

Fabrication of GEM foils in Mecaro (Korea) for the CMS GEM projects

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RD51 Mini-Week @ CERN

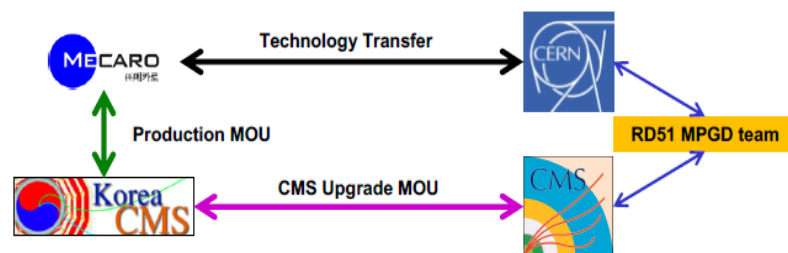
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- Overview of GEM foil production @ Mecaro
- QC results on Mecaro foils
- GE1/1 chamber with Korean foil and QC results

- Discharge Prob. and robustness measurements with $10\text{cm} \times 10\text{cm}$ chamber

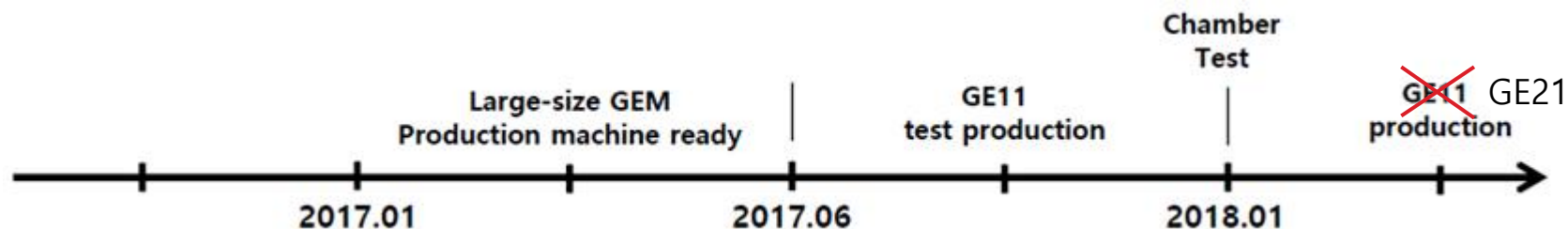
1 Overall Info. about GEM foil production @ Mecaro

- KCMS and Mecaro have worked on GEM foil production since 2012.
 - Two batches of test productions of GE11 foils.
Validation: ongoing.



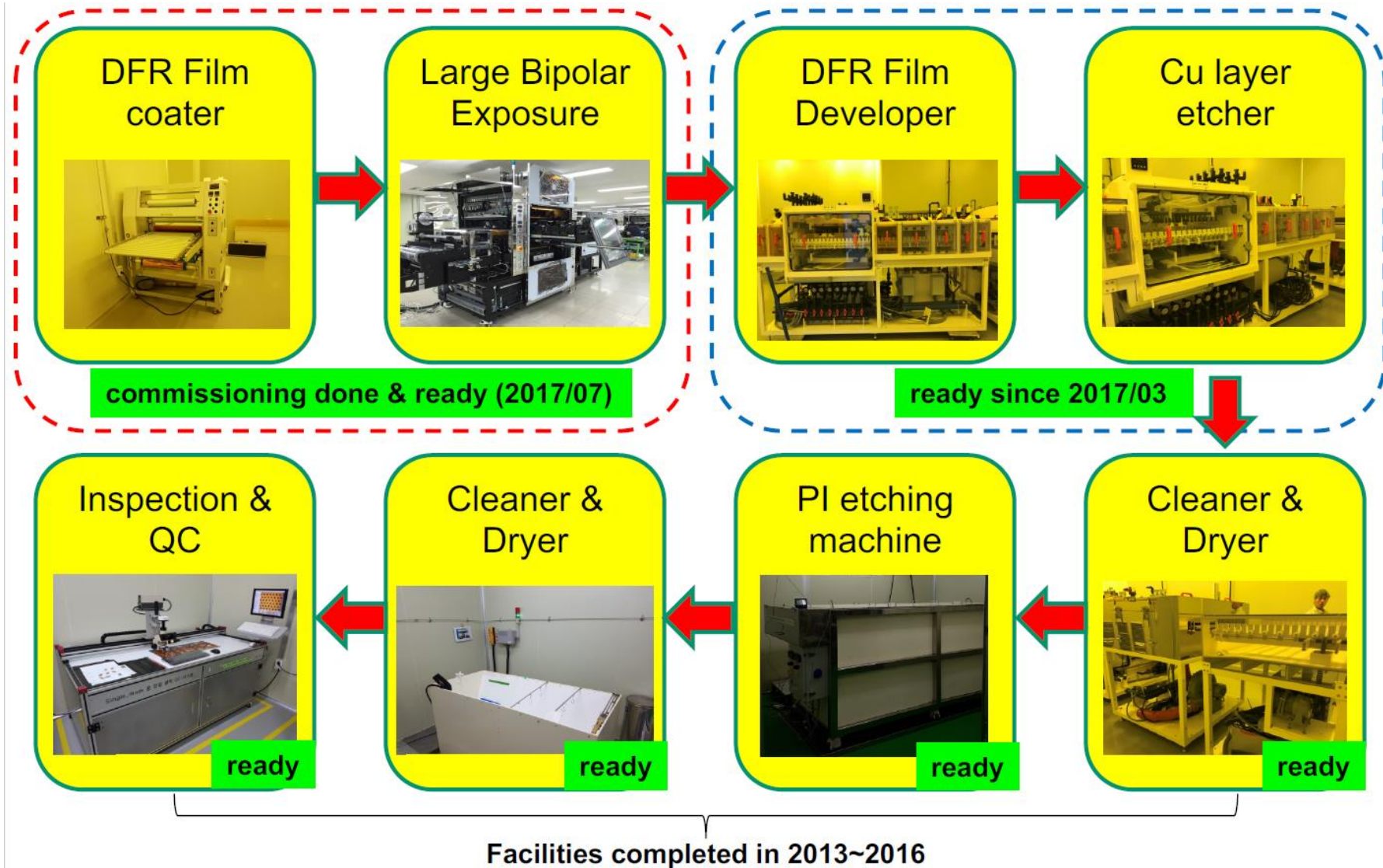
The result of the validation will be shown.

- Goal: supply GE21 and ME0 foils.



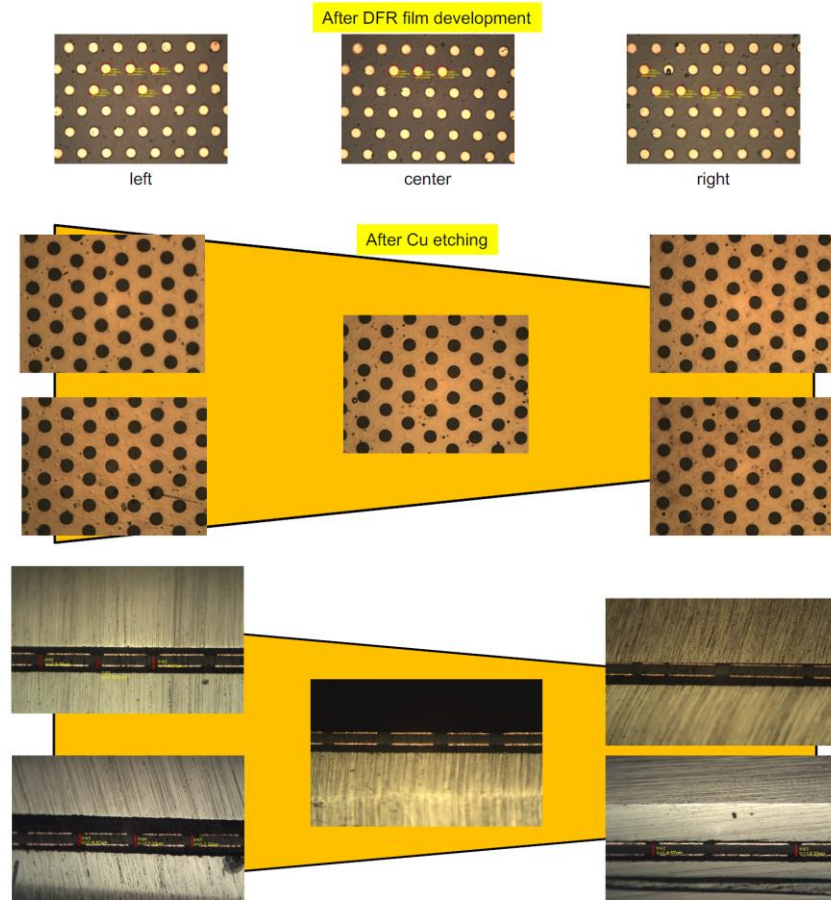
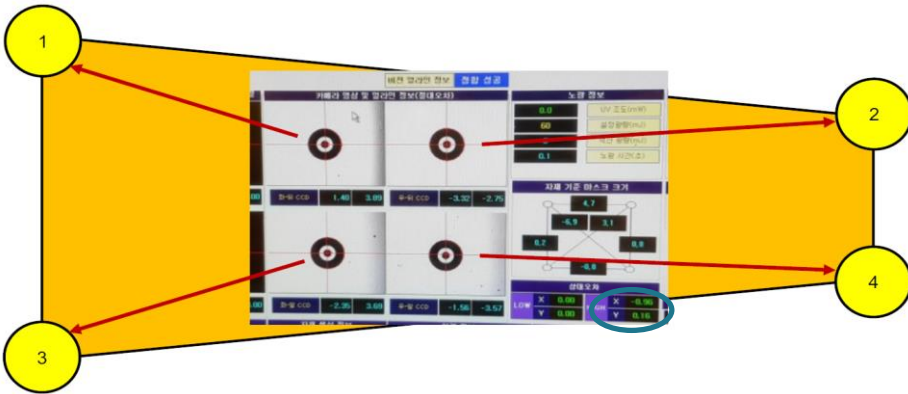
- Mecaro produces GEM foils with double mask technique.
 - Thanks to the double mask technique and automated machines, production rate is expected to be fast.

1 Overall Info. about GEM foil production @ Mecaro



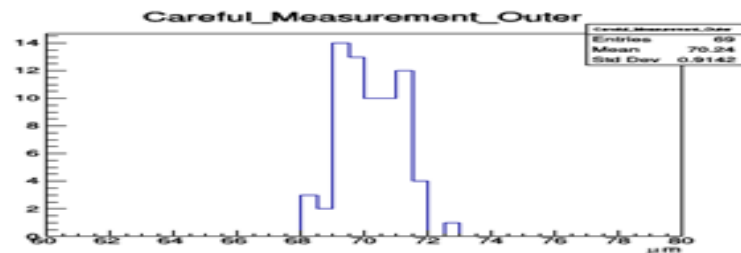
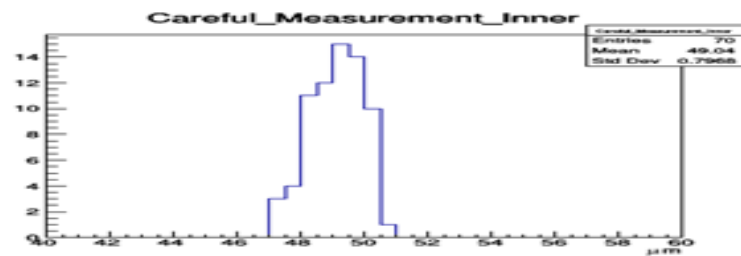
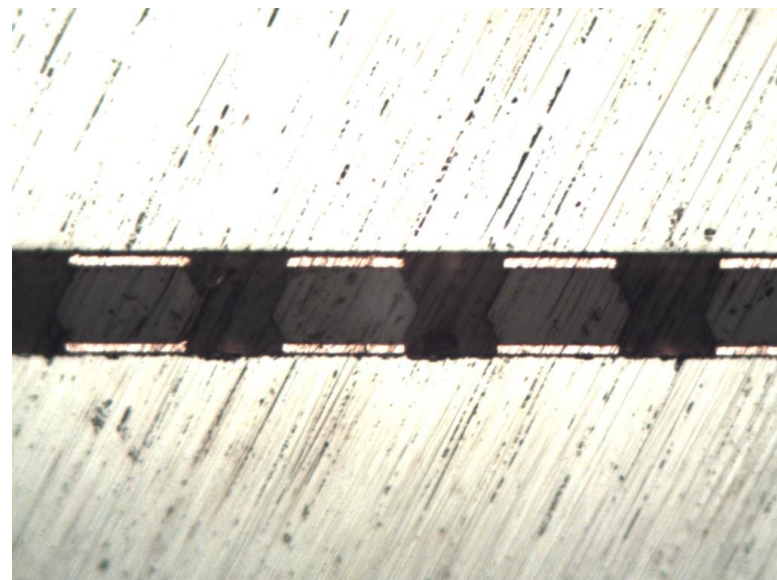
1 Overall Info. about GEM foil production @ Mecaro

- With the large bipolar UV exposure, foil up to $1300\text{ mm} \times 610\text{ mm}$ (machine size $1379\text{ mm} \times 813\text{ mm}$) is producible with residual misalignment $< 3\mu\text{m}$.
- Four bifocal microscope on corners are used for mask alignment



1 Overall Info. about GEM foil production @ Mecaro

- Hour glass shaped hole with
Inner hole diameter: $49.04 \pm 0.79\mu m$,
Outer hole diameter: $70.24 \pm 0.91\mu m$.
- Metallurgy test is ongoing to understand the detail of hole.
 - Waiting for nice microscopic pictures.
- Position-by-position holes size variation will be measured in soon to understand gain variation.



2 Summary of QC results on Mecaro GE11 foils

- Until now 23 (14+9) foils have been delivered.
 - Delivery of batch #1: 2017, Dec., 2nd
14 foils (including 1 bad foil for metallurgy test) delivered.
 - Delivery of batch #2: 2018, Jan., 29nd
9 foils delivered.
- Pasting silver epoxy on HV contact was missed for batch#1.
 - Epoxy was pasted and foils were recleaned @ Rui's Lab.
 - That's the reason of batch #2 foils were delivered.
- Batch #2 foils delivered 904 directly. QC has started.
 - Major problem found: only 3 foils passed QC2-Long. The 6 became short.
 - 6 foils were recleaned @ Rui's Lab and recovered. (QC2-Long not yet)
 - Currently we think cleaning process of Mecaro should be modified.



2017, Dec, 2nd
@ Geneva airport

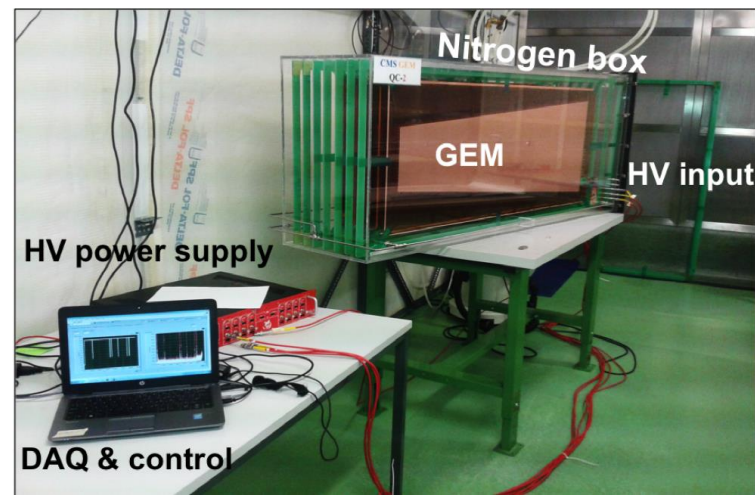
2 Summary of QC results on Mecaro GE11 foils

- Quality of hole size and hole uniformity is checked by Rui.
 - Via eye and microscope inspection, no major problem was found.
- Several minor defects.
 - 1) Soldering quality of SMD resistor.
 - 2) Dirty or even cut HV line: solved by thicker DFR for 2nd Cu etch.
 - 3) Strange PI dissolution problem: not observed in batch #2 foils.



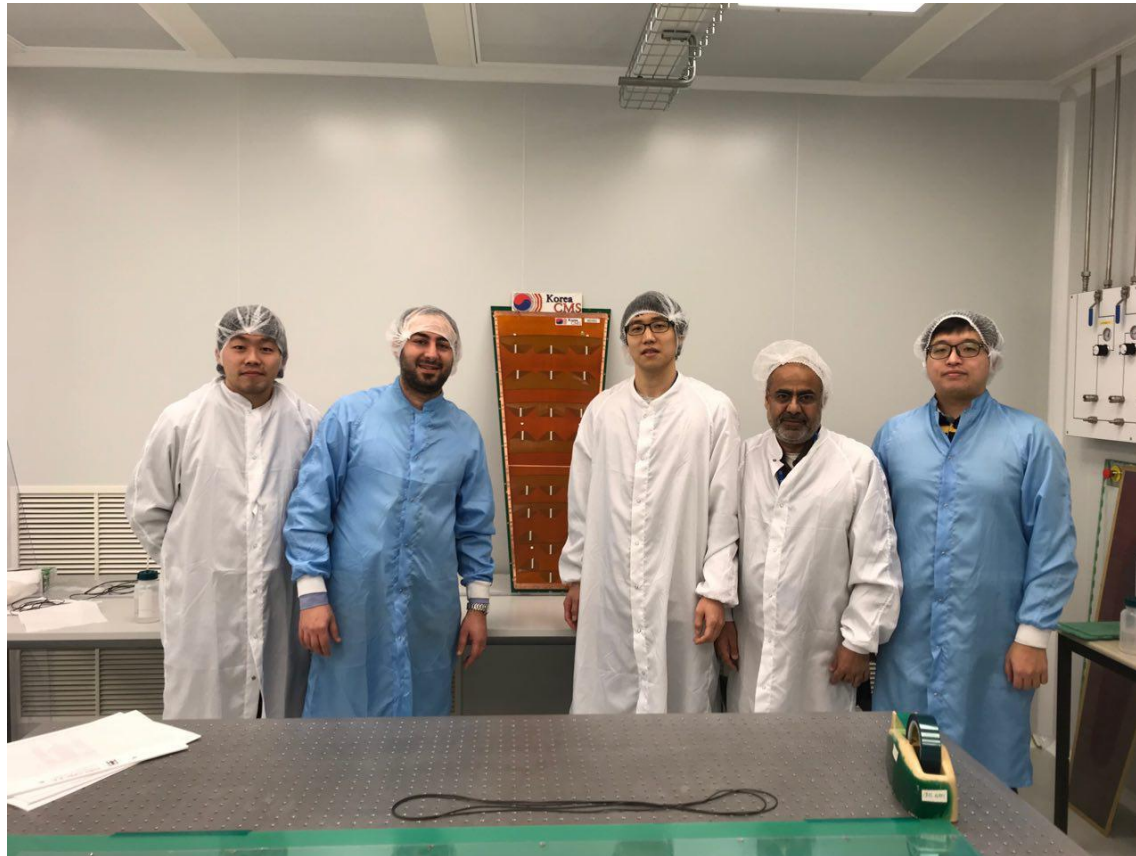
2 Summary of QC results on Mecaro GE11 foils

- Major problem: low QC2-Long pass prob.
- QC2-Long: long term (6h) leakage current measurement at high HV.
 - Procedure: ramp HV gradually up to 615V with $RH < 7\%$.
 - Goal: no short, no or a few discharges, leakage current $< 3\text{nA}$.
- At first, every batch #2 foils became short.
With intensive “electroburning”, 3 foils passed.
The 6 foils were recleaned @ Rui’s lab.
- We suspect cleaning process of Mecaro is not enough.
 - For batch #1 foils, Prob. $\sim 70\%$.

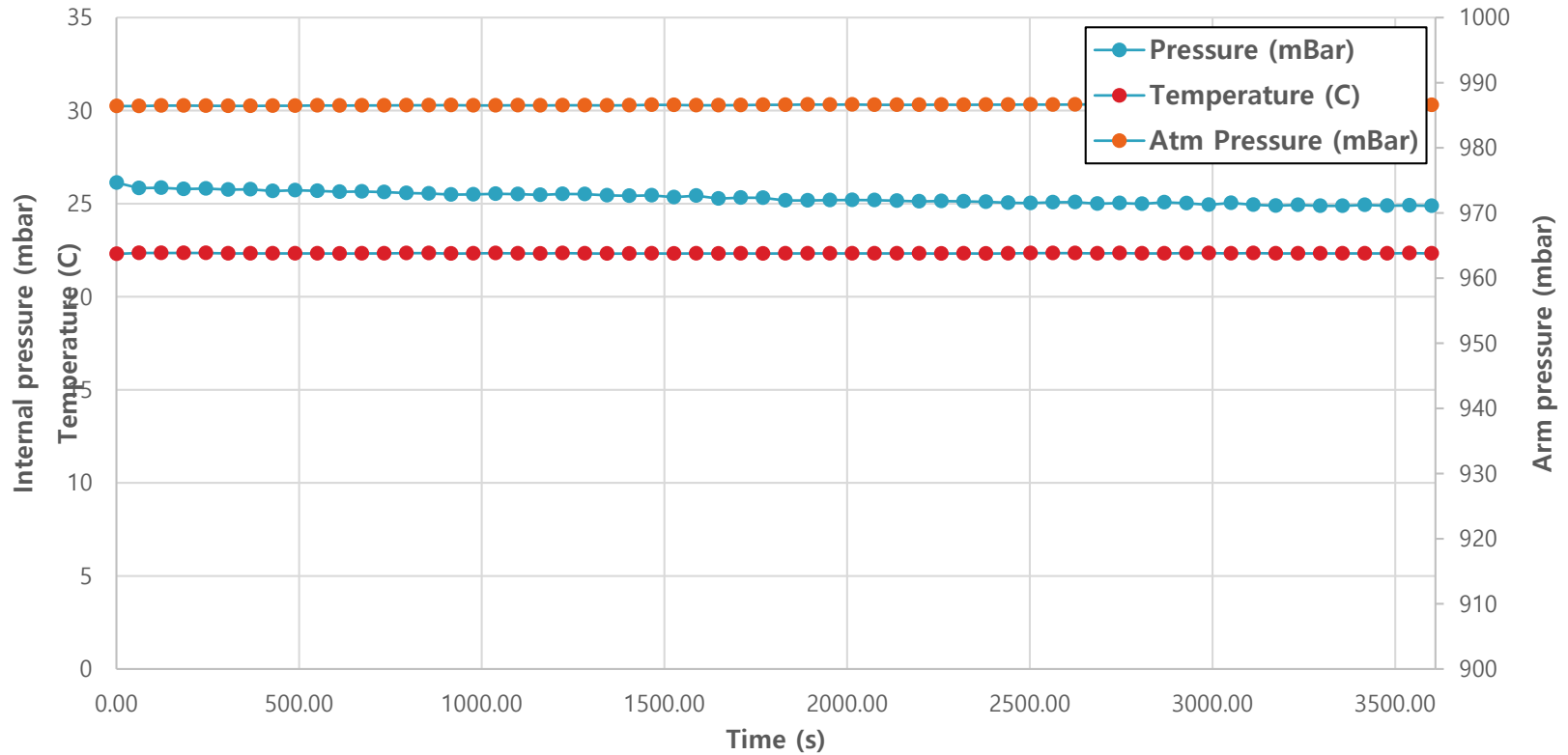


3 Building Korean GE1/1 chamber

- The first Korean GE1/1 chamber was assembled with the three Mecaro foils on 2017, Dec., 20th.

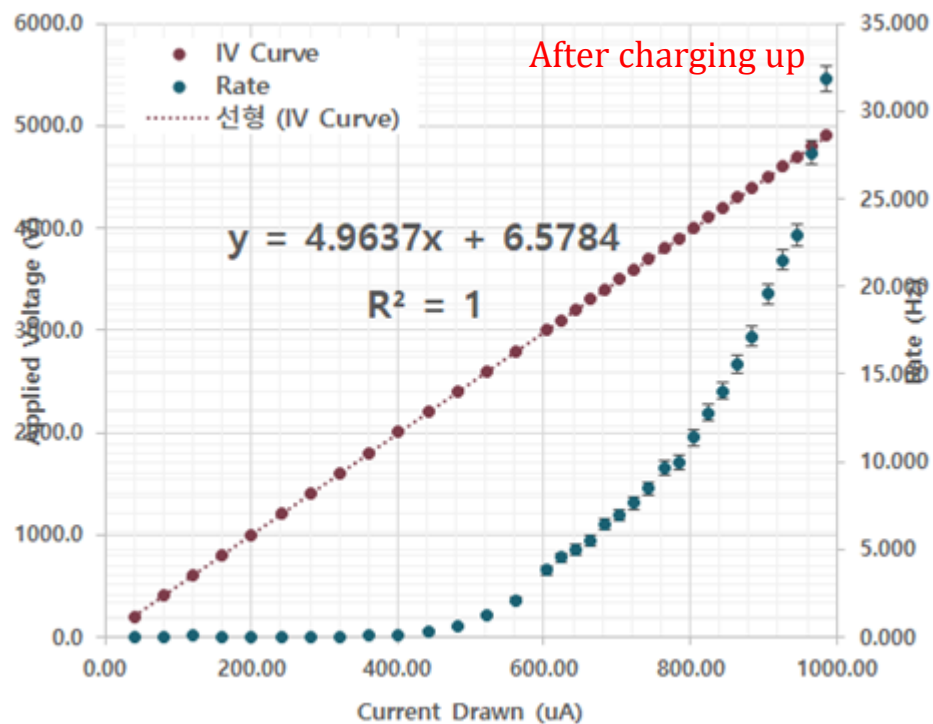


4 QC3, gas leak test on the Korean GE1/1 chamber



- 1 mbar drop was observed for Korean chamber.

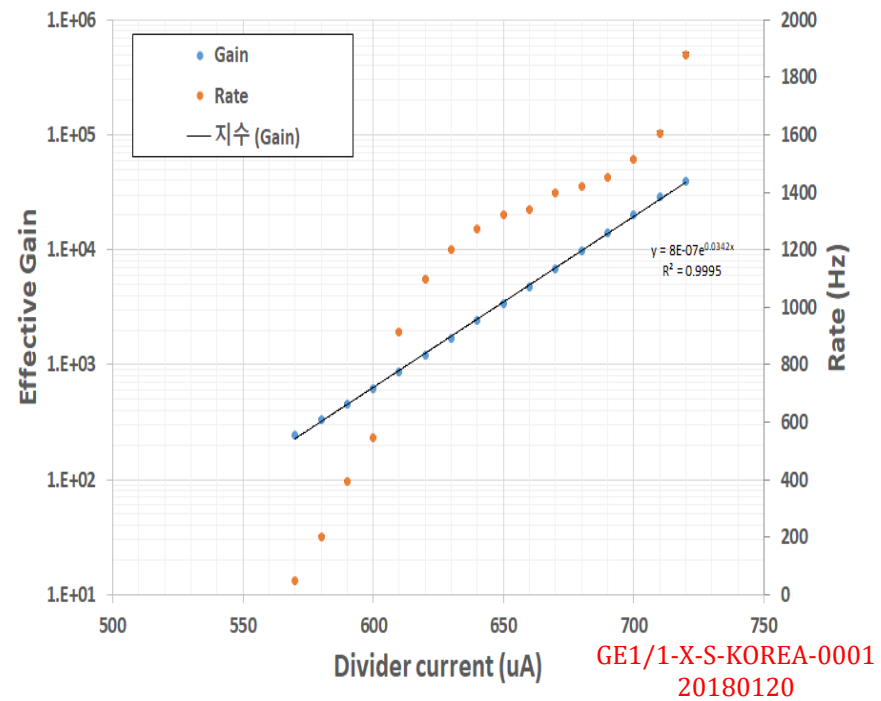
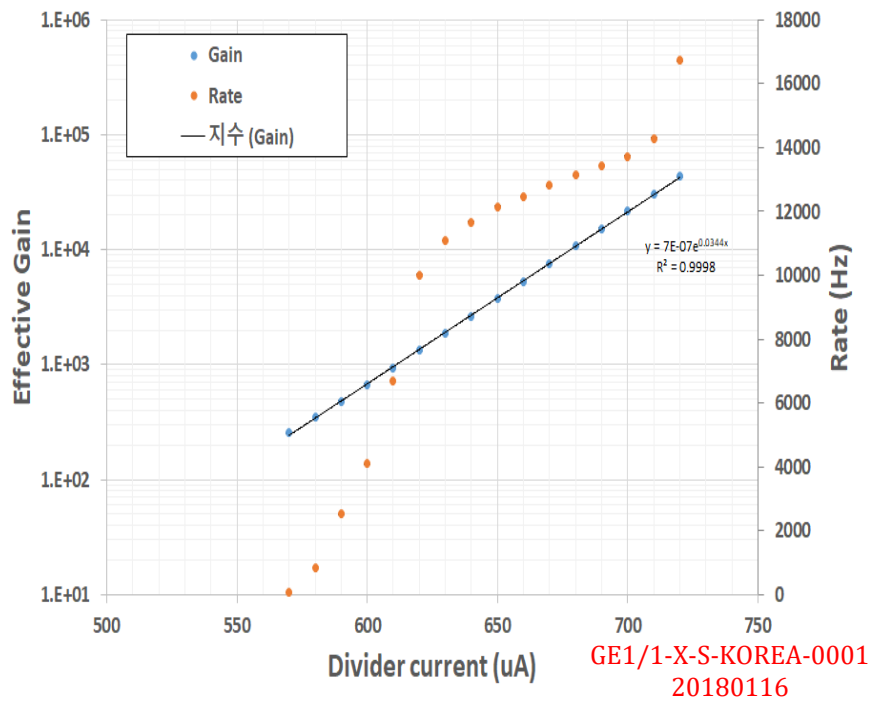
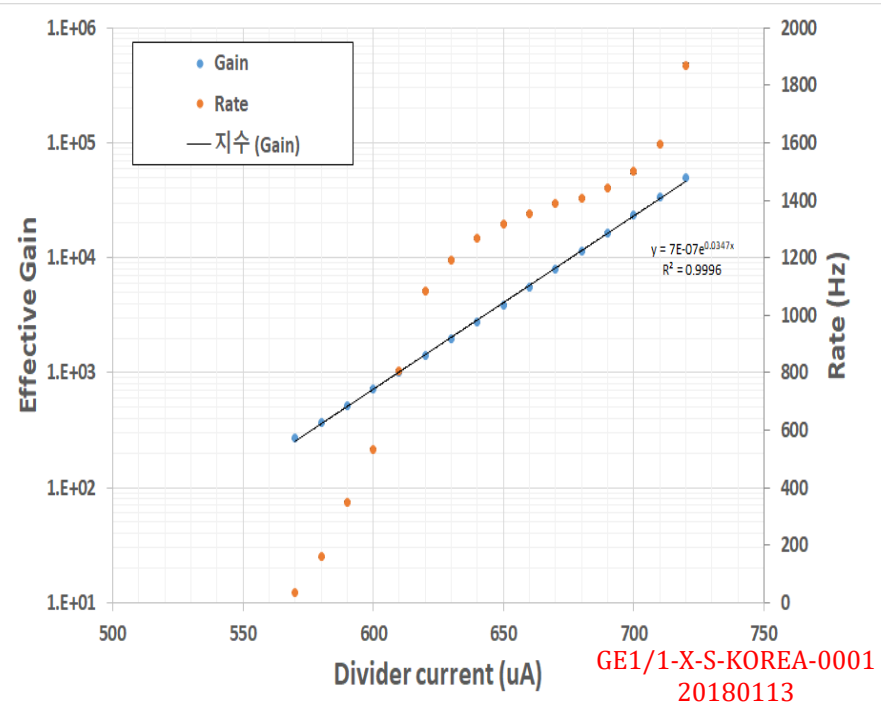
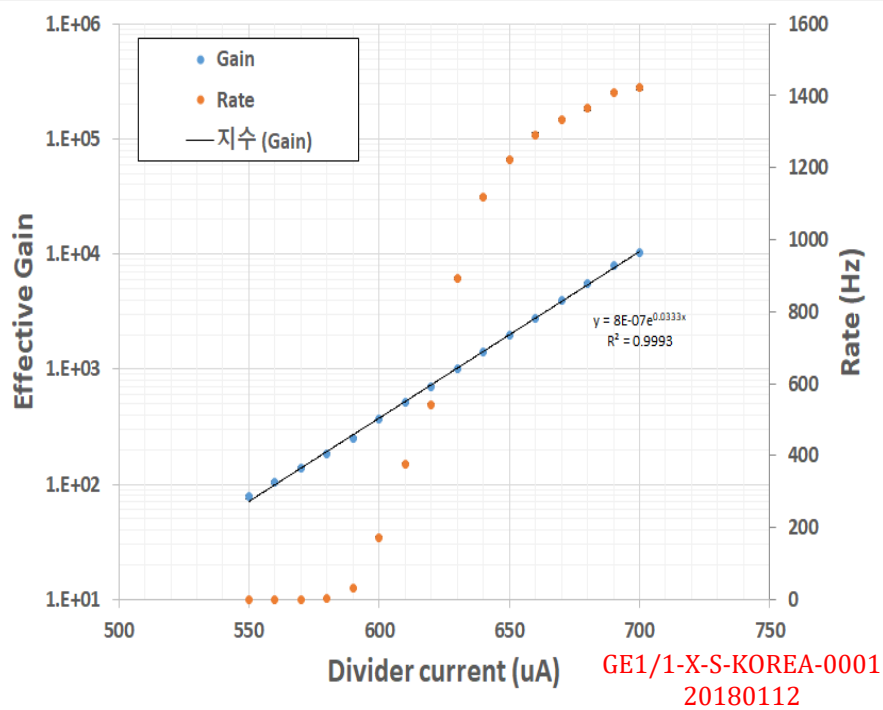
5 QC4, I-V curve and noise rate measurement



- I-V curve was ok. No discharge was observed up to 5kV.
- Noise rate was also ok after charging up.

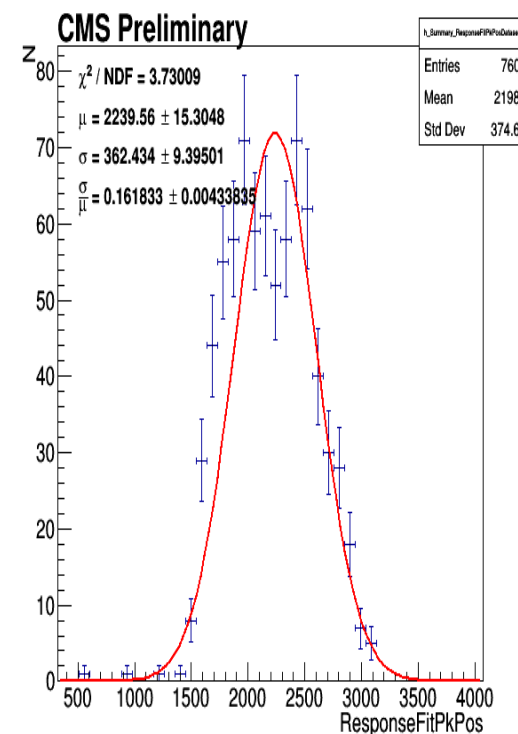
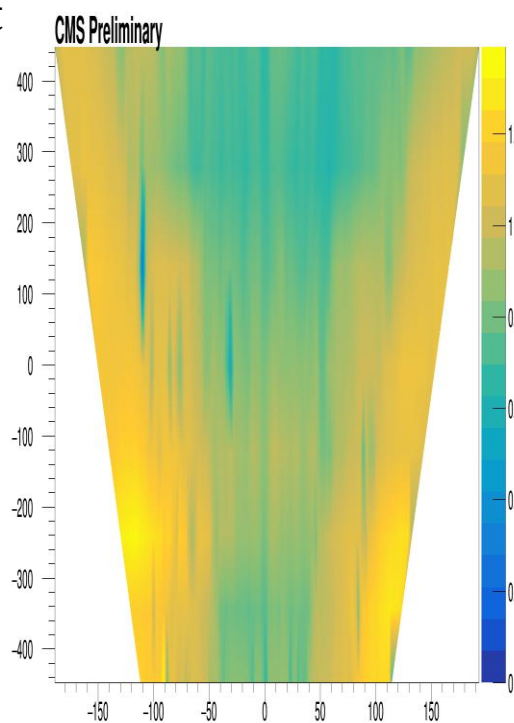
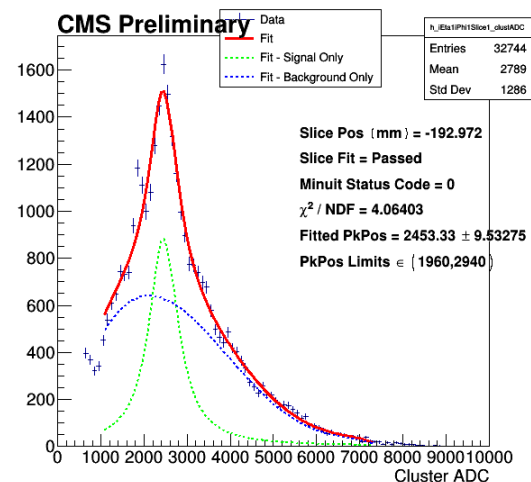
5 QC5 – the effective gain measurement

- The gain curves were measured 4 times.
 - The first measurement (Jan. 12th) shows 2 times lower gain than CERN chamber.
FYI, typical gain of CERN chamber 2×10^4 @ $700\mu A$.
 - The other measurements show consistent result with CERN chambers.
- We are trying to understand the reason of low gain was observed. However exact clue isn't found yet.
 - mistake or environment factor ??



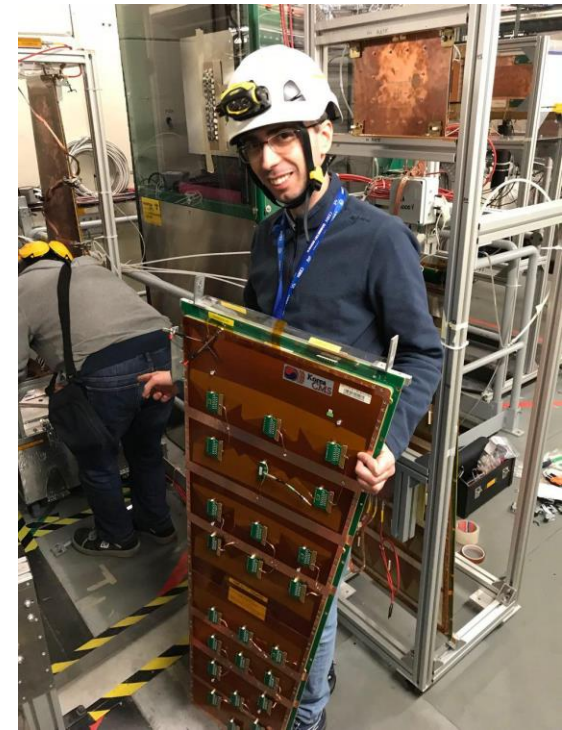
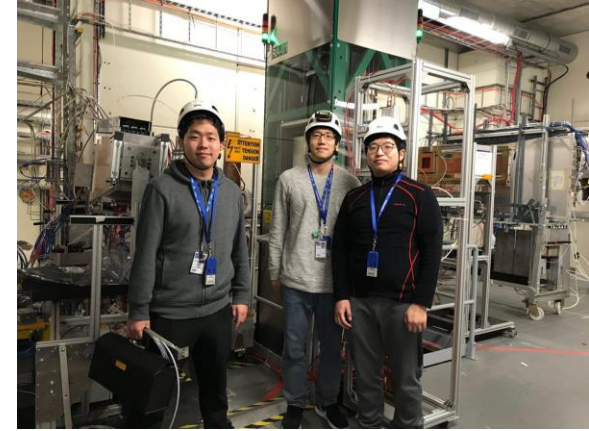
5 QC5 – the gain uniformity measurement

- Gain variance: 16%.
 - Slightly above TDR requirement (15%).
- The result doesn't imply the quality of foil is bad.
 - Key factor: not only foil quality but also PCB bending and foil sagging.
 - Many CERN chamber also show a bit higher gain variance.
- Further study i.e. hole size variance map will be done.



6 Aging test @ GIF++

- Installed in GIF++ on 2018, Jan., 24th.
- Dtaking is started.
 - 1 month is needed to reach GE21 requirement with safety factor 3.



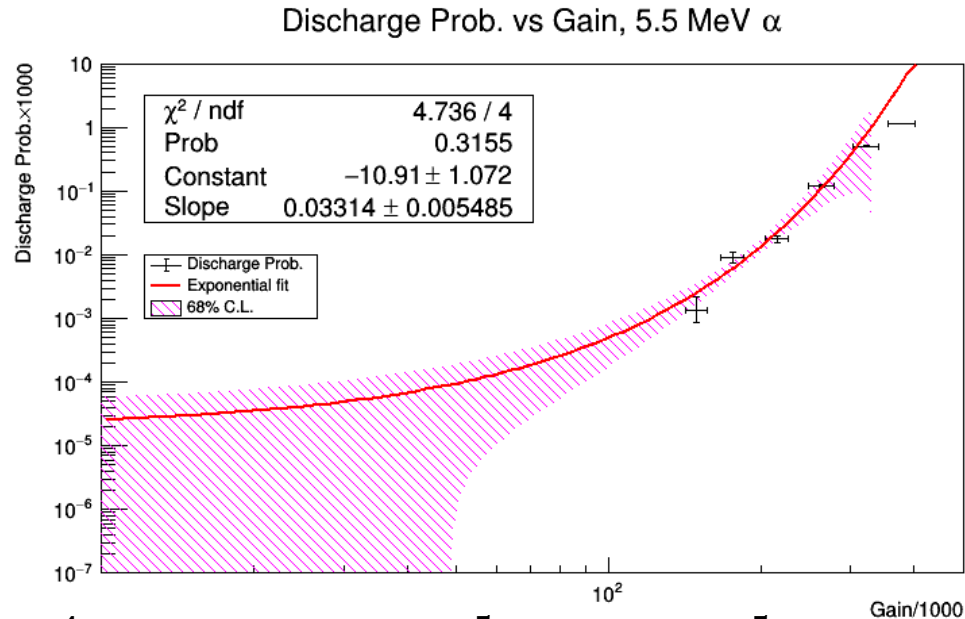
7 The performance measurement with 10*10cm chamber

- Discharge probability measurement are done with 10cm*10cm chamber.
The 10cm*10cm foil (produced in 2014) and GE1/1 produced with difference UV exposure. Those only share PI etching procedures!!
- Discharge Prob.
 - Prob. measurement itself is very preliminary.
 - Gain isn't affected by discharges.

7 The performance measurement with 10*10cm chamber

- Poor statistics.

The result might be biased due to previous rate capability measurement.

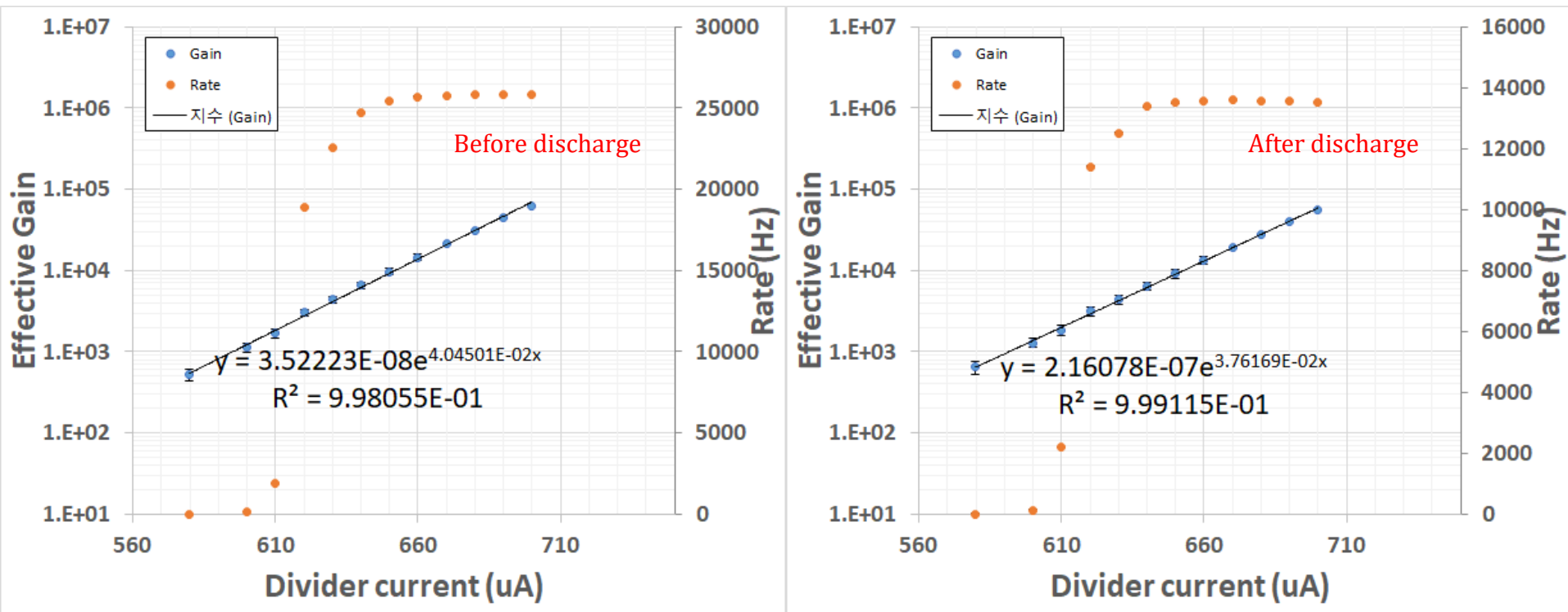


X-axis is 1000 times scale down and Y-axis is 1000 times scale up!!

- At $gain = 1 \times 10^4$, $Prob. = 2.5 \times 10^{-5} \pm 3.2 \times 10^{-5}$
At $gain = 2 \times 10^4$, $Prob. = 3.5 \times 10^{-5} \pm 4.2 \times 10^{-5}$

- For MIP, discharge Prob. is 1/100 times smaller.

7 The performance measurement with 10*10cm chamber



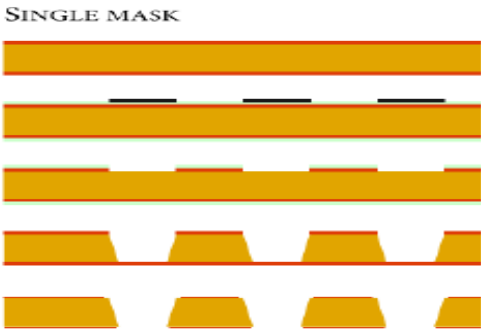
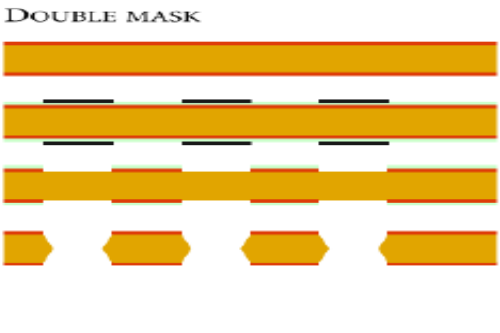
- During the measurement, we've observed at least 15,000 discharges. However no degradation of chamber performance is observed.

8 Summary

- KCMS and Mecaro produce GEM foil with double mask technique and plan to supply GE21 and ME0 foils.
- Two batches of Mecaro foils have been delivered.
 - Several minor problems were found. The symptoms are reported to Mecaro.
 - Cleaning process might be modified.
- Chamber with Mecaro foil has been assembled. Validation is ongoing.
 - Gain and its uniformity of Korea chamber is as good as CERN chamber.
 - Aging test is ongoing.
- Measurement with $10\text{cm} \times 10\text{cm}$ foils
 - Foil is robust to many discharges.

Back up

1 Overall Info. about GEM foil production @ Mecaro

	Single mask	Double mask
Production method	 <p>SINGLE MASK</p>	 <p>DOUBLE MASK</p>
Mask alignment	No need (film)	Crucial (glass)
Cost of necessary machines	Cheep	Expensive
Foil size	No limit	Limited by machine
Production process	Complicated	Simple
Production time	Long	Short
Labor cost	Expensive	Cheep
Robustness to FCCL quality	Vulnerable	Robust

Summary of Mecaro batch #1 foils status

Foil #	Eye inspection	QC2_Fast	QC2_Long	Comment
1	⊙	⊙ (25GΩ)	⊙	In the Korean-0001 chamber (GEM2)
2	⊙	⊙ (19GΩ)	⊙	
3	⊗ (bad wrinkle)	⊗	-	Missed PI around wrinkle, return
4	⊙	⊙ (15GΩ)	⊗	Short after discharge during QC2 long, optical inspection needed
5	⊙	⊙ (18GΩ)	⊙	In the Korean-0001 chamber (GEM1)
6	⊙	⊙ (30GΩ)	⊙	Short after discharge during QC2 long. Recovered now.
7	⊙	⊙ (21GΩ)	⊙	
8	⊙	⊙	⊙	Short after discharge during QC2 long. Recovered and finally passed QC2 long In the Korean-0001 chamber (GEM2)
9	⊗ (bad wrinkle)	⊗	-	Missed PI around wrinkle, return
10	⊙	⊙ (21GΩ)	⊗	Short after discharge during QC2 long High current 100nA@450V, reclean needed
11	⊙	⊙ (15GΩ)	⊗	a bit large current ~6nA during QC2_Long, reclean needed.
12	⊙	⊗	-	Destroyed during silver epoxy work
13	⊗ (bulk defect)	-	-	Known as bad. For metallurgy test
14	HV line cut, restored.	⊙	⊙	HV line restored by silver epoxy

Summary of Mecaro batch #2 foils status

Foil #	Eye inspection	QC2_Fast	QC2_Long	Comment
1	⊙	⊙(24GΩ)	⊗	Sparks@600V
2	⊗	⊙(25GΩ)	⊗	Sparks@600V
3	⊙	⊙(19GΩ)	⊙	
4	⊙	⊙(20GΩ)	⊗	Short
5	⊙	⊙(12.5GΩ)	⊗	Short
6	⊙	⊙(26GΩ)	⊙	
7	⊗	⊙(~200MΩ)	-	
8	⊙	⊙(12.5GΩ)	⊙	
9	⊙	⊙(~200MΩ)	-	