Preliminary results of Ion Backflow study for a single GEM detector

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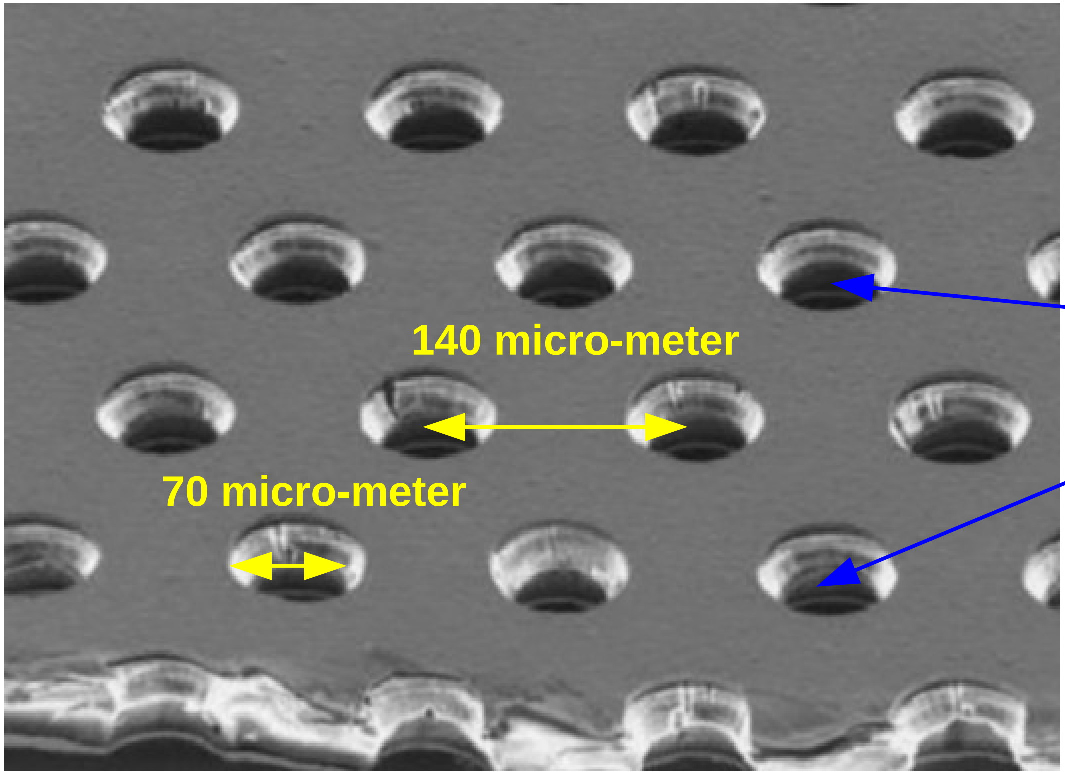
Outlook

- Operating principle of a Gas Electron Multiplier (GEM)
- GEM for the Time Projection Chamber (TPC)
- Problem of Ion Backflow in a TPC
- Assembling a single GEM at the Institute of Physics
- Results
- Discussion and future plan

Gas Electron Multiplier (GEM) is type of Micro-Pattern Gaseous Detector (MPGD), which is widely used in Low Energy Physics, High Energy Physics experiments, as well as in imaging / tomography based applications.



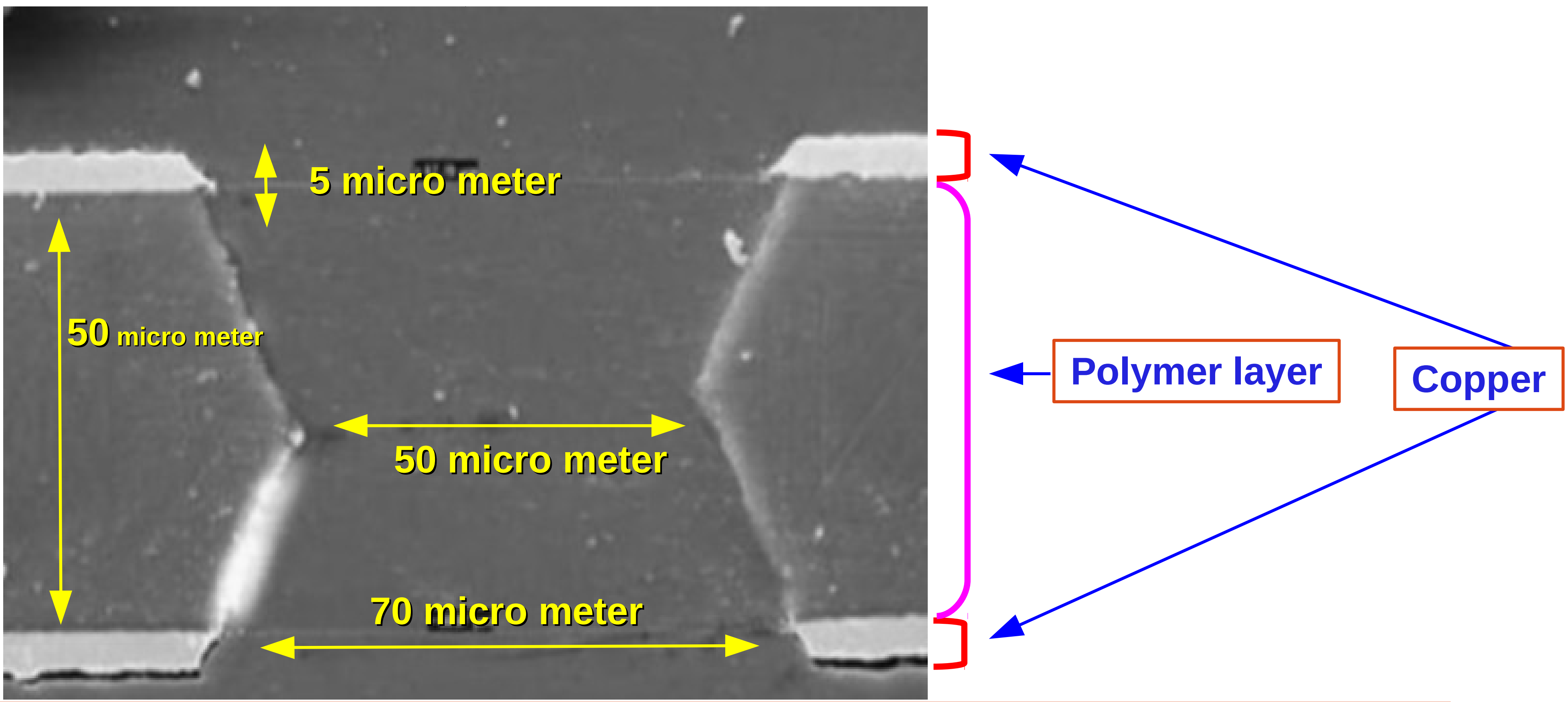
GEM Holes

Standard GEM of 70/140

A GEM comprises a polymer foil, with metal coating on both the sides. The foil is patterned with a matrix of identical holes, typically 50-100 per mm^2.

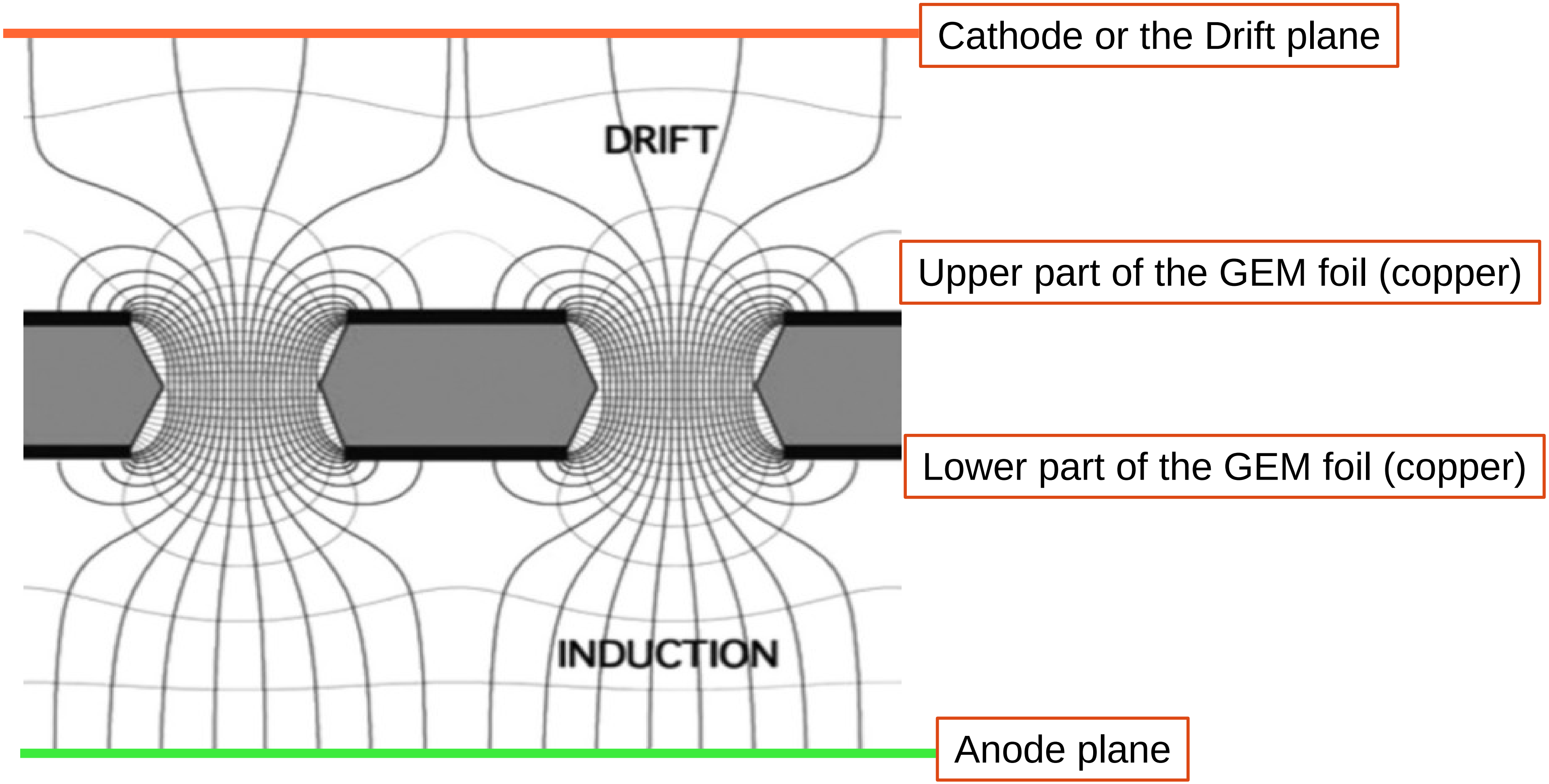
The GEM foil is pierced using chemical etching and photolithography technique.

The shape and the pitch of the holes may vary.
A typical and widely used shape is double-conical shape.

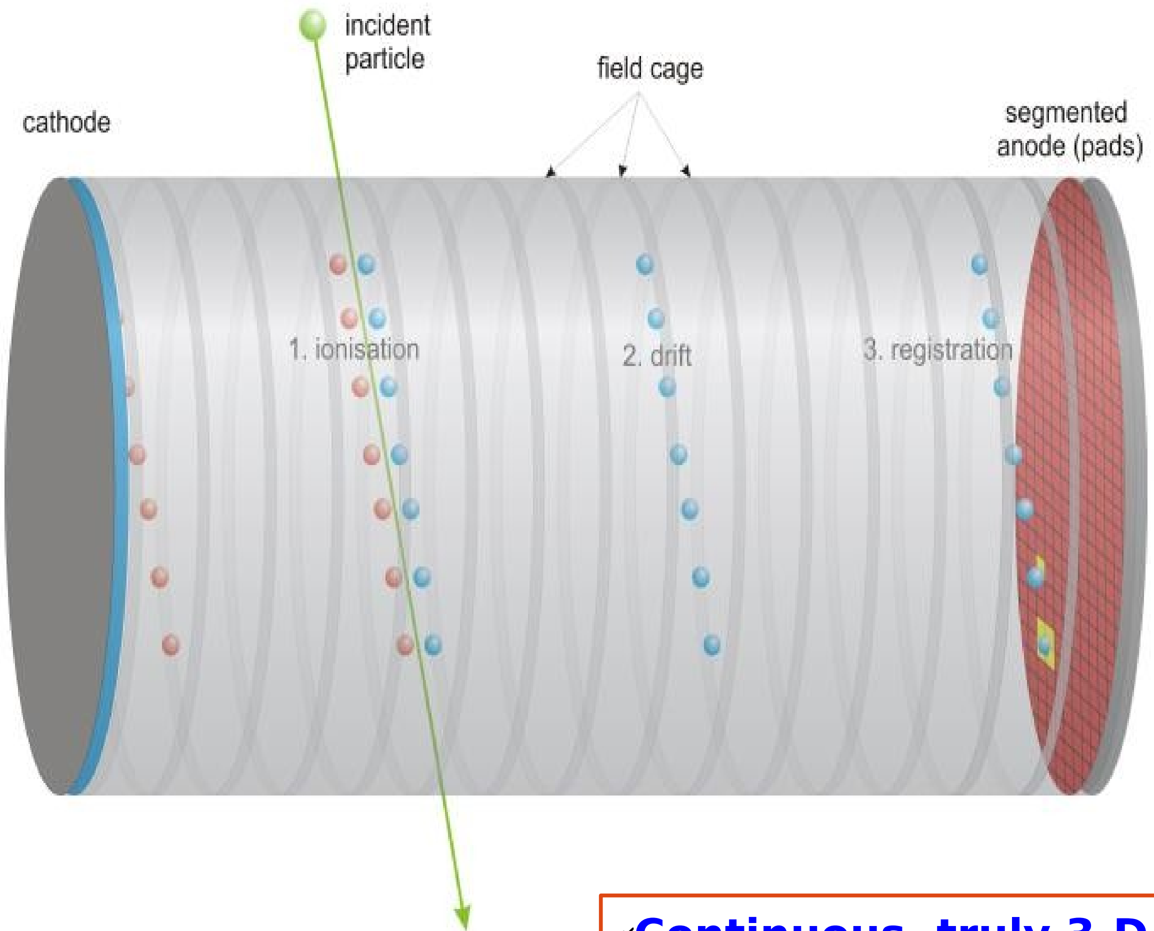


In our experiment, we are using a GEM foil of such geometry.

In a closed volume of gas, when the radiation ionizes the gas, by applying suitable potential difference between the two copper sides of a GEM foil, the electrons are collected, multiplied and then driven to the signal collection plane.



In the present-day as well as upcoming High Energy Collision Experiments, the Time Projection Chambers are adopted for tracking the charged particles.



Time Projection Chamber is a compact device, for projective track recognition, momentum measurement, and Particle Identification.

It consists of the cylindrical field cage, the cathode plane and the gas amplification devises on the anode plane.

- ✓**Continuous, truly 3-D tracking.**
- ✓**Robust pattern recognition.**
- ✓**High efficiency tracking over large momentum range.**
- ✓**Low material budget.**

The ALICE TPC

A TPC for tracking has been used by the ALICE detector and a TPC-based tracking is conceived by the ILD for the upcoming ILC.

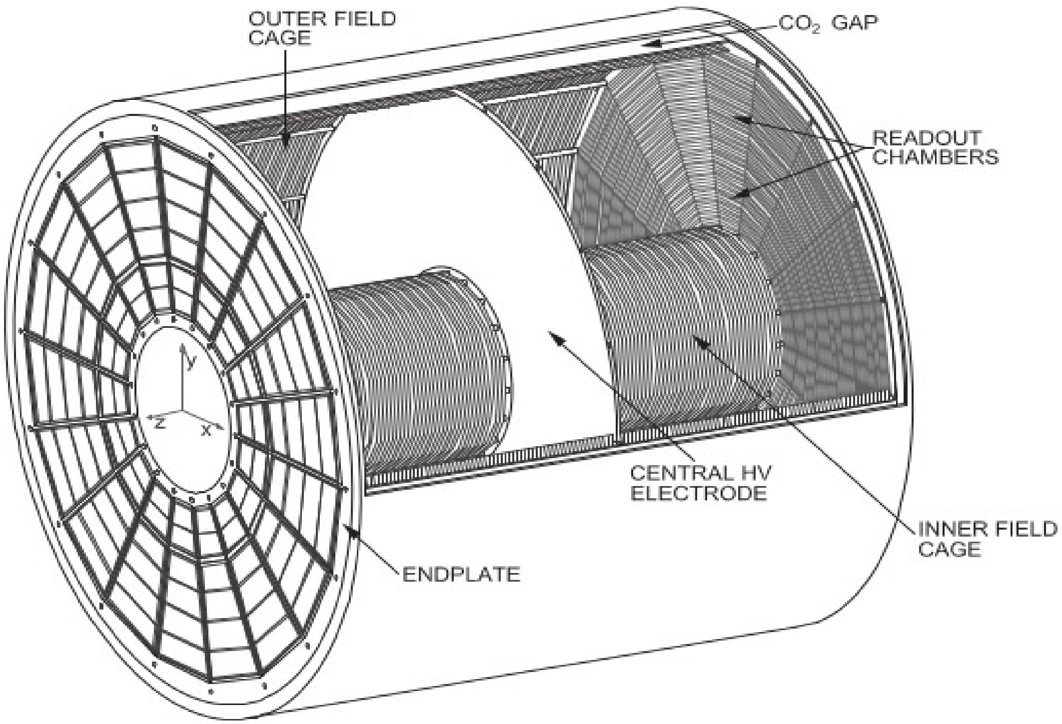


Figure 2.1: Schematic view of the ALICE TPC.

The ALICE applies a MWPC-based readout for their TPC. The readout plane comprises 72 MWPC-based readout chambers, thus in total 550,000 readout pads.

Problems due to Ion Backflow and the ALICE-TPC upgrade

The MWPC based gas amplification technique does not have intrinsic ion suppression. The ions from the amplification region slowly migrates to the drift volume. Because of their low mobility, the ions are accumulated in TPC, creating a localized distortion of drift field and thus resulting in gain drop and track distortion.

An active bipolar Gating Grid (GG) is operated in alternating potential of +-90 volt. The GG scheme effectively introduces a dead time of 280 micro-sec to the TPC, hence, limiting the TPC performance to 3.5 kHz.

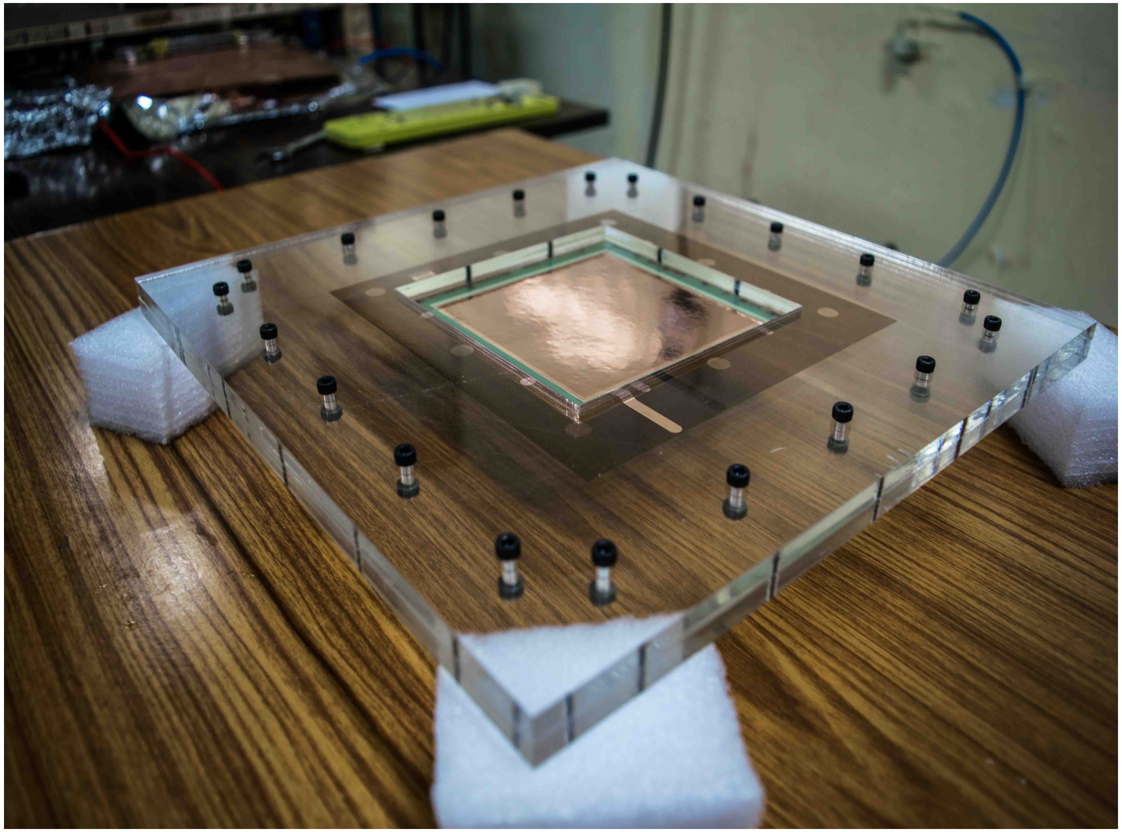
GEMs have shown efficient performance in high-rate environment and provide intrinsic ion blocking. A GEM-based readout is thus way better for a TPC to operate in ungated mode at the collision rates of 50 kHz.

Therefore the MWPC-based readout will be replaced by GEM-based readout after the increased Pb–Pb collision rate of the LHC in RUN 3.

Experimental Setup at Institute of Physics

We started study from a single GEM setup and measured the Ion Backflow for it.

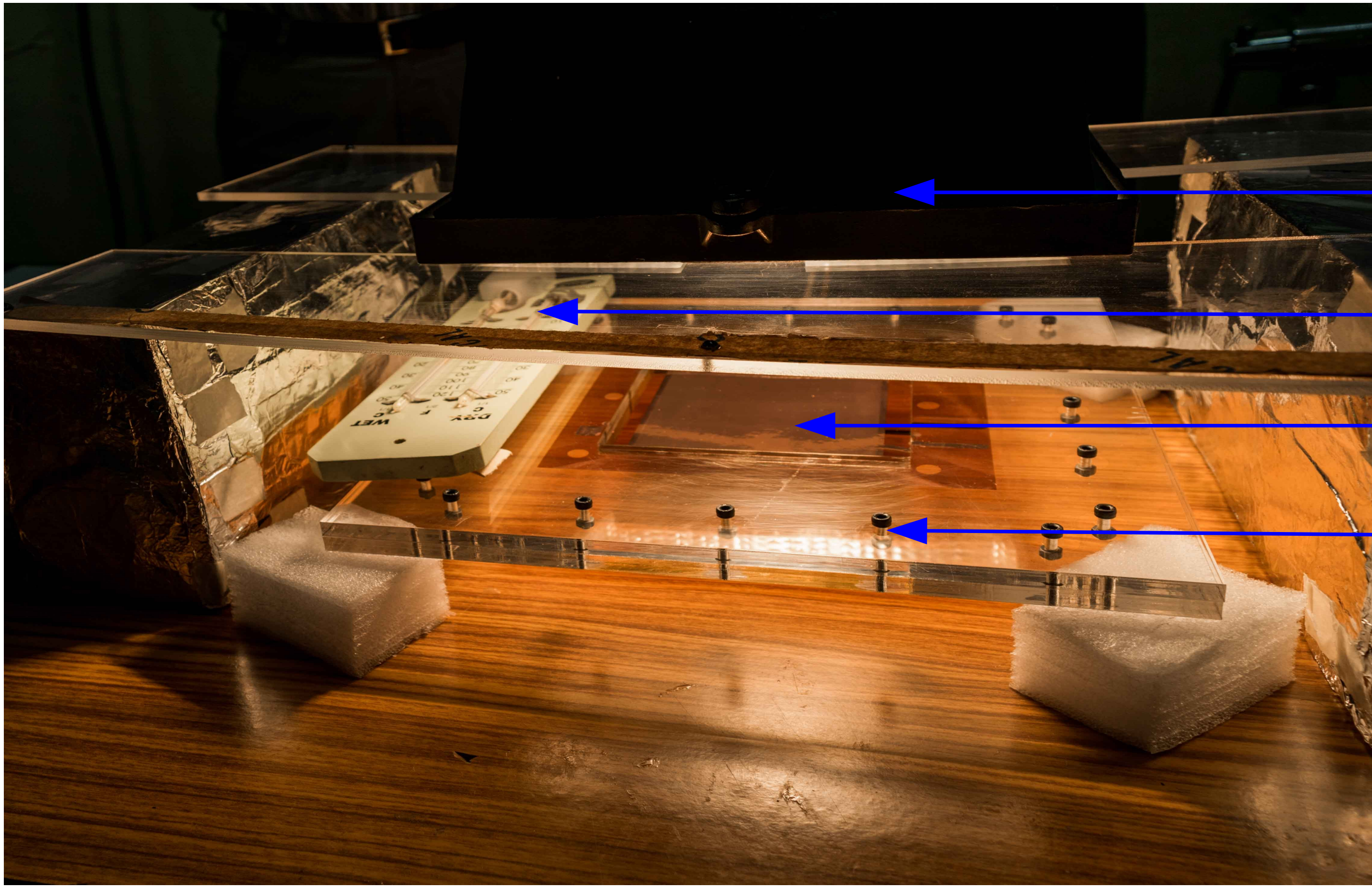
The GEM foils and the necessary components were procured from CERN. At the IOP-Lab, we stretched a GEM foil and then assembled a single GEM setup.



For thermal stretching of a GEM foil, we designed a 30 cm X 30 cm, two fold acrylic frame at the IOP-workshop.

The two halves of the frame are attached with the help of 20 equispaced Bolts to ensure uniform tension on the GEM foil.

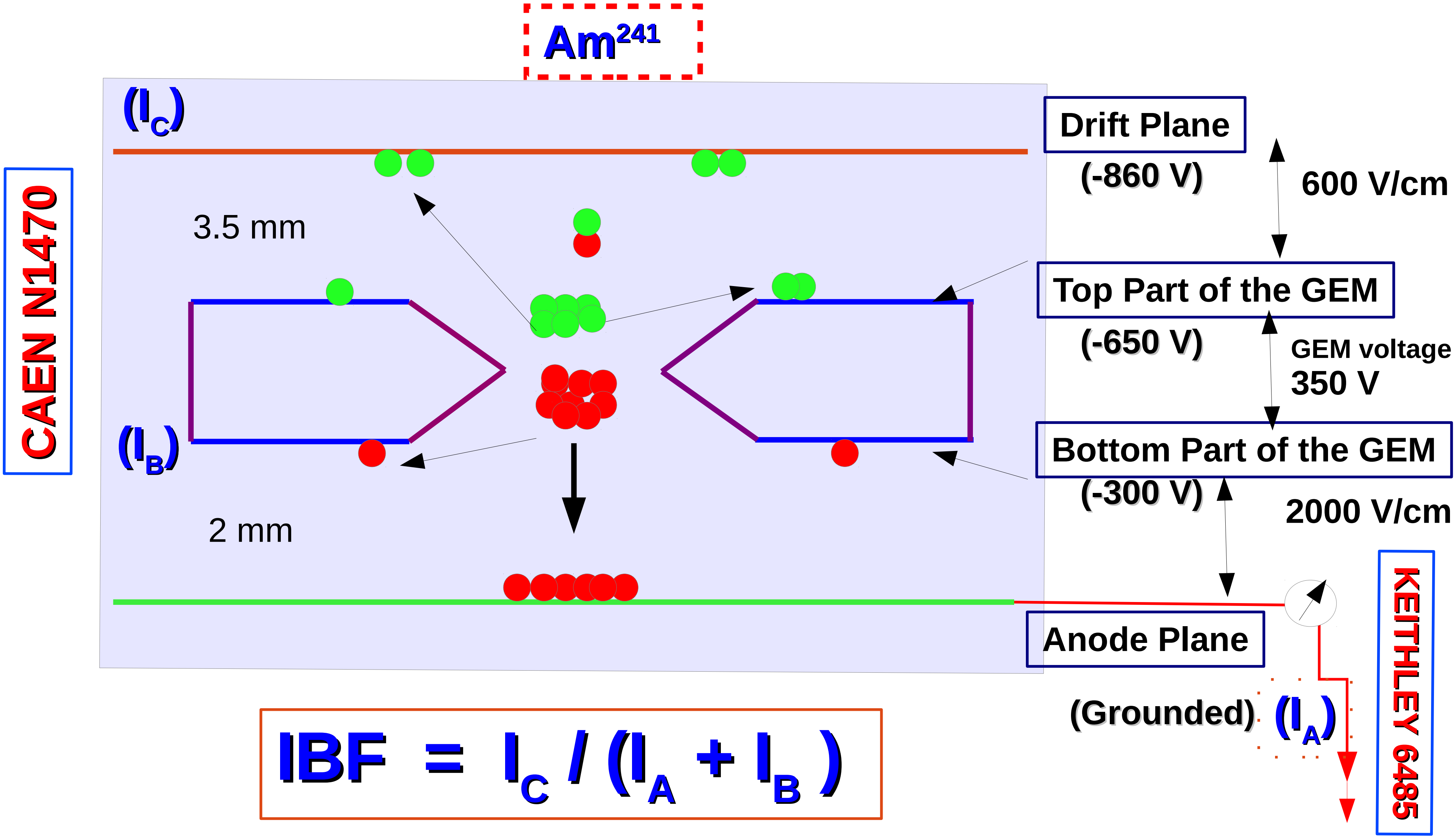
Experimental Setup at Institute of Physics



After the GEM foil is placed between the frames and the screws are uniformly tightened the system is heated in a controlled way.

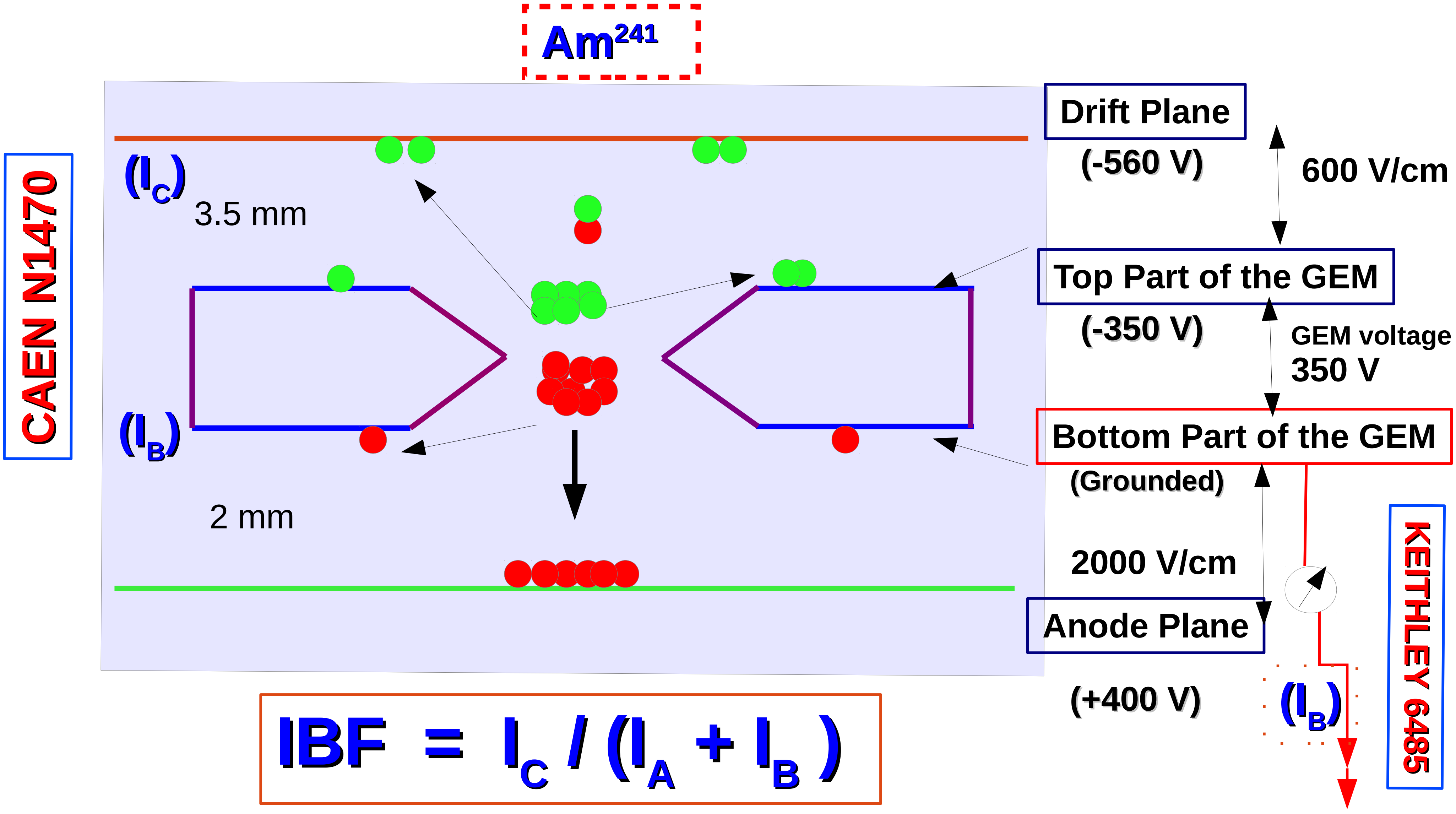
A Halogen Lamp is used as the heat source. A thermometer is kept nearby to monitor heat.
The glued frame is placed when the temperature is between 42^o – 44^o C.

Block Diagram for the single GEM setup



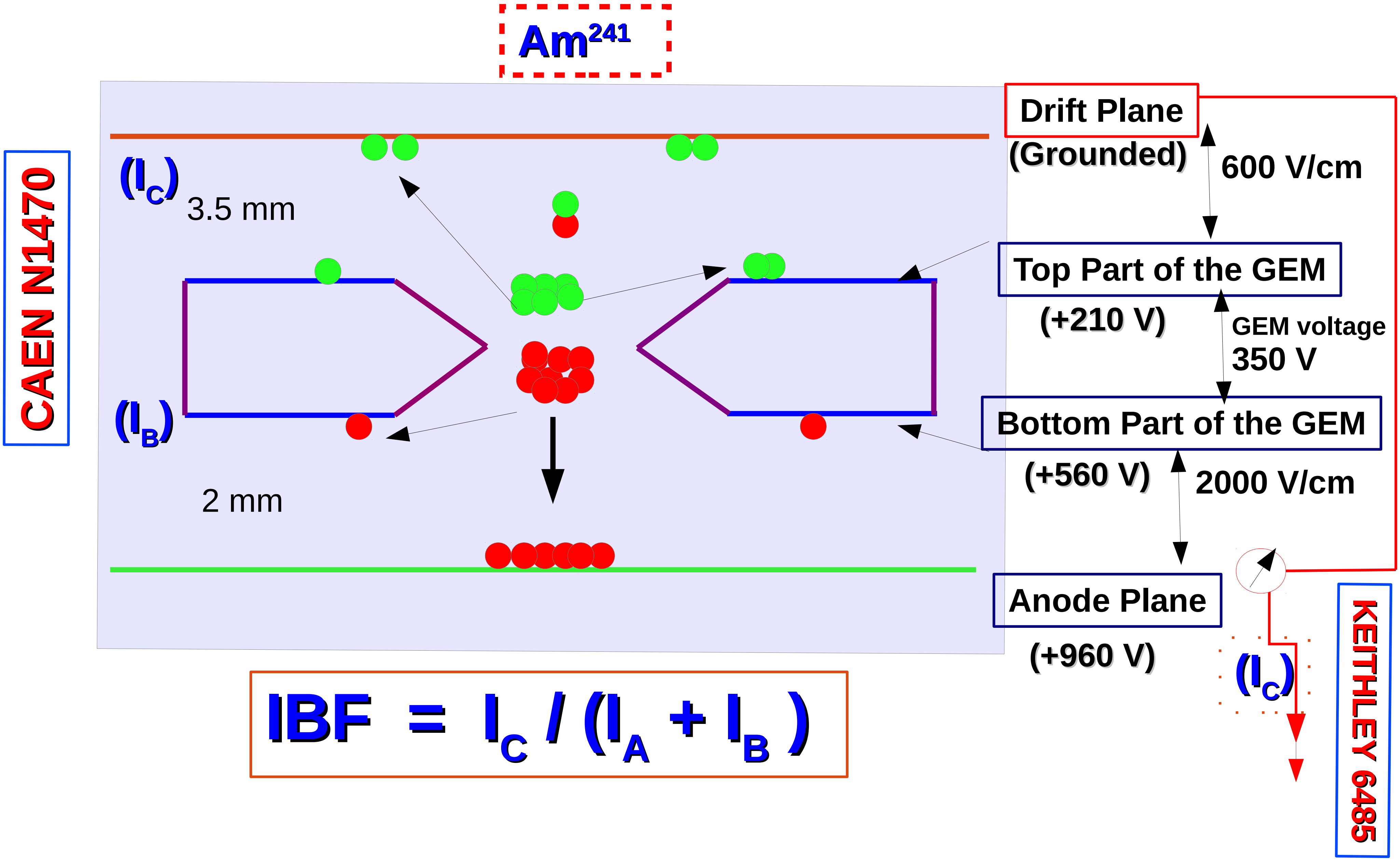
$$IBF = I_C / (I_A + I_B)$$

Block Diagram for the single GEM setup



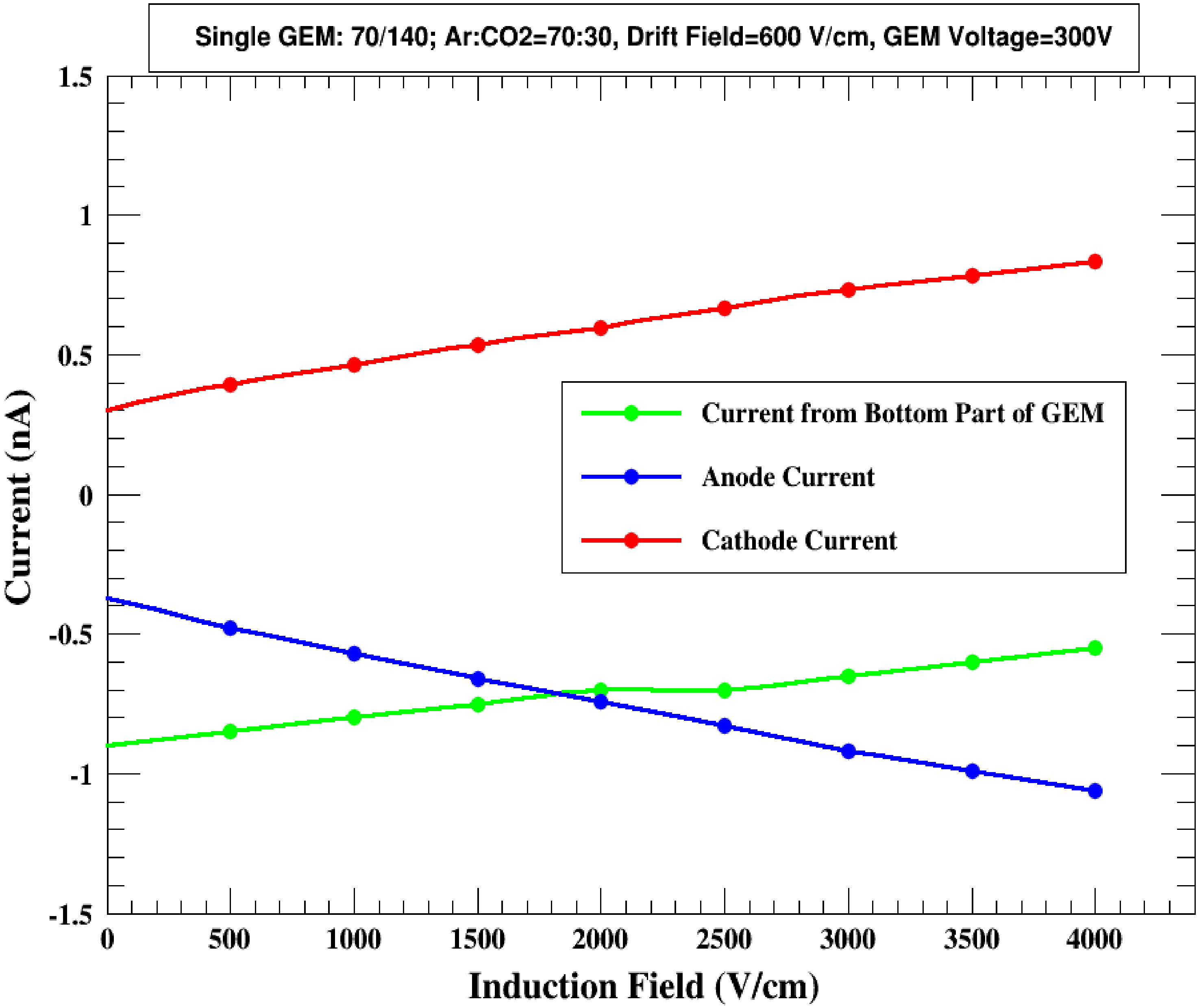
$$IBF = I_C / (I_A + I_B)$$

Block Diagram for the single GEM setup



$$IBF = I_C / (I_A + I_B)$$

Induction Field Scan

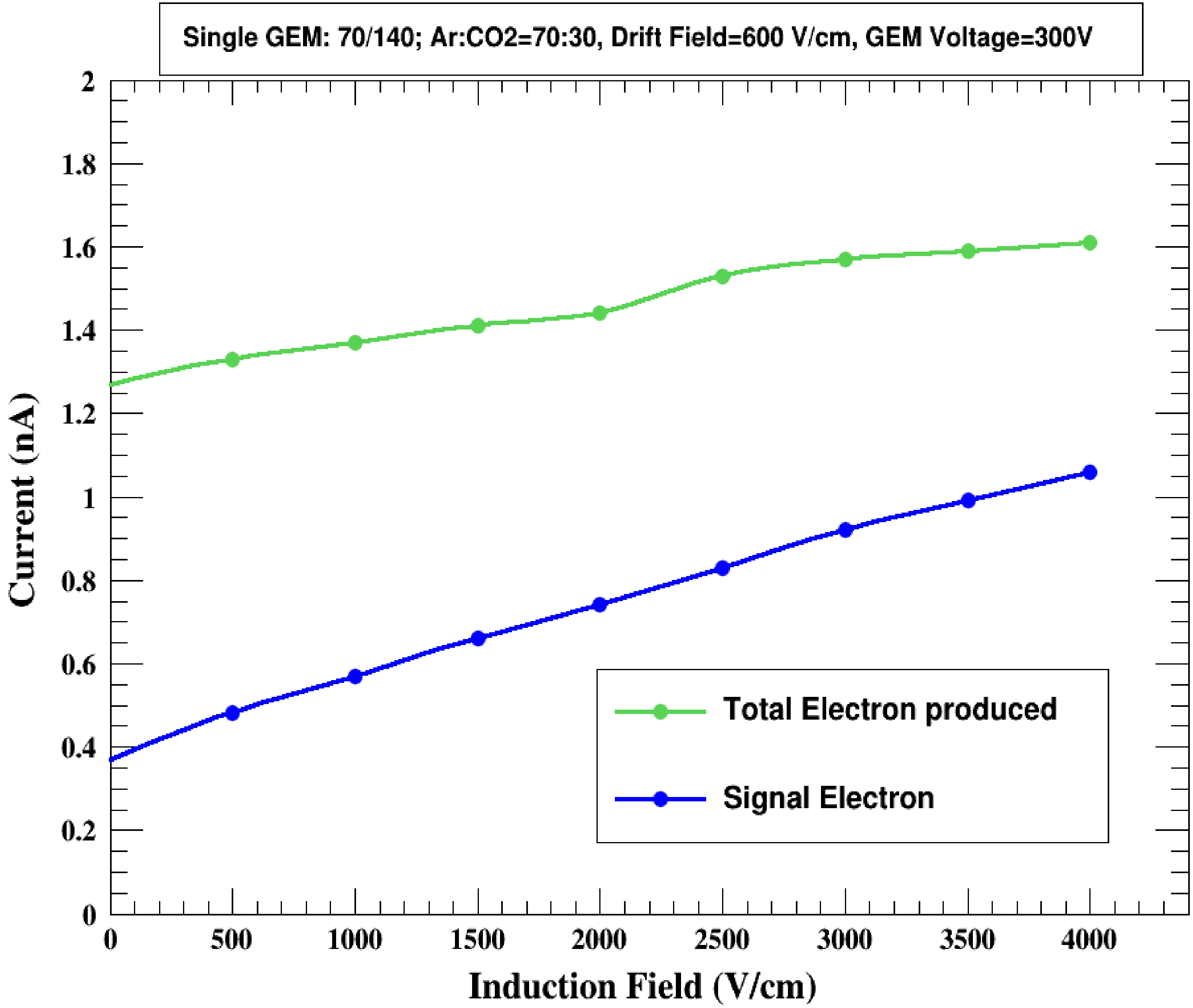


Anode (Electron) Current is increasing with Induction Field.

Since electron extraction is getting better, with increasing Induction field, the Bottom Current (Electron) is decreasing.

Cathode (Ion) Current is also increasing with Induction Field.

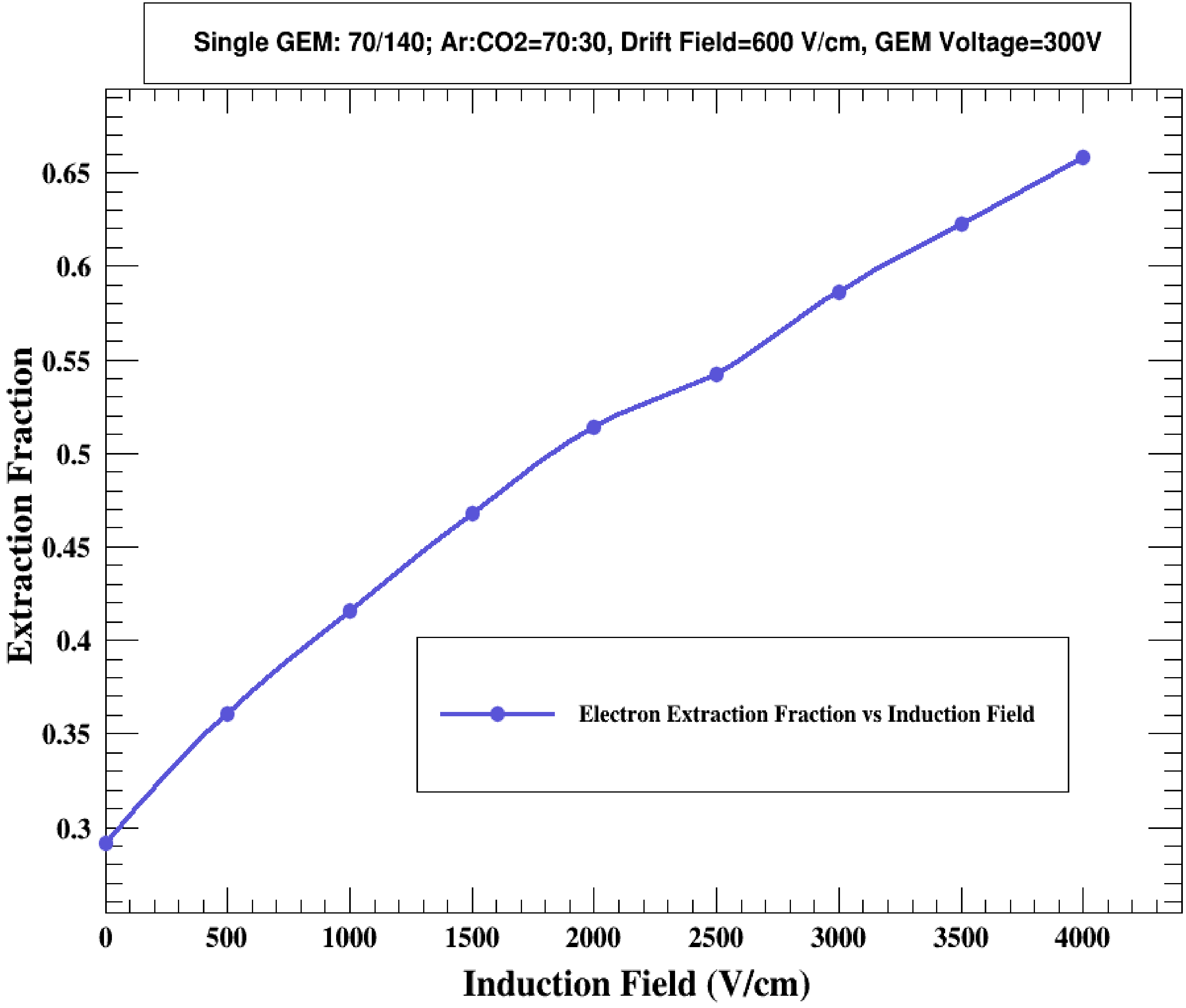
Induction Field Scan



$I_{Tot} = |I_A| + |I_B|$

$|I_A|$ (electron collection at anode) increases with Induction Field.

Induction Field Scan

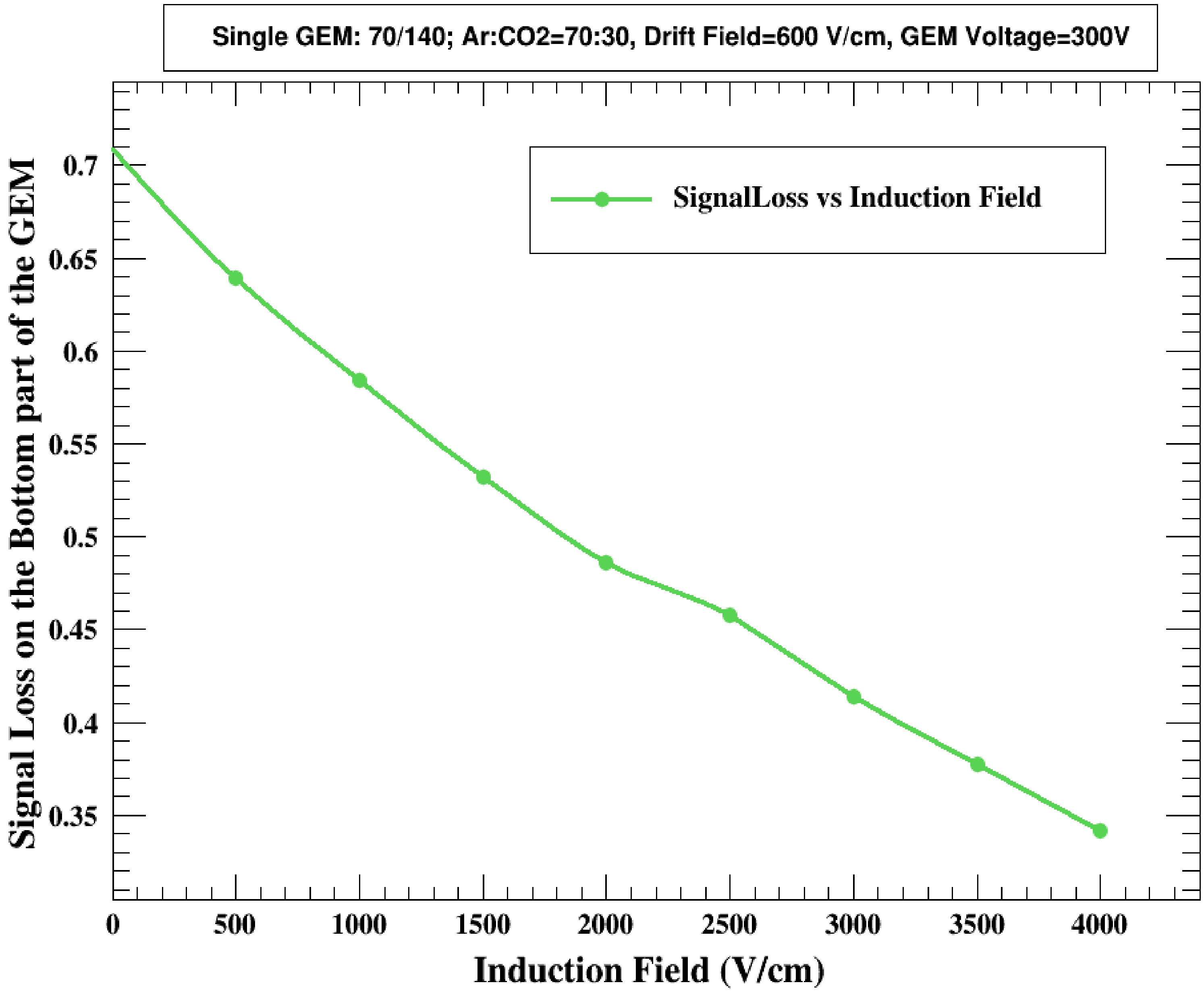


$$F_{Ex} = I_A \ / \ (I_A + I_B)$$

With increasing Induction field, the extraction of the electrons from the GEM holes also increases.

In present configuration, the extraction, for instance, at an induction field of 2kV/cm is nearly 50%.

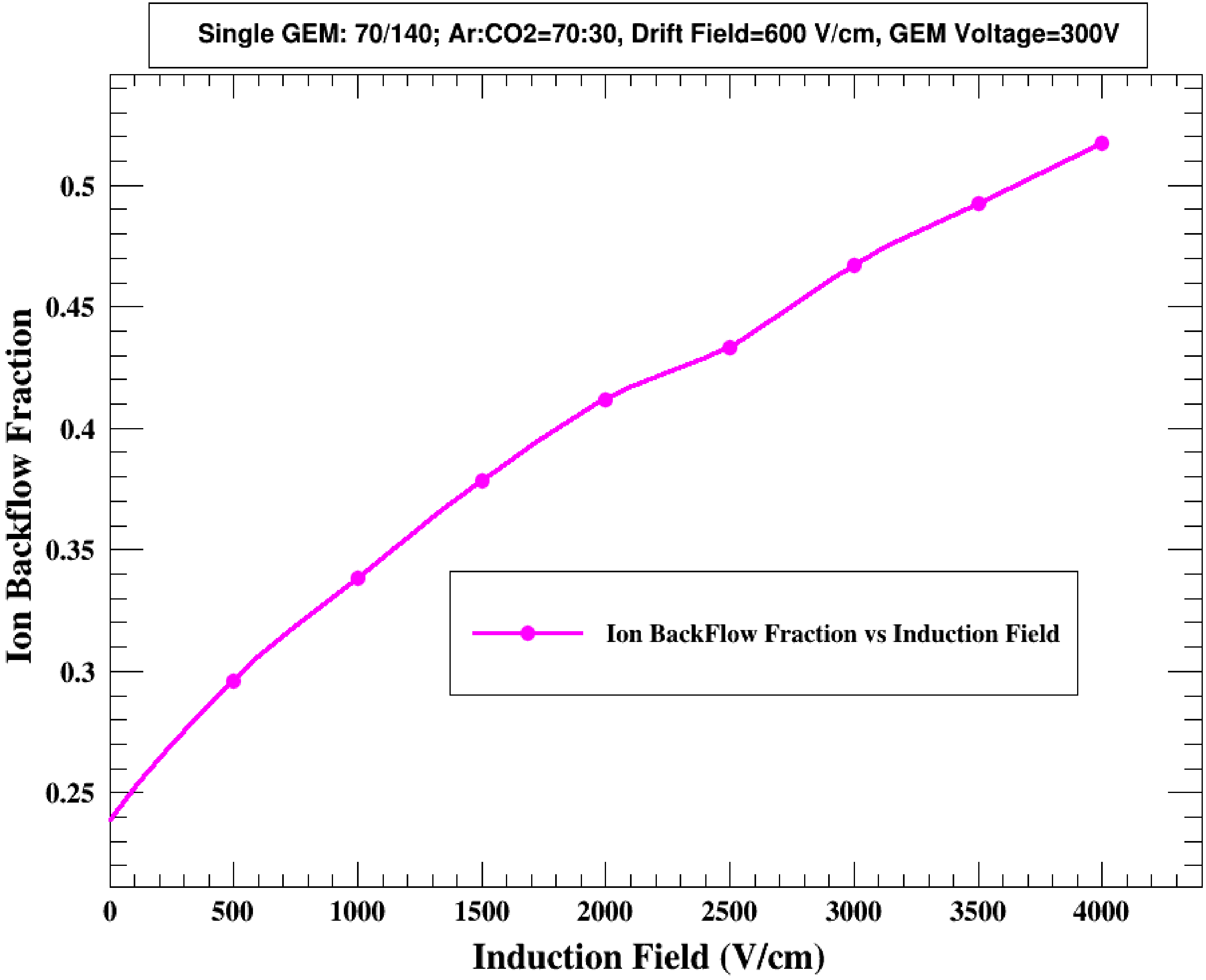
Induction Field Scan



$F_{Loss} = I_B / (I_A+I_B)$

Similarly, with increasing Induction Field, the signal loss at the bottom plane of the GEM foil decreases.

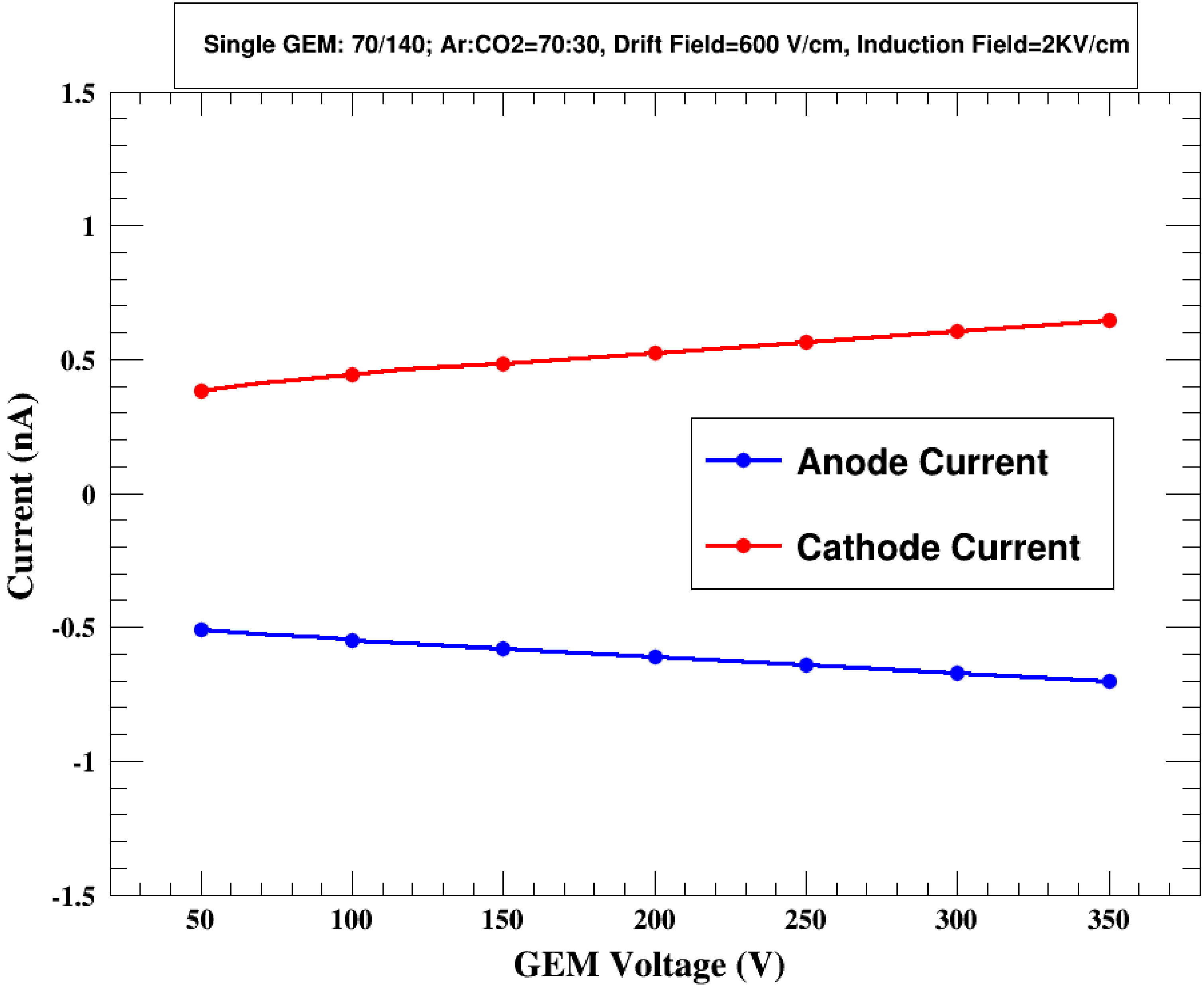
Induction Field Scan



IBF = $I_C / (I_A + I_B)$

IBF increases with Induction Field.

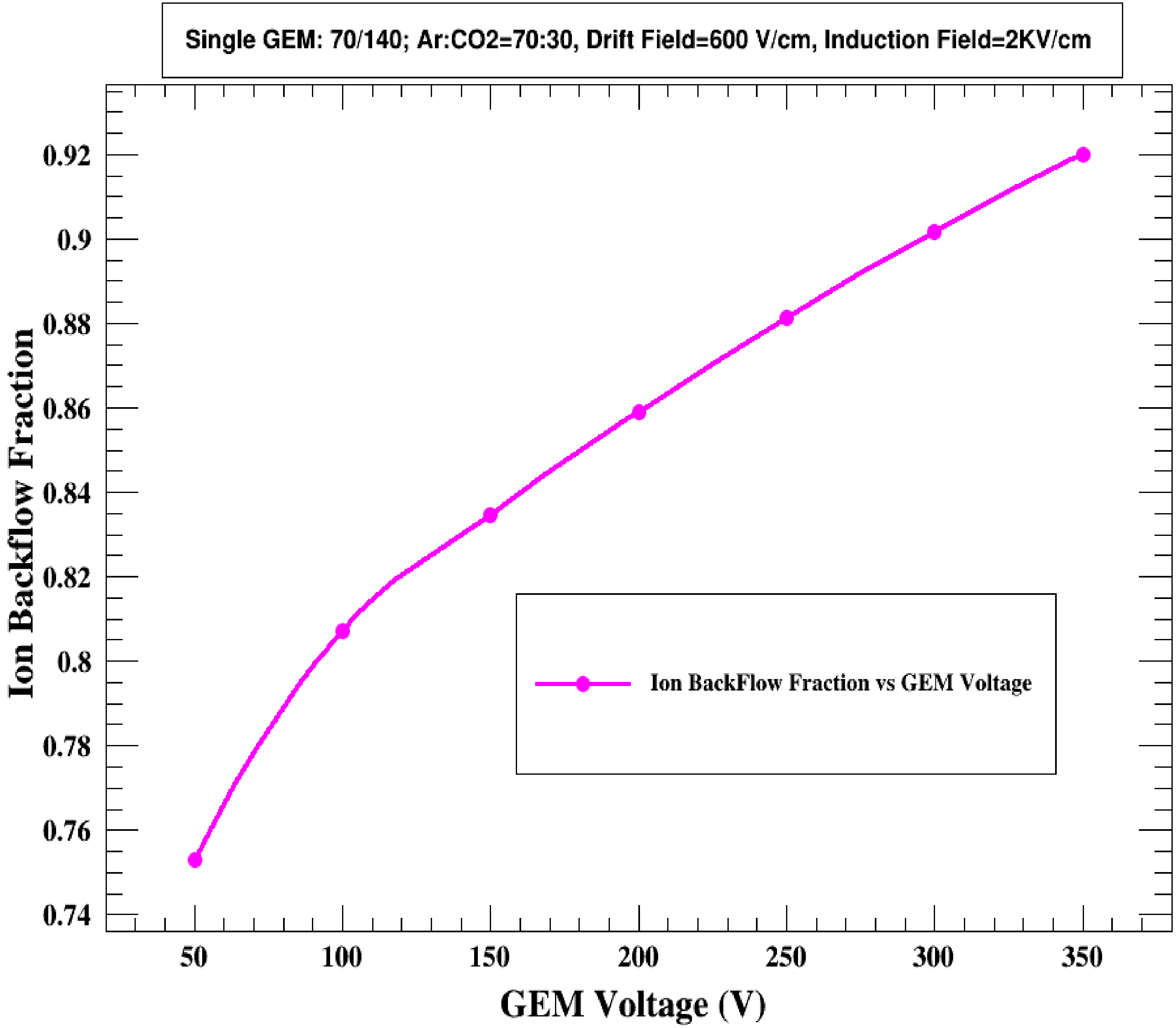
GEM Voltage Scan



Gas multiplication Increases with GEM voltage. Hence more Electron Ion pairs are produced.

Both Anode and Cathode Current increases with increasing GEM Voltage.

GEM Voltage Scan

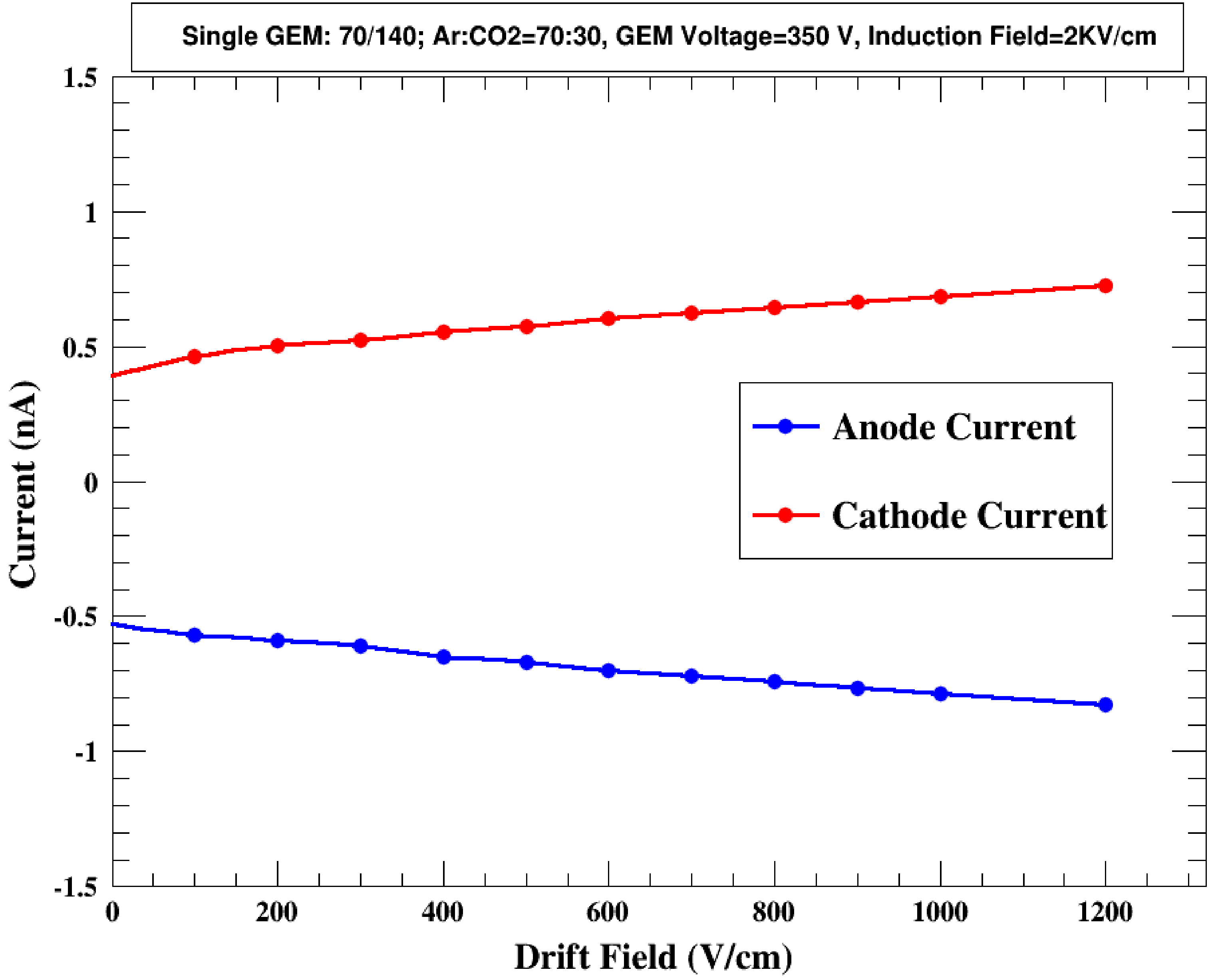


$$IBF = I_C / I_A$$

Since I_B is not measured here, an approximation of 100% extraction is assumed.

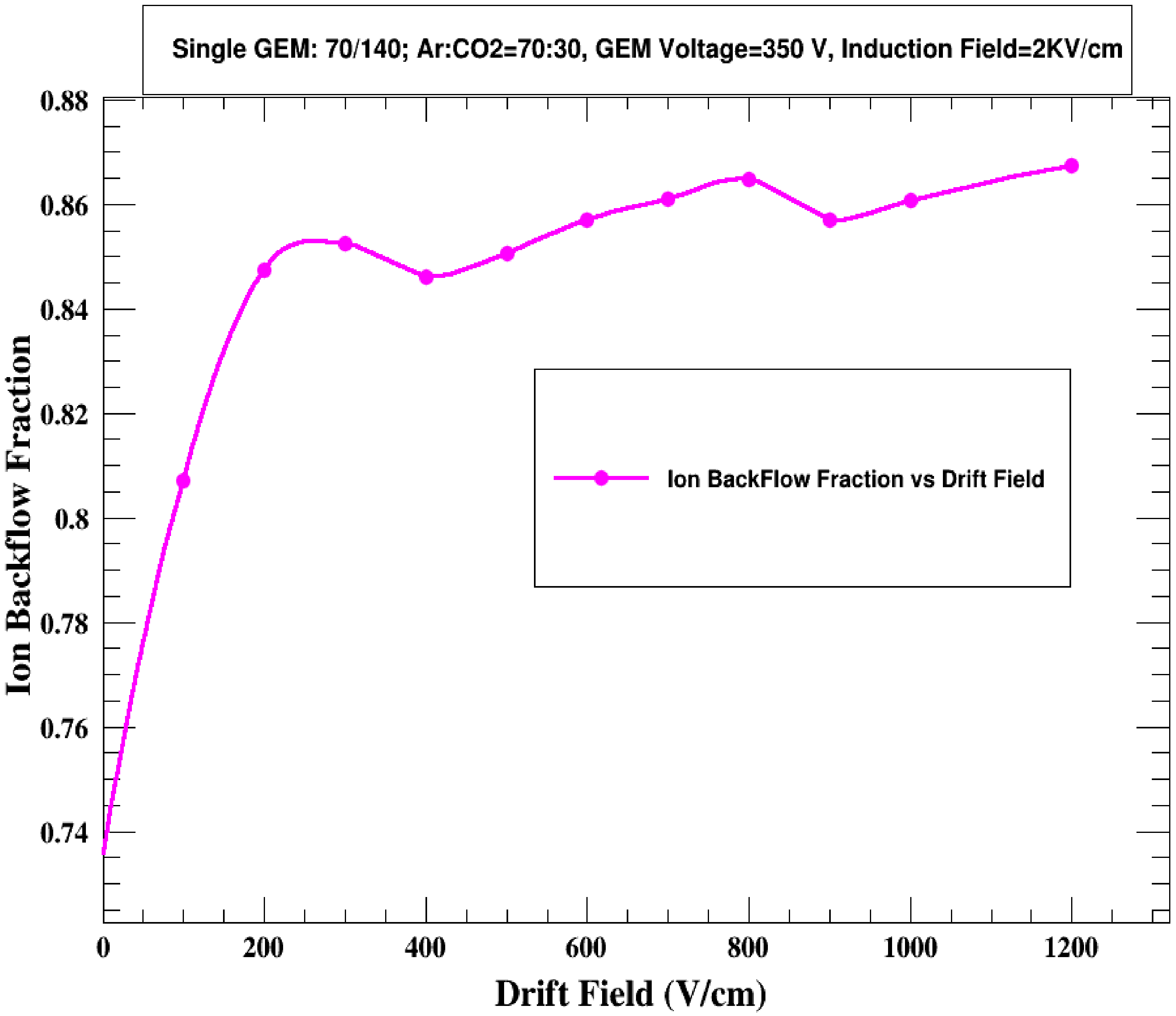
IBF increases with increasing GEM voltage.

Drift Field Scan



With Drift Field, both the Anode and the Cathode Current increase.

Drift Field Scan



IBF = I_C / I_A

Since I_B is not measured here, an approximation of 100% extraction is assumed.

With Drift Field, IBF first increases and then tends to saturate.

Summary and Future plan

- IBF is a major issue for a MWPC-based TPC at a high event rate environment.
- GEM-based TPC are being adopted in HEP experiments.
- We have assembled a single GEM setup at IOP and measured IBF for the setup. This gives the understanding of the behavior of a GEM foil which is helpful for GEM based application.

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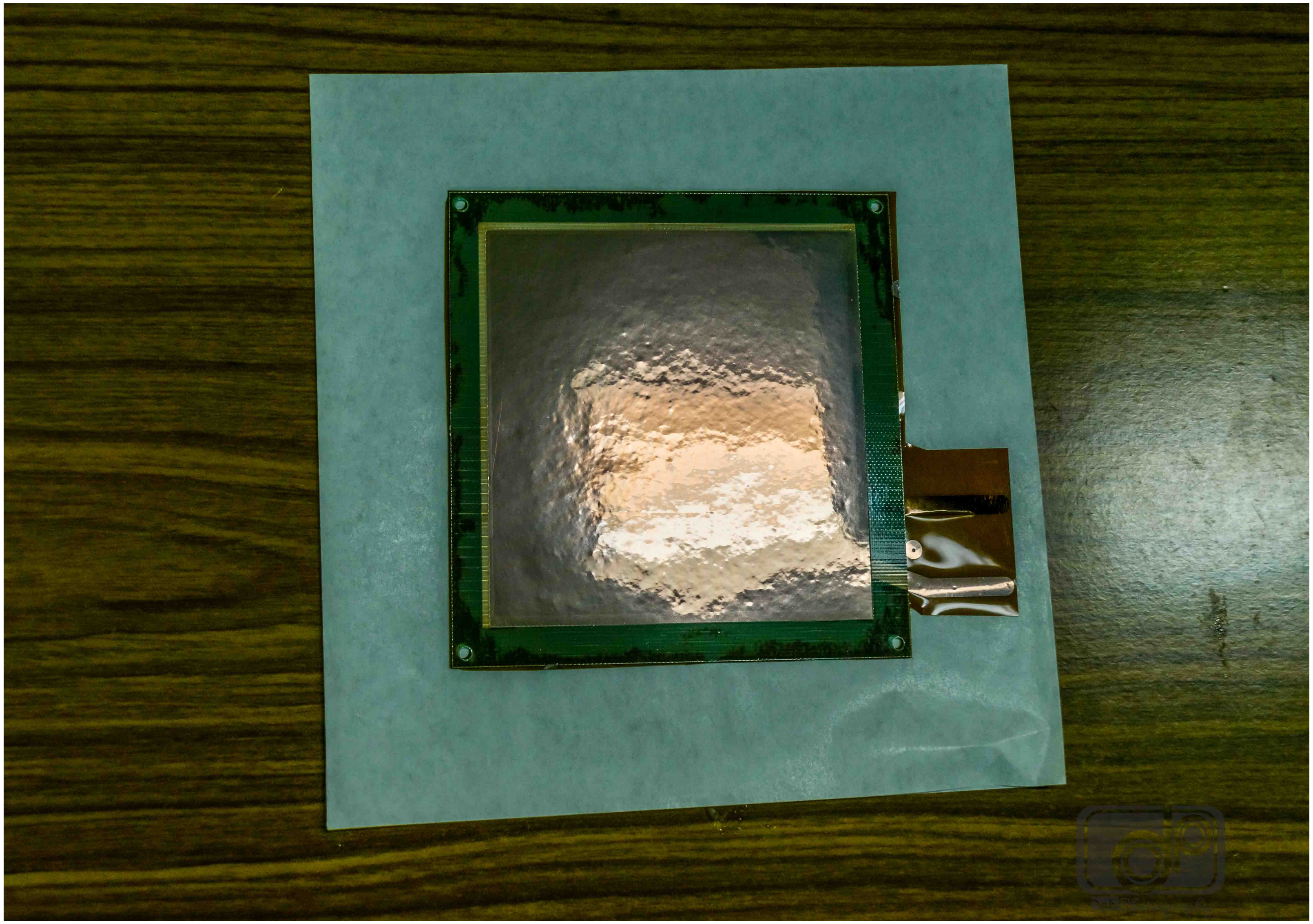
- We will measure currents from the top and the bottom part of the GEM for all other possible configurations and for different gas mixtures. We will perform a more detailed scan.
- We will pursue the same study for a multiple stack of GEMs for comparison.
- We also plan to build a hybrid detector by combining a GEM based pre-amplification and a Micromegas based multiplication at the readout in near future.

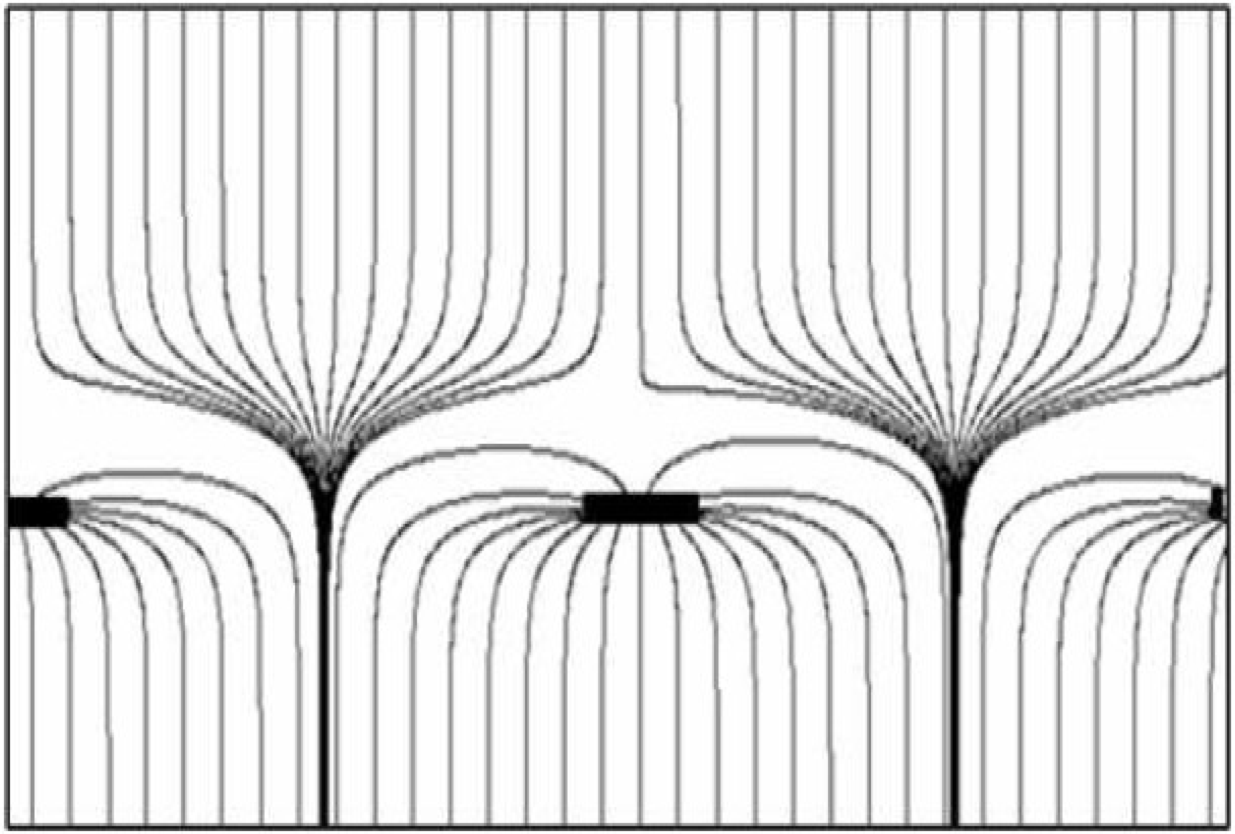
Thank you

Backup Slides



The GEM foil after stretching

Backup Slides



A semi analytical formula of IBF

$$BF \propto \left(\frac{R}{\sigma_t}\right)^2 = \frac{1}{FR}\left(\frac{p}{\sigma_t}\right)^2$$

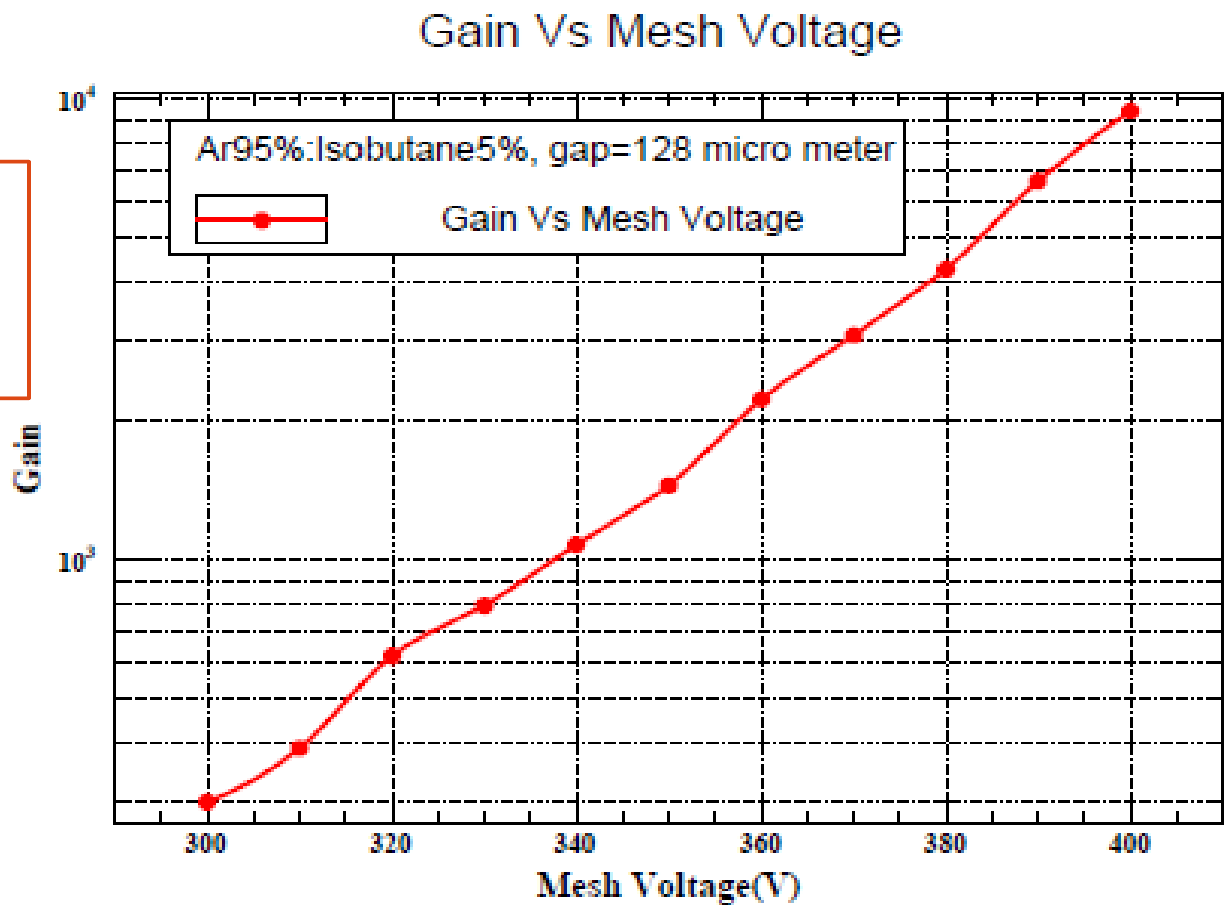
where, $\sigma_t = D_t\sqrt{Z}$, and p is the pitch

Backup Slides

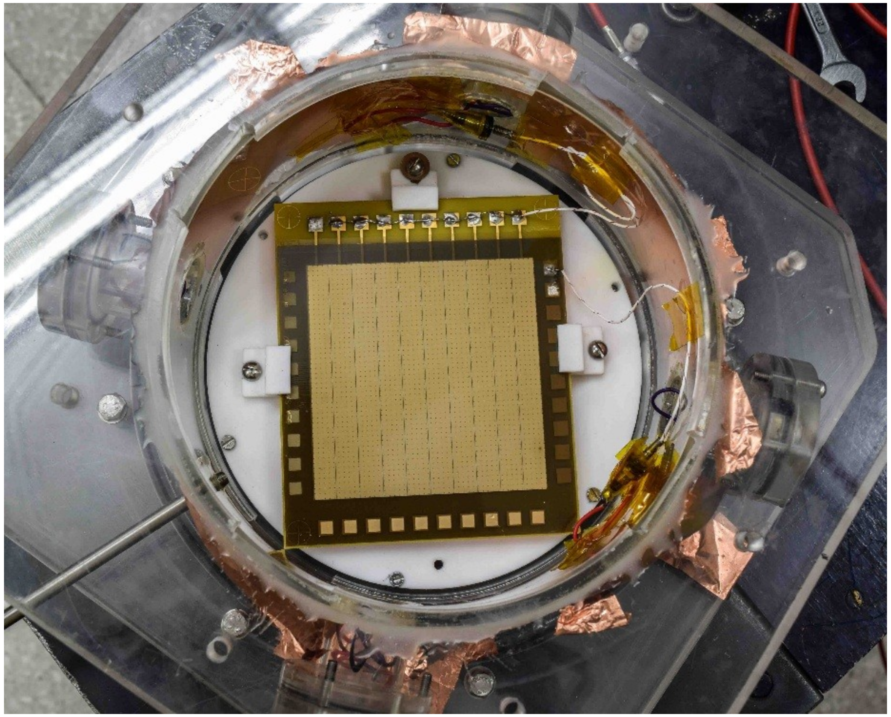
A Micromegas detector

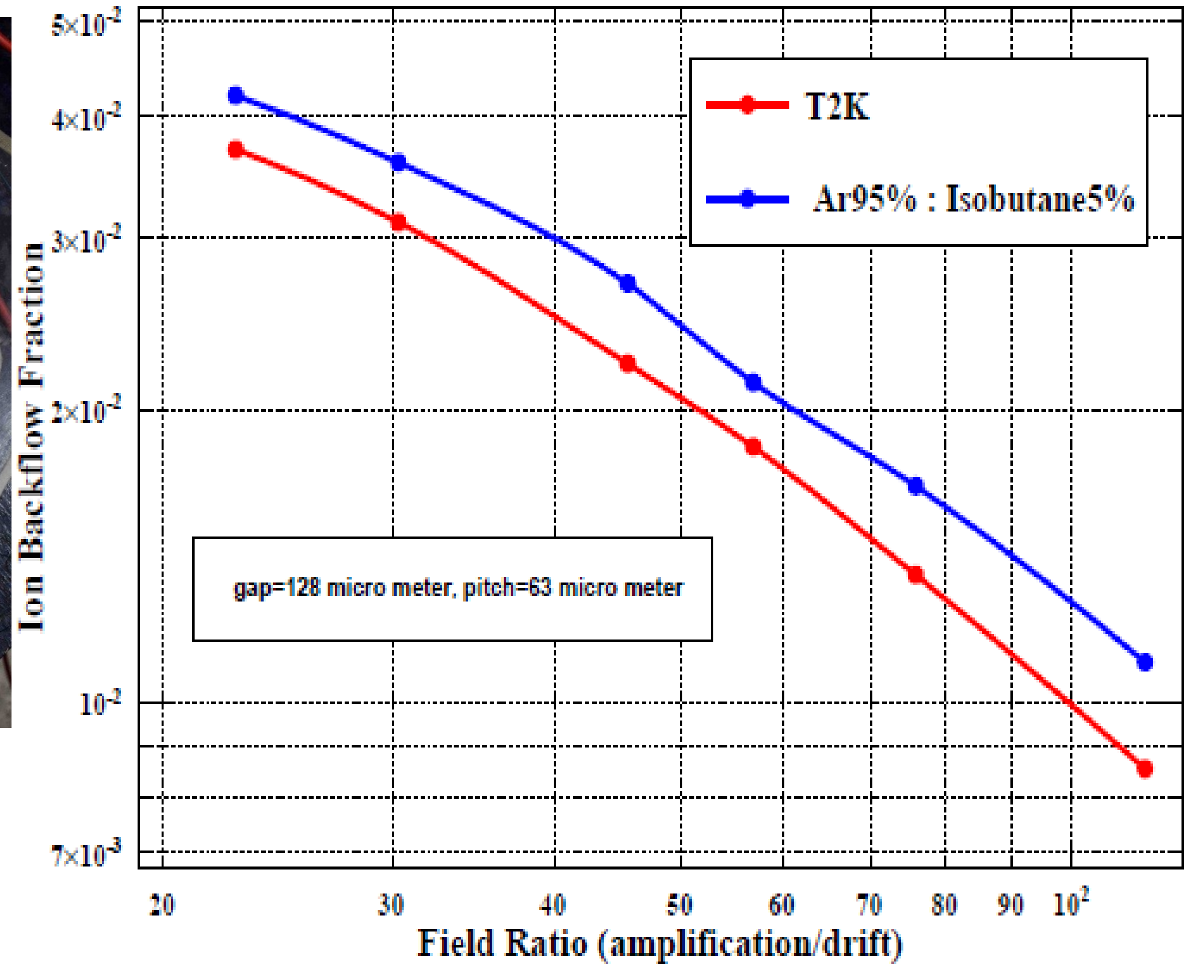
Micromegas detector works on a single stage amplification

Gain of a Micromegas detector is as high as 10^4.



Backup Slides





Micromegas Detector
In a small TPC

IBF of a Micromegas is as low as below 1 %.

Ion Backflow in a Micromegas Detector