MULTILEVEL PARAMETRIZATION OF FISSILE NUCLEI RESONANCE CROSS SECTIONS

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The effects of resonance interference exert an important influence on the resonance structure of neutron cross sections energy dependence at lowest energies. In practice, this reflects on the group averaged self shielding factors and, experimentally, on the specifical dependence of the group averaged transmission on the sample thickness. For the description of the detailed energy structure of the fissile nuclei: resonance cross sections with the same precision in the regions of the interferencial maximum and minimum, it is necessary to use the multilevel schemes of the cross section parametrization taking into account the resonance interference. The R-matrix theory results in the schemes of Reach-Moore and Vogt or S-matrix Adler-Adler formalism /1,2/ are to be used in such a case /1,2/. The Adler Adler scheme is most convenient for practical aims, as it gives the simplest representation of the resonance cross sections energy description as a sum of the usual Breit-Wegner resonances /2,1/. The total cross section is parametrized as:

$$\sigma(E) = \sigma_p + \pi k^{-2} \sqrt{E} \sum_{J} \sum_{K(J)} \frac{G_K \nu_K + (\mu_K - E) H_K}{(\mu_K - E)^2 + \nu_K^2} \qquad (1)$$

where σ_p is the potential cross section: μ_K, ν_K, G_K and H_K are resonance parameters; the sum contains all possible levels in the energy region in question with the total momentum J

and parity (for low energy fissile nuclei resonances only two systems of resonances with different J are possible). Similarly, the reaction cross section (n,c) can be expressed as

$$\sigma_c(E) = \sum_{J} \sigma_c^J(E) = \pi K^{-2}\sqrt{E} \sum_{J}\sum_{K(J)} \frac{G_K^c \nu_K + (\mu_K - E)H_K^c}{(\mu_K - E)^2 + \nu_K^2} \qquad (2)$$

with the additional parameters G_K^c and H_K^c.

At present the use of Adler's scheme for the fissible cross sections resonance structure representation in nuclear data libraries assumes the independent determination of the resonance parameters, G_K^c, H_K^c as constant (in energy) values for each of the cross sections - fission, capture and elastic scattering. In such a case, a violation is possible of one of the nuclear physics fundamental principles - collision matrix unitarity, which characterizes the intensity balance over all the channels/1/. Taking into account the unitarity, as shown in /3/, the absorption cross section parameters (fission plus capture) can be expressed by the total cross section parameters/1/ as

$$G_K^a + iH_K^a = (G_K + iH_K)\exp 2i\varphi - i\frac{\sqrt{E}}{2g(J)}\sum_{K'(J)} \frac{(G_K G_{K'} + H_K H_{K'}) + i(H_K G_{K'} - H_{K'} G_K)}{(\mu_{K'} - \mu_K) + i(\nu_{K'} + \nu_K)} \qquad (3)$$

where φ is the potential scattering phase shift; $g(J)$ spin factor; Summing comprises the same level system with spin J. In such a way the total cross section parameters obtained in the multilevel analysis are assumed to be independent of the energy, but the expression for absorption cross section (2) contains the parameters G_K and H_K depending somehow on energy (3). A similar energy dependence is also existing in the elastic scattering parameters/3/:

$$G_K^n = G_K - G_K^a, \quad H_K^n = H_K - H_K^a \qquad (4)$$

The most important interference effects are observed in the fission cross section energy dependence $\sigma_F(E)$. We obtain fission cross section parameters not dependent on energy (2) using the Adler's scheme for analysis of experimental data and the absorption parameters from expression (3) which allows to determine the capture resonance parameters $\sigma_\gamma(E)$ (2):

$$G_K^\gamma = G_K^a - G_K^F \quad , \quad H_K^\gamma = H_K^a - H_K^F \qquad (5)$$

with the same energy dependence/3/ as in G_K^a and H_K^a.

We performed selfconsistent analysis of the ^{239}Pu total and fission cross sections and obtained the set of Adler's parameters: μ_K , ν_K , G_K , H_K , G_K^F , H_K^F not dependent on energy/4,5/. The absorption, capture and elastic scattering cross sections constructed by using these parameters, the above described scheme of unitarity calculations and the existing information about the level spin identification are in good agreement with the recently obtained experimental information about these cross sections/3-6/. This can confirm the correctness of our scheme. For other fissile nuclei the difficulties in multilevel parametrization can be met because of lack of experimental data about neutron cross sections and information about level spin identification. Nevertheless, the use of the relation between the resonance parameters due to unitarity properties can be recommended for the analysis of the available experimental data and for the construction of cross sections where no possibilities exist to perform direct measurements/6/. The precision of the constructed cross sections can be the same as the precision of the measured total and fission cross section in the resonance region.

For practical use of the resonance cross section parametrization results in the proposed scheme, the problem of presentation of these results in ENDF/B format has been discussed. Using the accepted identification (/7/p.No.10A), the section of the resolved levels resonance parameters can be described in our case in a form similar to the accepted representation of Adler parameters (LRU=1 LRU=4). The proposal is to include the following sums not dependent on the energy instead of parameters

$$G'_{K} + i H'_{K} = \frac{1}{2} \sum_{K'(J)} \frac{(G_{K} G_{K'} + H_{K} H_{K'}) + i\,(H_{K} G_{K'} - H_{K'} G_{K})}{(\mu_{K'} - \mu_{K}) + i\,(\nu_{K'} + \nu_{K})} \qquad (6)$$

and to construct the parameters of capture, absorption and elastic scattering cross section according to our scheme (3),(4),(5). In such a way the inclusion of this method in the ENDF/B format is realized as a separate block (with its own LRF /7/) in any code complex, without additional change of all remaining elements of the library.

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/7/ ENDF-102 Data Formats and Procedures for the Evaluated Nuclear Data File, ENDF/B-V, BNL-NCS-50496.