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Letter to the Editor

Comparison of two methods for relocation of multichannel spectra

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Abstract

Two recently published methods of multichannel data relocation have been compared. One of them is deterministic and does not preserve the typical Poisson distribution of the data. The other one concerns a stochastic procedure that conserves the statistical fluctuation of the original data. It is shown that usual statistical tests are useless for the spectra relocated with the deterministic method.

Relocation of multichannel spectra is necessary in order to compare or add different spectra or to correct for effects of shifts and gain variations due to instabilities of the apparatus. Commonly, the new spectra produced in the relocation process must be analyzed in the same way as the original ones, by employing usual fitting procedures.

Recently, two methods of relocation were suggested [1,2]. The common point of both methods is the fit of polynomial functions to the data distribution before the redistribution of the counts among the new channels. However, one of the methods adopts a deterministic procedure in order to distribute the data of the original spectrum [1], while the other adopts a stochastic procedure [2]. The main purpose of this paper is to compare both methods.

Fig. 1 shows the counts $n_1, n_2, n_3, \ldots$ in successive channels of a spectrum to be relocated. Suppose that these counts are to be distributed among the new channels. For example the new channel 1′ must receive a fraction α of the counts in channel 1 and a fraction β of the counts in channel 2; the new channel 2′ must receive a fraction $1-\beta$ of the counts in channel 2 and a fraction γ of the counts in channel 3, etc., where α, β, γ, etc. are calculated from the fit of polynomials to the original spectrum distribution, and integrating the fitted function over the new channels. The deterministic procedure implies that

$$m_1 = \alpha n_1 + \beta n_2 , \quad m_2 = (1-\beta) n_2 + \gamma n_3 . \tag{1}$$

The variances of the new counts generated with this procedure do not obey Poisson distributions. For example, the variance of m_1 is

$$\sigma^2_{m_1} = \alpha^2 n_1 + \beta^2 n_2 \neq m_1 , \tag{2}$$

less than the expected value for Poisson distributed data.

The stochastic procedure attributes a number of counts m_1 to channel 1′ by drawing a binomial random number n_1' from n_1 with probability α plus a binomial random number n_2' from n_2 with probability β:

$$m_1 = n_1' + n_2' , \tag{3}$$

where

$$P_{n_1,\alpha}(n_1') = \frac{n_1!}{(n_1 - n_1')!n_1'!} \alpha^{n_1'} (1-\alpha)^{n_1 - n_1'} , \tag{4}$$

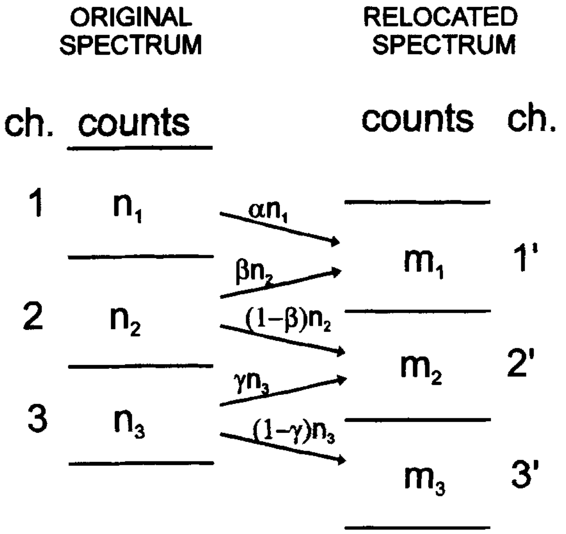

Fig. 1. Scheme of the distribution of multichannel events performed by a deterministic relocation method.

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$$P_{n_2,\beta}(n_2') = \frac{n_2!}{(n_2 - n_2')!n_2'!}\beta^{n_2'}(1-\beta)^{n_2-n_2'}, \qquad (5)$$

The contents of the other relocated channels are produced in a similar way. For the new channel 2′, the m_2 counts are obtained by

$$m_2 = (n_2 - n_2') + n_3', \qquad (6)$$

where n_3' is drawn from the binomial distribution $P_{n_3,\gamma}(n_3')$. As shown in Ref. [2], this procedure assures that the counts of the new channels do obey Poisson distributions.

Fig. 2a shows a simulated Gaussian peak in a multichannel spectrum which was relocated by 0.5 channel using both the deterministic (Fig. 2b) and stochastic (Fig. 2c) procedures. Results of the fit of a Gaussian function to these peaks, using the last squares method, are also shown in the inset. The fits were performed supposing that the statistical fluctuations are given by the square root of the number of counts and neglecting covariance between counts in different channels, as usual. It should be observed that the fitted areas shown in Figs. 2b and 2c agree with the area of the original spectrum of Fig. 2a, since both methods preserve the total counts. However, the deterministic relocation gives a very small chi-squared value and, consequently, a very high probability. This occurs due to the fact that the statistic fluctuation of the deterministically relocated spectrum is less than the corresponding Poisson distribution. Thus, the deterministic procedure nullifies any usual statistical test of the fit. By comparing the chi-square tests shown in Figs. 2a and 2c one sees that the original and stochastically relocated spectra present very close results.

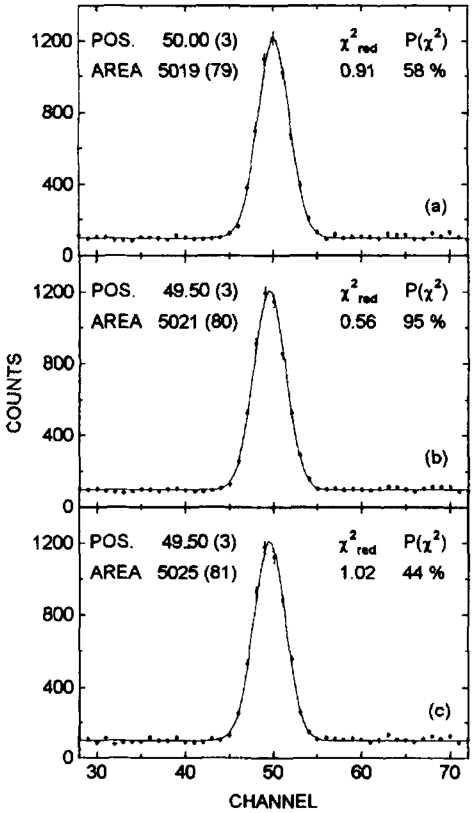

Fig. 2. A single peak fitted with a Gaussian curve plus linear background for the original spectrum (a), for the spectrum relocated by using the method of Ref. [1] (b), and for the spectrum relocated by using the method of Ref. [2] (c).

Fig. 3a shows a region of the gamma-ray spectrum of ^{133}Ba taken with an HPGe detector, showing the strong peak with 356 keV and the small background 352 keV gamma-ray from ^{214}Pb. Results for a Gaussian function fit with a second degree polynomial for the background are shown in the inset. The relocated spectra with the deterministically and stochastically procedures are shown in Figs. 3b and 3c, respectively. As can be seen, the presence of two peaks is very clear in all spectra but the chi-square

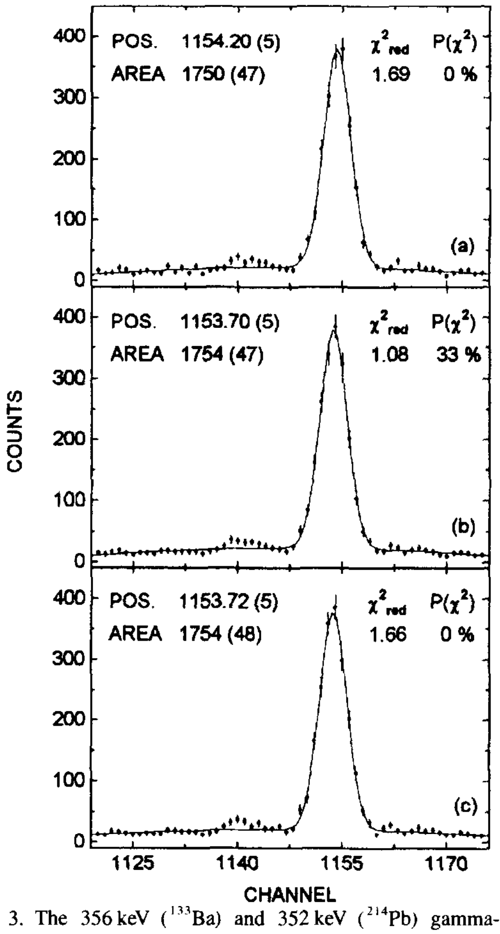

Fig. 3. The 356 keV (^{133}Ba) and 352 keV (^{214}Pb) gamma-rays fitted with a Gaussian curve plus a second degree polynomial background for the original spectrum (a), for the spectrum relocated by using the method of Ref. [1] (b), and for the spectrum relocated by using the method of Ref. [2] (c).

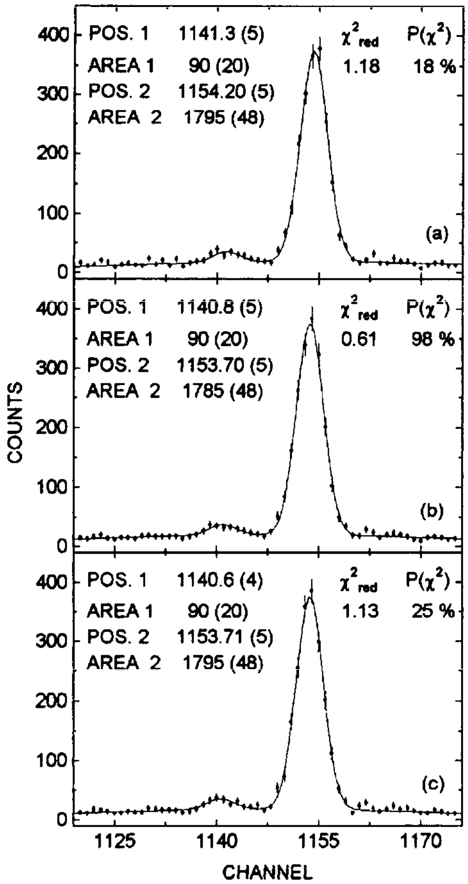

Fig. 4. The 356 keV (^{133}Ba) and 352 keV (^{214}Pb) gamma-rays fitted with two Gaussian curve plus a second degree polynomial background for the original spectrum (a), for the spectrum relocated by using the method of Ref. [1] (b), and for the spectrum relocated by using the method of Ref. [2] (c).

test applied to the deterministically relocated spectrum is compatible with a single Gaussian adjust, while for the original and stochastically relocated spectra the same test discards the single peak hypothesis. Figs. 4a–4c show the same spectra of Fig. 3, but fitted with two peaks. Now the chi-square tests for the original and stochastically relocated spectra indicate that the inclusion of two peaks is necessary to obtain satisfactory confidence in the fit. On the other hand, the fit of the deterministically relocated spectrum, that was already satisfactory with a single peak, gives now a very low and unrealistic chi-squared value.

The stochastic procedure has been used as a useful tool to relocate spectra obtained in experiments that need long time for the data acquisition [3] and no problem has been detected when employed within the limits described in Ref. [2].

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