Integration of high temporal resolution planes into AIDA-type telescopes for Sensor Characterization

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on behalf of the ETROC Fermilab & IFCA teams

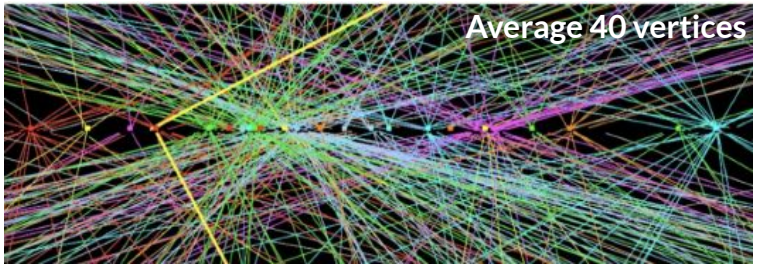
1st. DRD3 Week on Solid State Detectors R&D
CERN, June 21st, 2024

OUTLINE

- Test beam infrastructures for sensor characterization
- The ETROC2 ASIC for CMS Phase-2 upgrade timing layer
- AIDA Telescope for spatial and temporal Sensor Characterization

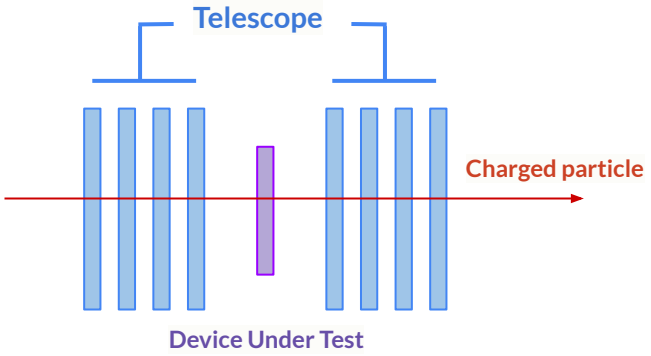
Entering into the 4D-tracking paradigm

- Next generation of experiments at (hadron) particle colliders will need to cope with large density of tracks
  - Time stamping particles track will allow to mitigate the increased pile-up

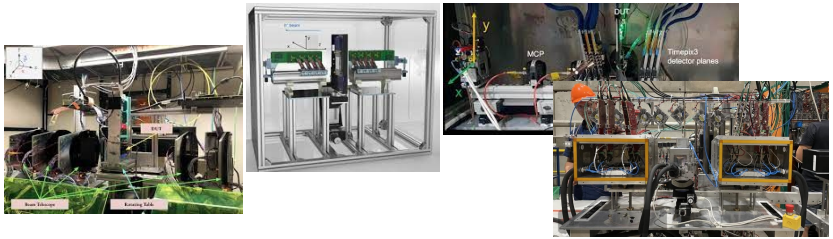


- Besides, sensor technological advances allow to reach high precision time, ~ O(tens of ps) in highly segmented structures
  - LGADS family (iLGAD, TI-iLGADs, AC-LGAD, TI-LGAD, …)
  - 3D pixels
  - HVCMOS
  - …

Sensor Characterization



- Test beam experiments are widely used to test new devices, such as particle detectors, and to optimize their performance



  - Each team that wanted to conduct test beam experiments had to build its own telescope, instead of focusing on the DUT itself.

- The EUDET (European Detector R&D for Future Colliders) project was conceived w[illegible] h[illegible] of developing the tools that would allow the experimental particle physics community to focus on the research and development of new sensors, detection concepts, and performance.

  EUDET started in 2005, finishing in 2010! But the aim of the project on their successors, the AIDA saga: AIDA, AIDA-2020 and the current AIDAInnova

https://www.eudet.org https://aida2020.web.cern.ch https://aidainnova.web.cern.ch

Sensor Characterization Infrastructure

The EUDET/AIDA project identified the construction of a test beam infrastructure for sensor characterization as a fundamental element for R&D in particle physics sensing: aimed to **provide a common interface** (hardware and software) **to beam lines**. The identified deliverables:

- A high-resolution position telescope to reconstruct particles
- A logical trigger unit to interconnect the telescope with the devices under test (DUTs) and trigger the readout systems
- A data acquisition system
- A reconstruction software

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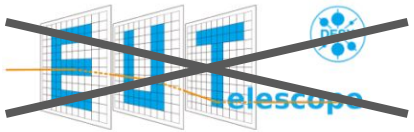


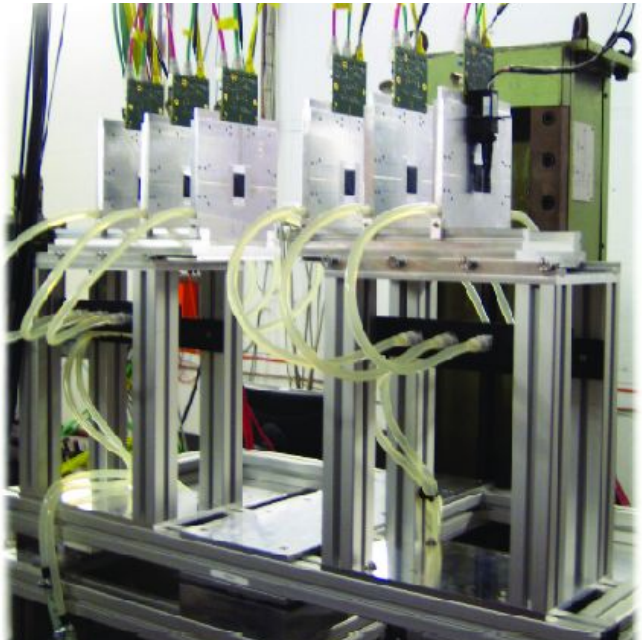
Discontinued

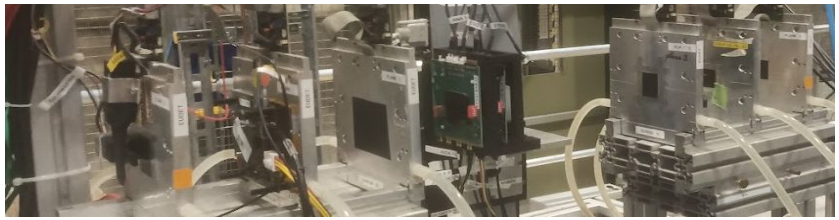
Corryvreckan

The Maelstrom for Your Test Beam Data

AIDA-type telescopes

- AIDA-type telescopes are one of the most successful outcomes. There are several permanently installed and ready to be used in several of the main particle physics labs in Europe and USA: CERN, DESY, Bonn and SLAC





- DESY (3)

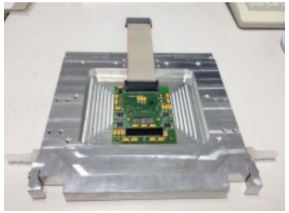
- CERN (2)

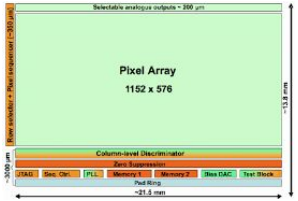
- ELSA (Bonn) (1)

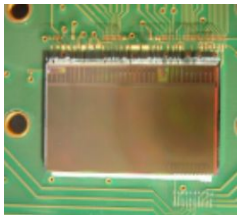
- SLAC/ TRIUMF (1)

AIDA-type telescopes

- 6 layers of MIMOSA26 monolithic active pixel sensors (MAPS)
  - Sensor size: 2 cm x 1 cm
  - Thickness: 50 µm
  - Pixel size: 18.4 µm x 18.4 µm
  - Rolling-shutter RO (115 µs per cycle, 2 cycles read out per trigger)
  - Other than that no hit time information
- Can provide a track resolution of few microns (~2 um)
- Stable operation
- Part of the test beam infrastructure at CERN and DESY

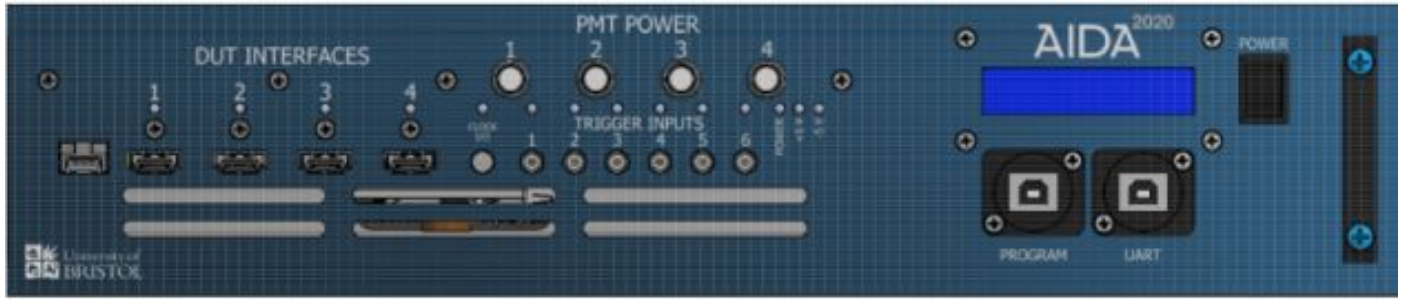






Trigger Logic Unit (TLU)

- Flexible and configurable device designed to provide trigger and interface devices
- Main characteristics:
  - 6-configurable inputs to create the trigger logic
  - 4 HDMI-differential DUT interfaces
  - DUT interface modes:
    - Trigger (and busy) → Trigger Global Busy Scheme → ONLINE SYNC by EVENT
    - Trigger, ID (and busy) → Trigger Local Busy Scheme → ONLINE SYNC by Trigger-ID
    - Trigger, clock and T_0 → Decentralized Data Scheme → OFFLINE SYNC



https://indico.cern.ch/event/1323113/contributions/5823585/attachments/2836907/4959134/cussans_aida_tlu_bttb12_april2024.pdf

Data Acquisition Software: EUDAQ (v2)

https://cds.cern.ch/record/2314266/files/AIDA-2020-NOTE-2018-001.pdf

RunControl (ONE)
Central **controller** for the full EUDAQ2 system

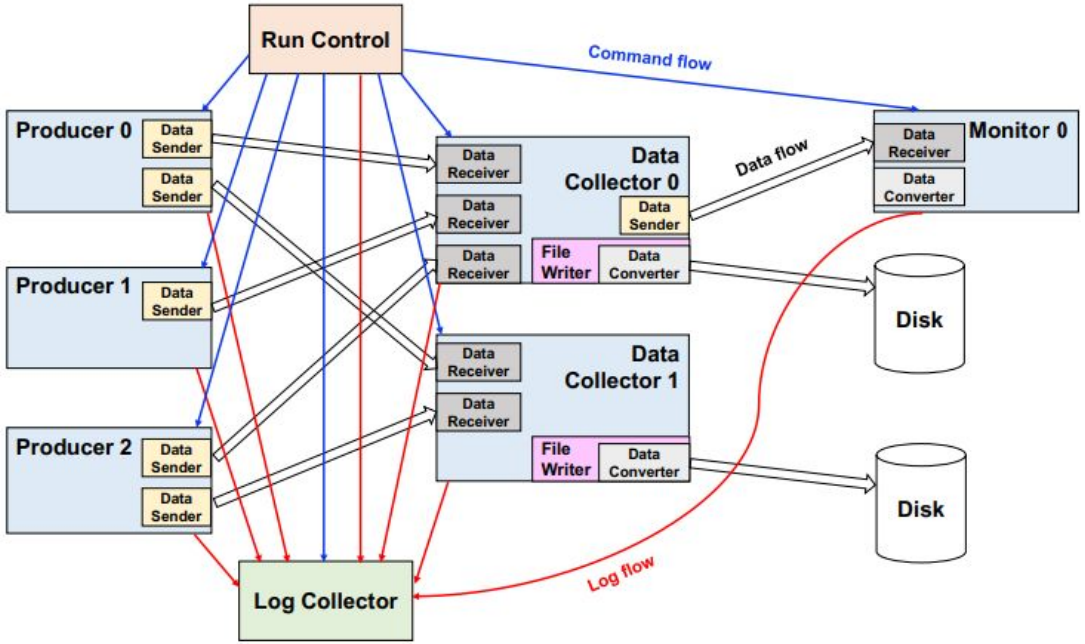
LogCollector (ONE) [OPTIONAL]
Collects log messages for the entire EUDAQ2 system

DataCollector (ONE or MANY)
Collects and merge data from individual Producers, then **stores** data to disk

Producer (ONE per Hardware Device)
Controls an individual detector and **sends** detector **data** to EUDAQ2

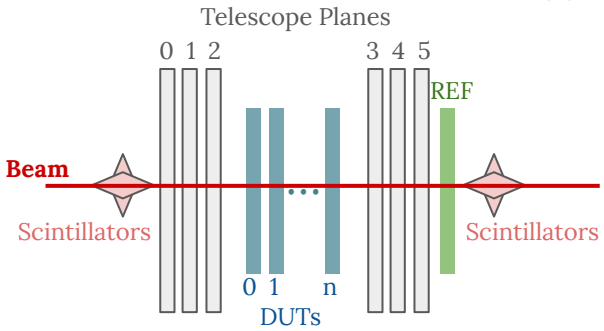
DataConverter (ONE per Hardware Device) [OPTIONAL]
Convert raw (undecoded) data into StdEvent format (or others)

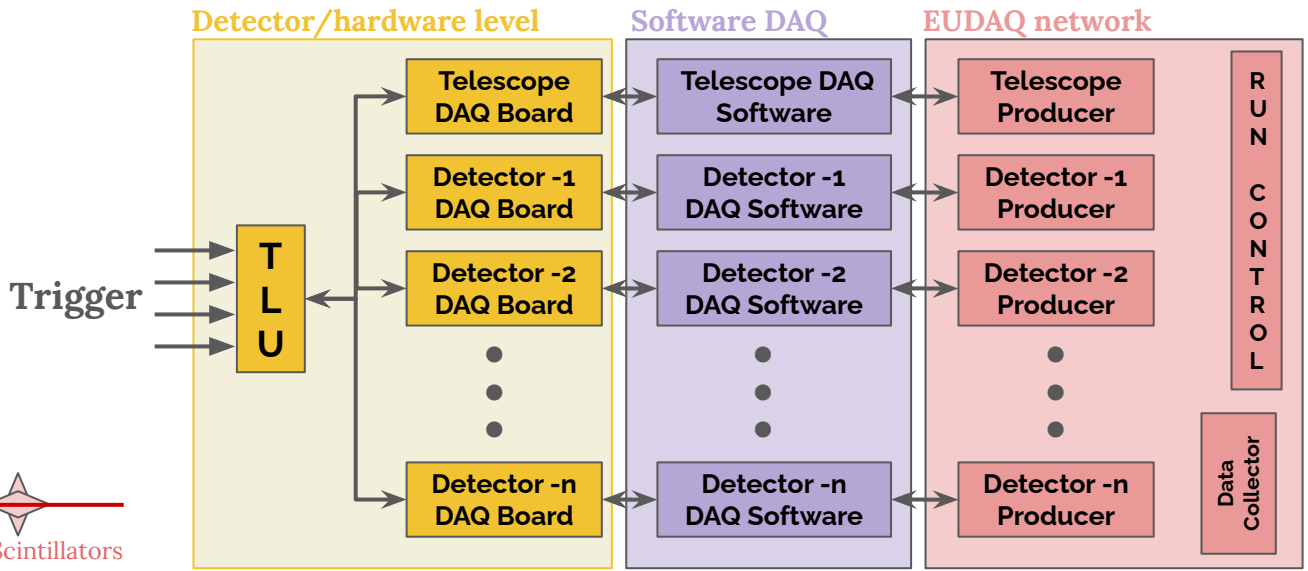
Monitor (ONE) [OPTIONAL]
Data quality **online monitoring**



Test beam layout: DUT integration into the infrastructure

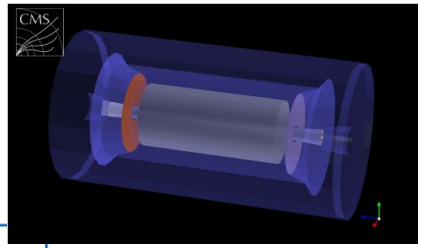
- Reference telescope
- Triggering logic (TLU)
- DAQ network
- n-Devices Under Test
- Reference plane



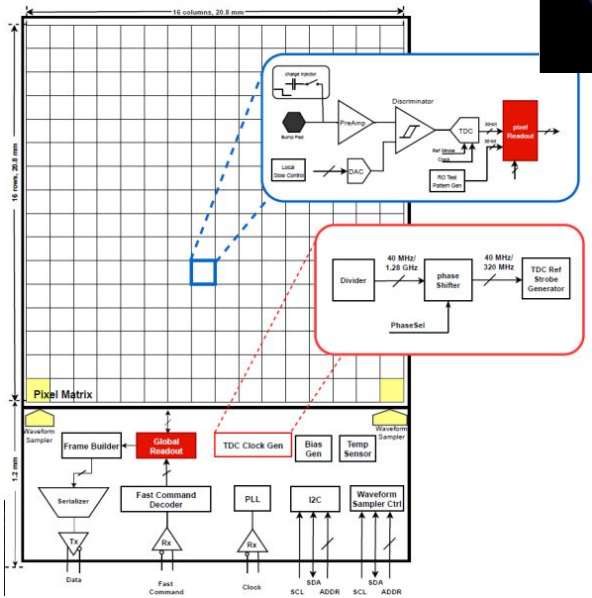


ETROC2: The ASIC for the CMS MTD

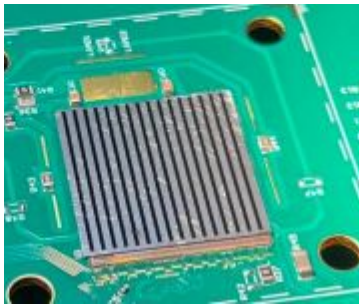
- Read out chip for the CMS ETL Endcap Layers: ETROC



- Main characteristics of the chip
  - 65 nm CMOS process
  - 16x16 pixel matrix of 21x23 mm^2
    - To be pixel size of 1.3 x 1.3 mm^2
  - Aime to provide resolution
  - Hit auto-calibration

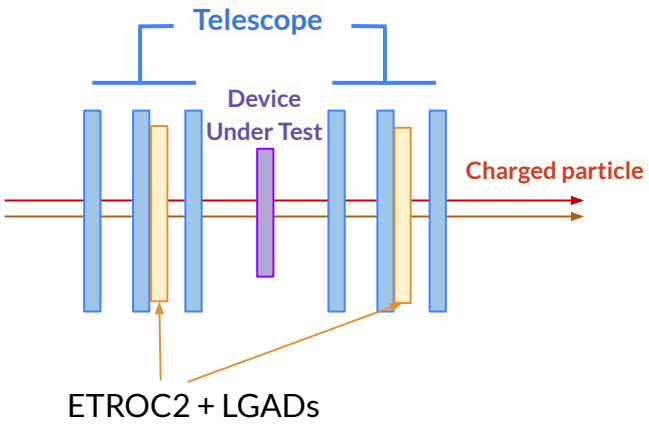


- Good candidates to ...GADs with ... of a ... hit time



ETROC2 as timing plane in the AIDA telescope

- Use ETROC2 as high temporal resolution timing planes for AIDA telescopes



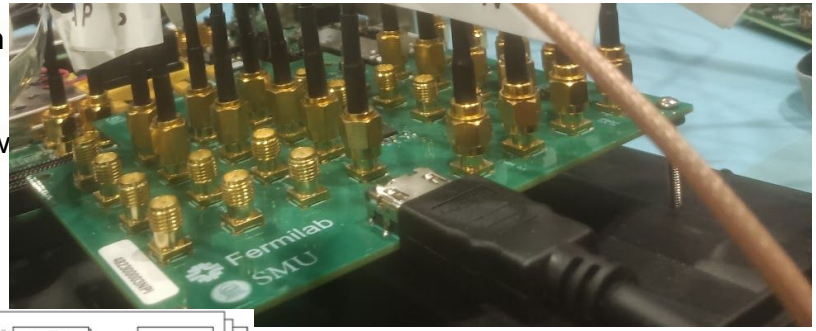
Position particle identification with high resolution

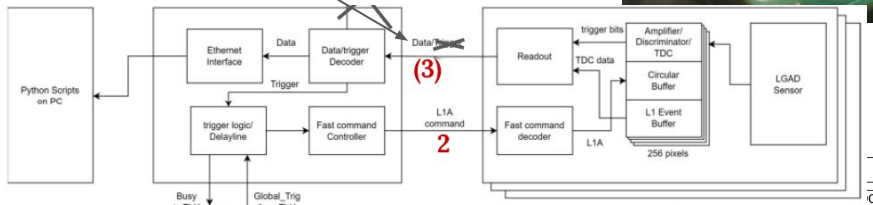
+

Time particle identification with high resolution

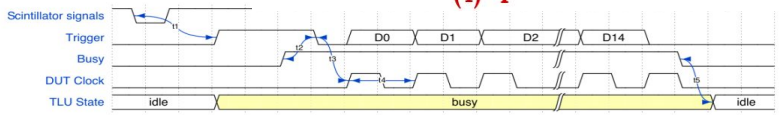
ETROC2 Integration

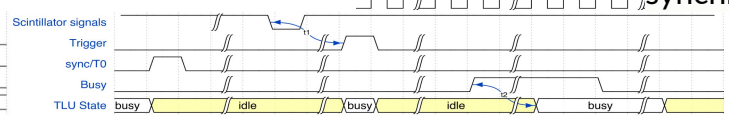
- Integrate the ETROC2 into the AIDA test beam infrastructure means:
  - Interface the ETROC2 with the TLU signals and protocols:
    - Build a FMC with connect it to the TLU
    - Write the firmw with the TLU protocols

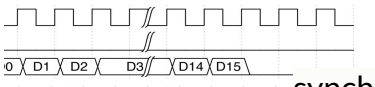




asynchronous modes



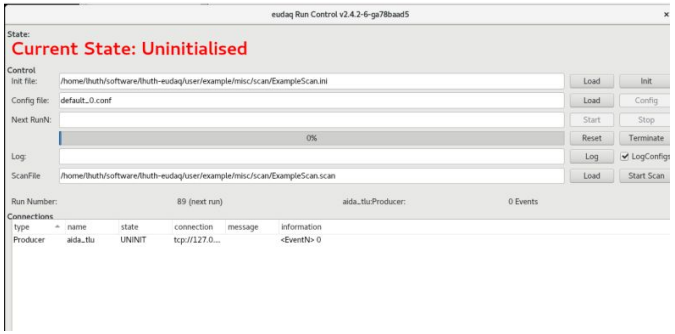


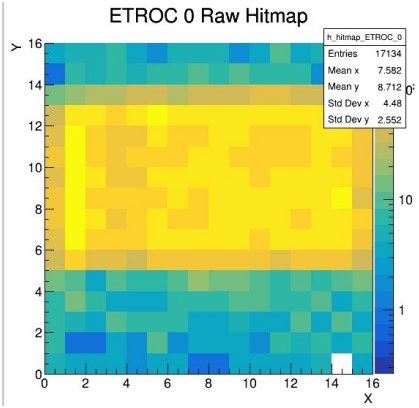


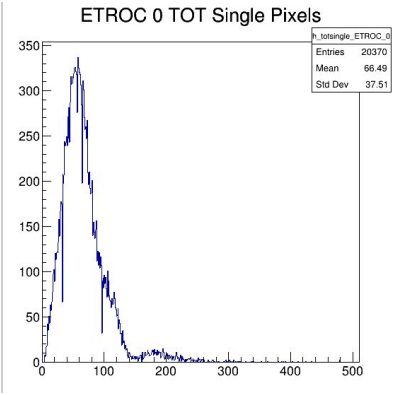
synchronous modes

ETROC2 Integration

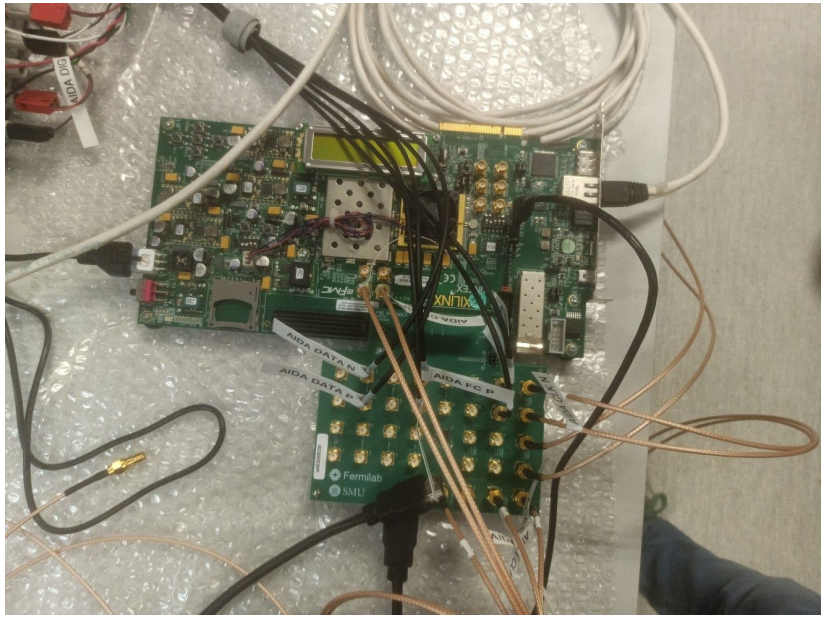
- Integrate the ETROC2 into the AIDA test beam infrastructure means:
  - Connect the ETROC2 DAQ software with EUDAQ
    - Write the producer to implement commands and raw data collection
    - Write the data converter to visualize and/or analyze data

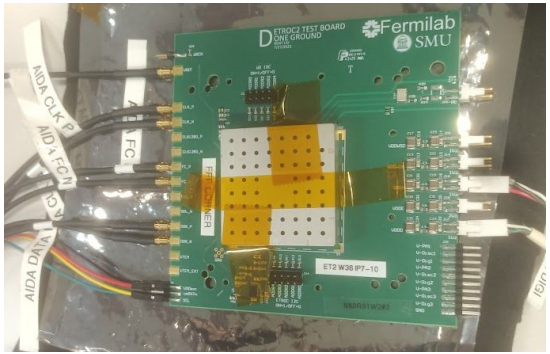




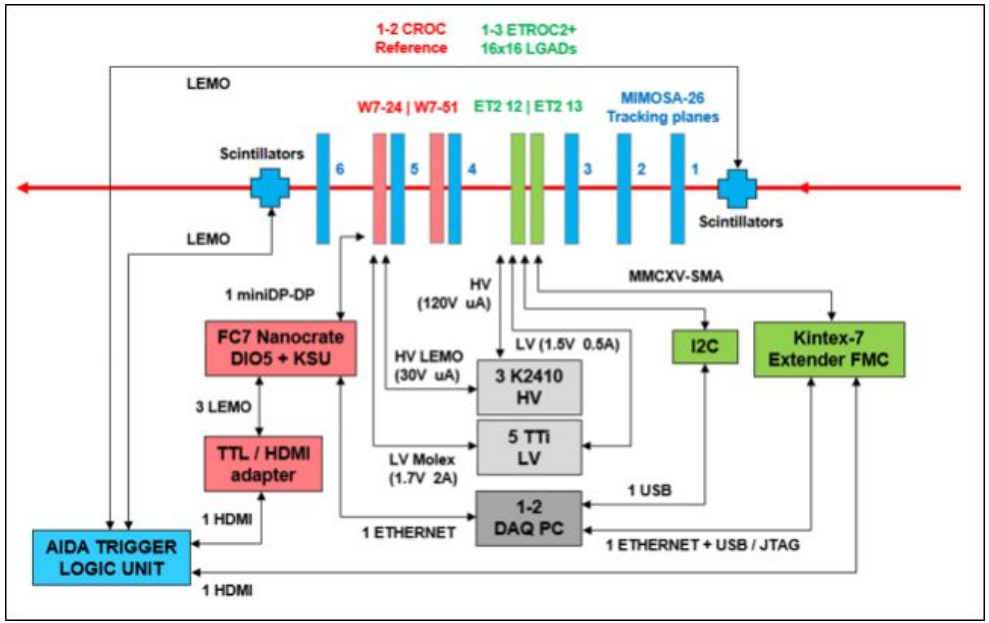


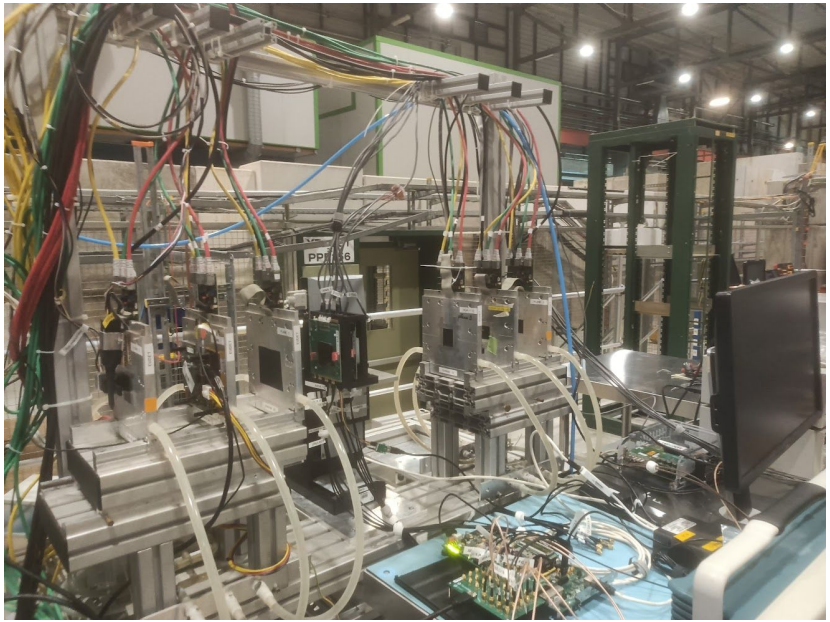
ETROC2 Integration:





ETROC2 Integration: test beams





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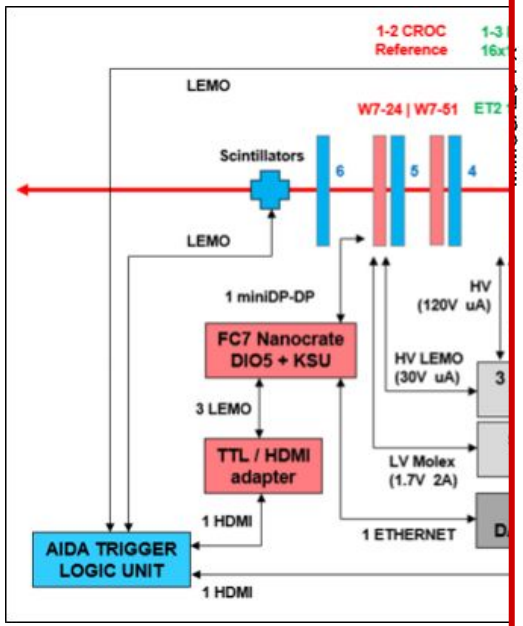

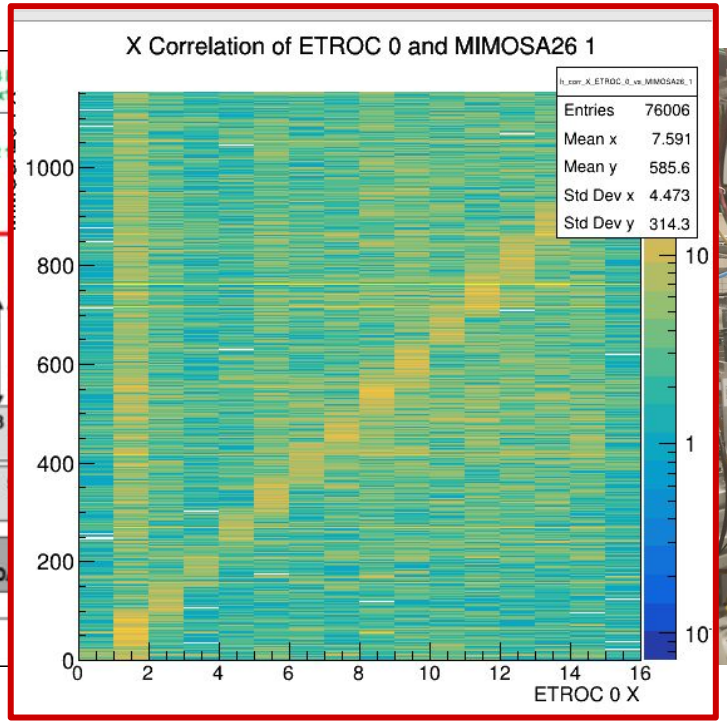

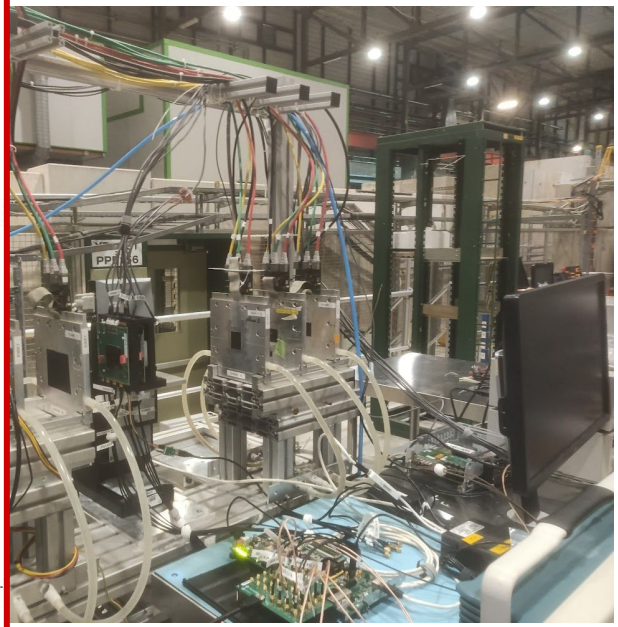

- ETROC2 is **completely integrated** into the infrastructure

Summary

- Well-established infrastructure for beam test sensor characterization
  - Widely used by the community
  - So far, high spatial resolution

- Use ETROC2 BB to LGADs sensor to provide the AIDA telescopes with high temporal resolution of orders of (less than) 50 ps
  - Enable telescopes to characterize sensors for tracking-4D

- Integration done and (almost) ready to be included

Thanks for your attention!

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Plan de Recuperación,
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