# Updates from the SoLID-GEM Chinese Collaboration

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**JLab**

# SoLID-GEM Chinese Collaboration

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China Institute of Atomic Energy

**Lanzhou University**

蘭州大學

**Institute of Modern Physics, CAS (IMP)**

中国科学院近代物理研究所
Institute of Modern Physics, Chinese Academy of Sciences

**Tsinghua University**

清華大學
Tsinghua University

**University of Science and Technology of China (USTC)**

中国科学技术大学
University of Science and Technology of China

# IMP

**Institute of Modern Physics, CAS**

中国科学院近代物理研究所

Institute of Modern Physics, Chinese Academy of Sciences

- A smart high voltage system for GEM/THGEM with pressure and temperature corrections

# Motivation
# -how to ensure a stable gain for long time running

- GEM/THGEM has multistage amplifications
- Each stage has many strips or sectors (a group of strips)
- Gain has a strong dependence on gas **T**emperature and **P**ressure inside the detector, the effect is enhanced in a multistage detector→ big effect on detection efficiency
  - G=G(**ΔVoltage, T/P**)
  - For COMPASS-RICH style THGEM detector:
    - ✓ΔT = 1 degree →ΔG ≈ 12 %
    - ✓ΔP = 10 mbar →ΔG ≈ 20 %
- The way out:
  - Compensate T/P variations by changing **ΔVoltage** continuously

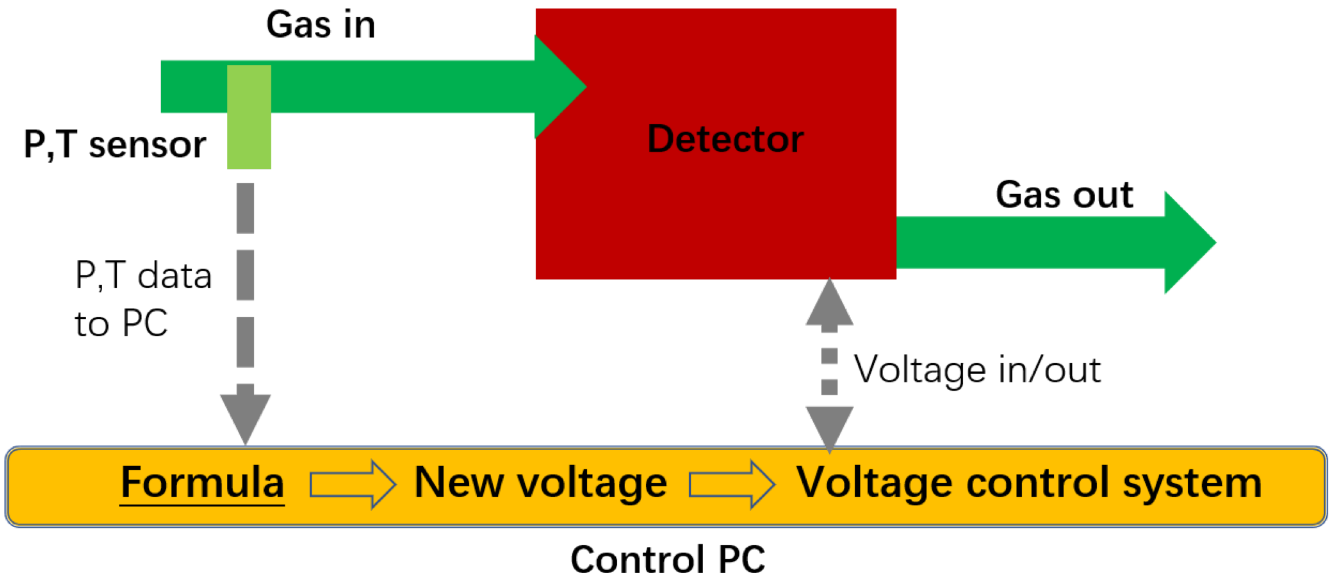
# A small system in lab

**Calibration** of gain for GEM/THGEM

- Voltage dependence
- Temperature dependence
- Pressure dependence

To get

**Formula** to calculate the voltage compensation due to temperature and pressure variations



# A real system is implemented in COMPASS RICH THGEM detector

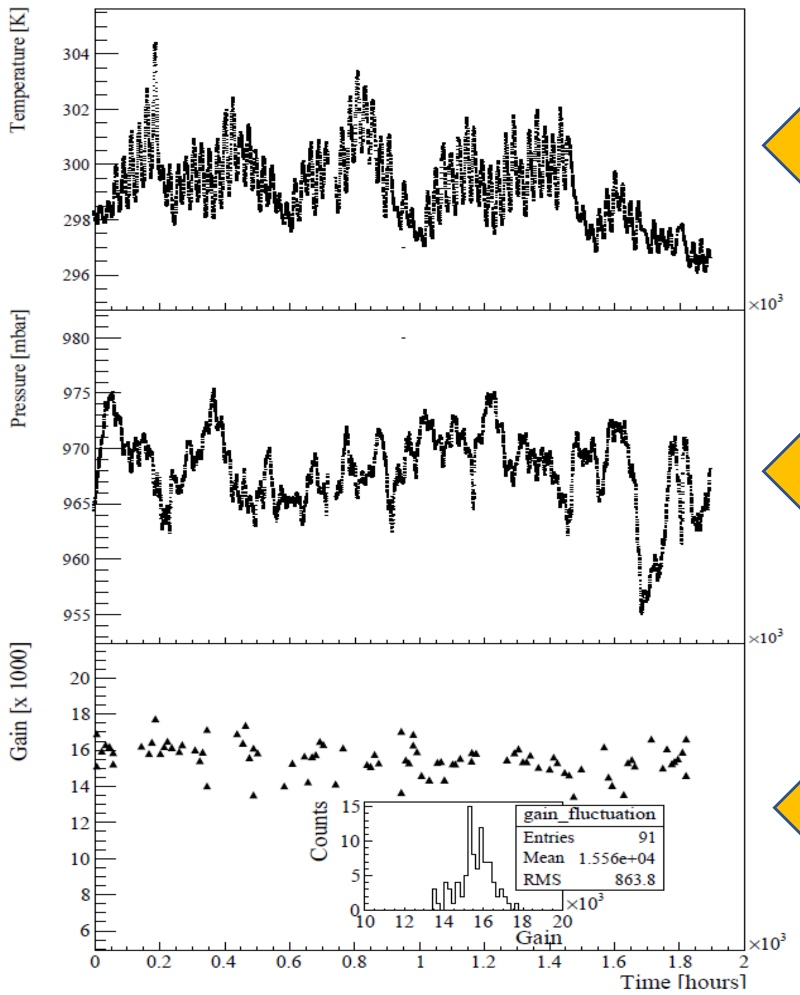
**please refer to J. Agarwala, ⋯, Y. X. Zhao* NIM.A 942 (2019) 162378 for details**

**Number of HV channels per detector:**

| Electrode | Protection wire plane | Drift wire plane | THGEM1 top | THGEM1 bottom | THGEM2 top | THGEM2 bottom | mesh | MM anode |
|---|---|---|---|---|---|---|---|---|
| Voltage | -300 V | -3520 V | -3320 V | -2050 V | -1750 V | -500 V | grounded | +620 V |
| Number of HV channels per detector | 1 | 1 | 4 | 4 | 4 | 4 | 0 | 4 |

Note: To have more flexibility in controlling the HV, no HV divider board is used

# Performance in a real experiment: 2000 hours of running




Temperature fluctuation

Pressure fluctuation

Gain fluctuation:

**RMS/MEAN ~ 6%**

A non-negligible achievement

# Short summary

- A HV system with gas pressure and temperature corrections for MPGD is developed and successfully used in the COMPASS THGEM detectors
    - The correction frequency can be achieved at 1Hz, even though not necessary in a real case. In COMPASS, it is done every 10 minutes

- The performance is quite good based on the online data monitoring for 2000 hours of running

- The whole software system is based on C/C++, can be easily compiled and embedded in any slow control system, or, used as it is in the lab activities

# LZU

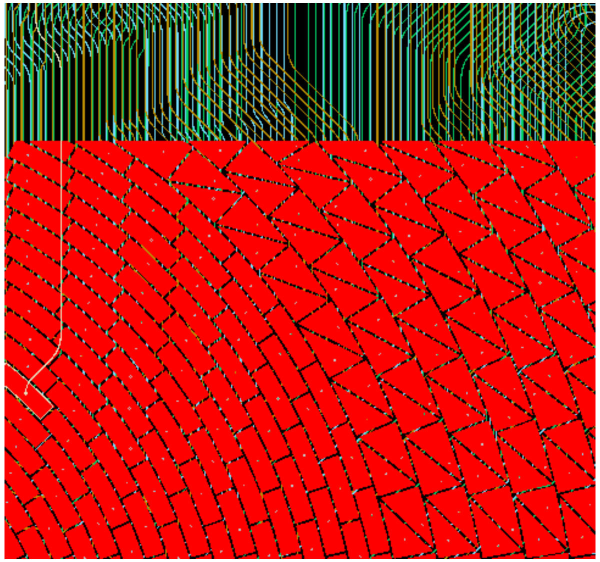
## Lanzhou University

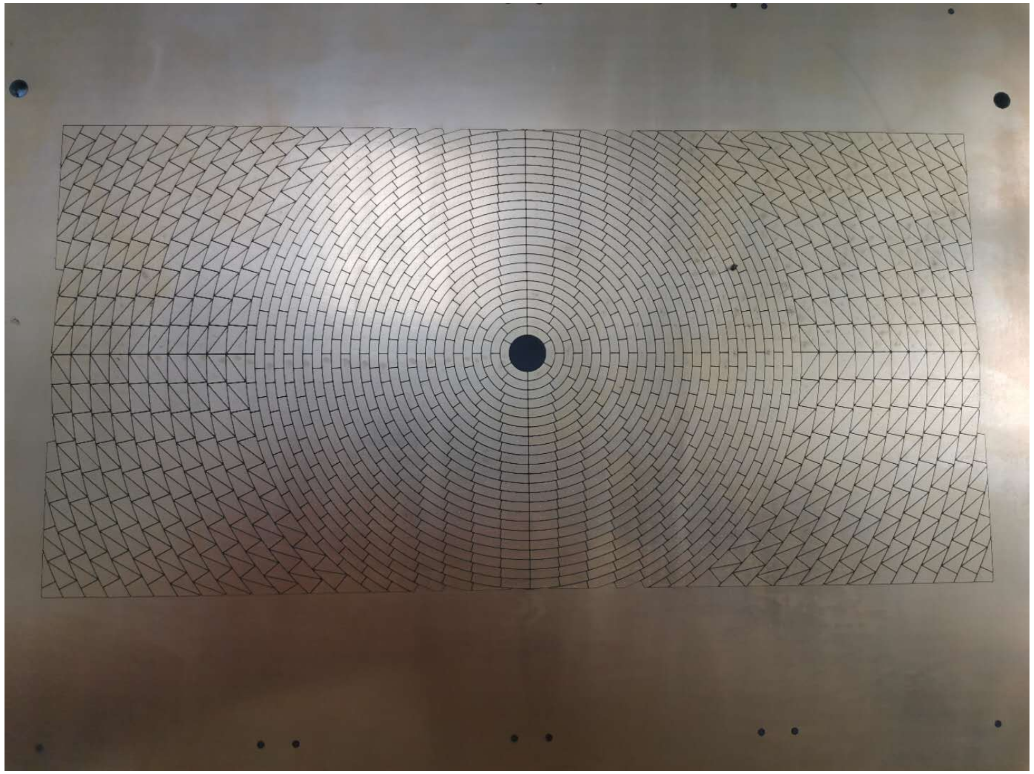
- Development of GEM readout for TPC

# The anode PCB

- Pad readout PCB with 1664 channels in total

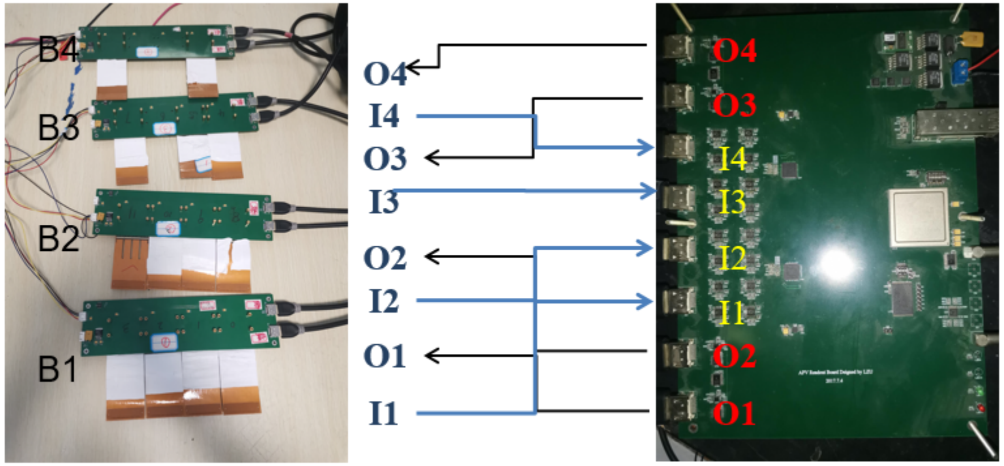
Pad size in inner ring : 2mm*6.25mm
Pad size in outer ring: 4mm*6.25mm
Pad gap: 0.2mm



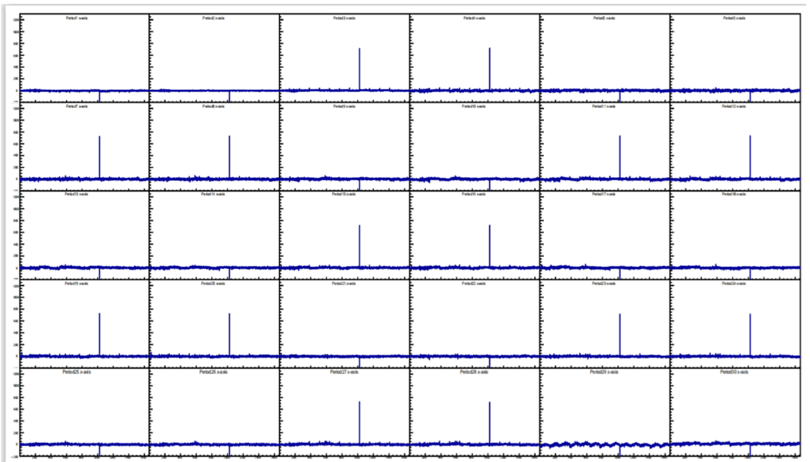


# APV25 readout

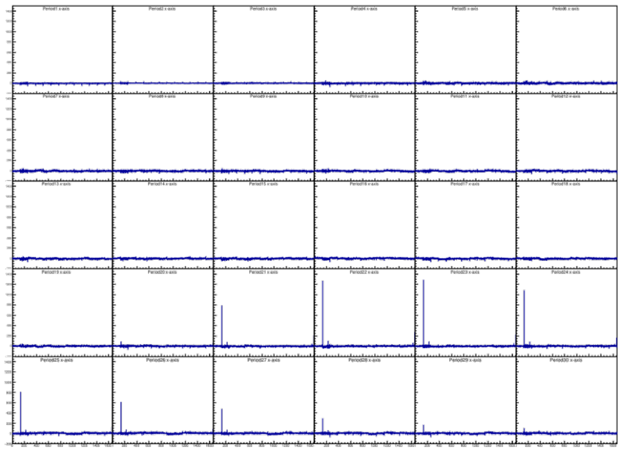
- Each mother board can connect 4 backplanes




Noise data



Fe55 data with a double-GEM



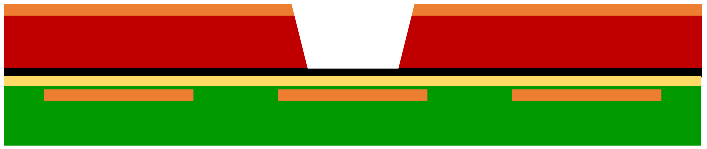
# USTC

中国科学技术大学
University of Science and Technology of China

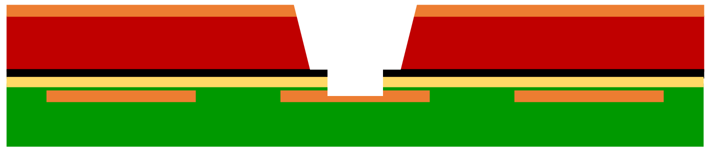
- Development of high-rate uRWELL detectors

# A novel idea to realize high-rate µRWELL

PEDF: Pattern , etch , drill & fill



Step1: Copper & APICAL etching to make a big hole with DLC on bottom.

Step2: Drill a small hole and expose the copper of the readout pad to the air.

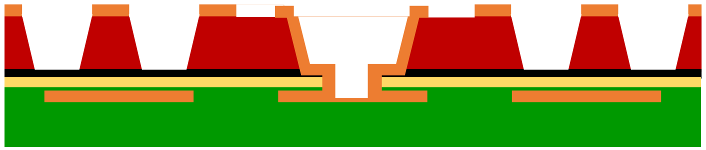
Step3: Connect the DLC to readout pad with silver glue.

Step4: Make µRWELL structure and remove the copper around silver glue.

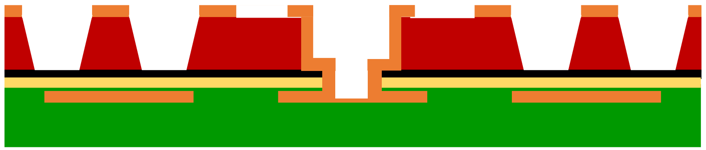
## Advantages:

1. No copper-coated DLC needed, so better resistivity control
2. No alignment issue even for large area
3. Larger contact area between DLC and silver glue resulting in better contact between the two.

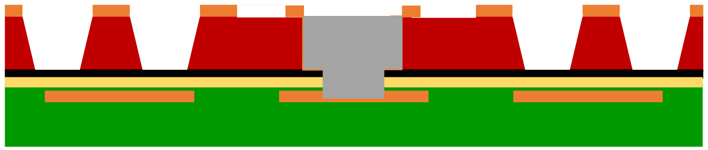
# Derivatives: PEDP,DEF,DEP µRWELL



PEDP: Pattern , etch , drill & plate



DEP: Drill , etch & plate



DEF: Drill , Etch & fill

Small-size uRWELL PCB prototypes for the four high-rate options (PEDF , DEF , PDEP , DEP) have been produced at CERN and sent to USTC.

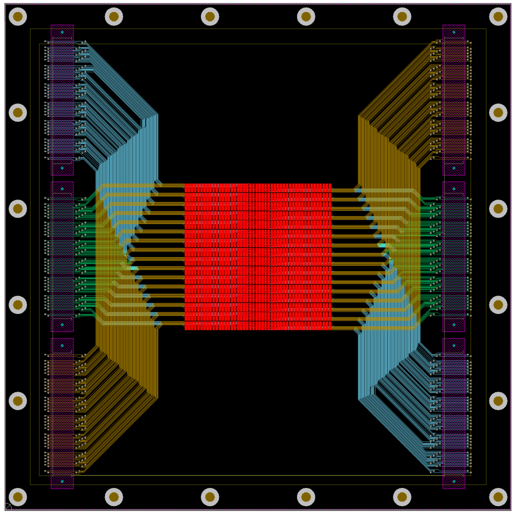
Thanks to Rui De Oliveira and CERN PCB workshop for technical support.

# High-rate μRWELL PCB

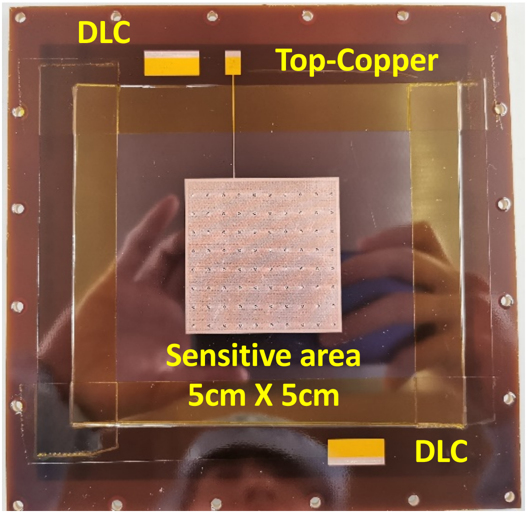
- Small-pad readout applied to high-rate μRWELL detectors in order to stand a very high particle fluxes (η~4).
- The parameters of readout pad almost same as small-pad readout MM.

Pad parameters
Size: 0.85mm @X & 2.85mm @Y
Pitch: 1mm @X @ 3mm @Y
Channel: 48(X) by 16(Y) = 768

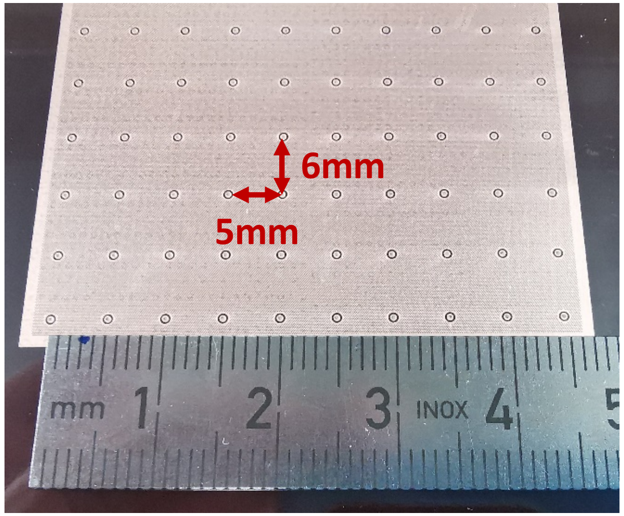
C. Di Donato., et al. Small-pads resistive Micromegas prototype. NIM A. Volume 958, 2020.



Small-pad readout




μRWELL PCB




Fast-grounding holes

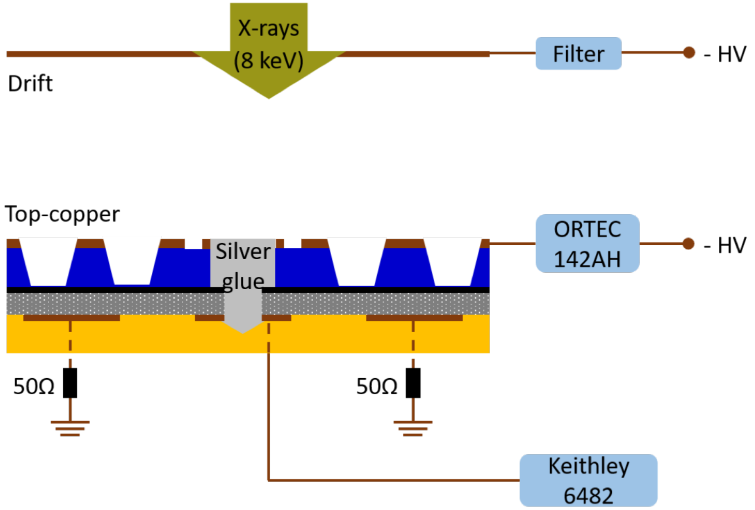
Fast-grounding hole: 1mm diameter, total 80 holes with a geometry acceptance of 97.5 %.

- These PCBs (PEDF,PEDP,DEF,DEP) are assembled to μRWELL detectors.
- The performance of these detectors are tested with X-rays.

# Test setup

**Work gas**: $Ar/iC_4H_{10}$ = 95/5

**Hirose adapter:** 128 readout pad → 1 channel → grounded by 50Ω terminator or keithley 6482 picoammeter.


**DLC resistive electrode**: grounded via a 50 Ω terminator or 6482 picoammeter.

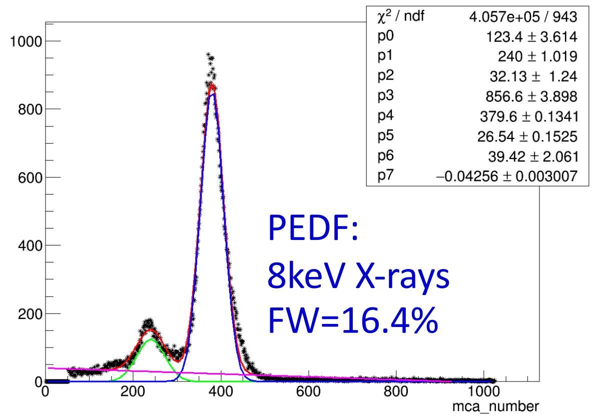
**Induced signal:** picked up from the top-copper or readout-pad.

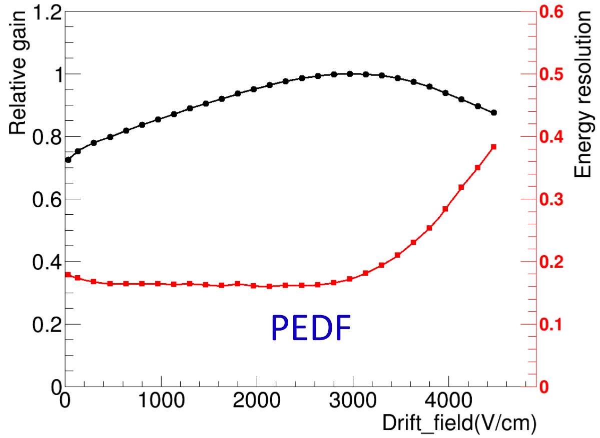
**Current signal:** picked up from readout-pad monitored by keithley 6482.

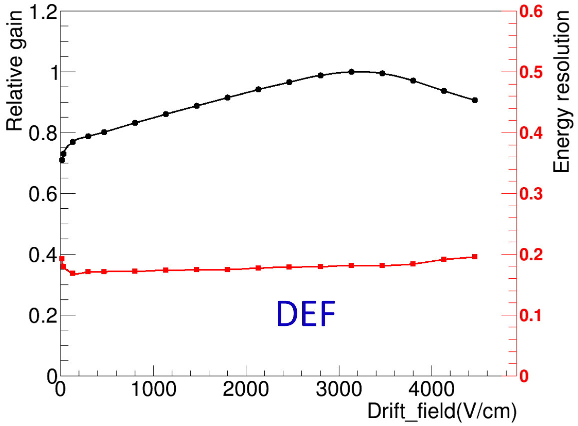
# Gain vs drift field

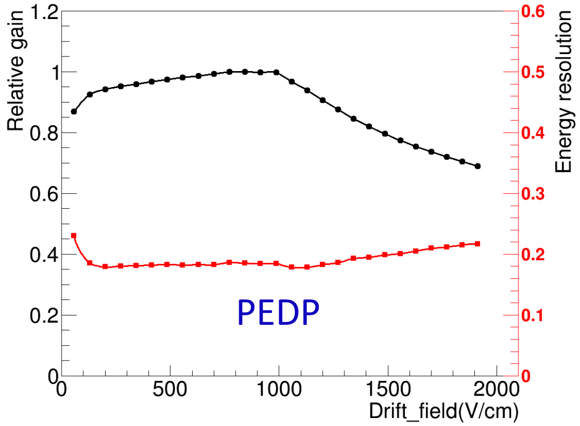
Normalized gain, fixed the avalanche electric field.

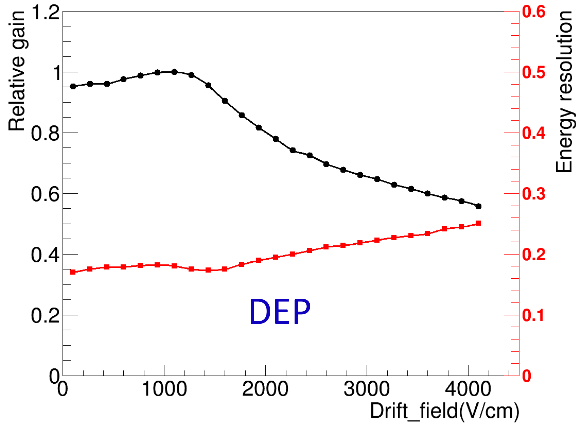
- PEDF&DEF: Maximum gain at ~ 3kV/cm.
- PEDP&DEP: Maximum gain at ~ 1kV/cm.



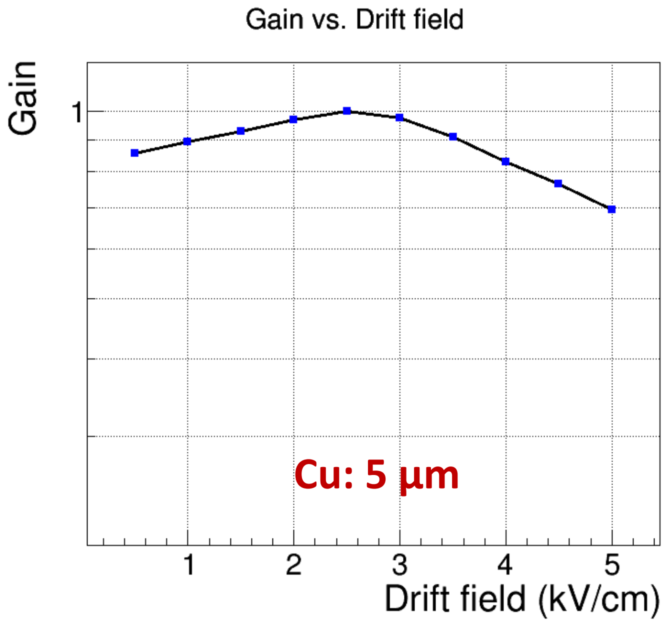



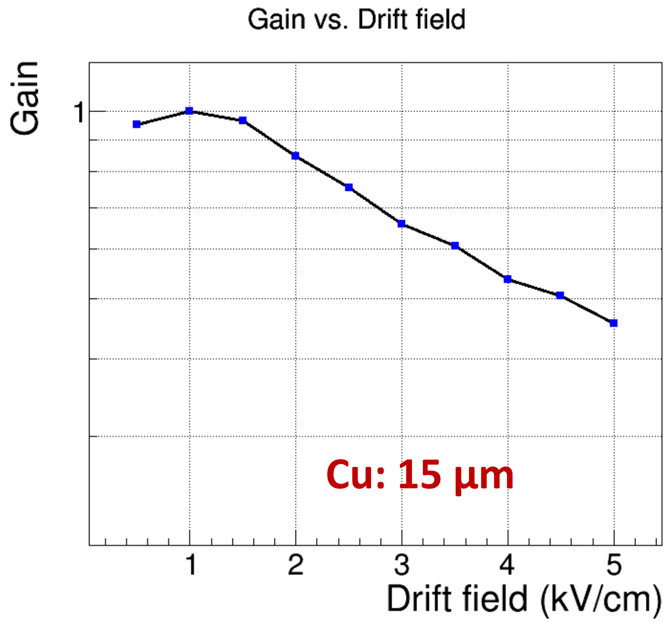

- The thickness of copper cladded on the APICAL is 5 μm (PEDF&DEF).
- The plating process make the thickness of copper up to 15 μm (PEDP&DEP). This could be the cause for the different behavior between PEDF and PEDP.

# Simulation of the gain vs. drift field

A simulation was carried out to understand the impact of the thickness of the top copper layer on the gain.

Detector geometry: ANSYS        Electron avalanche and the efficient gain: Garfield++



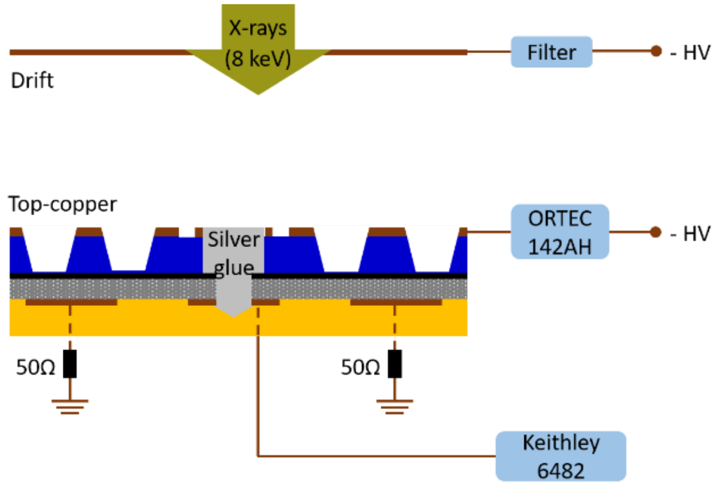

The simulation result is qualitatively consistent with the test result.

# Two different measured gas gains

1. Readout pad current gain: absolute gain, current signal exported from readout pad and recorded by Keithley 6482 picoammeter.

$$G = \frac{I}{R \bullet \frac{8keV}{E} \bullet q_e}$$

I: current   R: rate   E: average ionization energy



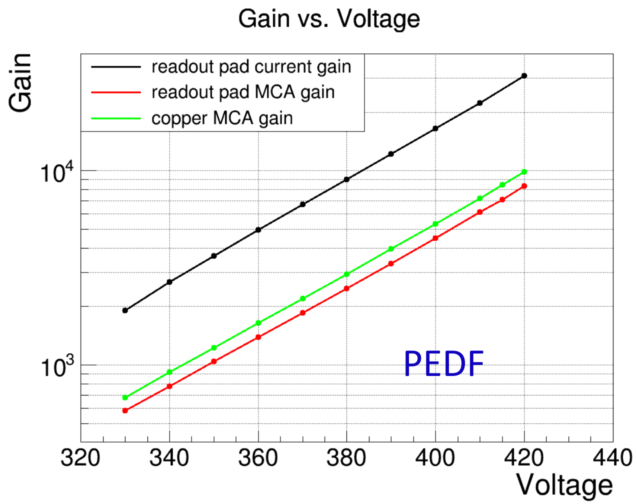

2. Readout pad & copper MCA gain: induced signal gain, induced signal exported from readout pad & copper electrode and recorded by MCA.

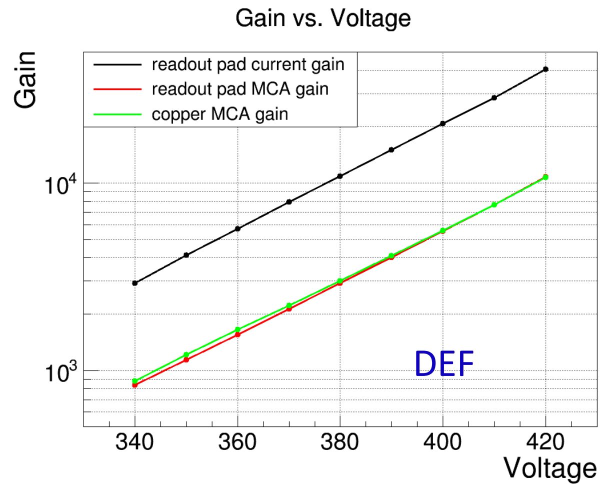
A pulse generate a signal , and it was input to the test port of  Pre-Amp to calibrate the test system.

$$G = \frac{C \bullet U}{\frac{8keV}{E} \bullet q_e}$$

C: capacitance of pre-AMP   U: effective voltage

# Gain vs avalanche electric field

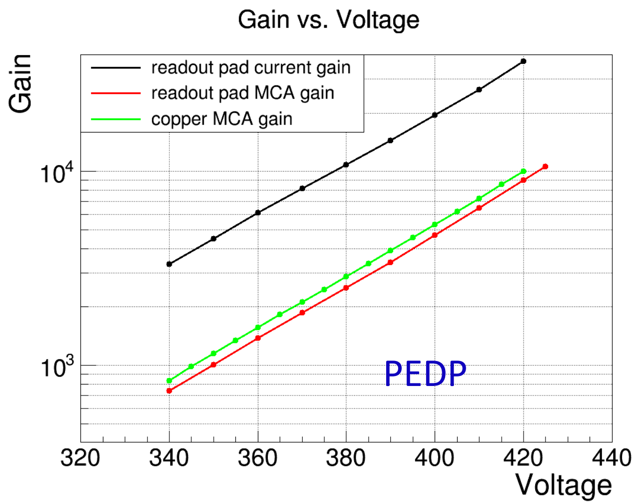


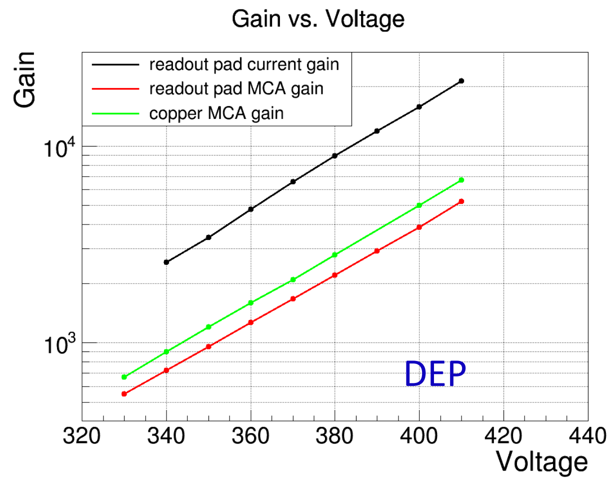




Absolute gas gain:
~30000 @420V
Induced gas gain:
~10000 @420V

The absolute gain is about 3 times higher than induced gas gain.

It is due to that the weighting field effect.



# Weighting field in μRWELL

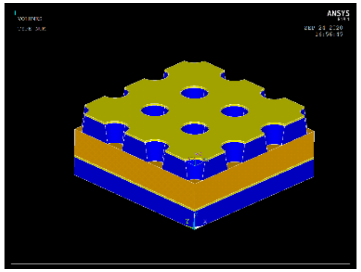
1. Ramo Theorem: induced signal :

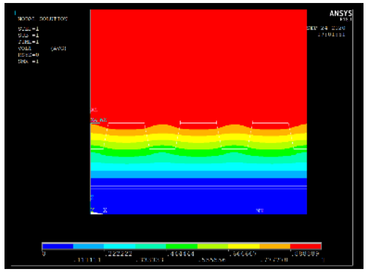
$$I_n^{ind}(t) = -\frac{Q_n^{ind}(\mathbf{x}(t))}{dt} = \frac{q}{V_w}\nabla\psi_n(\mathbf{x}(t))\dot{\mathbf{x}}(t) = -\frac{q}{V_w}\mathbf{E}_n(\mathbf{x}(t))\dot{\mathbf{x}}(t)$$

Induced charge: proportional to weighting potential.

2. Weighting field $\mathbf{E}_n(\mathbf{x})$: setting the voltage of interested electrode to 1, and other electrode to 0.

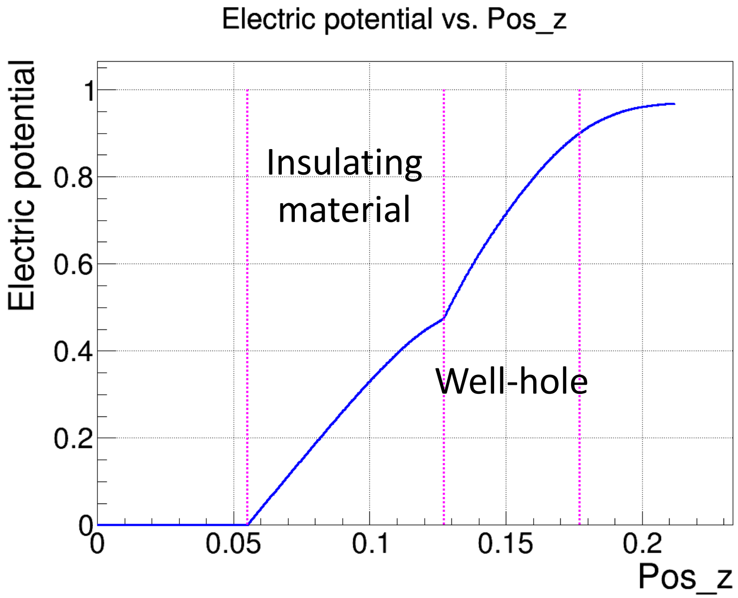
$$\mathbf{E}_n(\mathbf{x}) = -\nabla\psi_n(\mathbf{x})$$





μRWELL detector:

1. The secondary electrons only drift in the well-hole.
2. 70 μm insulating material (50um Prepreg+12um Kapton+10um epoxy glue) between readout pad and DLC electrode reduces the effective weighting field in well-hole.
3. The induced gain is then lower than the absolute gain.



# Rate capability (PEDP)

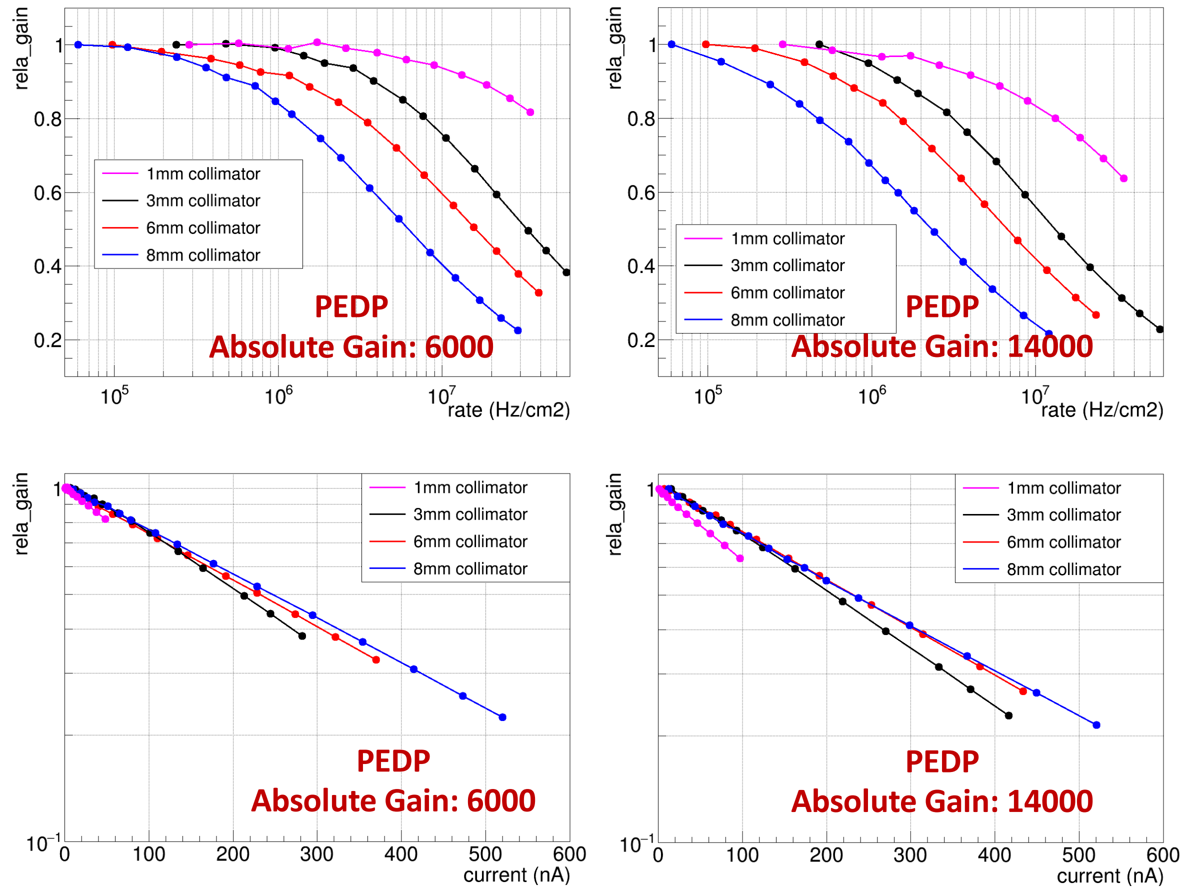
Rate capability is assessed by detector gain as a function of counting rate per unit area.

Different collimator diameters: 8 mm, 6 mm, 3 mm, 1 mm are used.

Rate: (1MHz/cm2)，

Gain (6000): 1 @1mm, 1 @ 3mm, 0.9 @6mm, 0.85 @ 8mm.

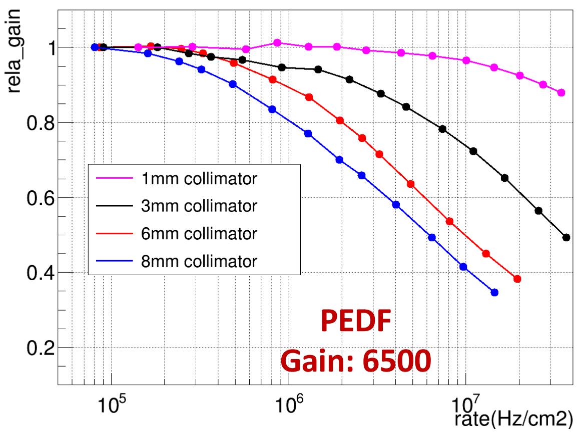
Gain (14000): 0.97 @1mm, 0.95 @ 3mm, 0.85 @6mm, 0.68 @8mm.

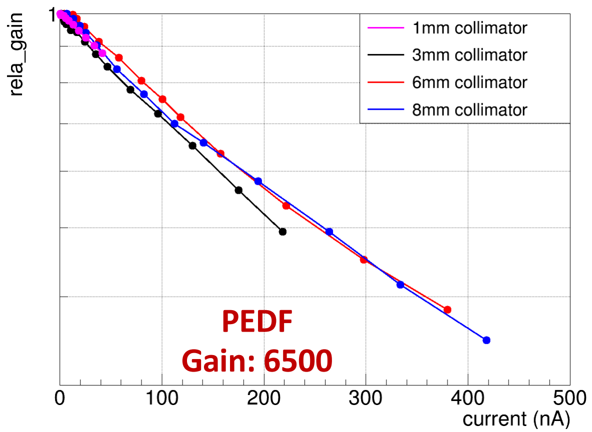


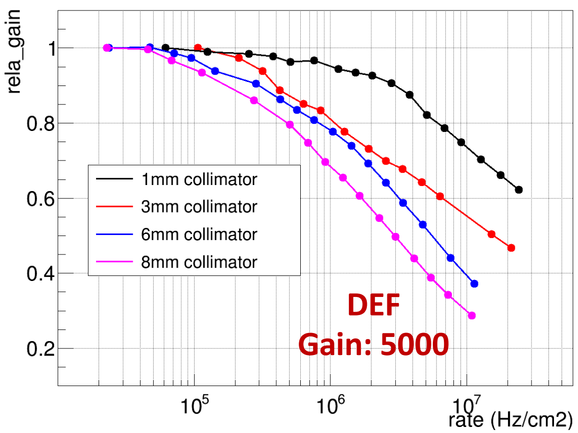

- The log of the relative gain drops linearly with current. The same current exported from readout pad in different gas gain, almost same gain drop.
- The ohm effect of DLC resistivity is responsible for the gain drop.

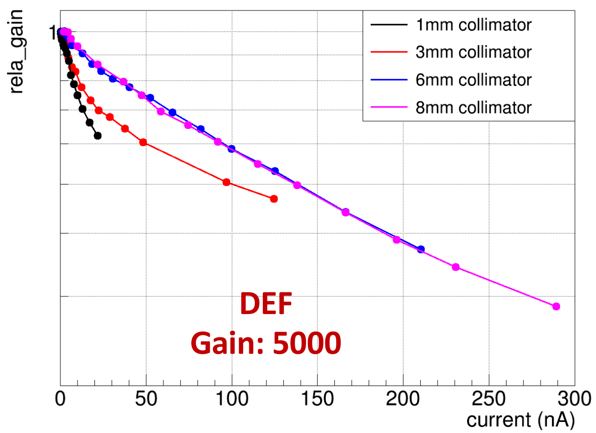
For a m.i.p. the primary ionization is 10 times smaller than 8 keV X-rays with a drift gas gap of 3mm.

# Rate capability (PEDF & DEF)




Rate: (1MHz/cm2)，

PEDF gain: 1 @1mm, 0.95 @ 3mm, 0.9 @6mm, 0.8 @ 8mm.

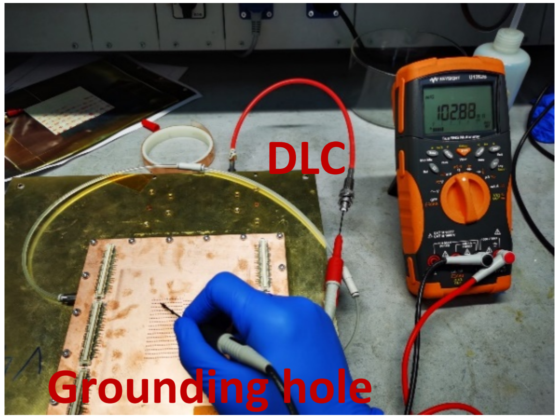
DEF gain: 0.95 @1mm, 0.85 @ 3mm, 0.8 @6mm, 0.7 @8mm.

The DEF detector doesn't make patterning during the etching process. It may make the holes irregular, and hence poor performance.

For PEDF and DEF: The filling process is not a standard process. The fast-grounding hole could be damaged when removing the excess silver glue. The rate capability of PEDP is better than PEDF.

# Resistivity measurement

Measuring the resistivity between DLC and fast-grounding holes.



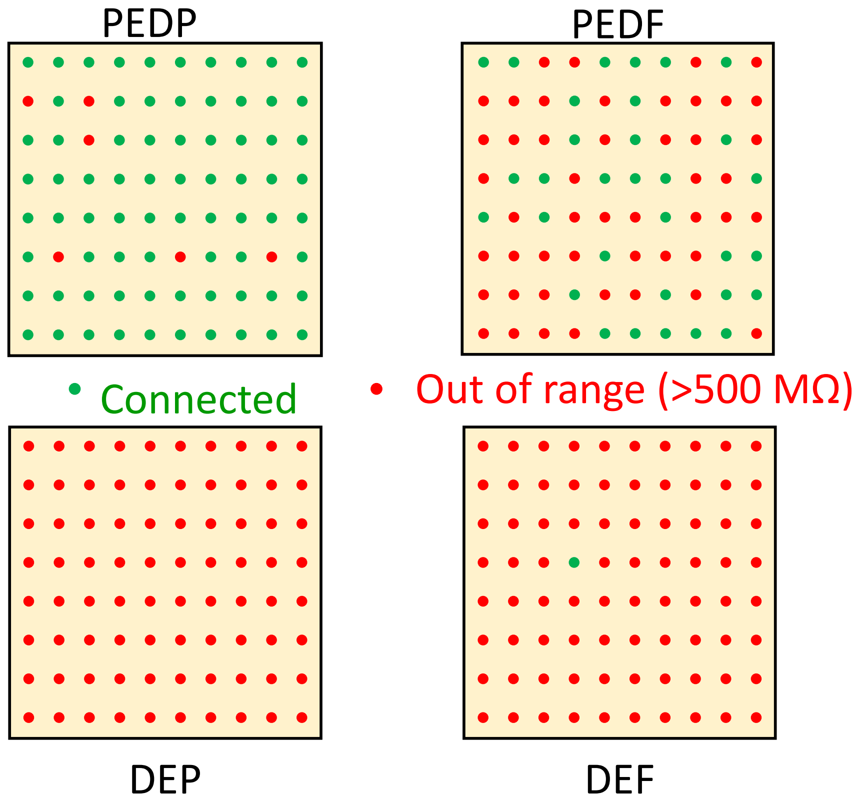

Measurement

PEDP: 6 holes disconnected.
Resistivity: 90 to 110 MΩ

PEDF: 32 holes connected.
Resistivity: 350 to 450 MΩ

DEP: All holes disconnected.

DEF: 1 holes connected.
Resistivity: 380 MΩ



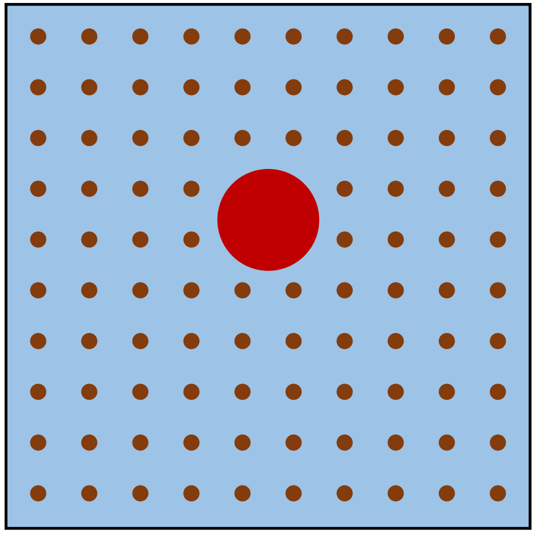

For DEP and DEF, it is uncontrollable when etching the grounding holes due to that no pattering before etching process. Bad connection between DLC and grounding holes.

For PEDF, the grounding holes would be damaged when removing the excess silver glue.
The PEDP shows the best connection between DLC and grounding holes

# Next to do for the testing

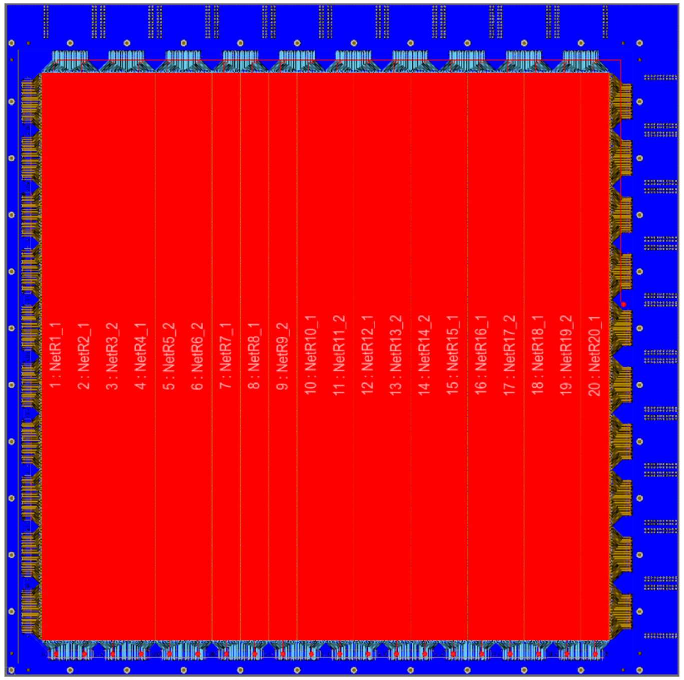
1. The rate capability will be tested with a larger area ($cm^2$) illuminated.

2. A cosmic-ray telescope will be set up to test the efficiency/position resolution/dead area of the uRWELL prototypes.

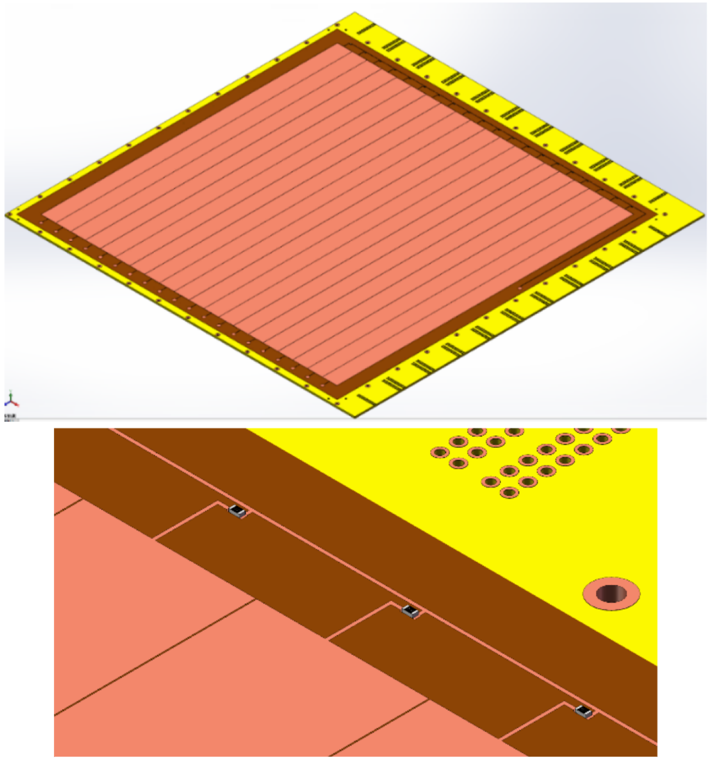


# Large-area high-rate μRWELL detector

A 50cmX50cm μRWELL have been designed, the PEDP technique will be used for the large area high-rate μRWELL.




The layout of the μRWELL-NT-50cmX50cm



The detector divided into 20 sectors