Abstract—A simulation study has been conducted for a PET detector design. The detector unit consists of 24x24 array of pixelated LSO, each pixel with 4x4x25mm³, and two large area microchannel plate(MCP) PMT, 102x102mm², coupled to both side of scintillator. The crystal pitch was 4.25mm and reflective media was inserted between crystals. The optical photon inside scintillator was simulated using Geant4 package and the electrical signal of MCP was formed using the measured characteristics of MCP and Geant4 output. The signals from MCP were readout using the transmission line(TL) scheme. The readout scheme at both side of scintillator enable us to extract the depth of interaction in addition to energy and timing in an event. The detector response was measured by impinging the pair of 511keV gamma upon the detector. As preliminary results, we obtained ~12% (FWHM) of energy resolution at 511keV and ~375ps(FWHM) coincidence timing resolution while keeping 36% detection efficiency at 511keV. The position resolution was measured ~4.25mm, which is the pitch between LSO pixels. We found that the energy asymmetry and time difference from both side MCPs can be exploited for depth of interaction by observing strong correlation between them. The fast timing characteristics of MCP combined with the high sensitivity of LSO makes this design suitable for TOF PET application.

I. INTRODUCTION

The microchannel plate(MCP) photomultiplier tube(PMT) [1] is a promising photodetector for PET application because of its position sensitiveness, fast time response and relatively compact size to conventional PMT. We investigated a PET detector design: LSO crystal coupled with MCP PET for photodetector. The high sensitivity of LSO, and fast timing characteristics of MCP would also enable this design suitable for TOF PET application [2]. Transmission line(TL) readout scheme [3] was used to measure signal from the MCP PMT. One TL strip collects the signal from a row(column) of scintillator pixels. Energy, position and timing informations can be extracted in TL readout scheme while keeping the number of readout channels relatively smaller than fully pixelated readout. TL readout scheme would be the efficient way for the large area coverage. The extensive research efforts on the large area MCP PMT development would eventually make it possible to reduce the costs for the production.

We have conducted Geant4 [4] based simulation works to prove the design concept. Simulation of electrical signals at TL was also made using the Geant4 outputs on optical photons inside LSO scintillator. Simulation setup and results are presented.

II. MATERIALS AND METHODS

A. Configuration

LSO was chosen for the scintillator because its high light yield(26,000/MeV) and fast decay time(~40ns). Each LSO pixel has dimension of 4mmx4mmx25mm and crystal pitch is 4.25mm. One detector module consists of 24x24 array of LSO pixels and two MCP assemblies which are coupled from both front and back of scintillator array. The detector configuration is depicted in Figure 1. The pair of 511keV gamma were generated with back to back at middle of two detector modules and sent to the center of each detector. The data set along the X axis were also generated to study the detector response uniformity. The optical photon’s generation, transport and detection through the media were handled using Geant4 simulation package.

Figure 2 shows a 2 inch Photonis Planacon MCP(XP85022) [5] and transmission board, which were used as models for the simulation. In simulation, transmission line structure was embedded inside MCP assembly as well as photocathode and microchannel plate structure. The overall dimension of MCP in simulation was 102x102x9.15mm³. The material effect due to front MCP on 511keV was turned out negligible by inserting a MCP unit in a separate real coincidence setup.

Figure 1. Simulation setup with two detector modules. Each module consist of 24x24 array of pixelated LSO scintillators and two MCPs coupled to the scintillators at both front and back side.

Figure 2. Photonis Planacon MCP(XP85022) with 1024(32x32) anodes(left) and Transmission line(TL) board with 32 microstrip(right). One microstrip is connected to one raw of MCP and signals are readout at both ends of a TL.

B. Simulation of electrical signal

The electrical signal was formed based on the measured XP85022 characteristics combining with the Geant4 simulation results: the optical photon’s position and arrival time at photocathodes. Once the optical photon reaches at photocathode, photo electron comes out depending on the quantum efficiency photocathode, which is 22% at 350nm for XP85022. To each individual photo electron, an asymmetric Gaussian shaped pulse(with ~500ps rise time) was
assigned, which was based on the measured MCP shape. The overall gain of MCP was assumed $10^6$ and $\sigma = 50$ps of MCP transit time spread was taken into account for timing simulation.

C. Readout scheme

Electrical signal for each TL was formed by summing pulses due to all the photoelectron within the area of TL strip. The signal formed in a TL then propagates to both ends of TL for energy and timing measurements. In the front MCP, all the TLs run vertically with 4.25mm pitch between adjacent TLs. By applying Anger logic to measured TL signals, a coordinate (along X axis) in horizontal direction can be reconstructed. In the backward MCP, TLs were rotated 90° with respect to TL in the front MCP. Therefore, the Y coordinate of the interaction could be obtained from this configuration. It was also possible to infer the position independently by measuring time difference at both ends of a TL.

III. RESULTS

A. Energy

Figure 3 shows the energy distribution of 511keV gamma. For energy reconstruction, the maximum signal TL was searched first in an event and then charges of 5 TLs were summed with the maximum energy TL at the center. 12.0%(FWHM) of energy resolution was measured at 511keV with Gaussian fit.

B. Timing

The event time was extracted by applying the leading edge pick-up with 10mV threshold to the maximum TL signals. The event time difference from up and down stream module is shown in Figure 4 and 375ps(FWHM) coincidence timing resolution while keeping 36% detection efficiency at 511keV. The position resolution was measured ∼4.25mm, which is the pitch between LSO pixels. We found that the energy asymmetry and time difference from both side MCPs can be exploited for depth of interaction by observing strong correlation between them. The fast timing characteristics of MCP combined with the high sensitivity of LSO makes this design suitable for TOF PET application.

The results shown here were obtained assuming the charge sensitive ADC and TDC with the leading edge in TL signal digitization. The full waveform sampling would be a possible option for the signal digitization, which is expected to give improved energy and timing performances [7]. The readout at both front and back MCPs enables to exploit several features for depth of interaction. In addition to energy asymmetry and time difference as shown, the differences in light spread can be also utilized.

IV. DISCUSSION AND SUMMARY

As preliminary results, we obtained ∼12%(FWHM) of energy resolution at 511keV and ∼375ps(FWHM) coincidence timing resolution while keeping 36% detection efficiency at 511keV. The position resolution was measured ∼4.25mm, which is the pitch between LSO pixels. We found that the energy asymmetry and time difference from both side MCPs can be exploited for depth of interaction by observing strong correlation between them. The fast timing characteristics of MCP combined with the high sensitivity of LSO makes this design suitable for TOF PET application.

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REFERENCES