FCFD design status and specifications for AC-LGAD strip sensors for barrel TOF

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FCFD design

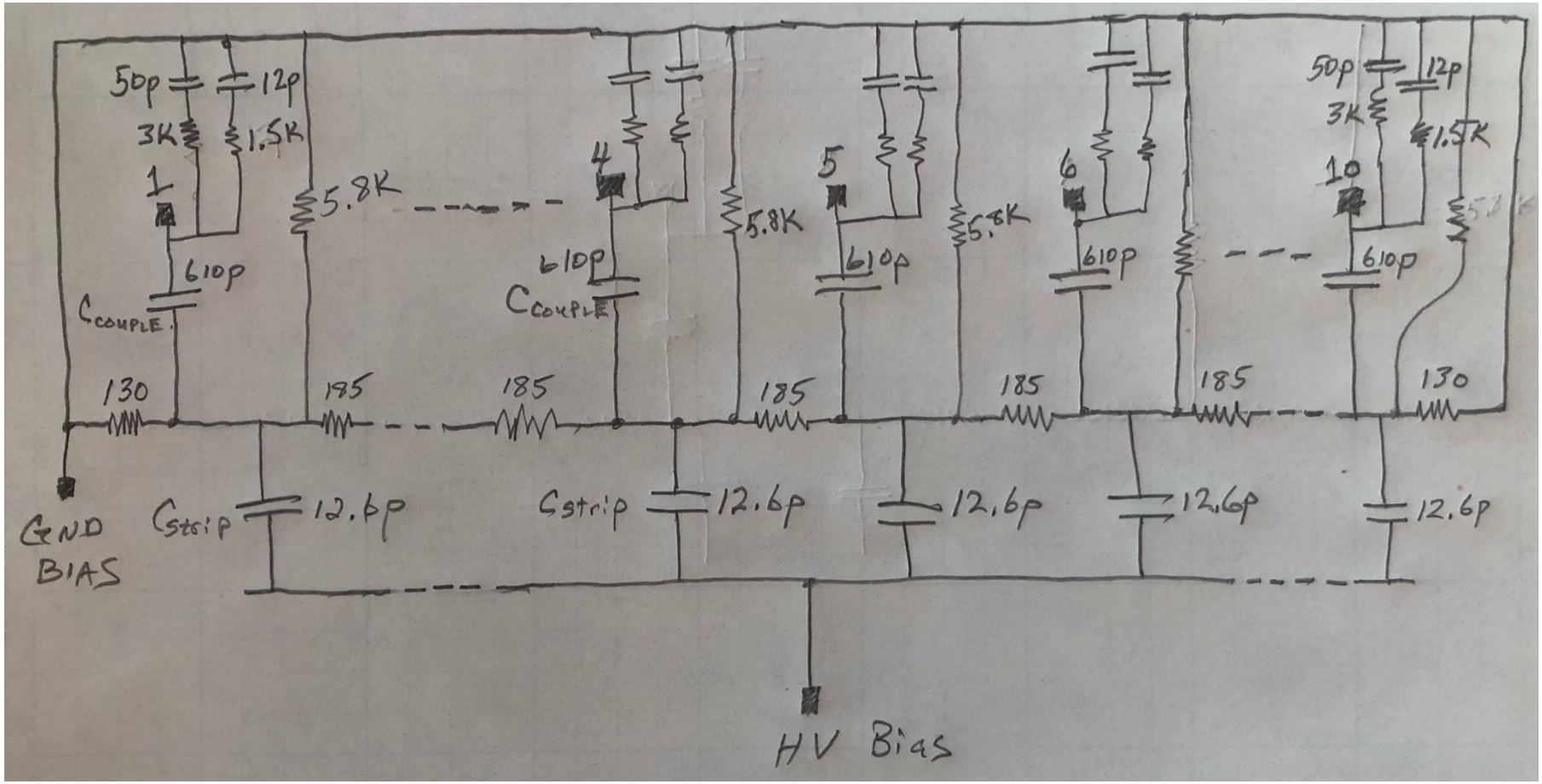
- Performance of the FCFDv1 was studied in test beams and presented in previous ePIC meetings
- We found that AC-LGAD strip sensors have a complicated RC-network characteristics that need to be specified precisely for designing the readout chip
- We performed detailed studies of HPK AC-LGAD sensors
  - Hamamatsu 1 cm long strips, 50 μm thick sensor
  - 500 μm pitch, 50 μm wide metal strips
  - Sheet resistance 1600 Ω/square

FCFD design status

- Currently working on the redesigned front-end
  - In order to achieve the desired performance with the 1-cm long sensors, a redesign of the front-end is required
  - A three-stage amplifier is being implemented now, results look promising
    - After this, implement a comparator with tunable threshold, and the neighbor readout (more on this in the following slides)
- The chip is designed in TSMC 65 nm process
  - We usually submit through CERN to IMEC, have done that for the past two versions, all agreements are in place
- Once the chip is received, during production, the chip should be wafer-tested to define good dies for modules assembly
  - During the R&D phase the plan is to perform the testing upon reception by the chip designers, which is followed by distribution to collaborators for further testing

Measurements of AC-LGAD sensors parameters

- A lot of detailed measurements, methodology will be documented in a separate paper/note

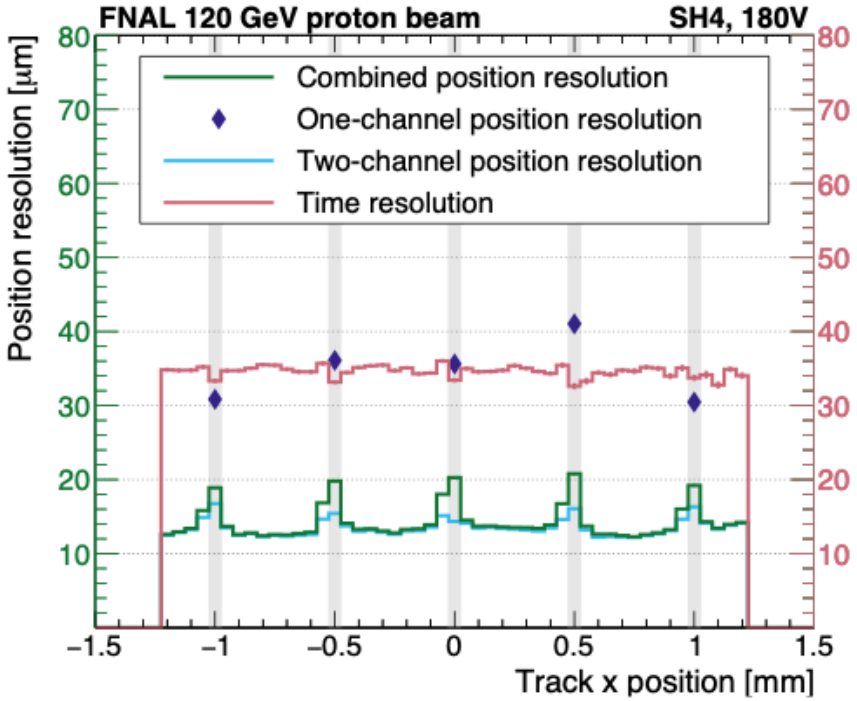


ASIC design specs

- The ASIC design needs to be optimized for the specific sensor that will be used with it
- We propose to use this HPK sensor's RC-properties as the specifications to optimize the FCFD v1.1
- We also need to define the input charge, dynamic range, and required amount of charge sharing
  - Propose to use the same HPK sensors that have been studied in test beams
  - Hamamatsu 1 cm long strips, 50 μm thick sensor
  - 500 μm pitch, 50 μm wide metal strips
  - Sheet resistance 1600 Ω/square
- In the next few slides will go over signal characteristics that we measured in the test beams and summarized in arXiv:2407.09928

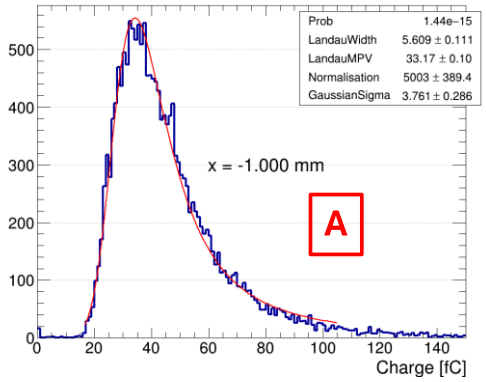
Time resolution measured in test beam

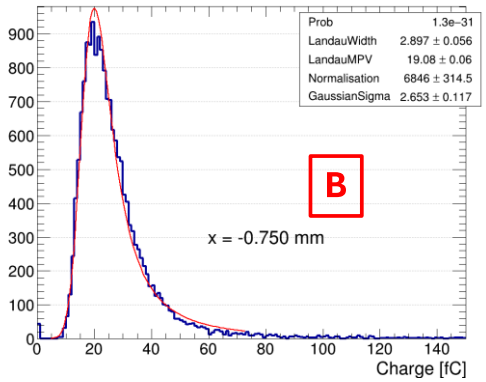
- Time resolution is measured by combining leading and sub-leading channels
- Measurements performed on dedicated readout boards using commercial amplifiers and with full waveform analysis
  - More details in the paper: arXiv:2407.09928

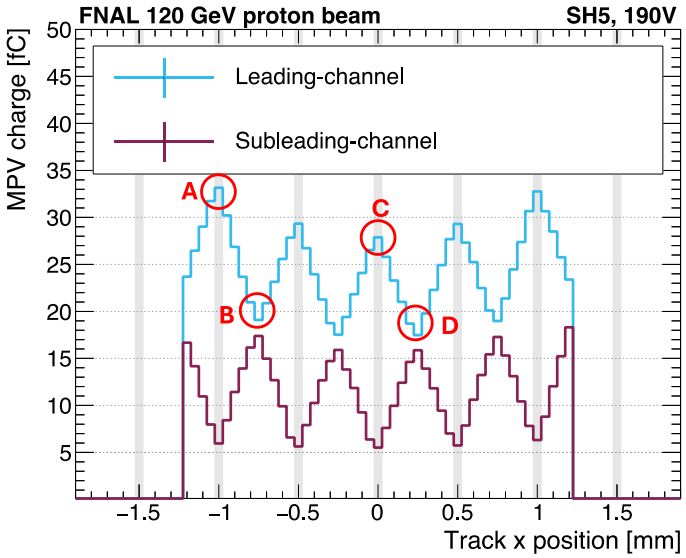


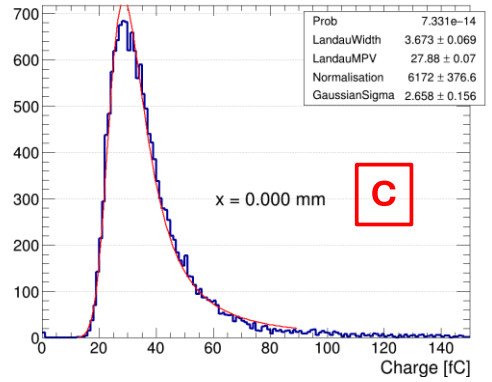
Fermilab

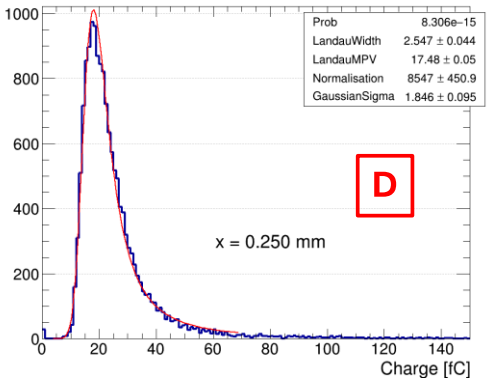
Signal characteristics







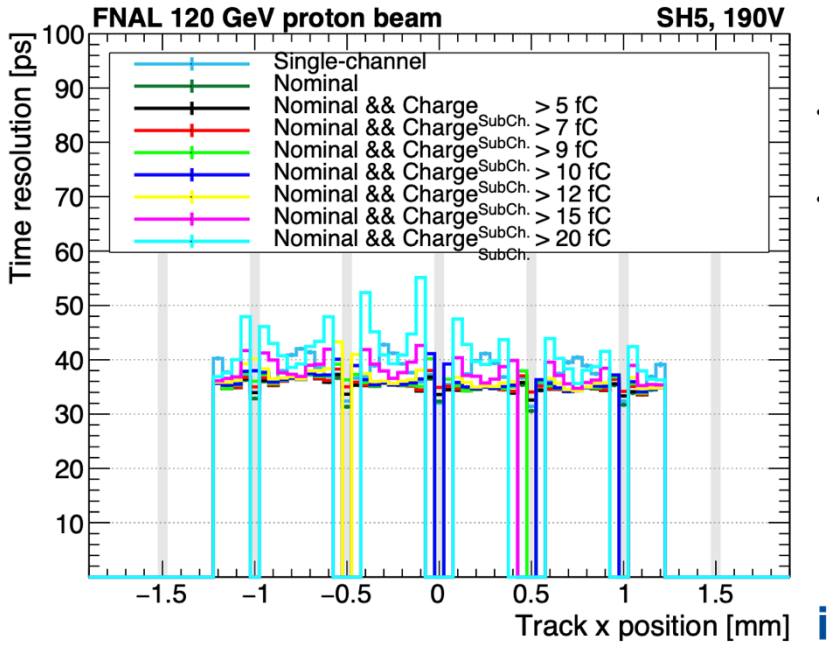




- Signal characteristics that went into plot on previous page
  - Dynamic range:10 - 70 fC
  - Signal MPV : 25 fC
  - Jitter at MPV : around 20 ps

Position resolution

- The readout is designed as follows :
  - Configurable threshold to trigger the comparator
  - If the signal is above ~10 fC → trigger readout of that strip, and the neighbor on each side (the 10 fC threshold is configurable)
- Studies from the test beam show that the combined time resolution improvement from using the neighborhood strips becomes negligible for charges below 10 fC



Next steps

- The ePIC production run of HPK sensors delivered recently
  - These sensors will need to undergo detailed characterization studies with beams and laser
- In order to proceed with the design of FCFDv1.1, the sensor spec needs to be agreed upon
- The proposal for specs:
  - Proceed with the existing HPK sensors (from page 3)
    - We can then revise the specs (if needed) once the ePIC production is tested, validated, and deemed to be the choice for the detector
    - Use the signal specs presented on page 3-7
- This proposal was discussed and endorsed by the ePIC AC-LGAD TOF DSC group on Oct 2, 2024