Second-Generation Fermilab CFD Readout ASIC for LGAD sensors

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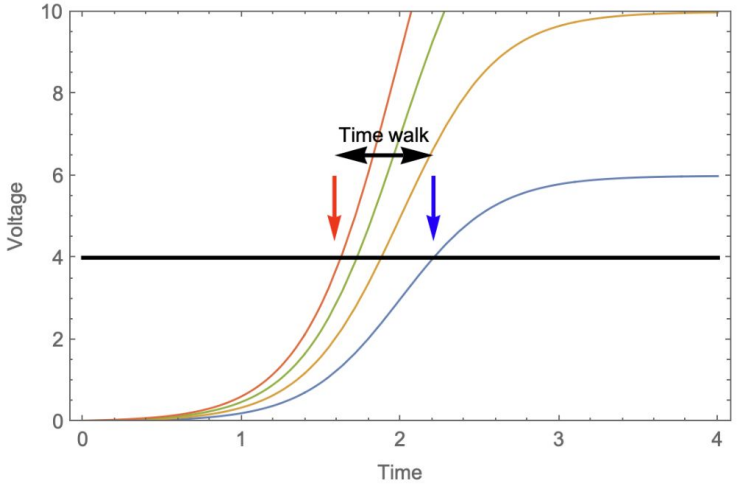
Hardware-enabled CFD Readout for Timing Detectors

- Time-walk effect is well known & must be corrected for best performance
- Conventionally addressed with online or offline corrections via some type of LUT
- But under harsh radiation environments of future colliders, corrections may be time-dependent and messy!



- We propose a **<u>hardware-enabled correction</u>** via CFD built into the readout ASIC design

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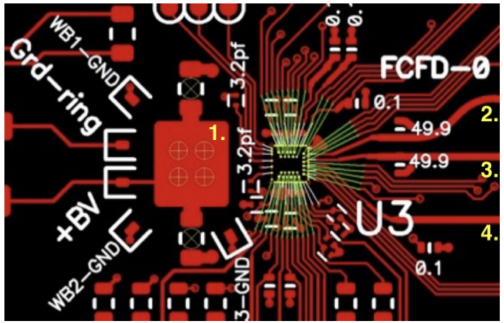
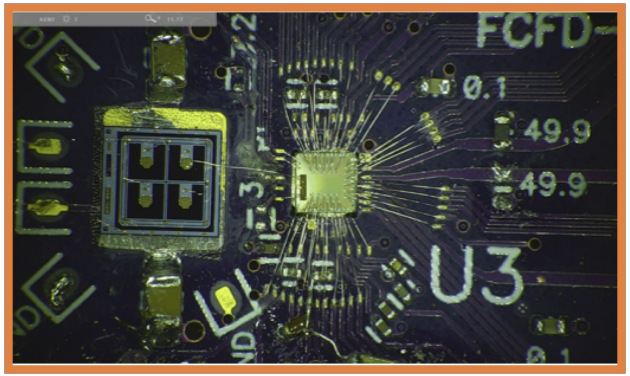
Fermilab CFD (FCFD) Chip

- Primary application is (AC-)LGAD sensors for MIP signals
  - But can be used for many types of precision timing detectors
- Previous version of the FCFD chip and performance presented at CPAD 2023 : https://indico.slac.stanford.edu/event/8288/contributions/7544/





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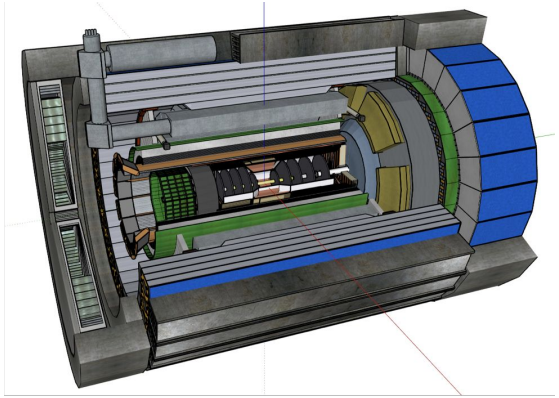
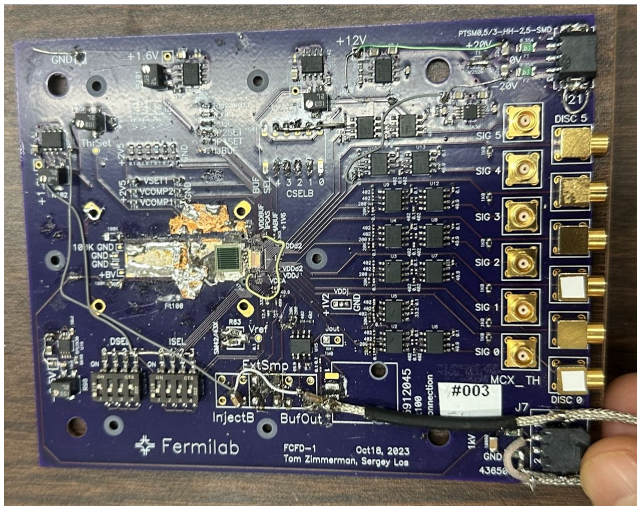
FCFD v1: 2nd-Gen ASIC

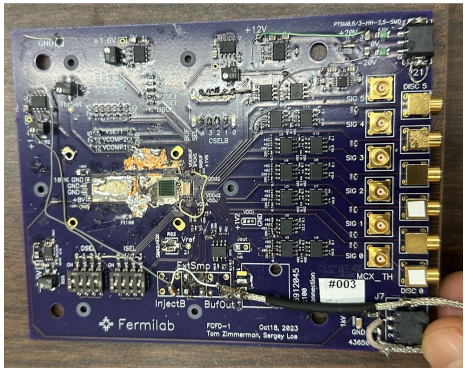
- New Features:
  - 6-channel readout
  - Design targets EIC TOF barrel detector AC-LGADs
    - 1cm long AC-LGAD, 500 μm pitch, 50 μm thickness
  - Wider dynamic range
  - Sensitivity to smaller signals
  - Additional signal amplitude readout for position measurement

Barrel TOF
AC-LGAD

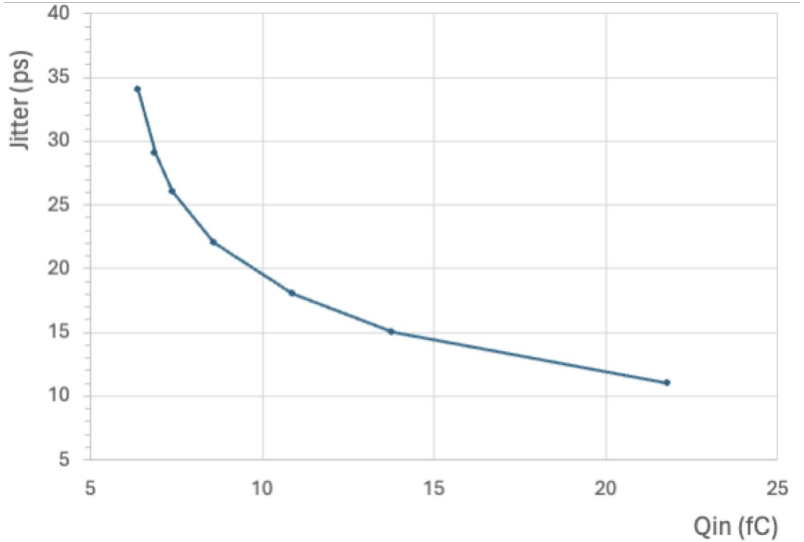




FCFD v1: Charge Injection Characterization



- Use internal LGAD-like signal charge injection mechanism (same as v0)
- Achieved 11 ps time resolution with input capacitance at 3.5 pF
- Analog output linear over range of input charge between 7-60 fC



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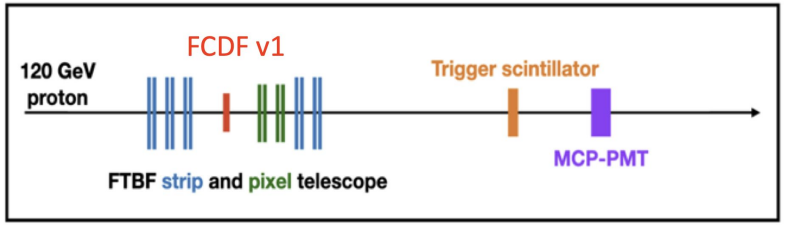
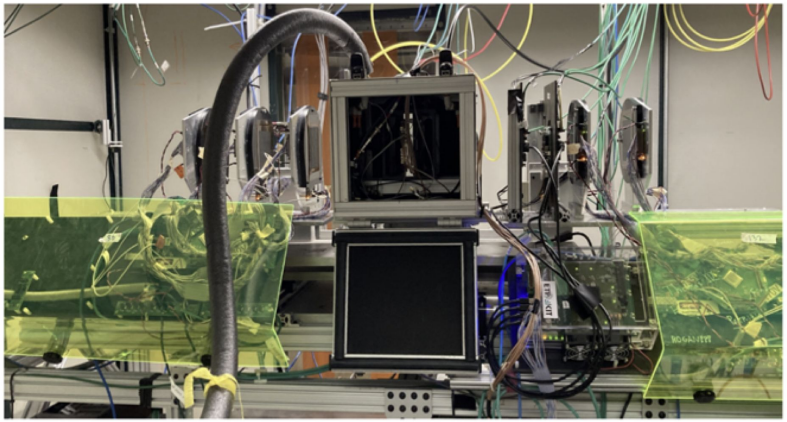
Fermilab Testbeam Facility Setup

- Use 120 GeV protons to characterize FCFDv1 in realistic operating conditions
- Tracking provided by 5 layers of strip silicon sensors and 2 layers of pixels
- Reference time measured by MCP-PMT (~10ps resolution)
- Maintain temperature at 20 C



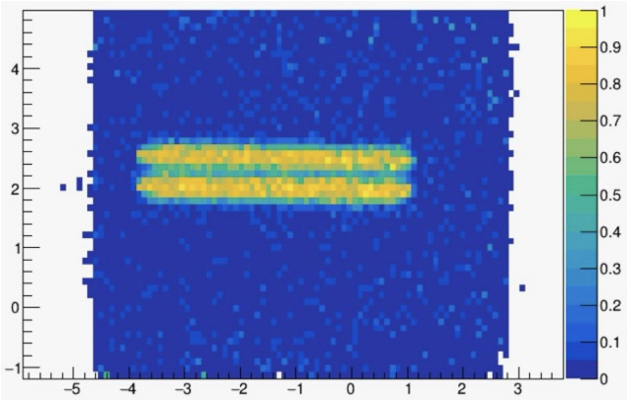


Beam Test Results

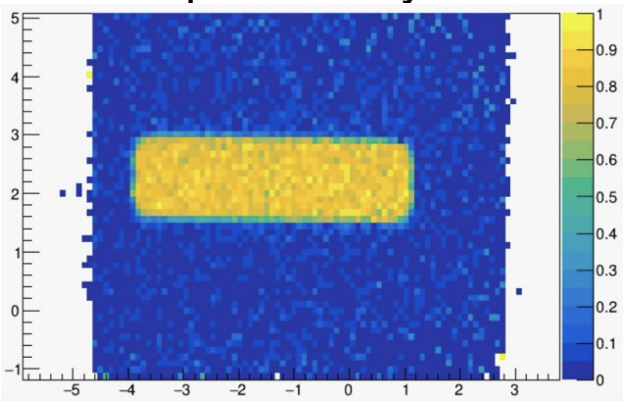
- Two-strip efficiency at 100%
- Initial noise levels were high
- Comparator misled by fake noise hits

- Temporary solution:
  - Added 7-pF capacitor in series to the AC-LGAD to mitigate noise (at cost of signal strength reduction)
- Also tested FCFDv1 with 2-pixel DC-LGAD to verify design performance specifications

Single -channel efficiency

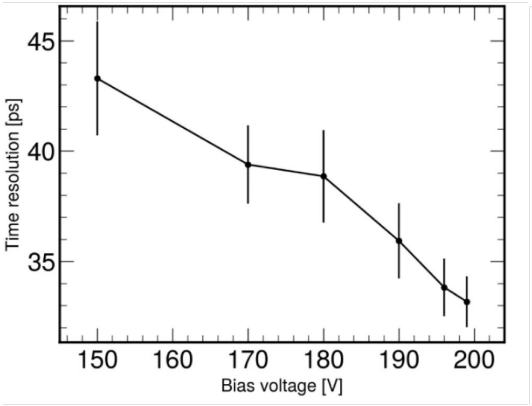


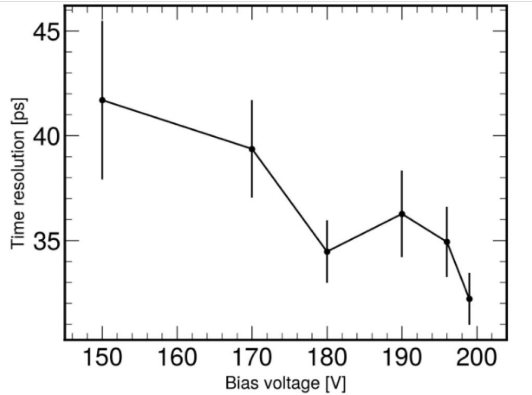
two-strip efficiency



Beam Test Results

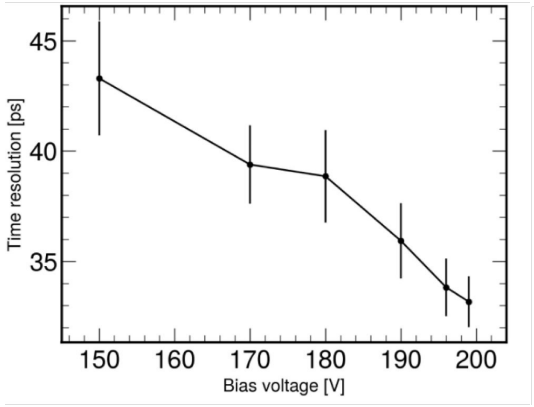
- Confirmed performance on DC-LGAD matches design specifications
  - Achieved 32 ps total resolution (for amplitude ~300mV)
  - No time-talk observed

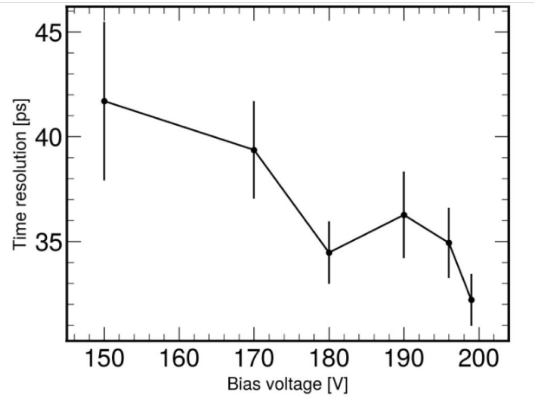


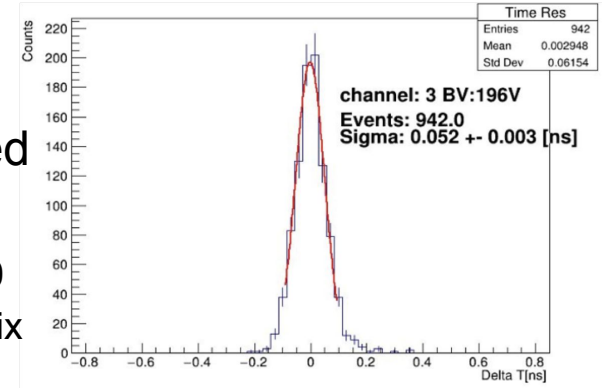


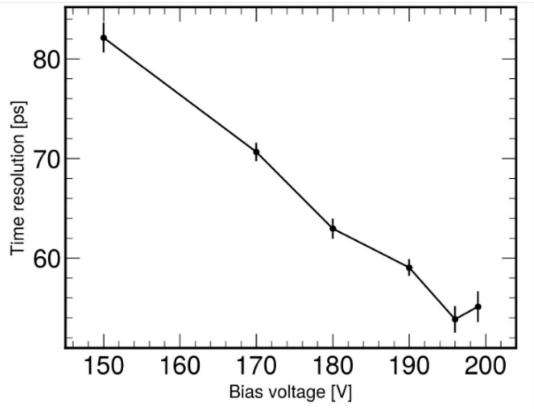
Beam Test Results

- Confirmed performance on DC-LGAD matches design specifications
  - Achieved 32 ps total resolution (for amplitude ~300mV)
  - No time-talk observed
- AC-LGAD resolution measured to be 52 ps
  - For smaller signal amplitude 130 mV due to the temporary noise fix









Summary

- Presented performance of 2nd-Gen FCFD ASIC optimized for EIC AC-LGAD applications
- For DC-LGAD, performance matches design specifications
- For AC-LGAD, larger noise observed and temporary fix resulted in slightly worse timing performance due to attenuated signal size

- Next steps:
  - Working on re-design of RC-coupling, accounting for sensor parameters
  - Design of full size FCFD v2 ASIC with EIC-DAQ compatible readout

Backup