NONSTATISTICAL EFFECTS

IN RESONANCES OF HEAVY NUCLEI

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50 ЛЕТ НА ПИКЕ НАУКИ

Introduction

In a report [1] at the First Geneva Conference (1955) of the Atomic Energy Institute (Kurchatov Institute, Moscow), attention was turned to the proximity of positions of neutron resonances of different isotopes (E_n grouping at ≈ 0.3 eV).

This effect was studied later by Yu. Konakhovich and M. Pevsner in ^{229}Th [2], but finally no resonance at such an energy was found in this isotope.

Similar groping effects in resonance spacing distributions at D = 11.1 - 16.6 - 27.7 – 33 – 187 eV (k =2, 3, 5, 6, 2×17) of strong resonances of ^{236}U and ^{239}U (with k - multiplicity of 5.5 eV) was observed [3-6].

The first time such an effect was considered by W. Havens [3].

In the case of similar stable intervals D = 99 eV = 18 × 5.5 eV in the resonance spacing distributions of three neighbouring isotopes ^{241,243,245}Pu (Fig. 1a [4]), we can notice that the doubled value of stable 2^+ excitations in these isotopes (42.8 - 42.0 - 44.5 - 44.2 keV in ^{240,241,242,244}Pu, see Table 1) is in the ratio 99(1) eV / 86(2)keV = =115·10^{-5}, close to $\alpha/2\pi$ = 116·10^{-5}, QED radiative correction. Such superfine structure intervals have been observed in many heavy nuclei [4-6].

Table 1. Excitations in heavy nuclei close to 42.5 keV=$\varepsilon_o/24$ and m(85 keV=$\varepsilon_o/12$).

Nucleus	^{229}Th	^{230}Th	^{230}Th	^{231}Th	^{232}U		^{234}U			^{236}U	
J_o^π, J_i^π	$\frac{5}{2}^+,\frac{7}{2}^+$	$0^+,8^+$	D	$\frac{5}{2}^+,\frac{7}{2}^+$	$0^+,2^+$	$0^+,12^+$	2^+	8^+	12^+	$0^+,2^+$	8^+
E^*,keV	$\boxed{42.5}$	594	594	$\boxed{42.0}$	47.6	1111	43.5	$\boxed{497}$	1024	45.2	$\boxed{522}$
m	1/2	7	7	1/2	(1/2)	13	1/2	6	12	1/2	12
m·85 keV	42.5	595	595	42.5	42.5	1112	42.5	511	1022	42.5	511
Nucleus	^{236}U		^{237}U	^{238}U			^{239}U				^{240}U
J_o^π, J_i^π	D	D	$\frac{1}{2}^+,\frac{17}{2}^+$	$0^+,2^+$	8^+	D	$\frac{5}{2}^+,\frac{7}{2}^+$	D	D	D	$0^+,2^+$
E^*,keV	512	1022	$\boxed{518}$	44.9	$\boxed{518}$	512	$\boxed{42.5}$	43	87	170	45(1)
m	6	12	6	1/2	6	6	1/2	1/2	1	2	(1/2)
m·85 keV	511	1022	511	42.5	511	511	42.5	42.5	85	170	42.5
Nucleus	^{236}Pu		^{236}Pu		^{240}Pu		^{241}Pu	^{242}Pu		^{244}Pu	
J_o^π, J_i^π	$0^+,2^+$	8^+	$0^+,2^+$	8^+	$0^+,2^+$	8^+	$\frac{5}{2}^+,\frac{7}{2}^+$	$0^+,2^+$	8^+	2^+	8^+
E^*,keV	44.6	$\boxed{516}$	44.1	$\boxed{514}$	$\boxed{42.8}$	497	$\boxed{42.0}$	44.5	$\boxed{518}$	44.2	535
m	1/2	6	1/2	6	1/2	6	1/2	1/2	6	1/2	6
m·85 keV	42.5	511	42.5	511	42.5	511	42.5	42.5	511	42.5	511

The possibility to check the common dynamics of the influence of physical condensate within a nuclear medium should be studied in different regions of the nuclear chart. In regions with stable collective excitations, such an analysis could be based on the expected relation between the well-established fine structure ($D=k\times 5.5$ eV) and the hyperfine structure corresponding to third-order effects with QED radiative correction parameter $\alpha/2\pi$.

Stable superfine structure intervals (1.32-1.48 eV in ^{238}Np, close to

5.5 eV/4 = 1.38 eV = ε'') are connected with stable intervals of hyperfine

structure $\varepsilon_o \cdot \alpha/2\pi^3$ corresponding to stable $E(8^+) = \varepsilon_o/2 \approx 511$ keV

(497 – 522 = 518 – 518 – 516 – 514 – 497 - 518 keV in ^{234,236,237,238}U, ^{236,238,240,242}Pu).

From the relation 6:20:42:72 for excitations with *J*=2, 4, 6, 8 one can expect

the possible appearance of an additional hyperfine structure with the value

(1.38 eV/72)×(6, 20, 42) or 100 meV, 400 meV and 800 meV. Intervals of the

hyperfine structure of the order of 300-400 meV, observed as resonance

positions in isotopes with Z=92-95, can be associated with the stability

of 4^+ and 6^+ excitations in heavy nuclei.

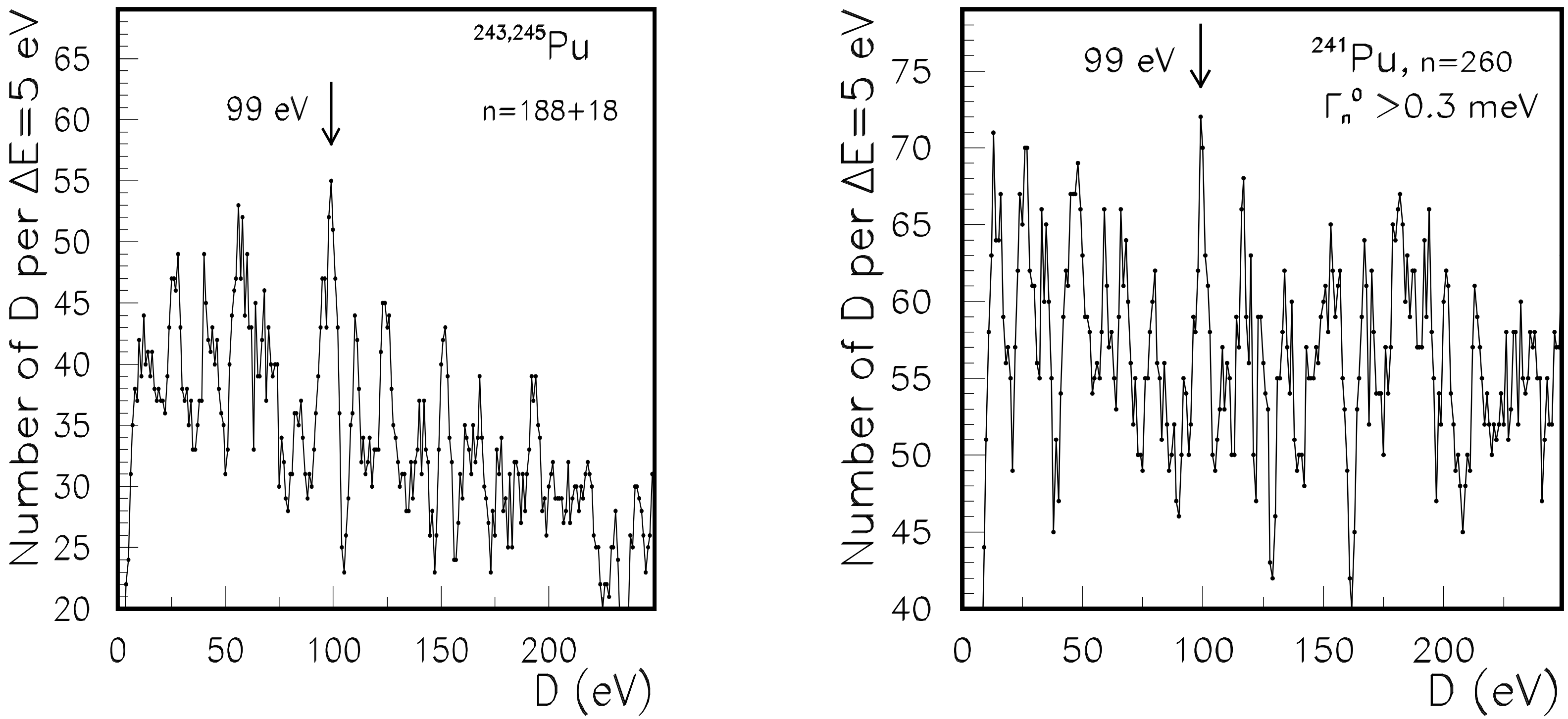

Figure 1a.

D - distributions in neutron resonances of heavy compound nuclei [4].

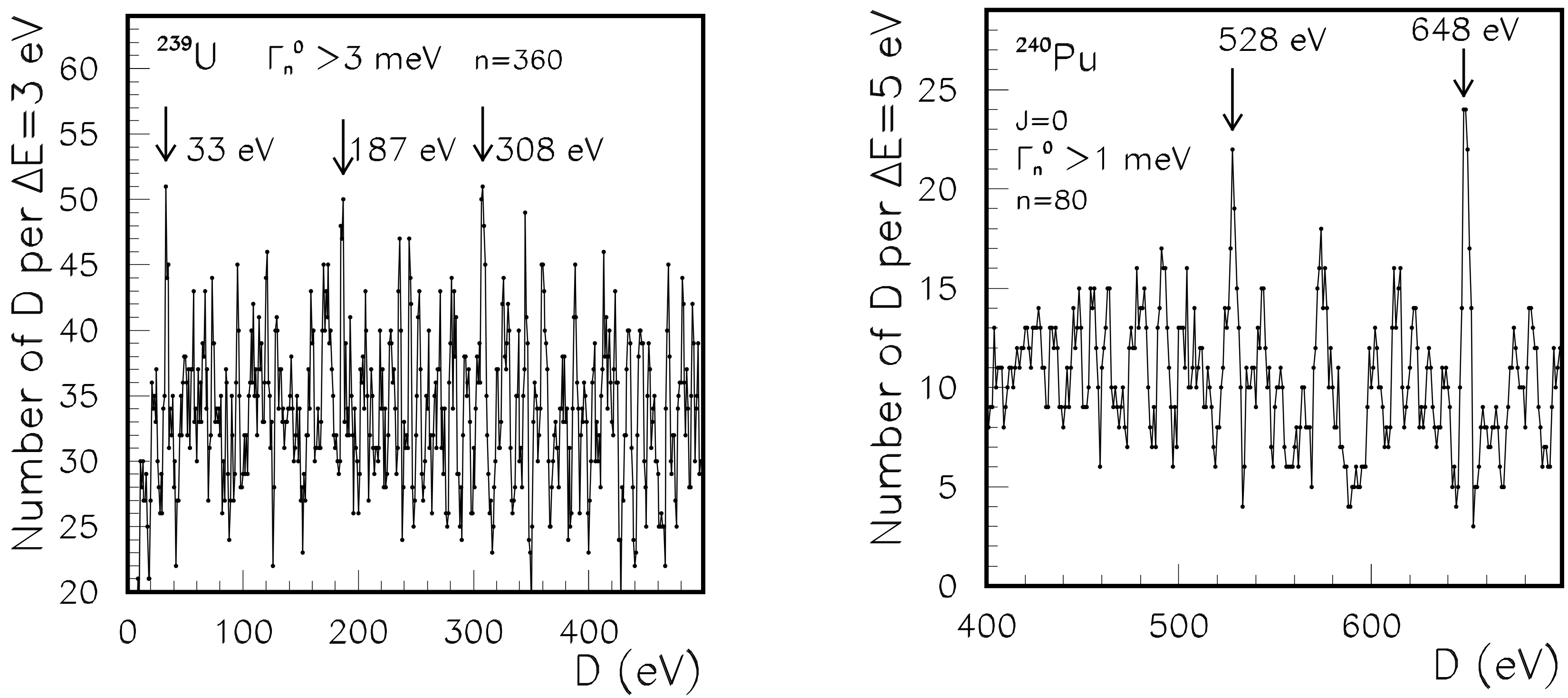

Figure 1b.

D - distributions in neutron resonances of heavy compound nuclei [4].

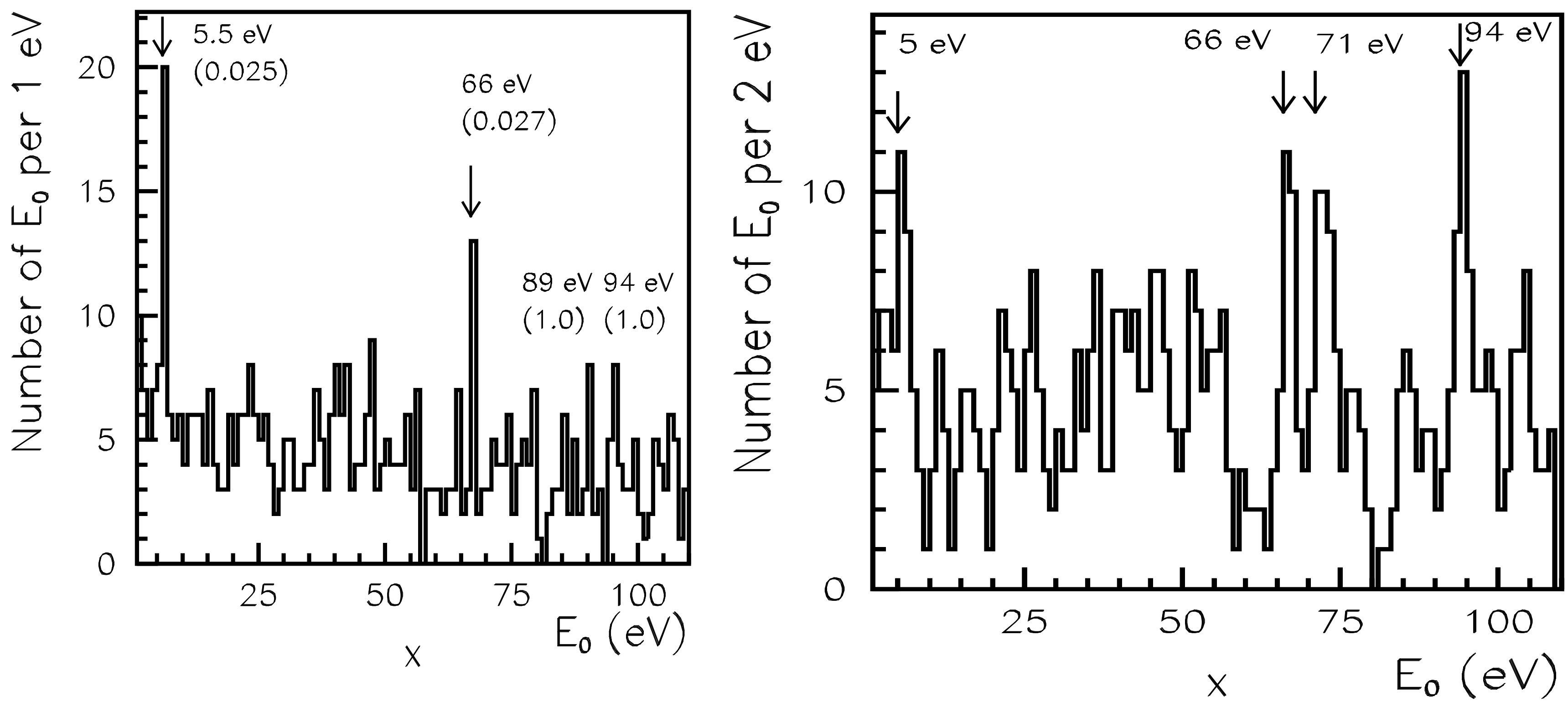

Figure 2a, b. Distribution of neutron resonance positions (known in 1970ties) by selection of one resonance (max Γ^o_n) in the interval 10 eV and 100 eV [5,6].

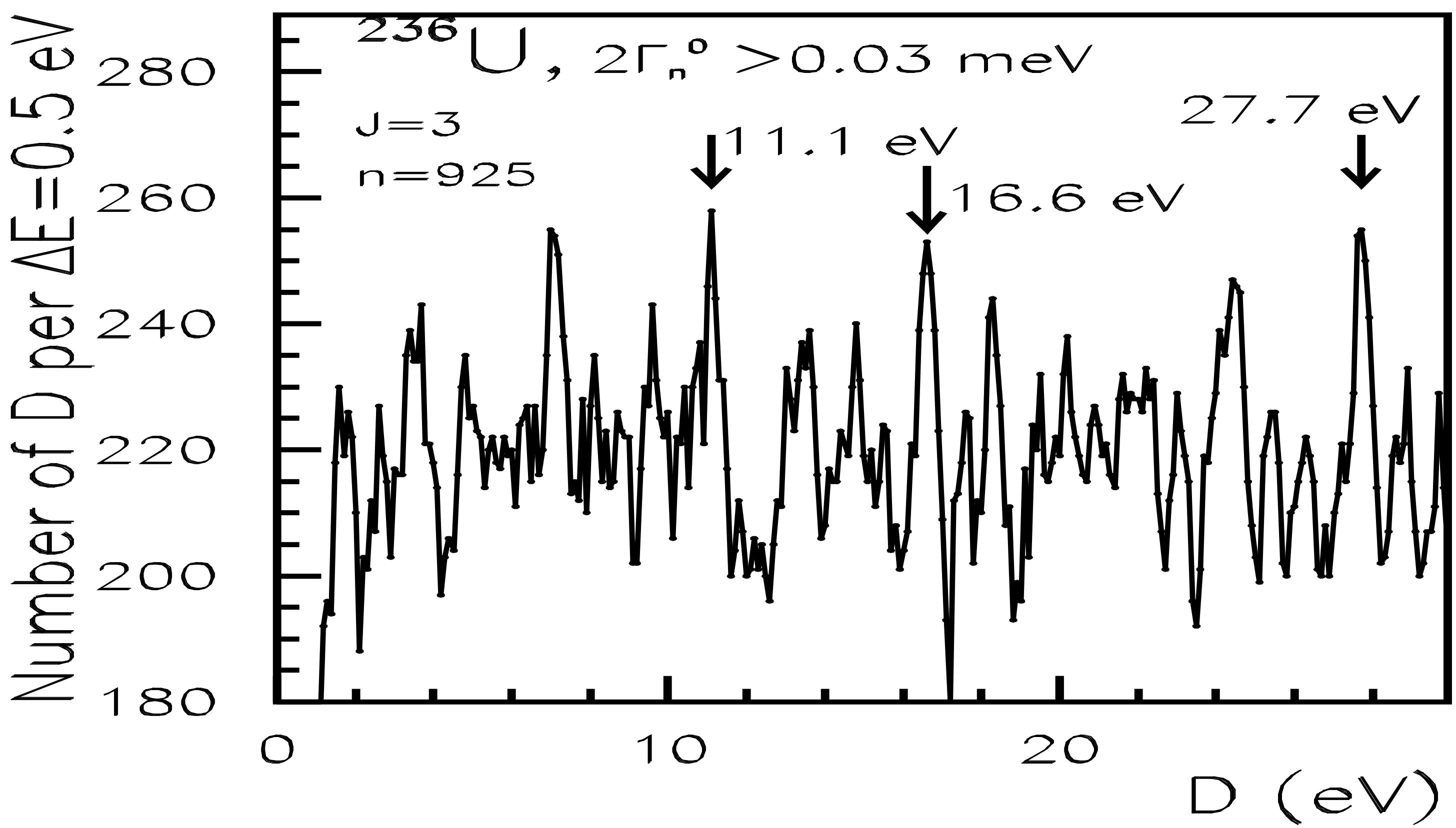

Figure 2c. Spacing distribution in *J* = 3 resonances of ^{235}U (n=1, 2, 3, 5, 12, 13 and17 of the period 5.5 eV = δ''/2 are marked) [4].

We show that a grouping of such small intervals in resonance spacing and resonance positions (hyperfine structure) can be considered as the next order effects in the spectra of nuclei where superfine structure (with intervals of the order of 1 eV and larger) takes place, this time in heavy isotopes with Z = 92, 94.

A presence of grouping effect at 5.5 eV, 66 eV and 94 eV (*k*=1, 12 and 17 of the period 5.5 eV) in the positions of resonances (Figure 2) was noticed.

Conclusions

The well-known effect of stability of low-lying excitations in heavy nuclei was used in this work to confirm the discreteness in the neutron resonance spacing distributions due to the possible influence of physical condensate considered by D. Schirkov [7].

References

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