EP 228 Particle Physics, Lecture Notes on Conservation Laws, Oct 2020

Conservation Laws

All particle reactions and decays obey certain conservation laws:

- Conservation of total energy
- Conservation of linear momentum
- Conservation of angular momentum (spin)
- Conservation of invariant mass (for all inertial coordinates)
- Conservation of charge
- Conservation of lepton number
- Conservation of baryon number
- Conservation of Strangeness (there is an exception for weak interactions)

For any decay: $X \rightarrow Y + Z$ $m_X > m_Y + m_Z$ (mass is not conserved)
For any collision: $1 + 2 \rightarrow 3 + 4$, may be $m_1 + m_2 \neq m_3 + m_4$ (mass is not conserved)

Quantum numbers

Some quantum numbers are assigned to fundamental particles

Conservation of lepton number	*Conservation of baryon number*	*Conservation of Strangeness*
L_e = +1 for e- and ν_e L_e = -1 for e+ and $\overline{\nu_e}$ L_e = 0 for all other particles L_μ = +1 for μ- and ν_μ L_μ = -1 for μ + and $\overline{\nu_\mu}$ L_μ = 0 for all other particles L_τ = +1 for τ- and ν_τ L_τ = -1 for τ+ and $\overline{\nu_\tau}$ L_τ = 0 for all other particles	B = +1 for all baryons B = -1 for all anti-baryons B = 0 for all other particles	Strangeness (S) is conserved in strong and electromagnetic interactions but it may not be conserved in weak interactions. ΔS = 0 for strong interactions ΔS = 0 for em interactions ΔS = 0 or 1 for weak inter.

Note that

- There is no conservation law for mesons
- There is no conservation law for photons

Solved Problems

[1]. Consider a neutrino originating from the decay $\pi \rightarrow \mu + \nu$. What is the type of the neutrino if pion is positively charged?

[2]. Determine the unknown particles denoted by X or Y in the following reactions:

$X + p \rightarrow p + p + p + \bar{p}$	$n \rightarrow p + e^- + X$	$\mu^- \rightarrow e^- + X + Y$
$X + p \rightarrow \mu^+ + n$	$\pi^+ + p \rightarrow K^+ + X$	$\Lambda^0 \rightarrow \pi^- + X$

[3]. Explain why the following reactions are forbidden?

$\mu^- \rightarrow e^- + \gamma$	$\overline{\nu}_\mu + p \rightarrow e^+ + n$

[4]. Which of the following weak decays is not possible for the Ω^- ?

$\Omega^- \rightarrow \Xi^- + \pi^0$	$\Omega^- \rightarrow \Lambda^0 + K^-$	$\Omega^- \rightarrow \Sigma^0 + \mu^-$

EP 228 Particle Physics, Lecture Notes on Conservation Laws, Oct 2020

[5]. A neutral particle X^0 decays as $X^0 \rightarrow p + \pi^-$. The measured momentum components of the decay products in GeV/c are given in the table. Determine particle X.

	p_x	p_y	p_z
p	-0.49	-0.20	2.11
π^-	-0.26	-0.05	0.47

Hint: Consider the natural units (c = 1) and use the following invariant mass formula:

$$m_X = \sqrt{(E_1 + E_2)^2 - (\mathbf{p}_1 + \mathbf{p}_2)^2}$$

[6]. An unknown particle X decays as follows: $X \rightarrow \gamma + \gamma$. Space momentum components of the photons in GeV/c are measured as p_1 = (-0.01, 0.04, 0.17) and p_2 = (-0.31, 0.91,-0.13). Calculate invariant mass of two photons and estimate the particle X.