Compact, MR Compatible SiPM Small Animal PET DOI Detector

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Introduction

Silicon photomultipliers are an already matured technology for the design of PET detectors. It's small size, and MR compatibility deems it as a good successor for the widely used PMT detectors. The fact that SiPMs are not susceptible to magnetic fields is what has made possible the development of PET inserts to be used on PET/MR systems.

One of the disadvantages of SiPMs when comparing them to PMTs is the pixel density, this means that for the same scintillator volume we will have more output channels than with PMTs, so there is a need for a high level of multiplexing. Previous studies, done at our group and at many others, have proven that it is feasible to use analog multiplexing to tackle this problem. One more issue with SiPMs is the negative effects that interconnecting several pixels using charge distribution networks have on the detector resolution.

The detector proposed in this work uses a multiplexing scheme that allow us to go from 64 channel outputs to only four analog outputs, minimizing the effect the interconnection have on detector resolution.

Materials

Crystals: We used a 16x16 matrix of 1.3x1.3x12mm^3 LYSO crystals with all faces chemically etched, using 0.1 mm thick Lumirror film as intercrystal reflector. The entry face of the matrix is also covered with the same reflector.

The matrix is larger than the active area of the SiPMs, the non-used matrix region is optically shielded with an opaque tape. The crystal matrix is coupled using a refraction index matching optical silicon. The matrix was illuminated with a ^{22}Na point source placed at the center of the detector, at 50 mm of distance.

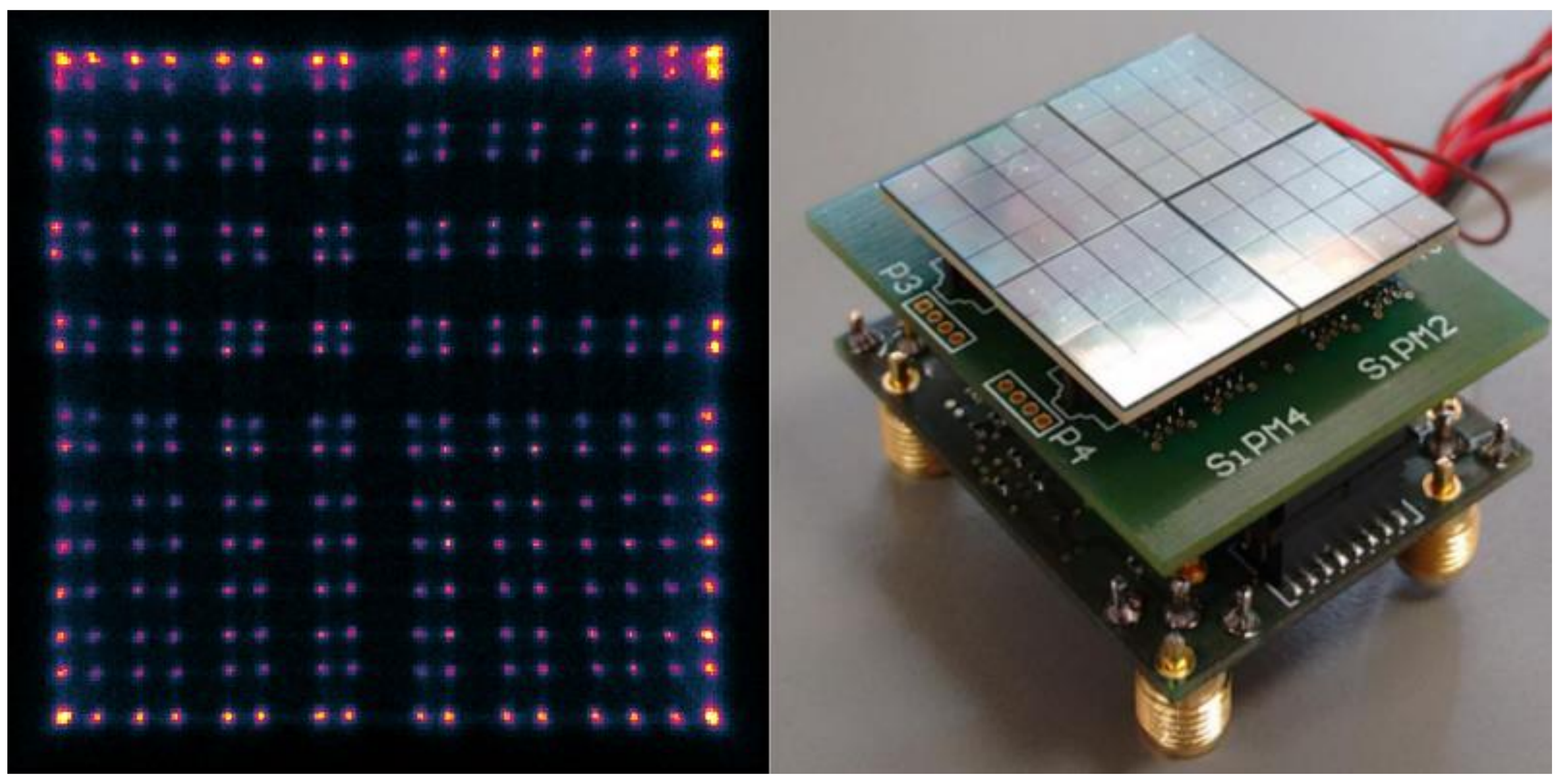


Fig. 1 Acquired image (without offset correction) and detector configuration used.

SiPM Detector Array: Four Hamamatsu S12642-0404PB SiPM detector arrays were tiled forming a 2x2 matrix. Each detector has a matrix of 4x4 channels, 3x3 mm^2 each.

The same bias voltage has been used for all the channels in the detector. These detectors are MR-compatible and have proven to be quite stable with temperature in our workbench, so no temperature compensation have been used in these tests, however the detector electronics include a temperature compensation circuit.

Results

Crystal Identification: In order to measure the ability of this system to identify the individual crystals. we used the Resolvability Index RI = FWHM/D, where D is the distance between crystals. Figure 2 shows profiles that are used to measure the RI. This resulted in a RI of 0.25. The worst RI value was 0.6, obtained for the top, this is due to the fact the matrix used was larger that the detector.

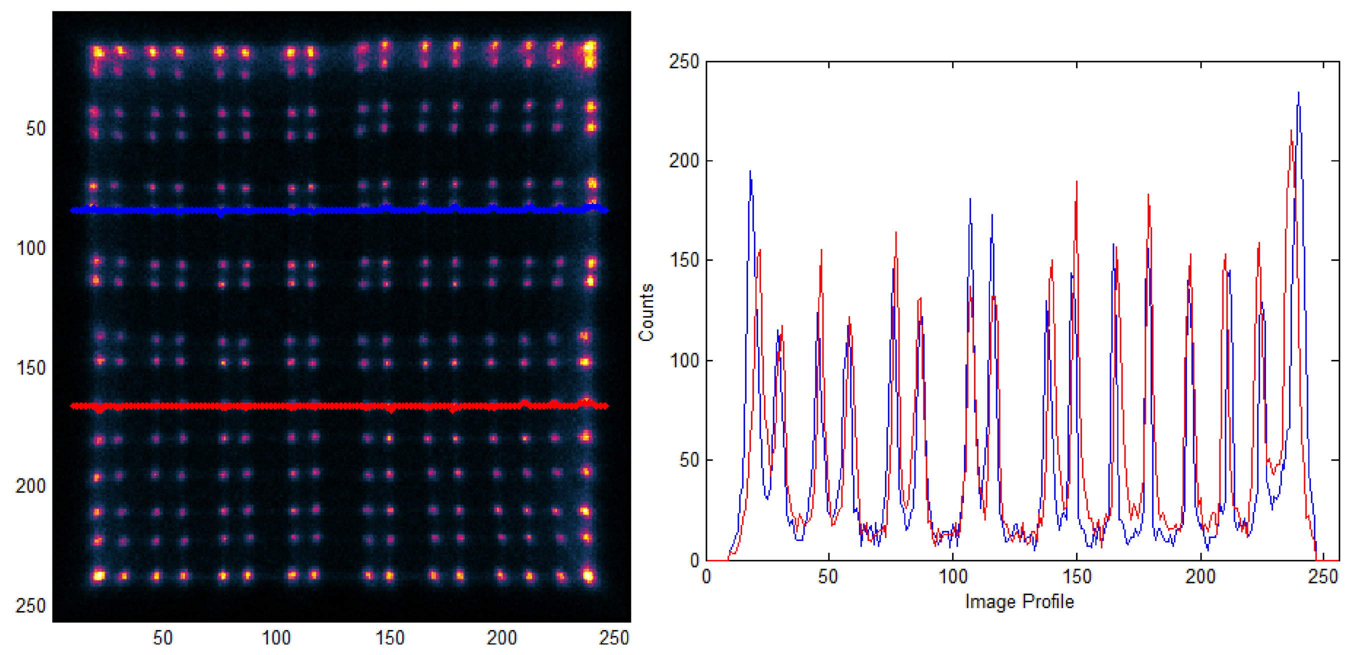
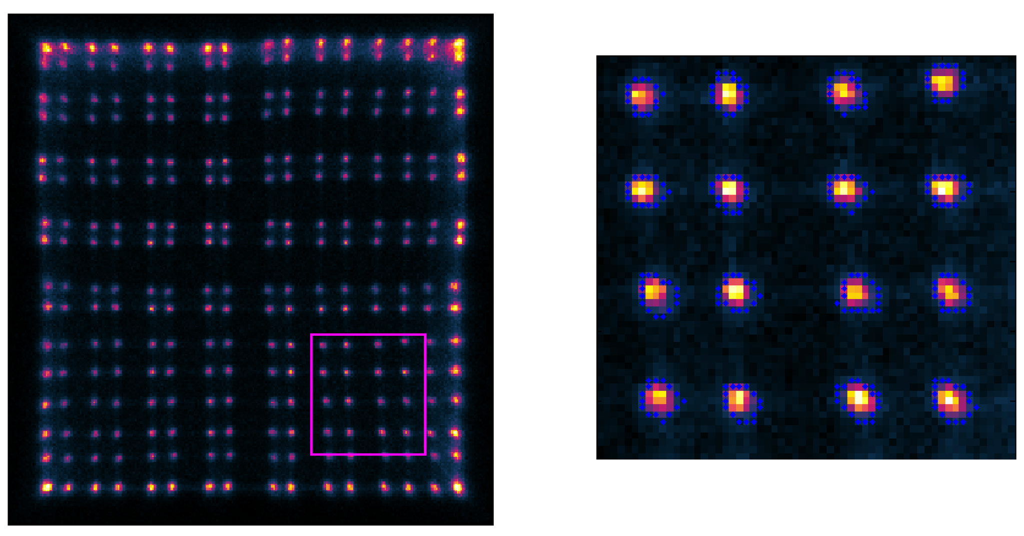


Fig. 2 Detector image and pixel profiles



Energy Resolution: The energy spectra for each pixel was acquired. The mean FWHM for the 511keV photopeak obtained was 13.7%(figure 3). The spectrum corresponds to the active pixel area, depicted in blue on the figure.

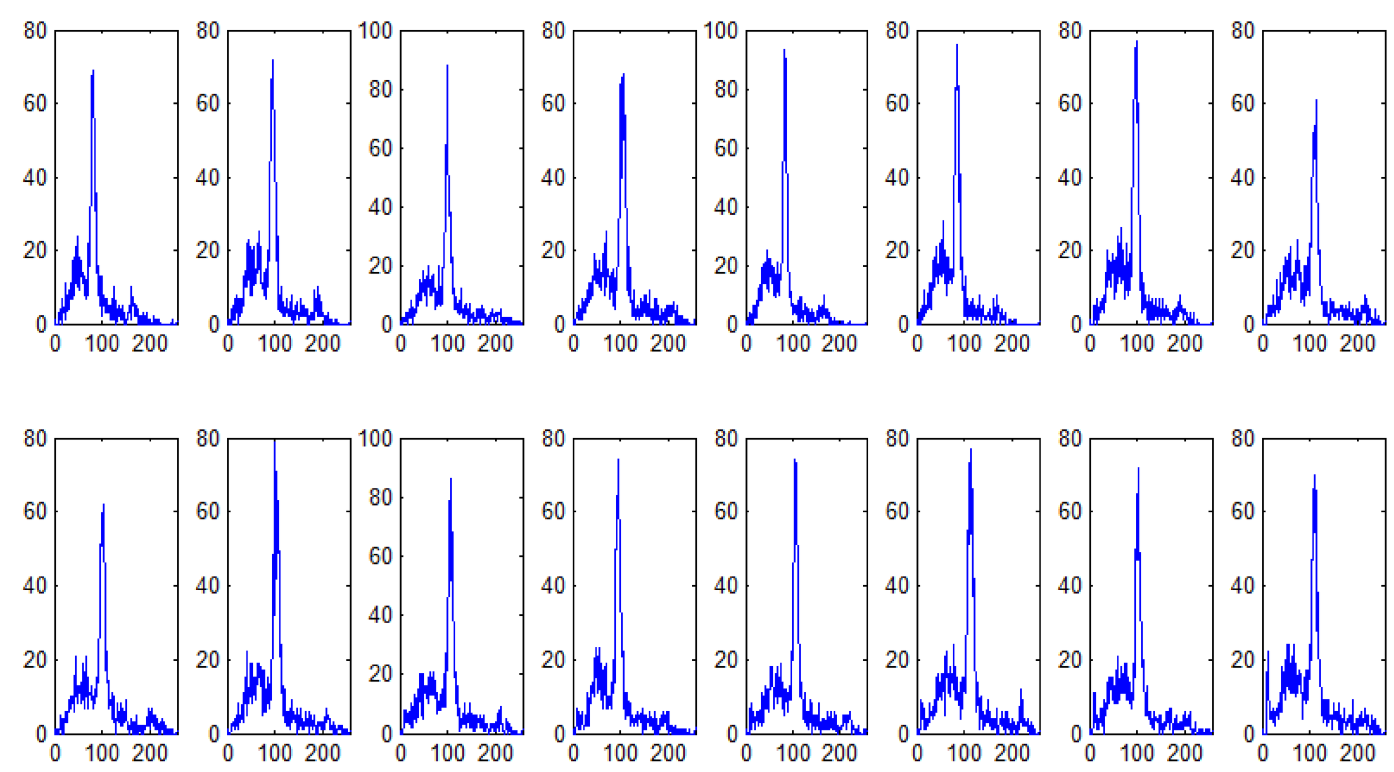


Fig. 3 Detector energy resolution measured on 16 pixels.

Depth of interaction: We assessed the ability of SiPM detectors to measure DOI by using a GSO/LYSO phoswich, using the delayed charge integration method. Results (figure 4) show that the two different crystals can be clearly separated.

However, further experiments are required to verify that this separation is equal or better for other crystal combinations (GSO/LYSO) that were used in our PS-PMT detector modules.

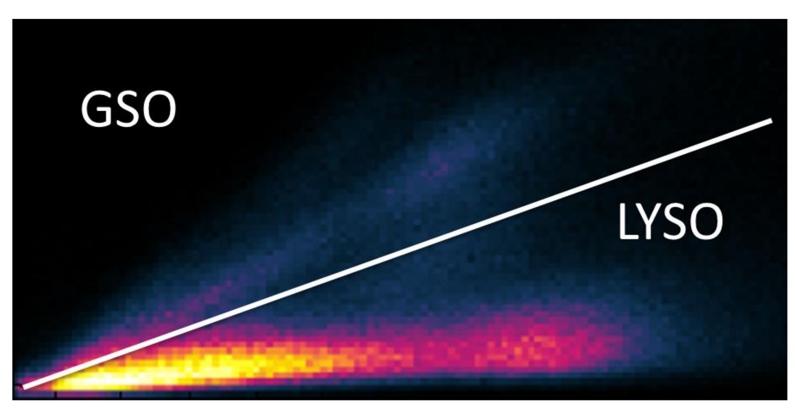


Fig. 4 Phoswich separation image. Axis are total energy (X) and delayed energy (Y)

Discussion and Conclusions

The performance of this compact detector that uses four SiPM arrays has proven to be equal or even better that those based on PS-PMT previously reported in terms of spatial, energy, and DOI. Timing resolution have been measured to be below 1ns, without using a dedicated timing output.

These results suggest that smaller crystal sizes could be resolved using this detector, thus increasing the overall resolution of the system.

We also verified that the DOI characteristics of this assembly are comparable or even better than those measured in high quality detectors based on PS-PMTs.

Next steps include the characterization of this individual detectors inside the MR gantry and the implementation of a detector ring that will go inside the MR bore.

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