Fractal properties applied to masses of elementary particles and nuclei, and applied to other nuclear data

Boris Tatischeff[1,2]

[1]Univ Paris-Sud, IPNO, UMR-8608, Orsay, F-91405
[2]CNRS/IN2P3, Orsay, F-91405
tati@ipno.in2p3.fr

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Brief presentation of fractal properties

The same physical laws apply for different scales of a given physics.

Continuous scale invariance: O(x) observable, x variable. O(x) is scale invariant under an arbitrary change x$\rightarrow$ λx, if a number $\mu(\lambda)$ exists, such that μ=O(x)/O(λx) .

O(x)=Cx^α where α=-lnμ/lnλ $\quad$ $\ln(O) = \alpha \ln(x) + b$ $\quad$ ($b = \alpha \ln C$).

Discrete scale invariance: the scale invariance is only observed for specific choices of λ.

Therefore complex exponents α inducing log-periodic corrections to scaling.

α = - $ln\mu/ln\lambda + 2ni\pi/ln\lambda$.

We apply the most general form of the distributions to the mass ratio:

$$f(r) = C(|(r - r_c)|^S [1 + a_1 cos(2\pi\Omega ln(|r - r_c|) + \Psi)]$$

adjust: S, a_1, and Ω.

"r" is the rank, r_C is the critical rank (arbitrarily fixed to $r_C = 40$), $\Omega = 1/ln\lambda$, S = $-ln\mu/ln\lambda$ fixes the general slope, a_1 measures the amplitude of the log-periodic correction to continuous scaling, Ψ is a phase in the cosine which determines a global translation of the distributions.

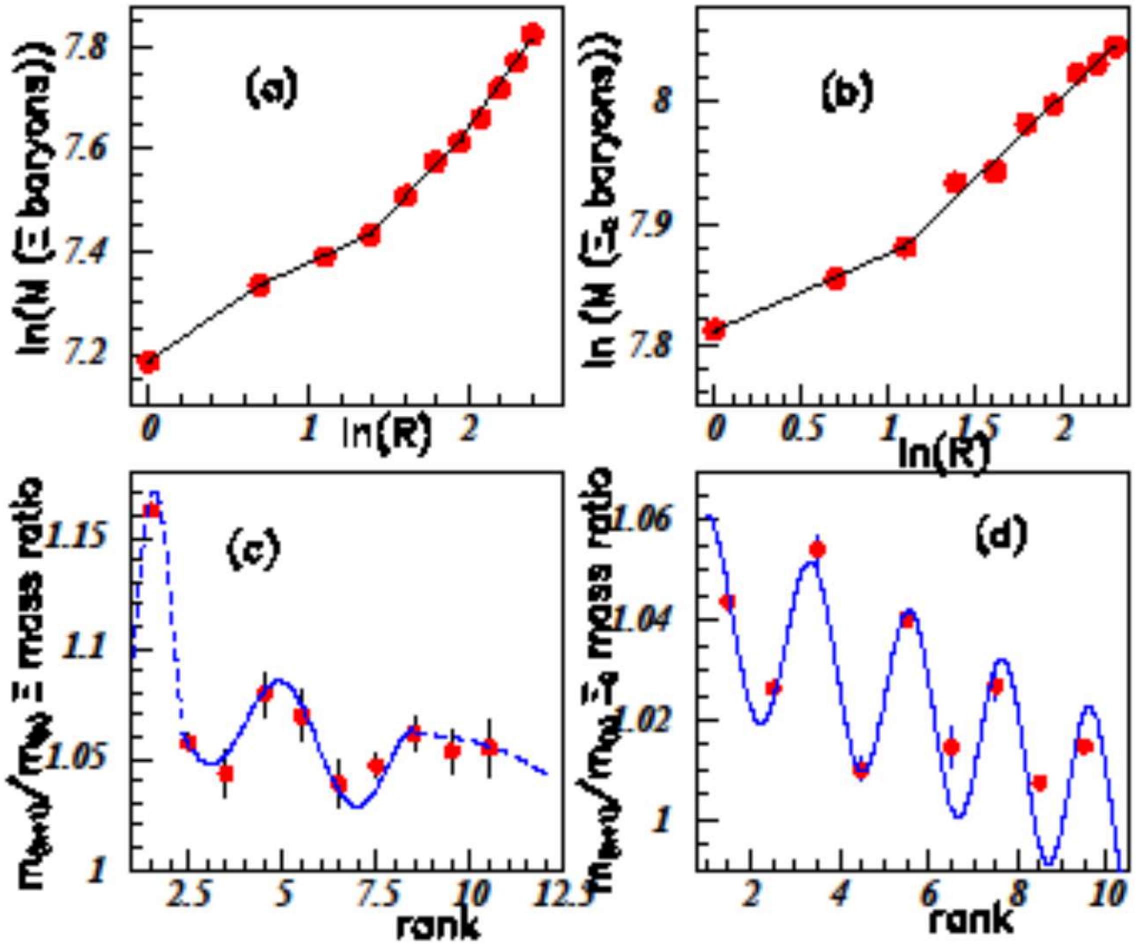
B. Mandelbrot, Les objets fractals (Flammarion, Paris 1975), *ibid* The fractal geometry of Nature (Freeman, San Francisco, 1982).

L. Nottale, The Theory of Scale Relativity, Comp. Antic. Systems CASY'303 (Liege 2003), (D.M. Dubois, Ed.); *ibid* Am. Inst. Phys. Conf. proceedings, 718, p68 (2004).

D. Sornette, Physics Reports 297, 239 (1998).

B. Sapoval, Universalités et fractales (Champs, Flammarion, Paris 2003).

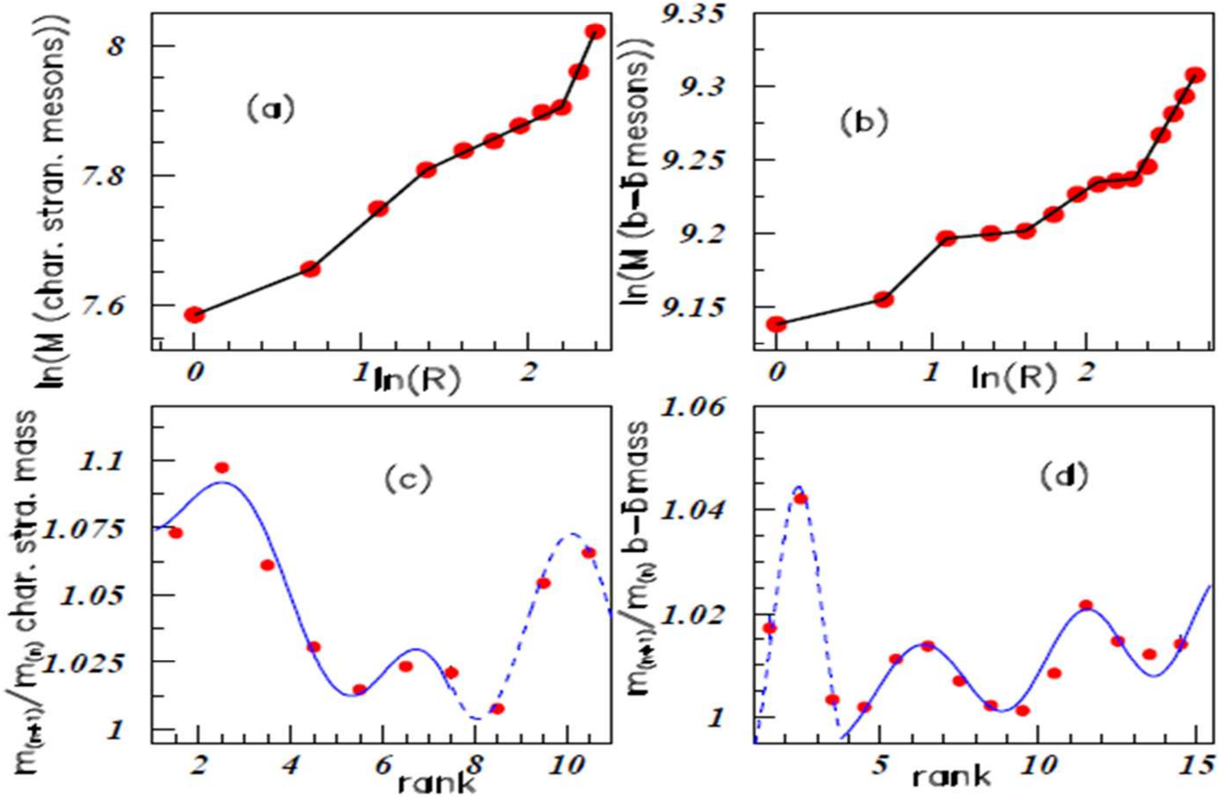
Fractal properties for baryonic masses



Ξ (uss, dss) baryons $\qquad$ Ξ_C (usc, dsc) baryons

B. T. arXiv:1105.2034v1 [physics.gen-ph] 5 May 2011

Fractal properties for mesonic masses

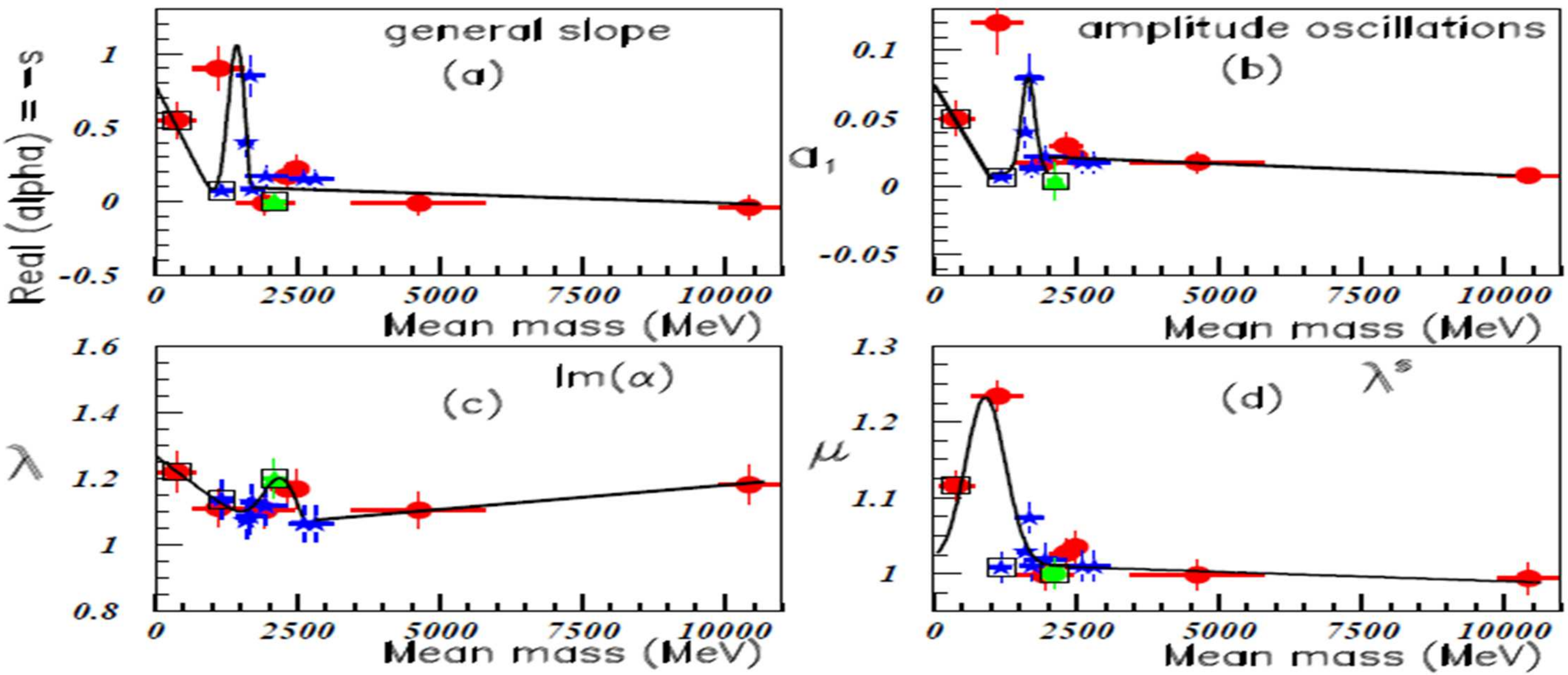


(a) and (b) log-log plots, equation (1)
(c) and (d) mass ratio distributions, equation (2)

Charmed, strange mesons	$b-\bar{b}$ mesons
$D_S^+(c\bar{s}), D_S^-(\bar{c}s)$	$b-\bar{b}$

B. T. arXiv:1105.2034v1 [physics.gen-ph] 5 May 2011

Fitted coefficients describing the mass ratio analyses

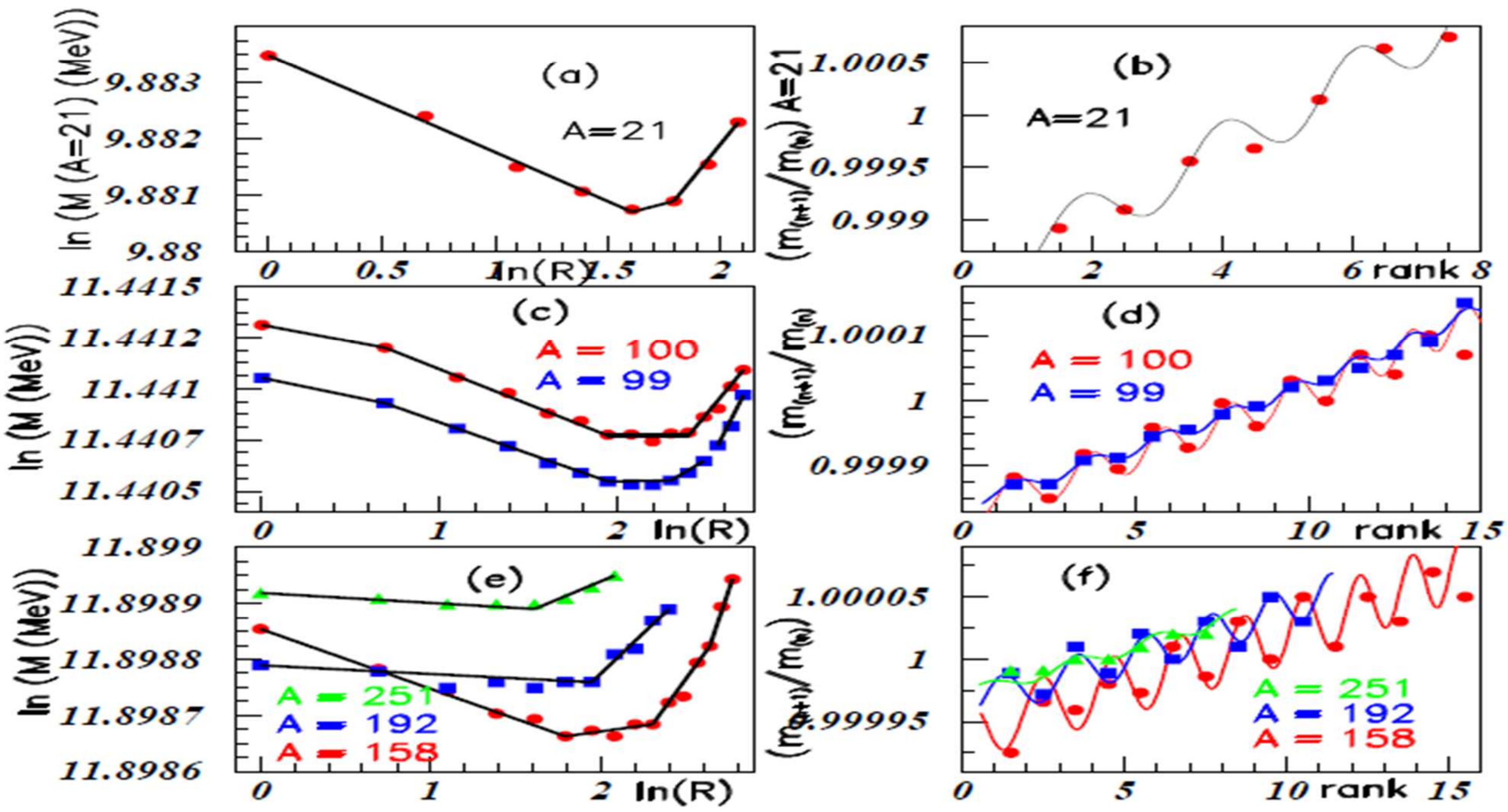


mesons, baryons, dibaryons

encircled black squares: narrow exotic hadrons.

B.T. arXiv:1105.2034v1 [physics.gen-ph] 5 May 2011

Fractals applied to nuclear masses

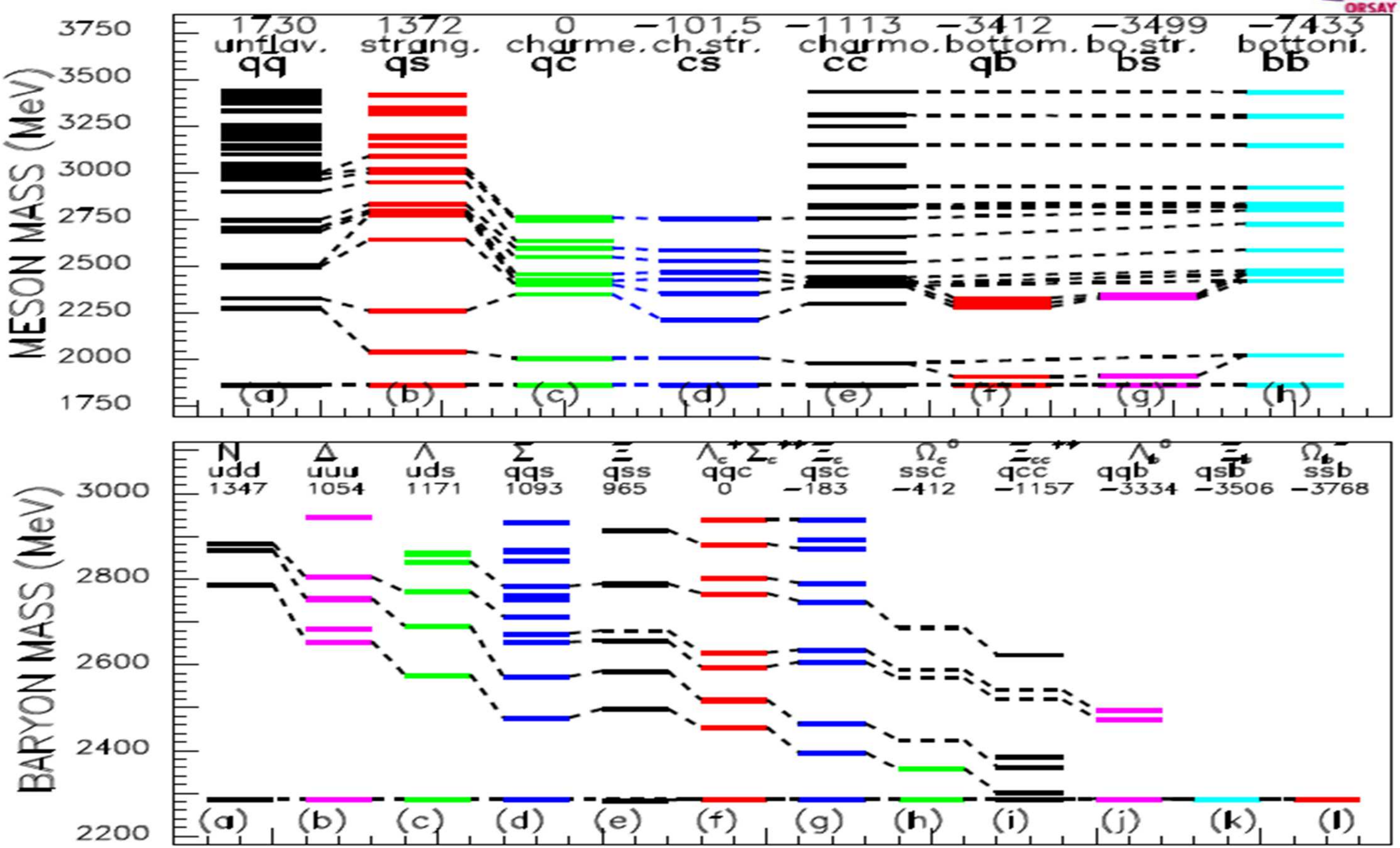


A constant, Z increasing. A.H. Wapstra, G. Audi, and C. Thibault. Nucl. Phys. A729, 337 (2003).
Arbitrary shifts, for clarity, in inserts (c) and (e).

Pairing effect

B.T. arXiv:1107.1976v1 [physics.gen-ph] 11 Jul. 2011

Comparison between Excited Hadronic Masses



B.T. arXiv:1105.2034v1 [physics.gen-ph] 5 May 2011

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PDG baryon /PDG baryon mass ratios

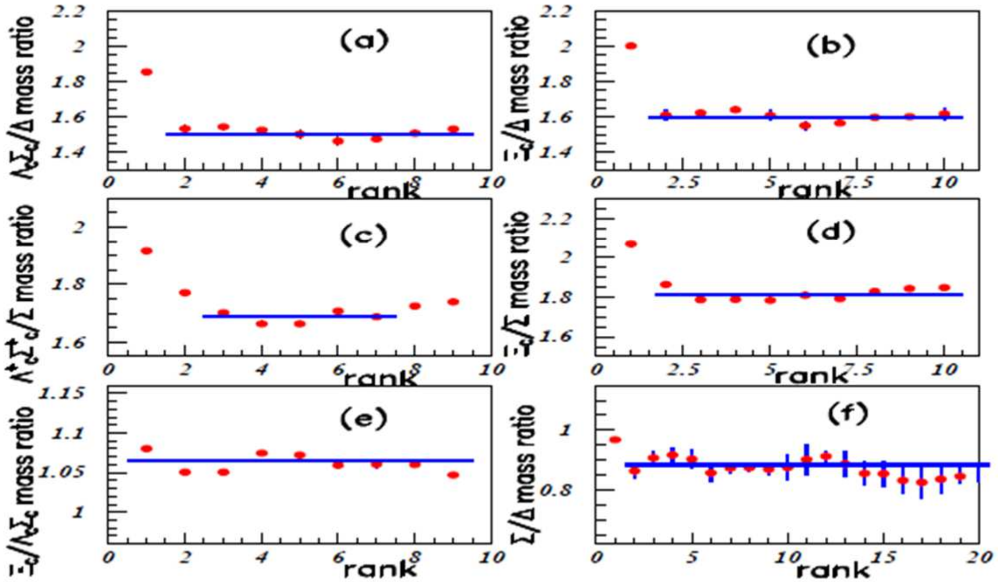


Table 1: PDG Baryon /PDG meson mass ratios.

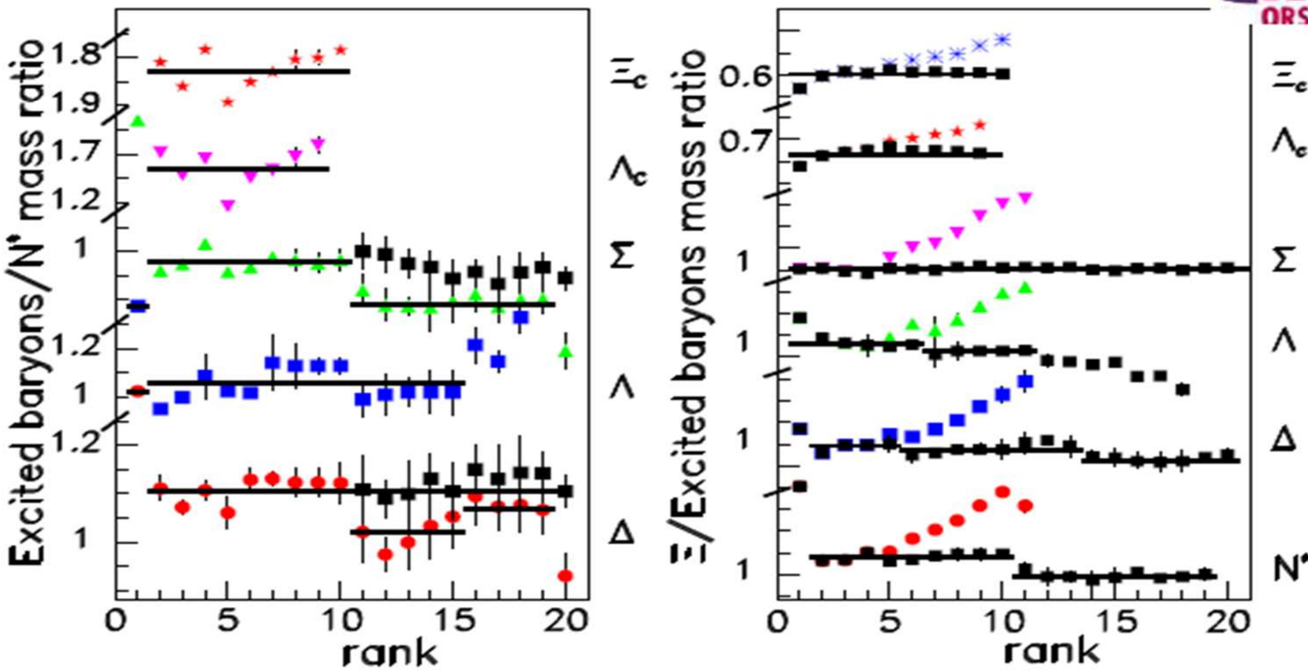
(a)	(b)	(c)	(d)	(e)	(f)
$\Lambda_C\Sigma_C/\Delta$	Ξ_C/Δ	$\Lambda_C\Sigma_C/\Sigma$	Ξ_C/Σ	$\Xi_C/\Lambda_C\Sigma_C$	Σ/Δ
udc, qqc/qqq	qsc/qqq	udc, qqc/qqs	qsc/qqs	qsc/udc, qqc	qqs/qqq

Constant mass ratios means constant interaction of QCD couplings and charges

q stands for u or d quark

flat ratios (except for the first mass ratios for all species)

Ratios of exc. bar. masses between different families



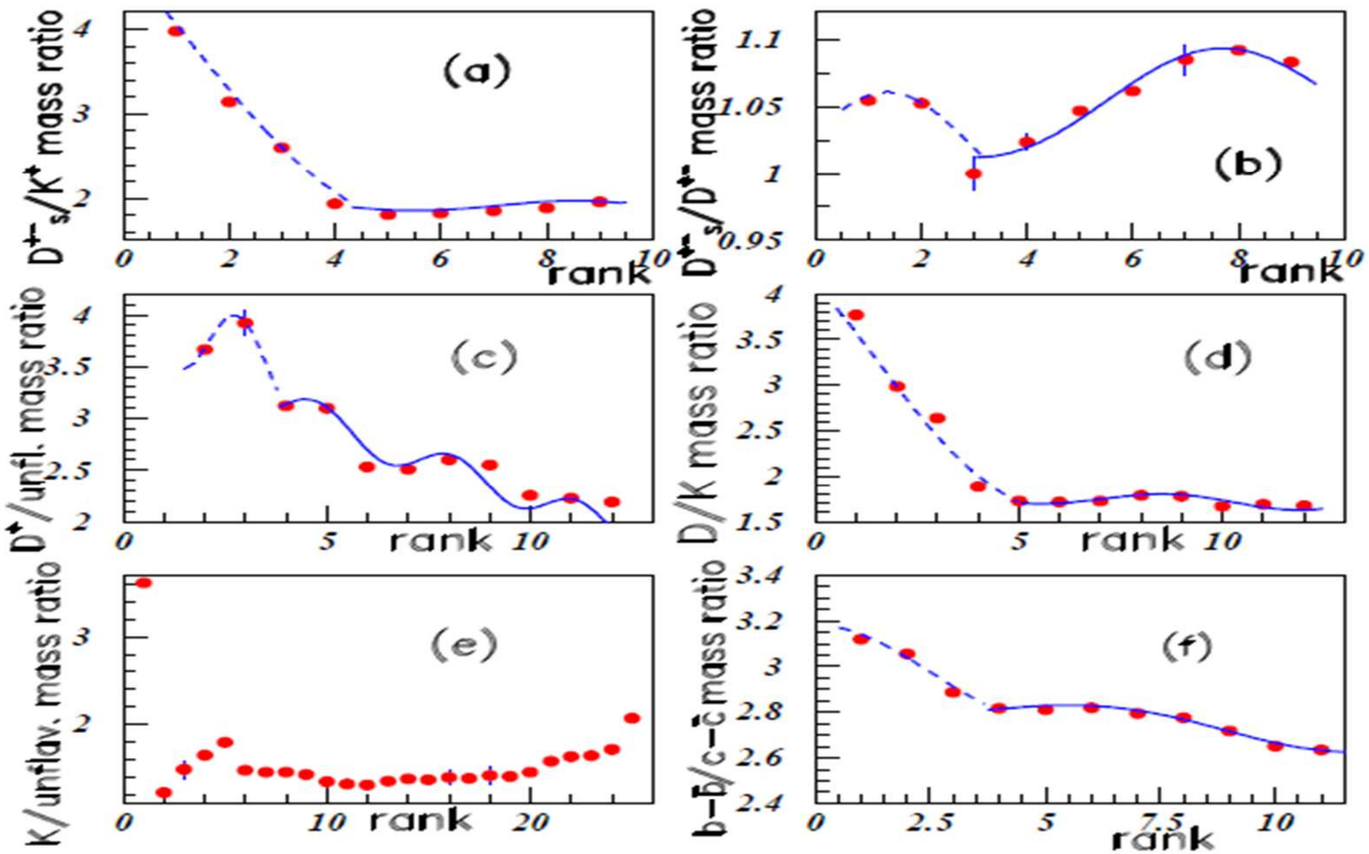
Missing a few N^* masses, after the 10^{th}, in the range $1720 \leq M \leq 1900$ MeV. Missing Ξ masses, after the 4^{th}. Several masses tentatively introduced, starting at M = 1750 MeV. Same masses used for all family mass ratios.

(a)	(b)	(c)	(d)	(e)	(f)
Ξ_C/N^* qsc/udq	$\Lambda_C\Sigma_C/N^*$ udc, qqc/udq	Σ/N^* qqs/udq	Λ/N^* uds/udq	Δ/N^* qqq/udq	Ξ/Ξ_C qss/qsc
(g)	(h)	(i)	(j)	(k)	
$\Xi/\Lambda_C\Sigma_C$ qss/udc, qqc	Ξ/Σ qss/qqs	Ξ/Λ qss/uds	Ξ/Δ qss/qqq	Ξ/N^* qss/udq	

Table 1: Mass ratios between several baryonic families.

B.T. arXiv:1205.2493v1 [nucl-ex] 10 May 2012

Mass ratios between different mesonic families

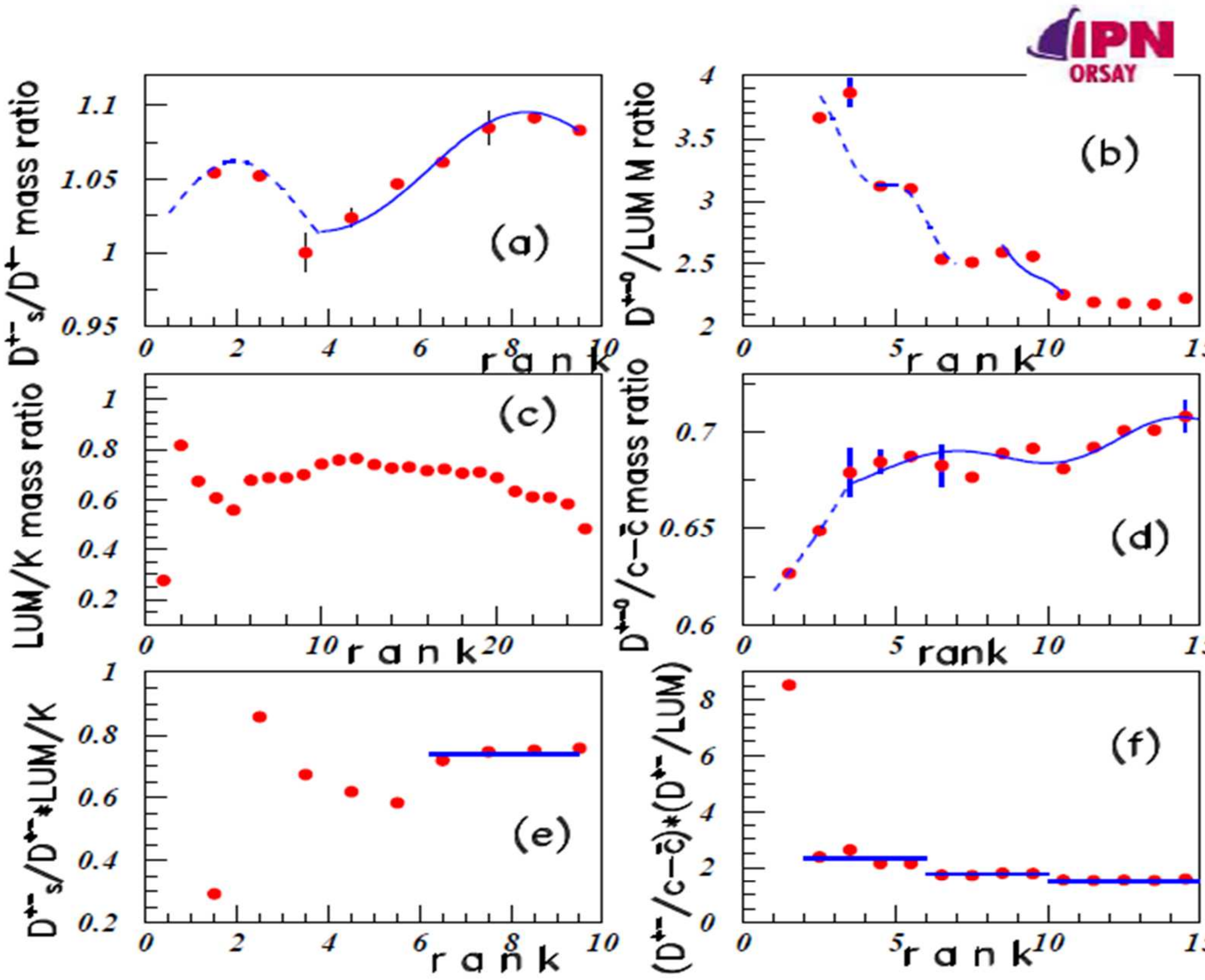


(a)	(b)	(c)	(d)	(e)	(f)
D_s^{+-0}/K^{+-}	D_s^{+-}/D^{+-0}	D^{+-0}/LUM	D^{+-0}/K^{+-}	K^{+-}/LUM	$b\underline{b}/c\bar{c}$
$\bar{s}c/\bar{q}s$	$c\bar{s}/\bar{c}q$	$\bar{q}c/q\bar{q}$	$c\bar{s}/q\bar{s}$	$s\bar{q}/q\bar{q}$	$b\bar{b}/c\bar{c}$

No flat ratios unlike ratios between different baryonic families.
Except in insert (e), all fits with two parameter sets, describe the first 4 ratios, then the next 7 - 8 ratios.

Is it possible to attribute the different behaviour between baryons and mesons, to the introduction of more complex quark and/or gluon configurations ? In that case, this should concern many mesons in all families ?

Double mass ratios between different mesonic families

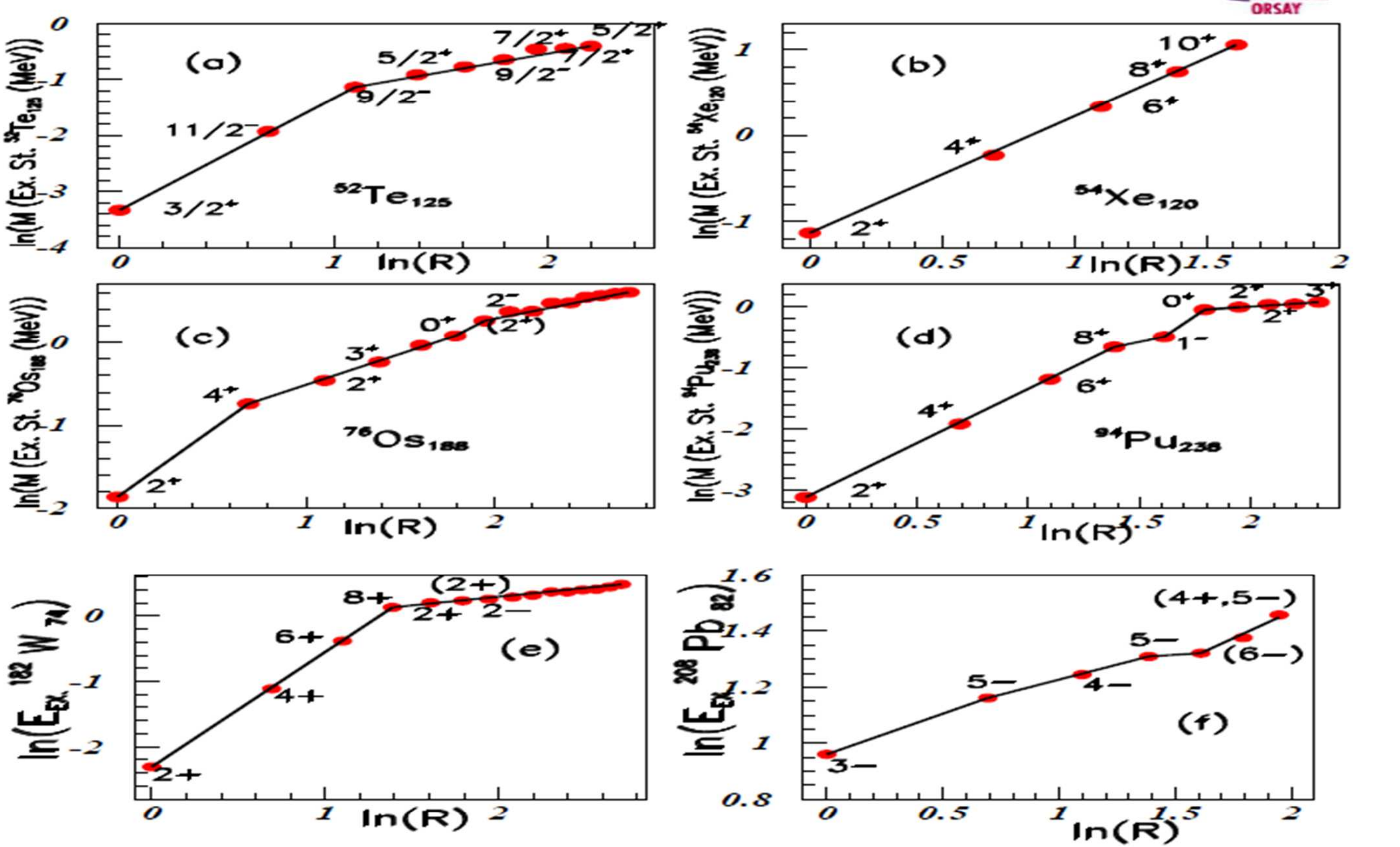


Elimination of quark masses (LUM: light unflavoured mesons) :

Insert (e) = (a) * (c) Insert (f) = (b) * (d)

$c\bar{s}/q\bar{c} * q\bar{q}/q\bar{s} = 1$ $q\bar{c}/q\bar{q} * c\bar{q}/c\bar{c} = 1$

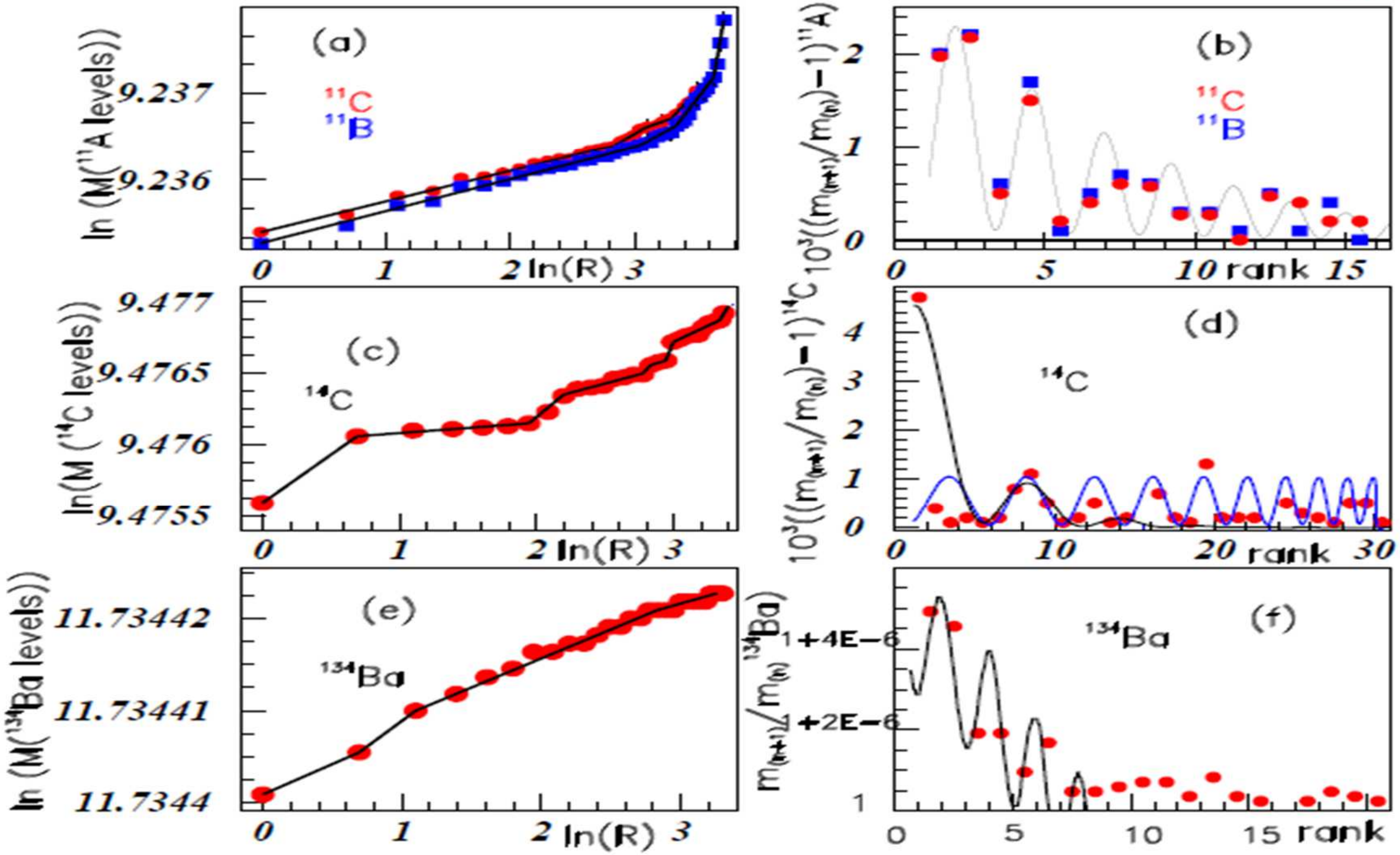
Excitation level masses of some nuclei



Fractal alignement for rotationnal spectra (inserts (b) and (d)).

Table of Isotopes, C.M. Lederer, J.M. Hollander, I. Perlman

Excited state energies of levels of some nuclei

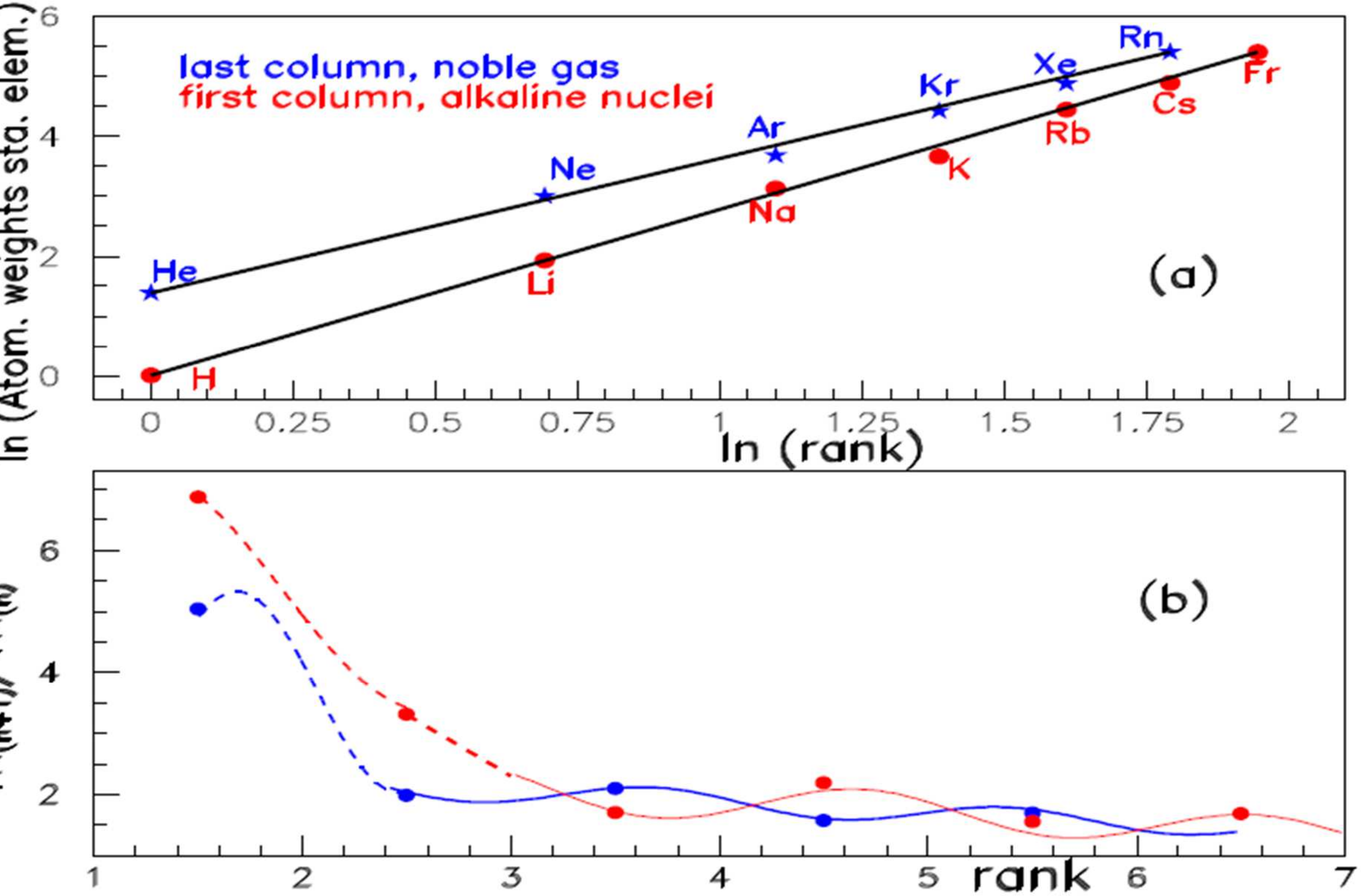


F. Ajzenberg-Selve and T. Lauristen, Nucl. Phys. A506,1 (1990), *ibid* Nucl.Phys. A523 ,1 (1991).

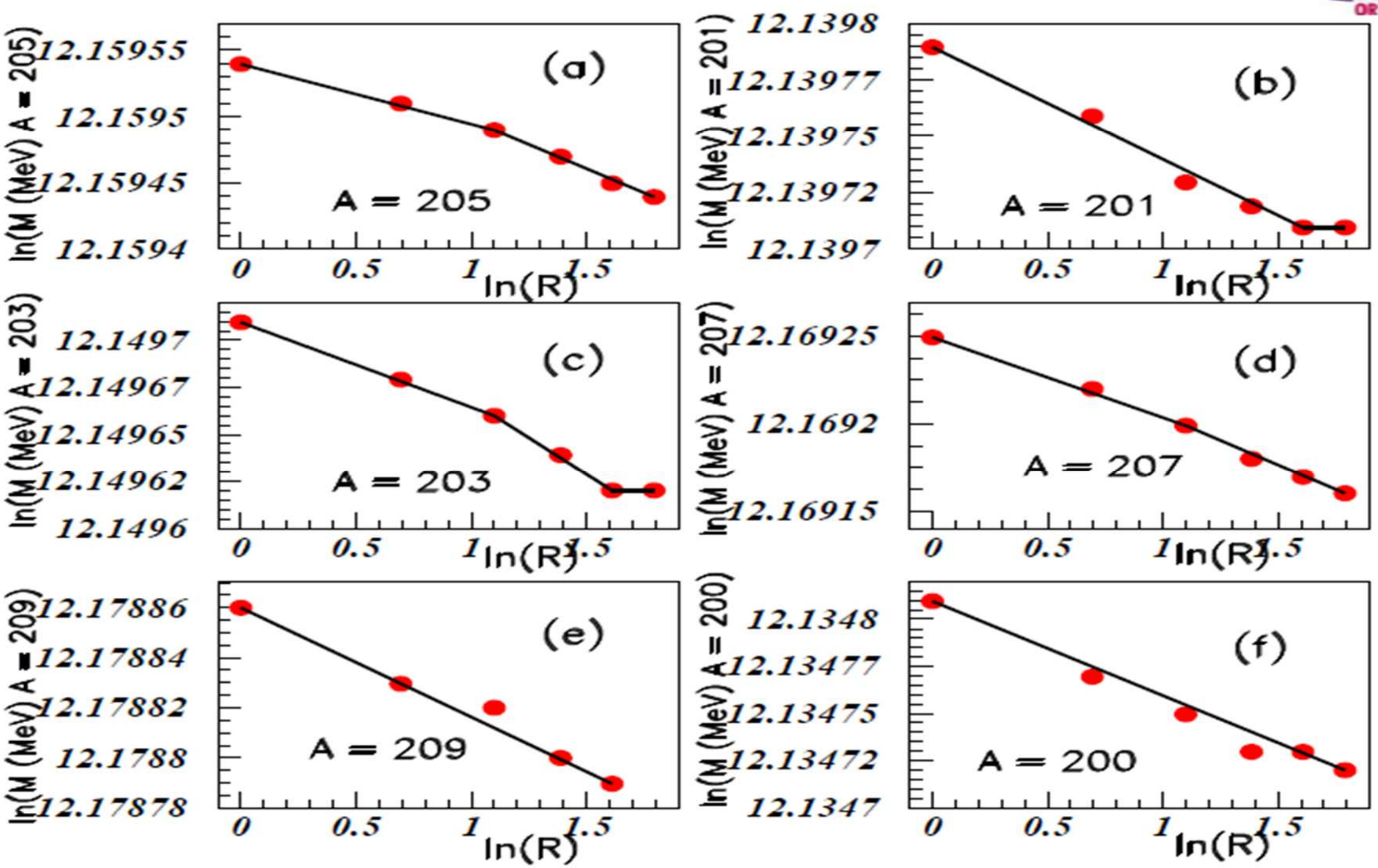
B.T. arXiv:1107.1976v1 [physics.gen-ph] 11 Jul. 2011

Atomic masses of the first and last Mandeleiev table columns

Atomic weights of stable elements



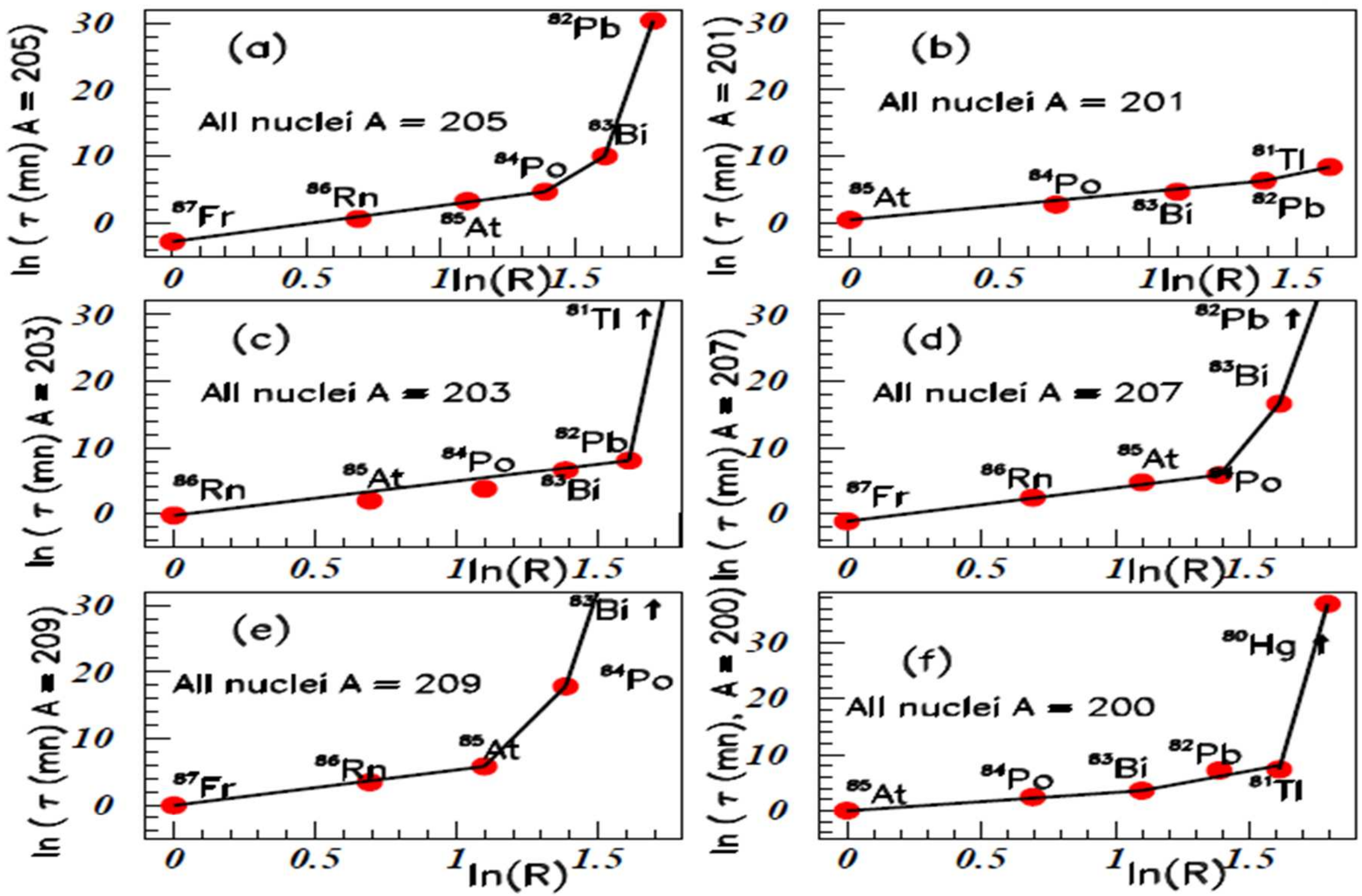
Masses of series following [EC] or β^+ disintegrations



Masses: Atomic mass table A.H. Wapstra and G Audi, Nucl. Phys. A442 1985.

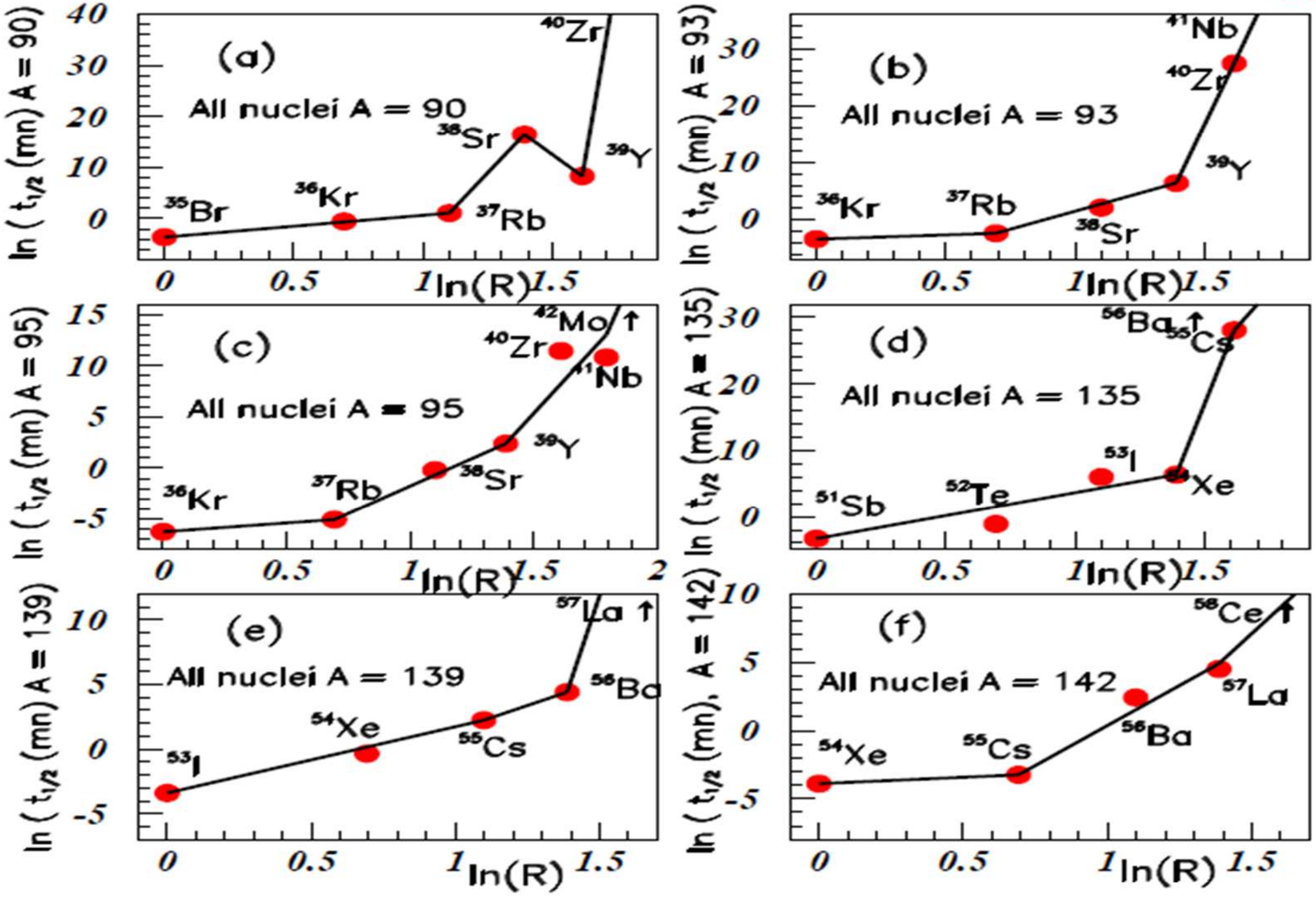
Chains of constant mass number A (close to A = 205), increasing N.

Half lives of series following [EC] or β^+ disintegrations



Half lives: Table of Isotopes C.M. Lederer, J.M. Hollander, I. Perlman
Chains of constant mass number A (close to A = 205), increasing N.

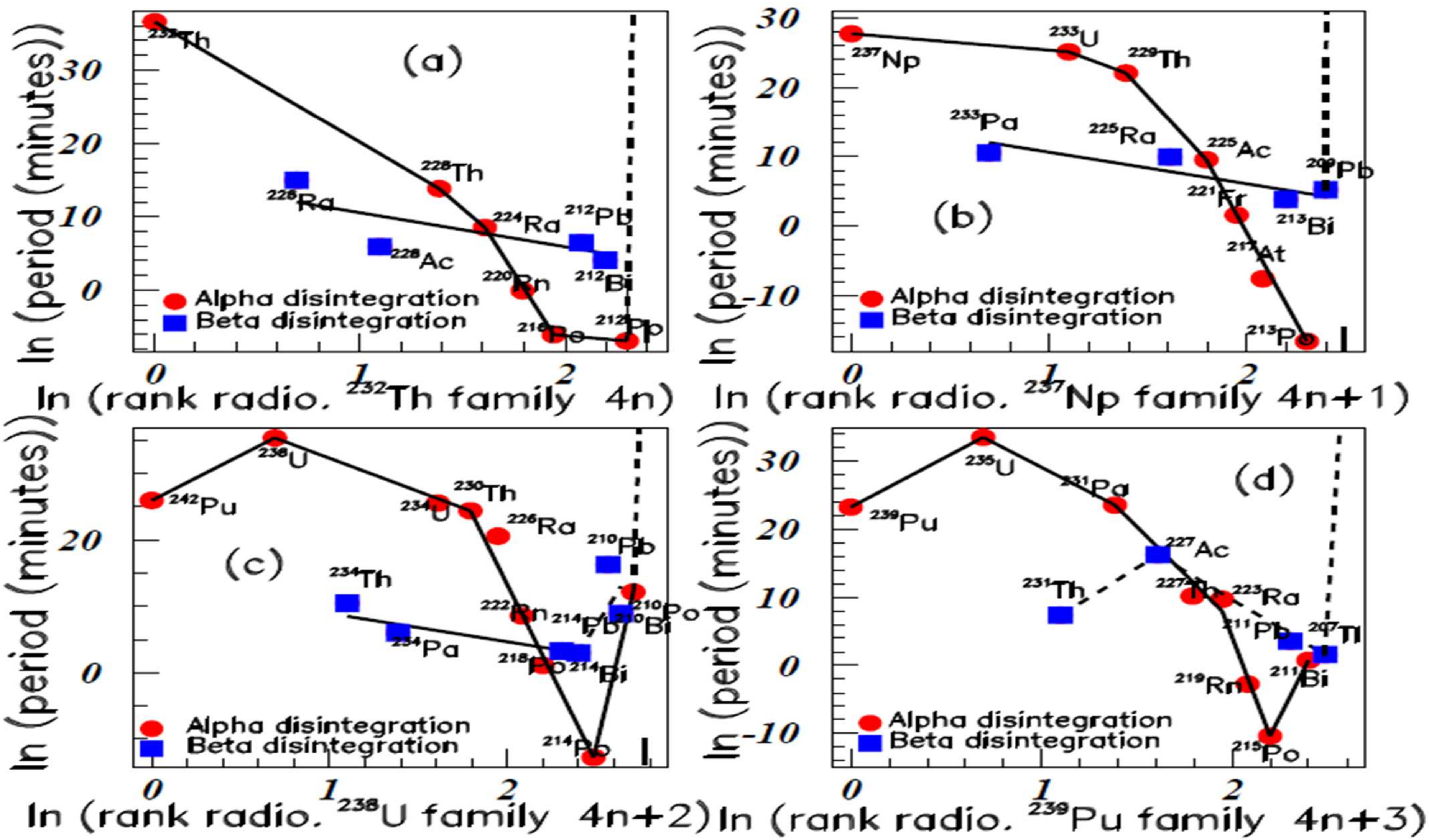
Half lives of series following β^- disintegrations



Half lives: Table of Isotopes C.M. Lederer, J.M. Hollander, I. Perlman

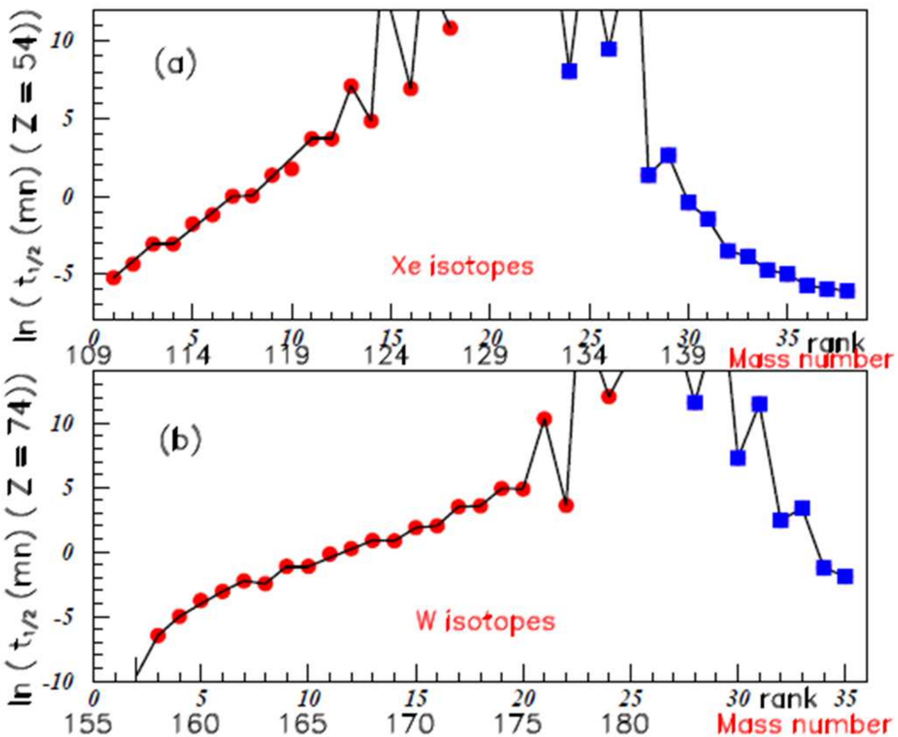
Chains of constant mass number A, increasing Z

The four radioactive family periods



Overlapping fractals

An example of log-periodic law: Half lives of Xe and W isotopes



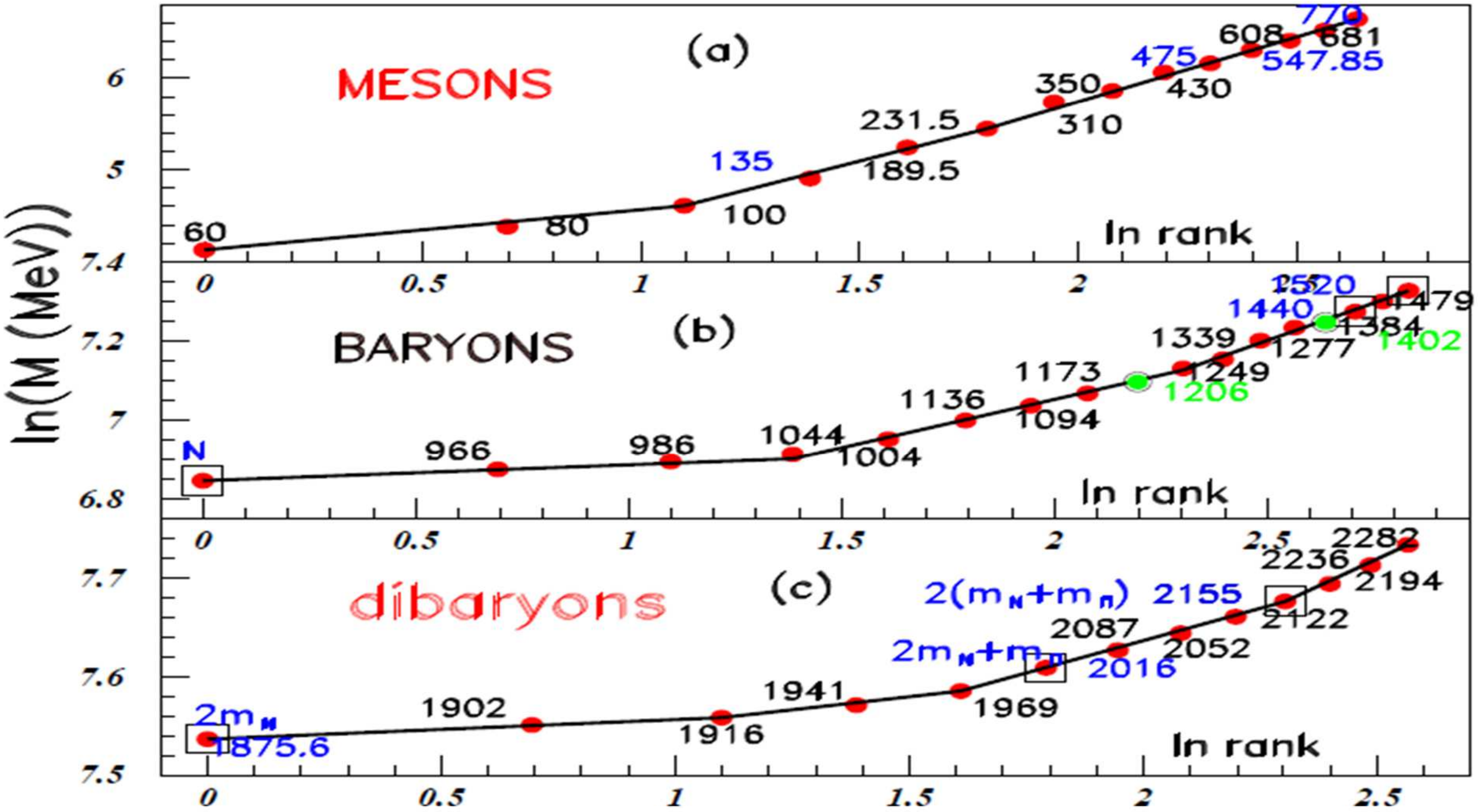
Xenon isotopes: (a); W isotopes: (b) Half lives (Wikipedia). Red circles: β^+ emission; blue squares: β^- emission. The lives outside the figure correspond to stable nuclei.

Acceleration (β^+ emission) up to the critical mass, then deceleration (decreasing) of half-lives (β^- emissions.) A is the mass number, A_C the critical mass number and n the rank.

The auto-similarity parameter "g", given by $(A_n - A_C)/(A_{n+1} - A_C) = g$, g=1.08±0.02.
(D. Sornette. L. Nottale, J. Chaline, and P. Grou Ed. Ellipses, p 124 (in french)).

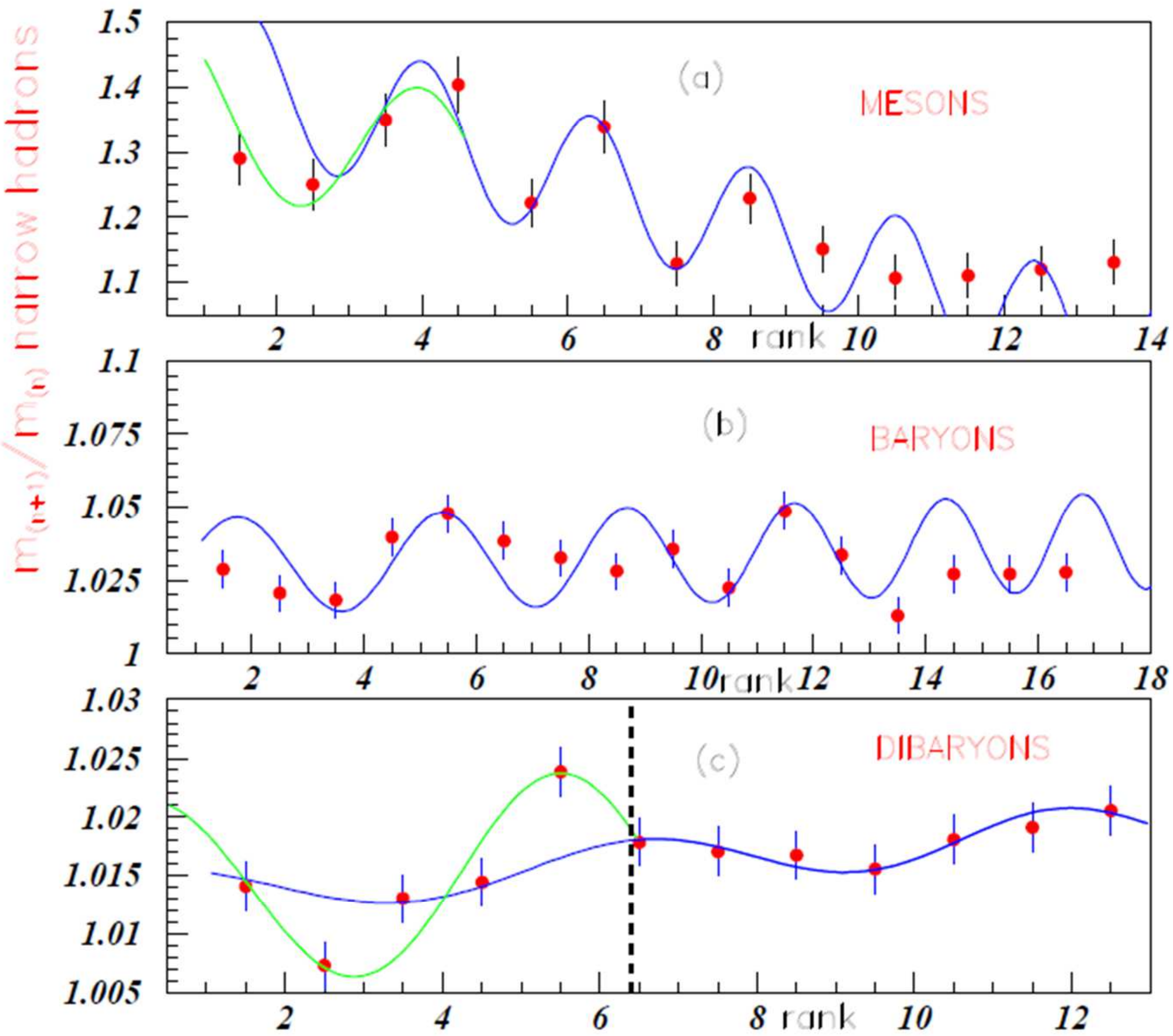
Similar laws for earthquakes, financial crashs, life trees, ...

Narrow Exotic Hadronic Masses



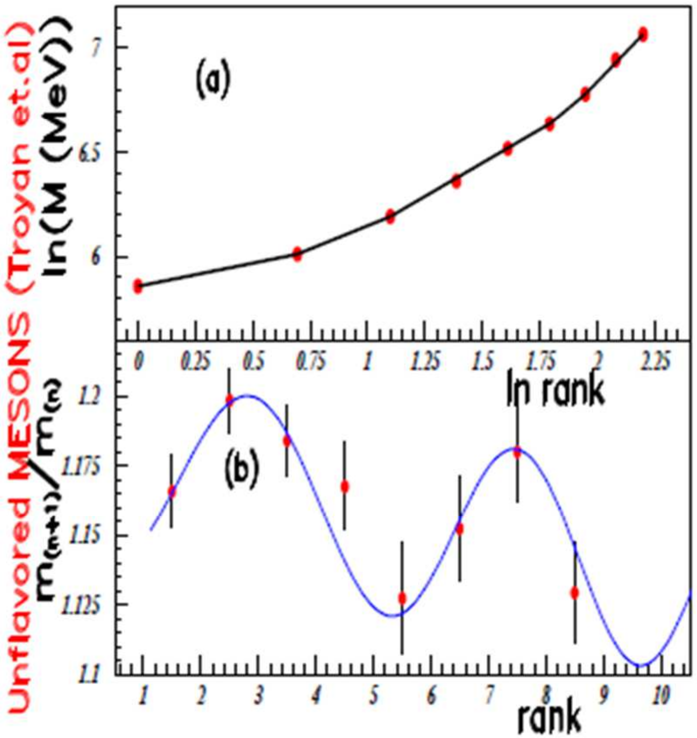
MESONS B. T. and E. Tomasi-Gustafsson, Phy. Elem. Part. Lett. 5, 363 (2008); B.T. *et al.*, Phys. Rev. C62, 054001 (2000); J. Yonnet *et al.*, Phys. Rev. C63, 014001 (2001).
BARYONS B.T. *et al.* Phys. Rev. Lett. 79, 601 (1997); *ibid* Eur. Phys. J. A17, 245 (2003), B.T. Proceedings XVI Int. Baldin Sem. Dubna (2002) p153.
B. Tatischeff and E. Tomasi-Gustafsson, arXiv:nucl-ex/0411044v1 22 Nov 2004.
DIBARYONS B.T. *et al.*, Phys. Rev. Lett. 52 2022 (1984); *ibid* Eur. Phys. Lett. 4, 671 (1987); *ibid* Phys. Rev. C59, 1878 (1999).

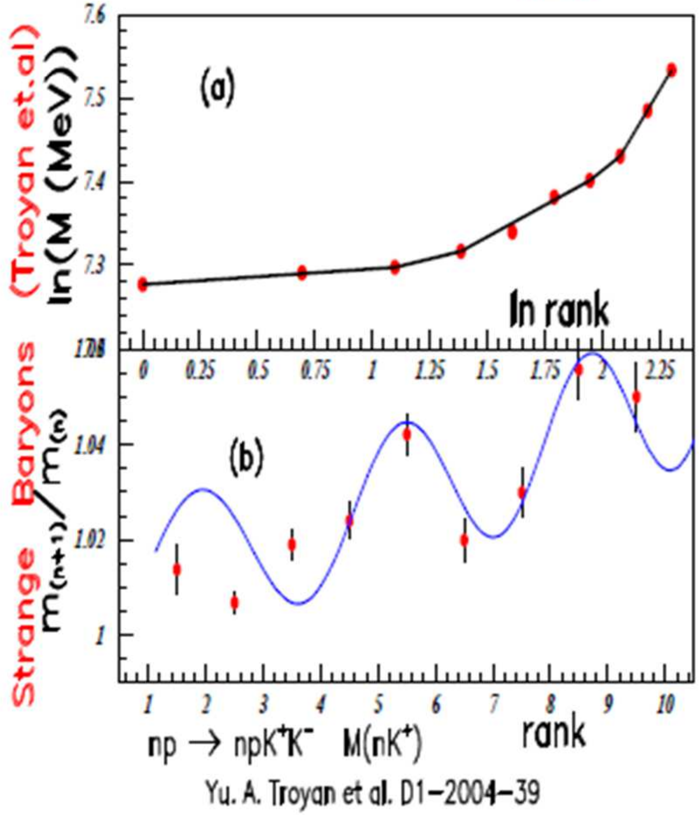
Narrow Exotic Hadronic Masses



Arbitrary relative errors introduced: 1.5/100 in (a), 0.3/100 in (b), 0.1/100 in (c).

Narrow Structures from Troyan's group (Dubna)





np→np$\pi^+\pi^-$ $M_{\pi^+\pi^-}$

np→npK^+K^- M_{nK^+}

Yu.A. Troyan et al.
Physics of Elem. Part. and Atom. Nucl.
Part. and Nucl. Lett. 9, 77 (2012).

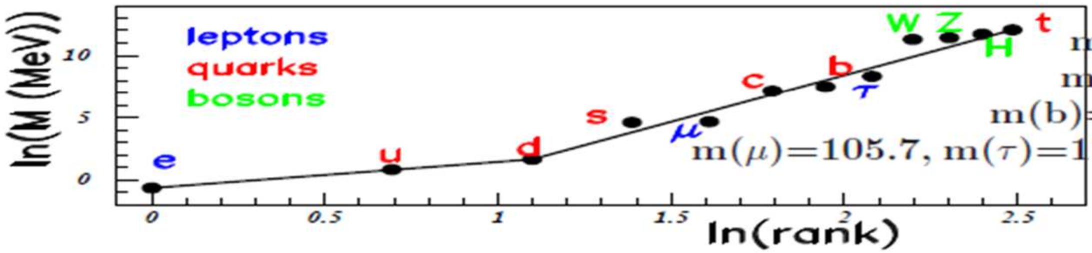
Yu.A. Troyan et al.
D1-2004-39

Conclusion

- Observe fractal properties in fundamental particle and nuclei masses, in half-life times of nuclei giving rise to β^+ or β^- disintegrations, or α disintegrations of radio- active families, etc...
- Use these properties to predict some still unknown particle masses.
- Strengthen the existence of exotic narrow hadrons, still not accepted by everybody.
- Common framework between baryon and meson masses.
- Still have to understand the not flat ratios between different mesonic family masses, opposed to the flat ratios between baryonic masses.

-Possible generalization of fractal properties applied to other fundamental data.

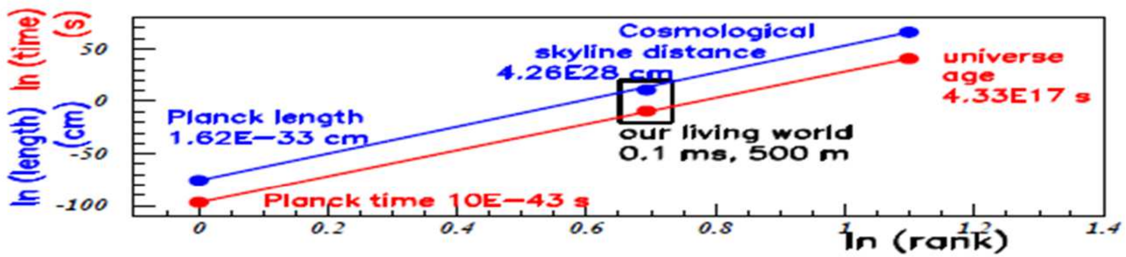
rank: increasing masses

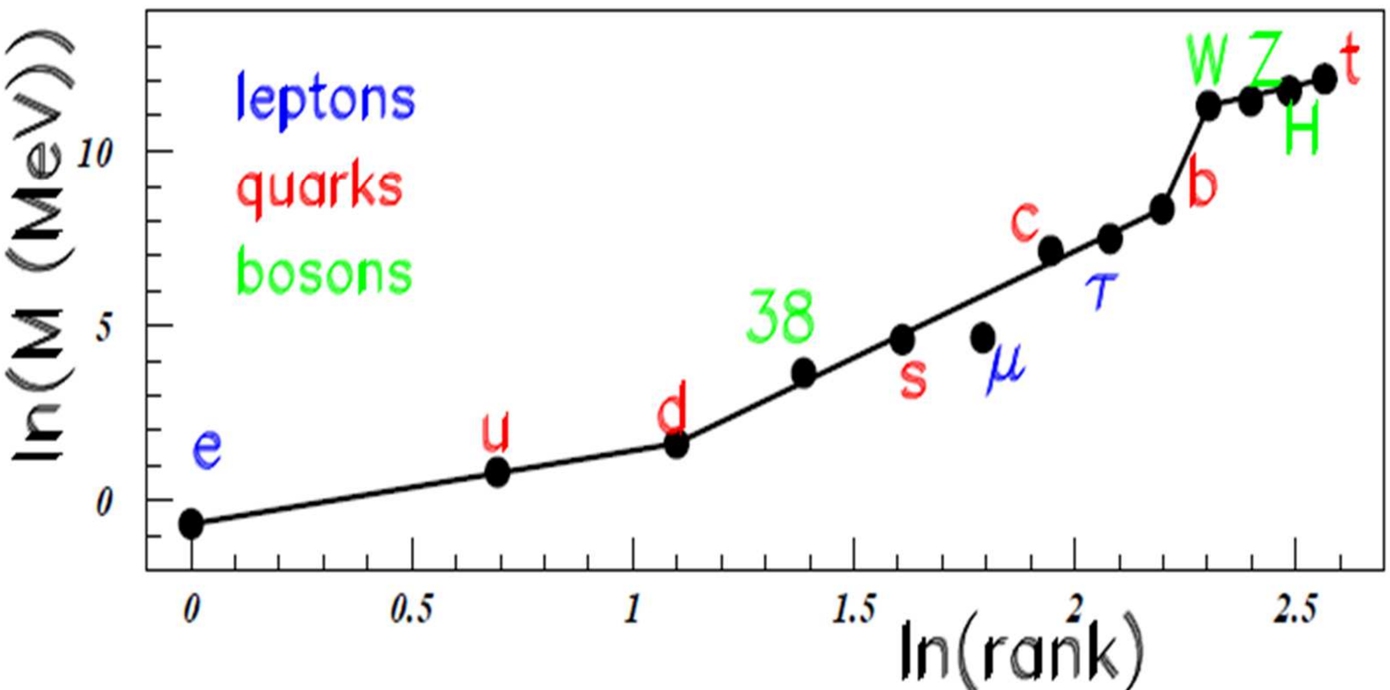


masses (MeV):

m(u)=2.28, m(d)=5.1
m(s)=101, m(c)=1270
m(b)=4200, m(t)=172000
m(μ)=105.7, m(τ)=1776.84, m(H)=124000

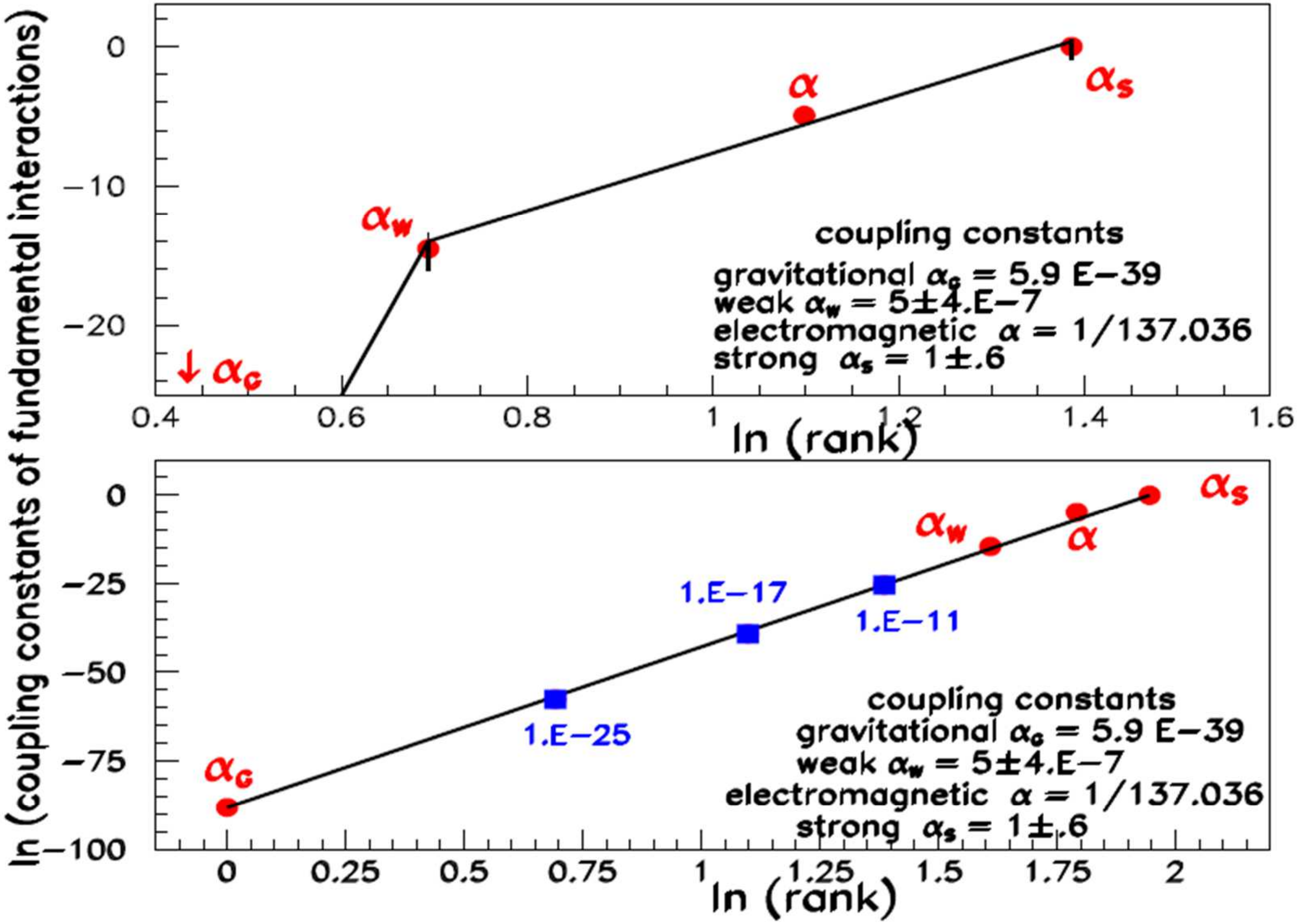
arbitrary rank





E. van Beveren and G. Rupp, arXiv 1202.1739, 1204.3287 (hep-ph)
Kh.U. Abraamyan et al. arXiv 1208.3829 (hep-ex)

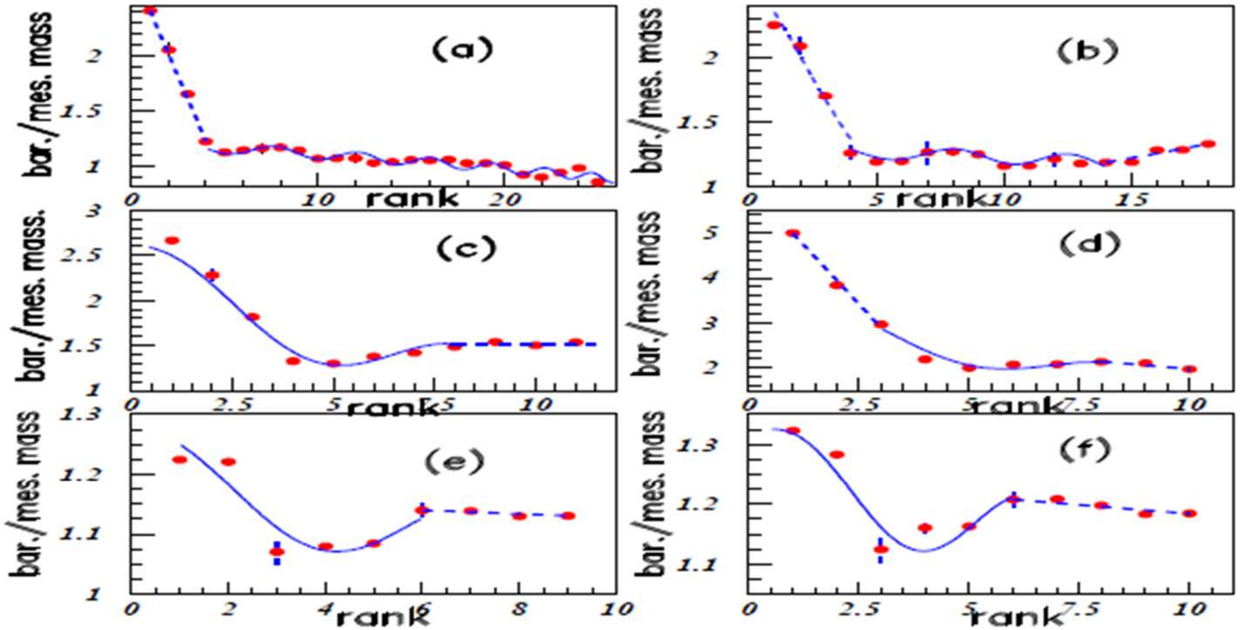
Possible existence of very small new interactions ?



Three new coupling constants in between gravitationnal and weak ?

Thank you for your attention

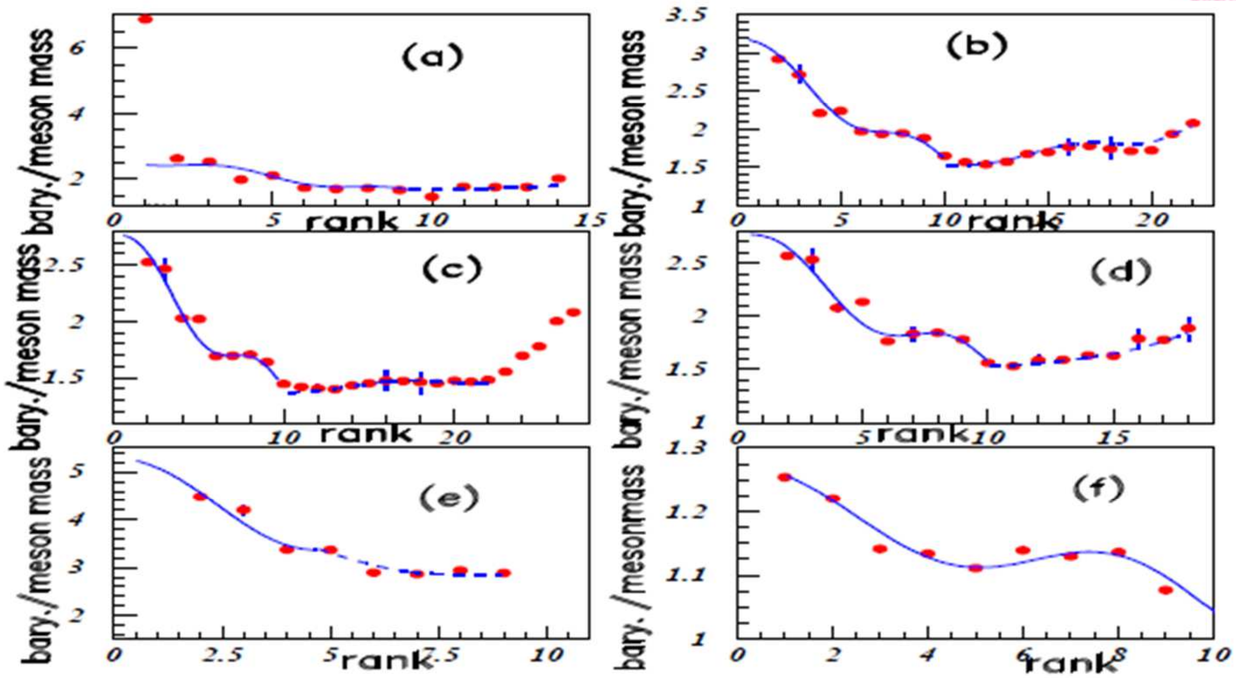
PDG Baryons /PDG mesons mass ratios



(a)	(b)	c)	(d)	(e)	(f)
$\Sigma/K,\bar{K}$	$\Lambda^0/K,\bar{K}$	Ξ/K	$\Xi_C/K,\bar{K}$	$\Lambda_C,\Sigma_C/D^{+,0,-}$	$\Xi_C^{0,+}/D_S^{+,-}$
$uqs/q\bar{s}$	$uds/q\bar{s}$	$qss/q\bar{s}$	$qsc/q\bar{s}$	$uqc/q\bar{c},\bar{q}c$	$qsc/c\bar{s},\bar{c}s$

q stands for u or d quark
close shapes between inserts (a) and (b) in one side (same quark contents);
and also between inserts (c), (d), (e), and (f) in the other side,
which differ by exchange between quarks q, s, and c
(the maximum range is smaller for the last four inserts).

PDG Baryons /PDG mesons mass ratios



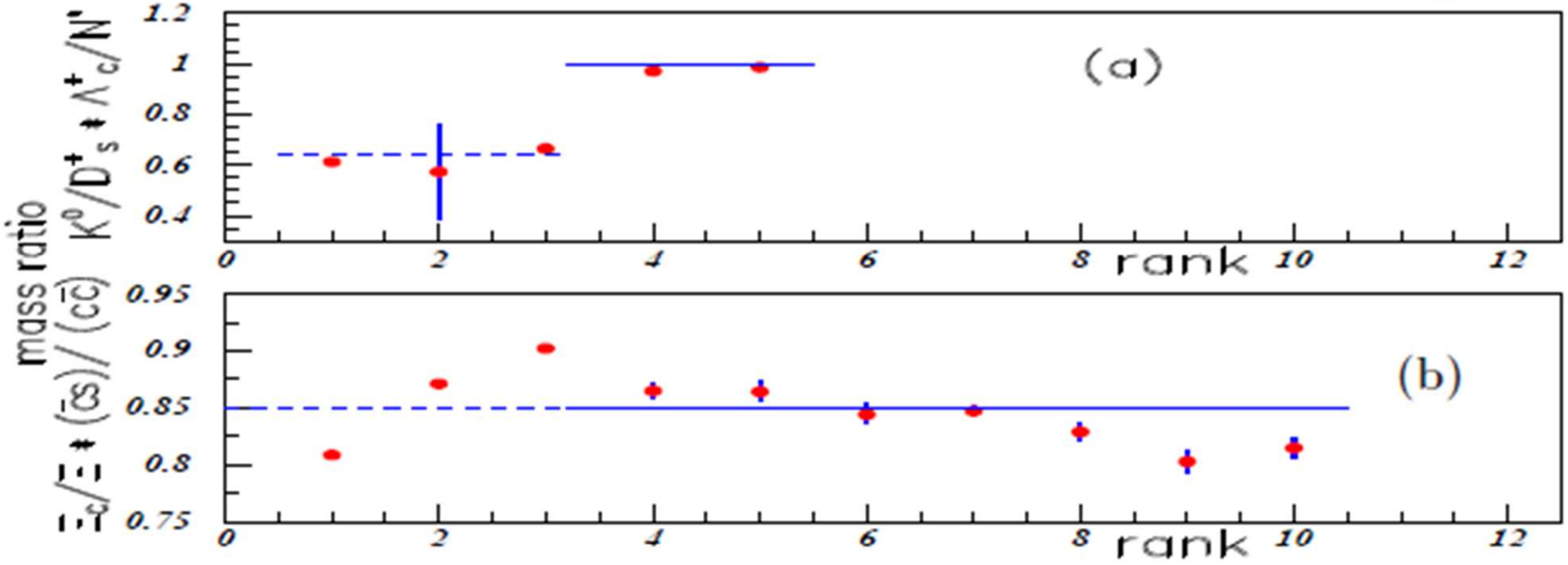
(a)	(b)	(c)	(d)	(e)	(f)
N*/LUM	Δ/LUM	Σ/LUM	Λ/LUM	Λ_C^+, Σ_C/LUM	$\Xi_C^{+,0}/D_S^+$
$uqd/u\bar{d}$	$uuu/u\bar{d}$	$uqs/u\bar{d}$	$uds/u\bar{d}$	$uqc/u\bar{d}$	$usc/c\bar{s}$

LUM=Light unflavored mesons

All inserts (except eventually (a)), exhibit closed shapes

If one excludes the states with questionable $q\bar{q}$ configurations (0^{++} : $a_0(980), f_0(975), f_0(1240)$, or $f_1(1420), f_2(1720)$) the decreasing slope of the first ranks will be more pronounced.

Double PDG baryon / PDG meson mass ratios

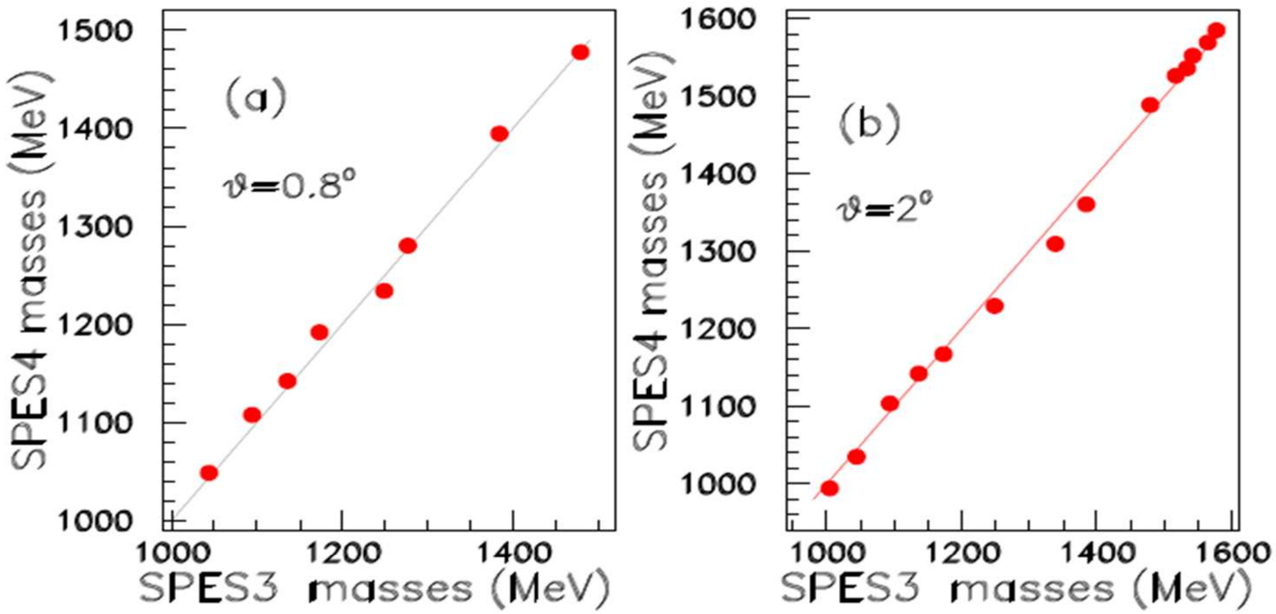


(a)	$K^0/D^+_S * \Lambda^+_C/N^*$	(b)	$\Xi_C/\Xi * D^-_S/c\bar{c}$
	$d\bar{s}/c\bar{s} * udc/qud = 1$		$usc/uss * \bar{c}s/c\bar{c} = 1$

The quark masses disappear, the ratios are $\neq 1$.

SPES3 versus SPES4 narrow baryonic masses

home/tati/var9m.tex



SPES3 mass		1004	1044	1094	1136	1173	(1210)	1249	1277	1339	1384		1479
pic marker		(α)	(β)	(γ)	(δ)	(ϵ)	(λ)	(η)	(ϕ)	(ν)			
SPES4 mass	0.8^0		1052	1113	1142	1202	1235	1262	1322	1370	1394	1428	1478
SPES4 mass	2^0	996	1036	1104	1144	1198	1234		1313	1370			1477

SPES3 mass		1505	1517	1533	1542	(1554)	1564	1577
SPES4 mass	2^0	1507	1517	1528	1544	1557	1569	1580

Agreement obtained using data, studied for different motivations and previously published, obtained by different physicists, using different experimental set-ups, and different beams and reactions.

Spes3 pp$\rightarrow$pπ^+n M_X, T_p = 1.52, 1.805, 2.1 GeV (altogether 15 angles) B. Tatischeff *et al.* Eur. Phys. J. A 17, 245 (2003).
Spes4 p(α,α')X M_X, T_α = 4.2 GeV, θ = 0.8 and 2^0, H.P. Morsch *et al.* Phys. Rev. Lett. 69, 1336 (1992).

Tentative introduction of sterile neutrinos

IPN ORSAY