GEM Simulations for the ALICE TPC Upgrade

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Overview

1. The ALICE TPC
2. GEM Simulations
3. Ion backflow vs magnetic field
4. Induced signal vs magnetic field
5. Conclusion and outlook

Introduction

The ALICE Time Projection Chamber performs Particle Indentification using $\frac{dE}{dX}$ vs p measurements.
Features-

- Active volume filled with gas mixture
- Uniform electric field in the active volume
- 0.5 T magnetic field for p measurements
- Endcaps fitted with gas based readout chamber (MWPC) to measure $\frac{dE}{dX}$

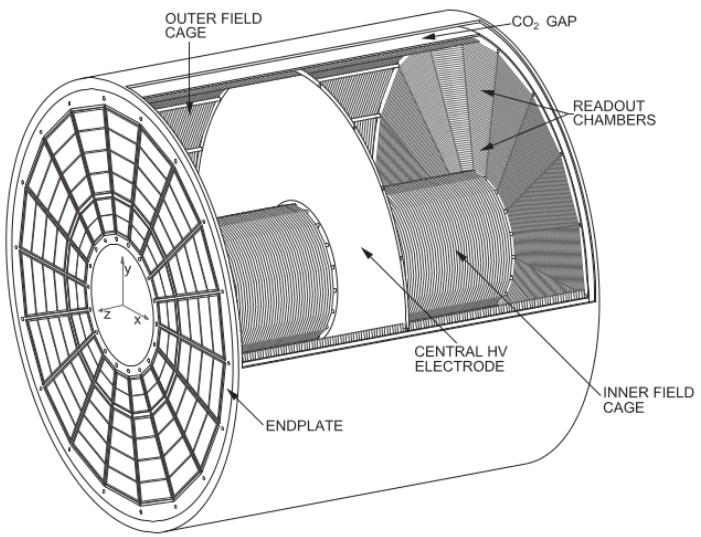

Figure : Schematic of the ALICE TPC [1]

TPC Upgrade

- The Multi Wire Proportionate Chamber generate ions which can distort the uniform field.
- Gating grid to trap ions results in dead time of detector 280 μs [1] (3.5 kHz)
- Increased luminosity in Run3 will results in pb-pb collision rates 50 kHz
- Quadruple Gas Electron Multiplier will replace the MWPC.
- GEM have intrisic ion blocking capabilities and hence a continuous readout.

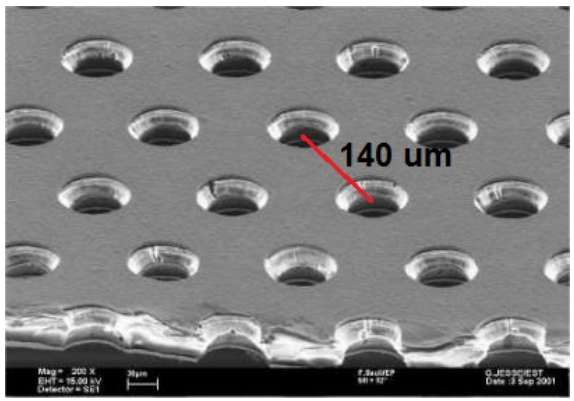

Figure : SEM image of the GEM foil [3]

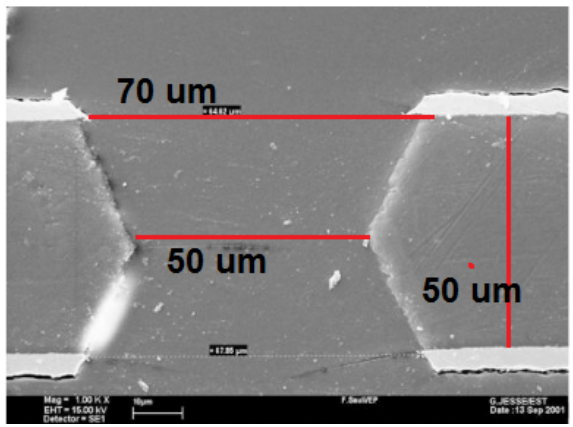

Figure : GEM cross section [3]

GEM Simulations

- Ansys to generate field maps and Garfield++ to drift electron and ions.
- The minimum periodic unit was utilized to perform simulations.
- Simulations were carried out at Spacetime Cluster, IIT Bombay

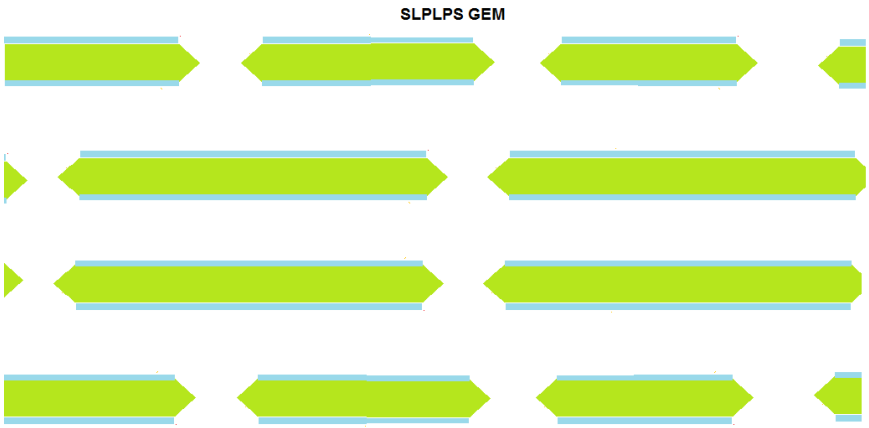

Figure : ALICE SLPLPS GEM

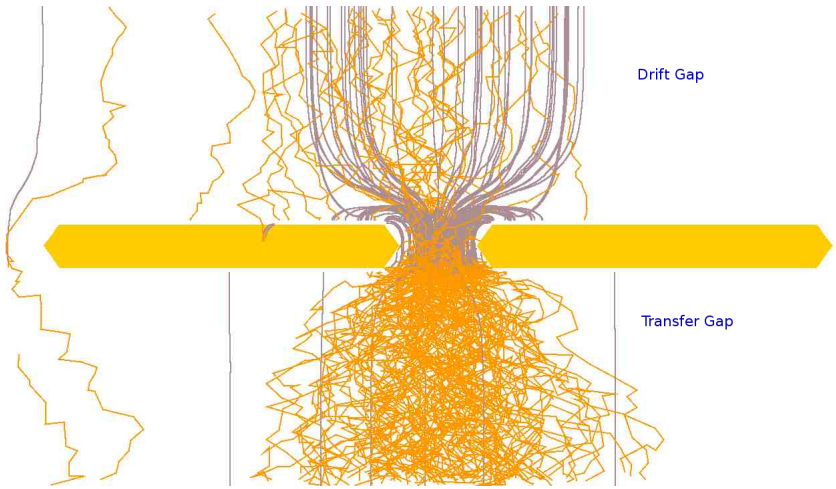

Figure : Avalanche simulated with Garfield++

Simulations with B field

Measurements carried out by Linear Collider TPC groups showed change in GEM performance at B= 5 T [2].
Simulations were performed to study the effect of B= 0.5 T on ALICE GEM performance.
Quantities of interest were

- Ion backflow- Defined as the ratio of cathode to anode current, also written as

$$IBF = \frac{1+\epsilon}{Gain} = \frac{ions\ reaching\ cathode}{electron\ reaching\ anode}$$

- Induced signal- The following characteristics of the signal were studied
  - Average Current (Iavg)
  - RMS Current (Irms)
  - Full Width at Half Maximum (FWHM)

IBF vs B

Ion backflow was calculated for each GEM separately as a function of B
GEM 1 and GEM 2 show no significant effect change in IBF upto B= 0.5 T

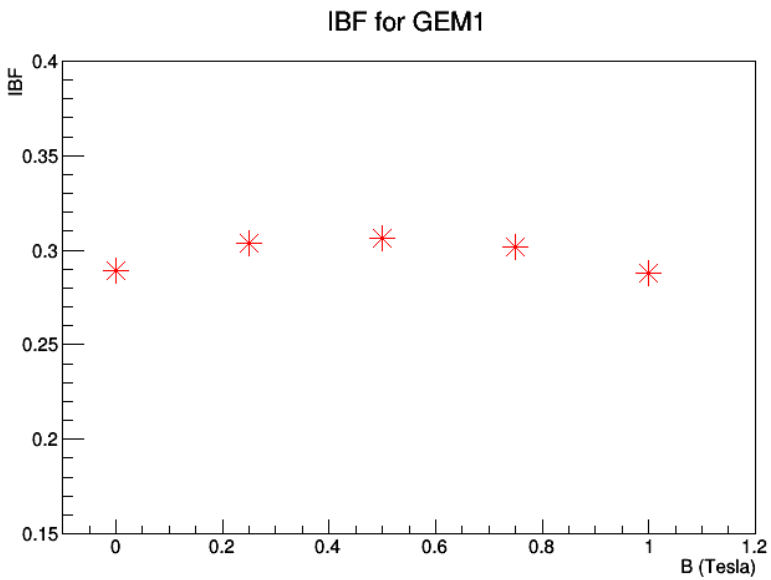

Figure : IBF for GEM1 vs B

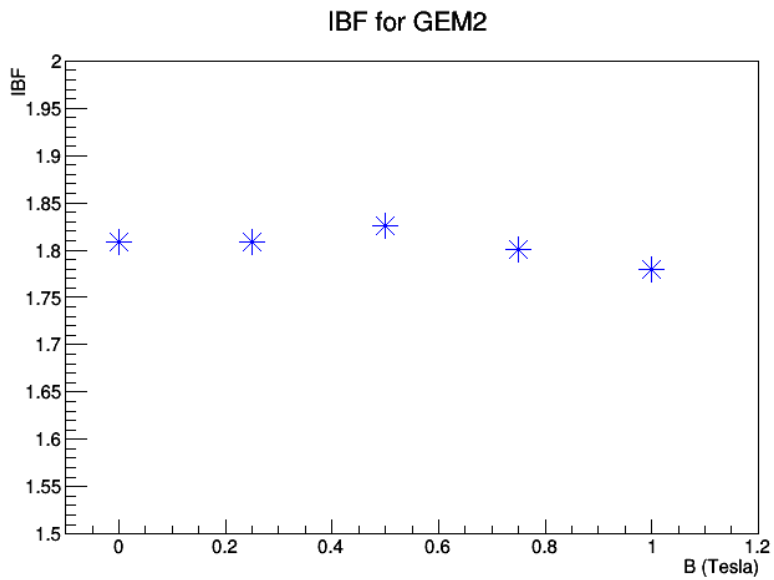

Figure : IBF for GEM2 vs B

IBF vs magnetic field (continued)

Ion backflow was calculated for each GEM separately as a function of B
GEM 3 showed a steady decrease in IBF with B, however the change was small upto 0.5 T.
Simulated IBF for the Quadruple GEM 0.65±0.040 % was close to the experimental value 0.7 %

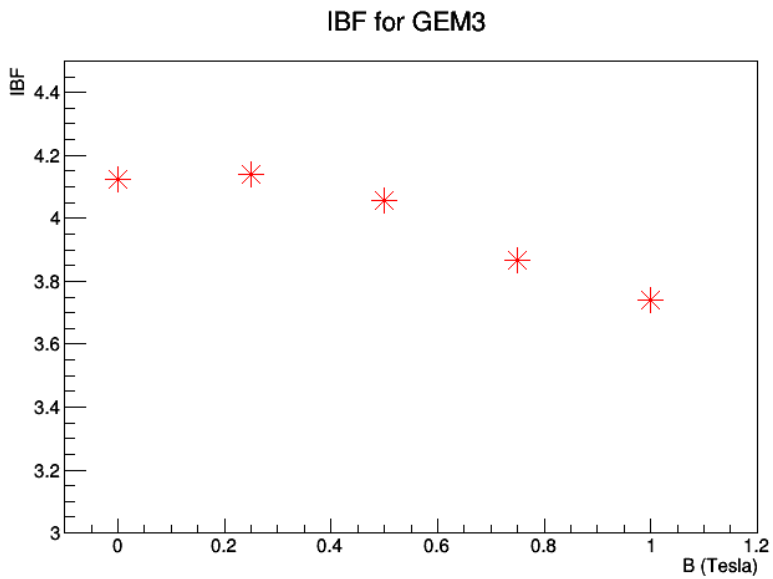

Figure : IBF for GEM3 vs B

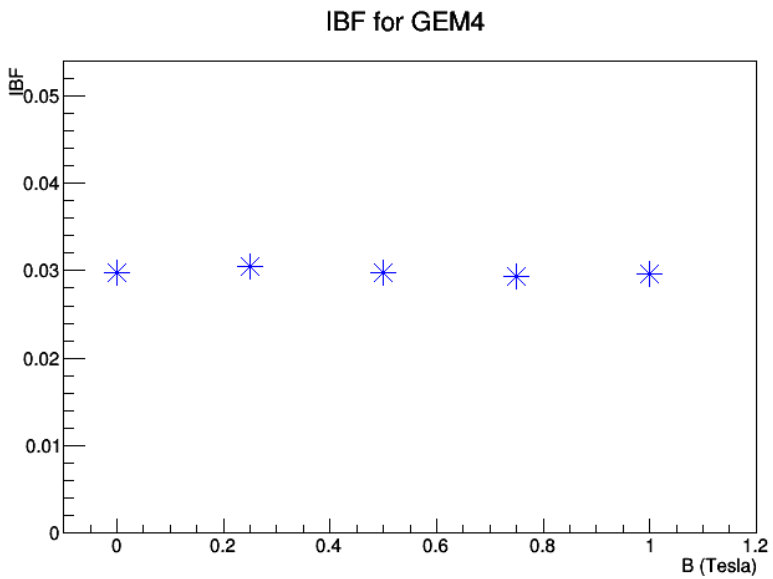

Figure : IBF for GEM4 vs B

Induced signal analysis

Indcued signal was simulated for 8000 electrons separately. The typical signal had a main pulse followed by smaller pulses
Difficult to analyse the peak position due to fluctuations

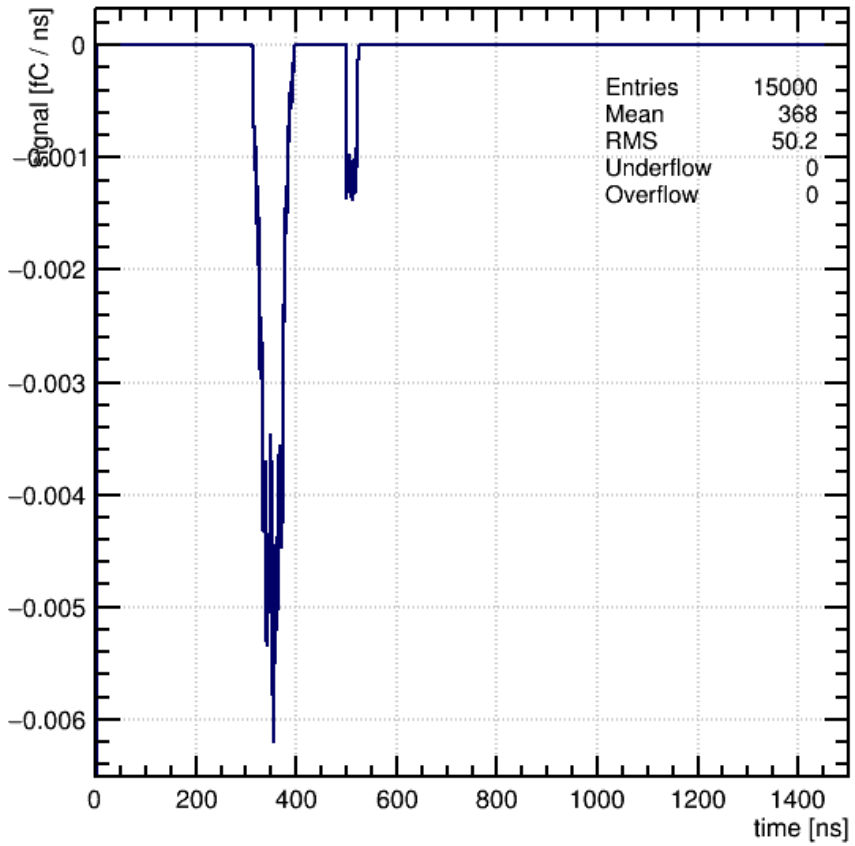

Figure : Induced current vs time for 1 incoming electron

Induced signal analysis

A moving average filter was applied to smoothen the pulses.
Peak identification algorithm can be applied on the filtered signal.

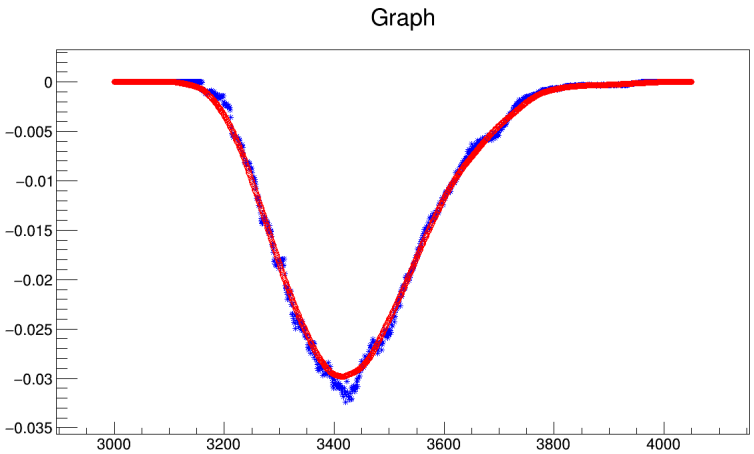

Figure : Filtered signal (red) plotted with raw signal (blue)

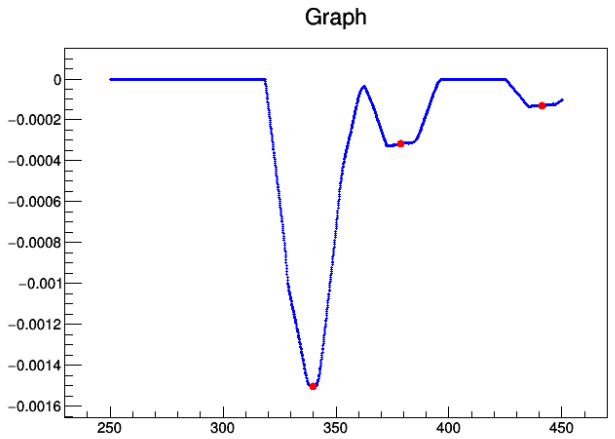

Figure : Peak identification for filtered signal

Iavg vs B

Average current for 1 electron signal was around -4 nA. It showed no significant variation with B.

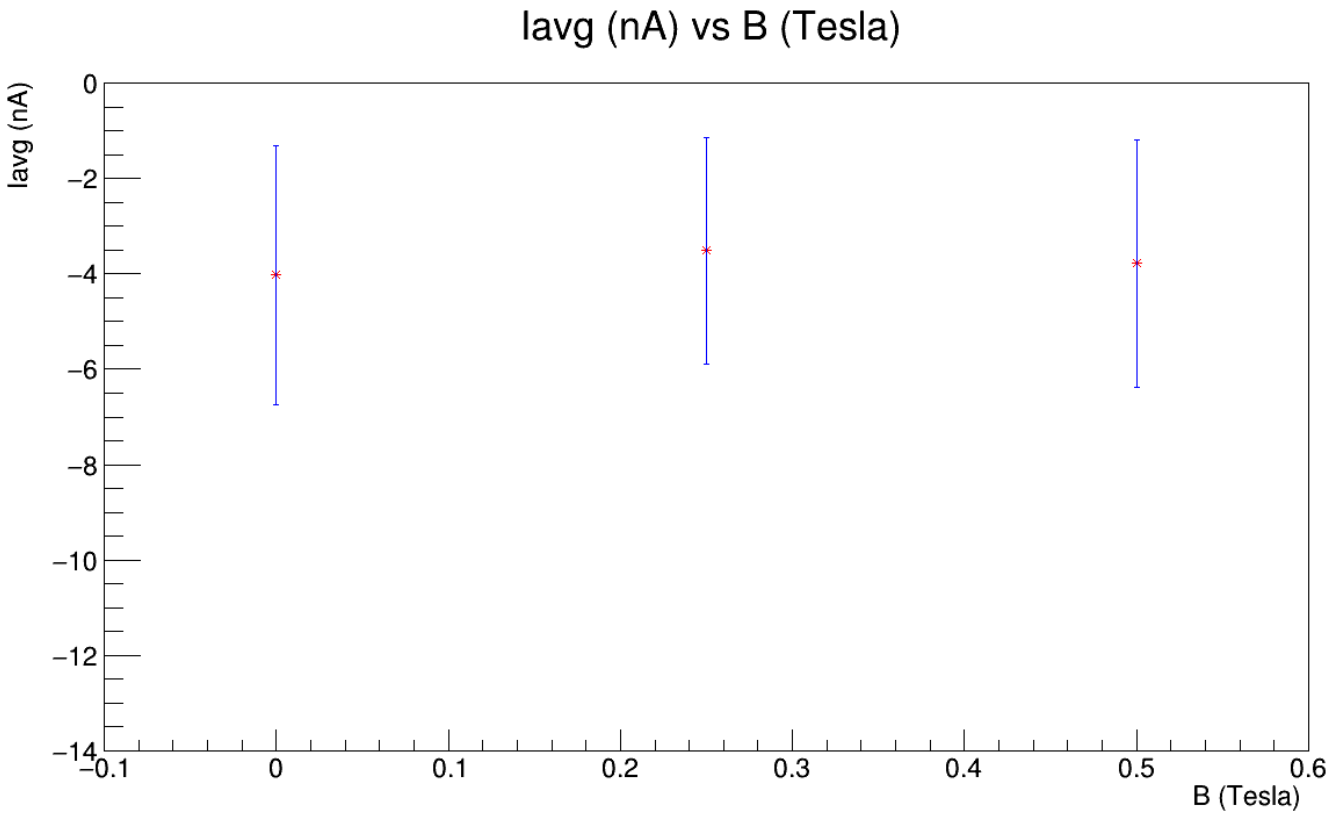

Figure : Iavg vs B

Irms vs B

RMS Current followed the same trend with B as average current.

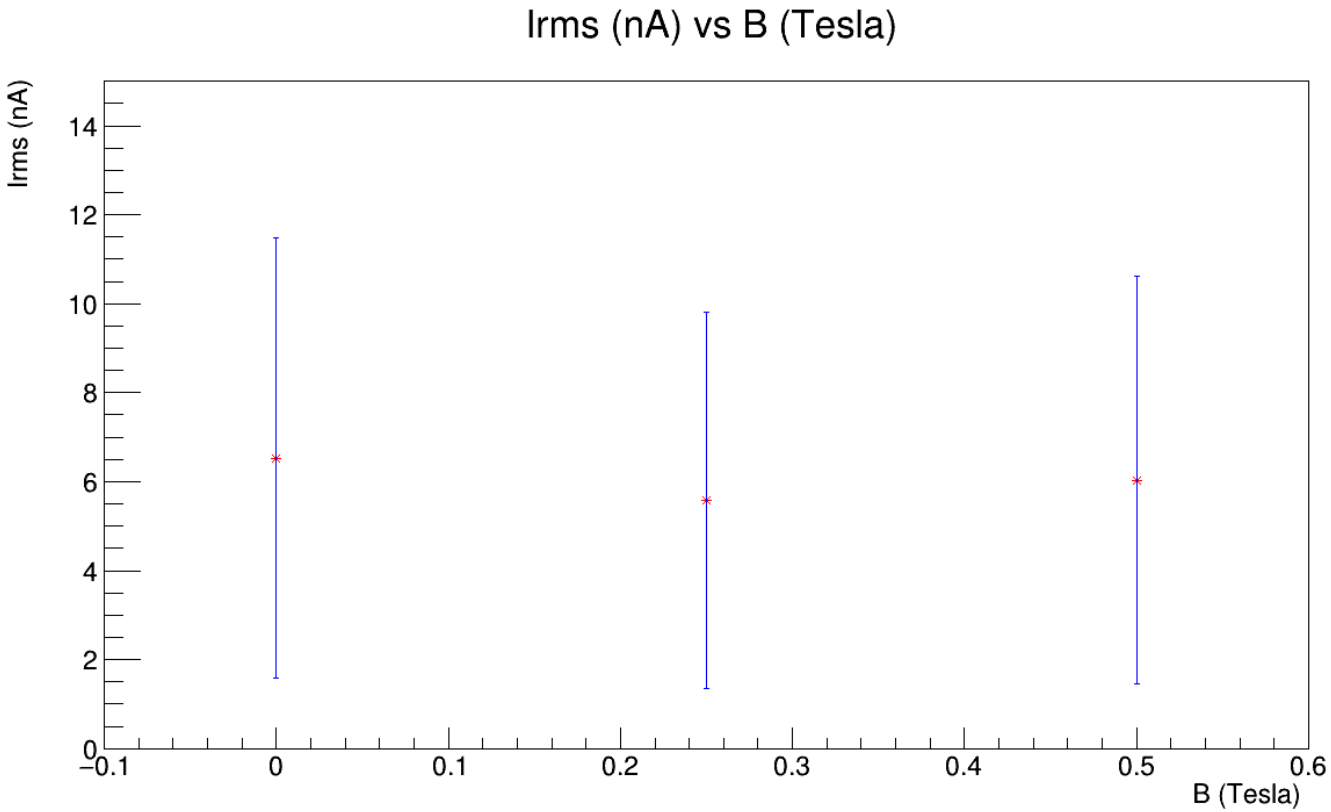

Figure : Irms vs B

Distribution of I avg and Irms

Irms and Iavg followed Landau Distribution

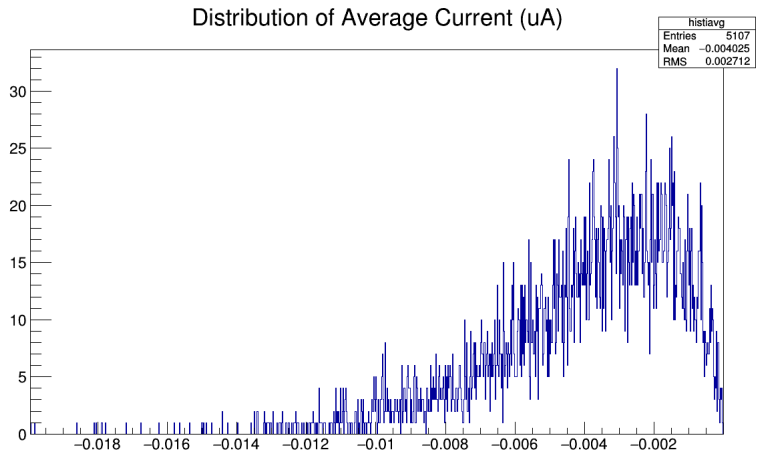

Figure : Distribution of I avg

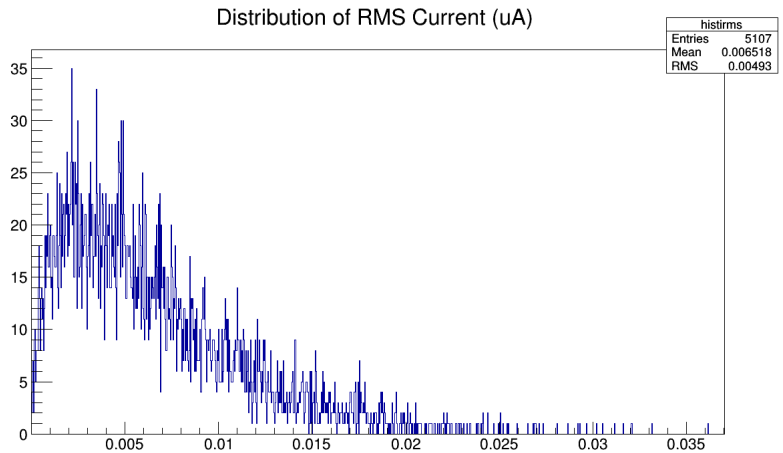

Figure : Distribution of I rms

FWHM vs B

The average FWHM for the pulse was around 28 ns, it showed insignificant variation with B.

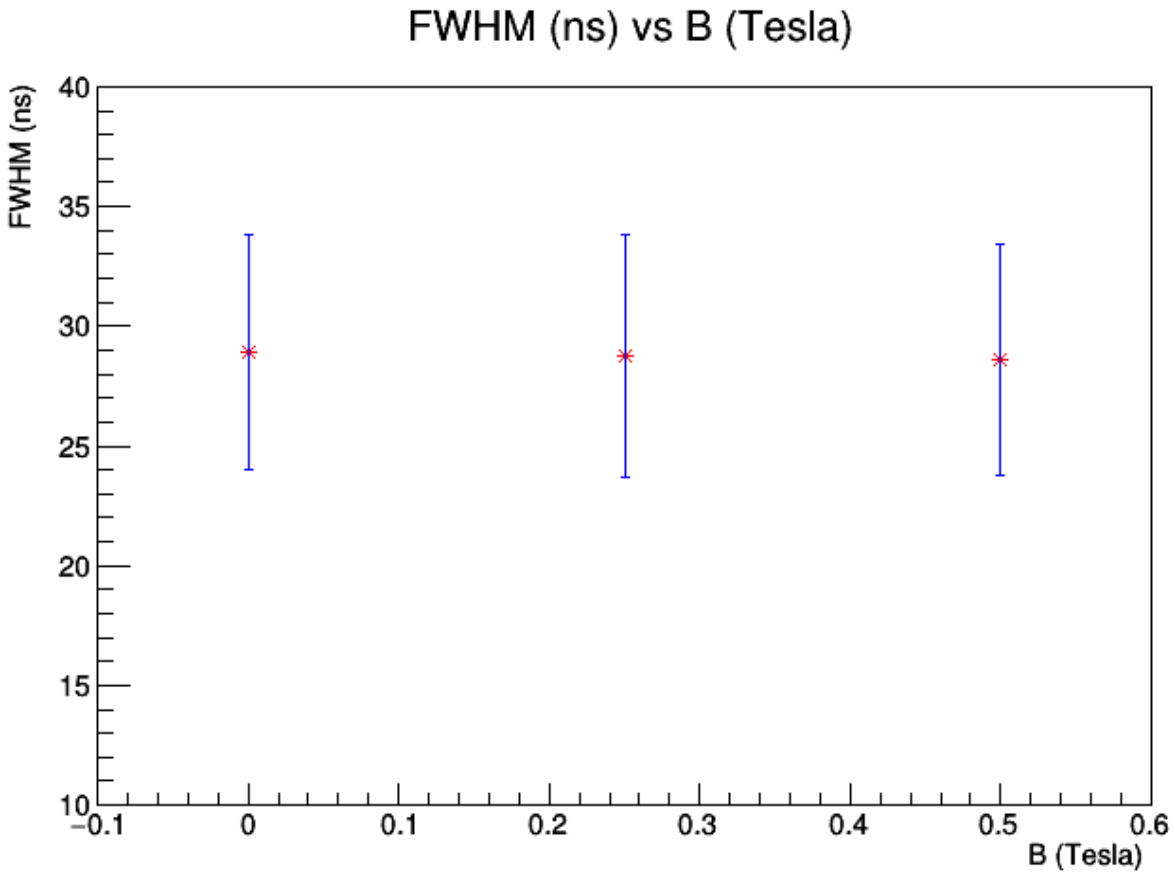

Figure : FWHM vs B

Conclusion and outlook

The ion backflow and the induced signal characteristics for the Quadruple GEM are not expected to change under B=0.5 T inside the ALICE TPC.

Further work will be focussed on understanding the smaller pulses observed in the induced signal. Signal simulations will be carried out with an electron cluster instead of a single incoming electron.

Thank you!

Backup

$$Geff_{stack} = Geff_1 . Geff_2 . Geff_3 . Geff_4$$

$$\epsilon_{stack} = \epsilon_1 + \epsilon_2 . Gef_1 . \alpha_1 + \epsilon_3 . Gef_1 . Gef_2 . \alpha_1 . \alpha_2 + \epsilon_4 . Gef_1 . Gef_2 . Gef_3 \alpha_1 . \alpha_2 . \alpha_3$$

References

- Technical Proposal: A Large Ion Collider Experiment (ALICE):
- Charge transfer and charge broadening of GEM structures in high magnetic fields, M. Killenberg et al, NIM A 530 (2004) 251257
- The CERN Gas Detector Group //gdd.web.cern.ch/GDD/