The radius of the electron and the mass of compound particles like the proton and neutron.

Bezverkhniy Volodymyr Dmytrovych.

Ukraine, e-mail: bezvold@ukr.net

Abstract: Taking into account the point structure of elementary particles as well as corpuscular-wave dualism, it is shown that the radius of an electron, like that of any elementary particle, is strictly equal to zero. Therefore, the experimental fixation of the radius of any particle indicates that the particle is not elementary. The mechanism of creating a mass of compound particles similar to the proton and neutron is also considered due to the relativistic increase in the energy of elementary particles that make up the corresponding system.

Keywords: Electron radius, elementary particles, point structure of particles, de Broglie wave, Compton wavelength, mass of composite particles.

INTRODUCTION.

It is interesting to consider the question of the electron radius. It can be shown that the exact radius of any elementary particle (photon, quark, etc.), including the electron, is equal to zero. This is exactly and strict.

It is important to note that the radius of the electron, like any other elementary particle, does not strive for zero, namely, strictly equal to zero.

According to the theory of relativity, all elementary particles must be considered as point objects. That is, objects that, by definition, have no size. In the textbook L. Landau and E. Lifshitsa “Field Theory” shows [1] that “...the theory of relativity makes the existence of absolutely solid bodies absolutely impossible...”.

If an elementary particle had a certain size (radius and other similar classical characteristics), then it is obvious that such a particle should be absolutely solid. But, the deformation of the particle means the theoretical possibility of its destruction and the possibility of independent movement of individual parts of the particle, which means that such a particle can no longer be considered elementary.

Consequently, the elementary nature of a particle unambiguously indicates the point structure of such a particle, which only confirms the fact of the structurelessness of an elementary particle.

RESULTS AND DISCUSSION.

For further discussion and analysis, here is a quote from the textbook [1]:

"...Thus, we arrive at the result that when the disk rotates, the ratio of its circumference to the radius (measured by a stationary observer) should change instead of remaining equal to 2π. The contradiction of this result with the assumption made shows that in reality the disc cannot be absolutely rigid and during rotation it inevitably undergoes some complex deformation, depending on the elastic properties of the material from which the disc is made.

The impossibility of the existence of absolutely rigid bodies can be convinced in another way. Let some solid body be set in motion by an external action at some point of it. If the body were absolutely solid, then all its points would have to move simultaneously with the one that was affected; otherwise, the body would be deformed. The theory of relativity, however, makes this impossible, since the impact from a given point to the rest is transmitted at a finite speed, and therefore all points of the body cannot simultaneously begin to move.

From what has been said, certain conclusions follow regarding the consideration of elementary particles, that is, particles for which we believe that their mechanical state is fully described by specifying three coordinates and three components of the speed of movement as a whole.

Obviously, if an elementary particle had finite dimensions, that is, would be extended, then it could not deform, since the concept of deformation is associated with the possibility of independent movement of individual parts of the body. But, as we have just seen, the theory of relativity shows the impossibility of the existence of absolutely rigid bodies.

Thus, in classical (non-quantum) relativistic mechanics, particles that we consider as elementary cannot be ascribed to finite sizes. In other words, within the limits of the classical theory, elementary particles should be considered as point...".

In addition, according to the principle of Heisenberg in quantum mechanics, particles do not have a trajectory by definition. Since according to the Copenhagen interpretation, the state of the elementary particle determines its subsequent state not unambiguously, but only with a certain probability.

That is, the position of the microparticles inside the de Broglie waves is determined by statistical determinism (quantum effects are manifested precisely inside the waves of de Broglie).

Based on the principle of Heisenberg, the exact definition of the particle coordinates will mean the complete uncertainty of its impulse.

$$\Delta x * \Delta p \geq \hbar / 2$$

$$\Delta p \geq \hbar / (2 * \Delta x)$$

$$\Delta x = 0 \quad \rightarrow \quad \Delta p = \infty$$

But, the fact is that the "waves of matter", that is, the waves of de Broglie, have their own minimum size - this is the compton's wavelength for a specific elementary particle, since the particle speed cannot exceed the speed of light in vacuum.

$$\lambda = h / (m * v)$$

$$v \rightarrow c$$

$$\lambda c. = h / (m * c)$$

Therefore, we will not be able to have the exact coordinate of the particle, we will only have a probabilistic description inside the de Broglie waves (according to the corpuscular-wave dualism). This is a consequence of the fact that the elementary particle has no size, but is a strictly point object. If the particle had a length in space, then this would also mean the presence of a trajectory.

It should be noted that inside the Compton wave, the minimum error in measuring the particle coordinate (Δx) corresponds to the momentum uncertainty ($m*c$), which corresponds to the minimum energy for the formation of a particle-antiparticle pair, and then the measurement process itself loses its meaning. That is, inside the Compton wave we can no longer consider an elementary particle even as a point object - only as a wave.

The fact that the elementary particle has a radius equal to zero can easily be understood if you bring an analogy with a mass of rest of the photon.

The photon can move only at the speed of light, and the mass of rest of the photon is strictly zero. If we could somehow stop the photon (when $v=0$), then its mass of rest could exist and be measured. But the photon moves only at the speed of light and therefore has no rest mass.

Similarly with the radius of an elementary particle: if we could somehow have the exact coordinates of the particle and, consequently, the trajectory (and not a probabilistic description inside the de Broglie waves), then the particle would also have a certain size in space. But, since the elementary particle does not have a trajectory, but is described only by statistical determinism, its radius is strictly equal to zero.

Thus, during experimental measurement of the electron radius, it will always be fixed that the electron radius is less than the accuracy of the device. Naturally, all elementary particles will behave similarly when measuring their radius.

Consequently, if we are able to experimentally measure the radius, extent, and similar characteristics of any particle, then we can safely say that this particle is not elementary.

CONCLUSION.

The surrounding world and increasingly complex particles eventually consist of elementary particles. Therefore, let's analyze exactly how the mass of compound particles (like the proton and neutron) is created from energy, because elementary particles are in constant motion and are characterized by a certain amount of kinetic energy.

According to A. Einstein [2]: “The mass of a body is a measure of the energy content in this body…”.

That is, if we have a certain amount of energy, then we inevitably get mass - the mass of a body is one of the forms of energy (Einstein).

To understand exactly how mass is created from energy, we will consider the proton and neutron, which are made up of three different quarks. And what is important: the proton quarks mass is only 1 % of the actual proton mass, and the neutron quarks mass is 1.3 % of the real neutron mass. In this example, we will see firsthand how nature creates a mass of compound particles like the proton and neutron.

But, first, let's recall the Bohr hydrogen atom, in which an electron in orbit moves with a speed of $v = 2.188 * 10^6$ m/s. Naturally, the mass of the electron in this case increases to the value $m = 9.109626 * 10^{-31}$ kg.

$$m = m0 / (1 - v^2/c^2)^{0.5}$$

m0 – electron rest mass, $m0 = 9.1093837 * 10^{-31}$ kg

What is especially important is that this relativistic addition of the electron mass (Δm) is exactly equal to the binding energy of the hydrogen atom (ionization potential) [3].

$$\Delta m = m - m0$$

$$E = \Delta m * c^2 = 2.1799567 * 10^{-18} \text{ J} = 13.606 \text{ eV}$$

Δm is the electron mass defect in the Bohr orbit.

This means that when a bound system of an electron and a proton (a hydrogen atom) is formed, the binding energy is released into the external environment (this is important!). Moreover, it is this energy that is literally “born” by a defect in the relativistic mass of an electron in the Bohr orbit.

Now consider a proton, which is made up of three different quarks. Let us assume that these quarks move at certain different speeds. According to the theory of relativity, the mass of all three quarks will increase.

Recall now that the addition of an electron mass in a hydrogen atom is released into the external environment in the form of binding energy.

But, quarks cannot exist outside the proton (unlike the electron and proton, which can exist separately - they can be removed from each other to infinity).

Therefore, the “binding energy” from the defect of the relativistic mass for quarks will be released into the “internal environment”, that is, inside the proton. Quarks cannot release energy into the external environment, since they do not exist in the external environment.

Consequently, all the energy generated by the movement of quarks will remain inside the proton.

And since “mass... is a measure of the energy content... in the body” [2], then the proton will have a certain mass according to the formula:

$$E = m(p) * c^2$$

$$m(p) = E / c^2$$

where E is the proton energy (rest energy),

m(p) is the rest mass of the proton,

c is the speed of light in vacuum.

Energy, like momentum, is an additive quantity (unlike mass). Therefore, the proton energy (E) will consist of three energies of the corresponding quarks:

$$E = E1 + E2 + E3$$

$$E1^2 = (p1 * c)^2 + (m1 * c^2)^2$$

$$E2^2 = (p2 * c)^2 + (m2 * c^2)^2$$

$$E3^2 = (p3 * c)^2 + (m3 * c^2)^2$$

where p, m, E1, E2, E3 are the momentum, rest mass, and energy of the corresponding quarks.

All of the above will be similar for the neutron, and in general for any system of bound particles like quarks (which cannot exist outside the bound system).

Thus, the mass of compound particles similar to the proton and neutron is created by the relativistic increase in the mass/energy of the corresponding elementary particles that make up the bound systems.

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