

Particle classification

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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{p} for antineutrinos, opposite for neutrinos.

Neutrinos seem to have a small ($\sim eV$) 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:

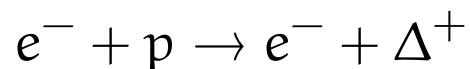
Baryon number $B = \pm 1$ for baryons/antibaryons,
 $B = 0$ for others.

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

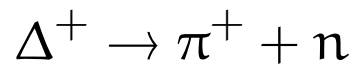
Strangeness Some heavy hadrons are produced in pairs in reactions, such as the K, Λ, Σ . They have **strangeness** numbers that are conserved in reactions.

Resonance particles

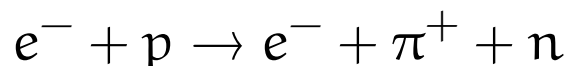
The very short lifetime Δ^+ , of mass $1231 \text{ MeV}/c^2$. Consider



followed in $6 \times 10^{-24} \text{ s}$ by



and the direct reaction



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{p}_{Δ} , but after the decay we can measure the outgoing particle properties, so $E_{\Delta} = E_{\pi} + E_n$ and $\vec{p}_{\Delta} = \vec{p}_{\pi} + \vec{p}_n$, and

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

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