Muon Detection

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Abstract

In this lab we investigate the use of trigger logic and scintillating material for the detection of cosmic ray muons. Scintillation light produced by the passage of atmospheric muons through the panels can be read by photomultipler tubes (PMTs) which are optically coupled to a scintillator. We will design a logic circuit in order to identify incoming cosmic ray muons, then adjust the bias voltage of the panel to characterize the trigger efficiency.

1 Coincidence Logic Circuit

Scintillating panels and their supporting equipment must be set up in order to view the light emitted from the interaction. The list of necessary equipment is below.

- Two muon veto panels at constant gain
- One muon veto panel with variable gain
- High voltage power supplies
- NIM logic modules
- NIM scaler module

First we will design a coincidence logic circuit in order to measure when two panels fire at the same time. The NIM modules available to you are as follows:

- Discriminator
- 4-Fold Coincidence Detector
- Scaler

On the board, design your coincidence detection circuit with your group, tracing the signal from the PMT through each component. Once you are satisfied, implement the circuit with the provided LEMO cables. Be sure to observe the output of the circuit on the provided oscilloscope to make sure the behavior works as designed.

Once this is finished, implement a similar circuit to count the coincidence of *three* PMTs for comparison.

2 Efficiency Measurement Operation

The panels should be stacked with the unknown panel between the two known panels. The unknown muon veto panel should kept below the maximum bias voltage of -1100 V while the known panels should be kept held at -1100 V during data-taking (PLEASE DO NOT TOUCH KNOBS CORRESPONDING TO KNOWN PANELS). The power supplies should be slowly ramped to the voltage, rather than instantly set to a large magnitude. The signal cables should be connected to the NIM logic for the known coincidence pair and the raw PMT signals can be viewed on the scope to ensure that the logic circuit is operating properly. Once proper operation is confirmed, the scalar is reset to zero and a timer started for a certain interval. Record the final count of the scalar after the interval with the known panels.

3 Analysis and Discussion

The counts for the data-taking periods can be converted to a rate for each by taking: $R_i = C_i / t_i$

where Ci is the count observed for dataset i and ti is the exposure time for the dataset.

1. What do you notice with the count rate as a function of unknown panel PMT bias voltage?

2. How much can you trust the calculated rates (what are the errors)?

3. How can these panels be used in contemporary particle physics experiments to aid in the discovery of new physics?

EXTRA:

The integral intensity of vertical muons above 1 GeV/c at sea level is around 70 $m^{-2}\ s^{-1}\ sr^{-1}$. Use this value to estimate the muon flux through one of the scintillating paddles.

Assuming distribution of muon direction of travel is proportional to $\cos\theta$ (where θ is the angle of incidence with respect to a vertical i.e. a θ of 0 is traveling directly downwards), estimate the rate for muon events which pass through all three paddles in their current orientation.