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MiniPIX Timepix3 – a miniaturized radiation camera with onboard data processing for the online measurement of particle fluxes and dose rates in mixed radiation fields

The MiniPIX TPX3 is a miniaturized, low-power radiation camera (see Fig. 1) based on the Timepix3 64k active pixel sensor, providing imaging, spectral and tracking information of individual particles in mixed-radiation fields. Timepix3 [1] is a high-granularity 256×256 pixel array of pitch $55 \mu\text{m}$, with two per-pixel signal chain electronics. The hybrid architecture supports the use of different sensor materials (e.g., Si, CdTe, GaAs) of varying thickness (typically in the $100 \mu\text{m} - 2000 \mu\text{m}$ range).

The high data rate performance makes use of the USB 2.0 readout port and operation by a PC/laptop computer. It utilises the PIXET software tool [2] which provides control, data acquisition and online visualization of single particle tracks. The maximum data and frame rate is 2.3 M hit pixels per second and 16 fps, respectively. The power consumption is in the range 1–2 W depending on the radiation field, intensity and resulting data rate. Raw data is readout and stored on an external PC/laptop where pre-processing can be performed by extended plug-in tools in the PIXET package. Steps performed include identification of single events registered in the form of pixelated cluster tracks (clustering) and application of the per-pixel energy calibration. Extensive data processing is performed offline for high-resolution, wide-range data evaluation and precise data products; such as selective particle fluxes, dose rates, LET spectra, deposited energy spectra, angular distributions, spatial- and time-distributions and charged-particle radiographs. High-resolution particle tracking coupled with advanced pattern recognition analysis of the single particle tracks provides enhanced resolving power of particle-type composition [3] for detailed analysis of radiation fields. A heuristic empirical approach, based on wide-range of calibrations of the Timepix detector in well-defined radiation fields, provides particle-type discrimination of up to 8 classes [3].

Onboard processing operation is enabled by firmware reconfiguration and the embedded microcontroller in the readout electronics. Control and communication is via the SPI port. A low power (0.5–1.5 W) mode is intended for space applications such as ESA's MIRAM payload intended for LEO and GEO orbit deployment [4]. Data processing can be performed to a limited extent for an online response. A detailed event-by-event mode provides position, timing, dose, deposited energy and LET data of single events for radiation field fluxes up to $105 \text{ cm}^{-2}\text{s}^{-1}$. An integrated summed mode suitable for high intensity radiation fields (up to $107 \text{ cm}^{-2}\text{s}^{-1}$) provides integrated limited information of total particle flux and total dose rate. Both modes provide basic particle-type discrimination (3 main classes are resolved – see Fig. 2).

[1] T. Poikela et al., Timepix3: a 65k channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout, J. of Instrum. JINST 9 (2014) C05013

[2] D. Turecek et al, USB 3.0 readout and time-walk correction method for Timepix3 detector, J. of Instrum. JINST 11 (2016) C12065

[3] C. Granja et al., Resolving power of pixel detector Timepix for wide-range electron, proton and ion detection, Nucl. Instrum. Meth. A 908 (2018) 60-71.

[4] S. Gohl et al., A miniaturized radiation monitor for continuous dosimetry and particle identification in space, contribution to this conference.

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