PHY 743 – Practical 2: Trigger Scintillators

1 Introduction

Plastic scintillators are frequently used for event triggering in nuclear and particle physics experiments. The efficiency of a scintillator trigger detector depends on the high voltage applied to the photomultiplier (PMT) as well as the discriminator level for which a signal pulse produces a logic pulse. The purpose of this practical is to get the student familiar with plastic scintillators, PMTs, and associated electronics used for event triggering on charged particles. In this practical the student will first determine the operating voltage of a PMT + plastic scintillator assembly by finding and plotting the efficiency plateau curve utilizing both a β source and cosmic rays. Next the student will determine the charge to energy calibration utilizing the known endpoint energies of various beta sources. Lastly, the student will predict the energy deposition of minimum ionizing cosmic ray muons in plastic scintillator and compare to data.

2 Determining the PMT plateau with a ^{90}Sr β source

One advantage of using plastic scintillators + PMTs for charged particle triggers is that they can generally be operated at a high voltage for which they have nearly 100% detection efficiency. For mono-energetic particles the efficiency for producing a trigger logic pulse will depend on both the high voltage applied to the PMT and the discriminator level for which signal pulses will produce logic pulses. At high enough voltage the efficiency will plateau at $\tilde{1}$00%. The ideal operating voltage is typically 50-100V into the plateau region such that the efficiency will remain stable. *On the other hand, operating the PMT at too high a voltage can cause damage to the tube.*

For reasons of safety, plase make sure to adhere to the following procedures:

- Verify with the instructor that you have the HV supply set to the correct polarity before turning on the supply. *The maximum HVs for the various tubes are -1500 for trigger 1 (S1), +1500 for trigger 2 (S2), and -1700 for the double anode PMT (S3).*
- Never connect or disconnect the HV cable with the supply turned on.
- Minimize your exposure to the β source and wash your hands after handling. Move the source by making contact with the circular sides and always direct the 'window' away from yourself and others.

One way of determining the plateau curve is to count pulses from a radioactive source. An example plot of such data is shown in Figure 1. For a Sr90 source the number of beta particles detected per 5 minute period will be plotted versus PMT high voltage. In principle the oscilloscope discriminator level and output TTL trigger pulse could be utilised for this,

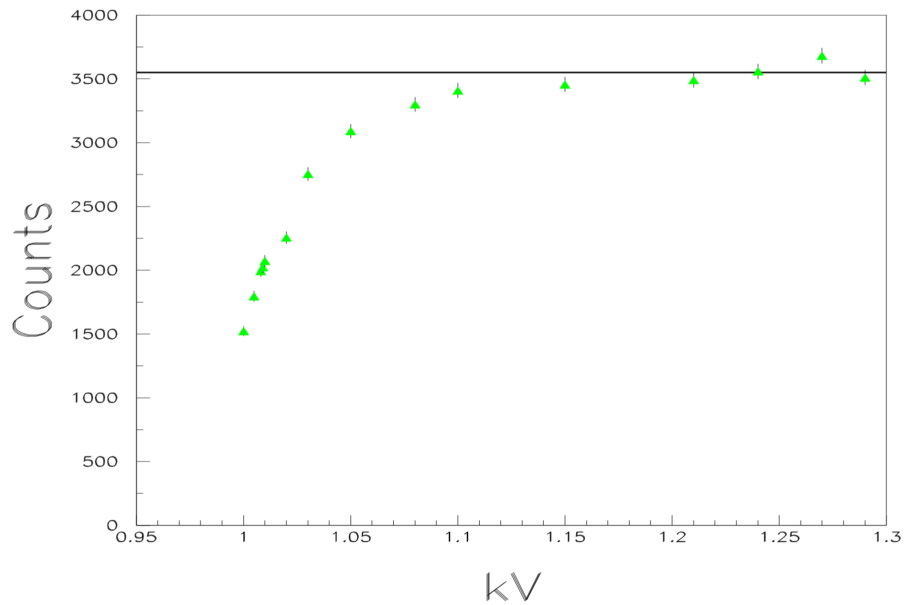

Figure 1: Example scintillator plateau curve from beta source. Plotted is the number of counts per 5 minute periods verses applied voltage in kilovolts.

however, since NIM discriminators will later be used for setting up a coincidence trigger it will be utilize here as well. These have a variable discriminator level which can be adjusted via a set screw and monitored on the front panel. Adjust the discriminator to the minimum level of 30mV for the remainder of this practical. Once the discriminator has been adjusted, connect the output logic pulse to the counter (negative) input. Count the number of pulses in a 3 minute period for a range of (at least) seven high voltage settings such that the plateau curve is mapped out. *Note that you should subtract off the cosmic background for each of the count measurements.*

- **Make a table of counts versus high voltage.**
- **Make a plot of counts versus high voltage and determine the operating voltage.**

3 Determining PMT plateau with cosmic ray trigger

Cosmic ray muons can also be used to determine the efficiency plateau curve. In this case a pair of trigger scintillators (S1 and S2) will be used to determine whether a cosmic ray muon *should* have hit the third scintillator (S3), for which we would like to determine the plateau. The coincidence of S1 and S2 discriminator output logic pulses will define the cosmics which *should* have hit S3. The efficiency of S3 can then be determined by the fraction of triggers for which there was also a pulse in S3.

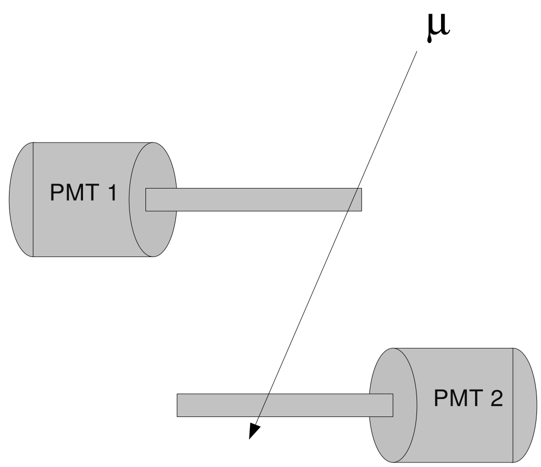

Figure 2: Cosmic trigger scintillators.

3.1 Set up the cosmic ray trigger

A diagram of the basic trigger setup is given in Figure 2. Mount the scintillators such that the S3 scintillator is between S1 and S2. To determine absolute efficiency, the trigger scintillators must be setup such that any coincidence between S1 and S2 will require a cosmic ray passing through S3 as well. Setup the coincidence NIM module to produce a coincidence logic pulse from S1·S2. The logic pulses produced from the S1 and S2 dicriminators should be within 10 ns of each other given similar cables and electronics paths. The time-of-flight (ToF) between them for relativistic muons will be small (<1 ns) for the separation distances used. Use the oscilloscope to verify that the individual trigger pulses are close in time and set the widths of these pulses to ≈ 60 ns to ensure that variations in the arrival time will still produce a coincidence trigger.

- **Make a diagram of the electronics utilized for the coincidence trigger.**
- **Make a diagram of the relative timing for the S1 and S2 logic pulses.**
- **Make a diagram of the physical setup.**

3.2 Set up the S3 scintillator

The S3 scintillator you will be using is not directly coupled to the PMT. Instead, the scintillation light is captured and transported to the PMT via an optical wavelength shifting (WLS) fiber. There are several advantages to this type of arrangement. Perhaps most importantly, the fiber is much smaller spacially so that many fibers can be coupled to the more recently

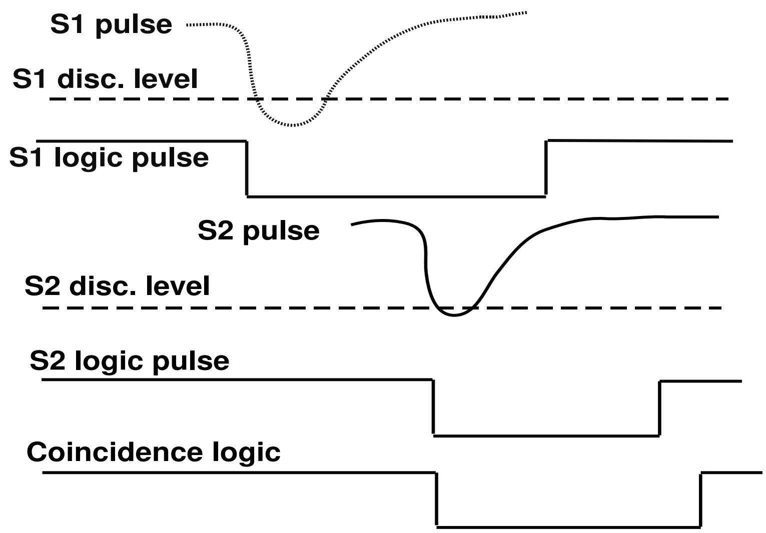

Figure 3: Coincidence trigger timing.

developed multi-anode PMTs (MAPMTs). For example the Hamamatsu M64 MAPMT has a square cathode face of $\approx$ 2 cm x 2 cm with an array of 64 pixels (8x8 arrangement) and scintillation light incident on each pixel is amplified and readout individually. The use of fibered scintillators and dense MAPMTs allow for much finer segmentation detectors for the same price compared to the use of conventional single anode PMTs. The S3 scintillator used in this practical consists of a pair of long scintillator bars with rectangular cross section which are coupled (inside the thick cardboard tubing) via WLS fibers to a double anode Hamamatsu R1548 PMT.

3.3 Determine the efficiency plateau and operating voltage for S3

Using the NIM logic pulses, setup the counters to determine the appropriate counts needed to calculate the efficiency of the S3 trigger. Plot the plateau curve for the S3 scintillator+PMT and determine the operating voltage. Make sure you take enough counts to determine the efficiency to at least 7-8% in the plateau region. *Make sure not to surpase the maximum operating voltage of 1700 V.*

- **Make table and plot of the efficiency versus HV for at least 4 HV settings. Do more settings if time allows.**
- **Explain possible sources of inefficiency for S3 in this setup.**