

8.701

Introduction to Nuclear
and Particle Physics

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2. Symmetries

2.2 Flavor Symmetry



Protons and Neutrons

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$$m_p = 938.28 \text{ MeV}/c^2 \quad m_n = 939.57 \text{ MeV}/c^2$$

Heisenberg proposed to regard them as two states of the same particle

$$N = \begin{pmatrix} \alpha \\ \beta \end{pmatrix} \quad \text{with} \quad p = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \quad \text{and} \quad n = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

Introduce isospin $p = |\frac{1}{2} \frac{1}{2}\rangle, \quad n = |\frac{1}{2} -\frac{1}{2}\rangle$

with proton carrying isospin “up” and neutron isospin “down”

Strong isospin

If the strong force is invariant under rotations in isospin space, it follows that isospin is conserved in all strong interactions

Heisenberg's assertion (1932): strong interactions are invariant under an internal symmetry group $SU(2)$ and the nucleon belong to the two dimensional representation.

For pions: $I = 1$: $\pi^+ = |1\ 1\rangle$, $\pi^0 = |1\ 0\rangle$, $\pi^- = |1\ -1\rangle$

Multiplicity = $2I + 1$

Gell-Mann-Nishijima formula

Third component of isospin, I_3 , related to electric charge, Q , of the particle

Assign max value $I_3 = I$ to the member of the multiplet of highest charge with A baryon number and S strangeness

$$Q = I_3 + \frac{1}{2}(A + S)$$

Empirical observation, but in context of the quark model it follows from isospin assignments of quarks

Extension to complete quark content

Table 4.4 Quark masses (MeV/c²)

Quark flavor	Bare mass	Effective mass
u	2	336
d	5	340
s	95	486
c	1300	1550
b	4200	4730
t	174000	177000

Warning: These numbers are somewhat speculative and model dependent [12].

Isospin with u, d, and s is a good symmetry. Symmetry badly broken with c, b, or t.

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