Antiparticle

Antiparticle is literally the "opposite" of a particle. In nature, there is symmetry between particles and antiparticles, which we can see in the following cases:

- an antiparticle has the same spin, the same mass, and the same average lifetime.
- on the other hand, it has the opposite sign of electric charge, magnetic moment, baryon number, lepton number, isospin, strangeness,...

The important piece of information is that antiparticles obey the **same laws of physics *as particles.***

History

Before the existence of antiparticles was proven, the British physicist Paul Dirac came up with the theory in 1928 that the electron must also have its antiparticle, i.e. the positron. He arrived at this result while calculating the so-called Dirac equation, which he derived from the Schrödinger equation:

$$\hat{H}(t)\Psi(\mathbf{r},t) = i\hbar\frac{\partial\,\Psi(\mathbf{r},t)}{\partial t}$$

(in the relativistic generalization known as the Klein-Gordon equation) and which worked out for him both positively and negatively. Dirac's relativistic equation was determined for counting elements with spin 1/2:

$$\left(i\hbar c\sum_{\mu=1}^{3}\gamma^{\mu}\partial_{\mu} - mc^2\right)\psi = 0$$

4 years later, the positron was actually discovered, specifically by the American physicist Carl Anderson. The positron was discovered in a cloud chamber while studying cosmic rays. In 1955 Emilio Sergé was conducting experiments at the Berkeley accelerator and succeeded in discovering the **antiproton.**

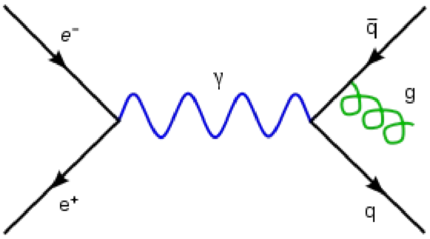
Characteristics

Particles are the basic building blocks of matter, while matter made up of antiparticles is referred to as antimatter. Antimatter can also be observed in space, but even there matter prevails over antimatter. Cosmology deals with the study of this disparity.

When a particle and an antiparticle collide, the so-called annihilation of matter and the generation of electromagnetic radiation gamma occur. It is during the collision of an electron and a positron that, thanks to the law of conservation of momentum and the law of conservation of energy, two photons (or bosons and mesons) are created, which move in opposite directions.

Occurrence

It is believed that at the beginning of the universe, the ratio between the amount of matter and antimatter was almost equal. But in the current universe, matter prevails over antimatter (the so-called baryon asymmetry), the reason for this predominance is still not entirely clear. Antimatter occurs very rarely, namely in cosmic rays (antiprotons and positrons make up 0.01%). Furthermore, they can arise during high-energy processes, such as supernova explosions. They are also obtained using particle accelerators (CERN, FermiLab) or during positron decay of radioactive elements.



The Feynman diagram represents the annihilation of an electron with a positron. A photon is created, which then produces a Quark-Antiquark pair. An antiquark emits a gluon

Importance

Positron emission tomography

Positron emission tomography (PET) is a nuclear imaging technique of nuclear medicine, thanks to which a 3D image of a certain part of the human body is obtained. It is mainly used in oncology, then in neurology, cardiology and other branches of medicine. A substance containing a radionuclide is injected into the blood, which has a half-life of the order of minutes and emits positrons. **Annihilation of positrons with electrons** then occurs and the released energy is absorbed by a detector recording gamma radiation. This technique is used in medicine in combination with CT and nuclear magnetic resonance NMR. It is a hybrid positron emission and computed tomography, which is used for **diagnosis of oncological and some inflammatory diseases** (the exact localization and extent of, for example, a tumor center and the subsequent steps of treatment are thus determined). In the Czech Republic, this technique was first put into practice at Na Homolce Hospital in 1999. Today, this PET center is one of the largest in Europe.

For more information see Positron emission tomography.

Antiproton Therapy

PET device

The second option is antiproton radiotherapy used to treat tumors. It belongs to hadron radiotherapy.

After penetrating the tissue, accelerated antiprotons (sweat protons) ionize in a similar way as ordinary protons (with a maximum in the so-called Bragg peak). In addition, an antiproton annihilates with a proton or neutron in the atomic nucleus of the irradiated substance (tissue) to form p-mesons. This releases additional E, which significantly increases the radiation effect (about 3 times compared to protons). An accompanying phenomenon during interactions are also positrons, whose annihilation gamma-photons can be detected using a PET camera and thus the real distribution of the radiation dose in the tissue can be monitored.

A certain disadvantage of antiproton therapy is a somewhat higher radiation dose outside the target volume (including whole-body dose), caused by penetrating pions, neutrons and g, flying in all directions from the site of antiproton interaction. The method is at the stage of laboratory testing in the largest nuclear laboratories (CERN, FERMILAB). Due to the extraordinary difficulty and cost, we can perhaps expect the introduction of this interesting method into clinical practice only in the distant future.

Importance outside of medicine

Antimatter composed of antiparticles can be used as the most efficient of the known types of energy, because when it reacts with matter it **releases energy with 100% efficiency.** But humanity is not yet technologically capable of using it in this way. We can only preserve antiprotons or positrons in so-called Penning traps, but we cannot yet preserve the antimatter created from these particles. Other antiparticle research is looking into the possibility of developing annihilation engines that would use antimatter to power spaceships (e.g. University of Pennsylvania).

Links and Resources

- WAGNER, Vladimir. *Antihmota jako zdroj energie* [online]. [cit. 2015-12-17]. <http://hp.ujf.cas.cz/~wagner/prednasky/antihmota/vyuziti/pohon.html>.
- REICHL, Jaroslav. *Částice a antičástice* [online]. [cit. 2015-12-17]. <http://fyzika.jreichl.com/main.article/view/898-castice-a-anticastice>.
- GEOGRAPHIC, National. *Antihmota jako lék na rakovinu? V Cernu už na tom pracují.* [online]. [cit. 2015-12-17]. <https://www.national-geographic.cz/clanky/antihmota-jako-lek-na-rakovinu-v-cernu-uz-na-tom-pracuji.html>.
- ULLMANN, Vojtěch. *Radioterapie* [online]. [cit. 2015-12-17]. <http://astronuklfyzika.cz/JadRadMetody.htm#6>.
- ACCELERATING SCIENCE, Cern. *ACE* [online]. [cit. 2015-12-17]. <https://home.cern/science/experiments/ace>.