A new Glass GEM with a single sided guard-ring structure

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Background

- GEM : widely used, superior performance.

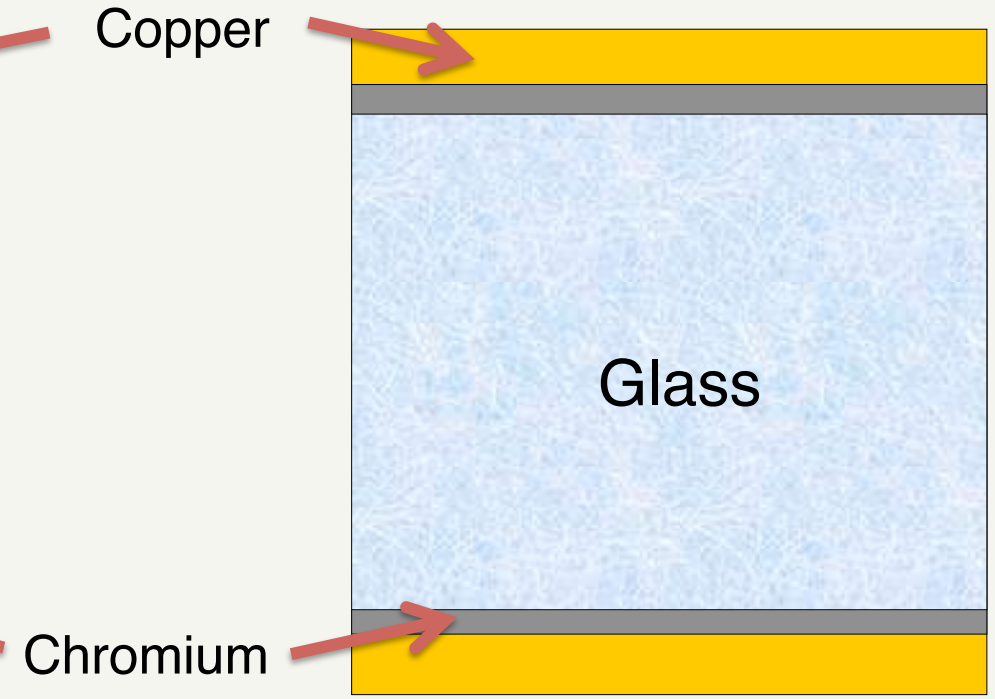
- What is "Glass GEM"? [1]
  - Substrate : Photosensitive Etchable Glass, PEG3 from HOYA Corporation, Japan
  - The holes are made by photolithography
- Advantages
  1. Hard material
     - Not deformed, easy handling
  2. Inorganic material
     - No outgas from the insulator, promising for sealed detector
  3. Lower resistivity
     - Low unfavorable charge-up on the insulator

	Unit	*Condition*	***PEG3***	***Polyimide***
Thermal conductivity	*W/m K*	*25℃*	*0.795*	*~0.3(20℃)*
Young's modulus	*GPa*		***79.7***	*18.6*
Dielectric ratio		*1GHz*	*6.28*	*3.55(1MHz)*
Volume Resistivity	*Ω・cm*	*25℃*	***8.5 x 10^{12}***	*~10^{18}*
Thickness	*um*		***300~1000***	*~50*

[1] H.Takahashi, Y.Mitsuya, T.Fujiwara, T.Fushie, Nuclear Instruments and Methods in Physics Research A 724 (2013) 1–4

Challenge – Spark Tolerance

After damaged by spark



Side view

- What happens when severe sparks happen?
  - The insulator (Glass) is spark tolerant material
  - But the copper part melts, chromium is exposed

Challenge – Spark Tolerance

- How GEM type detectors are damaged by sparks?

1. A GEM type detector has large capacitance, so a lot of electric charges are accumulated on its metal during its operation

2. A lot of charges are released when a spark occurs.

3. Severe sparks with huge amount of charges may damage GEM holes

Objective

- Developing a new type of Glass GEM which can protect GEM structure from the large capacitance and charges.

- Investigate its basic characteristics as a gaseous detector.

Solution – Guard ring

- Glass GEM with guard ring structure
  - Completely new type of Glass GEM
  - A metal ring is formed around each hole by laser
  - Rings are electrically floating
  - Guard ring structure is only on one side

- The Aim of the ring structure
  - Reduce the surface of metal, and reduce the amount of charges accumulated on the metal around the holes

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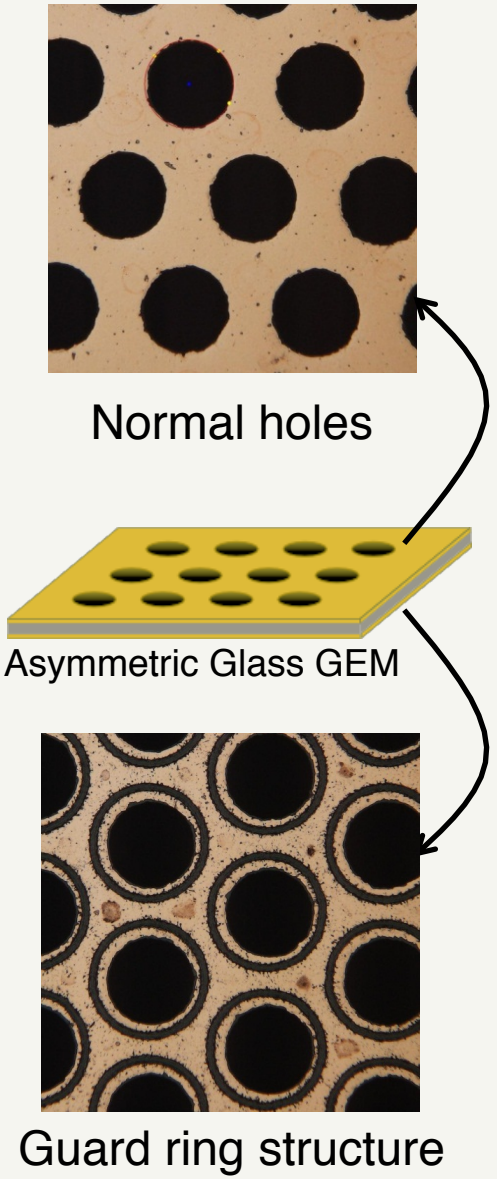
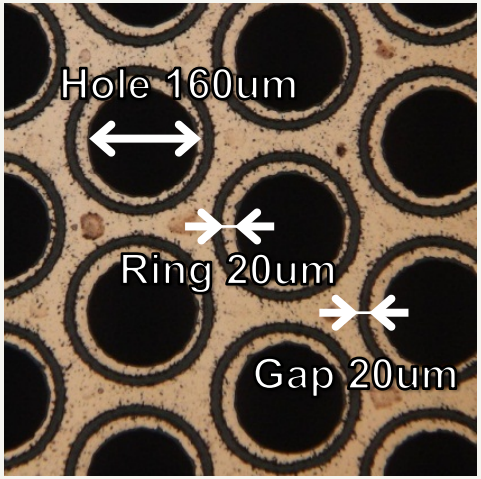
    Reduce the amount of charges in the spark events, and alleviate spark damage to the holes.



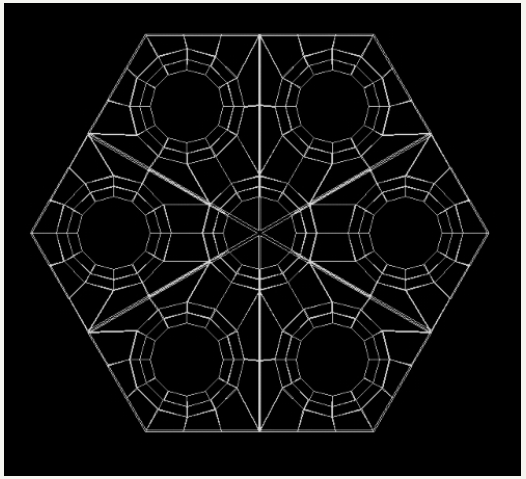
Simulation Models & Results

Simulation Model of Glass GEM

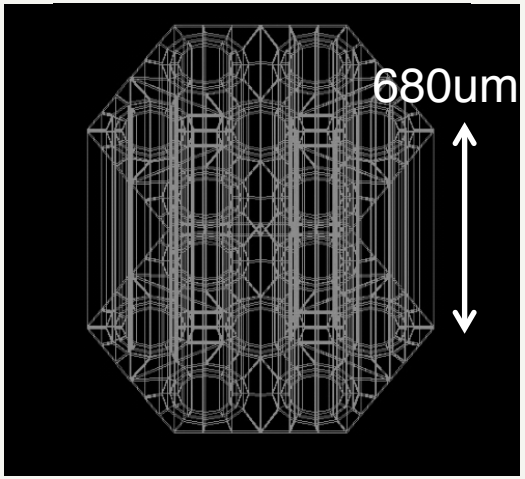
- Simulation with ELFIN code from ELF Corporation
  - ELFIN uses “Integrated Element Method” originally developed by ELF Corp.
  - With this method, no need to make fine mesh structures, good for micro pattern analysis
- A Model of holes of a Glass GEM



Actual guard ring geometry



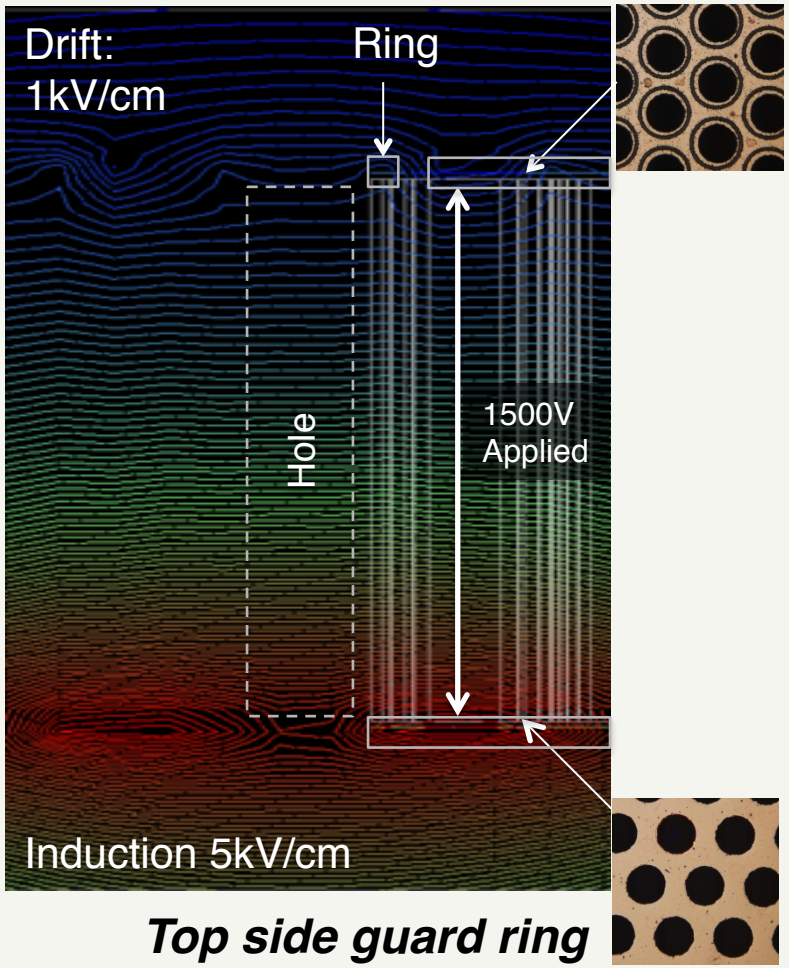
Top view



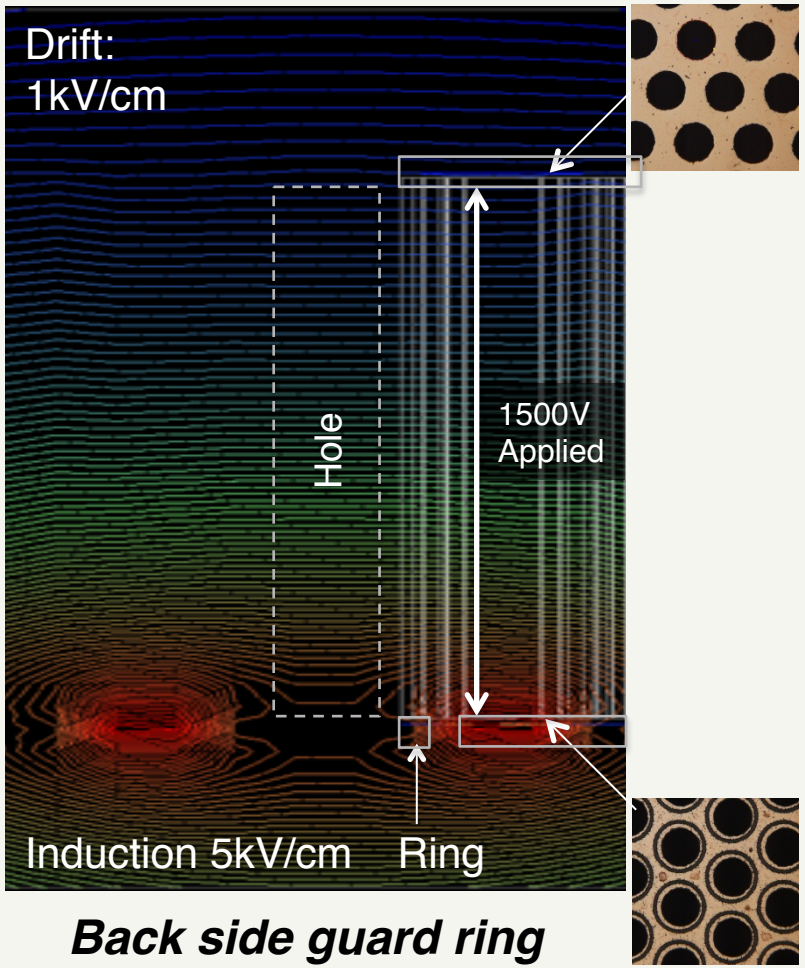
Side view

Simulation model by ELFIN

Simulation results – Electric field



Top side guard ring



Back side guard ring

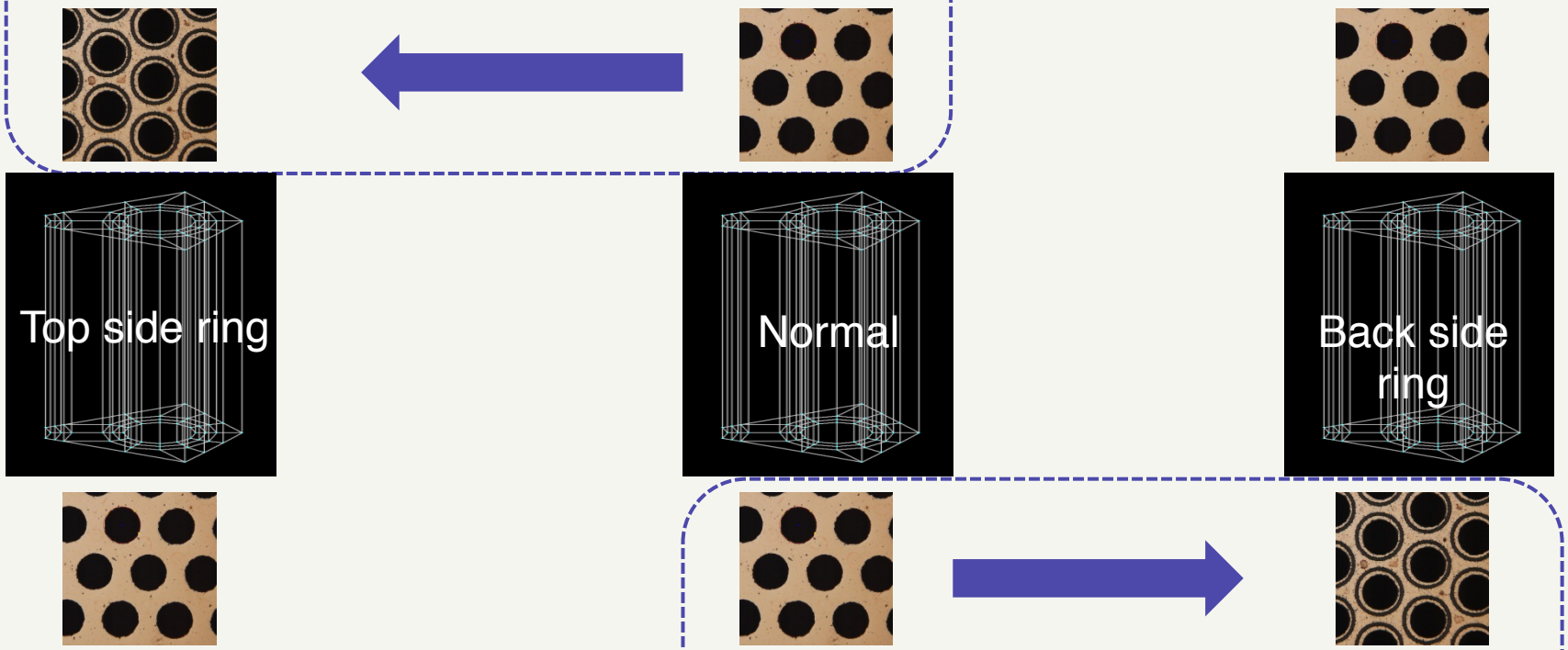
- Colored lines are equipotential lines
  - High electric fields are formed with both of models, high gas gain can be achieved.

Simulation results – Charge reduction

Charge Reduction

9.2% (20um Ring&Gap)

18.1% (25um Ring&30um Gap)



Charge Reduction

10.2% (20um Ring&Gap)

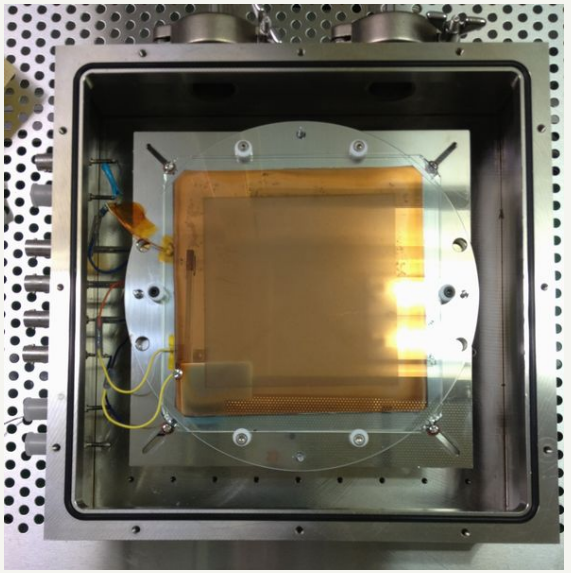
18.1% (25um Ring&30um Gap)

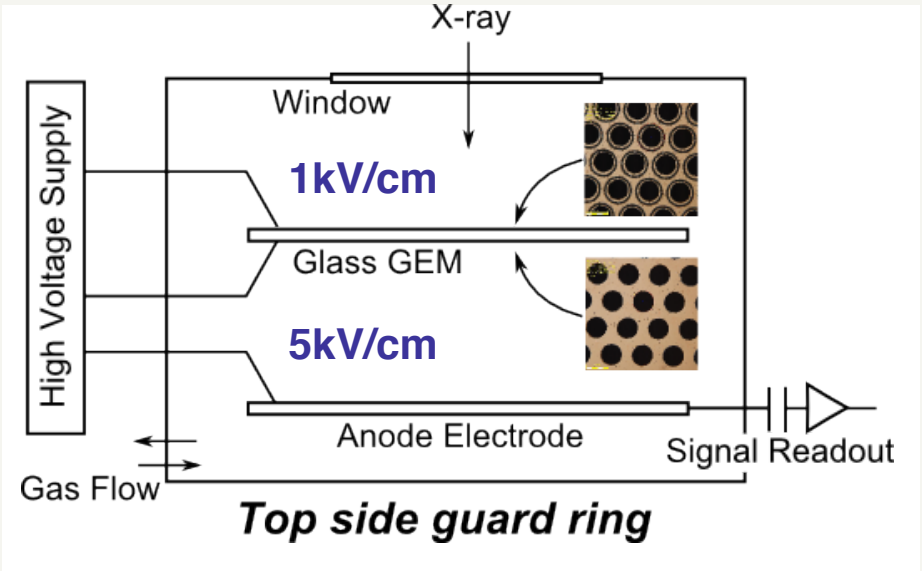
**With smaller holes like 140um, the reduction rate becomes higher up to around 30%.*

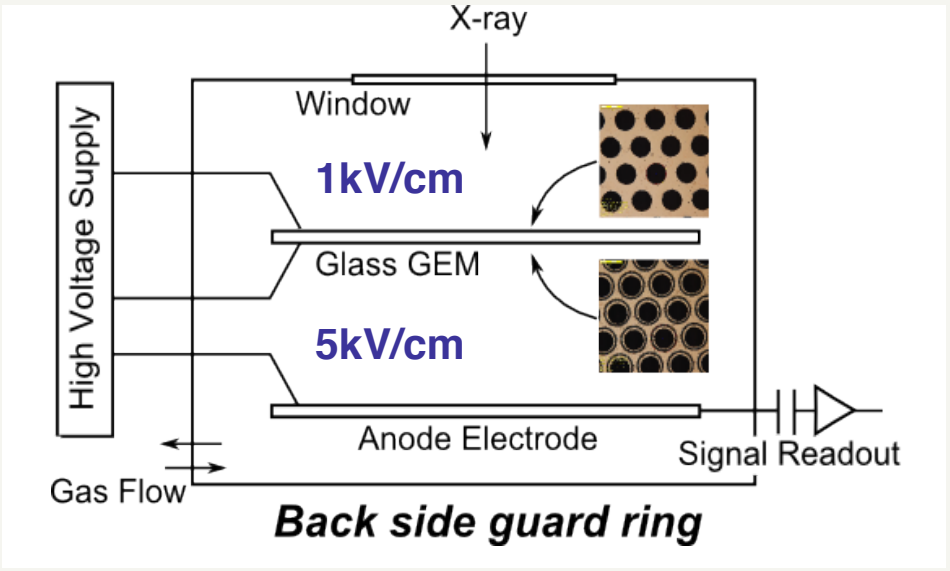
Experiments

Setup

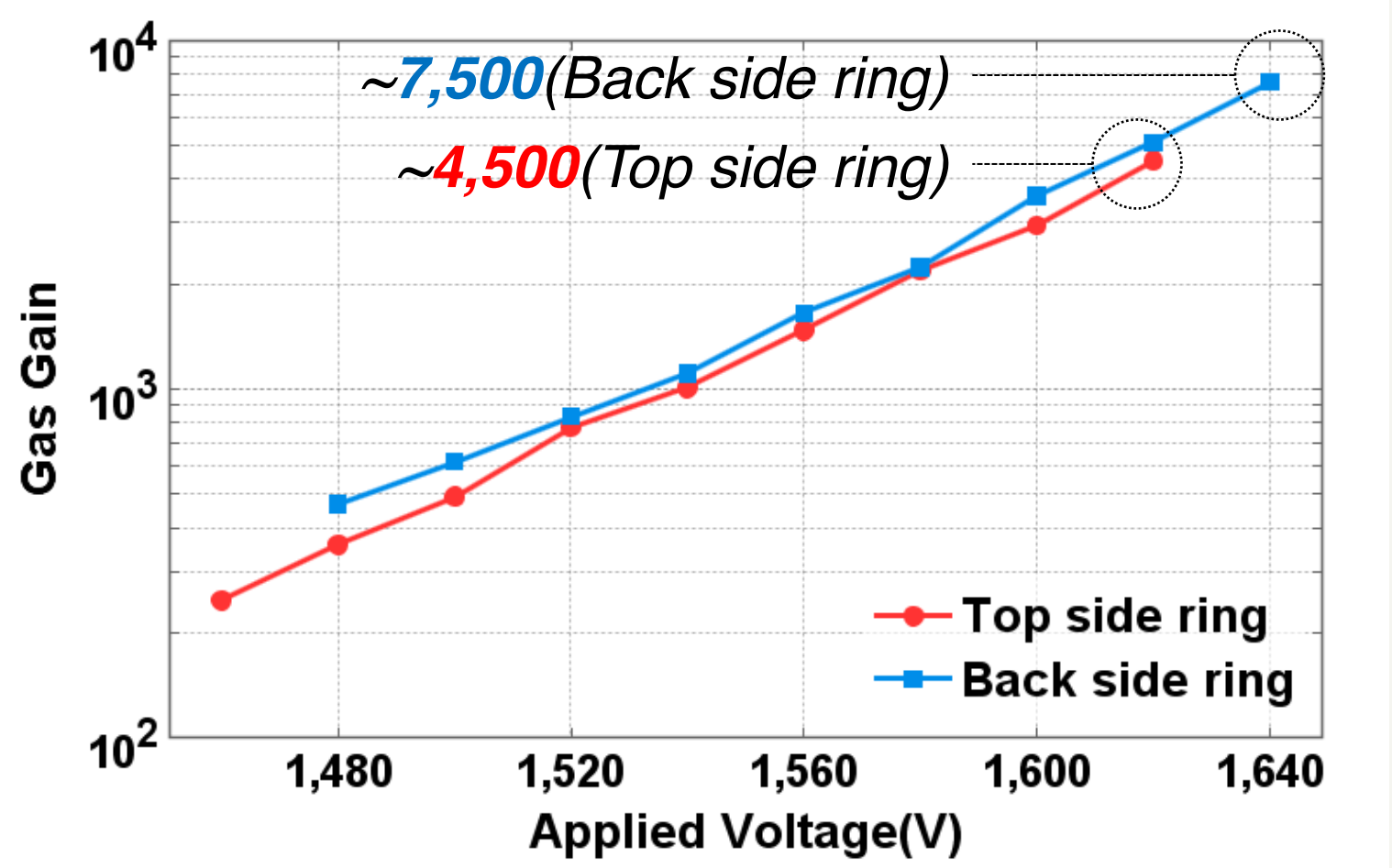
- Gas : Ar/CH4 90/10 (Gas flow)
- Sources
  - ^{55}Fe 5.9keV X-ray for uniform irradiation
  - 6keV X-ray collimated beam (60umx60um) from SR (The beam is for back side ring setup only)
- The geometry of Glass GEM
  - Sensitive area 10cm x 10cm
  - Hole diameter 160um
  - Ring and Gap width 20um
  - Thickness 680um





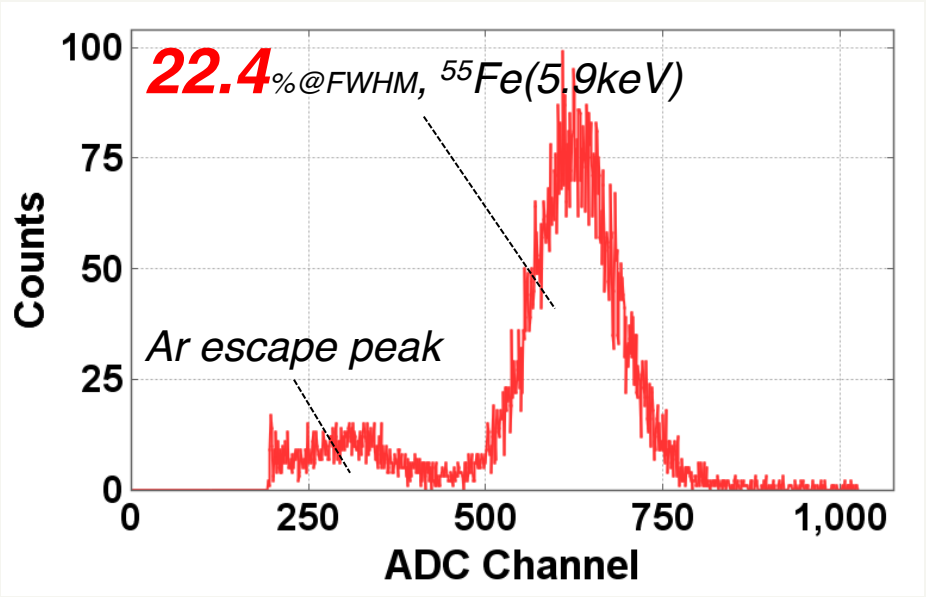


Gas Gain

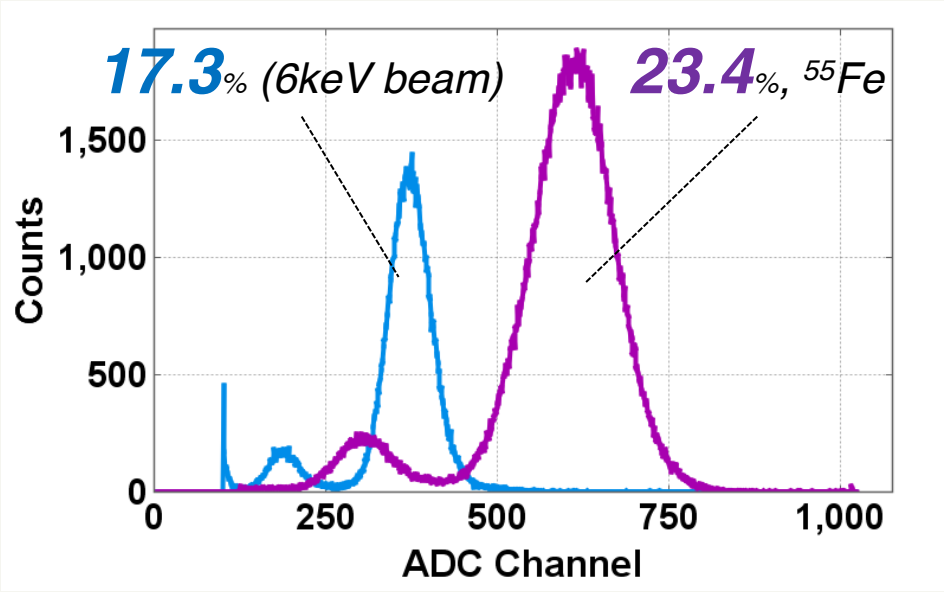


- High gain was achieved with single Glass GEM setup

Energy Spectrum



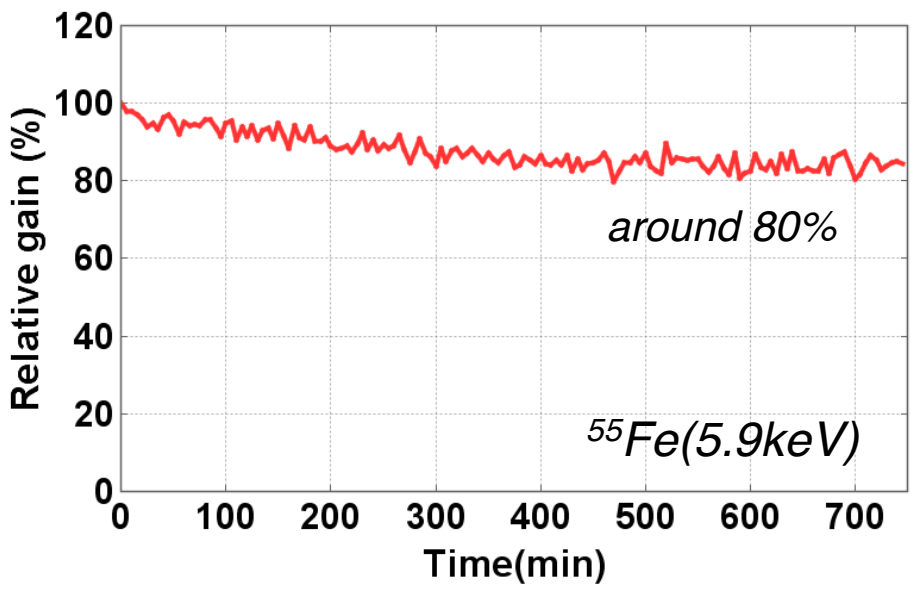
Top side guard ring



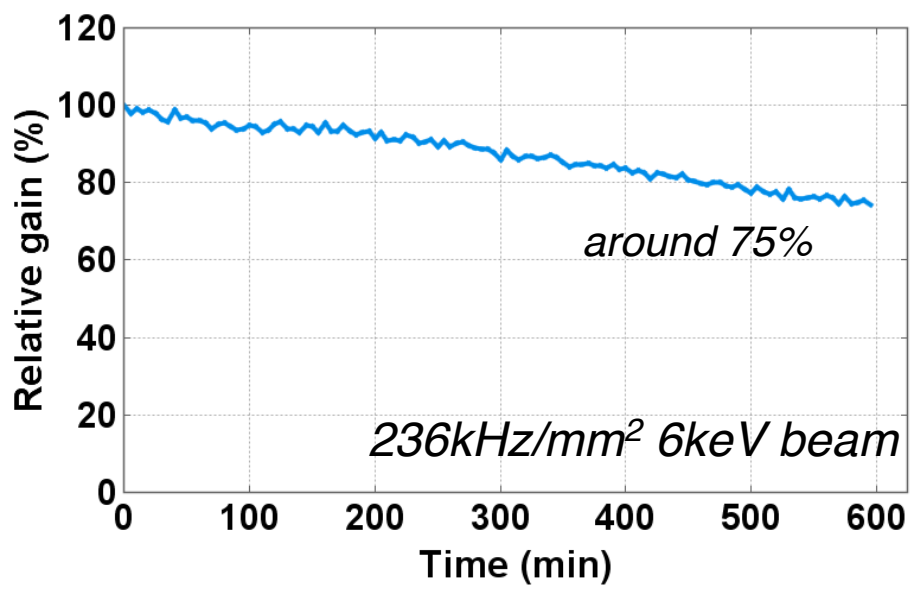
Back side guard ring

- High energy resolution was achieved with both setups.
- Top side guard ring
  - 22.4% @ ^{55}Fe uniform irradiation, gas gain ~1500
- Back side guard ring
  - 23.4% @ ^{55}Fe uniform irradiation, gas gain ~ 6300
  - 17.3% @ Collimated X-ray beam, gas gain ~ 2700

Long time stability



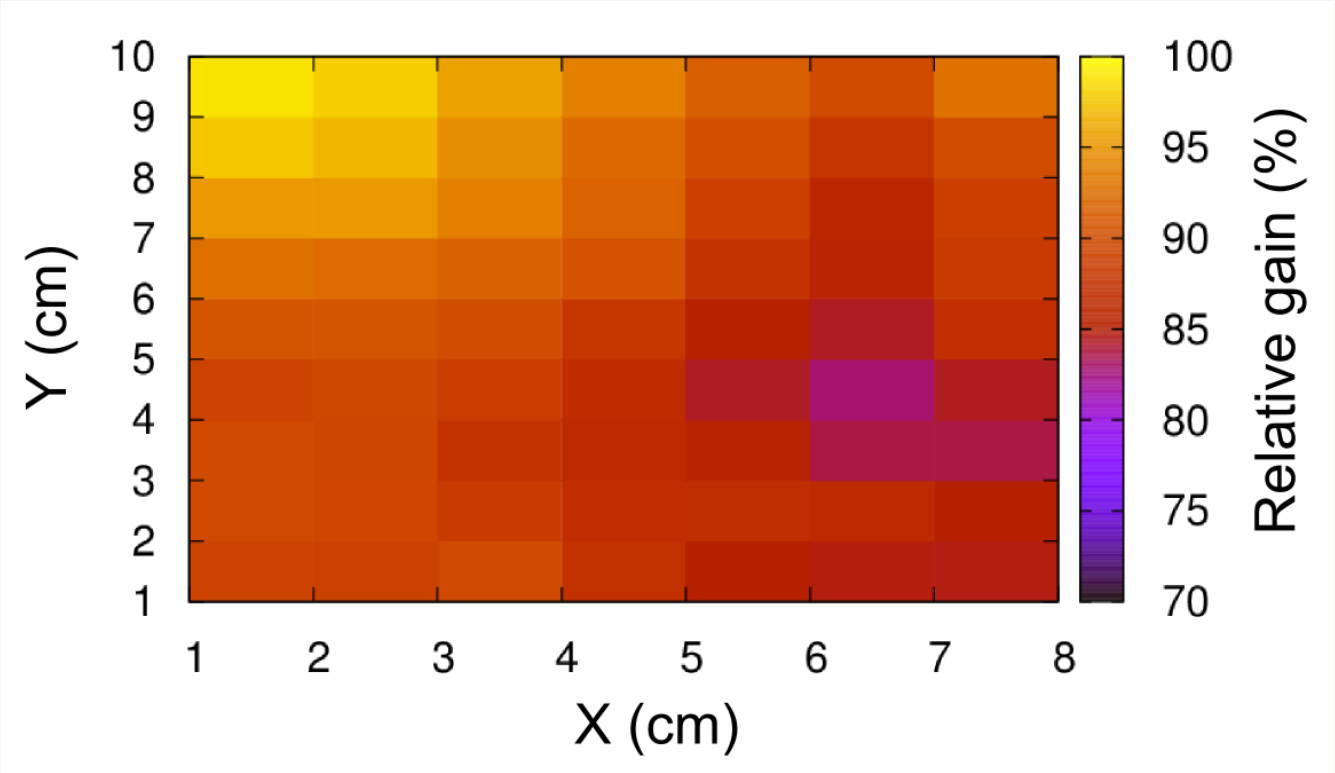
Top side guard ring



Back side guard ring

- The gain went down through the long time operation with both of the setups.
  - Charge-up effect, which usually pushes up the gain continuously, is not observed.
- About gain decrease
  - The surface resistance of inside of the holes decreased,
    the leakage current increased, then the effective voltage to the GEM decreased

Gain Uniformity



Back side guard ring

- Collimated beam scan, moving by 1cm each
- The lowest part showed 25% decrease compared with the highest.
  - It might be because of the effect of the induction field.

Conclusion

- We made a completely new Glass GEM with guard ring structure, and confirmed that electric charges were reduced with it by simulation.
- We also investigated its basic characteristics.

- Simulations
  - Electric charges were reduced (10~20%) compared with normal Glass GEM which does not have guard rings.

- Experiments
  - Investigated the basic characteristics of top side and back side ring GEM.
  - High gas gain 7500 was achieved.
  - High energy resolution 17.3% was achieved.
  - Long time stability and gain uniformity were also tested.

- Future work
  - Experiment : Quantitative study of the charge amount during spark events

Thank you for your attention

Appendix

Fabricating Process of Glass GEM

1. Glass Substrate

2. UV exposure (1st_exp)

3. Crystal formation
(1st heat treatment)

4. Via etching
(hydrogen fluoride wet etch)

5. Cu/Cr Plating and Sputtering

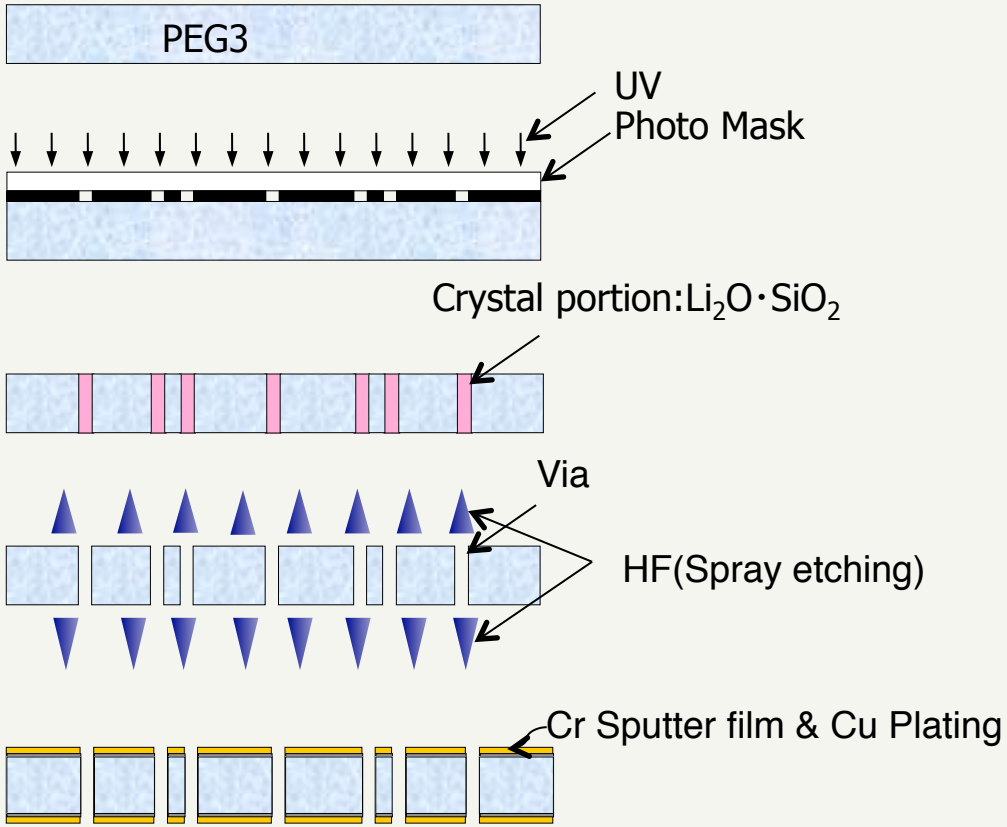
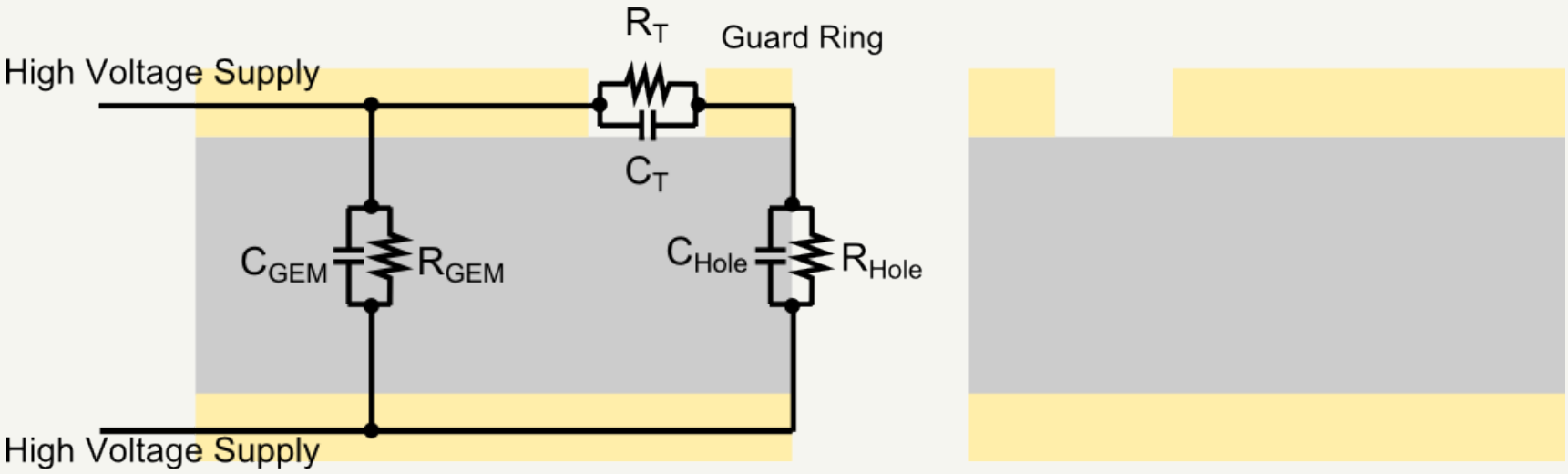
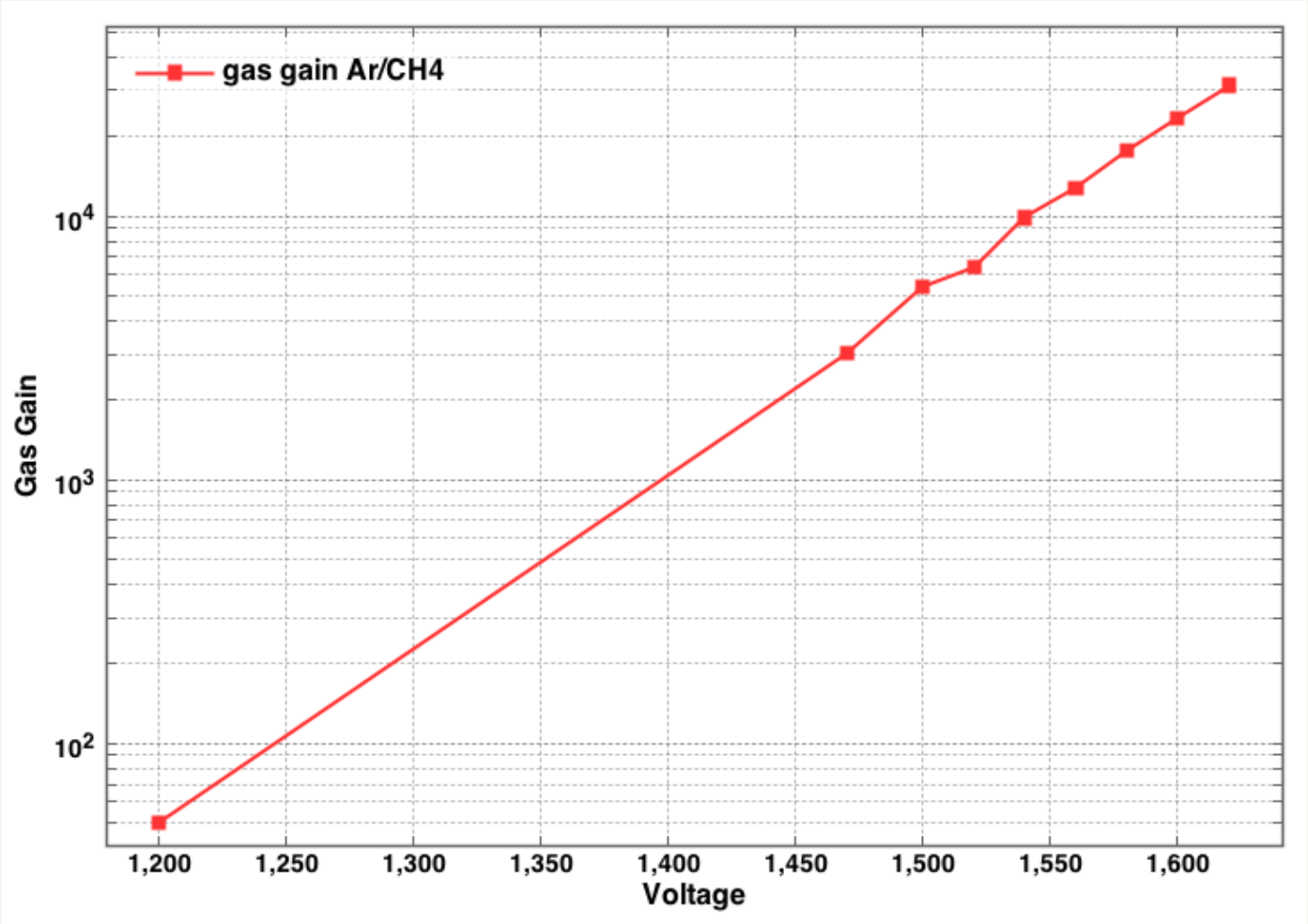


Photo Etchable Glass 3 : PEG3

Surface Resistance

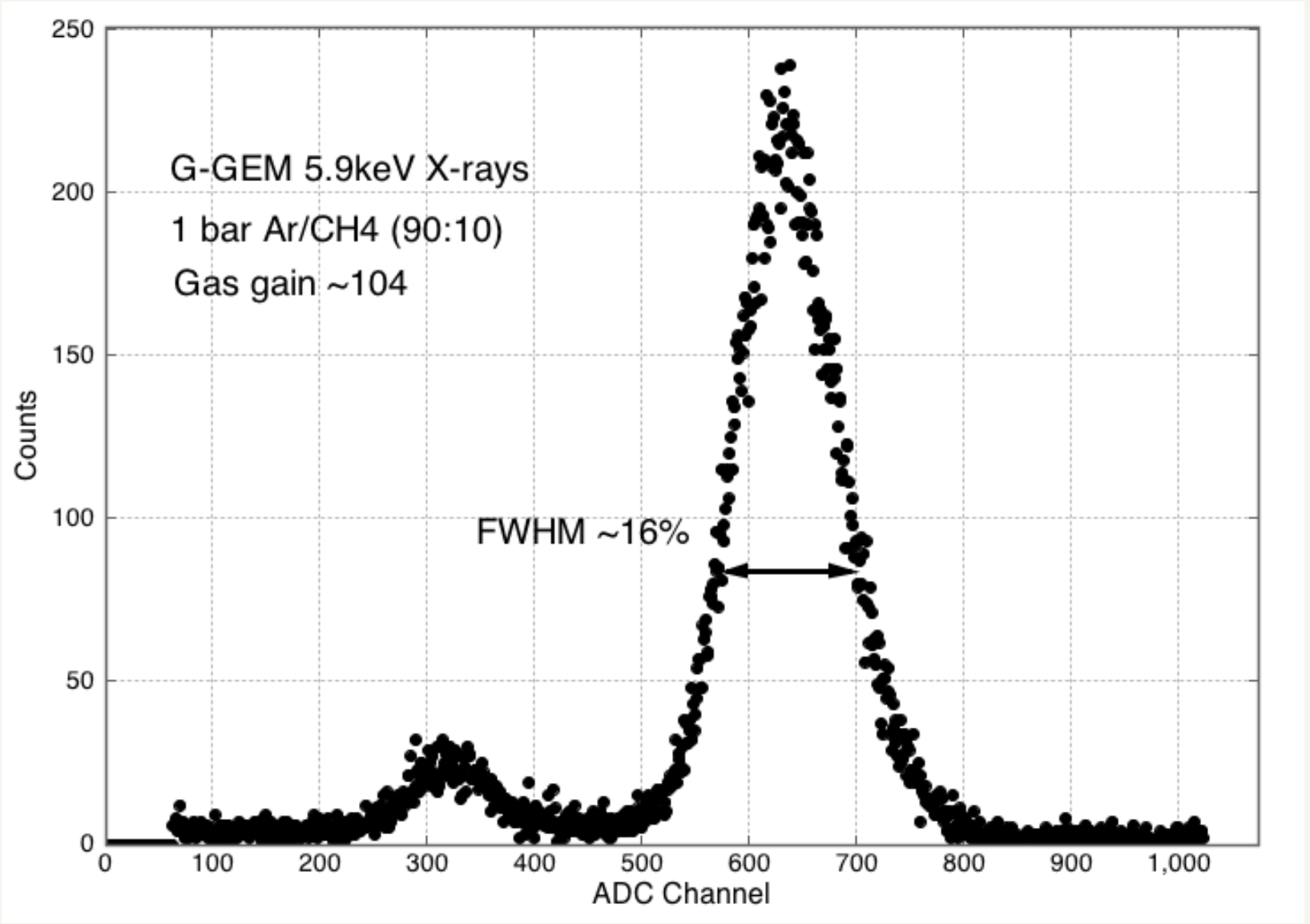


No ring - Gain curve

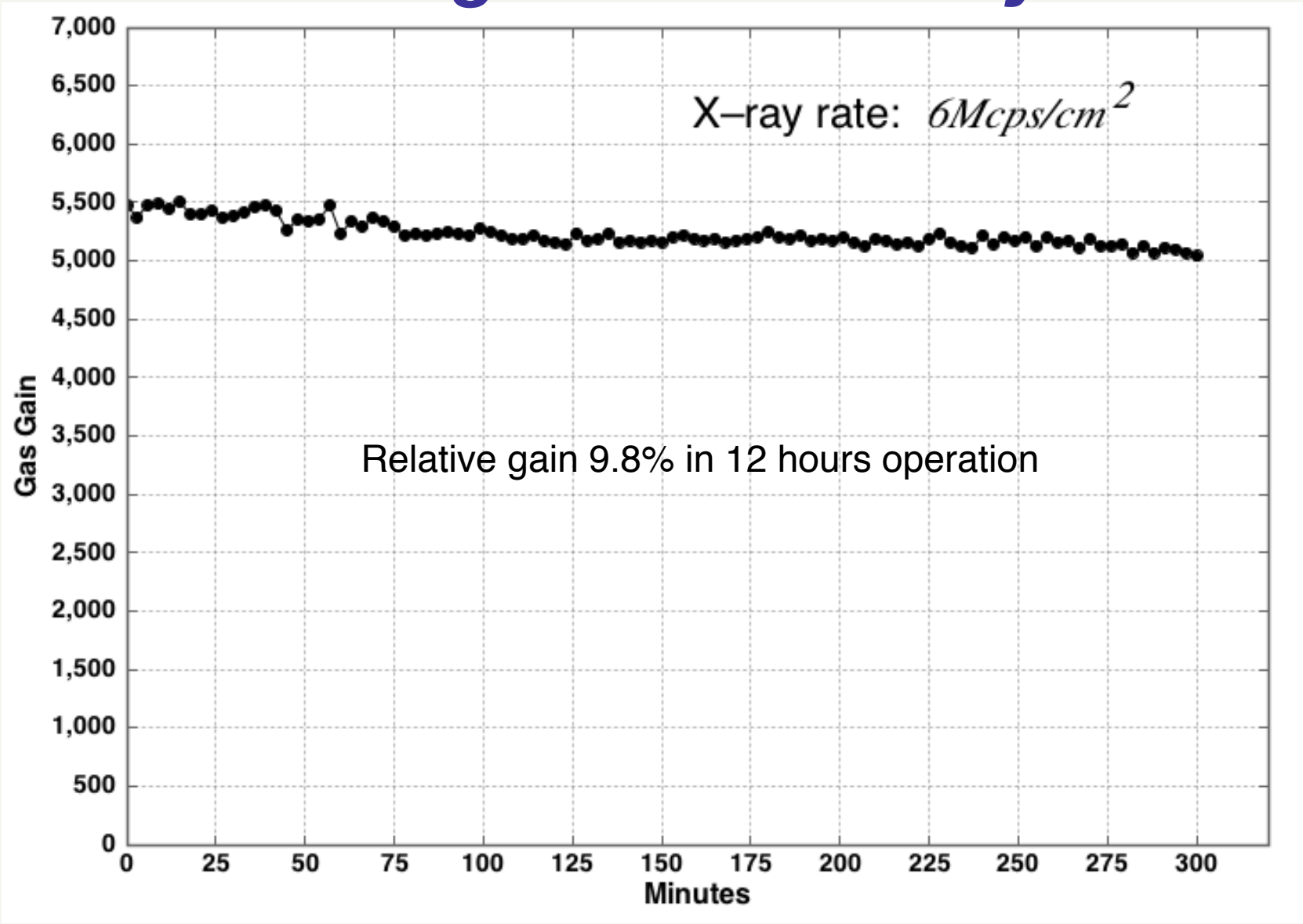


[GlassGEM] Thickness: 680μm, Hole diameter: 170μm

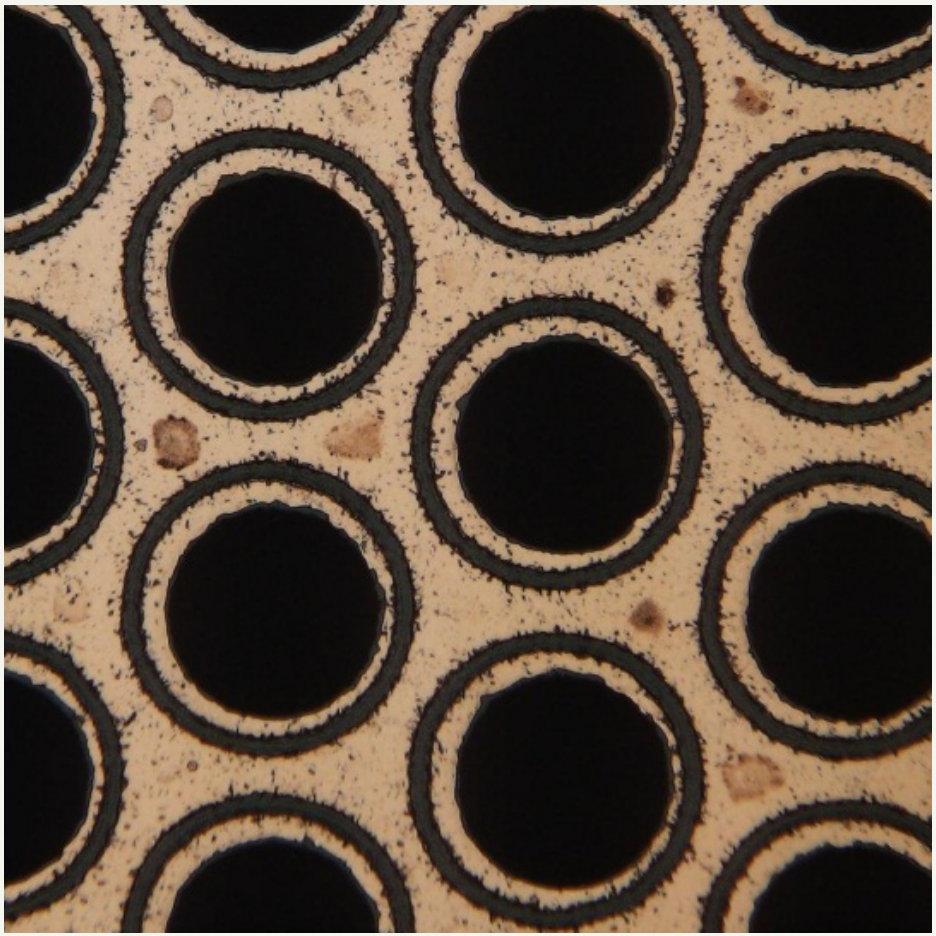
No ring – Energy spectrum



No ring – Gain stability



Ring



- Rings are formed off-center
  - causing gain variation, bad effect to the energy resolution