

4H-SiC LGAD Timing Pixel for Future Collider Experiments

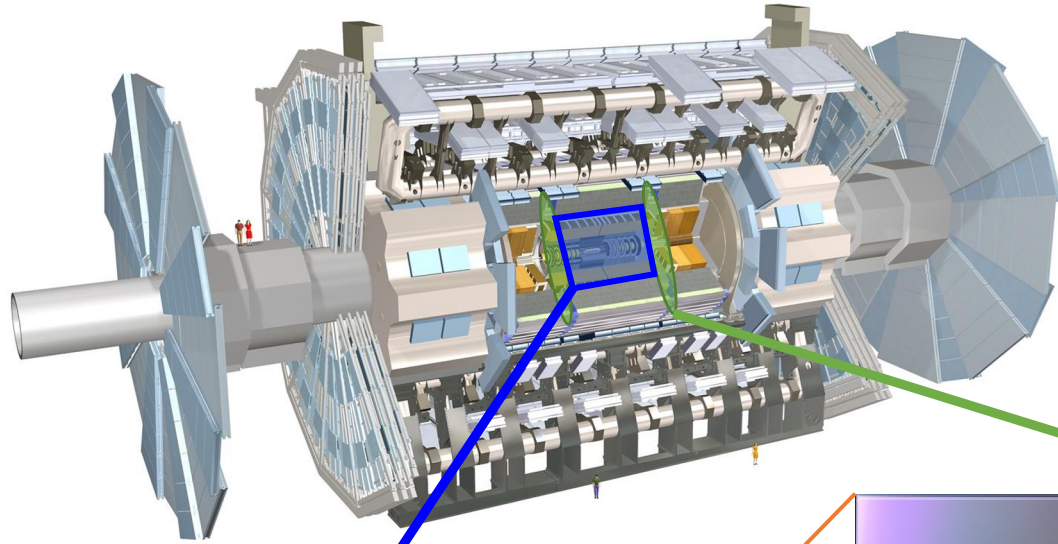
Xin Shi

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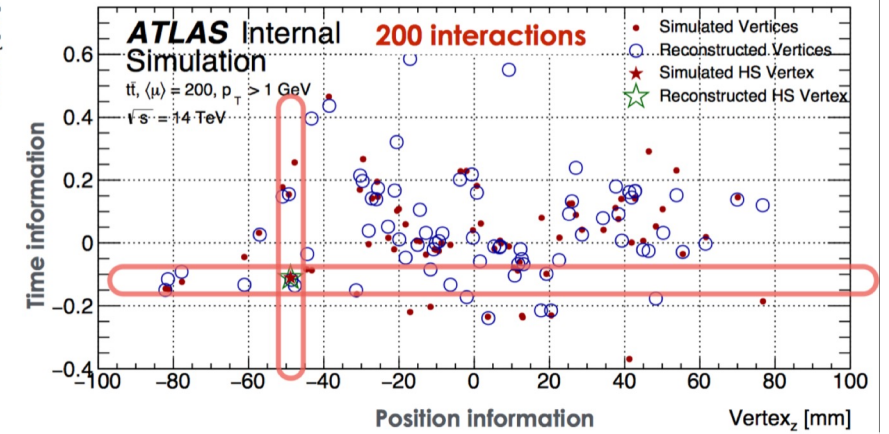
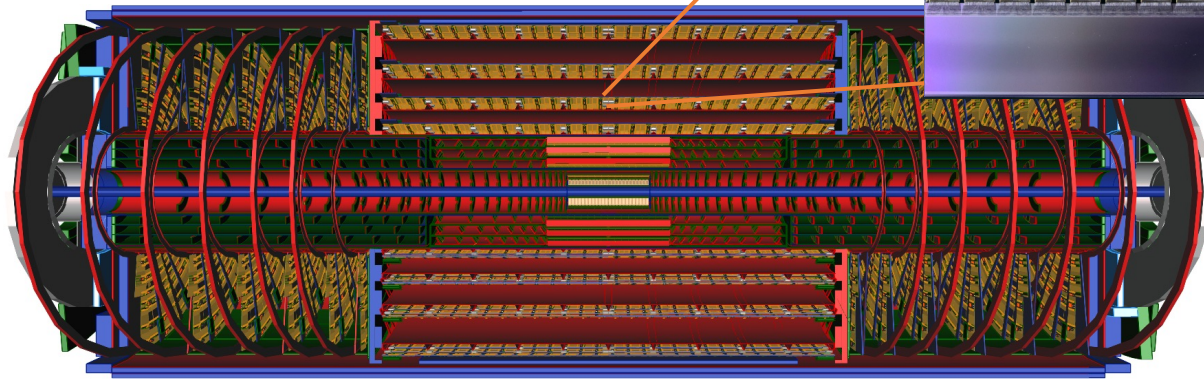
16 October 2026

The 2026 International Conference on Instrumentation
for Colliding Beam Physics (INSTR 2026)

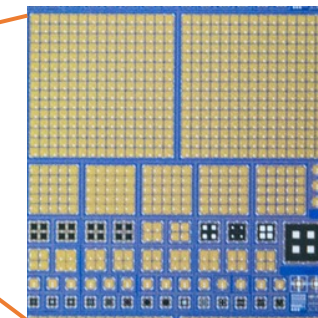
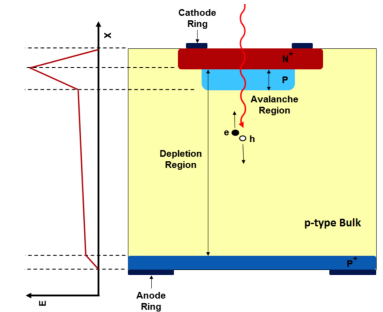
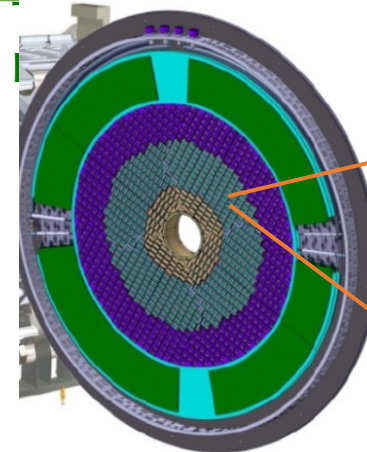
ATLAS Detector Upgrade – Silicon



Inner Tracker



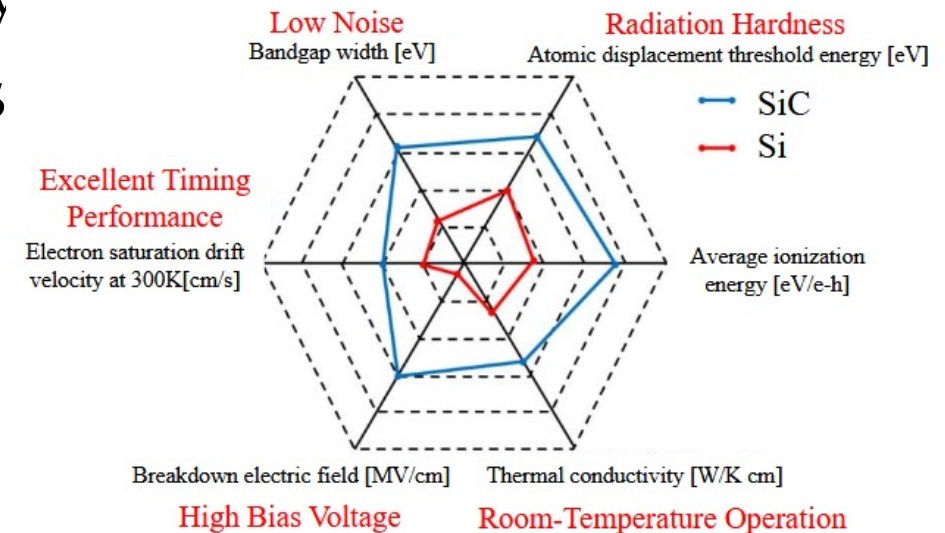
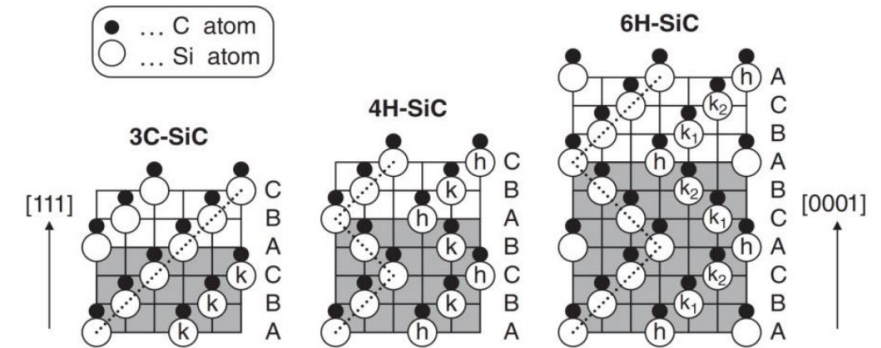
High Granularity



Silicon Limitations vs. SiC Advantages

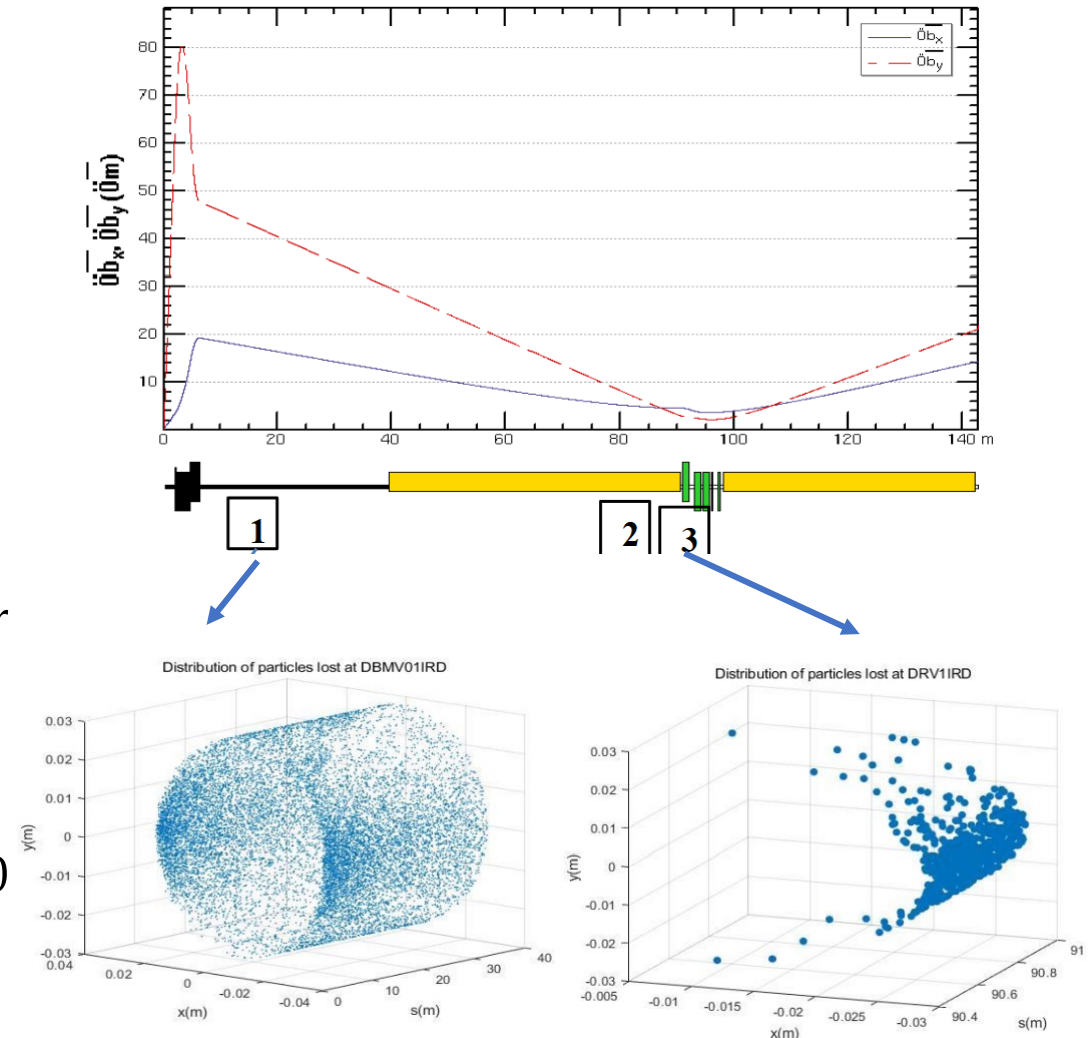
- **Conventional silicon detectors:** severe degradation in high-temperature, mixed-field environments
- **SiC (Silicon Carbide) solution:**
 - Wide bandgap → low leakage current
 - Superior radiation hardness → long-term stability
- Enables reliable operation where silicon fails
- SiC advantages:
 - Low noise, radiation hard, excellent timing,
 - High Bias Voltage, high-temperature operation

SiC Polytype



SiC for CEPC Fast Luminosity Monitor

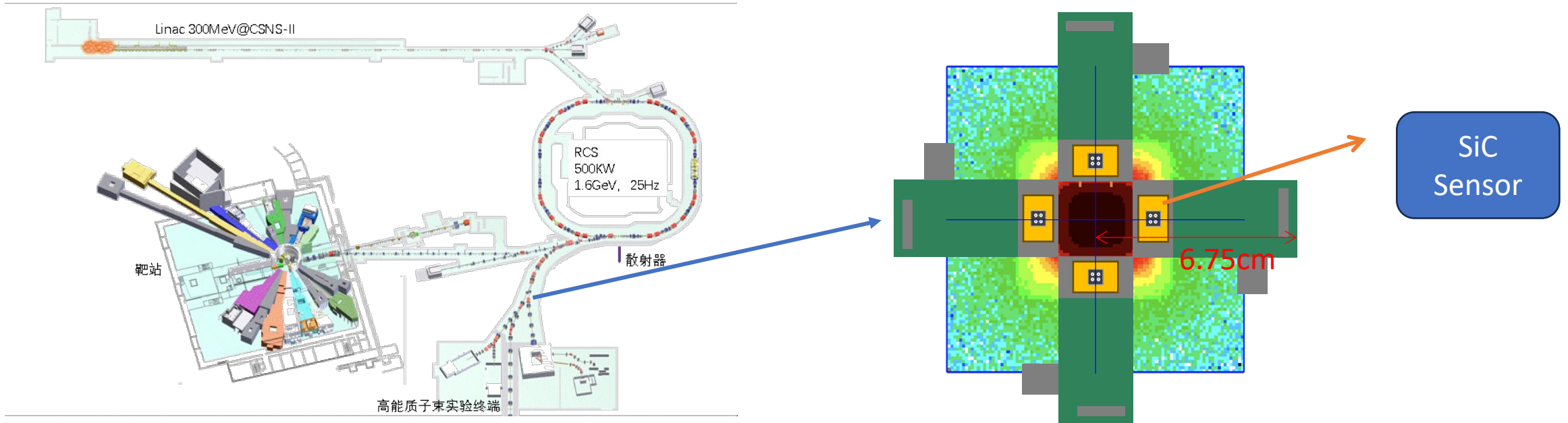
- CEPC MDI — Fast Luminosity Detector
 - Detects small-angle Bhabha showers to track horizontal IP offsets
 - Realize the real-time luminosity feedback and monitor the collision quality and efficiency
 - Employ the radiation-hard detector to ensure long-term stable operation
- SiC listed in the CEPC TDR as a fast luminosity detector
 - The FLM is positioned at two locations, 10 m and 90.5 m away from the IP
 - Precision requirement: $\nu \leq 2\%$ @1kHz
 - Number of detected Bhabha electrons $N_d \geq 2500$



<https://doi.org/10.1007/s41605-024-00491-8>

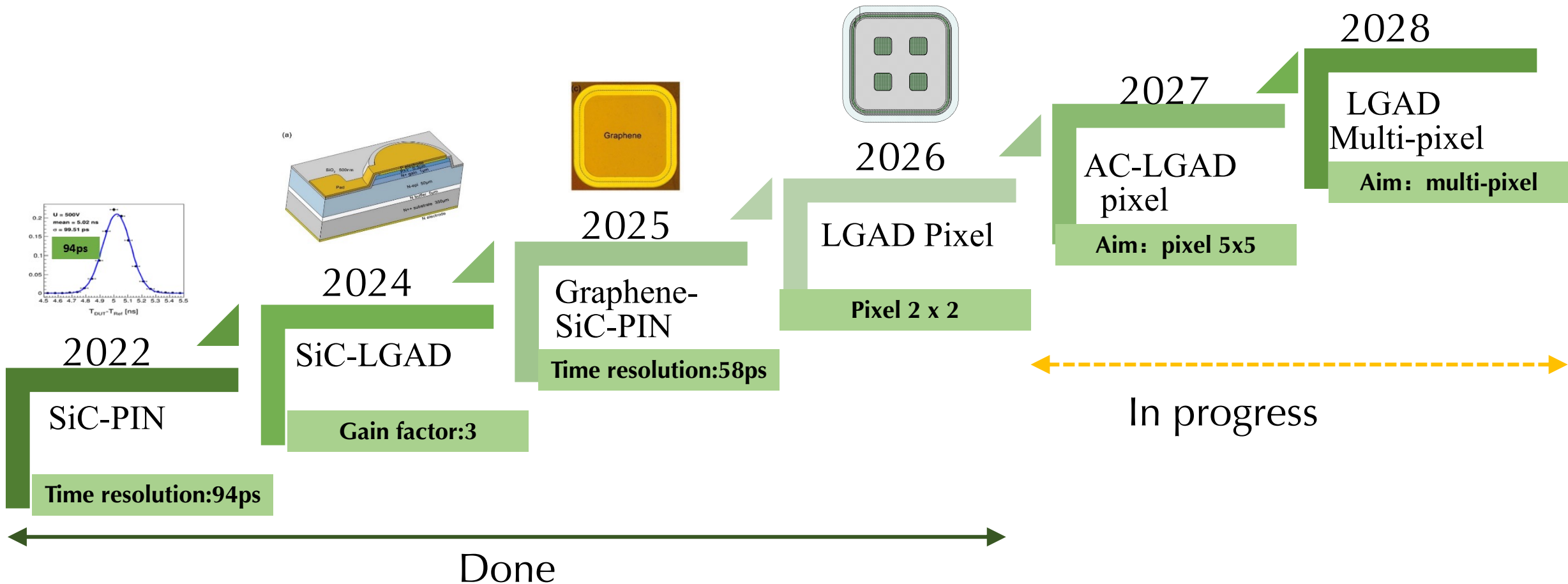
SiC for BMOS in CSNS-II Upgrade

- High Energy Proton Experimental Station (HPES)
- China's first 1.6 GeV proton source
- A beam monitoring system to detect the proton flux
- Using SiC as the beam monitor system (BMOS)

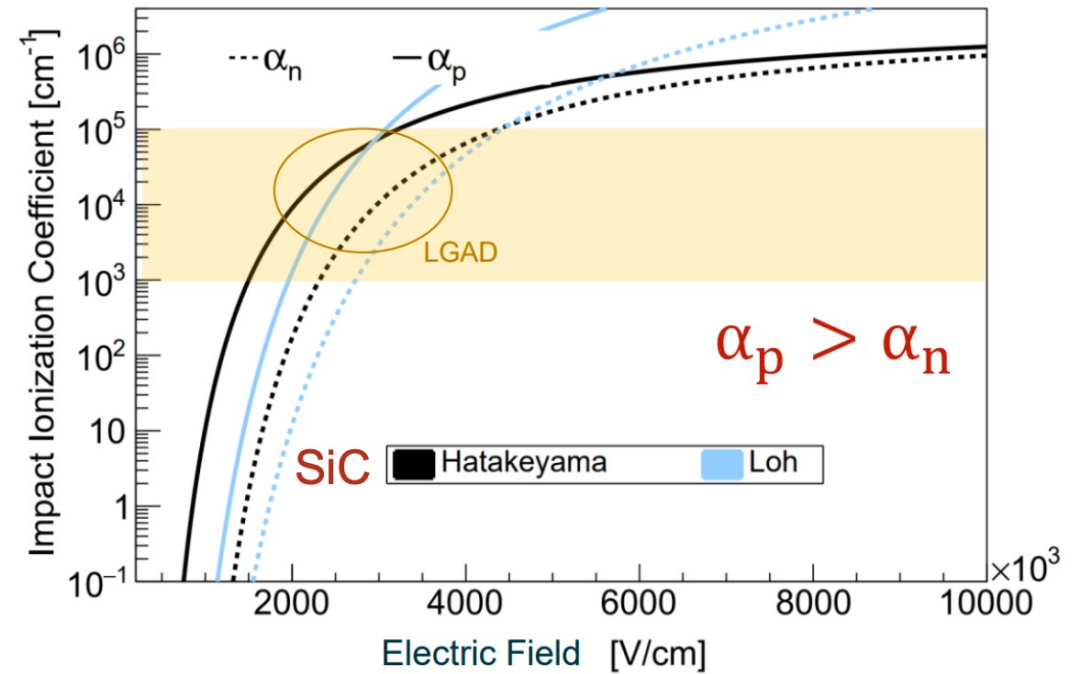
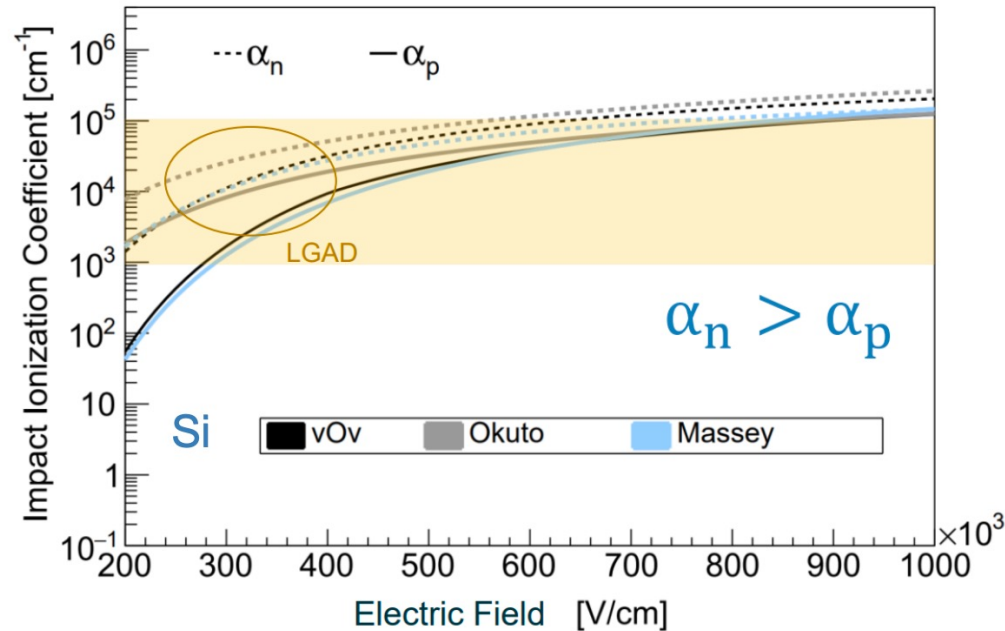


SiC development timeline by IHEP

- Systematically advancing device development and optimize performance



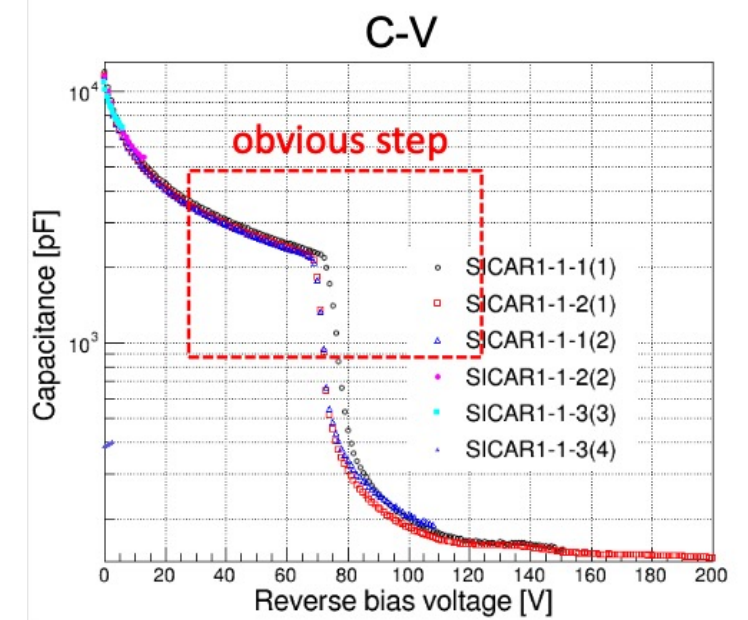
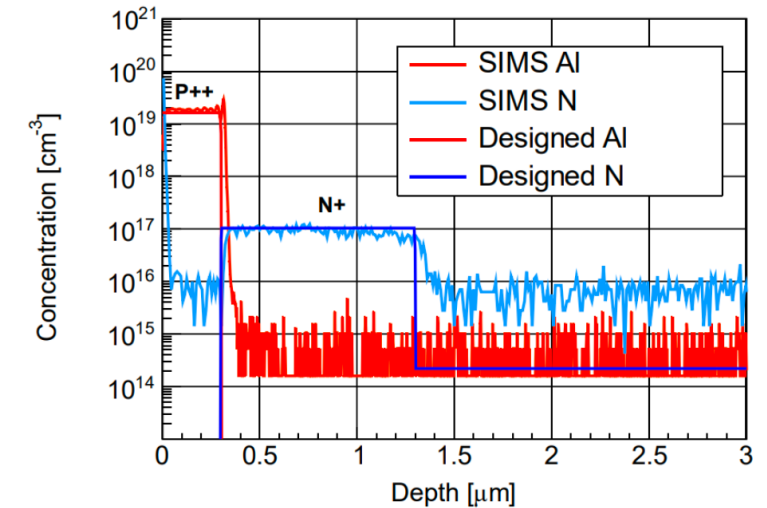
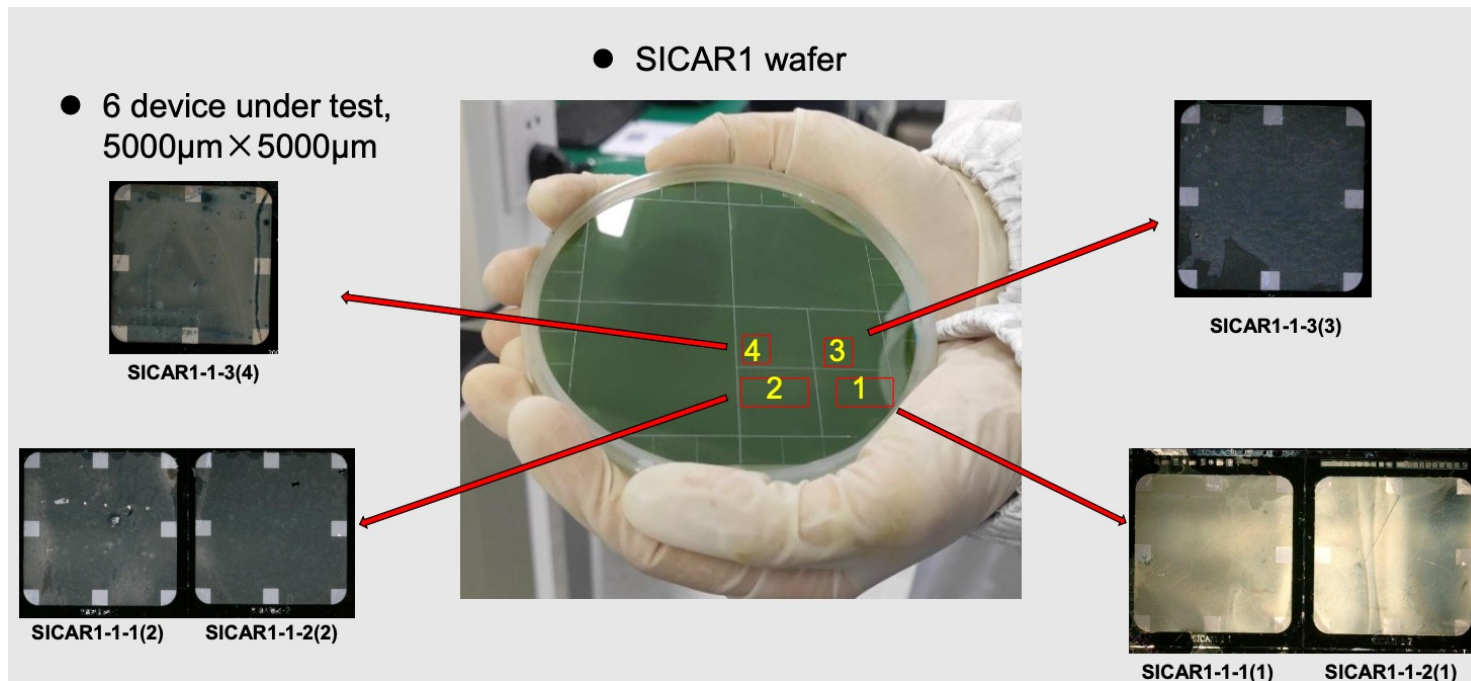
4H-SiC LGAD – Impact Ionization Coefficient



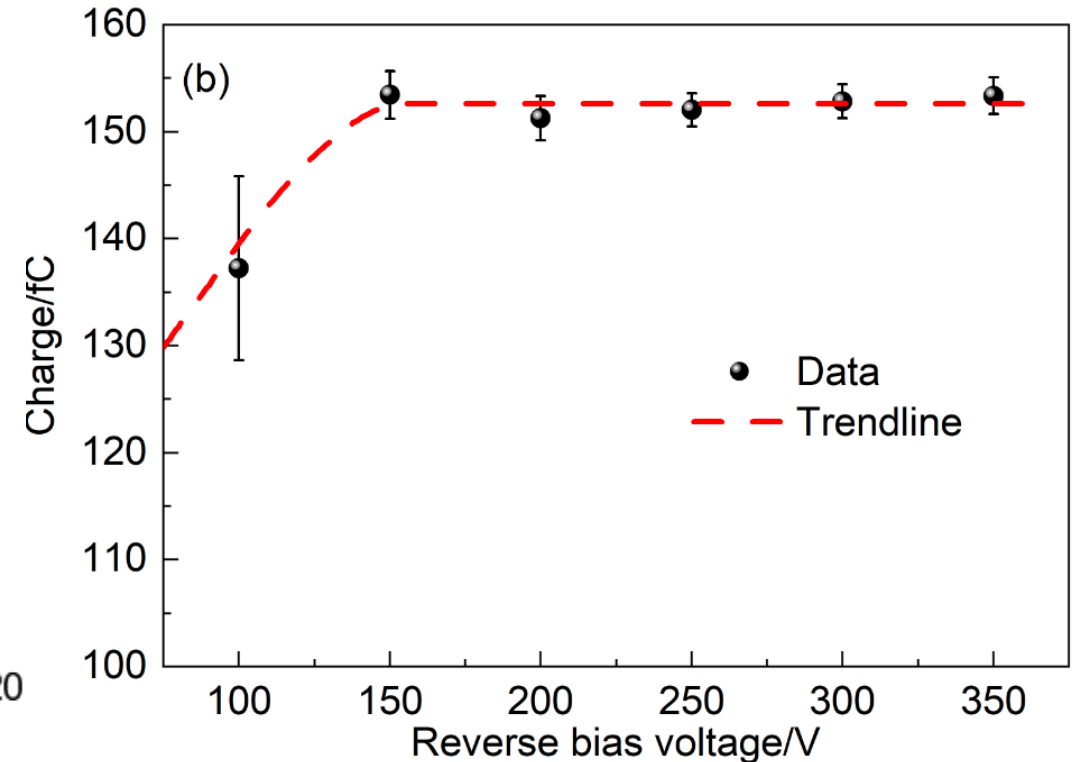
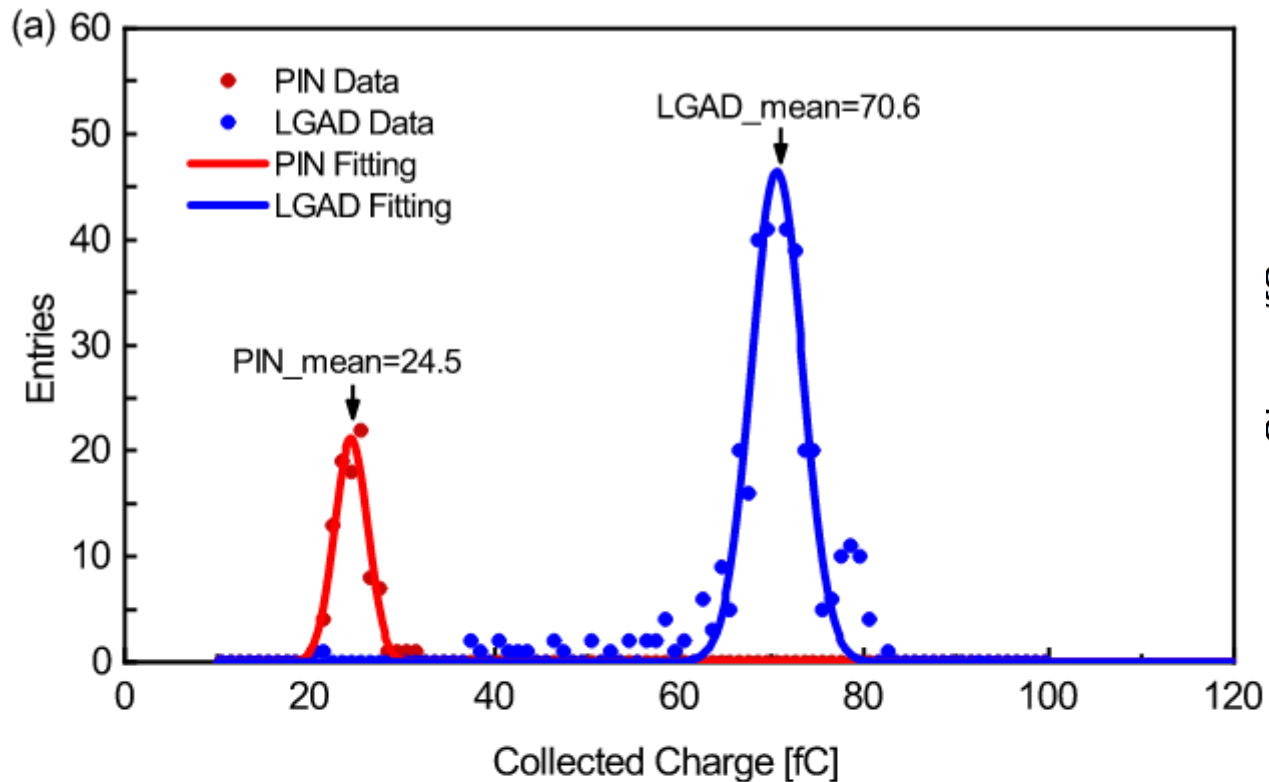
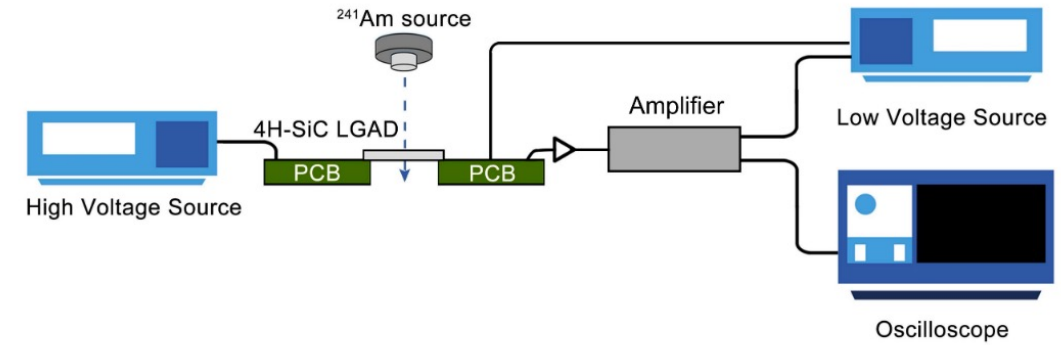
- Si LGAD: electron dominant avalanche P-type, electrical field strength 0.3 MV/cm
- 4H-SiC LGAD : hole dominant avalanche N-type, electrical field strength **2**MV/cm

SICAR1 – 4-inch wafer (2023)

- The first version indicates the gain layer structure



SICAR1 – α particle test



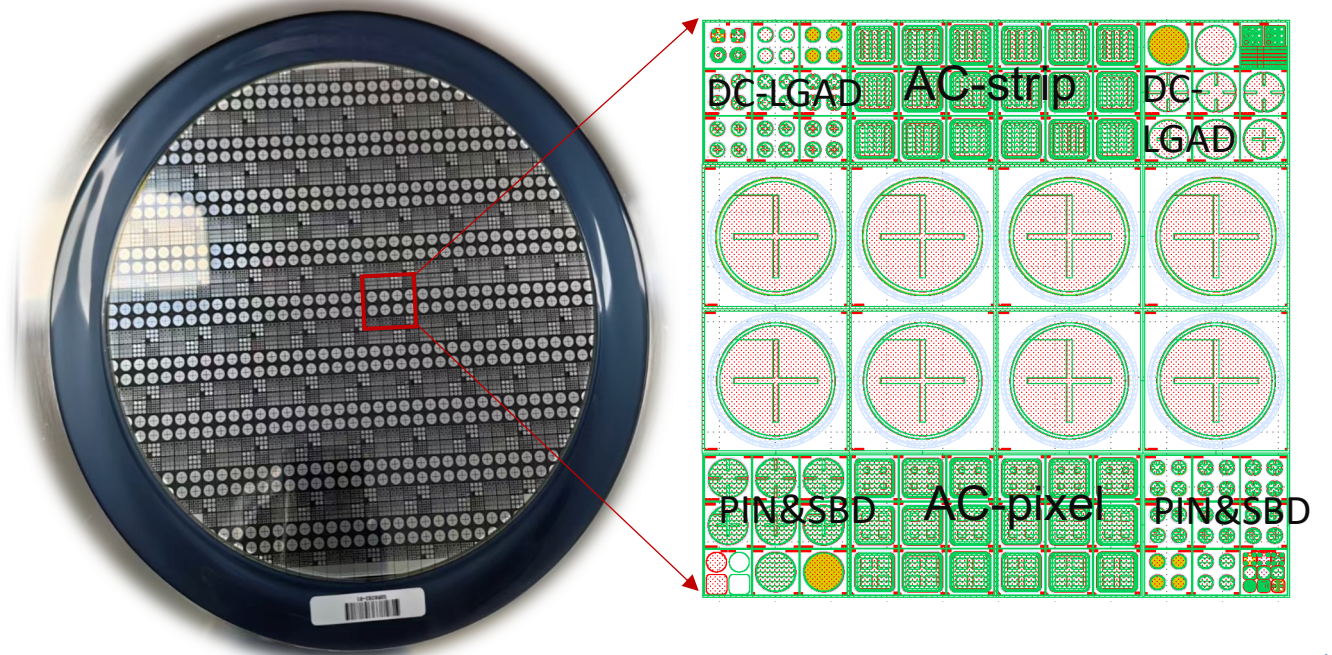
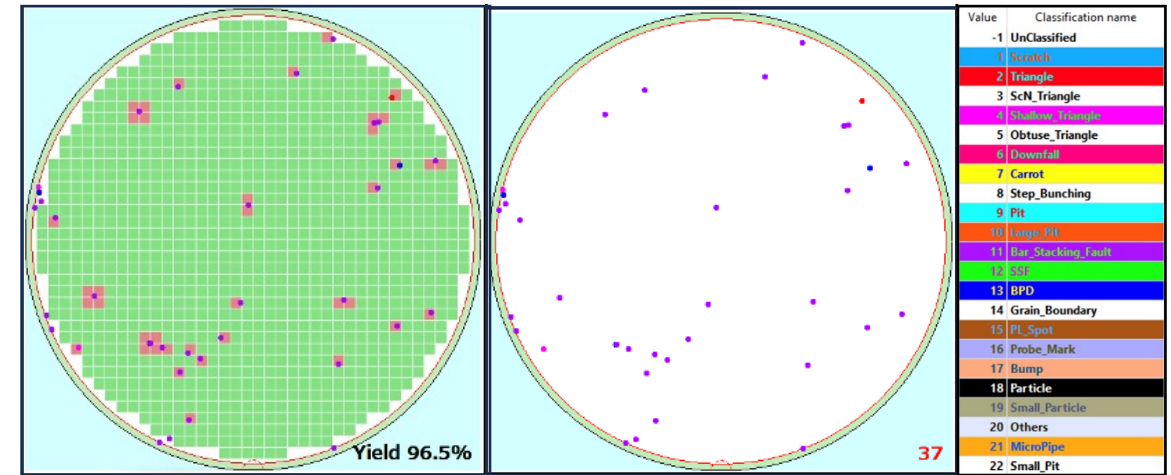
- Large charge collection compared with SiC PIN device

- Collected charge reached plateau 150V~ 350V

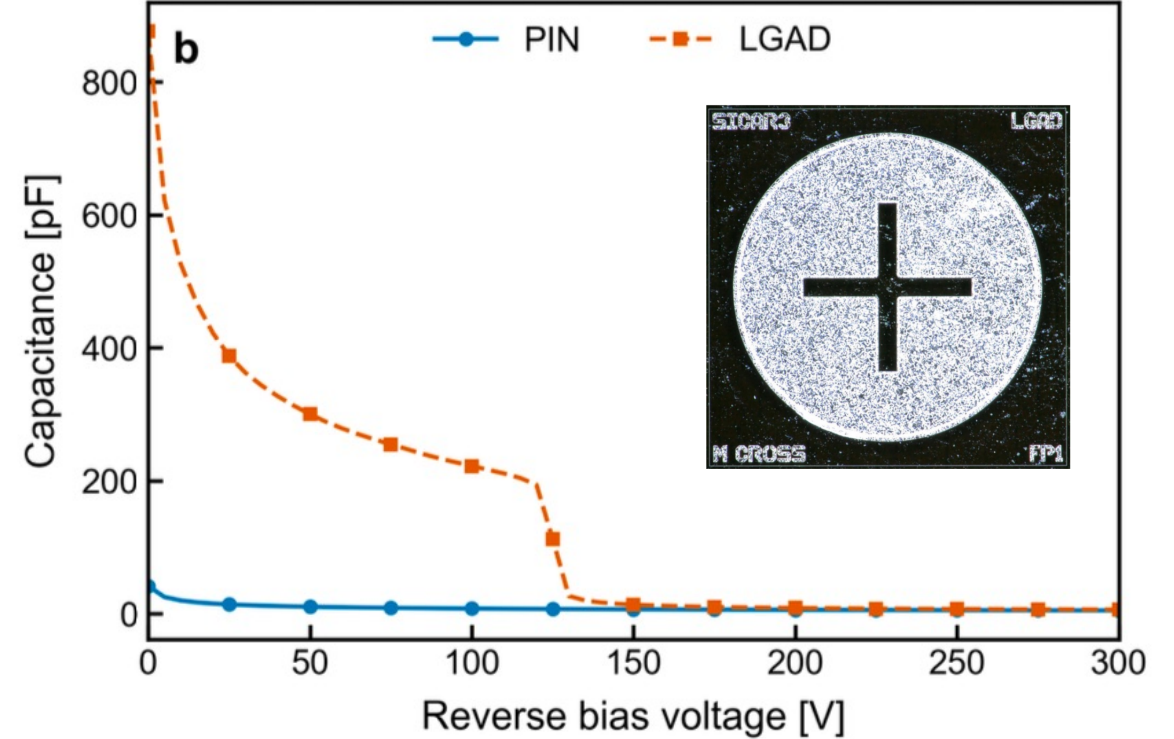
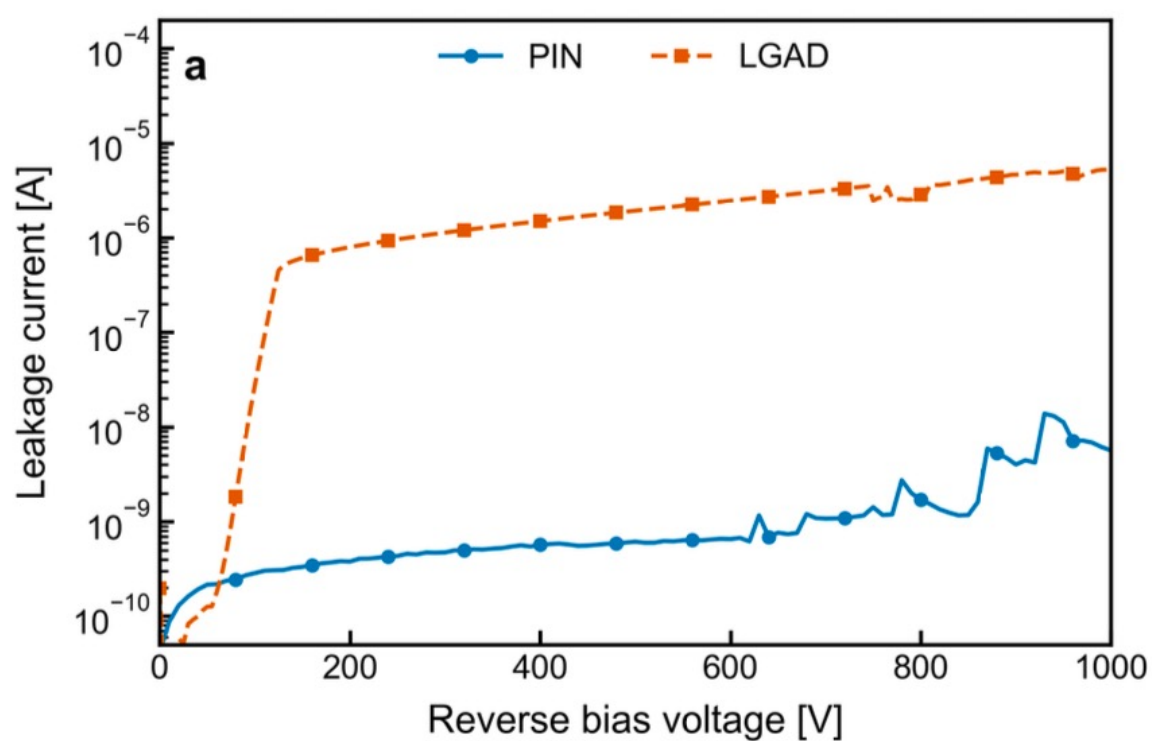
IEEE VOL. 71, NO. 11, 2024

SICAR3 - 8-inch wafer (2026)

- 8-inch epi wafer
 - 96.5% yield
 - Dominant defect: bar stacking faults
 - Reticle size: 2.2cm X 2.2 cm²
- Device fabrication completed
 - PIN: diameter ~1.4/ 0.5mm
 - Schottky Barrier Diode (SBD): diameter ~0.5mm;
 - LGAD: d ~ 1.4/ 0.5mm;
 - LGAD: AC-pixel/strip



SICAR3 IV & CV Test

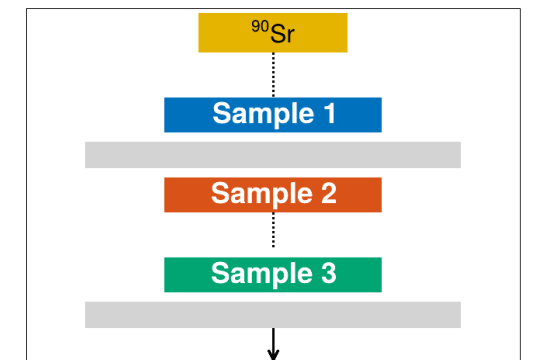
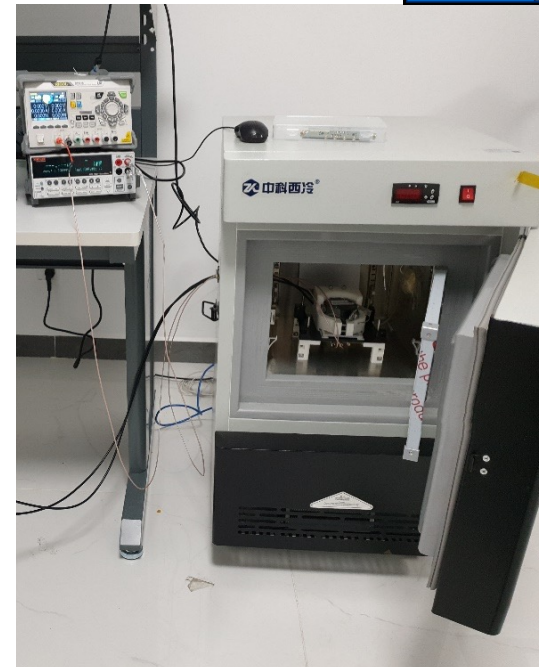
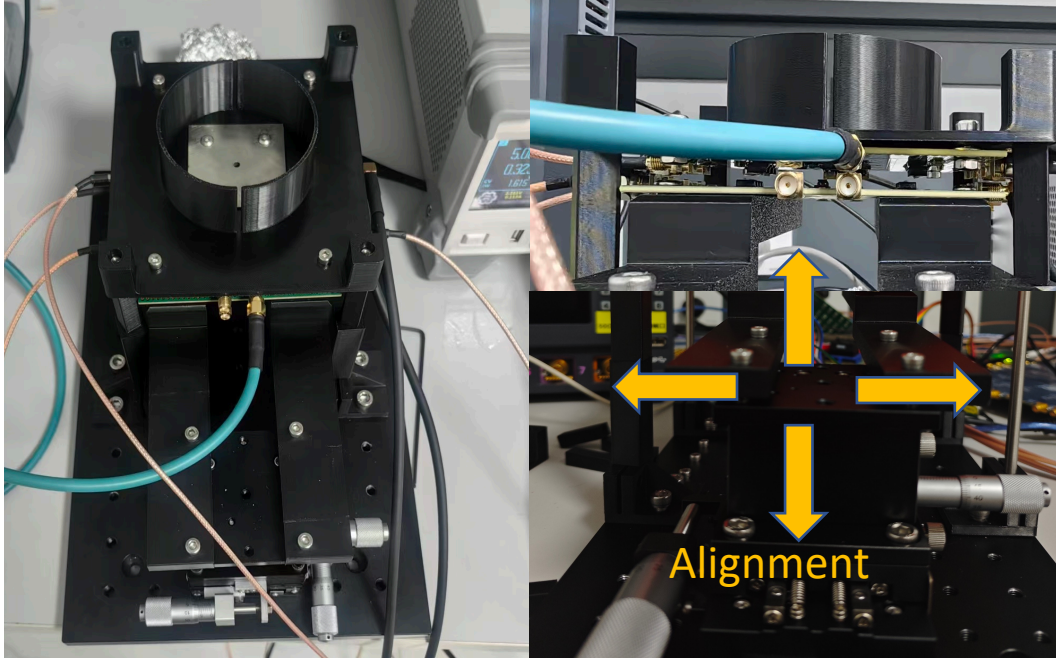
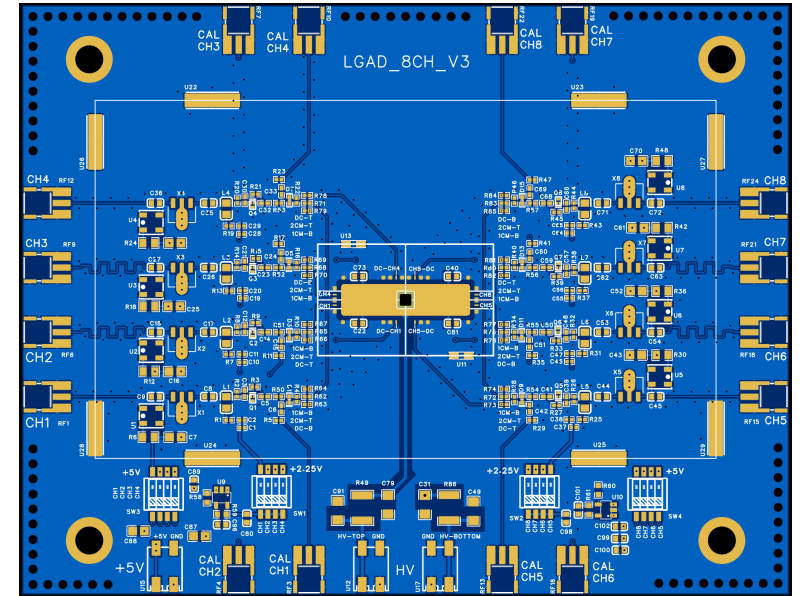


- Achieved ultra-low leakage current (<1 nA @ 1000V) in PIN diode
- Leakage current reaches ~ 1 μ A at 1000V in LGAD

- Gain layer depletion voltage: ~ 130 V
- Fully depleted capacitance: 3.8pF ($d \sim 1.4$ mm)
- Full depletion voltage ~ 900 V of LGAD
- Full depletion voltage ~ 1000 V of PIN

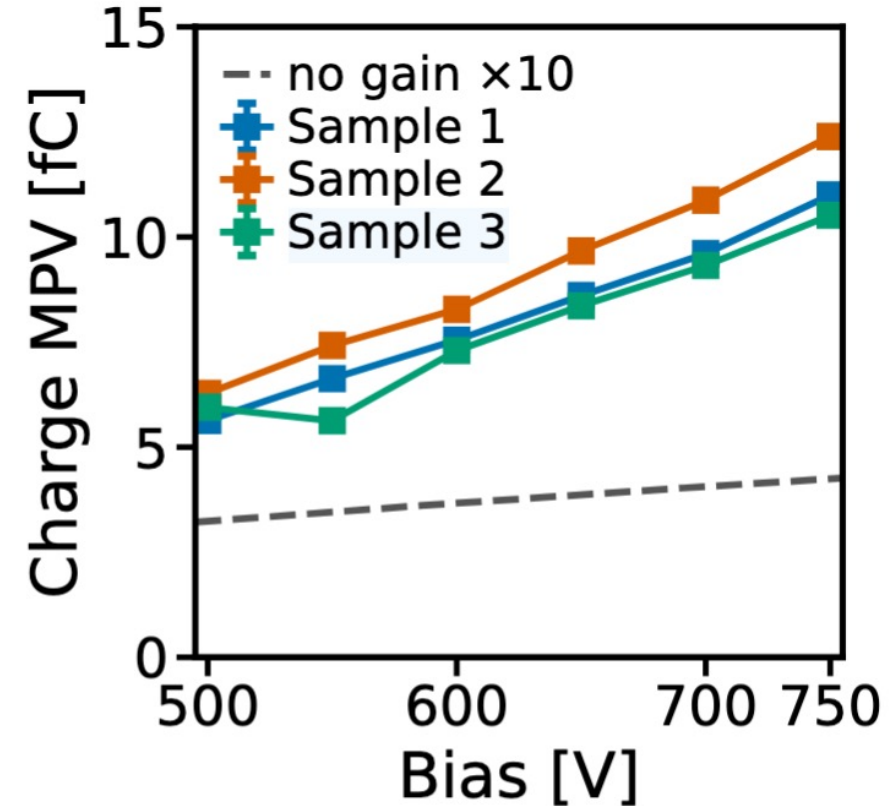
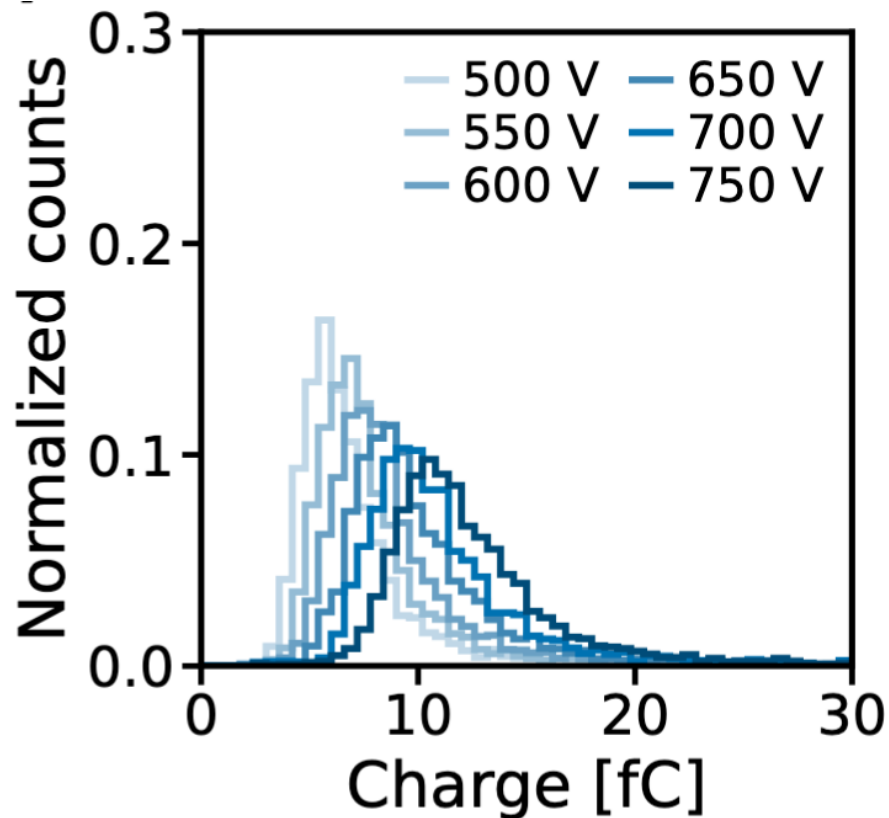
Test board and Test setup

- 8-Channel LGAD Pre-Amplifier Board:
 - Provides high-voltage bias for SiC sensors
 - 8 signal readout channels
 - TIA ($10 \times$) + Voltage Amp ($10 \times$) $\sim 100\times$ amplification per channel
- Coincidence Test System :
 - Movement of the three-axis stage (X, Y, Z)

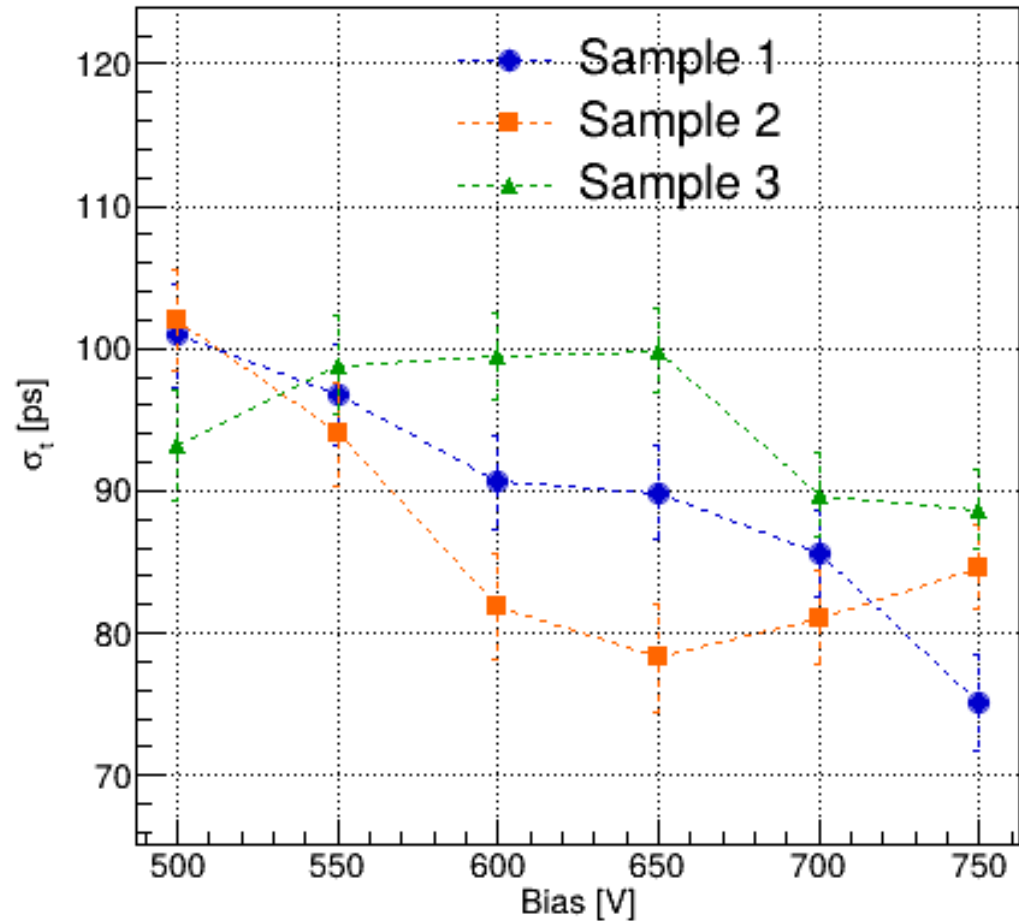
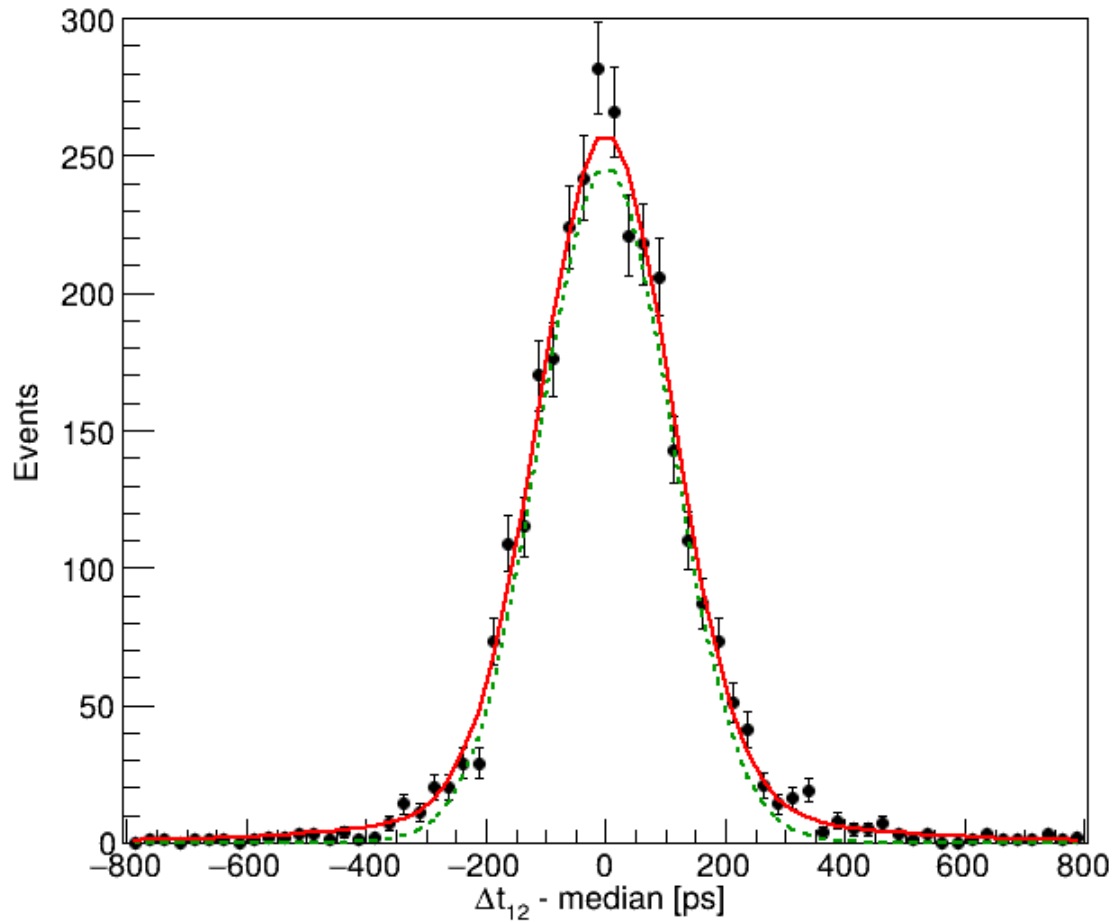


Charge collection measurement with beta source

- Signal amplitude increases with bias voltage;
- Charge collection reaches $\sim 12\times$ that of the PIN @ 750V



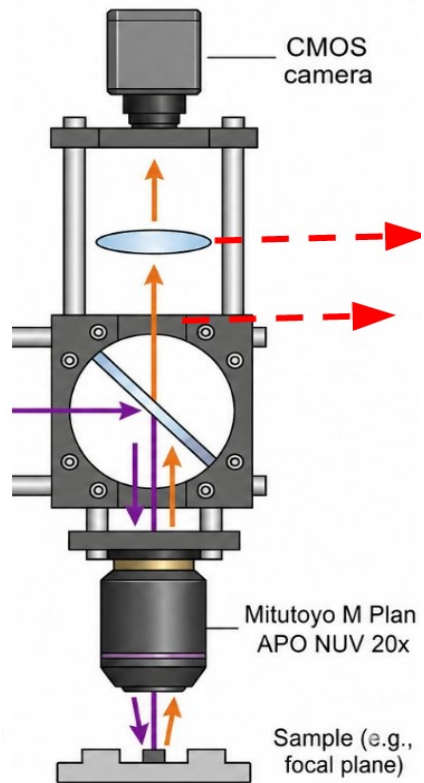
Time resolution with beta source



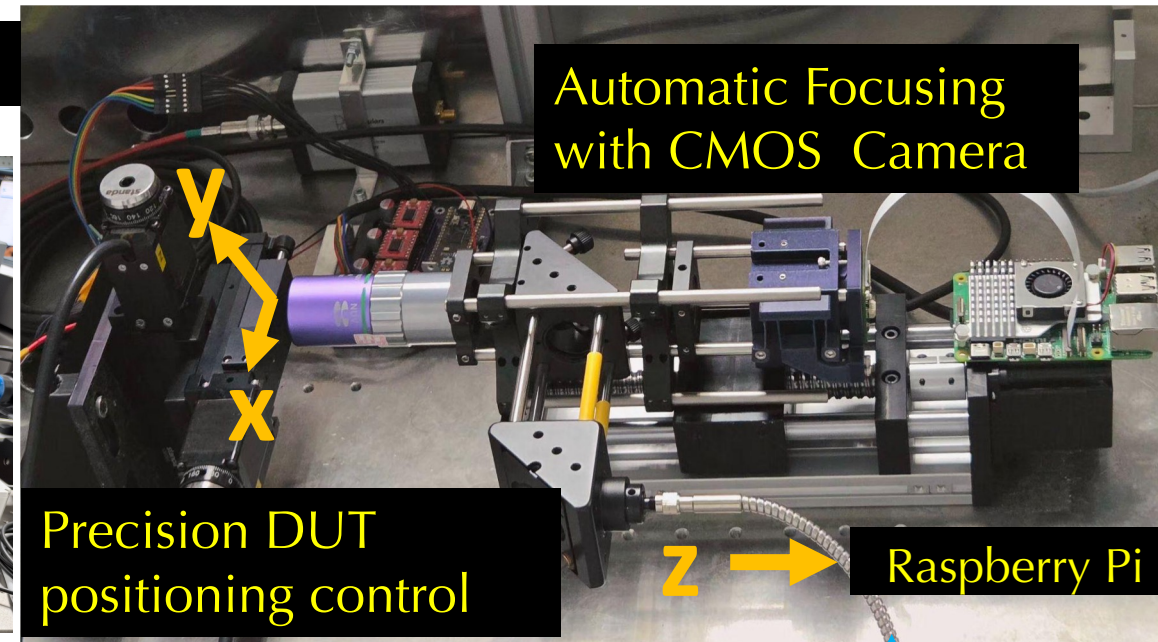
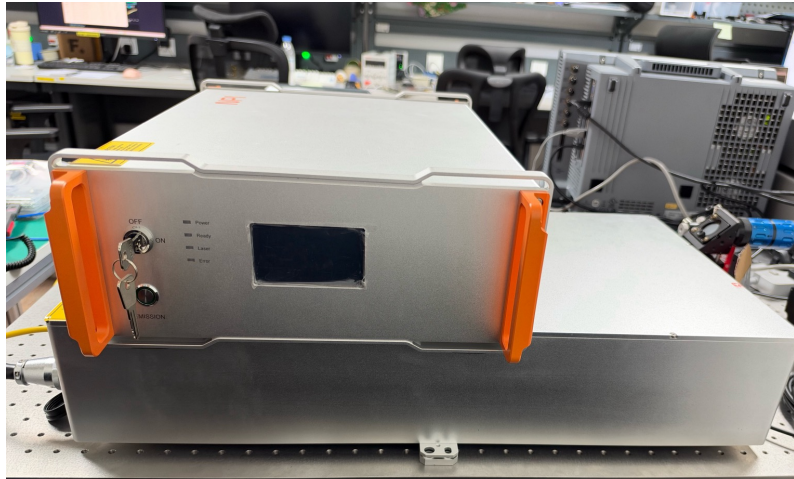
- Time resolution ~ 75 ps ($d \sim 1.4$ mm) @ 750V

Laser setup in progress

- Setup TPA-TCT (two-photon-absorption transient current technique)
- Explore spatial resolution for AC-pixel devices



- 515 nm (<200fs) laser



Summary and Plan

- Silicon Carbide is a promising material for future collider experiments
 - Low noise, high-temperature operation, radiation hard, excellent timing ...
- SICAR3 received in May 2026
 - LGAD demonstrates $12\times$ gain over PIN
 - Timing resolution could reach ~ 75 ps for pad structure (~ 1.4 mm)
- Plan
 - Setting up the TCT/ TPA system
 - Investigate spatial resolution for SiC pixel devices
 - Radiation effects and degradation mechanisms in LGAD devices