Performance of the GEM detector based on Korean foils for the CMS Muon Upgrade

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1. Introduction

Triple GEM detectors for the CMS Phase-II upgrade have been developed and planned to be installed in the endcap stations of the CMS muon system. This upgrade will improve the muon trigger and tracking performance in the high-eta region for the HL-LHC project. Not only CERN but also several suppliers participate in the production because the upgrade requires mass production of GEM foils.

Chambers assembled with Korean foils are produced using double-mask technique while CERN foils using single-mask technique. Even though alignment of the two masks on the top and bottom surface is challenging for a large size foil, this technique has advantages of more simple and faster production process.

We present the results of several quality control tests on the Korean GEM chambers.

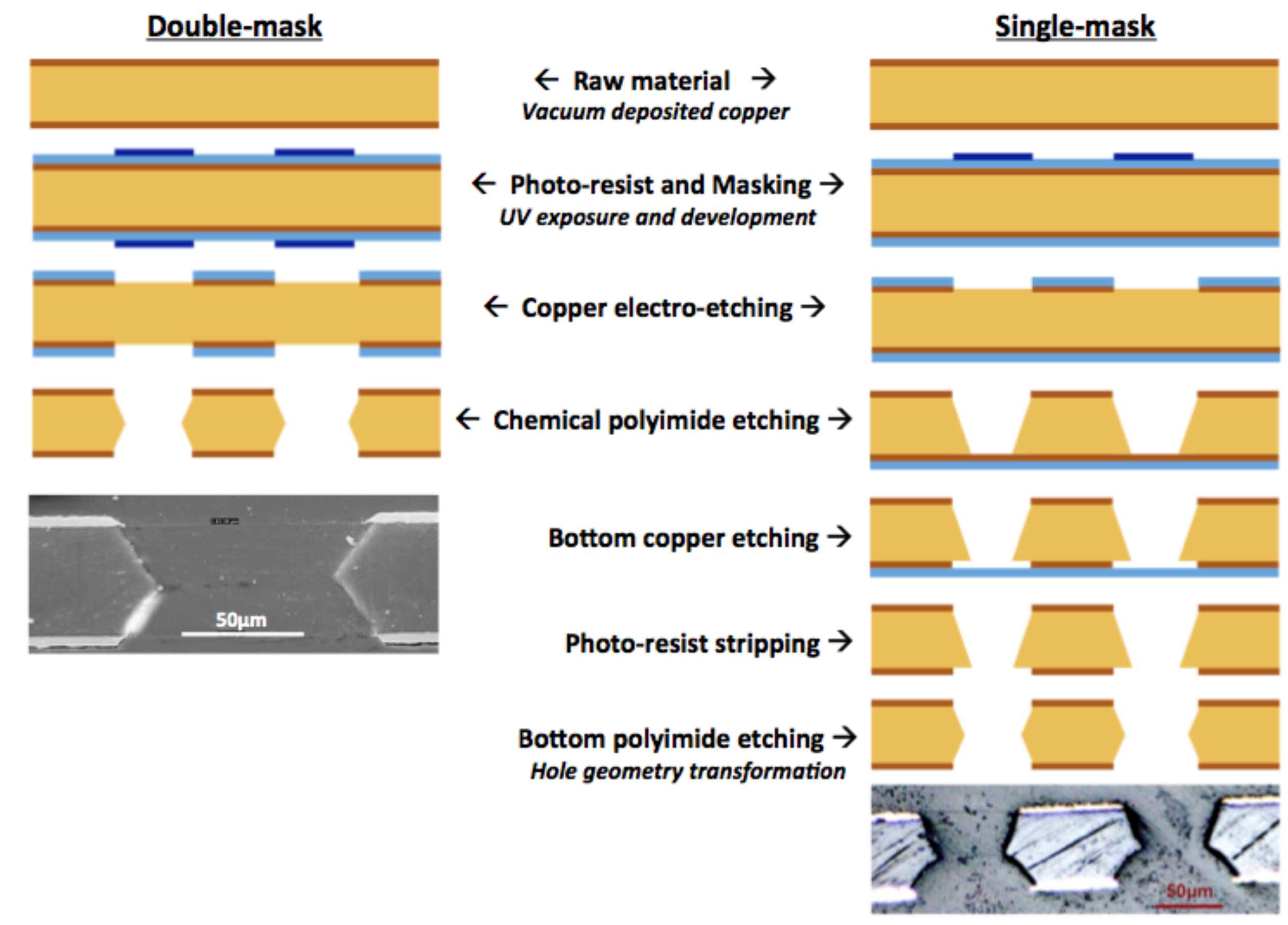


Fig.1 : Overview of the double-mask(L) and the single-mask(R) production processes [2]

2. Effective Gas Gain

- Definition of the effective gas gain

$$G = \frac{I_a}{R \times n_T \times e},$$

R : Interation rate
I_a : Readout current
n_T : # of primary electrons per incoming particle

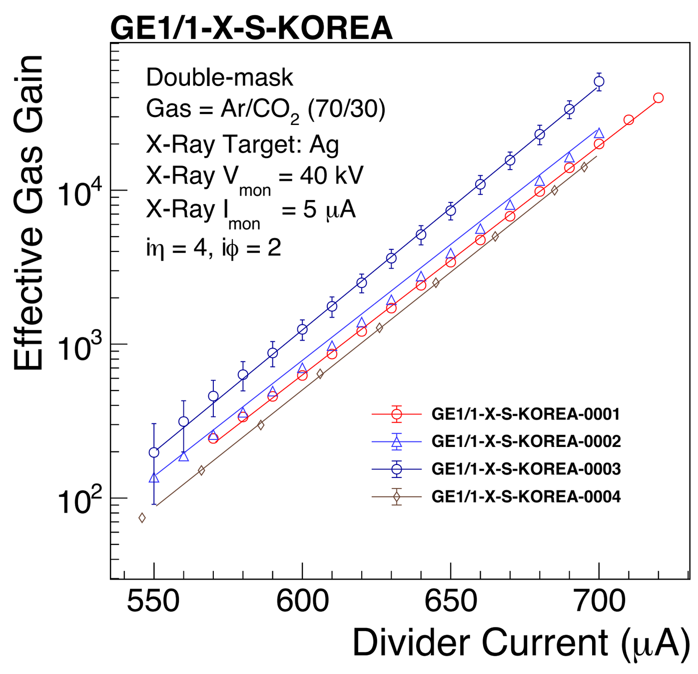


Fig.2 : Effective gas gains of the four Korea chambers

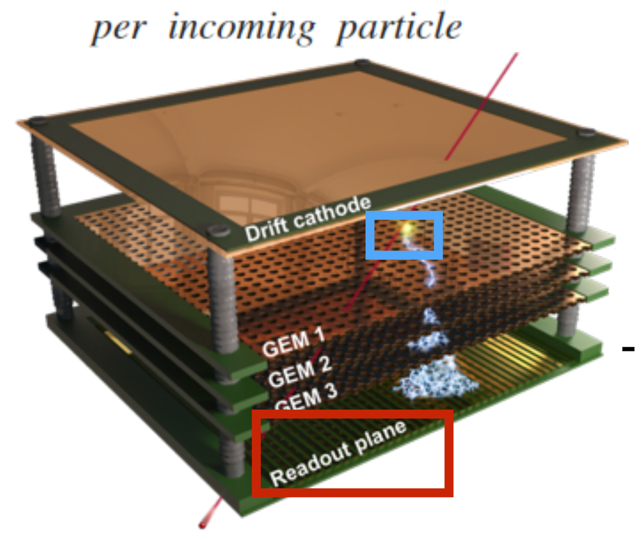


Fig.3 : Schematic view of triple GEM detector[2]

- (Current into readout) / (current by primary charge)
  - How much the amplification of primary charge is.
  - Measured gain = 1.3-5.1 · 10^4 @ 700 μA
  - Consistent with chambers using CERN foils (~ 10^4 @ 660 μA)[1]
  - Satisfy the the phase-2 upgrade requirement

6. Discharge Probability

- Rapid electric current between top and bottom surfaces of a GEM foil
- Damage on GEM detector
- Discharge induces the current change.

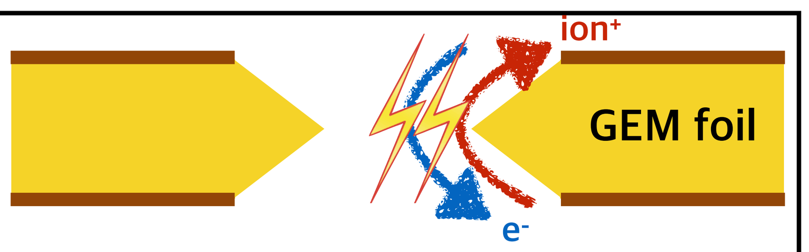


Fig.4 : Schematic figure of discharge on GEM foil

- A loop antenna is wound around a voltage divider wire to capture the induced signal from the current change in the HV circuit.
- 1st discharge probability measurement with GE1/1
- Low probability ~ 10^{-9} @ gain of 10^4

- Effective gas gain before/after 229 discharges
  → No significant difference
- ADC spectra before/after 229 discharges
  → No significant difference on detector resolution
- Small difference on the gas gains and peak positions can be understood as effect of enviromental parameter - Temperature & Pressure.

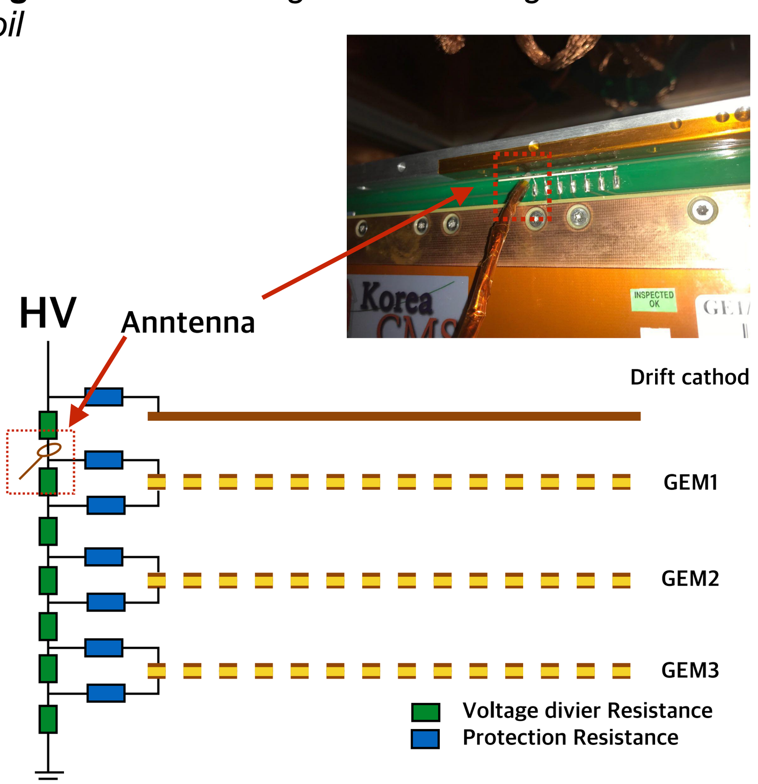
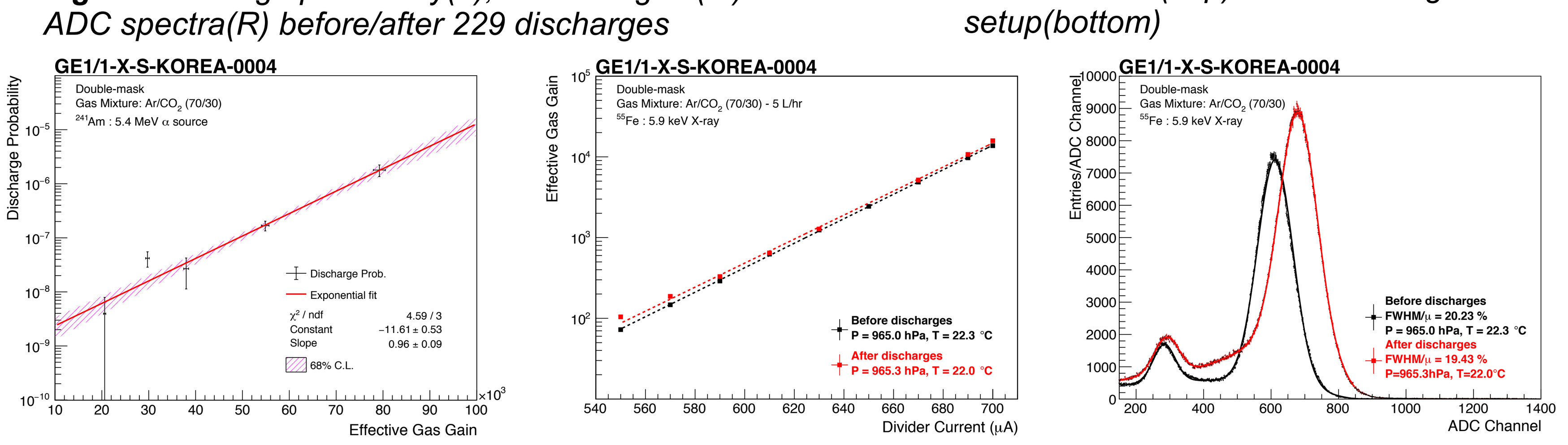


Fig.5 : Setup for discharge probability measurement(Top). Schematic figure of the setup(bottom)

Fig.6 : Discharge probability(L), Effective gain(M) and ADC spectra(R) before/after 229 discharges



3. Gain Uniformity

- Test the uniformity of the gas gain in all (iη, iϕ) regions of a GE1/1 chamber

- (96 slices in ϕ direction) * (8 regions in η direction)

= 768 clusters

- Measured uniformity = 10.2 ~ 16.2 %
- Consistent with the result of CERN foils [1]

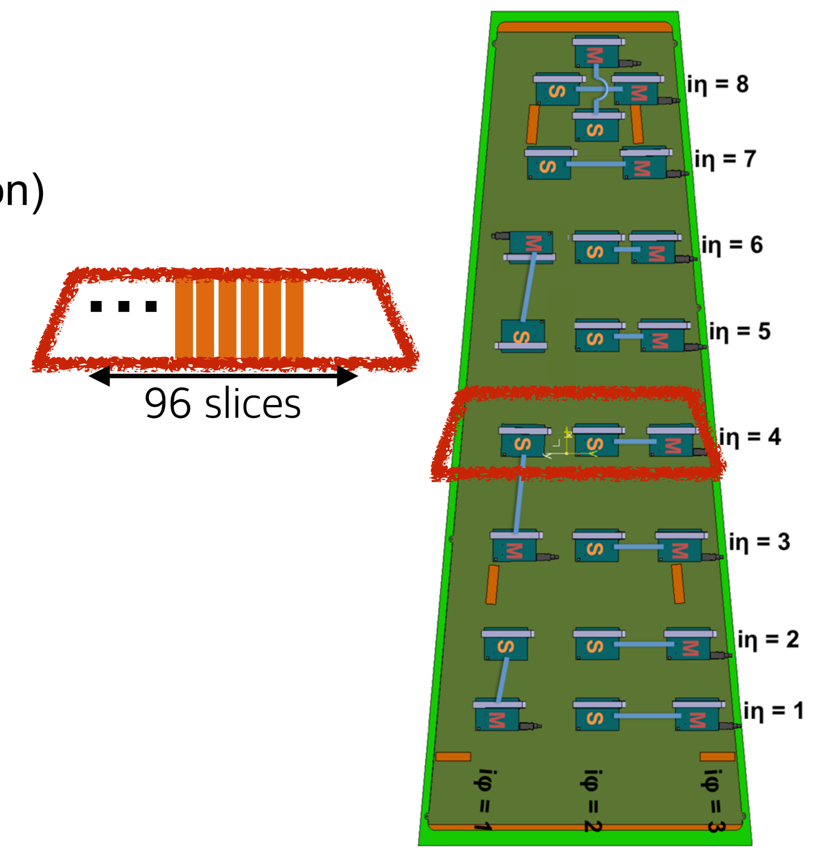


Fig.7 : An η partition divided into 96 slices(L) and (iη, iϕ) region on GE1/1 chamber(R)

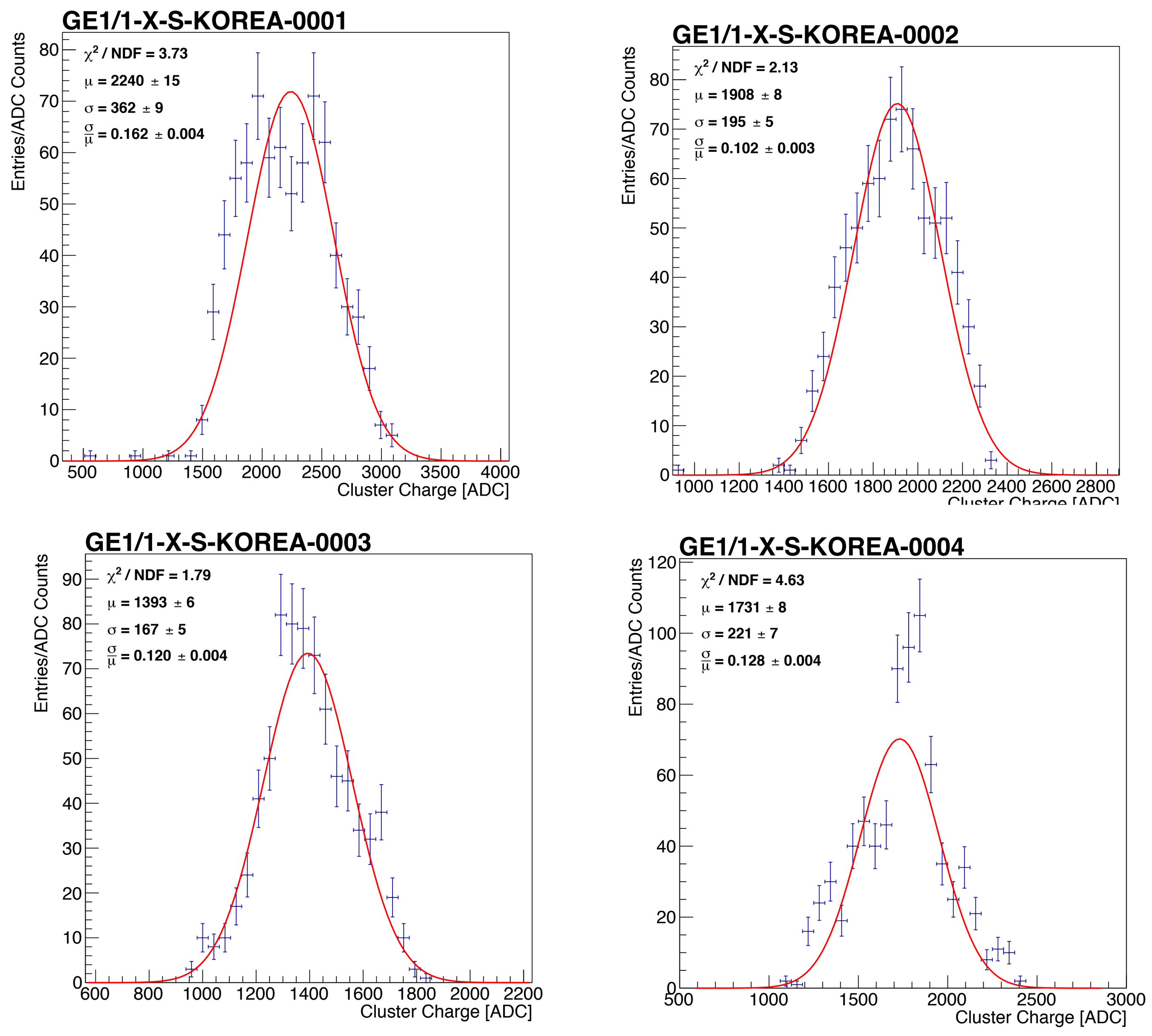


Fig.8 : Gain uniformity result of the 4 korea chambers

4. Aging Test

- Validate radiation hardness under HL-LHC
- Avalanche plasma
  → monomers from quenching molecules
  → polymers from the monomers
  → sticks to the conducting surface
  → Degradation on conductivity
- X-axis : Accumulated charge
: corresponds to the working time of the detector
- 66mC/cm² of accumulated charge
~ 217 years of GE2/1
~ 2.3 years of ME0 operation @HL-LHC
- No significant gain drop is observed
  → Validated in GE2/1 project (9mC/cm²)
  → ME0 project is on going (283mC/cm²

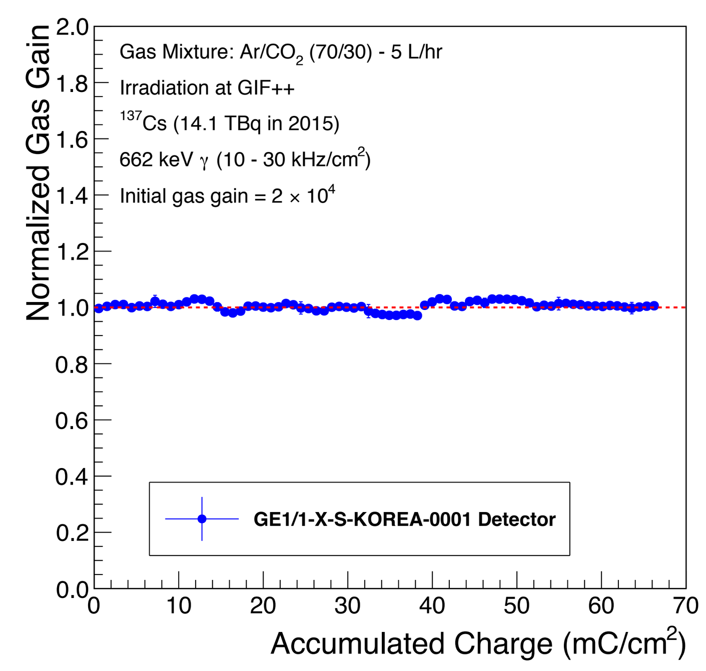


Fig.9 : Aging test result of GE1/1-X-S-KOREA-0001

5. Flux Capability

- High particle flux
  → Space charge ↑
  → decrease the electric field
  → degradation on the gas gain

- No gain drop to flux ~10^5 Hz/mm²

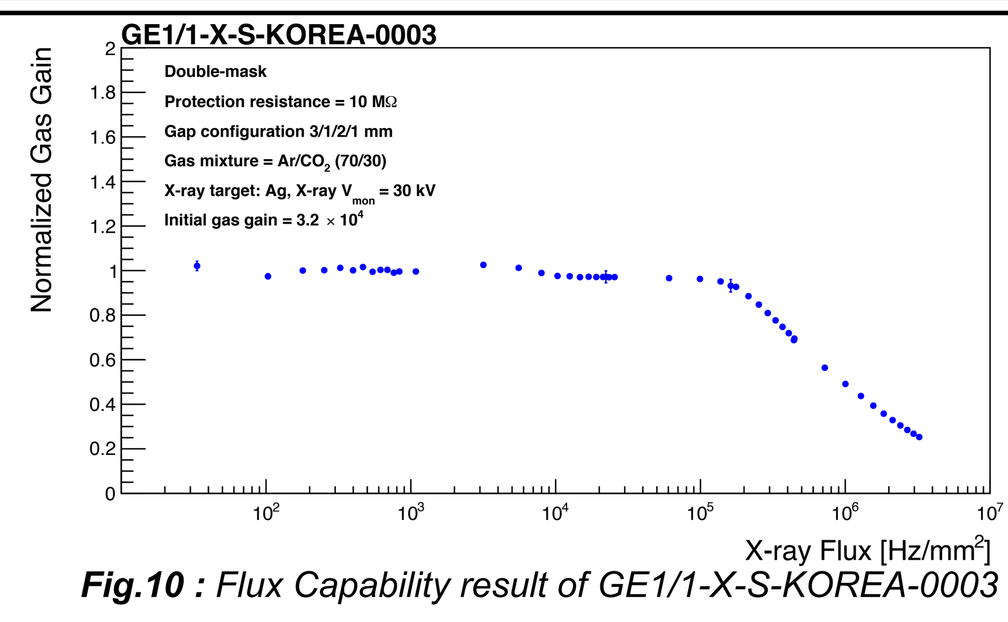


Fig.10 : Flux Capability result of GE1/1-X-S-KOREA-0003

- Gain drop from 10^5 Hz/mm²
  : Current between top and bottom surface of the foil
  → voltage drop by **high protection resistence(10 MΩ) on the GEM foil.**
  → Weaken the electric field

7. Summary

- Test Korean chambers in the aspect of effective gain, gain uniformity, aging, flux capability, and discharge
- Performance
  - Comparable to CERN foils
  - Satisfy the durability requirement @ HL-LHC
- Excellent prospect on Korean GEM foil production

Reference

[1] F. Fallavollita, Triple-Gas Electron Multiplier technology for future upgrades of the CMS experiment: construction and certification of the CMS GE1/1 detector and longevity studies, PhD Thesis, CERN-THESIS-2018-349.
[2] J. A. Merlin, Study of long-term sustained operation of gaseous detectors for the high rate rnvironment in CMS, PhD Thesis, CERN-THESIS-2016-041.
[3] CMS Collaboration, Production and quality control of the new chambers with GEM technology in the CMS Muon System, NIM A, 035 (2018)

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