Report from Oxford

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CMOS devices under study
- LFoudry
  - CCPD_LF
  - LF-CPIX
- TowerJazz
  - Investigator 1 and 2

Activities with CMOS devices
- Edge-TCT
- Irradiation at Birmingham
- Test-beam at DESY

AIDA2020 projects
**CMOS devices under test**

- **CCPD_LF**
  
  Small prototype
  
  125x33μm² pixel (6:2 FE-I4)
  
  Produced in 2 versions
  
  - A: large fill factor
  - B: small fill factor

  ![Diagram of CCPD_LF](image)

  **Read-out**

  To external read-out (standalone board)

  (Alternatively glued to FE-I4)
CMOS devices under test

- **LF-CPIX**

  - Large prototype (9.5x10mm²)
  - Standard FE-I4 pixel (250x50μm²)
  - Large (>60%) fill factor
  - Larger signal and collection area
  - Larger capacitance (noise)

3 “flavours” of Pre-amp implemented:
- NMOS
- PMOS
- CMOS

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Before Irradiation:
- Good behaviour of the depletion region
- Resistivity compatible with 4.2 kΩ·cm (foundry wafers 3±5 kΩ·cm)
After Irradiation:
- Good behaviour of the depletion region
- Depletion reaches ~70 μm at 140V bias

2 devices irradiated at Birmingham MC40 facility (AIDA2020)
- $1.0 \times 10^{15}$ $n_{eq}/cm^2$
- 120 Mrad
Board re-designed to be “edge-TCT friendly”

- In the original board design the chip is in the middle
  - Board components on laser direction
  - Need for tilting the board

Better shape of depletion region, no significant change in depletion depth value.
Both compatible with ~3 kΩ·cm resistivity
Version B limited by leakage current
CCPD_LF: Fe$^{55}$ spectrum

Good response to X-rays
Test-beam at DESY

- New AIDA2020 project involving Oxford
  - Identifier: AIDA-2020/DESY/2018/01
- Test beam at DESY
  - From 19/02/2018 to 04/03/2018 (2 weeks)
  - CMOS devices
    - 2 not irradiated LF-CPIX
    - 2 Irradiated LF-CPIX
    - 1 TowerJazz not irradiated Investigator1
  - Novel cooling system
  - Alternative synchronization with telescope
Novel cooling system

- Based on vortex cooler
  - Dry compressed air in
  - Hot air to one side
  - Cold air to the other


System tested in the lab:
-21 C at 6 bars, stable for an hour.

Required a dedicated air compressor in DESY.
Novel cooling system

- Details
  - 4 tubes provide warm dry air between adapter and chip card
  - Warm dry air from supply
  - Air stream separately regulated
  - Adapter card
  - Chip card with foam
  - Vortex cooler
  - Adapter
  - Divider
  - Telescope mounting brackets
Moving and installation in DESY

Van required to move the air compressor and the equipment
Performance

Cooling system for ~36 hours at 3 bar reaching -17.5 C
Devices are investigated through preamplifier output (analogue), 1 channel at a time

Hits recorded on the oscilloscope

Synchronization with telescope on the oscilloscope itself through the TLU
From the comparison of the trigger and trigger clock lines one obtains the trigger number to associate with the track.

Scope triggered independently from telescope: no integration with EUDAQ needed

- Simple and easy (one firmware + python scripts)
- Timing provided by oscilloscope
- Slow: depends on scope driver for saving the channels
  - With one channel investigated (50x250 µm²) low rate (3 Hz)
Results: not irradiated LF-CPIX

Track reconstruction with 2 planes only

Fit with box function convoluted with Gaussian.
Geometry fit parameters match with expectations:
- Width 250x50 µm
- Sigma about 22 µm (only two telescope planes used, pixel size 18.5x18.5 um)
Efficiency (scale factor) very low...

To do: reconstruction must be improved using all planes!
Conclusions

- Many CMOS activities in Oxford
- Several devices under study
  - Lfoundry
  - TowerJazz
- Many tests performed (AIDA2020 support)
  - Edge-TCT
  - Irradiation
  - Test beam
Backup: LF-CPIX board
The Fourier transform has a peak: the oscillation frequency. 0.0043 Hz, i.e. a period of ~233 seconds (almost 4 minutes): the compressor’s duty cycle!
Back-up: cooling system

- Performance details: external temperature

\[ y = -2E-05x - 14.03 \]
\[ R^2 = 0.8667 \]

Same trend as ambient temperature: day and night variation! (1.5 C)
We have to match the TLU numbers within a refreshment cycle (every $2^{15}$ events).
Backup: Telescope sync

First step: match all possible TLU numbers to see an excess

- Just match the TLUs between files.
- There might be random coincidences (same TLU number, different sequence)
- Track reconstructed with the 2 nearby planes

![Telescope coincidences for all data](image)
Second step: find the matching sequences

We plot the hit distribution for every possible combination of segment matching and check how many hits we have on the pixel region found before.

There are few coincidences between the first sequence on the oscilloscope and the second on the telescope.

Then both oscilloscope and telescope move to the next sequence and there is a similar amount of hits! And so on...