Beam test result of the C-μRGroove

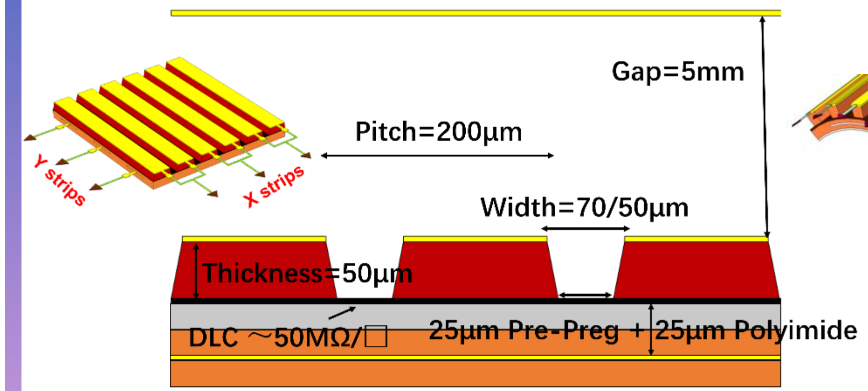
Siqi HE

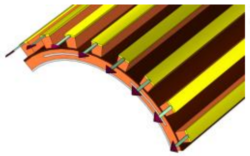
On behalf of USTC-MPGD Group

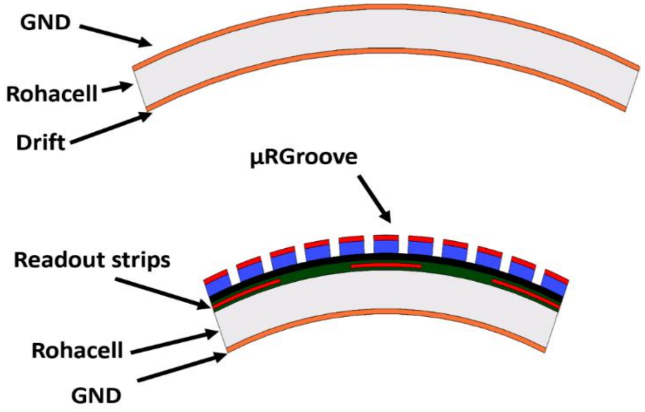
3rd DRD1-WG7, 12/12/2024

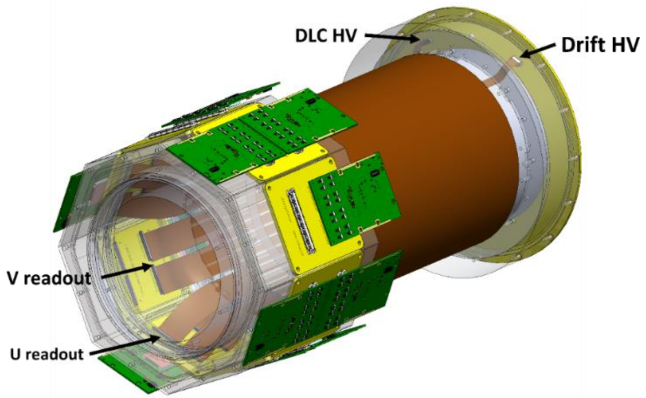
- Introduction
- Result without magnetic field
- Preliminary result with magnetic field
- Summary

Cylindrical μRGroove



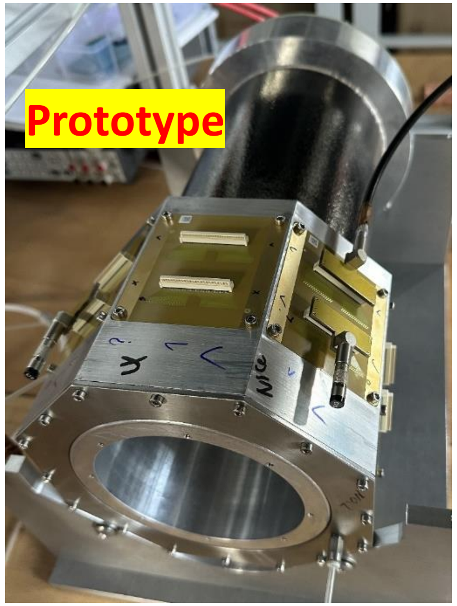






□ 1st C-μRGroove prototype:

- Size of active area: D=131.0mm, L=100.0mm;
- Out cylinder is drift and inner is μRGroove-PCB
- Detachable mechanical design
- Low-mass electrode design
- Vacuum gluing process

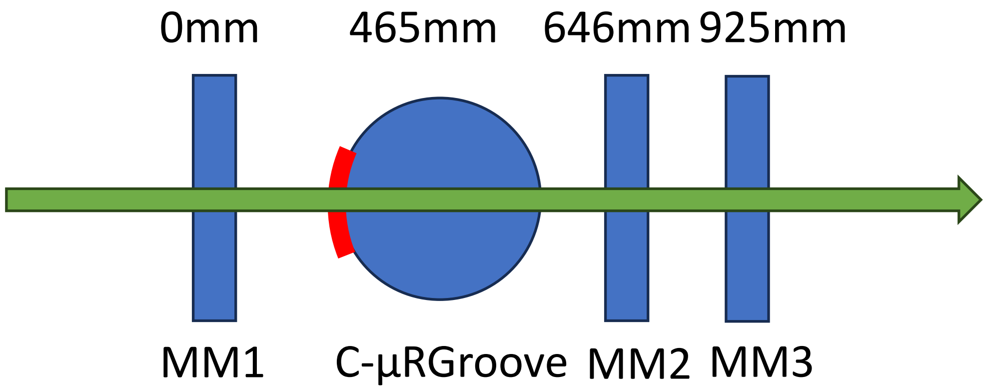


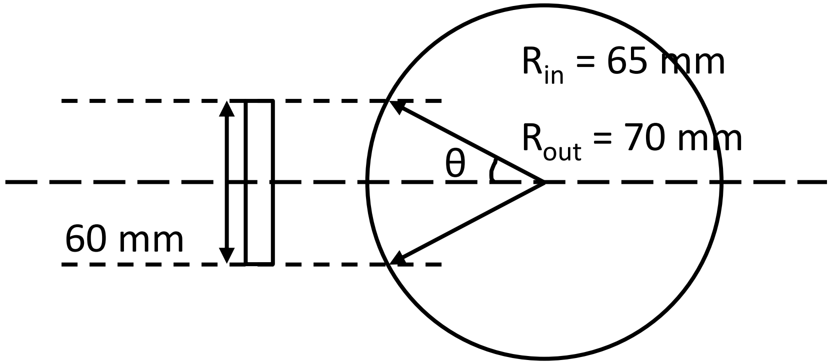
2021.09 - 2024.05: design and production

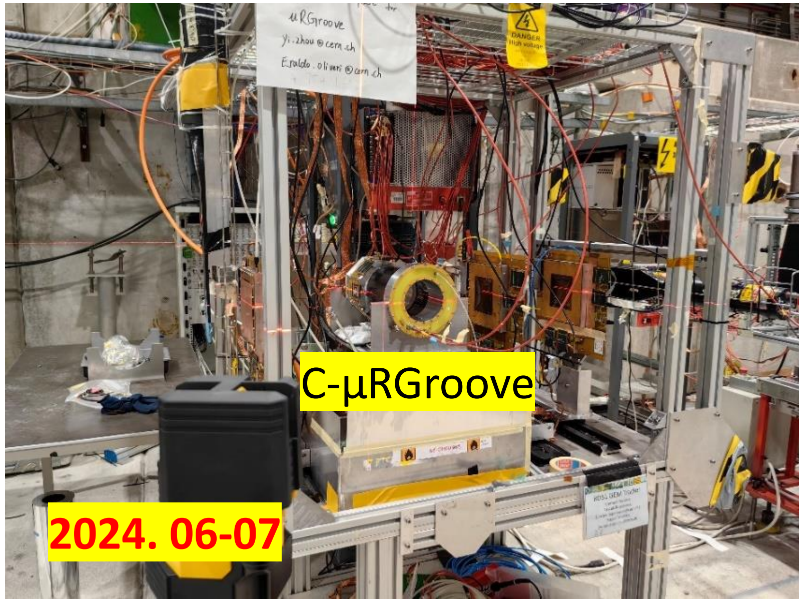
Beam test without magnetic field

Setup:

- Gas: Ar:CF_4:CO_2/45:40:15
- Readout from U strips (top cooper of µRGroove)
- V strips are grounded
- 3 micromegas trackers
- APV25+SRS+mmDAQ

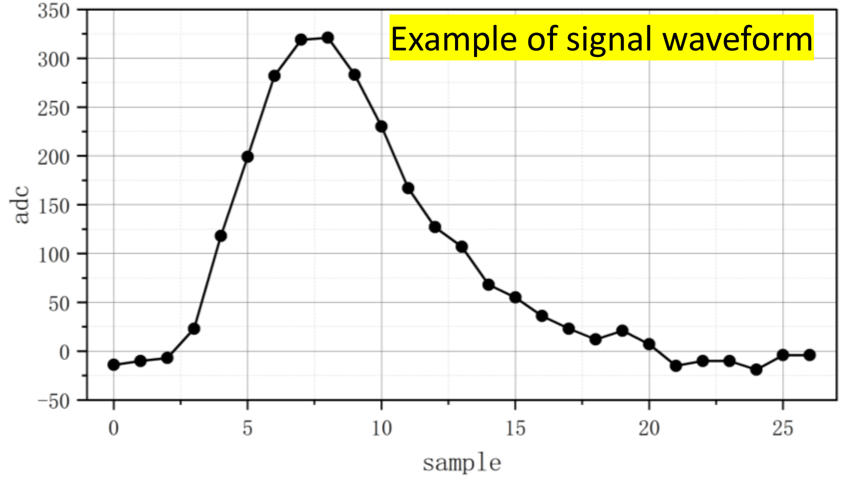


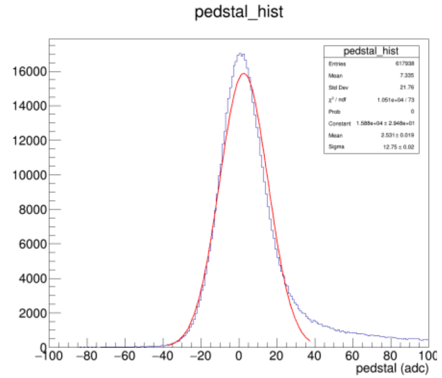


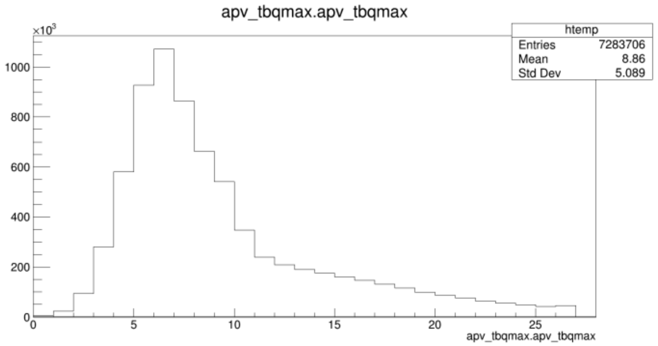


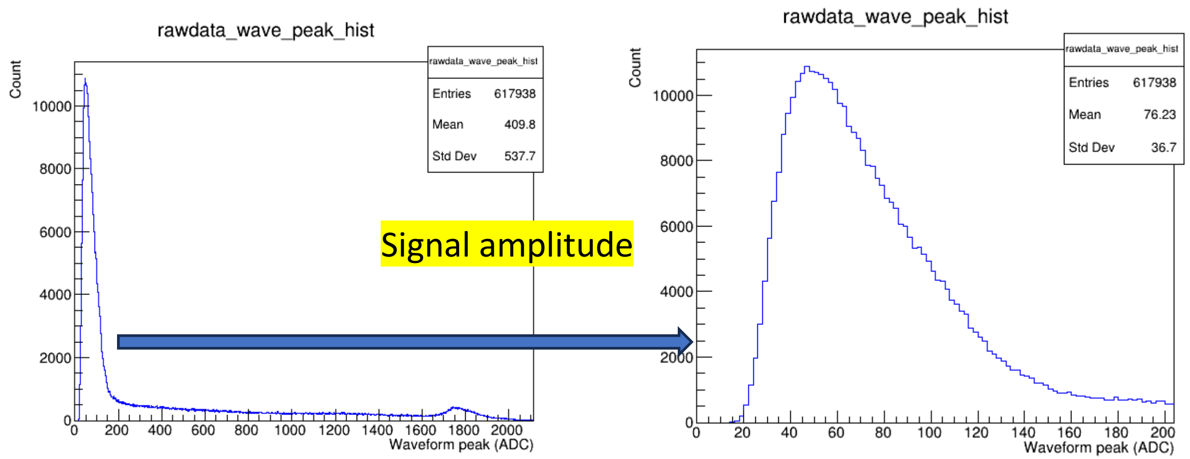
- The active area of the trackers is 6cm×6cm, covering θ: -27° ~ 27°
- 1 sector of C-µRGroove was readout, **covering θ: -22.5°~22.5°**

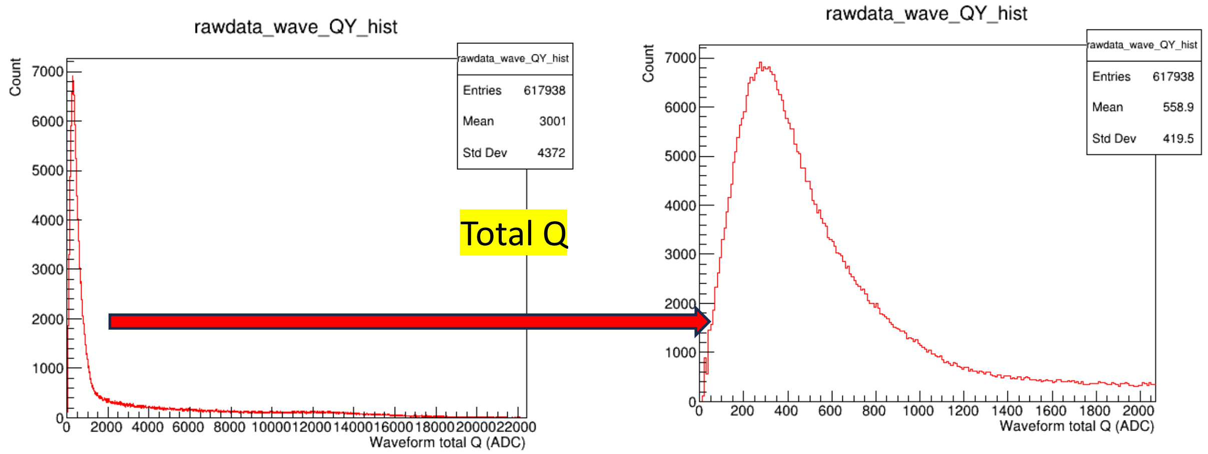
Analysis of raw data







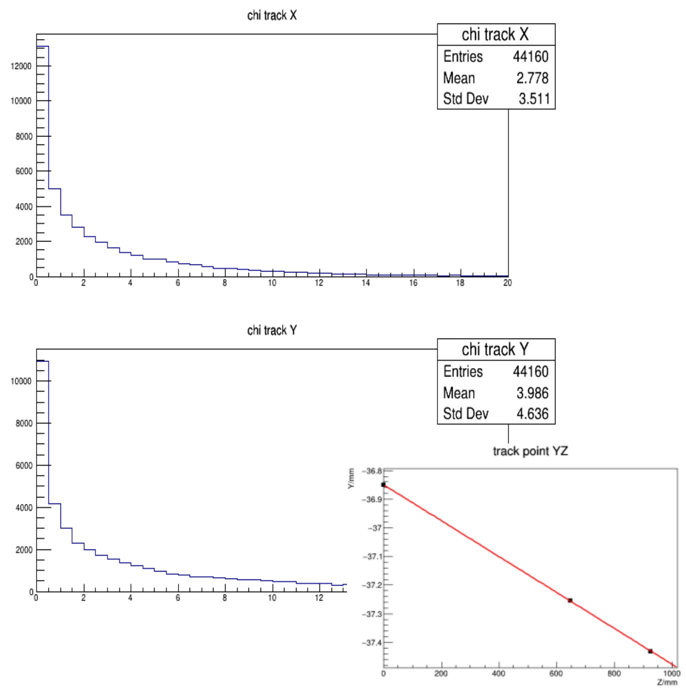




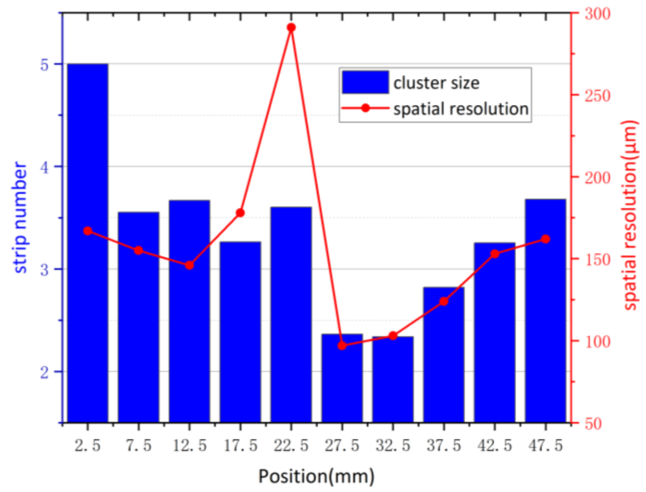
- 25ns per sampling point, 27 sampling points in total
- Sigma of 1st sample point distribution: ~12(adc)
- Mean of signal Amplitude: ~410(adc)

CC for perpendicular tracks

- **Charge Center of gravity(CC) for perpendicular tracks**

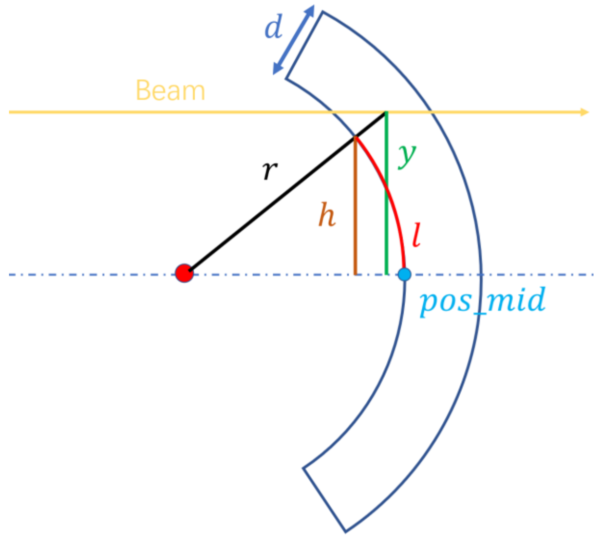


- Track fitting: Chi-square <10



- ✓ Find the middle area.
- ✓ Alignment and rotation correction
- ✓ Position correction of circular surface

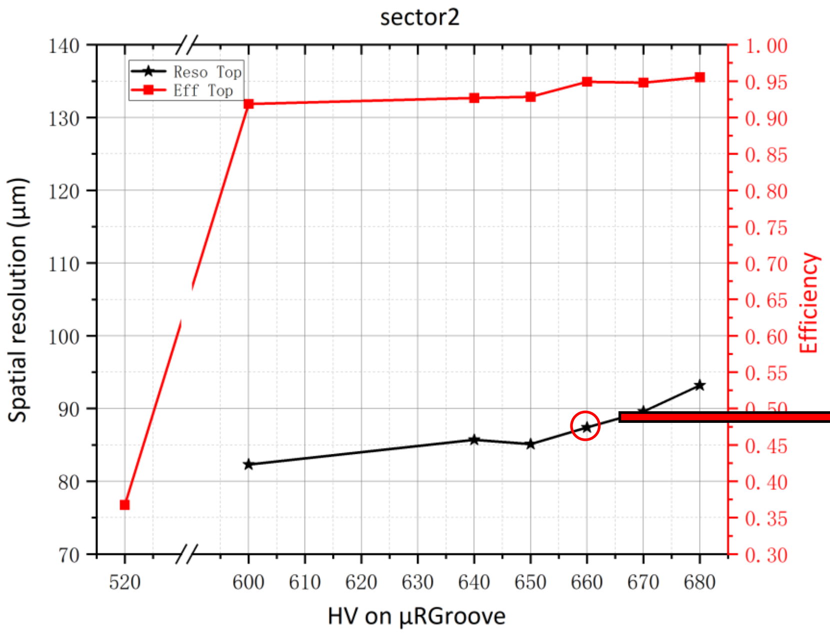
X **Wrinkles may degrade spatial resolution**

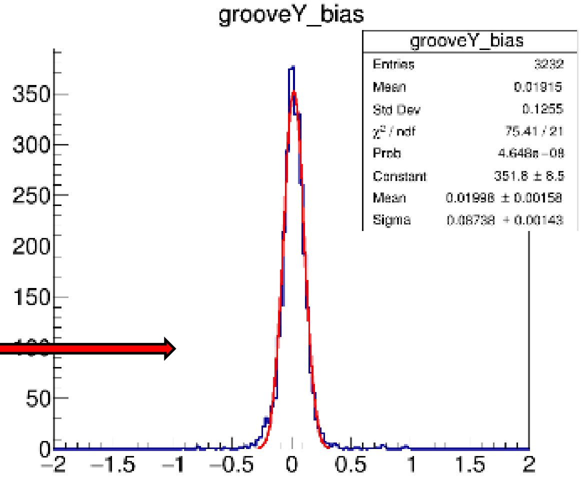


$$y = \left(r + \frac{d}{2}\right) \times \sin\frac{l}{r} + pos\_mid$$

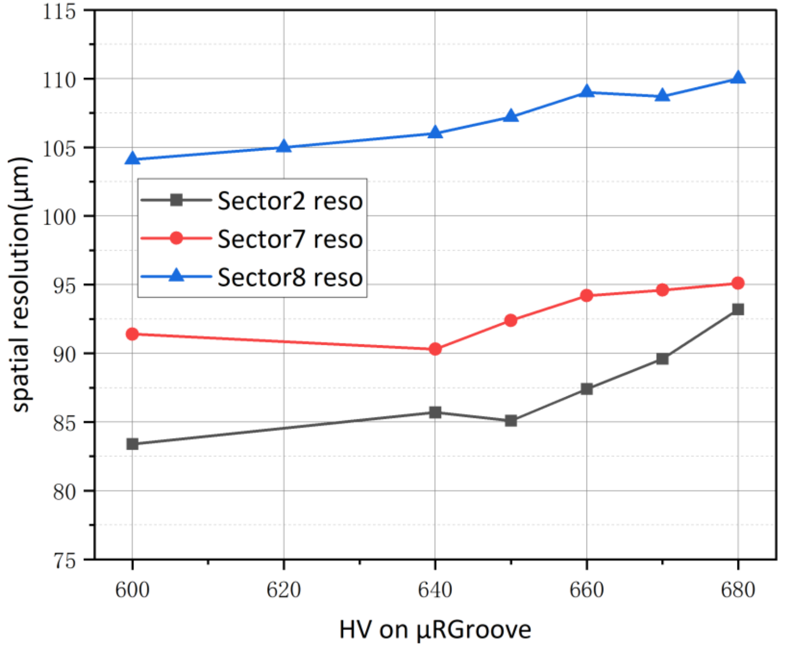
l : reconstructed position
y: truth hit position
pos_mid: middle point

Detection efficiency and spatial resolution





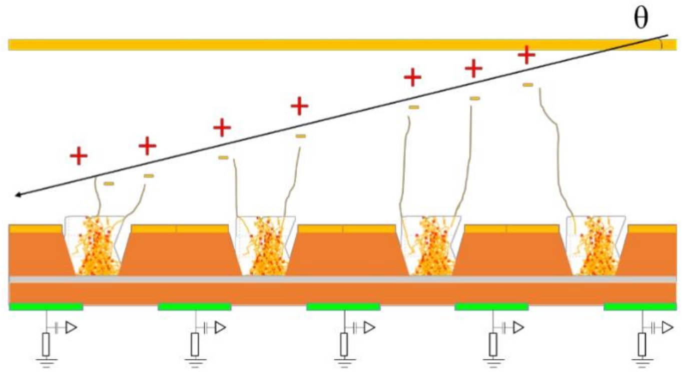
For perpendicular tracks

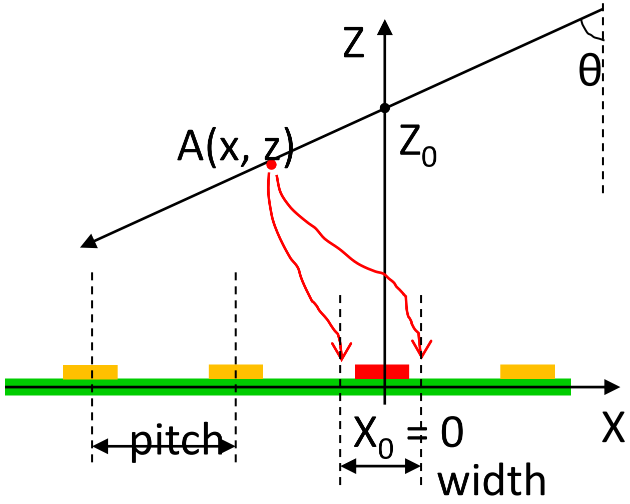


- ✓ **Spatial resolution for perpendicular tracks: 83~93μm.**
- ✓ **Detection efficiency >95%.**

X **Uniformity issues for different sectors**

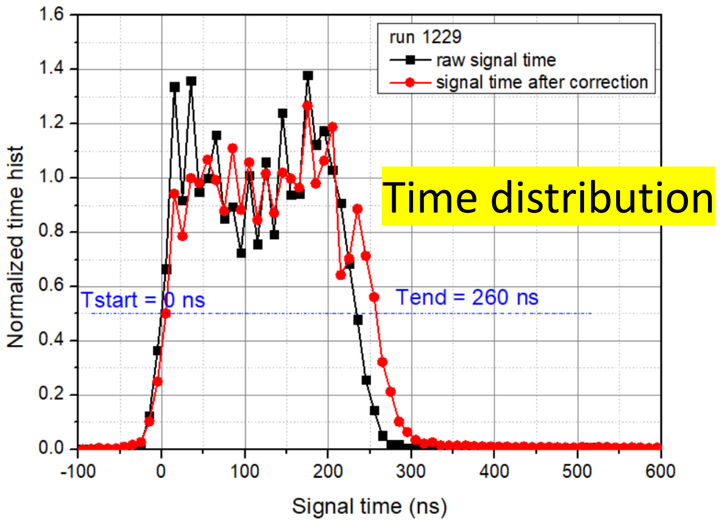
micro-TPC mode

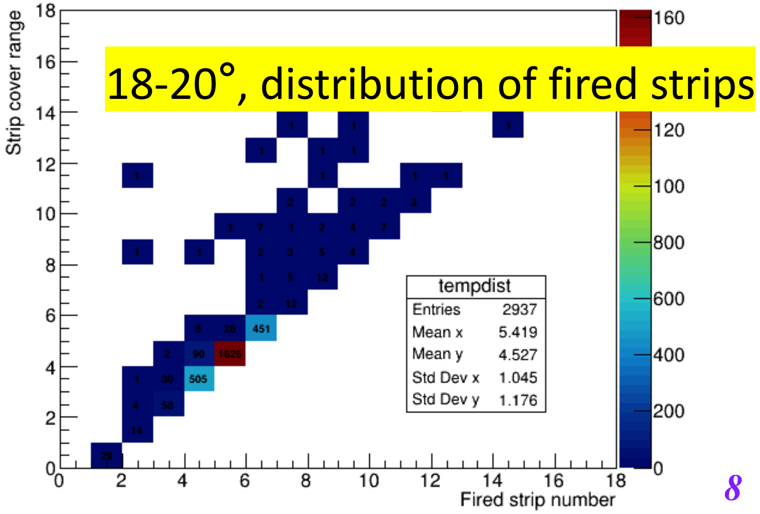




µTPC

- Constant ratio timing
- Time advance correction
- Cluster finding
- X-T Fitting

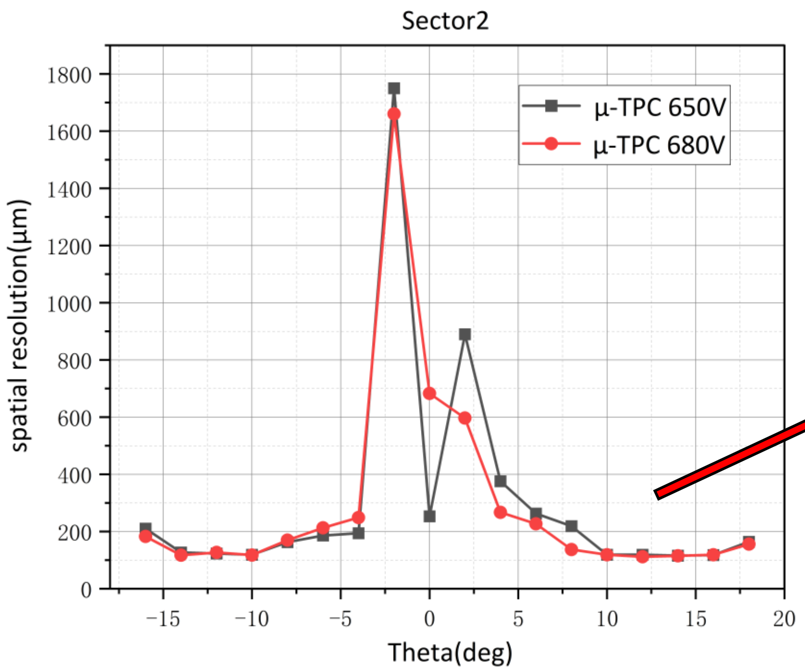


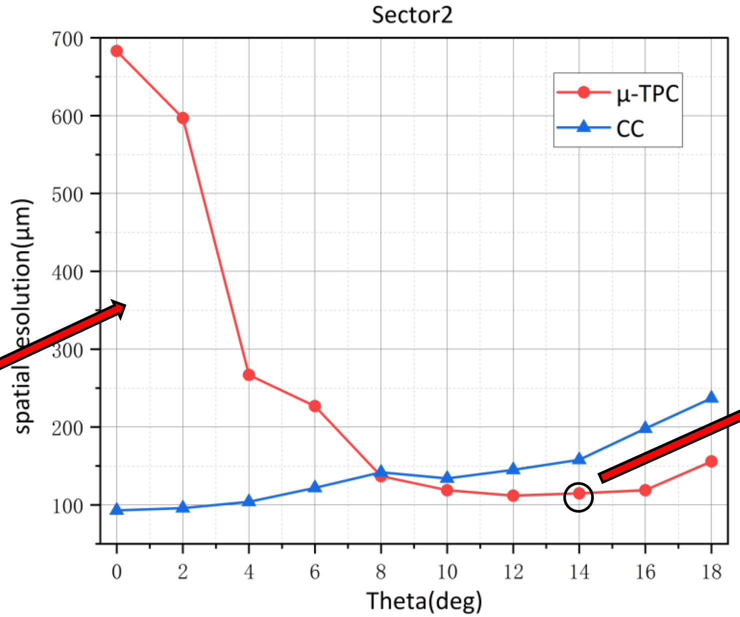


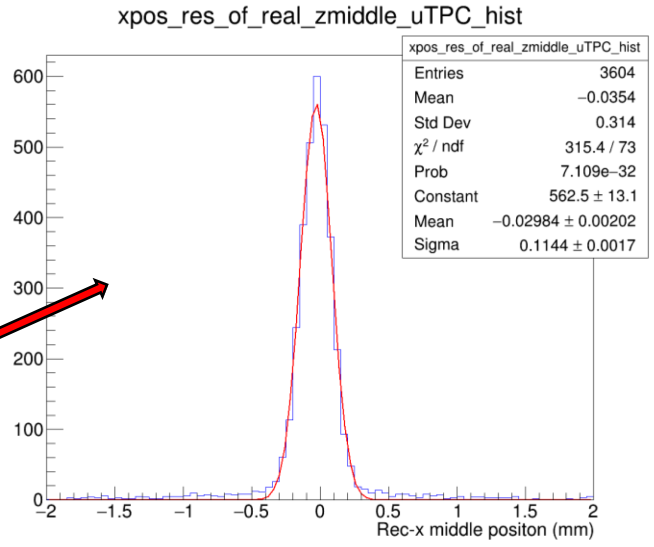
The timing advance effect is mainly caused by horizontal diffusion.
For more details, please refer to this poster from the MPGD2024.

[Zhujun Fang, MPGD2024, Study on the bias analysis and correction in MPGD µTPC mode]

Result of micro-TPC mode

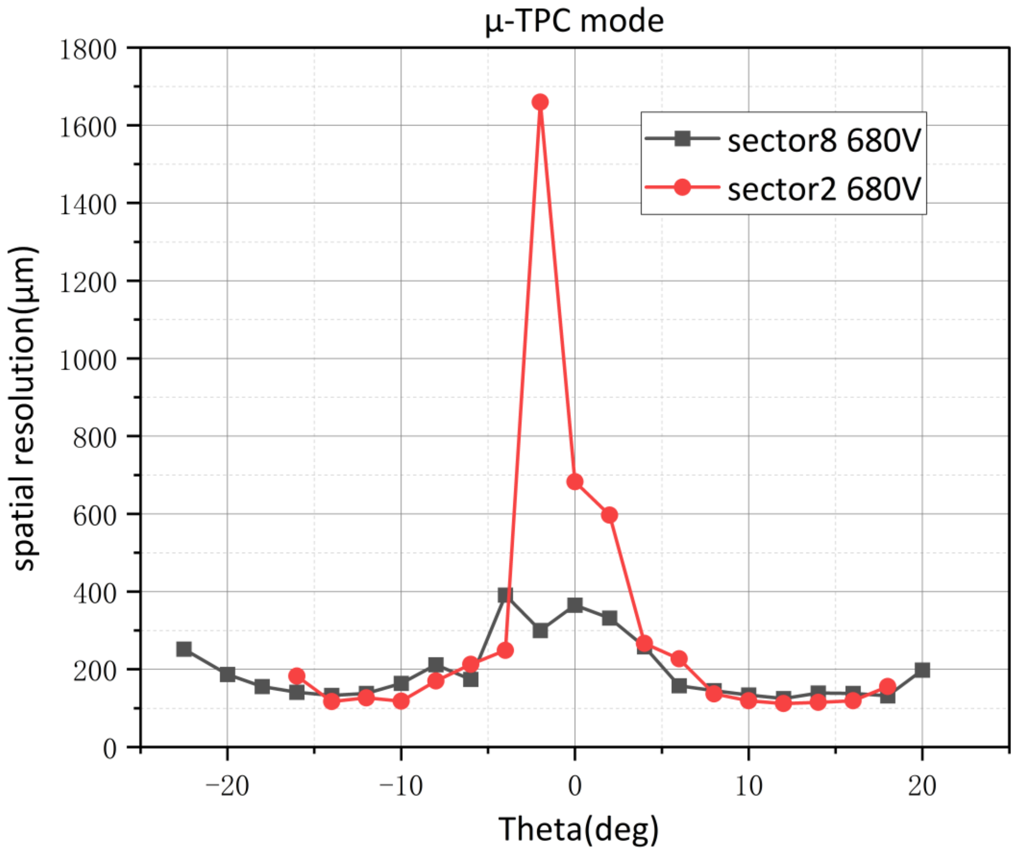






✓ CC is better when the track incident angle is <8°, μTPC is better when it is >8°, and the best result is better than 120μm

Result of different sectors

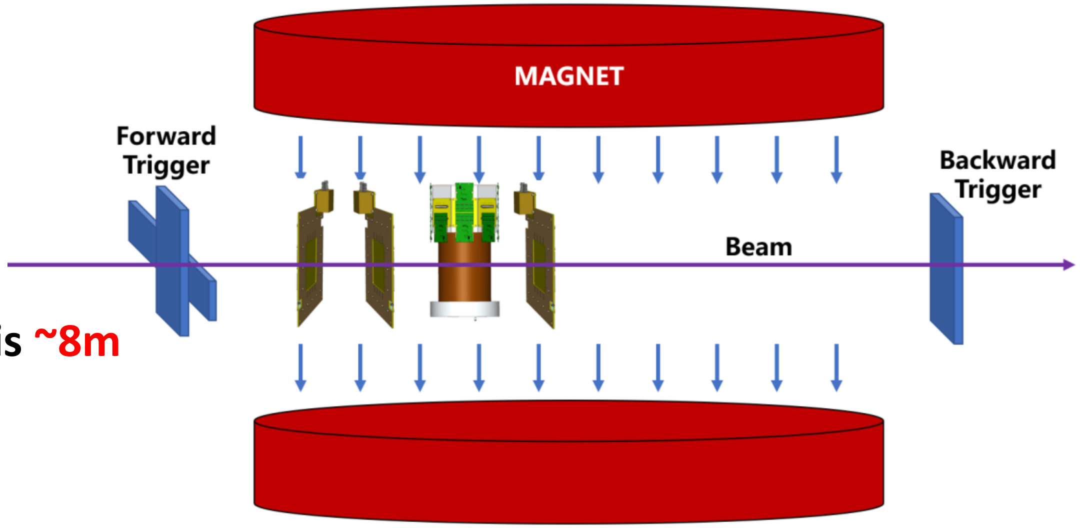


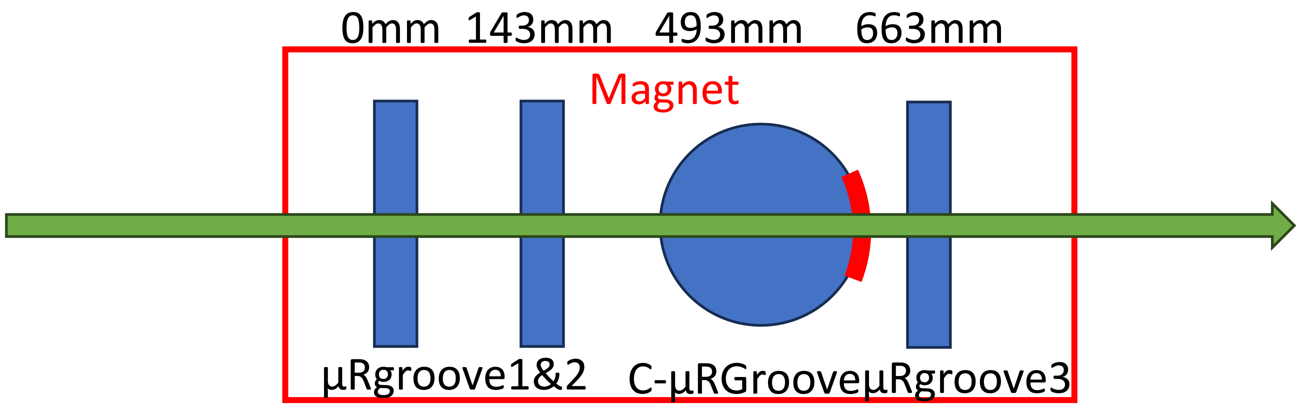
- The results of sector 2 are **slightly** better than those of sector 8.

Beam test with magnetic field

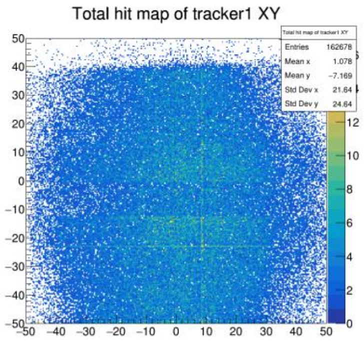
Setup：

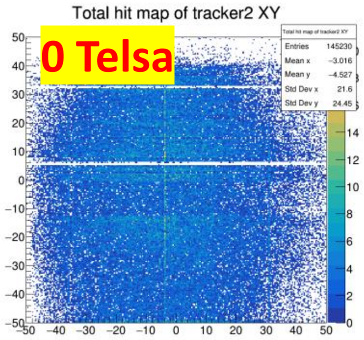
- Gas: Ar:CF_4:CO_2/45:40:15
- Readout from X strips (cathode)
- V strips are grounded
- APV25+SRS+mmDAQ
- Distance between forward and backward triggers is ~8m
- 3 μRGroove trackers
- 0.5-1.5Tesla magnetic filed



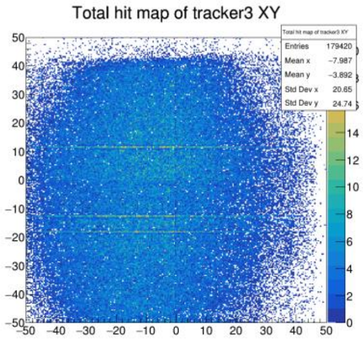


Beam test with magnetic field

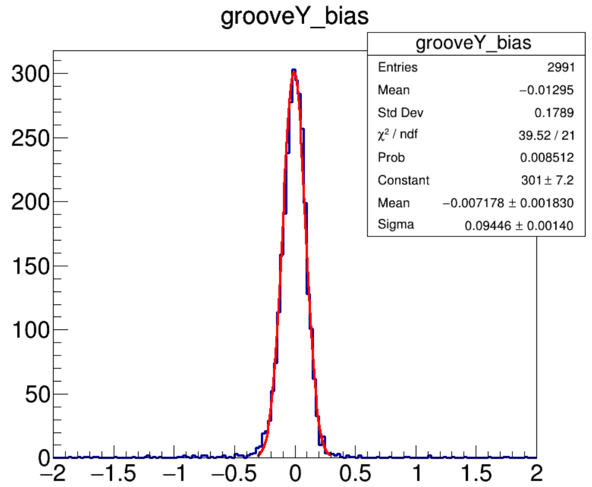




0 Telsa



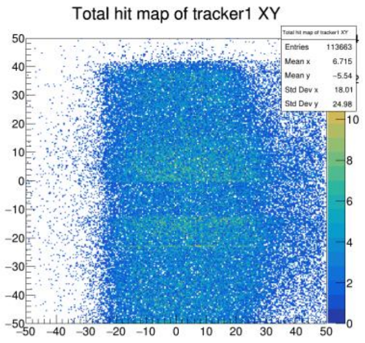
For perpendicular tracks, CC method

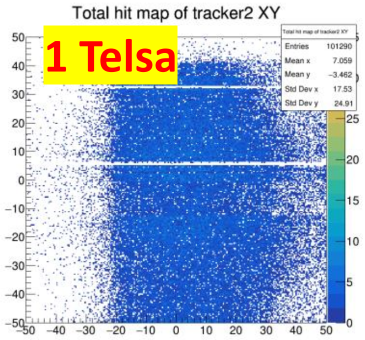


Spatial resolution is ~94μm as a reference @B=0T

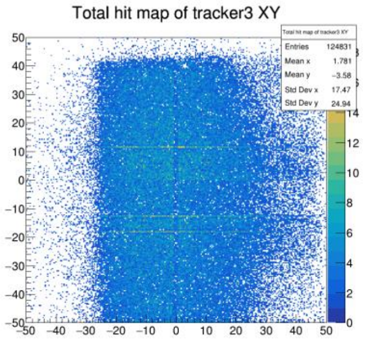
For 150GeV/c muon, $m \approx P$

$r = \frac{mv}{Bq} \approx 500m$ @B=1T

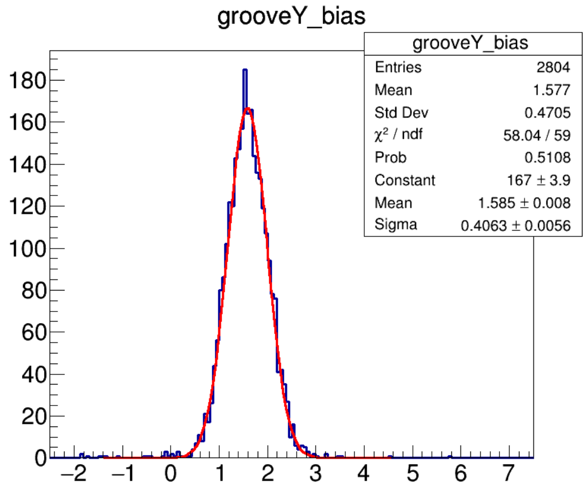




1 Telsa



For perpendicular tracks, CC method



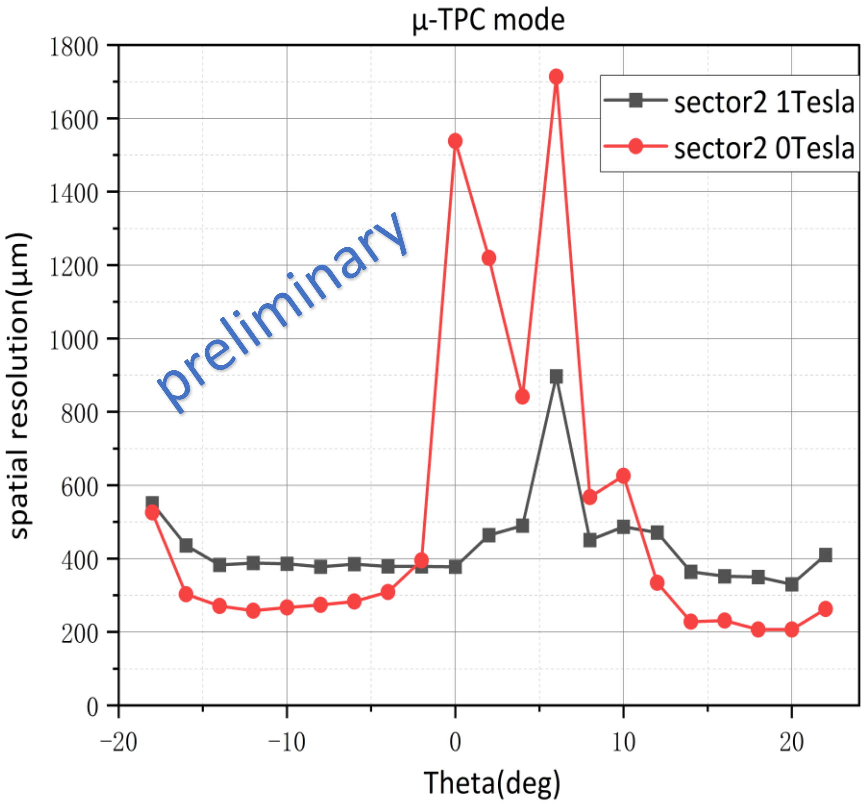
Spatial resolution is ~400μm

Bias: ~1.592mm, sigma: ~400μm

Lorenz angle: ~17.7°

Trackers' hit map shift caused by long distance between triggers.

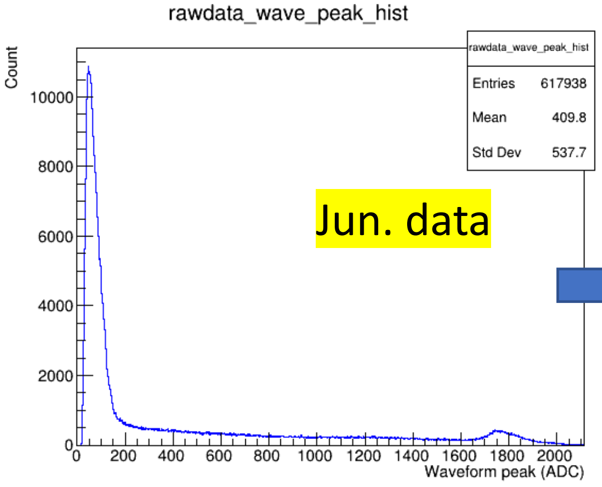
Preliminary result with magnetic field

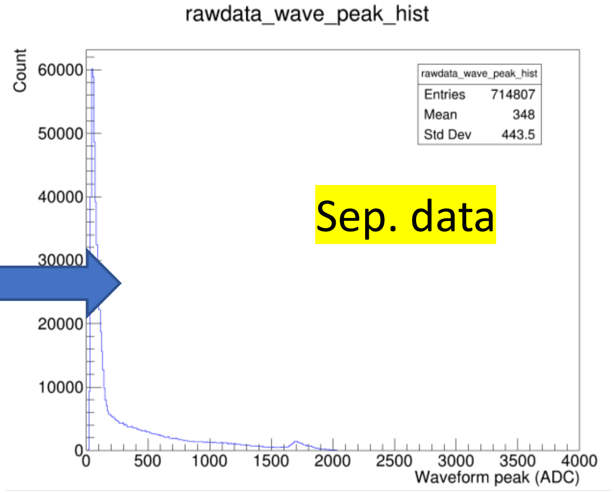


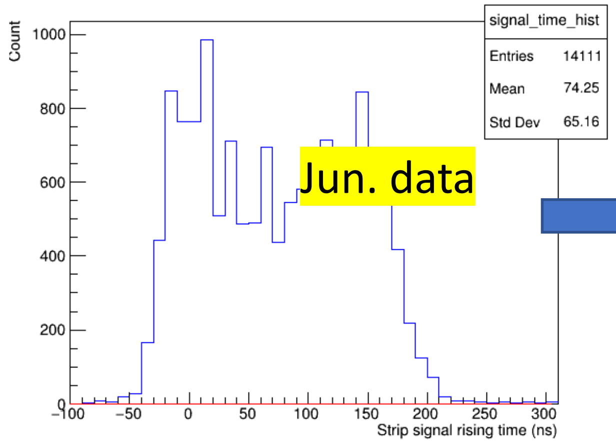
Very preliminary results：

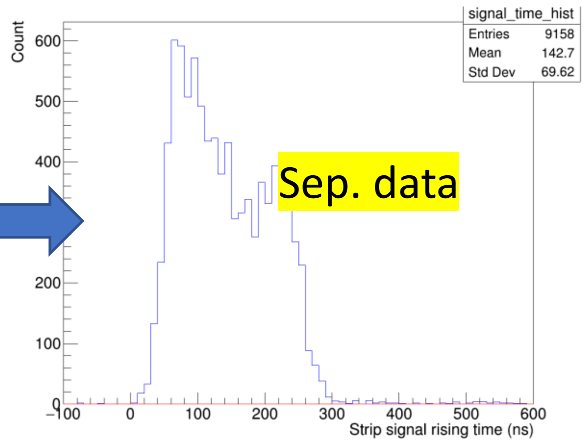
- Without magnetic field, the best result is **~200μm**, which may be related to gas changes.
- With 1T magnetic field, the best result is **~330μm**, which is significantly worse, indicating that the correction of the Lorentz angle is incomplete
- Further corrections are still needed

Comparison of June and September data







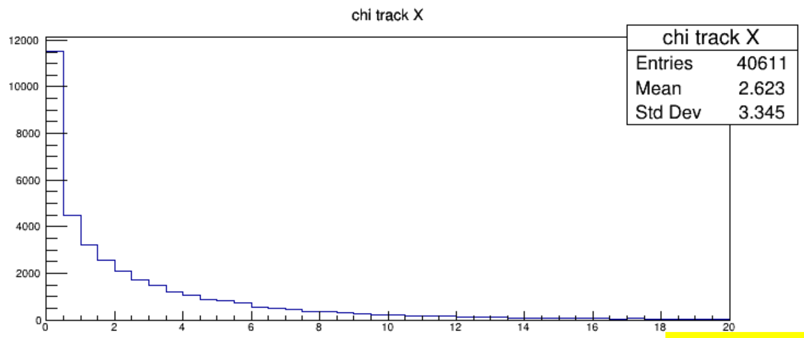


- **The signal amplitude drops by about 15%**

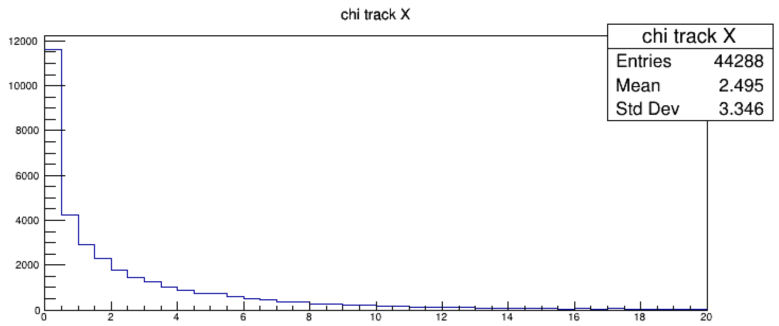
➢ Under the same voltage setting, the **gain becomes smaller** and the **drift velocity becomes faster**, which may be due to changes in gas composition.

- **(Tmax-Tmin) reduced by 40ns**

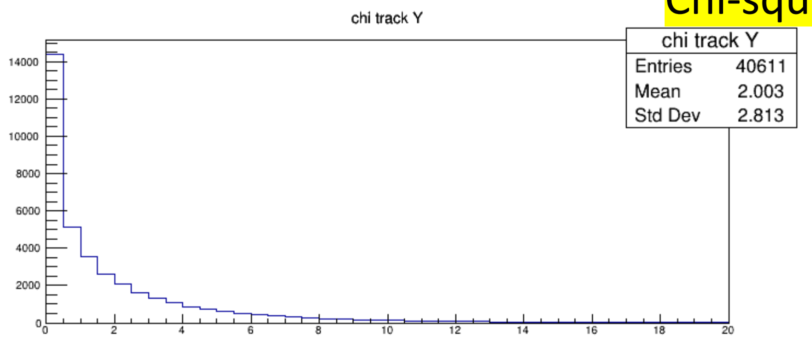
Effect of magnetic field on trackers

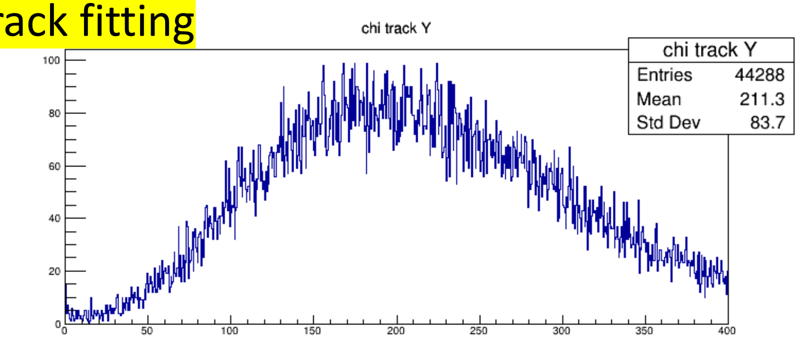


Sep. data



Chi-square distribution of track fitting

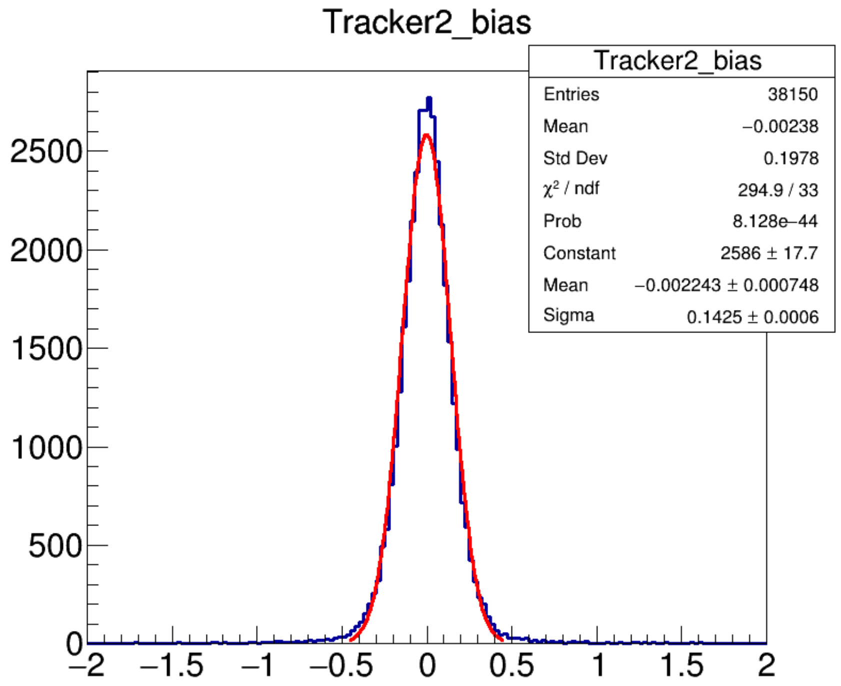


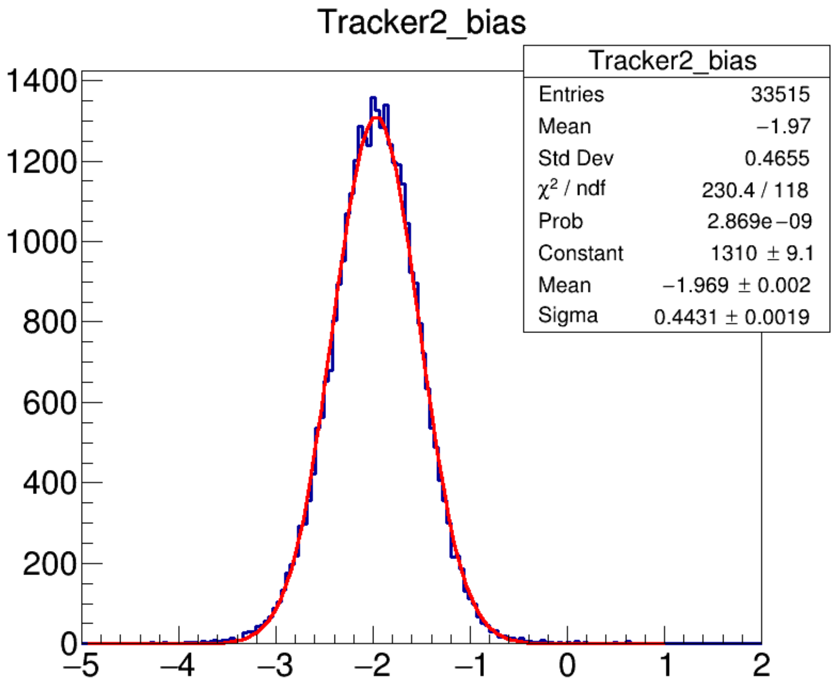


0T： Track fitted well

1T： The track quality become worse and the trackers were affected by the magnetic field , especially the primary electron drift process.

Effect of magnetic field on trackers





Use Tracker 1 and 3 to fit the tracks and calculate the spatial resolution of tracker 2

0T： 143µm

1T： 443µm

- **Magnetic fields have a significant impact on tracker system**

Summary

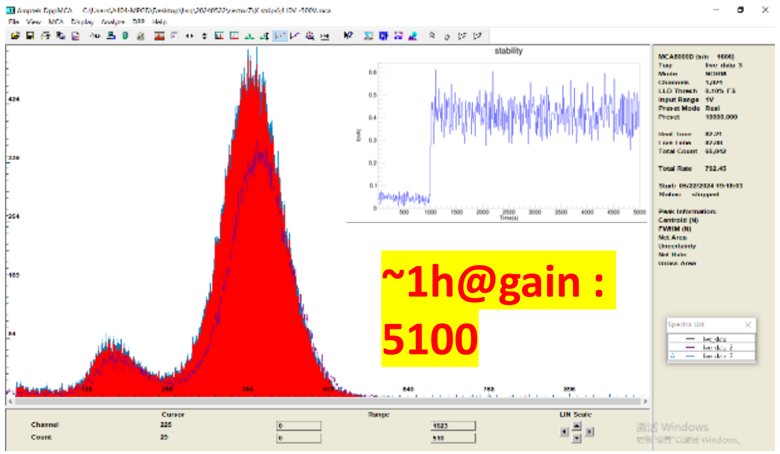
- Spatial resolution without magnetic field：
  - <100μm for perpendicular tracks
  - <120μm for Oblique incident tracks
- In the September beam test, CC result for perpendicular tracks is <100μm，while μTPC results were significantly worse, which may be caused by gas changes.
- Data analysis of magnetic field tests is still in progress
- **Beam test with magnetic field is required for next year**

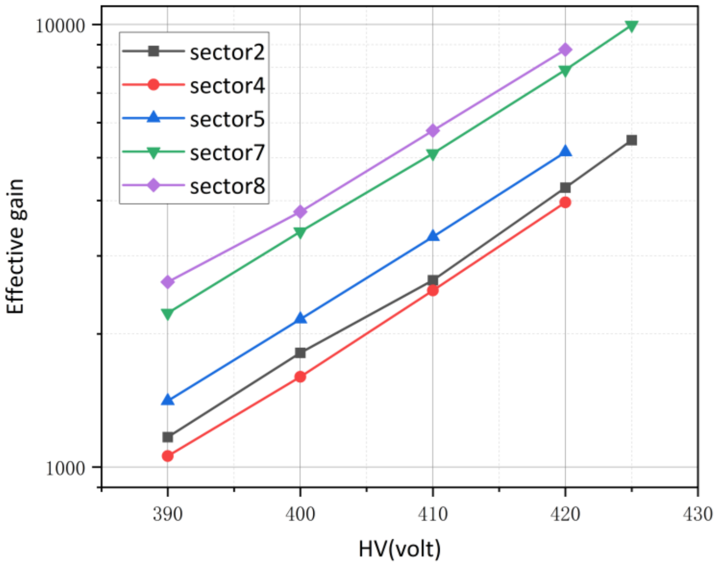
BACKUP

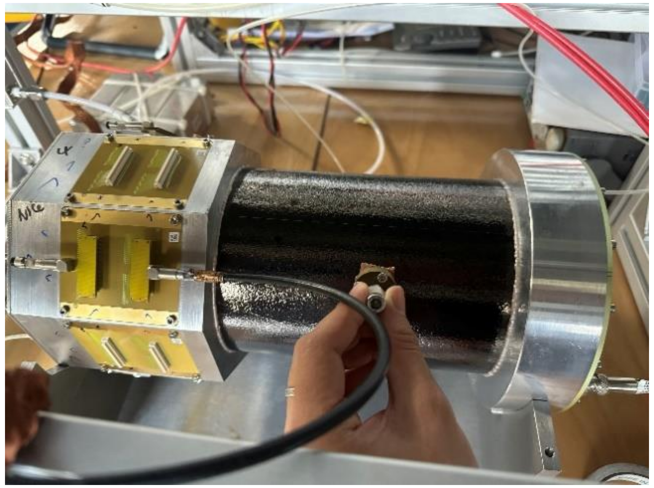
Gain and energy spectrum measurement

Setup：

- Gas: Ar:iC_4H_{10}/95:5
- Source: ^{55}Fe
- Readout from X strips (cathode)
- V strips are grounded
- Ortec142AH/671 + MCA
- Gain measured by signal amplitude spectrum





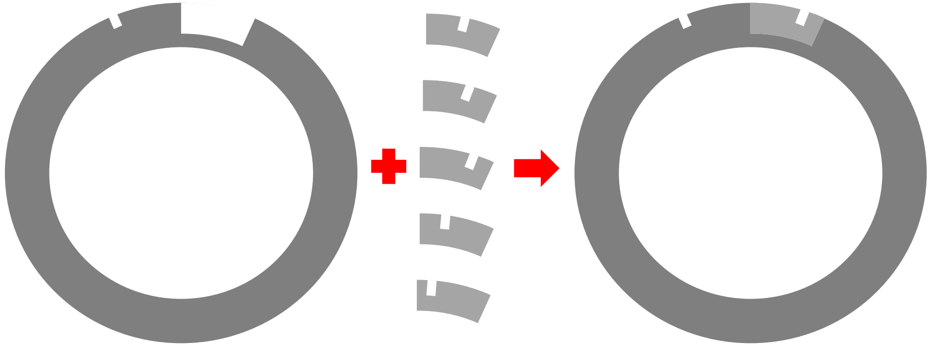


- ✓ Energy resolution: ~26%;
- ✓ Effective gain: 4000~10000;
- ✓ Similar signal amplitude on X&V readout strips;
- ✓ Good stability if the humidity can keep low enough;
- × 3 sectors not work (8 sectors in total);
- × Bad gain uniformity, caused by the gas(flow);

Redesign alignment holes to reduce the wrinkling

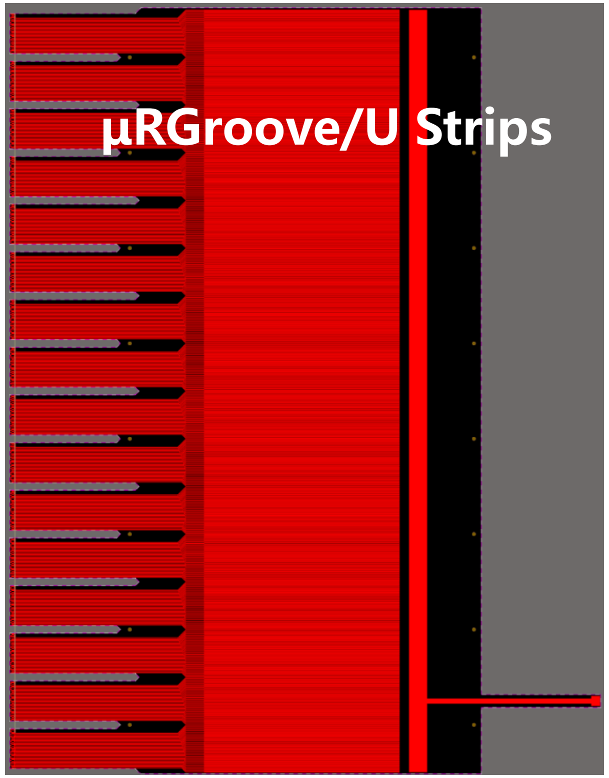
Impossible to predict the position of alignment holes

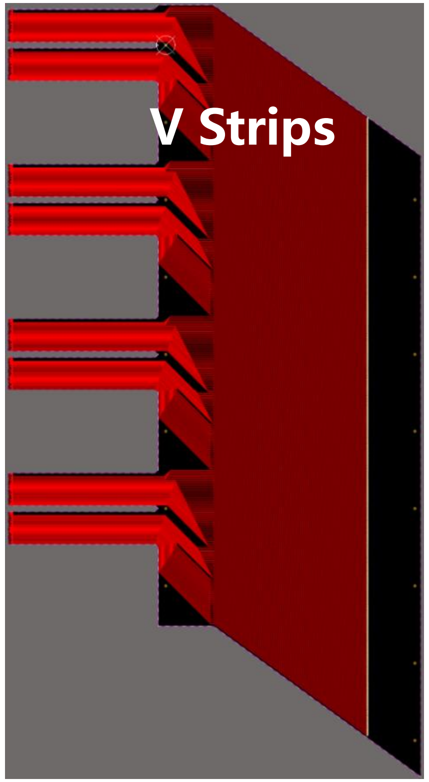
- × The fabrication tolerance of the detector parts in different batch;
- × Alignment accuracy during the detector assembling;
- × Tolerance of the Rohecall thickness and gluing process;



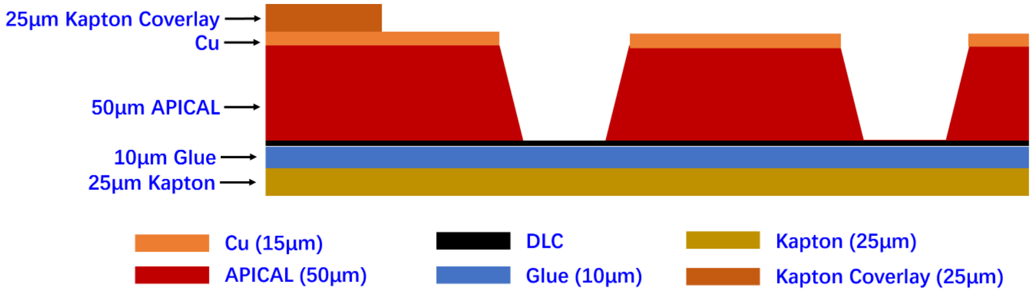
✓ This design can eliminate all the tolerance, we can even measure where the alignment holes should be before the foil gluing, then made the correct alignment parts.

µRGroove and Readout Strips

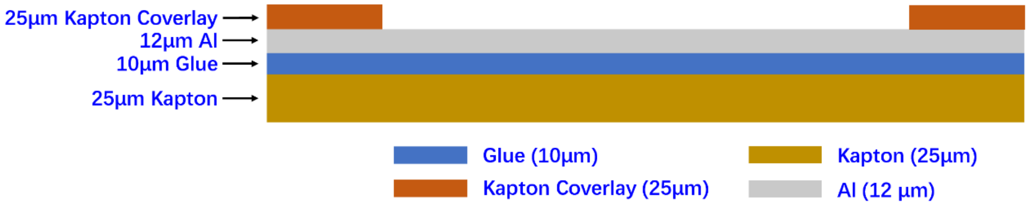




Layer stack of µRGroove

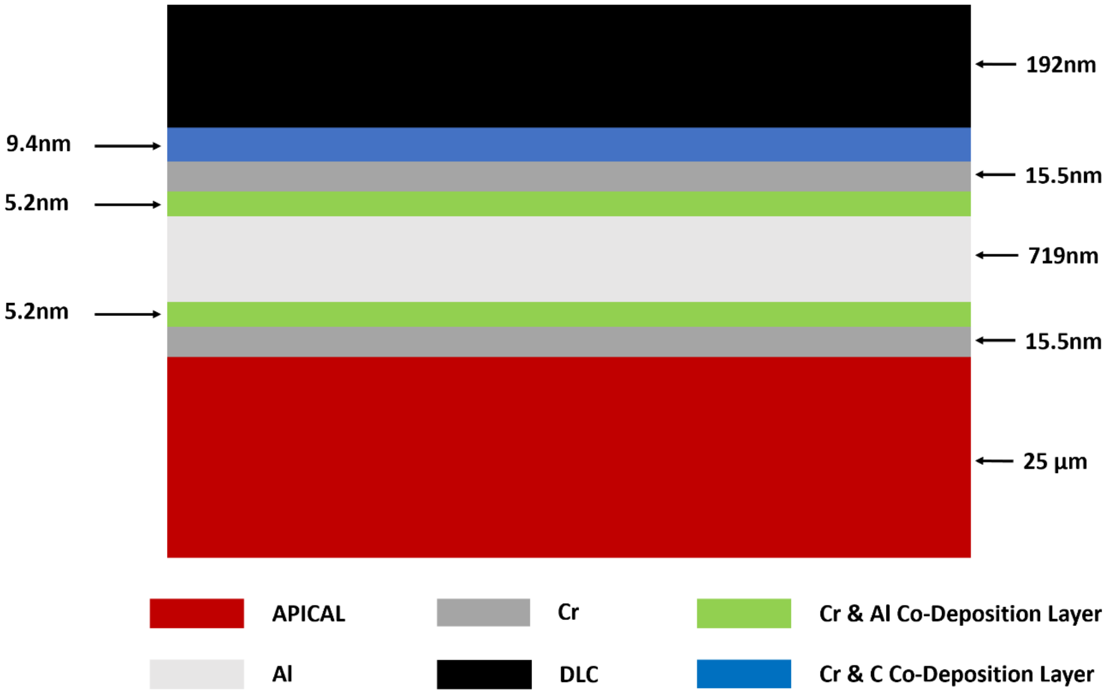


Layer stack of V readout



- U/V 2D strip-readout. Pitch: U strip is 0.4mm, V strip is 0.8mm, angel between UV is 15° .
- 2 PCBs each containing 1d strips are used.
- 25µm Kapton substrate
- Aluminum V-strips

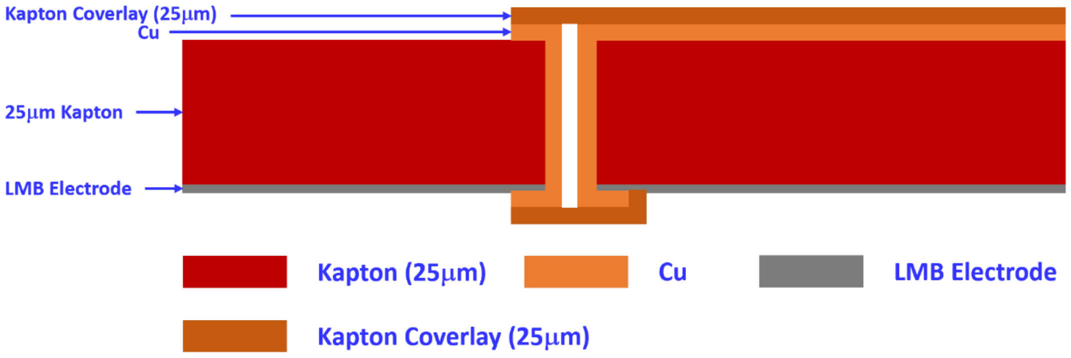
Low-mass electrode



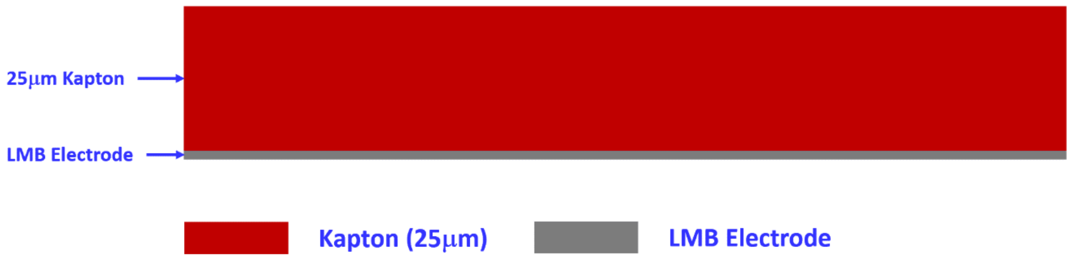
	X0 (mm)	Thickness (nm)	Material Budget (%X0)
C	188.4	193.6	0.0001028
Al	88.97	721.6	0.0008110
Cr	20.7	46.5	0.0002246
Total:			0.0011384

Zhou Lin, RD51 Collaboration Meeting, 21/06/2023

Layer stack of drift electrode

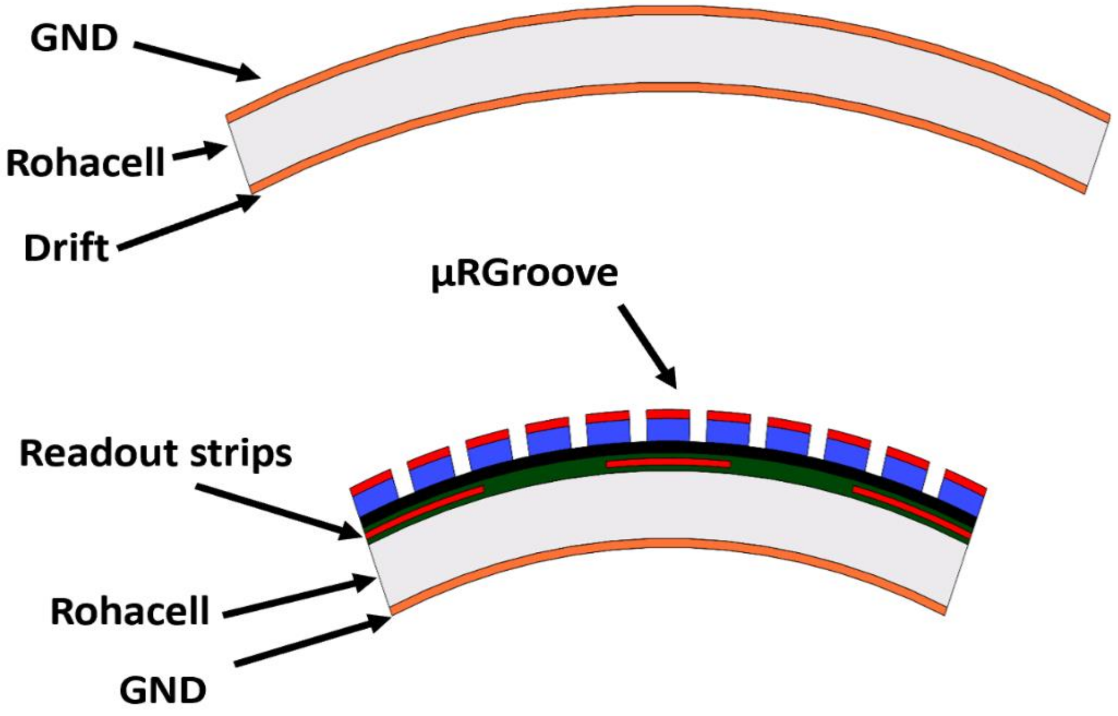


Layer stack of GND electrode



- **Low-mass electrode used for both drift and GND**

Material budget



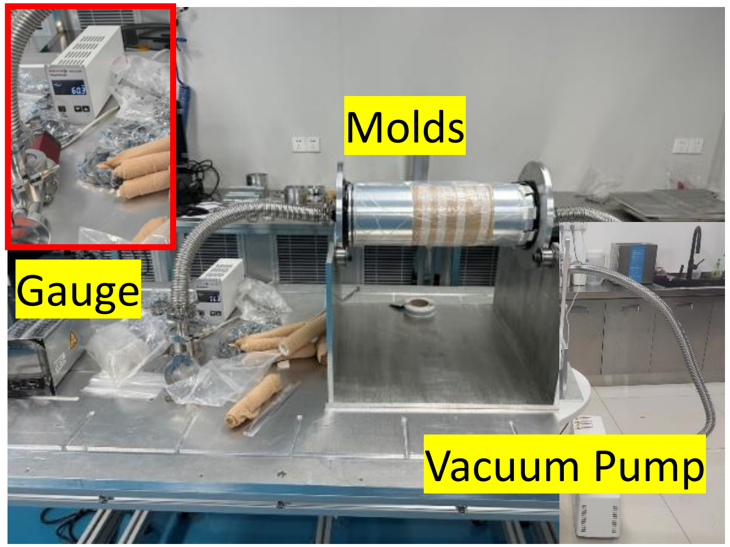
C-µRGroove

Structure	Material	Thickness (cm)	Material budget (X0)
Drift electrode	LMB-GND	---	2*0.001138%
	Polyimide (X0=28.57cm)	0.0025*2	0.0175%
	Glue (X≈20cm)	0.001*2	0.01%
	Rohacell (X0≈689cm)	0.2	0.029%
Gas volume	Argon-based gas mixture (X0=11760cm)	0.5	0.00425%
Inner cylinder (µRGroove foil)	Cu (X0=1.43cm)	0.0015*65%	0.0682%
	Cr (X0=2.077cm)	0.000001*65%	0.0000313%
	Apical (X0=28.57cm)	0.005*70%	0.01225%
	Glue (X0≈20cm)	0.001*5	0.025%
	Kapton (X0=28.57cm)	0.0025*2	0.0175%
	Al (X0=8.892cm)	0.0012*(1*32.5%)	0.00439%
	DLC (X0=12.13cm)	0.0001	0.00082%
	Polyimide (X0=28.57cm)	0.0025	0.00875%
	Rohacell (X0≈689cm)	0.2	0.029%
	LMB-GND	---	0.001138%
Total			0.2301%

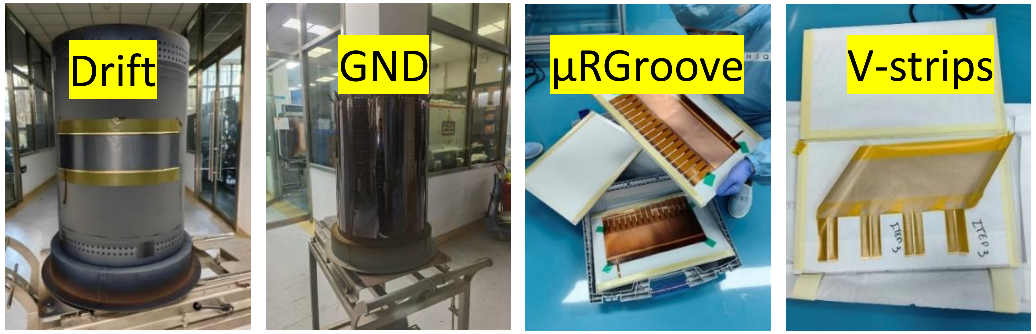
Consider Low-mass electrode, foams and bonding glues:

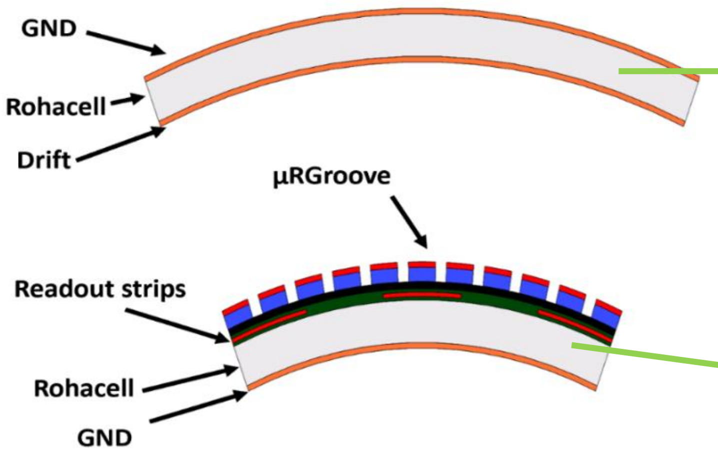
✓ **Total material budget: ~ 0.23%X_0**

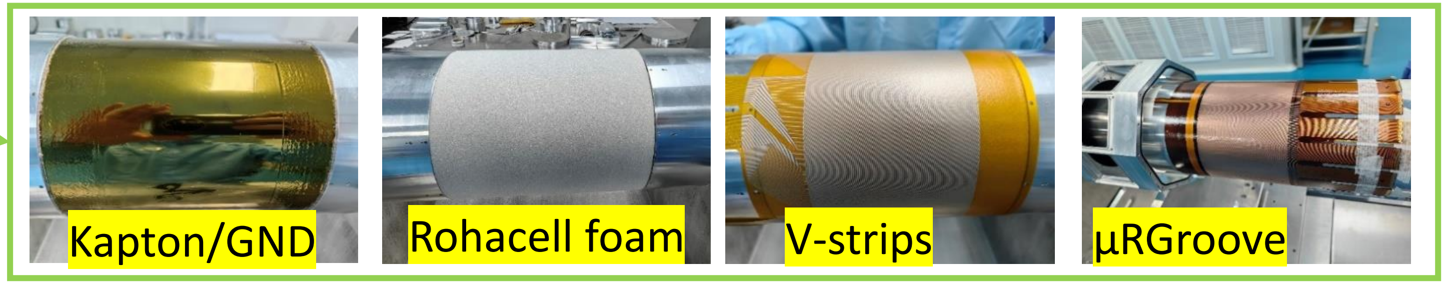
Electrode gluing process



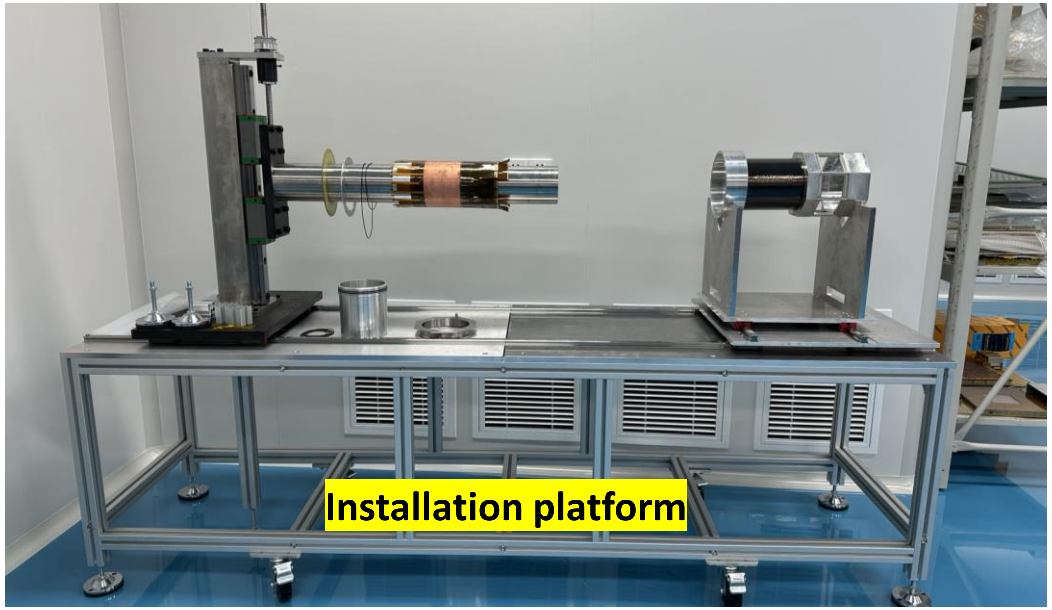
- ✓ Vacuum gluing system
- ✓ The uniform thin glue process: **thickness of glue film <10μm**

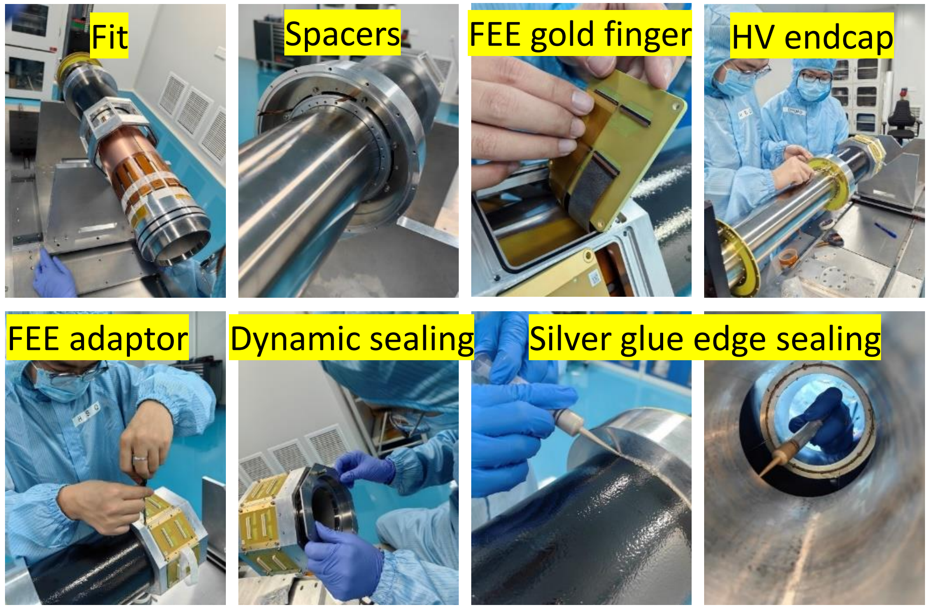


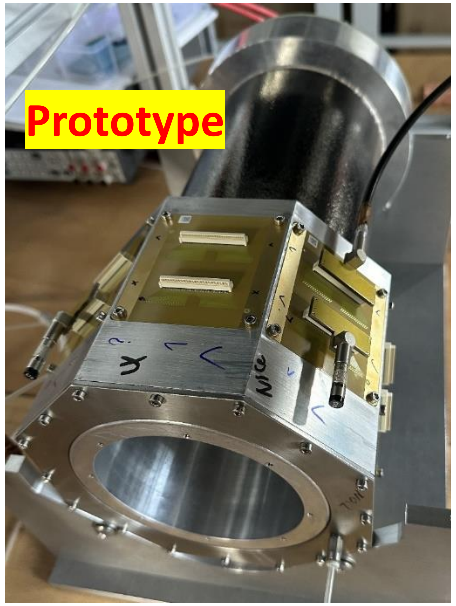




Detector assembling







- ✓ **An installation platform is designed**
- ✓ **Reversible installation process**