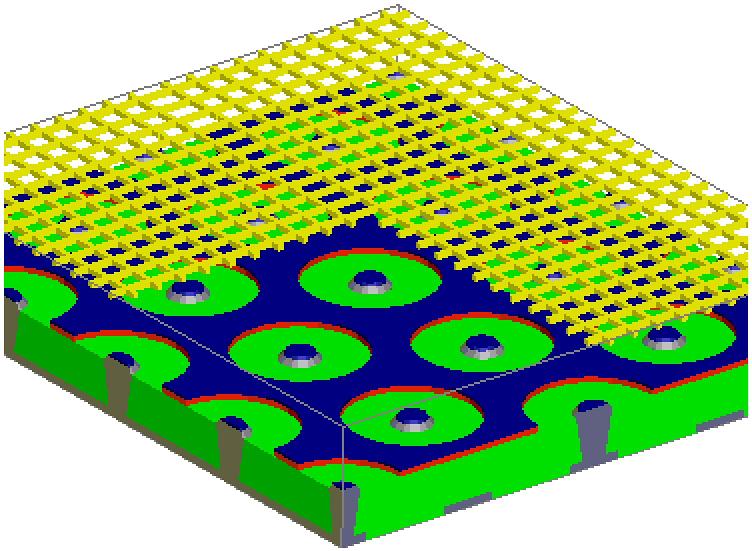
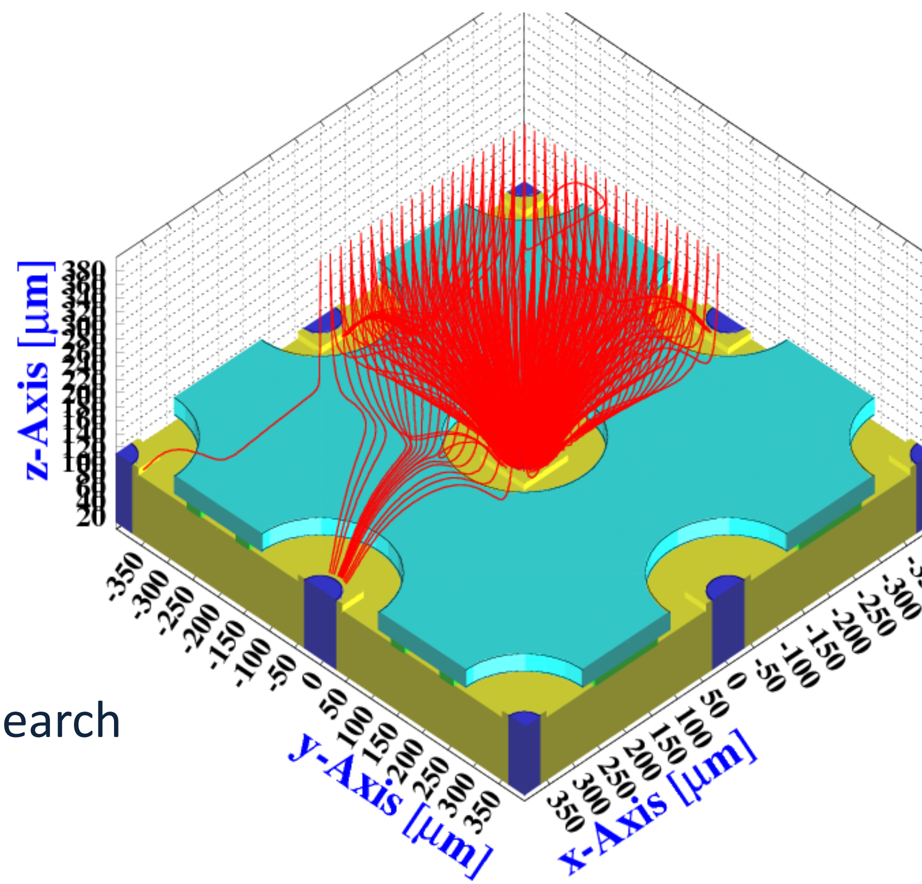


Kobe University
Particle Physics Labo.
MPGD (μ-PIC) group



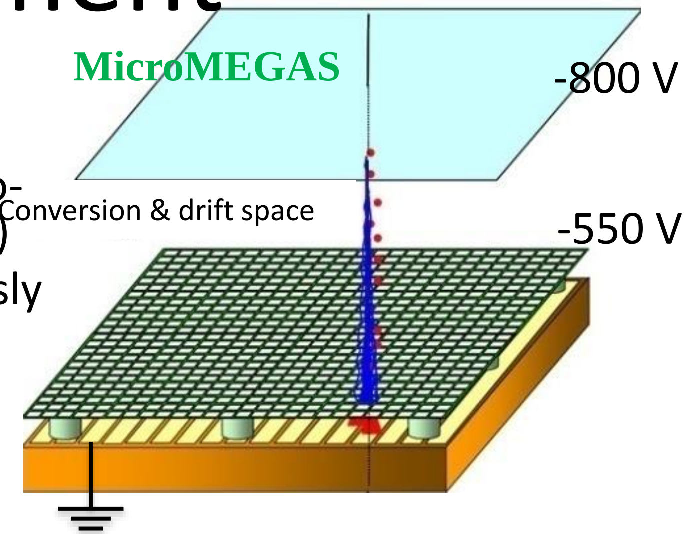
29/08/2014

KUBEC International workshop on DM search

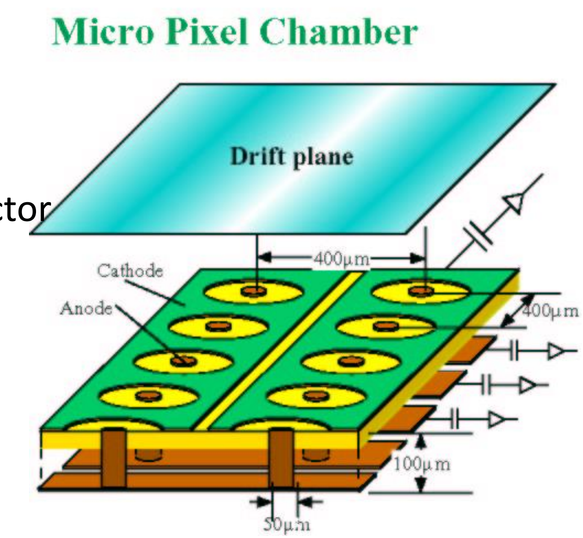
Atsuhiko Ochi

MPGD Development

- What is MPGD ?
  - Micro Pattern Gaseous Detector
  - Recent technology for gaseous detector, using micro-patterning (photo-lithography, laser patterning, etc.)
  - Key technology for realizing followings simultaneously
    - high position resolution (<100 μm)
    - high rate capacitance (> 10^6 counts/mm^2)
    - Large area (~ a few meter size)
    - Mass productivity (close to PCB industrial technology)



- R&D in Kobe PP labo.
  - μ-PIC
    - Development of imaging gas detector using resistive electrodes for stable operation.
    - Application for Dark Matter search (NEWAGE)
    - Application for ATLAS phase-II upgrade, High η muon detector
  - MicroMEGAS
    - For muon spectrometer in ATLAS phase-I upgrade
    - Developing new electrodes material, and operation test
  - RE-GEM
    - Stable, and spark free GEM (Just start to develop)



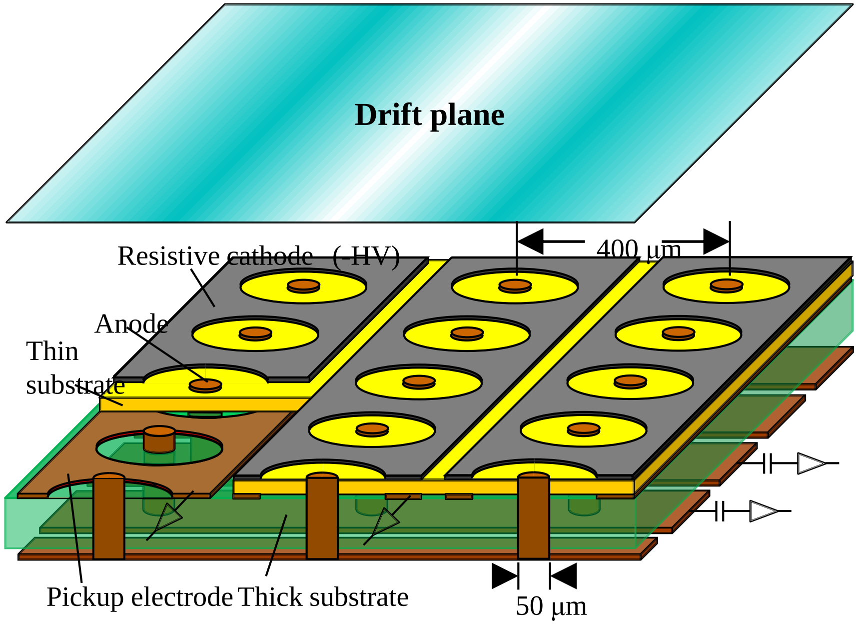
Common R&D themes for MPGDs

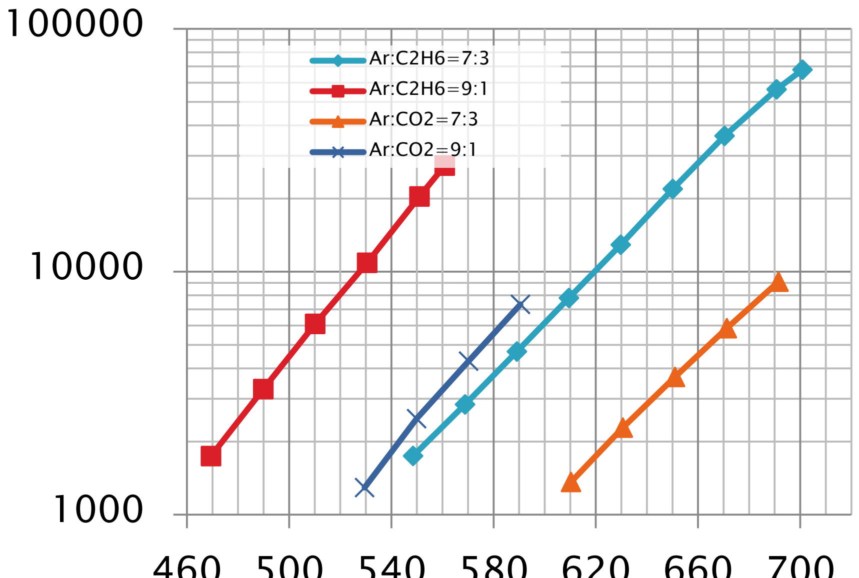
- Understanding for the MPGD operation
  - We need to share our experiences and information.
- Robustness for the spark
  - It was most critical problem.
- Large area production
  - It was big theme in RD51, depending on applications.
- Multi channel readout
  - KEK-DTP ASIC group and RD51 have already developed the system

μ-PIC
with resistive electrodes

μ-PIC with resistive cathodes with capacitive readout

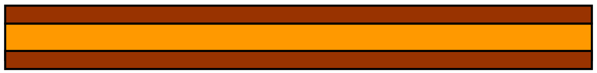
- The cathodes of μ-PIC is formed by resistive material.
- Large current from spark reduce the e-field, and spark is quenched.
- Signal from low energy deposit will observed with higher gas gain
- This design provide one promised possibility of MIP detector under hadronic background
- It takes enough gain (~7 x 10^5 , with Ar+ethane)
  - This work was followed by KAKENHI supporting research (2011-2014)



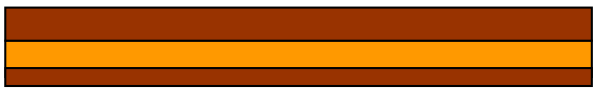


Process for manufacturing

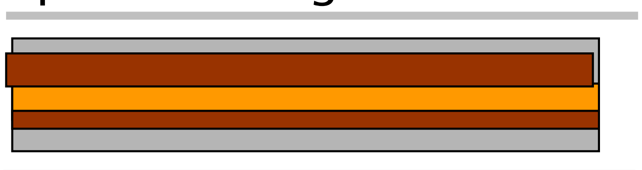
(a) Start from double sided kapton



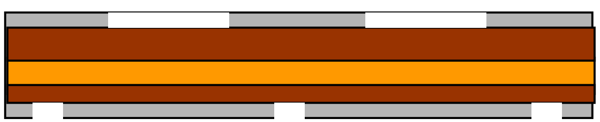
(b) Thick plating on surface (~ 50μm)



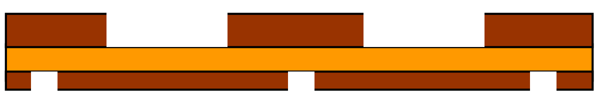
(c) Exposure using double side mask



(d) Developing resist

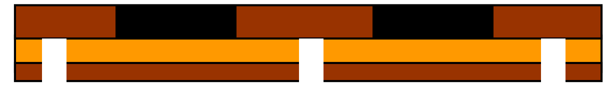


(e) Etching for the pattern



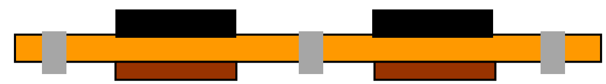
(f) Fill the resistive polyimide & cure

(g) Polishing the surface

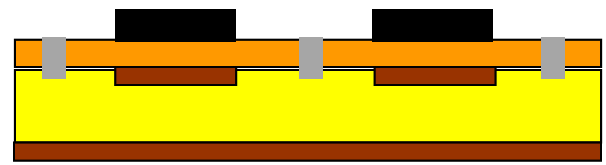


(h) Plating the anode pin

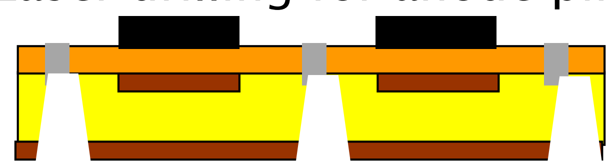
(i) Etching the metal layer



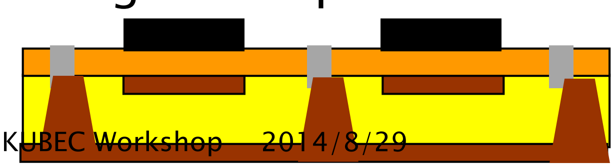
(j) Adhering the thick layer



(k) Laser drilling for anode pin



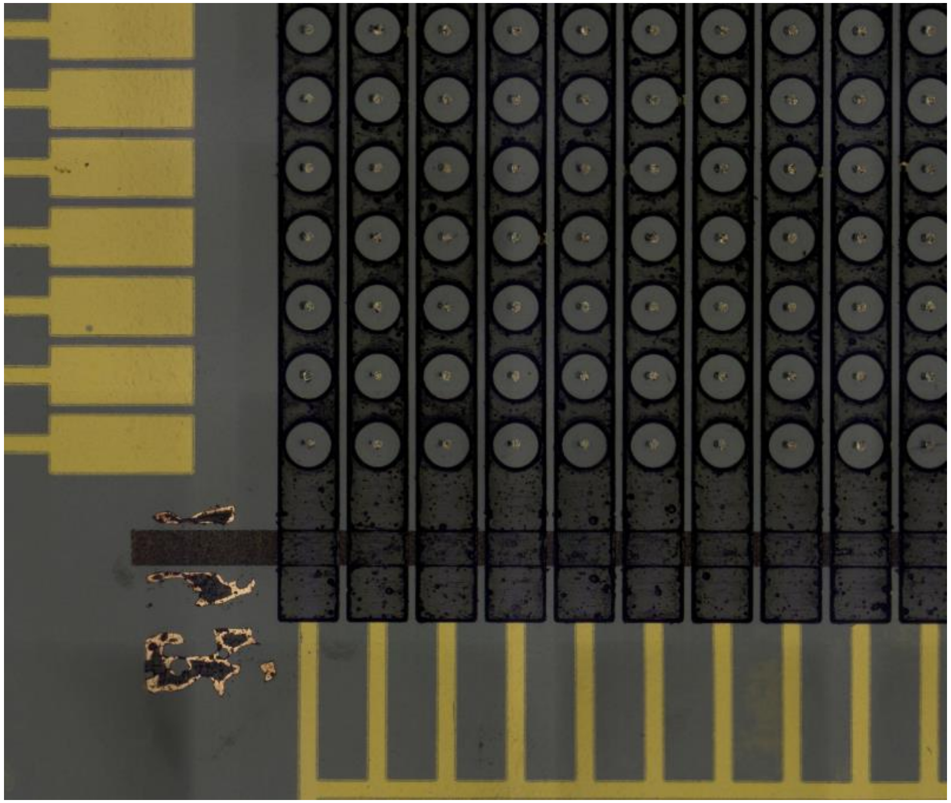
(l) Plating anode pin

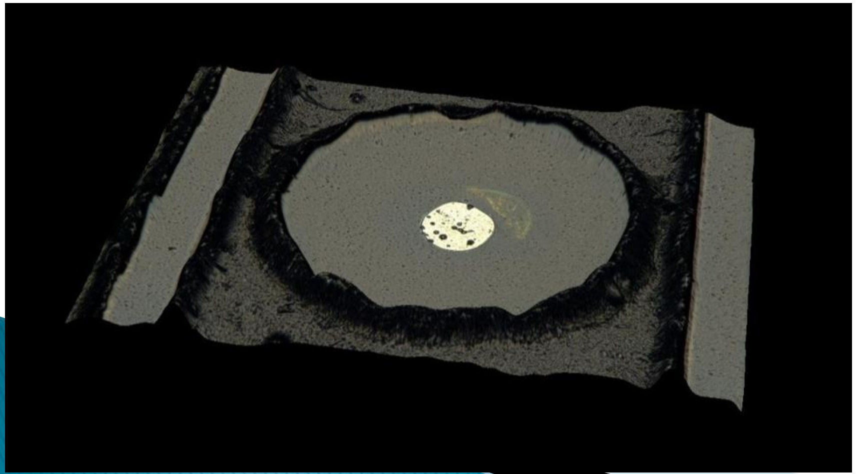


Micro scope picture of a prototype (RC27)

- Delivered at July 2012
- Very good accuracy (compared with previous samples)

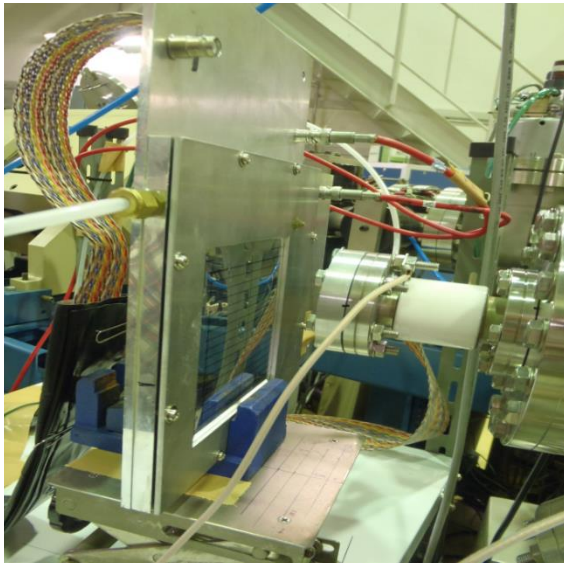
– Surface resistivity
  – About 50MΩ / strip (10cm)





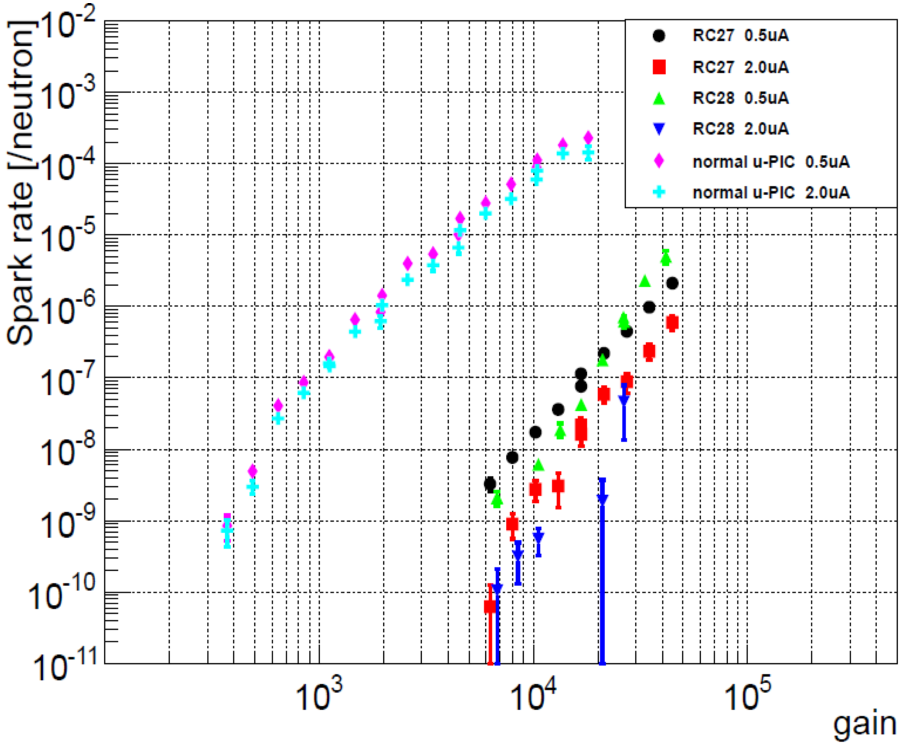
Spark test using fast neutron

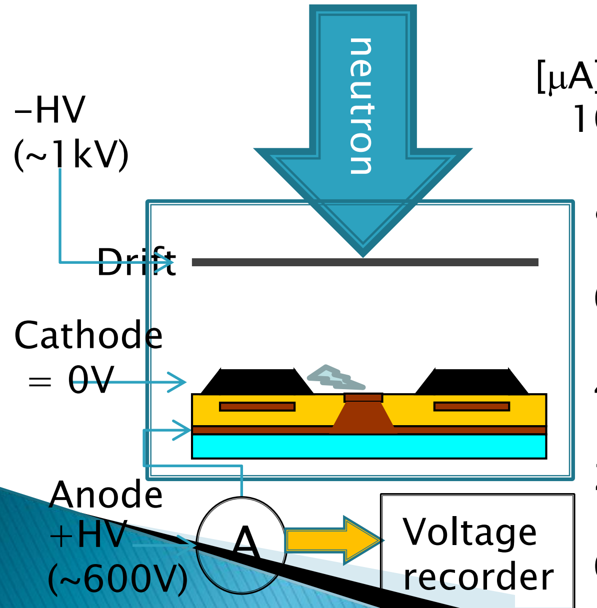
- A few MeV – few tenth MeV neutron will produce recoiled nucleon inside detectors
  - That produce great amount of energy deposit (a few MeV/mm^2) in gaseous volume.
- The concerned problem for gas detector
  - "Raether limit" … the electron cluster more than 10^{7-8} cause the detector to discharge.
- We can evaluate the spark probability for HIP by measuring the spark rate dependencies on neutron irradiation
- Neutron source
  - Tandem nucleon accelerator (3MeV deuteron) + Beryllium target. (Kobe University, Maritime dept.)
  - d+ ^{9}Be → n + ^{10}B
  - Neutron energy: mainly 2MeV

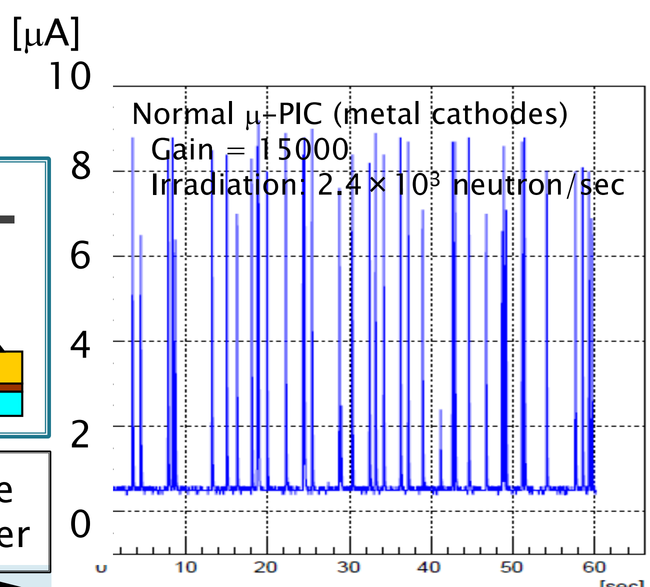


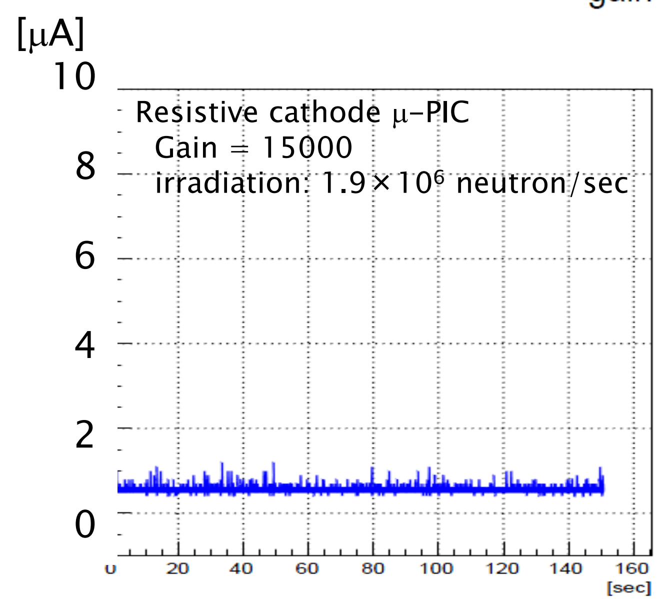
Results of spark reduction test

- HV current on anodes are monitored while neutrons are irradiated
- We found strong spark reduction using resistive cathode !!



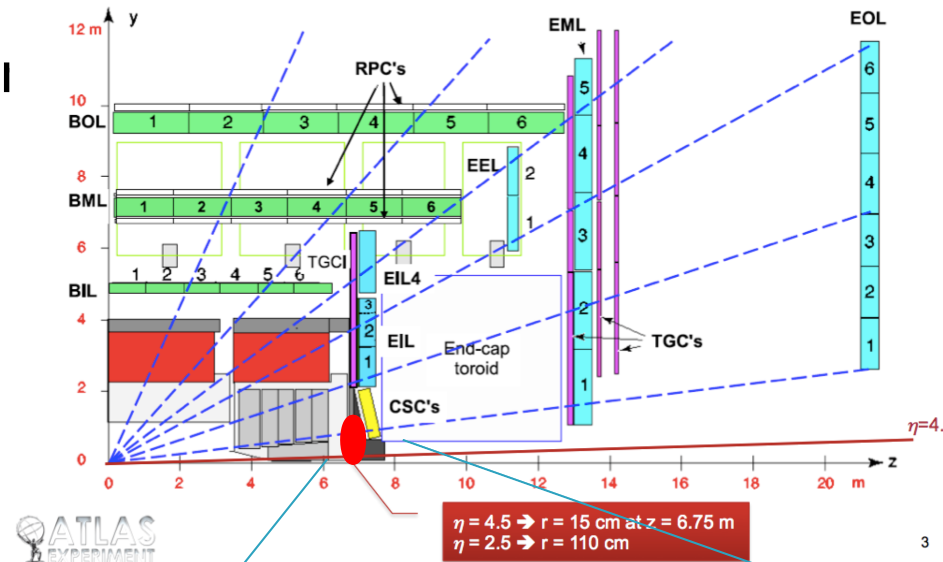


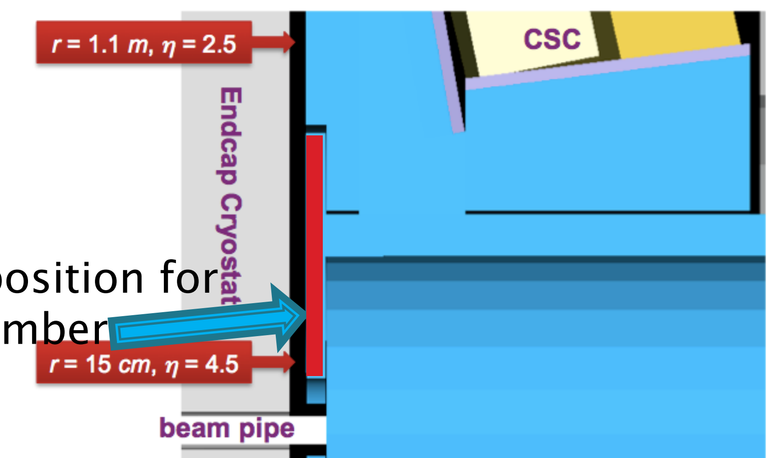




Application idea for ATLAS upgrade (phase-II)

- Very High η muon detector
  - 2.5 < η < 4.5
- Improving High pT acceptance
  → + a few tens %
- Available position:
  - 5cm width beside endcap cryostat
- High rate dose
  - 10^{16}n/cm^2
- Required granularity
  - 100μm X 100μm
- → Basic study is started by μ-PIC



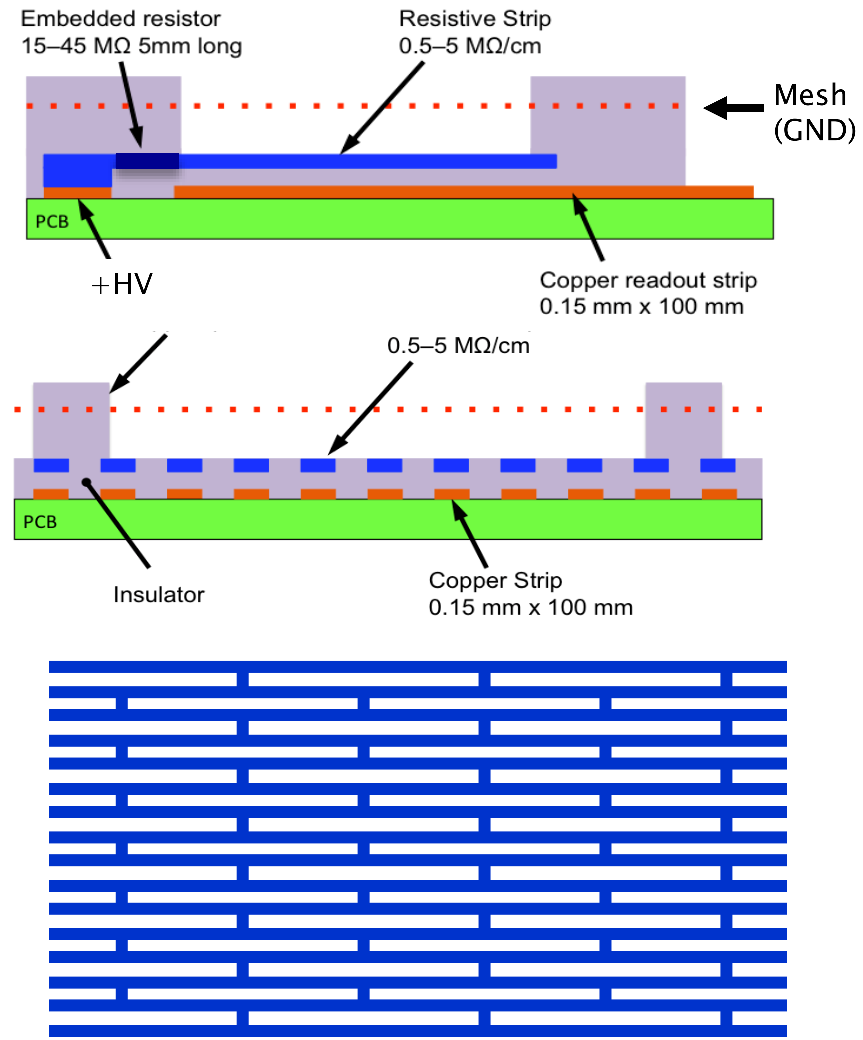


Candidate position for forward chamber

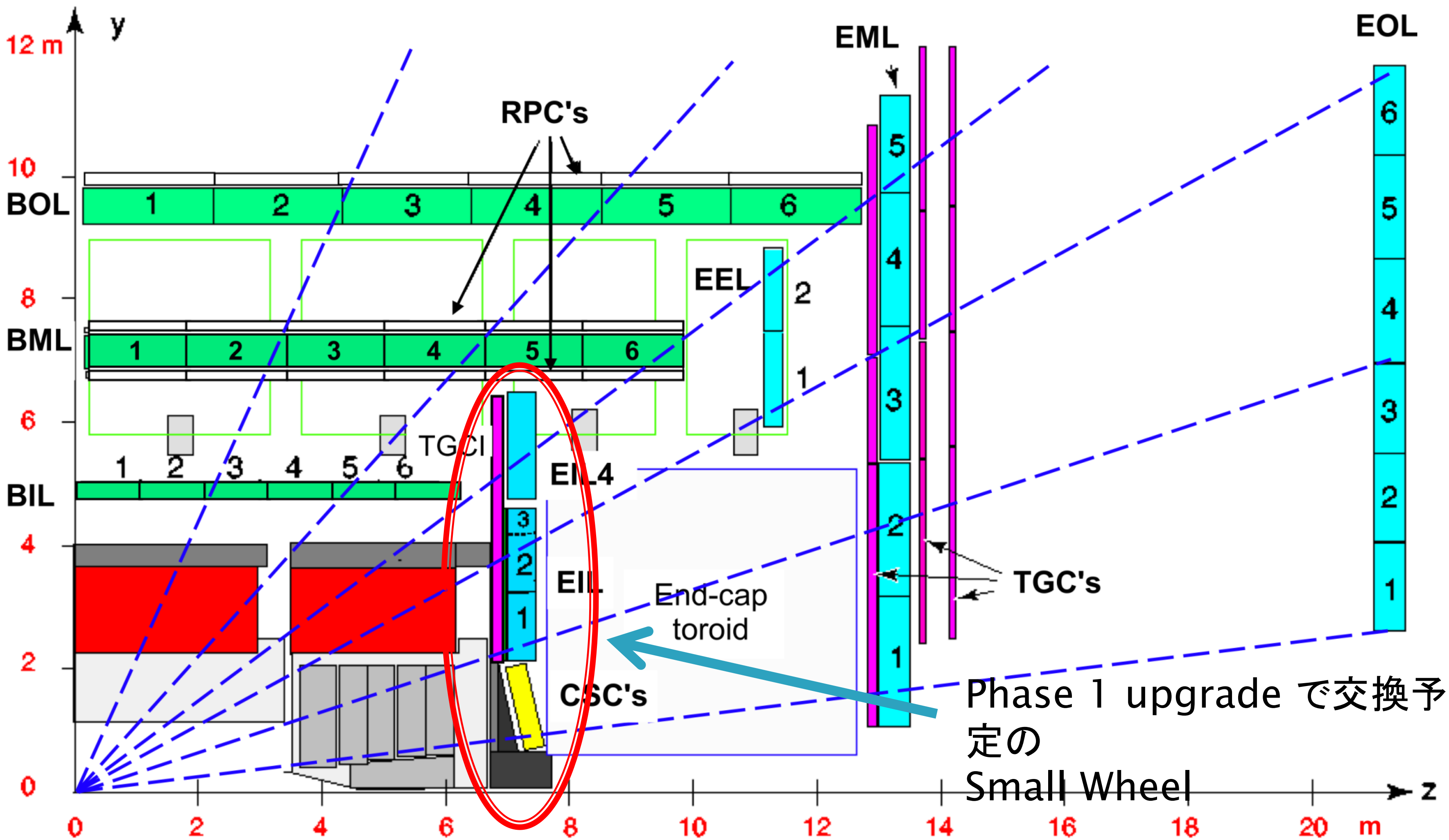
MicroMEGAS for ATLAS NSW

Requirements for ATLAS NSW MM

- High position resolution for one dimension
  - <100 μm for eta direction. (Resolution of a few cm is allowed for second coordinate.)
- Tolerant for high rate HIP particles
  - ~ 5kHz/cm^2
- Resistive layer should be formed as strips
- Resistivity: ~20MΩ/cm
  - To protect from spark
- Mass production should be available, with large size (1m)
  - ~2000 board should be produced in half year.
- Low cost



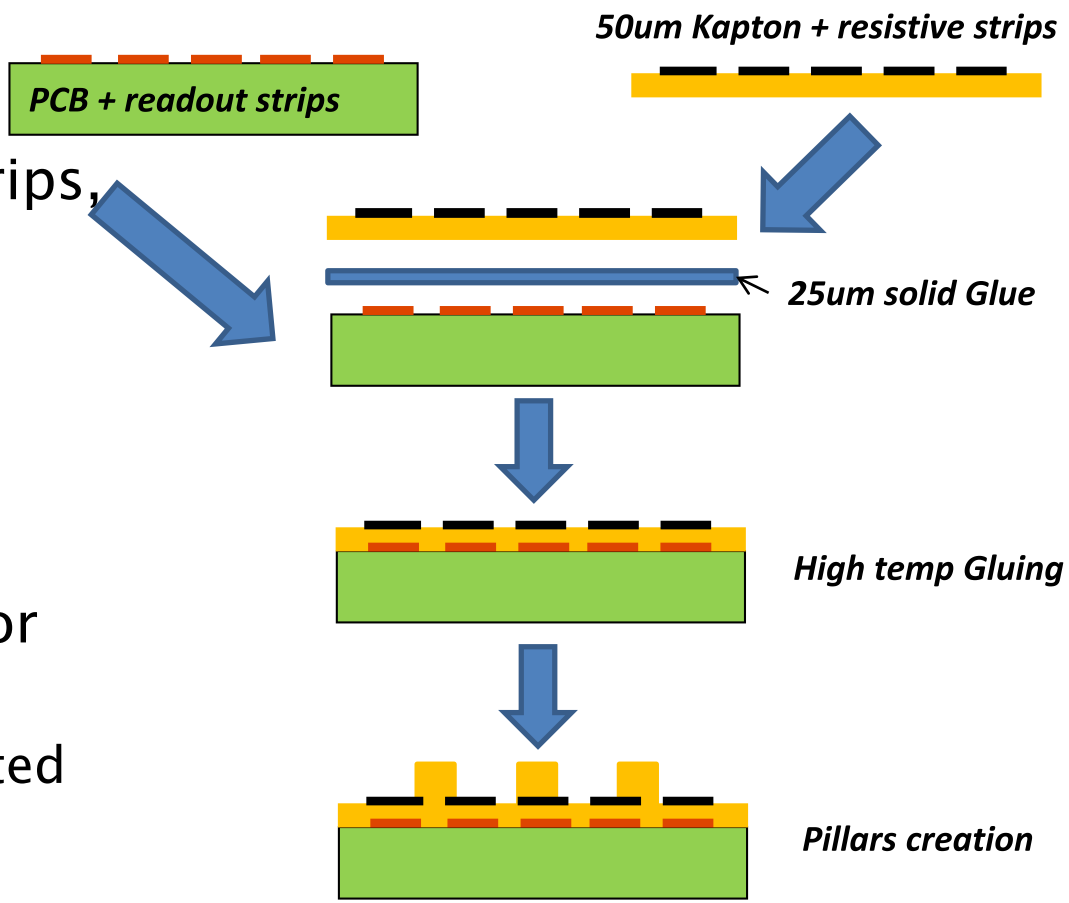
The Muon Spectrometer



Phase 1 upgrade で交換予定の
Small Wheel

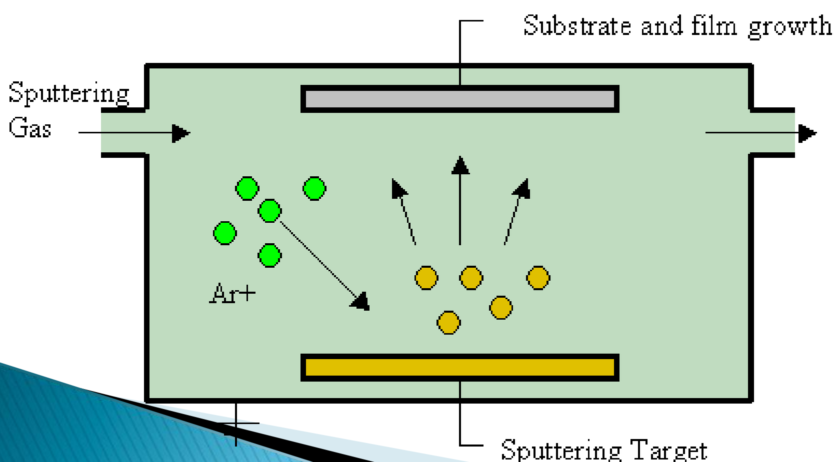
Resistive strips foil

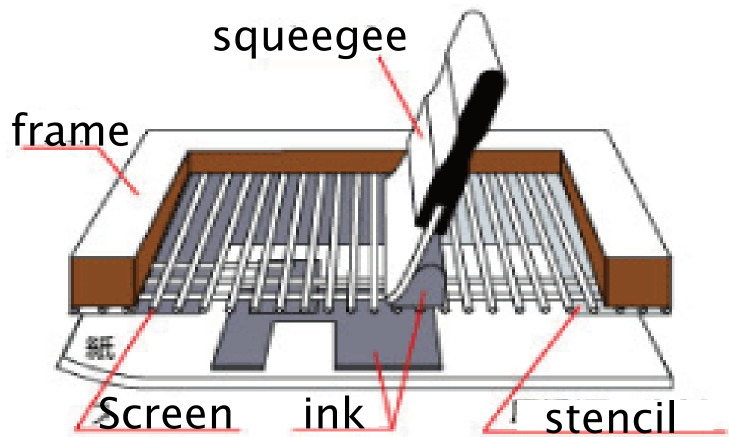
- Pattern
  - Along with readout strips, with inter connect pattern.
    - 300–350 μm width
    - 415–450 μm pitch
- Resistivity
  - Typically, 20MΩ/cm for each strips
    - +/− 20% will be accepted as “Grade A”
    - Maximum allowance: −67% / +200% (Grade C”)



Candidates for production

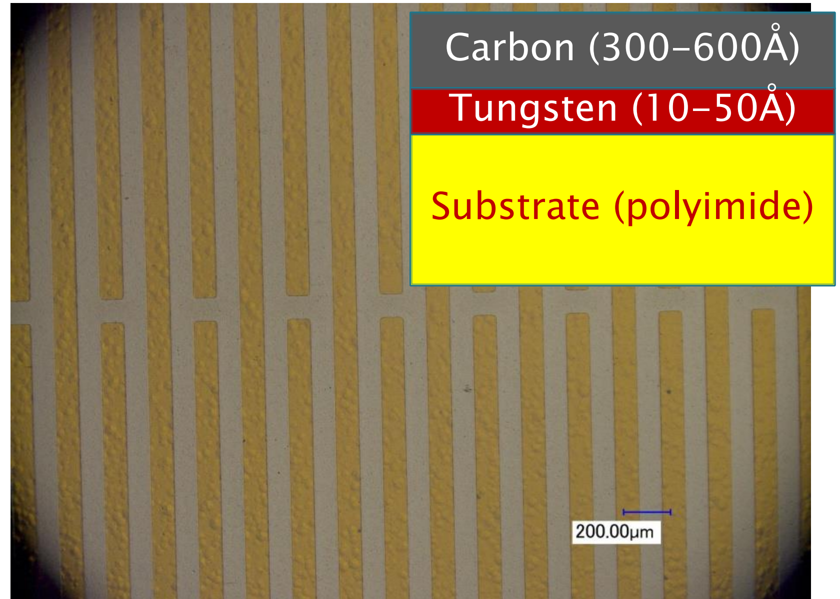
- Sputtering+liftoff
  - Pros.
    - Large area (>2m)
    - Fine pattern (<100μm)
    - Uniform resistivity
    - Strong attachment on substrate
  - Cons.
    - Production speed
      (Now, it will be OK, next slide)
    - High cost
- Screen printing
  - Pros.
    - Large area (>2m)
    - Fast production speed
    - Low cost for mass production
  - Cons.
    - Stability of resistivity
    - Thick pattern (~20 μm)
    - Lower tolerance for breakdown for high voltage

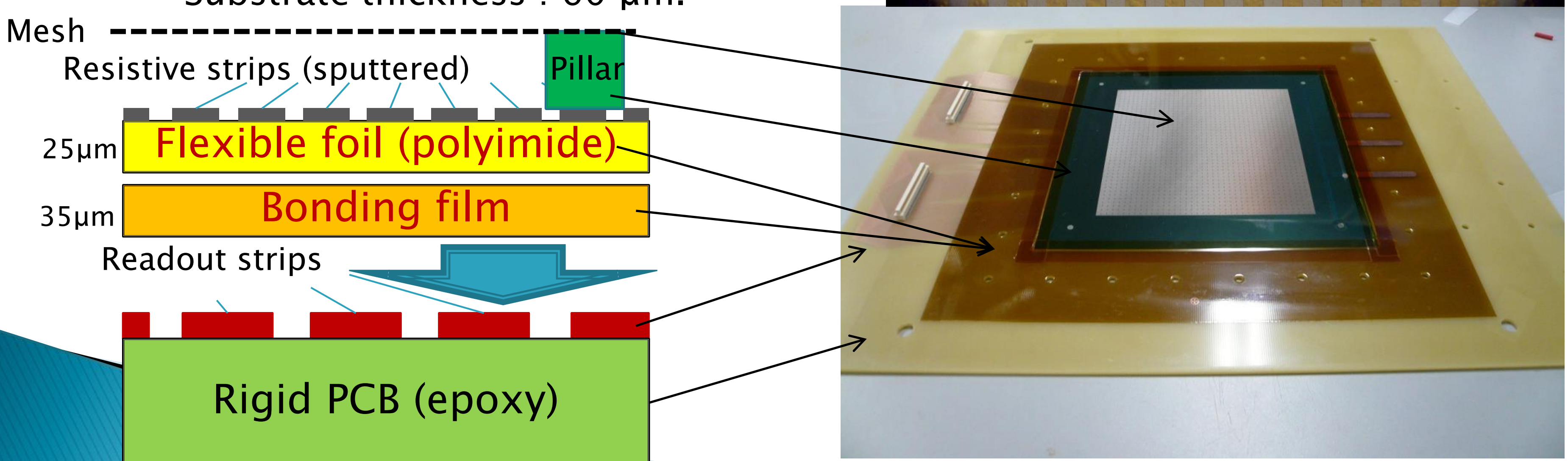




Prototype of small MicroMEGAS

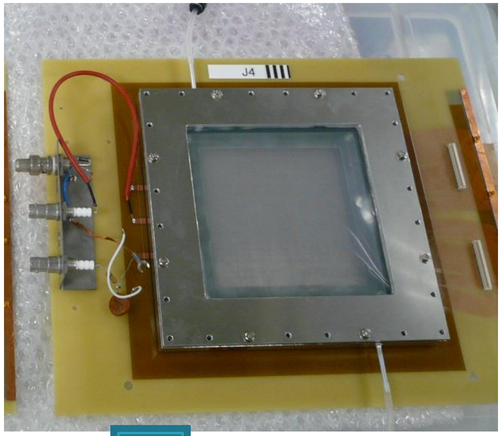
- June, 2013 – bulk MM
  - Surface resistivity: 10MΩ/sq.
    - With 300Å carbon + 50Å W
- November, 2013 – floating mesh
  - Surface resistivity: 500kΩ/sq.
    - With 3600Å carbon
- The readout board consists of
    - Readout strips (Rigid PCB).
    - Resistive strip foil (Polyimide film).
  - Fine strip pitch of 200 μm is formed on 25μm polyimide foil.
  - Substrate thickness : 60 μm.

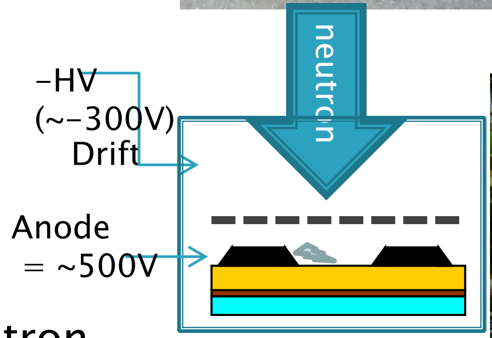


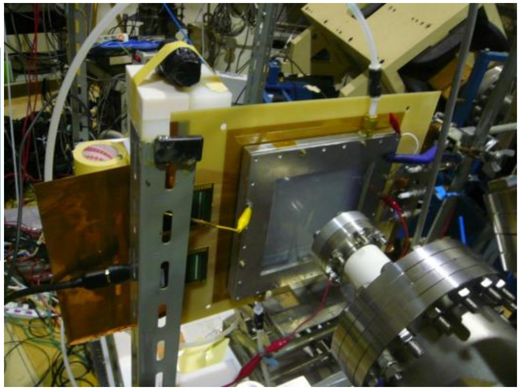


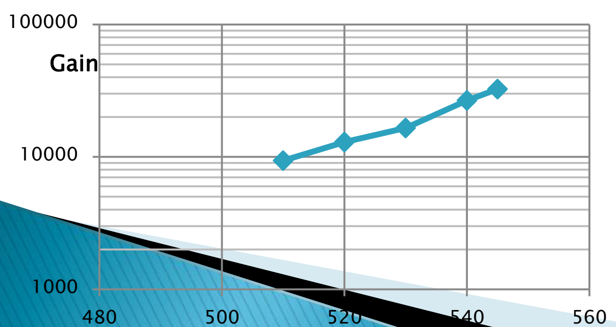
Fast neutron test

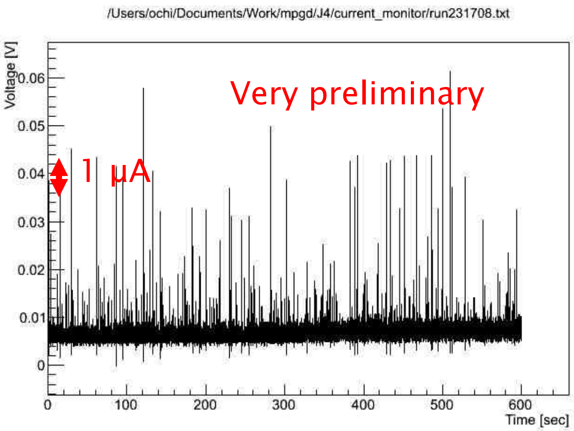
- Beamtests for sputtering MPGD
- Gain curve of 5.9 keV X-ray.
  - Drift = -300V
  - Drift spacing: 5mm
  - Gas: Ar(93%) + CO2(7%)
- Fast Neutron test for spark probability
  - @Kobe Univ.
    - 17-23 Jun. 2013
    - 20-27 Jan. 2014
  - HV current log under intense neutron.
    - Neutron intense : ~ 10^5 cps/cm^2.
    - 0.01V correspond to 1 μA
    - ~600nA of base current was found while beam ON.







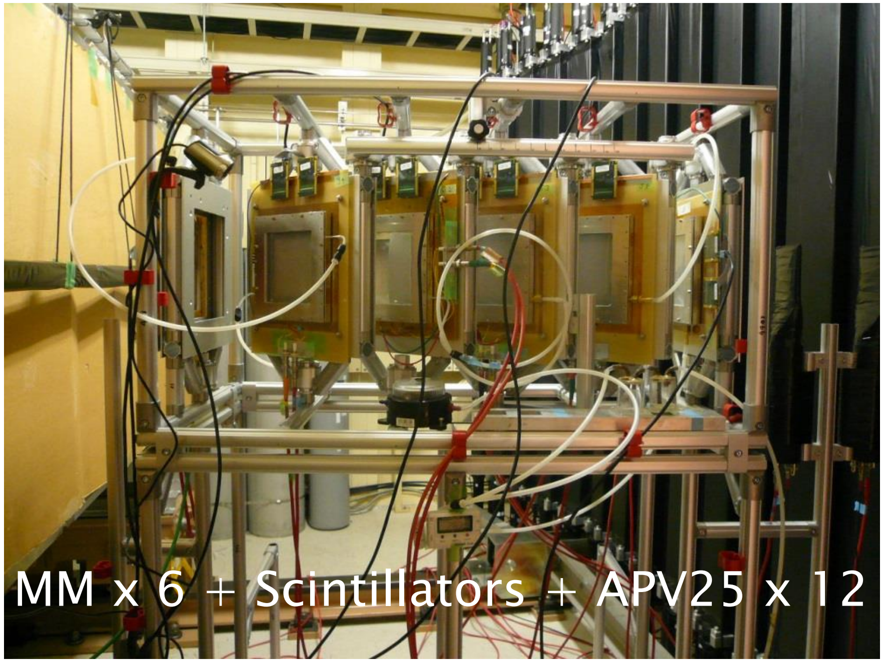


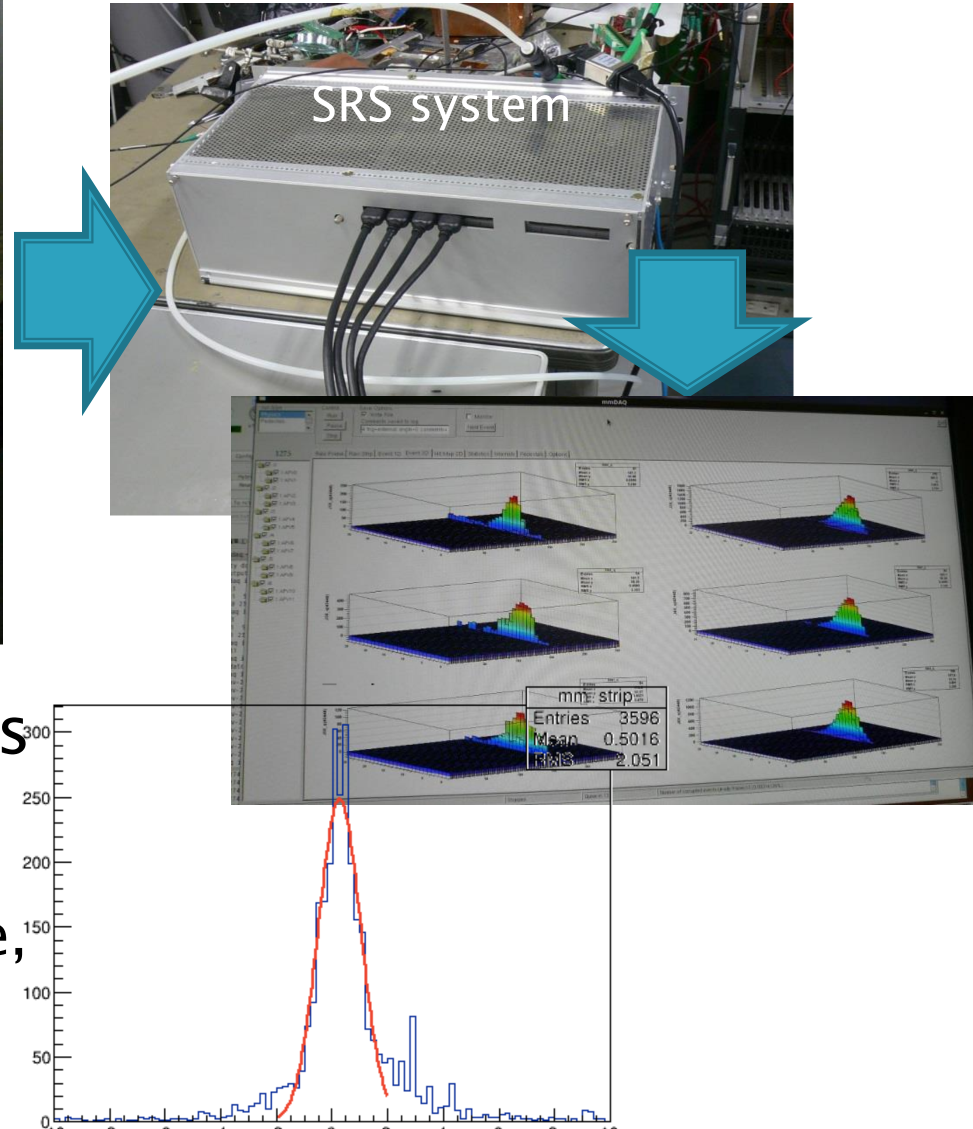


After sparks by neutrons

- No damage is observed on the resistive strips after neutron test

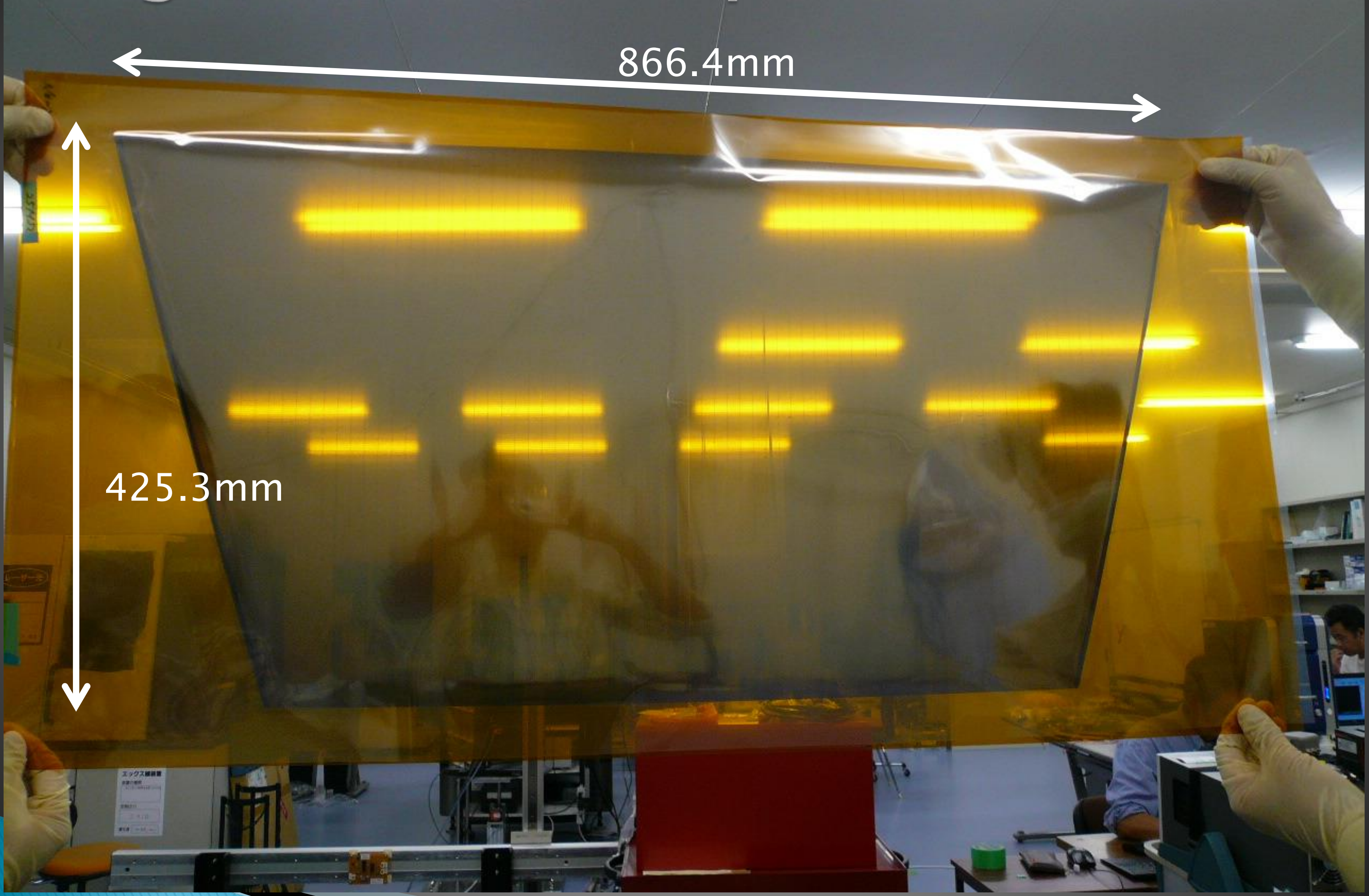
Charged particle tracking



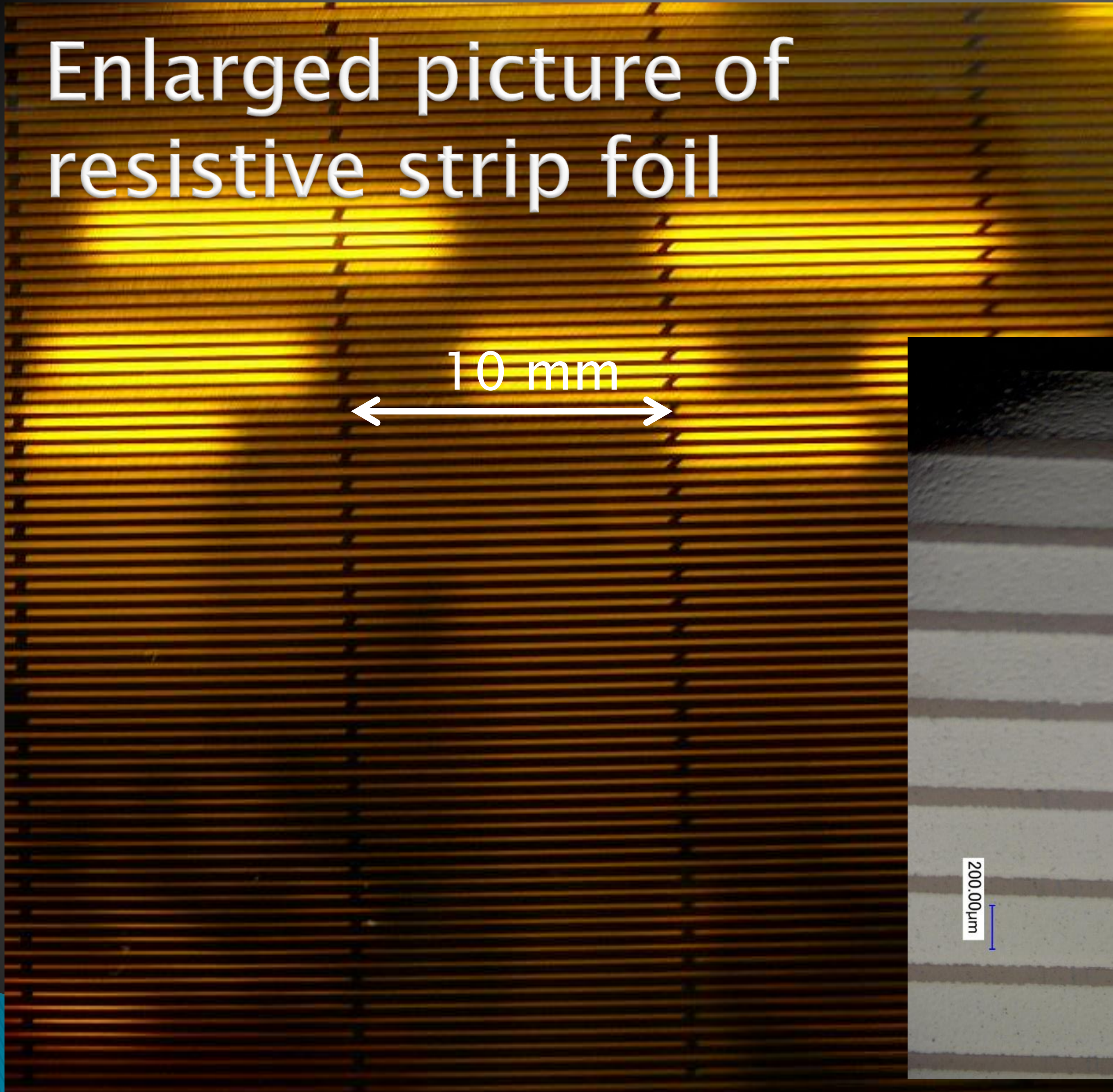


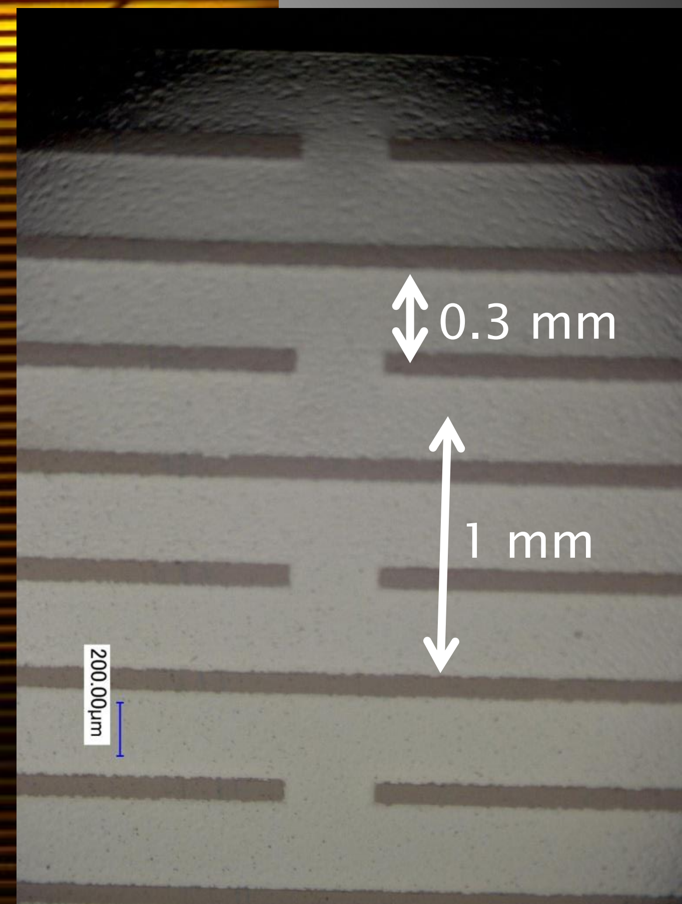
- Cosmic test using 4 MMs
  - At Kobe Univ, Sept. 2013
- 1.4GeV electron beam
  - At Spring-8 BL33 beamline, Nov. 2013

Large resistive strip foil for MSW



Enlarged picture of resistive strip foil

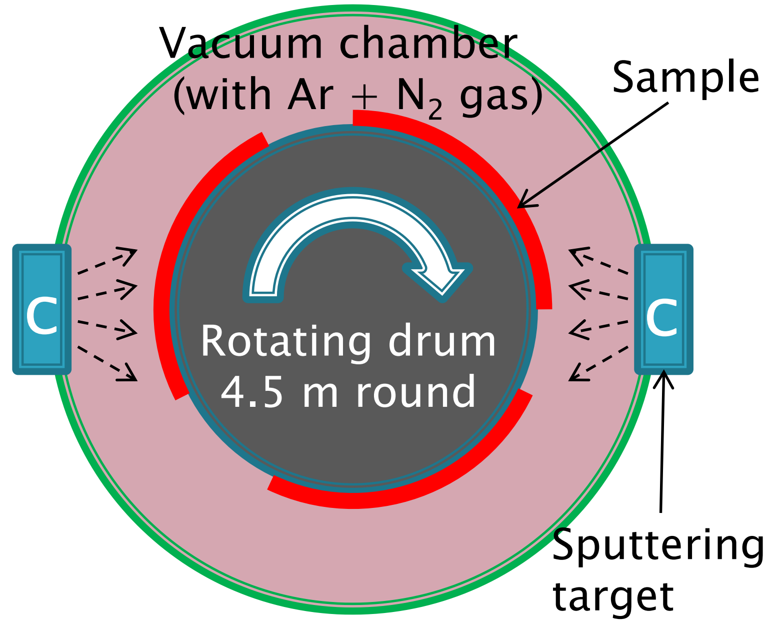


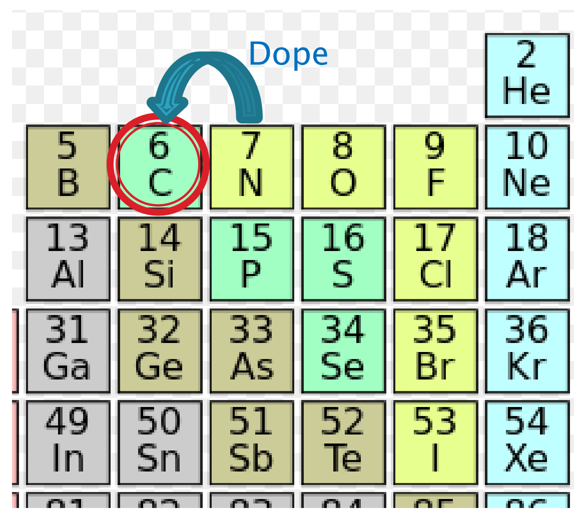


Carbon sputtering further developments

New idea: Nitrogen doping

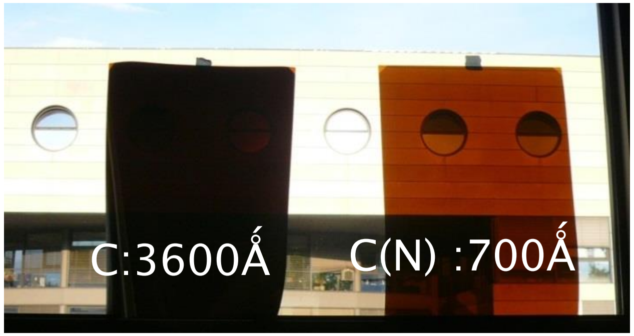
- The structure of the sputtered carbon is amorphous diamond like carbon (a-DLC).
- It is thought that the charge carrier is very few in the DLC
- So, I got an idea of nitrogen doping as a supplier of carrier electrons.
  - This is same story as the n-type semiconductor production.
- The nitrogen is easy to introduce into the sputtering chamber with Argon gas.

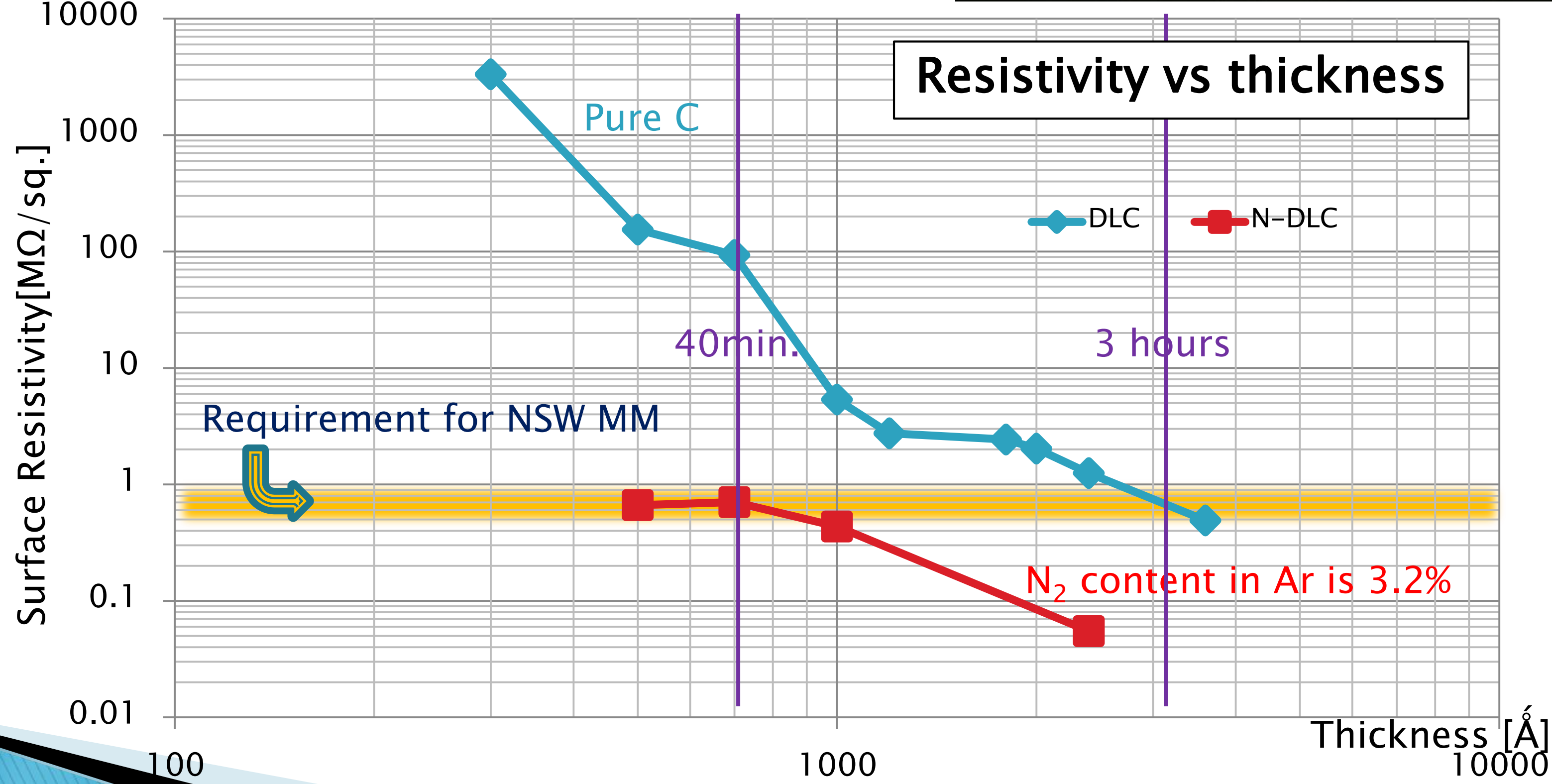




Resistivity vs thickness (June, 2014)

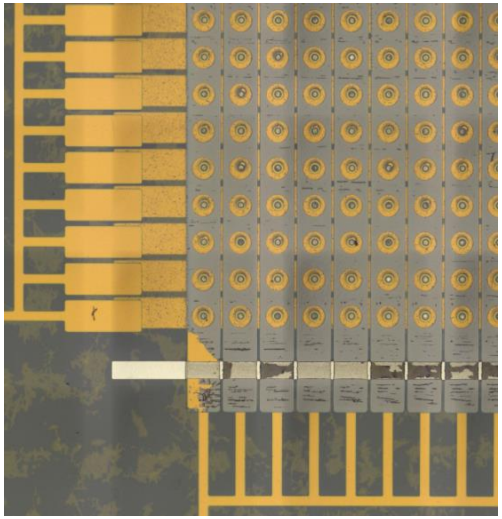
- For 3.2% N_2 content foils
  - 2400Å → 55kΩ/sq.
  - 700Å → 700kΩ/sq. (42min. sputter)

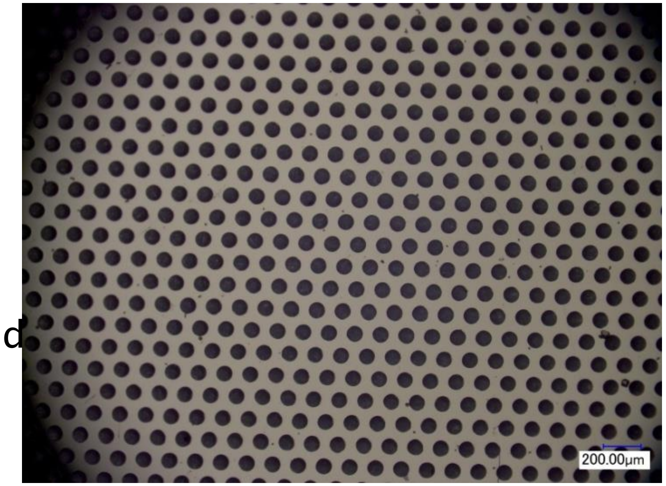


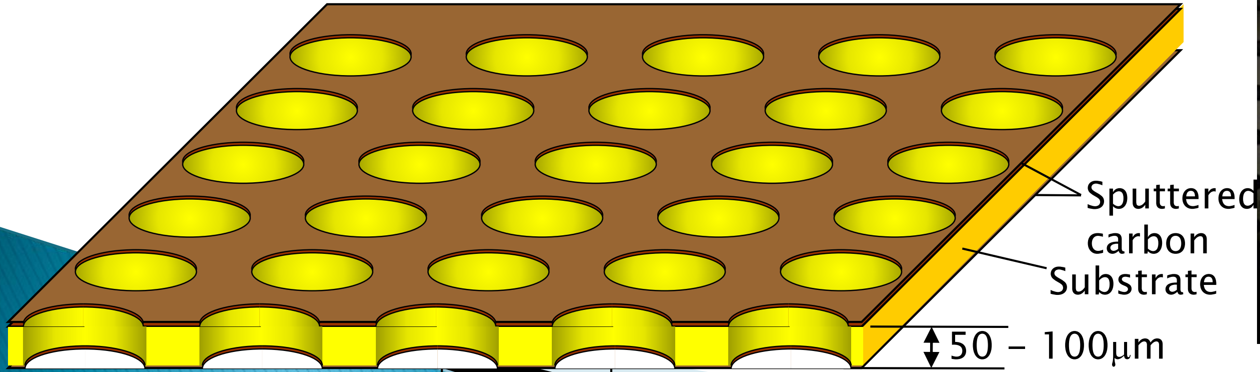


Other MPGD development using carbon sputtering

- Resistive μ-PIC
  - New version using carbon sputtering is being tested
- Resistive GEM
  - The resistive electrodes are made by very thin (50 – 300nm) material
    - It will improve the signal gain
  - We have just made it, and it is being tested now.
    - (Scienergy + Raytech)

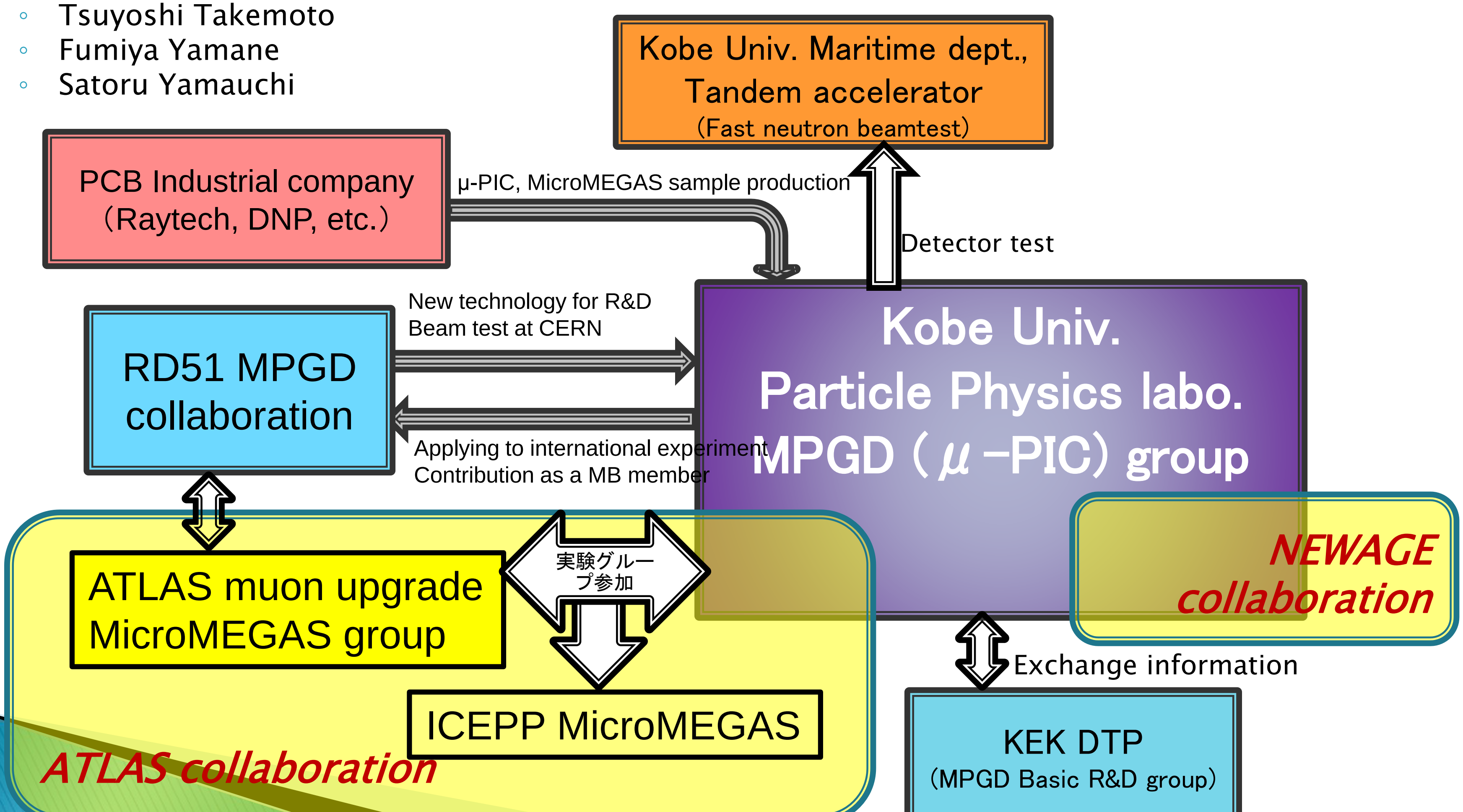






Synergy of MPGD group

- Kobe MPGD group Member (2014)
  - Atsuhiko Ochi
  - Kentaro Miuchi
  - Yasuhiro Homma
  - Tsuyoshi Takemoto
  - Fumiya Yamane
  - Satoru Yamauchi



Summary

- We are developing MPGDs as common technologies in particle physics experiments
  - MPGD with resistive electrodes
    - To suppress the electric discharge
  - μ-PIC : High rate → ATLAS phase-II upgrade
    Low rate → NEWAGE
  - MicroMEGAS : ATLAS NSW development
  - GEM : RE-GEM R&D has been started