Reduced parallel anode readout for 256 ch
Flat Panel PMT

Pani R. Member IEEE, M.N.Cinti Member IEEE, R.Pellegrini. M.Betti, P.Bennati Member IEEE, G.Trotta and A.Del Guerra Member IEEE

Abstract-- SPECT and PET need a good pixel identification to obtain high quality images. This is why new generations of PSPMT with anode array with smaller step have been developed till the recent Flat Panel PMT H9500 with 2" square area, 256 anodes array, 3 mm individual pitch. The realization of electronic chains with so high number channels demands dedicated electronics readout with high cost and high management difficulty. In this work we propose a new method of anode number reduction in parallel readout limiting the total chain number to 64. Starting from the evidence that event charge distribution is always contained inside a portion of the FP PMT anodic plane, we assume that only a quarter of the anodes are involved in the detection. Our approach consists on virtually dividing 16x16 anodes in 4 arrays with 64 anodes per each. Once the charge distribution is collected by the 4 anodic planes, each individual anodic charge is projected on one plane. Physically, each i,j element of one quadrant is associated to the corresponding i,j-element of the other three matrices. In terms of hardware, it is simply realized connecting one to each other the set of four i,j-anodes of the 4 quadrants. In this work an image reconstruction software has been developed and tested by measured charge distribution collected by 256 anodes Hamamatsu FP PMT. The final results, in term of spatial resolution and position linearity, are in agreement with ones collected by the total number of anodes.

I. INTRODUCTION

In the last years the requirements tied to single photon imaging, and in particular to that one dedicated to the small animals, have driven towards the research of technologies able to enhance image contrast values, to detect smaller and smaller image details. In such picture, the development of detectors with high spatial resolution, obtained through a sampling of narrow light distribution as produced by scintillation array with pixel size as small as 1 mm. For SPECT and PET applications, a good pixel identification can improve the imaging performances of the detectors. So a new generation of PSPMT with smaller step anode array have been developed till the most recent Flat Panel PMT H9500 with 2 inch square area and 256 anodes matrix, 3 mm individual pitch. Such tube is under investigation from several groups for different application in PET [1,2] or Compton telescope. For this PSPMT some authors have developed electronic readout based on resistive chains, reducing the channel number, while others authors have proposed 64 parallel channels, in order to observe aspects of gamma ray interaction in crystal event by event [3,4]. In any case, the development of parallel electronic chains with so high number of channels demands dedicated electronic readout with high cost and high management difficulty. In this work we propose a new method to reduce the total chain number from 256 to 64, for a parallel electronics readout. This approach could be also applied in multiple camera detector (2x2 PSPMT array) based on PSPMTs with 8x8 anodic plane.

II. MATERIALS AND METHODS

The Flat Panel Hamamatsu H9500 PSPMT has large sensitive area (49.0 mm x 49.0 mm) and a 16 x 16 multi anode matrix with 3.02 mm pitch. The small anode pitch can sample light distributions in case of short distance between two interaction points and the large sensitive area observes uniformly the spread of scintillation light.

The multi anodic readout system consists of 64 indipendent chains of preamplifiers, sample and hold and a multiplexer [5]. This system is connected to a ADC AT-MIO 6110 card of National Instruments. In Figure 1 we show a sketch of the electronic parallel readout.

Fig. 1. Sketch of electronics readout with 256 to 64 channel logic

The channels reduction logic is based on the experimental evidence that charge distribution of an scintillation event is always contained inside a portion of the Flat Panel PMT anodic plane; so we can assume that only a quarter of the anodes are involved in the detection. Our approach consists of
a virtually division in 4 arrays, with 64 anodes each, of 16x16 anodic plane. Physically, each i,j-element of one quadrant is associated to the corresponding i,j-element of the other three quadrants (see Figure 2).

In terms of hardware, it is simply realized connecting one to each other the set of four i,j-anodes of the all quadrants.

In Figure 3 a picture of the hardware connections is shown; the system presents four connectors, 16 signals each, to be connected to the 64 channel parallel readout, the 12 dynode signal, used by the electronic readout like trigger signal, and the HV connector, to supply the PSPMT.

Once the charge distribution is collected by the four anodic planes, each individual anodic charge is projected on a single plane with 8x8 anodes. To better explain the method, in figure 4 two examples of re-allocation of a single anode charge on the reduced 8x8 anodic plane are represented, where we assume a distribution of the total event charge on a 3x3 anodic area.

With this procedure we lose the information about the original quadrant where the event is occurred. So in order to correctly allocate the reconstructed charge distribution, in addition we introduced four quadrant pointer signals, obtained connecting three anodes for each quadrant, like is shown in figure 5.

In order to recover the information coming from anodes associated to the ones involved in the quadrant pointer, we generated twelve signals (terms) obtained from the total charge of the corresponding three anodes in the other quadrants. In Figure 6 we show an example of connection for one of these twelve terms. In this way we can reconstruct a new quatern signal combining the term and the quadrant pointer signal.

Due to the limitation to 64 channel readout, we need to disconnect four anodes for each quadrant, opportunely selected in the peripheral zone (see Figure 7).

In this work an image reconstruction software has been developed to decode and to reconstruct the original charge distribution involving 256 anodes. The decoding tests was performed on measured charge distribution, ranging from 4 mm to 10 mm FWHM, obtained by three different detector: a pixelled NaI(Tl) crystal, 2 mm pitch - 2 inch size, and a pixelled CsI(Tl) crystal, 2 mm pitch – 1 inch size, separately.
coupled to an H9500 Hamamatsu Panel PSPMT and a NaI(Tl) planar crystal, 1.5 mm thick-2 inch size, integral assembled with a H9500 Hamamatsu Flat Panel PSPMT; a similar detector with H8500 Hamamatsu Flat Panel is described in [6].

The analysis carried out in this work consists of the verification of distortions in the image reconstruction.

III. RESULTS

In Figure 8 examples of charge distribution reconstruction are shown, coming from three spot irradiations, by 2 mm collimated Co\textsuperscript{57} source, of the NaI(Tl) integral line detector: on the left, the original distribution; on the center, the projection on the reduced anodic plane and on the right the final reconstruction. The Figure 8a) represents a charge distribution coming from an event occurred in the center of the detector; in this case, the projected charge on the 8x8 plane presents a distribution with four tails on the each corner. In Figure 8b) the charge distribution of an event occurred in the peripheral zone of the detector is analyzed and finally in Figure 8c) an event impinging in the center of a quadrant is shown. The software, combining the information about the maximum anodic charge position and the quadrant pointer signal, seems to reconstruct correctly the original charge distribution for each analyzed case.

To test the decoding algorithm on different charge distribution, we utilized pixellated scintillator crystals coupled to the H9500 PSPMT. In Figure 9 the images of four spots in the central zone, of the 1 inch CsI(Tl) crystal are shown (2 mm Co\textsuperscript{57} collimated source). We utilized this scintillator to evaluate the algorithm performances on the central zone of the detector because it presents a small charge distribution (4 mm FWHM). The obtained result shows a reconstruction error is present in the central zone of the tube, where along a diagonal direction the two spots are not separated.

We utilized the 2 inch pixellated NaI(Tl) scintillator coupled to the H9500 PSPMT, to analyze the performances of the decoding algorithm in the central zone of each quadrant and in presence of larger charge distribution (8 mm FWHM). In Figure 10 the overlapped images of four spot irradiations (2 mm Co\textsuperscript{57} collimated source) in center of each quadrant is shown. In this case the algorithm reconstructs well the charge distributions.

To evaluate the possible reconstruction errors for the events occurred along one size of the detector, we applied the algorithm on a complete scanning (2 mm collimated Co\textsuperscript{57} source) of the central zone of two quadrants of the NaI(Tl) integral assembled detector. The original charge distribution for each position (Figure 11a) and the corresponding reconstructed charge distribution (Figure 11b) are shown. The figure shows the effectiveness of reconstruction method, demonstrating how the spatial resolution seems little affected by the proposed method of readout channels reduction.

IV. CONCLUSIONS AND FUTURE APPLICATIONS

The proposed method was tested on charge distribution ranging from 4 mm to 10 mm FWHM. For all distributions taken into account, the reconstruction algorithm carried out the same position response of the original 256 channel image.

The reconstruction method seems to be able to reallocate correctly the events in the interaction position in the major detection area and so the spatial resolution of the reconstructed image results invariate respect to original ones.

The critical area for the reconstruction is individuated in a 6x6 anodes array in the center of the tube, where the reduced charge distribution consists of four charge tails on the corresponding corners of the 8x8 quadrant (see figure 8a). Probably in this case the quadrant pointers doesn’t help the algorithm to individuate the original interaction quadrant and the algorithm doesn’t reconstruct well the original distribution.

Finally the idea of anodes reduction seems to be realistic from hardware and software point of view. We are working on the implementation of an new algorithm to well reconstruct the position events in the central area of the tube.

About future applications, we individuate a good possibility to apply the 256 to 64 reduction channel logic readout to make a 64 channel parallel readout for a 2x2 H8500 PSPMT array detector, like is shown in figure 12. In this case for quadrant pointer signals we can utilize the 12 dynode signals of each photomultipliers so the physical connections result simplified.

![Fig. 6. Sketch of the connection for a single tern.](image6.png)

![Fig. 7. Sketch of disconnected anodes](image7.png)
Fig. 8. Three examples of charge distribution reconstruction: on the left the original distribution on 16x16 anodic plane; on the center, the projection on the reduced 8x8 anodic plane and on the right, the final reconstruction on 16x16 anodic array. The different charge distributions are obtained by an event occurred in: a) the center of the detector; b) the peripheral zone and c) the center of one quadrant. Detector: NaI(Tl) integral line detector. Source: 1 mm Co$^{57}$ spot source.

Fig. 9. Images of four spots (2 mm Co$^{57}$ collimated source) in center of a pixelated CsI(Tl), 1 inch side, 1.9 mm pixel size coupled to H9500 PSPMT. On the left: experimental setting. On the right up, the overlapped zoomed image of two spots in one diagonal direction, on the right down, the same one for the other diagonal direction.
Fig. 10. Images of four spot irradiations (2mm Co$^{57}$ collimated source) in center of each quadrant for a pixellated NaI(Tl), 2 inch side, 2 mm pitch coupled to H9500 PSPMT. On the left: experimental setting. On the right up, the overlapped images of overall spots.

Fig. 11. Complete scanning between two quadrants of the NaI(Tl) integral assembled detector by 2 mm collimated Co57 source. a) The original charge distribution for each position and b) the corresponding reconstructed charge distribution.

Figure 12: 256 to 64 reduction channel logic readout applied on a 2x2 H8500 Hamamatsu PSPMT array.

V ACKNOWLEDGMENT

We would like to thank Dr. Stan Majewski for providing us with the NaI(Tl)+H9500 Hamamatsu PSPMT Integral assembled detector.

We greatly appreciated the faithful collaboration of Dr. F. Borgonovo

REFERENCES


