Time-stamped measurements of single FLASH pulses of primary electron beams in wide dose range and µs resolution with miniaturized Minipix-Timepix3-Flex camera

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Background and Aims

Finding viable solutions for beam monitoring, dosimetry and metrology of Ultra-High Pulse Dose Rate (UHPDR) beams is necessary to guarantee that the technique is successfully applied. The goal of our study was to test a customized detector for FLASH radiotherapy based on "MiniPIX-Timepix3-Flex" detector developed by ADVACAM [1].

23 MeV electrons FLASH measurements with Minipix Timepix3 Flex

The optimized ASIC-based Timepix3 (TPX3) detector MiniPIX-Timepix3-Flex (Fig. 1a) has a flexible cable which connects the electronic compounds with the sensor. A detector with GaAs sensor and a chip without sensor "Naked" were tested in wide range of dose rates (DR), to study their suitability for the characterization of primary UHPDR beams produced at the electron Microtron Accelerator of the NPI CAS, Rez, Czech Republic (see Fig. 1b). Timepix3 detectors operate each pixel simultaneously in time and energy mode. The time of arrival (ToA) can be identified with a resolution of 1.6 ns, whereas the Time over Threshold (ToT) of the respective pixel can be measured. Data were collected in data-driven mode (ToA+ToT) and frame mode (Event+iToT), measuring the integrated per-pixel energy deposited and number of hits in each pixel. The acquisition time was set to 500 µs to register individual pulses with pulse length of 3.5 µs. For time measurements, the detectors were operated in data-driven mode (ToA+ToT). The DR were measured in front of the bunker using the ionization chamber.

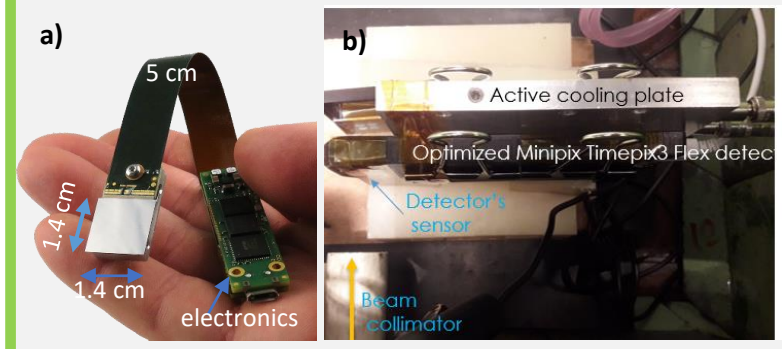

Figure 1. a) The customized Minipix TPX3 Flex. The 5 cm long PCB connects the electronics to the ASIC Timepix3 readout chip of 256x256 pixels, 1 px=55 µm. b) The experimental setup with detectors placed in the primary beam, in front of the collimator (3 cm diameter) behind a lead shield bunker.

Results: Per-pixel spectrometry and time measurements

The results demonstrate the detector's response and ability to measure individual UHPDR electron beams at various beam intensities form 1 pA to 2000 nA. The particle's deposited energy is shown in Fig. 2. The measured event count rate, for low-intensity pulsed fields, is shown in Fig. 3a.

Detectors with silicon sensors were successfully tested in FLASH stray radiation electron beams [1].

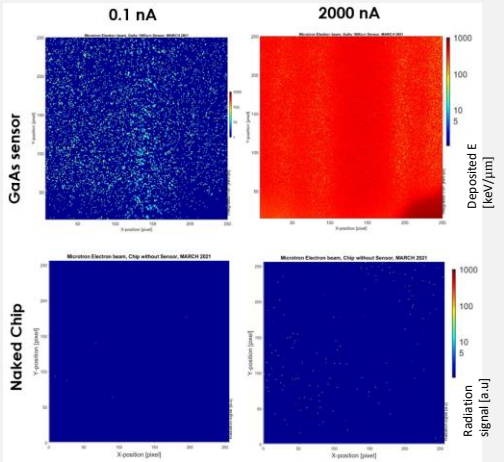

Figure 2. The per-pixel spatial distribution of integrated deposited energy for 3.5 µs pulse measured with Minipix-Timepix3-Flex detector, (top) GaAs sensor 550 µm thickness and (bottom) a Naked chip (without sensor).

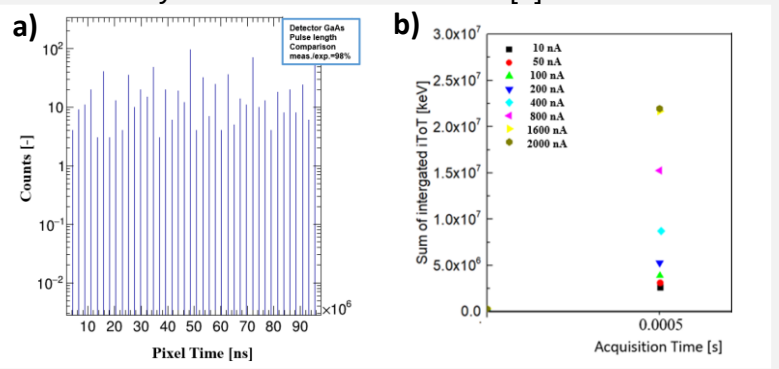

Figure 3. a) Real time measurements of individual pulses measured at the ms scale using a Minipix-TimePIX3-Flex GaAs 550 µm thick sensor at 1 pA beam intensity. b) Sum of integrated energy [iToT] over the entire detector area 2 cm², measured in frame mode for 500 µs, for various beam intensities.

Conclusions and further work

Preliminary results showed the detector with GaAs best measures the integrated deposited energy at FLASH level. Time and event rate measurements are provided at pixel level at low intensity (Fig. 3a). At high intensities the detectors were used in frame mode and the integrated per-pixel deposited energy was measured for individual pulses (Fig. 3b). At higher intensities the GaAs detector partly saturates. On the other hand, the detector in sensor-less architecture reduces the detector sensitivity but expands the response range to higher intensities. At these increasing intensities, the detector without sensor operates with proportional radiation intensity and event rate response. Necessary quantitative evaluation, further tests and calibration will be performed.

Reference: [1] C. Oancea et al. JINST (accepted publication), 2021

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The 18HLT04 UHDpulse project is founded by the EMPIR-programme