NEUTRON DETECTION IN UHPDR MIXED-FIELDS PRODUCED BY ELECTRON BEAMS USING ACTIVE PIXELSEMICONDUCTOR DETECTORS TIMEPIX3

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Motivation and Aims

This work aims to quantify the contribution of secondary particles including thermal neutrons produced in ultra-high pulse dose rate (UHPDR) electron beams.

Timepix3 detectors

In these studies, the Timepix3 detectors were exposed to an environment with high dose-rate (DR), so they were operated in frame mode (Event + iToT) the total/integrated per–pixel deposited energy and counts.

Timepix3 semiconductor pixel detector characteristics:

- ASIC chip with flexible PCB
- Architecture: miniaturized Minipix TPX3 radiation camera
- Sensors: Si of 100 and 500 µm thickness
- Time resolution per-pixel: 1.6 ns
- Operation mode: Frame
- Acquisition time: 0.1 s to register individual pulses (pulse length<3 µs).

Experimental setup at PTB

Experimental Setup:

- Detectors: 2x Minipix Timepix3 Flex and 1x Diamond detector
- Accelerator: LINAC, PRF: 5 Hz, Pulse width:1.3 µs to 3 µs, Dose per pulse at Zref: 1.8 Gy to 15 Gy, Beam energy: 20 MeV
- Detector calibration: for charged particles was done by Advacam and for thermal neutrons at CMI
- Neutron converter: made out of ^{6}LiF, detection efficiency between 0.43% and 2%.

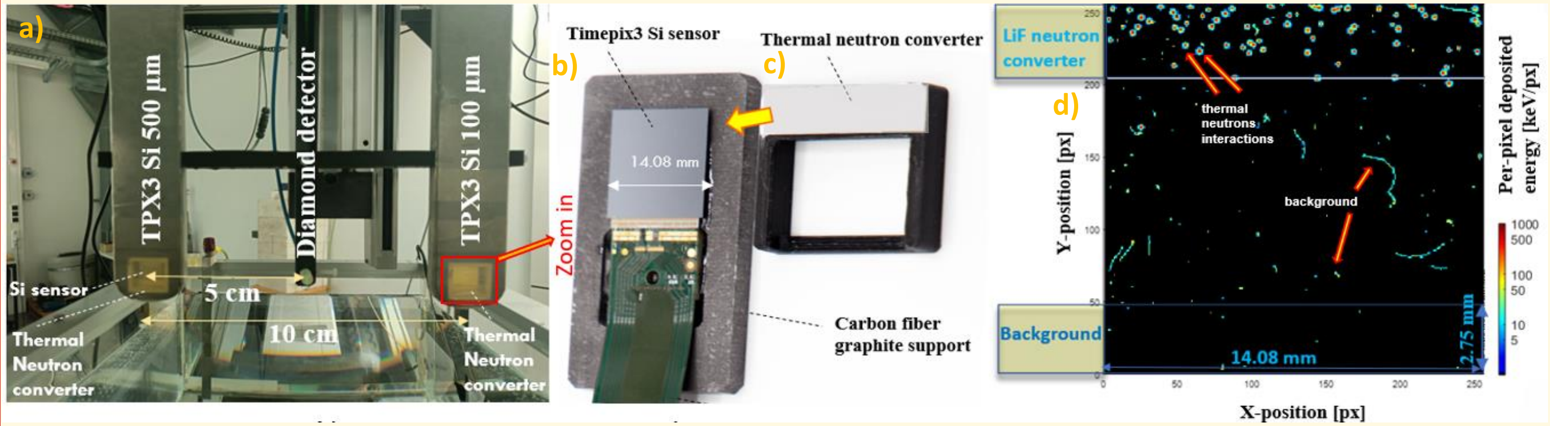

Figure 1. *a) The water phantom with 2 customized Minipix Timepix3 Flex and a Diamond detector. b) Enhanced view in the sensor area region where c) the ^{6}LiF neutron. d) Map of deposited energy in the Timepix3 detector with thermal neutron converter. Selected non-neutron region (bottom region).*

Flux of Thermal neutrons

Thermal neutron interactions with ^{6}LiF at depth of 18.5 cm

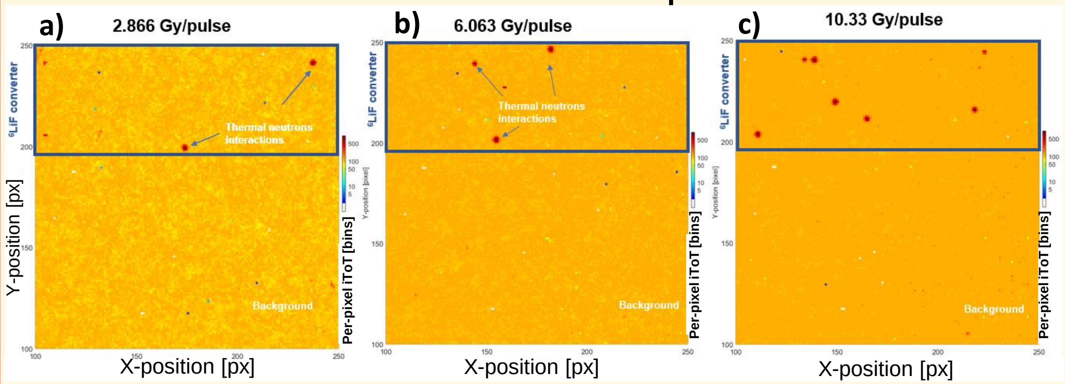

Figure 2. *Map of deposited energy in detector measured at depth of 18.5 cm, lateral 5 cm in a water-phantom irradiated with 20 MeV electron beam at various dose per pulses. Illustration of rounded tracks created below the neutron converter (top area) and stray radiation (bottom).*

Equivalent dose, H

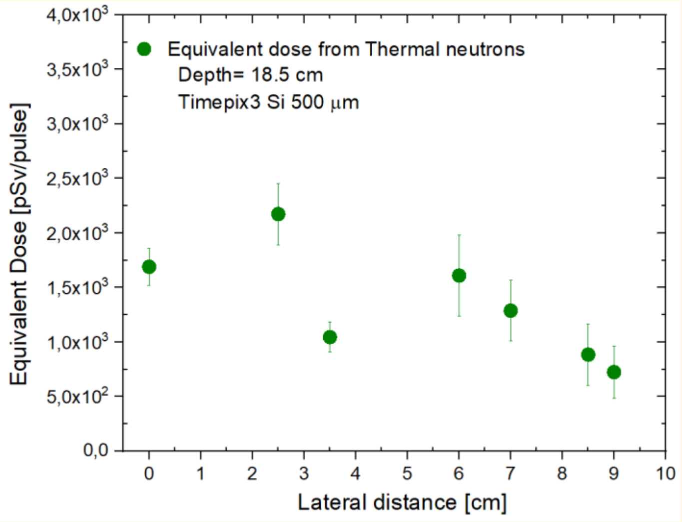

Figure 3. *H per pulse at 18.5 cm depth.*

- Based on MC simulations, the conversion coefficient from thermal neutron fluence to equivalent dose 2.0 pSv*cm^2 was calculated.
- The constant includes neutron dose and dose from photons generated by thermal neutrons at capture.
- H for individual UHDR pulses of *a* DR at Zref = 1.85 Gy/pulse, Frequency = 5 Hz, pulse length of 2.3 µs

Conclusions

- An experimental method for stray radiation characterization in wide range of components was presented.
- The neutron contribution in UHPDR electron fields was quantified. Their interactions can be imaged as high energy tracks well resolved and their flux was measured. The response of Timepix3 can be used at positions where the stray radiation deposited energy is smaller than the per-pixel energy deposited by the thermal neutron interactions.
- A constant for equivalent dose derivation based on MC simulations was applied to estimate the equivalent dose inside water from thermal neutrons. The results will be compared with the MC simulations and results with other detection systems.

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Oancea, C. et al. (2022). Stray radiation produced in FLASH electron beams characterized by the MiniPIX Timepix3 Flex detectorJINST, *17*(01), C01003.
Šolc, J. et al (2022). Monte Carlo modelling of pixel clusters in Timepix detectors using the MCNP code. *Physica Medica*, *101*, 79–86.

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