Commercial large size GEM foil production at Korea for the CMS GEM upgrade and others

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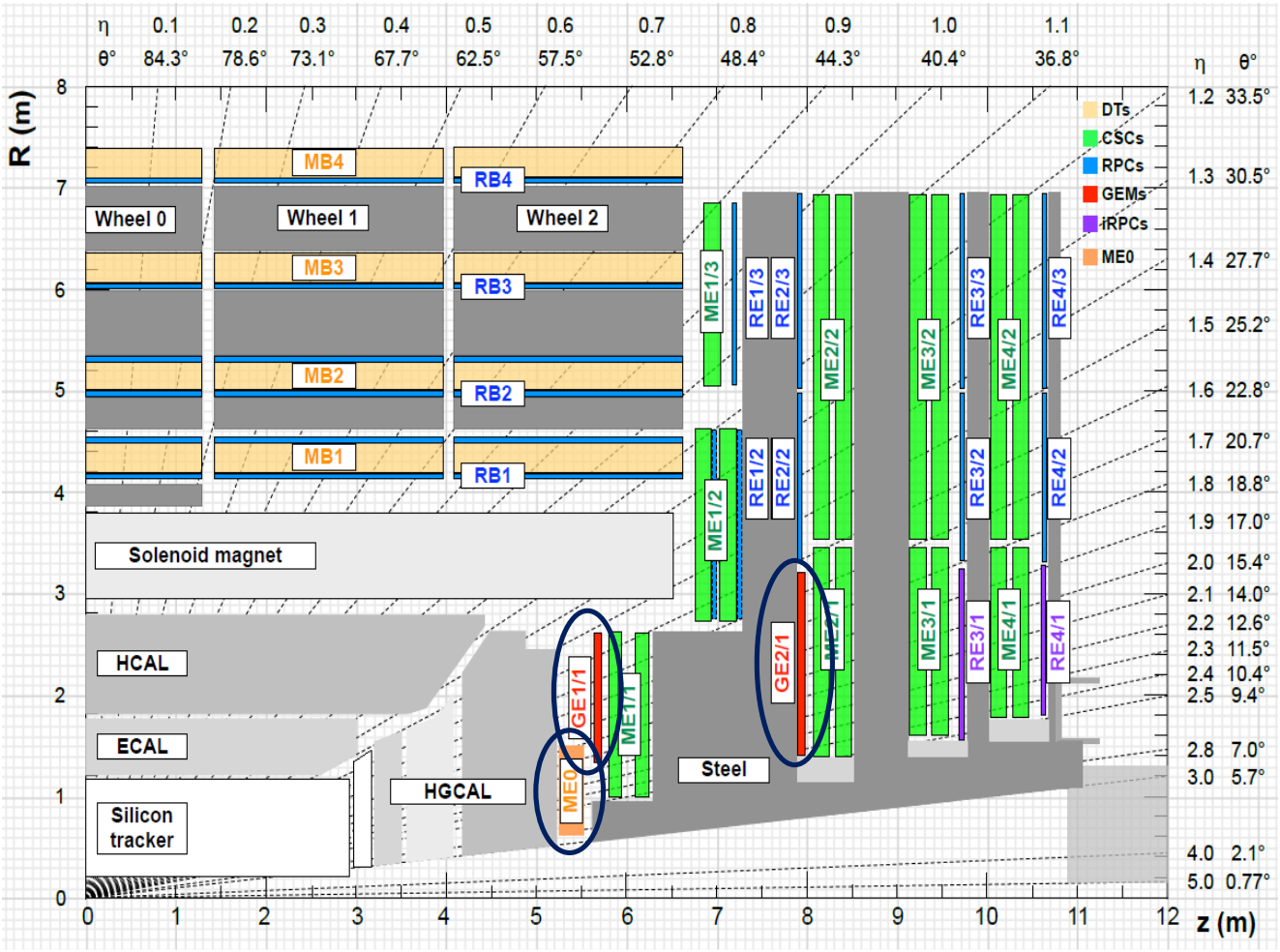
5th Japan-Korea PHENIX/sPHENIX/EIC collaboration meeting

@ Sejeong University

Contents

- The CMS phase-2 GEM upgrade
- GE1/1, GE2/1, and ME0 detectors
- GEM foil production @ Mecaro
- Quality validation with CMS GE1/1
- Mass production plan
- QC at Mecaro

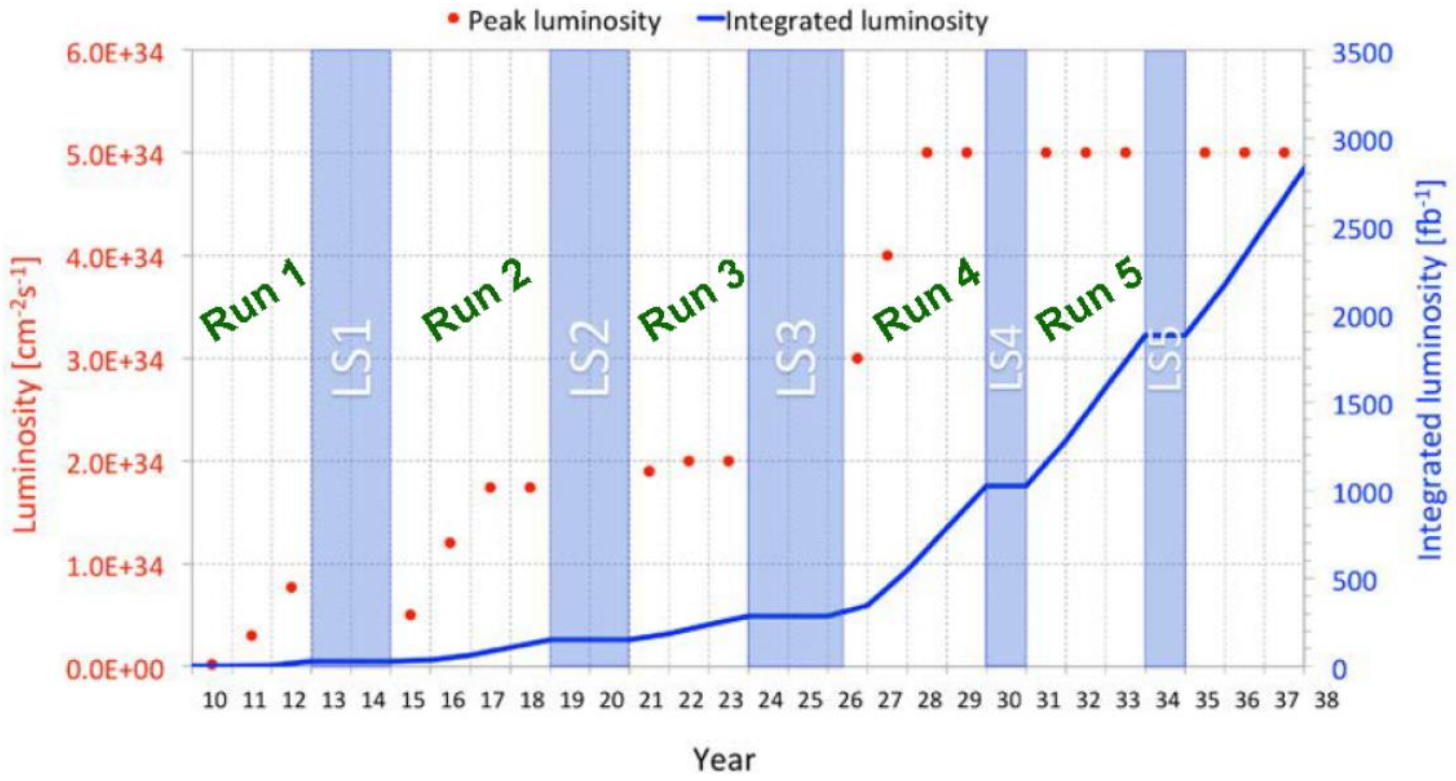
1 The CMS phase-2 GEM upgrade



- Three stations of GEM detectors; GE1/1, GE2/1, ME0

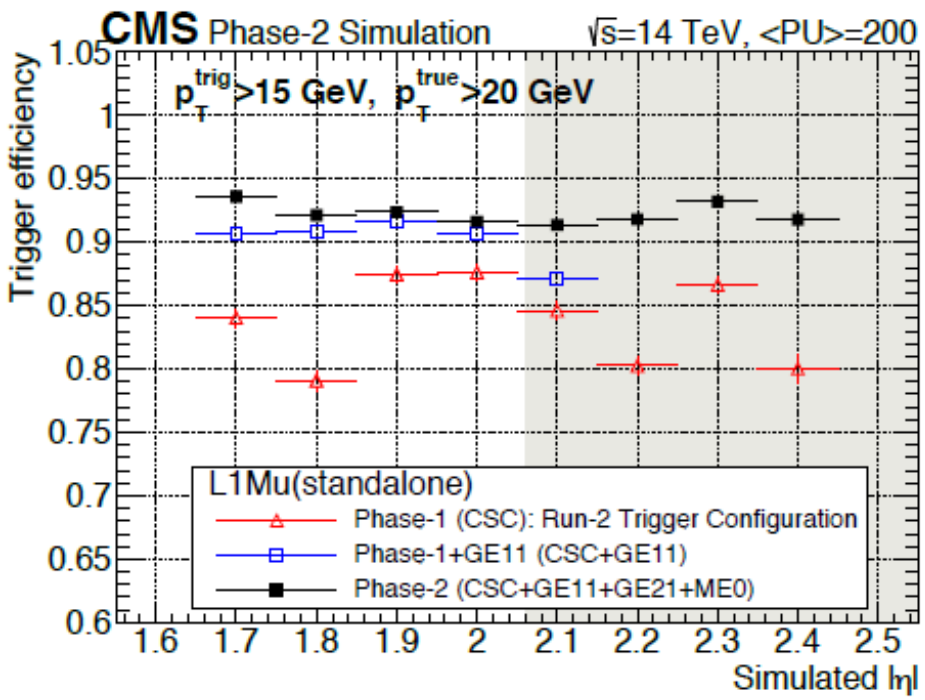
1 The CMS phase-2 GEM upgrade

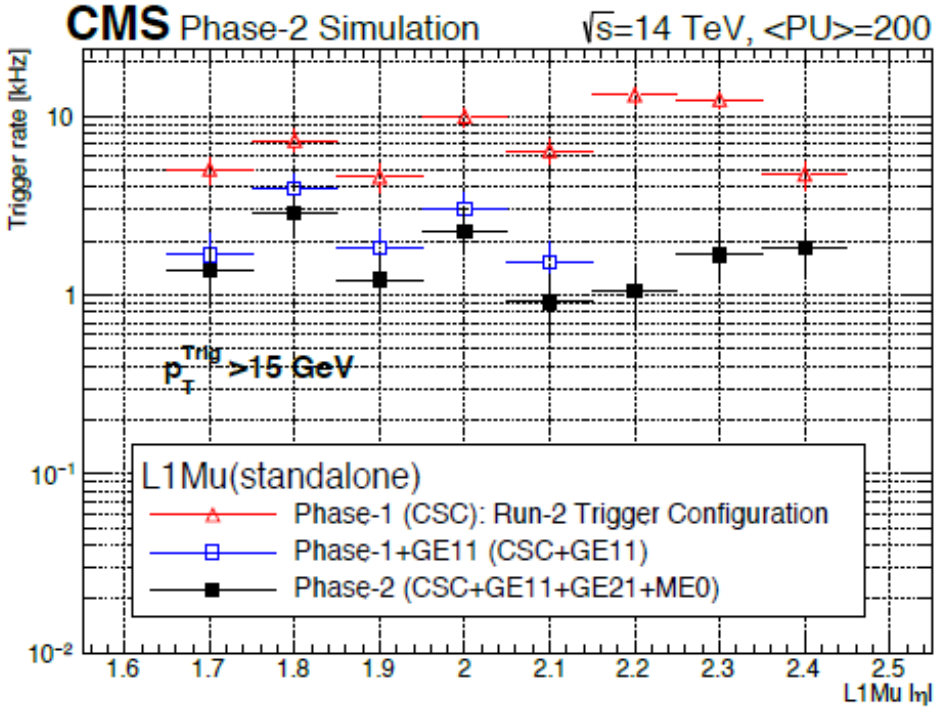
- HL-LHC upgrade



1 The CMS phase-2 GEM upgrade

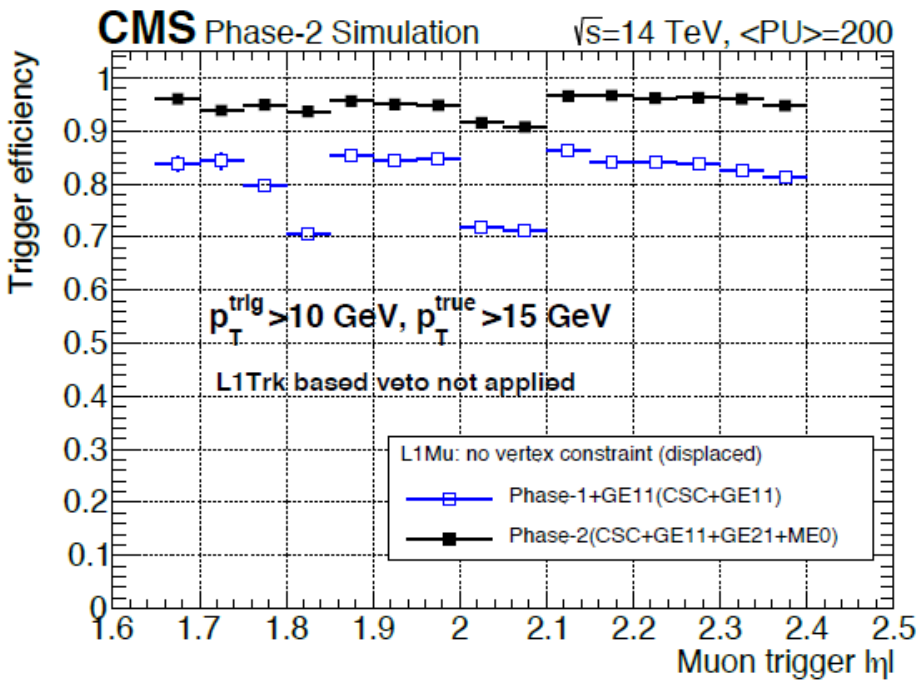
- To main L1 muon trigger performance after HL-LHC upgrade

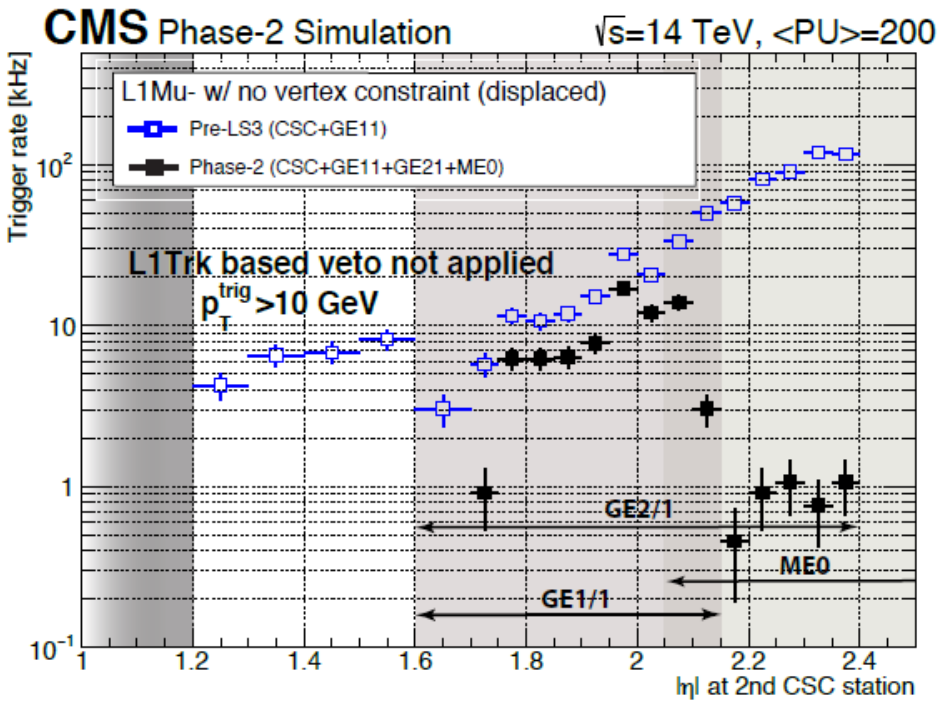




1 The CMS phase-2 GEM upgrade

- Trigger displaced muon for BSM search

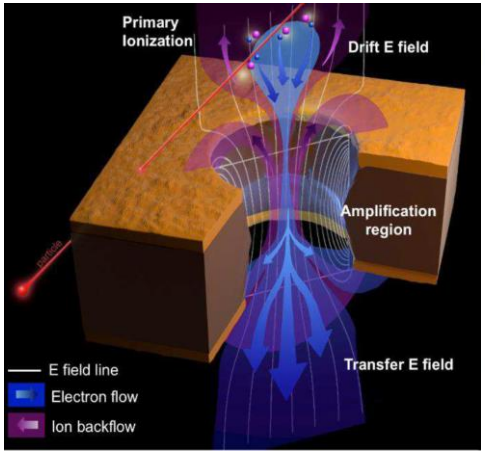


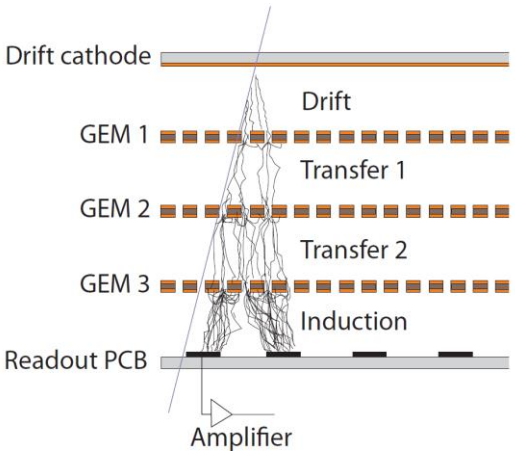


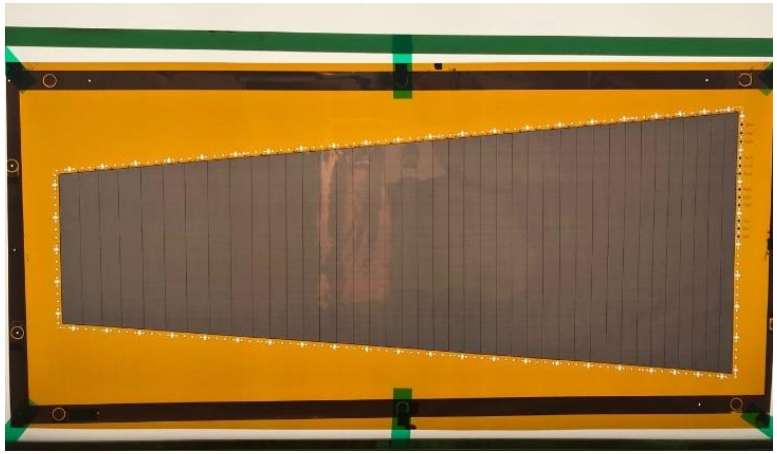
1 The CMS phase-2 GEM upgrade

- Extend rapidity acceptance from $|\eta| = 2.4$ to 2.8
  - Double parton scattering to WW: 1.5
  - A_{FB} of Drell-Yan event: 1.3

1 The CMS phase-2 GEM upgrade







- Gas electron multiplier

- Avalanche occurs at micro holes which are filled with high density electric fields

- Why GEM technology is chosen for the CMS phase-2 GEM upgrade?
  - High rate capability; can survive high η region where high flux of neutron
  - Hardness to classical aging
  - Thin

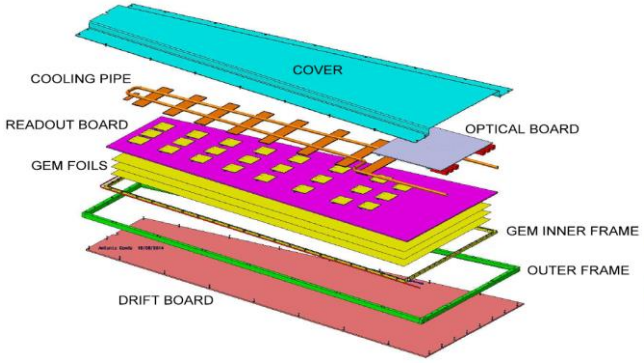
2 GE1/1, GE2/1, and ME0 detectors

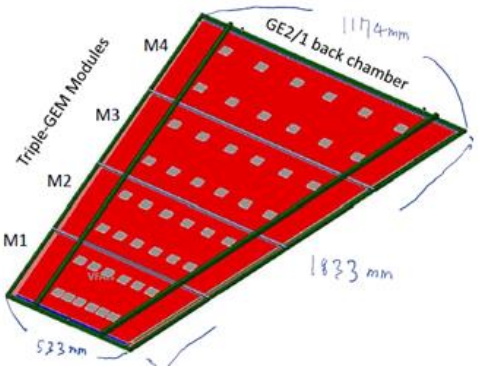
- Triple GEM detector
  - gap config: 3:1:2:1 mm, filled with $Ar: CO_2 = 70\ \%: 30\%$

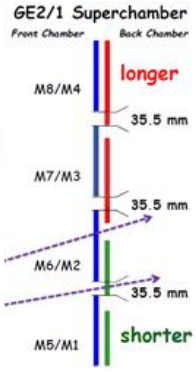
- GE1/1: cover 10°, 2 chambers to make super chamber
  - first project. Opportunity to validate Korean GEM foils

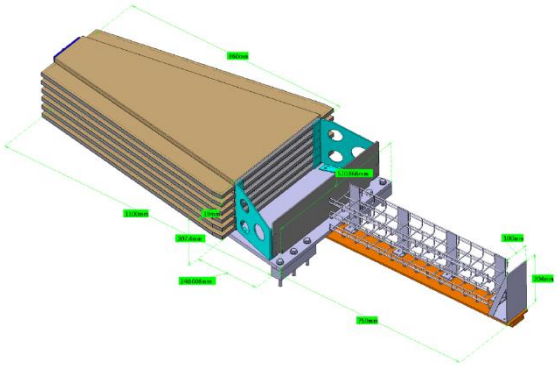
- GE2/1: cover 20°, 2 chambers to make super chamber

- ME0: cover 20°, 6 chambers to make super chamber



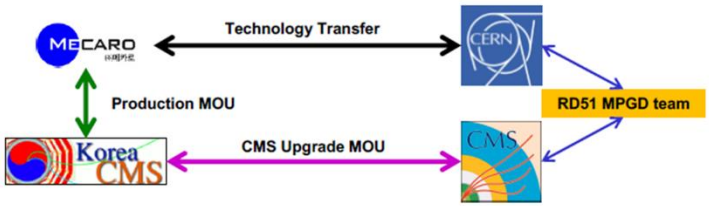




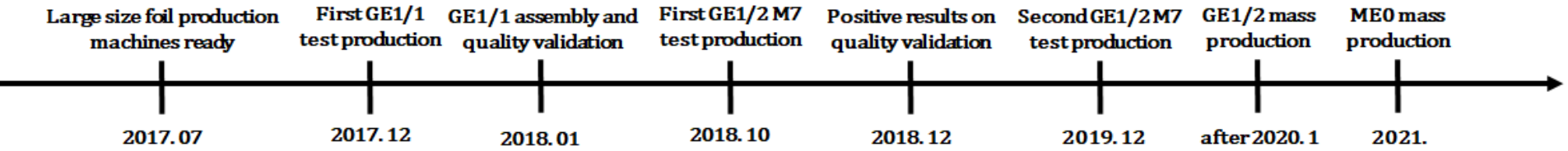


3 GEM foil production @ Mecaro

- KCMS has made the consortium with Mecaro to produce large size GEM foil since 2012
  - To be a second supplier for the CMS phase-2 GEM upgrade
  - CERN, only one large size GEM foil maker so far, can't satisfy foil demand
  - Two other company tried.



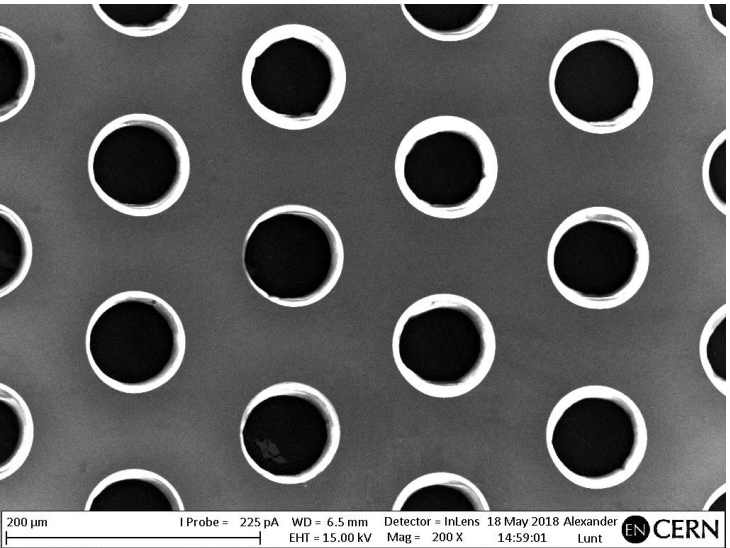
- KCMS will supply foils for middle four modules of GE2/1 and ME0
  - Intensive validation on foil quality is ongoing



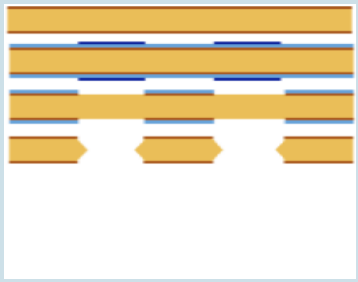
3 GEM foil production @ Mecaro

- Mecaro produces GEM foils with **double mask technique**.
  - Production rate is fast~10 foils/week even faster
    Cf) CERN 14-15 foils/5 week/technician
  - Foil up to 1300 $mm \times 610\ mm$ (machine size $1379mm \times 813mm$) is producible.

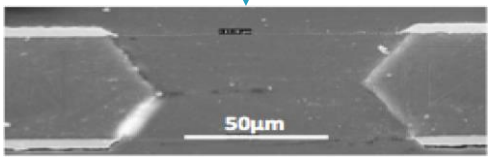
- Standard geometry: diameter of Cu (PI) hole=70 (50) μm, pitch= 140 μm
  - Symmetrically biconical hole.



3 GEM foil production @ Mecaro

	Single mask	Double mask
Production method		
Mask alignment	No need (film)	Crucial (glass)
Cost of necessary machines	Cheap	Expensive
Production process	Complex	Simple
Production rate	Slow	Fast
Good for	R&D	Mass production
Robustness to FCCL quality	Vulnerable	Rubust

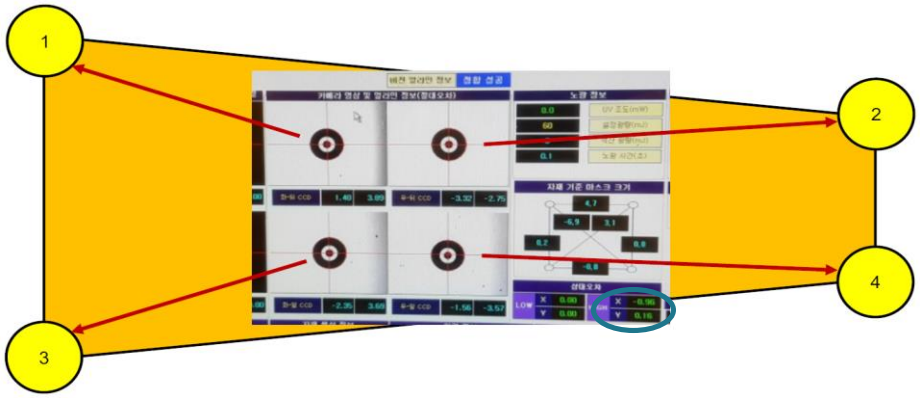
Double mask

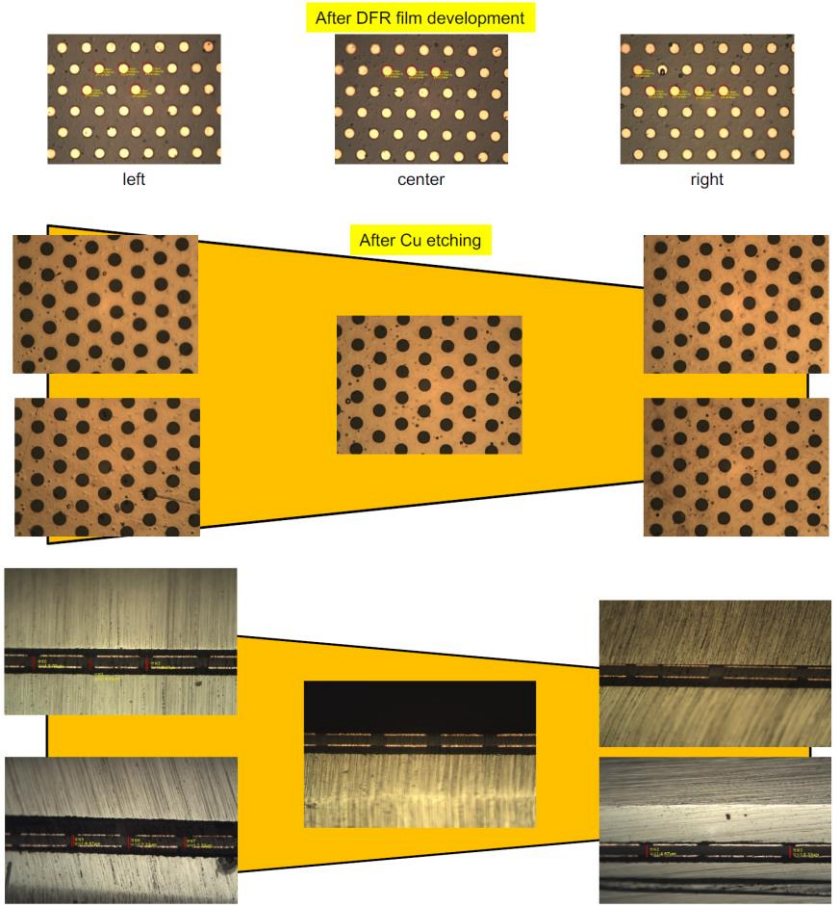


Single mask

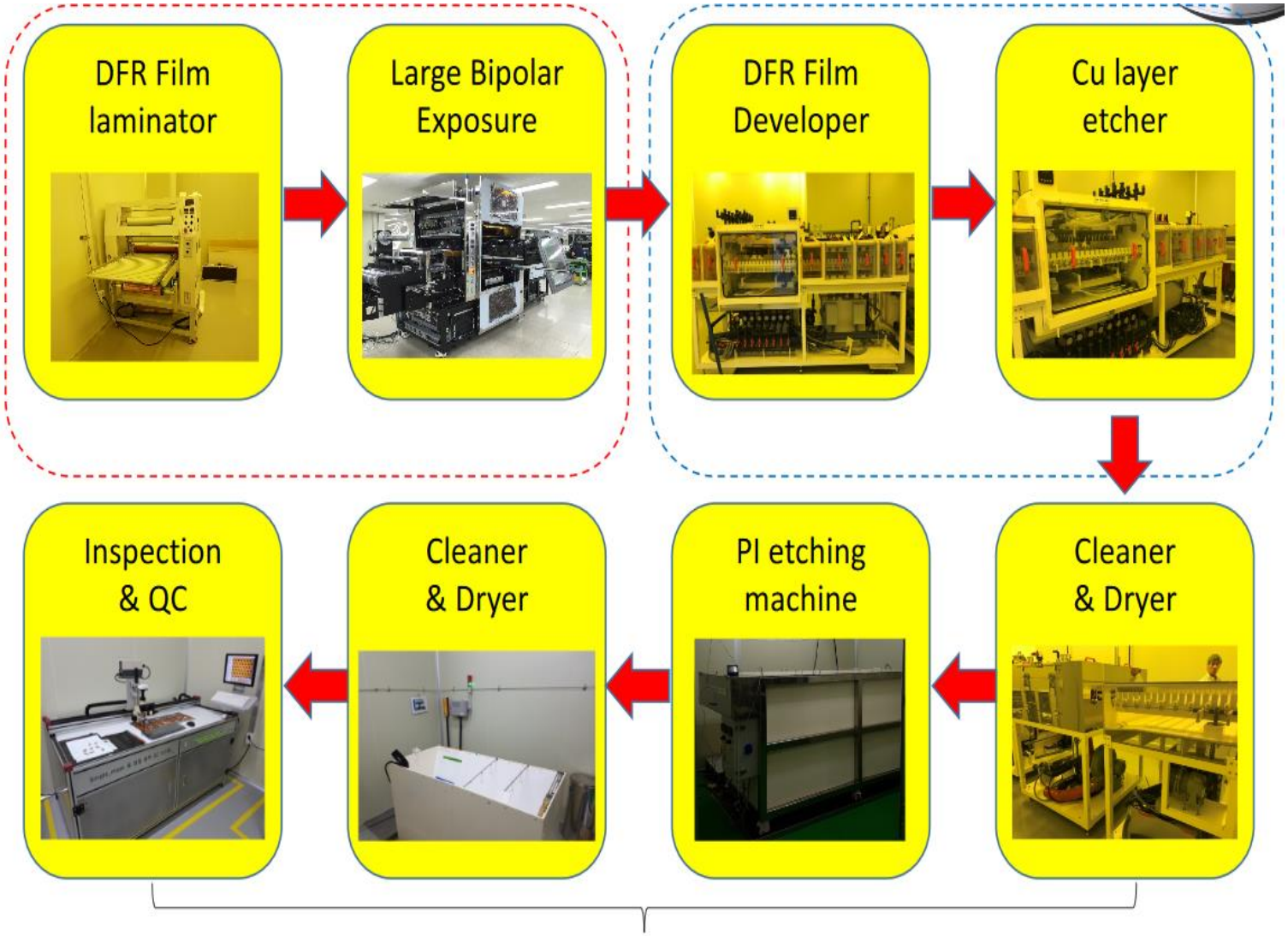
3 GEM foil production @ Mecaro

- Mask alignment; critical step for using double-mask technique
  - Four bifocal microscope on corners are used for mask alignment
  - Residual misalignment $< 3\ \mu m$





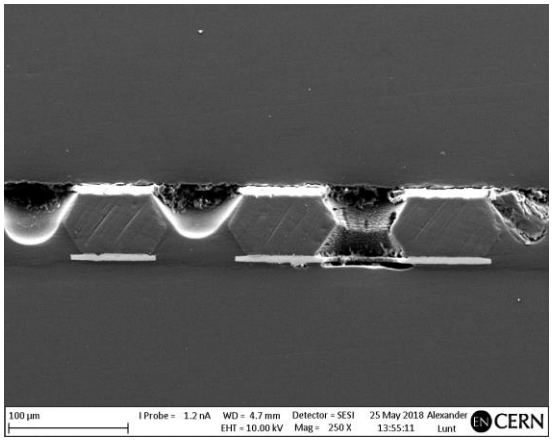
3 GEM foil production @ Mecaro



4 Quality validation with CMS GE1/1

- PI hole diameter: $49.04 \pm 0.79 \mu m$,
  Cu hole diameter: $70.24 \pm 0.91 \mu m$.
  - 450 holes

- Hole uniformity with automatic CCD scanner by Matt Posik, Temple Univ.

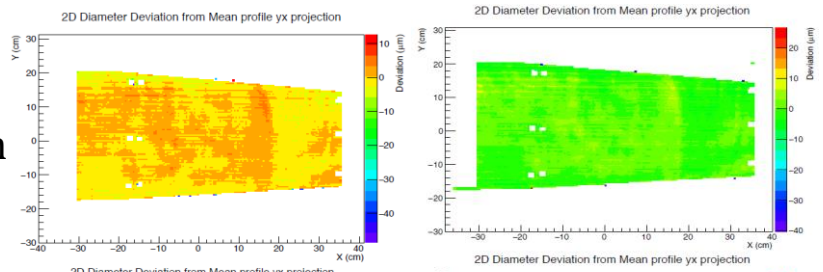


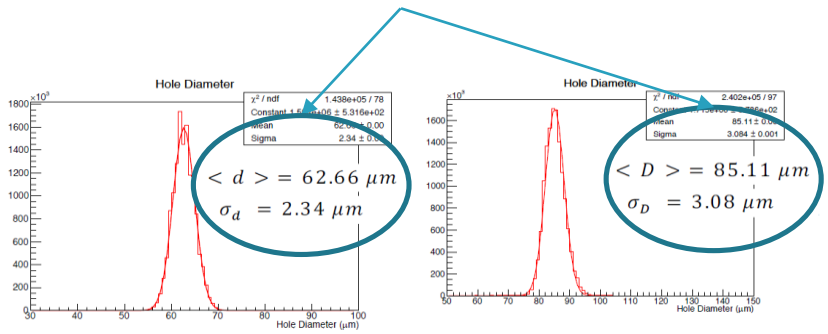
Cross section of Mecaro GE1/1 foil

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

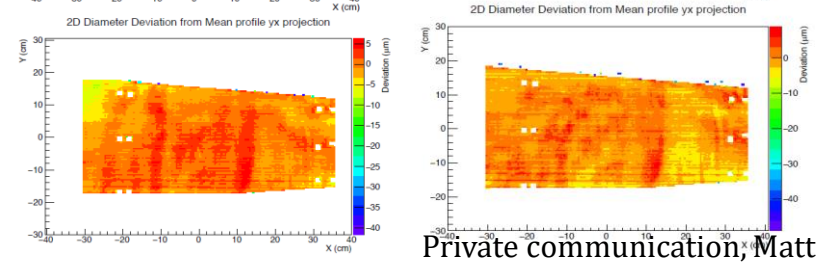
PI hole | Cu hole

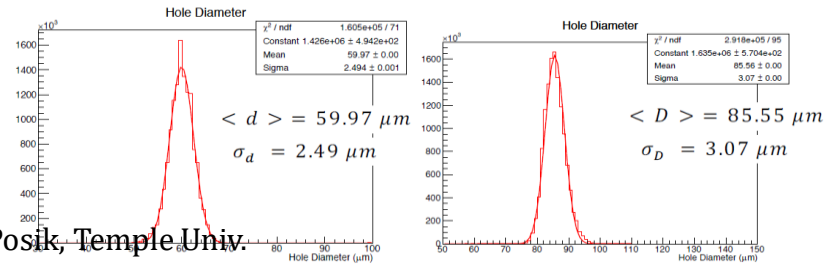
Bottom





Top

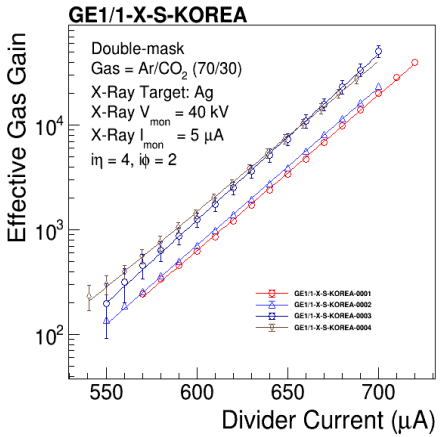


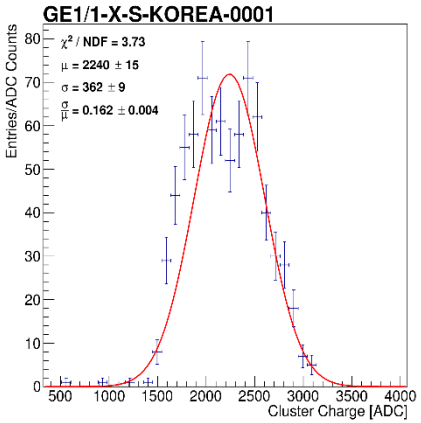


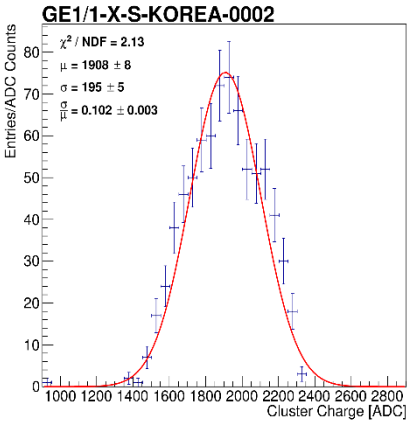
Private communication, Matt Posik, Temple Univ.

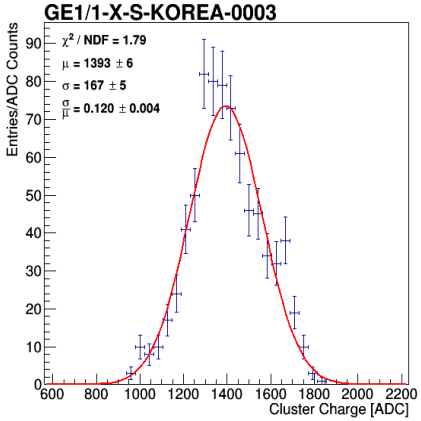
4 Quality validation with CMS GE1/1

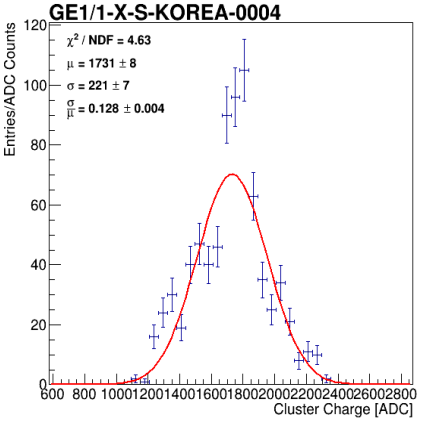
- Gain: $1 - 5 \times 10^4$ at 700 μA (operating voltage), gain variance: 10.2-16.2 %
  - Consistent with the results of the detectors with CERN foils.





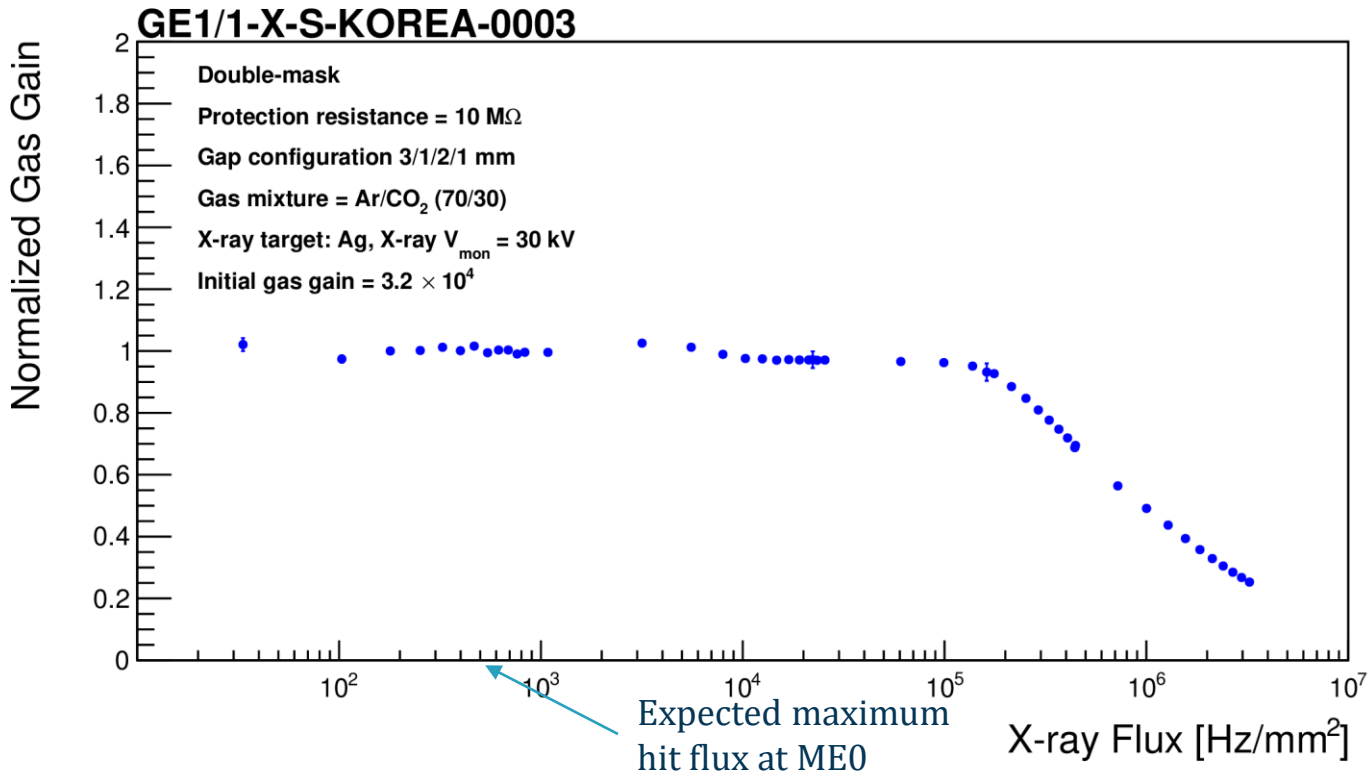






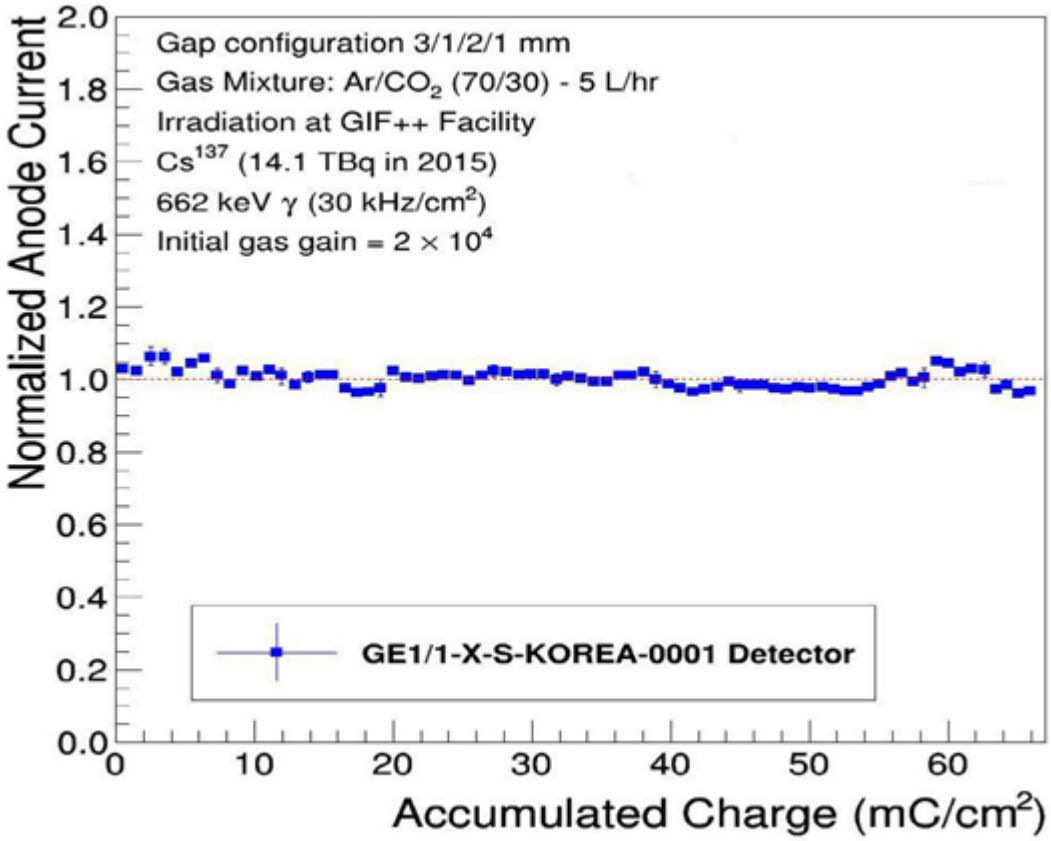
4 Quality validation with CMS GE1/1

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



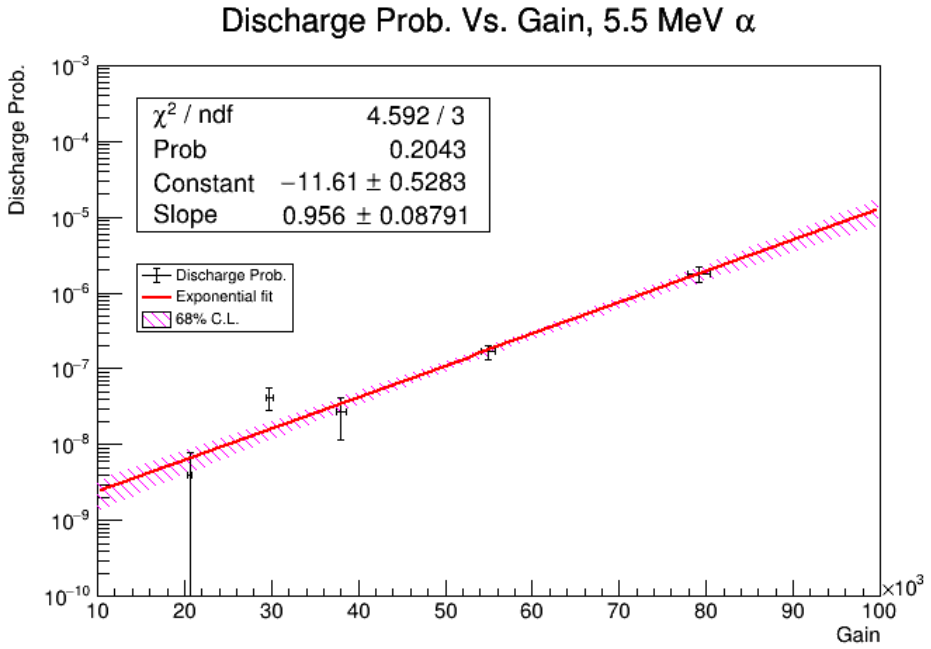
4 Quality validation with CMS GE1/1

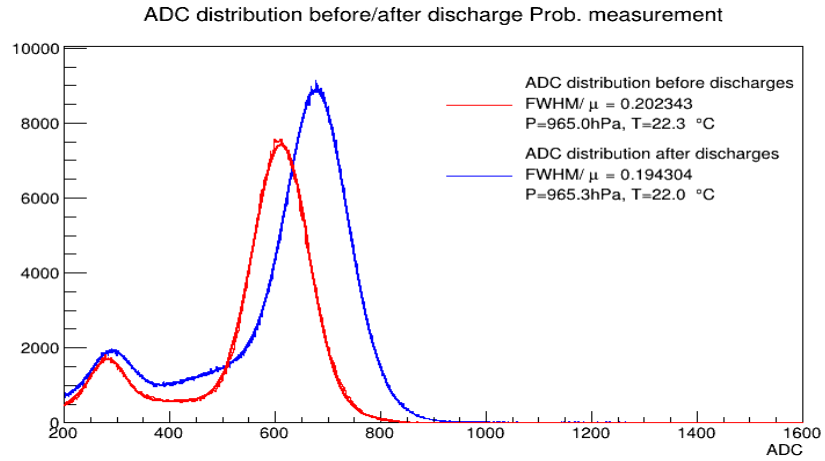
- No gain degradation due to aging is observed up to 66 mC/cm^2.
  - It corresponds to 219 years of GE2/1 and 2.3 years ME0 operation at HL-LHC.
  - CMS requires 30 years. So far, so good.

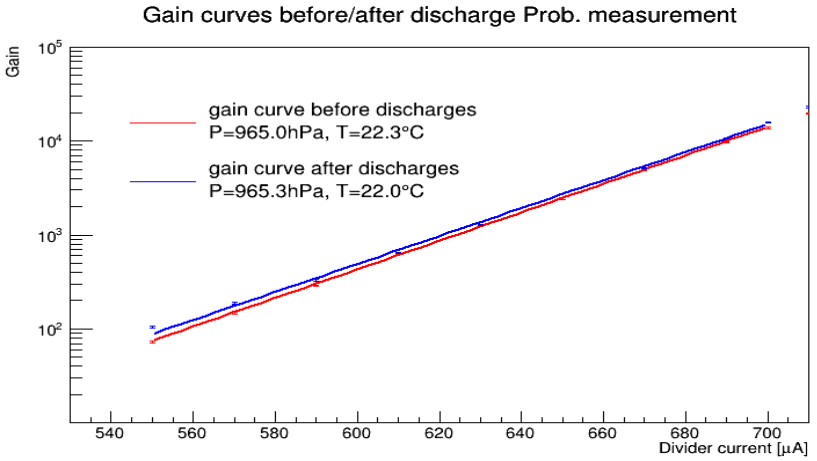


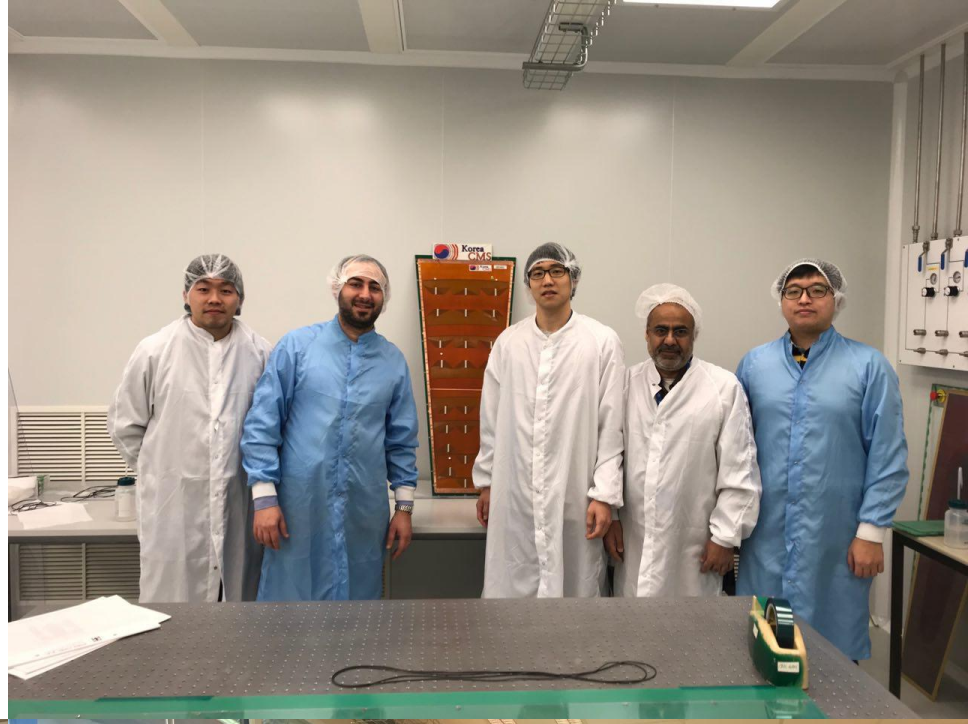
4 Quality validation with CMS GE1/1

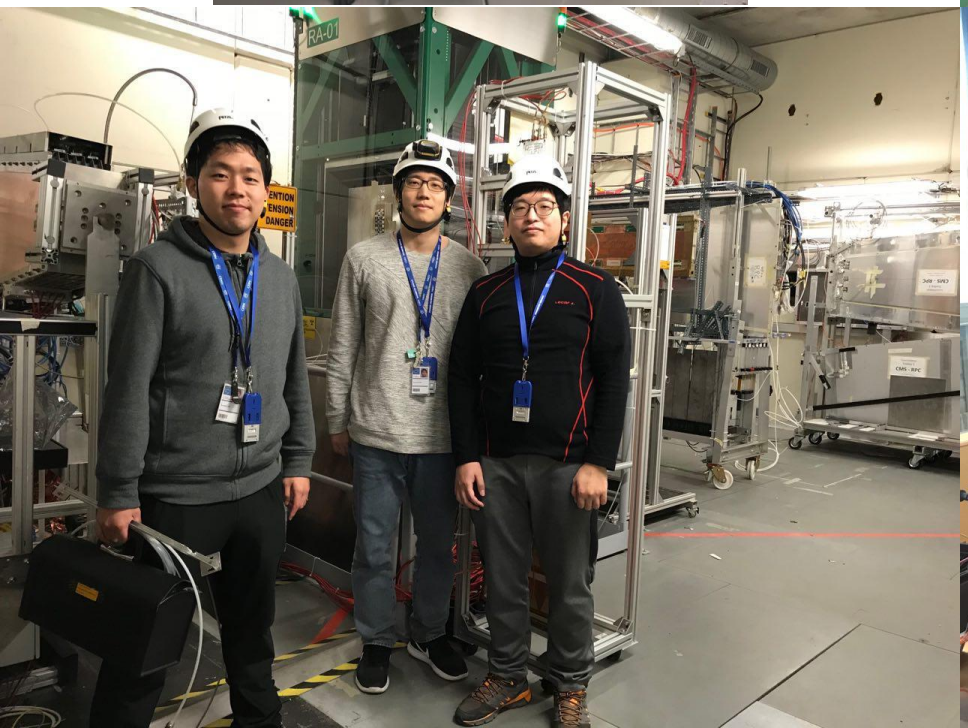
- Probability of discharge induced by α from ^{241}Am.
  - Special chamber with holes to let α enter detector.
  - Discharge Prob. (at gain=10^4) $= 2.4 \times 10^{-9} \pm 1.0 \times 10^{-9}$.
  - No degradation on detector performance after 229 discharges.

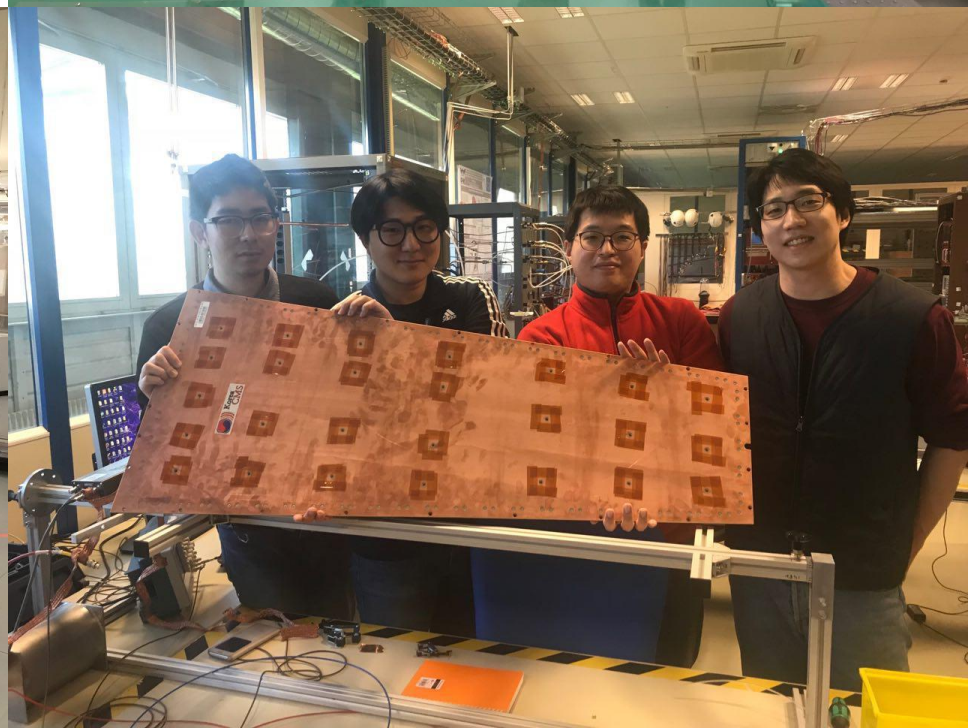







Korea
CMS


RA-01



5 Mass production plan

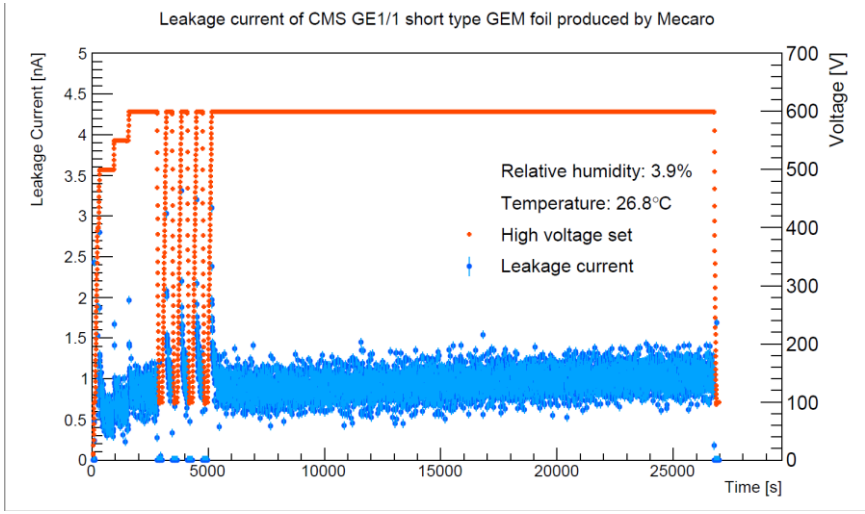
- Mecaro will produce foils for GE2/1 and ME0
  - Pre-production for design validation: 10 foils for each type
  - 114 foils for each four GE2/1 modules. 1 year
  - 666 foils for ME0. 1.5 year

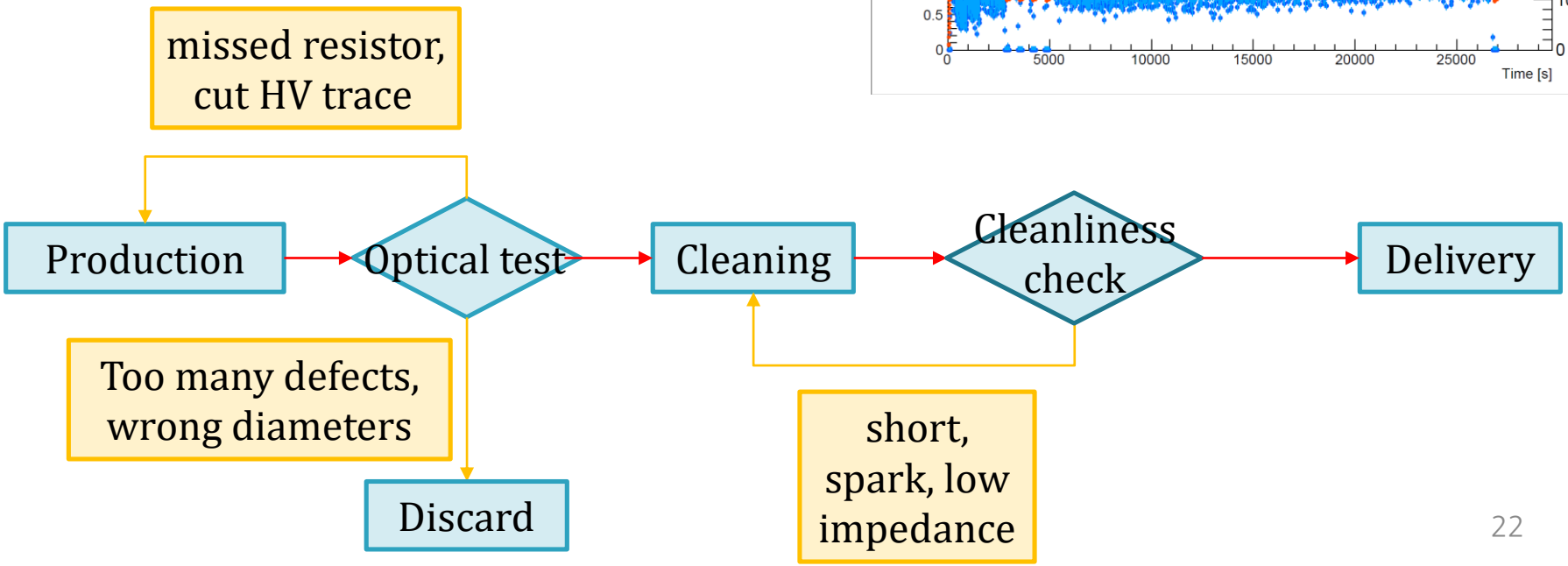
- Mass production will start early 2020
  - Opportunity to mature production technique
  - Exact production rate, yields and price will soon be known

  ⇒ Stay tuned! If the mass production ends successfully, your experiment will get a new supplier of GEM foil!

6 QC at Mecaro

- Hole diameter, impedance of foils, long term stability (at least 7 h) at dry condition, packaging and so on
  - Done by KCMS personnel
  - Very important step





7 Summary

- KCMS & Mecaro produce large size GEM foils for the CMS phase-2 upgrade
  - Double-mask technique

- Quality validation is ongoing with CMS GE1/1 chamber
  - Promising results were obtained
  - Hole development, gain, gain uniformity, rate capability, discharge prob. and hardness to discharge and ongoing aging study

- Mecaro will produce CMS GE2/1 foils and ME0 for CMS phase-2 upgrade
  - KCMS takes charge of QC

- Production technique will be matured during the mass production for CMS
  - Mecaro will be credible vendor your experiment!