Overview
AC-LGAD Time-of-Flight

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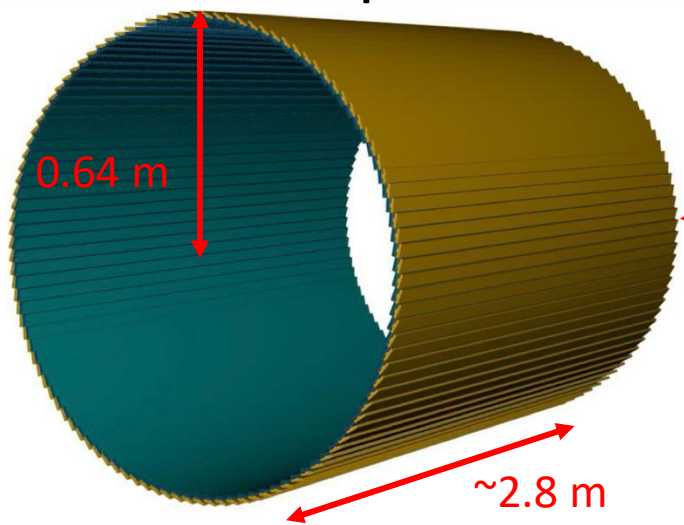
The 10th Detector Advisory Committee Review

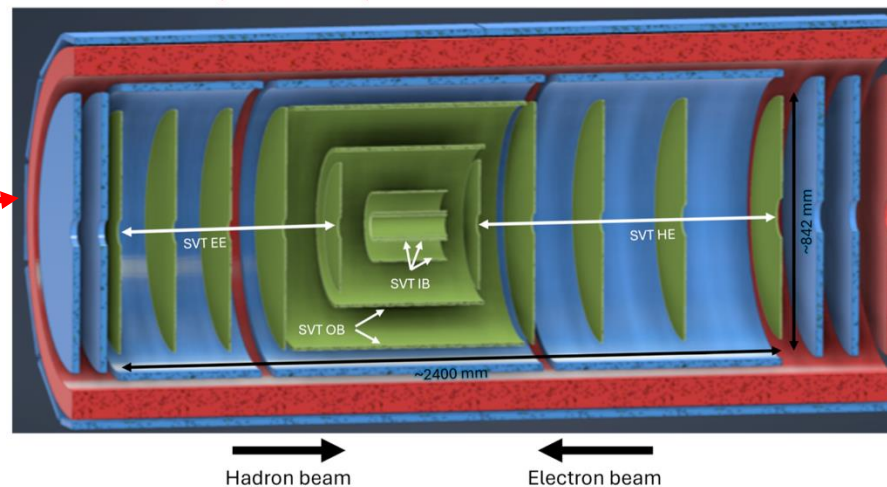June 11th – 13th, 2025

Recap of AC-LGAD TOF
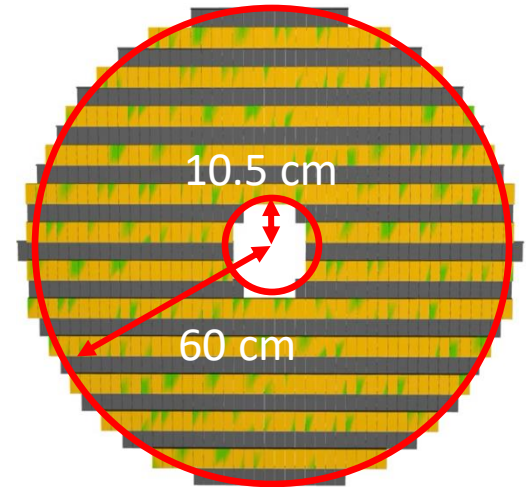
Barrel-TOF (BTOF)

-1.33<η<1.74

Forward-TOF (FTOF)

1.84<η<3.61

SVT ; MPGDs ; TOF (fiducial volume) ;

0.64 m

~2.8 m

SVT EE

SVT IB

SVT OB

SVT HE

~842 mm
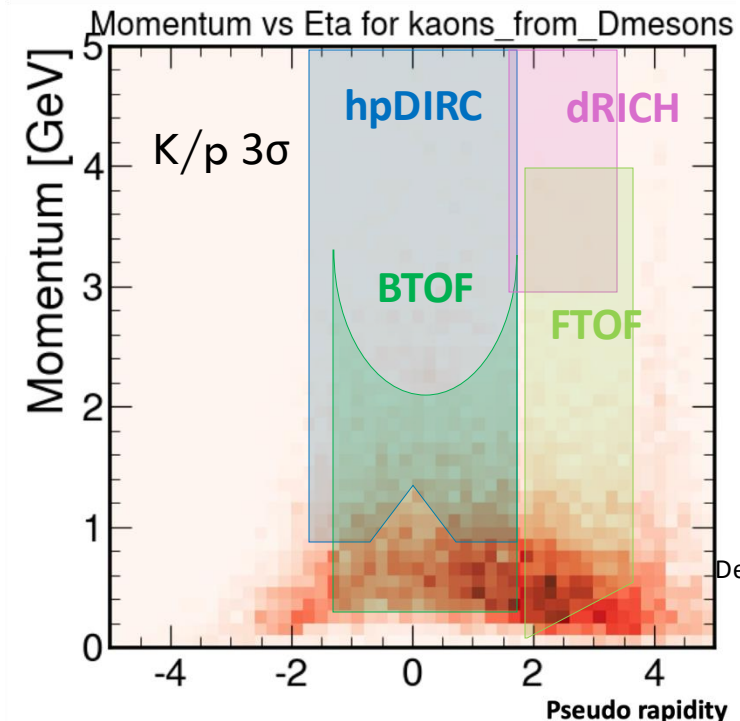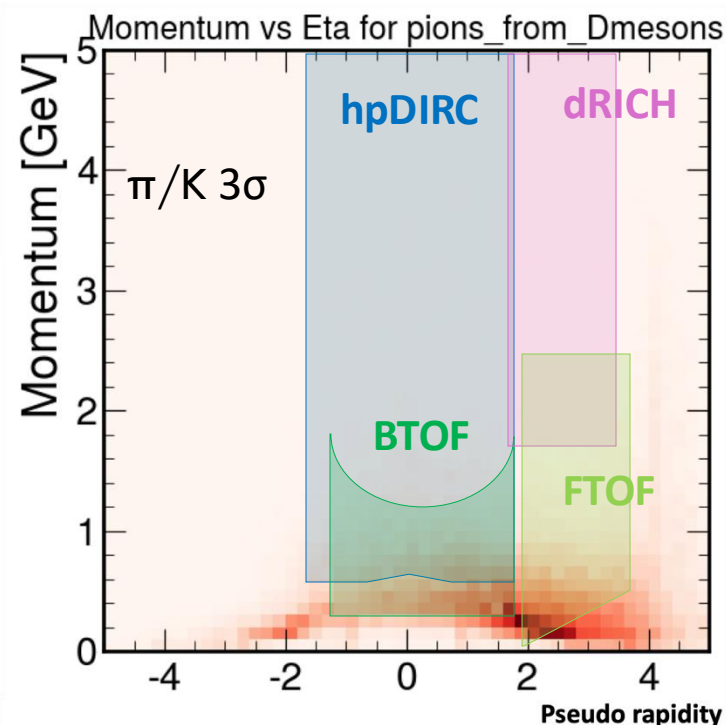
~2400 mm

Hadron beam

Electron beam

10.5 cm

60 cm

- The ePIC AC-LGAD TOF system is used for particle identification (PID), tracking, and background rejection in both mid-rapidity (BTOF) and forward-rapidity (FTOF) regions.

- A position resolution of O(10s ps) and a timing resolution of O(10s um) for PID and tracking within a space of less than 10 cm in thickness are required

Impact on the ePIC PID performance

- Focus of TOF is below p = 1 GeV/c
- Particle-Identification at low momentum region is the primary task
- Used in conjunction with Cherenkov light detectors to eliminate PID gaps and to cross-calibrate each other in overlapping regions

Assuming
BTOF σ_{tot} = 35 ps
FTOF σ_{tot} = 25 ps

Momentum vs Eta for pions_from_Dmesons

π/K 3σ

hpDIRC   dRICH

BTOF

FTOF

Momentum vs Eta for kaons_from_Dmesons

K/p 3σ

hpDIRC   dRICH

BTOF

FTOF

Decay products from D-meson in ep DIS @ √s = 141 GeV

Technology Choice: AC-LGAD

- Low Gain Avalanche Detector (LGAD) is a silicon detector with a thin gain layer making high electric field
  - High field increases the signal rise time and improves time resolution
  - Individual layer is implemented under each electrode, so inactive is not negligible and granularity limitation is there

- AC-LGAD uses AC-coupled readout with one large gain layer
  - Inactive area is eliminated by one large gain layer
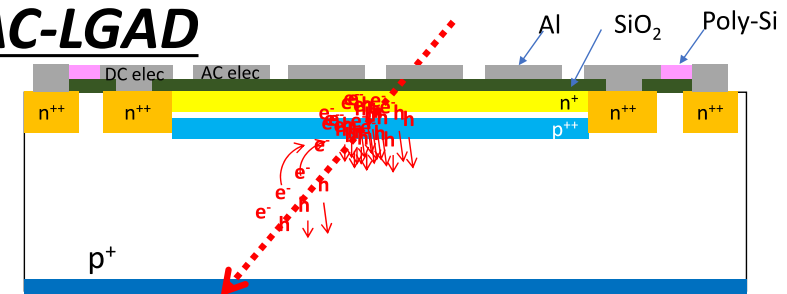 - Position resolution is improved by using the charge sharing
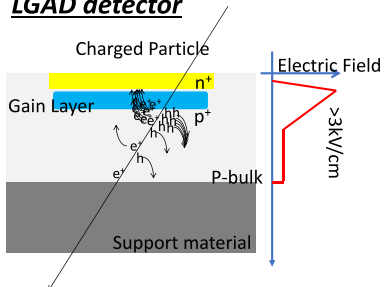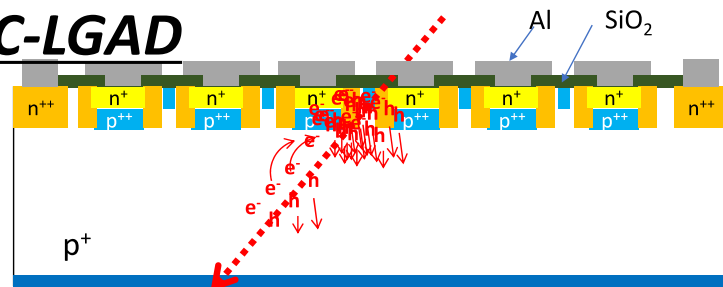
K. Nakamura et al., JPS Conf. Proc. 34, 010016 (2021)

AC-LGAD Sensor Design for TOF

- Strip-type sensor for BTOF
  - 32x20 mm^2 (full-size) and 32x10 mm^2 (half) size with 0.05x10 mm^2 pad
  - The readout geometry is 64x2=128 ch for full-size, 64x1=64 ch for half-size
  - Prototype best score: σ_{time} ~ 35 ps and σ_{pos} < 20 μm

- Pixel-type sensor for FTOF
  - 16x16 mm^2 size with 0.05x0.05 mm^2 pad
  - The readout geometry is 32x32=1024 ch
  - Prototype best score: σ_{time} ~ 20 ps and σ_{pos} ~ 20 μm

2 rows

64 cols
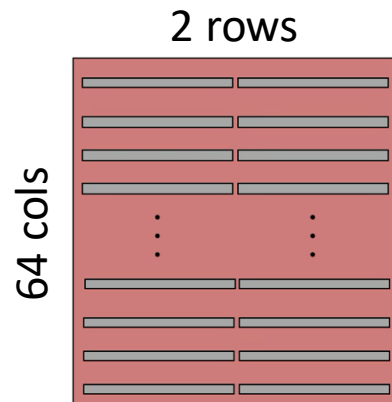
- **Strip-type for BTOF**
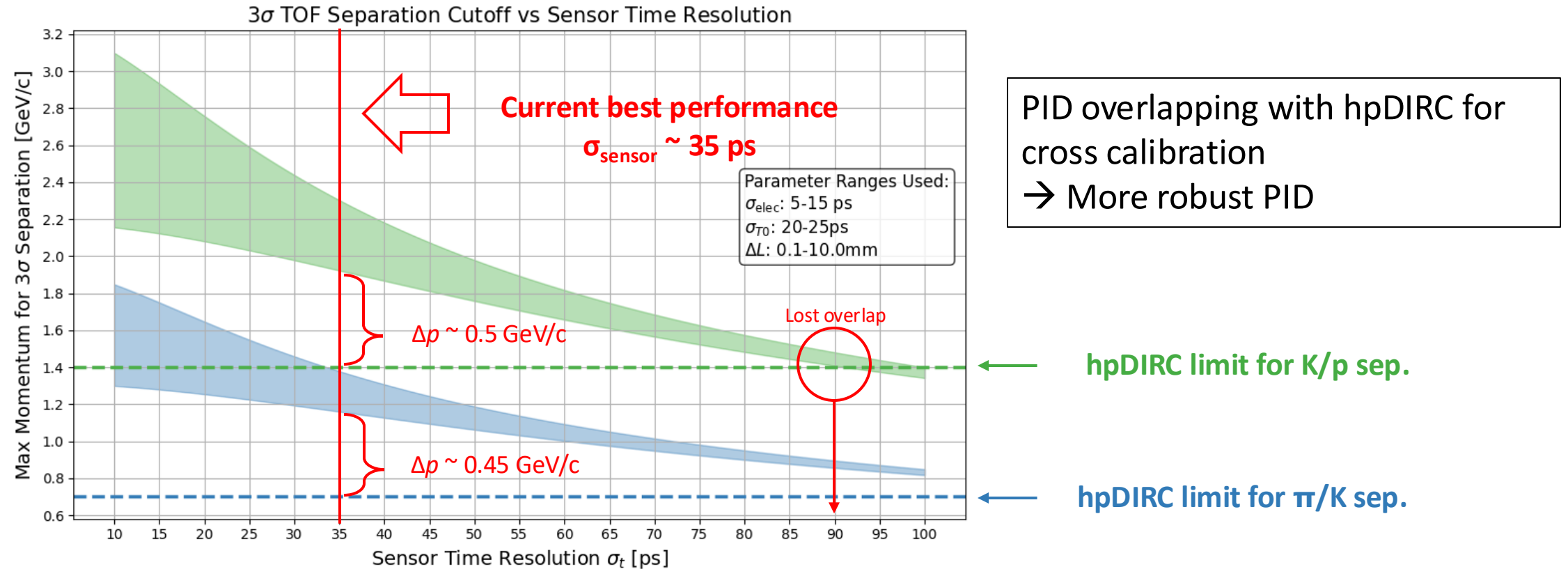 - # Full-size: ~13.8k
  - # Half-size: ~4.6k
  - ~12 m^2
  - ~2.4 M channels

32 rows

32 cols
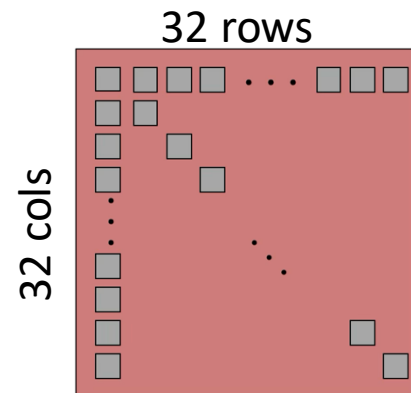
- **Pixel-type for FTOF**
  - # Sensor: ~3.6k
  - ~1.1 m^2
  - ~3.6 M channels

Sensor Timing Resolution on the entire PID performance

3σ TOF Separation Cutoff vs Sensor Time Resolution

Current best performance σ_{sensor} ~ 35 ps

Parameter Ranges Used:
σ_{elec}: 5-15 ps
σ_{T0}: 20-25ps
ΔL: 0.1-10.0mm

Lost overlap

Δp ~ 0.5 GeV/c

Δp ~ 0.45 GeV/c

Max Momentum for 3σ Separation [GeV/c]

Sensor Time Resolution σ_t [ps]

hpDIRC limit for K/p sep.

hpDIRC limit for π/K sep.

PID overlapping with hpDIRC for cross calibration
→ More robust PID

- Even in the worst case scenario, with current sensor performance (σ_{sensor}~35 ps), there is an overlap area with hpDIRC → Already no PID hole
- σ_{sensor}< 90 ps meets the requirement of having overlap region with hpDIRC in the worst case

Important Points in Development

- Performance of Large AC-LGAD Sensors
  - First application using AC-LGAD for HEP
  - Identify the elements necessary for stable operation by thoroughly understand the characteristics

- Mechanical and electrical design on a low material budget
  - Over 2.7 m length but within a few percent of material budget (for BTOF)
  - Accurate transmission of signal strength and timing information on a low material budget in a long distance
  - Thermal control due to AC-LGAD's high sensitivity to temperature gradients

Detail will be introduced by

BTOF → Simone Mazza (UCSC)   **FTOF → Mathieu Benoit (ORNL)**