Cosmic ray spectroscopy using plastic scintillator detector

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Introduction

A simple and new technique has been developed using plastic scintillator detectors for cosmic ray spectroscopy without single channel analyzer (SCA) or multichannel analyzer (MCA) [1]. In this technique only a leading edge discriminator (LED) and a NIM scaler have been used.

Plastic scintillator detectors has been used to measure the velocity of cosmic ray muons [2]. Here the time difference has been measured from the Tektronix DPO 5054 digital phosphor oscilloscope with 500 MHz and 5 GS/s. The details of experimental technique, analysis procedure and experimental results are presented.

Experimental technique and Results

In cosmic ray spectroscopy two plastic scintillator paddles of dimension 7 cm $\times$ 7 cm and 10 cm $\times$ 10 cm with 1 cm thick plastic have been used. The scintillator detectors are named as Sc-01 and Sc-02 respectively in this article. For the cosmic ray muon detection a constant voltage of - 1500 V has been applied to the photo multiplier tube (PMT) attached to the Sc-01. In a separate study we have observed that the efficiency of the detector reaches a constant (plateau) value close to 100% with HV beyond - 1450 V.The signals from the scintillator have been fed to the discriminator. The discriminator threshold has been increased in equal step of 2 mV from an initial threshold value of 12 mV. For each discriminator threshold settings the count rate has been measured. Data for each discriminator threshold settings has been taken for 30 minutes or more.

All the data analysis has been performed using ROOT, a data analysis framework developed by CERN [3]. The count rates (say C_1 and C_2) have been measured for two consecutive threshold settings (say T_1 and T_2). The difference of count rates for two consecutive threshold settings have been calculated (say $C=C_1-C_2$) and assigned to the pulse height of average of two threshold values [say $T=(T_1-T_2)/2$]. The noise are same for the two consecutive threshold settings, which is not true at the lower threshold. This aspect is reflected as a noise peak in the cosmic ray or minimum ionizing particle (MIP) spectra at low pulse height region.

The cosmic ray induced pulse height spectra have been obtained for Sc-01 and Sc-02 and that for Sc-01 is shown in Fig. 1. The plot has been fitted with the Landau distribution; as for the cosmic ray there is a large fluctuation of energy deposition in the detector material. These plots have been obtained keeping the PMT voltage constant at - 1500 V. MIP peak seems to have developed around $\sim$ 30 mV but large noise peak (below 20 mV) masks it. It has been observed that at the most probable value (MPV) the count rate is nearly double for the Sc-02 relative to Sc-01 as the area of the Sc-02 (area 100 cm^2) which is nearly double of that of the Sc-01 (area 49 cm^2). A calibration curve between pulse height and energy has been drawn for the Sc-01 at - 1500 V and

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the calibration factor has been found to be 0.054 MeV/mV [1]. As the Sc-01 has been operated at - 1500 V during the cosmic ray study it is seen from Fig. 1 that the most probable energy deposition in 1 cm thick plastic scintillator is $\sim$ 1.4 MeV.

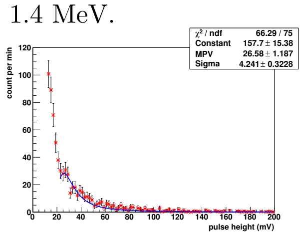

FIG. 1: Cosmic ray pulse height spectrum from detector Sc-01.

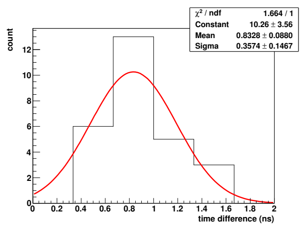

FIG. 2: Time difference spectrum.

The velocity of cosmic ray muons has also been measured by using two plastic scintillator paddles, each with dimension of 7 cm $\times$ 7 cm with 1 cm thickness. The scintillators have been mechanically aligned in such a way that the active area of two scintillators overlap properly. A voltage of - 1700 V has been applied using Quad HV power supply Model RPH-031 module to both the scintillators. The analog signals from the scintillators are fed to the two channels of the oscilloscope with RG-174/U coaxial cables having same length and 50 Ω termination to the oscilloscope. The cable length has been kept same to minimize the timing differences due to different length of cables. The time difference between the two signals has been measured manually from the oscilloscope pushing the singles button of the oscilloscope and registering the coincidence signals due to the same cosmic ray muon. 25 such readings have been taken and a spectrum of the measured time difference has been plotted as shown in Fig. 2. The time difference spectrum has been fitted with the Gaussian function and the mean of the fit value has been found to be 0.83±0.09 ns. So the average velocity of the cosmic ray muon has been found to be $v=\frac{21}{0.83}$cm/ns=25.30cm/ns=2.53$\times10^8$m/s, where the separation between two scintillators are 21 cm.

Conclusions

Cosmic ray muon pulse height spectrum has been obtained for two scintillators and fitted with Landau distribution. The most probable energy deposition in 1 cm thick plastic material has been found to be $\sim$ 1.4 MeV. The average velocity of the cosmic ray muons has been found to be $(2.53 \pm 0.25) \times 10^8$ m/s. In Ref. [2] the quoted value is $(2.978 \pm 0.007) \times 10^8$ m/s. To improve the results two ways may be proposed; the first is to increase the statistics i.e. registering more coincidence events and the second is to measure the time difference using time to digital converter (TDC). Both the processes are in our future plan.

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