THE QED CORRECTIONS IN THE STANDARD MODEL

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Introduction

- It was shown in [1-4] that QED correction $\alpha/2\pi = 1.159\text{x}10^{-3}$ known as the Schwinger term in expression for to magnetic moment of the electron coincides with the ratio between SM-parameters mμ and M_Z ($m_\mu/M_Z = 1.159\text{x}10^{-3}$). Such dimensionless factor was noticed in 70-ties in nuclear data: a ratio of stable (superfine structure) intervals in spectra of neutron resonances to stable (fine structure) intervals in nuclear low-lying levels was found to be close to $\alpha/2\pi \approx 1/(32\text{x}27) = 1.157\text{x}10^{-3}$.
- In the bottom part of Table 1 the observed stable nuclear energy intervals are represented as integer numbers n and m of the common parameter $16m_e$=delta with the first and the second powers (X=1 or 2, at left) of such small dimensionless factor.
- 1. S.I.Sukhoruchkin, Proc. Int. Conf. Nucl. Data for Science and Technol., Nice, 2007, p.179.
- 2. S.I.Sukhoruchkin, Nucl. Phys. A 782 (2007), p.37.
- 3. S.I.Sukhoruchkin, Proc. 6-th Int. Conf. Persp. Hadr. Phys., Trieste, 2008, AIP 1056, p.55.
- 4. S.I.Sukhoruchkin, Int. Review of Physics, August Issue, 2008, Praise Worthy Prize publ.

Table 3. Representation of parameters of tuning effects in particle masses (upper part) and in nuclear data by the expression $(n\times m_e(\alpha/2\pi)^x)\times m$ with $\alpha=137^{-1}$ [5]. Asterisk marks stable intervals observed in low-energy excitations and neutron resonances; ε_{np}=340 keV is discussed in the text, Fig.7

x	m	n=1/8	n=1	n=13	n=16	n=17	n=18
-1	1			M_Z=91.188	M_H=115		
GeV	3				$\boxed{2m_t=348}$		
0	1	$2m_e$	$16m_e$	m_μ=105.658		m_π-m_e	147=ΔM_Δ
MeV	1	ε_0	δ	106.4=ΔE_B	130=ΔE_B	140=ΔE_B	147=ΔE_B
	3				$M''_q=m_\rho/2\approx m_\omega/2$	$\boxed{M'_q=420}$	M_q=441=ΔE_B
1	1	1.2*	9.48=δ'*	123*	152*	161*	170*
keV	2			246*	303*	321*	ε_{np}=340=$\varepsilon_0/3$
	3			368*	455*	481*	$\boxed{511=\varepsilon_0/2}$
	8	9.5*	76*	984, Fig.8	1212*	1293=D_0	1360, Fig.8
2	1		11*	143*	176*	187*	D in neutron
eV	4	5.5*	44*	572*		750 - 1500*	resonances

QCD

- Recent progress in lattice QCD calculations and in application of
- Dyson-Schwinger Equations [5,6] resulted in clear interconnection between small values of "chiral quark masses" $m_q \approx m_\pi/2 = 70$ MeV
- and the large values of the constituent quark masses≈ 440 MeV=M_q
- (QCD quark-dressing effect shown in Fig.1).
- The parameter Mq coincides with three-fold value of the nucleon Δ-excitation (per one quark) 294 MeV/2=147 MeV=ΔM_Δ ,considered in NRQM -- Nonrelativistic Constituent Quark Model as a measure of the baryon (qqq) mass splitting due to one-gluon exchange 3Rqqq. The value 441 MeV(M_q) was introduced by Sternheimer [7] and Kropotkin [8] from the coincidence of differences of empirical masses m_Σ- m_N, m_N- m_{K^*} and m_η- m_μ.
- The Mq value is close to 1/3 of the initial nonstrange baryon mass (≈1350MeV) in NRQM calculation with one Goldstone boson exchange (Glozman, see [3,4] and Fig.2). During the analysis of stable intervals in nuclear binding energies ΔEB (for certain nucleon clusters) values 147 and 441MeV=3x147 MeV as well as 140, 130 and 106 MeV were observed [1-4] and due to their proximity to particle masses they are also included in the upper part of Table 1.
- [5] H.Iida et al., Proc. 17th Spin Phys. Symp.,Kyoto, 2006. AIP 915, 256.
- [6] M.S.Bhagat, I.C.Cloet and C.D.Roberts: arXiv:0710.2059v1[nucl-th] 10 Oct. 2007.
- [7] R. Sternheimer, Phys. Rev, 136 (1964), 1364.
- [8] P. Kropotkin, Field and Matter, Moscow Univ., 1971. p. 106.
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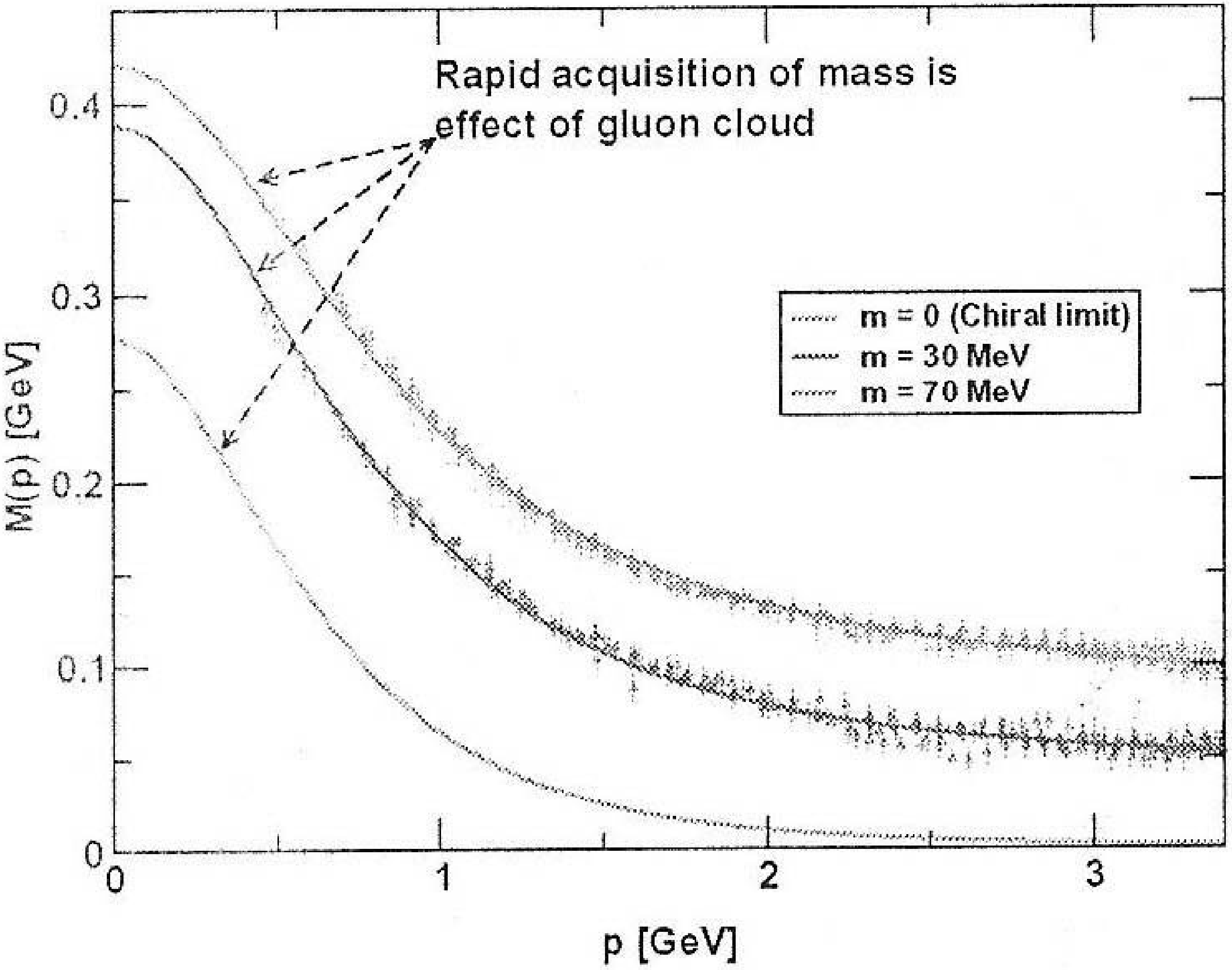

Fig.1. QCD gluon-quark-dressing effect calculated with Dyson-Schwinger Equation [9,13-17], initial masses m=0, 30 and 70 MeV; the constituent-quark mass arisses from a cloud of low-momentum gluons attaching themselves to the current-quark; this is dynamical chiral symmetry breacking: an nonperturbative effect that generates a quark mass from nothing even at chiral limit m=0, bottom curve) [9]..

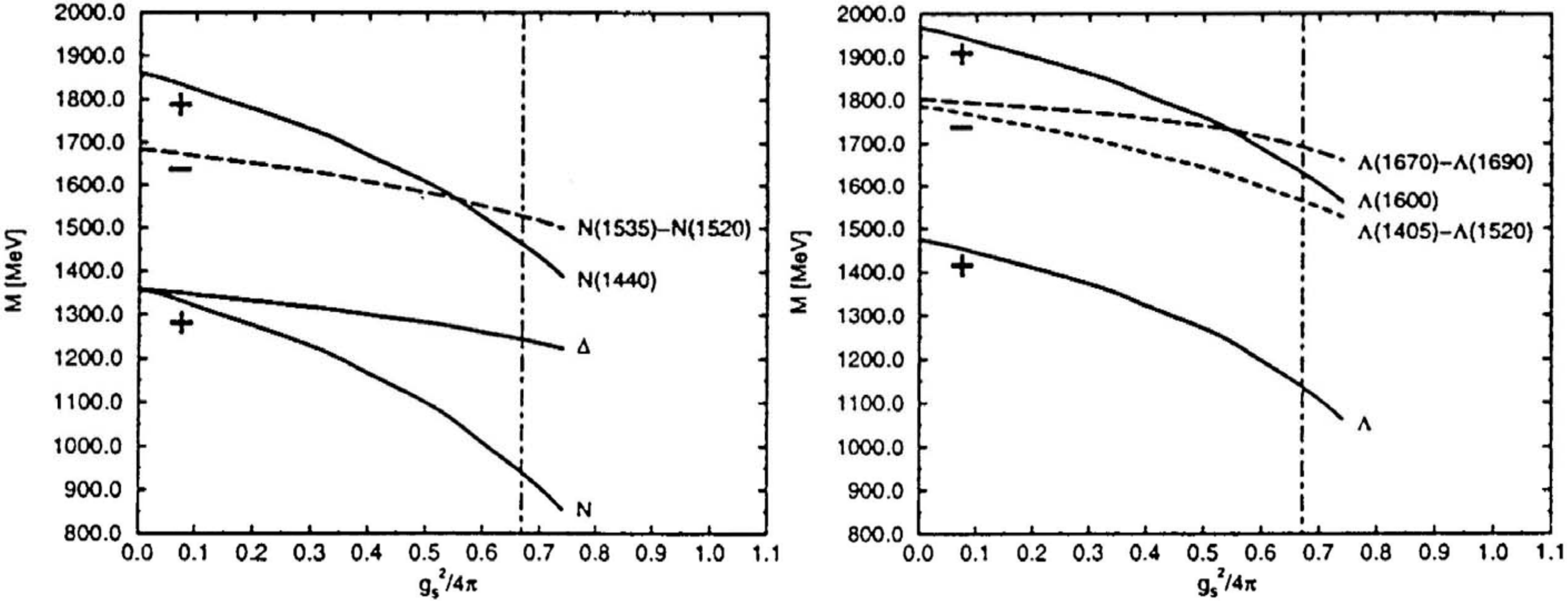

Fig.2. Calculation of nonstrange baryon masses (left) and Λ-hyperon masses as a function of interaction strength within GBECQM – Goldstone Boson Exchange interaction Constituent Quark Model [19]; initial baryon mass 1350 MeV=3×450 MeV=$3M_q$ is near the bottom "+" on the left vertical axis.

Nambu

- It was suggested by Namby [9] that a search for empirical relations in particle masses could be useful for the development of the Standard Model. It was noticed in 70-ties [10] that the well-known lepton ratio L=mμ\ me= 206.77 becomes the integer number 207=9 x 23=13 x 16-1 after a small QED radiative correction applied to the electron mass me (it becomes $m_\mu / m_e(1-\alpha/2\pi)=$ =207.01).
- The ratios between masses of vector bosons MZ and MW=80.40(3) GeV and estimates of the constituent baryon quark mass M_q=441 MeV= m_{Ξ^-}/3 [11] and the meson constituent quark mass estimates
- M_q''= m_ρ/2=775.5(4) MeV/2=387. 8 (2) MeV , namely, ratios
- M_Z/441 MeV=206. 8; MW/(m_ρ/2)= 207. 3 are close to L=207 [1].

- 9. Y.Nambu, Nucl.Phys.A 629 (1998), p.3c.
- 10. S.I.Sukhoruchkin, Stat. Ptop. Nucle, Albany, 1972, p.215.
- 11. C. Itoh et al., Phys. Rev. D 40 (1989), p.3660.
- 12. F.Wilchek, Nucl. Phys. B (Proc. Suppl.) 117 (2003), 410.
- 13. A.A.Pivovarov, Yad. Fyz., 65 (2002), p.1352.
- 14. Particle Data Group, J. Phys., G 33 (2006), p.1.
- 15. S.Ting, CERN-PPE/93-34, 1993.
- 16. R.Frosch, Nuovo Cimento, 104 (1991), p.913.
- 17. S.I.Sukhoruchkin, New Projects Lines Research, WS 2003, p.362.
- 18. S.I.Sukhoruchkin, Proc. 2nd Int. Conf. Neutron Cross Section, Washington, 1968, p.923.
- 19. Y.Nambu, Progr. Theor. Physics 7 (1952), p.595.
- 20. R.Feynman, QED the strange theory of light and matter, Princenton Univ. Press, 1985.

Wilchek

- We follow a remark by Wilchek [12] that top-quark mass is a natural value for the SM-mass scale. The ratio between (1/3) m_t (≈8x16 M_q) and $m_q = m_\pi/2$ is close to the QED correction for short distance with $\alpha_Z \approx 1/129$ according to [13,14] and Fig.3.
- Another empirical relation 3:2:1 between the well known top-quark mass mt and noncofirmed parameters 116 GeV and 58 MeV found in LEP experiments (by ALEPH [14] , Fig.4 and by S.Ting et al. L-3 experim. [15]) should be considered.
- We come to conclusion that QED radiative corrections (with α and α_Z) and the QCD-based estimates of quark masses (M_q, m_q,M_q'') are playing an important role in the Standard Model dynamics reflected in the empirical relations in particle masses.
- Observed tuning effect in particle masses (discreteness with the period $3m_e$ [16] and the parameter $16m_e$ [2,17]) and similar tuning effects in nuclear data [4] are reflection of this dynamics.

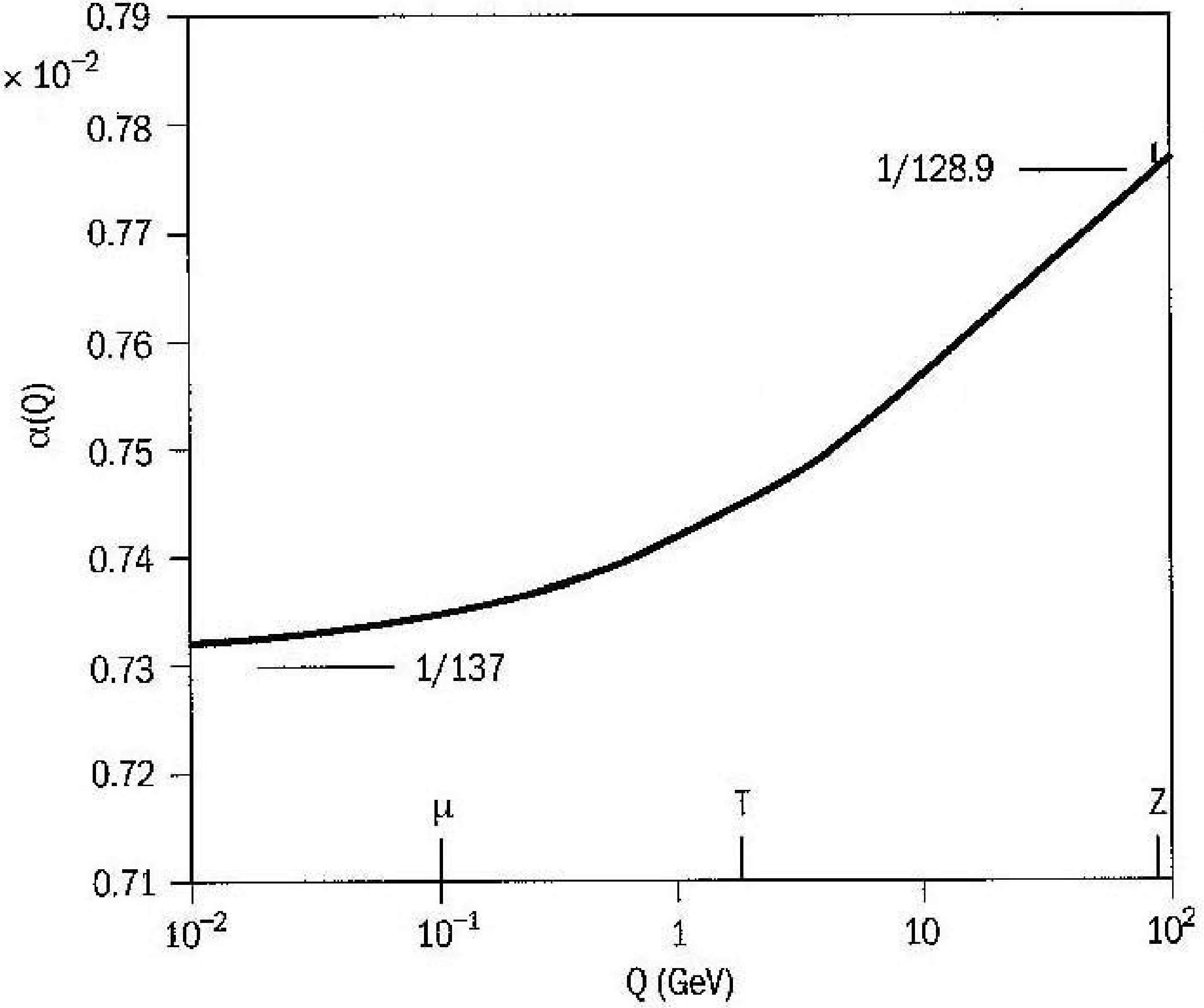

Fig.6. Momentum transfer evolution of QED effective electron charge squired. The momotonically rising theoretical curve is confronted with precise measurements at the Z mass at CERN LEP collider

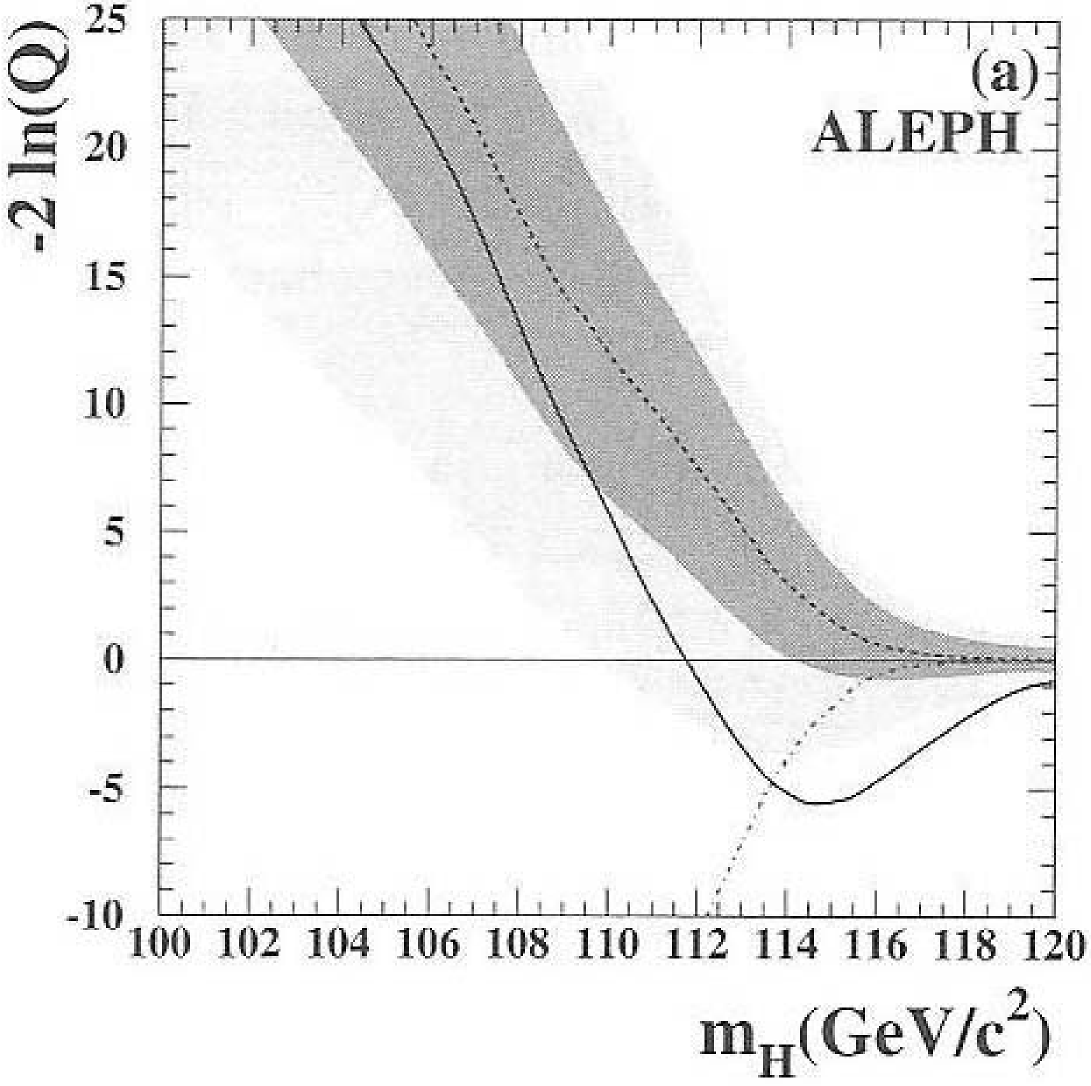

Fig.8. ALEPH results with about 3 standard deviation at mass 115 GeV; observed (solid line) and the expected behaviors of the test statistic (dark region) are presented and discussed in [1].

b-quark

- In this work we compared lepton ratio L=mu/me with the ratio between very massive objects (M_Z/M_q=L in Table 1). We know from 70-ties] that main relation m_e:(m_π-$m_{\pi 0}$= δm_π = $9m_e$):m_μ=1:9:(9x23=13x16-1)=207 holds with very good accuracy. The parameter 16me close to the pion doubled beta-decay energy $2(\delta m_\pi – m_e)$ was found to be useful for the mass presentation of muon, pion, neutron and many other particles [18].
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- At the large scale the central element of this main relation, namely, the value δm_π = 9me seen in nuclear binding energy as Δ , could be substituted by the initial mass of b-quark m_b - M_q due to the fact that two tabular values m_b [14] of 4.20 and 4.68 (+ 0.17 -- 0.07) GeV (of MS mass and of 1S mass) both are close to the value $10M_q$=4.41 GeV. The mass of the third lepton m_τ=1777.0(3) MeV [14] (close to $4M_q$=1764 MeV) coincides with the doubled sum m_μ+ m_ω of 1776.6(2) MeV [3,4].
- To finish the discussion on empirical relations in particle masses we should mention the distinguished role of the charged pion mass noticed earlier by Nambu [19] and later by many others. Some of these relations are presented in Table.3 and Fig. 5. Similar integer relations with M_q are presented in Table.4 and simultaneously in Fig.5.
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Feynman

- In this work we discussed a distinguished role of the lepton ratio which was commented by Feynman [19] in the following way: “This repetition of particles with the same properties but heavier masses is a complete mystery. What is this strange duplication of the pattern? As Professor I.I. Rabi said of the muon when it was discovered, “Who ordered that?”
- Recently another repetition of the list has begun. …
- The theories about the rest of physics are very similar to the theory of quantum electrodynamics: They all involve the interaction of spin ½ objects (like electrons and quarks) with spin 1 objects (like photons, gluons, or W’s) … . Why are all the theories of physics so similar in their structure?
- A … possibility is that things look similar because they are aspects of the same thing – some larger picture underneath, from which things
- can be broken into parts that look different, like fingers on the same hand. Many physicists are working very hard trying to put together a grand picture that unifies everything into one super-duper model.
- It’s delightful game, but at present time none of the speculators agree with any of the other speculators as to what the grand picture is.”
- We need confirmation of Higgs boson mass from LEP2 experiment.
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Table 1. Discussed in the literature closeness of masses or mass differences to the integer numbers (k) of the pion mass value $m_\pi^\pm$=139.5 MeV or to $2m_\pi^\pm+m_\pi^\circ=\kappa_T$=409 MeV.

Particle	Λ	Ω	(bb)(2S-1S)	(bb)(4S-2S)	ΔE_B
Mass or ΔM (MeV)	1115.683(6)	1672.45(29)	10023-9460	10579-10023	408.9
			=563	=556	
km_π or $2m_\pi^\pm+m_\pi^\circ=\kappa_T$	1116 k=8	1672 k=12	558 k=4	558 k=4	409 κ_T
difference, reference	0, [1,23-26]	0, [1,25,26]	-5, [1,26]	-2, [1,27]	0, [28]

Table 2. Discussed in the literature closeness of particle masses or mass differences to the integer numbers (k) of the nucleon Δ-excitation parameter Δ_Δ=147 MeV [23].

Particle	(cc) (2S-1S)	(cc) (1S)	Ξ^-	ω_3-ω	K_3^*-K^*(892)	ΔE_B
Mass or	3686.1-3096.9	3096.92(1)	1321.3	1667(4)-782.7	1776(7)-891.7	441.5 (Fig.4)
ΔM (MeV)	=589.2 k=4	3087 k=21	k=9	884(4) k=6	=884(7) k=6	k=4
kΔM_Δ	588	588	1323	882	882	441
diff., ref.	1,[1,25,29]	1,[1,25,29]	-2,[??]	2(4),[1,25,29]	2(7),[1,25,29]	0,[28]

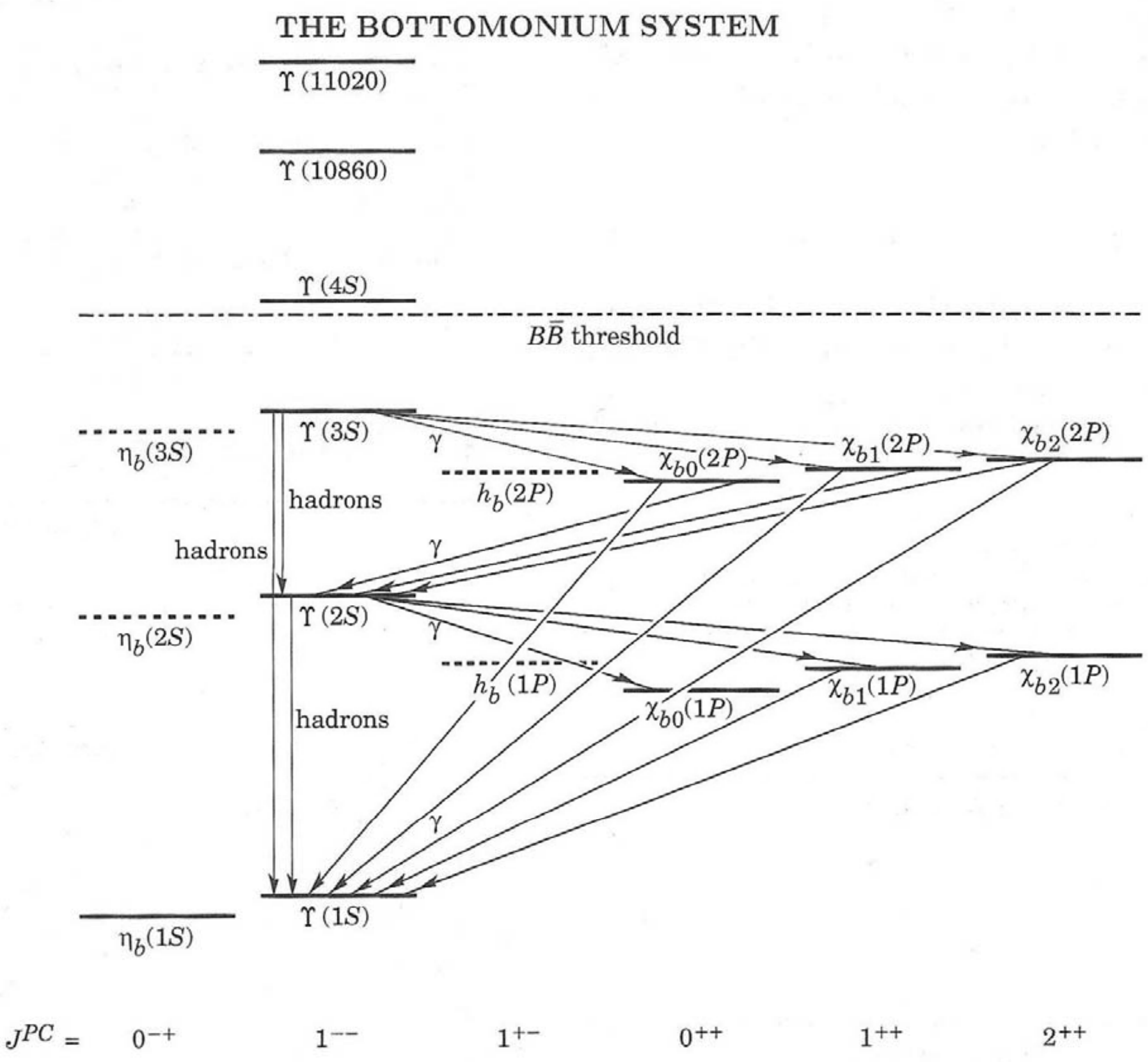
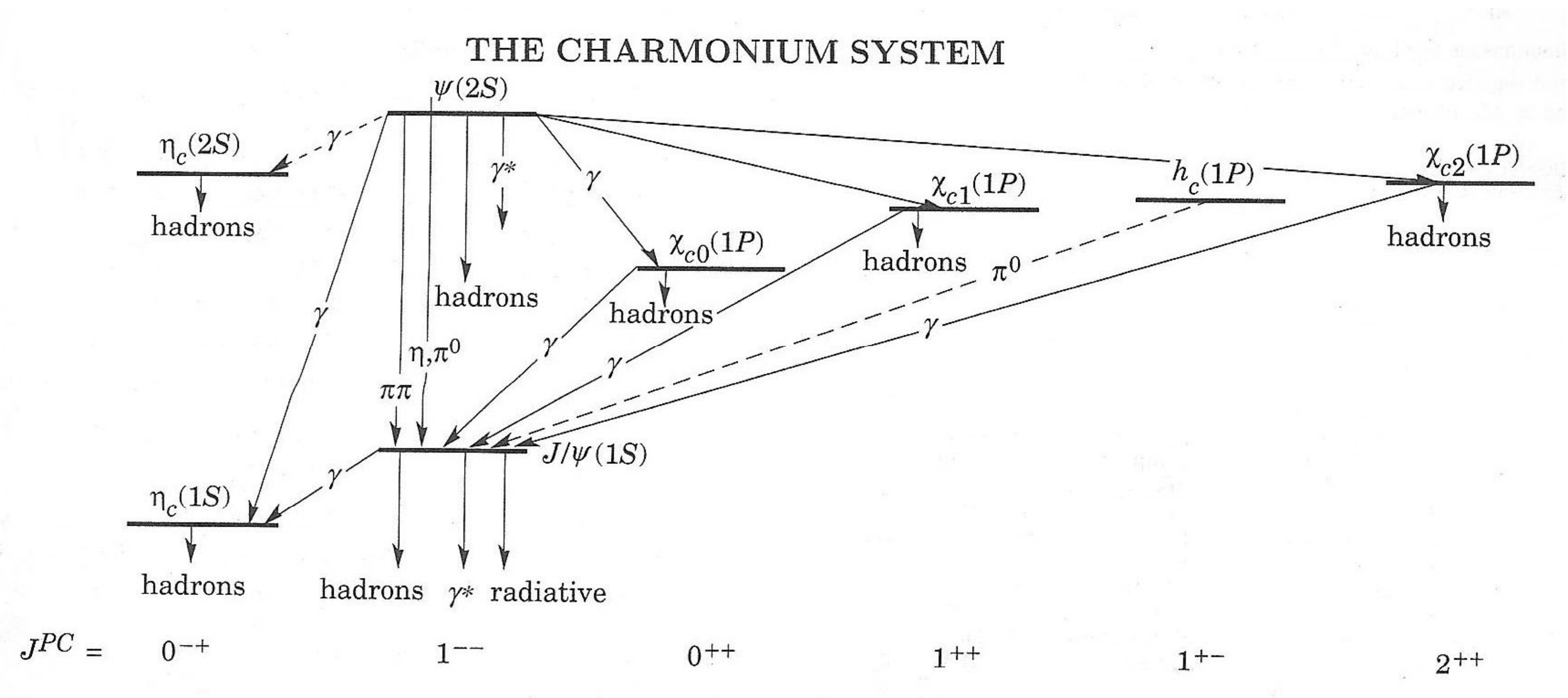


Fig.3. *Top* Mesons of (bb)-structure with radial excitations n=1 and n=1-3 close to $4m_\pi$ [1,27]; *Bottom* Mesons of (cc)-structure with radial excitation (n=1) close to $4\Delta M_\Delta$=4×147 MeV=588 MeV.



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Lepton ratio as the distinguished parameter

Earlier, as a realization of Nambu’s suggestion to search for empirical mass relations needed for SM-development, it was noticed in [5,6] that

1) the well-known lepton ratio L=$m\mu/m_e$=206.77 becomes the integer 207=9*23=13*16-1 after a small QED radiative correction applied to m_e (it becomes $m\mu/me(1-\alpha/2\pi)$=207.01)

2) the same ratio L=207 exists between masses of vector bosons M_Z=91.188(2) GeV and M_W=80.40(3) GeV and two above discussed estimates of baryon/meson constituent quark masses Mq=441 MeV=$m\Xi$¡/3=(3/2)(m_Δ-m_N) and $M''q = m\rho/2$=775.5(4) MeV/2=387.8(2) MeV

[1] (MZ/441 MeV=206.8; $M_W/(m_\rho/2)$=207.3 [5,6]). The origin of these effects should be considered in the complex analysis of tunung effects in particle masses and in nuclear data [5,6].

Conclusions

The QCD-based estimates of the constituent quark masses ($M0\ q$=420 MeV, Mq=441 MeV, $M''q$) could play important role in the description of Standard Model dynamics if the observed now empirical relations in particle masses (and value MH) would be confirmed in the experiment.

Nuclear data can provide some important additional information on fundamental properties of strong nucleon interactions and nuclear matter as well as general properties of fermion systems.

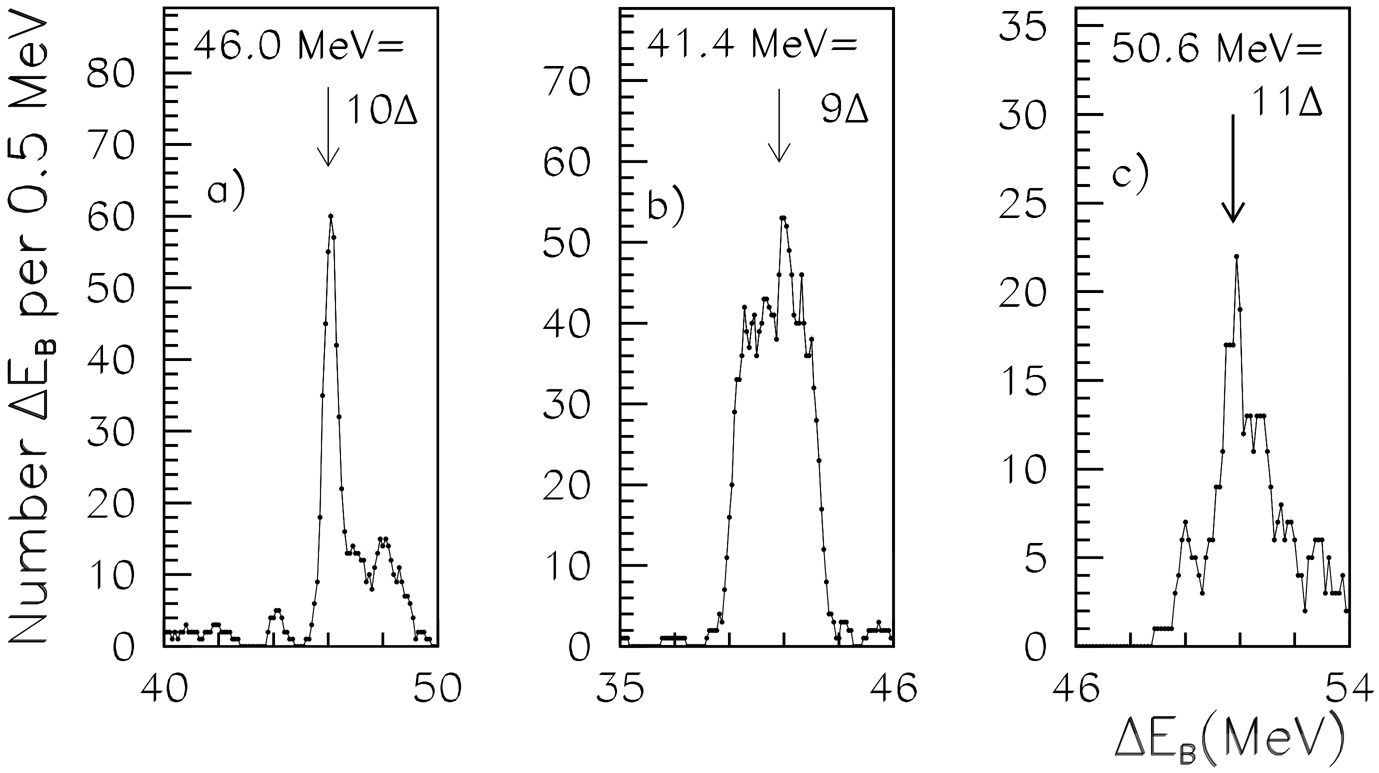


Fig. 4, *Top:* Distribution of ΔE_B in nuclei with $\Delta Z=2$, $\Delta N=4$, $Z=50$-58, 64-82 and $Z\leq28$ [26]
Bottom: The same in all even-even and nuclei [26], in even-even nuclei with $Z\leq58$ [29].

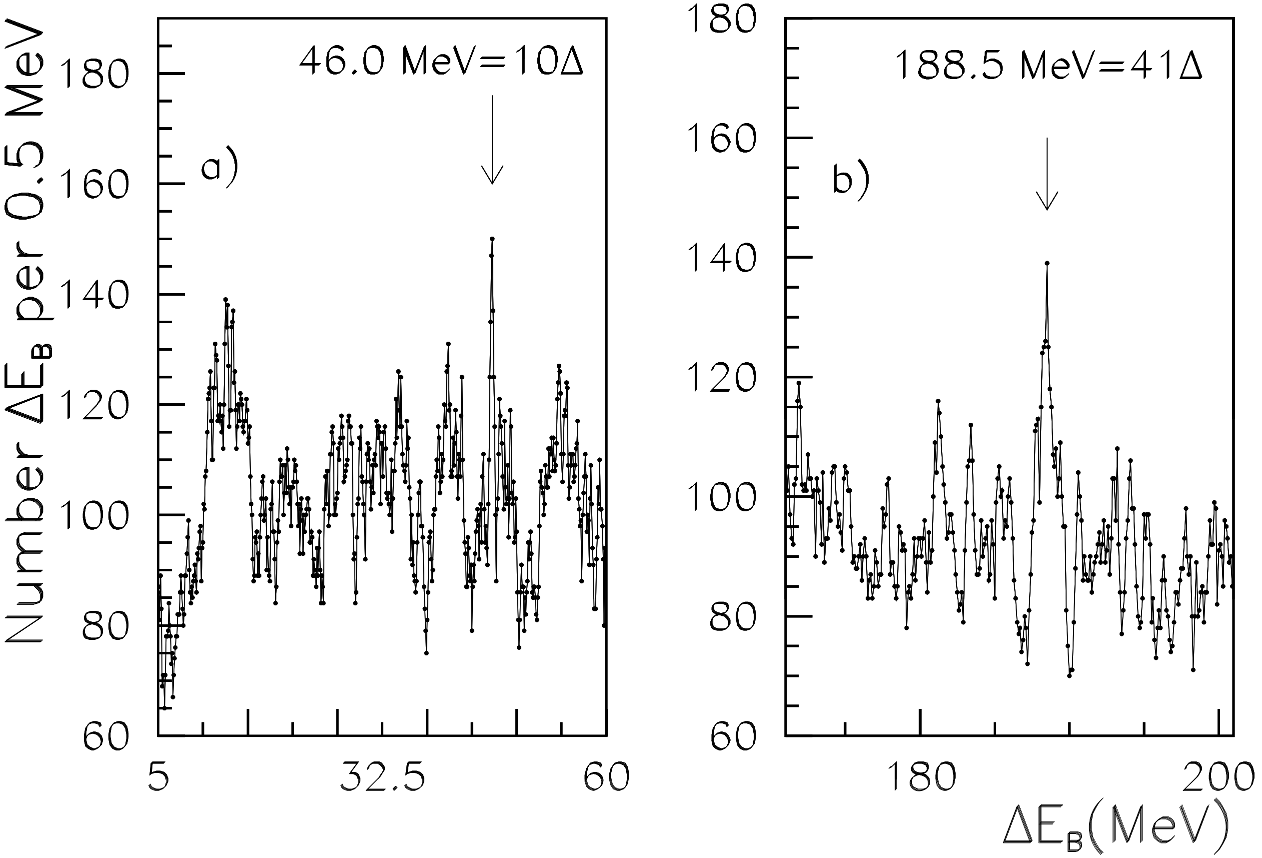


Fig. 4, *Top:* Distribution of ΔE_B in nuclei with $\Delta Z=2$, $\Delta N=4$, $Z=50$-58, 64-82 and $Z\leq28$ [26]
Bottom: The same in all even-even and nuclei [26], in even-even nuclei with $Z\leq58$ [29].

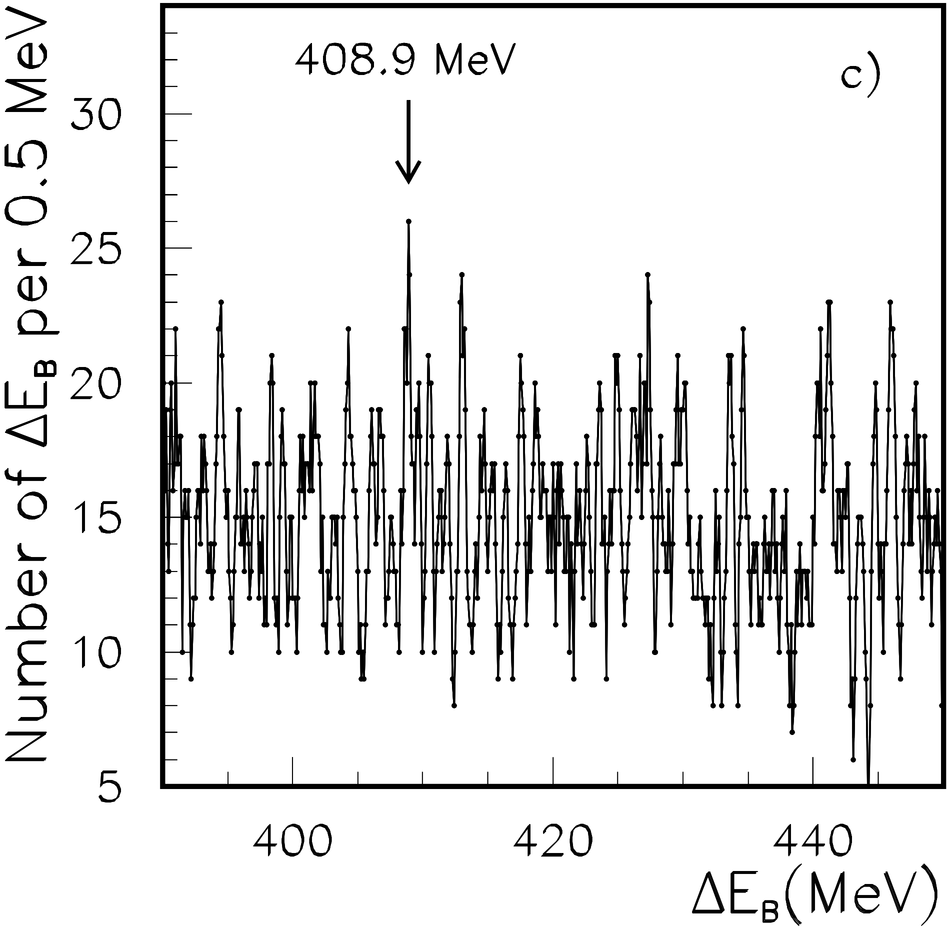


Fig. 4, *Top:* Distribution of ΔE_B in nuclei with $\Delta Z=2$, $\Delta N=4$, $Z=50-58$, $64-82$ and $Z\leq 28$ [26]
Bottom: The same in all even-even and nuclei [26], in even-even nuclei with $Z\leq 58$ [29].

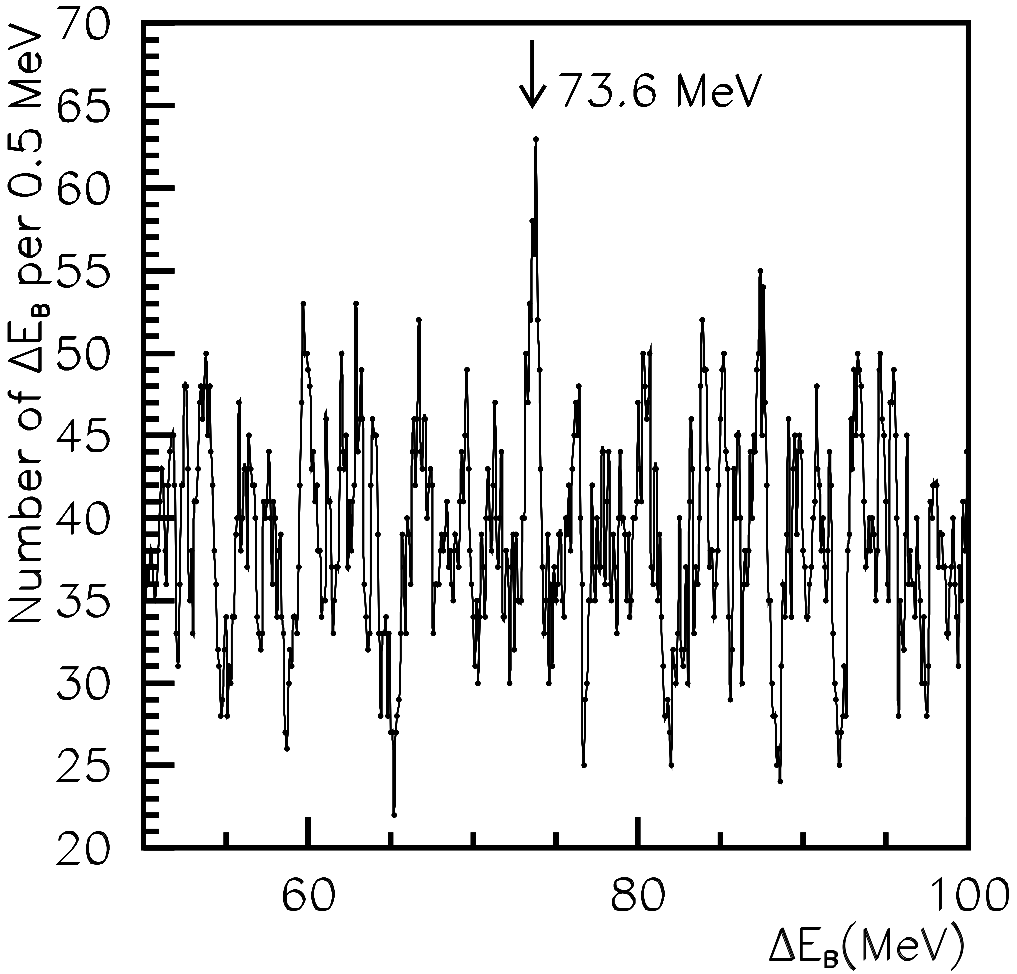
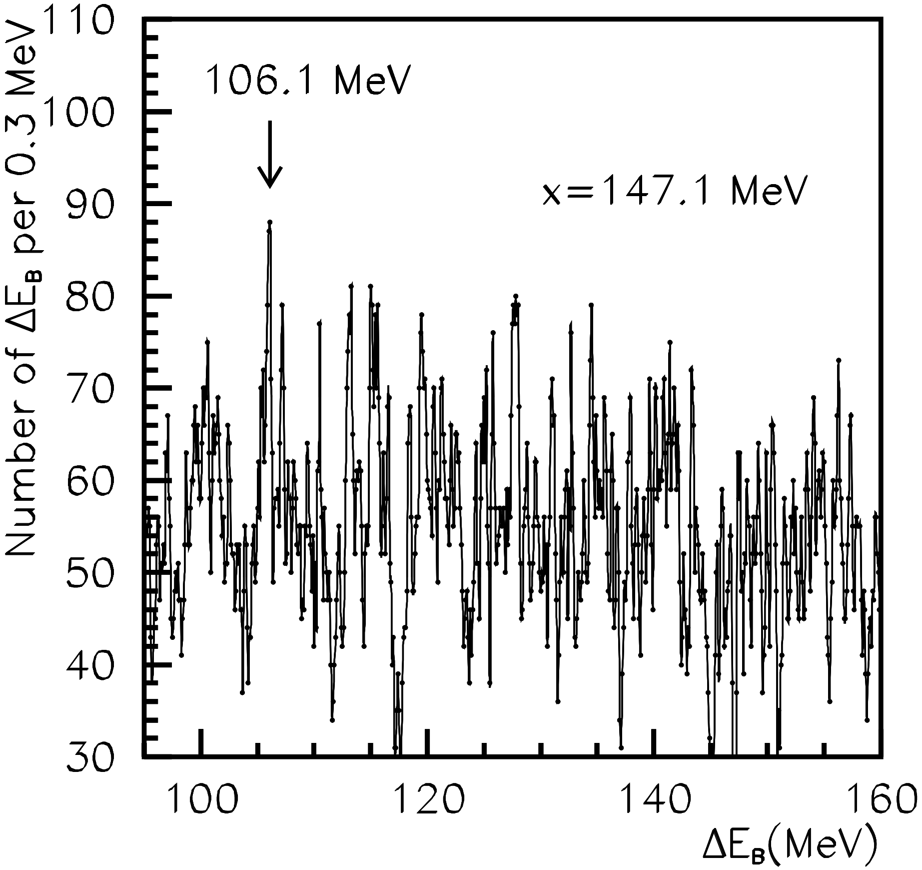


Fig. 5, *top:* Distribution of ΔEB in nuclei with ΔZ≤26; 4α- 2α-config. and all nuclei [6]);
center: Distribution of adjacent intervals $\Delta E_{B\text{-}AIM}$ in nuclei with Z≤26 for x=147.2 and 73.6 MeV [6]);
bottom: Distribution of ΔE_B in nuclei with ΔZ=8, ΔN=14 (Z=50-82); Distribution of $\Delta E_{B\text{-}AIM}$ in nuclei with ΔZ=65-81 for x=147.1 MeV [6]; Distribution of ΔE_B in all odd-odd nuclei [26].



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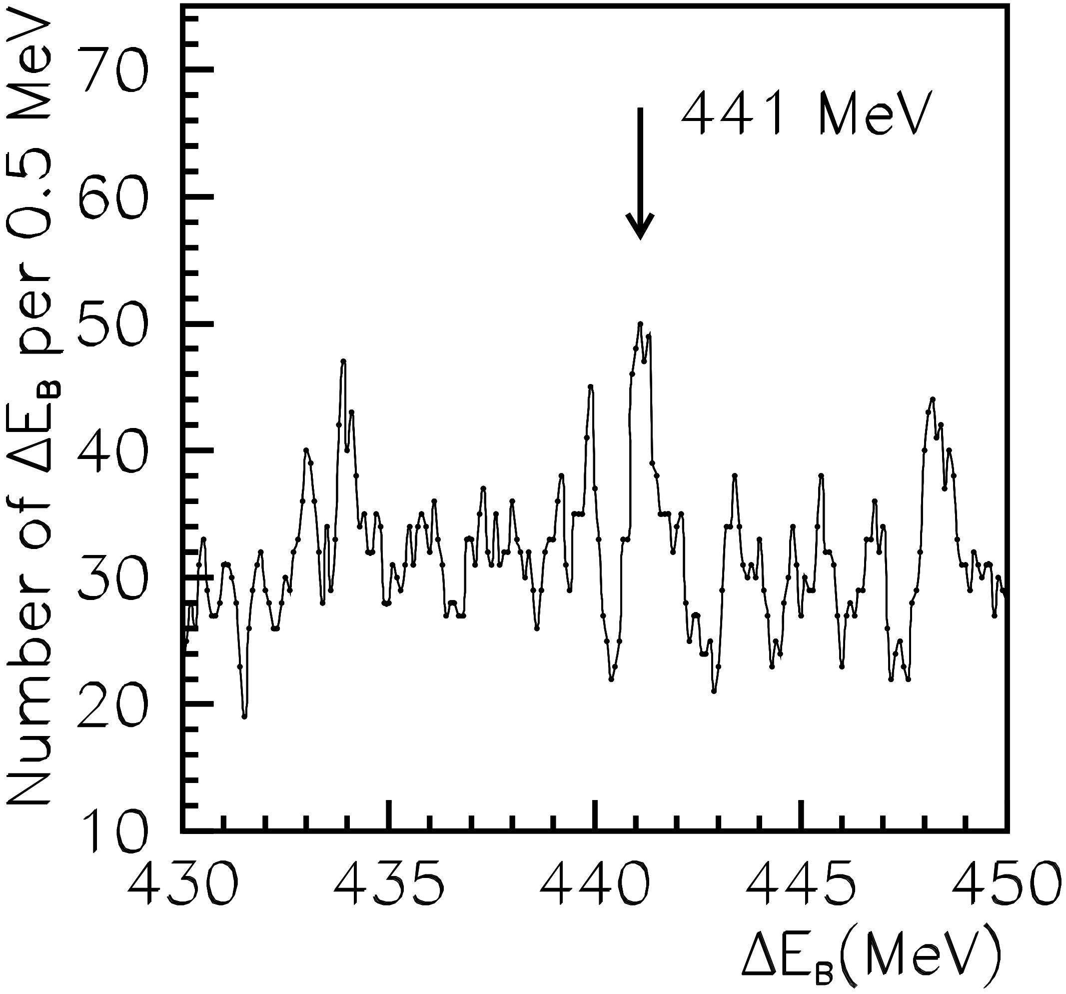

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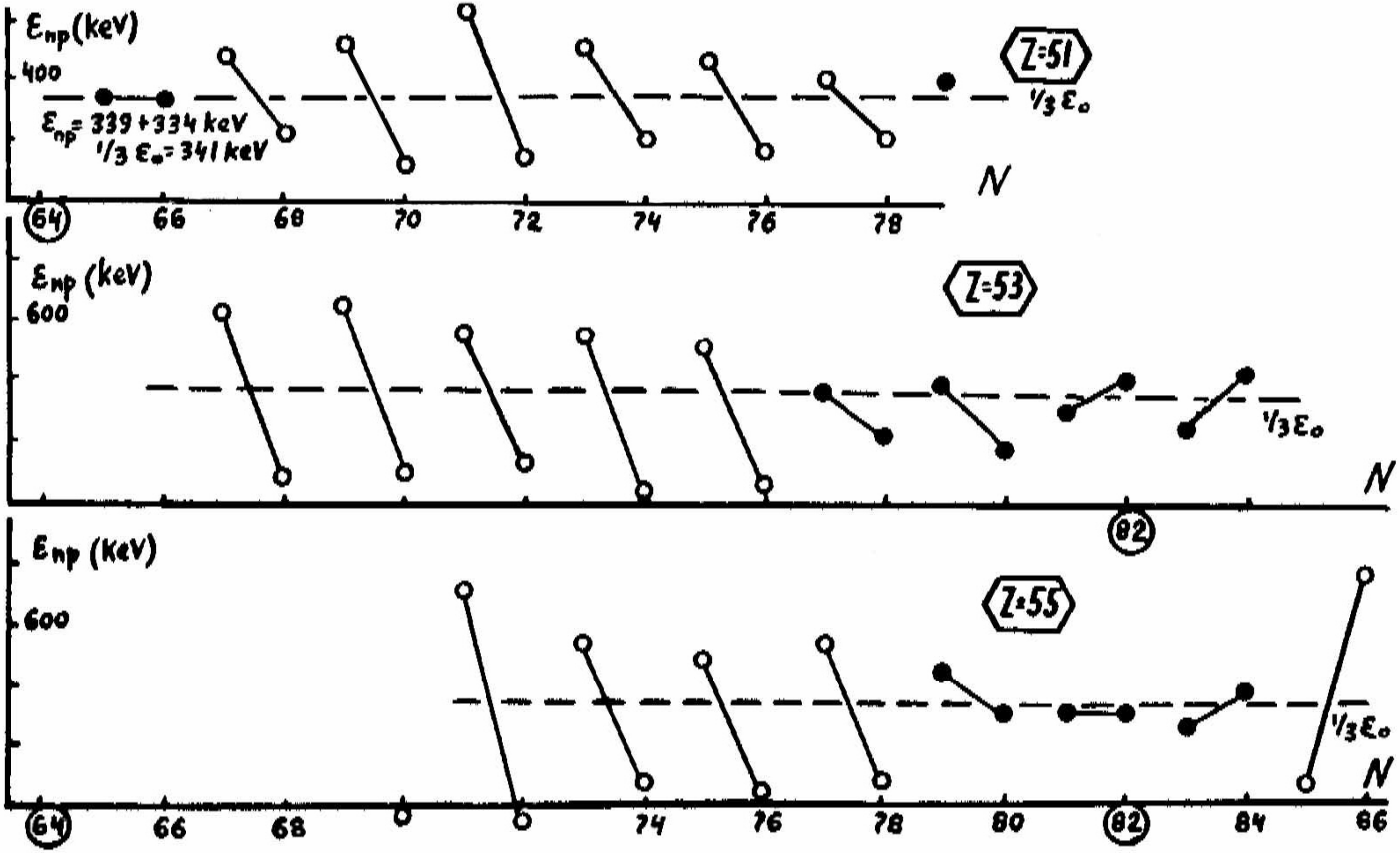
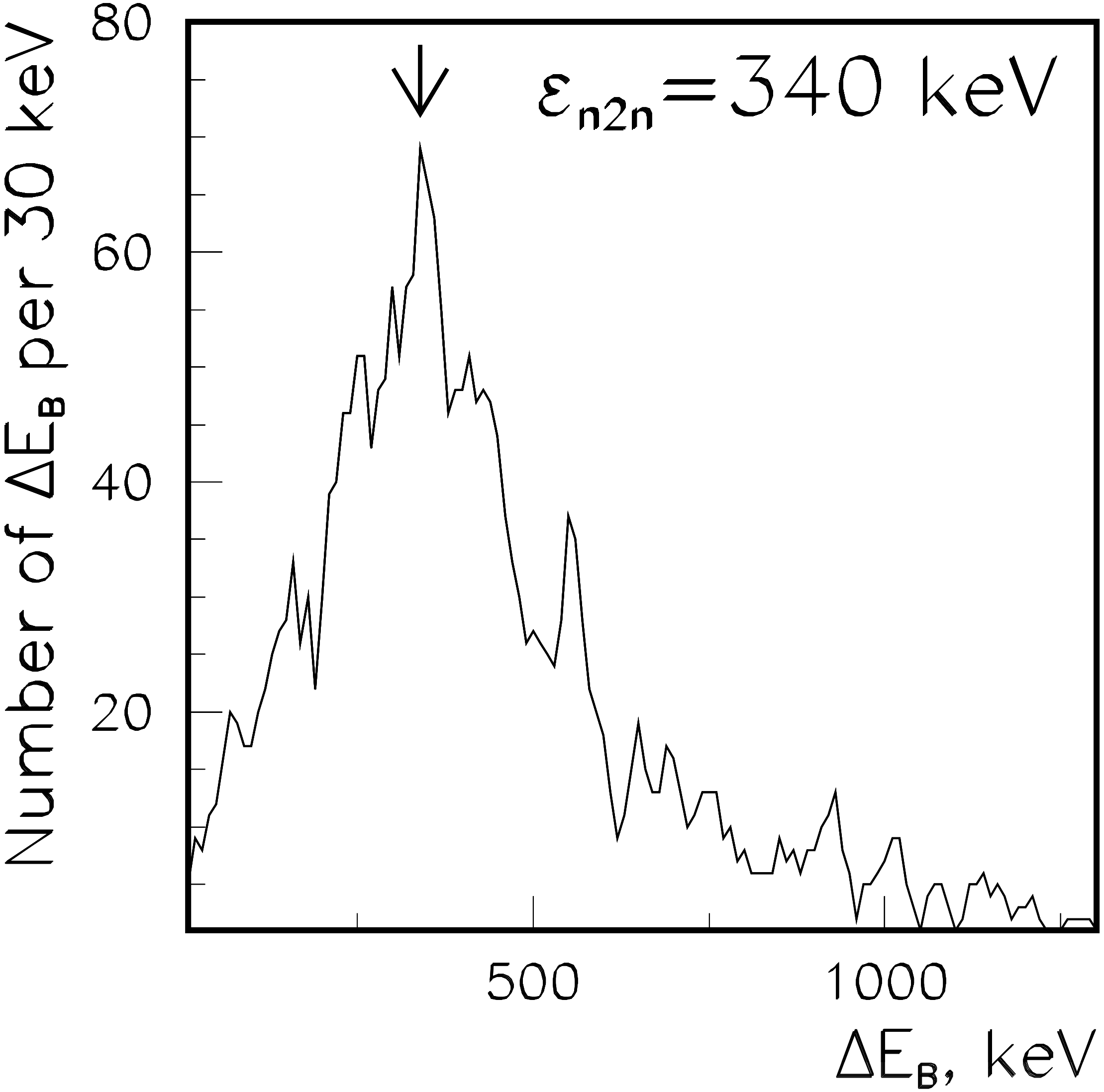
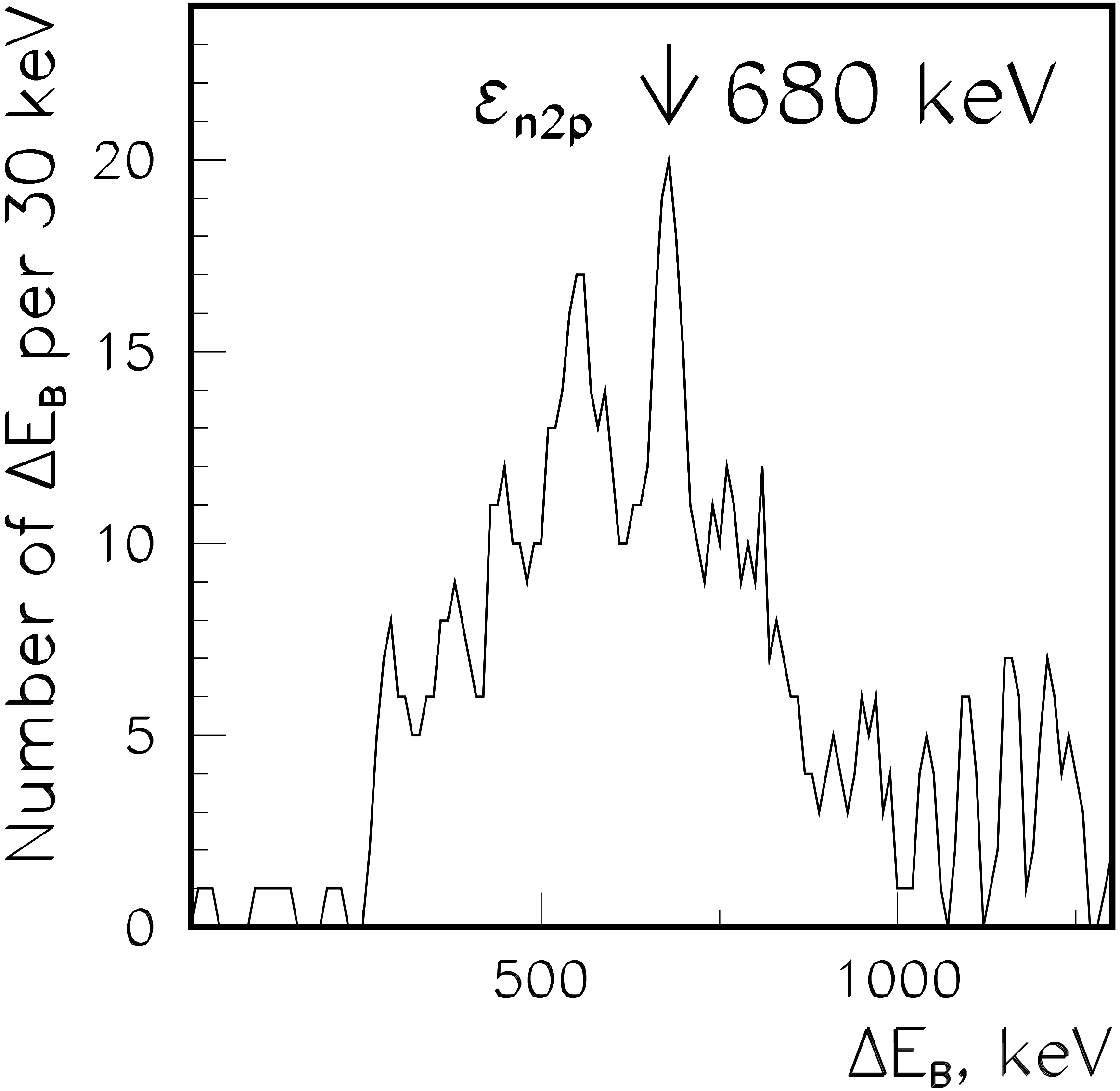
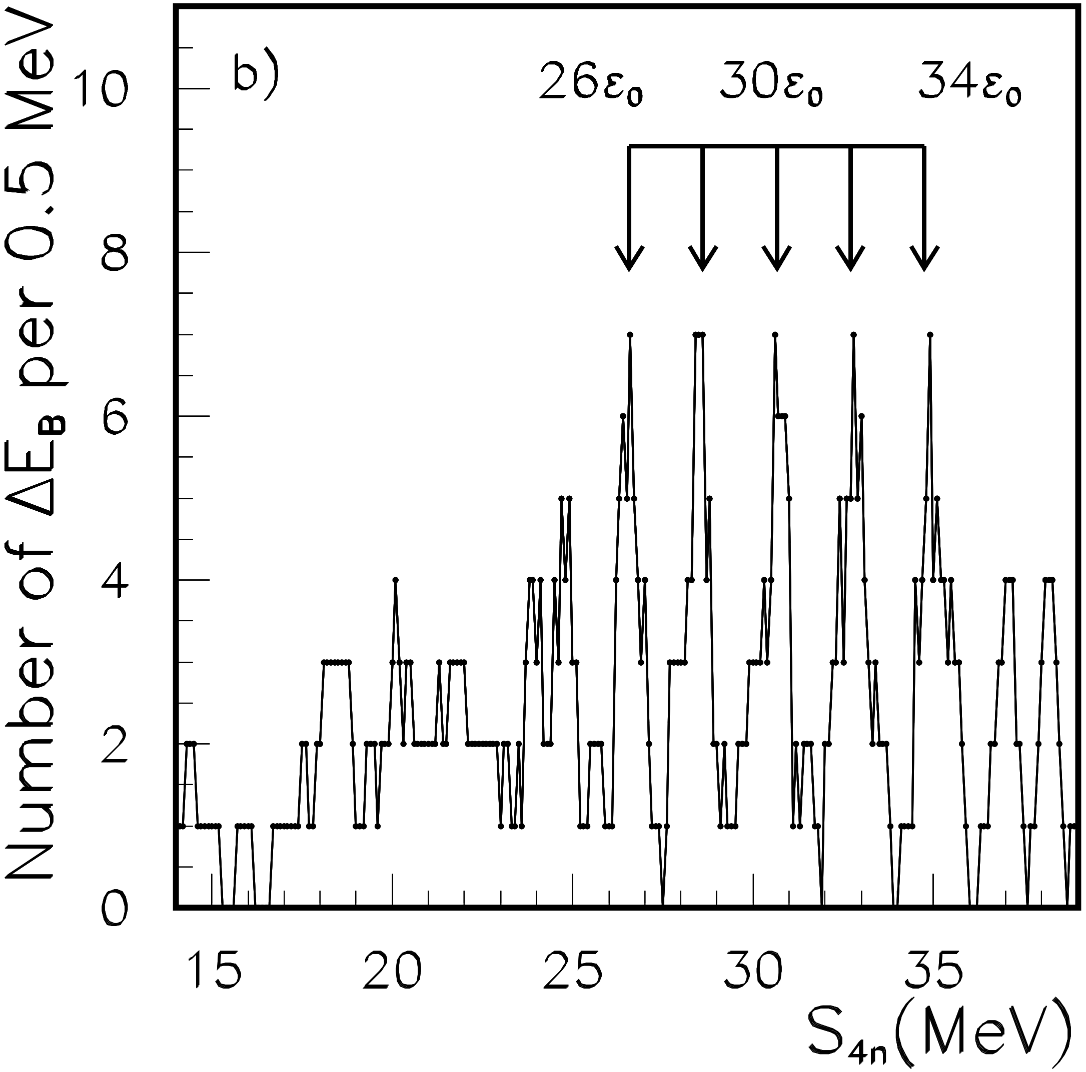


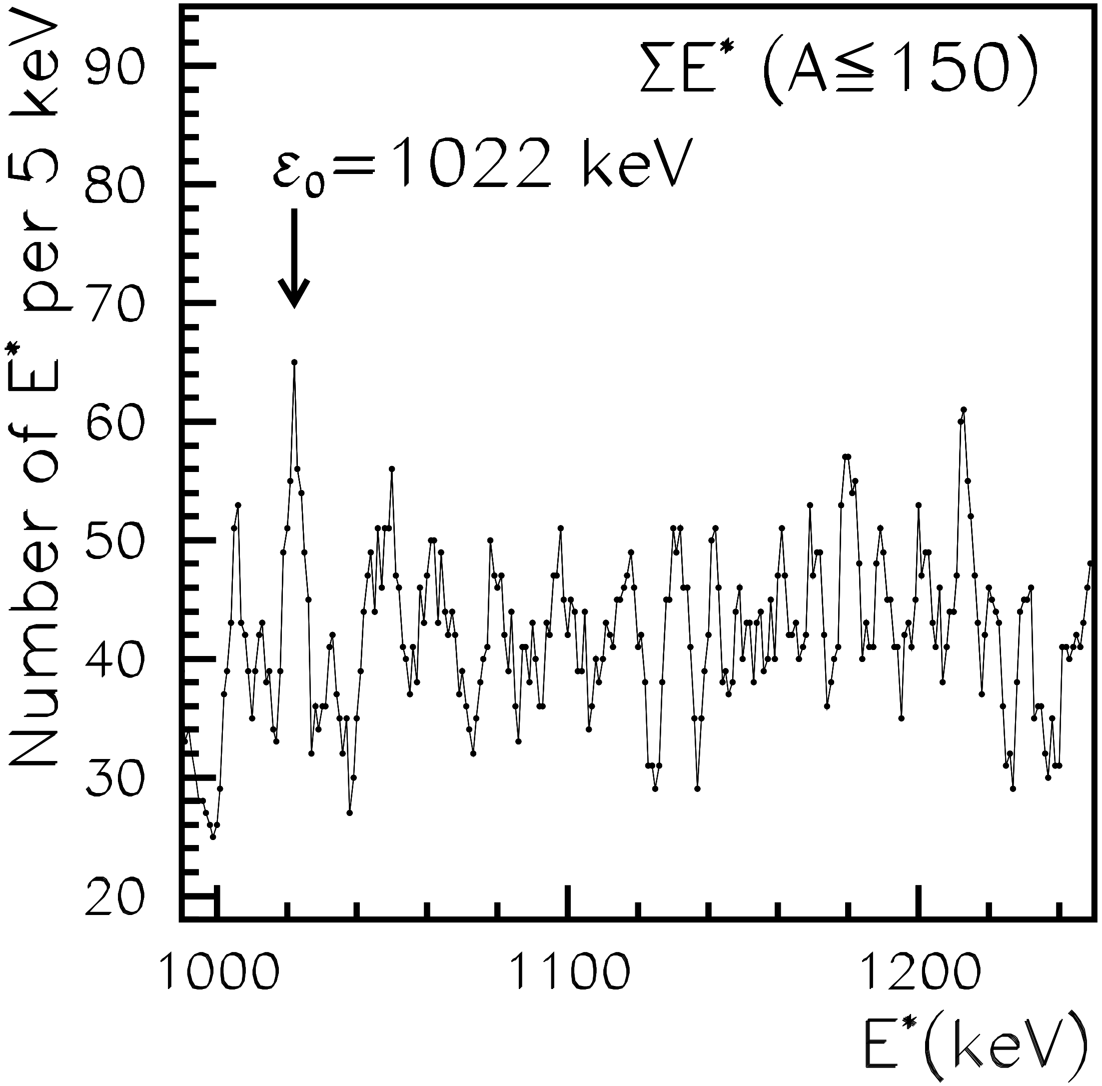
Fig.7. Parameters of the residual interaction ε_{np} from differences of S_p in Z-odd nuclei ($\Delta N = 1$). The value $\varepsilon_\circ/3$=341 keV is given by horizontal line

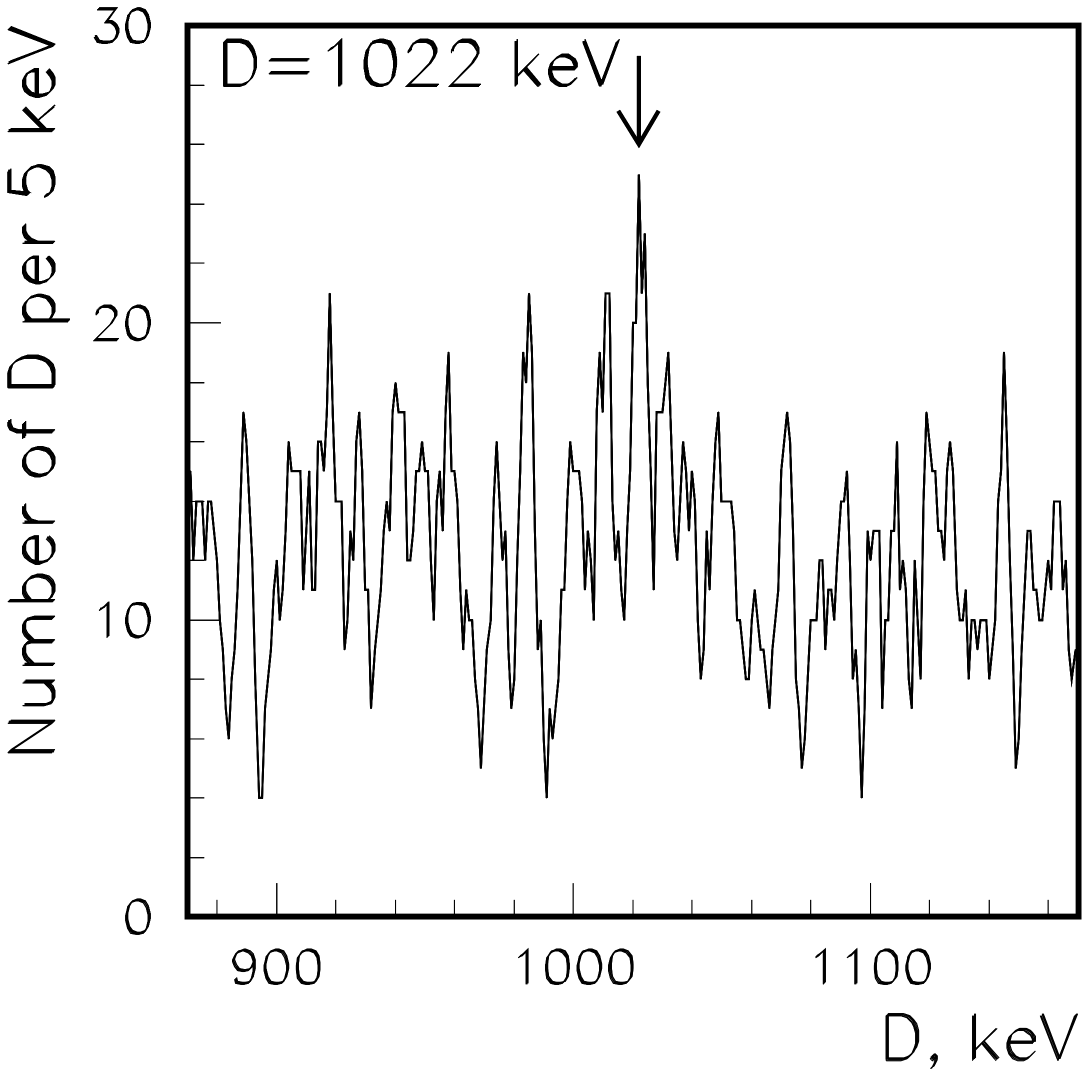


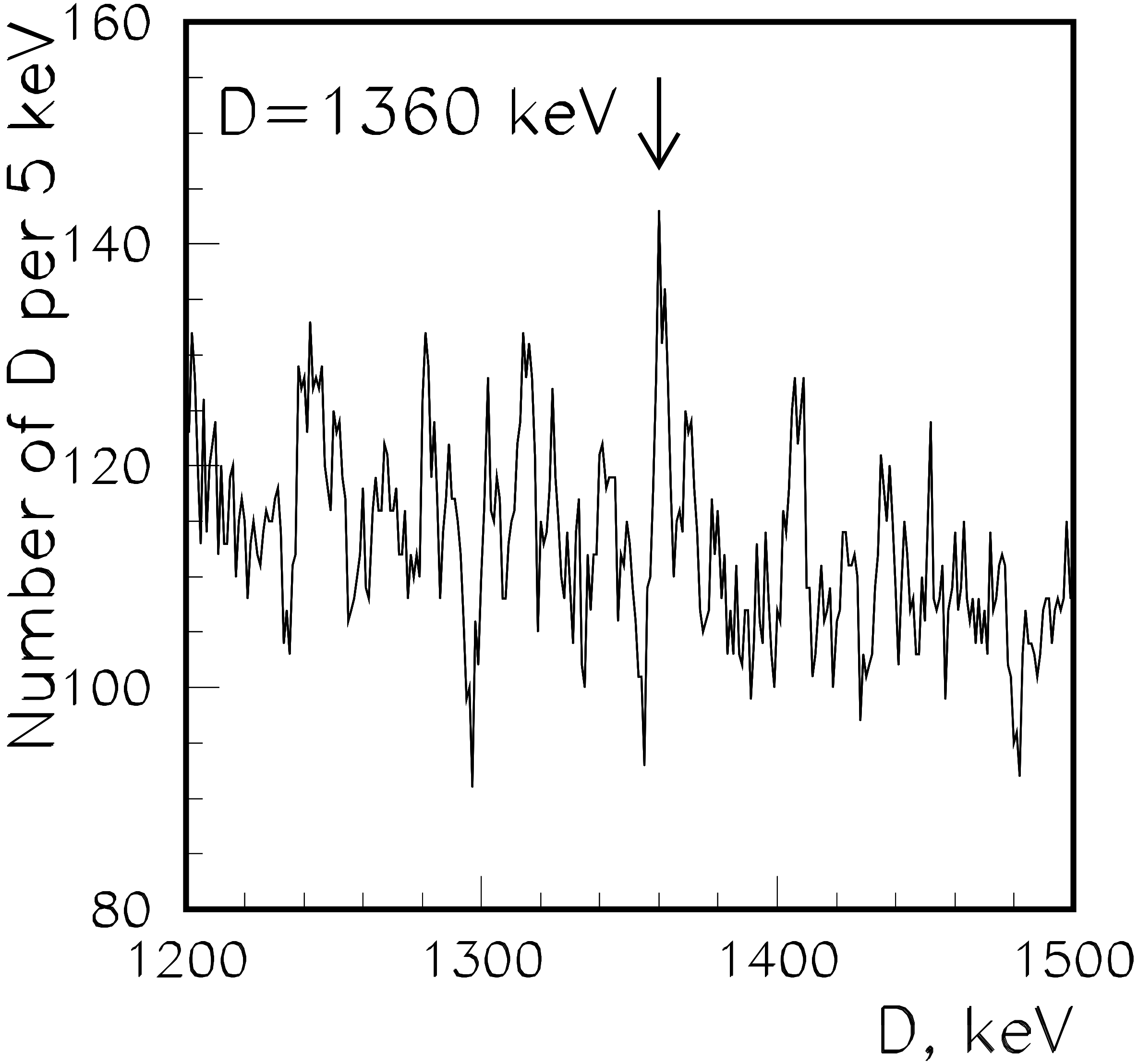
ε_{n2n}=340 keV
Number of ΔE_B per 30 keV
80
60
40
20
500
1000
ΔE_B, keV

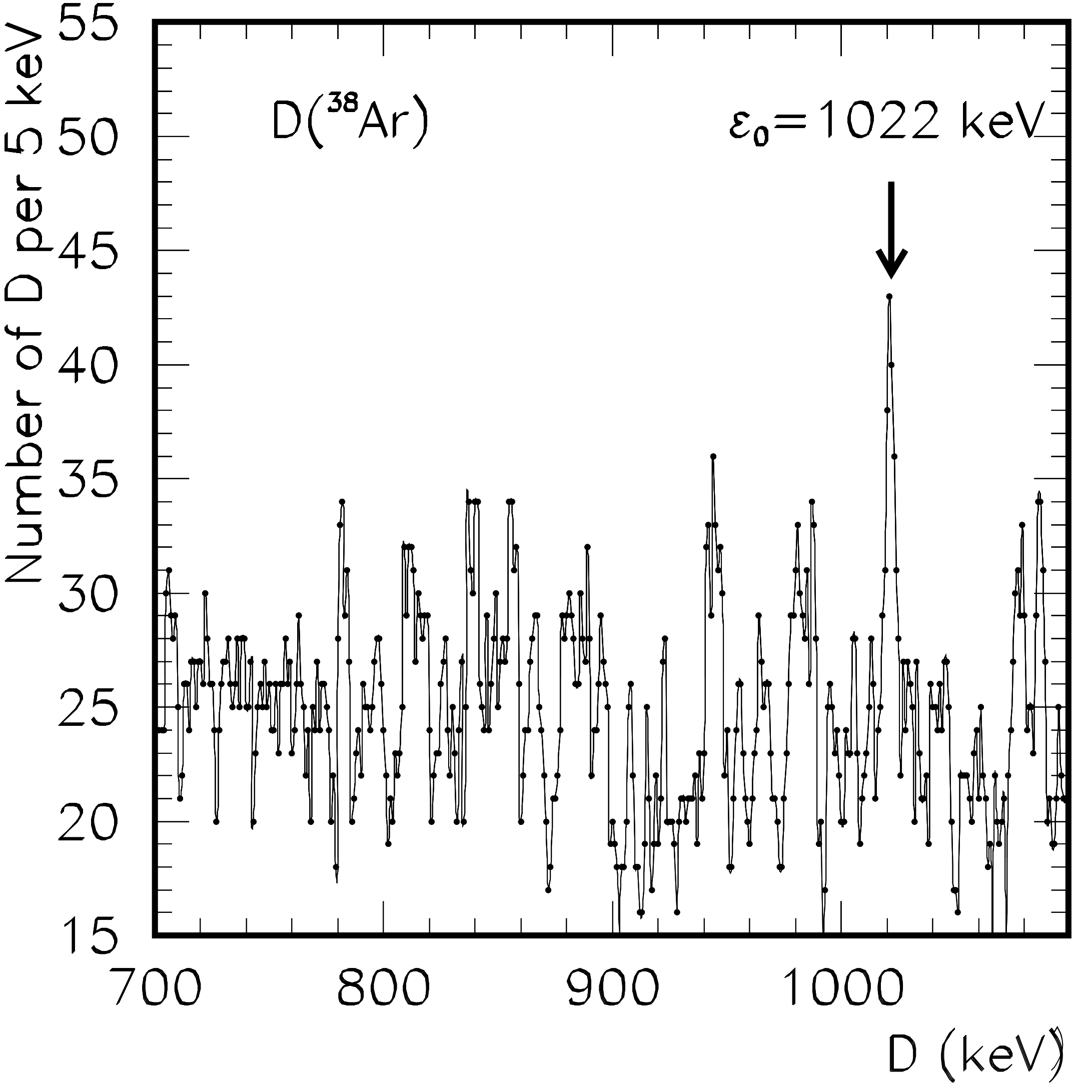

ε_n2p ↓ 680 keV
Number of ΔE_B per 30 keV
20
15
10
5
0
500
1000
ΔE_B, keV

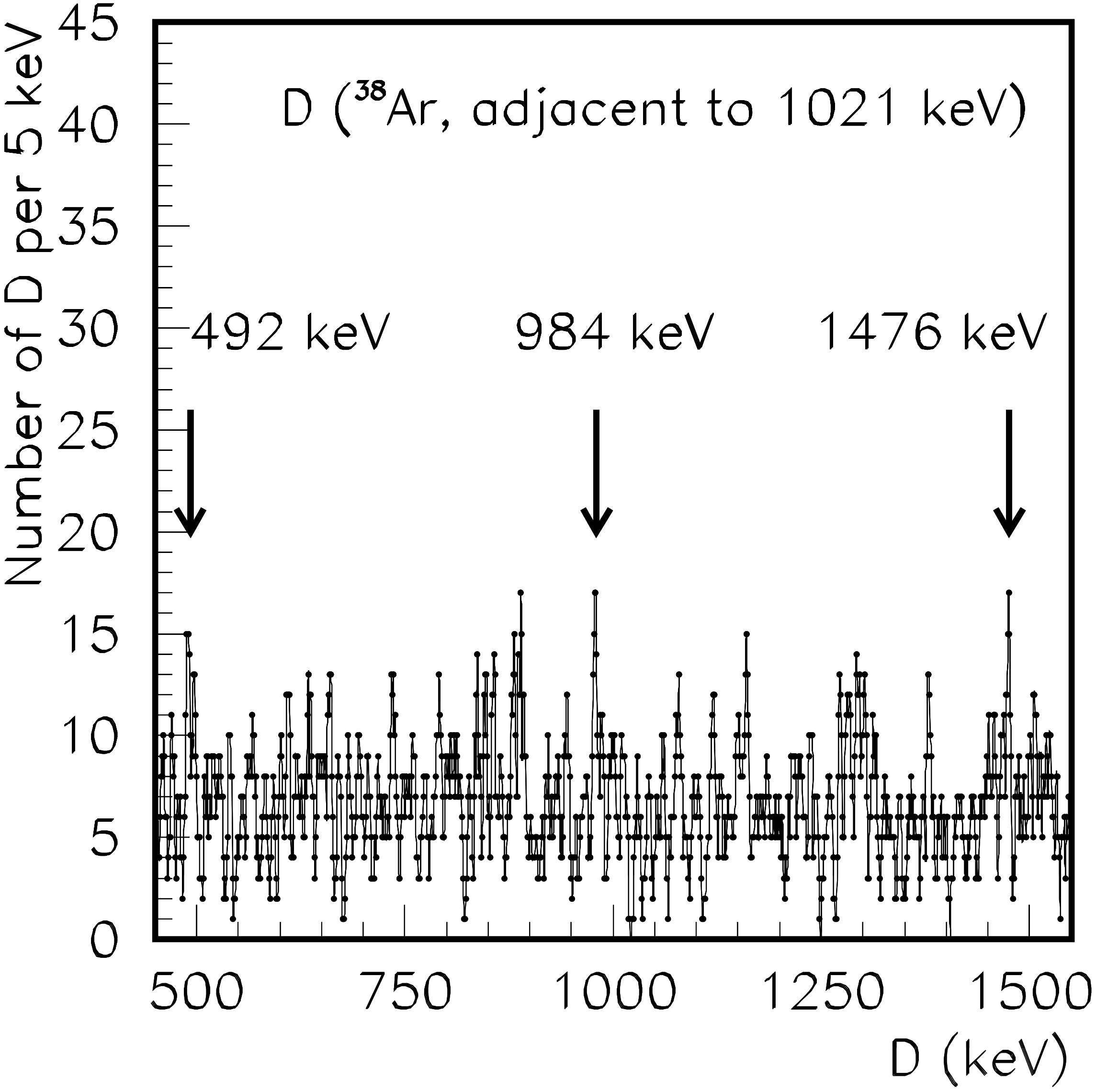

b)
$26\varepsilon_0$
$30\varepsilon_0$
$34\varepsilon_0$
Number of ΔE_B per 0.5 MeV
0
2
4
6
8
10
15
20
25
30
35
S_{4n}(MeV)

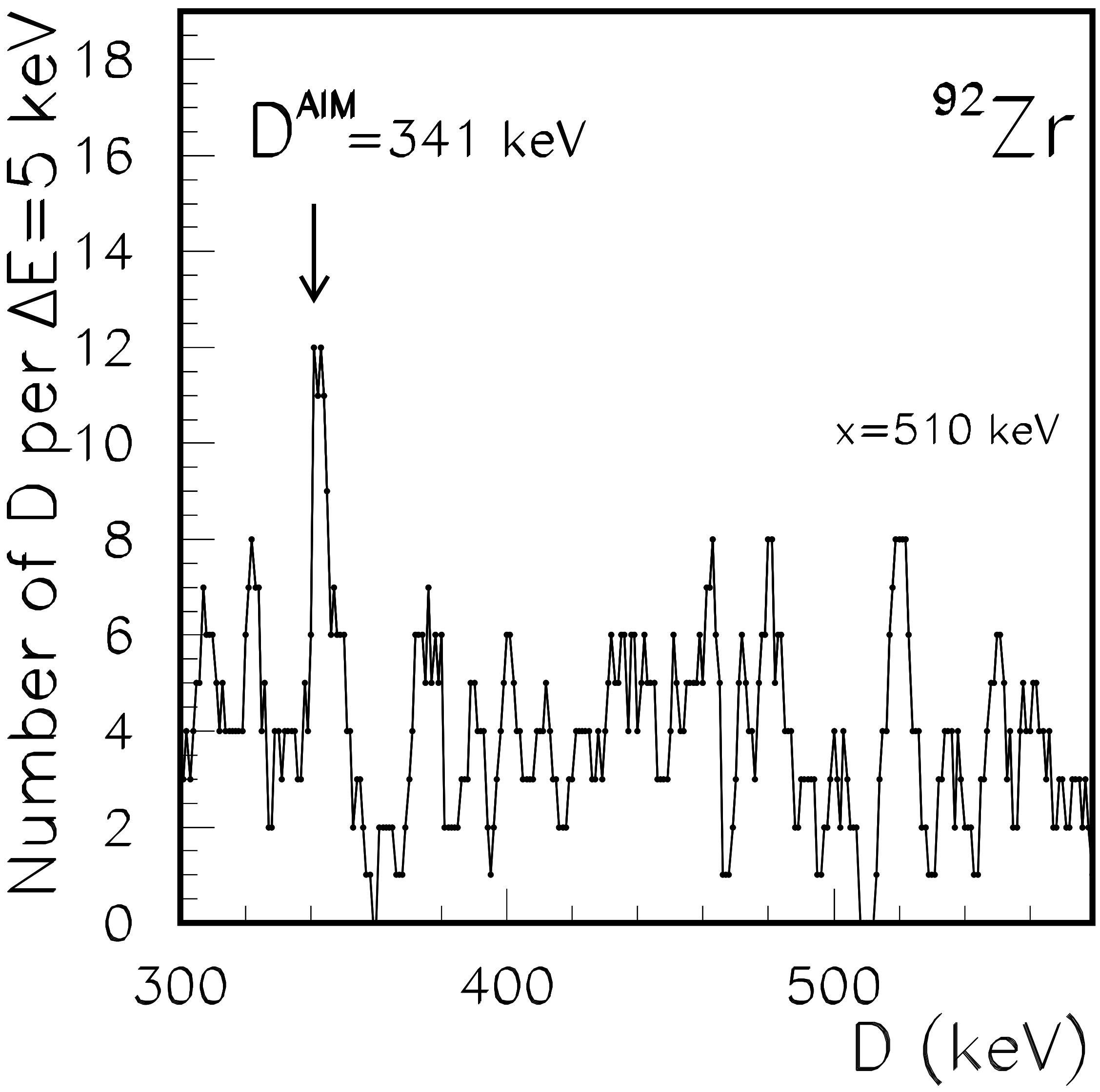

ΣE* (A≦150)
ε₀=1022 keV
Number of E* per 5 keV
20
30
40
50
60
70
80
90
1000
1100
1200
E*(keV)


D=1022 keV
Number of D per 5 keV
0
10
20
30
900
1000
1100
D, keV


D=1360 keV
Number of D per 5 keV
160
140
120
100
80
1200
1300
1400
1500
D, keV


D(^{38}Ar)
ε_0=1022 keV
Number of D per 5 keV
D (keV)
15
20
25
30
35
40
45
50
55
700
800
900
1000


D (^{38}Ar, adjacent to 1021 keV)
Number of D per 5 keV
45
40
35
30
25
20
15
10
5
0
492 keV
984 keV
1476 keV
500
750
1000
1250
1500
D (keV)



Number of D per ΔE=5 keV
0
2
4
6
8
10
12
14
16
18
300
400
500
D (keV)
D^AIM=341 keV
92Zr
x=510 keV

Table 3. Representation of parameters of tuning effects in particle masses (upper part) and in nuclear data by the expression $(\mathrm{n}\times m_e(\alpha/2\pi)^x)\times m$ with $\alpha=137^{-1}$ [5]. Asterisk marks stable intervals observed in low-energy excitations and neutron resonances; ε_{np}=340 keV is discussed in the text, Fig.7

x	m	n=1/8	n=1	n=13	n=16	n=17	n=18
-1	1			$M_Z=91.188$	$M_H=115$		
GeV	3				$\boxed{2m_t=348}$		
0	1	$2m_e$	$16m_e$	$m_\mu=105.658$		m_π-m_e	$147=\Delta M_\Delta$
MeV	1	ε_o	δ	$106.4=\Delta E_B$	$130=\Delta E_B$	$140=\Delta E_B$	$147=\Delta E_B$
	3				$M_q''=m_\rho/2\approx m_\omega/2$	$\boxed{M_q'=420}$	$M_q=441=\Delta E_B$
1	1	1.2*	$9.48=\delta'$*	123*	152*	161*	170*
keV	2			246*	303*	321*	$\varepsilon_{np}=340=\varepsilon_o/3$
	3			368*	455*	481*	$\boxed{511=\varepsilon_o/2}$
	8	9.5*	76*	984, Fig.8	1212*	$1293=D_o$	1360, Fig.8
2	1		11*	143*	176*	187*	D in neutron resonances
eV	4	5.5*	44*	572*		750 - 1500*	