MPGD developments using carbon sputtering

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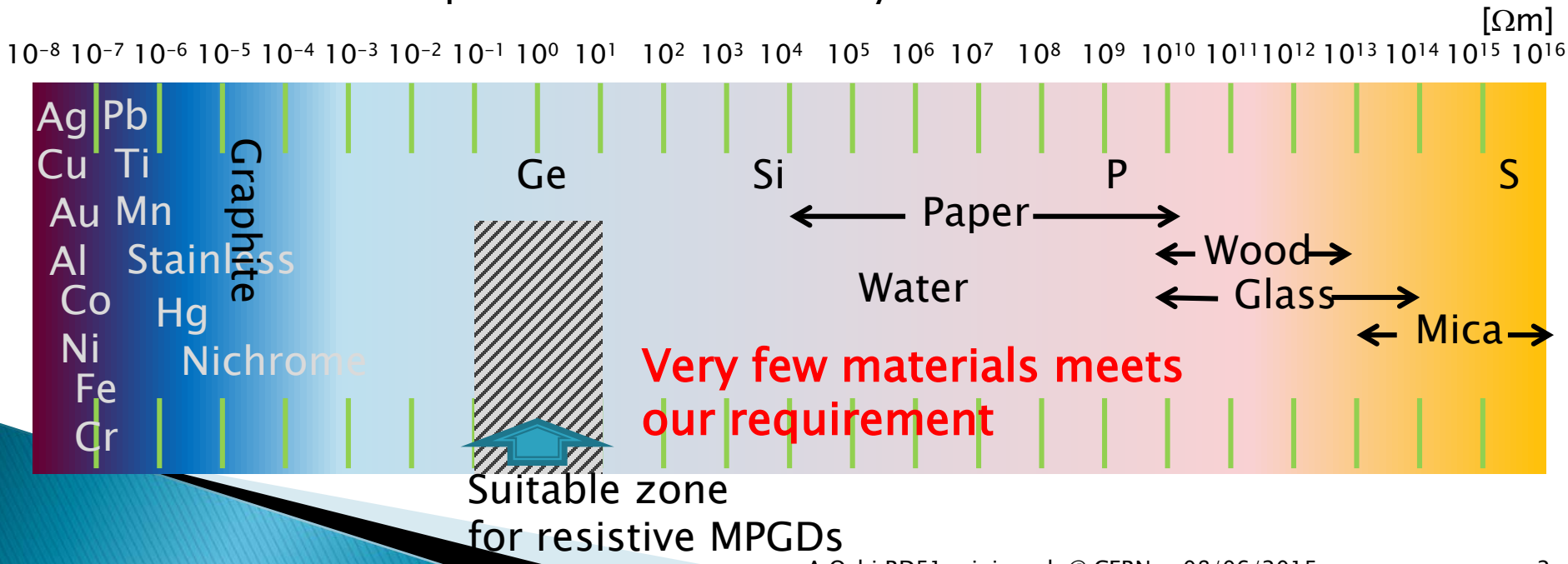
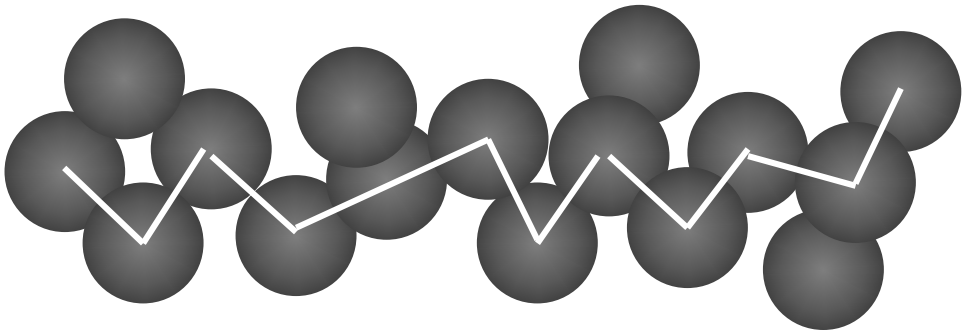
Resistive material for MPGDs

- Resistive electrodes is one of best choice for reducing the sparks on MPGDs.
- However, it is not easy to find the “resistive material” for Micro Pattern.
- In case, surface resistivity of 1MΩ/sq. is needed;
  - In general, the electrodes for MPGDs has 0.1μm – 10μm thickness.
  - Those correspond to bulk resistivity of 0.1Ωm–10Ωm.



Conventional way for making resistivity

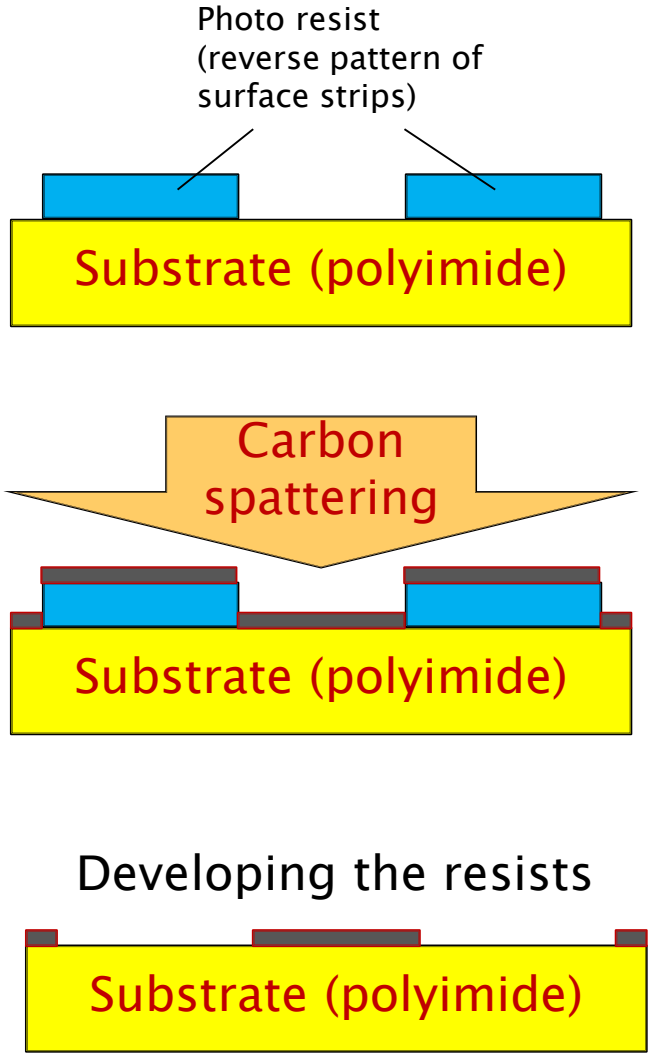
- Carbon black loaded paste/sheet have been used for resistive material
  - Carbon black: small particles, made from mainly graphite.
  - Those are used by mixing in plastic, epoxy, solvant etc.
  - Mechanism of resistivity development

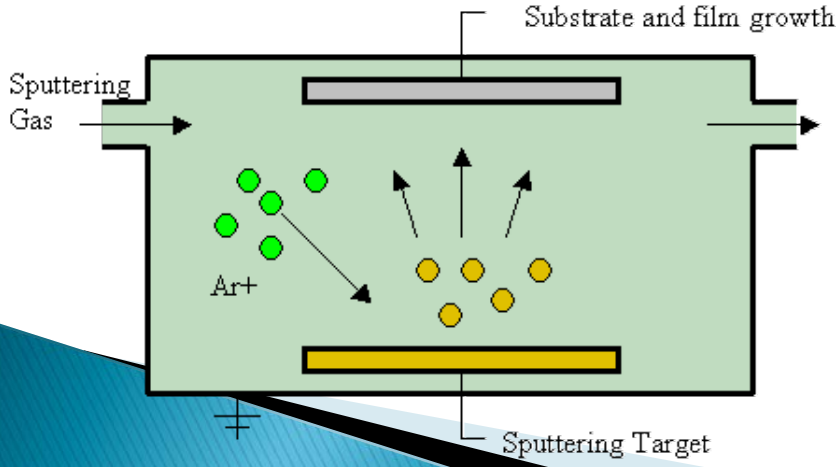


  - Carbon black particles contact each other on point, and it makes electrical path.
  - We need very small carbon black particles for fine structure of MPGD electrodes.

Our approach: Sputtered carbon

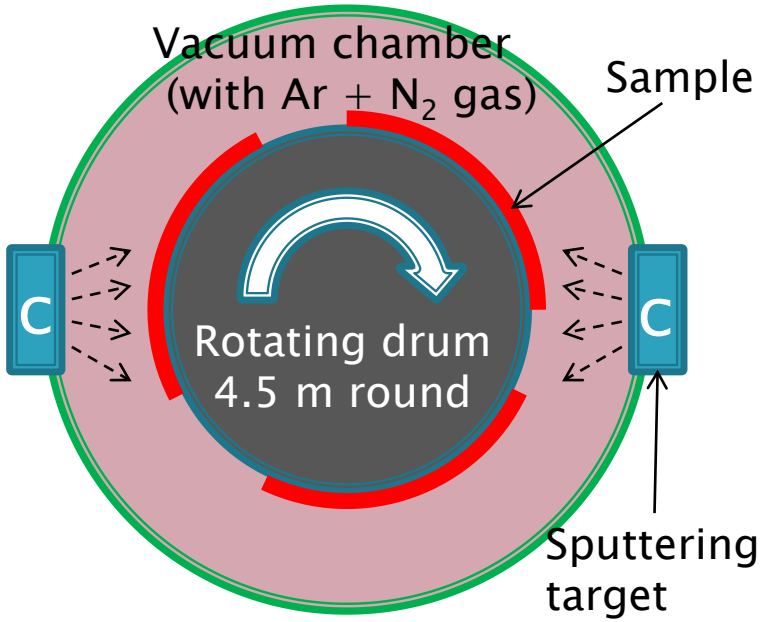
- Sputtered carbon
  - Diamond like, and amorphous structure
  - It means, carbon particles of molecular size!
- Fine structure with proper resistivity is available
  - with liftoff method

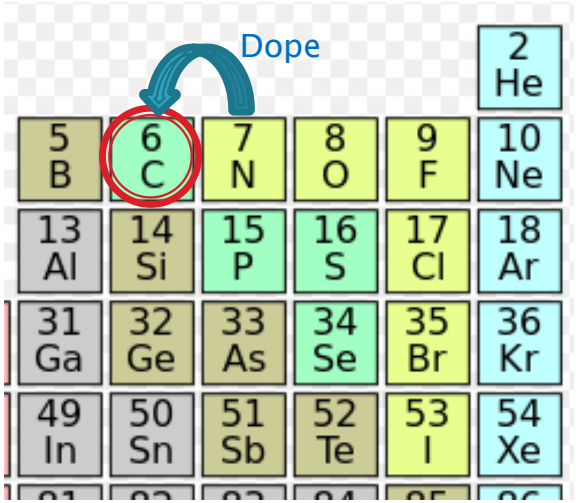




New idea: Nitrogen doping

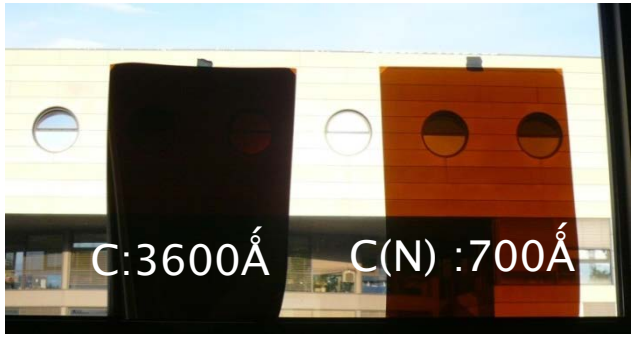
- The structure of the sputtered carbon is amorphous diamond like carbon (a-DLC).
- It is thought that the charge carrier is very few in the DLC
- So, I got an idea of nitrogen doping as a supplier of carrier electrons.
  - This is same story as the n-type semiconductor production.
- The nitrogen is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

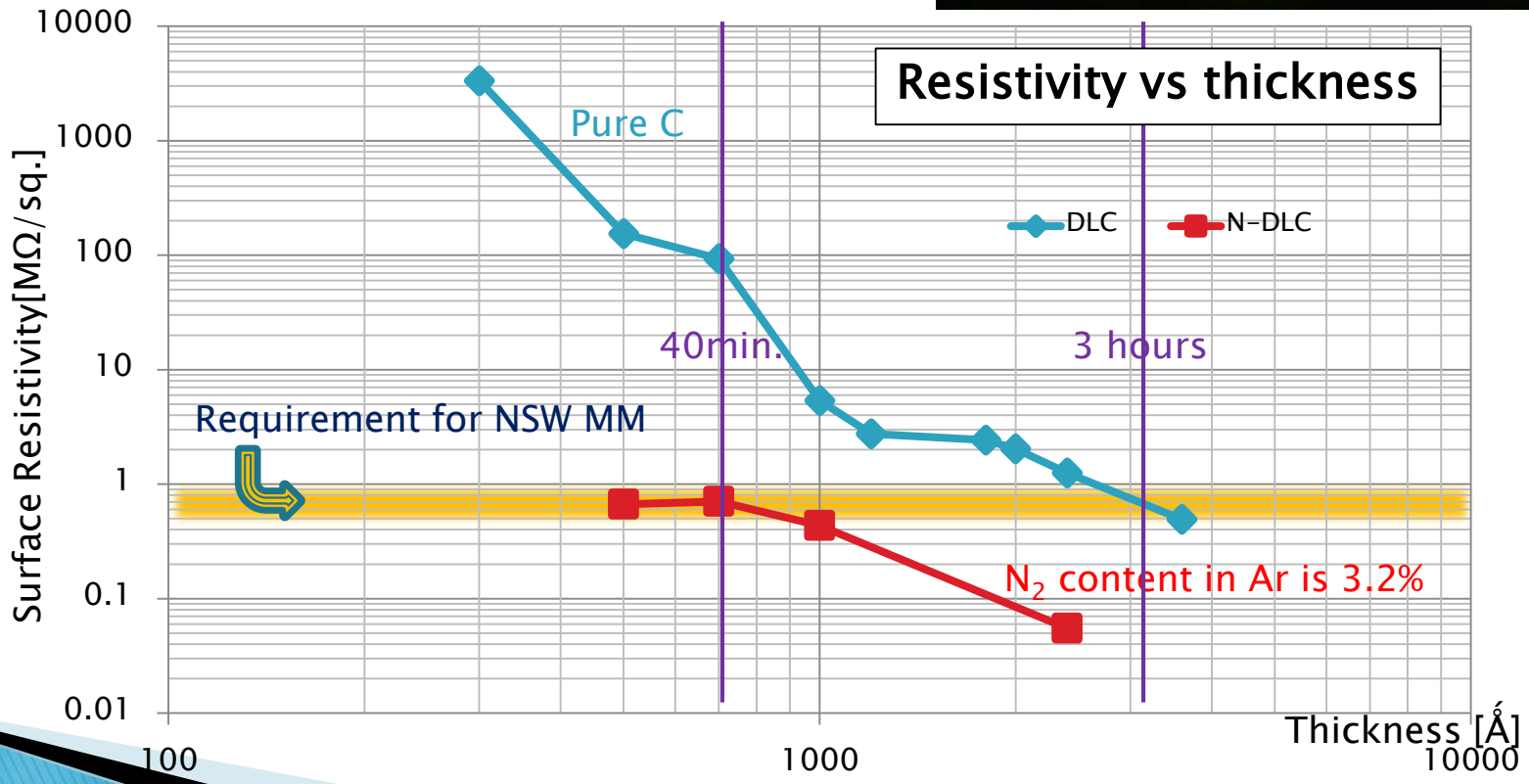




Resistivity vs thickness (June, 2014)

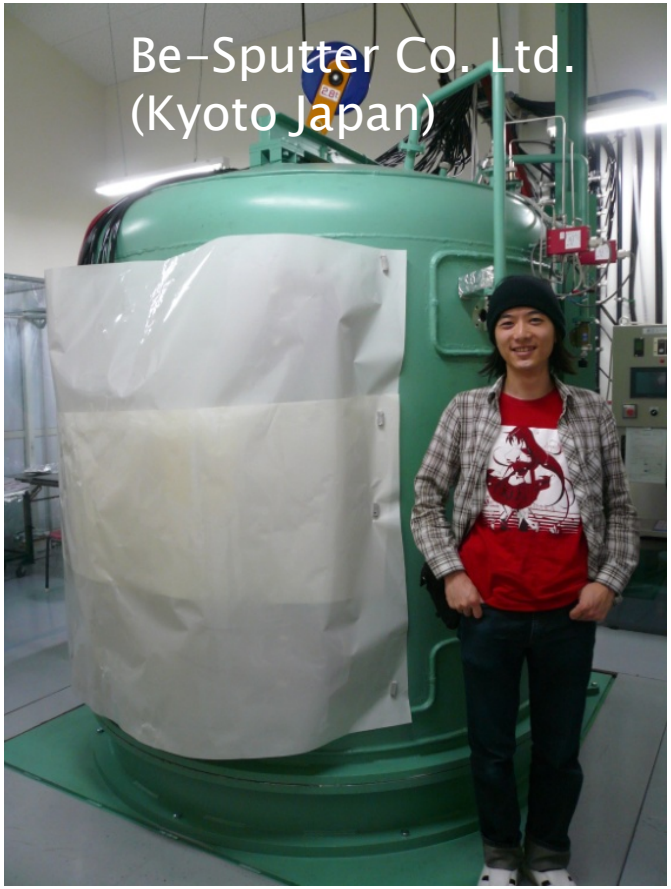
- For 3.2% N_2 content foils
  - 2400Å → 55kΩ/sq.
  - 700Å → 700kΩ/sq. (42min. sputter)





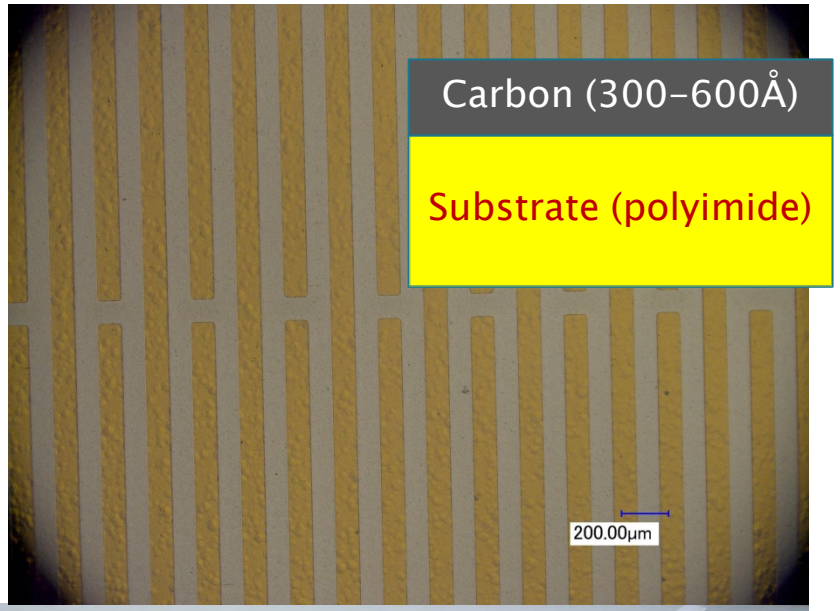
Prototype production for many type of MPGDs

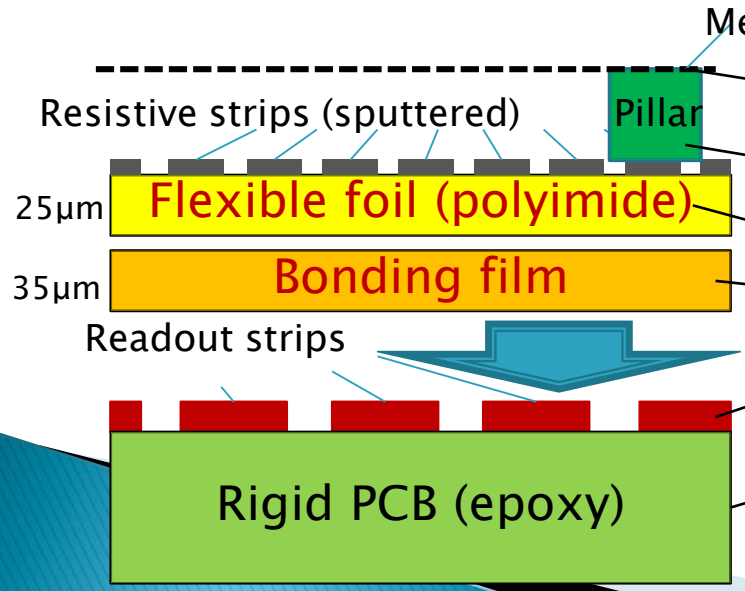
- Properties of the resistive electrodes by carbon sputtering
  - Fine structure
  - Chemical and physical toughness
  - Very thin (50nm – 500nm)
  - Large area is aveilable
- We have made following resistive MPGDs using carbon sputtering
  - MicroMEGAS
  - GEM
  - MSGC
  - Micro-PIC

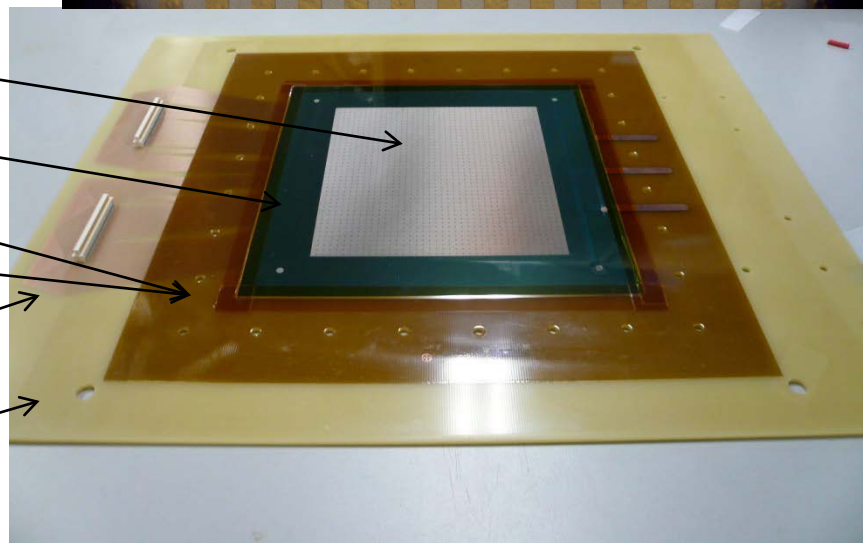


Resistive MicroMEGAS

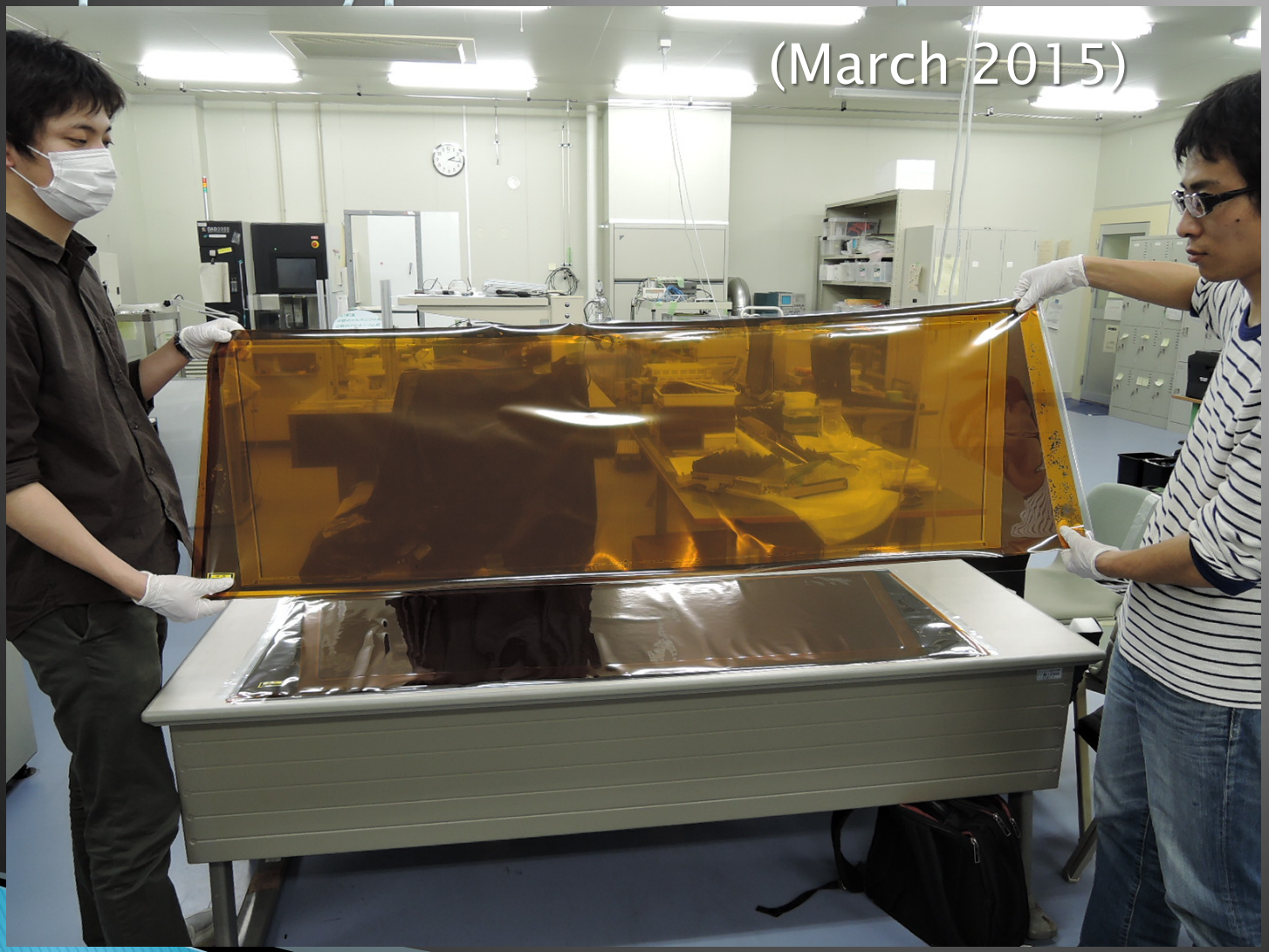
- First attempt to make MPGDs using carbon sputtering (from June 2013)
  - This R&D is aimed for ATLAS NSW MM.
  - Fine strip pitch of 200 μm or 400 μm is formed on 50μm polyimide foil.



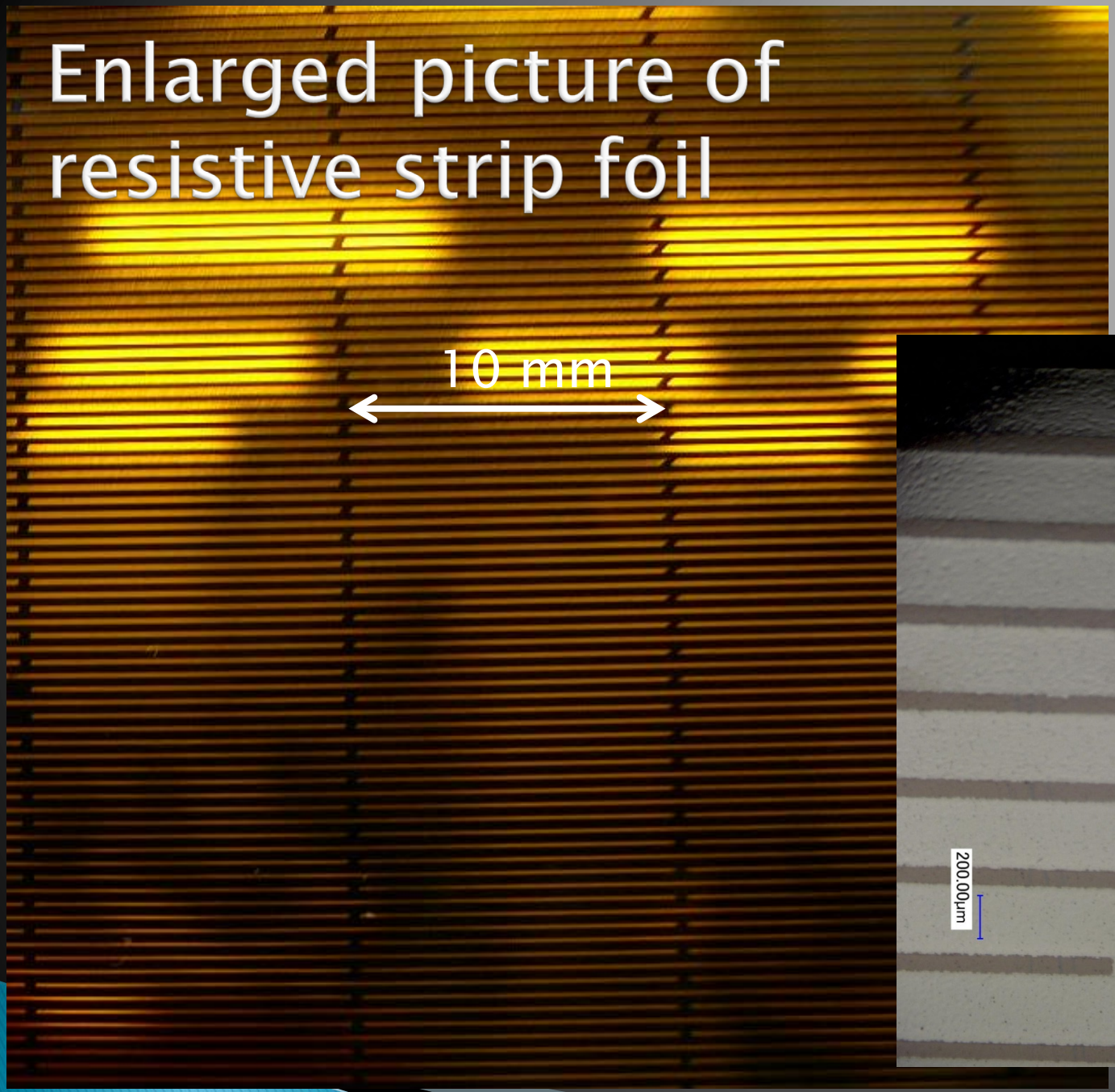


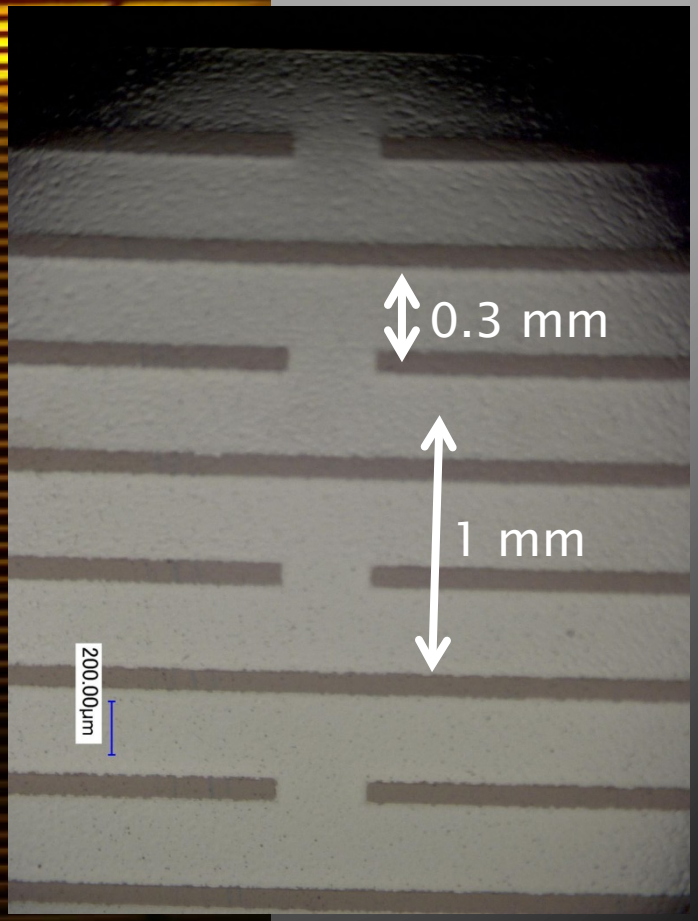


Large resistive strip foil for prototype of series production



Enlarged picture of resistive strip foil



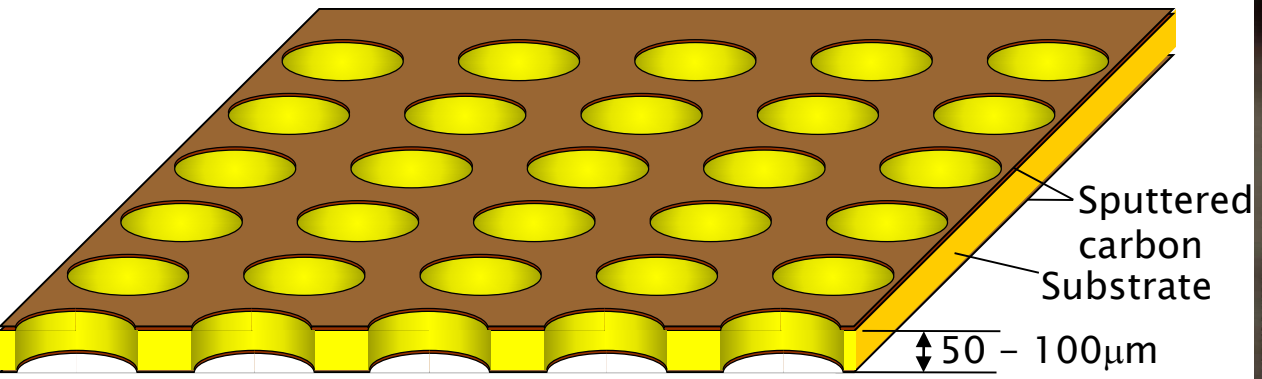


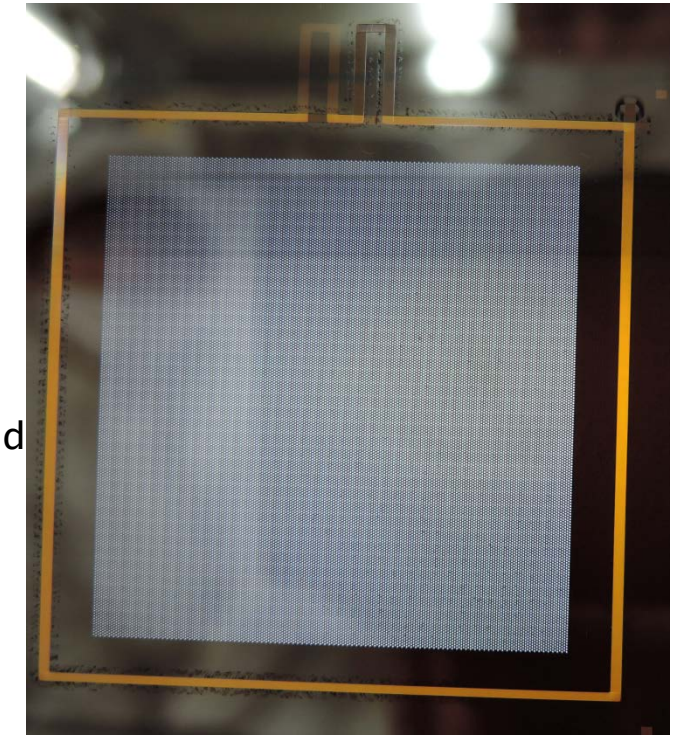
Resistive MicroMEGAS

- Resistive MM for ATLAS NSW
  - Technology for Large area and series production have been established.
  - There are many reports on operation tests.
  - However, production cost using screen printing is less than half, our first choice for resistive strip in NSW is screen printing.
    - Requirement on the ATLAS MM resistive strips are not so fine that printing technology is enough.
- Other MM with carbon sputter
  - We have provided planner carbon sputtered foil for prototype of ILC-TPC MicroMEGAS .
  - → Paul will talk “Diamond like carbon MM” in next talk.

Resistive GEM

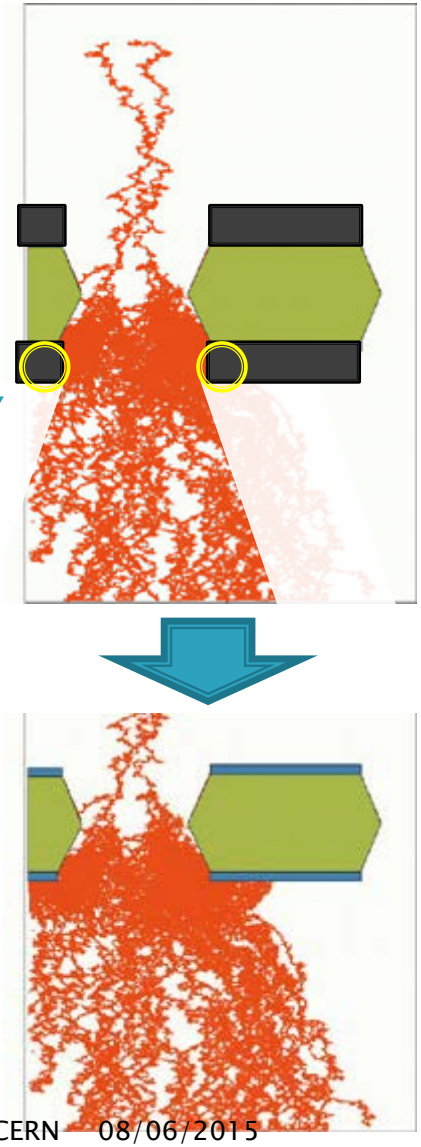
- Standard type GEM (holes with 140μm pitch, diameter with 70-85μm.) with resistive electrodes.
- The resistive electrodes are made by very thin (~100nm) sputtered carbon
  - It will improve the signal gain
  - Surface resistivity ~ 1MΩ/sq.
- Holes are made by laser drilling





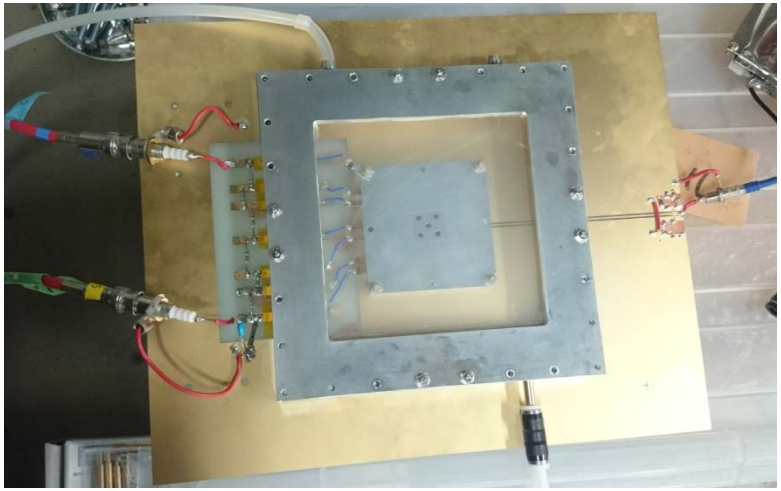
Aims of carbon sputtered GEM

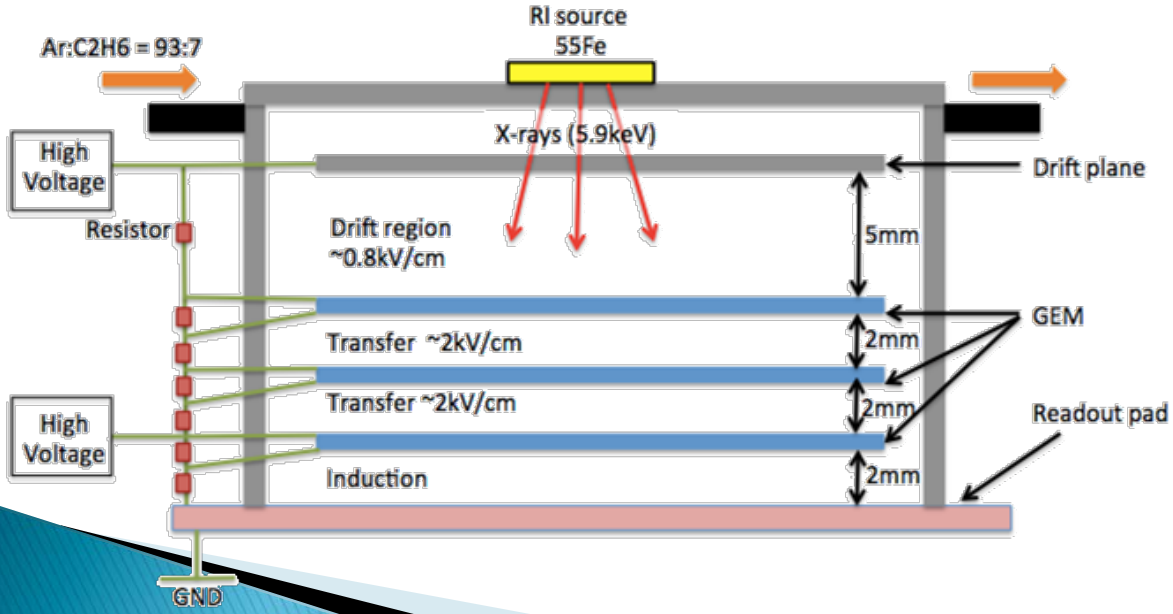
- Previous study:
  - (RIKEN RE-GEM, A. Yoshikawa et. al., 2012 JINST 7 C06006)
  - Resistive electrodes are made from resistive sheet with 25μm thickness.
  - In the simulation study, avalanched electrons cross over the thick resistive electrodes.
- Our prospects:
  - Sputtered electrodes are very thin
  - Avalanched electrons will not be interfered by electrodes.

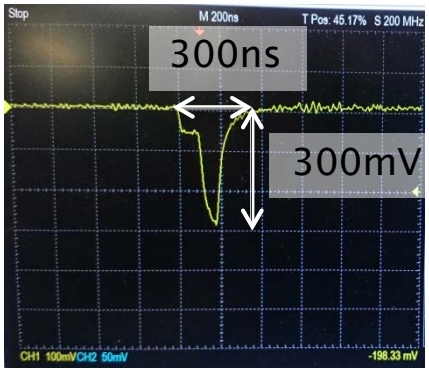


Current status: Signal found

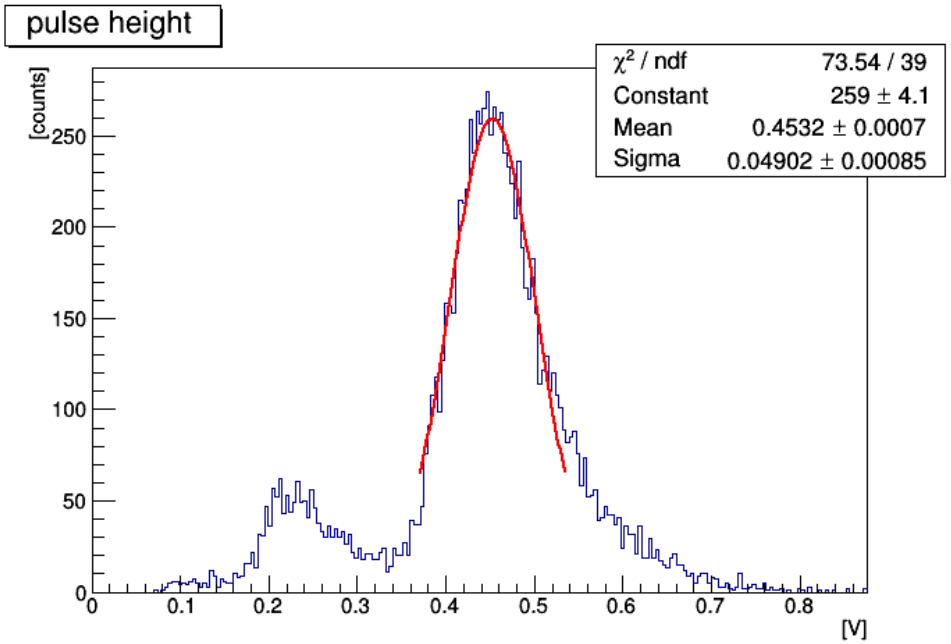
- RE-GEM was set as one layer of triple GEM
  - Other layer is standard GEM
- Signals with RE-GEM were compared to that without RE-GEM for obtain gas gain





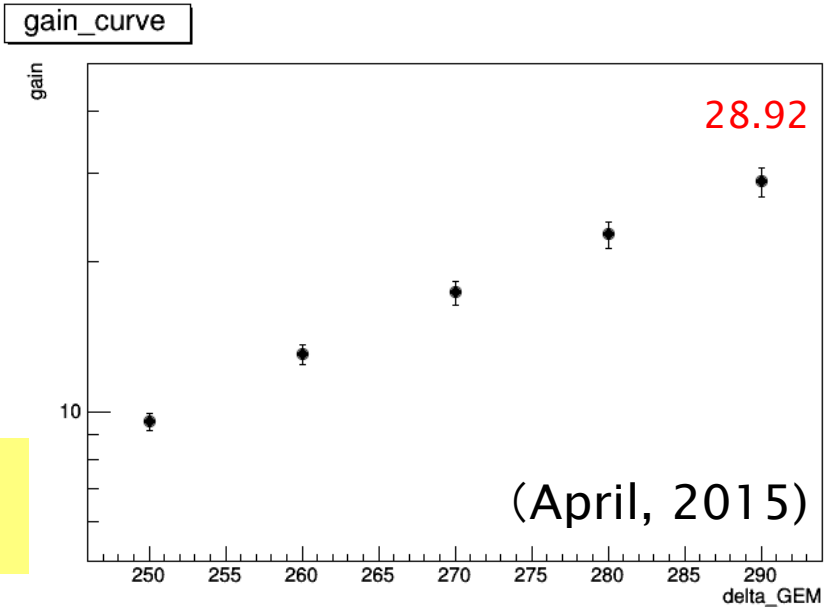


Spectrum and gain curve of REGEM



drift: 370
GEM1: 370
Transfer1: 370
GEM2: 370
Transfer2: 370
GEM3: 280
Induction: 747

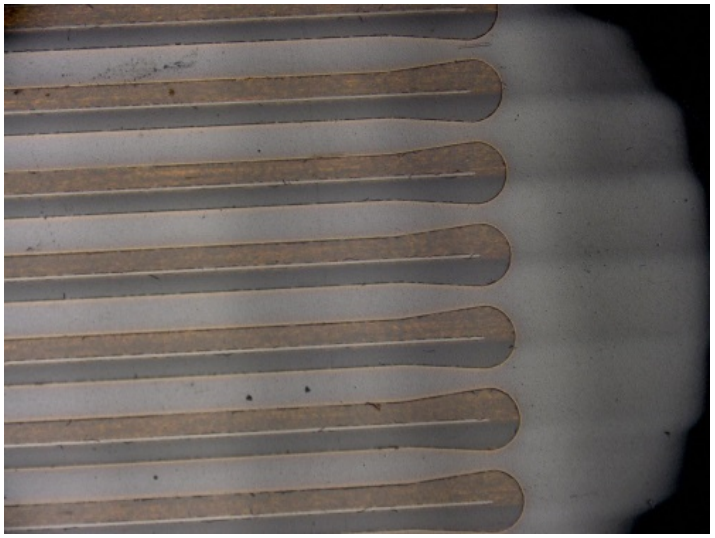
GEM3:
250~290V

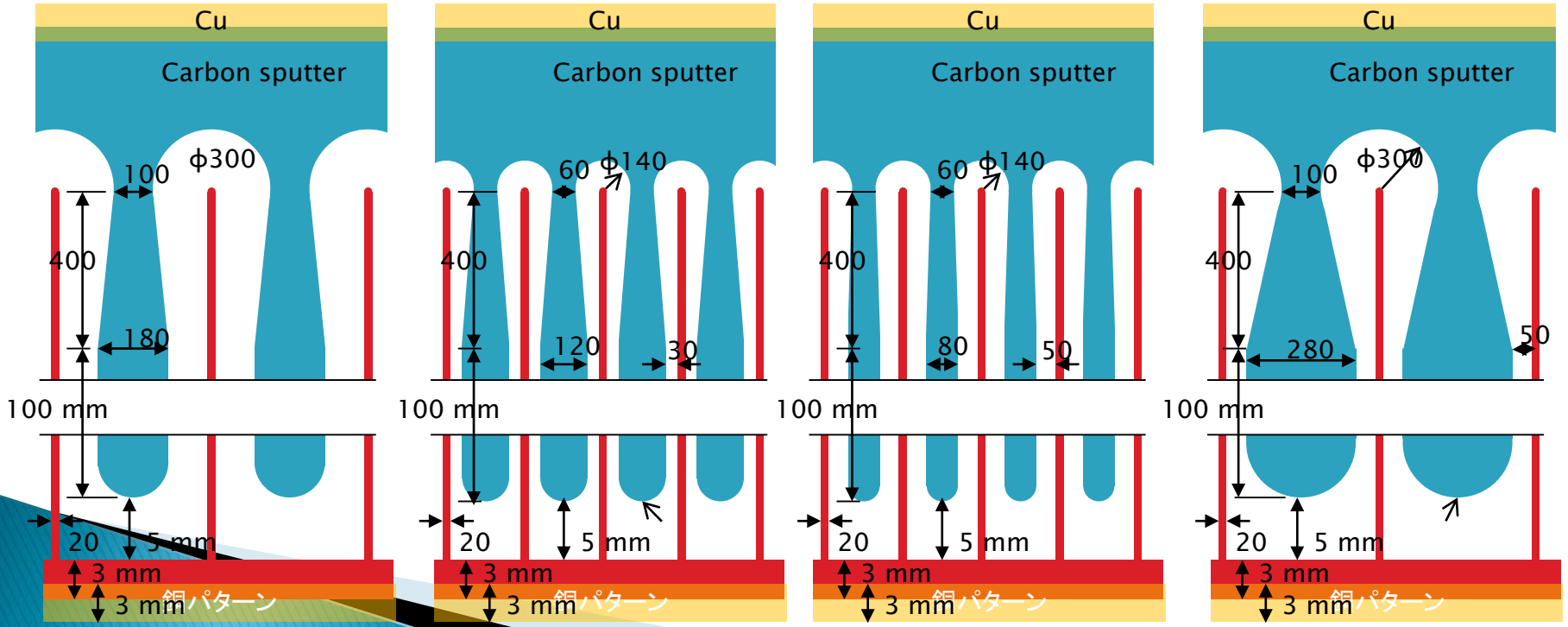


Those are all preliminary data
Developments and tests are ongoing!!

Resistive MSGC

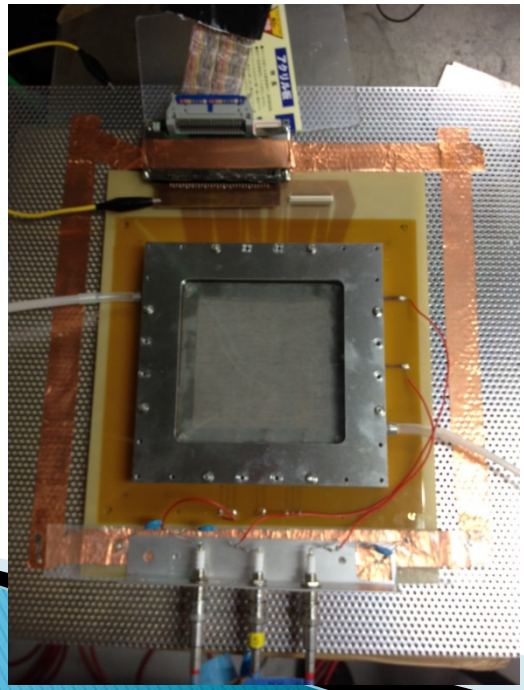
- To study basic properties of fine structure MPGD, prototype of RE-MSGC using carbon sputter have been made.
- 4 geometry with 2 different anode materials are made

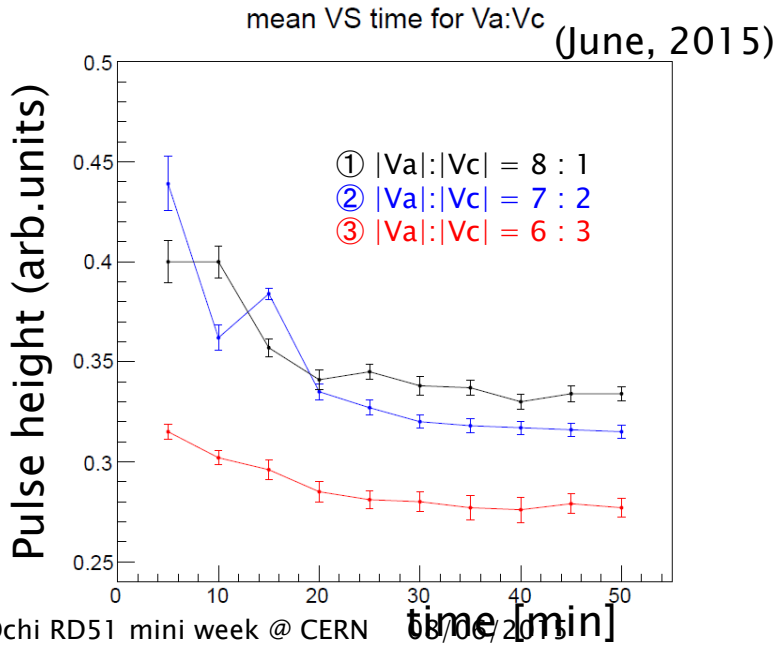




Signal from RE-MSGC

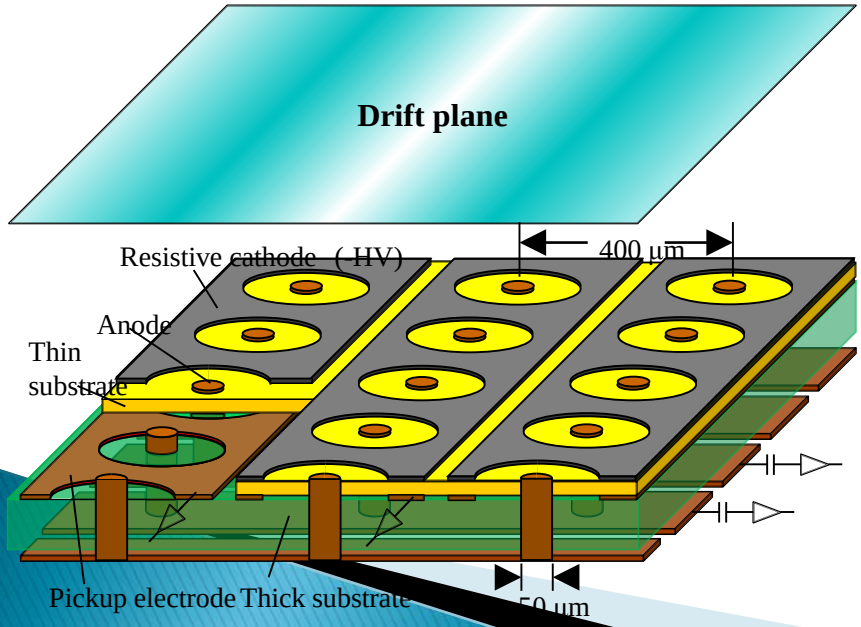
- Signal is read from back strip (induced carge)
- Gain variation along the time is found
- There are alignment problem between copper anode and sputtered cathode.
  - Those electrodes are made by different masks
- Those researches are just started, and ongoing

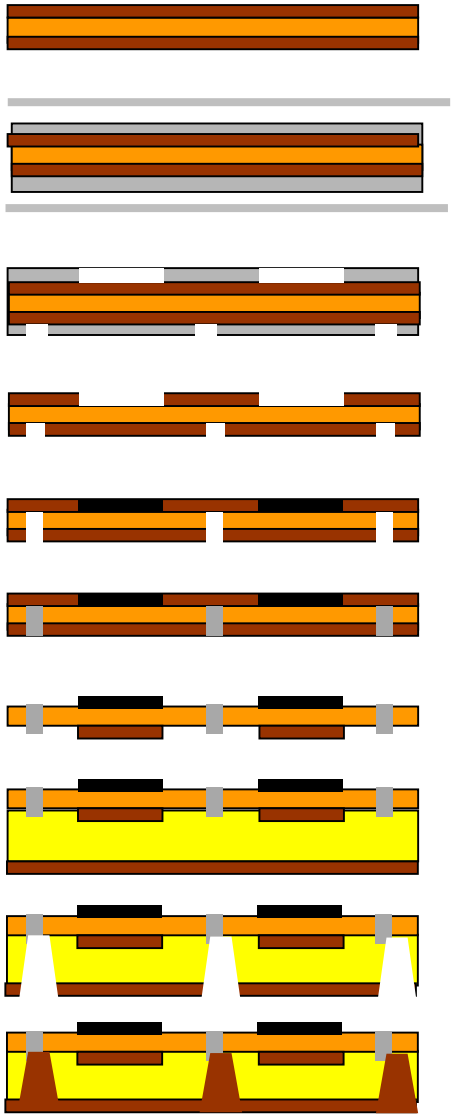




Resistive μ-PIC

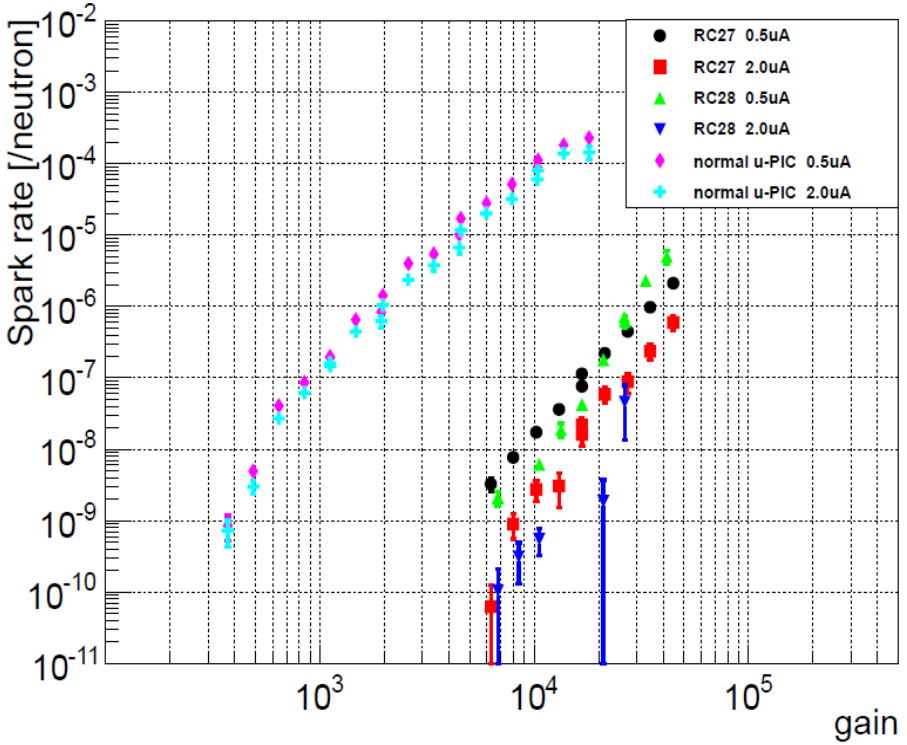
- The cathodes of μ-PIC is formed by resistive material.
- Large current from spark reduce the e-field, and spark is quenched.
- Signal from low energy deposit will observed with higher gas gain
- This design provide one promised possibility of MIP detector under hadronic background
- It takes enough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

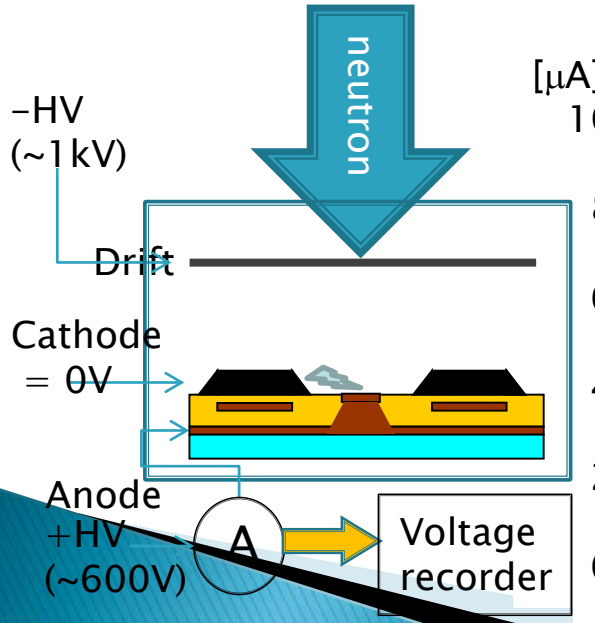


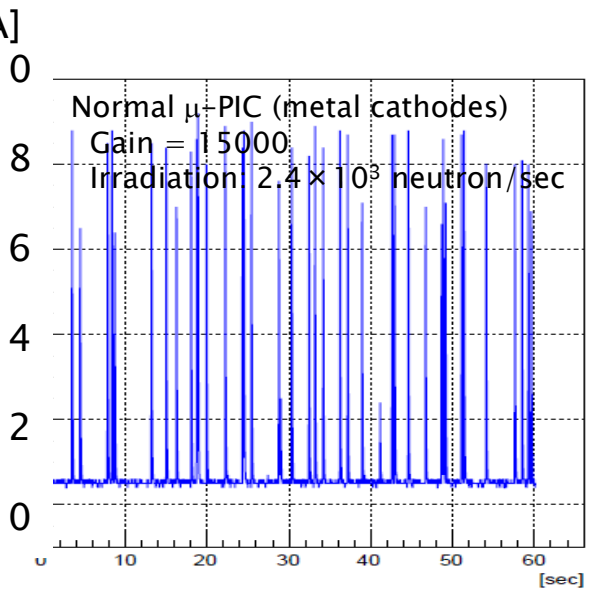


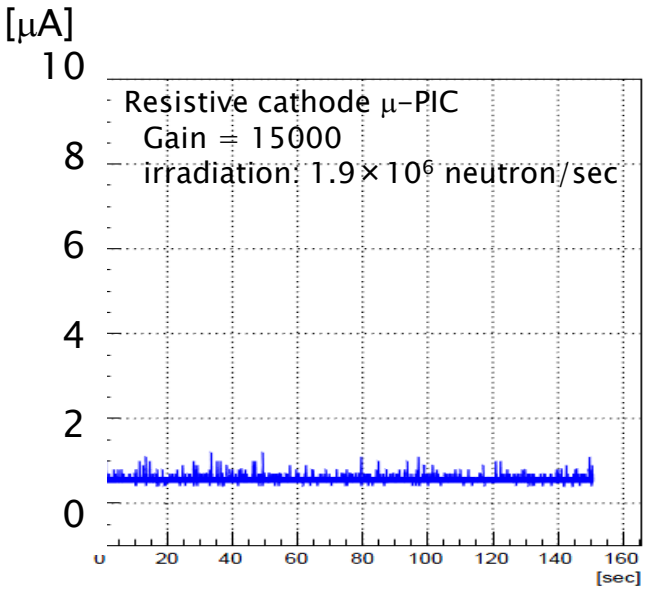
Results of spark reduction test

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



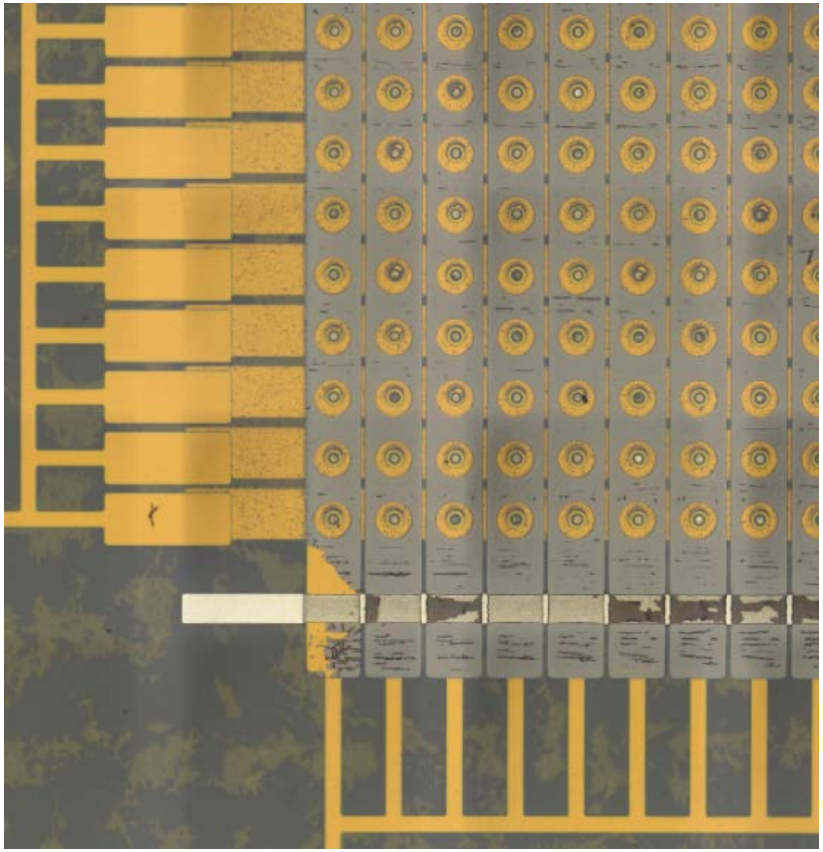






Carbon sputtered μ-PIC

- Cathode structure should be fine
- Sputtering with liftoff is very good method for those structures.
- Prototype was made, however, it has not operated yet.
  - Some problems for alignment of multi layer



Summary

- Carbon sputtering : Very fine and stable way for MPGD electrodes!
  - Less than 10μm structure
  - Tough chemically and physically
- Resistivity control
  - Available from a few kΩ/sq. to several tens MΩ/sq. using N dope method and thickness control
- Carbon sputter for MPGDs
  - MicroMEGAS (resitive strip)
    - Technology has already been established. Large area (~ a few m2) with mass production is available
  - GEM: Prototype has been worked. On going.
  - MSGC: Prototype has been worked.
  - μ-PIC
    - Principle operation has been checked with other resistive material.
    - Prototype production using carbon sputtering is ongoing.
- Carbon sputtering is very promising way for new structures of MPGDs!!