THE CLICTD MONOLITHIC CMOS SENSOR

Selected results from test-beam measurements

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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

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)
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)

CLICdp - work in progress
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