Characterisation of Timepix3 hybrid pixel detector assemblies and integration with the AIDA telescope

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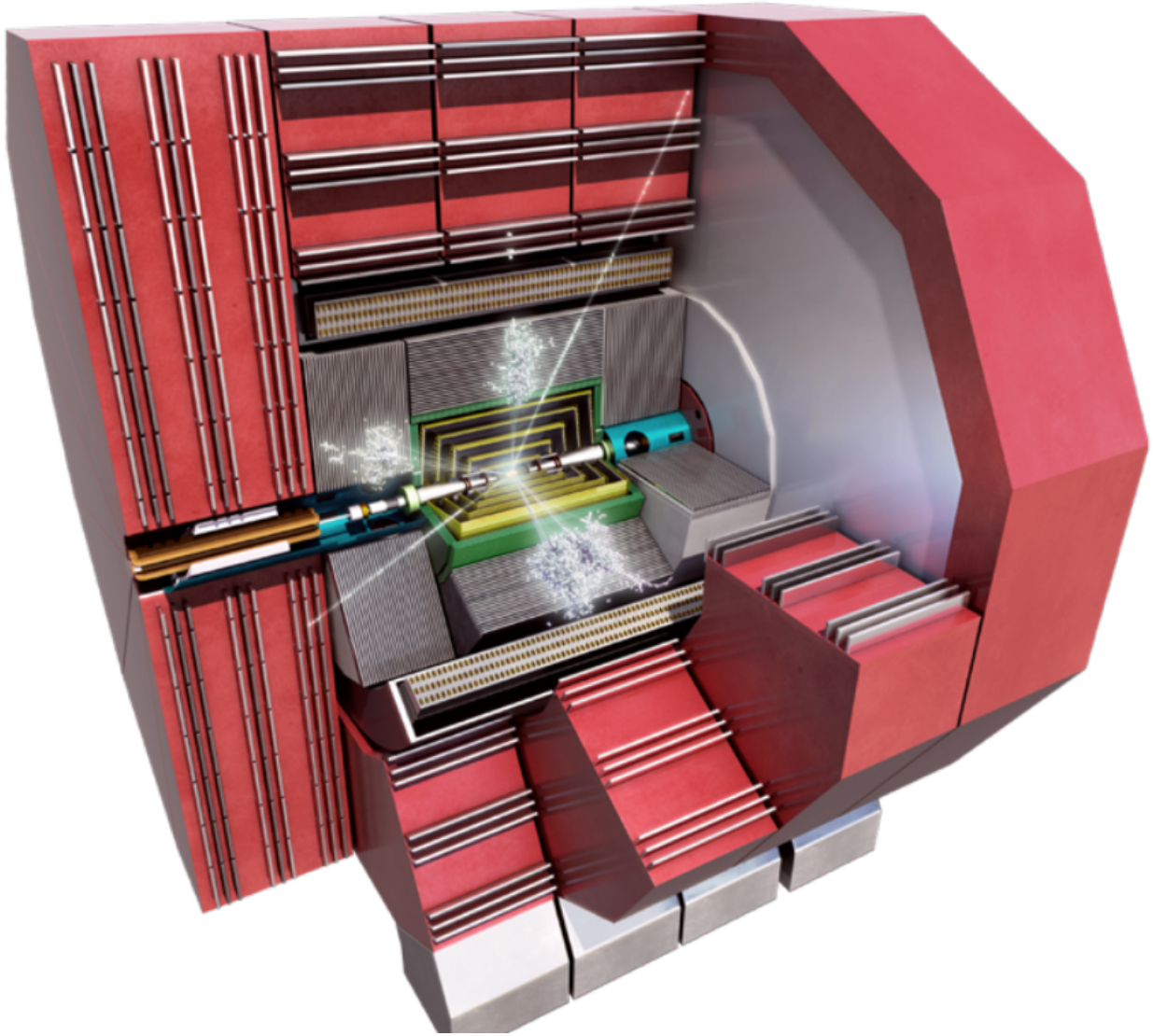
on behalf of the CLICdp collaboration

Outline

- The CLIC detector
  - Vertex Detector requirements
- Timepix/Medipix chip family
- Timepix3 description and readout
- Testbeam at CERN PS & SPS using AIDA telescope
  - Preliminary results
- Conclusions

The CLIC detector



Precision physics in a challenging environment: broad programme of R&D

Highly granular particle flow calorimetry, using tungsten absorber

5.5 m diameter cryostat for superconducting solenoid, B field 4-5 T

All silicon tracker

Instrumented steel return yoke

Complex forward region

Vertex detector requirements

→ Good single point resolution: $\sigma_{SP} \sim 3$ μm
  → Small pixels ~ 25x25 μm^2

→ Low material budget: $X \lessapprox 0.2\% X_0$ / layer
  → Corresponds to ~200 μm Si, including support and powering
  → Air-flow cooling + Low-power ASICs (~50 mW/cm^2)

→ 156 ns bunch trains, 20 ms train repetition rate
  → trigger-less readout, pulsed powering

→ Time stamping with ~10 ns accuracy, to reject background
  → high-resistivity sensors, fast readout

- No technology option available fulfilling simultaneously all requirements:
  → Simulation studies: impact of layout on performance
  → R&D on sensors & readout
  → Integration/assembly + cooling + power-pulsing studies

The Timepix/Medipix chip family

Chip	Year	CMOS Process	Pitch [μm²]	Pixel operation modes	r/o mode	Main applications
Timepix	2006	250 nm	55x55	∫TOT or ToA or γ counting	Sequential (full frame)	HEP (TPC)
Medipix3RX	2012	130 nm	55x55	γ counting	Sequential (full frame)	Medical
Timepix3	2013	130 nm	55x55	TOT + ToA, γ counting + ∫TOT	Data driven (5 Gbit/s)	HEP, Medical
Velopix	2015	130 nm	55x55	ToA, γ counting	Data driven (20 Gbit/s)	HEP: LHCb
Timepix4/ Medipix4	~2016	65nm	35x35	Similar to v3 familly	---	HEP/Medical
CLICpix demonstrator	2013	65 nm	25x25	TOT + ToA	Sequential (data comp.)	Test chip with 64x64 pixel matrix
CLICpix	tbd	65 nm	25x25	TOT + ToA	Sequential (data comp.)	CLIC vertex detector

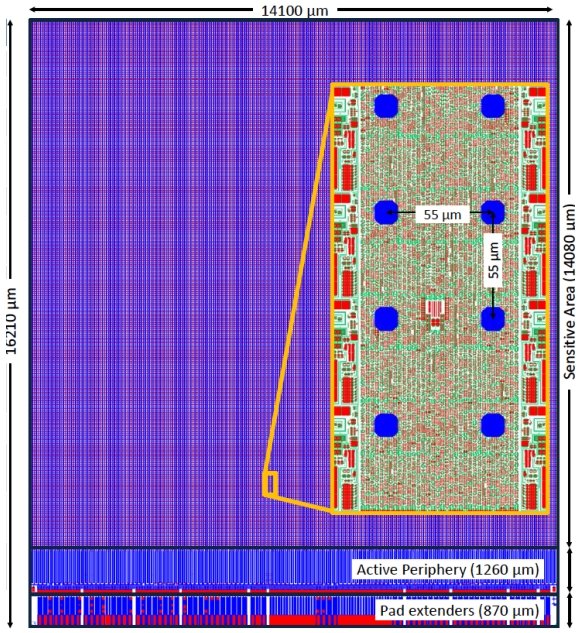
TOT: Time-Over-Threshold → Energy
ToA: Time-of-Arrival → Time stamping

- Taking advantage of smaller feature sizes:
  - Improved noise performance
  - Increased functionality and/or
  - Reduced pixel size

Timepix3 ASIC

Timepix3 ASIC was received at CERN beginning of 2014. it represents a revolution w.r.t. the Timepix1 ASIC, going from:

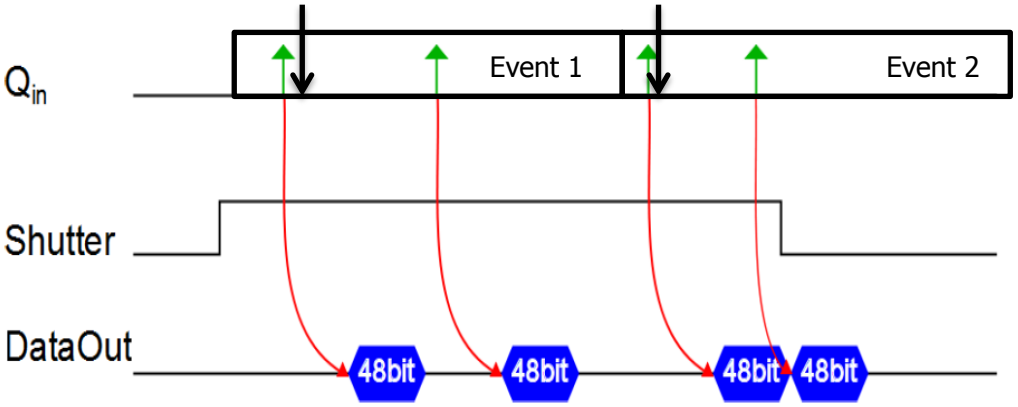
- ~10 ms readout time
  - Data driven @ 10Gb/s
- TOT or TOA
  - TOT(10bits) + TOA
- Proprietary DAQ
  - DAQ developed by NIKHEF and CERN, full control of hardware + software



Integration to AIDA telescope framework was much easier :

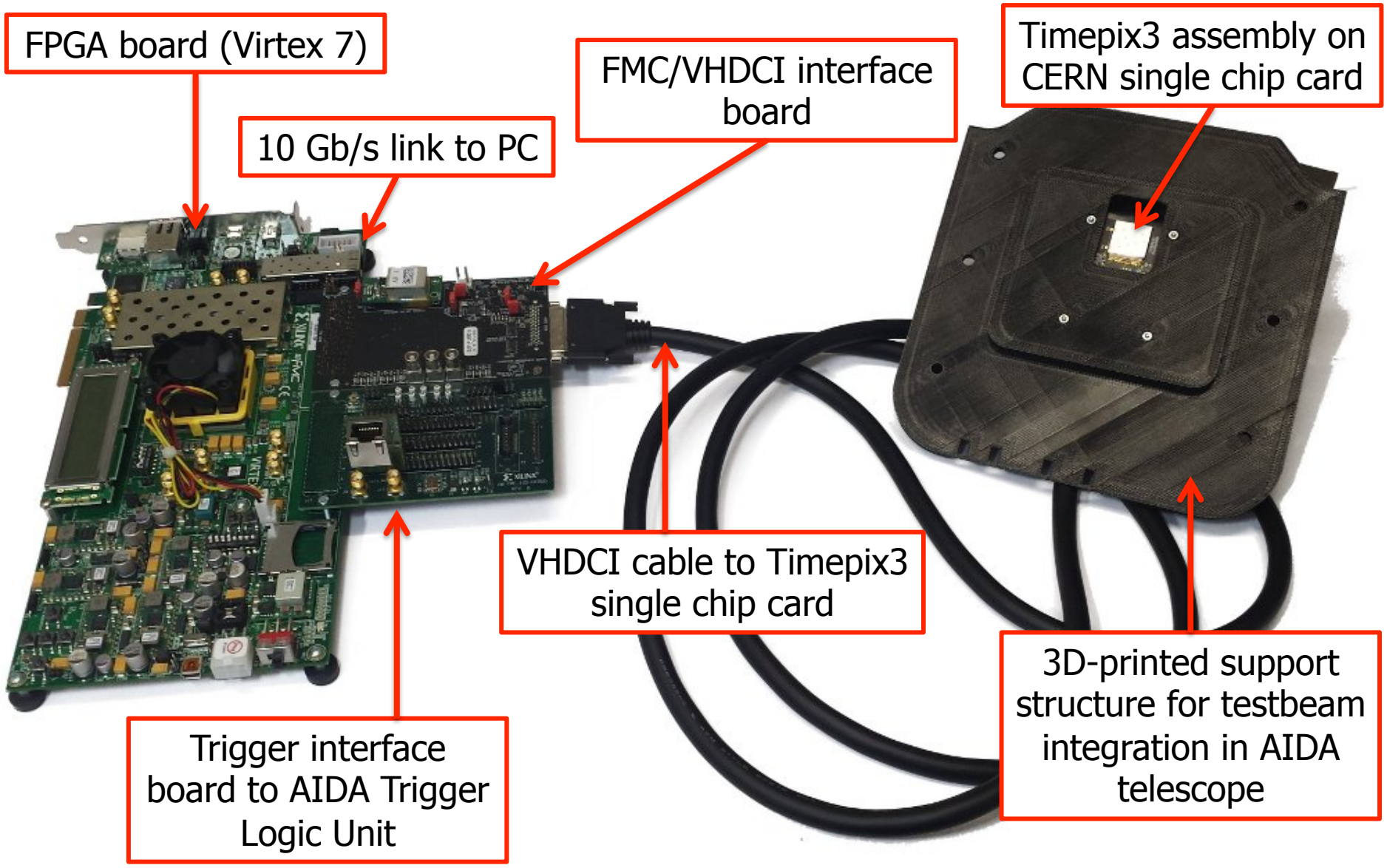
- 100% active during acquisition
- Hits and triggers issued by the telescope are time stamped with the same clock
- Data are sent to EUDET DAQ by TCP/IP, integrated to EUDET reconstruction flow.
- ~2kHz trigger rate reached, limited by beam/telescope
- ~25 reconstructed tracks per Mimosa shutter at SPS

TLU Trigger

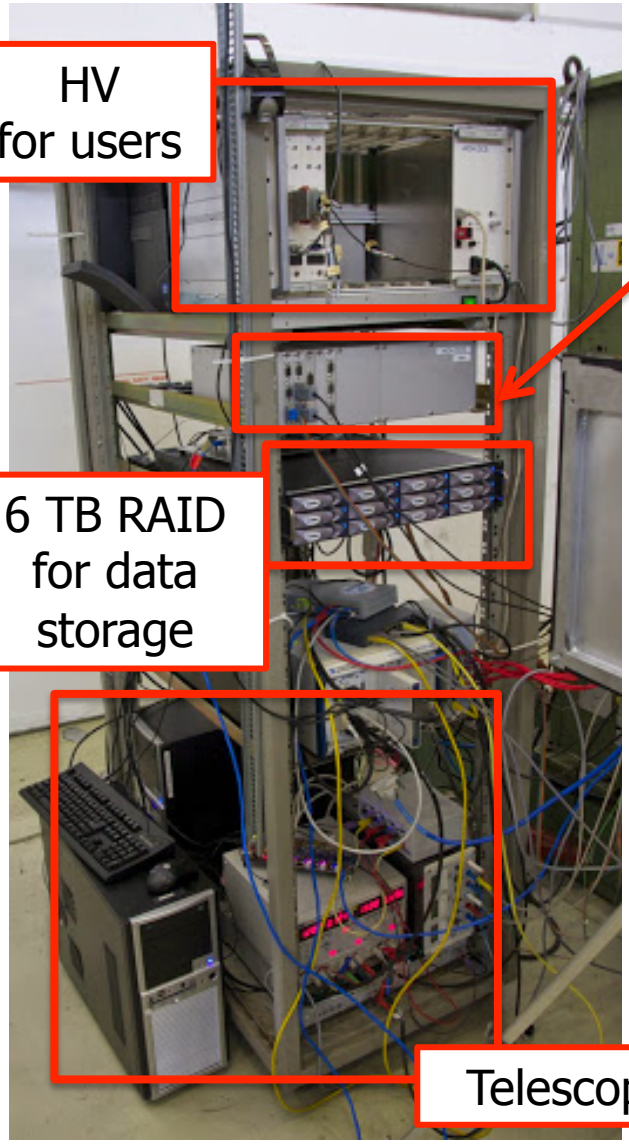


Data-driven readout mode.

Timepix3 readout

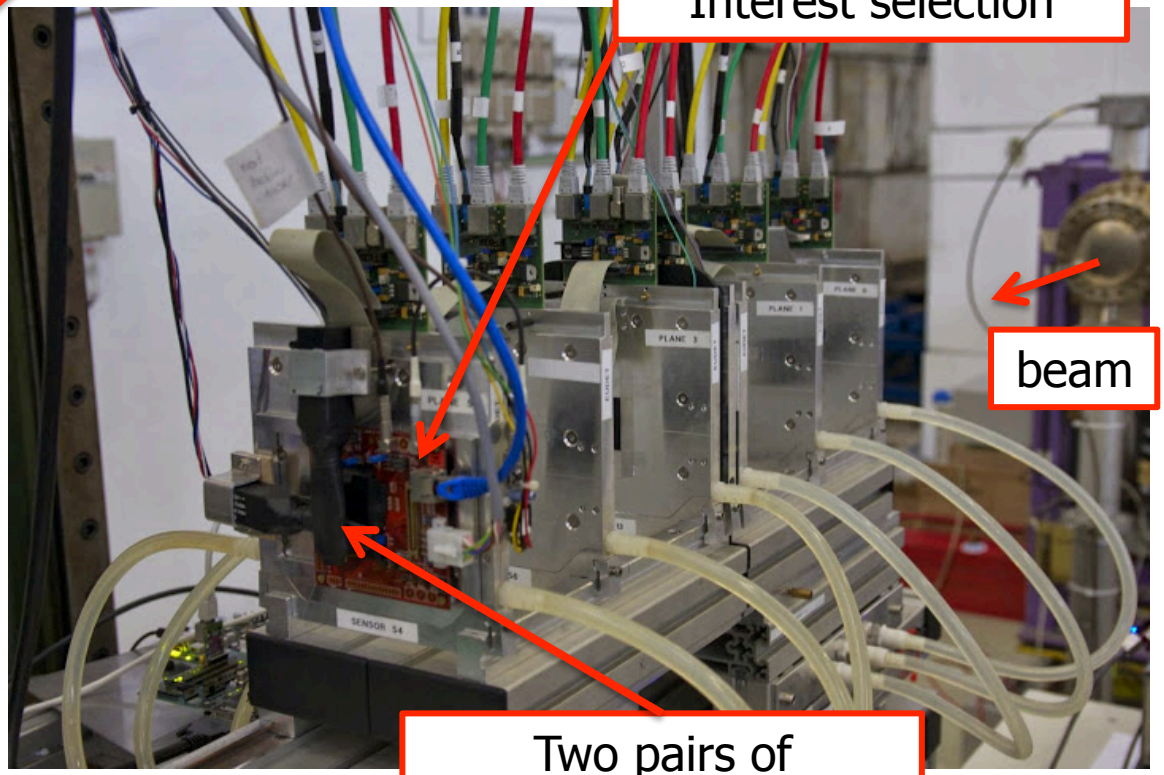


AIDA infrastructure

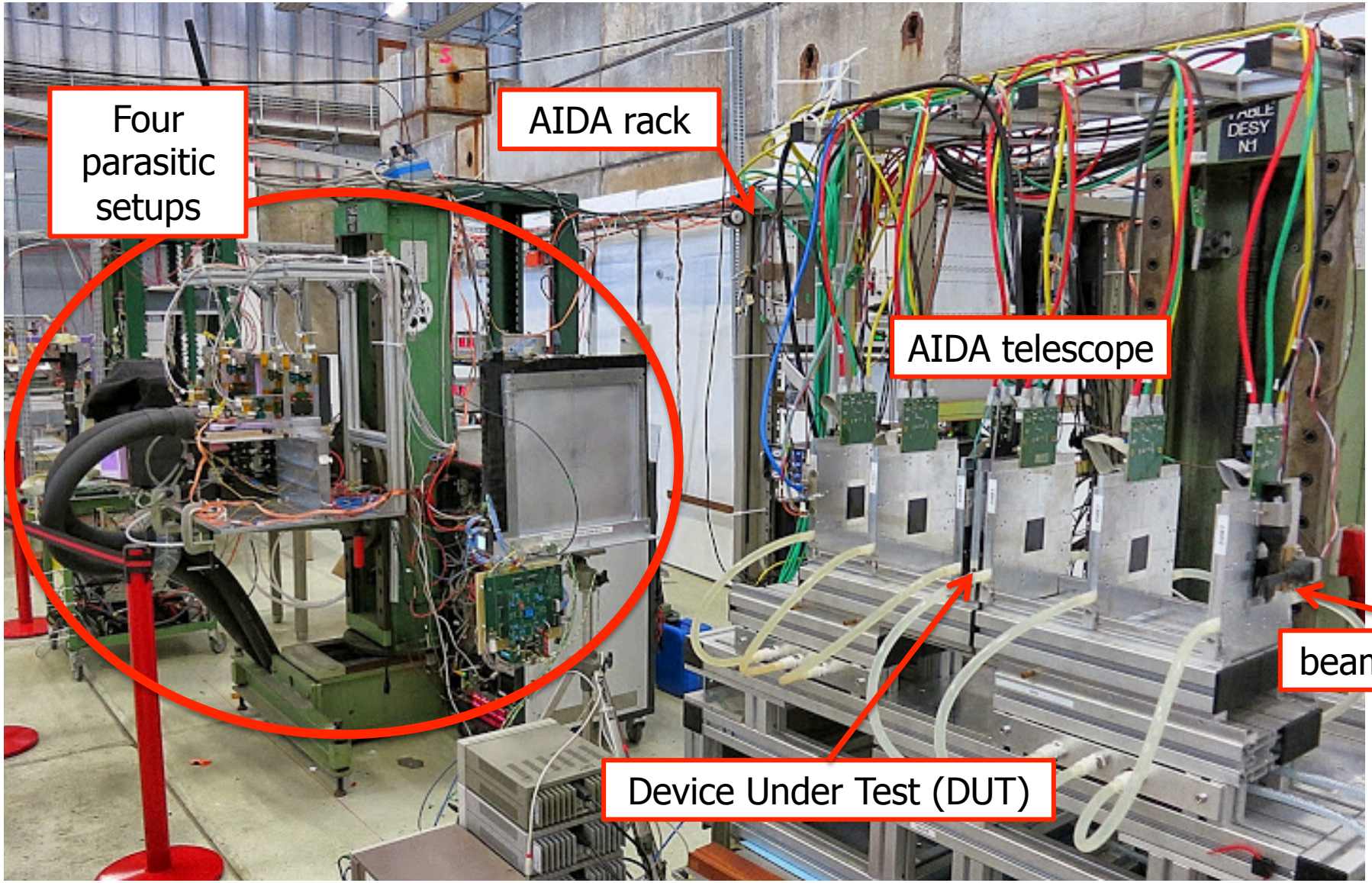


Temperature/Humidity monitoring

ATLAS FEI4 plane for timing and Region-Of-Interest selection

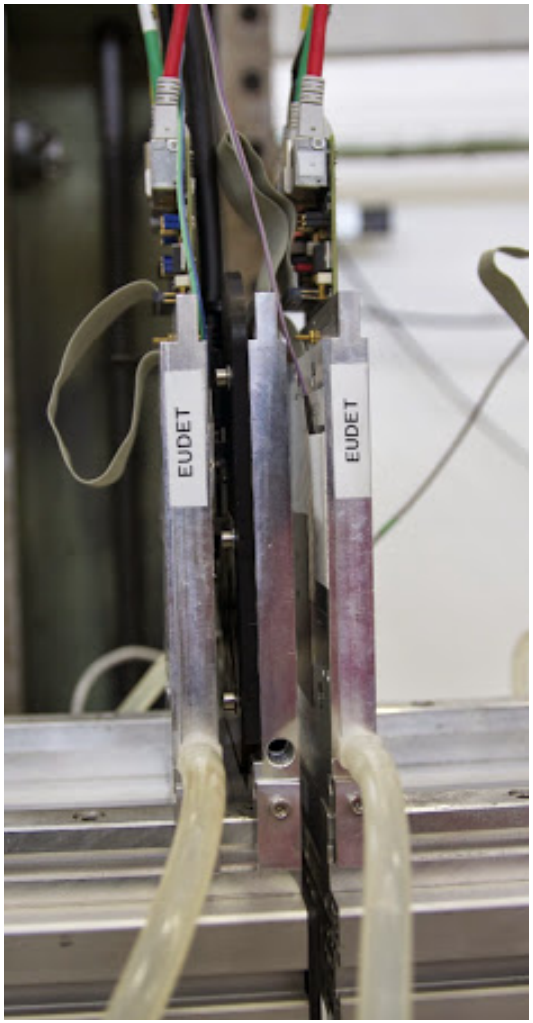


Setup at CERN PS

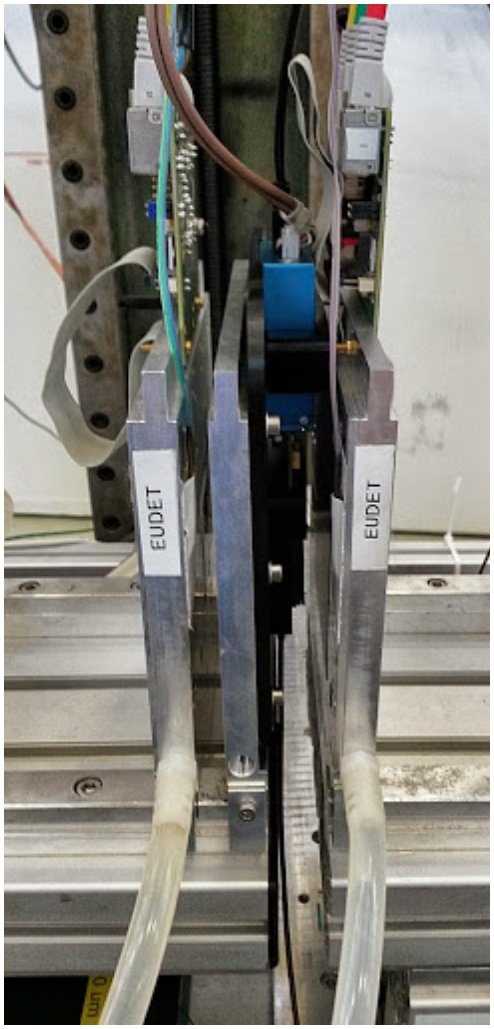


PS DUT integration

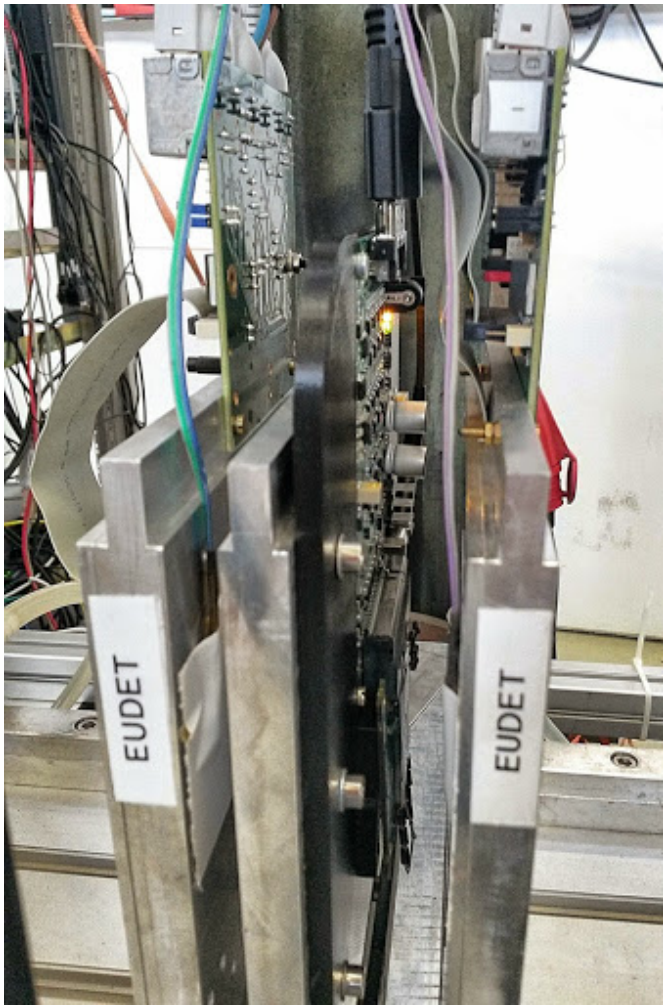
Timepix3



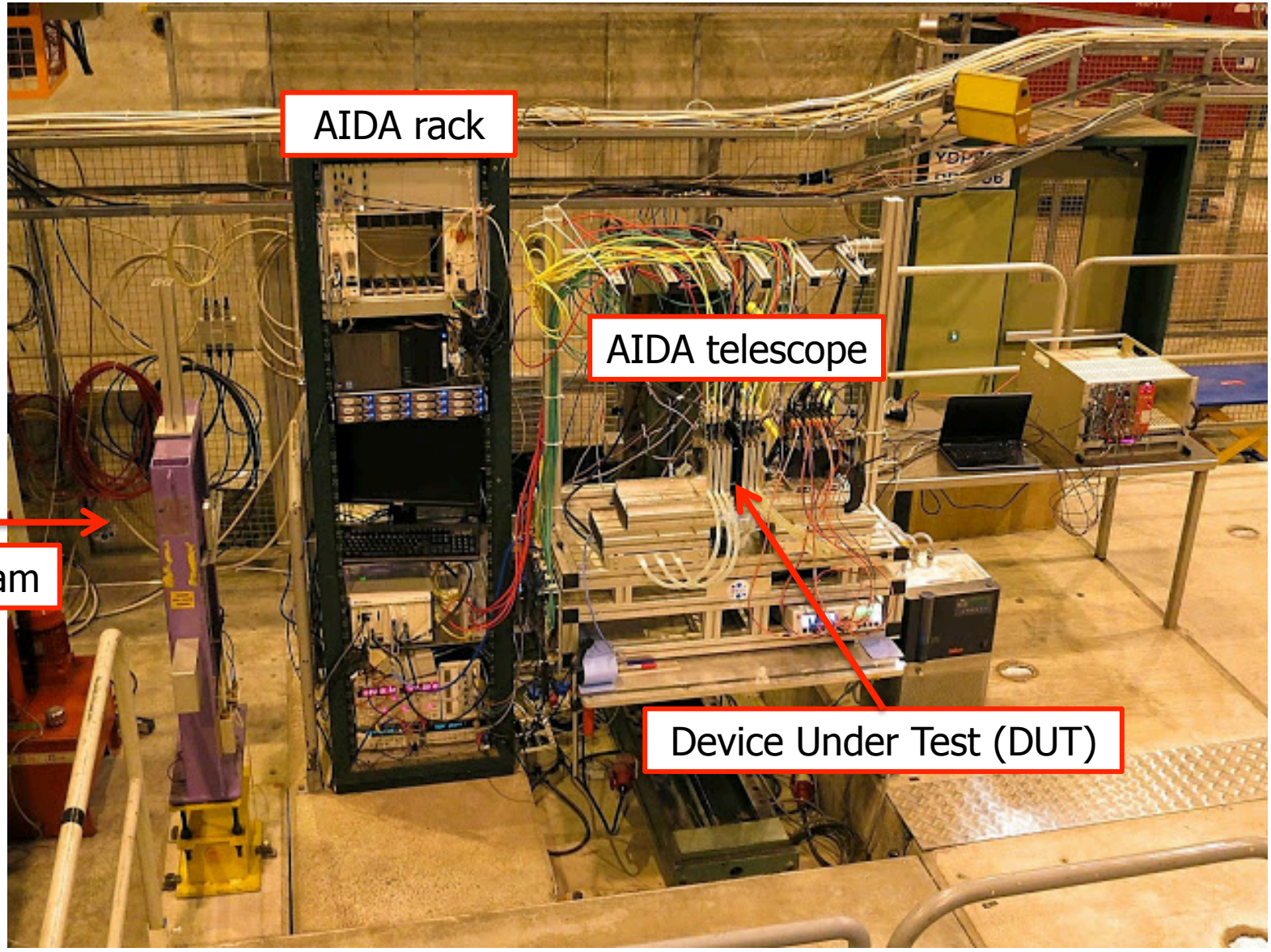
Timepix1



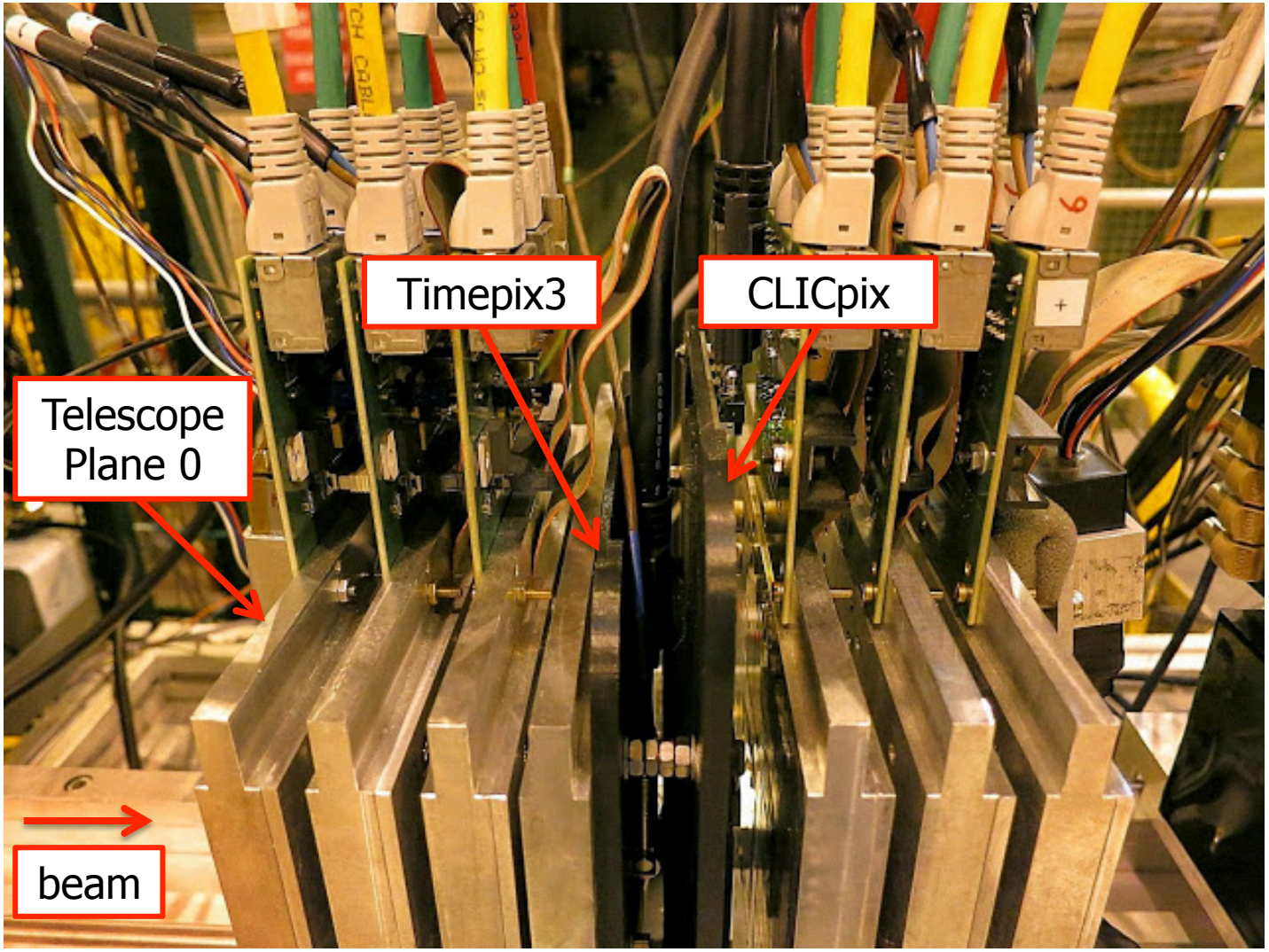
CLICpix



Setup at CERN SPS H6B



SPS DUT Integration

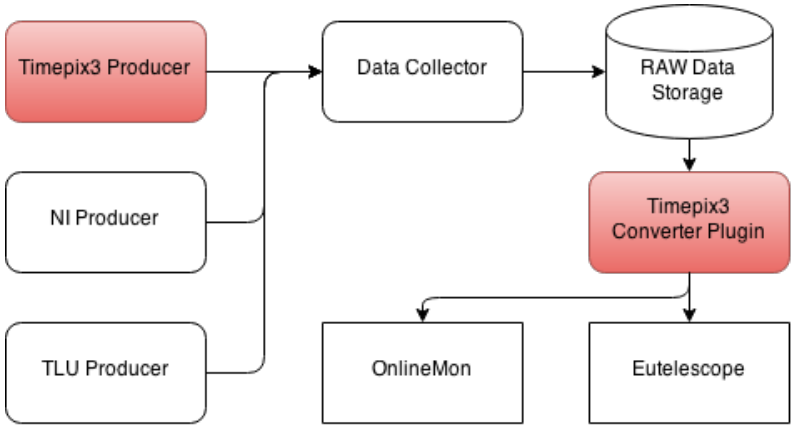


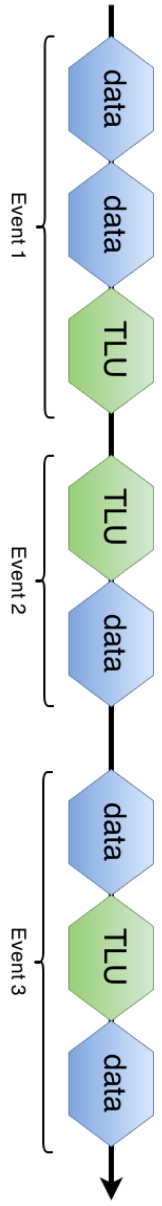
Compact telescope configuration is optimal for high momentum beam

Software integration in EUDAQ

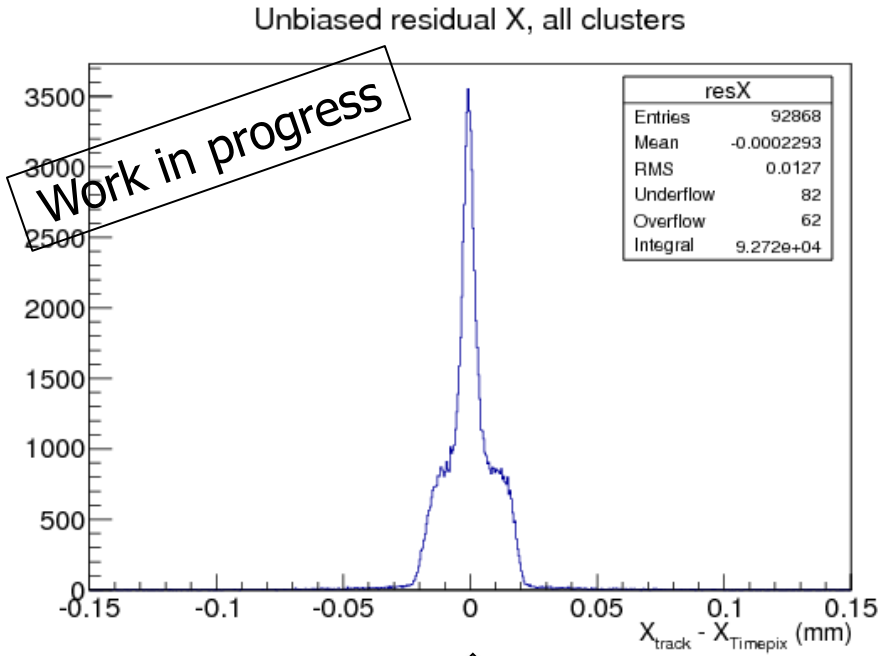
Timepix3 Producer

- Start/Stop run, Configure, Exit
- Configuration file
  - Timepix3 DACs and other configuration parameters
  - Bias Voltage, Threshold
- Bias voltage control (GPIB), temperature monitoring
- Data processing
  - use SPIDR library to fetch trigger (TLU) and data (Timepix3) packets from hardware
  - using timestamps, assign pixel data to specific trigger
  - pack data and send it to Data Collector



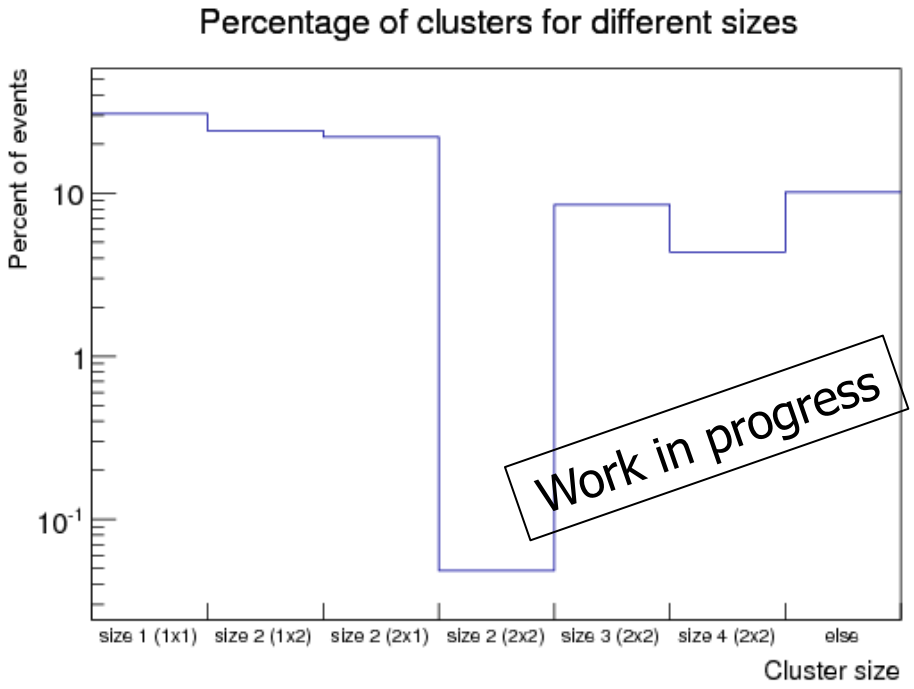


Timepix3 2014 testbeam results (1/2)



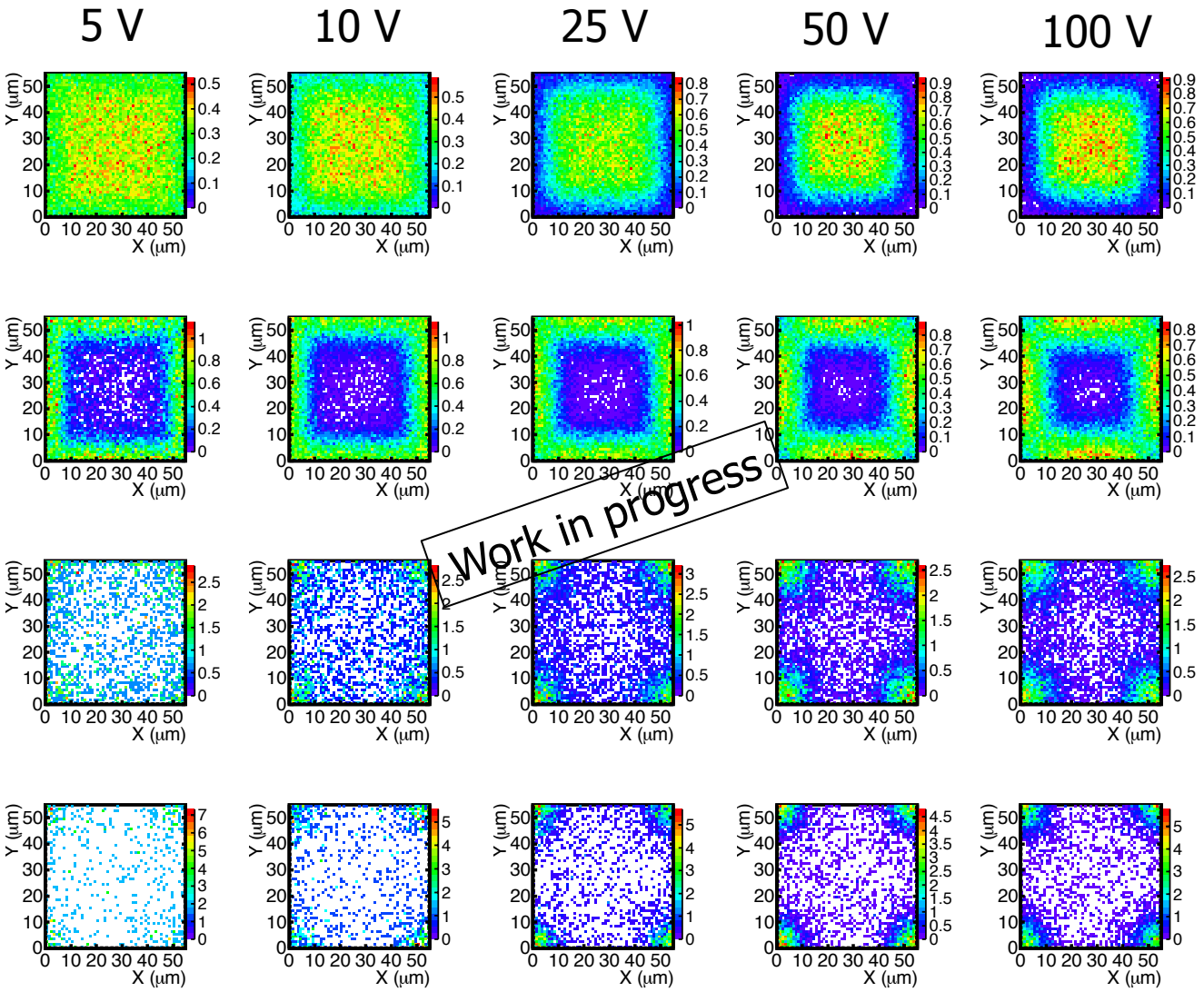
Unbiased residuals: successful alignment and reconstruction, estimation of single point resolution

Cluster size distribution shows charge-sharing under nominal conditions



Timepix3 2014 testbeam results (2/2)

Track hit probability inside a pixel – a good visualisation of charge-sharing



Summary

- R&D on sensor and readout for the CLIC Vertex detector is well under way
- The faster Timepix3 has been sucessfully integrated within the AIDA telescope infrastructure with its newly developed SPIDR readout
- Overall very successful data taking period at CERN PS & SPS
  - More beam time with new assemblies planned for 2015
  - Could benefit from better Telescope timestamping for timing studies
- More information
  - http://clicdp.web.cern.ch/content/wg-clic-vertex-detector-technology
  - https://wiki.nikhef.nl/detector/Main/SpiDr
  - https://twiki.cern.ch/twiki/bin/view/MimosaTelescope/WebHome

Timepix3 2014 testbeam SPS results