# Measurements of the electron transmission rate of a full-size gating GEM in the absence of magnetic field

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**on behalf of**

**the LC-TPC Asian group**

# Outline of My Talk

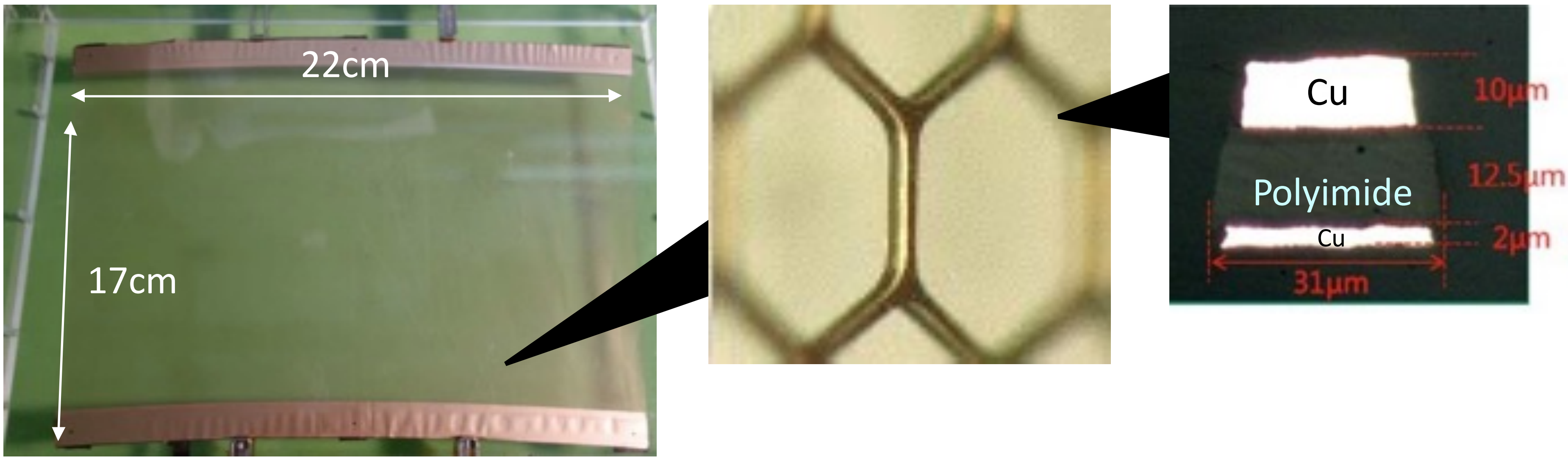
1. Brief Introduction
2. Measurement Technique
3. Measurement using an $^{55}Fe$ Source
4. Measurement using a UV Laser
5. Summary and Outlook
6. Brief Discussion

# Introduction



- ILC TPC problem:  Ion Back Flow -> Distortion of reconstructed tracks

- Expected Function  of  Gating GEM  for ILC-TPC:
  High Transparency for drift electrons at the OPEN state, and
  high blocking power for positive ions at the CLOSED state.

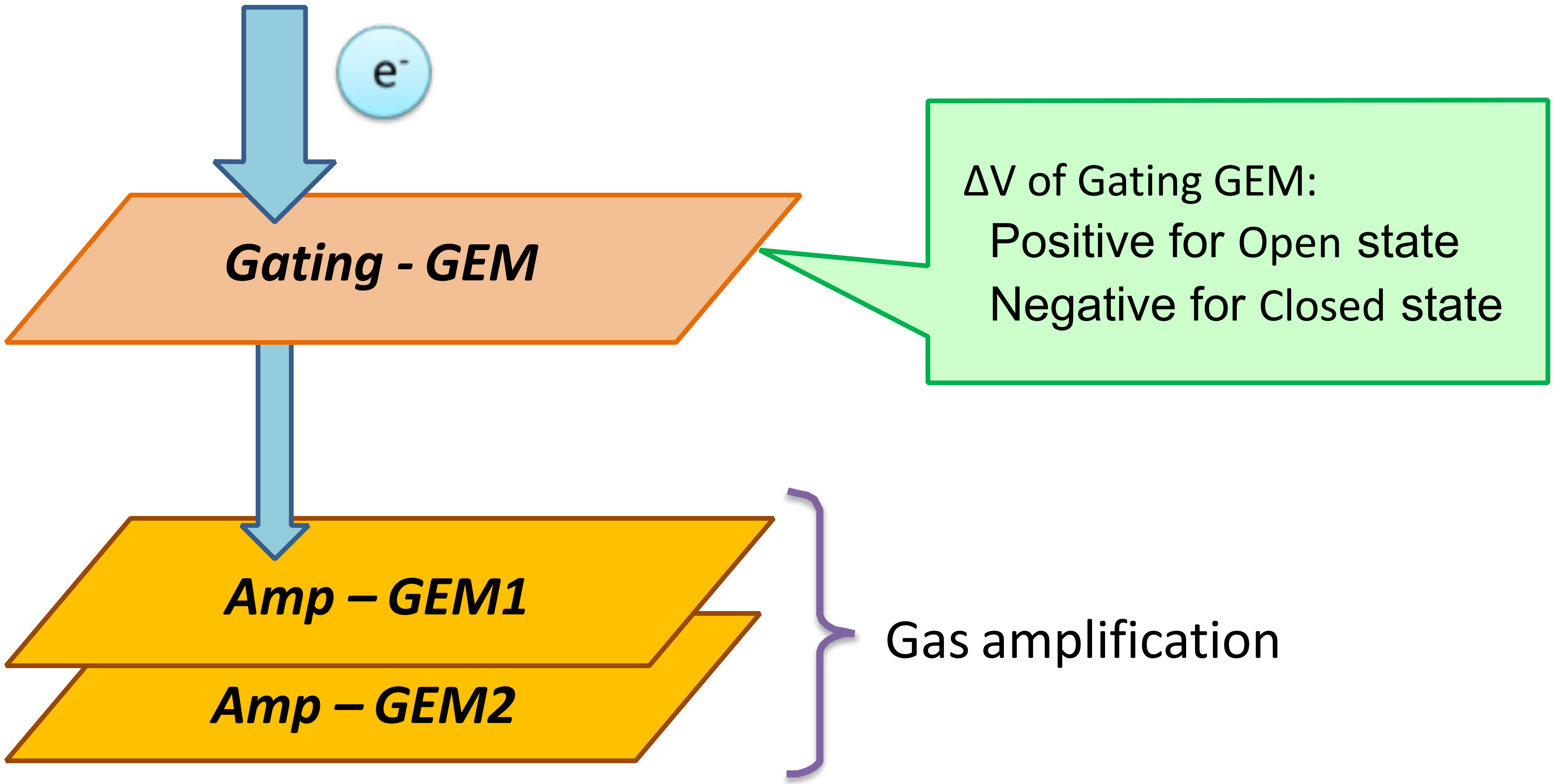



We measured the ELECTRON blocking power at the closed state
as well the transmission rate at the open state using a full-size gating GEM
in order to

- estimate the lower limit for the blocking power for positive ions, and
- study possibility for the application to TPCs, for which drift electrons needs to be efficiently prevented from entering the gas amplification region.

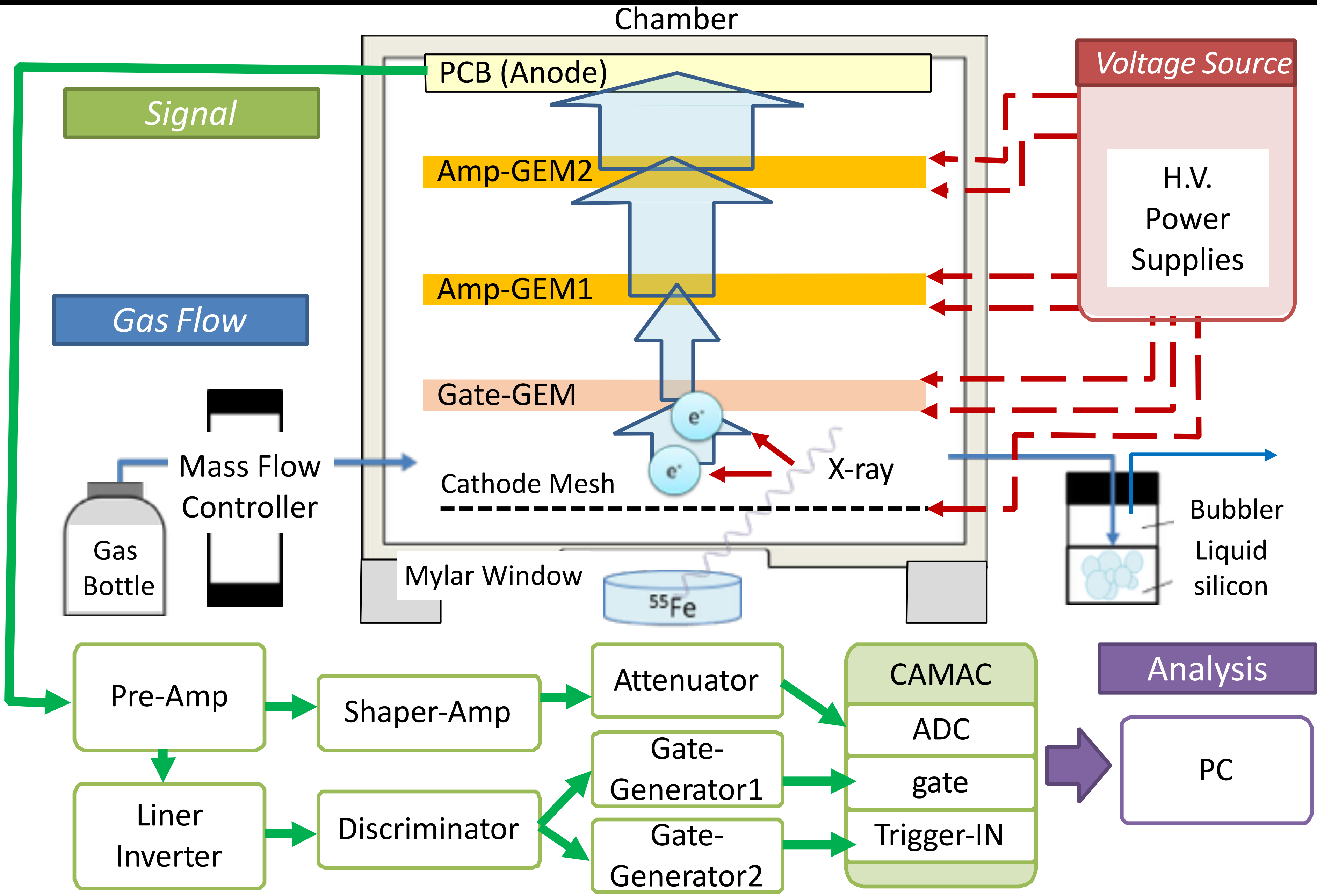
# Measurement Technique



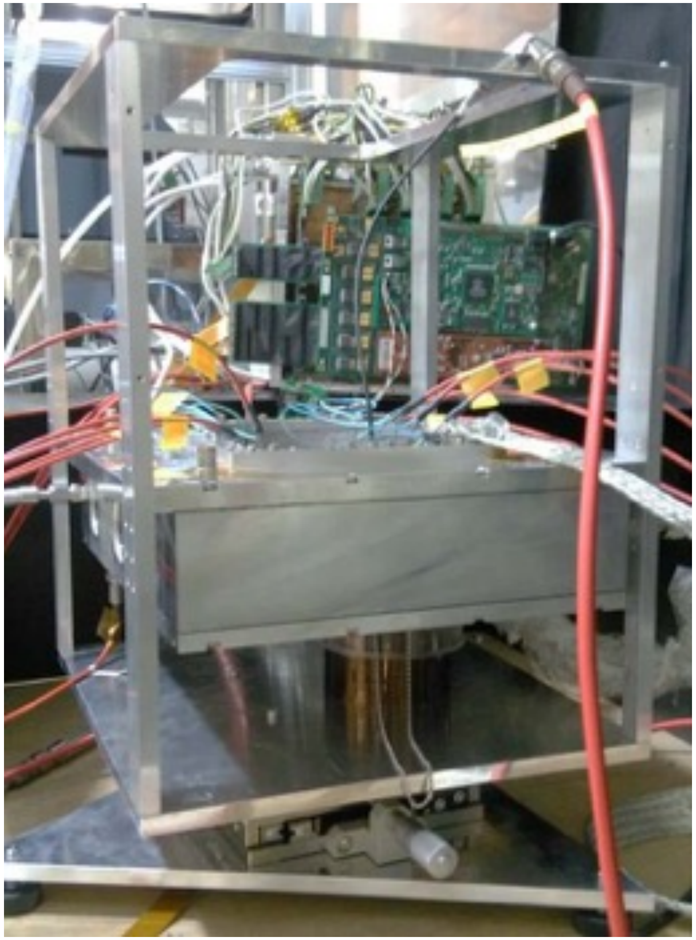



We measured the electron transmission (blocking) rate as a function of ΔV by observing the gas-amplified signals generated by an $^{55}Fe$ source or a UV laser.

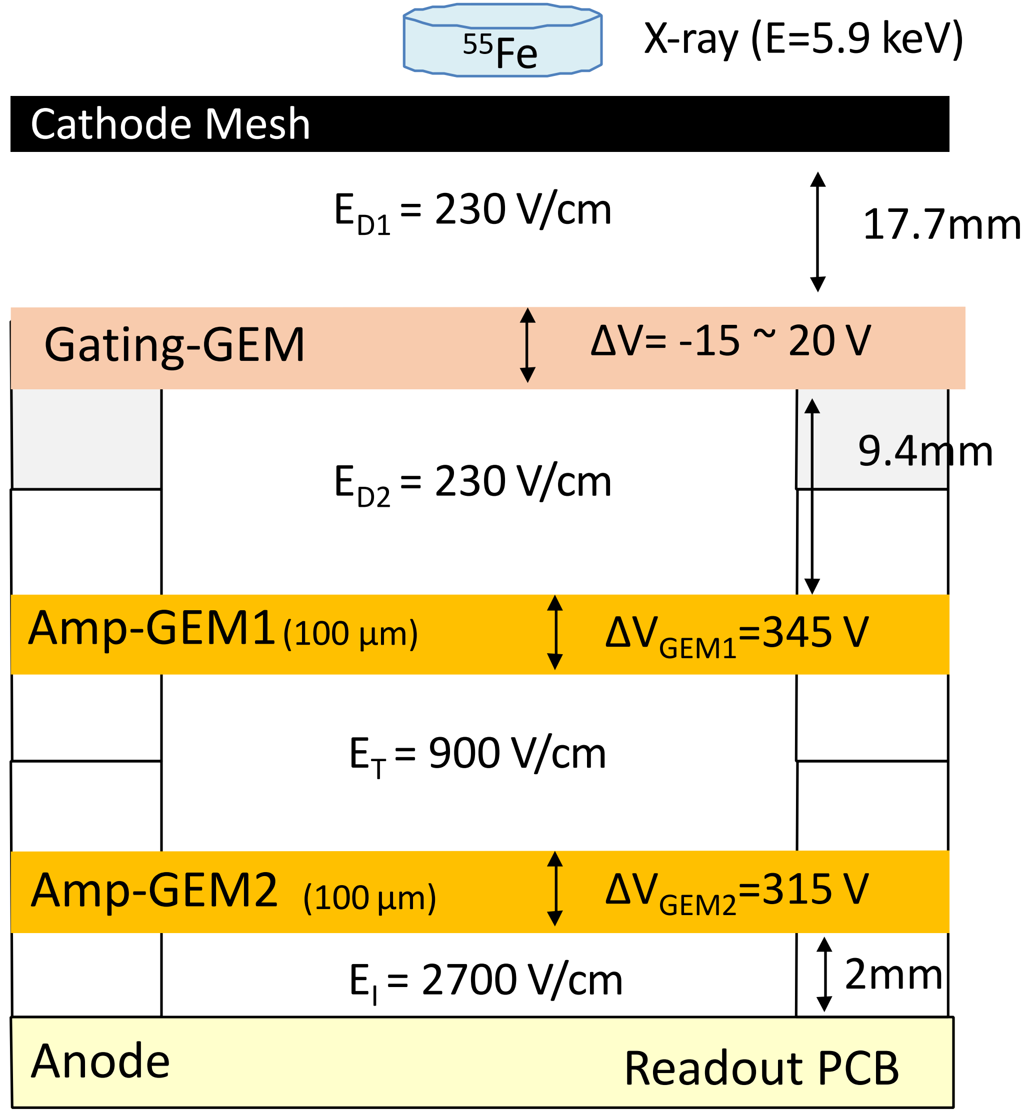
# *Experimental Setup using an $^{55}$Fe Source*



# *Experimental Setup using an 55Fe Source*



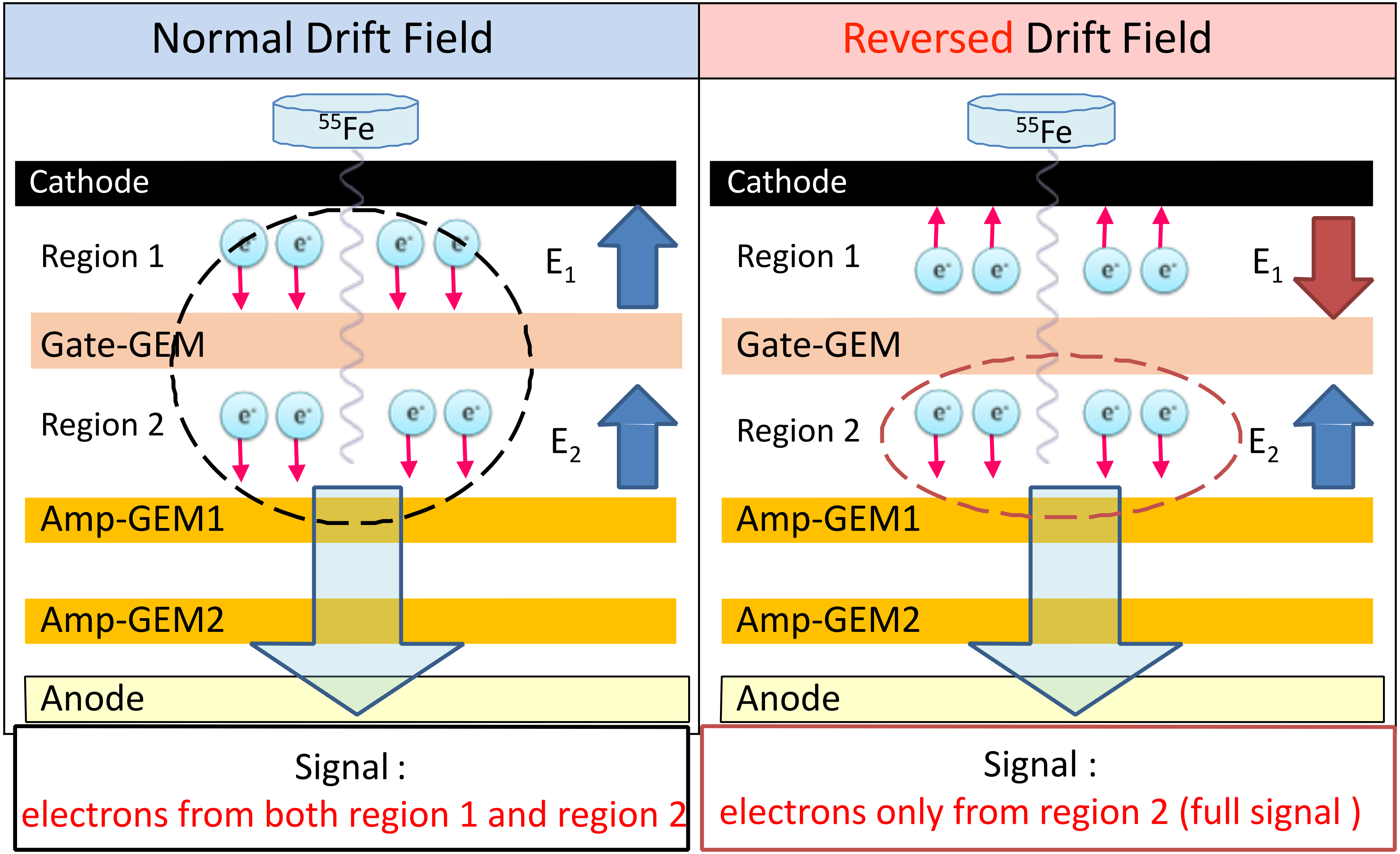
Chamber




- Used gas -> Ar : $CF_4$ ： Iso-$C_4H_{10}$ = 95 : 3 : 2 [%] （T2K gas）

# *Measurement using $^{55}Fe$*

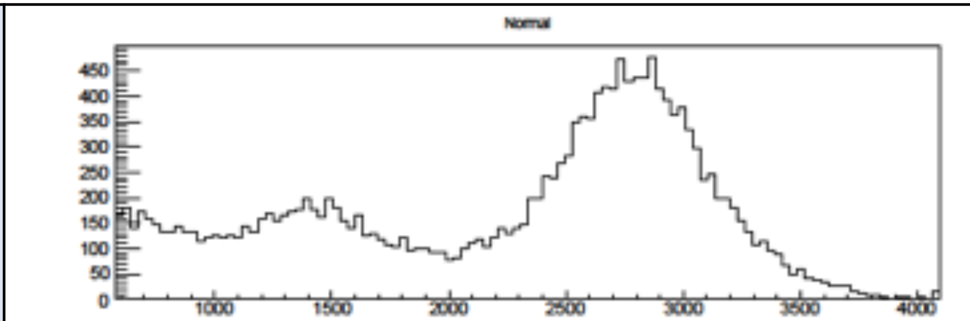
**We measured the signals with the normal and reversed drift fields for each ΔV.**



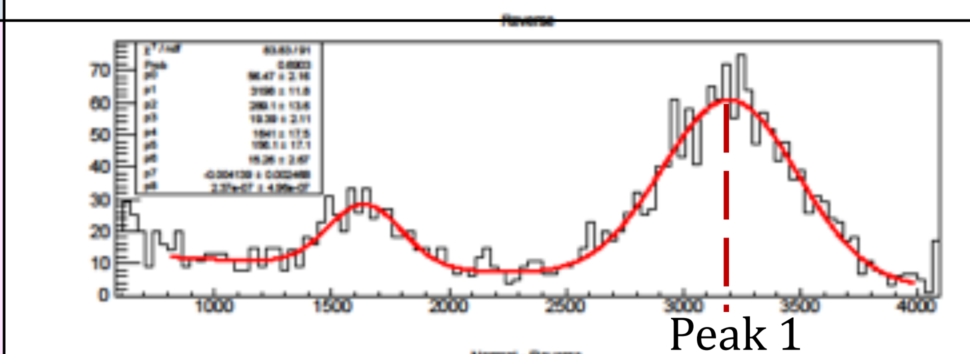
# Measurement using $^{55}Fe$

Examples of the pulse height distribution （$\Delta V_{Gate\text{-}GEM}$ = +2.5V）

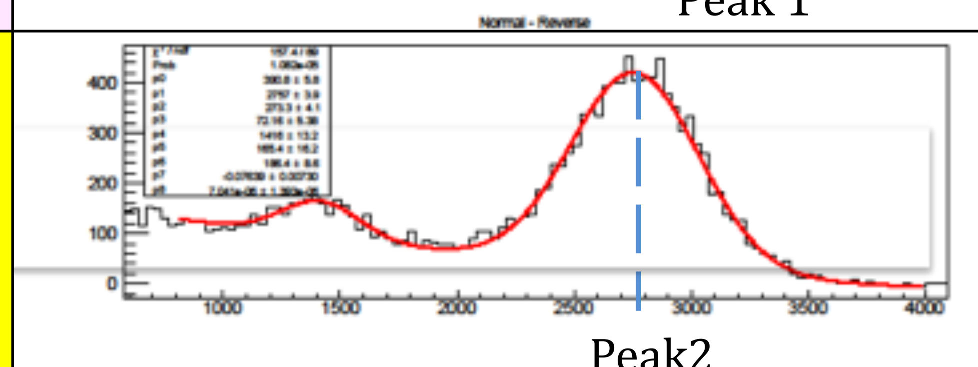
(1) Normal Drift Field
signals from the both regions
10-minute run




(2) Reversed Drift Field
signals only from region 2
(full signal charge)
10-minute run



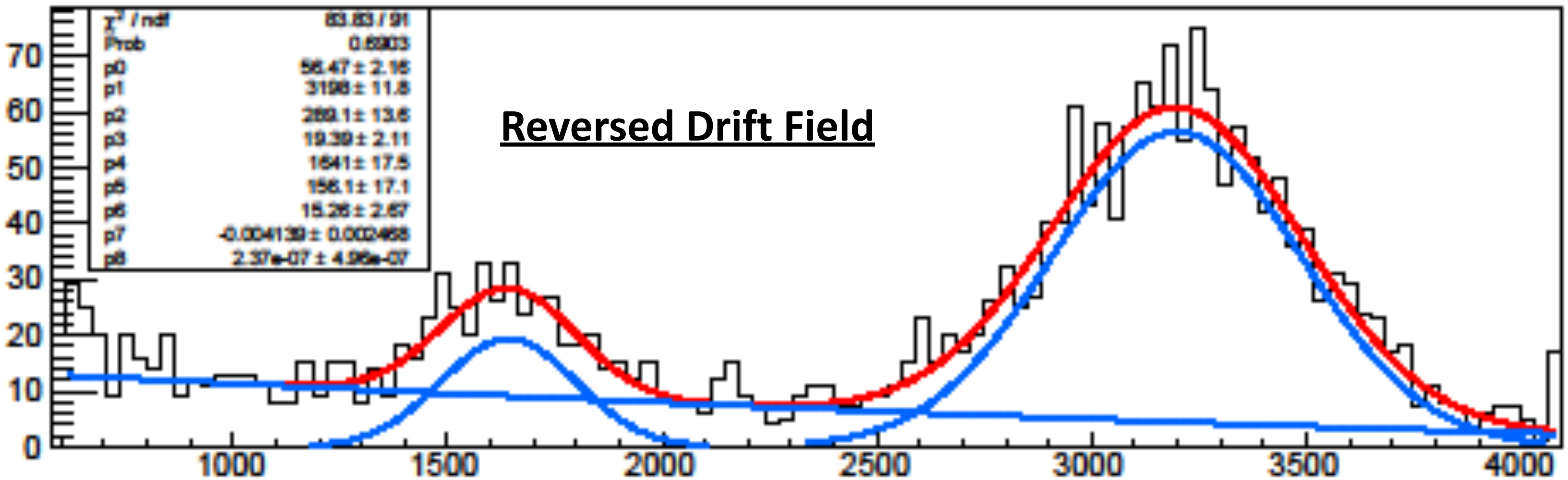

(1) - (2):
signals only from region 1

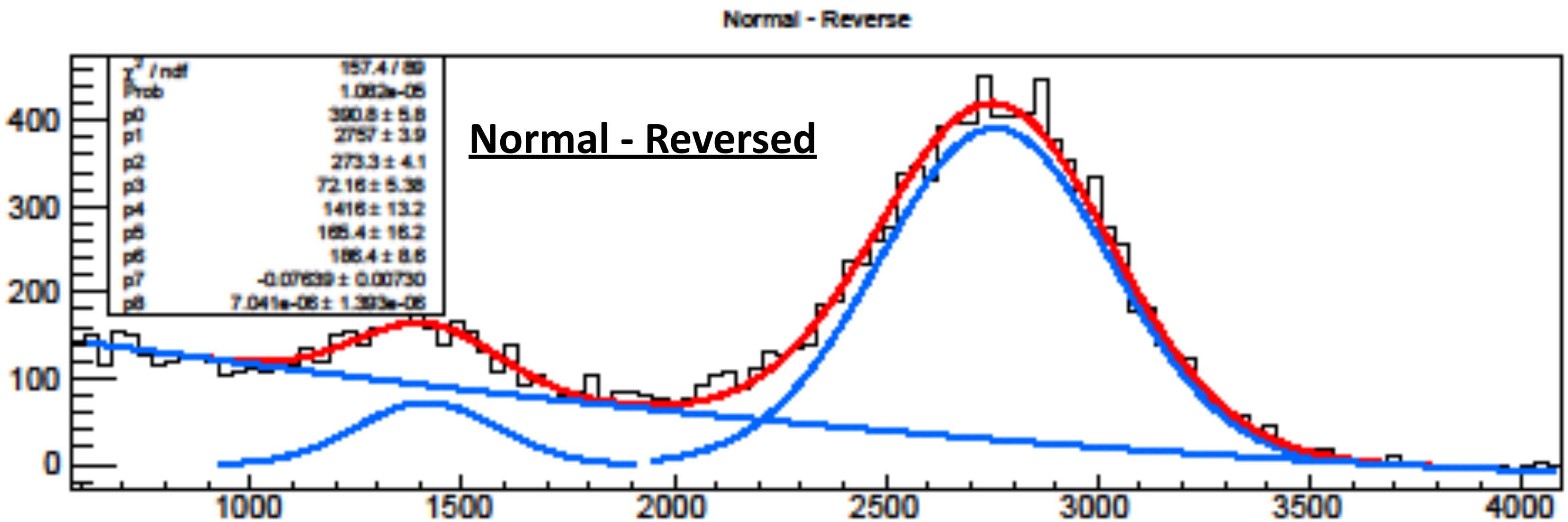



$$\text{Transmission rate} = \frac{\text{Peak 1 - Pedestal}}{\text{Peak2 - Pedestal}} \times 100 \quad [\%]$$

## Fitting of the pulse height distribution of $^{55}Fe$ signals with 2 Gaussians and a polynomial (background)

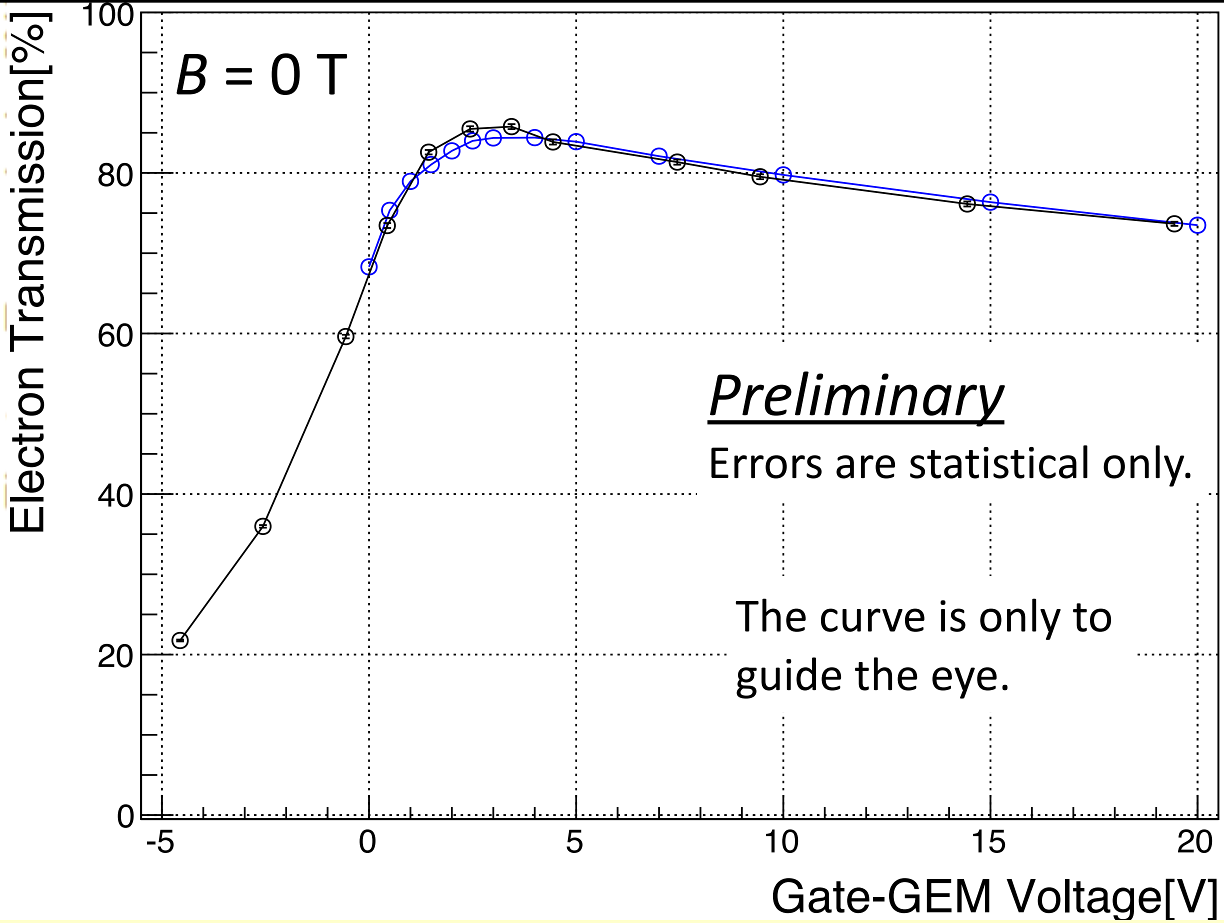
ΔV = + 2.5 V



# *Electron transmission rate vs. ΔV measured with $^{55}Fe$*






black circle : Data points

blue circle : K. Ikematsu, Conference Record

DOI: 10.1109/NSSMIC.2014.7431237

- The maximum transmission rate is about 86% at around ΔV = +3.5 V.
- The transmission rate decreases slowly above +3.5 V.
- It decreases rapidly with increasing negative ΔV.
- The measurement is difficult below ΔV = -4.5 V because of small signals.

# *Experimental Setup using a Laser*



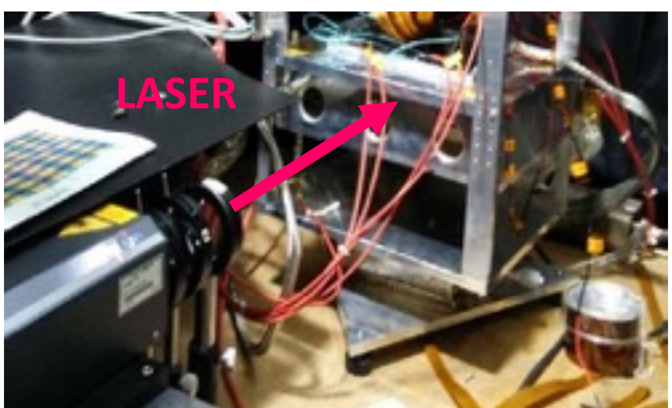
We measured the electron transmission rate at negative ΔV using a laser.

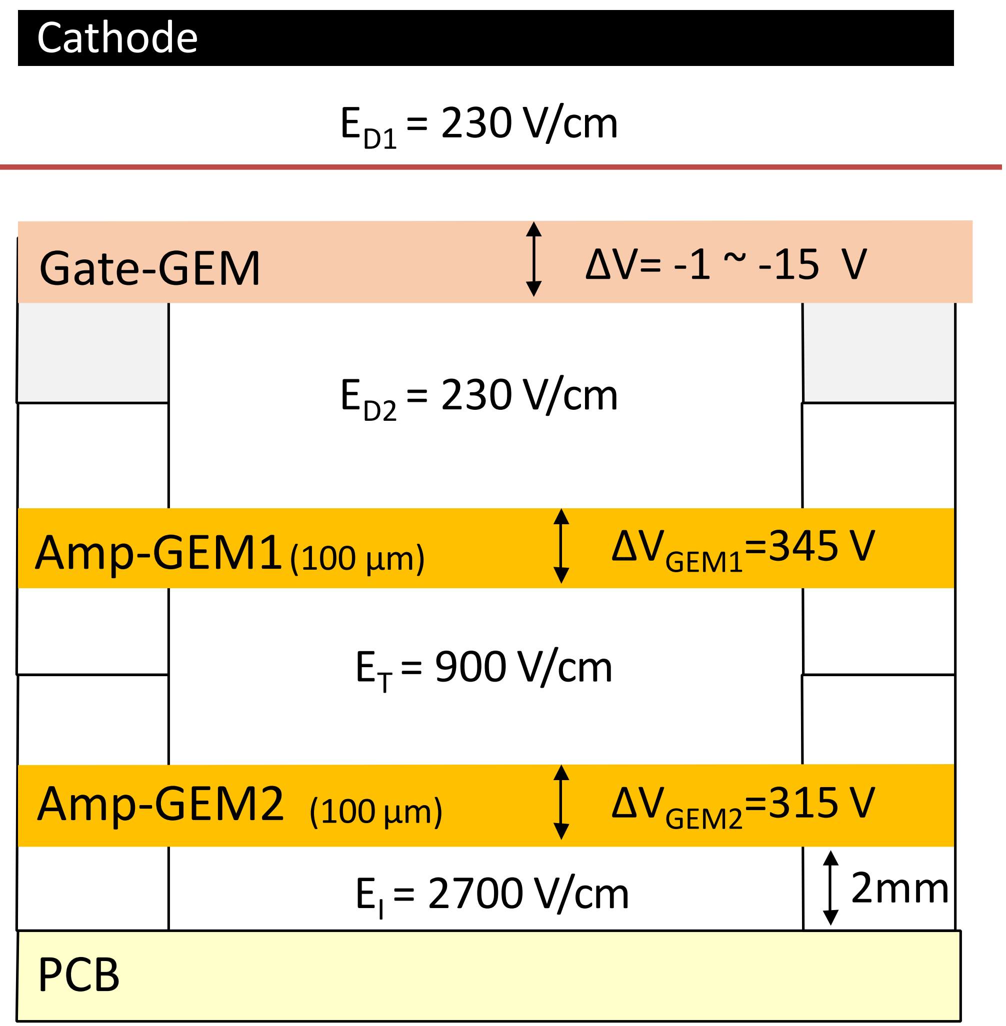
Laser

Nd:YAG (λ = 266 nm)

Rep. 20 Hz PFN. 95 %

Primary electrons: about 600 / pad row

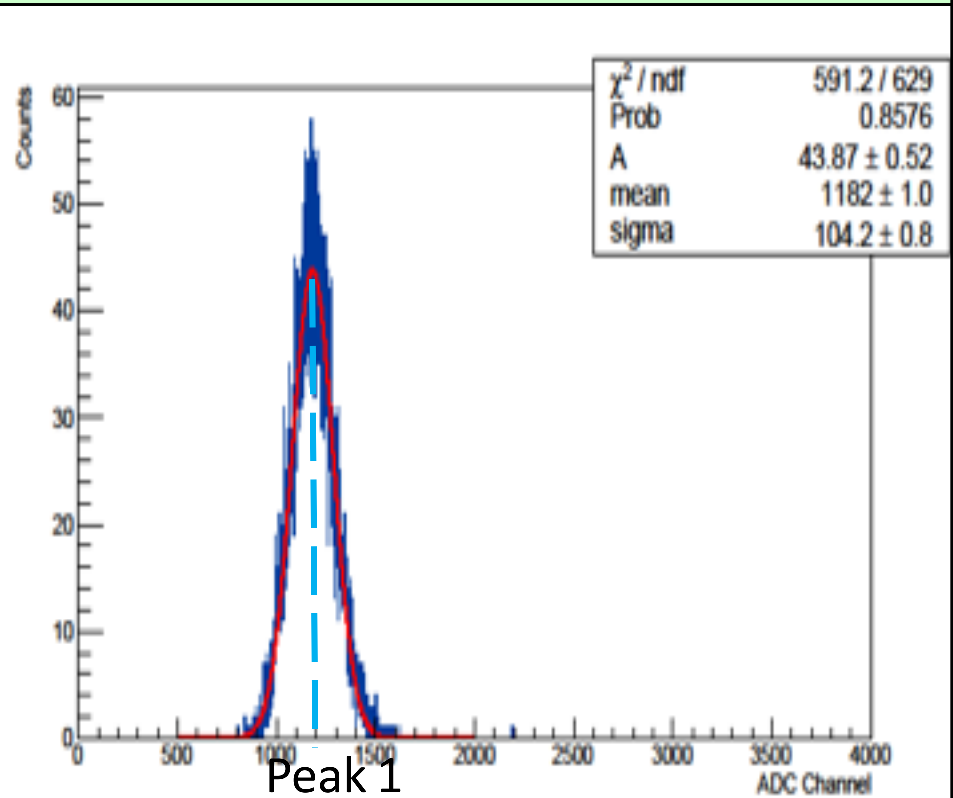


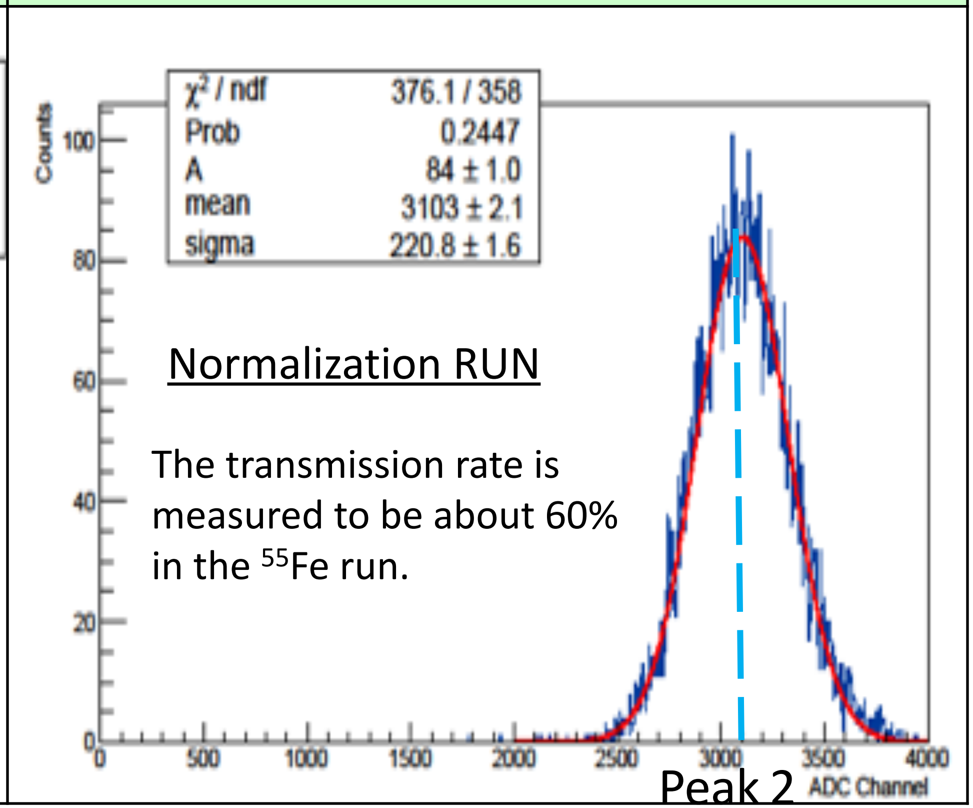



# Measurement using a Laser

## Examples of the pulse height distribution

| $V_{Gating\text{-}GEM}$ = -4.5 V | $V_{Gating\text{-}GEM}$ = -0.5 V |
|---|---|




$$\text{Transmission rate} = \frac{\text{Peak 1 - Pedestal}}{\text{Peak2 - Pedestal}} \times \underline{0.6} \times 100 \ [\%]$$

Pedestal = 55.0

↑ Transmission rate at $V_{Gating\text{-}GEM}$ (ΔV) = - 0.5 V measured with $^{55}Fe$

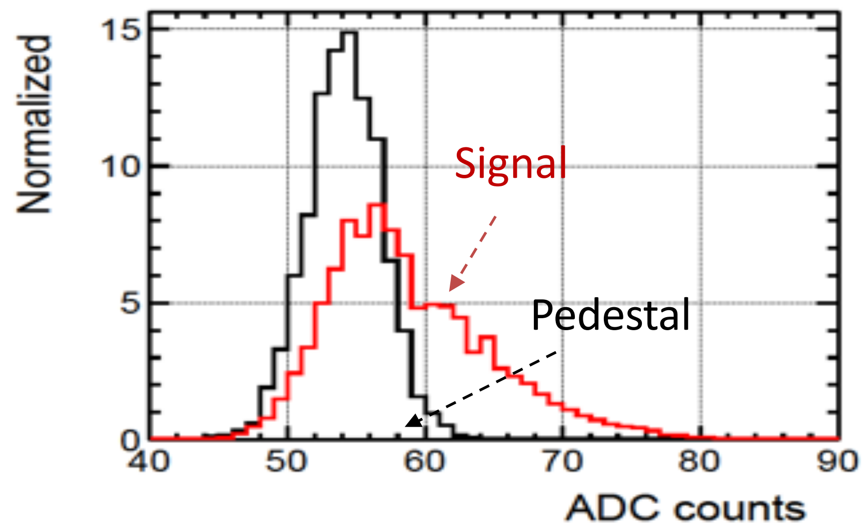
# *Measurement using a Laser (for Negatively High ΔV)*

Example: $V_{Gating\text{-}GEM}$ = -14.5 V

## Raw Pulse Height Distributions

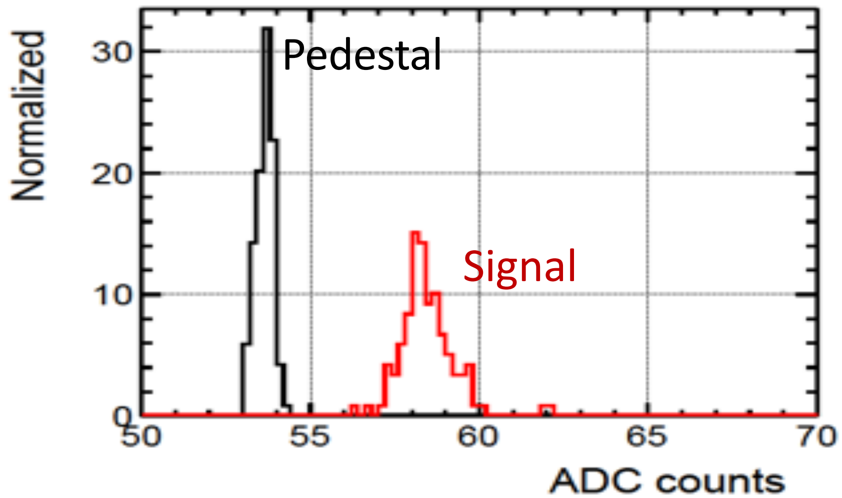
The signal is not well separated from the pedestal (noise) distribution.

The average laser signal can be obtained by taking the average of the distribution.




## Distribution of the averages taken for several hundreds of signals (pedestals).

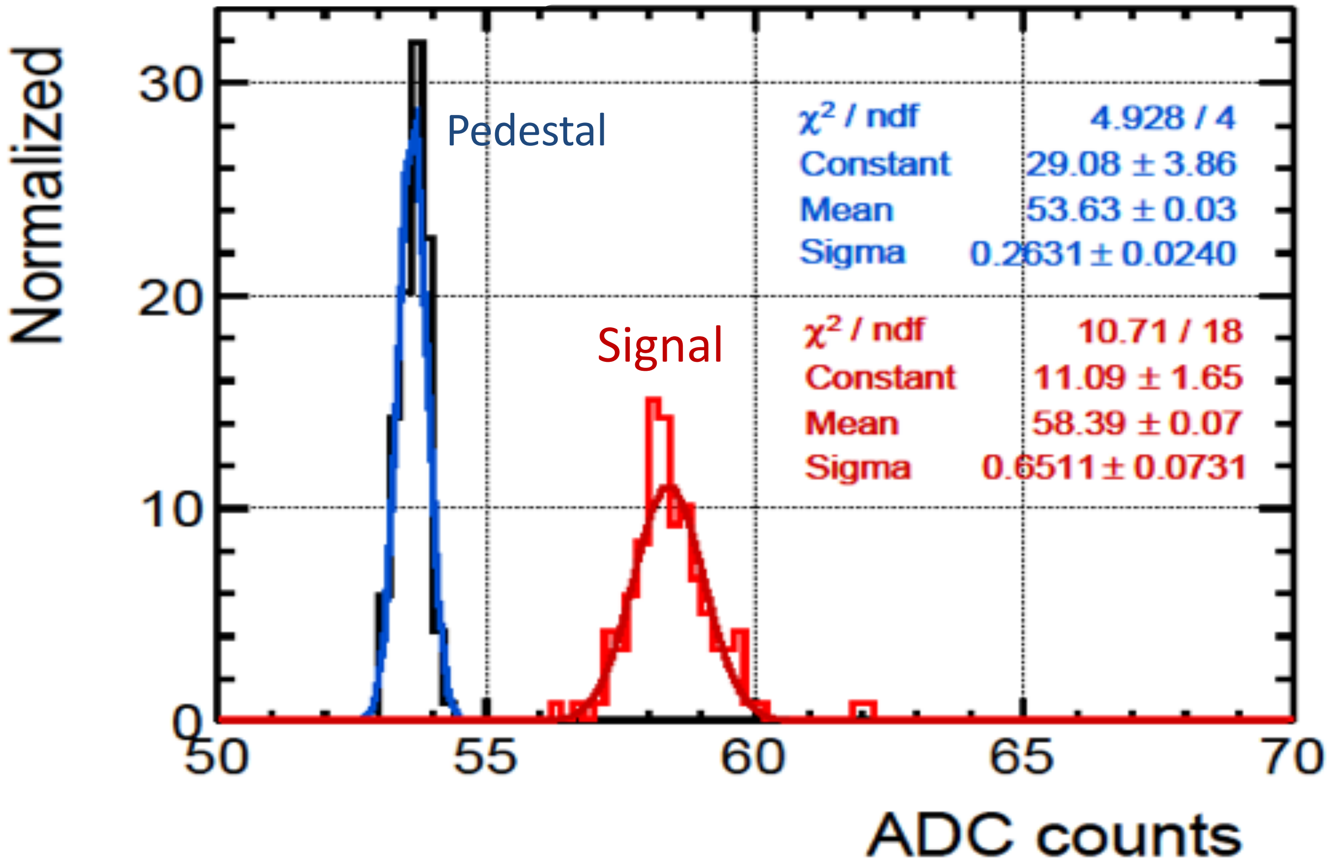
The existence of the laser signal is clear, and the average signal can be estimated by Gaussian fitting.



# *Measurement using a Laser (for Negatively High ΔV)*



Example: $V_{Gating\text{-}GEM}$ = -14.5 V

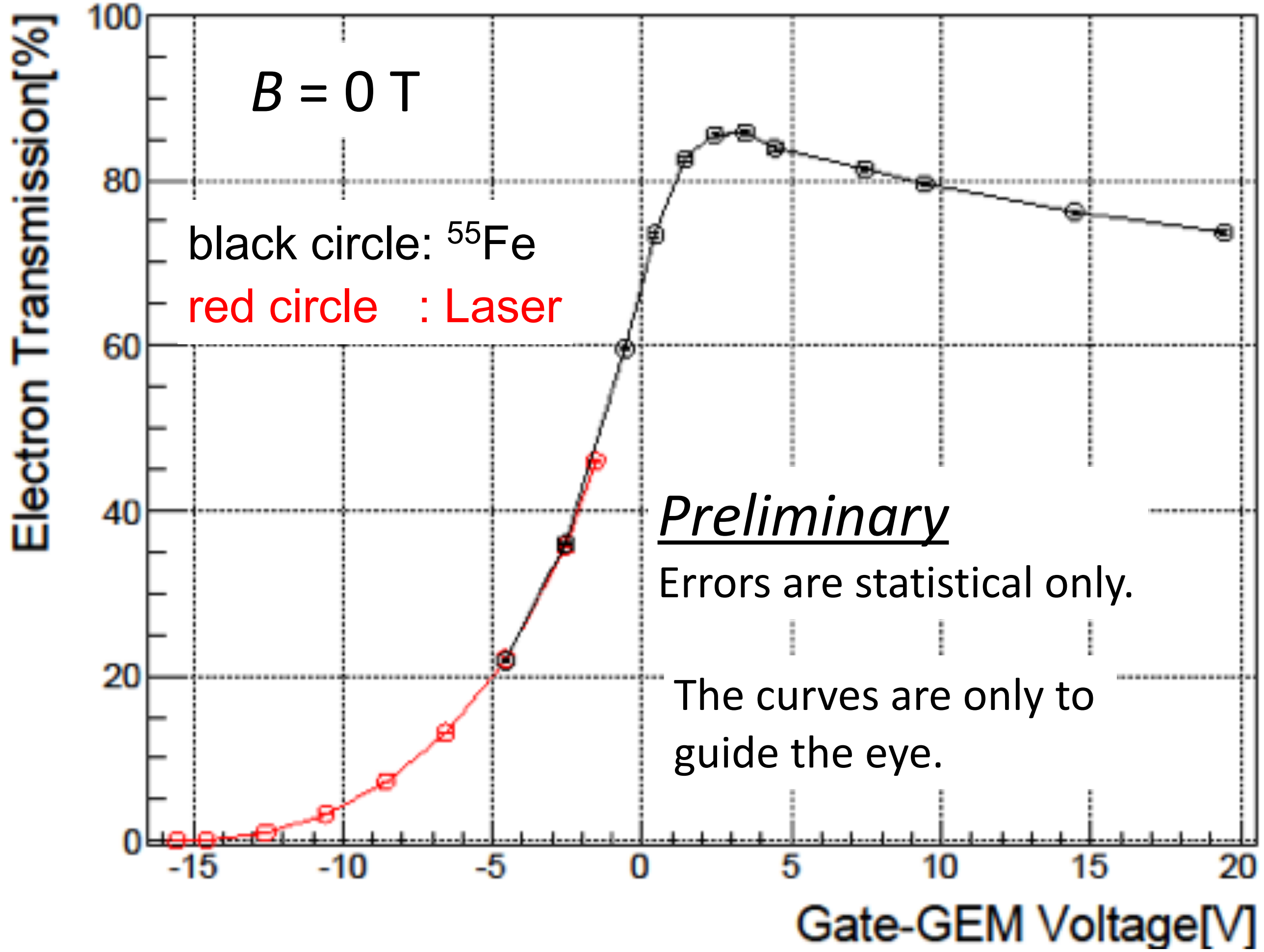



$$\text{Transmission rate} = \frac{\text{Peak 1 - Pedestal}}{\text{Peak 2 - Pedestal}} \times 0.6 \times 100 \ \ [\%]$$

with Peak 2 at $V_{Gating\text{-}GEM}$ = -0.5 V

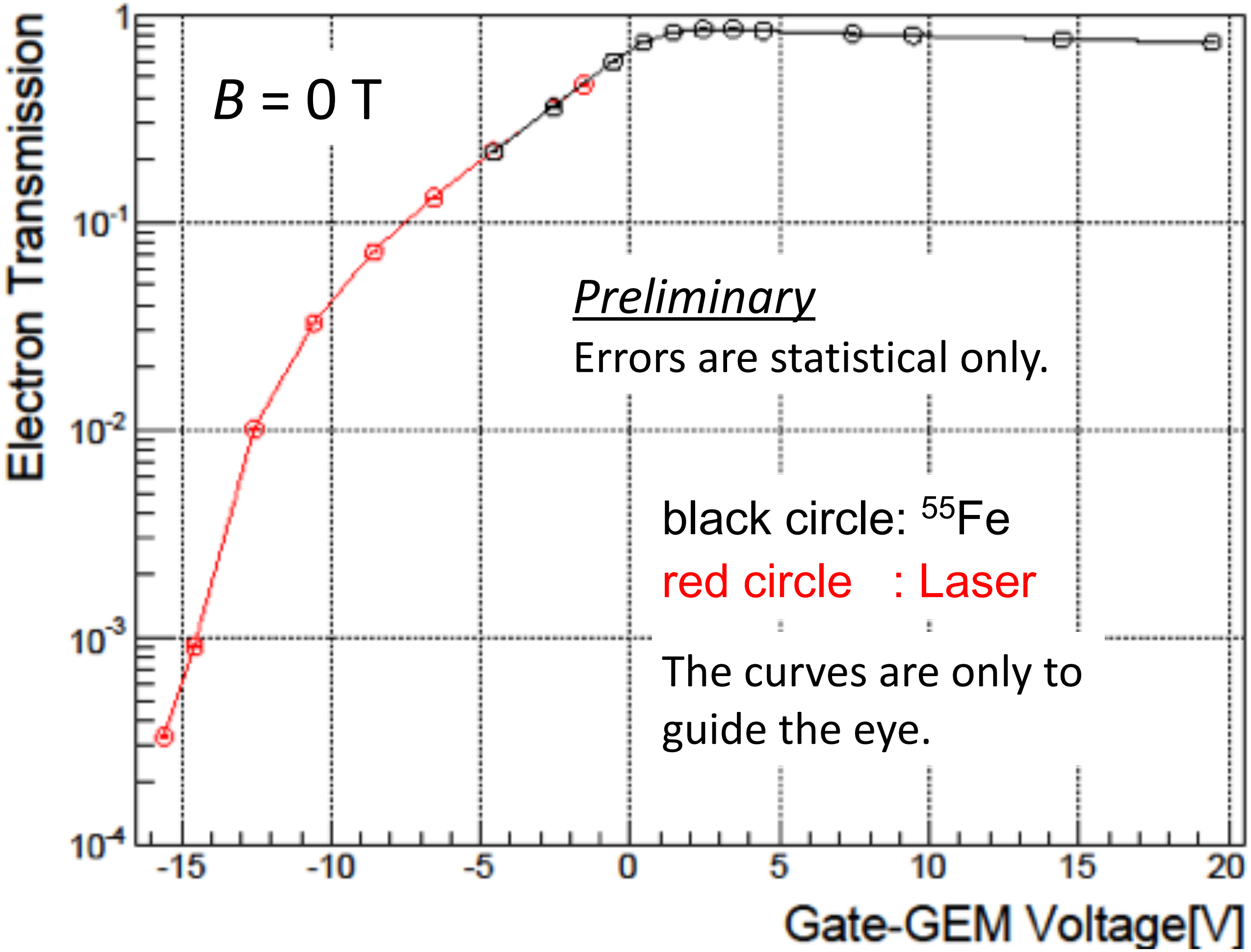
# *Electron transmission rate vs. ΔV Measure with the Laser and $^{55}$Fe*





# *Electron transmission rate vs. ΔV (Log Scale)*





# *Summary*



We have measured the electron transmission rate of a full-size gating GEM as a function of the potential difference ($\Delta V$) for $\Delta V$ between -15.5 V and +20 V in the absence of axial magnetic field.

- The maximum transmission rate is about 86% at around $\Delta V = +3.5$ V.
- The transmission rate is measured to be as low as $3.3 \times 10^{-4}$ at $\Delta V = -15.5$ V.
  We can expect adequate ion blocking power for the ILC-TPC
  with the present gating GEM (see discussion below).
- Gating GEM may be applicable to TPCs for which drift electrons needs to be stopped.
  A measurement in an axial magnetic field is necessary in order to prove it.

## Future plan

Direct measurements of the ion back-flow with/without a gating GEM.

# Discussion



If we assume 2000 for the gas gain and define *F* as the ion back-flow rate of the amplifying GEMs, the number of positive ions entering the drift volume is expected to be about $0.66 \cdot \mathrm{F}$ per drift electron with a gating GEM at ΔV = -15.5 V.

It should be noted that the positive ions are thermal, i.e. the diffusion is small. Therefore it is (much) easier to block positive ions than electrons.

In addition, their motion is hardly affected by the presence of a magnetic field.

Consequently, the blocking power measured for electrons without magnetic field gives the lower limit for positive ions with a sufficient margin.

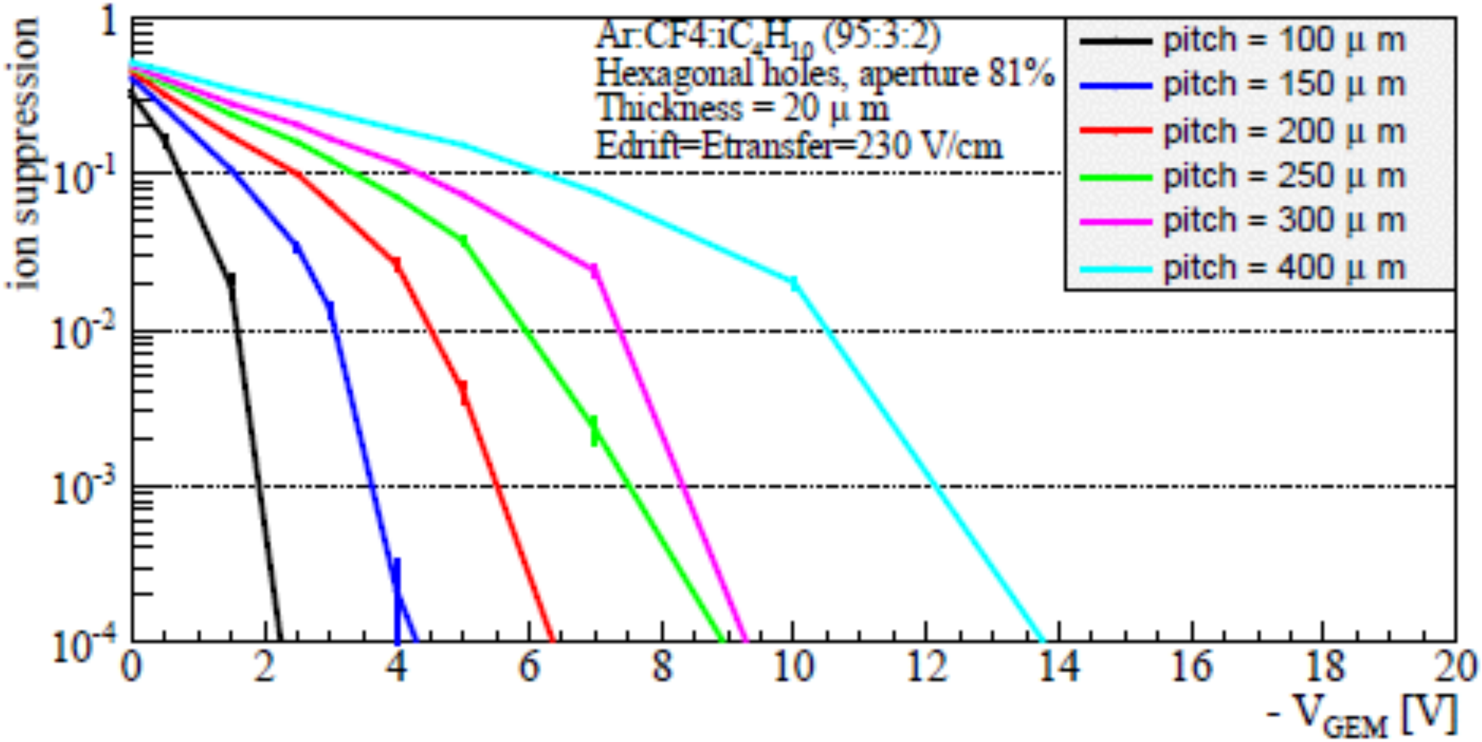
For example, if we assume (tentatively) 40% * for *F* (with respect to the effective gain) the total ion back flow is expected to be (much) less than 0.26 per drift electron* at ΔV = -15.5V.

See also the next slide for the result of a simulation for the ion back-flow suppression.

*The ion backflow fraction (F: IBF) of the amplifying GEMs assumed in the discussion is very conservative. Actually, 40% is a rough estimate (gestimate) for MWPC readout.
Please replace 40% with 10%, and "0.26 per drift electron" with "0.07 per drift electron", in order not to be excessively conservative.
The conclusion itself is unchanged: the blocking power of the gating GEM for positive ions is sufficient in our application. The next step is to measure directly the blocking power using an X-ray gun or a UV lamp.

## Simulation of the ion suppression (ANSYS + Garfield)

**P. Gros et al., JINST 8 (2013) C11023**



***FIN***

**Thank you for your attention.**