THE CLICTD MONOLITHIC CMOS SENSOR

Selected results from test-beam measurements

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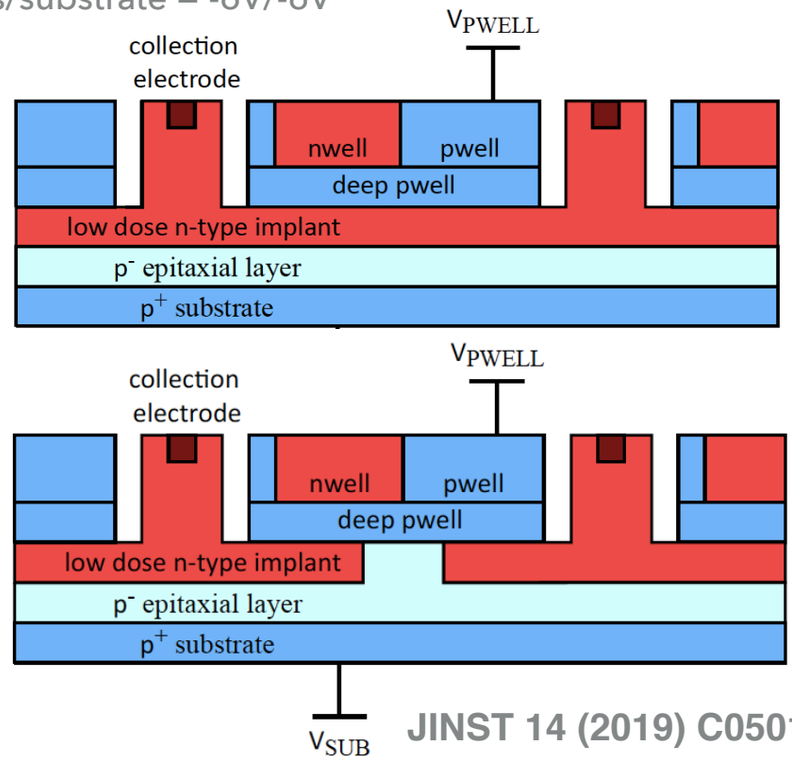
CLICTD TRACKER CHIP

The sensor targets the requirements of the tracking detector for the Compact Linear Collider (CLIC)

- Modified 180 nm CMOS imaging process with small collection diode
- Full lateral depletion in 30 µm epitaxial layer
- Optional: Gap in n-type implant in one spatial direction:
  - Speed up of charge collection
  - Improved timing resolution
  - Reduced charge sharing

Applied bias voltages to p-wells/substrate = -6V/-6V



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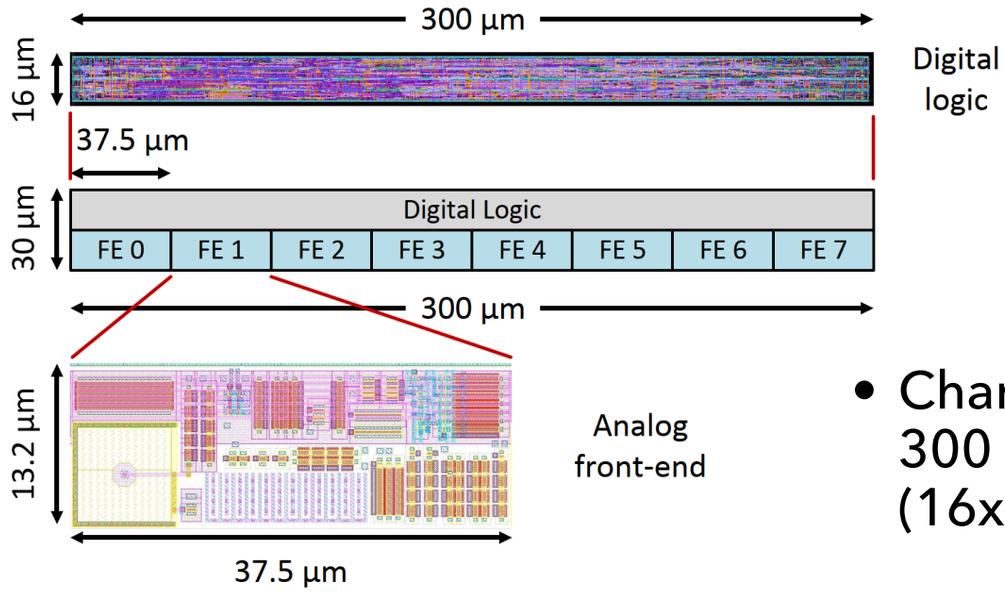

- Channel pitch: 300 µm x 30 µm (16x128 channels)
- Collection electrode pitch: 37.5 µm x 30.0 µm
- Detector channel consists of 8 sub-pixels (diode + analogue front-end) that are processed by a shared digital logic

  ➡ Save space for digital circuitry while maintaining small capacitance and fast charge collection

- 8-bit ToA (10 ns ToA bins) + 5-bit ToT (programmable from 0.6 - 4.8 µs) (combined ToA/ToT for every 8 sub-pixels in 300µm dimension)

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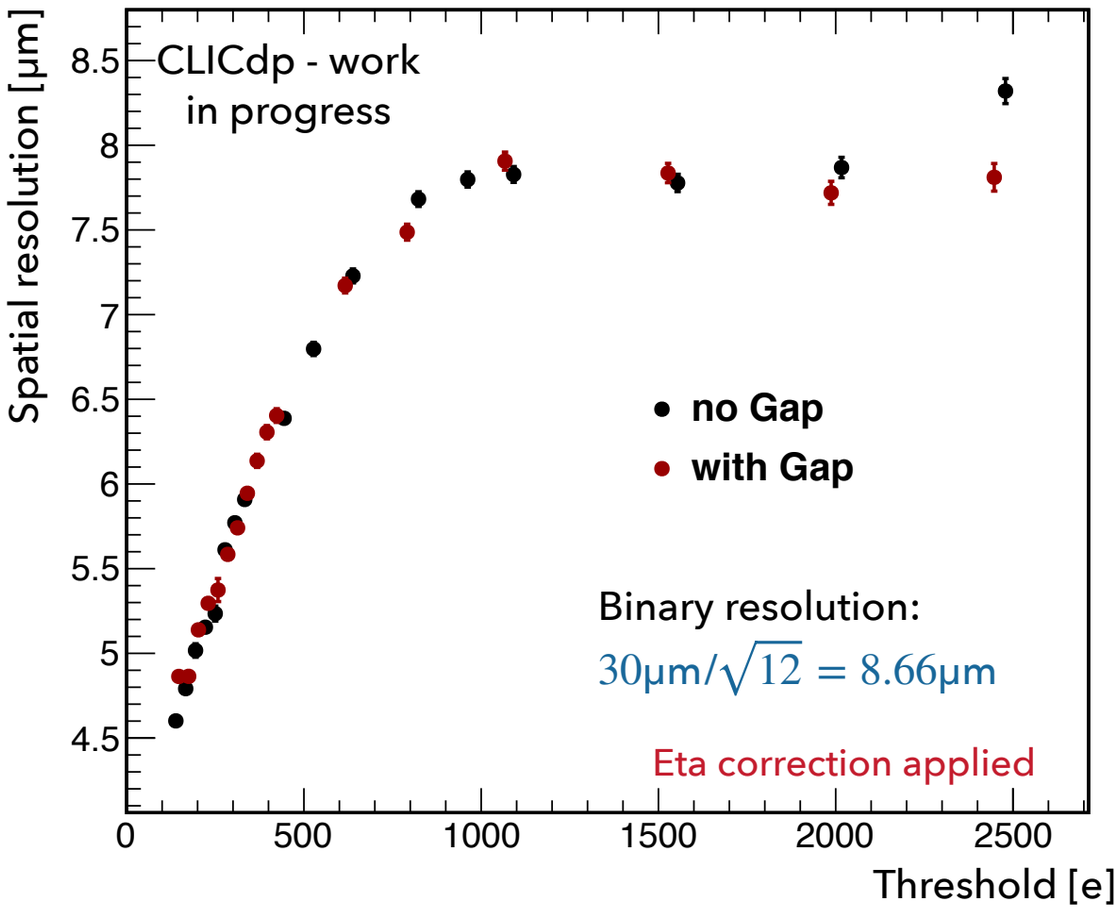
SPATIAL RESOLUTION IN TEST BEAM MEASUREMENTS

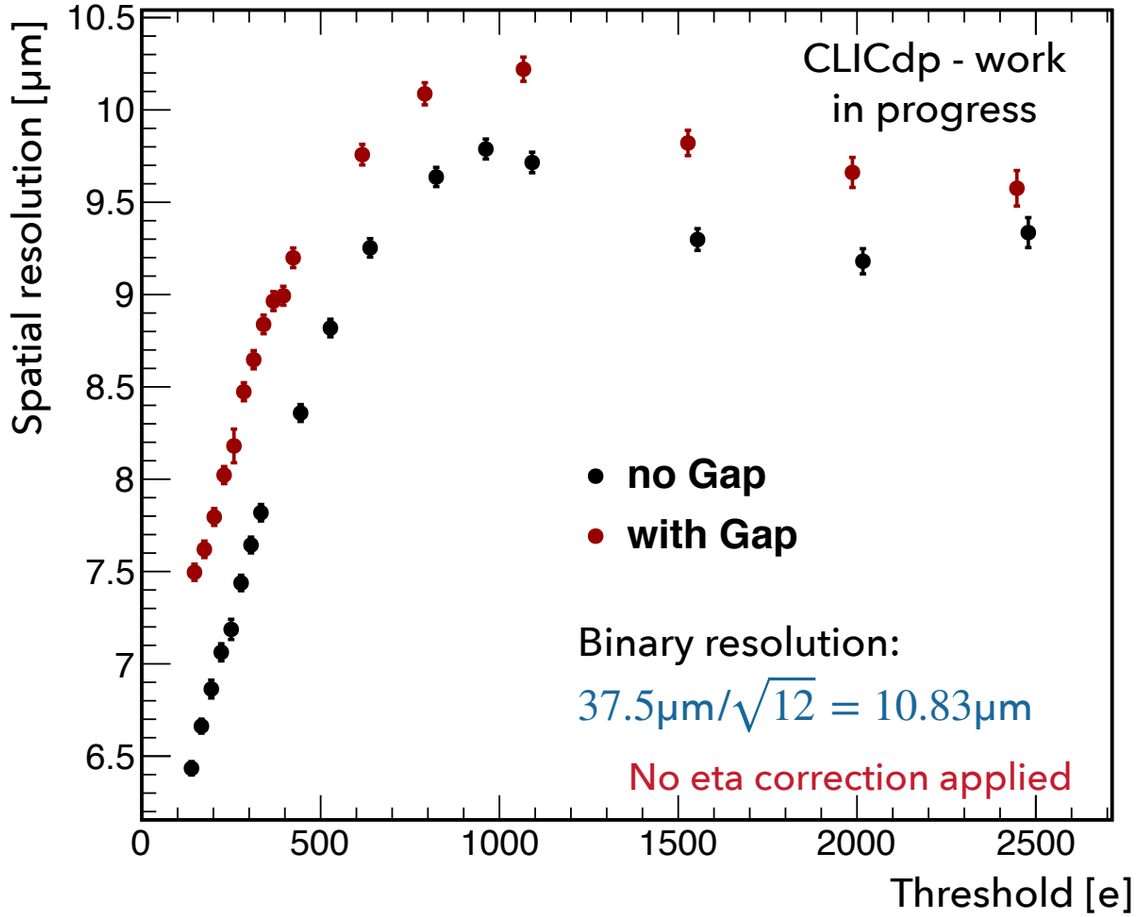
Resolution in short pixel direction (30 µm pitch)

Detector requirement on spatial resolution: < 7 µm



Resolution in long pixel direction (37.5 µm pitch)

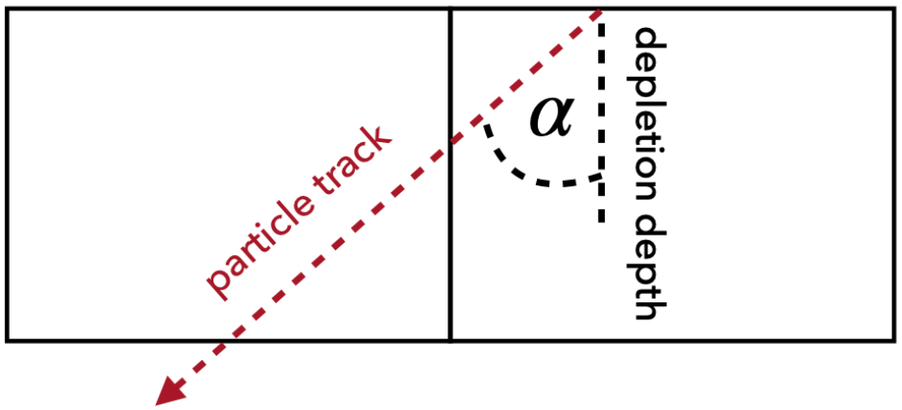
No stringent detector requirements in this direction



- Spatial resolution at minimum threshold (~140 e): 4.6 µm (telescope resolution of 2.5 µm quadratically subtracted)
- Spatial resolution worsens with increasing threshold due to decreasing cluster size
- Less charge sharing due to gap in the n-implant (only implemented in long pixel direction) leads to a smaller cluster size and decreasing spatial resolution
  - Still in line with detector requirements in this spatial dimension

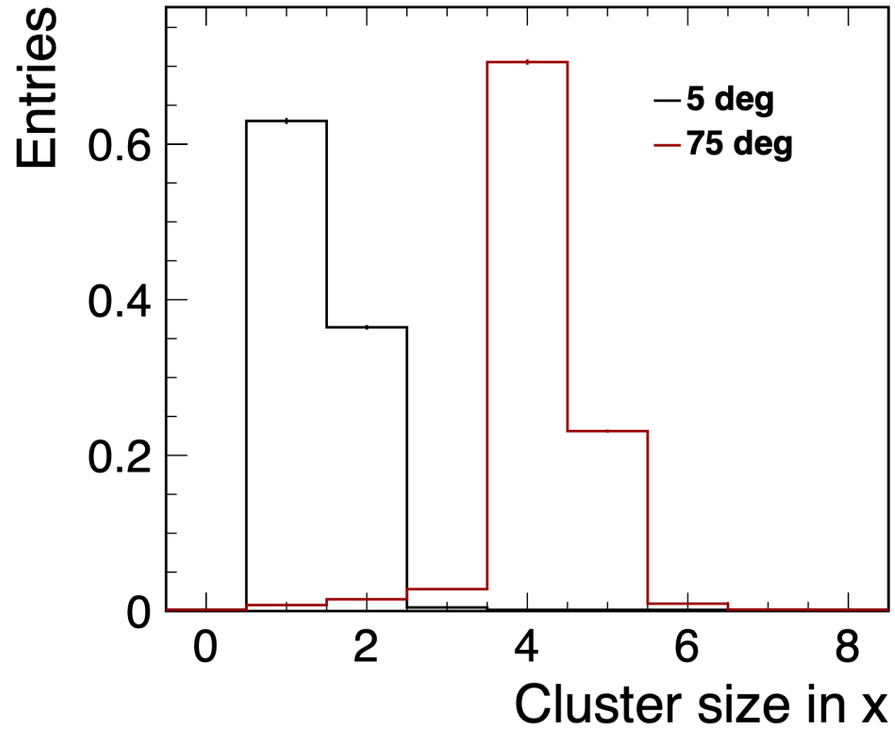
ACTIVE DEPTH FROM INCLINED TRACKS

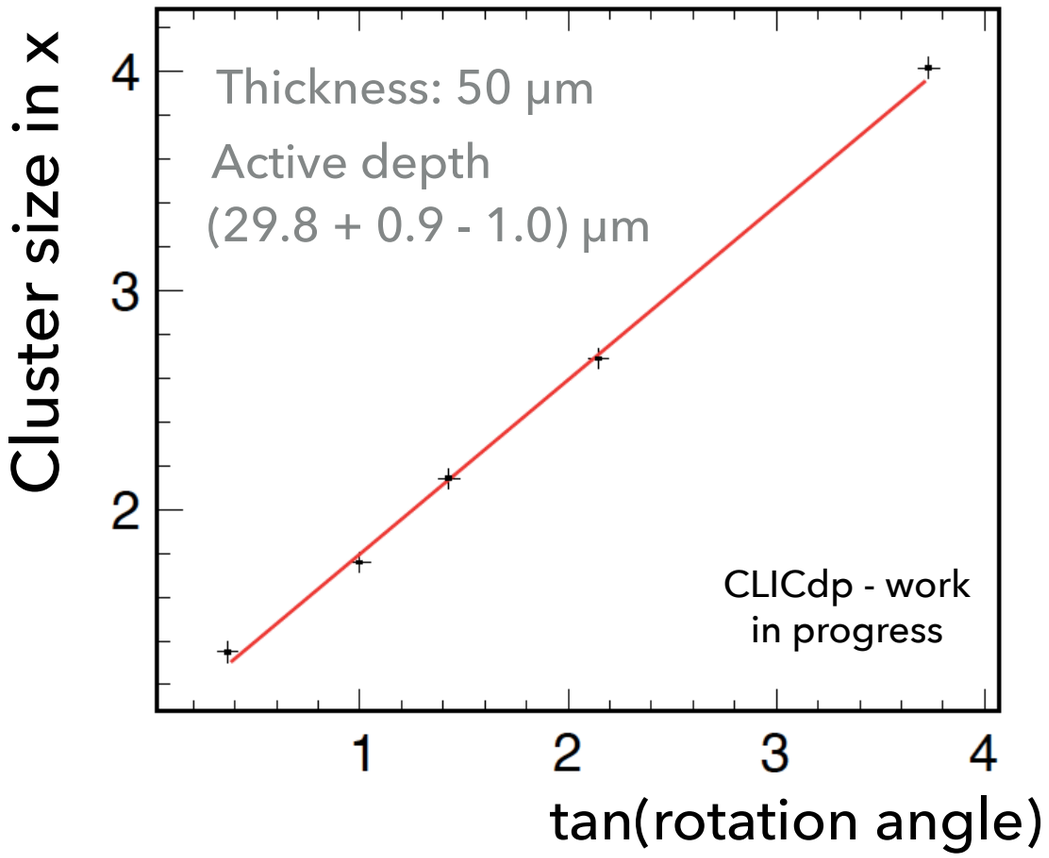
- Cluster size increases for inclined particle tracks since energy is deposited in several adjacent pixel cells
- Active depth can be estimated by rotation-dependent cluster size



$$\text{size}_x = \frac{d_{\text{depl}} \cdot \tan(\alpha)}{\text{pitch}_x}$$

- Active depth of approximately 30 µm was found for assemblies with different thicknesses (50 µm - 300 µm)
  - Thickness of epitaxial layer: 30 µm
  - Expected depletion depth: 23 µm (estimated from 3D TCAD simulations)





SUMMARY AND OUTLOOK

- The monolithic CLICTD HR CMOS sensor
  - Is fabricated in two sensor process variants
  - features an innovative front-end design with a sub-pixel segmentation scheme
- In beam tests, the sensor achieved a spatial resolution of down to 4.6 µm and a timing resolution of 5.8 ns which fulfil the CLIC tracking detector requirements
- CLICTD has shown to be fully efficient up to a threshold of ~450 e (min. operational threshold ~140e)
- Optimization studies for sensors in 65 nm CMOS designs are currently on-going

EP R&D

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Part of the measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany)