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ANOMALIES OBSERVED BY SKOBELTSYN IN THE BETA DECAY AND NEW RESONANCES IN QUANTUM ELECTRODYNAMICS

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The hypothesis that the particle of mass equal to about three electron masses introduced by D.V. Skobeltsyn for the explanation of the anomalous scattering of the beta-decay electrons is a resonance consisting of two electrons and a positron (e^-, e^-, e^+) is suggested. It is supposed that there exists a large sector of particles (relativistic atoms) that comprises the (e^+, e^-) resonances seen in GSI and resonances (e^+, e^-) and (e^-, e^-) discovered in the nonperturbative QED. Consequences, in particular a new beta-decay mode, are studied.

The investigation has been performed at the Laboratory of High Energies, JINR.

Аномалии, наблюденные Д.В.Скобельцыным в β-распаде, и новые резонансы в квантовой электродинамике

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Высказывается гипотеза о том, что частица с массой около трех электронных масс, введенная Д.В.Скобельцыным для объяснения аномального рассеяния электронов бета-распада, является резонансом,состоящим из двух электронов и позитрона (e^-, e^-, e^+). Предполагается, что существует большой сектор частиц – релятивистских атомов, в который входят такие (e^+, e^-)-резонансы, наблюденные в GSI, и резонансы (e^+, e^-), (e^-, e^-), обнаруженные в непертурбативной квантовой электродинамике. Изучаются наблюдаемые следствия, в частности новая форма бета-распада.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

In papers [1-3] published more than a half-century ago, mysterious phenomena in the scattering of the beta electrons emitted by a radioactive source (RaB + RaC) have been described. The source was placed near a cloud chamber. The primary momentum P_0, the scattering electron momentum P and the scattering angle θ were measured. The beta electron scattering of the cloud chamber gaz atoms was strongly differerent from the well-known Coulomb scattering. The scattering cross section at angles $\theta > 90^\circ$ was dozens times as large as the Coulomb scattering and, in contrast to the latter was, to a large extent, inelastic. The "anomalous scattering" was due to a considerable energy loss. This effect was then studied in a number of papers the conclusions of which were found to be contradictory.

In 1952 D.V.Skobeltsyn /4/ studied his experimental data /1-3/ starting from the hypothesis that the beta radiation near the source contains unstable particles with masses exceeding the electron mass several times. For brievity, we call them S particles. The experimental data that were available could be explained by assuming that the life-time of the S particles is of the order of 10^{-10} sec which corresponds to the path length of the order of 10 cm. D.V.Skobeltsyn has considered in detail the picture of the phenomenon, has analysed the available experimental data and has come to the conclusions that can be presented as follows:

— The S particle mass is equal to about three electron masses.

— If the S particle momenta are suggested to be distributed uniformly within the momentum intervals discussed then one succeeds in describing the observed angular distribution of the decay electrons.

— At angles $\theta > 90^\circ$ the "scattering" has a clear-cut inelastic behaviour which is revealed more evidently with increasing angle θ. As the particle slows down the angular distribution isotropy becomes more clear.

— The Coulomb scattering even for an angle $\theta < 90^\circ$ is a small part of the effect observed. The integral of the Coulomb scattering cross section is about 10 percent of the effect withtin the angular interval in question.

All these conclusions are so important that they deserved a careful study and thorough verification. Unfortunately, no exhaustive experimental study has been performed over the past fourty years. This situation was, to a large extent, affected by the assertions that the existence of a light charged particle whose mass is three times as large as the electron mass contradicts the Maxwell-Dirac quantum electrodynamics.

In the present paper I pay attention to the fact that these assertions are invalid if the S particle is a quasi-stationary state existing in the framework of QED and consider consequences of such a hypothesis.

Recently the existence of narrow resonances (unstable particles) in QED has been discussed and also has taken a quantitative shape. A possible existence of narrow resonances in the electron-positron system in a consistent consideration of relativistic bound states in the framework of canonical QED was shown in ref./5/ . The fundamental problem of describing the bound states in quantum field theory is far from being completely solved. However the quasipotential approach by A.A.Logunov and A.N.Tavkhelidze /6/ makes it possible to overcome a number of unclear points and is a natural generalization of an ordinary nonrelativistic approach to the theory of the atom. This approach enabled the authors /5/ to make the conclusion about the existence of quasistationary levels in the relativistic Coulomb problem and to explain on its basis the electron-positron resonances observed in heavy-ion collisions /7–9/. Neither the radical hypothesis on electrodynamic confinement /10/ or on anomalous electrodynamic vacuum /11/, nor the model considerations have been used in the calculations of ref. /5/. Also no subsidiary parameters, but the electron mass and the fine structure constant has been used. It is important to note that the resonances whose mass M is larger than the two electron masses $M > 2m$ where predicted not only for particles with opposite charges (e^+, e^-), but also for those with identical charges (e^-, e^-) and (e^+, e^+). The important paper /5/ removes the main objection against the interpretation by D.V.Skobeltsyn of his observations since it was shown in it that the existence of light particles does not contradict QED. These results suggest an idea that the S particle is the resonance state of two electrons and a positron.

The relativistic problem of three bodies is very complicated /6, c/ and a detailed description of the dynamics of three and more electrons seems to appear not soon. However it is possible to predict many properties of such systems by analogy with quark models and clarify the possibilities of search experiments.

If we ascribe to the electron an analog of the isotopic spin $T = 1/2$, then the system consisting of electrons and positrons will be characterized by the isotopic spin projection $T_3 = Q/2$, where Q is the charge. The states (e^+, e^+), (e^+, e^-) and (e^-, e^-) obviously form an isotopic triplet with isotopic spin equal to unity. This implies that the narrow resonances (e^+, e^-) with masses from 1 – 2 MeV detected in low-energy ion collisions must have double charged partners (e^+, e^+) and (e^-, e^-). Analogously the S particle must have, in addition to the state (e^-, e^-, e^+), three partners

$$(e^+, e^+, e^-)\,, \quad (e^+, e^+, e^+)\,, \quad (e^-, e^-, e^-)\,.$$

The isotopic spin is introduced only for the classification of the states since the problem of degeneration with respect to this characteristics is still open. The (e^+, e^-) and (e^-, e^-) resonance masses calculated in ref. /5/ exceed the sum of the electron masses by 0.22 – 2 MeV, i.e. the sum of the masses of the electrons entering the particle composition may turn out to be not the main fraction of the particle mass. Therefore the mass splitting in the multiplet may be of the order of the electron mass.

In our model the S particle must desintegrate into an electron and gamma quanta. If the decay mode $S \to e + \gamma$ is a main one, then all the kinematic calculations of D.V.Skobeltsyn remain valid (he assumed that the particle decays into an electron and a neutrino). The S particle can also decay into an electron and two gamma quanta. The ratio of the decay probabilities $S \to e + \gamma$ and $S \to e + \gamma_1 + \gamma_2$ must be two or three orders of magnitude since the emission of additional photon decreases the decay probability by a factor of the order of magnitude of the fine structure constant. If the S particle is assumed to consist of a quark e^- and a diquark (e^-, e^+), then starting from the analogy of the diquark and the positronium it is possible to estimate the S particle life-time

$$\tau_1 \; (S \to e^- + \gamma) \sim 10^{-10} \text{ sec and } \quad \tau_2 \; (S \to e^- + \gamma_1 + \gamma_2) \sim 10^{-7} \text{ sec.}$$

The difference between τ_1 and τ_2 and, respectively, between the path lengths by three orders of magnitude is an additional feature for providing the search for the S particles and the proof of their electromagnetic structure. It is especially important to detect in addition to the electrons, the photons. From the conservation laws

$$\tilde{P}_0 = \tilde{P} + \tilde{k}_1 + \tilde{k}_2 \qquad (1)$$

where $\tilde{P}_0$, $\tilde{P}$, $\tilde{k}_1$ and $\tilde{k}_2$ are the four-momenta of the S particle, electron and photons, respectively, we find

$$(\tilde{P}_0 - \tilde{P})^2 = (E_0 - E)^2 - (\vec{P}_0 - \vec{P})^2 = 2(\tilde{k}_1 \cdot \tilde{k}_2) = 2k_1 k_2 (1 - \mathrm{Cos}\,\alpha) , \qquad (2)$$

E_0 is the energy of the S particle, E the energy of the electron, $\vec{P}_0$, $\vec{P}$ $k_1 = |\vec{k}_1|$ and $k_2 = |\vec{k}_2|$ the three-dimensional momenta, α the angle between the photon momenta. From eq.(2) we obtain the squared S particle mass

$$M^2 = (\sqrt{(\vec{P}_0 - \vec{P})^2 + 2k_1 k_2 (1 - \mathrm{Cos}\,\alpha)} + E)^2 - P_0^2 . \qquad (3)$$

In the case of the one-photon decay the measurement of P_0, P and θ definitely results in the S particle mass,

$$M^2 = (\sqrt{(\vec{P}_0 - \vec{P})^2} + E)^2 - P_0^2 ,$$

while in the case of the two-photon decay such a measurement can give only lower boundary.

The angular distribution for the decay electrons obtained from the experimental data /1-3/ is well explained in ref. /4/ starting from the assumption on the isotropic distribution of the decay electrons in the rest system of the S particle. In the general case, if the spin of the S particle is 3/2, noticeable deviations from this angular distribution are possible. The study of the S particle decay under the conditions when in the final state, in addition to the electron, photons are also detected is urgent for proving the electromagnetic nature of the S particle and defining more exactly its properties.

The angular distribution of the decay electrons in the lab.system under the assumption about the isotropic distribution of the particle rest system is of the form

$$\frac{d\sigma}{d\Omega} = I \cdot \frac{P}{E_0 - E}, \qquad (4)$$

where the electron momentum P is given by the formula

$$P = \frac{P_0 M E^* \pm E_0 \cdot \sqrt{M^2 (P^*)^2 - m^2 P_0^2 \operatorname{Sin}^2 \theta}}{E_0^2 - P_0^2 \operatorname{Cos}^2 \theta}. \qquad (5)$$

Here E^* and P^* are the electron energy and momentum in the rest system of the S particle, m the electron mass. The use of the particular features of the angular distribution given by eqs.(4) and (5) is essential for the detection of S particles and determination of their properties. For example, the use of the limiting angle $\operatorname{Sin} \theta_{\lim} = \frac{MP^*}{mP_0}$. The measurement of the angular distributions is also important for determining the S particle spin.

At present the mechanism of the S particle production seems to be far from being clear. The neutral particles decaying by the scheme (e^+, e^-) are detected in collisions of heavy ions of large charge. This fact is often interpreted as a consequence of the existence of bags in an abnormal QED vacuum that capture electron and positron pairs. However if the life-time of these particles is larger than the time of flight of ions with respect to each other, then the S particles exist outside superstrong fields, in vacuum. Search for the resonance (e^+, e^-) states in the positron-electron scattering at appropriate energies implies restrictions of their width $\Gamma \lesssim 10^{-2}$ eV or the life-time $\tau > \frac{h}{\Gamma} \sim 10^{-13}$ sec. According to ref. /4/ the life-time of the charged S particles is $\tau \sim 10^{-10}$ sec. This value is by several orders of magnitude larger than the life-time of, e.g., a neutral π meson $\tau = 0.87 \cdot 10^{-16}$ sec. So, it is possible to speak with certainty about independence of the processes of the production and decay of the S particles and about the existence of them outside super-strong electromagnetic fields. It may turn out that strong fields are really necessary for the processes of the S particle production, since in weak interactions at small distances $r \lesssim 10^{-16}$ cm (beta decay) the super-strong electromagnetic fields are in the order of magnitude close to the electromagnetic fields due to heavy-ion collisions.

In ref./5/ the investigations of Yu.A.Troyan team/12,13/ in which narrow resonances in the proton-proton system are observed were also discussed. These observations are interpreted in ref. /5/ as a manifestation of the electromagnetic resonances under discussion. The proof of the validity of this interpretation would mean that the participation of the super-strong electromagnetic fields in the S particle production is not obligatory.

Of special interest is the search for two- and three-charged S particles in colliding (e^+, e^-) beams at energies sifficient for the production of W and Z bosons. The number of new resonances in QED is supposed to be very large. It ref. /5/ a large series of resonances in the (e^+, e^-) system is predicted. Similar resonances must exist if the S particles include, in addition to electrons, μ and τ leptons as the quarks. Finally, ordinary atoms should also have S resonances the discovery of which would enable us to speak about a relativistic atomic physics. The existence of such resonances is expected to affect in a definite manner the relativistic theory of electronic plasma, the theory of super-dense matter.

Thus, the verification of the above-mentioned ideas can open a wide field of particle physics. Extensive and relatively cheap programs of the investigation of a new nuclear decay mode and nonperturbative QED may be suggested. Of course, it is necessary to remember that the existence of the relativistic quasi-stationary states of atoms itself needs further experimental confirmation.

I am very much indebted to Dmitrij Vladimirovich Skobeltsyn for the discussion of the hypothesis on the electromagnetic nature of the S particles suggested in the present paper. It is necessary to emphasize that long before the observation of the (e^+, e^-) resonances he called attention to the necessity of a careful study of the problems in question.

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