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Determining decay data correlations and calibrating the detector efficiency with multigamma-ray sources.

RUY MORGADO DE CASTRO, VITO ROBERTO VANIN, OTAVIANO AUGUSTO MARCONDES HELENE, PAULO REGINALDO PASCHOLATI, ZWINGLIO DE OLIVEIRA GUIMARÃES FILHO, ROGÉRIO TRAMONTANO
Instituto de Física da Universidade de São Paulo
MARINA F. KOSKINAS, MAURO S. DIAS
Instituto de Pesquisas Energéticas e Nucleares

The aim of this work is to determine the steps needed to define the correlations between decay data. This problem is linked to the inverse problem, that is, detector efficiency calibration with multigamma-ray sources taking into account the correlations between the decay data. The calibration procedure must give sound results even in unfavorable geometry, for instance, when the source is placed near the detector. We describe first the calibration method, followed by the procedure to determine the decay data and variance matrix.

The number of counts in the full-energy peak observed with HPGe detectors depends on a number of quantities related to the decay scheme and also on many secondary detection effects. The formula are well described in the literature [1-5].

The idea is to fit an efficiency calibration curve or the decay scheme quantities directly to the peak-area data in a most straightforward calculation, avoiding corrections that would introduce uncertainties and correlations that are difficult or tedious to evaluate.

In almost any geometry, the summing of coincident gamma-rays must be corrected, which leads to choosing the parent's feeding ratios and daughter's branching-ratios as preferred decay data. Also a calibration of the total-to-peak detection ratio is required. The use of analytical calibration functions make the calculations easier.

The least-squares method (LSM) gives unbiased estimates for the parameters of the calibration function and, under the assumption of linearity near the estimated values of the parameters, it also gives the estimates of minimum variance. In complex calculations like this one, it is better to formulate the LSM with matrices. Both the LSM properties and the appropriate formalism are well described in the literature [6,7].

The calibration function can be fitted by the LSM to the experimental data. Besides the counting statistics, there are contributions to the data variances from the uncertainties in the activity, the quantities related to the decay scheme, and the total-to-peak detection ratio calibration. The fitting procedure is iterative, since the equations are not linear in the efficiency calibration parameters due to the correction of sum effects, quadratically dependent on the efficiency.

Therefore, from the point of view of the calculations presented here, we find that it is easier and more useful to standardize the feeding factors and the branching ratios than the gamma-ray emission probabilities.

The same formula used to model the peak areas in the calibration experiment can be used to determine the decay data with a previously calibrated detector, by using the appropriate design matrix. The variance matrix has four components: counting statistics, efficiency calibration, total-to-peak gamma-ray detection ratio calibration, and other decay data quantities such as conversion coefficients. Also in this case the fitting procedure is iterative because the formulas are generally not linear in the parameters.

Pile-up and sum with bremsstrahlung, both internal and external, must be always considered, at least to check whether they are negligible effects. Also the assumption that the directional correlation between gamma-rays is negligible when correcting sum effects may be inadequate.

A secondary standard with known correlations demands a detector system calibrated with monochromatic sources or sources with simple decay schemes that enable precise corrections, like ^{60}Co, which should be kept as robust primary standards. Also, monochromatic sources are always needed to calibrate the total-to-peak ratio.

For testing the procedure, we calibrate a 30% HPGe detector using sources of ^{88}Y (5000 Bq) , ^{60}Co (2000 Bq) and ^{137}Cs (25000 Bq), and then determine the ^{207}Bi decay data. The ^{88}Y and ^{60}Co sources were calibrated in a $4\pi\beta - \gamma$ detector, and we found that the activity values are uncorrelated. The accuracy of the geometrical dimensions of frames and encapsulation is 0.1 mm, which is enough to assure a 0.1% relative precision in the efficiency for the source-detector distance adopted, 20 cm. The ^{137}Cs (25000 Bq) was an Amersham commercial source.

After the efficiency and total-to-peak ratio calibrations, a ^{207}Bi Amersham commercial source was monitored and the decay data were determined. In this case, we obtained very small correlation coefficients, due to the characteristics of the ^{207}Bi decay scheme: each quantity derives mainly from one of the lines, and the efficiencies at the gamma-ray energies are almost uncorrelated because they are well separated in energy. Two quantities would be more correlated if they depended mainly on the same line, or if they were determined from different combinations (with significant weights) of the same set of lines.

From the set of decay data fitted, all the gamma-ray transition probabilities and their variance matrices can be determined by appropriate equations.

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Relocação de espectros gama multicanais por análise de evolução temporal

Thetonio M. Pauliquevis Júnior[a], Otaviano Helene, Zwinglio Guimarães Filho[b]
Instituto de Física - USP

A instabilidade do sistema eletrônico de amplificação e digitalização de pulsos gerados por detetores do tipo HPGe limitam as precisões finais que se pode conseguir em calibrações de energia. Com o objetivo de se contornar essa dificuldade, pode-se realizar várias medidas de curta duração. A análise dessas medidas pode ser feita uma a uma ou, alternativamente, corrigir numericamente as calibrações dos espectros individuais é somando-os de tal forma a obter um único espectro a ser analisado. A esse processo de correção de calibração denominamos relocação.
Neste trabalho procedemos a essa correção mas, ao invés de procurar os fatores de correção de calibração de cada espectro individual, procurou-se acompanhar as variações do ganho e determinar-se a função de correção que deveria ser aplicada a todos os espectros.
Foram relocados 87 espectros gama, de uma hora cada, de uma amostra composta de ^{192}Ir, ^{133}Ba,^{60}Co,^{57}Co e ^{137}Cs. Sendo esta uma medida longa, foi observada uma variação da posição central dos canais dos picos desse espectro.