A unified phenomenological description for the magnetodynamic origin of mass for leptons and for the complete baryon octet and decuplet.

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Abstract

The masses of the leptons and baryons are shown to be quantitatively described in terms of magnetodynamic energies considering as a fundamental feature the quantization of magnetic flux inside a zitterbewegung motion " orbit" performed by each particle in consequence of its interaction with the vacuum background(as proposed decades ago by Barut, Jehle, and Post). As a further proof in support of the soundness of the method, we present a plot of mass against magnetic moment in which the data for the spin-3/2 decuplet particles are shifted from the data for the spin-1/2 octet by the exact numerical factor predicted from the square root of the ratio between their spin angular momenta.

Introduction

Several authors have reported the dependence of the rest masses of particles upon the inverse of the alpha constant. Barut was able to associate such behavior with magnetic self-energy effects in the case of leptons[1]. The present author has taken account of magnetic energy effects phenomenologically[2], in a way similar to that adopted by Post many years ago[3]. This paper presents the extension of the approach to the full baryon octet and decuplet, and the inverse dependence with alpha is obtained. The masses of all these particles are shown to be described in terms of magnetodynamic energies considering as a fundamental feature the quantization of magnetic flux inside a zitterbewegung motion " orbit" performed by each particle in consequence of its interaction with the vacuum background(Jehle[4] proposed flux quantization inside zitterbewegung orbits of particles as early as 1967).

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

$$\frac{mR^2}{\mu} = \frac{nh}{2\pi ec} \tag{1}$$

In this equation *m* is mass, *R* is the range of the vibrational-rotational intrinsic motion of the particle, μ is the magnetic moment, *n* is the number of magnetic flux quanta trapped inside the motion(admitted as given by the nonrelativistic expression *hc/e*). The model adopts experimental values for *m* and μ. For the nucleons *R* was given by theoretical values calculated by Miller[5], and for the electron (and the muon) this parameter was assumed as equal to the Compton wavelength $\lambda = \hbar/mc$[6]. Good agreement between model and experiment was obtained for that reduced group of particles.

However, the extension of the model to other particles depends on the knowledge of the parameter *R*. In order to put the model to further test, in the present work we decided to simply try and eliminate the explicit dependence of the model upon *R*. For the leptons the following expression is known to be valid:

$$\mu = e\lambda/2 \tag{2}$$

Here $\mu = \mu_B$ is the magnetic moment in the case of the electron (μ_B is the Bohr magneton). Therefore, for the leptons and for the baryons considered in this work we will *assume* that in (2) $\lambda/\sqrt{2}$ can be directly replaced by *R*, so that *R* is eliminated from (1) in favor of μ (the scaling factor $1/\sqrt{2}$ to be applied here is rather arbitrary, but within the expected magnitude of 0.5 ~2) . It is clear that with this assumption the model associates mass to only two parameters, namely, to the number of flux quanta imposed by gauge invariance conditions and the charges of the constituents inside the baryons, and to the inverse of the experimental magnetic moment.

Inserting the definion for *R* into (1) and using the definition of the fine structure constant alpha, $\alpha = e^2/\hbar c$, we can rewite (1) in the form:

$$\frac{2c^2\alpha}{ne^3} m = \frac{1}{\mu} \tag{3}$$

It can immediately be noticed that if *n* and μ are proportional to each other, eq. (3) would produce an inverse dependence of *m* with the alpha constant, as reported in the literature. In the next section eq. (3) is applied to 19 particles with quantitative success.

Application to Leptons and Baryons

A.O.Barut [7,8] proposed an alternative theory for the inner constitution of baryons and mesons, in which the basic pieces would be the individual, *stable* particles, namely the proton p, the electron e^-, and the neutrino ν(ν'will indicate antineutrinos, below), rather than quarks with fractionary charges which do not manifest themselves externally as individual entities. The muon μ^- would also be included and considered responsible for effects usually denoted as "strangeness". Barut proposed also that the short range strong interactions between such internal constituents would be magnetic in nature. In order to account for the same conservation rules as a model based upon the fractionary quarks does, the constitution of the baryon octet, for instance, should be as follows[7,8]: proton =p= (p e^- e^+), neutron=n= (p e^- ν'), Σ^- =(p e^- μ^- ν' ν'), Σ^0 =(p μ^- ν'), Σ^+ =(p e^+ μ^-), Ξ^- =(p μ^- μ^- ν ν'), Ξ^0 =(p μ^- μ^- e^+ ν'), Λ =(p μ^- ν ν'). We see that the proton is present in all these baryons but is itself a composite particle, supposedly containing an electron and a positron. Our interest on Barut´s ideas is related to the concept that baryons are formed by individual particles inside them as opposite to the quarks which do not manifest themselves individualy.

As shown below, our recently proposed model (which assumes particles inside the baryons can be considered individually[2]) can be applied to the baryons octet and decuplet with almost perfect accuracy through eqs. (1)-(3). However, a quantum-theoretical method for a precise determination of the values of *n*, the number of flux quanta in (3), still has to be developed. The strict determination of these numbers would require the knowledge of the proper topological properties of each baryon and how to sum individual contributions from its constituents. Relativistic effects if relevant would certainly also have an effect on these numbers, which might even be half-integers. A previous attempt, in a model that also related particles to zitterbewegung was proposed by Jehle[4], associating particles to the topology of torus knots. Instead of a single *n* Jehle associates flux quantization to a complicated combination of winding and whirling numbers.

However, there actually exists a semiclassical treatment that offers a way to deal with this issue[9]. Self-magnetic field effects would impose a cyclotron rotation to a particle, superimposed to its intrinsic(spin) rotation, and both effects taken together lead to the conclusion that *one fundamental magneton (either Bohr´s, or nuclear) produced by the self-field is related to exactly one quantum of magnetic flux trapped inside the orbit*[9]. 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 Bohr magneton units) into a number of flux quanta *n*. Ideally, this implies that the ratio n/μ(n.m.)$\rightarrow 1$. Consistently with what is expected from [9], 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, we take for *n* the integer or half-integer number which is closest to the observed magnetic moment in nuclear magneton units. The results for the leptons and baryon octet are displayed in Table 1 and we immediately notice that the ratio n/μ is approximately the same for all baryons. All the magnetic moment data for the baryons (octet and decuplet) come from [10]. Table 2 presents the data for the baryon decuplet particles.

Analysis: The Effect of Spin in Mass Determination.

Figure 1 shows the plot of eq.(3) and the lower straight solid line indicates perfect agreement with theory. We observe that Equation (3) describes very well the data available for leptons (solid triangles) and the octet of baryons (circles) with the values of *n* in Table 1. Relativistic corrections are apparently very similar (or absent)for all these spin-1/2 particles. When we plot the data for the decuplet (open triangles) we notice a quite revealing shift of the points parallel to the lower straight line by a factor of 1.7. This is a very important result, which gives further proof of the soundness of the present ideas. The baryons of the decuplet are spin-3/2 particles. The spin angular momentum is given by the product of the frequency of rotation times the moment of inertia of the particle(such picture persists even in a detailed field-theoretical treatment of the zitterbewegung rotation; see [6]). In this case the frequency is the zitterbewegung rotation frequency which is proportional to mass, while the moment of inertia is proportional to the mass and to R^2. One immediately concludes that for the same value of mass, the ratio between the values of R^2 for the octet and the decuplet particles is proportional to 1/3. Therefore, from eq. (2) and the text that follows it , since R is proportional to the moment μ, a shift of the double-logarithmic plots of magnitude $\sqrt{3}=1.73$ at constant m for different values of $1/\mu$ (with the octet line ahead) is expected, which is exactly what is obtained in the Figure.

One notices also that there are (neutral) particles which have very small magnetic moments in nuclear magneton units (Λ, and $\Sigma^0(J = 3/2)$, for instance) and are difficult to analyze with the simple assumption of taking integer or half-integer numbers of flux quanta. In this case we simply took the limit $n/\mu(\text{n.m.}) \rightarrow 1$, following [9]. It must be pointed out that the data for the magnetic moments for the decuplet are theoretical and vary according to the parameters adopted in the calculations [10]. In reality this entire analysis is developed with a single adjustable parameter, which can be considered as the factor relating R and λ .

The influence of topology(introduced through the concepts of flux quantization and gauge invariance) is evident in view of the importance of the sequence of values for *n* in the Tables, and their association with the actual magnetic moment data, which can only be interpreted in such geometrical terms.

There exists a wealth of references in the literature in which scaling laws are proposed based[11-13] on experimental results, to associate mass for all particles with the inverse of α. We see from eq. (3) and Figure 1 that such relation with α indeed is part of our results, since following [9] the ratio n/μ is essentially the same for all baryons. In particular, the analysis in ref. [13] might probably be reproduced if the ratio n/μ in (3) is made part of the *free* parameter N in ref. [13].

Conclusions

In resume, this paper has shown that if one properly inserts quantum conditions in a closed-orbit intrinsic zitterbewegung motion for the fundamental particles (even in a nonrelativistic limit), in order that gauge invariance is introduced in the treatment, the masses for these particles are directly dependent only upon the inverse of their magnetic moments and upon the number of magnetic flux quanta inside the zitterbewegung orbits. The shift between the plots for the decuplet as compared to the octet of baryons can be quantitatively attributed to the greater spin. The analysis in this paper reinforces the perception that geometrical or topological effects dominate the problem of mass determination, and thus the consideration of magnetic effects in the subnuclear scale is essential, as proposed by Barut, and Jehle, among others.

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Table 1: Data utilized in Figure 1 for leptons and the <u>octet</u> of baryons. Following [9], the values of *n* are chosen as the integer or half-integer numbers that follow as close as possible the sequence in the last column for the baryons, in order to fit theory to data. The (experimental) magnetic moments are from ref. [10]. 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
$\Sigma+$	1189	2.5	2.46
$\Sigma 0$	1192	1	~0.7(theor.)
$\Sigma-$	1197	1.5	1.16
$\Xi 0$	1314	1.5	1.25
$\Xi-$	1321	1	0.65
Λ	1116	0.61*	0.61

(*) In the case of Λ the magnetic moment was considered sufficiently small to simply make $n = \mu$ (n.m.) in order to simulate the limit when both n and $\mu \to 0$ keeping their proportionality[9].

Table 2: Data utilized in Figure 1 for the decuplet of baryons. Following [9], the values of *n* are chosen as the integer or half-integer numbers that follow as close as possible the sequence in the last column, in order to fit theory to data. The magnetic moments are from ref. [10](only the first and last are experimental results; the remaining are calculated). The Δ^0 particle is not included since its (theoretical) moment is zero. 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.)
Δ++	1230	4.5	4.52
Δ+	1234	2.5	2.81
Δ−	1237	2.5	2.81
Σ +	1379	2.5	3.09
Σ 0	1380	0.5	0.27
Σ −	1382	2.5	2.54
Ξ 0	1525	0.5	0.55
Ξ −	1527	2	2.26
Ω −	1672	2	2.02

Figure 1: Plot of eq. (3). Solid triangles are leptons, solid circles represent the baryon octet, and open triangles the decuplet. The upper line is a factor of 1.7 above the lower line, which corresponds to perfect agreement with eq. (3). This shift is attributed to the ratio 3 between the spin of the decuplet and octet particles, which shifts the horizontal scales for each plot by a factor of √3 (see text).