

The fundamental particles of matter

Elementary particles of matter

Since the beginning of human existence, various ideas about the composition of matter have arisen. Confirmation of the ancient theory of the atom as the basic component of matter was brought by research from the 19th century, when it was specified that the atom consists of **elementary particles - a proton , a neutron and an electron** . During the 20th century, a number of other particles and antiparticles (mirror particles that have the same mass but opposite electrical charge) were discovered . The discovered elementary particles can be divided into two main groups. They are *leptons* and *hadrons*.

Leptons

Leptons are the first group of elementary particles , which includes the electron and its related particles. We do not observe any internal structure in them up to current experimental possibilities, i.e. up to 10⁻¹⁸ m. All particles have spin 1/2, so they are so-called **fermions** (particles with half-numerical spin) interacting by weak interaction . Electrically charged particles (electrons) also interact electromagnetically and are able to interact with matter , unlike electrically negative particles (neutrinos), which only react very weakly with matter. Lepton interactions are governed by the **law of conservation of lepton number L**, which must match before and after the interaction. Today, 3 different lepton numbers are known, which are equal to +1 for electrons, muons , taus and their neutrinos, and -1 for their antiparticles and antineutrinos . We know 12 types of leptons, 3 of which are charged (electron, muon, tauon), 3 neutrinos (electron, muon, tauon) and their 6 antiparticles .

Lepton generation

1st generation – electron and its neutrino

2nd generation – muon and its neutrino

3rd generation – tauon and its neutrino

We can artificially prepare these particles in accelerators. Antiparticles also belong to all generations.

Quarks

Quarks are the fundamental particles that make up hadrons . Individually occurring quarks have never been observed.

There are six types of hadron-forming quarks, distinguished by their "**smells**" (**up , down , strange , charm , bottom , top**).

Pairs of quarks, together with their antiquarks , are divided into **three generations** :

1st generation – u (up), d (down) quarks

2nd generation – s (strange), c (charm) quarks

3rd generation – quarks b (bottom), t (top).

Commonly found in nature are 1st generation quarks .

Clustered quarks form two types of hadrons – baryons and mesons . Baryons are formed by a triplet of quarks **qqq** , a proton by a triplet **uud** , and a neutron **udd** . Mesons always consist of one quark and one antiquark (**q \bar{q}**) .

Quarks are colored charged particles. Each quark carries a color charge in one of three possible values - **green , blue or red** (RGB), each antiquark has one of three values of complementary charge. Quarks are never found alone, they are always combined in hadrons. The interaction energy between quarks in hadrons is greater the farther apart they are. It takes an infinite amount of energy to release a quark.

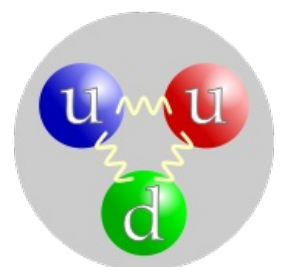
Strong interactions between quarks in hadrons are mediated by **gluons** - color-charged particles carrying the charge of **color-anticolor pairs** (eg red/anti-blue). A hadron as a whole must always be **neutral in color** , because that is the only way it can exist independently. Therefore, each quark in a baryon carries a different color.

The high-energy collision of hadrons can cause them to "melt" and create a so-called **quark-gluon plasma** . In it, quarks can move freely. This state of matter was supposed to be in the universe 20–30 microseconds after the Big Bang and can be created for an extremely short time in a particle accelerator.



$$\begin{pmatrix} e^- \\ \nu_e \end{pmatrix}, \begin{pmatrix} \mu^- \\ \nu_\mu \end{pmatrix}, \begin{pmatrix} \tau^- \\ \nu_\tau \end{pmatrix}$$

Leptons



The quark structure of the proton.

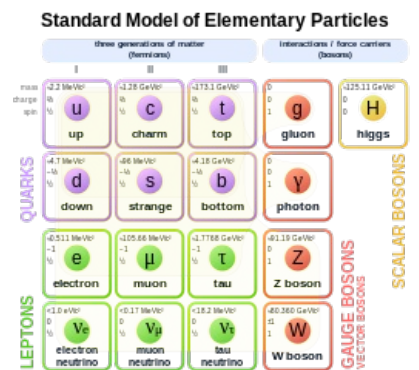
Links

External Links

- Elementary Particles (https://www.wikipedia.org/wiki/cs:Element%C3%A1rn%C3%AD_%C4%8D%C3%A1stice)
- Systematic overview of elementary particles (<https://www.aldebaran.cz/astrofyzika/interakce/particles.html>)

References

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Standard Model of Elementary Particles

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