Comment on "Chaos in Nuclei and the K Quantum Number"

In a recent Letter, Rekstad, Tveter, and Guttormsen [1] have analyzed the average intensities of gamma rays from neutron capture in the target nuclei ^{167}Er and ^{177}Hf, which both have spin I and projection K equal to $\frac{7}{2}$. They compared transitions ending up in final states with the same spin but with different values of K and found that high values of K (from 2 to 5) were favored over low values by a factor of 2.8 ± 0.7, energy-dependent terms having been accounted for in a semiempirical way. Rekstad, Tveter, and Guttormsen concluded that this result contradicts the hypothesis that K is completely mixed in the neutron resonance region.

In this Comment, I would like to point out that a more likely explanation is in terms of correlations between entrance and exit channels. This is possible because complete mixing in the statistical model, in fact, means that the individual resonances have a wide spread in their composition leading to the well-known Porter-Thomas law for the partial widths in one reaction channel. My assumption is that those resonances that have large components with $K=3,4$ in their wave function will be favored both in the neutron capture and in the subsequent $M1$ and $E1$ decays connecting to states with $K=2$–5. An estimate of the possible magnitude of this effect may be obtained as follows.

The experimental intensities used by Rekstad, Tveter, and Guttormsen were obtained with filtered neutrons covering a 1–2-keV-wide band in energy and hence represent an average over several hundred resonances with a mean spacing of a few eV. For a given resonance let us assume that the partial neutron width Γ_n can be expressed as the product of its local average with a random variable x, which is Porter-Thomas distributed and has a mean value of unity. Similarly, the partial gamma width Γ_γ (to a specified final state) is taken to be proportional to the random variable y. With these assumptions the K mixing is complete in both reaction channels and the Porter-Thomas law is obeyed. (Note that the notation used here omits indices specifying the resonance and the final level.)

The total width $\Gamma_t = \Gamma_n + \sum \Gamma_\gamma$ is known to be dominated by the (nonfluctuating) total gamma width, of the order of 0.06–0.09 eV. It is therefore permissible to use the single-level Breit-Wigner formula for calculating the observed gamma intensity to a particular final state with a given I and K. This is proportional to the quantity

$$I_\gamma = \langle \Gamma_\gamma \Gamma_n / \Gamma_t \rangle = \langle xy \rangle \Gamma_\gamma^{\mathrm{av}} \Gamma_n^{\mathrm{av}} / \Gamma_t \,, \tag{1}$$

where, to make the argument more transparent, the averaging over energy and resonance spin has not been made explicit. (This is at most a small effect.)

For the case in which the final level has low K, there is no special reason for assuming x and y to be correlated, so that $\langle xy \rangle = 1$. If, however, for high values of K, the two channels are fully correlated ($x=y$), then the proportionality factor becomes $\langle x^2 \rangle = 3$. This result follows from the properties of the Porter-Thomas distribution and is in excellent agreement with the number obtained by Rekstad, Tveter, and Guttormsen. The correlation effect discussed here is a special example of a fluctuation correction in nuclear spectroscopy. This subject is covered in a recent paper [2], which also discusses the statistical properties of the variables xy and x^2. It is worth noting that they have very large standardized variances, respectively, 8 and 10.7, so that the "theoretical errors" are large, even for a sample of several hundred resonances.

P. G. Hansen
Institute of Physics
University of Aarhus
DK-8000 Aarhus C, Denmark

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[2] P. G. Hansen, B. Jonson, and A. Richter, Nucl. Phys. **A518**, 13 (1990).