FUNDAMENTAL ASPECTS OF NEUTRON SPECTROSCOPY

S.I. Sukhoruchkin, Z.N. Soroko, M.S. Sukhoruchkina

Petersburg Nuclear Physics Institute NRC "Kurchatov Institute"
Gatchina

50 ЛЕТ НА ПИКЕ НАУКИ

Neutron resonance spectroscopy provides data on a large number of highly excited states. This information can be used to check nuclear microscopic models, including the Nonrelativistic Constituent Quark Model (NRCQM), which R. Feynman considered as very successful.

A global extension of NRCQM, called the
Electron-based Constituent Quark Model (ECQM),

combines the properties of hadrons and leptons with the universal character of the influence of physical condensate (vacuum) and provides a possibility to estimate the discreteness in nuclear excitations and binding energies, as well as nonstatistical effects in the neutron resonance positions and spacing distributions.

We show a systematic character of these effects, connected with a presence of CODATA relations for nucleon masses, manifested in the proximity to $\alpha/2\pi$ of exact value of the ratio of parameters of fine and single-particle structures and expected systematics in superfine structure in neutron resonances.

The properties of the ECQM model (the electron mass as a unique parameter, its symmetry and QED radiative correction to the particle masses) have been considered in many nuclei.

Here we discuss recent results obtained for nuclei Z = 58 - 64. In these nuclei with closed shells N = 82 and N = 90, stable intervals were found that are multiples of the value of

the first fine structure parameter $m_e/3$ = 170 keV, namely,

in ^{141}Ce resonances *D* = 21.7-43.1-86.2 keV = 170 keV/2,

stable 0^+ excitations in ^{150}Nd, ^{152}Sm,

^{154}Gd (675, 684, 681 keV = 4×170 keV) (see Fig.1).

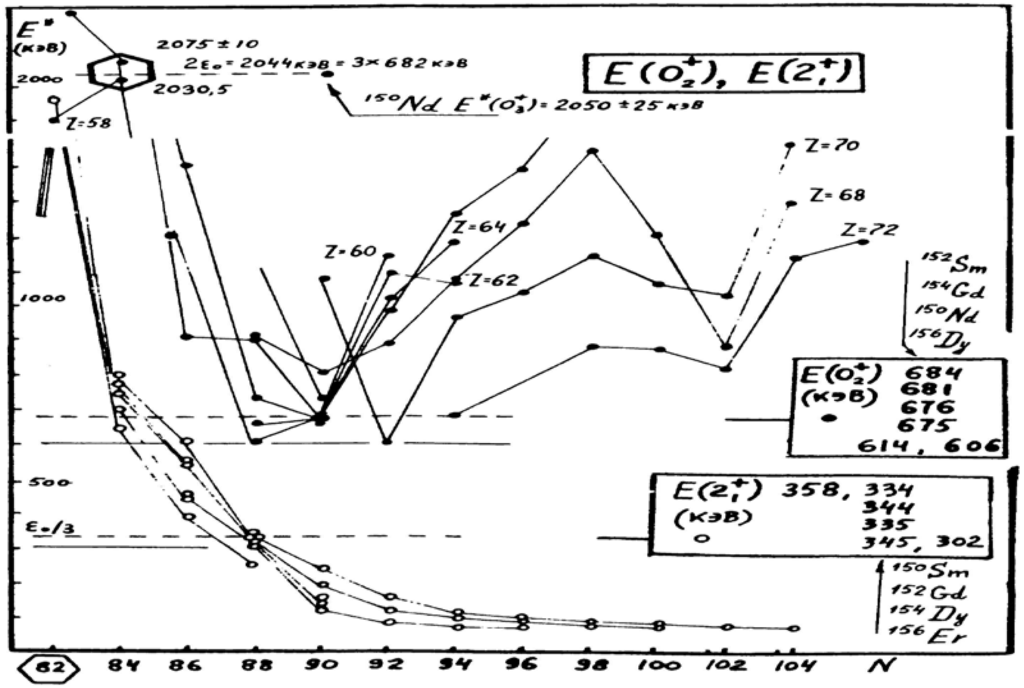

Figure **1.** Bunching of energies of 0^+ excitations of nuclei with the number of neutrons 90 (filled $2f_{7/2}$ neutron subshell) at a value of 2/3 ε_o = 682 keV. The values of the excitations are indicated by dark circles and are connected by lines for each serial number with the corresponding *Z* on the right side. In the same nuclei (with the number of neutrons N = 62-104), the first excitations (2^+) are shown in the figure with light circles. When the number of neutrons is 88 = 90-2, the grouping of the values of 2^+ excitations occurs at a value of 340 keV = ε_o / 3. The ε_o / 3, (2/3) ε_o / 3 and 2 ε_o energy levels are shown with dashed lines. The top of the figure shows the closeness to 2 ε_o of the energies of the levels the nuclei ^{132}Ce (N = 84 = 82 + 2) and ^{150}Nd (N=90).

Additionally, it was noticed, that in near-magic ^{145}Sm a single-

particle (J=7/2-11/2) excitation E^*=1538 keV≈3m_e is close to

stable nuclear interval 3.67 MeV, observed in spectra of many nuclei.

Simultaneously, in the positions of the strong neutron resonances of the magic ^{141}Ce,
the exact ratio 9:4=21.6 keV : 9.57 keV was found by M. Ohkubo (common period 21.6+9.6 keV/9+4=2.4 keV=2ε').

In this work, we show that in D-distributions of neutron resonances in ^{145}Sm (for orbital momenta L=0 and 1, see Fig. 2 top and bottom), the maxima are located exactly at 3ε' and 2ε'.

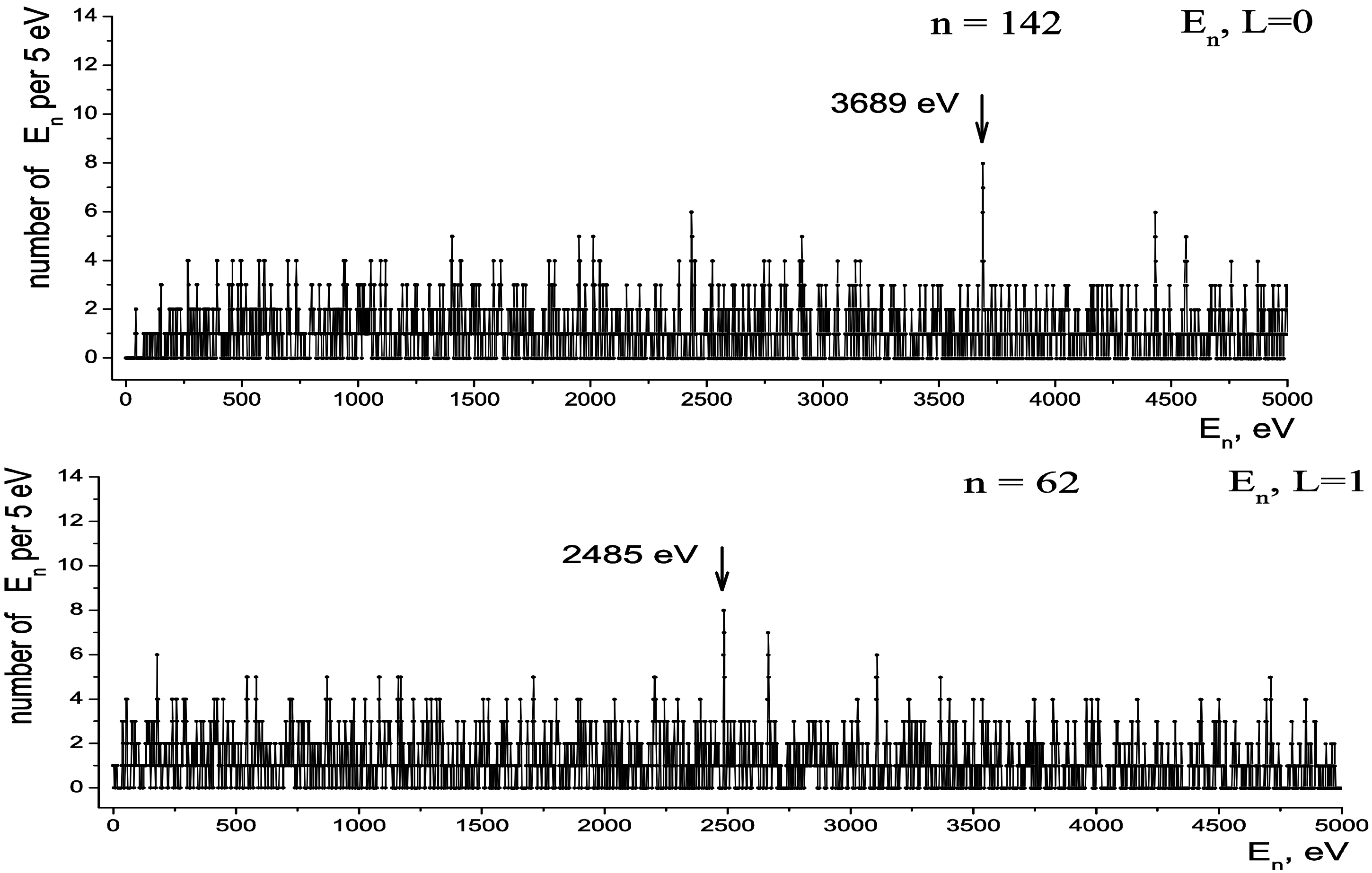

Figure **2**. Spacing distributions of neutron resonances in ^{145}Sm (for orbital momenta L=0 and L=1 with maxima at 3ε' and 2ε', the ratio 3689 eV/2485 eV = 1.48 ≈ 3/2, period ε'=1.229 keV).

An example of superfine structure in spacing distribution of strong neutron resonances (corresponding to highly excited states with relatively simple structure of the wave-function) was found in the nucleus ^{238}Np.

Selecting neutron resonance reduced widths larger than 50 and 100 μeV we obtained spacing distributions shown in Figures 4-6.

From the proximity of positions of the doublet of resonances at 1.32 and 1.48 eV 5.6 eV to ε'' = 5.5 eV/4 = 1.38 eV, and the position of the strongest resonance (Γ^{o}_{n} = 218 μeV) at 5.78 eV to 5.5 eV we see that stable intervals 4.1 eV, 5.6 eV and 16.4 eV are close to $3\varepsilon''$, $4\varepsilon''$ and $12\varepsilon''$.

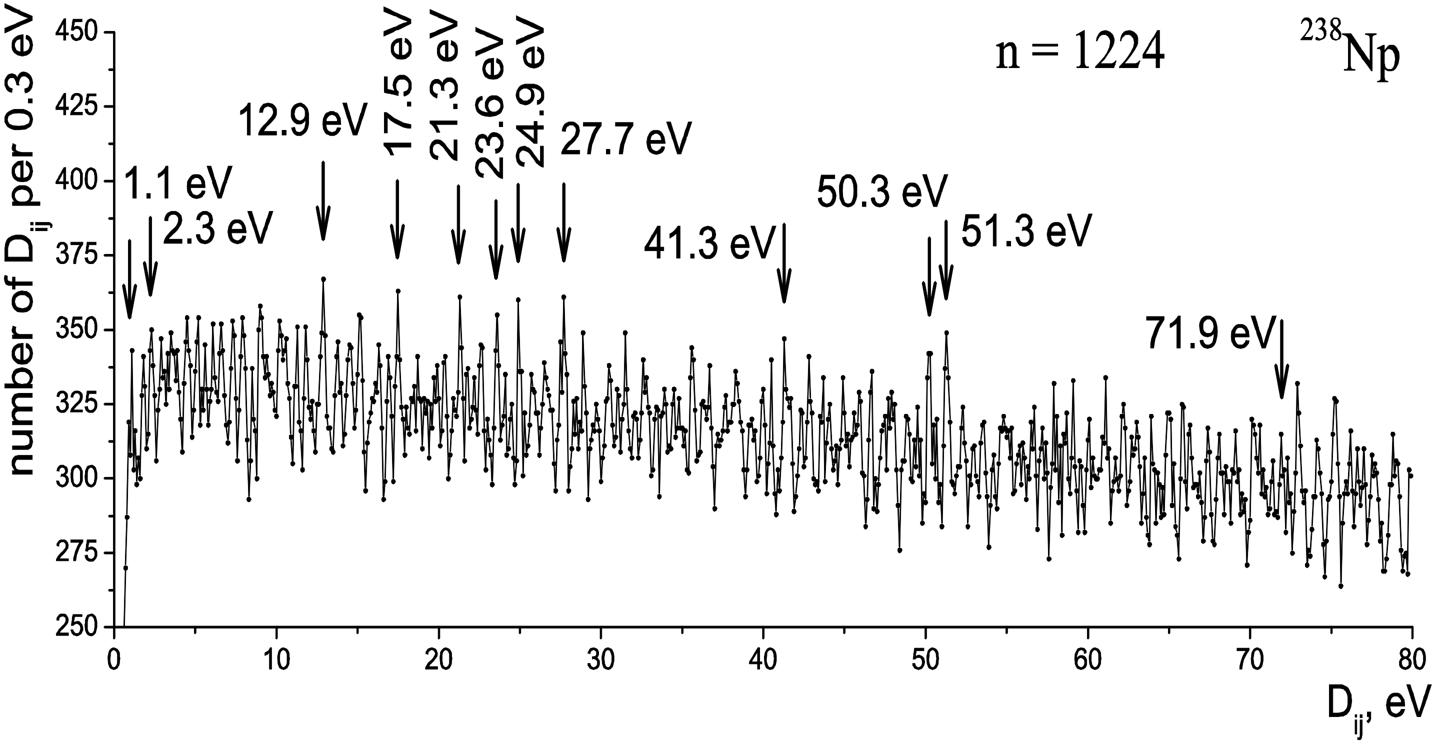

Figure **3**. Total spacing distribution of all resonances in ^{238}Np.

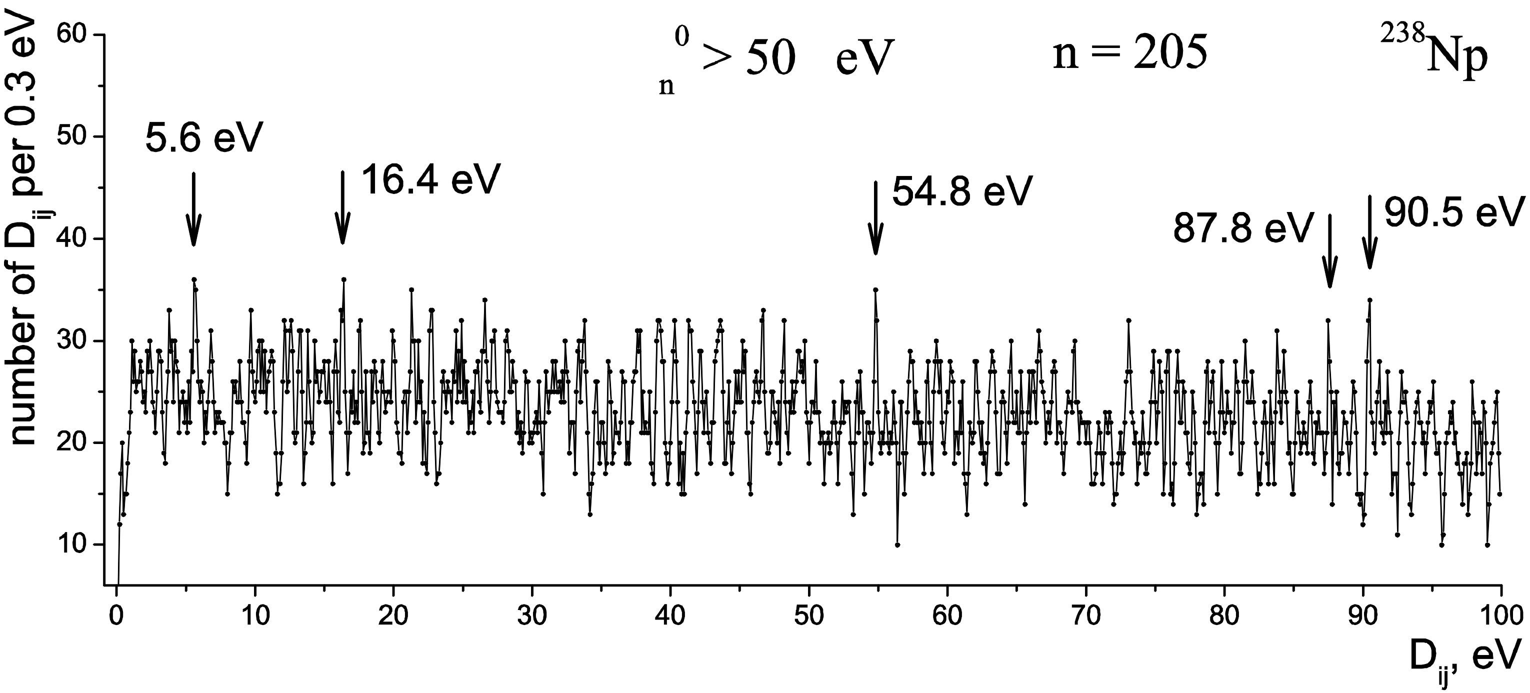

Figure **4**. Spacing distribution of resonances in ^{238}Np with $\Gamma^o_n \geq 50$ μeV.

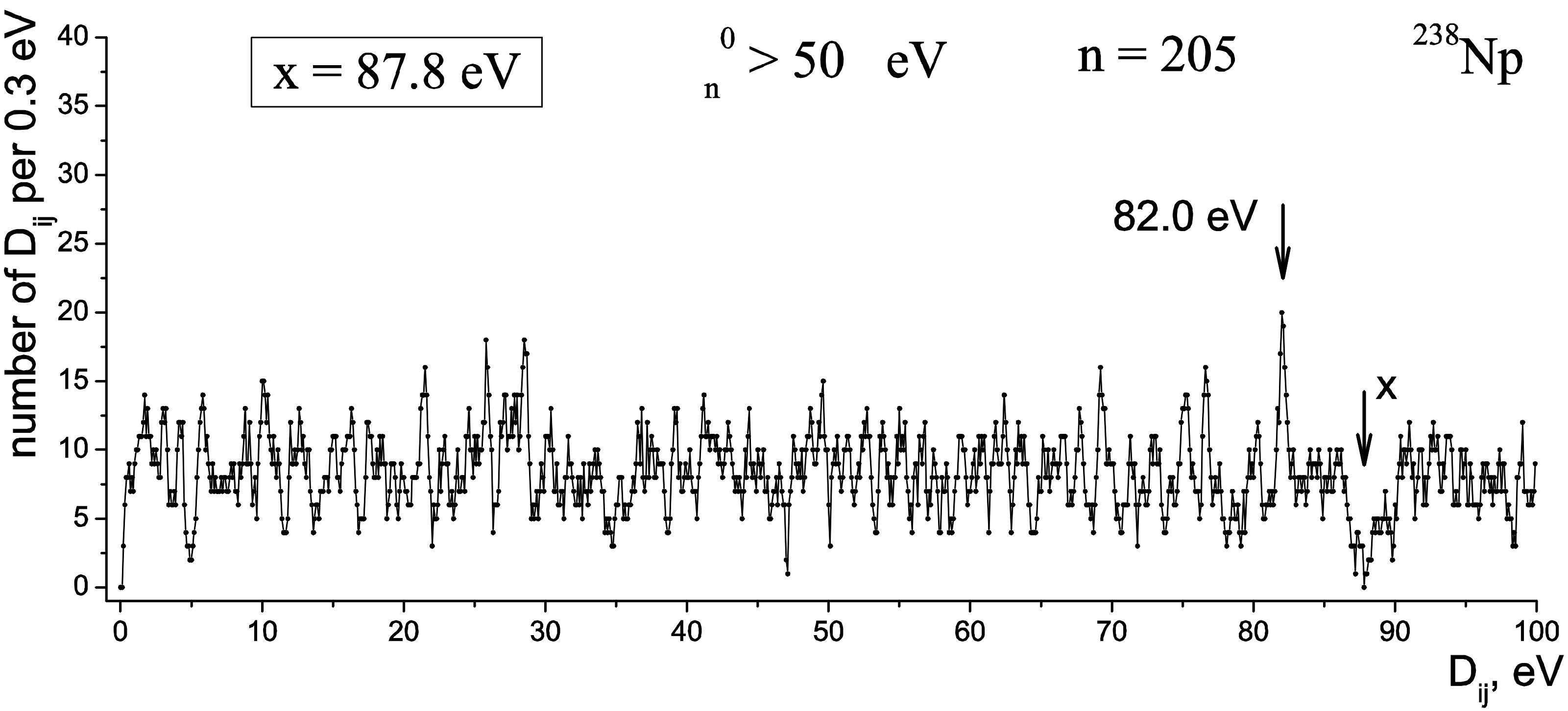

Figure **5**. Adjacent spacing distribution of resonances in ^{238}Np with $\Gamma^{o}_{n} \geq 50$ μeV for the fixed interval x=87.8 eV.

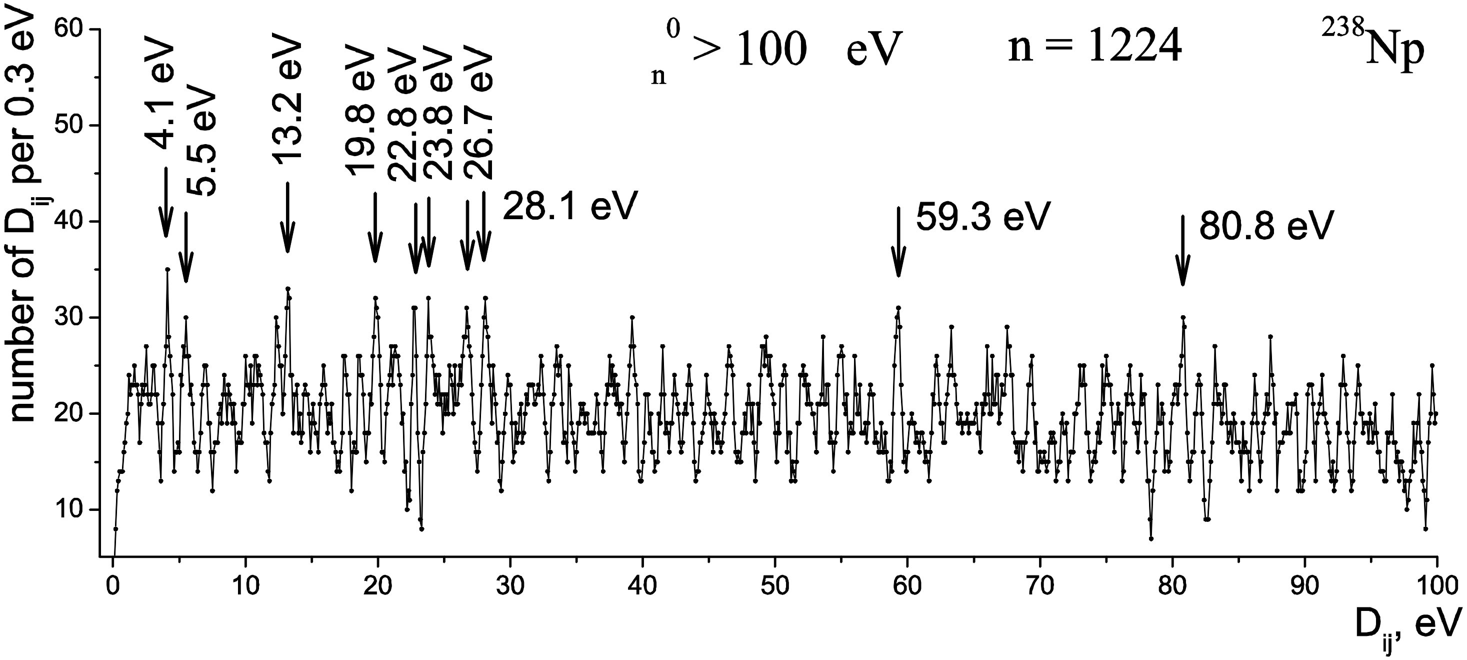

Figure **6**. Spacing distribution of resonances in ^{238}Np with $\Gamma^{o}_{n} \geq 100$ μeV.