3D Compton Tomography: A Promising Modality For Vectorized α/β Radiotherapy Imaging ?

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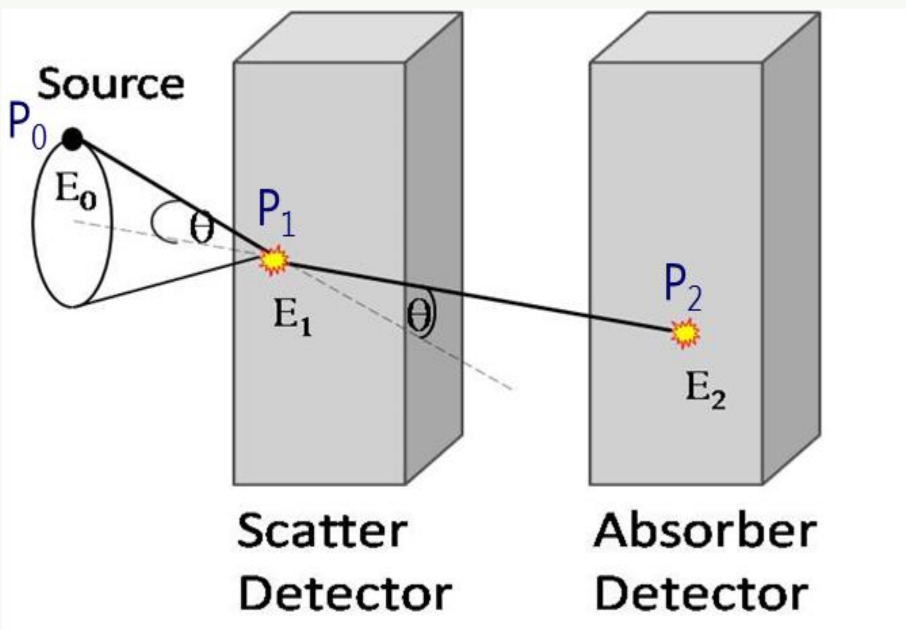
Position Of The Problem

Compton camera has been studied for years but has failed so far to find applications in nuclear medicine. The main drawbacks of Compton camera in medical imaging are poor image quality and artefacts at low statistics.

We have developed for nuclear applications a Compton camera with good spatial resolution and good signal/noise on detected Compton events. We show in this presentation the results obtained with Sparse 3D Compton tomography from three orthogonal views giving 3D information without any movement between the camera and the object.

The Concept

Our camera is of classical asymmetrical Compton camera design with 2 detection planes physically separated by 30 mm. Each detection plane is composed of a monolithic low radioactive background CeBr3 plate read out by a digital Si-PM : the diffuser plate is 32x43x5mm, the absorber plate is 32x32x12 mm.



Compton reconstruction principle

Our algorithms record for every gamma ray interaction the position and energy of the event in both the plates, including depth-of-interaction (DOI), even for the thin one, and the relative detection times between the two plates. (2) Allowing a coincidence veto that excludes non-Compton events. This explains why our camera has a very good signal/noise.

Experimental Methods

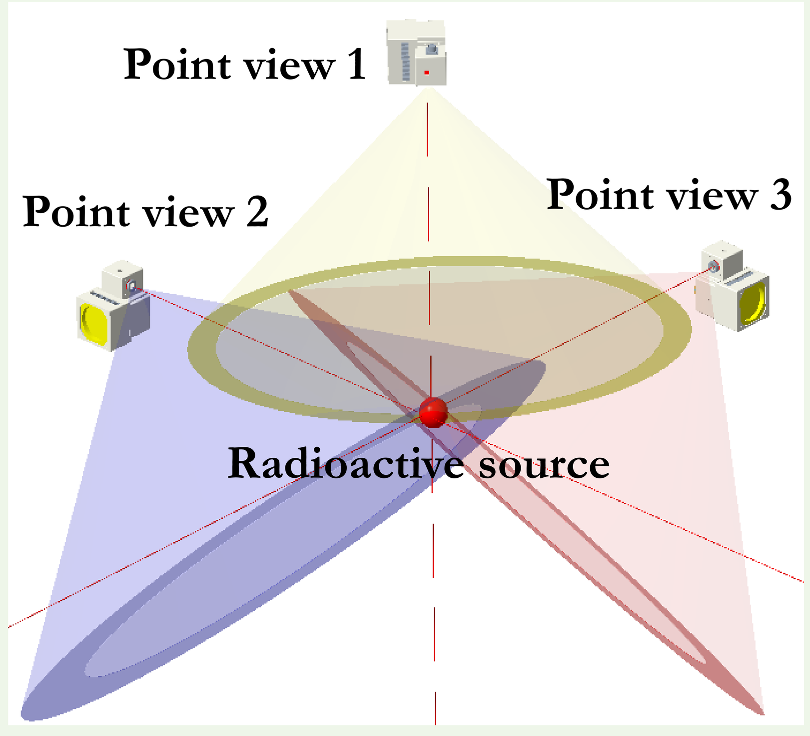
The Compton camera is integrated in a system whose is < 4 kg that includes acquisition and processing electronics, detector cooling and power supply.

Portable Compton camera Temporal V3

The energy resolution of both the plates was evaluated for 511 keV gamma rays: it amounts to 8 % FWHM for the scattering plate and 7 % FWHM for the absorber plate.

A coincidence time resolution (CTR) of 180 ps FWHM without DOI corrections was measured by placing a 22Na source between the 2 plates.

The positions of the events in both plates were calculated using time corrected light distributions. The spatial resolution (X,Y) was 1 mm FWHM for the scattering plate and 1.5 mm FWHM for the absorber plate.

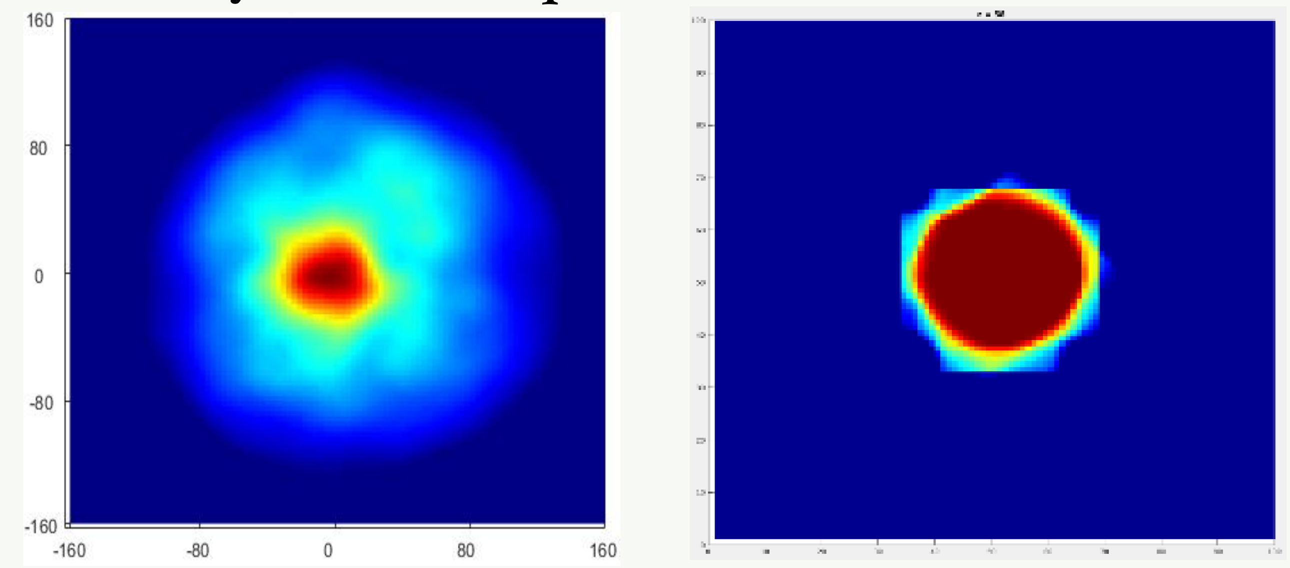


3D Compton image reconstruction

For 3D imaging the cones from the 3 views are intersected in 3D voxelized space. In this method of reconstruction, the radioactive sources are measured from different viewpoints. For Each Compton cone measured from each different positions we calculate a probability for each voxel. Then, the 3D spatial distribution was obtained as the sum of all back-projected Compton cones. Finally, the image is smoothed using LM-MLEM method [3]. LM-MLEM reconstruction tends to bend the reconstructed volumes. To improve our reconstruction quality, we have tested the usage of a total variation denoising algorithm for regularization.

The Results

With this Compton camera we have imaged a homogeneous cylinder of 22Na with an activity of 1.5 MBq.



Cross section of a ^{22}Na cylinder (left): Without regularization (right): with regularization

Cylinder dimensions were 11 cm length and a diameter of 7.5 cm. With our standard single view 2D reconstruction, the cylinder appears as an ovoid shape. Ounce a regularization process is applied, the cut perpendicular to axis is circular and shows a homogeneous distribution and the noise outside the cylinder is much lower. The cut along the axis shows a rectangle with softened corners.

We have also imaged a 75 mm diameter DERENZO mini-deluxe phantom where rods were filled with a ^{18}F solution of total activity 33 MBq.

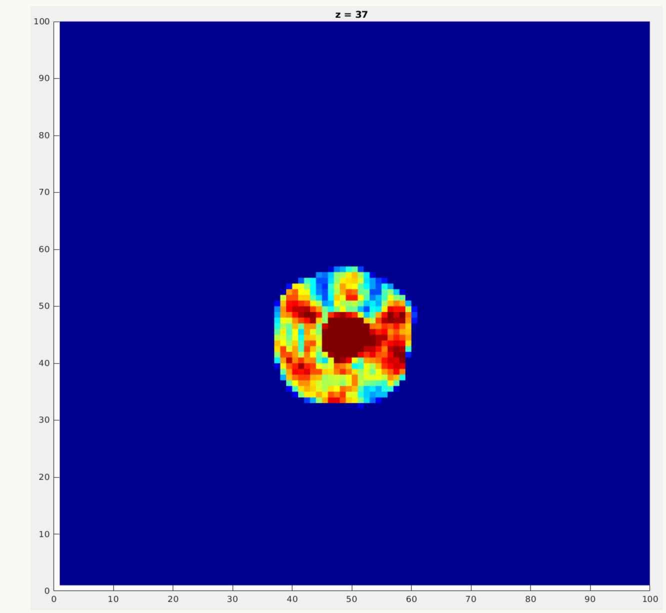


Image of ^{18}F D= 70 mm Derenzo phantom

The image presented here is a cut perpendicular to axis from a reconstructed 3D image. A regularization process was also applied. In this image through we have succeeded to clearly reconstruct the sectors of the phantom, we cannot resolve the rods yet.

Conclusion

Here we show results obtained with Sparse 3D Compton tomography from three orthogonal views giving full 3D information without any movement between the camera and the object. Using a total variation denoising algorithm for regularization allows good shapes to be reconstructed. For us the most promising application of such an imaging system is α/β vectorized radiotherapy dose deposition imaging. We have obtained some preliminary results on the liver of a patient treated with ^{90}Y.

[1] R. W. Todd, J. M. Nightingale, et D. B. Everett, « A proposed γ camera », Nature, vol. 251, no 5471, p. 132-134, sept. 1974.
[2] A. Iltis et al., « Temporal Imaging CeBr 3 Compton Camera: A New Concept for Nuclear Decommissioning and Nuclear Waste Management », presented at international conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications, Liége, Belgium, 2017.
[3] Z. Hmissi et al., « Passive Isotope Specific Gamma Ray Tomography of a Nuclear Waste Drum using a CeBr3 Compton Camera », presented at International conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications, Prague, Czech Republic, 2021.