Performance Studies of PEN and TPB as UV Wavelength Shifting Coatings in Liquid Argon

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Abstract

Tetraphenyl Butadiene (TPB) has been employed as a wavelength shifting coating in LArTPCs, but recent studies of TPB's stability in liquid argon found detectable concentrations of TPB after periods of less than ∼ 24 hours and the dissolved TPB produced measurable wavelength shifting effect in the argon bulk. Here, we study the performance of Polyethylene Naphthalate (PEN) as an alternative coating, while also repeating measurements with TPB. Here, the relative light yields are compared, while sample emanation studies from each coating are also ongoing.

Merits of PEN and TPB

TPB coatings have traditionally been used to convert VUV light to visible for detection by conventional photodetectors. However, recent studies have shown that TPB emanation in liquid argon may become a source of extraneous light if the TPB is not filtered out.[1] TPB is also a challenging coating to apply to surfaces, requiring large vacuum chambers for deposition like the one in Fig. 1., with deposition potentially taking days. PEN, an alternative wavelength shifting coating, is already used as a scintillator in some physics experiments, and may prove more affordable and easier to apply. It is, however, known to have a lower wavelength shifting efficiency, which is investigated further here.[2]

Figure 1: A vacuum chamber used to coat surfaces with TPB. [2]

Light Yield Testing System

A light-tight, low noise system was assembled at UTA to assess the performance of PEN when compared with a bare reflector panel and TPB. The system consisted of the following:

- A light-tight argon bath
- Four silicon photomultipliers (SiPMs)
- Amplifiers, leading into a scope and NIM counters to observe rates
- Power supply for the SiPMs and readout
- Sample holder with a reflective backing for the TPB or PEN
- Dewar and feed-through to replenish the argon
- A fiberoptic cable to allow for laser or LED illumination

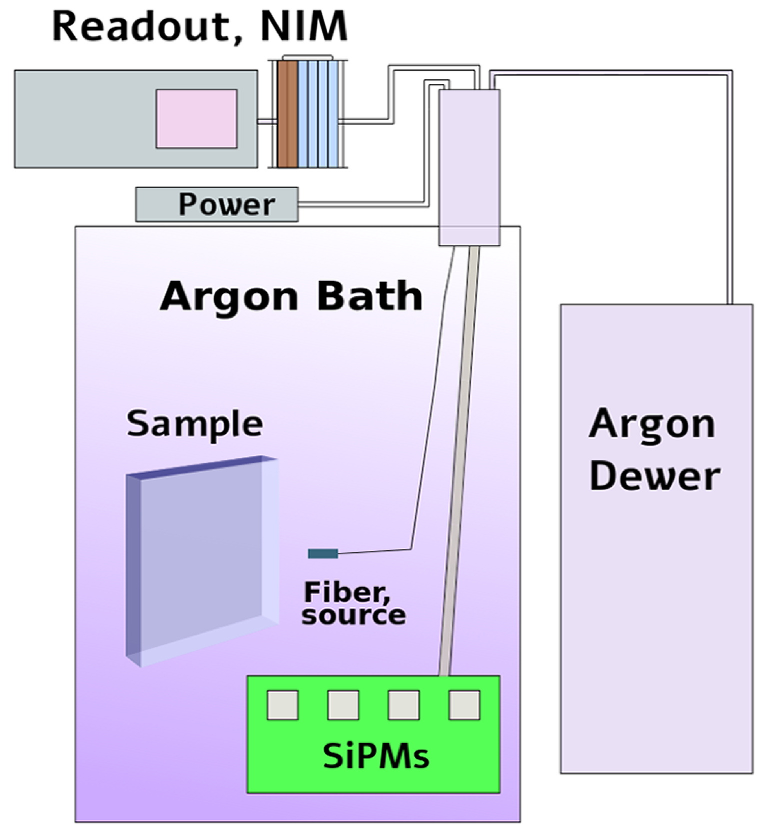

Figure 5: The testing apparatus at UTA.

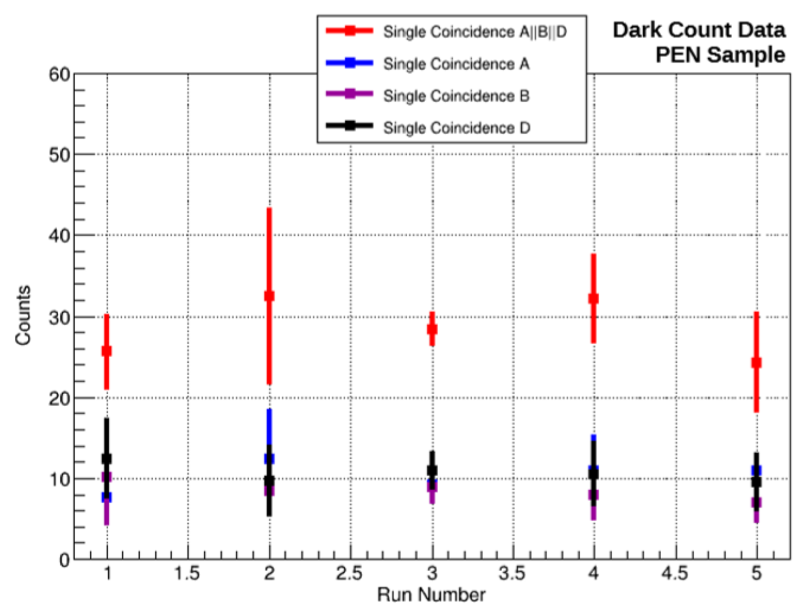

Figure 6: Dark count rates with a PEN sample present.

Relative Light Yields of PEN and TPB

Data Sample	Sample	Average
Single Coincidence A||B||D	PEN	13353.1
Single Coincidence A||B||D	TPB	79432.2
Single Coincidence A||B||D	Bare Reflector	3928.3
Ratio(TPB/PEN)		**5.9**
Two Fold Coincidence (A||B||D)	PEN	18.3
Two Fold Coincidence (A||B||D)	TPB	605.3
Two Fold Coincidence (A||B||D)	Bare Reflector	1.5
Ratio (TPB/PEN)		**33.1**

Figure 2: Counts and relative rates for each sample during a 15s time interval.

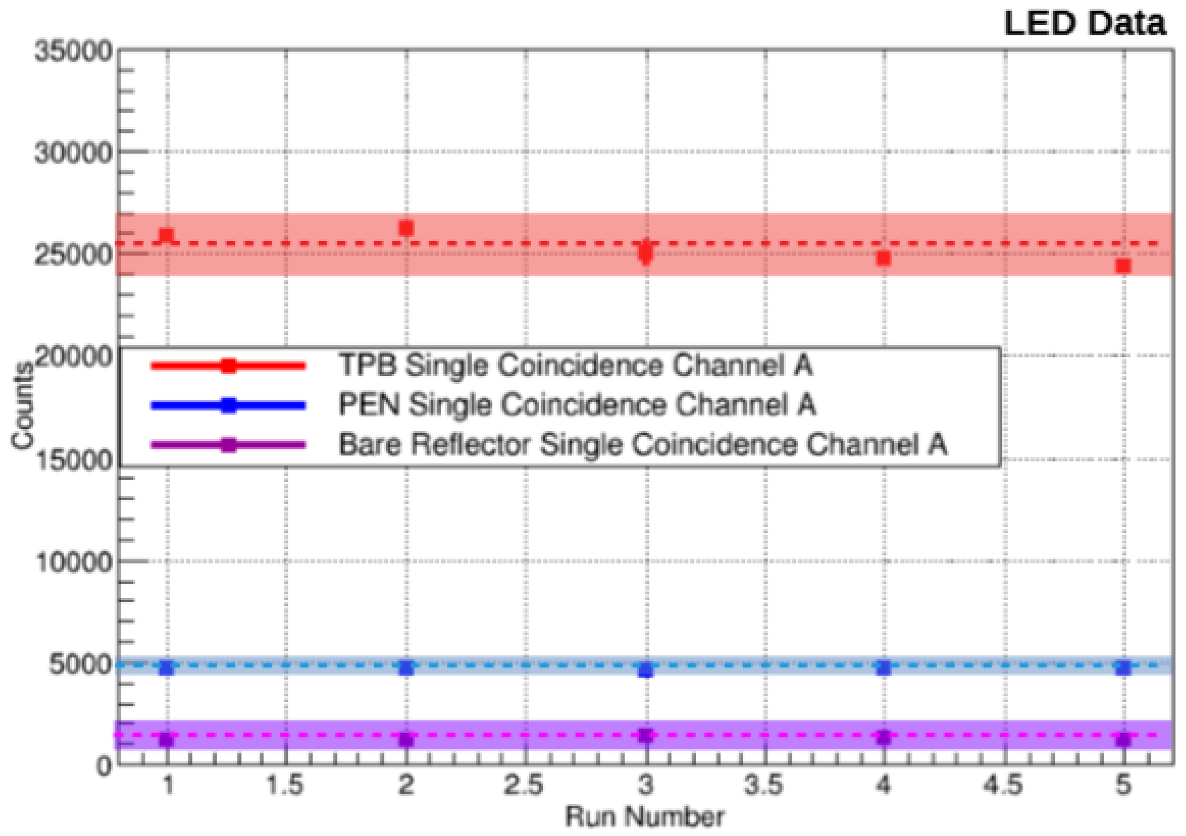

Figure 3: Rates of each sample over time, showing the relative stability of the system.

Performance of PEN Samples

Several PEN samples are undergoing testing, including an older sample, previously exposed to the lab environment, and a new sample stored in isolation. The older sample showed worse performance than expected, indicating that proper storage and treatment of PEN samples is critical for stable longterm performance. It should be noted, however, that even the poorer PEN sample still performed better than a bare reflector. A newer sample showed better performance, but still had light yields

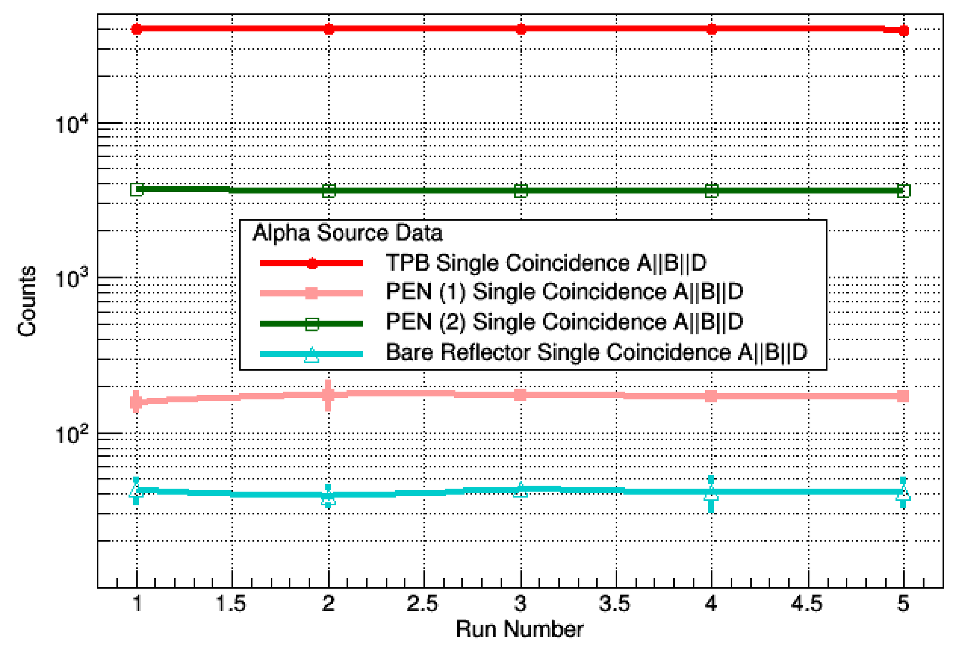

Figure 4: Comparisons of two PEN samples, and TPB

Discussion

Previous studies demonstrated PEN's potential as a UV wavelength shifting coating, showing roughly 38% the WSLE of TPB. PEN is readily available, inexpensive, and easier to deploy compared to TPB, which is often applied as an evaporative coating. While these studies don't show an efficiency as high as previously seen, there was some variation between samples and further tests are needed to investigated why.[2] In particular these are several things to still consider:

1. PEN's light yield is lower than TPB, but storage, handling, or environmental factors may affect the results
2. PEN's emanation in liquid argon still needs to be compared with TPB
3. Though PEN's efficiency may be lower than TPB, it may still prove an effective tool
4. Alternatively, though TPB was shown to emanate in liquid argon, this may be adapted to or taken advantage of in its own right.

Future Steps

As a followup, emanation measurements of PEN in liquid argon would complement to previous results for TPB and give an additional basis for comparison of the materials. It may be that PEN is more stable in the cryogenic environment, in which case that remains an advantage over the TPB coatings. It would also be worthwhile to measure the scintillation time constants of the two materials to see if TPB or PEN has a faster response. Finally, simulations would be useful to confirm the results and point the way to the next steps.

References

[1] J. Asaadi, B. J. P. Jones, A. Tripathi, I. Parmaksiz, H. Sullivan, and Z. G. R. Williams. Emanation and bulk fluorescence in liquid argon from tetraphenyl butadiene wavelength shifting coatings. *Journal of Instrumentation*, 14(2):P02021, February 2019.

[2] M. Kuźniak, B. Broerman, T. Pollmann, and G. R. Araujo. Polyethylene naphthalate film as a wavelength shifter in liquid argon detectors. *European Physical Journal C*, 79(4):291, April 2019.