DEVELOPMENT OF THE CONCEPT OF NUCLEAR EXCHANGE BETA-FORCES. ON THE POSSIBILITY OF OBTAINING NEUTRON SUBSTANCE IN LABORATORY CONDITIONS

G.B. Ryazantsev[1], I.N. Beckman[1], G.K. Lavrenchenko[2], I.M. Buntseva[1], S.S. Nedovesov[3]

[1]*Lomonosov Moscow State University, Leninskie Gory, Moscow, Russia, anis-mgu@rambler.ru*
[2]*LLC «Institute of Low Temperature Energy Technology», POB188, Odessa,Ukraine, lavrenchenko.g.k.@gmail.com*
[3]*Shevchenko National University of Kyiv, Ukraine, pc.remont.tk@gmail.com*

ABSTRACT. In 1932, Heisenberg suggested that the interaction of a neutron with a proton is due to the exchange of an electric charge between these particles [1]. E. Fermi proposed in 1934 the theory of β-radioactivity [2], in which the proton can, under certain conditions, become a neutron and vice versa; at the same time, the electric charge of a heavy particle is changed due to the emission or absorption of two light particles: a neutrino and an electron or positron. The Fermi theory, therefore, contains a certain mechanism for the exchange of electric charge between a proton and a neutron, which was considered by Heisenberg as the basis for the interaction of these particles, and makes possible a theoretical calculation of this interaction, based on data on β decay. The emission and absorption of light particles (electrons, positrons, neutrinos) by heavy particles (protons and neutrons) must be due to the interaction of heavy particles (Heisenberg-Fermi field) in the same way as the emission and absorption of photons is due to the interaction of electric charges (Maxwell's field) . E. Fermi, D.D. Ivanenko and I.E. Tamm arrived at this conclusion independently and almost simultaneously. The calculation of the neutron-proton interaction, based on the Fermi β-decay theory, was carried out by Tamm and his result was very disappointing for ordinary nuclei. The theory of Tamm [3], which he put forward at one time (1934) to explain the mechanism of nuclear forces for ordinary nuclei was not consistent for them. Tamm himself valued his "unsuccessful" theory of nuclear forces more than his Nobel work on Cherenkov radiation.

However, there is reason to believe that the Tamm interaction can be realized precisely for superheavy nuclei (neutron matter) of an appropriate scale (of the order of 200–300 or more femtometers), giving it additional stability. In strongly interacting systems, many virtual particles are present and all kinds of interactions are allowed, resolved by considerations of invariance. V.L. Ginzburg and E.L. Feinberg believed: "... although these beta forces, of course, exist, they do not ensure the stability of the nuclei" [3]. This is true for ordinary nuclei, but is fundamentally changing for super heavyweight. The “original” theory of exchangeable β-nuclear forces Tamm (e - exchange of nucleons), and not only its modification of Hideki Yukawa (π-exchange of nucleons), is still waiting for its recognition and "dominates" in the neutron matter of the Universe, ensuring its stability and wide cosmic distribution, as well as the possibility of obtaining neutron matter in laboratory conditions [4,5].

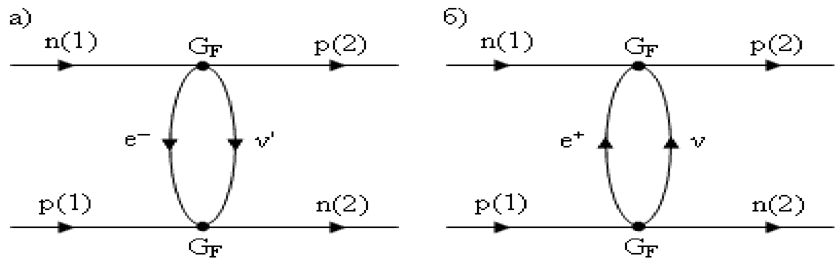
Introduction

It should be noted that from the very beginning electrons were assigned a significant role in the atomic nucleus. According to E. Rutherford's model before the discovery of the neutron, it was believed that the nuclei consist of protons and electrons. This model was based on two experimental facts: in nuclear reactions with α-particles protons fly out of nuclei, and electrons in radioactive β-decay. In accordance with the classical concepts of the composite system, the nucleus should have seemed to consist of these particles. But on this path there were insurmountable obstacles. To solve these problems, N. Borh even suggested that electrons, entering nuclei, "lose their individuality" and their own moment — spin, and the energy conservation law is satisfied only statistically, i.e. may be violated in individual β-decay acts.

The assumption about the presence in the nucleus of neutral particles with spin 1/2 was already contained in the well-known letter of V. Pauli, where in 1930 he expressed the hypothesis of the existence of a certain neutral particle ejecting from the nucleus along with the β-electron escaping observation energy conservation law in β-decay. But only after the discovery of the neutron was the idea of the possibility of electron production in the process of β decay allowed D.D. Ivanenko suggests that nuclei are composed of protons and neutrons.

Problem of β-nuclear forces

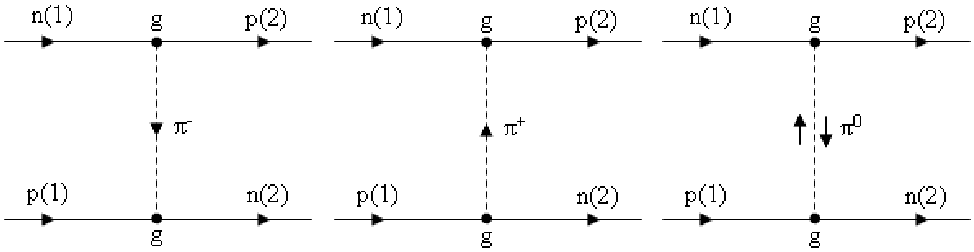
Consider the problem of β-nuclear forces from the standpoint of the theory of β-decay. Immediately after the work of Fermi, I.Ye. Tamm [6] and D.D. Ivanenko [7], it was independently hypothesized that the short-range interaction between a neutron and a proton in the nucleus can occur due to the exchange of an electron-antineutrino pair according to the scheme If we present the Tamm interaction in the form of a Feynman diagram:



The exchange interaction between the neutron n and the proton p, arising according to the idea of Tamm and Ivanenko due to β-forces.

Neutron n(1), emitting an electron e^- and antineutrino ν ', turns into proton p(2), and proton p(1), absorbing electron and antineutrino - into neutron n(2) (a). The proton p(1), emitting a positron e^+ and a neutrino ν, turns into a neutron n(2), and a neutron n(1), absorbing a pair (e^+ and ν) - into a proton p(2). Gf is a constant characterizing β-forces (b).
The undertaken estimates, based on the experimentally determined β-interaction constant of the Gf, showed, however, that the forces arising between the nucleons due to the exchange β-interactions turn out to be 14–15 orders of magnitude smaller than those needed to hold the nucleons in the atomic nucleus. It would seem that the authors suffered a failure. But the work of Tamm and Ivanenko stimulated the Japanese physicist H. Yukawa, who had alluded to this work, to put forward a new hypothesis. Yukawa suggested that the interaction between the nucleons occurs through the exchange of an unknown previously charged particle, the mass of which he predicted, based on the experimentally known radius of action of nuclear forces.

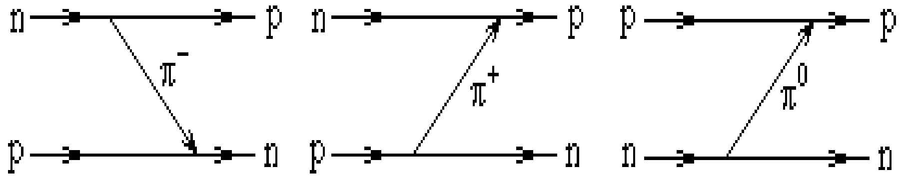
Neutron n(1), emitting a negatively charged π-meson, transforms into proton p(2), and proton p(1), absorbing π-meson, into neutron n(2) (a). The proton p(1), emitting a positive π^+ -meson, turns into the neutron n(2), and the neutron n(1), absorbing the π^+ -meson, into the proton p(2) (b). The interaction of nucleons through the exchange of a neutral π^0-meson ensures, together with the exchange of charged pions, the charge independence of the nuclear forces (c); g is a constant characterizing the magnitude of the interaction between the nucleons and the pion.



Nuclear forces that arise according to the Yukawa hypothesis as a result of the exchange of mesons.

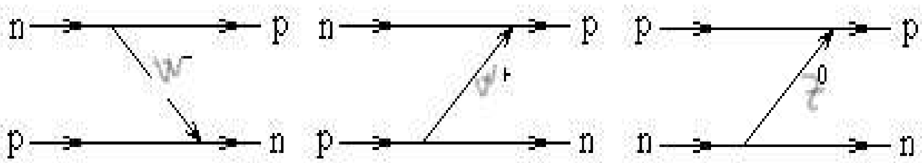
Neutron n(1), emitting a negatively charged π- meson, transforms into proton p(2), and proton p(1), absorbing π-meson, into neutron n(2) (a). The proton p(1), emitting a positive π^+ -meson, turns into the neutron n(2), and the neutron n(1), absorbing the π^+ -meson, into the proton p(2) (b). The interaction of nucleons through the exchange of a neutral π0-meson ensures, together with the exchange of charged pions, the charge independence of the nuclear forces (c); g is a constant characterizing the magnitude of the interaction between the nucleons and the pion.

The mass of the exchange particle turned out to be about 300 electron masses, i.e. lying between the masses of the electron and the proton. Therefore, it was called the meson. As for the strength of the unknown interaction of mesons with nucleons, it could be estimated on the basis of the required value of the nuclear forces. The dimensionless constant of this interaction turned out to be approximately three orders of magnitude greater than the dimensionless constant of electromagnetic interaction. Thus, the notion of a strong interaction, differing by 14–15 orders of magnitude from weak interaction, arose. Or more familiar and modern:



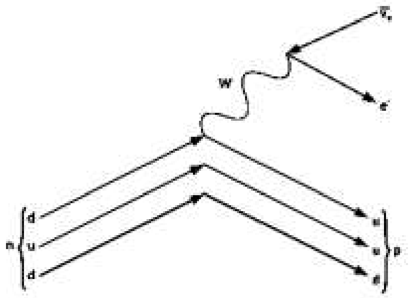
We now know that before the final beta decay into an electron and antinenutrino and in K-capture there are intermediate bosons (W, Z).

Then the Tamm interaction could be presented in a modern version using intermediate bosons:

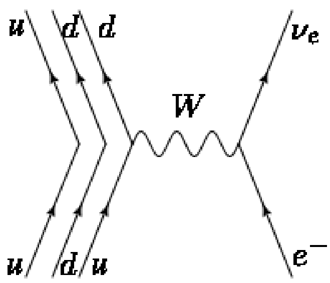


The exchange interaction between the neutron n and the proton p, arising according to the idea of Tamm, but with the participation of intermediate bosons.

Both beta decay and K-capture go through the intermediate boson stage:

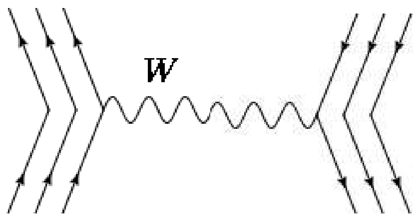


Beta decay



K-capture

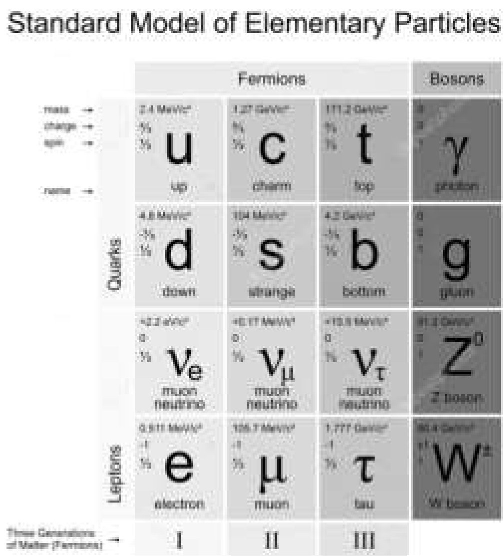
Why not combine them?



So we got the Tamm-interaction in the modern version using intermediate bosons.

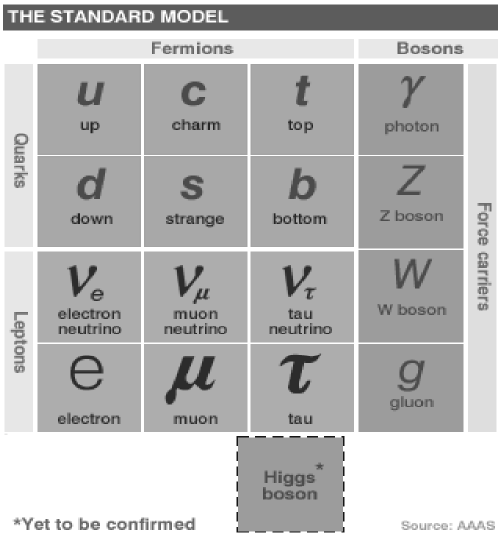
But this is a typical, so-called weak interaction, which does not correspond to real nuclear forces, both in intensity and in distances. To implement the Tamm interaction, lighter bosons are needed. The discovery of the X-boson [8] brings us closer to an understanding of the reality of the Tamm interaction and suggests the existence of different generations for bosons, as well as for fermions. The possibility of the existence of various generations for bosons is also indicated by papers claiming the existence of heavy Higgs bosons [9], the presence of a particle with a mass of about 700 ± 75 GeV. Briefly speaking, existing bosons do not fit into just one generation in the SM elementary particles.

Generations of bosons



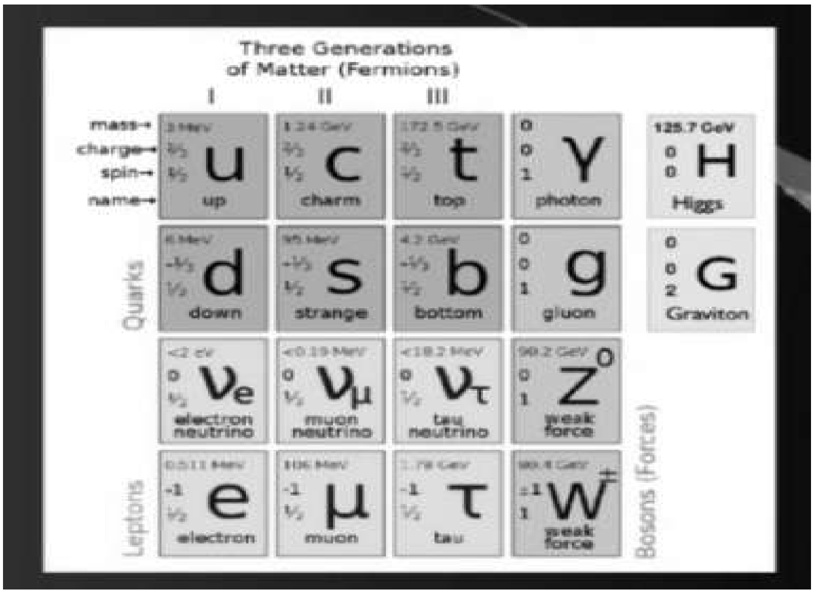
The existing tabular forms of the SM contain the number of open bosons more than four and do not fit into one generation.

Because of this, or the special significance that is attached to it, the Higgs boson is distinguished by a special position.



The Higgs boson is often carried out separately, it is logical to assume that it already belongs to the new generation.

Then there is a place not only for him, but also for the graviton, which in other schemes has to be ignored.



From symmetry considerations, we can assume the existence of three generations of bosons, as well as fermions.

I	II	III	I	II	III
3 MeV 2/3 1/2 u up	1.24 GeV 2/3 1/2 c charm	172.5 GeV 2/3 1/2 t top	0 0 1 γ photon	125.7 GeV 0 0 H Higgs	
6 MeV -1/3 1/2 d down	95 MeV -1/3 1/2 s strange	4.2 GeV -1/3 1/2 b bottom	0 0 1 g gluon	0 0 2 G Graviton	
<2 eV 0 1/2 ν_e electron neutrino	<0.19 MeV 0 1/2 ν_μ muon neutrino	<18.2 MeV 0 1/2 ν_τ tau neutrino	90.2 GeV 0 1 Z^0 weak force		
0.511 MeV -1 1/2 e electron	106 MeV -1 1/2 μ muon	1.78 GeV -1 1/2 τ tau	80.4 GeV ±1 1 $W^\pm$ weak force		

Then there is a place for the long-awaited and sought light bosons and probable heavy Higgs bosons. Heavy Higgs bosons as well as missing light bosons can claim empty cells.
Finally, imagine a system of particles in a more familiar form, just like a system of chemical elements: an increase in mass from left to right and from top to bottom.
Where the heavy Higgs is a boson [9] is probably identical to H_1, and the X boson [8] corresponds to Z_2 and there is a possibility that there is an even lighter boson – Z_1 (close in mass to the electron), which is even better responding to Tamm – interaction.

I	II	III	I	II	III
<2 eV 0 ½ ν_e electron neutrino	<0.19 MeV 0 ½ ν_μ muon neutrino	<18.2 MeV 0 ½ ν_τ tau neutrino	0 0 1 γ photon	0 0 1 g gluon	0 0 2 G Graviton
0.511 MeV -1 ½ e electron	106 MeV -1 ½ μ muon	1.78 GeV -1 ½ τ tau	? W_1	? W_2	80.4 GeV ±1 1 $W^{\pm}$ weak force
3 MeV ⅔ ½ u up	1.24 GeV ⅔ ½ c charm	172.5 GeV ⅔ ½ t top	? Z_1	? Z_2	90.2 GeV 0 1 Z^0 weak force
6 MeV -⅓ ½ d down	95 MeV -⅓ ½ s strange	4.2 GeV -⅓ ½ b bottom	125.7 GeV 0 0 H Higgs	700GeV? H_1	? H_2

Conclusion

The "original" theory of exchangeable β-nuclear forces by V. Heisenberg, E. Fermi, D. Ivanenko, and I. Tamm can get its rebirth in the modern approach to the physics of nuclear forces and elementary particles. That light, not yet open boson and close in mass to an electron can be called a β-boson in honor of the long-predicted β-nuclear interaction by outstanding physicists of the last century. Beta-nuclear forces manifest themselves weakly in conventional nuclei (1fm is the area of the nuclear forces of Yukawa) and enter into their rights at much longer distances (10 fm –X-boson and, probably, 200–300 fm for β-boson).

Thus: Beta - nuclear interaction between nucleons carried out by means of light bosons (at distances of 10-200 fm) and electrons at large distances requires serious attention and close study, is realized in neutron matter, giving it additional stability.

Beta - nuclear interaction can explain many previously incomprehensible phenomena and "dominates" in the neutron matter of the Universe, providing it with stability and wide cosmic distribution, as well as the possibility of obtaining neutron matter in the laboratory [4,5].

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