Ceramic GEM test at Iwate U.

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RD51 collaboration meeting

20-Jun-2018

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Motivation of this study

In operation of the GEM, we always have to take care of the damage by the 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)

Low Temperature Co-fired Ceramic (LTCC)

- The ceramic is sintered at lower 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.
- 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.
- Good thermal conductivity
- Robust against mechanical and thermal stress.
- Low production costs due to simple process.

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-GEM

Hirai Seimitsu Kogyo Corporation, Japan

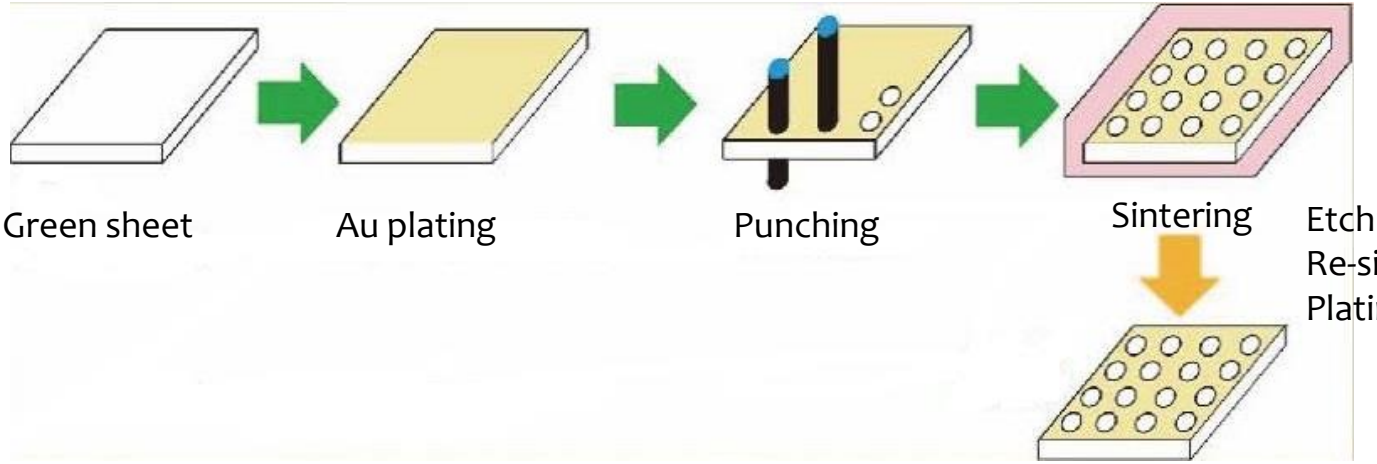
The material has been developed through collaborative research of Dr. Komiya and Hirai Seimitsu

Process:

Green sheet -> Plating Au -> Punching -> Sintering

-> Etching to remove Au residue -> sintering

-> Plating Au -> Completed



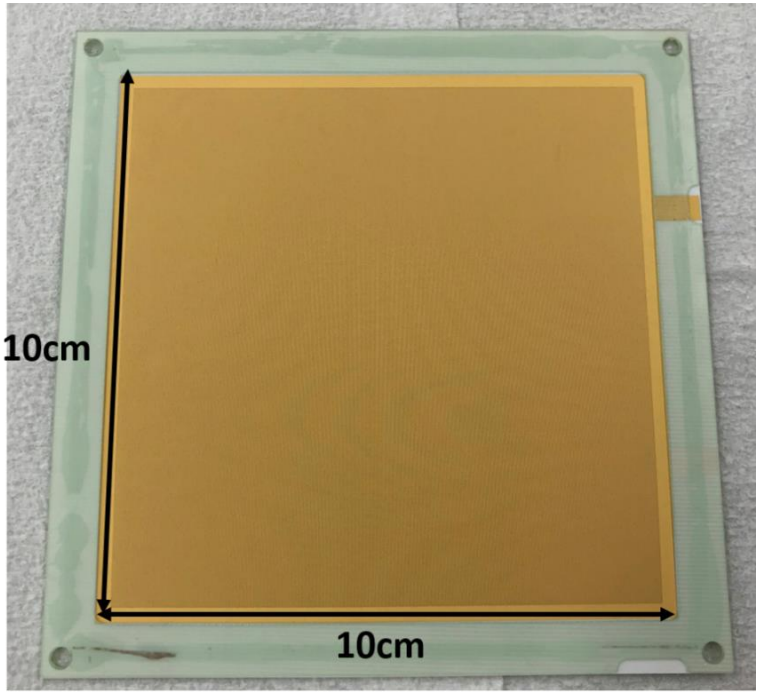
LTCC-GEM

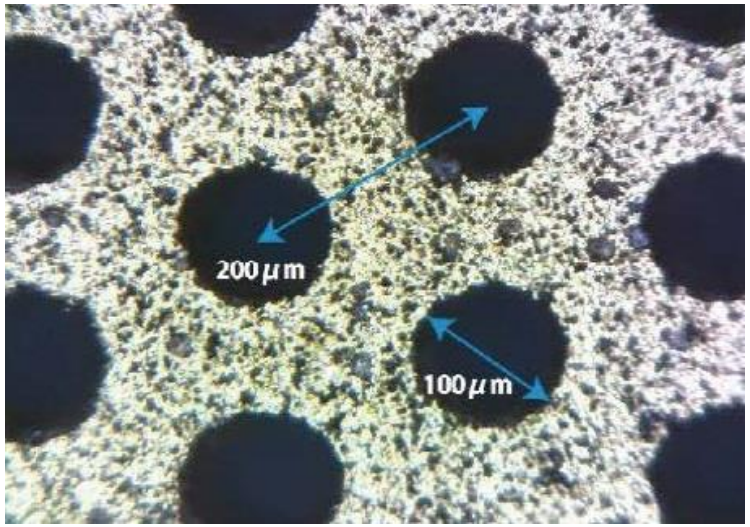
Area
- Substrate: 12.4 cm x 12.4 cm
- Hole region: 10 cm x 10 cm

Thickness: 100 μm or 200 μm

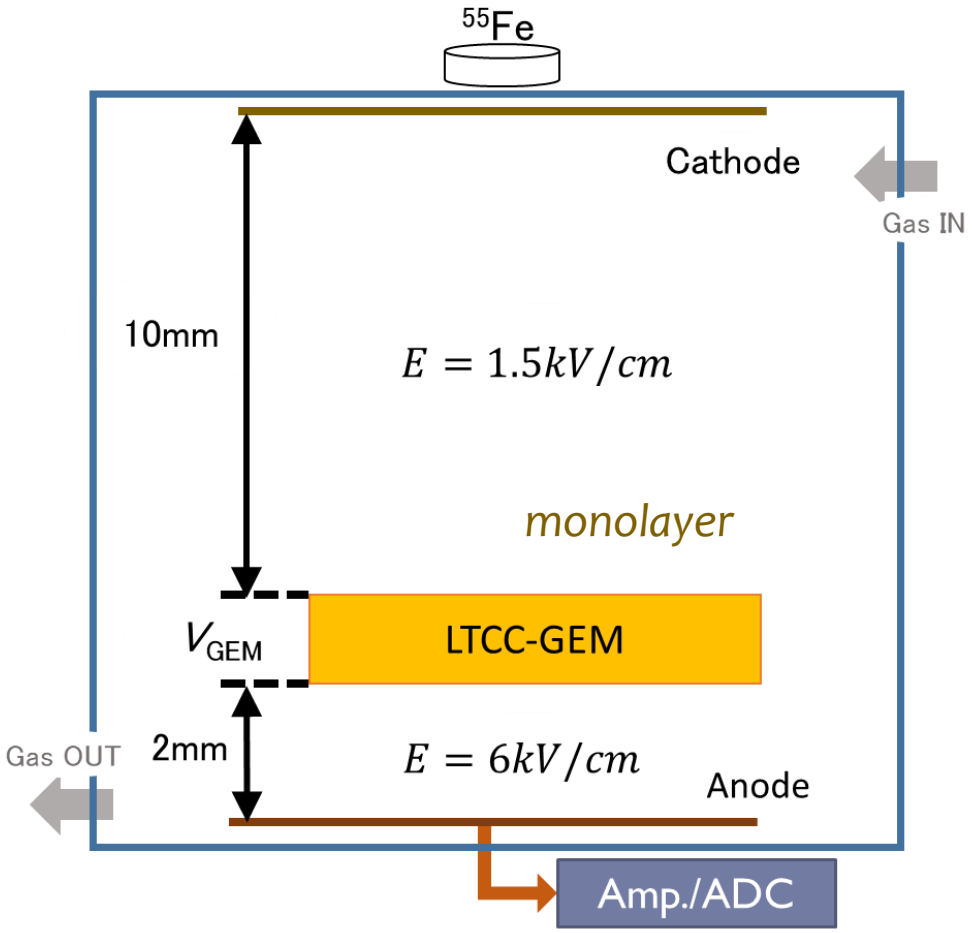
Hole size: ϕ100 μm

Hole pitch: 200 μm





Experimental setup



Anode: Cu pad (10cm x 10cm)

LTCC-GEM: t=200μm

Source: ^{55}Fe X-ray (E=5.9keV)

Gas:

Ar/CO_2 (70% / 30%)

T2K=Ar/CF4/iC4H10 (95% / 3% / 2%)

E-field

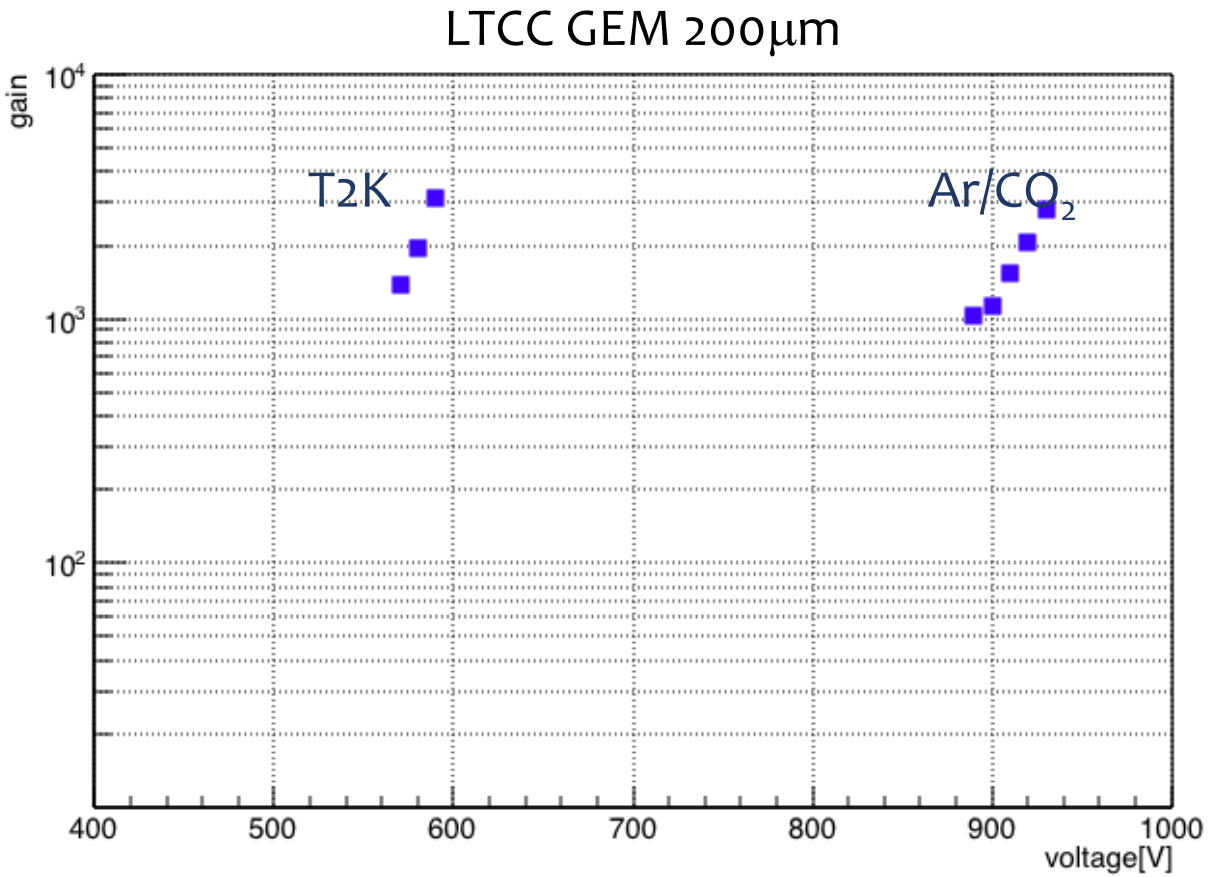
Drift region 1.5kV/cm

Induction region 6kV/cm

(not optimized)

- Gain
- Resolution
- Long term stability

Gain-HV (Ar/CO_2, T2K)

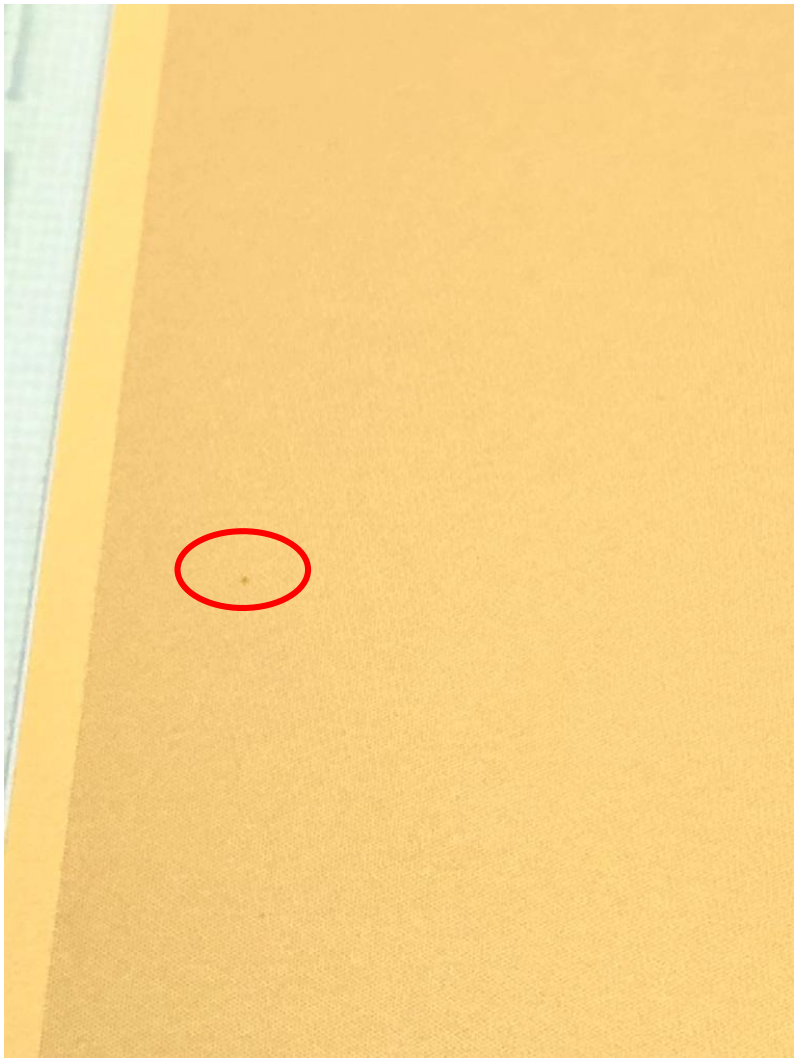


The gain was found to be up to ~3000 at ~920V for Ar/CO_2

~580V for T2K

Promising to achieve high gain with mono-layer

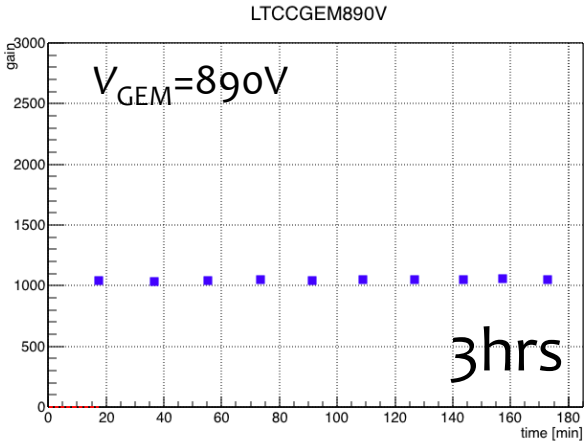
Discharge trace on the surface

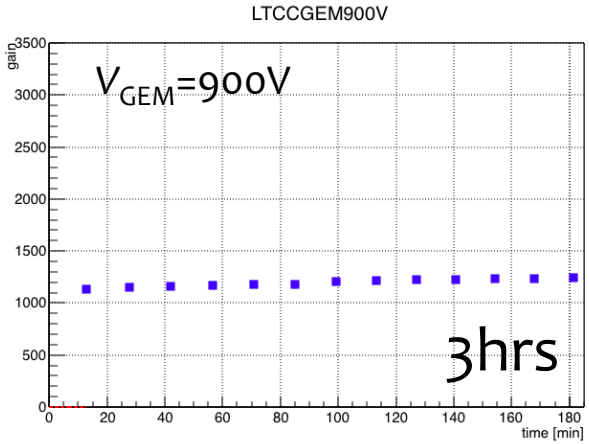


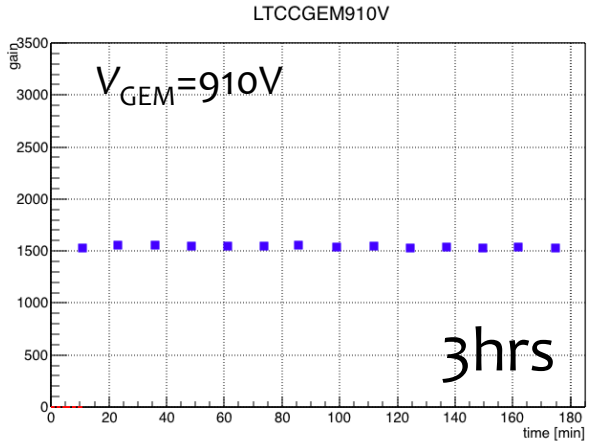
A discharge trace was found after the experiment with Ar/CO_2 applying V_{GEM}=920V.

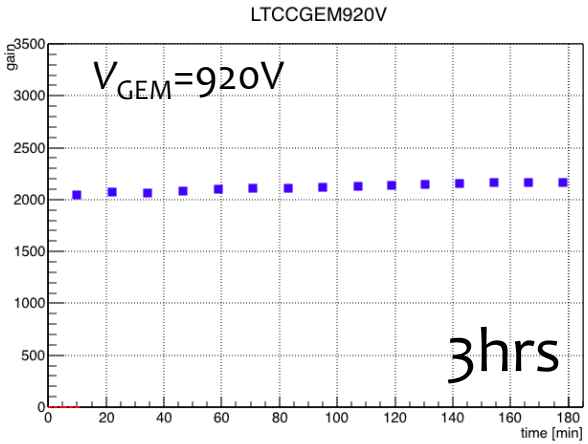
We tested this GEM again and it still worked without degrading.

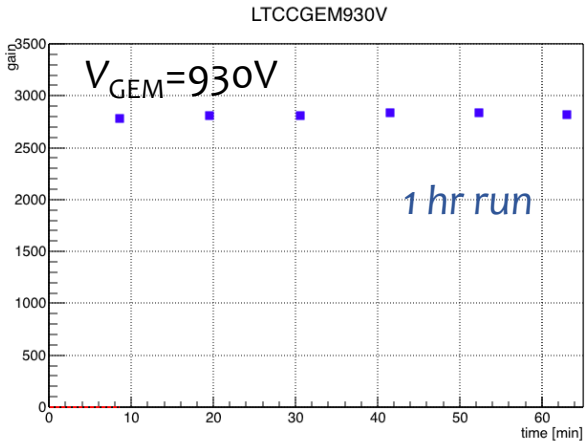
Time variation of Gain (Ar/CO_2)







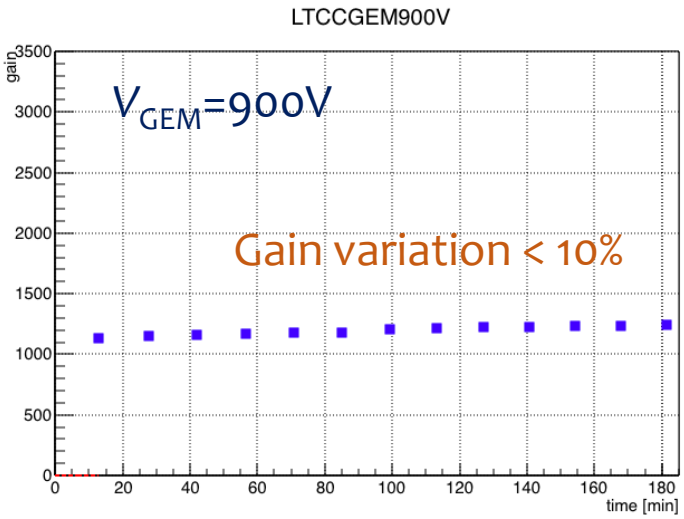


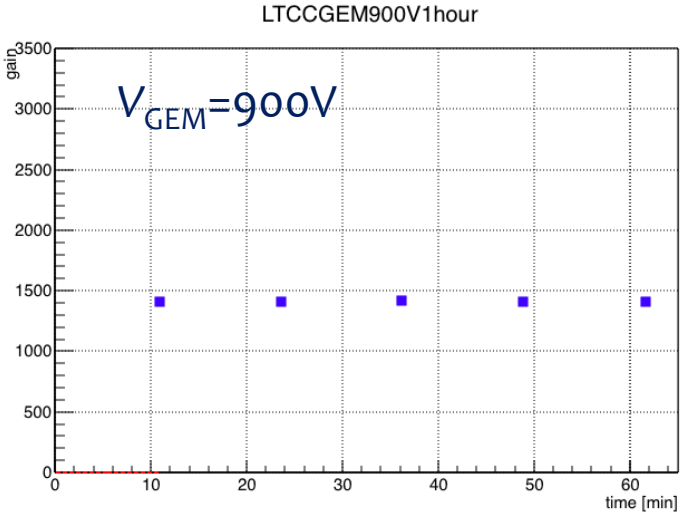


Without correction by environmental condition, temperature and pressure.

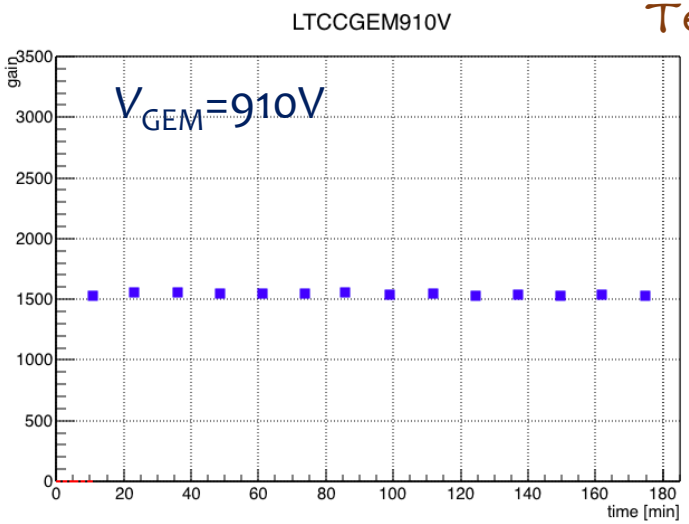
The gain variation was found to be < 10% in a few hours.

Gain stability

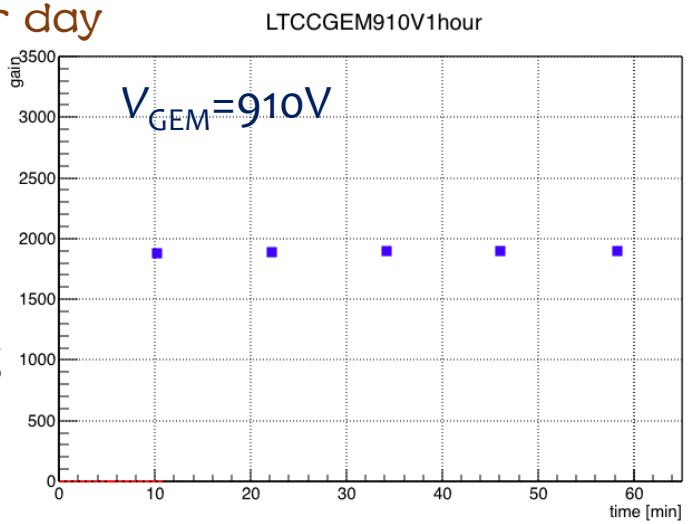




Tested another day



increased > 20%

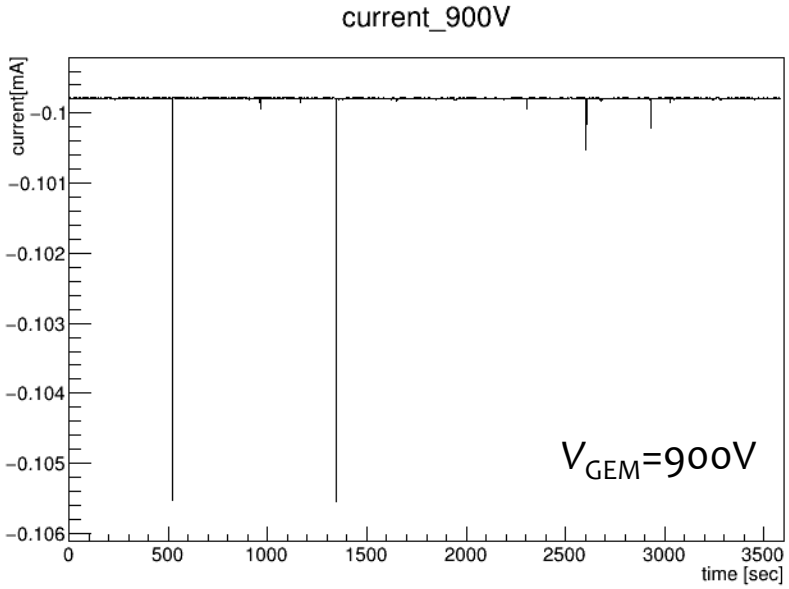


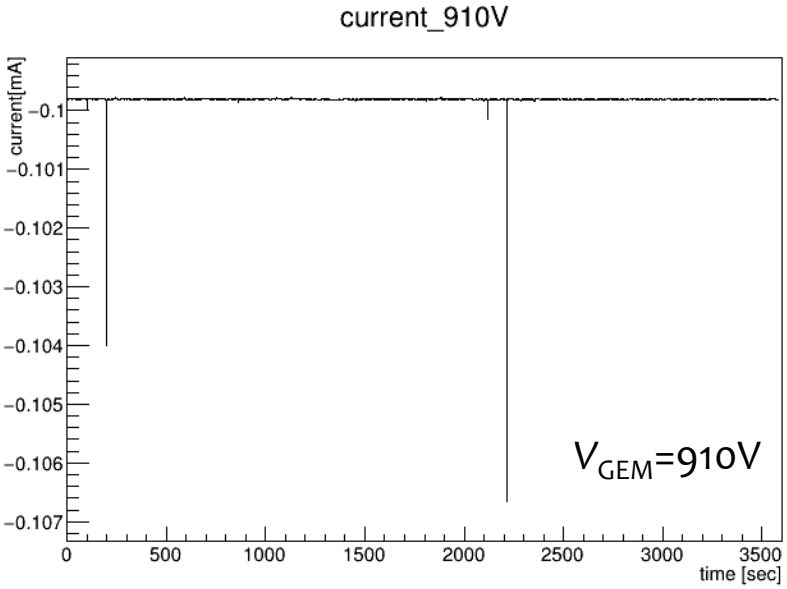
Without correction by T and P.

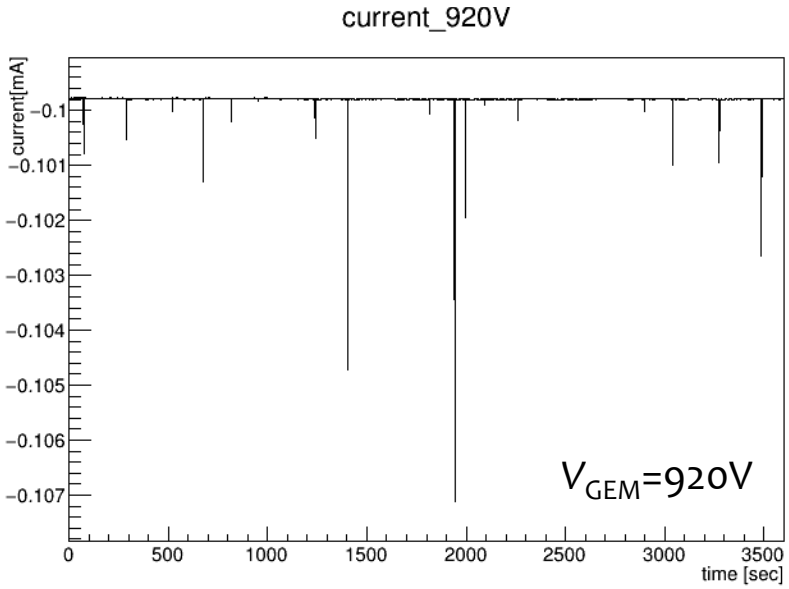
→ These gain variations might be explained by T and P dependence.

Current monitor (Ar/CO_2)

The monitored value includes offsets





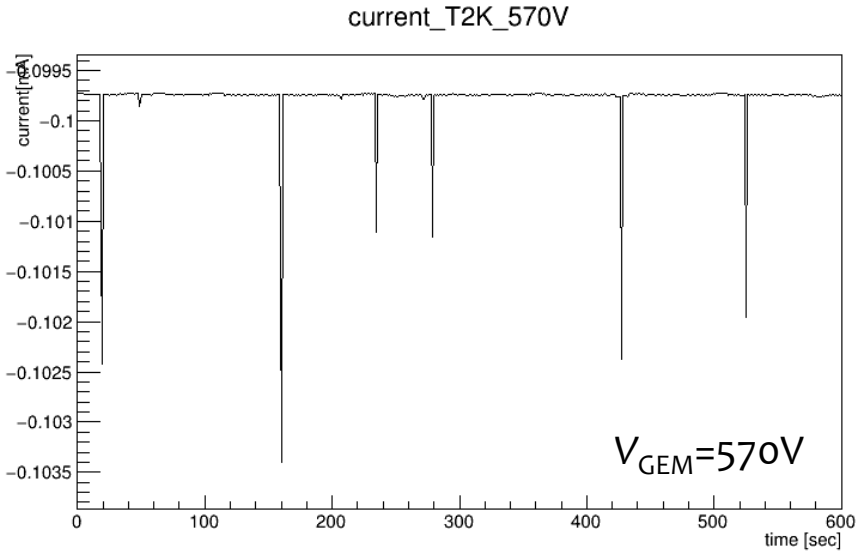


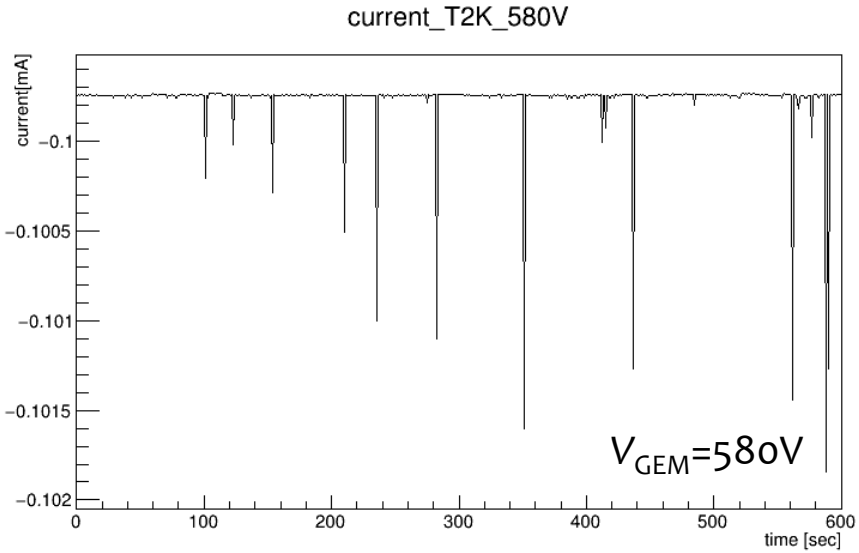
Instantaneous increase of the current is supposed to be induced by discharge.

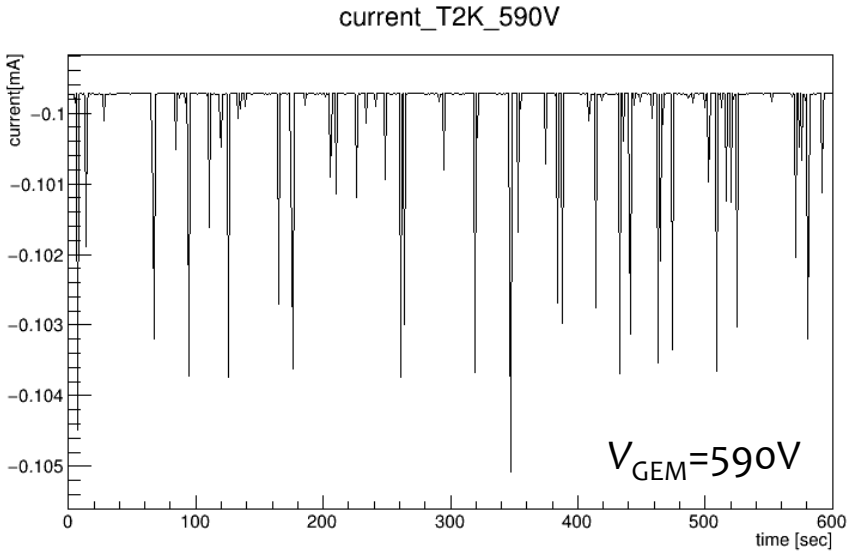
We observed discharge occurred frequently as increasing V_{GEM}.

Current monitor (T2K)

The monitored value includes offsets







Discharge occurred frequently as increasing V_{GEM}.

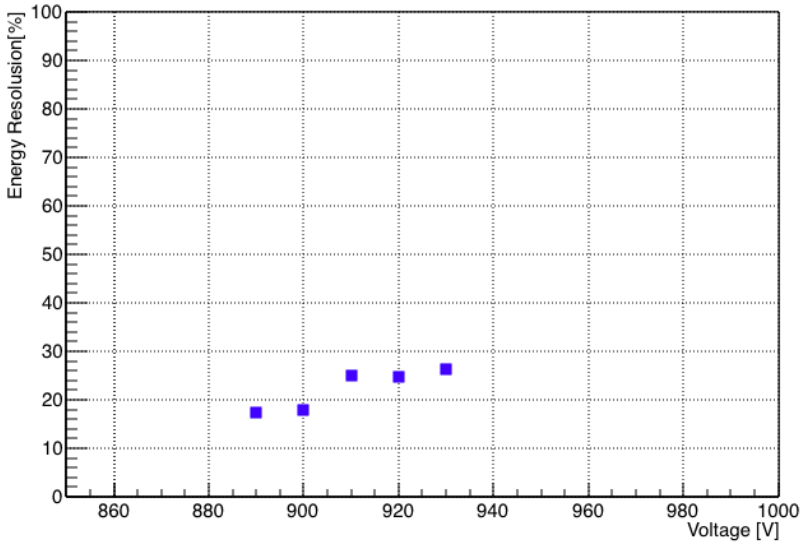
Discharge occurred more frequently with T2K gas.

The GEM worked without any degradation even after these runs.

Resolution

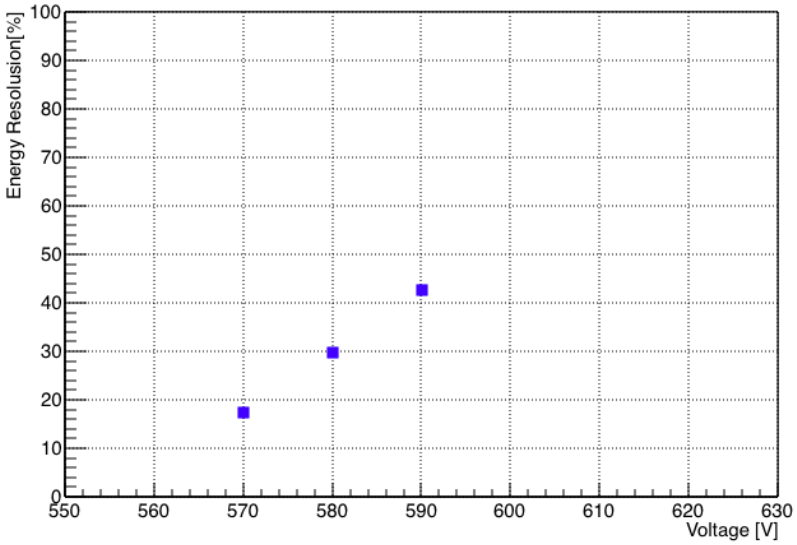
The energy resolution was estimated by (FWHM)/Mean in signal charge distribution.

Ar/CO2



The resolution was found to be 20~30 % and became worse at higher voltage.

T2K

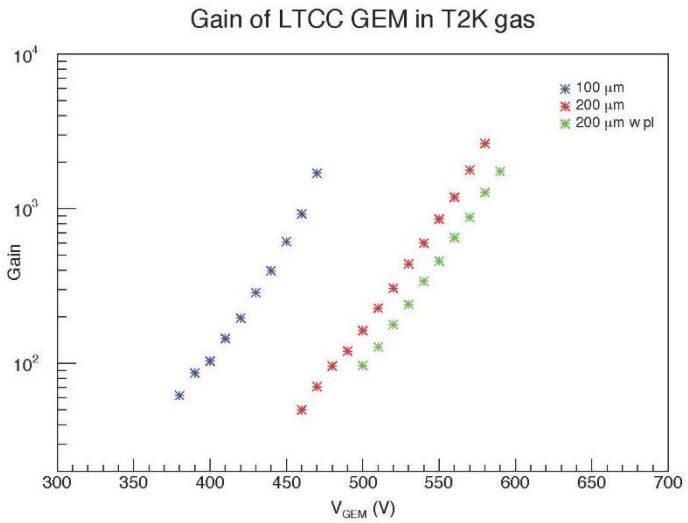


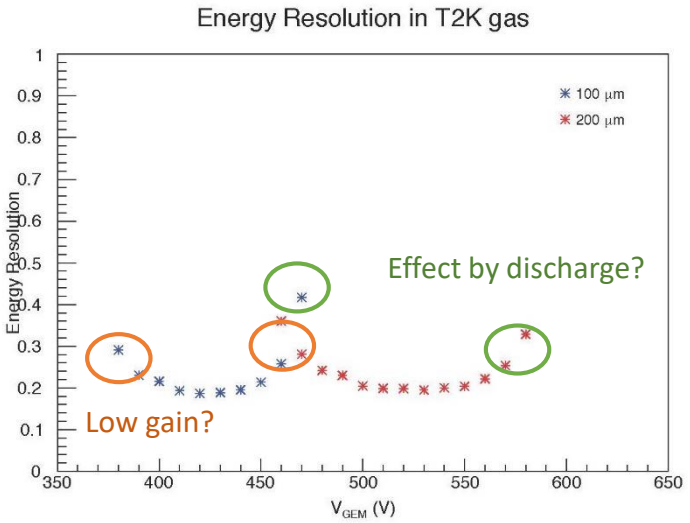
The resolution depends on the discharge remarkably.

LTCC-GEM study @ Kindai U.

Y.Kato-san has been testing the LTCC-GEM systematically at his lab.

Results of Gain and Energy resolution





Maximum Gain
- 100μm: 1800
- 200μm: 3000

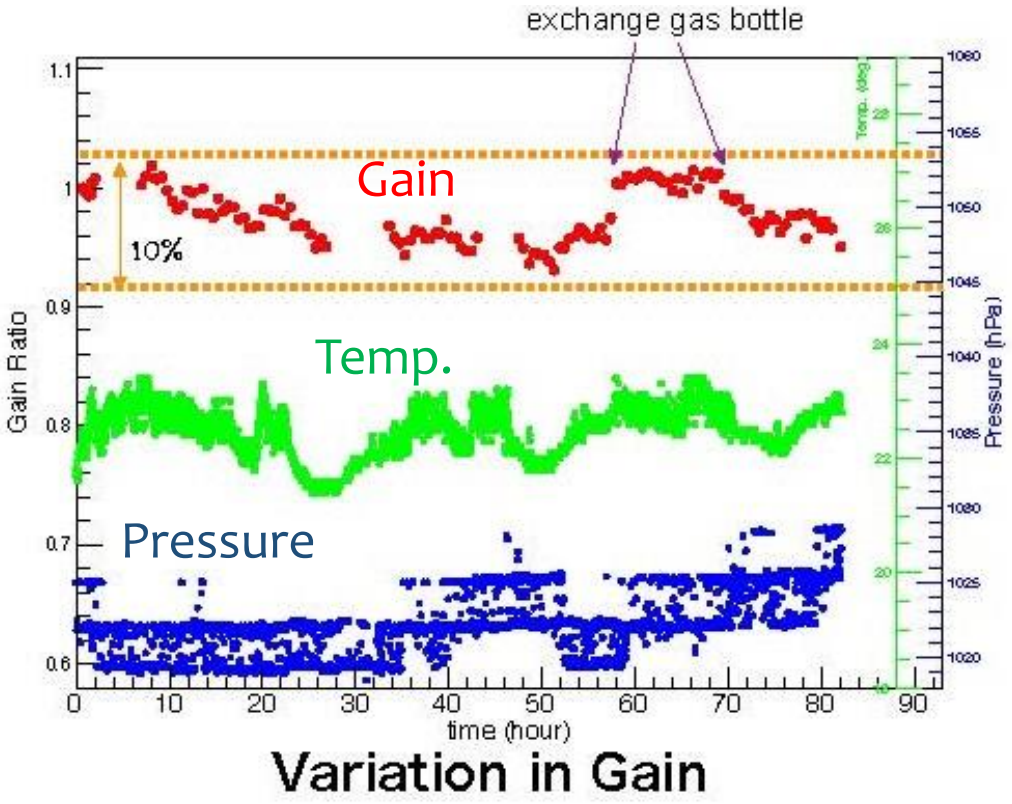
Energy resolution: 20%~40% (FWHM)

Presented at LC-TPC Japan group meeting (21-Apr-18)

LTCC-GEM study @ Kindai U.

Long term measurement

Tested 200μm GEM for 90 hr (T2K gas)



Gain variation for 90h is less than 10%.
(without any correction)

Conclusion

- We have tested the LTCC-GEM which is expected to have hardness to discharge.
- We found the maximum gain is ~3000 at
  V_{GEM} ~ 920V with Ar(70%)/CO_2(30%) gas
  V_{GEM} ~ 580V with T2K gas
- Time variation of the gain was found.
  -> need to consider the variation of environmental condition.
  The effect in aging of the material should be also investigated.
- The energy resolution was found to be 20-30%, but depends on the gas type.
- The feedback from our experience may help modification/optimization of the fabrication process.
- We would consider a new application of LTCC-GEM for a specific detector system.