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Energy Calibration for a Plastic Scintillator Beta-Detector Telescope

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A plastic scintillator beta-detector telescope has been built and calibrated. Tests show that the uncertainty of linear energy calibration in the range of endpoint energy between 0.7 and 6.1 MeV for both ß⁻ and ß⁺-emitters is 35 keV.

The plastic scintillator beta-detector telescope is extensively used for ß-measurements, especially for the ß-γ coincidence measurements to extract $Q_ß$ or Q_{EC} values of the nuclei far from stability because of its high efficiency, fast rise time and low cost. However, its poor energy resolution and nonlinear energy response give rise to the distortion of ß-spectrum, inconvenient energy calibration, and considerable uncertainty of endpoint energy determination of ß-decay.

The linearity for a plastic scintillator beta-detector telescope was tested by R. Stippler et al. in 1978 with a conversion electron spectrometer[1]. A small nonlinearity was found, and corrected by a second order parabola. Seven reference sources of ß⁻-emitters were measured and the results analyzed by using Fermi-Curie plot calculation based on a Gaussian energy response function with a $\sqrt{E}$ dependence FWHM and the parabola correction for energy nonlinearity. Finally, the endpoint energies of seven sources were extracted, and the uncertainty resulting from this calibration was determined to be 50 keV in the range between 1 and 9 MeV. Another plastic scintillator beta-detector telescope was calibrated by J. M. Wouters et al. in 1982 using a similar method[2]. Five ß⁺-emitters were used as reference sources. The calibration linearity of this telescope for

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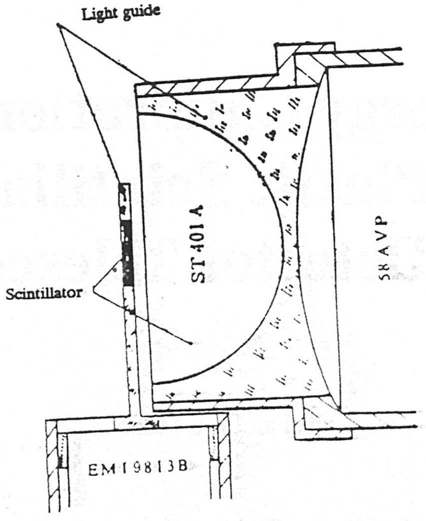

FIG. 1

Schematic view of the plastic scintillator beta-detector telescope.

β^+-emitters in the endpoint energy range between 2.7 and 4.6 MeV was very good and did not require to be corrected by a second order parabola.

Our telescope consists of a ϕ100 mm hemispherical plastic scintillator (ST401A) and a 0.6 mm $\times\phi$20 mm plastic ΔE-detector (Fig.1). In order to minimize the distortion of energy spectrum and the nonlinearity of energy response, the E-detector had a hemispherical shape[3], the tested source was put as close to the center of the sphere as possible, and the high voltage of the photomultiplier (58AVP) was carefully adjusted. It has been found that the output current of the photo-multiplier is proportional to the intensity of the light readily accepted by its cathode an in H. V. region of 1350 V -- 1450 V. The electrical signals from the last dynode of the photomultiplier were directly fed to a fast amplifier . The following ß-emitters and conversion electron emitter ^{207}Bi were chosen as the reference sources[4]:

$$^{204}\mathrm{Tl}(\beta^-) \quad E_\beta = 763.4 \pm 0.2\,\mathrm{keV};$$
$$^{90}\mathrm{Y}(\beta^-) \quad E_\beta = 2281.5 \pm 2.5\,\mathrm{keV};$$
$$^{63}\mathrm{Zn}(\beta^+) \quad E_\beta = 2345.1 \pm 1.6\,\mathrm{keV};$$
$$^{66}\mathrm{Ga}(\beta^+) \quad E_\beta = 4155 \pm 3\,\mathrm{keV};$$
$$^{64}\mathrm{Ga}(\beta^+) \quad E_\beta = 6143 \pm 4\,\mathrm{keV}.$$

in which ^{63}Zn, ^{66}Ga and ^{64}Ga were produced by (p, n) reactions with a 35 MeV proton beam from a linear accelerator at the Institute of High Energy Physics, Beijing. Both the electron- and positron-spectra were measured when the H. V. of the photomultiplier was set at 1450 V. The measured ß-spectra were analyzed by using Fermi-Curie plots (Fig.2) based on a Gaussian energy response

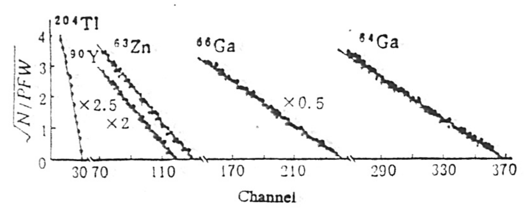

FIG. 2
Fermi-Curie plots of ^{204}Tl-, ^{90}Y-electron spectra and ^{63}Zn-, ^{64}Ga-, ^{66}Ga-positron spectra.

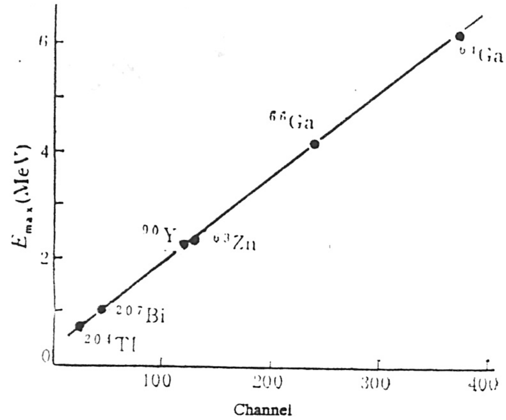

FIG. 3
Linear energy calibration of the plastic scintillator beta-detector telescope using six reference sources listed in the text.

function with a $\sqrt{E}$ dependence FWHM. This proportional coefficient was determined by means of the measurement of the conversion electron spectrum of ^{207}Bi. Then their endpoint energies were extracted. The neat fit of the Fermi-Curie plot to the experimental data in a wide energy range indicates a good linearity to the energy response of the telescope. The root mean square of the deviation of linear energy calibration for the endpoint energies of the reference sources is about 35 keV in the range between 0.7 and 6.1 MeV without any nonlinearity correction (Fig.3)

$$\chi(= \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\Delta E_i)^2} \ ,$$

where ΔE_i is the energy deviation of the ith experimental data point from calibration line and N the total number of the experimental data points. The same linear calibration is suitable for both β^+ and β^--decay. The upper limit of linear calibration can be extended up to 10 MeV, if 1350 V -- 1450 V is applied to the photomultiplier.

The linearity calibration of our plastic scintillator beta-detector telescope can be easily performed, and the precision of the calibration is appropriate for both Q_β and Q_{EC} measurements in a wide energy range for rather unstable nuclei, because the uncertainty of end point energy induced by the statistical fluctuation for those nuclei is usually 50--100 keV.

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