Virtual Particles Encyclopedia Article

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Virtual Particles

Virtual particles are quantum mechanical particles that act as short-lived intermediate states during the interactions between real particles. By their nature, they do not live long enough to detect. However, the theory suggesting their existence has brought such success that it is widely accepted by physicists today that they do exist.

Both virtual and real quantum mechanical particles exhibit certain characteristic properties that determine their particle type. For a quantum particle to be considered an **electron**, for example, it must have an electrical charge equal to -e = -1.6x10-19 C, a **mass** equal to m = 2.0x10-26 lb (9.1x10-27 kg), and a total intrinsic spin **angular momentum** of h/4pi. (The parameter h is **Planck's constant**, equal to 6.626x10-34 Js.) In addition to these characteristic properties, all quantum mechanical particles must obey a set of fundamental conservation laws including the conservation of electrical charge, spin angular **momentum**, **energy**, and the **linear momentum**.

A real quantum mechanical particle is one whose total relativistic energy is related to its rest mass m by the equation E = m c2 / (1 -v2 / c2), where c is the speed of **light** in a **vacuum**, measured to be 186,000 mi/s (300,000 km/s), and v is the speed of the particle. If this relationship is true for a particle, then we say that such a particle is on the mass shell, or real. A particle whose total energy does not obey this equation is said to be off the mass shell, or virtual. The amount of deviation from this equation, dE, determines how long the virtual particle can live. Heisenberg's uncertainty principle says that such a virtual particle can only exist for an approximate time h/dE.

In electron-positron acceleraators, electrons and **positron** (anti-electrons with all of the same characteristic properties as electrons but having positive electrical charge, +e) collide to form virtual photons. (Photons are the quantum mechanical particles that make up light.) The conservation of electrical charge and spin angular momentum indicates that the intermediate state formed by the electron-positron collision must be a **photon**. However, the **conservation of energy** and linear momentum says that the photon must be virtual. Therefore, the photon lives for a very short time and then can decay into a variety of different final state particles.