Mass of baryons from self-magnetic fields energy: influence of flux quantization.

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Abstract

In previous papers the author has analyzed data for leptons and baryons which converges to the association of magnetic energy to the rest enegies of these particles. In this paper a crucial parameter in this model, the number of flux quanta *n* trapped inside the region covered by an intrinsic motion of a particle, is considered in detail. Strictly fitting theory to experiment for baryons results in fractionary *n* which lie close but deviate from the expected numbers from a classical calculation. We show that the data diaplay a tendency to form Shapiro-like steps at integer numbers of flux quanta, which seems at least in part responsible for the observed deviations from the classical prediction.

Introduction

In a series of papers [1-3] we have made a detailed analysis of existing theoretical and experimental data for the rest energies and magnetic moments of leptons and baryons. The analysis of these data has essentially been based upon the energy-mass relation originally proposed by Post in 1986[4](and independently adopted by this author in 2013 [2] through the analysis of a related problem). The model converges towards the "inverse alpha" dependence of mass reported by many authors in the past seventy years. As discussed in a recent paper, in the late 1970s Barut quantitatively obtained the inverse-alpha dependence for the leptons by considering a QED radiation-reaction term introduced in the Dirac equation for a lepton[5-7]. Barut´s proposal is physically quite clear: mass is a consequence of the kinetic energy stored in a confined region. Such confinement is classically associated to the motion under a central force produced by the interaction of the intrinsic magnetic moment with the self-magnetic field (this would be a classical picture adopted to represent the radiation-reaction field-theoretical terms). As discussed by London [8]such kinetic energy term is accompanied by a magnetic energy of same magnitude.

In our model the magnetic energy is conveniently expressed in terms of the current produced by a charge in its confined motion times the amount of magnetic flux confined inside this orbit. This is actually a quite pragmatic approach for the testing of the concepts since the magnetic moment, which is usually known for many particles[9], can be introduced in the phenomenological model, decreasing the level of arbitrariness frequently associated with other models of particles. In our previous papers [2] we argued about the imposition of magnetic flux quantization inside the orbit as a necessary condition related to gauge invariance of the particle wave function. Such condition is fullfilled by the electron and the muon but composite particles like the baryons might display non-integer numbers of *hc/e* flux quanta in view of averaging-effects over different possible spin configurations of the constituents. In previous papers we have attempted to adopt integer numbers of flux quanta in the analysis to keep consistency with such ideas. Scattering of the data around an average results from this approach. In fact, as shown in this paper, strictly fitting theory to experiment results in fractionary n which lie close but deviate from the expected numbers predicted from a classical calculation. We show that a tendency to form Shapiro-like steps at integer numbers of flux quanta is actually present in the data, and this seems to be a reason for the deviations from the classical prediction.

Our previous work begins with the concept of gauge invariance and consequent flux quantization associated with the zitterbewegung intrinsic motion of fundamental particles[2]. We then associated the magnetodynamic energy of the motion with the rest energy of a particle[2,4]. The main result of such phenomenological analysis was eq. (3) of [2]:

$$\frac{mR^2}{\mu} = \frac{nh}{2\pi ec}$$

As explained in [3], *R* can be taken proportional to μ. Inserting the definition for *R* into the above equation and using the definition of the fine structure constant alpha, $\alpha = e^2/\hbar c$, we can rewite it in the form:

$$\frac{2c^2\alpha}{ne^3}m = \frac{1}{\mu} \qquad (1)$$

It can immediately be noticed that if *n* and μ are proportional to each other, eq. (1) would produce an inverse dependence of *m* with the alpha constant, as reported in the literature.

Application to Leptons and Baryons

A.O.Barut [10] proposed an alternative theory for the inner constitution of baryons and mesons, in which the basic pieces would be the individual, *stable* unit-charge particles, namely the proton and the electron (and in addition, the neutrino). After so many years, evidence has accumulated in support of the quark model as far as the inner structure of baryons is concerned. However the fact that the decay products of baryons are unit-charge particles is an important result which is explored in the analysis that follows. Barut proposed also that the short range strong interactions between such internal constituents would be magnetic in nature. Although we do not develop such proposal in detail, the present model , whose main result is eq. (1), follows similar lines as the energies involved are magnetodynamic. The application of eq. (1) requires a quantum-theoretical method for a precise determination of the values of *n*, the number of flux quanta. Our analysis has shown that our predictions for mass for the octet particles can be made as precise as those obtained from perturbation calculations carried out using as part of the baryon hamiltonian the λ_8 generator of the (1,1) representation of SU(3), firstly adopted by Gell-Mann in 1961. As an alternative, there actually exists a semiclassical treatment that offers a way to deal with this issue[11]. Self-magnetic field effects produced by the intrinsic (spin) motion of a particle would impose also a simultaneous cyclotron rotation. Both effects taken together produce magnetic flux across the orbit, which leads to the conclusion that *one fundamental magneton (either Bohr´s, or leptonic, or nuclear) of magnetic moment produced by an elementary unit of charge is related to exactly one quantum of magnetic flux trapped inside the orbit*[11]. The derivation is valid for unit-charge leptons and the proton. That is, considering that *flux conservation* is followed in the decay of baryons, even in the absence of knowledge about how to impose flux quantization to quarks one might concentrate only on the unit- charged final products of the decay. From the standpoint of the present analysis this establishes a scaling criterion to convert the experimental values of the magnetic moment for particles (in nuclear or leptonic magneton units) into a number of flux quanta *n*. Following this classical calculation, this implies for the baryons that the ratio n/μ(n.m.)$\rightarrow 1$. Consistently with what is expected from [11], in Table 1 we notice that the magnetic moments for the baryon *octet* in the last column are ordered in almost integer, small numbers of nuclear magnetons. Considering that the magnetic moments should be proportional to the number of flux quanta trapped in the zitterbewegung motion, in Table 1 we take for *n* the integer or half-integer number which is closest to the observed magnetic moment in nuclear magneton units.

Analysis

Figure 1 shows the plot of eq.(1) and the straight solid line should be followed for a perfect agreement with theory. We observe that eq. (1) describes very well the data available for leptons (solid triangles) and the octet of baryons (circles) with the values of *n* in Table 1, but there exists some scattering around the line. In the present work we concentrate on the baryon octet only, and decided to check if it might be possible to make the masses calculated here accurate enough to comply with the Gell-Mann-Nishijima rules. This would require a judicious choice of values for the *n*. The following results are obtained for each of the eight particles in the form (particle, new *n*): (Λ, 0.75), (Σ+, 3.1), (Σ0, 0.9), (Σ-, no change), (Ξ0, 1.8), (Ξ–, 0.93), (n, 1.9), (p, 2.9).

Figure 2 shows the plot of the new *n* against the magnetic moments in n.m. units for each of the eight baryons. It seems evident the tendency for the number of flux quanta to assume integer numbers like in the famous Shapito steps of the Josephson Effect in superconductivity. The present analysis supplements that in ref. [1] as further demonstration of the accuracy with which the mass of particles can be described in terms of magnetic energies accounting for flux quantization inside a zitterbewegung orbit, showing that both leptons and baryons masses can be treated in similar theoretical terms.

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Table 1: Data utilized in Figure 1. The values of *n* are chosen as the integer or half-integer numbers that follow as close as possible the (apparent !) sequence in the last column for the baryons, in order to fit theory to data. The magnetic moments are from ref. [9]. One needs to convert mass to grams, magnetic moments to erg/gauss (all CGS units).

part	Rest energy(MeV)	n	(Abs)Magnetic moment(n.m.)
e	0.511	1	1836
muon	105.66	1	8.89
p	938.27	3	2.79
n	939.56	2	1.91
Σ +	1189	2.5	2.46
Σ 0	1192	1	~0.7(theor.)
Σ −	1197	1.5	1.16
Ξ 0	1314	1.5	1.25
Ξ −	1321	1	0.65
Λ	1116	0.5	0.61

Figure 1: Plot of eq. (1). The dotted lines indicate a factor of 2 around the solid line. Triangles are leptons and circles are baryons.

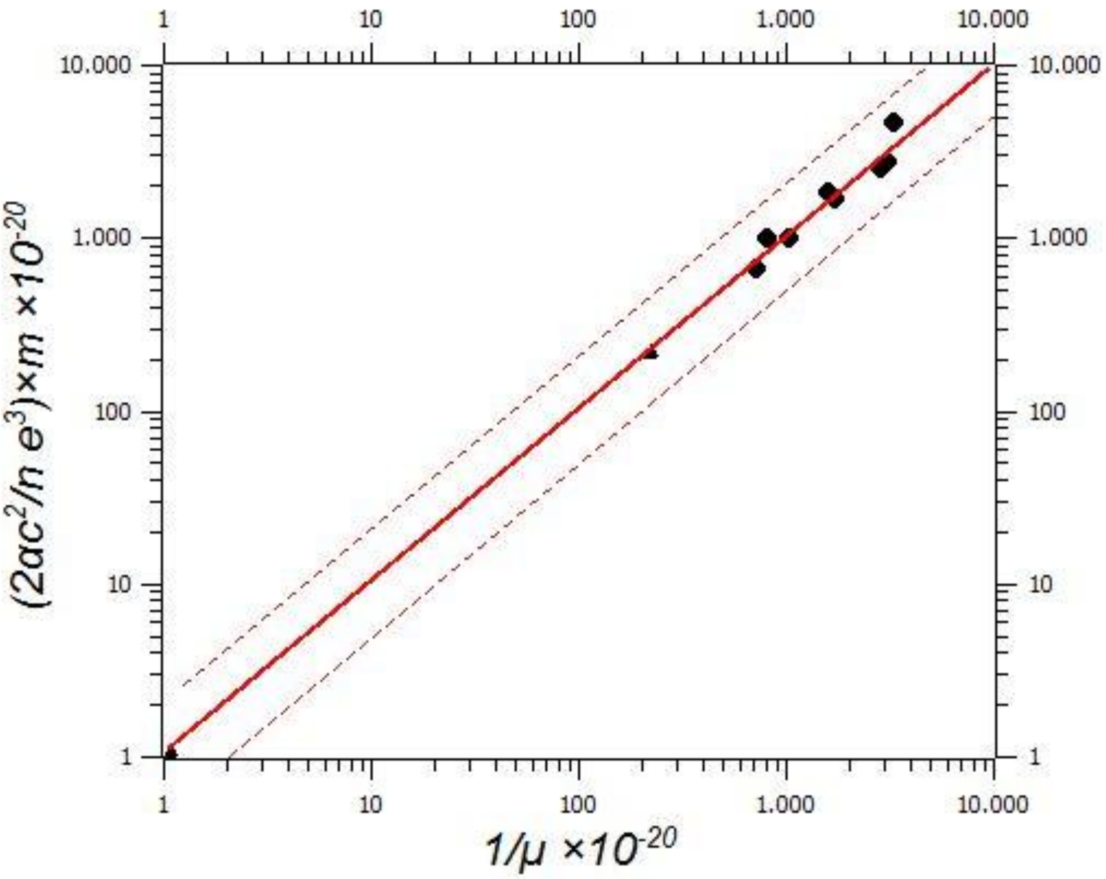

Figure 2: In this figure the slightly altered new values of *n* (see text) are chosen to make the mass values fit the experimental ones with almost perfect accuracy. The solid diagonal line indicates agreement with the n/μ =1 classical prediction from [11]. The traced line is a guide to the eye. The horizontal steps at integer numbers of flux quanta are closely followed by the adapted *n* suggesting a strong resemblance with the Shapiro steps due to flux quantization in the case of superconductor Josephson junctions.