A unified phenomenological description for the origin of mass for leptons and for the complete baryon octet and decuplet, including the reported inverse dependence upon the alpha constant.

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Abstract

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. The present author has taken account of magnetic energy effects phenomenologically, in a way similar to the adopted by E. Post many years ago. 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.

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 intrinsic motion of the particle, μ is the magnetic moment, *n* is the number of magnetic flux quanta(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 application 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:

$$\mu = e\lambda/2 \qquad (2)$$

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 to be applied here is rather arbitrary, but of order 0.5 ~2) . It is clear that such possiblity associates mass to only two parameters, namely, 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:

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

It can immediately be noticed that *n* and μ should in principle be directly associated with each other, which would produce an inverse dependence of *m* with the alpha constant, as reported in the literature

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 physically 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 $'\nu'$), Ξ^0 =(p μ^- μ^- e^+ ν $'$), Λ =(p μ^- ν ν $'\nu'$). We see that the proton is present in all these baryons but is itself a composite particle, supposedly containing an electron and a positron. The analysis below shows that assuming Barut´s ideas are correct, our recently proposed model (which assumes particles inside the baryons can be considered individually[2]) can also be applied to the baryons octet and decuplet with almost perfect accuracy. However, the 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 relates 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 points a way ahead[9]. Self-magnetic field effects would impose a cyclotron precession superimposed to the strinsic(spin) rotation of the electron, and both effects taken together lead to the conclusion that *a fundamental magneton (either Bohr´s, or nuclear) is related to exactly one quantum of magnetic flux*[9]. From the standpoint of the present analysis this establishes a scaling law to convert the values of the magnetic moment for particles (in nuclear or Bohr magneton units) into a number of flux quanta *n*. In Table 1 we notice that the magnetic moments for the baryon *octet* in the last column are almost perfectly ordered in 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 adopted the following procedure. We take for *n* the integer or half-integer number which is closest to the observed magnetic moment in nuclear magneton units. The results are 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] but the data and data analysis for the decuplet are *only shown* in Figure 1.

Analysis

Figure 1 shows the plot of eq.(3) and the straight solid line would indicate perfect agreement with theory. We observe that Equation (3) describes very well the data available for leptons (triangles) and the octet of baryons (circles) with the values of *n* in Table 1. The same procedure was applied to the decuplet (open triangles) and we notice a (not unexpected !) shift of the points parallel to the straight line of a factor of 1.7. The fact that the shift is parallel indicates the model remains sound for these particles. This factor lies within the uncertainties in the value of R, as well as other factors mentioned in the previous section. However the data for the decuplet are theoretical and vary according to the parameters adopted in the calculation [10]. The present analysis has a precision compatible with the accuracy of the data available!

The influence of topology(introduced through the concepts of flux quantization and gauge invariance) is evident in view of the importance of the empirical sequence of values for n in Table1, and their clear 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 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 orbits. This demonstrates the influence of geometrical or topological effects on the problem of mass determination.

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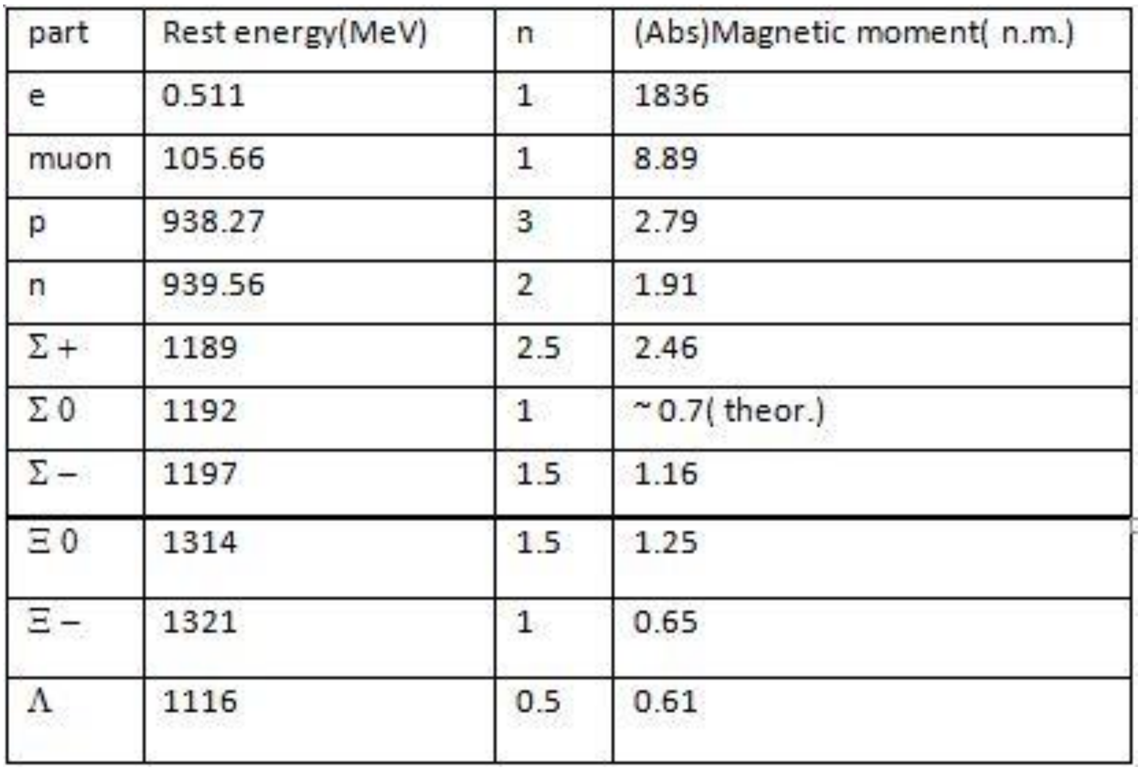
Table 1: Data utilized in Figure 1 for leptons and the octet of baryons. Following [9], the values of *n* are chosen as the integer or half-integer numbers that follow as close as possible the sequence in the last column for the baryons, in order to fit theory to data. The magnetic moments are from ref. [10]. Data for the decuplet are also tabled in [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
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. (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).