Scintillator Detection Characteristics and Efficiency

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In recent years, particle physics has become the “hot issue” for physicists worldwide. As a result of cutting edge technology, sub-atomic particle experiments have achieved inordinate precision levels. Physicists have directed their attention to particles that exist for less than a few nanoseconds. In order to study such particles, atoms must be accelerated to nearly the speed of light and exploded to expose sub-atomic particles. Devices must be engineered to detect many specific sub-atomic particles that are exposed.

Most experiments have implemented scintillation detectors to accurately study these target particles. Scintillation detectors are a combination of two major components: first, the scintillating material; and second, a photo-multiplier tube (PMT). When a nuclear particle strikes the scintillating material several photons are released within the material. The free photons then “bounce around” in the scintillating material until they are either reabsorbed or reach the PMT. The PMT converts photons to electrons and amplifies the number of electrons by a constant factor through a series of photo electric interactions. The PMT is linked to a scope which enables one to observe the signal created by a nuclear particle passing through the scintillating material. Such scintillation devices are used to detect specific particles observed in rare particle decays in most current experiments. As a result, scintillators must be very accurate and experimentalists must be very comfortable with the scintillator’s characteristics and efficiency; thus requiring vast research.

In the past, most scintillator studies used cosmic rays as input photon sources because they are naturally accruing and produce large signals in a scintillator. Unfortunately, cosmic rays are inconsistent. So, in order to study scintillator qualities, input parameters in the scintillating material were controlled by using a light emitting diode (LED) that directly inserted photons in the scintillating material (as shown on left). This was accomplished by attaching an LED to a pulse generator. When the LED would receive a pulse it would turn on, and a fiber would deliver photons from the LED to specific locations in the scintillator as shown in Figure 1. This method enabled consistent data collection and the system required a large amount of testing to ensure the accuracy of each component.

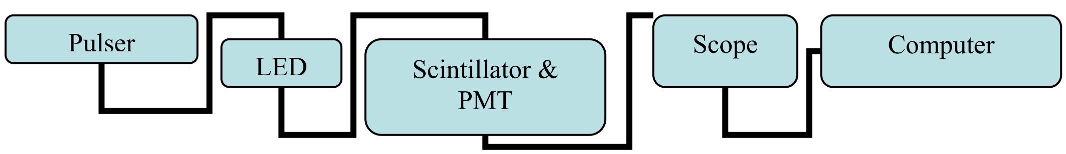

Figure 1. LED Set-up.

The LED set-up was tested and calibrated strenuously by verifying the accuracy of the LED output, PMT output, and scintillator variation. Using the LED set-up several scintillators were tested. The BC404 scintillator, a Bicron product, was tested most strenuously. Tests included:

- Attenuation Length- The distance photons travel in scintillating material before 64% (1/e) are absorbed. This is important for particles which deposit very few photons and are potentially undetectable. The ratio of signal size between locations near to the PMT and far from the PMT reveals the number (or percentage) of photons absorbed.
- Signal Consistency- This is the consistency of signals created by identical LED input settings. If signals fluctuate significantly at constant input settings then it becomes impossible to distinguish between different particles. The areas of a thousand signals (created with constant LED settings) were plotted as a histogram and analyzed.
- Wrapping Comparisons- Wrapping is used to effects signal shape. The type and location of wrapping creates signals which are more desirable for analysis.
- Small Signal Response- Signals were recorded using minimal input photons to verify the scintillator’s ability to detect all particles.

As a result of the scintillator studies the BC404 scintillator was determined an adequate device for the KOPIO project at Brookhaven National Lab. More important, the use of an LED and pulse generator to control input photons proved to be a worthwhile method for scintillator study, which will aid the KOPIO team in future scintillator device studies.