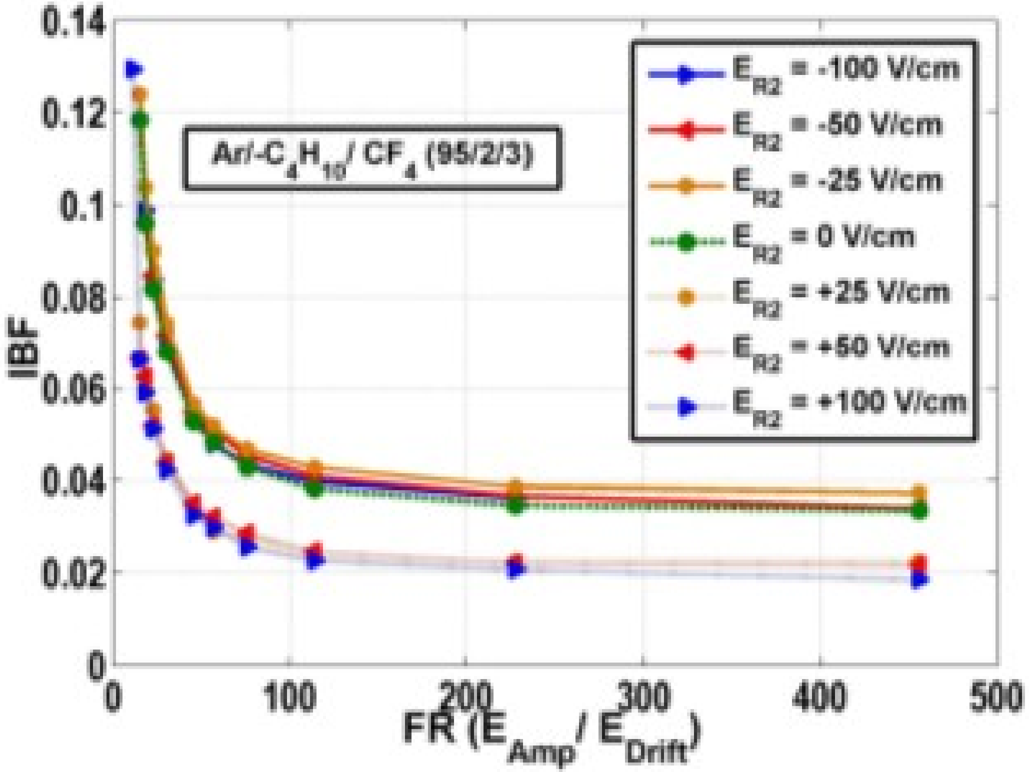


Fig 11 : Variation of IBF with field ratio.

IBF Measurement for Ar + CO_2 (80:20)

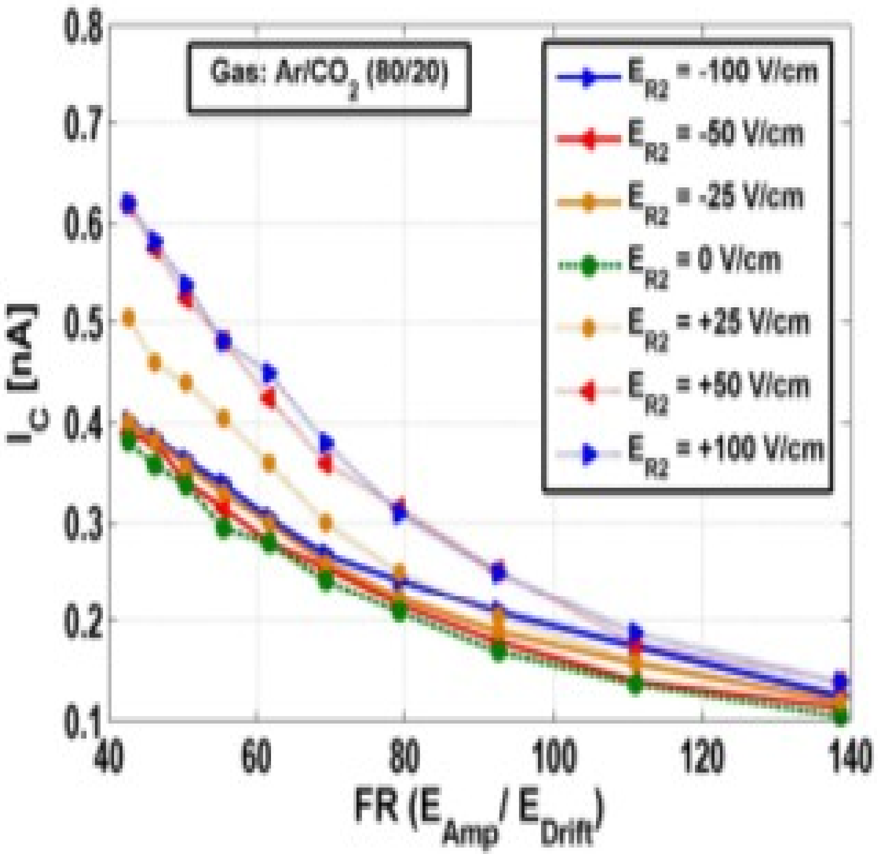


Fig 12 : Variation of I_c with field ratio

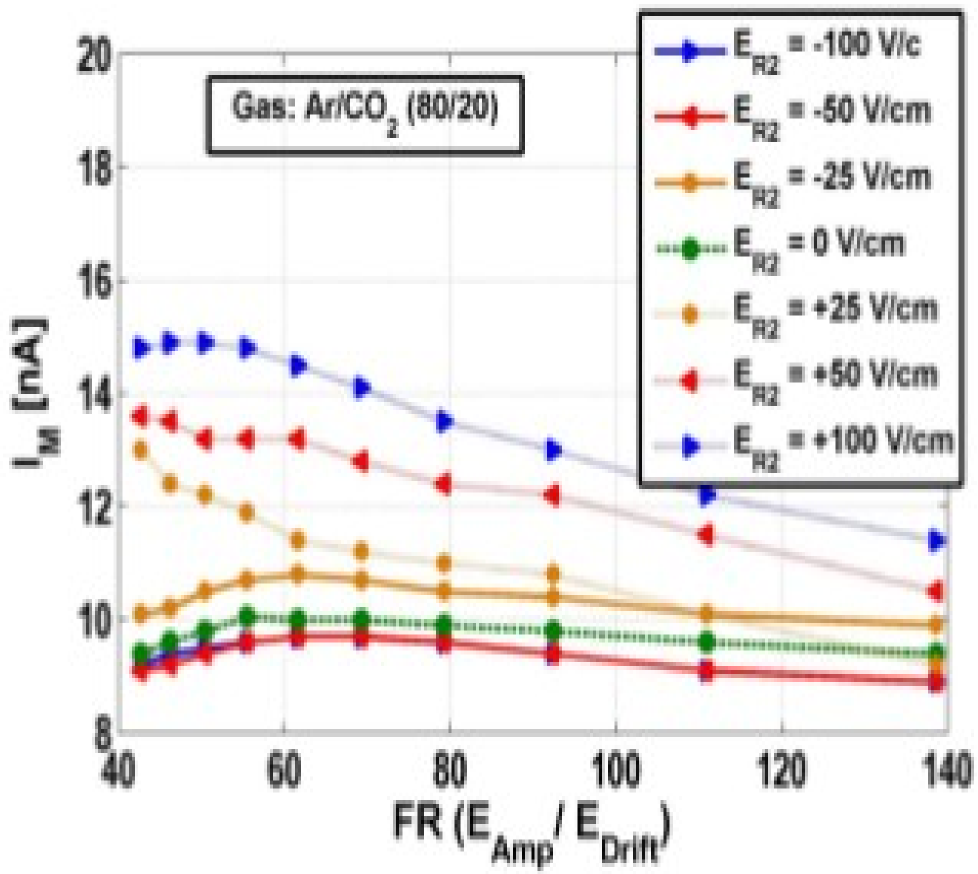


Fig 13 : Variation of I_m with field ratio

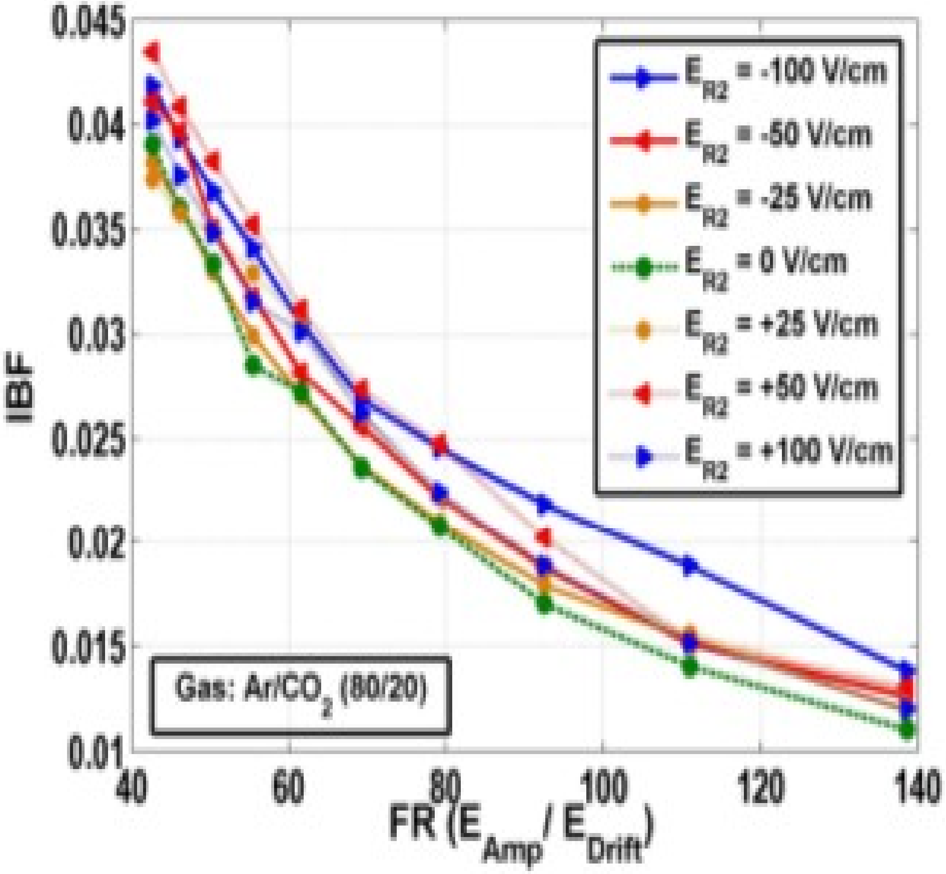


Fig 14 : Variation of IBF with field ratio

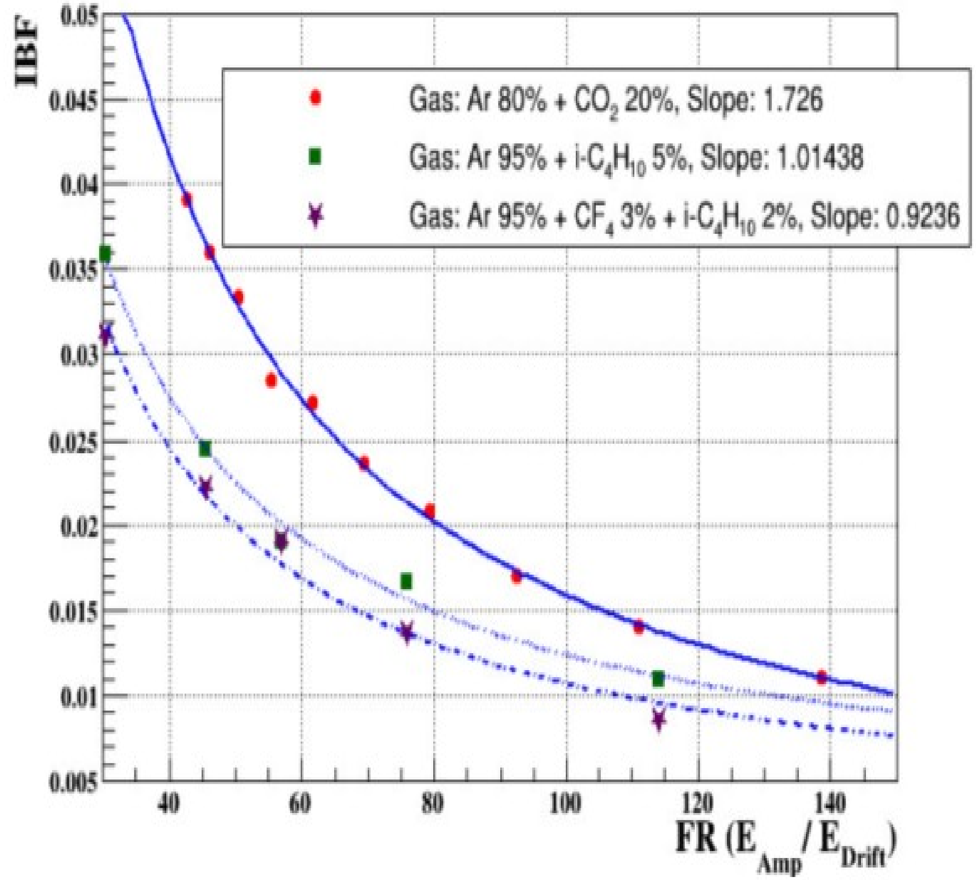


Fig 15 : Variation of Comparison of IBFs with field ratio for different gas mixtures

Conclusion

- The present work involves the measurements of cathode and the mesh currents for three argon Ar-based gas compositions and estimation of corresponding ion backflow fraction of a 128 μm bulk micromegas detector using experimental setup comprising two drift meshes.
- The Ar + CO2 composition leads to the largest IBF on comparing with other gas compositions.
- We applied potential difference between two drift meshes. A small negative field along z seems to be better to reduce ion backflow.
- However, the estimation depends on many parameters such as the gas composition, electrical, and geometrical configurations, the optimization is non-trivial and may need to be studied on a case to case basis.

Thank You