



AC-coupled LGAD for electron-positron collider

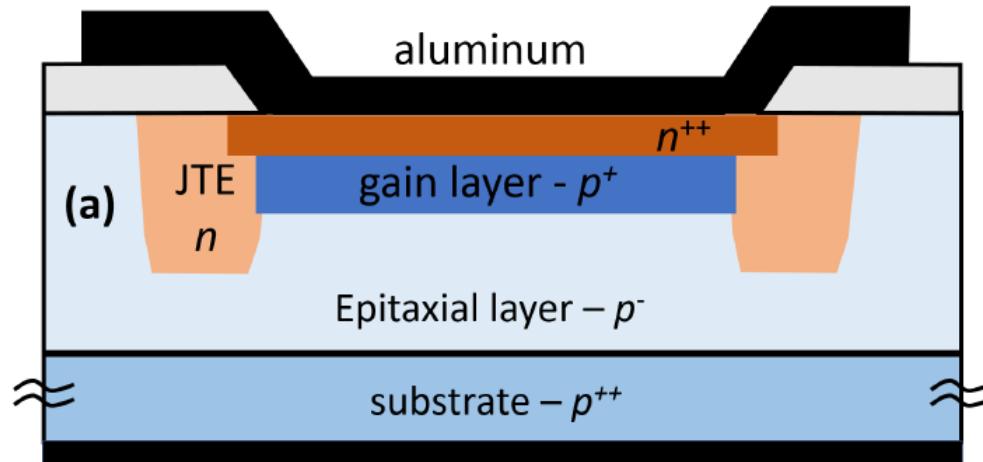
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On behalf of IHEP HGTD group

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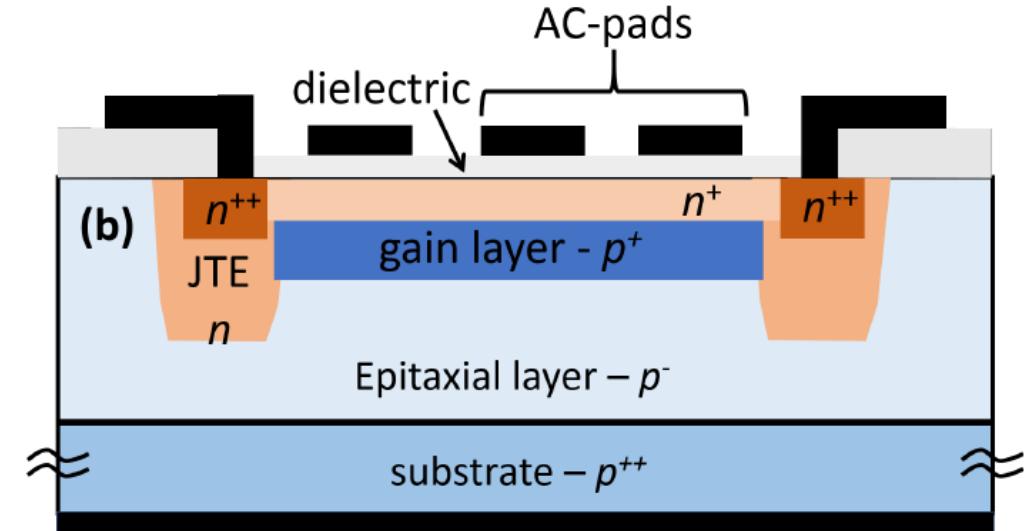
August 17, 2021



1. Introduction of AC-LGAD



LGAD (Low-Gain Avalanche Diode)



AC-LGAD (AC-coupled LGAD)

LGAD

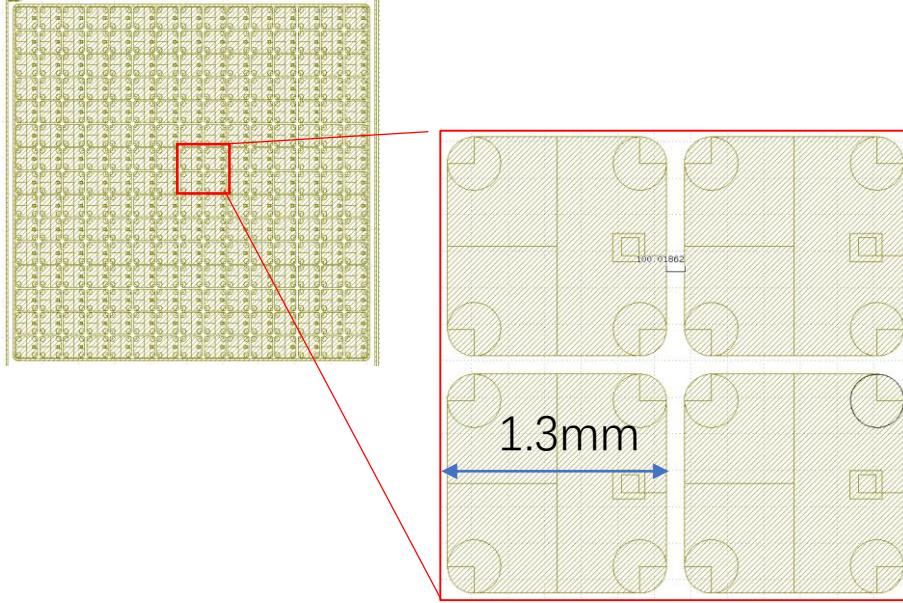
- The read-out electronics is connected to n++ layer
- Time resolution $\sim 30\text{ps}$
- Position resolution: sensor size

AC-LGAD

- Metal AC-pads separated from the n+ layer by a thin dielectric (SiO₂)
- Large area, no dead zone
- Time resolution $\sim 30\text{ps}$
- Position resolution: 10-50 μm

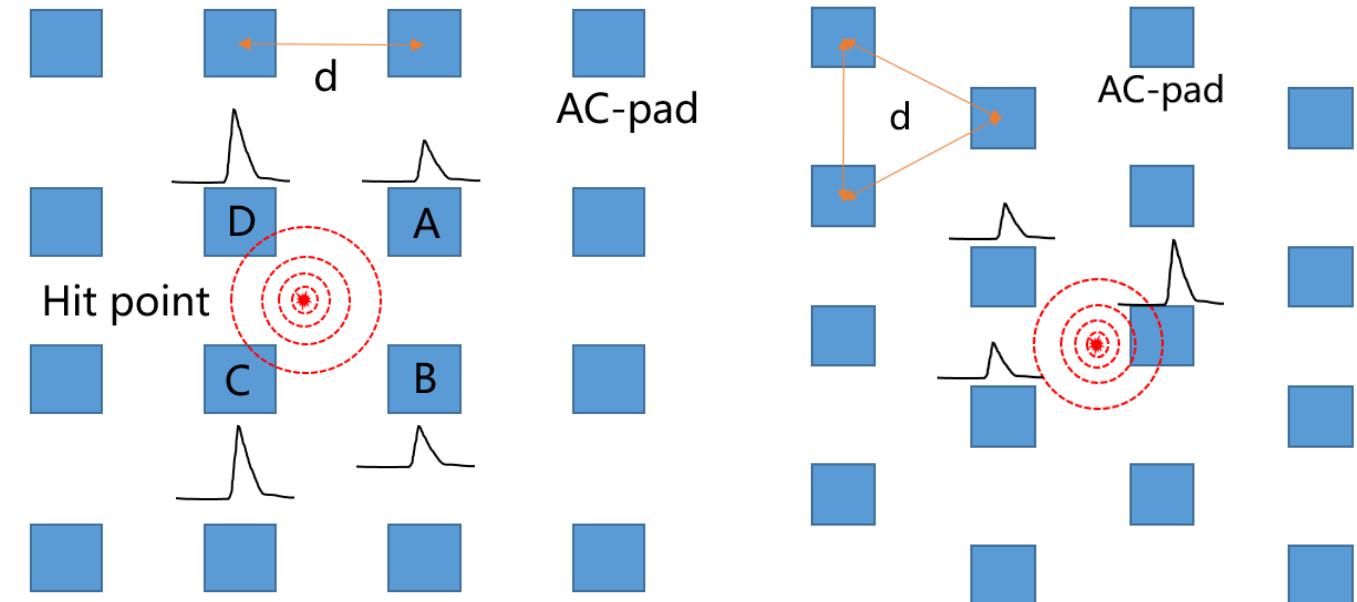


1. Introduction of AC-LGAD



15×15 LGAD for ATLAS HGTD project

- Dead zone : >0.1mm
- Position resolution: 1.3mm



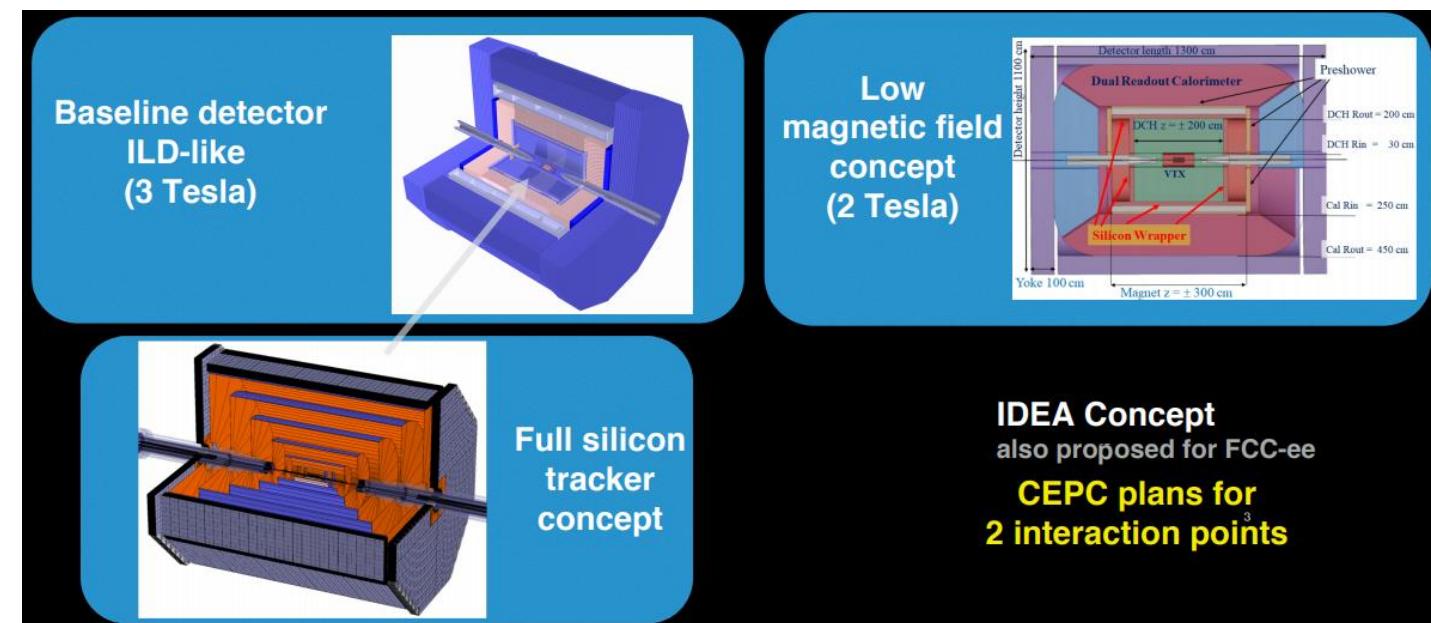
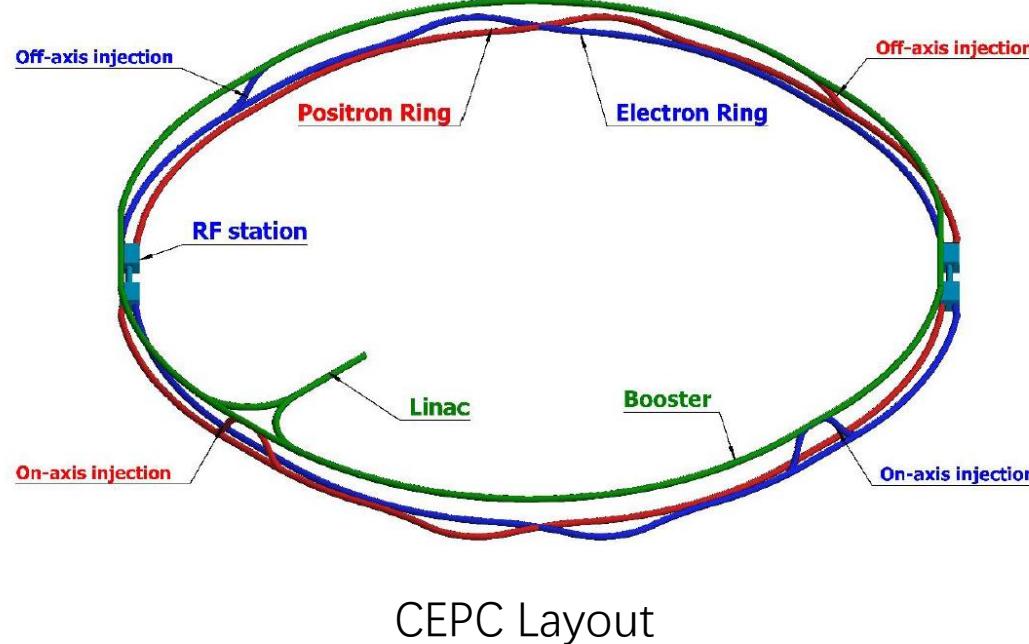
AC-LGAD: two layout schemes for AC-pads

- Dead zone : 0mm
- Position resolution: 10-50 μ m
- **4D detector: position + time**



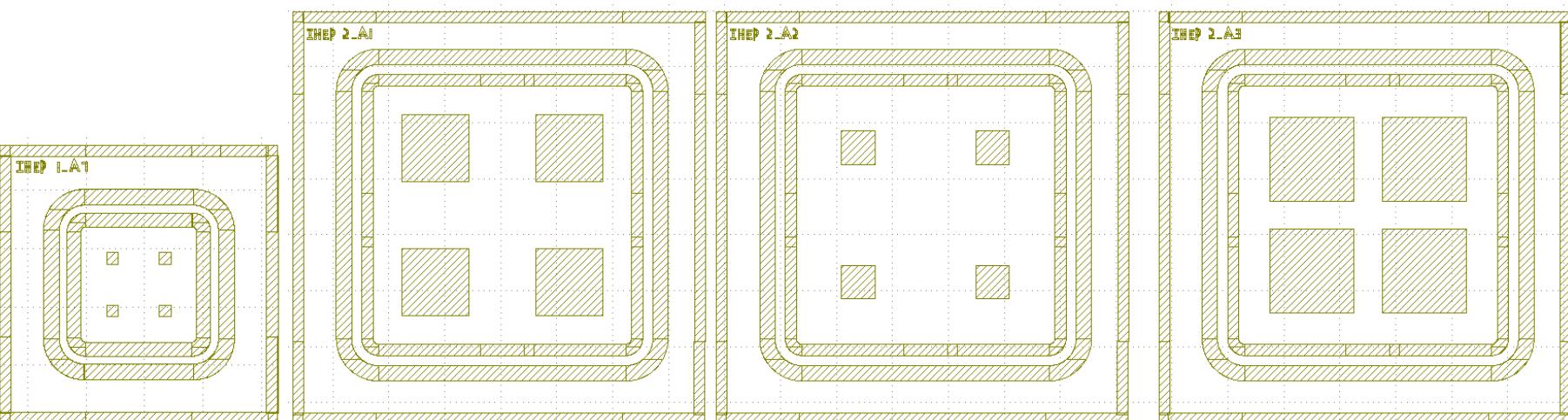
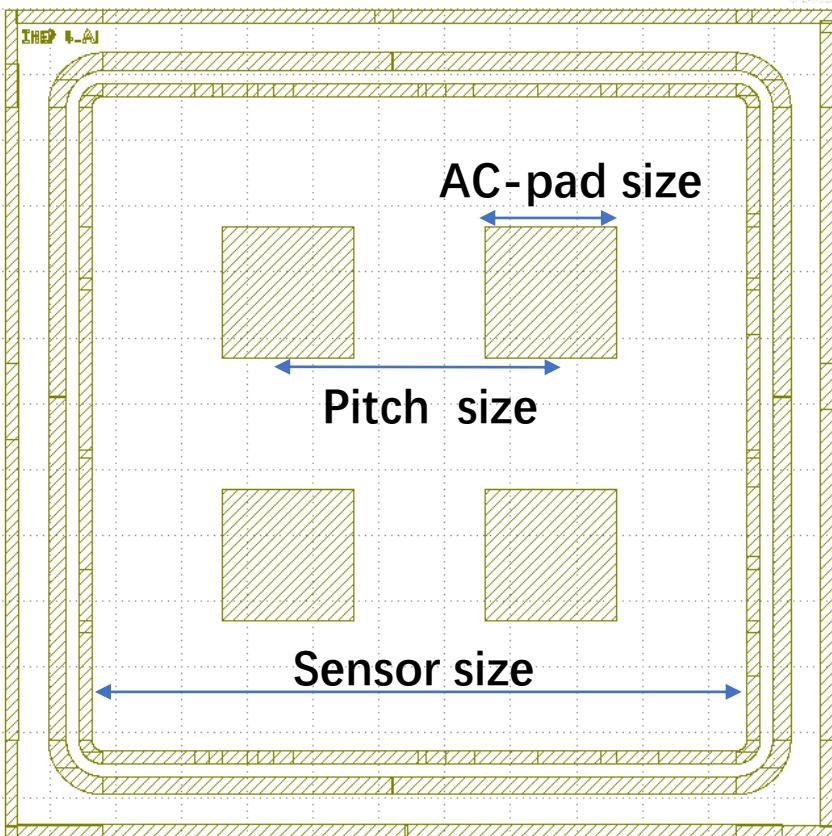
1. Introduction of AC-LGAD

- AC-LGAD can be used as a 4D detector for future electron collider experiments
- FCC-ee/CEPC will produce Tera Z ($\sim 10^{12}$) Z boson at Z pole -> Rich flavor physics
- High-precision 4D detector is powerful for particle identification (PID)



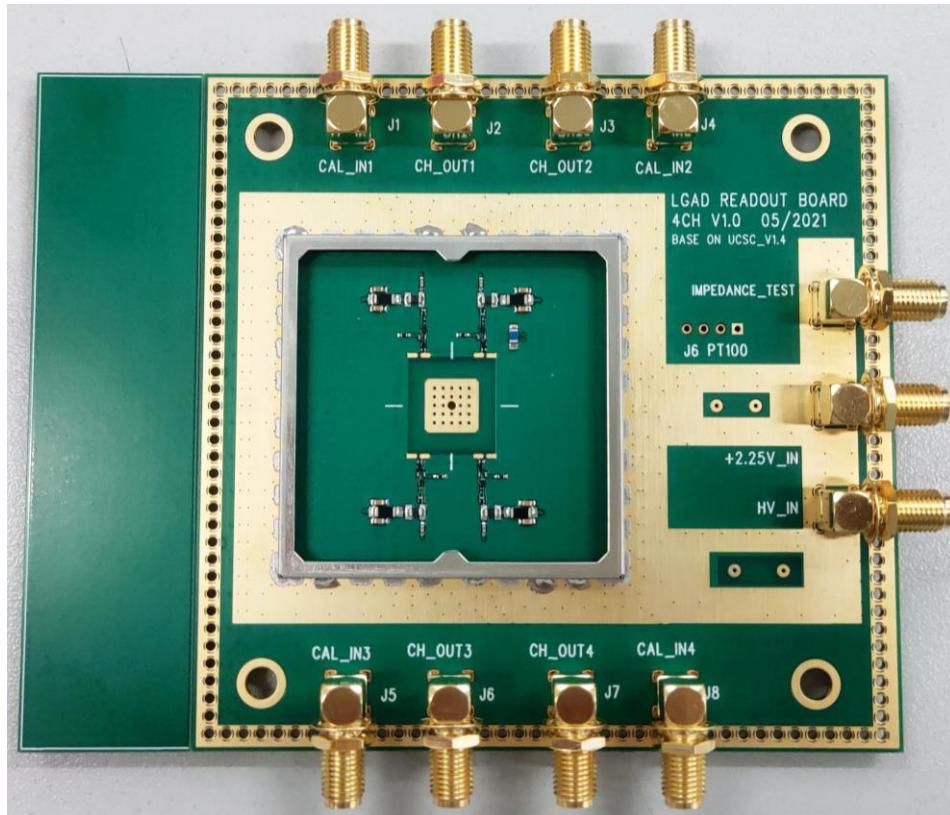
2. AC-LGAD sensors development by IHEP

Sensors	Sensor size [μm]	AC-pad size [μm]	Picth size [μm]
1-A7	1000	100	450
2-A2	2000	300	1200
2-A1	2000	600	1200
2-A3	2000	750	1000
4-A1	4000	1000	2000

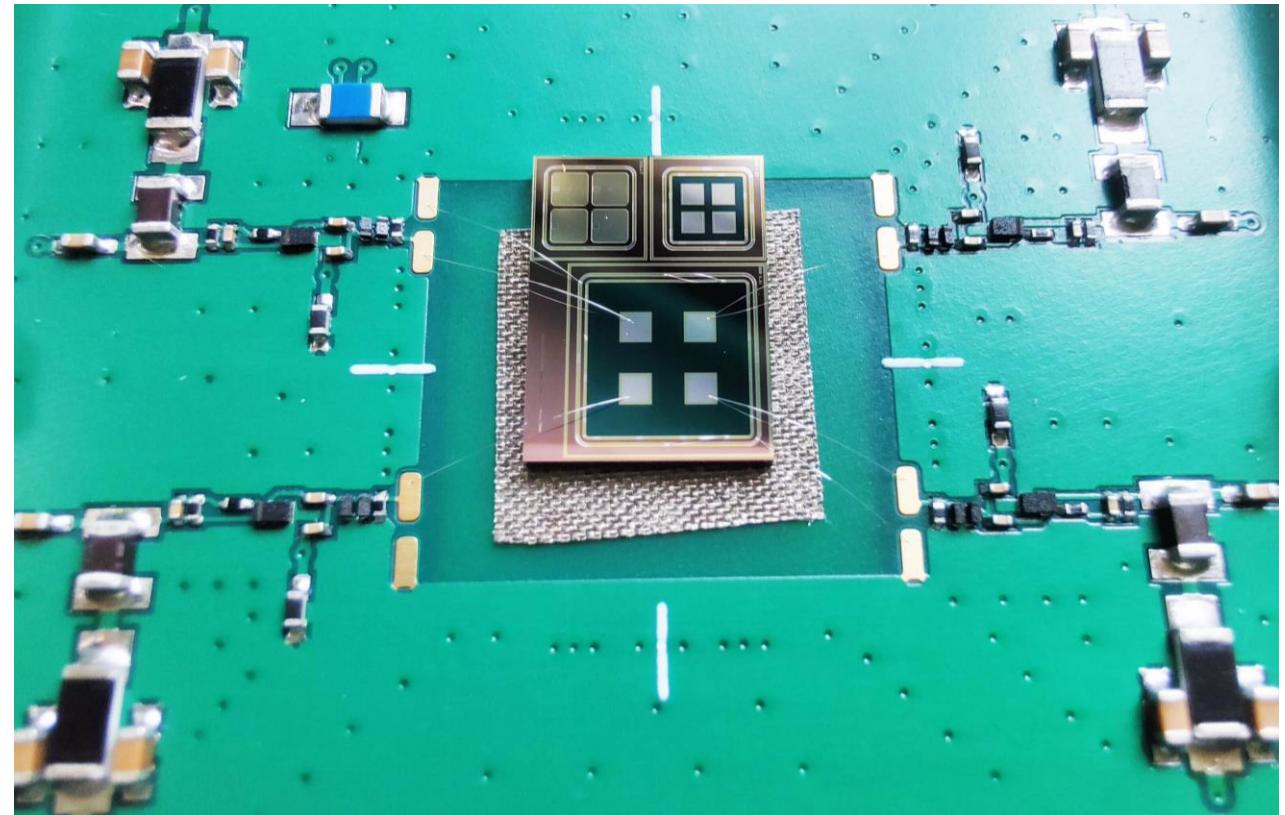




3. Picosecond laser test

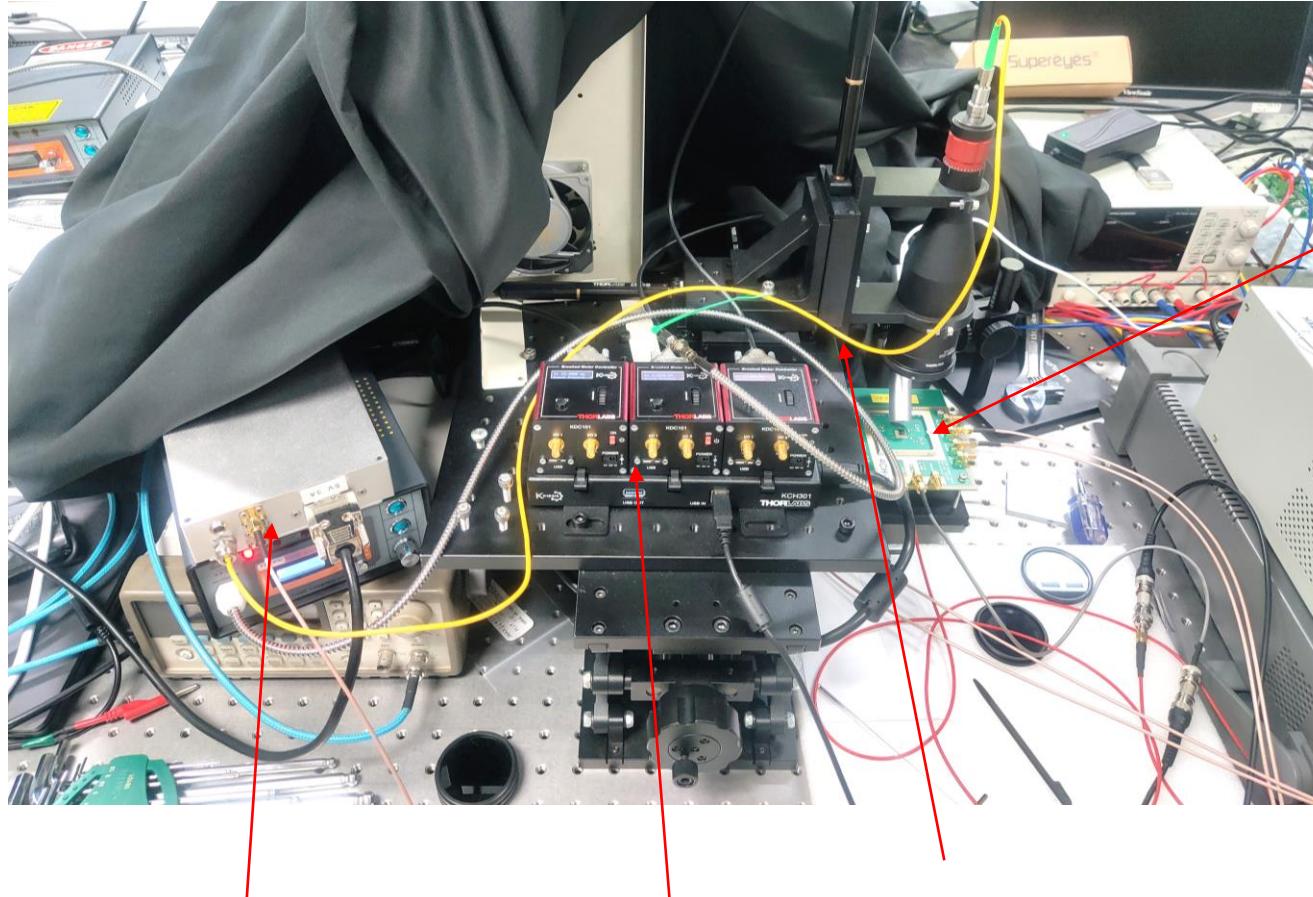


4CH readout board for AC-LGAD sensors



Sensor bonded to the 4CH readout board

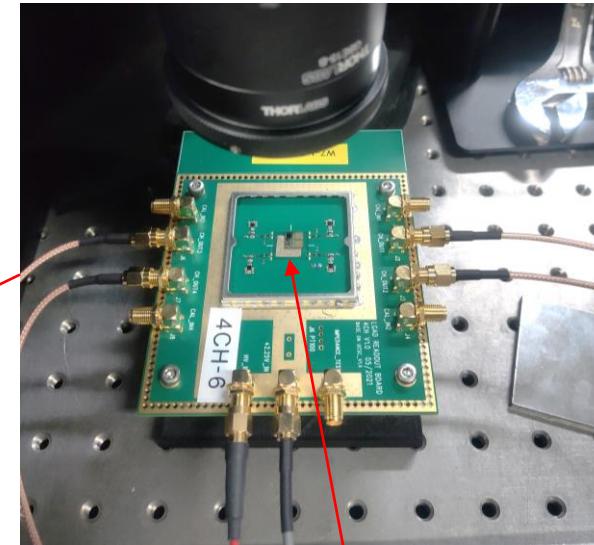
3. Picosecond laser test



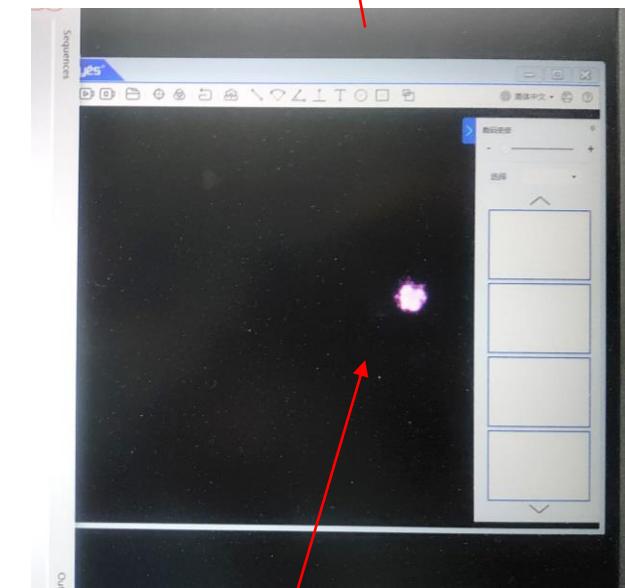
Picosecond laser
1064nm

3D stage

fiber

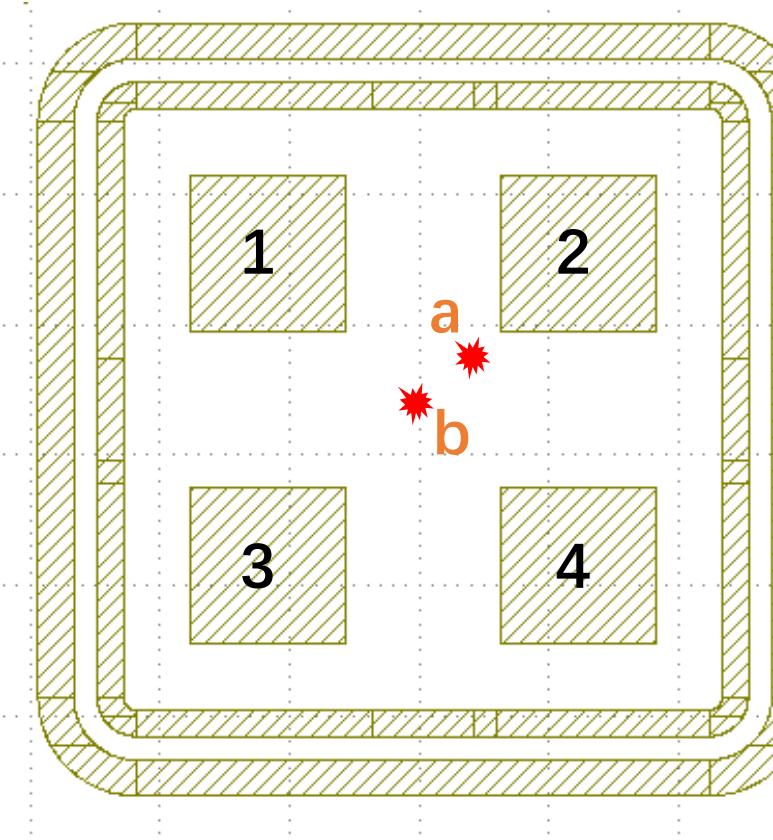
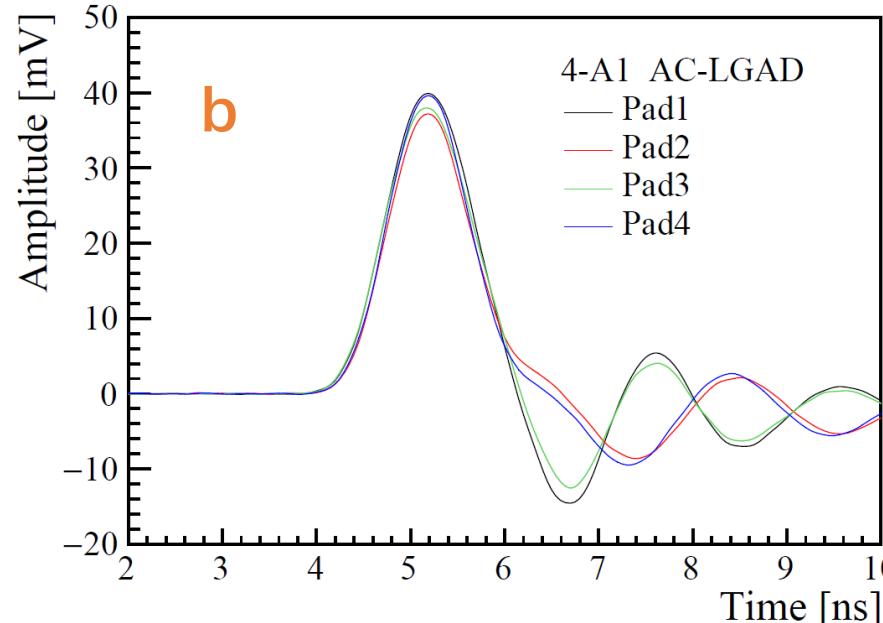
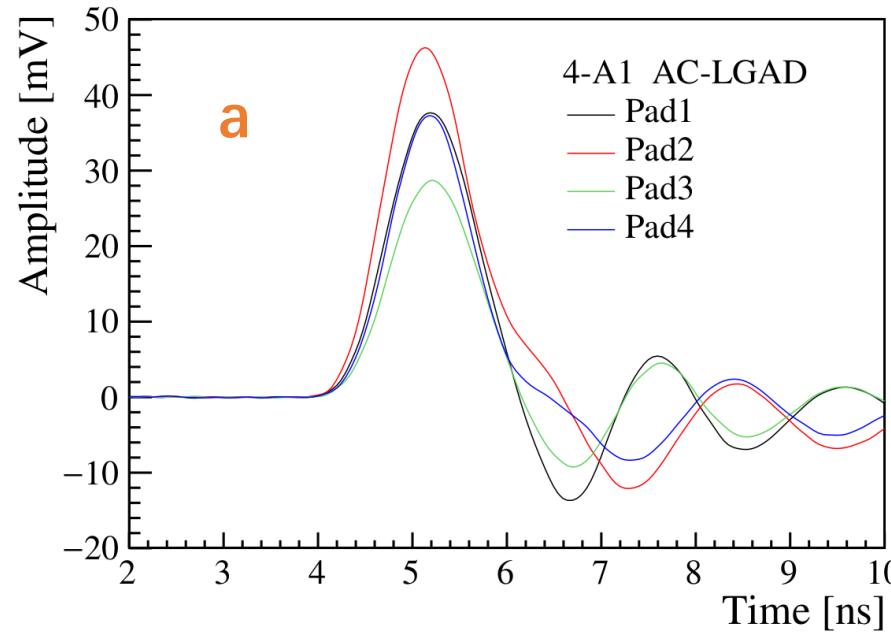


Sensor & Board



focusing on the sensor

4. Position Reconstruction

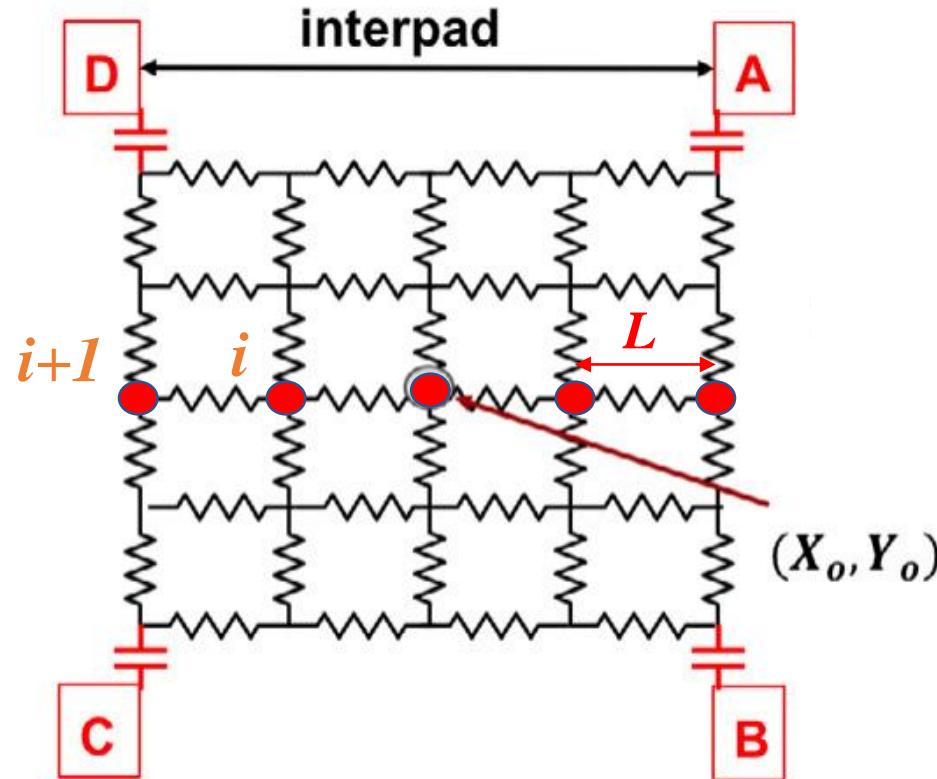


The coupled signal is closely related to the position of the laser



4. Position Reconstruction

Discretized Positioning Circuit model (DPC)



$$X = X_0 + k_x \left(\frac{q_A + q_B - q_C - q_D}{q_A + q_B + q_C + q_D} \right) = X_0 + k_x m$$

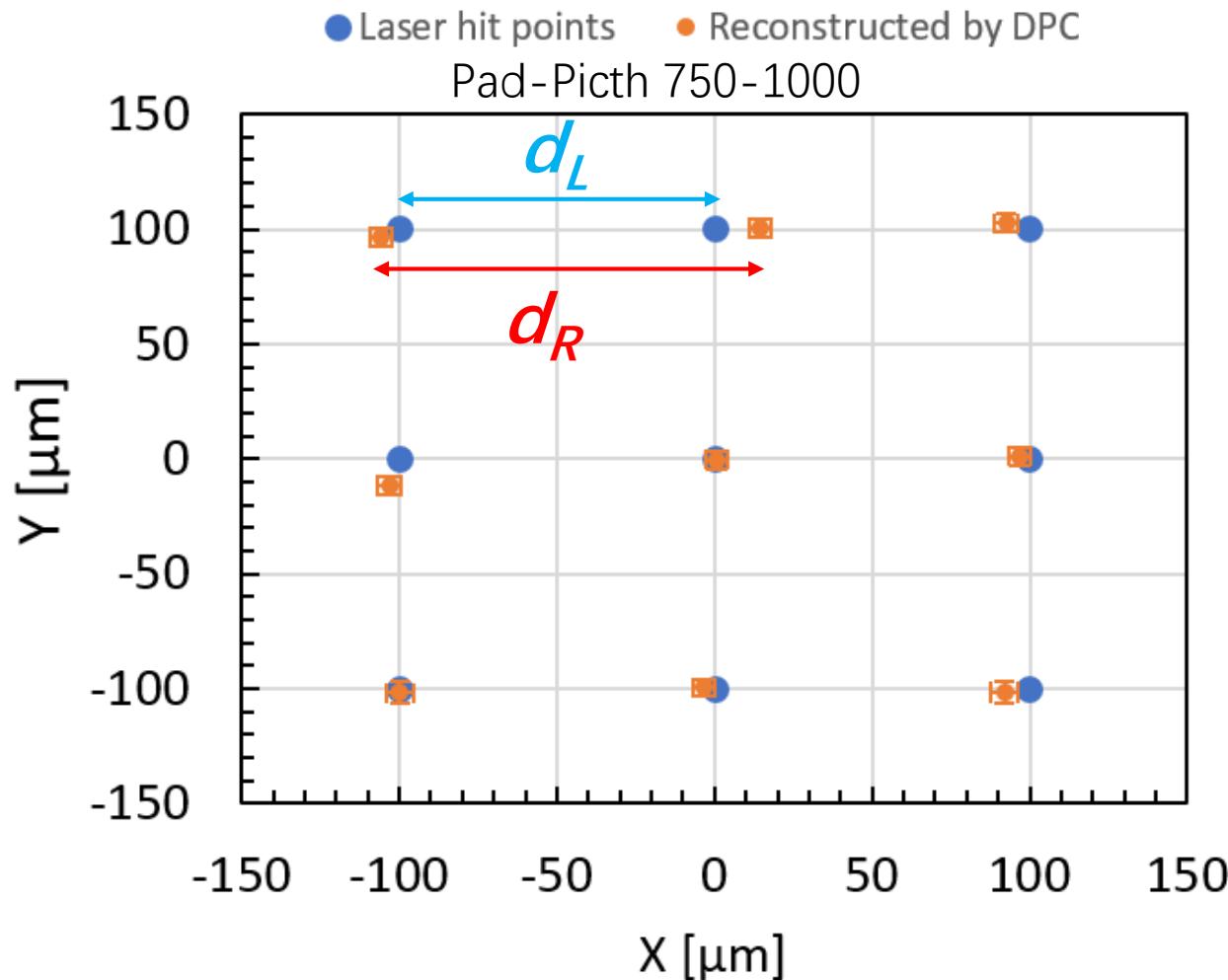
$$Y = Y_0 + k_y \left(\frac{q_A + q_D - q_B - q_C}{q_A + q_B + q_C + q_D} \right) = Y_0 + k_y n$$

$$k_x = L \frac{\sum (m_{i+1} - m_i)}{\sum (m_{i+1} - m_i)^2}$$

$$k_y = L \frac{\sum (n_{i+1} - n_i)}{\sum (n_{i+1} - n_i)^2}$$

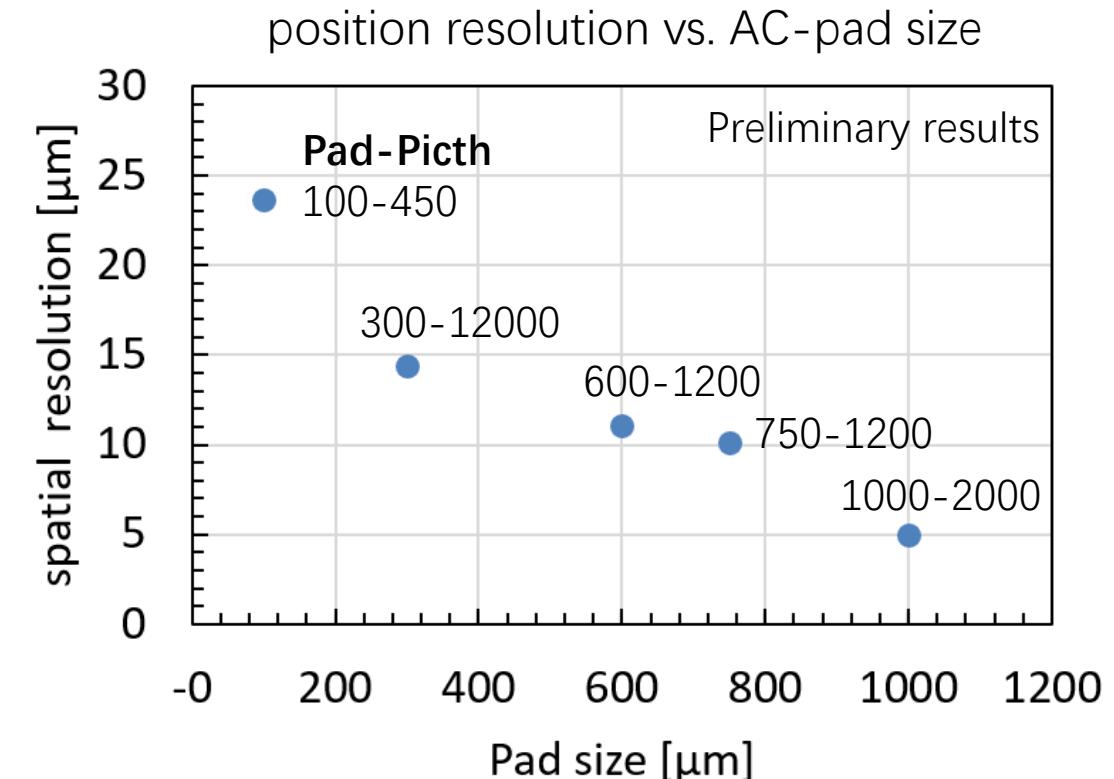


4. Position Reconstruction results



Position resolution:

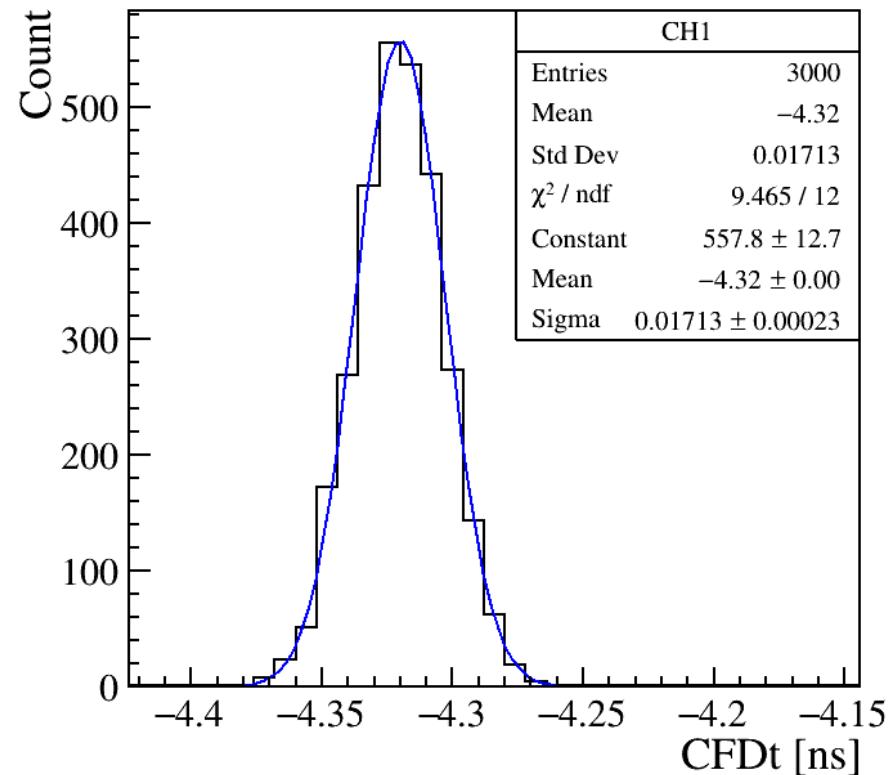
The standard deviation of the displacement difference between the laser and the reconstruction ($d_L - d_R$)



- The larger the AC-pad, the better the position resolution.
- From the current RC design, the large AC-pad has a longer RC, the ballistic deficit of the signal is small.
- The best can reach **5μm** (4-A1)



5. Timing resolution



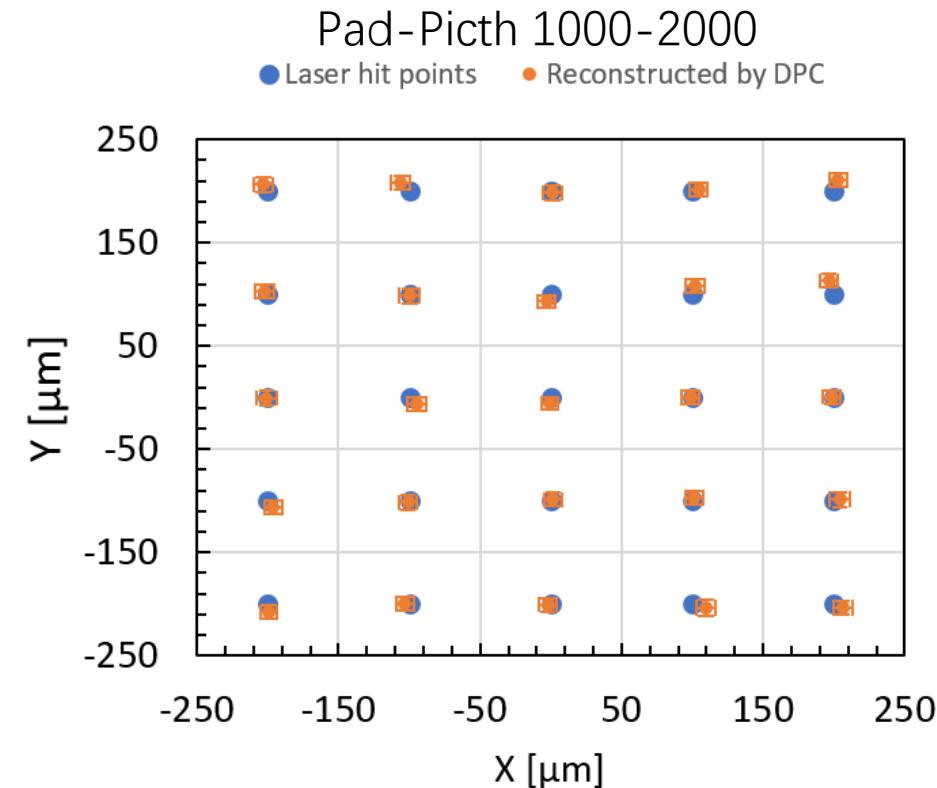
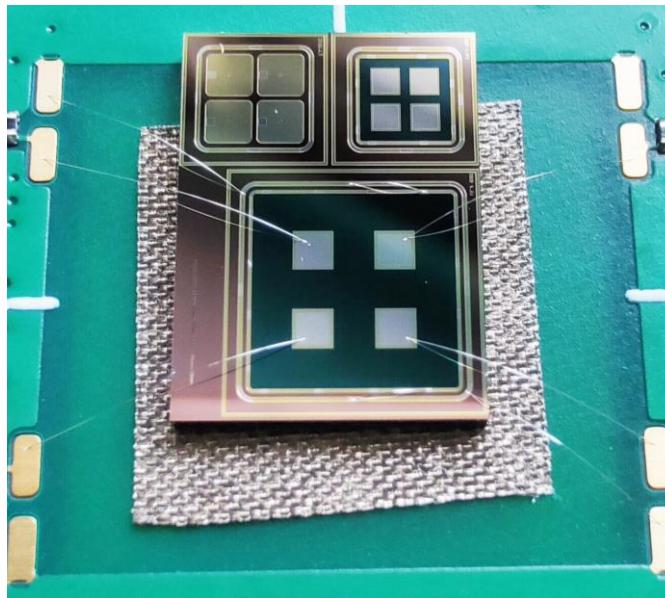
Arrival time distribution obtained by CFD method

Sensors	Timing resolution [ps] (Laser test)
1-A1	15.378
2-A1	15.916
2-A2	17.37
2-A3	17.486
4-A1	17.372



6. Summary

- AC-LGAD is a new 4D detector (position + time)
- IHEP has designed several AC-LGAD sensors
- Picosecond laser test and reconstructed by DPC model
- **The best position resolution $\sim 5\mu\text{m}$**
- **Timing resolution $\sim 17\text{ps}$ (Laser test)**





Thanks