Report from Oxford

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AIDA2020 Third Annual Meeting

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Outline

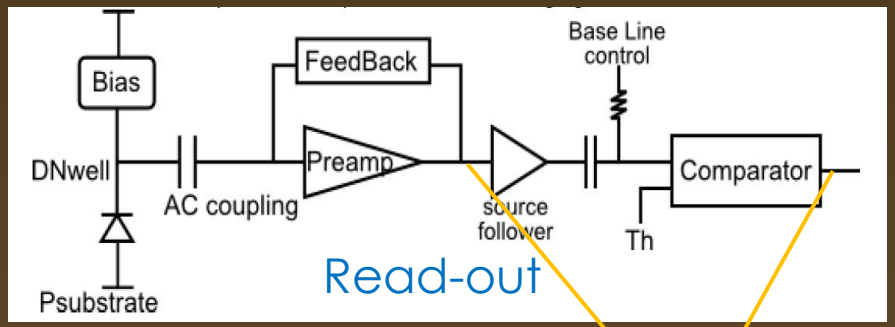
- CMOS devices under study
  - LFoundry
    - CCPD_LF
    - LF-CPIX
  - TowerJazz
    - Investigator 1 and 2
- Activities with CMOS devices
  - Edge-TCT
  - Irradiation at Birmingham
  - Test-beam at DESY

AIDA2020 projects

CMOS devices under test

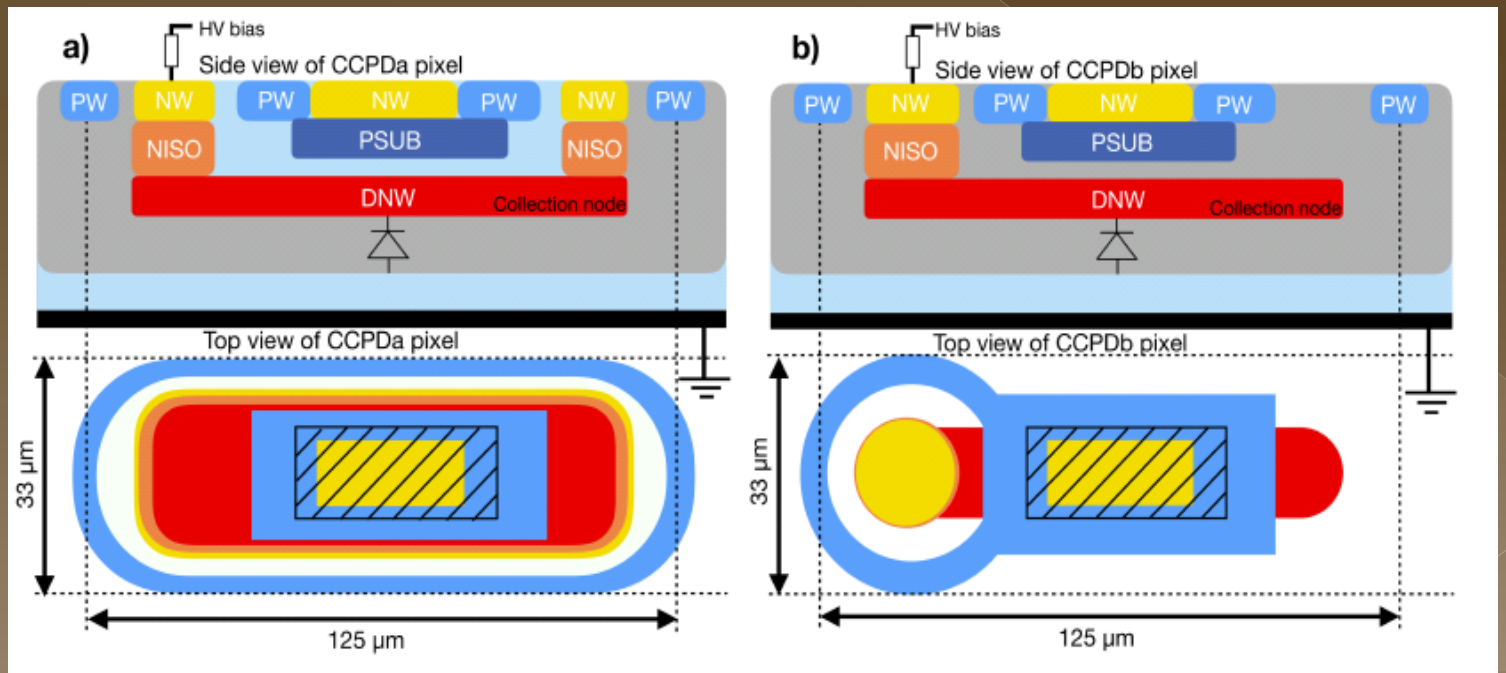
- CCPD_LF

Small prototype
125x33μm^2 pixel (6:2 FE-I4)
Produced in 2 versions
- A: large fill factor
- B: small fill factor



To external read-out (standalone board)

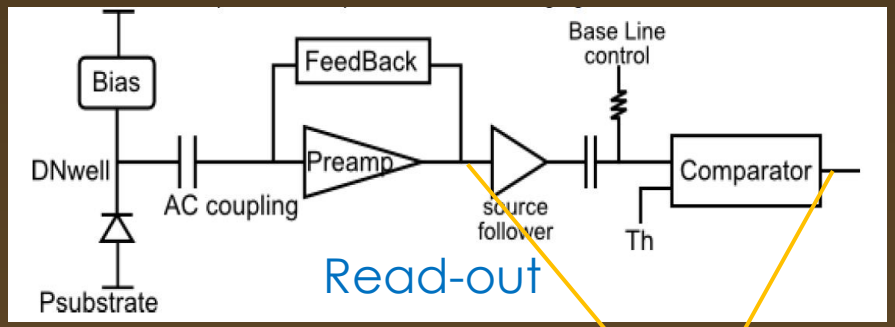
(Alternatively glued to FE-I4)

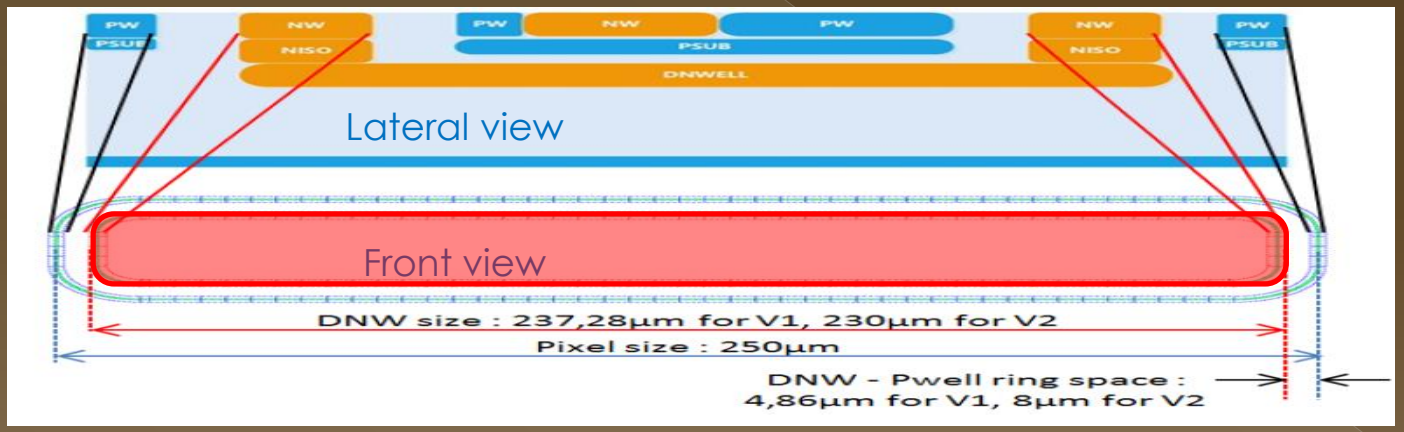


CMOS devices under test

- LF-CPIX

  Large prototype (9.5x10mm^2)
  Standard FE-I4 pixel (250x50μm^2)
  Large (>60%) fill factor
  Larger signal and collection area
  Larger capacitance (noise)





To external read-out (standalone board)

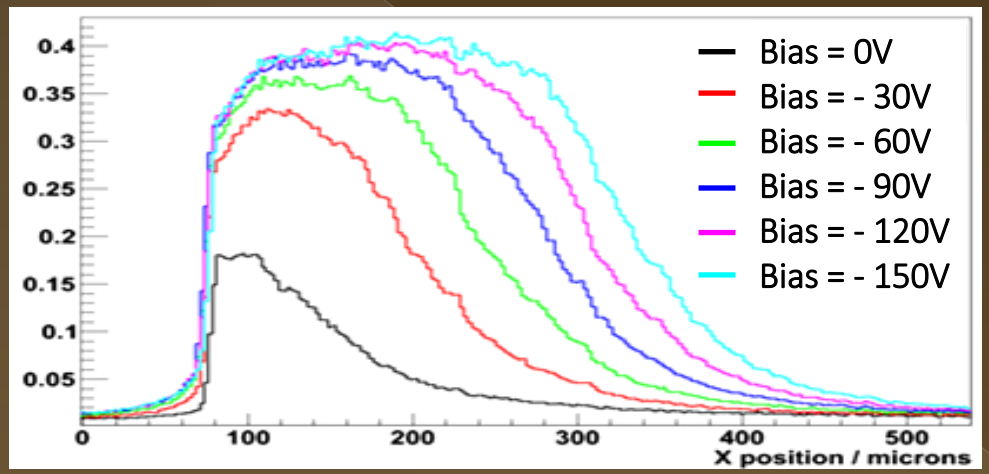
(Alternatively glued to FE-I4)

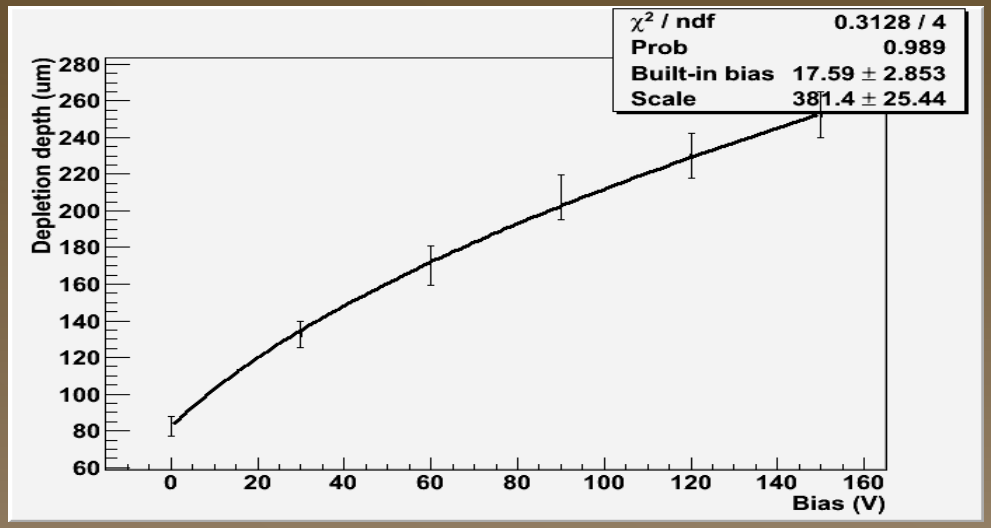
T. Hirono et al, "CMOS pixel sensors on high resistive substrate for high-rate, high-radiation environments", Nuclear Instruments and Methods in Physics Research Section A, Volume 831, 2016

3 "flavours" of Pre-amp implemented:

NMOS PMOS CMOS

LF-CPIX: Edge-TCT

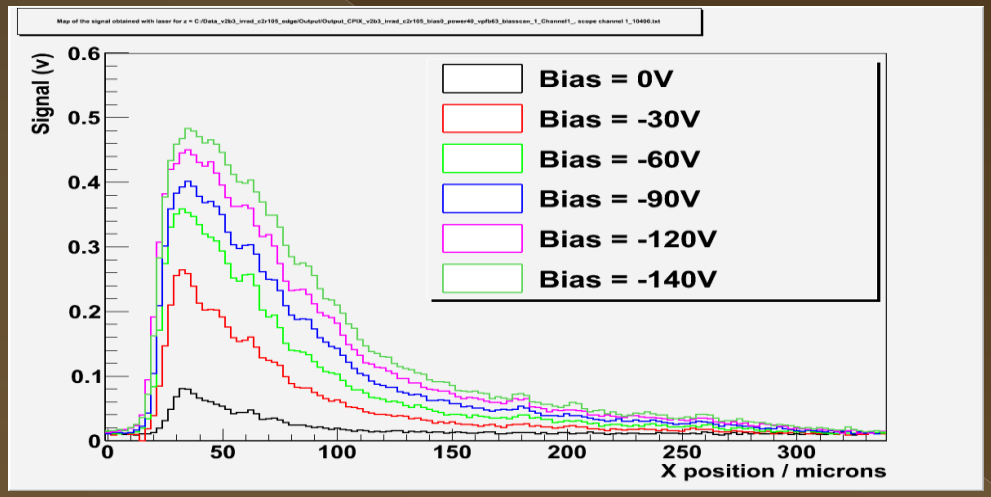


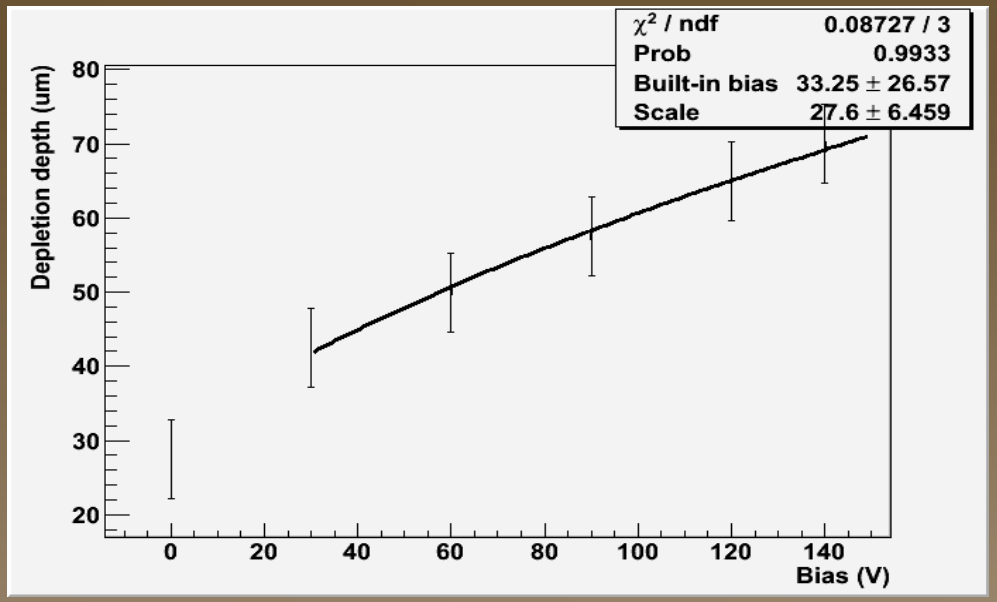


Before Irradiation:

- Good behaviour of the depletion region
- Resistivity compatible with 4.2 kΩ·cm (foundry wafers 3÷5 kΩ·cm)

LF-CPIX: Edge-TCT





2 devices irradiated at Birmingham MC40 facility (AIDA2020)

- 1.0×10^{15} n_{eq}/cm^2
- 120 Mrad

After Irradiation:

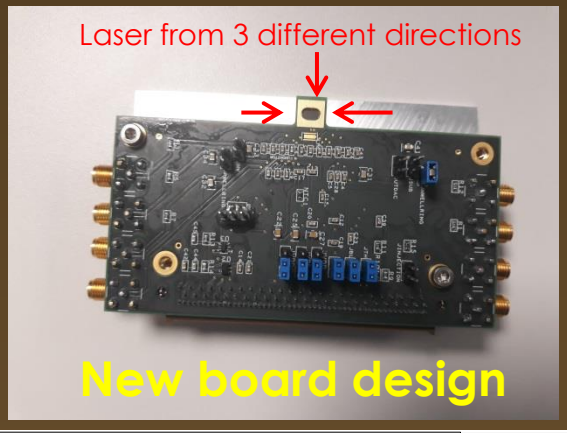
- Good behaviour of the depletion region
- Depletion reaches ~70 μm at 140V bias

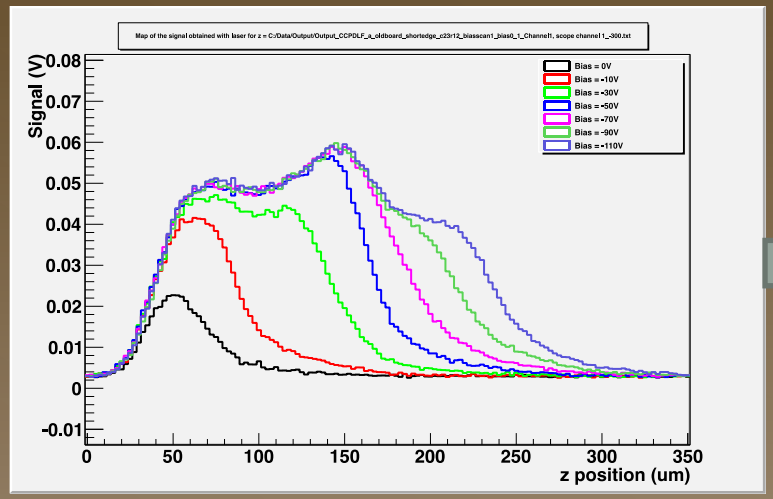
CCPD_LF: Edge-TCT

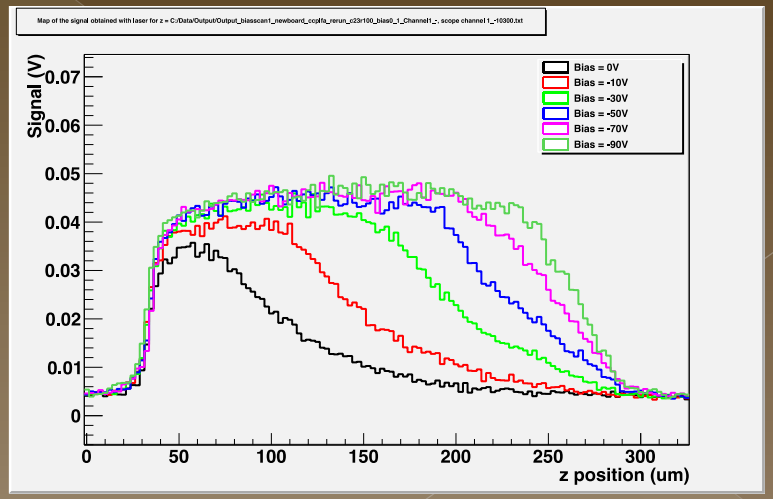
- Board re-designed to be "edge-TCT friendly"

In the original board design the chip is in the middle

- Board components on laser direction
- Need for tilting the board



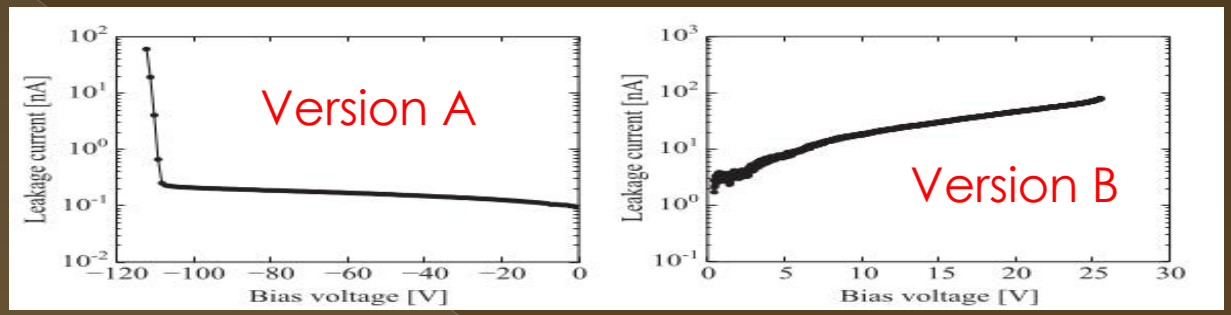




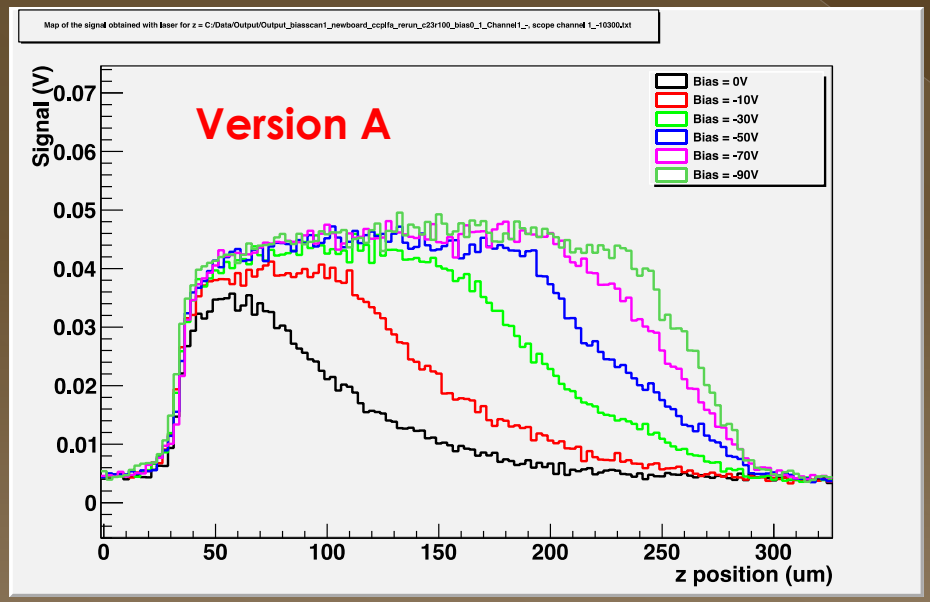
Better shape of depletion region, no significant change in depletion depth value.

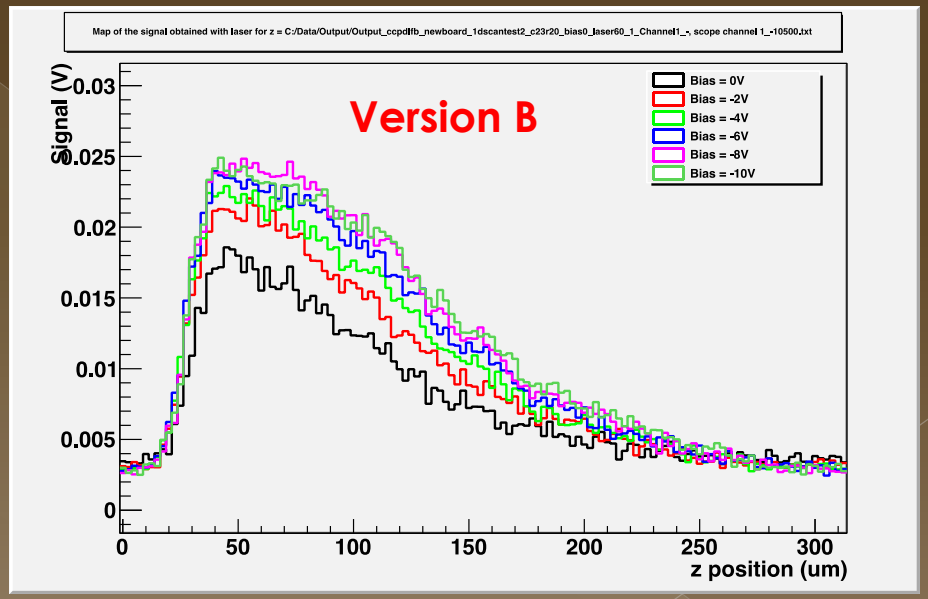
CCPD_LF: Edge-TCT

IV curves



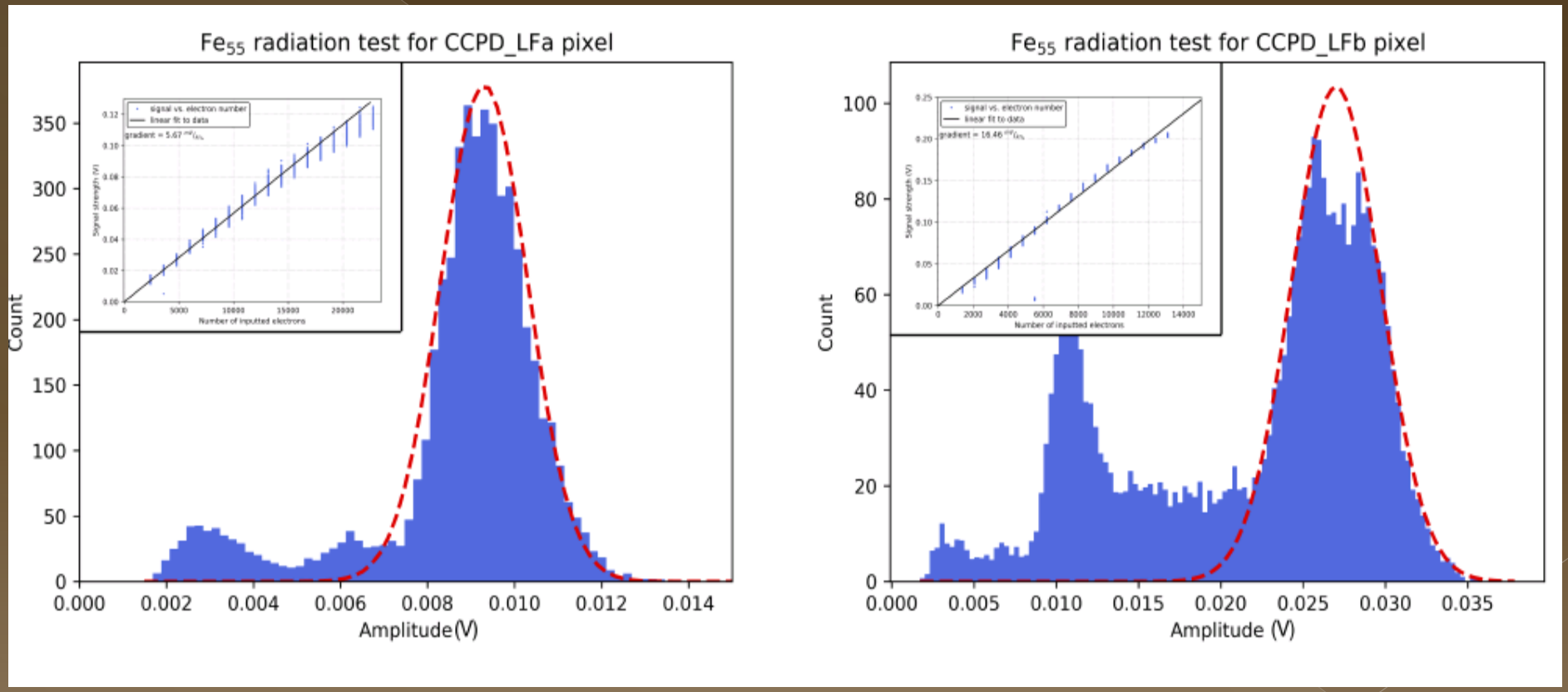
T. Hirono





Both compatible with ~3 kΩ·cm resistivity
Version B limited by leakage current

CCPD_LF: Fe^{55} spectrum



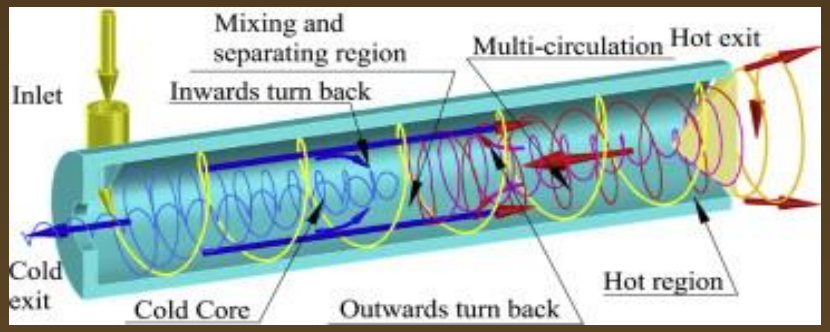
Good response to X-rays

Test-beam at DESY

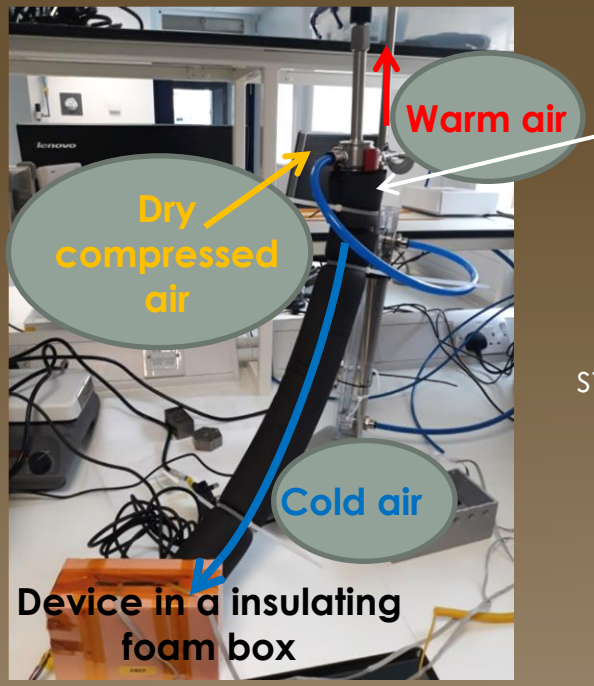
- New AIDA2020 project involving Oxford
  - Identifier: AIDA-2020/DESY/2018/01
- Test beam at DESY
  - From 19/02/2018 to 04/03/2018 (2 weeks)
  - CMOS devices
    - 2 not irradiated LF-CPIX
    - 2 Irradiated LF-CPIX
    - 1 TowerJazz not irradiated Investigator1
  - Novel cooling system
  - Alternative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

Novel cooling system

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



Y. Xue, M. Arjomandi, R. Kelso, "The working principle of a vortex tube", International Journal of Refrigeration, volume 36, 2013, pages 1730 - 1740, https://doi.org/10.1016/j.ijrefrig.2013.04.016



Vortex cooler

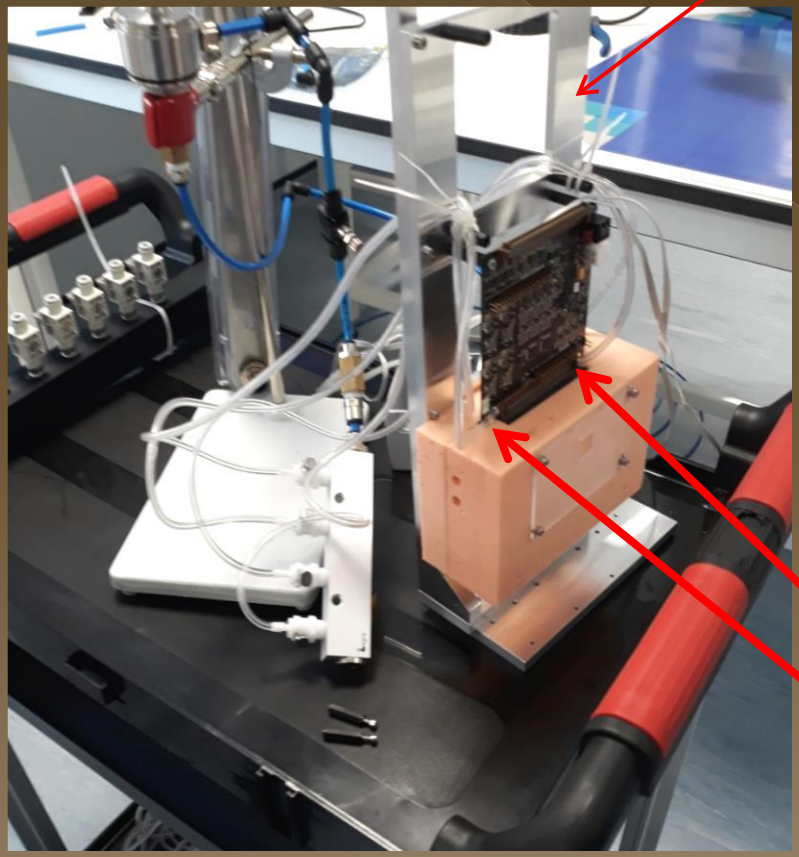
System tested in the lab:
-21 C at 6 bars, stable for an hour.

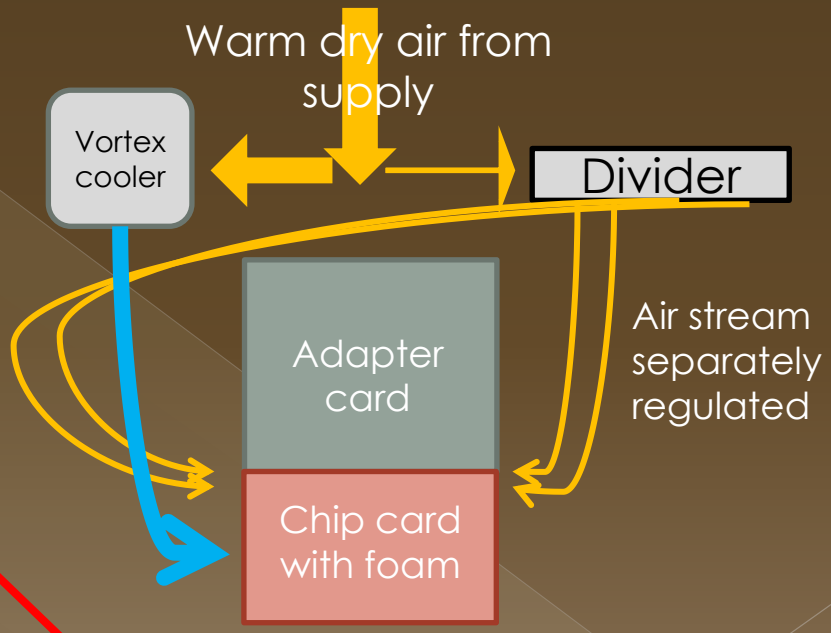
Required a dedicated air compressor in DESY.

Novel cooling system

- Details

Telescope mounting brackets

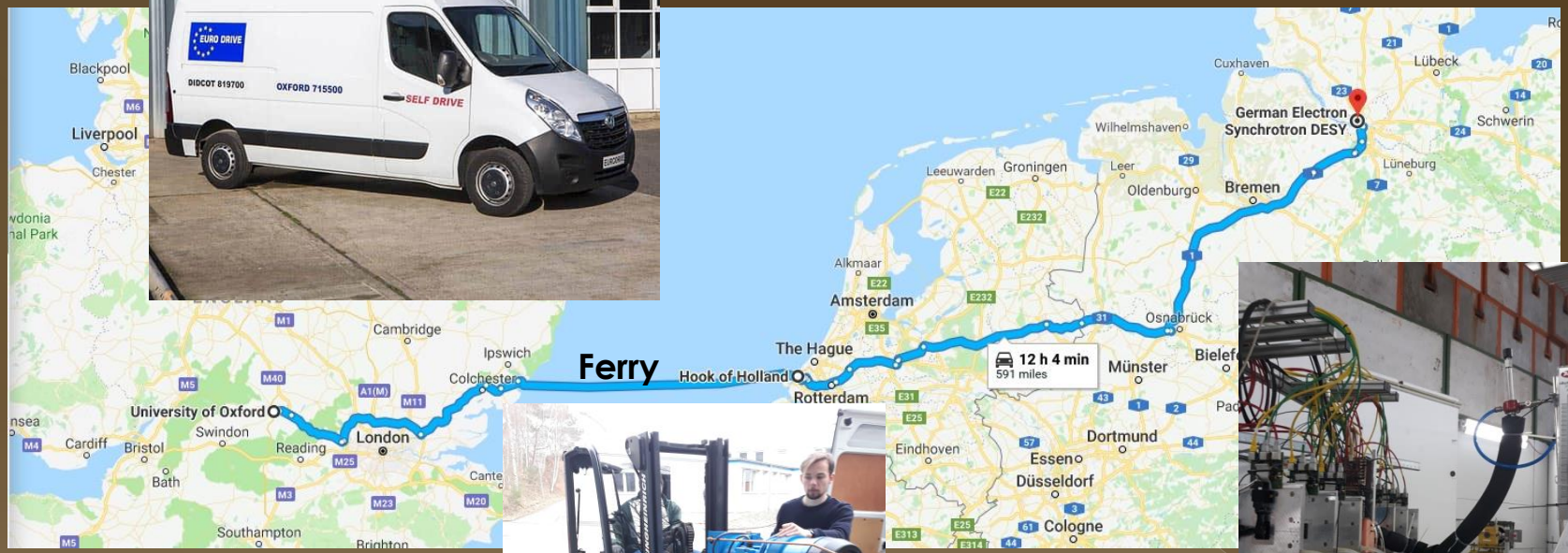




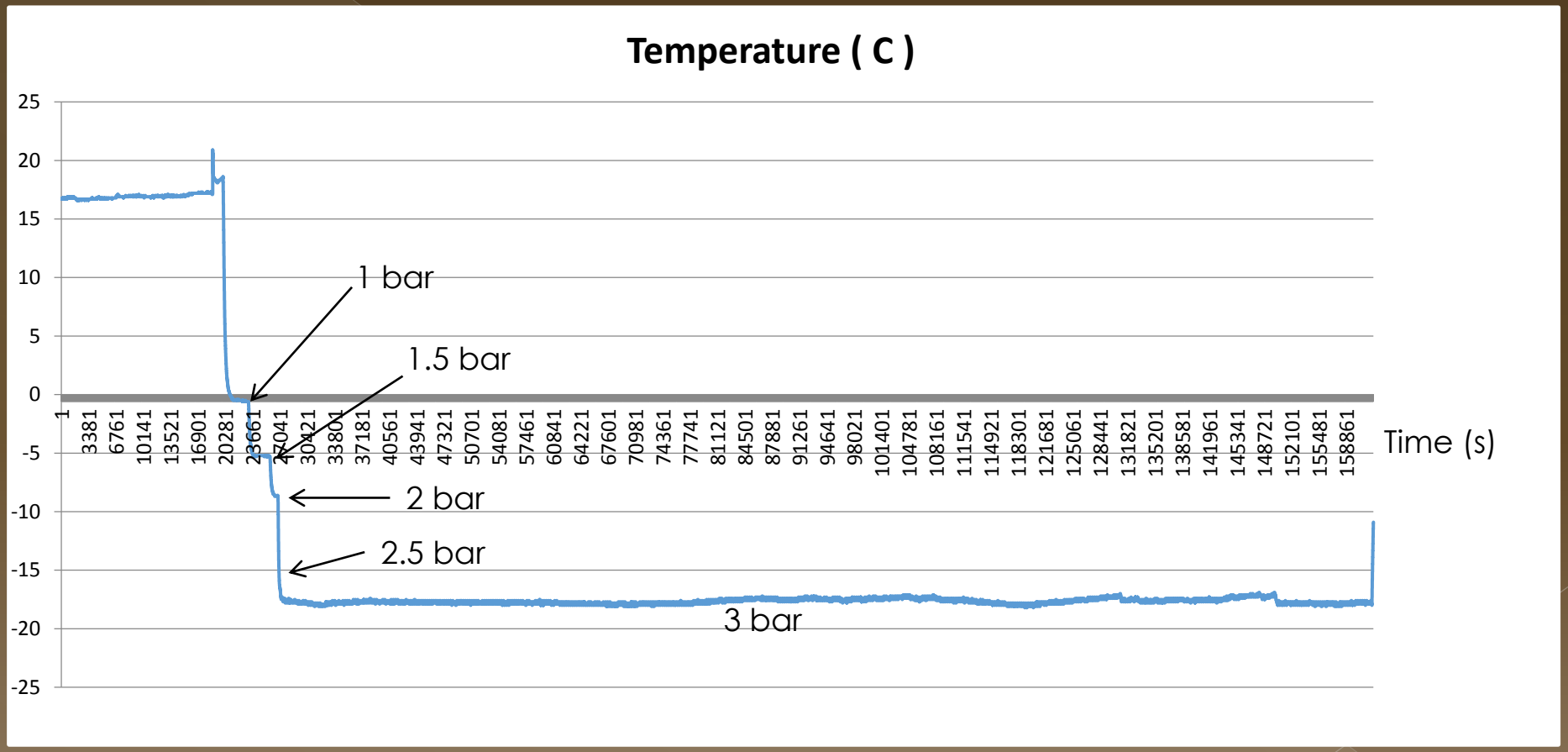
4 tubes provide warm dry air between adapter and chip card

Moving and installation in DESY

Van required to move the air compressor and the equipment



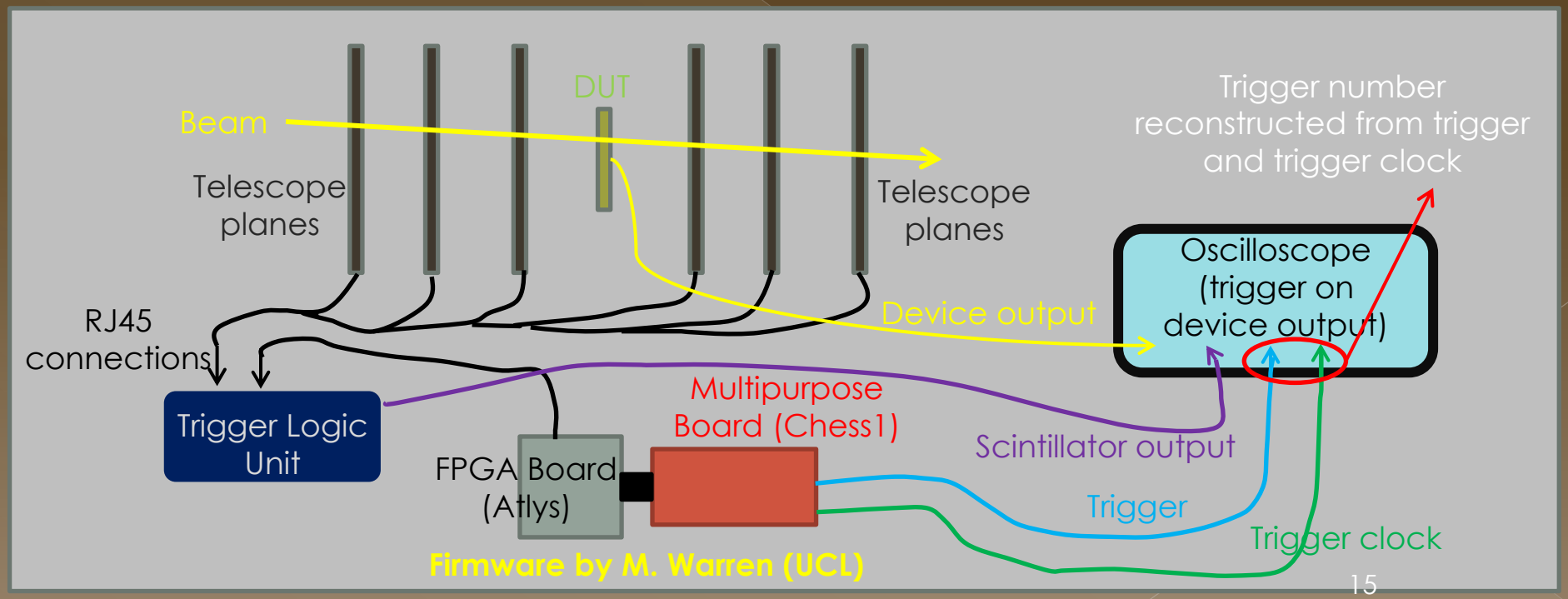
Performance



Cooling system for ~36 hours at 3 bar reaching -17.5 C

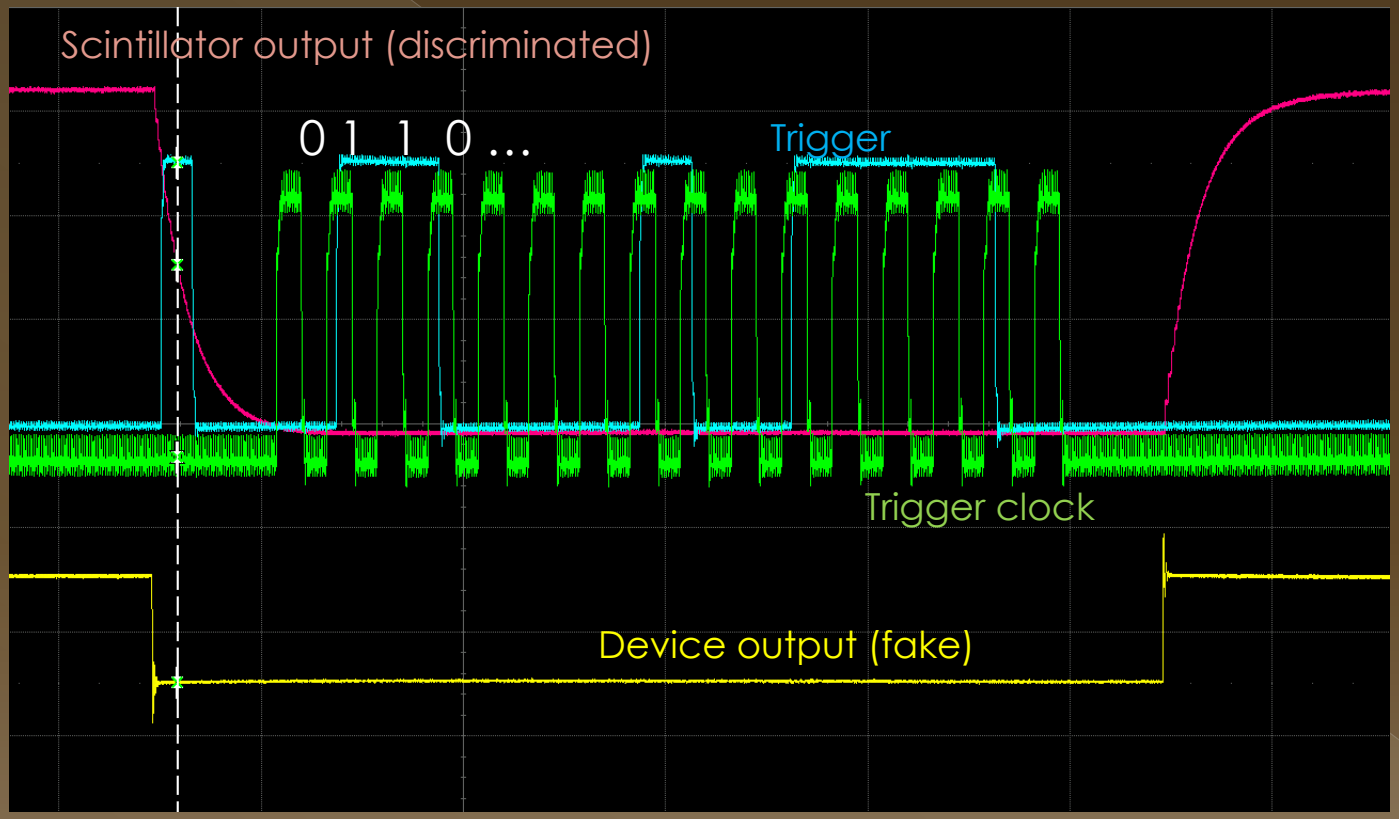
Alternative synchronization

- 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



Alternative synchronization

Oscilloscope channels



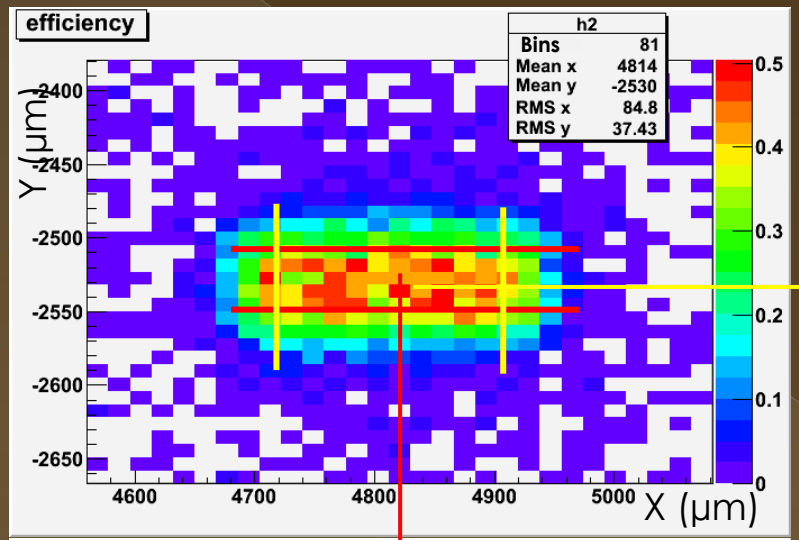
From the comparison of the trigger and trigger clock lines one obtains the trigger number to associate with the track.

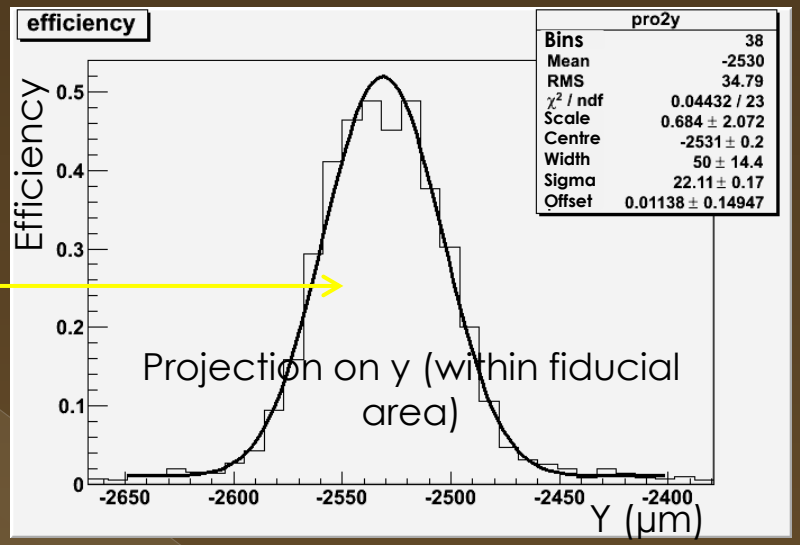
Scope triggered independently from telescope: no integration with EUDAQ needed

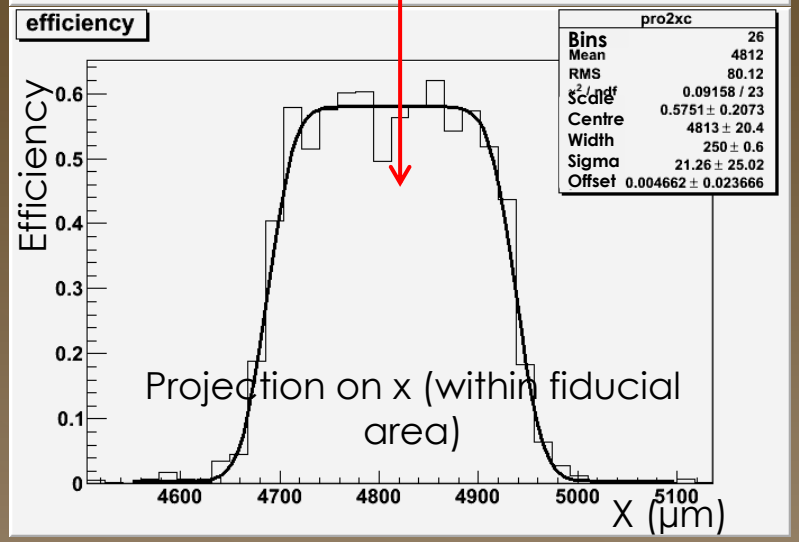
- Simple and easy (one firmware + python scripts)
- Timing provided by oscilloscope
- Slow: depends on scope driver for saving the channels
  - With one channel investigated (50x250 μm^2) low rate (3 Hz)

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)

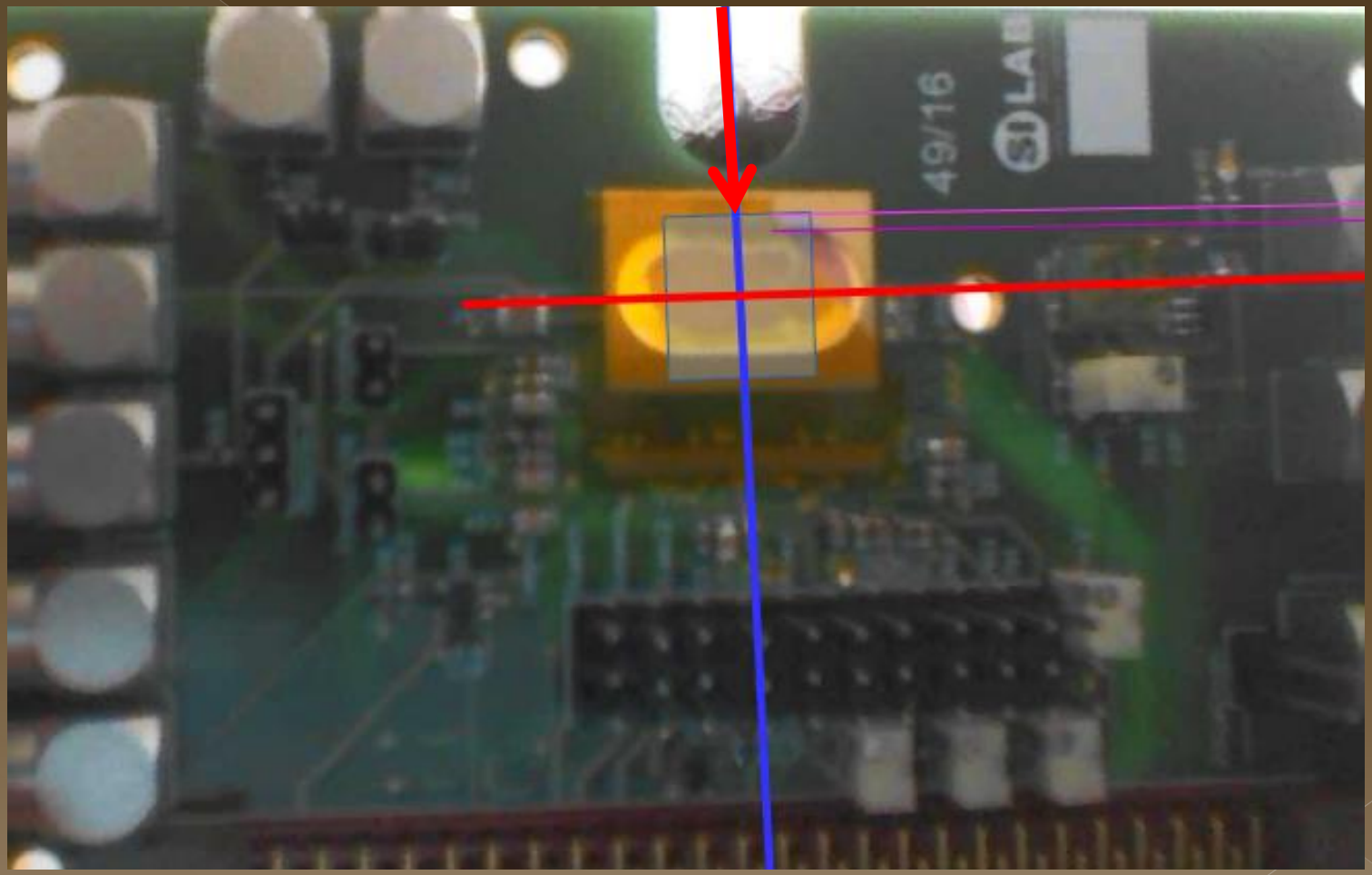
Efficiency (scale factor) very low…

To do: reconstruction must be improved using all planes!

Conclusions

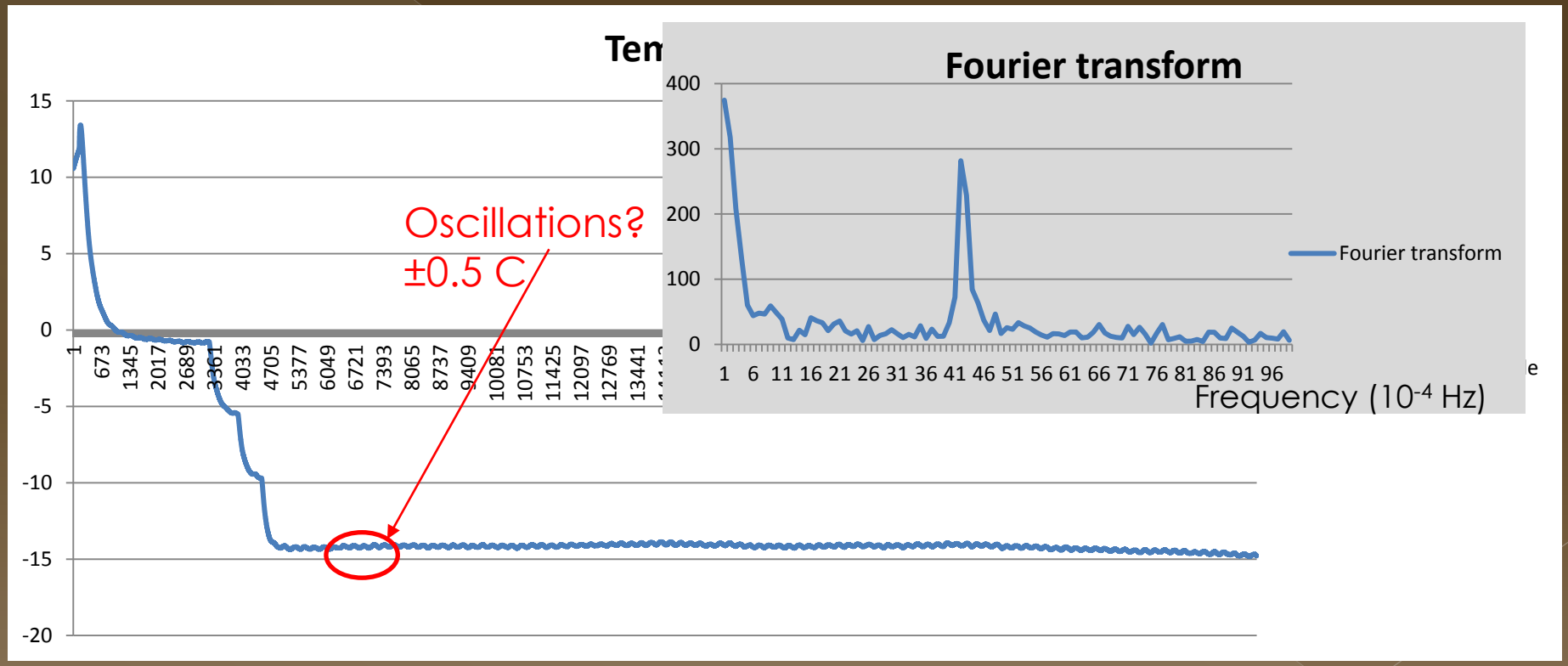
- Many CMOS activities in Oxford
- Several devices under study
  - Lfoundry
  - TowerJazz
- Many tests performed (AIDA2020 support)
  - Edge-TCT
  - Irradiation
  - Test beam

Backup: LF-CPIX board



Back-up: cooling system

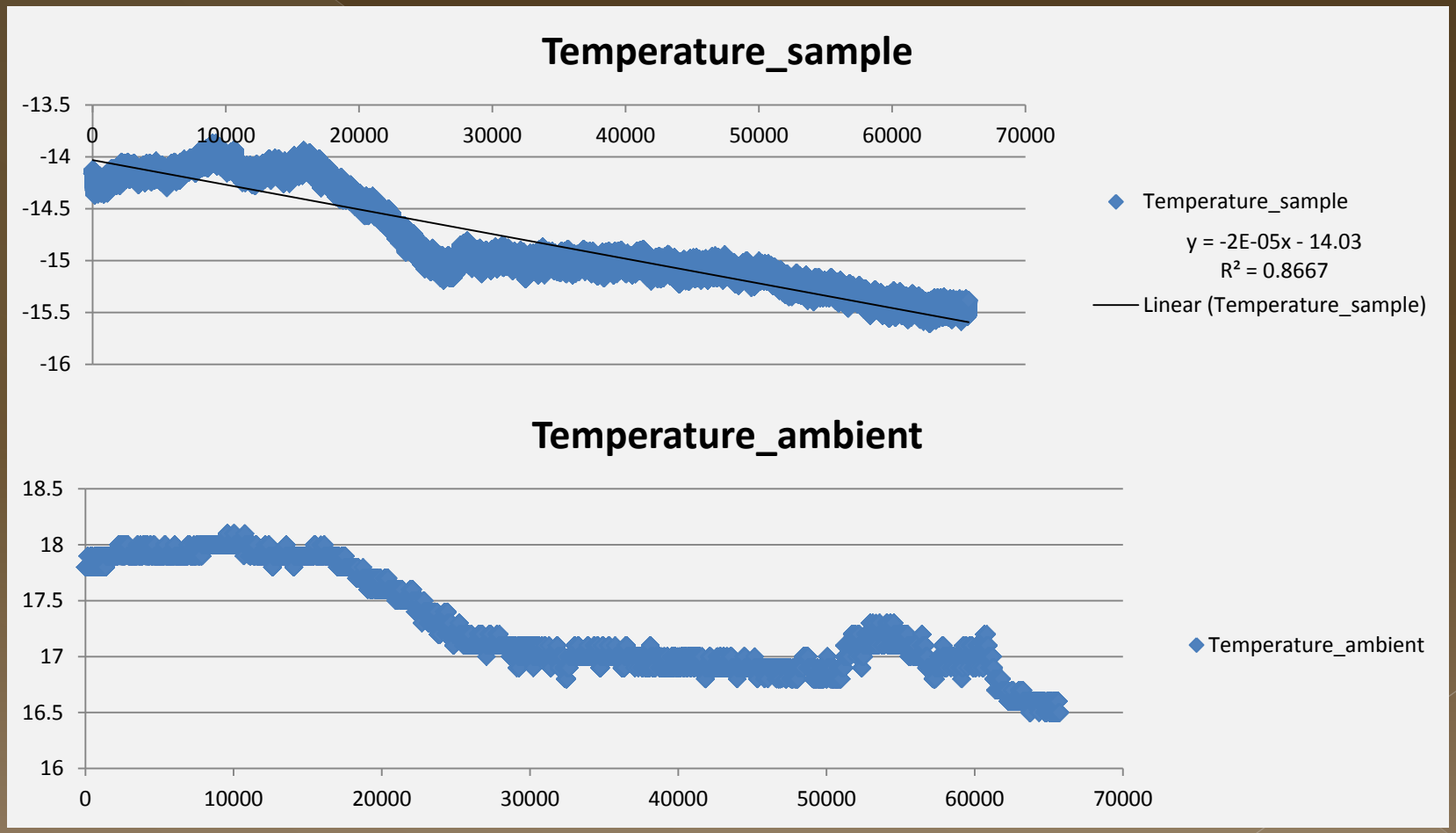
- Performance details: oscillations



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!

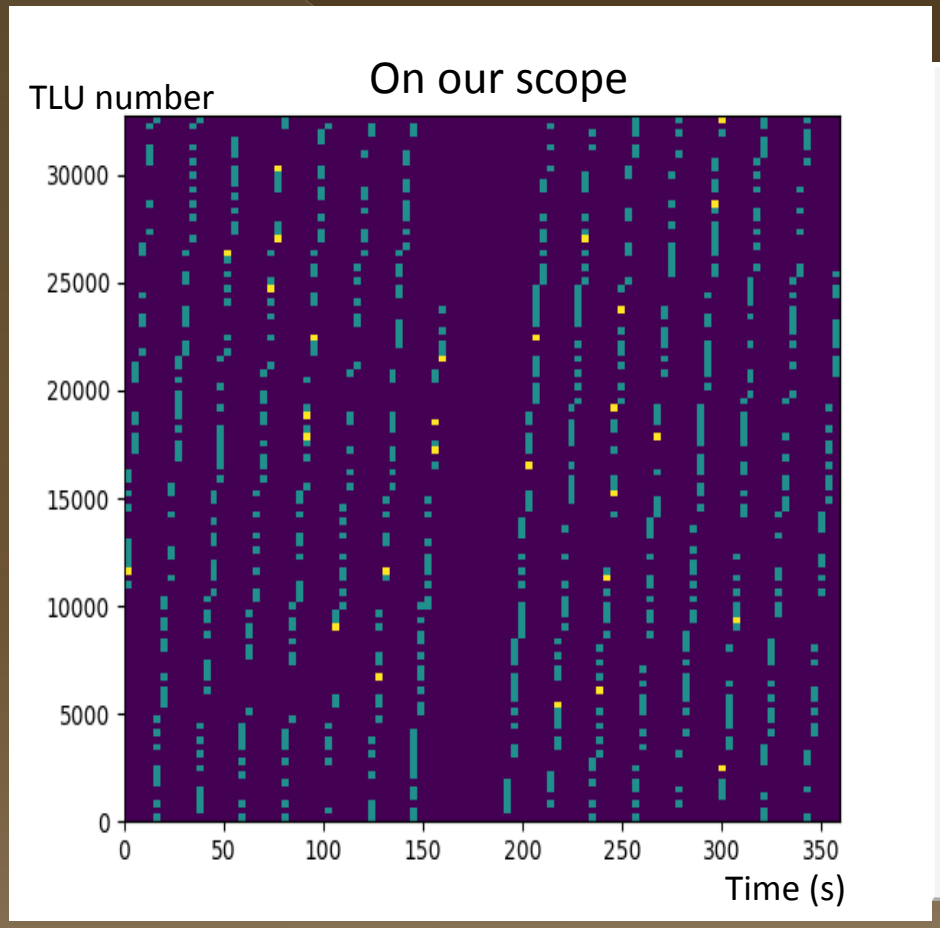
Back-up: cooling system

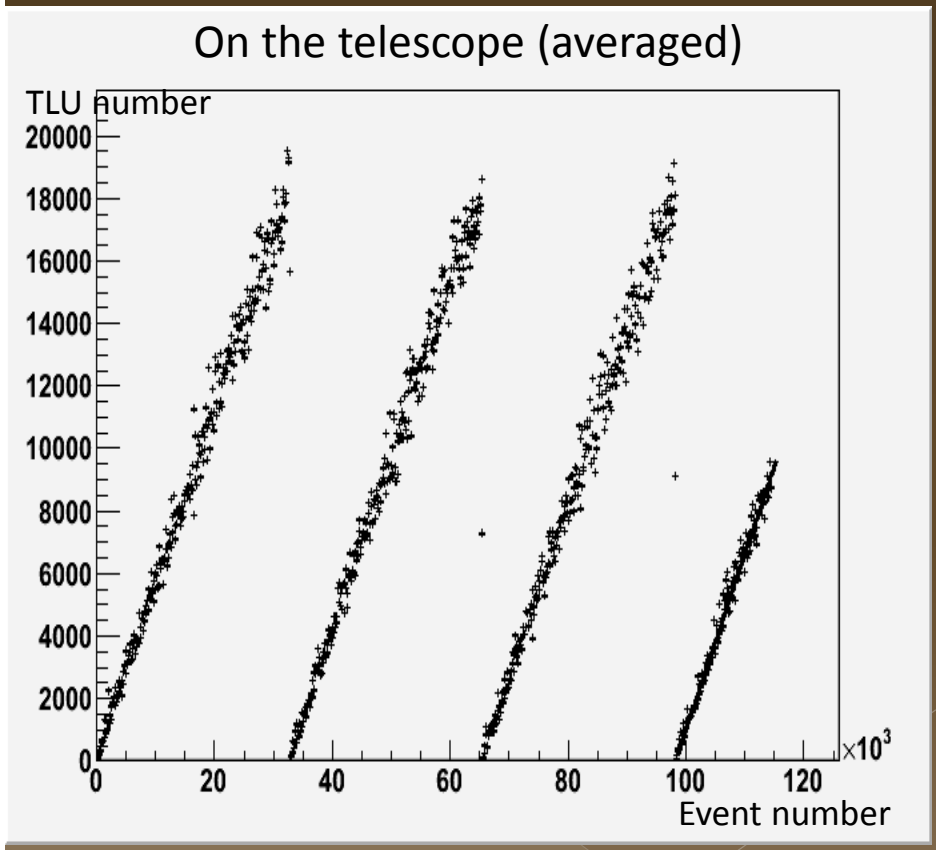
- Performance details: external temperature



Same trend as ambient temperature: day and night variation! (1.5 C)

Backup: Telescope sync



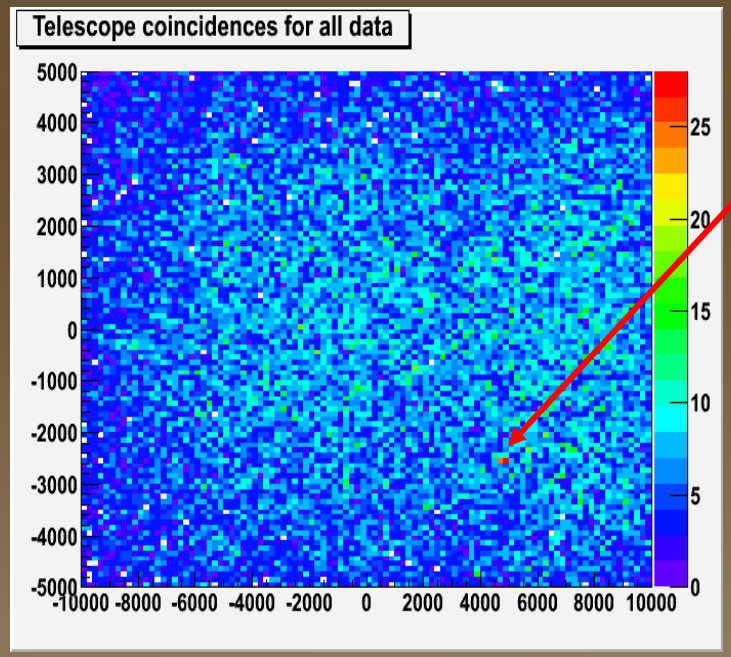


We have to match the TLU numbers within a refreshment cycle (every 2^{15} events).

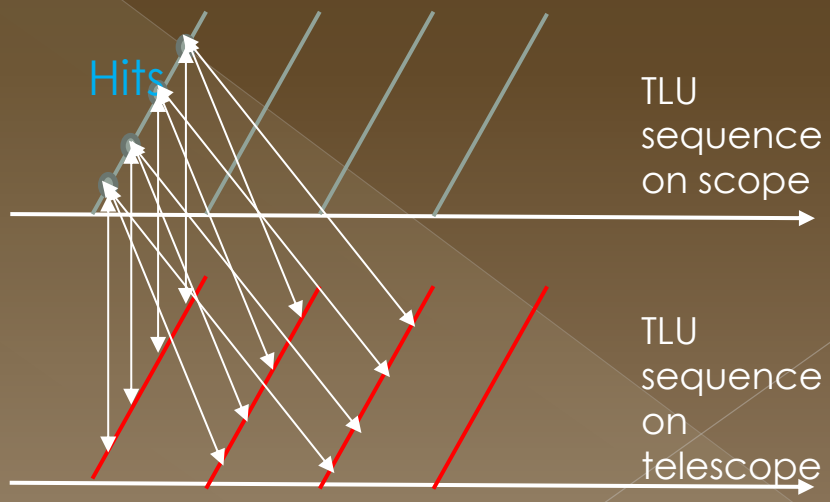
Backup: Telescope sync

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

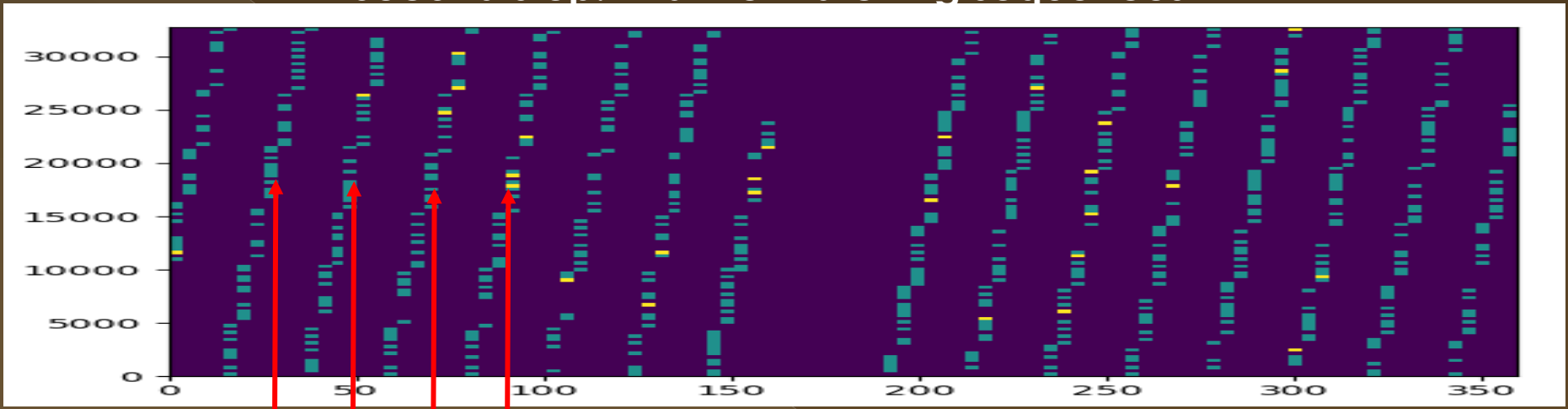


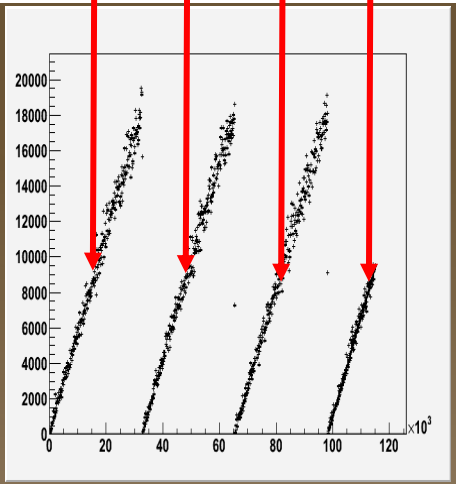
Pixel??



Backup: Telescope sync

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