GEM study at Iwate University

Kentaro Negishi (Iwate University)

RD51 collaboration meeting

22-Oct.-2019

Contents

- Motivation
- What is LTCC-GEM
- Experiments
    - Gain & Resolution
    - Stability
    - Uniformity
- Conclusion

Motivation

- Using traditional LCP-GEM,
  we can not apply high voltage to GEM,
  in order to be careful for damage due to discharge.
  → An insulator material with discharge tolerance is desired.
  In addition, requiring …
  - Sufficient gain even with a mono-layer
  - Mechanically high strength, rigid structure
    → for easy handling and gain uniformity
  - Simple production process
  - Cost effective
- Possible candidate is the Low Temperature Co-fired Ceramic

The LTCC-GEM has been originally proposed and developed
by Dr. Komiya (Tokyo Metropolitan Industrial Technology Research Institute)

LTCC(Low Temperature Co-fired Ceramic)

- The ceramic is sintered at low temperature (<1000 ˚C) by adding SiO_2 to Al_2O_3.
- This process allows the co-firing with highly conductive materials such Ag and Au.
- Robust against mechanical and thermal stress.
- Low production costs due to simple process.
- Good thermal conductivity
- The LTCC is used for RF devices and highly integrated circuits.
- The electric parts such as resistor and capacitor can be embedded to the LTCC.

Material	GCS71
Coefficient of thermal expansion [10^{-6}/K]	5.5
Thermal conductivity [W/m・K]	3.2
Specific heat [J/g・K]	0.66
Young's modulus [GPa]	95
Dielectric constant	7.1
Volume resistivity [Ω・cm]	$>10^{14}$

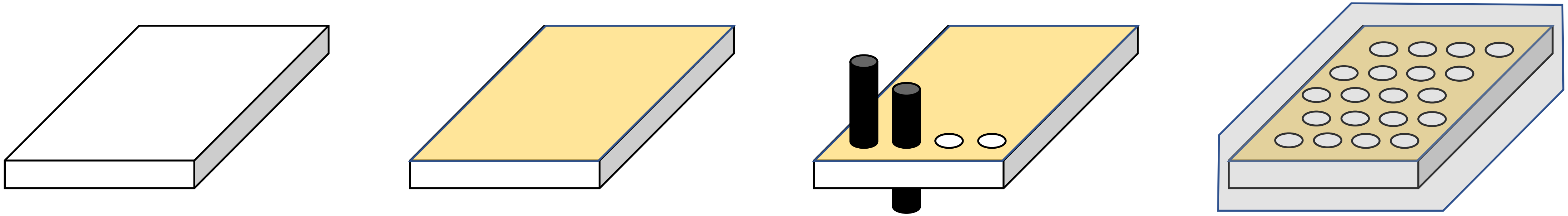
LTCC has no Carbon and is expected to have discharge tolerance.

LTCC-GEM

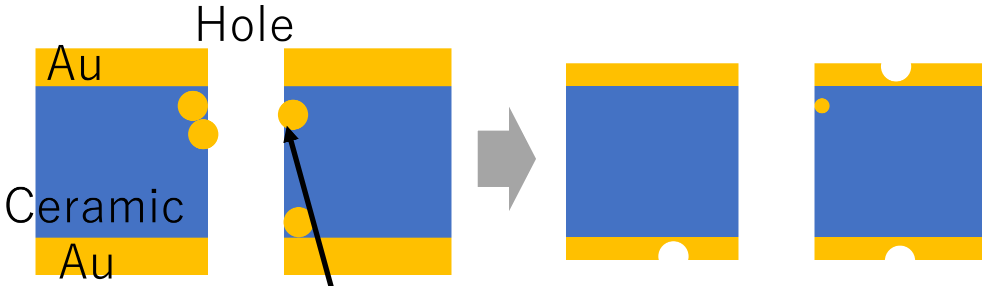
Hirai Seimitsu Kogyo Corporation, Japan

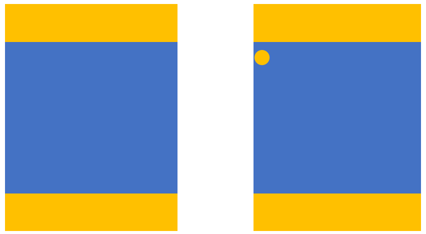
The material has been developed through collaborative research of Dr. Komiya and Hirai Seimitsu

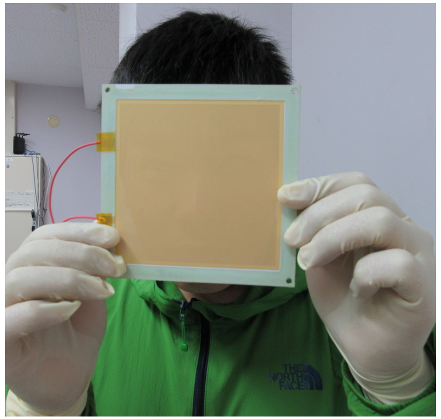
- Process:
  - Green sheet → Plating Au → Punching → Sintering



Etching → Re-sintering → Plating Au → Completed



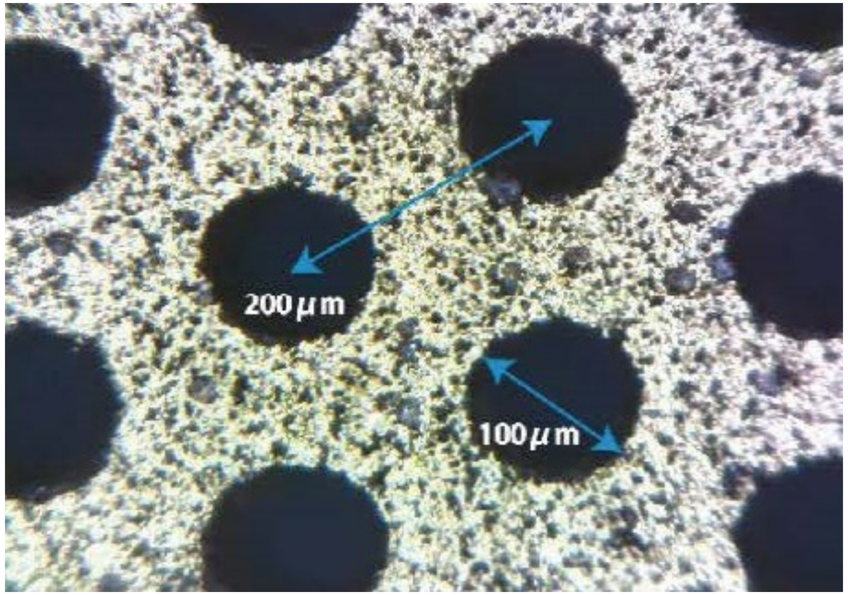


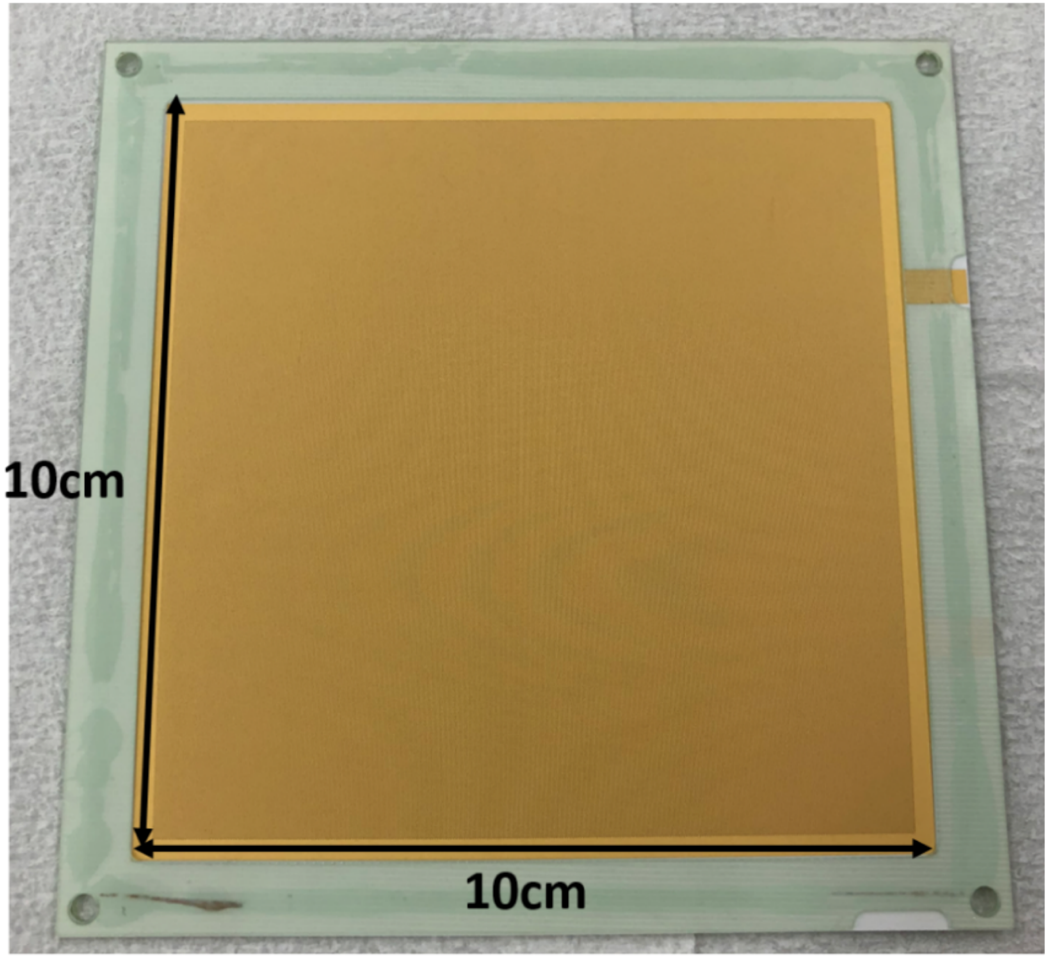


to remove Au residue

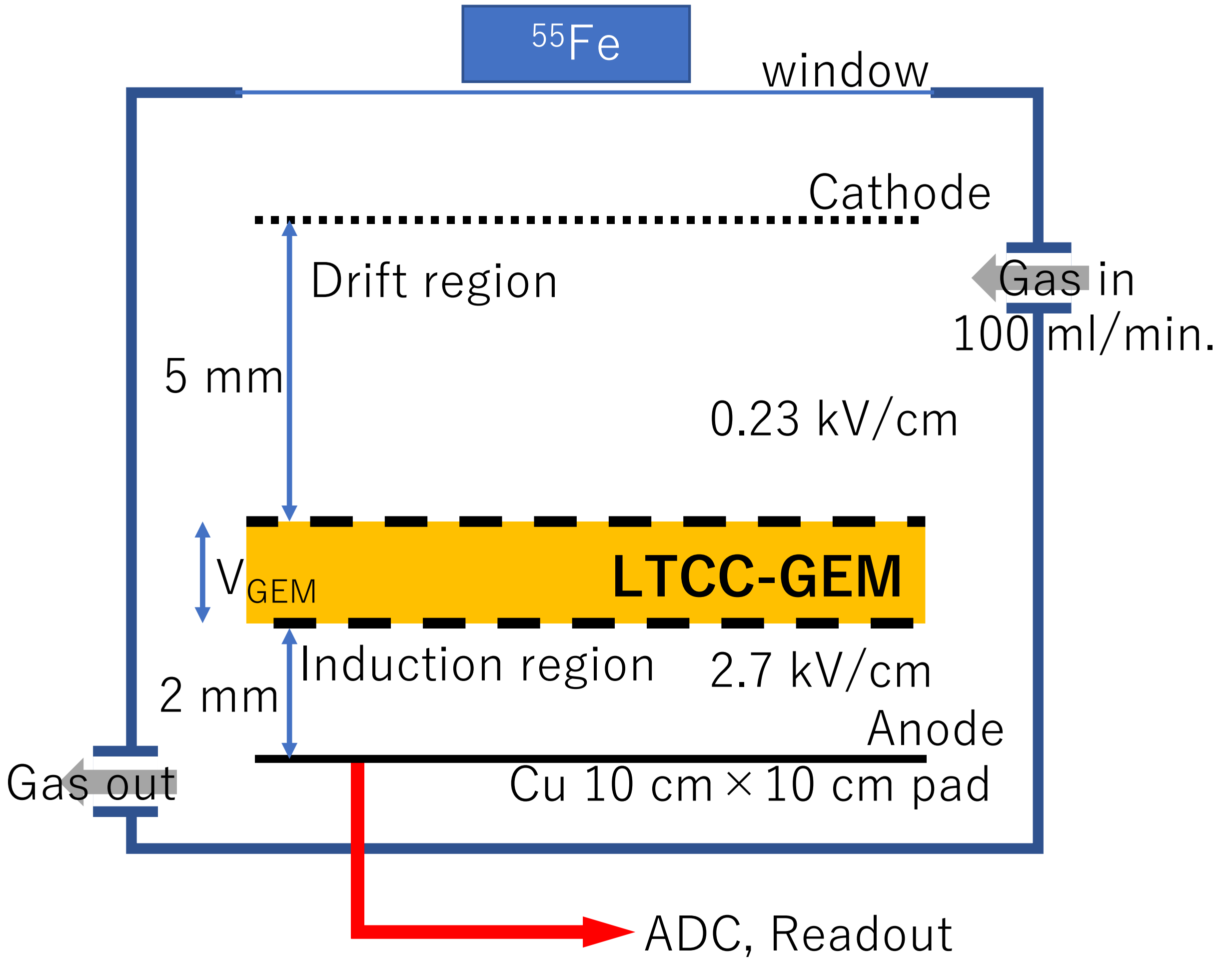
LTCC-GEM @ Iwate-U

- Effective region 10 cm × 10 cm
- Thickness 200 μm
- Hole diameter 100 μm
- Hole pitch 200 μm





Experiment



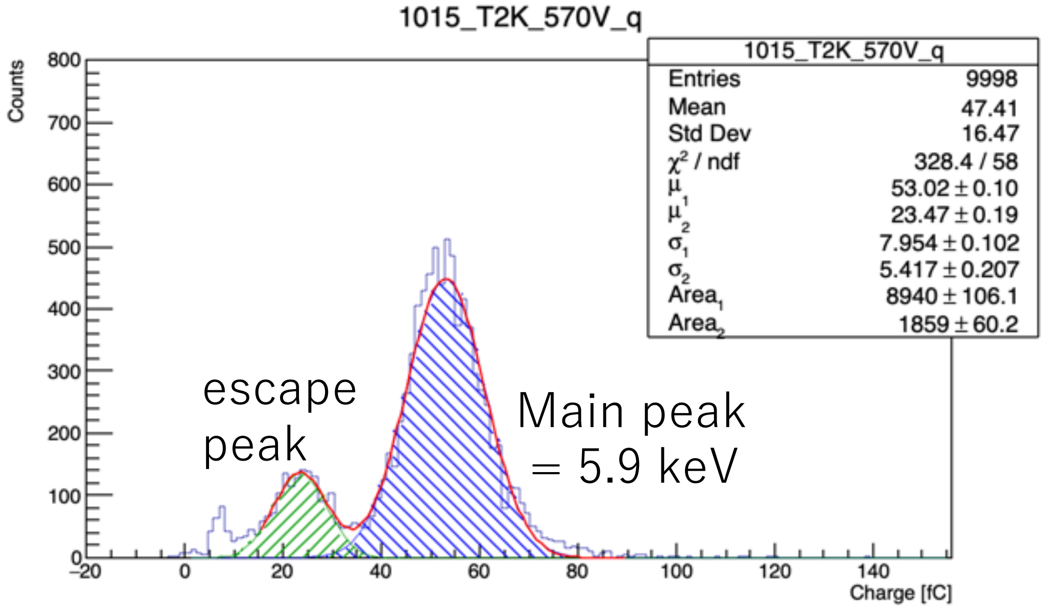
- LTCC-GEM: thickness 200 μm
- Source: ^{55}Fe Xray (5.9 keV)
- Gas:
  - Ar/CO_2 (70% / 30%)
  - T2K=Ar/CF4/iso-C_4H_{10} (95% / 3% / 2%)
- E-field

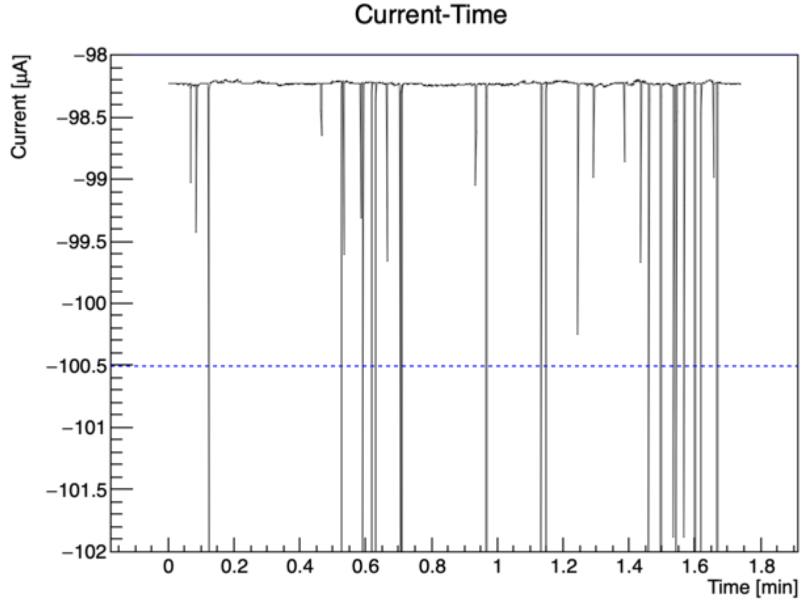
	(ArCO_2)	(T2K)
Drift region	1.5 kV/cm	0.23 kV/cm
Induction region	6 kV/cm	2.7 kV/cm

We report
- Gain
- Long term stability
- Uniformity

Gain, energy resolution and discharge rate

e.g.) 200 μm thick LTCC-GEM, V_{GEM} = 565 V, T2K gas

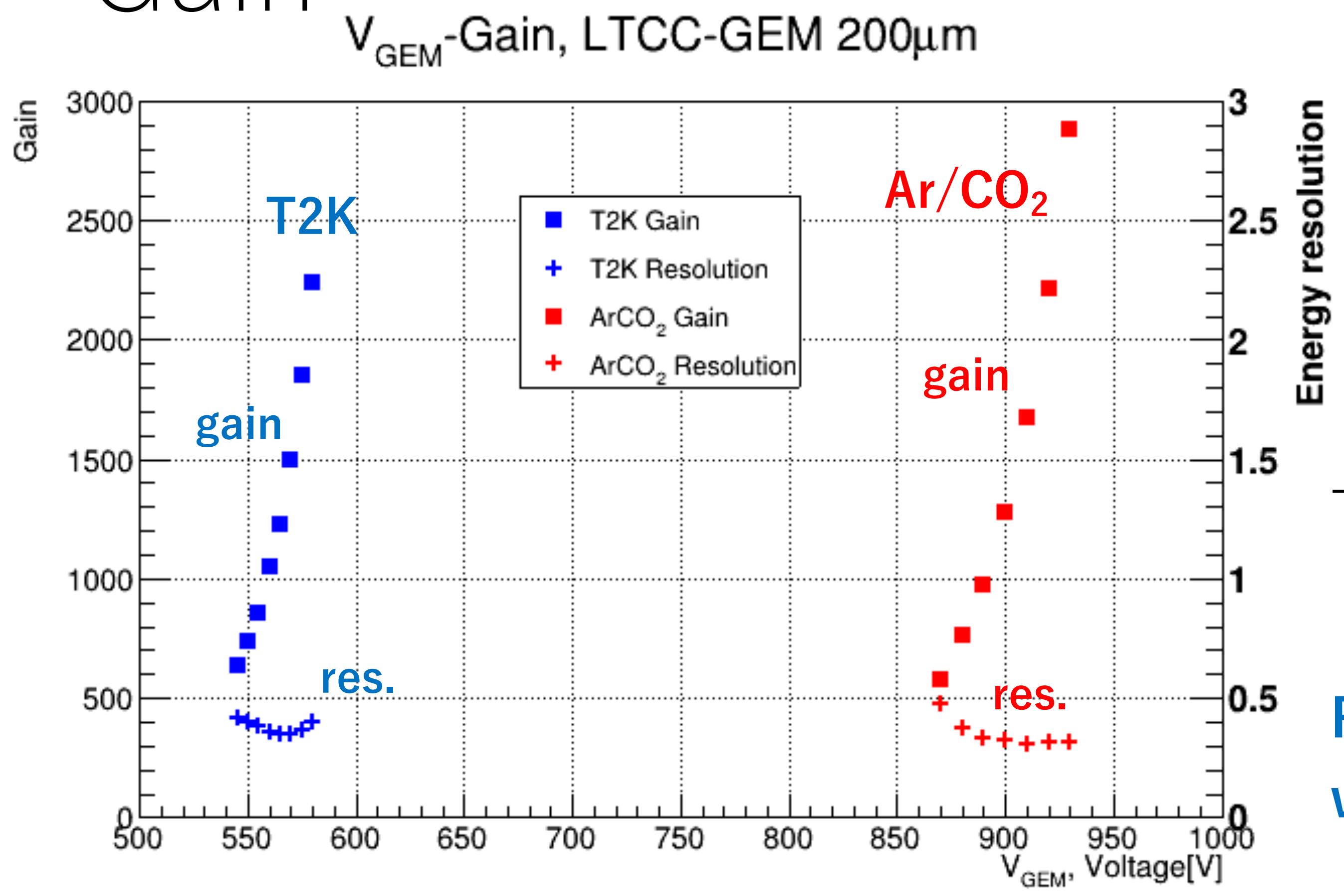




Assumption of 2 gaussians for main peak and escape peak.
Gain is obtained from mean charge of main peak.
Energy resolution is obtained from HMFW/mean of main peak.

HV current is monitored.
We define the discharge as the current falls below $I_{thr.}$.

Gain



The gains are observed to be

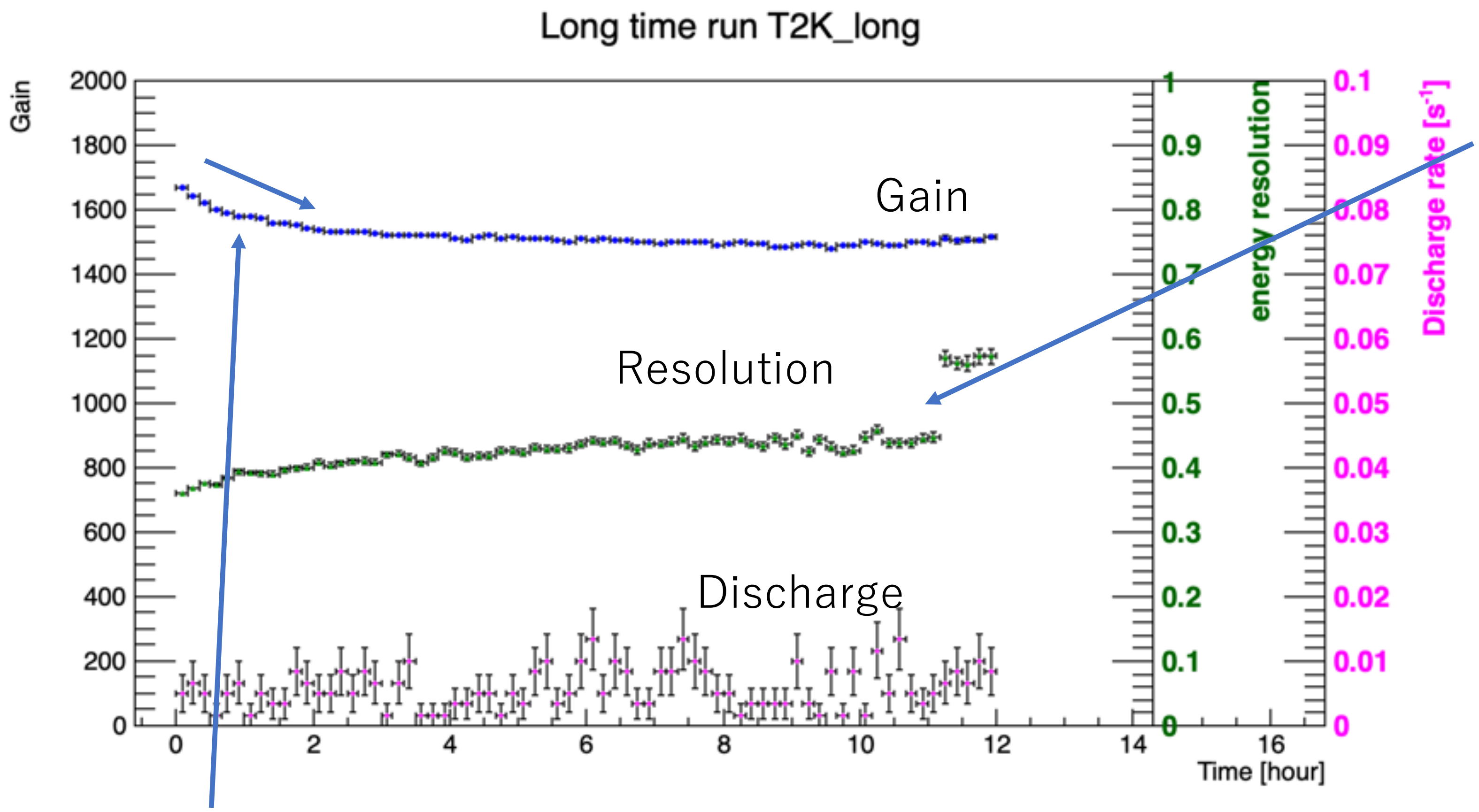
~ 3000 at V_{GEM}~930 V for Ar/CO_2
~ 2000 at V_{GEM}~580 V for T2K.

Promising to achieve high gain with mono-layer.

In using T2K gas, energy resolution due to the increase in applied voltage is considered to be affected by discharge.
in using $ArCO_2$, no significant discharge has occurred yet in this voltage range.

Gain stability

Experiments are performed after enough time(10h) for gas replacement.

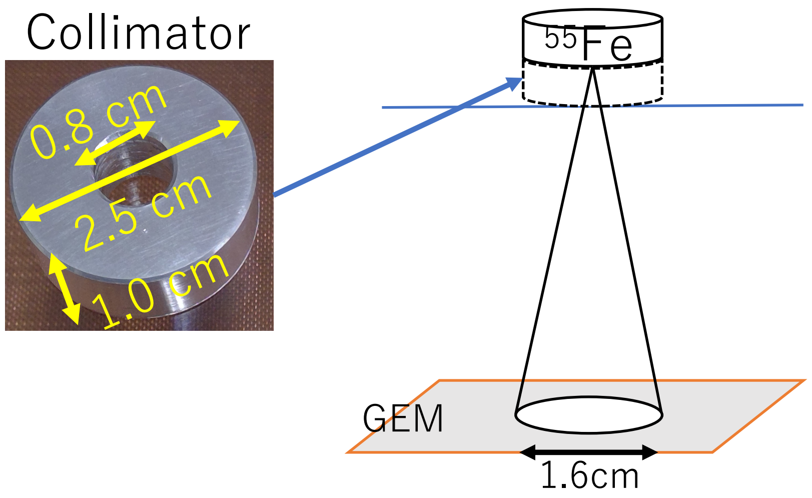


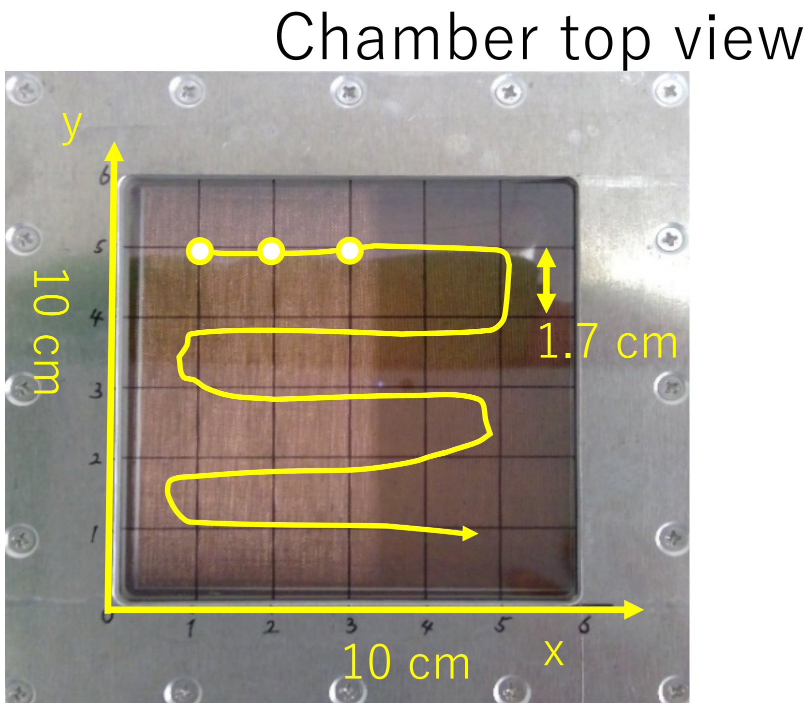
Resolution changes uncontinuously at 11h after starting, at the same time the gain and discharge rate are not change.
We think that it increased noise from external factors.

The gain decrease 10 % in 2~3 hours is observed.
We think this is due to GEM charging up,
and we plan to further study the effects of GEM charge-up.

To study more further.
We has plan to operate more long measurement.

Gain uniformity test





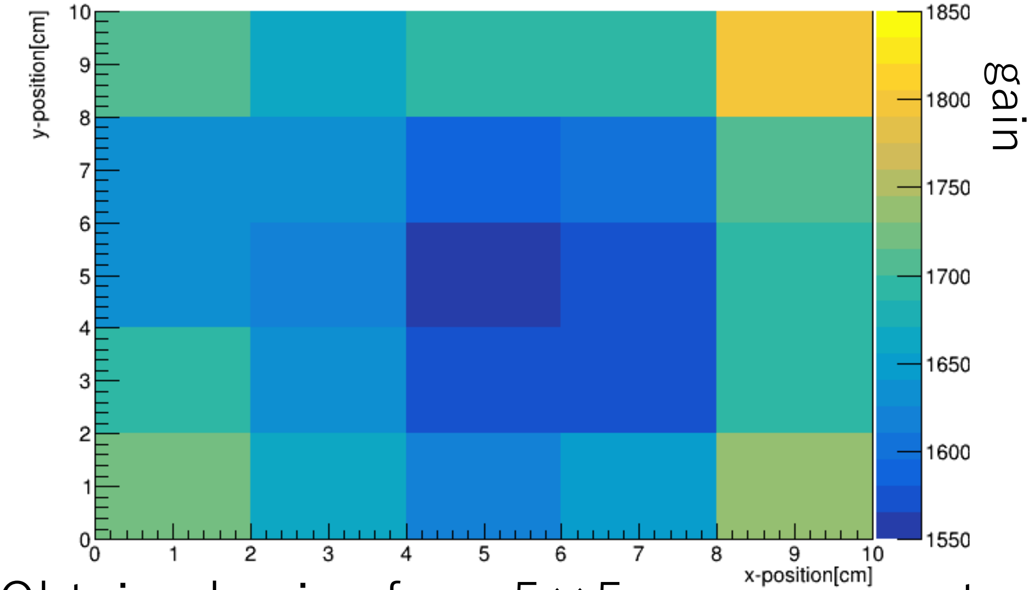
5 × 5 measurement points

With 10 cm × 10 cm LTCC-GEM 200 μm thick, T2K gas

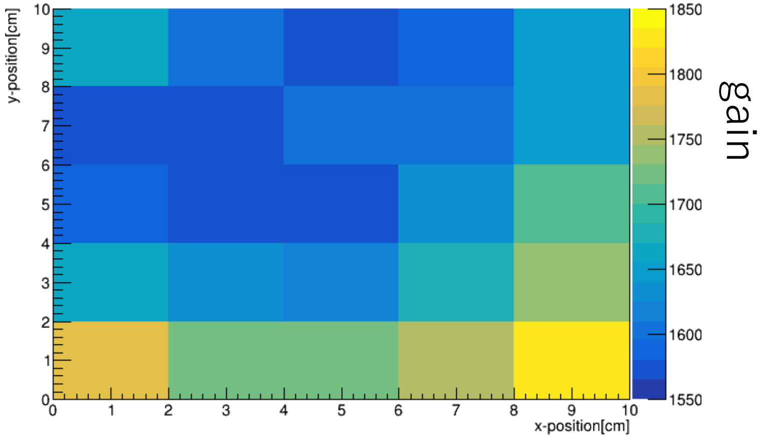
- Using the collimator, the angle at which the GEM is seen from the source is limited to have a 1.6 cm diameter spread on the GEM.
- Drawing 5 × 5 lines at window above GEM sensitive area, and gain measurements are performed with placing a ^{55}Fe source at each intersection.

Gain uniformity for GEM

Those measurements are performed after gain saturated(>15hours).



Obtained gains from 5×5 measurements.

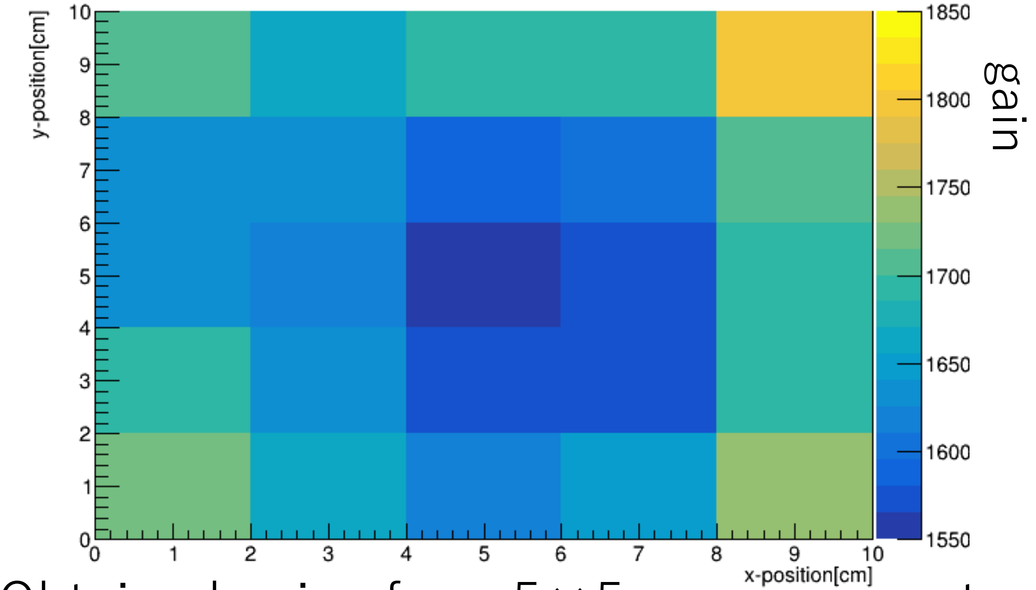


The same measurement is also performed by rotating the GEM 90˚.

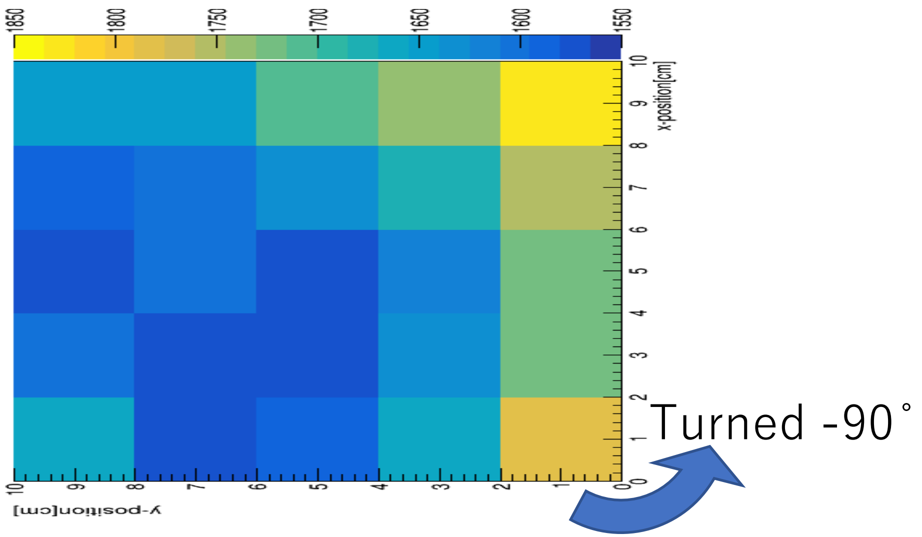
We also check whether the gain non-uniformity is due to GEM foil itself or other experimental environment.

Gain uniformity for GEM

Those measurements are performed after gain saturated(>15hours).



Obtained gains from 5×5 measurements.



The same aligned.

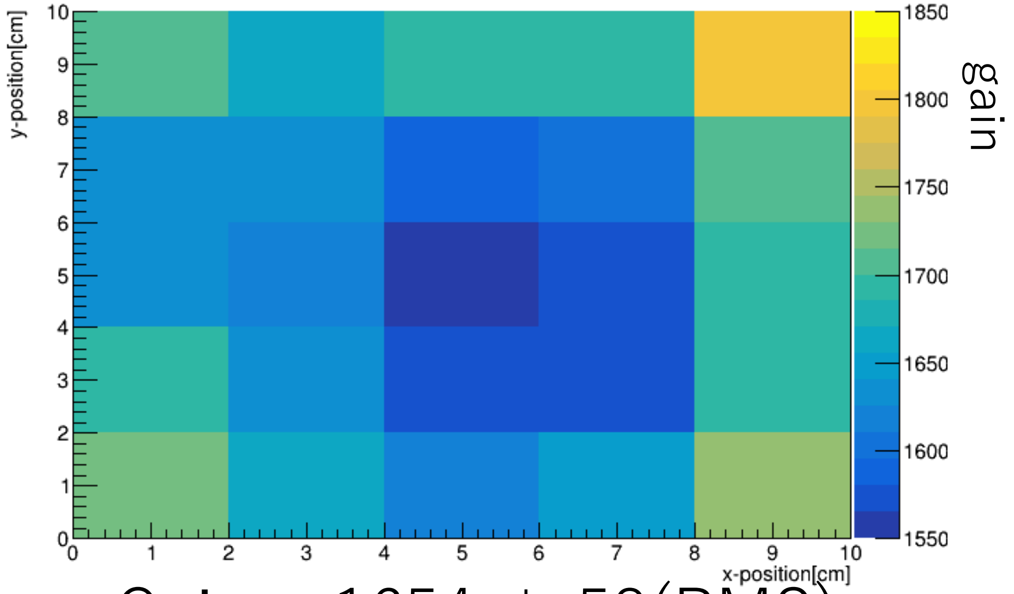
We also check whether the gain non-uniformity is due to GEM foil itself or other experimental environment.

From 2 measurements, almost the same results are obtained.

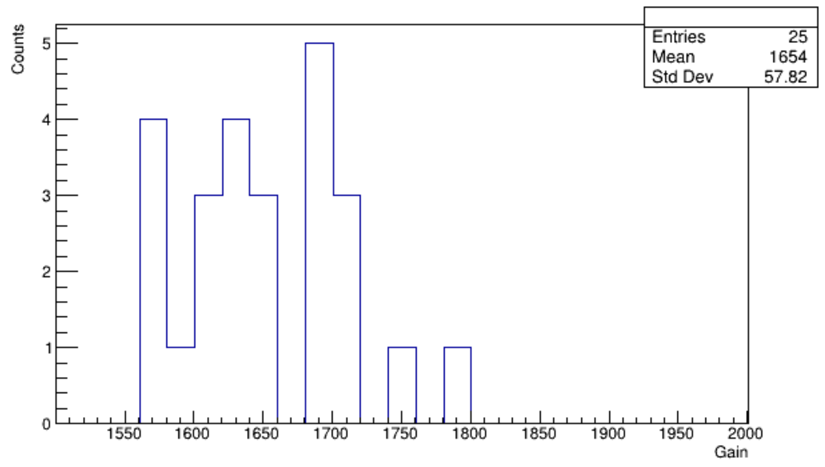
→ **We can obtain the characteristic of the GEM itself.**

Gain uniformity for GEM

Those measurements are performed after gain saturated(>15hours).



Gain = 1654 ± 58(RMS)



5×5 obtained gains distribution.

Our 10 cm×10 cm LTCC-GEM(200 μm thick) gain uniformity is 3.5%.
Gains in corner are measured higher.

→ We study further the cause of this non-uniformity.

e.g) Considering about measurement of GEM thickness, hole diameter, and so on.

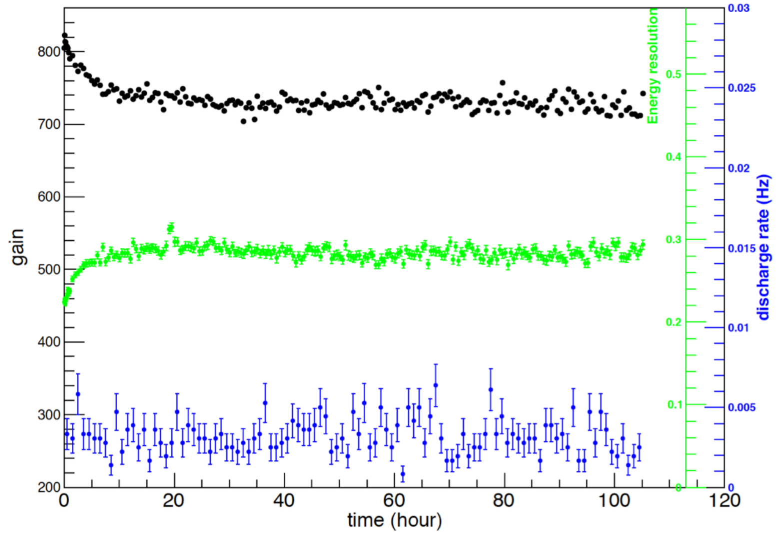
LTCC-GEM @ Kindai Univ.(Kato-san)

Size 6 cm × 6 cm, 10 cm × 10 cm
Thickness 200 μm, 100 μm
Hole diag. 100 μm
Hole pitch 200 μm

Kato-san has 4 kind of LTCCGEM, and is making 25 cm × 25 cm LTCC-GEM.

Logn term stability

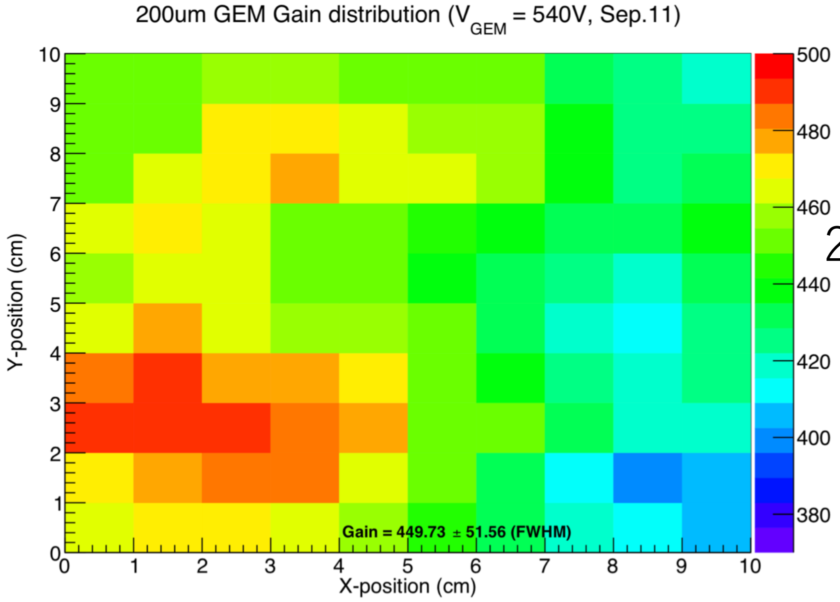
200 μm thick, 6 cm × 6 cm, T2K gas



Gain, Energy resolution, Discharge rate
(Gain is corrected with p/T.)

Kato-san observed that GEM gain decrease (820→730@10h).

Gain uniformity



200 μm thick, 10 cm × 10 cm, T2K gas

Gain uniformity: 11.5 %(FWHM)
Energy resolution uniformity: 20.7 %(FWHM)

Conclusion

- LTCC-GEM is expected to have discharge tolerance.
- Gain > 2000 is archived
  - V_{GEM} ~ 920V with Ar(70%)/CO_2(30%) gas
  - V_{GEM} ~ 580V with T2K gas
- Gain long term stability was tested(12 hours). Gain changes about 10 % decrease in 2~3 hours.
  - considering a method to evaluate GEM charge-up.
- Gain uniformity for 10 cm × 10 cm LTCC-GEM, is estimated to be ~ 3.5 %.
  - considering non-uniformity of thickness of GEM, we are thinking about measurement of GEM thickness.

Backup

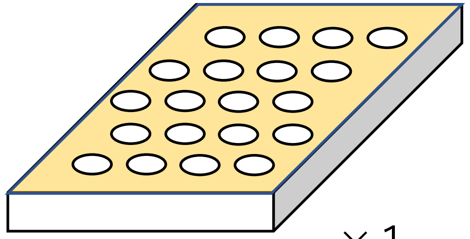
LTCC-GEM

@ Iwate U.

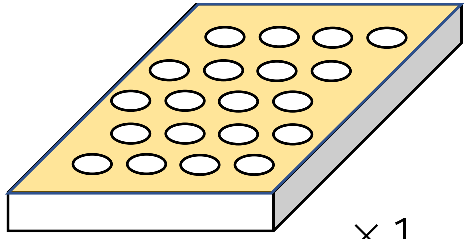
- Effective region 10 cm × 10 cm
- Thickness 200 μm
- Hole diameter 100 μm
- Hole pitch 200 μm

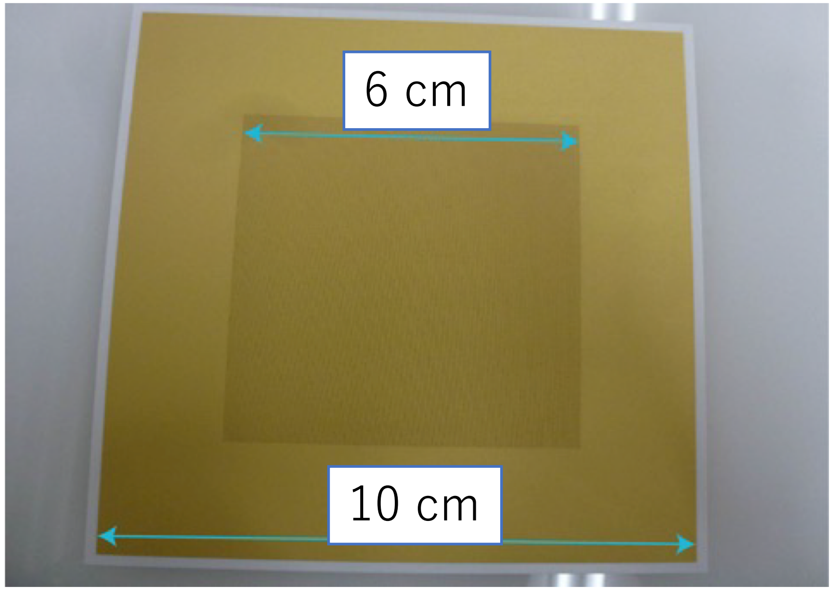
@ Kindai U. (Kato-san)

- Effective region 6 cm × 6 cm, 10 cm × 10 cm
- Thickness 200 μm, 100 μm
- Hole diameter 100 μm
- Hole pitch 200 μm



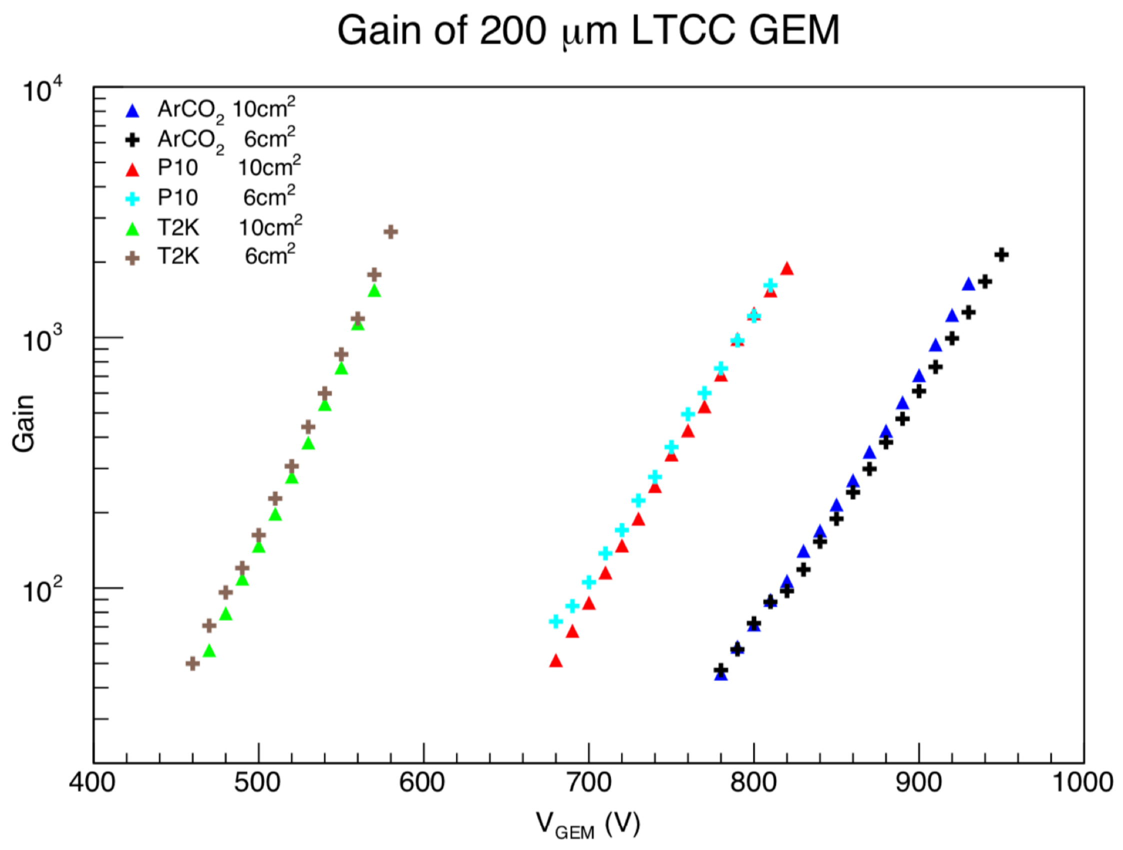
no etching process

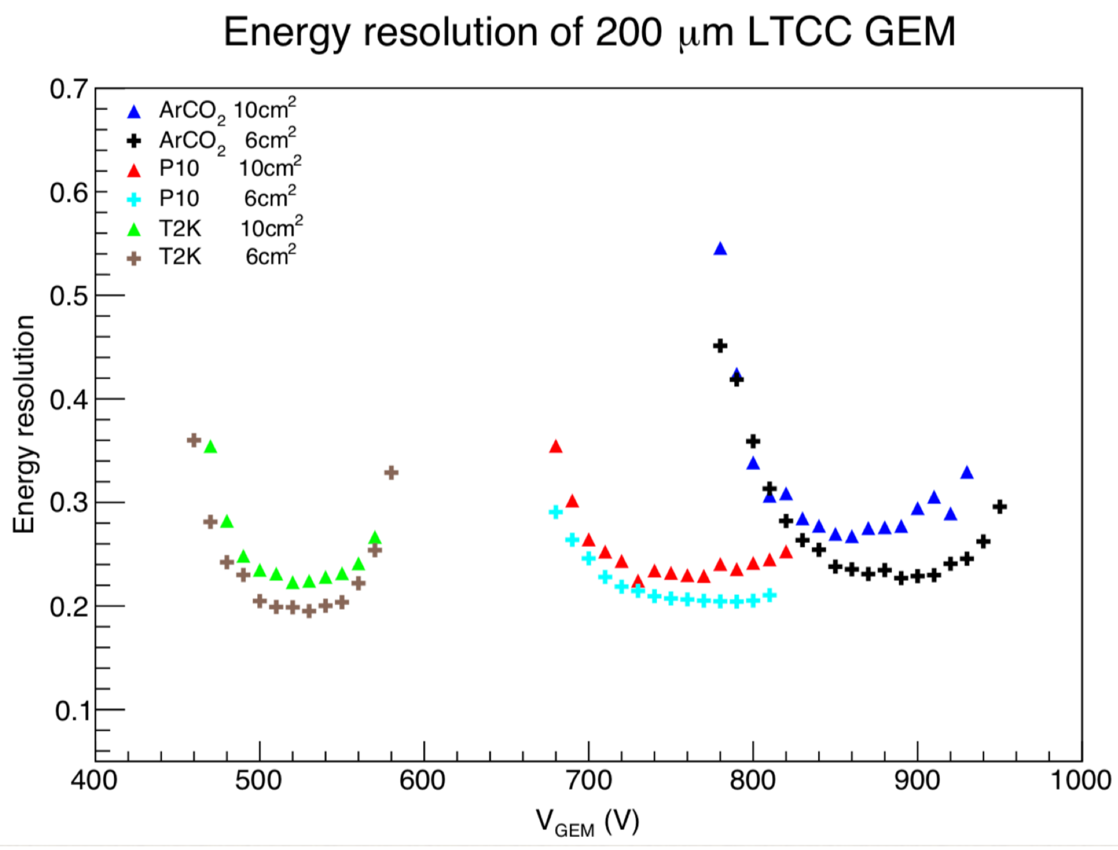




Gain and energy resolution

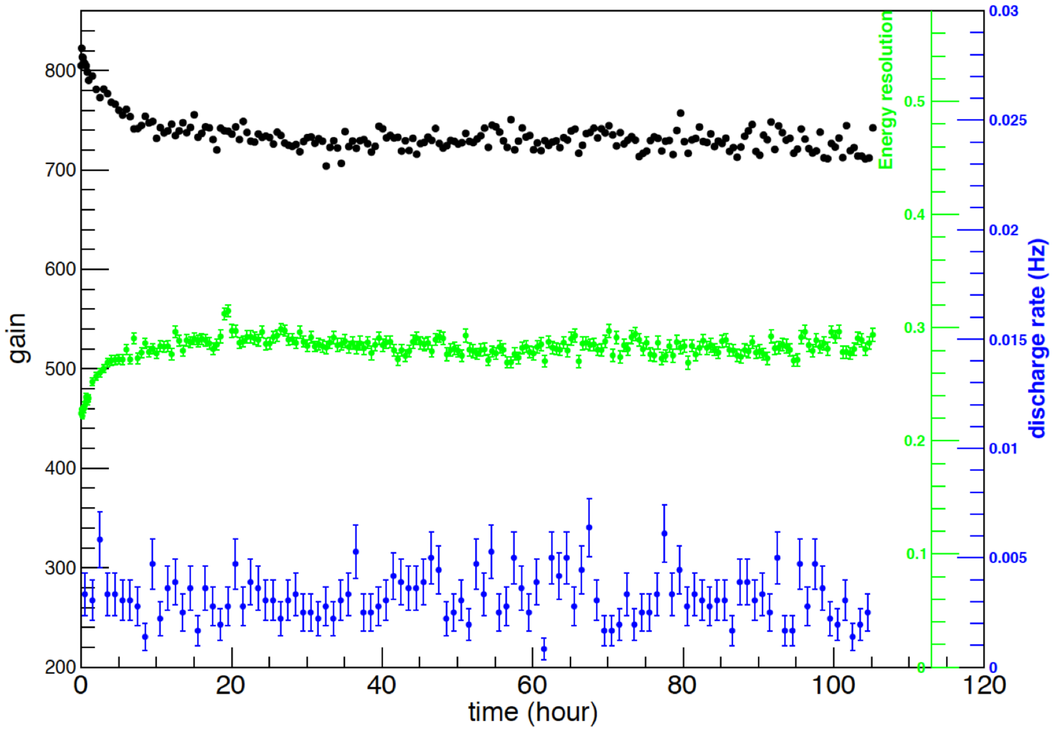
@ Kindai U.





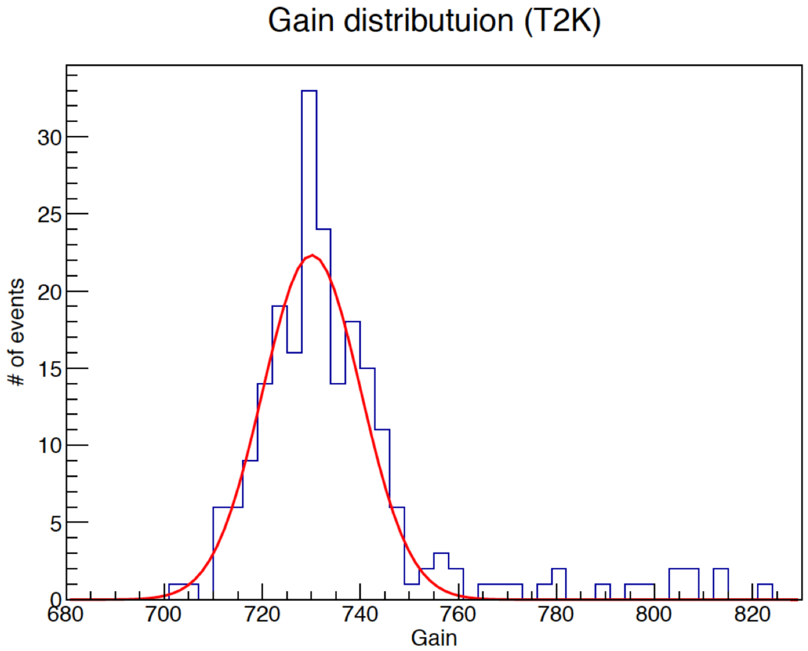
Long term stability @ Kindai U.

T2K

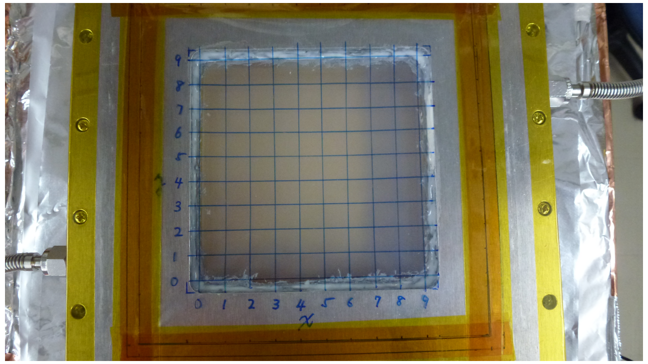


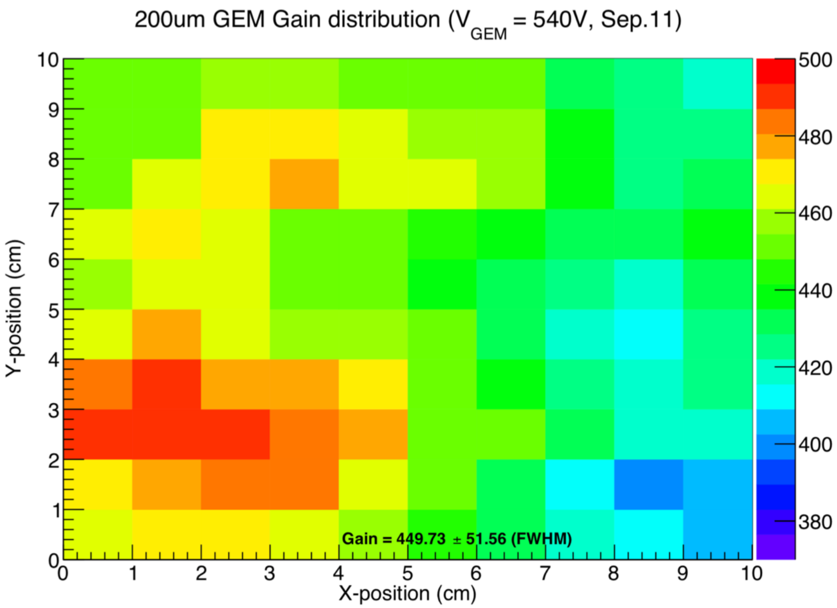
Gain, Energy resolution, 放電率の時間変動

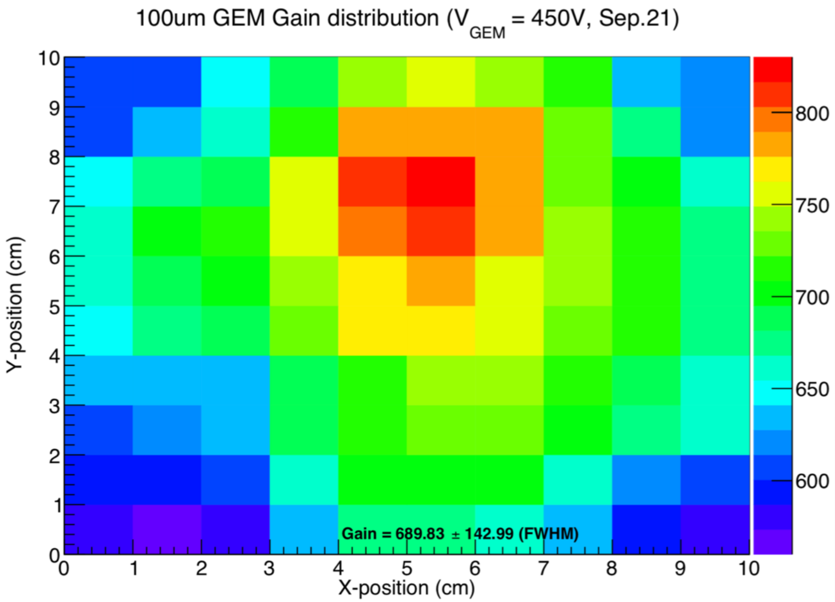
（Gainは温度と圧力の補正済）



Gain uniformity for GEM @ kindai U.



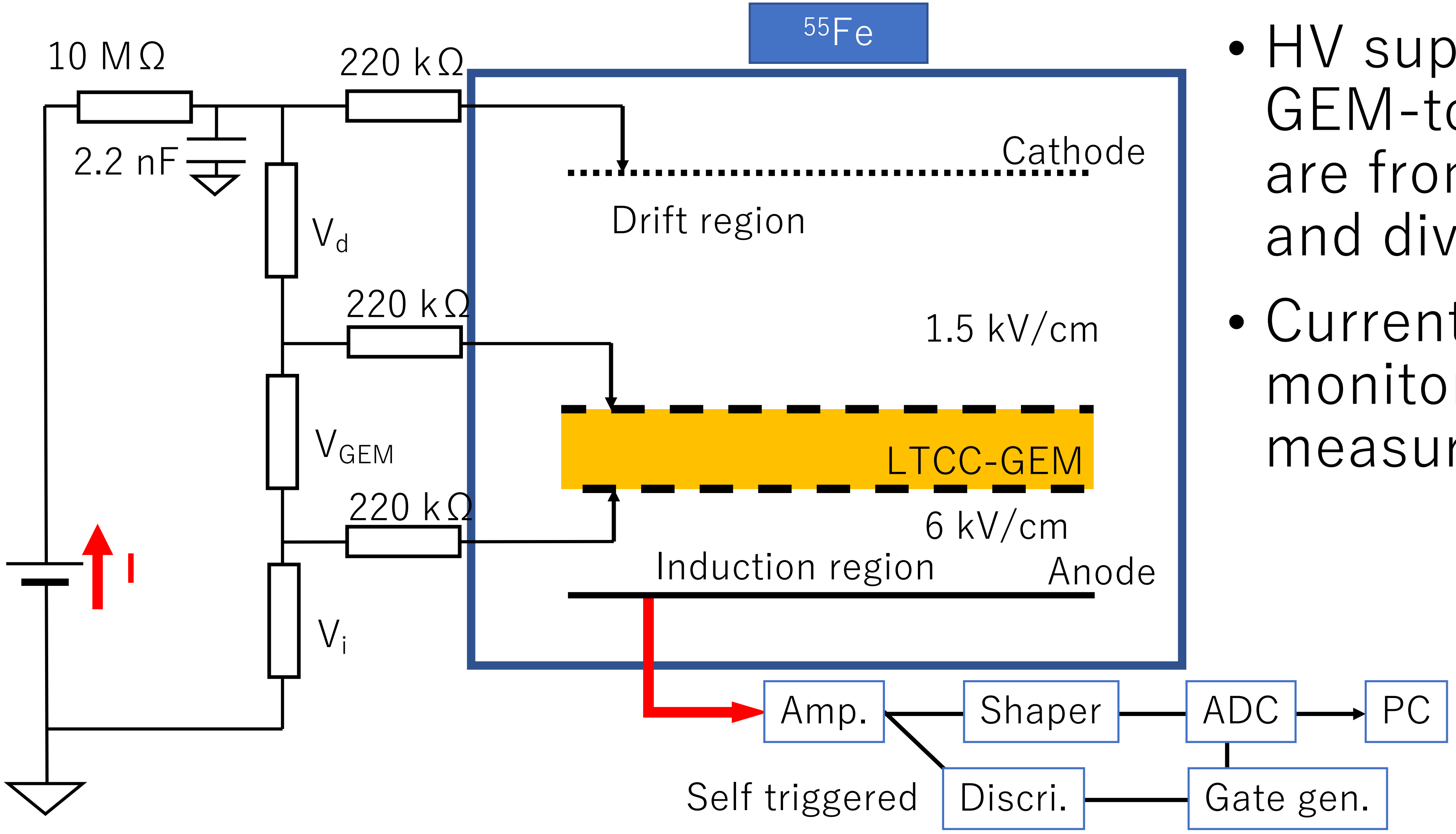




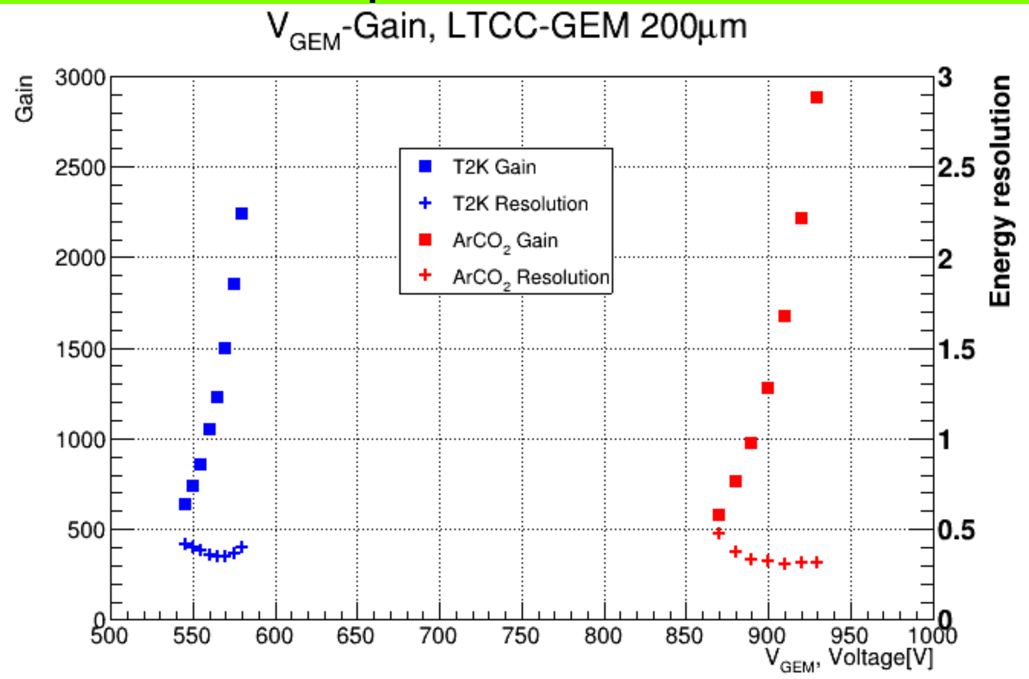
Thickness: 200 μm
Gain = 449.73 ± 51.56(FWHM)
uniformity ~ 4.9 %

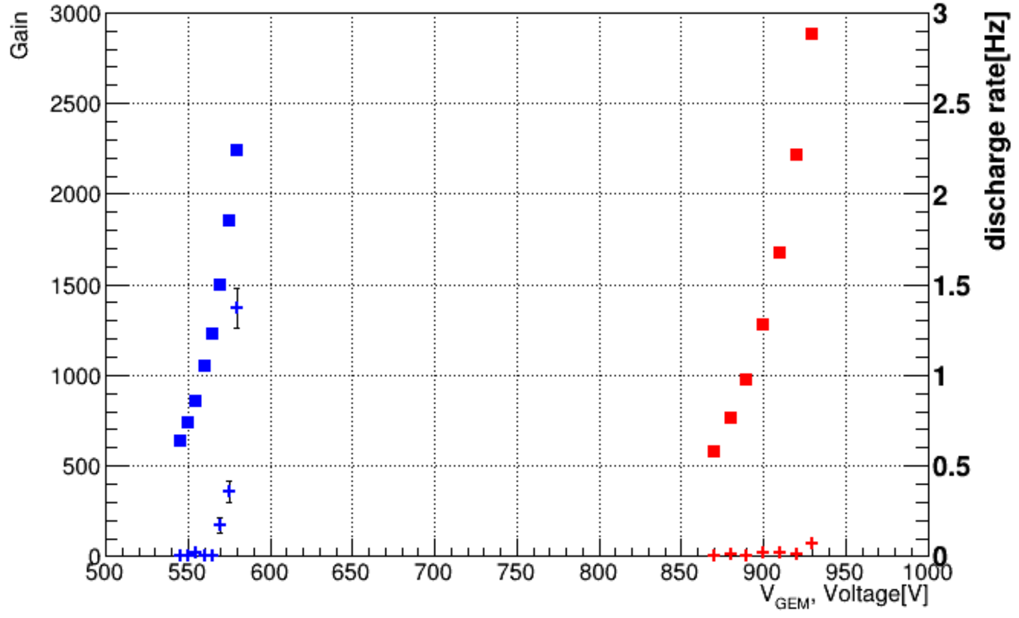
Thickness: 100 μm
Gain = 689.83 ± 142.99(FWHM)
uniformity ~ 8.8 %

HV setup



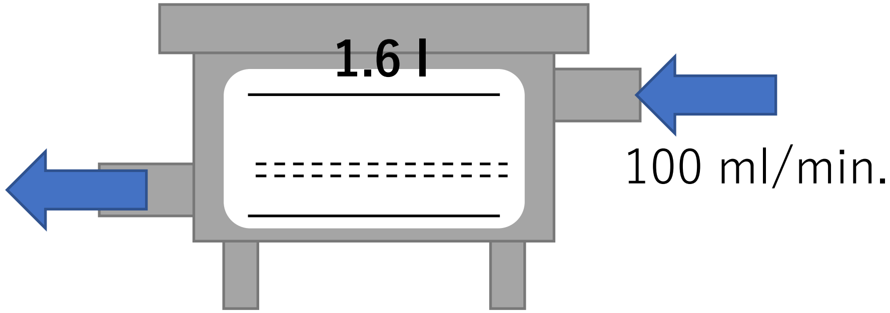
- HV supply for Cathode, GEM-top and bottom are from a HV module and divider.
- Current of HV is monitored at measurements.

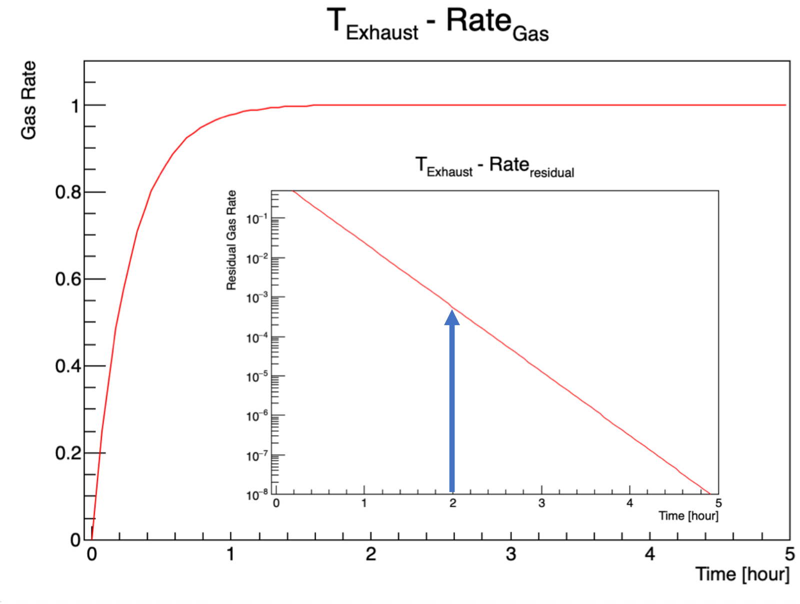

V_GEM-Gain, LTCC-GEM 200μm
Gain
Energy resolution
T2K Gain
T2K Resolution
ArCO2 Gain
ArCO2 Resolution
V_GEM, Voltage[V]

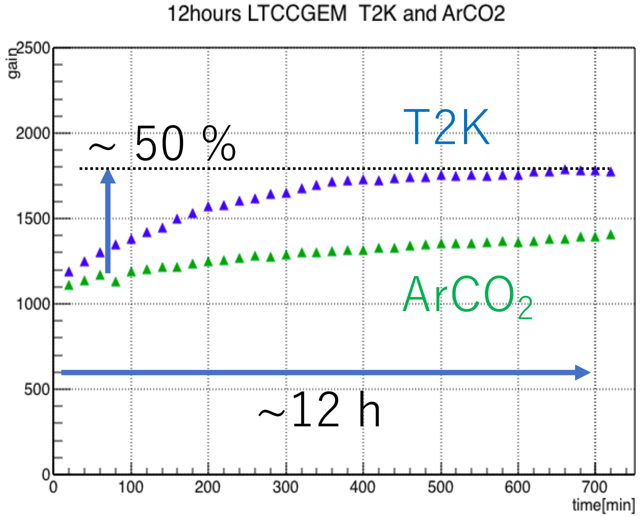

Gain
discharge rate[Hz]
V_GEM, Voltage[V]

Gas replace

- Chamber (+pipes): 1.6 l
- Gas out is non-return using silicon oil.
- Inner pressure is slightly higher than atmospheric.
- Gas flow rate 100 ml/min.



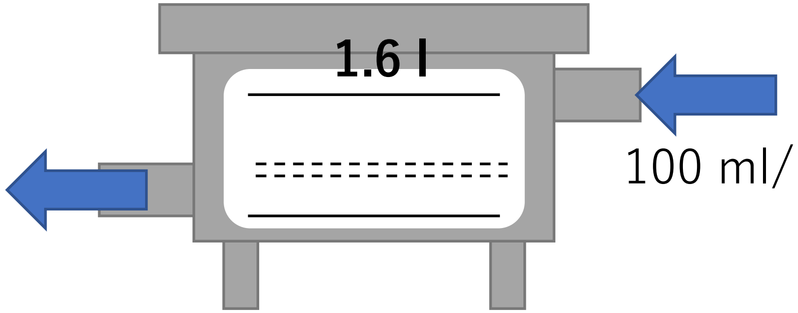




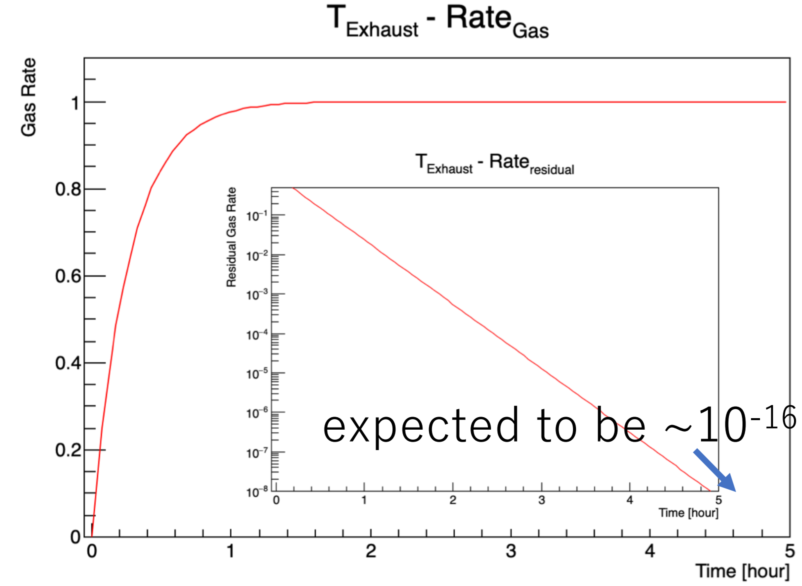
Assuming 0.1 % gas rate is enough, so left gain behavior is observed from measurements which start data taking after 2 hours gas replacement.

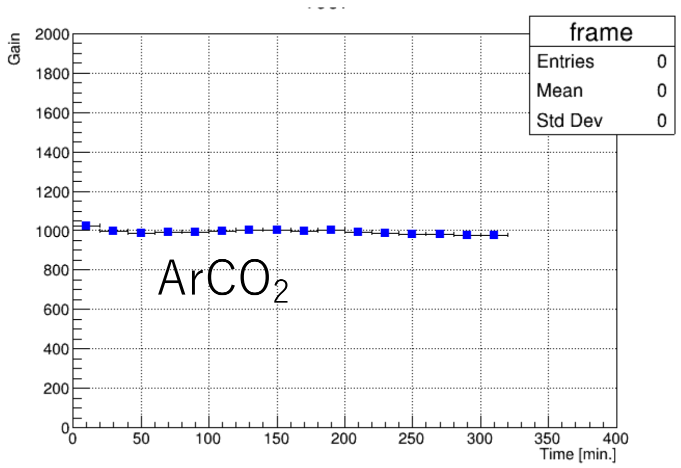
Gas replace

- Chamber (+pipes): 1.6 l
- Gas out is non-return using silicon oil.
- Inner pressure is slightly higher than atmospheric.
- Gas flow rate 100 ml/min.



100 ml/min.





Assuming 0.1 % gas rate is enough, so left gain behavior is observed from measurements which start data taking after 2 hours gas replacement. However, from another measurement (10h gas replace) we observe that the gain hardly changed.