Feasility study on the discrimination of fluor-concentration in the liquid scintillator using PMT waveform and short-pass filter

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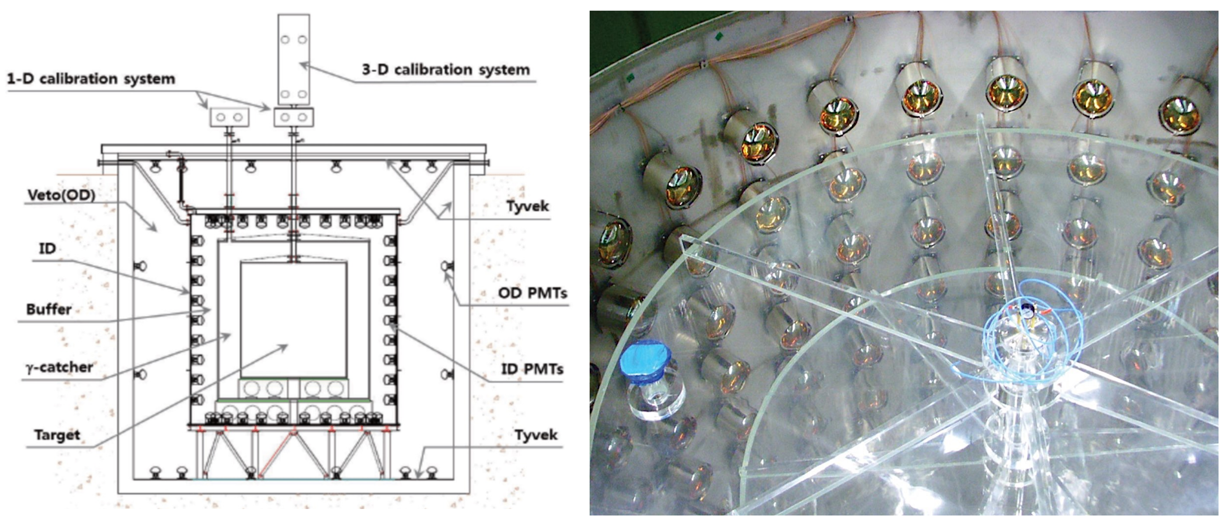
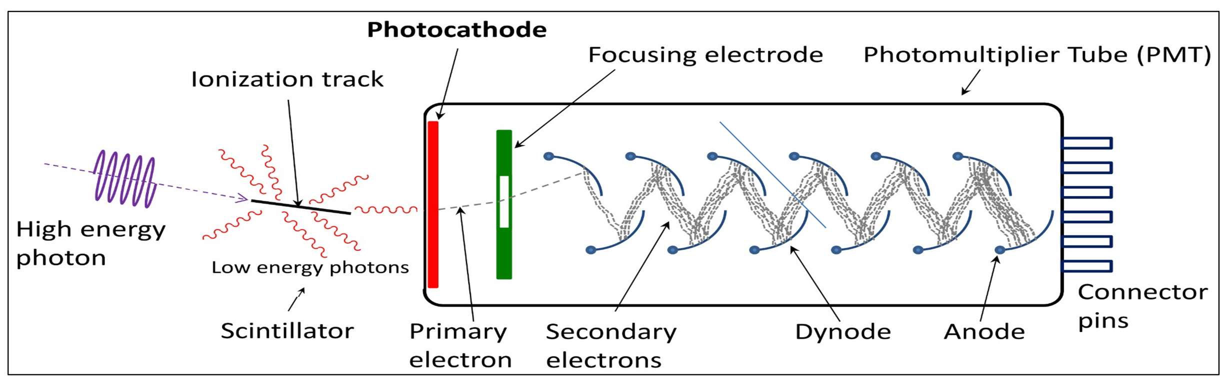
Abstract

Neutrinos are difficult to detect because they weakly interact with matter, making their properties least known. The response of the neutrino detector depends on the optical properties of the liquid scintillator (LS). Monitoring any characteristic changes in the LS helps to understand the temporal variation of detector response. In this study, a detector filled with LS was used to study the characteristics of the neutrinos detector. We investigated a method to distinguish the concentrations of PPO and bis-MSB, which are fluor added to LS, through a photomultiplier tube (PMT) acting as an optical sensor. Conventionally, it is very challenging to discriminate the flour concentration dissolved in LS. We employed the information of pulse shape and PMT coupled with the short-pass filter. To date, no literature report on a measurement using such an experimental setup has been published. As the concentration of PPO was increased, changes in the pulse shape were observed. In addition, as the concentration of bis-MSB was increased, a decrease in the light yield was observed in the PMT equipped with the short-pass filter. This result suggests the feasibility of real-time monitoring of LS properties, which are correlated with the fluor concentration, using a PMT without extracting the LS samples from the detector during the data acquisition process.

Introduction



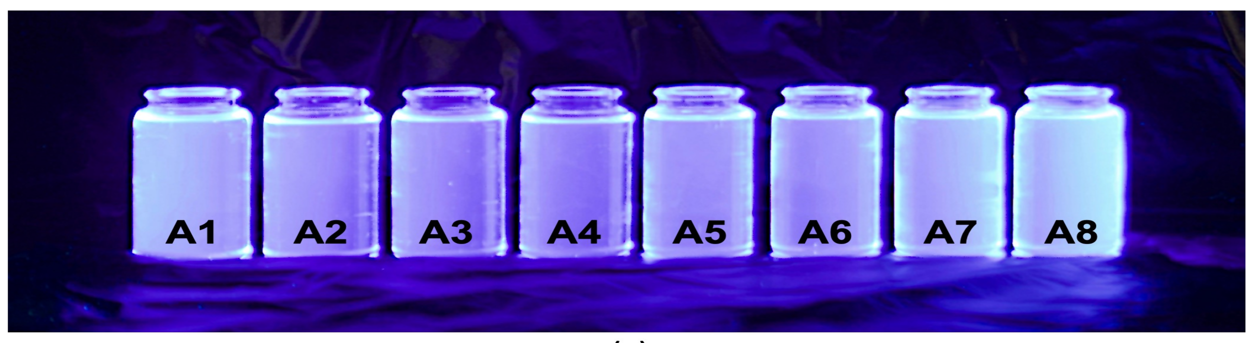
Detector which using a LAB based liquid scintillator : (left) Schematic diagram of RENO neutrino detector. The detector consist with number of cylindrical vessol and PMT which used as a photon sector (right) The number of PMT are attached in the barrel of the detector .



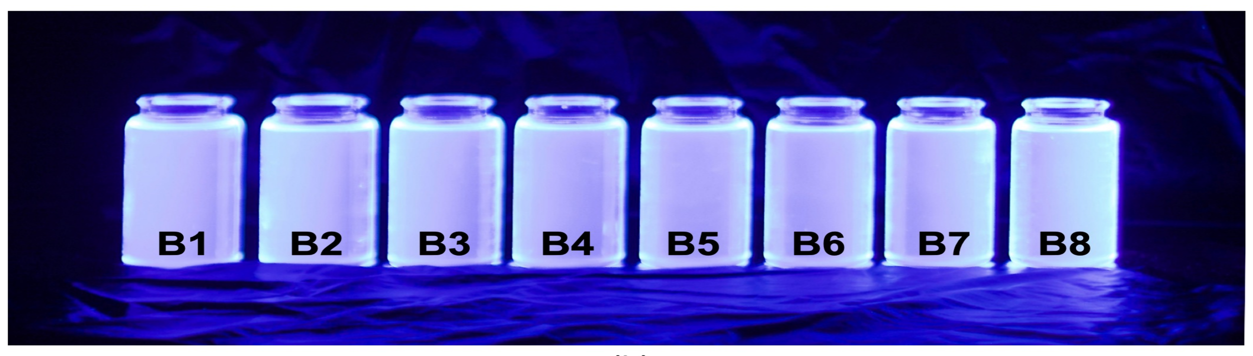
A scintillation events observed by PMT : The scintillation photons yielded from the LS converted into photoelectrons and multiplied in the photomultiplier. The multipliced electron are discharged at anode and observed as a waveform.

In this study, we present a method to distinguish the concentration of the fluor dissolved in the LS in real-time using the signal obtained by the photomultiplier tube (PMT) used as the sensor of the detector. We utilized the waveform information of the PMT affected by the decay time of the LS and adopted a short-pass filter to the PMT to discriminate the change in the emission spectrum of the LS.

Liquid scintillator(LS) samples

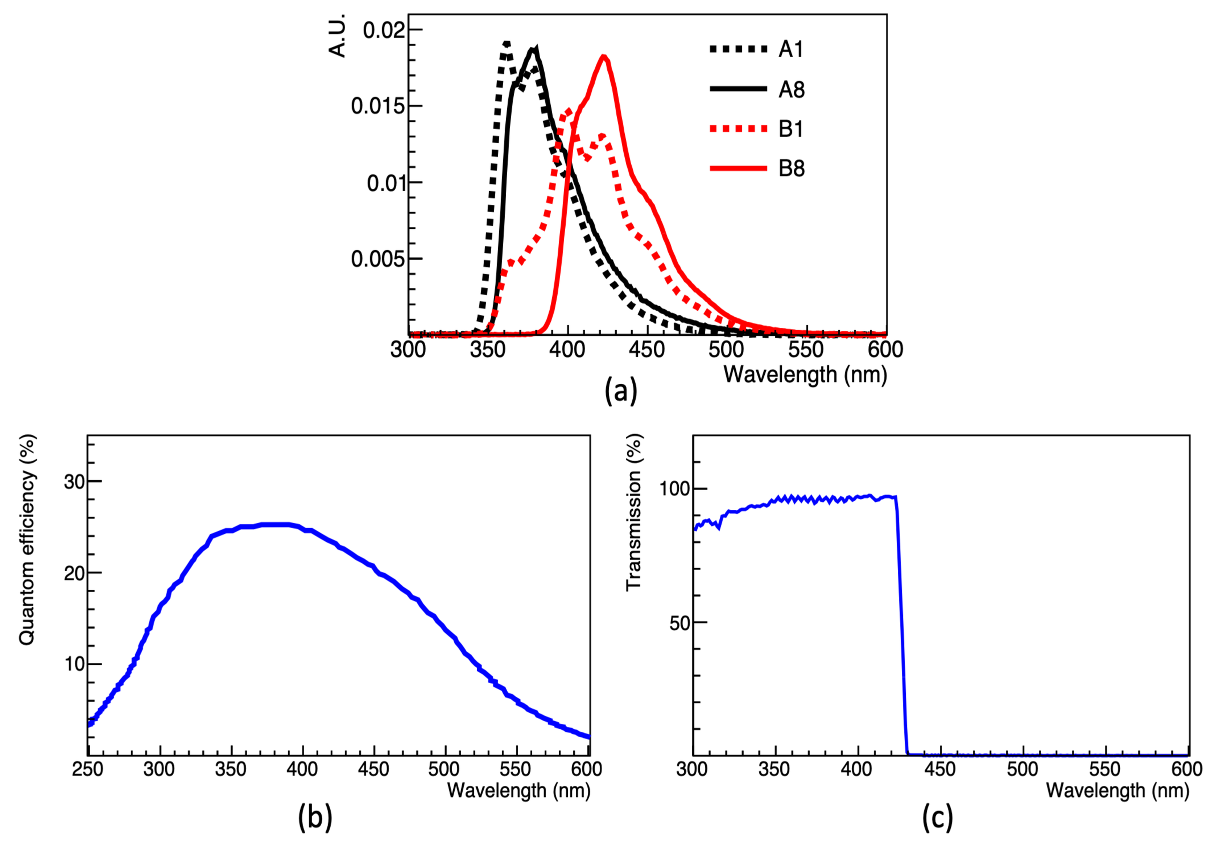


(a)



(b)

Scintillation light emitted from LS samples using UV light:
(a) Eight samples made with different PPO concentration. The sample A1 to A8 aligned from the left; (b) 8 samples made with different concentrations of bis-MSB. The PPO concentration is kept constant at 3 g/L. The sample B1 to B8 has been aligned from the left.



(a) Emission spectra of LS samples with different PPO and bis-MSB concentration. **(Black lines)** The PPO is 0.5 g/L(A1) or 10 g/L(A8). **(Red lines)** The PPO is 3 g/L and the bis-MSB is 1 mg/L(B1) or 50 mg/L(B8); (b) Photon detection efficiency of H7195 PMT according to wavelength. (c) Transmission of short-pass-filter as a function of wavelength.

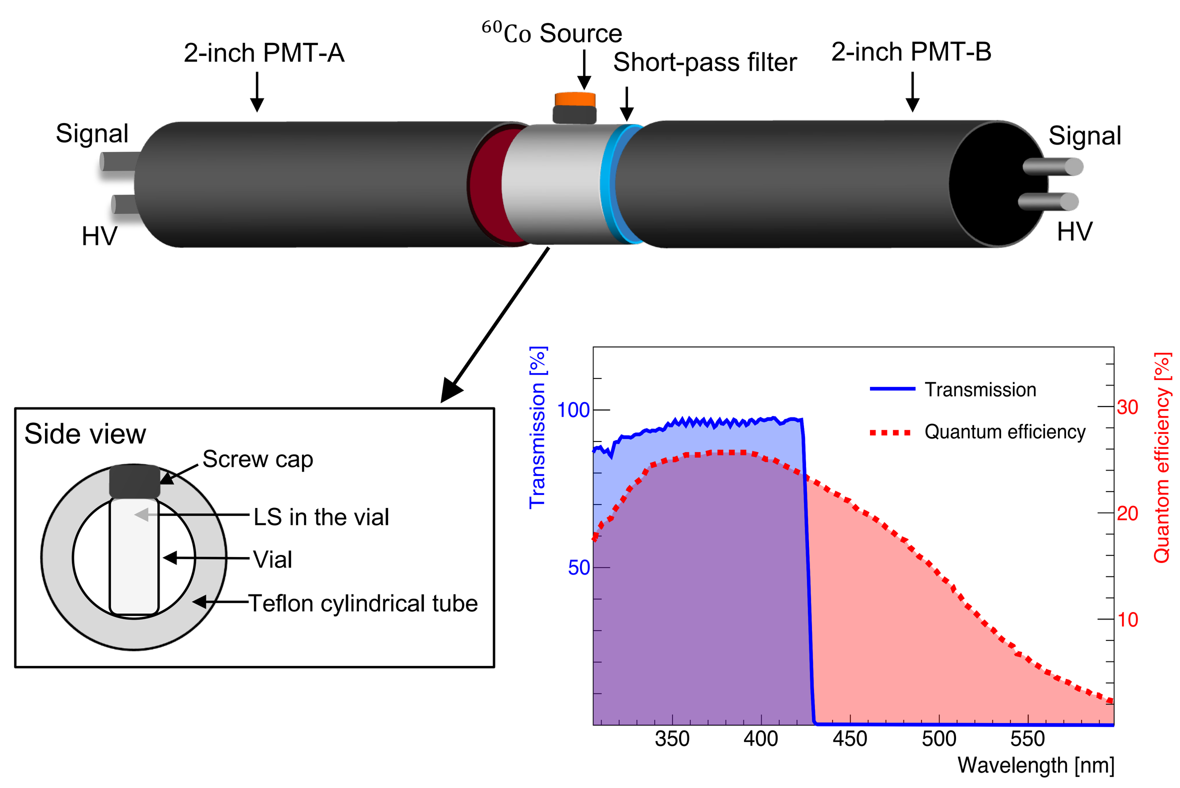
LS samples with different PPO concentrations.
The concentration of PPO varied from 0.5 g/L to 10 g/L. The bis-MSB was not dissolved in the samples.

Sample	PPO concentration (g/L)
A1	0.5
A2	1
A3	1.5
A4	2
A5	3
A6	4
A7	7
A8	10

LS with different PPO and bis-MSB concentration.
The concentration of PPO fixed with 3g/L and the concentration of bis-MSB varied from 1 mg/L to 50 mg/L.

Sample	PPO concentration (g/L)	bis-MSB concentration (mg/L)
B1	3	1
B2	3	2
B3	3	3
B4	3	5
B5	3	10
B6	3	15
B7	3	30
B8	3	50

Experimental setup

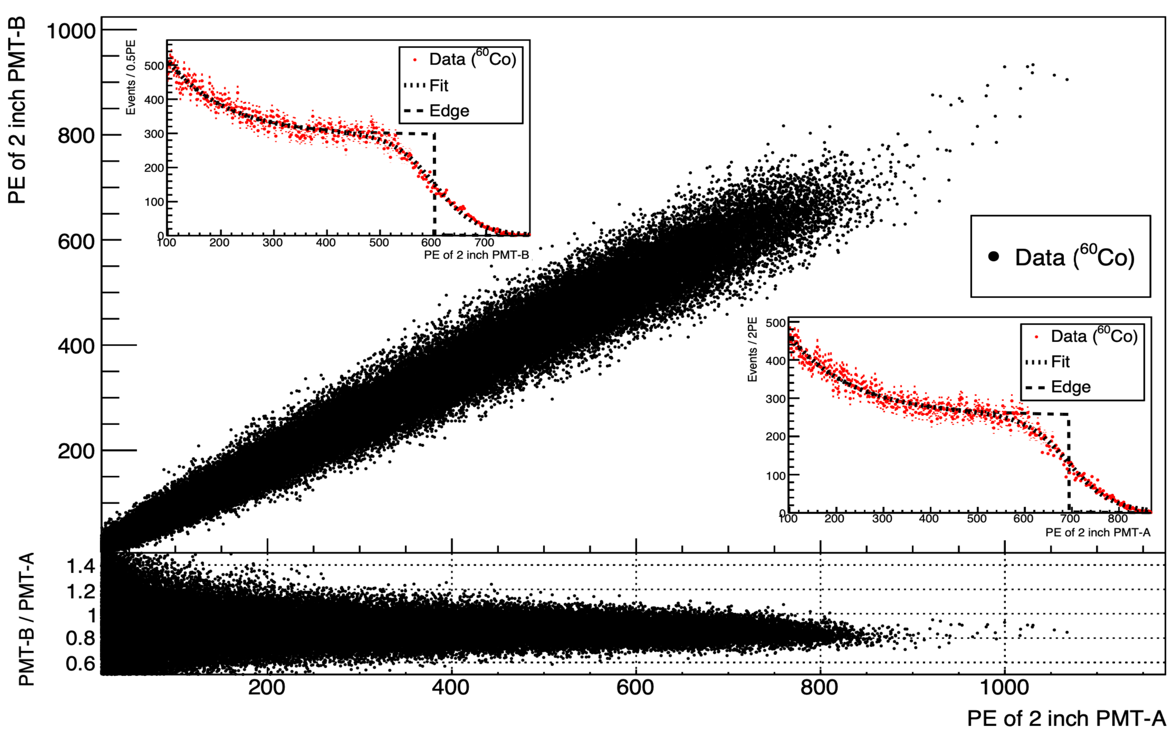


Schematic setup for the scintillation response measurement: The LS contained in the vial emits scintillation light due to the Compton scattering of the gamma ray emitted by 60Co. A short-pass filter is fitted at PMT-B to discriminate the wavelength shift of the scintillation lights. The transmittance (or quantum efficiency) of the filter is shown as a blue solid line, while that of the PMT is represented by a red dotted line.

The details for the filters used for the 425 nm Short-pass

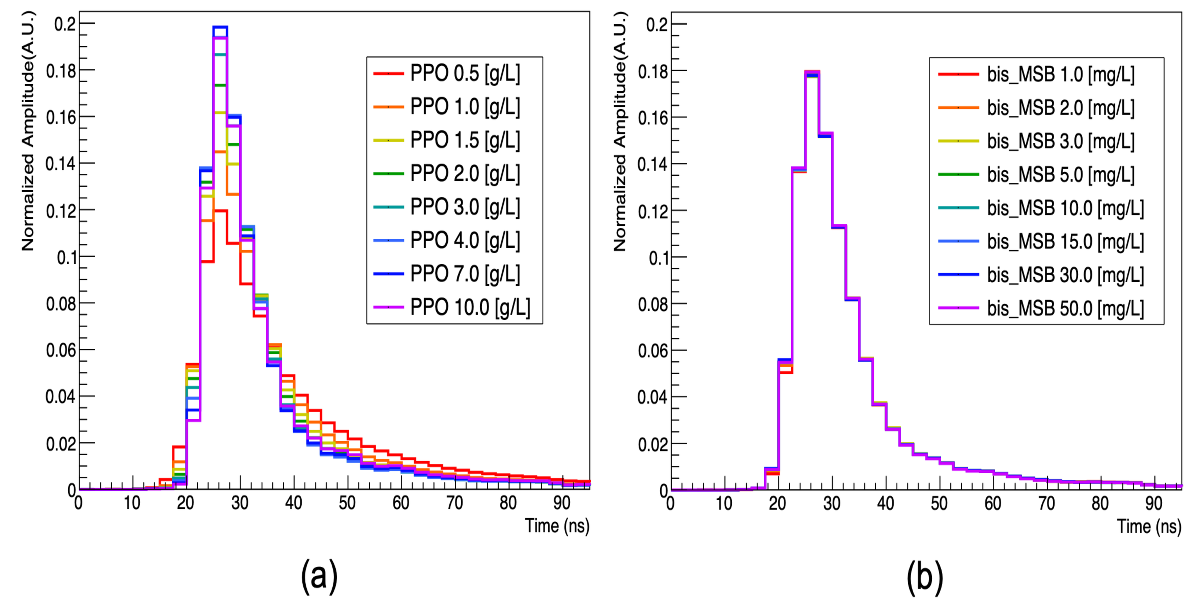
Short-pass filter information	
Substrate	Fused silica
Cut-off wavelength (nm)	425
Diameter (mm)	50.00+0.0/-0.2
Pass	Short
Shape	Circular
Manufacturer	Edmund Optics

Measurement & Results

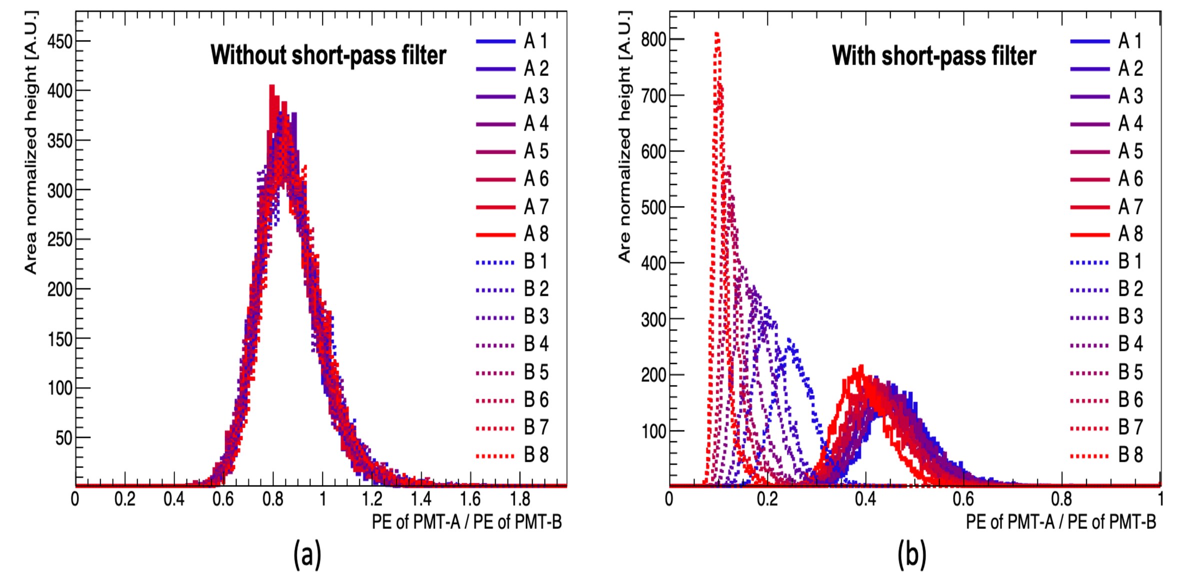


Observed light yield of sample B3 using the experimental setup

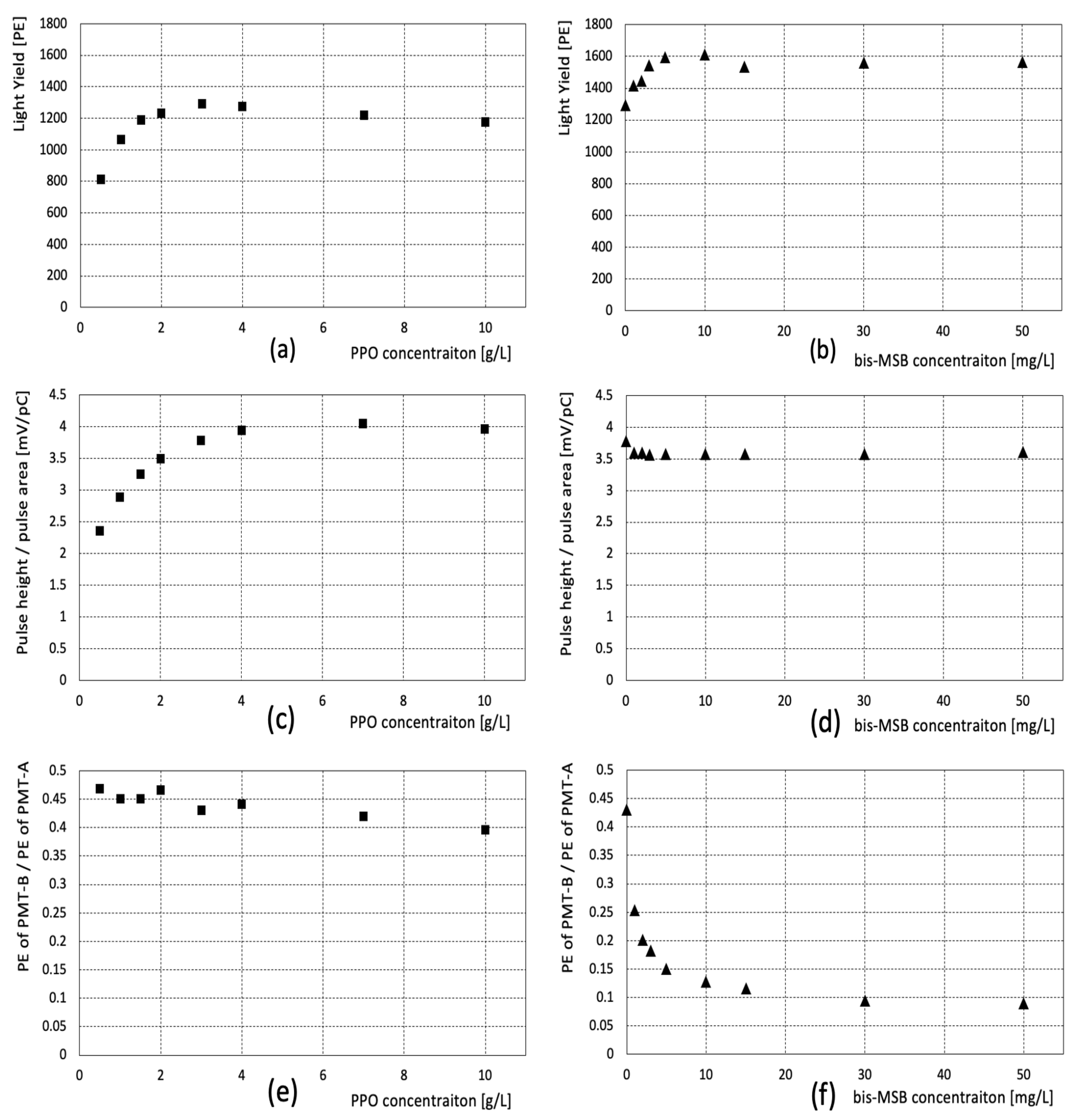
The two PMT observed the scintillation lights from the LS, and a clear PE correlation was observed between the two PMT. The inset presents a 1D projection plot for observed PE. The upper(lower) inset corresponds to the PE distribution of PMT-B(A). Each PE distribution was fitted to determine the Compton edge. The dotted line represents the fitted edge with the ideal resolution.



Area normalized waveform with different PPO and bis-MSB concentration: (a) Pulse shape with varying PPO concentration; (b) Pulse shape with varying bis-MSB concentration. The PPO concentration is kept constant at 3 g/L.



The observed PE ratio between PMT-A and PMT-B according to fluor concentration : (a) Measurement without the filter; (b) Measurement with the filter. The PE ratio distribution decreases monotonically with fluor concentration when the filter is used. The PMT-A and PMT-B observed the scintillation light with different quantum and collection efficiency. The difference in photon detection efficiency is about ~15%.



(a) Scintillation light yield with different PPO concentration; (b) Light yield with different bis-MSB concentration; (c) Area normalized pulse height according to the concentration of PPO; (d) Area normalized pulse height according to the concentration of bis-MSB; (e) The ratio of PE passing through the pass filter according to the concentration of PPO; (f) The ratio of PE passing through the short-pass filter according to the concentration of bis-MSB. At the Figure (b), Figure(d), Figure(f) the PPO concentration is kept constant at 3 g/L.

Summary

In this study, the additional featured characteristics sensitive to the fluor concentration, the waveform, and changes in the emission spectrum have been selected and measured.

The changes in timing properties of LS according to the PPO concentration are observed by the waveform differences. The shift of emission spectra according to the PPO and bis-MSB concentration was observed using a PMT coupled with a short-pass filter.

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