Test Beam Results of Irradiated Silicon Sensors with Modified Pixel Layout

7th BTTB Workshop 2019

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DO-B03 and DO-B04

- Bias grid variations
- Pixel size: 250µm x 50µm (same as IBL)
- V0 is the standard ATLAS IBL pixel layout
- $n^+$-in-n wafer process
- Sensor thickness: 285µm

Blue: $n^+$
Grey: metal
Orange: bump bond openings
All designs on one sensor
  - Grouped in eight structures
    - 10 columns and 340 rows for each design
    - Each design on the left and right side
  - Readout: FE-I4B
Test Beam at CERN

May 2018

- 120GeV Pions
- ACONITE Telescope (resolution ~4µm)
- DUTs cooled to -40°C
- DO-B03: irradiated to $5.5 \times 10^{15} n_{eq}/cm^2$
- DO-B04: irradiated to $1.6 \times 10^{16} n_{eq}/cm^2$
- Different positions, tunings, voltages

with neutrons at SANDIA
- Interested in in-pixel efficiency maps
- Red line marks the expected middle of the pixel layout

Efficiency Pixel Map DUT 22 Design V1

Efficiency Pixel Map DUT 22 Design V2

DO-B03, $5.5 \times 10^{15}$ n$_{eq}$/cm$^2$
400V, 3200e, 6ToT@20ke
The axis of symmetry derived from the pixel layouts shifts with sensor x position

- Observed for DO-B03 and DO-B04

Analysis with TBMon2

DO-B04, $1.6 \times 10^{16} n_{eq}/cm^2$

400V, 3200e, 6ToT@20ke
Rotation of the sensor not corrected by TBMon2

Implemented rotations around all three axes

- In EuBuildTrack.cc
Rotations in TBMon2

- Expected axis of symmetry is not shifted anymore, stable around 33µm

DO-B04, $1.6 \times 10^{16} \text{ n}_{\text{eq}}/\text{cm}^2$

400V, 3200e, 6ToT@20ke
Asymmetric In-pixel Maps

- In-pixel efficiency maps are not symmetric in y-direction
- Symmetry axis expected around 25µm, seen around 33µm

→ Compare tracks and hits:

DO-B04, $1.6 \times 10^{16} n_{eq}/cm^2$
400V, 3200e, 6ToT@20ke
Asymmetric In-pixel Maps

- Hit distribution results in asymmetric residuals
- Residuals cause the failure of the alignment step

DO-B04, $1.6 \times 10^{16} \text{ } n_{eq} / \text{cm}^2$
400V, 3200e, 6ToT@20ke
Asymmetric In-pixel Maps

- Peak heights differ by a factor of ~3
- Peaks not symmetric around zero
- Special treatment for these sensors in CheckAlign.cc
  → Find highest value in the two peaks, define fit range
  → Fit gaussian distribution around these bins
  → Calculate the distance between their means
  → Shift all trackY positions to lower values
Asymmetric In-pixel Maps

- Symmetry axis is closer to the centre of the y-axis (before 33µm, now 27µm)

**Efficiency Pixel Map DUT 23 Design V1**

**Efficiency Pixel Map DUT 23 Design V2**

**Efficiency Pixel Map DUT 23 Design V3**

**Efficiency Pixel Map DUT 23 Design V0**

DO-B04, $1.6 \times 10^{16} \text{n}_{eq}/\text{cm}^2$

400V, 3200e, 6ToT@20keV
Conclusion and Outlook

- Implemented rotations around all three axes for TBMon2
- Special treatment for these sensors to avoid asymmetric in-pixel efficiency maps

- Investigate why the efficiency distribution is not symmetric within the pixel (caused by the sensor?)

Efficiency Pixel Map DUT 22 Design V1

Efficiency Pixel Map DUT 23 Design V1