Method of Self-Consistent Evaluation of Absolute Emission Probabilities of Particles and Gamma Rays

S.BADIKOV[1] , V.CHECHEV[2]

[1]National Research Nuclear University "MePHI",Moscow,Russia

[2]V.G.Khlopin Radium Institute, St. Petersburg, Russia

MOTIVATION

- most of decay schemes are disbalanced → there is a need in a development of the evaluation methods providing exact balance relationships

- the evaluated data must meet the metrology requirements; GUM (JCGM 102, 2011) defines the results of the multidimensional evaluation as complete if those contain three types of the data: vector of estimates, its covariance matrix and the confidence region. None of existing decay data evaluation methods provides such complete data set for the evaluated emission probabilities

- this study is of interest from the theoretical point of view as an example of the analysis of multiparticle closed system

Table 1 Level balance checking in decay of ^{244}Cm (DDEP evaluation)

Level	Level energy, keV	Sum feeding	Sum emitting	Relative error, %
1	42.824	23.3	23.4	0.324
2	141.69	0.0240	0.0239	0.305
3	294.32	0.00356	0.00355	0.281
4	497.60	0.0000400	0.0000400	0
5	597.34	0.0001416	0.0001420	0.2817
6	648.85	0.0000211	0.0000169	24.9
7	860.71	0.000149	0.000134	11.2
8	900.32	0.0000500	0.0000530	5.66
9	938.06	0.00000470	0.00000890	47.2

Basic features of the method

- a decay process is considered as a transformation of the closed system from one state to another one;
- the object of the evaluation is a multidimensional vector
- the self-consistency of the evaluated data is provided by applying the iterative procedure in calculations
- the method is a unified in the sense that the same mathematical instrument (the least squares method with restrictions) is used for the decay data evaluation of any radionuclide,
- not easy in use since an order of the calculations, a choice and justification of the normalization factor for the transformation of relative gamma intensities to absolute ones are individual for each evaluation

Table 2 The evaluated ^{242}Cm and ^{244}Cm gamma emission intensities and their uncertainties for most intense transitions compared to the uncertainties of other evaluations (per 100 decays)

N	E_γ,keV	this work	DDEP	ENDF/B-VII.1	JEFF-3.1
0 (^{242}Cm)	44.08	0.0329(7)	0.0330(7)	0.03294(8)	0.032(9)
1 (^{242}Cm)	101.92	0.00250(9)	0.00251(14)	0.00259(13)	0.0024(7)
2 (^{242}Cm)	157.42	0.00145(11)	0.00145(16)	0.00144(16)	0.00096(30)
0 (^{244}Cm)	42.82	0.0256(4)	0.0258(7)	0.0264(38)	0.0254(10)
1 (^{244}Cm)	98.86	0.00136(6)	0.00136(9)	0.00142(23)	0.00174(18)
2 (^{244}Cm)	152.63	0.00102(5)	0.00102(5)	0.00105(15)	0.00107(3)

On the whole, method of self-consistent evaluation provides lower uncertainties of the gamma emission intensities compared to the uncertainties of other evaluations

Table 3 The evaluated ^{242}Cm and ^{244}Cm alpha emission probabilities and their uncertainties for most intense transitions compared to the uncertainties of other evaluations (per 100 decays)

N	E_α, keV	this work	DDEP	ENDF/B-VII.1	JEFF-3.1
0 (^{242}Cm)	6113	74.04(4)	74.06(7)	74.08(7)	74.0(9)
1 (^{242}Cm)	6069	25.92(4)	25.94(7)	25.92(6)	26.0(9)
2 (^{242}Cm)	5969	0.034(1)	0.034(2)	0.035(2)	0.035(1)
0 (^{244}Cm)	5805	76.76(10)	76.7(4)	76.9(1)	76.6(1)
1 (^{244}Cm)	5763	23.21(10)	23.3(4)	23.1(1)	23.4(1)
2 (^{244}Cm)	5665	0.0204(6)	0.0204(15)	0.0204(15)	0.027(3)

1. The uncertainties of the emission probabilities evaluated by the method of interest are lower (by 30-50% for ^{242}Cm) than the uncertainties of other evaluations.

2. At first glance, all the evaluations are consistent within declared uncertainties. In reality this conclusion is incomplete and somewhat false since a consideration of the uncertainties of multidimensional evaluations, carried out separately from the correlations, leads to incorrect interpretation of the evaluated results. An adequate interpretation of the multidimensional evaluations can be obtained by a construction and comparison of the confidence regions for each of the evaluations.

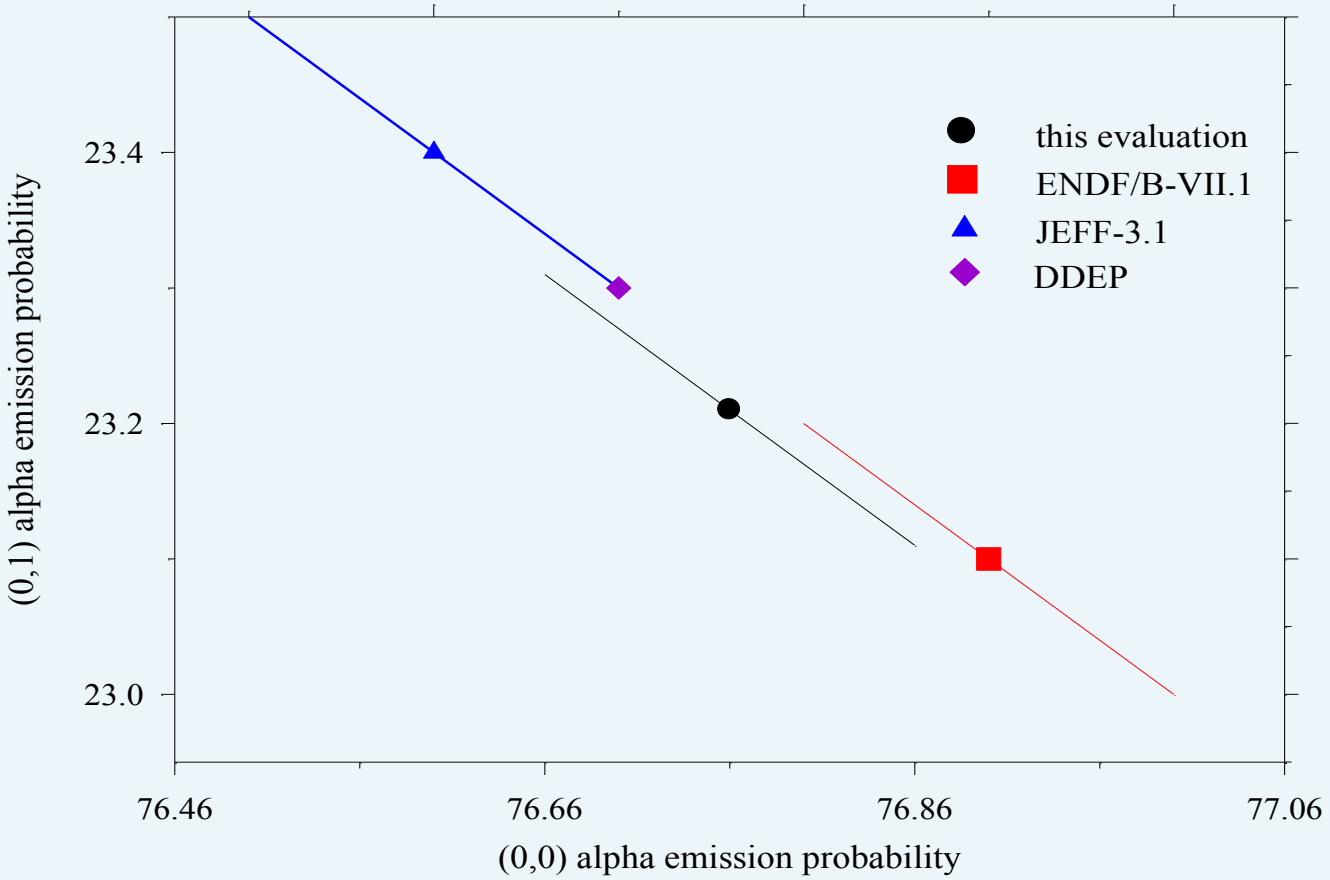

Fig.1 Confidence regions of evaluated (0,0) and (0,1) absolute alpha emission probabilities in decay of Cm-244 from this work and the ENDF/B-VII.1, JEFF-3.1 evaluations.

Correct conclusion: present multidimensional evaluation is inconsistent with other evaluations since these evaluations don't take the strength of weak alpha transitions into account. At the same time making the projections of the confidence regions to x- and y-axis we can conclude that all the evaluations for the single (0,0) and (0,1) alpha emission probabilities are consistent

Summary

- The method of self-consistent evaluation provides the exact balance relationships in the decay schemes. The inclusion of the balance relationships into evaluation process results in decreasing uncertainties (compared to the traditional methods) of the evaluated parameters and installing strong correlations between some of them.

- The method admits an evident extension for the inclusion of energy conservation laws into evaluation process