

Quality validation on Mecaro GEM foils and CMS GE2/1 foils production plans

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RD51 Mini-Week @ CERN

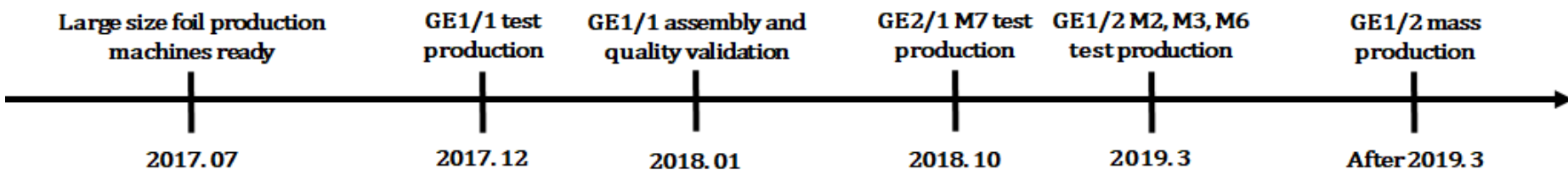


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1 Overall Info. about GEM foil production @ Mecaro

- KCMS & Mecaro consortium have been created to be a second supplier of large size GEM foils for the phase-2 upgrade of CMS.
 - Three batches of test production of CMS GE1/1 foils for quality validation.
 - One batch of test production of CMS GE2/1 M7 foils for quality validation.
- The validations show promising results.
 - Hole geometry & uniformity, gain & gain uniformity, rate capability, discharge prob. and radiation hardness were measured with Mecaro foils.
 - After validation is finished, mass production of CMS GE2/1 foils will be started.



1 Overall Info. about GEM foil production @ Mecaro

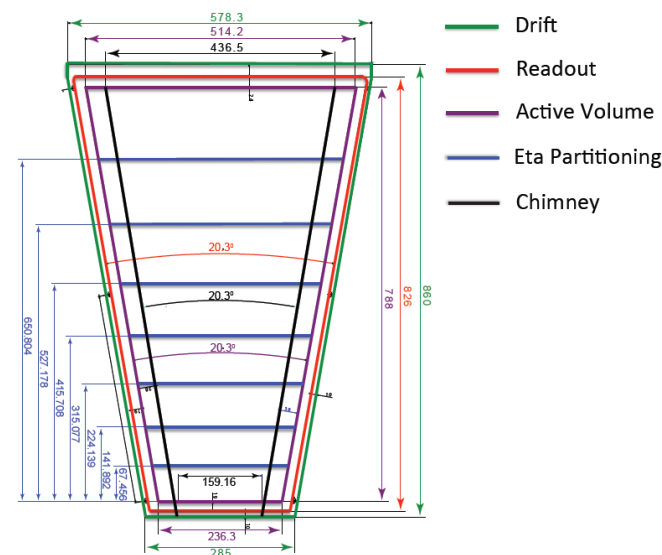
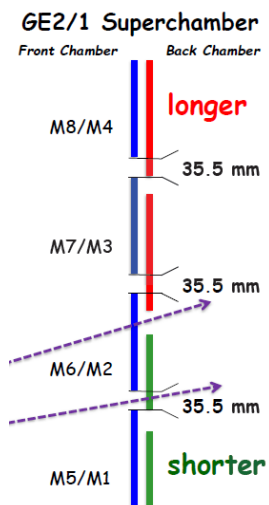
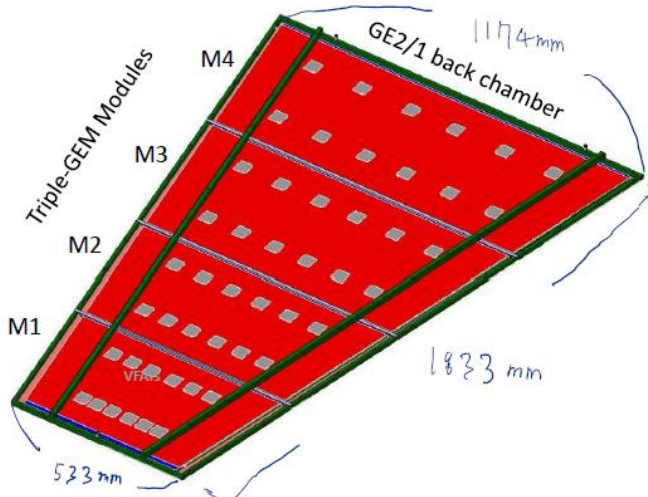
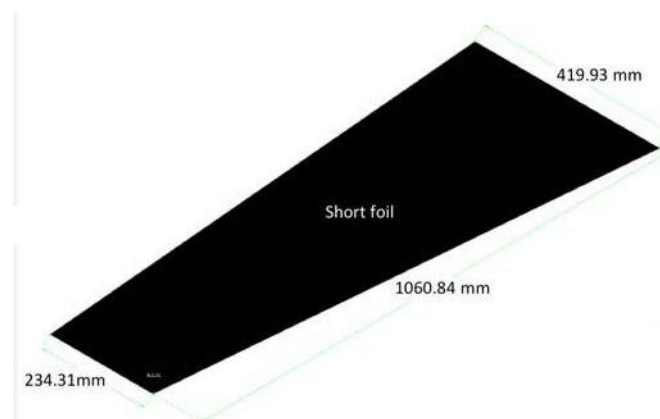
- Mecaro produces GEM foils with double mask technique.
 - Thanks to the double mask technique and automated machines, production rate is fast~10 foils/week.
 - Residual misalignment $< 3 \mu m$
 - Foil up to $1300 mm \times 610 mm$ (machine size $1379mm \times 813mm$) is producible.
- Standard geometry: diameter of Cu (PI) hole= $70 (50) \mu m$, pitch= $140 \mu m$
 - Symmetrically biconical hole.



Large size bipolar UV exposure

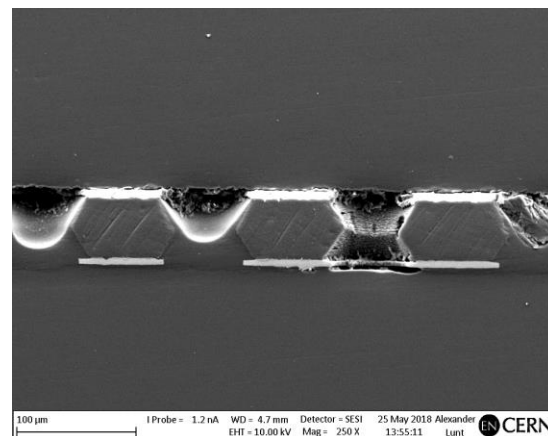
2 CMS GEM upgrade plan – GE1/1, GE2/1, ME0

- Mecaro foils will be used to build GE2/1 and ME0.
 - M2, M3, M6, and M7 of GE2/1.
- Mecaro foil quality validation is ongoing with GE1/1.
 - The larger foils, the harder to be produced.
 - If Mecaro shows capability to produce GE1/1 well, we can think Mecaro can produce GE2/1 and ME0 also.



3 Quality validation with CMS GE1/1

- PI hole diameter: $49.04 \pm 0.79 \mu\text{m}$,
Cu hole diameter: $70.24 \pm 0.91 \mu\text{m}$.
- Well calibrated manual microscope. 450 holes
- Hole uniformity with automatic CCD scanner by Matt Posik, Temple Univ.
- Not so well calibrated.

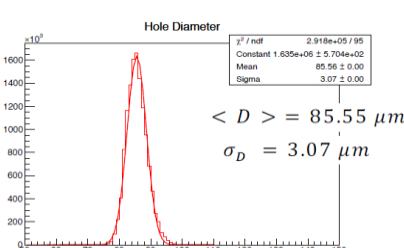
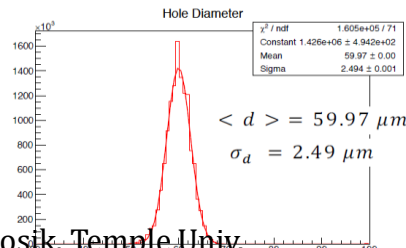
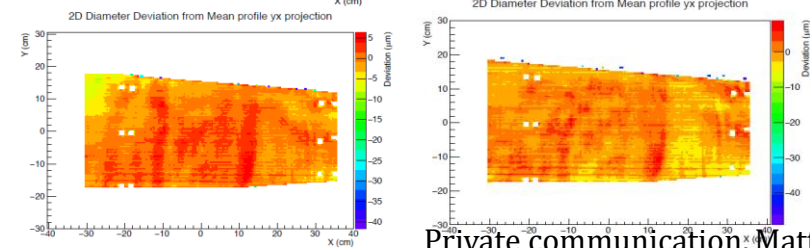
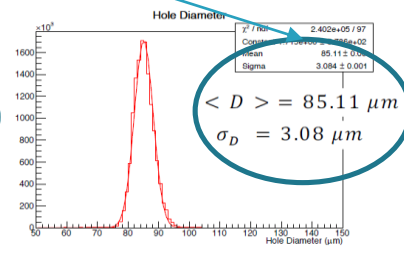
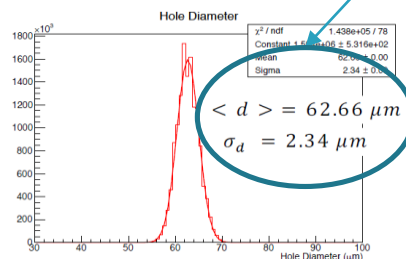
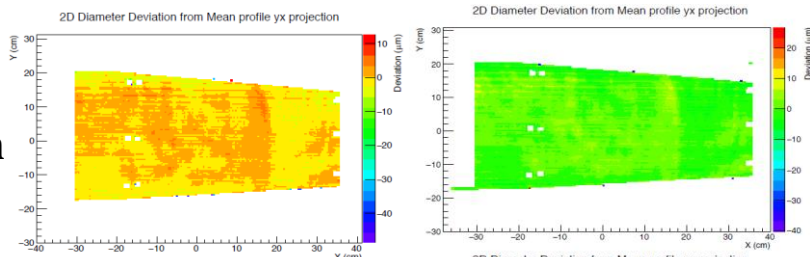


Cross section of Mecaro GE1/1 foil

Calibration wasn't correctly done. 1.2 times over measured.

PI hole

Cu hole



Bottom

Top

3 Quality validation with CMS GE1/1

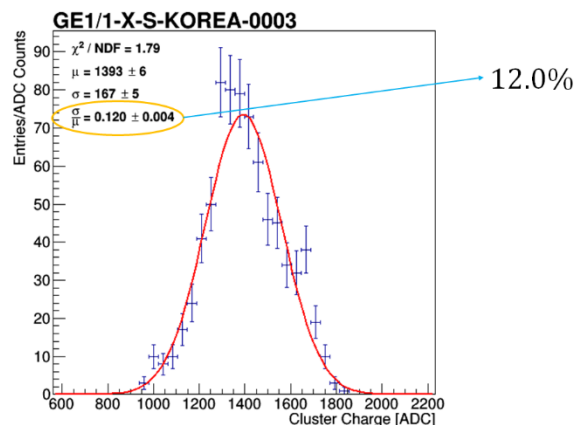
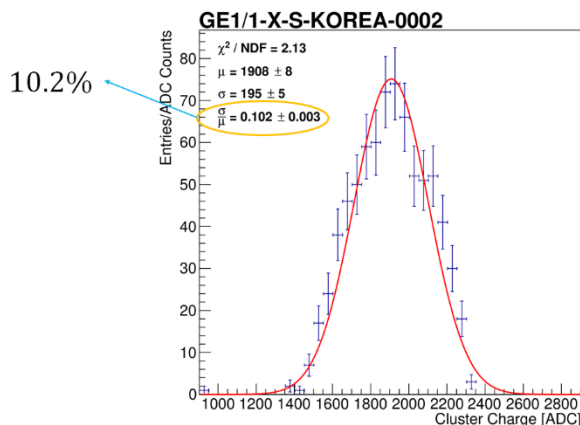
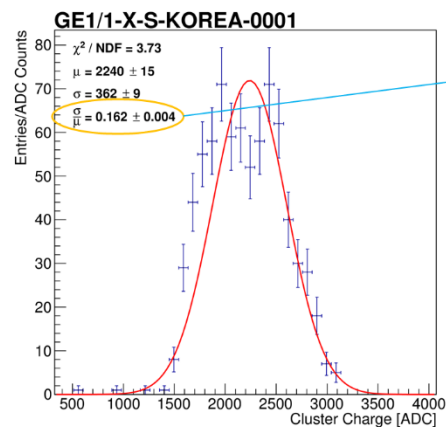
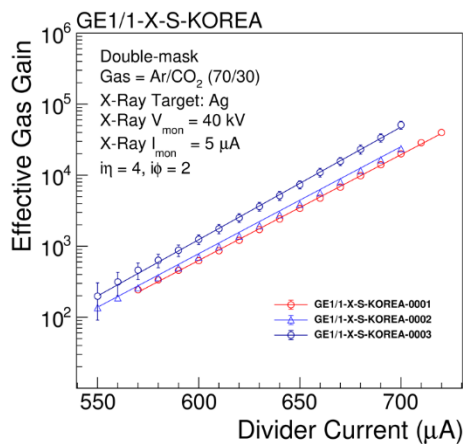
- Cleanliness of foils: “CMS QC2-Long”
 - Impedance $> 120 \text{ G}\Omega$ @ 600 V, RH $<7\%$ for 6 h wo/ sparks.
 - Mecaro foils are clean enough to pass the QC2-Long now.

- Actually, we had issue on foil cleaning at first.
 - Foil became short or sparked.
 - After we updated cleaning solution, the issue has been resolved.

- Then, chamber with Mecaro foils has been assembled.
 - Gain, gain uniformity, rate capability, radiation hardness and discharge Prob.
 - Results are quite promising.

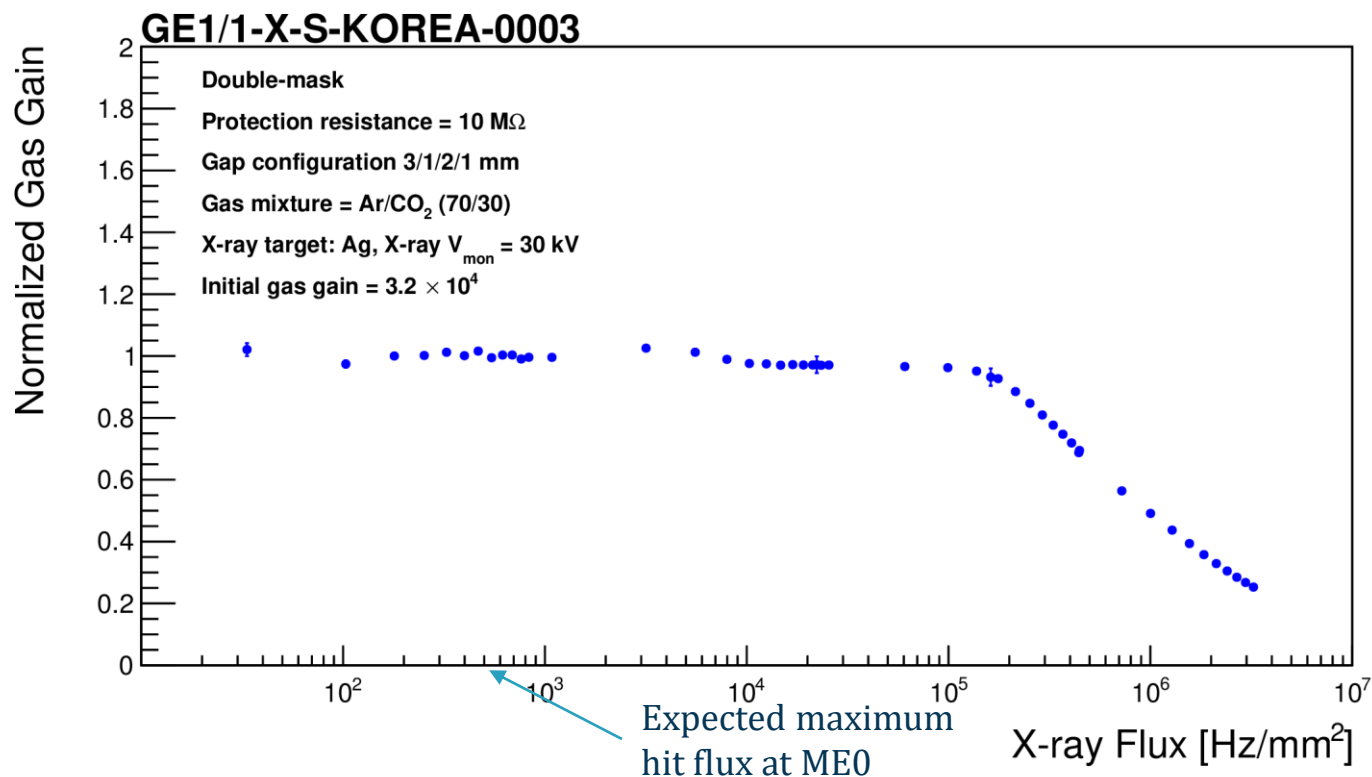
3 Quality validation with CMS GE1/1

- Gain: $2 - 5 \times 10^4$ at $700 \mu\text{A}$ (operating voltage), gain variance: 10.2-16.2 %
 - Consistent with the results of the detectors with CERN foils.



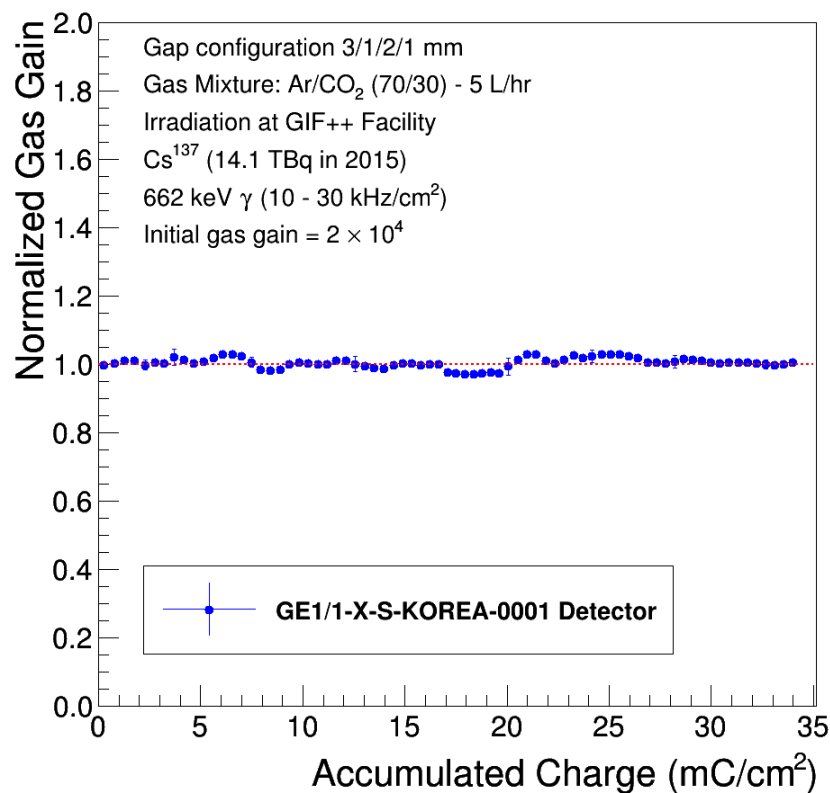
3 Quality validation with CMS GE1/1

- Gain remains stable x-ray flux up to $1 \times 10^5 \text{ Hz/mm}^2$.
 - Enough capability for the phase-2 upgrade.
 - Gain drops at very high flux because of voltage drop at protection resistor.



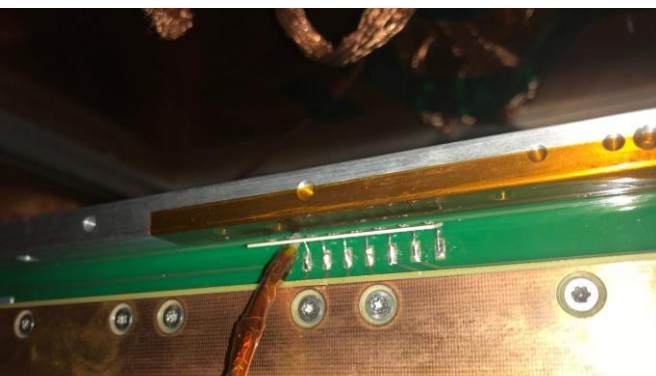
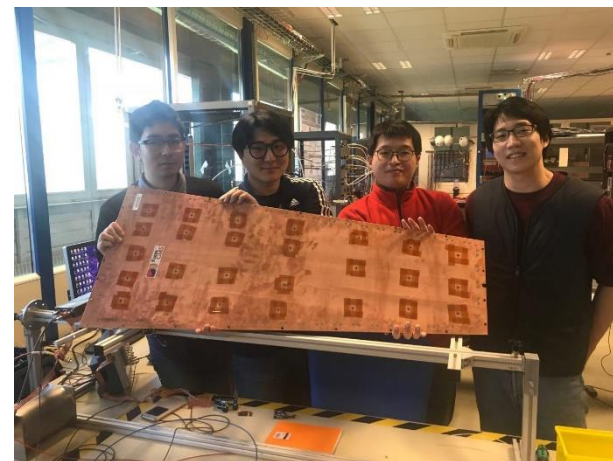
3 Quality validation with CMS GE1/1

- No gain degradation due to aging is observed up to 34 mC/cm^2 .
 - It corresponds to 113 years of GE2/1 and 1.2 years ME0 operation at HL-LHC.
 - CMS requires 30 years. So far, so good.

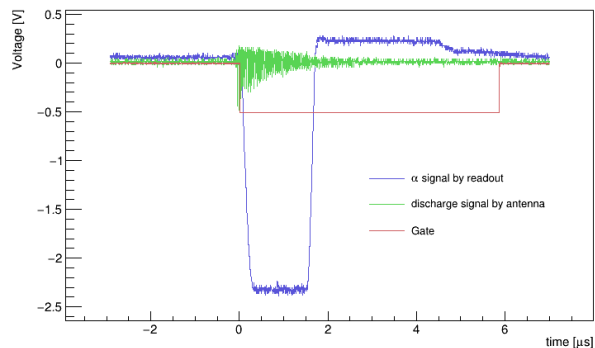


3 Quality validation with CMS GE1/1

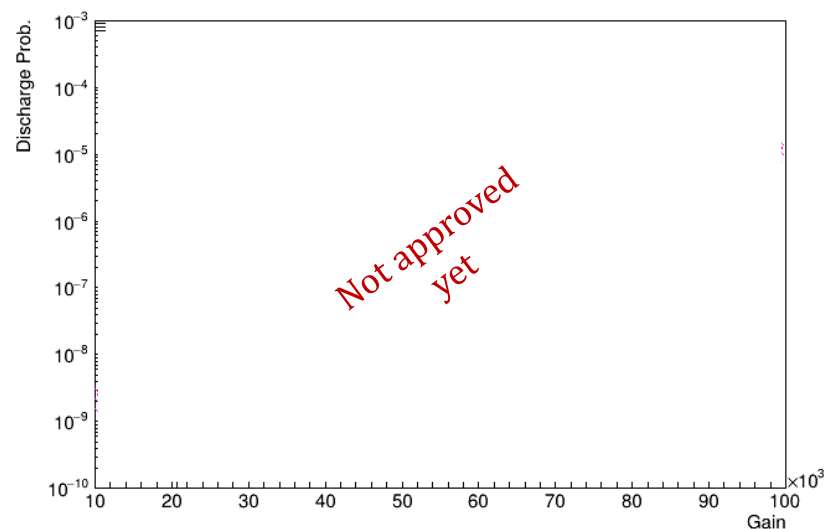
- Probability of discharge induced by α from ^{241}Am .
 - Special chamber with holes to let α enter detector.
 - Promising result has been obtained.



Signal shape of discharge induced by α

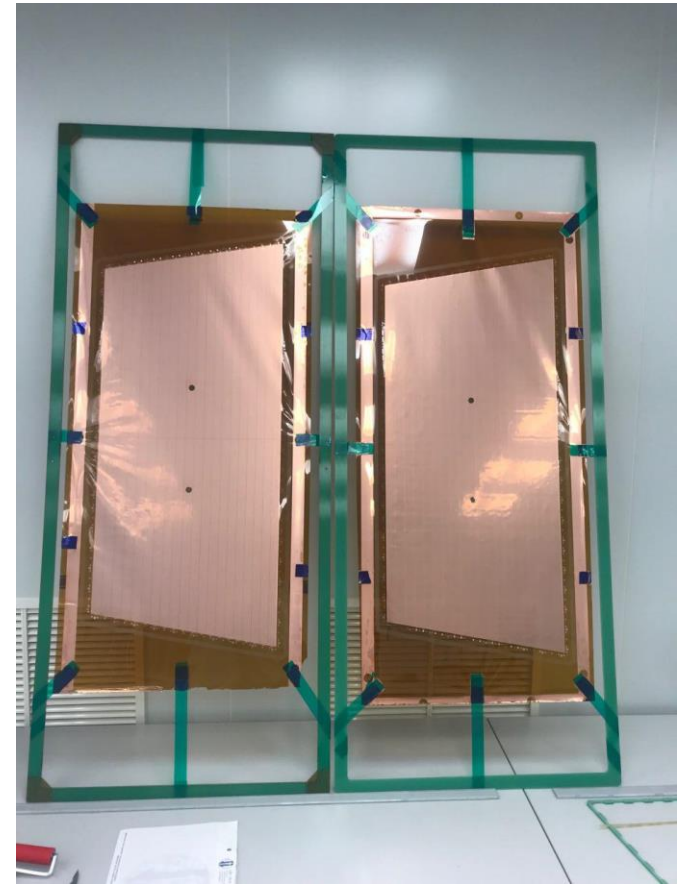


Discharge Prob. Vs. Gain, 5.5 MeV α



4 CMS GE2/1 M7 production and QC results

- As validation is being proceeded well, Mecaro is considered to be capable of producing GE2/1 foils.
- GE2/1 M7 foils has been produced and delivered on 23th, Oct. 2018.
 - Cleanliness test (QC2-Long); foils have passed QC2-Long smoothly.
 - Several hole diameter measured; diameters of PI holes were measured to be slightly smaller.
⇒ PI etchant and etching processes will be reviewed.
 - Due to delayed production of RO, chamber assembly hasn't been done yet.



5 Further production plans

- Test production of CMS GE2/1 M2, M3, M6 will be done until Feb.
 - Full CMS GE2/1 assembly and final validation should be done by Mar. 2019.
- Mass production
 - After test production for validation over, mass production should be started immediately.
 - First 24 pieces of each four modules should be delivered until Aug., 2019.
 - In total, 114 pieces of each four modules will be produced to build 38 CMS GE2/1 detectors(=36+1(test bench)+1(spare)).
 - After GE2/1 production over, ME0 production will be started.
- Mecaro is being ready for mass production.



6 Summary

- Mecaro produces large size GEM foils for CMS phase-2 upgrade.
- Quality validation is ongoing with CMS GE1/1 chamber.
 - Promising results were obtained.
- Mecaro produced CMS GE2/1 M7 foils for validation.
 - Foils has passed QC2-Long smoothly.
 - Other modules will be produced until Feb. 2019.
- Mass production for GE2/1 assembly will start from Mar. 2019.
 - 114 foils of each four modules will be produced by Mecaro.

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