Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 953 (2016) 95–116

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Local even–odd effect based on the number of configurations of pre-formed and formed fragmentations in a fissioning nucleus

A. Tudora [a,*], F.-J. Hambsch [b], G. Giubega [a]

[a] *University of Bucharest, Faculty of Physics, Bucharest Magurele, POB MG-11, R-76900, Romania*
[b] *EC-JRC Institute for Reference Materials and Measurements (IRMM), Retieseweg 111, B-2440, Geel, Belgium*

Received 27 January 2016; received in revised form 6 April 2016; accepted 26 April 2016

Abstract

The present paper proposes a modeling of the local even–odd effect based on the number of configurations in a nucleus undergoing fission at two stages along its fission path. One is the fissioning nucleus stage just after passing through the outer saddle point when the fragments are considered as pre-formed and the intrinsic energy is not yet shared. The other stage is at the end of the fission path when the scission is imminent. Then the intrinsic energy is already partitioned and the fragments are completely formed. The probability that a pre-formed fragmentation arrives at the end of the fission path (i.e. at scission) when the fragmentation is completely formed is expressed by the ratio of the number of configurations of the formed fragmentation to the one of pre-formed fragmentation. The local even–odd effect is defined as half of the difference between these normalized ratios corresponding to even-Z and odd-Z fragmentations.

Both numbers of configurations in the fissioning nucleus, in which the fragments are pre-formed and completely formed, are calculated using level densities described by the constant temperature function (justified by the small values of the intrinsic energy before scission).

The obtained local even–odd effect results describe well the experimental data, including the increase at asymmetry values corresponding to fragmentations in which one of the fragments is magic or double magic (i.e. fragmentations in which $Z_H = 50$ and/or $N_H = 82$ and very asymmetric fragmentations in which $Z_L = 28$).

---

[*] Corresponding author.
E-mail addresses: anabellatudora@hotmail.com (A. Tudora), atudora@gmail.com (A. Tudora).

http://dx.doi.org/10.1016/j.nuclphysa.2016.04.037
0375-9474/

Keywords: Even–odd effect in fission; Phenomenological nuclear level density; Nuclear fission

---

1. Introduction

The even–odd effect is an interesting aspect of the fission process. The most prominent observation regarding the even–odd effects concerns the even–even fissioning nuclei for which the fragment distributions clearly show a larger amount of even–charge splits than of odd–charge splits in the asymmetric fission region. Both global and local even–odd effects decrease with increasing mass of the fissioning nucleus.

It is considered that the even–odd effect is mainly due to the pairing residual interaction but the shell effects also influence the experimental observable even–odd effect. The multi-modal fission concept leading to non-Gaussian fragment distributions may play a role, too.

The local even–odd effect can be related to the number of configurations of fragments inside a fissioning nucleus. This nice idea is exploited in the model proposed in Ref. [1] where the number of configurations of pre-formed fragments is taken into account. Thus, the yield of even-Z and odd-Z configurations is taken as the ratio of the number of configurations of even-Z and odd-Z pre-formed fragmentations, respectively, to the number of configurations of all pre-fragmentations. The local even–odd effect is defined in Ref. [1] as half of the logarithmic difference between the yields of even-Z and odd-Z configurations. The algorithm of Ref. [1] is detailed in the Appendix.

In most of cases the intrinsic energy before scission calculated as in Refs. [2–5] is low. Hence the fragment level density description by the constant temperature function over the entire energy range (over which the integration giving the number of configurations is done) can be considered as a straightforward assumption.

In the case of level densities in the Fermi-gas regime, for which the energy scale $U = E - \Delta$ is currently employed, the level densities of neighboring even–even and odd-A nuclei can be estimated from the level density of odd–odd nuclei [6] i.e. $\rho_{odd\text{-}A}(E) = \rho_{oo}(E - \delta)$; $\rho_{ee}(E) = \rho_{oo}(E - 2\delta)$.

In the case of Ref. [1] where the level densities in the reduced U scale are expressed by the constant temperature function in which the parameter T is approximated as $T \propto 1/A^{2/3}$ (MeV), the equality of level densities of neighboring nuclei with different even–odd character means the equality of the shifted E_0 parameter in the U scale, i.e. $E_0' = E_0^{(oo)} = E_0^{(odd\text{-}A)} - \delta = E_0^{(ee)} - 2\delta$.

In Ref. [1] the numbers of configurations of pre-fragmentations with different even–odd characters, calculated in the reduced U scale using parameters of the constant temperature function without shell effects, i.e. $T \propto 1/A^{2/3}$ and $E_0' = -2\delta$ with $\delta = 12/\sqrt{A}$ (MeV), lead to results of the local even–odd effect exhibiting a smooth behavior, in overall agreement with experimental data. In other words the local even–odd effect is explained in Ref. [1] exclusively on the basis of pairing energy because the parameterizations mentioned above for T and E_0' (in the reduced U scale) do not include shell effects and other corrections.

When more refined and reliable level density parameters are used in the model of Ref. [1], i.e. parameters provided by valuable systematics or prescriptions currently used in nuclear reaction calculations, then local even–odd effects results in disagreement with experimental data (even including negative values) are obtained.

This fact made us to think that maybe the number of configurations of pre-formed fragmentations in a fissioning nucleus, on which the model of Ref. [1] is based, is not enough to explain the local even–odd effect.