Development of a large-area RWELL detector with DLC coating for CEPC-DHCAL Application

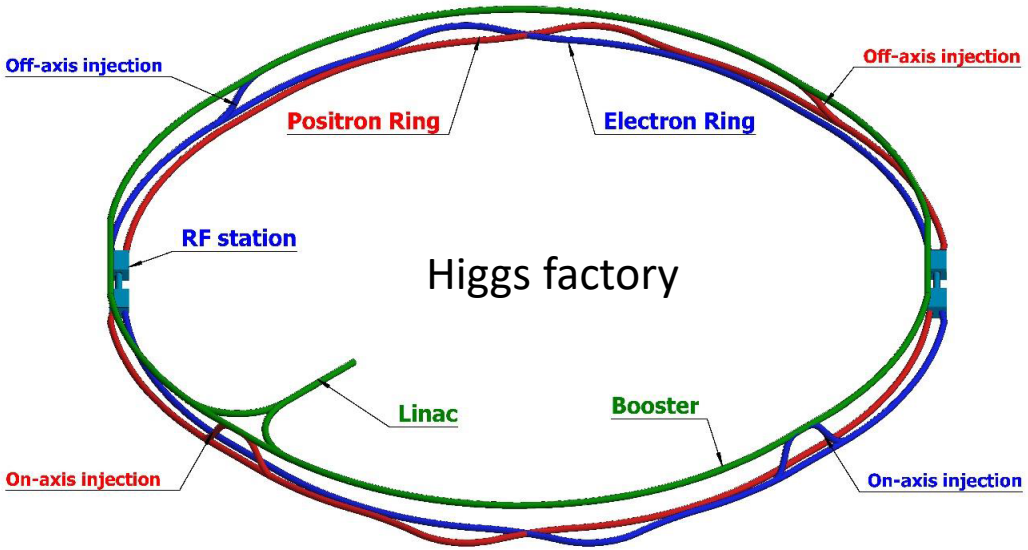
Daojin Hong
On behalf of the USTC MPGD Group
State Key Laboratory of Particle Detection and Electronics
University of Science and Technology of China

15th.June.2021

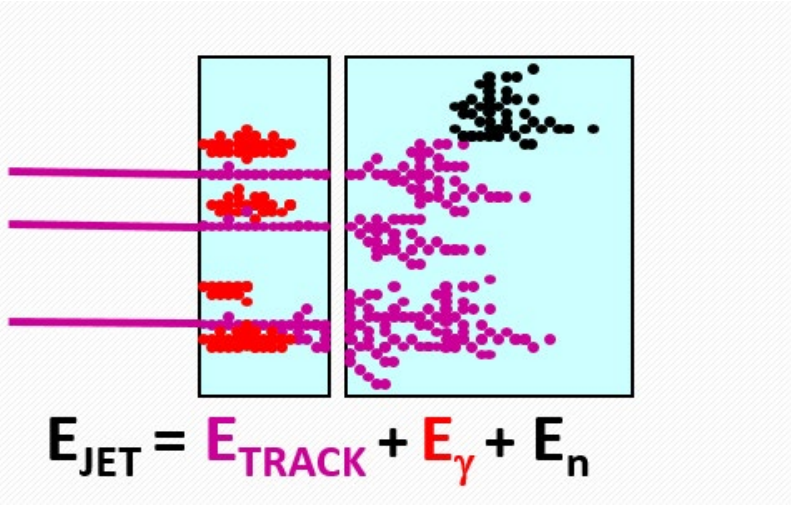
RD51 Collaboration Meeting and Topical Workshop on FE electronics for gas detectors,
14th-18th June 2021

Introduction

- The Circular Electron Positron Collider (CEPC)



- The baseline detector concept-guided by Particle Flow Principle



Key component：high-granularity calorimeter

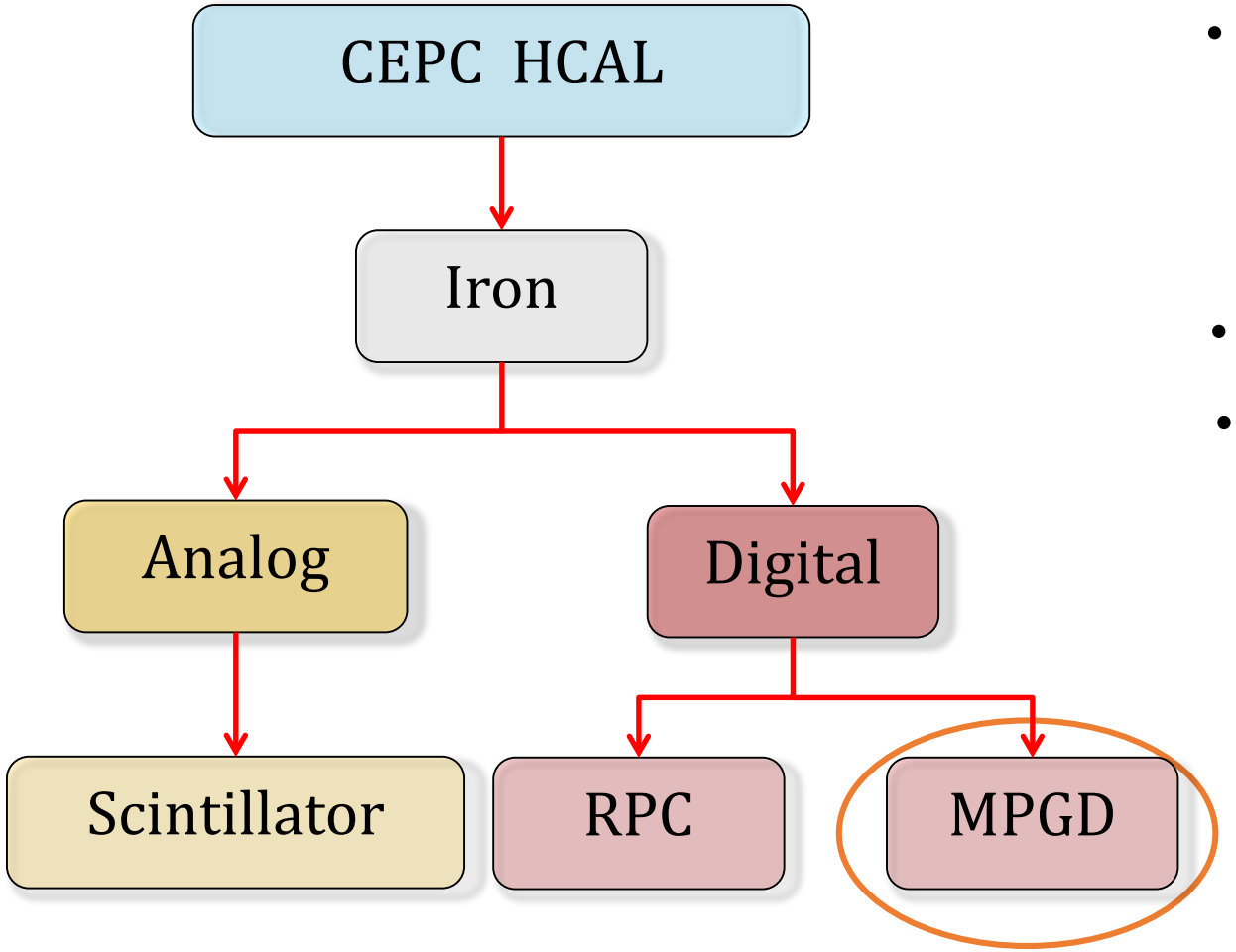
- Parameters:

Operation mode	$\sqrt{s}$ (GeV)	L per IP ($10^{34}\,\mathrm{cm^{-2}s^{-1}}$)	Years	Total $\int L$ ($\mathrm{ab^{-1}}$, 2 IPs)	Event yields
H	240	3	7	5.6	1×10^6

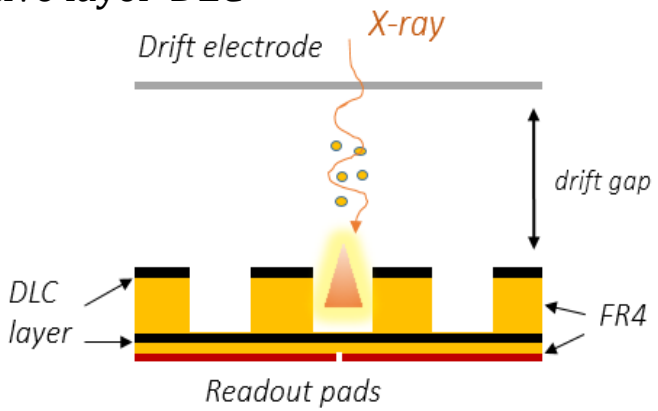
- Performance requirement:

$H \to q\bar{q}, WW^*, ZZ^*$	BR($H \to q\bar{q}, WW^*, ZZ^*$)	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV

Options for CEPC PFA HCAL



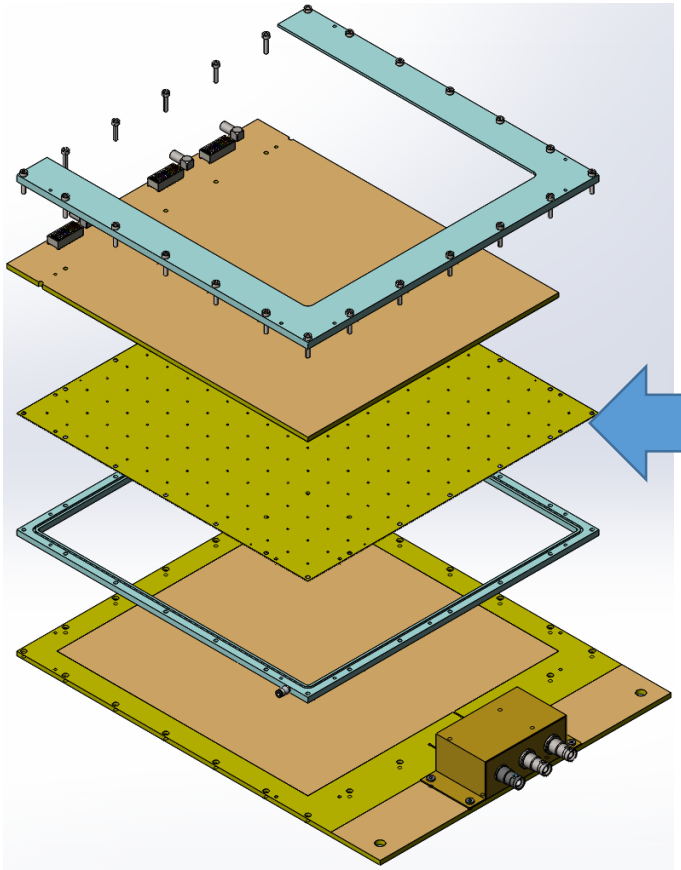
- Requirements of sensitive detector:
  1. Compact
  2. High detection efficiency
  3. Scalable to large size
- MPGD： one of the candidates
- Resistive WELL detector (RWELL):
  1. Only a drift gap
  2. Only one stage amplification, high gain
  3. Resistive layer-DLC

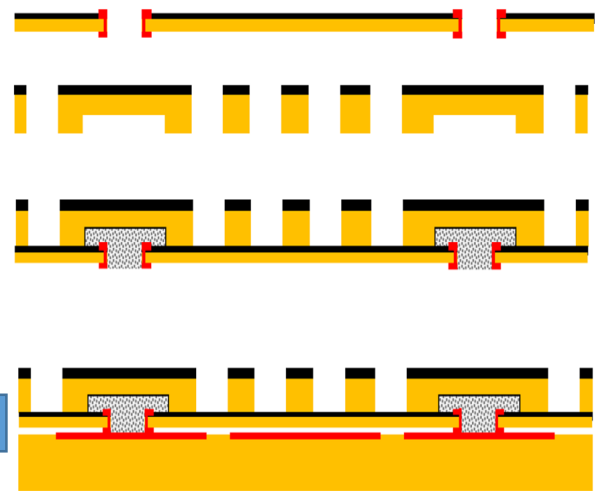


- **RWELL: A promising candidate for sensitive detector of DHCAL**

Idea of RWELL prototypes

25cm×25cm RWELL



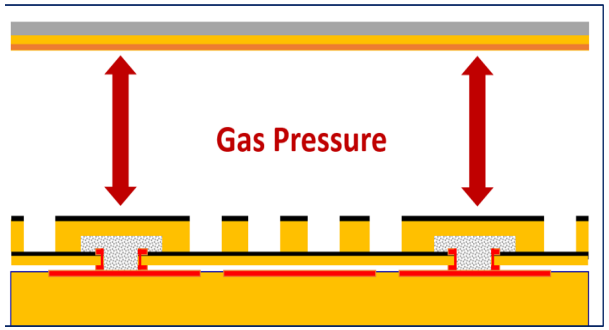


DLC is coated on thin FR4 sheet（0.2 mm resistive layer）

Single-sided THGEM with conductive DLC

Glue single-sided THGEM and resistive layer (RWELL part)

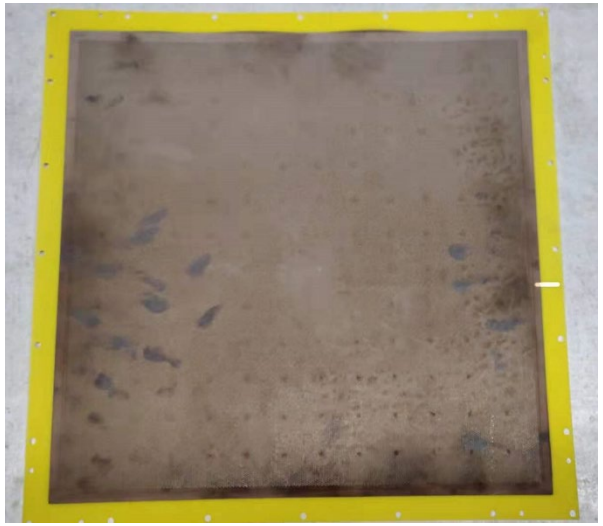
Stack the RWELL part and readout PCB together without any glue

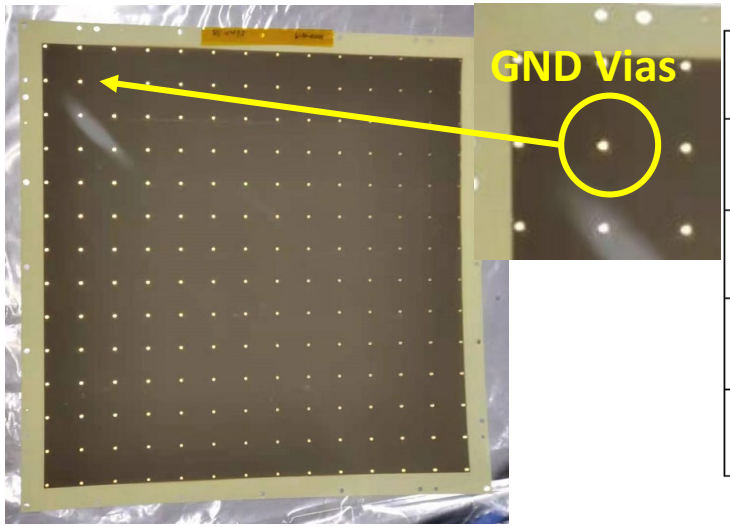


- The gas pressure in the detector chamber can ensure that the metalized vias and readout pads have good electrical connection.
- Charges are collected by Resistive layer and going into the ground through the vias to achieve certain rate capability. Signals are induced on the readout pads.
- Without glue on the readout PCB, easy for dismount of the readout PCB.

Problems found in the 25cm×25cm RWELL

- The top electrode of THGEM PCB are not able to be divided into small sectors if it is made by DLC, (lift-off method is not accepted by the PCB factory)；
- Some of the Vias have bad connection to the DLC layer, due to its very small contacting area with DLC;
- Metal pads of some GND Vias don't have good touching with the readout Pad, due to the mechanical tolerance of the PCB.





25 cm×25 cm THGEM foil && Resistive PCB

√	O	√	√	√
O	√	X	√	√
√	X	X	X	O
X	√	√	X	O
√	√	√	√	√

√ Connect well

O Connect not well

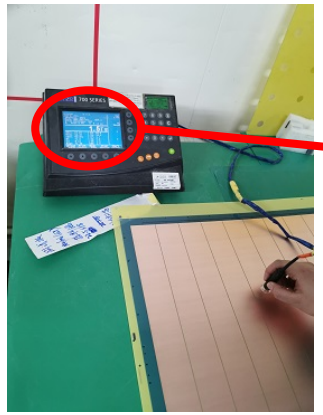
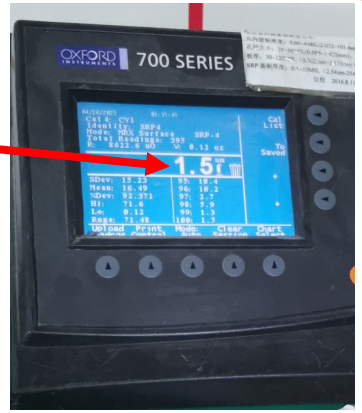
X Not connect

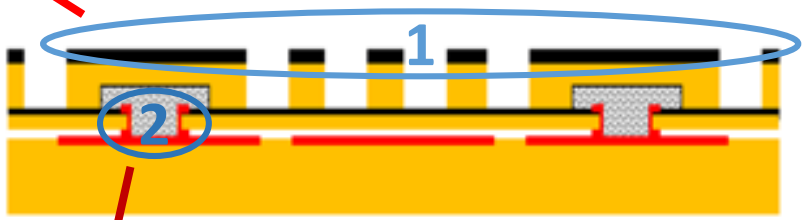
GND vias connection status

Improvements

- Use thin copper to replace the DLC on top of the THGEM part

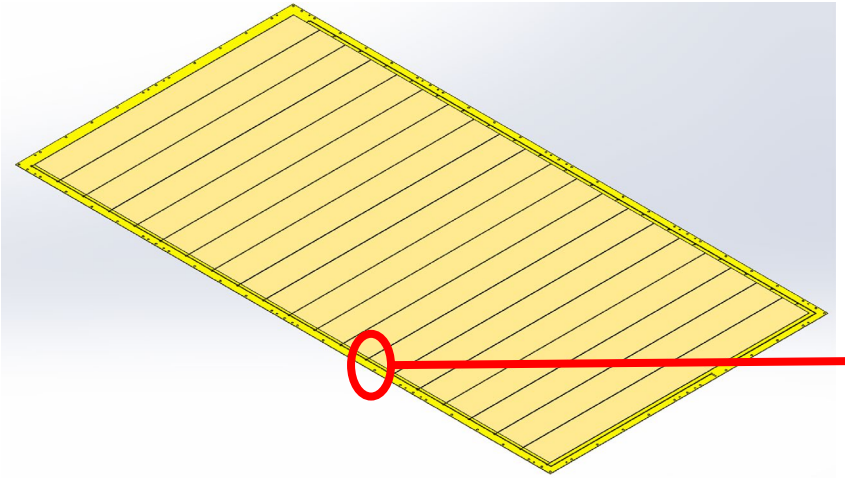
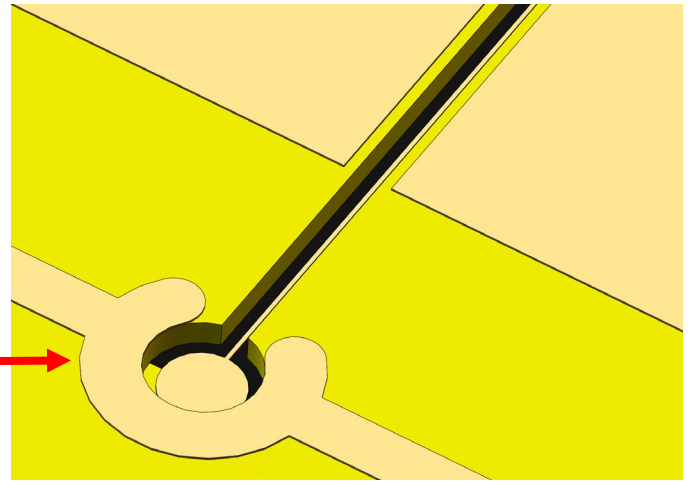




  - Use the standard copper reduction line in PCB factory to reduce the copper thickness to less than 2μm

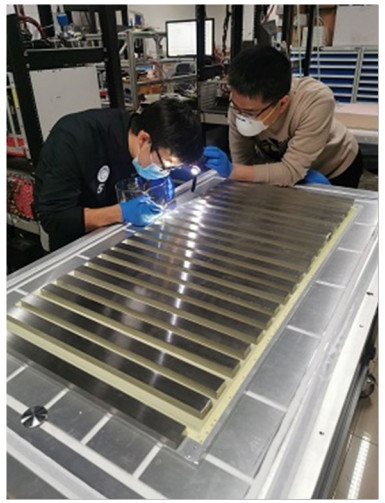
- Glue the THGEM PCB and the resistive layer together to get the RWELL PCB

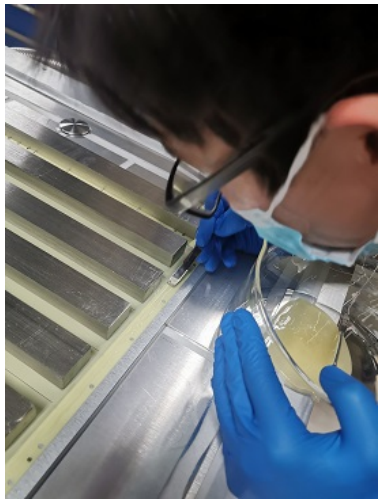
- With copper on the top of THGEM, we are able to divide the whole active area into 20 sectors by normal PCB technique;
- GND lines on Resistive layer PCB and then coat DLC on the surface;
- A slot between the adjacent sectors to let the GND line located in, to make sure it is flat after gluing;

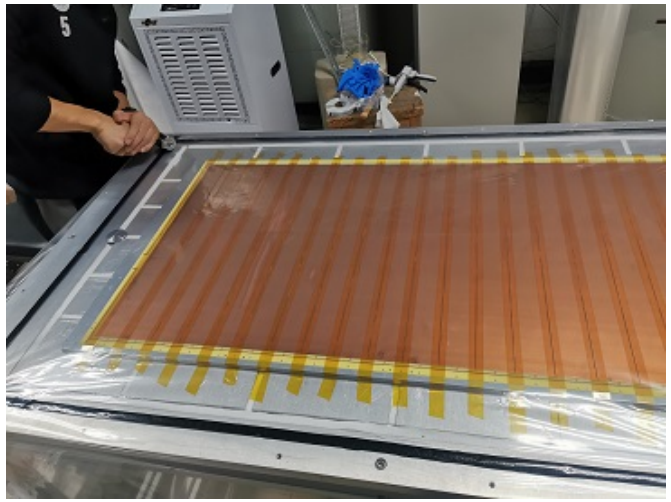
Fabrication of 100cm×50cm RWELL detector

1st 100cm×50cm RWELL:

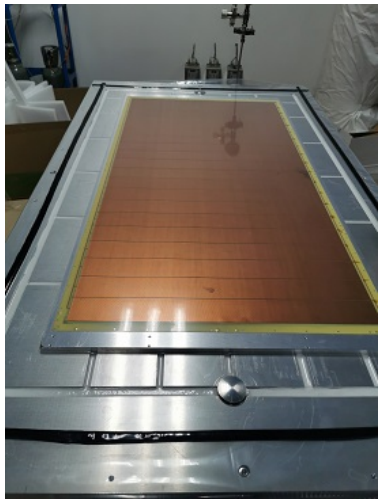


Painting the glue

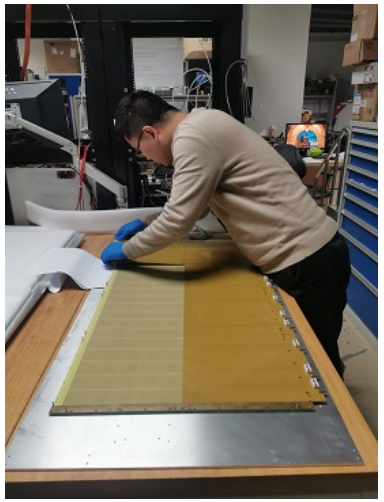




Seal the platform

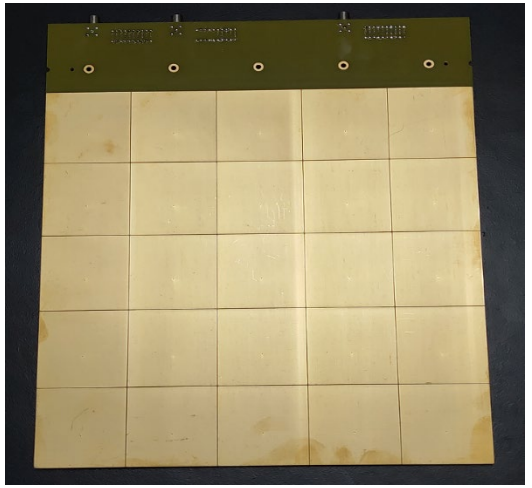


Pumping and drying



Assembling

- We make a special PCB and use it as the gluing mask;
- We put glue on both resistive layer PCB and THGEM PCB;
- A vacuum platform was used for gluing;
- 8 pieces of readout PCB are used, there are 25 pad(Pad size 5cm×5cm) on each pcb

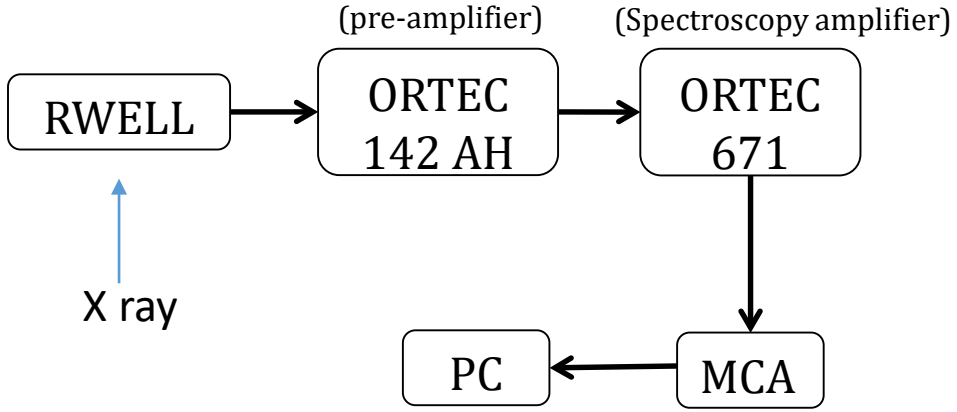


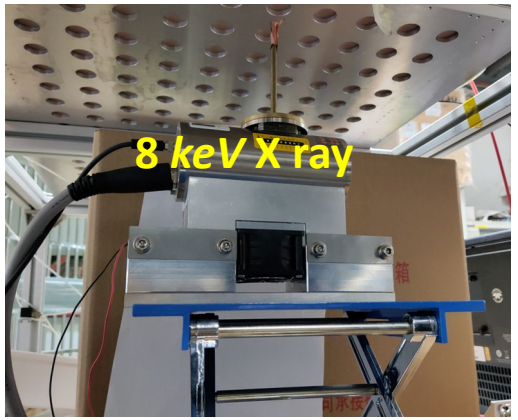
25 cm×25 cm Readout PCB

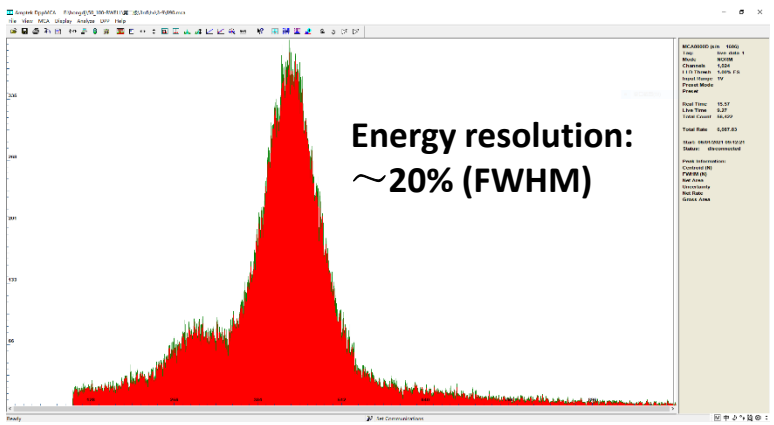
Gain .VS. HV

- Test setup

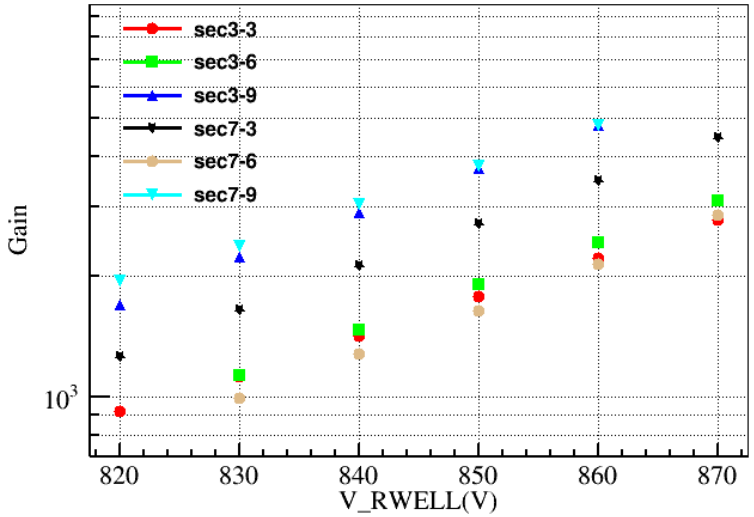
Gas: Ar-5%iC_4H_{10}

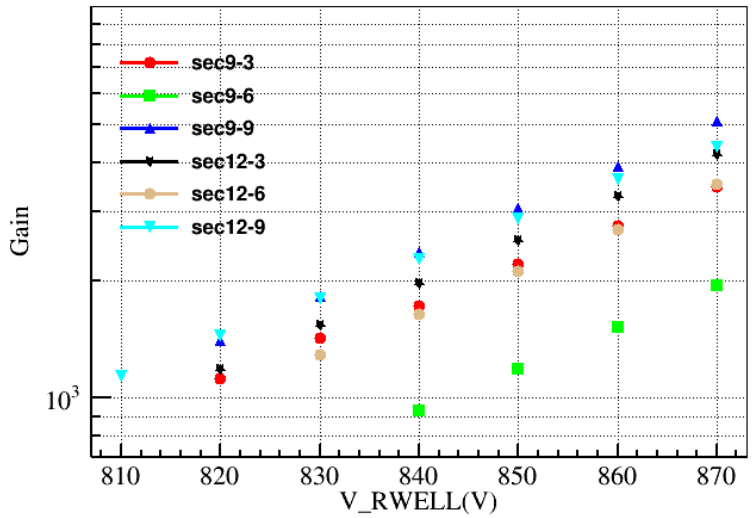


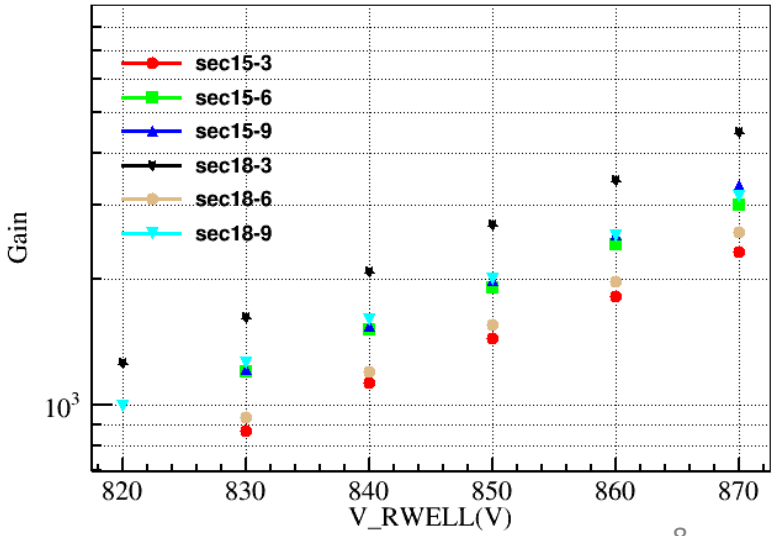




- Gain vs HV：





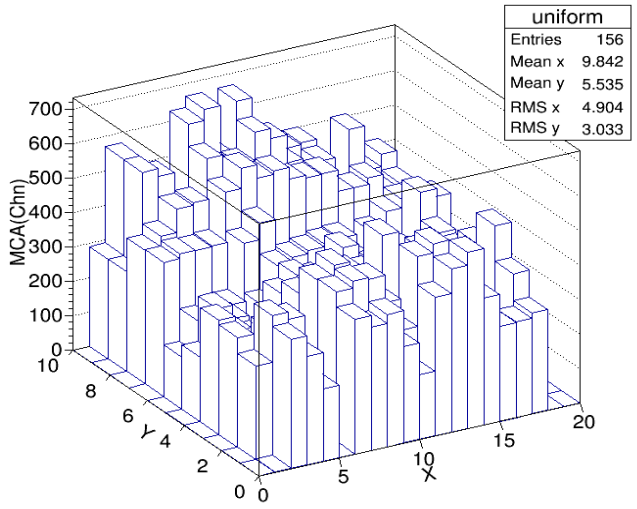


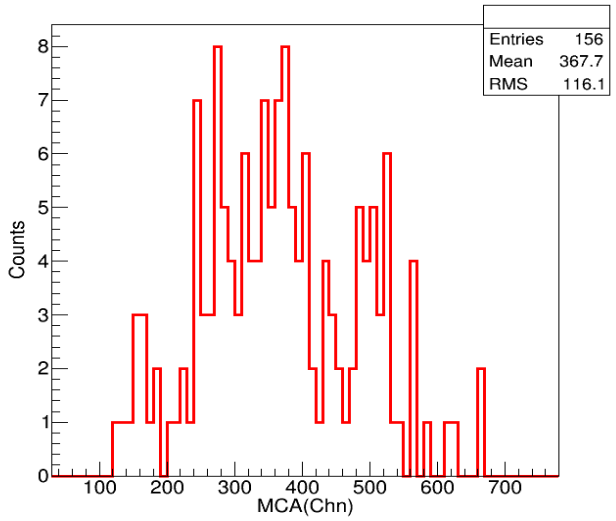
Gain uniformity & Rate capability

- 200 pads in total, but only 156 pads are calculated.

■ **Two sectors discharge seriously(disconnected);**

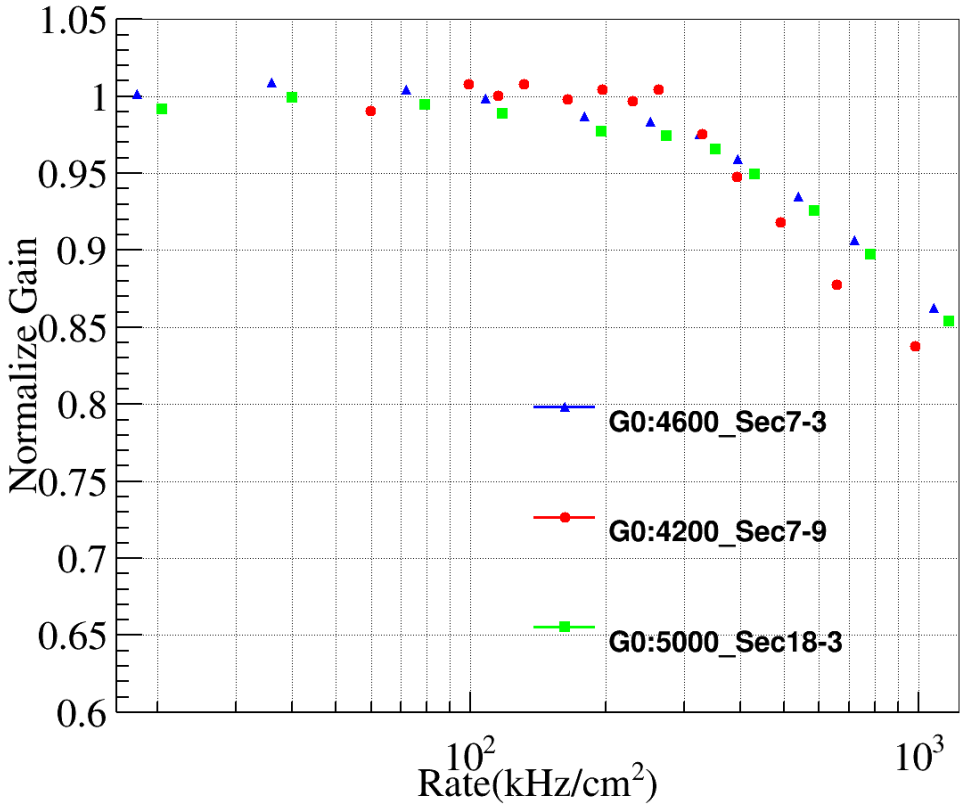
■ **Small signals in some area;**





Gain Uniformity： RMS/Mean～31.6%@～2100 gain

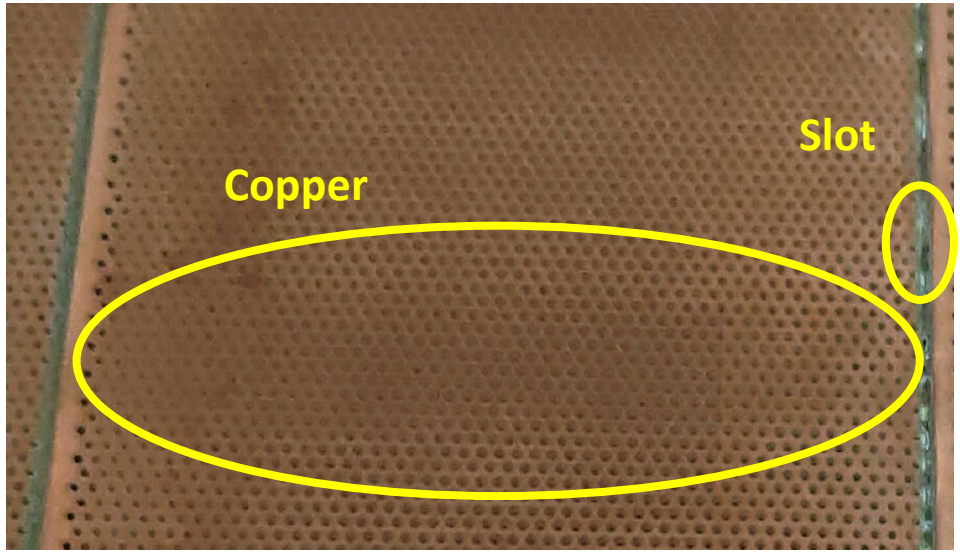
■ **Collimator dia:5.5mm, 8keV X-ray**

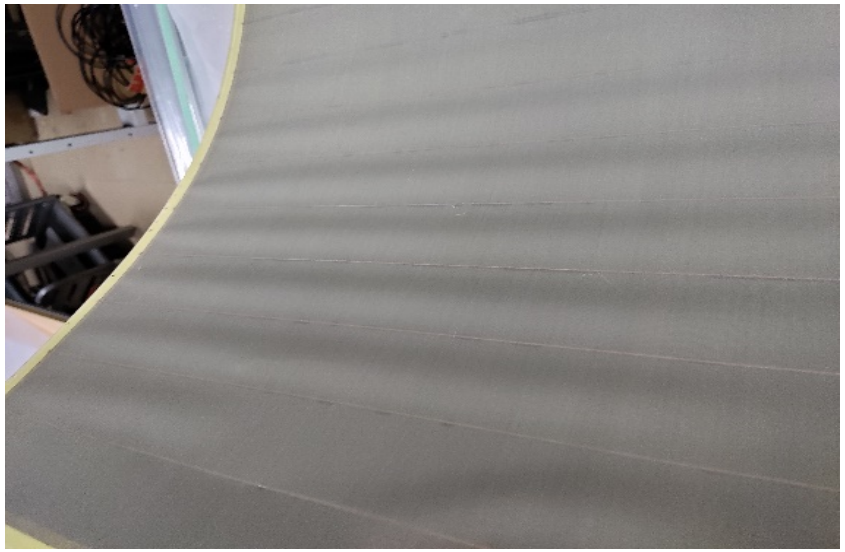


Rate capability： >500kHz/cm² @90% Gain

Problems in 100cm×50cm prototype

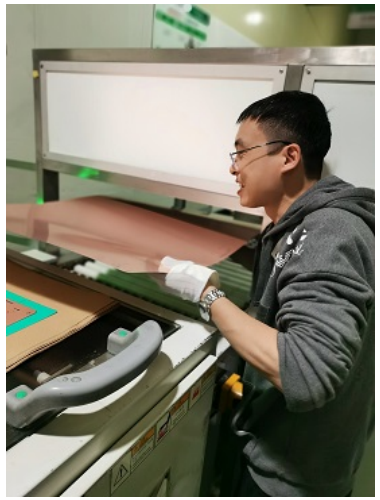
- Slotting in the THGEM reduce mechanical strength of the foil
- Incomplete gluing on the slot cause discharge easily
- Reducing copper to less than 2μm may lead to exposure of the substrate
- Gluing on the slot only is not enough, the center part of the sectors still can move





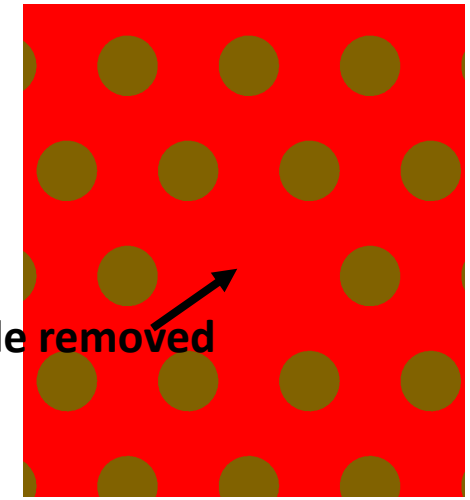
Improvements on the 100cm×50cm prototype

- Thickness of the copper electrode is increased to 5 μm;
- Thickness of the GND line on resistive layer is reduced to 4～5 μm, and slots between two adjacent sectors are removed
- Additional gluing points are added(2.5 cm for each, the hole is removed) on the THGEM foil



Cu reducing of resistive layer PCB

Gluing area of the THGEM PCB

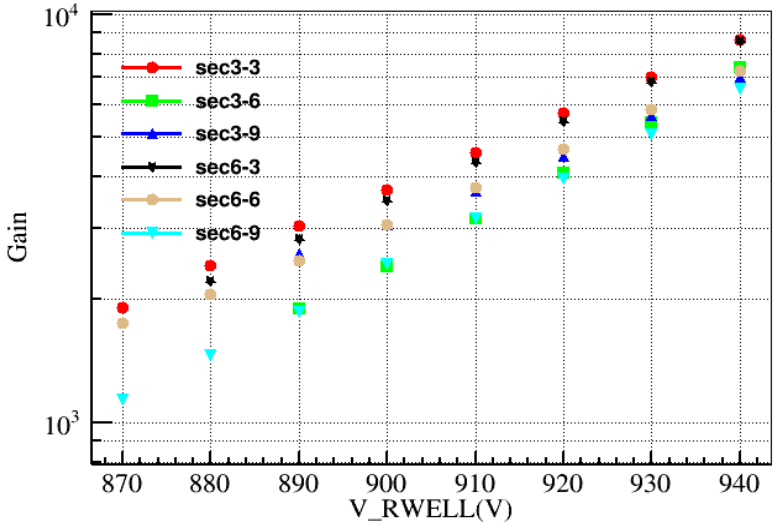


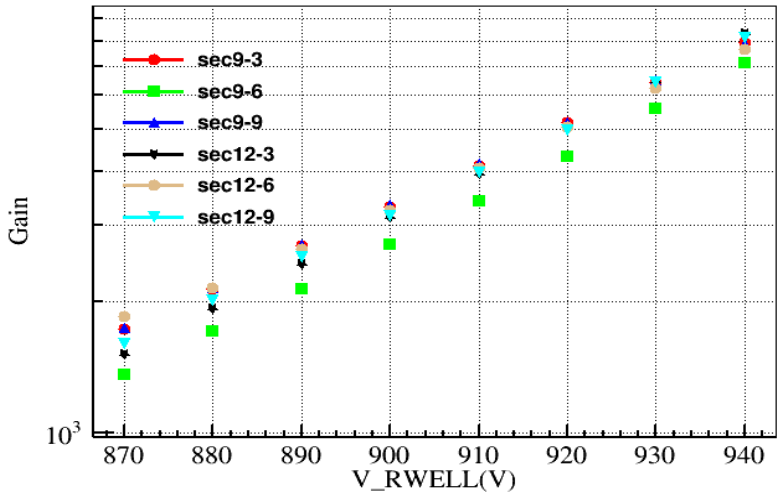
Remove the hole each 2.5cm in center of the sectors for gluing

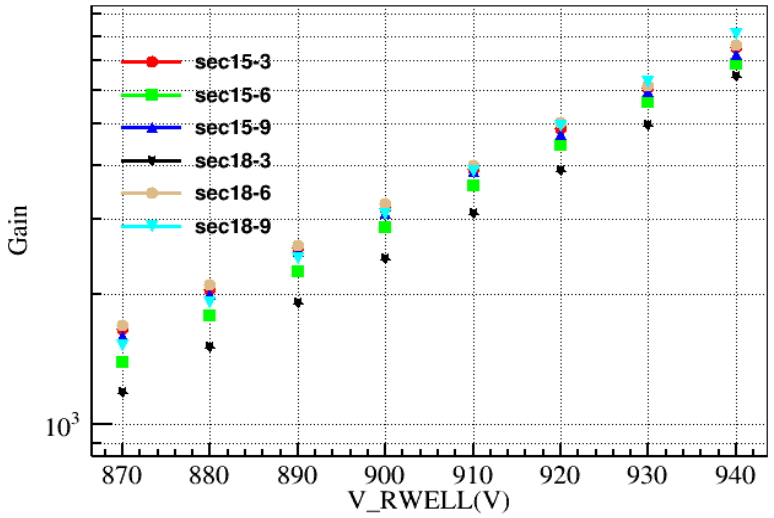
Performance

- **Gain vs HV:**

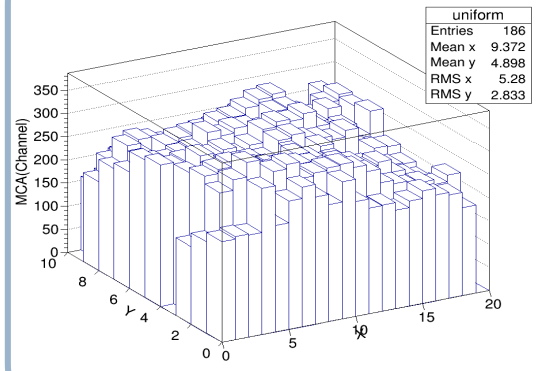
Gas: Ar-5%iC_4H_{10}

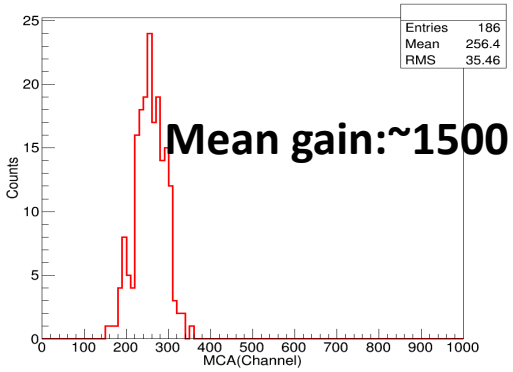






- **Gain uniformity :**

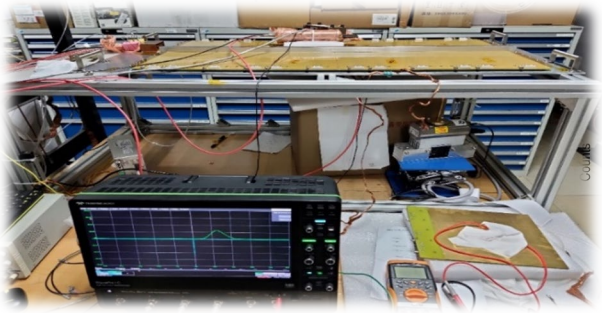


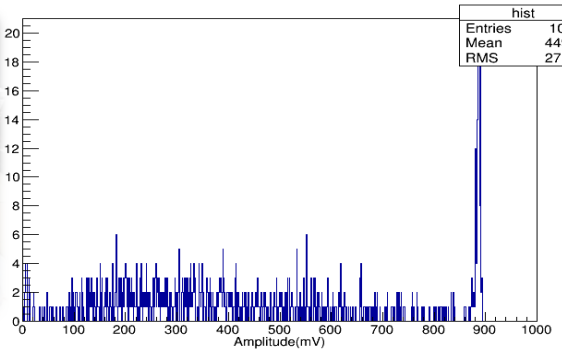


Mean gain:~1500

RMS/Mean=35.46/256.4～13.8% <31.6%(1st RWELL)

- **Cosmic ray test:**



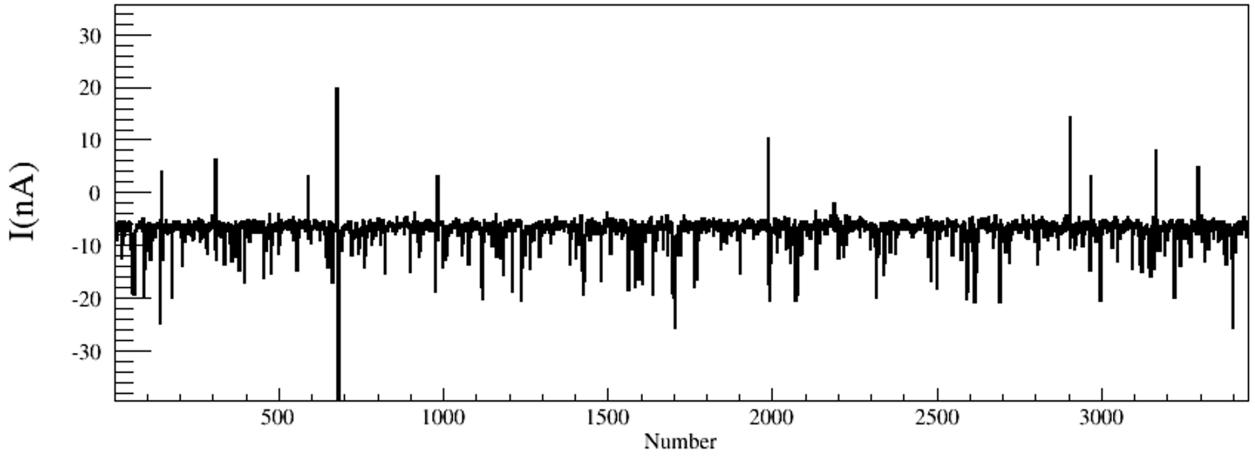


Detection efficiency：

978/1003～97.5% @5000 induced signal gain

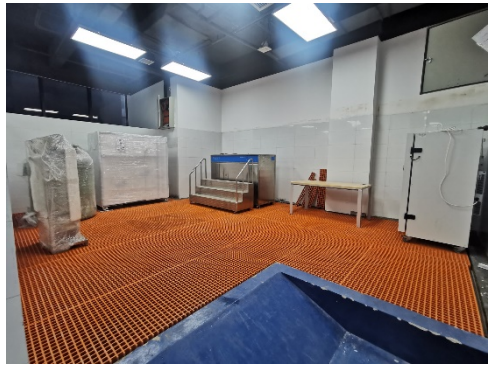
Summary

- Two versions of 100 *cm*×50 *cm* RWELL detectors were developed. Gain uniformity of the second RWELL detector is about 14%, which is significantly improved than the first one. And the detection efficiency to MIPs is about 97.5% @5000 induce signal gain(Dead area included).
- All the bonding and fabrication processes were in a non-cleaning environment due to our lab and clean room is moving to the new building, this caused some sectors can not work well.
- Relatively high discharge frequency is still a problem. We will try to use chemical clean in future.

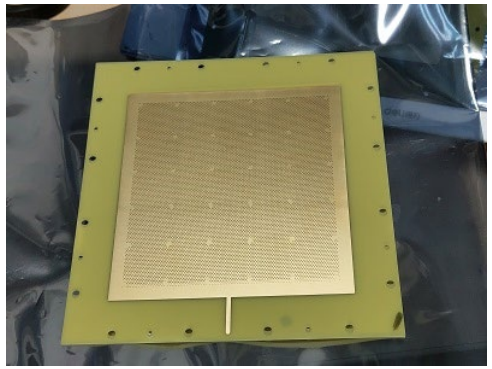
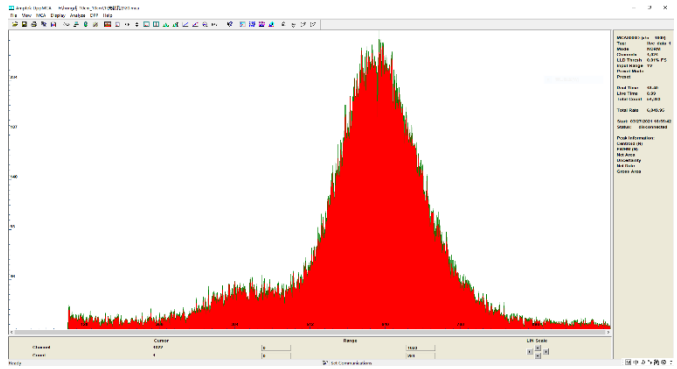


Outlook

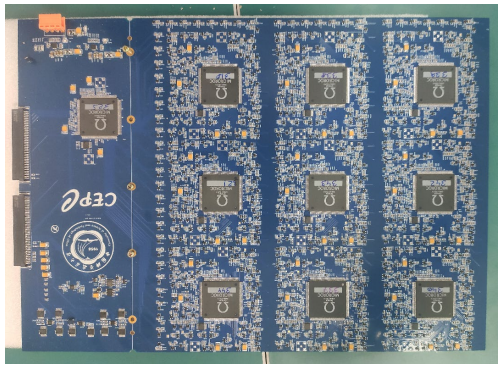
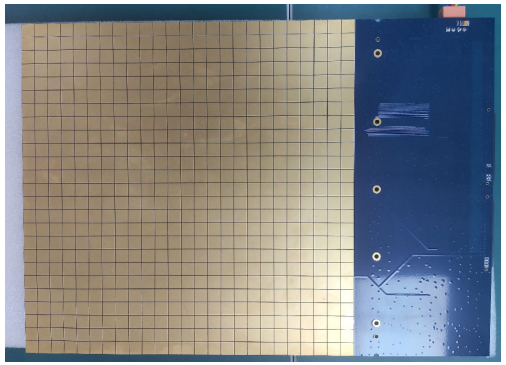
- New cleaning room, washing room, and lab is under construction， the next RWELL detector will be assembled in the new clean room.


- The “Cu reduction—Hole drilling—Pattern transfer—Gold deposition” technique for 10cm×10cm samples is tested, With gold protected, the foils can be cleaned by the chemical method. This technique will be soon used on the 100cm×50cm RWELL PCB.

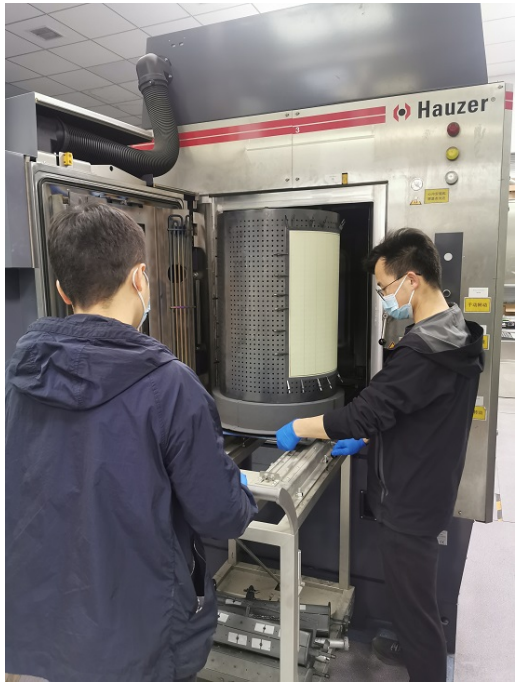



- New front end electronics with 1cm×1cm readout pad are under development, they will be tested in near future

Special thanks to:

Lanzhou Institute of Chemical Physics and China Fastprint



兴森科技 FASTPRINT

For their great help on the detector manufacture