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Compton imaging for dose monitoring in boron neutron capture therapy

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Boron Neutron Capture Therapy (BNCT) is an experimental form of radiotherapy that uses boron, injected to the patient within a target molecule that accumulates selectively in cancerous cells. This therapy exploits the large neutron capture cross-section of boron to deliver a targeted dose from neutron irradiation. BNCT has shown great promise with the advent of accelerator-based technologies, which facilitate high-quality neutron beams in clinical environments [Hir21, Tor21].

One of the primary challenges in current BNCT is the accurate determination of the dose delivered to the patient. The state-of-the-art method involves measuring the boron concentration in the patient using PET with a 18F-labeled boron compound, followed by determining the boron concentration in blood during the neutron irradiation to estimate the boron dose. Since neutron captures in boron produce 478 keV gamma rays in 94% of reactions, this radiation could be potentially used for real-time dose monitoring using various imaging techniques. To date, SPECT and Compton imaging have been explored; however, the main challenges remain in achieving the spatial resolution required, true online capabilities and dealing with the harsh radiation backgrounds induced by the neutron beam during treatment.

The i-TED Compton Camera array, originally designed for nuclear physics measurements of astrophysics interest, recently has expanded its application into medical physics through ion-range monitoring in hadron-therapy [Ler22,Bal22], and is venturing further in this field aiming now at BNCT. Its large efficiency design and low neutron sensitivity make i-TED especially well suited for this task.

This contribution will present additional adaptations of the original i-TED imager, to optimize its performance for the BNCT dosimetry application. In this context, an evaluation of the detector thicknesses has been performed to optimize it for the 478 keV gamma rays characteristic of BNCT. Additionally, since BNCT requires imaging of large areas (e.g. the human head or torso) we have integrated LM-MLEM algorithms into our imaging suite to enable 3D image reconstruction and tomographic capabilities [Tor24].

Moreover, we have conducted an initial experimental campaign with one iTED module at the high-flux nuclear reactor of the Institut Laue-Langevin (ILL, Grenoble, France) as proof-of-concept of the imaging of 478 keV gamma rays [Ler24]. A second campaign was performed with the complete i-TED array of four Compton imagers under more realistic conditions, using HDPE and water phantoms surrounding borated water disks in concentrations comparable to actual BNCT treatments [Tor24].

I will provide an overview of the main adaptations of i-TED for BNCT, our latest developments in 3D image reconstruction, the results of the first proof-of-concept experiment with one i-TED module, and the status of the analysis of the recently performed experiment using the full i-TED array in more realistic conditions.

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Abstract

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