Development of Micromegas detectors with high radio-purity and energy-resolution using a thermal bonding method for the PandaX-III experiment

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Abstract: High pressure gaseous Time Projection Chamber (TPC) with Micromegas, which is considered to be a very attractive solution for the next generation of ton scale 0νββ experiment, features the high granularity, high energy resolution, and low radioactive background. The PandaX-III experiment adopted the TPC scheme and will search for 0νββ of Xe-136 at China Jinping Underground Laboratory. In this work, we present R&D of Micromegas with thermal bonding method at USTC. Thermal bonding Micromegas offers spark-resistant and dead-channel-free readout modules for readout. The specific design and manufacturing process for this radio-pure and high energy resolution Micromegas detector with active area of 200mm×200mm is introduced. The prototypes were characterized under 10 bar pressure and the performance such as gas gain, energy resolution etc, the results are presented and show a promising solution for PandaX-III experiment.

Introduction

- In order to meet the requirements of PandaX-III experiment, we have designed 5 versions of anode plane, and developed specific manufacturing process of thermal bonding Micromegas detector.
- The performance of different version thermal bonding Micromegas detectors are shown, such as transparency, gas gain, energy resolution etc.
- The high pressure test up to 10 bar was performed in a stainless steel vessel, results are present at last.

PandaX-III experiment

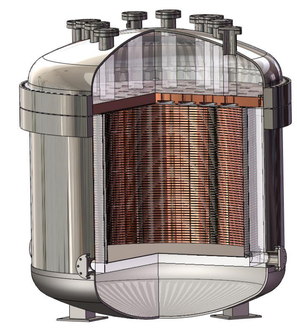


Fig. 1 Schematic of TPC and readout plane

The PandaX-III experiment adopts high pressure gaseous TPC to search for 0νββ of ^{136}Xe, at China Jin-Ping Underground Laboratory. The working gas is 10 bar Xe (99%)-TMA (1%) construct a 200 kg scale TPC, with a cylindrical volume of 1.5 m in diameter and 2 m in length.

Requrirements:

- 20×20 cm² MMs for charge readout (52)
- 3% energy resolution @ 2.459 MeV
- Low radioactivity materials
- X-Y strip readout

The versions of anode plane

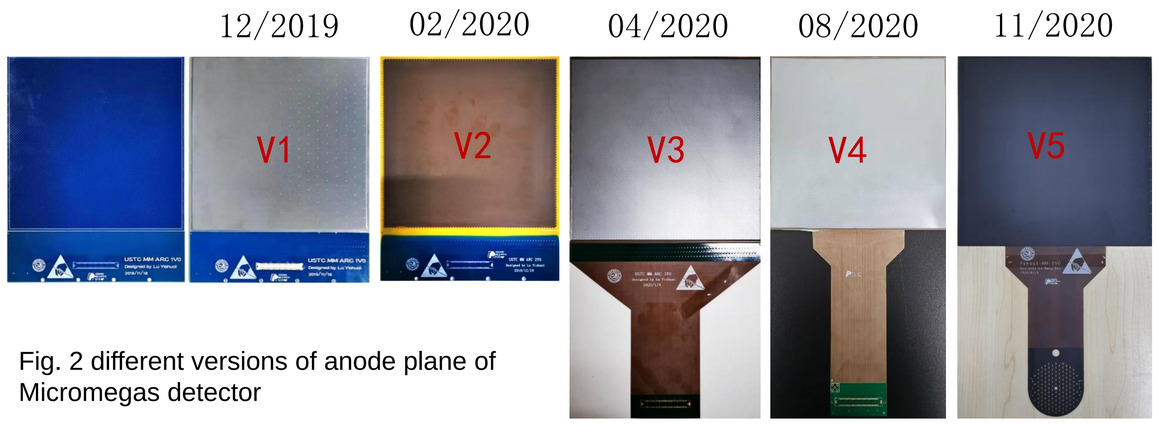


Fig. 2 different versions of anode plane of Micromegas detector

- Hard (FR-4) PCB: V1,V2
  To validate the narrow bonding region and the performance of 200mm*200mm effective area detector.
- Flexible (polyimide) PCB: V3-V5.
  Realize the radio-pure requirement and toward engineering version

Radioactivity of the detector materials

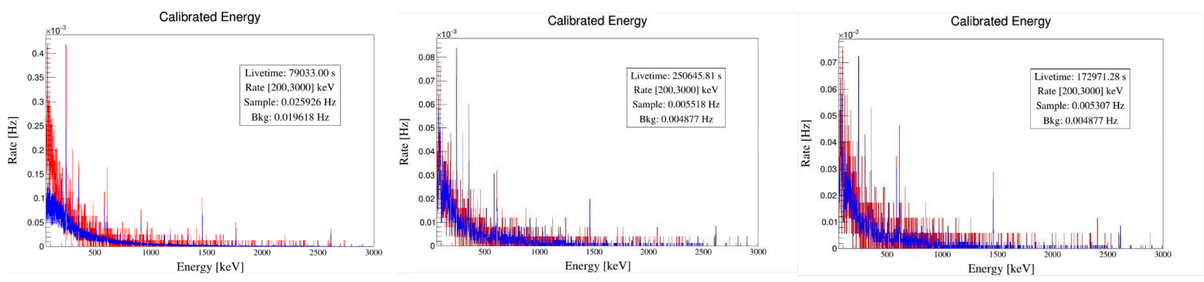


Fig. 3 the radioactivity test results of the detector materials, a. anode plane, b. mesh, c. adhesive film.

Conclusion

- Thermal bonding method developed at USTC provides an effective and lab-friendly way to fabricate the detectors.
- We developed a method to manufacture Micromegas with very low radioactivity, high gain and better energy resolution. The engineering version V6 will be manufactured soon.
- The high pressure performance presents the thermal bonding method detector can meet the high gas pressure environment requirement.

Manufacturing process for detector

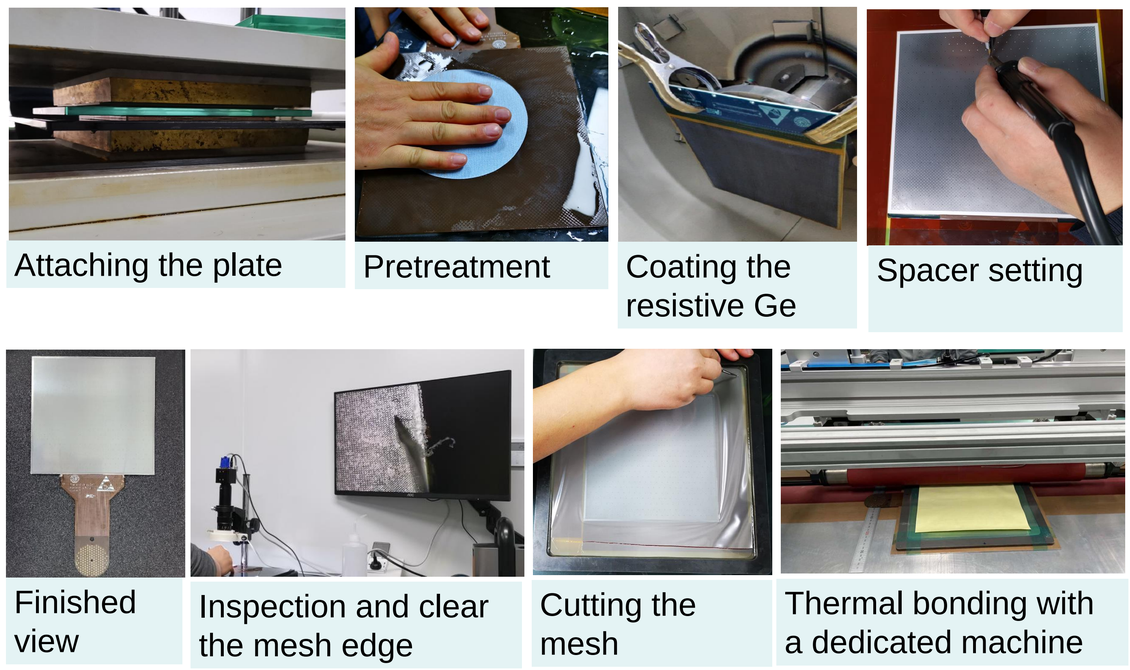
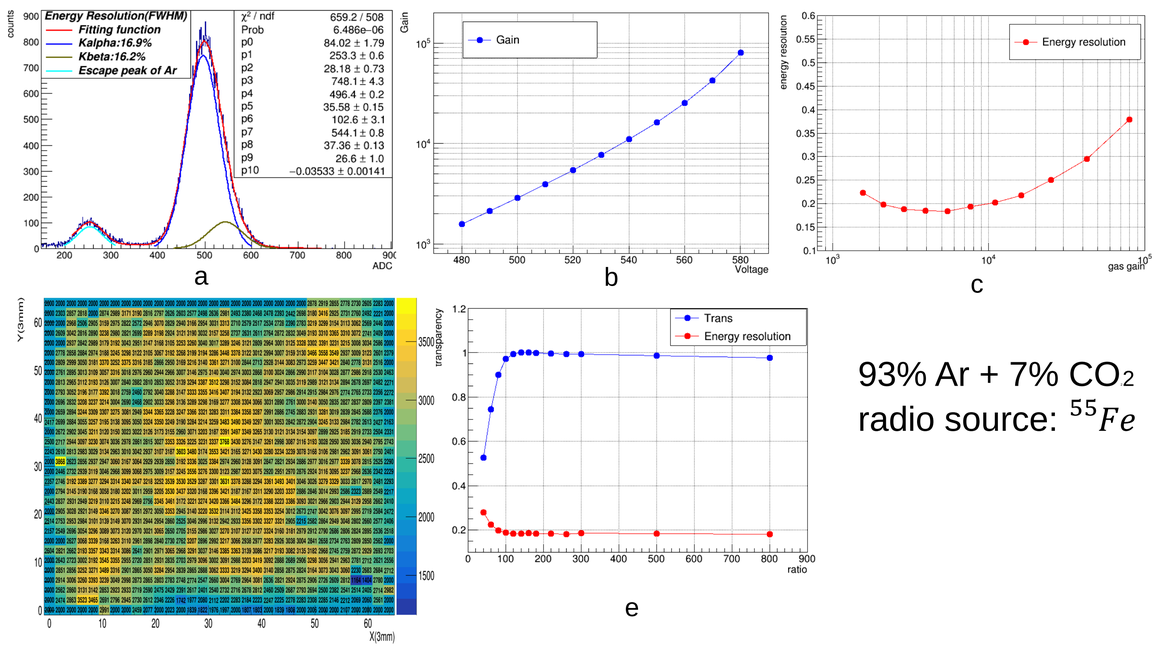


Fig. 4 the thermal bonding manufacturing process for V5 Micromegas detector

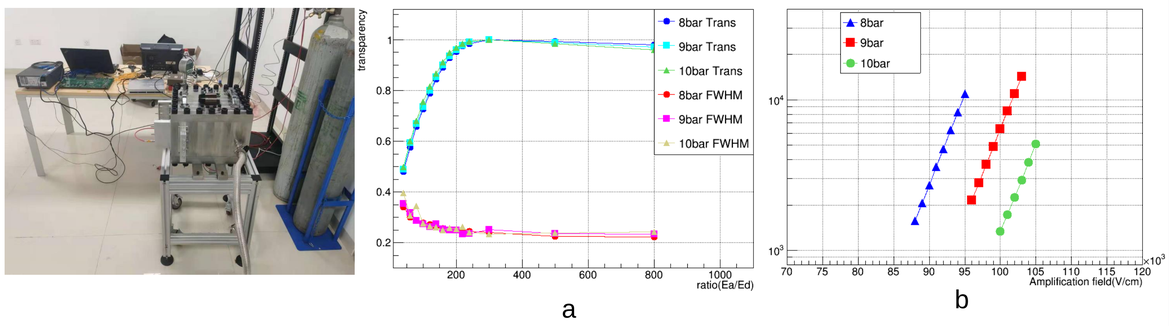
The performance of the detector



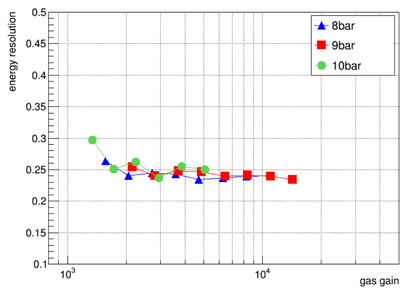
93% Ar + 7% CO_2
radio source: ^{55}Fe

Fig. 5 the performance of V5 Micromegas detector.
(a. MCA spectrum, b. the gas gain can up to 80000, c. the best energy resolution ~16.9%(FWHM), d. the uniformity RMS = 10.6%, e. transparency)

High pressure test result of the prototype



- The designed stainless steel vessel gas pressure is 12 bar.
- The mixed gas is 97.5% Ar + 2.5% Iso.
- The radio source: ^{55}Fe.
- The maximum gas gain at 10bar can up to 5000(b), and the correspond energy resolution is about 23%(FWHM@5.9keV).



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