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TOPICAL ISSUES IN HIGH-ENERGY AND PARTICLE PHYSICS

New discoveries in science, in particular physics, occur almost every day. Several of them are known all over the world, others are the heritage of a minor part of the scientific community. High energy physics is now on everyone's lips. Indeed, everyone has heard of the Large Hadron Collider and the discovery of the Higgs boson with the help of it. It is known, however, that the construction of accelerators to obtain higher and higher energies continues. This forces us to face the following question: what are the promising avenues in modern high-energy physics?

At first, there is a certain amount of collected experimental results (primarily related to cosmology and astrophysics, but also obtained in laboratories) suggesting that the Standard Model (SM) is incomplete. For instance, the SM doesn’t characterize dark matter in any way. However, there is no longer any doubt that dark matter really exists. Moreover, some values of the SM parameters are not fully natural and not calculable in the theory, notably, the fermion mass hierarchy and the hierarchy of symmetry-breaking scales.

Another still unsolved problem is the problem of generations of matter. Nowadays quarks and leptons are considered to be the smallest structureless particles. Leptons are independent particles (e.g. electron, neutrino), and quarks are part of heavy particles susceptible to strong interaction - hadrons (e.g. proton, neutron). It is known that there are three generations of quarks and leptons. Generations differ from each other only in mass: each next generation is heavier than the previous one. Our universe is created from four first-generation particles: up and down quarks and two leptons - an electron and a neutrino. Particles of other generations have been discovered in cosmic rays and accelerators. So, the question to which we haven’t found an answer yet is: why are there three generations of quarks and leptons taking into consideration the fact that our universe consists only of particles of the first generation.

Moreover, it is not known at present whether a neutrino is an antiparticle. Difficulties in studying neutrinos emerge due to the fact that they belong to neutral particles, and hence almost do not interact with the medium, which complicates their detection and exploration. All leptons and quarks can be described by complex solutions of the Dirac equation. But the Dirac equation also has a real solution, which is correct only for neutral particles. Since the neutrino has no electric charge, it can also be described using this solution found by Ettore Majorana and in this case neutrino is an antiparticle, and two such particles annihilate upon collision. If the neutrino satisfies the Dirac solution, then it is not an antiparticle and cannot annihilate. In order to find out whether a neutrino is a Dirac or Majorana particle, it is necessary to conduct an experiment with the collision of two neutrinos and find out whether they annihilate.

Of course, this is only a small part of the currently existing problem area. However, even this part shows that despite the fact that all principle statements of quantum theory and its applications to particle physics remain virtually unchanged, this does not mean stagnation in the development of elementary particle physics. There are many problems to be solved and unite physicists all over the world in an attempt to understand the essence of our amazing universe.