

A Thermal–Bonding Method for Fabrication of Micromegas and its applications

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La Rochelle, France

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Outline

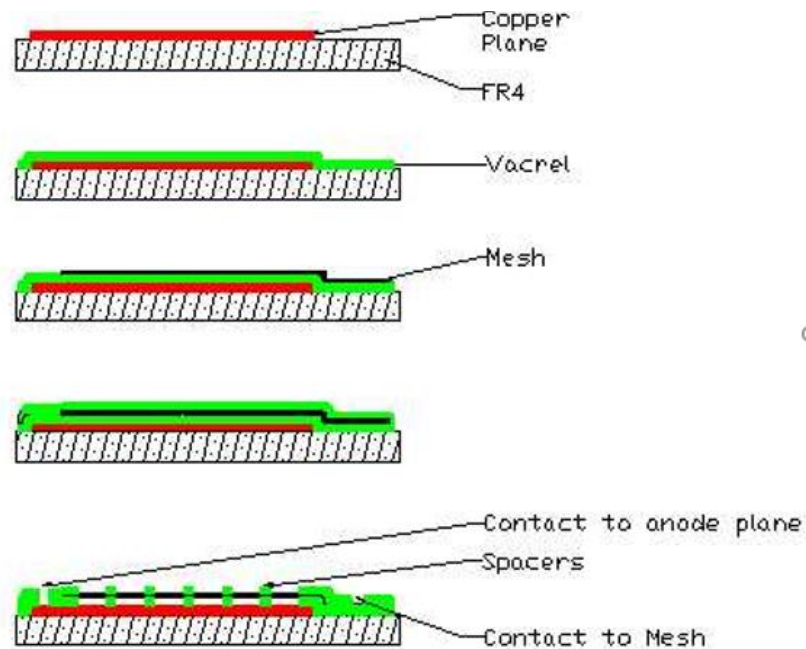
- Thermal-bonding method
 - Fabrication process
 - Materials and Specifics
- Resistive anode
 - Resistive paste, Germanium film
- Performance of TB-Micromegas
- Towards large area
- Applications
- Summary

Thermal-bonding method

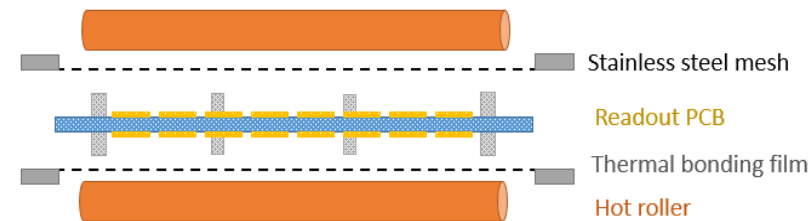
Micromegas: A very popular and mature MPGD

Very small avalanche gap without insulator: fast signal, no charge-up, high rate, good spatial and time resolution ...

Micromegas in a Bulk

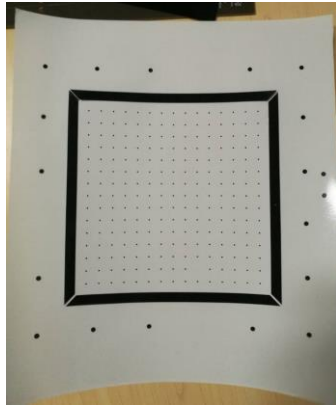


Thermal bonding processing



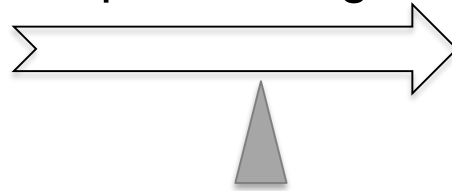
- No etching, no pollution
- Easy to handle at lab
- Easy to make new structures
- Cheap
- $\Phi 0.5\text{mm}-\Phi 1\text{mm}$ spacers, $\sim 1\text{cm}$ pitch
 - easy to clean, especially for large area
 - less than 1% spacer area

Fabrication process

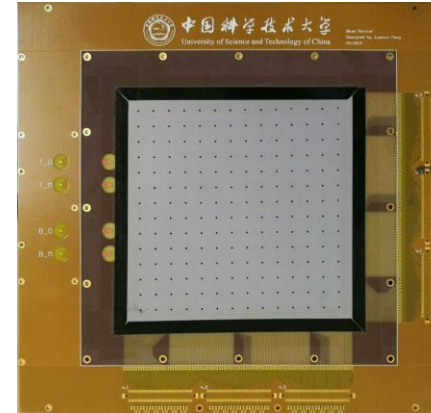


Making spacers on a
release-paper substrate
laser cutting

Transferred to PCB by
pre-heating

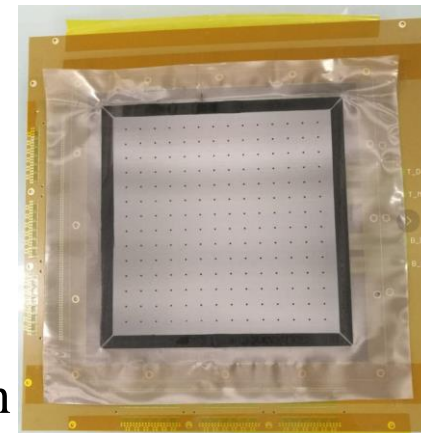
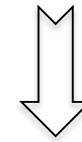


A hot roller

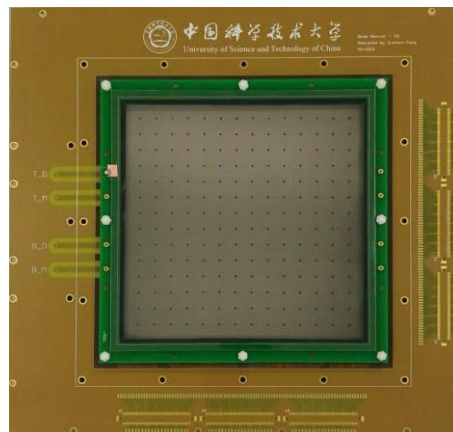
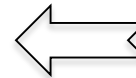


- $\Phi 1\text{mm}$ spacer
- 10mm spacer pitch
- 150mm \times 150mm

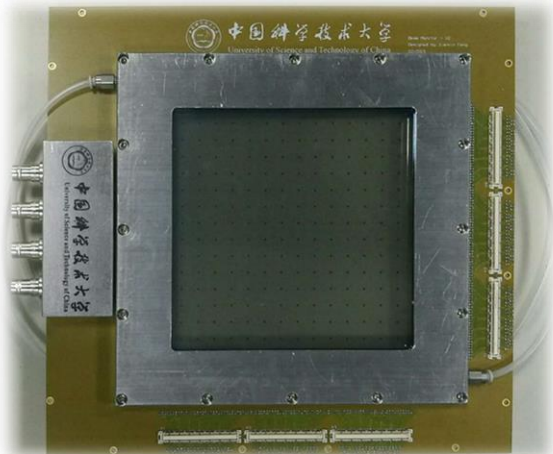
Thermal bonding



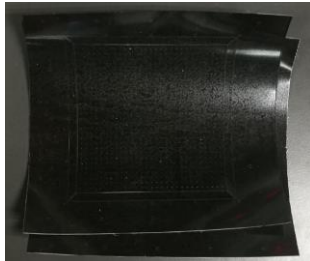
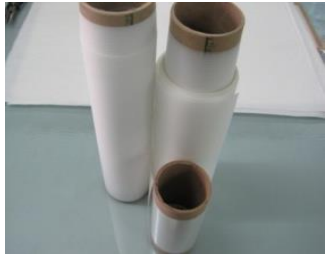
Cutting mesh



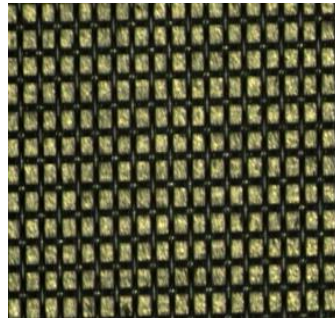
Assembling



Materials and Specifics



Thermo-bond films with a dry (hot-melt type) adhesive on both sides.
A variety of specifications to choose.



Abundant types to choose:
Thickness: 20-40 μ m, Density: 260-640 LPI
Opening rate: 30-70%, Tension: up to 30N/cm



Pure germanium Graphite target

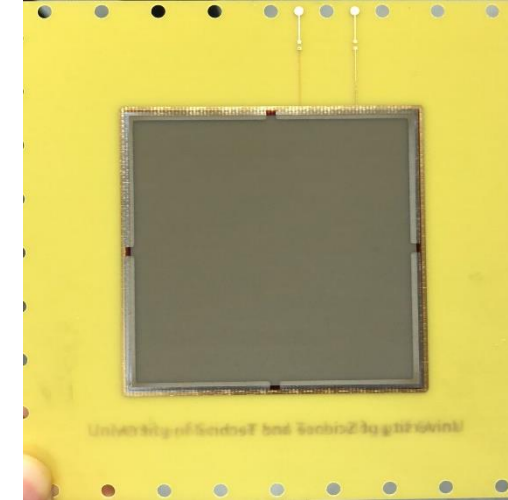
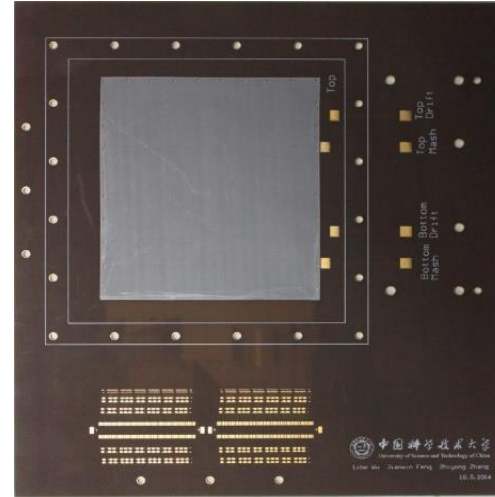
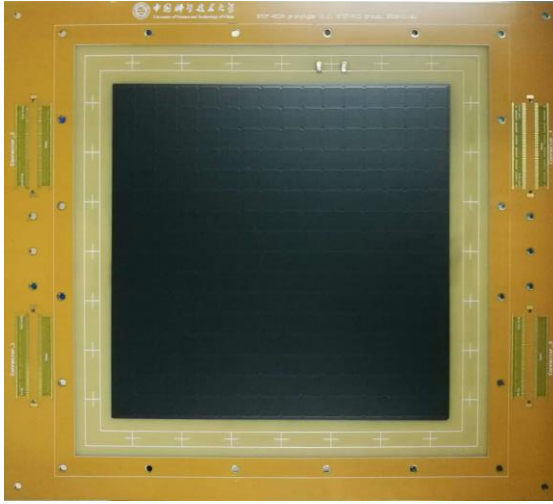
Resistive paste



Resistive anode:

- Resistive paste printing: $k\Omega/\square$ - $200M\Omega/\square$
- Germanium coating: $M\Omega/\square$ - $200M\Omega/\square$
- DLC, **now is a super star in MPGDs!**

Resistive anode



resistive paste by screen printing:
10-20 μm

- o Complex pattern
- o Large area
- o Low Cost
- Δ High temperature curing
- Δ Controllability for resistivity
- ? Sputtering up

Ge film by thermal evaporation
coating: 0.1-1 μm

- o Controllability for resistivity
- o Purity for low background applications
- o Large area
- Δ Complex pattern
- ? Irradiation hardness & aging

DLC deposited by magnetron
sputtering:

an attractive alternative
(every knows)

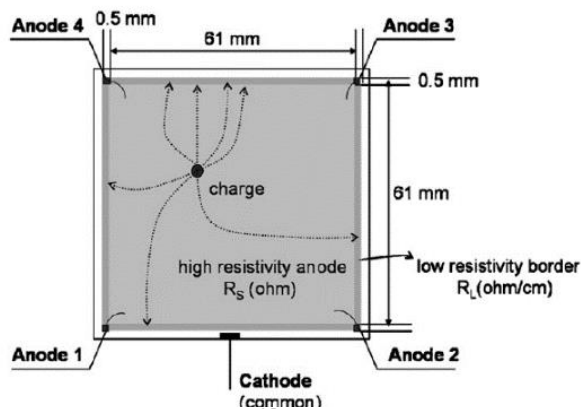
I will focus on the RP &
Ge film.

Resistive paste

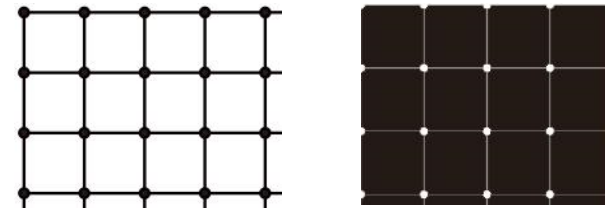
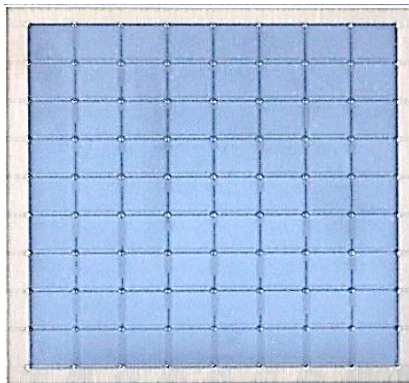
Easy to make Complex pattern

- Micromegas with four-corner readout to reduce number of readout channels while maintaining reasonable spatial resolution.
- Developed for the **readout panel of the RICH detector**

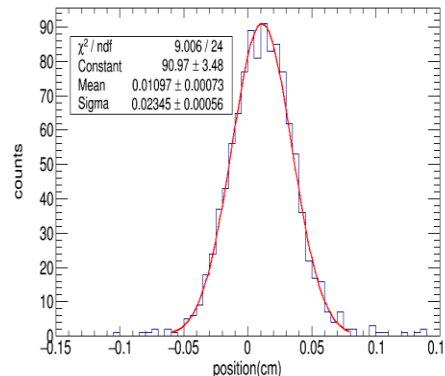
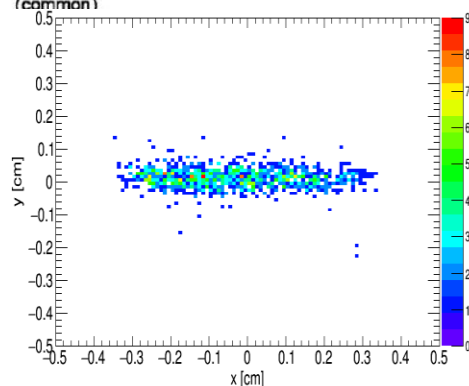
4-corner readout concept



A 10 cm × 10 cm readout PCB for Micromegas



- cell-size: 1 cm × 1 cm
- Grid with ~1 k Ω /□ low resistivity
- Pads with ~100 times higher



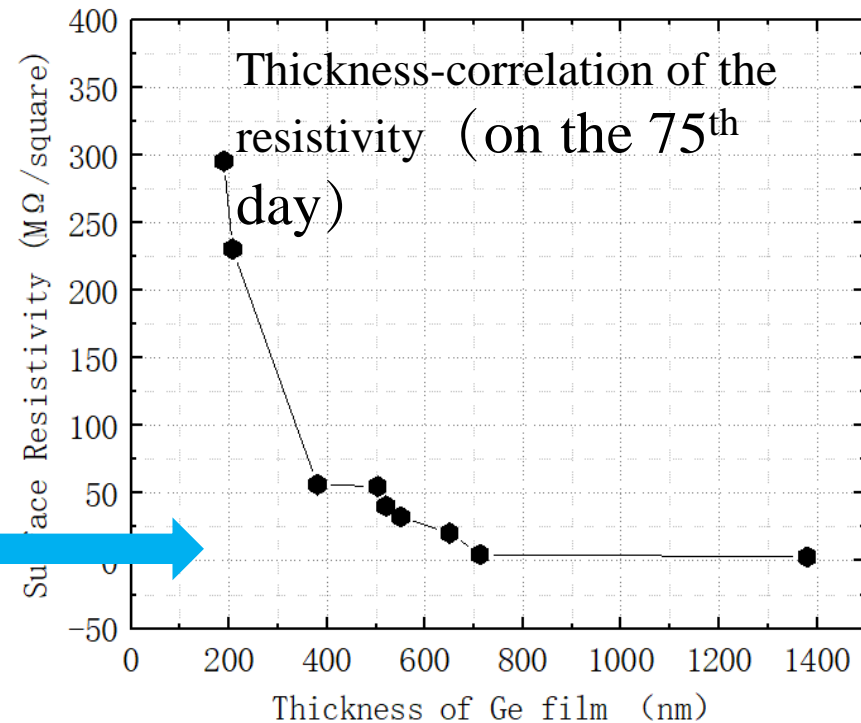
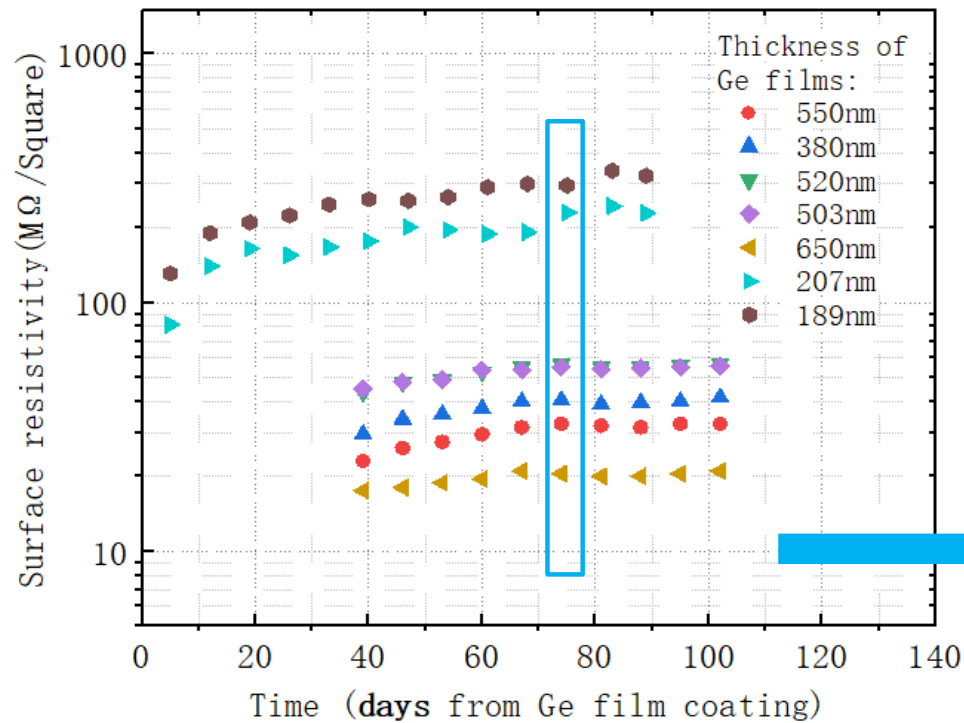
Sigma = 235 μ m, Better than 1mm² granularity pixel readout.

Spatial resolution measured with X-rays

Ge film

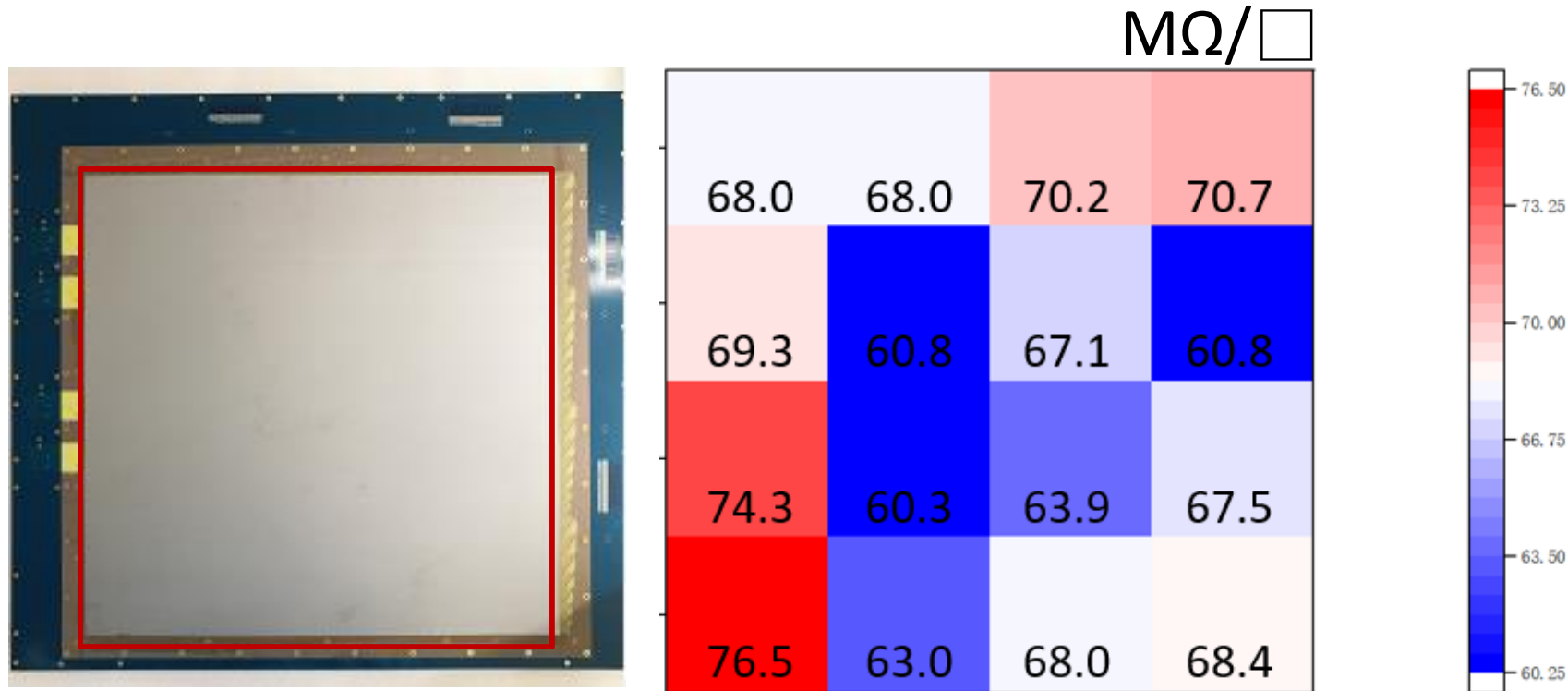
Long-term stability & thickness correlation:

- ✓ Coated on FR-4 substrate;
- ✓ 200 nm to 1400 nm;
- ✓ >100 days monitoring (In the laboratory environment) ;



Ge film

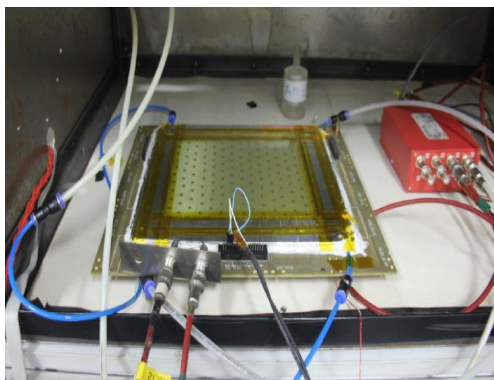
Non-uniformity of the resistivity: **400mm × 400mm**
coating area, **500nm**;



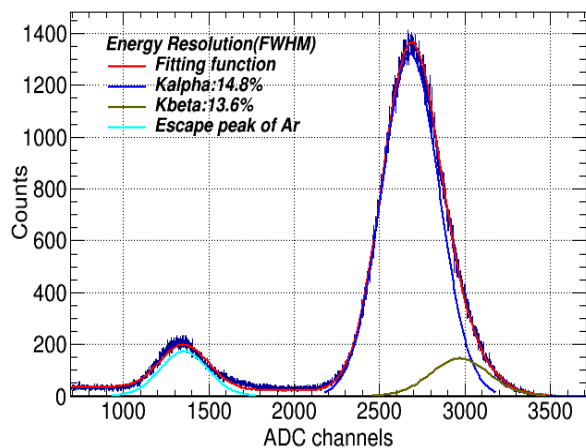
Non-uniformity : $\text{RMS}/\text{mean} = 4.65/67.4 = 6.9\%$
Better results are desirable after optimizations.

Performance of TB-Micromegas

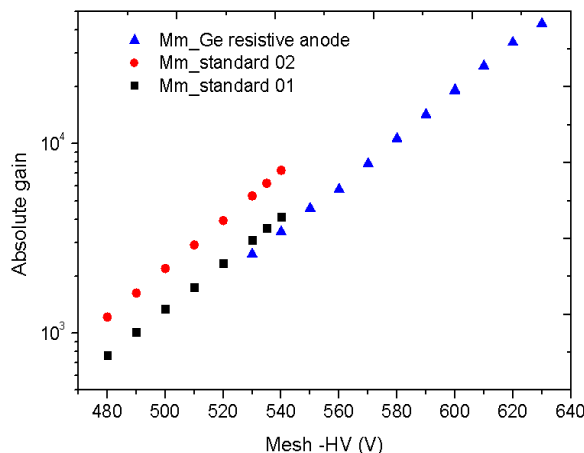
A $20 \times 20 \text{ cm}^2$ Micromegas with Ge anode



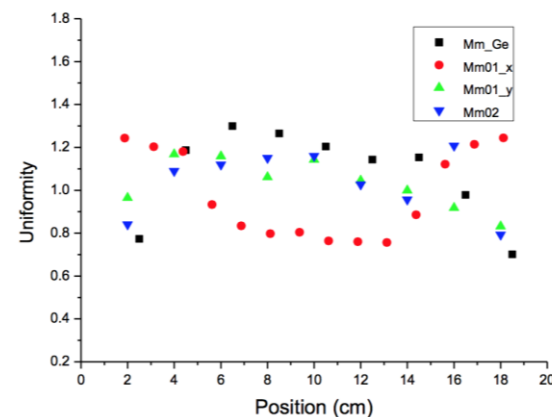
- Good energy resolution for 5.9keV x-rays: **14.8% (FWHM)**
- High gain up to 4×10^4
- High rate capability: up to 10^6 Hz/cm^2



^{55}Fe x-ray spectrum



Gain v.s. mesh voltage



Non-uniformity: $\pm 30\%$

Towards large area

Some key techniques are already available:

- ❑ **Spacer setting**: laser cutting and pre-heating
- ❑ **Resistive anode**: m^2 scale can be achieved by screen printing RP & Ge coating
- ❑ **Mesh bonding**: A thermal bonding machine (30 cm width) is developed.

Laser dicing
for spacers



5 hours to prepare $1 m^2$ area

Screen printing with 0.2
mm accuracy for pattern



Resistive anode up to m^2 scale

Vacuum chamber
for evaporation



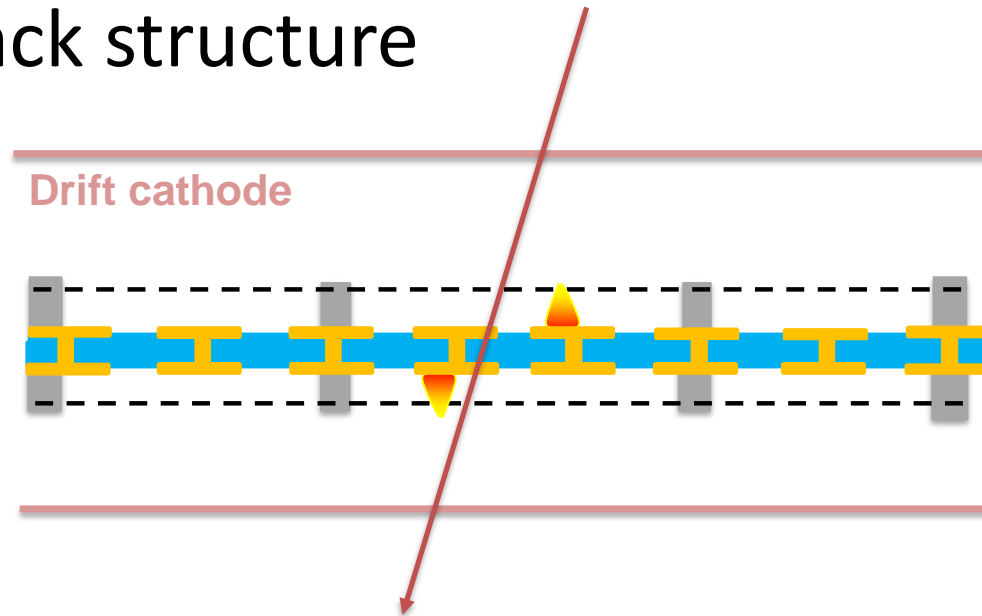
Hot roller for
thermal bonding



30 cm width available,
1m will come soon.

Applications: New structure-I

- Back to back structure



- Double meshes cancel out tension on PCB
 - no support materials
- Time resolution should be improved by a factor of 2.
- Good for efficiency
- A good two-dimension tracker

A 4-layer tracking system has been built to study on this structure with cosmic rays.

Applications: New structure-II

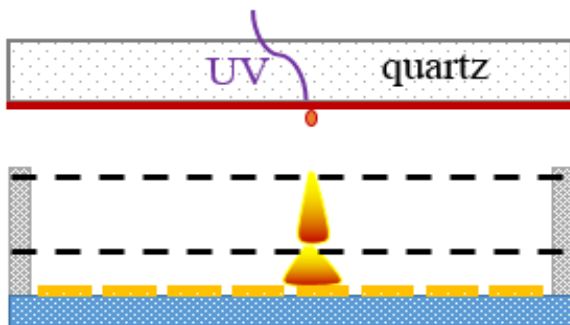
DMM performance:

Low IBF ratio: $<0.03\%$ (optimized)

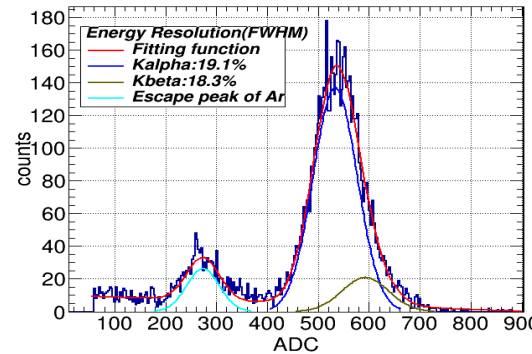
High gain up to 3×10^6 for S.P.E.

See Jianbei's talk and the publications below.

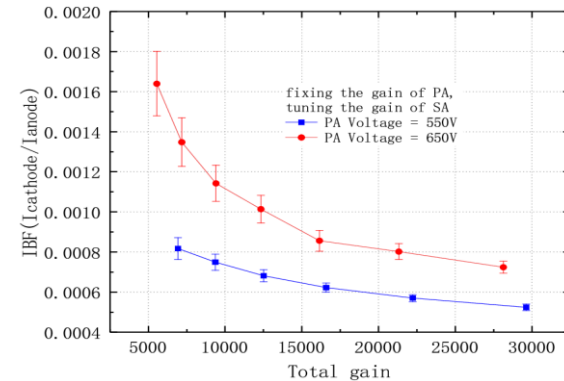
$<0.01\%$ IBF was observed with a TMM prototype.



A 5.9keV x-ray spectrum

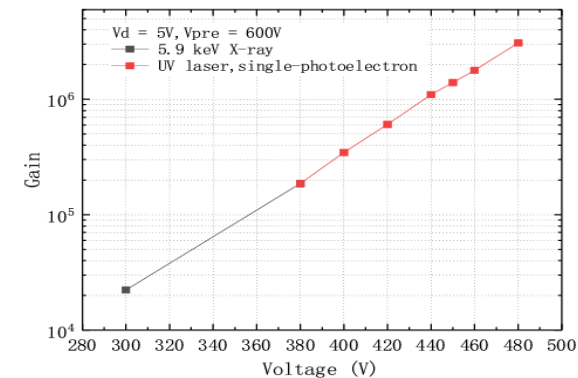
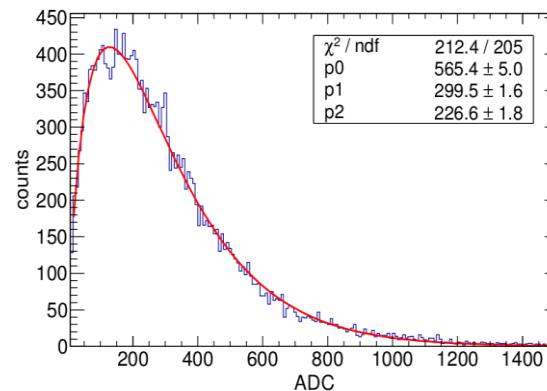


~ 0.0005 IBF ratio



Typical pulse height spectrum of single electron

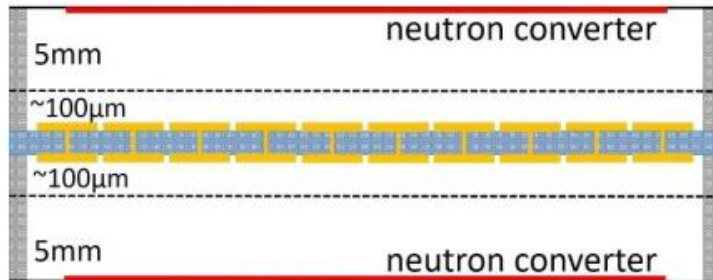
3×10^6 high gain for single photoelectron



- A high-gain, low ion-backflow double micro-mesh gaseous structure for single electron detection, *NIM-A*, 889 (2018) 78–82.
- Study on the double micro-mesh gaseous structure (DMM) as a photon detector, <https://doi.org/10.1016/j.nima.2019.03.033>

Applications: neutron detector

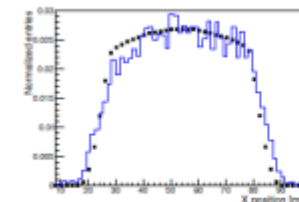
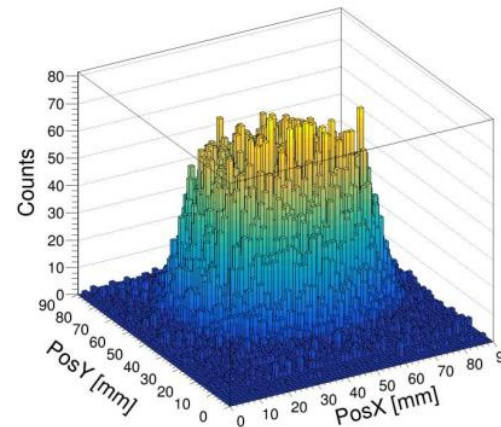
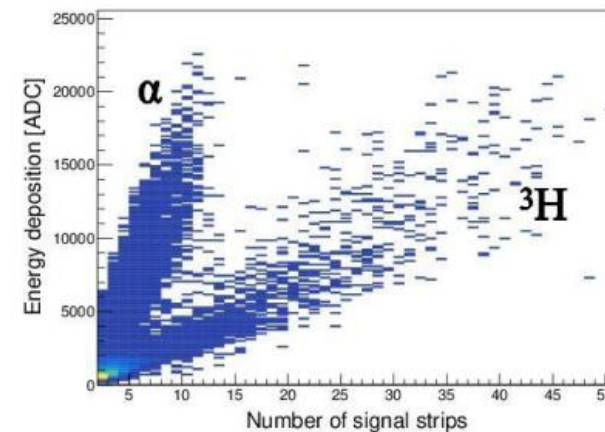
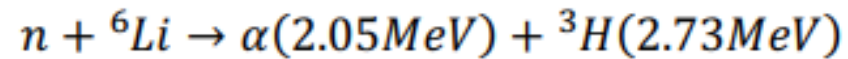
Beam monitor for the “Back-n” white **neutron beam** line at the Chinese Spallation Neutron Source



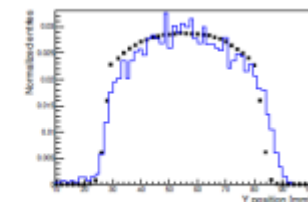
Detector structure



Micromegas and AGET electronics



Projection on X



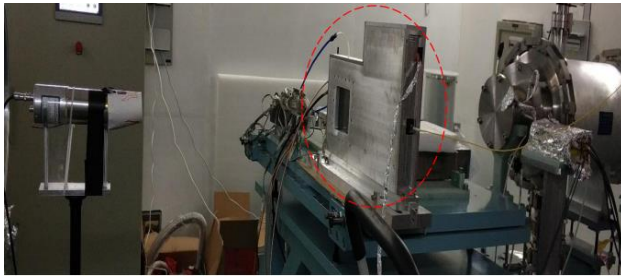
Projection on Y

Good consistence between MC and measurements

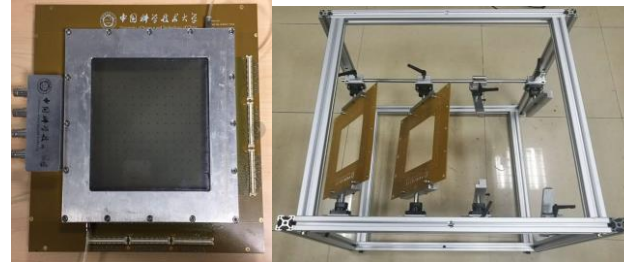
2D neutron beam profile was measured for the first time at the CSNS

Applications: more potentials

Again For Back-n of CSNS



Drift chamber for nuclear fission

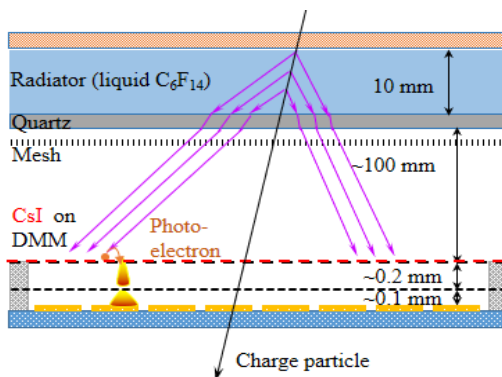


Beam monitor for charged particle



Tracking system for muon imaging research

R&D for future colliders (STCF, CEPC, etc.)



RICH Photon detector

Low-IBF
DMM

Thermal
bonding
MM

Others:

High rate TPC, gas PMT, DHCAL etc.

Summary

- A new method for fabricating Micromegas– thermal bonding method is presented
 - No etching, simple and flexible, lab-friendly, cheap
 - No fundamental issue with going to large size
 - A convenient way to optimize & develop new MPGDs
 - Gain uniformity needs to be further improved
 - Irradiation and aging test are planned
- Many interesting applications have been explored
 - TB-Micromegas-based neutron detector have been operated at CSNS for > 1.5 years
 - DMM are used as photon detector for RICH in the R&D of future colliders.
 - More potentials: 2D imaging monitors and trackers, High rate TPC, gas PMT, sensitive readout for DHCAL, etc.

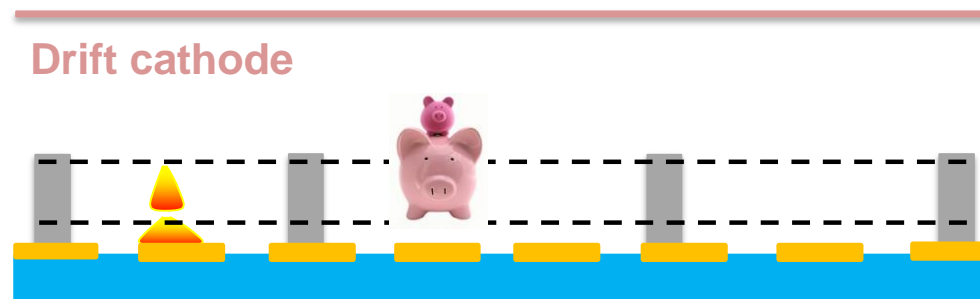
Thank you for your attention.

Backup slides



New structures (II)

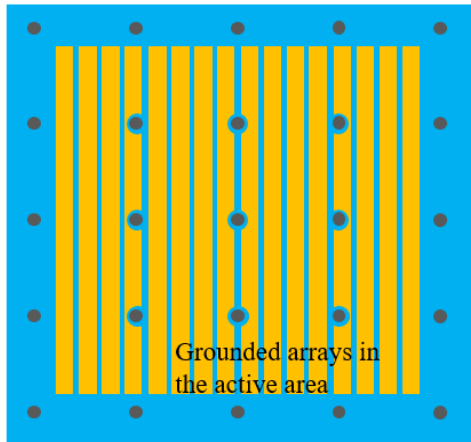
- A Double Micro-mesh structure (DMM)



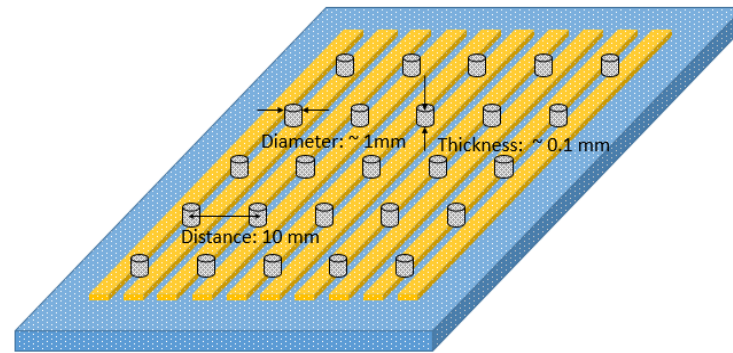
- Stacked two meshes
- Gap between the stacked meshes: 200-300 μm , serving as pre-amplification
- Gap between the bottom mesh and anode: 50-100 μm for main amplification
- This structure allows to achieve very high gain, and yet significantly reduce ion back-flow.

Towards large area

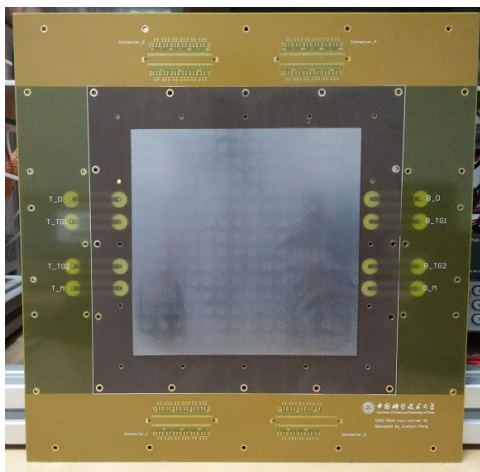
Grounding at edge is not enough when going to large area



Multi-point grounding

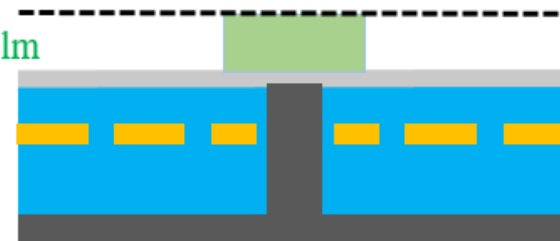


To cover the grounding point with the thermal bonding spacers



Thermal bonding film spacer ϕ 1mm

Grounded pillar $< \phi$ 0.5mm



Mesh
Ge film
Readout strips
PCB board

A 160mm \times 160mm readout PCB is manufactured using this method, will be validated soon.