Preliminary study of a 3D-CZT based Single-stage Compton Camera for BNCT therapeutic dose monitoring

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Introduction: The BNCT clinical outcome depends on the ^{10}B selective accumulation inside cancer cells. The ^{10}B therapeutic dose can be monitored in vivo through the measurement of the 0.478 MeV dis-excitation photon of $^{7}Li^*$. The 3CaTS project, funded by INFN, aims to realize this real-time dosimetry using an innovative 3D-CZT drift strip detector. The traditional SPECT method relies on the use of high Z, highly attenuating collimators thus heavily limiting the efficiency and spatial resolution of the imaging system. However, the Compton Camera (CC) is an electronically collimated imaging system that uses the kinematics of Compton scattering, thus it can reach higher spatial resolution and better performance than traditional SPECT method. This work focuses on the preliminary feasibility simulations of a 3D-CZT based Single-stage CC for BNCT therapeutic dose monitoring.

Materials and Methods: The long term goal of 3CaTS project is to have a modular photon sensor where the overall detection area is built and optimized by stacking individual CZT crystals of 5×20×20 mm^3. The simulations started considering a single crystal to which one/two/three other crystals were added to simulate the aforementioned modular sensor. An ideal, point-like, isotropic 0.478 MeV γ-source was implemented in Geant4. The PhysListEmStandard was utilized to simulate the photoelectric effect, the Compton scattering (with Klein-Nishina model) and the Rayleigh scattering for photons as main interactions while the bremsstrahlung, the ionization and the multiple scattering for electrons. The deposited energies and interaction positions for Compton scattering and photoelectric absorption are recorded respectively, in particular when belonging to a true event, which is defined as the sequence of a single Compton scattering of the original photon followed by a photoelectric absorption.

Results: The range of Compton scattering angle for reconstruction can be extended up to 180° for Single-stage CC while it must belong to a limited range (0°-90°) for two-detectors CC. Thus, Single-stage CC has higher detection efficiency than two-detectors CC and can realize 4π Compton imaging. The true events relative efficiency reaches 17.6% for 20×20×20 mm^3 detector at 0.478 MeV, while it’s 16% for 40×40×5 mm^3 CZT at 0.45 MeV [1], and 21% for 128×128×10 mm^3 CdTe at 0.5 MeV [2]. Thanks to the normalization of the relative efficiency to the total number of particles entering the detection volumes, we can say that our CZT-based Single-stage CC shows the same relative efficiency with other reported systems.

Conclusion and future perspective: This work aims to evaluate the feasibility of a 3D-CZT based Single-stage CC to obtain the ^{10}B dose distribution in BNCT. Considering the thermal neutrons and the complex photon contamination of a BNCT facility, the next steps of this work will be: (i) the evaluation of the effect of the mixed (n+γ)-radiation field on the 3D-CZT CC detection performances which, by turn, will lead to (ii) the optimization of the geometrical parameters of the imaging system, in particular, the source-to-detector distance and the whole detecting area of the photon sensors. In the talk, both the preliminary results and the possible future studies will be presented and discussed.

References

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