AIDA-2020-SLIDE-2019-004

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Presentation

LYCORIS, a large area strip telescope for the DESY test beam

Wu, Mengqing (DESY)

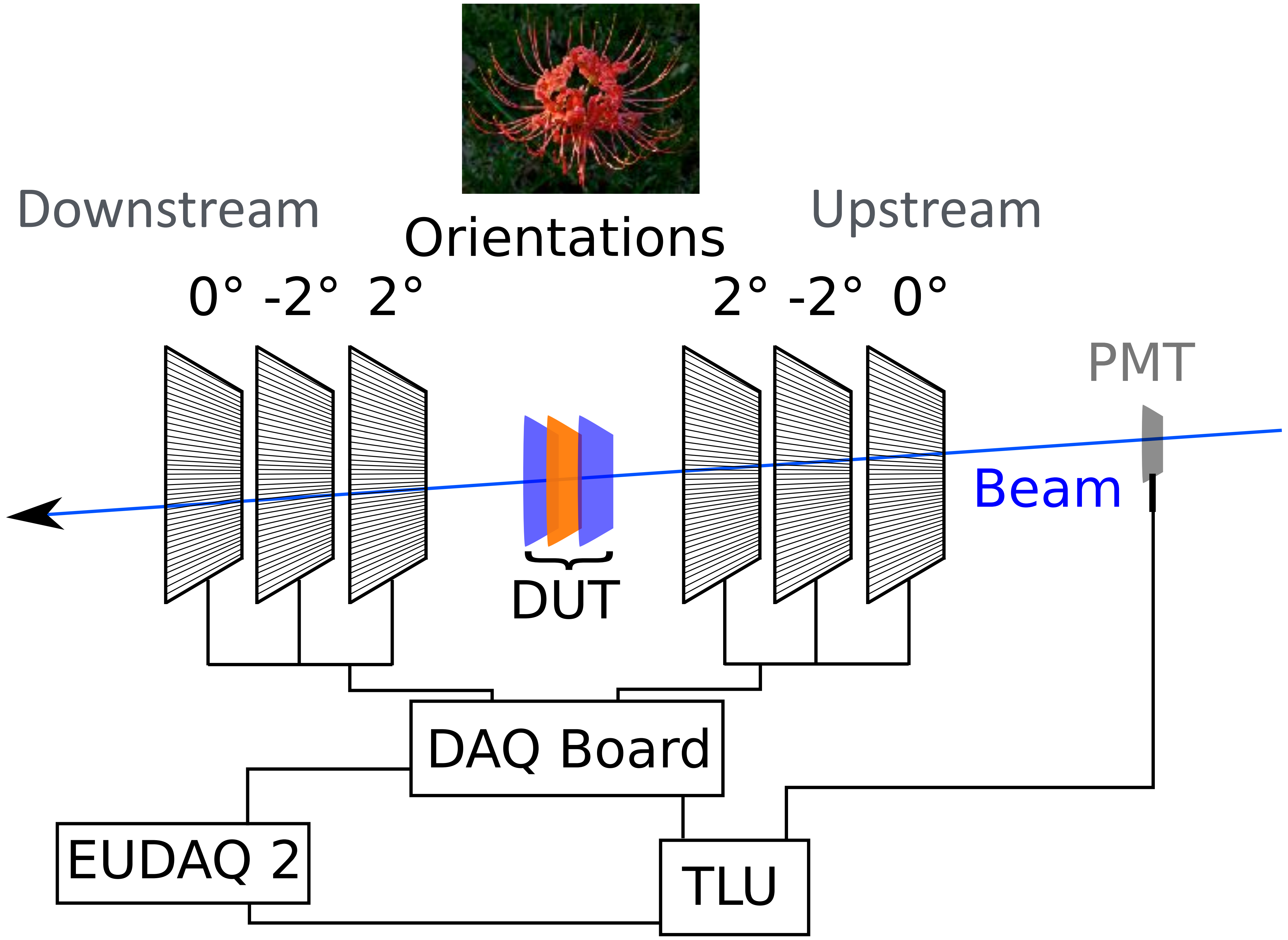
29 May 2018

The AIDA-2020 Advanced European Infrastructures for Detectors at Accelerators project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

This work is part of AIDA-2020 Work Package **15: Upgrade of beam and irradiation test infrastructure**.

LYCORIS, a large area strip telescope for the DESY test beam

Wu, Mengqing, DESY
on behalf of the LYCORIS telescope team



ALCW2018, Fukuoka
May 29, 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

AIDA 2020 DESY TEST BEAM. SLAC NATIONAL ACCELERATOR LABORATORY DESY.

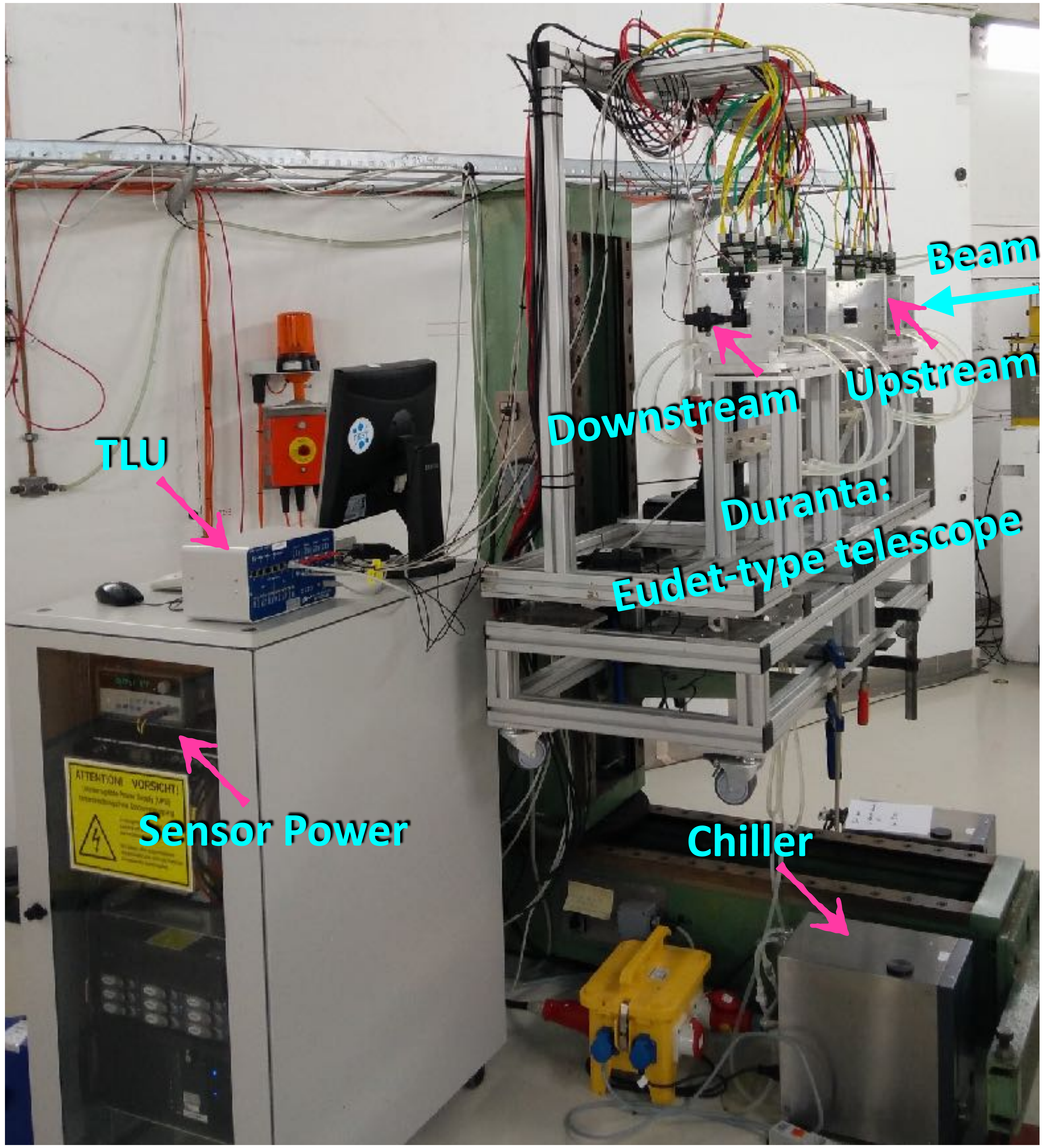
Beam Telescopes at DESY

Telescope Concept Intro:

- Infrastructural Tool **for detector R&D,** user like ATLAS/CMS and etc;
- Provide **reference track** for the Device Under Test (DUT), required:
  - Good spatial resolution;
  - Low material budget;

EUDET-type Telescope: Mimosa26 based (7 worldwide, 2 at DESY)

- **Hardware**: 6 sensor planes
  - Find pitch of 18.4 µm → a resolution of 5.3 µm;
  - Low material budget → 50 µm thick.
- **Trigger Logic Unit** (TLU)
- **DAQ software: EUDAQ**
  - TLU & many users integrated
- **Recon. software: EuTelescope** w/ GBL implemented;
  - Based on ILCSoft : LCIO, Gear, Marlin;
  - Various DUTs integrated, e.g. ATLAS ITKStrip;



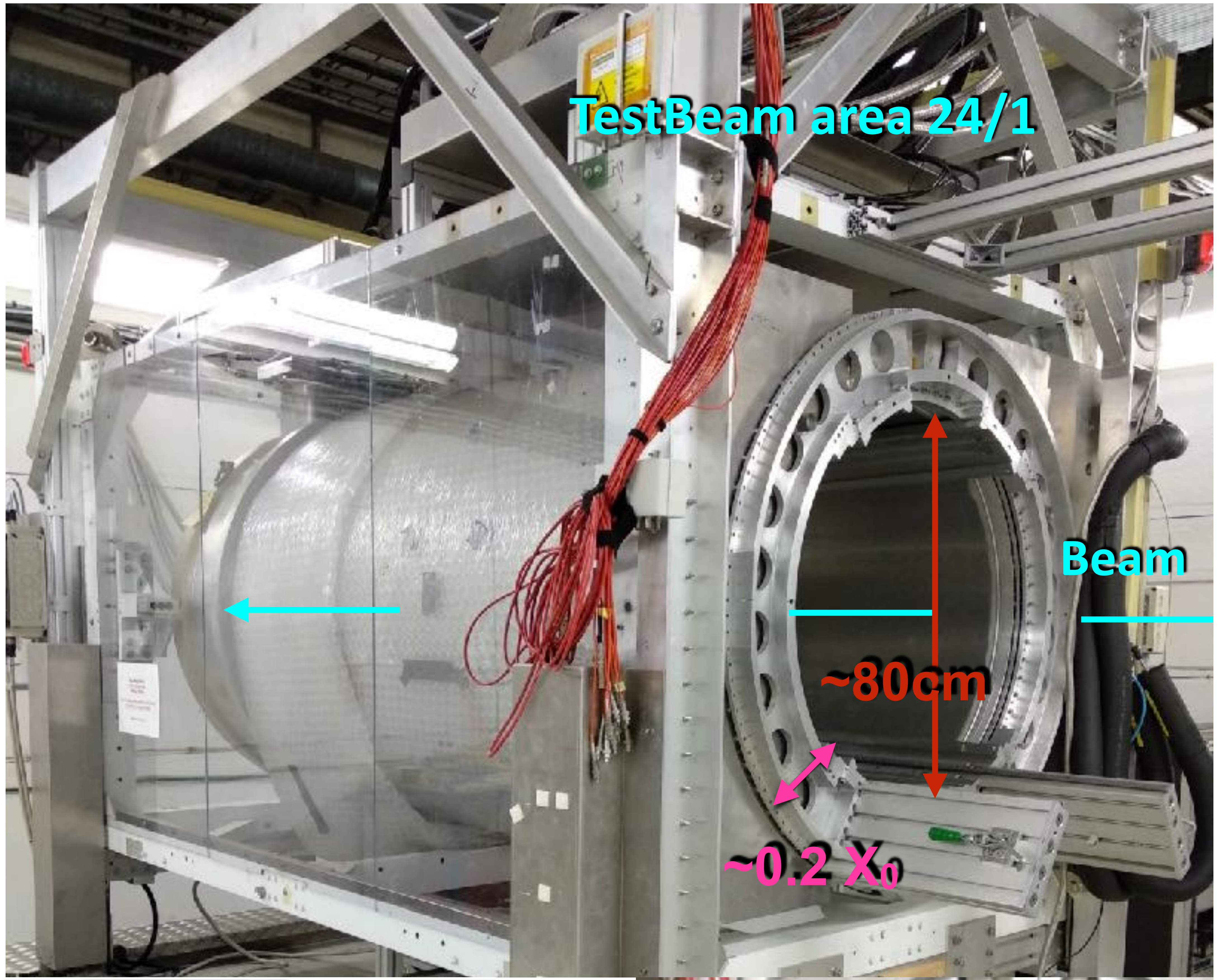
Beam area T24/1 at DESY

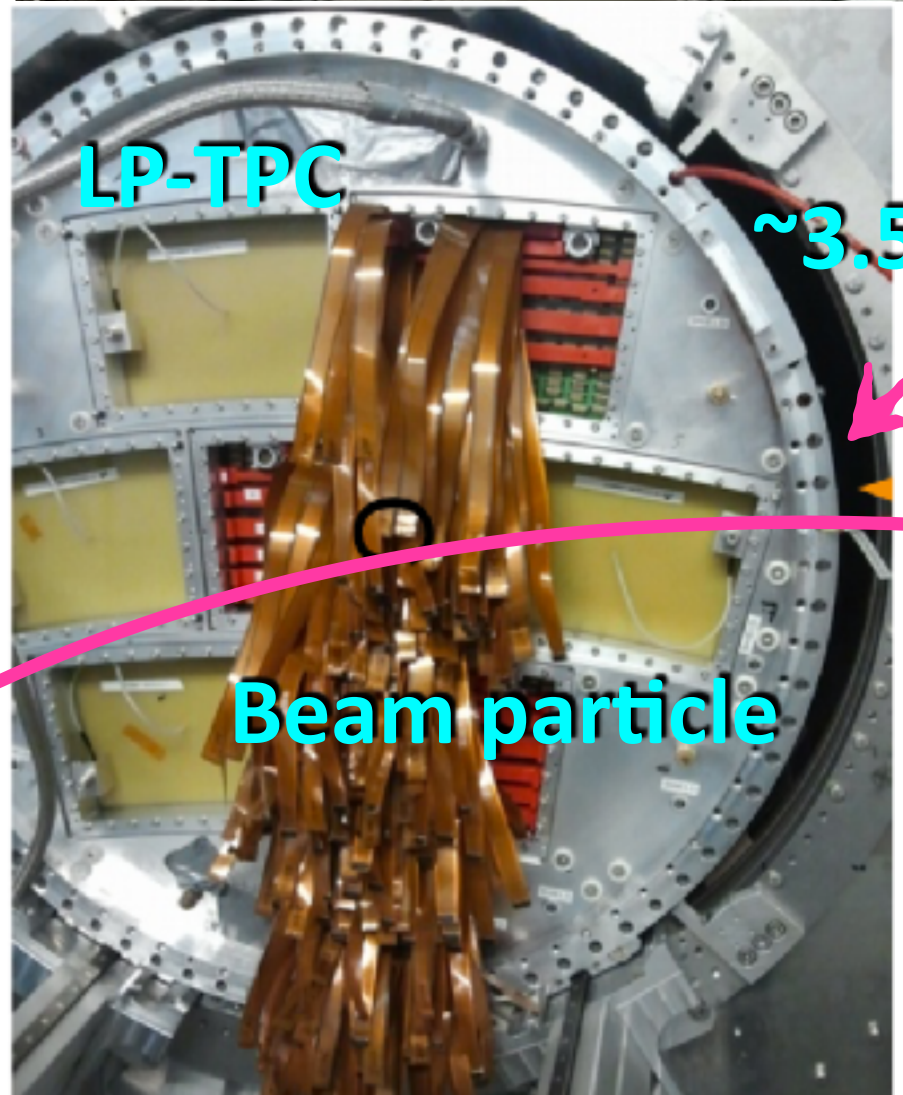
A 1T solenoid, PCMAG

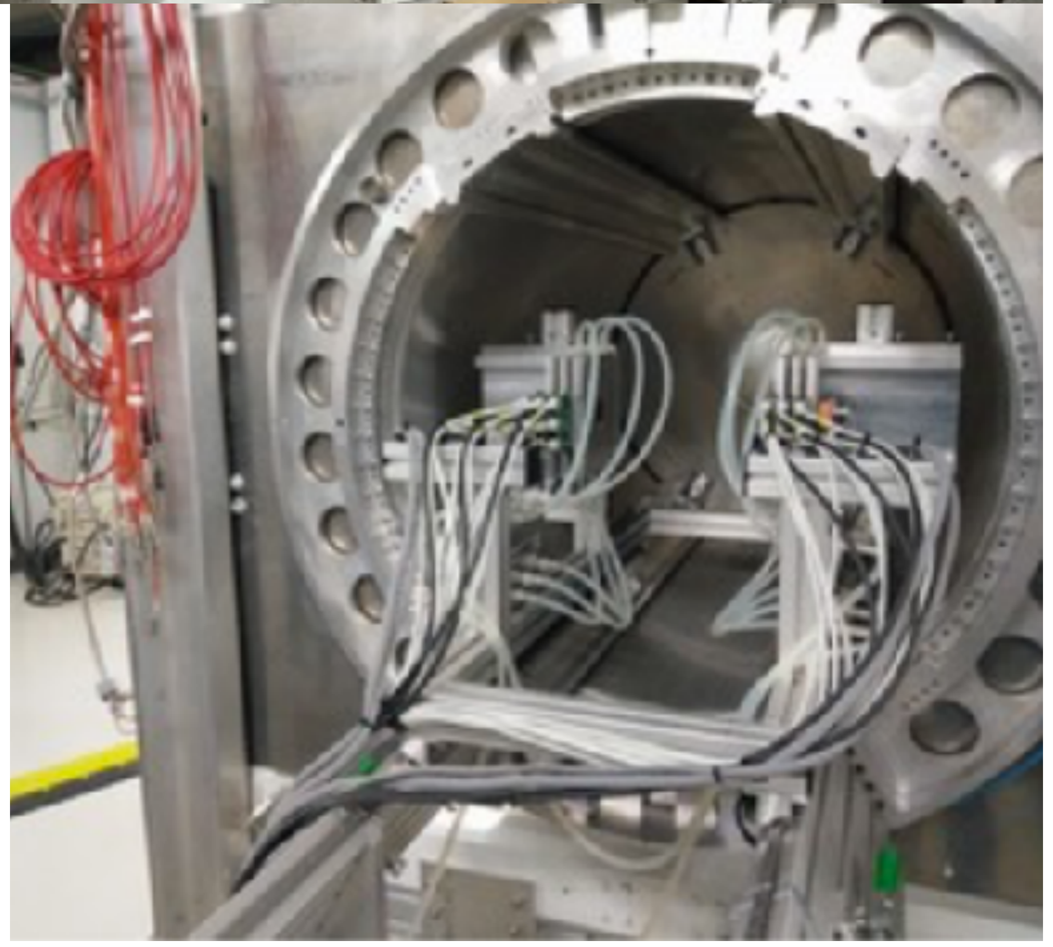
- Equipped with a **1 T Solenoid** to put DUT inside:
  - Wall material budget **0.2 X_0** (momentum smearing)
  - Possible to install a EUDET telescope (small DUT)

However, **not cover use cases** that needs:

- **Momentum measurements** inside the PCMAG, requiring a large active area for curvature covering;
  - EUDET-type: small active area: 1x2 cm^2;
- For **large DUT**, such as a LP-TPC: Limited space (~3.5 cm) left for telescope;
  - EUDET-type: high amount of channels → dedicated water cooling; support structure demands a lot space;
- For users who want **higher event rate**:
  - EUDET-type: relatively slow integratioin time (~100 µs)



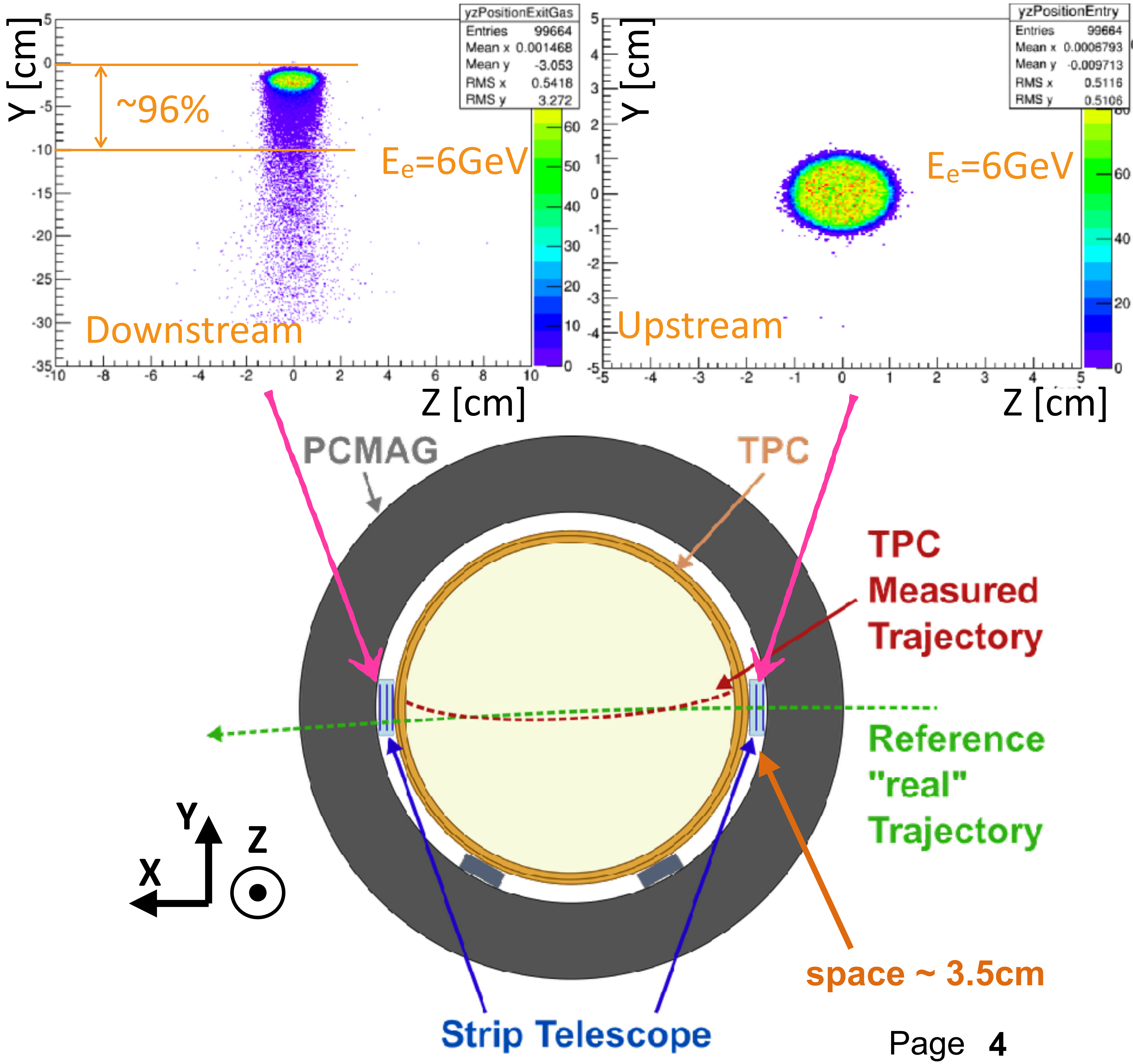




A new telescope to address the user demands

Funded by AIDA2020, in collaboration w/ SLAC

- **Target**: Build a new large area strip telescope (LYCORIS) in beam area 24/1:
  - movable, suitable for large DUT in the 1T solenoid;
- **Status:** R&D currently;
- Design requirements to address the user demands:
  - Large active area (**10 x 10 cm²**) → **90 - 96%** particles (1 - 6 GeV);
  - Support in a thickness of **~3.5 cm** to cover the first large DUT case (LP-TPC);
  - Momentum measurements: spatial resolution better than **10 μm** along **bending direction Y**;
  - Resolution along **field direction Z** less important: **σ_Z > 1 mm**



LYCORIS Design Overview: the SiD strip sensor

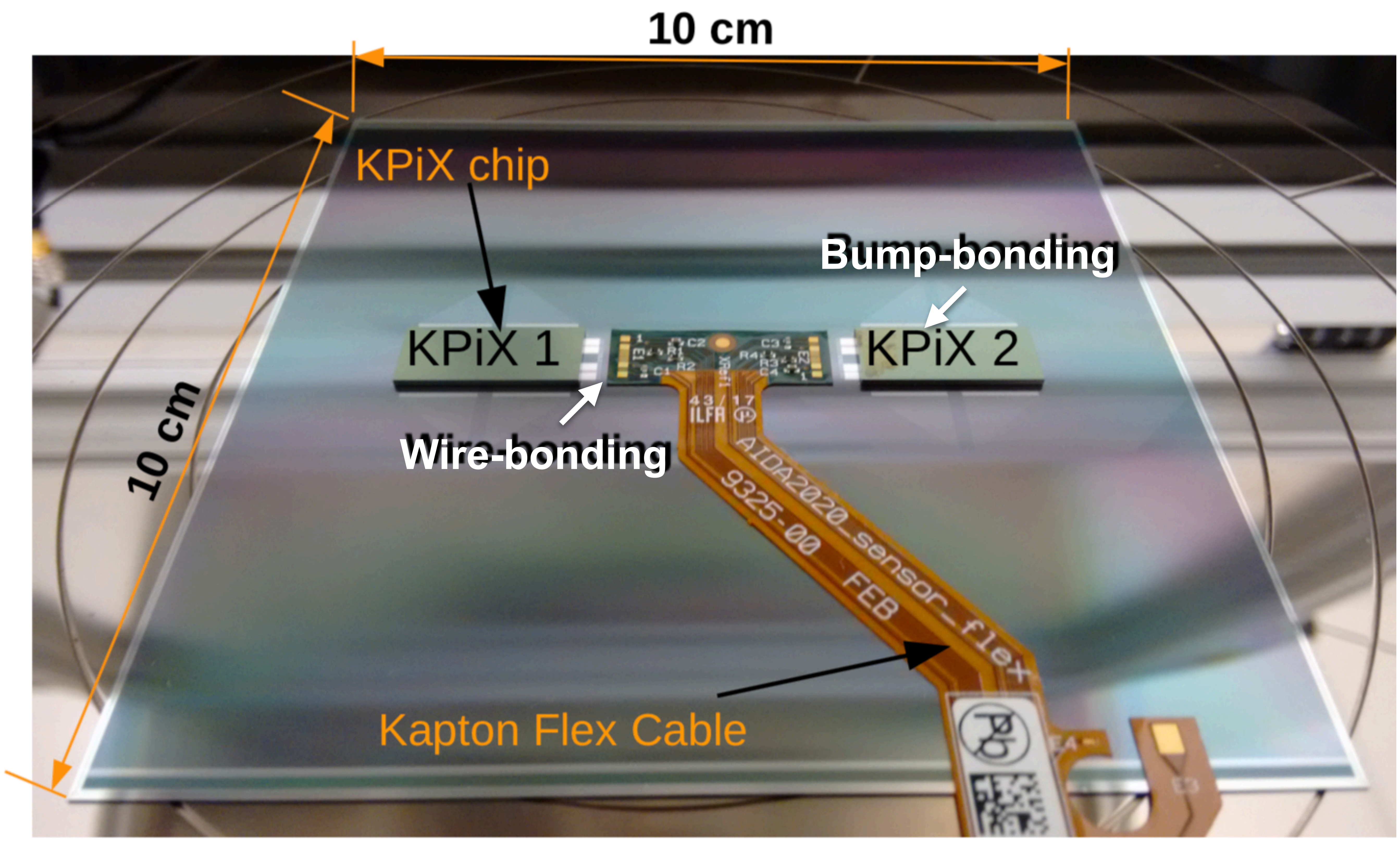
Designed by SLAC for an ILC environment

Strip Silicon Sensor

- Size of **10 x 10 cm²**;
- Thickness of 320 μm → **0.3% X_0**;
- Pitch of **25 μm**, thus hit resolution **~7.2 μm**;
- Alternate strips readout.

Readout & way to power

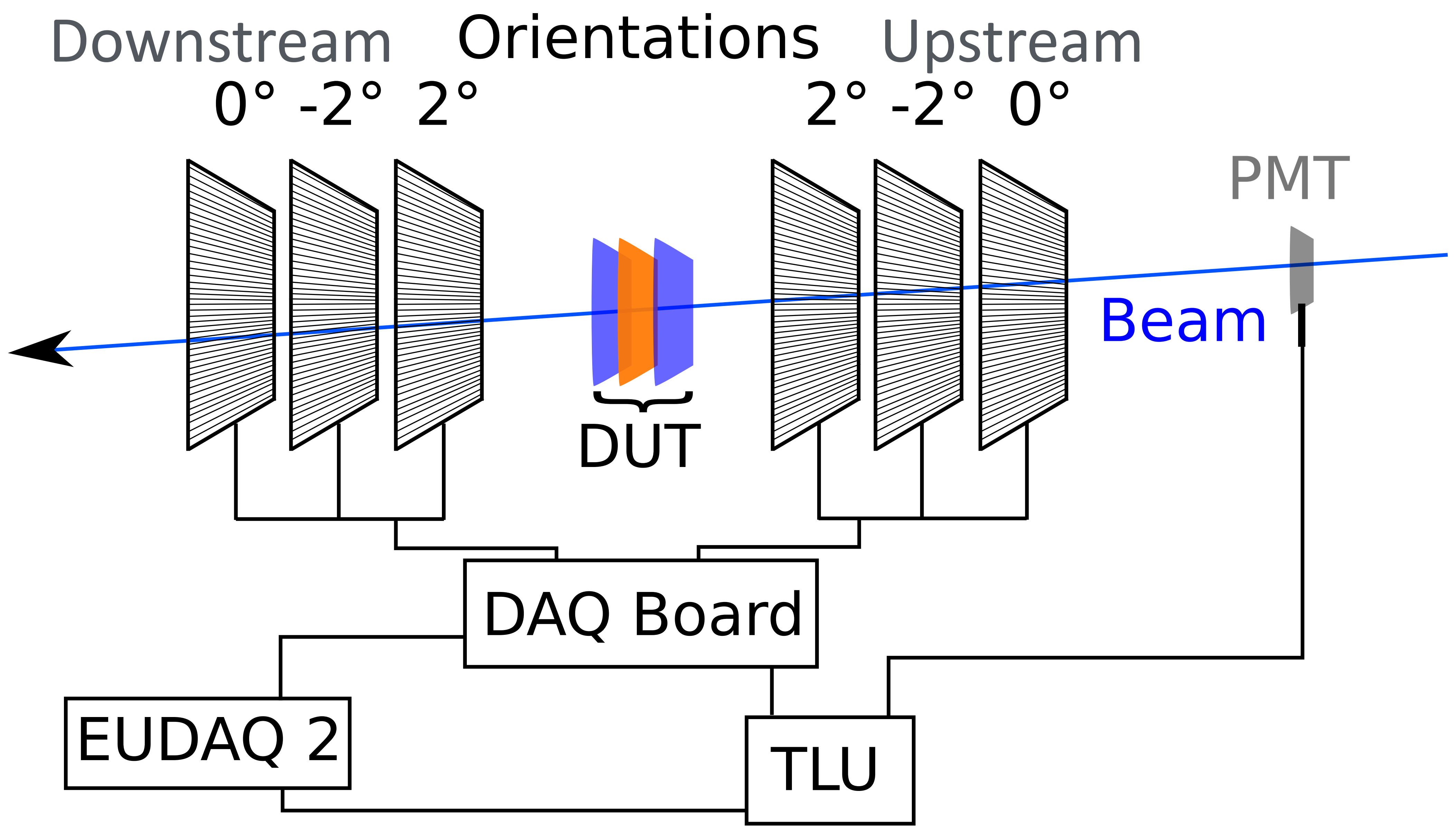
- An integrated (bump-bonding) pitch adapter and digital readout ASIC: **KPiX**;
- A Kapton Flex Cable glued (Araldite2011) + wire-bonded to the sensor
  - Provide **bias voltage** to the sensor;
  - KPiX is **communicated/powered** via it.

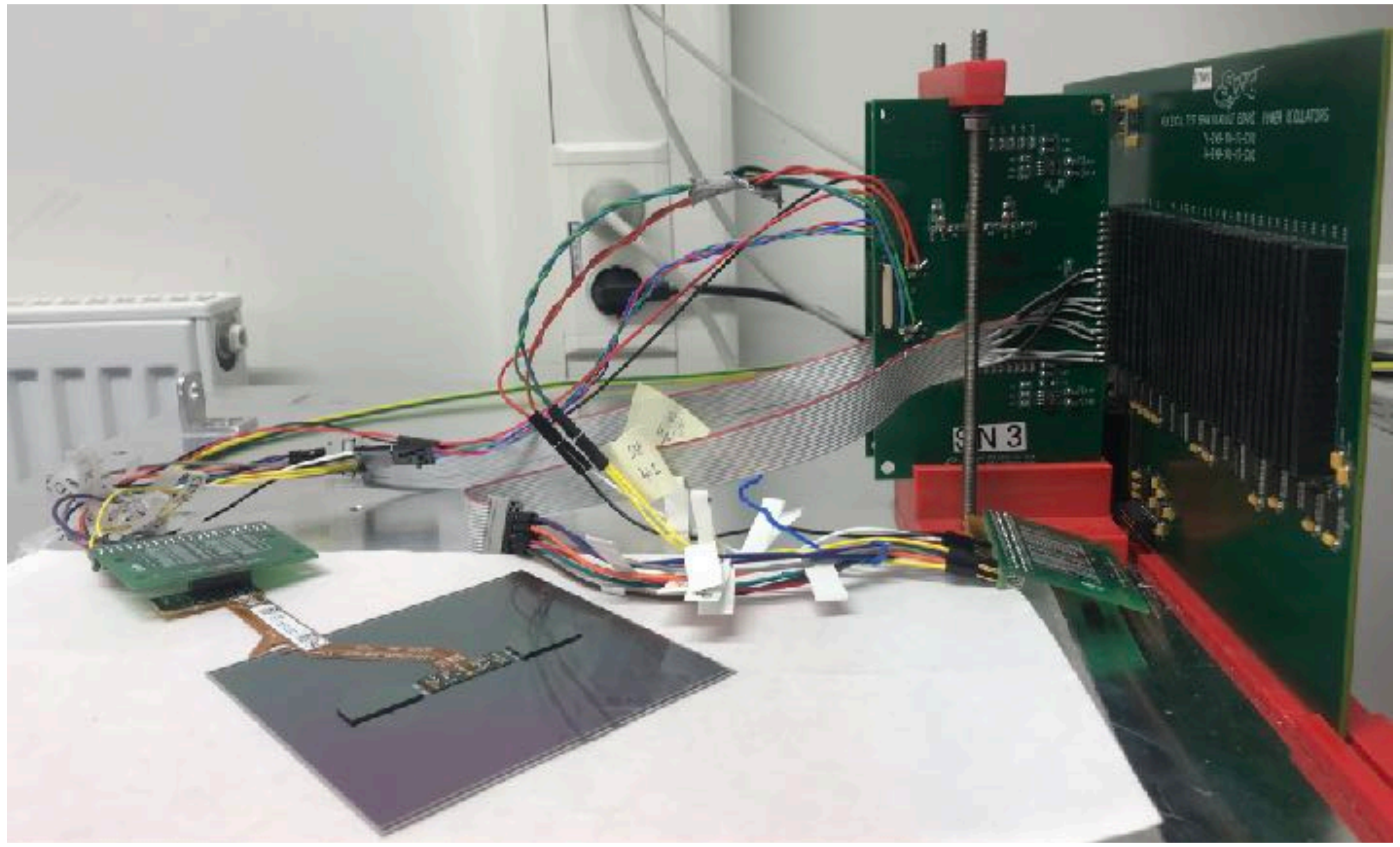


LYCORIS Design Overview: Data Acquisition

Choose a common DAQ, EUDAQ2

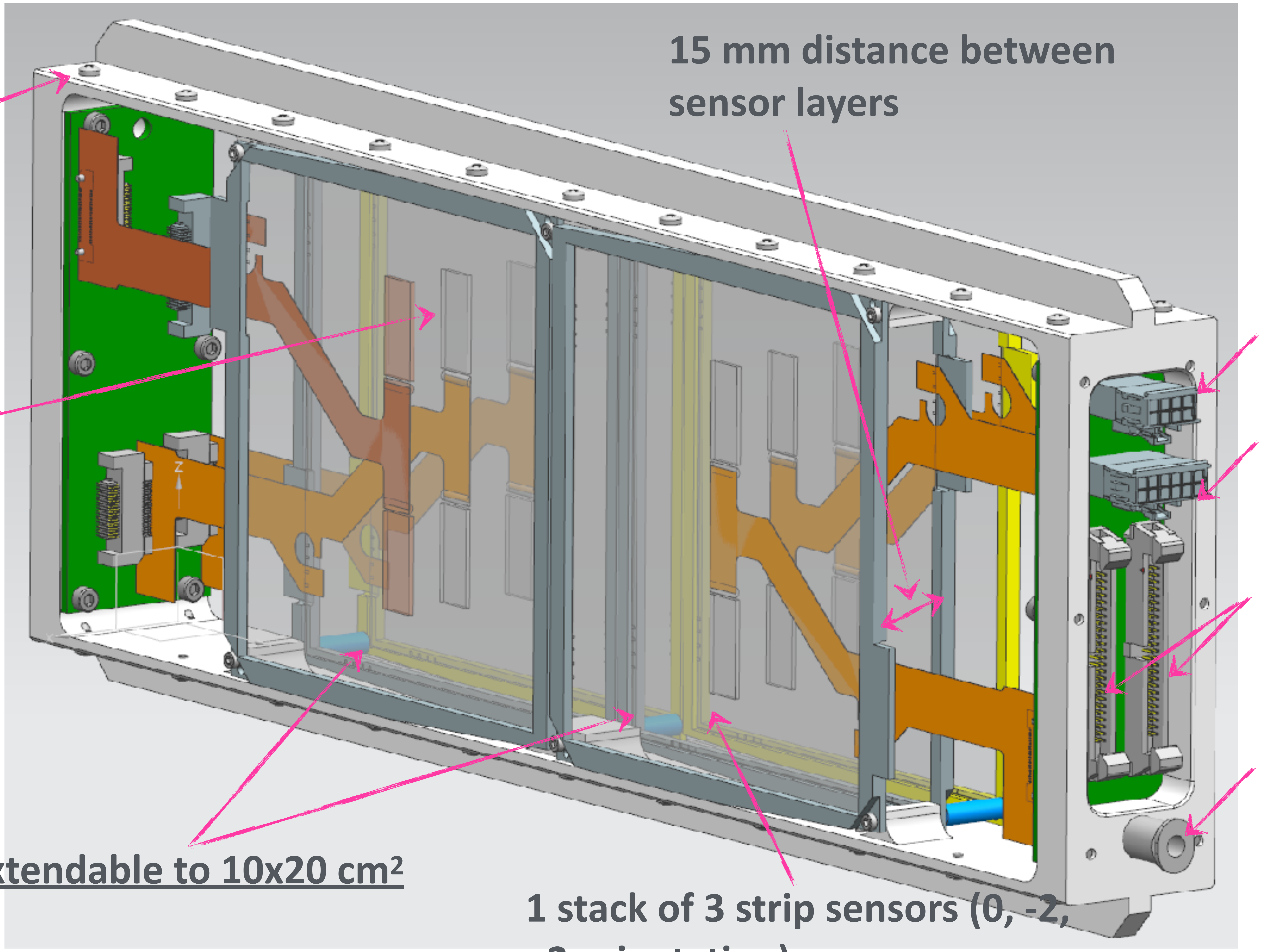
- KPiX runs in pulse cycles, max. 4 evts/channel/cycle;
- Run control by EUDAQ2, implemented via a DAQ board;
- Data Acquisition:
  - **In** each **cycle**, once a particle passing through:
    - PMT triggered → TLU sent trigger to DAQ board
    - Trigger sent to all connected KPiX: ADC count on all activated channels recorded by KPiX;
  - **End** of a **cycle**:
    - digitize recorded KPiX data and send to DAQ board,
    - DAQ board pack & send to EUDAQ2 via optic fibre.





LYCORIS Design Overview

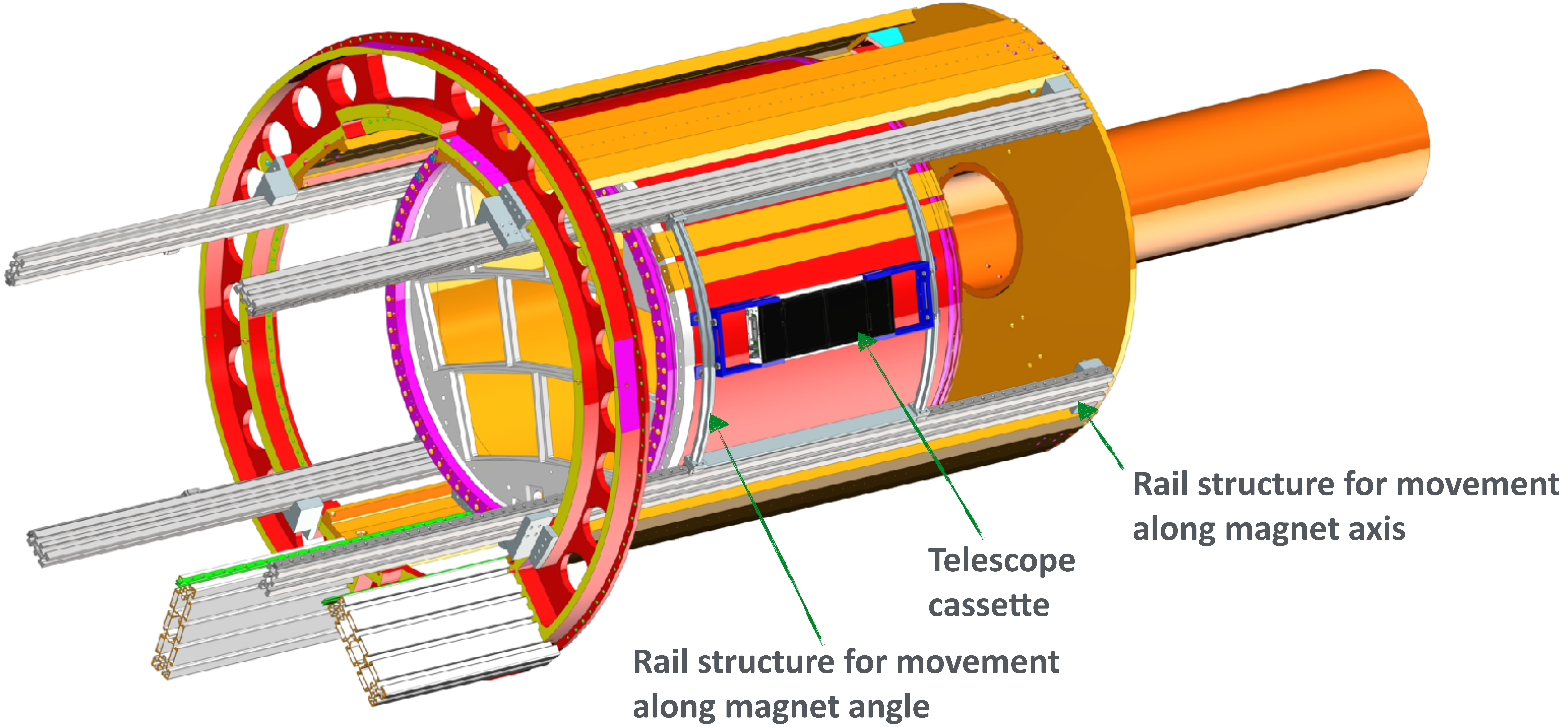
Sensor downstream holder (mirror symmetric to the upstream)



<u>Final active area extendable to 10x20 cm²</u>

LYCORIS Design Overview

Magnet telescope structure



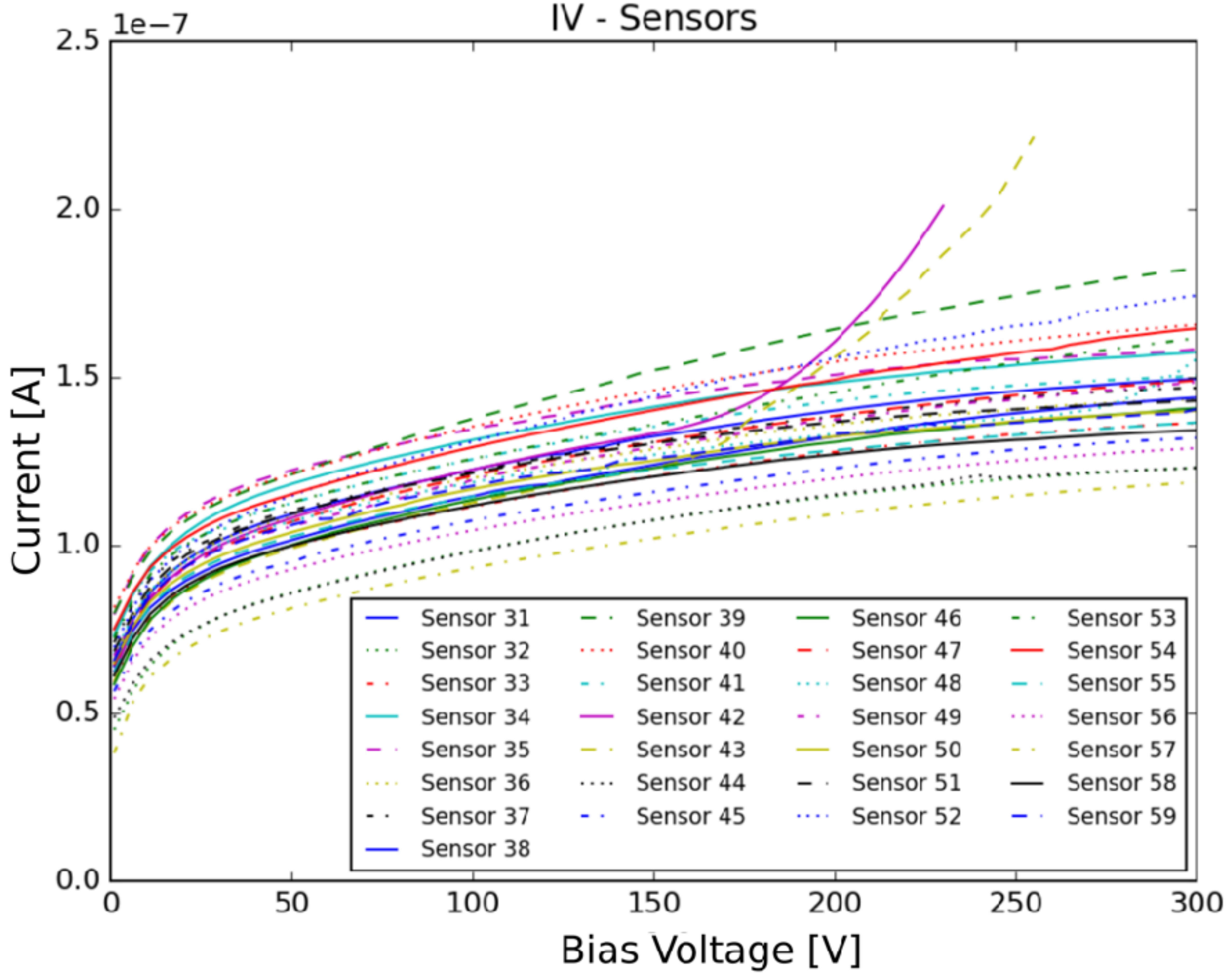
SiD Strip Sensor

The SiD strip sensor: IV/CV curves

Sensor characterization

Timeline

- **Nov 2016**: ordered at Hamamatsu
- **July 2017**: sensor arrived
  - IV/CV curves ~ Sep 2017
    - **Good behaviour**:
      - ~100 nA currents and stable up to 300V;
      - Two sensors show the beginning of a breakdown around 280V.



The SiD strip sensor: IV/CV curves

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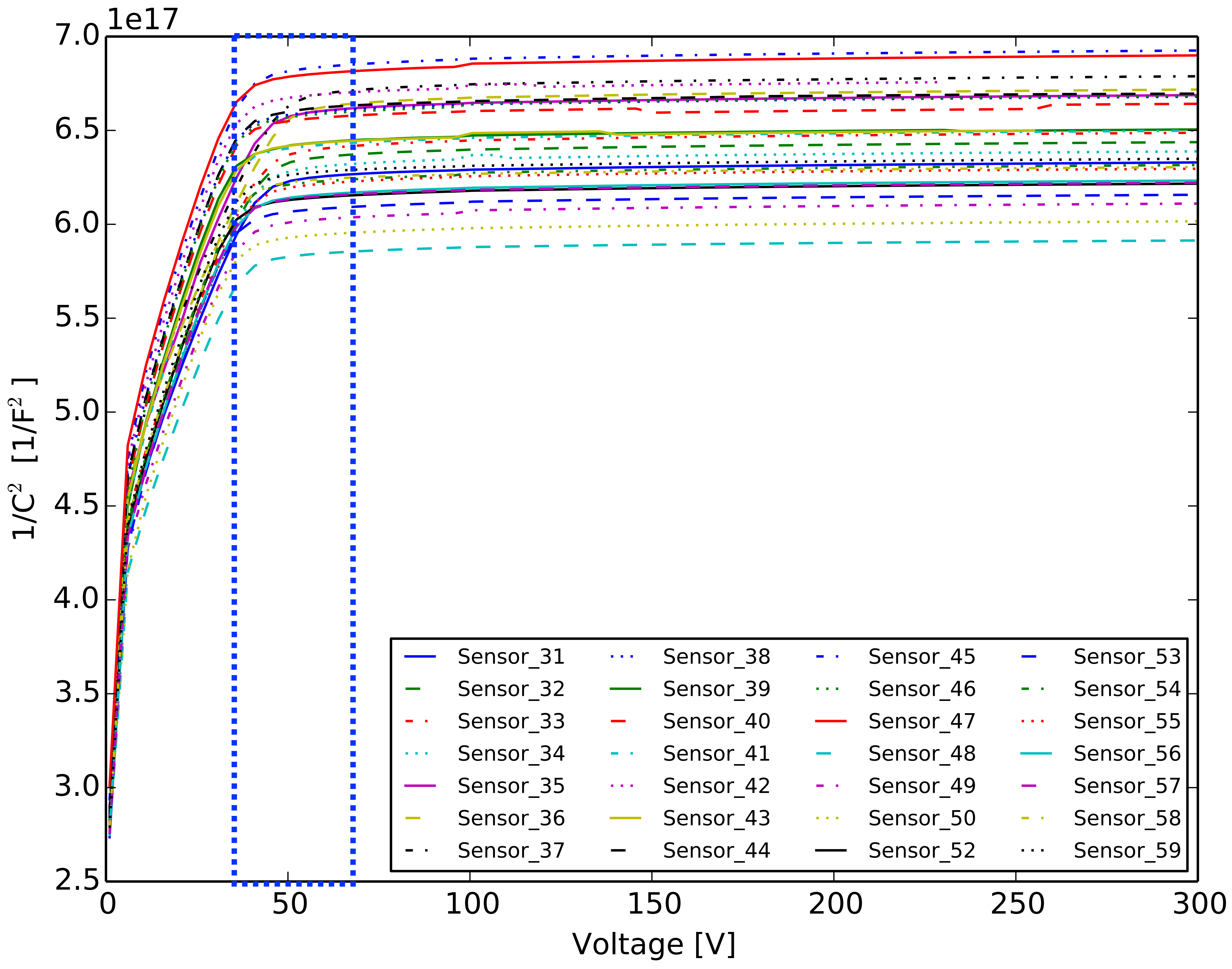
  - IV/CV curves ~ Sep 2017
    - **Good behaviour**:
      - ~100 nA currents and stable up to 300V;
      - Two sensors show the beginning of a breakdown around 280V.
    - All sensors **fully depleted** around **50V**;

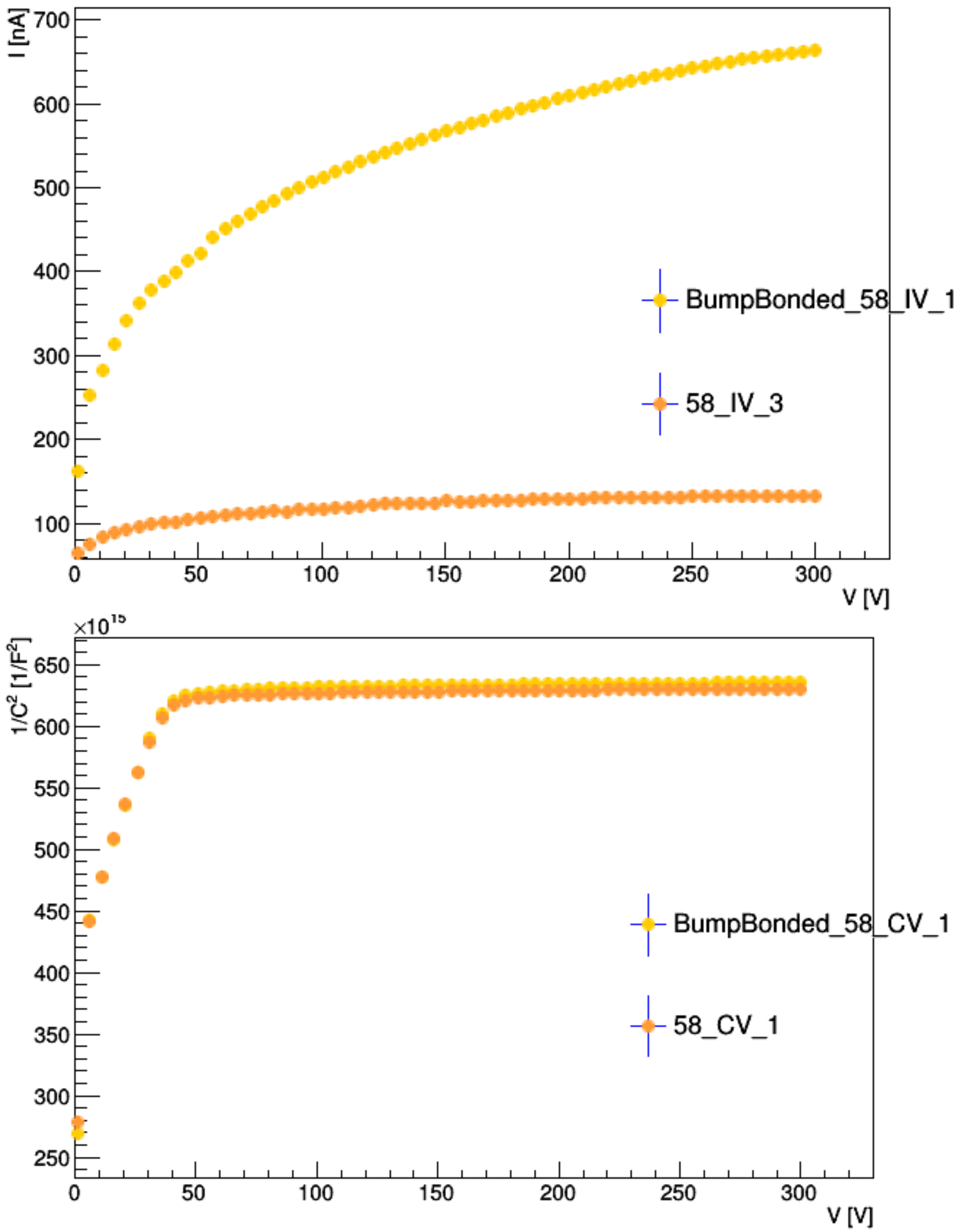


The SiD strip sensor: IV/CV curves

Sensor characterization

Timeline

- **Nov 2016**: ordered at Hamamatsu
- **July 2017**: sensor arrived
  - IV/CV measurements: Good behaviour, depleted at ~50V
- **Jan 2018**: 27 bump-bonded sensors delivered back by IZM-Berlin (sent mid-Sep 2017)
  - **Good IV/CV response**: expected higher current (less than 1 uA), same depletion voltage;
- **Feb 2018**: Start final assembly process → glue & wire-bond kapton flex cable.

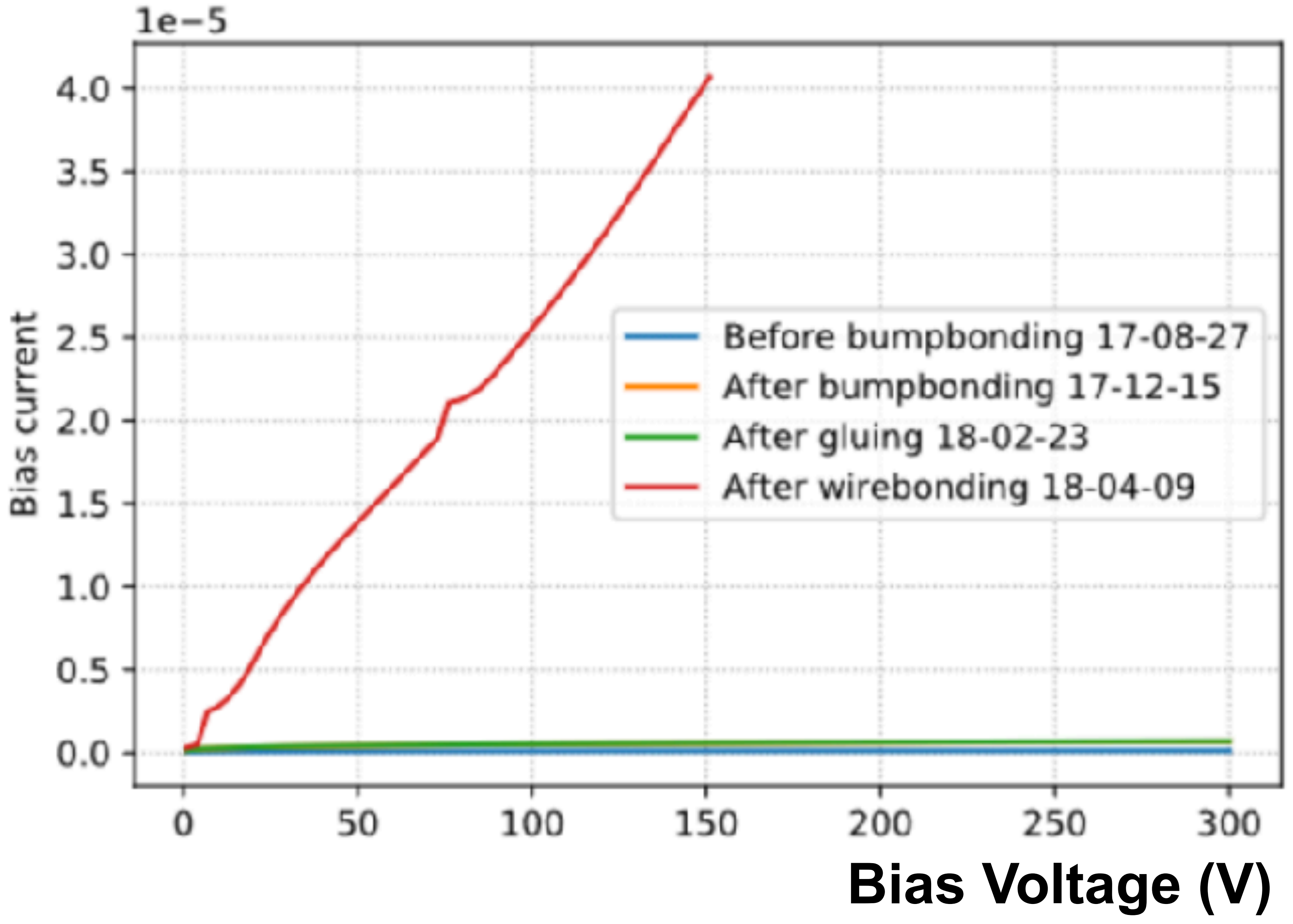


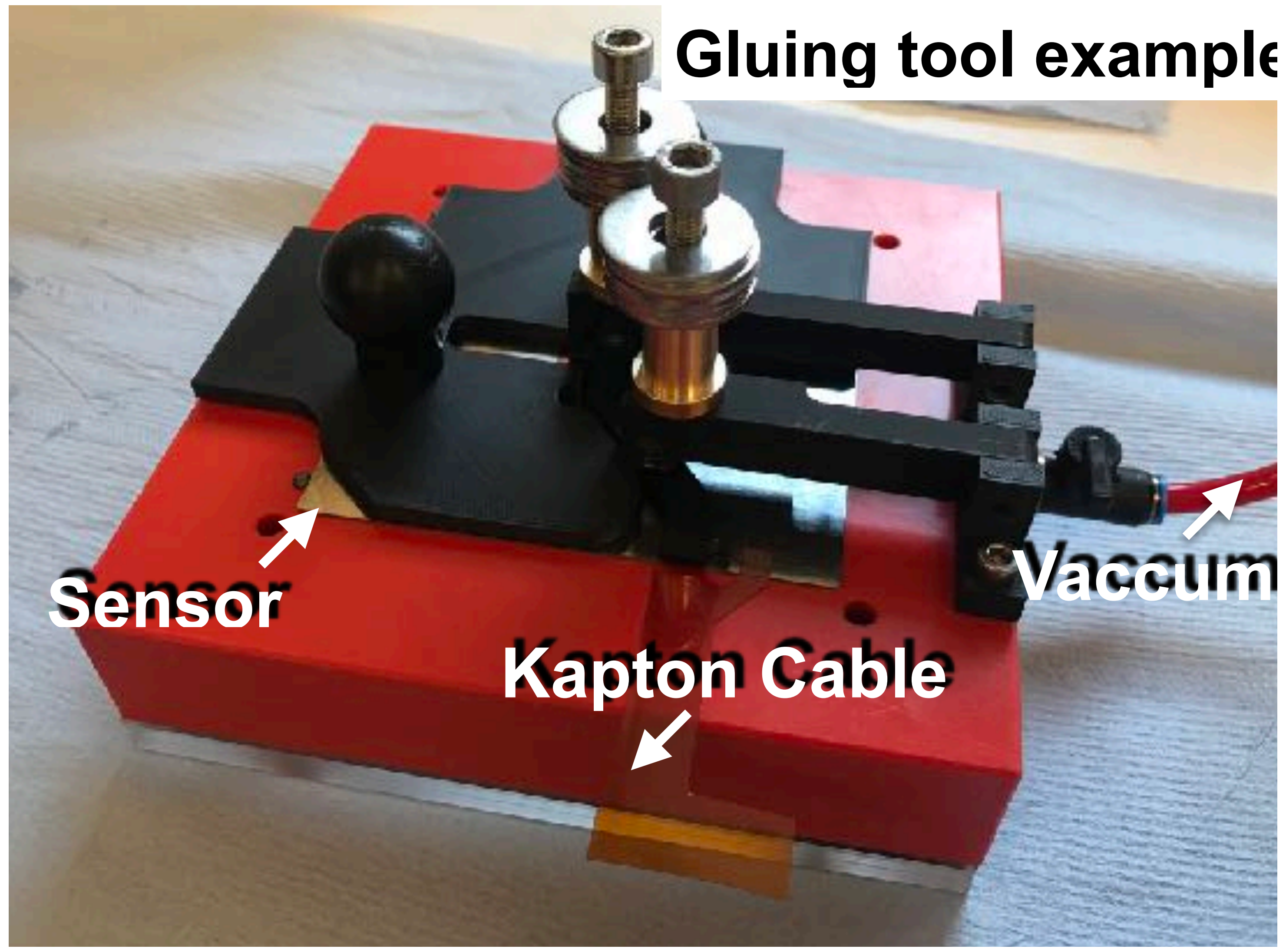
Final Assembly Process

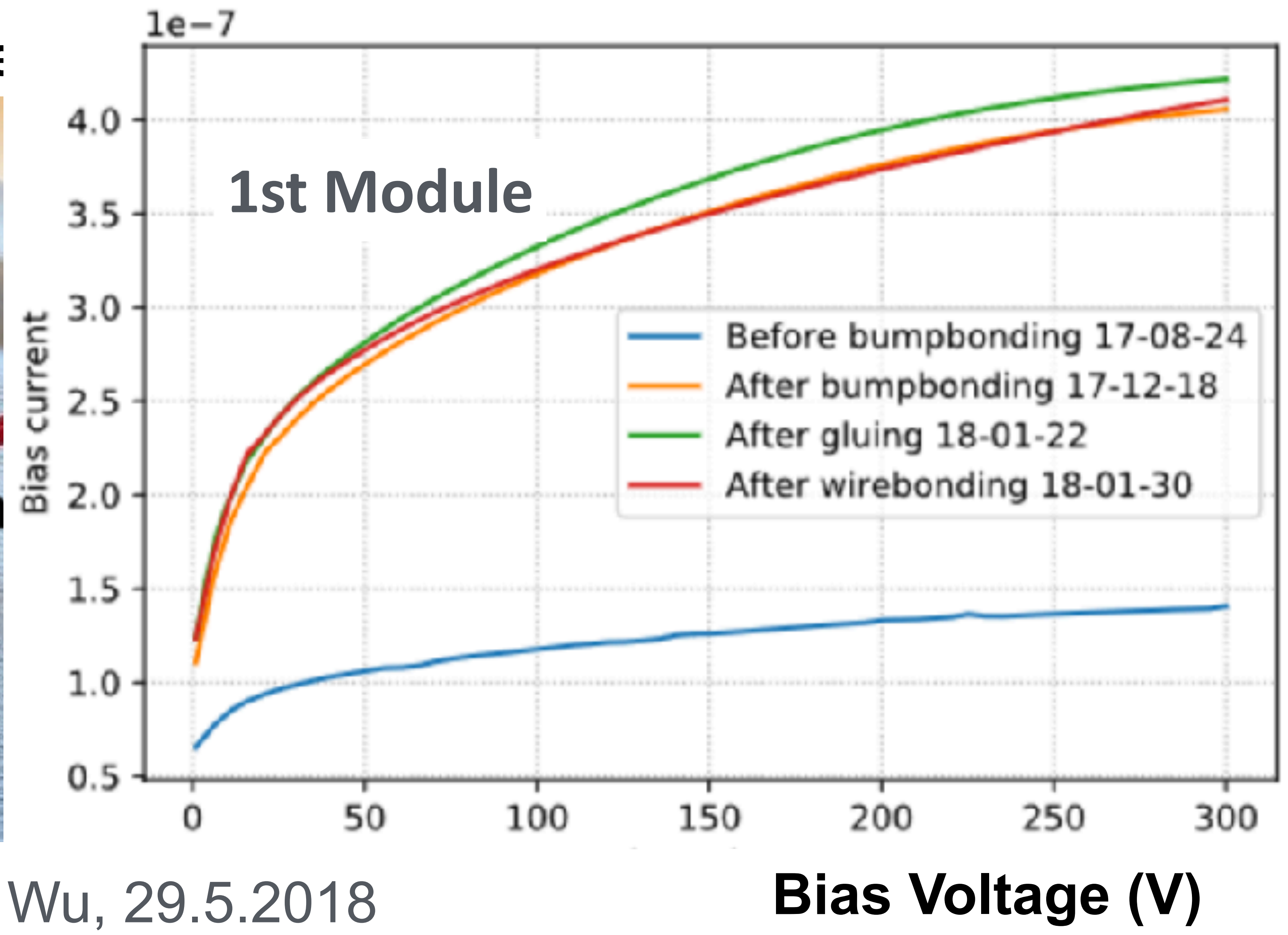
Glue & wirebond the kapton cable onto sensor

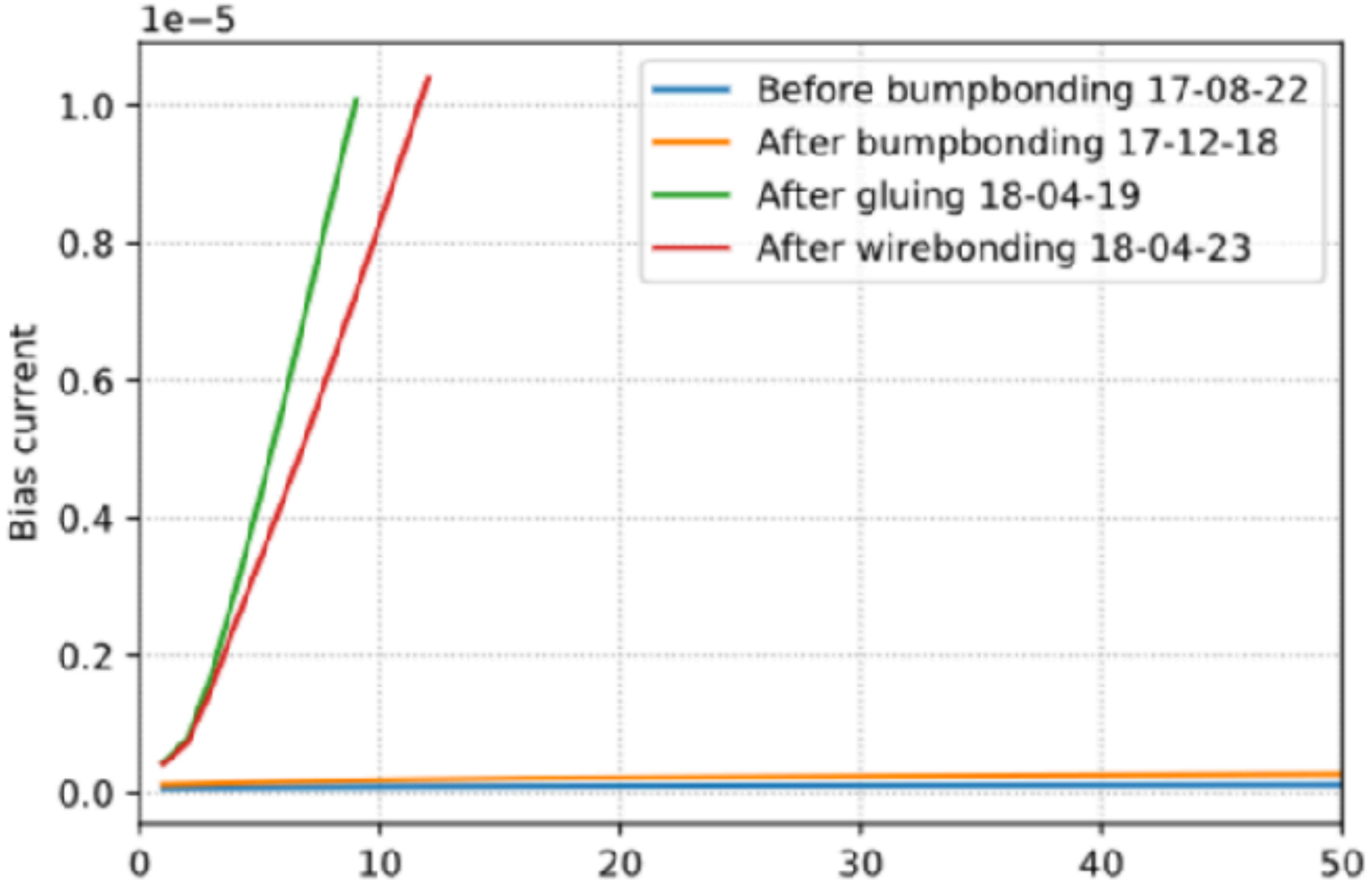
Behaviour not understood (noise, IV curves and etc.)

- Examples in terms of IV curves, non-homogenious 'bad' reaction:
  - 1st Module produced end of Jan 2017:
    - IV curve looks good;
  - Two more modules produced:
    - 1 acts like resistor, 1 break down early (arrives 1uA for <10V).







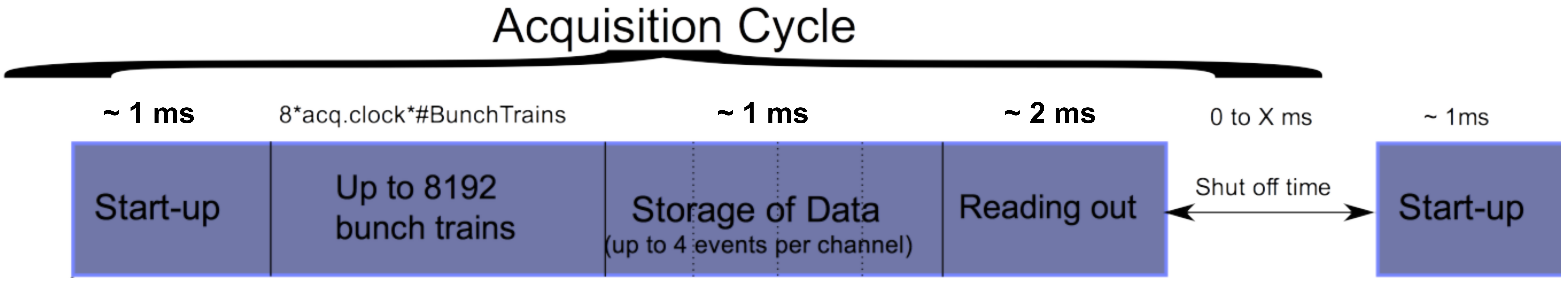



DIGI
Analogue
FPGA
BIAS
DAQ board
KPiX1
KPiX2
Assembled module

KPiX: Sensor readout ASIC

Designed / produced by SLAC for an ILC environment

- Fully digital readout with 13 bit resolution (ADC range up to 8192)
- **2** trigger modes:
  - Self trigger = 4 events *per* channel *per* cycle stored
  - External trigger = 4 events *per* cycle stored
- Length of the opening period / cycle depends on timing resolution + bunch trains (up to 8192)
  - 100 MHz acq. clock → min. timing resolution is **8 x 10 ns** (particle event);
  - Only open for a max. time of (8192 x 8 x acq.clock);
    - e.g. with a timing resolution configured as 2560 ns → 20.97 ms max. open-time



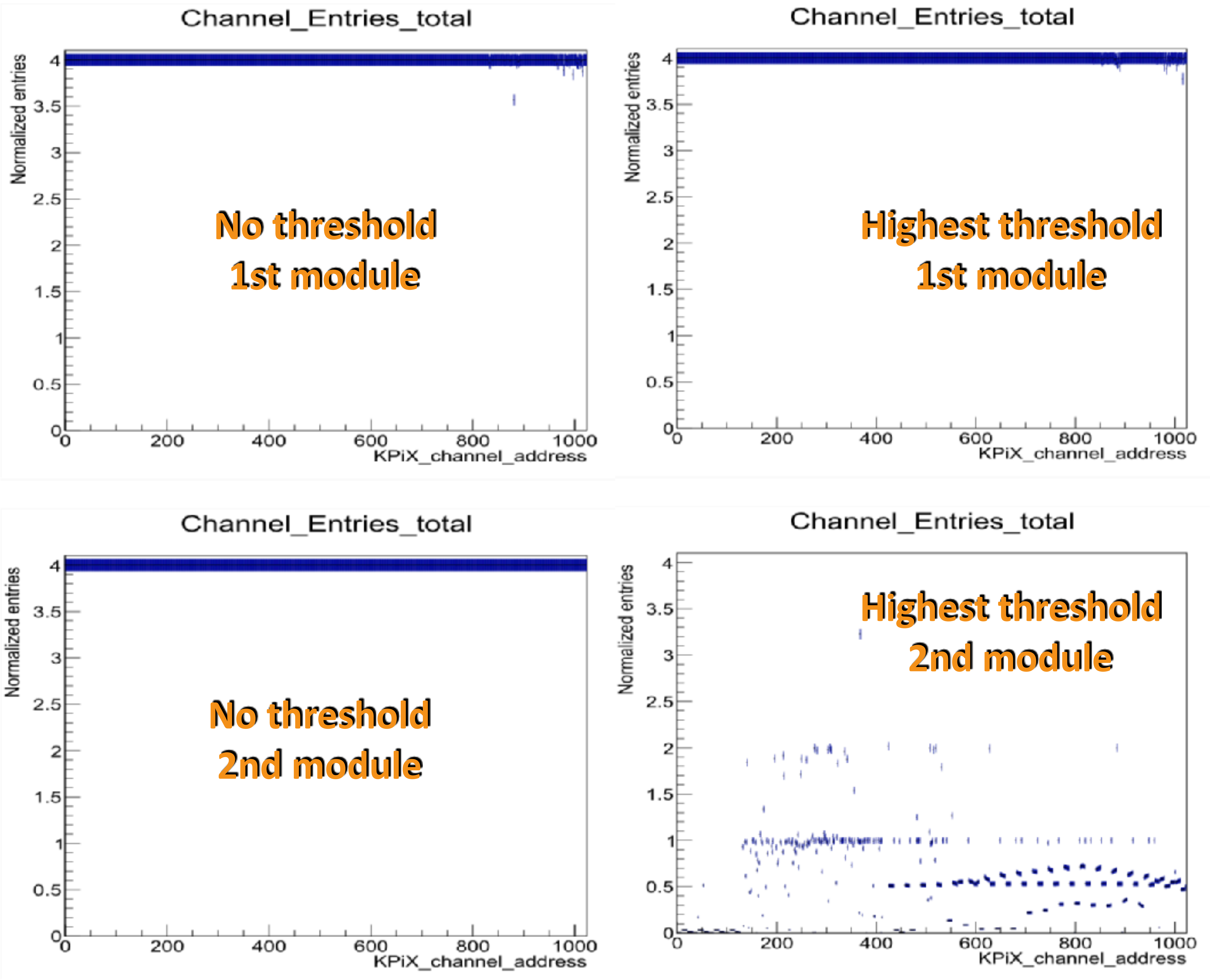
Example to show the noise level

Based on 1st & 2nd module

- Self-trigger mode, pedestal running
- for each KPiX data taking **cycle**: each readout channel can record **max. 4** particle **events**;

- 1st module did not responde to any threshold, always triggered;
- 2nd module respond, but weird block seen.

==> for the working one, try to point a radioactive source to see the response.

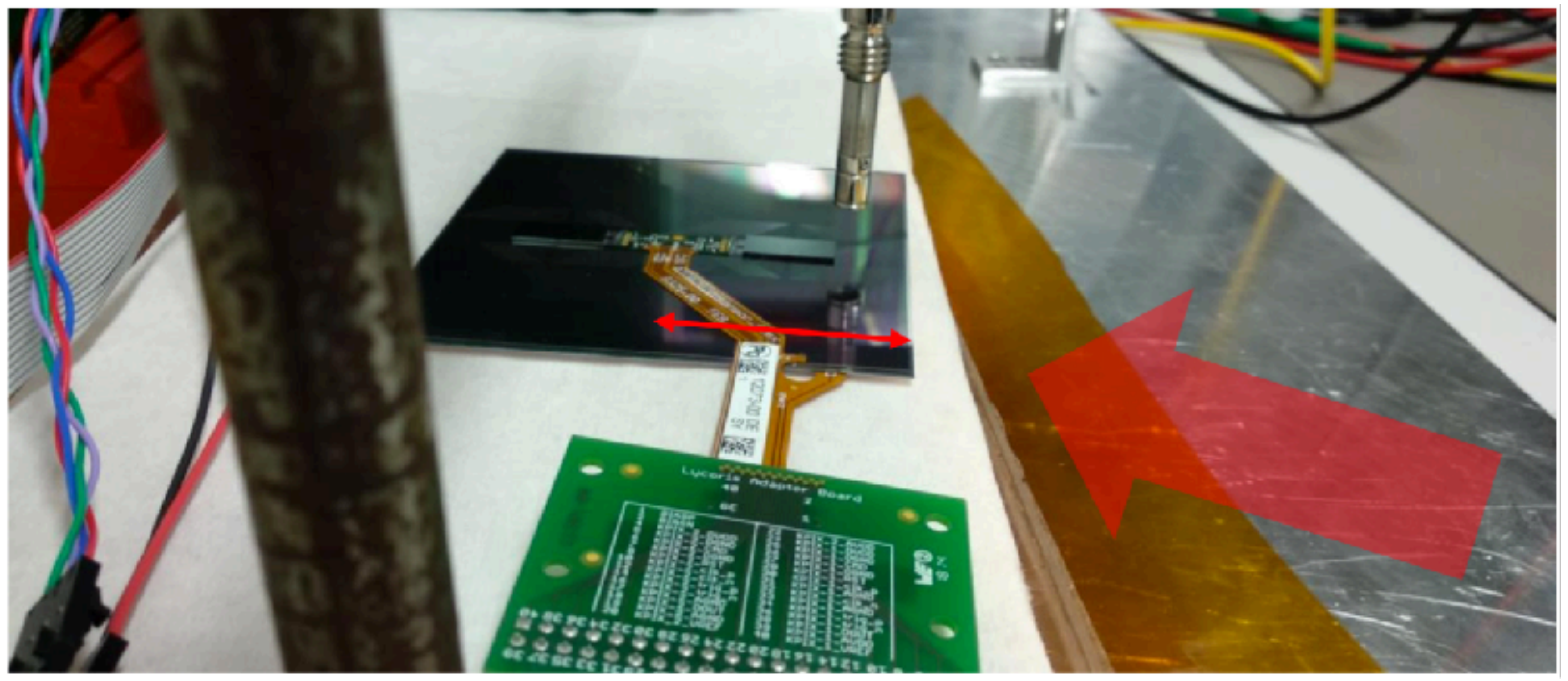


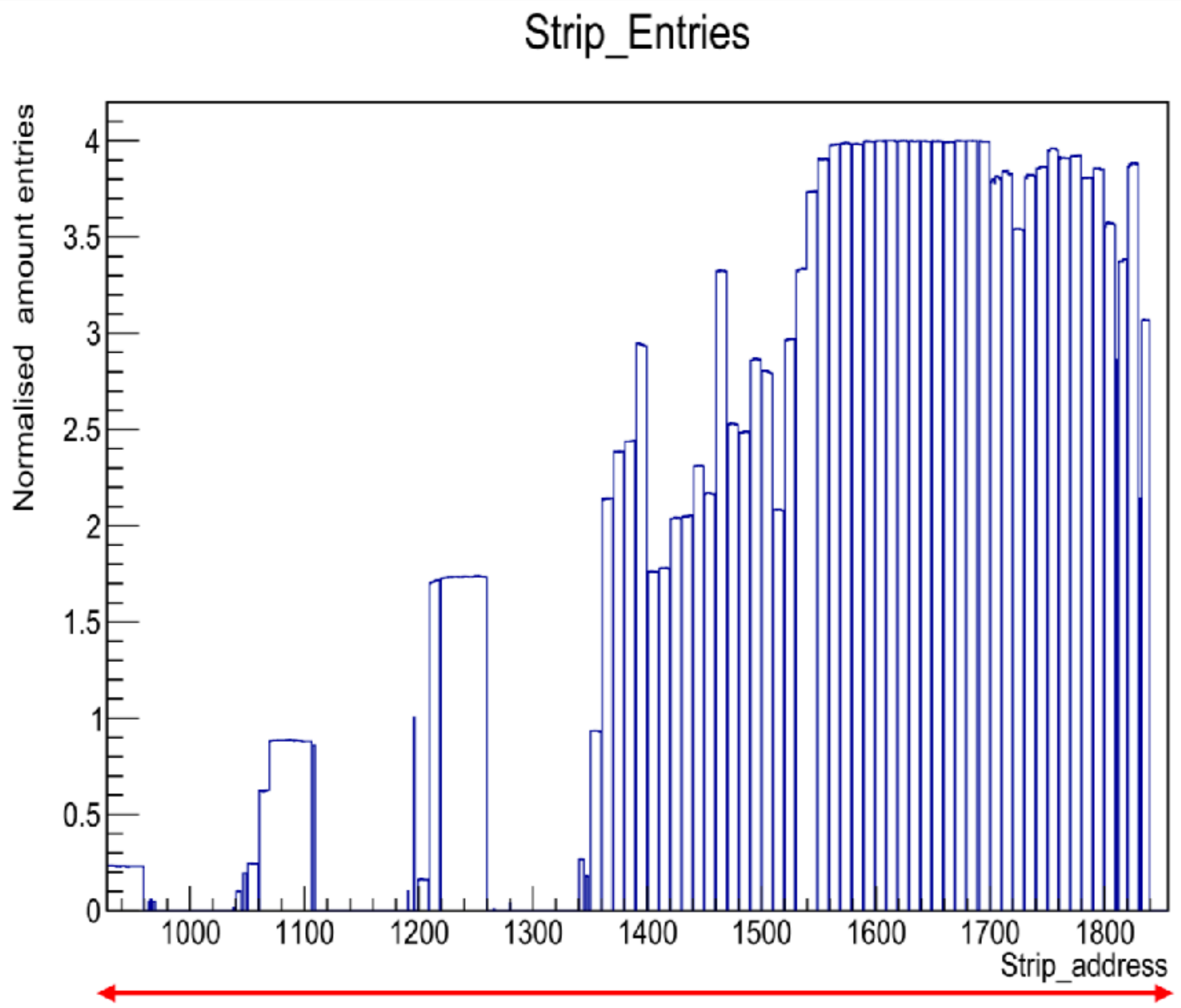
1 working example with radioactive source

Based on 2nd module

- Point a Sr90 source to test signal response;

- pointing to the kpix2, next to the right edge:
  - expecting to see strips at right fired most, with a graduately decay to left;
  - Quite good response, but weird block still there.



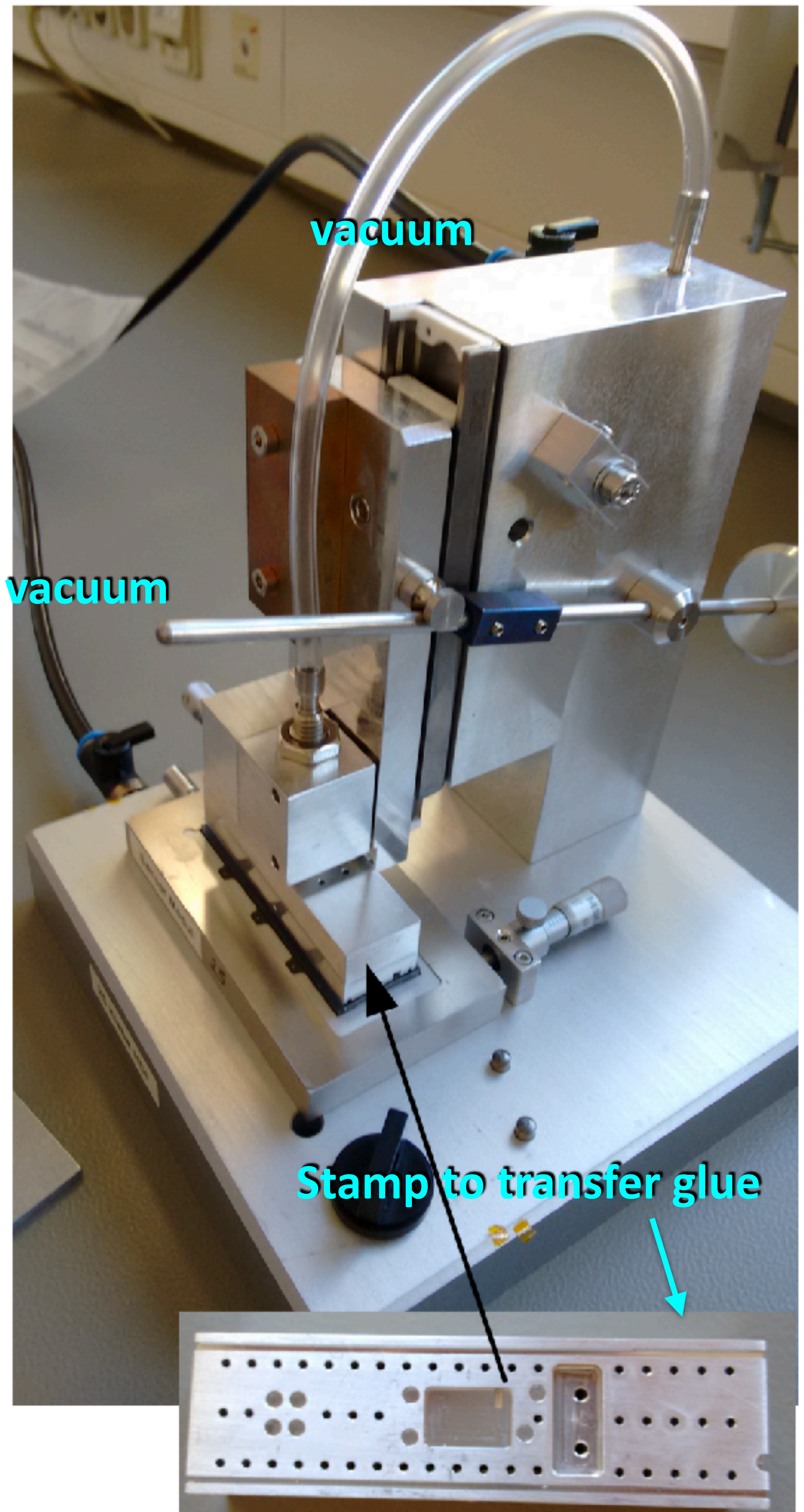


Revise the Assembly Process

New gluing tool

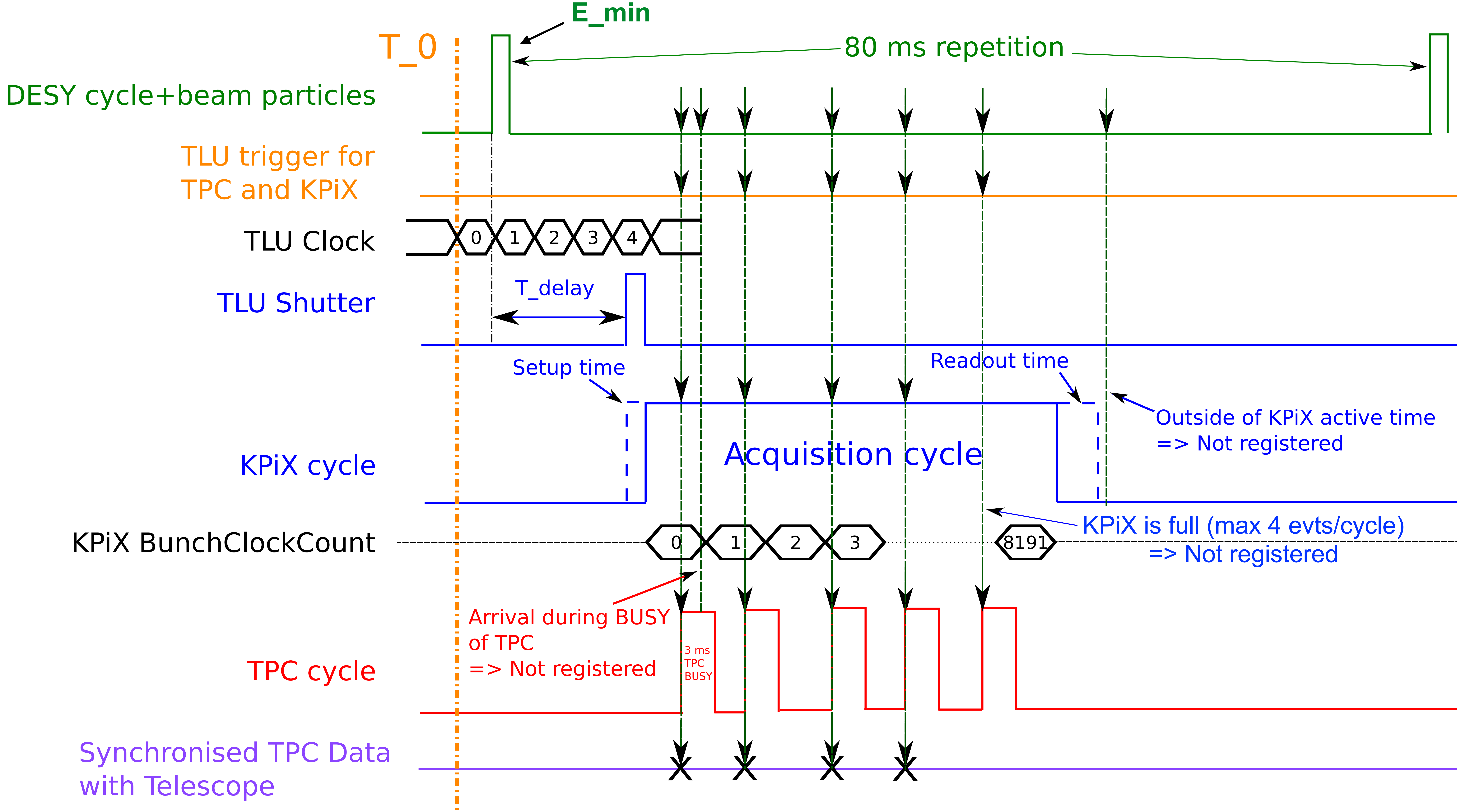
- Learnt from CMS group of the University of Hamburg : their gluing tool for CMS silicon upgrade;

- Checked with Engineer → only a few changes needed to adjust the design for us:
  - Vacuum pick up and placement of the kapton flex
  - Program in the pathway
  - Some dummy gluing tests
  - Adjust the vacuum head, tool could also be used to place sensor into the frame



Multiple Device Synchronization

Telescope + Beam + 1 DUT (TPC as example) → implemented by a TLU



- **KPiX** sync to **DESY** via a shutter signal generated by **TLU** to start the KPiX acq. cycle:
  Status: **tested/validated** by feeding a manipulated shutter signal to KPiX.
- **KPiX** synced to **TLU** via a common TLU clock:
  Status: to test, new TLU exp. mid-June.
- **TPC** synced to TLU by counting triggers, so sync **TPC** & **KPiX** by a common start **T_0**
  Status: to test, testbeam exp. this fall.

Data Analyzing: EuTelescope

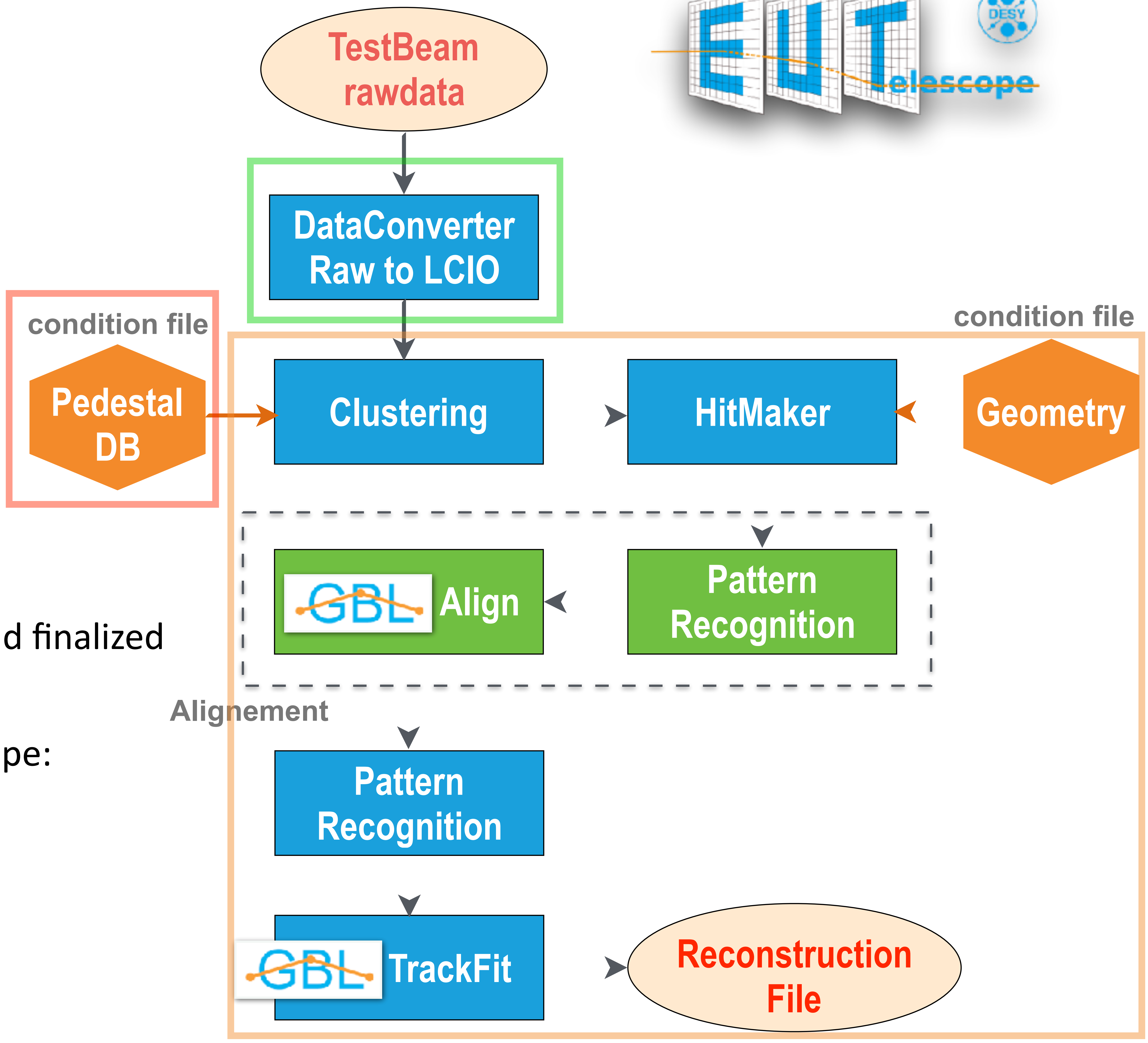
Motivation & status

Motivation

- Integrate to a common reconstruction software
- Characterize Lycoris using EUDET telescope
  == > we have to use its analysis software anyway
  == > EuTelescope

Current status

- Challenges:
  - no tracker data available to prepare the code;
  - tight schedule: code needs to be ready in this fall, and finalized by the delivery due 01/2019;
- Flow chart of one version for strip DUT w/ pixel telescope:
  - Con: binary readout, no pedestal DB used;
  - Con: only one strip layer as DUT w/ Mimosa;
  - Pro: Raw to LCIO converter: done in EUDAQ side;
  - Other modules: to be tuned;



LYCORIS Summary

Project Overview

Milestones to achieve before delivery in Jan, 2019

- Key target: convey a 1st user analysis —> testbeam w/ TPC forseen in fall 2018:
- Hardware to be ready:
  - **Mechanics** for final system: well track to be on time; in progress
  - Make assembled Lycoris sensor **module** work;
  - **New DAQ board** exp. 18/06/2018: 1-2 weeks to SLAC to learn & test; TBD
  - **New** AIDA2020 **TLU** exp. 06/2018: both hardware & software to test, and w/ new DAQ board; TBD
- Software to be ready:
  - Lycoris module works w/ TLU + mimosa on simple e-lab tests: EUDAQ2 to be ready; TBD
  - **Alignment**, **characterize module** w/ mimosa: beam time needed
    - event definition and EuTelescope to be ready. TBD

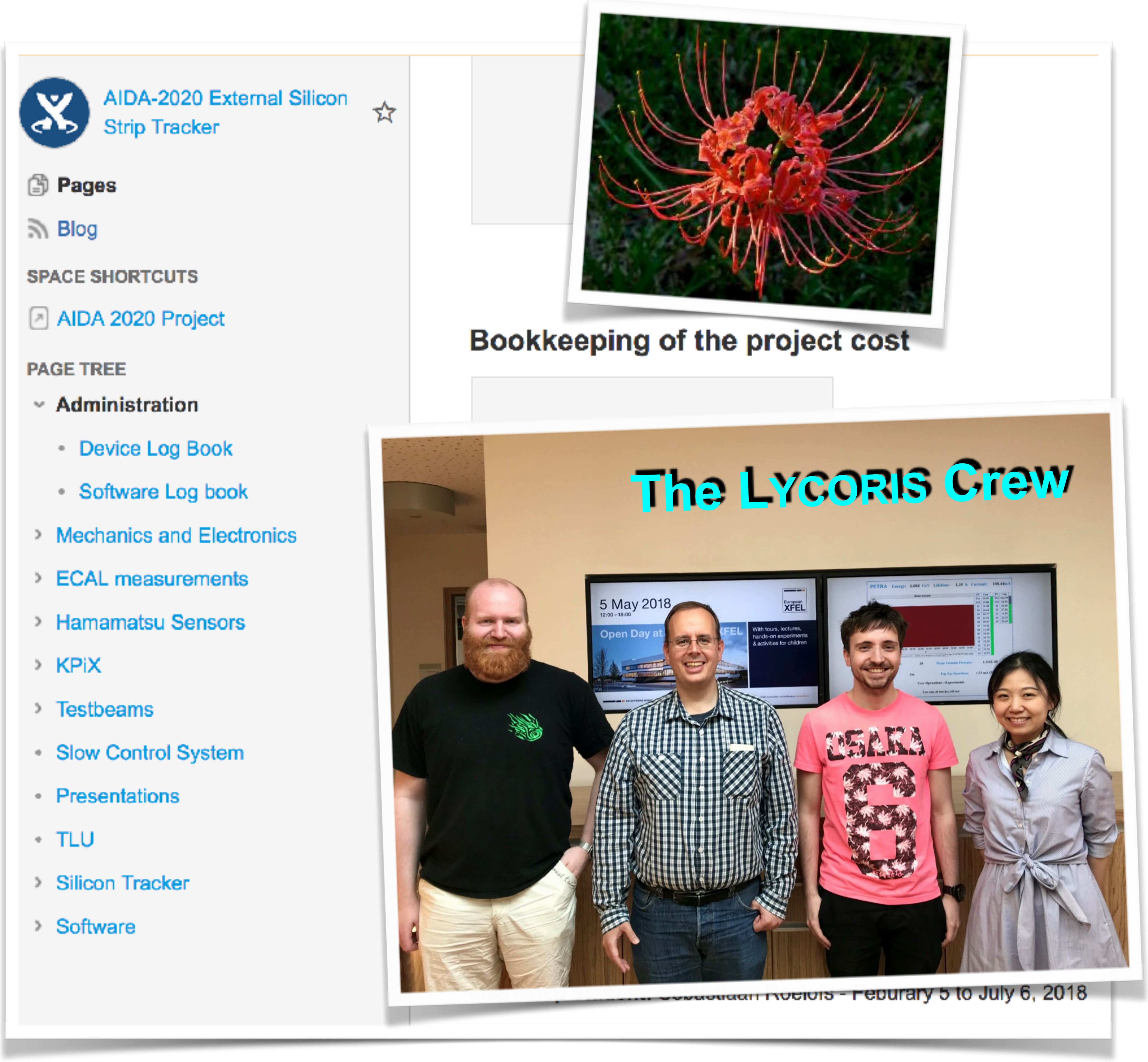
==> Many efforts ongoing under collaborations with SLAC, University of Bristol, and cross-group support locally at DESY

LYCORIS Summary

Documentation & Outlook

Well organized/tracked to face the reality

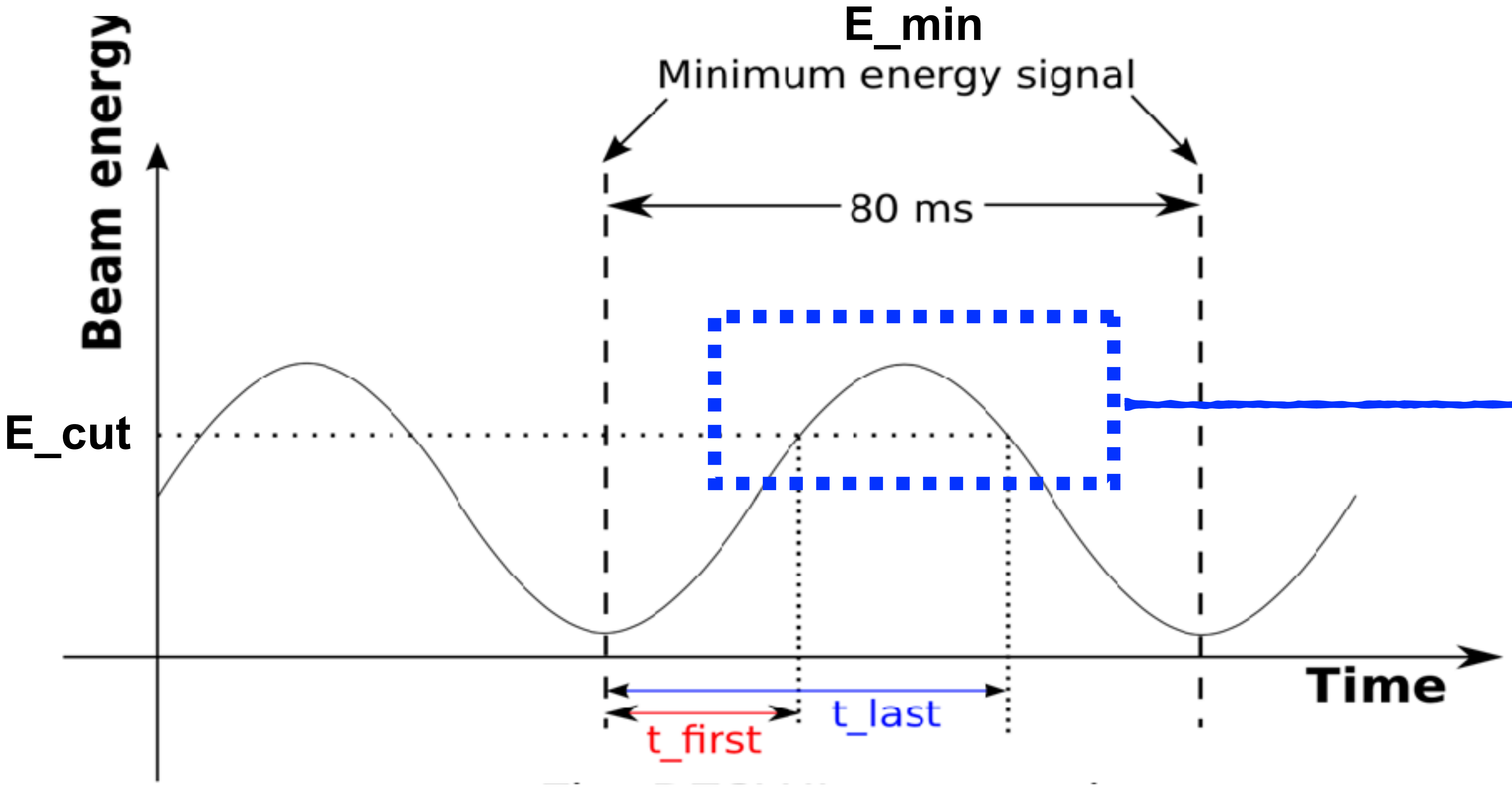
- **Documentations:**
  - Confluence page to log all working activities;
  - Notes: project milestone report, KPiX note, software manuals etc in lively updating.
- **Outlook**
  - 1st real case application of the SiD sensor;
  - portable and movable to serve for various use cases
    - upgradable to 10 x 20 cm^2, distance between sensors ajustable, sensor orientation adjustable and etc.
  - Important: local support group at DESY!
  - More contribution to the beam telescope community.

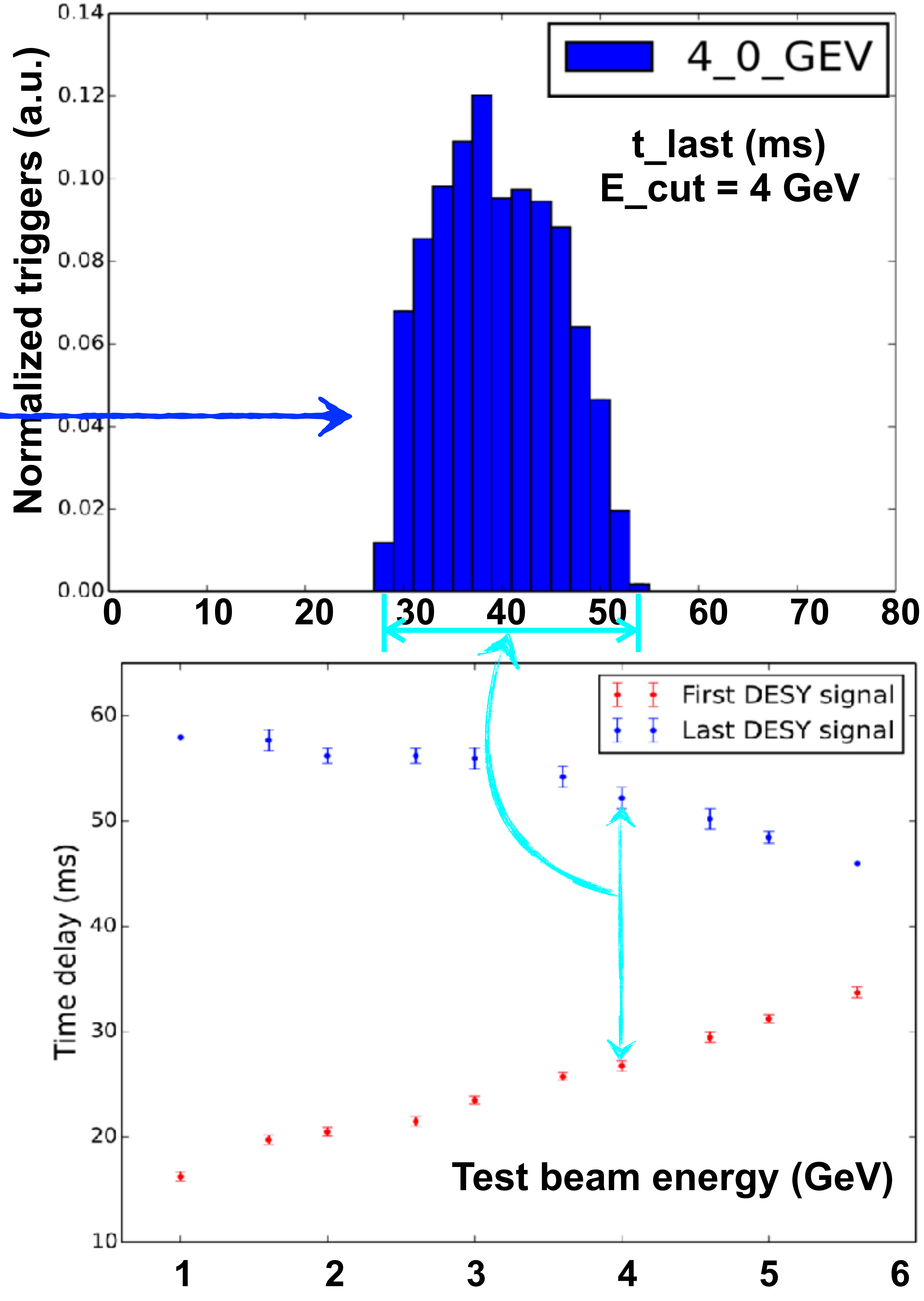


Thank you for your attention !

Everyone needs back-up!

Beam spill structure



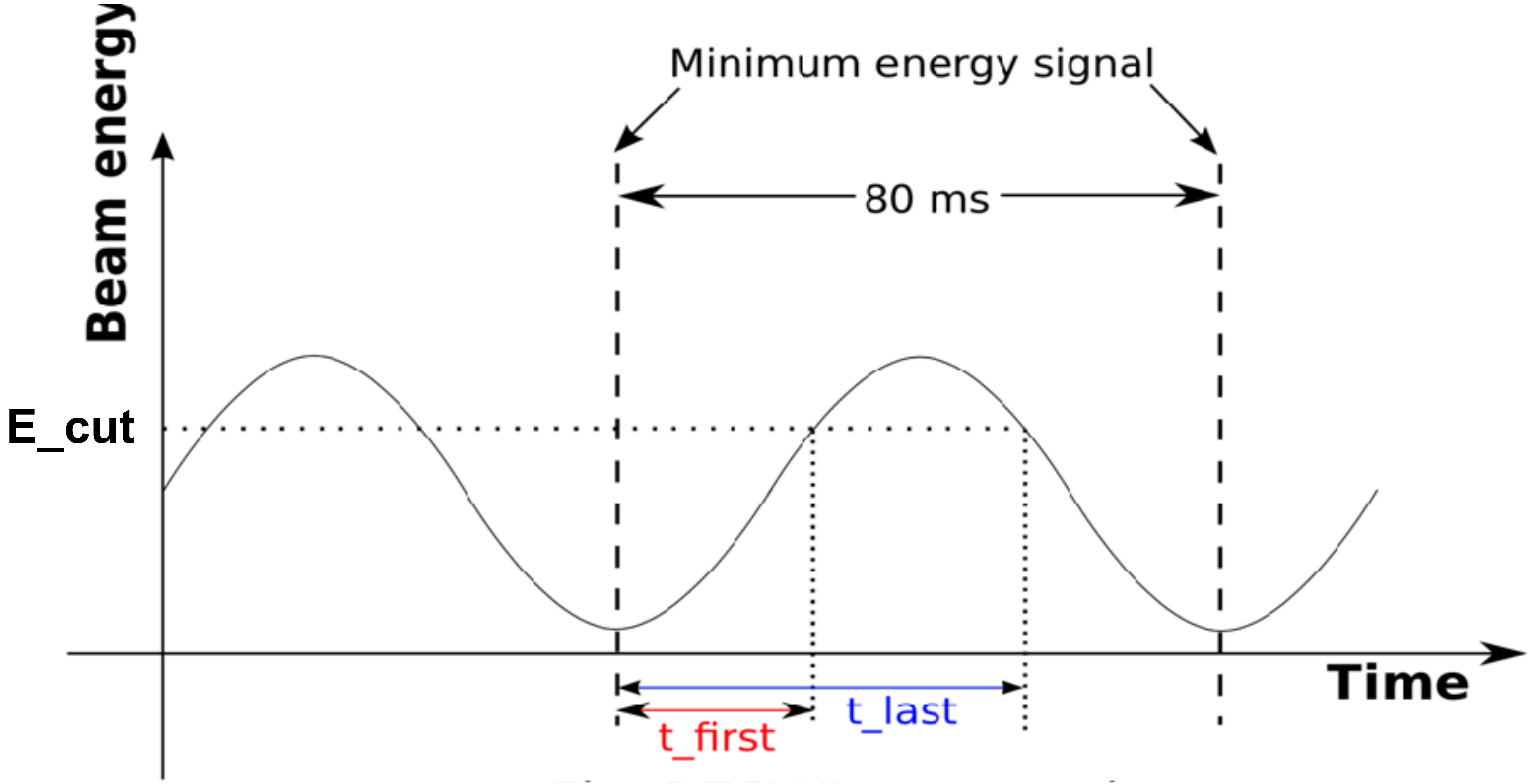


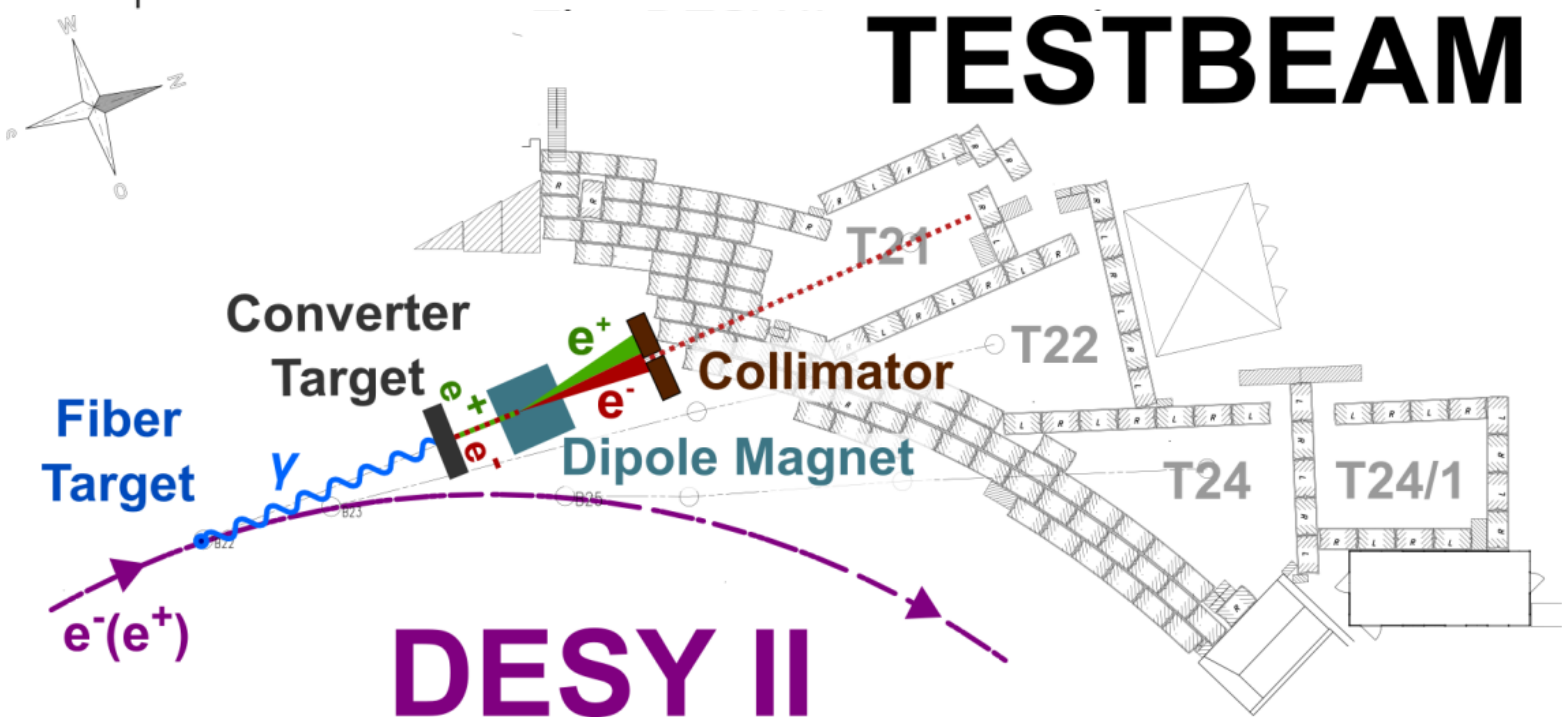
- DESY-II Beam energy cycle follows a sinoidal curve:
  - **80 ms** repetition;
- For a beam mometum cut (E_cut), say **4 GeV**, scintillator in test beam area sees particles for **~20 ms** (~1/4 cycle);
  - t_first: 1st trigger time,
  - t_last: last trigger time.
- Particle time period as a function of different **E_cut**:

Beam avaibility

— copyright goes to Dr. Marcel Stanitziki

- DESY II synchrotron
  - 6.3 GeV electrons
  - Main purpose: injector for the Petra-III top-up
  - Test beam is thus a parastic user
- Beam structure
  - 500MHz RF
  - Basic magnet cycle 12.5Hz s(accelerating from 450 MeV to 6.3 GeV)
  - 1 bunch per fill (30 ps)
- Interruption during beam extraction for Petra (sec-min)
  - otherwise almost DC beam —> no spill structure

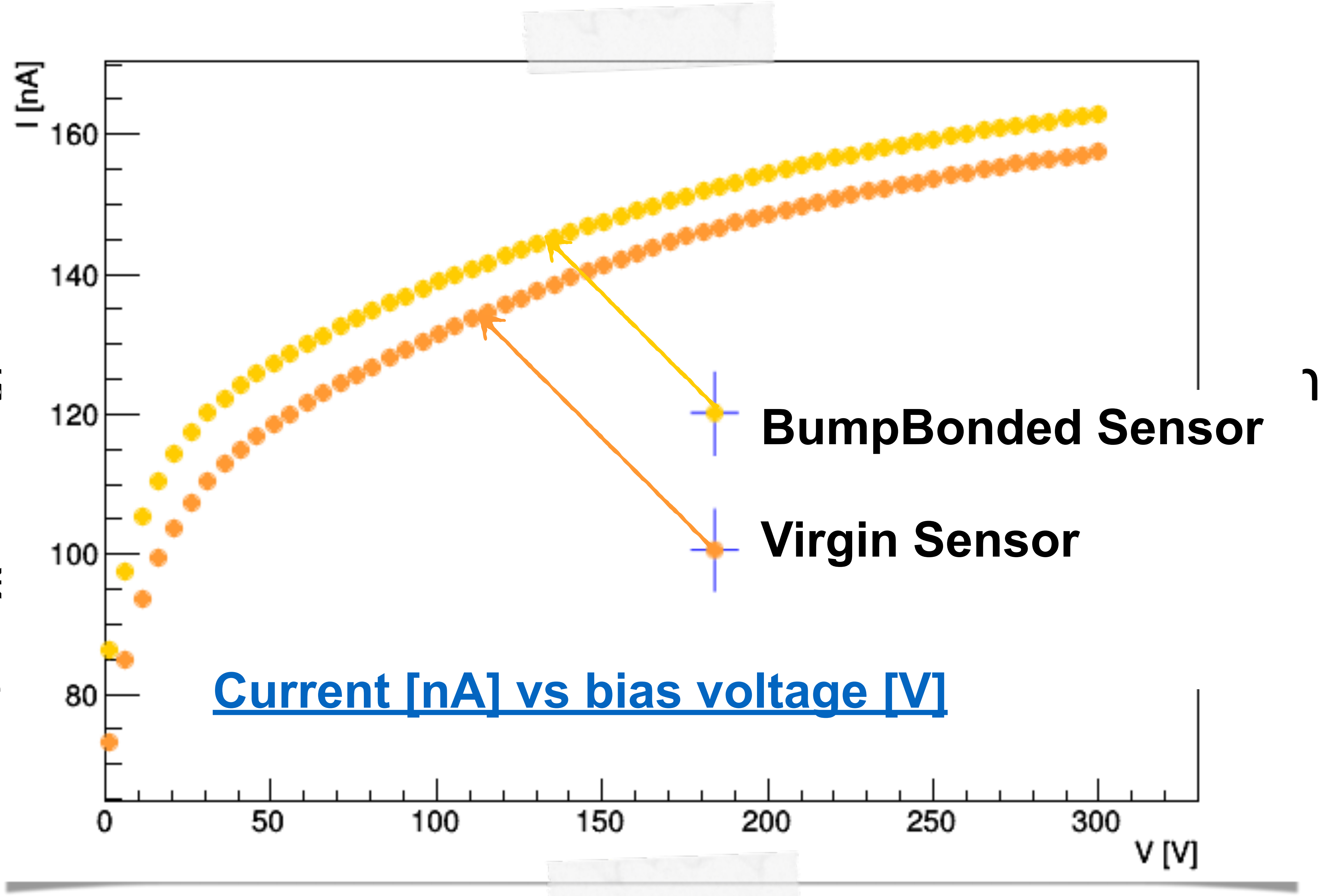


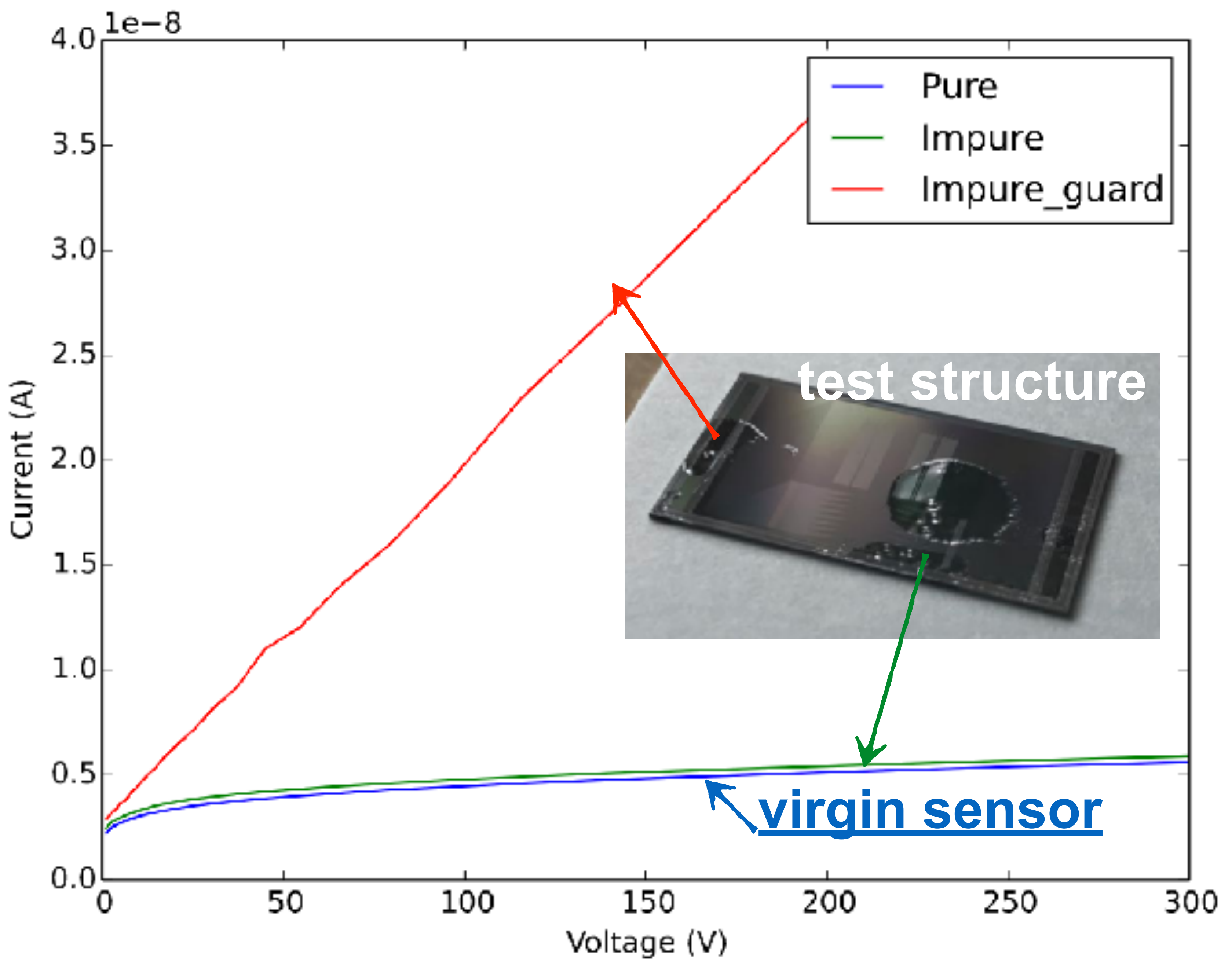


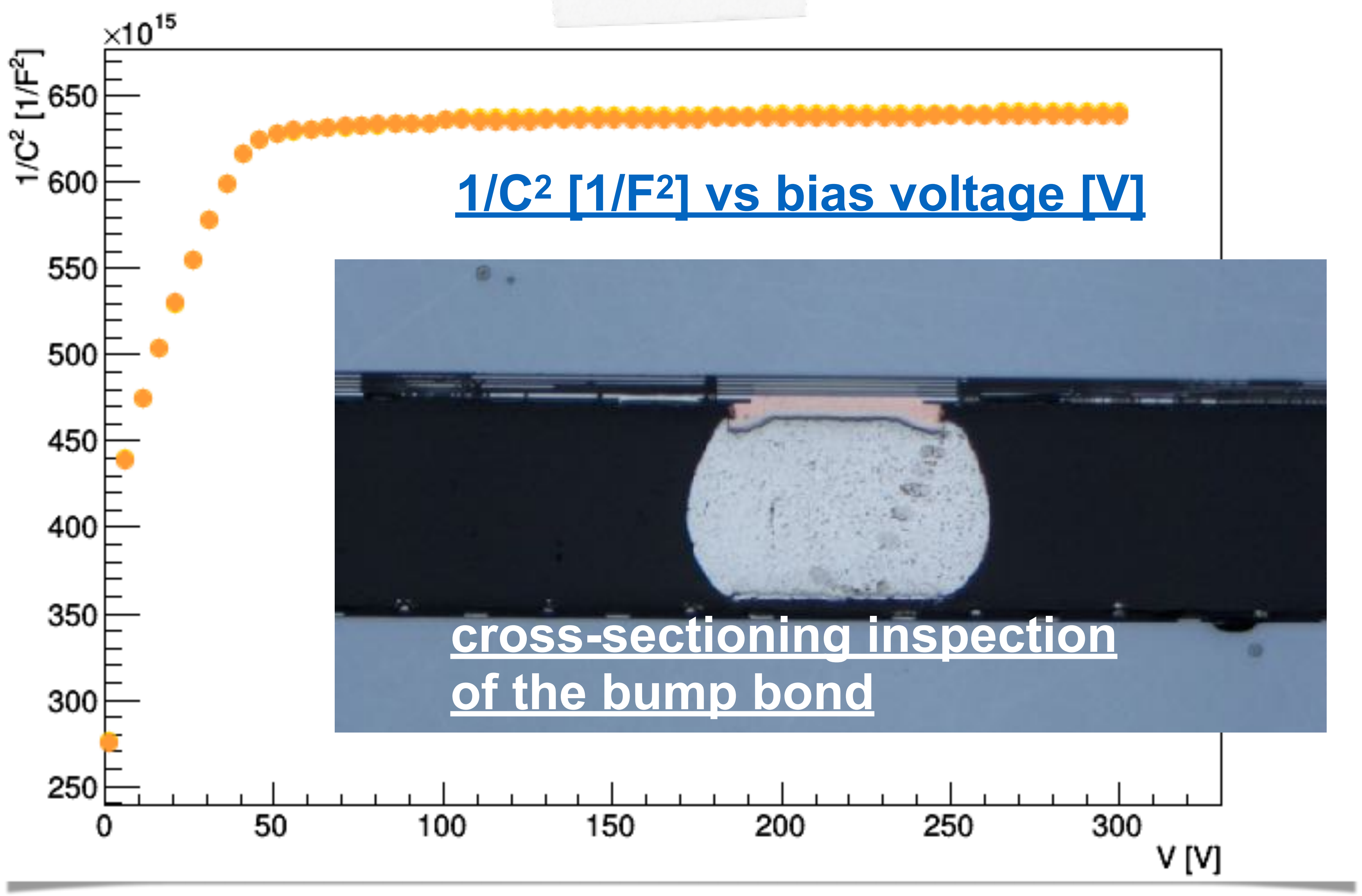
Strip Sensor inspections

Subheading, optional

- Comparing IV/CV curves from bump-bonded sensors ... n the cross-section inspection of a bump bond;
- Further inspection before glue the kapton cable to se
  - IV measurements at different steps of putting glue
    ➜ **avoid glue on outter rings**.



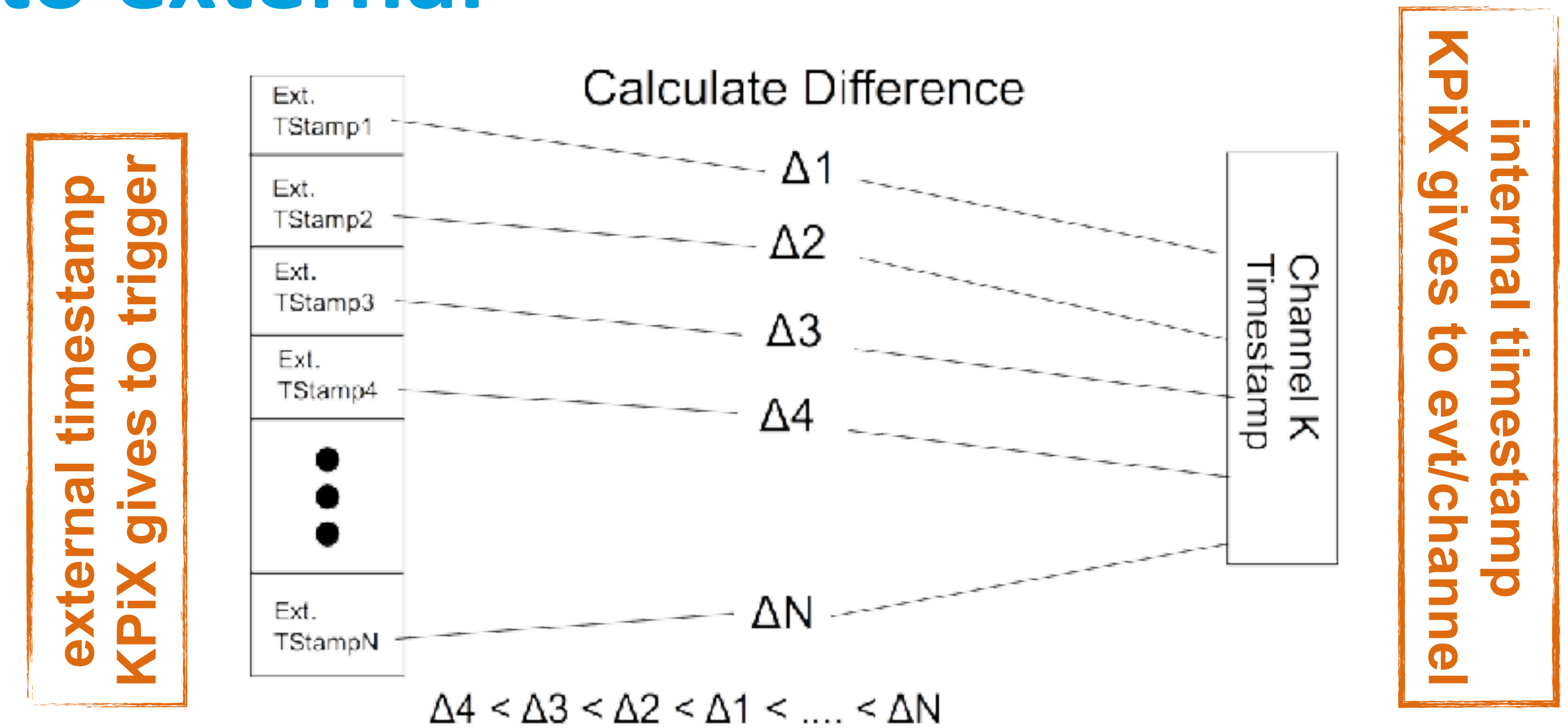




KPiX Timing Studies: diff from internal to external

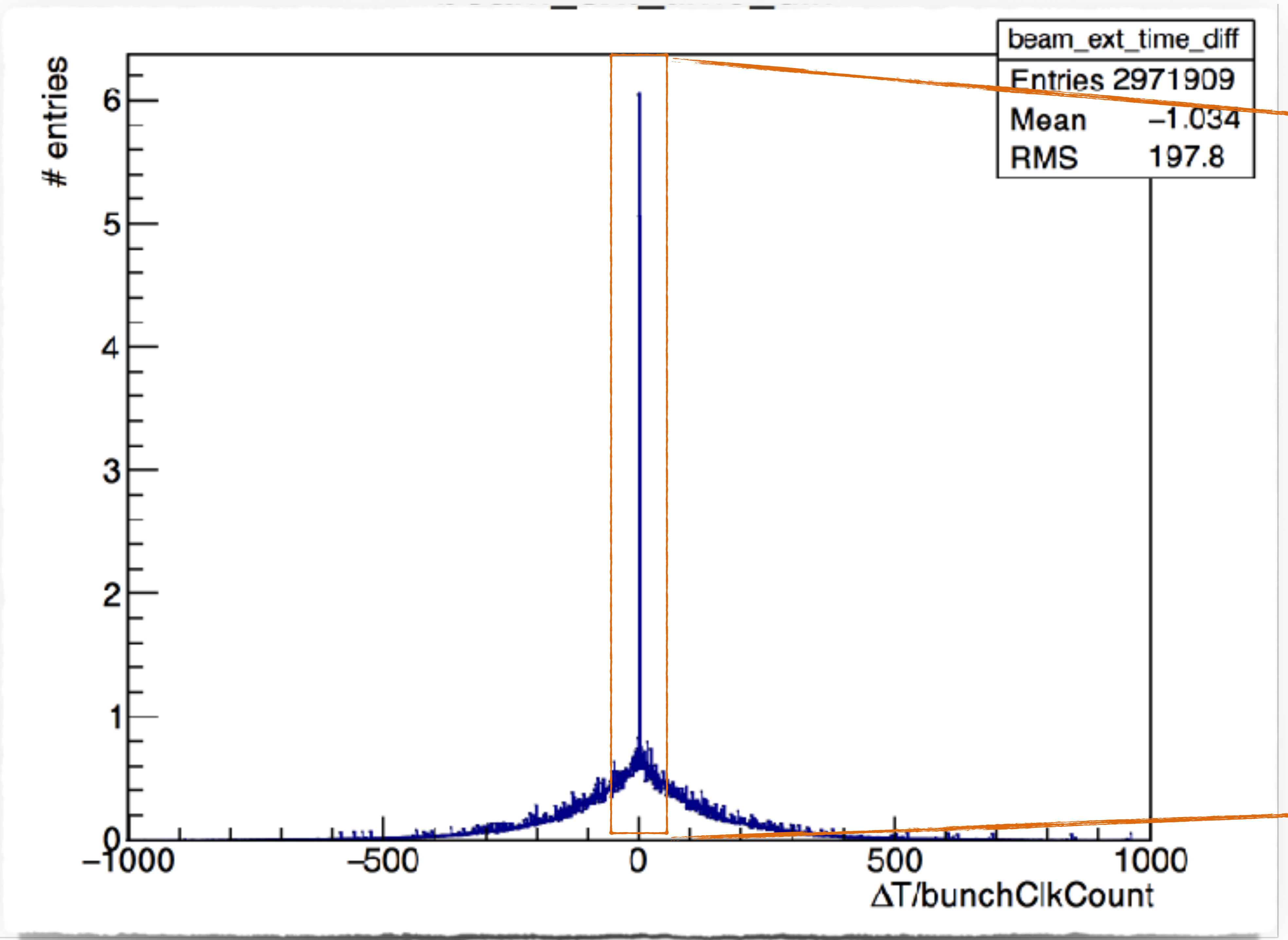
Study based on an hexagonal ECal sensor

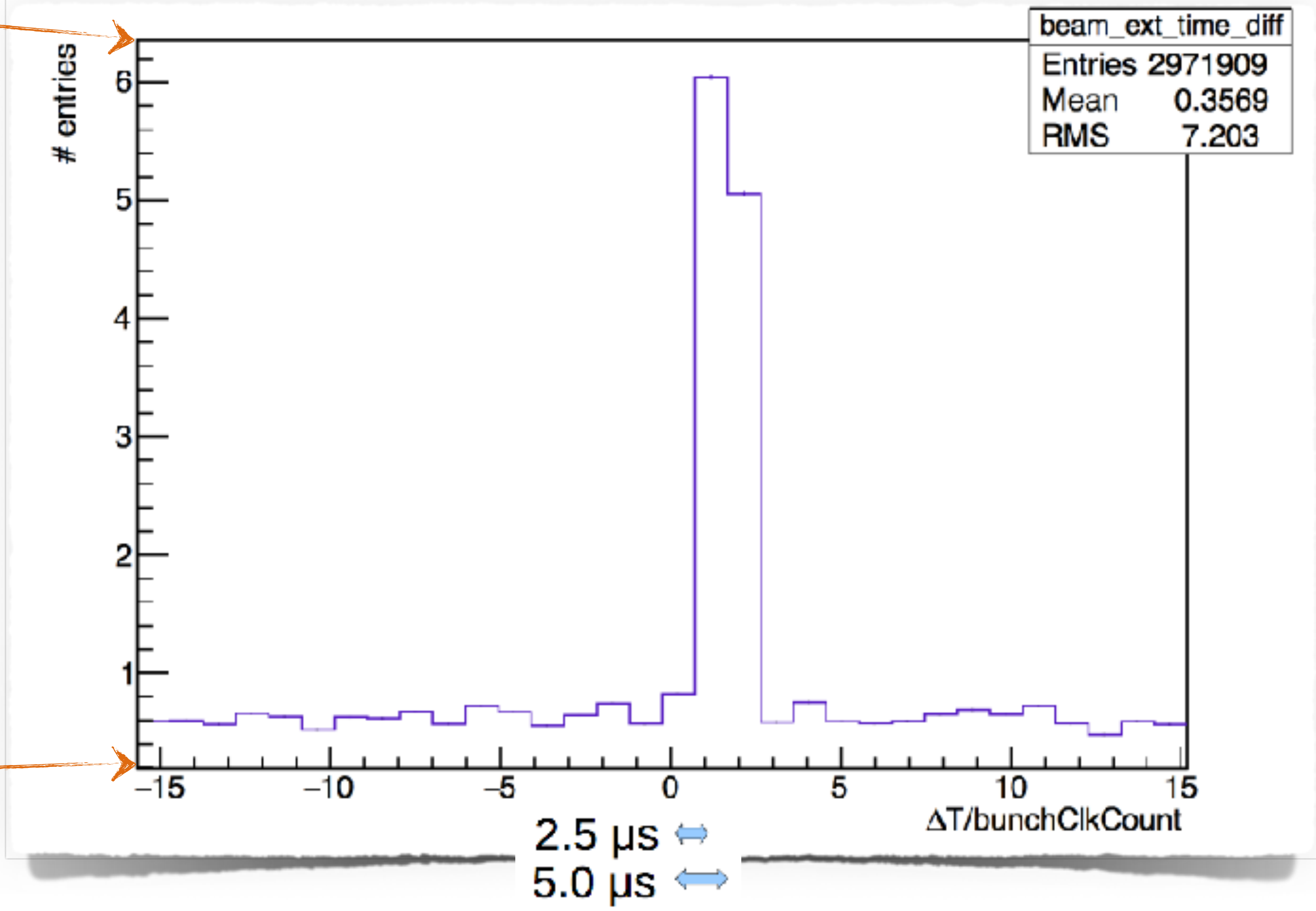
- Matching between external timestamps and internal timestamps shows a small delay between signals.
- Event selection will be done using this information



Δ4 < Δ3 < Δ2 < Δ1 < .... < ΔN

=> Δ4 = Time difference for channel K

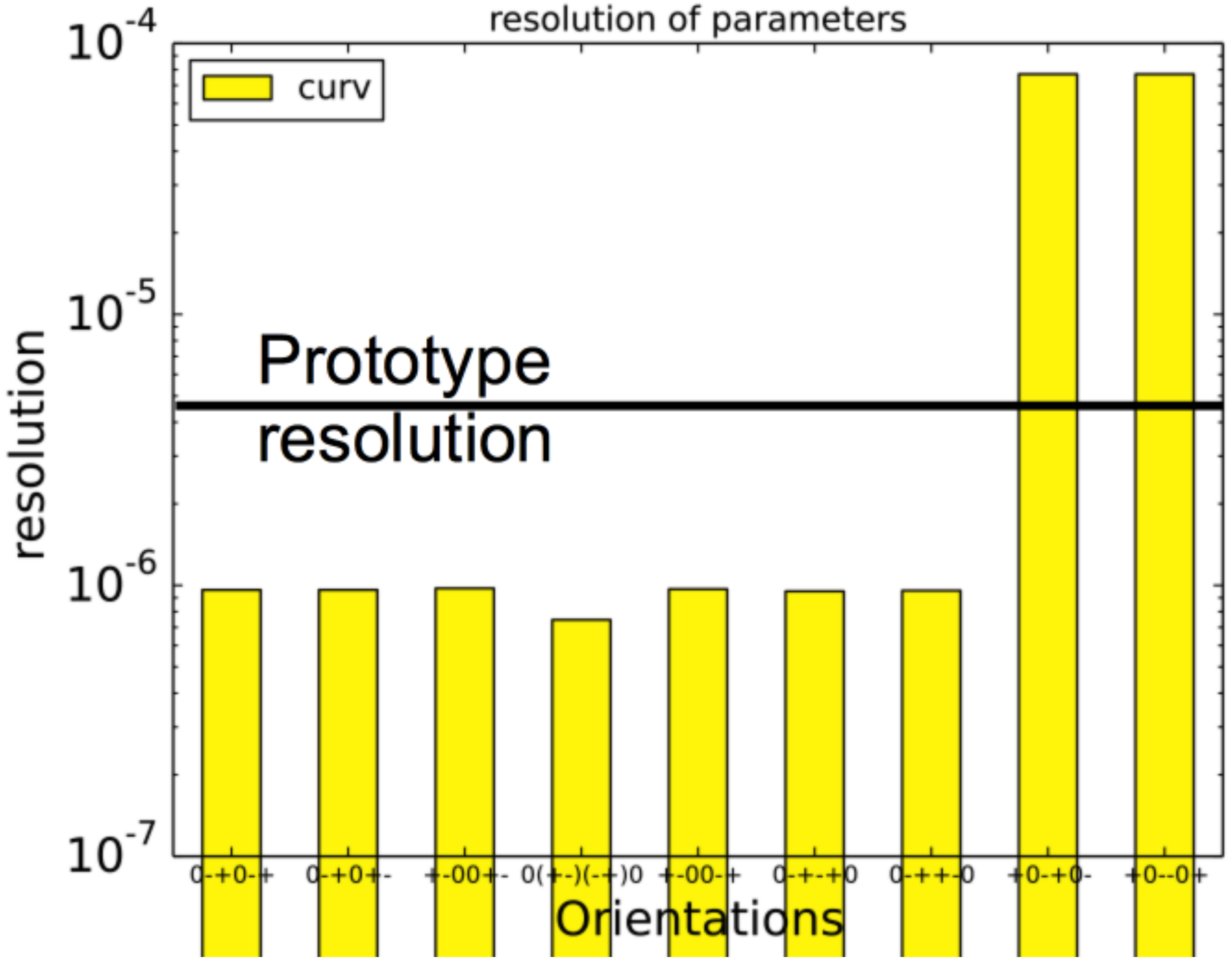


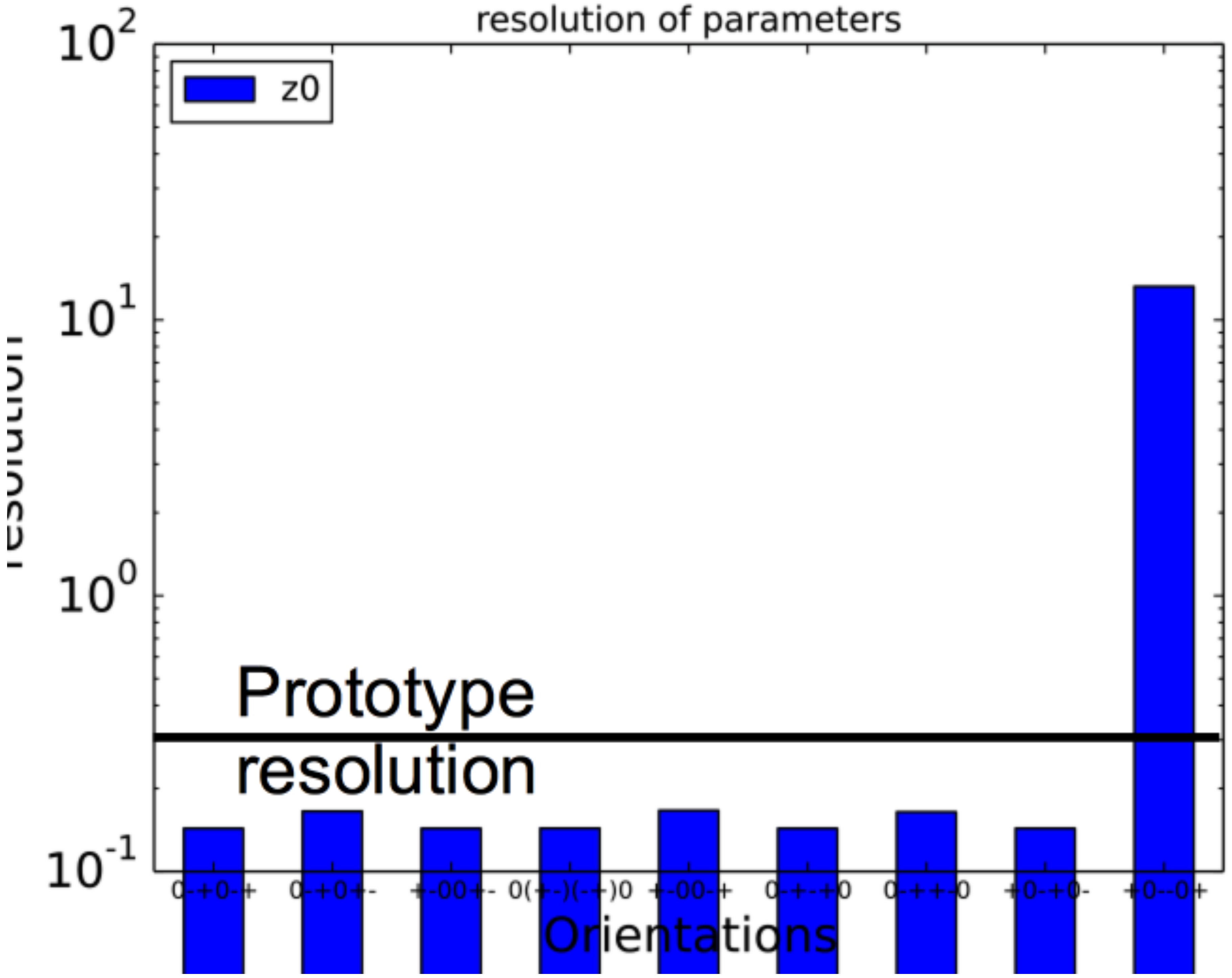


Study on Sensor Orientation

By comparing to user demand

- Analytical calculations using GeneralBrokenLines (GBL) by Claus Kleinwort with a 25 µm pitch strip sensor;
- Depending on the orientations, correlations between planes severely limit the resolution;
- The right orientation means the Telescope can easily achieve the curvature resolution needed for the LP TPC.



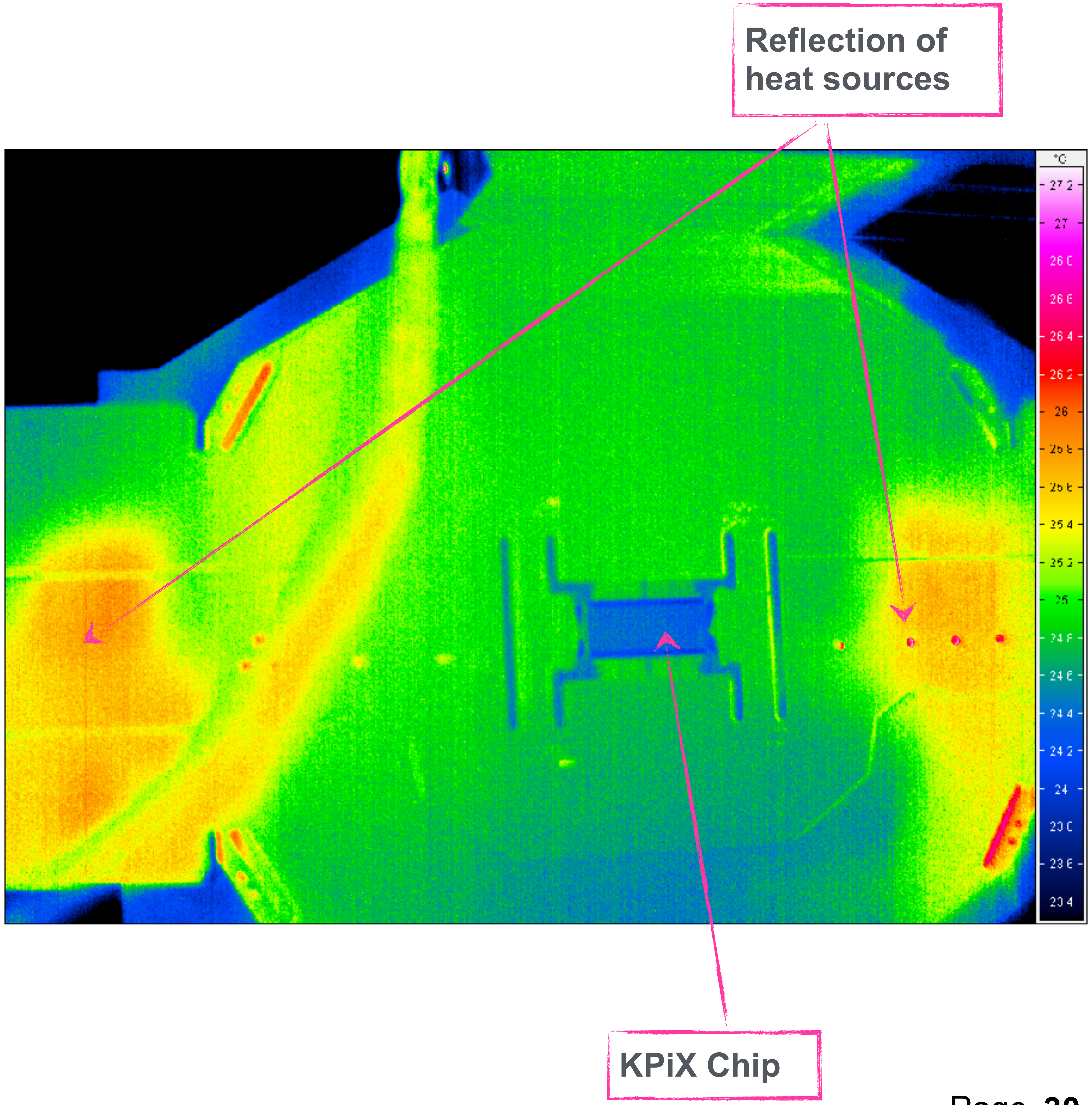


KPiX studies: do we need cooling?

Infra camera measurements

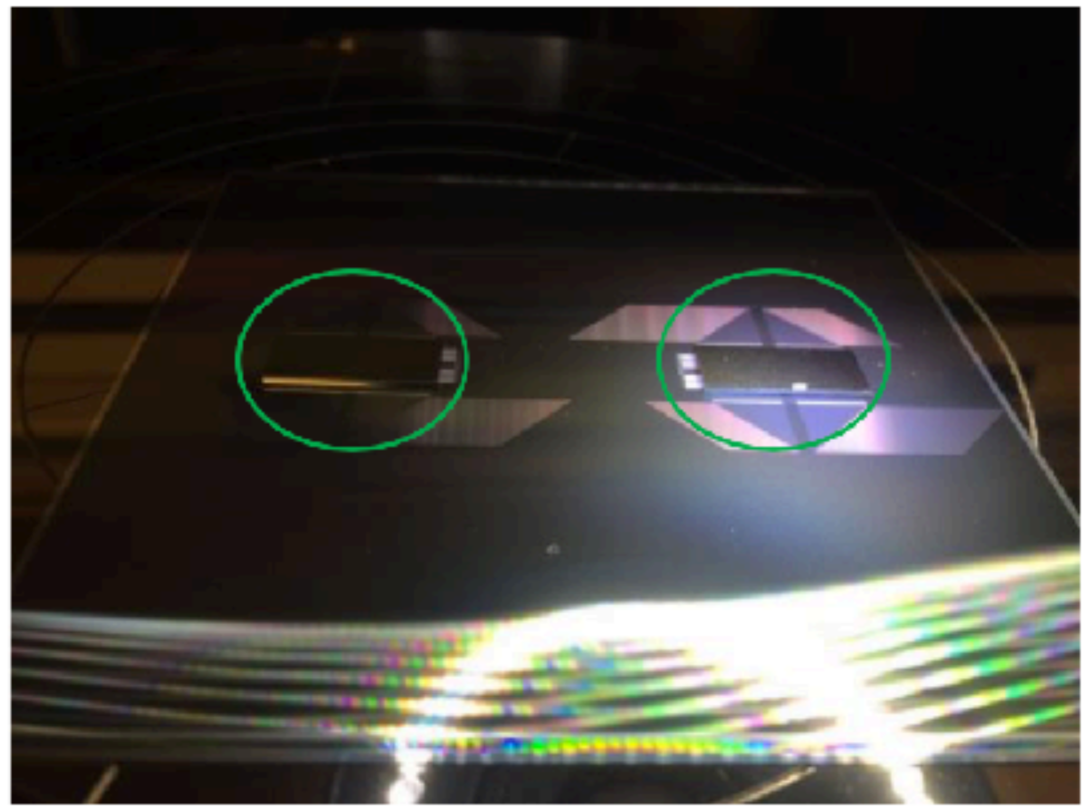
- As a result of power pulsing and only 1024 readout channels
  → a low Power Consumption is expected (40 mW in total)
- Measurement of heat production done via infrared camera
- Overall power consumption and heat generation is negligible

→ No dedicated cooling needed



Assembled modules

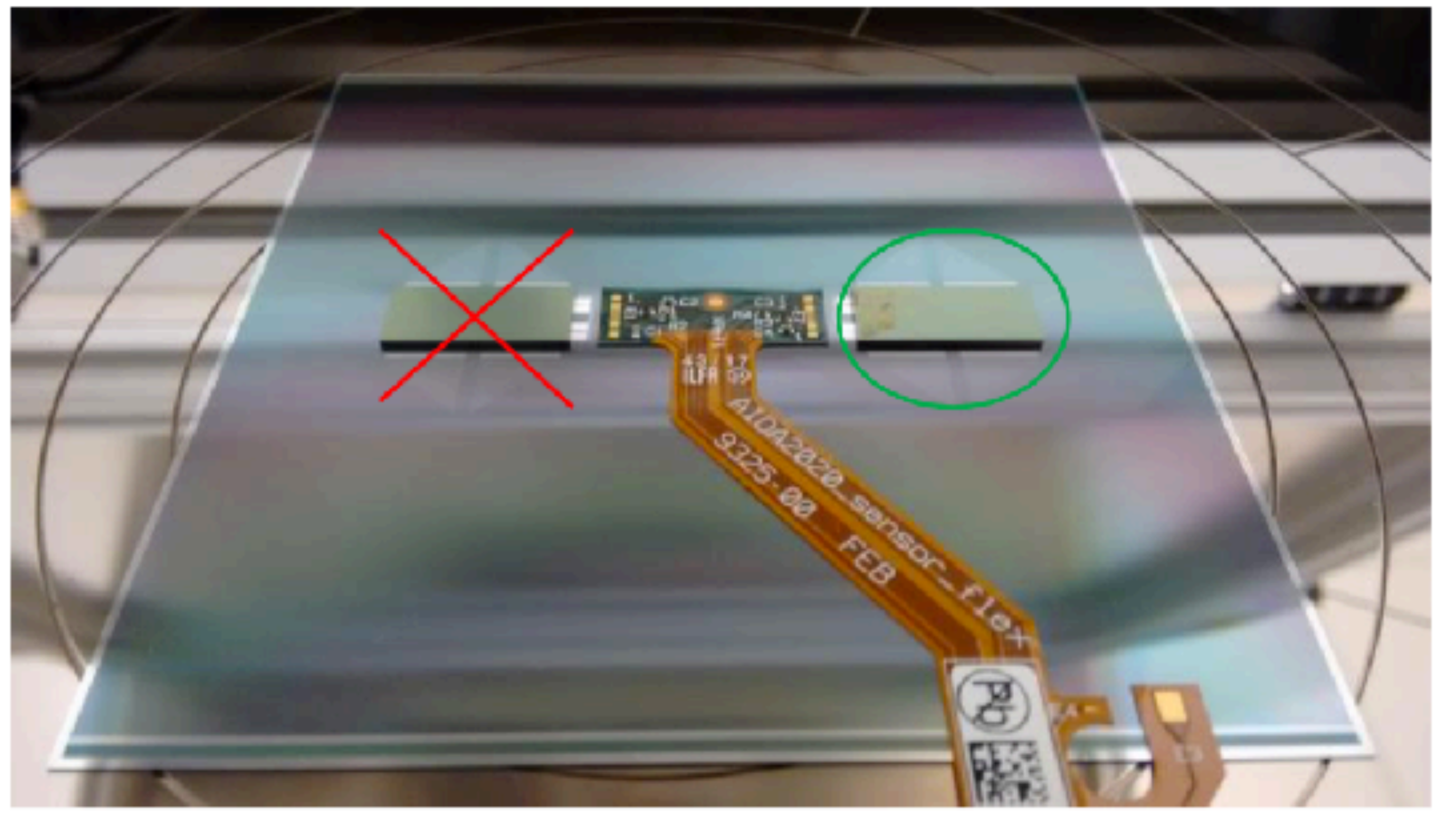
Sensor 59



Characteristics:

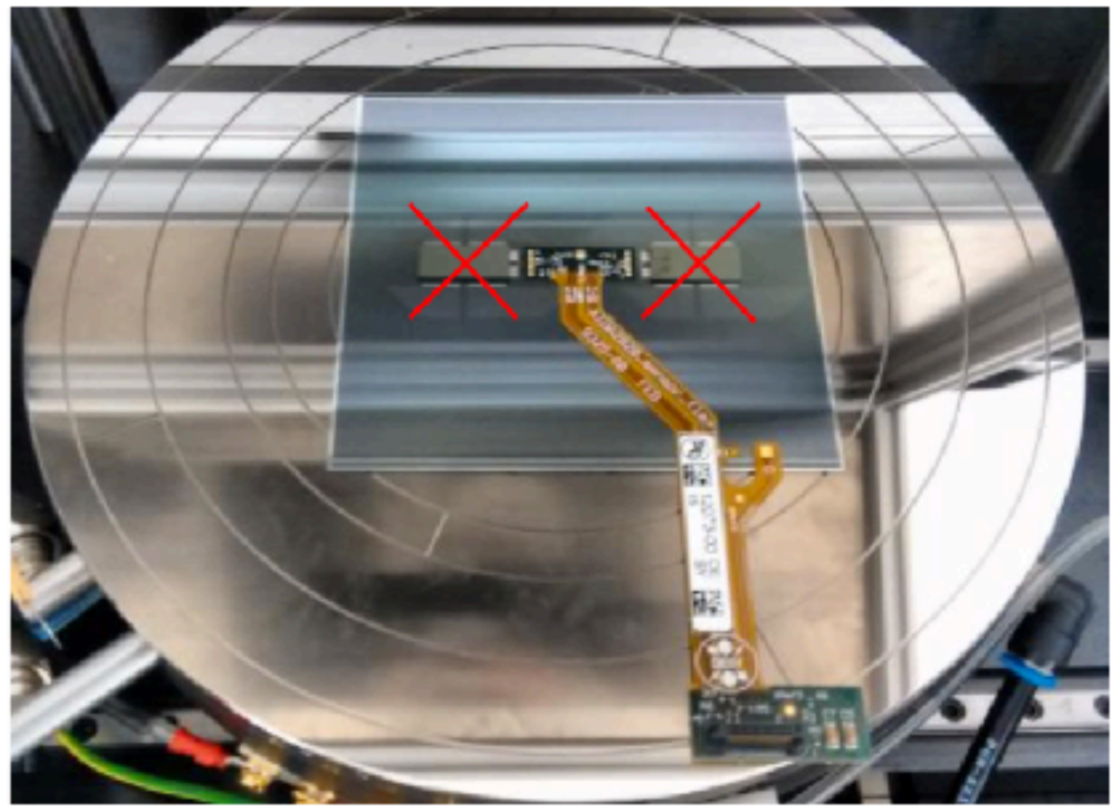
- **KPiX 2 shows very good calibration results**
- **Very high noise level**
- **Sensor depletes**
- KPiX cannot take data together
- **KPiX 1 has 128 channels bad ADC channels**

Sensor 58



- Characteristics:
  - **KPiX 2 can take data**
  - **Sensor does not deplete**
  - KPiX 1 cannot be talked to
  - KPiX 2 has supposedly 300 disconnected channels
  - **KPiX 2 shows a block structure when data is taken**

Sensor 52

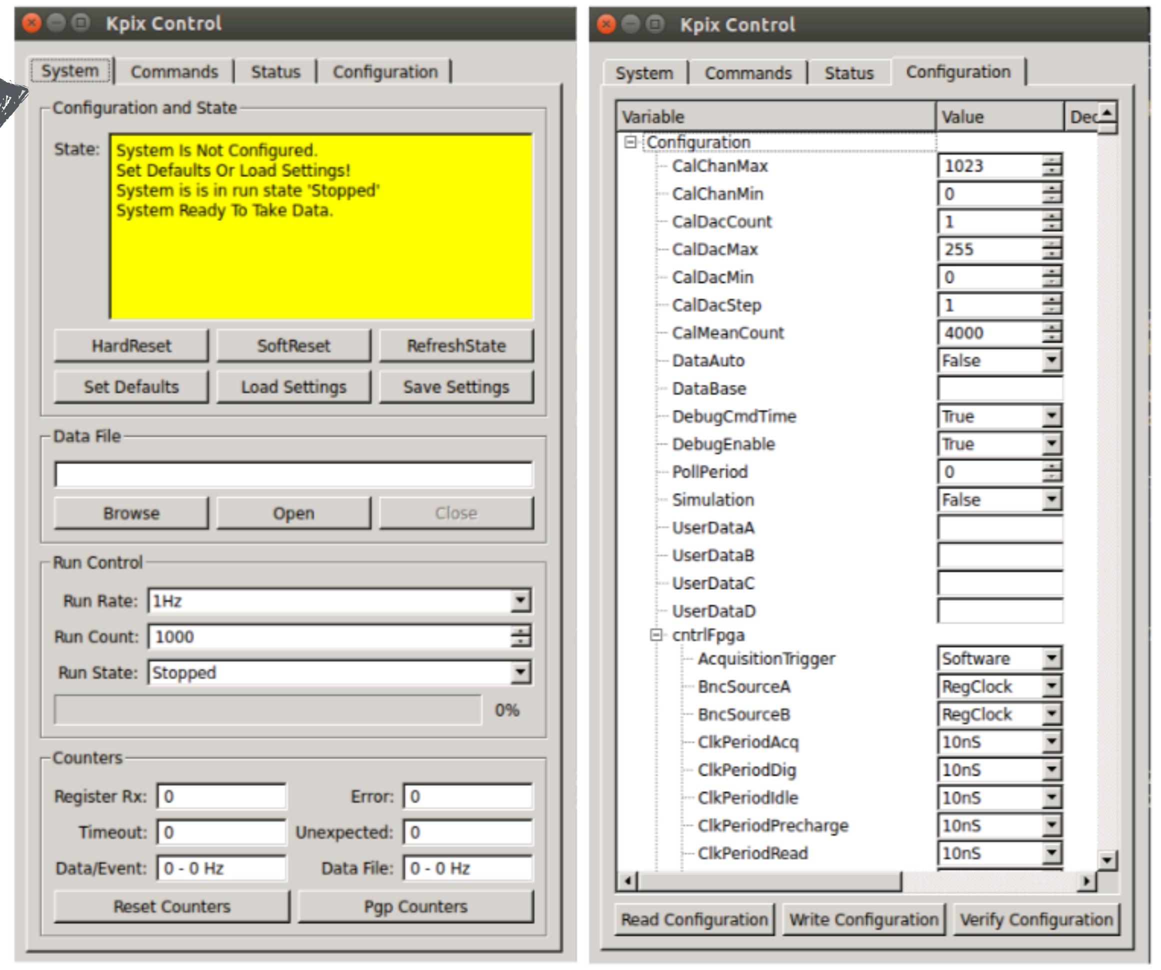


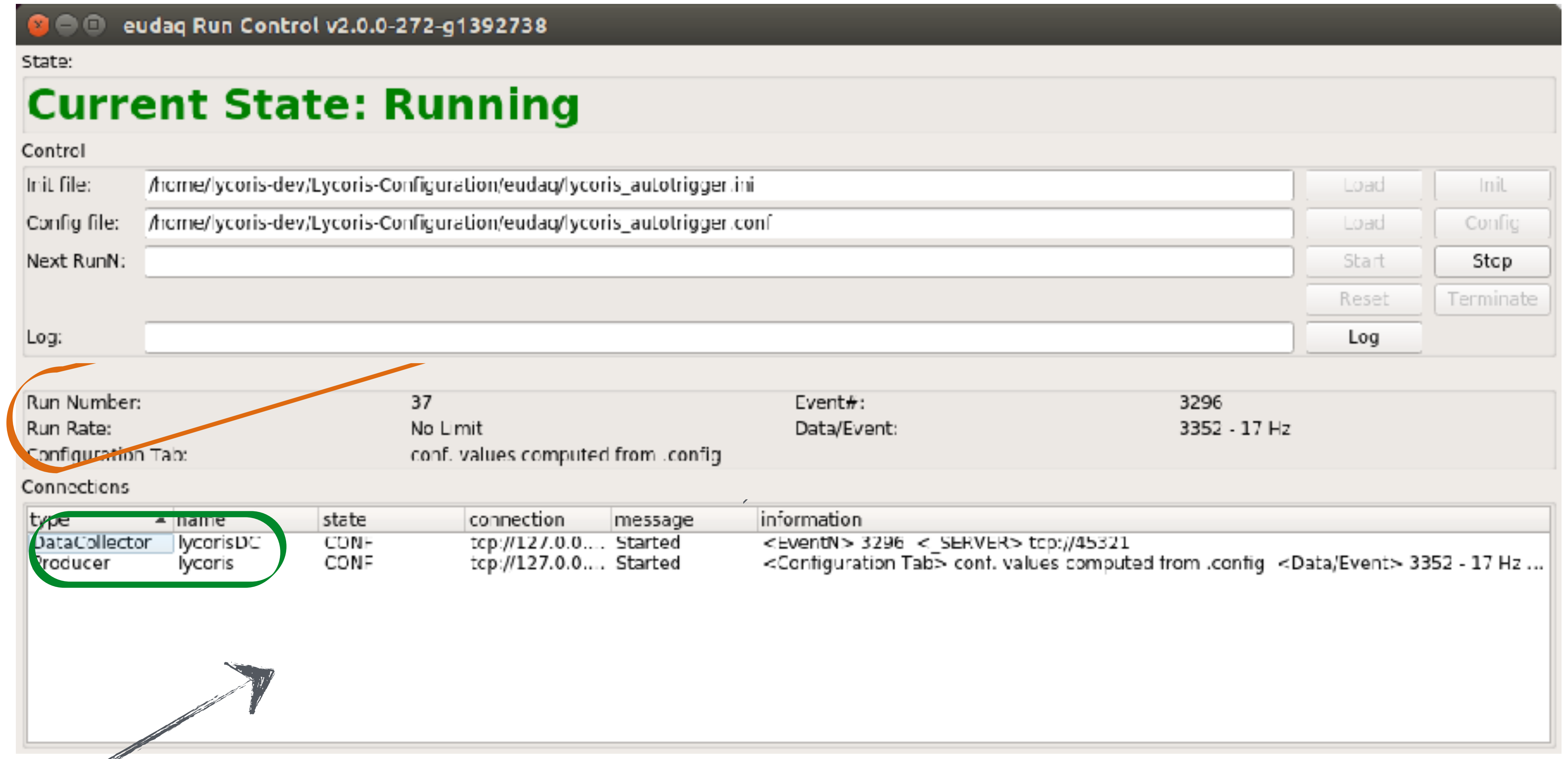
- Characteristics:
  - **Both KPiX show very bad calibration results**
  - KPiX 1 can take data
  - **Sensor does not deplete**
  - KPiX 2 does not send data
  - Calibration results suggests that the sensor cannot be used

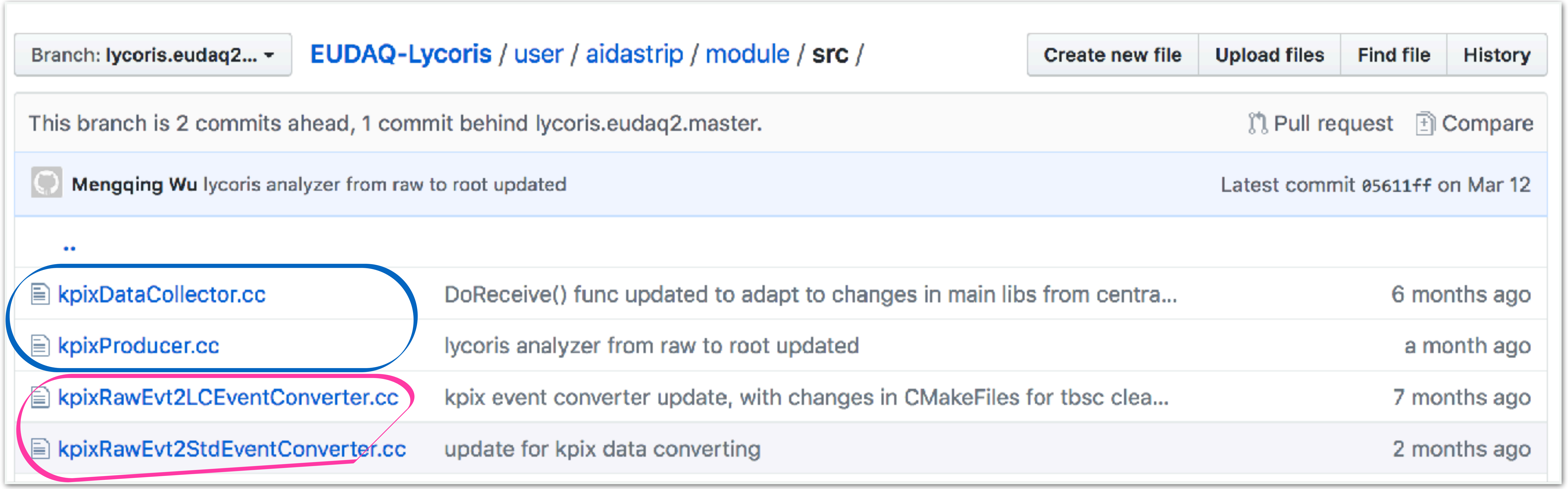
EUDAQ2 integration

Status

- Sensor **readout AISC KPiX** has its **own DAQ**
- Customized Modules:
  - dedicated **RunControl** module with its **GUI customized** to show more **info**
  - dedicated **Producer/ DataCollector** modules with KPiX DAQ as dynamic lib
  - corresponding **DataConverters** in progress



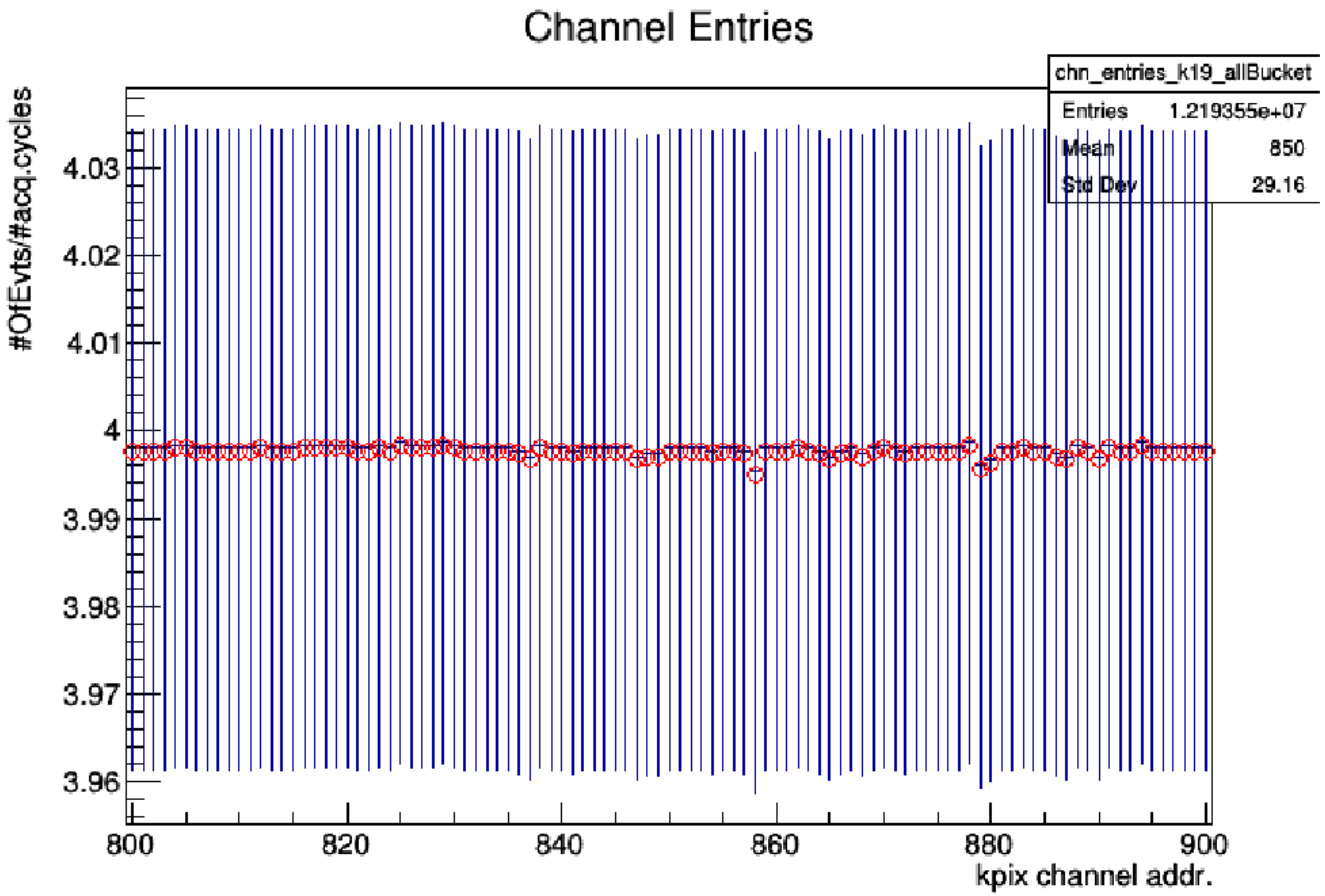




EUDAQ2 integration: Validate data buffering

Validation

- EUDAQ2 using FIFO to stream data from KPiX DAQ
  - many other ways tried, failed (time shift…)
- Validate data collected by EUDAQ2:
  - compare w/ data from KPiX DAQ.
- **Target**: sanity check w/ diff. run conditions (external trigger/internal trigger, sync/unsync to beam)
  - data output from both KPiX DAQ side and EUDAQ2 side in the same run.
- **Status**: validated
  - internal trigger: perfect agreed
  - external trigger: agreed w/ understood delay issue (not affect using EUDAQ2)



Red: KPiX binaries
Blue: EUDAQ raw

Data Analyzing: EuTelescope

— copyright goes to ATLAS-ITkStrip

A comprehensive set of MARLIN processors. Each reconstruction step has a steering file containing multiple processors

– **converter**(noisypixel): converter (determine noisy pixels/strips)

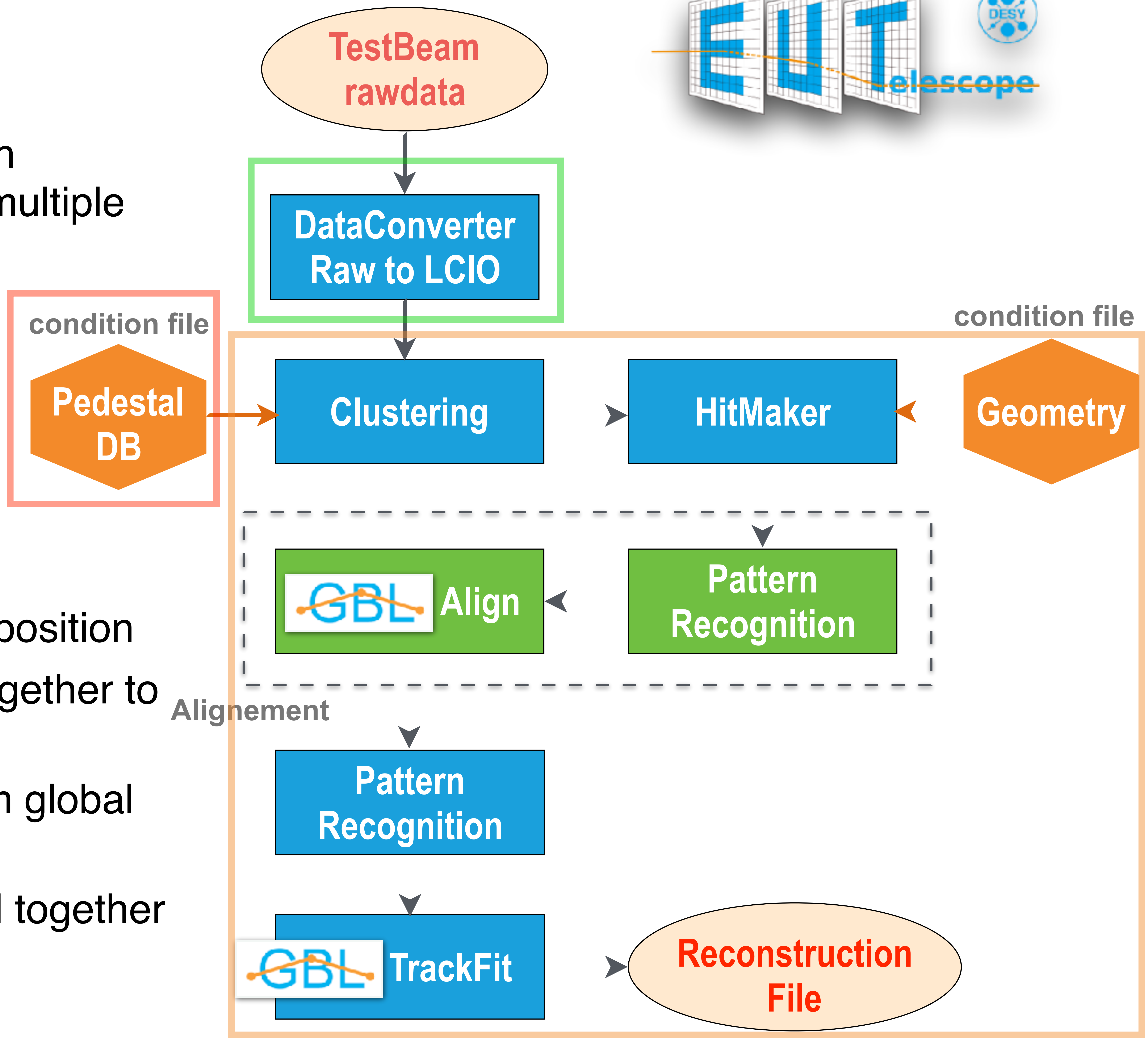
– **clustering**: retrieve the geometry of the sensor and give the coordinate of the strips/pixels center; group nearby strips/pixels together with noise pixel/strips removed

– **hitmaker** : find the cluster center to give the hit position

– **patternRecognition** : attach hits from planes together to form a track

– **GBLAlign** : determination of transformation from global frame to each local plane frame

– **GBLTrackFit** : fit of the track using hits attached together from pattern recognition



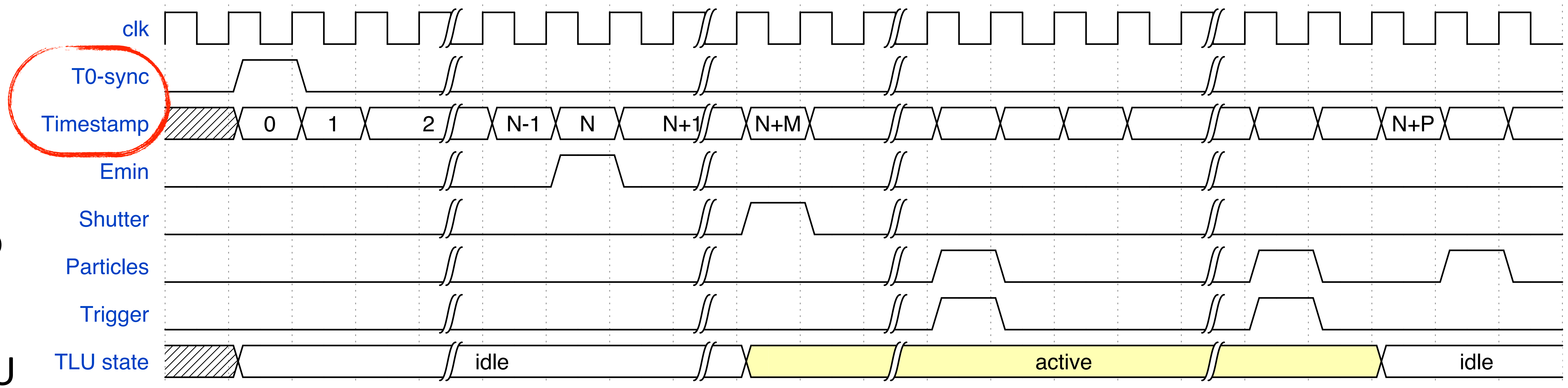
TLU integration: KPiX sync to DUTs

DUTs can use common TLU clock

from David Cussans

In general, DUTs can be categorized: <u>sync to TLU or not</u>

1. a DUT sync to the TLU:
   - The **TLU** common **global clock** to **sync** all devices;
   - Activation (shutter) issued by TLU
   - Busy signals (TLU state idle) to TLU: either global or local
     - <u>Global</u>: no trigger when any device is busy;
     - <u>Local</u>: trigger continuously issuing though some device busy



Shutter: activation signal
T0_sync: 1 per run, common start signal

TLU integration: KPiX sync to DUTs

DUTs can not use common TLU clock

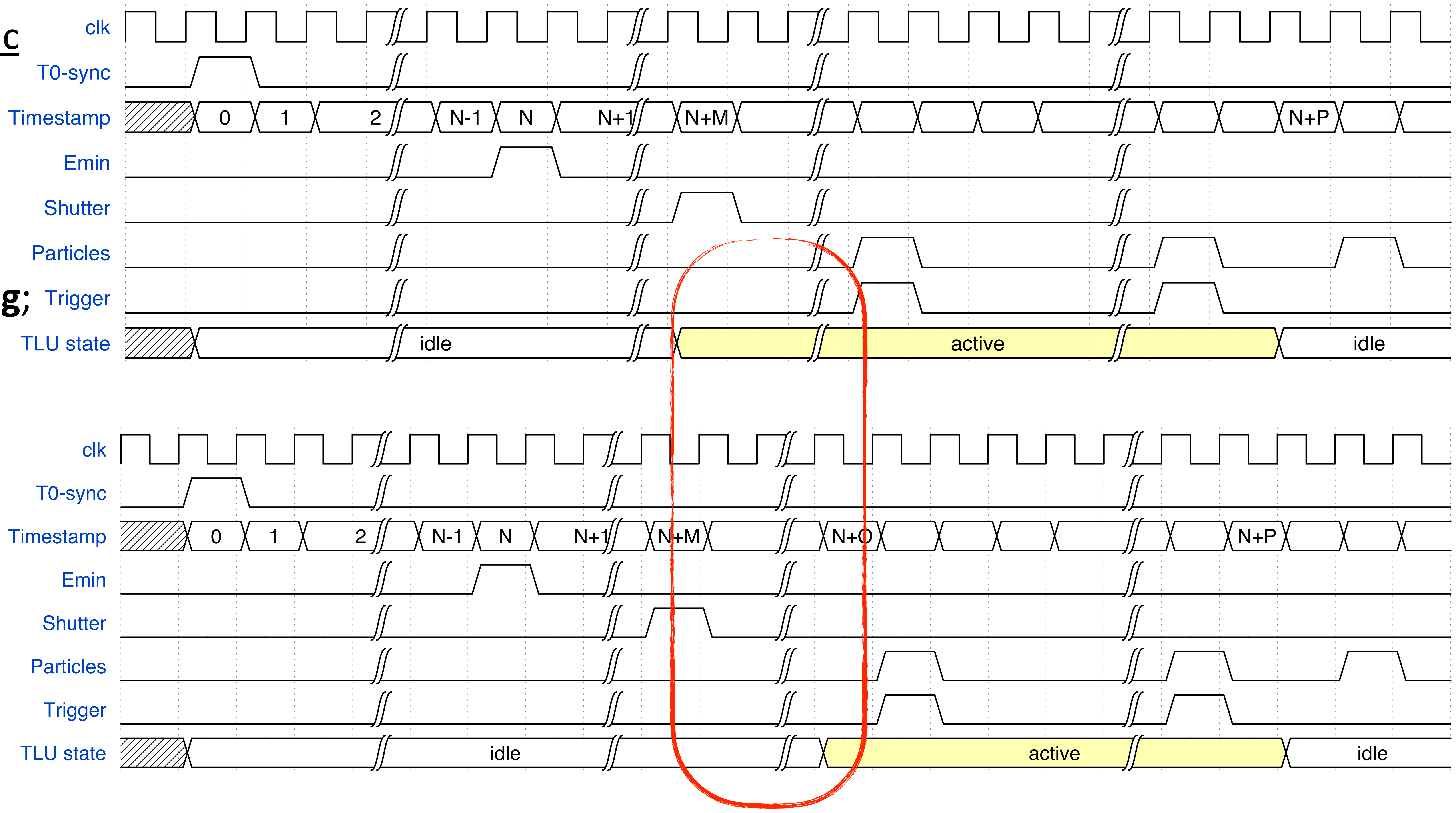
from David Cussans

In general, DUTs can be categorized: <u>sync to TLU or not</u>;

1. a DUT sync to the TLU:
2. a DUT unsync to the TLU:
   - Synchronization by **trigger counting**;
   - <u>Global busy</u> used: no trigger sent, when either device is busy;
   - Add-on TLU func: **configurable delayed** TLU active period

Status:

- new TLU will be issued by end of this month;
- a first use case needed to test.



Shutter: activation signal
T0_sync: 1 per run, common start signal