Sample: Nuclear Physics - Quarks

Quark is an elementary particle in quantum chromodynamics, regarded as part of the hadrons. The existence of six different types of quarks is assumed, to distinguish them such characteristic as a "flavor" is introduced. For brevity, the quarks are assigned the following names: u-quark, d-quark, c-quark, s-quark, t-quark, b-quark. Hadrons, the particles that interact via the strong interaction, are divided into baryons and mesons. As quarks have spin of ½ h (they are fermions), baryons as particles with half-integer spin are composed of three quarks, and mesons consist from quarks and antiquarks as they have an integer spin. Quark hypothesis can be used to explain many of the properties of symmetry (eg, the multiplets of particles) observed in hadrons.

History

The quark model of hadrons was first proposed by Murray Gell-Mann and, independently, by George Zweig in 1964. Earlier, in 1960, Gell-Mann formulated a classification system of particles, known as the eightfold path, and based on the SU (3) group symmetry. There were another models, that were proposing classification of hadrons based on combination few subparticles and using different symmetries, as the number of observed particles grew rapidly (to tens and hundrets). Examples of such models are: Goldhaber model (beside protons and neutrons, more K-mesons were considered as fundamental particles, remaining particles were obtained as combination of these three); Markov model; Sakata model (baryons were fundamental in those two and mesons were composed from baryons) and others.

Those systems were a vital link that led to the quark model. The idea that hadrons are composite particles is likely to have originated in 1949, when Fermi and Yang suggested that the peony is composed of a nucleon and antinucleon.

The word "quark" was borrowed by the Gell-Mann from the novel by James Joyce's "Finnegans Wake", where in one of the episodes of the phrase sounds «Three quarks for Muster Mark!». The word «quark» in this phrase is presumed to be imitating sea bird’s shout.

In the basic Gell-Mann model there were only three quarks. Less than a year after the appearance of the quark model, Glashow and Bjork predicted fourth quark flavor as a new degree of freedom, which they called charm. This allowed them to better describe the decay of the weak interaction of quarks, to equalize the number of quarks with a number of well-known at the time of the leptons, and implement refined formula for estimating the mass of the mesons. Introduction to the theory of the strange quark (s-quark) enabled us to explain the properties of kaons (K) and a pion (π), opened in 1947 in cosmic rays and other particles found in accelerator experiments.

In 1968, experiments with deep inelastic scattering of particles at the Stanford Linear Accelerator Center (SLAC) have shown that the proton consists of some pointlike objects and therefore is not elementary (indivisible into parts) particle.

The number of hypothetical quarks increased to six by 1973 at this time Kobayaci and Maskawa found that the experimental observation of CP-violation could be explained if we introduce two quarks , which was later called the true and charming . Particles containing charmed quarks were discovered in 1974 , almost simultaneously at the proton synchrotron at Brookhaven and at SLAC in Stanford. As a result, discovered particles that were mesons have different designations J and ψ, and became known as the J / ψ mesons. In 1977, the National Center for Nuclear Studies . Fermi (U.S.) was found bottom quarks , and in 1995 in the collisions of protons and antiprotons - the true quark . Quark mass of the latter was much greater than that expected.

Properties.

By yet unknown reasons quark are naturally grouped into three so-called generations . In every generation, one quark has a charge of +2/3 , and another – 1/3 . Division into generations extends to the leptons .

The characteristic of quark, the defines how it is going to interact in strong interaction is called color. Each quark can be one of three colors – red, blue or green.

Quarks are involved in the strong , weak, electromagnetic and gravitational interactions. Strong interactions (gluon exchange) can change the color of the quark, but do not change its flavor. Weak interactions , by contrast, do not change color , but they can change the flavor. The unusual properties of the strong interaction leads to the fact that a single quark can not move to any significant distance from the other quarks , which means that quarks can not be observed in the free form (a phenomenon called confinement) . Only " colorless " combinations of quarks – hadrons - can exist.

Because of the unusual properties of the strong interaction, the confinement, non-specialists often ask: why are we sure that quarks exist, if no one will ever see in a free form? Maybe they are only a mathematical abstraction? The reasons that quarks are considered real objects are are as follows:

- Firstly, in the 1960s, it became clear that all of the many hadrons are subject to more or less simple classification : they are combined into multiplets and supermultiplets . In other words, the description of these multiplets require a very small number of free parameters. That is, all hadrons have a small number of degrees of freedom: all baryons with the same spin have three degrees of freedom , and all mesons - two . Originally quark hypothesis is precisely in this observation , and the word "quark ", in fact , it was a short form of the phrase " subhadronic degree of freedom."
- Further, when the spin was taken into account, they found out that each of these degrees of freedom can be attributed to the spin ½, and moreover, each pair may be attributed quark orbital moment -like if they are the particles, which can rotate relative to each other. From this assumption they get explanation to the diversity of the spins of hadrons and their magnetic moments.
- When era of high-energy accelerators came, it became possible to study the distribution of momentum in, for example, the proton. It turned out that the momentum of the proton is not distributed evenly over it , and is concentrated in certain parts of the degrees of freedom (called partons) . With increasing energy, it was found that the number of partons increases, but such a result is expected in the quark model at very high energies . Also, it became possible to try to knock out a single quark of hadron collisions at high energy . The quark theory gives an accurate prediction of how the results should look like – it must be in the form of jets . Such jets are indeed observed in the experiment. Note, that if the proton wasn't consisting with quarks, that the jets would not be observed.
- Etc

Applications in society, in future and impact on scientific thinking

Discovery of quarks had a huge impact on the elementary particle and nuclear physics. These particle became part of the Standard Model - a theory that unites weak, strong and electromagnetic interactions in one model. The recent discovery of Higgs boson is excellent confirmation of this theory. This theory is first step of building Theory of Everything and quarks are important part of it. From the other hand, discover of quarks again open discussion about theory of fractal nature of the University. Atoms are not the most elementary particle of the matter and neither protons are. How knows, is there something more elementary then quarks?

Biblograpy

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