The Structure and Properties of Elementary Particles

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Abstract

We have developed simple models of the elementary particles based on the assumption that the particle interior is influenced by just two force fields, gravity and electrostatics. The fundamental particles are electrons, positrons, neutrinos and photons. All the other elementary particles are composed of these fundamental entities. A semi-classical approach is used to obtain simple expressions that give properties all in good agreement with experimental results. This approach is able to make several predictions. For example:

- All the elementary particles are composed of the particles they decay into.
- All particles are made of matter. There is no antimatter.
- The muon is not point-like. It is a composite particle with internal structure.
- Neutrinos have a small quantity of mass and charge.
- The neutron also has a small charge determined by the charge of its neutrino.
- A particle's lifetime is determined by its size relative to its Schwarzschild radius.
- Single protons should be produced in electron-positron collisions below the two-proton energy threshold.

1 Introduction

One of the most basic questions in particle physics is: what are protons (and other particles) composed of?

The analysis of deep-inelastic electron-proton and electron-deuteron scattering data indicates that there is at least one small, charged scattering centre inside the proton and the neutron[1]. Feynman named these point-like particles partons [2] and the name has stuck. So, the current view is that protons (and neutrons, etc.) are composed of partons and that there are negatively and positively charged partons plus neutral partons. But what are partons?

The Standard Model of particle physics assumes that partons are small, fractionally-charged negative and positive particles with spin half called quarks, and neutral field particles with spin one called gluons. The fractional charge is either one-third or two-thirds of the electron or positron charge. The quark model had a lot of success decades ago in describing the static symmetry properties of elementary particles, but no direct experimental evidence has ever been found to prove that quarks are real particles that might be observed in a particle detector, such as a tracking device or a vertex detector. Indeed, some of the experimental results that are claimed to support the notion that partons are quarks are in direct contradiction with other experimental results for which the same claims are made [3]. Perhaps the most damning indictment against the Standard Model assumption is that it does not allow the calculation, from first principles, of any elementary particle properties such as mass and lifetime. In addition, it is known that the electron charge is, to within one part in 10^{21} [4], exactly equal in magnitude to the proton charge. Why this should be is unexplained in the Standard Model. In other words, there is no known reason why quarks should have exactly two-thirds and one-third of the electron charge magnitude since electrons and quarks have no known charge relationship. Spin is another problem. An experimental study of the proton spin, using muons as probes, led to a "spin crisis" three decades ago when results showed that the proton spin is not equal to the sum of the quark spins [5]. To the best of our knowledge this has never been convincingly and rigorously explained within the framework of the Standard Model.

It has been known for almost sixty years that, when a proton and an antiproton annihilate each other, after all the unstable particles have decayed away, the end-products are always electrons, positrons and neutrinos (with occasionally a photon or two). There is, therefore, a good logical reason to assume that the partons are electrons, positrons, neutrinos and photons and this paper discusses the consequences on elementary particle structure of making this assumption. We show in the following sections that not only are we able to calculate elementary particle properties, but all of the Standard Model issues noted above are avoided.

In our nomenclature, electrons, positrons, neutrinos and photons are point-like objects and we refer to them as fundamental particles. All other particles are composite objects with a measurable internal structure and we refer to them as elementary particles.

For the fundamental particles we use a static self-mass approach. We assume that there are only two force fields in nature. These are gravitation and electrostatics. Both vary geometrically and inside the fundamental particles are in exact balance.

For a composite particle our approach is simple and straightforward. The first step is to identify the constituents. We assume that a particle is composed of the fundamental particles it decays into; the constituents are the decay products. We identify the simplest possible model using these constituents and then use an effective mass calculation plus an orbital constraint to derive the particle mass in terms of the constituent radii. Finally we calculate the strength of the attractive force that binds the constituents together.

If possible we derive an equation of motion or a static self-mass relationship to give the field strength. If that approach is not possible we use our hypothesised stability condition. This states that, for an unstable particle, the orbital radius of the outer constituent is at least 1.5 times the particle Schwarzschild radius, R_S. This factor of 1.5 originates in the observation that massless particles orbit at a radius of 1.5 R_S from a Schwarzschild black hole [6]. We note that in our neutron model, this factor is calculated rather than assumed and is equal to 2.1. Therefore the factor of 1.5 is likely to be an underestimate.

We start in section 2 with a discussion of a model of the proton that is based on its measured internal charge distribution. The model assumes an orbital structure similar to that of the Bohr hydrogen atom model and uses the effective mass of the constituents to calculate the proton mass. Since the internal charge distribution of the neutron has also been determined experimentally, we are able to construct a similar orbital model of the neutron and this is presented in section 3.

After discussing these composite elementary particles (proton and neutron), we turn our attention to the point-like electrons, positrons and neutrinos. These are described in section 4 by a model that uses a static self-mass calculation to obtain an expression for the particle mass.

All of these particle models involve a very strong internal attractive force that is consistent with a very strong form of gravity. We obtain estimates of the strength of this field and use semi-classical arguments to provide an interesting way to investigate particle stability. We find that we can explain the lifetime of the neutron and predict the proton lifetime. This is discussed in section 5.

The Standard Model assumes that the muon is a point-like particle. We assume that the muon is a composite particle and our muon model is similar to the proton model. This is described in section 6. We follow the muon discussion with a similar discussion of the pions in section 7.

In section 8 we turn our attention to the strong, attractive force that is responsible for maintaining the internal structure of these particles. It is a central force that is proportional to the particle masses and inversely proportional to the distance-squared between them. It could be a new, strong nuclear force that behaves like gravity. Rather than inventing a new fundamental force field, it is more logical to assume that it is gravity, albeit with a much larger proportionality constant. In this paper we refer to it as gravity and assume that is what it is.

Finally, in section 9 we turn our attention to spin and magnetic moments and end, in section 10, with conclusions, comments and predictions.

Some of the material in this paper has been described elsewhere [3, 7, 8, 9, 10, 11, 12]

2 The Proton

The simplest assumption that we can make is that the proton is composed of two positrons and an electron. The proton system is held together by a strong, attractive force. There is also a weak attractive electrostatic force between the electron and the positrons and a weak repulsive electrostatic force between the positrons. These have some effect on the proton internal structure, but they are too weak to have any effect on the detailed calculations presented below.

We assume that the strong attractive force between two partons is proportional to the product of their masses using either rest mass or relativistic mass. The electrostatic force is proportional to the product of their charges.

We emphasise that there are only two static force fields for which there is direct experimental evidence and that we are therefore sure exist in nature. These are gravitation and electrostatics and in both cases the force between two objects is inversely proportional to the distance between them squared. That is, the forces are geometrical. So, we assume that the forces between the constituents inside the proton exhibit the same $1/R^2$ behaviour. One of these is the usual electrostatic force acting on the parton charges. The other force acts on the parton masses and we refer to it as gravity.

The simplest and most likely topology for the proton internal structure is two positrons in orbit around a central electron. Electrostatic repulsion will cause the positrons to be on opposite sides of the electron. That is, the electron is "dressed up" with two positrons, and the resulting three-body system resembles a stick that is rotating close to the relativistic limit. It is a natural feature of this model that the proton charge magnitude is exactly equal to the electron charge magnitude.

For each positron, the de Broglie wavelength is given by $\lambda = h/p_e = n2\pi R$, where R is the radius of the positron orbit, h is the Planck constant and p_e is the positron momentum. The constant n gives the number of wavelengths that fit into the positron orbit. We assume $n = 1$.

So, rearranging, $p_e R = \hbar$, where $\hbar = h/2\pi$. But, p_e may be written $p_e = \gamma m_e v$, so the orbit equation becomes $\gamma m_e v R = \hbar$.

The charge distribution inside the proton has been determined experimentally [13, 14, 15]. It is zero at $R = 0$ fm, rises to a maximum at $R \sim 0.4$ fm and tails off to zero at $R \sim 1.5$ fm. Experimental uncertainty is typically a few %. We have fitted this distribution to a normalized sum of three gaussian line shapes, representing the electron and two positrons. We obtain best fit values of:

$$R(e^-) = 0.0 \text{ fm}, \quad \sigma(\mathrm{e}^-) = 0.56 \text{ fm}, \quad \mathrm{R}(\mathrm{e}^+) = 0.421 \text{ fm}, \quad \sigma(\mathrm{e}^+) = 0.43 \text{ fm}. \tag{1}$$

Note that, for the sake of simplicity (and symmetry), we assume that both positrons have the same value of R and σ. We have also performed fits in which we allow the two positrons to have slightly different values of R, so long as they are consistent with the proton charge distribution. All of the following points remain valid.

The mass of the proton (m_p) may be obtained by calculating the effective mass of the electron plus two positrons, giving:

$$m_p = m_e + 2\gamma m_e = m_e + \frac{2\hbar}{vR}. \tag{2}$$

Entering the values for m_p and m_e from [4] we get, $\gamma \sim 1000$ and $v \sim c$ (to within 1 part in 10^6. Therefore:

$$m_p = m_e + \frac{2\hbar}{cR}. \tag{3}$$

With $R = 0.421 \pm 0.004$ fm the calculated proton mass is 938 ± 10 MeV/c^2. Alternatively, since the proton mass is better determined than R, we may use the known proton mass to obtain a value for the positron orbital radius. We obtain $R = 0.420847021$ fm with a tiny uncertainty.

A simple equation-of-motion for either positron is given by equating the centripetal force to the sum of the gravitational and electrostatic central forces:

$$\frac{\gamma m_e v^2}{R} = \frac{G_0 \gamma m_e^2}{R^2} + \frac{G_0 \gamma^2 m_e^2}{4R^2} + \frac{k_0 e^2}{R^2} - \frac{k_0 e^2}{4R^2}. \tag{4}$$

In these equations, m_e is the positron (or electron) rest mass, e its charge, v is the orbital speed of either positron and $\gamma^{-1} = \sqrt{(1 - v^2/c^2)}$, where c is the speed of light *in vacuo*. The factor G_0 gives the strength of the attractive gravitational forces and k_0 the strength of the electrostatic forces. As discussed later, in section 8, G_0 might be a constant or it might be a function of R.

The much smaller electrostatic forces may be ignored and, as already noted, $\gamma \sim 1000$ and $v \sim c$, so we may ignore the first term on the right-hand side of equation (4) and:

$$\frac{\gamma m_e v^2}{R} = \frac{G_0 \gamma^2 m_e^2}{4R^2}, \tag{5}$$

or:

$$G_0 = \frac{4Rc^2}{\gamma m_e}. \tag{6}$$

From the orbit equation:

$$\gamma m_e = \frac{\hbar}{vR} = \frac{\hbar}{cR}, \tag{7}$$

so, equation (6) becomes:

$$G_0 = \frac{4R^2 c^3}{\hbar} = \frac{16\hbar c}{(m_p - m_e)^2}. \tag{8}$$

With the same values for R, c and $\hbar$ as above, $G_0 = 1.81 \times 10^{29}$ N.m^2/kg^2. To put this value of G_0 into context, the equivalent factor in macroscopic gravity is, $G_N = 6.67 \times 10^{-11}$ N.m^2/kg^2[4].

We note that, with this value of G_0, the Schwarzschild radius of the proton, $R_S = 2G_0 m_p/c^2 = 6.7$ fm. The significance of this will be discussed in section 5.

An alternative way to calculate the proton mass is to assume that it comes from the energy needed to assemble it from its constituents, that is its self-mass. In this case, we obtain:

$$m_p c^2 - m_e c^2 = \frac{G_0 \gamma m_e}{R} + \frac{G_0 \gamma^2 m_e^2}{2R}. \tag{9}$$

Or, using equations (7) and (8):

$$m_p c^2 - m_e c^2 = \frac{G_0 \gamma^2 m_e^2}{2R} = \frac{2\hbar c}{R}. \quad (10)$$

The two mass determinations give the same result when $v = c$.

The antiproton is composed of two electrons and a positron. The positron is not an antielectron; it is simply a positively charged electron. The antiproton is not composed of antimatter; it is simply a negatively charged proton. Just as the electron has two charge varieties (positive and negative), so does the proton. There is no antimatter.

Finally, we note that we could also assume that the proton is composed of three quarks and use the same model. Unfortunately, the masses of the quarks have never been measured, but there are phenomenological estimates [4] and we can use these. It is interesting that, using quark charges, the fit to the proton charge distribution is poorer and the resulting proton mass is too low at 902 $\pm$ 9 MeV/c^2. In addition, the assumption of the same type of $1/R^2$ behaviour for the force that holds the quarks in orbit would be in disagreement with the asymptotic freedom of the Standard Model strong force.

Critics might point out that our model is too simple. After all, the Bohr model is also criticised these days. And, as simple and naive as it might be, the Bohr model provided a crucial stage in our understanding of atomic structure. In response, we note that our model can provide simple relationships for physical quantities that are in good agreement with measurements. The Standard Model does not do that.

3 The Neutron

We use an approach identical to the one described for the proton in section 2 although we cannot be as exact as in the proton case. The neutron decays to a proton, an electron and a neutrino and, in our model, the proton is composed of two positrons and an electron. Therefore we assume that the neutron is composed of two positrons, two electrons and a neutrino.

The distribution of charge inside the neutron has been obtained from its electric and magnetic form factors [13, 14]. A recent particle physics planning report gives the status as of a few years ago based on a compilation of all available data [15]. The charge is zero at the neutron centre ($R = 0$), rises to a positive maximum at $\sim$ 0.3 fm, falls and passes through zero at $\sim$ 0.6 fm, rises to a negative maximum at $\sim$ 1 fm and falls slowly to zero by 4 fm. More than 95% of the neutron charge is within a radius of $\sim$ 2 fm. The experimental uncertainty at the positive peak is $\sim$ 15% and at the negative peak it is $\sim$ 20%.

We made a fit to this charge distribution using a sum of four gaussians. We started the fit with the proton values for the inner positrons plus electron and the additional electron at a radius of 1 fm. The resulting best fit had an electron and a positron at $R = 0$ fm, a positron at $R = 0.28$ fm and an electron at $R = 0.89$ fm. In more detail, the best values are:

$$R(e^-) = 0.0 \text{ fm}, \quad \sigma(e^-) = 0.45 \text{ fm}, \quad R(e^+) = 0.0 \text{ fm}, \quad \sigma(e^+) = 0.65 \text{ fm}. \tag{11}$$

$$R(e^-) = 0.89 \text{ fm}, \quad \sigma(e^-) = 0.55 \text{ fm}, \quad R(e^+) = 0.28 \text{ fm}, \quad \sigma(e^+) = 0.20 \text{ fm}. \tag{12}$$

The neutron has an electron plus a positron at rest in the centre ($R = 0$), a positron at $R_2 = 0.28$ fm and an electron at $R_1 = 0.89$ fm. There is also a neutrino at $R = R_\nu$. Why don't the e^+ and e^- at $R = 0$ annihilate? Indeed, why don't any of the e^+, e^- pairs annihilate inside the proton and neutron? According to the gaussian fits, all of the e^+ and e^- charge distributions are different. We suggest that there has to be complete overlap of their charge distributions (i.e. identical R and σ values) before the e^+ and e^- can annihilate.

Following the proton treatment in section 2, the effective mass of these five constituents is:

$$m_n = 2m_e + \gamma_1 m_e + \gamma_2 m_e + \frac{E_\nu}{c^2} = 2m_e + \frac{\hbar}{cR_1} + \frac{\hbar}{cR_2} + \frac{\hbar}{cR_\nu}. \tag{13}$$

The approximate self-mass equation gives:

$$m_n c^2 - 2m_e c^2 = \frac{G_0 \gamma_1 \gamma_2 m_e^2}{(R_1 \pm R_2)} + E_\nu = \frac{G_0 \hbar^2}{R_1 R_2 (R_1 \pm R_2) c^2} + E_\nu, \tag{14}$$

where the + and − solutions represent the e^+ and e^- on opposite and same sides of $R = 0$, respectively.

As in the proton case, we have assumed the Bohr-like orbit equations:

$$\gamma_1 m_e c R_1 = \gamma_2 m_e c R_2 = \frac{E_\nu R_\nu}{c} = \hbar. \tag{15}$$

The fitted values of R_1 and R_2 give $\gamma_1 \sim 400$ and $\gamma_2 \sim 1400$, so all other electron and positron terms may be ignored and the approximation $v = c$ is justified. We will return to the neutrino term below.

Entering the values for R_1, R_2, c and $\hbar$ into equation (13) gives $m_n = 925 \pm 20$ MeV/c^2 + E_ν/c^2, suggesting that $E_\nu \sim 15$ MeV and therefore $R_\nu \sim 14$ fm. Entering the same values of R_1, R_2, c and $\hbar$ into equation (14) gives two extreme values for G_0. These are $G_0 = 1.82 \times 10^{29}$ N.m^2/kg^2 when the e^+ and e^- are on the same side of $R = 0$ and $G_0 = 3.5 \times 10^{29}$ N.m^2/kg^2 when they are on the opposite side. Coulomb attraction will perhaps tend to bring the e^+ and e^- to the same side so this is the preferred solution. With the "same-side" value of G_0, the neutron Schwarzschild radius $R_S = 6.7$ fm. The significance of this will be discussed in section 5.

Inside the neutron there is a proton composed of two positrons and an electron. However, it does not resemble a free proton. It is reduced in size by approximately 35% and has a correspondingly smaller mass of approximately 700 MeV/c^2. We refer to it as a "dwarf" proton. The partons inside the dwarf proton have a different momentum behaviour from those inside a free proton. This might also be true of protons and neutrons inside nuclei and this might be the source of the so-called EMC effect [16].

The antineutron is also composed of two electrons, two positrons plus a neutrino. The internal structure is different from that of the neutron and the neutrino is different (see section 9). Inside the antineutron there is an electron at $R = 0.28$ fm and a positron at $R = 0.89$ fm. The central two electrons plus a positron form a "dwarf" antiproton. Since both neutrons and antineutrons are composed of electrons and positrons, neither is an antimatter particle. There is no antimatter.

As in the case of the proton model, we could also assume that the neutron is composed of three quarks. There are the same issues as in the proton case (unknown quark masses and $1/R^2$ force) and, again, the fit to the neutron charge distribution is not as good. In addition, the resulting neutron mass is a long way from the known mass at 1100 MeV/c^2.

4 The Electron, Positron and Neutrino

In a way, the electron and positron are much simpler particles. Since they are both point-like objects we have no internal structure to consider. Instead, we follow the approach described elsewhere [7, 17].

The self-mass of a particle with internal attractive gravitational forces in exact balance with repulsive electrostatic forces is given by:

$$m = m_0 + \frac{G_0 m^2}{R} - \frac{k_0 Q^2}{R}, \tag{16}$$

where m_0 represents the "bare" particle mass, m is its observed mass, Q its charge and G_0 and k_0 represent the strengths of gravity and electrostatics inside the particle. For a point-like particle, $R \sim 0$ and therefore:

$$m = m_0 \text{ and } \frac{\mathrm{G_0}}{\mathrm{k_0}} = \frac{\mathrm{Q^2}}{\mathrm{m^2}}. \tag{17}$$

With $\mathrm{m} = \mathrm{m}_e$, the electron rest mass and $Q = e$, the electron charge, this gives $G_0/k_0 = 3.09 \times 10^{22}$ C^2/kg^2.

This value of the ratio of gravitation to electrostatic parameters gives, by definition, an electron with self-mass exactly equal to its known, measured mass and charge exactly equal to its measured charge. The two charge states (electron = e^- and positron = e^+) have exactly the same quantity of mass and charge.

With $k_0 = 8.99 \times 10^9$ N.m^2/C^2 [4], this would give $G_0 = 2.77 \times 10^{32}$ N.m^2/kg^2. This is a factor of $\sim$ 1500 times the value found inside the proton and neutron and gives a Schwarzschild radius of 5.6 fm for the electron. We will discuss this in sections 5 and 8.

If we set the charge Q to zero, our model gives a point-like particle with zero rest-mass. It is possible to identify this particle with the neutrino, although this seems somewhat contrived. It is more likely that the neutrino has a small mass and charge consistent with equation (17). In that case there would presumably be two neutrinos, one with positive and one with negative charge (see section 9). This would suggest that the only particle with zero rest mass and zero charge is the photon.

5 Particle Stability

We hypothesise that the stability of a composite particle is related to the relative size of its Schwarzschild radius, R_S and the largest constituent orbital radius, $R_{\max}$; that is the radius of the outermost parton. If $R_{\max}$ is greater that R_S, the particle is unstable.

The $e^{\pm}$, ν and proton are all stable particles. The neutron, muon and pions are all unstable and all have constituents outside their respective Schwarzschild radii.

We can use our models to investigate the lifetimes of these particles.

Inside the neutron there is an electron at a mean distance of 0.89 fm from the centre. In order for the neutron to decay this electron has to be outside R_S at 6.7 fm from the centre. There is a neutrino at a mean distance $\sim$ 2 times R_S and this is the reason the neutron is much less stable than the proton. The fit to the internal charge distribution shows that above $\sim$ 0.5 fm it is well described using a gaussian line-shape with mean 0.89 fm and $\sigma = 0.55$ fm.

This can be used to calculate, P, the probability that the distance of the electron from the centre of the neutron is greater than 6.7 fm. We assume that the mean lifetime of the neutron is given by $\tau_n = \tau_0/P$ where τ_0 is a characteristic time given by the orbital period at 0.89 fm. With an orbital speed of c, the orbital period is 1.86×10^{-23} s. From the properties of the gaussian, P is calculated to be 2.2×10^{-26} and the neutron mean lifetime is 850 ± 80 s. For such a simple model, this is in remarkably good agreement with the experimental value of 880 s [4]. Any electron orbit further from the neutron centre has a larger escape probability and therefore it gives a shorter neutron lifetime. Any electron orbit closer to the neutron centre has a smaller escape probability and therefore a longer neutron lifetime. The entire exponential neutron lifetime distribution is simply a reflection of the charge distribution of the internal electron at 0.89 fm.

The proton has two positrons at a radius of 0.421 fm from the central electron. In order for the proton to decay, both of these have to be outside $R_S = 6.7$ fm. The fit to the internal charge distribution described in section 2 has two gaussian line-shapes with $R = 0.421$ fm and $\sigma = 0.43$ fm. The probability that both positrons with these properties are outside R_S is $P = 2 \times 10^{-96}$. Again, we assume that a characteristic time-scale of the proton is determined by the positron orbits. The time to make one complete orbit for either of the two positrons is 8.8×10^{-24} s. Dividing this by P, we get an estimate of the proton lifetime, that is, the time it takes for both positrons to fluctuate from their usual orbital locations to a location outside 6.7 fm. The result is 1.4×10^{67} years.

For the muon and the $\pi^{\pm}$ we can use the same technique but in the opposite direction;

that is we use the measured particle lifetime to determine the size of the central electron charge distribution. In other words, we use the measured lifetime to determine the width of the central $e^{\pm}$ gaussian. This is discussed in the following two sections.

We summarise all of the quantities discussed in this section in the following table along with the measured and calculated lifetimes (τ) for proton and neutron [4]:

particle	R_S (fm)	$R_{\max}$ (fm)	G_0 ($\times 10^{29}$ N.m^2/kg^2)	τ (meas.)	τ (calc.)
$e^{\pm}$, ν	5.6	~ 0	2770	Stable	—
p	6.7	0.42	1.81	$> 2 \times 10^{29}$ y	1.4 $\times 10^{67}$ y
n	6.7	~ 14	1.82	880.2 $\pm$ 1.0 s	850 $\pm$ 80 s

6 The Muon

We propose that the muon is a composite particle. It has internal structure. As far as we know, this has never been investigated experimentally, although there are two pieces of indirect experimental evidence in support. The first is that the muon is unstable; it has a lifetime of approximately 2.2 μs. The second is that if muons are used to probe the charge size of the proton, one obtains a significantly different result than if electrons are used.

The muon decays into an electron and two neutrinos, so we assume that is what it is composed of.

In our proton model, two positrons are in orbit around a central electron. They are on opposite sides of the electron. If we propose a similar model for the muon, then the two neutrinos, in the absence of a Coulomb repulsion, will not necessarily be on opposite sides of the central electron or positron. In addition, the neutrino-neutrino interaction is unknown. Under these circumstances, it is difficult to develop a plausible equation-of-motion or a self-mass relationship such as we described in the proton case. However, as in the proton case, an expression for the mass of the muon may be obtained from the effective mass of the three constituents. We assume that the electron is at $R = 0$ and the two neutrinos have orbital radii of R_1 and R_2. Therefore, the effective mass relationship gives:

$$m_\mu = \frac{E_e}{c^2} + \frac{E_1}{c^2} + \frac{E_2}{c^2} = \frac{E_e}{c^2} + \frac{\hbar}{cR_1} + \frac{\hbar}{cR_2}. \tag{18}$$

Where E_e is the total energy of the central electron and E_1 and E_2 are the energies of the two neutrinos. We are assuming that E_1/c^2 and E_2/c^2 play the same role in the neutrino orbit equations as γm_e plays in the positron equations of the proton model.

If we assume that the two neutrinos are on opposite sides of the central electron and $R_1 = R_2$ then $E_e = m_e c^2$ and $E_1 = E_2 = E_\nu$ and equation (18) gives:

$$E_\nu = \frac{(m_\mu - m_e)c^2}{2}, \tag{19}$$

and

$$R_\nu = \frac{\hbar c}{E_\nu} = 3.75 \ \text{ fm.} \tag{20}$$

On the other hand, if we assume that the two neutrinos are on the same side of the central electron and $R_1 \sim R_2$ and $E_1 \sim E_2 = E_\nu$, then:

$$E_\nu = \frac{(m_\mu^2 - m_e^2)c^2}{4m_\mu}, \tag{21}$$

$$E_e = \frac{(m_\mu^2 + m_e^2)c^2}{4m_\mu}, \tag{22}$$

and

$$R_\nu = \frac{\hbar c}{E_\nu} = 7.5 \ \text{ fm.} \tag{23}$$

The first solution, or "opposite-side", is the preferred one and the one we continue with from now on.

The muon is an unstable particle and our hypothesis is that the two neutrinos are at a radius that is at least 1.5 times the Schwarzschild radius. As stated earlier, this factor of 1.5 originates in the observation that massless particles orbit at a radius of 1.5 R_S from a Schwarzschild black hole [6]:

$$R_\nu \geq 1.5 R_S. \tag{24}$$

This can be used to estimate G_0:

$$G_0 \leq \frac{R_\nu c^2}{3m_\mu}. \tag{25}$$

Entering the values for R_ν, c and m_μ gives:

$$G_0 \leq 6 \times 10^{29} \text{ N.m}^2/\text{kg}^2. \tag{26}$$

Finally, as discussed in section 5, the muon lifetime can be used to obtain an estimate of the width of the gaussian charge distribution of the central electron. We obtain ≤ 0.3 fm. This result suggests that the muon has a blob of electrostatic charge at its centre contained within a diameter ≤ 1 fm.

7 The Pions

Similar to the muon, we assume that the pions are composite particles with internal structure.

The π^0 has a mass of 135 MeV/c^2 and is composed of two photons each with energy $E_\gamma = m_\pi c^2/2$, where m_π is the π^0 mass. The Bohr orbital condition gives $E_\gamma R_\gamma = \hbar c$ and therefore $R_\gamma = 2\hbar/m_\pi c = 2.9$ fm. The π^0 is very unstable and we therefore assume that the two photons have a radius at least 1.5 times the Schwarzschild radius. This can be used to estimate G_0:

$$G_0 \leq \frac{R_\gamma c^2}{3m_\pi}. \tag{27}$$

Entering the values for R_γ, c and m_π gives:

$$G_0 \leq 3.6 \times 10^{29} \text{ N.m}^2/\text{kg}^2. \tag{28}$$

The charged pion ($\pi^\pm$) has a mass of 140 MeV/c^2 and decays to an electron and a neutrino or a muon and a neutrino. Since the muon is an excited electron, we assume that the $\pi^\pm$ is composed of an electron and a neutrino. The effective mass formula gives:

$$m_\pi c^2 = E_e + E_\nu, \tag{29}$$

where m_π is the $\pi^\pm$ mass. This can be solved to give:

$$E_e = \frac{(m_\pi^2 + m_e^2)c^2}{2m_\pi}, \tag{30}$$

$$E_\nu = \frac{(m_\pi^2 - m_e^2)c^2}{2m_\pi}. \tag{31}$$

The neutrino orbital radius is $R_\nu = \hbar c/E_\nu = 2.8$ fm.

The effective mass of the central electron is far from the electron rest mass. We refer to it as a “giant” electron. It’s mass is closer to m_μ than it is to m_e and this is presumably why the $\pi^\pm$ decays predominantly to $\mu\nu$ rather than $e\nu$ even though it is composed of an electron and a neutrino.

Since the $\pi^\pm$ is unstable, we assume that the neutrino radius is at least 1.5 the Schwarzschild radius and this can be used to estimate G_0:

$$G_0 \leq \frac{R_\nu c^2}{3m_\pi}. \tag{32}$$

Entering the values for R_ν, c and m_π gives:

$$G_0 \leq 3.4 \times 10^{29} \text{ N.m}^2/\text{kg}^2. \tag{33}$$

As in the muon case, the pion lifetime can be used to obtain an estimate of the width of the gaussian charge distribution of the central electron. We obtain ≤ 0.23 fm. The published value for the root-mean-square charge radius of the $\pi^\pm$ is 0.659 ± 0.004 fm [4]. Similar to the muon, these results suggest that the charged pions have a blob of electrostatic charge at their centre contained within a diameter ≤ 1 fm.

Finally, a note on isospin. It is customary, within the framework of the Standard Model, to assume that the π^0 and the $\pi^\pm$ are the same particle. They are distinguished only by a different value of the third component of isospin. Similarly, the proton and neutron are assumed to be the same particle with the third component of isospin being the only property that distinguishes them. As experimentalists, we know this to be nonsense. The π^0 and the $\pi^\pm$ are totally different particles with totally different properties. The proton and neutron are also totally different particles. Isospin might be a useful concept for a theoretician, but it has nothing to do with reality, in other words experimental results.

8 Gravity

Our models provide good evidence that inside the elementary particles there is a very strong gravitational interaction that holds the constituents together. The proton model gives a value of $G_0 = 1.81 \times 10^{29}$ N.m^2/kg^2 and the muon, neutron and pion models are consistent with this value.

In the following table, we summarise all of the results for the proton, neutron, muon, pion, electron and neutrino models discussed in the previous sections. The second column gives the value of G_0 in N.m^2/kg^2 with, for comparison, the last row showing the value of G_N, the macroscopic Newton gravitational constant which has been determined for distances $\sim$ 1 cm and above. The third column gives $R_{\max}$, the radius of the outermost parton in fm. In every model there is a parton pair that dominates the calculations. The distance between this dominant pair is ΔR in fm. The fifth column gives the value of the Schwarzschild radius used in the stability calculations of the previous sections. In the proton, neutron, muon and $\pi^\pm$ models there is a central electron represented by a gaussian charge distribution. The sixth column gives the values obtained for the gaussian σ parameter. The last column gives the particle lifetimes. For proton and neutron these are our calculations. For muon, π^0 and $\pi^\pm$ they are the published values [4].

particle	G_0 (N.m^2/kg^2)	$R_{\max}$ (fm)	ΔR (fm)	R_S (fm)	σ_e (fm)	τ
$e^\pm$, ν	2.77×10^{32}	~ 0	~ 0	5.6	—	—
p	1.81×10^{29}	0.42	0.84	6.7	0.56	1.4×10^{67} y
n	1.82×10^{29}	~ 14	0.61	6.7	0.45 - 0.65	850 ± 80 s
μ	$\leq 6 \times 10^{29}$	3.75	7.5	2.5	≤ 0.3	2.2×10^{-6}
π^0	$\leq 3.6 \times 10^{29}$	2.9	2.9	1.94	—	8.5×10^{-17} s
$\pi^\pm$	$\leq 3.4 \times 10^{29}$	2.8	2.8	1.86	≤ 0.23	2.6×10^{-8} s
macro	6.67×10^{-11}	$\geq 10^{13}$	—	—	—	—

Is it possible that G_0 varies as a function of particle size? The proton, neutron, muon and pion models are all consistent with the same value of G_0. This implies a single short-range value, but on the other hand, the distances involved in all these particle models are all very similar. What about the electron model? For G_0 inside the electron to have the same short-range value the microscopic electrostatic parameter k_0 would have to be a factor 1500 times smaller than the macroscopic value. This would have a huge impact on QED calculations and is hardly likely.

To summarise. The macroscopic value of the gravitation parameter (distances greater than ∼0.01 m) is $G_N = 6.67 \times 10^{-11}$ N.m^2/kg^2 [4]. The microscopic value is in the range 1.81×10^{29} N.m^2/kg^2 to 2.77×10^{32} N.m^2/kg^2. The larger value is favoured by all particles except the point-like $e^{\pm}$ and ν.

For every order of magnitude increase in size, between the proton and the macroscopic world, the value of G_0 decreases by approximately three orders of magnitude. If this holds true over the full range from zero to 1 cm, then the value of G_0 at the atomic scale would be $\sim 10^{14}$ N.m^2/kg^2.

9 Particle Magnetic Moments and Spin

The spins of the point-like fundamental particles ($e^{\pm}$ and ν) are intrinsic properties of the particles. For all other particles, the spin of the particle comes from the vector addition of the spins of the point-like constituents plus their orbital angular momenta. So, for example, in the proton the three spins are aligned and the two orbital angular moment are anti-aligned.

The neutron and $\pi^{\pm}$ are more complicated. If the neutrino is a massless particle, there is no way to add the intrinsic and orbital angular momenta to get spin-half, in the case of the neutron, and spin-zero, in the case of the pion. If the neutrino has a small mass the problem is solved. Equation (17) implies that, if the neutrino has a mass then it must also have a charge. According to our model, if the neutrino has a charge then the neutron must also have the same charge. In fact the neutron charge has been measured. The result (with large errors) is -6.4×10^{-41} C [18]. If the neutrino mass-to-charge ratio is equal to that of the electron, this gives a neutrino mass of 2.1×10^{-16} eV. If the neutron has a small negative charge, then the antineutron must have a small positive charge. In this situation there must be two different neutrinos, one with negative charge and one with positive charge as suggested by equation (17).

The magnetic moment of the proton (μ_p) may be written as the sum of two terms. These are the current loop of the two orbital positrons and the mass-scaled magnetic moment (μ_e) of one of the positrons; all other terms cancel. So, $\mu_p = \mu_e m_e/m_p + IA$, where I is the current and A is the area of the loop. The current loop term for each orbital positron (radius R and velocity c) may be written $IA = eRc/2$, so, the expression for the proton magnetic moment becomes: $\mu_p = \mu_e m_e/m_p + eRc$. With $R = 0.421$ fm, $\mu_p = 15 \times 10^{-27}$ J/T = 2.9 ± 0.2 nuclear magnetons; this is in good agreement with the measured value of 2.793 nuclear magnetons [4].

The neutron magnetic moment is the sum of eight terms, one of which is the unknown, but small [4], intrinsic neutrino term. Most of the terms cancel or are negligible and we are left with $\mu_n = \mu_e m_e/m_n + eR_1c - eR_2c$. With $R_1 = 0.28$ fm and $R_2 = 0.89$ fm,

$\mu_n = -9.4 \times 10^{-27}$ J/T = -1.9 ± 0.3 nuclear magnetons, which is in good agreement with the measured value of -1.91 nuclear magnetons [4].

10 Conclusions and Predictions

We have developed simple models for the fundamental particles ($e^{\pm}$ and ν) and for some of the elementary particles (protons, neutrons, muons and pions). We have based our models and the associated calculations on well-established experimental facts. Thus, for example, we have made the assumption that an elementary particle is composed of its observed decay products. In addition, we only include the two static fields that are known experimentally to exist. These are gravity and electrostatics. Gravity acts on masses and electrostatics on charges. Both forces are proportional to one over distance-squared. In our models there is no separate nuclear strong field and there is no separate nuclear weak field. In addition, our models do not need a Higgs mechanism and therefore there is no Higgs field. We completely avoid the use of *ad hoc* quantum numbers such as isospin, strangeness, charm *et al*.

The partons, of which all elementary particles are composed, are the fundamental particles: electrons, positrons, neutrinos and photons. In our models there are no quarks or gluons and there is no anti-matter. None of our models provide results in agreement with experiment if we assume partons are quarks. It is a necessary and sufficient assumption that partons are electrons, positrons, neutrinos and photons.

The electron has negative electrostatic charge and the positron has an equal quantity of positive electrostatic charge. There are two types of neutrino; one has a very small negative charge and the other a very small positive charge. The neutron has the same charge as its neutrino. The photon plays a rôle in the structure of the neutral pion.

With these simple assumptions, we use semi-classical calculations to obtain expressions for the properties of the most important elementary particles, all of which are in good agreement with experimental determinations. In the following we review the main results for each particle and finally emphasise some general comments and predictions.

Electron and Positron: The ratio of charge-to-mass is derived from the static self-mass formula and gives $e/m_e = \pm\sqrt{G_0/k_0}$. Using the measured values for the electron charge, e, and mass, m_e, we get $G_0 = 2.77 \times 10^{32}$ N.m^2/kg^2, if k_0 has the usual value 8.99×10^9 N.m^2/C^2 [4]. The magnitude of the electron charge is exactly equal to the magnitude of the positron charge. Neither positron nor electron are antimatter

Neutrino: We use the same static self-mass formula with neutrino charge $= 4.0 \times 10^{-21} e$. The magnitude of this charge is a factor approximately 2.5×10^{21} times less than the electron charge. The mass of the neutrino is also approximately 2.5×10^{21} times less than the electron mass. This predicts a neutrino mass of 2.1×10^{-16} eV/c^2. There are two neutrinos; one with a small positive charge and one with a small negative charge. A powerful enough magnet could be used to deflect them and test this.

Proton: The proton is composed of two positrons and an electron. The electron is at the centre ($R = 0$) and the positrons are in orbit at $R = 0.421$ fm. The antiproton is composed of two electrons plus a positron. Neither proton nor antiproton are antimatter. Both proton and antiproton masses are given by $m_p = m_e + 2\hbar/Rc$. Taking R from a fit to the measured internal charge distribution of the proton gives m_p in excellent agreement with measurement. The charge of the proton is, by design, exactly equal to the charge of the positron and the charge of the antiproton is exactly equal to that of the electron. The proton spin is the vector sum of the spins of the point-like constituents plus their orbital angular momenta. It is the same as the spin of the electron ($\hbar/2$). We predict proton-like particles with spin $\hbar/2, 3\hbar/2, 5\hbar/2$ and $7\hbar/2$. The proton magnetic moment is given by $\mu_p = \mu_e m_e/m_p + eRc = 2.9 \pm 0.2$ nuclear magnetons, in good agreement with measurement. The proton Schwarzschild radius is much larger than R and the proton lifetime is predicted to be 1.4×10^{67} years.

Neutron: The neutron is composed of two positrons, two electrons plus a neutrino. The neutrino has a very small negative charge equal to the neutron charge. This is -6.4×10^{-41} C. The three central constituents of the neutron form a "dwarf" proton with mass ~ 200 MeV less than the free proton. The antineutron is also composed of two positrons, two electrons plus a neutrino, but the internal structure is different from that of the neutron. The neutrino inside the antineutron has a very small positive charge equal to the antineutron charge. The three central constituents of the antineutron form a "dwarf" antiproton. Neither neutron nor antineutron are antimatter and neither are electrostatically neutral. They both have a very small charge equal to the charge of the constituent neutrino. The neutron has a very small negative charge and the antineutron has a very small positive charge. This should be possible to investigate in an experiment. The neutron spin is the vector sum of the five point-like constituents plus the orbital angular momenta of the outer three. It is the same as the proton spin ($\hbar/2$). If the neutrino were massless it would not be possible to add all the angular momenta to get $\hbar/2$. This suggests that the neutrino is not massless. Our models suggest that therefore the neutrino is not a neutral particle. In addition to the neutron, we predict neutron-like objects with spin $\hbar/2, 3\hbar/2, 5\hbar/2, 7\hbar/2, 9\hbar/2$ and $11\hbar/2$. The neutron magnetic moment is given by $\mu_n = \mu_e m_e/m_n + eR_1c - eR_2c = -1.9 \pm 0.3$ nuclear magnetons, where R_1 and R_2 are the orbital radii of the outer positron and electron. The orbital radius of the neutrino is two-times larger than the neutron Schwarzschild radius and this is why the neutron is unstable. The neutron mean lifetime is predicted to be 850 ± 80 s, in good agreement with measurement.

Muon: The $\mu^\pm$ is a composite object containing a central $e^\pm$ plus two neutrinos with orbital radius 3.75 fm. This is larger than the muon Schwarzschild radius and explains why the muon is unstable. The measured muon lifetime indicates that the charge of the central $e^\pm$ may be represented by a gaussian with $\sigma \leq 0.3$ fm. The muon is a gravitationally excited electron or positron.

Pions: The π^0 is a $\gamma\gamma$ bound system with radius = 2.9 fm. Since the π^0 is unstable, its Schwarzschild radius is < 2.0 fm. The $\pi^\pm$ is composed of a central electron plus a neutrino with orbital radius 2.8 fm. This is larger than the pion Schwarzschild radius and explains why the pion is unstable. The central electron has an effective mass ~ 150 times the electron mass. This is much closer to the muon rest mass than the electron rest mass and explains why the $\pi^{\pm}$ decays predominantly to $\mu\nu$ rather than $e\nu$. The measured $\pi^{\pm}$ lifetime indicates that the charge of the central $e^{\pm}$ inside the $\pi^{\pm}$ may be represented by a gaussian with $\sigma \leq 0.23$ fm. The $\pi^{\pm}$ is a gravitationally excited electron or positron.

General Comments and Predictions: Finally we emphasise a few important features of our particle models.

The strong force that keeps the elementary particles intact is a very strong form of gravity. For example, inside the proton and the neutron, the gravitation parameter G_0 is $\sim 3 \times 10^{39}$ larger than the macroscopic value. The value of G_0 inside the muons and pions is consistent with this. If this is interpreted as a continuously decreasing G_0 as we leave the particle domain and approach the macroscopic world, this would imply a value of G_0 some 10^{25} times larger at the atomic scale than is usually assumed. This would provide attractive gravitational forces still much smaller than the electrostatic forces, but their effect might be measurable.

There is no antimatter, therefore there is no mystery regarding where the antimatter in the universe has gone. The positron is simply a positively charged electron. The so-called antiproton is simple a negatively charged proton. The neutron and all the atoms are composed of an equal number of e^+ and e^-.

A well-designed e^+e^- experiment at a centre-of-mass energy above the proton threshold and below the threshold for proton-antiproton production should be able to detect protons and antiprotons. These would be formed in reactions like $e^+e^- \rightarrow e^-$proton and $e^+e^- \rightarrow e^+$antiproton.

There are two distinct neutrinos and they both have a small quantity of mass and charge a factor $\sim 2.5 \times 10^{21}$ less than the electron and positron mass and charge. There are also two distinct neutrons and both have a quantity of charge equal to the neutrino charge. A well-designed experiment ought to be able to investigate these predictions.

All the unstable elementary particles have a finite, and measurable radius. They are all composite particles. The muon has always been considered point-like. But, with a finite radius, the different values of the proton radius obtained using electrons and muons as probes can be explained. In fact, re-analysis of the data could provide an independent estimate of the muon radius. Alternatively, the radius of the muon could be measured in an electron-muon storage-ring experiment.

All the elementary particles are composed of the particles that they decay to. If a charged pion decays to an electron and a neutrino then it is composed of an electron and a neutrino and always has been throughout its existence.

When elementary particles (resonances) decay, the decay products are not affected by the energy acquired by the particle in, for example, a particle accelerator. The acquired energy is stored in the internal field structure of the particle, increasing its mass and lifetime and decreasing its radius, but not changing the internal constituents.

The stability of a particle is related to its size relative to the size of its Schwarzschild radius. When the parton orbital radii are known, this assumption allows us to calculate elementary particle mean lifetimes to compare with experiment. The proton lifetime is predicted to be $\sim 10^{67}$ years. The neutron model produces a lifetime estimate of 850 ± 80 s, in good agreement with measurement.

This paper and our earlier papers describe work that attempts to understand and describe the internal dynamics of the elementary particles. The electron charge-to-mass ratio demonstrates an internal balance between electrostatic and gravitational forces and provides an estimate of the internal gravitational field-strength parameter. The proton is considered as a fast-rotating positron-electron-positron stick-like structure with a radius much smaller than its Schwarzschild radius. In terms of the electron mass, m_e, the reduced Planck constant, $\hbar$, the vacuum speed of light, c, and the orbital radius, R, of the internal positrons, the proton mass m_p is given by :

$$m_p = m_e + \frac{2\hbar}{cR}. \tag{34}$$

The gravitational field-strength parameter inside the proton is given by:

$$G_0 = \frac{4R^2c^3}{\hbar} = \frac{16\hbar c}{(m_p - m_e)^2} = 1.81 \times 10^{29} \text{ N.m}^2/\text{kg}^2. \tag{35}$$

All the other elementary particles we have investigated have a value of G_0 consistent with the proton value.

The neutron is modelled as a compressed, low-mass proton with an orbiting electron inside its Schwarzschild radius and an orbiting neutrino well outside its Schwarzschild radius. This model gives the correct mass and lifetime for the neutron. Similar models and semi-classical calculations have enabled us to derive the measured properties of several elementary particles and make some interesting and maybe important predictions.

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