Contribution ID: **215** Type: **Oral presentation**

Development of a high resolution module for PET scanners with DOI capabilities

Friday 22 September 2017 12:00 (15 minutes)

In order to ensure early stage detection of cancer, PET scanners have to achieve high performances in terms of spatial resolution and sensitivity.
An innovative PET detector module able to provide high spatial resolution was developed [1]. The high spatial resolution can be achieved thanks to a new method to extract Depth Of Interaction (DOI) information while keeping the complexity and the cost of the module low. This result is possible by means of light sharing and recirculation: the ratio between the light read by the MPPC directly coupled to the crystal hit, and the total light that hit the photodetectors array, collected using a reflector on the back side of the matrix, is correlated to the DOI information.
This method was calibrated and validated using an external tagging crystal. The procedure however is slow and infeasible on a full size detector. For this reason, an innovative calibration method was also developed [2]. This method consists in deriving a relation between the distribution of the coordinate reconstructed and the DOI, and showed a very good agreement with experimental data obtained using the tagging bench.
The possibility to improve the timing resolution taking advantage of the DOI information was investigated as well. The idea is to correct the timestamps measured by each detector in the MPPC array using the DOI information, and then combine for each scintillation event the timing information provided by the detector directly coupled to the scintillation crystal and by the surrounding detectors in order to obtain the best possible timing estimator time of interaction between the incident gamma and the crystal. This approach was preliminarily studied by means of computer simulations using the Geant4 Monte Carlo toolkit. The results are encouraging and suggest a substantial improvement in timing resolution can be achieved with this method.
This work has been performed in the frame of the Crystal Clear Collaboration and funded by the Knowledge Transfer department of CERN.

[1] M Pizzichemi, G Stringhini, T Niknejad, Z Liu, P Lecoq, S Tavernier, J Varela, M Paganoni, E Auffray, A new method for depth of interaction determination in PET detectors. 2016 Physics in Medicine and Biology, 61 (12) 4679.
[2] G Stringhini, M Pizzichemi, A Ghezzi, A Stojkovic, M Paganoni, E Auffray, Development and evaluation of a practical method to measure the Depth of Interaction function for a single side readout PET detector. 2016 JINST 11 P11014.

Has accepted

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Session Classification: Applications

Track Classification: S15_applications 3 (Orals)