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# Timepix2-radiation camera for single particle imaging in high count-rate particle therapy

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**Background and Aims:** Accurate energy measurements imparted by single particles under high-flux conditions are essential for various applications including radiotherapy, space applications, and accelerator physics. Challenges emerge when: i) particle count rate on the detector exceeds 10^5 particles/s and particle overlapping occurs, ii) short-pulsed beams necessitate high temporal resolution, iii) highly ionizing particles induce quenching effects/energy saturation in detection systems.

**Materials and Methods:** For this work, a novel ASIC-based MiniPIX-Timepix2 pixel detector with a silicon sensor was used to address the aforementioned challenges. The detector's ability to resolve challenges related to high-linear energy transfer (LET) particles including ions, with therapeutic fluxes over 10^7 particles/cm^2/s and single particle deposited energies exceeding 5 MeV, is examined. The Timepix2 chip enables the detector operation for very short shutter open times down to the nanoseconds level, whereas in the Timepix3 chip the acquisition time could be decreased up to microseconds level. The experiments were carried out using carbon and proton beams with energy ranging from 97 to 400 MeV/u at MedAustron a medical synchrotron accelerator (in air), and alpha particles from a 241Am source (in vacuum and in air) with energy of 5.5 MeV.

**Results:** Single-particle imaging (see Figure 1) at high-flux was possible utilizing a short frame-level acquisition time of 100 ns combined with a novel detector customized configuration with adjusted per-pixel signal shaping/discharging time, see figure 1c. The energy spectra measured in clinical carbon ion flux are given in Figure 2. Furthermore, a comparison between various configurations of the detector is given together with a high-energy per-pixel calibration function, intended to correct for energy saturation effects when occur. This new calibration function for Timepix2-based detectors with standard configurations is an extension of the calibration presented by Jakubek 2011 and Sommer 2022 and it is effective above a per-pixel deposited energy threshold of~ 815 keV/pixel. Additionally, deposited energy spectra obtained in proton, carbon, and alpha-particle beams were compared against reference values from Monte Carlo simulations and experimental databases.

**Conclusions:** In conclusion, the newly developed and calibrated detection system based on Timepix2 chips provides an effective means of characterizing radiation fields through single-particle detection and identification.

**References:**

Jan Jakubek, Precise energy calibration of pixel detector working in time-over-threshold mode, NIMA, Volume 633, Supplement 1, 2011, Pages S262-S266, https://doi.org/10.1016/j.nima.2010.06.183.

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