Mass Rules, Shell Models and the Structure of Hadrons

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FIAS Kolloquium

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origin of the idea

1971 p-p elastic at ISR: kink in $d\sigma/dt$

1972 no quarks found at the ISR

1973 e-p DIS at SLAC:
point-like spin ½ partons, gluons, sea, ..

what are the partons, if not the quarks?

idea, looking at decays in PDG listings:

the stable leptons

count number of stable leptons in decays, (gamma = 2): muon =3, pion = 4, …

-> N(leptons) proportional to the mass; shell structure like in atoms and nuclei?

-> identify 4 shells: pi, K, p, Ω

A SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN
California Institute of Technology, Pasadena, California

Received 4 January 1964

If we assume that the strong interactions of baryons and mesons are correctly described in terms of the broken "eightfold way" [1-3], we are tempted to look for some fundamental explanation of the situation. A highly promised approach is the purely dynamical "bootstrap" model for all the strongly interacting particles within which one may try to derive isotopic spin and strangeness conservation and broken eightfold symmetry from self-consistency alone [4]. Of course, with only strong interactions, the orientation of the asymmetry in the unitary space cannot be specified; one hopes that in some way the selection of specific components of the F-spin by electromagnetism and the weak interactions determines the choice of isotopic spin and hypercharge directions.

Even if we consider the scattering amplitudes of strongly interacting particles on the mass shell only and treat the matrix elements of the weak, electromagnetic, and gravitational interactions by means

ber $n_t - n_{\bar{t}}$ would be zero for all known baryons and mesons. The most interesting example of such a model is one in which the triplet has spin $\frac{1}{2}$ and $z = -1$, so that the four particles d^-, s^-, u^0 and b^0 exhibit a parallel with the leptons.

A simpler and more elegant scheme can be constructed if we allow non-integral values for the charges. We can dispense entirely with the basic baryon b if we assign to the triplet t the following properties: spin $\frac{1}{2}$, $z = -\frac{1}{3}$, and baryon number $\frac{1}{3}$. We then refer to the members $u^{\frac{2}{3}}$, $d^{-\frac{1}{3}}$, and $s^{-\frac{1}{3}}$ of the triplet as "quarks" [6] q and the members of the anti-triplet as anti-quarks $\bar{q}$. Baryons can now be constructed from quarks by using the combinations (qqq), $(qqqq\bar{q})$, etc., while mesons are made out of $(q\bar{q})$, $(qq\bar{q}\bar{q})$, etc. It is assuming that the lowest baryon configuration (qqq) gives just the representations **1**, **8**, and **10** that have been observed, while the lowest meson configuration $(q\bar{q})$ similarly gives just **1** and **8**.

P. Palazzi

1975 (unpublished)

Indicazioni di una struttura a shell delle particelle e conseguenze relative

Elaborato presentato al concorso-esame per l' idoneita' al grado di R5 (ricercatore) dell' INFN.

giugno 1975

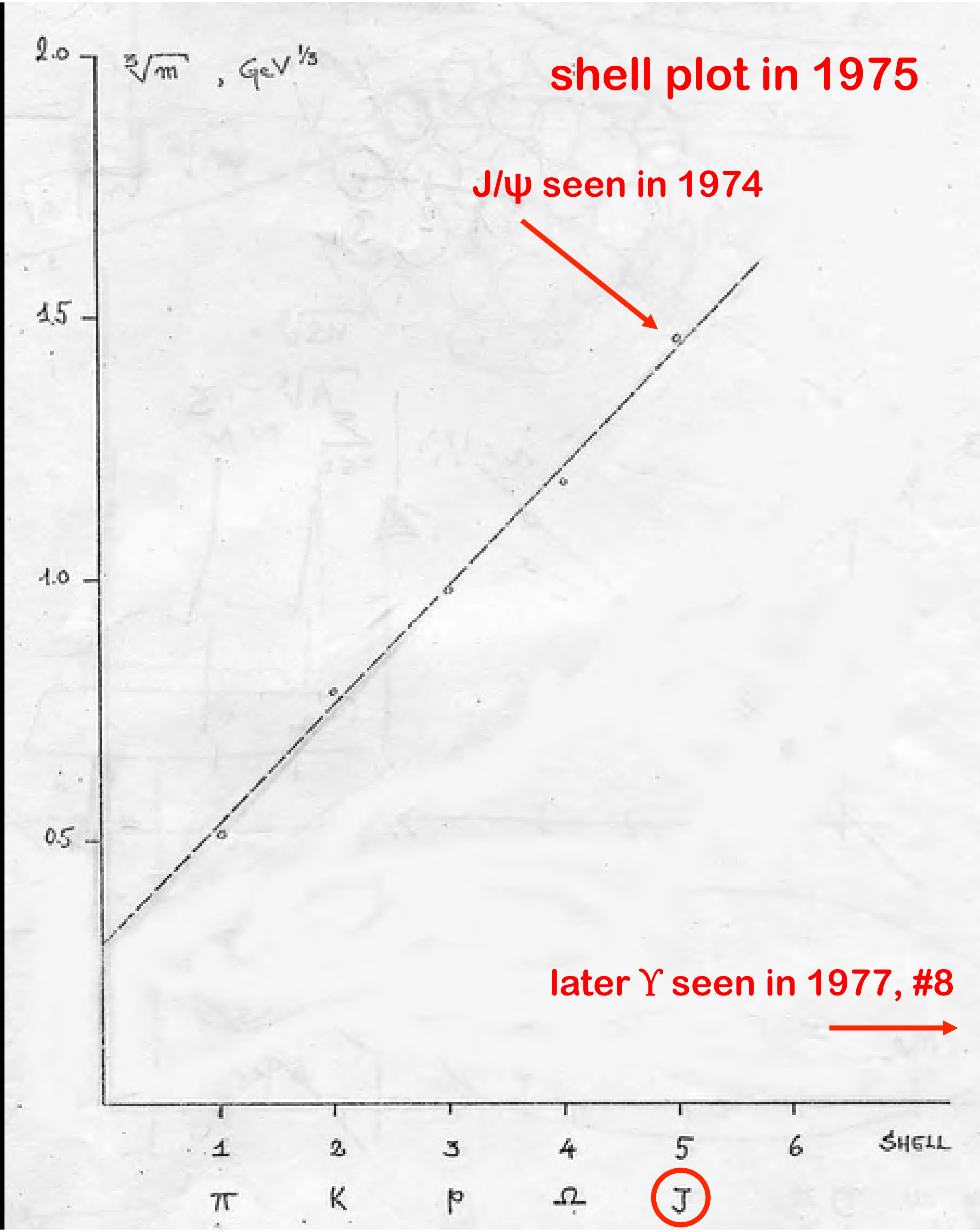
RIASSUNTO

Un'ipotesi generale sul contributo dei componenti (sconosciuti) delle particelle alla massa totale, associata ad un semplice concetto geometrico di stabilita', implica che le radici cubiche delle masse delle particelle relativamente piu' stabili sono equispaziate.

La relazione suindicata e' verificata sullo spettro di massa, e si predicono ulteriori zone di stabilita' attorno a 4.6 GeV e 6.8 GeV .

Si stabilisce un' analogia con i nuclei ed i numeri magici.

Si traggono delle conclusioni sul numero dei componenti elementari del pione, e si formula l' ipotesi che i leptoni stabili siano i costituenti elementari della materia. Ne derivano alcune proprieta' dell' interazione di legame, e conseguenze sul significato dei numeri quantici, in particolare il numero barionico.


shell plot in 1975
J/ψ seen in 1974
later ϒ seen in 1977, #8
2.0
1.5
1.0
0.5
$\sqrt[3]{m}$, GeV$^{1/3}$
1
2
3
4
5
6
SHELL
π
K
p
Ω
J

I was not alone:

- mass difference of 70 MeV/c^2 :
  - Nambu in 1952,
  - Mac Gregor in 1970, and a few others
- stable leptons as constituents:
  - Barut in 1979

m$_e$/α = **70.02 MeV/c^2**

Table I.
Change of coupling constant from the simple formula (4) and (5).

Meson Kinetic Energy (Mev)	40	80	120	160
$(g_I^{\rm effective}/g)^2$	0.52	0.40	0.28	0.17
$(g_{II}^{\rm effective}/g)^2$	1.32	1.39	1.46	1.51

Coupling constant was taken $g_1 = 0.8g$ and the mass of V^0-particle to be $3000m_e$. For $g_{II}^{\rm effective}$, we put $g_0 \sim g$ in (5), which is not sensitive to the value listed.

considerably in its magnitude, but the above simple arguments permits us to discuss roughly their angular distributions as follows ; the normally scattered meson has angular distribution which is nearly the same as in reference 2, because the effect of V^0-particle is only to change the coupling constant. But as to the charge exchange scattering, the angular distribution is more like that of Process II, because this scattering is composed of process I and II and, exact evaluation shows that the process II is predominant[4]. Since the angular distribution of scattered meson given in reference 2 is nearly the same for process I and II, and we may roughly expect almost the same angular distribution for normal- and exchange-scattering.

In conclusion, the writer wishes to express his sincere thanks to Prof. M. Kobayasi and to Mr. S. Takagi for their kind interest taken in this work.

1) For summary of references, see A. Pais, preprint.
2) J. Ashkin, A. Simon and R. E. Marshak, Prog. Theor. Phys. 5 (1950), 634.
3) P. J. Isaacs, A. M. Sachs and J. Steinberger, Phys. Rev. 85 (1952), 803; Fermi et al. Phys. Rev. 85 (1952), 934, 935, 936.
4) Owing to the choice of coupling as given in Fig. 3, for $\pi^- + P \to \pi^0 + N$, we have as effective coupling constant, in (4) and (5)

$$g_I^{\rm eff} = g g_N + \frac{[m+m_1][(p_0+q_0)^2-\mu^2]}{2m[(p_0+q_0)^2-m_1^2]} f_1 g_{N_1},$$

$$g_{II}^{\rm eff} = g g_P + \frac{[m+m_1][(p_0-q)^2-\mu^2]}{2m[(p_0-q)^2-m_1^2]} f_1 g_{P_1}$$

$$= -\left(g g_N - \frac{[m+m_1][(p_0-q)^2-\mu^2]}{2m[(p_0-q)^2-m_1^2]} f_1 g_{N_1}\right)$$

and thus, $(g_I^{\rm eff}/g g_N)^2$ is just corresponding quantity in Table I, $((g_1 g_N)^{1/2} = 0.8 (g g_N)^{1/2})$, but $(g_{II}^{\rm eff}/g g_N)^2$ is

40	80	120	160
0.72	0.67	0.62	0.59

An Empirical Mass Spectrum of Elementary Particles

Y. Nambu

Osaka City University

May 14, 1952

1952

It seems to be a general conviction of current physicists that the theory of elementary particles in its ultimate form could or should give the mass spectrum of these particles just in the same way as quantum mechanics has succeeded in accounting for the regularity of atomic spectra. Even if we disregard any philosophical background in such a postulation of theoretical physics, the recent discovery of many unstable, apparently elementary particles drives us to the efforts towards a systematic comprehension of the variety of elementary particles. With the present undoubtedly insufficient accumulation of our knowledge, however, it may perhaps be too ambitious and rather unsound to look for an empirical "Balmer's law". Nevertheless we should like here to present one such attempt because it

!

happens to be extremely simple, and because the significance and utility, if any, of this kind of attempt could best be appreciated at the stage where it awaits more experimental data to prove or disprove itself by its own predictions.

The nature of V_0 particles[1)] and τ-mesons[2)] has been investigated by several authors. Among other things, we note that their decay Q-values are rather uniform, i.e. of the same order of magnitude of the rest mass of the daughter π-mesons. This gives us a hint that some regularity might be found if the masses were measured in a unit of the order of the π-meson mass. The π-meson mass, being $\sim 274 = 137 \times 2$ electron masses (m_e), gives us a second, rather fanciful hint that $137\ m_e$ could be chosen as the unit. The ensuing result is given in the accompanying table. We see

particle	mass no. n	$137 \times n$	experimental mass
lepton	0	0	~ 0
photon	0	0	0
μ	1½	206	$210 \pm 3\ m_e$
π	2	274	$276 \pm 3\ (\pi^\pm)$
V_{02}	6	822	800 ± 30
τ	7	959	966 ± 10
$\varkappa$			$1000 \sim 1500$
nucleon	13½	1849	1837, 1839
V_{01}	16, 16½	Q=35, 70 Mev	35 ± 5, 75 ± 3Mev
V^*	17½	Q=280 Mev	~ 280 Mev

that the "mass number" of the observed particles is either integer or half-odd, which is generally valid within a deviation of about $\sim \pm 15 m_e$, or $\sim \pm$ 1/10 mass unit, for those cases in which the experimental error is also of this order of magnitude. In the above table, we have adopted the view that the heavy V_0 particles have two kinds of Q-values, namely $\sim$35Mev (1/2 mass unit) and $\sim$70Mev (1m.u.)[3)], decaying into a proton and a π-meson. V^* means the nucleon isobar whose existence is being conjectured from γ-π reaction and π-proton scattering,[5)] with an excitation of roughly about 280 Mev (4 m.u.).

We can make a few comments on the result. 1 As was pointed out by Enatsu[4)], the adopted mass unit incidentally agrees with Heisenberg's natural unit. 2 Bosons seem to have integral, while fermions half-integral, mass numbers. 3 The small mass value of the electron cannot be explained by the above rule. But we can take the view that this as well as the proton-neutron and $\pi^\pm$-π^0 mass differences correspond to a kind of fine structure. Indeed, their magnitude is just of the order of 1/137 m.u.

It goes without saying that this rule is purely of an empirical nature, and might turn out to be entirely illusory or accidental in the event of getting more reliable data or establishing the true theory of mass spectrum. But the rather strange distribution of the observed mass numbers might simply mean the lack of our knowledge. Indeed, only those particles which have favorable lives as well as abundances for detection have so far been observed, and we have no grounds at all to exclude the possibility that there exist other particles which are liable to escape direct observation. At any rate, an effective and close-by test of this rule may be provided by more accurate determination of the masses of the observed particles. In particular, the $\varkappa$-meson may be predicted to have any of $\sim$1030, $\sim$1100, $\sim$1160, $\sim$1230, $\sim$1300,... electron masses (7½, 8, 8½, 9, 9½,... m.u.).

1) E. g., R. Armenteros et al., Phil. Mag. **42** (1951), 1113.
2) P. H. Fowler et al., Phil. Mag. **42** (1951), 1040.
3) S. D. Wanlass et al., Bull. Amer. Phys. Soc. **27** (1952), No. 3, 7.
4) Remarks by H. Enatsu at the Tokyo meeting of the Physical Society of Japan. April 1–3, 1952.
5) K. A. Brueckner, Bull Amer. Phys. Soc. **27** (1952), No. 1, 50.

$m_e/\alpha = 70.02\ \mathrm{MeV}/c^2$

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OCT
CALIFORNIA
70 MEV

STABLE PARTICLES AS BUILDING BLOCKS OF MATTER *

A.O. Barut **

International Centre for Theoretical Physics, Trieste, Italy.

ABSTRACT

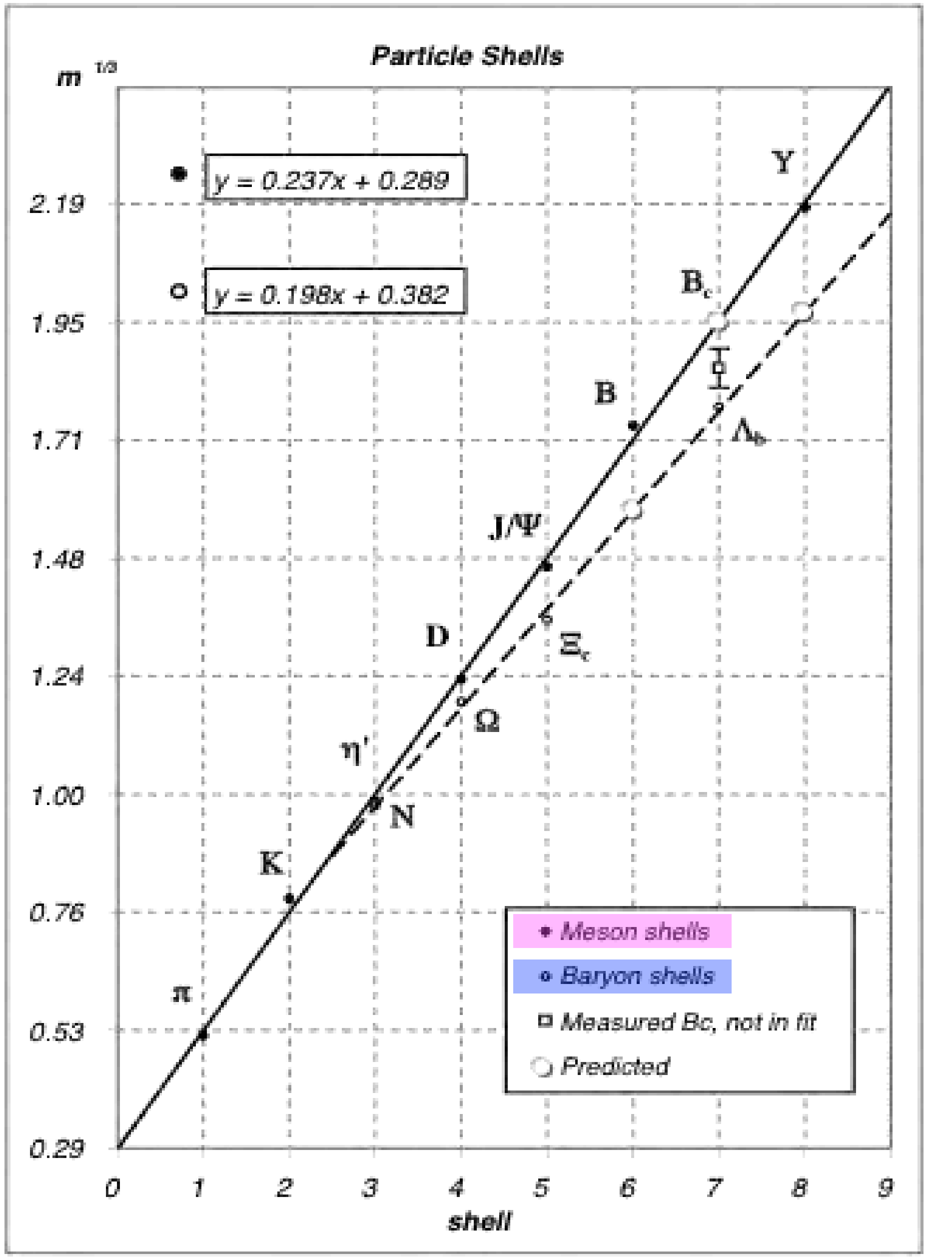
Only absolutely stable particles can be truly elementary. A simple theory of matter based on the three constituents, proton, electron and neutrino (and their antiparticles), bound together by the ordinary magnetic forces is presented, which allows us to give an intuitive picture of all processes of high-energy physics, including strong and weak interactions, and make quantitative predictions.

MIRAMARE - TRIESTE

April 1979

~ 30 years later

CERN-OPEN-2003-006
19 Mar 2004



CERN-OPEN-2003-006
24-JAN-2003
Revision 2, 19-MAR-2004

Particles and Shells

Paolo Palazzi, CERN

Abstract

The current understanding of particle masses in terms of quarks and their binding energy is not satisfactory. Both in atoms and in nuclei the organizing principle of stability is the shell structure, while this does not seem to play any role for particles. In order to explore the possibility that shells might also be relevant at this inner level of aggregation, atomic and nuclear stability are expressed by "stablines", alignments of the 1/3 power of the total number of constituents of the most stable configurations. Could similar patterns be found in the particle spectrum? By analyzing the distribution of particle lifetimes as a function of mass, stability peaks are recognized for mesons and for baryons and indeed the cube roots of their masses follow two distinct stablines. Such alignments would be a strong indication that the particles themselves are shell structured assuming only that each constituent contributes a constant amount to the total mass. This is incompatible with the prevalent view that the partons —real physical constituents seen in deep-inelastic scattering experiments—are the quarks. The mass of the B_c predicted by interpolation with the meson stabline is 7.4 ±0.2 GeV. On the baryon stabline two missing states are predicted at 3.9 and 7.6 GeV.

trouble...

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Download from: http://weblib.cern.ch/abstract?CERN-OPEN-2003-006

must establish

statistically relevant

hadron mass rules!

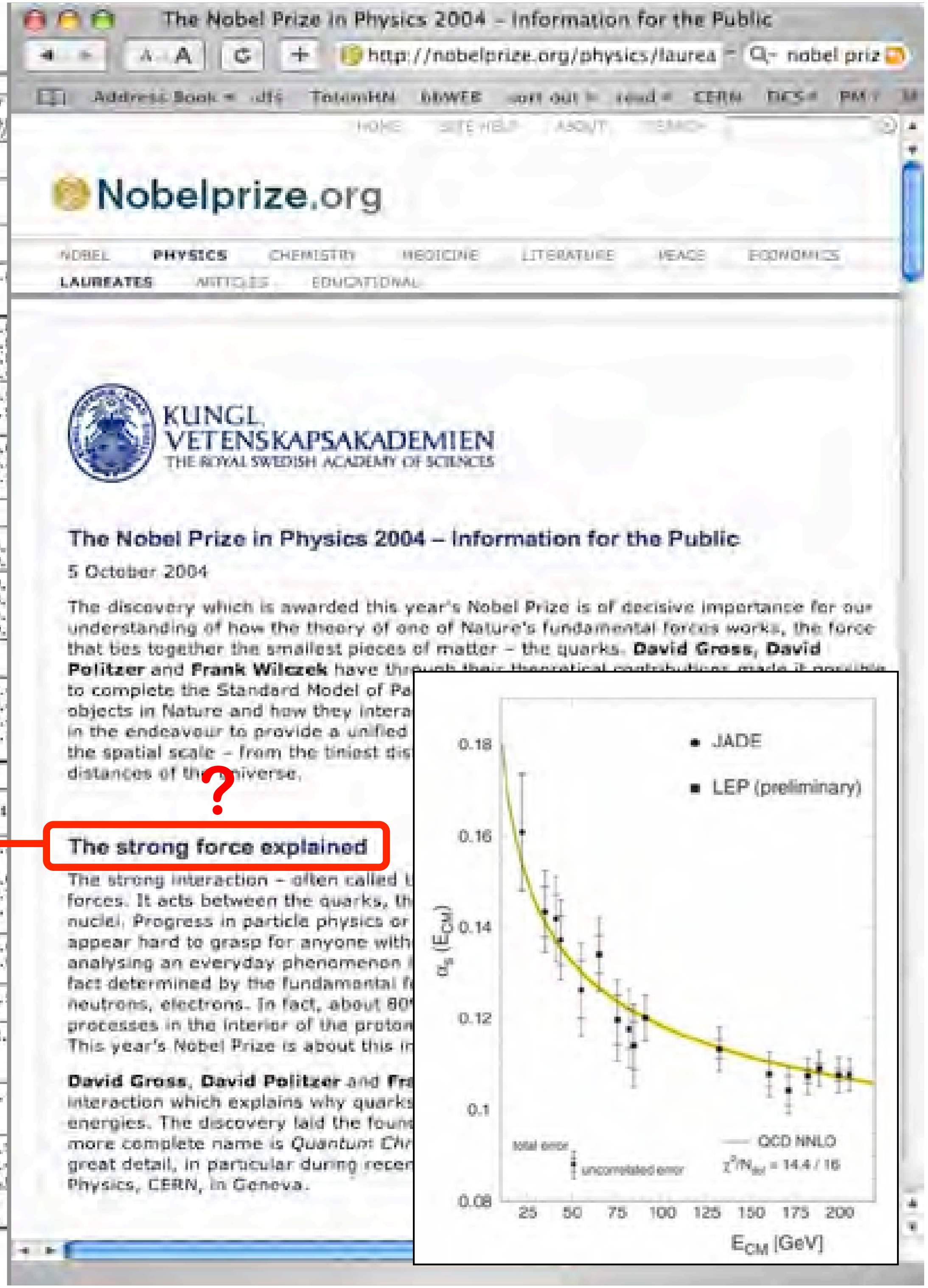
TABLES FROM UCRL-8030(rev.) June 1964

Table S - Stable particles

?

		$I(J^{PG})C_A$	Mass (MeV)	Mass diff. (MeV)	Mean life (sec)	Mass^2 $(\text{BeV})^2$	Important decays: Partial mode	Fraction	Q (MeV)	p or P_{max} (MeV/c)
	γ	$J^P=1^-C^-A^+$	0		stable	0	stable			
LEPTONS	ν_e ν_μ	J=1/2	0(<0.2 keV) 0(<4 MeV)		stable	0 0	stable			
	$e^\pm$	J=1/2	0.511006 ±0.000002		stable	0.000	stable			
	$\mu^\pm$	J=1/2	105.659 ±0.002	-33.95 ±0.05	2.2001×10^{-6} ±.0008 ×scale=2.5	0.011	eνν	100%	105.15	52.
MESONS	$\pi^\pm$	$1(0^-)G^-A^-$?	139.60 ±0.05		2.55×10^{-8} ±.26	0.019	μν eν μνγ $\pi^0e\nu$	100% $(1.24\pm.05)10^{-4}$ $(1.24\pm.25)10^{-4}$ $(1.5\pm.3)10^{-8}$	33.95 139.10 33.94 4.08	29. 69. 29. 4.
	π^0		135.01 ±0.05	4.590 ±.004 ×scale=2.4	1.80×10^{-16} ±.29 ×scale=1.3	0.018	γγ γe^+e^-	98.8 (1.19±.05)%	135.01 133.99	67. 67.
	$K^\pm$	$1/2(0^-)A^-$?	493.8 ±0.2	-4.2 ±0.5 ×scale=1.2	1.229×10^{-8} ±.008	0.244	μν $\pi^\pm\pi^0$ $\pi^\pm\pi^-\pi^+$ For other decays see Table S Decays	(63.1±.4)% (21.5±.4)% (5.5±.1)%	388.1 219.2 75.0	235. 205. 125.
	K^0		498.0 ±0.5		50% K1, 50% K2					
	K_1			$-0.71\times1/\tau_1$ ±0.07 ×scale=2.3	0.92×10^{-10} ±.02	0.248	$\pi^+\pi^-$ $\pi^0\pi^0$	(69.4±5.1)% (30.6±1.1)%	218.8 228.0	206. 209.
	K_2				5.62×10^{-8} ±.68	0.248	$\pi^0\pi^0\pi^0$ $\pi^+\pi^-\pi^0$ πμν πeν	(27.1±3.6)% (12.7±1.7)% (26.6±3.2)% (33.6±3.3)%	93.0 83.8 252.7 357.9	139. 133. 216. 229.
	η	$0(0^{-+})C^+A^-$?	548.7 ±0.5		Γ<10 MeV	0.301	γγ $3\pi^0$ or $\pi^0 2\gamma$ $\pi^+\pi^-\pi^0$ $\pi^+\pi^-\gamma$	(35.3±3.0)% (31.8±2.3)% (27.4±2.5)% (5.5±1.3)% ×scale=1.1	548.7 143.7 134.5 269.5	274. 179. 174. 236.
BARYONS	p	$1/2(1/2^+)$	938.256 ±0.005	-1.2933 ±.0001	stable	0.880				
	n		939.550 ±0.005		1.01×10^3 ±.03	0.883	$pe^-\nu$	100%	0.78	1.1
	Λ	$0(1/2^+)$	1115.40 ±0.11		[illegible] ±.02 ×scale=1.5	1.244	pπ $n\pi^0$ pμν peν	[illegible] ×scale=1.2 (31.6±2.6)% $<1\times10^{-4}$ $(.88\pm.08)10^{-3}$ ×scale=1.7	[illegible] 40.9 71.5 176.6	[illegible] 103. 130. 163.
	Σ^+	$1(1/2^+)$	1189.41 ±0.14	2.9	0.788×10^{-10} ±.027	1.415	$p\pi^0$ $n\pi^+$ For other decays see Table S Decays	51.0±2.4% 49.0±2.4%	116.13 110.26	189. 185.
	Σ^0		1192.3 ±0.3		$<1.0\times10^{-14}$	1.422	Λγ	100%	77.0	74.
	Σ^-		1197.08 ±0.19 ×scale=1.4	4.75 ±.10	1.58×10^{-10} ±.05	1.433	$n\pi^-$ For other decays see Table S Decay	100%	116.94	191.
	Ξ^0	$1/2(1/2^+)$?	1314.3 ±1.0	6.5 ±1.0	3.06×10^{-10} ±.40	1.727	$\Lambda\pi^0$ For other decays see Table S Decay	100%	76.9	150.
	Ξ^-		1320.8 ±0.2 ×scale=1.3		1.74×10^{-10} ±.05	1.745	$\Lambda\pi^-$ $\Lambda e^-\nu$ $n\pi^-$	100% $(3.0\pm1.7)10^{-3}$ $<5\times10^{-3}$	65.8 204.9 214.7	138. 169. 303.
	Ω^-	$0(3/2^+)$? ?	1675 ±3		$\sim0.7\times10^{-10}$		Ξπ ΛK	? ?	221 66	296 216

A. H. Rosenfeld, A. Barbaro-Galtieri, W. H. Barkas, P. L. Bastien, J. Kirz, M. Roos
UCRL-8030 - Part I. June 1964.



atomic physics timeline

CHEMISTRY
1808 Dalton: chemistry is atomic

TAXONOMY
1869 Mendeleyev: periodic table

ENERGY LEVELS
1885 Balmer: spectral rules
1890 Rydberg: extended spectral rules

CONSTITUENTS
1987 Thomson: electron

MODEL
1907 Lenard: model with (+,-) charges
1904 Nagaoka: planetary model
1913 Bohr: model of the H atom

THEORY
1925 Heisenberg: matrix (QM)
1926 Schroedinger: equation (QM)
1926 Schroedinger: H atom
1927: Heitler and London, quantum theory explains chemical bonding
1928 Dirac: equation

particle physics timeline

TAXONOMY
1961 SU(X) multiplets: plausible but incomplete

ENERGY LEVELS (MASSES)
lots of data, but no rules:
1962-64 GMO and 1962 Chew-Frauschi plot,
no longer quoted by the PDG

CHEMISTRY
1963 Cabibbo: later re-expressed as quark mixing, later CKM

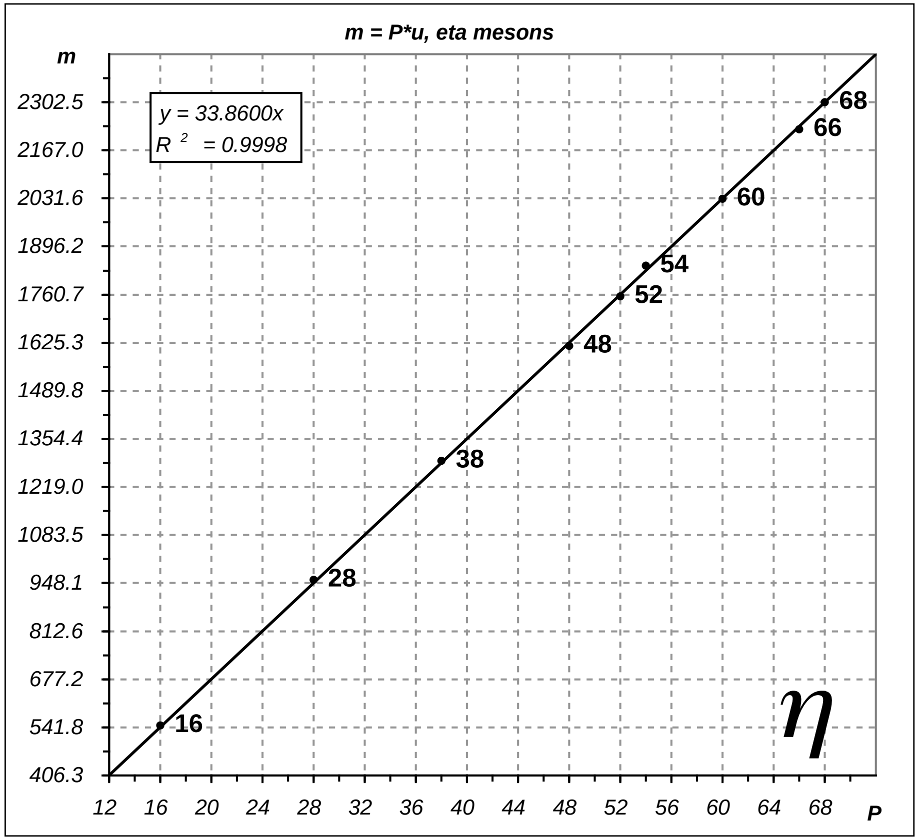
MODEL
1964 quark "model" evolved from taxonomy, schematic

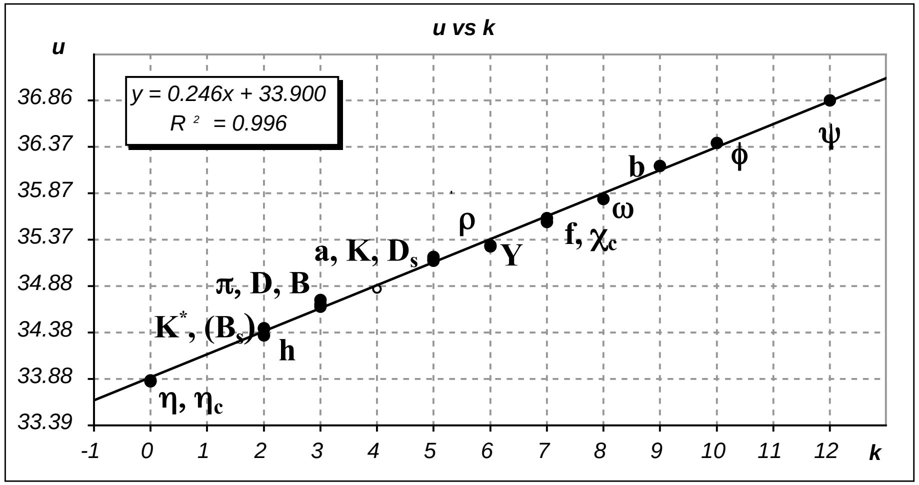
? ? ?

CONSTITUENTS
1969 partons (.. = quarks, undeconfinable)

THEORY
197x, blessed in 2004: perfect, but ...

the meson mass system





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28-JUL-2004
Revision 1, 5-APR-2005

Patterns in the Meson Mass Spectrum

Paolo Palazzi **2004**

Abstract

The conjecture that particle masses are multiples of a unit u of about 35 MeV has been proposed in various forms by several authors: mesons are even multiples of u, leptons and baryons odd multiples. Here this mass quantization is reassessed for all particles with mass below 1 GeV (stable leptons and $f_0(600)$ excluded), and found to be statistically significant. Subsequently all the mesons listed by the PDG are grouped in families defined by quark composition and J^{PC}, and analyzed for even mass multiplicity with a unit close to 35 MeV separately for each group. For all the the families that can be analyzed unambiguously this multiplicity hypothesis is found to be statistically significant. Most scalar and vector families show a dependence of u from the spin, while for pseudoscalars the effect is not present. Only 5 states out of 120 are rejected due to abnormally large fit residuals. The mass units of the various families are quantized on a grid of 12 intervals of about 0.25 MeV, ranging from 33.88 up to 36.86 MeV. The location of the values on the u-grid shows an intriguing pattern of correlation with the quantum numbers.

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Download from: http://www.particlez.org/p3a/

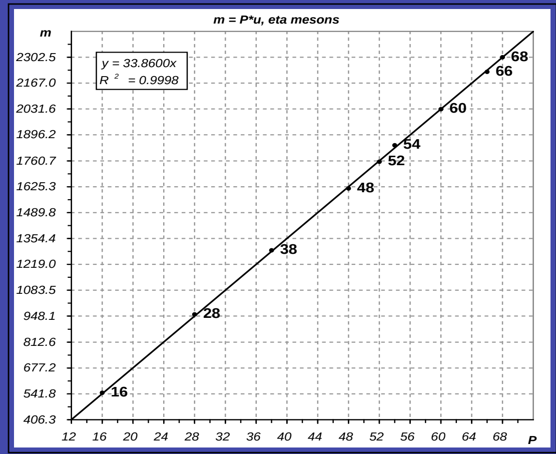
NB: two kinds of plots

- mass unit:
  mass vs integer: linear-linear

m vs P

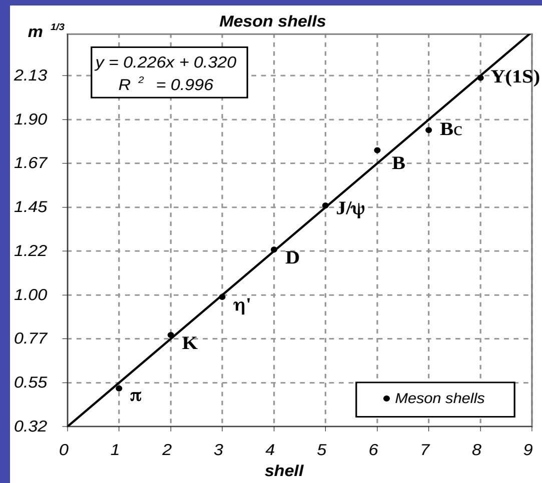
(also mass unit vs integer)

u vs k



- shells:
  $X^{1/3}$ vs integer: cuberoot-linear

$m^{1/3}$ vs i_S



mass unit: $u \cong 35$ MeV/c^2 to avoid half-integers

hypothesis:

$m_i = u * P_i : P \in$ E for mesons

($P \in$ O for baryons and leptons)

test procedure:

FOREACH set of [mesons / (q-qbar, J^{PC})] DO:

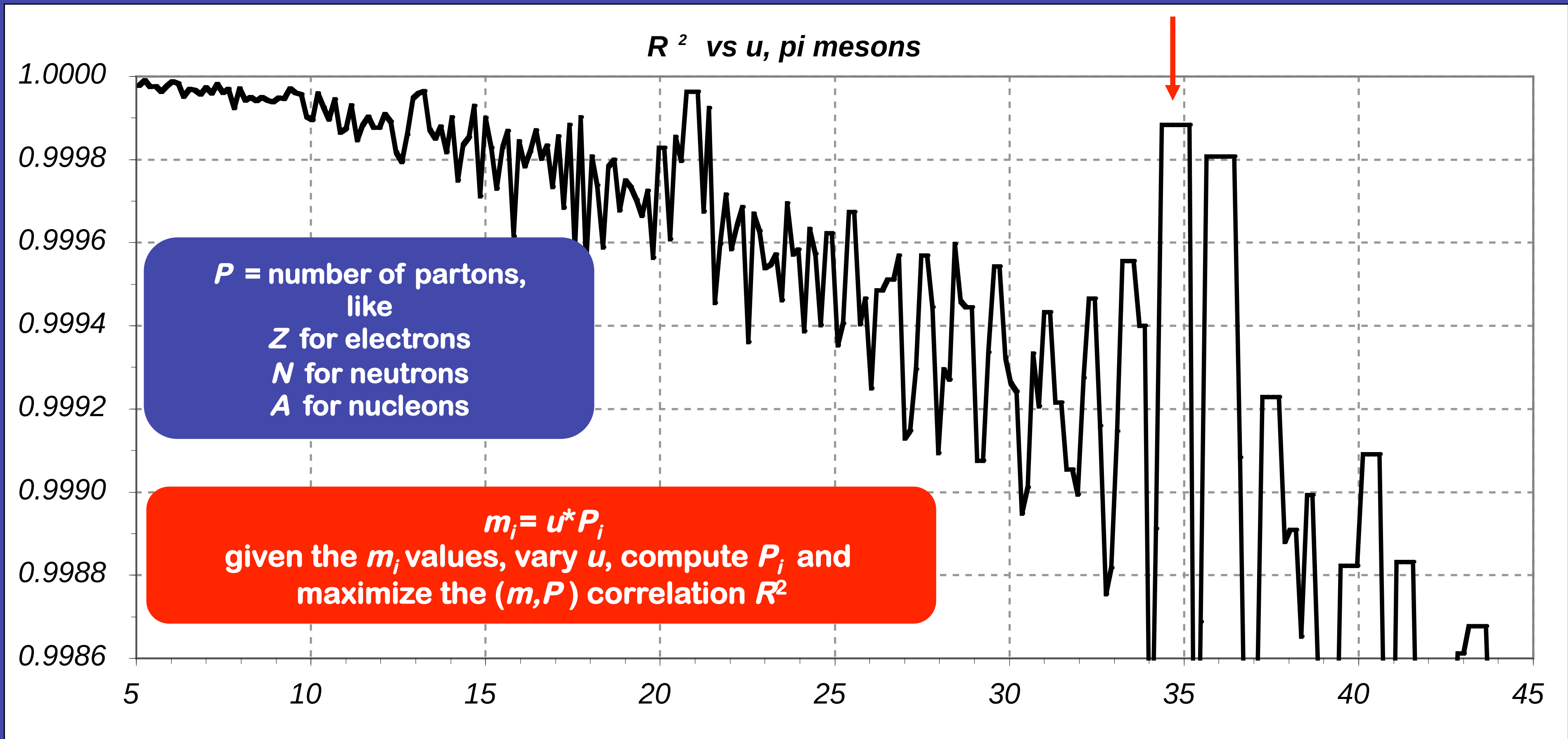
1. discard states with large *errm*
2. maximize $R^2(m,P)$ varying u around 35 MeV/c^2
3. fit u with the least squares
4. remove outliers with Chauvenet's criterion
5. check for spin dependence du / dJ
6. compute statistical relevance as $p(H_0)$ by MC

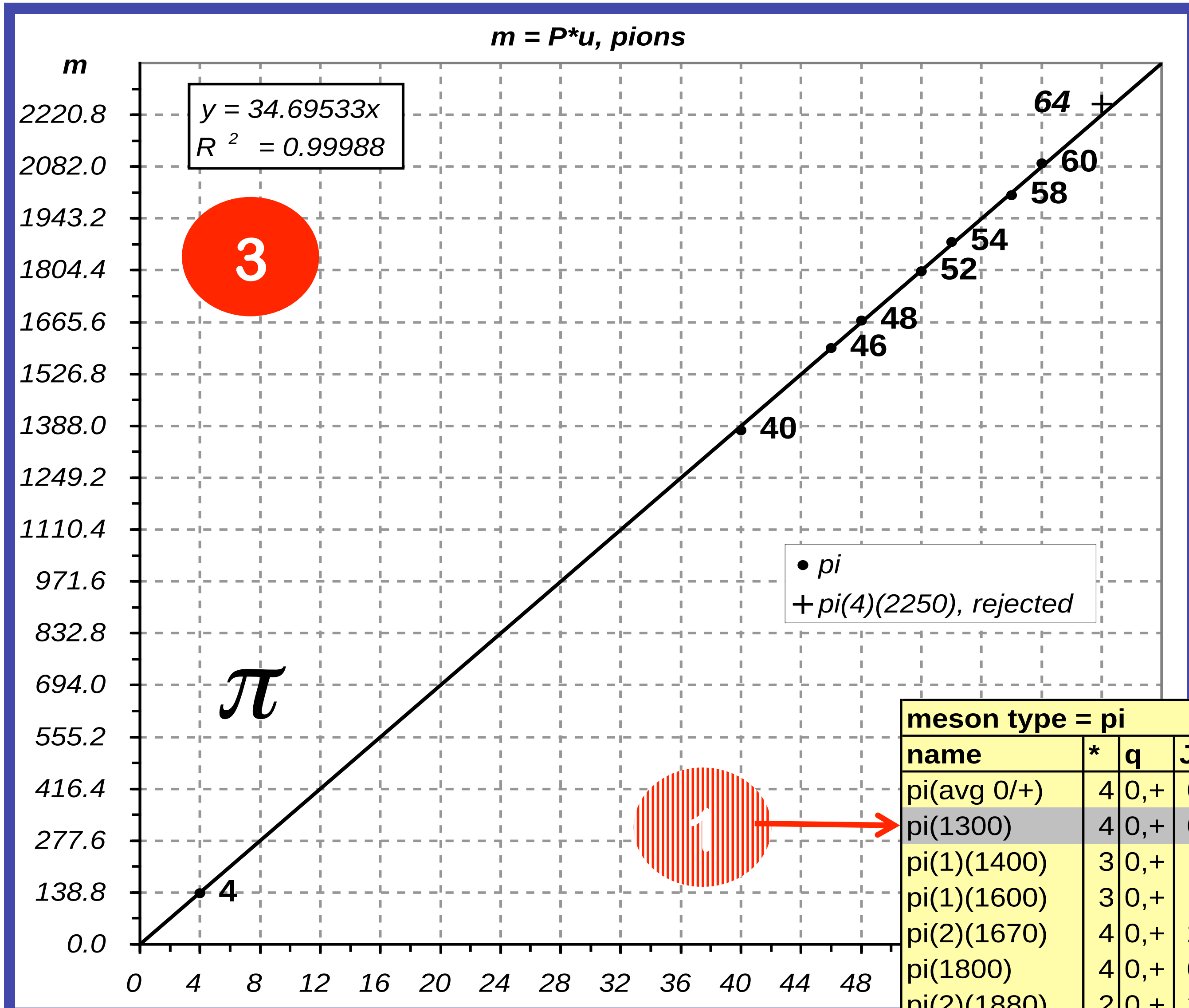
ENDDO

example: the pions

1 remove states with large errors

2 maximize R^2 varying u





residuals, compare with [-34.7, 34.7] uniform

meson type = pi										
name	*****	**q**	**J**	**x**	**P**	**m**	**errm**	**u=m/P**	**dm**	**dm/m**
pi(avg 0/+)	4	0,+	0		4	137.3	6.0E-04	34.318	-1.8	1.33%
pi(1300)	4	0,+	0	1	38	1300.0	100.0	34.211	-18.4	1.42%
pi(1)(1400)	3	0,+	1		40	1376.0	17.0	34.400	-14.9	1.09%
pi(1)(1600)	3	0,+	1		46	1596.0	20.0	34.696	-3.6	0.22%
pi(2)(1670)	4	0,+	2		48	1670.0	20.0	34.792	0.9	0.05%
pi(1800)	4	0,+	0		52	1801.0	13.0	34.635	-7.2	0.40%
pi(2)(1880)	2	0,+	2		54	1880.0	20.0	34.815	2.2	0.12%
pi(2)(2005)	2	0,+	2		58	2005.0	15.0	34.569	-11.9	0.59%
pi(2)(2100)	3	0,+	2		60	2090.0	29.0	34.833	3.6	0.17%
pi(4)(2250)	2	0,+	4	3	64	2250.0	15.0	35.156	24.5	1.09%

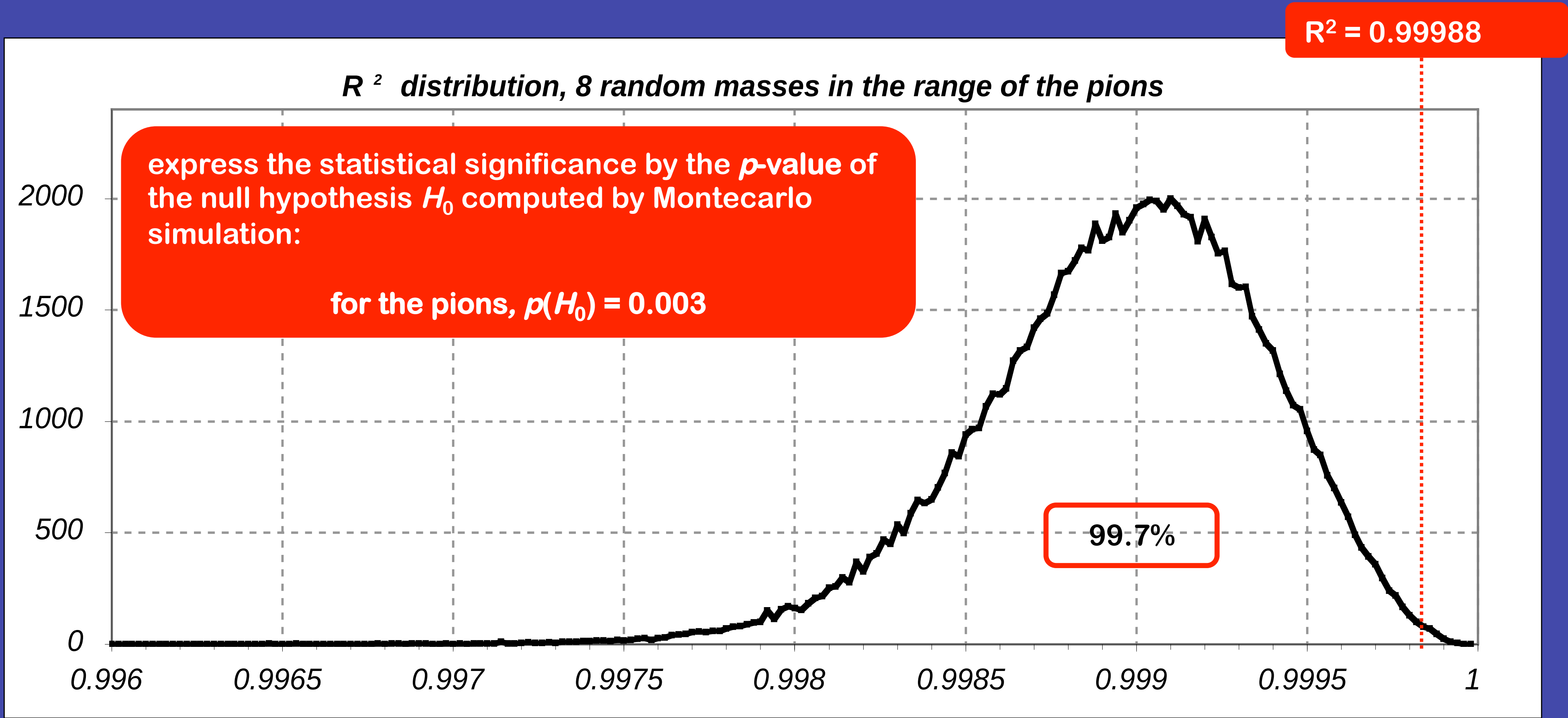
4

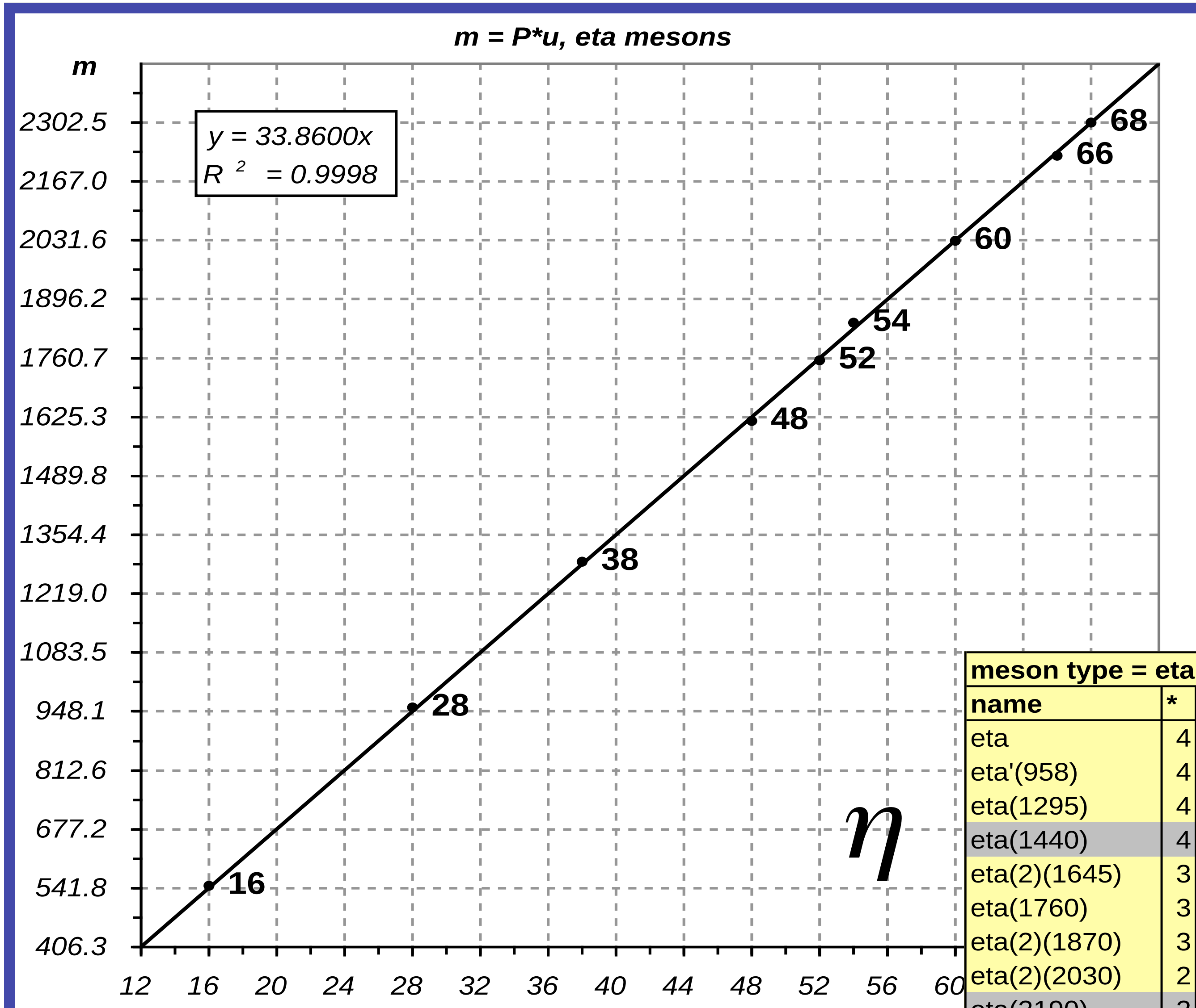
summary pi mesons	
u	34.69 ± 0.051
p-value	0.997 --> $p(H_0)$ = 0.003
spin dependence	no
omitted	3 = 1 averaged + 1 large errm + 1 Chauvenet

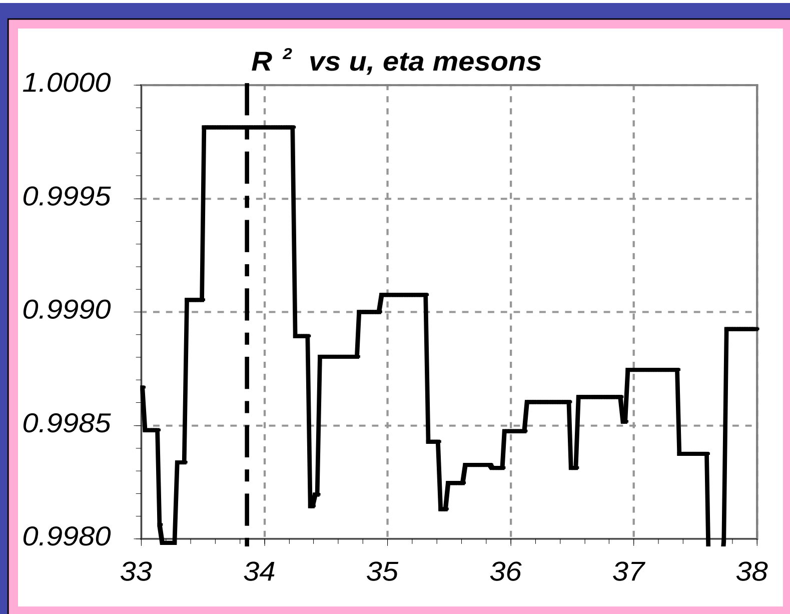
5

6

statistical relevance





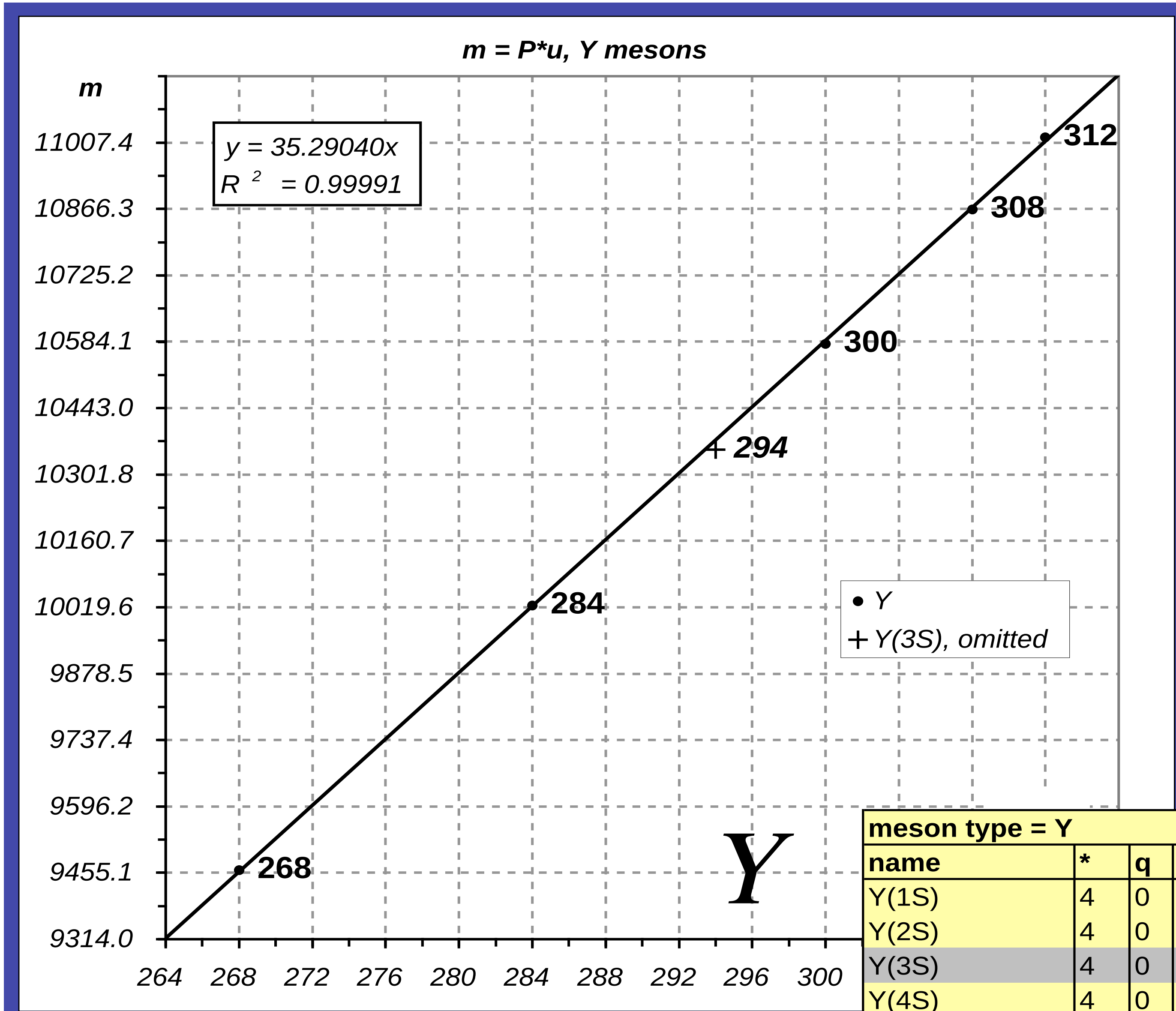


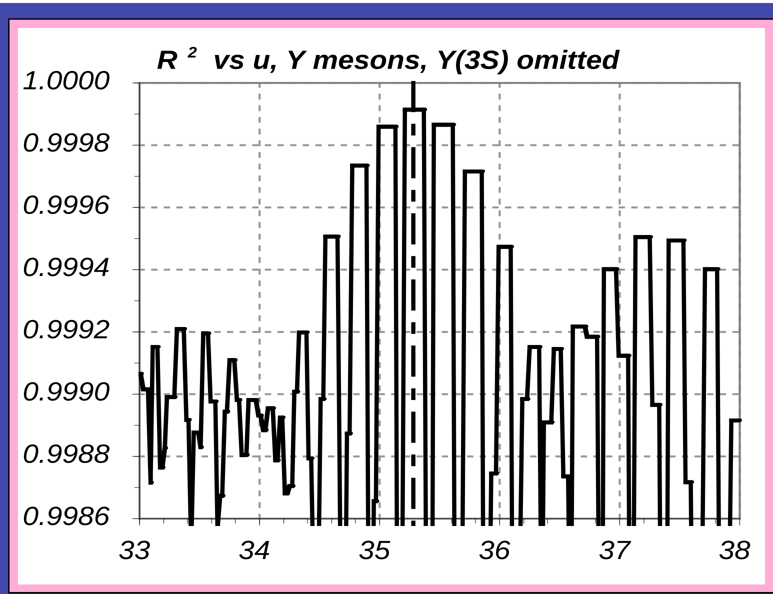
residuals

meson type = eta										
name	*	q	J	x	P	m	errm	u=m/P	dm	dm/m
eta	4	0	0		16	547.3	0.1	34.206	5.5	1.01%
eta'(958)	4	0	0		28	957.8	0.1	34.206	9.7	1.01%
eta(1295)	4	0	0		38	1293.0	5.0	34.026	6.3	0.49%
eta(1440)	4	0	0	1	42	1435.0	35.0	34.167	12.9	0.90%
eta(2)(1645)	3	0	2		48	1617.0	5.0	33.688	-8.3	-0.51%
eta(1760)	3	0	0		52	1756.0	11.0	33.769	-4.7	-0.27%
eta(2)(1870)	3	0	2		54	1842.0	8.0	34.111	13.6	0.74%
eta(2)(2030)	2	0	2		60	2030.0	20.0	33.833	-1.6	-0.08%
eta(2190)	2	0	0	1	64	2190.0	50.0	34.219	23.0	1.05%
eta(2)(2250)	2	0	2		66	2225.8	13.0	33.723	-9.0	-0.40%
eta(2225)	3	0	0	1	66	2227.0	35.0	33.742	-7.8	-0.35%
eta(2280)	3	0	0		68	2302.5	12.0	33.860	0.0	0.00%
eta(4)(2320)	2	0	4	1	68	2328.0	38.0	34.235	25.5	1.10%

summary eta mesons	
u	33.86 ± 0.053
p-value	0.999 --> $p(H_0)$ = 0.001
spin dependence	no
omitted	4 large errm

low mass

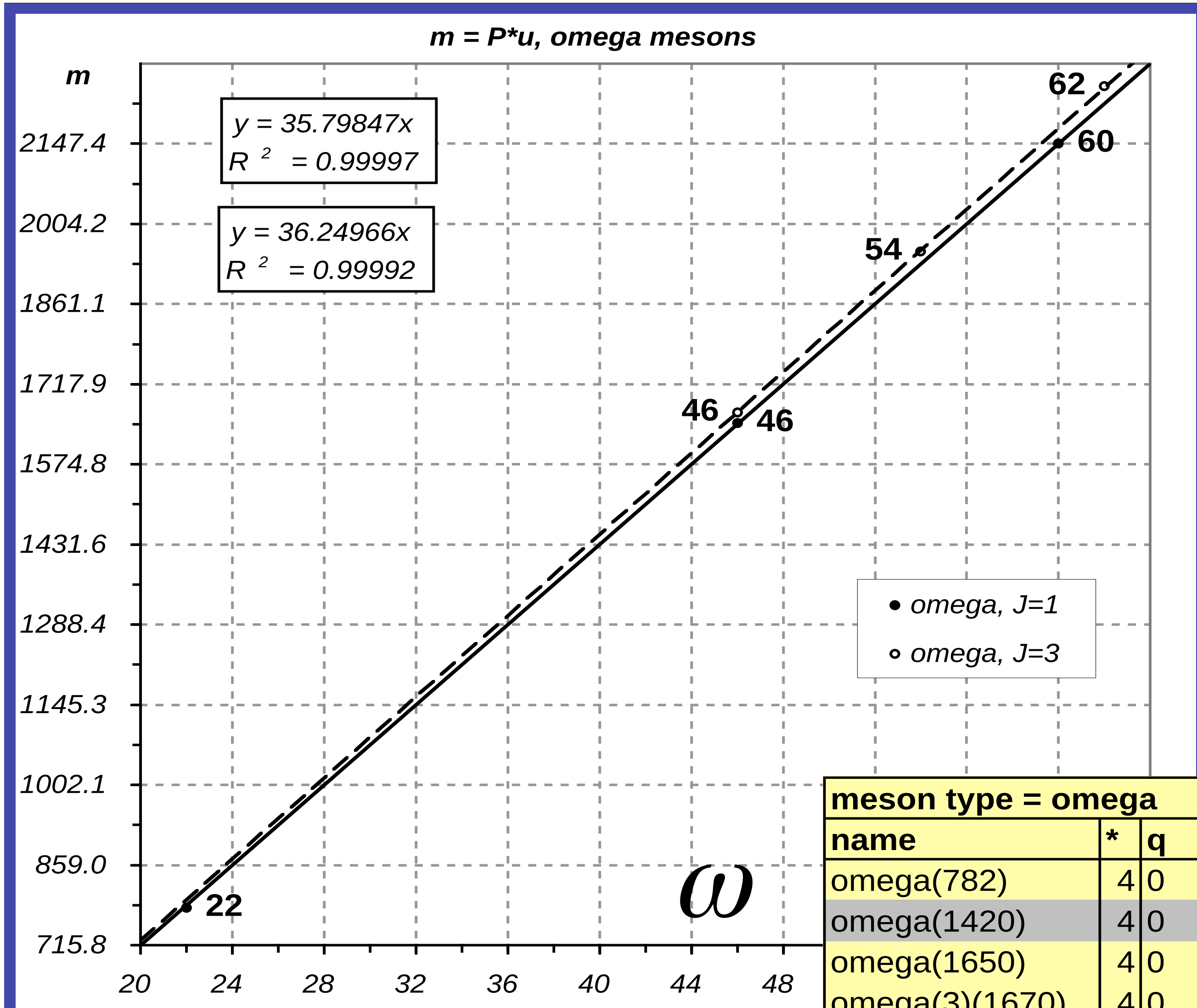




meson type = Y										
name	*	q	J	x	P	m	errm	u=m/P	dm	dm/m
Y(1S)	4	0	1		268	9460.3	0.26	35.300	5.5	0.06%
Y(2S)	4	0	1		284	10023.3	0.31	35.293	4.0	0.04%
Y(3S)	4	0	1	3	294	10355.2	0.50	35.222	-16.8	-0.16%
Y(4S)	4	0	1		300	10580.0	3.50	35.267	-3.7	-0.04%
Y(10860)	4	0	1		308	10865.0	8.00	35.276	-0.9	-0.01%
Y(11020)	4	0	1		312	11019.0	8.00	35.317	11.9	0.11%

summary Y mesons	
u	35.29 ± 0.009
p-value	0.985 **--> $p(H_0)$ = 0.015**
spin dependence	not assessed, all states are J=1
omitted	1 Chauvenet

high mass



meson type = omega										
name	*	q	J	x	P	m	errm	u=m/P	dm	dm/m
omega(782)	4	0	1		22	782.6	0.1	35.571	-5.0	-0.64%
omega(1420)	4	0	1	1	40	1419.0	31.0	35.475	-12.9	-0.91%
omega(1650)	4	0	1		46	1649.0	24.0	35.848	2.3	0.14%
omega(3)(1670)	4	0	3		46	1667.0	4.0	36.239	-0.5	-0.03%
omega(3)(1995)	2	0	3		54	1955.0	30.0	36.204	-2.5	-0.13%
omega(2145)	2	0	1		60	2148.0	15.0	35.800	0.1	0.00%
omega(3)(2250)	2	0	3		62	2250.0	20.0	36.290	2.5	0.11%

summary omega mesons	
omitted	1 large errm
spin dependence	yes, Z=13.9
u, J=1	35.80 ± 0.049
p-value	> 0.934 (all states), 0.942 for J=1, 0.947 for J=3

spin dependence du/dJ

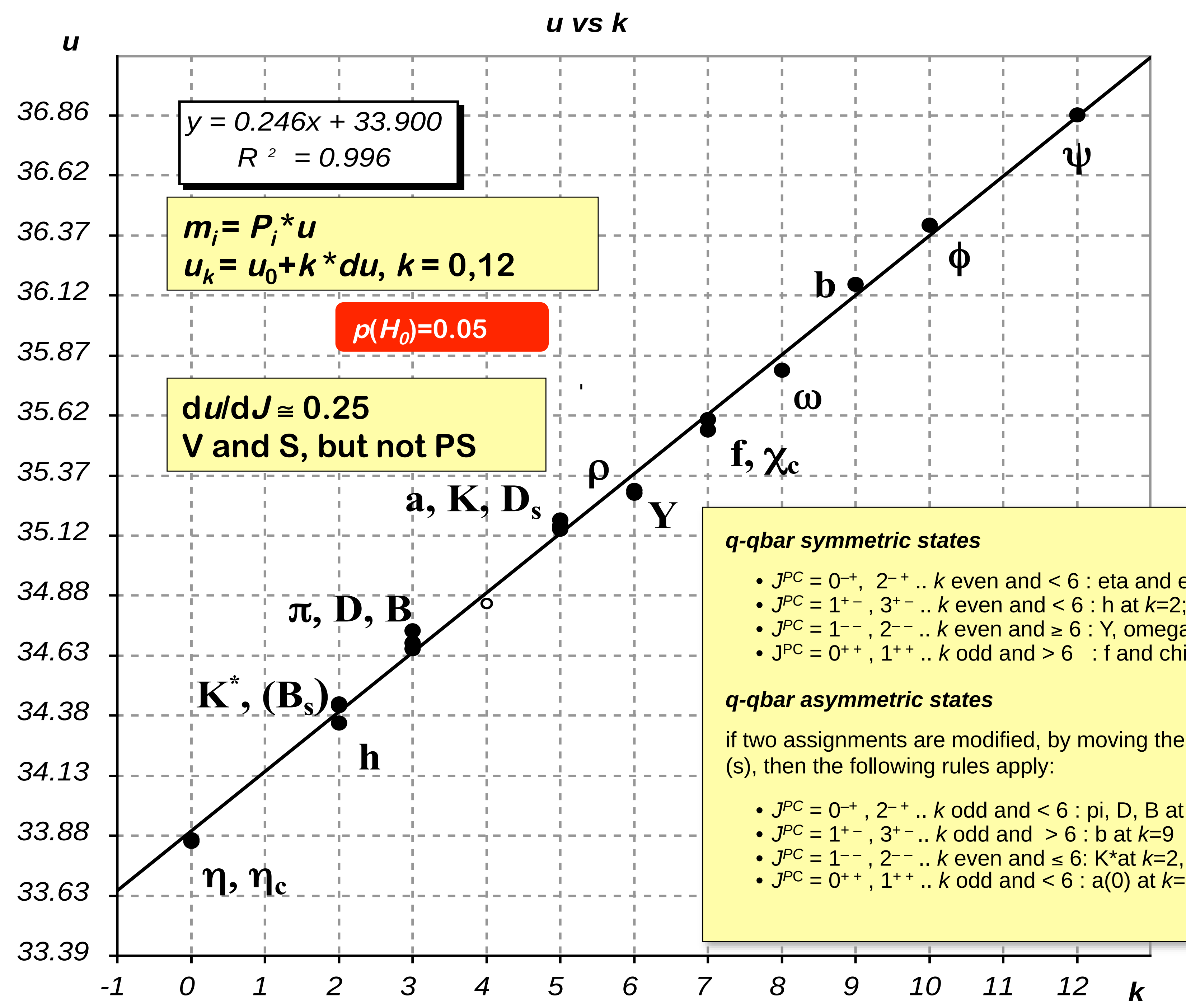
summary

Summary of mass unit analysis, mesons

							states	omitted					used	
type	k	u	erru	uw	p-value	du/dJ	PDG	(1)	(2)	(3)	(4)	tot		rating
pi	3	34.69	0.051	34.68	0.997	N	11	1		1	1	3	8	****
b	9	36.16	0.050	36.16	0.990	N	3						3	***
rho	6	35.19	0.071	**35.31**	0.973	N	11	2		1		3	8	***
a					0.995	Y	13	2				2	11	****
a(0)	5	35.00	0.073	**35.17**	0.941									
K	6	35.34	0.073	35.39	0.943	N	11				1	1	10	***
K*					0.882	Y	12	1		1	2	4	8	
K*(1)	2	34.35	0.016	34.35										****
eta	0	33.86	0.053	33.86	0.999	N	13	4				4	9	****
h	2	34.42	0.056	34.43	0.975	N	6	2				2	4	****
omega					0.934	Y	7	1				1	6	****
omega(1)	8	35.80	0.049	35.81	0.943									
phi					0.732	Y	3						3	**
phi(1)	10	36.51	0.050	**36.41**										
f	7	35.78	0.070	**35.60**	0.998	?	33	5	18			23	10	***
D^+	3	34.67	0.016	34.66	0.997	N	5						5	****
D^0		34.58	0.023	34.60	0.960	N	4						4	****
D(s)	5	35.16	0.021	35.15	0.997	N	6						6	****
eta(c)	0	33.89	0.022	33.87			2						2	**
psi	12	36.84	0.034	36.87	0.959		7			1		1	6	****
chi(c)	7	35.57	0.006	35.56		Y	3						3	**
B	3	34.74	0.005	34.73			3				1	1	2	*
B(s)	2	34.42	0.004	34.42			2						2	*
Y	6	35.29	0.009	35.30	0.985		6			1		1	5	****
		avg->	0.044		0.949		161	18	18	5	5	46	115	**<-tot**
leptons	4	34.84	0.022	34.84			2						2	**

u-quantum

du/dk



q-qbar symmetric states

- $J^{PC} = 0^{-+}$, 2^{-+} .. k even and < 6 : eta and eta_c at k=0
- $J^{PC} = 1^{+-}$, 3^{+-} .. k even and < 6 : h at k=2;
- $J^{PC} = 1^{--}$, 2^{--} .. k even and ≥ 6 : Y, omega, phi, psi at k=6, 8, 10, 12;
- $J^{PC} = 0^{++}$, 1^{++} .. k odd and > 6 : f and chi_c at k=7

q-qbar asymmetric states

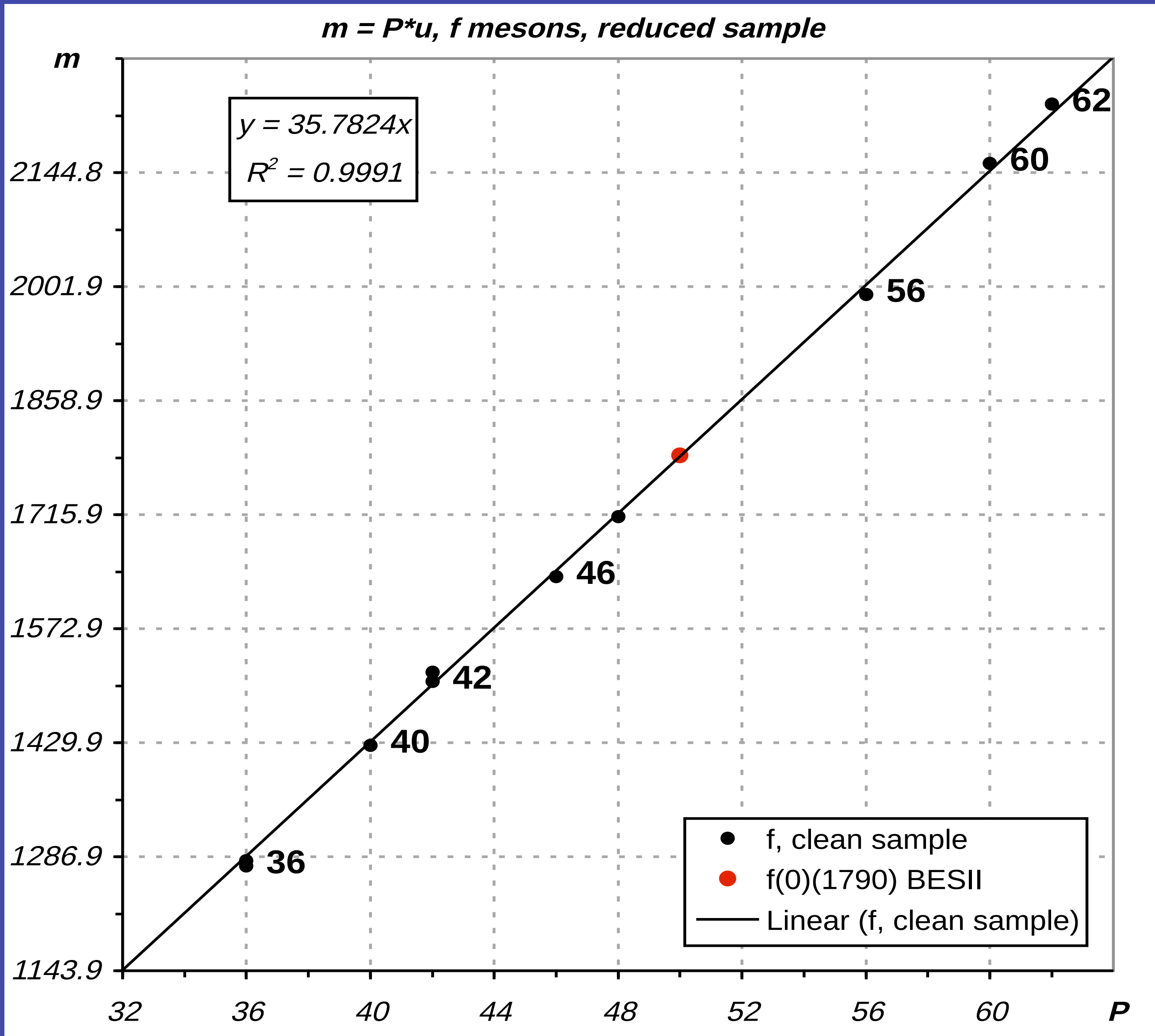
if two assignments are modified, by moving the K from 6 to 5 and neglecting the B (s), then the following rules apply:

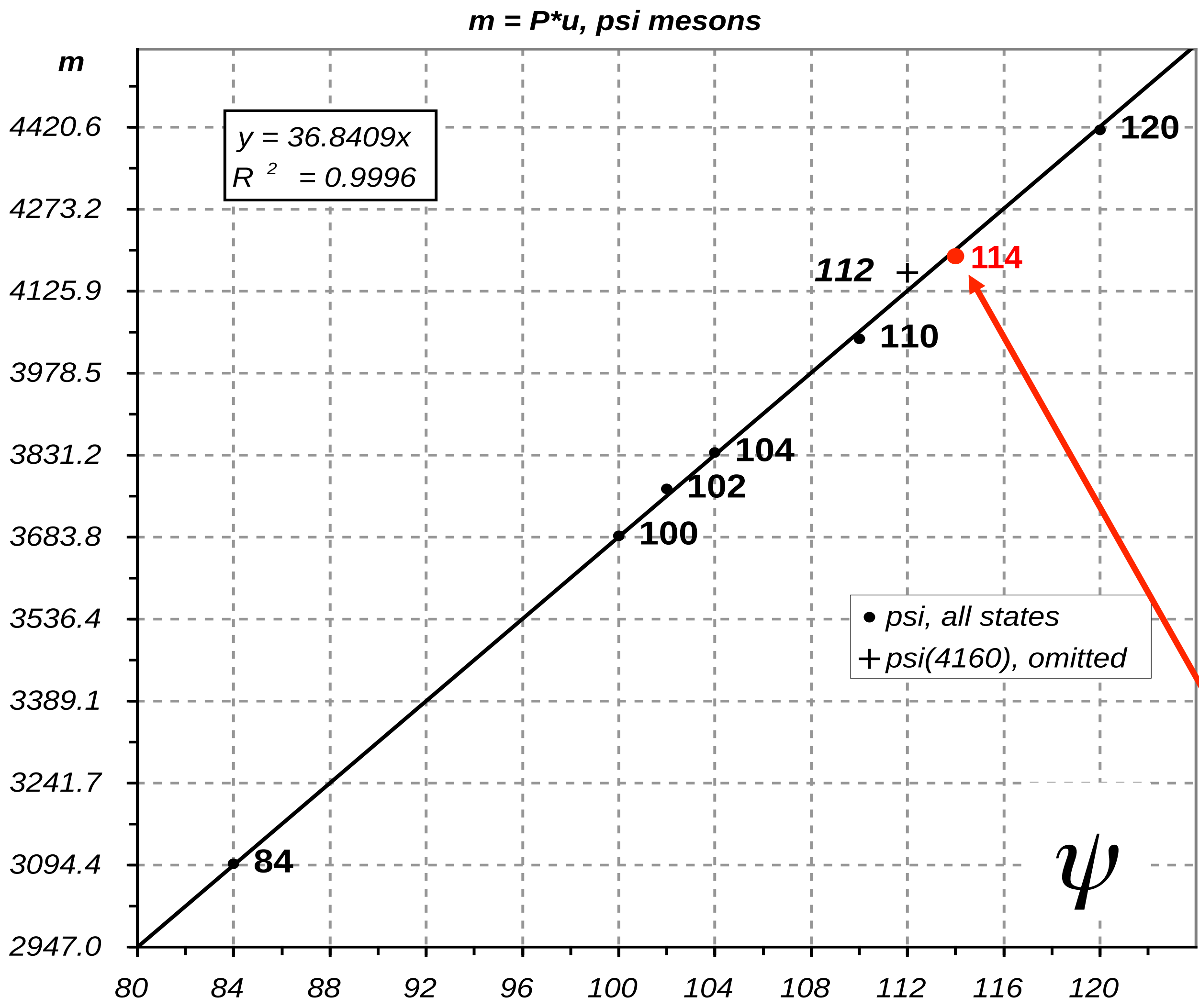
- $J^{PC} = 0^{-+}$, 2^{-+} .. k odd and < 6 : pi, D, B at k=3
- $J^{PC} = 1^{+-}$, 3^{+-} .. k odd and > 6 : b at k=9
- $J^{PC} = 1^{--}$, 2^{--} .. k even and ≤ 6: K*at k=2, rho at k=6
- $J^{PC} = 0^{++}$, 1^{++} .. k odd and < 6 : a(0) at k=5;

$p(H_0)$= 0.000...

predictions

new states must agree (and they do)





Reject: psi(4160)

2004: psi(4160) rejected

The psi(4160) with a residual of 33, rejected by Chauvenet' s criterion. Its mass quoted by the PDG is based on a single measurement by DASP, and in the DASP paper the result of their analysis is compared with MARK1 data showing a more complex peak structure.

Above the psi(4040) the MARK1 data show a peak at around 4110 and possibly more. The psi(4415) is seen unambiguously by both experiments. The DASP view of the discrepancy is: "..our data are in closer agreement with those of SLAC-LBL but show some differences in the finer details of the energy dependence. For instance the 4.16 structure is not resolved in the SLAC-LBL data".

For sure there are differences, but the DASP interpretation is questionable. Apparently some MARK1 peaks were never identified or never made it to the PDG. A possible interpretation of their spectrum around 4100 is: psi(4040), P=110; psi (4125), P=112; possibly a psi(4200) , P=114; no psi (4160).

2007: new BES value = 4191.6 ± 6.0

outliers

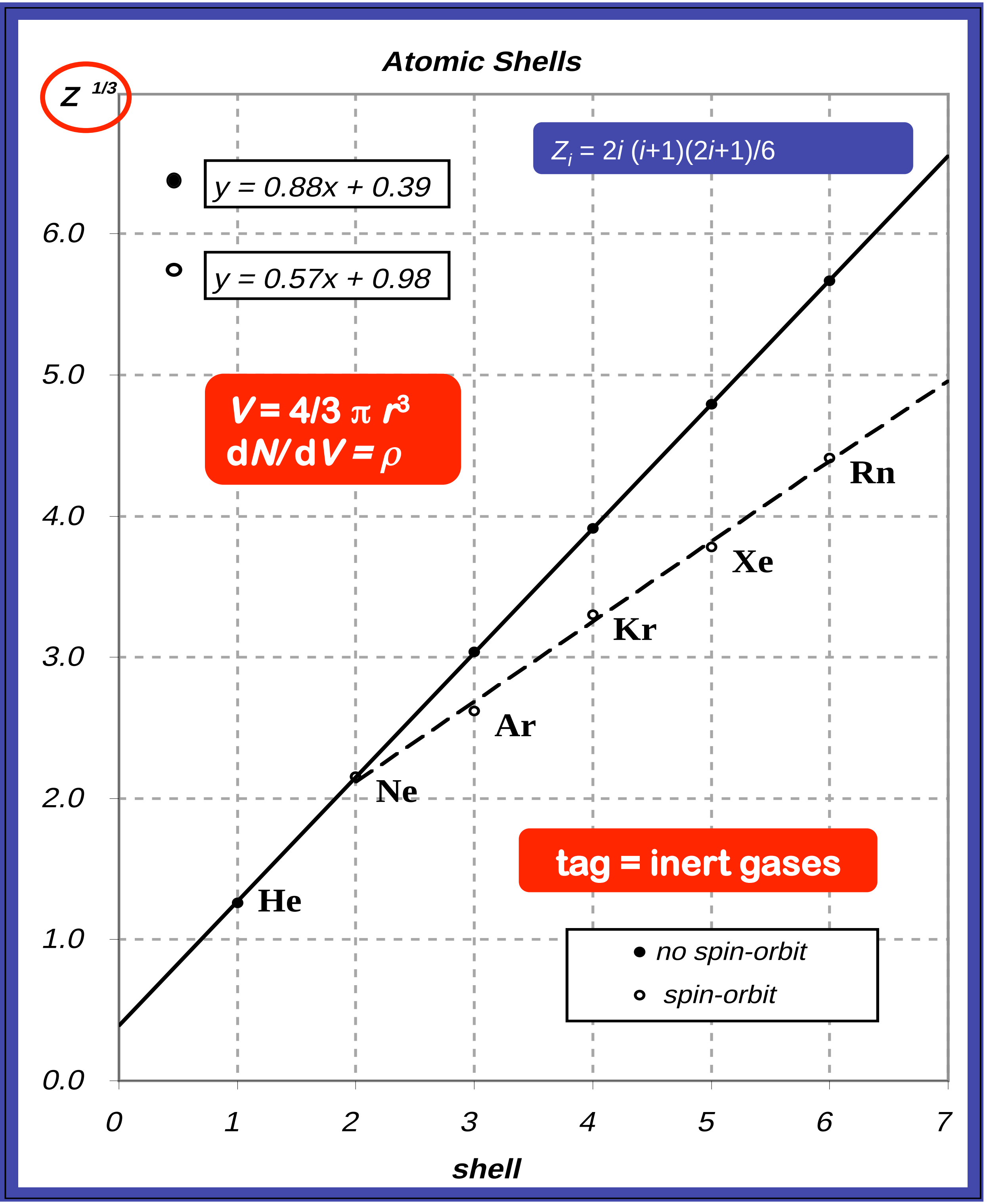
meson type = psi

name	*	q	J	x	P	m	errm	u	dm	dm/m
psi(1S)	4	0	1		84	3096.9	4.0E-02	36.868	2.2	0.07%
psi(2S)	4	0	1		100	3686.0	9.0E-02	36.860	1.9	0.05%
psi(3770)	4	0	1		102	3769.9	2.5	36.960	12.1	0.32%
psi(3836)	3	0	2?		104	3836.0	13.0	36.885	4.5	0.12%
psi(4040)	4	0	1		110	4040.0	10.0	36.727	-12.5	-0.31%
psi(4415)	4	0	1		120	4415.0	6.0	36.792	-5.9	-0.13%
psi(4160)	4?	0	1	3	112	4159.0	20.0	37.134	32.8	0.79%

back to meson shells

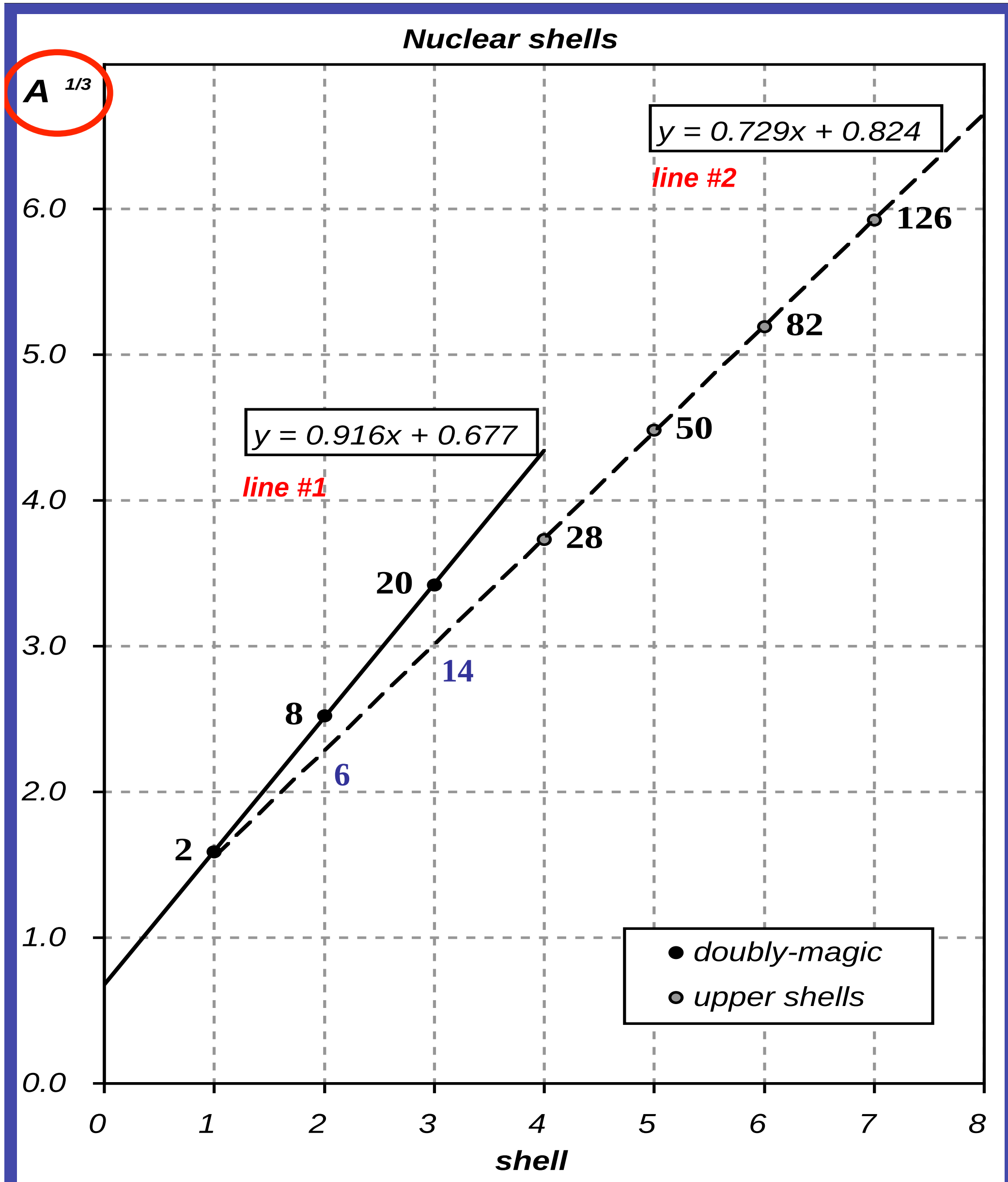
atomic shells

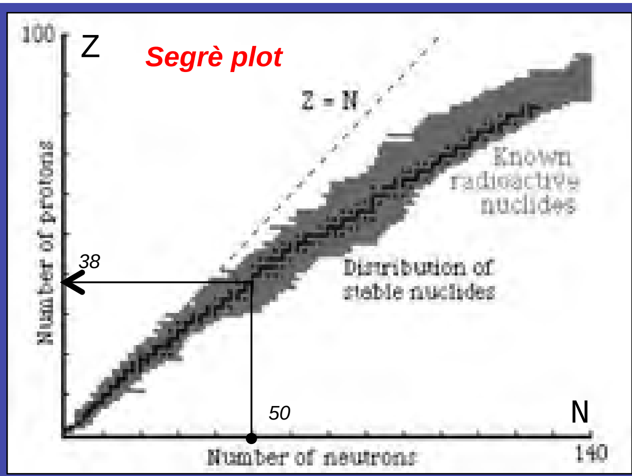
$Z^{1/3}$



nuclear shells

$A^{1/3}$





2 shell lines with interesting properties:

- **cross at the first shell**, He-4 (δy<3%);
- in shells 2 and 3, line #2 corresponds to values of *A* of **12=6+6** and **28=14+14**; 14 recognized long ago as quasi-magic; the “magicity” of 6 is a more recent result;
- the **ratio of the cubes of the slopes of the two lines is 1.99**, very close to 2: the number of nucleons in series #2 grows from one shell to the next at a rate = 1/2 the one of series #1;
- in line #1 the **"packing fraction" is maximal**:

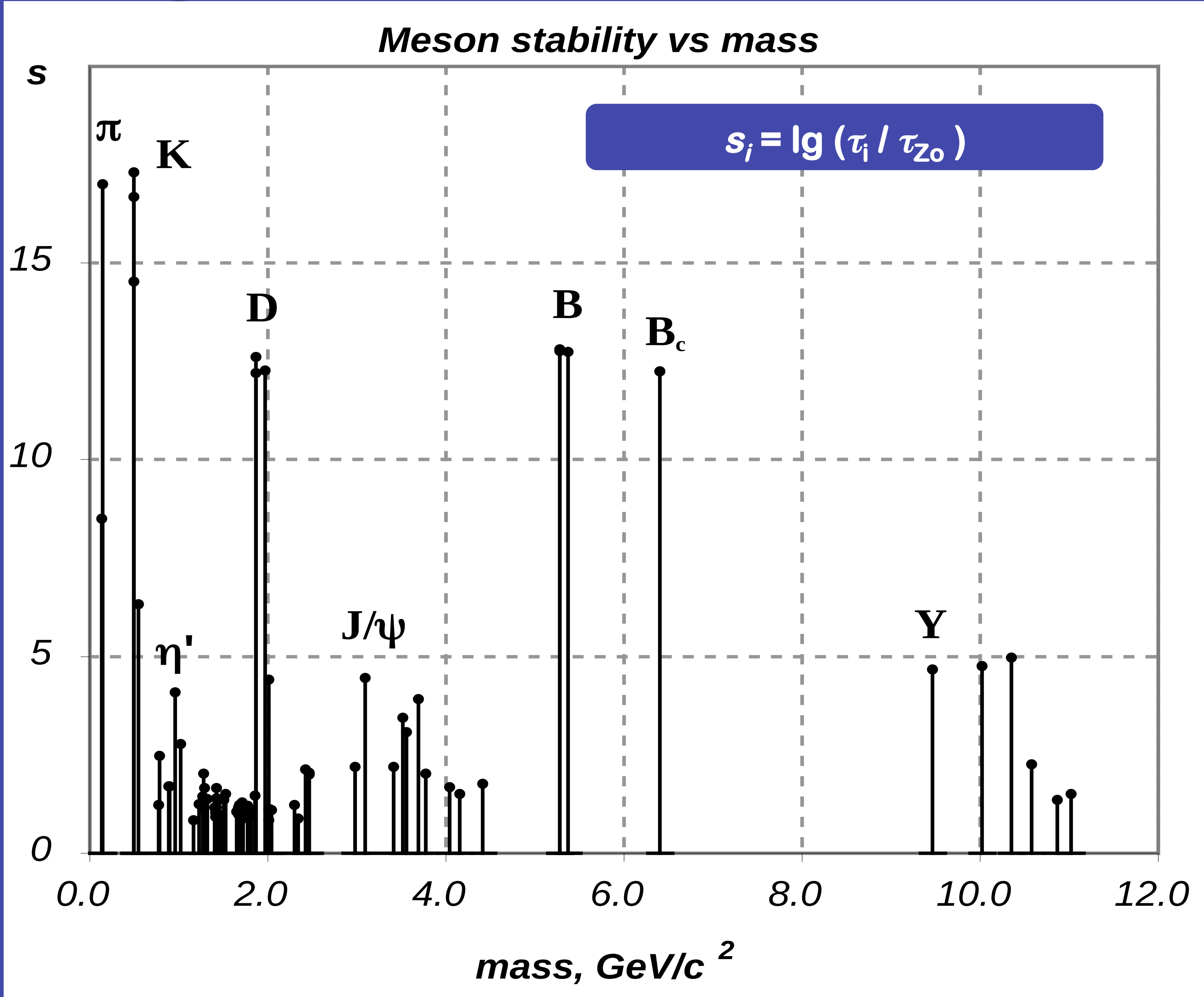
$$(0.916)^3 = 0.768$$

N_i = 2, 8, 20, 28, 50, 82, 126: magic
Z_i from Segrè plot, max. stability
$A_i = N_i + Z_i$
plot $A_i^{1/3}$ vs i, tag = N_i

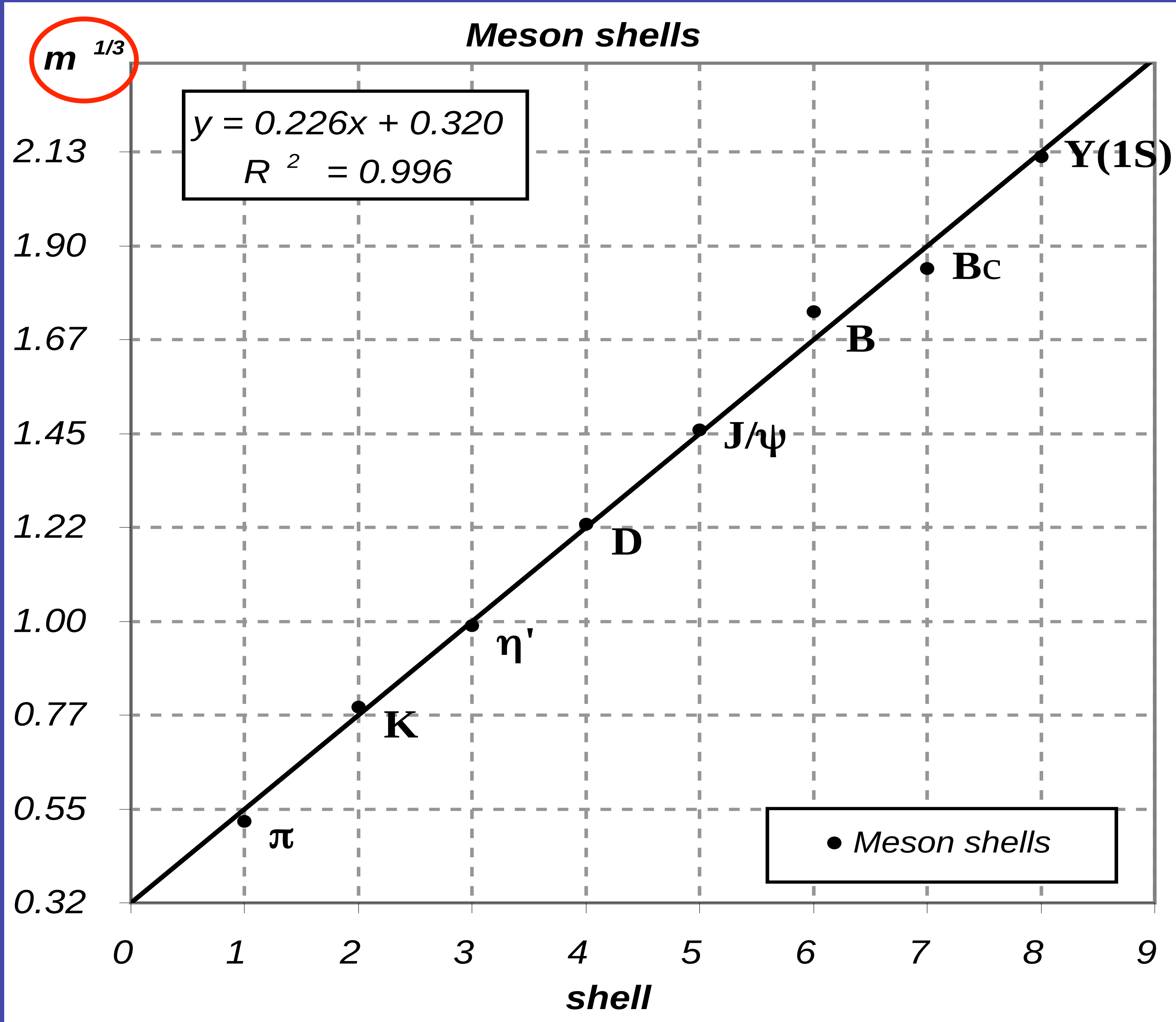
$A1(n) = 2*[\Sigma(i+1)*i,\ \ i=n,1,1] = 2*[(n+1)*n + n*(n-1) +..+2*1]$
$= 4, 16, 40, 80, ...$

$A2(n) = 2*[\Sigma(i+1)*i,\ \ i=n,1,2] = 2*[(n+1)*n + (n-1)*(n-2)+..]$
$= 4, 12, 28, 52, 88, 136, 200, 280$

meson stability



meson shells



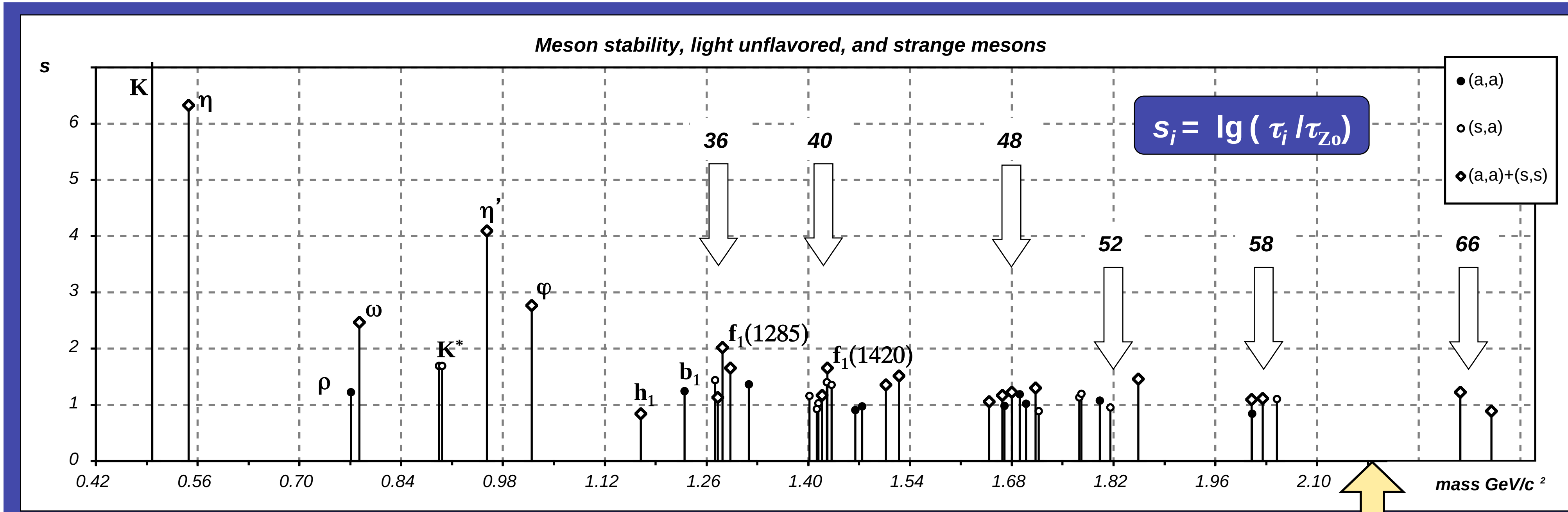
combine meson mass shell plot with mass units:

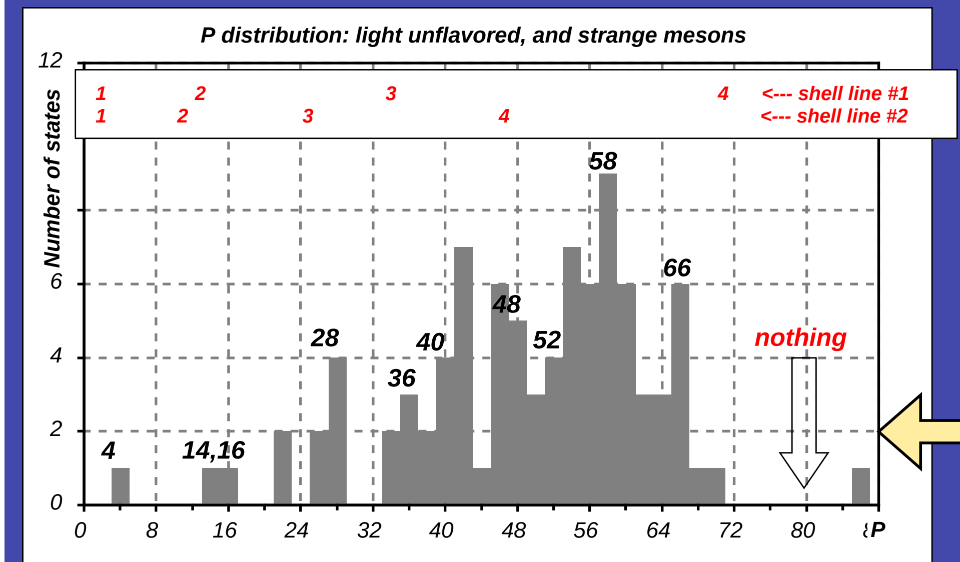
35 MeV/c^2 = 1 constituent

***M(i)*: (4, 14, 28, 54, 84**, 152, * , 294) [*i* =1,8], y = **0.712** * x + **0.894**, R^2 = 0.9981

very similar to the corresponding values for the second nuclear line

***N(i)*: (4, 12, 28, 52, 88**, 140, 208) [*i* =1,7], y = **0.729** * x + **0.824**, R^2 = 0.9999





meson stability up to 2 GeV/c^2 with mass scale in steps of 70 MeV/c^2:

- the η **at *P*=16**, analogous of the **doubly-magic O-16**
- three clusters around 1260 MeV/c^2 (*P*=36), 1420 MeV/c^2 (*P*=40), and 1680 MeV/c^2 (*P*=48).
- three further clusters with fewer states, ~ 1820 MeV/c^2 (*P*=52), 2030 MeV/c^2 (*P*=58), and 2310 MeV/c^2 (*P*=66).

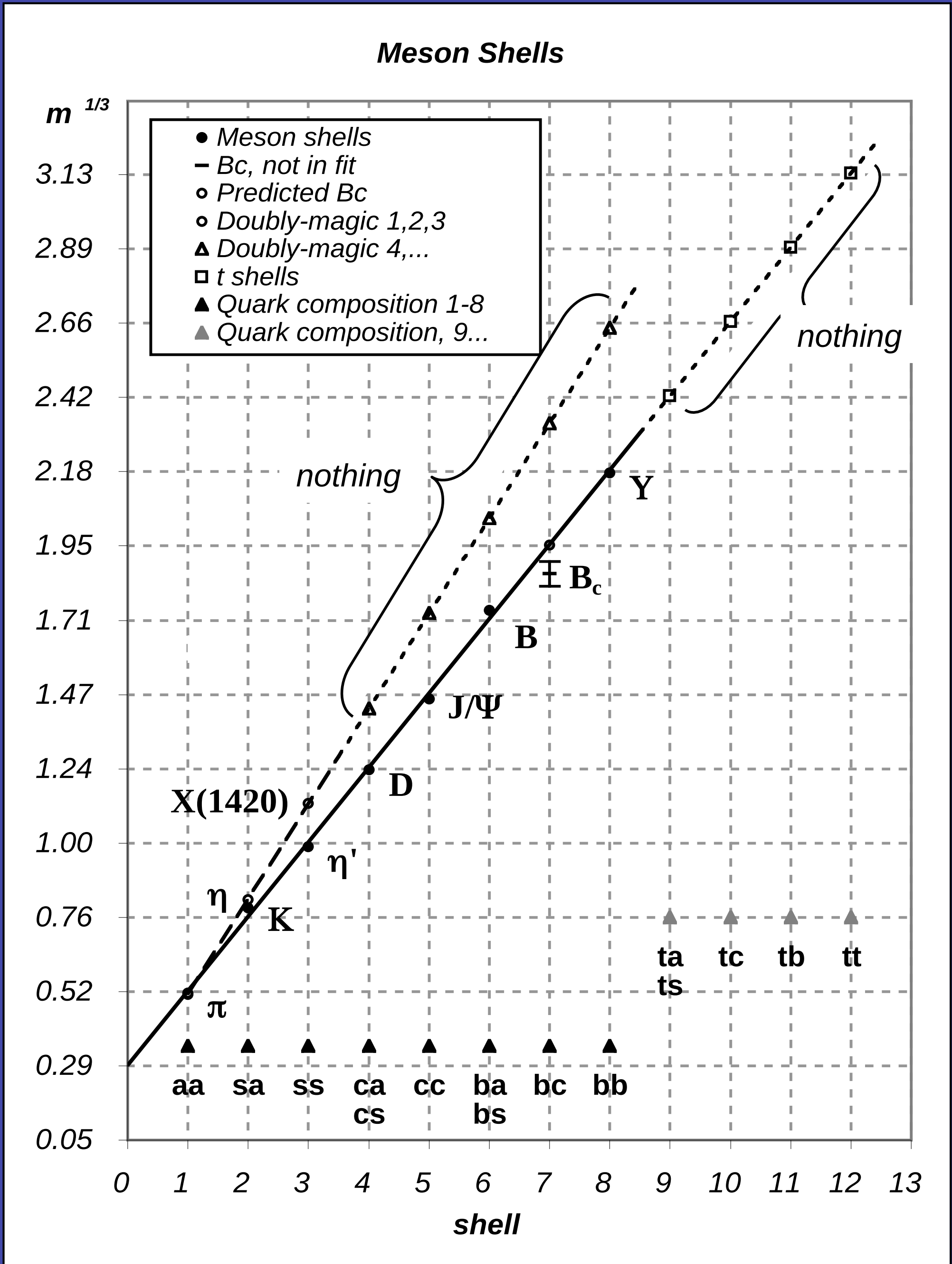
P=40 corresponds to shell 3 in the nuclear line #1, the **doubly-magic Ca-40**.

the *P* distribution for all (a,a), (s,a) and (s,s) states confirms the three clusters around **36, 40** and **48**, as well as at **52, 58** and **66**. In the shell interpretation the peaks at *P*=36, 48, 52, 58 and 56 would correspond to **sub-shells** (to be developed).

***P*=80** is the **doubly-magic shell 4** ~ 2800 MeV/c^2; the histogram is empty from *P*=72 to 84: as in nuclei, the **doubly-magic-equivalent shell series stops at 3.**

sub-shells

meson shells summary



- meson shells 1 to 8 corresponds to nuclear shell line #2, and also **doubly-magic** shells can be identified:
  1) π at P = 4 ~ He-4
  2) η at P =16 ~ O-16
  3) states at P = 40 ~ Ca-40

  but no states are known near the extrapolated mass values for the following shells in that series, P=80, ...;

- on the main meson shell line, the **quark composition progression** from shell 1 to 8 is:

  aa, sa, ss, ca+cs, cc, ba+bs, bc, bb ; (a = u or d)

  – intriguing role of the s quark,

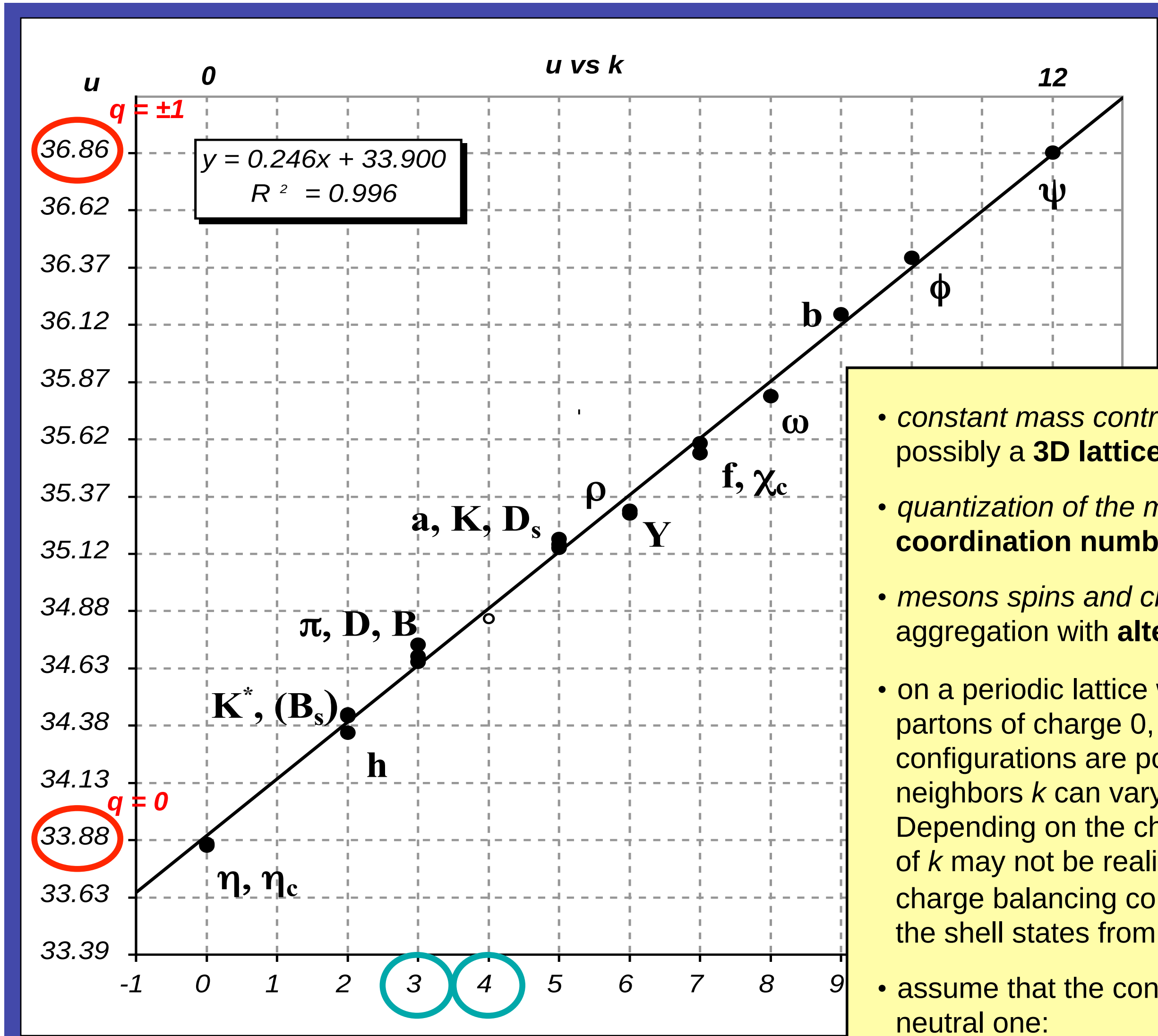
  – explanation of **the mysterious values of “quark masses”** (for whatever it is worth);

- **t quark:** expect 4 more shells at specific mass values in the range 14 - 31 GeV/c^2, none observed;

  – is shell **8** the **structural limit** for this kind of bound states, like 6 for atoms and 7 or 8 for nuclei?

  – what are the **top events**?

$$\boxed{m(t) = m(W) + m(Z^0)}$$

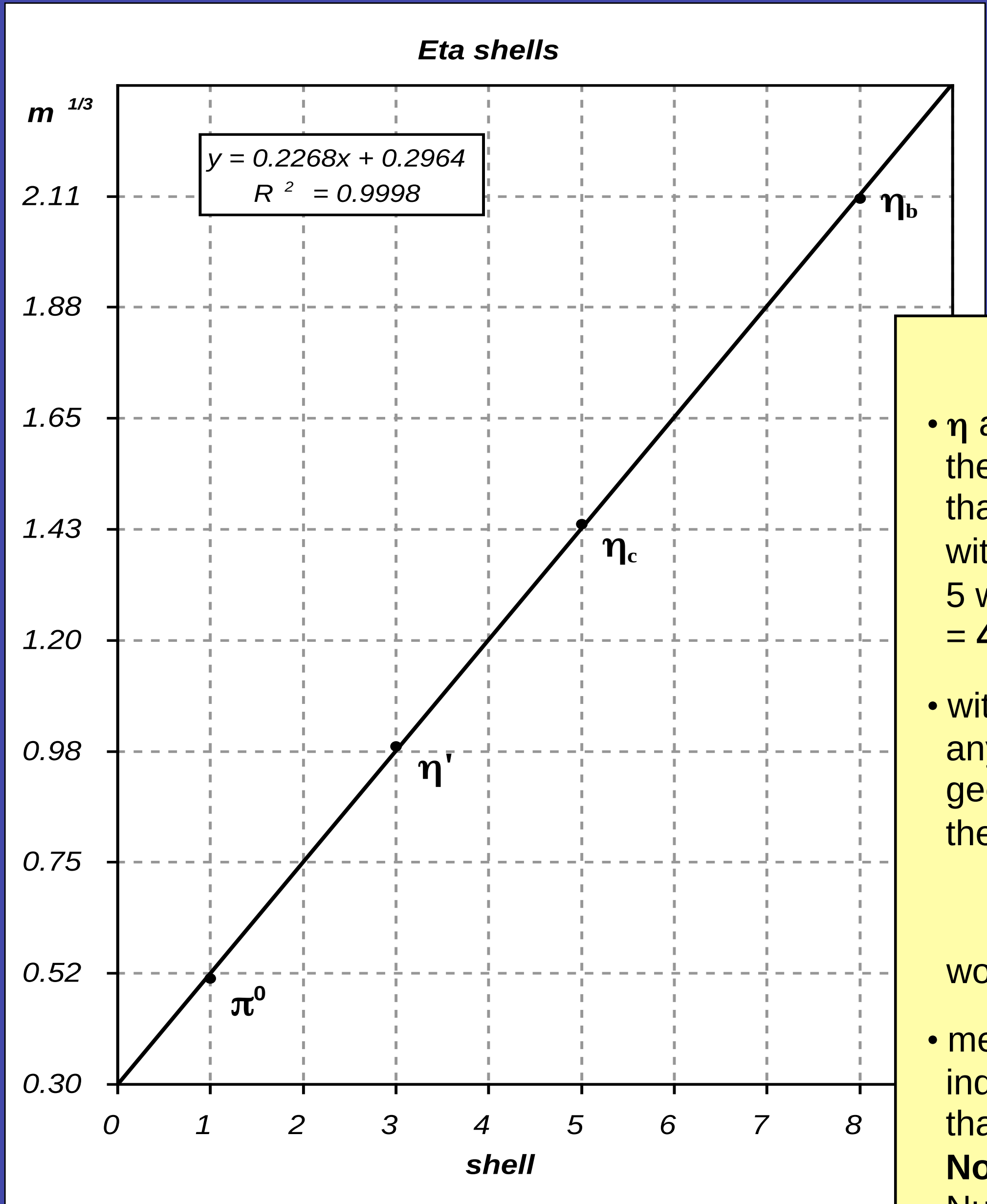


- **solid-phase**
- **coordnum = 12: fcc**
- **charges**

- *constant mass contribution for each parton*: suggests **solid-phase** aggregates, possibly a **3D lattice** organization;
- *quantization of the mass unit on a grid of **13=12+1** values:* may be related to the **coordination number** of the lattice;
- *mesons spins and charges equal or close to 0, with a large number of partons:* aggregation with **alternating up/down spins and +/- charges**.
- on a periodic lattice with **coordination number = 12** (such as the **fcc**), with spin-1/2 partons of charge 0, -1 and +1, arranged as a partially charged "ionic" lattice, several configurations are possible. For a given node of the lattice, the number of charged neighbors *k* can vary from 0 (all neutral) to 12 (all charged), **a total of 13 values**. Depending on the charge balancing constraints on these lattice variants, some values of *k* may not be realized, while other may correspond to more than one configuration; charge balancing constraints might be the reason for the deviation of the value of *P* of the shell states from series S2.
- assume that the contribution to the total mass is larger for a charged parton than for a neutral one:
  - $u(0)$ = 33.88 MeV/c^2, neutral parton,
  - $u(12)$ = 36.84 MeV/c^2 charged parton;

  this assumption agrees with the charges of the final products of the decays of the μ (1 charged out of 3 = 4/12, k=4) and of the $\pi^{\pm}$(1 charged out of 4 = 3/12, k=3) as verified by the position of the corresponding points on the u-grid. This would not be true with the neutral parton heavier than the charged one.

interpretation



- η and η_c is at ***k*=0 on the u-grid**, with **all constituents neutral**; the specific mass unit of the π^0 is 33.74, close to *u*(0)=33.88, so that 4 neutral constituents can be assumed; the pion is at shell 1 with *P*=4, while the η' is at shell 3 with *P*=28, and the η_c at shell 5 with *P*=88, right at the nominal values of *P* in the series A2(*n*) = **4**, 12, **28**, 52, **88**, ...

- with no charged constituents, the η and η_c do not need to obey any **charge balancing constraints** and can sit right at the geometrical shell closure; this should also apply to the η_b, therefore it is expected that the mass shell line with:

  π^0, η', η_c, η_b in shells **1, 3, 5, 8**

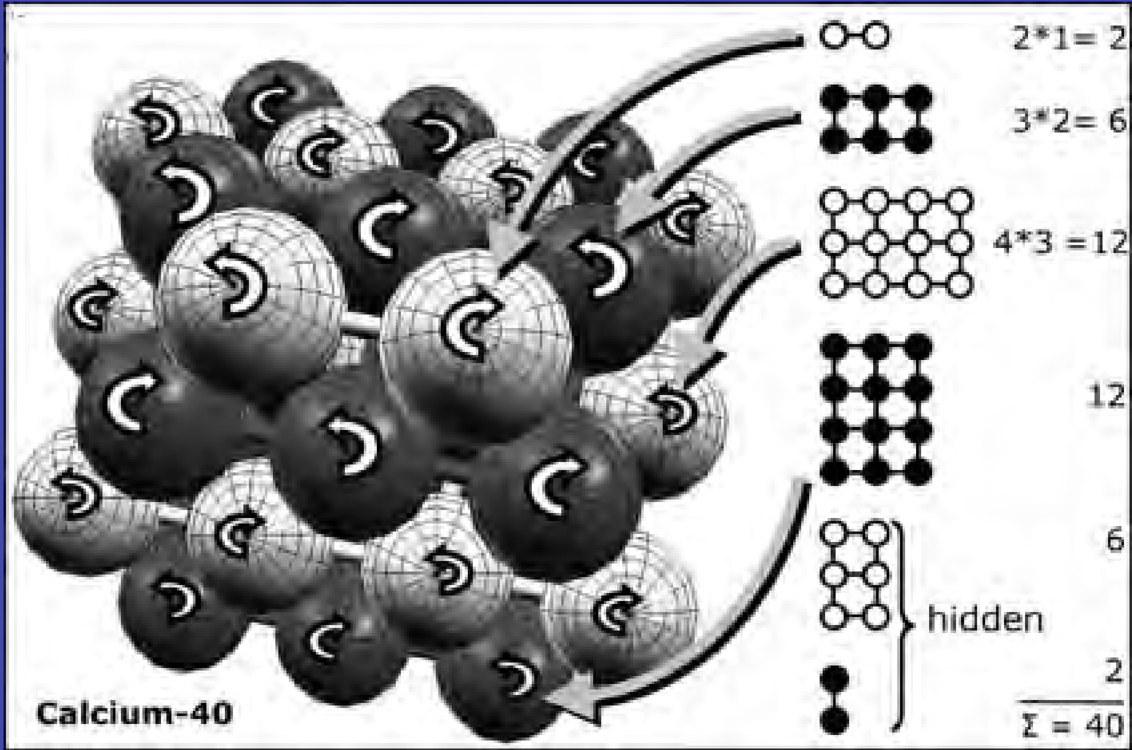
  would show a **sharper alignment,** as verified by the chart;

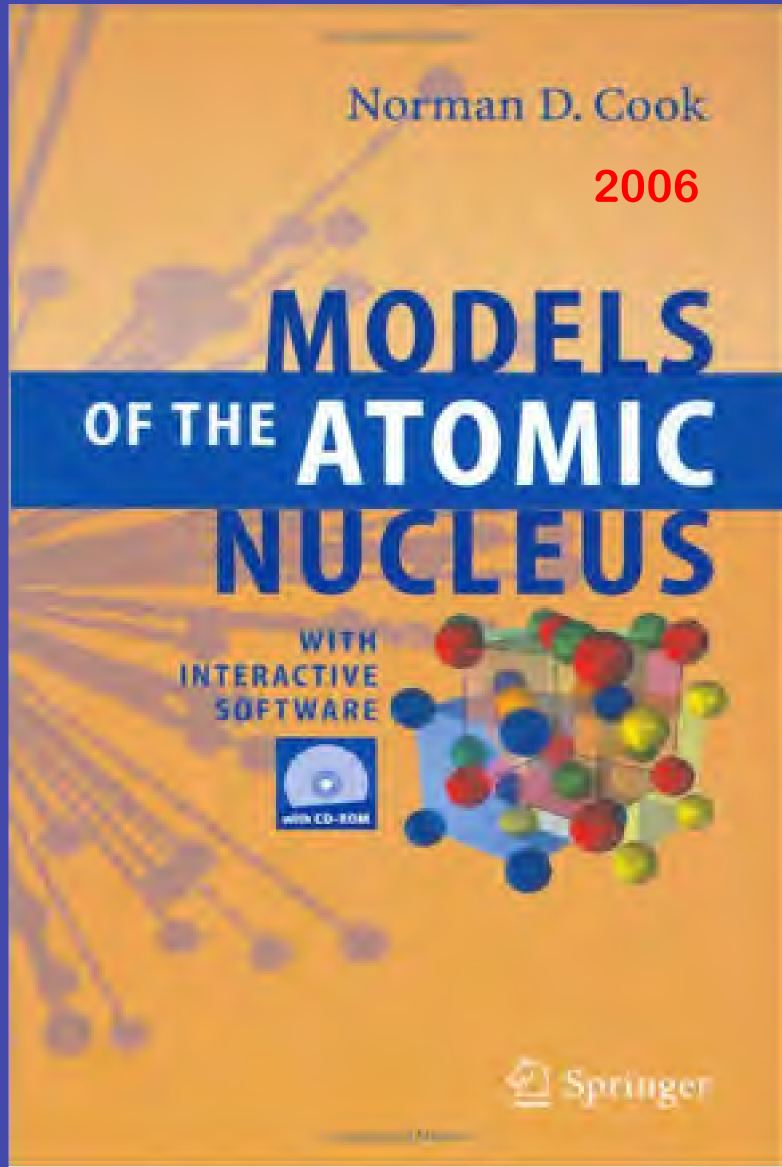
- mesons are similar to nuclei and at the same time show indications of a solid-phase fcc structure, and this may be more than a coincidence: **fcc nuclei** are not new, see the work of **Norman D. Cook**, and his recent book: Models of the Atomic Nucleus (Springer).

η shells: sharper

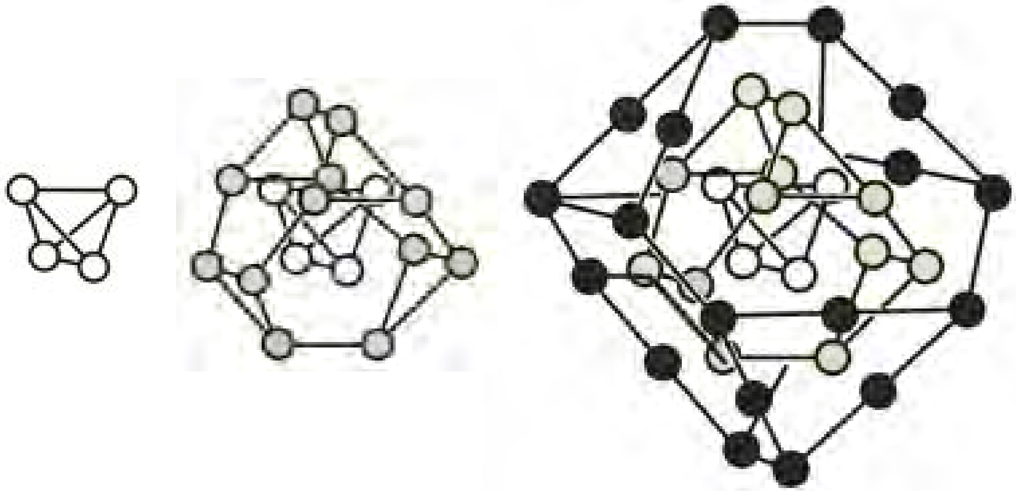
$A1(n) = 2*[\Sigma(i+1)*i,\ i=n,1,1] = 2*[(n+1)*n + n*(n-1) +..+2*1]$

$A2(n) = 2*[\Sigma(i+1)*i,\ i=n,1,2] = 2*[(n+1)*n + (n-1)*(n-2)+..]$





[tetrahedrically-truncated tetrahedrons]



He-4 O-16 Ca-40

Looking for neutral and charged partons and antipartons with spin 1/2 and mass less than 30 MeV/c^2, and with **more than one type of neutrals**, among the known particles there is only one possible choice:

the stable leptons -->

constituents:

stable leptons?

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STABLE PARTICLES AS BUILDING BLOCKS OF MATTER

1980

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Only absolutely stable indestructible particles can be truly elementary. A simple theory of matter based on the three constituents, proton, electron and neutrino (and their antiparticles), bound together by the ordinary magnetic forces is presented, which allows us to give an intuitive picture of all processes of high-energy physics, including strong and weak interactions, and make quantitative predictions.

I. INTRODUCTION

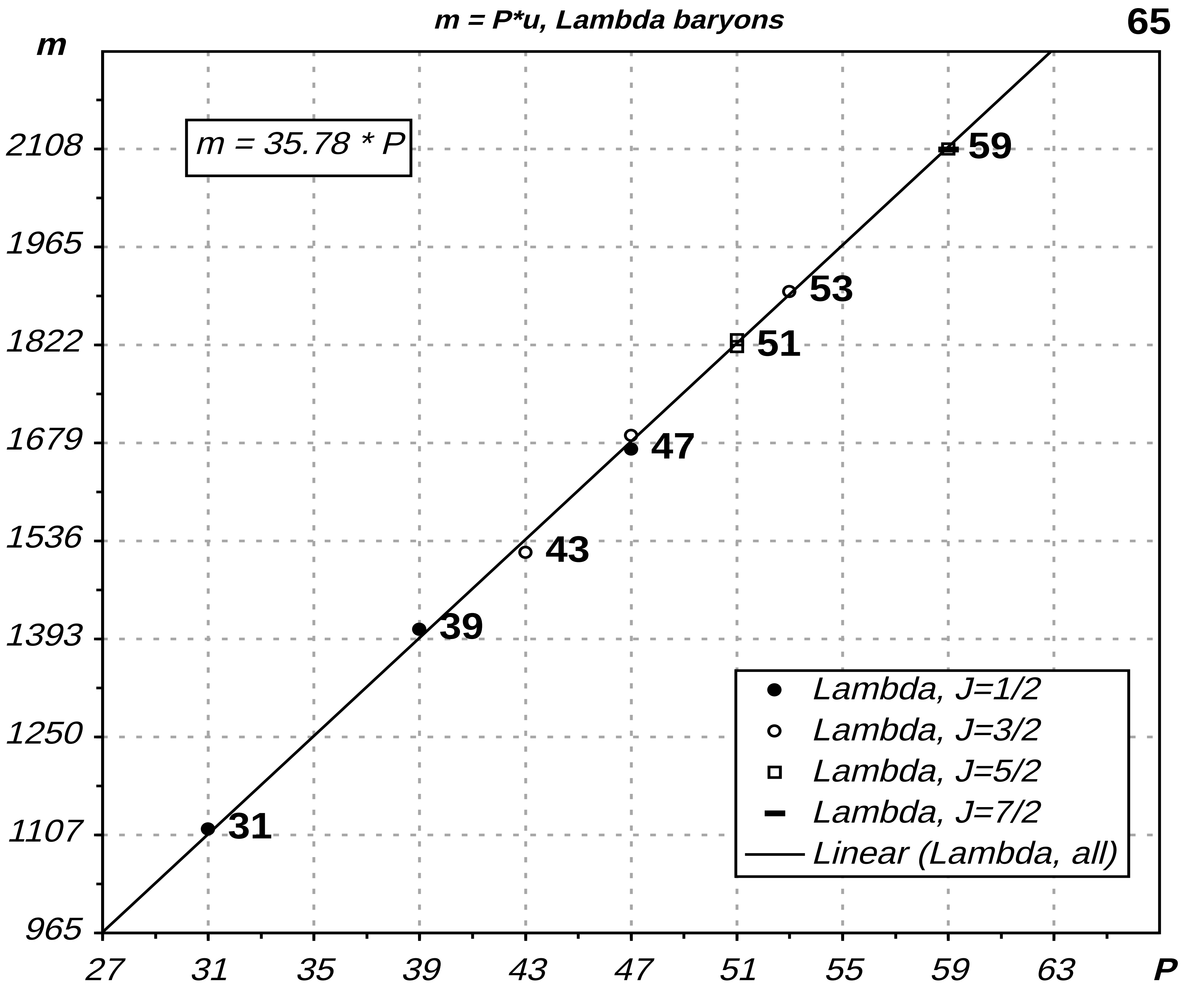
SU(3) from permutations

At present, the picture of elementary particle physics mostly used in high-energy phenomenology is becoming admittedly very complicated. Besides leptons (which we see), one introduces families of "quarks", each with different colours, then the so-called "gluons", which are the gauge vector mesons binding the quarks, then there are the so-called "Higgs particles", which give masses to some of the vector mesons (all of which are not seen in the laboratory). One is already beginning to talk about a second generation of more fundamental and simpler objects for these quarks and gluons etc., even though these first generations of "basic" objects have not been seen. This type of framework seems to create more problems than it solves [1].

the baryon mass system

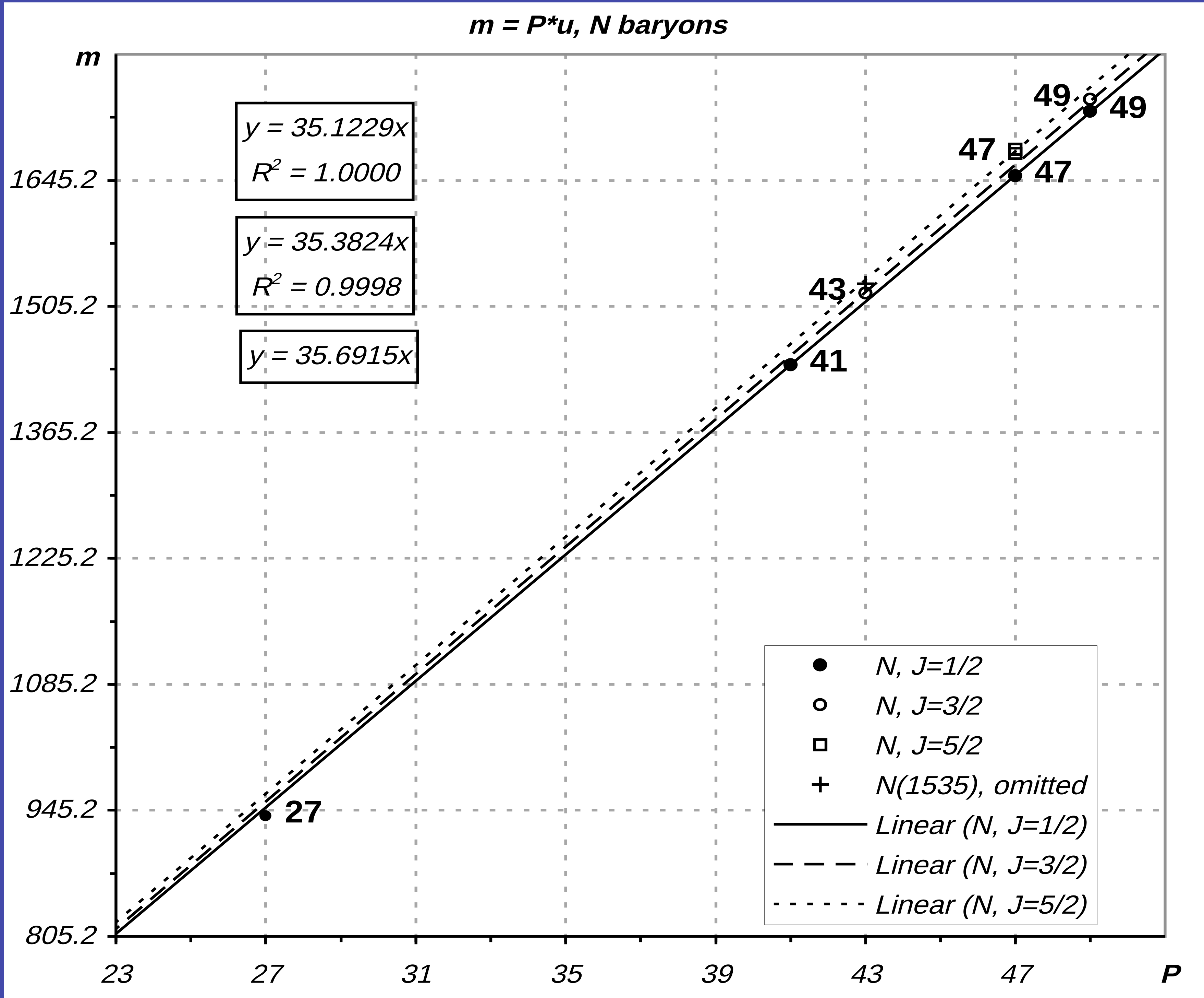
same analysis, P is odd

Λ


m = P*u, Lambda baryons
m
m = 35.78 * P
2108
1965
1822
1679
1536
1393
1250
1107
965
27
31
35
39
43
47
51
55
59
63
P
31
39
43
47
51
53
59
Lambda, J=1/2
Lambda, J=3/2
Lambda, J=5/2
Lambda, J=7/2
Linear (Lambda, all)

N

du/dJ

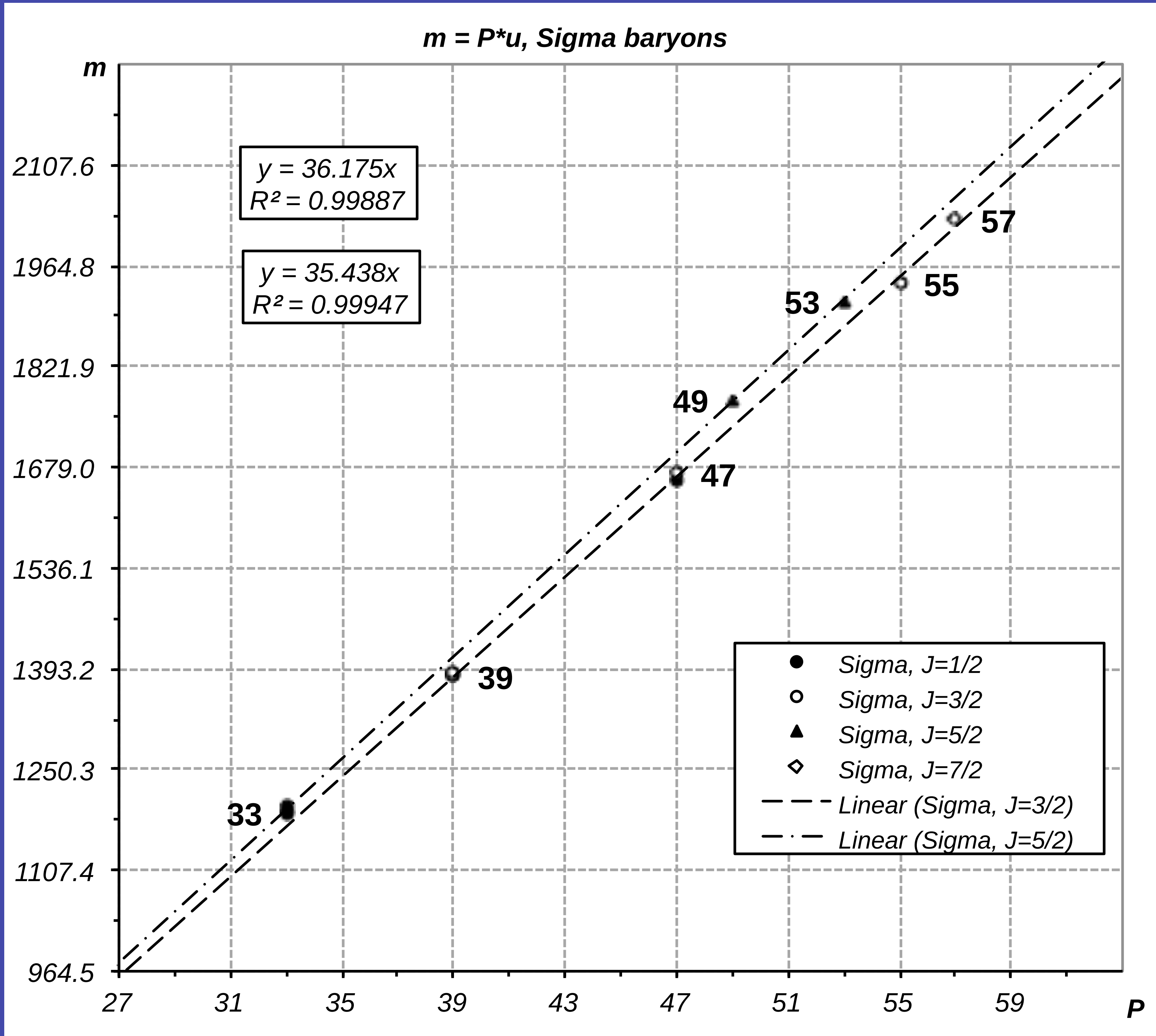


m = P*u, N baryons
m
y = 35.1229x
R^2 = 1.0000
y = 35.3824x
R^2 = 0.9998
y = 35.6915x
1645.2
1505.2
1365.2
1225.2
1085.2
945.2
805.2
23
27
31
35
39
43
47
P
27
41
43
47
47
49
49
N, J=1/2
N, J=3/2
N, J=5/2
N(1535), omitted
Linear (N, J=1/2)
Linear (N, J=3/2)
Linear (N, J=5/2)

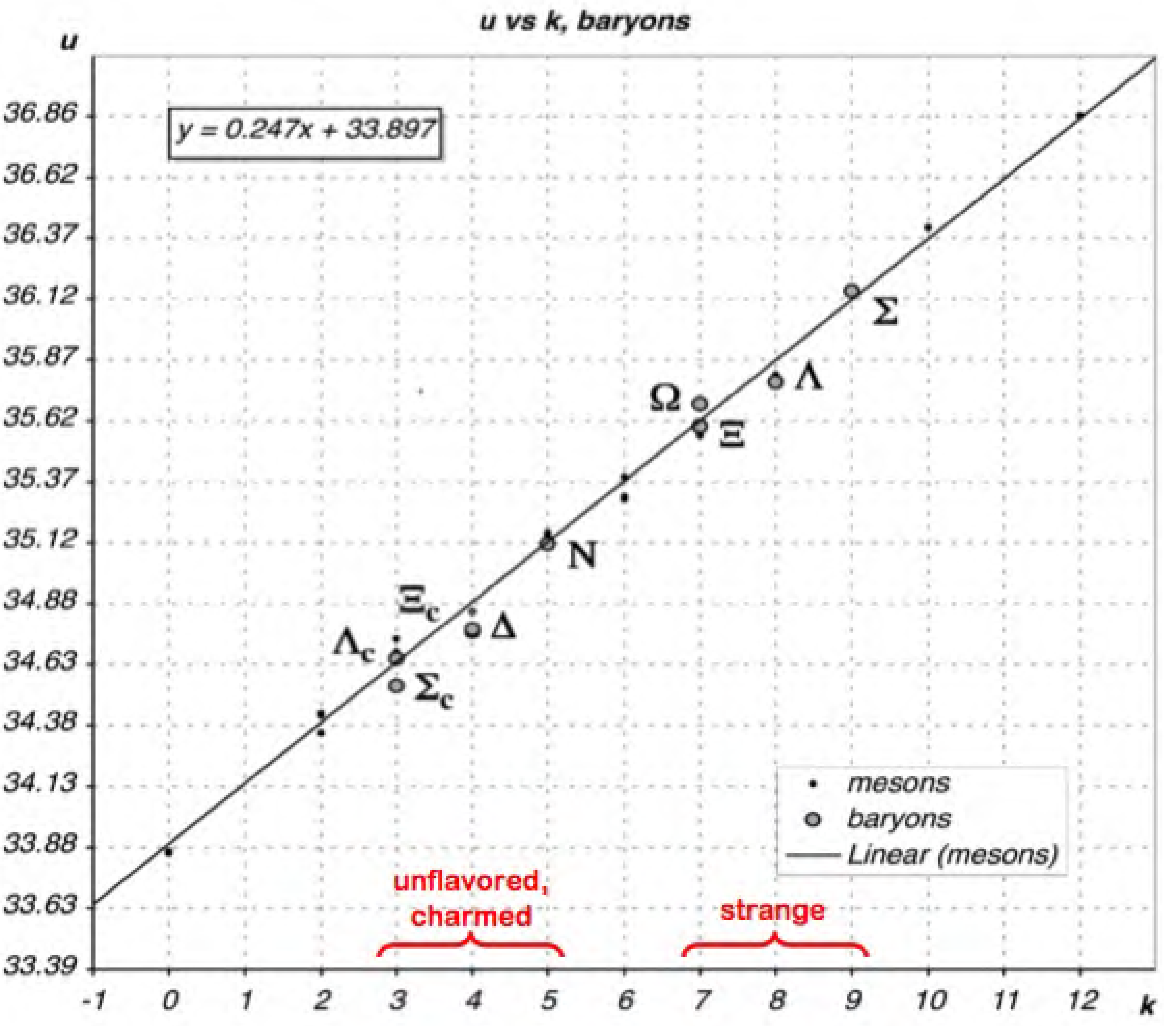
Σ

du/dJ

flip-flop



u vs k

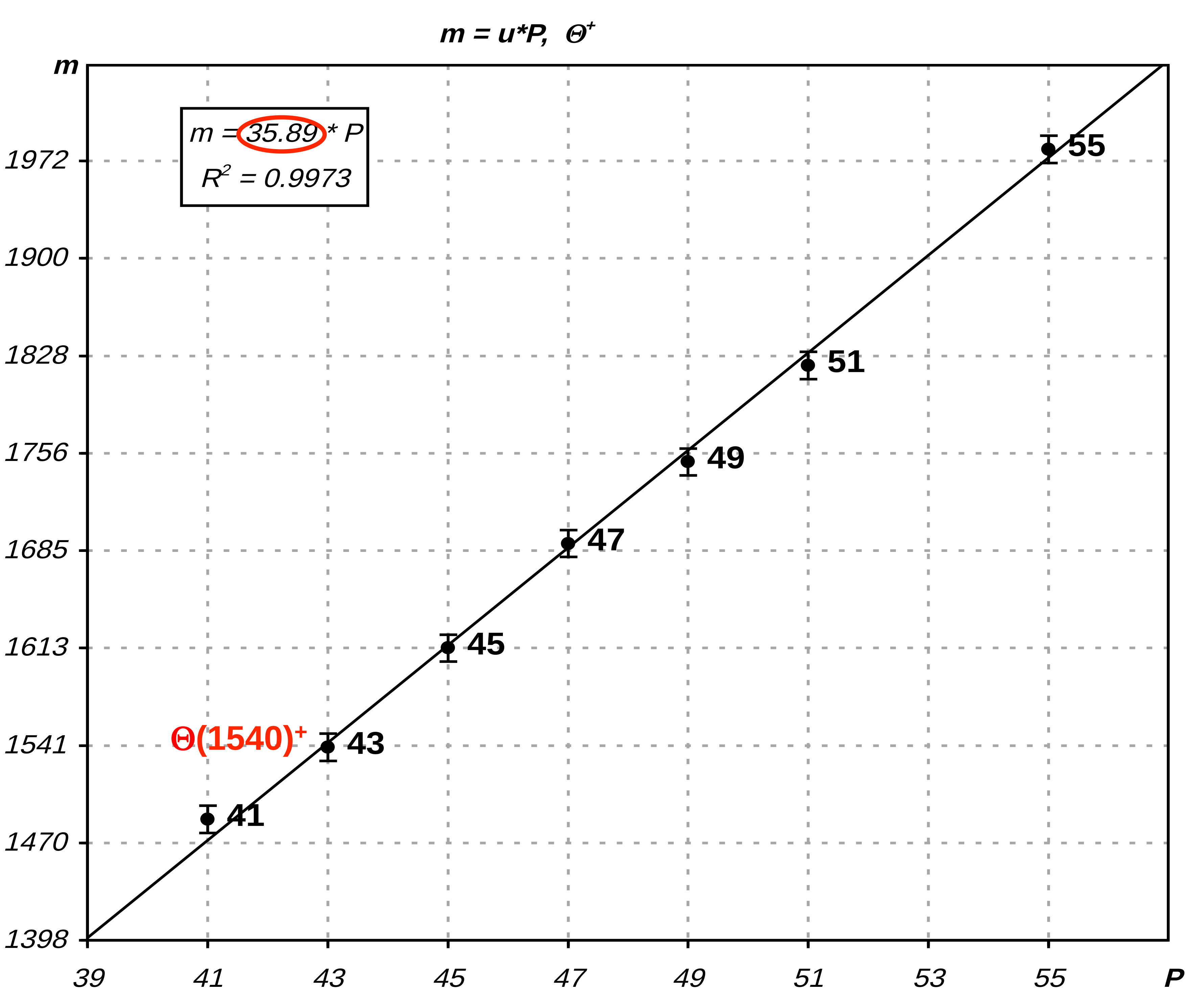


u vs k, baryons
u
k
y = 0.247x + 33.897
36.86
36.62
36.37
36.12
35.87
35.62
35.37
35.12
34.88
34.63
34.38
34.13
33.88
33.63
33.39
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
Σ
Λ
Ω
Ξ
N
Ξ_c
Δ
Λ_c
Σ_c
mesons
baryons
Linear (mesons)
unflavored,
charmed
strange

Θ^+

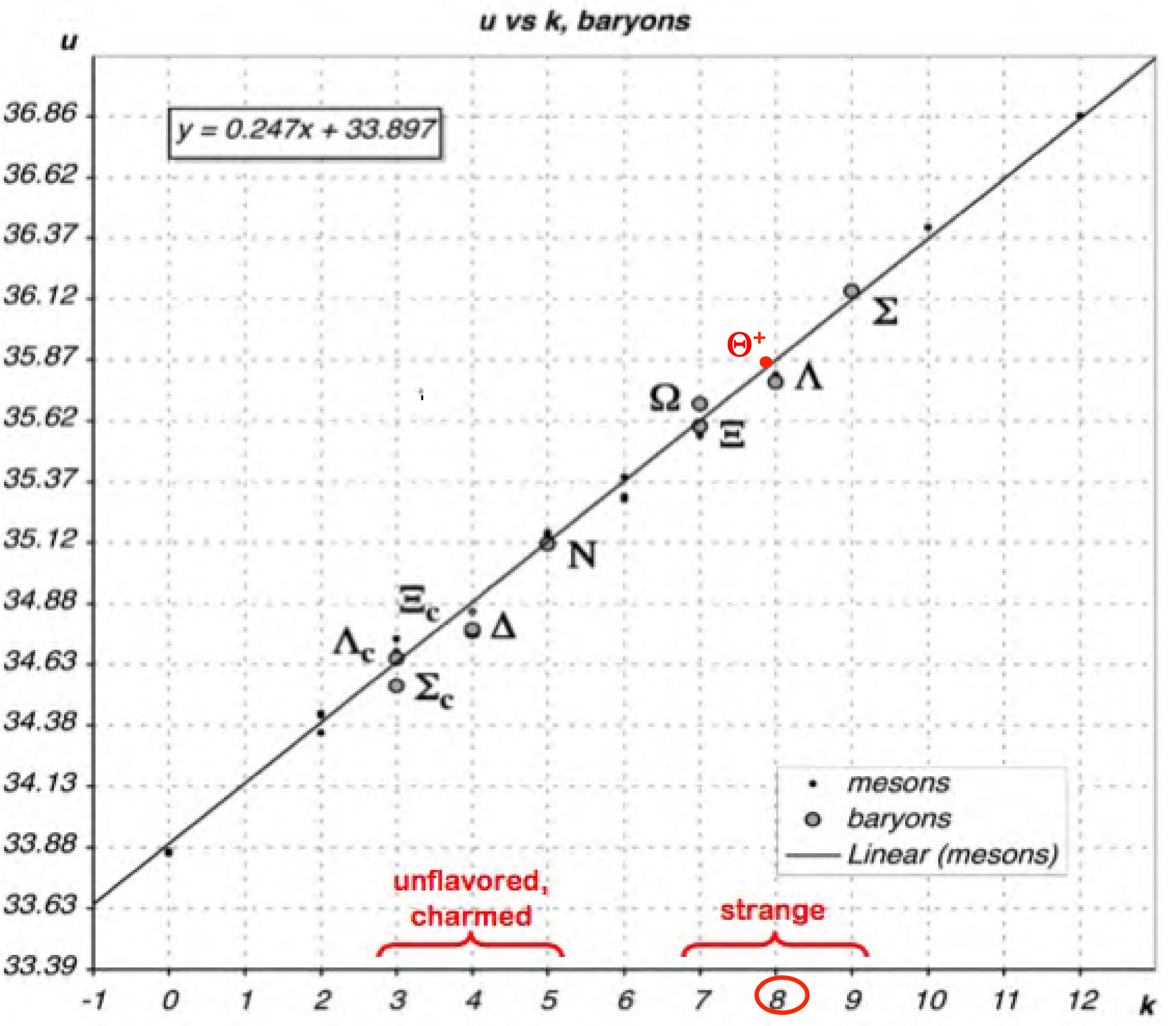
7 states

P. Aslanyan



u vs k

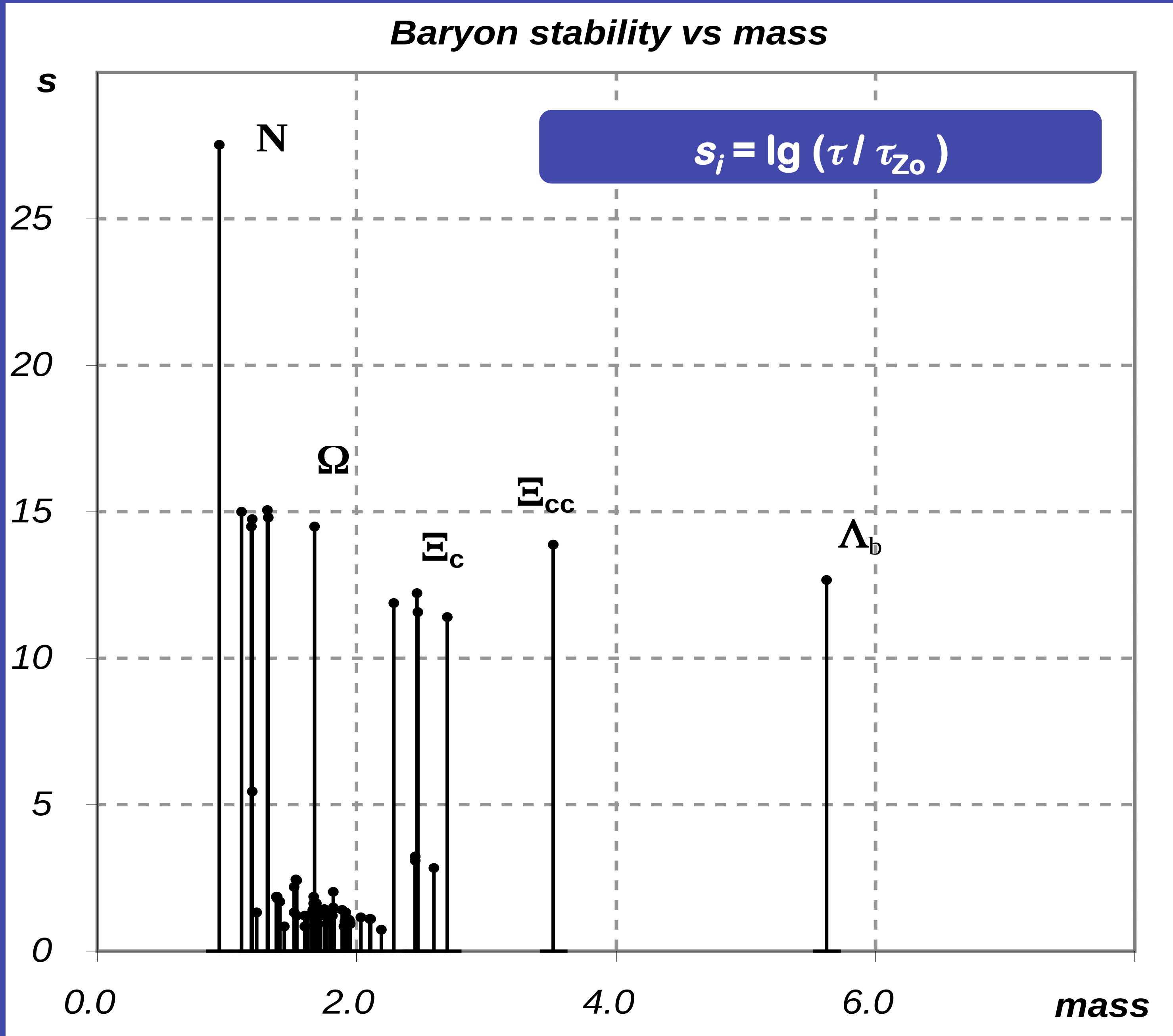
Θ^+



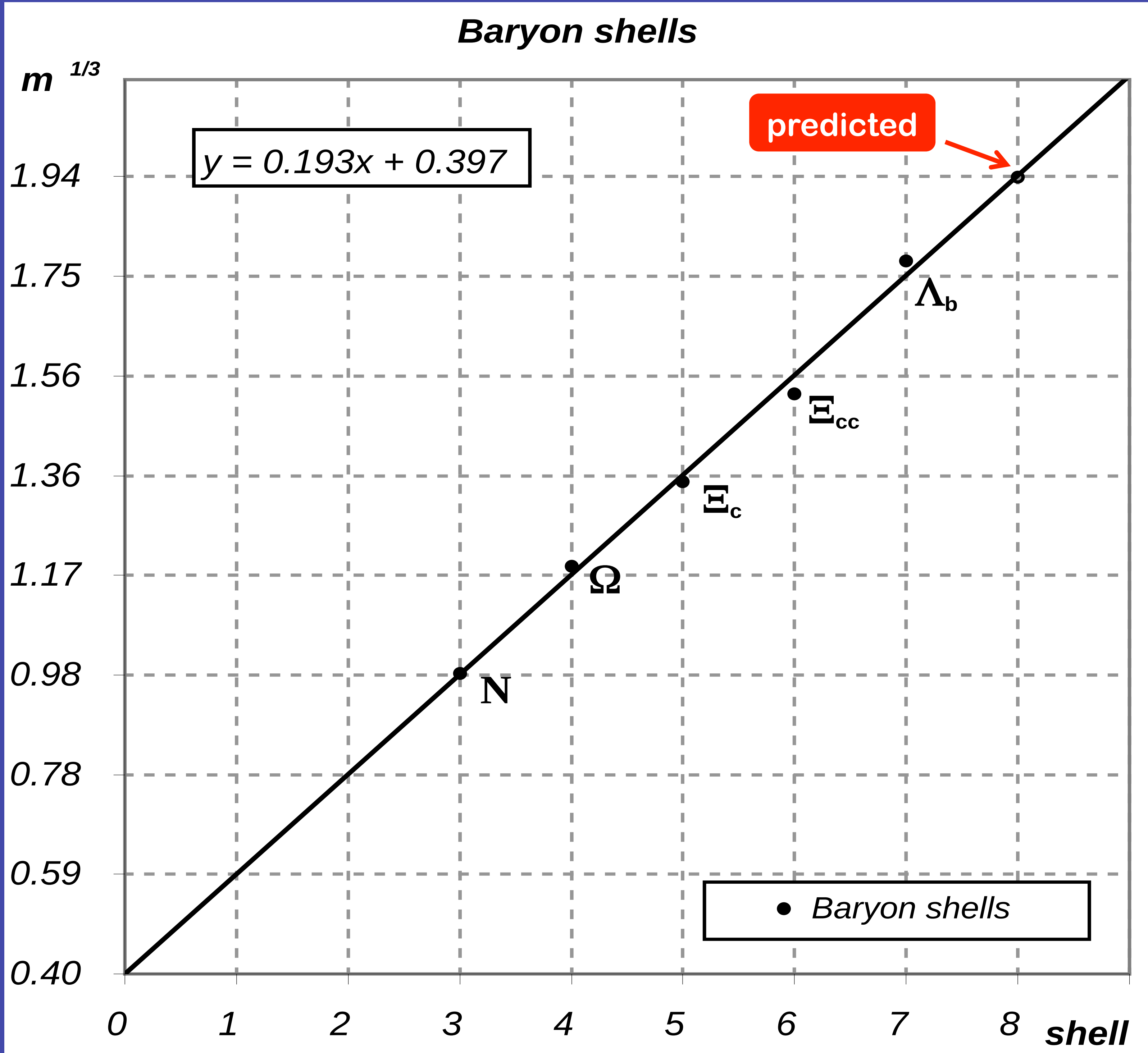
u vs k, baryons
u
y = 0.247x + 33.897
36.86
36.62
36.37
36.12
35.87
35.62
35.37
35.12
34.88
34.63
34.38
34.13
33.88
33.63
33.39
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
k
Σ
Θ+
Λ
Ω
Ξ
N
Ξc
Δ
Λc
Σc
mesons
baryons
Linear (mesons)
unflavored, charmed
strange

baryon shells

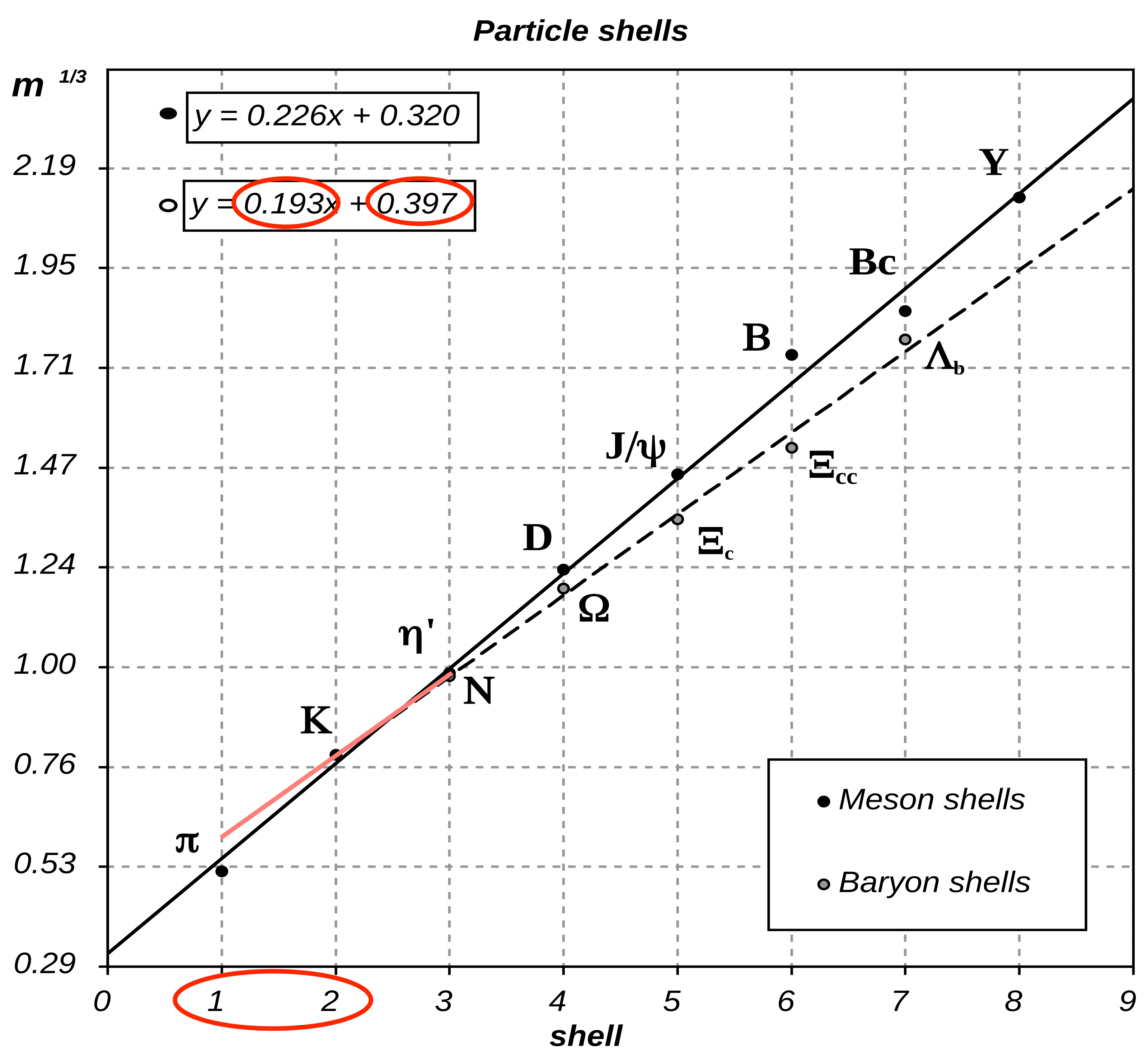
baryon stability



baryon shells



baryon vs meson shells



baryon shells organization, clues:

- shells 1 and 2 are not cohesive
- packing density ≅ 1/3 of the full FCC
- 6 nodes at shell 1

diamond lattice? maybe...

interaction

Q uantum sure

~~C hromo~~ no need, lattice

~~D ynamics~~ none, in 1^{st} approx

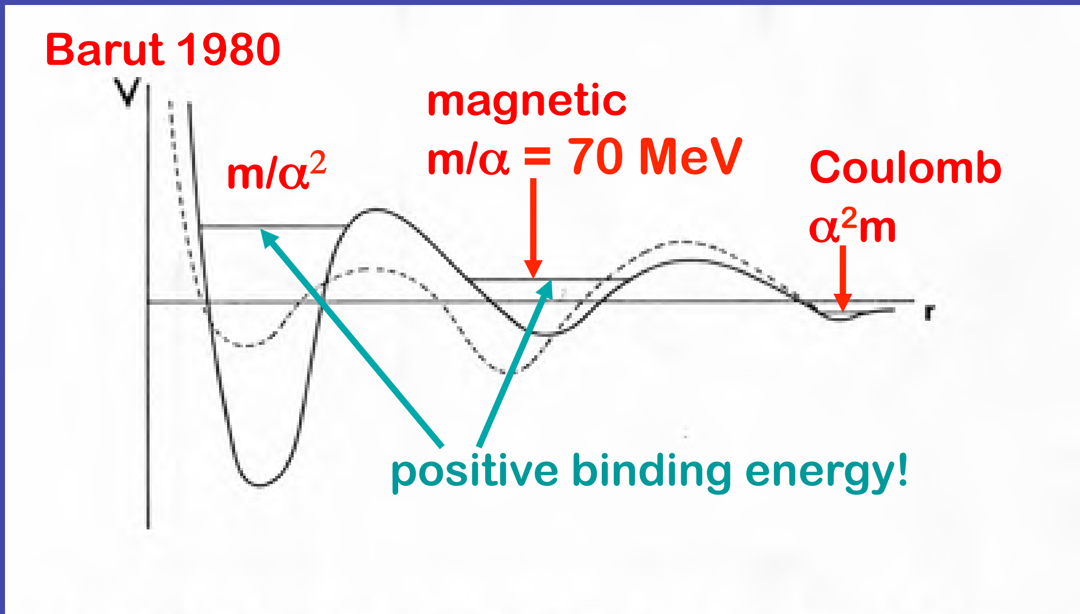


FIGURE 1. Schematic form of the effective radial magnetic potential V as a fuction of the radial distance r for two different fixed values of energy and angular momentum.

Q uantum

M agneto

S tatic

implications

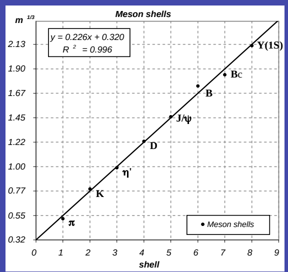
- quark-lepton relationship elucidated
- "quark masses" rationalized
- color is not needed
- baryon number may relate to a different lattice
- antimatter asymmetry shifts from the universe to the atom
- 13 out of the >26 SM parameters are gone
- electro-strong unification
- α_s computed in bound state = 0.101 ± 0.0014

problems

- top, but m(t) ≅ m(Z) + m(W)
- ...


LE CHEF D'ŒUVRE DU CINÉMA FRANÇAIS
JEAN GABIN
DITA PARLO
PIERRE FRESNAY
ERIC VON STROHEIM
dans
LA GRANDE ILLUSION
Un film de
JEAN RENOIR
avec
CARETTE · MODOT · PECLET
et
DALIO
GRAND PRIX DU JURY INTERNATIONAL DE VENISE

Thank you for your attention !



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