Statistical Tests of ^{238}U Resonance Parameters and Structure of Cross Sections in the Unresolved Range

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Accurate ^{238}U cross sections in the unresolved range are of primary importance for the design of fast reactors. A new evaluation of ^{238}U average cross sections in the unresolved range 20 – 300 keV is in progress at the Oak Ridge National Laboratory (ORNL) and at the Commissariat à l'Energie Atomique (CEA). Unresolved range evaluations are traditionnaly based on the statistical theories of nuclear spectra [1] and on statistical model of nuclear reaction originally developed by Hauser, Feschbach and Moldauer [2]. The purpose of this work is to investigate these models by analyzing the latest ^{238}U neutron resolved-resonance data (thermal to 20 keV) and the cross-section experimental measurements in the unresolved range (below 150 keV).

First, several statistical tests are applied to the ^{238}U resonance parameters (energies and neutron widths of s and p waves) below 20 keV, recently evaluated by ORNL [3]. Statistical properties of the ORNL set are compared with expected properties of orthogonal ensemble (OE) theories, which describe the compound nuclear states in terms of real symmetric matrices. The Gaussian orthogonal ensemble (GOE), in which elements of the matrices are random Gaussian distributed and circular orthogonal ensemble (COE) developed by Dyson and coworkers, are examined for level spacings and reduced neutron widths. The long-range correlations between levels predicted by COE are studied through the usual Δ_3 statistics [4] and short range correlations are measured by the linear correlation coefficient between nearest neighbor level spacing $\rho(S_i, S_{i+1})$. The results presented in this paper do not show any significant deviations of the prediction from COE below 5 keV for s-wave resonances as shown in Table 1.

The F-statistic developed by Dyson [5] and other classic missing-level estimators are also used to detect the presence of missing or spurious levels. This analysis permits the determination of the ^{238}U strength functions S_0 and S_1 for s- and p-wave resonances as well as the level spacing D_0.

Fluctuations of total and capture cross sections in the unresolved range (20 – 100 keV) have been measured at the Oak Ridge Electron Linear Accelerator (ORELA) and are briefly presented (see Figure 1). Statistical tests are performed to determine if the fluctuations observed in cross sections are consistent with the statistical model or if the fluctuations indicate the presence of intermediate structure effects (presence of special

Table 1: Calculated Δ_3 and $\rho(S_i, S_{i+1})$ on ^{238}U s-wave population compared with COE theoretical predictions

Energy range	ρ (theory = -0.27)	Δ_3 exp.	Δ_3 theory
0 - 500 eV	-0.28	0.216	0.315 ± 0.11
0 - 1 keV	-0.21	0.254	0.383 ± 0.11
0 - 3 keV	-0.31	0.471	0.494 ± 0.11
0 - 5 keV	-0.29	0.765	0.545 ± 0.11
0 - 10 keV	-0.25	1.595	0.616 ± 0.11

nuclear states or doorway states). Autocorrelation functions are computed to detect if the experimental cross sections show correlation longer than those predicted by statistical theory, and the Wald-Wolfowitz statistic [6], used to detect intermediate structures, is also applied to experimental data.

The structures in the cross section studied in this work are not represented in the existing ^{238}U evaluations. In the present approach, an energy-dependent strength function S_0 and average radiative widths $< \Gamma_\gamma >$ within the standard Hauser-Feschbach-Moldauer model as implemented in the SAMMY code [7] are fitted to the experimental data (capture and transmission) to improve the representation of the ^{238}U cross section in the unresolved range. The impact of this structure on reactor calculations (e.g, k_{eff}, reaction rate, self-shielding factors) is not yet known and remains to be assessed.

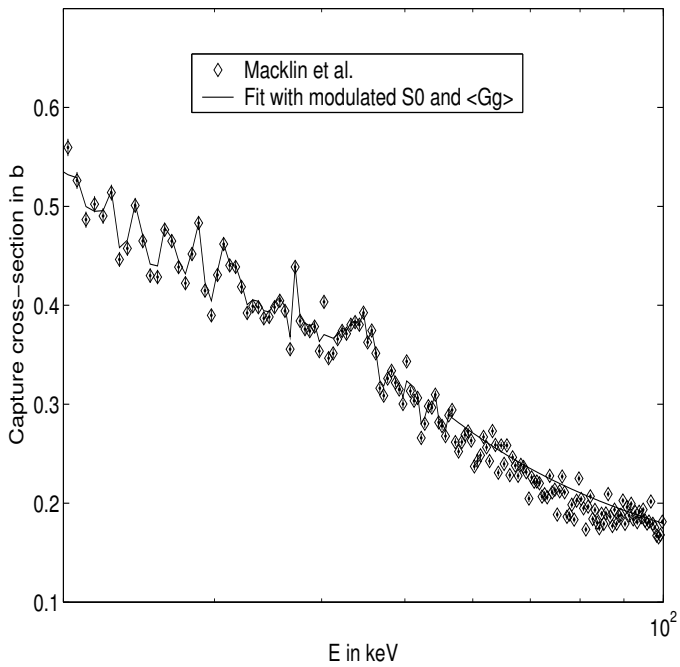

Figure 1: ^{238}U capture cross section measured by Macklin et al. [8] and fitted with the Hauser-Feschbach-Moldauer model of SAMMY using fluctuating s-wave neutron strength function and radiative widths

References

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