

Special Aging Study with GEMs

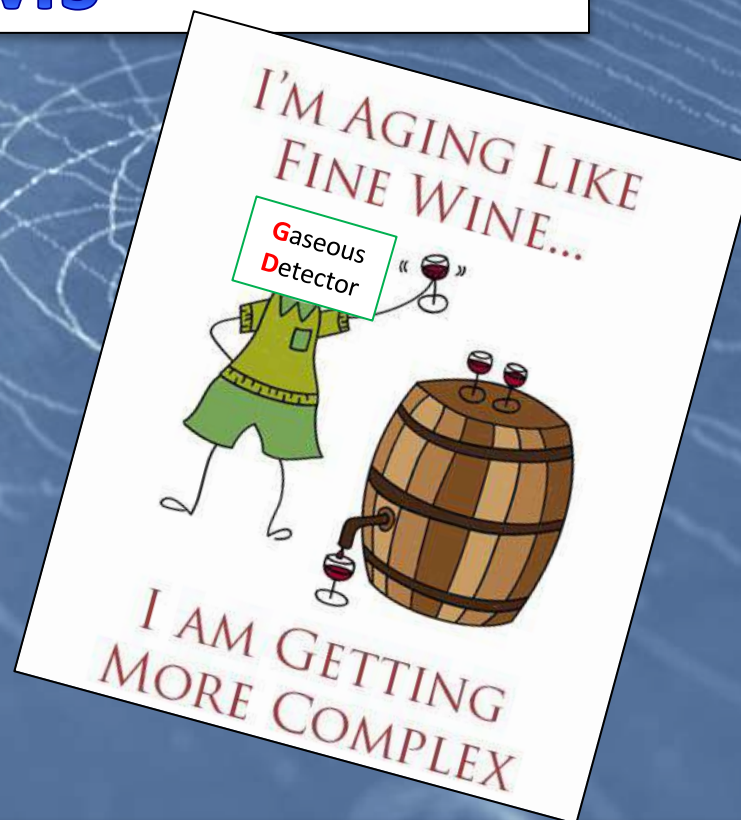
RD51 Mini Week
04/12/2018

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CMS GEM Aging Tests at Gamma Irradiation Facility

2013

Aging test :

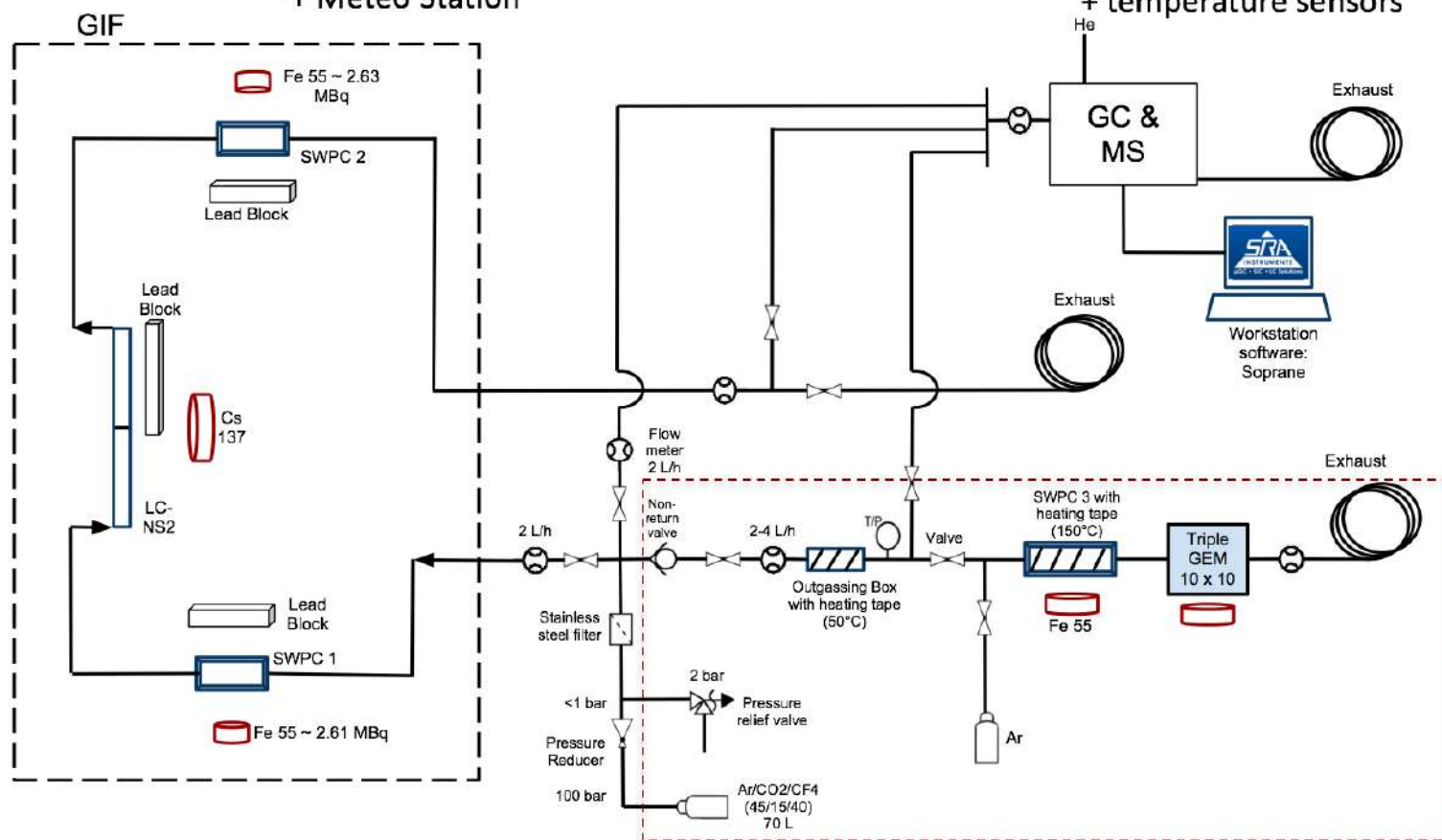
- Full-size GE1/1 Detector under ^{137}Cs irradiation
- Monitoring : Gain stability Vs Accumulated charge
- Reference : SWPCs under Fe55 irradiation
- External Parameters : GC+MS for gas composition

+ Meteo Station

Outgassing Test :

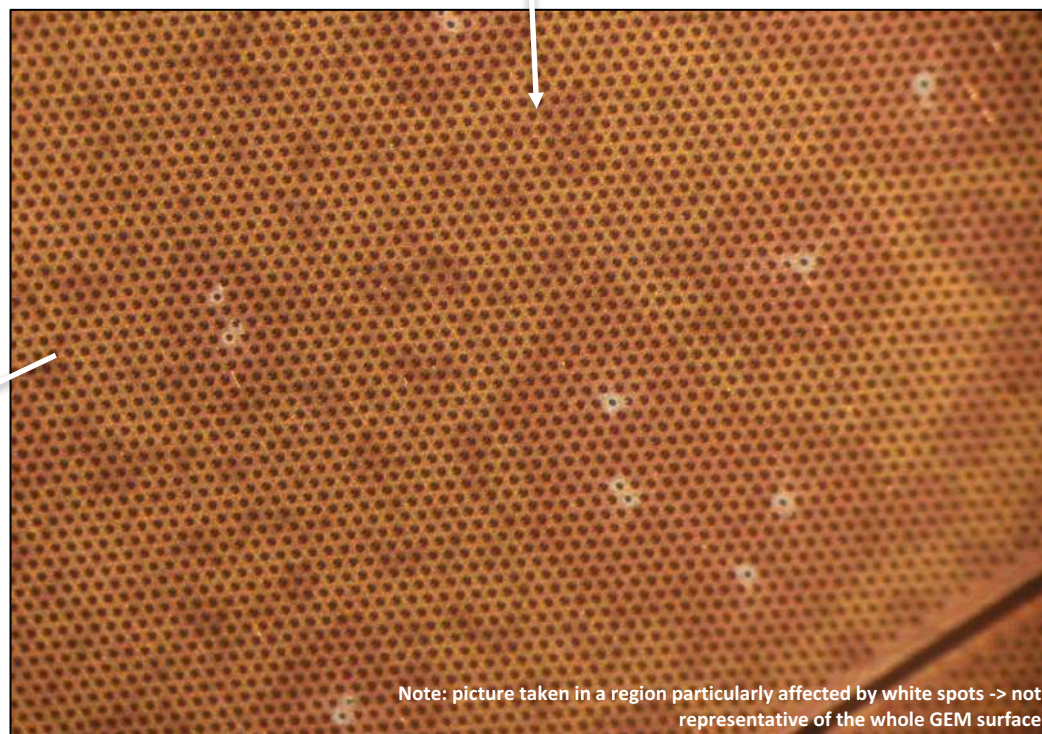
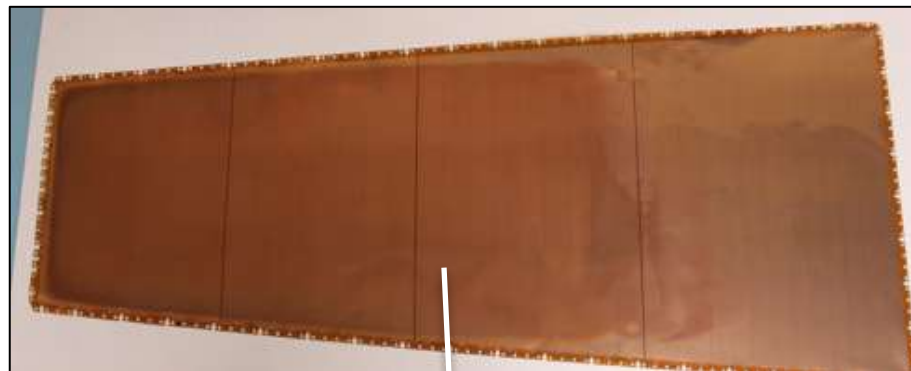
- Outgassing box up to 50 °C
- Monitoring : Gain drop (SWPC) Vs materials
- Additional : 10x10 triple GEM under Fe55
- External Parameters : GC+MS for gas composition

+ temperature sensors

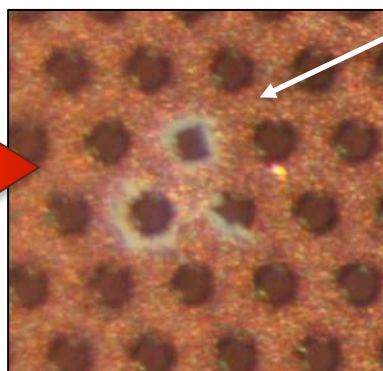


Past Observations

- No aging observed up to 52 mC/cm^2 (Ar/CO₂/CF₄)
- Evidence of pollutants in the gas system
- Optical inspection revealed presence of white spots (few holes over the entire GEM surface)

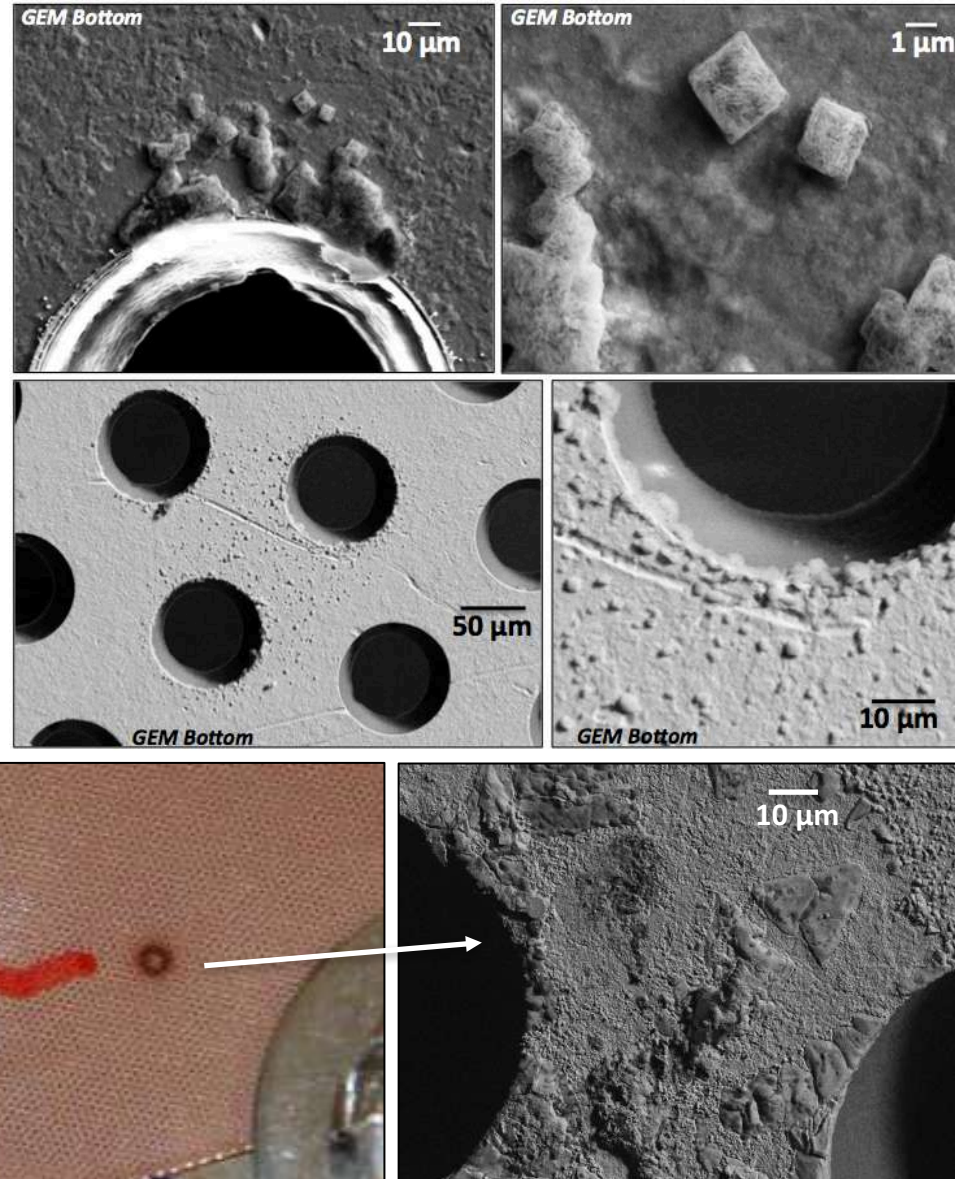


What and Why ?

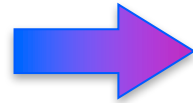


Past Observations

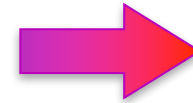
- *SEM showed perfectly clean foils expect near the visible white spots*
- *Deposits seem to affect only holes that were subjects to discharges (typical copper splashes)*
- *Deposits on GEM holes have similar composition to the ones found on the aged wire chambers*



Hypothesis



Implications



Applications

- *Polymerization rate depends on the energy transferred through the holes*

- *Primary charge plays an important role in the aging process*
- *Higher primary charge means higher aging rate ?*

- *Accelerated aging tests in laboratory should consider the whole particle spectrum encountered in the experiments (especially HIP)*

HIP can trigger aging that can't be visible with usual photon irradiation (?)

How to test the:

Influence of *primary ionization* on the *aging rate*



- Comparison study:
- Same environment under continuous monitoring
- Working with a unique 10x10 triple-GEM detector



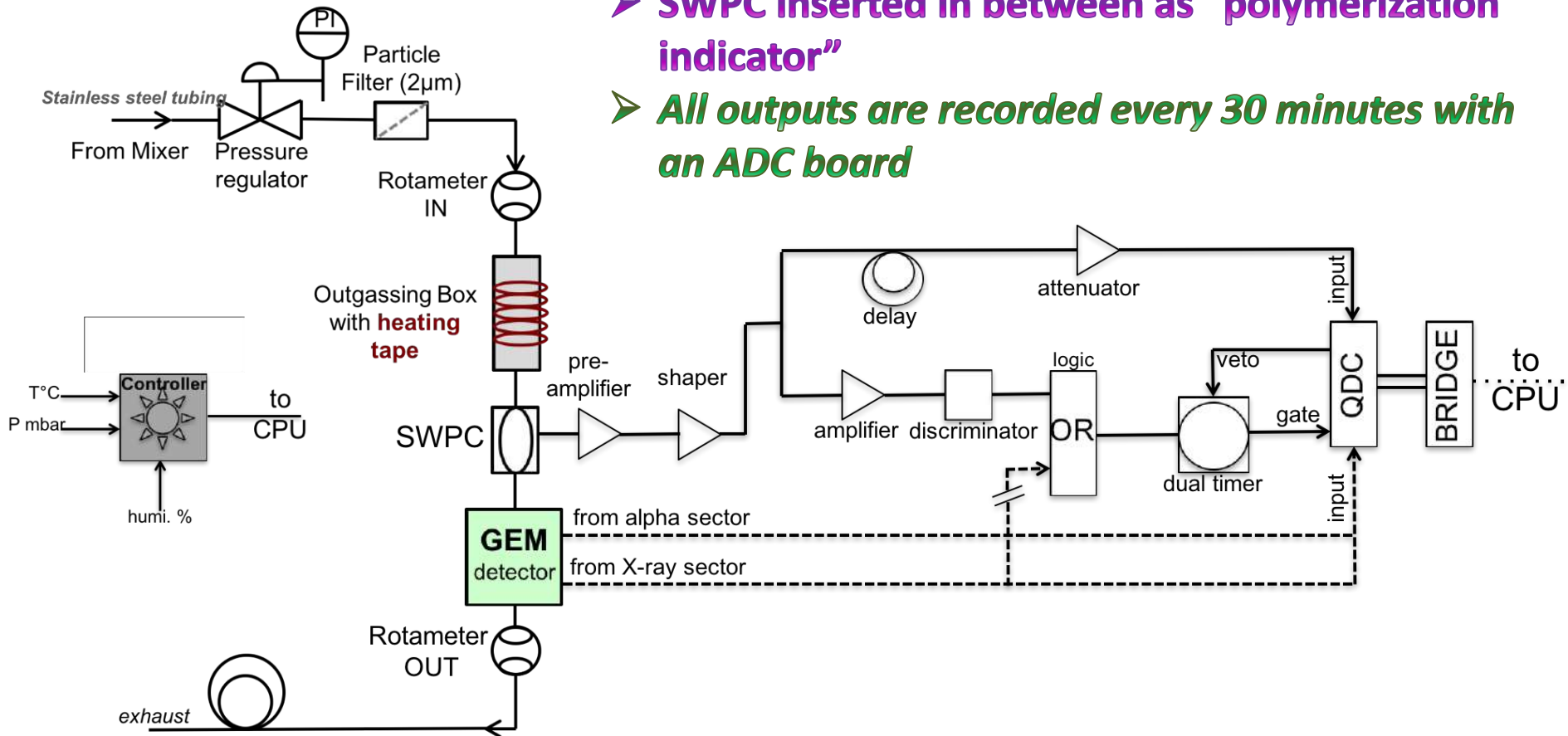
- Use of different sources:
- Low energy X-rays (5.9 keV) $N_{\text{primaries}} \sim 2 \times 10^2$
- Alpha source (5.5 MeV) $N_{\text{primaries}} \sim 2 \times 10^4$



- Trigger aging:
- Introduce contaminants in the gas system (Si)
- Confirm the presence of contaminant and polymerization

Setup Overview

- *10x10 detector operating downstream an outgassing box with heating tape*
- *SWPC inserted in between as “polymerization indicator”*
- *All outputs are recorded every 30 minutes with an ADC board*



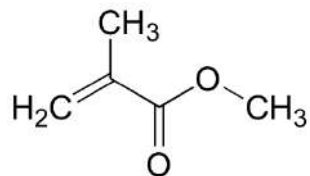
SWPC and Outgassing box

➤ *Outgassing box filled with:*

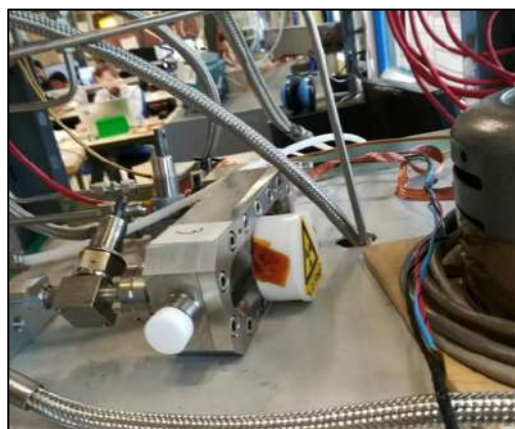
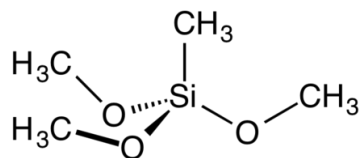
- 3140 RTV (Dow Corning)
- Acrifix 1R 0192 (PVC glue)

➤ *Expected contaminants:*

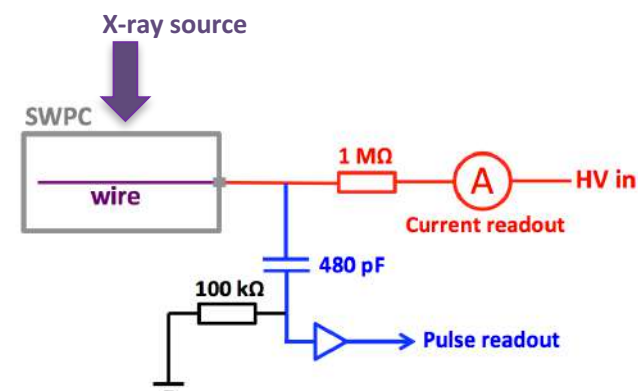
- *Methyl Methacrylate*



- *Methyltrimethoxysilane*



➤ *SWPC continuously irradiated by ¹⁰⁹Cd to follow the presence and the effect of pollutants*



Triple-GEM 10x10 (CMS GE1/1 configuration)

➤ *Standard CERN 10x10 detector with double-mask GEM foils*

➤ *CMS GEM configuration (3/1/2/1mm) + typical GE1/1 fields*

➤ *Gas Ar/CO₂ @ 5 L/hr*

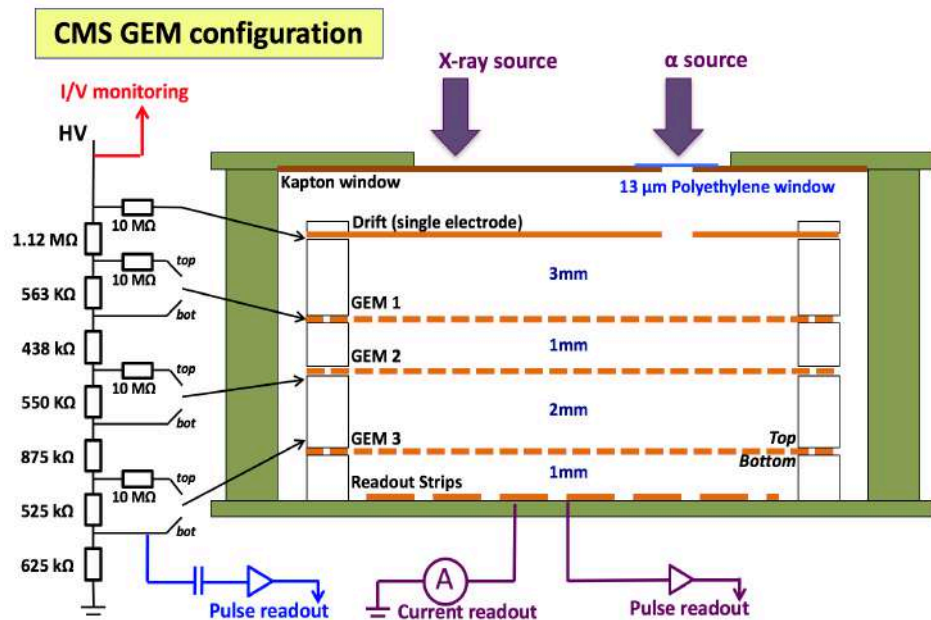
➤ Alpha sector (special opening):

- ²⁴¹Am: α rate ~ 600 Hz

➤ X-ray sector:

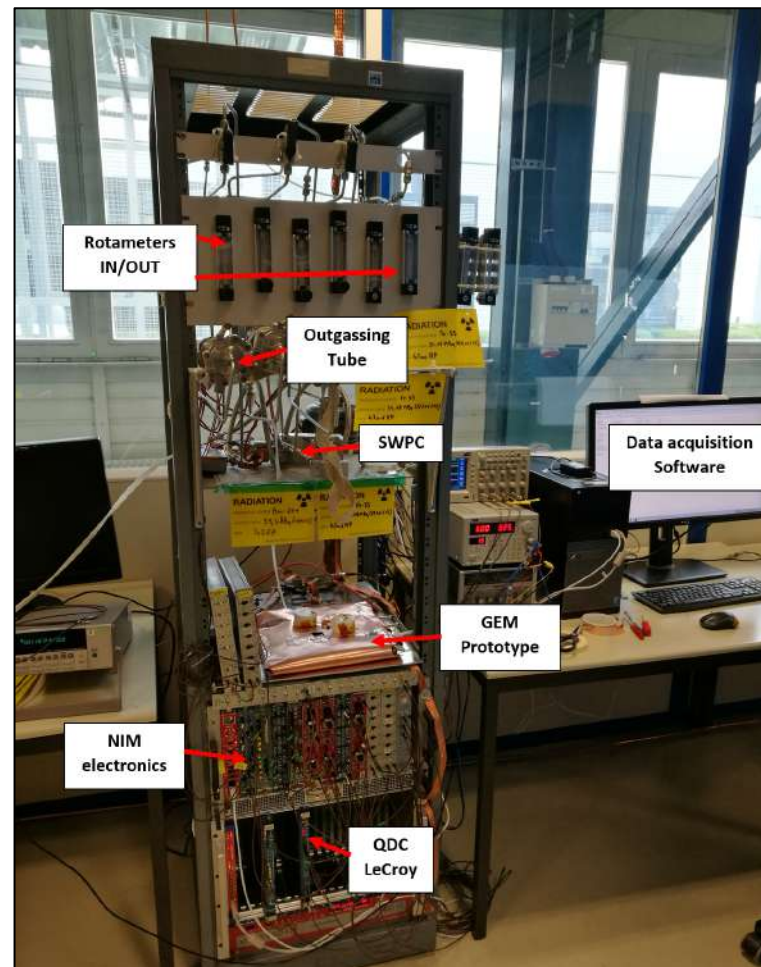
- ⁵⁵Fe: X-ray rate ~ 900 Hz

➤ One sector kept as reference



Triple-GEM 10x10 (CMS GE1/1 configuration)

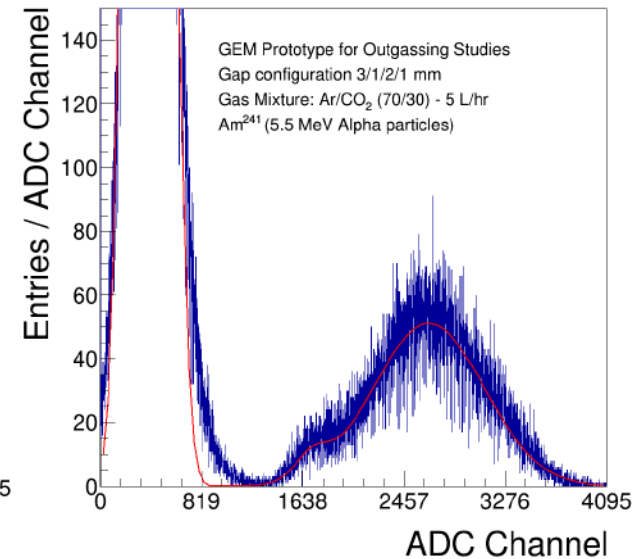
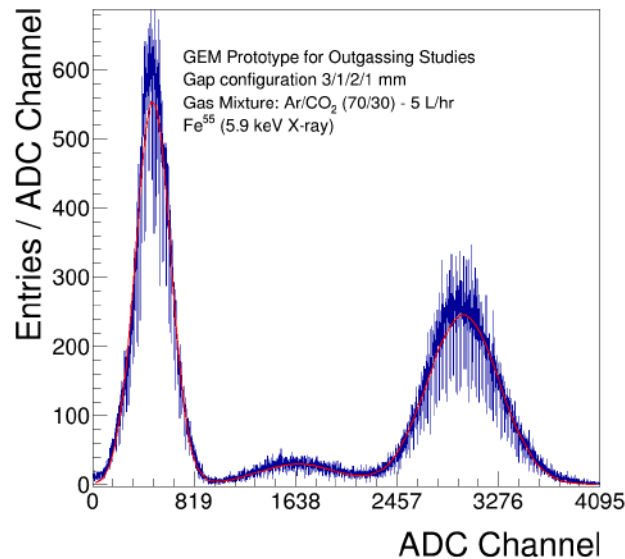
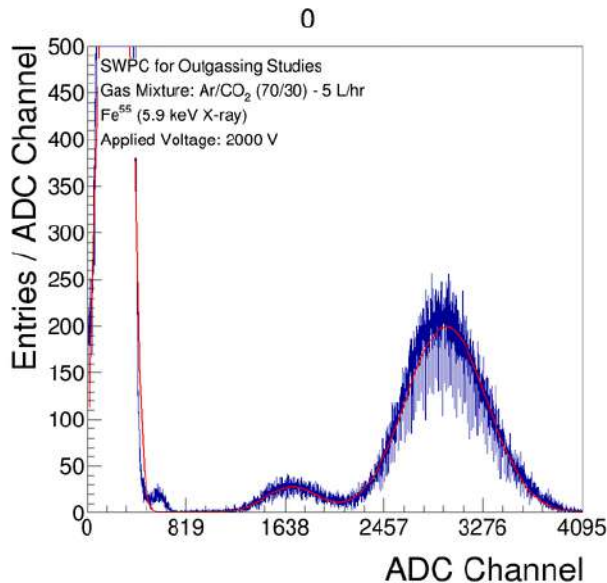
- *Standard CERN 10x10 detector with double-mask GEM foils*
- *CMS GEM configuration (3/1/2/1mm) + typical GE1/1 electric fields*
- *Gas Ar/CO₂ @ 5 L/hr*
- Alpha sector (special opening):
 - ²⁴¹Am: α rate \sim 300 Hz
- X-ray sector:
 - ⁵⁵Fe: 34 MBq
- One sector kept as reference



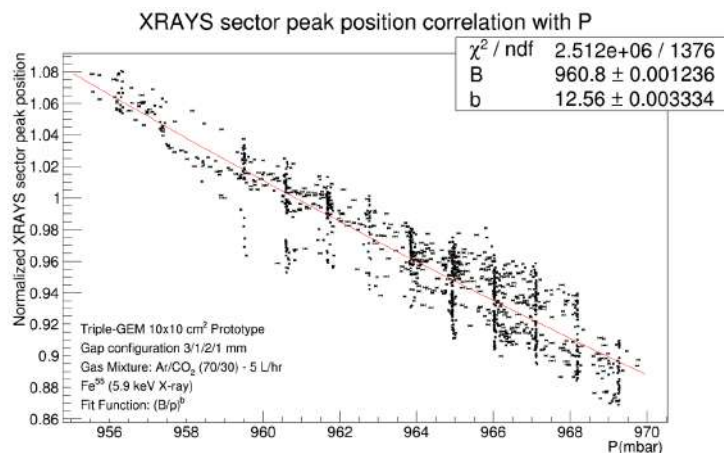
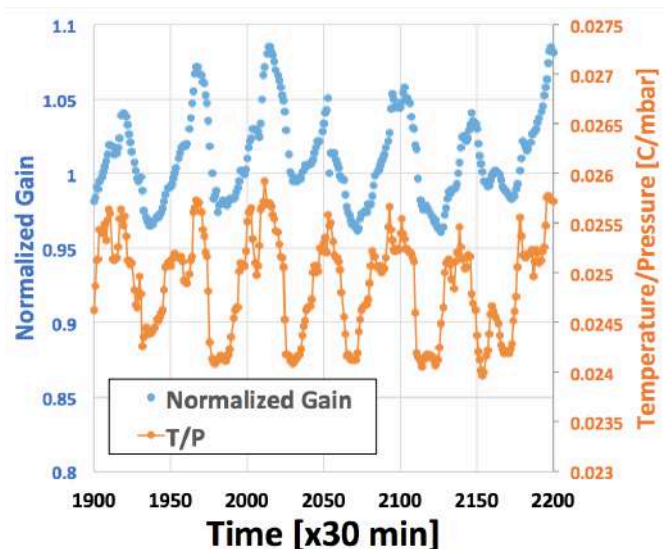
Gain variations in GE1/1 detectors

- *GEM and SWPC fully calibrated and characterized before and during the test*
- *ADC spectra recorded every 30 minutes during the long runs*
- *Run duration depends on the charge collected per sector (to reach the same charge regardless the radioactive source) → based on an initial charge calibration*
- *Polluting material heated up to 50 C during the second half of the test*

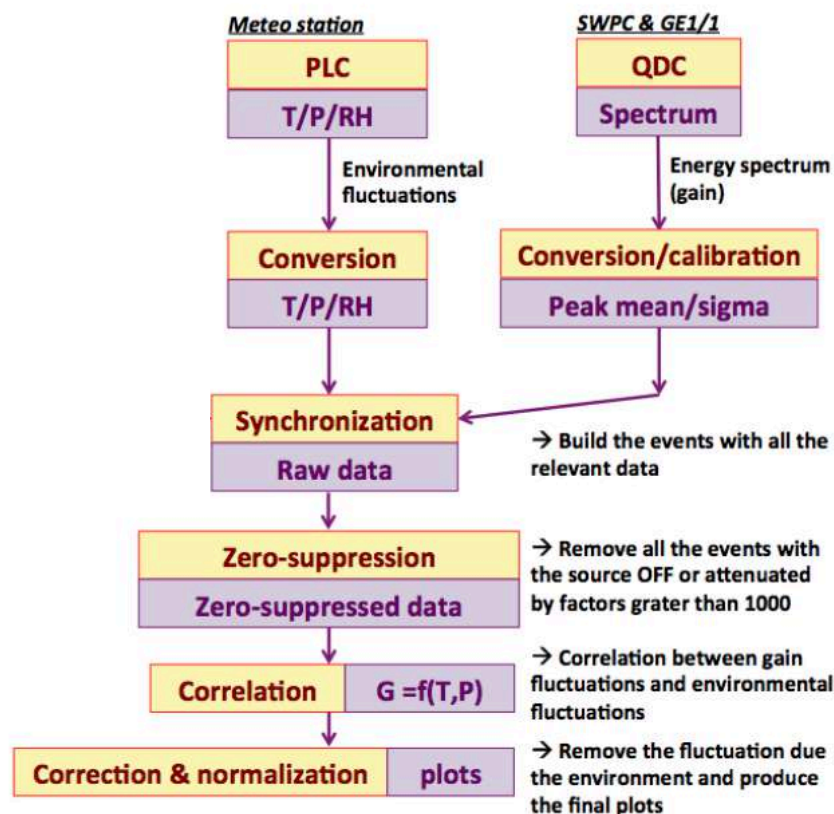
➔ Total charge 170 mC/cm² // >70 days of continuous irradiation



Environmental Corrections

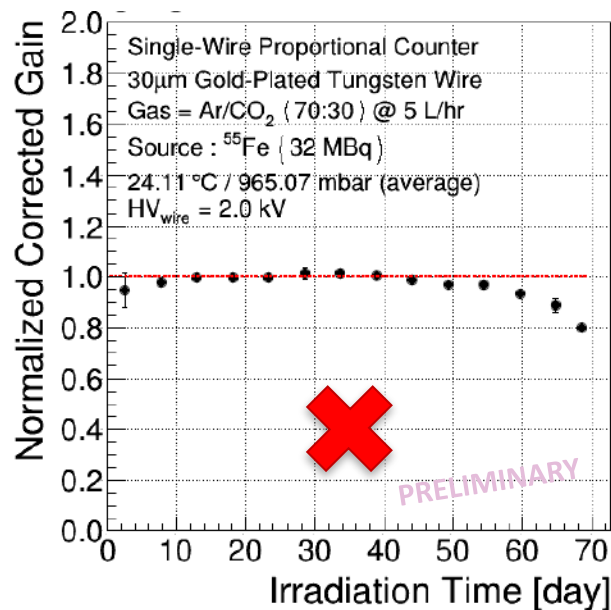


- Identify the correlation between P and T and the detectors response
- Apply corrections and normalize to the initial values

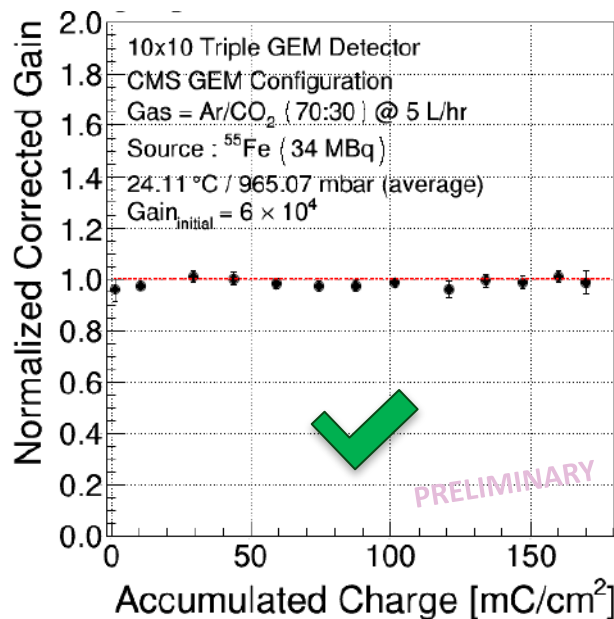


Gain Stability

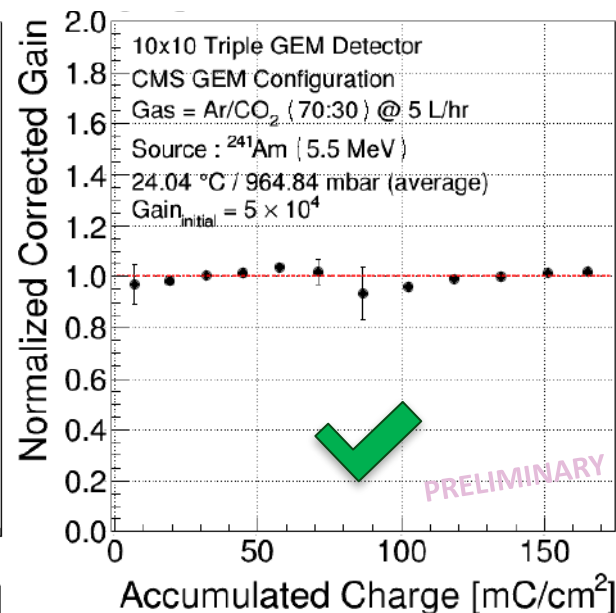
- **GEM and SWPC fully calibrated and characterized before and during the test**
- **ADC spectra recorded every 30 minutes during the long runs**
- **Run duration depends on the charge collected per sector (to reach the same charge regardless the radioactive source) → based on an initial charge**



Aging

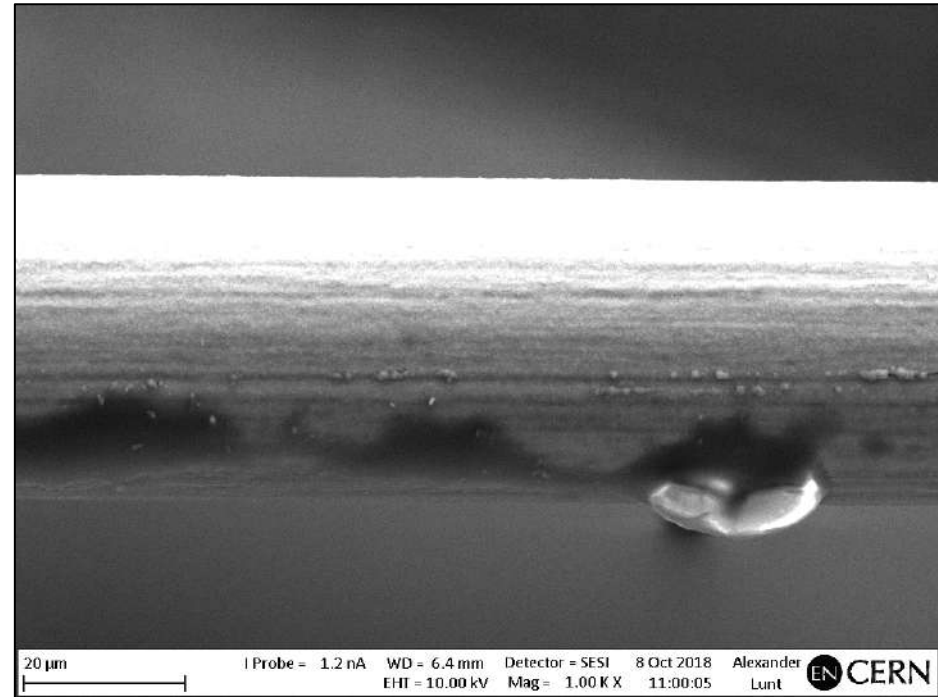
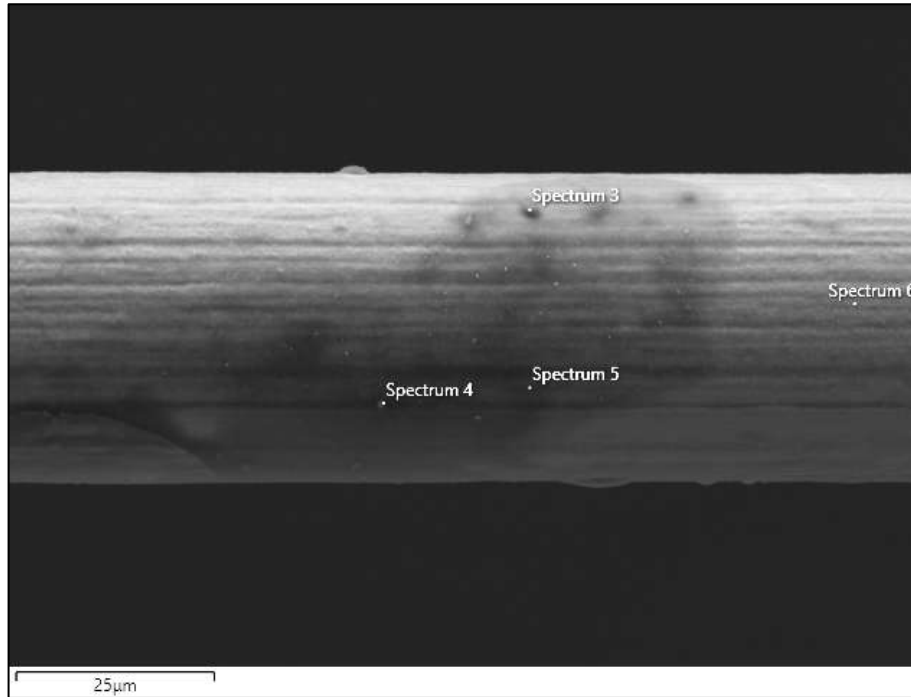


No Aging



No Aging

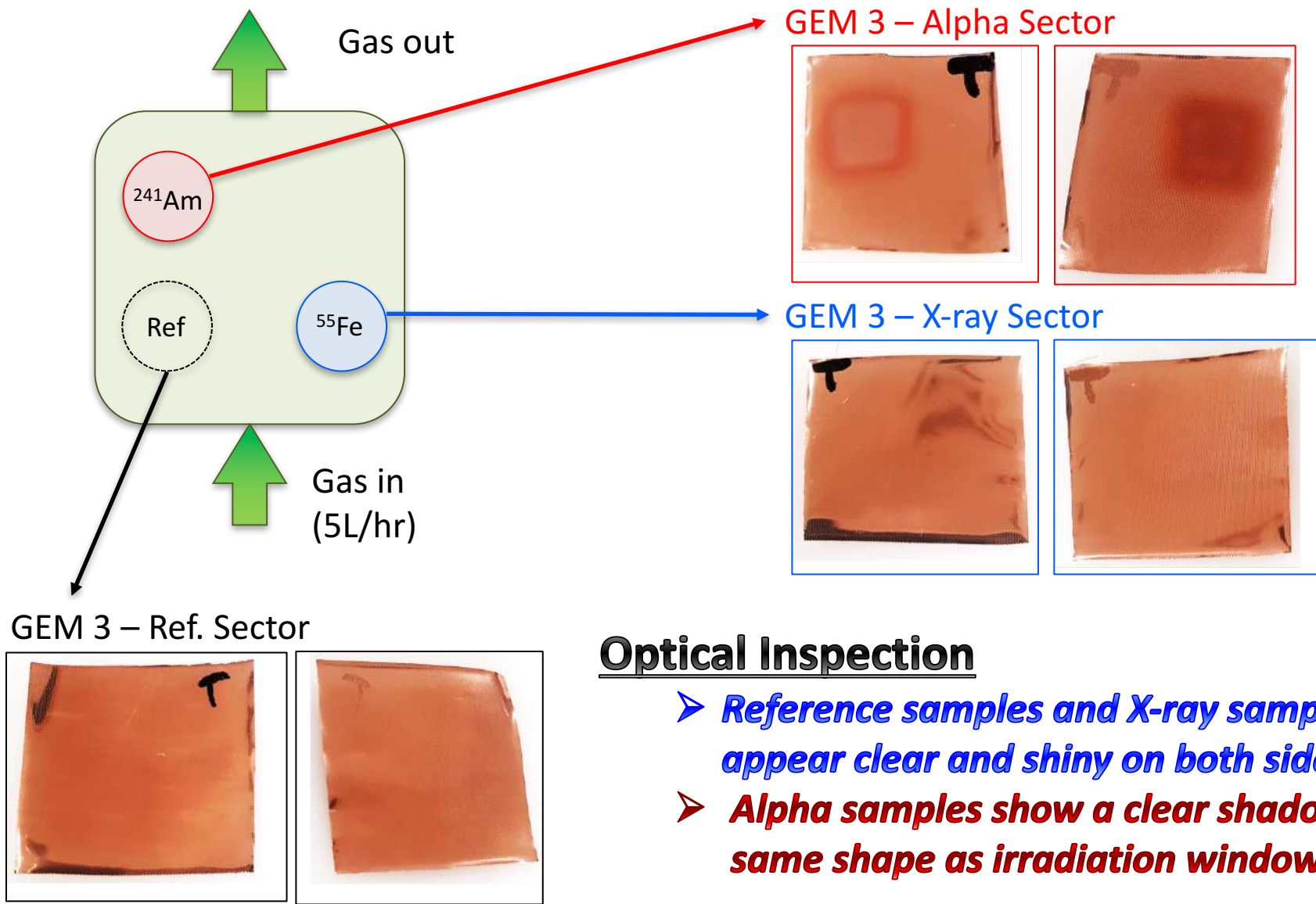
EDS Analysis



%	Au	C	O	Si	Na	+ traces
Spectrum 3	7.9	67.8	17.7	2.8	1.5	Al, Mg, K, Cl, S, F, Ca
Spectrum 4	9.6	13.2	26.4	27.3	2.2	Al, Mg, K, Cl, S, F, Ca
Spectrum 5	62.4	14.2	10.7	8.3	1.6	Al, Mg, K, Cl, S, F, Ca
Spectrum 6	78.1	4.0	13.0	4.2	0.2	Al, Mg, K, Cl, S, F, Ca

SEM/EDS Analysis

- **Clear evidence of Si deposits in the irradiated region**
- **Responsible for the gain loss observed during the last run**

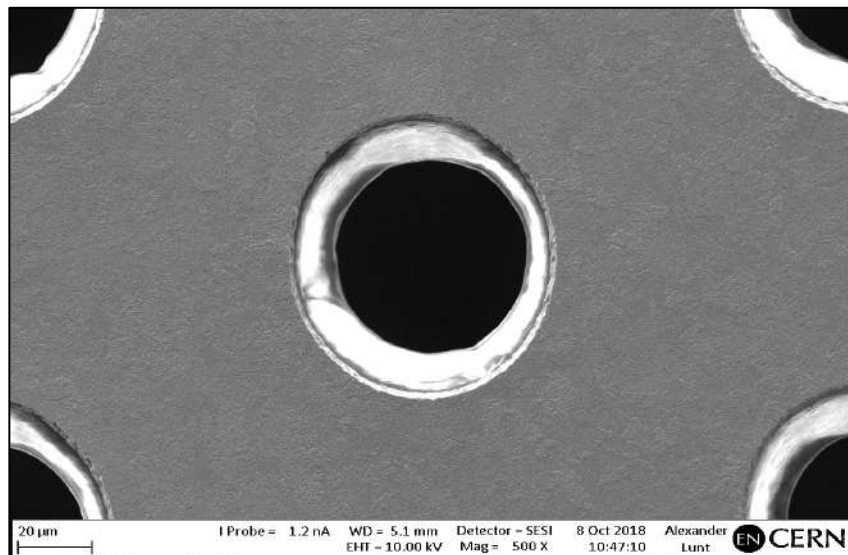


Optical Inspection

- *Reference samples and X-ray samples appear clear and shiny on both sides*
- *Alpha samples show a clear shadow with same shape as irradiation window...*

SEM Analysis

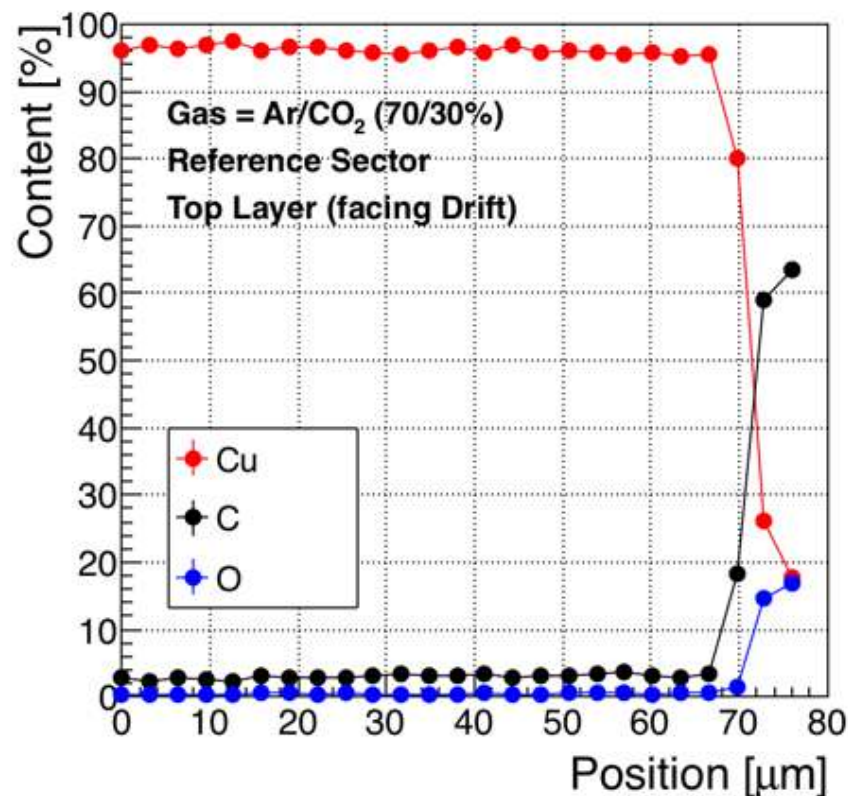
Reference Sector (Top)



EDS Analysis

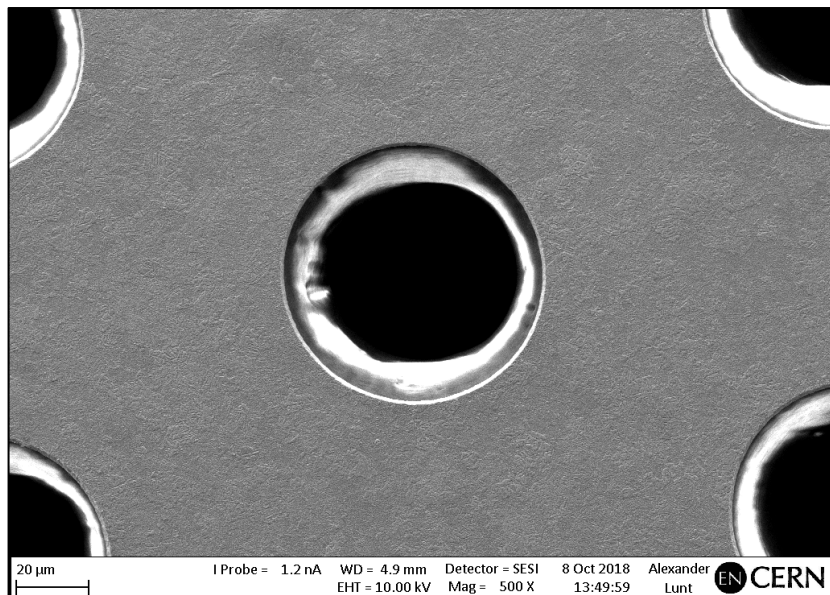
- *Clean surface with 97% Cu*
- *PI clearly identified with the sudden increase of C and O*

Linear EDS Analysis



SEM Analysis

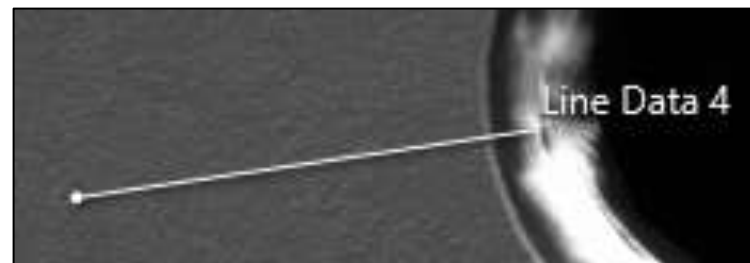
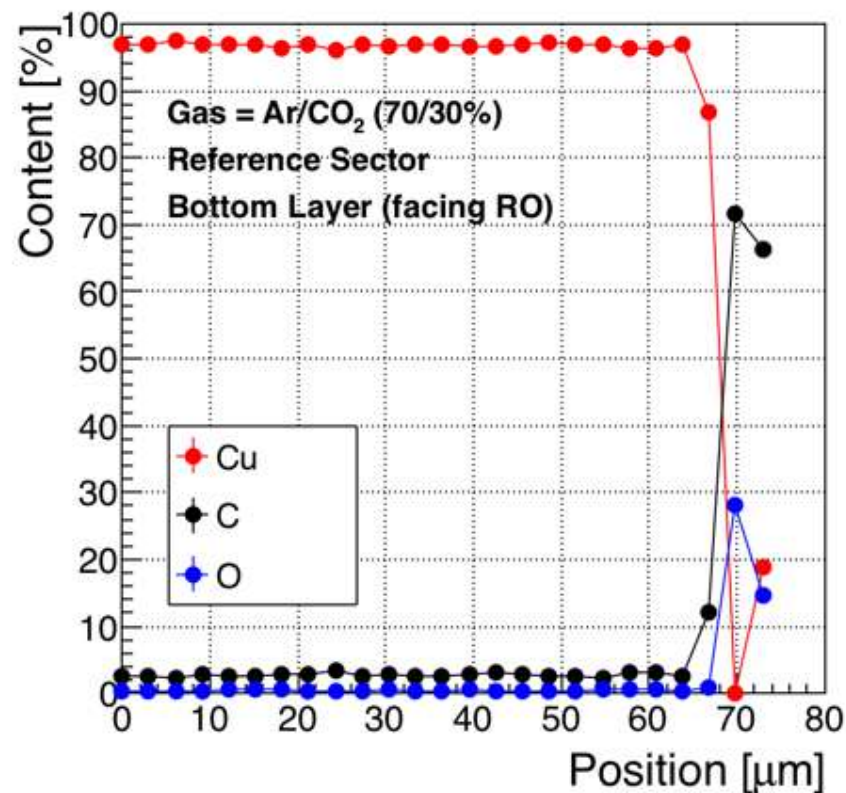
Reference Sector (Bottom)



EDS Analysis

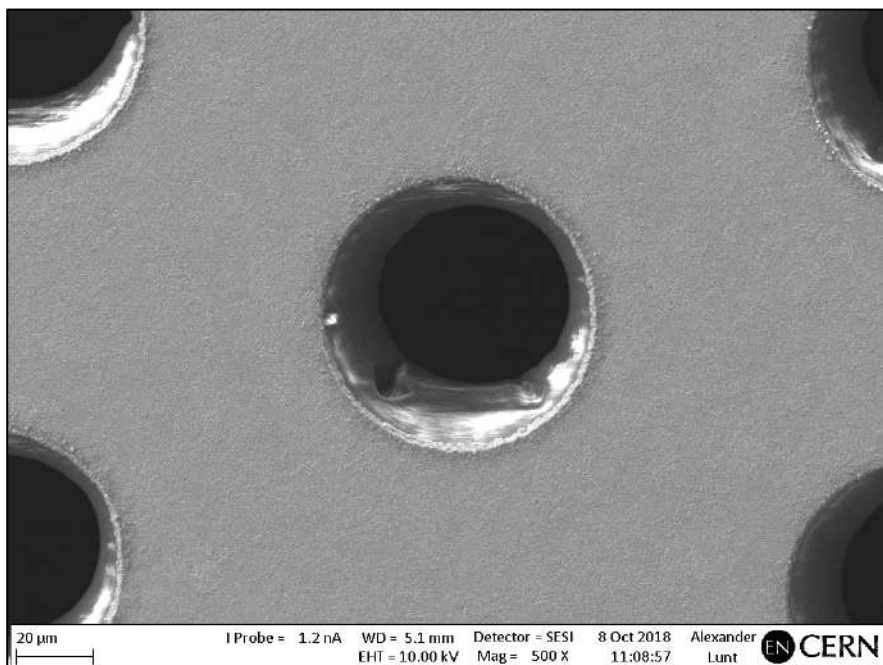
➤ *Same composition as on top*

Linear EDS Analysis



SEM Analysis

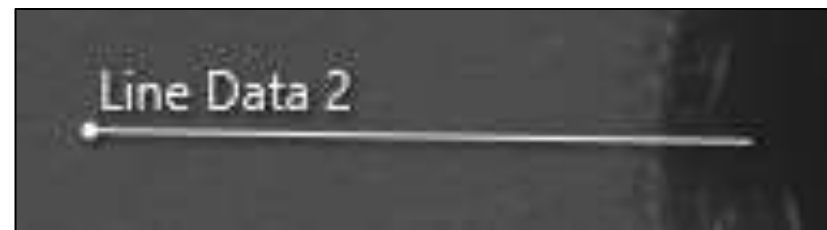
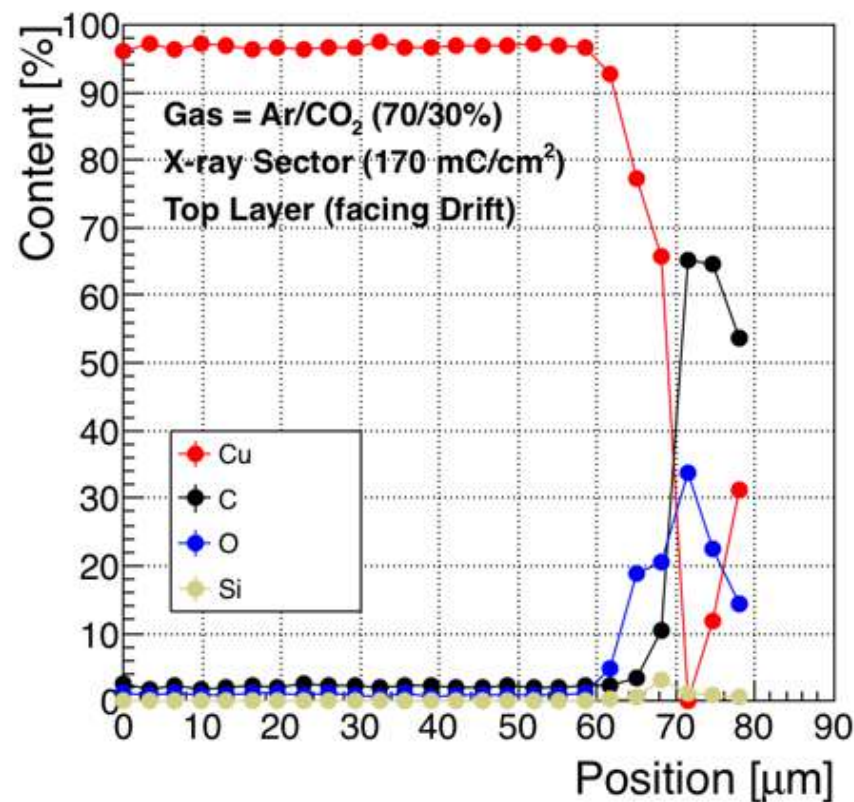
X-ray Sector (Top)



EDS Analysis

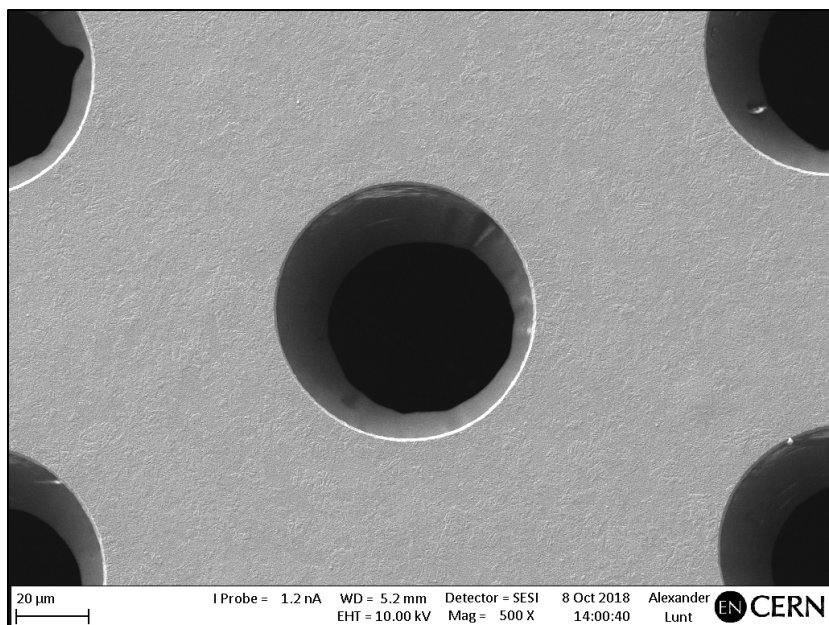
- **Presence of Si deposits at the very edge of the holes**
- **Rest of the foil is clean**

Linear EDS Analysis



SEM Analysis

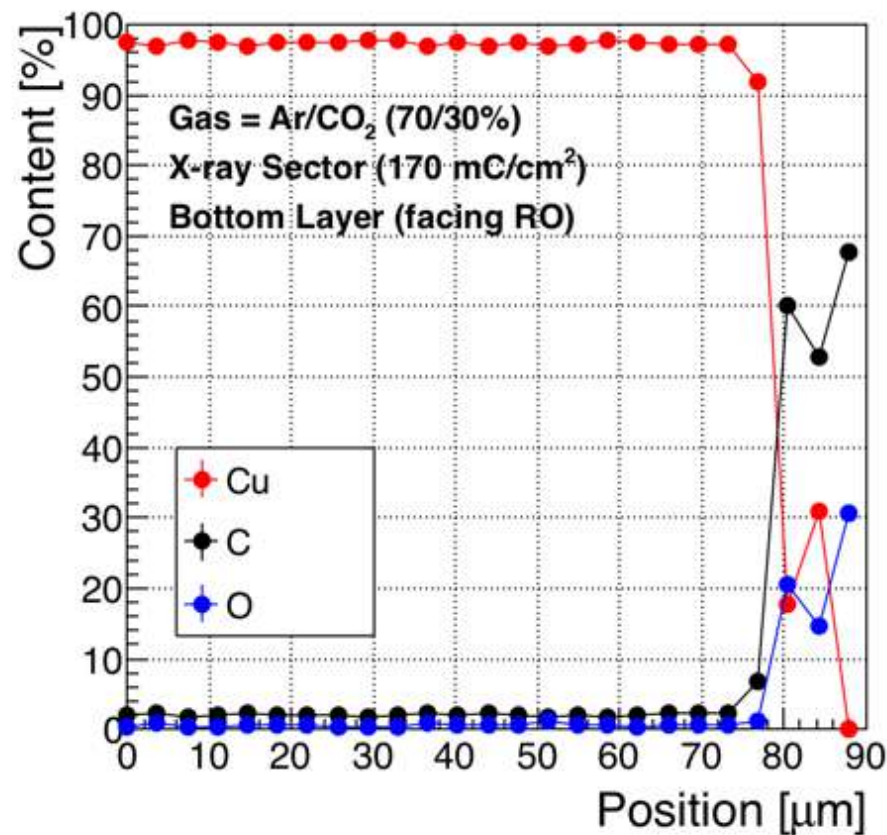
X-ray Sector (Bottom)



EDS Analysis

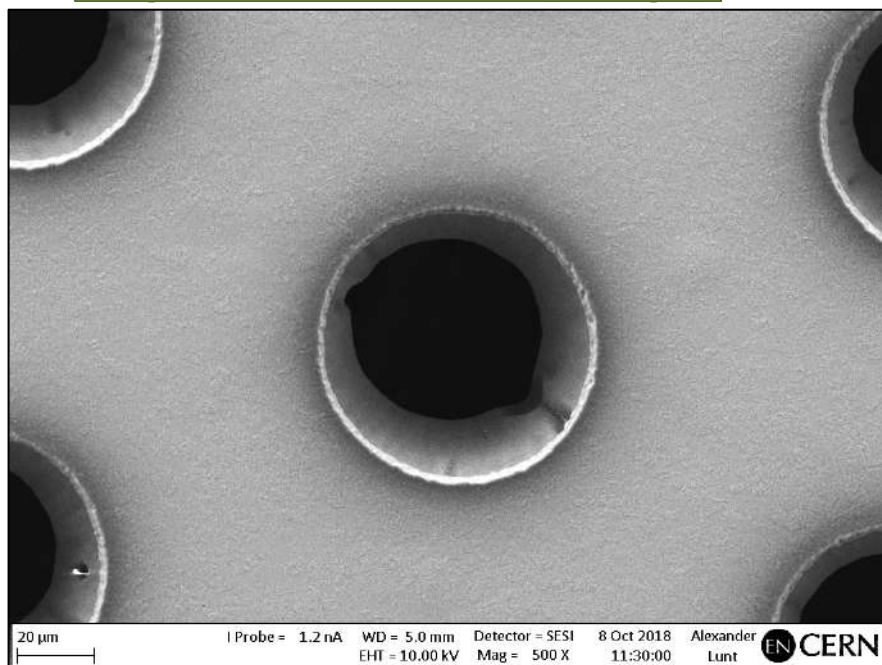
➤ *Clean foil even at the hole rim*

Linear EDS Analysis

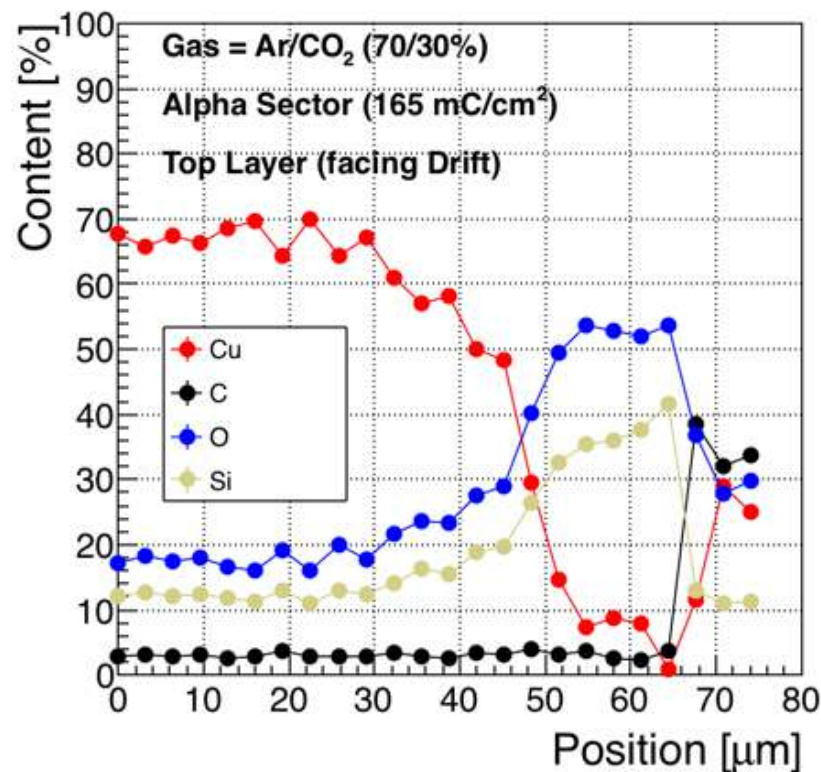


SEM Analysis

Alpha Sector (Top)



Linear EDS Analysis



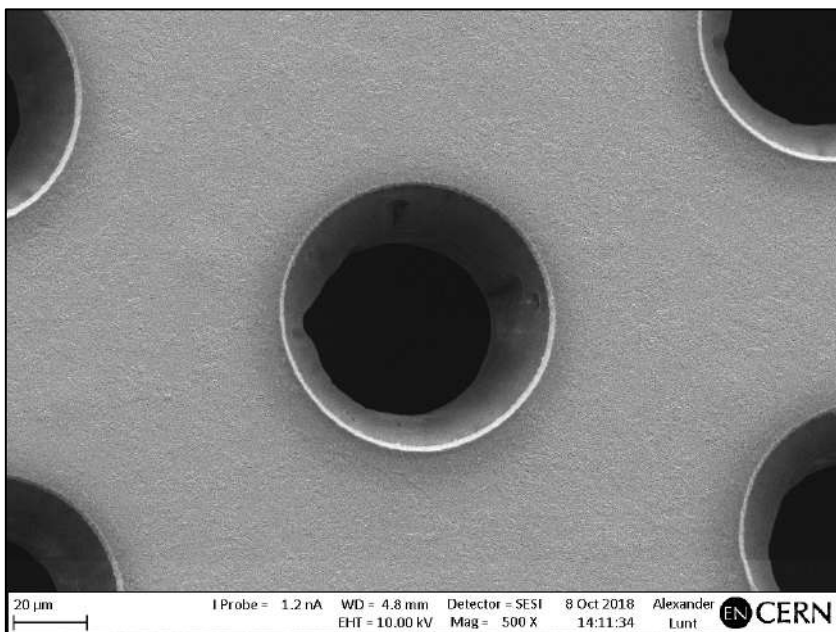
EDS Analysis

- **Presence of Si deposits everywhere**
- **Increase of the Si content at the rim, forming a ring of deposits around holes**

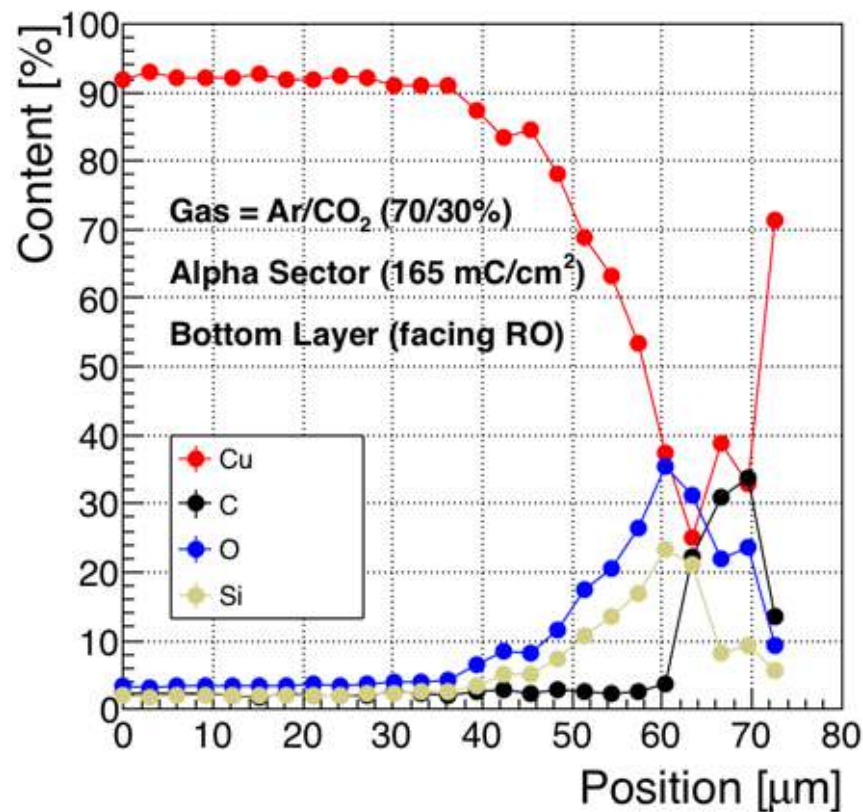


SEM Analysis

Alpha Sector (Bottom)

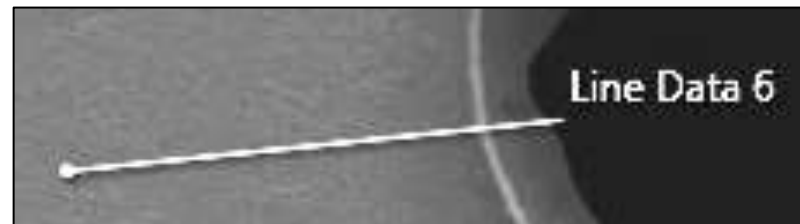


Linear EDS Analysis

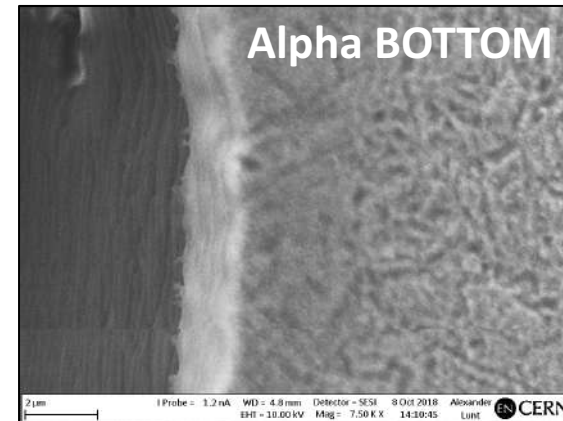
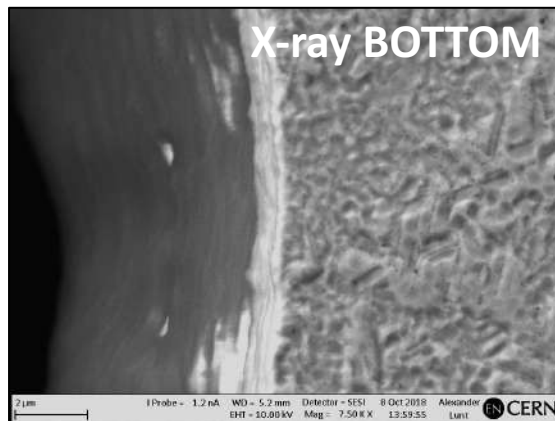
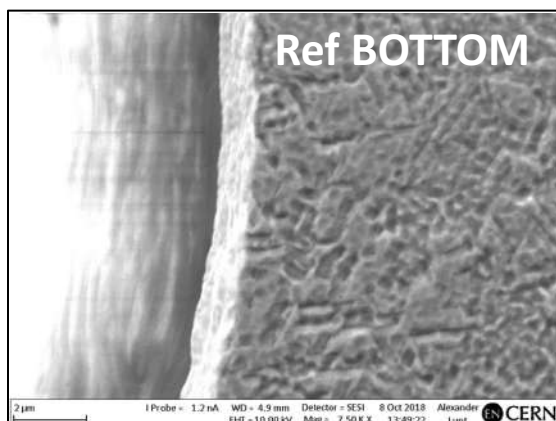
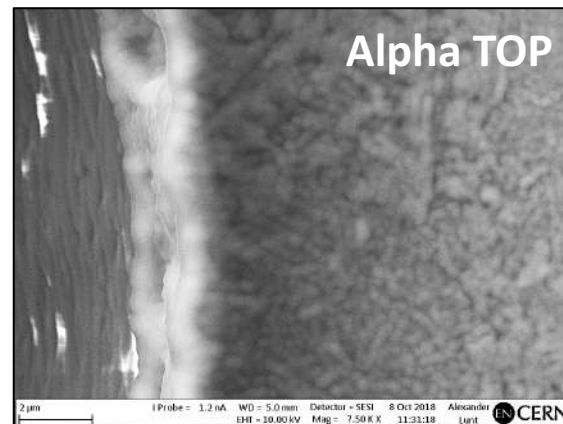
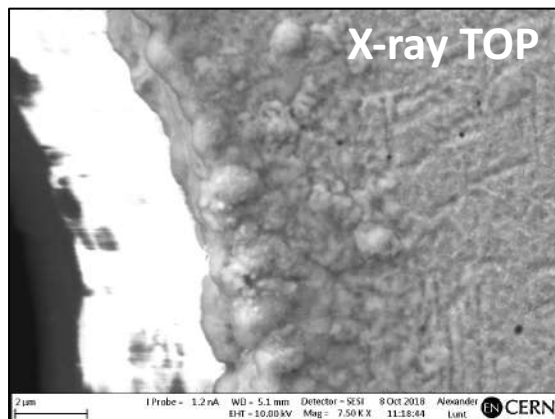
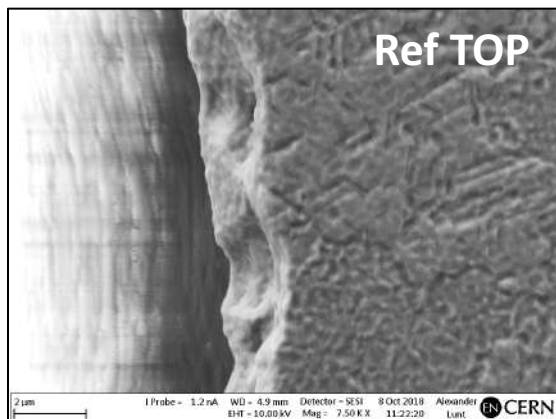


EDS Analysis

➤ **Lower Si content than on top but small amount present everywhere and increasing near the holes**



Edge Analysis



Clean and sharp edges

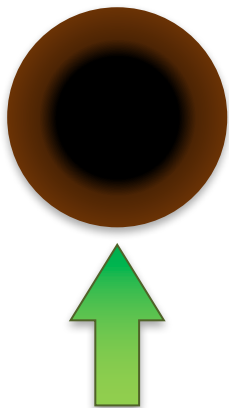


Si build-up on the top rim



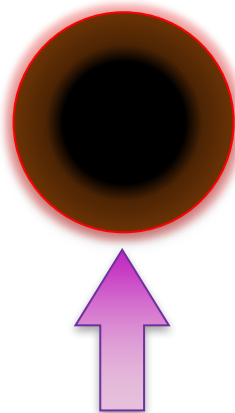
Wide Si deposits on both sides

Main Observations



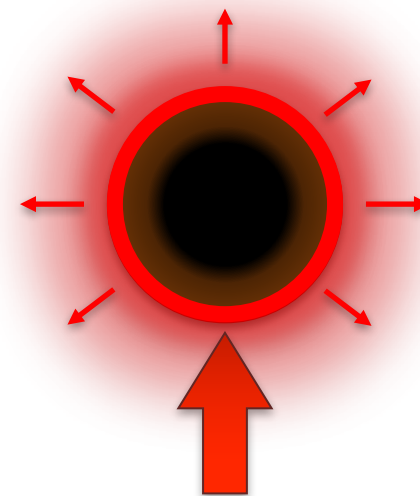
➤ Reference

- Clean GEM surface
- 97 % Cu (no deposits, no defects etc ...)



➤ X-rays

- Light Si deposits on the top layer around the holes ($2-3 \mu\text{m}$)
- Perfectly clean surface on the bottom side



➤ Alphas

- Si deposits on the entire top surface with larger structure in a strip of $10-15 \mu\text{m}$ around the holes
- Similar effects on the bottom layer

Special Aging test

- *Initial aging studies triggered interest in studying the dependency between primary charge and aging rate*
- *Special aging test with different radioactive sources on the same detectors*
- *DAQ and Analysis procedures similar to past CMS GEM aging tests*

Test Setup

- *Forced aging (strong contamination – not representative)*
- *Use of SWPC to identify polymerization*
- *No aging observed in the GEM chamber after 70 days of irradiation*
- *Clear aging measured in the SWPC*

Chemical Analysis

- *Si deposits are much more present in the sector irradiated with alphas compared to X-rays*
- *Deposits first grow on the top side of the foil near the hole rim*

Next steps

- *Confirm this effect with other gaseous technologies (wire, parallel plate)*
- *Introduce neutron in long term aging tests*

Aging tests of gaseous detectors should consider HIPs in order to properly represent the long-term behavior in real experiments

Thank you !

Chemical Analysis

- *Si deposits are much more present in the sector irradiated with alphas compared to X-rays*
- *Deposits first grow on the top side of the foil near the hole rim*

Next steps

- *Confirm this effect with other gaseous technologies (wire, parallel plate)*
- *Introduce neutron in long term aging tests*

Past Observations (2013 aging test)

- *No aging observed up to 54 mC/cm² (Ar/CO₂/CF₄)*
- *Gas tubing was probably contaminated, as indicated by the aging of the wire chambers.*

