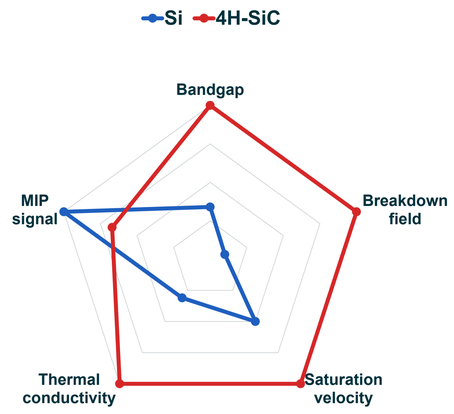
Ultra-Fast 4H-SiC LGADs for 4D Tracking

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Why Silicon Carbide

- 4H-SiC offers **low leakage current**, **fast carrier saturation drift** and **excellent thermal stability** for future collider detectors
- A MIP deposits only **~2/3 the charge** of Si, so fast SiC timing sensors need **internal gain**



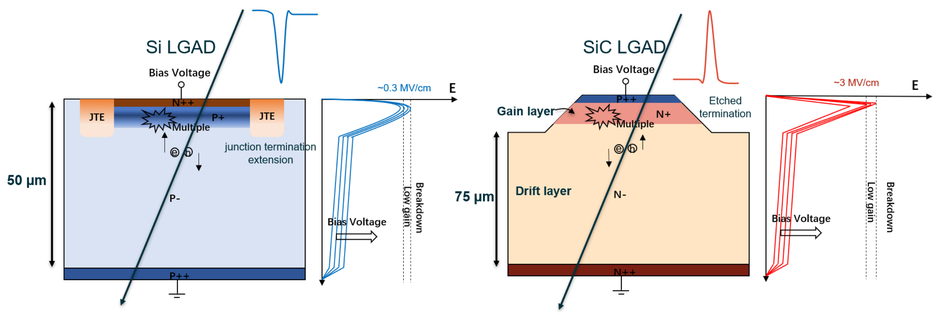
Why Silicon Carbide LGAD

- SiC's small MIP signal limits PiN timing to **~100 ps**; a **gain layer** amplifies the signal for fast single-MIP detection
- 4H-SiC LGADs keep LGAD timing while adding **higher voltage tolerance**, **faster drift** and **low leakage**

Si LGAD vs. 4H-SiC LGAD: structure, multiplication and electric-field profile

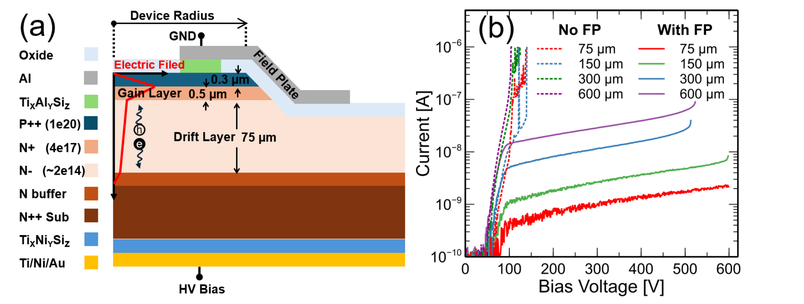
- 50 µm P-type (~1e13 cm^{-3}) drift layer
- Primary electrons multiplication, hole drifting
- Ion implantation for gain layer and JTE
- Electric field: ~0.3 MV/cm
- Gain layer doping: ~1e16 cm^{-3}

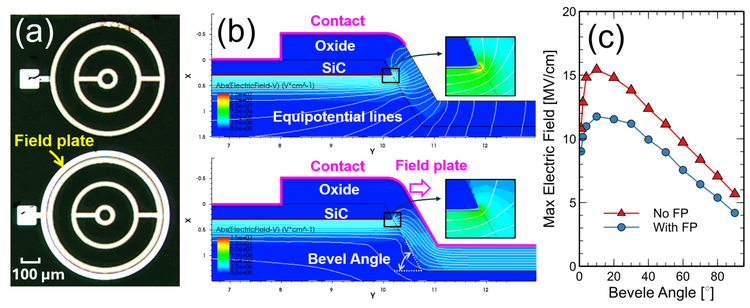
- 75 µm N-type drift layer(~2e14 cm^{-3})
- Primary holes multiplication, electron drifting
- Epitaxial stack with etched termination (or ion implantation)
- Electric field: ~ 3 MV/cm
- Gain layer doping: > 2e17 cm^{-3}



Sensor Design

- 0.5 µm N$^+$ gain layer on 75 µm N$^-$ drift, 300 µm diameter
- Isolated devices by etching terminations .
- **Field plate** suppress edge breakdown

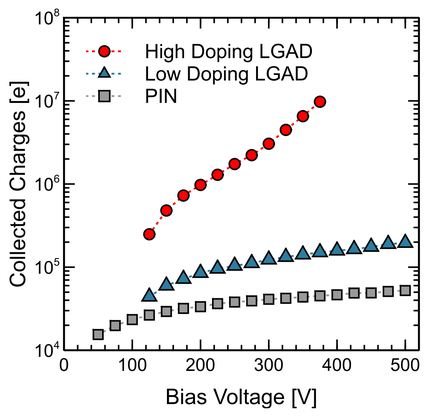




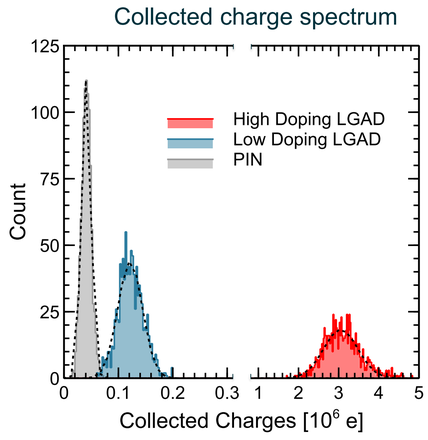
Impact of Gain Layer Doping

- Two LGADs identical except gain-layer doping, **4×10^{17}** vs **5×10^{17} cm^{-3}**, plus a PIN from the same wafer
- **25% more doping gives ~100× more gain** at the same bias; gain spans 3.7 to 216
- UV-TCT timing is best at **gain 20–80**: noise jitter falls with gain until multiplication shot noise dominates

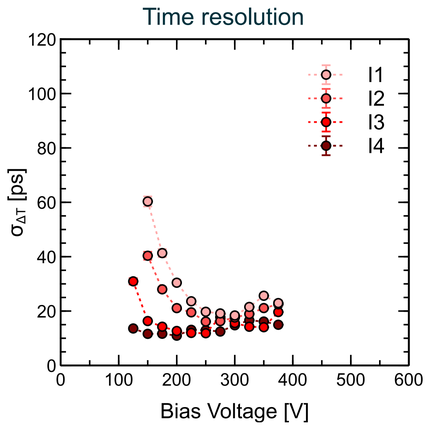
Collected charge vs. bias voltage



Collected charge spectrum



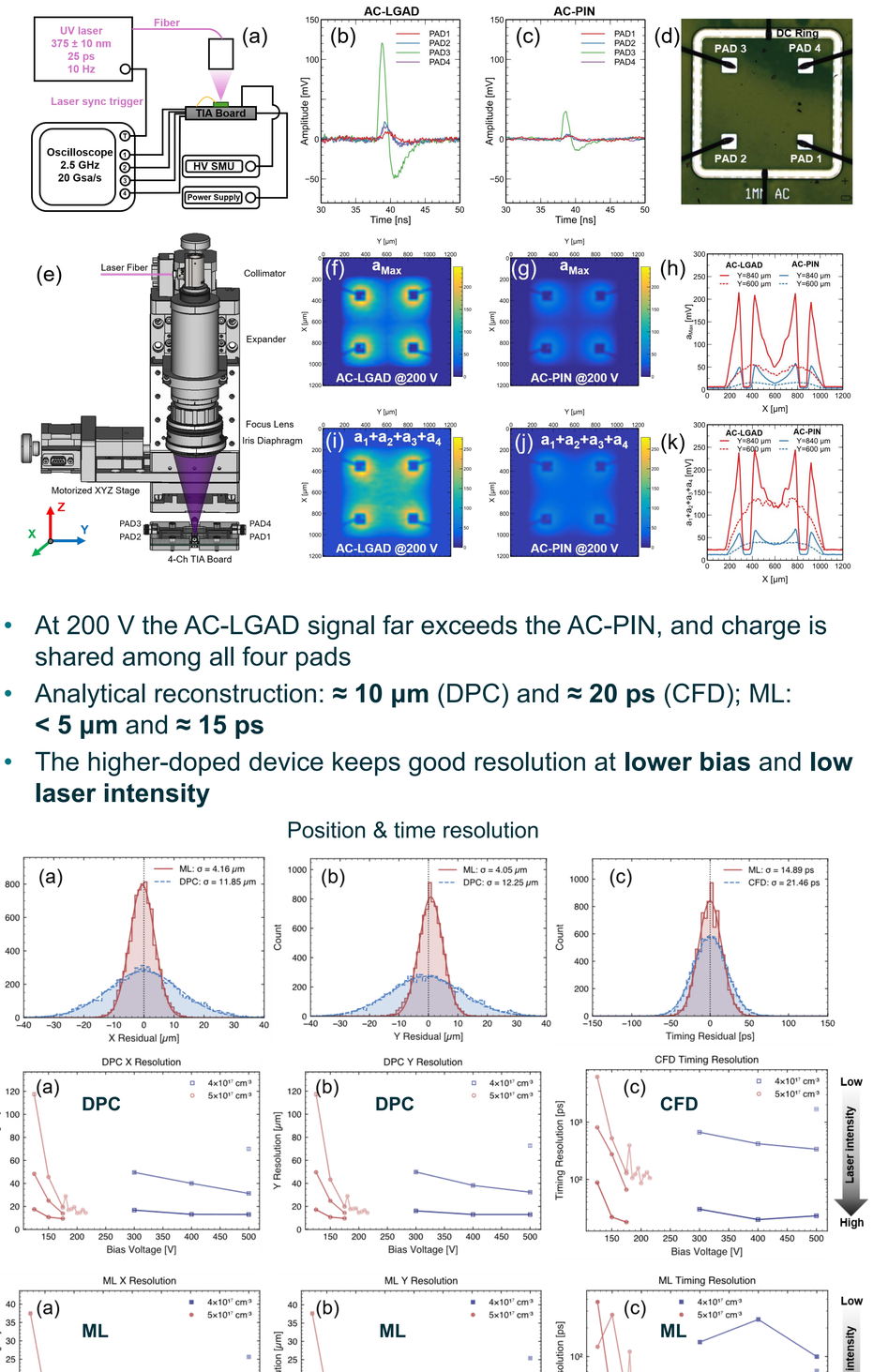
Time resolution



Test Setup & Sensor Performance

- **UV-TCT:** 375 nm, 25 ps laser focused to a ~50 µm spot; XYZ scans with a 4-channel TIA board and 2.5 GHz scope
- **4H-SiC AC-LGAD:** 1.0 × 1.0 mm^2 area, 2 × 2 AC pads at 500 µm pitch

UV-TCT test setup

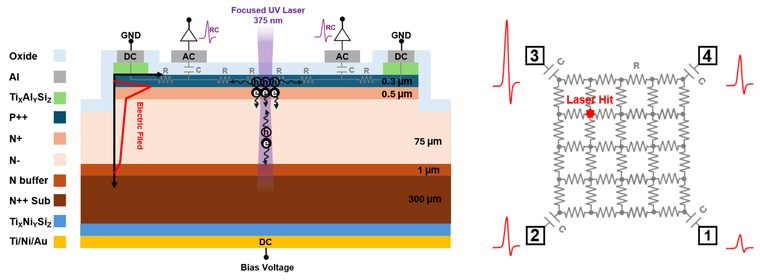


- At 200 V the AC-LGAD signal far exceeds the AC-PIN, and charge is shared among all four pads
- Analytical reconstruction: **≈ 10 µm** (DPC) and **≈ 20 ps** (CFD); ML: **< 5 µm** and **≈ 15 ps**
- The higher-doped device keeps good resolution at **lower bias** and **low laser intensity**

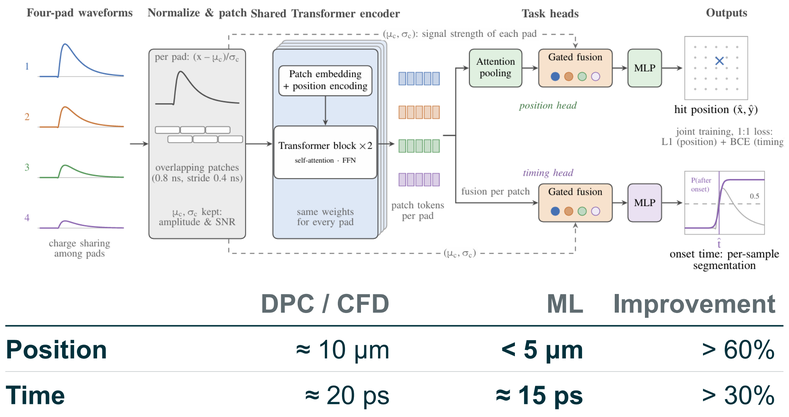
Position & time resolution

4D Tracking Reconstruction

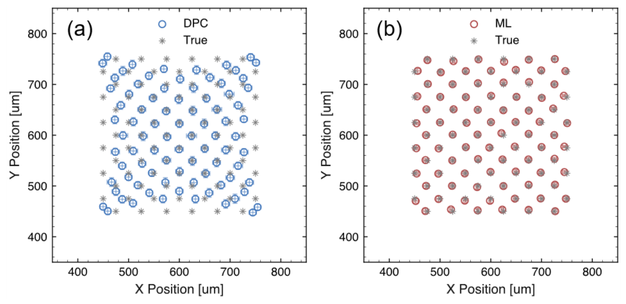
- Hit position from charge sharing among the four pads



- **DPC** (discretized positioning circuit): hit (x, y) from pad amplitude ratios
- **CFD** (constant fraction discrimination): pad times at a fixed fraction of peak
- **ML** (machine learning): a transformer reads all four waveforms

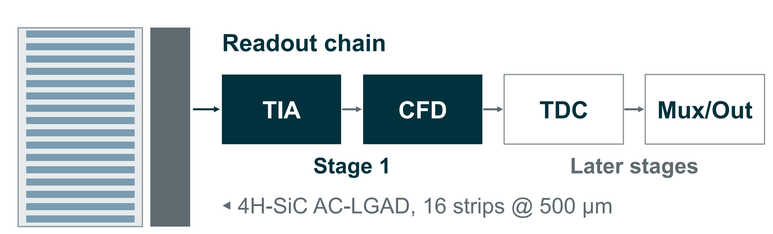


	DPC / CFD	ML	Improvement
Position	≈ 10 µm	**< 5 µm**	> 60%
Time	≈ 20 ps	**≈ 15 ps**	> 30%



Next: Large Scale Strip 4H-SiC LGAD

- **AC-coupled strip sensor:** 5 × 8 mm², 5 mm strips at 0.5–1 mm pitch (8–16 channels)
- **Front-end readout** beside the sensor, toward a cooling-free timing layer.



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