中国科学技术大学
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Development of RWELL detectors for large area & high rate application

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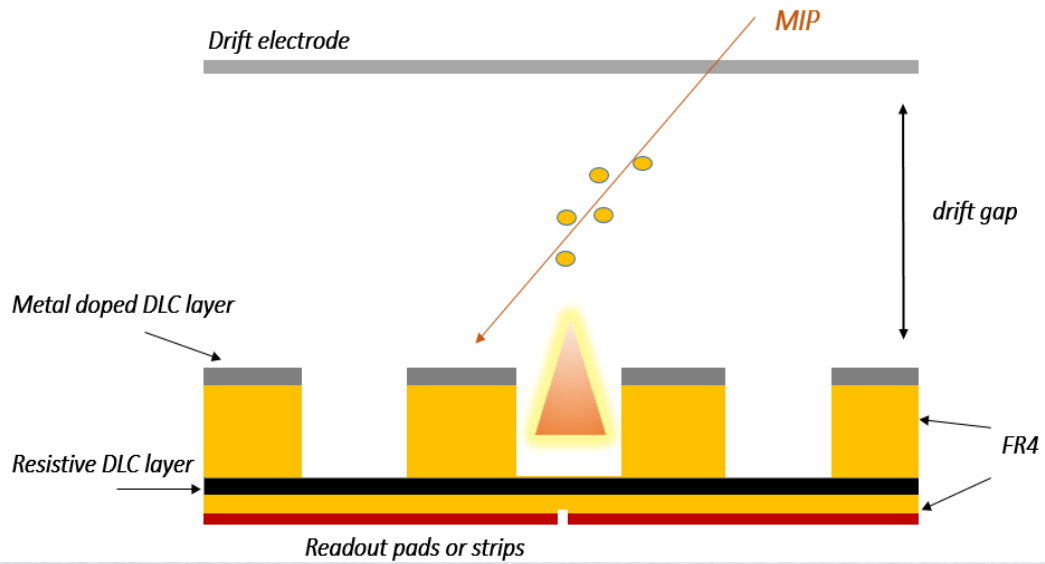
6th.Oct.2020
RD51 Collaboration meeting

Contents

- Introduction
- High rate RWELL with 2D readout
  - Detector fabrication
  - Performance test
- Large area RWELL for DHCAL
  - Detector fabrication
  - Performance test
- Summary and next work plans

Introduction

RWELL configuration

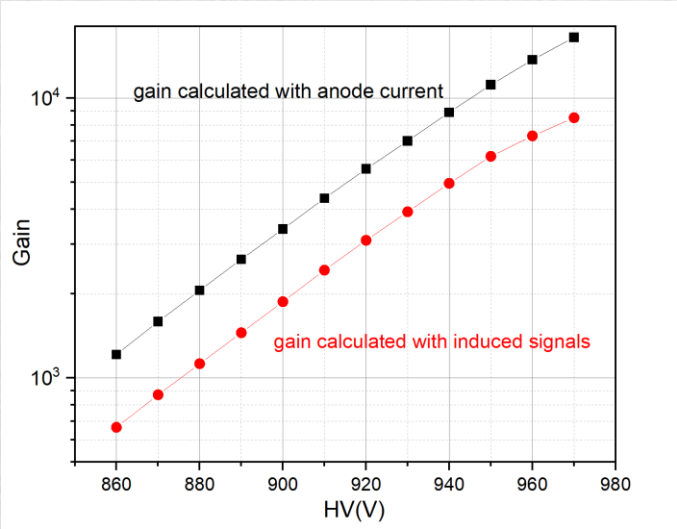


- ✓ Compact Structure, Spark-resistant, high dynamic range.
- ✓ Conductive & resistive layers are produced by Magnectron sputtering, easy for large area production

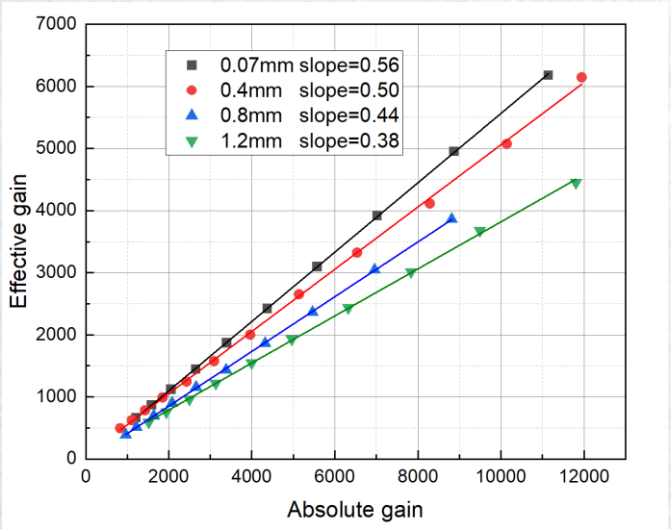
- Applications
  - Tracker with 2D readout
  - DHCAL sampling elements for the CEPC
- Performance indicators
  - High-rateTracker
    - position resolution few hundred micrometers
    - Rate capability >1MHz/cm^2
  - DHCAL RWELL
    - Detector thickness <6mm
    - Detection efficiency >95%
    - Sensitive area:100cm×50cm
    - Gain uniformity factor <20%

RWELL fabrication requirements

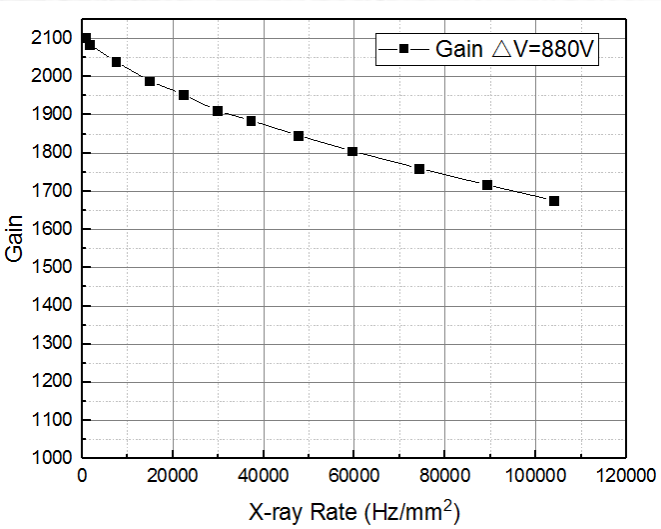
Gain curves of an 5cm ×5cm RWELL



RWELL with different thickness of dielectric between resistive layer and readout pad



Gain dependence on irradiation X-ray rate of a *5cm ×5cm RWELL*



- The effective gain should be measured with induced pulse height.
- Increase the rate capability by adding GND connecting points on resistive layer.
- RWELL amplification part need to be assembled by gluing method.

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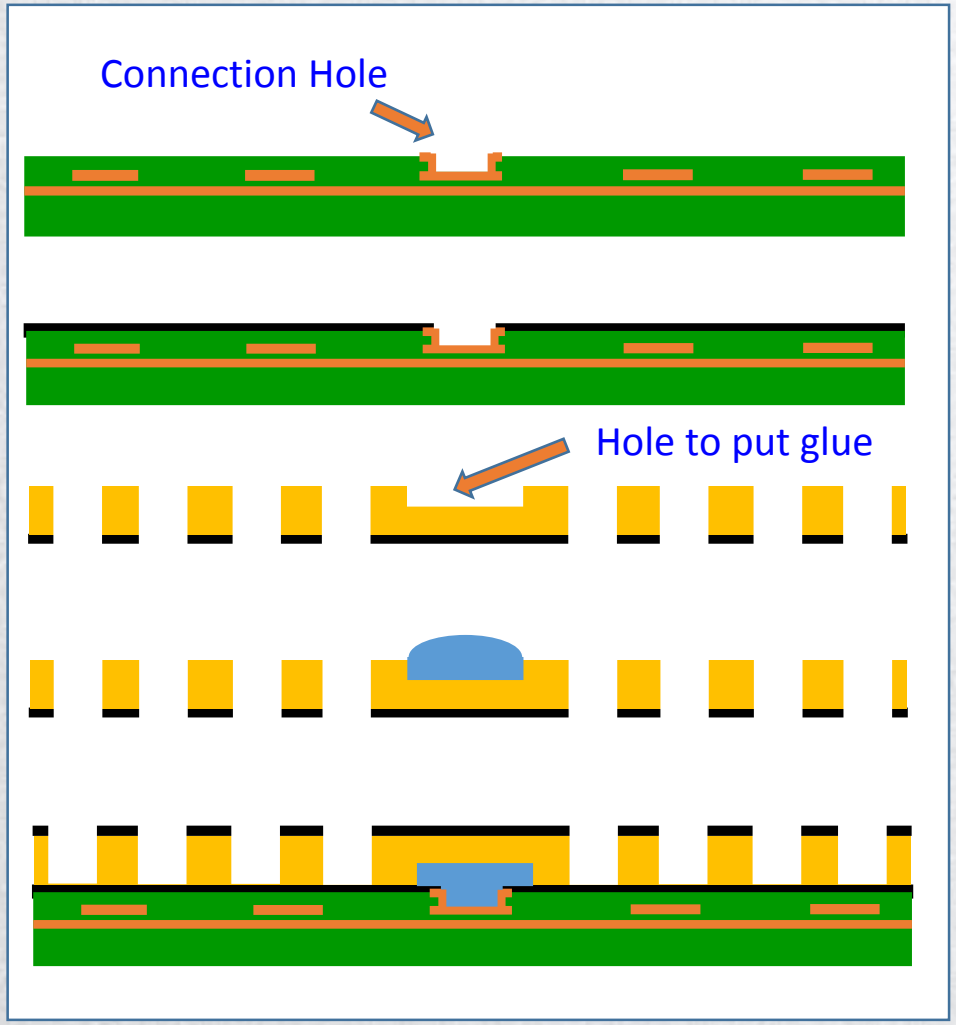
RWELL with 2D readout

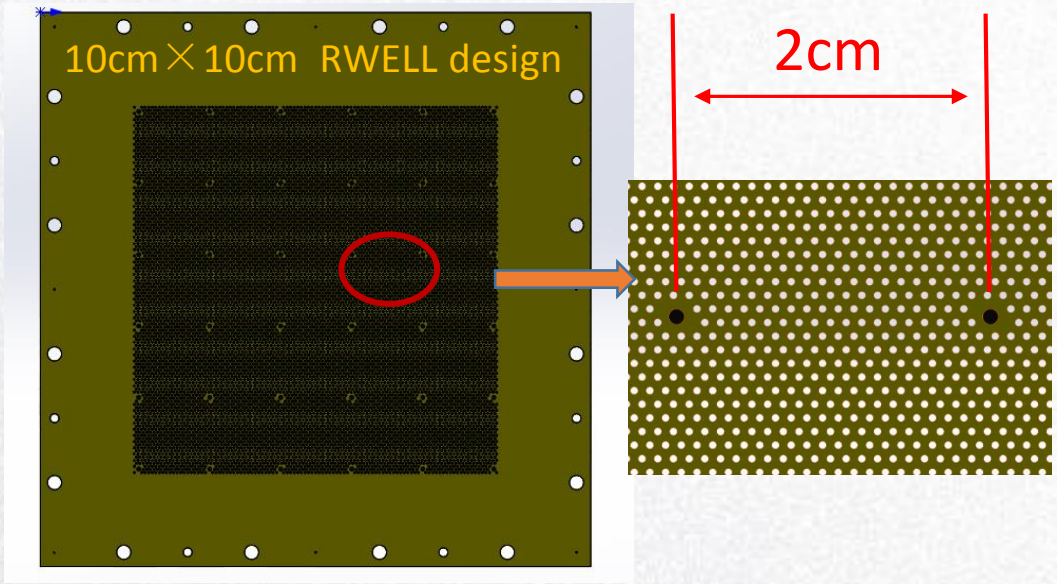
2D readout

Coat DLC on readout

Single-faced THGEM

Glue THGEM and readout with epoxy glue

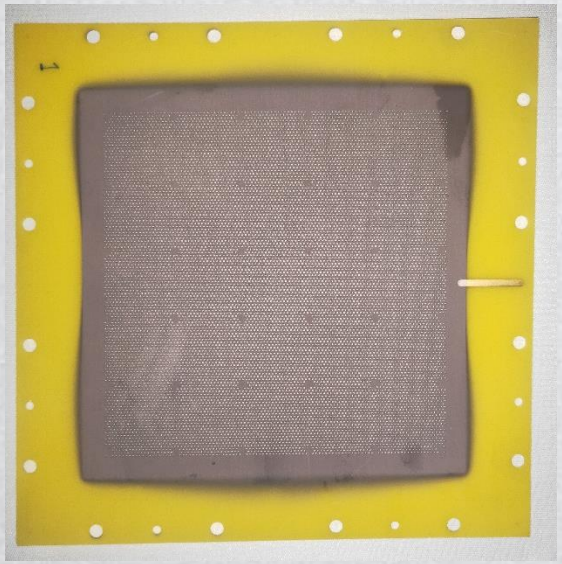


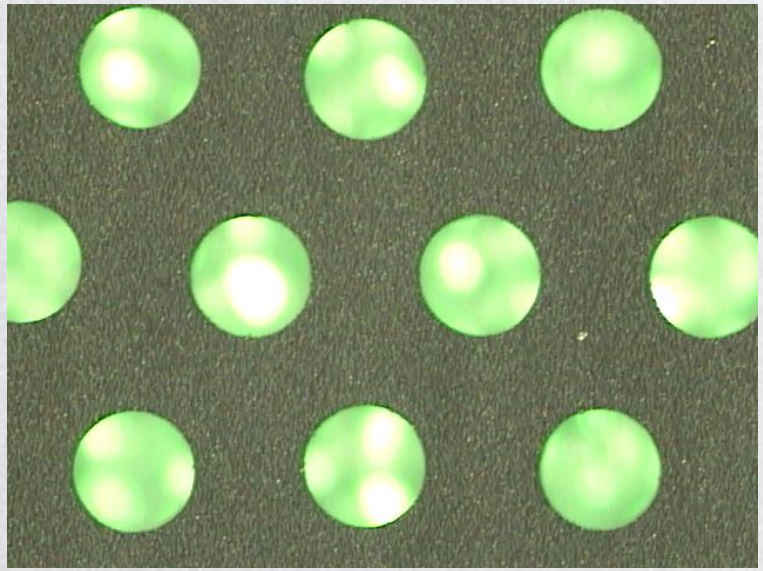


- DLC Resistive layer is connected to readout strips by the Metallized via holes

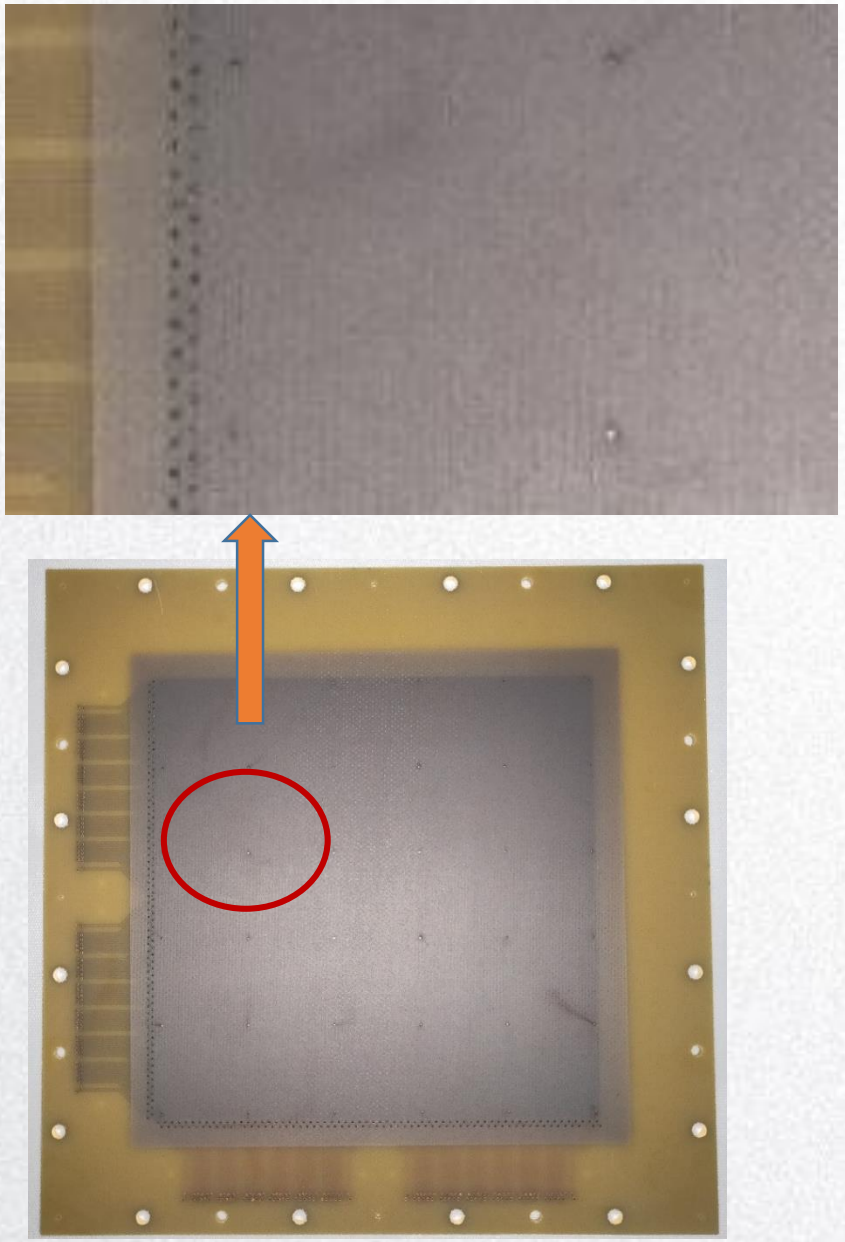
THGEM and readout PCB

- Active area: 10cm ×10cm
- Single-sided THGEM
  - Cr+DLC
  - Thickness 0.5mm， diameter 0.5mm， pitch 1mm
- Readout PCB
  - DLC resistivity： MΩ~GΩ
  - 2D strips in the middle layers





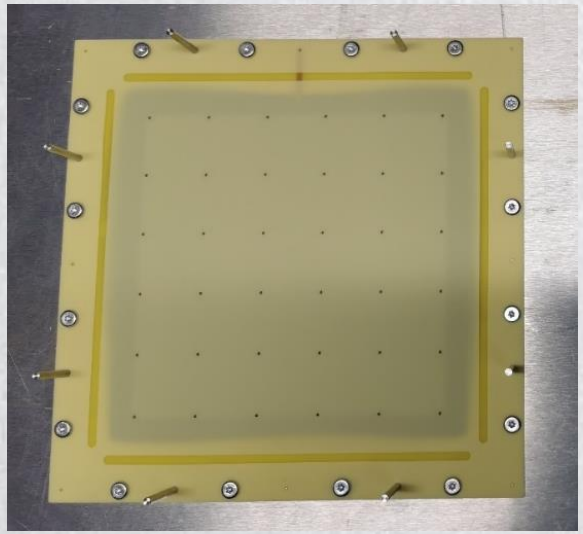
Single-sided THGEM



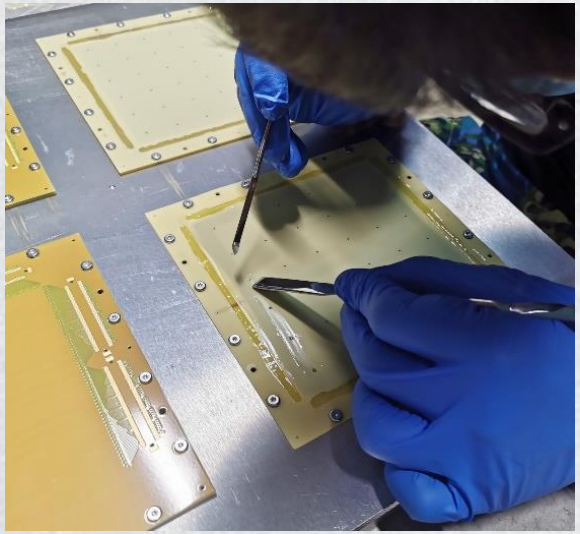
Readout PCB with resistive DLC layer

RWELL gluing process

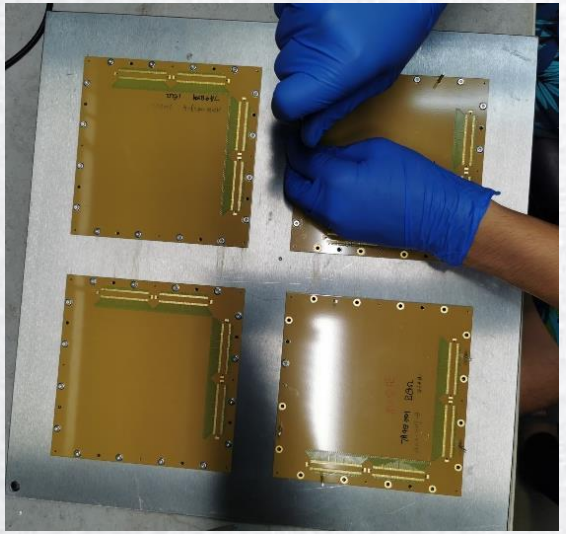
① Aligned THGEM and gluing mask



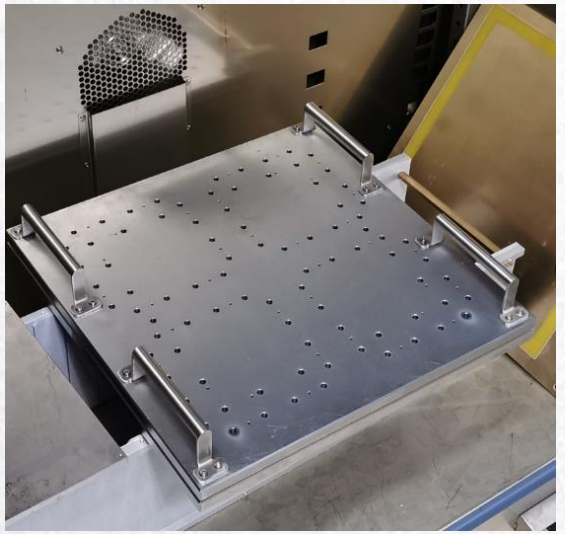
② Apply epoxy glue



③ Remove the mask and attach the readout PCB

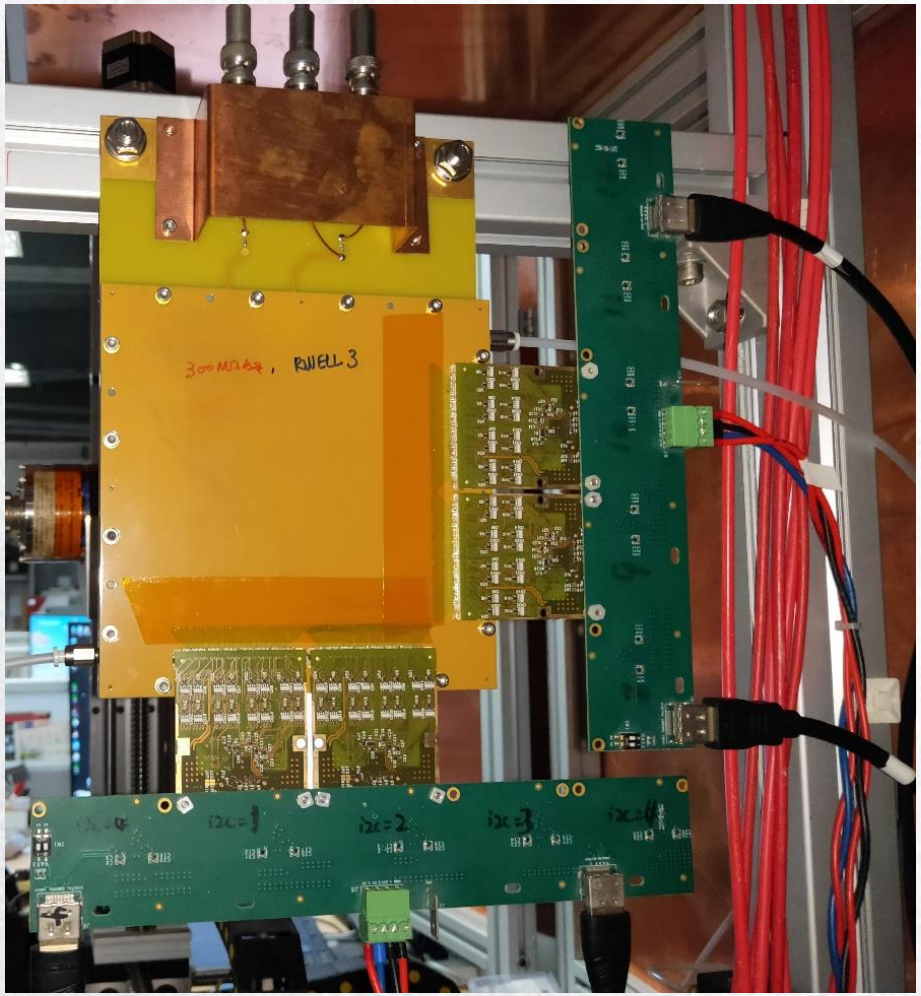


④ Press the PCBs with a heavy steel plate and baking.



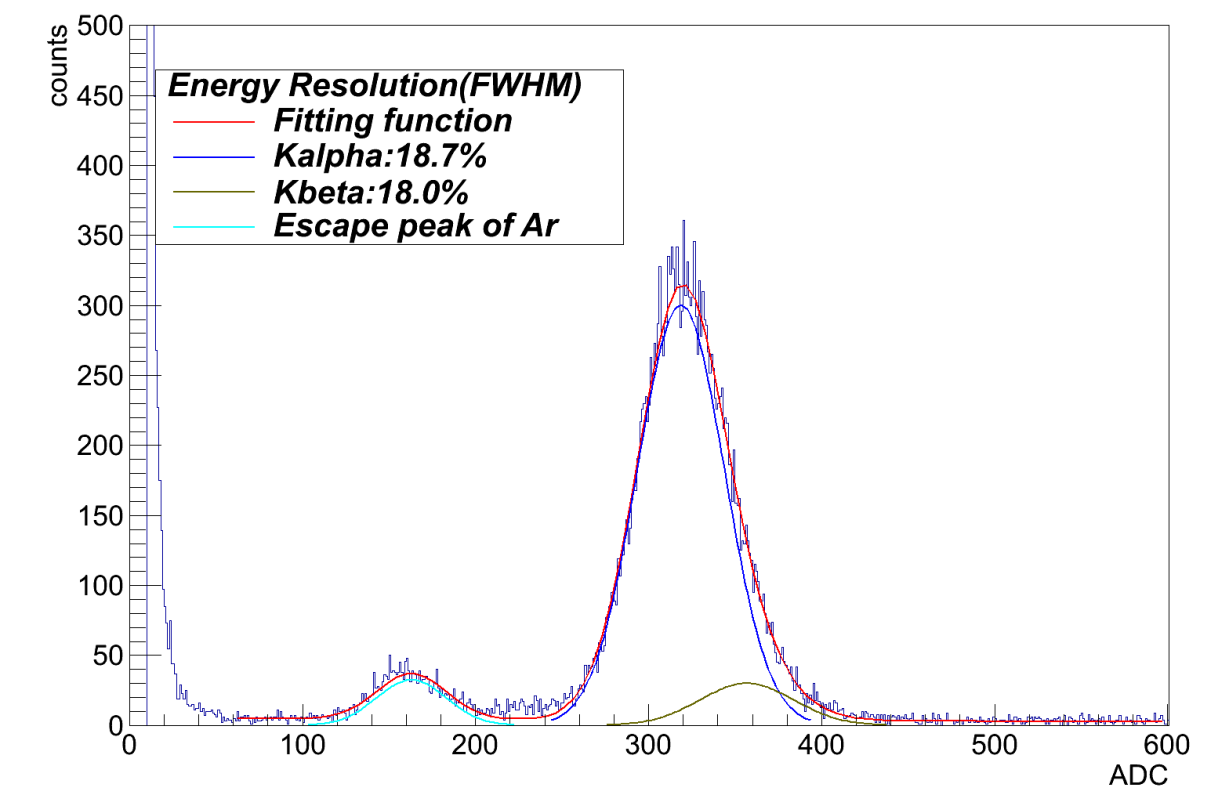
Experimental setup

- RWELL: Active area 10cm×10cm, Drift gap 10mm
- 2D readout： strip pitch 0.39 mm （10 cm / 256 channel）
- APV25 Electronics and PreAmp, amplifier, MCA…
- Source: 8keV X-ray and Fe55 source
- Gas: Ar/Isobutane(5%)

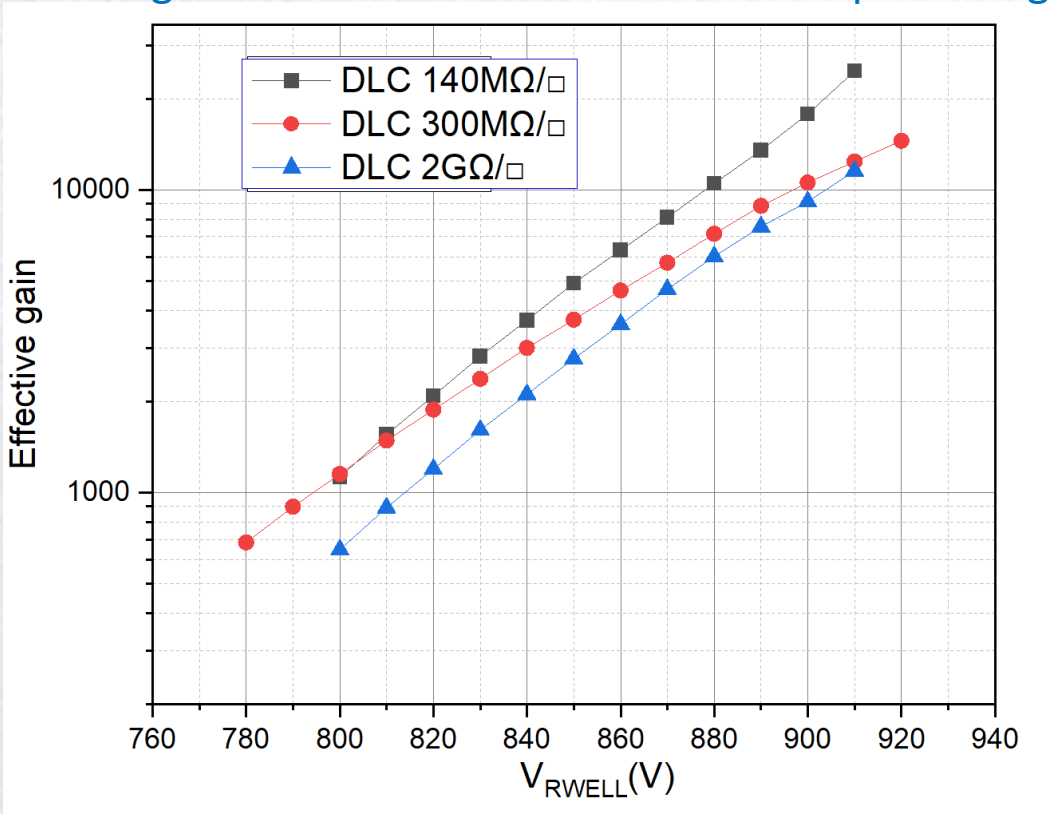


Gain vs. HV

Fe55, Ar/Isobutane (95/5)
Signals induced on the top electrode of THGEM were measured.



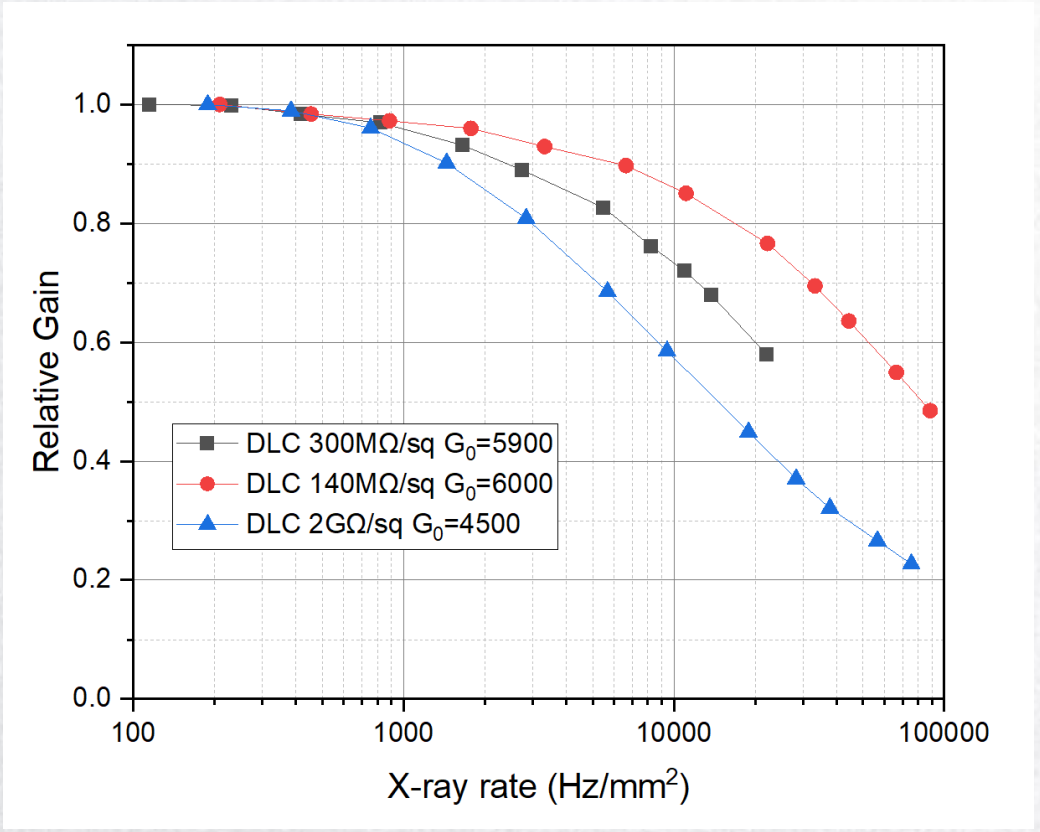
Detector's gain curves measured with induced pulse height



Gain vs. X-ray rate

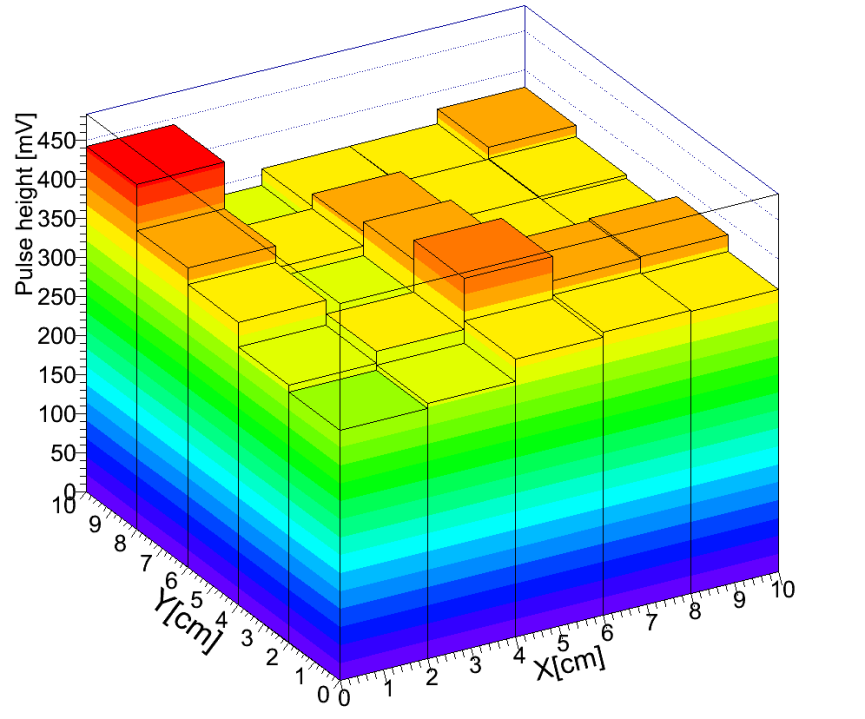
- Cu target X-ray, Collimator diameter: 5 mm
- The gain is calculated with anode current. The induced signal is smaller. We should measure the rate capability at higher gain in the future.
- The distance between grounding holes is 20mm, we should use larger beam size to measure rate capability in the future.

Relative gain vs. X-ray rate

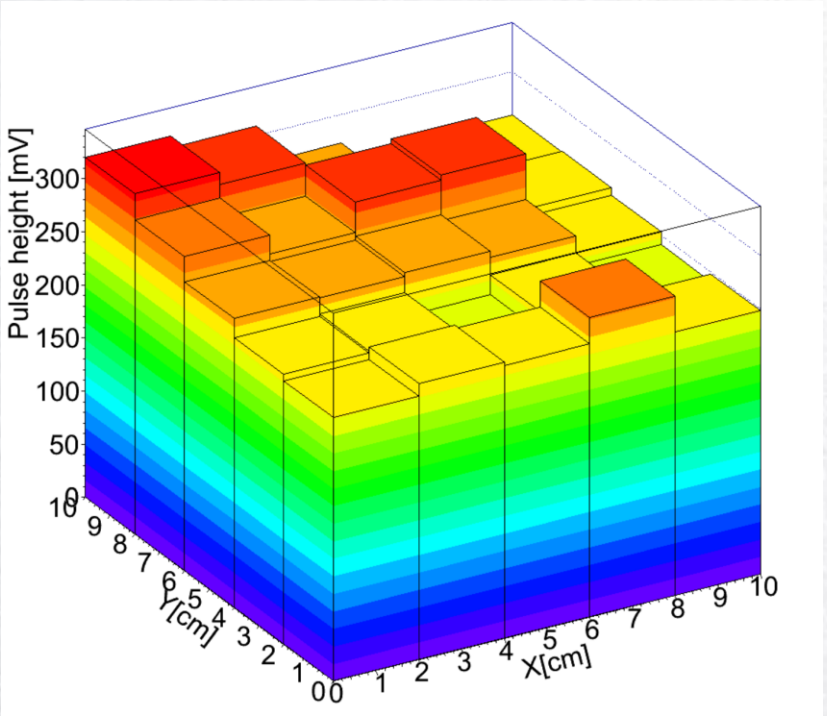


Gain uniformity

DLC resistivity 140MΩ/□ ,HV=850V, Gain~4000, RMS/Mean=7%

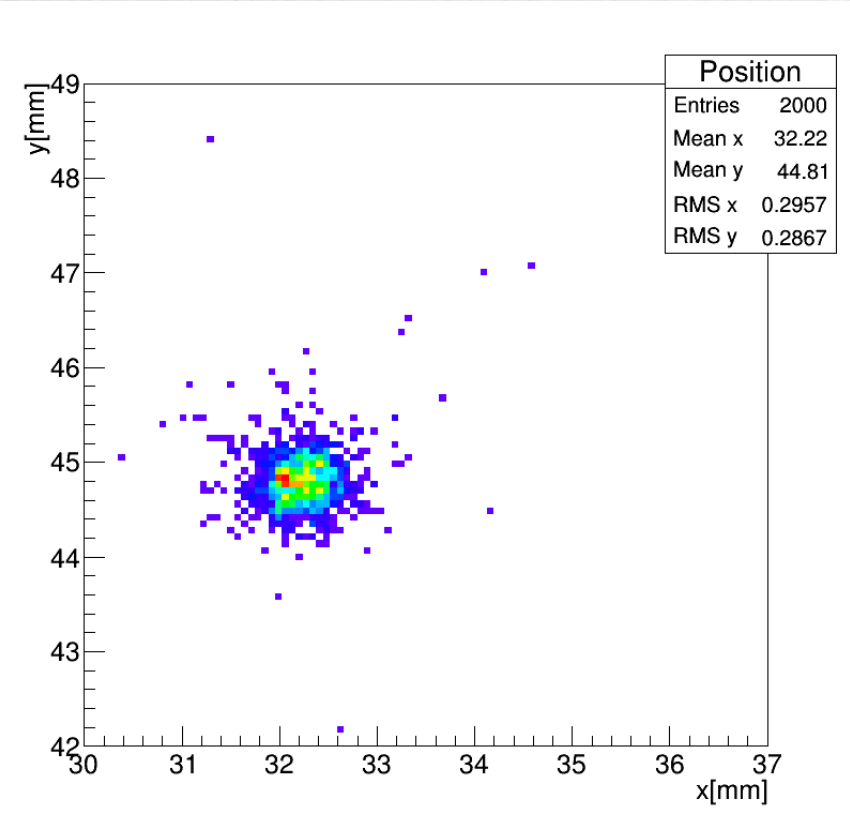


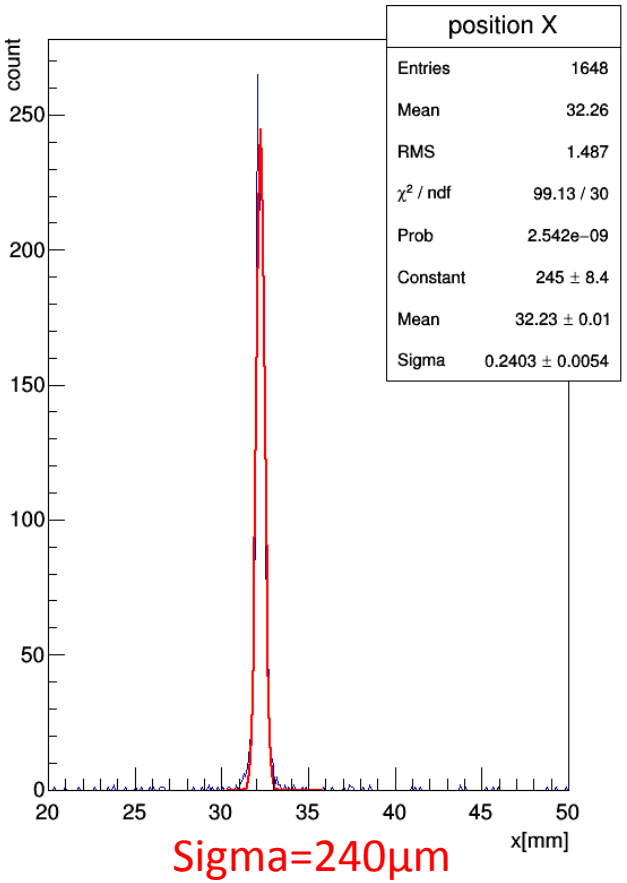
DLC resistivity 300MΩ/□, HV=850V, Gain~3000, RMS/Mean=8%



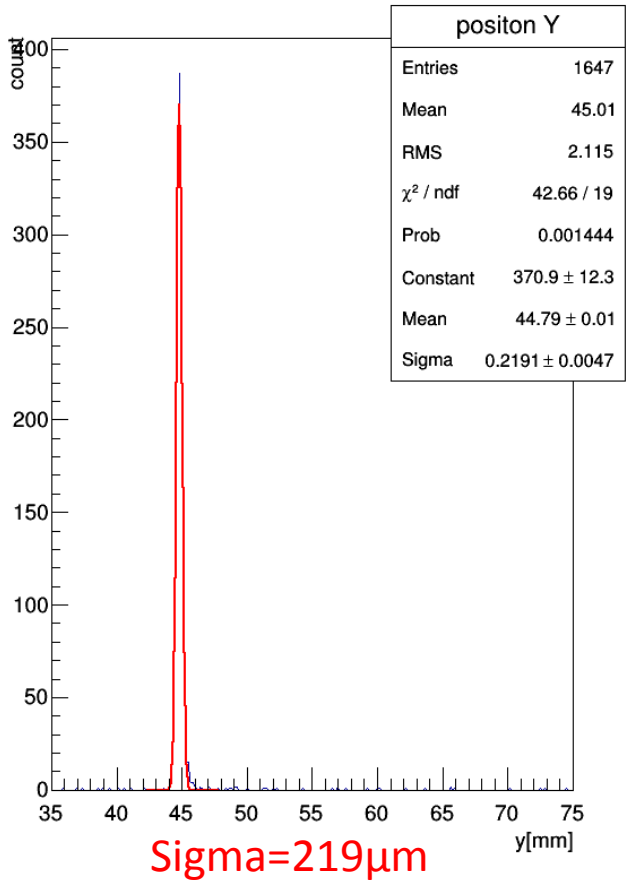
X-ray hit position reconstruction

- Collimated X-ray: 80μm×80μm
- Charge centroid method



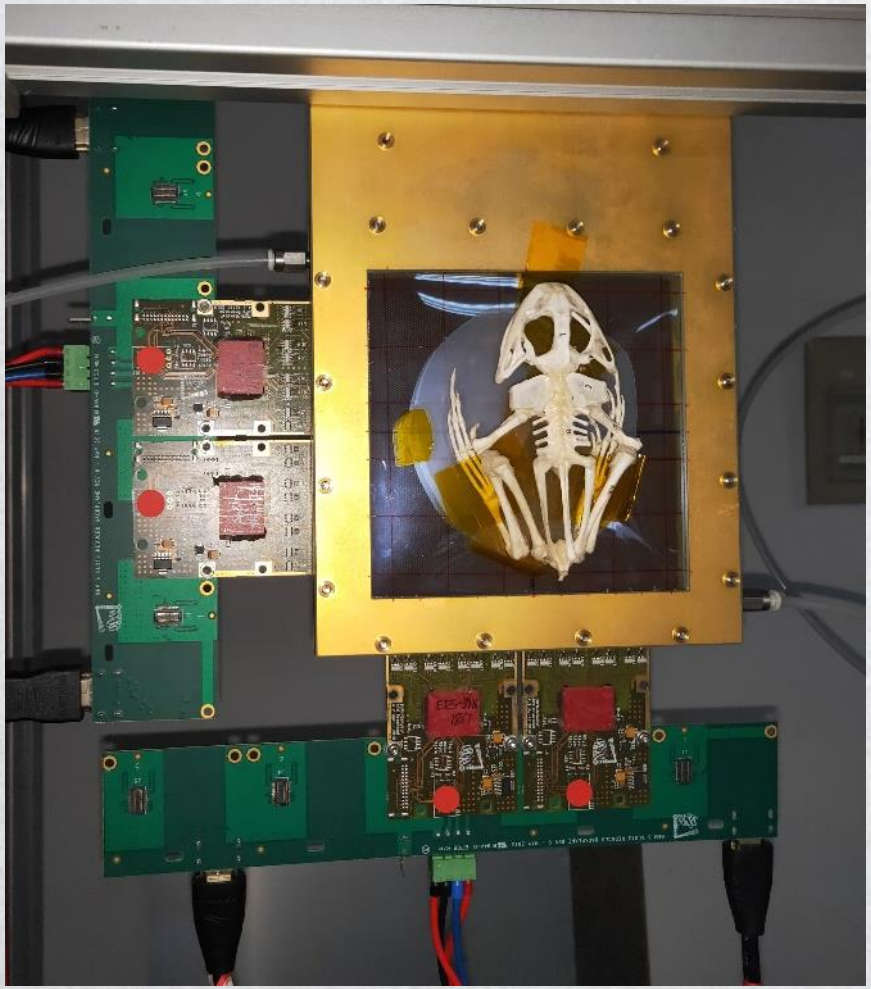


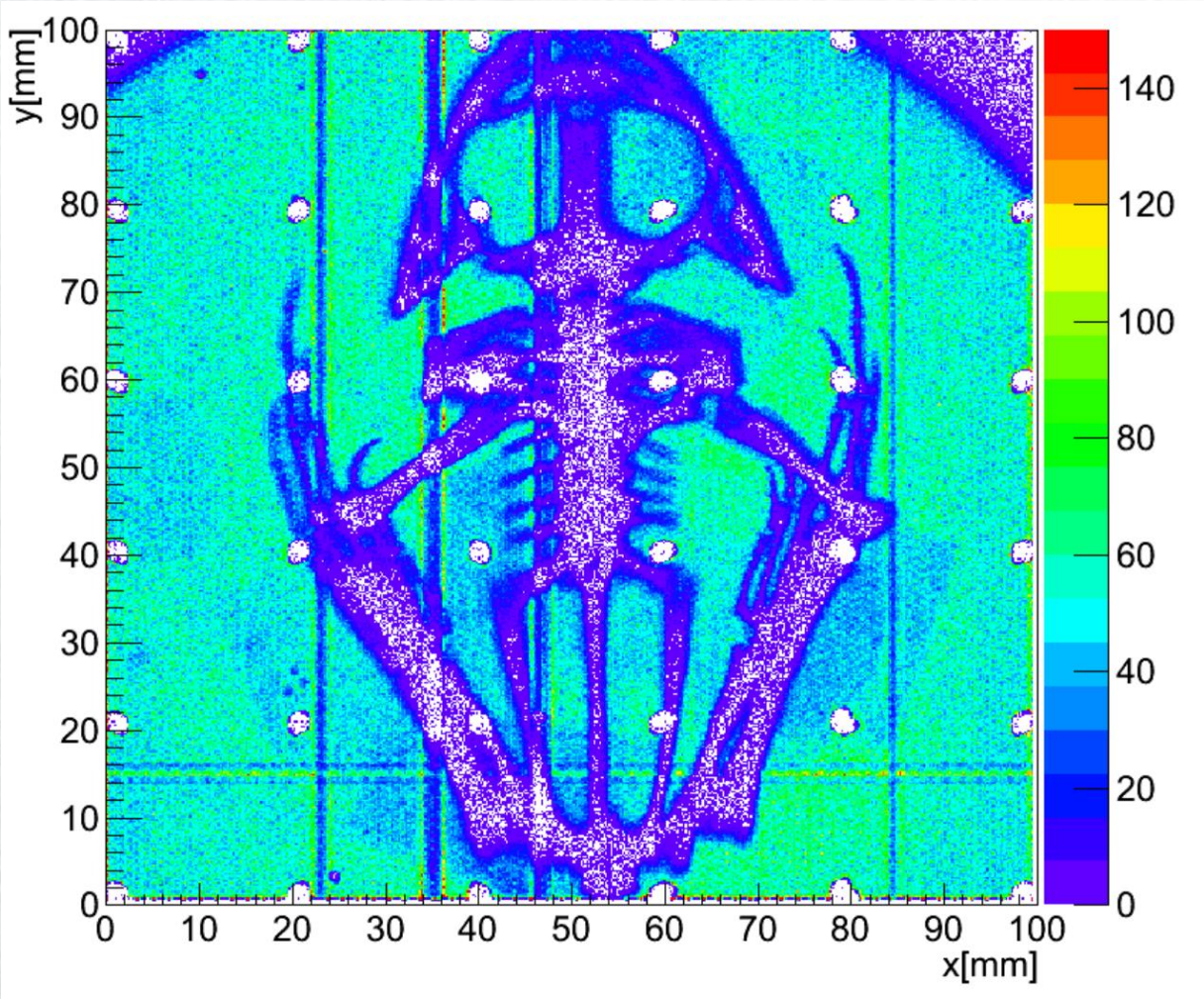
Sigma=240μm



Sigma=219μm

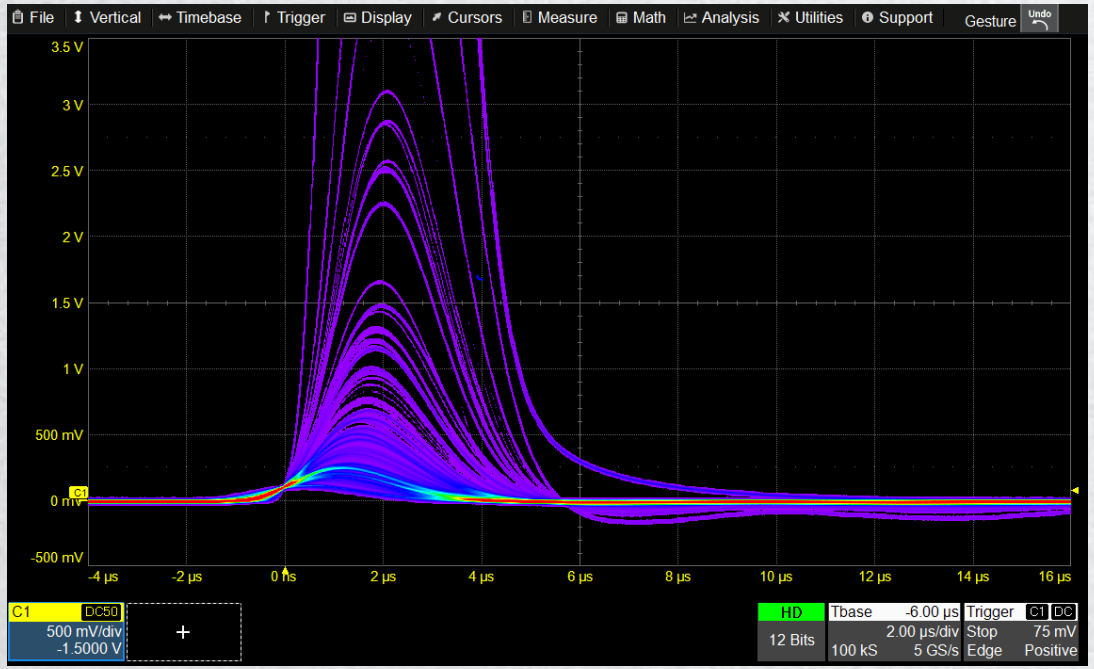
X-ray imaging



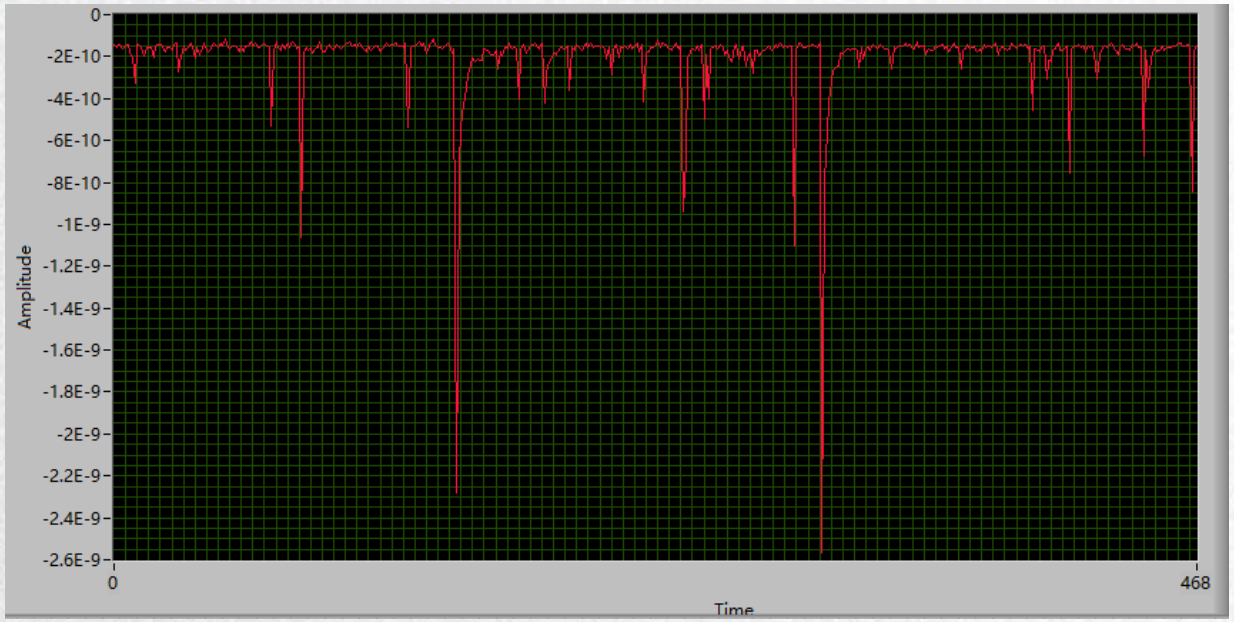


Discharge problem

HV=850V, no X-ray



Anode current vs. time



Discharge rate ~10Hz

- Micro discharges rate ~10Hz
- Try chemical etching or segment the electrode to suppress the discharge rate?

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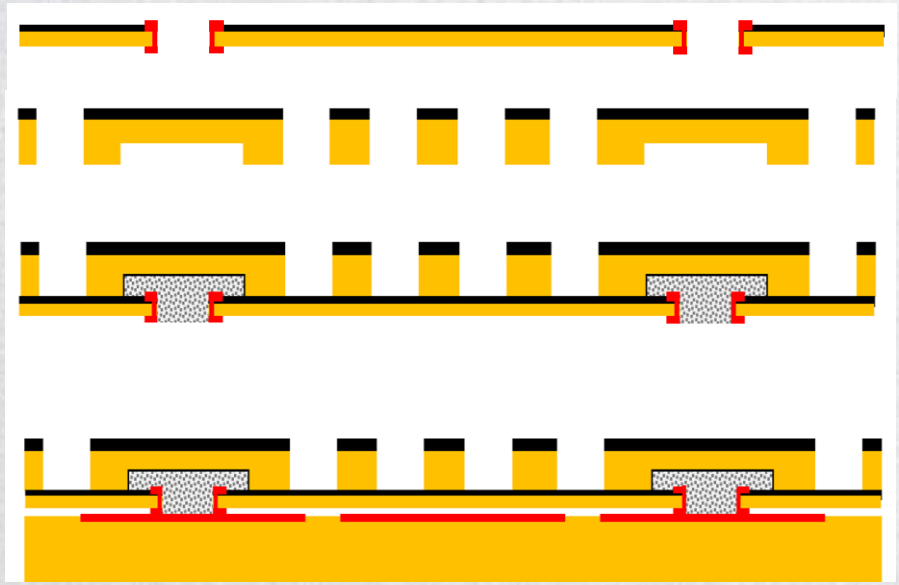
Fabrication difficulty for DHCAL RWELL

- The fabrication method for 10cm×10cm RWELL is not suitable for the large arera DHCAL RWELL
- Detector final active area: 100cm×50cm
  - Readout PCB can not roll to the supporting cylinder of the DLC coating device
- Readout electronics need to be integrated into the readout PCB
  - The previous gluing method may damage the electronics.(press with steel plate, baking)
- Method： Separate the resistive layer and readout PCB.

Fabrication method for DHCAL RWELL

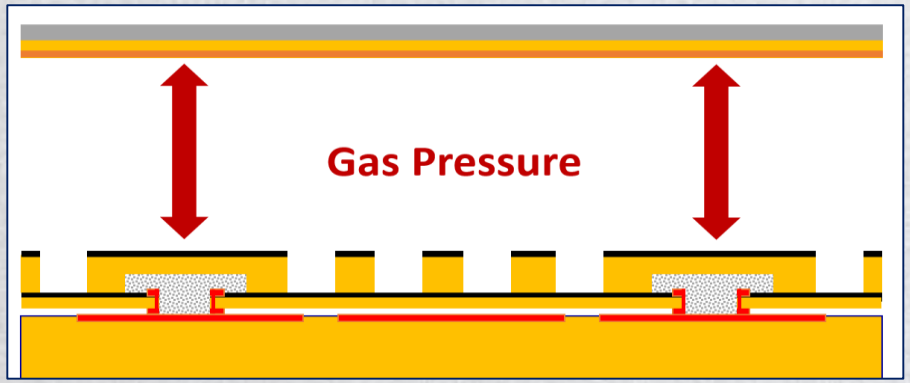


Resistive layer is coated on thin FR4 sheet（0.2 mm）

Single-sided THGEM with conductive DLC

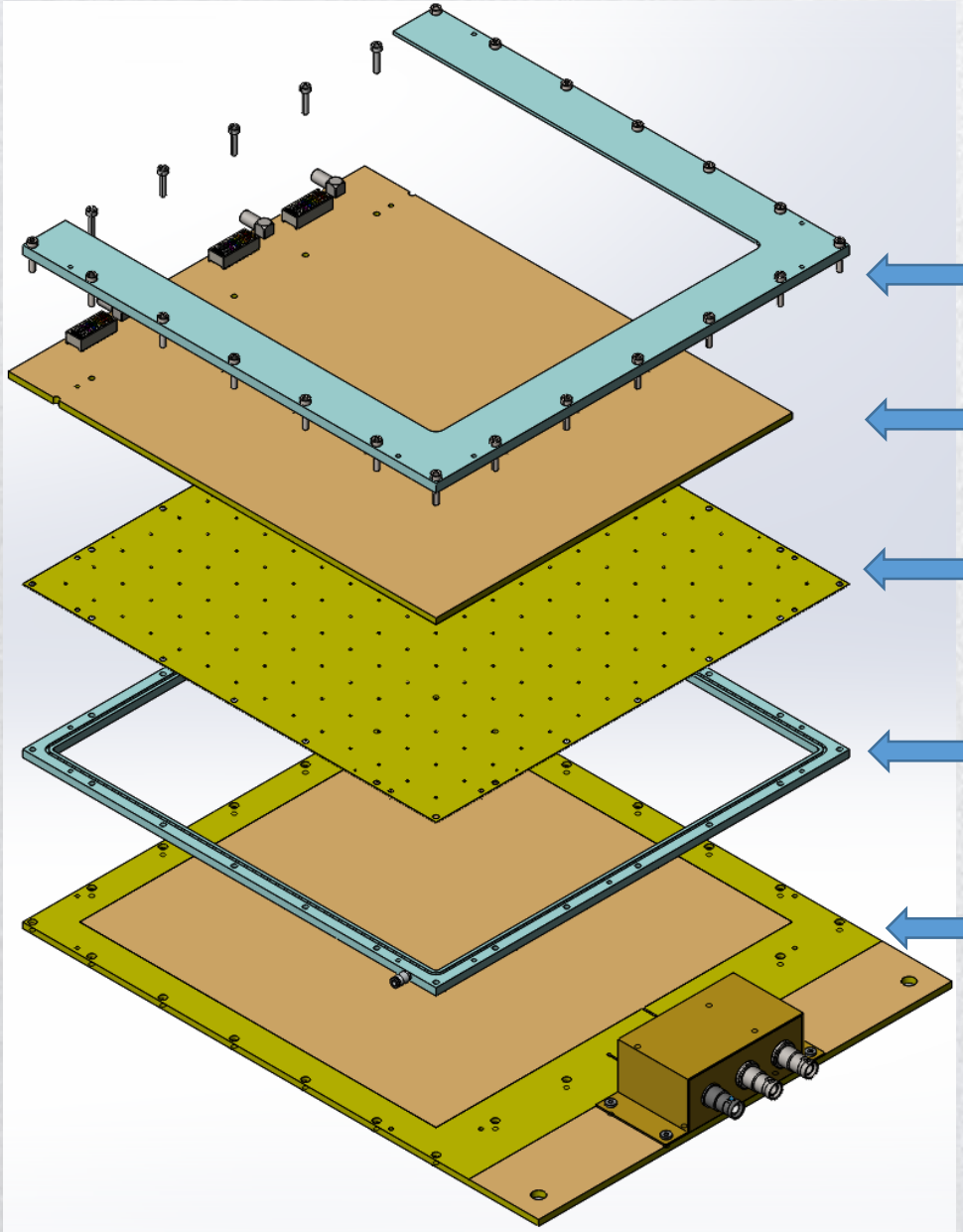
Glue single-sided THGEM and resistive layer (RWELL part)

Stack the RWELL part and readout PCB together without any glue

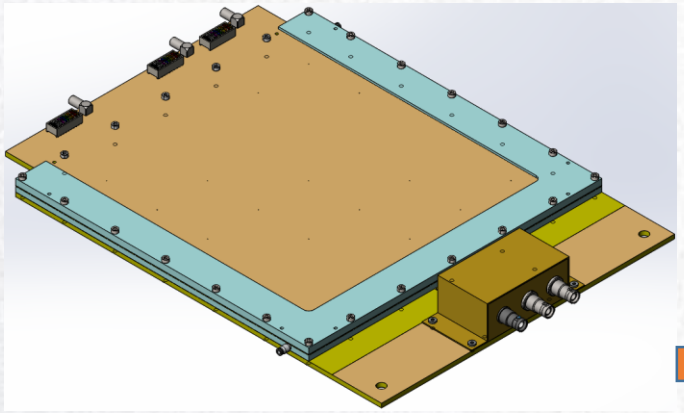


- The gas pressure in the detector chamber can ensure that the metalized vias and readout pads have good electrical connection.
- Charges are collected by Resistive layer and going into the ground through the vias to achieve certain rate capability. Signals are induced on the readout pads.
- Without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

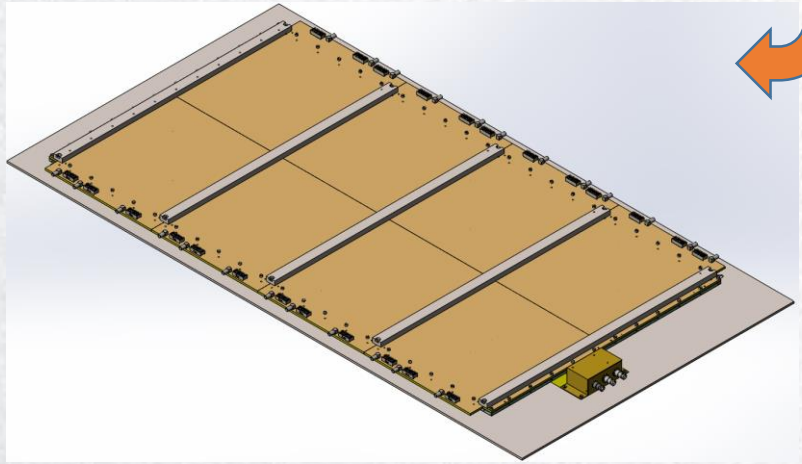
25cm×25cm RWELL detector assembling



25cm×25cm RWELL



100cm×50cm RWELL

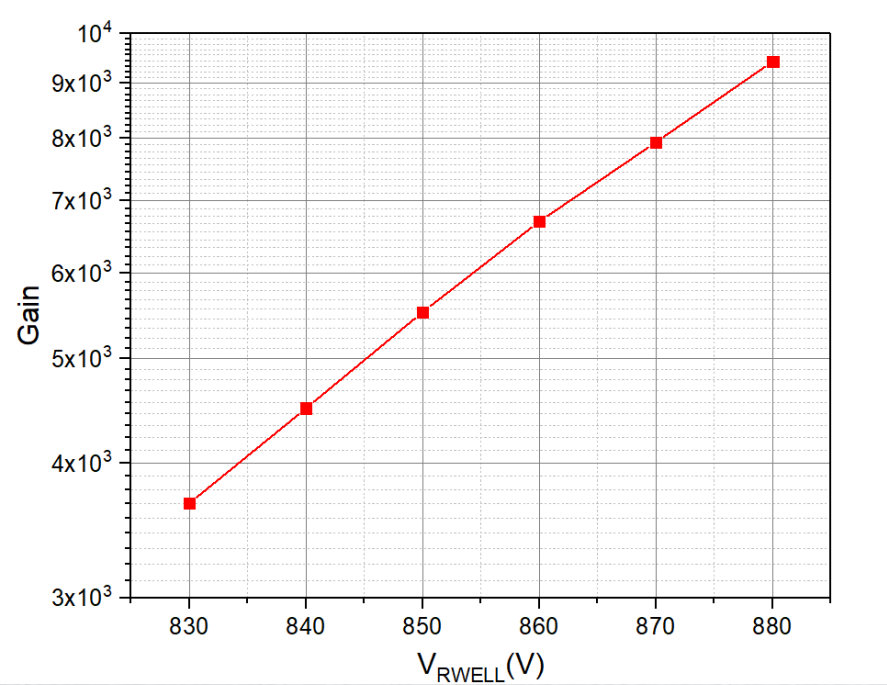


The large area RWELL detector is modular, the readout PCB with integrated electronics is same as the smaller RWELL's, which make it easy for fabrication and convenient for later maintenance .

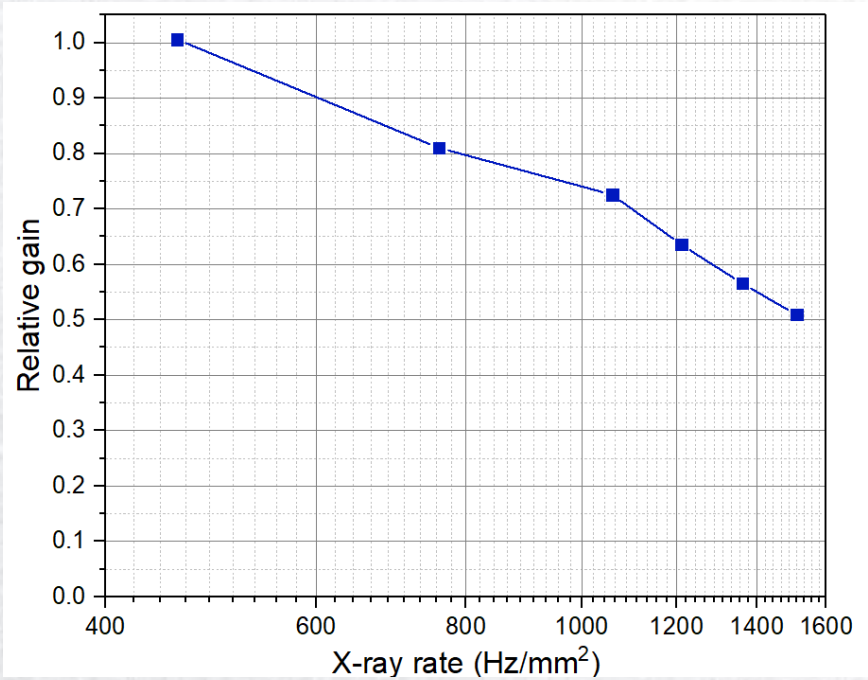
25cm×25cm RWELL detector

- 8keV X-ray, Ar/Isobutane(5%), Drift gap 4.5mm
- DLC resistivity 2GΩ/□

Gain vs. HV



Gain vs. X-ray rate (V_{RWELL}=860V)



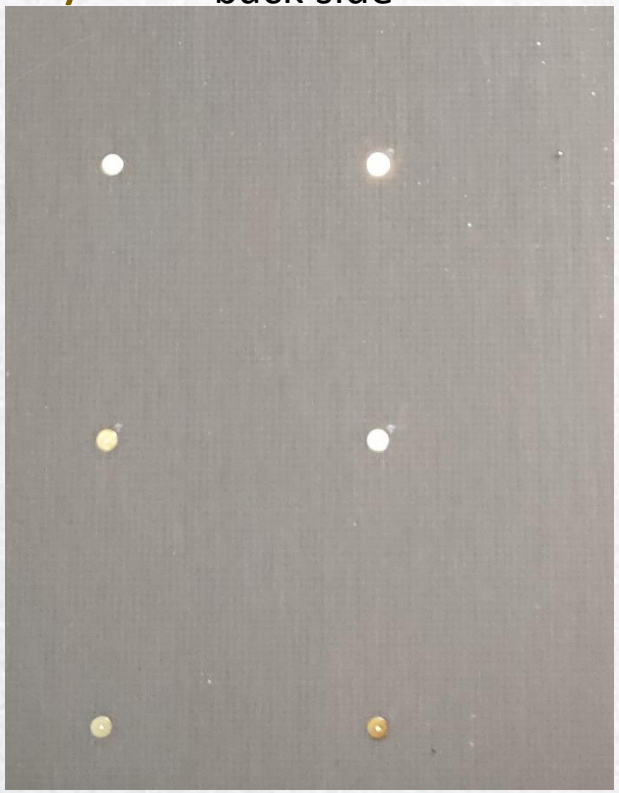
- **Gain decreased significantly at higher irradiation rate**
  - **The DLC resistivity is very high**
  - **DLC layer is not well connected to the vias**

Problem

- Some of the vias have bad connection to the DLC layer. Very large resistance between vias.

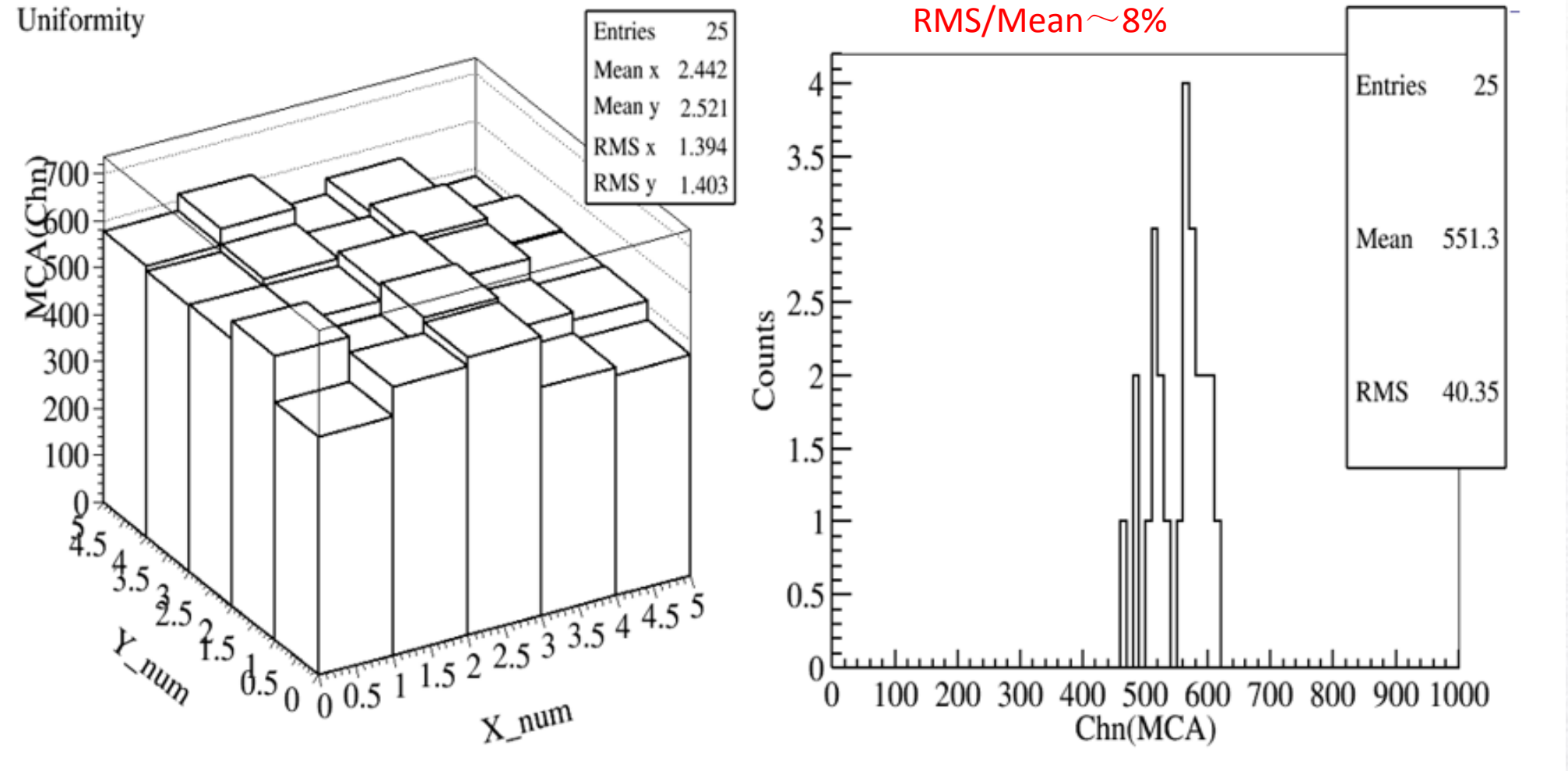
- Possible reason: unclean surface, DLC layer too thin（<100 nm）. The epoxy glue leak to the readout pad surface.
  - Ultrasonic clean the FR4 before coating.
  - Adjust the coating parameter for thick DLC coating
  - Block the via with resin.

Front side Resistive layer back side



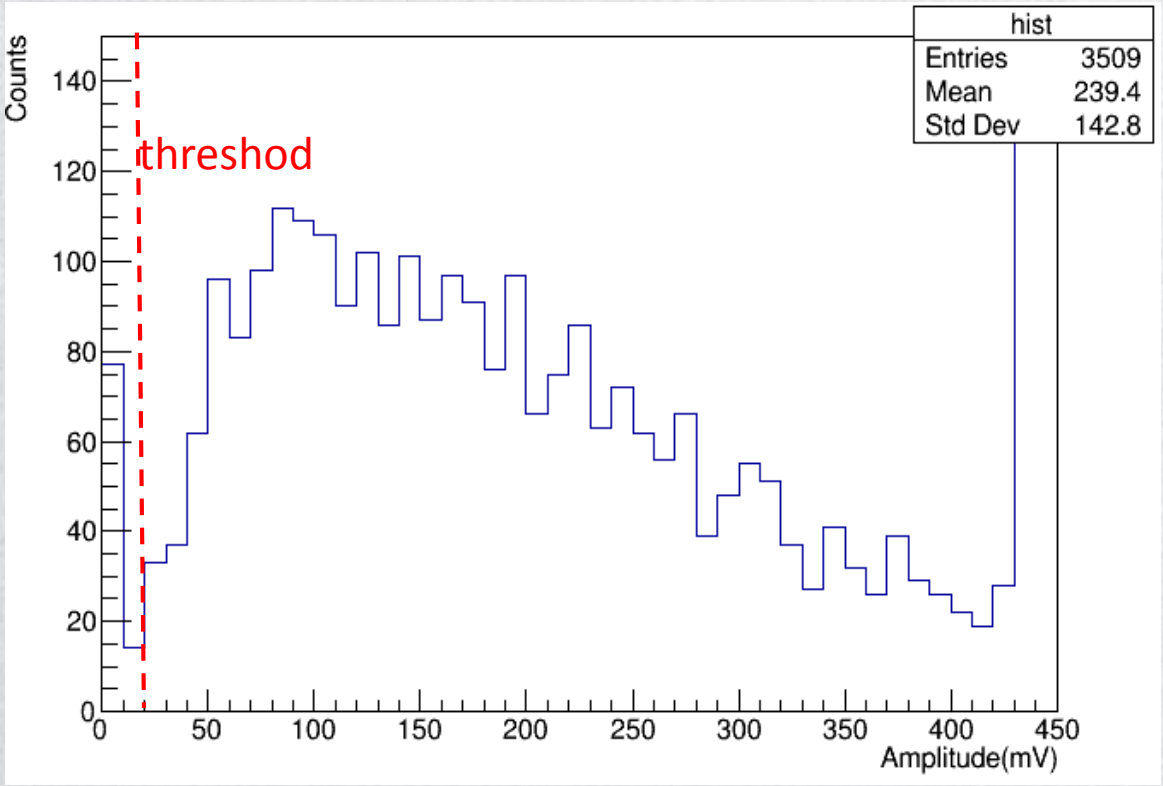
25cm×25cm RWELL detector

Gain distribution over active area at 860V HV



Cosmic ray test

Cosmic ray spectrum



3413/3509～97.3%

Detection efficiency On different area of the detector

94.6%	96.1%	**97.3%**
96.5%	96.3%	96.8%
95.8%	94.5%	94.4%

efficiency>94%

Summary and next work plans

- 10cm×10cm RWELL with 2D readout and 25cm×25cm RWELL fabricated and tested
- Detector performance
  - Maximum gain in Ar/5%Isobutane ~10^4
  - Gain Uniformity across detector active area~8%
  - Position resolution: ~200μm for collimated X-ray
- Problems and next work：
  - Rate capability need to be improved: adjust the DLC resistivity；
  - Micro discharge problem: try chemical etching the THGEM and segment the electrode to minimize the discharge rate；
  - Based on the work on 25cm X25cm RWELL , we will fabricate 100cmX50cm RWELL detector as DHCAL prototype.