

# Review of the Readiness for Foil Production in Korea

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2019 / 10 / 04

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CMS GEM Workshop 24

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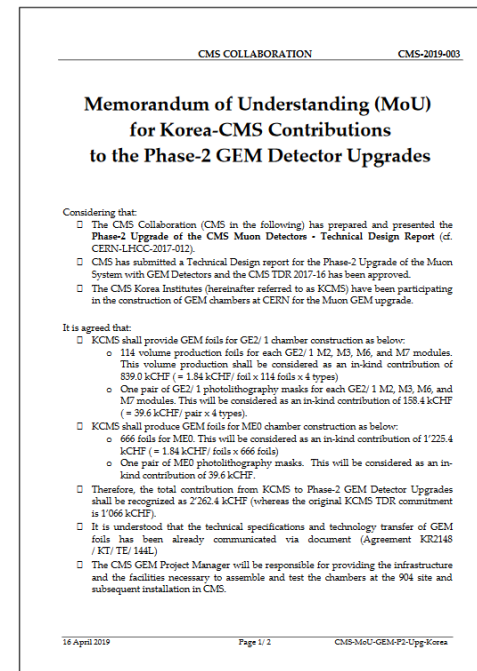
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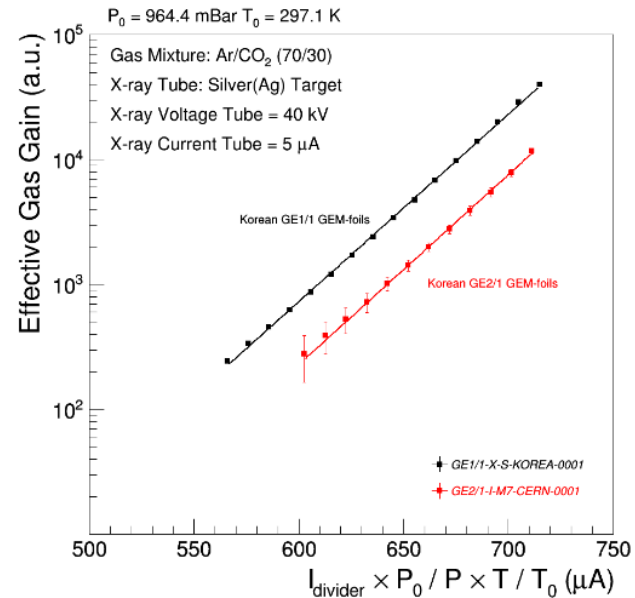
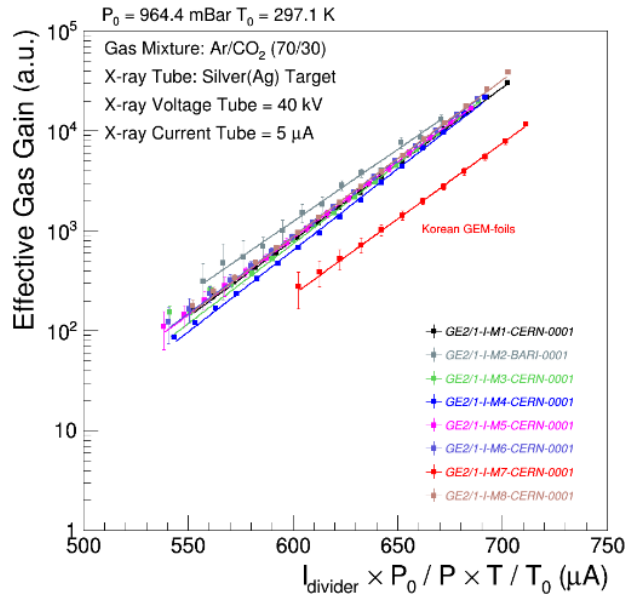
- Administrative progress and request
- Investigation on hole diameters and gain issue
- Current status of Mecaro
- Priority issue
- Production schedule
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- Summary

# 1 Administrative progress and request

- MoU between CMS and Korean government has been signed on 16<sup>th</sup>, Apr., 2019
  - MoU covers in-kind contributions of 114 GE2/1 foils×4 types + 666 ME0 foils and masks
- Based on the MoU, KCMS and Mecaro has reached a verbal contract on GE2/1 foils production on 30<sup>th</sup>, Sep., 2019.
  - The contract is being documented.
- KCMS requests the CMS official letter which confirms foils design is finalized.
  - The MoU doesn't cover R&D cost.
  - Mask production will start after the letter arrives.



## 2 Investigation on hole diameters and gain issue



Francesco, GEM Phase2 Upgrade Coordination Meeting 20190426

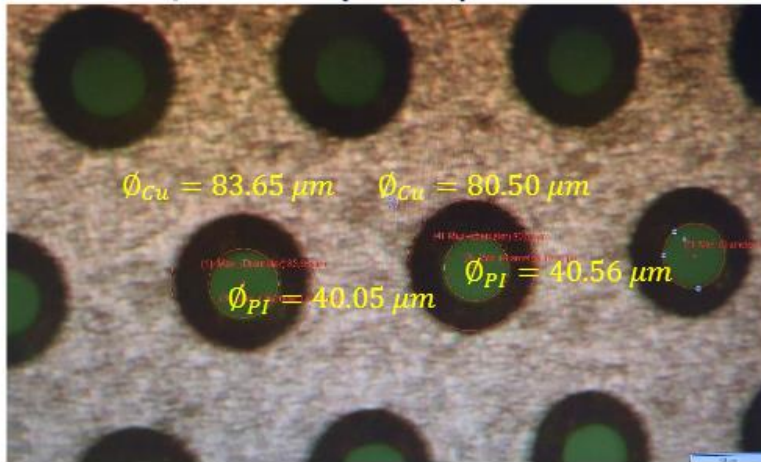
- Three times lower gain was observed for chamber with Mecaro GE2/1 M7 foils
- Wrong geometry is suspected as the reason

## 2 Investigation on hole diameters and gain issue

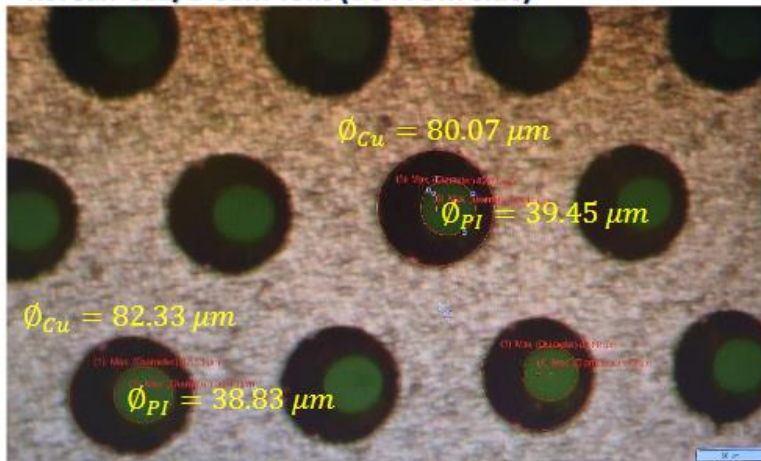
### Korean GEM-foils Optical Inspection

Francesco, GEM Phase2 Upgrade Coordination Meeting 20190426

Korean GE2/1 GEM-foils (TOP side)



Korean GE2/1 GEM-foils (BOTTOM side)



- optical inspection performed on several portions of the GEM-foils (corner / middle / corner) and on both sides (TOP and BOTTOM)
- Results:
  - Optical inspection by backlight → good
  - Holes Uniformity → good
  - Holes diameter → out of specs !
- Copper rings diameter:  $\Phi_{Cu} \sim 80 \mu m$   
→ required specs:  $70 \pm 5 \mu m$
- Polyimide rings diameter:  $\Phi_{PI} \sim 35/40 \mu m$   
→ required specs:  $50 \pm 5 \mu m$
- The larger copper rings and the smaller polyimide rings is definitively the reason of the lower gain: the resulting electrical field is definitively distorted and lowered

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## 2 Investigation on hole diameters and gain issue

- Now the reason of the wrong geometry is understood.
  - Mecaro had changed microscope to stereo type before GE2/1 production.
  - Stereo microscope should not be used to measure distance because it has intrinsic distortion.
    - ⇒ The reason of diameter calibration failed.
- Mask is used as known length for microscope calibration.
  - Specimen of CERN GE1/1, Mecaro GE1/1 and Mecaro GE2/1 (wrong geometry) in Mecaro
- Five double-segmented GE2/1 M7 foils will be produced to validate Mecaro capability.

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## 3 Current status of Mecaro

- After successful R&D based on GE1/1 and GE2/1, Mecaro relocated its GEM to new facilities building unfortunately.
  - Unavoidable because the decision based on long-term plan of Mecaro
- Relocation: Apr., 2019 to Sep., 2019  
Machine setup & check: Sep., 2019 to Oct., 2019  
10 cm\*10 cm evaluation: ongoing



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## 3 Current status of Mecaro

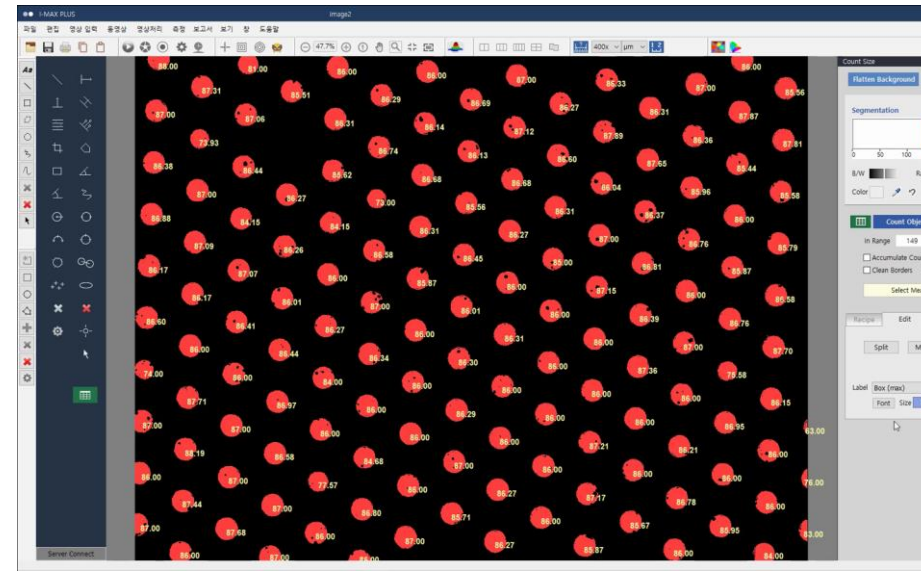
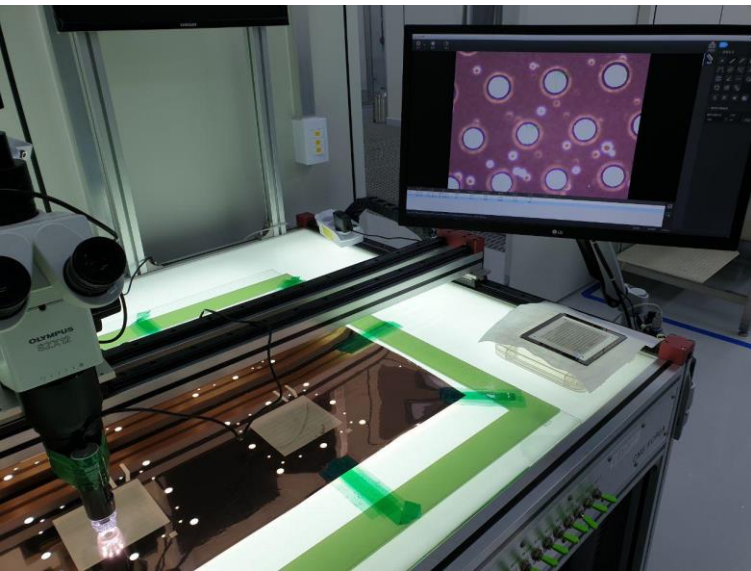
- Relocation has been done without any major accident
  - Spacious 1000 class clean room
  - Working condition has been improved thanks to better space layout and sewerage facilities.
- Re-setup of machineries has been done
  - Optical alignment of the large bipolar UV exposure has been done





### 3 Current status of Mecaro

- 10 cm\*10 cm foil production and alignment evaluation is ongoing
  - At glance, quality of produced foils is good
  - The 10 cm\*10 cm foils and large foils are produced same way
- Automatic diameter recognizer has been installed
  - Can't control position of microscope. Thinking how to add the recognizer to local QC at Mecaro



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## 3 Current status of Mecaro

- Every item for mass production is secured.
  - FCCL
  - Chemical etchants
  - Two Mecaro technicians
  - Trained KCMS students for QC

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## 4 Priority issue

- Due to delayed contract and mass production, KCMS has loosed production priority.
  - Production of 64 foils for domestic experiment (IBS) has a priority.
  - 64 foils is not large number but tricky shape of IBS foils will hinder production rate
  - Mounting foil too thin frame will be time consuming work
- Due date of delivery of IBS is 14<sup>th</sup>, Jan., 2020
- KCMS still has priority for 5 GE2/1 M7 foils production for gain issue and aging test.

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## 5 Production schedule

- 1) About 20 “10 cm\* 10 cm foils”
  - Good chance to evaluate machine status
  
- 2) 64 IBS foils until 14<sup>th</sup>, Jan., 2020
  
- 3) 5 GE2/1 M7 foils for R&D can start after 10\*10 foils production in between IBS foils after the letter arrives
  
- 4) Production of CMS foils will start after completion of IBS foils~14<sup>th</sup>, Jan., 2020

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## 6 My input to evaluate expected impact from delayed production

- If production rate 40-50 foils/week is kept, delay of production can compensate and impact on GE2/1 production will be limited.
  - 40-50 foils/week is estimation based on R&D production
  - Might wrong because it's first mass production for Mecaro
- If production rate is slower than necessary rate, KCMS or Mecaro can allocate more technicians
  - Two technicians working on RPC R&D can be allocated on GEM production
  - For trivial but time consuming work such as soldering SMD resistance and pasting Ag epoxy on HV pad

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## 7 Summary

- KCMS and Mecaro have made verbal contract to produce GE2/1 foils based on MoU between CMS and Korean government
  - KCMS requests the official letter that foils designs are officially finished
- The reason of the wrong geometry issue is understood; wrong choice of microscope
- Relocation of Mecaro has been done without any issue
  - Small foils production and evaluation are ongoing
- Due to priority issue, mass production can be started after 14<sup>th</sup>, Jan., 2020
  - KCMS still has priority for R&D production of 5 GE2/1 M7 foils

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# Back Up

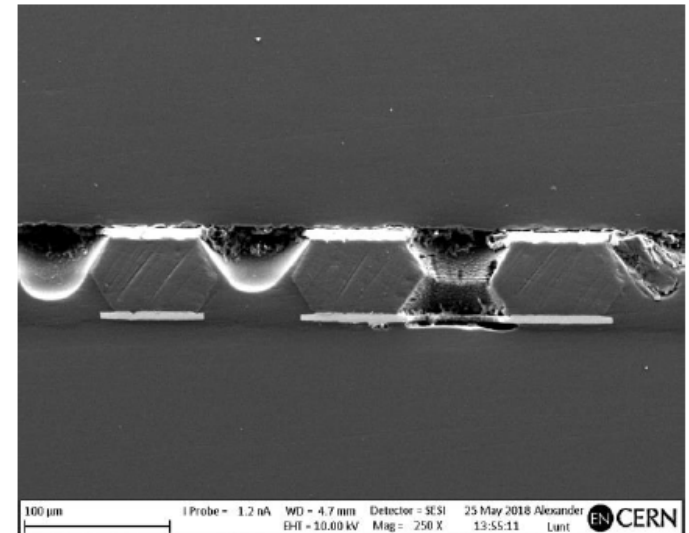


# Large-Size Foil Production R&D

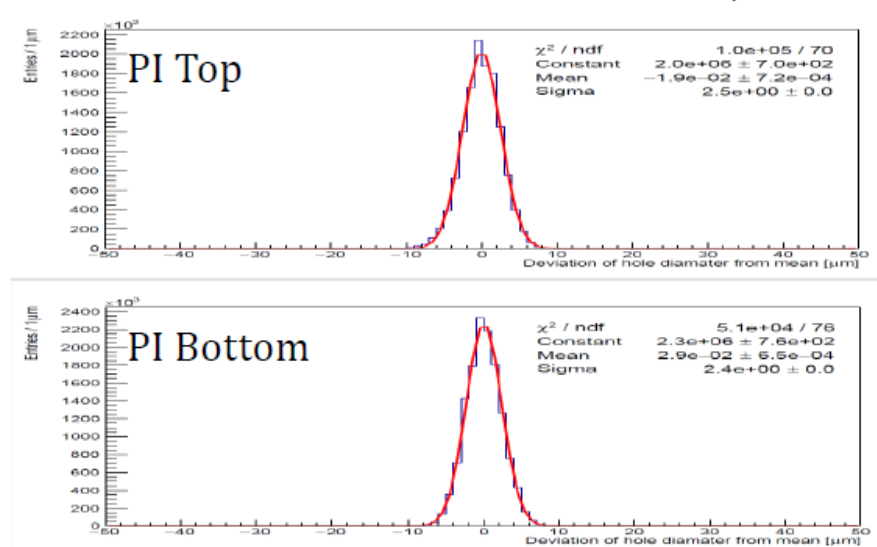
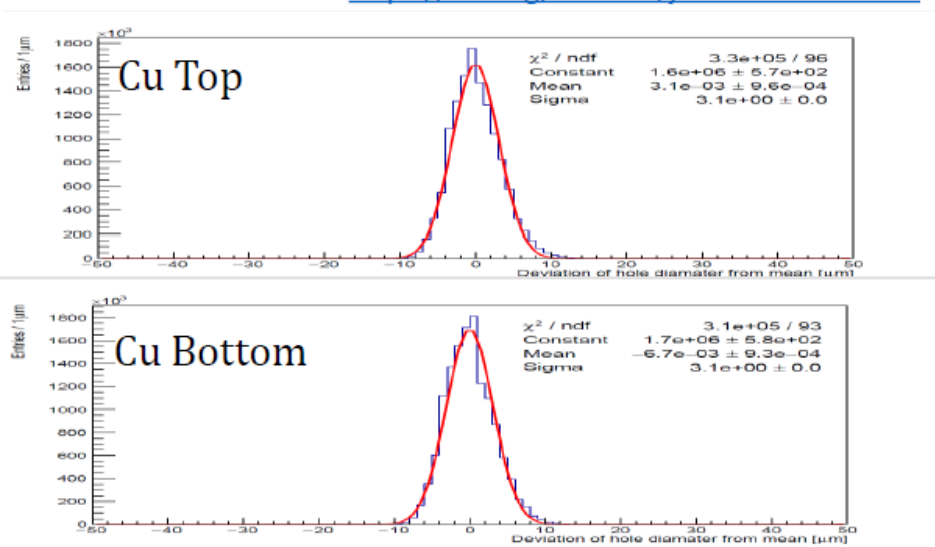
- Extensive early work to establish generic GEM foil production capabilities using double mask technology
  - 10x10 cm and 30x30 cm foils since 2012
- Since 2017, shift focus to working out the manufacturing flow for large-size foil production and establishing QA/QC procedures
  - **Batch 1: Dec 2017:**
    - Aim to qualify Mecaro's ability to produce large-size foils of the required geometry
    - Goal achieved, but validation revealed that a pasting Ag epoxy has been missed at Mecaro. The missing step has been performed at CERN following foil re-cleaning.
  - **Batch 2: Jan. 2018:**
    - Aim to exercise the full production cycle for the first time including updated QA/QC procedures and assess the production rate capabilities
    - Achieved, but the QC2 discovered that the foils short or spark at lower voltages than expected. Traced to insufficient foil cleaning. Cleaning protocol and packaging methods have been revised, including the use of a different solution. Introduce additional QC stages to be performed at the production site at Mecaro
  - **Batch 3: Jun. 2018:**
    - Aim to iterate on the improvements established following batch 2
    - Goal achieved: foils have successfully passed all standard CMS GEM QC tests
- Valuable technical experience as well as establishing efficient communication lines and technical collaboration with Mecaro
  - Mecaro and Korean physicists working together on identifying and correcting issues, training of the personnel at Mecaro, a much improved understanding of the process

# Mecaro Foil Validation: Geometry

- Double mask technology became well understood yielding desirable mechanical parameters
- Measured hole diameter using a microscope (sampled over 450 holes):
  - Cu:  $70.24 \pm 0.91 \mu\text{m}$
  - PI:  $49.04 \pm 0.79 \mu\text{m}$
- Hole uniformity measured using the automatic CCD
  - Hole uniformity exceeds requirements
  - Thanks to M. Posik (Temple Univ.)
    - <https://doi.org/10.1016/j.nima.2015.08.048>

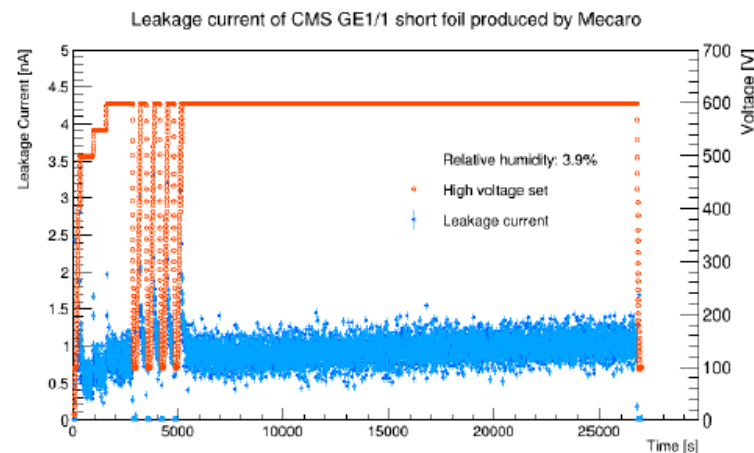


Cross section of Mecaro GE1/1 foil



# Mecaro Foil Validation: Electrical

- Foil cleanliness is a critical parameter affecting foils performance
  - Evaluated using the standard CMS GEM QC2 protocol
- Early problems with the first large size foils have been understood, including full understanding of the causes, and corrected
  - See page 12



# Mecaro Foil Validation: Assembly

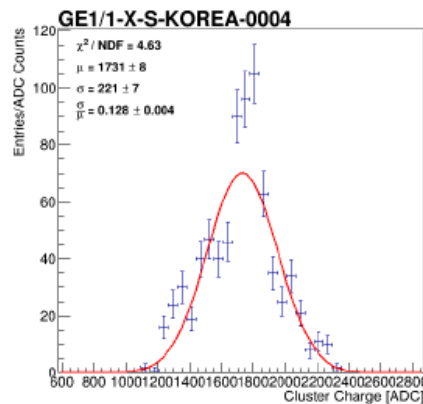
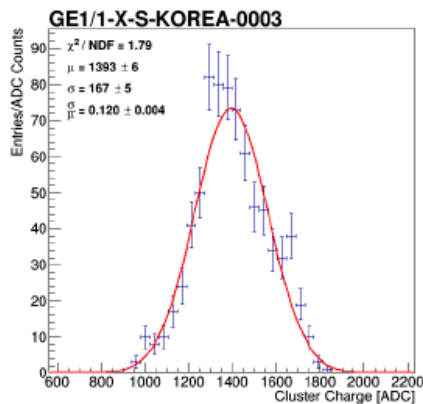
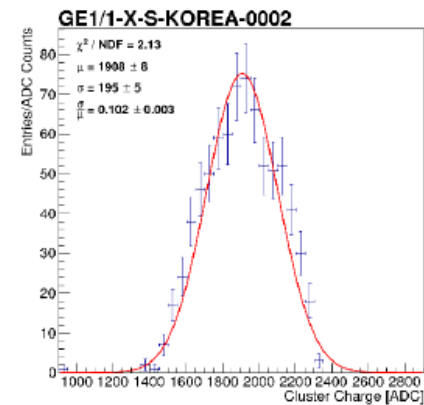
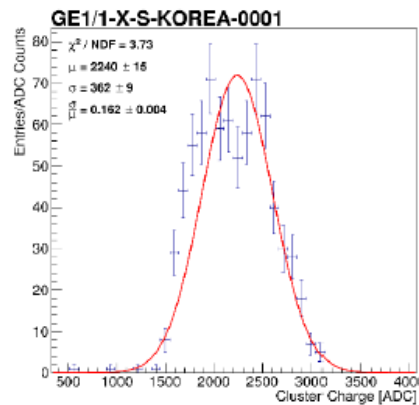
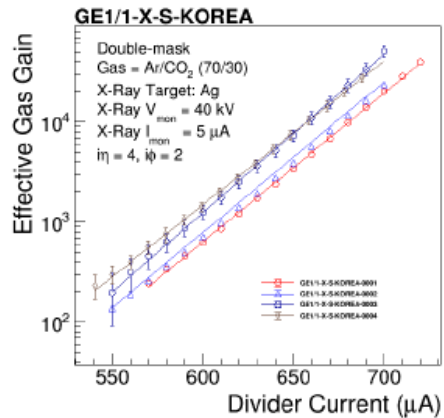
- Four GE1/1 chambers with Mecaro foils assembled at CERN
  - Full standard QC testing
    - Gas tightness, I-V curve, spurious signal rate, gain, gain uniformity etc.
    - Additional measurements: rate capability, aging, discharge probability
- Meets and exceeds the requirements for HL-LHC operations





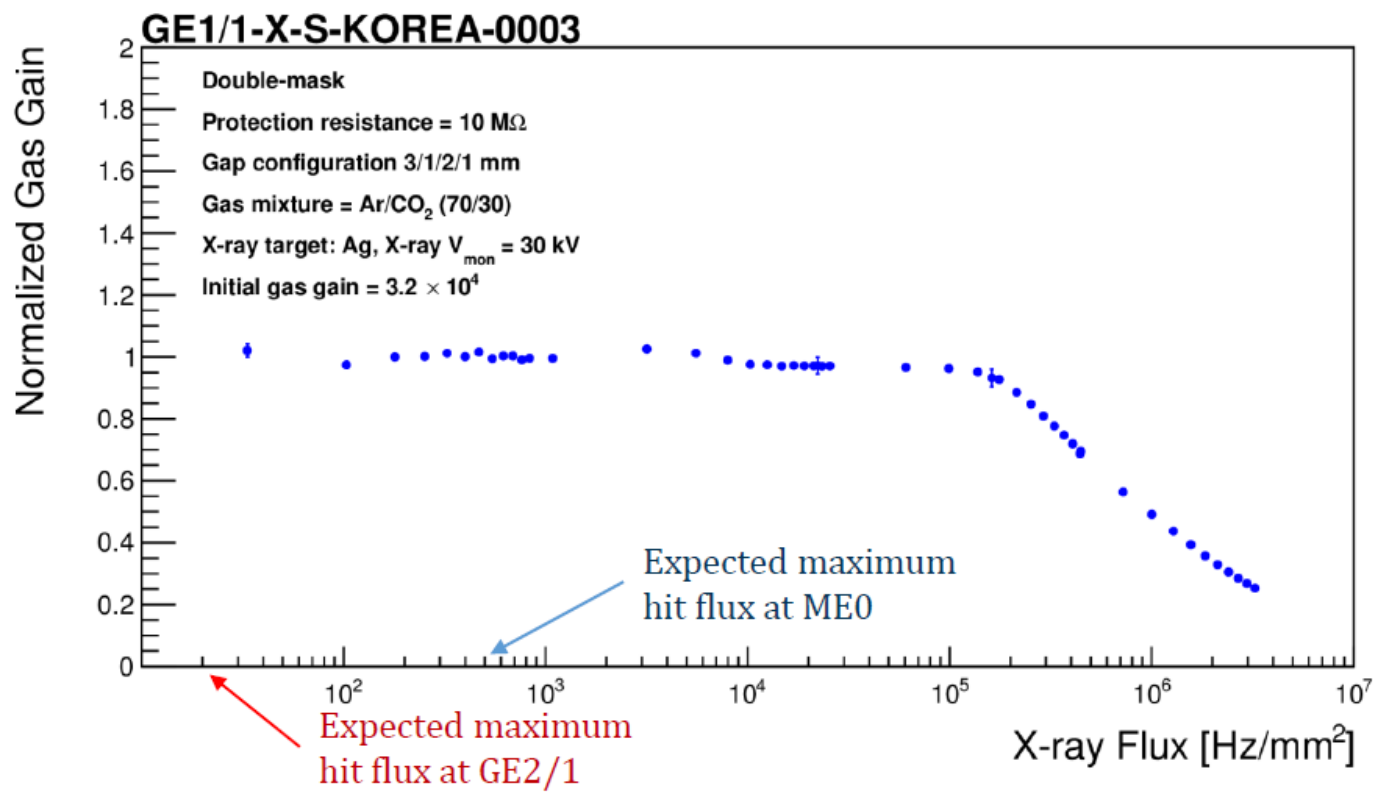
# Mecaro Foil Validation: Gain

- Gain measurements consistent with the detectors built with CERN foils
  - Gain:  $0.5 - 1.1 \times 10^4$  at  $660 \mu\text{A}$  (operating voltage)
  - Gain variance: 10-16%
- Meets and exceeds the requirements for HL-LHC operations



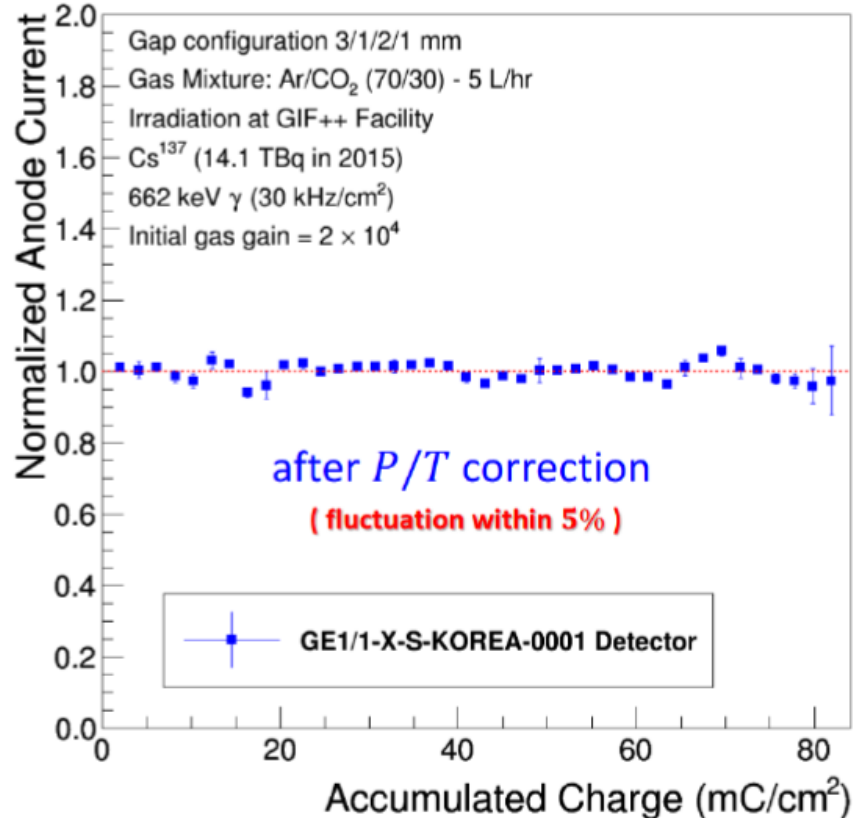
# Mecaro Foil Validation: Rate Capability

- Gain remains stable x-ray flux up to  $1 \times 10^5 \text{ Hz/mm}^2$ 
  - Gain drops at very high flux because of voltage drop at the protection resistor
- Meets and exceeds the requirements for HL-LHC operations



# Mecaro Foil Validation: Aging Properties

- No gain degradation due to aging is observed up to 82 mC/cm<sup>2</sup>
  - Corresponds to 273 years of GE2/1 operations at HL-LHC
- Meets and exceeds the requirements for HL-LHC operations

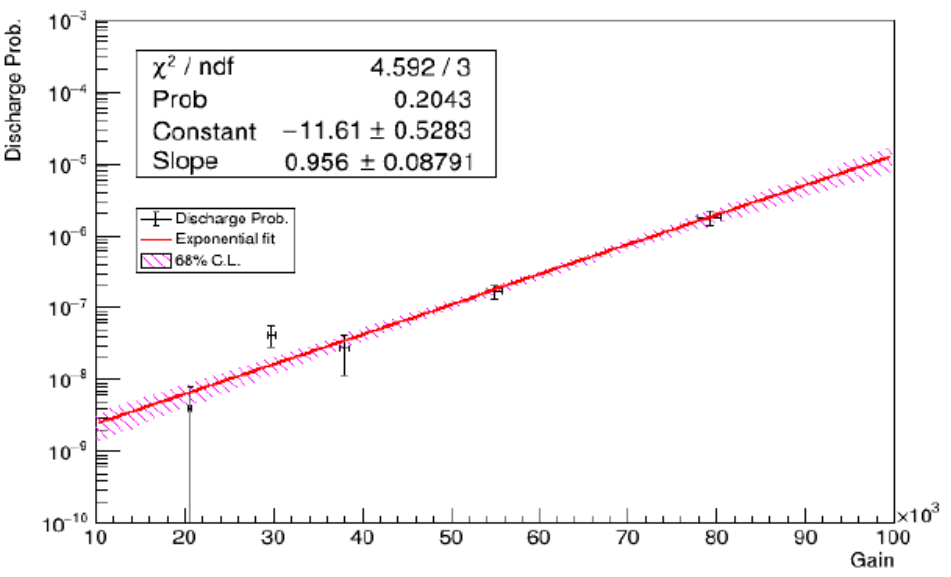




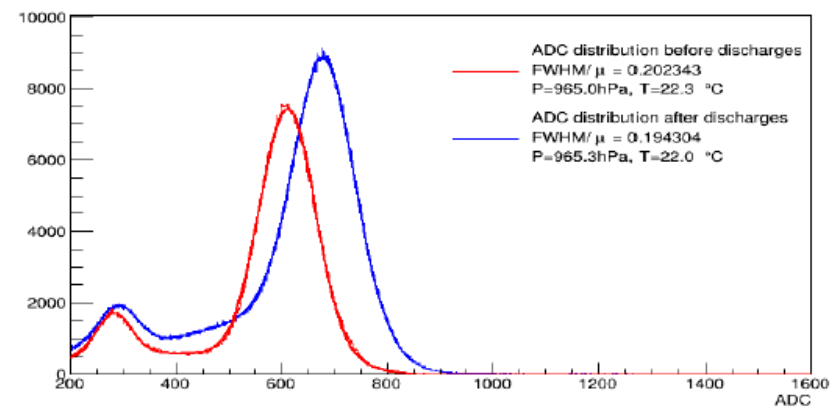
# Mecaro Foil Validation: Discharges

- Probability of discharge induced by  $\alpha$  from  $^{241}\text{Am}$ .
  - Discharge Prob. (at gain= $1 \times 10^4$ ) =  $2.4 \times 10^{-9} \pm 1.0 \times 10^{-9}$ .
  - No degradation on detector performances after 229 discharges
- Meets and exceeds the requirements for HL-LHC operations

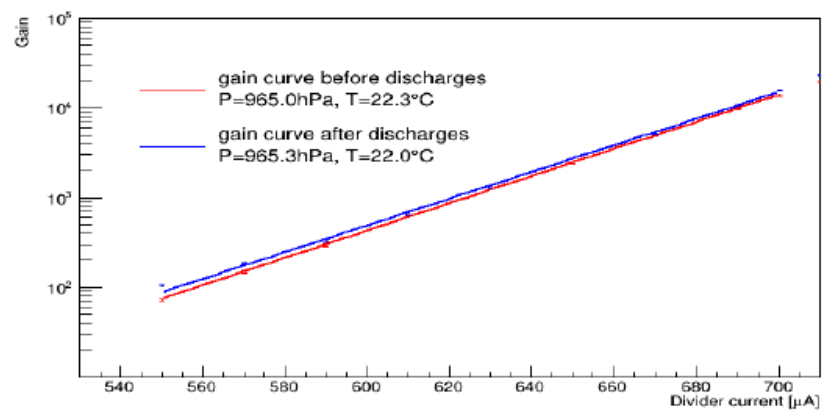
Discharge Prob. Vs. Gain, 5.5 MeV  $\alpha$



ADC distribution before/after discharge Prob. measurement



Gain curves before/after discharge Prob. measurement



## Large Foil Validation (Mecaro)

	Requirement	Measured	
Diameters	Cu: 65-75 $\mu m$ PI: 50-55 $\mu m$	Cu: 70.24 $\pm$ 0.91 $\mu m$ PI: 49.04 $\pm$ 0.79 $\mu m$	
Cleanliness	Pass QC2 fast and long	Pass since The 3 <sup>rd</sup> GE1/1	
Gain	$(1.0 \pm 0.5) \times 10^4$ @ 660 $\mu A$	$0.5 - 1.1 \times 10^4$ @ 660 $\mu A$	
Gain variance	Less than 36 %	10-16 %	
Rate capability	Larger than $2.1 \times$ $10^1 Hz/mm^2$	$1 \times 10^5 Hz/mm^2$	
Aging	Larger than 9 $mC/cm^2$	82 $mC/cm^2$	Ongoing for ME0
Discharge Prob.	Does not impede performance or operation	$2.4 \times 10^{-9} \pm 1.0$ $\times 10^{-9}$	induced discharge by $\alpha$ from $^{241}Am$

# QC protocol

- After foils produced by Mecaro, KCMS crews will perform QC protocol.
- The QC is designed based on several R&D productions

