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Katherine Readout for Timepix4: A Novel Acquisition Ecosystem for Timepix4-Based Detectors

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The Timepix4 [1] readout chip introduces significant improvements over its predecessor, Timepix3 [2], in multiple aspects. One of the key advantages is the 3.5× larger active area, which allows for the coverage of a wider surface. Another major improvement is support for Through-Silicon Vias (TSV) technology. This feature enables the construction of large-area detectors with minimal dead zones —a crucial factor in many imaging applications. Despite the increased size, Timepix4 retains the same 55 µm pixel pitch as Timepix3, resulting in a resolution of 512×448 pixels. A significant enhancement is also found in time resolution, with 195 ps time binning for Time-of-Arrival (ToA) data. This enables novel applications such as Compton-scattering-based detectors or advanced Time-of-Flight measurements. Timepix4 also offers significantly higher data throughput compared to Timepix3. It features 16 data output lines, each capable of 10 Gbps, resulting in a theoretical maximum data rate of 3.58×10^6 hits/mm²/s, or approximately 2.5 Ghits/s per chip.

To support our research and meet the needs of the Medipix community, a novel acquisition system —the Katherine readout for Timepix4 —has been developed as the successor to the widely used Katherine acquisition systems for Timepix2 and Timepix3 [3, 4]. It is primarily targeted at laboratory measurements and test beam experiments, and may also serve as a platform for more demanding experiments in the future, including x-ray imaging systems using large-area detectors.

The presented device is capable of operating up to four Timepix4 detectors (with future support for the Timepix4 Quad chipboard). It supports up to 8 serial data lines from Timepix4, each operating at speeds up to 10 Gbps (although 2.5 Gbps is commonly used due to chip limitations). The device performs low-level data processing directly in hardware, converting raw data into fixed-point representations of energy (ToT) and timestamps (ToA). This eliminates the need for data decoding in the control software. In addition, configuration data handling is simplified —each pixel can be addressed directly via its position. For data transfer to a host computer, two interfaces are provided. The first is Gigabit Ethernet, which offers convenient remote access but is limited in throughput (approximately 10 Mhits/s). The second is PCI Express Gen3 x4, which enables significantly higher data rates —up to 350 Mhits/s. As with previous Katherine devices, several GPIOs are available for integration into complex experimental setups. These include support for external triggers, feeding external signals into Timepix4 digital pixels, and time-stamping of external events (via an FPGA-based TDC or a dedicated hardware TDC with 50 ps binning). A high-voltage bias source is also integrated, supporting a range from -1 kV to +1 kV with leakage current monitoring.

However, the Katherine acquisition system is more than just a data readout device. It also supports the broader use of the Timepix4 chip. Our contribution presents dedicated chipboards and a modular approach in which Timepix4 assemblies are mounted on small PCBs that can be plugged into baseboards. This enables reusability of detectors and facilitates rapid setup of customized experiments without the need for new wirebonding. The ecosystem also includes user-friendly control software.
This contribution presents the capabilities of the developed ecosystem and demonstrates them using measured data from radioactive sources, x-ray imaging, and test beam experiments.

References:
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Workshop topics

Front-end electronics and readout

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