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Hands-on activities with X-ray photon counting hybrid pixel detectors based on the Timepix4 ASIC

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Timepix4 is the latest application-specific integrated circuit (ASIC) developed by the Medipix4 international Collaboration at CERN. It features a 448x512 pixel matrix with a 55 μm pitch, designed for compatibility with a wide range of semiconductor sensors. This adaptability allows for optimization in various applications, including X-ray spectroscopy, high-energy particle detection, and medical imaging.

Timepix4 is fully prepared for Through-Silicon-Via (TSV) processing, enabling it to be tiled on four sides to cover large areas with negligible dead regions, while providing sub-200 ps time resolution. It supports two operation modes: frame-based and data-driven. In the frame-based mode, each event generating a signal above a programmable threshold increments a counter at the pixel level, and the counters of the entire matrix are read out synchronously with the core clock. In contrast, the data-driven mode operates such that a pixel transmits an output packet immediately after being hit. While the frame-based readout provides only photon-counting information, the data-driven readout also enables the measurement of Time-of-Arrival (ToA) and Time-over-Threshold (ToT), providing additional temporal and energy-related data. With a maximum hit rate of up to 5.0×10^9 hits/mm^2/s and the ability to handle data rates up to 160 Gbit/s, it offers high-performance capabilities for demanding applications.

INFN joined the Medipix4 collaboration in 2020. Two experiments have been funded by INFN-CSN5, MEDIPIX4 (2021-2024) and TIMEPIX4 (2025-2027) with the aim of studying and testing the possible applications of the read-out chips in a wide range of fields, from X-ray spectral imaging to nuclear medicine and dosimetry. The characterization of Timepix4 assemblies bump-bonded to various sensors, such as Si, CdTe, and GaAs, is currently ongoing at INFN. In this contribution, we will present an overview of this innovative technology and the results of the hands-on activities carried out.

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