Carbon sputtering technology for ATLAS MicroMEGAS resistive

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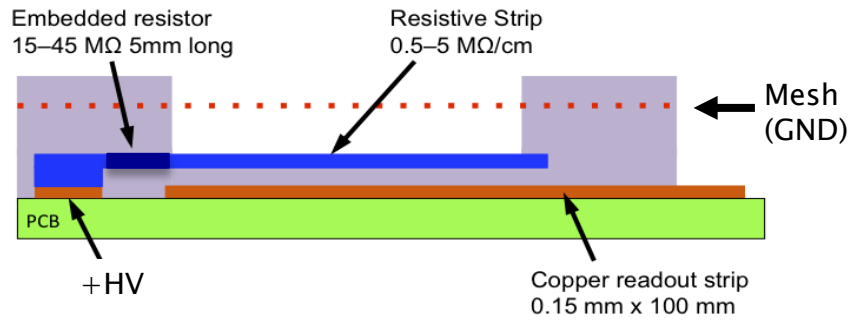
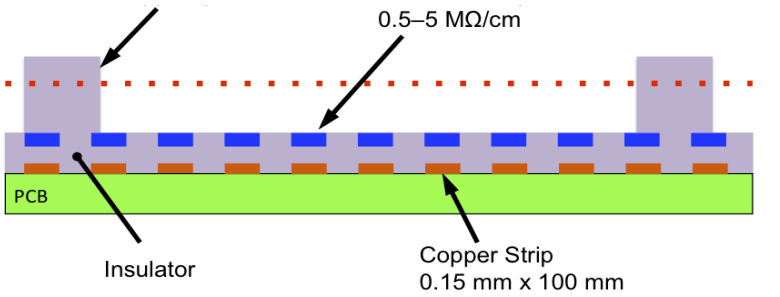
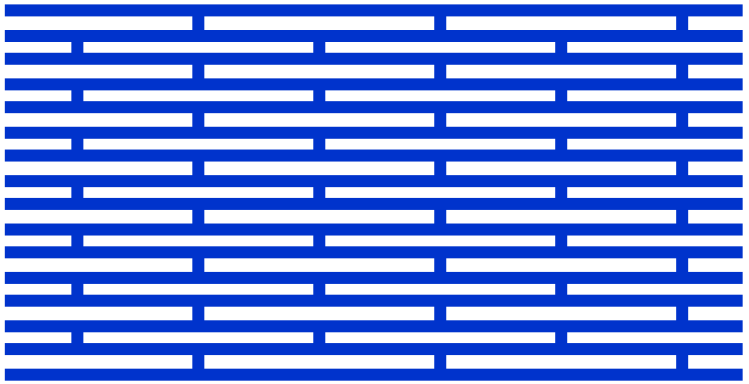
Requirements for ATLAS NSW MM

- 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





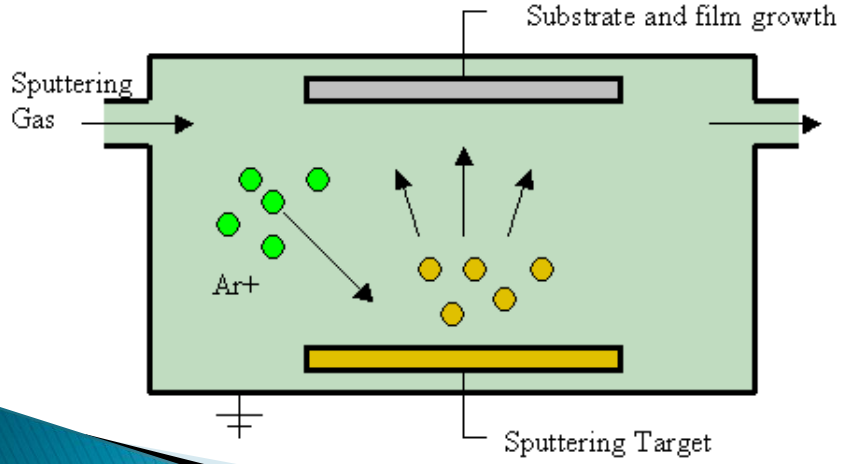


Two option for resistive electrodes

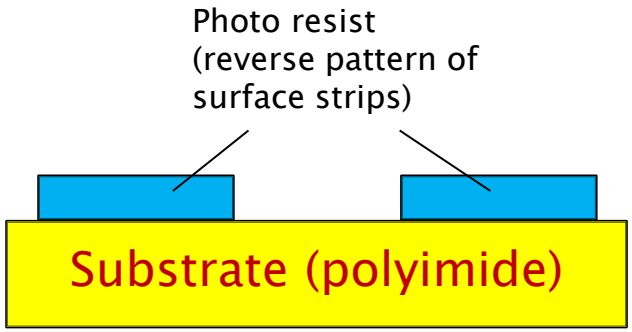
- Screen printing
  - Already several prototypes (@ CERN and Japan) has been produced.
  - Made from carbon loaded polymer.
  - Large size (>1m^2) is available
  - 400 μm pitch was available for MAMMA production.
- Carbon sputtering with liftoff process
  - New technique. (Since 2013)
  - Fine pattern (~10μm) is available.
  - Large size (>1m^2) is available in industrial facilities.
  - Production quality is very well.
    - It is not affected by production environment

Liftoff process using sputtering

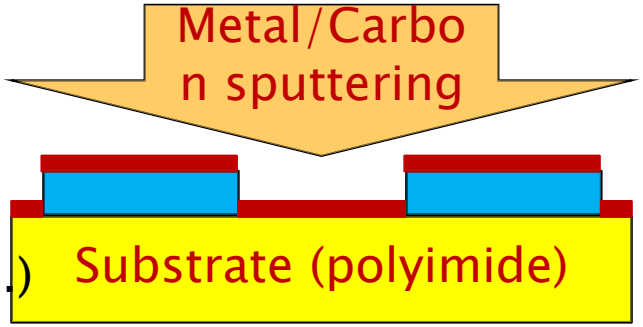
- Very fine structure (a few tens micro meter) can be formed using photo resist. (same as PCB)
- Surface resistivity can be controlled by sputtering material and their thickness



@PCB company (Laytech inc.)



@Sputtering company (Be-Sputter inc.)

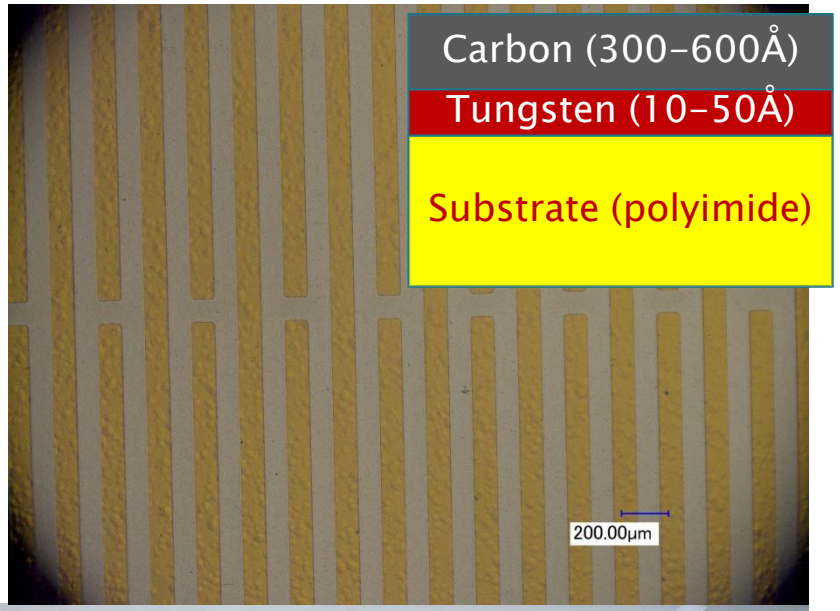


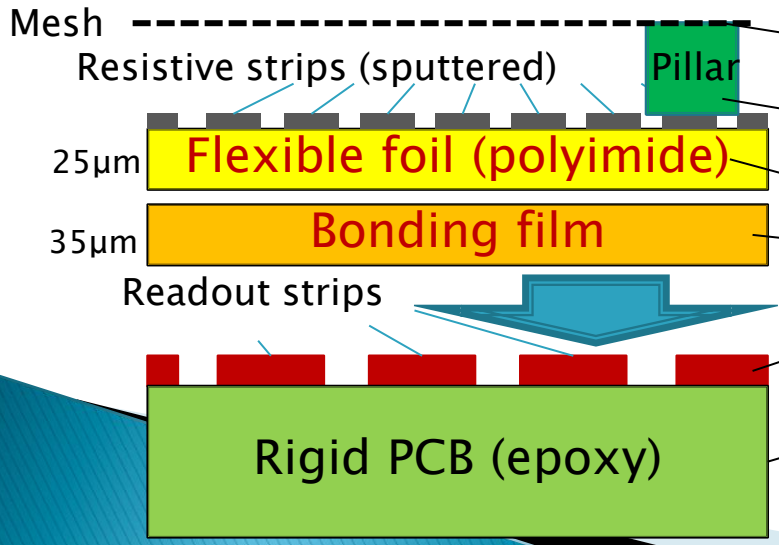
Developing the resists

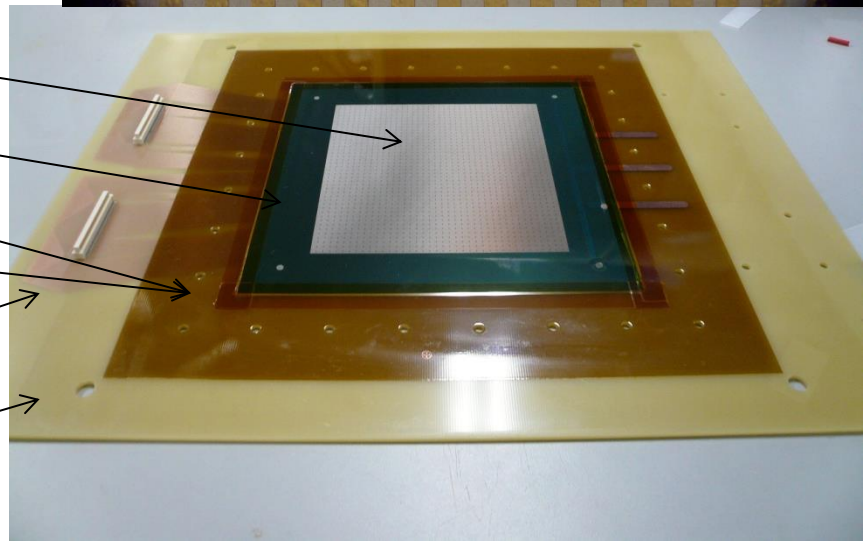
@PCB company (Laytech inc.)

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.

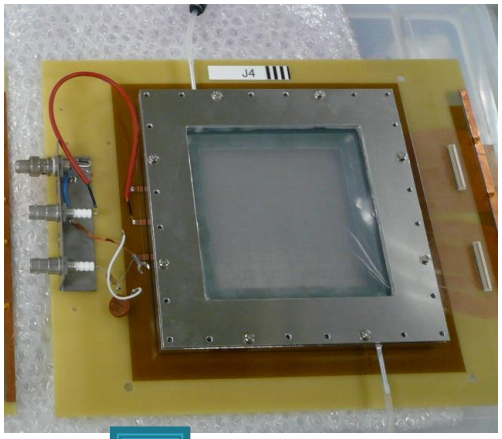


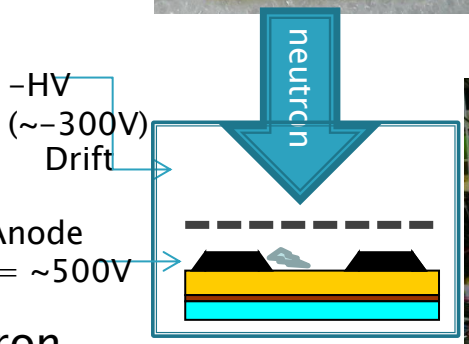


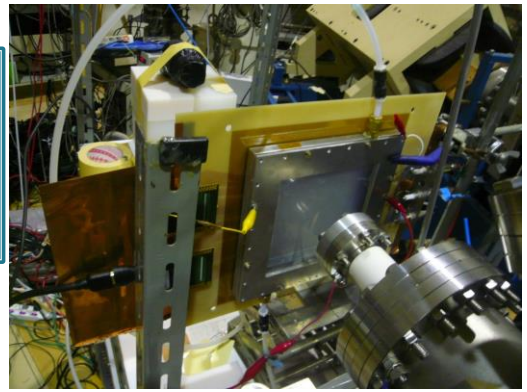


Fast neutron test

- 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.







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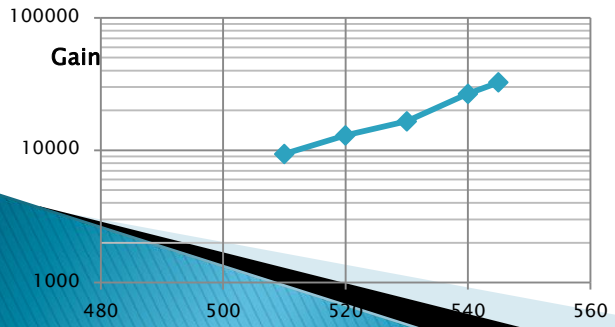
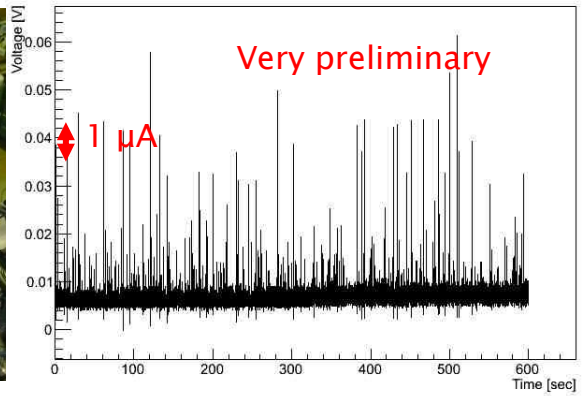
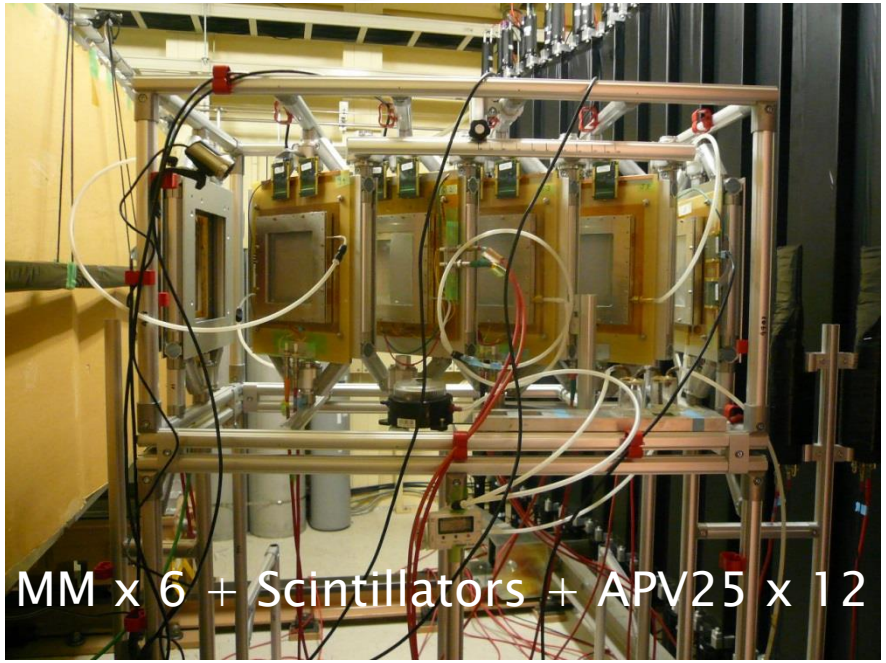


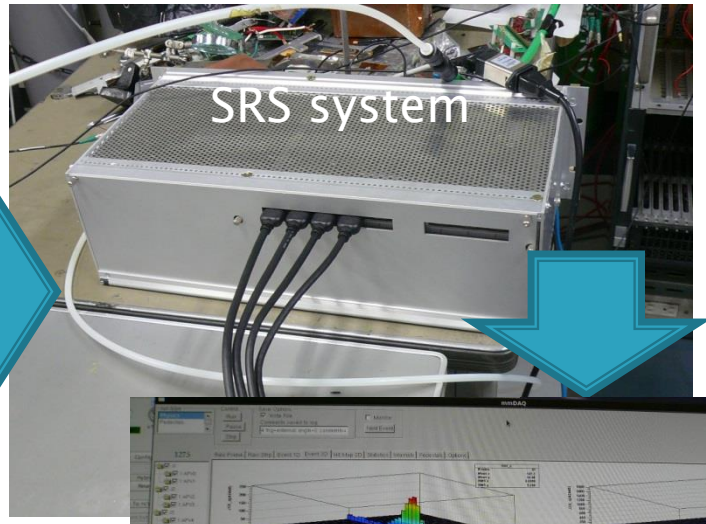


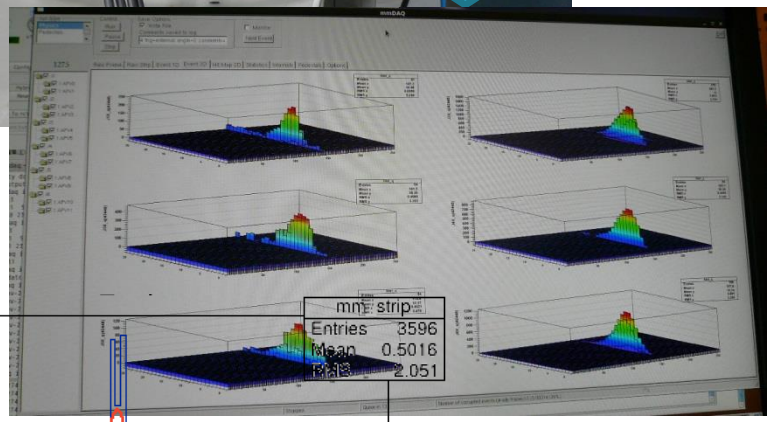
After sparks by neutrons

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

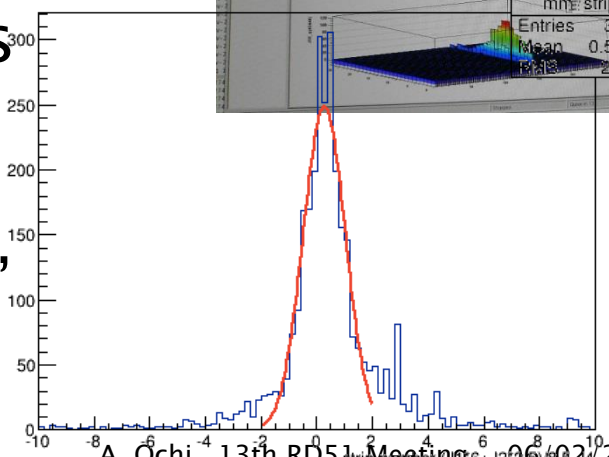
Charged particle tracking







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

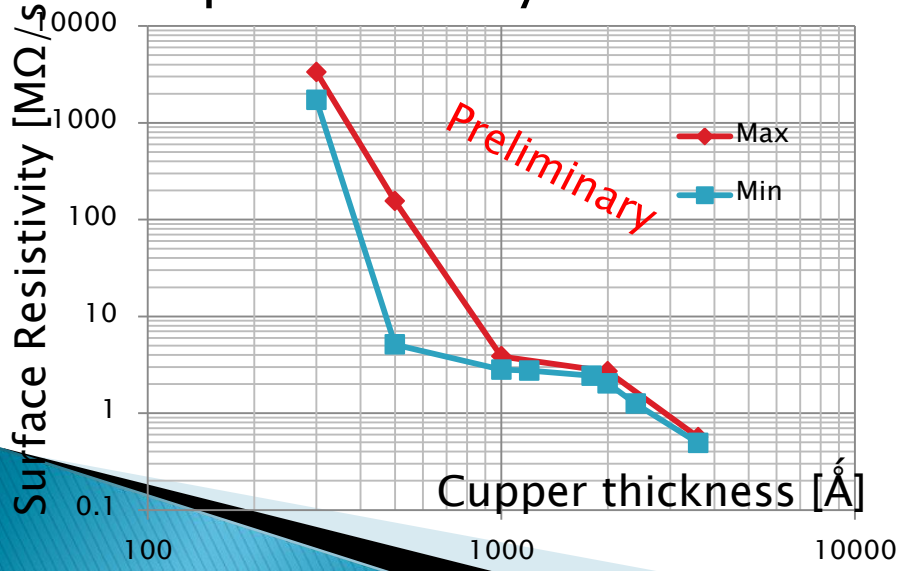


Further improvements and tests for carbon sputtering

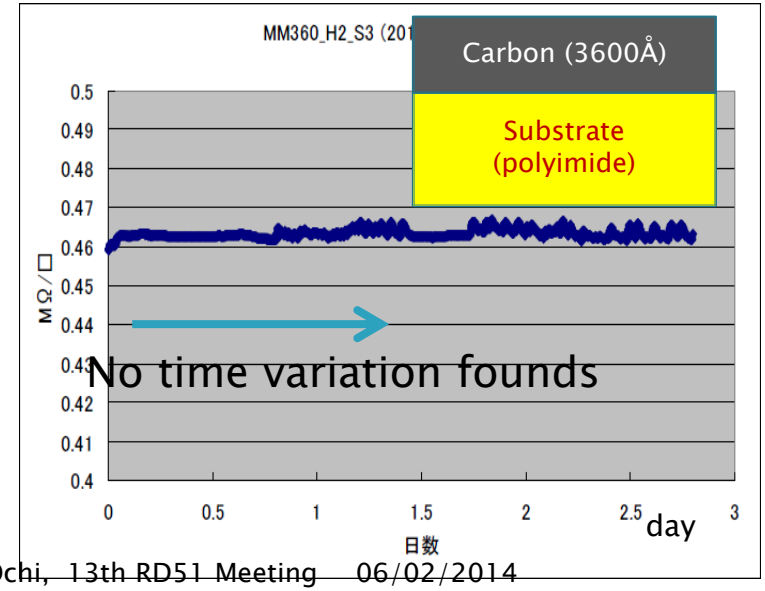
- Requirements for carbon strips
  - Resistive control
    - 20 MΩ/cm is required
      - It correspond to 600kΩ/sq. for 300μm line width.
      - Our first prototype has 10MΩ /sq.
      - Thicker carbon sputter is required
    - Long time stability of resistivity
      - The resistivity of early prototypes were growing up as time goes on (~2%/day)
      - It was thought that the oxidation of metal (tungsten layer)
      - Is the carbon sputtering without metal layer possible?
  - Mechanical / chemical robustness test
    - Peeling off property (cross cut method)
    - Resistive stability against the bending of the foil
    - Chemical stabilities
      - For alkali and acid, used for PCB process.

Resistivity and it's stability

- Resistivity dependence on carbon thickness
  - 300Å → 2GΩ/sq.
  - 3600Å → 500kΩ/sq.
  - Conductivity is not proportional to the thickness (t < 1000Å)
  - At t > 1000Å, good reproducibility found

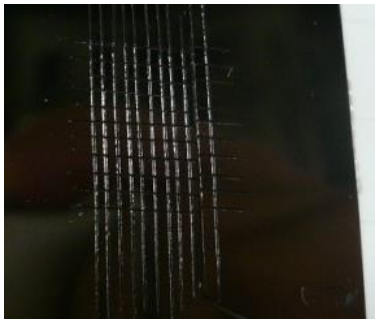


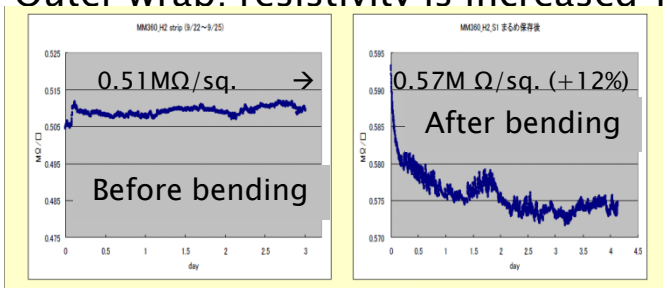
- New prototype: (delivered at September)
  - Carbon, 3600Å
  - Surface resistivity ~ 500kΩ/sq.
  - No time variation founds after several days from sputtering



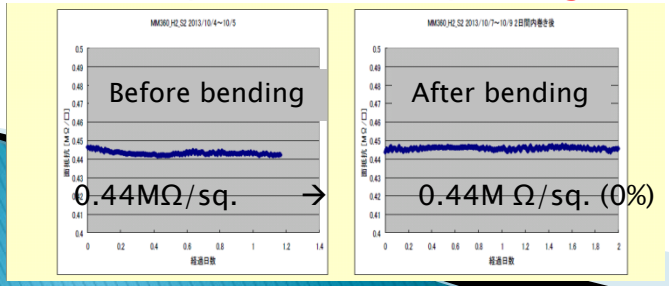
Mechanical robustness for thick sputtering carbon

- Adhesion test
  - Cross-cut test (JIS k5400-8.5 standard, similar to the ISO 2409)
  - No peeled carbon founded
- Bending test
  - Bending diameter > 4cm → No resistivity change found
  - Jackknife bending → Conductivity is lost
  - Bending diameter = 1.2cm → Outer wrap: resistivity is increased 10-20%



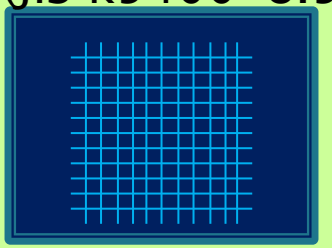


→ Inner wrap: no resistivity change

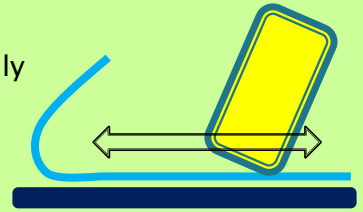


Cross-cut test (JIS k5400-8.5)

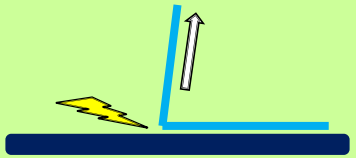
Making cut lines as grid (11 x 11, 1mm pitch)



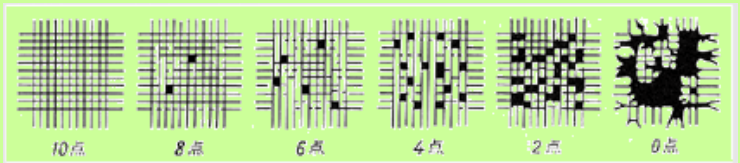
Tape up the foils strongly



Peel off the tape at once



Observe the tape and foils.

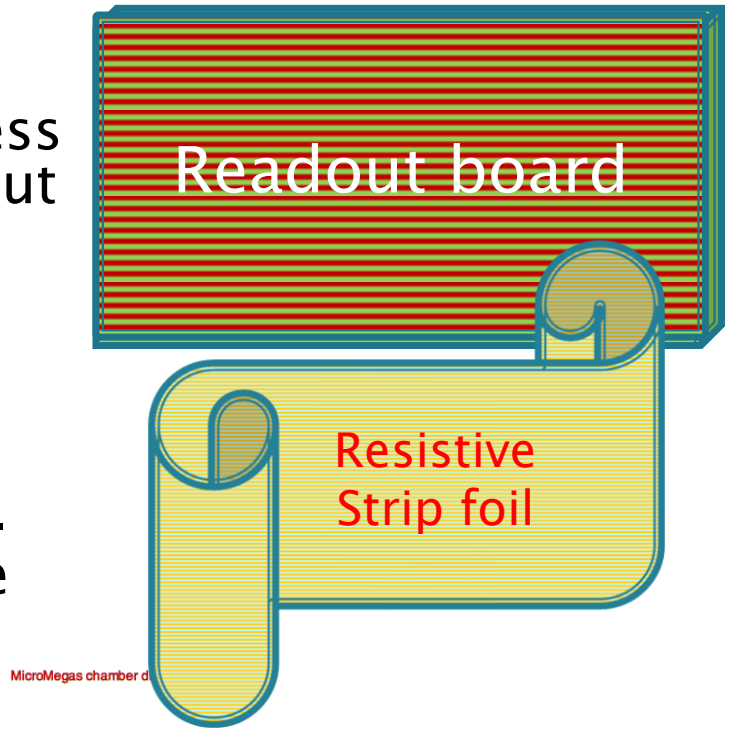


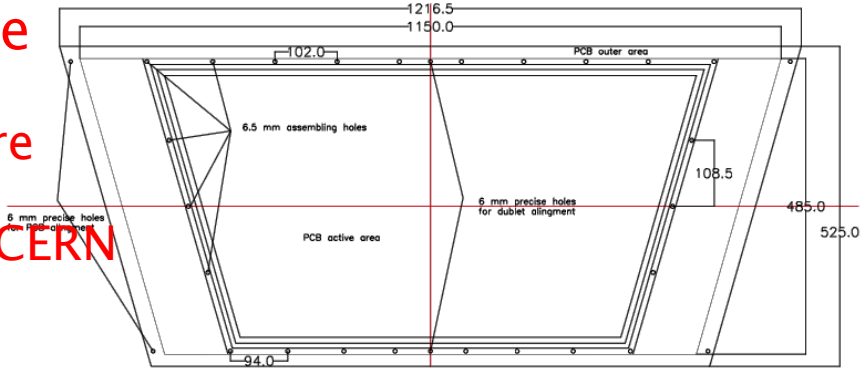
Chemical robustness for new sputtering carbon

- Acid and alkali for PCB processing
  - Hydrochloric acid
  - Nitric acid
  - Sulfuric acid
  - Sodium carbonate
    → No damage on sputtered carbon
  - Sodium hydroxide
    → No damage for short dip
    → Peeling is found after 90 minutes dipping
- **Almost all process of PCB production will not affect to the sputtering carbon**

Prototype of large MMs

- We can divide the production process of resistive strip from that of readout board.
  - Resistive strip is formed on thin foil
  - We don't need fine alignment between resistive strips and readout strips.
- Dividing those processes will make the yield of production growing up.
- We are preparing the large resistive strip foil.
  - Size of foils: 500mm x 1000mm
  - 4 foils are need for a quadruplet
- 8 Foils (4 foils and 4 spare) were delivered to us at 25th October.
  - Some basic resistive parameters are checked.
  - Those have been already come to CERN





For patterning process

RAYTECH

- PCB company
  - They are expert for FPC (Flexible Printed Circuit) production.
  - Liftoff is basic process for FPC production

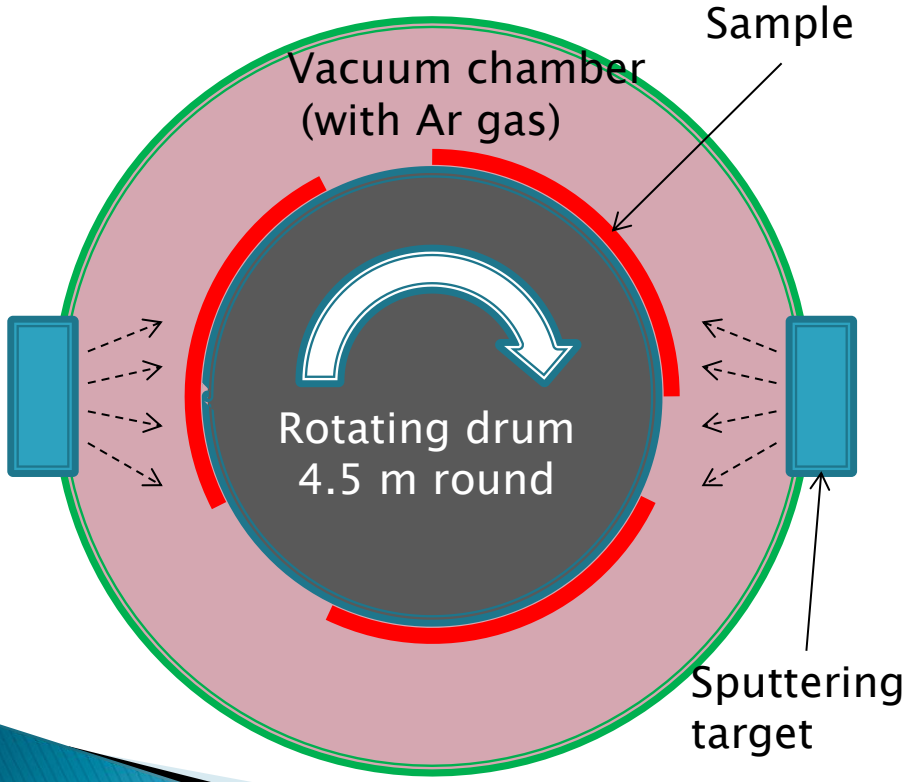
Exposure machines in clean room

Electro forming machines

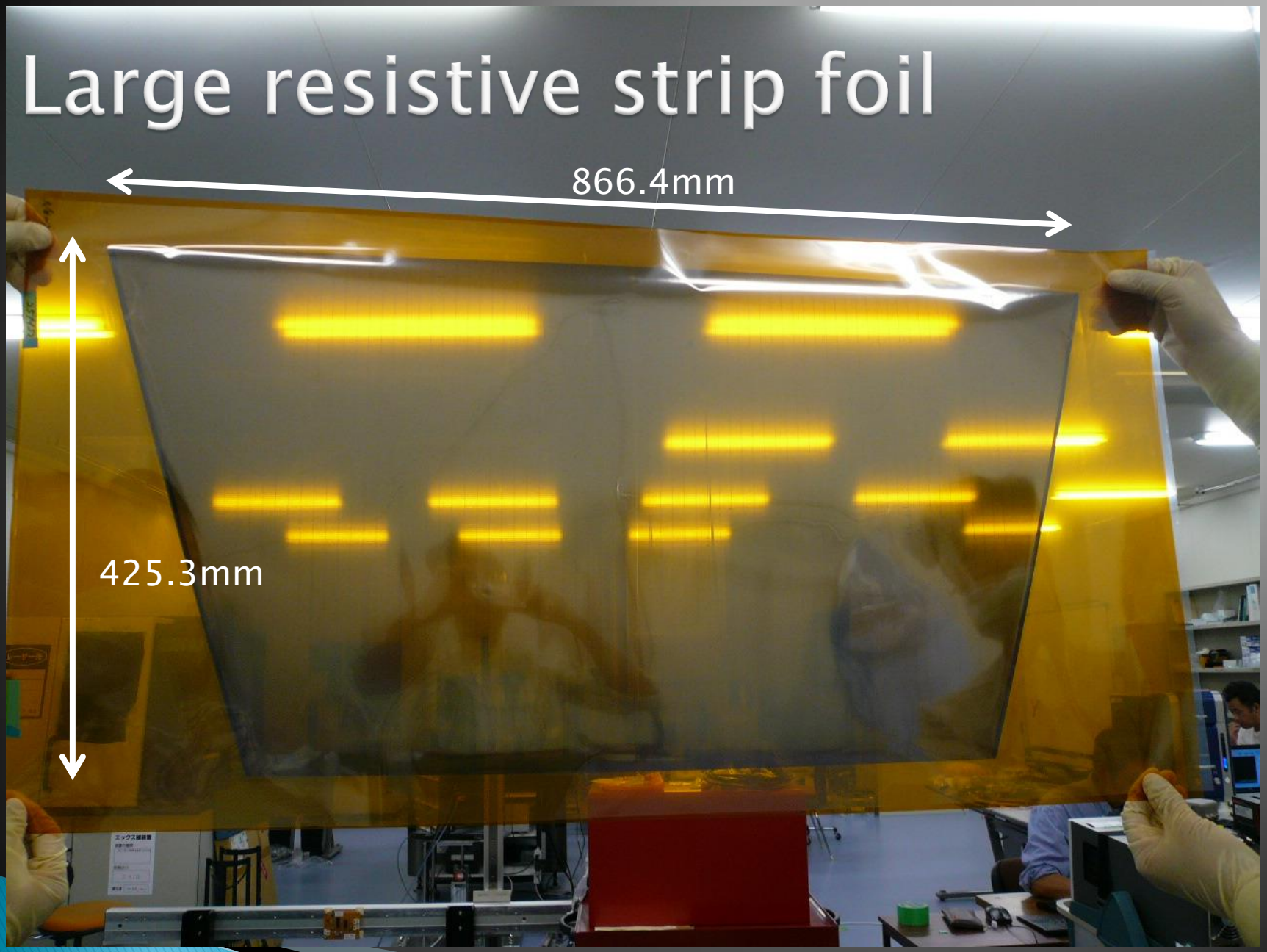
Etching machines

Sputtering facilities

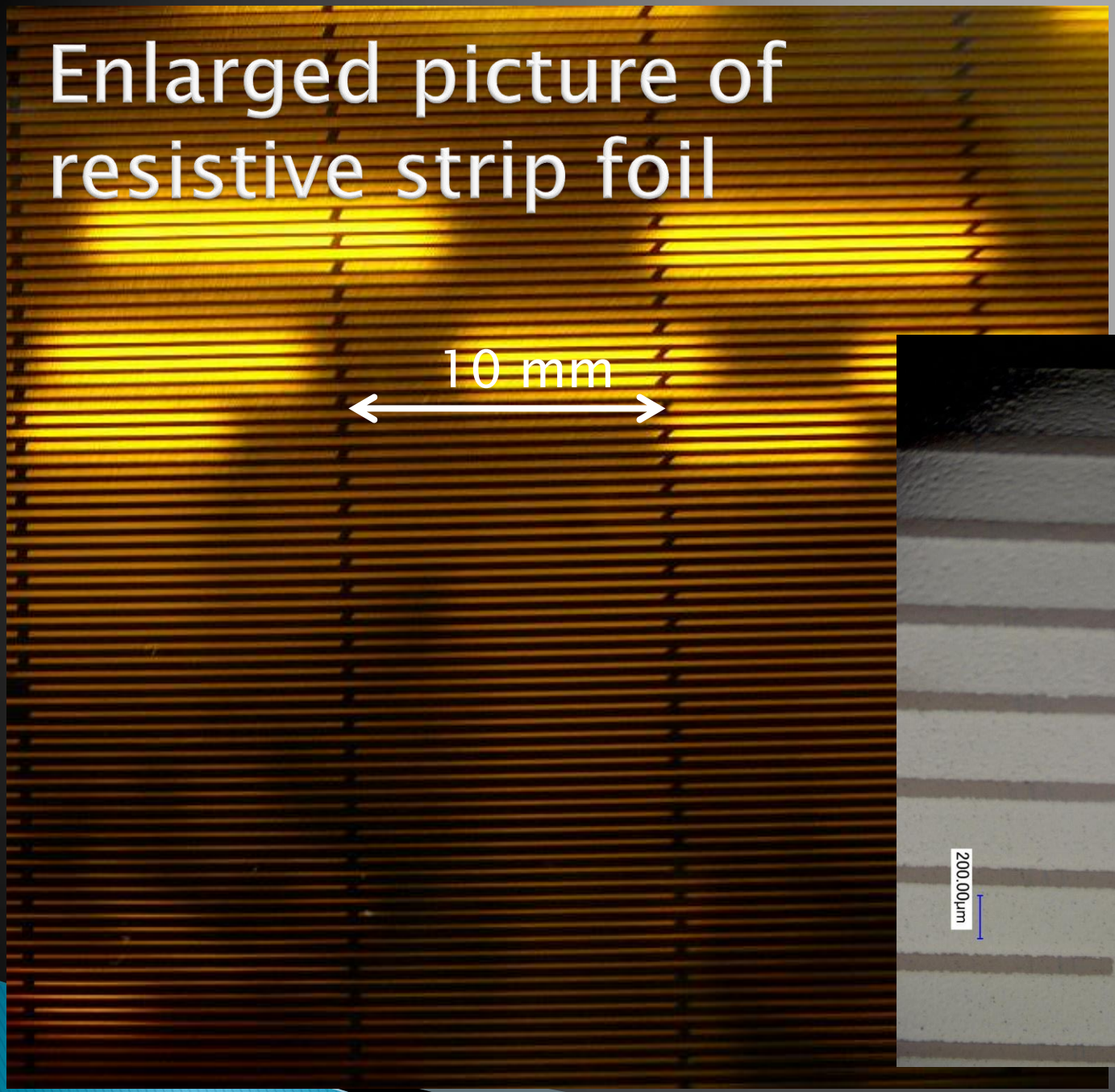
- Large size sputtering is available
  - 4.5m x 1m for flexible film

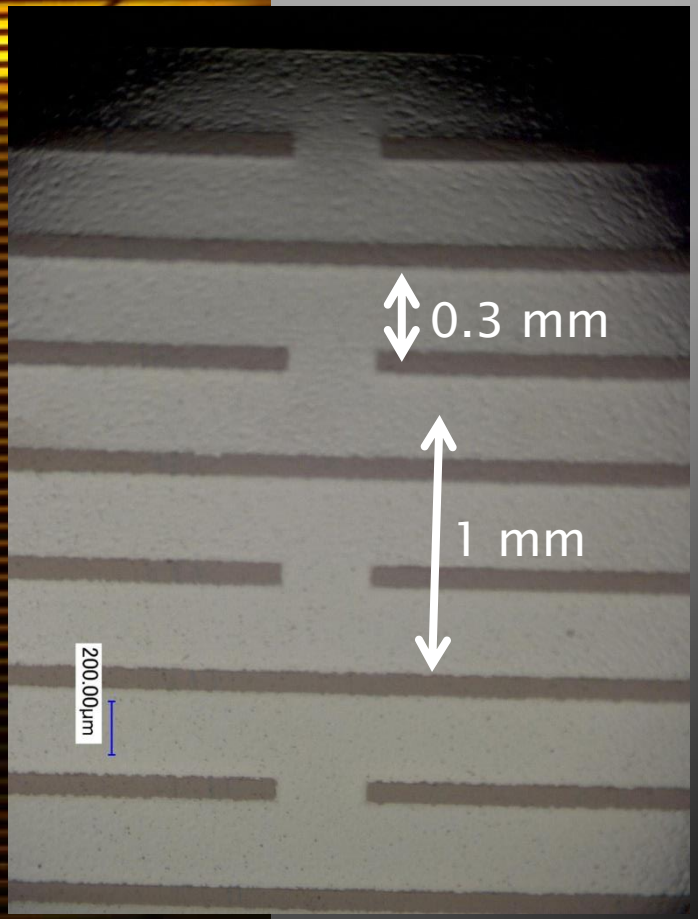


Large resistive strip foil



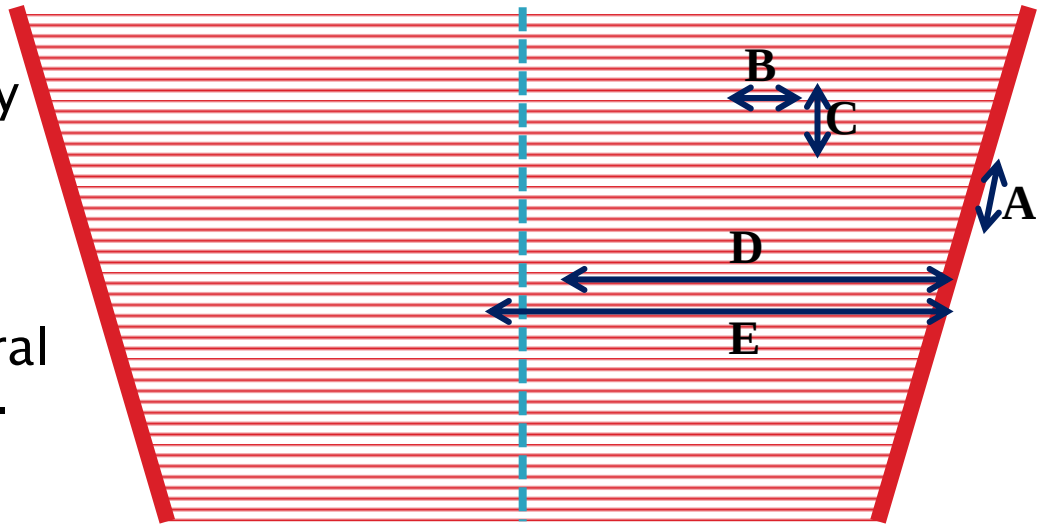
Enlarged picture of resistive strip foil





Resistivity check

- We have no systematic way for resistivity test yet, so these results are based on rough measurements.
- However, we have check surface resistivity on several points for 8 foils as figure.
- The prove has about 2cm width.
- Distance between proves are, A,B,C: 1.5-2.5 cm, D: 30 cm, E: cross over a center line.
- "Inf" means more than 50MΩ.

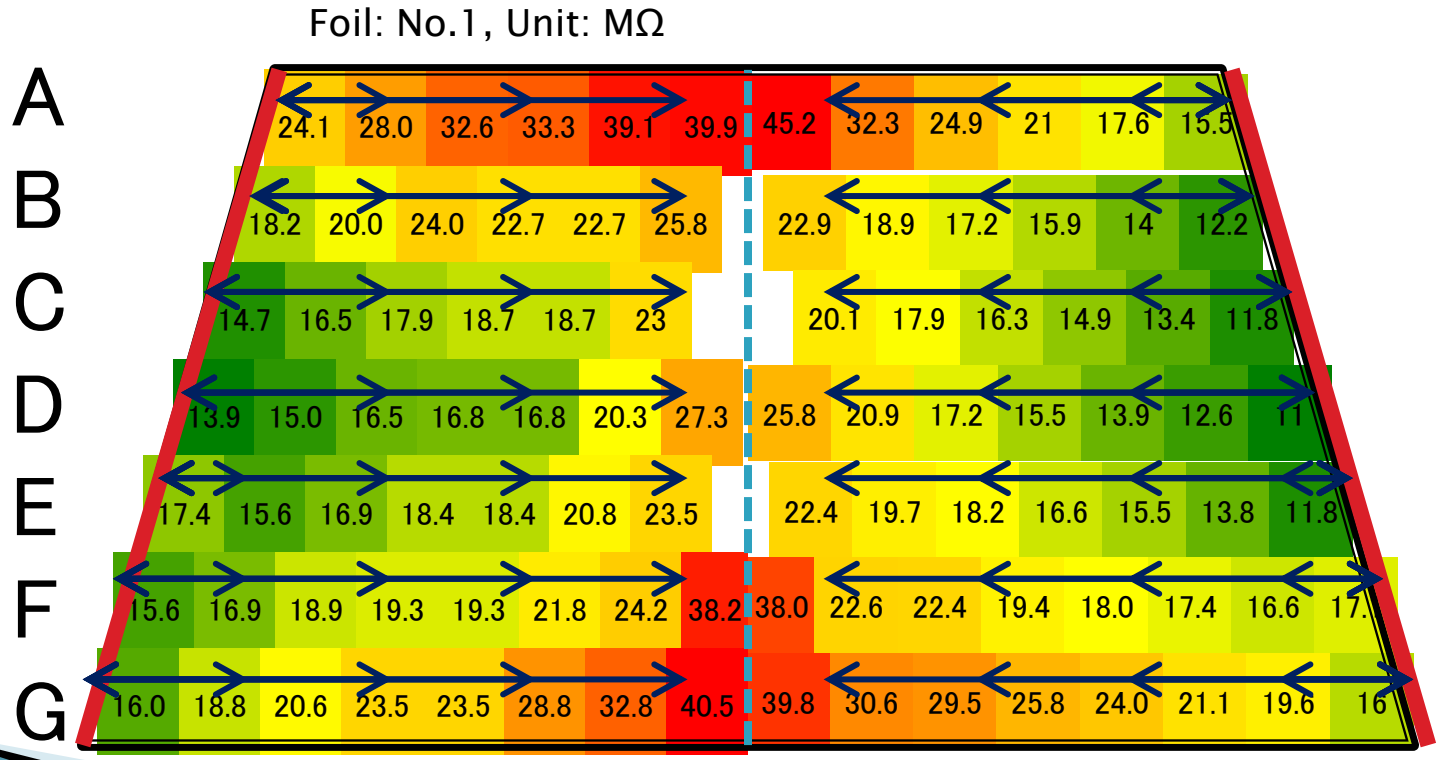


Unit: MΩ

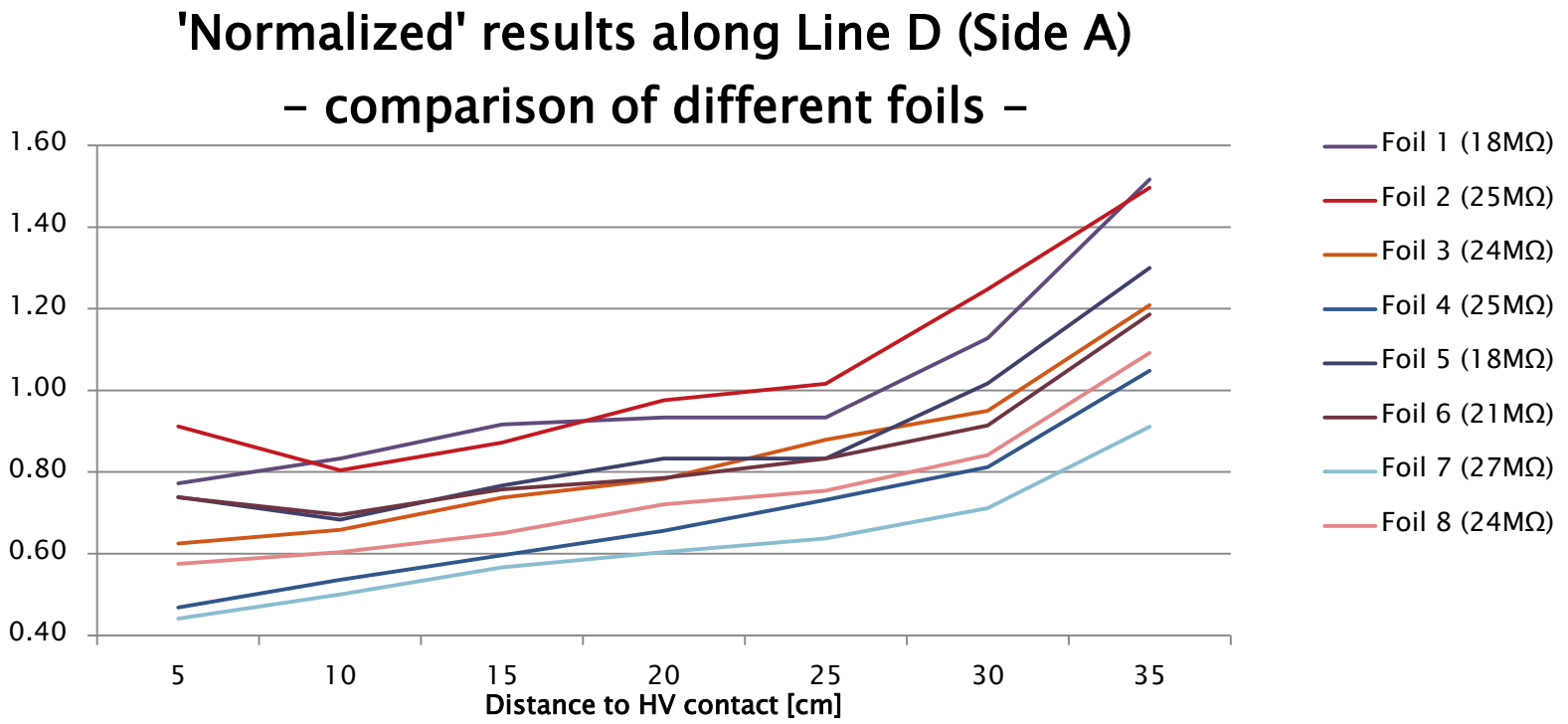
No.	A	B	C	D	E
1	1.4	4	15	6	Inf
2	2.7	2.2	15	9.5	Inf
3	1.5	2.2	13.1	8.3	Inf
4	2.8	1.5	11	6.6	Inf
5	2.2	1.8	10.5	6.3	Inf
6	1.9	2.1	10	6.9	Inf
7	2.5	2.3	10.6	7.4	Inf
8	2.4	2.5	12.3	7.3	Inf

Resistivity check

- Resistivity from edge to lattice point (5cm x 5cm) were measured (by Fabien Kuger).



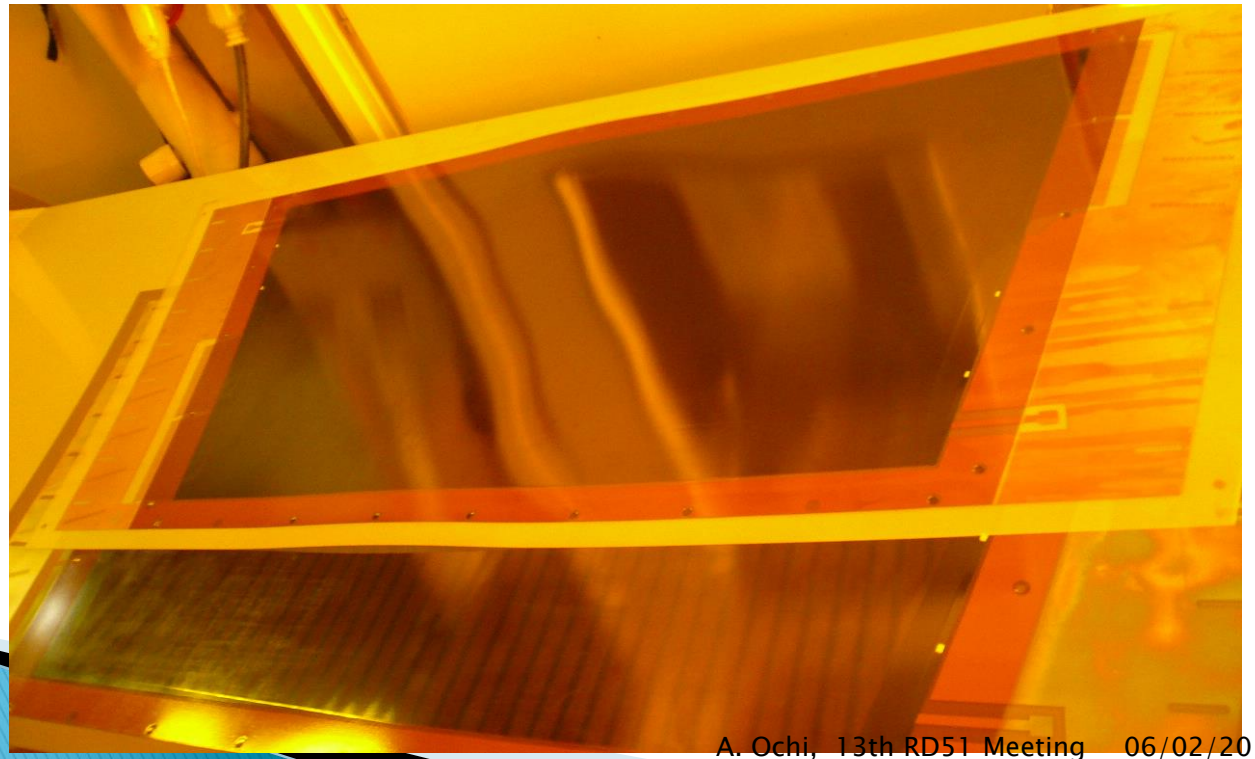
Comparison of different foils



- Variability of ~ 30% were found for different foils
  - Reducing it is one of future issue

With readout board

- 4 foils are attached to readout board successfully (at Rui's workshop)
  - For making quadruplet prototype (MSW)
  - Resistivity did not change after gluing
- Pillars will be formed soon



Conclusion

- Sputtering technology is very promising for making MPGD resistive electrodes
  - Fine structure (~10μm)
  - Large area (a few meter)
- Prototype of MicroMEGAS using sputtered resistive electrodes were produced and tested.
  - It works as same as conventional resistive strip MicroMEGAS
  - Gain curve, operation in HIP were tested. It's OK.
- Carbon sputtering process is improved for ATLAS MicroMEGAS
  - Appropriate resistivity ~ 500kΩ/sq with thick (3600Å) sputtering.
  - Good mechanical/chemical properties
- Large resistive strip foils (0.5m x 1m) are produced for functional prototype (MSW).
  - Qualitative resistivity check is ok.
  - The foils are already put on the readout board.
  - No resistivity change found before/after foil gluing.