Masses of the Sub-Nuclear Particles

Theodore M. Lach Nucl-th/0008026 @ http://xxx.lanl.gov. July 4, 2003 update

The masses of the quarks and leptons are for the most part a mystery in the Standard Model of particle physics. Currently there seems to be no correlation between the masses of the elementary particles. This paper is an attempt to formulate a new theory that would begin to explain the relationship between the sub-nuclear particle masses. An appropriate name for this new theory may be the Extended Standard Model.

A key premise of the Standard Model is that there are 3 and only 3 generations of quarks and leptons. The currently accepted masses of the elementary particles are: (*1*)

Table 1.

Generation # 1	Generation # 2	Generation # 3
u quark = 3 MeV, (1-5)	Charmed quark = 1.25 $\pm$ 0.1 GeV	Top quark = 175 $\pm$ 5 GeV
d quark = 6 MeV (3-9 MeV)	Strange quark = 100 MeV (75-170 MeV)	Bottom quark = 4.2 GeV $\pm$ 0.2 GeV
Electron = 0.5109989MeV	Muon = 105.6583 MeV	Tau = 1777.1 MeV

Note: The above masses represent the "free" quark masses usually called the "current algebra" masses

The neutrino masses in the standard model are still a hotly debated issue, yet most current references put the upper bound of the three neutrinos at:

Table 2.

Electron neutrino	= 10 ev	(5 – 17 ev)
Muon neutrino	= 270 KeV	(200 – 270 KeV)
Tau neutrino	= 31 MeV	(20 – 35 MeV)

In an attempt to determine why the quark masses predicted in the CBM (2), Checker Board Model of the nucleus, do not fit into the standard model, this paper will expand upon the S.M. and assume that the CBM quark masses in table 3 are correct and that there are more than 3 generations. This is obviously physics beyond the standard model and therefore this theory suggests "New Physics".

Table 3.

"up" Quark = 237.31 MeV
"dn" Quark = 42.39 MeV

This theory will attempt to explain how the masses in table 3 fit into a self- consistent theory of the masses of the sub nuclear particles. In the rest of this paper the terms "up" and "dn" refer to the CBM predictions of the mass of the quarks in the proton and neutron, and the terms "u" and "d" to refer to what up until now the S.M. has called up and down. This paper will intend to prove that the u and d quarks do exist and form the low mass mesons, but they are not the same as the up and dn quarks which form the proton and neutron. This paper will use the term family of up quarks or family of dn quarks to refer to all 2/3 or –1/3 charged quarks in this model. Similarly term electron family to refer to all leptons of charge –1, and the term neutrino family to refer to all neutrinos of all generations. A specific up or dn quark will be referred to by using the nomenclature up(5) to refer to the 5th generation of up quark. Perhaps a fitting name for this new theory is the “Extended Standard Model” (ESM) since much of this theory is built upon the data in the S.M.

The first step in this process is to assume that a new generation of quarks exists between the electron generation and the muon generation. This conclusion came slowly over many years of consideration. This resulted in an opening for two new lepton particles that go along with the up and dn quarks. A possible name for these “new” leptons should be “nu” (pronounced “new”, and the Greek letter for n). Consequently, the “new” particle in the electron family would be called the nuon. To fit into ESM the nuon must have a rest mass of about 7.57 MeV. Figure 1 shows a curve fit of the 4 lepton masses including the newly hypothesized 7.57 MeV nuon. This “new” generation, which includes the up and dn quarks and the nuon, could be called the missing or “nu” generation.

Recent discovery of neutrino oscillations have led to the hypothesis that at least one new “sterile” neutrino must exist. (*3- 6*) Some theorists put the mass of this new neutrino between the mass of the electron and the mass of the muon neutrino. In a recent special issue of Fermi News in an article by Mike Perricone, he states that there is a quip among neutrino circles, no one knows who said it first, but it says: “Sterile neutrinos are like cockroaches. Once you get one in your theory, there’s no stopping them.”(*7*)

Interestingly, back in 1985, John Simpson, a Canadian Physicist at the University of Guelph, thought he had discovered a “new” neutrino with a mass of about 17 KeV. (*8,9*) In 1991 and 1992 there was a great debate about whether to accept this data. In the end the physics community determined that the standard model should not be modified, based upon the results of six different independent experiments, to include this "Neutrino from Hell". Stuart Freedman, a very well known and respected neutrino physicist, is apparently quoted as saying that he is still impressed that more than six different kinds of experiments have shown an effect, and all at the 17 KeV mark. "It is very surprising that different experiments get the same value for these things. It is hard to believe that it's a bunch of random systematic errors."(*10*)

Therefore, the justification for adding this new generation is based upon: **1**. The up and dn quarks predicted by CBM are too heavy to be the u and d quarks in the S.M., **2**. The suspicion that there is a new neutrino (sterile or not) between the electron and muon neutrino to help explain neutrino oscillations, **3**. The fit of the leptons along a straight line in Figure 1. and **4**. It is interesting to note that slope of this line (ln (0.511 / 1777.1) = - 3e) represents a slope of "e" to better than 1 part in 10,000 which is about the same precision as the mass of the tauon.

Next, this theory accept the S.M. masses of the charmed and bottom quarks. Since these quarks are so heavy, their relativistic effects within the J/ψ meson and the upsilon Υ meson are small and therefore the intrinsic mass of these two quarks has been determined using non-relativistic quantum mechanics. (11) Seeing how the four leptons fit on a smooth linear exponential curve in Figure 1, a similar technique was used for the dn like quarks. Using the mass of dn at 42.39 MeV and the mass of the bottom quark at 4238 $\pm$ 006 MeV based upon the work of

Voloshin (12), it seemed appropriate that the strange quark should be 424 MeV and the d quark should be 4.2 MeV. A mass of 4.2 MeV for the d quark is close to the standard model's prediction of 3-9 MeV, since the uncertainty of this estimate is very model dependent. See Figure 2 for a plot of the dn family quarks. It seemed interesting that when the curves for the electron family and dn quark family were extended, they seemed to converge at about 413-424 GeV. Most theorists expect a convergence like this to occur, resulting in the grand unification at a long sought after super massive Higgs Boson.

The mass differences of the K^- and K^0, and the mass differences of the π^- and π^0 mesons suggest that there is a "dn-like quark" (-1/3e) which must be about 4 MeV more massive than an "up-like quark"(+2/3e). The Extended Standard Model would suggest that a "u" quark of 38 MeV (4 MeV lighter than the dn quark , 42.39 MeV) would satisfying this constraint. Using the 424 GeV point as a pivot point, the mass of the up quark, (237.31 MeV) and 1500 MeV for the mass of the charmed quark based upon Alvarex (*13*), and the 38 MeV for the "u" quark, one can then draw a straight line of best fit through these four points. (see Figure 2) This value of the mass of the u quark is significantly outside the range of the S.M. theoretical "free" quark mass estimate of 1-5 MeV, but since we have eliminated the need for the u quark to be less massive than the d quark, this is no longer a big problem for ESM.

Note, a massive quark generation (generation #1) was inserted between the hypothesized 424 GeV mass (generation #0) and the Tau generation (generation #2). Quoting the quip from before, once you let one of those cockroaches in, more will be sure to follow. Figure 2 suggests that there is a 65 GeV massive up quark [up(1) or T'] and a massive dn quark [dn(1) or B'] of 42.4 GeV and an associated electron family member of 27 GeV. In support of this new massive generation, G. Arnison et.al. published, in 1984 as part of a130 member UA1 collaboration at CERN, a paper which established experimental data for the existence of a quark with mass between 30 and 50 GeV, with the most likely value at about 40 GeV. (*14*) This finding was later rejected, but as one can see from the proceedings of the first Aspen Conference on High Energy Physics in 1985, the report was much discussed and appeared at that time to have significant supporting evidence. (*15*) The Extended Standard Model suggests that instead of finding the top quark, this collaboration actually found the B' quark. Therefore the Extended S.M. extends to 5 the number of generations in the universe. It is interesting that the initial slope of the electron family line (ln (27,000/424,000)) is also approximately "e" the natural logarithm.

Figure 3 adds the best estimates of the upper bounds of the neutrino masses (from table 2) to the curves in figure 2. To first order a straight line of best fit through these upper bound masses seem to extrapolate to the same point in generation zero, yet the fit is off by about 75 GeV, a small difference on the scale of this plot. This degree of deviation is not too surprising since these "are" upper bounds of the estimates. Notice how nicely an opening for a 1.7 KeV neutrino (a John Simpson like neutrino, a nu neutrino) would fit into this model. Although this 1.7 KeV is an order of magnitude lower than what Simpson found (17 KeV), it must be understood that experimental determination of neutrino mass is very difficult and refined numbers usually end up being lower. If we take an approach similar to what we did on the up like quark line, we start and assume 424 GeV is a pivot point and assume that 10 eV is approximately correct for the mass of the electron neutrino, we find that the geometric progression multiplier is approximately 137, surprisingly close to a number that is the reciprocal of the fine structure constant of the universe (137.036). If we then use the 424 GeV value and assume the geometric progression (sequence) multiplier *is* 137, the mass of the electron neutrino turns out to be 8.8 eV, well within the accepted range accepted by the S.M. This gives values of: 1.2 KeV, 165 KeV, 22.6 MeV, and 3.10 GeV for the other neutrino masses, well within the range of the accepted values by the S.M..

The Extended S.M. is most notably at odds with the currently accepted mass of the top quark. The ESM predicts a mass of the top quark of between 10 to 11 GeV. This is significantly at odds with the discovery at Fermi Lab in 1995 that determined the mass of the top quark at 175 GeV. This new model does not suggest what the 175 $\pm$ 5 GeV particle / resonance might be, perhaps a combination of massive quarks from generation one, perhaps two up(1) and one dn(1) quarks (T'-B'-T'), and since the half- life of this excited state is only 0.4 yoctoseconds (0.4 X 10^{-24} seconds) (*16*) it is hard to make detailed studies of this particle. A reason perhaps why the top quark in the Extended S.M. has not been found (or recognized) is that its mass is almost identical with (and therefore hidden by) the Υ (S4) upsilon meson which decays into two bottom quarks (sometimes referred to as naked bottom). This may be why the Υ (S4) meson (10,580 MeV) resonance is broader, unlike the other upsilon resonances and also is not tied to the other resonances by photon decay transitions. (*17*)

The Extended Standard Model predicts a mass for the strange quark significantly heavier and outside the range of the currently accepted "free" quark value (75-170 MeV) based upon the Standard Model. Michael Shaevitz, a member of the NuTeV team, is quoted as saying, "what we have found is that the strange content is much smaller than expected [based upon the standard model], about one-half the amount of the up or down quark sea." (*18*) The hope is that this new predicted mass of the strange quark (424 MeV) would help explain this finding. Also regarding the sea of quarks in the proton, "Michael Leitch (of the Los Alamos National Laboratory) and his colleagues on another Fermilab experiment, nicknamed NuSea, [in 1998] uncovered an even more startling inconsistency [in the Standard Model]. The number of antiup quarks in the proton sea is not the same as the number of antidowns." (*18*) Perhaps the predicted masses of the "up" and "dn" quarks will resolve this problem also. Also as mentioned in a note under table 1, the 75-170 MeV is a "free" quark mass (current algebra). The constituent mass model gives the "rest mass" of the strange quark as 500 MeV, with references ranging from 300 to 500, thereby more consistent with the 424 MeV in the ESM. As a side note, the constituent mass model gives a value of 1500 MeV for the mass of the charmed quark. (19, 20, 21),{which better agrees with Alvarex et.al. data} whereas the current algebra values is 1250 MeV.

Is there any justification for a 424 GeV mass particle?(22) In 1996, according to William Carithers the co-spokesperson of the CDF collaboration at Fermilab, CDF had "observed an unexpectedly large number of 'hard,' or violent collisions between quarks. This is just the sort of effect you would see if the quarks were not fundamental particles but had some sort of internal structure." According to Cuido Altarelli of CERN, "If quark substructure was true, then its relevance [the CDF findings] would be very, very large".(23) What was found in this experiment were two jets, one with an energy of 424 GeV. Could this be the first evidence of the Higgs or lepto- quark the Extended S.M. suggests?

Note, the three lines predicting the masses of the up, dn and electron families fit so neatly onto equally separated curves on a semi log plot. The exponent of the best fit trend lines differ from one another by an approximately the same amount 0.425 vs. 0.437. (2.7287 – 2.304 – 1.8667) What this implies is that there is a simple "geometric mean" relationship that ties all of these sub- nuclear particles together. Example: 42.39 is the geometric mean of 237.31 and 7.57 MeV. That is how the value of 7.57 was selected. *(NOTE: 7.74 MeV would have been selected if we wanted to exactly fall on the exponential "e" slope line between the Tau and the electron. The geometric multiplier for a slope of "e" would be 15.154. This would make the values of the other members of the electron family: .511000 MeV, 7.744 MeV, 117.35, 1778.3, 26948, and 408380 MeV.)* Also within a particle family (say for example dn quarks) 42.39 is the obvious geometric mean of 424 and 4.24 MeV. In generation zero 424 GeV would be the geometric mean of 408.4 and 440.2 GeV. In other words:

$M_i = (M_{I+1} * M_{I-1})^{1/2}$ (where I = Generation # within a family type)

Therefore all the masses of the elementary sub- nuclear particles seam to fit into one equation:

$$M_{(F, G)} = \mathbf{H}\, e^{-kG} \qquad (1)$$

where:

F is the family type, G is the Generation number,

k_1 (for the family of up quarks) = 1.8667

k_2 (for the family of dn quarks) = 2.304 almost exactly ln(10)= 2.3025

k_3 (for the electron family) = 2.7287 approximately "e" = 2.71828.

G = Generation number for the particle: for the electron G = 5

H is the mass of the heaviest lepto- quark, perhaps the theoretical Higgs boson.

One concern is that the muon does not fall on the line as well as it should. It is about 12 MeV below the line of best fit, but perhaps this is due to corrections needed in the experimental data, based upon the existence of a new 7.65 $\pm$ 0.1 MeV nuon and the kinetic energy carried away by the nuon and its neutrino.

A more approximate observation is that the progression of the series of mass numbers appears to be related to $(\pi/2)^{\pm G}$. From the dn family masses you get the up quark masses by using the + exponent and you get the lepton masses by using the negative exponent. Example: pi over two is about 1.5708. Take the mass of the bottom quark and divide it by $(\pi/2)^2$. This is 4240 / 2.467 or 1719, i.e. approximately the mass of the tau lepton. Using the positive exponent we get 4240 * 2.467 = 10,460 for the mass of the top quark. Taking as a second example, using the mass of the strange quark (424 MeV), which is in generation 3 give a multiplier of $(\pi/2)^{\pm 3}$.which is 3.876. 424 / 3.876 is 109.4 which is approximately the mass of the muon, whereas 424 times 3.876 is 1643, approximately the mass of the charmed quark. The last example, using the mass of the d quark as 4.24 eV in generation 5 gives a value of 40.5 for the u quark and .44 eV for the electron. As you can see this is only an approximate relationship.

How do we tie in the slope of the neutrino mass line? As we said earlier it appears the geometric multiplier of the neutrino line is 137, to first order the inverse of the fine structure constant. Also amusing, by using a ruler and measuring the distances between up(5) and dn(5) as a scale, the distance between the electron and its neutrino is 5 units of measure (in the 5th generation). Similarly the distance between the muon and its neutrino is 3 units of measure (in the 3rd generation) and so on. See Figure 4 where these distances are marked off on the graph. If we take the geometric multiplier ratio of the electron line (assuming exactly e slope) 15.154 and divide that by 137, the geometric multiplier of the neutrino line we get approximately (1/9), ie $(1/3)^2$. If we look at the ratio of the geometric multiplier of the dn like quark line with the electron line we get 10/15,or about 2/3. Similarly the best exponent for the up like line (assuming the electron line has a slope of exactly “e”) is 1.8871 (to maintain the geometric mean relationship), which results in a geometric multiplier of 6.60 for the up like quarks (15.15426 and 6.5988 have a geometric mean of 10). Therefore again the ratio of 6.6 to 10 is approximately 2/3 too. The corresponding values for the revised up quarks predicted by the Extended S.M. then become: 36.0 MeV, 237.31 MeV, 1566 MeV, 10340 MeV, 68230 MeV, and 450 GeV. These values, along with the other predicted values made by the ESM are seen in Figure 4.

Gordon Kane in his book “Modern Elementary Particle Physics” observed in chapter 29 an interesting ratio of the masses of the lepton with their associated neutrino.(24) Gordon observes that those ratios are:

Electron- m_{ν} / m_{e}	$< 1.6 \times 10^{-5}$
Muon- m_{ν} / m_{υ}	$< 2.4 \times 10^{-3}$
Tauon- m_{ν} / m_{τ}	$< 2 \times 10^{-2}$

Using values now determined by the ESM those ratios can be expressed as

$$m_{\nu} / m_{x} < 1.7 \times 10^{-G}.$$

The nuon fits into this pattern since its ratio of the nuon neutrino mass to the mass of the nuon is 1.55×10^{-4}. The new ratios (based upon ESM values) become: 1.7×10^{-5} for the electron, 1.6×10^{-4} for the nuon, 1.4×10^{-3} for the muon, and 1.3×10^{-2} for the tauon.

Equation (1) can also be rewritten as: log (m/H) = constant for a given family. As Frank Close points out in the book “The New Physics”, “Renormalization requires a dimensional parameter to set the scale of the logarithm. This is called the renormalization scale (in the ESM that value is H). It is arbitrary in principle, but in fact, for any given calculation, some renormalization scales are more convenient than others because of the presence of logs of m/H. If all the masses and momenta in a process are of the same order of magnitude, it pays to choose [H] in the range to minimize the effects of the logs and make the perturbation theory better behave. It is this logarithmic dependence on the renormalization scale which is responsible for the renormalisation group dependence of parameters on the distance or momentum scale, first discussed by Gell-Mann and Low."(25) Therefore, from a dimensional analysis it seems like a log (m/H) function of mass, has some basis for being considered part of this theory.

This theory also does a better job explaining the low mass mesons. The current standard model has established that the Upsilon meson (ϒ (S1)) is a meson of two bottom quarks and it has a mass of 9460.37 $\pm$ 0.21 MeV. Also the standard model has established that the meson combined of two charmed quarks is the eta sub c (η_c) and it has a mass of 2980 MeV. Using the accepted free quark masses of the Charmed and Bottom quarks in table 1 we get:

Table 4.

Meson	Quarks	Mass of meson MeV	Mass of 2 Quarks MeV	Delta Mass MeV	Delta mass as % of meson Mass
ϒ (S1)	b b	9460.37	8400	1060 MeV	11 %
η_c	c c	2980	2500	480	16 %

(Note: I am using the nomenclature b to indicate the anti particle of the b quark.)

Therefore the standard model accepts the mass of the composite meson to be 11% to 16% higher than the rest mass of its constituent quarks, at least for these two examples. How does this process work for the lighter meson? First using the S.M. mass values for s and u.

Table 5.

Meson	Quarks	Mass of Meson MeV	Mass of two Quarks MeV	Delta Mass MeV	Delta Mass as %of meson Mass
Eta primed	s $\underline{s}$	957.77	200	758	79 %
Eta	u $\underline{u}$	547.30	6	541	99 %
K^-	.u s	493.65	103	391	20.6%
K^o	.d s	497.67	106	392	21.3%

As we can see, the %delta mass is not anywhere near 11% to 16%. Actually the standard model predicts the eta meson is a mixture of states, $(u\underline{u} – d\underline{d})/2^{1/2}$. Since the mass of both the u and d in the standard model is very low, and about the same, the above calculation is still approximately correct. This mixture of quark states was one of the first indications that the standard model lost some of its beauty and charm.

How does the data look with the masses in the ESM theory?

Table 6.

Meson	Quarks	Mass of Meson MeV	Mass of two Quarks MeV	Delta Mass MeV	Delta Mass as %of meson Mass
Eta primed	s $\underline{s}$	957.77	848	110	11.5 %
Eta	up $\underline{up}$	547.30	474.6	72.7	13 %
K^-	.u s	493.65	462	31.6	6.4%
K^o	.dn s	497.67	466	31.7	6.3%

Notice with the new mass of up and s from the ESM, the numbers in table 6, appear to have the same %delta mass excess as the η_c and Y (S1) heavier mesons.

Finally how do the π^- and π^0 fit into this model.

Table 7.

Meson	Quarks	Mass of Meson MeV	Mass of two Quarks MeV	Delta Mass MeV	Delta Mass as %of meson Mass
π_-	dn u	139.5699	42+38 = 80	60	43 %
π^0	u u	134.9764	38 X 2 = 76	59	44 %

Note the delta mass %are not in the 11% to 16% range anymore, but these are very light mesons, and that may account for this change. Had we used the S.M. mass of 3 MeV for u and 6 MeV for d, then this exercise would have resulted in much higher (94%) Delta Mass values as a percentage of pi meson mass, which the S.M is willing to accept. These few examples support the credibility to this new ESM.

Table 8.

Meson	Quarks	Mass of Meson MeV	Mass of two Quarks MeV	Delta Mass MeV	Delta Mass as %of meson Mass
ρ^+	u s	770	237+424=661	109	14 %
B^0	s b	5379 MeV	424 + 4240	715	13 %

On a more speculative note, table 8 shows how the rho plus and B zero mesons fit into this pattern assuming they are composed of the strange –1/3 quark instead of the d (– 1/3) quark.

If this model is correct, experimetalist have not yet found the lightest meson, the d $\underline{d}$ meson. It should have a mass of about (4.2 X 2 + 50%) or about 12 MeV. Perhaps it should be called η_d. Perhaps η' (primed) should be renamed η_s and η should be renamed η_{up}. π^0 could be renamed η_u but that would be more confusing than helpful.

As mentioned in the first paper that stimulated this work (Checker Board Model of the Nucleus), there appears to be some repeating mass delta's in the excited states of the pi meson. This pattern was recognized long ago (see pgs 40- 41 Particles and Fields, Scientific American 1980 with an introduction by W.J. Kaufmann). Here we see the beginning of a pattern of mass deltas starting with eta 548, eta 782 (now called W 782), eta 1020 (now called Phi 1020), and eta 1250. These mesons all related to the pi meson (made with up and down quarks) with quantum states " 0^- (1^{--}) have a mass difference of about 237 MeV. As mentioned in that original paper the currently accepted mass for Phi(1020) is 1019.413 $\pm$ 0.008 MeV. The currently accepted mass for the W(782) is 781.94 $\pm$ 0.120 MeV. Therefore the mass differences of these two precisely known excited states of the pi meson is 237.47 MeV, well within an acceptable error of the predicted up quark in the ESM theory at 237.31 MeV.

Predictions:

All new theories must make predictions to determine how well they can predict what is not yet known. The ESM predicted that a heavy generation of quarks and leptons had not yet been found. A 65 GeV up like quark, a 42.4 GeV dn like quark, and a 27 GeV lepton. In June 1979 the first evidence of three JET events began coming from the TASSO collaboration. These three JET events had a characteristic energy of 27.4 GeV (27). Also at energies of 11.5, 45, and 63 GeV many collaborations found two JET events (28)(29). The 1995 average for four collaborations for the two jet energy $\sqrt{s}$ = 42.5 GeV in almost perfect agreement with the ESM.(30, 31) The particle, thought to be the discovery of the gluon at 27.4 GeV is in very good agreement with the ESM and more significantly, this was indeed a prediction, since at the time of uploading of the first version of this paper on the Los Alamos web server, these findings were unknown to the author. Perhaps we should call the lepton in generation 1 the gluon, since in this model gluons are no longer required to hold the quarks together, since it is the standing wave (de Broglie relativistic wave length consistent with the circumference of the nucleon) of the quarks that hold them (keeps them) in the nucleon as explained in the CBM..

Conclusion:

This paper attempts to present a self- consistent theory of the masses of sub nuclear particles (elementary particles, mesons and hadrons) based upon the assumption that the masses of the up and dn quarks as determined in the CBM of the nucleus are correct since they explain the magnetic moments and masses of the proton and neutron along with the explanation of the strong nuclear force in terms of electromagnetic flux couplings. However, all this effort is academic unless (until) a 7.65 ± 0.1 MeV nuon lepton is found. This may be difficult since a number of low energy nuclear phenomenon exist in this energy range, for example the typical binding energy per nucleon to name just one. The validity of this theory may also be strengthened by the rediscovery and confirmation of the John Simpson neutrino especially if turns out to have a mass closer to 1.2 - 1.7 KeV rather than 17 KeV.

1. Groom, D.E., et.al. (Particle Data Group), Eur.Phys.Jour. **C15**, 1 (2000).

2. Lach, T.M., “Checker Board Model of the Nucleus”, *Infinite Energy*. **30,** 59- 63 (2000).

3. Fukuda, Y., et.al., “Evidence for Oscillations of Atmospheric Neutrinos, *Physical Review Letters,* **81**, #8, 1562 (1998).

4. Normile, D., Heavy News on Solar Neutrinos, *Science* **280**, 1839 (1998). D. Normile, “Weighing in on Neutrino Mass,” *Science*. **280,** 1689 (1998).

5. Raghavan, R.S., “Solar Neutrinos – From Puzzle to Paradox,” *Science* **267**, 45 (1995)

6. Bahall, J.N., Lande, K., Lanou R.E. Jr., Learned, J.G., Hamish, R.G., Wolfenstein, R., Wolfenstein, L., “Progress and Prospects in Neutrino Astrophysics”, *Nature*, **375**, 29 (1995).

7. Perricorn, M., “The Forth Neutrino and maybe more,” *Fermi News Letter June*, **30**, 12 June (2000)

8. Flam, F., “Physicists Close in on a Weighty Quarry,” *Science*, **254**, Nov 29, 1298 (1991).

9. Taubes, G., “Are Neutrino Mass Hunters Pursuing a Chimera?” *Science* **257**, 731(1992).

10. Flam, F., “Physicist Rock the Standard Model in Dallas,” *Science*, **257**, 1044 (1992).

11. Hughes, I.S.,“Elementary Particles” 3rd ed. Cambridge University Press, 279- 299 (1991)

12. Voloshin, M.B. et al., IJMP, **A10**, 2865 (1995)

13. Alvarex, M.P. et al., CERN, NA14/2 collab., Zphy **C60,** 53 (1993).

14. Arnison, G., et.al., Associated Production of an isolated Large Transverse Momentum Lepton (electron or muon) and two jets at the CERN p p(bar) collider, *Physics Letters*, **147B**, no. 6, 493- xxx (1984).

15. First Aspen Winter Physics Conference, editor E.M. Block, *Annals of the NY Academy of Sciences*, **461**, p.13, 38, 83, 99,125, 684 (1995).

16. Quigg, C.,“Top- ology,” *Physics Today*, May, 20 (1997)

17. Gottfried, K., Weisskopf, V.F.,“Concepts in Particle Physics” Vol 2. Oxford University Press, 324, 331, (1986)

18. Stone, R.,“Exploring the Proton Sea”, *Science*, Jan 22, p. 472.(1999)

19. Kane, G., “Modern Elementary Particle Physics”, Perseus Books, 8, (1993).

20. Carrigan,R.A., Trower, W.P.,“Particles and Forces, At the Heart of the Matter, reading from Scientific American”, W.H. Freeman Co. New York, (1990) pg. 5, reprint of Chris Quigg’s 1985 article “Elementary Particles and Forces”.

21. Hodgson, P.E., Gadioli, E., Erba, E. G., “Introductory Nuclear Physics” Oxford Science Publications, Clarendon Press, (1997)

22. Kane, G., “Modern Elementary Particle Physics”, Perseus Books, 190, (1993).

23. Glanz, J. “Collisions Hint that Quarks Might not be Indivisible”, Science **271**, Feb 9, 758 (1996).

24. Kane, Gordon, “Modern Elementary Particle Physics”, Perseus Books, p. 303, (1993)

25. “The New Physics” edited by P. Davies, Cambridge University Press, p. 453,(1994).

26. Ehrenstein, D. “Slicing an Electron’s Charge into Three”, Science **277**, Sept 19, 1766 (1997).

27. “The Rise of the Standard Model” editors: L Hoddeson, L. Brown, M. Riordan, M. Dresden, Cambridge University Press, p. 608- 618.(1997)

28. “Annual Review of Nuclear and Particle Science” editor, J.D. Jackson, Annual Reviews Inc., **35,** p. 120,(1885)

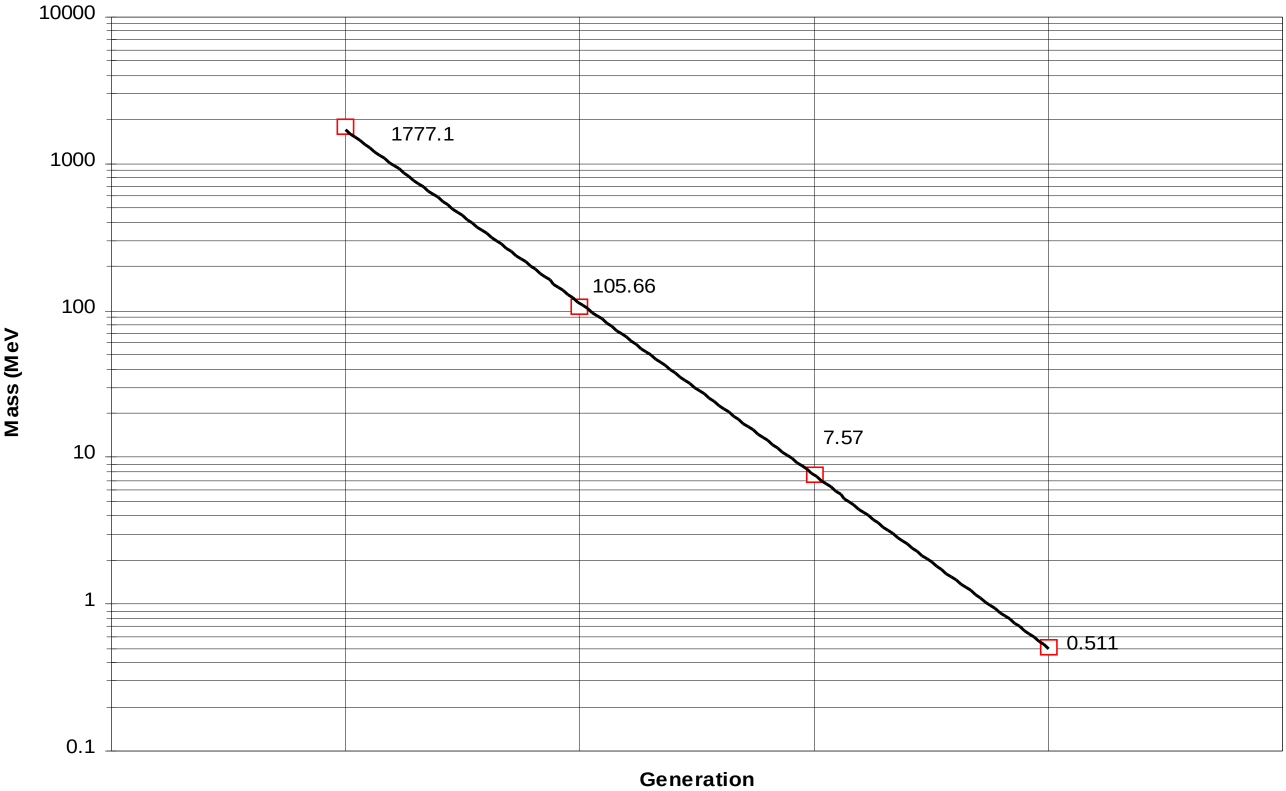
29. “AIP Conference Proceedings No. 68 Particles and Fields Sub- series No. 22, High Energy Physics- 1980, XX International Conference

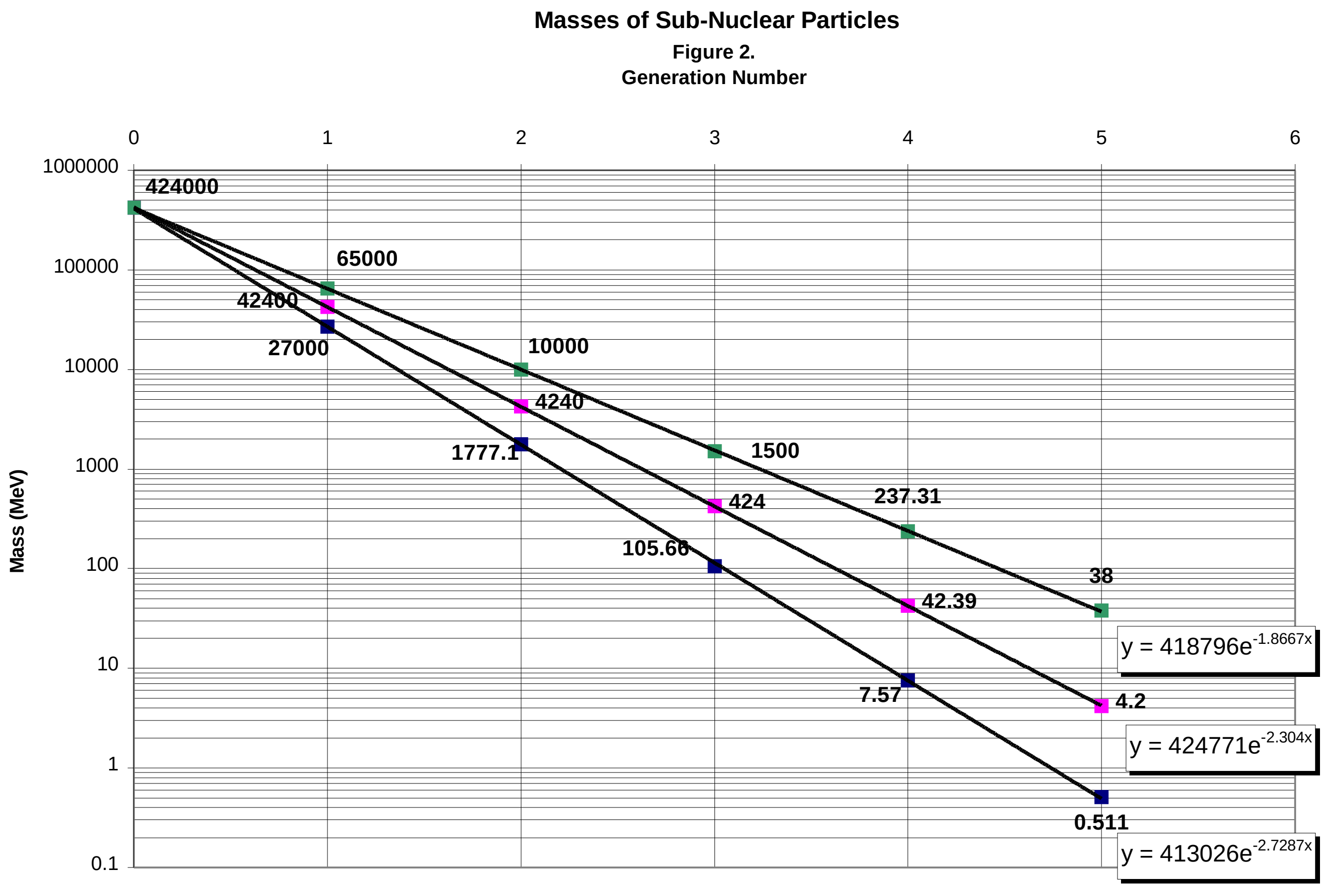
Madison Wisconsin", editor, L. Durand and L.G. Pondrom. American Institute of Physics, p. 1435, (1981)

30. First Aspen Winter Physics Conference, editor E.M. Block, *Annals of the NY Academy of Sciences*, **461**, p.684 (1995).

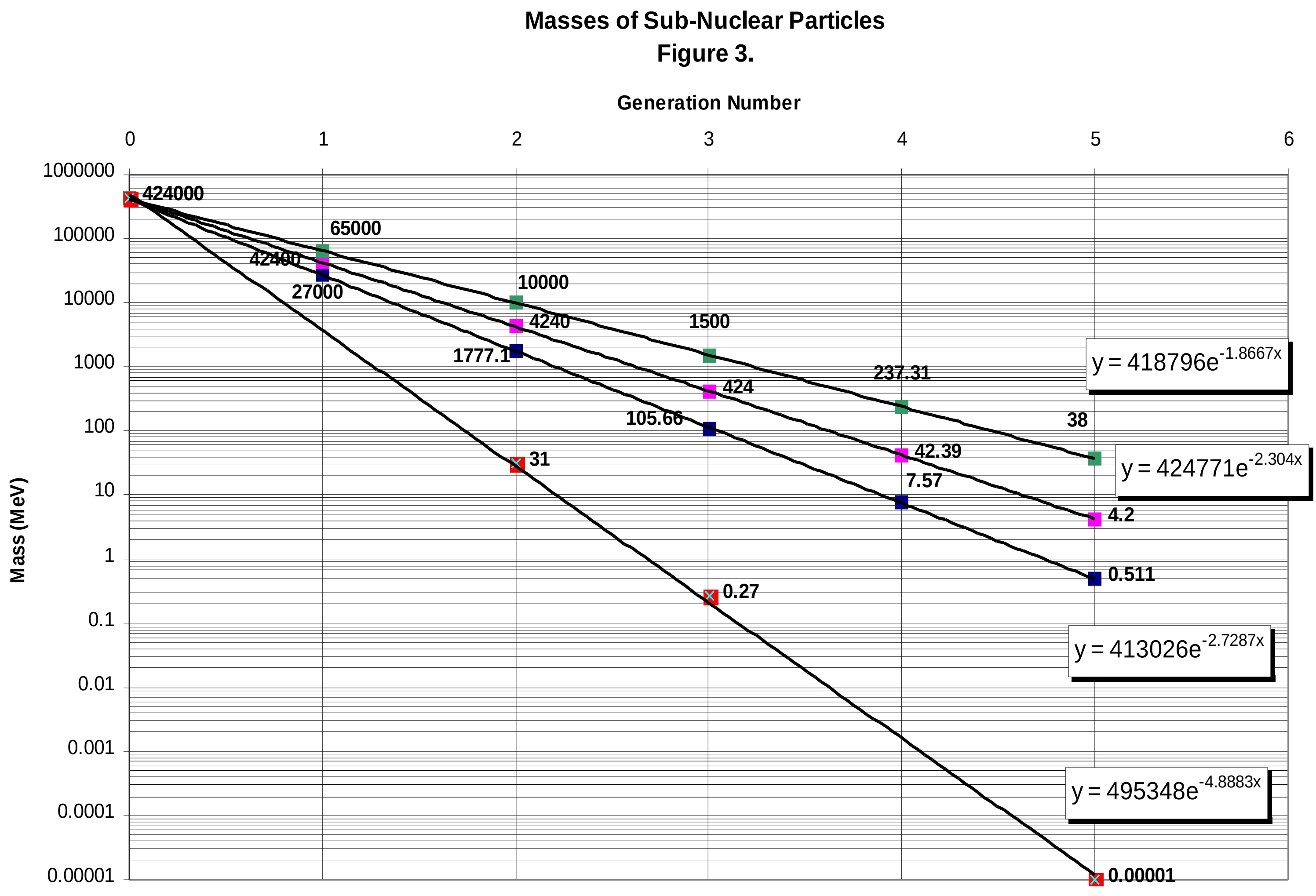
31. High Energy Physics in the 1990's, Snowmass 1988, editor Sharon Jensen, World Scientific, 1989, p.211 and p.153.

Mass MeV vs. Generation Number
Figure 1





Masses of Sub-Nuclear Particles
Figure 2.
Generation Number
0
1
2
3
4
5
6
1000000
100000
10000
1000
100
10
1
0.1
Mass (MeV)
424000
65000
42400
27000
10000
4240
1777.1
1500
424
237.31
105.66
38
42.39
7.57
4.2
0.511
y = 418796e-1.8667x
y = 424771e-2.304x
y = 413026e-2.7287x



Masses of Sub-Nuclear Particles
Figure 3.
Generation Number
0
1
2
3
4
5
6
Mass (MeV)
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001
424000
65000
42400
27000
10000
4240
1777.1
31
1500
424
105.66
0.27
237.31
42.39
7.57
38
4.2
0.511
0.00001
y = 418796e^-1.8667x
y = 424771e^-2.304x
y = 413026e^-2.7287x
y = 495348e^-4.8883x

Masses of Elementary Particles
Figure 4.