# The 115 GeV signal from nuclear physics.

Alejandro Rivero *

July 30, 2004

### Abstract

According standard models of nuclei, steepest variations of binding energy at the drip lines should happen for nuclear masses of 45, 68, 92, 115, 175 and 246 GeV. We explore the coincidence of these masses with another ones from well known HEP research and we wonder how much, of it, is an experimental measurement coming from low energy research.

## 1  Signals to be pursued

At the time of the closure of LEP2, a deviation from background at 115 GeV was estimated to be worth of further investigation, and it still remains as the only one worth which the researches felt that more data was needed. Besides it, a similar phenomena happened in 1984, when UA1 [29, 21] announced a 40-45 GeV deviation suspected of being a top quark —discarded after further data collection and modeling— and around 1998, when L3 [18, 19] got almost four sigma deviation at 68-70 GeV, suspected of being a charged scalar —discarded after consideration of new background data from the collected database—.

To these signals, we add the well known ones in the massive side of the spectra, namely the quark top about 175 GeV and the W and Z0 particles at 81 and 92 GeV respectively. As explained in the corresponding section, we do not expect W to have a role similar to the rest of signals.

The quark top being a confined particle, one could expect to pursue instead the family of top based mesons, also around the same mass.

Finally, a natural scale in the GeV range is the one of electroweak vacuum expected value, 246 GeV. We add it to the list in the suspicion that some models could favour some particle near it.

We can not assess how biased our selection is, specially for the three values in the first paragraph. In their age, they generated more attention than other deviations, including – in two cases– editorial comments from Nature. But an exhaustive list of deviations from background for all the 1-300 GeV range is lacking, partly because of the long time span, partly because model independent searches are very difficult to implement. In the Tevatron such search has been attempted [9], pointing to some high energy events no far from the above suggested 246 GeV level, but not being too concrete about lower levels. Thus, by now, exhaustiveness of this list is argued only from the memory of the author, who do not remember any other signal so interesting as the three first ones. Given the extraordinary consistence of the data, memory repression can not be discarded, and I will thank any information about forgotten signals.

---

*EUPT (Universidad de Zaragoza), 44003 Teruel, Spain

## 2 Drip lines matter

For a nucleus of atomic number $A = N + Z$ in the beta stability line, we can consider the corresponding nuclei $(Z - k, N)$ in the proton drip line and $(Z, N - k')$ in the neutron drip line, with respective masses $A_p, A_n$. The main mass models in the market (eg, from [30]) predict a very small difference $A_p - A_n$, which even becomes zero in isolated points under the action of microscopical corrections.

We have studied this difference for the classical Weizsäcker formula[7],

$$E_b = a_1 A - a_2 A^{2/3} - a_3 \frac{Z^2}{A^{1/3}} - a_4 \frac{(A - 2Z)^2}{A}$$

An analytical -even if very large- expression can be given if instead of taking $A$ as the independent variable, we fix the mass $A_0$ in the drip lines. Then solving the second degree equation in the proton drip line

$$M[Z, A_0] - M[Z - 1, A_0 - 1] - m_z = 0$$

and the third degree one in the stability line (we take $m_p - m_n \sim 0$ but it is not necessary)

$$Z = \frac{2a_4 A}{a_3 A^{2/3} + 4a_4}$$

we can get the corresponding mass A and proton and neutron numbers $Z, N (= A - Z)$ of the stable nucleus. We compare this neutron number with the one got from the neutron drip line equation

$$M[A_0 - N_0, A_0] - M[A - N_0, A_0 - 1] - m_n = 0.$$

The difference $d(A_0) = N - N_0$ results a very convenient function to input in a numerical-analytical program such as, for instance, *Mathematica*, because we can plot dependences with any of the four free parameters of the model, as well as mixed plots $d(A_0, a_i)$ or $d(a_i, a_j)$. It is specially relevant to check the dependence in $a_3$, because it has a natural minimum for the zero value, but it is not uniformly increasing; there is a second minimum in the $\sim 1$ MeV area, but this one has also a dependence on $A_0$ so we can no expect it to coincide exactly with the usual value $a_3 = 0.711$ MeV. Still, this minimum can be interpreted as the cause of our equidistancy.

For the usual values

$$a_1 = 15.75 \text{MeV}, a_2 = 17.8 \text{MeV}, a_3 = 0.711 \text{MeV}, a_4 = 23.0 \text{MeV},$$

it can be seen that $d(A_0)$ gets the higher value for $A_0 \sim 300$; it is only -0.815 when proton and neutron masses are equal, and this maximum discrepancy moves by only about two units when proton and neutron masses are given different value, so for simplicity one can find convenient to keep with $m_p - m_n \sim 0$ as we do here.

The function is not linear, so for mid-range masses the difference is appreciably smaller. Generically we can say that the equidistance property $k = k'$ with different proton and neutrons masses holds within a 2%.

As we have said, it can be noticed in most models of nuclear masses, and our function $d(A_0)$, or alternatively any measure of the discrepancy between $k$ and $k'$, is an interesting parameter to consider when studying the properties of a mass model.

An explanation of this property should be that really some important mass dependent effect is enhanced at the drip lines, so this effect forces mass formulae to adjust themselves to fit. The effect does not need to happen uniformly in all the mass range, it is enough to force the coincidence in isolated points, perhaps the ones having strong microscopical corrections, as noted above.

# 3 Magic numbers

When we consider the points of steepest change in binding energy -the traditionally "magic numbers"-, a new relationship between driplines adds to the one revealed in the previous section. A nucleus having at the proton drip line a magic (or semimagic) Z number will correspond to a nucleus of the same mass at the neutron drip line and a corresponding N magic or semimagic number.

The correspondence follows this table:

| At neutron dripline, N= | 28-30 | 50 | (64) | 82 | 126 | 184 |
|---|---|---|---|---|---|---|
| At proton dripline, Z= | 28 | (40) | 50 | (58) | 82 | 114 |

Let us to stress that the correspondence has being done in terms of mass values at drip lines. Of course, due to the equidistance rule of previous section, these magicities will meet near the beta stability line, then causing very strong double magic nucleus. Particularly interesting are Z=40, N=50 and Z=58, N=82, points that are too evident -even excesively- when studying beta decay of unstable nuclei.

To resume, we have two sources of evidence of some effect in the nuclear driplines: on one side, nuclear models adjust themselves in a way such that they are equidistant to stability. On other side, the position of the drip lines stablishs a correspondence between magic (or semimagic) numbers for Z and N.

Now, let me to ennounce the main result of the paper: the atomic mass values relevant for this correspondence at the drip lines are,

| Atomic mass (in GeV) | $\sim 44$ | 68 | 91.2 | 115 | 175 | 246 |
|---|---|---|---|---|---|---|
| Atomic mass (in u.) | $\sim 47$ | 73 | 98 | 123 | 187 | 264 |

There is a variation about a few percent depending of the mass model chosen to predict the drip lines, but it is mostly negligible.

Thus we can suspect that the effect at drip lines is related to mass values of elementary particles.

# 4 Deviations in semi empirical models

Historically, we found the above relationship while examining small corrections in mass models. The main clue came from 1992 FRDM. It shows error at W and Z, but the fit at other energies is right. Studying the model, we learn that the additional precision is got from a series of microscopic corrections and shape corrections. Figure 1 shows all nuclei where a extra correction $\epsilon_3$ is applied. We have taken directly the plot from [22], only adding the diagonal isobars. Neutron dripline is exactly the one drawn by the original authors ten years ago. This clue pointed us to study the drip lines instead of the filling procedure (which we did in [25])

We were surprised with the apparition of the 246 GeV scale, which, as said above, is simply the vacuum expected value of the Higgs field. Examining $\epsilon_3$ does not help, but a plot (figure 2) of the corresponding values of $\epsilon_6$ -the parameter that is substituted by $\epsilon_3$- shows qualitative differences between this scale and the others. In any case, this event forced upon us the need to expand the search to other speculated particles.

On a different take, if part of nuclear stability comes from unaccounted interactions with elementary particles, then an unexplored field is to look for deviations in theoretical and semiempirical mass models. We took a look to this in previous versions of this paper, which the reader could be interested to glance. A typical example is figure 3. Semiempirical models adjust the parameters from some fit to determined nuclei, so a given model does not need to show error in all the points we are looking to, and besides one must consider other mathematical sources of deviation.

For comparison, we show in the figure 4 the error plot from the FRDM, to confirm that it is excessively noisy in the low area and excessively corrected in the high. At these time we had not added the lower masses to our research.
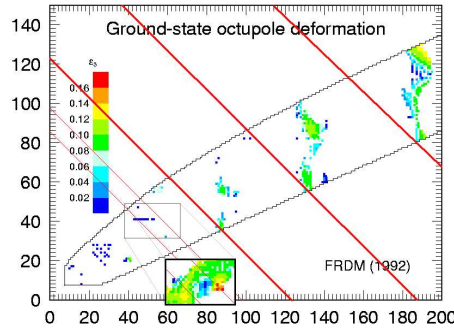
Figure 1: figure 10 of [22], plus an inset -showing local error- of figure 20. We translate between GeV and atomic mass units via the conversion constant 1u. = 0.9315GeV. The only addition to the original plot are the diagonal isobars, at $M_W$, $M_Z$, 115 Gev, $M_t$ and 246 Gev.
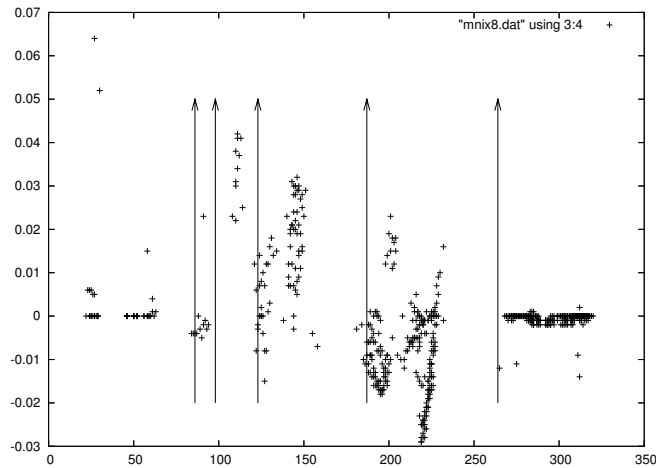


Figure 2: values of $\epsilon_6$ discarded in the FRDM when using instead the deformation parameter $\epsilon_3$. Note the qualitative difference in the signal of electroweak vacuum.

Another interesting input comes from purely microscopical models with an empirical force. In figure 5 we see how close the effects seem to follow our standard model particles. This model, from [10], also calculates the 2-proton and 2-neutron driplines, and we can infer how the proton magic numbers are generated at the proton dripline.

# 5   HEP systematic error?

Lacking still of a theoretical model, we are unable to say if this empirical analysis is a prediction of the Higgs or just a prediction of an anomaly in the background when detecting energies in the 115 GeV area. In the later case, the -nuclear- physics at the detectors would be the one to blame.

During experiments at CERN it has occurred sometimes that an excess of events has been announced for a very concrete energy range, but additional statistical analysis, or renewed experimental input, has smoothed down the initial deviations. Our first three points, at 40 GeV [29, 21], 68 GeV [18, 19] and 115 GeV [1], are in this category.

We should to stop a moment to examine if all the three signals can be linked to an unlocated calibration problem. It could happen if an unforeseen non-uniformity in distributing
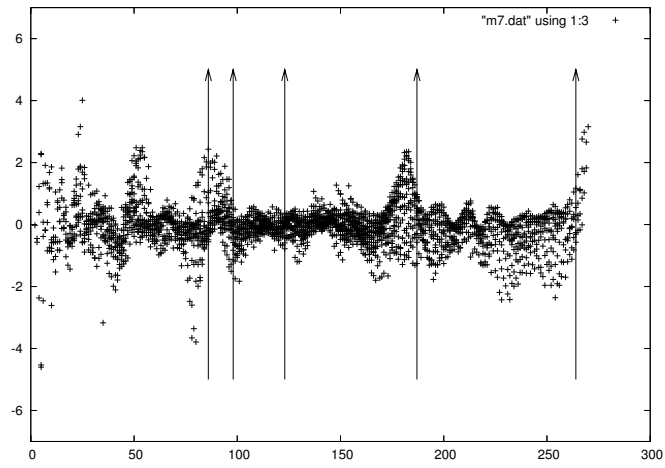
Figure 3: error in mass prediction for a model from Takahiro Tachibana, Masahiro Uno, Masami Yamada, and So Yamada. Please refer to v2 for more examples
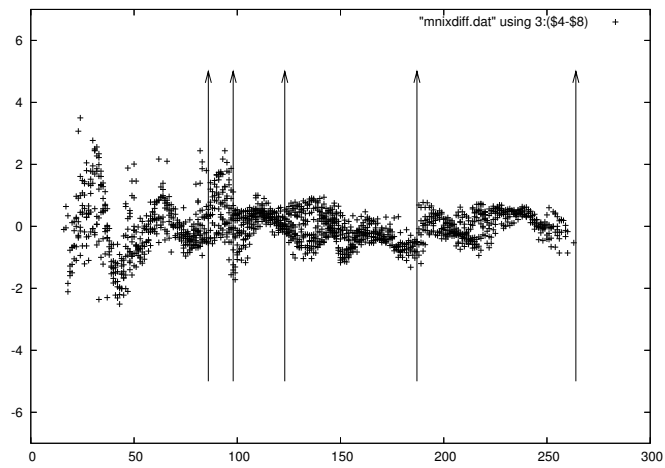


Figure 4: error in mass prediction for the FRDM model

5

energy causes some background events to accumulate, simulating to be a signal. If a naive nuclear mass model is used at some point in the physics calculations in detectors, noise patterns similar to the ones in the previous section could propagate to the data.

Thus if a calibration or a detector depends, say, on secondary decay from near proton drip-line nuclei, a mass model taking these masses into account should be used for the physics of the material. The same would happens with secondary decays near neutron drip line, but this line is rarely reached experimentally. If simple analytic approximations, such as Weisaker formula, are used instead, we can expect errors to happen related to these mass values. As all the CERN experiments share legacy code both for simulations and actual calibration of measurements, it could be that such approximation were hidden in some shared code.

Of the four values in CERN reach, three of them correspond very accurately to the troubled event excesses, while the other is just under the peak of the Z0 particle, so that a error there should be masked under the huge quantity of real Z0 events.

On other hand, physical reality of the nuclear points could be claimed on grounds of the two extant masses, 175 and 246 GeV, which do not correspond to CERN measures but are also commonly associated to high energy physics.

Additional support for the physical reality of the excesses could be coming now from HERA [8] where some events have been reported about 40 GeV. A common bug between the code of HERA and CERN is more unlikely that between CERN experiments.

# 6   A theoretical proposal

Recoil corrections to the bound states of a relativistic two body system $m < M$ can be expressed as a polynomial $P_m(1/M)$. If the small particle $m$ has an additional coupling to a yukawian field of mass M', one can use the shape of $P_{m,M'}(1/M)$ to determine the mass of the field $M'$. We call this method the *Lamb's Balance*.

The *Lamb's Balance Conjecture* is to suppose that the shape of $P_{m,M'}$ presents a maximum when $M \sim M'$. The nuclear LBC assumes that this effect will be measurable at proton and neutron drip lines, where external nucleons are far from the rest of the nucleus —neutrons even are in a distinctive skin— and their exchanged momentum is small, so that the rest of the nucleus can be seen as a single particle.

In these conditions, the nuclear LBC would be able to assign a particle to each magic number as they cross the drip lines.

As before, the analysis is more or less model independent; one-nucleon or two nucleon driplines either from FRDM95 or FRDM92 or from any other popular model can be used without sensible differences (except for the neutron line around the values of $W$-$Z0$). Besides, if $P_{m,M'}(1/M)$ decreases smoothly after peaking, the effect will be noticed globally, for instance as a contribution to the the surface terms of $M(A,Z)/A$ in liquid drop model.

As an alternative to be researched too, the extra particles could influence directly the spin orbit correction of the bound state, instead of its recoil correction. In any case the influence would imply a missed subtlety in traditional scale separations as low momenta electroweak interactions, where we always have felt justified to use Fermi constant as an approximation to the Z0 and W propagators. It should happen that the existence of a coupled virtual particle M' modifies the propagator in almost the same way as if it were a real available mode, so the low energy limit should reflect it. The author, presently, can not calculate if such unlikely modification does indeed exist.

# 7   The role of charged bosons

Perhaps the more doubtful issue is the role of $W^{\pm}$, that, sandwiched between $Z0$ and the 68 GeV signal, only seems to correspond to weak semimagicities if any. But here one must
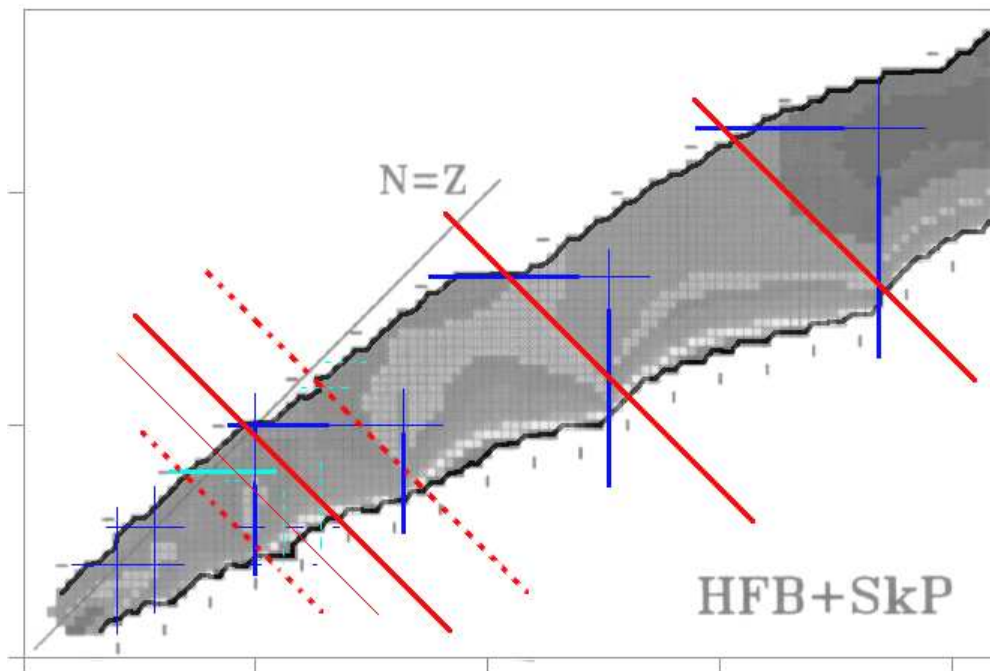
Figure 5: Figure 7 of [10], with our masses over-imposed. Diagonal isobars correspond to masses, horizontal and vertical lines to magic numbers. The background, taken from a (lost) HFB+SkP model, shows the calculated difference between proton and neutron radius. 2N and 2P driplines are shown; check for instance [30] for 1N, 1P drip line predictions from other models

remember the very special role that $W^\pm$ has in the nuclear table, as it is the responsible of the process of beta decay. Then a virtual $W^-$, besides to contribute to the dressing of nucleons, is able to draw energy from them and to decay to electron plus antineutrino; a process a lot more important that dressing and recoiling.

The point about any charged particle is that its role in the model above compites with its role as a mediator of nuclear beta decay, when the nucleus has enough energy to implement this decay path. A neutral boson, on the other side, does not have this possibility for nuclear ground states, which are the ones we are studying. For a charged scalar very weakly coupled to leptons, we can expect an equilibrated competition, while for the W particle most of the eggs seem to be in the decay nest.

An histogram of all the known beta decays[1], binned by atomic mass, shows a strong peak for atomic mass of 81 GeV, and a previous step about 68 GeV, but unfortunately the strong peak coincides with the extra stability from the magic nucleus Z=40, N=50. In fact the strongest peak in the histogram comes from decays near other magic nucleus, Z=58, N=82. Still, it could be possible to extract some information if the histogram is separated according forbidness, parity, and change of angular momentum of the decay mode.

# 8   Recapitulation and remarks

We have extracted the following clues:

- A mass at 146 GeV, the scale of electroweak vacuum, contributes the Z=114 and N=184 magic numbers.

- A mass at 175 GeV, the one of top quark and its mesons, generates the Z=82 and N=126 magic numbers

- A mass at 115 GeV, the same signal that was detected at ALEPH, generates the N=82 magic number. It should generate also the subshell closing around 60 protons, but the higgs coupling to protons is expected to be lower, due to their different quark composition.

- A mass at 91 GeV, the one of the Z boson, generates the Z=50 magic number. Perhaps it helps to the N=50, Z=50 double magicity too, as well as to a subshell closing in N.

- Extra noise is seen around the mass scale of the charged boson W; how this boson could contribute to the N=50 magicity it is not clear, and probaly it doesn't.

- A mass of 68 GeV, time ago suspected of a charged scalar, generates the N=50 and Z=40 magic numbers.

- A mass around 40-45 GeV, time ago examined as a candidate for the top quark, could contribute to the magicity of both N=28 and Z=28

- Lower subshell values 20, 8, 2, would come mainly from the nuclear well potential.

If the signals are to be taken seriously, they strongly points towards a non minimal Higgs sector, say 2DHM, Zee, etc. When the LBC becomes a computational tool, it will be possible to distinguish a bit more between pseudoscalar, scalar, and vectorial particles.

One particle should appear within a very few percent of the 264 GeV vacuum. This strongly restricts the parameters in model building. On other hand the mass at 175 GeV is known to be the one of the Top quark... If the Top couples to the nucleon after all, it should be by using its family of very short lived mesons, a very weak method. So another possibility is to suppose one of the extant bosons from the higgs sector to be mass-degenerated

---

[1]See author's website, at `http://dftuz.unizar.es/%7Erivero/research/`

with the top quark. This degeneration between a boson and a fermion could be the only residual of a SUSY scheme.

In any case, the complete particle spectra surpasses the Minimal Standard Model, and it is not compatible with expectations for the Minimal Supersymmetric Standard Model.

Lets note that recent research on Dimensional Deconstruction, by Georgi et al, has brought a new family of models needing at least a pair of higgs doublets but independent of the existence of supersymmetry. It could be worth to examine its compatibility with our mass spectrum. Dimensional deconstruction gets symmetry breaking from extra dimensions, a old theme whose pretties representative is the Connes Lott model. But contrary to NCG, it does not requires a minimal higgs sector.

Respect to magicity, generation should be understood as contribution. This is because we have still the complementary, traditional, contribution to spin orbit couplings from nuclear relativistic effects. Still, these effects have never been able to justify completely the corrections to binding energy. Traditionally it was considered that a lack of computing power was the cause, and semi empirical models felt perfectly able to complement this lack by fitting arbitrarily the spin orbit force. In view of the observed coincidences, perhaps the arbitrariness should be constrained to depend on our masses.

Other explanations could be explored. For example, it could happen that the same mathematical symmetry-breaking acts in nuclear physics and, for different causes, in elementary particle physics. Then the only remaining coincidence would be the one between the end of the stability islands and the electroweak vacuum. Even if this is the case, it should be mathematically worth to examine the mechanism in nuclear physics, because it includes both the electroweak bosons and top quark mass values in a same unifying schema.

The special role of external shells invites also to look for experimental methods such as stop antiproton or antineutron bombarding in order to get more detail of the properties of this kind of nucleus. Perhaps the final clue pointing to the Higgs is already buried in the data banks of ancient CERN machines.

# Appendix

When referring to the Appendix in the previous version of this preprint, please note this modification of point (6): Two quantities of 68 and 45 euro are to be added to the sequence.

# References

[1] ALEPH Collaboration *Observation of an excess in the ALEPH search for the Standard Model Higgs boson* http://arxiv.org/abs/hep-ex/hep-ex/0108001

[2] Nima Arkani-Hamed, Andrew G. Cohen, Howard Georgi *(De)Constructing Dimensions.* http://xxx.unizar.es/abs/hep-ph/0104005

[3] Nima Arkani-Hamed, Andrew G. Cohen, Howard Georgi *Electroweak symmetry breaking from dimensional deconstruction* Phys.Lett. B513 (2001) 232-240 http://xxx.unizar.es/abs/hep-ph/0105239

[4] N. Arkani-Hamed, A.G. Cohen, T. Gregoire, E. Katz, A.E. Nelson, J.G. Wacker *The Minimal Moose for a Little Higgs* JHEP 0208 (2002) 021 http://xxx.unizar.es/abs/hep-ph/0206020

[5] Nima Arkani-Hamed, Andrew G. Cohen, Thomas Gregoire, Jay G. Wacker *Phenomenology of Electroweak Symmetry Breaking from Theory Space* JHEP 0208 (2002) 020 http://xxx.unizar.es/abs/hep-ph/0202089

[6] N. Arkani-Hamed, A.G. Cohen, E. Katz, A.E. Nelson *The Littlest Higgs* JHEP 0207 (2002) 034 `http://xxx.unizar.es/abs/hep-ph/0206021`

[7] H. A. Bethe and R. F. Bacher *Nuclear Physics A. Stationary States of Nuclei* Rev. Mod. Phys. 8, 82-229 (1936)

`http://link.aps.org/abstract/RMP/v8/p82`

[8] T. Carli, D. Dannheim, L. Bellagamba *Events with Isolated Charged Leptons and Large Missing Transverse Momentum at HERA* `http://arxiv.org/abs/hep-ph/0402012`

[9] D0 collaboration, *A Quasi-Model-Independent Search for New Physics at Large Transverse* Momentum Phys. Rev. D 64, 012004 (2001)

`http://arXiv.org/abs/hep-ex/0011067`

[10] J. Dobaczewski, W. Nazarewicz, T. R. Werner *Neutron radii and skins in the Hartree-Fock-Bogoliubov calculations* Zeitschrift fr Physik A 354 Iss 1 (1996) pp 27-35

[11] J. R. Ellis *The 115 GeV Higgs Odyssey* `http://arxiv.org/abs/hep-ex/0011086`

[12] R.B. Firestone, *LBNL Isotopes Project Nuclear Data Dissemination Home Page*. Retrieved May 2003, from `http://ie.lbl.gov/toi.html` and `http://ie.lbl.gov/toimass.html`

[13] Pablo Garcia-Abia *Search for charged Higgs bosons in L3* `http://arxiv.org/abs/hep-ex/0105057`

[14] S. Goriely et al., *Further explorations...*, Phys. Rev. C 68, 054325 (2003).

[15] I. Hamamoto, S. V. Lukyanov, X. Z. Zhang *Kinetic energy and spin-orbit splitting in nuclei near neutron drip line* Nucl.Phys. A683 (2001) 255-265 `http://xxx.unizar.es/abs/nucl-th/0005074`

[16] Jorge G. Hirsch, Alejandro Frank, Victor Velazquez *Residual correlations in liquid drop mass calculations* Phys.Rev. C69 (2004) 037304 `http://arxiv.org/abs/nucl-th/0306049`

[17] P. F. A. Klinkenberg *Tables of Nuclear Shell Structure* Rev. Mod. Phys. 24, 63-73 (1952) `http://link.aps.org/abstract/RMP/v24/p63`

[18] L3 Collaboration *Search for Charged Higgs Bosons in e+e- Collisions at $\sqrt{s}$ = 189 GeV* `http://arxiv.org/abs/hep-ex/9909044`

[19] L3 Collaboration *Search for Charged Higgs Bosons in e+e- Collisions at Centre-of-Mass Energies up to 202 GeV* `http://arxiv.org/abs/hep-ex/0009010`

[20] D. Lunney, J. M. Pearson, C. Thibault *Recent trends in the determination of nuclear masses* Rev. Mod. Phys. 75, 1021 (2003) `http://link.aps.org/abstract/RMP/v75/p1021`

[21] J. Maddox, *CERN comes again on top* Nature 12 July 1984, p. 310

[22] P. Möller, J. R. Nix, W. D. Myers, W. J. Swiatecki *Nuclear Ground-State Masses and Deformations* Atom.Data Nucl.Data Tabl. 59, 185-381 (1995) `http://arxiv.org/abs/nucl-th/9308022`

[23] R. C. Nayak *Disappearance of nuclear magicity towards drip lines* Phys. Rev. C 60, 064305 (1999) `http://link.aps.org/abstract/PRC/v60/e064305`

[24] Particle Data Group, *Review of Particle Physics*, Phys. Rev. D 66 (1-I), p. 1 (2002)
`http://pdg.lbl.gov/`

[25] A. Rivero *Standard Model Masses and Models of Nuclei*
`http://arxiv.org/abs/nucl-th/0312003`

[26] L. Satpathy *New Magic Numbers and New Islands of Stability in Drip-Line Regions*
`http://arxiv.org/abs/nucl-th/0105064`

[27] Sharma et al. Reply to a Comment on "Shell Effects in Nuclei Near the Neutron-Drip Line" Phys. Rev. Lett. 73, 1870 (1994)
`http://link.aps.org/abstract/PRL/v73/p1870`

[28] Pedro Teixeira-Dias *The Standard Model Higgs boson search at LEP: combined results* `http://arxiv.org/abs/hep-ex/0108002`

[29] UA1 Collaboration, *Associated production of an isolated, large-transverse-momentum lepton (electron or muon), and two jets at the CERN pp collider.* Phys. Lett. B. 147 (1984) p. 493-508 see also [21]

[30] Masahiro Uno, *Current status of nuclear mass formulae and their predictability* RIKEN review, 26 (2000), 38-44
`http://www.riken.go.jp/lab-www/library/publication/review/conts/conts26.html`

[31] VV. AA., Atom.Data Nucl.Data Tabl. 39, 185 (1988)