Assessment of DOI Resolution in a Fully Mounted PEM Scanner

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INTRODUCTION

- The ClearPEM scanner is a dedicated system designed to perform breast imaging using Positron Emission Tomography [1] (Fig. 1).
- There are already two prototypes fully mounted. One of them has capability of acquiring ultrasound images [2].
- The scanner is composed of two planar detectors, with LYSO:Ce crystals with 2x2x20 mm^3

Fig. 1: ClearPEM-Sonic Scanner

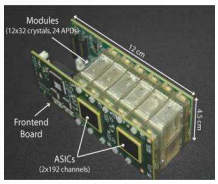

Fig. 2: Detector module with 2 APDs per crystal

- The scintillating light pulse produced in each crystal is read by 2 APDs, one per light extraction face (Fig. 2), allowing to precise the depth of interaction (DOI) coordinate.
- One of the scanners is currently installed at the Institute of Nuclear Sciences Applied to Health, in Coimbra, Portugal, to perform tests with phantoms, volunteers and small animals [3].

DOI MEASUREMENT

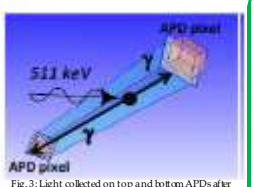

Fig. 3: Light collected on top and bottom APDs after irradiation by an external source

- The DOI information of each event is calculated as the signal amplitude asymmetry (A) at each APD pixel using:

$$A = \frac{E^{top} - k_{rel}.E^{bot}}{E^{top} + k_{rel}.E^{bot}}$$

- E^{top} stands for the integrated charge from the light collected on the top APD, and E^{bot} is the same for the bottom APD. k_{rel} is a calibration constant calculated for each crystal [4].

- Before assembling, this method was tested in a large number of modules with a collimated beam from a Na-22 positron source.
- The crystals were irradiated in different positions along its axis (Fig 3.), establishing an analytical relation between the DOI and the asymmetry.
- The DOI resolution achieved with these tests was 2.0 mm [4].
- After the assembling, the calibration is performed taking advantage of presence of ^{176}Lu in the LYSO:Ce crystals, uniformly distributed along its entire volume.
- The results obtained at this stage were consistent with a 2 mm DOI resolution [5].

EFFECT OF DOI IN IMAGE QUALITY

- The ability of obtaining an accurate measure of DOI is a key characteristic in high resolution PET scanners due to the impact of the parallax effect on the image spatial resolution.
- To illustrate this impact on our system we show in Fig. 4. reconstructed images with point sources, in different FOV positions, with and without DOI information.
- Images correspond to the 5th iteration obtained with OSEM3D algorithm (with 4 subsets) from STIR library, adapted to our acquisition geometry [6].
- The absence of DOI information results in a degradation of the image spatial resolution of more than 2.6 mm.

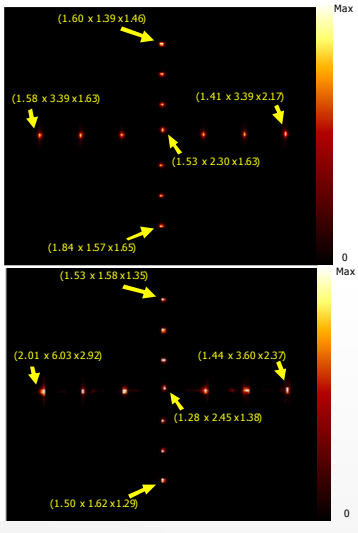

Fig. 4: Image reconstruction with (top) and without (bottom) DOI information. Values represent spatial resolution in mm, being the first value measured horizontally, the second vertically and the third perpendicularly to the image plane. The vertical axis corresponds to the rotation axis. The acquisition was performed with 154 mm detector heads separation

METHODS

- Detectors were placed in a static position with the maximum separation possible (300 mm).
- A point source was placed as close as possible of one of the detector heads and data was acquired for several hours.
- To have an exact location of the source, independently from any image reconstruction algorithm, we have determined the point in the FOV that minimizes the average distance to all LORs (Fig. 5)

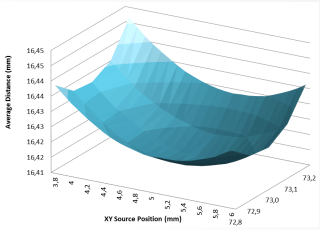

Fig. 5: Average distance to all LORs in a fixed slice.

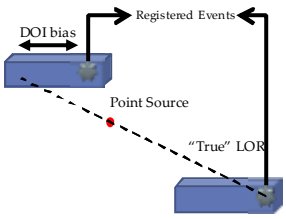

Fig. 6: "True" LOR based on the point source location and the farthest event and determination of the DOI bias.

- The effect in the LOR definition of an error of the DOI information from the farthest detector is negligible compared with an error of the DOI information from the closest detector.
- For each coincidence, a "true" LOR is defined as the line between the source position and the event detected in the farthest detector (Fig. 6).
- Each "true" LOR was extended and DOI bias was calculated as the distance between the intersection point and the point where the event was registered in the closest detector.

RESULTS

- All LORs with a distance to the source larger than the maximum bias that could be introduced by the absence of DOI information and all LORs that did not intersect the crystal where the closest event was registered were excluded.

- DOI resolution was calculated as the Full Width at Half Maximum (FWHM) of the Gaussian curve fitted to the bias distribution (Fig. 7).
- At the time of the experiment, the DOI resolution of the scanner was 2.8 mm

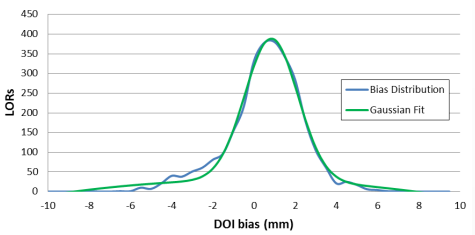

Fig. 7: Distribution of the DOI bias

DISCUSSION

- This method allowed the assessment of the DOI resolution with the ClearPEM scanner fully mounted.
- The results obtained are consistent with measurements during laboratory tests.
- Minor differences may be explained because there are still effects, such as random coincidences and scatter inside the detector heads that were not present in the laboratory tests and are not completely solved.
- Further work will be done to isolate this analysis from these factors.
- This method is simple to execute and is not very time consuming.
- It is a good option to be performed during quality control tests
- The method can also be applied to any high resolution planar PET detector.

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Acknowledgements:
This work was supported in part by Fundação para a Ciência e a Tecnologia - Portugal (grants numbers SFRH/BD/43376/2008, SFRH/BPD/29696/2006, SFRH/BD/47448/2008, SFRH/BD/66008/2009, SFRH/BD/33667/2009 and SFRH/BPD/64846/2009) and by Quadro de Referência Estratégico Nacional, QREN (Project PET II-b QREN 1590)

MIC15.S-122