GEM activities of Korea

- KCMS GEM projects and Future

2022 / 11 / 17

Inseok Yoon (SNU)

KSHEP @ PNU

Contents

- Introduction to GEM

- KCMS GEM Projects

- R&D History
  - Validation with GE1/1
  - First GE2/1 production
  - Redesign of GE2/1 HV segmentation
  - Ongoing R&D: Aging experiment, Production feasibility of random segmented foils

- Mass production so far

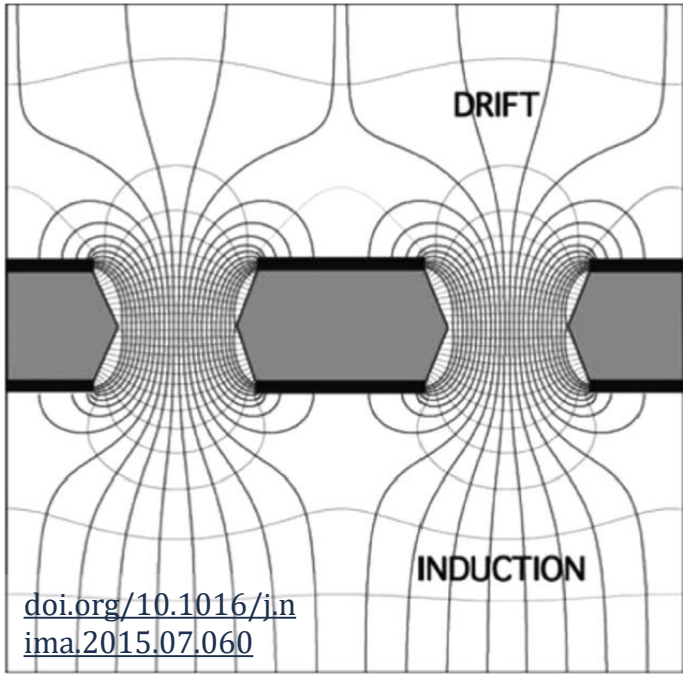
- Site relocation & production plan

- Potential μRWELL contribution to Detector 1, EIC

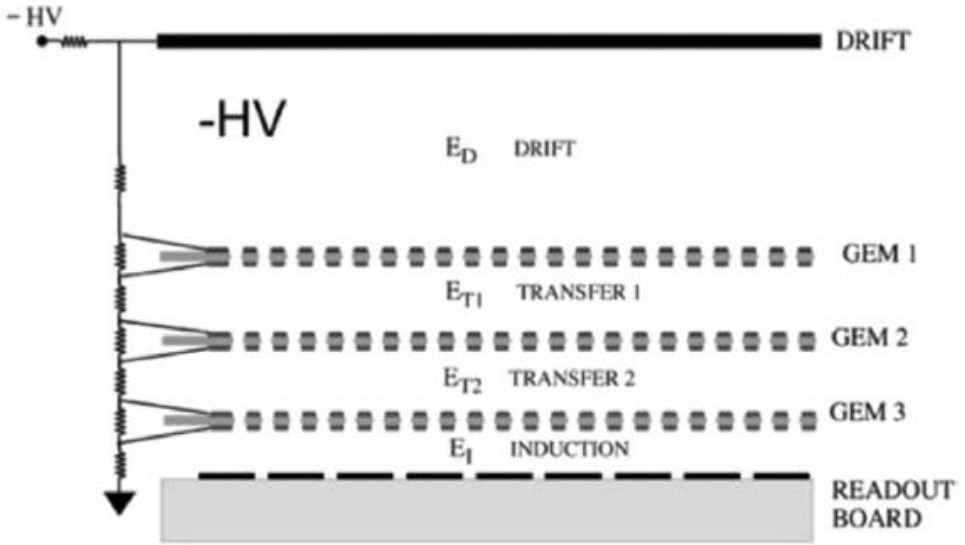
1. Introduction to GEM

- Gas Electron Multiplier
  - Detour spark generation via the step-by-step amplification
  - Good multi-track resolution, better than 1 mm
  - Reasonably good time resolution $< 10\ ns$
  - Extremely high rate capability $\sim O(1 \times 10^4 Hz/mm^2)$
  - Extremely robust to classical aging
  - Suppression of positive ion backflow
  - High material budget

⇒ Optimum detector for muon tracker of Lumi. frontier



doi.org/10.1016/j.nima.2015.07.060

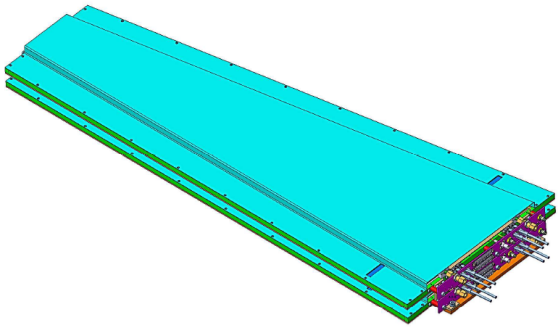


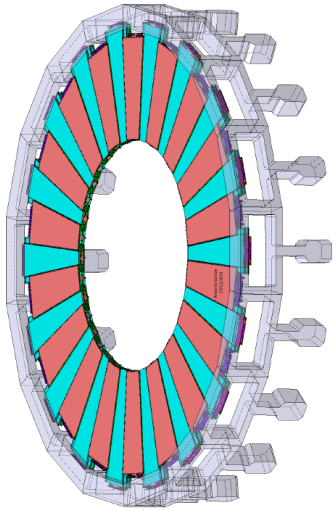
2. KCMS GEM projects – Overview

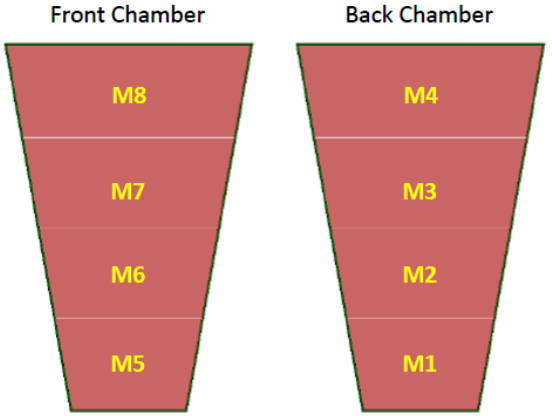
- CMS GEM upgrade for HL-LHC
  - GE1/1, GE2/1, and ME0 upgrades
  - To increase trigger rejection factor by increasing online muon P_T resolution
  - Triggering displaced muon
  - Increase acceptance

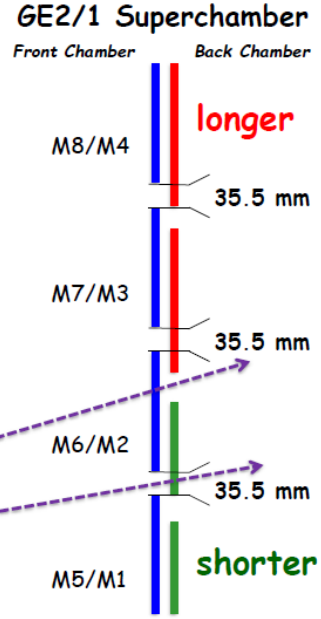
- Why GEM?
  - Thin
  - High rate capability
  - Robust to classical aging

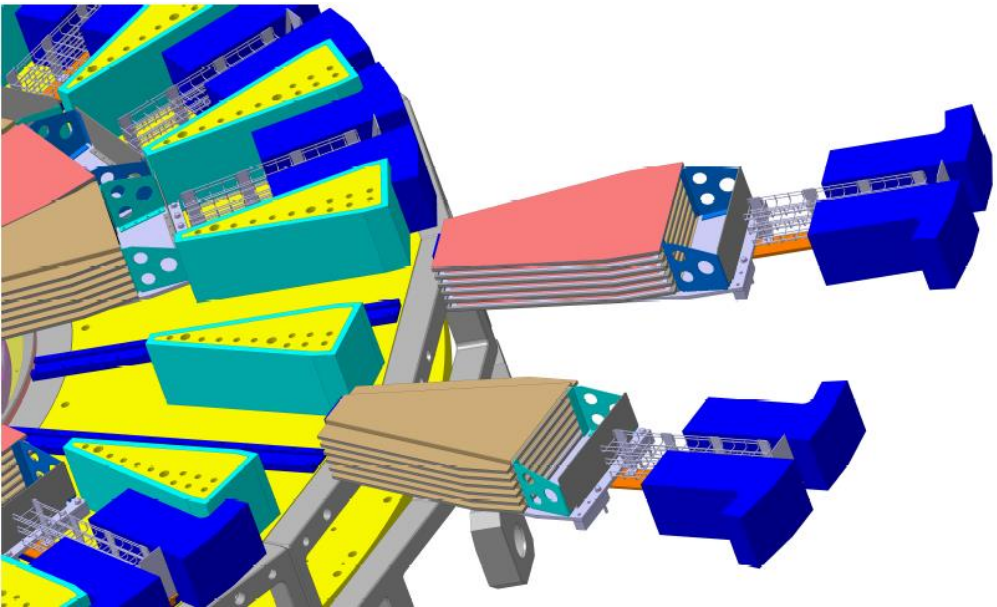
2. KCMS GEM projects – Overview

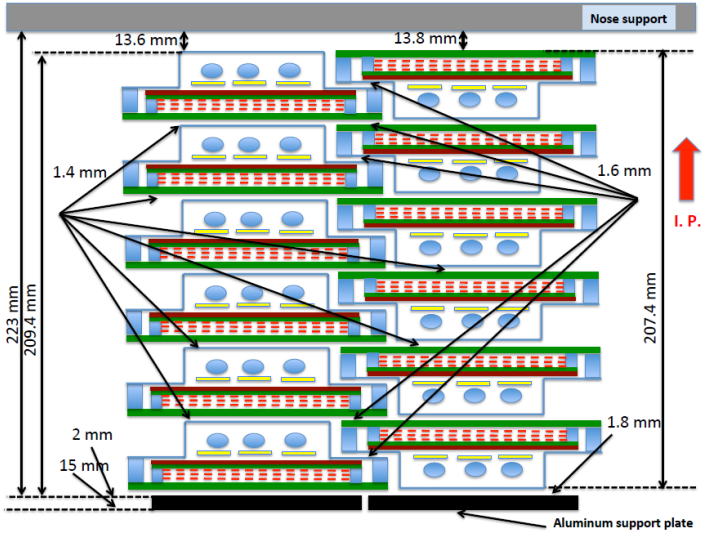




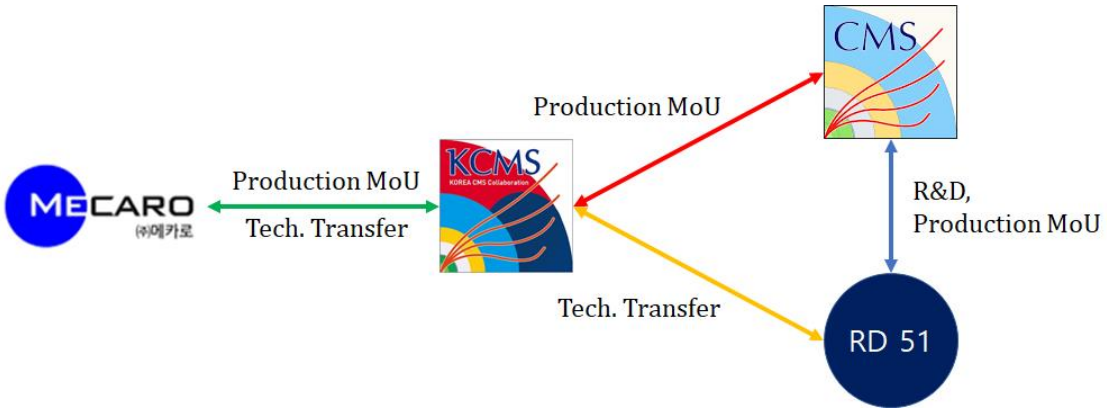




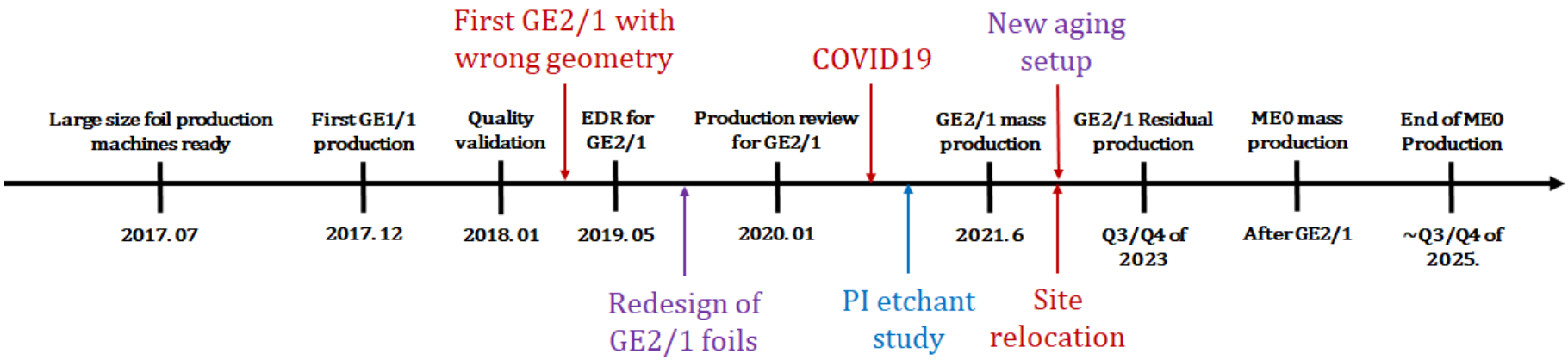




2. KCMS GEM projects – Overview



- KCMS is supplying the large-sized GEM foil for the CMS upgrades
  - World only two vendors of the large-sized GEM foils
  - GE1/1: Chance to validate foil quality produced by KCMS
  - GE2/1: KCMS shall provide half of necessary foils
  - ME0: KCMS shall provide all ME0 foils



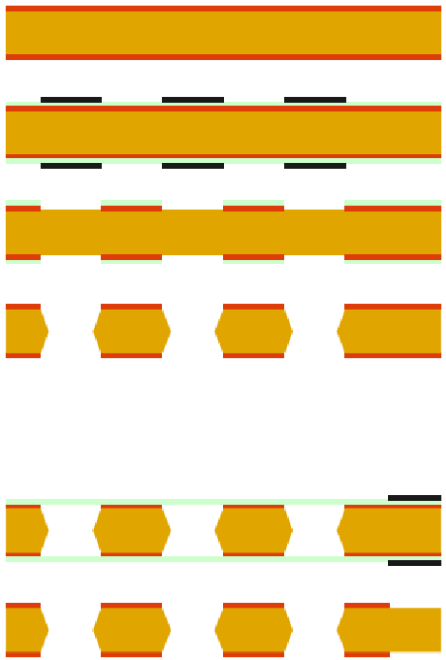
2. KCMS GEM projects – Production Processes

- Double-mask technique for simpler processes and faster production
  - Alignment become very crucial
  - Residual misalignment$< 5\mu m$

- Wet etching
  - Cu: $FeCl_3$
  - Polyimide: KOH+mono ethanolamine

LC of MEA to mice for 2h $> 2430\ mg/m^3$

Cf LC_{50} of EDA to mice $= 300\ mg/m^3$



3. R&D History – Validation with GE1/1

- Foil quality validation with GE1/1
  - Assemble four GE1/1 detectors with foils produced by KCMS

- Properties of the detectors were consistent with Ref. detectors
  - Gain, gain uniformity, rate capability,
    discharge prob. & robustness to discharges, aging properties

- Issue: several foils became short when HV applied after delivery
  - Foil cleaning processes, QC and packaging processes
  - QC @ production site

- In-cash contribution to GE1/1 project
  - Due to lack of aging measurement

The most important moment

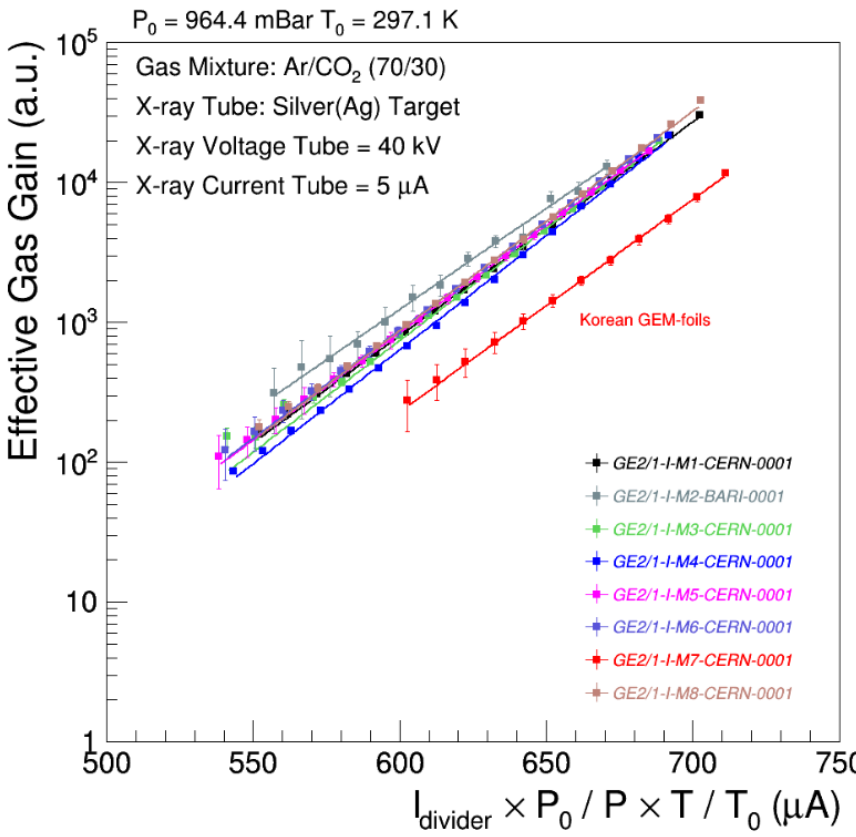
2017, Dec, 2nd
@ Geneva airport

3. R&D History – First GE2/1 Production

- First GE2/1 M7 was delivered on Oct. 2018
  - Lower gain was observed
  ∵ PI hole diameters were smaller than design

⇒ QC protocol @ production site was reviewed
  - Electrical assessment couldn't reject it
  - Optical assessment has been included

- Fixed during PI etchant review
  - PI etching processes was updated



3. R&D History – Redesign of GE2/1 HV Segmentation

- Unexpected large spark rate was observed by GE1/1 slice test

∵ Spark propagation between foils

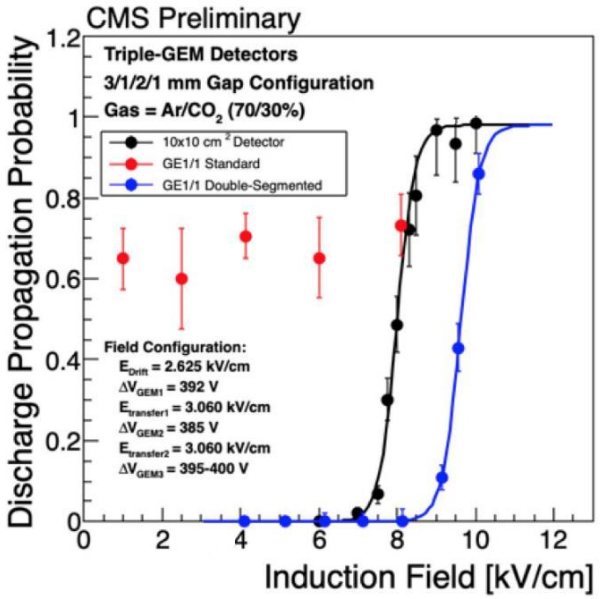
- Key parameter: capacitance of gap

- To reduce the capacitance, double-segmented foils

- Smaller capacitance of induction gap caused X-talks

⇒ Double-segmented foils for GEM1&2

Single-segmented foils for GEM3

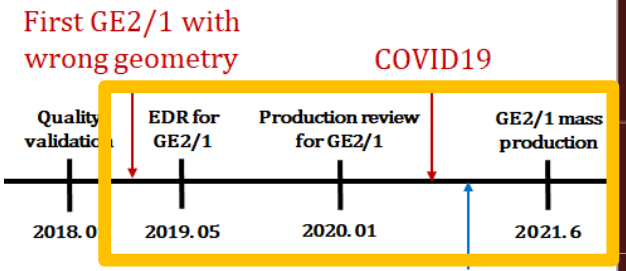


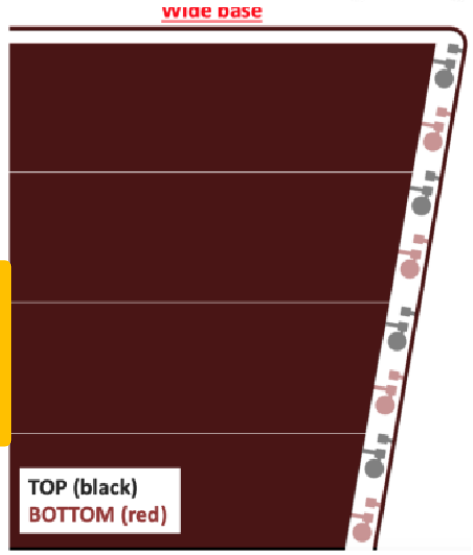
- Negative impact to producer

- Production rate dropped due to doubled soldering

- First mask became useless

- Mass production delayed



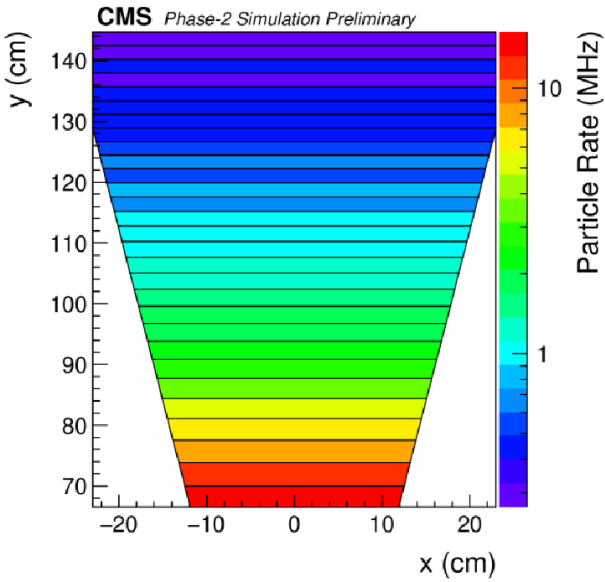


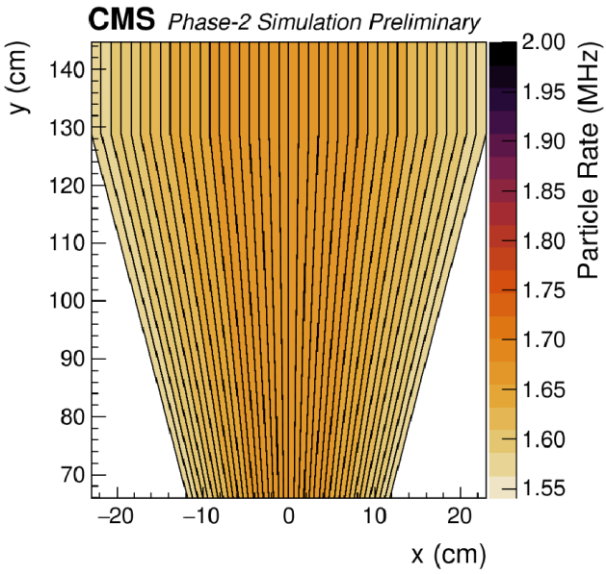
3. R&D History – New Estimation of ME0 Background

• New simulation revealed background rate at ME0 will be much higher than TDR estimation
- Redesign of HGCal & Improper assumption of TDR simulation
⇒ Aging goal increased, Radial-segmentation, Shielding

• HV segmentation
- To reduce capacitance
- Even sectors are short, the others are operational

• Protection resistor
- To protect foils from shorting by spark
- Control power consumption when sectors become short ($^{V}/_{R^2}$)
- Induce voltage drop (IR)

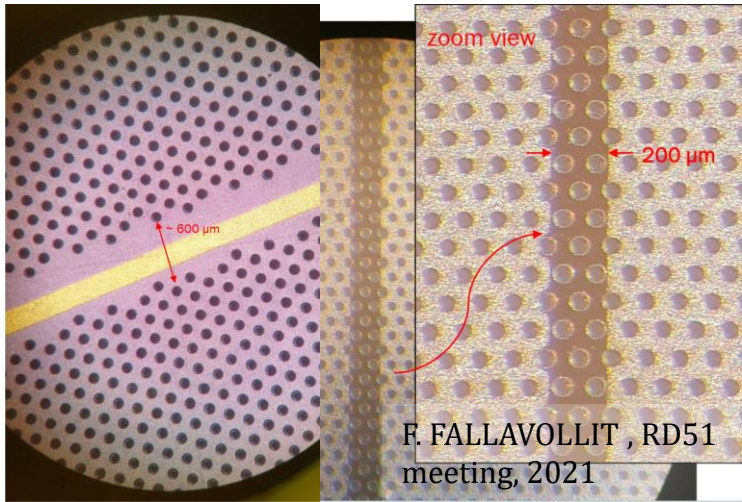




3. R&D History – Ongoing R&D

- Aging study @ UoS (Led H. Lee)
  - Expected accumulated charge: 283 $mC/cm^2 \rightarrow 7.93\ C/cm^2$
  - Aim to accumulate unprecedented amount of charge
  - Special chamber with smaller protection resistors
  - 40 W X-ray gun
  - Measure anode current variation while detector exposed to x-ray
  - Accumulation rate~$52mC/cm^2day$
  - Already 1.01 C/cm^2 accumulated

- Production feasibility
  - Random & radial segmentation with double-mask technique
  - Production may be harder
  - Rui: "Production of random sectorized foils with double-mask technique has high delamination risk"

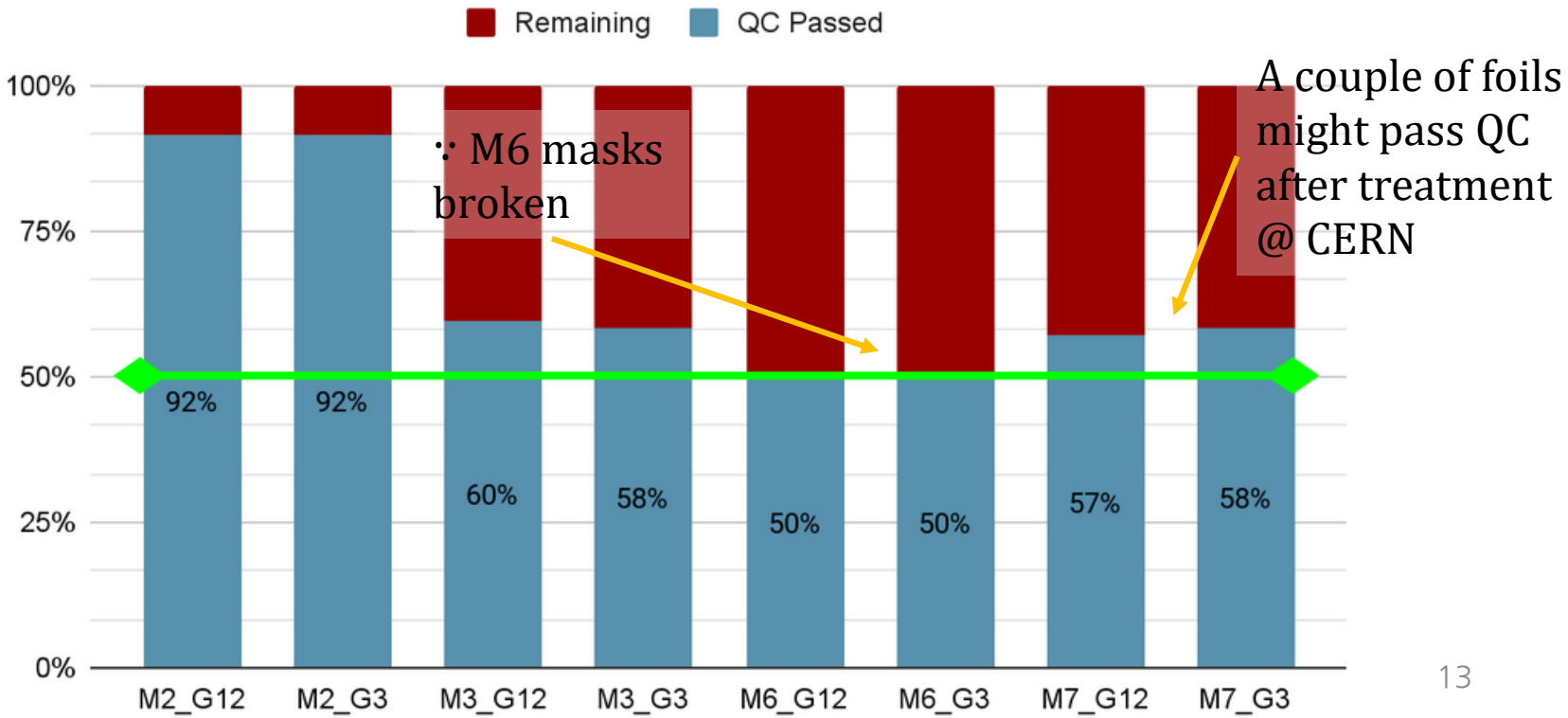


F. FALLAVOLLIT , RD51 meeting, 2021

4. Mass Production so far

- Since Jun. 2021, 284 foils have passed QC
  - Led by Dr. D. Kim

- The quantity to assemble “Disk-1” is barely satisfied



5. Site Relocation & Production Plan

- KCMS & Mecaro consortium has ended
  - Looking for alternative production site

- Delays due to production shutdowns are choking us, but as long as a new site become available, we'll have advantage
  - After the giving GEM up became known internally, technicians didn't work hard

- IBS is best option
  - Equipment transportation has already been completed
  - Installation of cleaning room should started ASAP

- The wet processes will be done at external factory located at Ansan (안산)
  - Getting chemical handling permit will take long time
  - Ultimately, we hope all processes can be carried out within single organization

- Internal goal to resume foil production
  - March, 2023 (Optimistic scenario)

5. Site Relocation & Production Plan

- Disk-1 should be prepared before Aug. 2023
  - Order a couple of M6 (~8) and M7 (< 8) foils to CERN ∵ the assembly need spare foils

- Residual GE2/1 production
  - 114 foils×4 type – 284 foils - order for spare ~ 164 foils
  - Production rate @ Mecaro: 30-32 foils/month
  - Hard to expect the rate @ IBS
    ↓↓ Additional transportation
    ↑↑ KCMS controls all things

- Disk-2 should be prepared until Jun. 2024
  → Expected deadline: ~Q3 or early Q4 of 2023
  ⇒ If things go well, KCMS can finish GE2/1 production

- Contingency plan: Order foils to CERN
  - We need to warn Rui by 1st Dec.

5. Site Relocation & Production Plan

- ME0 production

- 666 foils

- Disk-1 (Disk-2) should be ready before Aug. 25 (June. 26)

→ Expected deadline: Q3 of 2025

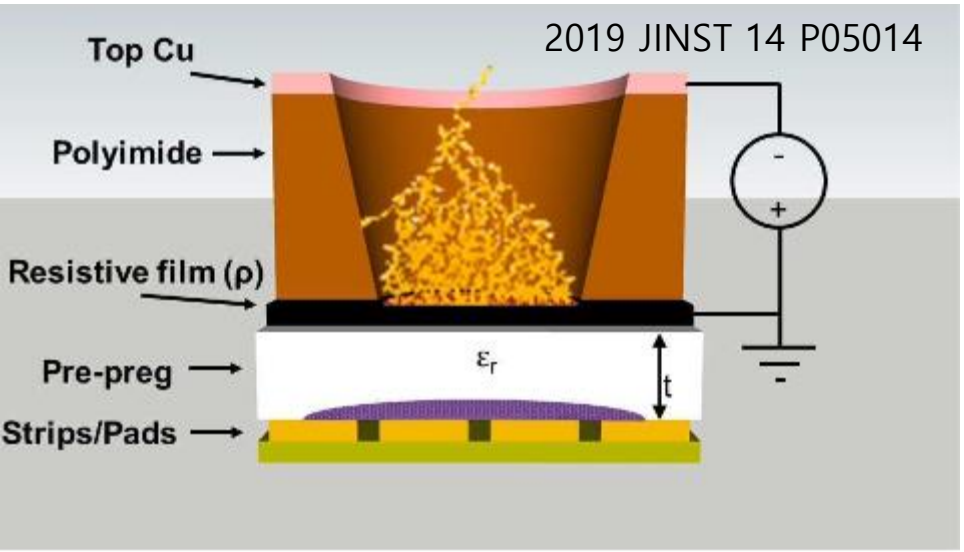
⇒ If we start ME0 production after GE2/1 production done, production is feasible

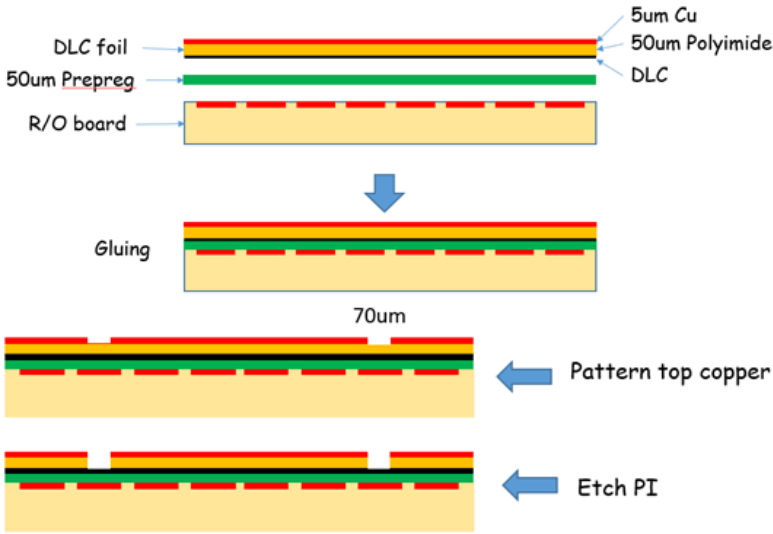
6. Potential μRWELL contribution to Detector 1 @ EIC

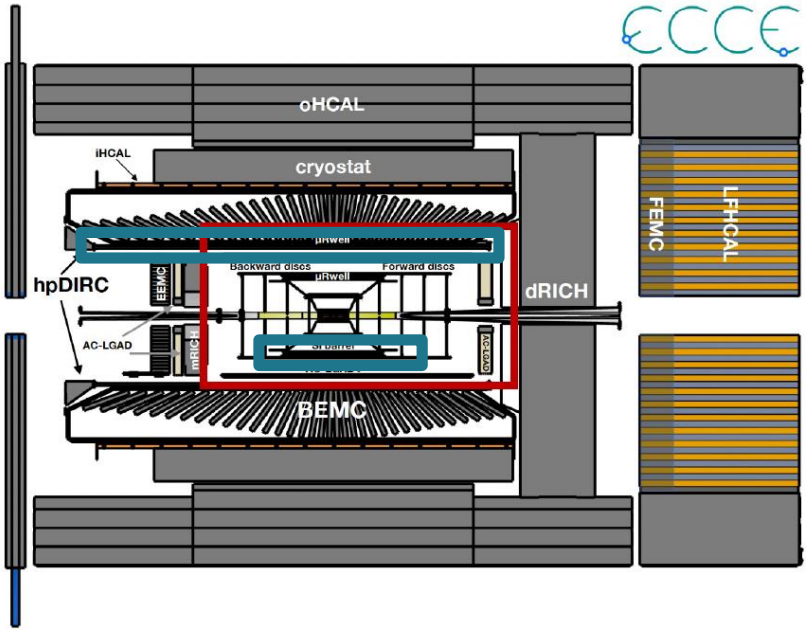
- Two μRWELL barrels are planned for Detector 1, EIC
  - We can contribute μRWELL

- Operating principles of μRWELL
  - Multiplication principle: GEM like
  - Spark mitigation principle: RPC like

- GEM and μRWELL share similar production processes
  - Only one missing technique is DLC sputtering





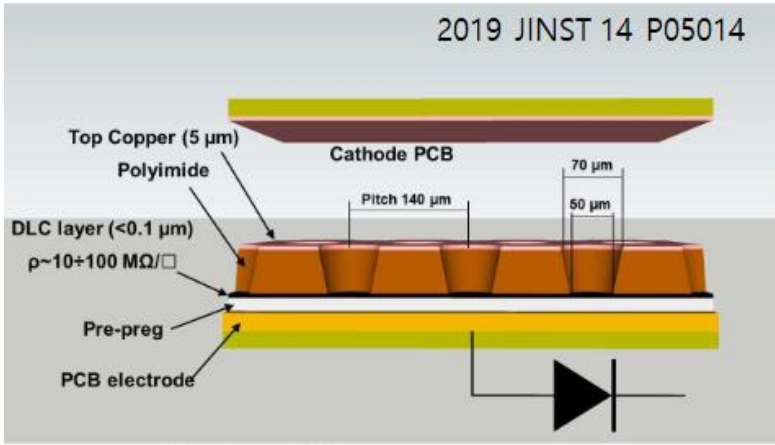


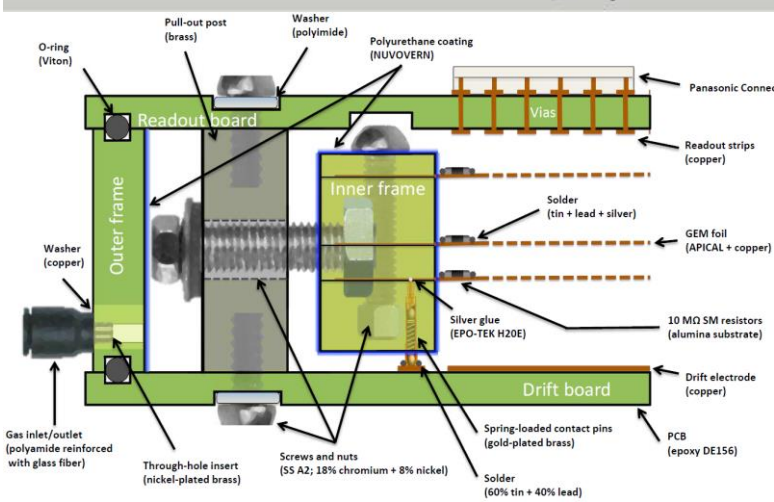
6. Potential μRWELL contribution to Detector 1 @ EIC

- Advantages
  - Leading role in EIC physics
  - Maintain the initiative within MPGD production
  - μRWELL is charming

- Advantages of μRWELL
  - Only one foil to achieve high enough gain
  - Easy handling
  - Simpler assembly
  - Mass production friendly

  ⇒ Cheap
  - Reasonably good performances
  - Low material budget





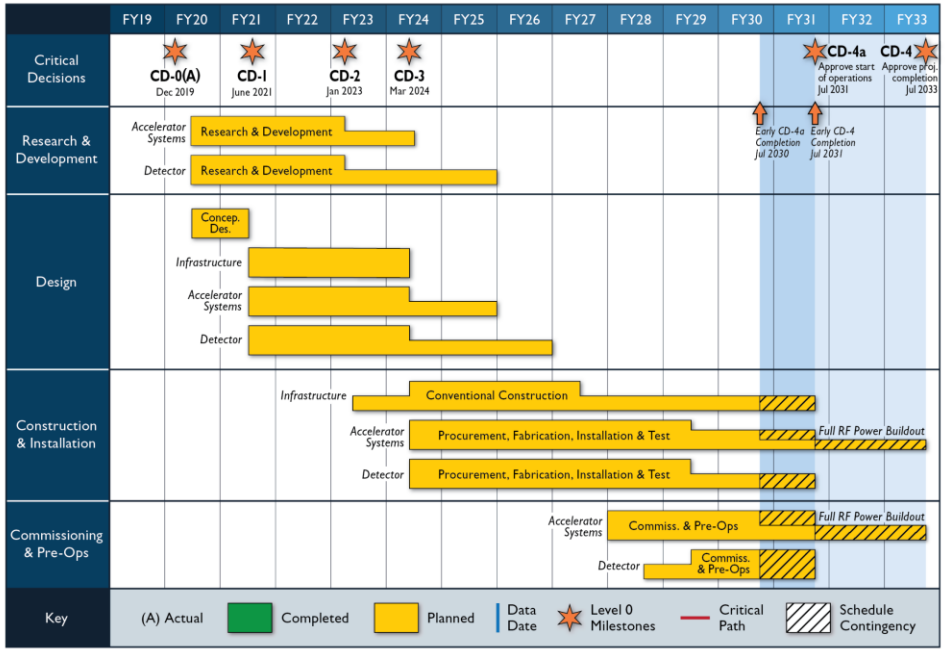
6. Potential μRWELL contribution to Detector 1 @ EIC

- Feasibility
  - Need to secure: DLC sputtering technique
  - Common technique in engineering for surface hardening, abrasion resistance, ETC

- Person power
  - Large pool trained during KCMS GEM projects

- Schedule
  - CMS production will be ended around Q3 of 2025

⇒ We can contribute to EIC with our own original technology!



Summary

- KCMS is supplying large-sized GEM foil for CMS GEM upgrades
  - We've participated several R&D for foil production and detector R&D

- Mass production was smooth until KCMS & Mecaro consortium ended
  - So far, 284 foils have passed QC
  - ~16 foils should be ordered to CERN

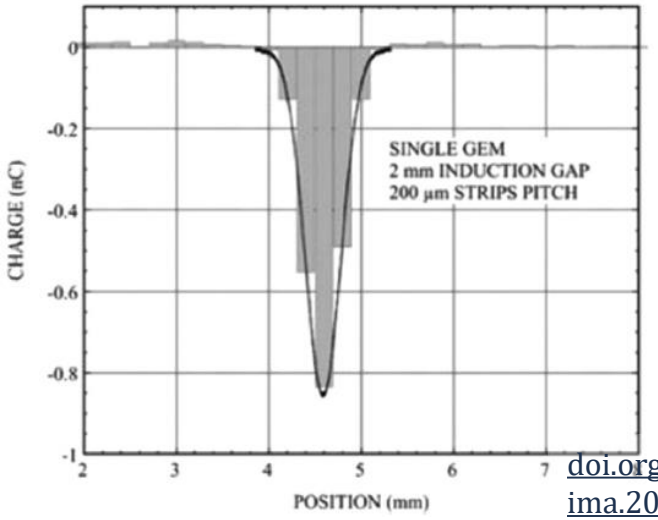
- Dry processes will be done at IBS and wet processes will be done at external factory
  - Installation of clean room will start in soon
  - Contract process in ongoing with the external factory

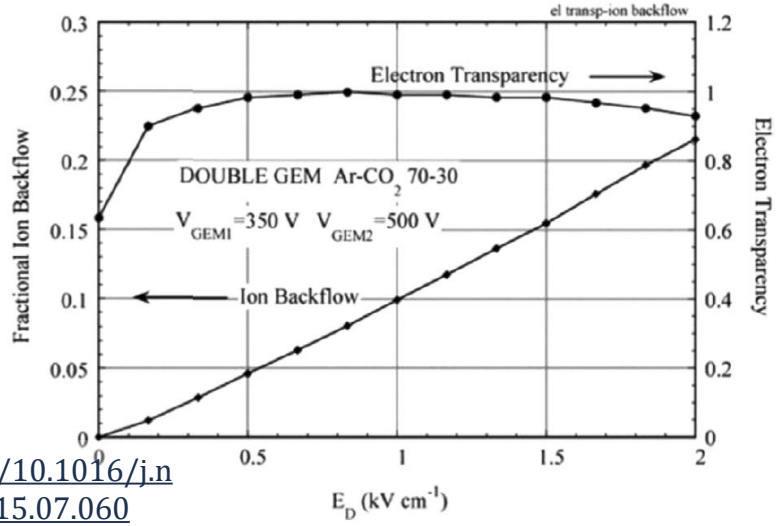
- If things go well, KCMS can produce residual GE2/1 foils

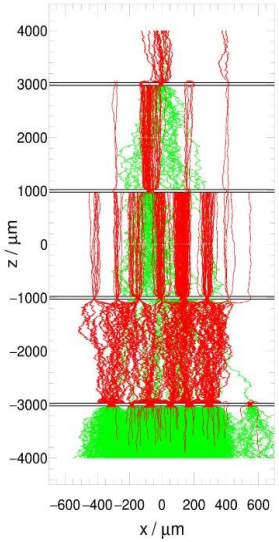
- We can contribute μRWELL to EIC with our own original technology!
  - Feasible

Back Up

Introduction to GEM

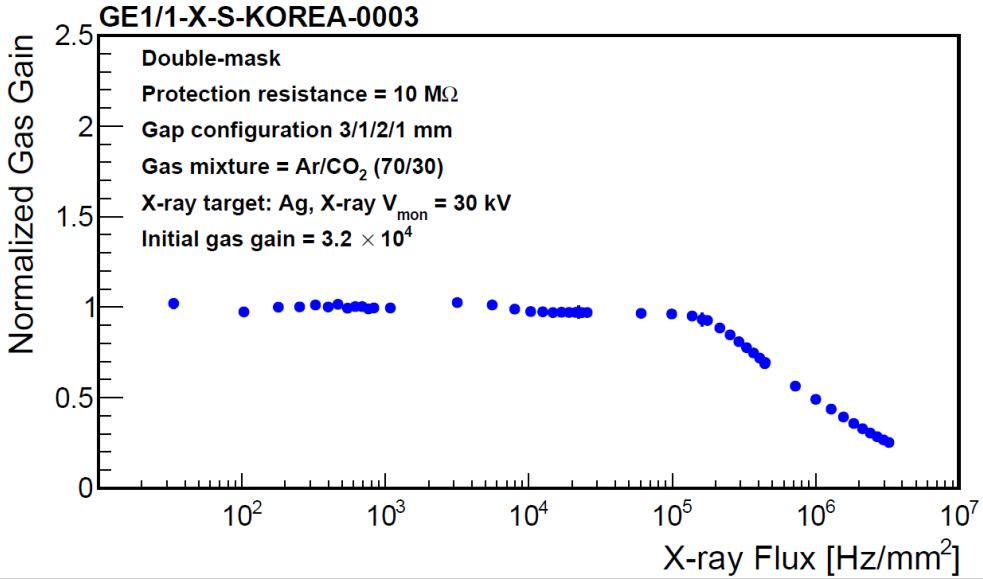


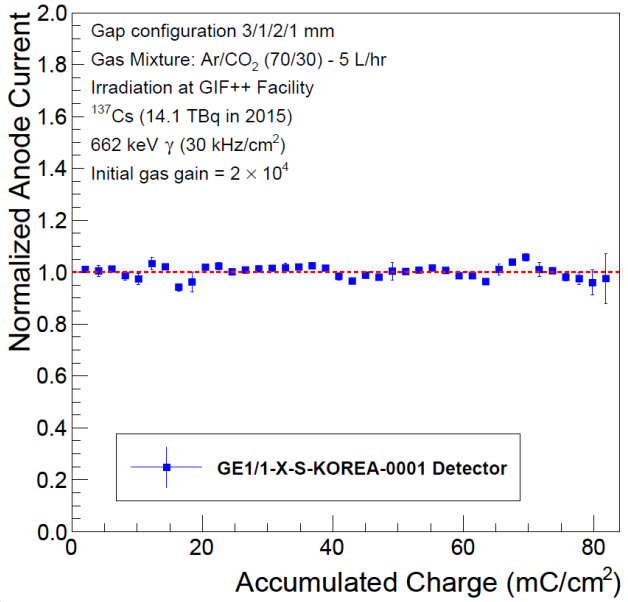




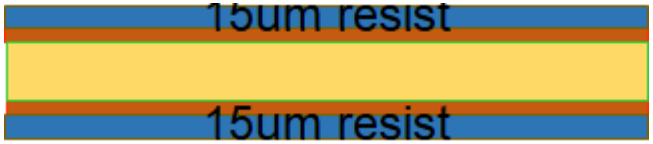
doi.org/10.1016/j.nima.2015.07.060

J. Ottnad,
RD51 meeting, 2018.05.12



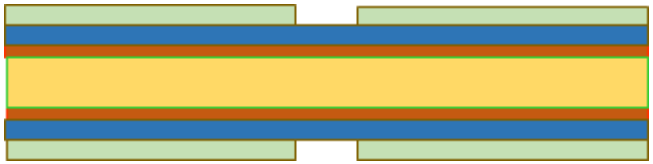


KCMS GEM project – Production Process

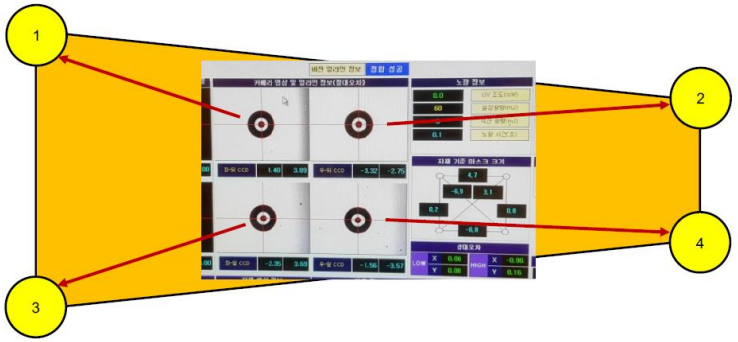


- Laminate DFR

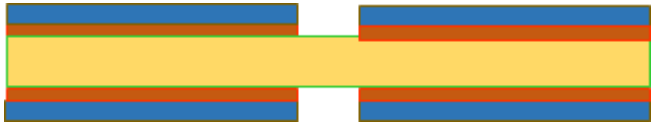
KCMS GEM project – Production Process



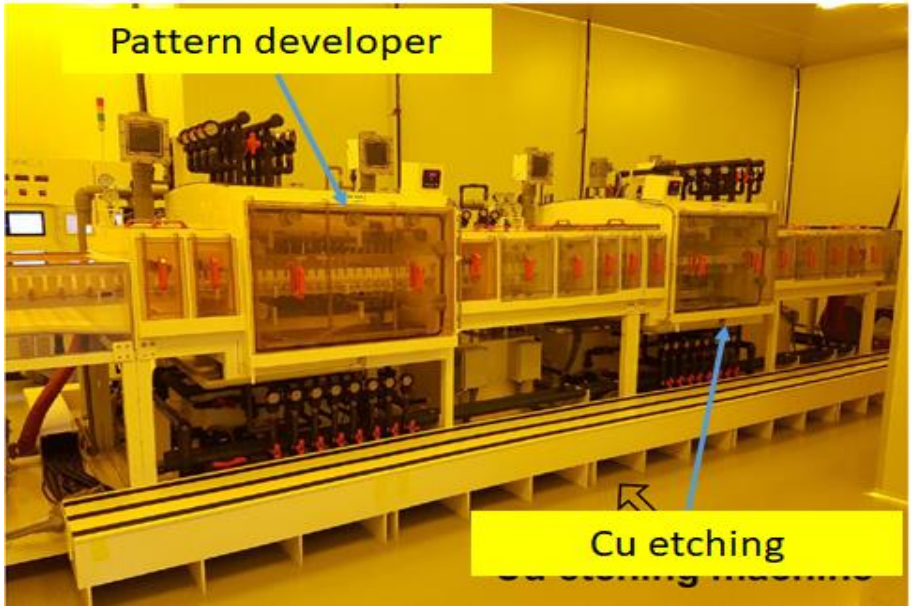
- UV exposure and pattern implantation
  - Double-mask technique for simpler production processes & faster production
  - Alignment of masks become crucial



KCMS GEM project – Production Process



- Developing pattern and 1st Cu etching
  - Developer: Na_2CO_3
  - Cu etching: $FeCl_3$



KCMS GEM project – Production Process

- DFR stripping
  - $NaOH$
  - Careful observation is needed to tweak dipping duration
    ∵ $NaOH$ etches Cu

KCMS GEM project – Production Process

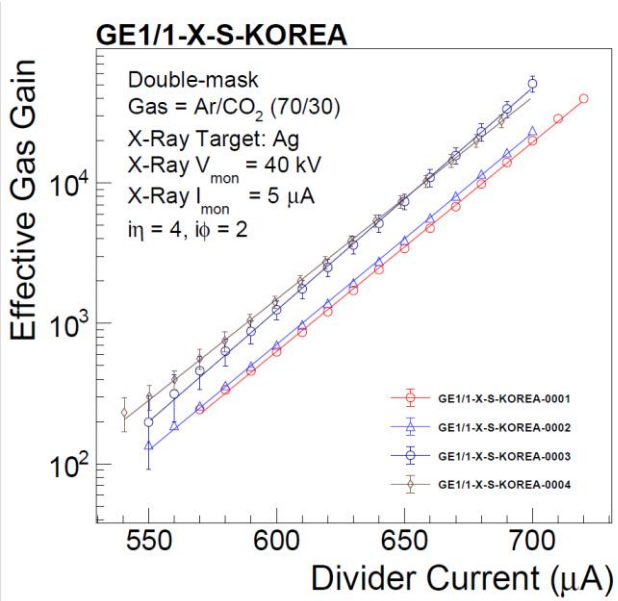
- Seed etching
  - $KMnO_4$

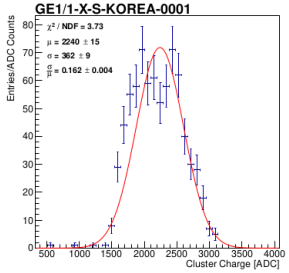
KCMS GEM project – Production Process

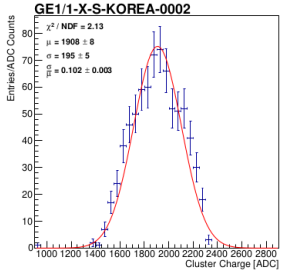
- PI etching
  - Mixture of MEA and KOH
  - Geometry is tunable
  - We are using MEA instead of EDA for safety

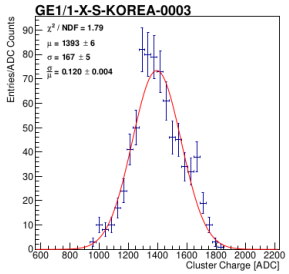
    LC of MEA to mice for 2h $> 2430\ mg/m^3$ Cf LC_{50} of EDA to mice $= 300\ mg/m^3$
  - Need to be tuned every use

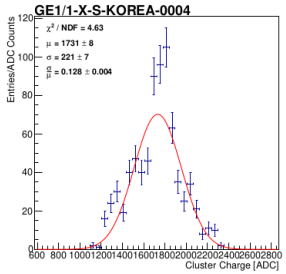
R&D History – Validation with GE1/1

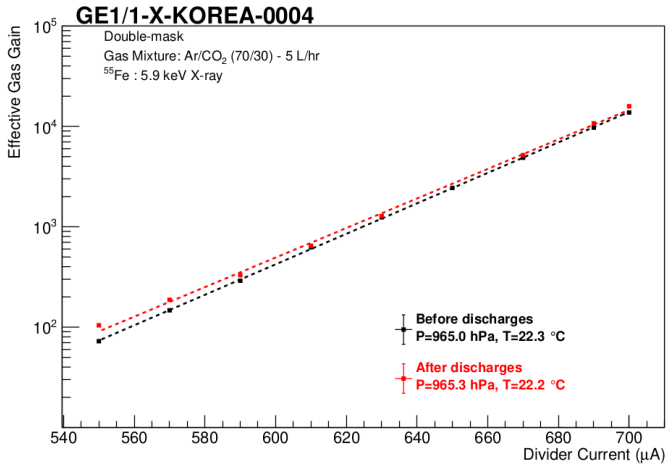


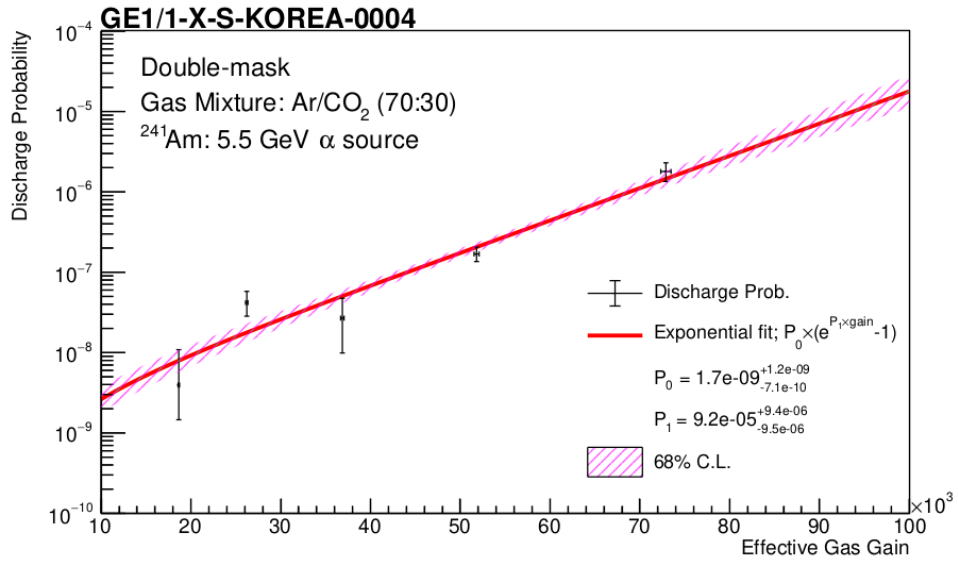


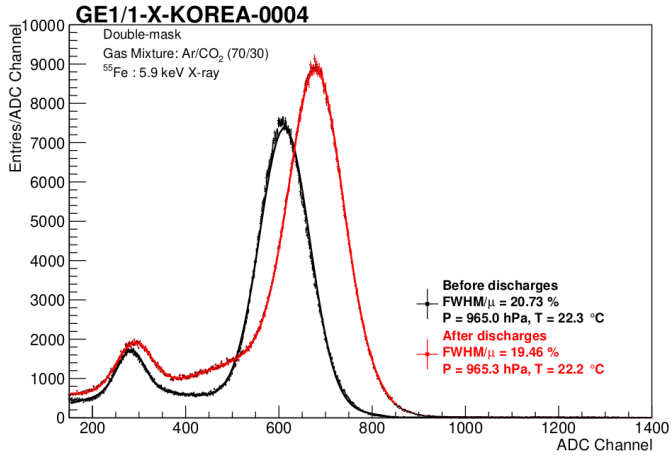












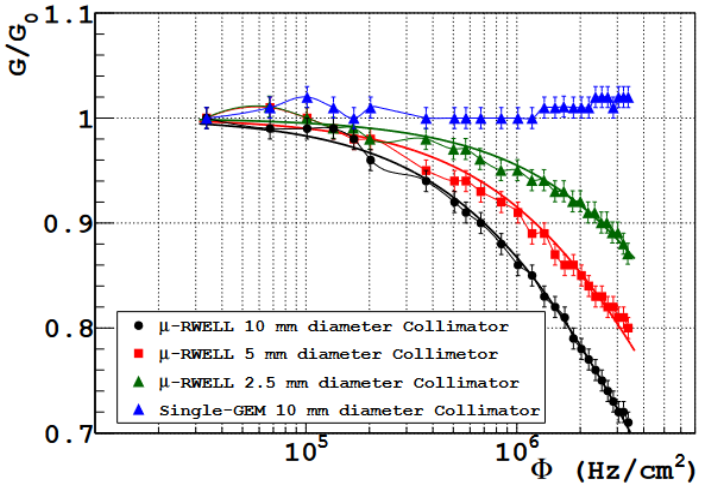
μRWELL

- $\mu RWELL$ is an attractive detector
  - Good position ($\sim 70-80\ \mu m$) & time resolution ($\sim 6\ ns$)
  - Further research is needed on the aging effect, but it is at least more robust than MWPC
  - Mass production friendly, and cheap
  - Easy handling (rigid) and assembly without foil stretch

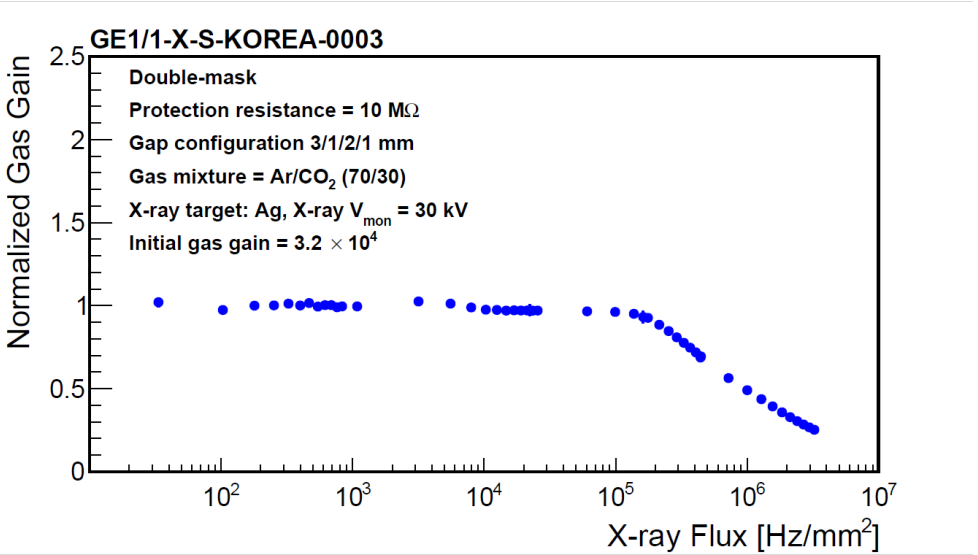
- Low rate capability compared to GEM

⇒ For experiments with low occupancy, $\mu RWELL$ will be used widely (my guess)

⇒ If low material budget is needed, MWPC



2015 JINST 10 P02008



10 Micro Pattern Gaseous Detectors

- $\mu RWELL$ is an attractive detector

- Easy handling (rigid) and assembly without foil stretch

- GEM and $\mu RWELL$ share very similar production processes