2021 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) | 978-1-6654-2113-3/21/$31.00 ©2021 IEEE | DOI: 10.1109/NSS/MIC44867.2021.9875509

High-Resolution 3-D CZT Drift Strip Detectors for Prompt Gamma Ray and Neutron Detection in BNCT

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***Abstract*– Spectroscopic imagers based on high-Z and wide-bandgap compound semiconductor detectors are widely proposed for the detection of prompt gamma rays in boron neutron capture therapy (BNCT). BNCT is a therapy based on the neutron capture reaction ^{10}B (n,α)^{7}Li. To perform a real-time monitoring of the spatial distribution of ^{10}B during the treatments, the detection of the prompt gamma rays (478 keV), produced by the ^{7}Li recoil nuclei, can be helpful. In this work, we presented the potentialities of new high-resolution CZT drift strip detectors, recently developed by our group, for BNCT measurements. The detectors, exploiting the analysis of the collected-induced charge pulses from anodes, cathodes and drift strips, show excellent energy resolution < 1% at 662 keV at room temperature. The results of preliminary gamma ray measurements under thermal neutrons at the T.R.I.G.A. Mark II research nuclear reactor of Pavia University (Italy) are shown.**

I. Introduction

Recently, great efforts have been made in the development of room temperature spectroscopic gamma ray imagers for real-time dosimetry during boron neutron capture therapy (BNCT) [1]. BNCT is a dedicated therapy employed to treat tumour cells using a ^{10}B compound and thermal neutrons. The high LET of alpha particles produced from the ^{10}B (n, α)^{7}Li reaction is very important in tumour treatment. Real-time monitoring of ^{10}B is desired during BNCT treatments and several spectroscopic imagers [2,3] have been proposed to detect the prompt gamma rays of 478 keV emitted during the (n,α) reaction. The main critical issue of these systems is represented by the poor energy resolution, very important to resolve the 478 keV photons from the background produced by neutrons and gamma rays. Recently, new high-resolution CZT drift strip detectors were developed by our group with energy resolution less than 1% at 662 keV [4]. As well known, CZT/CdTe detectors show now appealing properties in room temperature X-ray and gamma ray measurements [5-16]. In this work, we will present the potentialities of these detectors for real-time dosimetry in BNCT. The preliminary results from measurements at the T.R.I.G.A. Mark II research nuclear reactor of University of Pavia (Italy) are shown.

II. The Detectors

The drift-strip detectors are based on THM-CZT crystals (20 x 20 x 6 mm^3) [14-16] and characterized by gold cross-strips on the cathode and anode sides. Figure 1 shows the strips of the cathode side. The anode strips have a pitch of 0.4 mm, the cathode strips, orthogonal to the anode strips, a pitch of 2 mm. The strips of the anode are organized in collecting strips and drift strips, negatively biased to optimize the electron charge collection. A voltage of -350 V was used for the cathodes, -200 V and -100 V for the drift strips on the anode. We used low noise (ENC < 1 keV) charge sensitive preamplifiers (CSPs) and digital electronics to process the pulses from the detectors. Both the CSPs [4] and the digital electronics [17-21] were developed at University of Palermo.

Fig. 1. Overview of the cathode electrode bonding of the 3D drift strip CZT detectors.

Manuscript received December 10, 2021. This work was supported by the Italian Space Agency (ASI) (ASI/INAF agreement No. 2017–14-H.O), by the National Institute for Nuclear Physics (INFN) (project No. 3CaTS) and by the Italian Ministry for University and Research (MUR), under AVATAR X project No. POC01_00111.

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III. PRELIMINARY RESULTS

Figure 2 shows the measured ^{137}Cs energy spectrum from a collecting anode after spectral correction. The energy spectrum was corrected by using a novel technique [4,22], which exploits the relation between the height of the collecting anode pulses and the negative saturation level of the pulses from the drift strips. The detectors are characterized by excellent energy resolution at room temperature (0.8% FWHM at 662 keV).

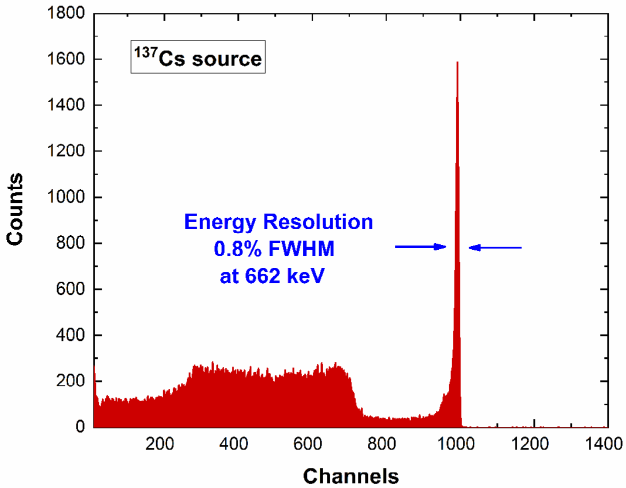

Fig. 2. Measured ^{137}Cs spectra (uncollimated source). The energy resolution, after correction [4], is of 0.8 % FWHM at 662 keV.

The gamma-ray response of the detectors to thermal neutrons was investigated at the T.R.I.G.A. Mark II nuclear reactor of the University of Pavia (Italy). To measure the typical gamma ray products from a BNCT set-up, a sample containing ^{10}B and water was irradiated with thermal neutrons. Figure 3 shows the measured energy spectrum from ^{10}B/water under thermal neutrons.

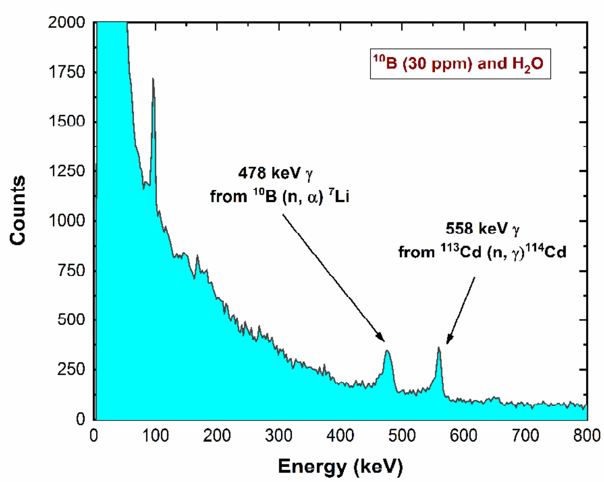

Fig. 3. Gamma-ray energy spectrum measured with the CZT drift strip detectors in a BNCT environment. The flat top of the 478 keV peak highlights the Doppler broadening effect.

The Doppler broadening of the 478 keV peak is well highlighted from the flat top of the energy peak. Moreover, the absence of a well defined 511 keV peak, due to annihilation gamma-rays, is justified by the absence of shielding/collimation materials.

IV. CONCLUSIONS

The spectroscopic potentialities of new CZT drift strip detectors for SPECT systems and Compton cameras in BNCT are presented. The detectors are characterized by excellent room temperature energy resolution of 0.8 % FWHM at 662 keV. Measurements under thermal neutrons showed the abilities of the detectors to well detect the 478 keV photons from the typical (n, γ) background of BNCT environment.

ACKNOWLEDGMENT

We thank Mr Marcello Mirabello and Dr Luigi Tranchina for their technical support in measurements.

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