Measuring the Scintillation Decay Constant of PEN and PET with 120 GeV Proton Beam Excitation

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***Abstract*—We report the scintillation decay constants of polyethylene naphthalate (PEN) and polyethylene terephthalate (PET) determined by excitation of the plastic substrate with an accelerated beam of protons and resulting light yield measured as a function of time with a photomultiplier attached to an oscilloscope. The decay constant of PEN was found to be 35 ns and PET 7 ns.**

I. Introduction

THE light yield of a scintillator excited by an accelerated particle is proportional to the energy of the particle [1]. This property allows a scintillator to be an energy measurement device. Plastic scintillators' ease of manufacture and low cost makes them attractive for experiments in particle physics.

As experiments seek out exceedingly rare events, the rates of beam collisions at collider experiments in particular require scintillators to generate their light and shed it quickly so that the next event can leave its mark without remnants of a previous or neighboring particle contaminating the measurement. The technical term for this phenomena is pileup [2].

Polyethylene naphthalate (PEN) and polyethylene terephthalate (PET) were recently observed to have good scintillation properties [3], and are cheap and easily manufactured plastics. We wanted to determine if they would be of use in future experiments. We set out to excite the plastic and measure its real-time scintillation decay using a photomultiplier directly coupled to the scintillator.

For example, the design event rate at the Large Hadron Collider is 40 MHz, or a collision once every 25 ns. To avoid issues with pileup altogether, a scintillator should be able to be read out completely within 25 ns of it being transited by a particle.

In practice, single detector elements are rarely hit back to back, but as the beam intensity increases, the odds of back to back events hitting the same detector element go up significantly. This effort is focused with the HL-LHC [4] in mind. We observed that PEN has a decay constant of 35 ns, and PET 7 ns.

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II. Experimental Setup

Samples of PEN and PET were obtained via the companies Scinterex and Goodfellow respectively. The samples were cut into 10 cm x 10 cm x 1 mm tiles by the University of Iowa Machine Shop. The tiles were directly coupled to a Hamamatsu R7525 PMT and wrapped in light-tight Tyvek. The samples were then placed plane-perpendicular to the beam line at the Fermilab Test Beam Facility. The test beam facility has a laser guided system for easily and precisely pinpointing the beam center. The center of the tile was aligned with the beam.

A 1 cm x 1 cm x 1 cm scintillator and PMT was used with a 5 cm x 5 cm x 1 cm and PMT as inputs to a coincidence unit, which was used to trigger the oscilloscope to record a waveform. If both the trigger counters saw an event above a certain threshold, it was certain that particle also transited our PEN or PET sample.

Twenty five thousand events were recorded. Each event was a single 120 GeV proton passing through the sample. The data recorded was a waveform from an oscilloscope triggered by a coincidence unit. A

The data was than cleaned with quality selection criteria, including pedestal subtraction, leaving 6,250 events remaining for use in our analysis.

The 6,250 remaining events were averaged together to produce the light yield profile as a function of time for the scintillators. By fitting exponential decay functions to the light yield profiles, we determined the decay constants of the scintillators.

III. Results

A scintillator can be modeled with two (or more) decay constants corresponding to two (or more) components in the decay, most commonly a slow component and a fast component. We observed both components in the PET sample, but only one component, a slow component, in the PEN sample. Each component was fit to the standard decay function $\frac{A}{\tau}e^{-t/\tau}$, where A is an arbitrary constant and τ is the decay constant. In the case of PET, two fit functions were added together to produce a single fit, with two relative constants A and B, and a τ_{fast} and τ_{slow} component.

The results and fits are shown in Figs. 2 and 3.

IV. Discussion

Both scintillators PEN and PET are candidates for use in the HL-LHC. The total light yield of PEN is significantly higher than PET, but its decay constant is significantly slower, making a potential combination of the two an attractive thought.

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Fig. 1. Samples of PEN in the beam line. From left to right: PEN Sample, 1 cm x 1 cm trigger, 5 cm x 5cm trigger.

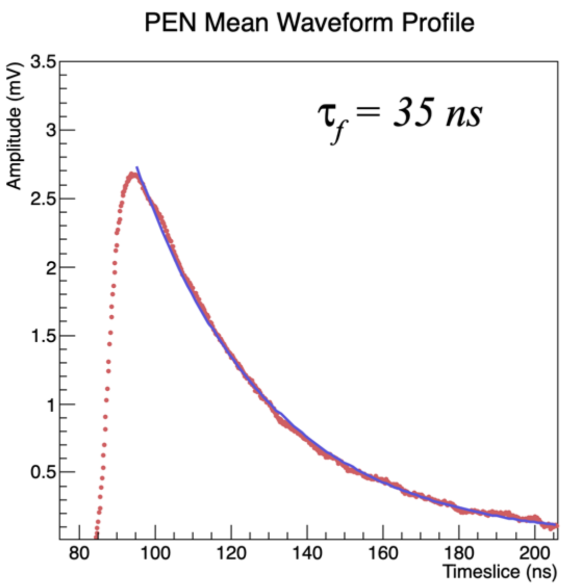

Fig. 2. The average waveform generated by 6250 protons passing through the PEN sample as seen by a direct couple PMT, with the exponential decay constant.

A research program to maximize the light yield and minimize the decay constant of a combination of PEN and PET might be worth pursuing.

V. Conclusion

Samples of polyethylene naphthalate (PEN) and polyethylene terephthalate (PET) were bombarded with 120 GeV protons at the Fermilab Test Beam Facility. The light generated by the protons in the samples was recorded using an oscilloscope, reading out a photomultiplier tube. Each event produced a voltage vs time graph. The events were averaged together to produce an average waveform, which was fit using a standard exponential decay function. The dominant decay constants of

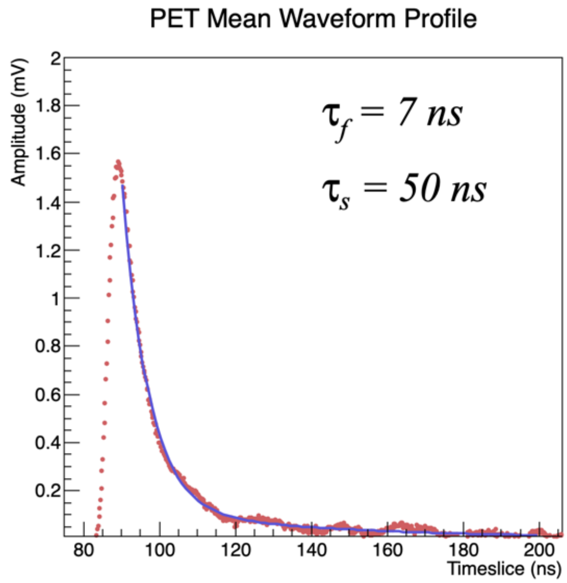

Fig. 3. The average waveform generated by 6250 protons passing through the PEN sample as seen by a direct couple PMT, with the exponential decay constants for the fast and slow components.

PEN and PET were found to be 35 ns and 7 ns, with PET having a slow component extending to 50 ns.

Acknowledgment

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