Timepix4 assembly characterization using a monochromatic X-rays source at the ELETTRA facility

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Overview

Timepix4 *[1]* is the last application-specific integrated circuit (ASIC) of the Timepix family, developed by the Medipix4 collaboration for tracking and imaging:

- 448x512 pixels with a **55 µm** pitch;
- Time-of-Arrival (**ToA**) measured with a bin width of **195 ps**;
- Time-over-Threshold (ToT) with a bin width of 1.56 ns (**~200 e^- rms charge resolution**).
- readout bandwidth up to 160 Gb/s.

Several applications possible, varying coupled sensor materials and thickness.

Necessary to characterize Timepix4 assembly (e.g. energy calibration and dead-time) and to develop automatic characterization procedures.

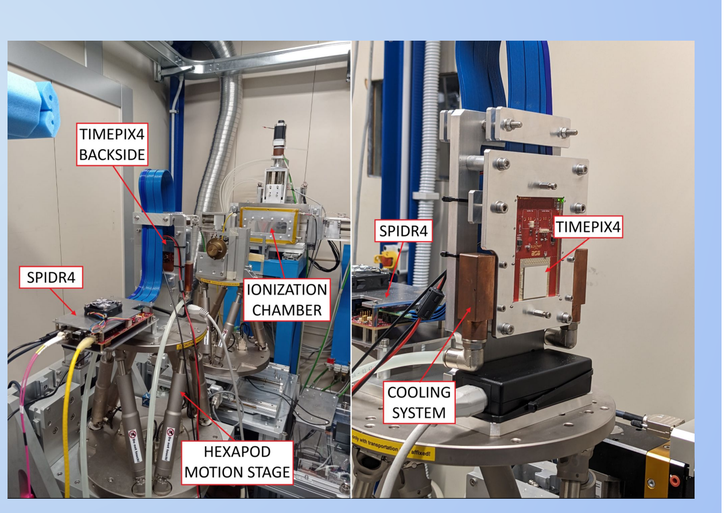
Experimental setup

Monochromatic Beam

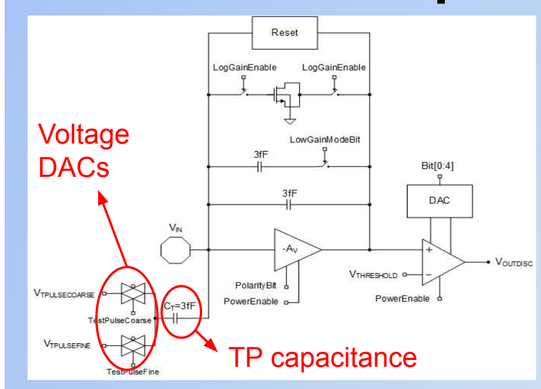
- SYRMEP beamline at **ELETTRA synchrotron**, in Trieste
- Monochromatic beam energy between 8.5 keV and 40 keV
- Beam geometry: 3.0 x 28.0 mm with gaussian vertical profile

Data Acquisition System

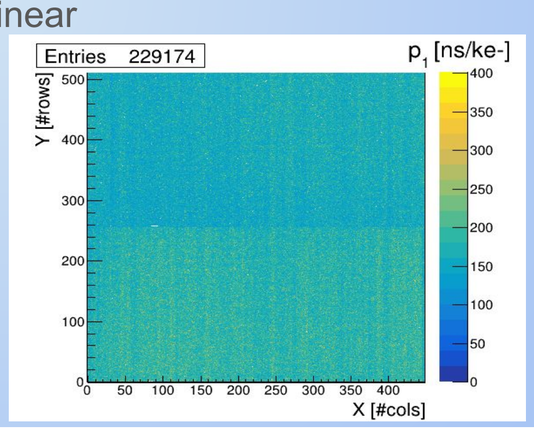
- Timepix4v2 assembly bonded to **300 µm thick Si p-on-n** sensor
- Spidr4 control board
- Custom cooling system to keep Timepix4 at 15°C
- **Ionization chamber** for beam monitoring
- **Custom software**: online monitor and analysis (see N. Biesuz poster)



Per-pixel calibration



- **Internal test-pulse** (TP) tool to calibrate ToT at pixel level
- **Voltage DACs** and **input capacitance** to generate injected charge
- Possibility to scan low charge region, where calibration is not linear



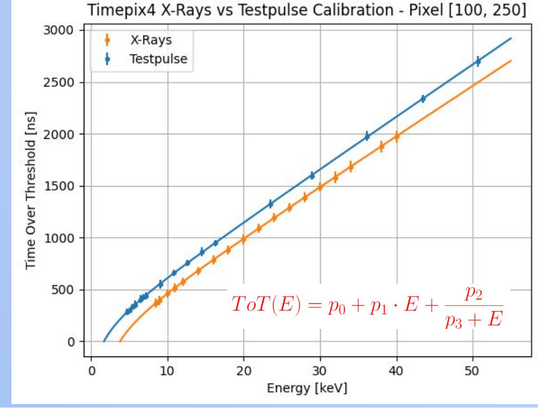
- **Automatic algorithm** exploiting fast readout
- **Pixel-by-pixel calibration** over the whole matrix (~230k pixel)
- Calibration parameter distribution

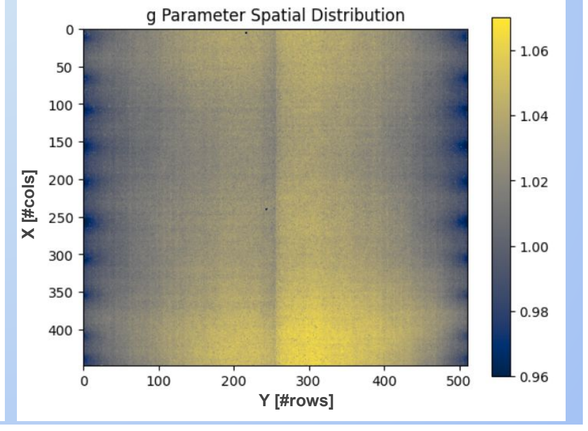
Mixed calibration

- Discrepancies between TP calibration and monochromatic beam calibration
- TP calibration corrected introducing **g (slope correction)** and **h (offset correction)** parameters to match the beam calibration:

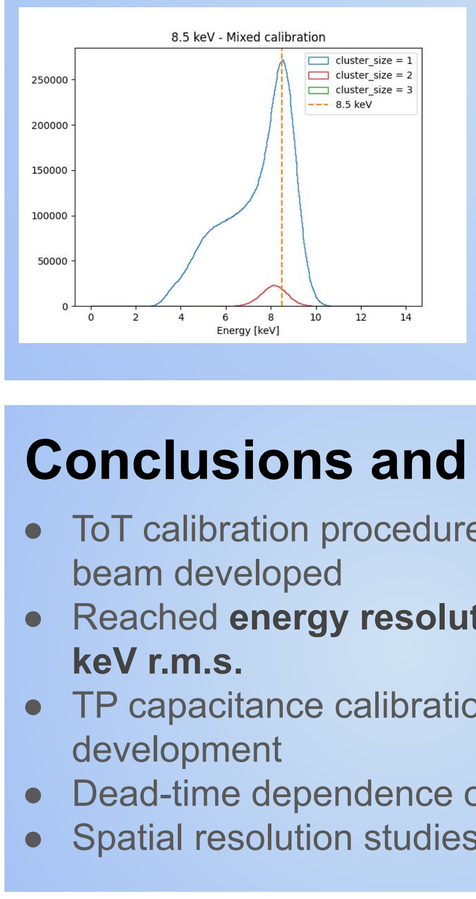
$$ToT_{TP} \rightarrow ToT_{TP}+h \qquad E_{TP} \rightarrow E_{TP} \cdot g$$

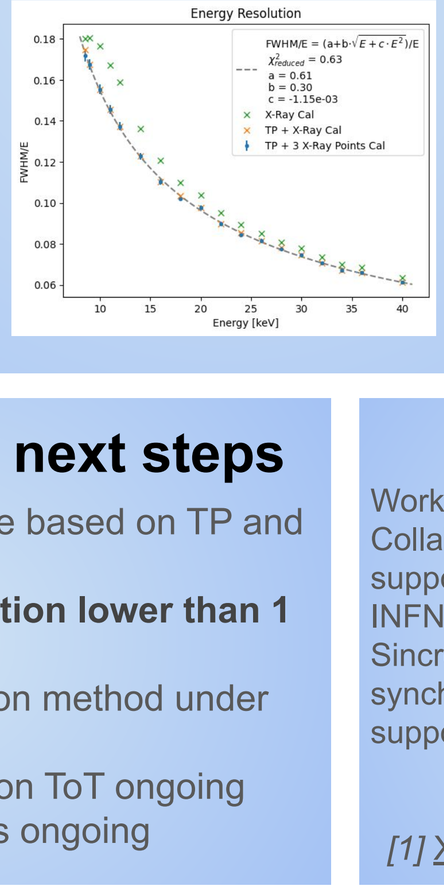
- g and h parameters can be used to **calibrate TP input capacitance** at pixel level





Improved resolution

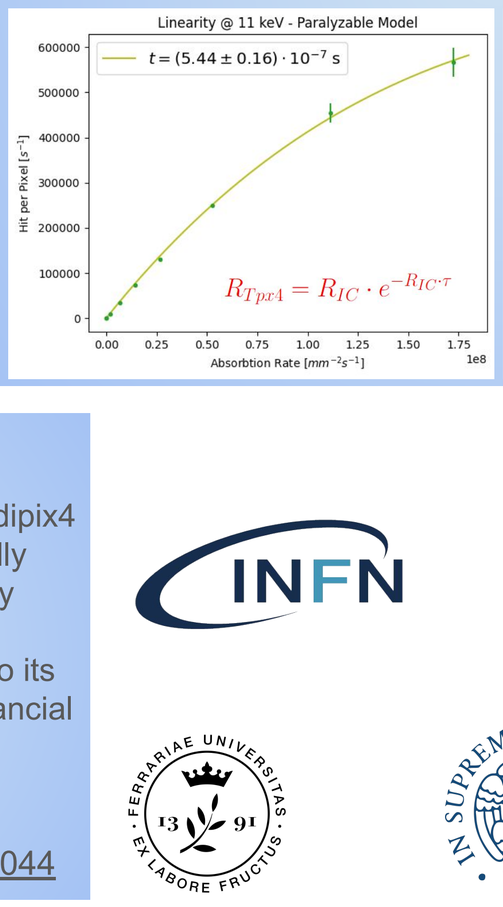


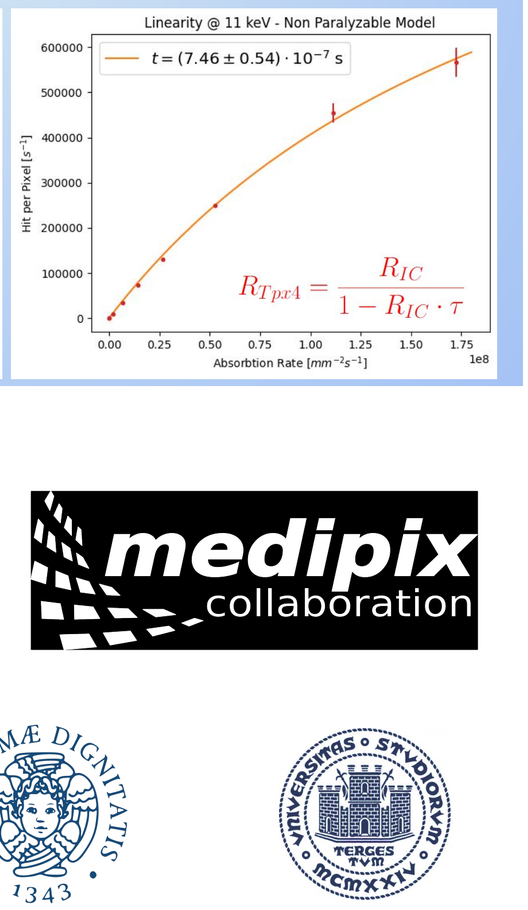


- Both **resolution and accuracy improved** at low energies
- Results improved both with respect to TP-only and beam-only calibrations
- Resolution improved on clusters, where charge is spread among more pixels, with a low amount of charge deposited on some of them
- Results improve even when the TP calibration correction is based on a beam calibration done on a few points

Dead time estimation

- **High rate measurements**, with few pixels unmasked to avoid readout bandwidth saturation
- Ionization chamber used to estimate the expected hits rate per pixel (R_{IC})
- Both **paralyzable and non-paralyzable models** used to estimate the pixels dead-time (τ) from hit rate on Timepix4 (R_{Tpx4})
- Compatible results: **dead-time lower than 1 µs**





Conclusions and next steps

- ToT calibration procedure based on TP and beam developed
- Reached **energy resolution lower than 1 keV r.m.s.**
- TP capacitance calibration method under development
- Dead-time dependence on ToT ongoing
- Spatial resolution studies ongoing

Acknowledgements

Work carried out in the contest of the Medipix4 Collaboration based at CERN, and partially supported by MEDIPIX4 project funded by INFN-CSN5. We acknowledge Elettra Sincrotrone Trieste for providing access to its synchrotron radiation facilities and for financial support under the IUS internal project.

[1] X. Llopart *et al* 2022 *JINST* **17** C01044