Particle classification

D. Craig

2006–04–17

Categories

Hadrons interact via strong force

Mesons spin 0,1 and $m_e < m < m_p$

Baryons spin $\frac{1}{2}, \frac{3}{2}, \frac{5}{2}$ $m \geq m_p$. Including p, n. Decay products always include a p.

Leptons , spin $\frac{1}{2}$, appear to be structureless point particles.

- electron (e^-), electron neutrino ν_e
- tau τ^-, tau neutrino ν_τ
- mu, μ^-, mu neutrino ν_μ.

Plus their respective antiparticles.

Neutrino physics

Neutrinos have a **helicity:** spin is aligned with $\vec{\mathbf{p}}$ for antineutrinos, opposite for neutrinos.

Neutrinos seem to have a small (~eV) mass. This is difficult to measure.

Neutrino **oscillations** have been recently confirmed. The different neutrion types can among themselves as they propagate from a source. This explains the **solar neutrino problem** and should permit determination of the neutrino masses.

Conservation Laws

In nuclear reactions or decays, the following are conserved, adding up the numbers for the types of particles:

Baryon number $B = \pm 1$ for baryons/antibaryons, $B = 0$ for others.

Lepton number $L = \pm 1$ for electrons and their neutrinos, muon and tau families hav $L = 0$.

Strangeness Some heavy hadrons are produced in pairs in reactions, such as the K, Λ, Σ. They have **strangeness** numbers that are conserved in reactions.

Resonance particles

The very short lifetime Δ^+, of mass 1231 MeV/c^2. Consider

$$e^- + p \to e^- + \Delta^+$$

followed in 6×10^{-24} s by

$$\Delta^+ \to \pi^+ + n$$

and the direct reaction

$$e^- + p \to e^- + \pi^+ + n$$

where no Δ^+ is produced. How to tell them apart? The Δ^+ will not last long enough to leave a track.

The decay of the Δ^+ must satisfy

$$E_\Delta^2 = (p_\Delta c)^2 + (m_\Delta c^2)^2$$

or

$$m_\Delta c^2 = \sqrt{E_\Delta^2 - (p_\Delta c)^2}$$

We can't measure E_Δ and $\vec{\mathbf{p}}_\Delta$, but after the decay we can measure the outgoing particle properties, so $E_\Delta = E_\pi + E_n$ and $\vec{\mathbf{p}}_\Delta = \vec{\mathbf{p}}_\pi + \vec{\mathbf{p}}_n$, and

$$m_\Delta c^2 = \sqrt{(E_\pi + E_n)^2 - (\vec{\mathbf{p}}_\pi + \vec{\mathbf{p}}_n)^2 c^2}.$$

This will be 1231 MeV *if a Δ^+ decay is involved.* If not, a broad range of values is possible for the direct reaction.

A histogram of energy values for this type of reaction will show a peak at the particle energy for a rapidly decaying particle. See fig 15.8