CMS Triple-GEM Aging Test @ GIF++

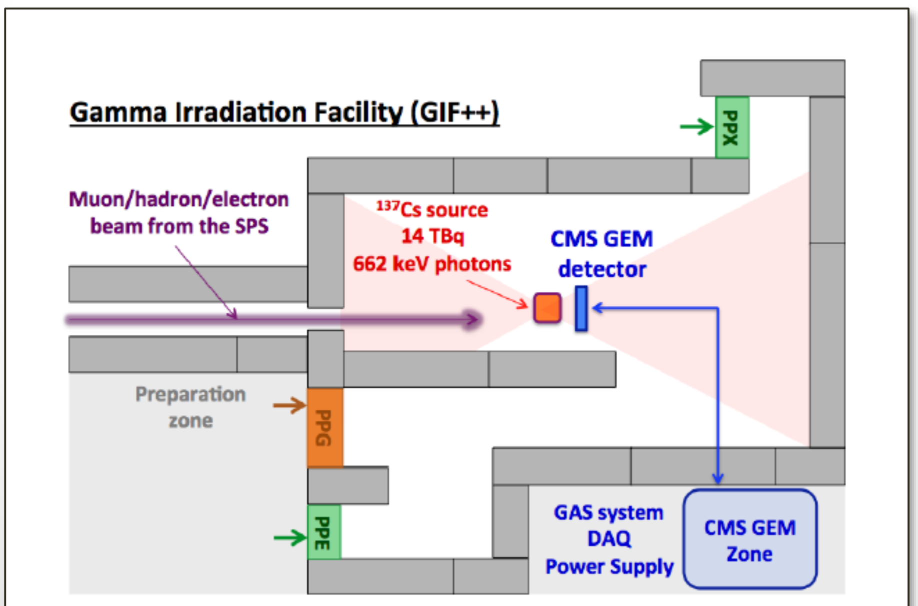
M. Abbas, M. Bianco, F. Fallavollita, M. Gruchała, S. Hassan, J.A. Merlin

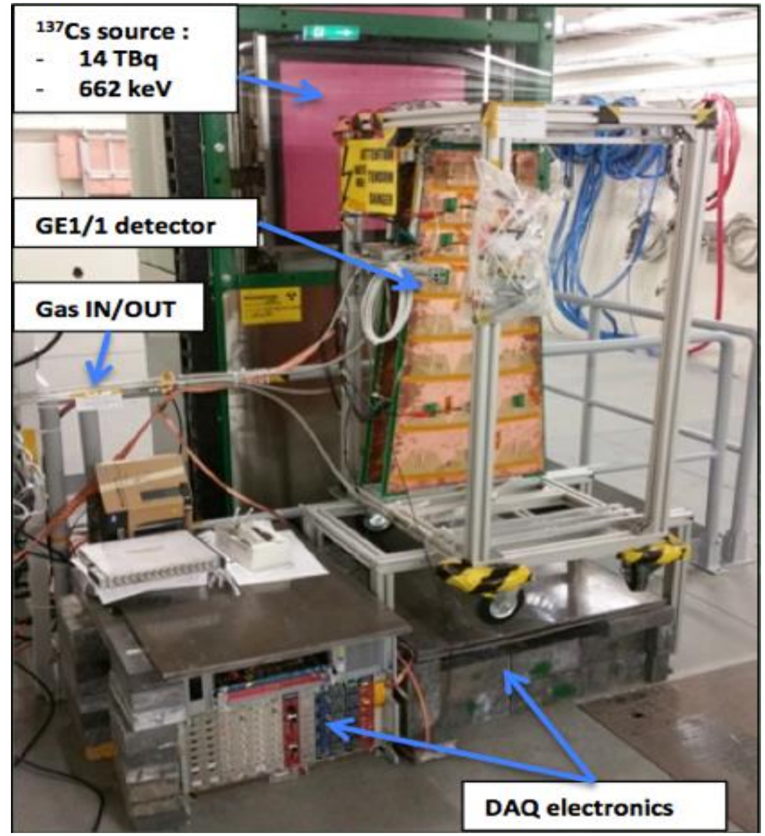
Installation of new setup for Triple-GEM Aging Test @ GIF++

- ***GE1/1 & GE2/1 Aging Studies***
- ***Goal of the new Aging Test @ GIF++***
- ***CMS Triple-GEM Setup***
- ***Installation inside the GIF++ Bunker***
- ***The Readout System***
- ***Preliminary Analysis @ GIF++***
- ***Schedule and Conclusion***

GE1/1 & GE2/1 Aging Studies

- Triple GEM technology (***GE1/1 IV***) similar to the final design already tested at the GIF++ facility.
- Aging test to validate the Triple-GEM technology for the *GE1/1* and *GE2/1* project.





Tests performed by J.A. Merlin with a dedicated setup located in the D_1 position.

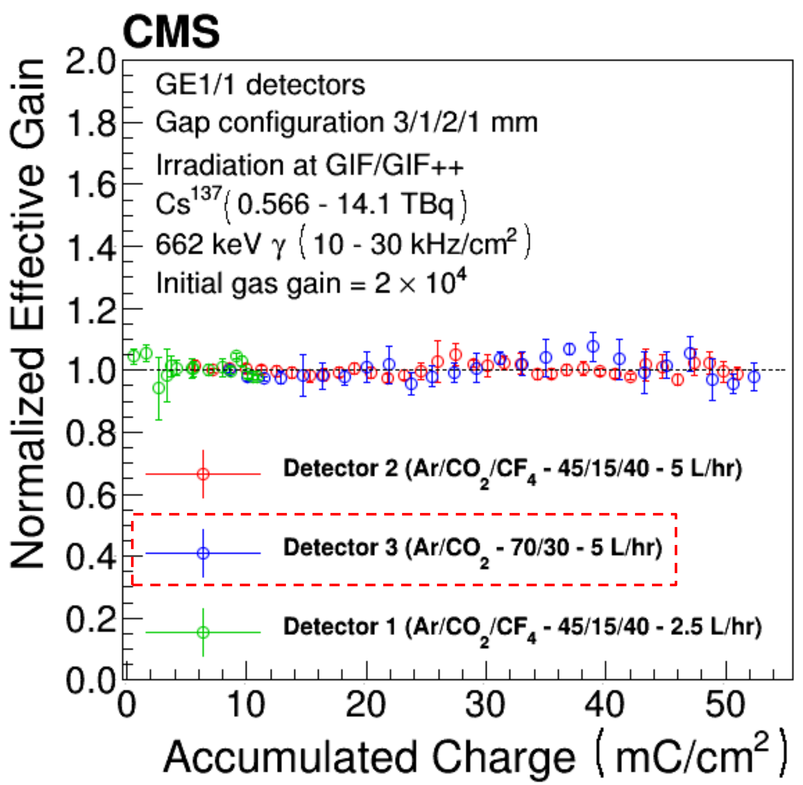
D_1 Position for new Triple-GEM setup already approved in Nov. 16

GE1/1 & GE2/1 Aging Studies

Aging Test in Ar/CO_2 @ GIF++

- GE1/1 IV (similar to the final design)
- 6 months of operation in Ar/CO_2
- No aging observed up to $\sim 55mC/cm^2$

Conclusion:
The Ar/CO_2 (70/30) configuration is validate for GE1/1 and GE2/1



Aging Test in $Ar/CO_2/CF_4$ @ GIF++

- GE1/1 IV (similar to the final design)
- 12 months of operation in $Ar/CO_2/CF_4$
- No aging observed up to $\sim 53mC/cm^2$

Conclusion:
The $Ar/CO_2/CF_4$ (45/15/40) configuration is validate for GE1/1 and GE2/1

Muon Upgrade Workshop (28/07/2016)

Dr. Jeremie A. Merlin
CERN

Goal of the new Aging Test @ GIF++

- The goal is to validate the Triple-GEM technology for the new ME0 project;
- 283 mC/cm^2 of integrated charge needed to fully validate the Triple-GEM technology for the new ME0 station (no safety factor);
- Extensive test are planned and restarted on 1^{st} May 2017 @ GIF++ (Gamma Irradiation Facility);
- From the past experience about *3 years* are needed to reach this value, assuming standard GIF++ duty cycle.

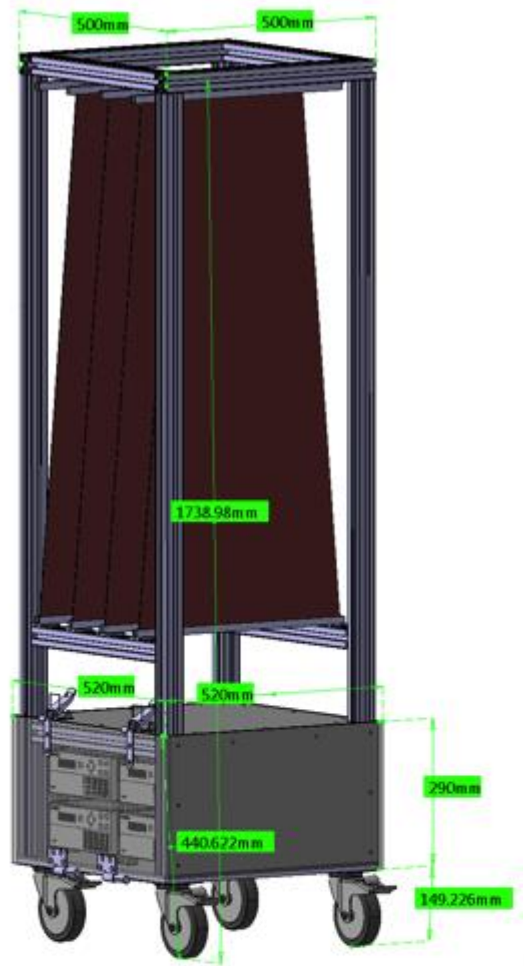
CMS Triple-GEM Setup

Triple-GEM setup:

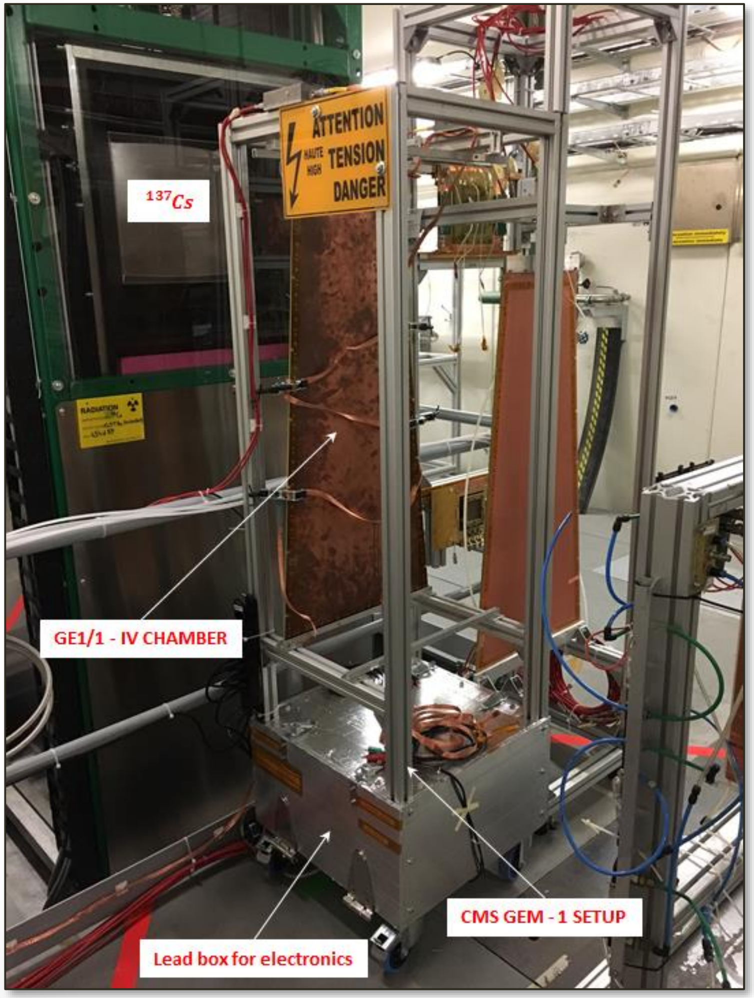
New setup has been designed and assembled to host the Triple-GEM chambers.

Detector Under Test:

- **GE1/1 - IV generation irradiated chamber**
  (gas mixture: $Ar/CO_2 - 70/30$)
  - Irradiated chamber @ GIF++ during Jeremie's aging studies to validate the Triple-GEM technology for *GE1/1* & *GE2/1* project;
  - $\sim 55\, mC/cm^2$ collected in about 6 months of continuous tests.
- **GE1/1 - X generation NOT irradiated chamber**
  (gas mixture: $\mathrm{Ar}/CO_2 - 70/30$)
  - Korean GEM foils produced at Mecaro;
  - Aging Test to validate the Korean GEM foils for *GE2/1* project.



Installation inside the GIF++ Bunker

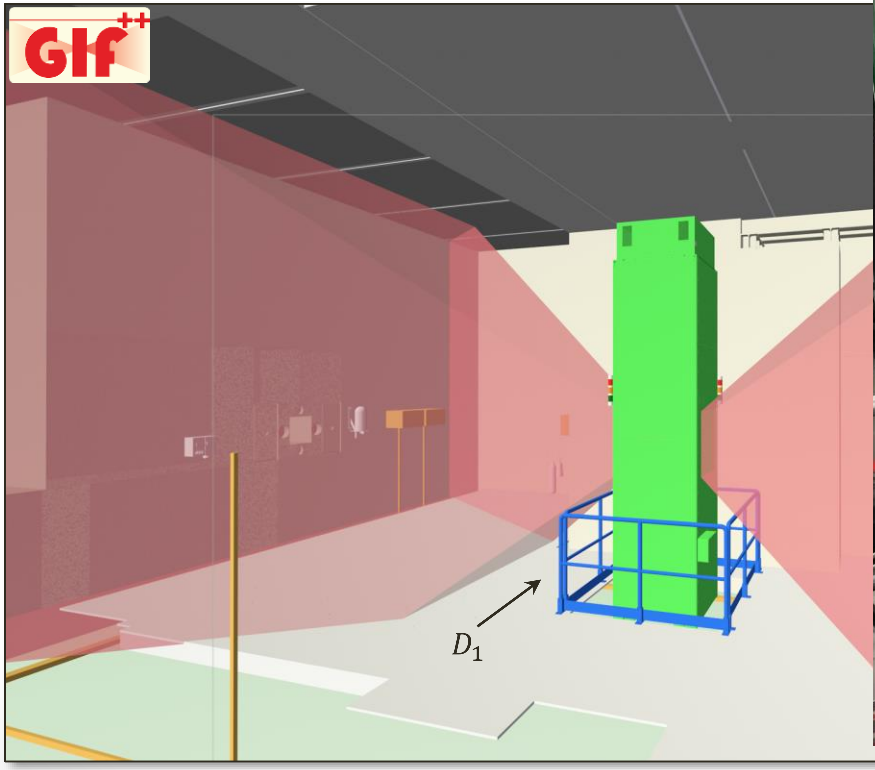


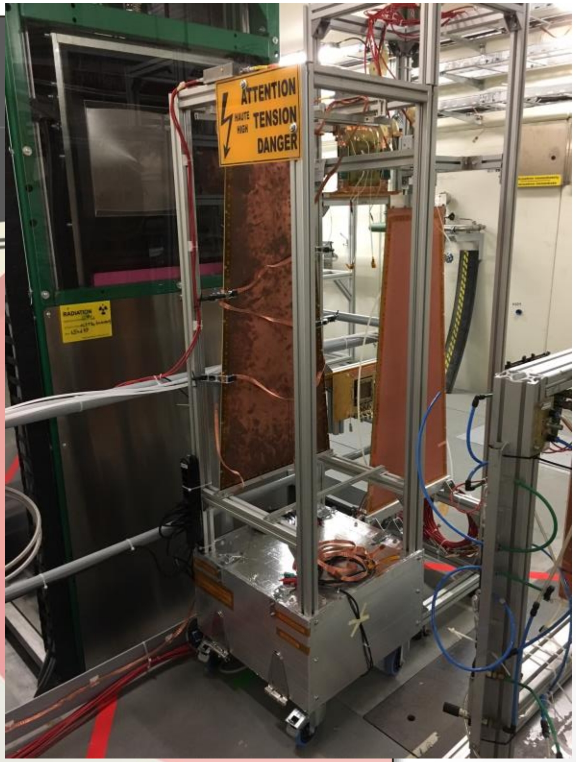
CMS-GEM1 setup inside the GIF++ bunker (back view)

CMS-GEM1 setup inside the GIF++ bunker (front view)

Installation inside the GIF++ Bunker

- The GE1/1 detector under test is placed at $\sim 1m$ from the source point (D_1 position):
  - half of the chamber is directly in front of the irradiator and is operating under a particle flux just below $10^8 Hz/cm^2$
  - the other half, protected by the shielding of the irradiator, receive a flux lower by four orders of magnitude.





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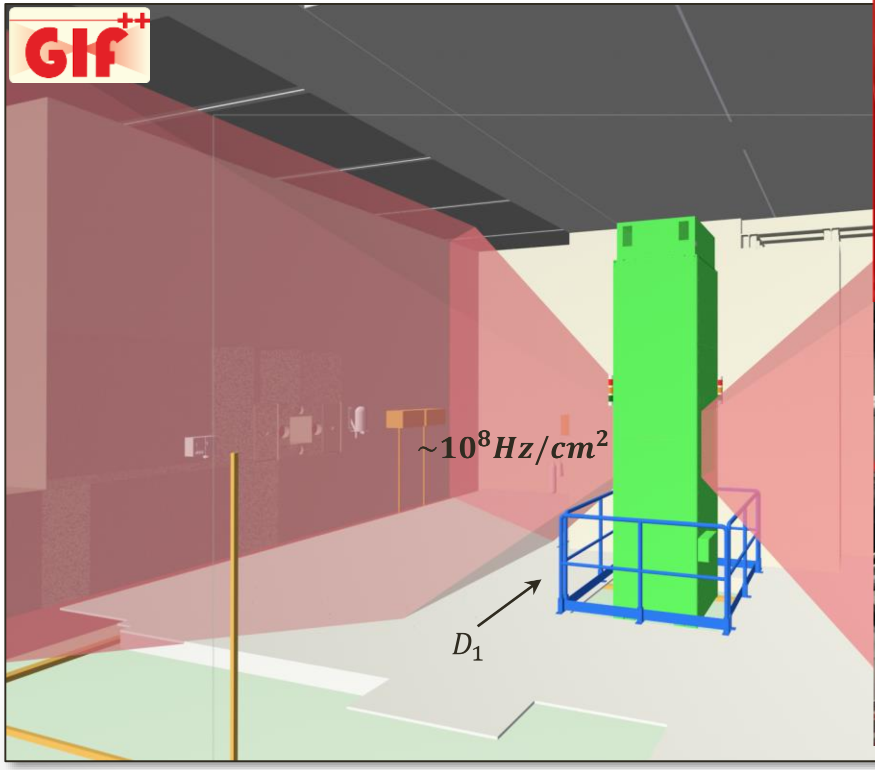

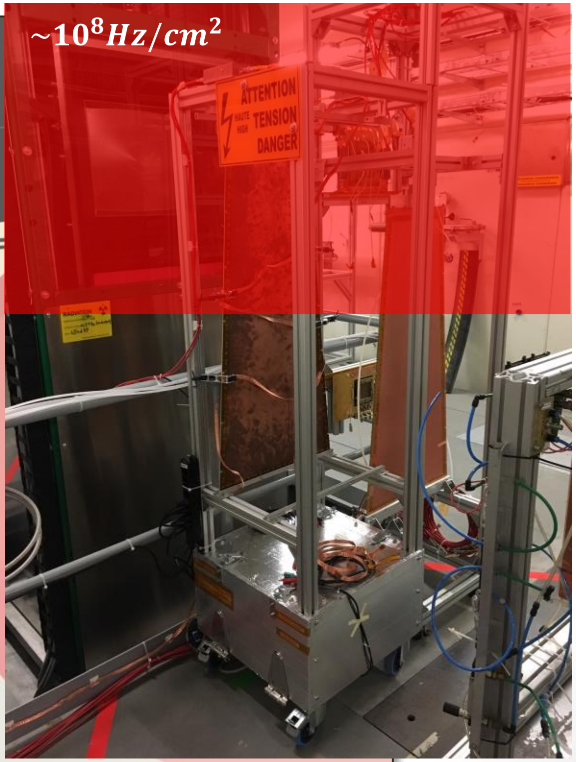

Installation inside the GIF++ Bunker

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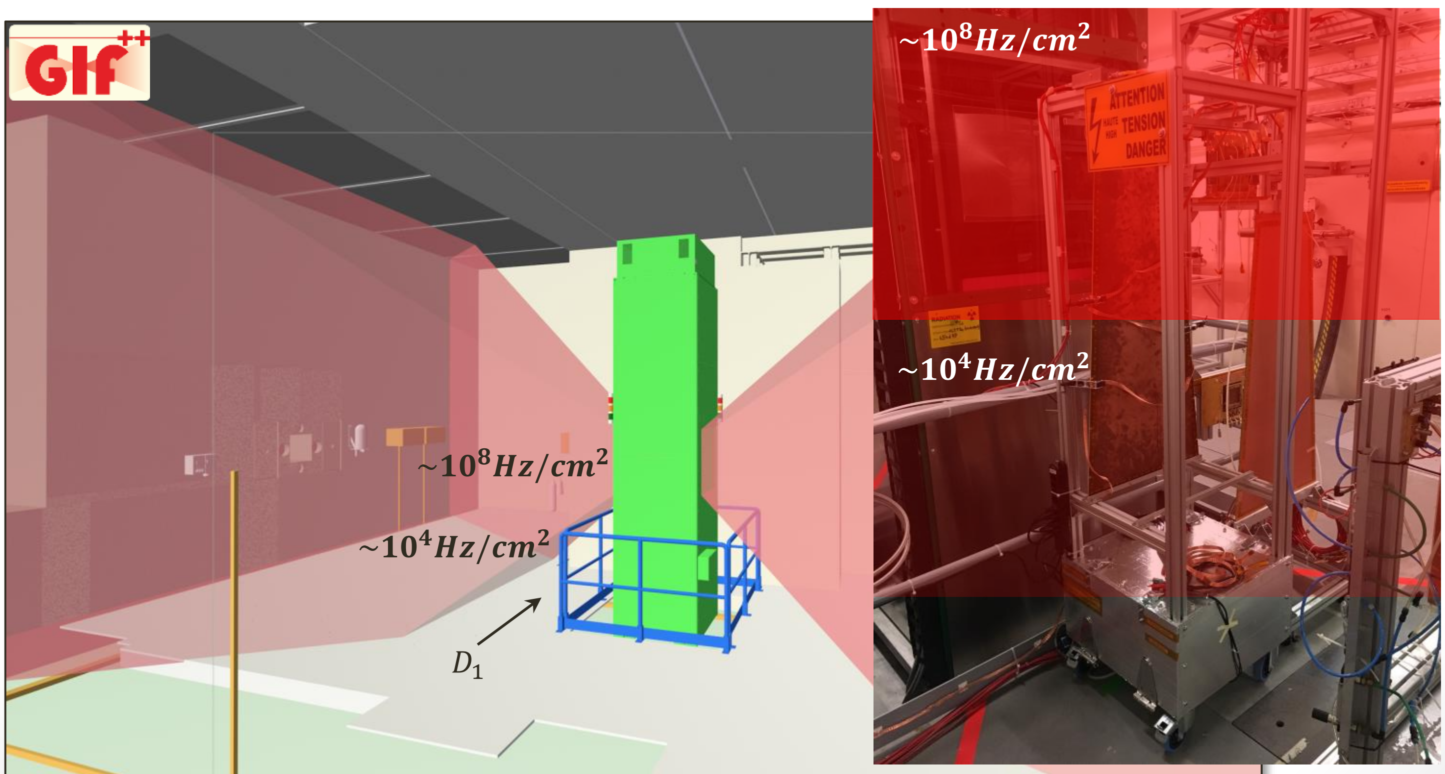
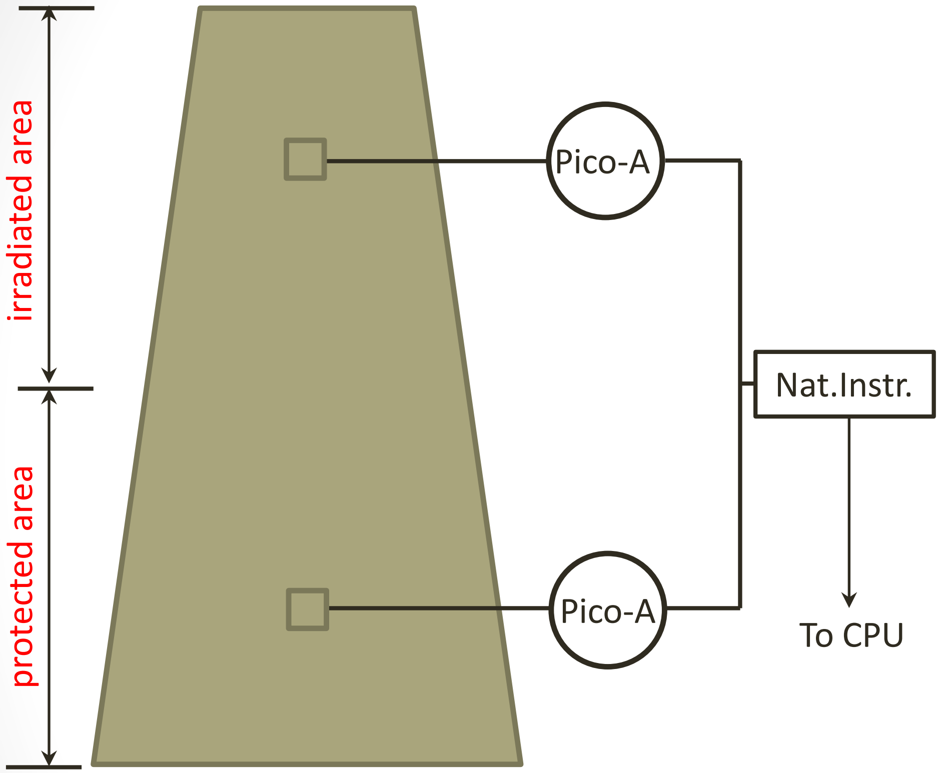


The Readout System

Schematic view of the DAQ system at GIF++

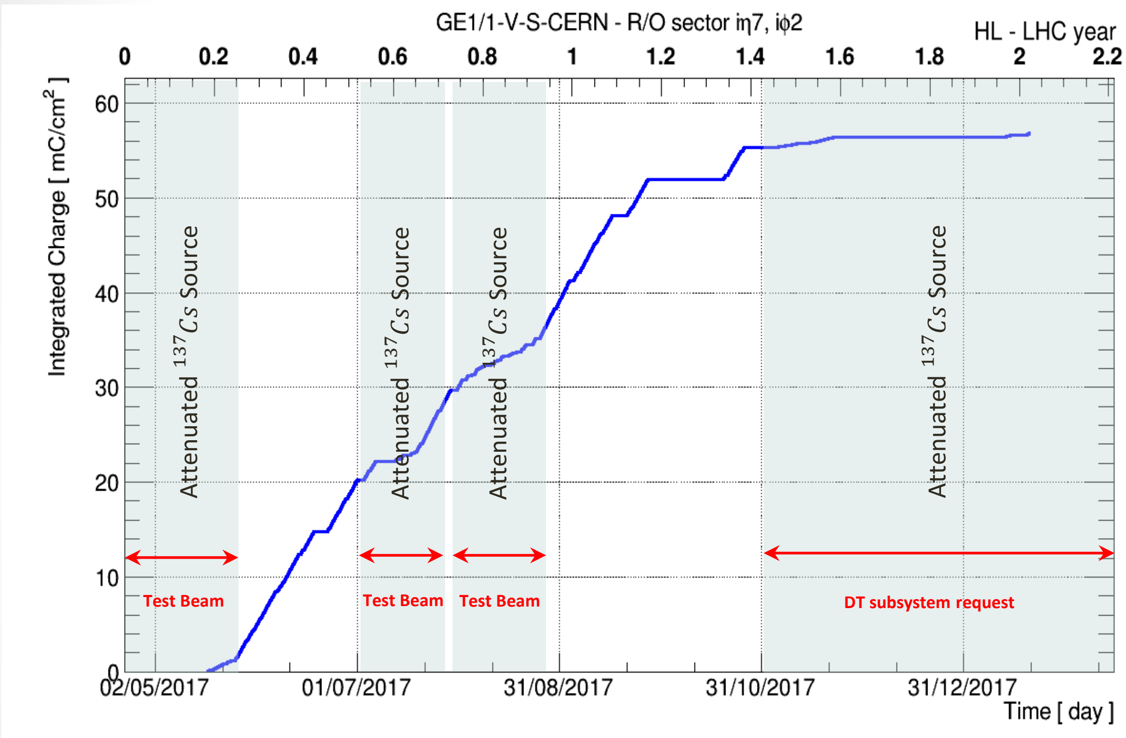


CMS-GEM1 setup inside the GIF++ bunker

- one pico-ammeter on the readout sector $i\varphi = 2, i\eta = 7$ (in the irradiated area);
- one pico-ammeter on the readout sector $i\varphi = 2, i\eta = 2$ (in the protected part).

Preliminary Analysis @ GIF++

Integrated charge @ GIF++ up to 1st February: $\sim 55\ mC/cm^2$



$$\varepsilon_{GIF++} = \frac{exposure\ time}{total\ time} \sim 75\%$$

Efficiency @ GIF++

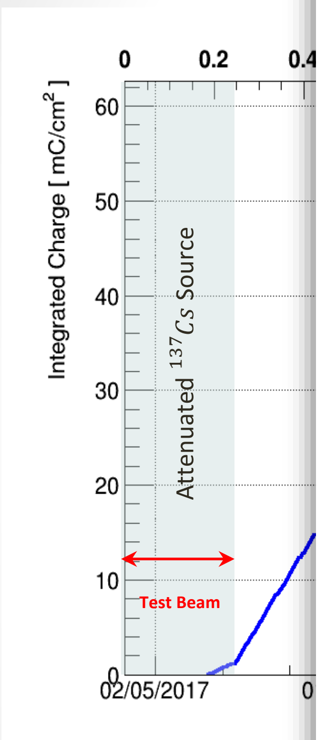
$$R(Q_{int})_{75\%} \sim 11.4\ mC/cm^2 \cdot \text{month}$$

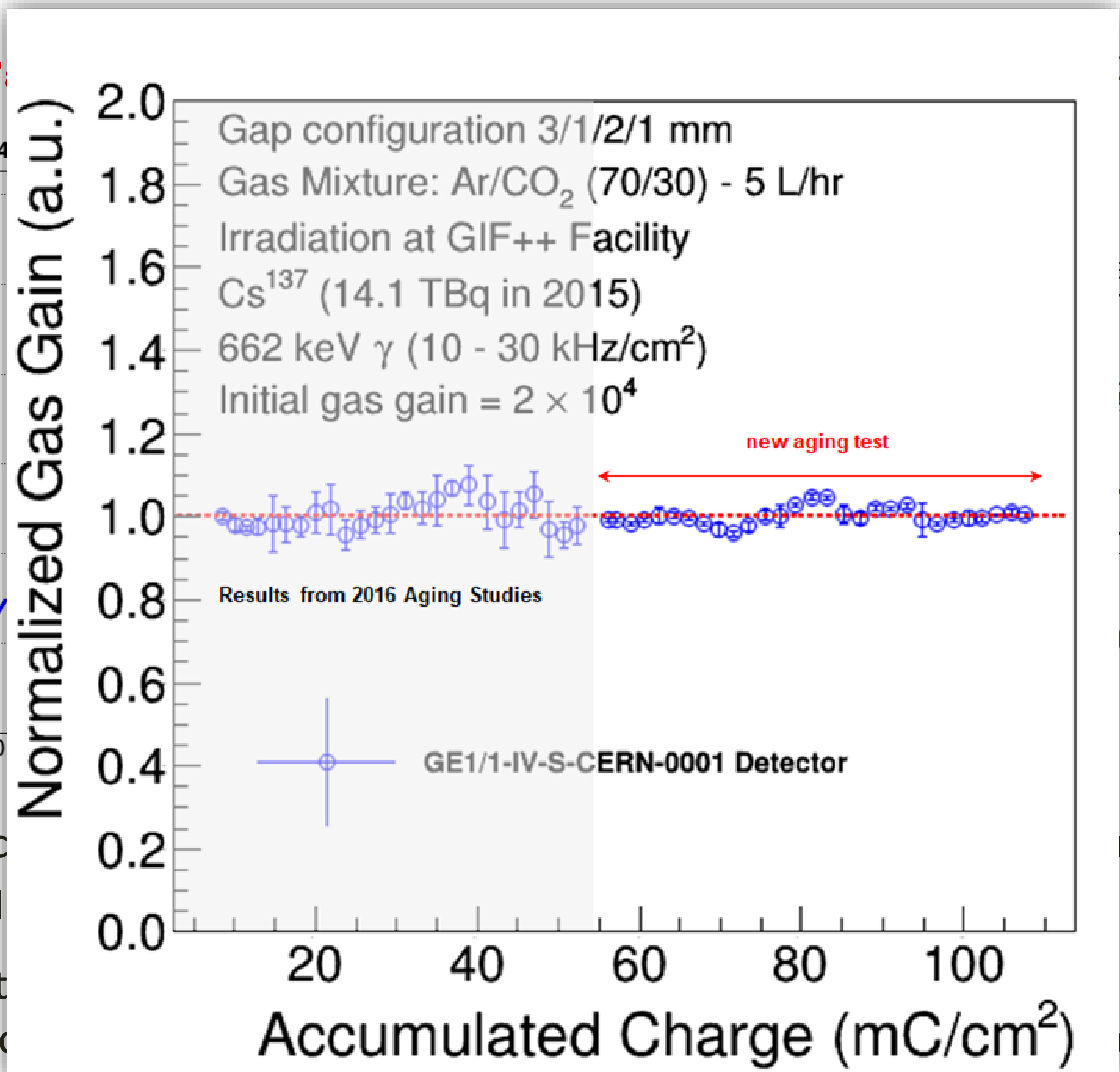
Integrated Charge Rate @ GIF++

- To reach $283\ mC/cm^2$ (no safety factor), $\sim 2\ years$ continuous irradiation are required;
- The estimated exposure time should include at least 50% extra time to take into account test beams, source filter scans, maintenance, etc. **The reasonable time estimation is between 2.5 to 3 years**.

Preliminary Analysis @ GIF++

Inte... m^2





...e time / ...ime $\sim 75\%$

...@ GIF++

...$C/cm^2 \cdot$ month

...Rate @ GIF++

- To reac... ...radiation are req...
- The est... ...e to take into ac... ...etc. **The reasonable time estimation is between 2.5 to 3 years**.

Schedule @ GIF ++

Current Irradiated Schedule (May 2017 – January 2018):

$\sim\mathbf{22day\ of\ continous\ irradiation\ per\ month}$ ($\mathbf{efficiency \sim 75\%}$)

$$R(Q_{int})_{75\%} = 11.4\, mC/cm^2 \cdot month$$

Integrated Charge Rate @ GIF++

- **Presently, it is irradiating with an attenuation factor 15 to allow DT detectors to integrate required charge;**
- **24th January 2018 - Korean GE1/1 chamber installation** (in order to validate the Korean GEM-foils for the GE2/1 project);
- Taking into account an efficiency of 75%, $\sim 2.5 - 3\, years$ are needed to reach 283 mC/cm^2;
- Extending the Aging Test up to May 2022, you could reach an integrated charge of about $\sim 620\, mC/cm^2$ with safety factor ~2.2.

We investigated the possibility of using the X-Ray Source in order to accelerate the Aging Tests in the 904-Lab.

CMS Triple-GEM Aging Test @ 904Lab.

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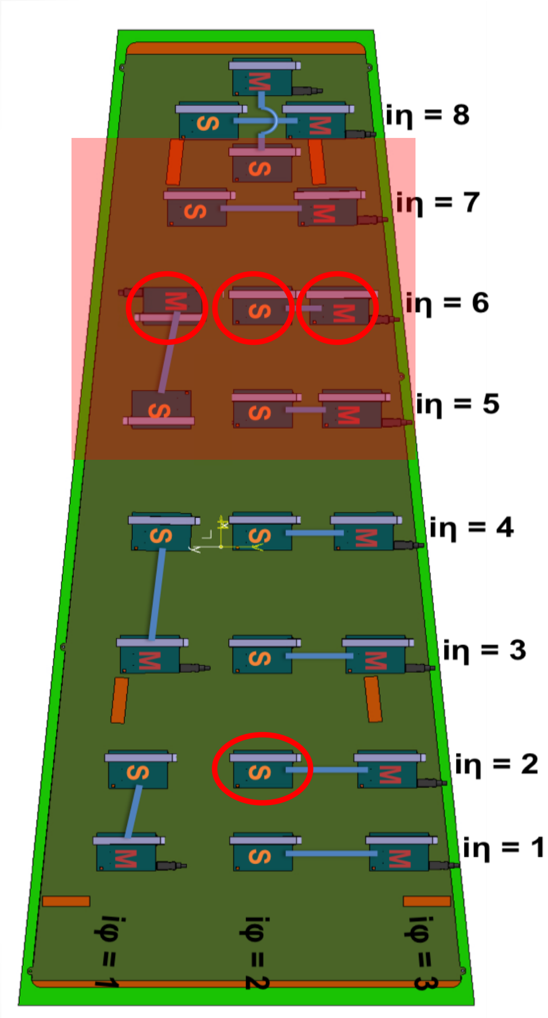
Installation of new setup for Triple-GEM aging test @ 904Lab.

- ***Final Configuration for the Aging Test***
- ***Preliminary Analysis @ 904-Lab.***
- ***R/O Sector Under Test - Summary Table***

Configuration for the X-ray Aging Test (1/3)



= Sector Under Test

= Irradiated Zone

X-Ray Settings:

- ***Voltage-Tube:*** $40\ kV$
- ***Current-Tube:*** $70\ \mu A$
- ***x-axis:*** $12.0\ cm$ *(from the detector)*
- ***y-axis:*** $32.5\ cm$ *(from the Cu-box floor)*
- ***Board Temperature:*** $42\ °C$

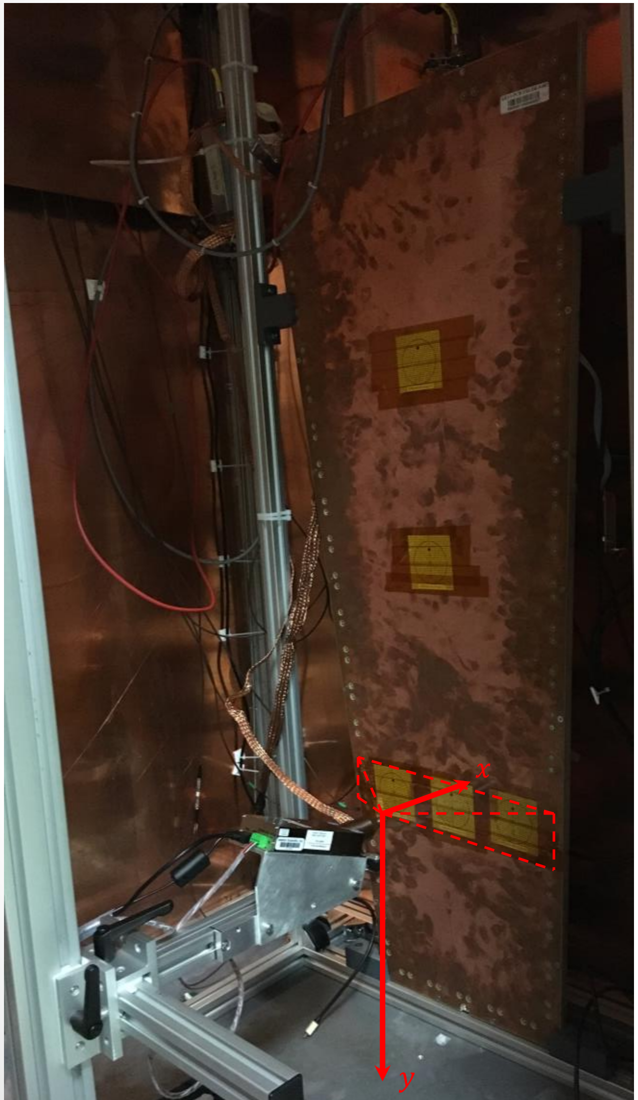
R/O System:

- ***3 pico-ammeters on irradiated zone:***
  - *R/O sector* $i\eta = 6, i\phi = 1$
  - *R/O sector* $i\eta = 6, i\phi = 2$
  - *R/O sector* $i\eta = 6, i\phi = 3$
- ***1 pico-ammeter on not irradiated zone:***
  - *R/O sector* $i\eta = 2, i\phi = 2$

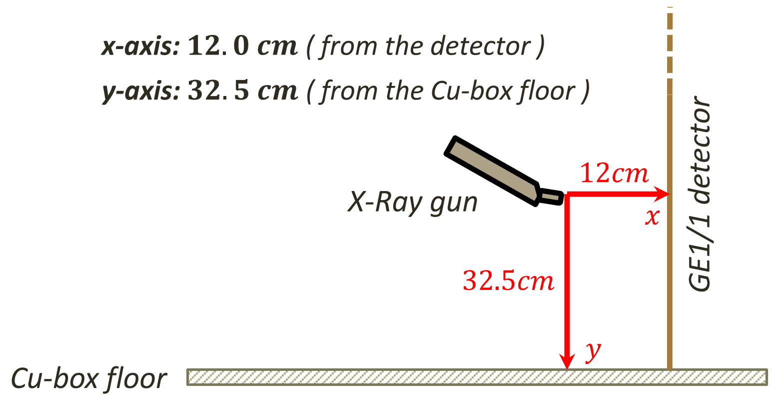
Meteo Station:

Arduino Meteo Station inside the Cu-box to monitor environmental parameters.

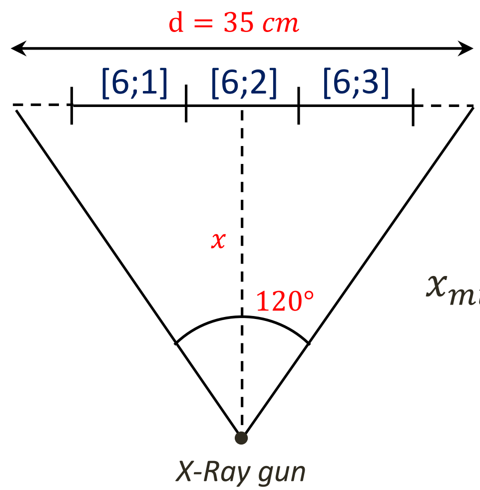
Configuration for the X-ray Aging Test (2/3)



Position of the X-Ray source with respect to the detector



Minimum distance to irradiate the sectors [6;1], [6;2] and [6;3]



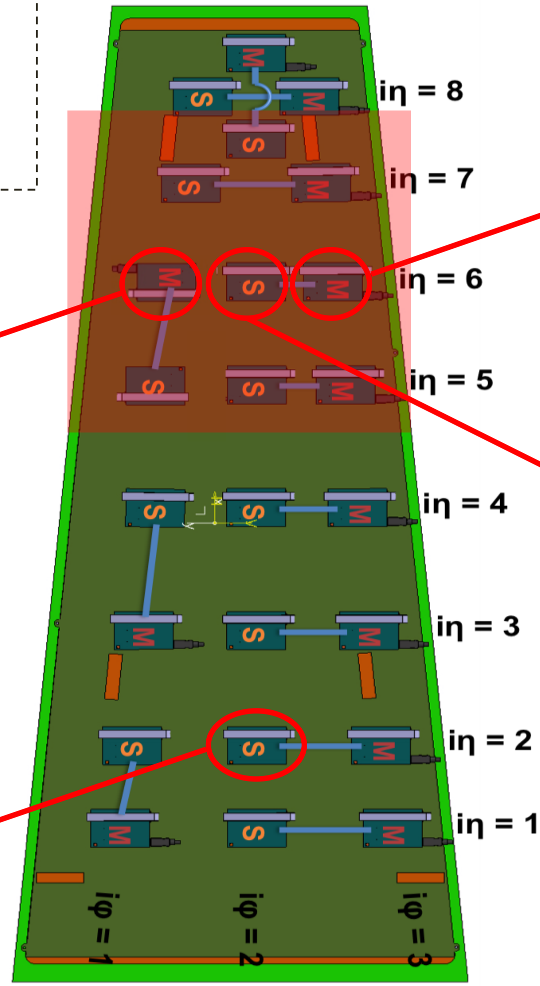
$$x_{min} = \frac{2 \cdot tan(60°)}{d} \sim 10\ cm$$

The X-Ray source has been placed at 12cm from the detector in order to irradiate the GEM-foils, frame, O-ring, etc.

Configuration for the X-ray Aging Test (3/3)

Working Point: $684.2\ \mu A$
(with compensation)

Effective Gas Gain: $\sim 2 \times 10^4$



R/O sector $i\eta = 6, i\phi = 3$
$\langle I_{anode} \rangle = 15.2\ nA/cm^2$
$f_{GIF++} \sim 1.9$

R/O sector $i\eta = 6, i\phi = 1$
$\langle I_{anode} \rangle = 24.4\ nA/cm^2$
$f_{GIF++} \sim 3.1$

R/O sector $i\eta = 6, i\phi = 2$
$\langle I_{anode} \rangle = 64.2\ nA/cm^2$
$f_{GIF++} \sim 8.1$

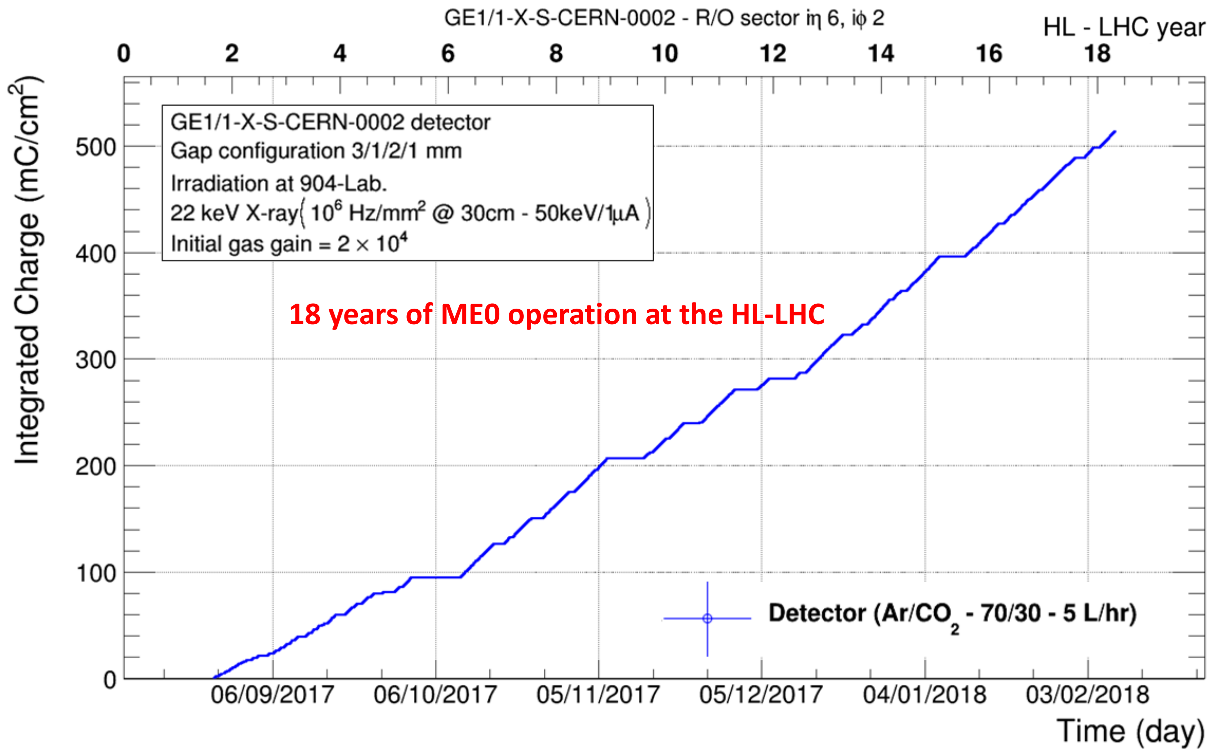
R/O sector $i\eta = 2, i\phi = 2$
$\langle I_{anode} \rangle = 0.33\ pA/cm^2$

= Sector Under Test

= Irradiated Zone

Preliminary Analysis @ 904-Lab.

Integrated charge @ 904-Lab. up to 8th February: ~ 515 mC/cm^2



R/O sector under test: $i\eta = 6, i\phi = 2$ - $f_{GIF++} \sim 8.1$

$$\varepsilon_{904Lab} = \frac{exposure\ time}{total\ time} \sim 77\ \%$$

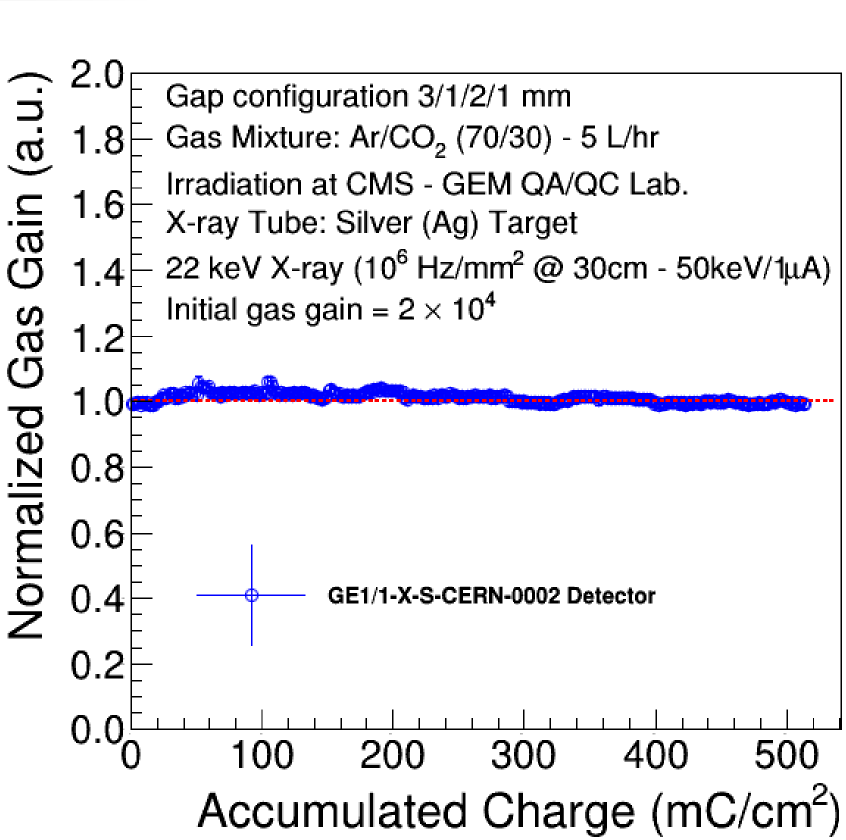
Efficiency @ 904-Lab.

$$R(Q_{int})_{77\%} \sim 4.3\ mC/cm^2 \cdot day$$

Integrated Charge Rate @ 904-Lab.

Preliminary Analysis @ 904-Lab.

R/O sector under test: $i\eta = 6, i\phi = 2$ - $f_{GIF++} \sim 8.1$



X-ray Aging Test @ 904-Lab

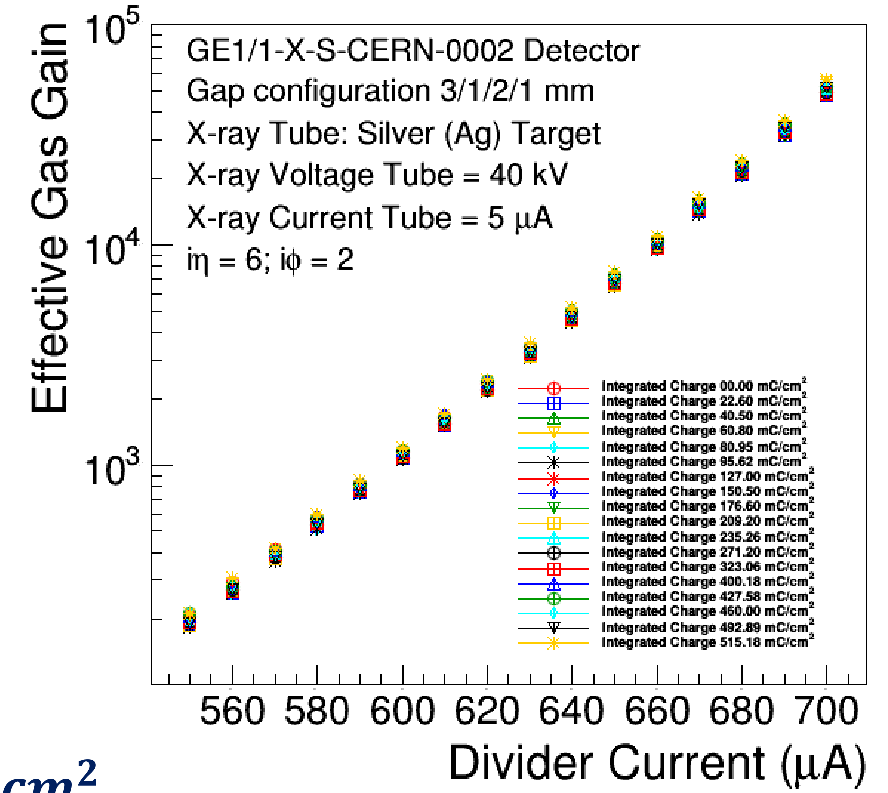
(82 days of continuous tests)

$\sim 515\ mC/cm^2$

NO aging observed up to $\sim 515\ mC/cm^2$

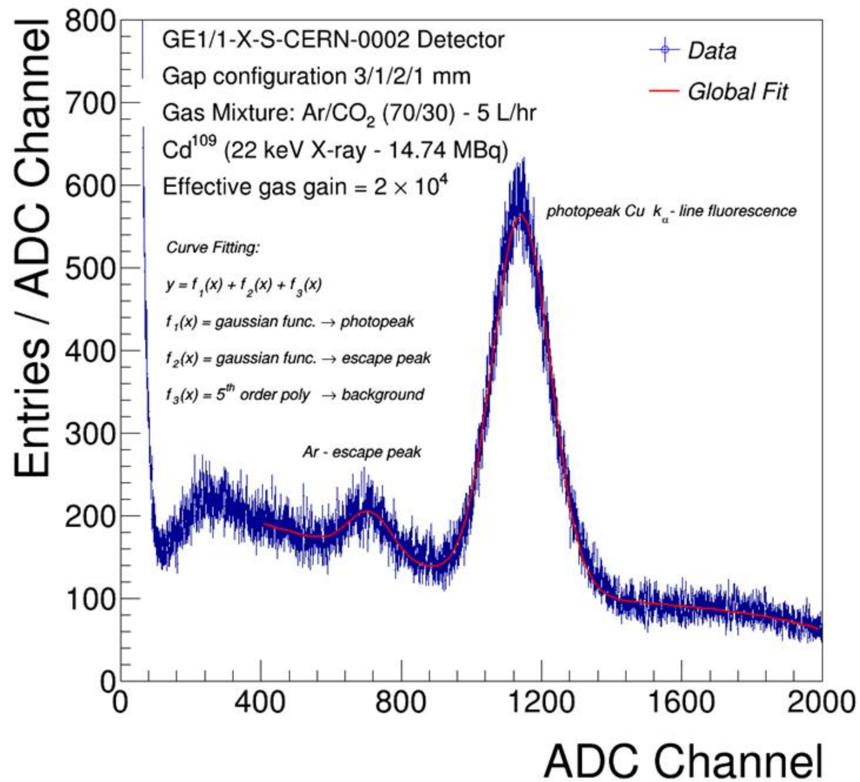
Weekly QC5-Eff. Gas Gain Measurement

$(\mathbf{i.e.\ every} \sim \mathbf{20\ mC/cm^2})$



Preliminary Analysis @ 904-Lab.

R/O sector under test: $i\eta = 6, i\phi = 2$ - $f_{GIF++} \sim 8.1$



Curve Fitting:

$$y = f_1(x) + f_2(x) + f_3(x)$$

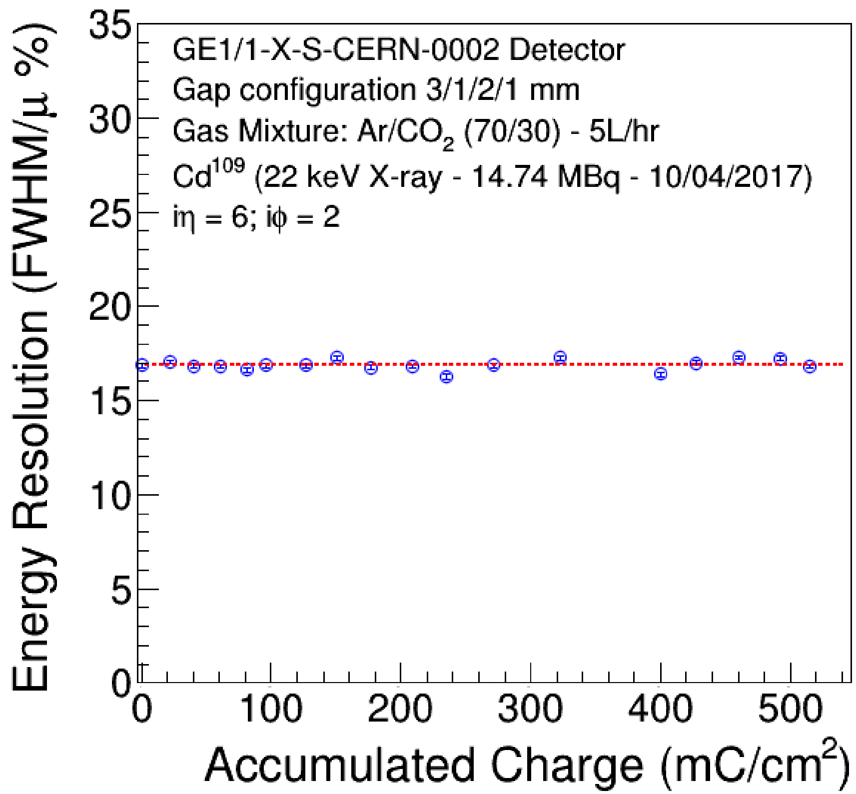
$$f_1(x) = gaussian\ func. \rightarrow photopeak$$

$$f_2(x) = gaussian\ func. \rightarrow escape\ peak$$

$$f_2(x) = 5^{th}\ order\ poly \rightarrow background$$

Weekly Energy Resolution Measurement

(**i.e. every** $\sim$ **20 mC/cm^2**)



R/O Sector Under Test - Summary Table

Irradiated R/O Sectors

R/O sector	Integrated Charge	Integrated Charge Rate	Gas Gain Stability	Energy Resolution
$\eta = 6, \varphi = 1$ ($f_{GIF++} \sim 3.1$)	$\mathbf{213.9\ mC/cm^2}$	$1.8\ mC/cm^2 \cdot day$	No gain drop observed	$(17.3 \pm 0.1)\%$ Energy Res. Stable
	~ 76% of the total ME0 operation @ HL-LHC			
$\eta = 6, \varphi = 2$ ($f_{GIF++} \sim 8.1$)	$\mathbf{515.2\ mC/cm^2}$	$4.3\ mC/cm^2 \cdot day$	No gain drop observed	$(16.8 \pm 0.1)\%$ Energy Res. Stable
	18 years of ME0 operation @ the HL-LHC			
$\eta = 6, \varphi = 3$ ($f_{GIF++} \sim 1.9$)	$\mathbf{106.7\ mC/cm^2}$	$0.9\ mC/cm^2 \cdot day$	No gain drop observed	$(16.9 \pm 0.1)\%$ Energy Res. Stable
	~ 38% of the total ME0 operation @ HL-LHC			

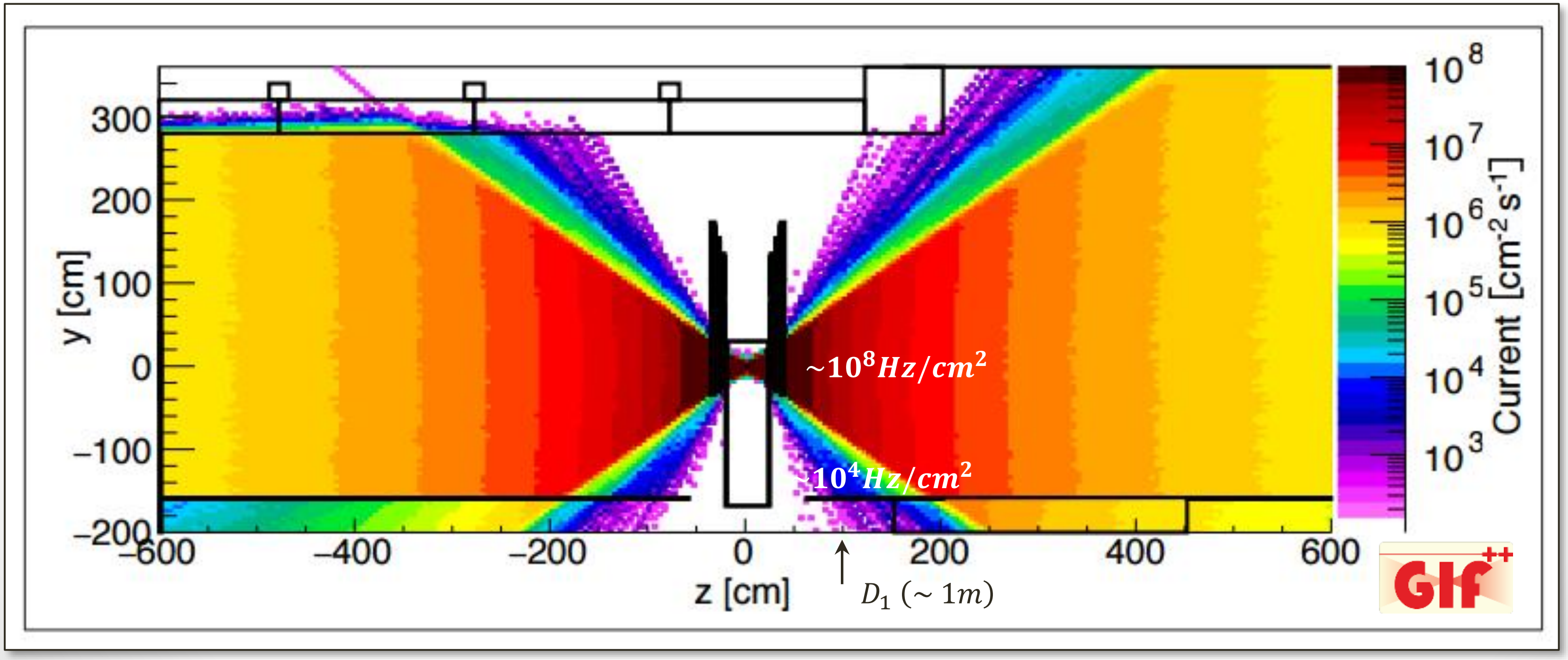
Non-Irradiated R/O Sector

R/O sector	Integrated Charge	Integrated Charge Rate	Gas Gain Stability	Energy Resolution
$\eta = 2, \varphi = 2$	$\mathbf{2.8\ \mu C/cm^2}$	$0.02\ \mu C/cm^2 \cdot day$	No gain drop observed	$(17.1 \pm 0.1)\%$ Energy Res. Stable

Backup - Slides

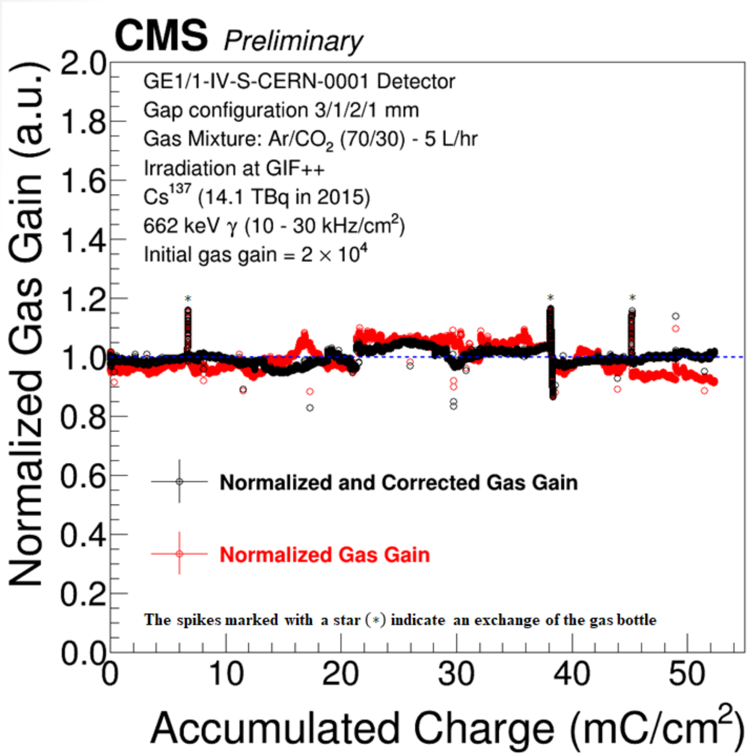
Installation inside the GIF++ Bunker

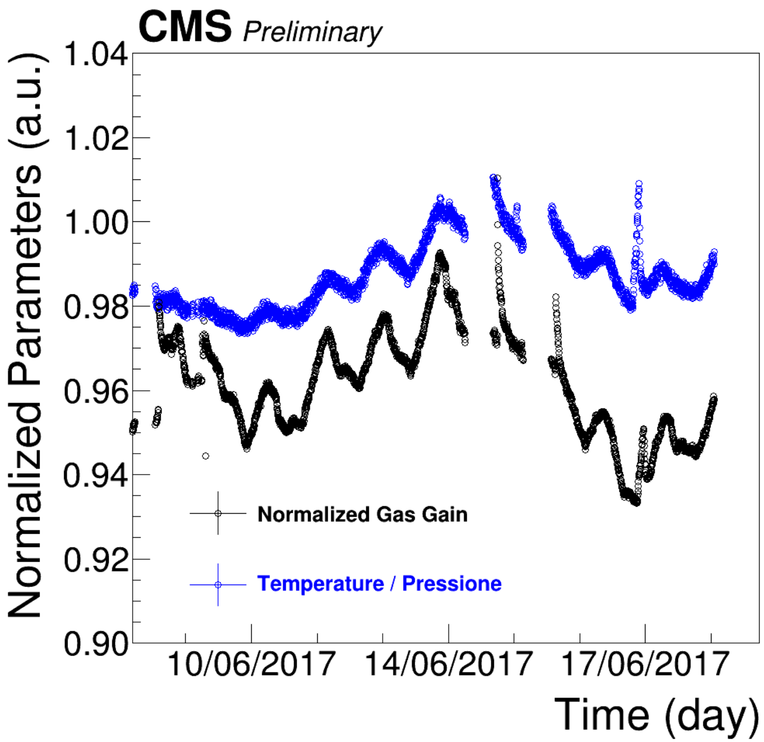
- The GE1/1 detector under test is placed at $\sim 1m$ from the source point (D_1 position):
  - half of the chamber is directly in front of the irradiator and is operating under a particle flux just below $10^8 Hz/cm^2$
  - the other half, protected by the shielding of the irradiator, receive a flux lower by four orders of magnitude.



Photon current in the vertical plane through the source (yz plane)

Preliminary Analysis @ GIF++





Jeremie's Aging Studies + **new Aging Test**

(6 months of continuous tests) $\sim 55\ mC/cm^2$

(4 month of continuous tests) $\sim 55\ mC/cm^2$

NO aging observed up to $\sim 110\ mC/cm^2$

The gain fluctuations ($Gain$) clearly follow the ratio temperature over pressure (T/P)

$$G_{meas.} = \frac{G_{real.}}{A \cdot exp(B \cdot T/P)}$$

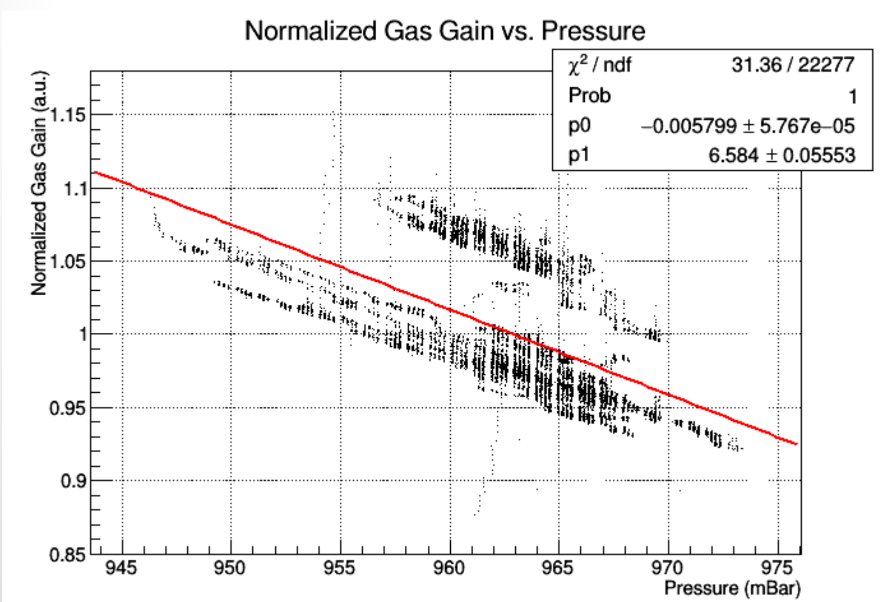
Temperature / Pressure Correction

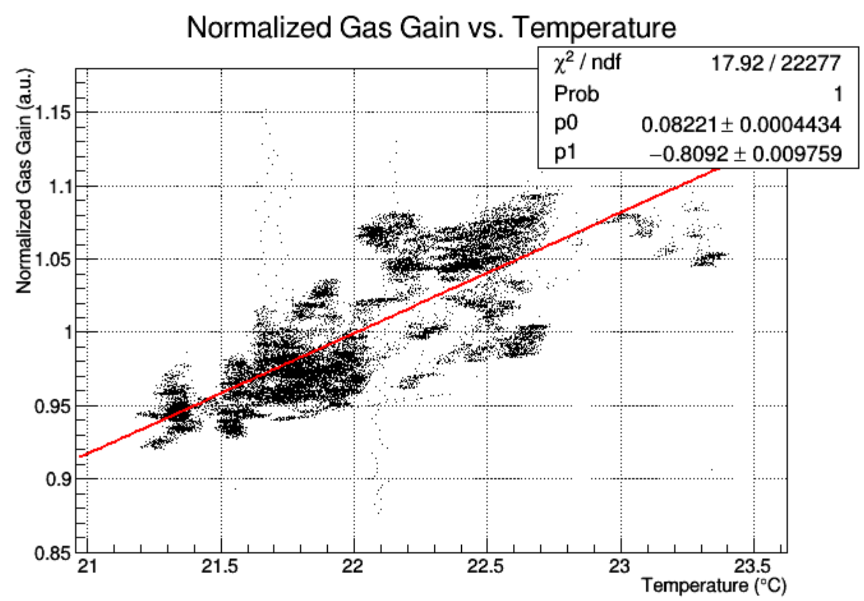
Temperature / Pressure Correction

The relation between the measured gain $G_{meas.}$ and the real gain $G_{real.}$ is given by:

$$G_{meas.} = \frac{G_{real.}}{A \cdot exp(B \cdot T/P)}$$

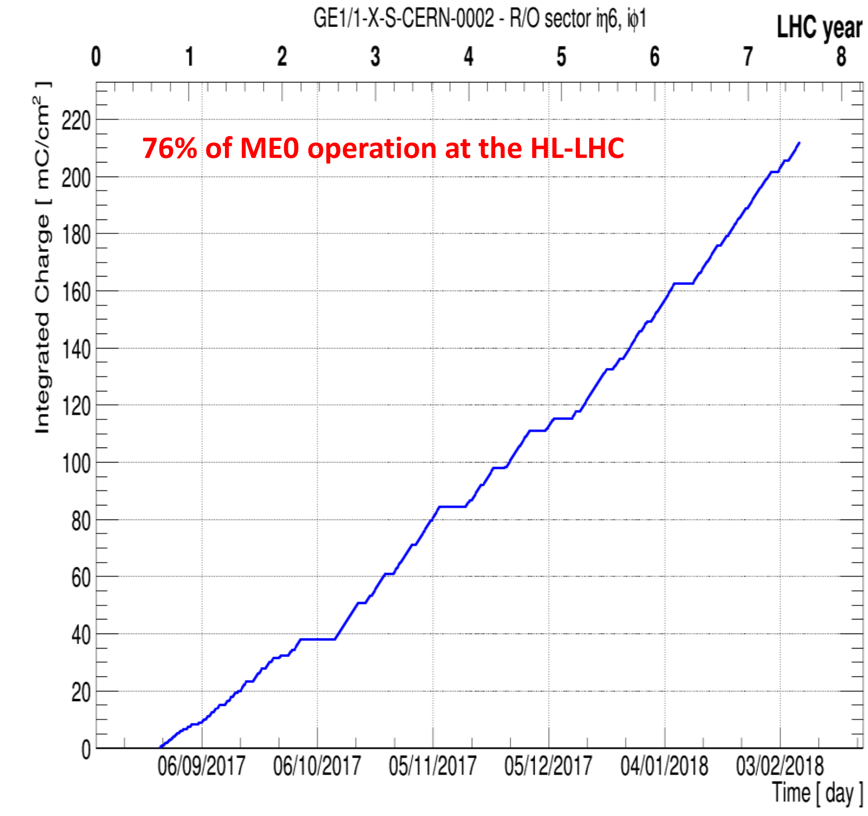
where A and B are experimental constants depending on the gas and on the temperature range. They are determined by fitting the exponential functions of T and P plotted:





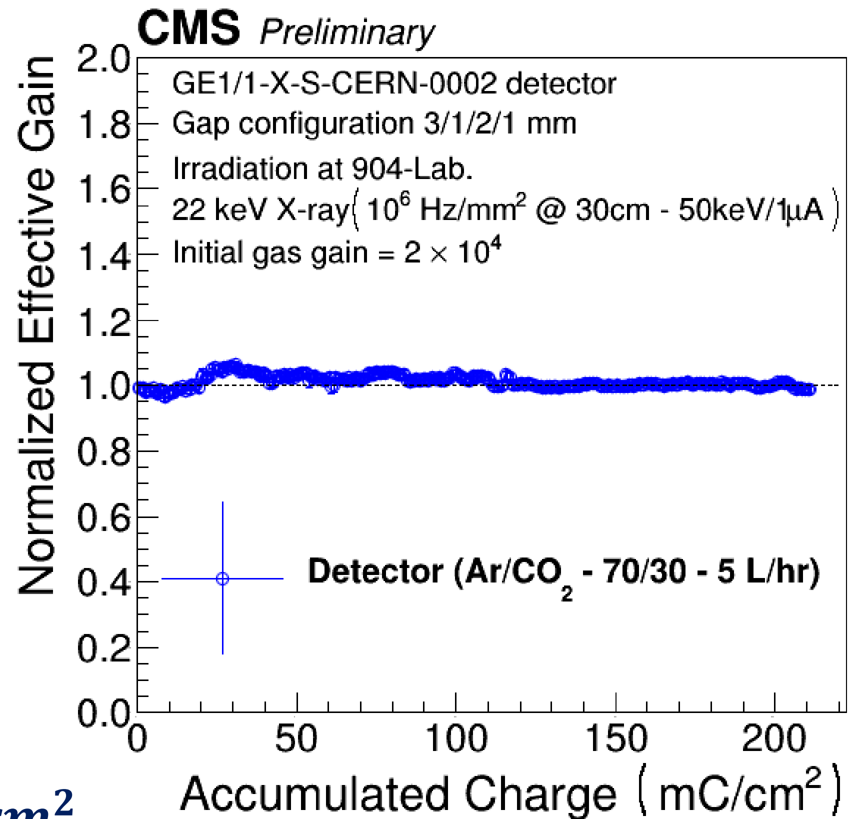
Preliminary Analysis @ 904-Lab.

R/O sector under test: $i\eta = 6, i\phi = 1$ - $f_{GIF++} \sim 3.1$



$R(Q_{int})_{77\%} \sim 1.8\ mC/cm^2 \cdot day$

Integrated Charge Rate @ 904-Lab.



X-ray Aging Test @ 904-Lab

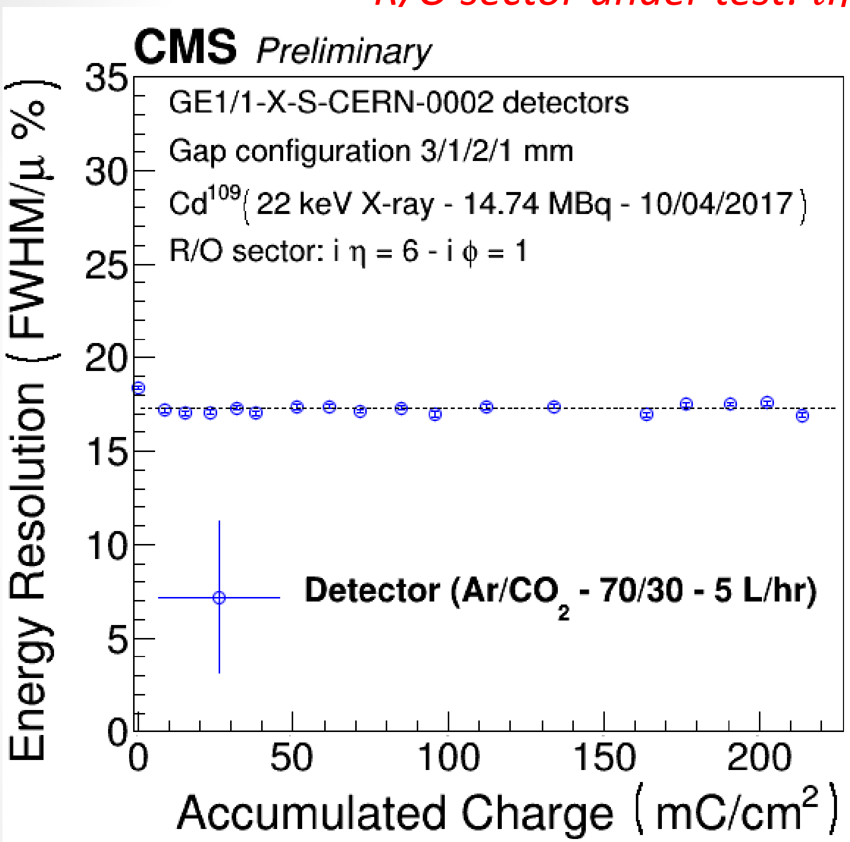
(82 days of continuous tests)

$\sim 214\ mC/cm^2$

NO aging observed up to $\sim 214\ mC/cm^2$

Preliminary Analysis @ 904-Lab.

R/O sector under test: $i\eta = 6, i\phi = 1$ - $f_{GIF++} \sim 3.1$

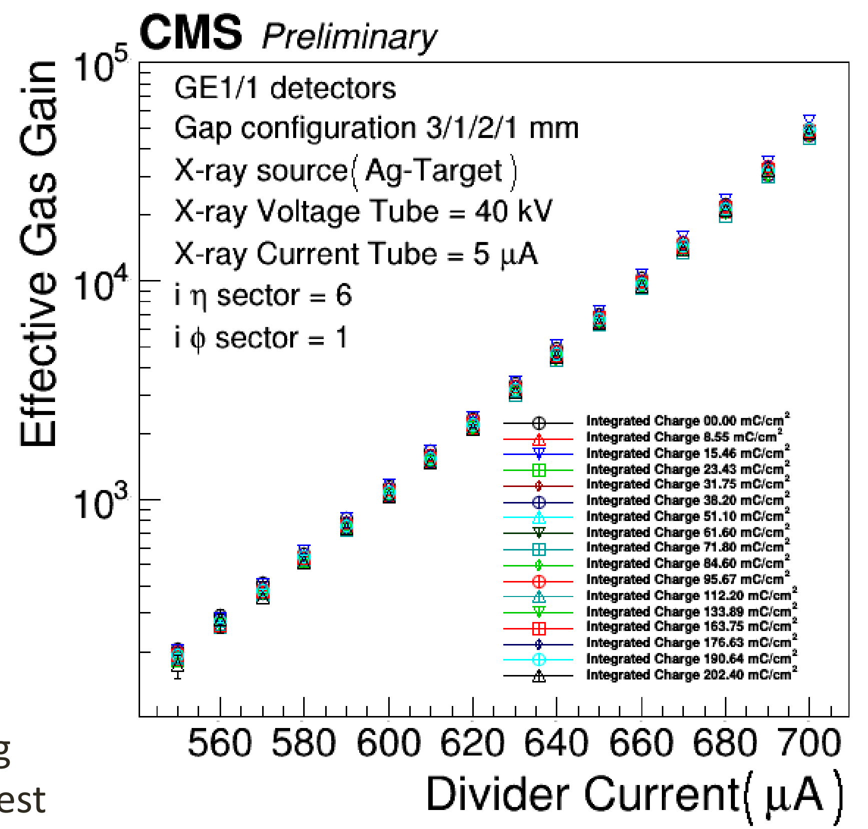


Weekly Energy Resolution Measurement

The energy spectrum of the ^{109}Cd source is measured every weeks and the corresponding energy resolution is stable during the ongoing test

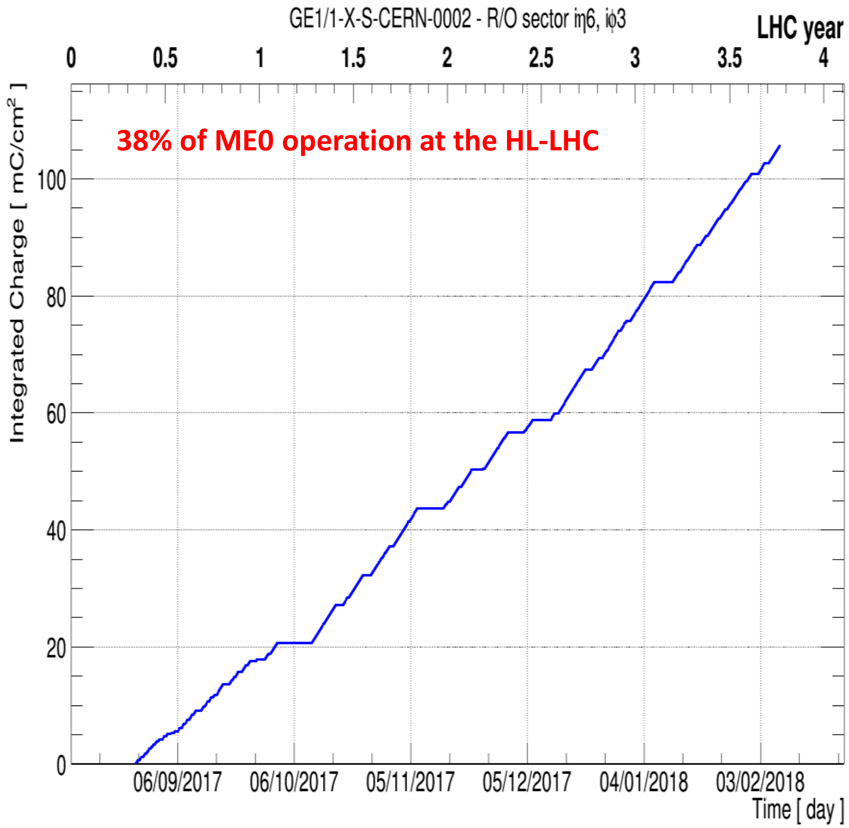
Weekly QC5-Eff. Gas Gain Measurement

$(\mathbf{i.e.\ every} \sim \mathbf{7\ mC/cm^2})$



Preliminary Analysis @ 904-Lab.

R/O sector under test: $i\eta = 6, i\phi = 3$ - $f_{GIF++} \sim 1.9$



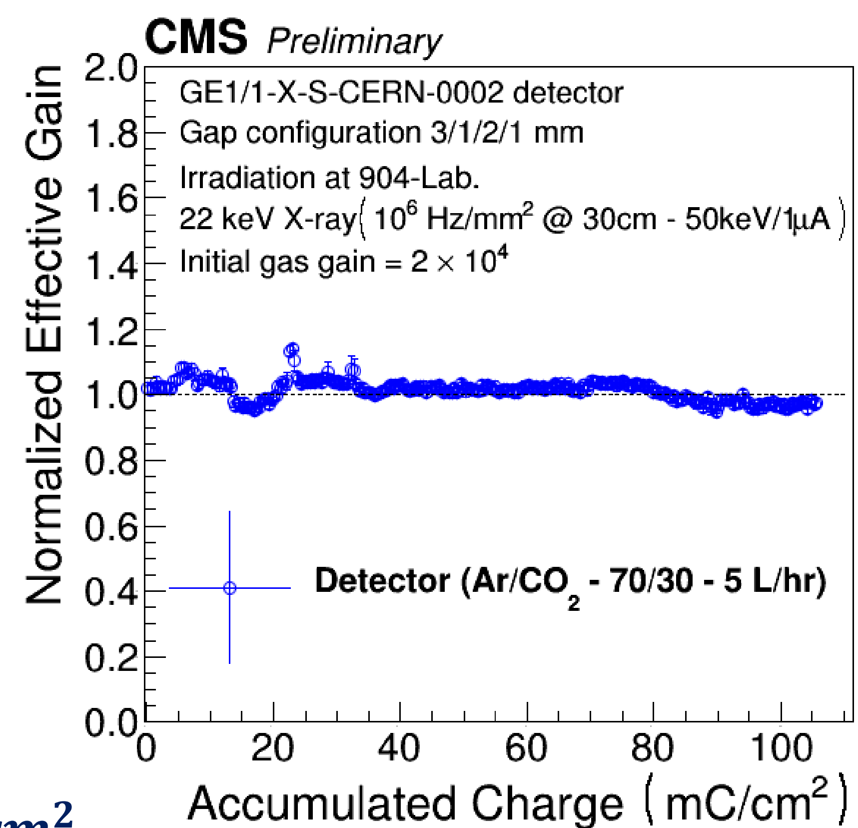
X-ray Aging Test @ 904-Lab

(76 days of continuous tests)

$\sim 107\ mC/cm^2$

$$R(Q_{int})_{77\%} \sim 0.8\ mC/cm^2 \cdot day$$

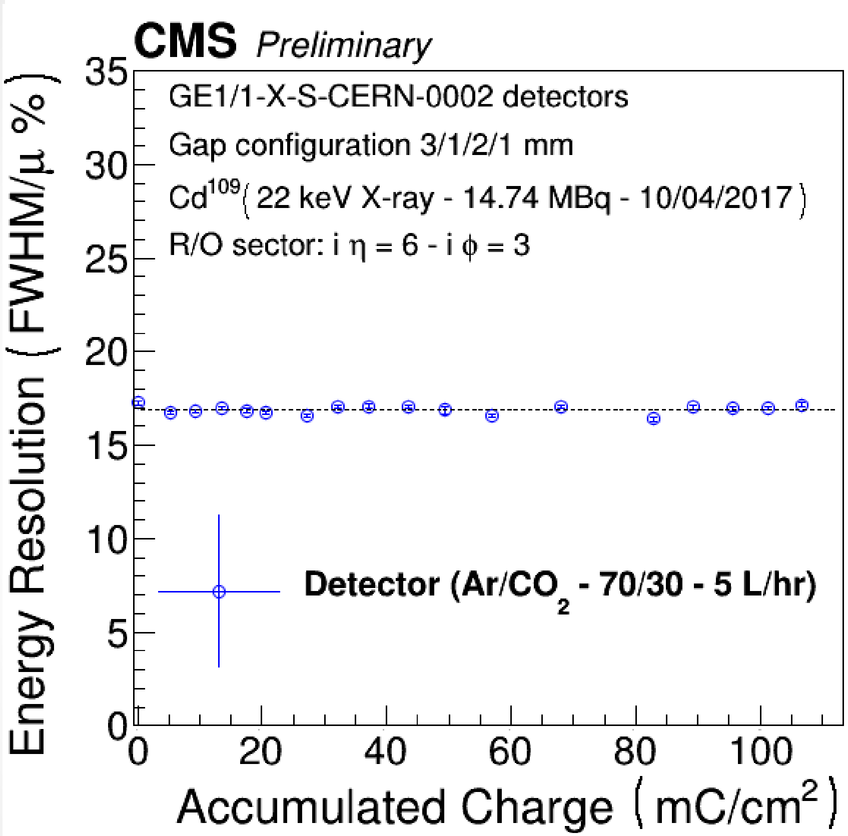
Integrated Charge Rate @ 904-Lab.



NO aging observed up to $\sim 107\ mC/cm^2$

Preliminary Analysis @ 904-Lab.

R/O sector under test: $i\eta = 6, i\phi = 3$ - $f_{GIF++} \sim 1.9$



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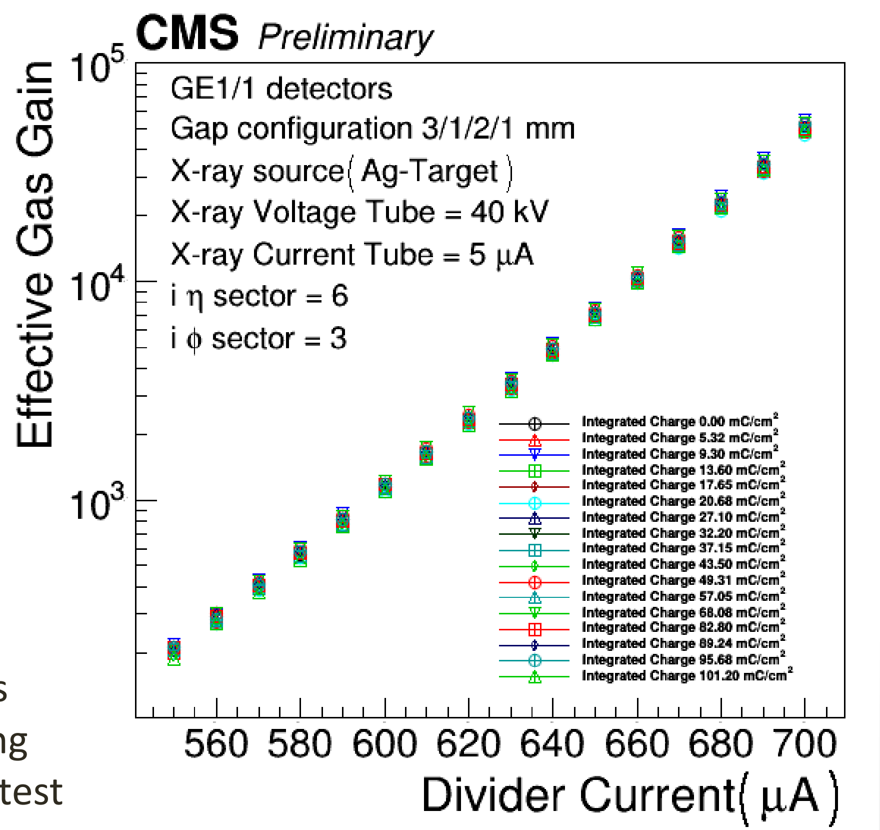
The energy spectrum of the ^{109}Cd source is measured every weeks and the corresponding energy resolution is stable during the ongoing test

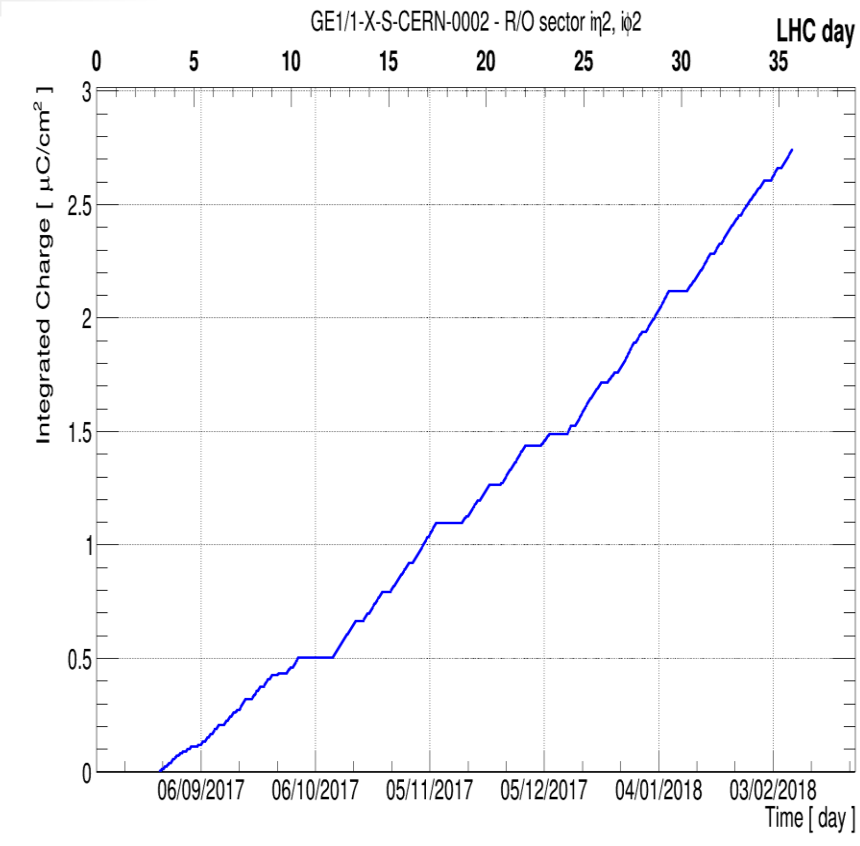
Weekly QC5-Eff. Gas Gain Measurement

$(\mathbf{i.e.\ every} \sim \mathbf{4\ mC/cm^2})$



Preliminary Analysis @ 904-Lab.

R/O sector under test: $i\eta = 2, i\phi = 2$ *- non-irradiated sector*



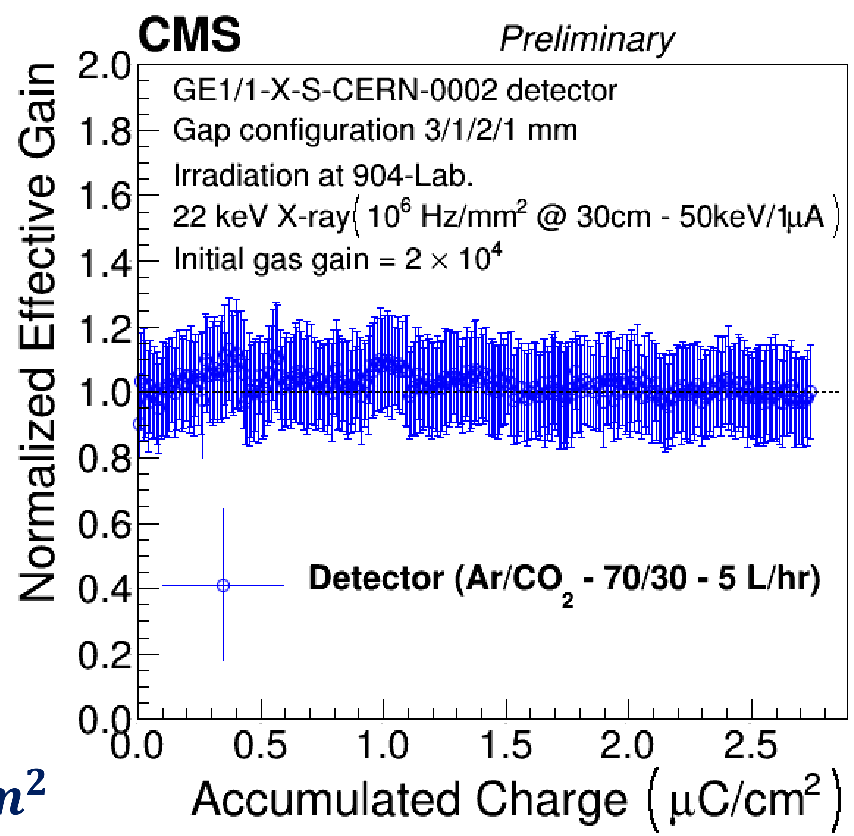
X-ray Aging Test @ 904-Lab

(76 days of continuous tests)

$\sim 2.8\ \mu C/cm^2$

$R(Q_{int})_{77\%} \sim 0.02\ \mu C/cm^2 \cdot day$

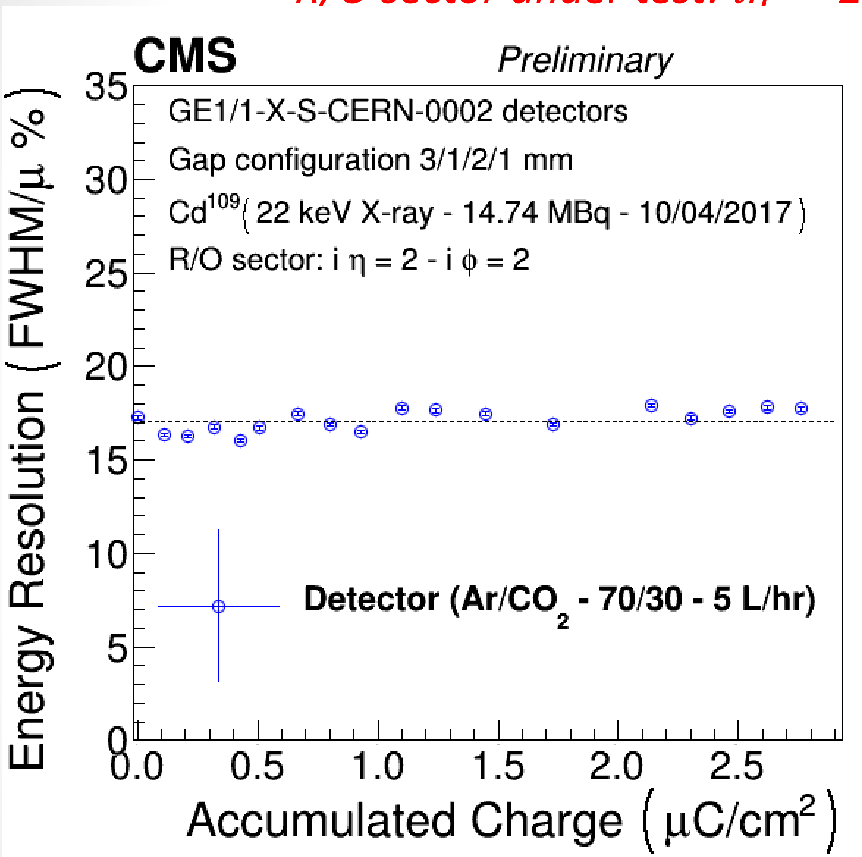
Integrated Charge Rate @ 904-Lab.



NO aging observed up to $\sim \boldsymbol{2.8\ \mu C/cm^2}$

Preliminary Analysis @ 904-Lab.

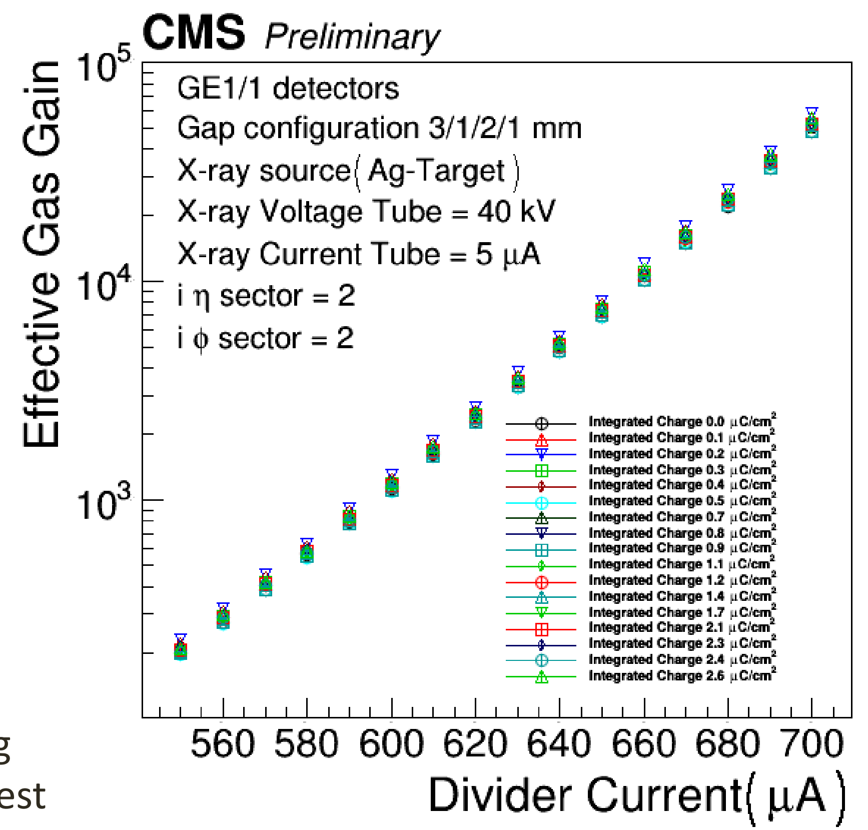
R/O sector under test: $i\eta = 2, i\phi = 2$ - non-irradiated sector



Weekly Energy Resolution Measurement

The energy spectrum of the ^{109}Cd source is measured every weeks and the corresponding energy resolution is stable during the ongoing test

Weekly QC5-Eff. Gas Gain Measurement



Schedule @ 904-Lab.

Current Irradiated Schedule (September 2017 – January 2018):

$$\sim 18h\ of\ continous\ irradiation\ per\ day\ (efficiency \sim 75\%)$$

R/O sector $\eta = 6, \phi = 1 \rightarrow R(Q_{int})_{75\%} = 1.8\ mC/cm^2 \cdot day$

- Extending the Aging Test up to April, you could reach an integrated charge of about 350 mC/cm^2 with safety factor $\sim$ 1.2

R/O sector $\eta = 6, \phi = 2 \rightarrow R(Q_{int})_{75\%} = 4.3\ mC/cm^2 \cdot day$

- Extending the Aging Test up to April, you could reach an integrated charge of about 850 mC/cm^2 with safety factor $\sim$ 3

R/O sector $\eta = 6, \phi = 3 \rightarrow R(Q_{int})_{75\%} = 0.8\ mC/cm^2 \cdot day$

- Extending the Aging Test up to April, you could reach an integrated charge of about 180 mC/cm^2 which represents $\sim$ 64% of the total ME0 operation