# Wavelength-Shifting Performance of Polyethylene Naphthalate in a Liquid Argon Environment

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## Abstract

Here we present the results of recent investigations into the wavelength-shifting and optical properties of polyethylene naphthalate (PEN), a proposed alternative to Tetraphenyl Butadiene (TPB).[1] TPB is commonly 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.

## Merits of PEN and TPB

TPB coatings have traditionally been used to convert liquid argon's VUV scintillation light to visible for detection by conventional photodetectors. However, studies have shown that TPB emanation in liquid argon may become a source of extraneous light if the TPB is not filtered out.[2] 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.[3]


**Figure 1:** A vacuum chamber used to coat surfaces with TPB. [3]

## Light Yield Testing System

A light-tight, low noise system was assembled to compare the performance of PEN, TPB, and a bare ESR reflector panel. The system consisted of the following:

- A light-tight argon bath
- Three 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
- Dewar and feed-through to replenish the argon
- A fiberoptic cable to allow for LED illumination

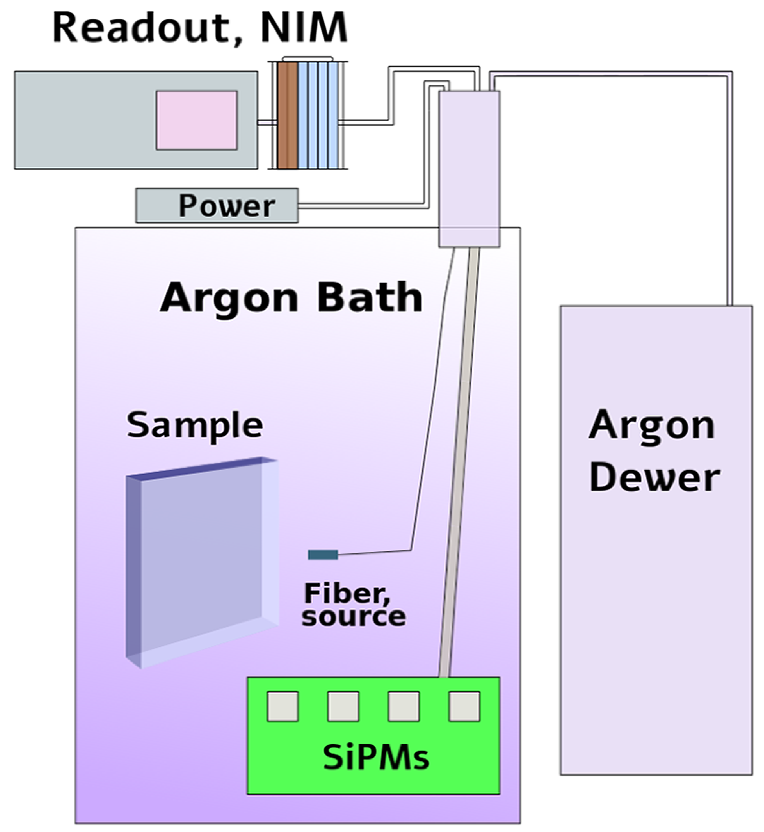


**Figure 6:** The testing apparatus at UTA.

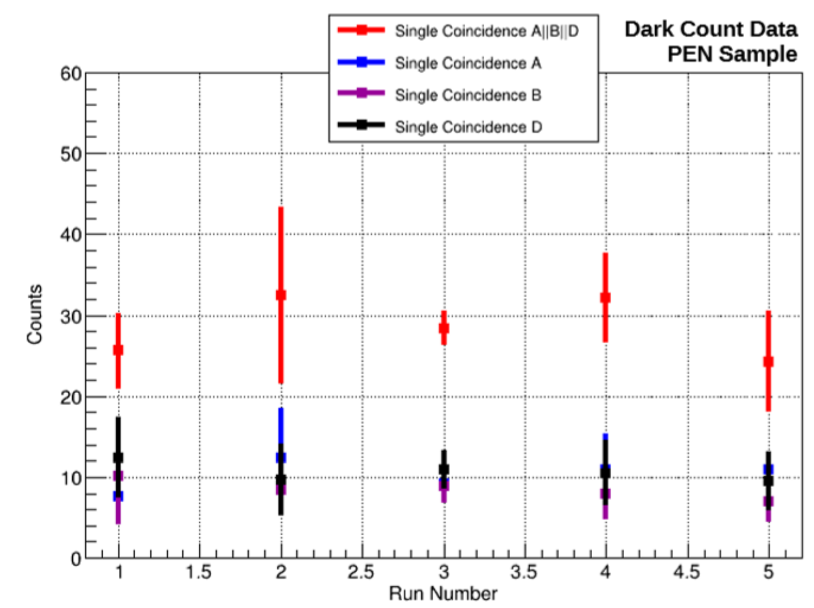


**Figure 7:** Dark count rates with a PEN sample present.

## Relative Light Yields and Stability of PEN and TPB

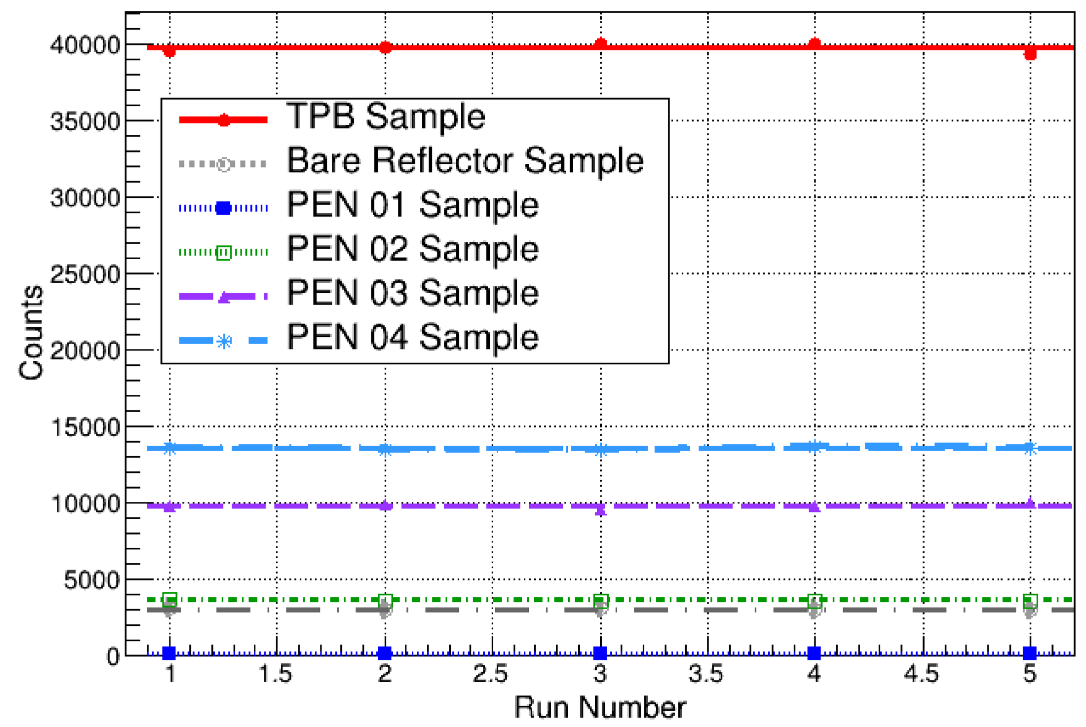


**Figure 2:** Count rates for each sample over a period of ∼ 8 hours, showing their relative WLS efficiency.

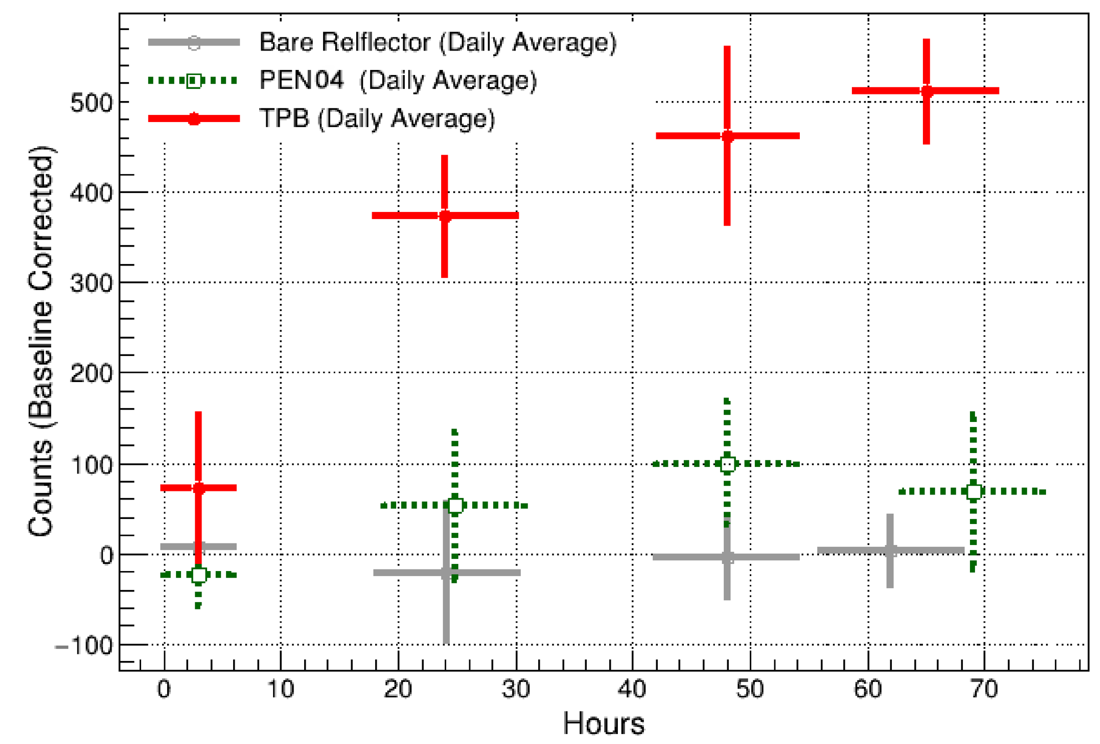


**Figure 3:** Longer stability measurements, taken over ∼ 72 hours, demonstrating the effects of TPB emanation in LAr.

## Performance of PEN Samples

Four PEN samples underwent testing, including samples of hazy Teonex Q53 (PEN03-04) and clear Teonex Q65FA (PEN01), showing varying performance. Plausible origins of these variations were identified, including differences in optical properties, molecular orientation, and optical coupling to the reflector.

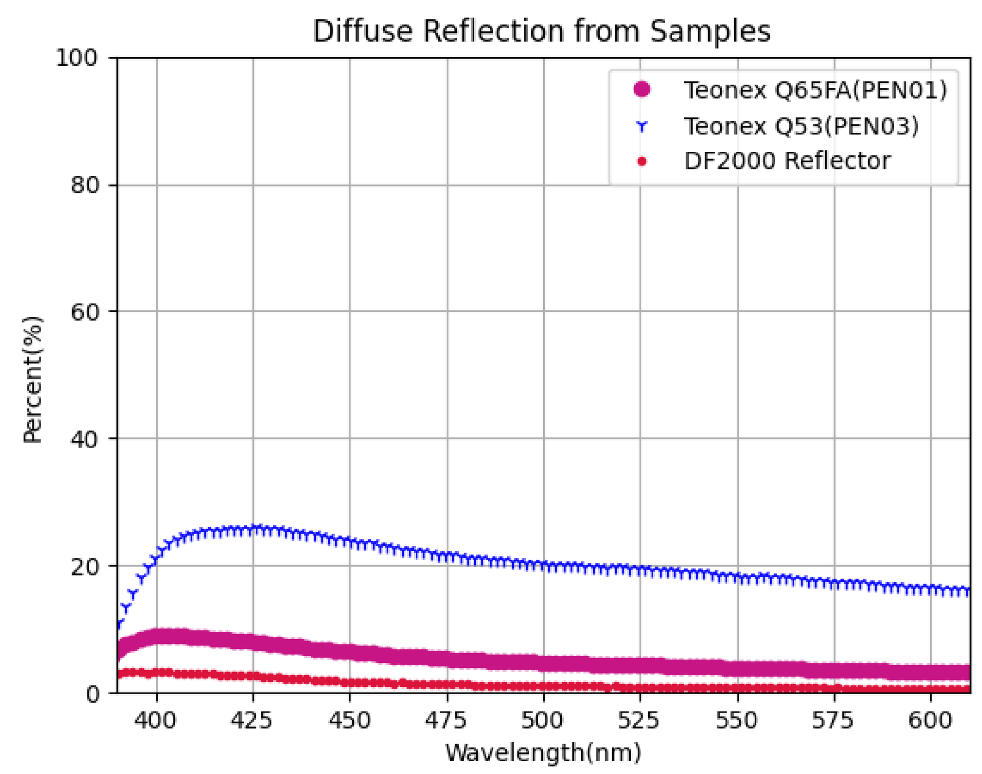


**Figure 4:** Comparison of diffuse reflectance of two PEN varieties. Hazy, biaxially oriented Teonex Q53 performed better.

## Discussion

Here we evaluate PEN's WLS performance relative to TPB in a liquid argon environment similar that those used in TPCs like MicroBooNE, and ProtoDUNE. Samples performed 34.0 ± 1.1% as well as TPB, though performance varied from sample to sample. We also evaluate the stability of PEN and TPB over longer runs, again observing evidence of emanation from TPB, while PEN's count rates remained close to the baseline of the bare reflector within uncertainty. Despite somewhat lower efficiency, PEN remains a viable alternative to TPB. PEN is readily available, inexpensive, and easier to deploy compared to TPB, which is often applied as an evaporative coating.

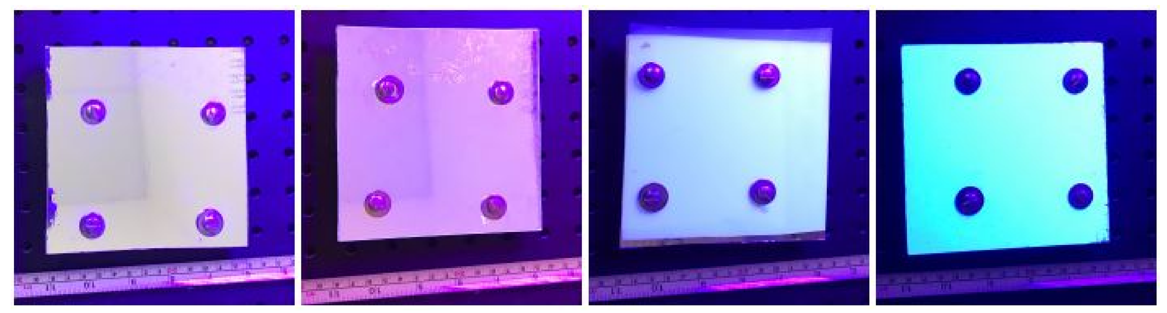

**Figure 5:** Visual appearance under a UV lamp of the bare reflector (left) two PEN-containing samples (PEN01, PEN04) and one TPB-containing test sample (right).

## References

[1] Y. Abraham, J. Asaadi, V. Basque, W. Castiglioni, R. Dorrill, M. Febbraro, B. Hackett, J. Kelsey, B. R. Littlejohn, I. Parmaksiz, M. Rooks, and A. M. Szelc. Wavelength-shifting performance of polyethylene naphthalate films in a liquid argon environment. 2021.

[2] 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.

[3] 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.

## 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.