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The Role of Rotational Dynamics of the Dinuclear System in the Formation of Fission Fragment Spins

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The angular momenta acquired by fission fragments are formed already at the stage of the compact dinuclear system. One of the sources of their excitation is collective rotational degrees of freedom associated with deviations of the fragments from the coaxial configuration. However, the transition from the collective motion of the system to the individual angular momenta of the fragments is not unambiguous: the result depends on the choice of coordinates used to describe the rotational motion and on which quantities are assumed to be conserved during such motion. This issue is of particular importance for transverse oscillations, which are commonly identified with the bending degree of freedom. Geometrically, the corresponding motion can be represented as a change in the mutual orientation of the fragments with respect to the fission axis. However, such a description alone does not determine the distribution of angular momentum between the intrinsic rotation of the fragments and the rotation of the dinuclear system as a whole. This ambiguity leads to different effective moments of inertia used in fission models [1–4]. If the transverse motion is treated as an independent relative degree of freedom, conservation of the total angular momentum implies opposite directions of rotation of the fragments. The energy of such motion is characterized by the reduced moment of inertia constructed from the moments of inertia of the fragments themselves [1,2]. In this case, no additional orbital rotation of the dinuclear system is introduced, and the bending excitation is directly associated with oppositely directed angular momenta of the fragments. An alternative approach to constructing the rotational degree of freedom arises when oscillations about the equilibrium rotational state of the dinuclear system are considered [3,4]. In this case, a change in the orientation of one of the fragments is accompanied by a rearrangement of the motion of the entire system. Consequently, part of the angular momentum associated with the excitation of the transverse motion is orbital. Depending on the scheme adopted, the rotation of either the light or the heavy fragment may be considered, compensated by a rotation of the remaining system. From a physical point of view, this means that the same term, bending mode, may be used for motions having different angular-momentum structures. In the first case, the motion corresponds to pure relative rotation of the fragments, whereas in the second case, the excited degree of freedom contains an additional collective component. Therefore, a direct comparison of the results of different models based solely on the magnitude of the effective moment of inertia may be inappropriate. For the schemes considered in [3,4], it appears appropriate to use the term pseudo-bending motion, since the corresponding description includes a change in the orbital angular momentum. This distinction manifests itself directly in the transition from collective dynamics to the observable spins of the fission fragments. In the statistical description of rotational degrees of freedom, the mean-square angular momentum is determined by the effective moment of inertia and the excitation temperature. Consequently, a change in the mechanical model of the bending motion, while keeping the other parameters of the system unchanged, leads to a change in the predicted fragment spins. At temperatures of the order of 1–2 MeV, the contribution of the considered degree of freedom may reach several units of $\hbar$, making it comparable with characteristic fragment-spin values. In the present work, a systematic comparison of the effects of different descriptions of the rotational dynamics on the angular characteristics of fission products is performed. Within the framework of the cold-fission model, the reactions 238U(n,f) and 232Th(n,f), as well as the spontaneous fission of 252Cf, are considered. Different prescriptions for the moments of inertia of the fragments, corresponding to the hydrodynamic and superfluid limits, are employed. For each case, the quantities determining the formation of fragment spins and orbital angular momenta, as well as their correlations, are calculated. The obtained results are compared with the calculations and exper-

imental data presented in [5]. The analysis makes it possible to assess the extent to which the predictions of spin characteristics are determined by the properties of the fragments themselves and the extent to which they depend on the adopted description of the collective rotational degree of freedom. It is shown that the choice of the effective moment of inertia of the bending motion is not merely a formal element of the model and can lead to significant changes in the quantitative characteristics of the angular momenta of the fission fragments. References J. Randrup, R. Vogt, Phys. Rev. C 89, 044601 (2014). J. R. Nix, W. J. Swiatecki, Nucl. Phys. 71, 1 (1965). J. Randrup, T. Døssing, R. Vogt, Phys. Rev. C 106, 014609 (2022). T. M. Shneidman et al., Phys. Rev. C 65, 064302 (2002). J. N. Wilson et al., Nature 590, 566 (2021).

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