New results on high-resolution 3-D CZT drift strip detectors

L. Abbene, F. Principato, G. Gerardi, A. Buttacavoli, S. Altieri, C. Gong, N. Protti, M. Bettelli, N. Sarzi Amadè, S. Zanettini, A. Zappettini, N. Auricchio, S. Del Sordo and E. Caroli

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***Abstract*–Intense research activities have been carry out in the development of room temperature gamma ray spectroscopic imagers, aiming to compete with the excellent energy resolution of high-purity germanium (HPGe) detectors (0.3 % FWHM at 662 keV) obtained after cryogenic cooling. Cadmium-zinc-telluride (CZT) detectors equipped with pixel, strip and virtual Frisch-grid electrode structures represented an appealing solution for room temperature measurements. In this work, we present the performance of new high-resolution CZT drift strip detectors (19.4 x 19.4 x 6 mm^3), recently fabricated at IMEM-CNR of Parma (Italy) in collaboration with due2lab company (Reggio Emilia, Italy). The detectors, working in planar transverse field (PTF) irradiation geometry, are able to perform 3D positioning and energy measurement of X rays and gamma rays: 2D positioning through cross-strip electrode patterns on the cathode/anode electrodes and the third coordinate by exploiting the C/A ratio and/or the drift time. A 32-channel digital electronics was used to process and analyze the zoo of collected/induced charge pulses from the strips. Excellent room temperature energy resolution (0.9 % FWHM at 662 keV) characterizes the detectors, after the application of a new correction technique. These activities follow the goals of two Italian research projects (3DCaTM and 3CaTS projects funded by ASI and INFN, respectively) on the development of spectroscopic X-ray and gamma ray imagers (10 keV-1 MeV) for medical and astrophysical applications.**

I. Introduction

RECENTLY several room temperature X-ray and gamma ray spectroscopic imagers, based on cadmium zinc telluride (CdZnTe or CZT) detectors, with sub-millimetre spatial resolution in three dimensions (3D) and high-energy resolution up to 1 MeV have been proposed and developed [1-4]. These systems, stimulated by several applications in astrophysics, medical imaging and nuclear security, should be able to ensure room temperature high-resolution measurements of energy, timing and 3D positioning of X rays and gamma rays. In particular, great efforts have been made to compete with the impressive energy resolution obtained with germanium (HPGe) detectors after cryogenic cooling (0.3 % FWHM at 662 keV) [5-6]. Regarding the CZT material, its appealing properties for room temperature measurements are now widely recognized [7-11]. 3D CZT detectors are currently developed with pixel [1] and virtual Frisch-grid [2] CZT detectors, obtaining important energy resolution in the gamma energy range (< 1 % FWHM at 662 keV). In this work, we will present new 3D CZT spectroscopic imagers characterized by a drift strip electrode geometry. This electrode layout, by exploiting the different pulses from the cross strips, ensures the 3D detection with a lower number of readout channels, if compared with pixelated detectors. The detectors, due to moderate leakage currents between the drift strips, allow high drift bias voltages with strong benefits in charge collection efficiency and energy resolution. The results of spectroscopic investigations and the benefits of a new spectral correction technique will be shown.

II. Detectors and Electronics

The detectors (19.4 x 19.4 x 6 mm^3) were fabricated from CZT pixel detectors produced by Redlen company. Gold strips were realised on both the cathode and anode electrodes by IMEM (Parma, Italy) and due2lab company (Reggio Emilia, Italy) [12]. The anode side is characterized by strips with a pitch of 0.4 mm (strip width of 0.15 mm and inter-strip gap of 0.25 mm); while, the cathode side is divided into strips, orthogonal to the anode strips, with a pitch of 2 mm (strip with of 1.9 mm and inter-strip gap of 0.1 mm). The strips of the anode worked as collecting strips (pitch of 1.6 mm) and drift strips (pitch of 0.4 mm), which are negatively biased to enhance the collection of the electrons on the collecting strip. We used a cathode bias voltage of -350 V, -200 V and -100 V for the electron focusing drift strips (Fig. 1). All strips were ac coupled to low noise (ENC < 100 electrons) charge sensitive preamplifiers (CSPs) and processed by a 32-channel digital electronics. Eight digitizers characterize the 32-channel digital electronics (DT5724, 16 bit, 100 MS/s, CAEN S.p.A., Italy; website: http://www.caen.it), driven by an original firmware developed at University of Palermo [13-15]. The detectors are designed to work in planar transverse field (PTF) irradiation geometry, in

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Leonardo Abbene is with Department of Physics and Chemistry (DiFC) - Emilio Segrè, University of Palermo, Viale delle Scienze, Edificio 18, Palermo, 90128, Italy. (corresponding author, telephone 0039-091-23899081, e-mail: leonardo.abbene@unipa.it).

F. Principato, G. Gerardi, and A. Buttacavoli are with Department of Physics and Chemistry (DiFC) - Emilio Segrè, University of Palermo, Viale delle Scienze, Edificio 18, Palermo, 90128, Italy.

A. Zappettini, N. Sarzi Amadè and M. Bettelli are with IMEM/CNR, Parco Area delle Scienze 37/A, 43100 Parma, Italy.

S. Zanettini is with due2lab s.r.l., Via Paolo Borsellino 2, 42019 Scandiano, Reggio Emilia, Italy.

E. Caroli and N. Auricchio are with INAF/OAS of Bologna, Italy.

S. Del Sordo is with INAF/IASF of Palermo, Italy.

S. Altieri, C. Gong and N. Protti are with Department of Physics, University of Pavia, via Agostino Bassi 6, Pavia, 27100, and PV-INFN Italy.

order to enhance the detection efficiency. Fig. 2 shows an overview of the total/photoelectric efficiency versus the material thickness at three key photon energies. In particular, 20 mm thick CZT material ensures a total (photoelectric) efficiency of 68 % (18 %) at 511 keV. Fig. 3 shows a picture of the detector (cathode side) and the electrical connections to CSPs.

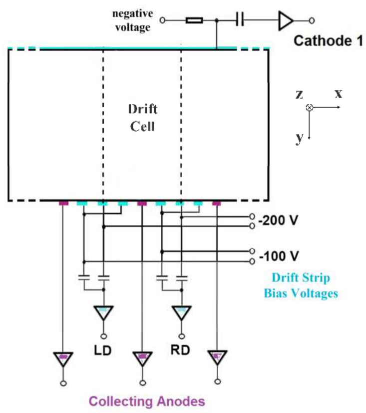

Fig. 1. Electrode layout of the cathode and anode strips. The signals of the drift strips are measured from left (LD) and right (RD) drift strip groups.

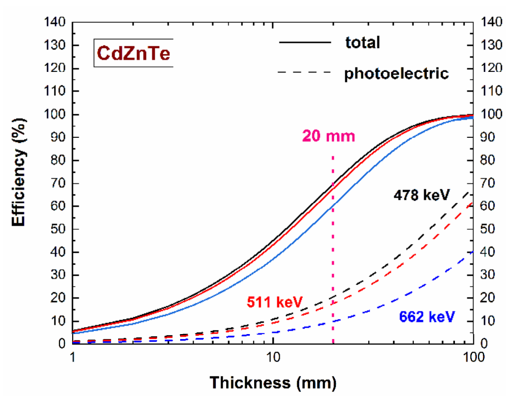

Fig. 2. Detection efficiency versus CZT material thickness.

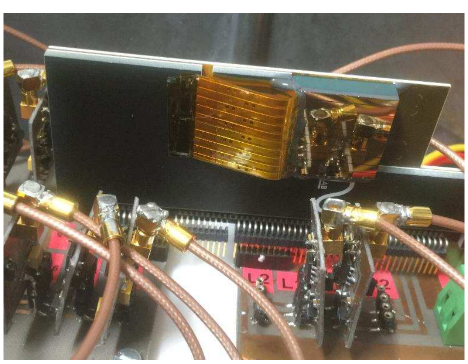

Fig. 3. Overview of the cathode side of the detector; the electrical connections to the CSPs are also visible. The green surface (XY plane) is the irradiated area in the PTF irradiation geometry.

III. Measurements and Results

Figs. 4 and 5 show the raw energy spectra of a collecting anode strip with no spectral correction, measured at room temperature. By analyzing the different shapes of the pulses from the drift strips, we implemented a new correction technique. In particular, we observed and demonstrated that the negative saturation levels (Fig. 6), present in several induced pulses from drift strips, are related to the charge induced by trapped holes. Therefore, taking into account the relation of this negative level with the pulse height from the collecting anodes, we obtained important improvements in the measured energy spectra (Fig. 7).

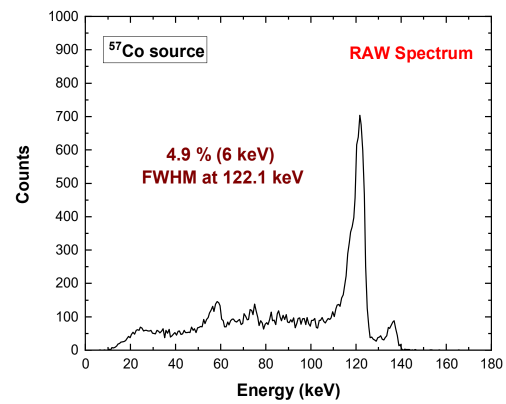

Fig. 4. Uncollimated ^{57}Co spectra with no spectral correction.

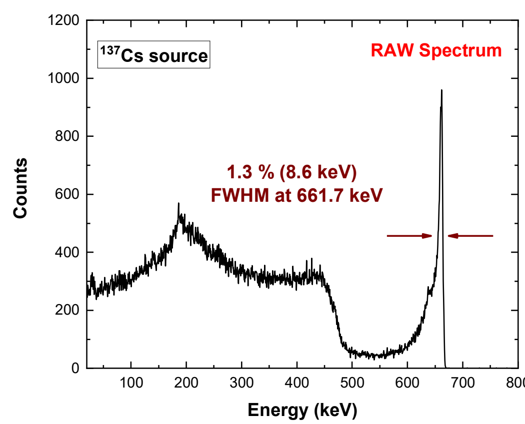

Fig. 5. Uncollimated ^{137}Cs spectra with no spectral correction.

IV. Conclusions

We presented the performance of new high-resolution 3D CZT drift strip detectors for gamma spectroscopic imaging up to the MeV region. Interesting room temperature energy resolution (1.3 % FWHM at 661.7 keV) of the raw energy spectra (without correction) highlighted important advances in detector fabrication technology obtained by our group. Moreover, excellent energy resolution was obtained (0.9 %

FWHM at 661.7 keV) by using a new correction technique, exploiting the negative saturation levels of the induced-charge pulses form the drift strips.

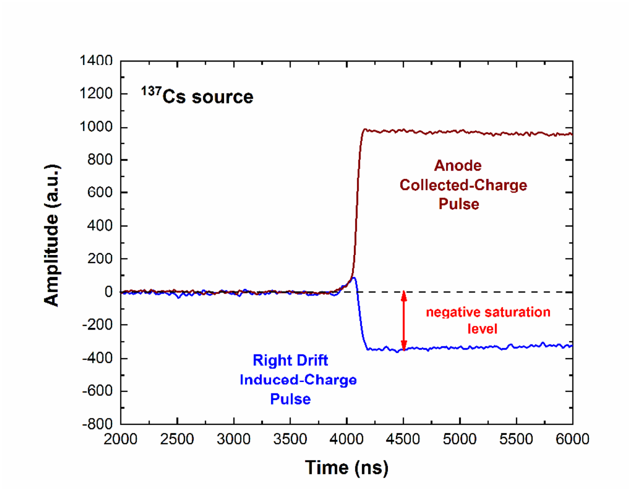

Fig. 6. Collected-charge pulse form a collecting anode measured in temporal coincidence with induced-charge pulse from a drift strip. The negative saturation level is due to the charge induced by the trapped holes.

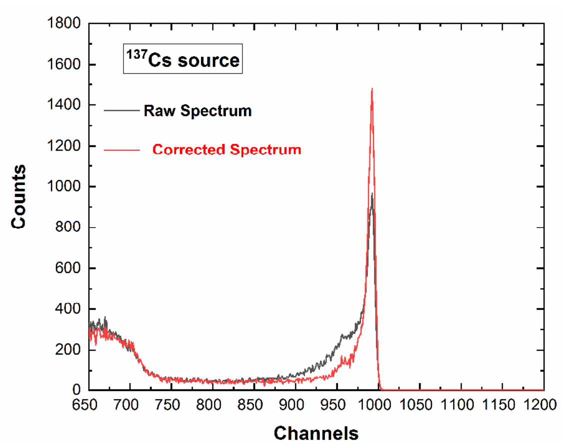

Fig. 7. Raw (black line) and corrected (red line) ^{137}Cs spectra (uncollimated source). The energy resolution, after correction, is of 0.9 % FWHM at 661.7 keV. A novel correction technique, based on the pulses from drift strips, was used.

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