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Compton Telescope Prototype Based on LaBr3-SiPM Detectors

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A Compton telescope prototype for dose monitoring in hadrontherapy is under development at IFIC Valencia within the European project ENVISION.
The detector characterization has been completed and the first imaging tests have been carried out with two detectors operated in time coincidence. The first detector consists of a 16x18x5mm LaBr3 continuous crystal coupled to a SiPM array from Hamamatsu Photonics. The array has 16 elements of 3mmx3mm size, in a 4.05x4.5mm pitch. The second detector is made of a continuous LYSO crystal coupled to a similar SiPM array. The characterization of the LaBr3 detector has shown an energy resolution of 6.5% FWHM at 511 keV. The spatial resolution is better than 1 mm FWHM, and the timing resolution is 2 ns FWHM.
Data have been taken with the two detectors in coincidence, with a Na-22 point-like source in different positions, and images have been successfully reconstructed with real data. In addition, a GEANT4 simulation allows us to predict the imaging results with this device both in optimized conditions, and in realistic conditions.

Larger detectors consisting of a 32mm x 36mm LaBr3 crystal coupled to four SiPM arrays (of the type previously tested and also monolithic) have been assembled and are being tested. Different readout systems, based on two SPIROC ASICs or on the VATAHDR ASIC are under study for this application

Optional extended abstract

A Compton telescope is an option under study to detect the prompt gammas produced in the interaction of the treatment beam with the tissue. The origin of prompt photons is correlated with the dose deposition and in turn to the Bragg peak and can so be employed to monitor dose delivery[1,2]. A Compton telescope prototype based on continuous LaBr3 crystals and SiPMs is under development within the European project ENVISION. The prototype consists of a stack of three LaBr3 detectors, each one coupled to a SiPM array structure. LaBr3 has a high Compton scattering probability and a high light yield which results in very good energy resolution and timing properties. SiPMs are compact and fast, and they allow several detectors to be stacked within the telescope, with a relatively simple assembly and operation.

The detector characterization has been completed and the first imaging tests have been carried out with two detectors operated in time coincidence. Both detectors consist of a 16mm x 18mm x 5mm crystal coupled to a SiPM array from Hamamatsu with 16 3x3mm pixel elements. The first detector is a LaBr3 crystal and the second detector is a LYSO crystal. The SPIROC1 ASIC has been employed as readout electronics[3].
The LaBr3 detector has been fully characterized. The energy resolution obtained is 6.5% FWHM applying offline gain compensation factors to the different MPPC elements, and the coincidence timing resolution is close to 2 ns FWHM, without time-walk compensation or photopeak event selection. Tests to improve the resolution by the individual adjustment of the bias voltage of each pixel in the matrix by means of an imput DAC in the ASIC are also underway.

A position determination algorithm for continuous crystals that determines the interaction position in 3D (including depth of interaction DOI information) has been applied. A spatial resolution better than 1 mm FWHM has been achieved in x or y, and the z coordinate (DOI) is successfully determined with simulated data. Tests are ongoing for the DOI determination with real data.

Two SPIROC1 boards are operated simultaneously for the coincidence tests. Coincidence data have been taken with Na-22 and Cs-137 sources. The data show the expected behaviour: the photons Compton scatter in the first detector, and are again scattered or photoabsorbed in the second detector. A dedicated image reconstruction MLEM algorithm has been developed. Images have been successfully reconstructed with real data, with the Na-22 source in different positions.
In addition, Geant4 simulations allow us to predict the imaging results in the device both in optimized conditions, and in realistic conditions.

Larger detectors that will compose the first telescope prototype are under development, consisting of a continuous crystal coupled to four MPPC arrays, with a total number of 64 detector elements. Two types of SiPM arrays are being tested to address this aim: the ones employed in the tests previously described (detector size 32mm x 36mm), and monolithic matrices recently developed by Hamamatsu with reduced gaps between the photodetector elements, which will allow us to decrease the dead area of the photodetector and thus enhance the energy resolution.

Also, different approaches for the readout of the 64-channel detectors are under study. One is the use of two SPIROC1 ASICs, each acquiring 32 channels. The second one is the use of the VATA64HDR16 (SPIDER) ASIC from GammaMedica- Ideas, with 64 channels, employing a data acquisition system developed by the group.

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[2] F. Fiedler et al. Requirements on the Instrumentation of a Prompt Gamma Measuring Device. Nuclear Science Symposium Conference Record (NSS/MIC), 2010 IEEE. 1047 - 1049 . ISBN: 978-1-4244-9106-3
[3] G. Llosá et al., First tests in the application of silicon photomultiplier arrays to dose monitoring in hadron therapy. Nucl. Instr. and Meth A. 2011, volume 648, p S96-S99.

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