drimPET: determination of DoI in LYSO crystals and application of a multiplexing resistive circuit for MPPC readout

P.M.M.Correia[1)*] , I.F.C. Castro [1,2)] , A.L. Silva [1)] , N. Romanyshyn [1)] , F.C. Rolo [1)] and J.F.C.A. Veloso [1)]

universidade de aveiro

[1)] Physics Department & i3N, University of Aveiro, 3810-193 Aveiro, Portugal
[2)] RI-TE Radiation Imaging Technologies, Lda Incubadora de Empresas da Universidade de Aveiro, Campus Universitário de Santiago, Edifício 1, 3810-193 Aveiro

i3N INSTITUTE FOR NANOSTRUCTURES, NANOMODELLING AND NANOFABRICATION

Abstract

The determination of the depth-of-interaction (DoI) of 511 keV gamma photons in scintillator crystals is of great interest in small diameter positron emission tomography (PET) systems, in order to achieve high spatial resolution with good uniformity within the entire field-of-view. **drimPET** is new concept for DoI determination wherein a single layer ring of 128 LYSO crystals is read out on both ends: on the outer end, each crystal is directly coupled to a SiPM, while on the inner end groups of several 32 crystals are indirectly coupled to only 1 or 2 SiPMs, using intermediate wavelength-shifters (WLS). This results in a simpler and less expensive readout when compared to the typical dual-ended readout method. Also, less components on the inner side of the ring allow more proximity to the FoV and thus increased sensitivity. Proof-of-concept studies were performed on a single detector cell with electronic collimation. The amount of light detected on each side of the crystal and the achievable DOI resolution with drimPET were measured, as well as the energy resolution, for different positions of a 22Na source along the crystal depth. Experimental studies using a multiplexing circuit based in resistive chain configuration readout and GATE simulations of drimPET are presented to evaluate the feasibility of applying the method in full detector rings for a small animal PET system, considering different number and dimension of the wavelength-shifting fibers.

drimPET concept

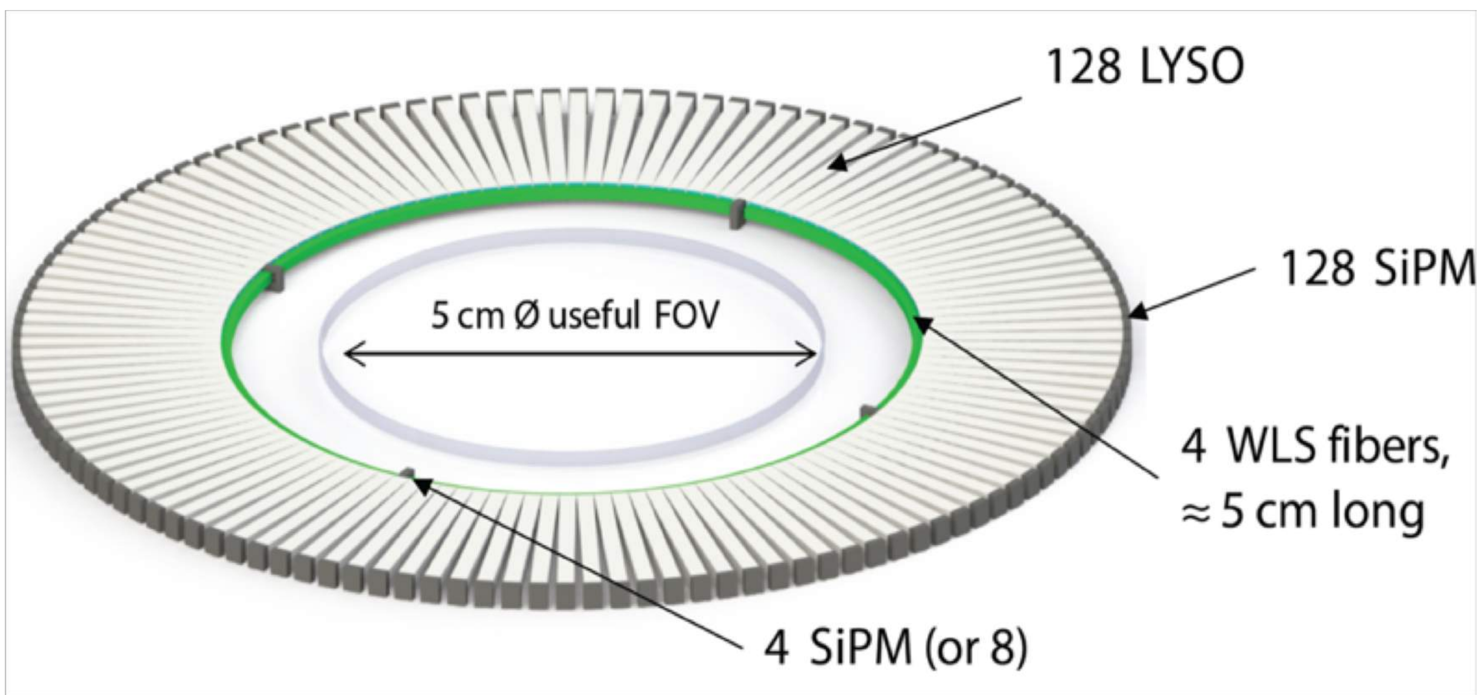

Fig 1. Sketch of the DRIMPET detector ring, using 128 LYSO crystals and only 4/8 WLS + 4/8 SiPMs for DoI determination (components drawn to scale).

Conclusions and Future Work

A new concept for DoI determination has been presented. It consists in the indirect readout of one end of the crystal using WLS instead of individual crystal coupled photodetectors.

This approach reduces the number photodetectors needed, simplifies the readout and allows an increased sensitivity. Experimental results from the drimPET dual-ended readout method using MPPC shown a DOI spatial resolution up to 6 mm. Strategies to improve these values are being performed. The initial development of the electronic readout system based in a multiplexing resistive chain circuit, developed for a group of 32 MPPC, is presented. The circuit will allow to reduce the readout complexity, thus simplifying the electronic circuit needed and reducing production costs.

Experimental Setup

A 1.5x1.5x20 mm^3 LYSO crystal (Kinheng Crystals) was first coupled on both ends to 1x1 mm^2 SiPMs (Hamamatsu Photonics), and then a WLS was coupled to one end of the crystal, with both its ends by readout by SiPM(Fig. 2). Electronic collimation was performed using a second crystal. Using an automated mechanic system based on a stepper motor, the electronic collimator (LYSO crystal + 22Na ½ in. disc source) was moved in small steps, scanning the whole crystal depth and performing synchronized acquisitions at each position. A CAEN V1724 digitizer was used for data acquisition. At each position, the **Ratio** between the signals from both ends of the crystal was determined. GATE[2] simulations were performed in order to compare results.

To avoid single electronic readout of all the detectors, a resistive chain multiplexing circuit is implemented. This reduces the problem to 2 front-end electronic channels to be analyzed per each group of detectors.

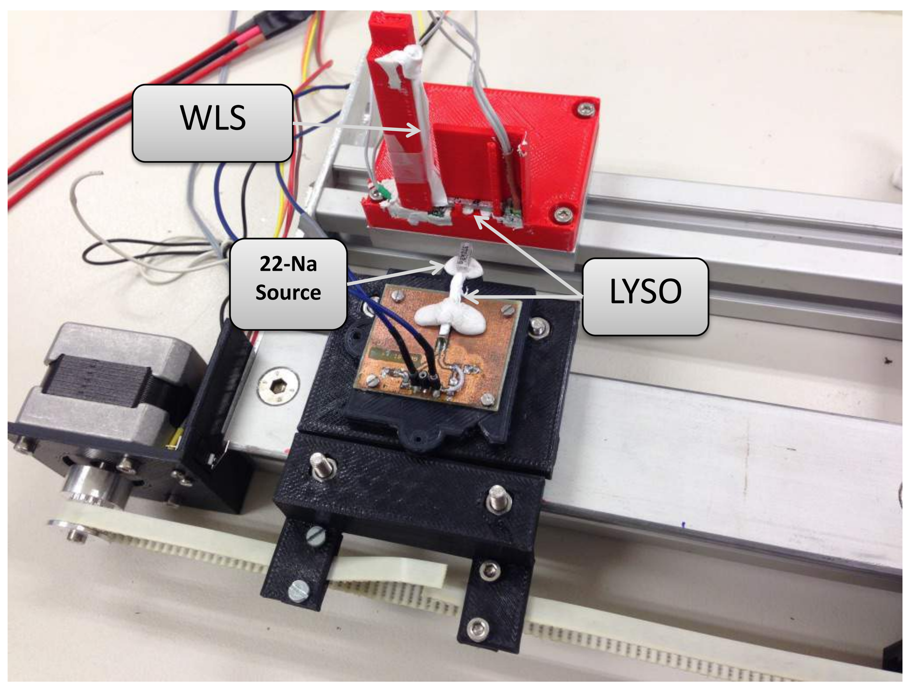

Fig. 2) Experimental setup for the DoI determination.

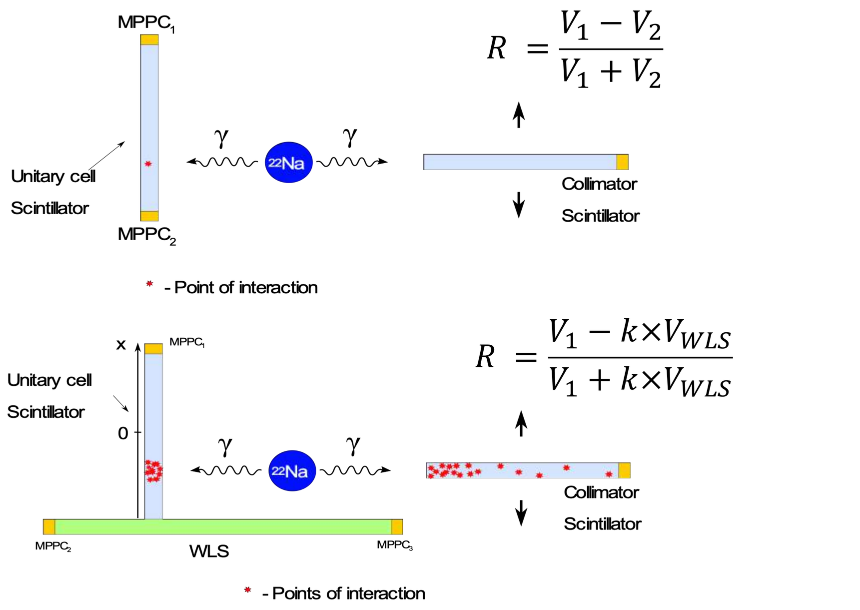

Fig. 3) Schematics of the single cell DoI study in LYSO crystal with drimPET, without and with the WLS configuration.

Experimental Results

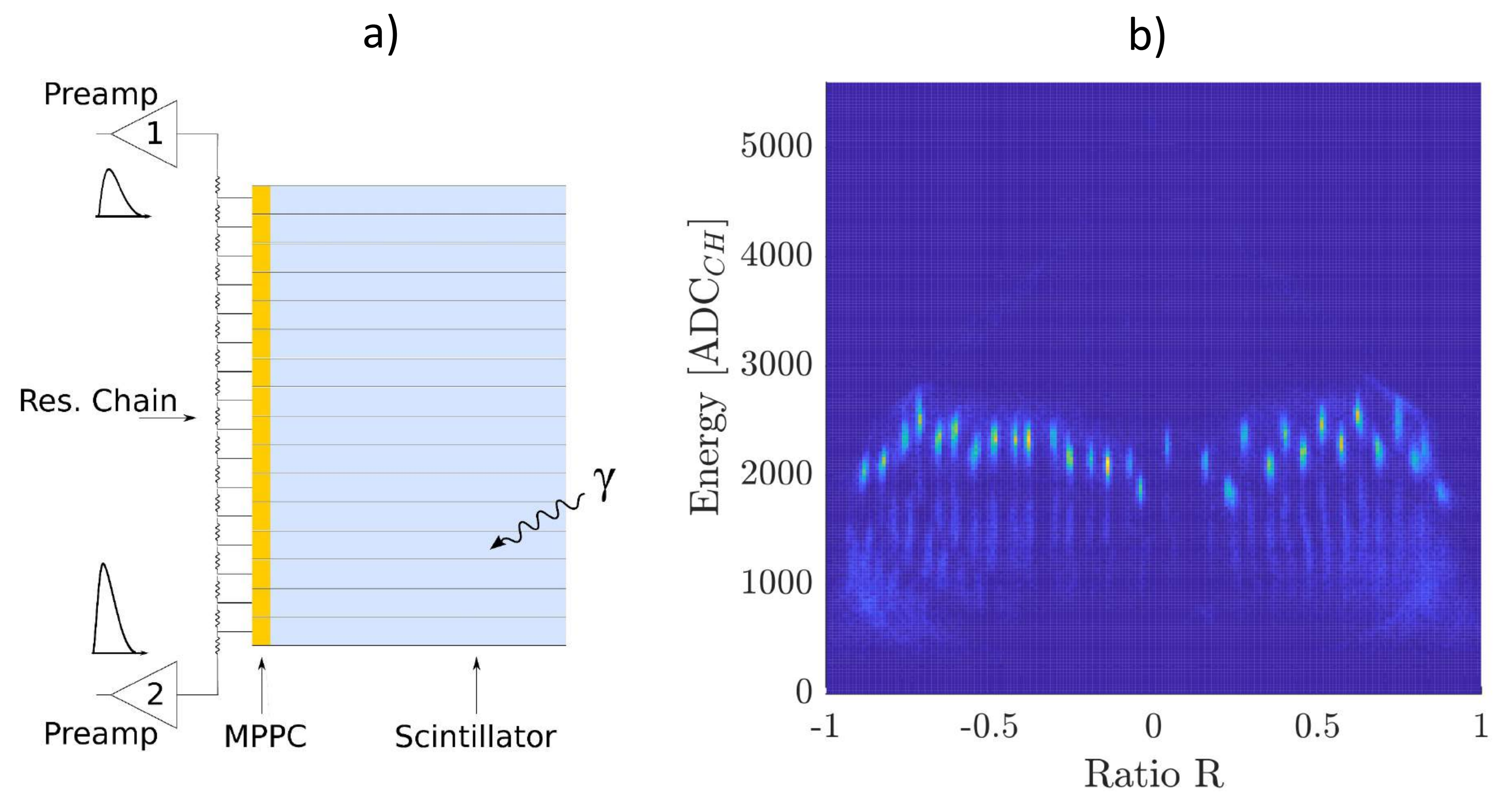

Fig 3. a) Scheme of a group of 16 detector cells (MPPC coupled to a scintillator), and the resistive chain multiplexing circuit used for readout, with 1 electronic channel at each end. **b)** Typical experimental bivariate histogram of Energy and R. 31 of 32 groups of events are distinguishable (one is missing, probably due to some defect of the MPPC soldering). The 511 keV peak is visible in all the group.

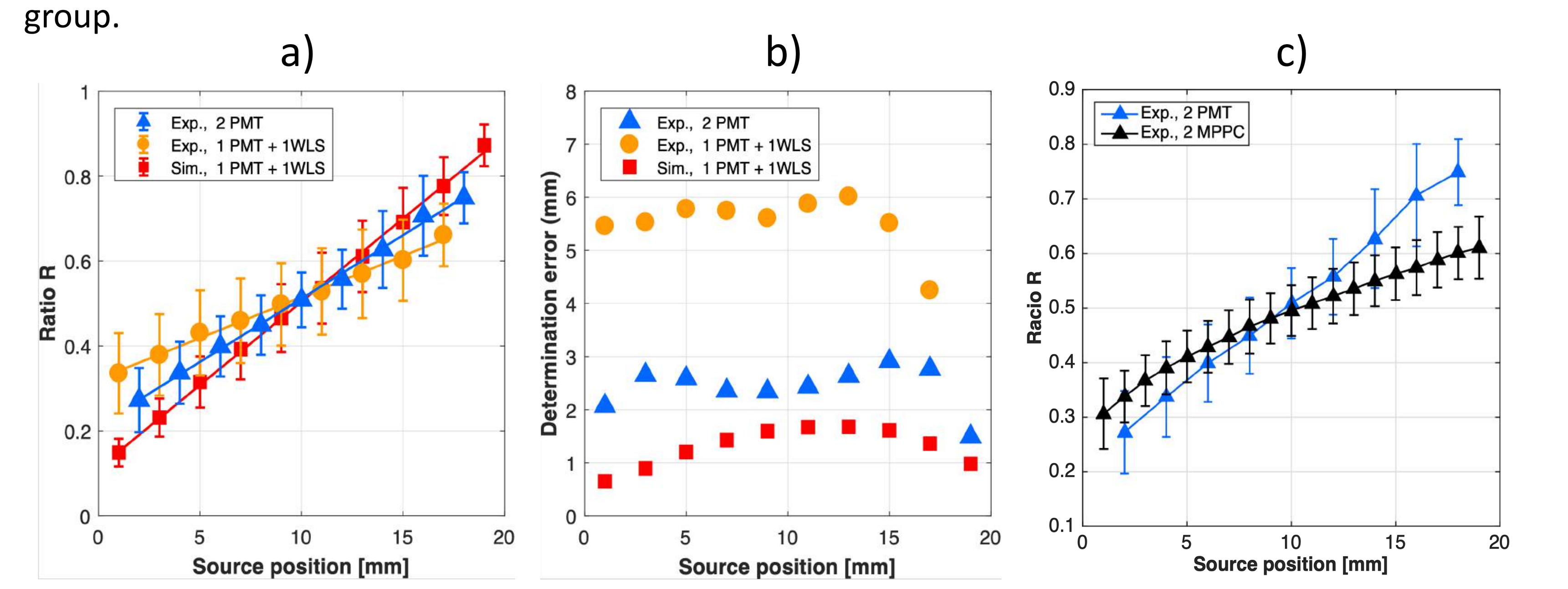

Fig 4. a) DOI ratio for different configurations, and comparison with GATE simulations. **b)** DOI determination error for the situations on the left. **c)** DOI ratio comparison for dual-ended readout method using PMTs and MPPC.

Contact:

P. M. M. Correia
pmcorreia@ua.pt

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

PORTUGAL 2020

UNIÃO EUROPEIA
Fundos Europeus Estruturais e de Investimento

COMPETE 2020
PROGRAMA OPERACIONAL COMPETITIVIDADE E INTERNACIONALIZAÇÃO

References

[1] Y. Yang et al., "A Prototype PET Scanner with DOI-Encoding Detectors", J Nucl Med, 49 (7), pp. 1132-1140, 2008.
[2] Jan, S. et al., "Gate: a simulation toolkit for pet and spect," Physics in Medicine and Biology 49(19), 4543 (2004)

Acknowledgments

P. M. M. Correia is grateful to the I3N laboratory, funded by UID/CTM/50025/2013
P. M. M. Correia is supported by the FCT (Lisbon) scholarship BD/52330/2013.
This work was partially supported by project POCI-01-0145-FEDER-016855 and PTDC/BBB-IMG/4909/2014 through COMPETE, FEDER, POCI and FCT (Lisbon) programs