A simple technique for gamma ray and cosmic ray spectroscopy using plastic scintillator

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Abstract

A simple technique has been developed using plastic scintillator detectors for gamma ray and cosmic ray spectroscopy without single channel analyzer (SCA) or multichannel analyzer (MCA). In these experiments only a leading edge discriminator and scaler have been used. Energy calibration of gamma spectra in plastic scintillators has been done using Co\textsuperscript{60} and Cs\textsuperscript{137} sources. The details experimental technique, analysis procedure and experimental results has been presented in this article.

Keywords: Plastic Scintillator, Gamma ray, Cosmic ray, Spectroscopy, Energy Resolution

1. Introduction

Special type of plastic scintillator can be used for gamma ray spectroscopy\textsuperscript{1}. Normal plastic scintillator detector, used for triggering particle in high energy physics experiments can also be used for gamma ray spectroscopy. A simple and new technique has been introduced with plastic scintillator paddle for gamma ray and cosmic ray spectroscopy without using single channel analyzer (SCA) or multi channel analyzer (MCA). In this technique only a LED and scaler have been used. Using this technique gamma ray spectrum has been obtained for Co\textsuperscript{60} and Cs\textsuperscript{137} sources. Cosmic ray muon spectrum i.e. the spectrum for minimum ionizing particle (MIP) has also been obtained for two scintillators. The experimental technique and the data analysis technique have been described in Section 2 and Section 3 respectively, the experimental results have been described in Section 4.

2. Experimental technique

A new technique has been developed to get and analyze the gamma ray spectrum and cosmic ray spectrum without using single channel analyzer (SCA) or multi channel analyzer (MCA). Only a leading edge discriminator and scaler have been used. In the measurements 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.

For the gamma ray spectroscopy the source (Co\textsuperscript{60} and Cs\textsuperscript{137}) has been placed on the scintillator material. Constant voltage of -1500 V has been applied to the photo multiplier tube (PMT) of the Scintillator Sc-01 as it has been measured that the efficiency of the detector reaches a plateau at about 100\% from -1450 V onwards. The signals from the scintillator have been fed to the discriminator. The discriminator threshold has been increased in equal interval of 0.5 mV from an initial threshold value of 7.5 mV. For each discriminator threshold setting the count rate has been measured with the source and also without source.

For the cosmic ray also the applied voltage to the PMT has been fixed at -1500 V but the discriminator threshold has been increased in equal interval of 2 mV from an initial threshold value of 12 mV. In this case also the count rate has been measured for each discriminator threshold settings. Data for each discriminator threshold settings has been taken for 30 minutes or more for the cosmic ray.

3. Data analysis technique

All the data analysis has been performed using ROOT, A Data Analysis Framework developed by CERN\textsuperscript{2}. In the case of gamma ray spectrum the difference of the count rate with and without the gamma ray source for a particular threshold setting gives the gamma ray count rate (say C\textsubscript{1}) at that threshold. Likewise the gamma ray count rate (say C\textsubscript{2}) has been measured for the next threshold setting. The difference of gamma count rate for two consecutive threshold settings gives the gamma ray signal count rate (say C\textsubscript{1}-C\textsubscript{2}) with pulse height between those consecutive threshold values. The average of these two threshold values have been taken and the C has been said to be gamma ray count rate of pulse height at that average value. The count rate has been plotted as a function of the discriminator threshold i.e. as a function of the pulse height.

The cosmic ray or minimum ionizing particle (MIP) spectrum has been obtained in the same way described above. In this case also the difference of count rates for two consecutive
threshold settings have been calculated (say C=C1-C2) and assigned to pulse height with the average of these two threshold values. Here only one assumption has been taken that the noise level are same for the two consecutive threshold settings, which is not at all true at the lower threshold value. This is the reason of a noise peak in the MIP spectra at low pulse height region, which will be described in detail in the Section 4.

4. Result

![Figure 1: Co\textsuperscript{60} spectrum, a curve of count per minute as a function of pulse height.](image)

![Figure 2: Cs\textsuperscript{137} spectrum, a curve of count per minute as a function of pulse height.](image)

For the gamma ray spectroscopy Co\textsuperscript{60} and Cs\textsuperscript{137} sources have been used. Gamma ray spectrum for Co\textsuperscript{60} source has been plotted in Figure 1. The characteristic 662 keV peak has been fitted with Gaussian function; as for the cosmic ray there is a large fluctuation of energy deposition in the detector material. Both the plots are fitted well as revealed from the \( \chi^2 \) per degrees of freedom. These plots have been obtained keeping the PMT threshold constant at - 1500 V. From both the plots it is clear that there is a MIP peak and a long tail as measured up to 200 mV threshold. For both the plots there is a big noise peak below 20 mV. This peaks come due to our assumption that the noise level are nearly same for the two consecutive threshold settings, which is not true for the very low threshold. From the Figure 1.

Cosmic ray spectrum has also been obtained in this set-up as described in Section and Section. The spectra have been obtained for two detectors Sc-01 and Sc-02 and are shown in Figure 4 and Figure 5 respectively. Both the plots have been fitted with Landau distribution; as for the cosmic ray there is a large fluctuation of energy deposition in the detector material. Both the plots are fitted well as revealed from the \( \chi^2 \) per degrees of freedom. These plots have been obtained keeping the PMT voltage constant at - 1500 V. From both the plots it is clear that there is a MIP peak and a long tail as measured up to 200 mV threshold. For both the plots there is a big noise peak below 20 mV. This peaks come due to our assumption that the noise level are nearly same for the two consecutive threshold settings, which is not true for the very low threshold. From the Figure 4.
and Figure 5 it is also clear that at 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$^2$) is nearly double of that of the Sc-01 (area 49 cm$^2$). As the calibration curve has been drawn for the Sc-01 at -1500 V and the Sc-01 has been operated at -1500 V during the cosmic ray study it is seen from Figure 4 that the most probable energy deposition in 1 cm thick plastic scintillator is $\sim$ 1.4 MeV.

### 5. Conclusions and outlook

A simple and new technique has been developed for gamma ray and cosmic ray spectroscopy without using SCA or MCA. Only a leading edge discriminator and a NIM scaler have been used in this technique. Gamma ray spectrum has been obtained for Co$^{60}$ and Cs$^{137}$ sources. Proportionality in energy and pulse height has been observed. The energy resolution for the detector has been found to be 9.3% and 7.6% for the Co$^{60}$ 1.17 MeV and 1.33 MeV peak respectively and 10.2% for 662 keV peak of Cs$^{137}$. Cosmic ray muon 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. Although the energy resolution is not so good but still using plastic scintillator detector gamma spectroscopy and cosmic ray spectroscopy can be done.

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