Gain Measurements of new GEM prototypes for CMS

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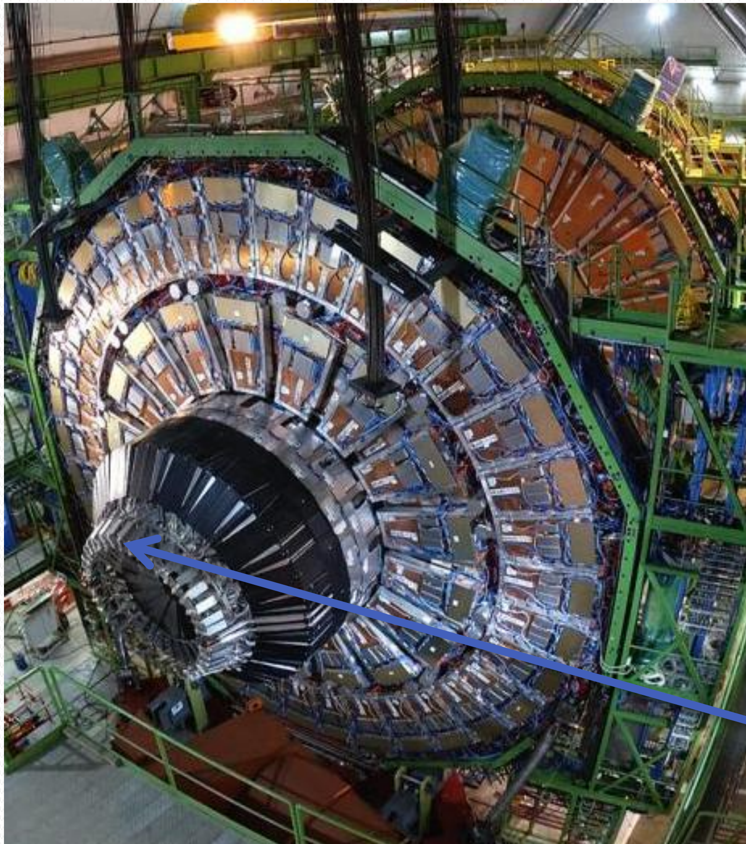
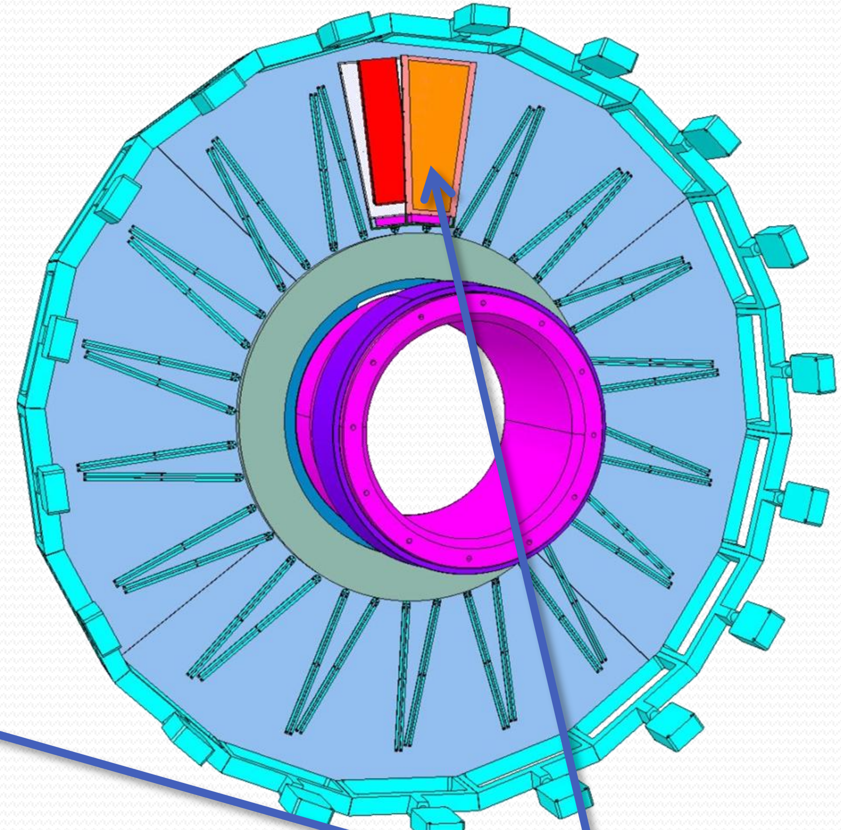
Outline

- Introduction
- How to perform the gain measurements
- Measurements of detectors with CERN GEM foils
  - GE1/1_I prototype
  - GE11_II prototype
  - Timing GEM
- Conclusion and future plans

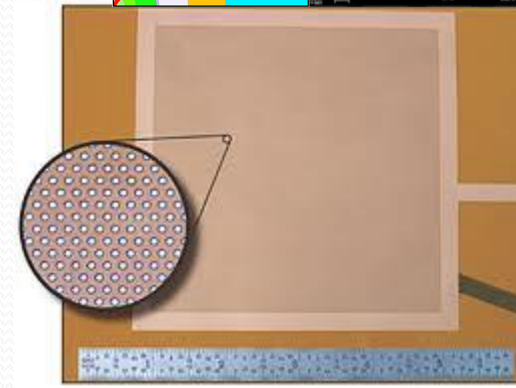
CMS high-eta





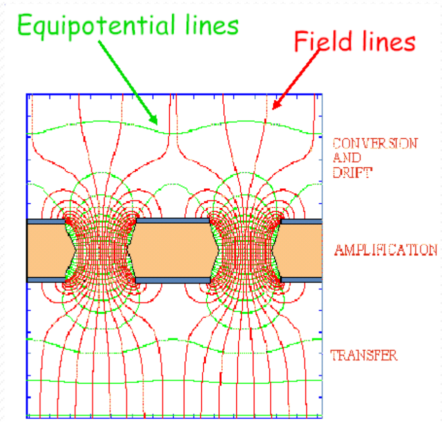
The Forward Muon RPC trigger system is equipped with detectors at $\eta<1.6$, then high η region of CMS is presently vacant and presents an opportunity to instrument it with a detector technology that could sustain the environment and be suitable for operation at the LHC and its future upgrades.

The case for GEMs



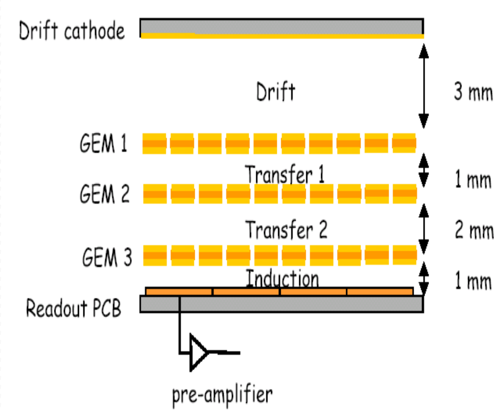
Combine <u>triggering and tracking</u> functions

Spatial/Time resolution: ~ 100 μm / ~ 4-5 ns
Efficiency > 98%



Gas Mixture: Ar-CO_2 (non flammable)
Potential for going to large areas ~ 1m x 2 with industrial processes (cost effective)

Long term operation experience in Compass and LHCb at CERN
Large margins of operation at full efficiency



Detector constructions

CMS_timing_GEM: Double mask 10x10cm2, 1D readout, (3/2/2/2), 128 channels

SingleMaskGEM: Single mask 10x10cm2, 2D readout, (3/2/2/2), 512 channels

Honeycomb: Standard double mask 10x10cm2, 1D readout (3/2/2/2), 256 channels

CMS_Proto_III: Single mask 10x10cm2, [N2] (3/1/2/1), 256 channels

Korean_I: Double mask 7x7cm2 (3/2/2/2), 256 channels

CMS_Proto_I: Single mask FULL_SIZE 1D readout (3/2/2/2), 1024 channels

CMS_Proto_II: Single mask FULL_SIZE 1D readout (3/1/2/1), 3072 channels

- No Stretch No Spacer [NS2] on the way…

CMS_Proto_IV: Single mask 30x30cm2 [NS2], (3/1/2/1), 256 channels

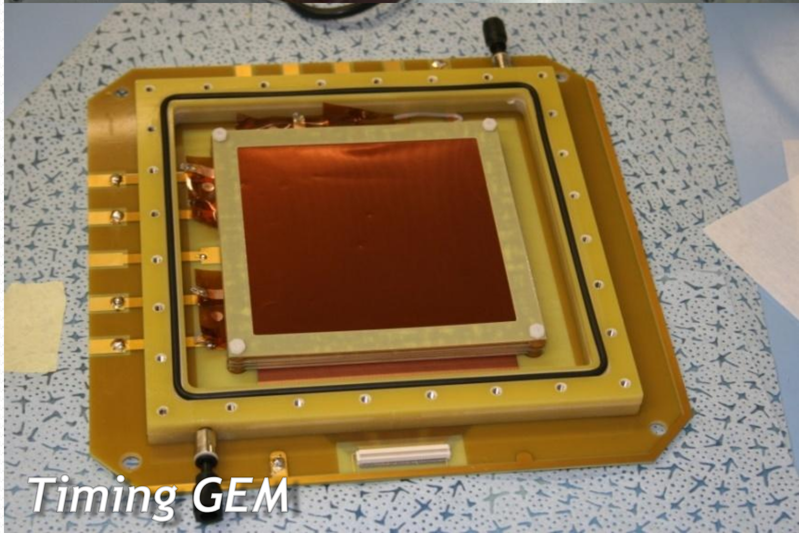
CMS_Proto_V: Single mask FULL_SIZE 1D [NS2], (3/1/2/1), ~3072 channels

Measurements of detectors with CERN GEM foils

- Prototype GE1/1_I
  - Configuration: 3-2-2-2
  - Sectors analysed: all
    - Gas composition used $ArCO_2$ (70:30)
    - $ArCO_2CF_4$ (45:15:40)

- Prototype GE1/1_II:
  - Configuration: 3-1-2-1
  - Sectors analysed: 2-2, 5-2, 8-2
  - Gas compositions used:
    - $ArCO_2$ (70:30)
    - $ArCO_2CF_4$ (45:15:40)

- Timing GEM
  - Configuration: 3-1-2-1
  - Gas compositions used:
    - $ArCO_2$ (70:30)
    - $ArCO_2CF_4$ (45:15:40)



How to perform gain measurements

- HV scan and counts measurements in various X-Ray filament current configuration (with and without absorber)
- Pulse height spectra at different voltages
- HV scan while reading the anode current
- Gain stability – HV in the plateau region, read the current for a hour (short term stability)

What we need to compute the gain

- Compute the number of counts in condition of high current on the X-Rays filament, without any absorber
  - This count cannot be straight measured in small prototypes (pile-up effect)
  - It is computed using the attenuation factor’s formula, measuring
    - counts in low current with the absorber
    - counts in low current without the absorber
    - counts in high current with the absorber
- Measure the anode current from the PCB readout with a picoamperemeter

How to compute the gain

$$G = \frac{i_{anode} \cdot \Delta t}{e \cdot \#_{p/\gamma}} \left(\frac{\#_\gamma(L,w)}{\#_\gamma(L,w/o) \cdot \#_\gamma(H,w)} \right)$$

G =effective gain

$\#_\gamma$ = number of photons

$\#_{p/\gamma}$ = number of primaries per photon

i_{anode} = readout current

e = electric charge

Δt = time of counts measurement

$$\#_{p/\gamma} = E_\gamma \left(\frac{\%Ar}{W_{i(Ar)}} + \frac{\%CO_2}{W_{i(CO_2)}} + \frac{\%CF_4}{W_{i(CF_4)}} \right)$$

Where

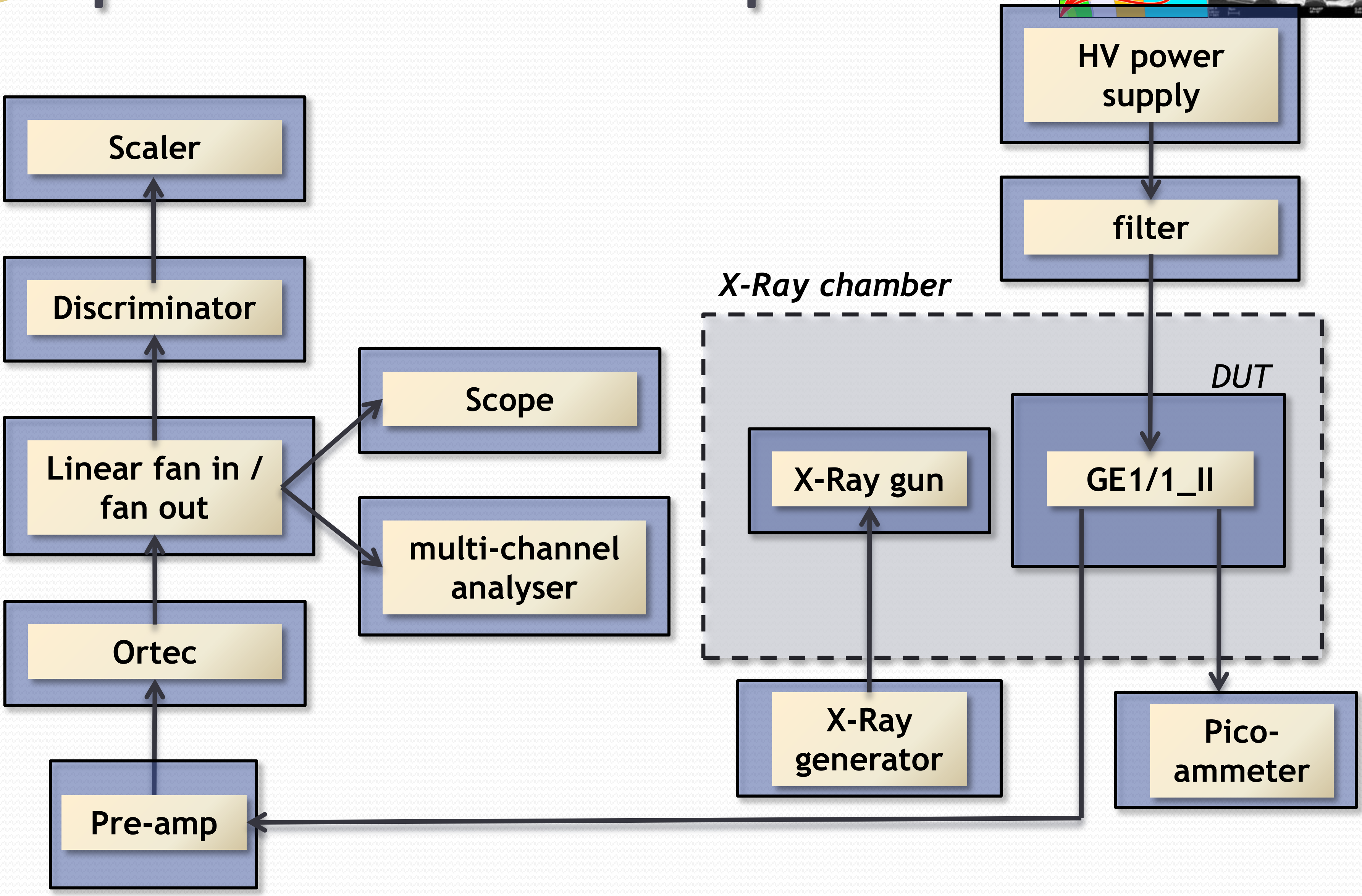
E_γ = energy of photons

Wi = ionisation energy of the gas

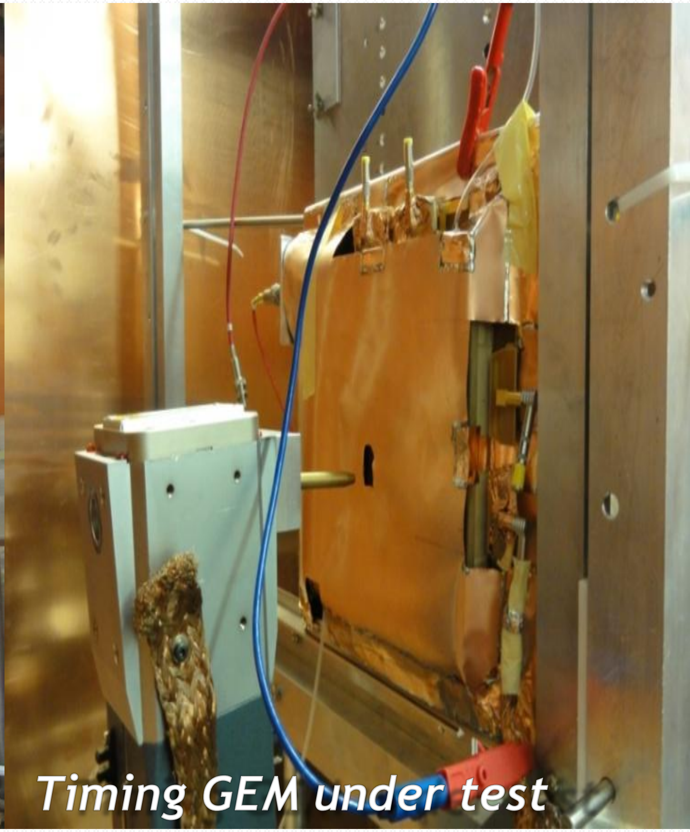
$$\frac{\#_\gamma(L,w/o)}{\#_\gamma(L,w)} = \frac{\#_\gamma(H,w/o)}{\#_\gamma(H,w)}$$

Ratio used to calculate the number of photons at high current without the absorber to measure the gain

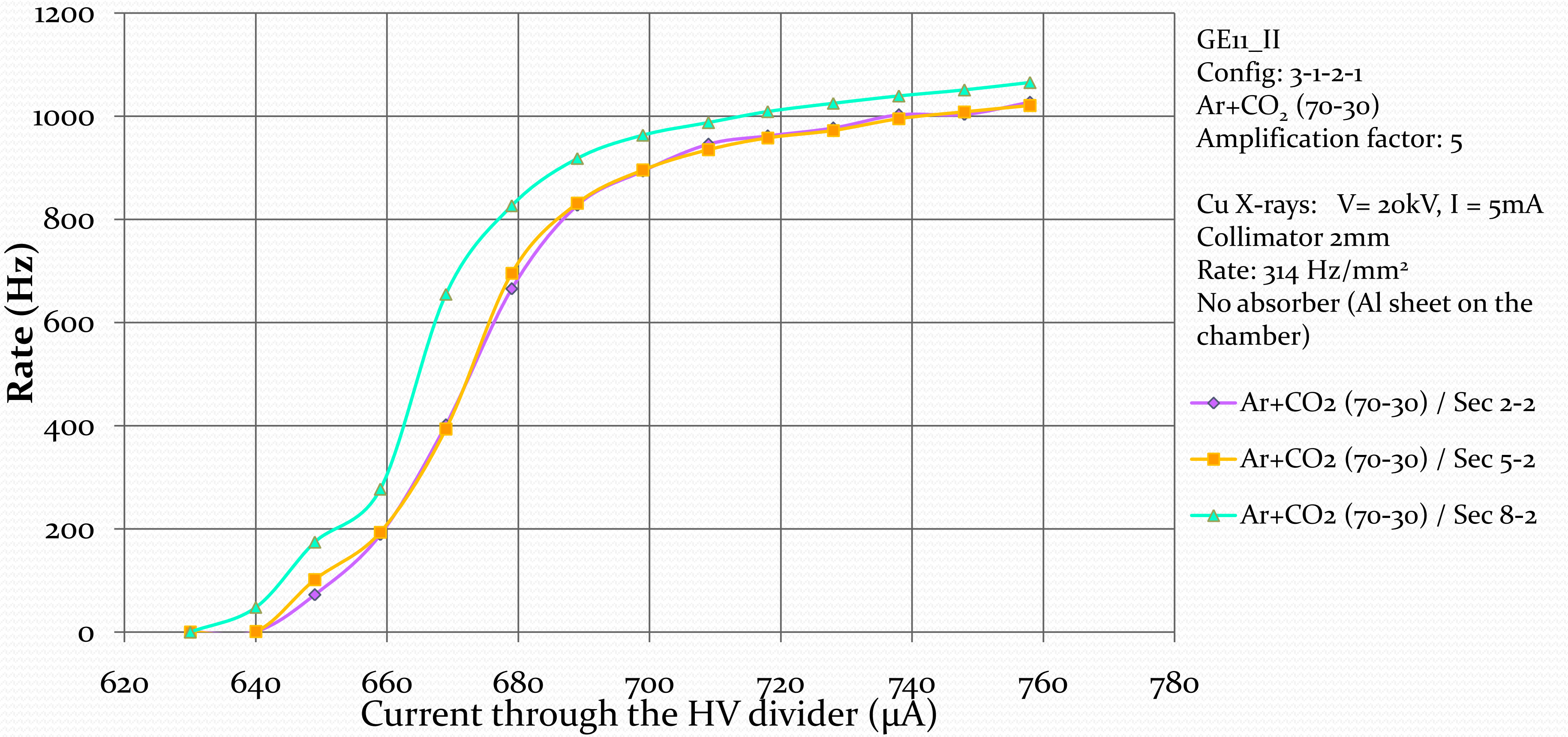
Experimental setup



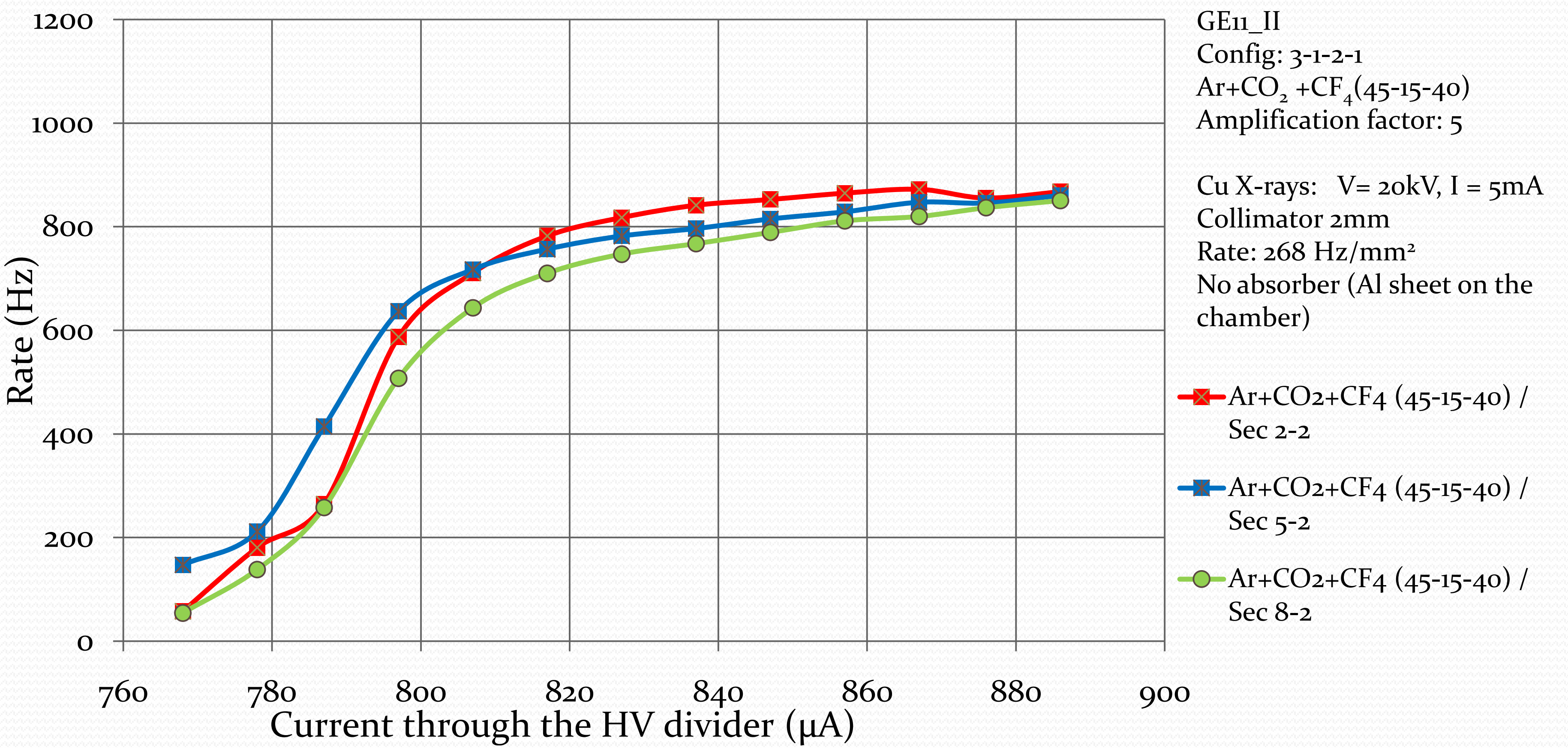
Experimental setup



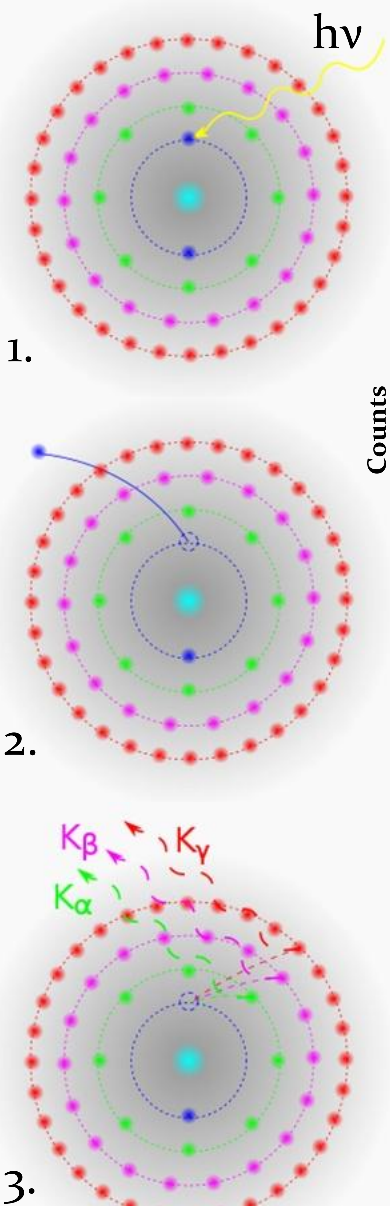
GE11_II in $ArCO_2$ (70:30): Plateau region



GE11_II in $ArCO_2CF_4$ (45:15:40): Plateau region



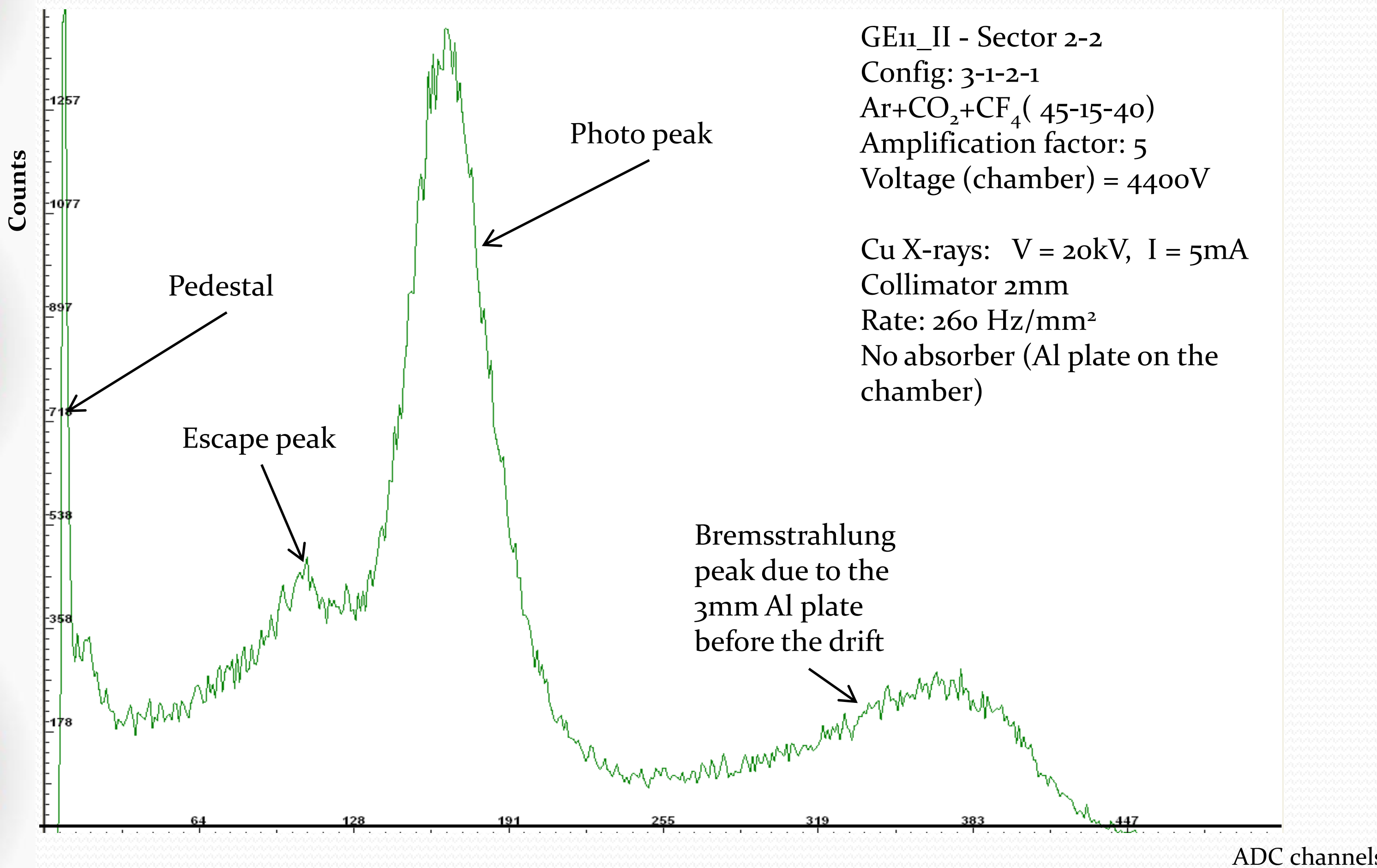
GE1/1_II : an example of Pulse height spectrum



1.

2.

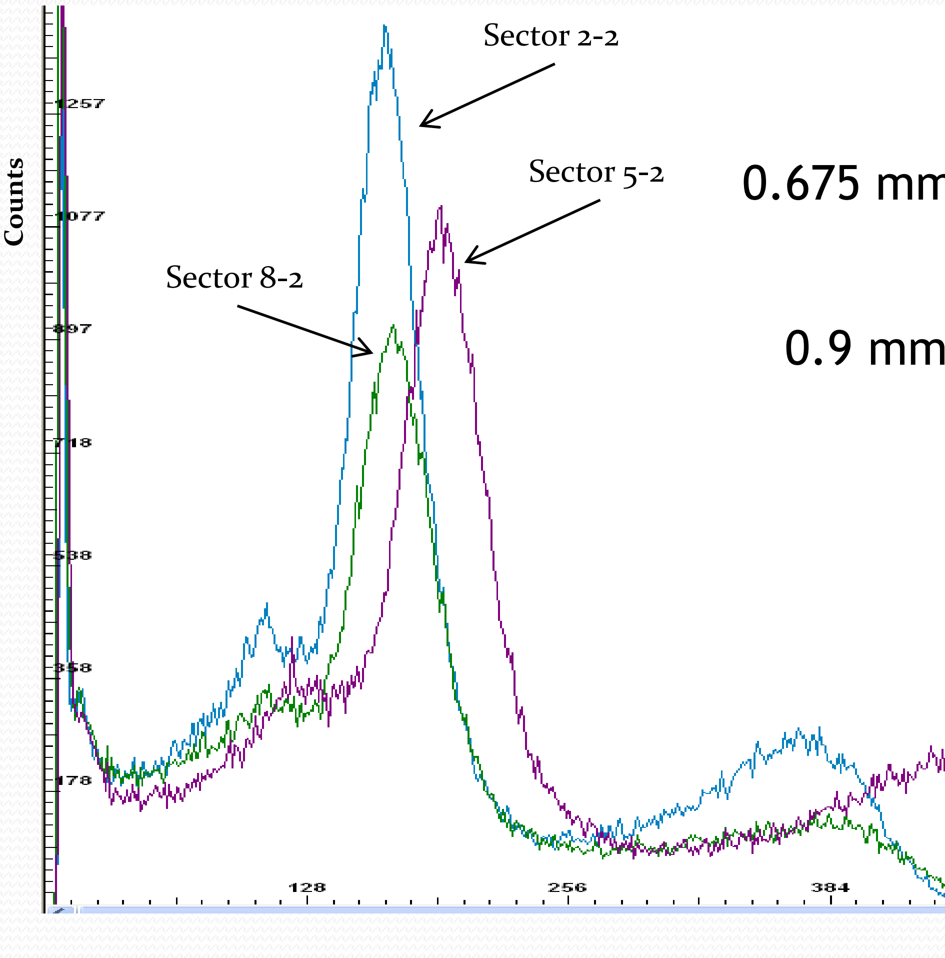
3.

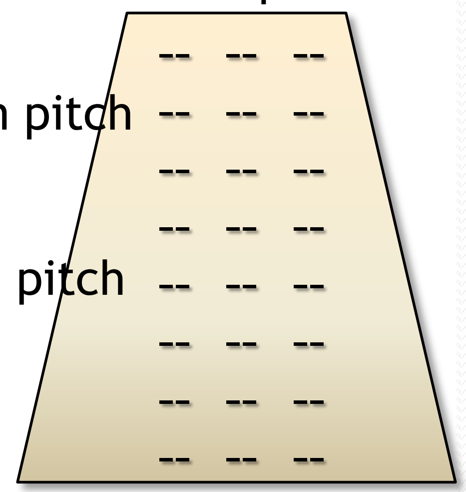


GE11_II - Sector 2-2
Config: 3-1-2-1
Ar+CO_2+CF_4(45-15-40)
Amplification factor: 5
Voltage (chamber) = 4400V

Cu X-rays: V = 20kV, I = 5mA
Collimator 2mm
Rate: 260 Hz/mm²
No absorber (Al plate on the chamber)

GE1/1_II in $ArCO_2CF_4$ (45:15:40) Pulse height spectra





GE11_II - Sectors 2-2, 5-2, 8-2
Config: 3-1-2-1
$Ar+CO_2+CF_4$(45-15-40)
Amplification factor: 5

Cu X-rays: V= 20kV, i = 5mA
Collimator 2mm
Rate: 268 Hz/mm^2
No absorber (Al sheet on the chamber)

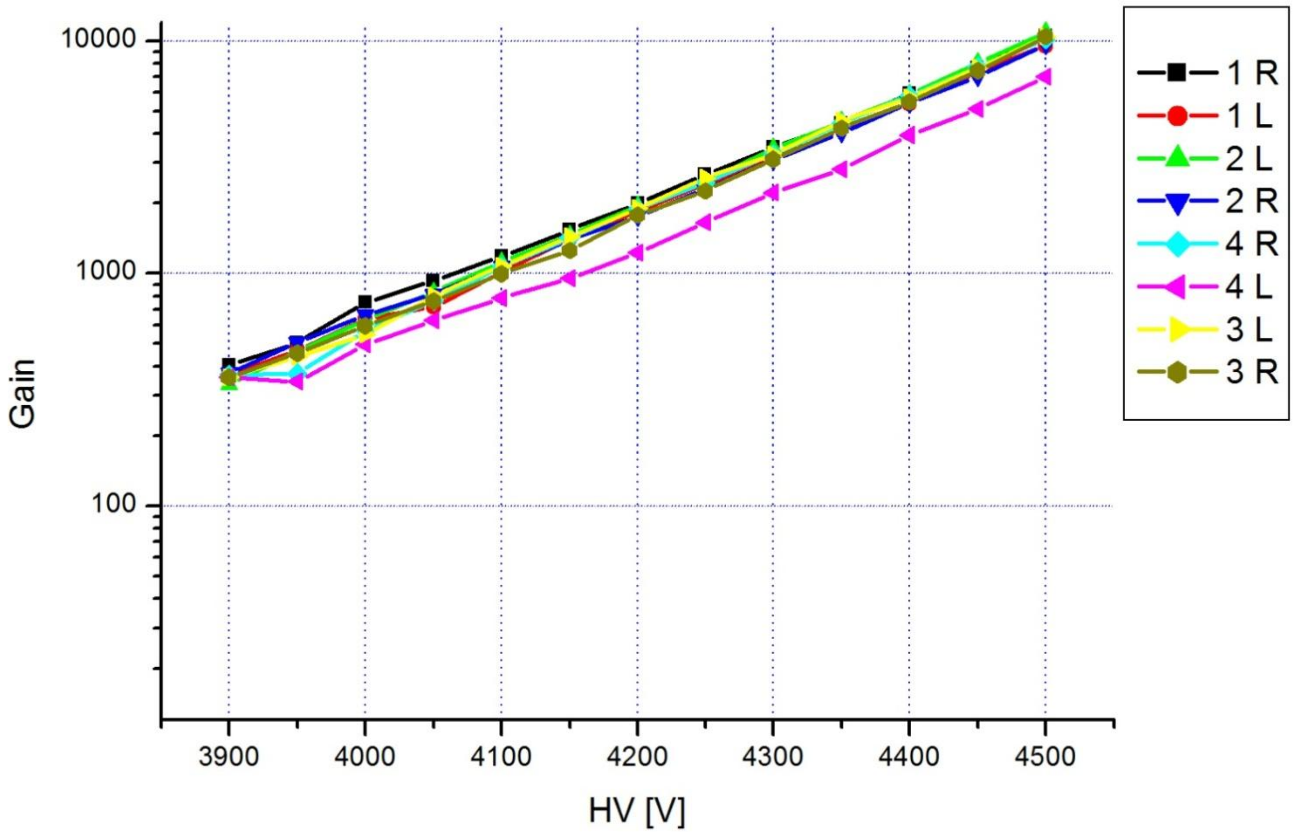
The peak height depends only on the total data acquisition time

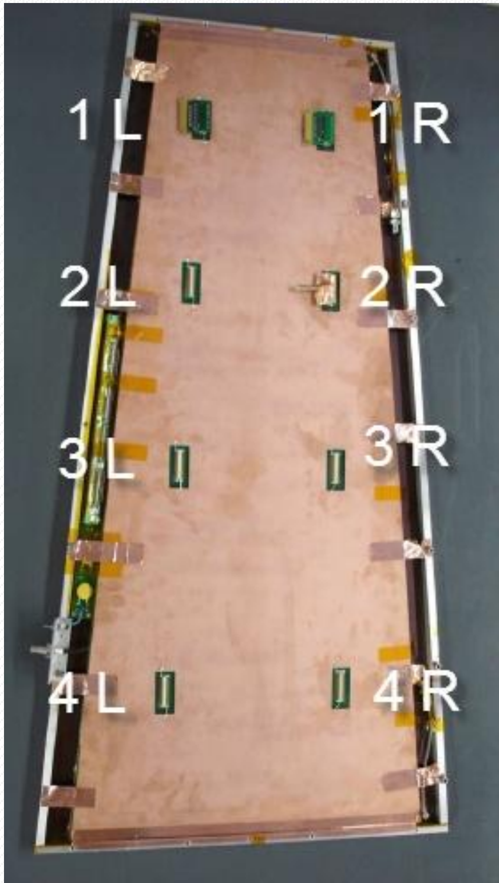
GE11_I: Gain calibration

GE1/1_I
Config: 3-2-2-2
$ArCO_2$(70:30)
Amplification factor: 5

Cu X-rays: V= 20kV, I = 10mA
Collimator 2mm

No absorber



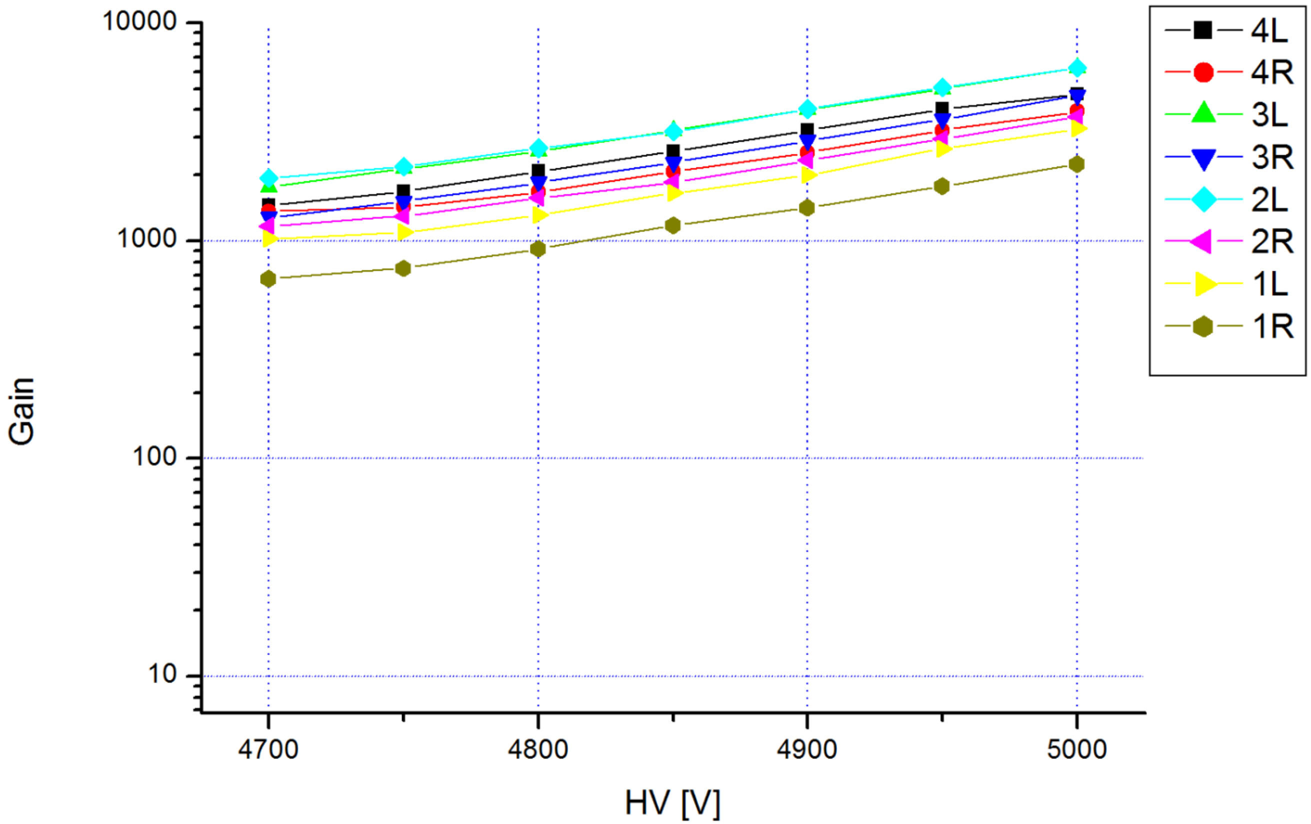


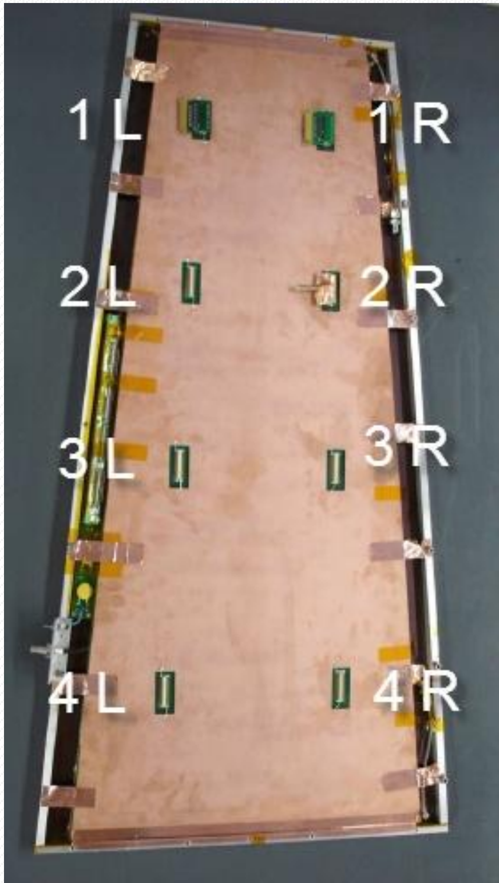
GE11_I: Gain calibration

GE1/1_I
Config: 3-2-2-2
$ArCO_2CF_4$(45:15:40)
Amplification factor: 5

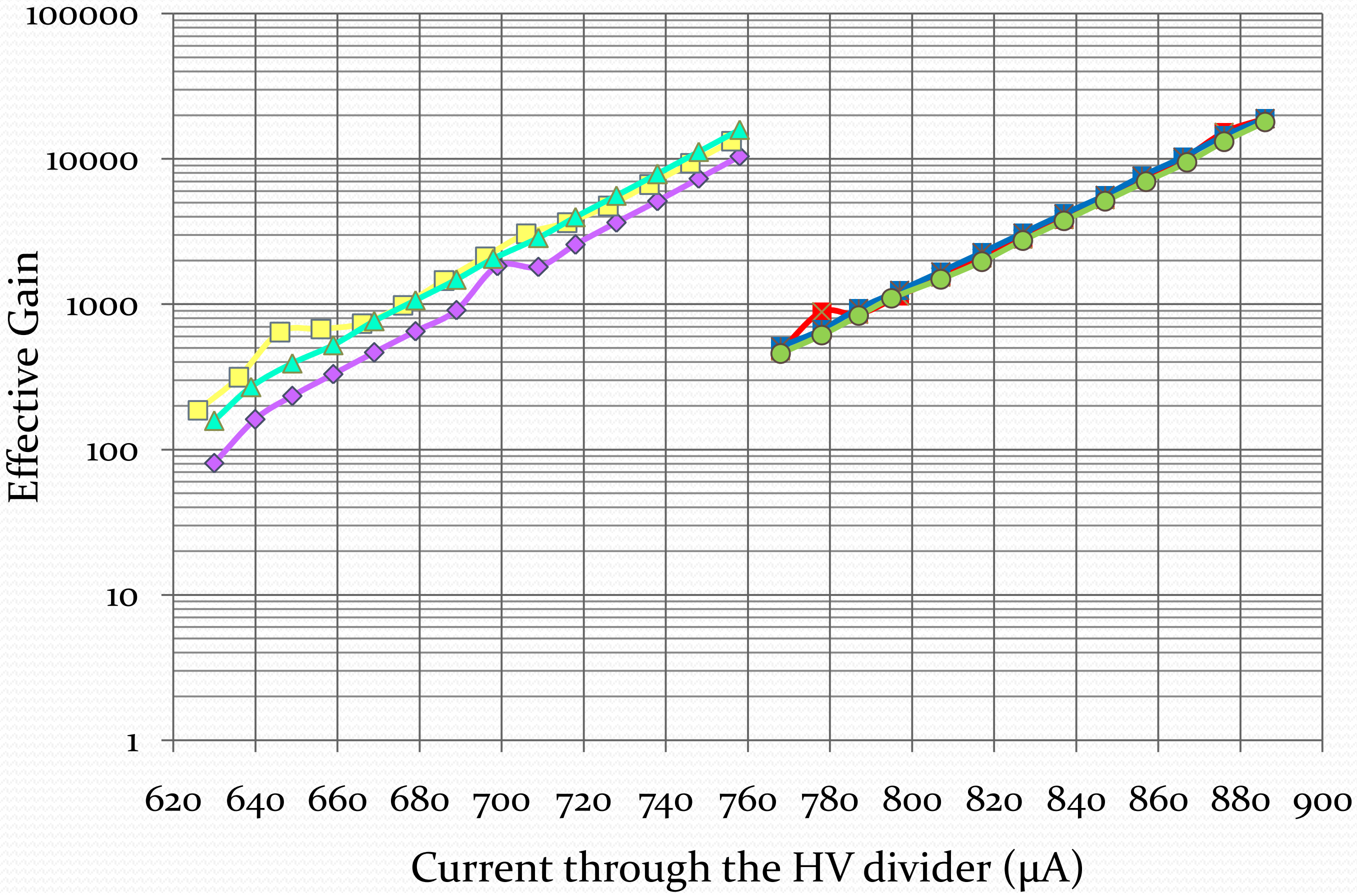
Cu X-rays: V= 20kV, I = 10mA
Collimator 2mm

No absorber





GE11_II: Gain calibration

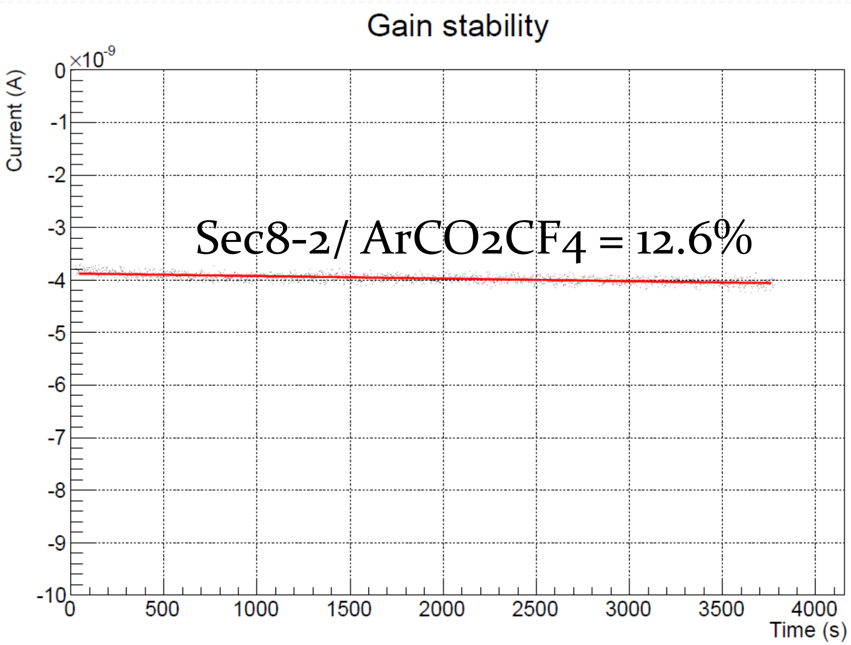


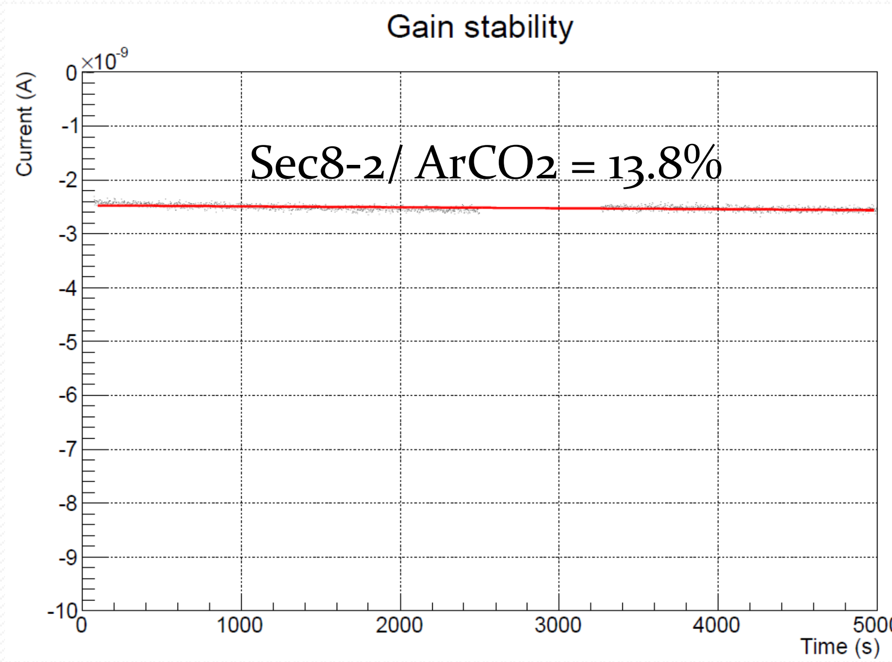
GE1/1_II
Config: 3-1-2-1
$ArCO_2$(70:30) or
$ArCO_2CF_4$(45:15:40)
Amplification factor: 5

Cu X-rays: V= 20kV, I = 5mA
Collimator 2mm
Rate: 268 Hz/mm²
No absorber

Good gain uniformity of the chamber

GE11_II: Gain stability





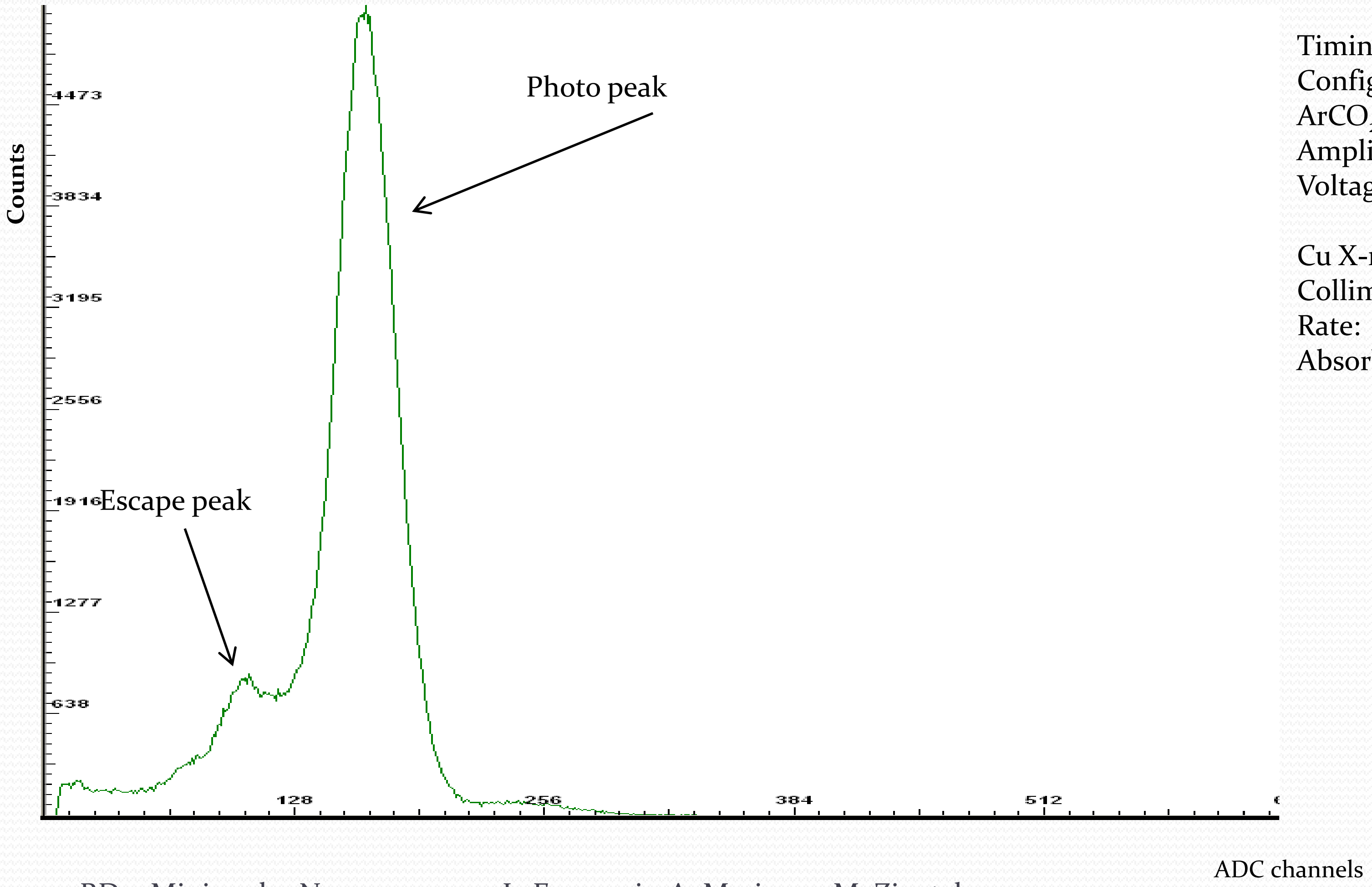
Maximum variation
(relative difference between the maximum and the minimum points of the whole range):

- for Ar+CO_2 (70-30): 12.6%
- for Ar+CO_2+CF_4 (45-15-40): 13.8%

GE11_II sec 2-2
Config: 3-1-2-1
Ar+CO_2(70-30)
→ V(chamber) = 3700V
Ar+CO_2+CF_4(45-15-40)
→ V(chamber) = 4400V
Amplification factor: 5

Cu X-rays: V= 20kV, I = 5mA
Collimator 6mm
Rate: 32 Hz/mm^2
No absorber (Al sheet on the chamber)

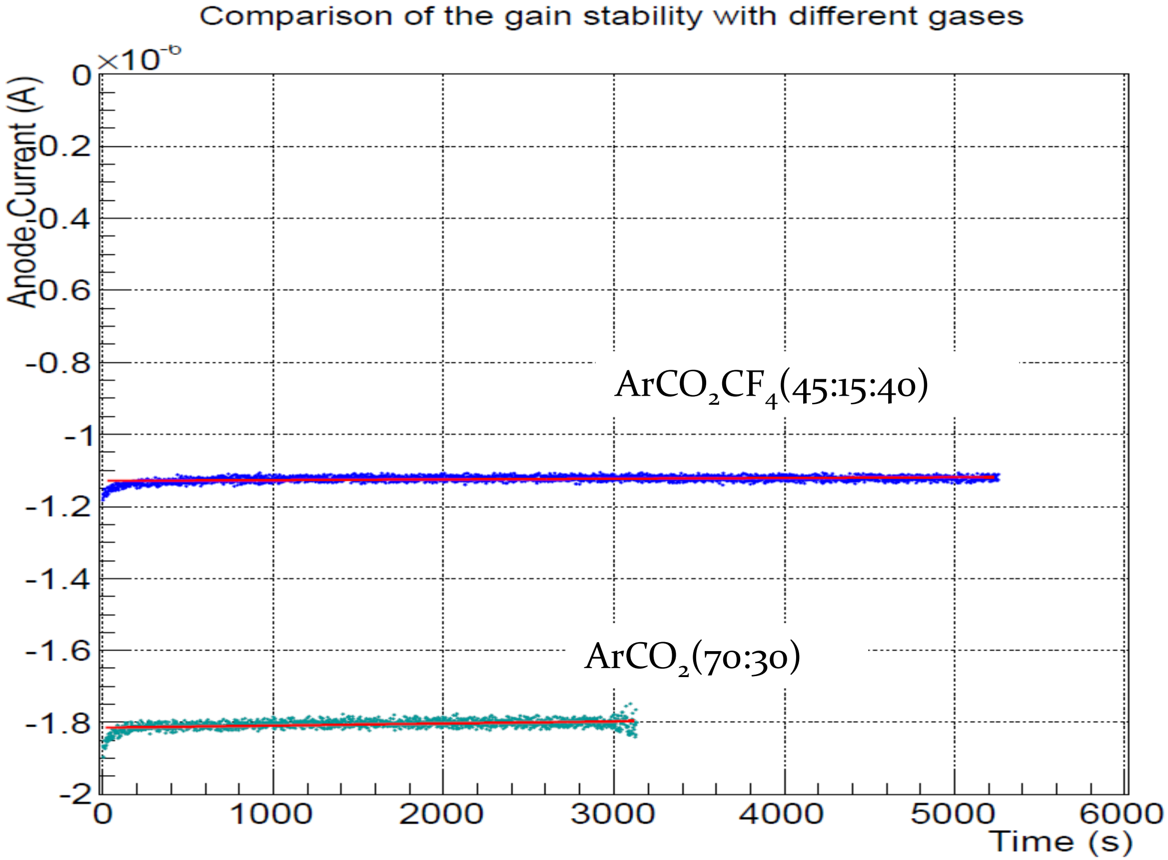
Timing GEM: an example of pulse height spectrum



Timing GEM
Config: 3-1-2-1
$ArCO_2$(70:30)
Amplification factor: 5
Voltage (chamber) = 3800V

Cu X-rays: V= 10kV, I = 0.6mA
Collimator 2mm
Rate: 149 KHz/mm^2
Absorber: 135 μm Cu tape

Timing GEM: Gain stability



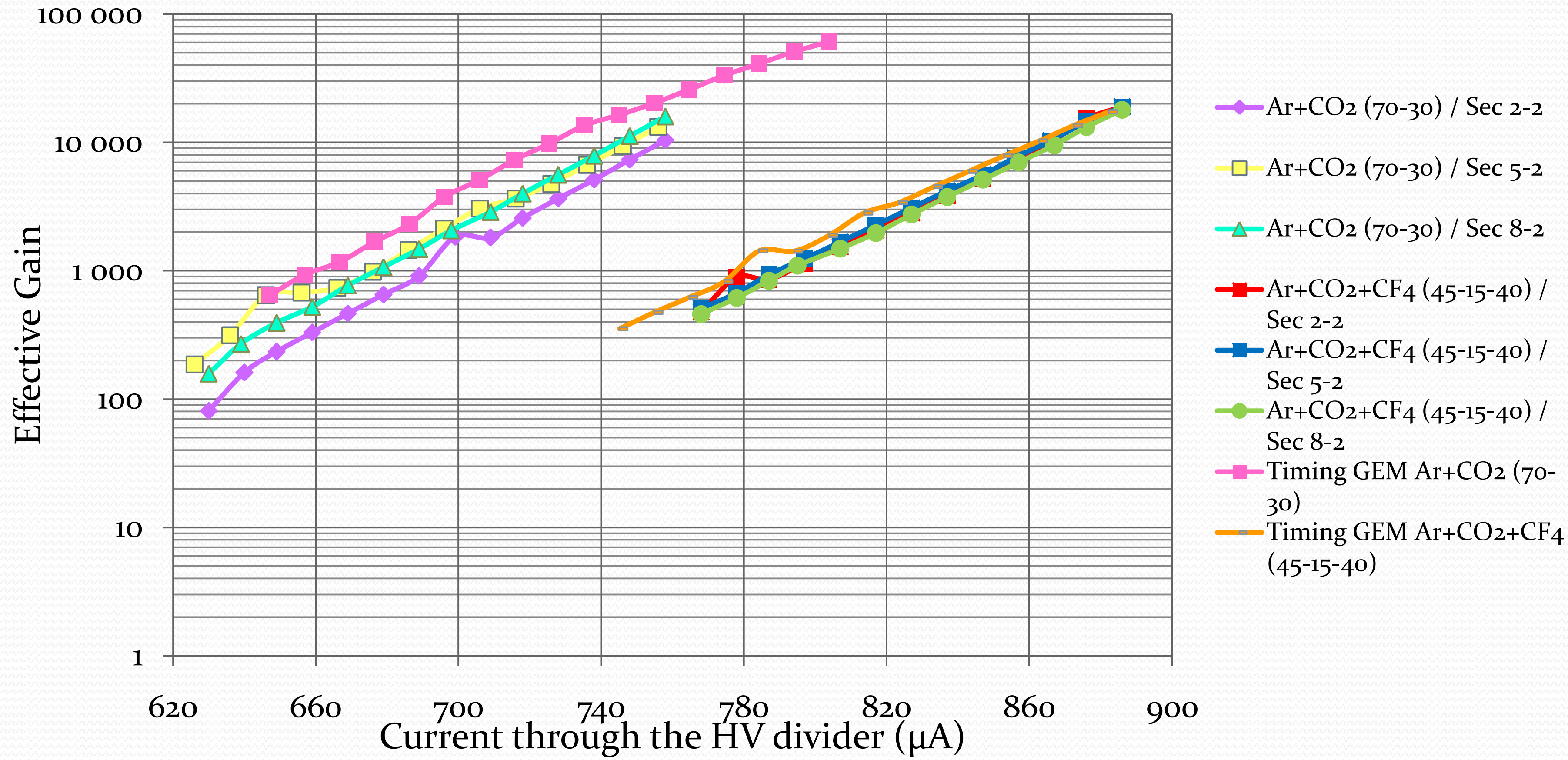
Timing GEM
Config: 3-1-2-1
$ArCO_2$(70:30)
→ V(chamber) = 3800V
$ArCO_2CF_4$(45:15:40)
→ V(chamber) = 4400V
Amplification factor: 5

Cu X-rays: V= 10kV, i = 1.6mA
Collimator 6mm
Rate: 16 KHz/mm²

Maximum variation:

- for $ArCO_2$ (70:30): 7.8%
- for $ArCO_2CF_4$ (45:15:40): 6.5%

Comparison between GE1/1_II and Timing GEM



NS2 30x30 cm^2 Triple GEM (CERN) prototype

- Properties:
  - Self stretched (NEW stretching method)
  - Ceramic HV divider
  - Gap configuration (a.t.m.): 3-1-2-1

Conclusions

Fully operational GEM prototypes have been designed, produced and tested after long intense work on small size prototypes

- The new prototypes, GE1/1_II, have uniform gain
- The maximum gains of the Ge1/1_II are
  - $\approx 1{,}8 \cdot 10^4$ in $ArCO_2CF_4$ (45:15:40)
  - $\approx 1{,}3 \cdot 10^4$ in $ArCO_2$ (70:30)

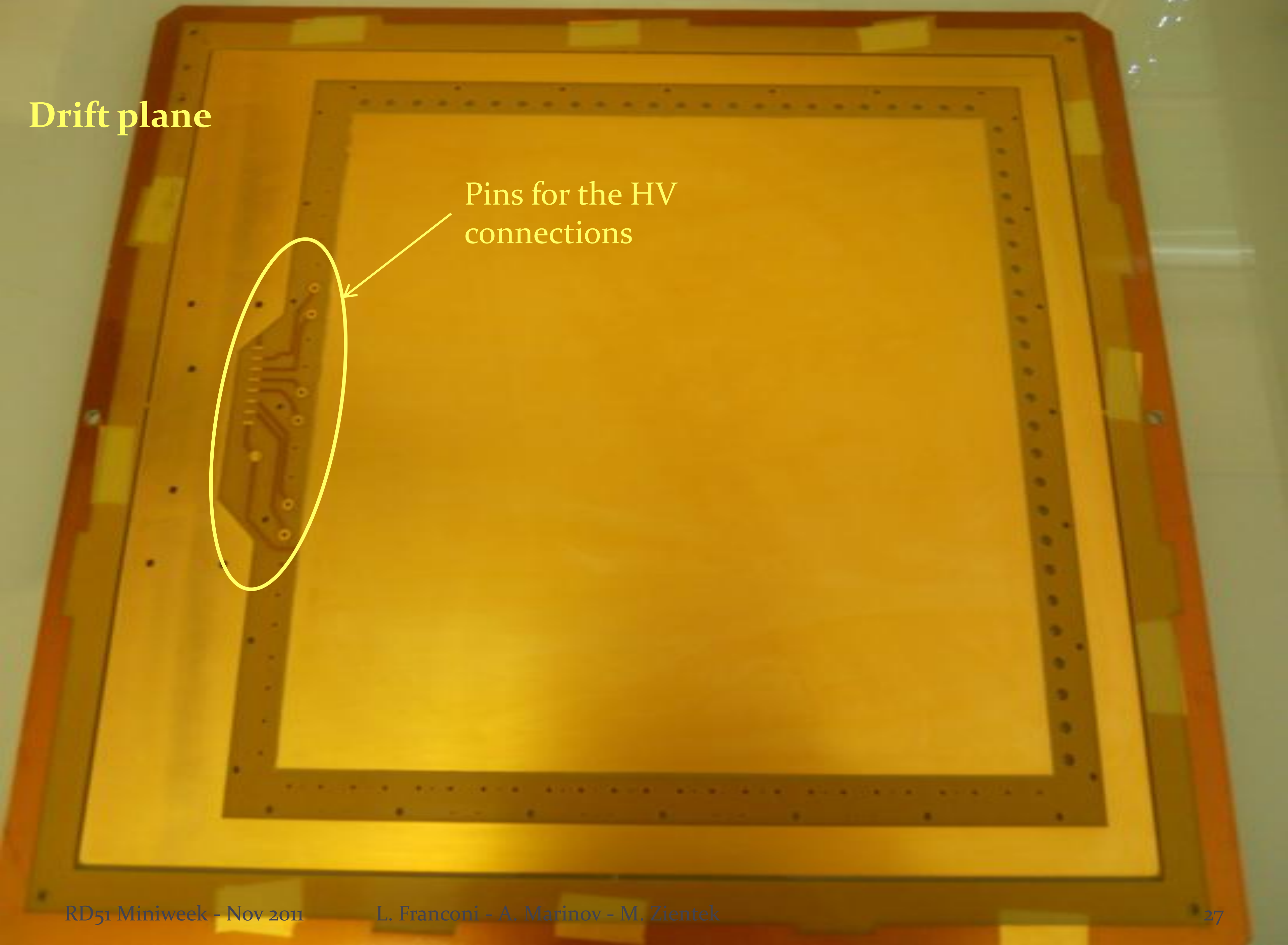
Future plans

- Gain tests on the 30x30 cm^2 GEM detector


GEM foil
Holes for the stretching

Readout strips

Drift plane



Thank you

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