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NUCLEAR MODEL TESTS WITH NEUTRON RESONANCE DATA

S. F. MUGHABGHAB AND C. DUNFORD

BROOKHAVEN NATIONAL LABORATORY

UPTON, N.Y., 11973, U.S.A.

ABSTRACT

The spin dispersion parameter of the level density formula, σ, as determined from the spin dependent level spacings of neutron resonances, is compared with theoretical expressions and found to be in agreement with the results of Ericson. On the basis of the present results, the level density parameters, a, for a few nuclides were then derived and found to be lower than previous determinations by about 20%. The impact of the present findings on the LAHET calculations of neutron yields from thick targets of W is discussed.

Previous determinations of the level density parameter, a, as derived from analyses of resonance parameter data, were carried out on the basis of the Gilbert-Cameron [1] theoretical relation for the spin disperssion parameter, σ. However, other different theoretical expressions for σ have been derived previously on the basis of various nuclear models, such as the Fermi gas model, the unified Bohr-Mottelson [2] model with and without inclusion of nucleon pairing correlations [3], and the Hartree-Fock model. The different expressions for σ would impact the derivation of the a parameter. Because of these considerations, a new examination of the level density parameter, devoid of a reliance on a theoretical expression for σ, is of great importance in various computations in the fields of reactor physics, astrophysics, and spallation neutrons.

The approach followed here is a determination of σ from the spin dependent average level spacings of neutron resonance data [4]. At first, reliable estimates of the average neutron resonance level spacings for each spin state were derived by application of the Porter-Thomas distribution of the amplitudes of reduced neutron widths to those nuclide with a large number of assigned spin values (≥20). To take into account the undetectability of weak neutron resonances, special emphasis was focussed on the least-squares fits of the cumulative number of resonances versus the amplitude of neutron widths in the regions of large amplitudes. Then the spin disperssion parameters for target nuclides with non-zero spins were derived from the two level spacings of s-wave resonances with spin values $I + ½$ and $I - 1/2$. Subsequently, non-linear least squares fits were carried out for the determined spin dispersion parameters for the investigated nuclide .

The results of the present preliminary study of σ can be summarised as follows:

1. The fit to the data yields: $\sigma = 0.052*(U/a)^{0.22} * A^{0.885}$, which is in reasonable agreement with the Ericson relation $\sigma = 0.072*(U/a)^{0.25} A^{0.667}$ for the case of nuclides with low nuclear temperature or no unpaired nucleons .

2. The present results for σ are consitently lower than the Gilbert- Cameron [1] expression , as well as the Bohr-Mottelson relation in terms of a rigid body moment of interia [2] .

3. There seems to be correlation between σ and the spin of the target nucleus.

On the basis of the present results, the level density parameters were then determined and found to be generally low by about 20% when compared with other determinations, such as those of reference [5].

Since the calculated neutron yields per proton in spallation processes are sensitive to the values of the level density parameters [6-7], the validity of the present results are assessed by comparing the results of the combined LAHET and MCNP calculations with the measurements of yields [7] for a thick W target (Table 1). In columns 1-2 are shown the incident proton energies and the corresponding neutron yields, as measured by an array of ^{3}He detectors surrounding the W target . The neutrons/proton code computations, wich are based on three sets of level density parameters are displayed in columns 3-5 (see footnonets of Table 1). As shown, the agreement between calculations and measurements is best achieved on the basis of the present level density parameters.

TABLE 1. NEUTRON YIELD/PROTON COMPARISONS BETWEEN MEASUREMENTS AND LAHET COMPUTATIONS FOR A TUNGSTEN 60 CM LONG AND 10.1 CM DIAMETER.

ENERGY (GEV)	NEUTRONS/P (EXP.).[a]	NEUTRONS/P CAL.[b]	NEUTRONS/P CAL.[c]	NEUTRONS/P CAL.[d]
0.80	4.230	4.97	4.51	4.38
1.00	5.705	6.58	6.21	5.51
1.20	6.820 (e)	8.11	7.27	6.94
1.40	7.935	9.43	8.55	8.00

a) Zucker et. al. BNL measurements [ref. 7] at the alternating gradient synchrotron.
b) Gilbert-Cameron-Cook-Ignatyuk level density representation as implemented in LAHET.
c) Juelich level density parameters of LAHET.
d) Juelich level density parameters reduced by 20% on the basis of the present preliminary results and implemented in LAHET.
e) No measurements were carried out at this energy for tungsten. The quoted value is an interpolation between 1.2 and 1.4 GeV.

The study of the spin dispersion , as well as the level density, parameters will be updated by carrying out a re-eveluation of the resonance parameters by considering recent resonance parameter data published since 1981. Furthermore, additional comparisons between measured neuton yields per proton and LAHET computations based on updated level density parameters will be carried out for other nuclides, such as Pb, Fe, and Co.

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