Gas Electron Multiplier

for heavy ion experiments

RIBF detector workshop

March 18, 2008 at RIKEN

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Cosmic Radiation Laboratory

RIKEN

Collaboration

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- **Yamagata Univ.**

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- **HIMAC**

  N. Yasuda, T. Kitamura

- **INFN/Pisa**

  R. Bellazzini

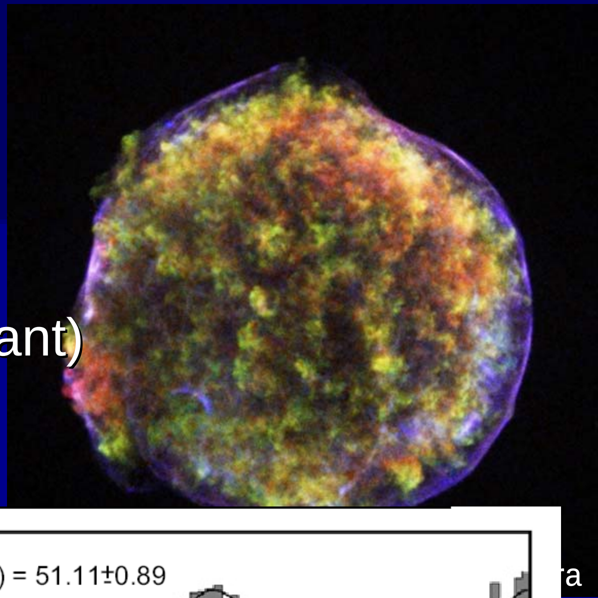
Outline

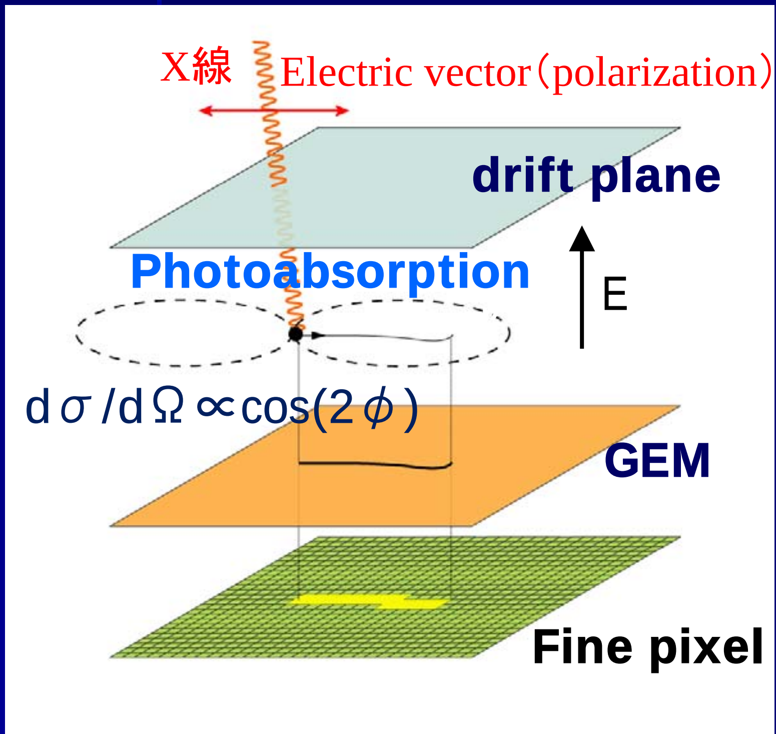
1. **Introduction**
2. **GEM basics**
3. **Development of GEMs in Japan and their properties**
4. **GEM heavy ion tests at HIMAC**
5. **Summary and Future plans**

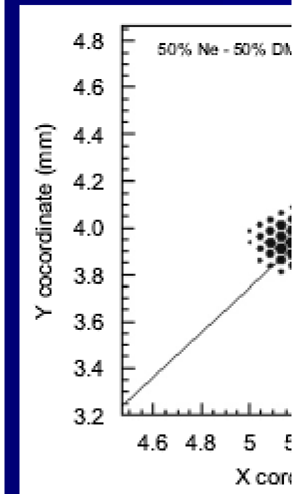
Cosmic X-ray polarimeter

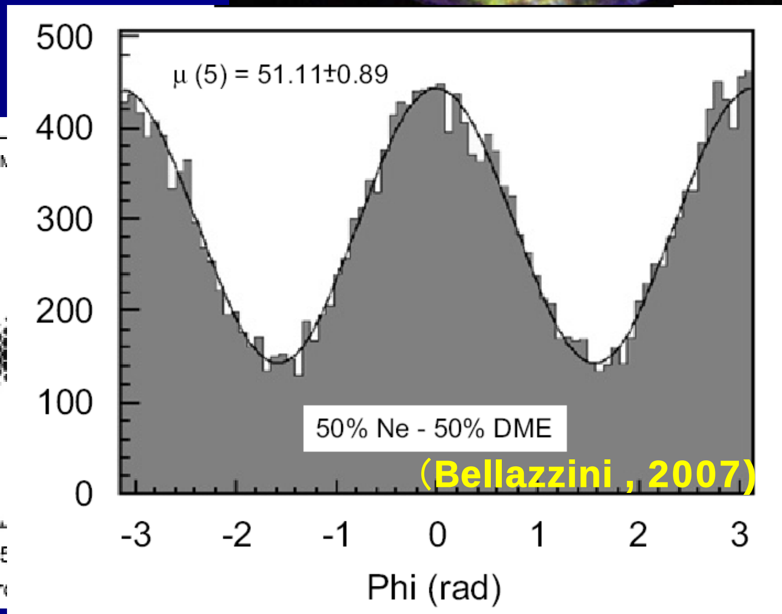
- X-ray polarization measurements
  = Direct evidence for particle acceleration in the universe

  (eg. synchrotron X-ray from supernova remnant)









<u>GEM is a key device. (Fine pitch and low risk of discharge.)</u>

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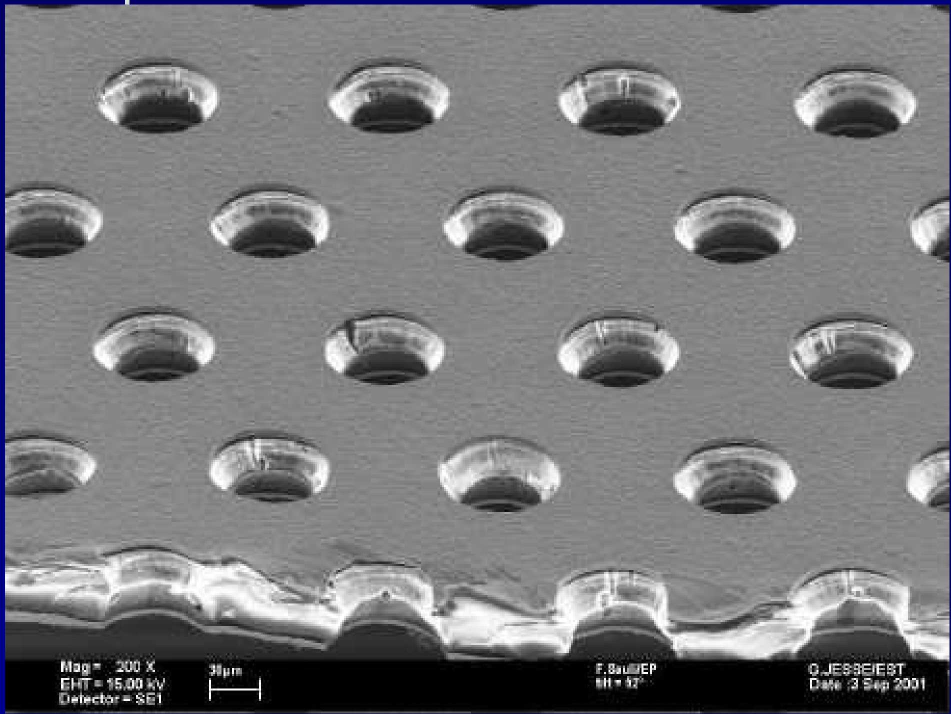
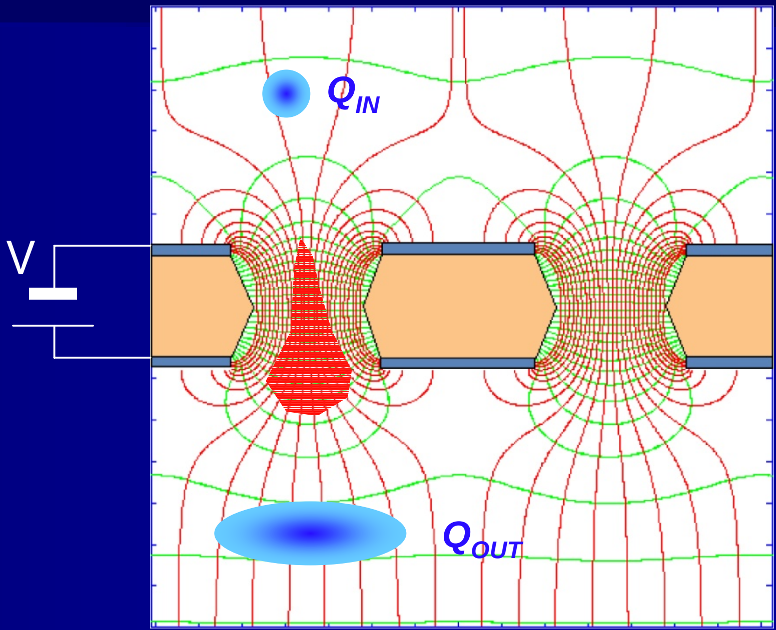
GEM operating principle

TYPICAL GEM: 50 µm Kapton
5 µm Copper
70 µm holes at 140 µm pitch



HIGH FIELD IN HOLE INDUCES AVALANCHE MULTIPLICATION



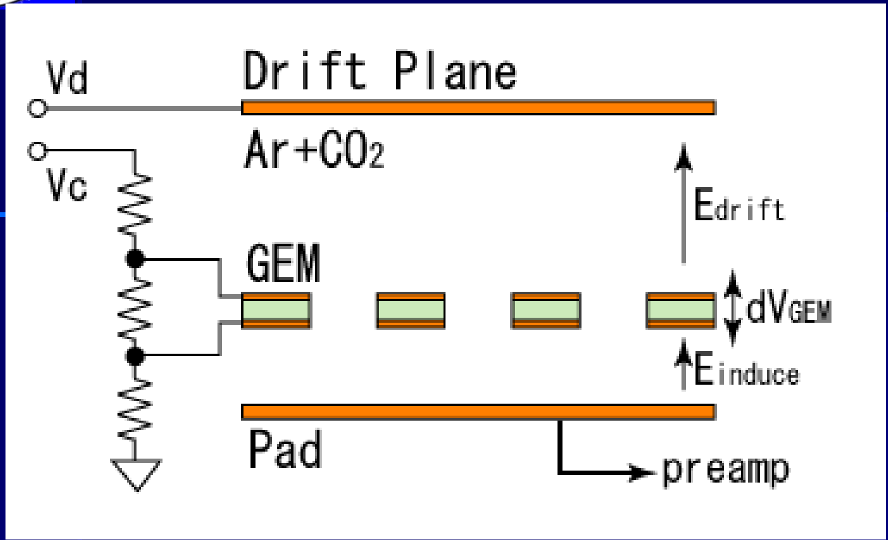
GAIN = Q_{OUT} / Q_{IN}

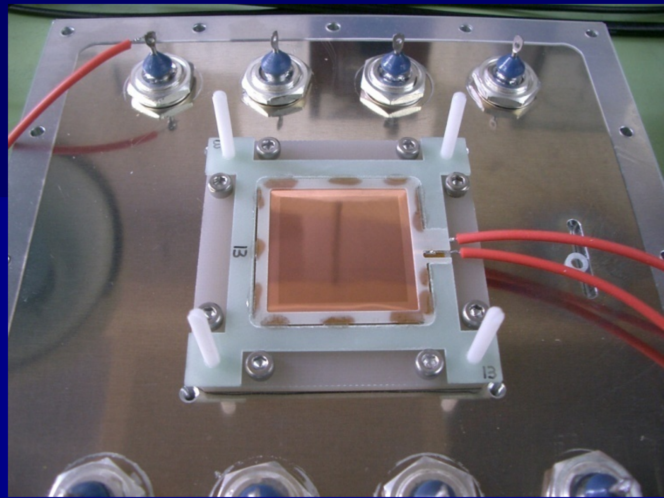
<u>~10,000 independent proportional counters per cm^2</u>

F. Sauli, Nucl. Instr. and Meth. A386(1997)531

(transparency from Sauli 2007)

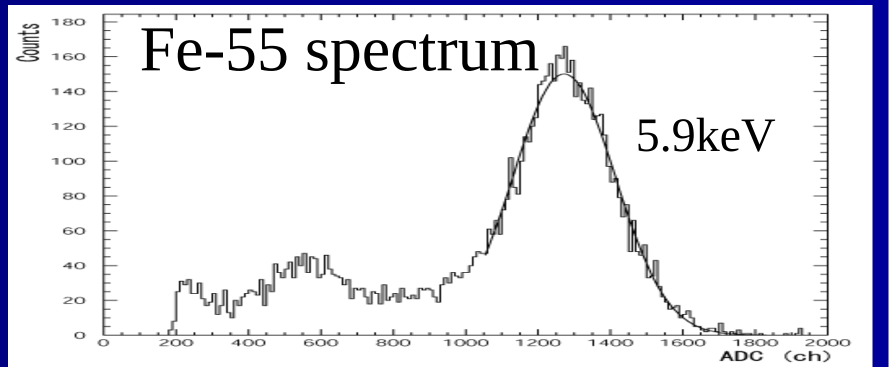
Standard GEM Operation





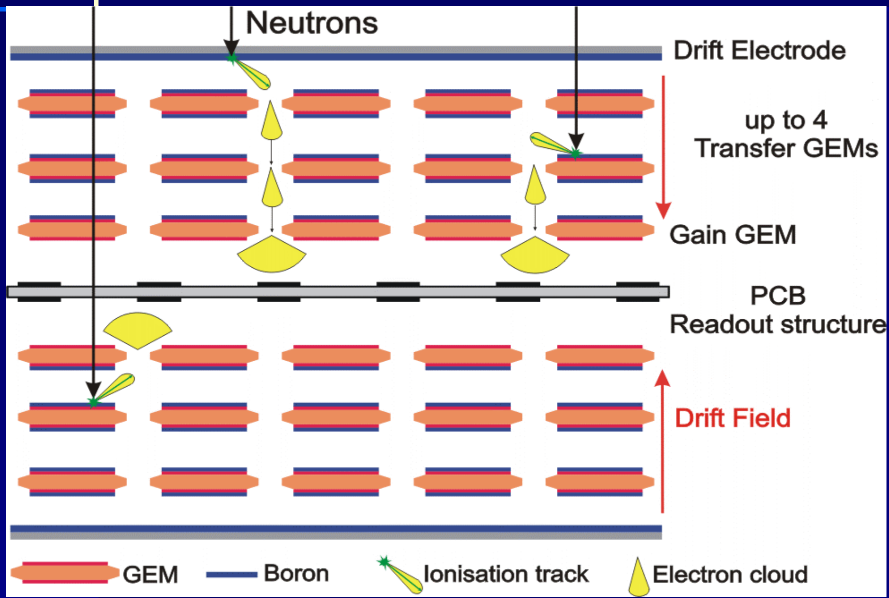
- **parameters**
  - **HV supplied through resister chain**
  - **Ed=2.5kV/cm, Ei=4~5kV/cm, ⊿VGEM=300~600V**
  - **Gas: Ar+CO_2(30%) flow**
  - **Readout by 1cm x 1cm pad**
- **Gain measurement**
  - **Gain vs applied voltage**
  - **X-ray from Fe-55 (5.9keV)**

dE/E~20% @5.9keV



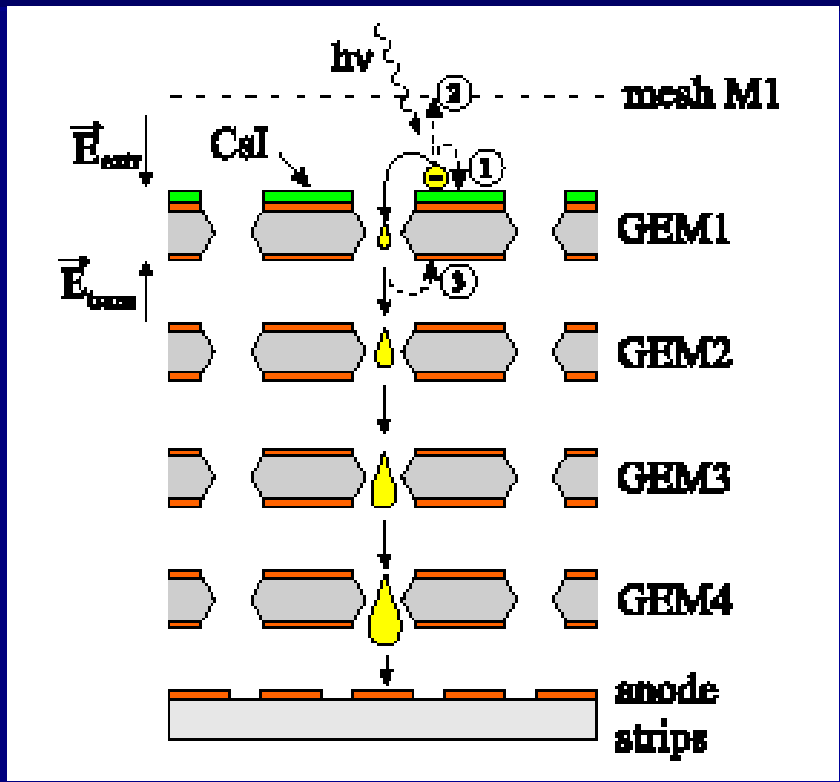
Applications

Neutron Detector



ε ~25% at 2 Å

Gas Photomultiplier



Of course, tracking chambers in nuclear and high energy physics

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Manufacturing (wet process at CERN)

50 µm Polymer
+5 µm Cu both sides

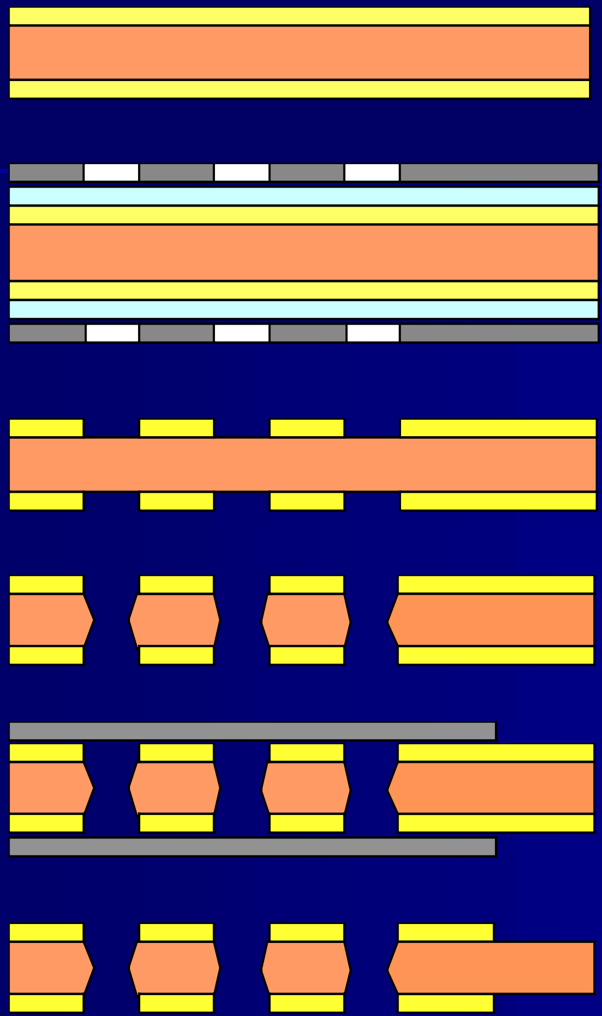
Photoresist coating,
masking,
exposure to UV light

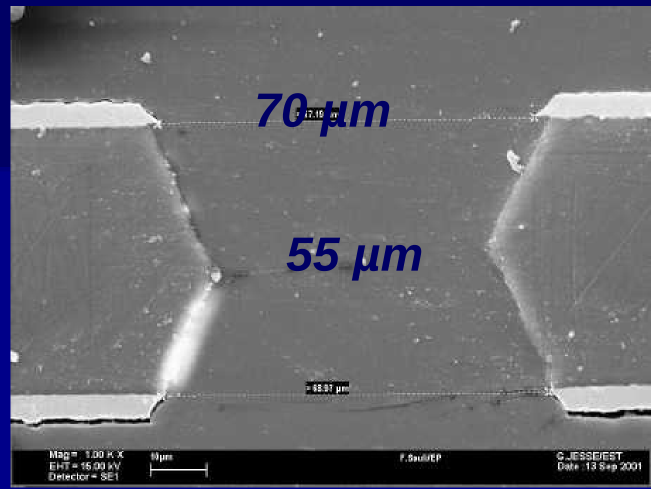
Metal etching

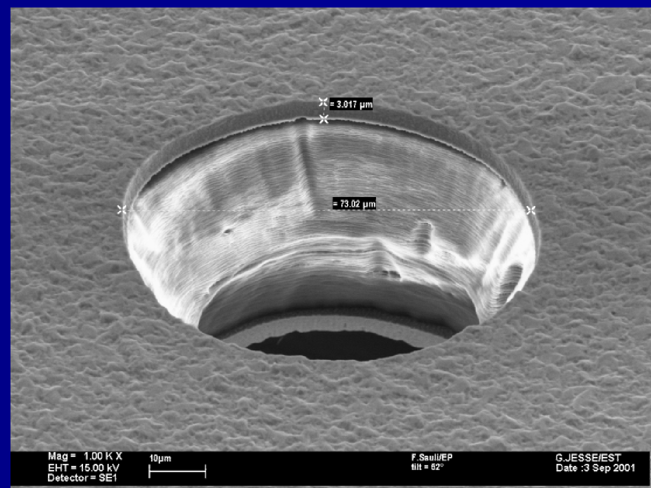
Polymer etching

Second masking

Edge metal etching
and cleaning

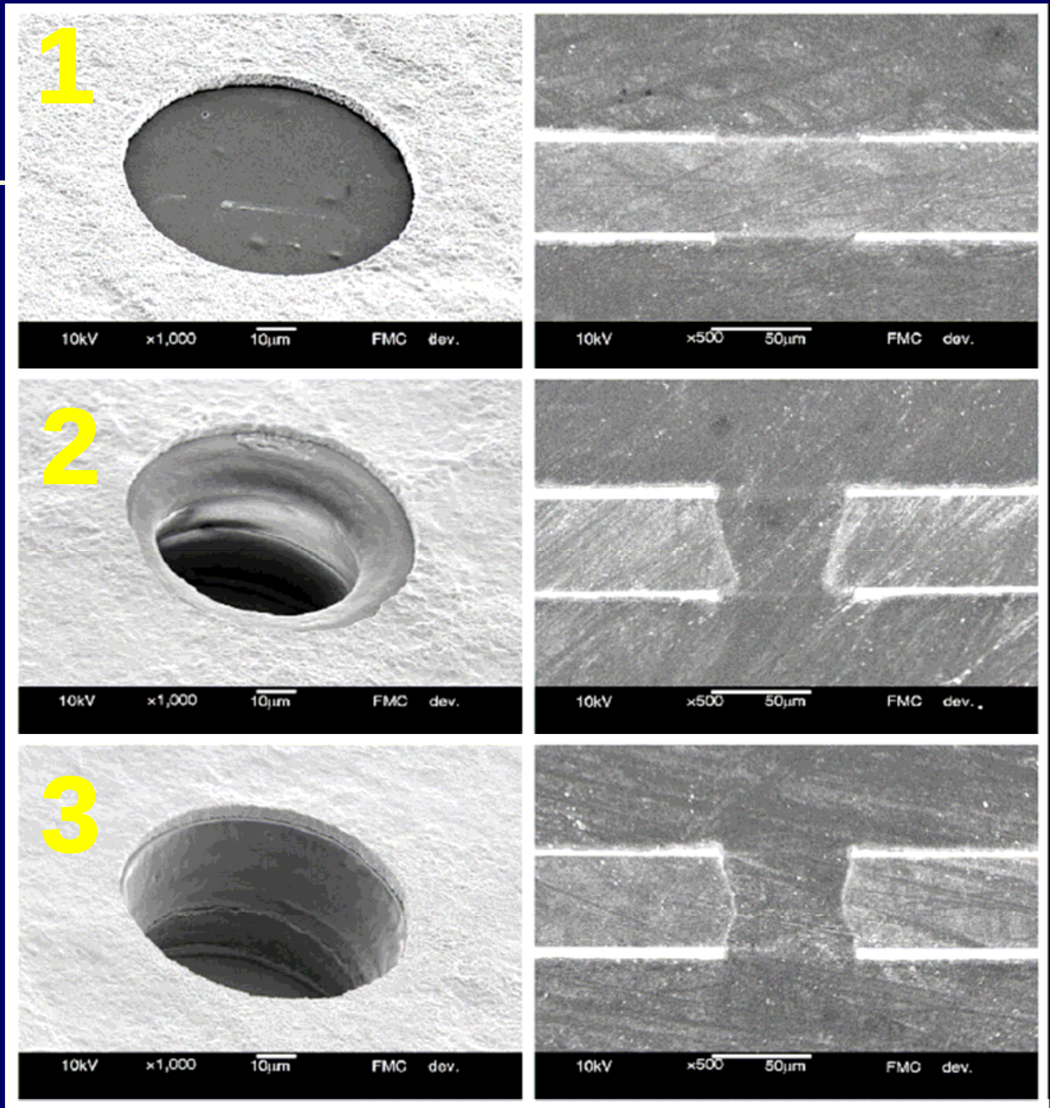






(transparency from Sauli 2007)

RIKEN/CNS Manufacturing

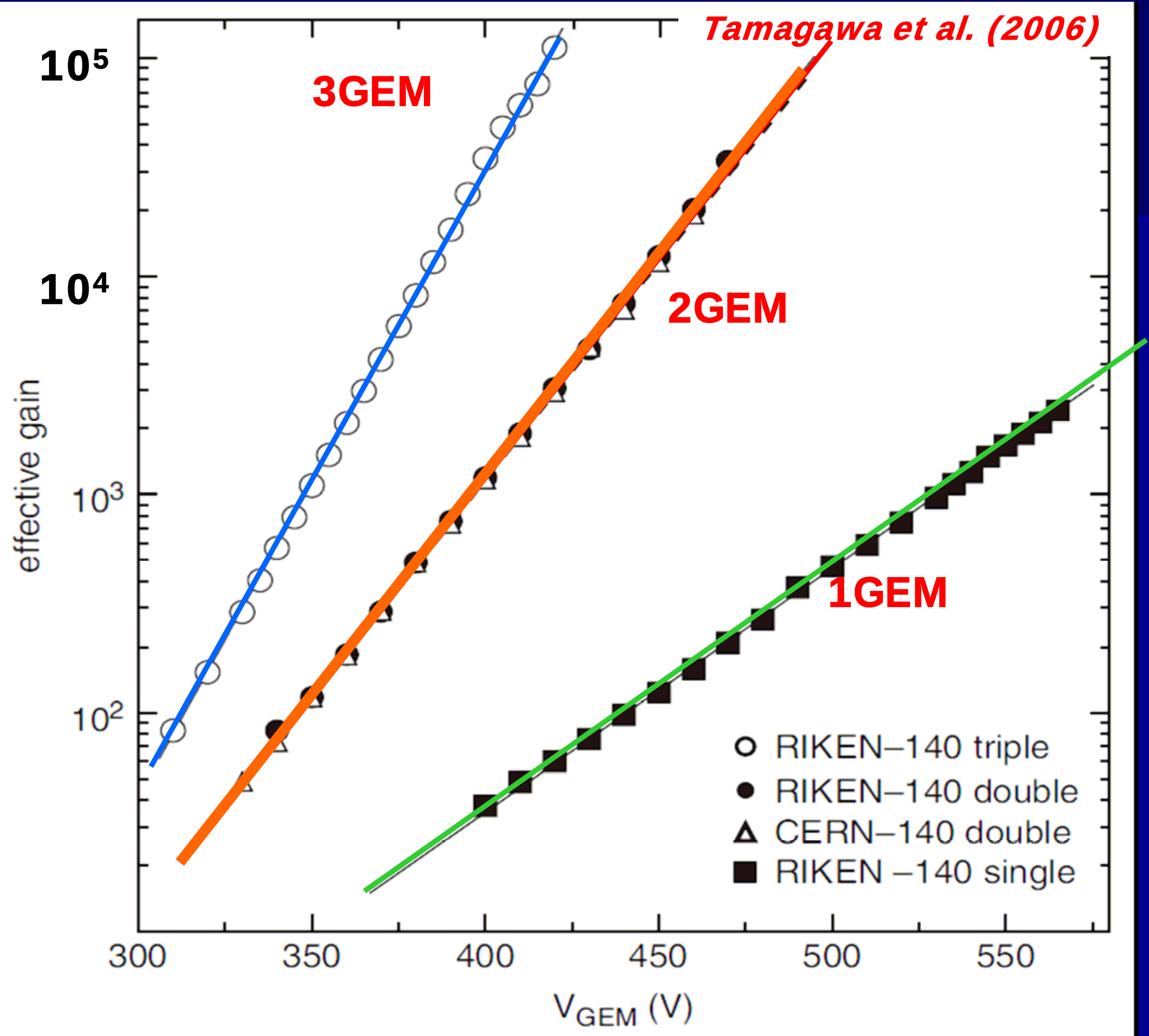


Remove copper by wet etching

Irradiate CO_2 laser

Remove remaining edge from the other side

Effective gain of GEMs



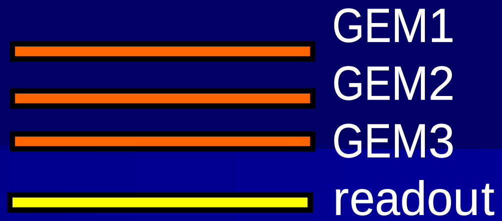
Pitch 140um
Hole 70um
Thickness 50um
Ar+CO_2 (30%)

In 2003

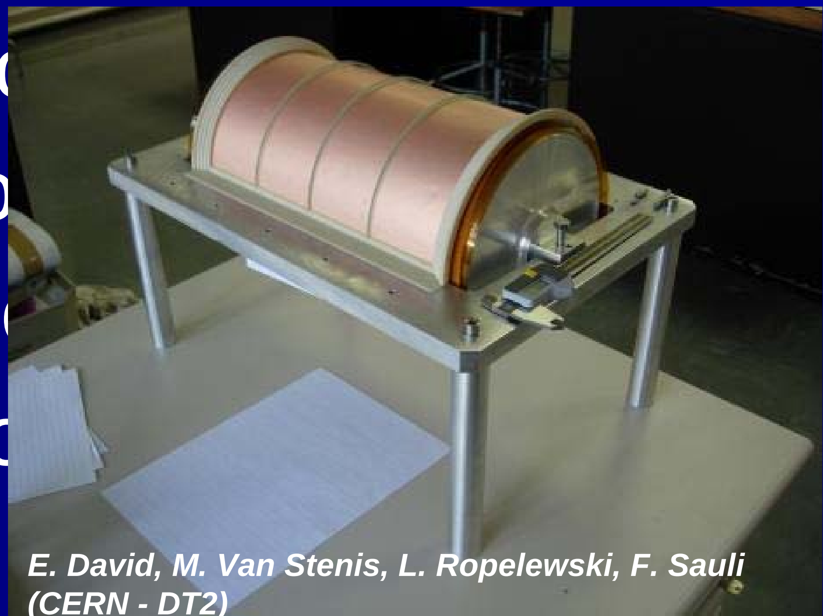
- Almost identical gain as CERN one

Advantages over wire chambers

- Multilayer operation
  - Enough gain at low voltage
  - Preamp inside a chamber for u-PIC or MSGC



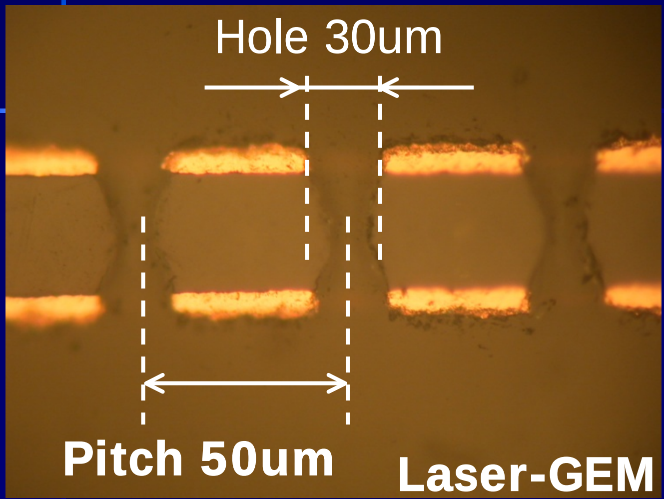
- Separation of readout electronics from GEMs
- Two dimensional electr
- Very good position reso
- Less drift back ions (go
- Flexibility at mounting c

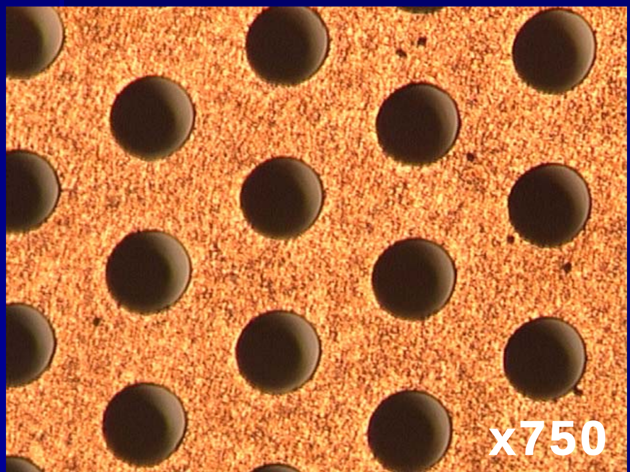


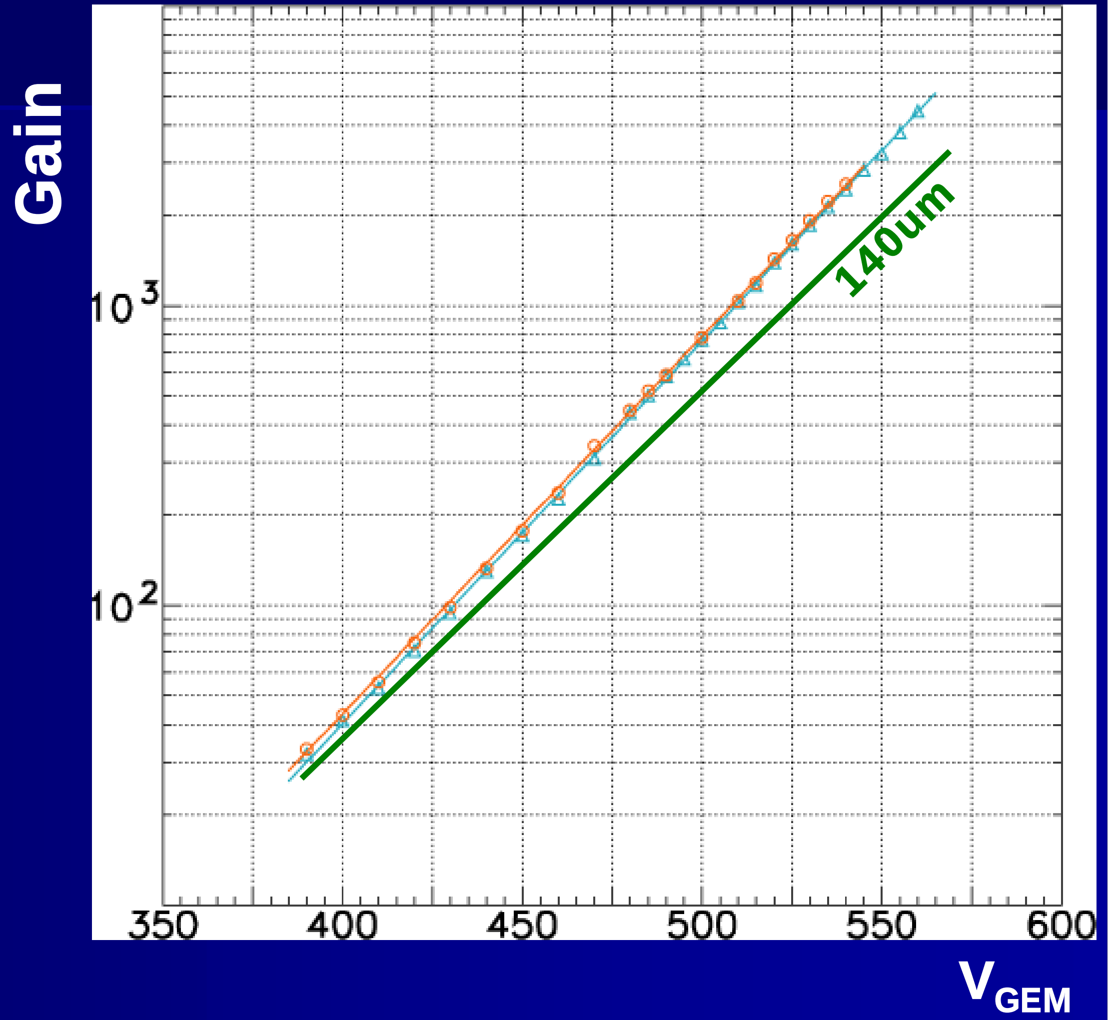
E. David, M. Van Stenis, L. Ropelewski, F. Sauli (CERN - DT2)

The Finest pitch GEM

Pitch: 50um, hole 30um

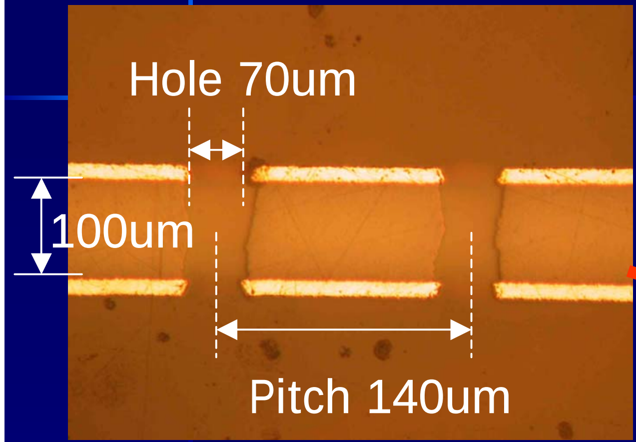




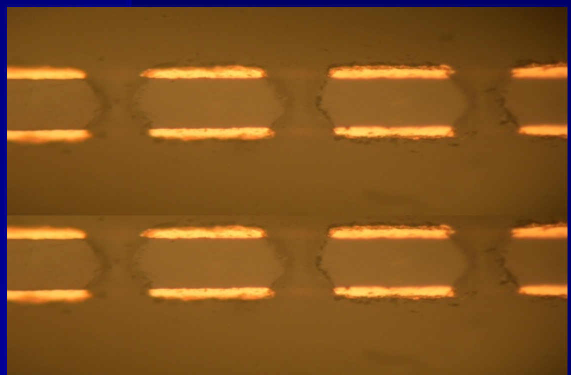


Thick-foil GEMs

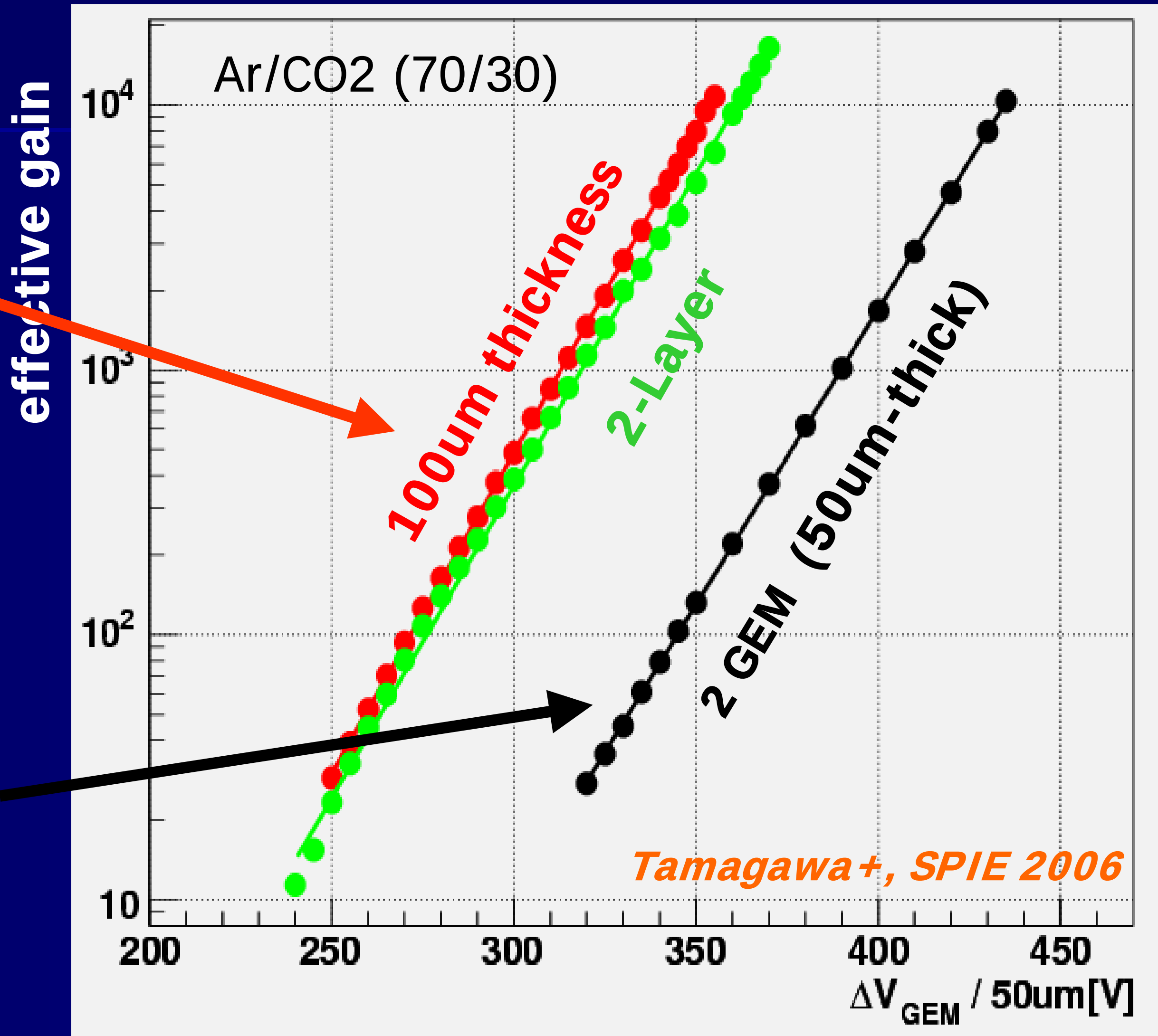
To keep discharge point at high gain



Thick-foil GEMs



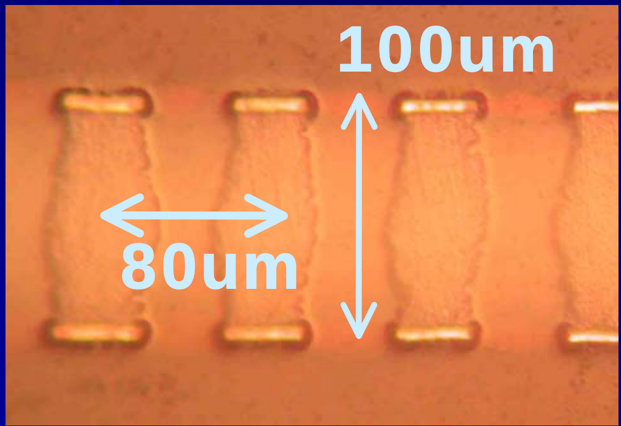
2 GEM

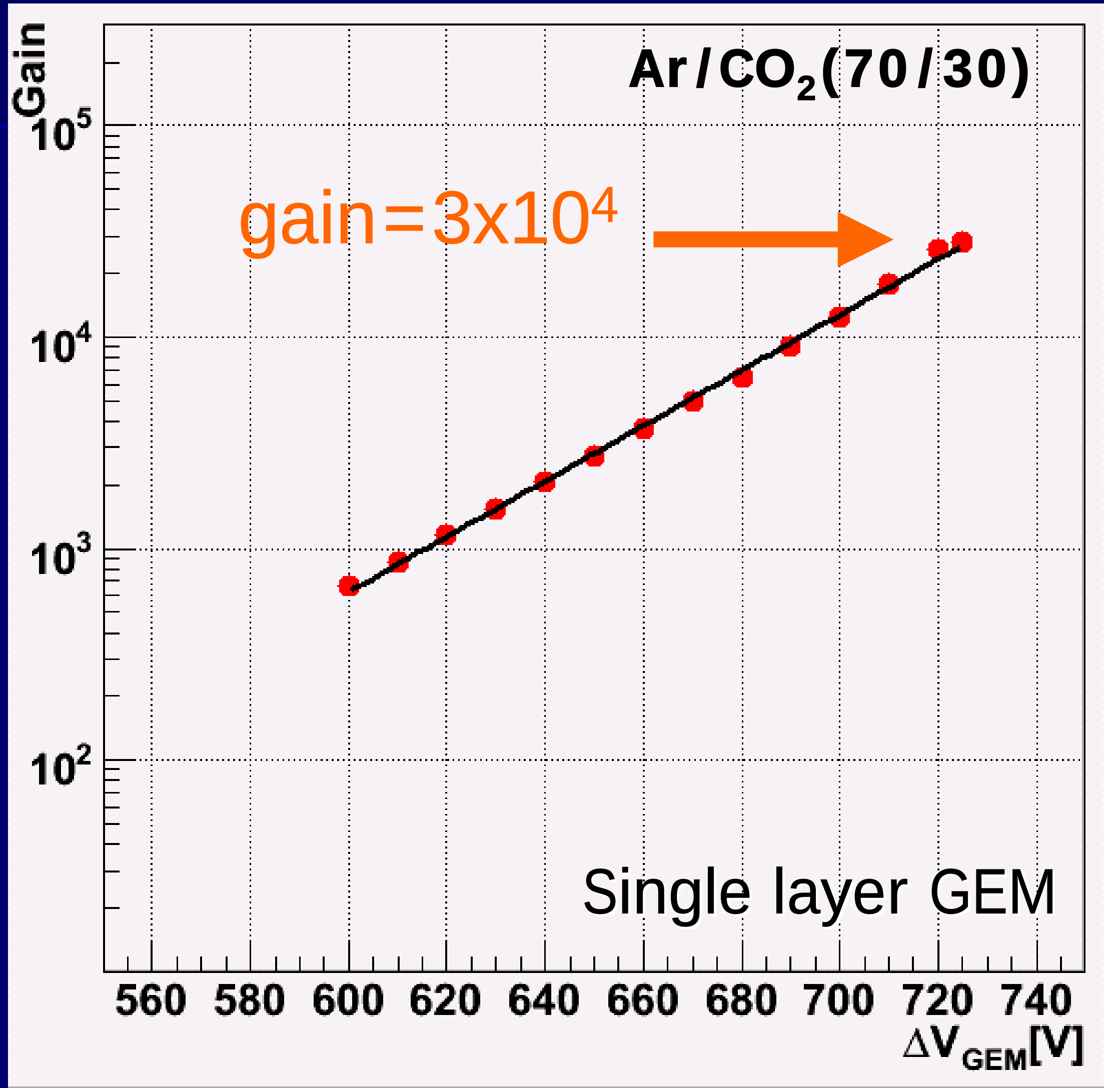


Thick-foil and fine-pitch GEMs

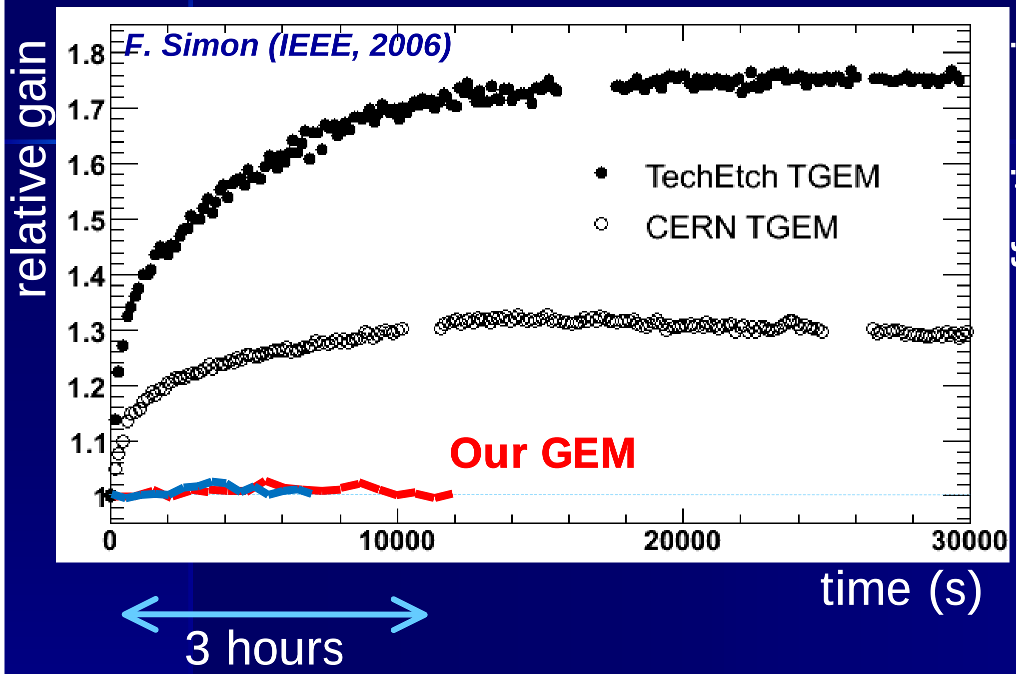
Pitch 80 um, hole 40 um, thickness 100 um

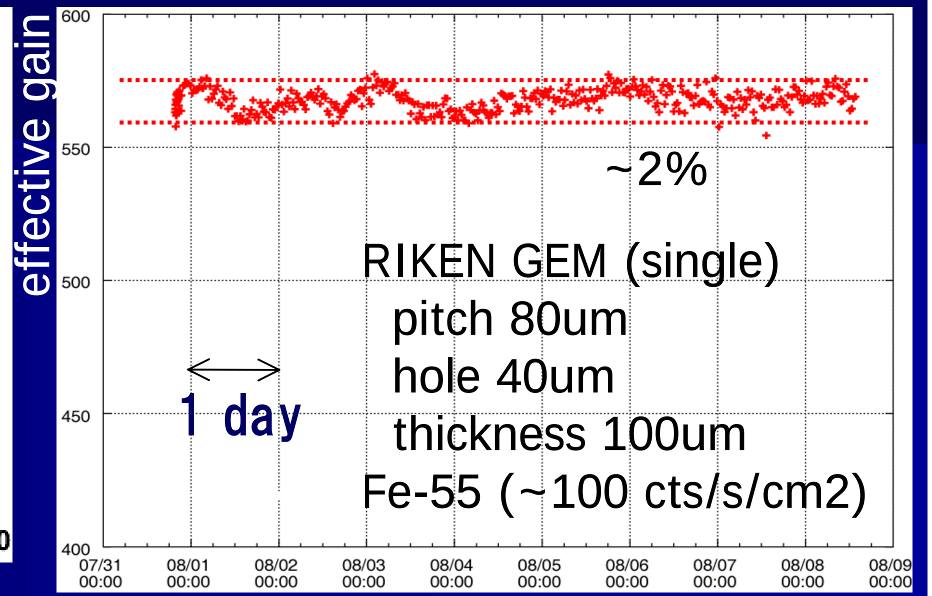
To keep good spatial resolution and keep discharge point at high gain





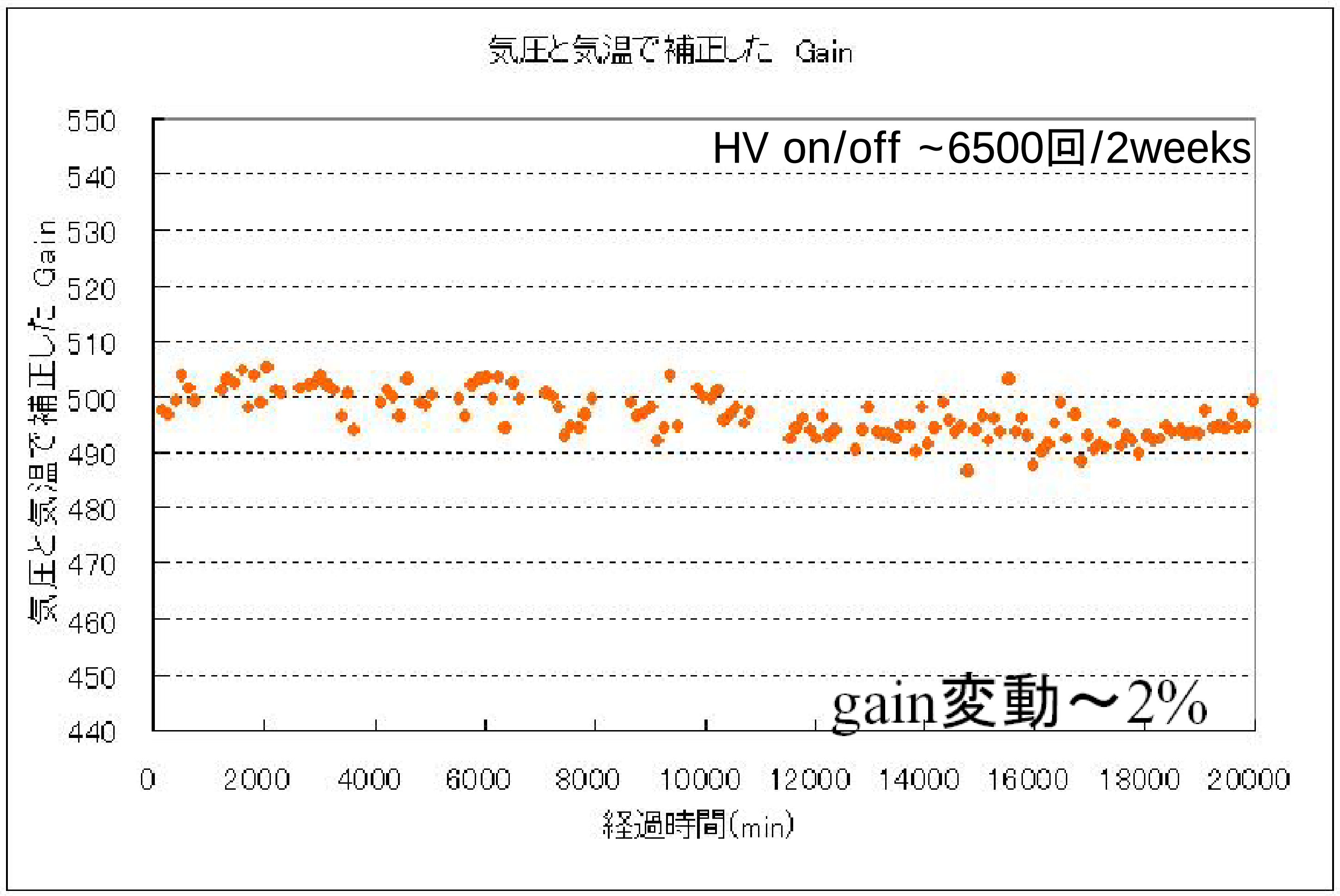
Short/long-term gain stability





- **No gain increase in short and long-term measurements**
- **This is not for a special batch of GEMs but for all GEMs we produced**
- **Possible reasons;**
  - ✓**Less charging-up due to cylindrical hole shape**
  - ✓**Less polarization of Liquid Crystal Polymer**

HV ramp-up/down



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2007年度卒業論文

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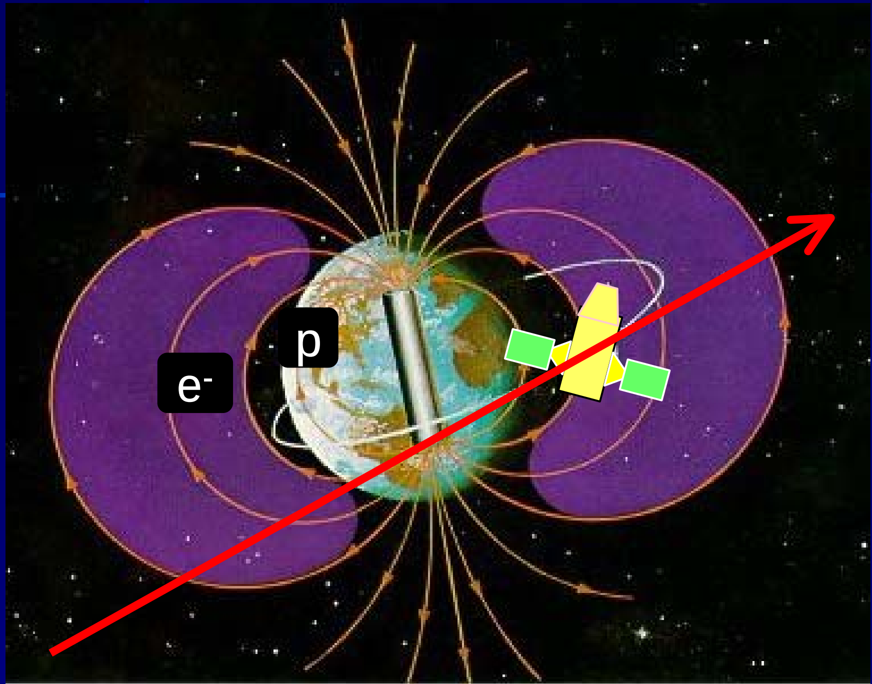
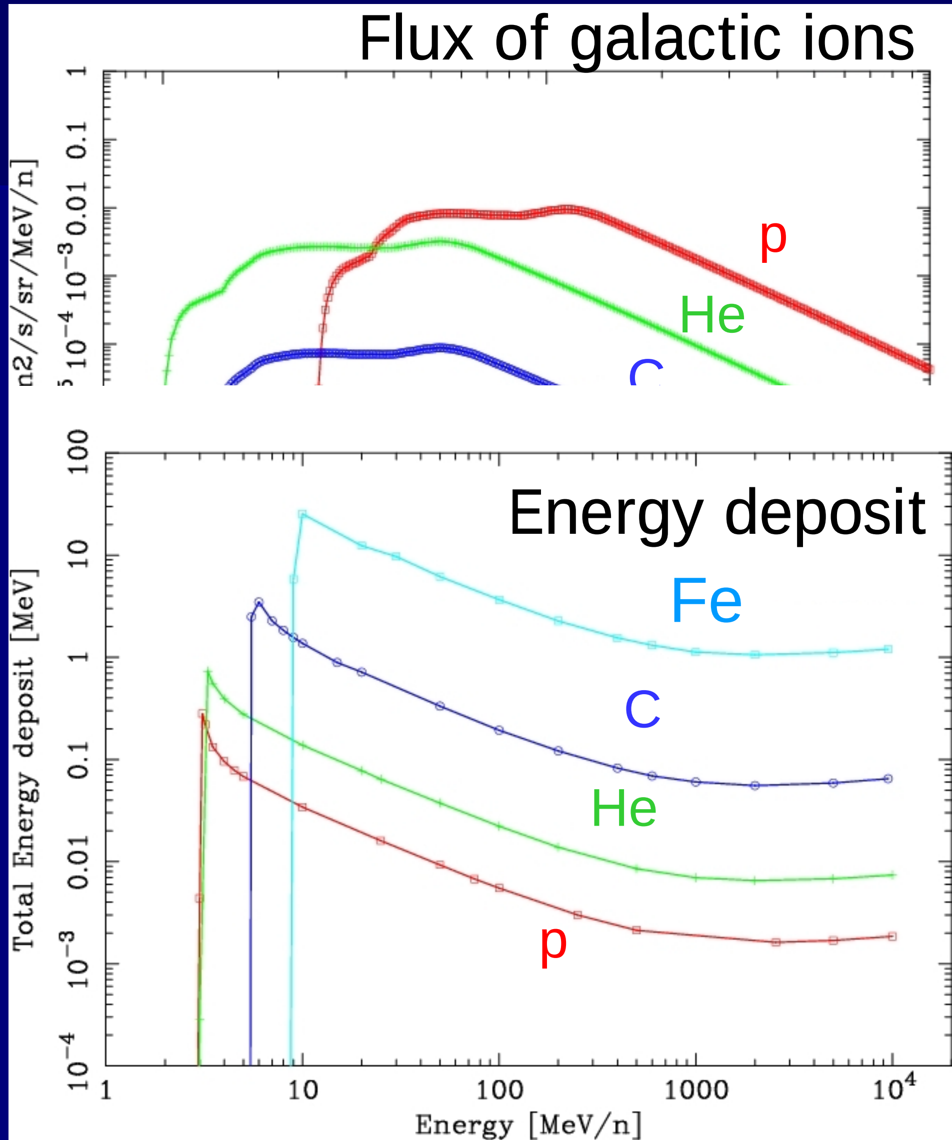
Particle irradiations in low Earth orbit

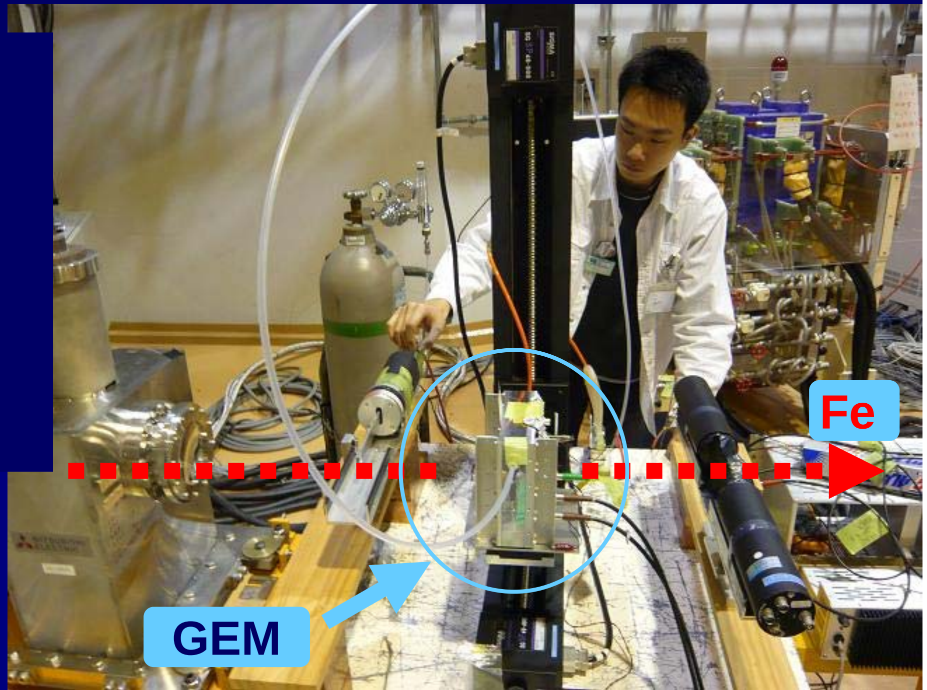


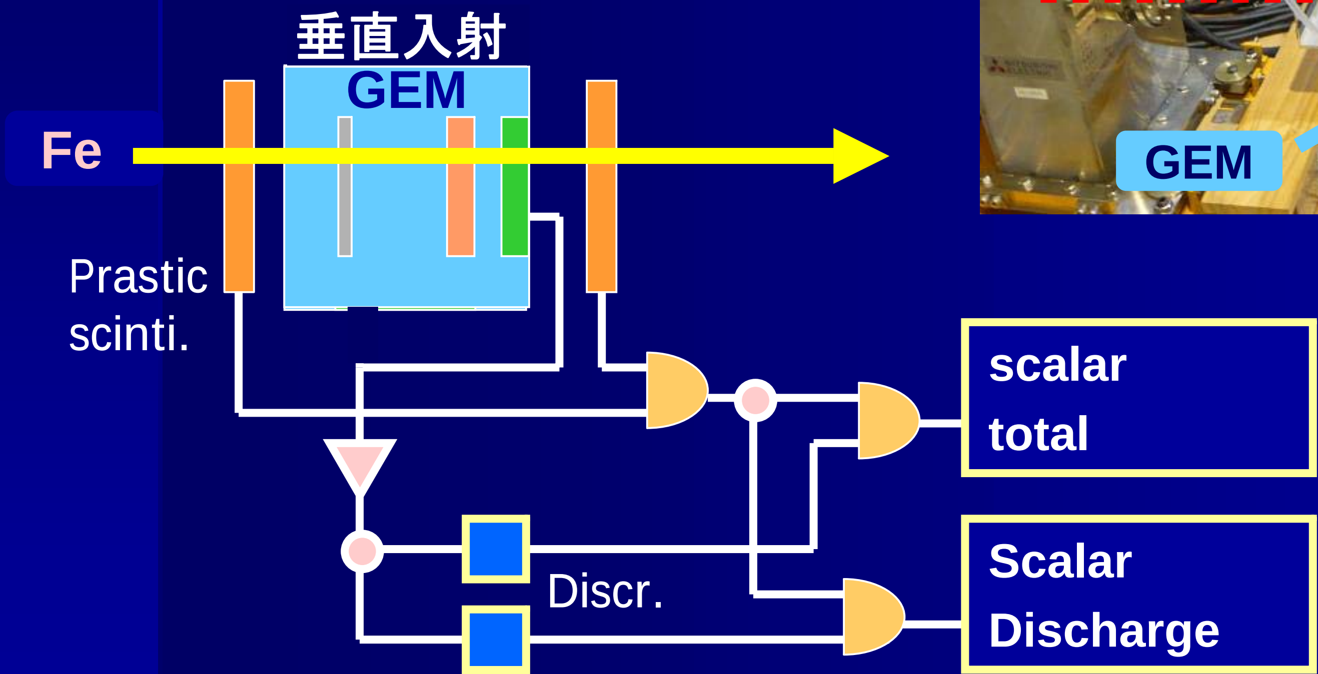


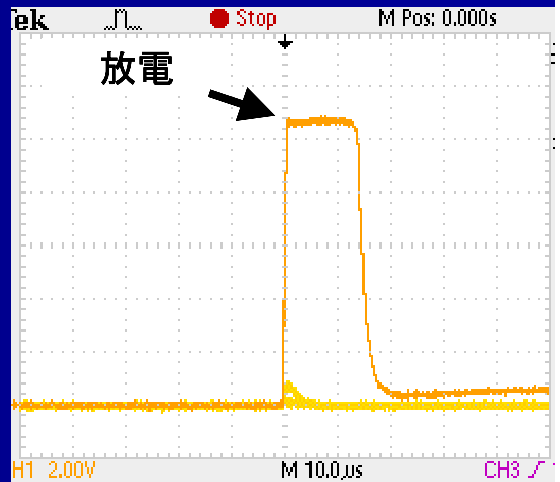
- Trapped protons
- Trapped electrons
- Galactic heavy ions
  - Pp, He, C, O, Fe...

Heavy ion irradiation at HIMAC

Fe: 500 MeV/n
Rate: ～120 counts / sec
（宇宙環境の 約4万倍）
GEM: parallel to the beam direction
perpendicular to the beam







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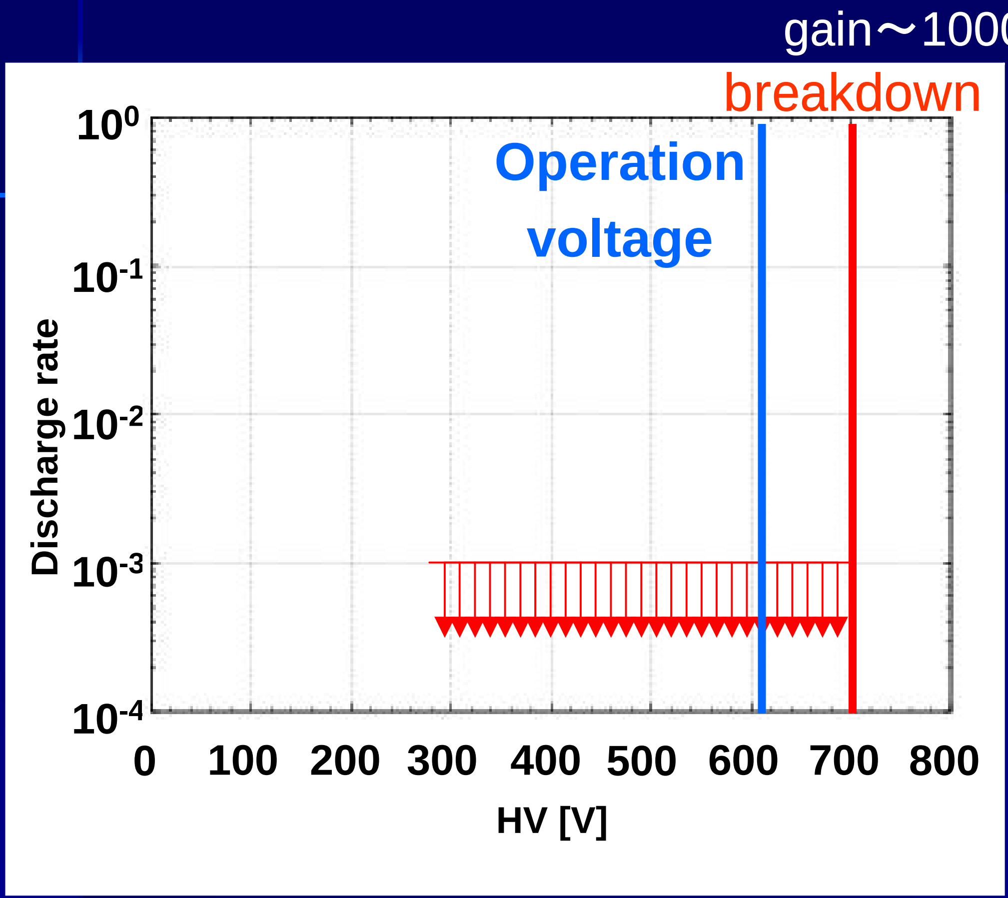
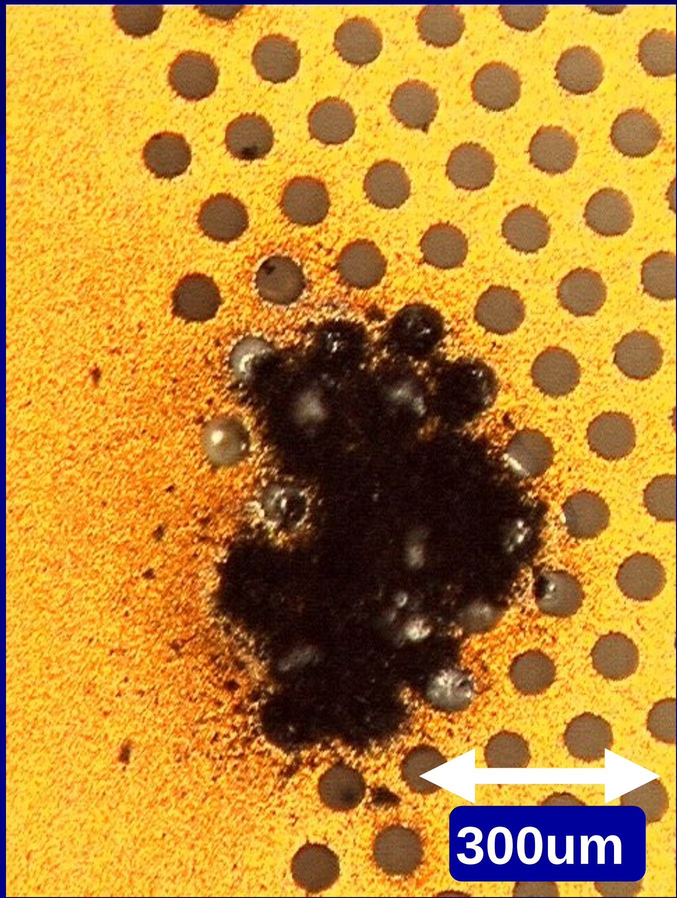
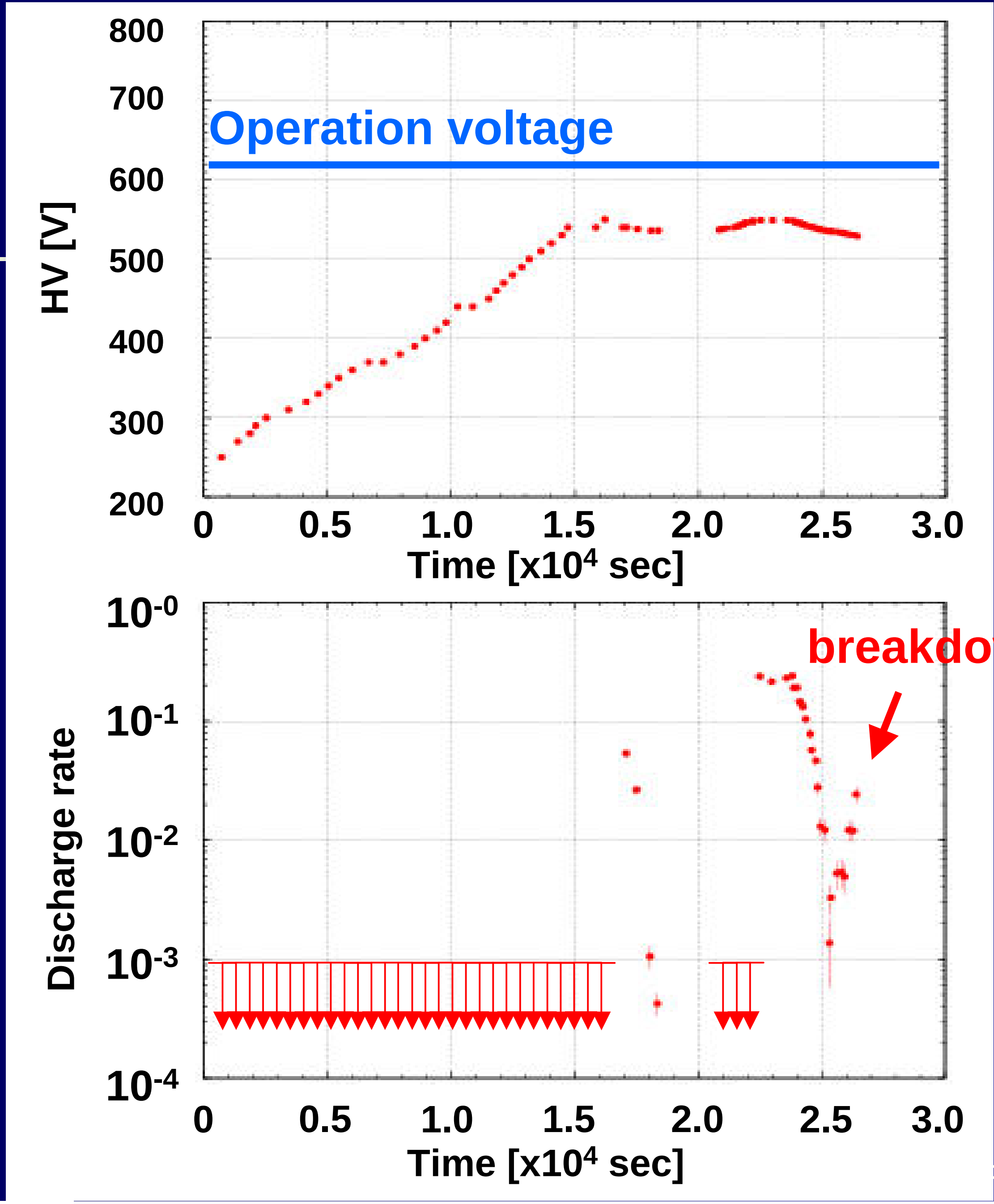
Result (parallel case)

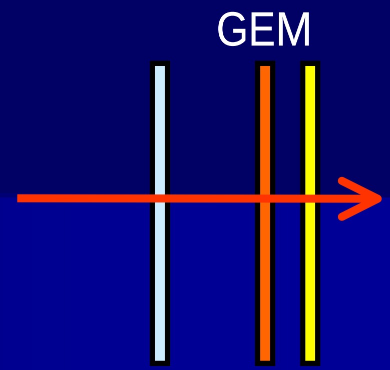




Vgem~700V : limitation of insulator

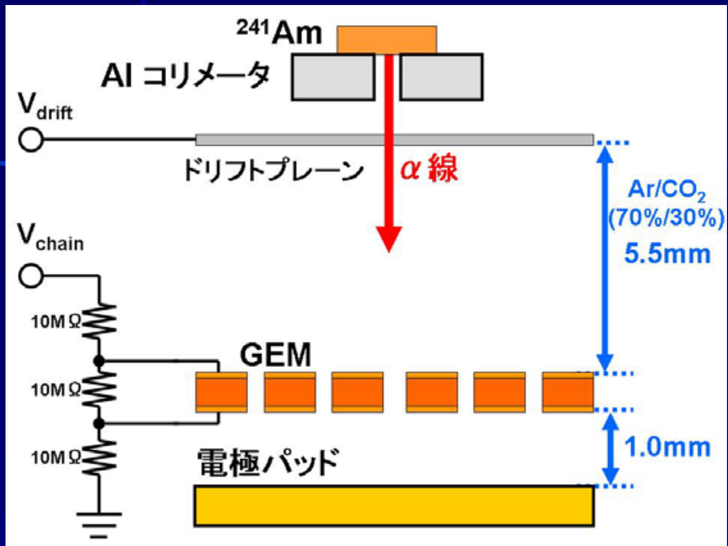
Result (perpendicular case)

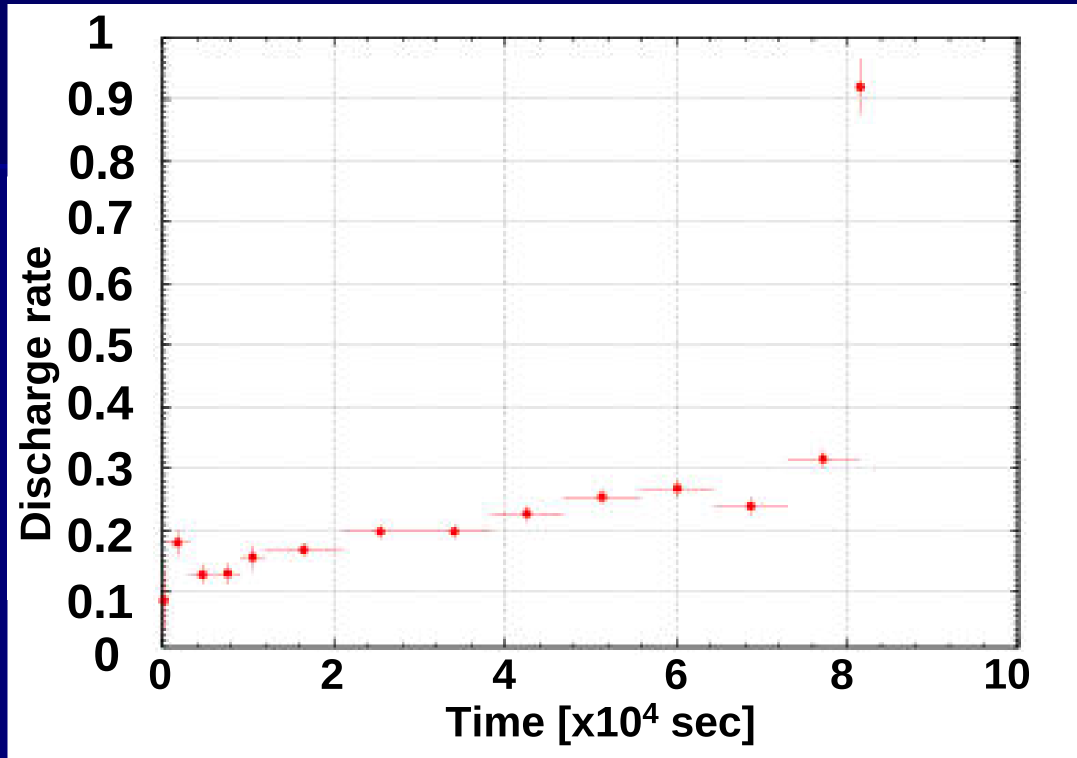




Energy deposit
~ 1 MeV

^{241}Am α-ray irradiation





Energy deposit ~ 1 MeV

～0.3 counts / sec

Keep voltage more than 24 hours = 440 years in space

N_discharge × exp(HV) = N_discharge × gain = const.

Future plans

- HIMAC beam time
  - 2008/7/08: Fe 500 MeV/u on GEM and readout ASIC for latch-up test
  - 2008/7/23: proton 160 MeV irradiation on GEM for studying radiation damage of insulator layers
- Looking for chance of GEM beam test at RIKEN
- We would like to transfer our know-how to the person who wants to use GEMs on his/her experiments!

Summary

- We have developed GEMs in Japan with laser etching technique for astrophysics applications.
- We have obtained better gain properties especially for thick-foil and fine-pitch GEMs.
- We have irradiated heavy ion beam at HIMAC. Breakdown mechanism is under investigation.
- 購入方法
  – （株）サイエナジーへ
  – 納期は一か月ほど