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On the structure, mass and thermodynamics of the Z^o bosons

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HIGHLIGHTS

- The mass of gravitationally bound rotational e^+–ν–e^- states is that of Z bosons.
- The Z boson is apparently a relativistic rotational e^+–ν–e^- structure.
- The gravitational Bohr type analysis uses SR and has no adjustable parameters.
- Gravitational and Coulombic forces suffice to model hadrons and bosons.

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ABSTRACT

In a recent work we have shown that the mass of $W^\pm$ bosons can be computed from first principles by modeling these bosons as relativistic rotational bound states consisting of $e^\pm$–ν_e pairs, and by employing the de Broglie wavelength equation together with Newton's universal gravitational law but with gravitational instead of rest masses (Vayenas et al., 2016). Here, we present similar calculations for the Z^o boson which we model as a bound state of e^+–ν_e–e^- with an electron antineutrino at the center of the rotating ring. This appears consistent with the fact that Z^o bosons are known to decay primarily to e^+–e^- pairs. The above models contain no adjustable parameters. The computed Z^o boson mass (91.72 GeV/c^2), as well as the ratio of the masses of Z^o and $W^\pm$ bosons, differ by less than 0.6% and 0.9% respectively from the experimental values.

1. Introduction

In the Standard Model the $W^\pm$ and Z^o bosons mediate the Weak Interaction. Their masses are 80.42 GeV/c^2 and 91.19 GeV/c^2 respectively, i.e. two orders of magnitude larger than those of baryons ($\sim$1 GeV/c^2) and five orders of magnitude larger than the masses of positrons and electrons ($\sim$0.511 MeV/c^2). The W^+ and W^- bosons are known to decay to e^+–ν_e and e^-–ν_e pairs respectively [1,2]. The Z^o bosons are known to decay primarily to e^+–e^- pairs, but also to μ^+–μ^-, τ^+–τ^- and q–$\bar{q}$ pairs, the latter leading to the formation of hadrons [1,2].

After the discovery of neutrino oscillations [3,4], it has been established that neutrinos have nonzero rest masses, which for electron neutrinos are extremely small, of the order of 0.1 eV [5,6]. However, it is easy to show that if one uses gravitational masses in Newton's gravitational law [7,8], then the gravitational interactions between highly energetic relativistic neutrinos can be quite strong [7,8], as anticipated from Wheeler's analysis of neutrino geons [9].

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The idea that hadrons may be viewed as microscopic black holes [10,11], where gravitational collapse is prevented by the uncertainty principle, has been discussed recently in Refs. [12,13]. The use of Bohr-type models to establish a link between black holes and quantum gravity has also been discussed recently in Refs. [14,15].

In a series of papers [7,8,16,17] we have shown that when accounting for the equivalence principle of inertial and gravitational mass ($m_i = m_g$) [18,19], and for the inertial mass dependence on the rest mass m_o and the Lorentz factor γ via the expression $m_i = \gamma^3 m_o$, which was originally derived by Einstein for linear motion in Ref. [20] and was recently shown to hold also for arbitrary motion in Ref. [8], then Newton's universal gravitational law takes the following form:

$$F = \frac{Gm_{g,1}m_{g,2}}{r^2} = \frac{Gm_{1,0}m_{2,0}\gamma_1^3\gamma_2^3}{r^2}, \tag{1}$$

which for $m_{1,0} = m_{2,0} = m_0$ and $\gamma_1 = \gamma_2$ reduces to

$$F = \frac{Gm_o^2\gamma^6}{r^2}. \tag{2}$$

This equation has been used by the authors and others in a simple three or two-rotating neutrino Bohr-type model [7,8] to show that the resulting gravitationally confined structures have masses of the order of 1 GeV. For the case of three rotating particles the mass of the resulting bound state is given by [16]

$$m = 3^{13/12} n_B^2 (2\ell_B + 1)^{1/6} m_{Pl}^{1/3} m_o^{2/3}, \tag{3}$$

where n_B is a positive integer $(1, 2, \ldots)$, ℓ_B is zero or a positive integer $(0, 1, 2, 3, \ldots)$ and

$$m_{Pl} = \left(\frac{\hbar c}{G}\right)^{1/2}, \tag{4}$$

is the Planck mass.

The masses computed from Eqs. (3) are of the order of the masses of hadrons. This result has also been confirmed via the use of Schwarzschild geodesics of general relativity (GR) [8].

A similar equation has been used very recently to compute the masses of W$^\pm$ bosons, modeled as relativistic $e^\pm$–ν_e pairs [21]. The resulting equation

$$m_{W^\pm} = (2m_{Pl}m_e m_\nu)^{1/3} = 81.71\ \mathrm{GeV/c^2}, \tag{5}$$

is in very good agreement with the experimental value of 80.42 GeV/c^2 [1,2].

It is interesting to note that the good agreement between the relativistic gravitational Newtonian Law of Eq. (1) and general relativity (GR) holds not only for *fm* size systems, such as hadrons, but also for macroscopic planetary systems, where the perihelion precession angle of Mercury computed from Eq. (1) is found to coincide with that predicted by GR [22,23], in qualitative agreement with the results of the semiempirical special relativistic (SR) approach of Silberstein back in 1917 [24].

It is also worth noting that the relativistic gravitational Newtonian Law of Eqs. (1) and (2) provides a simple explanation for dark matter, since omitting the Lorentz factors γ_1^3 and γ_2^3 terms leads to an underestimation of the actual gravitational attraction between stars and between galaxies which leads to the need of postulating the existence of dark matter [7].

The remarkable ability of models of relativistic neutrinos, as well as of other fast particles, to produce bound rotational states with rest masses which are many orders of magnitude larger than the rest mass of the constituent particles, is simply due to energy conservation.

For example, denoting by γ_3 $(= (1 - \mathrm{v}^2/c^2)^{-1/2})$ the Lorentz factor of a neutrino in a rotating three-neutrino system, whose center of mass is at rest with respect to the observer, we find

$$E = mc^2 = 3\gamma_3 m_o c^2, \tag{6}$$

where m is the mass of the composite system, thus

$$m = 3\gamma_3 m_o. \tag{7}$$

The value of γ_3 for the three-particle Bohr-type model turns out to be [7,8,16]

$$\gamma_3 = 3^{1/12} n_B^2 (2\ell_B + 1)^{1/6} m_{Pl}^{1/3} / m_o^{1/3}, \tag{8}$$

thus, via (7) one obtains Eq. (3), where the non-negative integer ℓ_B is analogous to the second quantum number in the Bohr model of the H atom. In earlier studies [7,8] we had used in Eqs. (3) and (8) the notation $2n - 1$ with n a positive integer instead of $2\ell_B + 1$. Here, we use the symbol $\ell_B = n - 1$, which is consistent with the notation of ℓ for the quantum number of the H atom, which similarly with our analysis, provides a measure of the angular momentum of the state of the system. The symbol n_B (where "B" stands for Bohr) is reserved for another quantum number which plays a role similar to that of the