Quantum-interference phenomena in the femtometer scale and the description of mass for baryons in terms of confined currents.

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Abstract: In a previous paper we have related rest energy to magnetodynamic energy for the baryons. The hypothesis of a zitterbewegung vibrating motion is essential to the scheme. To impose gauge invariance to the model and the continuity of the wavefunctions, we adopted the criterion that the magnetic flux linked through the region covered by the particle vibrations should be quantized in units *n* of *hc/e*. Our results, however, displayed some "scattering" of the data around the theoretical line, which was not analyzed in that previous work. To elucidate this point, the imposition of a fixed criterion on the possible values for *n* has been replaced in the present paper by the calculation of *n* from the model equations. Such procedure led to advances in our interpretation of mass in terms of magnetodynamic energy. It has now been shown that the data actually follow a sinusoidal pattern in a plot of mass against *n*. The previous criterion implied the exclusive existence of fully coherent wavefunctions (several baryons indeed comply with strict flux quantization), but the sinusoidal behavior can be attributed to additional interference involving also incoherent waves, which are now introduced in the model. Therefore, confined magnetic flux modulates currents which cross through internal boundaries (or topological constraints) inside baryons, in analogy with transport through Josephson Junctions between superconductors. This results in the undulations observed in our new plots of *n* against the magnetic moments of particles, and of the mass against *n* for all baryons. The proposal by A.O.Barut in the 1970s that every baryon contains a proton as constituent is also consistent with our data analysis, as well as the conclusion that inner constituents of baryons manifest as correlated unit-charged quasiparticles of topology dictated by the symmetry properties of each baryon.

1. Introduction.

In recent work [1] we have shown that through the imposition of gauge invariance conditions to the wavefunctions of a particle(represented in energy terms by a closed loop of current and performing zitterbewegung motion), it is possible to relate rest energy to magnetic energy for the baryons. Gauge invariance and the continuity of the wavefunctions require that the magnetic flux linked through the region covered by the particle "orbit" be quantized in units *n* of $\phi_0 = hc/e$, the flux quantum. We therefore *adopted* integer (allowing also for half-integer) values of *n* in the analysis for the baryons, guided also by the criterion that *n* should be proportional to the magnetic moment (in n.m. units) in the classical limit of flux generated by self-fields. The model predicts an inverse dependence of mass with the fine structure constant alpha, in agreement with experimental data analysis reported in the literature[1].

Such model is essentially based upon heuristic arguments, and in particular the assumption that zitterbewegung currents flow inside complex particles like the baryons is the extension of a similar proposal made for the electron. The model produces a reasonable agreement between the calculated magnetic(plus kinetic) energies and the rest energies, revealing also a clear dependence of rest mass upon the square root of the spin angular momentum, of the form predicted and observed in the literature. However, a noticeable scattering of data around the theoretical line still remained. The meaning of such scattering was not addressed in the previous work.

To better understand if such deviations might have a physical meaning rather than indicating possible limitations of the model, we decided that the data should be analyzed again in a slightly different way, by avoiding any previous assumption about the values of *n*. The number of flux quanta is now allowed to "fluctuate", determined through the model by the product of the known values of mass and magnetic moment (through the same eq.(3) of [1]; see below). Such "model-adapted" values of *n*, calculated from the available data, become the object of this new analysis.

In the present work we try also to eliminate the effects on the rest energies, of kinetic energy contributions specifically attributable to the "excess" spin angular momenta of decuplet particles(spin-3/2 particles) as compared to the spin-1/2 octet particles, which were evident in our previous paper[1]. In fact, the finding that the logarithmic plots for different values of spin in Figure 1 of [1] are parallel to each other indicates that the difference in mass has no magnetic origin(just notice that the $1/n$ term in the vertical scale of that Figure essentially *balances* the $1/\mu$ in the horizontal scale for all points; since these are the magnetic terms, the shift between the parallel lines of data is not therefore attributable to magnetic unbalanced differences between octet and decuplet). For the range of mass values covered by these particles the elimination of such excess kinetic energy can be made by subtracting from the masses of the decuplet particles the average difference between the actual masses of decuplet and octet particles (244 Mev/c^2). The resulting "*transformed masses*" m_t of the decuplet have the same average as the masses of the octet particles. This eventually makes all baryons fit the mass-energy expression derived for spin-1/2. These masses should all have similar contributions of magnetic and (remaining) kinetic energy origins, and thus are comparable for the purposes of this theoretical analysis.

As expected, the new values of *n* are not substantially different from the ones adopted previously(see [1] for details), but have the characteristic of perfectly relating mass to magnetic moment for each particle through the proposed model energy-mass relation. In this way, the margin of arbitariness in the choice of *n* inherent to the previous criterion is eliminated and the determination of this parameter for each baryon becomes an objective for the model. From the new analysis it should therefore be possible to better evaluate the internal consistency of the model itself, including the evaluation on whether the proposed interpretation of *n* as a true number (integer or not) of magnetic flux quanta is physically meaningful, as well as analysing how appropriate is the utilization of closed currents as a means of representing complex particles.

As shown in the following sections, the approach proved valuable. As far as results are concerned new important features have arisen from the analysis. Firstly, the calculated values of *n* split particles into two groups: one of these groups of particles quite precisely adopts integer numbers of flux quanta–as initially expected in previous stages of this research project– while the other group(called hereafter the "second group") does not. About seven of the baryons indeed have rest energies associated with their magnetic moments through the simple criterion that they confine integer numbers of flux quanta(within a better than a few % accuracy).

Furthermore, by plotting against *n* both the octet baryons masses and the transformed rest masses m_t of the decuplet baryons of the mentioned second group, we obtain the novel result that a simple sinusoidal function, with *n* in the sine argument, is capable of fitting all the points. That is, the rest energy (given by magnetodynamic terms) for such second group of particles includes a sinusoidal dependence on magnetic flux.

This is a quite revealing result. In fact, there actually exists in Physics an specific system with this exact latter behavior, which is the Josephson (tunneling) Junction joining two superconductors[2]. Through Josephson Junctions it is still possible to obtain resistanceless current flow, provided a limit critical current is not surpassed. The effect of the Junction is to break coherence between the phases of wavefunctions of quasiparticles (Cooper pairs) crossing through the Junction, and generate interference between such wavefunctions. Note that this is an important additional feature not previously considered in this analysis, since the concept of assuming integer values for *n* corresponded to take only fully coherent closed wavefunctions into consideration. We have thus found a reasonable justification for the occurrence also of non-integer values for *n* in a zitterbewegung-like motion(see equations below), which is the continuous modulation of charge flow of incoherent wavefunctions, and identified the generation of interference patterns.

The predicted tunneling current depends on the sine of the wave functions phase difference across the Junction. The continuity of the wavefunctions around a closed path crossing through junctions, and confining magnetic flux, requires that in the argument of sine a flux-dependent term be included. It seems clear then that the previously observed scattering of the points indeed may have a physical meaning, which can be quantitatively described.

As a result of this analysis, a new plot of mass against *n* is presented. This plot clearly displays an *undulating* behavior of the second group of values of mass, while the first group of particles forms “spikes” in the plot at integer values of *n*.

Undulations in intensity for waves of any kind immediately suggest the occurrence of interference of these waves. In the following sections we show that such undulations can be precisely attributed to quantum interference of wavefunctions in the femtometer scale of baryons, similar to those observed in macroscopic Josephson Junctions due to interference between wavefunctions of Cooper-electron pairs. The symmetry properties of such traveling wavefunctions at nuclear-scale are unknown. However, magnetic moments have been precisely calculated for all baryons taking as starting point the imposition of an SU(3) algebra for combinations of quarks contributions, assumed as spin-1/2 particles[3], so that one would expect that an SU(3)-based geometry applies.

It is a basic assumption of the model adopted in this treatment [1]that currents generate magnetic moments[4], which give rise to self-magnetic fields and flux within particles, with an associated magnetodynamic energy which we identify with the rest energy of the particles. It appears that the resulting trapped magnetic flux modulates the currents of wavefunctions running across contacts between constituents through the imposition of a phase factor, in agreement with Josephson Junctions theory, and such phase differences vary from one baryon to another. The magnetic energy depends on such modulation, and thus also the mass along the baryons family.

Another important observation is that a single sinusoidal curve describes the undulatons observed in the plot of mass against *n*. This implies that the critical current across junctions, the parameter in Josephson Junction theory which determines the undulation amplitude, can be assumed the same for the baryons of the octet and decuplet (with their transformed masses, as previously explained). This indicates that the baryons internal arrangement of constituents manifests in some averaged way which would differ very little from one baryon to another.

This of course raises questions about what baryons individual consituents actually are, and if a fractionary-charge quark picture is necessary. As far as constituents are concerned, Barut(whose ideas were introduced in the 1970s as an alternative to the quark model) proposes the universal presence of a proton as constituent of all baryons[5]. As shown below, our data analysis fully supports such hypothesis. Furthermore, tunneling formulas adopted here are consistent with moving *unit-charged* objects, and not with isolated fractionary charges, in view of the expression for the flux quantum which is consistent with the former(once again in agreement with Barut´s ideas). In fact, what we call "constituents" apparently behave like *correlated quasiparticles*, manifesting themselves collectively rather than as isolated objects. Internal geometrical restraints upon current paths(of SU(3) symmetry perhaps) seem to be an essential part of the correlated structure. Therefore, it would be readily understandable why such quasiparticles do not manifest outside the baryon, since the geometrical restraints which are part of them would no longer apply. Outside the baryon only bonafide stable particles are observed, in agreement with the external symmetry conditions.

The analysis indicates currents are carried in unit-charged objects, but we have not obtained evidence that would determine their topological features, and how hypothetical individual constituents would assume such features (without going deeper in this latter issue, Barut [5] proposes that baryons would differ in the number of constituent unit-charged muons and electrons, as well as neutrinos, and their antiparticles, which are the particles that are actually detected in decay and interactions with other particles). In addition, the minimum mass is the proton mass. Since, in Barut´s interpretation the proton should be a constituent of all baryons, this would establish the lower bound for the undulations amplitude, as observed in this analysis(see below).

All these results are considered in detail in the Discussions section. The next section describes the elements of quantum interference theory to be applied to the contacts between constituents(following Josephson Junctions theory). A review of previous results of the model is also added for the sake of completeness of exposition.

2. Theory.

Isolated current-loops containing a single quantum of flux of value $\phi_0/2$ are well known from type-II superconductivity[6]. The formation of superconductor current loops is a many-body effect, though. In a series of papers we have investigated if there might exist single-particle systems confining flux in a similar manner[1]. It is essential that such proposal be quantitatively supported by experimental data. Let's consider the actual case of particles of the baryon octet. All the eight particles have well-established rest masses and magnetic moments. E.J. Post [7]considered how to write an energy-mass relation in a tentative model for *the electron*. Post showed that the magnetic moment for the electron could be obtained up to the first-order correction (from QED) with the equation:

$$mc^2 = \phi\, i/c + eV \qquad (1)$$

Here the left side is the rest energy of the electron, which from the right side is considered as fully describable by electromagnetic quantities. The first one on the right side is the energy of an equivalent current ring of value i linking an amount of flux ϕ, that should occur in a number n of flux quanta ϕ_0 . In spite of the adopted parameters from electromagnetic theory, such term contains similar amounts of magnetic and kinetic energy contributions of moving charges, as discussed by London[8]. The second (electrostatic energy) term is much smaller than the first (it will be neglected hereafter) and accounts for the radiation-reaction correction for the magnetic moment which is proportional to the fine structure constant α, as is well known[7]. Post associates the current with the magnetic moment μ and the size R of the ring with the equation:

$$\mu = \pi R^2 i/c \qquad (2)$$

One then inserts equation (2) into equation (1) (without the electrostatic small term) and thus eliminates the current. The parameter R has been calculated/measured for the nucleons only, but it remains part of the final expression for all baryons obtained after the combination of (1) and (2). We may conveniently eliminate R from this treatment by adopting for all baryons an expression which is valid for the leptons (for $R= \lambda$, the Compton wavelength), and for the proton[1], namely:

$$\mu = eR/2 \qquad (3)$$

In the present case we are interested in assessing a sufficiently large group of particles in order that flux quantization can be properly investigated, and the baryons form such a group.

The model by Post was devised to fit a single fundamental particle, the electron, and there was actually no discussion either on the issue of coherence of wavefunctions around the orbit, or about the application to other particles. We are now able to justify (see section 3) the proposal that the motion of constituents inside baryons can also be described in terms of currents, so that a similar model should apply. The combination of equations (1)-(3) with $\phi = n(hc/e)$ can therefore be cast in the form (inserting $\alpha = e^2/\hbar c$):

$$n = (2c^2\alpha/e^3)\, \mu\, m. \qquad (4)$$

3. Discussion: coherent and incoherent currents in the femtometer scale.

Equation (4) stresses the fact that in this work n is the parameter to be determined from the data available for mass and moment (note that it is the same eq.(3) of [1] written in another form). Note also that equation (4) can be rewritten in a very useful form by isolating in it the expression for the nuclear magneton (n.m.), $e\hbar/2m_p c$, yielding

$n = (m/m_p)\, \mu$(n.m.).

Here m_p is the proton mass and the magnetic moment is given in n.m. units. A plot of n against μ with a fixed value for m (for all particles) would therefore be confined to a straight diagonal line.

The continuity of a coherent wavefunction around the loop would require n to be an integer. All the parameters on the right side of eq.(4) are known for the eight baryons of the octet, and are listed in Table 1(data from [9]). Figure 1 shows the plot of the calculated n against the magnetic moment for each particle. Note the presence of a diagonal line. There is also a tendency to form Shapiro-like steps at integer numbers of flux quanta[6], but the approach to the steps has an undulating shape rather than being sharply defined.

The interpretation of the diagonal line in Figure 1, $n = \mu$(n.m.), is fundamental for this analysis. The actual existence of such diagonal *baseline* experimentally characterizes the presence of a common, *minimum* amount of mass in all baryons (which might be called the *unit* of mass), which would establish the *minimum* amount of flux for a given magnetic moment value. From eq.(4), it becomes clear that the proton mass would be this unit of mass.

We will come back to this important point later, but we now turn to the analysis of the origin of the undulations in the Figure. As expected from the theory, the undulations lie above the diagonal line since it characterizes a minimum mass.

In fact the undulations prove that the *wave character* of the moving charged particles is essential to the analysis. Integer values of *n* (at the steps in Figure 1) characterize fully coherent loops of waves. Undulations in intensity for waves of any kind indicate the occurrence of interference and the *breaking of coherence* of the waves. Therefore, considering the wave character is essential.

The theory of transport across Josephson Junctions between superconductors provides a proper description for such interference [2]. Up to now we have assumed that there is no break in coherence in the flow of the currents inside a baryon particle. It would be consistent with the picture proposed many years ago by Herbert Jehle[10] that electrically charged constituents have their proper topological structures (like a trefoil, for instance) and individually rotate with the zitterbewegung frequency, and might even superpose and cross one another. We now develop the theory and show that the data display evidence that the waves interfere with each other. Quantum interference of the kind considered in the theory of Junctions might then take place. In the DC case (in which a direct current is injected through a junction) it can readily be shown that the current *I* through a contact boundary between superconductors is determined by the phase difference θ of the wavefunctions on both sides across the boundary[2]:

$$I = I_c \, sin(\theta) \tag{5a}$$

where I_c is the critical current for the junction. We are interested in the case of closed current loops. In a closed circuit confining magnetic flux ϕ, and containing at least two coherence-breaking junctions, the continuity of the wavefunctions around the circuit makes equation (5a) adopt the form:

$$I = I_c \, sin(\theta + 2\pi \, \phi/\phi_0) \tag{5b}$$

Where $\phi = n \, \phi_0$, in which n is not in general an integer. In fact, θ might assume a range of values and thus an average must be calculated (an additional oscillating term would appear, but it vanishes when the integration of the current is carried out and the average in θ is taken, so that it has been discarded from this expression). Equation (5b) characterizes an wavefunction interference process, which is the quantum analogue to the Young-Fresnel light-interference, with the parameter n replacing the position along the projection screen for light[2,6].

We must now reconsider the magnetic energy term in eq. (1). If the currents remain coherent that expression should be valid with integer n. On the other hand, if currents across contacts become relevant the magnetic energy calculation will require the integration over n of the current form eq. (5b), to account for the build up of flux beginning from no flux at all, up to the final confined flux given by n flux quanta. The expression for mass would not be given by eq.(1), but rather by:

$$mc^2 = I_c\phi_0/\pi c \quad sin^2(\theta/2 + \pi\, n) \qquad (6)$$

Coming back now to Figure 1, expression (6) has the expected form to justify undulations in the plot for *n* , but notice that the diagonal baseline is not included! The mass *m* acquires a pure squared sine form, dependent on phase and on *n*.

Since there is no constant term in eq.(6), we conclude that the diagonal baseline in Figure 1 must have an independent origin, which has been mentioned earlier.

Barut [5] offers an explanation since his interpretation for the inner structure of hadrons proposes that the *stable proton is present in all baryons*. The diagonal baseline therefore would be interpreted as corresponding to a minimum contribution represented by the proton mass. Indeed, as discussed earlier, the proton is a particle for which the magnetic moment in nuclear magneton units matches the number of flux quanta, in the same way as the neutron does(cf. Table 1). This implies that the nucleons mass would be the unit of mass mentioned earlier (neglecting the difference between the masses of the nucleons).

Incidentally, Barut´s model for hadrons does not consider the origin and inner structure of the fundamentally stable particles, namely the proton, the electron, and the neutrino. They are literally taken, in Barut´s own words[5], as "the building blocks of matter".

However, a relation between the proton mass and the critical current across a junction can be proposed, as follows. It is a well known phenomenom in superconductors the establishment of current distributions restricted by the critical value I_c, the so-called "critical state". Magnetic flux profiles are formed in such a way that at every point the local current density reaches the maximum, critical value. It seems that a similar effect is observed in this case. The rest energy described by eq. (6) is produced by an "incoherent "(and subcritical) additional current dependent on confined flux, and must be added to the mass of the proton included in a baryon. If one writes the proton mass as the energy of a loop of current, it would be consistent with the critical state concept that such minimum, stable mass would be related to the critical current energy value $I_c\phi_0/c$, and this would sit on the diagonal line in Figure 1 in order to keep consistency also with the magnetic moment of the proton. Since the magnetic moment can be calculated from the SU(3) algebra we conclude that the establishment of this critical-state analogy should be another consequence of geometrical constraints of a *given symmetry*, acting upon the paths of currents of the quasiparticles. Such symmetries are therefore incorporated in the particles wavefunctions themselves. What we call a proton would be the result of the formation of a stable critical current loop with symmetry-adapted topological properties..

In resume, the diagonal line in Figure 1 would thus correspond to a critical-state internal current distribution, physically represented by the stable proton, and the unit of mass. The other baryons would then be obtained from deviations of such fundamental critical state through additional subcritical tunneling currents flow. The values of n, m, and μ would be consistently connected through eq.(4).

Therefore, the general formula for a baryon mass, including the presence of a proton, and including the effects of confined magnetic flux upon incoherent tunneling currents inside a particle should be:

$$mc^2 = I_c\phi_0/c\{1 + 1/2\pi\ (1 - b/\pi\ \sin(\pi/b)\cos(2\pi n))\} \tag{7}$$

In equation (7), to simulate different contact strengths, the phase angle θ in eq.(6) has been averaged over a symmetric arbitrary range of angles $-\pi/b$ to π/b (which actually turns eq.(7) rather insensitive to the value adopted for the parameter b in view of the sine term, which essentially cancels it out).

Equation (7) predicts undulations of $1/\pi$ = 31% maximum amplitude in units of the proton mass $m_p c^2$, which we take as $I_c\phi_0/c$. Figure 2 displays the comparison between the data in Tables 1 and 2 (except those with integer n values) with equation (7), with no additional fitting parameters added.

Figure 3 includes all data in the Tables. Spikes are formed since many particles tend to follow the integer-n rule with n = 3 and n=1.

No strict theory exists for the counting of the number of flux quanta, given a particles composition. However, in view of the quark model for the baryons, the concentration of particles at n=3 flux quanta might in some way be expected. On the other hand, we have not found any clear correlation between such favored n=3 value and the compositions proposed by Barut for the different baryons, which would supposedly contain besides a proton a variable number of muons, electrons, positrons and neutrinos [5]. It actually seems that inside baryons the constituents are affected by constraints and behave like collectively correlated quasiparticles, rather than as isolated objects. The dominance of n=3 might be a result of such an "averaging", and overall superposition. Such constraints should follow the symmetry rules applicable to the baryons wavefunctions, since the constraints are supposed to have imposed the forms of the wavefunctions. In a similar way, the different masses along the spikes for same integer n should be related to the representation of SU(3) corresponding to each of the baryons, as the respective magnetic moments do, and this association is phenomenologically included in eq.(4) through the values of the moment μ(calculated in [9]).

Incidentally, starting from the conception that particles might have an origin related to cosmological theory, Fred Hoyle [11,12] performed calculations for the masses of baryons by considering their respective description in terms of representations of SU(3), and then taking the necessary parameters from heuristic/phenomenological arguments. Symmetry therefore appears to be such a dominating factor in the determination of mass, that calculations based upon such symmetry arguments are capable of overcoming even the gretest differences between the specific theories adopted for the structure of baryons and the (usually unknown) details of the internal interactions, provided the considerable number of phenomenological parameters is properly chosen in each case.

4. Conclusion

We effectively started this project with a relatively simple proposal: the description of baryons masses through magnetic energies related to a current loop picture of their intrinsic motion. Flux quantization would be imposed to fulfill gauge invariance conditions. The model became more sophisticated. We are able now to show that flux quantization is indeed followed in some cases and not in others. When it is not followed (since the condition becomes unnecessary due to additional phase factors) we obtain evidence for quantum interference to take place. *The masses of the baryons display the minimum contribution of a proton,* and an essentially sinusoidal additional dependence on *n*. In these cases the role played by the number of flux quanta is the same as in the case of closed circuits containing Josephson junctions. This gives support to the very initial assumption of this model, which was that *particles can theoretically be treated as loops of currents*.

Coming back to the remark made in the Introduction, the interpretation given to this parameter *n* *as a true number of flux quanta is supported by the results*, even considering that in this model *n* has been calculated straight from the product of the measured mass times magnetic moment in eq. (4). The whole set of ideas turns out internally consistent, and the data analysis eventually converges towards this new concept of quantum-interference in the femtometer scale of particles.

The actual kinds of constituents (quasiparticles) inside baryons are fully open to discussion. Geometrical constraints for currents, of SU(3) (or related) symmetry must indeed exist since coherence breaking interference requires something analogous to boundaries, and we indeed found evidence for interference. The constraints are part of the structure of the quasiparticles, as happens in solid-state theory with the electrons in motion inside solids. Within this picture it is not surprising that consituents do not manifest outside baryons, since the topological constraints would cease to exist. No constraints, no constituents. What the analysis actually shows about these consituents is that they are fully correlated structures, and manifest as currents due to unit-charged objects, which is in agreement with the ideas of Barut. However, the proposal of Barut of the *individual* existence and manifestation of muons, electrons and neutrinos inside the baryons has no quantitative support(at least) from our analysis(it seems the same might be stated about individual quarks). The dominance of n=3 among the particles might however indicate an averaging over the effects of three quarks.

Note that the hypothetical presence inside particles of isolated heavy muons (or otherwise, isolated quarks of different masses) would impose local changes in the baseline of Figures 2 and 3 for different baryons in the plot, which would reflect in a heavier scattering of data, and no sinusoidal relation between *m* and *n*. On the other hand, the presence of a proton proposed by Barut is consistent with our analysis, and the proton position on the diagonal line of Figure 1 serves to define a mass unit and a critical current from the direct relation between the magnetic moment of the proton and its confined magnetic flux.

Again, upon the decay or reaction of a baryon the topological constraints are gone and the particles and fields which result afterwards tell nothing about the previously existing situation.

Further theoretical work should determine the symmetry details for each individual baryon internal current paths, compatible with the representations of SU(3) spanned by each baryon.

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Table 1: Data for the baryon octet(moments μ from ref. [9]).

According to equation (4) in gaussian units, n= 1.16x10^{47} $\mu\, m$.

	abs μ (n.m.)	μ(erg/G) x 10^{23}	m(Mev/c^2)	m(g) x 10^{24}	n from eq.(4)
p	2.79	1.41	939	1.67	2.73
n	1.91	0.965	939	1.67	1.9
Σ^+	2.46	1.24	1189	2.12	3
Σ^0	0.82(theor.)	0.414	1192	2.12	1
Σ^-	1.16	0.586	1197	2.12	1.5
Ξ^0	1.25	0.631	1314	2.34	1.7
Ξ^-	0.65	0.328	1321	2.34	0.9
Λ	0.61	0.308	1116	1.98	0.7

Table 2: Data for the baryon decuplet (moments μ from ref. [9]). The average difference between the decuplet and octet particles masses is discounted as discussed in the text and the resulting mass is put in columns 4 and 5. According to equation (4) in gaussian units, n= $1.16\text{x}10^{47}\ \mu\, m$. The plot of $m_t\,/m$(proton) against n are shown in Figure 2, and in Figure 3 with the integer-n particles added..

	abs μ (n.m.)	μ(erg/G) x 10^{23}	m_t=m - 244 (Mev/c^2)	m_t(g) x 10^{24}	n from eq.(4)
Δ^{++}	4.52	2.28	986	1.75	4.64
Δ^{+}, Δ^{-}	2.81,2.81	1.42	990	1.75	2.9 , 2.9
Σ^{+}	3.09	1.56	1135	2.02	3.65
Σ^{0}	0.27	0.136	1136	2.02	0.32
Σ^{-}	2.54	1.28	1138	2.02	3
Ξ^{0}	0.55	0.28	1281	2.28	0.73
Ξ^{-}	2.25	1.14	1283	2.28	3
Ω^{-}	2.02	1.02	1428	2.54	3

Figure 1: Plot of n against the magnetic moment for the octet following eq (4) and Table 1. The diagonal line is the classical prediction of one flux quantum per nuclear magneton (n.m.). Nucleons are on the line. Horizontal (Shapiro-like) steps at integer values of n are shown. The data display undulations, and a tendency to reach for the steps (traced line as guide).

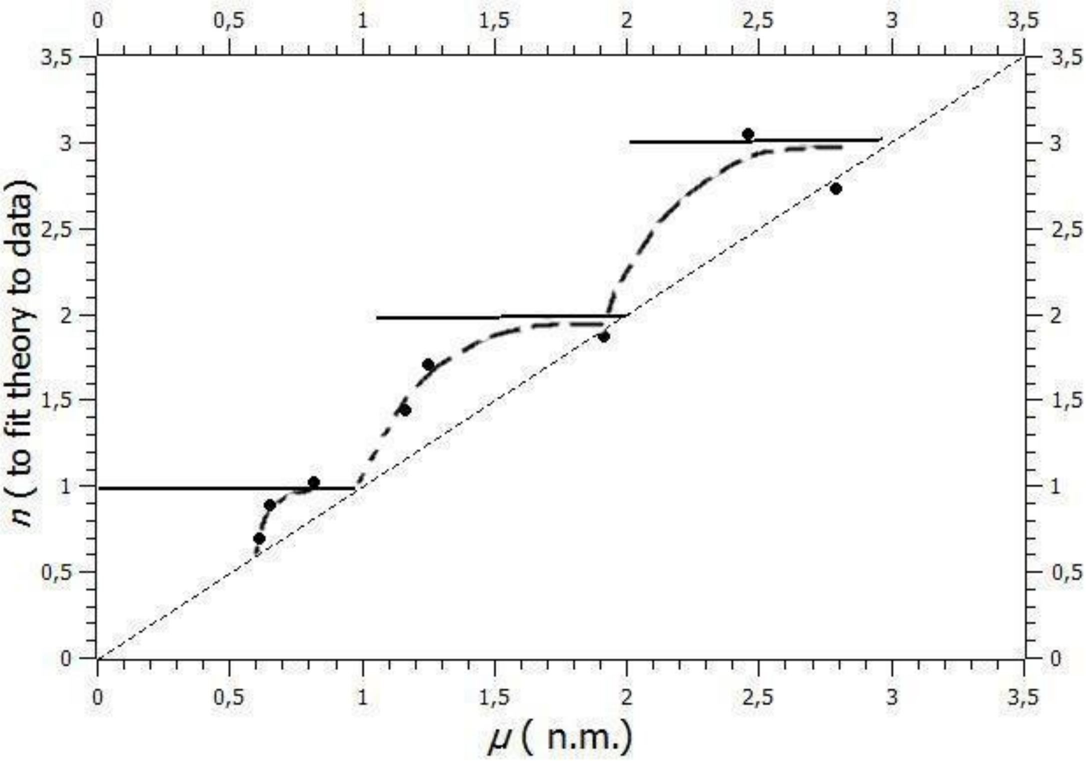

Figure 2: Plot of equation (7) with data from Tables 1 and 2 for octet (solid triangles) and decuplet particles (m_t used, open triangles). The θ variable was integrated for a symmetric range of values around zero to simulate a distribution of different coupling strengths and directions of flow. The full amplitude is 1/π= 0.31. The curve might be displaced sideways if an asymmetric range of θ is chosen. Nucleons are on the basis of the figure.

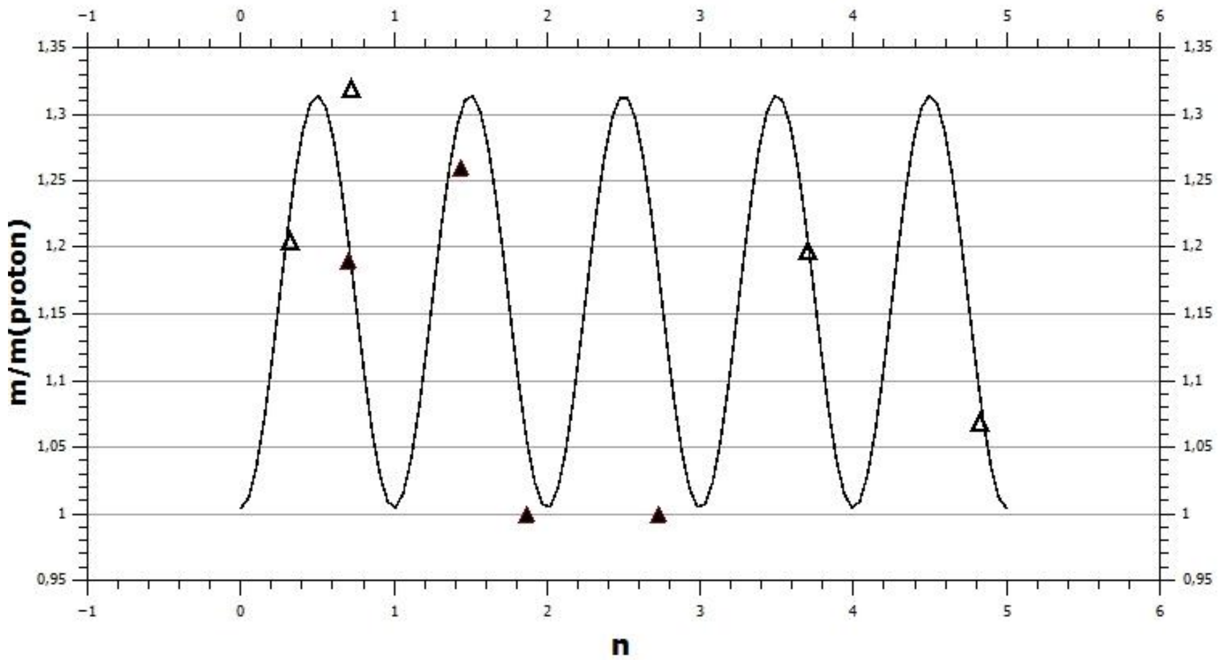

Figure 3: Similar to Figure 2 but with the inclusion of the baryons which fulfill the integer-*n* condition(cf. Tables). Triangles are octet particles and diamonds the decuplet particles. Dotted vertical lines indicate the integer values of *n*. Note the "spikes" at *n*=1 and 3. The upper isolated point at *n*= 1.7 might actually be associated with the *n*=2 dotted line.