Light emission time from organic scintillators

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Introduction

Scintillators (scintillating materials, inorganic and organic, solid and liquid) are widely used as a medium for the detection of charged particles for numerous applications in science, medicine and other areas [1].

Liquid organic scintillator give both the fast and high light yield for charged particles detection. It is similar to plastic scintillator in properties but is somewhat cost effective yet harder to handle. With liquid scintillator, one can create large detection volumes that are symmetric and yet retain high light detection due to high transparency and low attenuation length in the scintillator. Different wavelength shifters affect the scintillation light by changing the output spectrum into the best detection region. New materials, such as novel water-based liquid scintillator material, aim to reduce and control both the light yield and cost [2]. Also, composition affects the light pulse width that is important for any timing measurement using scintillator.

The composition of scintillator affects not only its performance, but also the cost of the components. Optimization of this composition provides the ability to design particle detectors [3] with a certain light yield and emission spectra of the detection medium or maximize the light yield while optimizing the expenses [4]. This work presents the component optimization for the toluene-based liquid scintillator that uses PPO as a fluor and POPOP as a secondary shifter.

A sample of liquid organic scintillator under the UV light.

Composition:

- Toluene (methylbenzene)
- PPO (2,5-diphenyloxazole)
- POPOP (1,4-di-(5-phenyl-2-oxazolyl)-benzene)

A sample of organic plastic scintillator under the sunlight.

Composition:

- Polyurethane
- PPO (2,5-diphenyloxazole)
- POPOP (1,4-di-(5-phenyl-2-oxazolyl)-benzene)

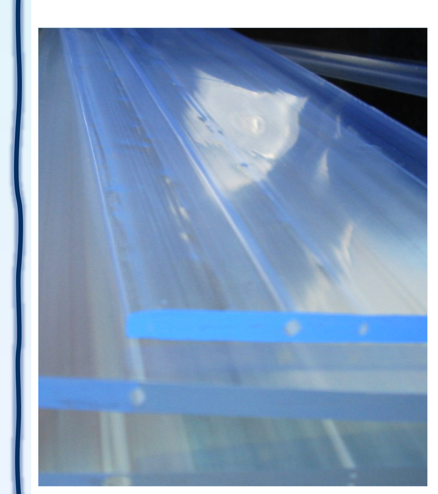


***Figure 1:** Organic liquid and solid scintillators glow excited by UV light.*

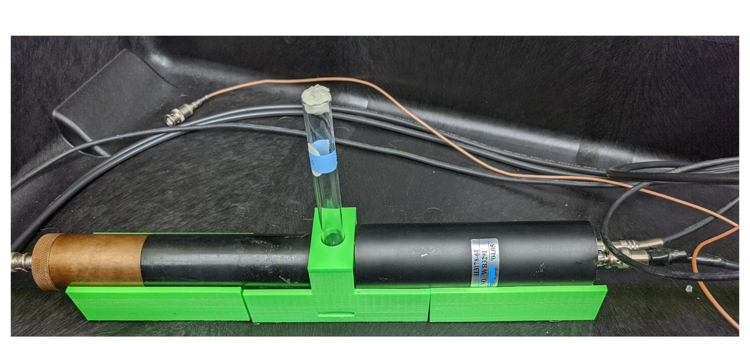
Experimental Setup

The experimental setup was built in the light tight 'dark' box using the two Photo-multiplier tubes (PMT) in a setup shown in Figure 2 (left) : Hamamatsu R580 PMT and MELTZ FEU-115 PMT

The 12-bit 500 MHz Analog-to-Digital Converter (ADC) shown in Figure 2 (right). An oscilloscope was used to preview and monitor the signals. The full view of the experimental setup is given in Figure 3.

A back-to back setup design [3] with double coincidence reduced any external noises in the system. The small sample size and the quick data taking process with the ADC of only few seconds, thus reducing a contribution from cosmic rays to negligible amount (the cosmic rays' flux is ~ 1 muon per cm^2 per minute per steradian).

To excite the scintillator, ^{90}Sr source is used.



CAEN DT5730S 500MHz flash ADC

https://www.caen.it/products/dt5730/

***Figure 2:** Two PMTs and the liquid scintillator sample (left) and CAEN ADC (right).*

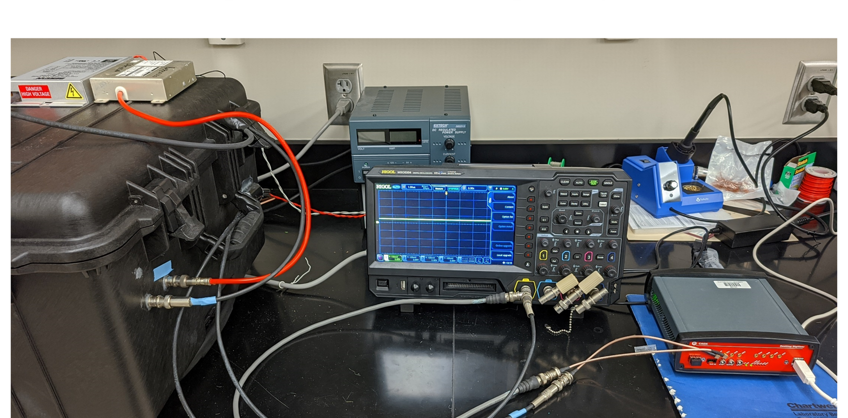


***Figure 4:** Overview of the experimental setup.*

Experimental Results

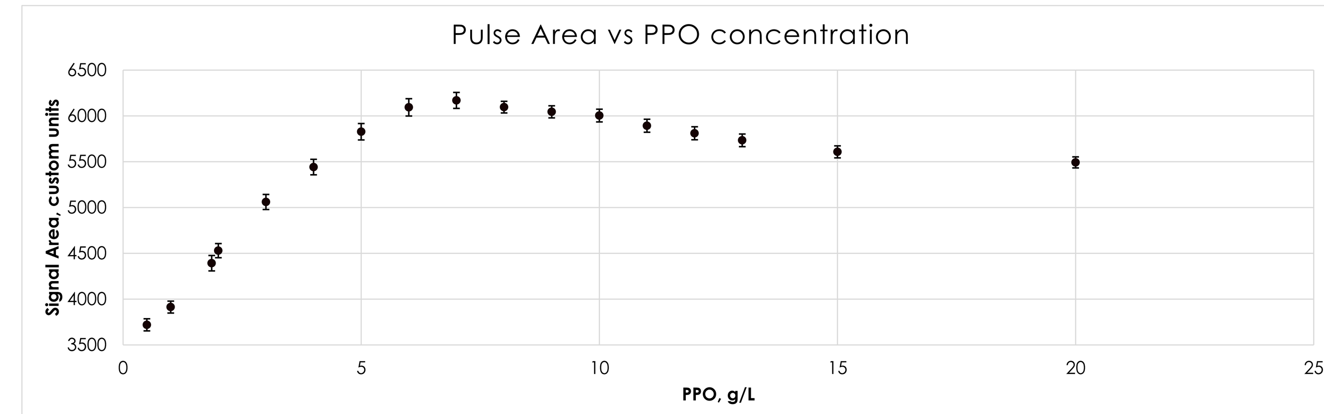


***Figure 5:** R580 PMT total response to scintillator light as pulse area for different PPO concentrations*

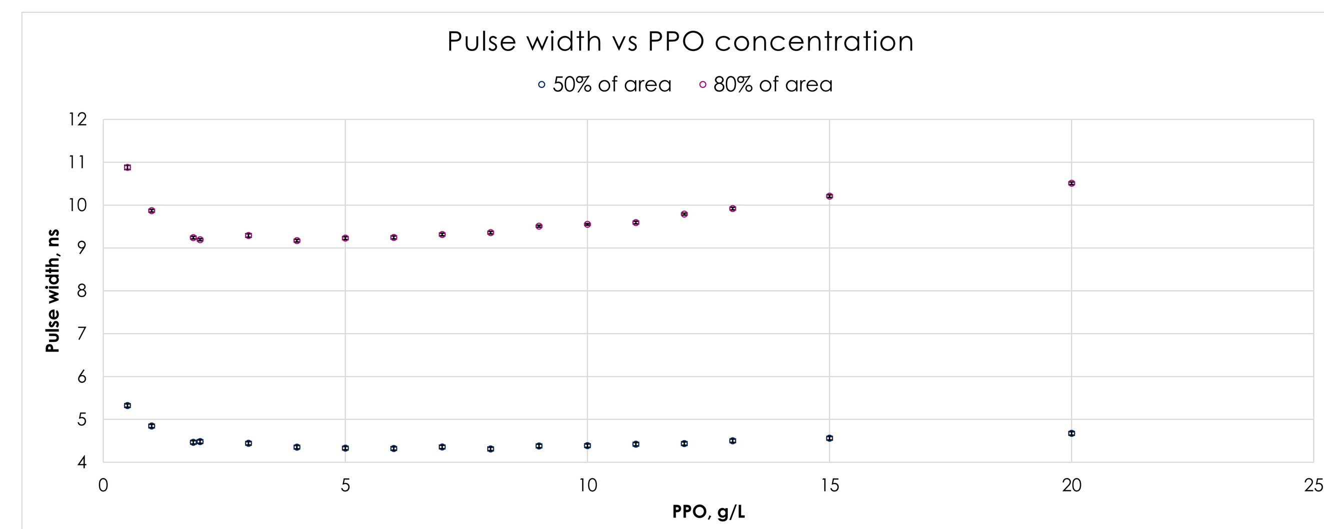


***Figure 6:** R580 PMT pulse width at 50% and 80% of the total area at different PPO concentrations.*

- Addition of primary shifter (fluor) PPO allows the scintillating light to be seen by PMT in principle. There seems to be a concentration with maximal light yield, then the light is being absorbed by the PPO itself, reducing overall response.
- The pulse width seems to first drop and then increase with the PPO concentration

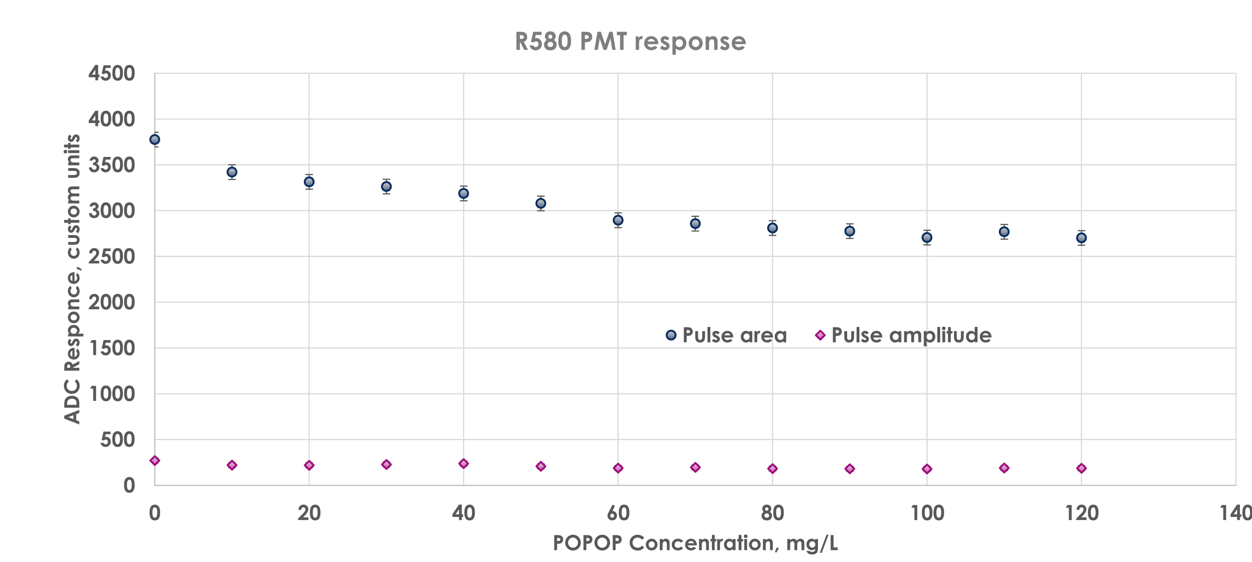


***Figure 7:** R580 PMT response vs POPOP concentration.*

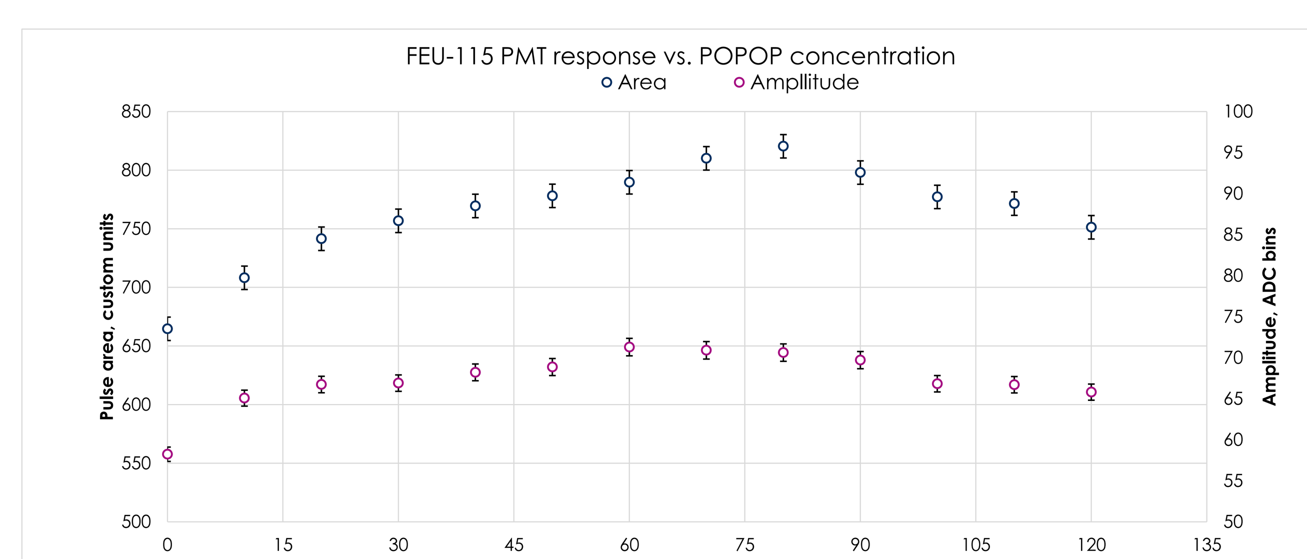


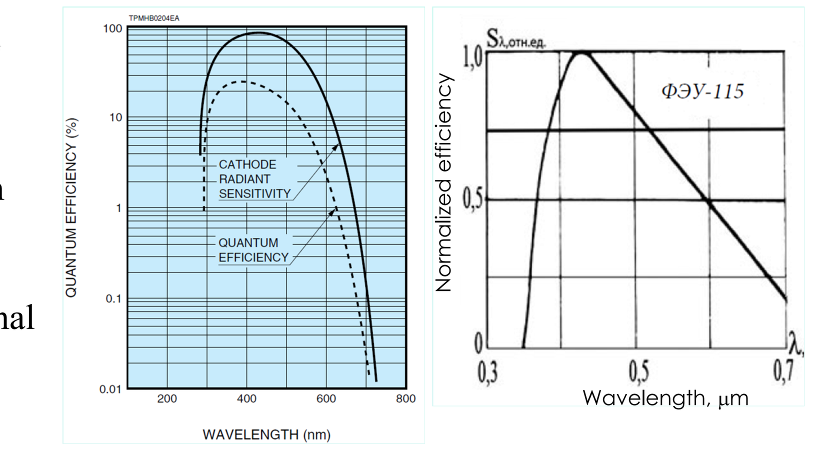
***Figure 8:** FEU-115 PMT response vs POPOP concentration.*

- The R580 PMT is partially UV sensitive, so the addition of secondary shifter removes higher amount of light due to conversion efficiency than adds signal by shifting light into higher detection sensitivity part of the spectrum of the PMT.
- FEU-115 is not UV sensitive so we see the increase in the overall response up to a certain concentration of the shifter.

Experimental Results

***Figure 9:** Spectral sensitivity for R580 (left) and FEU-115 (right)*

- FEU-115 is not UV sensitive so we see the increase in the overall response up to a certain concentration of the shifter.
- The R580 PMT is partially UV sensitive, so addition of secondary shifter removes additional light due to conversion efficiency than adds signal by shifting light into higher detection sensitivity part of the spectrum of the PMT.



Work in Progress

Investigate the changes in the output spectra vs PPO and POPOP concentrations using spectrophotometer and fluorometer. Some preliminary results are shown in Figure 10.

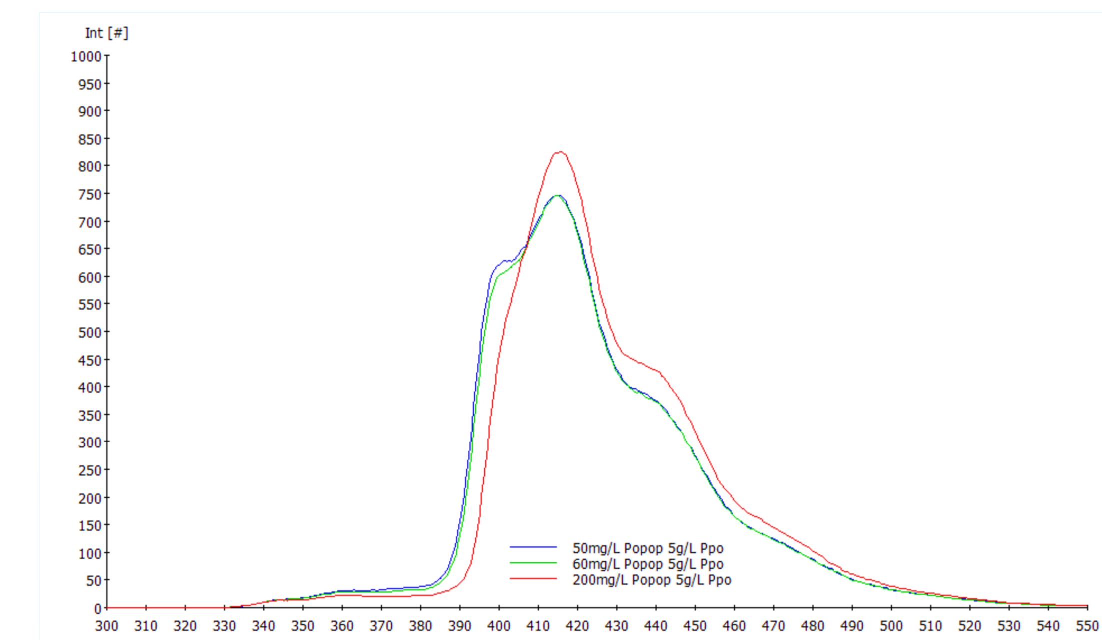


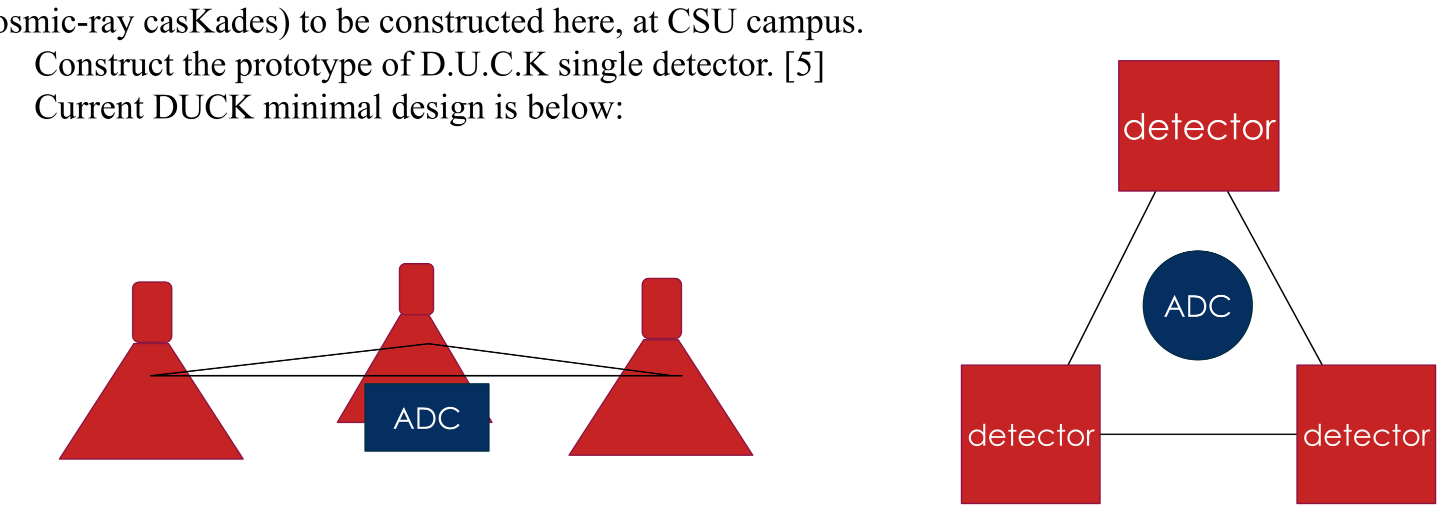
***Figure 10:** Shift in liquid scintillator output vs. POPOP concentration (for illustration only)*

Future Work

- Measure the attenuation length of scintillation light in the long tube for different dopant concentrations.

Further plans

- Investigate the possibility of liquid scintillator use for D.U.C.K (Detector system of Unusual Cosmic-ray casKades) to be constructed here, at CSU campus.
- Construct the prototype of D.U.C.K single detector. [5]
- Current DUCK minimal design is below:



References

[1] Adil Baitenov, Alexander Iakovlev and Dmitriy Beznosko. 2016. "Technical manual: a survey of scintillating medium for high-energy particle detection." arXiv preprint arXiv:1601.00086.
[2] Lindsey J Bignell, Dmitriy Beznosko, et al,. 2015. "Characterization and modeling of a Water-based Liquid Scintillator." Journal of Instrumentation, 10, 12, Pp. P12009.
[3] D Beznosko et al., 2017. "Fast and simple glass-based charged particles detector with large linear detection range." Journal of Instrumentation, 12, 07, Pp. T07008.
[4] Dmitriy Beznosko et al., 2018. "Optimization of the Liquid Scintillator Composition for Radiation Monitoring Detectors." Materials Today: Proceedings, 5, 11, Pp. 22770–22775.
[5] D. Beznosko et al., "Probing Fundamental Physics With Multi-Modal Cosmic Ray Events", arXiv:2204.04045 [hep-ex], 04/2022, https://doi.org/10.48550/arXiv.2204.04045