NUCLEAR DATA AND THE STANDARD MODEL PARAMETRS

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We consider fundamental aspects of nuclear physics and particle mass spectrum.

The Standard Model with representation:

$SU(3)_{col} \times SU(2)_L \times U(1)_Y$ [1]

is the basic theory of all interactions.
The Nonrelativistic Constituent Quark Model is a part of hadronic physics – an important component of the Standard model.

The main NRCQM parameters are the pion mass m_π = 140 MeV, initial baryon constituent quark mass $M_q = m_\Xi / 3 = m_e(\alpha/2\pi)^{-1}$ = 441 MeV, introduced as "gammon" by P. Kropotkin. It is coincidence of the ratios between the electron mass m_e (the main SM parameter) and the constituent quark mass M_q with QED radiative correction $\alpha/2\pi = 115.96 \cdot 10^{-5}$.

The standard estimate of the constituent quark mass is $M^\omega{}_q = m_\omega/2$ = 391 MeV.

It was introduced by G. Wick and confirmed by observation of exact presentation of lepton and nucleon masses. These relations contain integer representation of particle masses with a period $16m_e=\delta$, derived directly from pions mass splitting and muon and pion masses $m_\mu=13\delta - m_e$, $f_\pi=130$ MeV $= 16\delta$ and $m_\pi = 17\delta + m_e$. Constituent quark masses are represented: $M^\omega{}_q = 3\cdot16\delta = 48\delta$ and $M_q = 3\cdot18\delta = 54\delta$.

Besides representation of particle masses with a period $16m_e$, a very accurate relation between parameters of the Standard and NRCQM models were observed. This second aspect of particle mass correlation is seen, for example, in the mass of the third lepton m_τ =1776.86(12) MeV, which is exactly twice the sum of m_μ and $M^\omega{}_q$=1776.62(24) MeV. All these values are shown in Fig. 1.

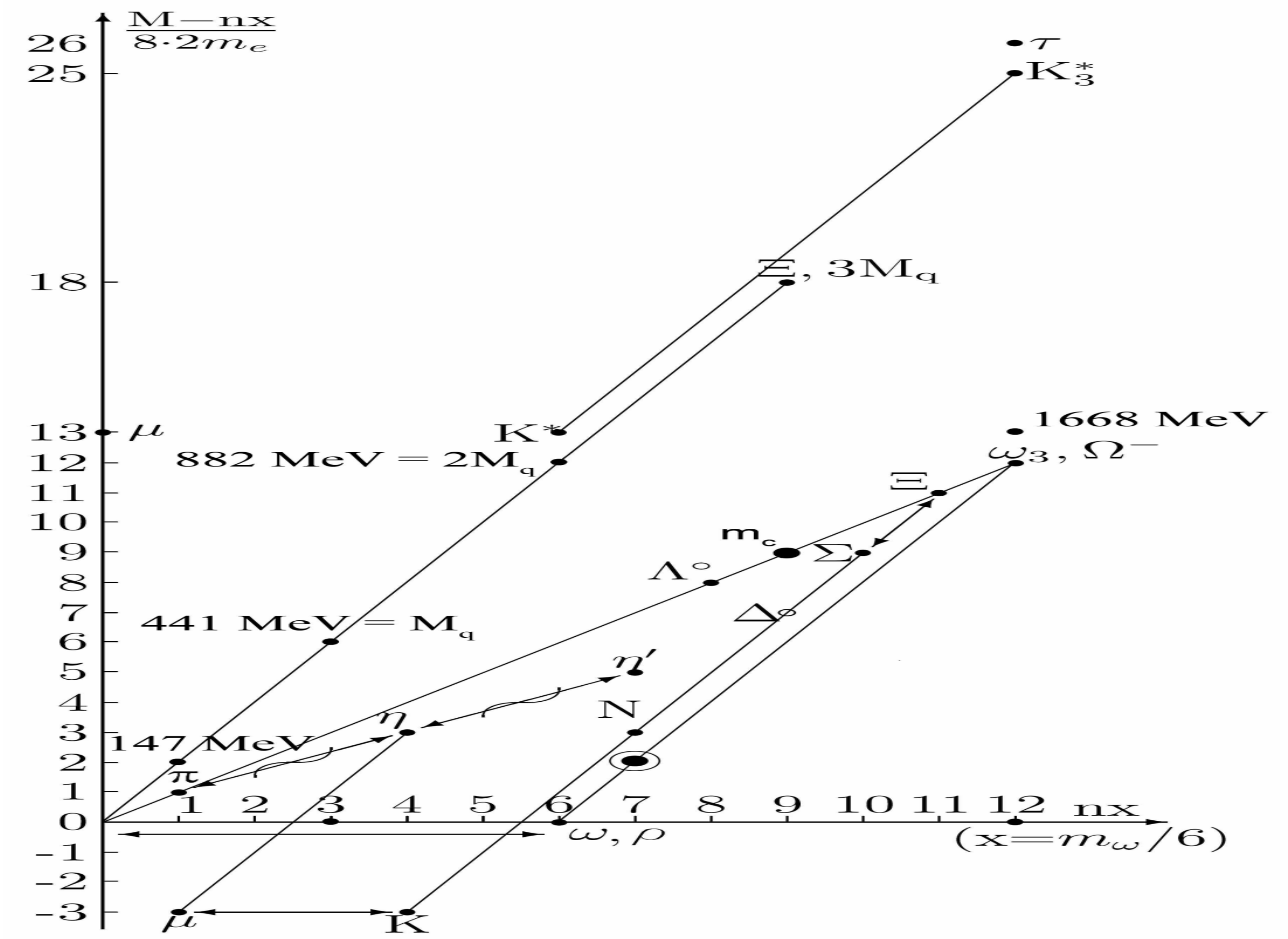


Fig. 1. Two-dimensional representation of particle masses and NRCQM parameters.

The evolution of the baryon mass from $3M_q$ to Δ-baryon and nucleon masses is shown here in a two-dimensional representation: the values on the horizontal axis are given in units $16\cdot16m_e = f_\pi=130.7$ MeV, remainders $M_i\text{-}n(16\cdot16m_e)$ are along the vertical axis in units $16m_e$. Lines with three different slopes correspond to the three pion parameters $f_\pi=16\delta$, $m_{\pi\pm}=17\delta$ and $\Delta M_\Delta=18\delta$. The line with $m_\pi=140$ MeV$=f_\pi+\delta$ (N=16+1) passes through the masses of Λ-, Ξ-, Ω-hyperons (=$8m_\pi$, $11m_\pi$, $12m_\pi$). The stable interval in the pseudoscalar mesons $m_{\eta'}-m_\eta=m_\eta-m_{\pi\pm}$ (crossed arrows) is close to $M^{\Delta q}$=410 MeV$=m_d/3=50\ \delta$. The nucleon mass in the nuclear medium (m_{nucl}, circled point) is close to the sum of $\Delta M_\Delta+6f_\pi$, which corresponds to the important role of the pion parameters f_π and ΔM_Δ. The values $3M_q=9\ \Delta M_\Delta$ and $6f_\pi+\Delta M_\Delta$ are the initial and final stages of the nucleon mass evolution. The mass of the charmed quark $m_c=9m_\pi$ is marked on the line between the pion (π) and Ω^-.

The second example of high accuracy relations in massses of nucleons is their representation by integers m_e and an additional shift dm = k ($\delta m_N/8$) with k = 1 and 9 for neutron and proton, respectively (CODATA relations [1] with $\delta m_N = m_n - m_p$):

$m_n = 115 \cdot 16 m_e - m_e - \delta m_N/8$;

$m_p = 115 \cdot 16 m_e - m_e - 9(\delta m_N/8)$;

The initial shift dm = 161 keV is

$dm_\pi = (\alpha/2\pi) m_\pi$, the QED correction to m_π.

The analysis of particle masses and nonstatistical effects in nuclear data, carried out in the 1960s, showed that the QED radiative correction $\alpha/2\pi = 116\cdot10^{-5}$ (together with fermion masses) is an important SM parameter and is responsible for the influence of physical vacuum on the magnetic moment and particle mass [1,2]. Neutron resonance data are important in confirmation of QED radiative correction.

In 1970ties, the same relationship with QED correction was found empirically between the stable intervals of superfine ($\varepsilon`` = 1.34$ eV = 5.5 eV/4) and fine ($\varepsilon` = 1.2$ keV) structures in neutron resonances and nuclear levels in the works of IAE and ITEP (under direction of I. V. Kurchatov and A.I. Alikhanov).

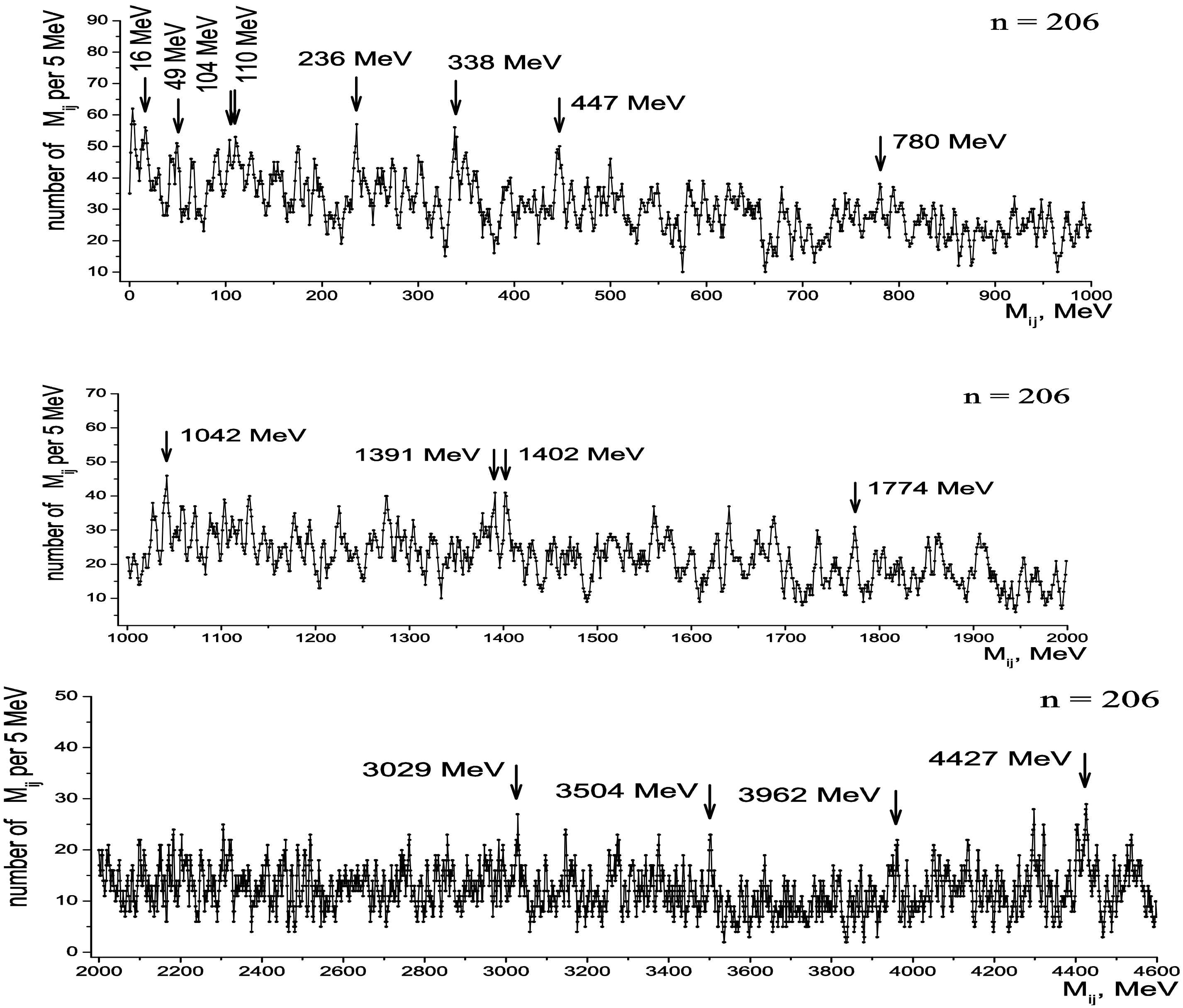
Stable nuclear intervals 161 keV=$\delta m_N/8$, 1293 keV= δm_N and 3067 keV= $6m_e$ were found as maxima in independent spacing distributions in many nuclei.

The mass of u-quark $m_u = 2.16(49)$ MeV close to $3m_e = 1.53$ MeV.

The mass of d-quark $m_d = 4.67(18)$ MeV is close to $9m_e = 4.599$ MeV.

The mass of c-quark $m_c = 1270(20)$ MeV is close to $9m_\pi$, and the mass of b-quark m_b=4180(30) MeV is close to $9M_q$.

The third aspect of observed correlations in particle masses and nuclear data consist in their global character, i.e., sum distributions allow to determine stable mass-energy intervals close or rational to the well-known parameters of the Standard and NRCQM models (particle masses and the constituent quark masses). Results of combined analysis of particle masses (Fig. 2) and nuclear excitations (Fig. 3) are given.



n = 206
number of M_{ij} per 5 MeV
16 MeV
49 MeV
104 MeV
110 MeV
236 MeV
338 MeV
447 MeV
780 MeV
M_{ij}, MeV
n = 206
number of M_{ij} per 5 MeV
1042 MeV
1391 MeV
1402 MeV
1774 MeV
M_{ij}, MeV
n = 206
number of M_{ij} per 5 MeV
3029 MeV
3504 MeV
3962 MeV
4427 MeV
M_{ij}, MeV

Fig. 2.

Вверху:
Δ M - распределение всех разностей масс частиц из PDG-2021 (интервал усреднения 5 МэВ) в области 0—1000 МэВ. Максимумы при 16 МэВ=2δ, 49 MeV=6δ, 338 MeV ≈ $m_\omega - M_q$, 447 MeV ≈ M_q, 780 MeV=m_ω.
Центр:
То же для области 1000—2000 МэВ с максимумами при 1042 МэВ = $8f_\pi$, 1931-1402 МэВ = $10m_\pi$ и 1774 МэВ ≈ m_τ.
Внизу:
То же для области 2000—4600 МэВ с максимумами при 3504 МэВ ≈ $8M_q = \delta^0/2$, 3962 МэВ ≈ $9M_q$ и 4427 МэВ ≈ $10M_q$.

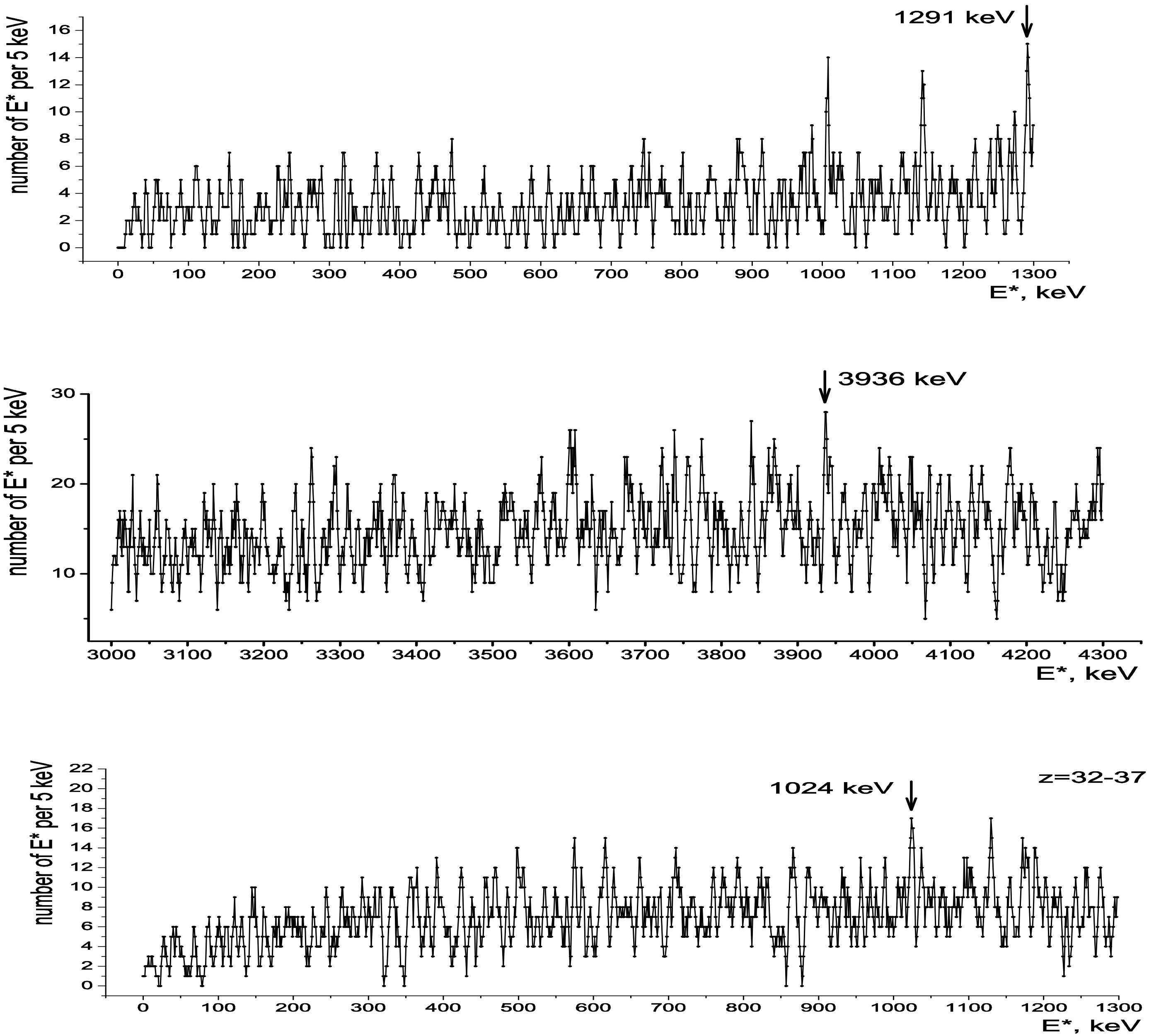

1291 keV
number of E* per 5 keV
E*, keV
3936 keV
number of E* per 5 keV
E*, keV
1024 keV
z=32-37
number of E* per 5 keV
E*, keV

Fig. 3.

Вверху:

Распределение E^* в ядрах с Z = 4 - 29, E^*<1300 кэВ. Стрелкой отмечена δm_N.

Центр:

Распределение E^* в ядрах с Z = 4 - 29, E^* = 3000 – 4300 кэВ. Стрелкой отмечен максимум при $4\times8\times13\ \delta'$ = 3936 кэВ.

Внизу:

Распределение энергий возбуждения во всех ядрах с Z = 32 - 35.

Максимум при 1024 кэВ = $6\times18\ \delta'$.

We show here confirmation of the dimensionless ratio, close to the QED radiative correction, in modern high-precision data on neutron resonances (compound nuclei):

^{80}Br, ^{104}Rh, ^{105}Pd, ^{146}Nd, ^{149}Nd, ^{233}Th,

^{177}Hh, ^{179}Hh, ^{239}U and ^{241,243,245}Pu [3].

In 1950s, I.V. Kurchatov as a director of IAE sent to ITEP a communication about the observation of the proximity or coincidence of neutron resonance positions in 4 compound nuclei: ^{240}Pu (0.296 eV), ^{242}Pu (0.264 eV), ^{242}Am (0.3051 eV) and ^{244}Am (0.419 eV). Mean value of these quantities 0.321 eV is named here as hyperfine structure parameter.

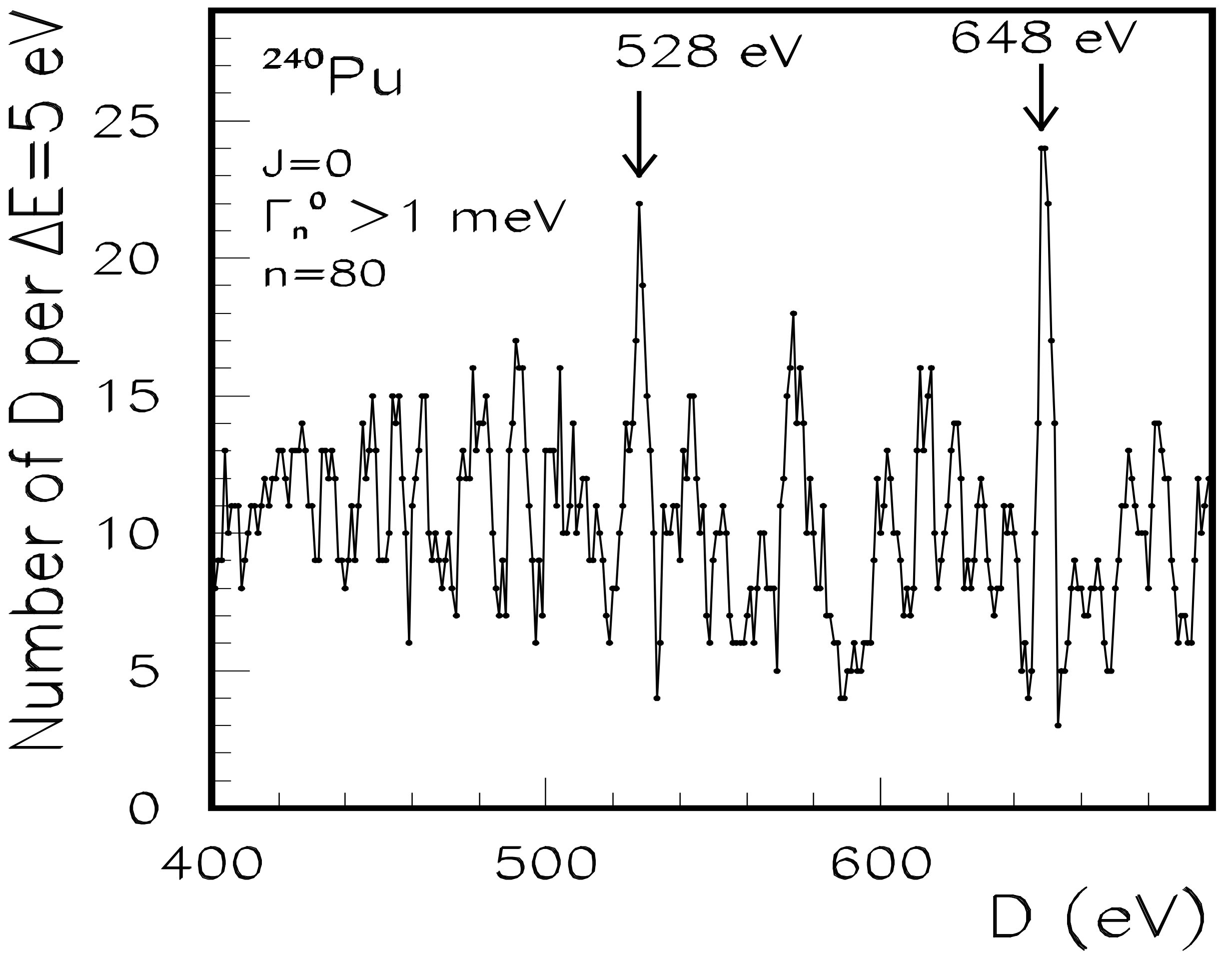


Fig. 4. *D* distribution in 0^+ resonances ^{240}Pu.

In spacing distribution of J=0 resonances of ^{240}Pu (Fig. 4) maxima were found at 528 eV and 648 eV.

The hyperfine structure parameter of 0.321 eV and a half of the first maximum are in a ratio $122 \cdot 10^{-5}$, close to the QED correction.

For confirmation of the hyperfine structure parameter recent data can be used.

Correlation analysis of nuclear data provides an independent confirmation of integer relations in parameters of the Standard model, a theory of all interactions.

1. S.I. Sukhoruchkin, Nucl. Part. Phys. Proc. 312-317, 185 (2021).
2. V. Belokurov, D. Shirkov, *Theory of Part. Interacions.* AIP (1991).
3. S.I. Sukhoruchkin, Z.N. Soroko, D.S. Sukhoruchkin and M.S. Sukhoruchkina. Proc. ISINN-28, Dubna, 2021. JINR E3-2021-48, pp. 234, 247, 259.