© 2016 IJSRST | Volume 2 | Issue 3 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

A Comparative Study of Odd-Even Effect in Level Density Parameter in Different Formalism

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Abstract- The knowledge of nuclear level densities is a crucial input in various field /applications such as the creation of consistent theoretical description of excited nucleus properties and the nuclear reaction cross-section calculations for many branches of nuclear physics and nuclear astrophysics. Nuclear reactions calculations based on standard nuclear reaction models play an important role in determining the accuracy of various parameters of theoretical models and experimental measurements. Especially, the calculations of nuclear level density parameter. In literature several different authors have used different formulations for it. In this work an attempt has been made to study odd-even effect in level density parameter in different formalism.

Keywords : Free Parameter, Cross-section, Level density, Odd-Even effect.

Introduction- Level density is one of the key ingredients of nuclear reaction cross section calculation. The level density [1,2] which describes the excited state of the residual nuclei at higher excitation energies is of crucial importance in theoretical calculations. It determines the emission probabilities and plays an important role in deciding the shape and absolute values of the excitation functions. The level density model parameterization is traditionally based on counting both the discrete levels near the ground state and the neutron resonances around the neutron binding energy. The first analytic expression of NLD was determined under the frame work of Fermi gas model with the additional assumption that the single-particular states are uniformly distributed and the Fermi gas is highly degenerate. The level density for a nucleus with mass number A and excitation energy E under the Fermi gas approximation can be obtained as [3].

$$\rho\,(A,E) = \frac{\exp\,(2\sqrt{aE}\,)}{4\sqrt{3}\,E} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where the level density is mostly determined by level density parameter a, which is related to the density of single partical near the Fermi energy by the relation

$$a = \frac{\pi^2}{6}\, g\,(\epsilon_F\,) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .2$$

Gilbert-Cameron Prescription

Gilbert and Cameron [4] have suggested to use two different level density formulations in the two different energy regions, and developed the systematics of the even-odd corrections to excitation energies and suggested to approximate the shell changes of the level density parameters by the relation.

$$\frac{a}{A} = 0.00917\,\big(S(Z) + S(N)\big) + Q(Z,N),$$

Where S (N) are the shell corrections for protons and neutrons, respectively, and Q (Z,N) = 0.142 for 54 < Z < 78, 86 < N < 122, and Q (Z,N) = 0.120 for 86 < Z < 122, 130 < N < 182. To take this effect into account it is usual to introduce the so-called effective excitation energy, defined as:

$$U = \begin{cases} \delta_Z + \delta_N & \text{for even} - \text{even} \\ \delta_Z & \text{for even } Z \\ \delta_N & \text{for even } N \\ 0 & \text{for odd} - \text{odd}, \end{cases}$$

Back Shifted Fermi Gas Model- In back shifted Fermi gas model [5] the binding energy of nuclei with even number of protons or neutron is more compared to the neighboring odd-Z or odd-N nuclei by an amount equal to the pairing energy. This odd-even effect can be somewhat taken care by replacing the energy E in the level density formula of eq.1 by an effective energy E-Δ , where Δ is the shift in the ground state energy.

$$\Delta = n\frac{12}{\sqrt{A}}$$

$$n = \begin{cases} -1 & \text{for odd-odd nuclei} \\ 0 & \text{for odd-A nuclei} \\ 1 & \text{for even-even nuclei} \end{cases}$$

However the average value of Δ can be approximated by the neutron as shown by the continuous line in Fig.1.

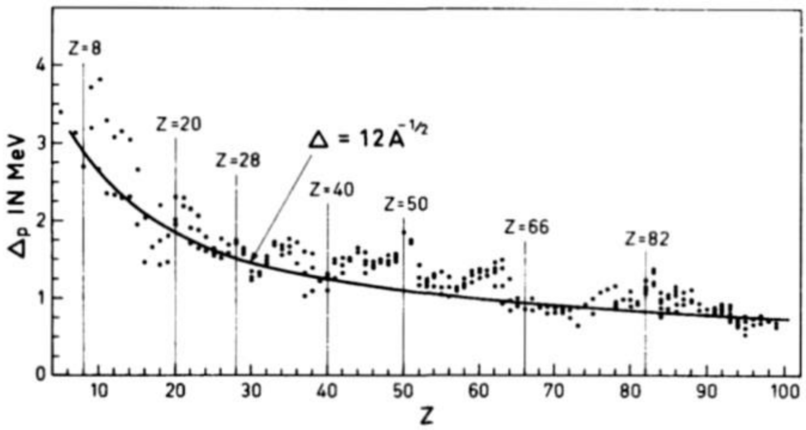

Figure 1. : *The odd-even mass differences for protons from Ref [1].*

Result and Discussion- The Gilbert-Cameron approach and the back-shifted Fermi gas model are widely used in practical calculations of nuclear level density. In the Gilbert-Cameron approach the energy shift and the temperature are treated as adjustable parameter to fit the experimental data and provide a better representation of nuclear level density at low excitation energy on the other hand the level density prescription given by back-shifted Fermi gas model woks reasonably well at higher energies, but it could not explain the variation of cumulative number of levels at the lower excitation data in this energy region. These factors could result in the uncertainty of the deducted level density for other spins. Therefore, it is important to use a different technique for acquiring the experimental level density that would cover wider excitation energy, spin and parity ranges.

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