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An optimized C++ software for the management of Timepix4 data acquisition and analysis

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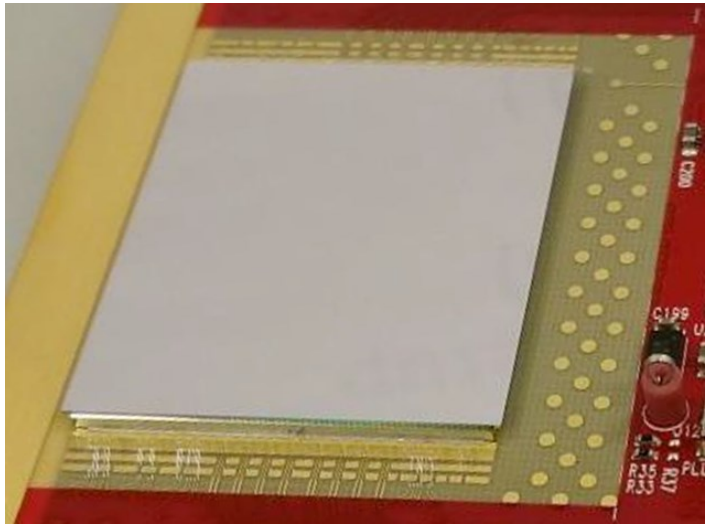
Outlook

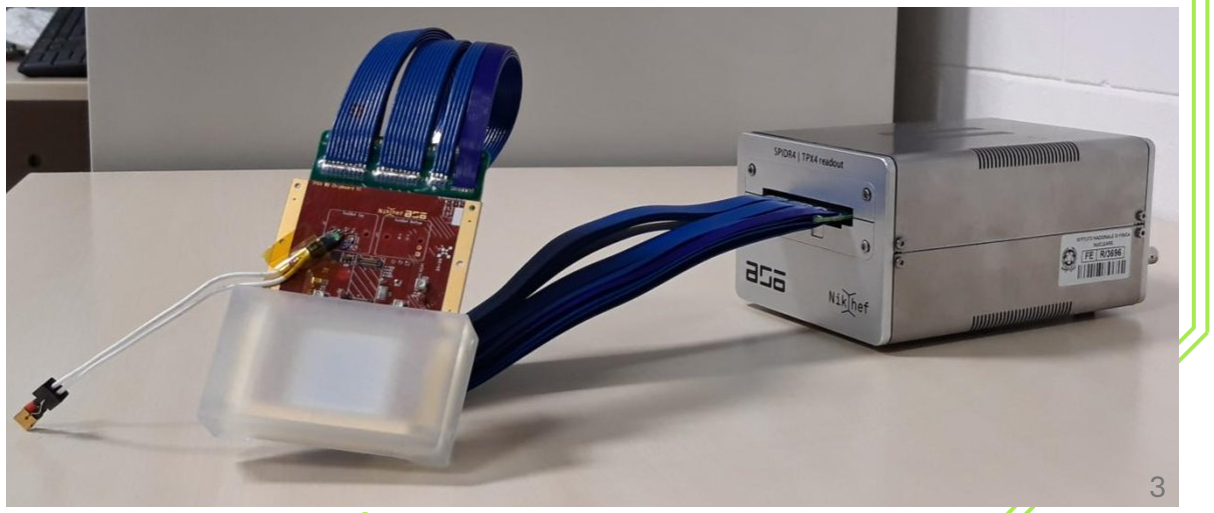
- Timepix4 and the 4DPHOTON project
- Configuration and data-acquisition software
  - Slow control configuration and acquisition
  - Fast readout acquisition
  - Online monitoring, clustering and analysis
- Results
- Conclusions and Acknowledgements

Timepix4

Timepix4 is an ASIC (*Application Specific Integrated Circuit*) developed by the Medipix Collaboration at CERN, in 2019.



- Dimensions: 24.7 x 30.0 mm^2 (active area **~7 cm^2**)
- Pixel: 448 x 512 (pitch of 55 µm) with amplifier, programmable threshold discriminator and time-to-digital converter with **195 ps** bin (allows to measure time-of-arrival and time-over-threshold)
- *Multi-purpose*
- Configurable Registers: more than 15000
- Links: 1x Slow Control (1 Gbps)
  16x Fast Links (10 Gbps,
  total of **160 Gbps**)



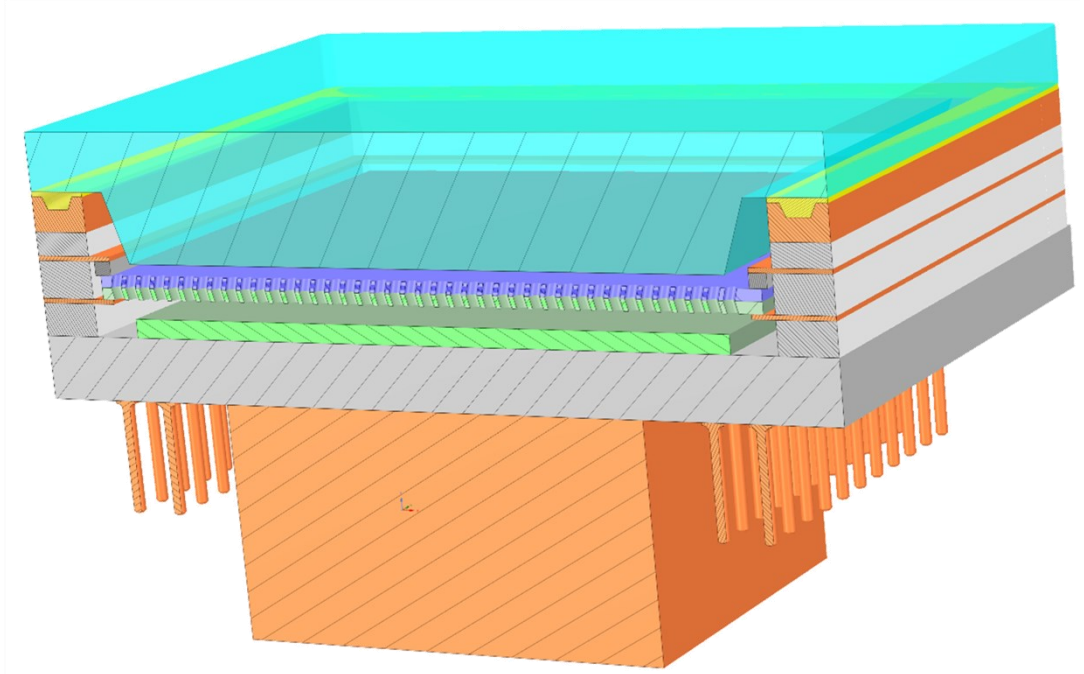
The 4DPHOTON Project

Goal of the 4DPHOTON project is the development of a new single-photon detector with excellent timing and spatial resolutions and a low noise at room temperature.

The detector will be based on:

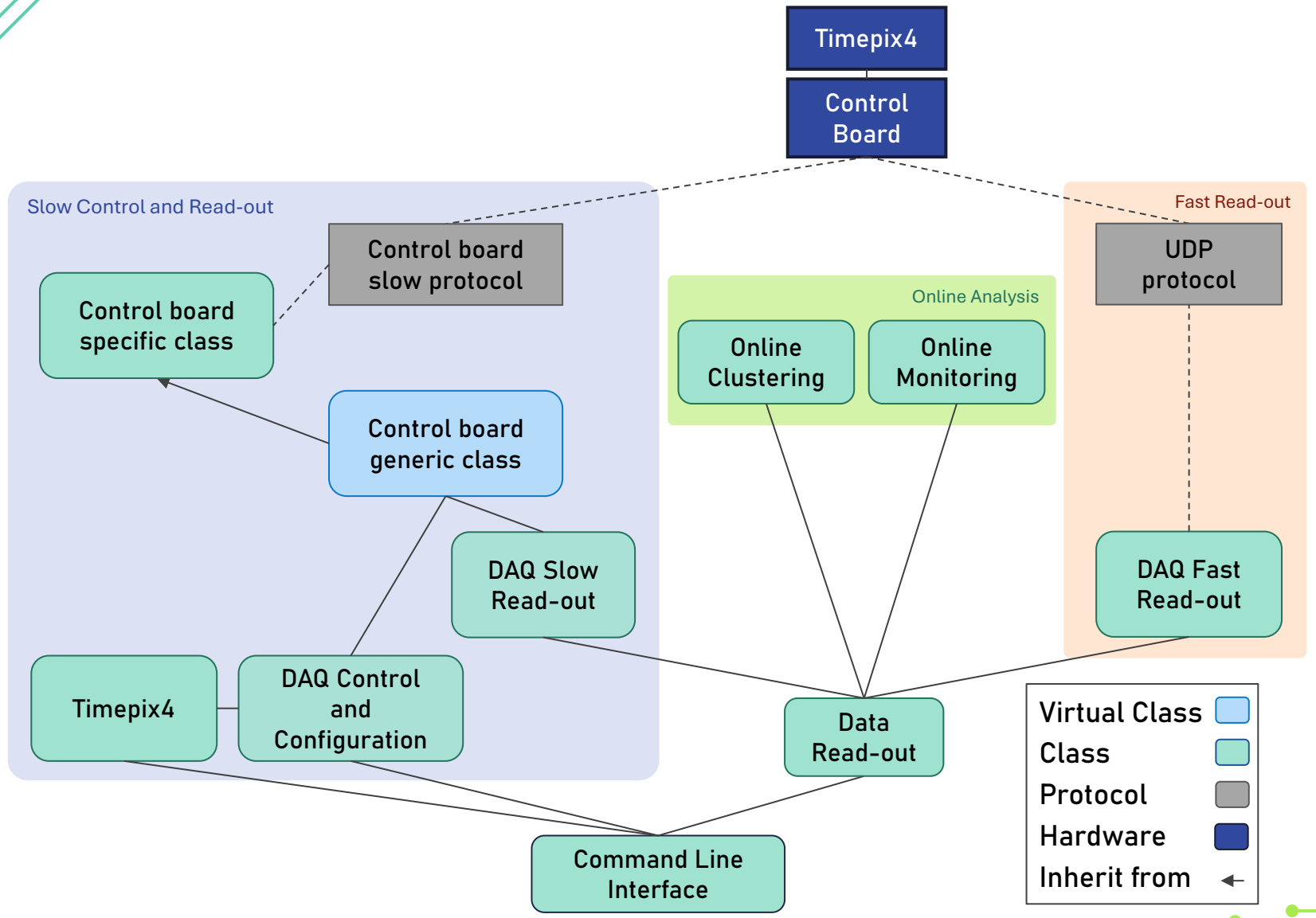
- a vacuum tube
- a photocathode with high QE in the spectral region of interest
- a micro-channel plate stack
- a pixelated CMOS read-out anode with integrated front end electronics: **Timepix4**

Timing resolution	few 10 ps
Position resolution	5-10 μm
Maximum rate	10^9 hits/s
Dark count rate	10^2 counts/s
Active area	~7 cm^2
Channels	230 k



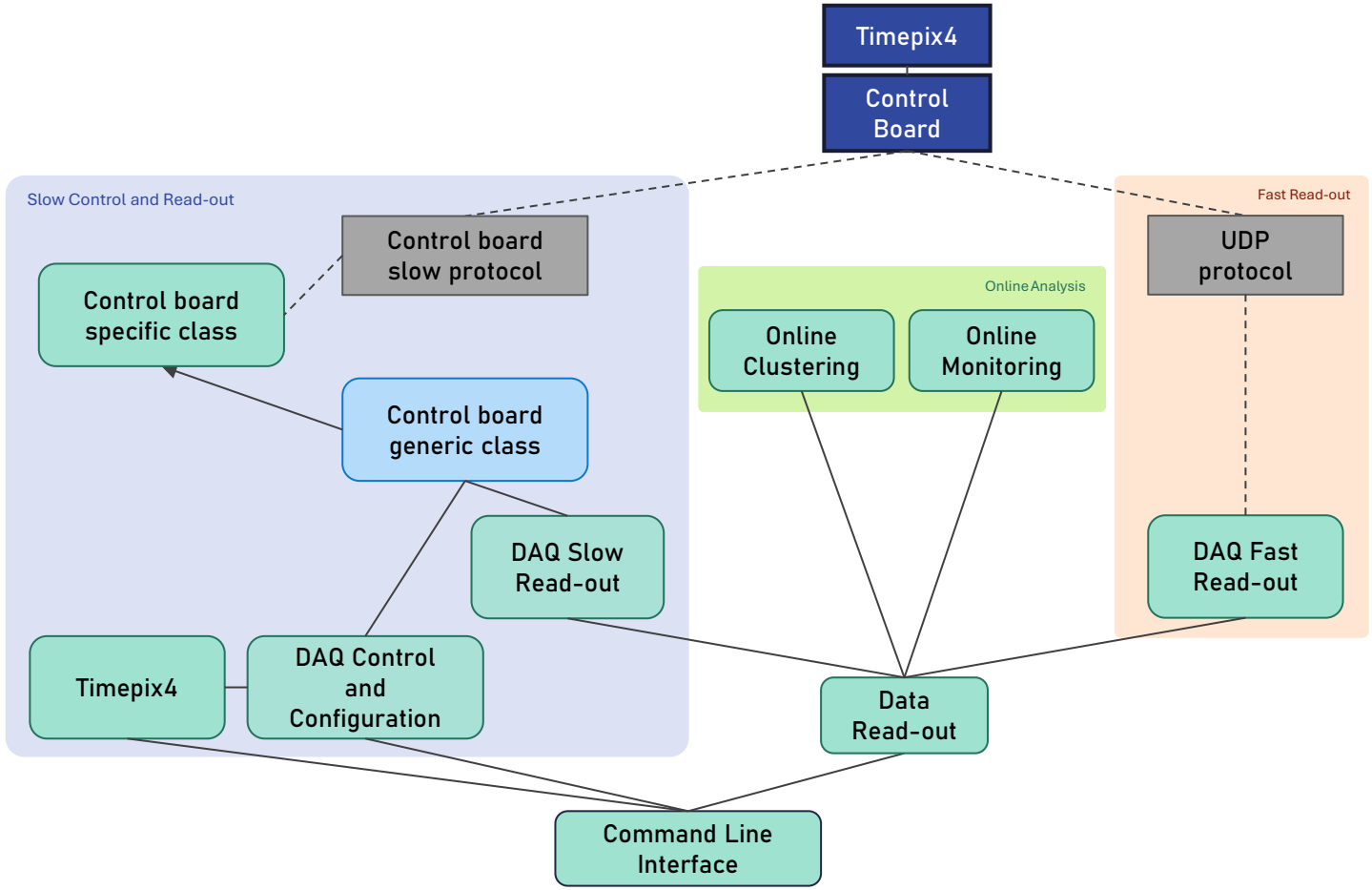
[M. Fiorini et al, JINST 13 (2018) C12005]

Configuration and data-acquisition software



- Object-Oriented, entirely written in C++, multi-thread and open-source
- Configuration and data read-out (fast and slow) in a unique framework (but can be divided)
- Solid but flexible architecture, adaptable to any control board (using Timepix4)
- User-friendly but customizable Timepix4 configuration and read-out

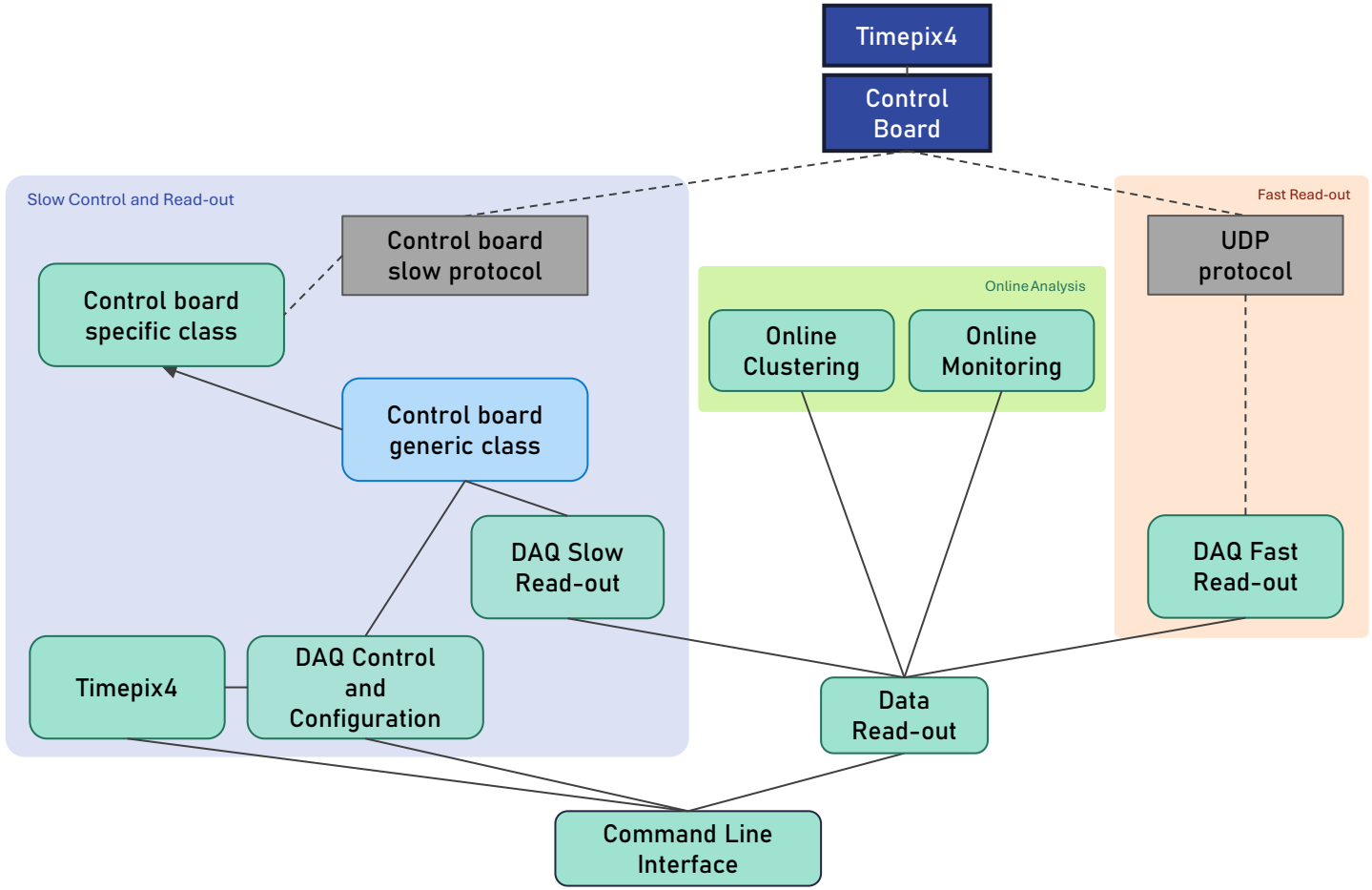
Slow Control: Configuration and Slow Read-out



Slow Control and Read-out

- Timepix4 Configuration
- DAQ Configuration
- Slow Read-out (maximum of 1 Gbps)
- Dependent from DAQ communication protocol
- Contains simple standard configuration routines, but also low level function for finest personalization
- Timepix4 class contains useful information about the ASIC, the registers, the DACs, …

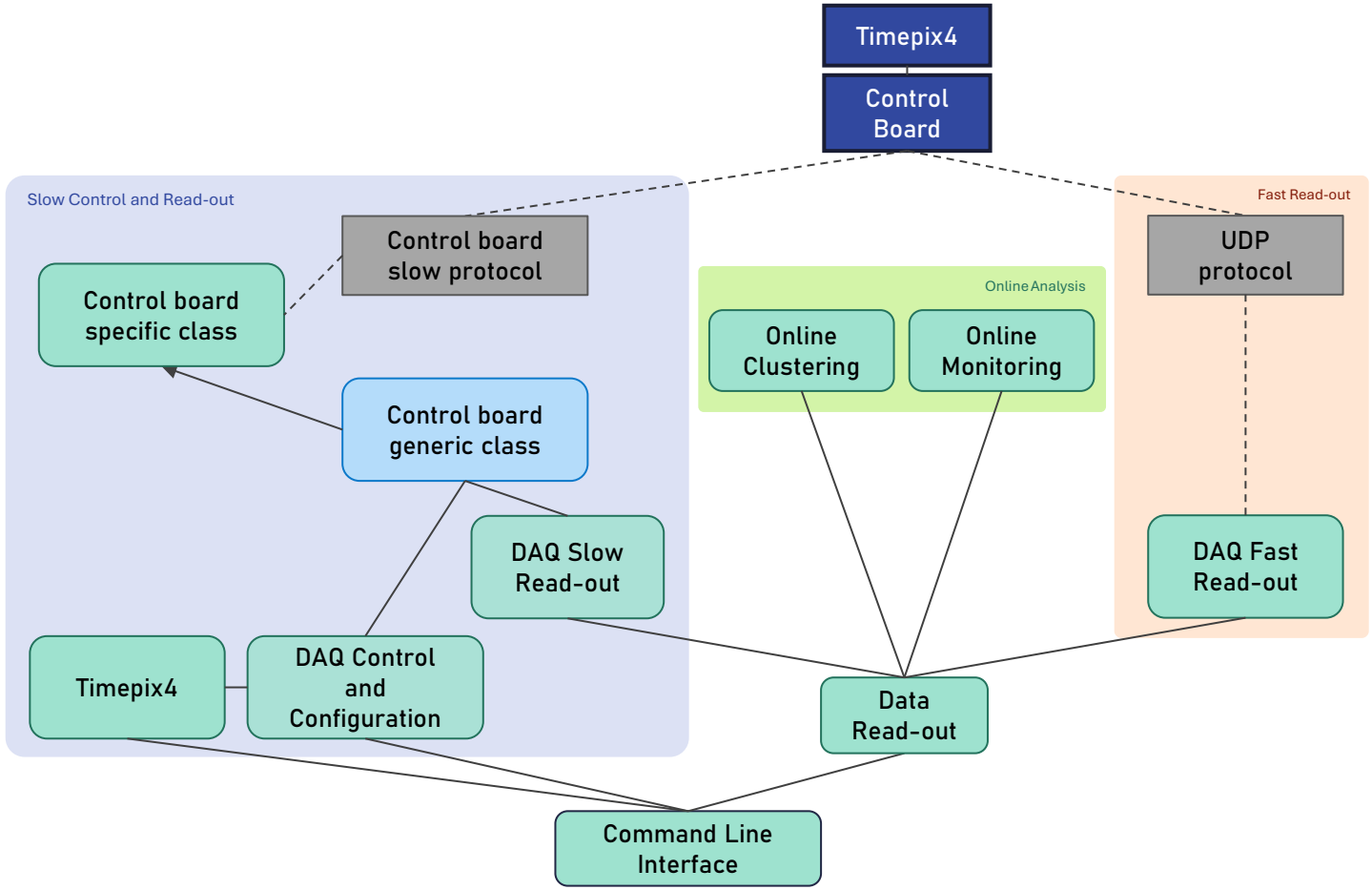
Fast acquisition



Fast Read-out

- Fast data read-out
- Independent from DAQ communication protocol (uses UDP)
- Works with data-driven and frame-based acquisition
- A maximum of 16 x 10Gbps programmable optic link (160 Gbps)
- Two dedicated threads for each link exploiting reader-writer paradigm (customizable size of buffer zone)

Online analysis



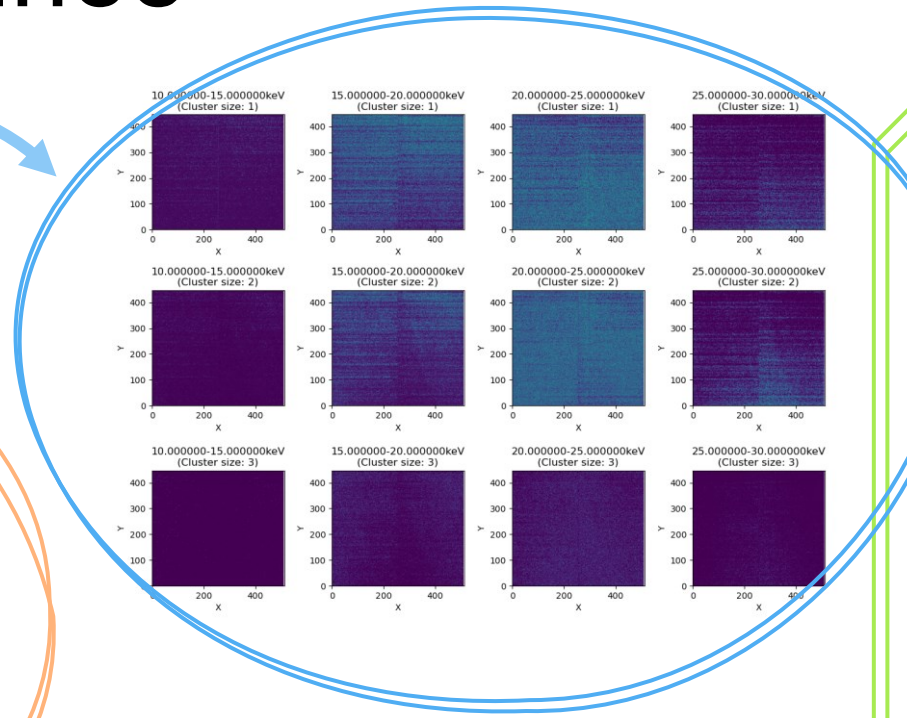
Online Analysis

- Online monitor shows real-time photon-counting events
- Online clustering shows real-time clusterized events (can be used offline)
- Real-time plot made with Root libraries
- Work with slow and fast acquisition modes (no limit on how many threads)
- Slower than read-out threads, but independent from them (no data loss)
- User can choose how much RAM should be dedicated to them, and how frequently the plots are refreshed

Clustering performance

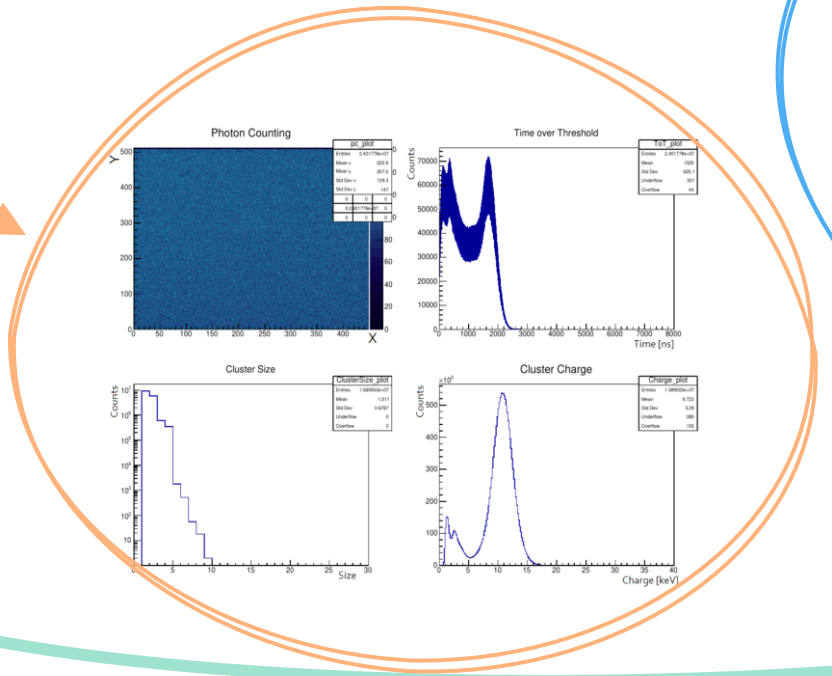
Photon Counting images

- Up to **O(Gevents/s)**
- One ‘image’ for each charge bin
- Useful for imaging



PDF plot

- Up to **O(Mevents/s)**
- Useful online with high rate
- To be analysed offline



ROOT File with cluster info

- Up to **O(Mevents/s)**
- Useful online with low rate
- No need for offline analysis

For each cluster:
- Cluster ID
- Cluster Size
- Weighted X and Y
- Charge and ToT
- Weighted ToA

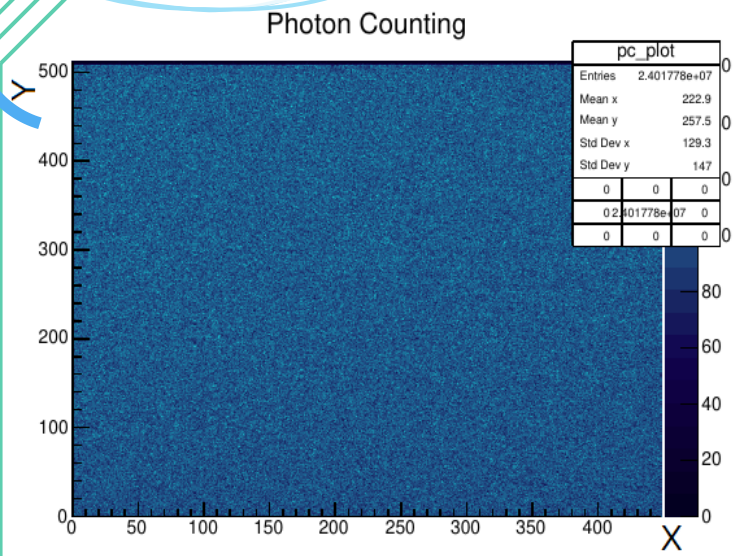
ROOT File with all info

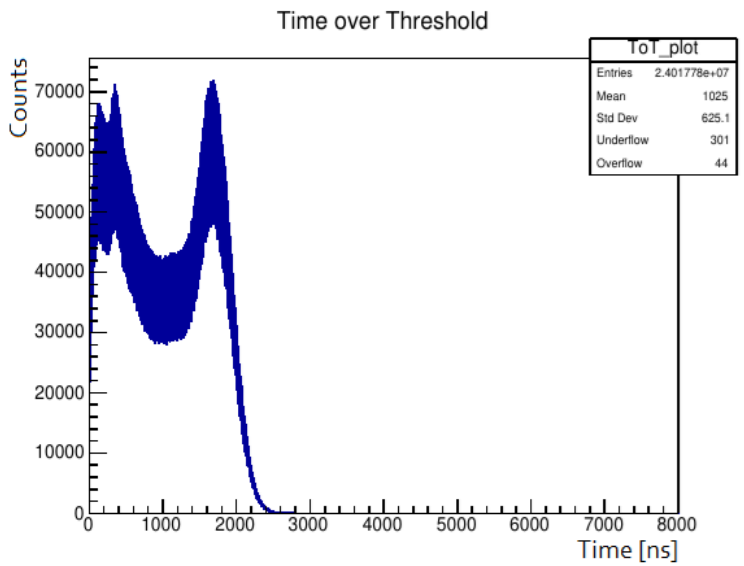
- Up to **O(100 kevents/s)**
- Useful offline (or online with very low rate)
- Saves all information about acquisition

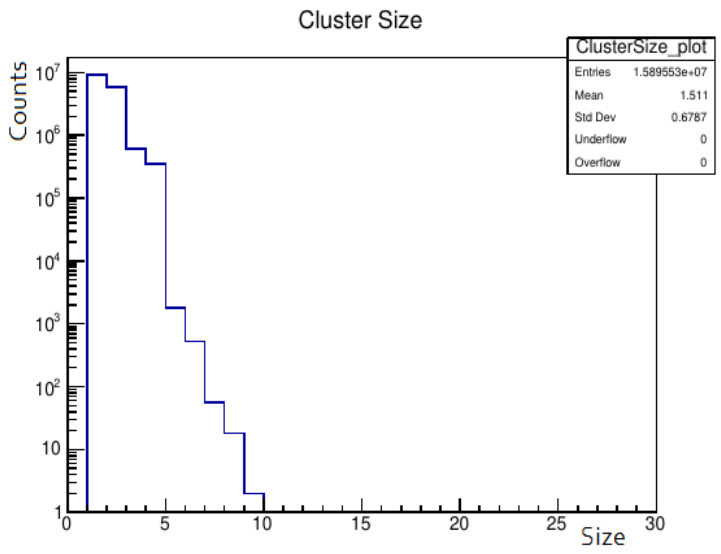
Possible to add:
- Hits Xs and Ys
- Hits Charges and ToTs
- Hits ToAs

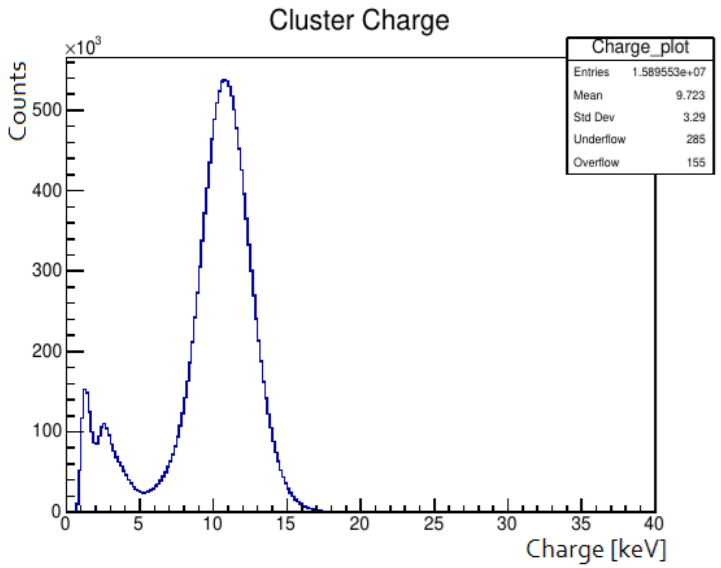
X-Ray flatfield from measurements at Elettra Synchrotron Facility (Trieste, Italy)

Results









Configuration and data acquisition

- In use with different setup and control boards in Italy (Ferrara, Pisa, Trieste, Napoli) and at CERN
- Configuration and raw data acquisition classes in use in the last 2 years

Online analysis

- Real-time events are plotted in a photon counting 2D histogram
- Real-time events could be also clusterized and analyzed, displaying more statistics

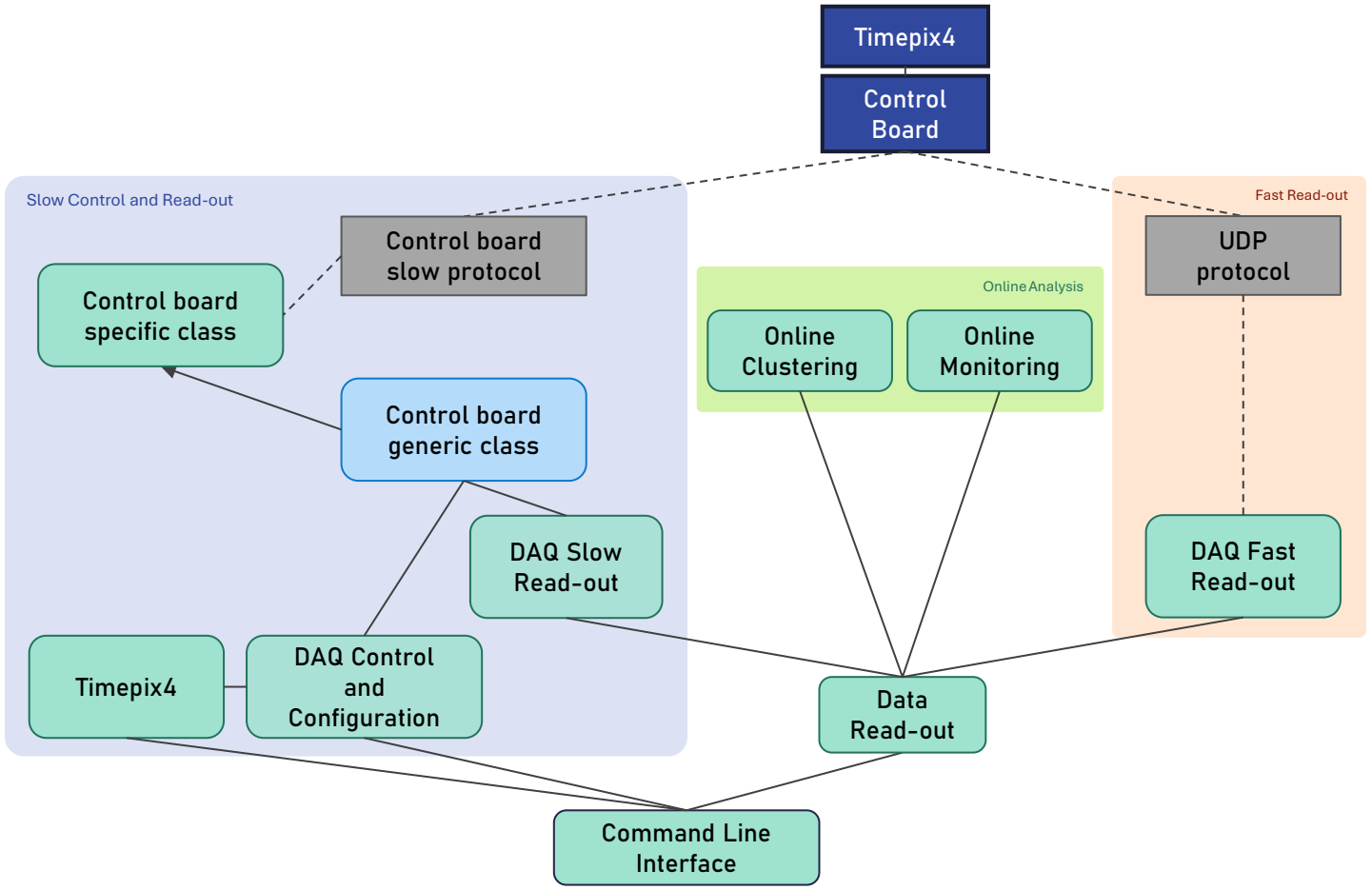
First Testbeam at ELETTRA

- Correctly stored over 500 GB of data
- Stress-test for online monitoring

Testbeam at CERN

- Test 4DPHOTON with Cherenkov light
- Starting in a few days!

Conclusions and Acknowledgements



Timepix4 Software

- Developed by INFN Ferrara
- Entirely open-source
- Adaptable to different hardware
- Clustering algorithm connected to read-out for online clustering
- Can analyze online all events (if low rate) or a part of them (to have real-time statistics)

If you are interested, contact us!

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Thank you
for your attention!

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