MPGD R&D Activity in Japan

Kobe University
Atsuhiko Ochi

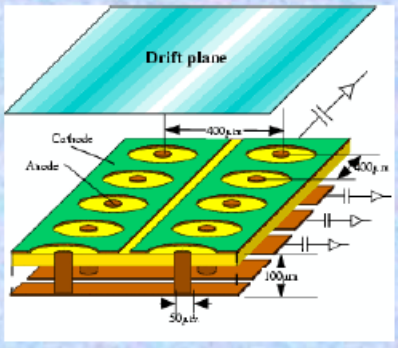
10 June. 2013 Cygnus 2013 workshop at Toyama

What's MPGD ?

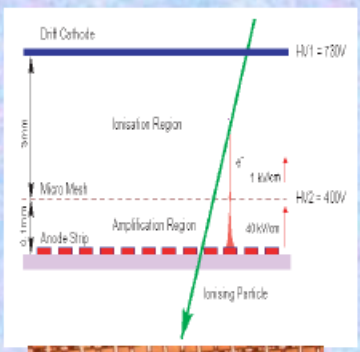
MPGD: Micro Pattern Gaseous Detector

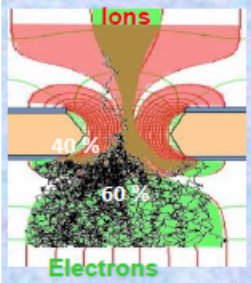
- **Micromegas**
- **GEM**
- **Thick-GEM, Hole-Type Detectors and RETGEM**
- **MPDG with CMOS pixel ASICs ("InGrid")**
- **Micro-Pixel Chamber (μPIC)**

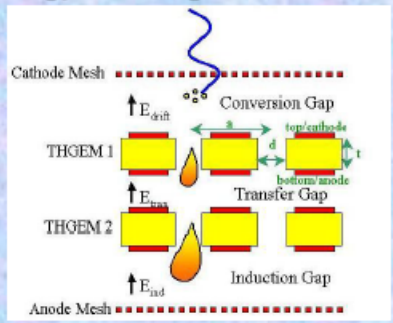
μPIC

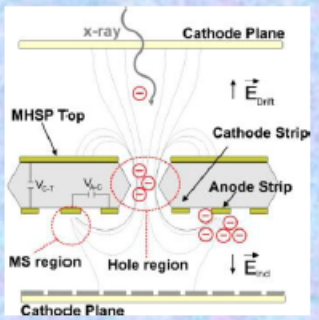


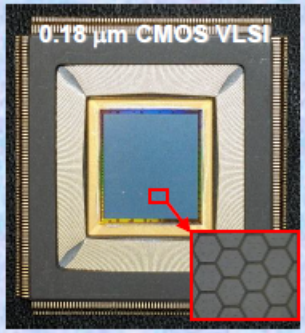
CMOS high density readout electronics

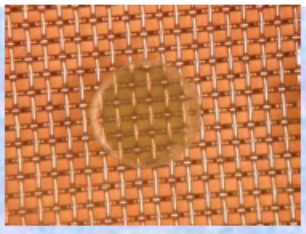




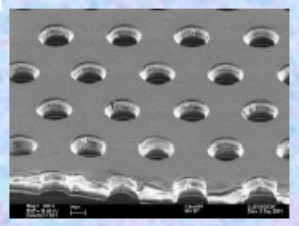




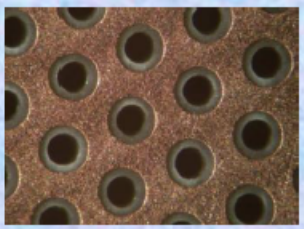




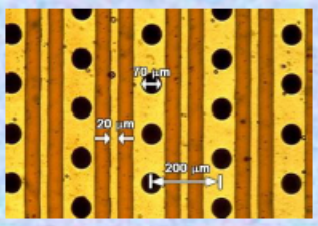
Micromegas



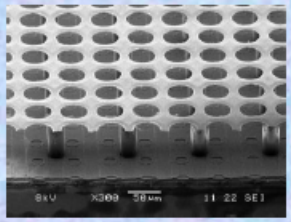
GEM



THGEM



MHSP



Ingrid

From M. Titov, 110th LHCC meeting

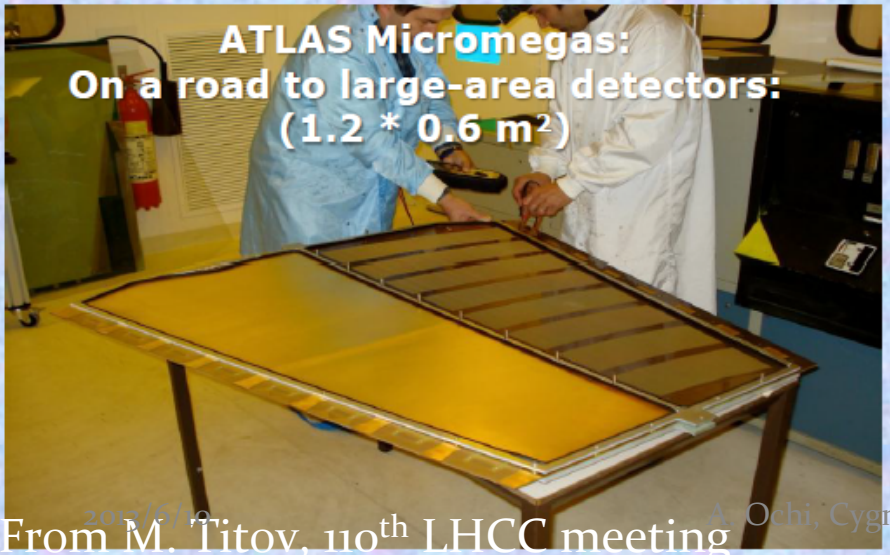
Properties of MPGDs

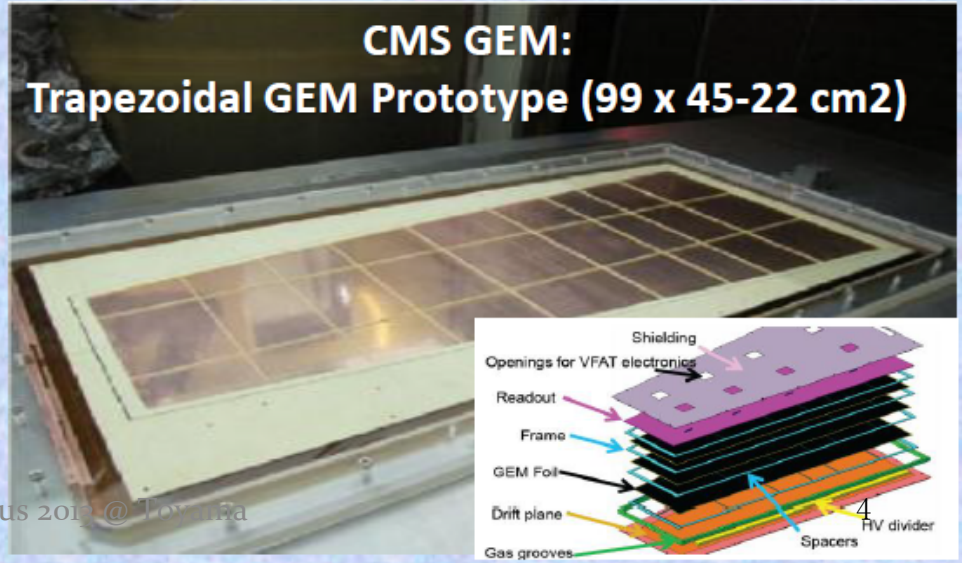
- Gas multiplication and/or read out are performed by "micro pattern" instead of conventional wire chambers
- Fine patterning realized …
  - Fine position resolution (< 100 micron)
  - Fine timing resolution (< 10nsec)
  - High operational capacity for intense irradiation (> 10^7 counts/mm)

MPGD Technologies for Energy Frontier (sLHC, LC)

Ongoing R&D Projects using MPGDs in the framework of HEP Experiments

	Vertex	Inner Tracker	PID/ photo-det.	EM CALO	HAD CALO	MUON Track	MUON Trigger
ATLAS	GOSSIP /InGrid	GOSSIP /InGrid				Micromegas	Micromegas
CMS						GEM	GEM
ALICE		TPC (GEM)	VHPMID (CsI-THGEM)				
Linear Collider		TPC(MM, GEM, InGrid)			DHCAL (MM,GEM, THGEM)		





From M. Titov, 110th LHCC meeting

Growing Demand for the Micro-Pattern Gaseous Detectors

… MPGD are mostly used/proposed for high-rate tracking and photodetectors

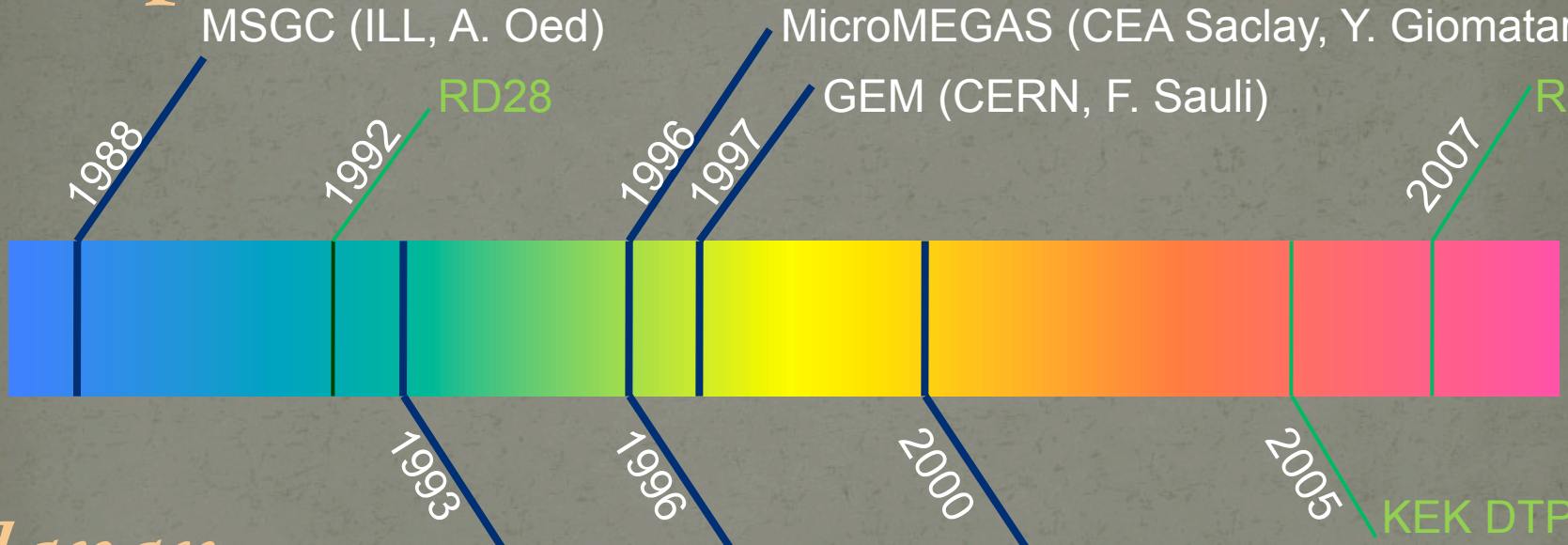
… not even a complete list …

- **COMPASS Upgrade:**
  - Micromegas and GEM detectors for high-rate tracking
  - Photon Detectors Using THGEM technology for RICH 1
- **KLOE2 Upgrade:**
  - Large-area cylindrical GEMs for Inner Tracker
- **RHIC Upgrades:**
  - GEM Tracking for STAR Experiment
  - GEM Tracking for PHENIX Experiment(+ drift micro-TPC); development of Ring Imaging version of HBD for particle ID
- **Future JLAB Projects:**
  - Thin-Curved Micromegas for JLAB/CLAS12
  - GEM Tracker for JLAB/Hall A High Luminosity (SBS) experiments
- **Future FAIR Facility:**
  - GEM Tracker and GEM TPC for the PANDA Experiment
  - GEM/Micromegas tracking in CBM Muon Chamber (MUCH)
- **Future Electron - Ion Collider Facility:**
  - Tracking and particle ID detectors based on MPGD-technology

From M. Titov, 110th LHCC meeting

History of MPGD development in JAPAN

Europe



Japan

μ-PIC (A. Ochi, T. Tanimori)

Capillary plate (Yamagata U., H. Sakurai)

2D-MSGC (Tokyo Inst. Tech., T. Tanimori)

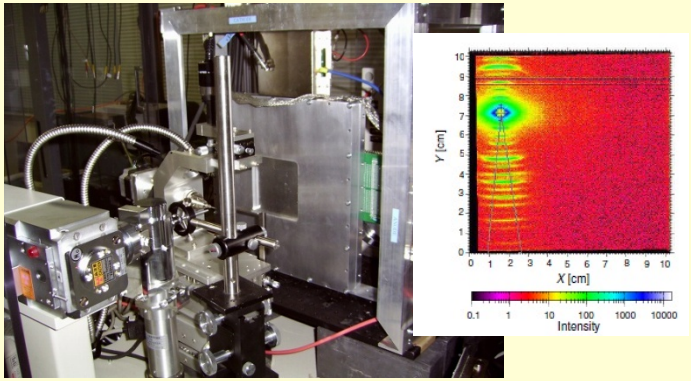
MPGD R&D in JAPAN
(Not even a complete list)

- Structure studies
  - GEM (Gas electron multiplier)
    - @Many institutes … KEK, RIKEN, JAEA, U. Tokyo, Kyoto U., Saga U., TIT, Kinki U., TUAT ….
  - THGEM, Capillary plate,
    - Yamagata U., TMU, U.Tokyo,
  - MicroMEGAS
    - Saga U., Kobe U.
  - μ-PIC (Micro Pixel Chamber)
    - Kyoto U., Kobe U., ICRR,
- Material studies (Substrate (conventional, polyimide))
  - LCP (Liquid crystal polymer)
    - KEK, RIKEN, U.Tokyo, (SiEnergy co.)
  - Glass
    - U.Tokyo (+HOYA), Yamagata U.
  - PTFE
    - Tokyo IRI, RIKEN
- Resistive electrodes
  - Organic material
    - KEK
  - Carbon loaded polyimide
    - Kobe U., RIKEN
  - Sputtering carbon/metal
    - Kobe U.
- Applications
  - Particle physics (Acc./ Non Acc.)
    - Kobe U. KEK, Kinki U. Saga U.
  - Neutron imaging
    - Kyoto U., KEK
  - Nuclear physics
    - TIT, U.Tokyo., JAEA
  - Astrophysics
    - Kyoto U., RIKEN
  - Gas Photomultiplier
    - Yamagata U, TMU, ICRR
  - X/gamma ray imaging
    - Kyoto U., KEK,
  - Medical imaging
    - Kyoto U.

μPIC Projects in Kyoto Univ.

Time Resolved X-ray Imaging

K.Hattori et al. Journal of Synch. Rad. Vol. 16, Part 2, (2009) p231-236.

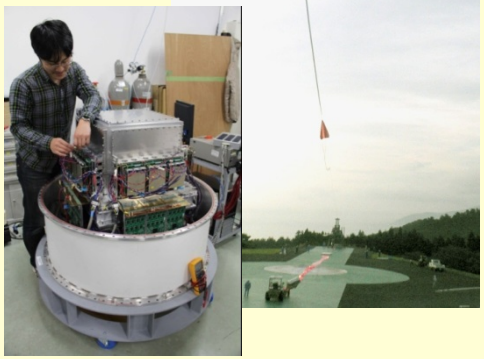


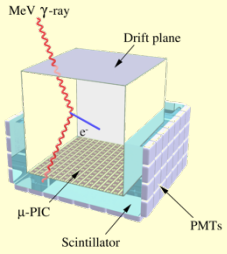
Electron tracking Compton Camera

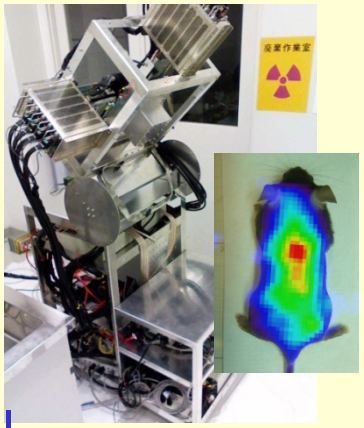
A.Takada et al. NIM-A 546, 2005 p258

A.Takada et al., *J. of the Phys. Soci. of Japan, 78 (2009) Suppl. A, pp. 161-164*

Gamma Astronomy





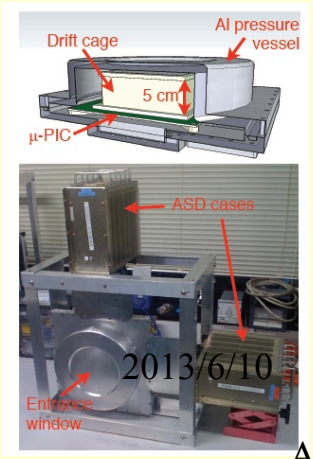


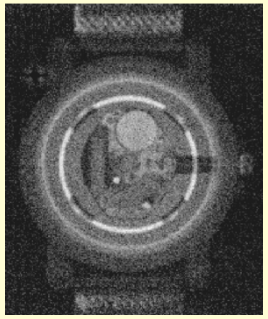
Medical

Neutron Imaging for J-PARC

Tanimori et al. NIM-A 529, 2004 p373

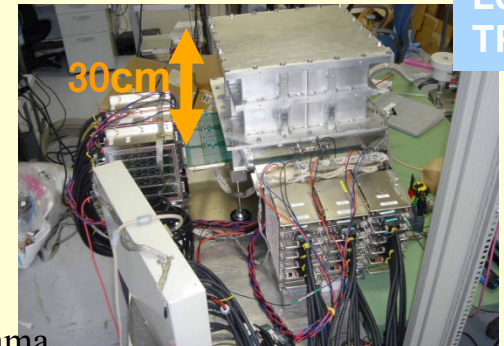
ID=264(Gaseous detector 11/06 TIPP)



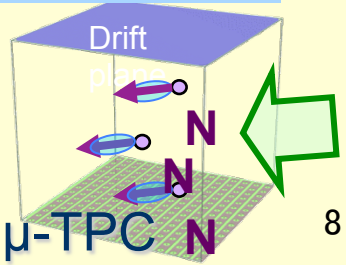


Dark Matter Wind Detector(Newage) with Kobe Univ.

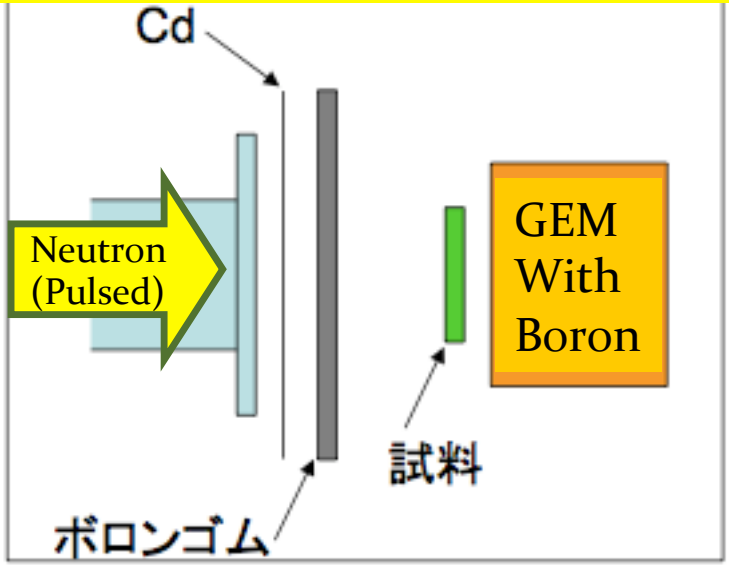
H.Nishimura et al.,. Astropart. Phys., Vol.31, 3, (2009), Pages 185-191

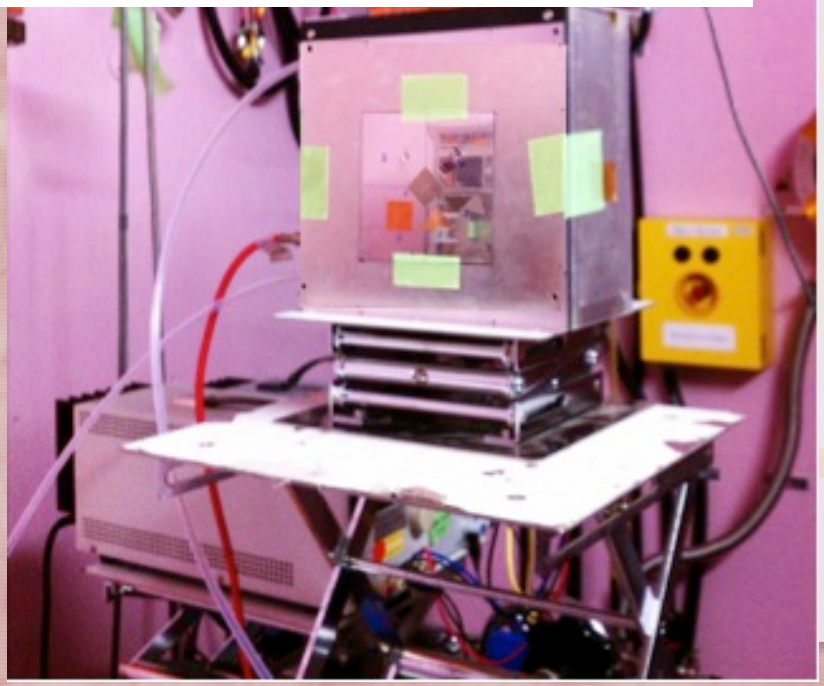


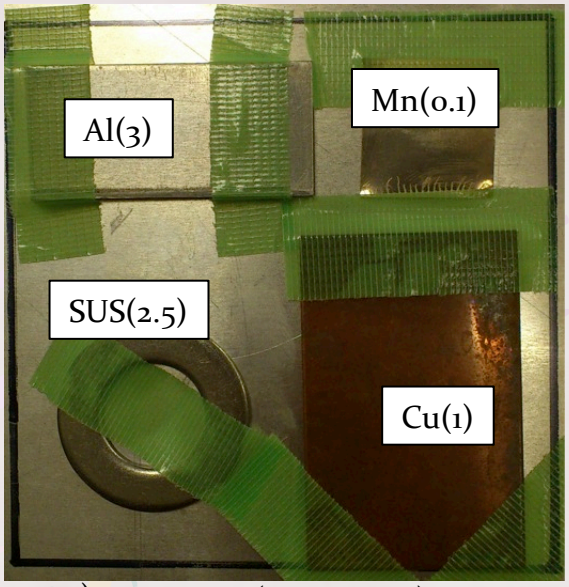
Low or High Pressure TPC(30cm cubic)



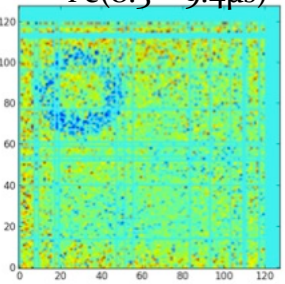
Neutron radiography with GEM (KEK)



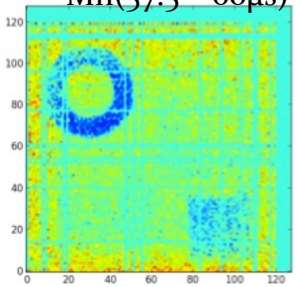




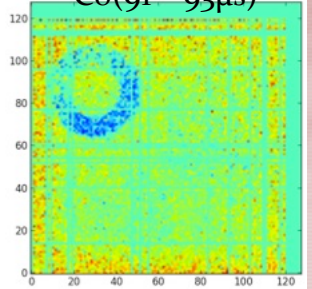
Fe(8.3～9.4μs)



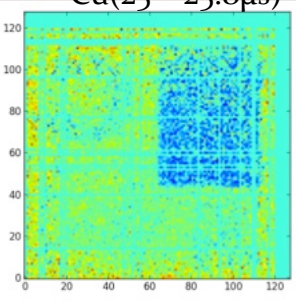
Mn(57.5～60μs)



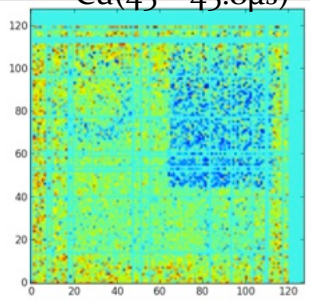
Co(91～93μs)



Cu(25～25.8μs)



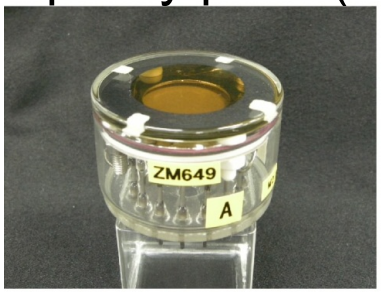
Cu(45～45.8μs)

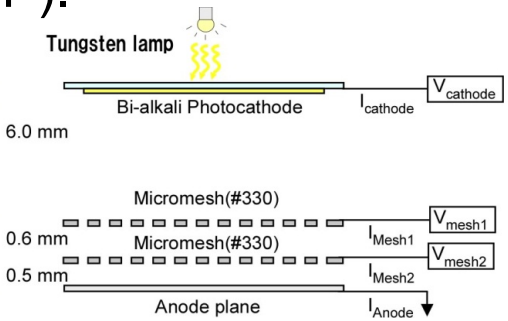


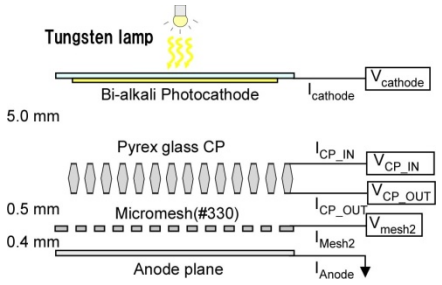
Gaseous PMT

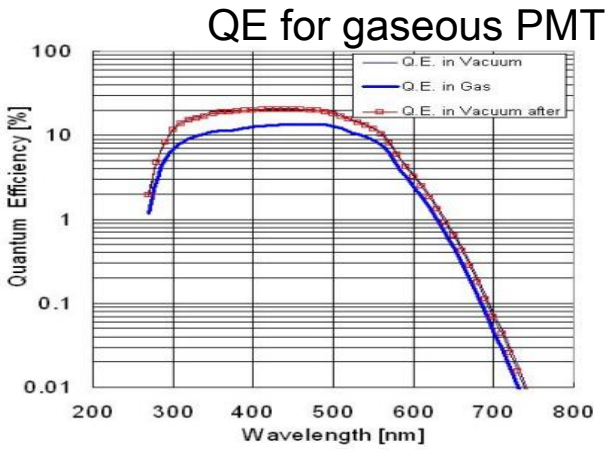
Yamagata U. TMU, HAMAMATSU

- To suppress the ion- and photon-feedback,we have been developing a gaseous PMT using MPGDs such as GEM, Micromegas and glass capillary plate (CP).









Sensor type	Sensitivity	Position Resolution	Timing Resolution	Uniformity	Price	Magnetic Field	Effective Area
Vacuum PMT	◎	△	◎	△	○	△	○
CCD / CMOS	△	◎	×	◎	△	◎	×
Gaseous PMT	○	○	○	○	◎	◎	◎

- The advantage of the **gaseous PMT**:
  - ✓It can achieve a **very large effective area** with moderate **position** and **timing** resolutions.
  - ✓It can be easily operated under a **very high magnetic field**.

R&D requirements and status

- Now, MPGD has already been used for many applications
- However, there are many requirements for future experiments
  - Protecting from sparks
  - New micro processing technology
  - Large size, mass production
- R&D Approach from …
  - Material studies on substrate
  - Spark protection using resistive electrodes

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(Not even a complete list)

- Structure studies
  - GEM (Gas electron multiplier)
    - @Many institutes … KEK, RIKEN, JAEA, U. Tokyo, Kyoto U., Saga U., TIT, Kinki U., TUAT ….
  - THGEM, Capillary plate,
    - Yamagata U., TMU, U.Tokyo,
  - MicroMEGAS
    - Saga U., Kobe U.
  - μ-PIC (Micro Pixel Chamber)
    - Kyoto U., Kobe U., ICRR,

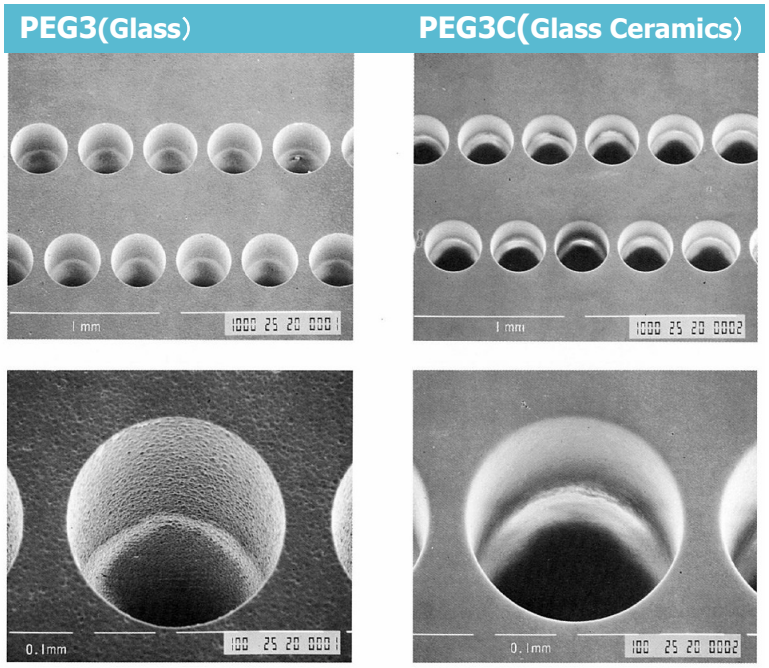
- Material studies (Substrate (conventional, polyimide))
  - LCP (Liquid crystal polymer)
    - KEK, RIKEN, U.Tokyo, (SiEnergy co.)
  - Glass
    - U.Tokyo (+HOYA), Yamagata U.
  - PTFE
    - Tokyo IRI, RIKEN

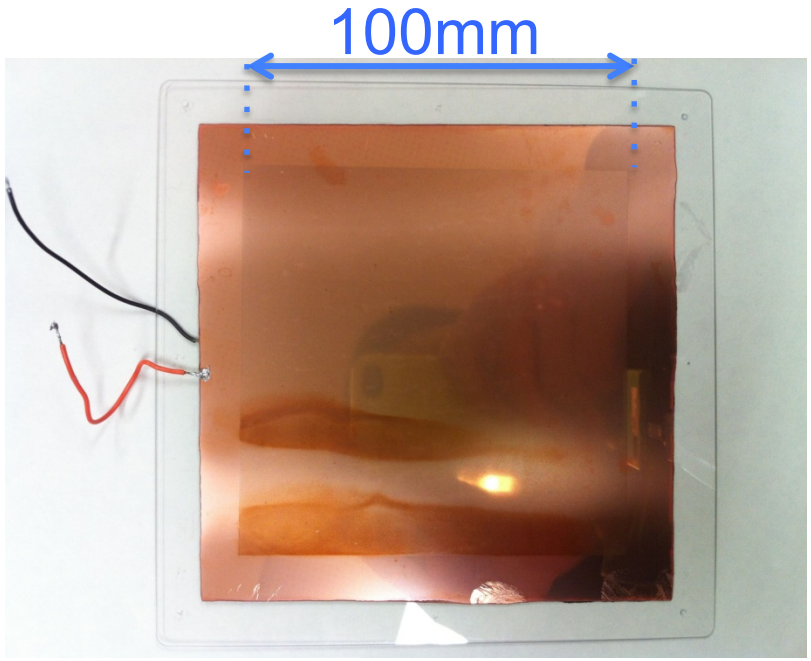
- Resistive electrodes
  - Organic material
    - KEK
  - Carbon loaded polyimide
    - Kobe U., RIKEN
  - Sputtering carbon/metal
    - Kobe U.

- Applications
  - Particle physics (Acc./ Non Acc.)
    - Kobe U. KEK, Kinki U. Saga U.
  - Neutron imaging
    - Kyoto U., KEK
  - Nuclear physics
    - TIT, U.Tokyo., JAEA
  - Astrophysics
    - Kyoto U., RIKEN
  - Gas Photomultiplier
    - Yamagata U, TMU, ICRR
  - X/gamma ray imaging
    - Kyoto U., KEK,
  - Medical imaging
    - Kyoto U.

Univ. Tokyo, Fujiwara group

THE UNIVERSITY OF TOKYO





HOYA corporation
Innovative Glass Material Developer in Japan

Photo Etchable Glass 3 : PEG3

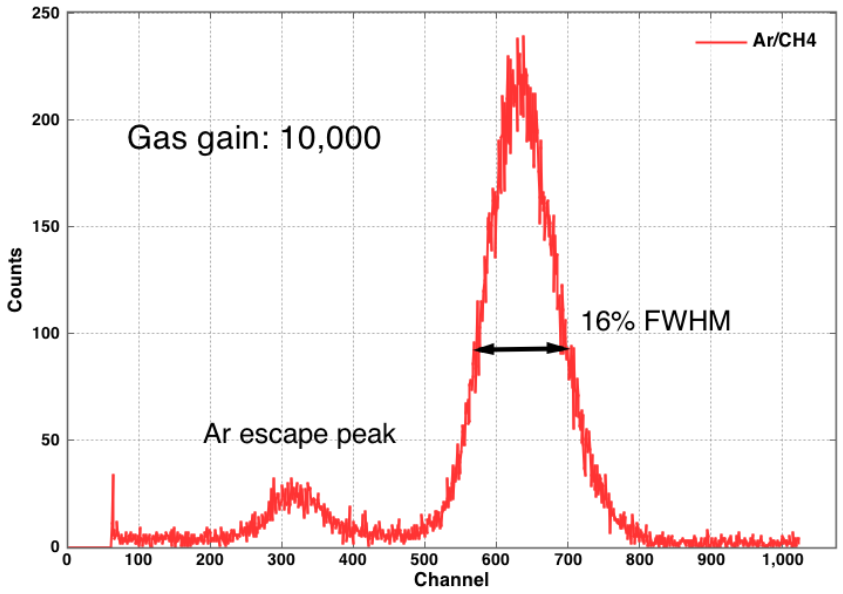
GEM fabricated with photo-etchable glass
- *No outgas*
- *Stable material*

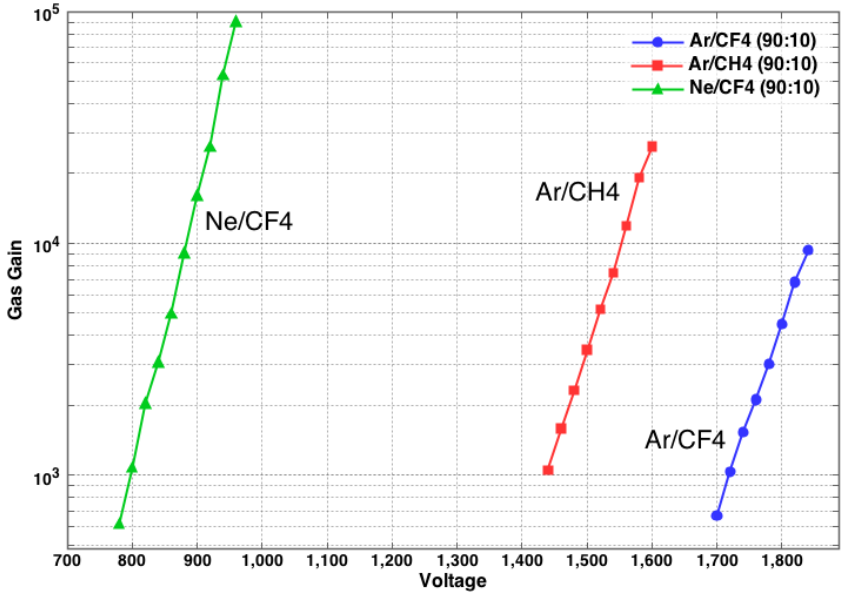
- Substrate:PEG3
- Thickness: 680μm
- Hole dia.: 170μm

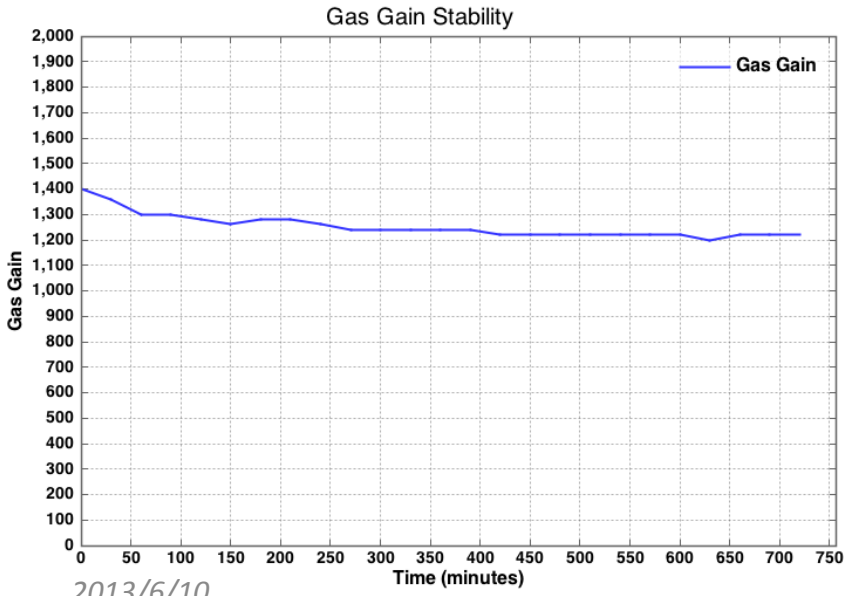
Summary of Glass GEM

Univ. Tokyo, Fujiwara group

THE UNIVERSITY OF TOKYO





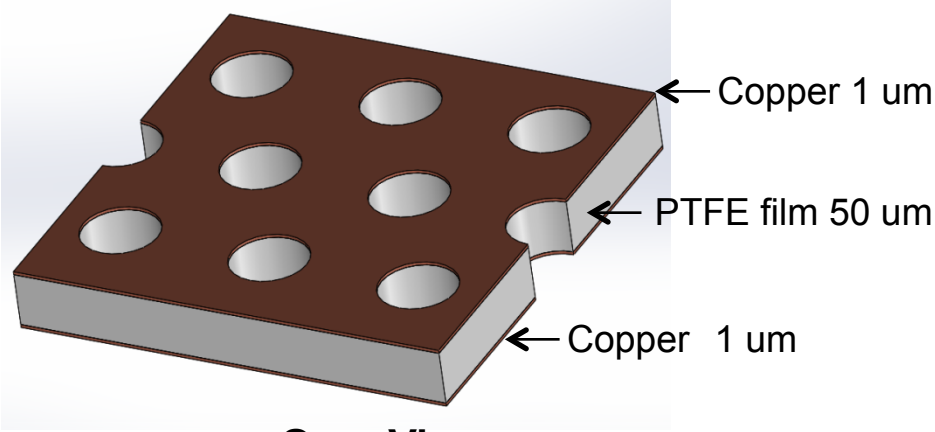


- Succeed in fabricating GEM with new material
  - **photo etchable glass**
- Effective size: 100 * 100mm^2
- Fabricated with **PEG3 substrate** (HOYA corp.)
- High Gas gain : 3 × 10^4 @Ar/CH4 (90:10, 1bar)
- High Gas gain : 9 × 10^4 @Ne/CF4 (90:10, 1bar)
- Energy resolution: 15 to 18%
- Glass GEM is a **outgas free** material : suitable for sealed gas application

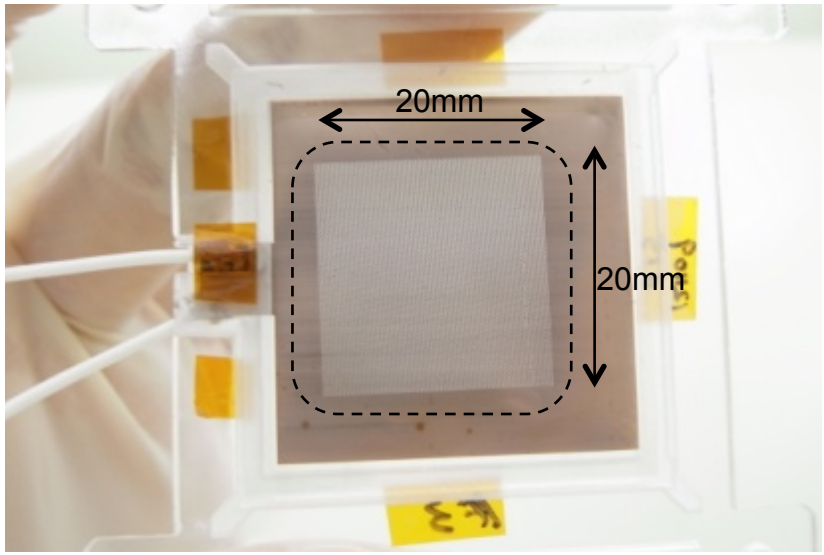
PTFE-GEM foil

Tokyo IRI, RIKEN Group

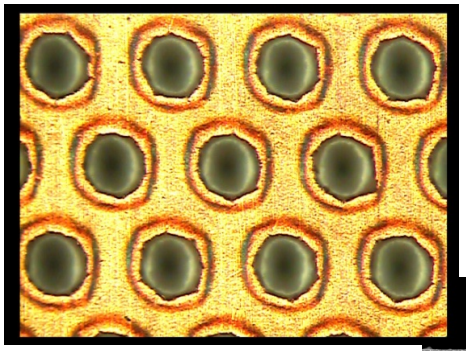
PTFE GEM foil (50um)



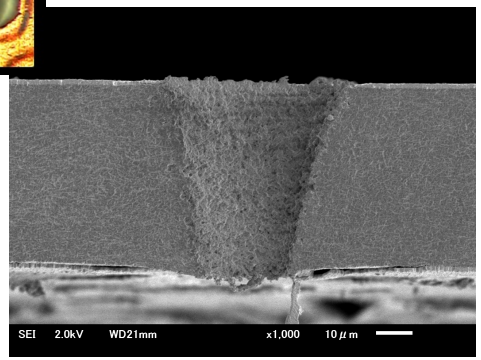
Over View



Top View



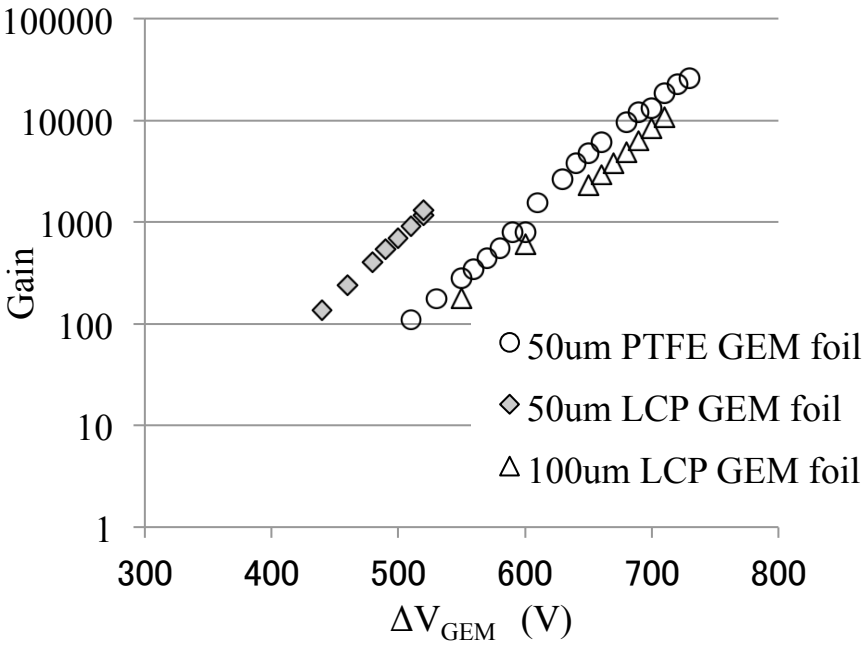
Top View



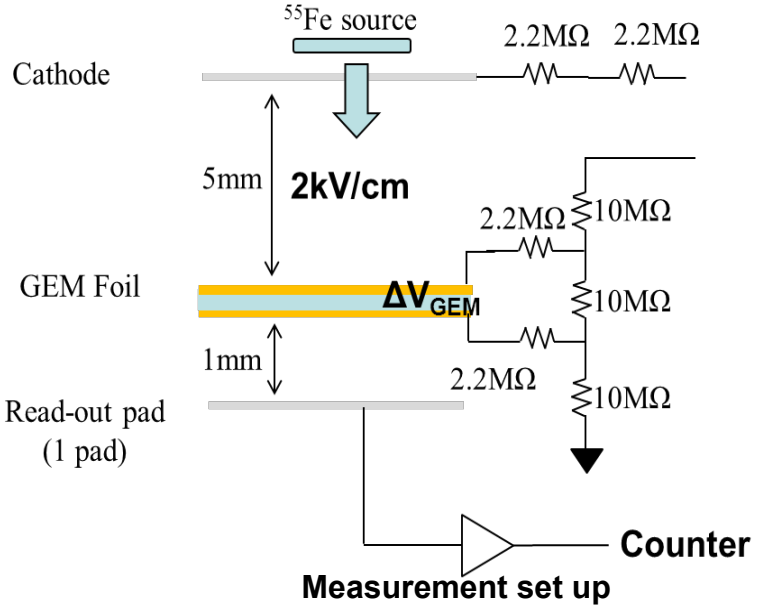
Side View

PTFE-GEM foil

Tokyo IRI, RIKEN Group



Gain-ΔV_{GEM}



Measurement set up

◆Gas gain

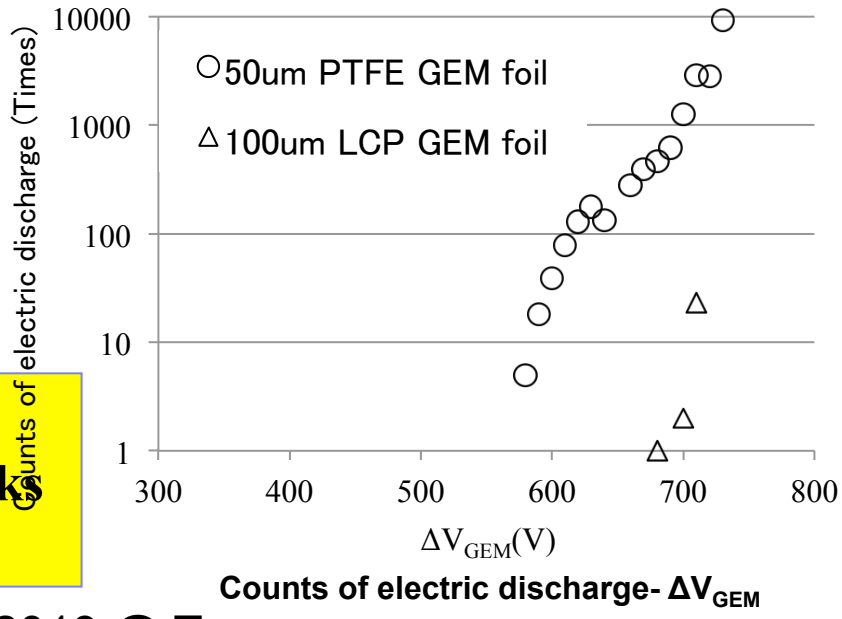
26440@ΔV_{GEM}=730V

Very high gain, using single GEM

◆**Tolerant for spark**

No damage are observed by 20000 sparks

→ Very high reliability

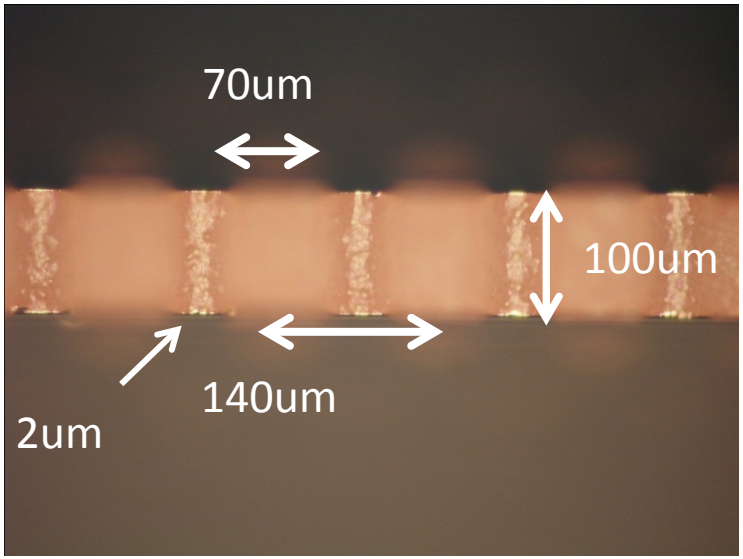


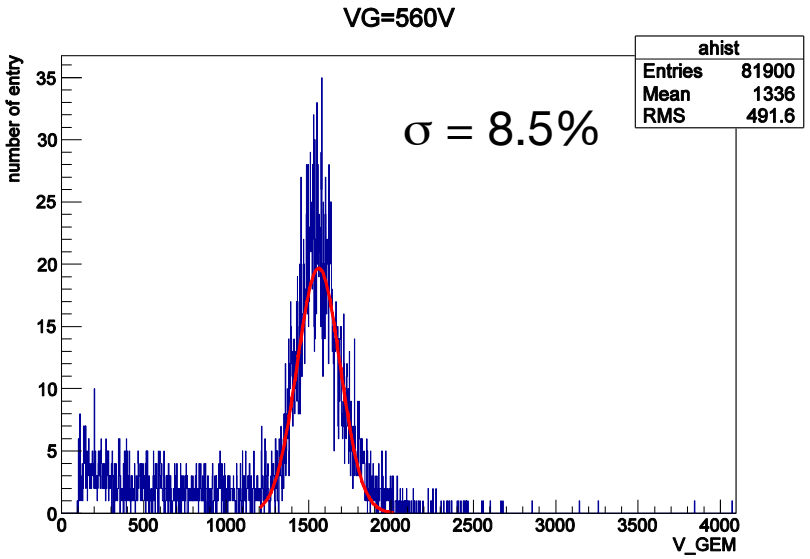
Counts of electric discharge- ΔV_{GEM}

Development of Glass GEM

Univ. Tokyo, CNS group

- Possible applications
  - Neutron counter: no hydrogen -> small background
  - Gaseous PMT: clean material
- Photosensitive Etching Glass: HOYA PEG3C
- Pitch 140 μm & hole size 70 μm & thickness 100 μm
- Reasonable gain & resolution with Ne/CF_4 (90/10) & Ne/CO2(80/20)





COBRA T-GEM

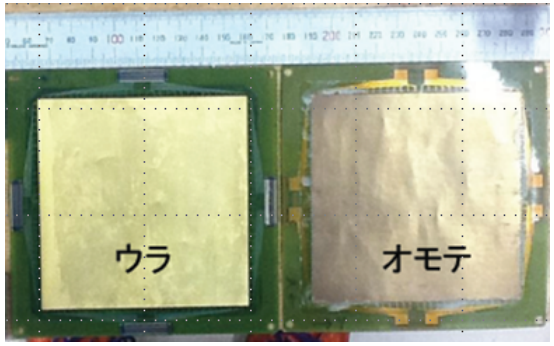
Univ. Tokyo, CNS group

- Purpose: small ion back flow (IBF~0.25%) for continuous operation of TPC without gating grid at LHC ALICE experiment
- COBRA patterned Thick-GEM
  - 400 μmT / 300μmϕ / 1mm pitch
  - 200 μmT / 150 μmϕ / 500 mm pitch
- ANSYS + Garfield simulation
  - Effective ion absorption on the top side for large ΔV_{gap}
- Tests with a X-ray source
- Encouraging result
  - Up to 10 times reduction of Ion Back Flow with large ΔV_{gap}

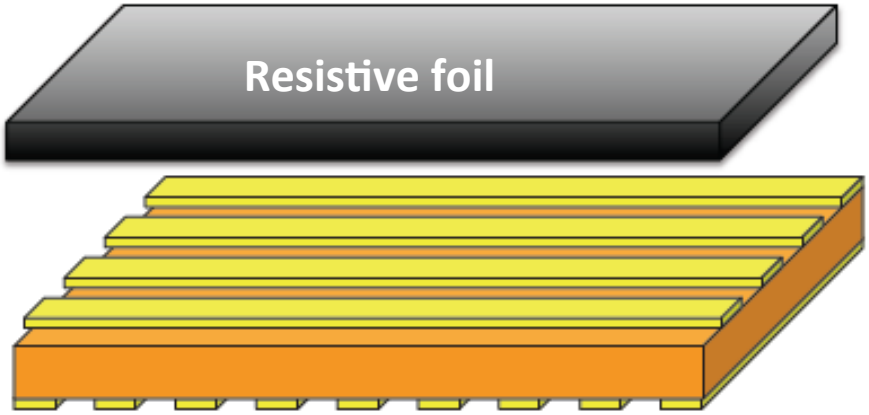
MPGD R&D in JAPAN
(Not even a complete list)

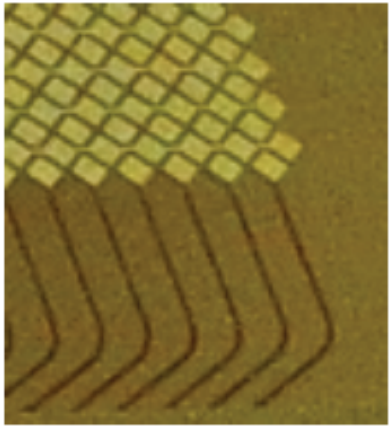
- Structure studies
  - GEM (Gas electron multiplier)
    - @Many institutes … KEK, RIKEN, JAEA, U. Tokyo, Kyoto U., Saga U., TIT, Kinki U., TUAT ….
  - THGEM, Capillary plate,
    - Yamagata U., TMU, U.Tokyo,
  - MicroMEGAS
    - Saga U., Kobe U.
  - μ-PIC (Micro Pixel Chamber)
    - Kyoto U., Kobe U., ICRR,
- Material studies (Substrate (conventional, polyimide))
  - LCP (Liquid crystal polymer)
    - KEK, RIKEN, U.Tokyo, (SiEnergy co.)
  - Glass
    - U.Tokyo (+HOYA), Yamagata U.
  - PTFE
    - Tokyo IRI, RIKEN
- Resistive electrodes
  - Organic material
    - KEK
  - Carbon-loaded polyimide
    - Kobe U., RIKEN
  - Sputtering carbon/metal
    - Kobe U.
- Applications
  - Particle physics (Acc./ Non Acc.)
    - Kobe U. KEK, Kinki U. Saga U.
  - Neutron imaging
    - Kyoto U., KEK
  - Nuclear physics
    - TIT, U.Tokyo., JAEA
  - Astrophysics
    - Kyoto U., RIKEN
  - Gas Photomultiplier
    - Yamagata U, TMU, ICRR
  - X/gamma ray imaging
    - Kyoto U., KEK,
  - Medical imaging
    - Kyoto U.

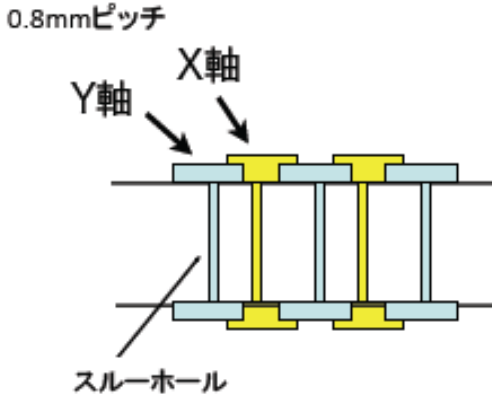
- GEM readout with resistive foil cover
  - Readout electrodes design is independent from resistive layer.



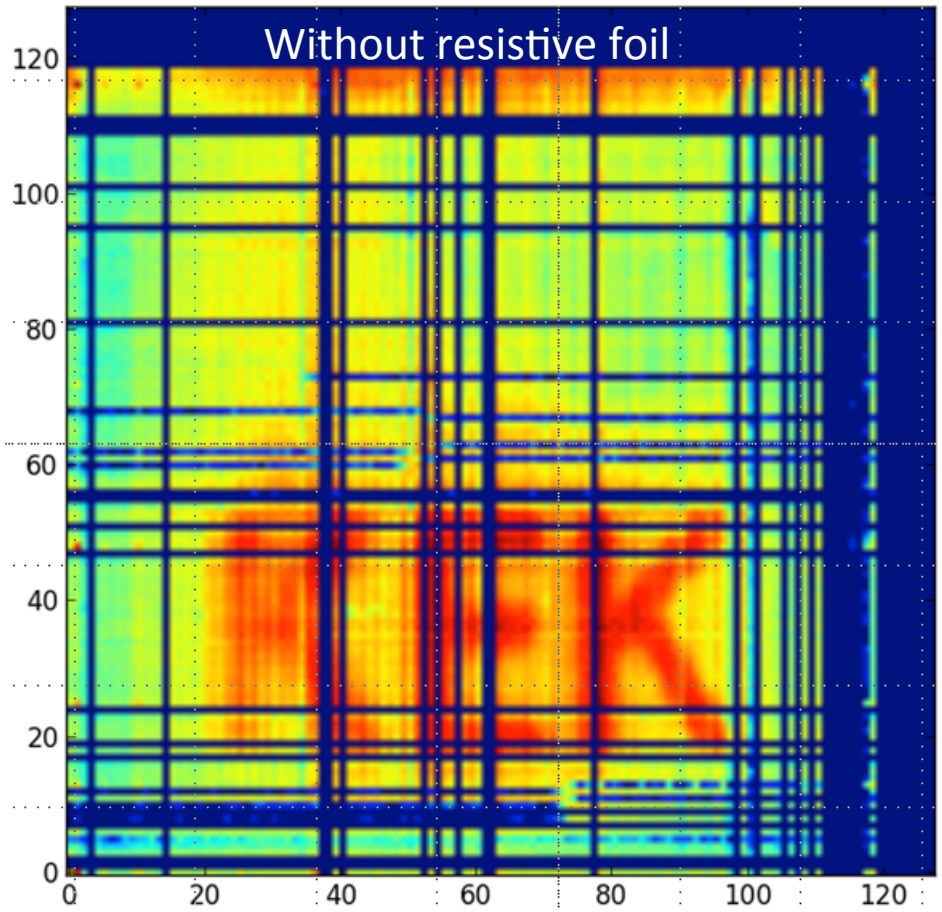
#	Resistive Material	(MΩ/□)	Insulator	Bond	memo
1	None				Nothing Attached
2	Dupont XC100*	2		Silicon	
3	Mitsubishi Material's**	10	Mylar Tape	Spray Glue	
4	Dupont XC100*	2	W-sided Mylar Tape	W-sided Mylar Tape	Mylar: 15μm Thick

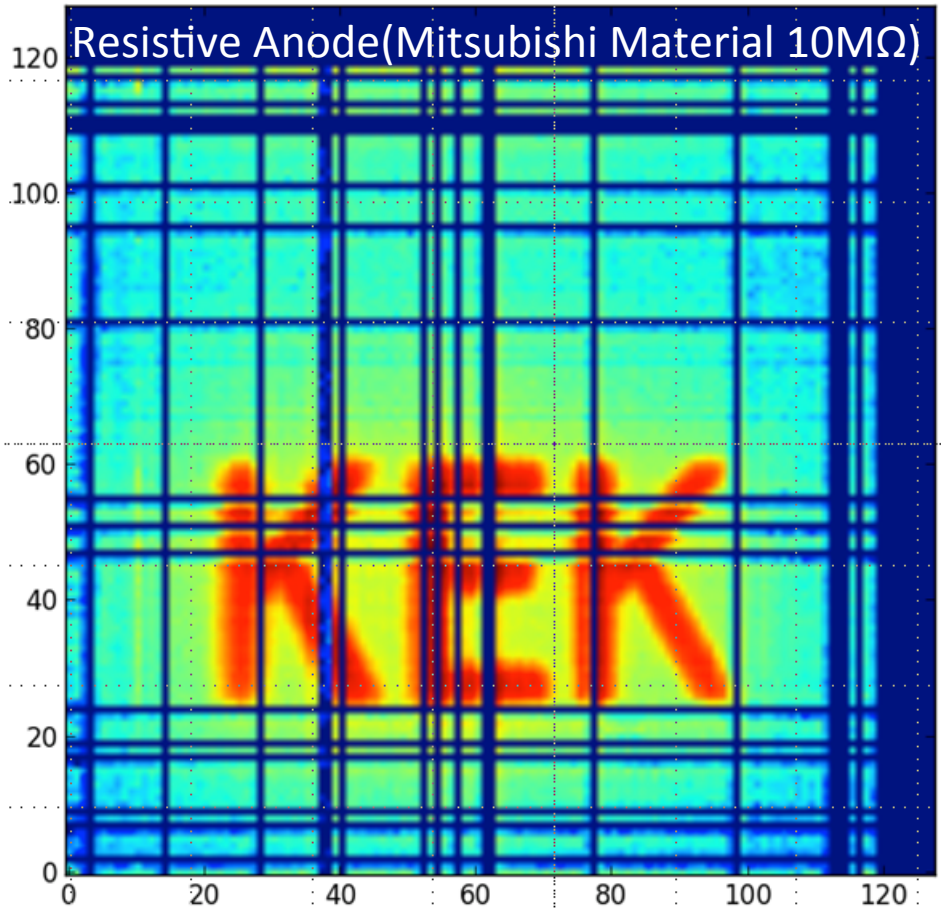


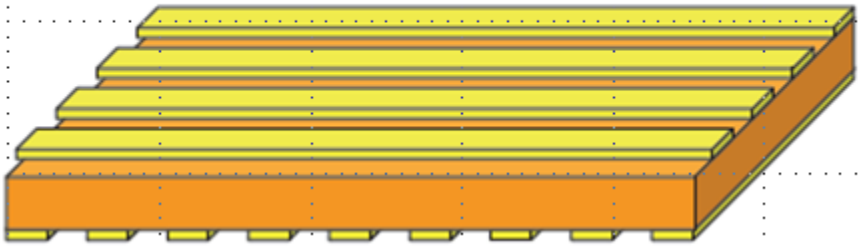


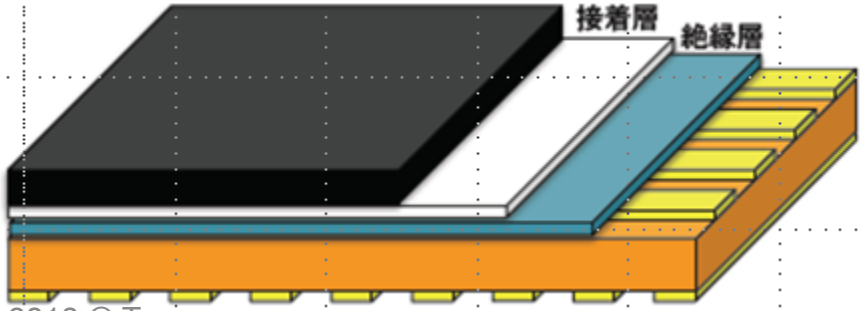


KEK, TUAT


Without resistive foil
120
100
80
60
40
20
0
0
20
40
60
80
100
120


Resistive Anode(Mitsubishi Material 10MΩ)
120
100
80
60
40
20
0
0
20
40
60
80
100
120




接着層
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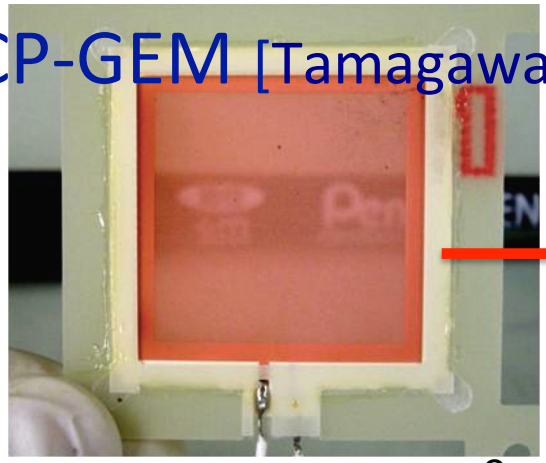
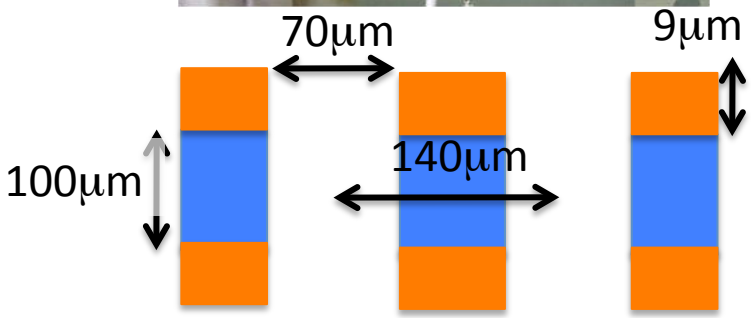
Resistive Electrode GEM (RE-GEM), RIKEN

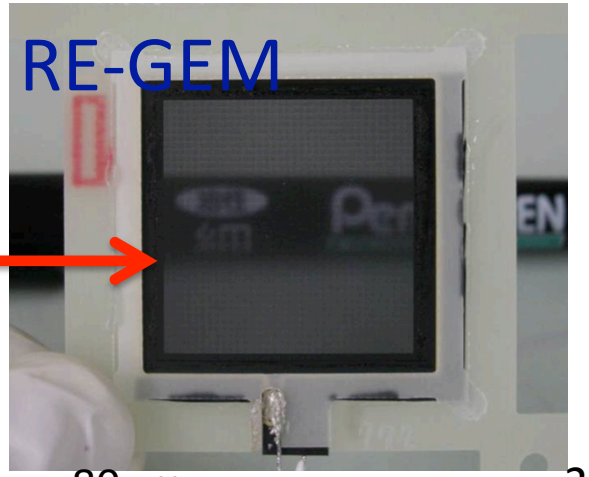
- Replacing copper electrodes of our LCP-GEM with resistive electrodes.
- Processed by Scienergy
- Resistive kapton foils (Dupont XC series) are
- Holes are drilled by laser

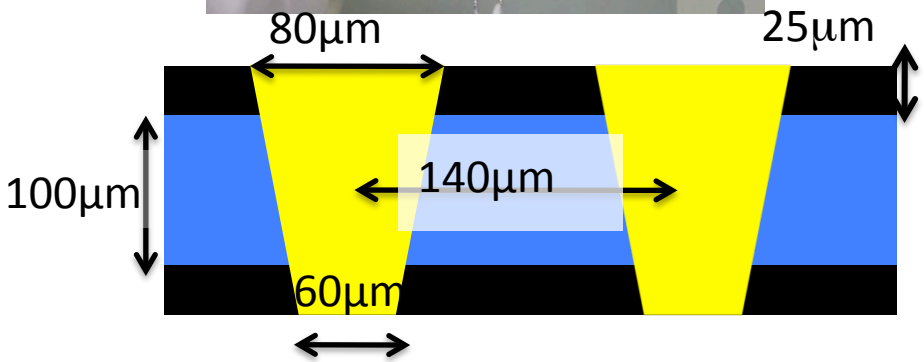
➢ LCP-GEM [Tamagawa +2009]





➢ RE-GEM

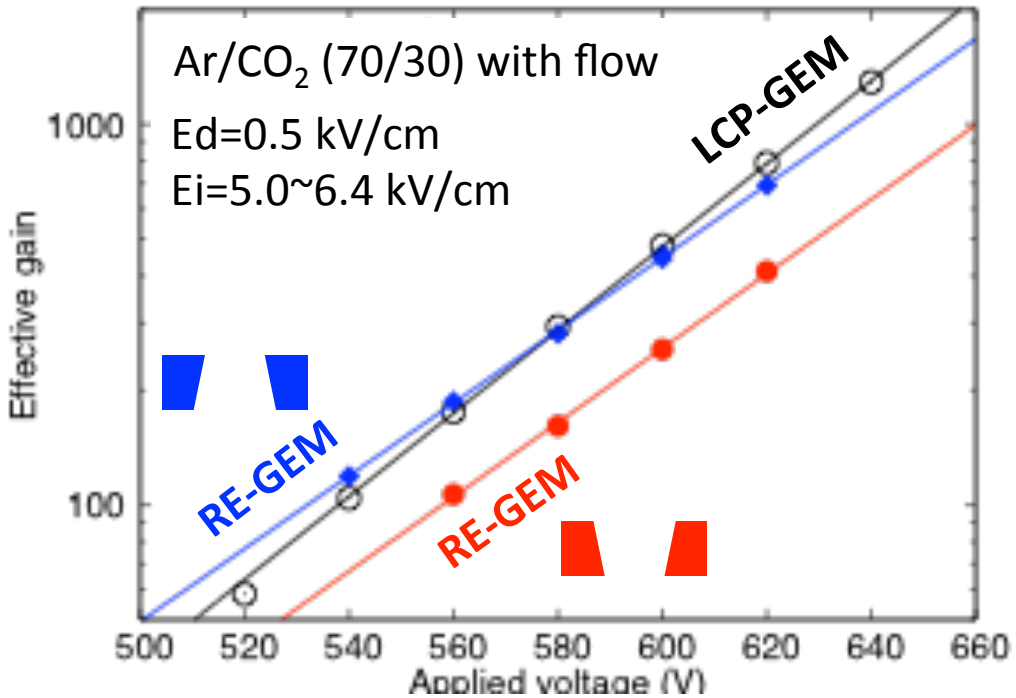


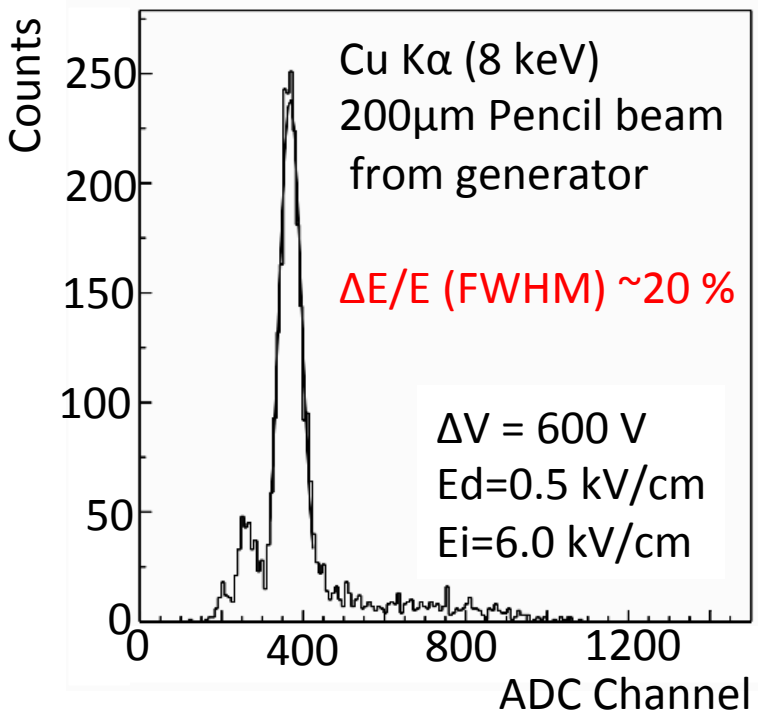


We succeeded to make the world's first Resistive-GEM with a fine pitch and a thinner insulator.

akifumi@crab.riken.jp

The Gain and Spectrum of RE-GEM (RIKEN)





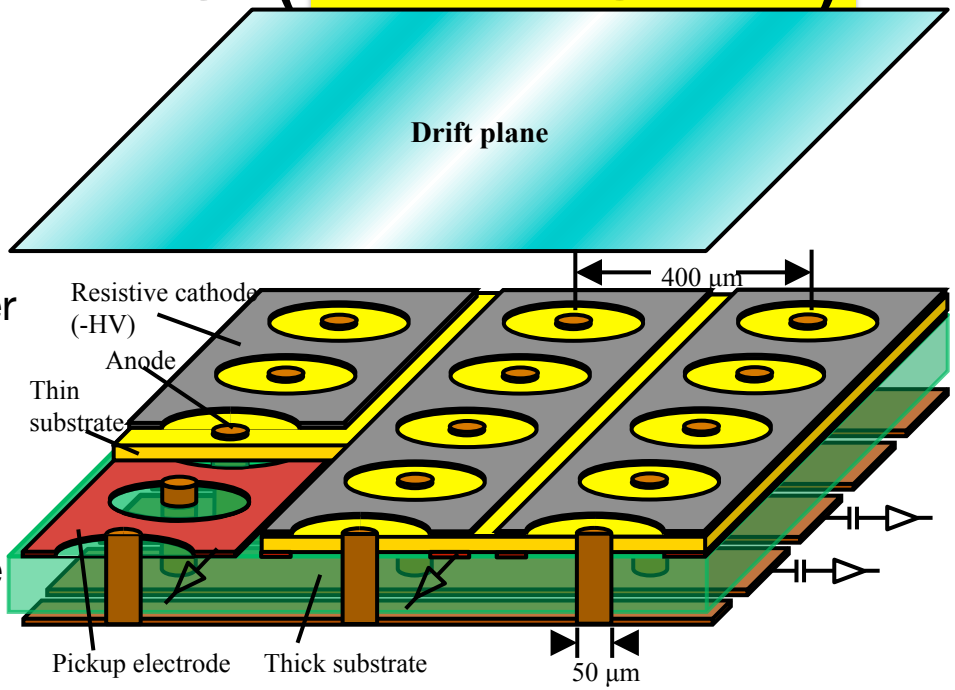
- The slope of gain curves of RE-GEM is almost the same of LCP-GEM.
- The maximum gain is about 650 due to the discharges.
- The energy resolution is about 20%.

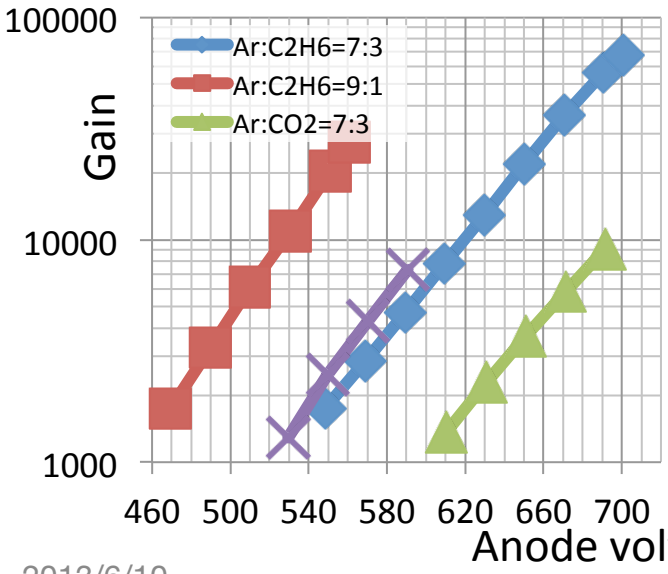
Our RE-GEM is the first GEM with fine pitch and relative high gain.

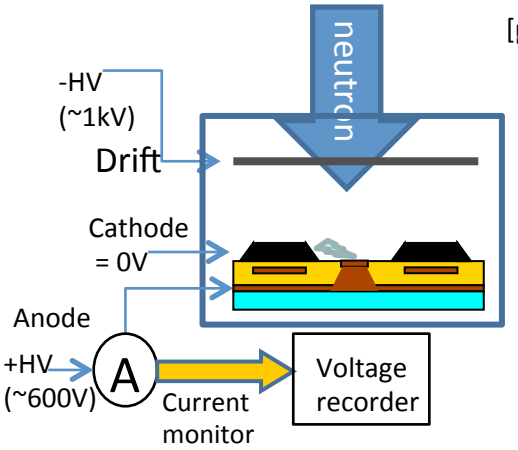
akifumi@crab.riken.jp

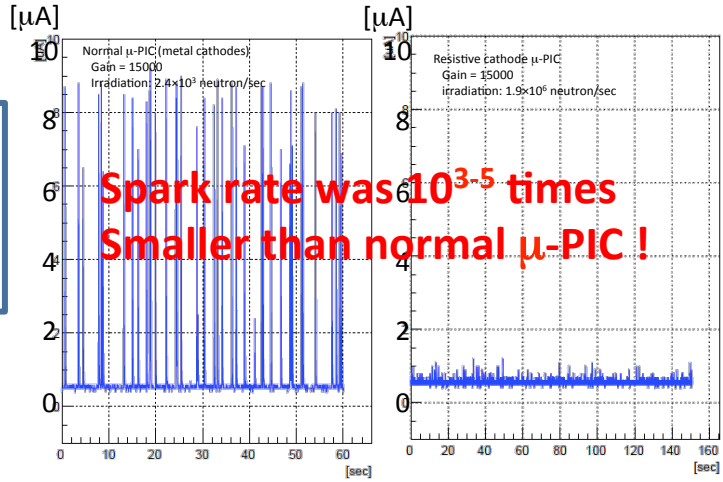
Resistive μ-PIC (Kobe Univ.)

- No floating structures are used, such as mesh or foil.
- All cathodes are made from carbon-polyimide.
- Pickup electrodes are lied under cathodes and insulator.
- 2nd dimensional signals are read out from anode.
- Spark between anode and cathode is strongly quenched due to voltage drop on resistive cathode



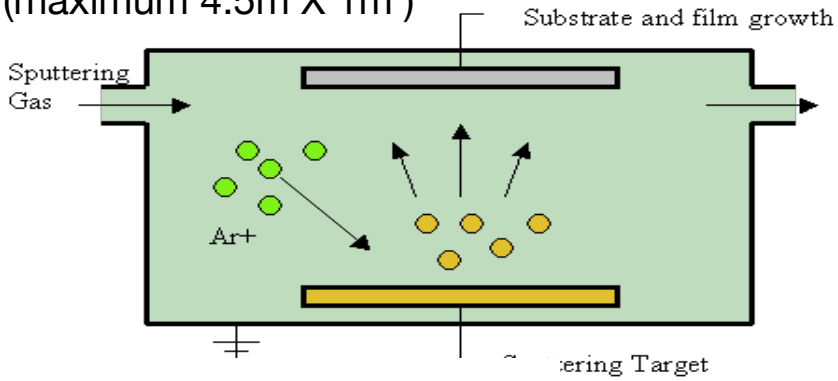


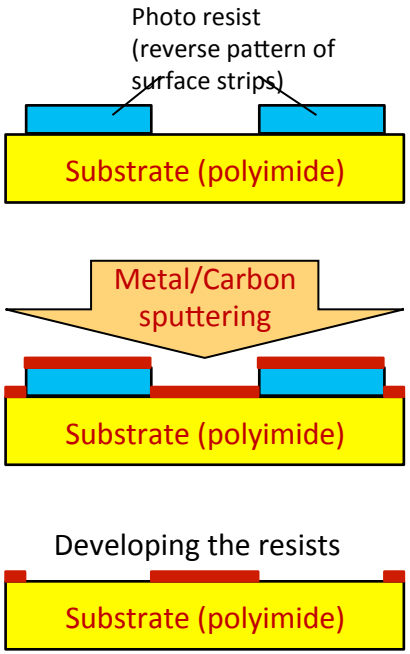


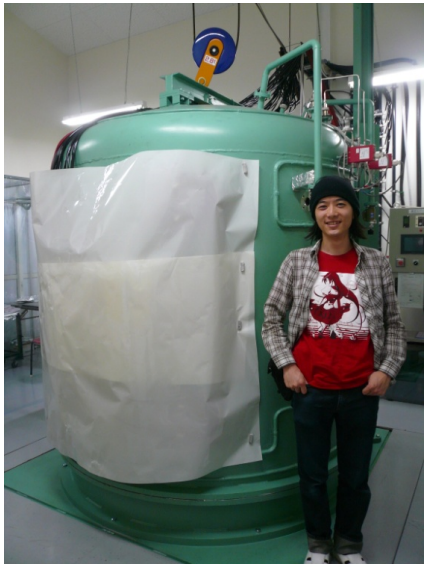


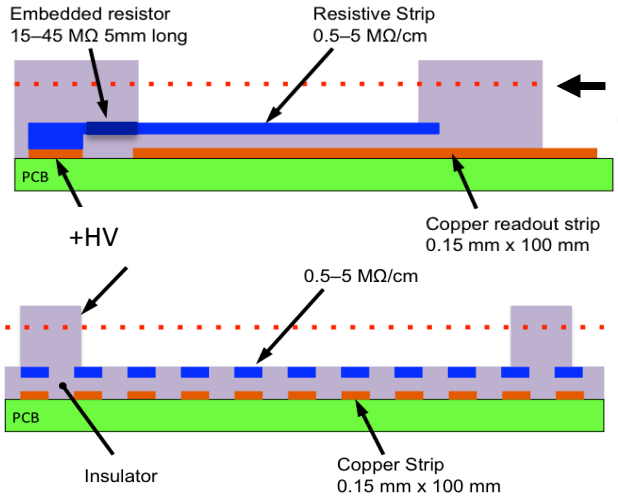
MicroMEGAS with sputtering resistive anode (Kobe Univ, ICEPP)

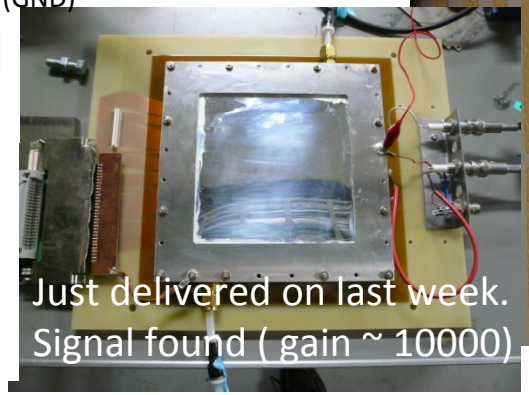
- Developed for ATLAS NSW upgrade
- Using liftoff process with carbon spattering
- Very fine structure (a few tens micro meter) can be formed using photo resist. (same as PCB)
- Large size sputtering is available (maximum 4.5m X 1m)

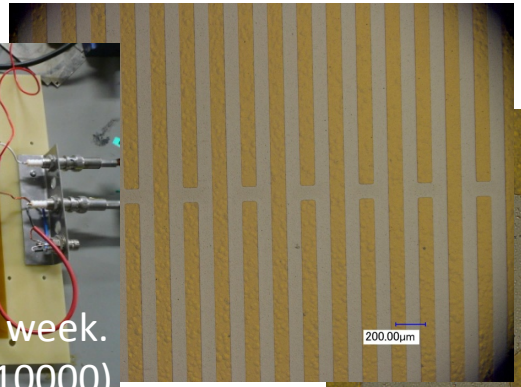


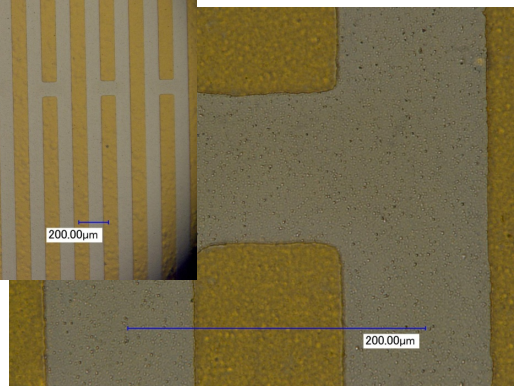












Summary

- High activities and variety of MPGD developments in JAPAN
  - GEM, THGEM, MicroMEGAS, μ-PIC
  - Both application developments and basic detector studies are very active.
  - There are many R&D on MPGD structure, material studies
- There are many other activities on MPGD in Japan
  - Electronics, simulation, production tech. etc.
- The MPGD is common technology in particle physics (in a broad sense).

- **We should bring our experiments to a successful conclusion by exchanging our knowledge, experience and know-how**

Thank You