Measurements of scattered radiation produced in electron beams using MiniPix TimePix3 Flex

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Introduction and goal

Recent studies in radiotherapy show remarkable discoveries in the treatments that involve high dose rates, known as FLASH beams [1]. Having detectors suitable for such ultra-high beam intensities that are used in FLASH treatments is crucial for the clinical implementation of this new technique [2].
TimePix3 detector is an active pixeled detector, based on the ASIC chip semiconductor infrastructure from the MediPix group, capable of measuring significant properties of the incident beam, such as deposited energy, particle fluxes, temporal information about events, linear-energy transfer [3].
This work aims to provide a comprehensive analysis of the ultra-high dose (UHD) rates electron beams using a prototype of the pixel TimePix3 detector. Spectral and quantitative aspects of the backscatter radiation produced by those UHDpulses beams were measured at the Microtron electron Accelerator from the Nuclear Physics Institute CAS (UJF CAS), Prague, Czech Republic.

Methodology

Data presented in this work were collected with customized versions of the MiniPix TimePix3 detectors (see Fig. 1). Two configurations of the TimePix3 detector were used in this work, 100 and 500 µm thickness of the Si sensor, in dose rates of the incident electron beam up to 40 Gy/s for validating the performance of the detectors. Individual electron pulses of 3.5 µs duration were used. The measurements of the secondary radiation were done with the TimePix3 detector placed behind a 1 cm PMMA plate. The lateral position of the detectors was provided by the shifting stage that facilitates the movement inside the set-up (see Fig. 2).

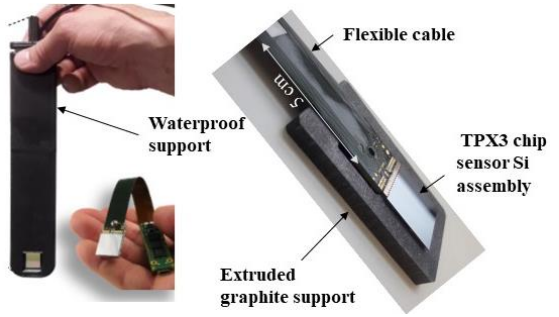

Figure 1. Customized MiniPix TimePix3 with the electronic design located at 5 cm distance from the active surface. All metal holders, screws and cooling elements were changed with carbon or ABS plastic.

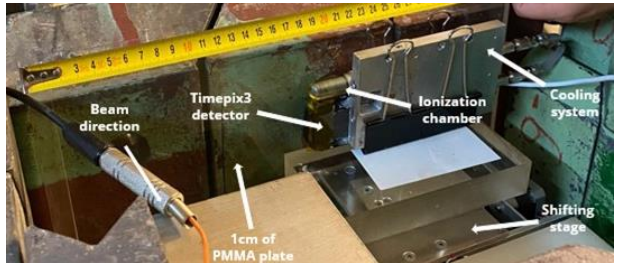

Figure 2. Experimental setup: the beam was collimated at the entrance in the bunker using a 3 cm collimator. The TinePix3 Flex was placed laterally to the beam behind 1 cm PMMA PMMA plate and 15 cm from the incident electron beam, on a shifting stage. The setup is placed inside a massive Pb shielding to avoid large background from the accelerator.

Results and Conclusion

Integrated deposited energy at 10 and 15 cm distance measured with TimePix3 detector, Si sensor of 100 µm thicknesses, for 200 pulses represent a linear response to the delivered dose rate of the incident electron beam (see Fig. 3). The Timepix3 detector show the total integrated energy of the particles at different dose rates of the secondary beam (see Fig. 4).
Considering the longer path of the particles in the MiniPix TimePix3 Flex Si 500 µm, the value of the integrated deposited energy is superior relative to the same position of the Si 100 µm detector.
The preliminary results validate the current design of the TimpePix3 detector as a good candidate for characterization of the scatter radiation in ultra-high dose rates electron beam [4].

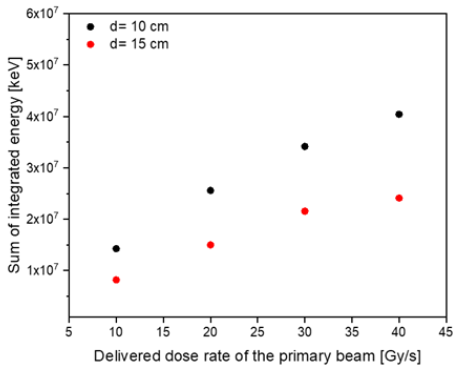

Figure 3. The sum of the integrated energy at different dose rates of the primary beam. The Timepix3 Flex detector with Si sensor with 100 µm thickness, was placed at 10 (black) and 15 (red) cm from the beam and measured the energy of the particles at different dose rates.

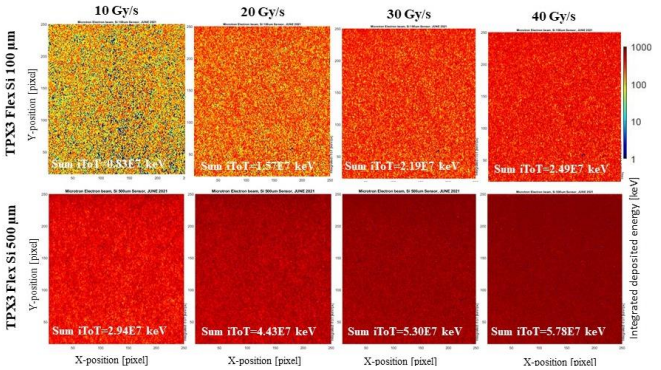

Figure 4. Integrated per–pixel energy measured at 15 cm distance from the beam core using the TimePix3 Flex Si sensor of **(top row)** 100 µm and **(bottom row)** a 500 µm thickness at a pulsed-field of 15.7 MeV electrons of 10, 20, 30 and 40 Gy/s delivered DR. Each frame contains 256 x 256 pixels and represents the response of individual pulses with a length of 3.5 µs. The detector's acquisition time was set at 500 µs.

References

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Acknowledgements

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