Gas Electron Multiplier (GEM) for TPC gating applications

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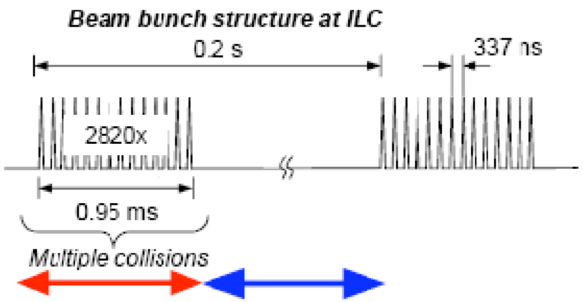
Introduction (1)

Why we need gating GEM

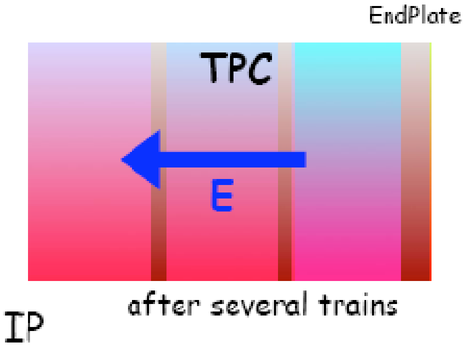
Why gating

Large pair background at ILC
and other bkg sources

primary ions are another issue



Ions produced at gas amplification build ion dense disk
and may deteriorate electric field dynamically



but ILC beam structure enable to use "gating mode"

MPGD has an inherent ability of ion blocking
3 GEM structure has a few x 10^{-3}
Micromegas has a few x 10^{-3}

Do we need GATE ??

Maybe... in case of GEM

Typical ion back drift of single GEM ~O(10%)
if we use @gain=10, same amount of ions as prim. e go back

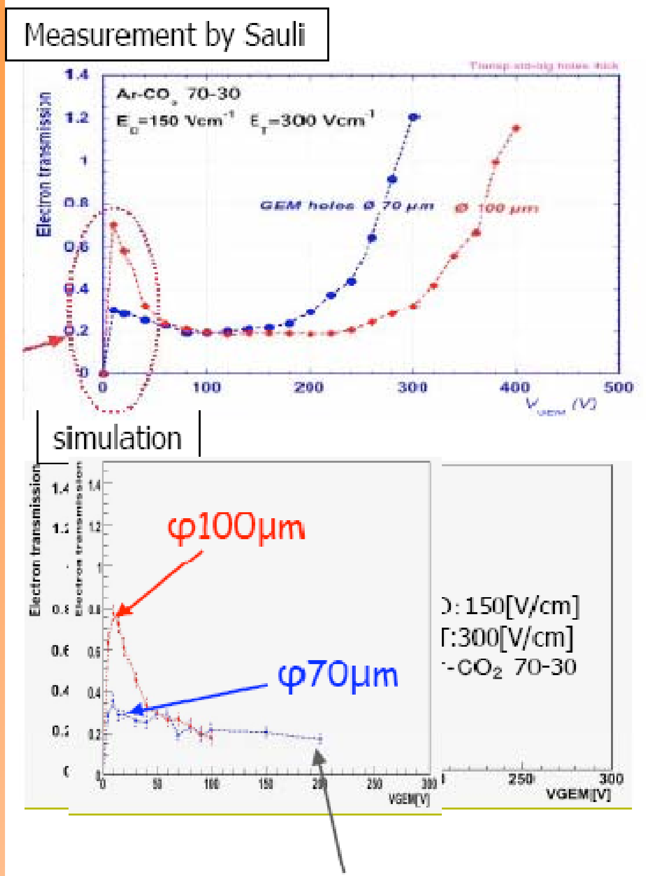
A. Sugiyama R&D Gating GEM talk (RD51 Workshop Nikhef 15-18 April 2008)

Introduction (2)

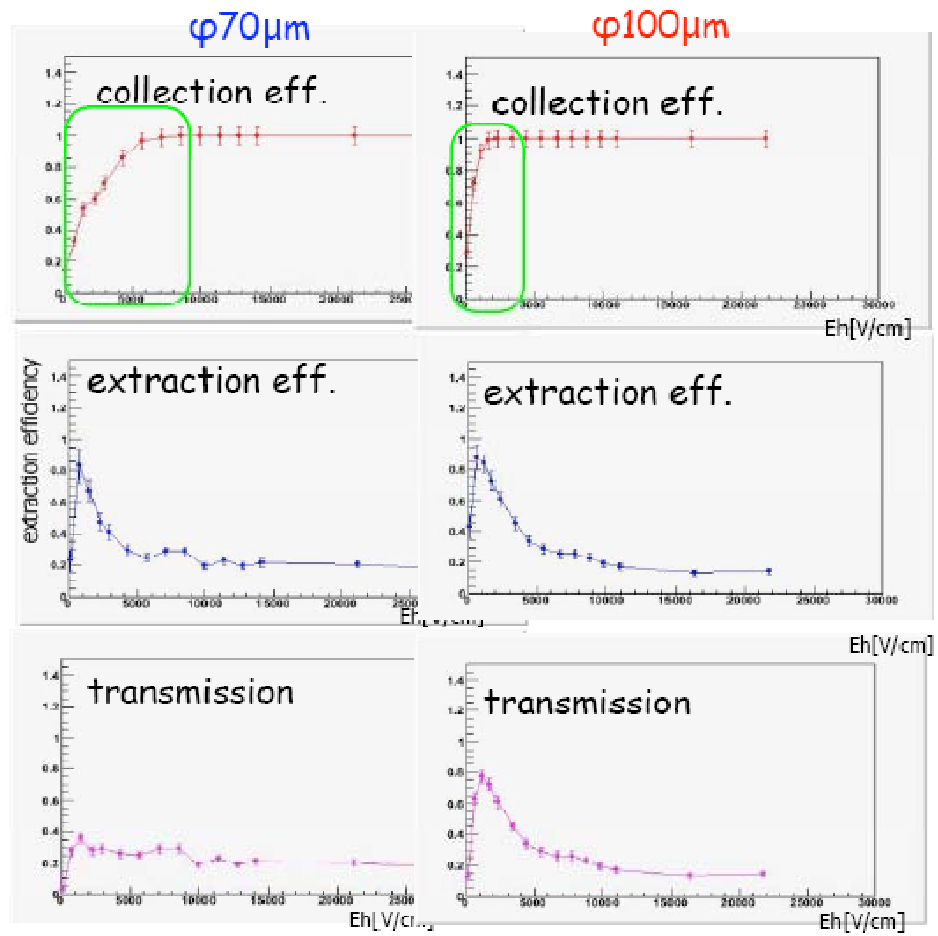
reproduce Sauli's exp. data by simulation

model/param. tune of Maxwell3D/Garfield

Electron transmission
Hole size dep.

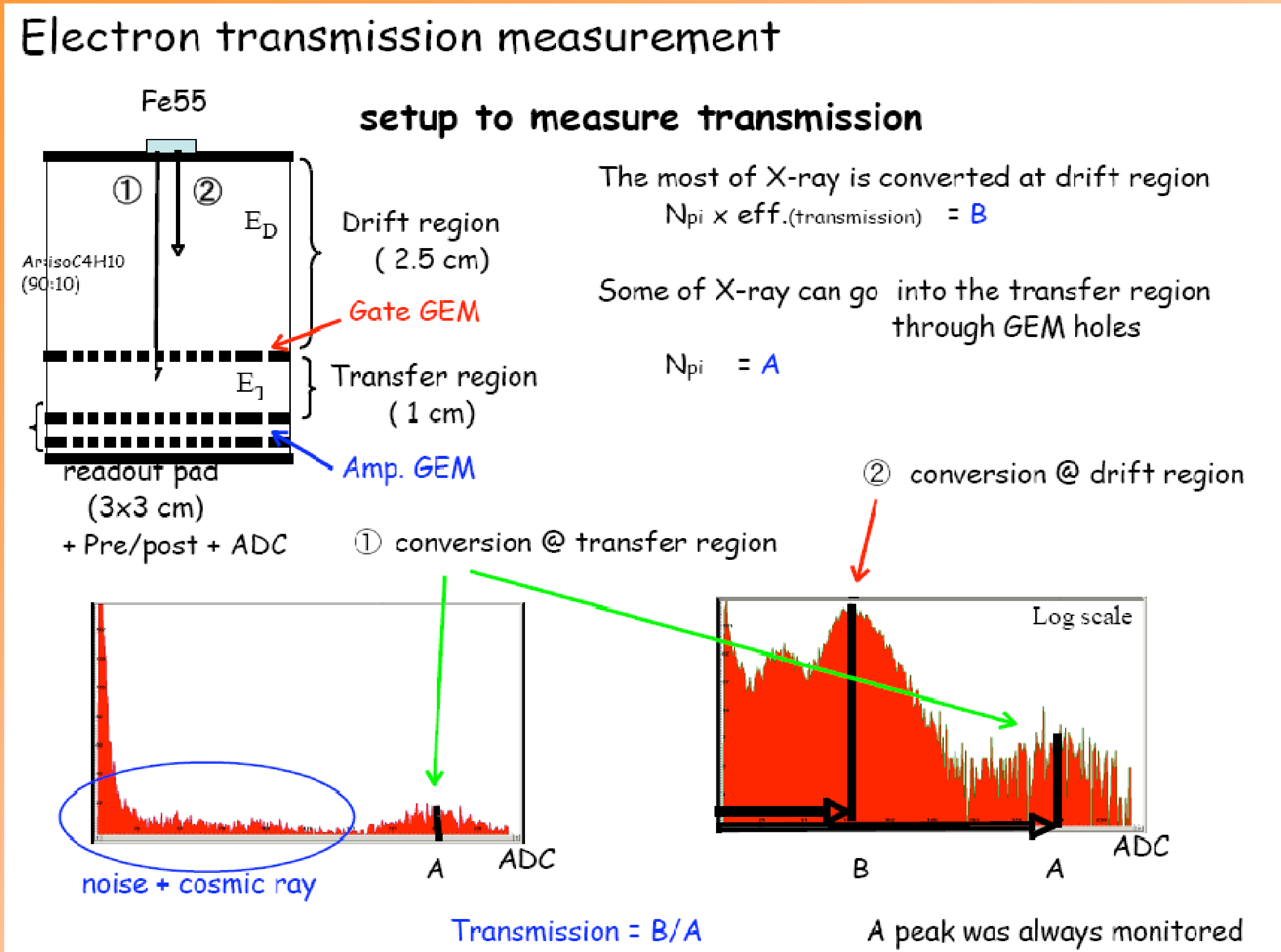


Gas gain is not included



Collection eff. improve transmission
due to large aperture

Introduction (3)



A. Sugiyama R&D Gating GEM talk (RD51 Workshop Nikhef 15-18 April 2008)

Aims

- Development of a completely GEM-based TPC readout
- Use of a GEM for gating purposes (Gating GEM) by pulsing it with a very low potential difference (40 V)

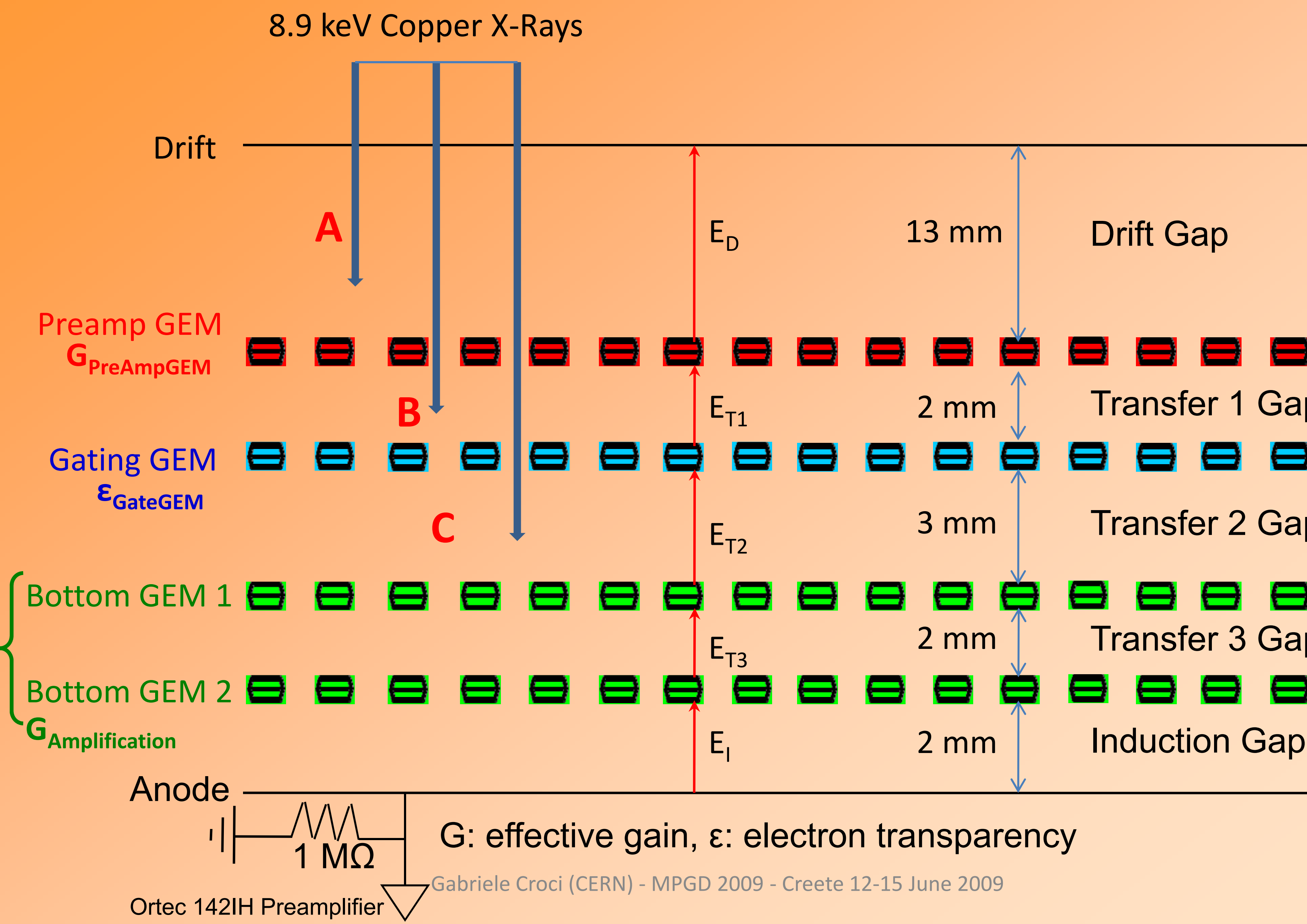
Motivations

- The employment of a Gating GEM results in degradation of energy resolution
- The addition of a GEM (Preamplification GEM) in front of the Gating GEM shows an improvement of energy resolution while keeping the ion feedback at the level of primary ionization

Experimental Parameters

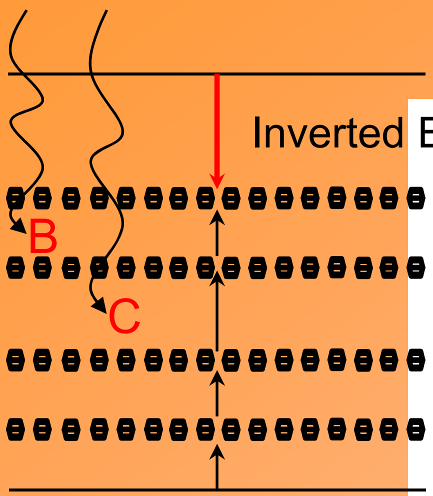
- 10 x 10 cm^2 Std. GEM (biconical, kapton hole diameter 50 µm, copper hole diameter 70 µm, pitch 140 µm, thickness 50 µm)
- Gas Mixture: Ar/CO_2 70%/30%
- Radioactive Sources: Cu 8.9 KeV X-Rays
- Full Metal Plane Readout (10 x 10 cm^2)
- Ortec 142iH Preamplifier and Ortec 450 research amplifier
- Keithley 6517A picoamperometer

Detector Setup

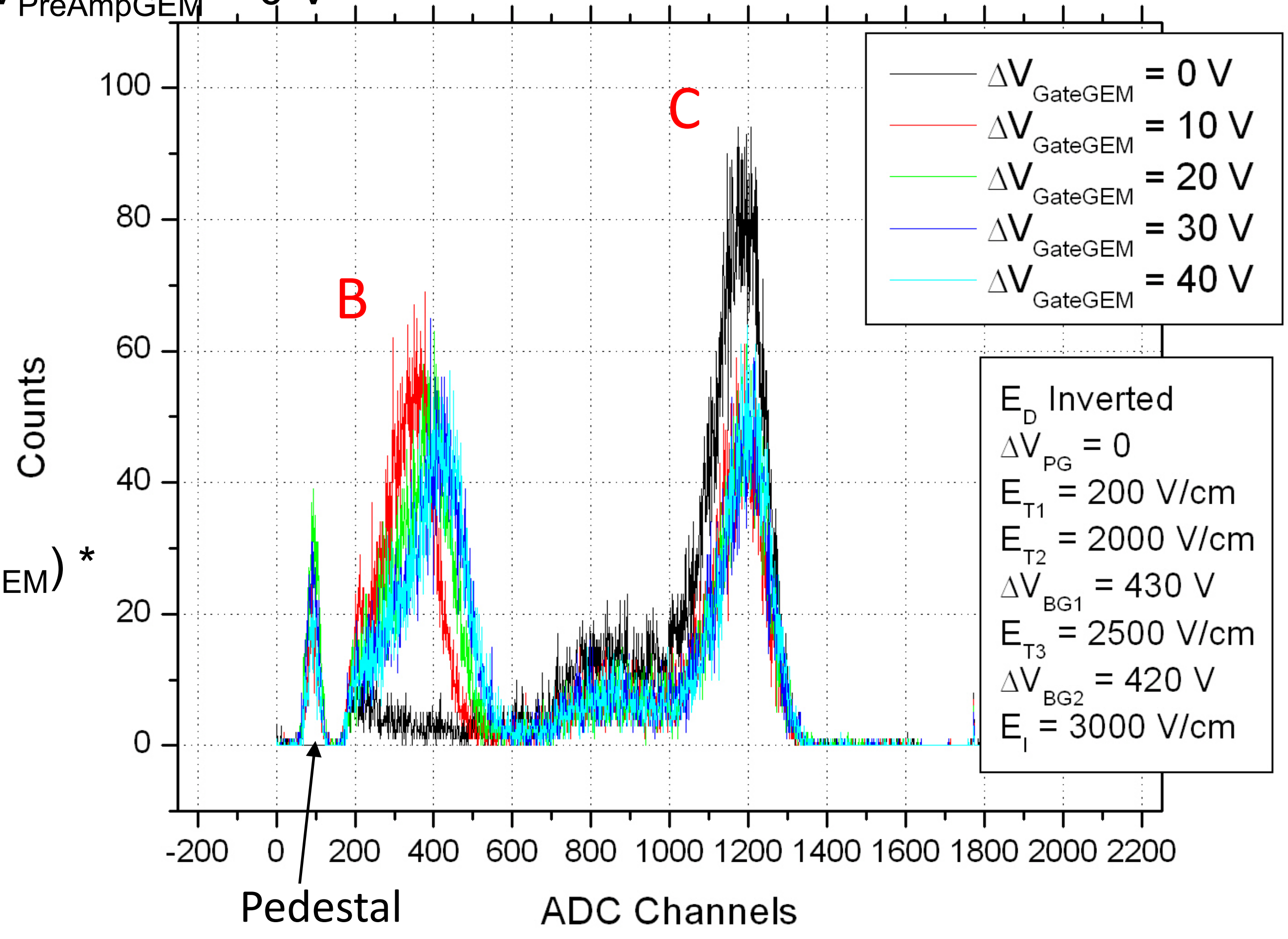


G: effective gain, ε: electron transparency

Measurements without Preamplification GEM



$\Delta V_{PreAmpGEM} = 0$ V



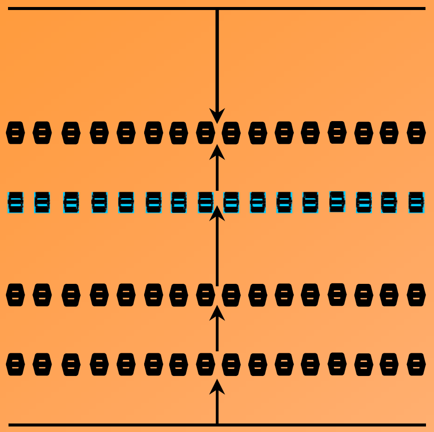
$C = n_p * G_{Amplification}$

$B = n_p * \varepsilon_{GateGEM} (\Delta V_{GateGEM}) * G_{Amplification}$

Electron Transparecy measurement

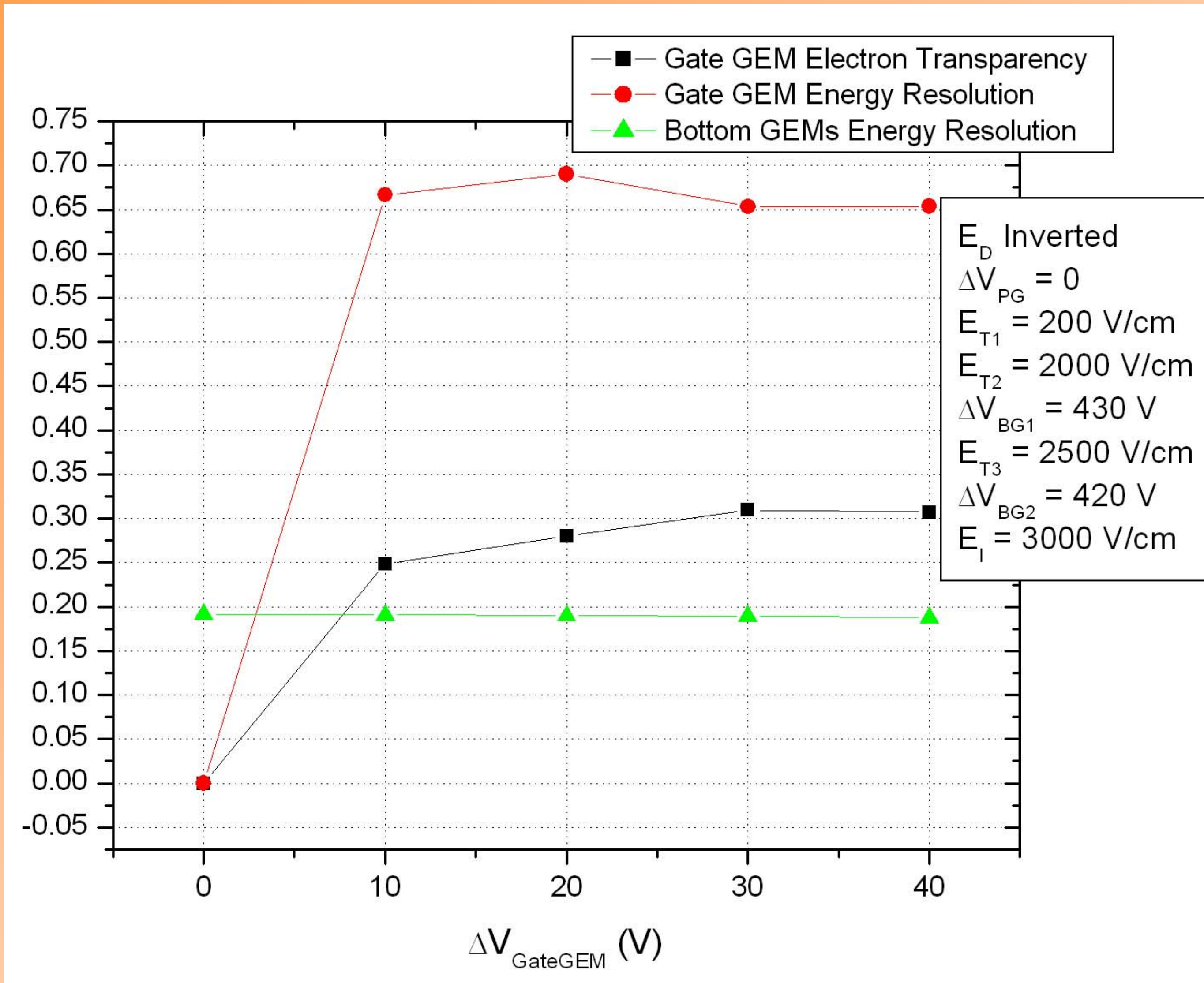
$\varepsilon_{GateGEM} = B/C$

Gating GEM Voltage Scan



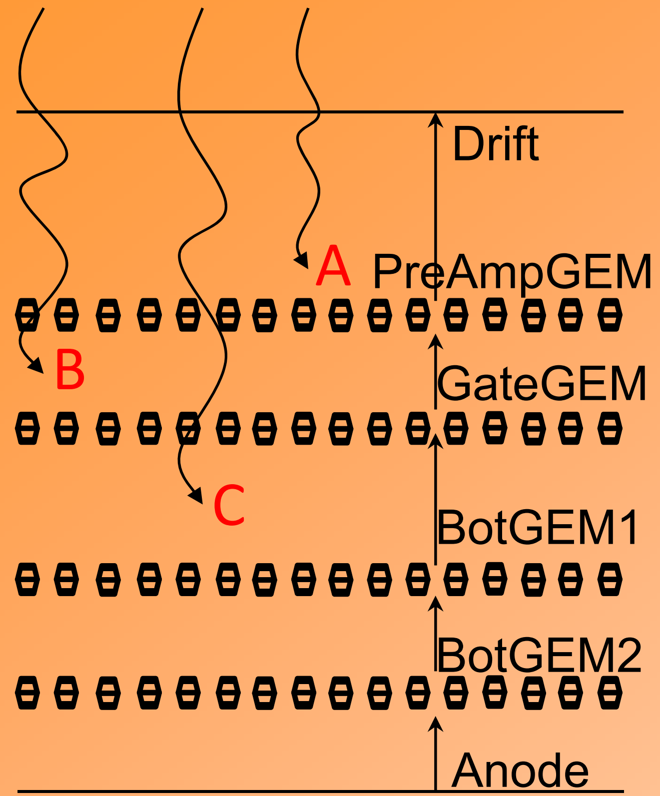
Energy Resolution=

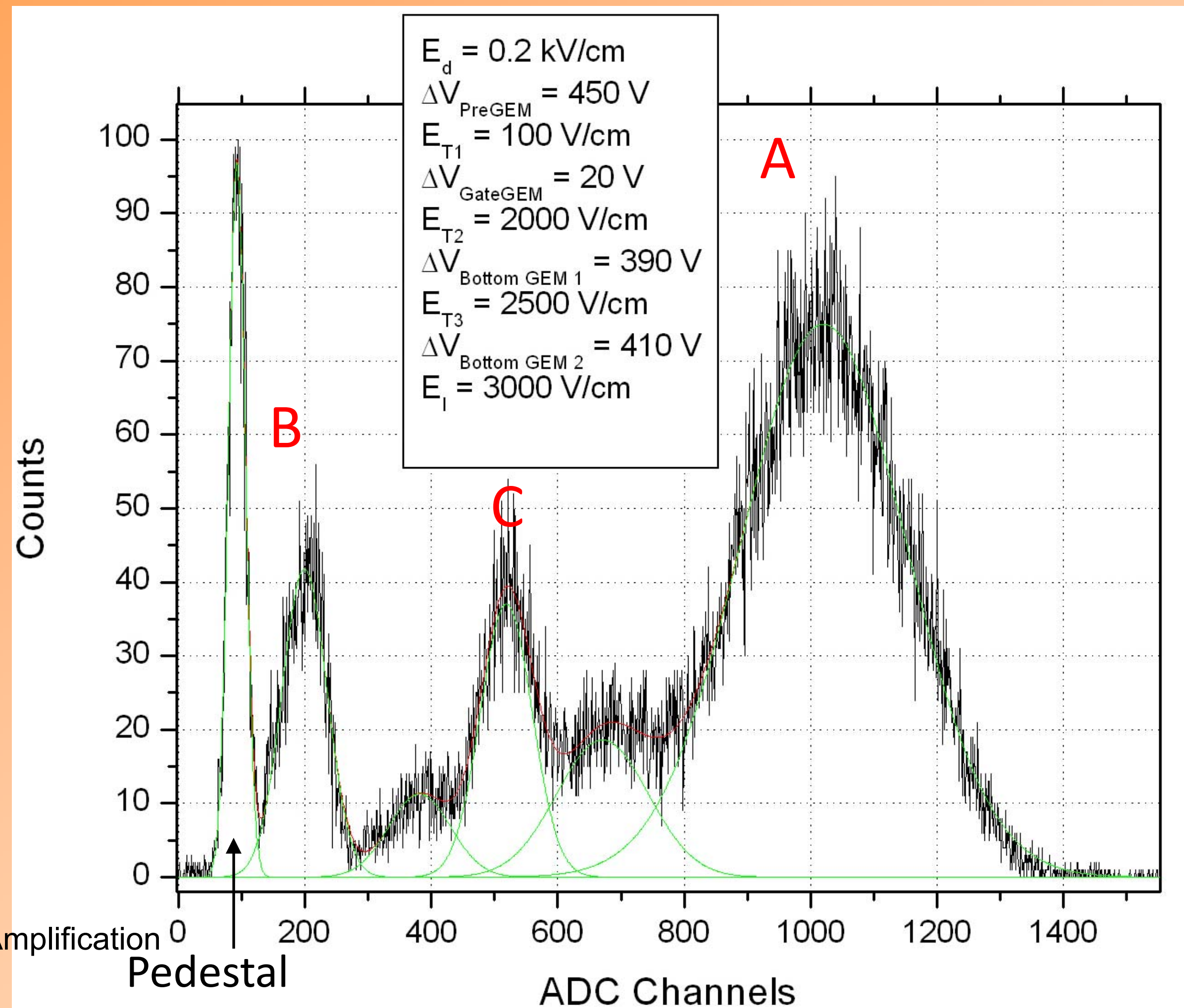
FWHM/PeakPosition



We measured an electron transparency of about 30% for
$10\text{ V} < \Delta V_{GateGEM} < 40\text{ V}$

Measurements with PreAmplification GEM





$C = n_p * G_{Amplification}$

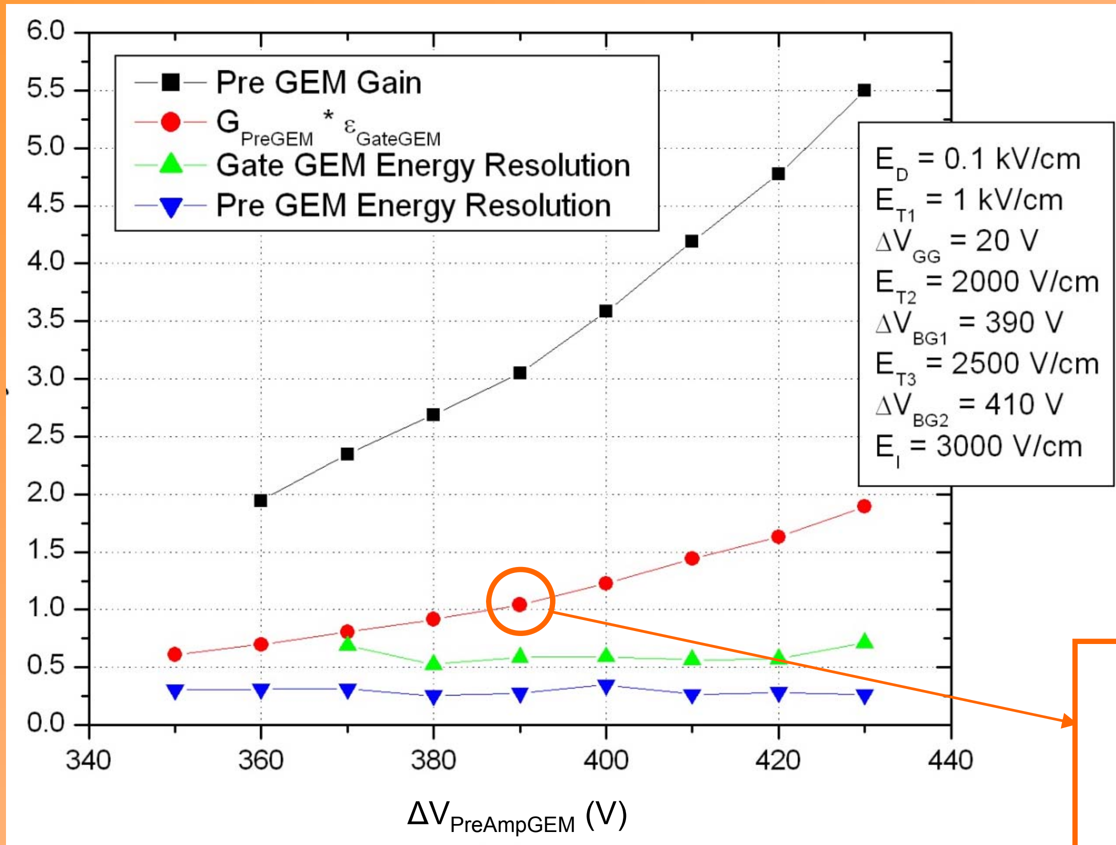
$B = n_p * \varepsilon_{GateGEM} * G_{Amplification}$

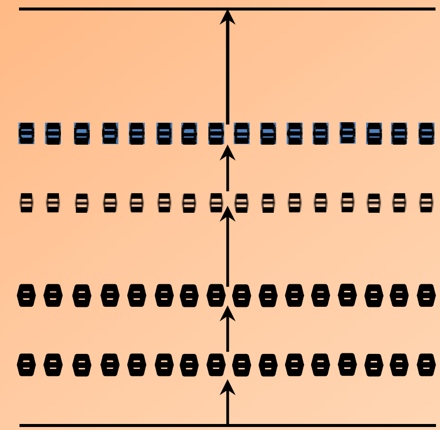
$A = n_p * G_{PreAmpGEM} * \varepsilon_{GateGEM} * G_{Amplification}$

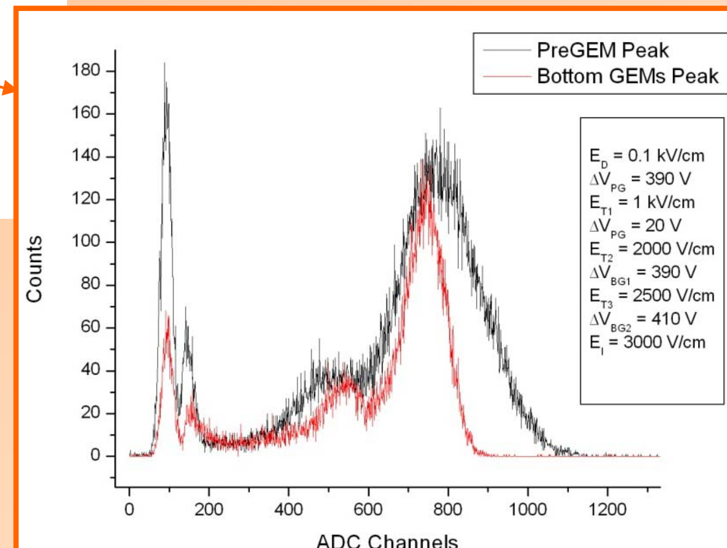
$\varepsilon_{GateGEM} = B/C$

$G_{PreAmpGEM} * \varepsilon_{GateGEM} = A/C$

PreAmp GEM Voltage Scan

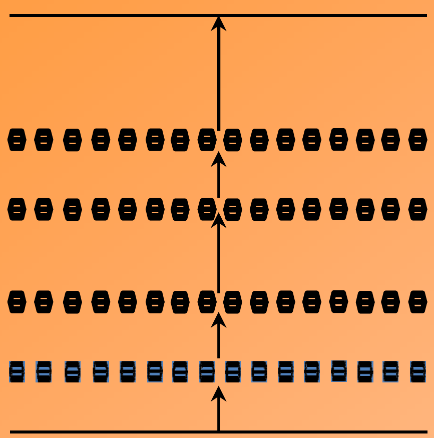


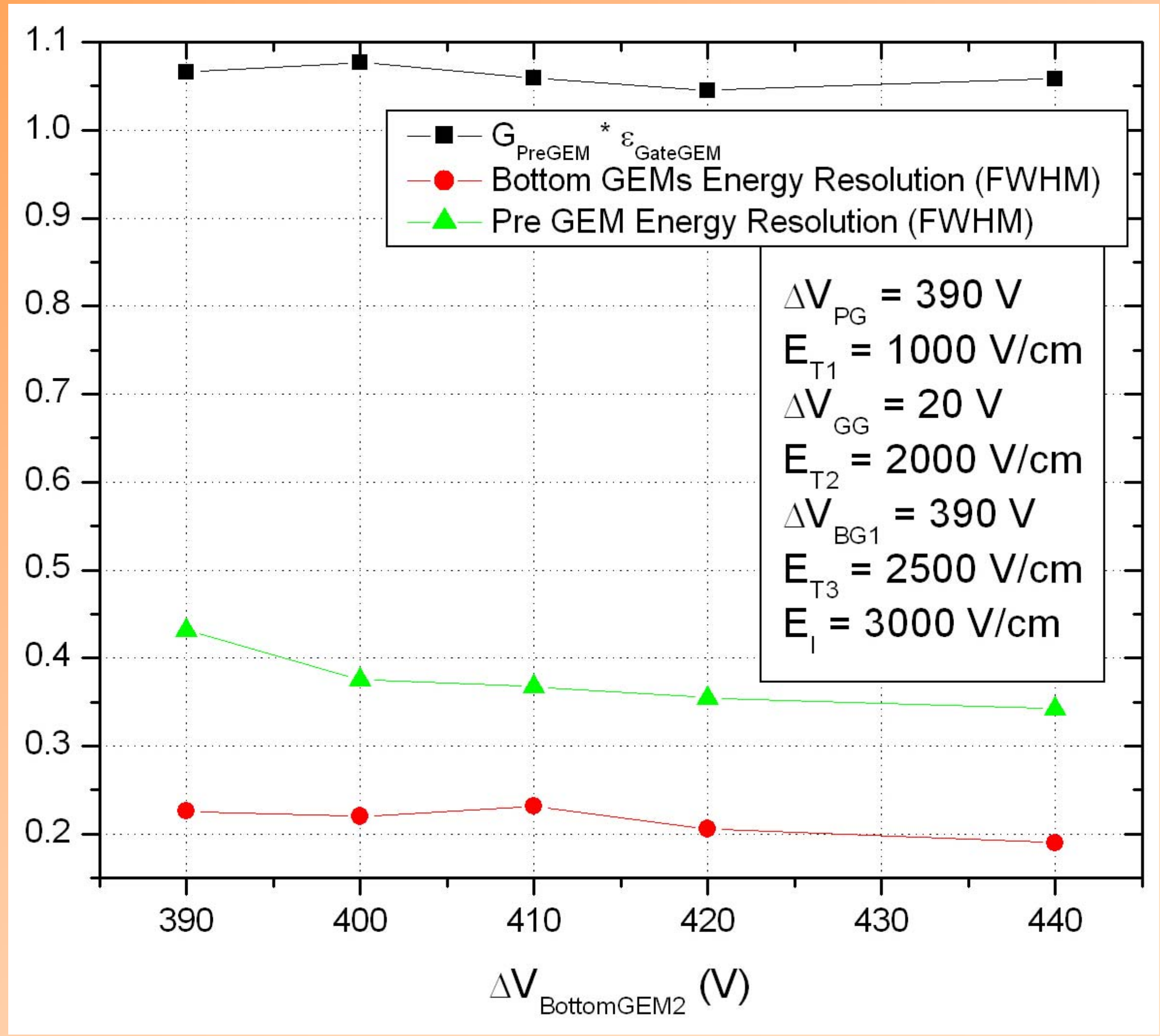




We managed to find a configuration in which the parameter $G_{PreAmpGEM}*\varepsilon_{GateGEM}$ is very close to 1. In this case we observed an overlapping of the two main peaks obtained through the conversion in the drift gap and below the Gating GEM. The spectrum for the Bottom GEMs was aquired with closed gate ($\Delta V_{GateGEM}$ = -20 V)

Bottom GEMs Scan
(Varying the Gain of the amplification stage)

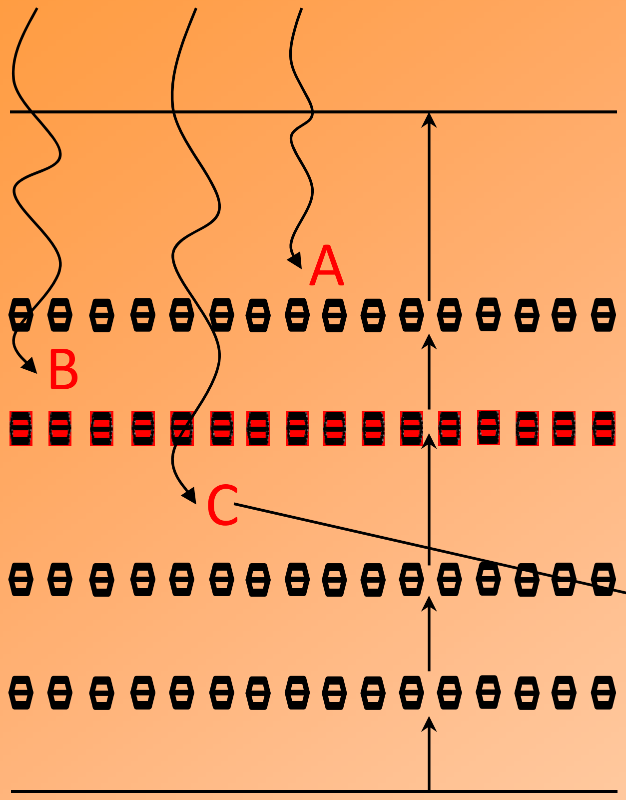


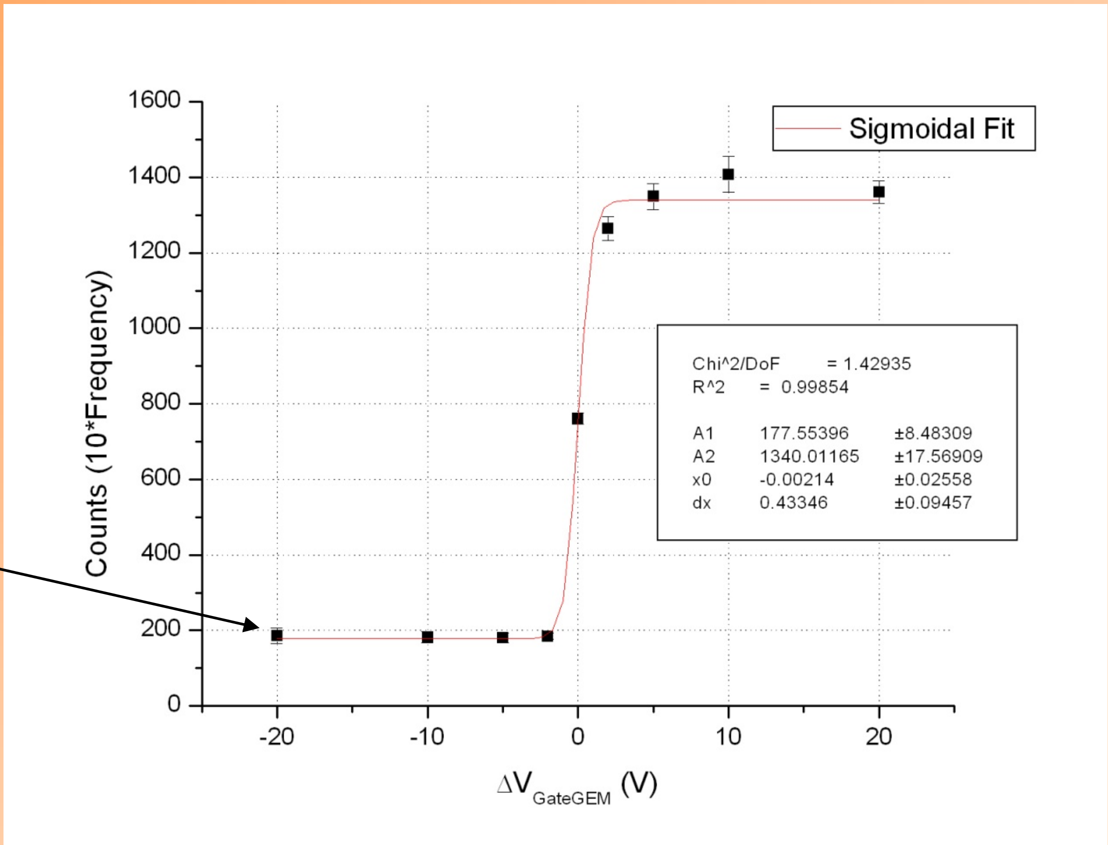


The parameter $G_{PreAmpGEM}$*$\varepsilon_{GateGEM}$ does not depend upon the gain of the amplification stage.

At $\Delta V_{BottomGEM2}$ = 410 V the overall gain of the full detector is about 800

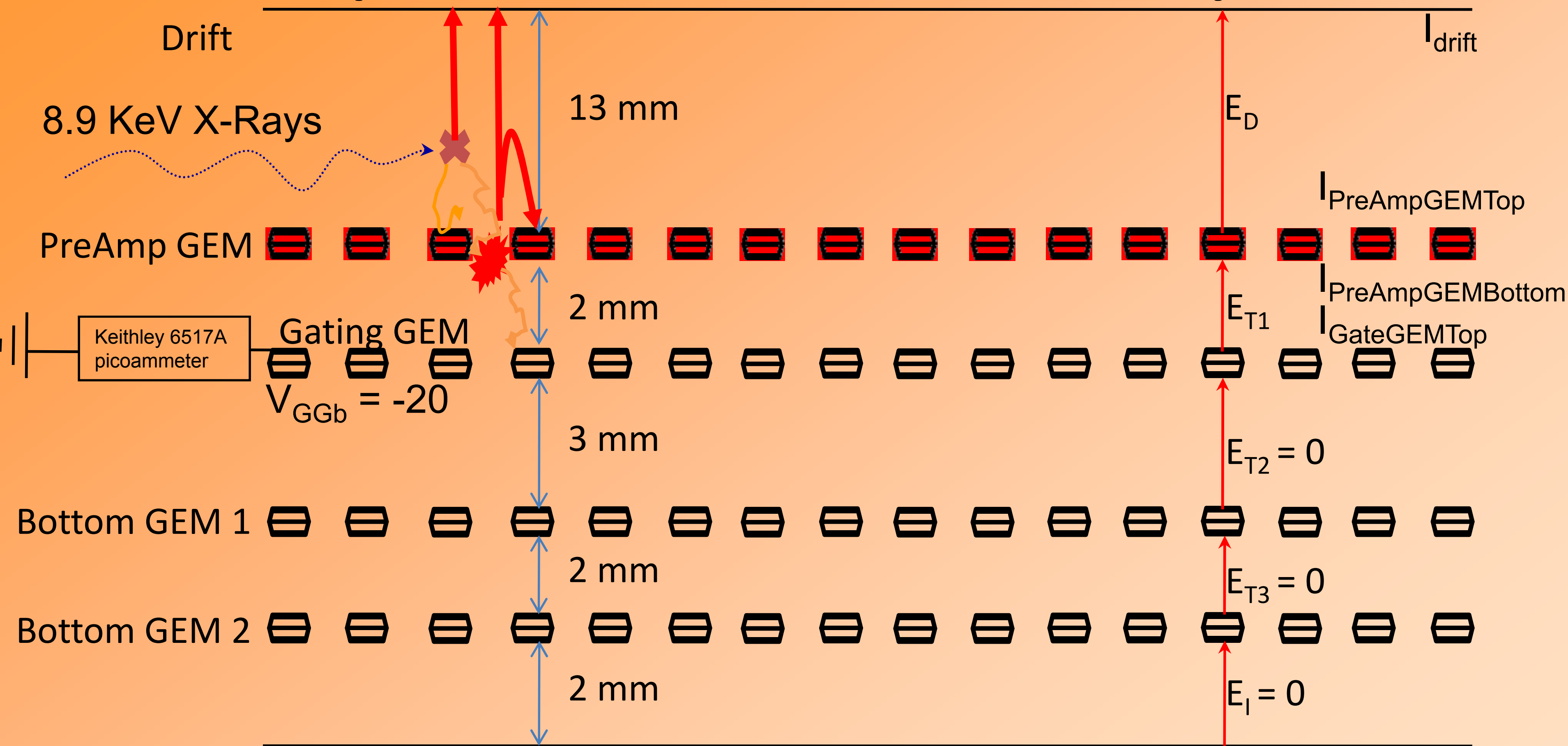
Gate GEM scan with Preamplification





Varying the voltage on the Gating GEM by 40 V, it is possible to completely close the gate. The obtained counts are higher than zero @ $\Delta V_{GateGEM}$ = - 20 because of the conversions after the gate.

Evaluating Ion Feedback of PreAmp GEM (current mode measurements)



Normalized Ion Feedback (NIF) definition:

Ion current in the drift region normalized to the primary ionization current

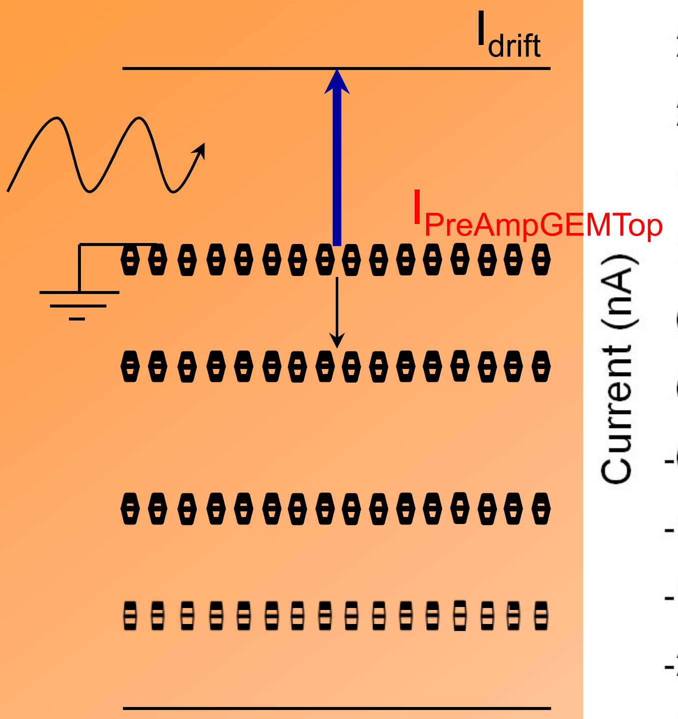
$NIF = I_{drift}/I_{ionization}$

Common Ion Feedbak definition (CIF):

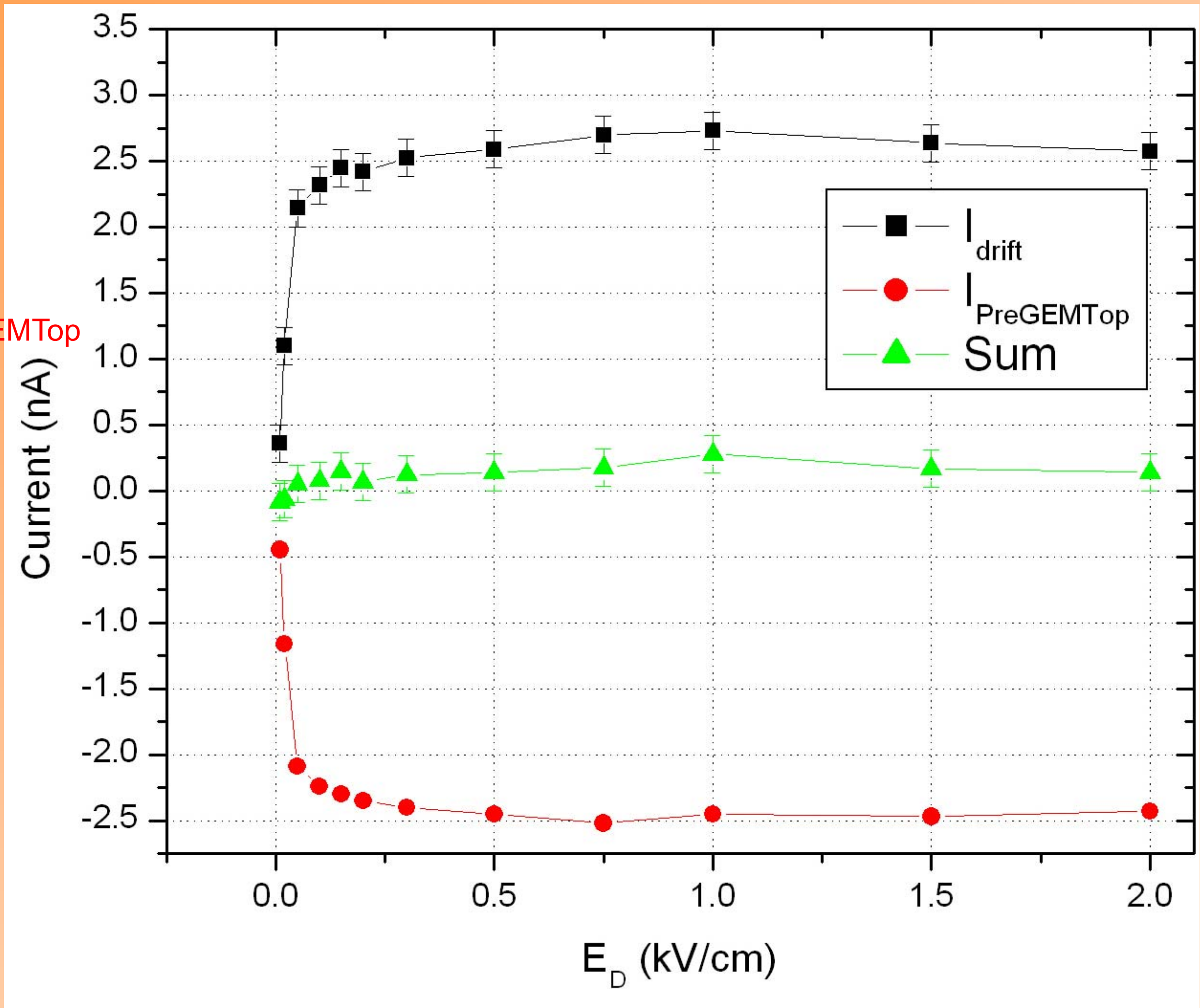
$CIF = NIF*I_{ionization}/I_{readout}=NIF/Gain_{FullDetector}$

→ The best value is $CIF = 1/Gain_{FullDetector}$

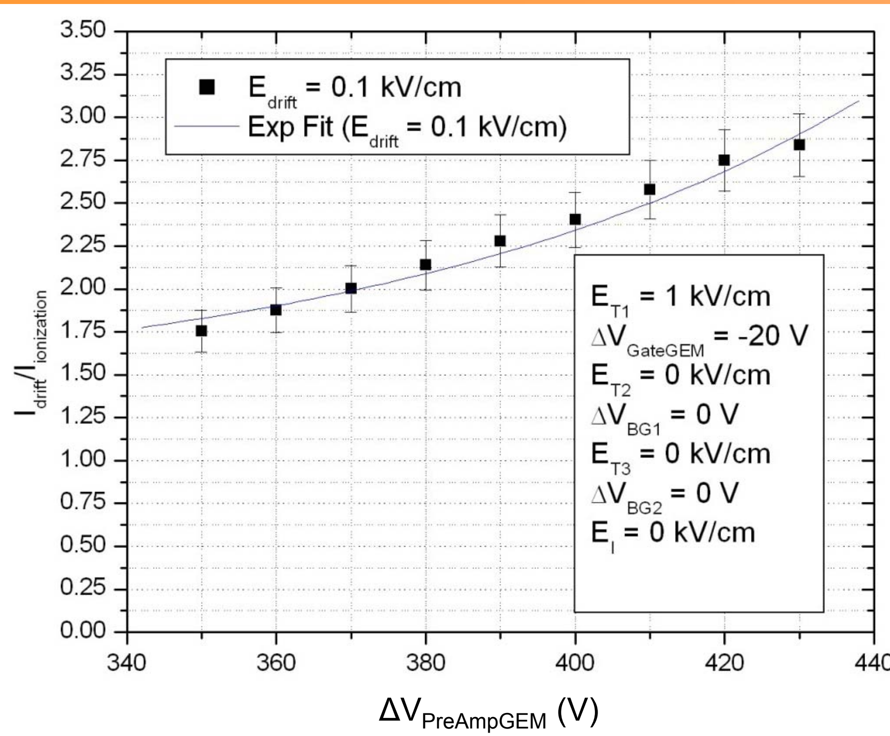
Ionization Current Measurement

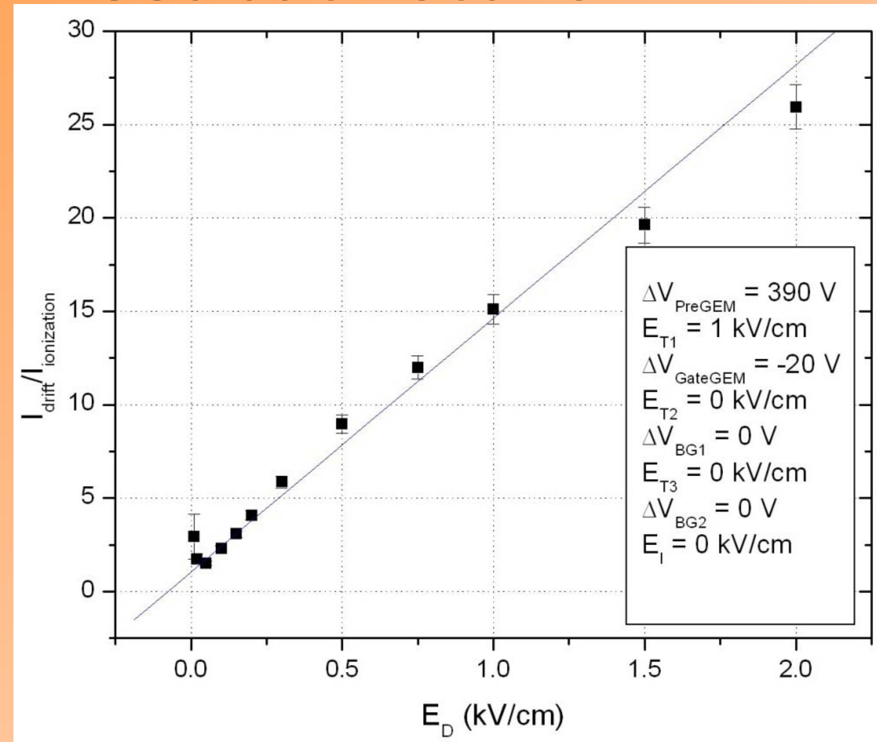


$V_{PreAmpGEMBottom} = -20V$



Normalized Ion Feedback scans

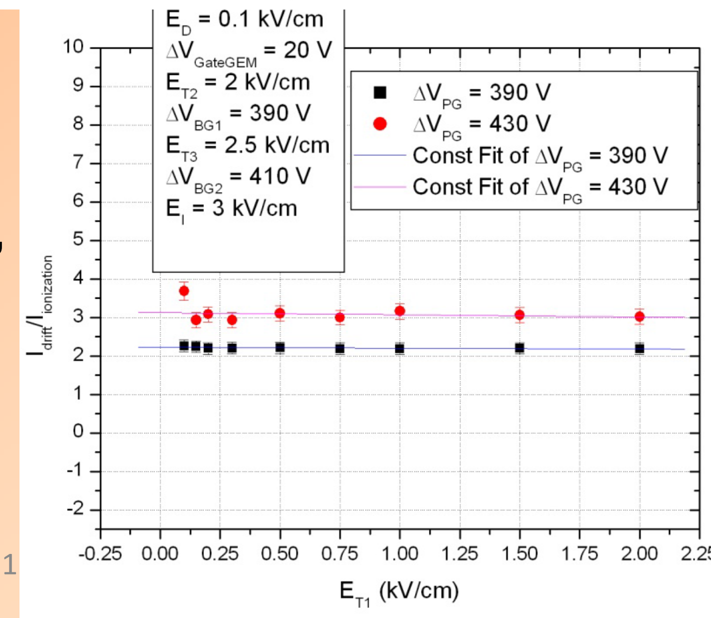




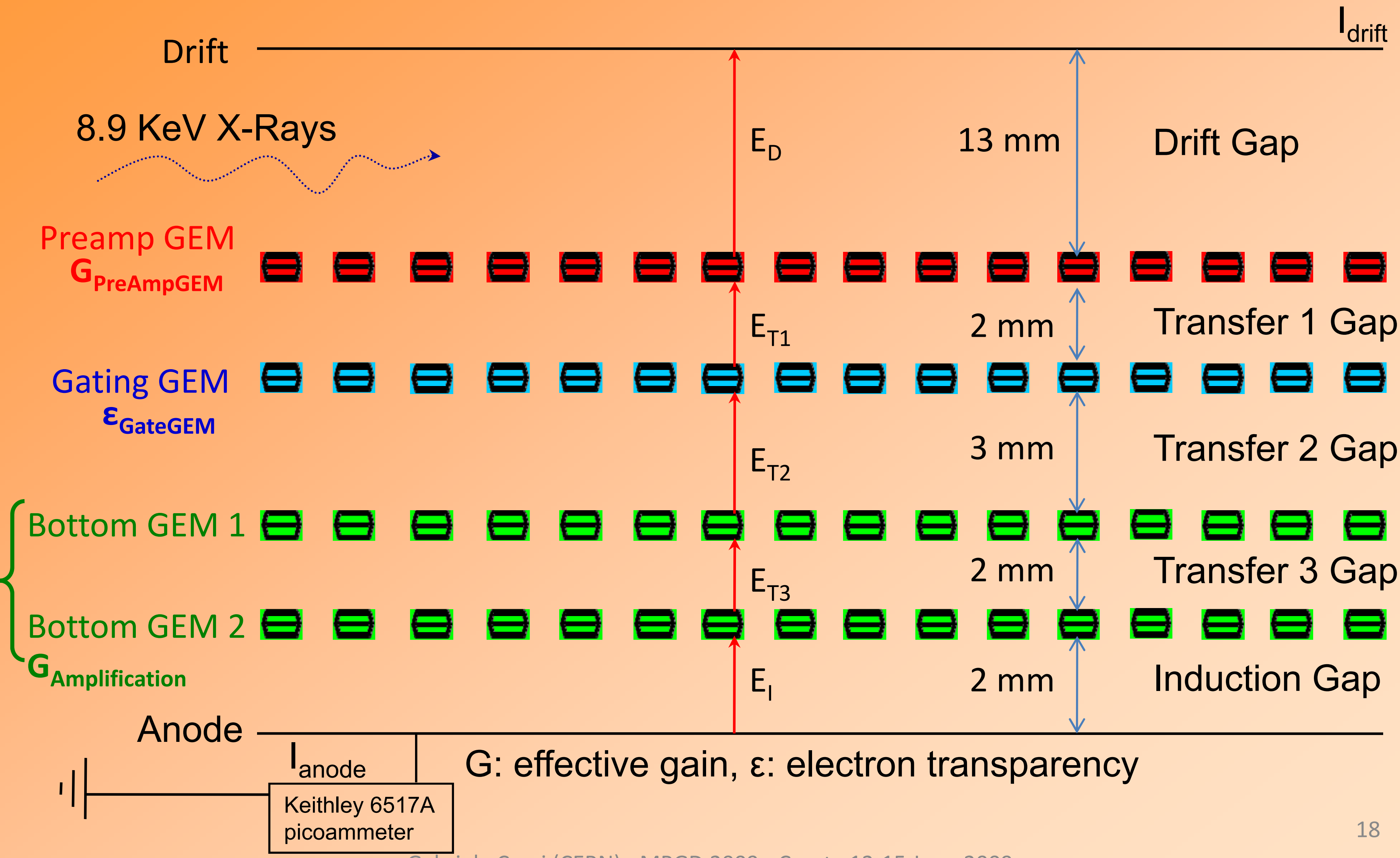
Using a Drift Field of 0.1 kV/cm (the same that is usually present in a TPC gas volume), the NIF @ $\Delta V_{PreAmpGEM}$ = 390 V is 2-3.

The NIF increases if the drift field is higher.

The NIF does not depend on tranfer field 1

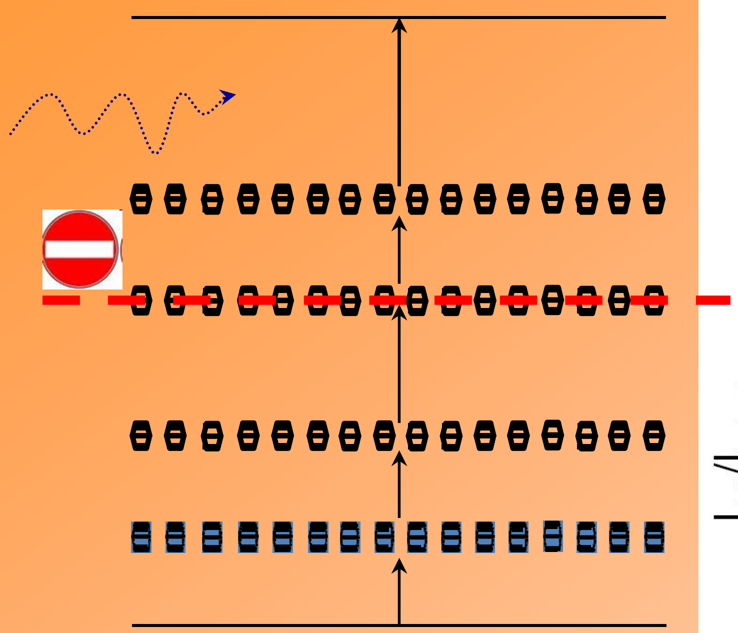


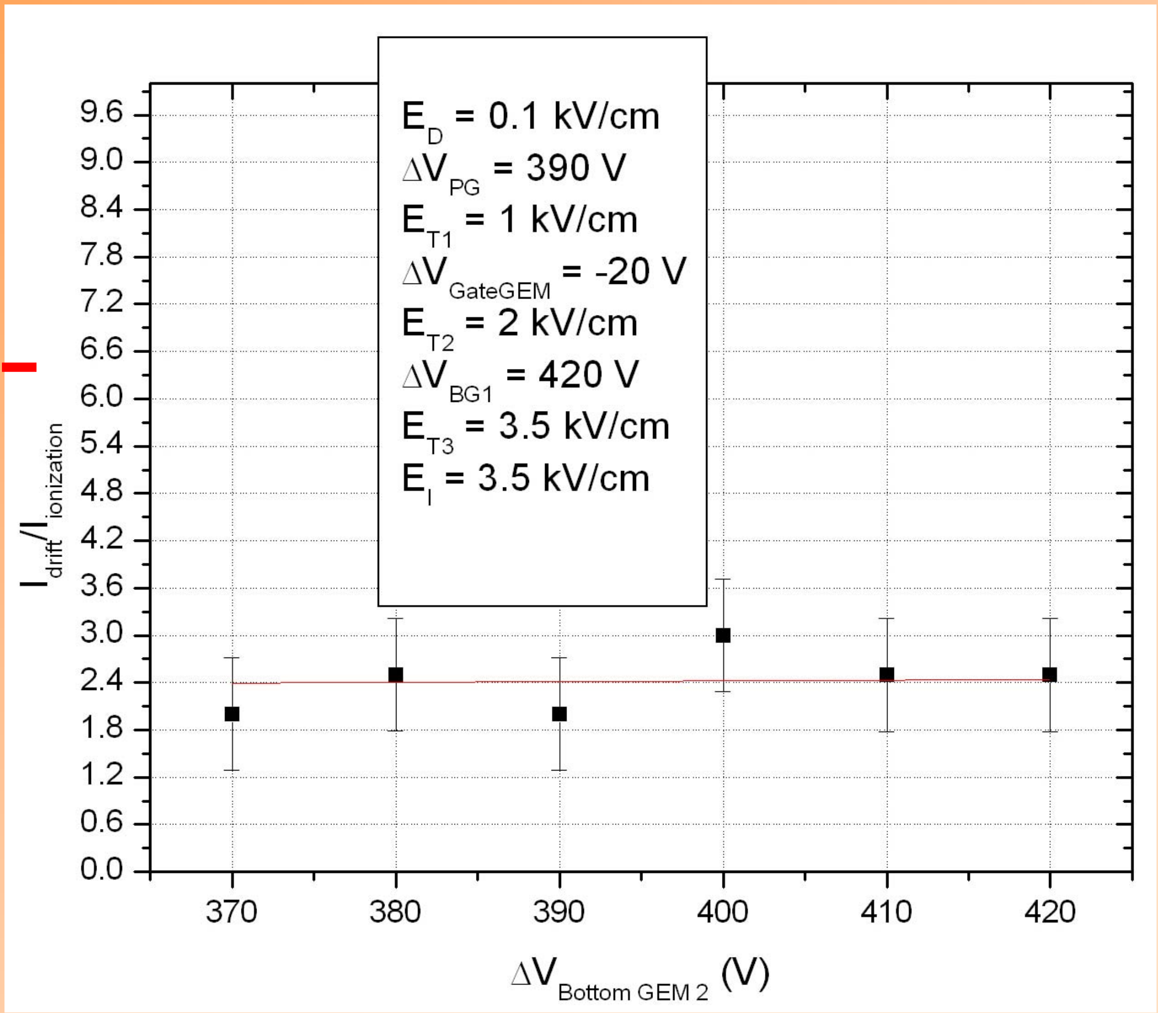
Detector Setup
(current mode measurement)



G: effective gain, ε: electron transparency

Amplification NIF Scan with closed gate





The NIF does not depend on the gain of the amplification stage if the gate is closed ($\Delta V_{GateGEM}$ = -20).

The NIF is only given by the PreAmp GEM

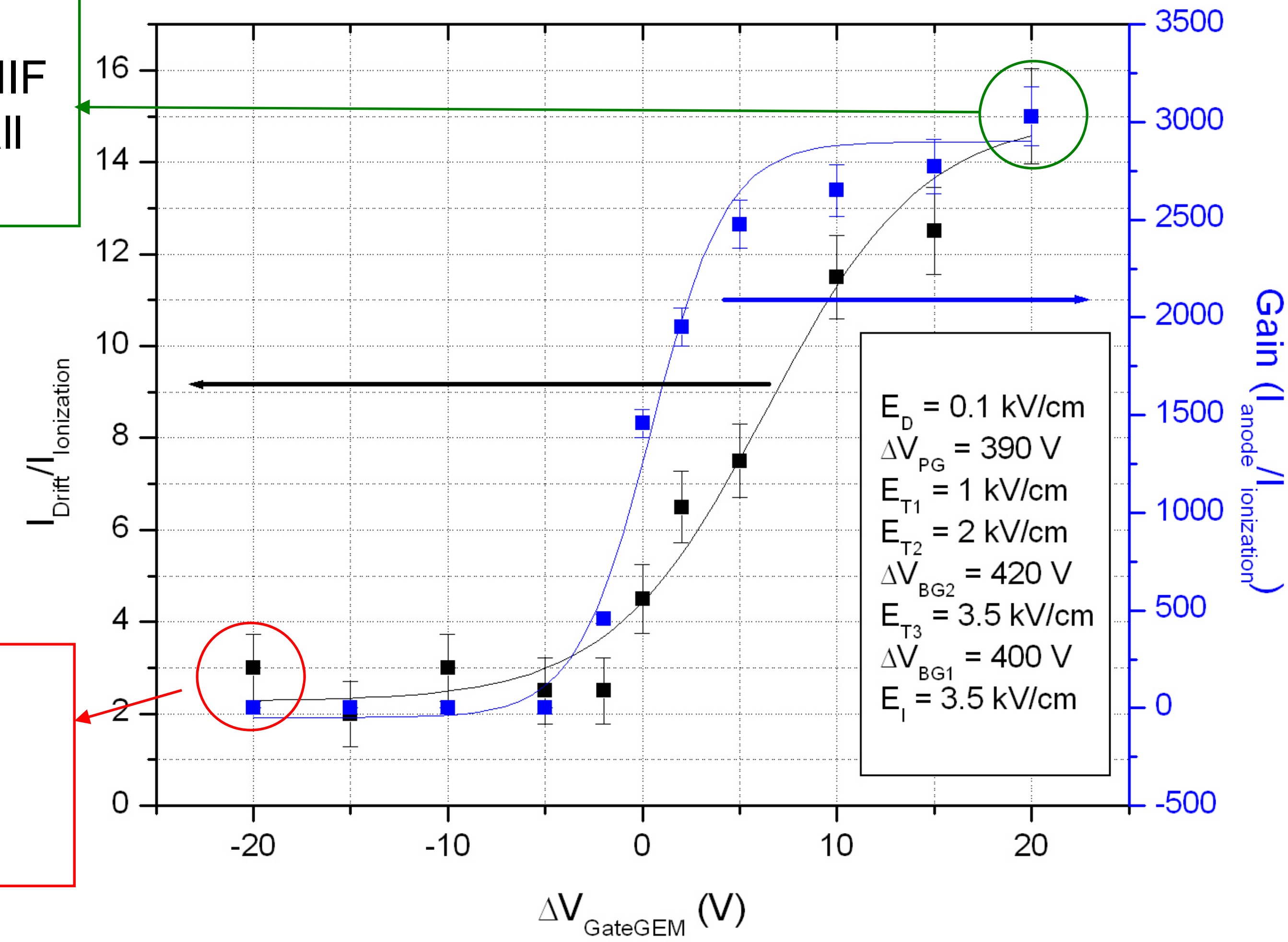
In this case
$CIF = NIF/G_{FullDetector}$
and since the Full detector Gain can be as high as required (eg. 10^4 ,10^5) the CIF is very low

With open gate (ΔVGateGEM = 20) the point at 400 corresponds to an effective detector gain of about 3000

Full Detector behaviour with respect the Gating GEM Voltage

With open gate (ΔVGateGEM = 20) the NIF is about 15 and the overall gain is around 3000.

With closed gate (ΔVGateGEM = 20) the NIF is about 3 and the overall gain is zero.

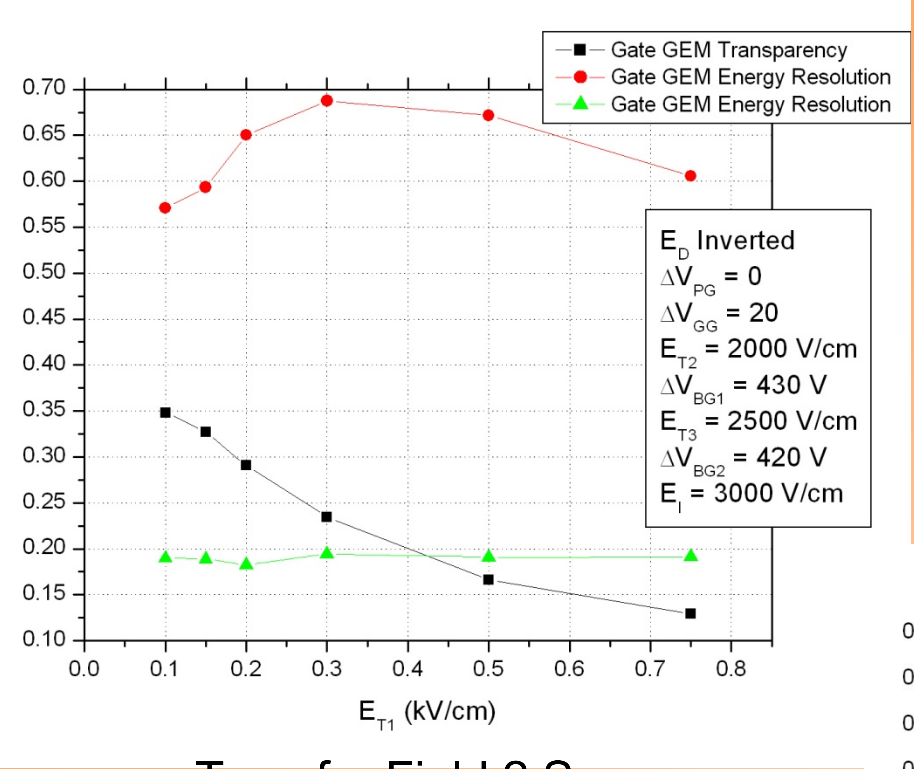


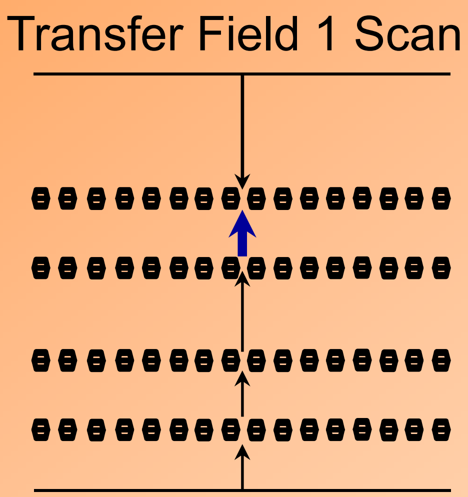
Conclusions

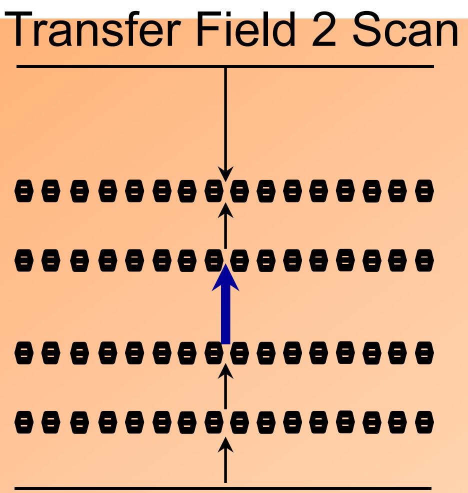
- The addition of a preamplifying GEM in front of Gating GEM results in an improvement of energy resolution @ 8.9 keV: from 60% FWHM to 30% FWHM.
- The NIF given by the PreAmpGEM is 2-3
- A small pluse of about 30-40V completely closes the gate. Pulsing the gate with such a small voltages allows the possibility to open/close the gate with very high rate
- The gain of the last stage can be as high as required by the experiment

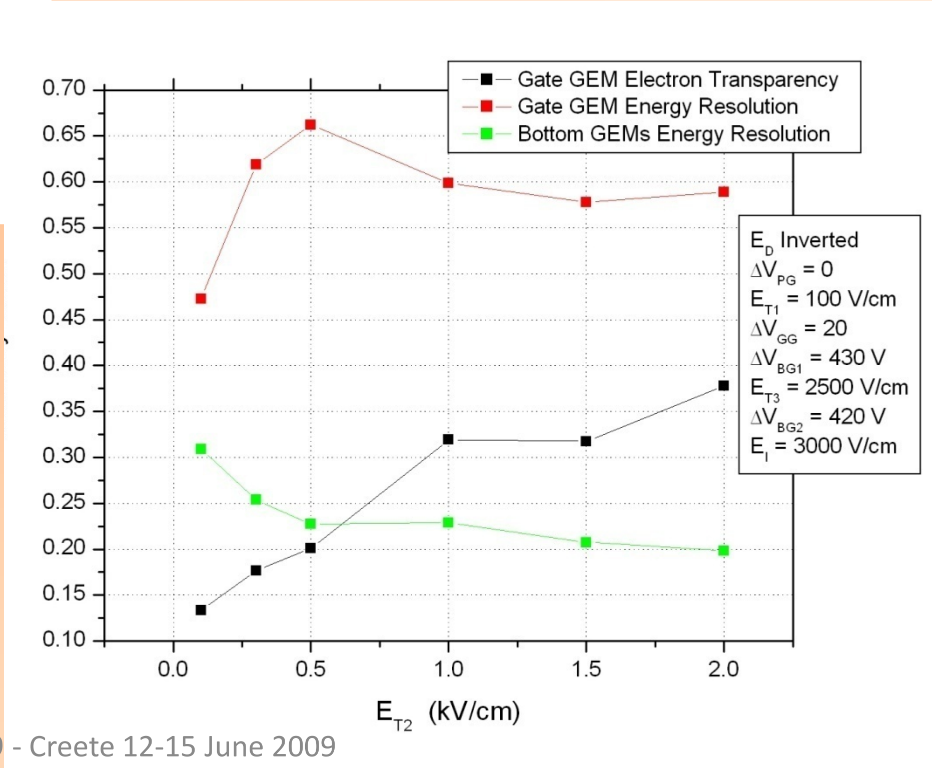
Spare Slides

Transfer Field Scans without PreAmpGEM

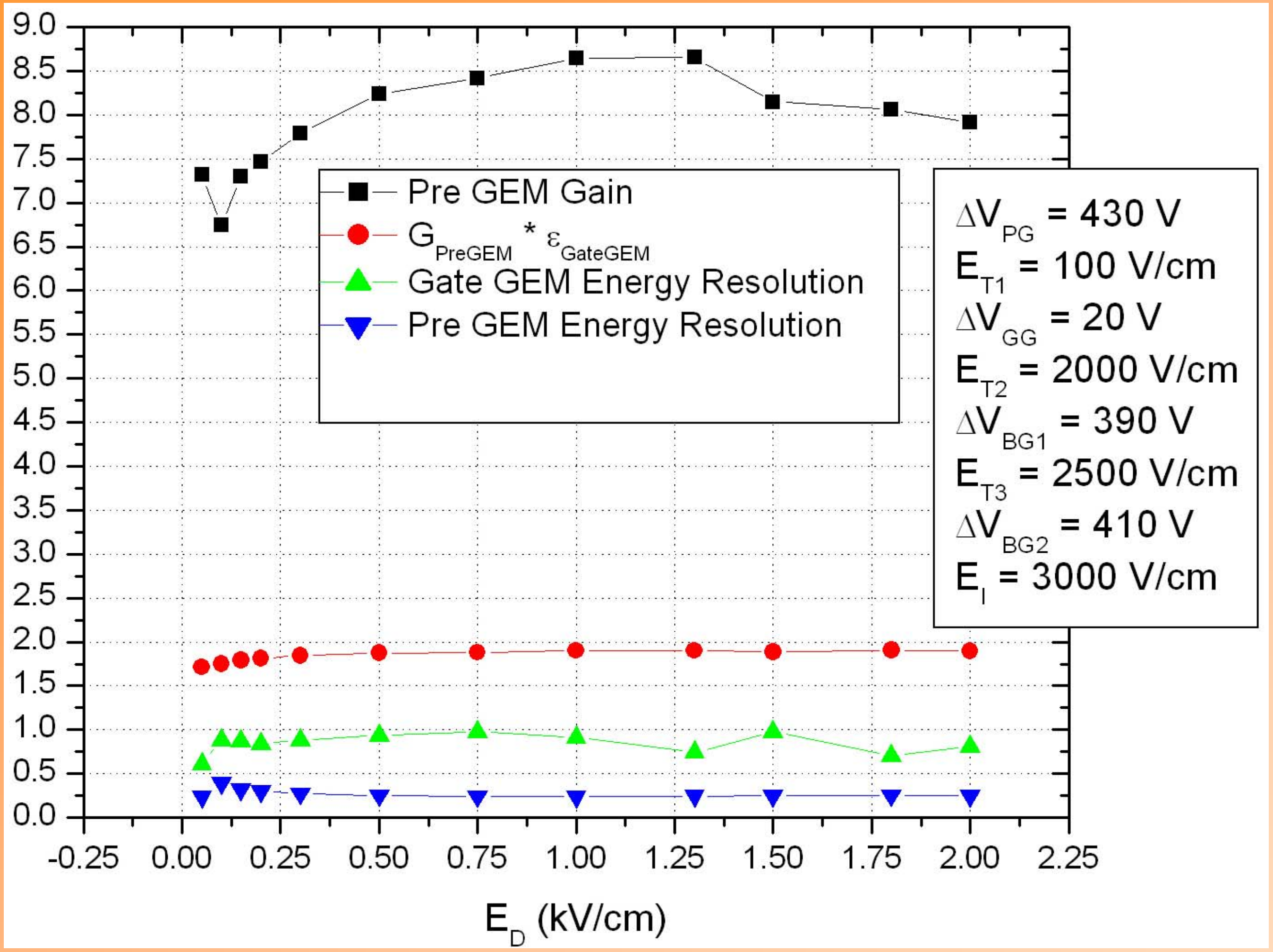


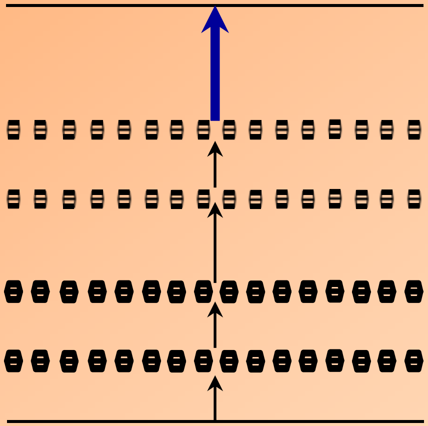






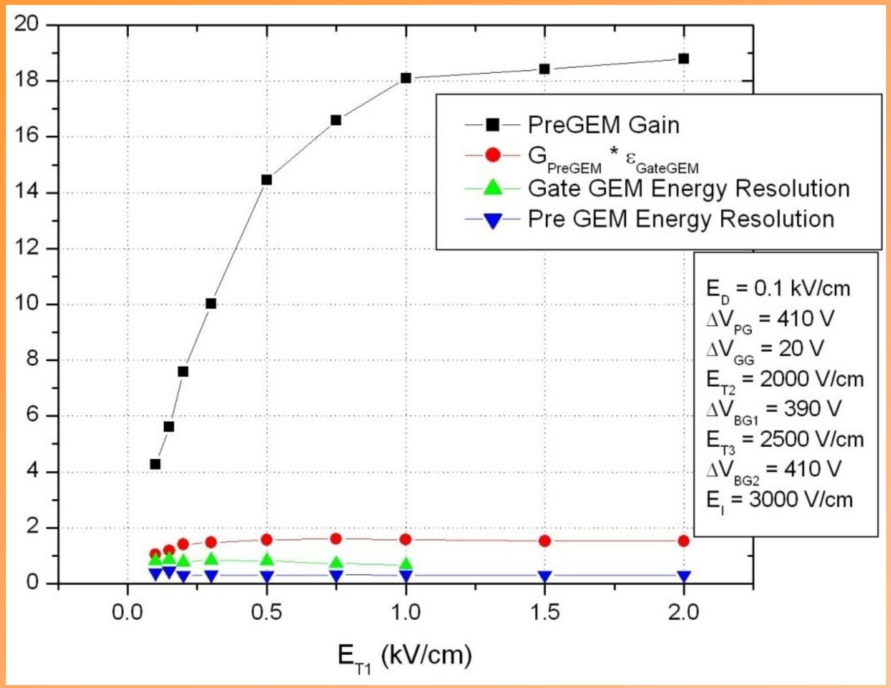
Drift Field Scan

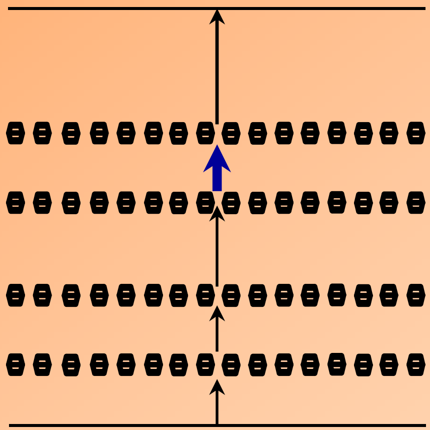




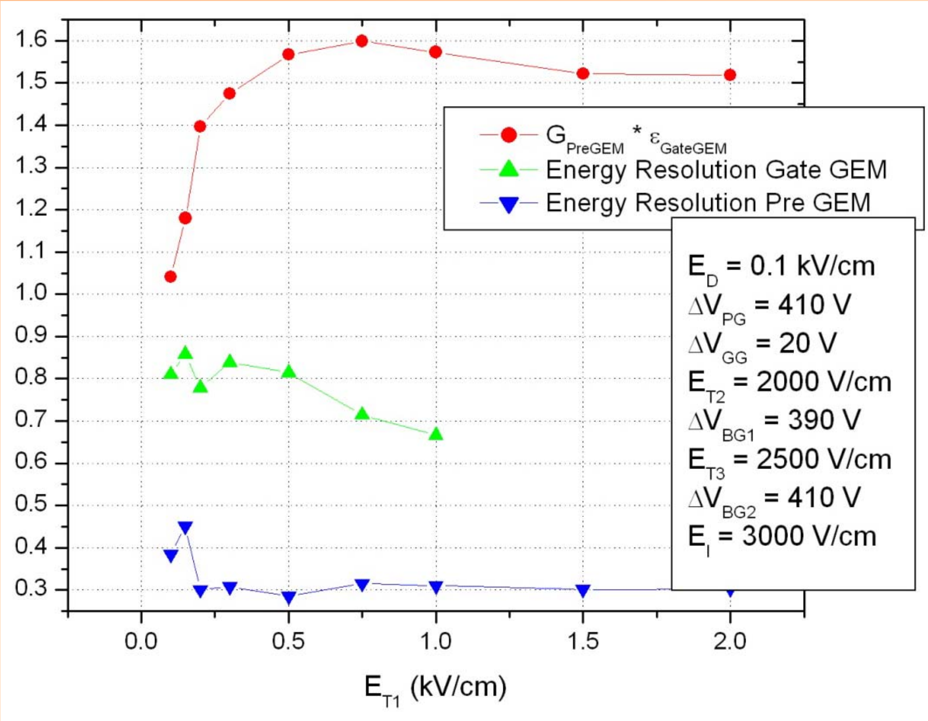
The value of the parameter $G_{PreAmpGEM}*\varepsilon_{GateGEM}$ is not unitary because an higher PreAmpGEM voltage was applied. In addition we observed that its value is almost independent from the drift field

Transfer Field 1 (E_{T1}) Scans





zoom



Increasing E_{T1} value has two opposite effects: the extraction efficiency of the PreAmpGEM is higher but the loss of the electrons on the top of the Gating GEM is increased. We managed to find an optimum between these two behaviours