# *Development and production of thermal bonding Micromegas detectors for the PandaX-III 0vdbd experiment*

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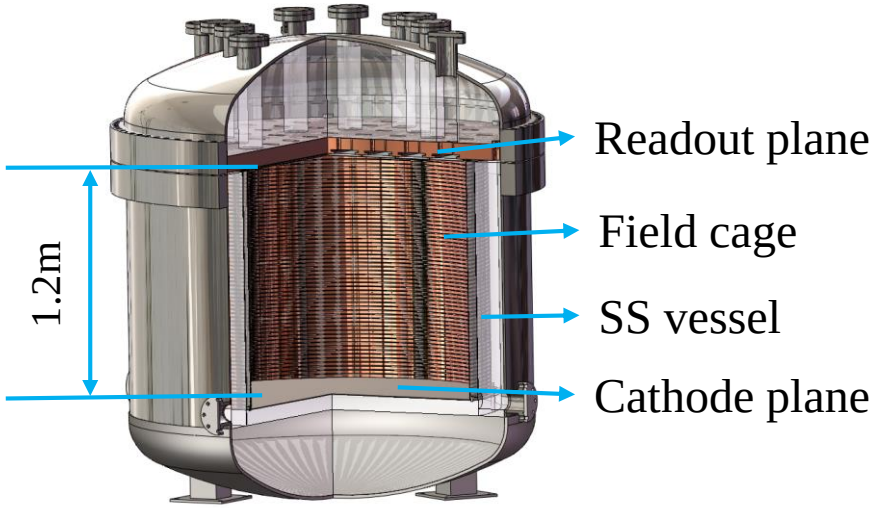
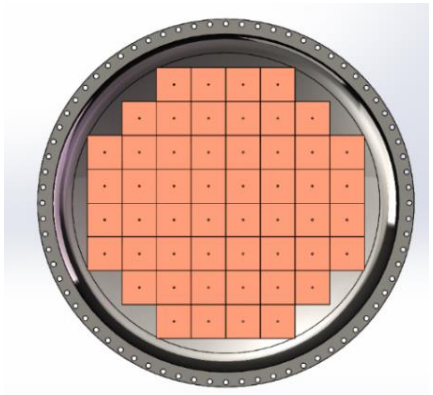
# Contents

# PandaX-III Experiment



Readout plane:
Micromegas array

The PandaX-III experiment uses high pressure Time Projection Chamber (TPC) to search for Neutrinoless Double Beta Decay (NLDBD) of $^{136}Xe$, at the China Jin-Ping underground Laboratory II (CJPL-II) .

**Requirements of the readout plane:**

- $20 \times 20$ cm$^2$ MMs for charge readout (52)
- 3% energy resolution @ 2.459 MeV
- Low radioactivity
- X-Y strip readout
- Stable gain > 1000 @ 10 bar to ensure good Signal Noise Ratio
- Stable operation for a long time @ 10 bar

# Thermal Bonding Method

Over the past decade, the thermal bonding method (TBM) has been developed for the efficient fabrication of Micromegas detectors at USTC. This method provides a concise and etching-free mass-productive process to fabricate Micromegas-like detector.

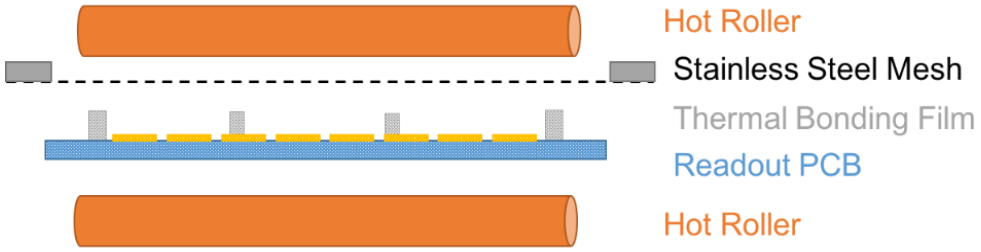
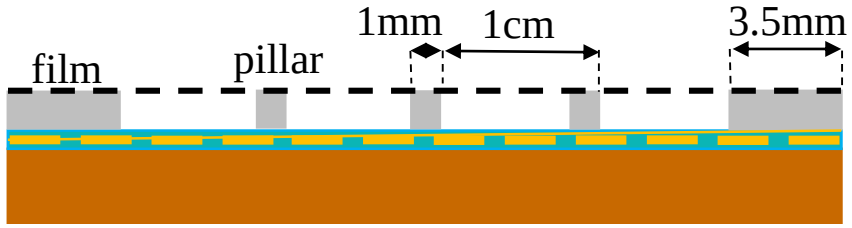
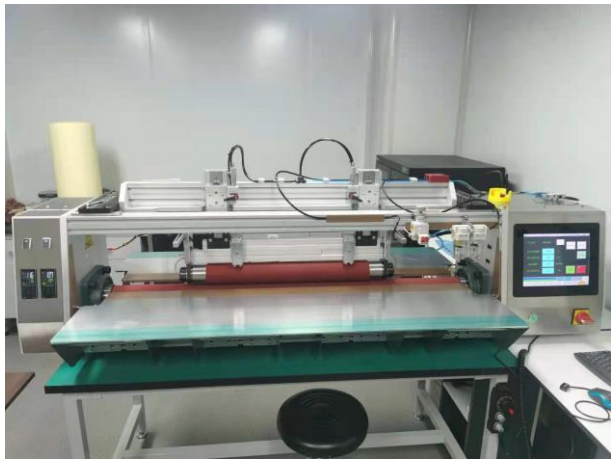
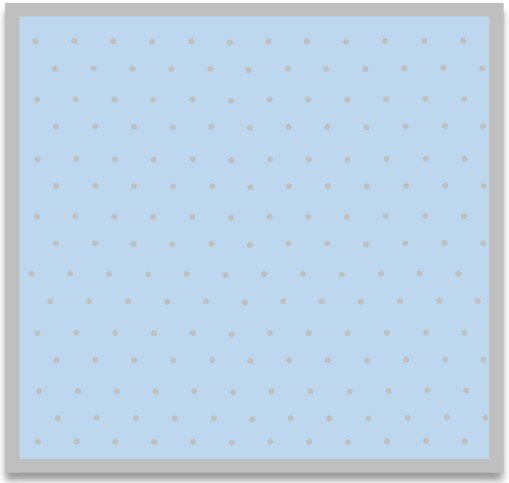



Diagram of the thermal-bonding method




Lateral View of Detector





Vertical View of Detector

Advantages of TBM:

- No etching, no pollution
- Easy to handle at lab
- Easy to make new structures
- Low cost
- Φ0.5mm- Φ1mm spacers, ~1cm pitch
  - ➔easy to clean, especially for large area
  - ➔less than 1% spacer area

# Development of Micromegas for PandaX-III

| 12/2019 | 02/2020 | 04/2020 | 08/2020 | 11/2020 | 06/2021-12/2022 |
|---|---|---|---|---|---|
| V1 | V2 | V3 | V4 | V5 | V6 |
| Solved Problems: | narrow bonding region | low radioactive | energy resolution | uniformity and stable operation | |






Hard PCB

Flexible PCB

Hard PCB： V1, V2

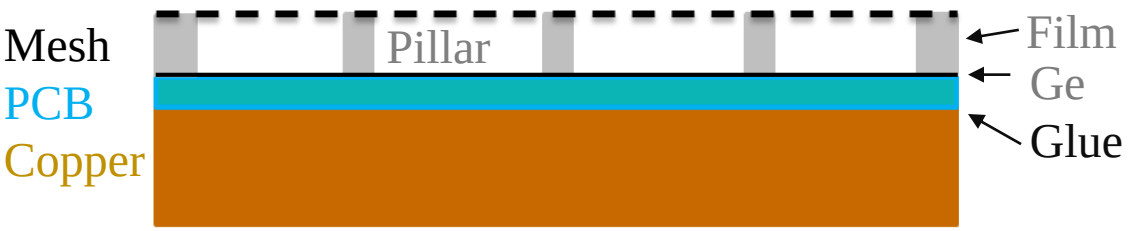
- To validate the narrow bonding region, performance of energy resolution and long time stable working ability

Flexible PCB: V3~V6

- Low radioactivity and flexible connection

# Low Radioactivity Materials of Detector

All materials are low radioactive





Radioactivity Measurement

- Samples: The materials of the thermal bonding Micromegas
- Facility: Low background gamma spectrometer
- Site: Jinping Underground Laboratory, China

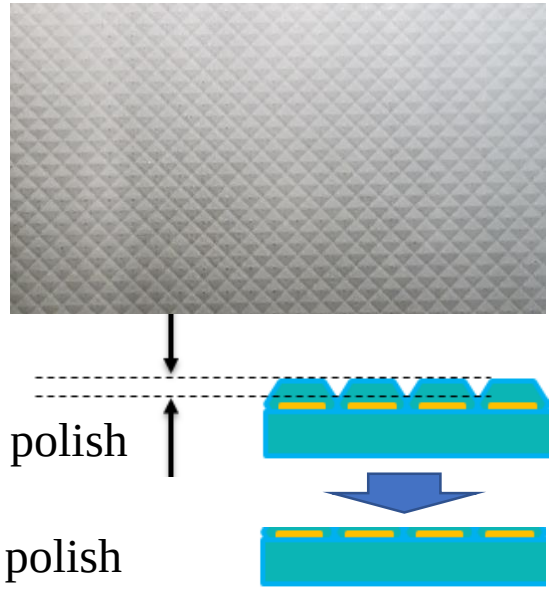
Unit: μBq/cm$^2$

| Sample | $^{232}$Th | $^{235}$U | $^{238}$U | $^{40}$K | $^{60}$Co |
|---|---|---|---|---|---|
| PCB | 0.91±1.42 | - | 0.28±0.55 | 22.6±9.07 | 0.37±0.31 |
| SS wire mesh | 0.24±0.12 | <0.01 | 0.08±0.04 | 0.69±0.58 | <0.01 |
| Film | 1.00±0.33 | <0.01 | 11.57±1.57 | 1.67±1.28 | - |
| Epoxy glue | 1.40±0.75 | - | 0.05±0.25 | - | - |
| **Total** | **3.55±1.64** | <0.01 | **11.98±1.68** | 24.96±9.22 | 0.37±0.31 |
| **Microbulk-Micromegas** | **<9.3** | <13.9 | **26.3±13.9** | 57.3±24.8 | <3.1[a] |

Thermal bonding Micromegas and Microbulk Micromegas are both with low radioactivity

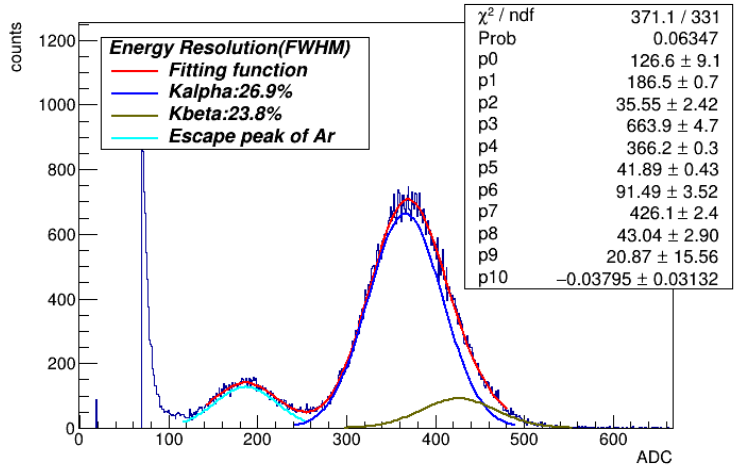
Microbulk Micromegas result is cited from S. Cebrian et al. Radiopurity of Micromegas readout planes

# Energy Resolution Improvement by Polishing PCB

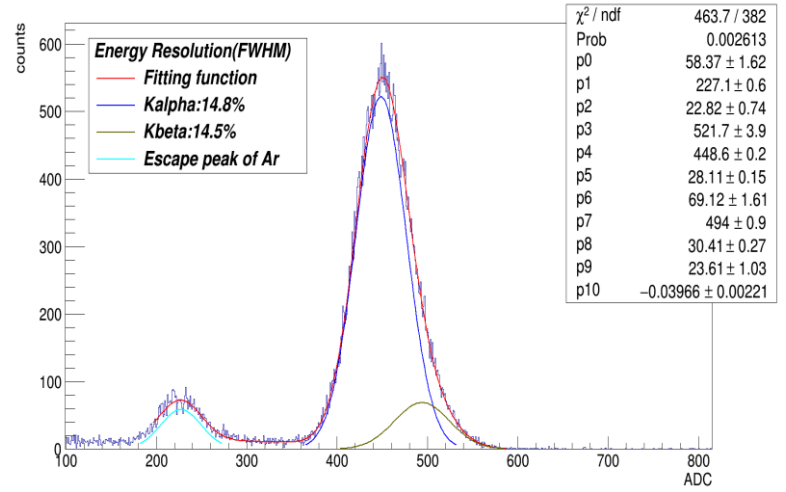



Polishing PCB surface

In the process of using low radioactivity flexible PCB to make detector, it is found that the insulation layer on the PCB surface is not smooth, resulting in poor energy resolution.




Energy resolution before polishing:
~27%(Ar+3.5%Iso@5.9keV)

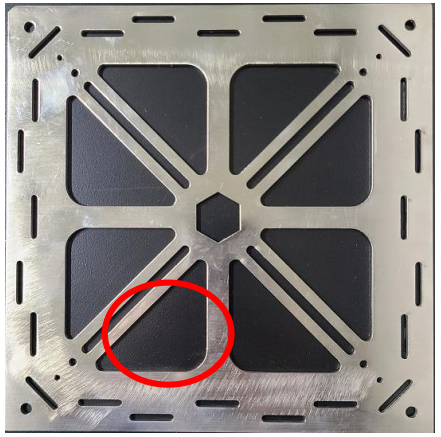


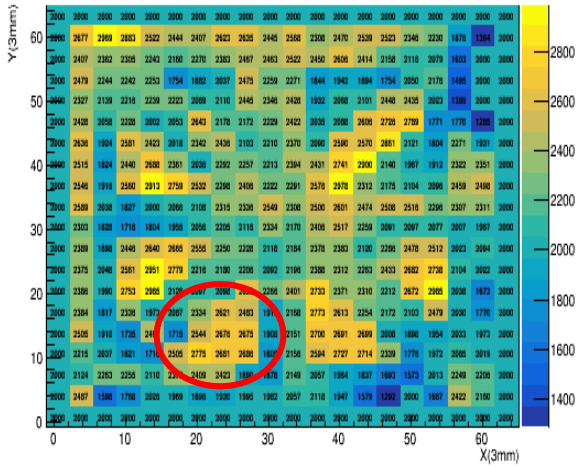

Energy resolution after polishing:
~15% (Ar+2.5%Iso@5.9keV)

The polishing process can effectively improve the energy resolution

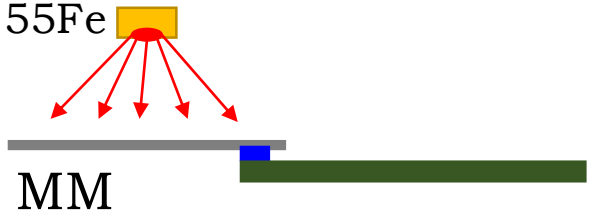
# Uniformity Improvement by Changing Substrate

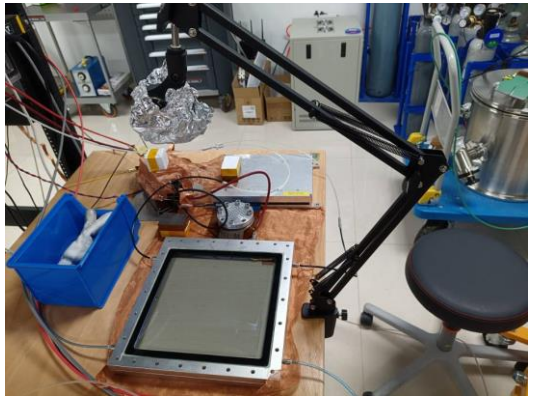
V 4






Hollows result in worse nonuniformity

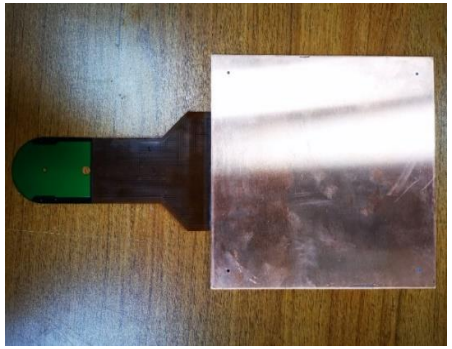


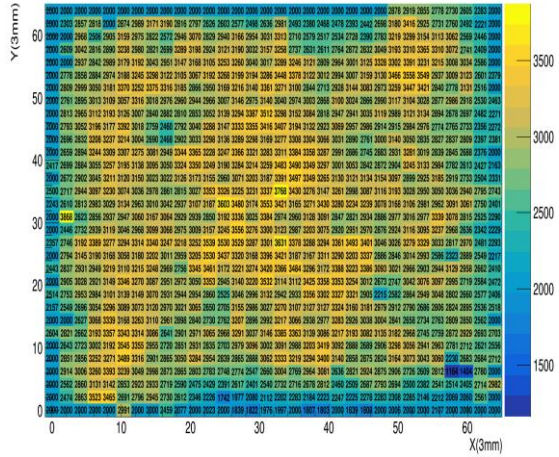



Diagrammatic sketch and photo of uniformity testing

V 5

Using flat copper substrate plate



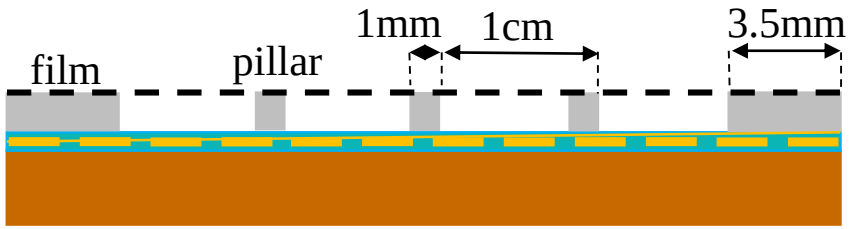



- The substrate plate with **hollows** have obvious influence on the uniformity of the detector
- The uniformity of the detector can be improved by the **flat** copper substrate plate

# Uniformity Improvement by Suitable Edge Film

Gas Gap is **narrow** → Gain is **high**

Gas Gap is **wide** → Gain is **low**

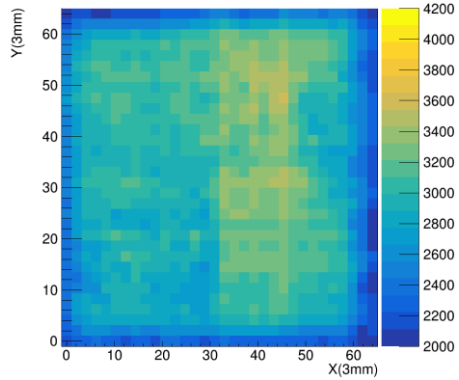


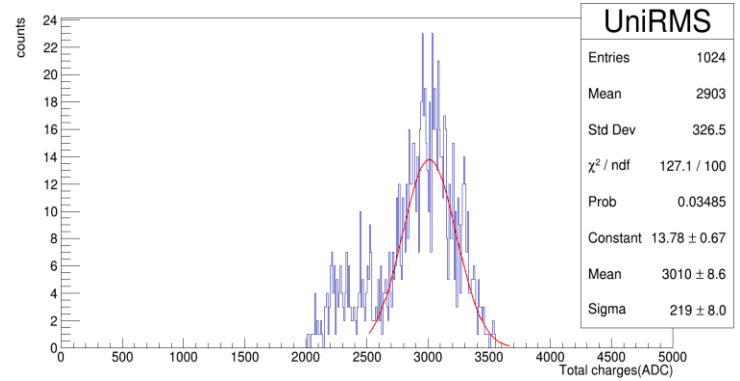

Lateral View of Detector

- Selecting suitable film to make edge and central gain similar
- After several choices, we found a film close to the requirement
- A large step forward for uniformity from ~10% to ~5%

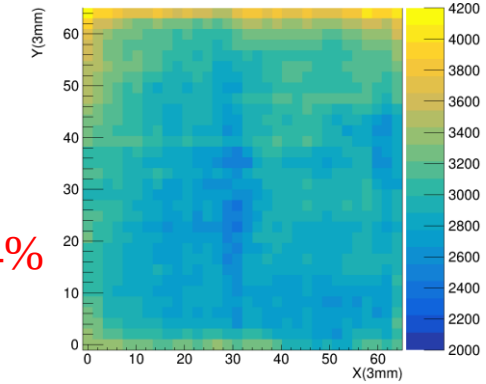
(Uniformity = RMS/Average)

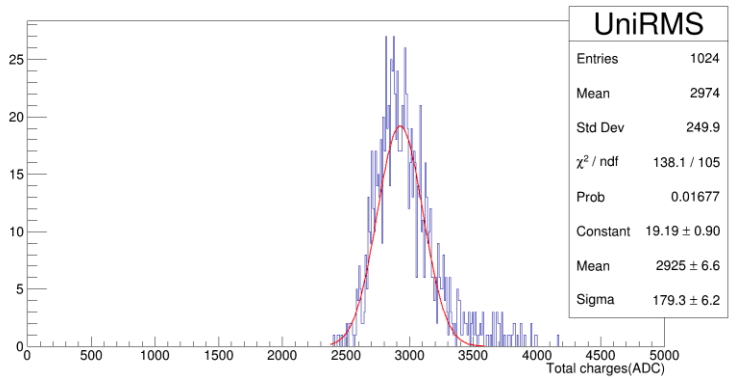
V6110
Uniformity：11.2%



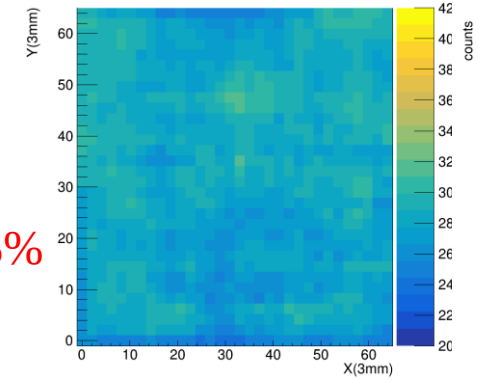



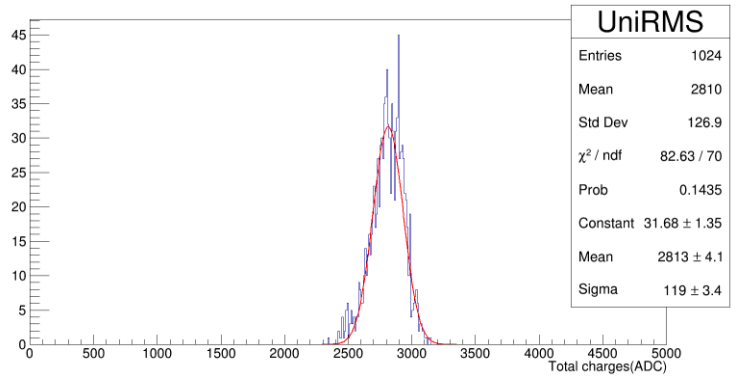

V6115
Uniformity：8.4%




V6118
Uniformity：4.5%

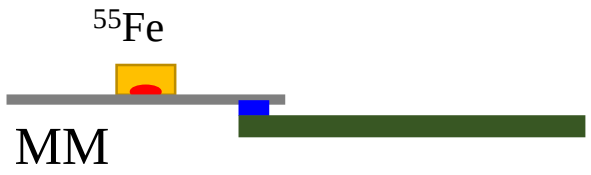


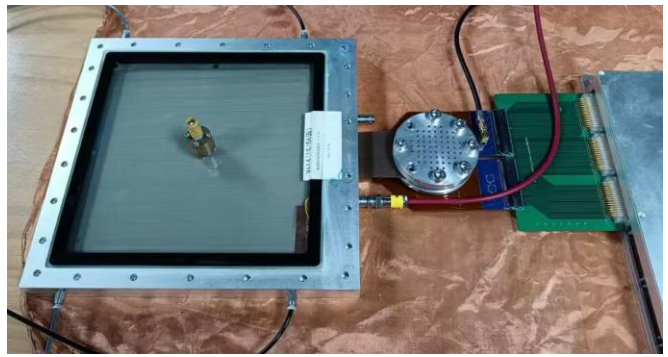



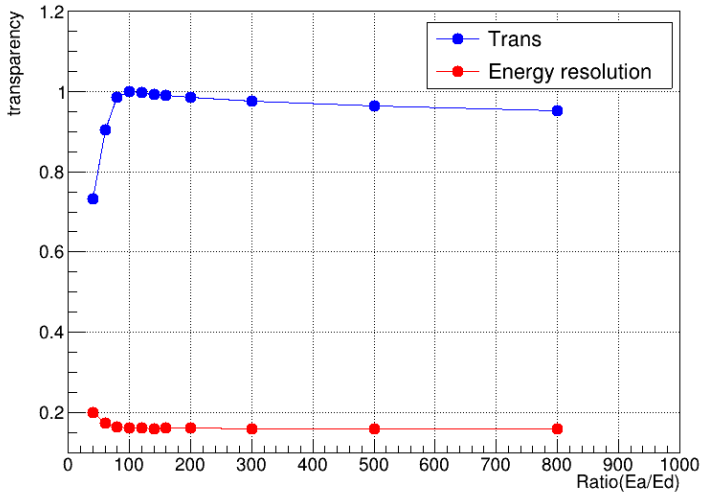
# Performance in Atmospheric Pressure Gas

Testing **transparency、gain、energy resolution** by MCA

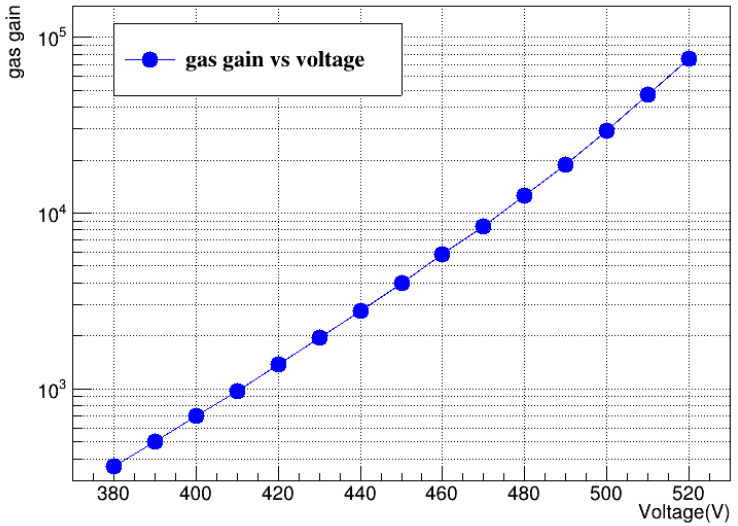
Gas: Ar+ 7%Iso



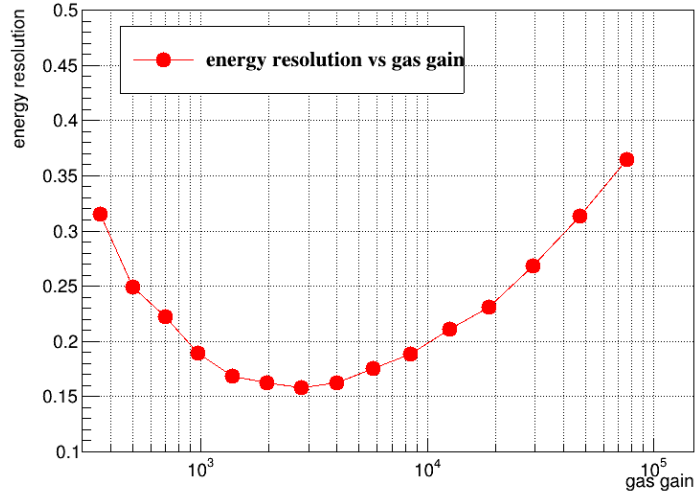






Relative transparency




high gain up to 80,000



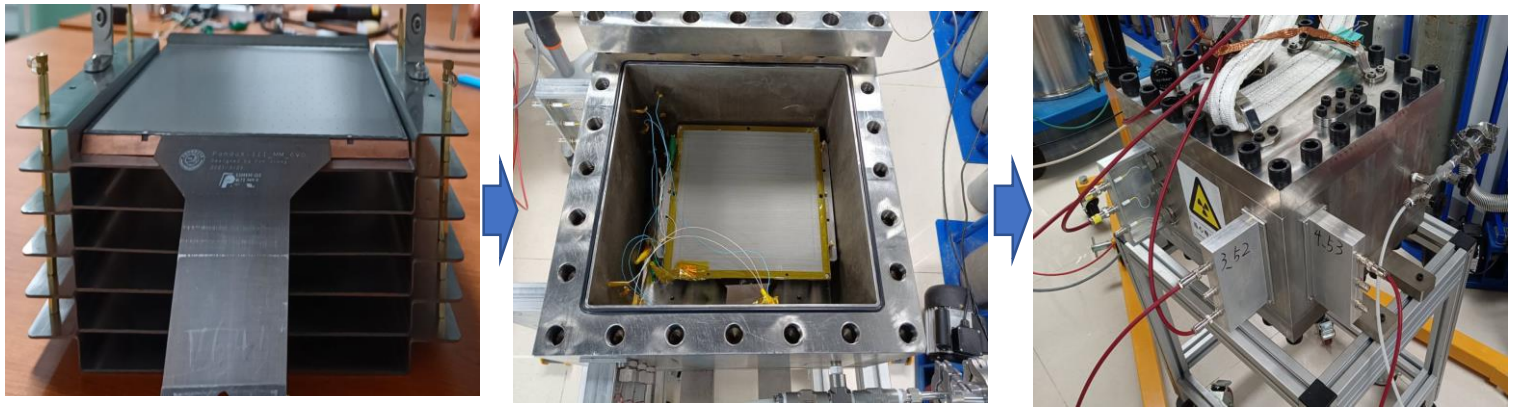

good energy resolution

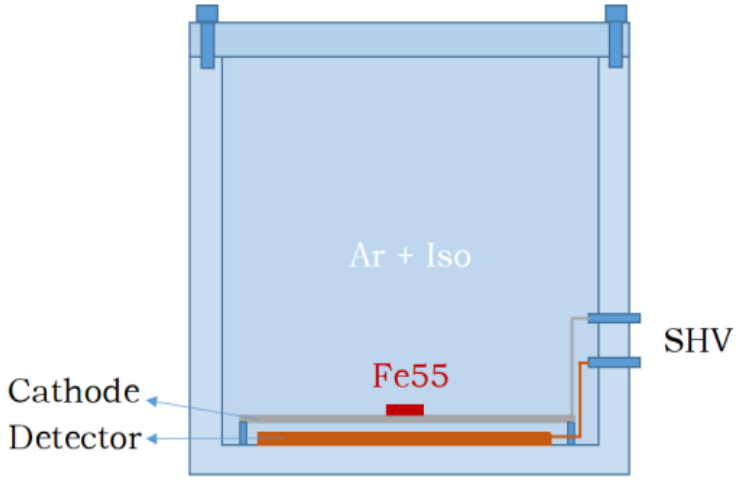
# Performance in High Pressure Gas

Testing **transparency、gain、energy resolution** by MCA

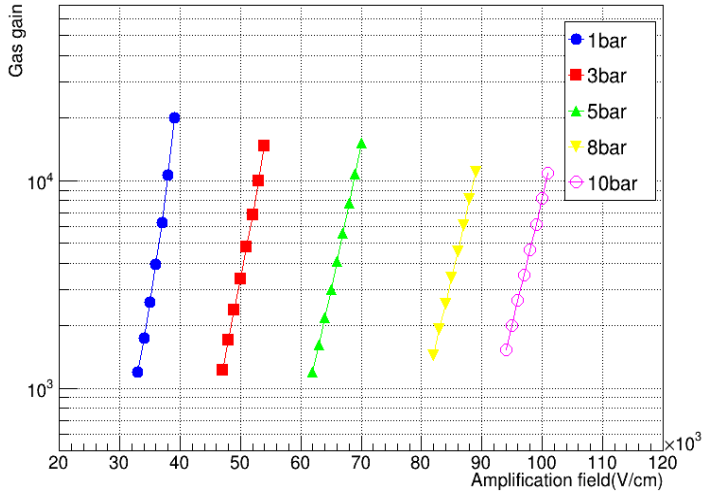
Gas: Ar+2.5%Iso

Gas Pressure: 1,3,5,8,**10 bar**

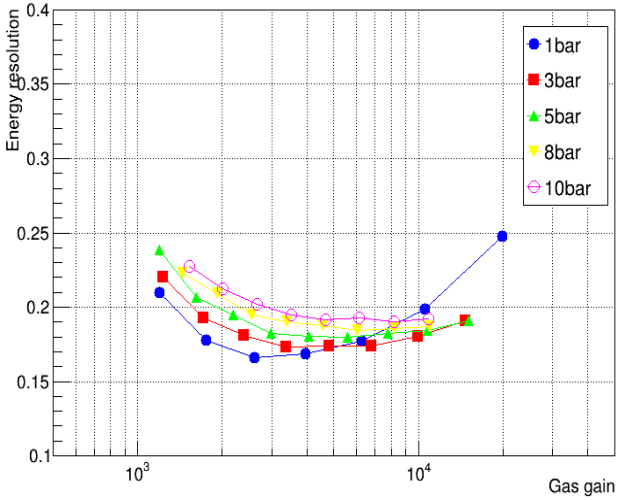





High pressure test platform

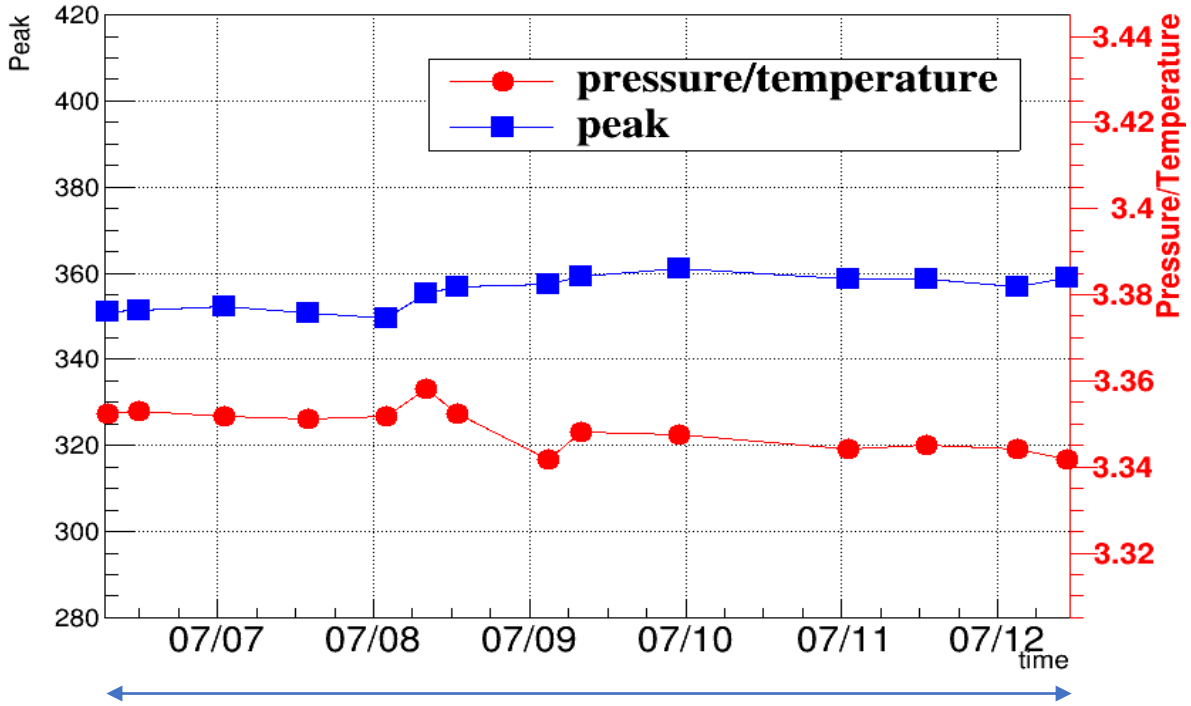



Gain up to 10,000



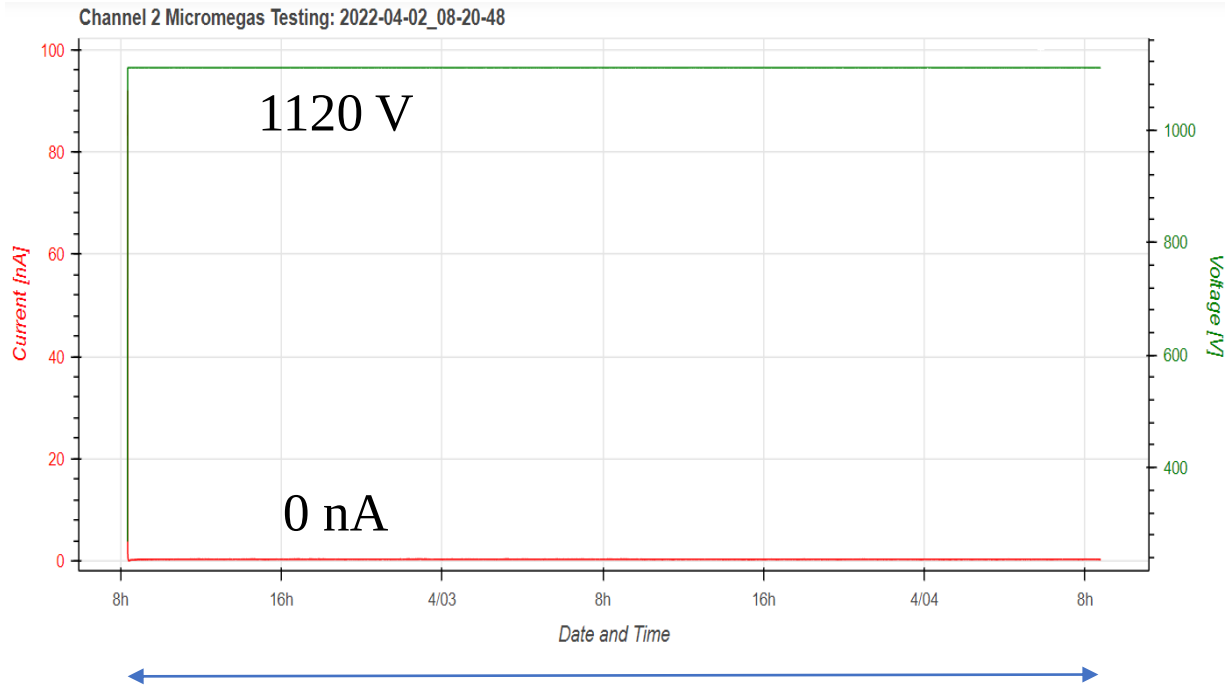

Energy resolution ~ 20%

# Stable Operation in High Pressure Gas




Stable operation > 6 days

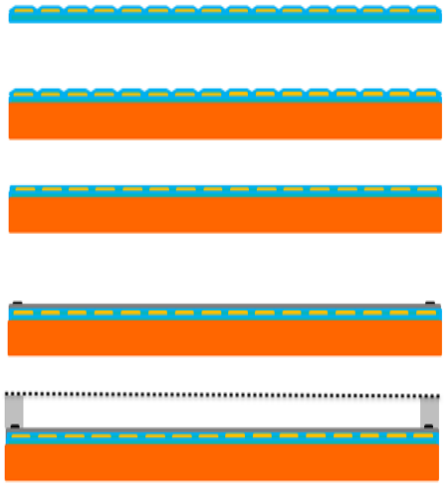
The peak(gain) improves gradually(< 3%) for leaking of gas




Stable operation > 24 hours

Long time voltage and current monitoring

# IV Mass Production Process



Flexible PCB

Copper Substrate

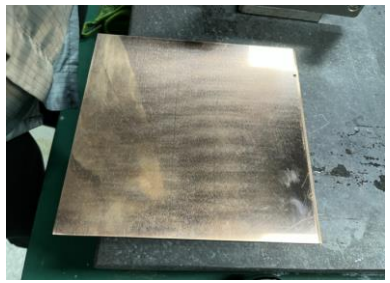
Polish

Coat Ge

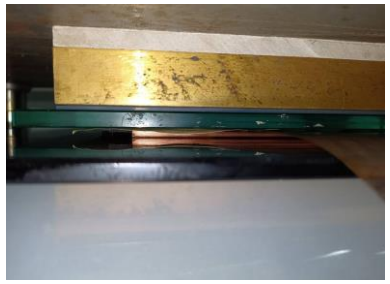
Supporting Structure

Thermal-Bonding

Production process



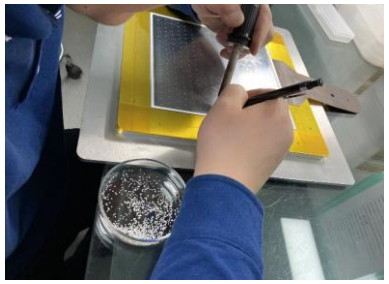
**Polish** copper plate



**Attach** PCB on the copper plate

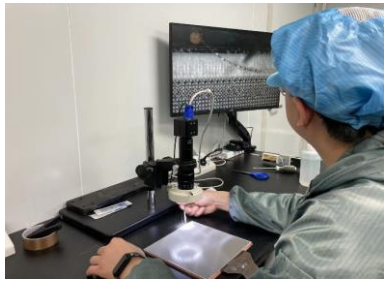
**Polish** PCB plate

Coat resistive **Ge**



Put pillars on PCB

**Thermal bonding**

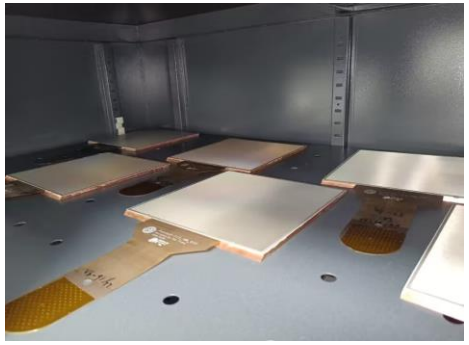


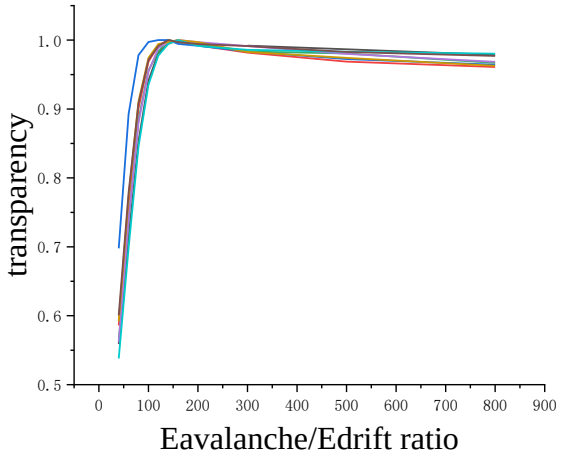
Cut、inspect and clear the mesh edge

Simple test

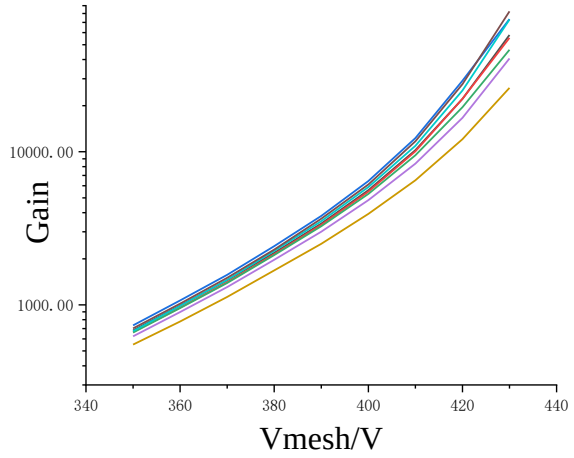
# IV Quality Control

- Testing **transparency、gain、energy resolution**
- Testing **uniformity**
- Most detectors have **consistent performance**
- Quality control is great

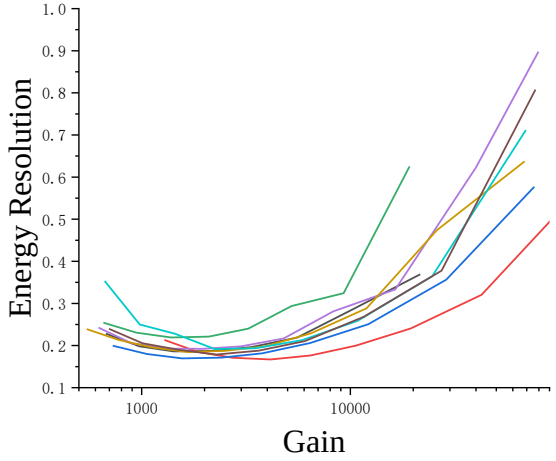




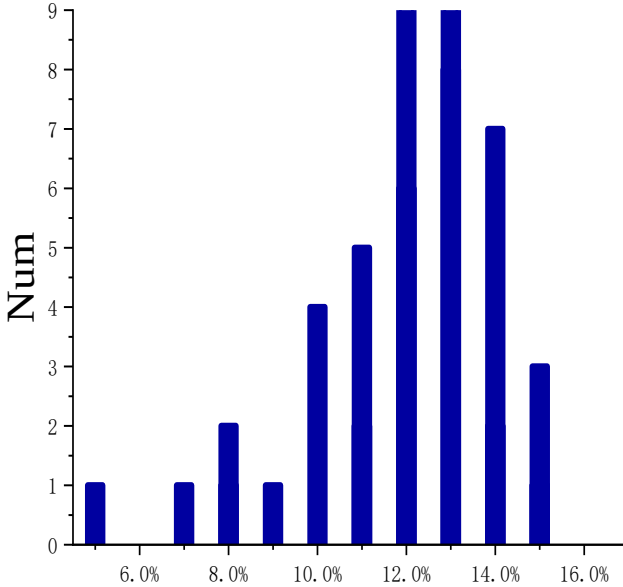

Transparency




Gain



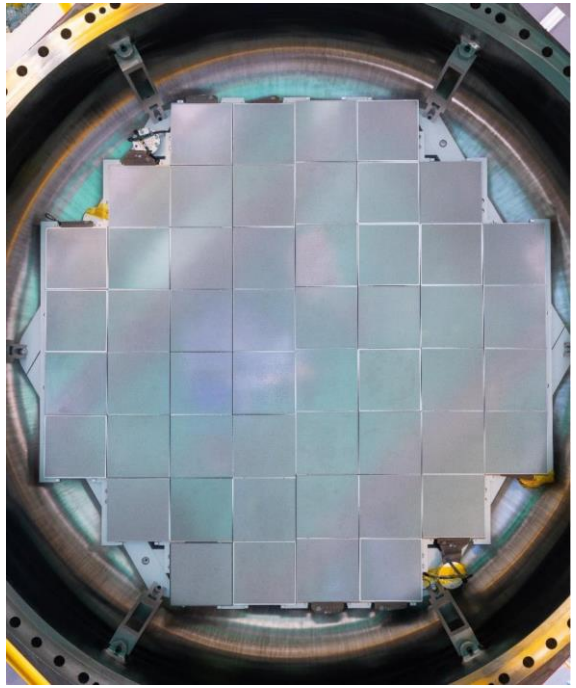

Energy resolution



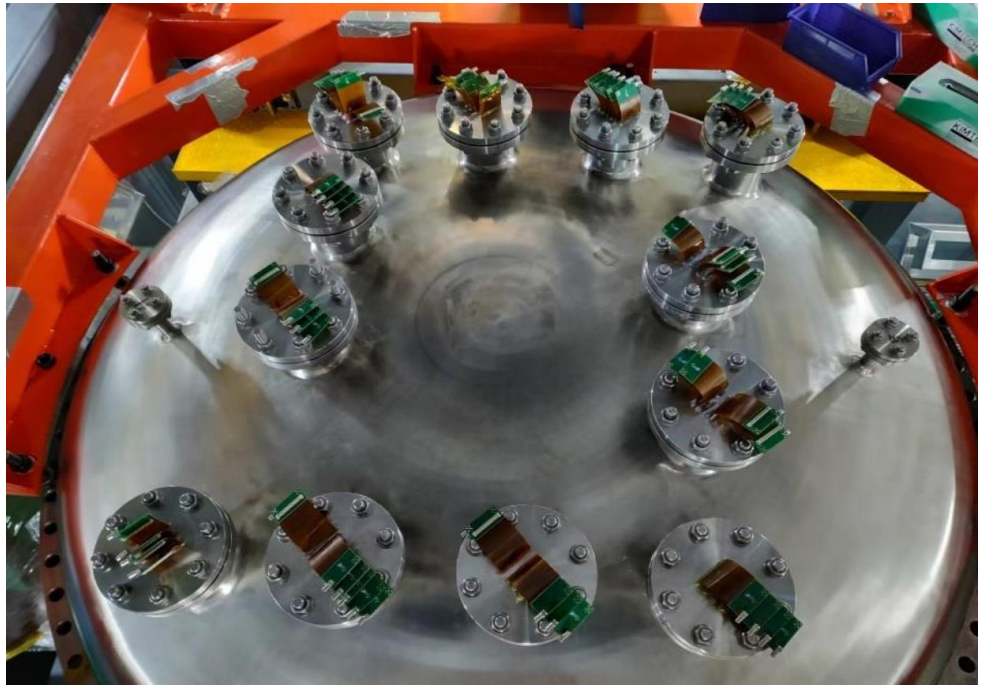

Uniformity of 52 MMs

# IV Installation In TPC Prototype

- Now, all 52 Micromegas have been installed in a prototype at SJTU
- The TPC has been started to operate to collect some data



**Readout plane (52 MMs)**



**Readout electronics**

# V Summary

- Thermal bonding method developed at USTC is a very promising method in low background and high energy resolution experiments.
- After developments of 6 versions, narrow dead area, low radioactivity, high energy resolution, low nonuniformity, high gain and long time stability has been achieved.
- Mass production process was well established.
- Mass production micromegas performed consistently for excellent quality control.
- 52 Micromegas have been installed in TPC prototype

# Thanks for listening