Shell and asymmetry effects in nuclear statistical level densities

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Many nuclear properties can be described in terms of the statistical level density, ρ = $\rho(E,N,Z)$ as function of the total energy *E*, and number of neutrons *N* and protons *Z* in a nucleus. Within the semiclassical periodic orbit theory (POT), using the mean field approach, the level density was derived [1] within the micro-macroscopic approximation (MMA) beyond the Fermi gas (FG) model. We obtain $\rho \propto I_\nu(S)/S^\nu$, with $I_\nu(S)$ being the modified Bessel function of the entropy $S = 2(aU)^{1/2}$, where *U* is the excitation energy, and *a* is the level density parameter (LDP). With subscripts (n,p), the LDP is given in term of the single particle (s.p.) level density g(ε), where ε is the s.p. energy, by $a = \pi^2 g(\lambda)/6 = a_n + a_p$. The s.p. level density, $g(\varepsilon) = g_n + g_p \cong \tilde{g}(\varepsilon) + \delta g(\varepsilon)$, taken at the chemical potential, $\varepsilon = \lambda$ ($\lambda_n \approx \lambda_p \approx \lambda$), depends on shell structure through the periodic-orbit shell correction $\delta g(\varepsilon)$. When the contribution of $\delta g(\varepsilon)$ is small (named as case MMA1), one obtains the Bessel function order $\nu = (n+1)/2$, where n is the number of integrals of motion. Strong oscillating components $\delta g(\varepsilon)$ (case MMA2) lead to the value $\nu = (n+3)/2$. For large entropy S the MMA level density reaches the FG limit, $\rho \cong \exp(S)[1+O(1/S)]/(2\pi S^{2\nu+1})^{1/2}$, while for the case of small S (the case of small excitation energy U) the level density reaches the finite combinatorics limit $\rho(S) \cong \rho(0)\left[1+S^2/4(1+\nu)+O(S^4)\right]$.

In Fig. 1, we present some results of our calculations. The Figure shows a comparison of MMA approaches with our shell-structure FG (SFG) asymptotic for relatively large excitation energies U, and with the experimental data. These data are obtained by the sample method from the low energy states (LES) range below neutron resonances in ^{195}Pt (large number, L>>1, of very LES's below about 1 MeV) and in ^{196}Pt (for small number of LES's, L~1). The results for the MMA2b level density in ^{195}Pt (L>>1) and those for the close MMA2a and MMA1 (and SFG) approaches for ^{196}Pt (L~1) agree well with the experimental data. The values of inverse level density parameter (LDP) *K* , given by *K=A/a*, where *A* is the number of nucleons, are found to be significantly different from that of neutron resonances, due to major shell effects. We also investigated correlations of the shell corrections in *K(*A*)* with those in *δE(A)* as functions of particle numbers A within a large chain of the Pt isotopes.

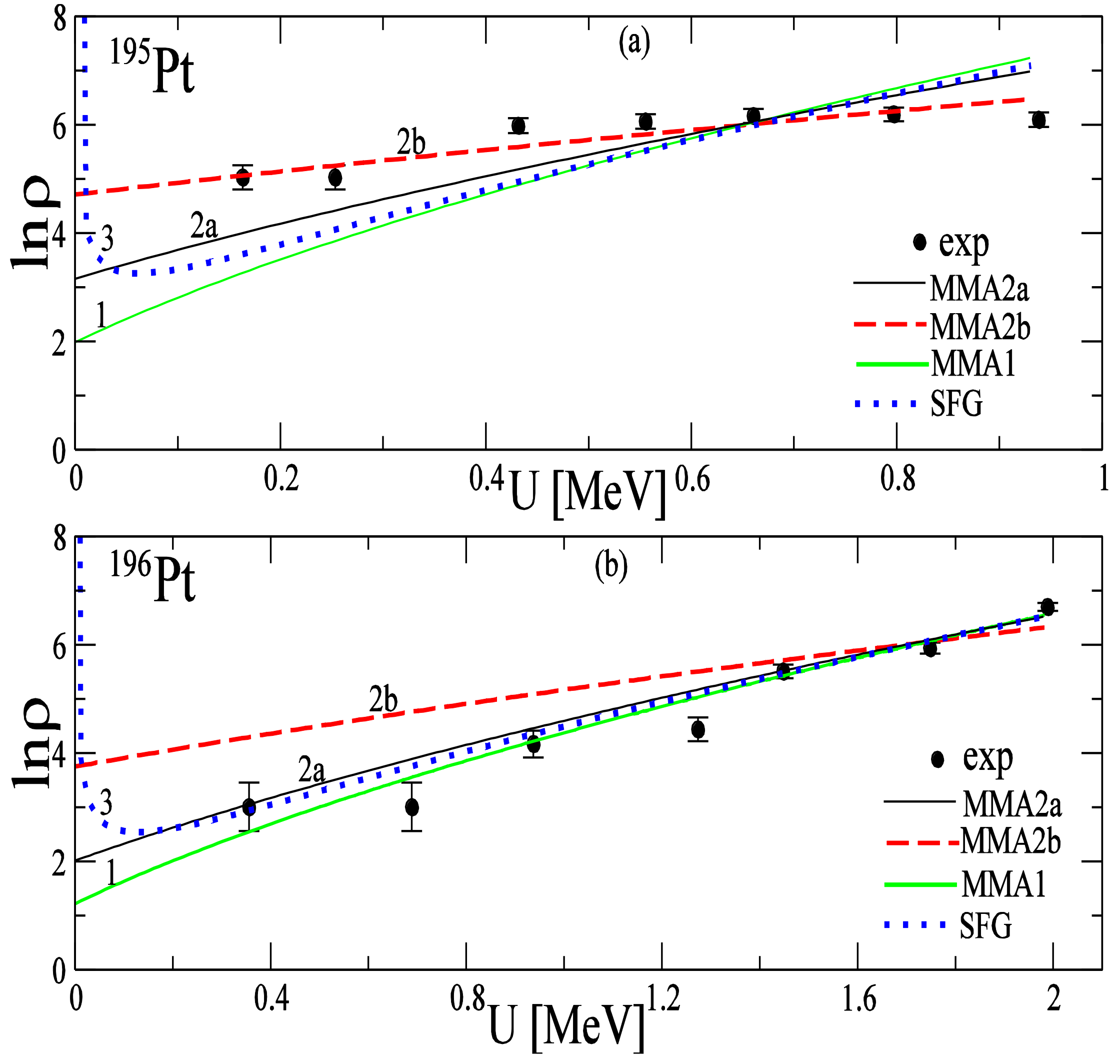

Fig. 1. Level densities, $\ln \rho$, for different MMA approaches. The MMA2a is the MMA2, taken at the fitted inverse level-density parameter, $K = A/a$, for energy shell corrections δE from Moeller *et al.* [2]. The MMA2b is that in the limit of small shell corrections δE but with large contributions of their derivatives. SFG is the shell-structure Fermi-gas asymtotic for large excitation energies U. Dots are the experimental data obtained by the sample method on the plateau conditions over inverse level density parameter K.

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[2] P. Moeller, A.J. Sierk, T, Ichikawa, and H. Sagawa, Atom. Data Nucl. Data Tables **109-110**, 1 (2016).