

# Thermal neutron detection with Boron-coated GEM

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# Overview

## Neutron detection:

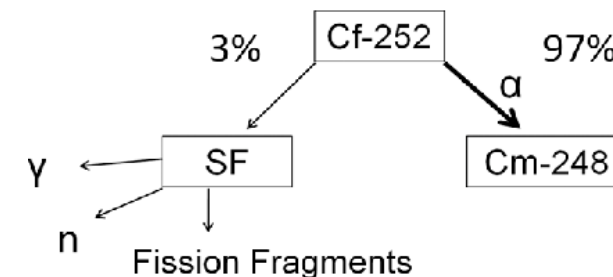
- Built a 10 cm x 10 cm prototype of Boron-coated GEM detector and testing with  $^{252}\text{Cf}$  neutron source at VECC.
- GEANT4 Simulation: for the optimization of converter thickness and efficiency estimation.

GEM detectors

- Gas Electron Multiplier (GEM) detectors belongs to the family of Micro-pattern gaseous detectors.

## $^{252}\text{Cf}$ neutron source :

- emit neutrons as a result of spontaneous fission with a probability of about 3 %.



# Neutron detection with GEM

## Motivation

-> Alternative of He-3 based detectors  
owing to limited availability of He-3 gas

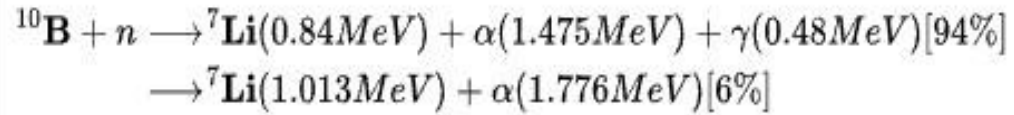
### Applications:

- Neutron beam monitor
- High flux at new neutron sources
- Neutron radiography
- High rate and Scattering experiments

### Advantage of GEM :

- High rate capability
- High gas gain
- Low discharge probability
- Good spatial and time resolution
- Can be built for large area
- Good 2-D imaging ability
- Low gamma sensitivity ( at lower gain)

# Principle of boron-coated GEM



- Good neutron cross-section, high spatial resolution and low gamma sensitivity of  ${}^{10}\text{B}$  based GEM makes a good candidate for neutron detection.
- Charge particles ionizing gas, primary electrons produced in this stage are then further multiplied by the triple GEM structure and the signal is read out by the front-end electronics connected to the padded anode.

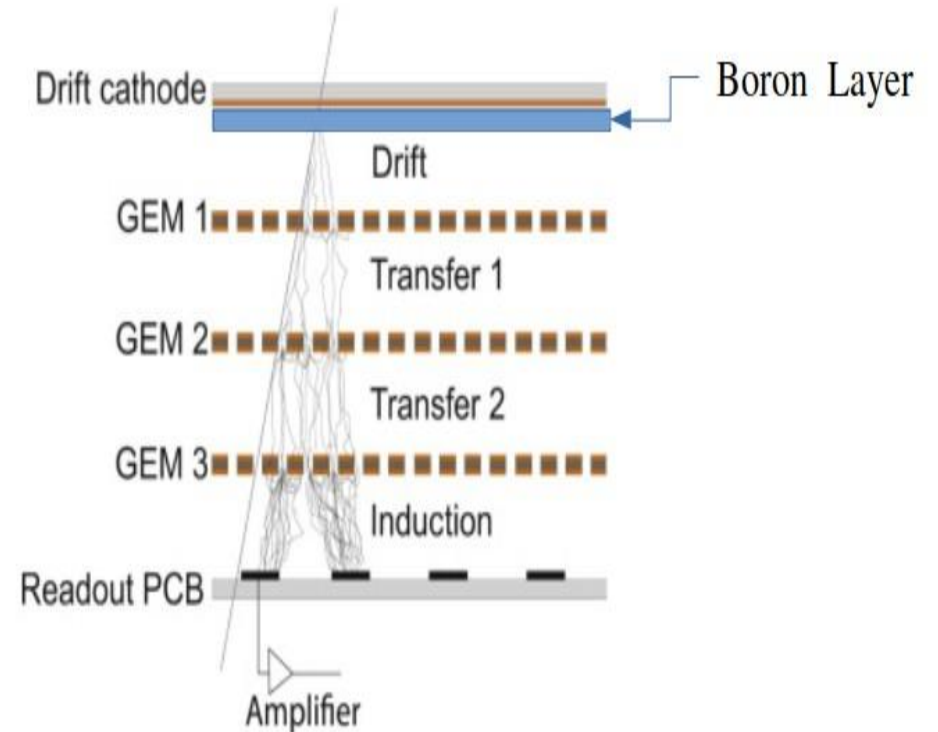
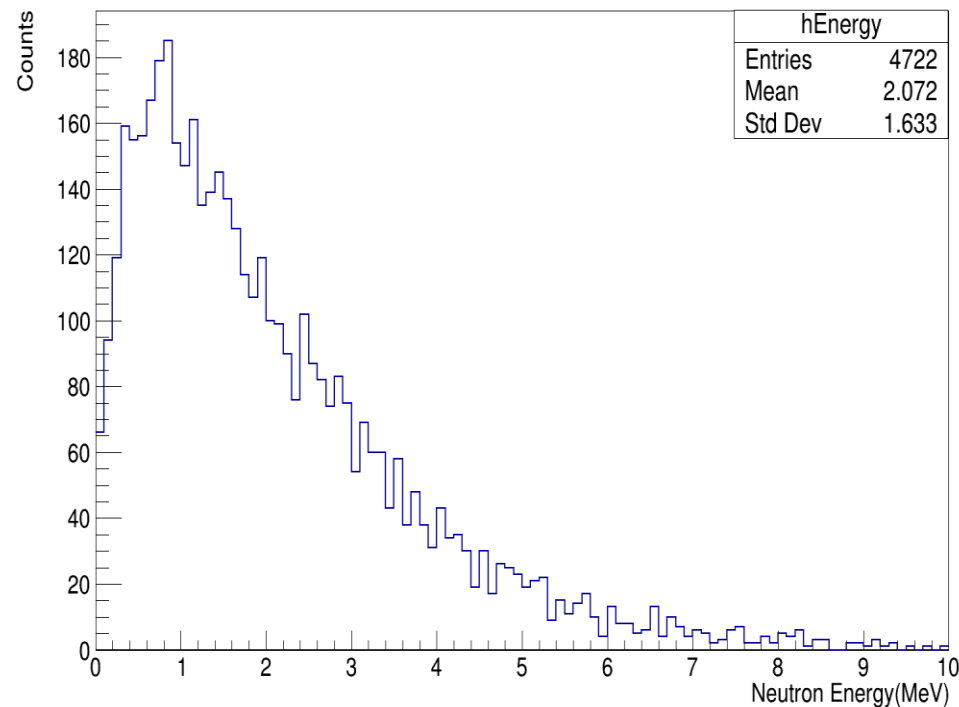


Fig.: Boron coated triple GEM

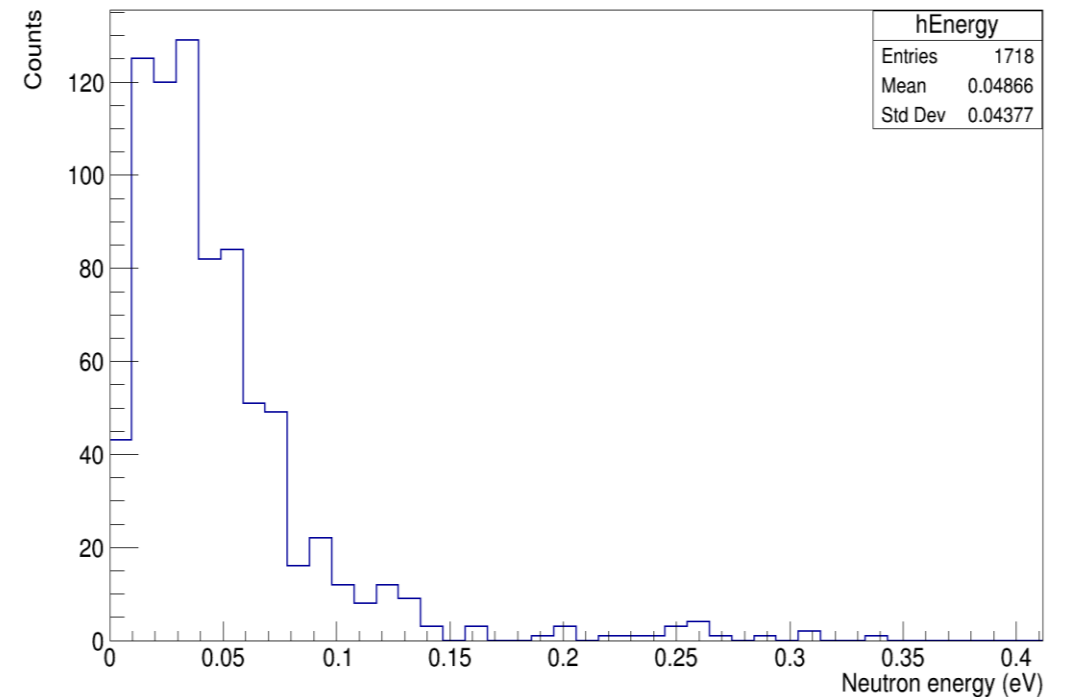
# GEANT4 Simulation results

$^{252}\text{Cf}$  neutron energy spectra (Incident on detector drift)

Without HDPE



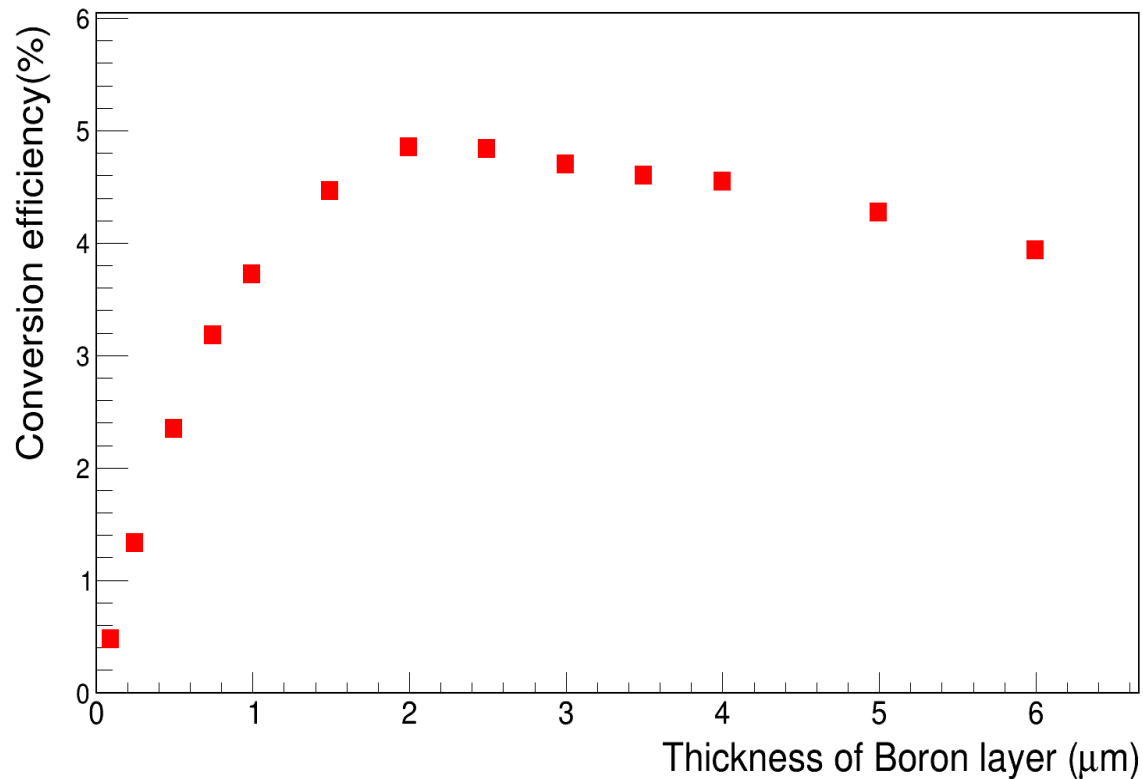
With HDPE (10 cm)



- High density polyethylene (HDPE) moderator, used to thermalize the high energy (fast) neutrons to lower energies( thermal), as the reaction cross-sections are higher.

# Simulation results

## Efficiency plot for different B-10 thicknesses



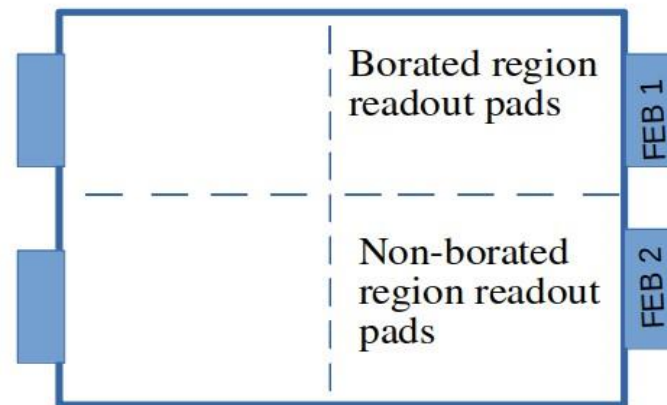
- The conversion efficiency is observed to increase first and reach its maximum (~ 5%) at a certain thickness (~ 2.5  $\mu\text{m}$ ), after which it decrease 6

- The neutron efficiency is defined as the ratio of neutrons detected (via counting the total number of charge particles depositing energy in detector region to number of neutrons incident on the detector).
- For a lower thickness , fewer charge particles are generated in the converter material region leading to lower efficiency and for a thickness larger self-absorption of charged particles occurs in the converter material itself, not detected in the active region of the detector leading to a decrease in the efficiency value.

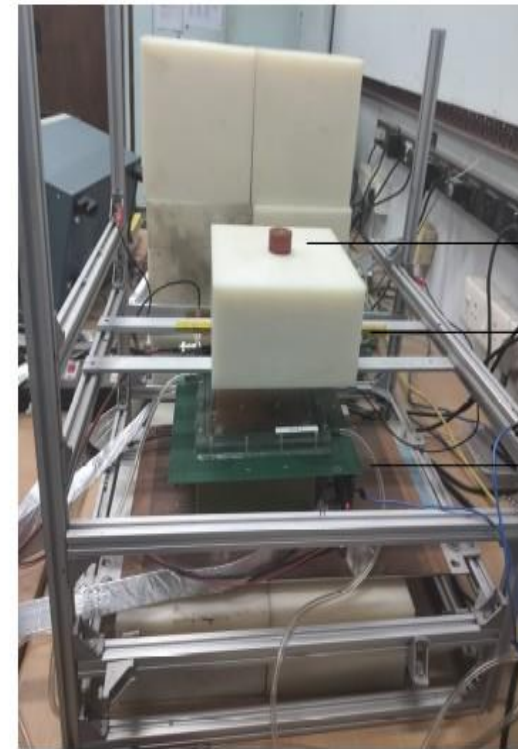
# Experimental setup

Detector design : Hybrid drift cathode of 3 cm x 3 cm (boron-10 coated and non-borated) , pad readout, Gas medium : Ar/CO<sub>2</sub> (70:30) multichannel ASICs (FEBs) and self-triggered data acquisition

## Detector readout



**Triple GEM detector**



$^{252}\text{Cf}$  Source

HDPE: 10cm

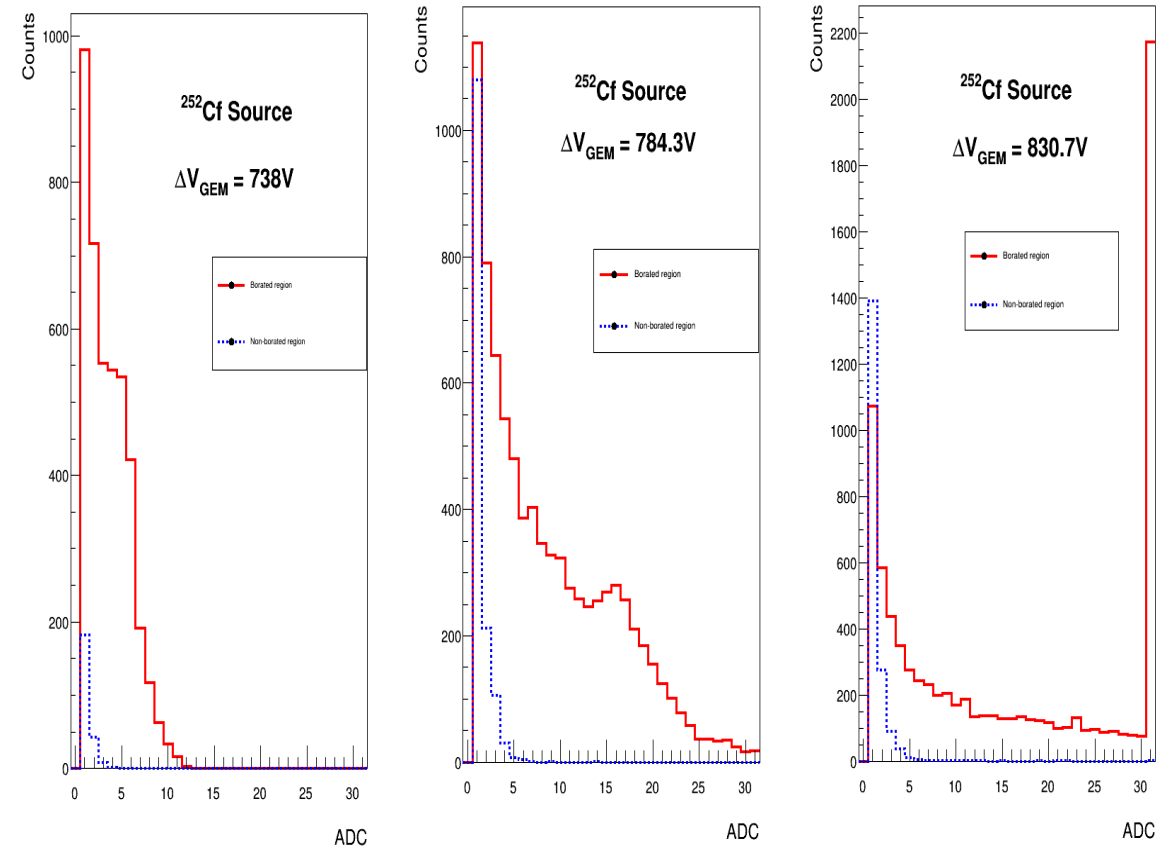
Triple GEM  
(borated & non-borated  
drift plate and pad readout)

Experimental setup

# Experimental results of $^{252}\text{Cf}$ source

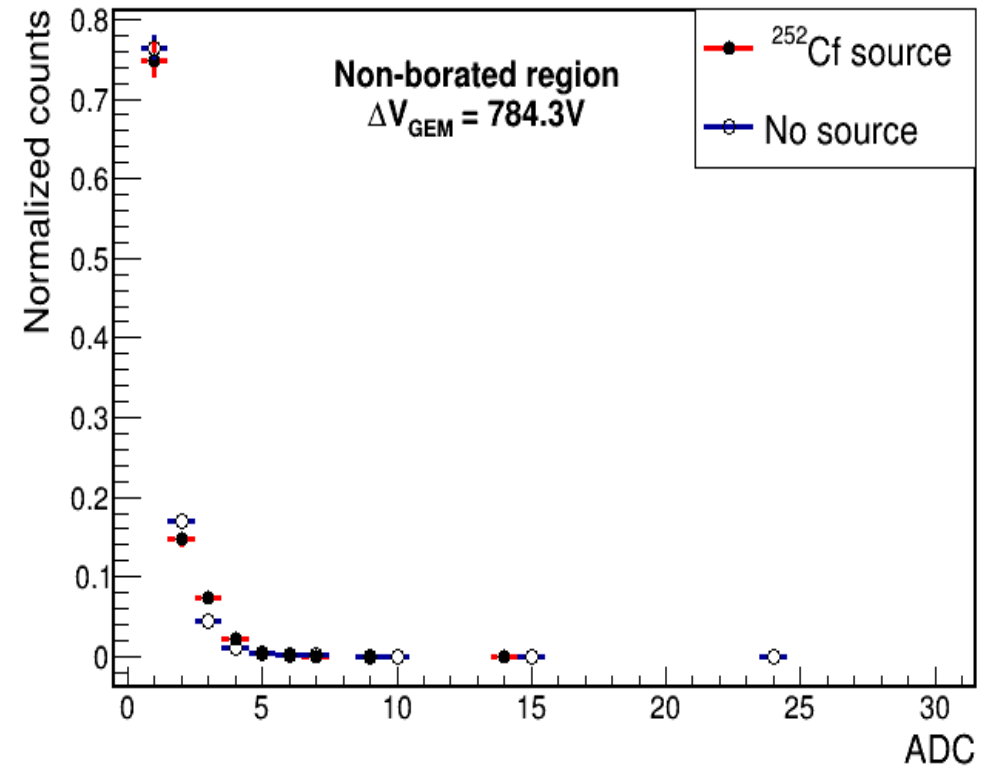
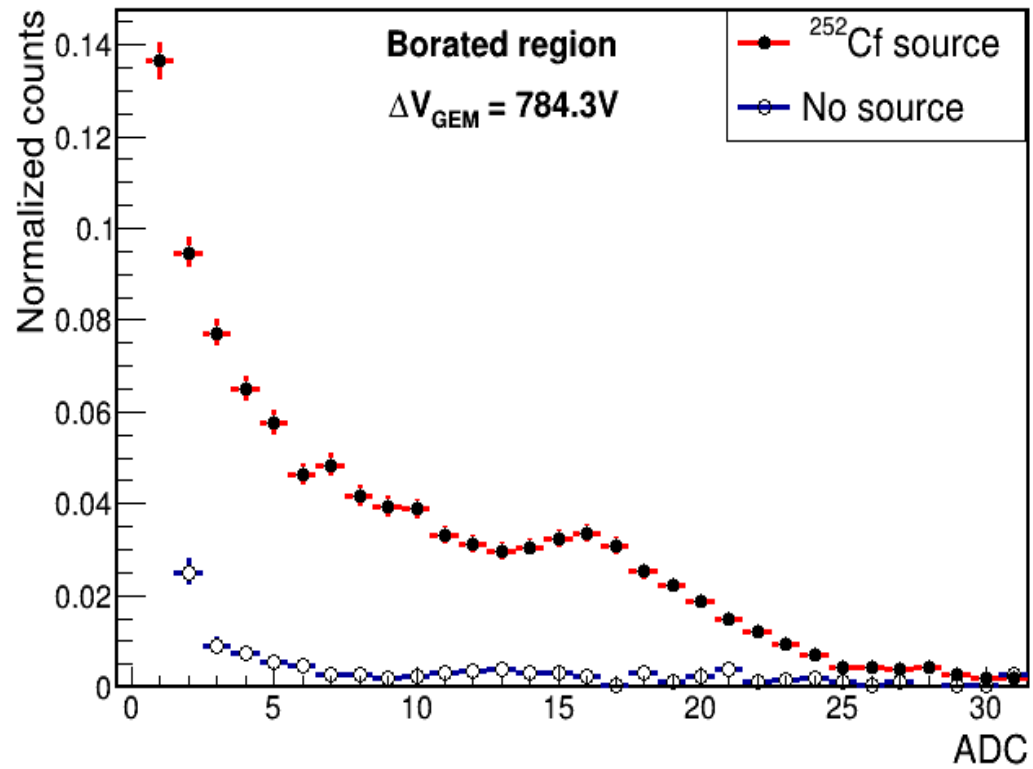
S. No.	HV (V)	I ( $\mu\text{A}$ )	$\Delta V_{\text{GEM}}$ (V)	Gain
1.	3000	461.2	692	1.03
2.	3200	492.05	738	3.12
3.	3300	507.45	761.2	5.45
4.	3400	522.85	784.3	9.48
5.	3500	538.30	807.4	16.50
6.	3600	553.75	830.6	28.82
7.	3800	584.45	876.7	87.01
8.	4000	615.3	923	264.54
9.	4200	646.1	969.1	799.83

ADC (pulse height) distribution



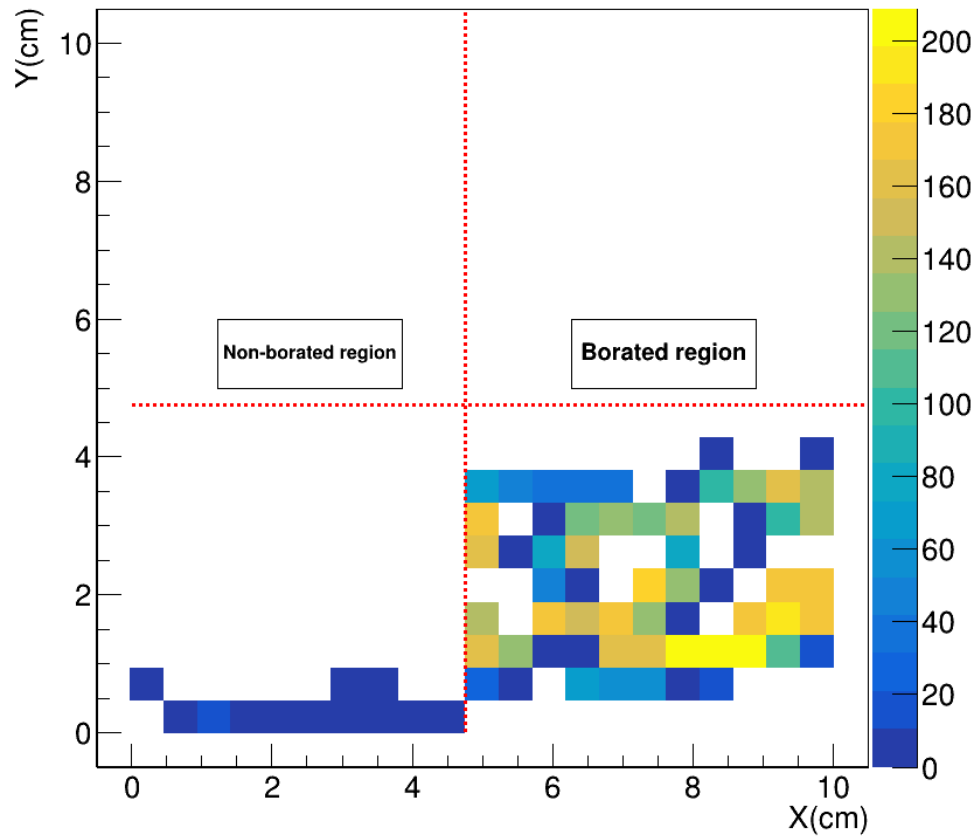
- Data taken for source and no source (noise study) cases for various GEM voltages.
- Detector operated at lower gain (<100) for Gamma rejection
- Electron threshold: 6fC
- Measurement of detector gain with  $^{55}\text{Fe}$  X-ray source
- Operating voltage: optimal compromise between charge saturation and gamma rejection

# ADC spectra comparison of borated and non-borated region

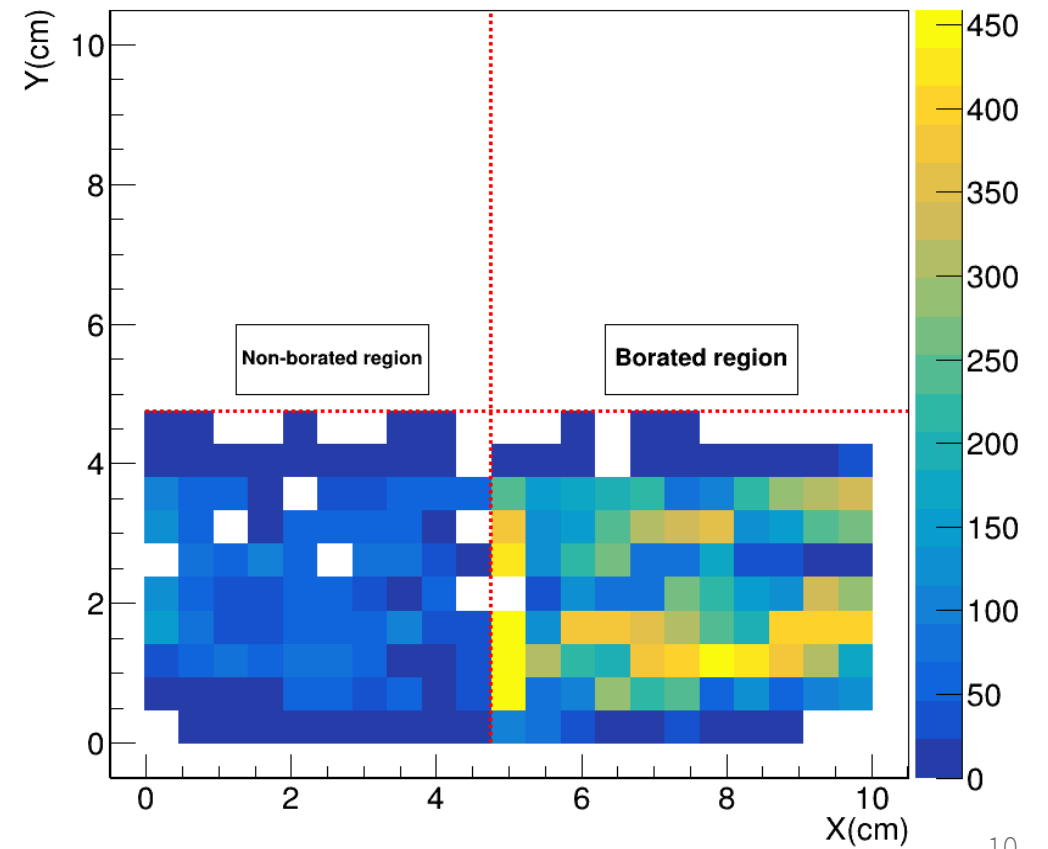


# 2-D readout (XY distribution)

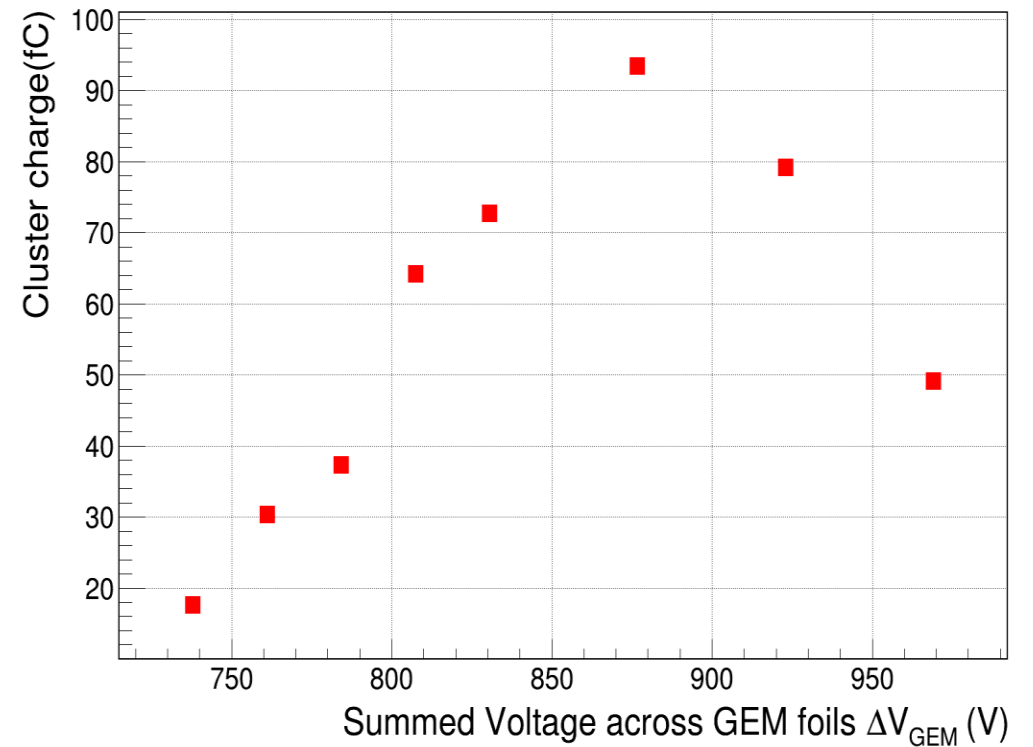
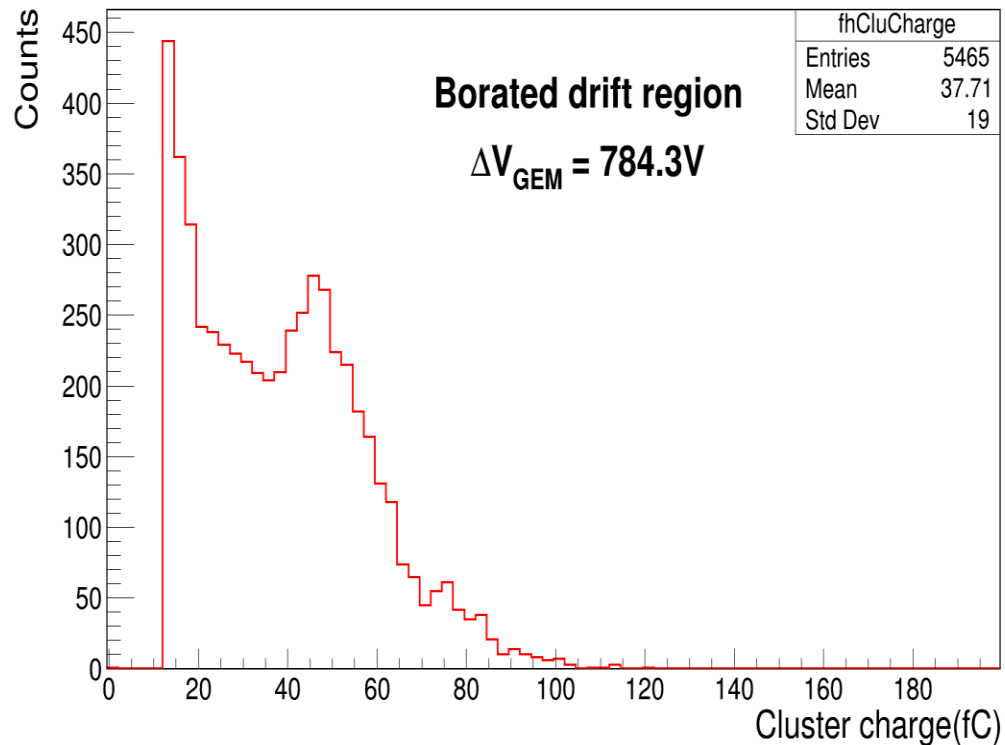
3400 V (Gain ~10)



4200 V (Gain ~800)



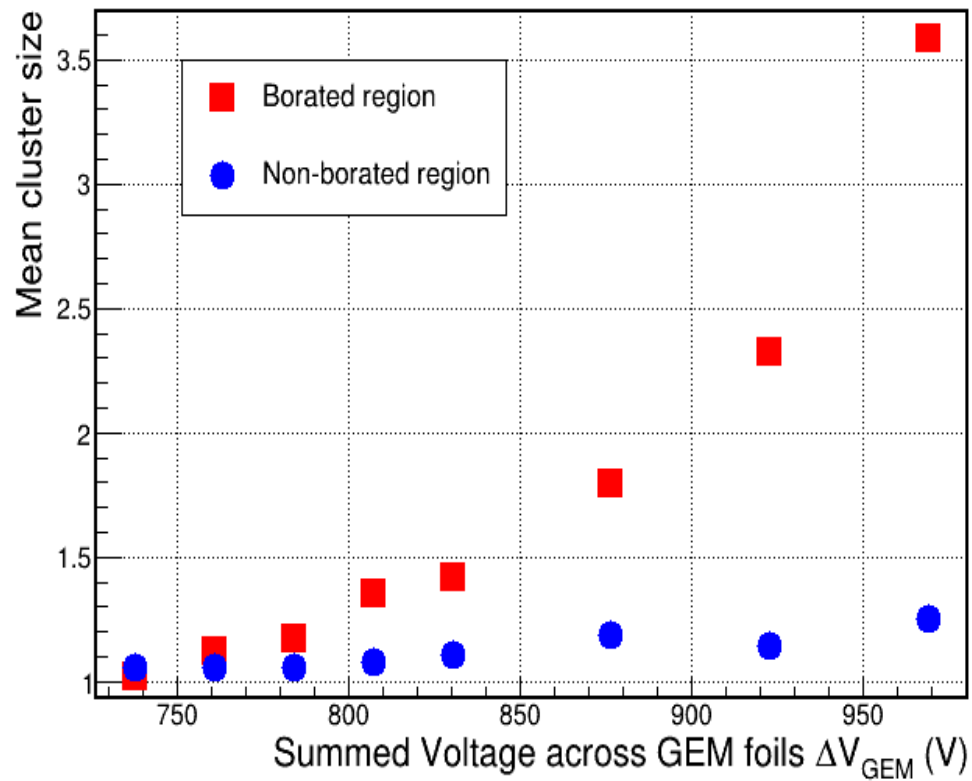
# Cluster charge spectra for borated region



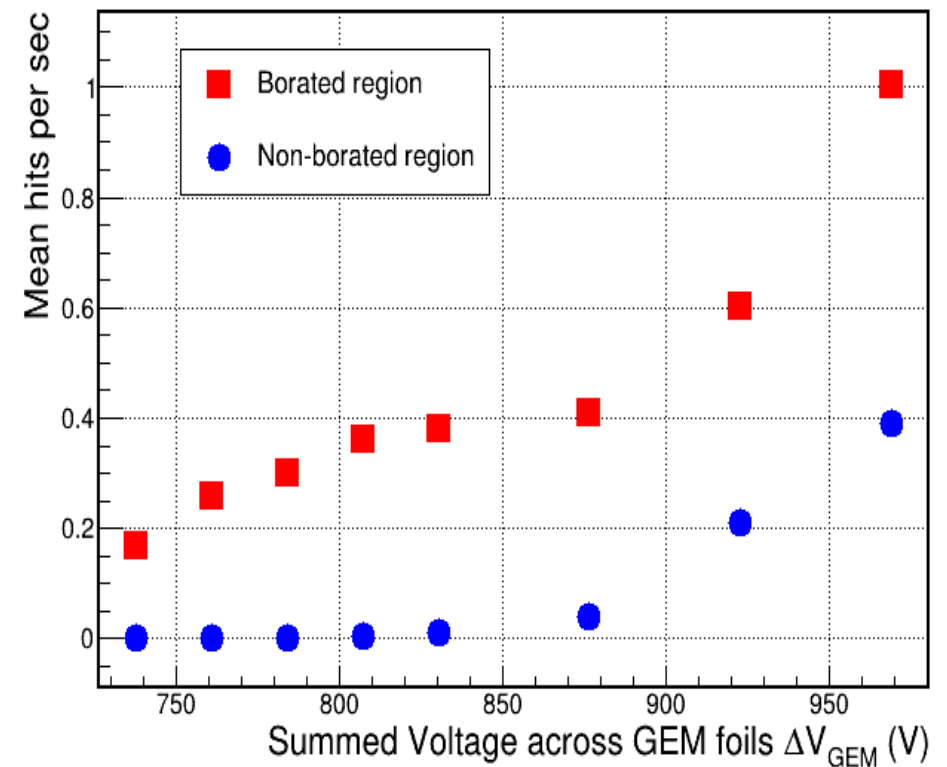
$$\text{Cluster Charge (fC)} = \Sigma (6 + 2.5 \times \text{Cluster ADC of digis})$$

# Cluster size characteristics

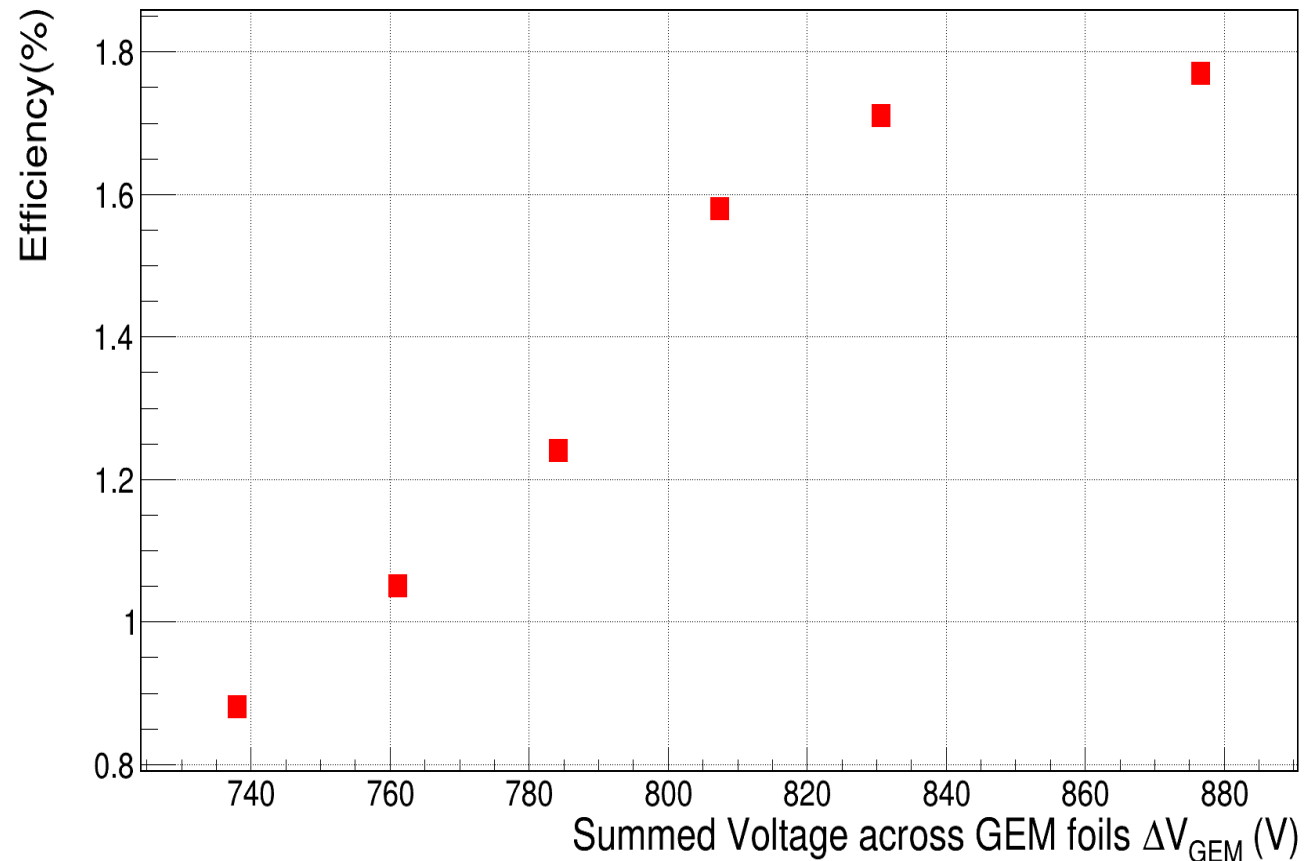
## Cluster size spectra



## Mean hits per sec



# Neutron detection efficiency



- The neutron detection efficiency is defined as the ratio of neutrons detected (via counting the total number of charge particles depositing energy in detector region) to number of neutrons incident on the detector.
- The incident numbers of neutron on the drift plate can be calculated from the activity of source & solid angle. For the detected neutron signals, hits from the charged particles i.e.  $\alpha$  or  $\text{Li}^7$  are considered
- Efficiency increases until the gain of  $\sim 16$ , and shows a presence of saturating thereafter.
- Efficiency at 784.3V voltage is found to be  $\sim 1.3\%$

# Summary and Future plan

- We successfully detected neutron-induced signals using a boron-coated GEM detector.
- A clear distinction between borated and non-borated regions was observed
- Gamma rejection is effective at low gain operation
- The measured neutron detection efficiency is around 1–2%, consistent with expectations for a single boron layer.
- Boron coating on large size drift cathode, experiment with different thicknesses of boron-layer, neutron rate capability have to be studied in future.



Thank you

# GEANT4 Simulation

- The aim of the GEANT4 simulations is primarily to estimate neutron detection efficiency for different converter thicknesses.
- The realistic setup was modeled in GEANT4,
- $^{252}\text{Cf}$  neutron source : emit neutrons as a result of spontaneous fission with a probability of about 3 %.

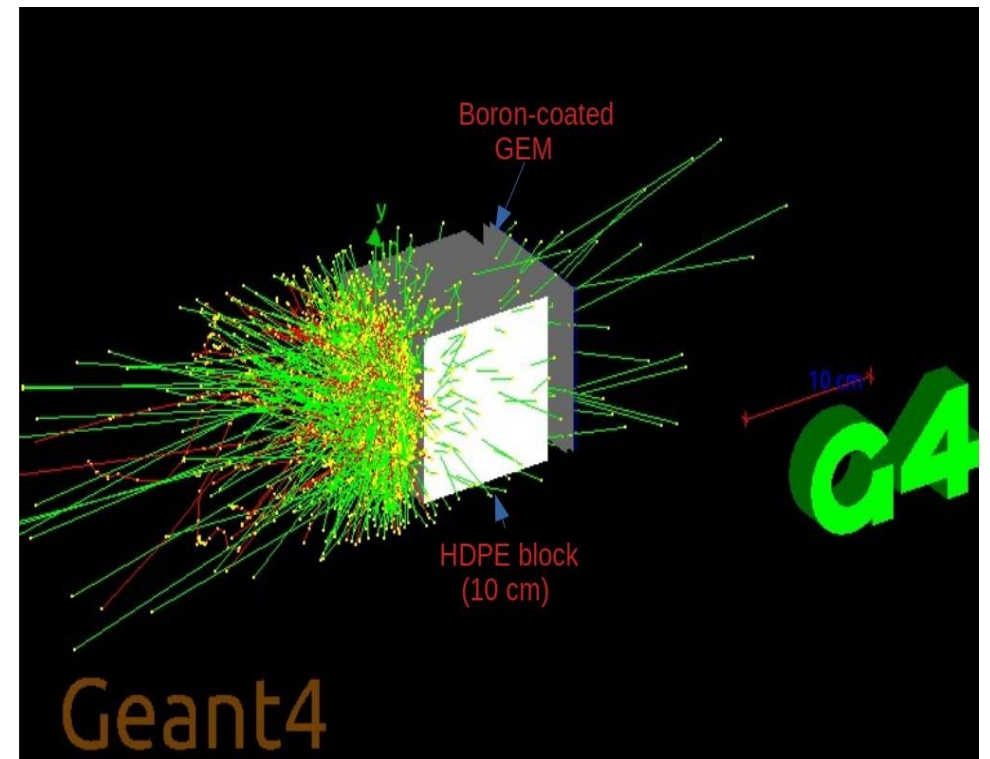
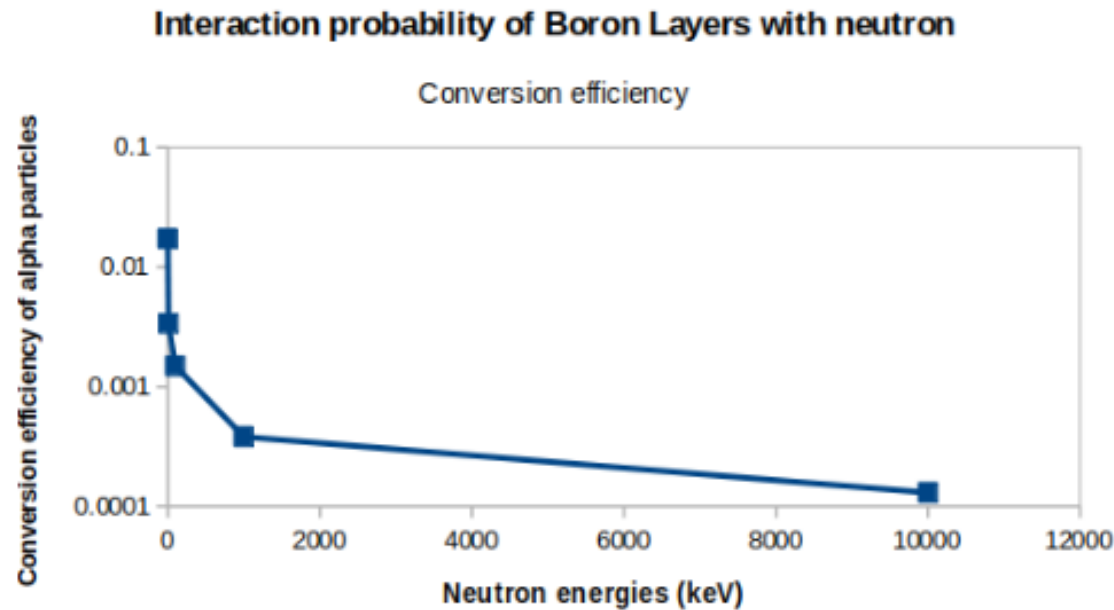


Fig.: Snapshot of simulation

## Conversion efficiency

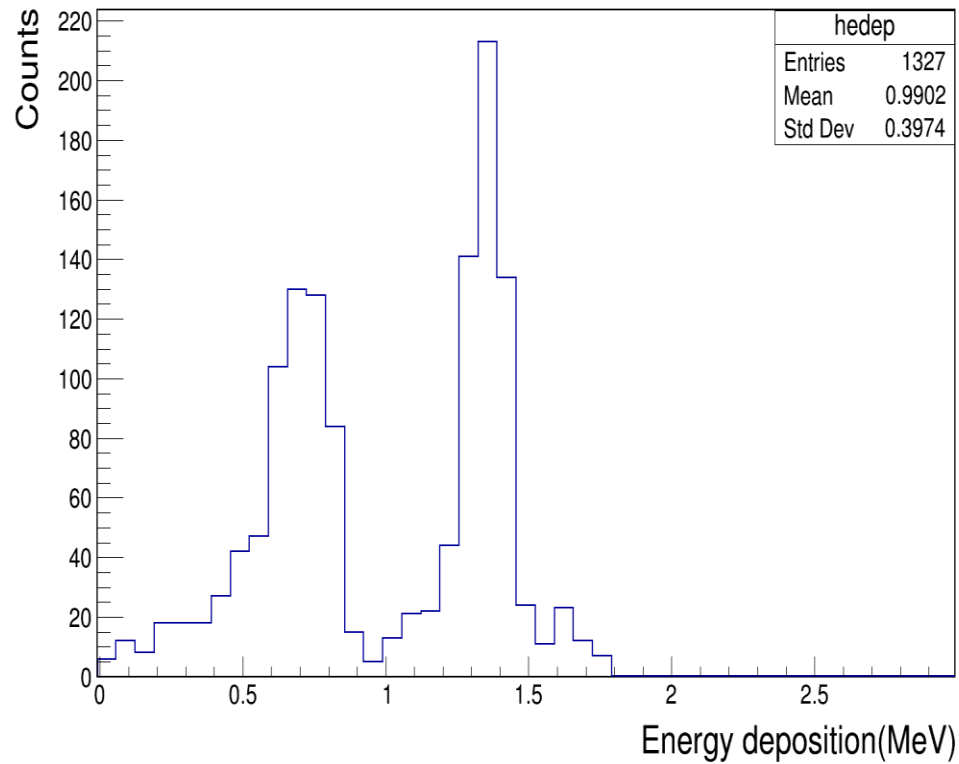
- As neutron energies increases number of charge particle produced in reaction decreases as interaction probability of boron layer with neutron is inversely proportional to incident neutron energies.



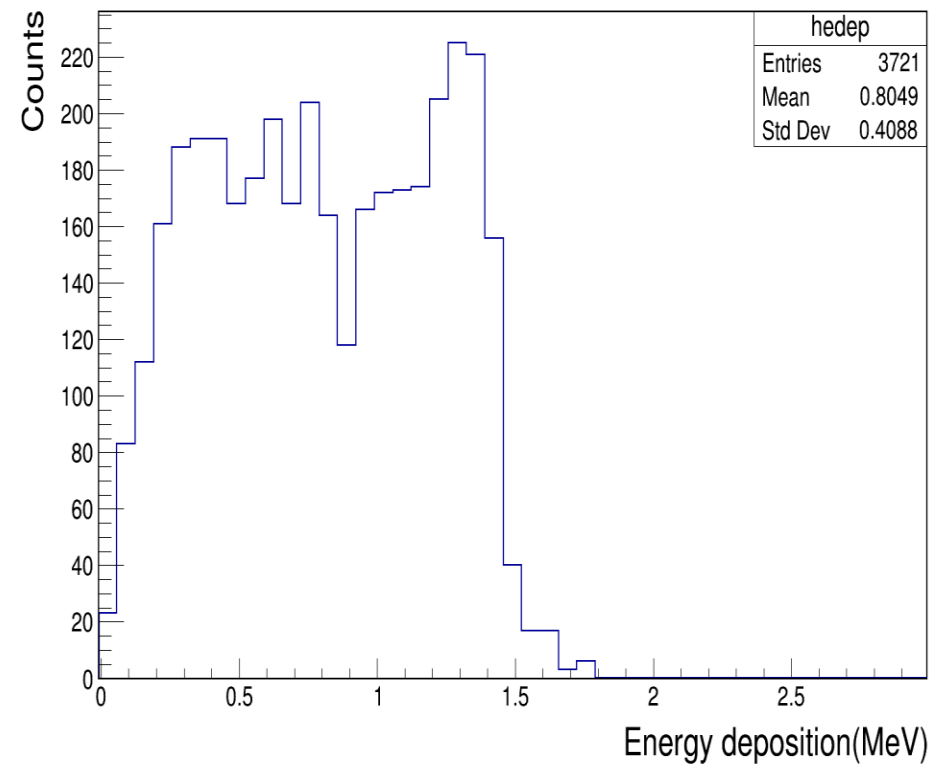
# Simulation results

## Energy deposition spectra of reaction byproducts

0.25  $\mu\text{m}$  B-10 thickness

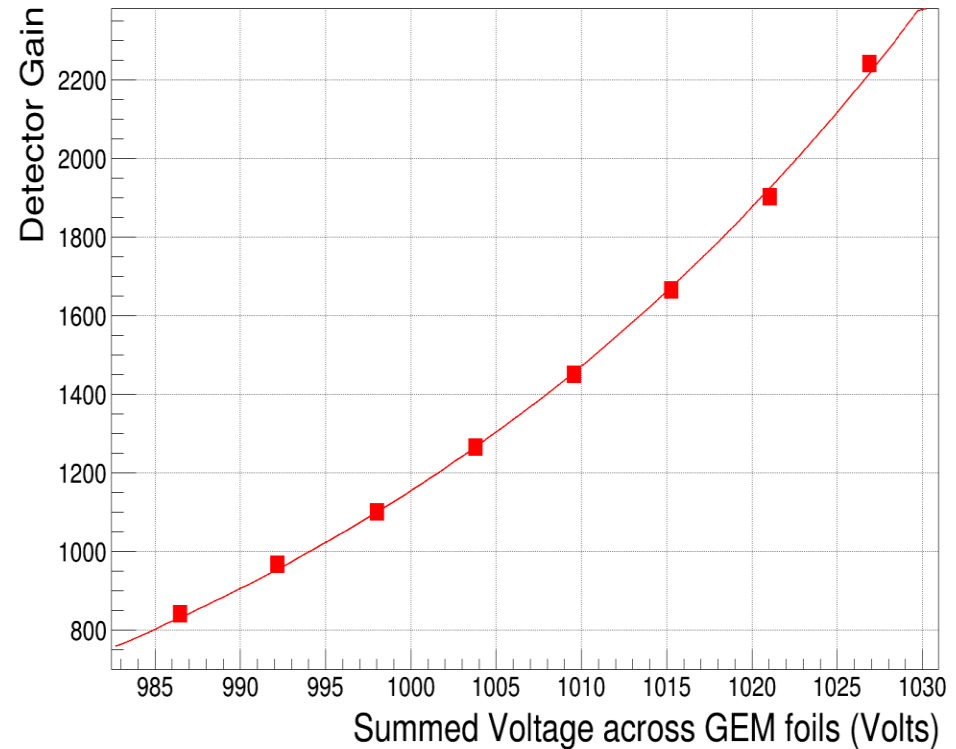
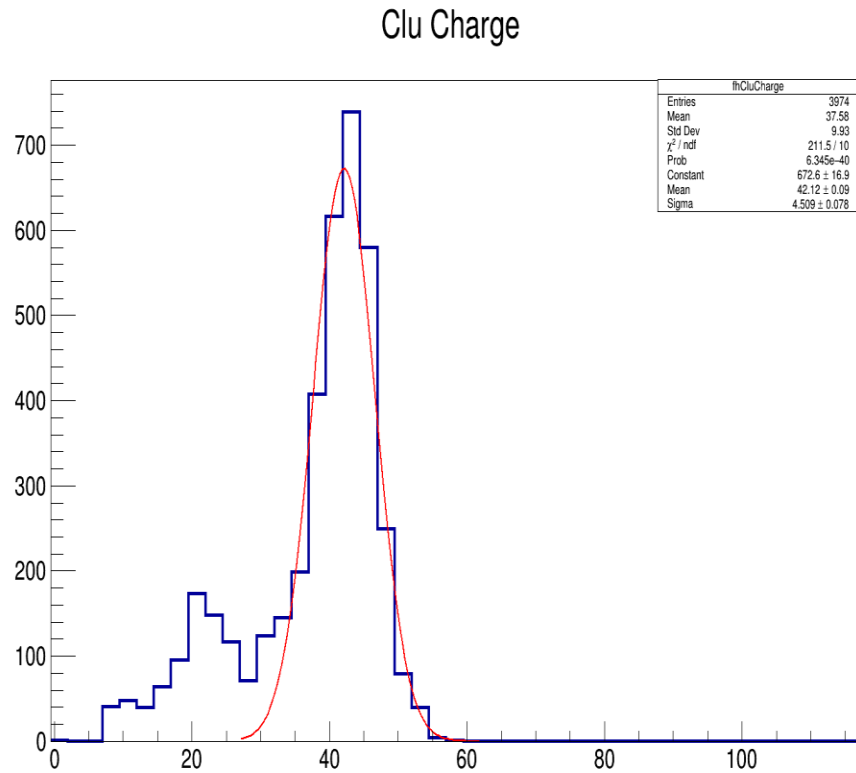


1  $\mu\text{m}$  B-10 thickness



- Energy deposition by byproducts of reaction of thermal neutron (0.025eV) with boron-10 in the 3 mm gas medium i.e. Ar:CO<sub>2</sub>(70:30)

# Measurement of detector gain with $^{55}\text{Fe}$ X-ray source



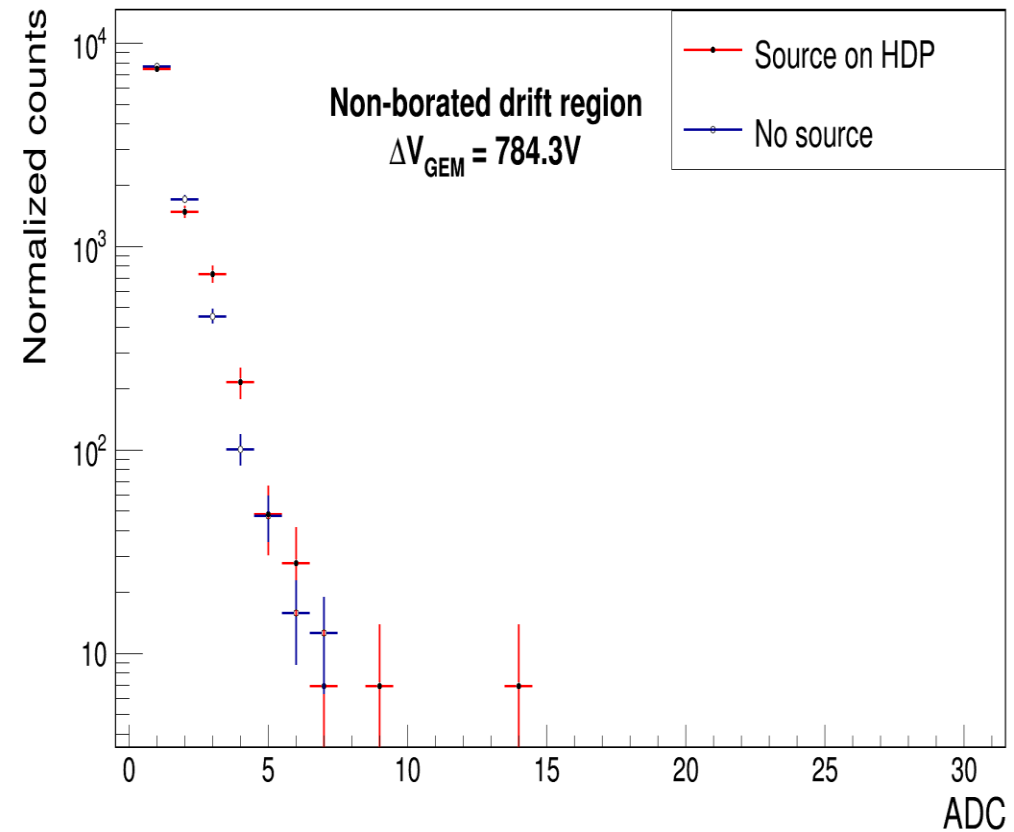
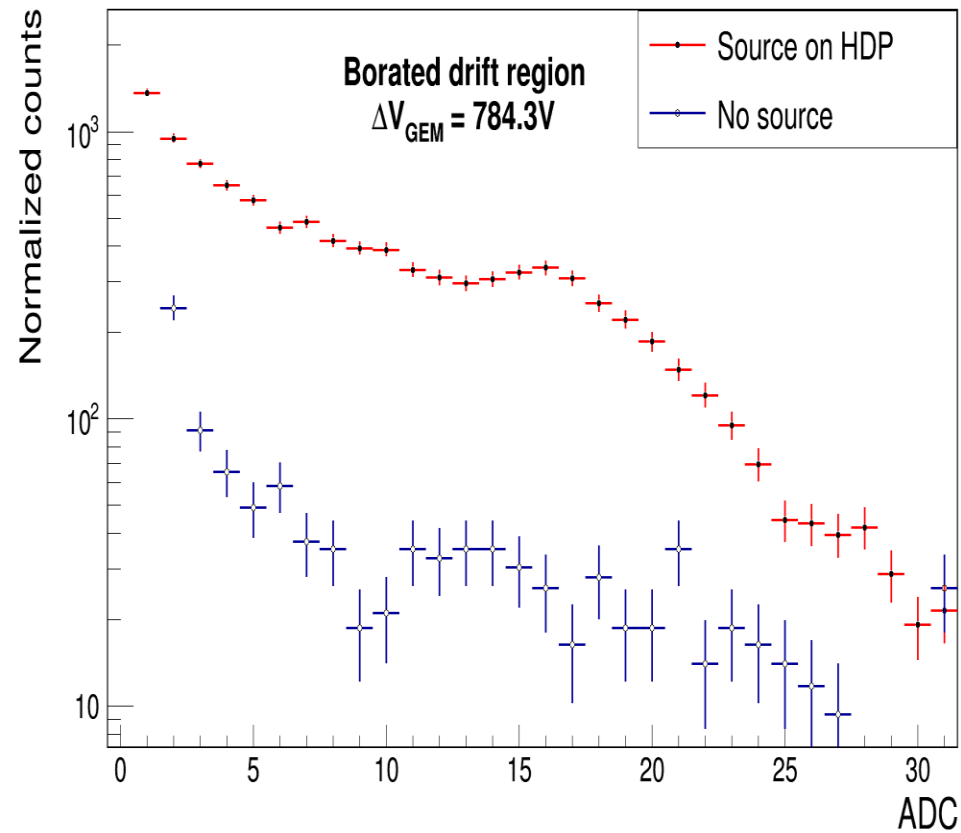
Typical charge distribution plot at summed 1024V

Gain eqn.  $y = ex p(p_0 + p_1x)$ ,  $p_0 = -1.5739$ ,  $p_1 = 0.0236486$

# Experimental results of $^{252}\text{Cf}$ source

## ADC spectra comparison of source and no-source data

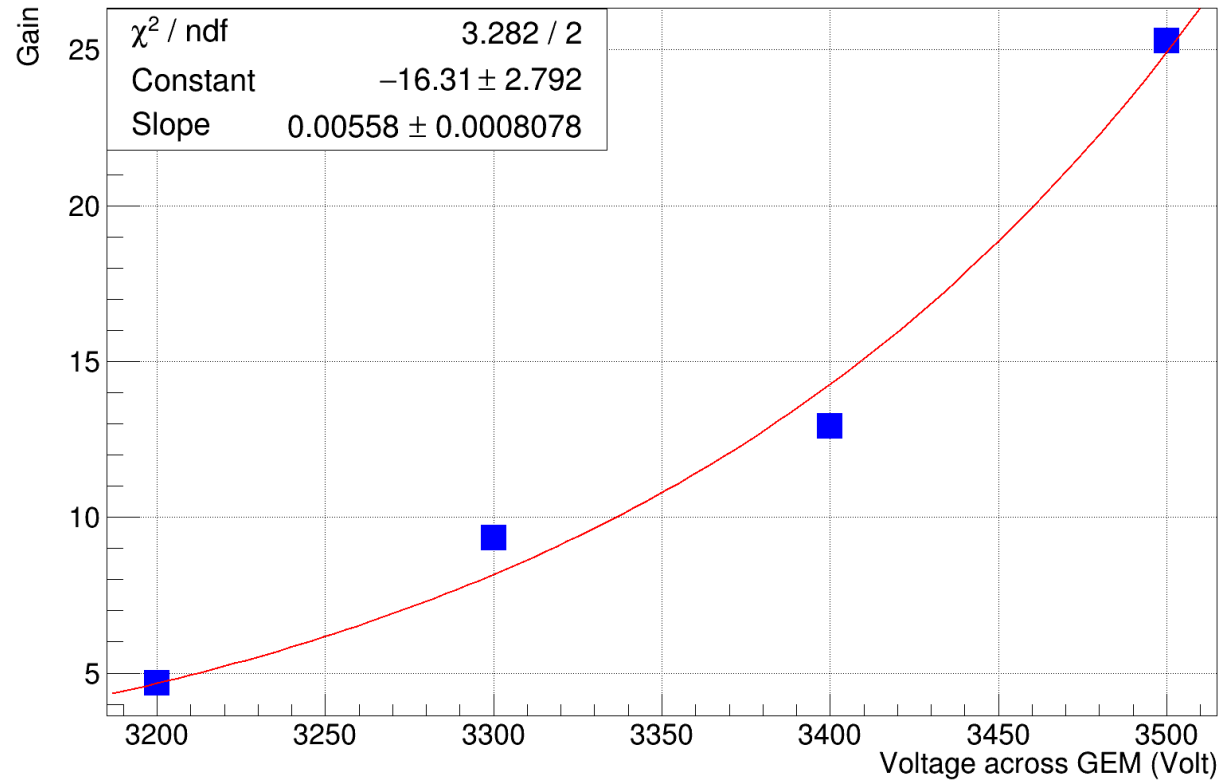
3400 V



# Experimental results

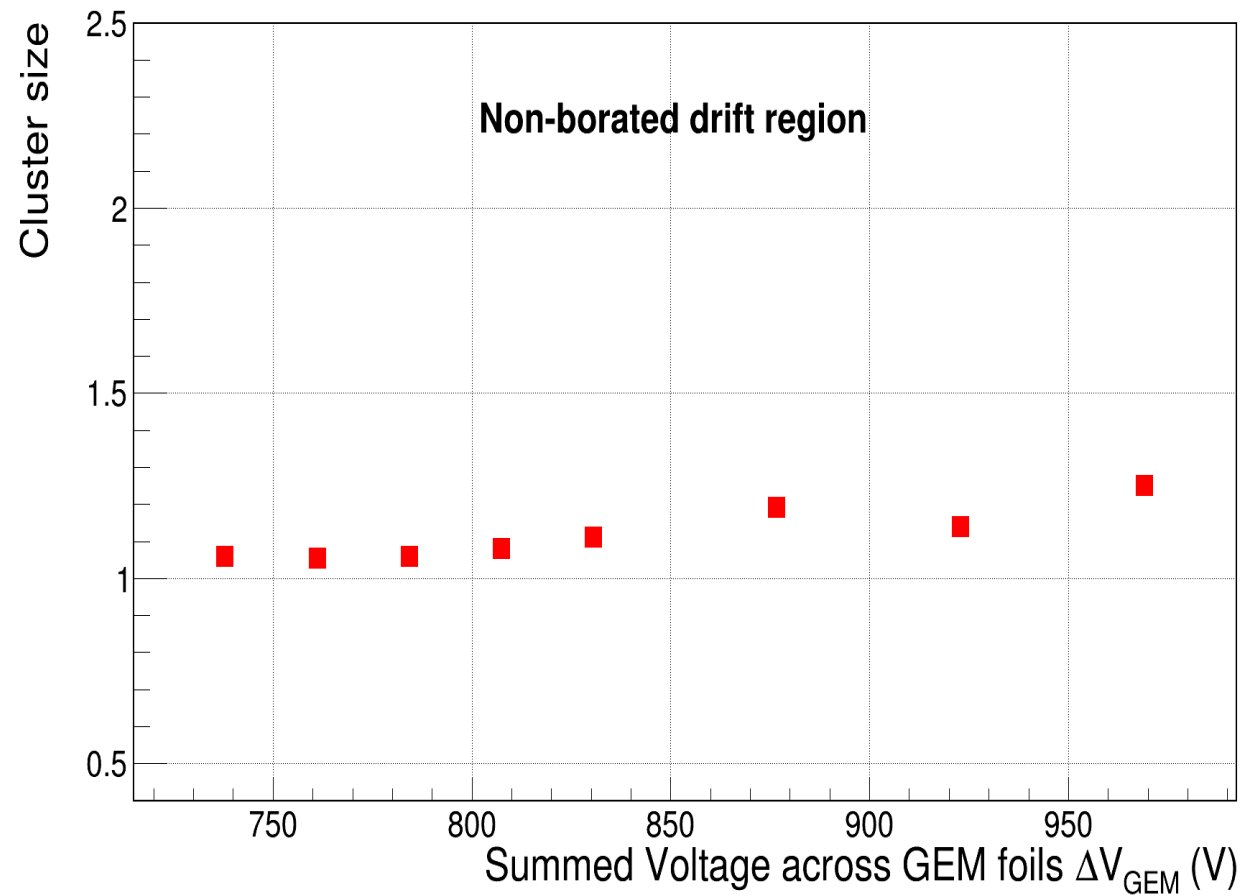
Detector gain measurement with  $^{252}\text{Cf}$  source

Gain vs HV of D11 GEM Detector with  $^{252}\text{Cf}$



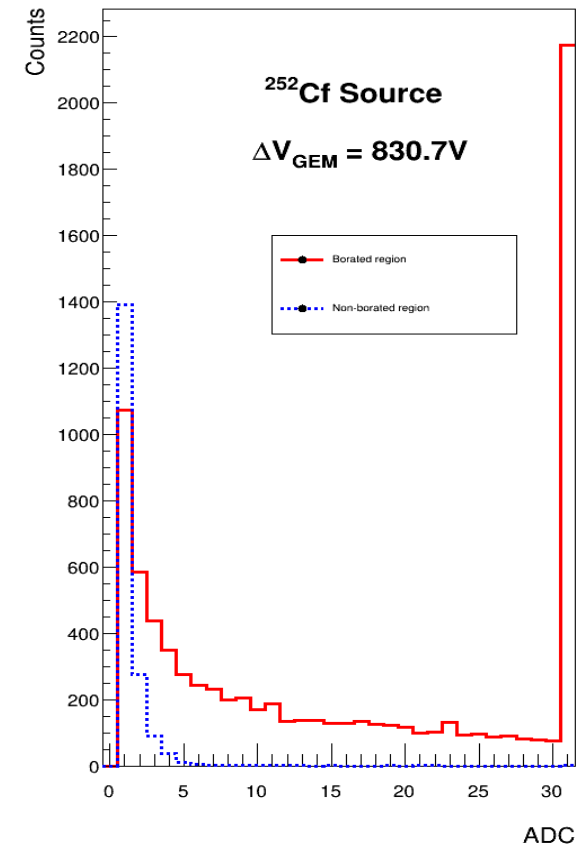
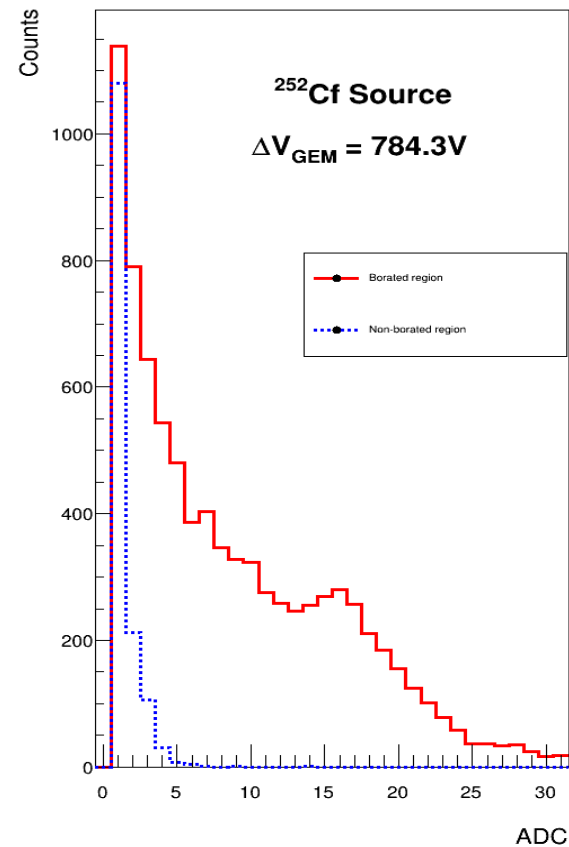
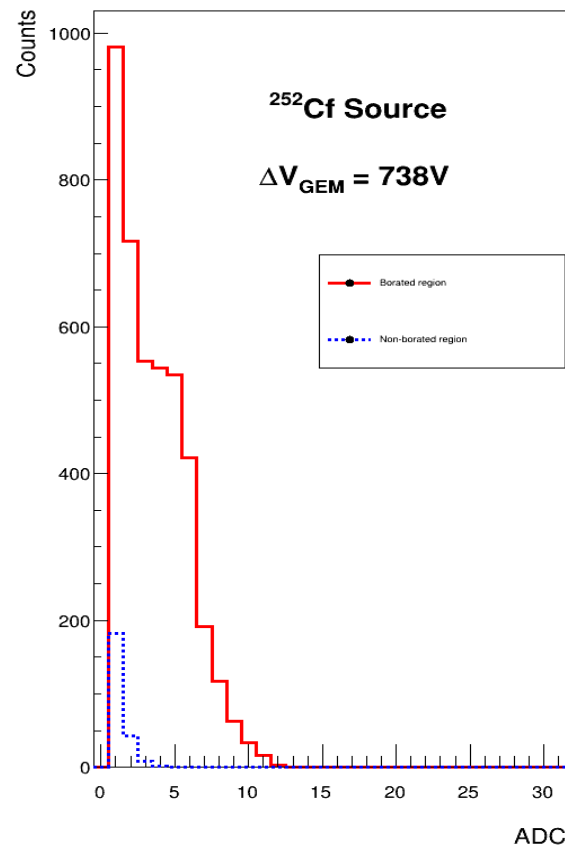
# Experimental results of $^{252}\text{Cf}$ source

Cluster size spectra for non-borated region



# Experimental results of $^{252}\text{Cf}$ source

ADC (pulse height) distribution



# Experimental results of $^{252}\text{Cf}$ source

Digi per TS comparison of source and no-source data for borated region

3400 V

4200 V

