Lecture 8 : Symmetries - 2

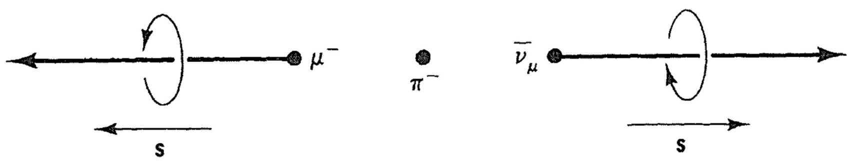
Discrete symmetries :

a) **Parity :** In 1956 Lee and Yang performed an experiment to test the parity invariance in weak interactions. They studied the direction of the emitted electrons in the following radiactive beta decay :

$$^{60}\mathrm{Co} \rightarrow {}^{60}\mathrm{Ni} + e + \overline{\nu}_e$$

They observed that most electrons are emitted in the direction opposite to the neclear spin. Hence the mirror image of this process does not exist in nature, which indicates that the parity is not an invariance of the weak interactions.

All the observed neutrinos in nature are left handed, and all the anti-neutrinos are right handed. This fascinating fact also shows inarguably that neutrinos maximally violate the parity invariance. For example in the decay of the pions to muons all the antineutrinos are seen to be right handed.



b) **CP Parity :** If we combine the space and charge conjugation parities then the following weak decays are seen to obey CP parity and thus this new and enlarged symmetry might restore back the parity concept in weak interactions.

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\pi^- \rightarrow \mu^- + \overline{\nu}_\mu$$

c) **Neutral Kaons and CP violation :** In 1956 Cronin and Fitch reported that in neutraş K meson systems CP is violated. CP even and CP odd eigenstates K_1 and K_2 decays in the following way :

$$K_1 \to 2\pi, \quad K_2 \to 3\pi$$

Hence K_1 is short lived and K_2 is long lived.Their experimental lifetimes are

$$\tau_1 = 0.895 \times 10^{-10} \text{ sec}$$

$$\tau_2 = 5.11 \times 10^{-8} \text{ sec}$$

So in a beam of

$$|K^0\rangle = \left(\frac{1}{\sqrt{2}}\right)(|K_1\rangle + |K_2\rangle)$$

Detectors far away the source must find only three pion decays. However their experiment prooved that a tiny fraction of the decays at the far detector were aşso two pions decays, which violates the CP invariance in weak interactions.

d) **Time reversal and CPT theorem :** Quantum field theory has a deep result that combined discrete symmetry CPT is an invariance of any fundamental interaction. Since CP is violated by the weak interaction the same interaction shuould also violate the time reversal invariance T. However it is almost impossible to experimentally observe a time reversed decay process. But for example exşstence of permanent electric dipole of a fundamental particle violates T invariance. So the measurements of the electron and neutron electric dipole moments could play a crucial role here. The upper limits fort hem are

$$d_n < (6 \times 10^{-26} \text{ cm})\, e, \quad d_e < (1.6 \times 10^{-27} \text{ cm})\, e$$

No experiment has shown a direct evidence for the time reversal violation yet.

Homework

Solve the following problems at the end of the Chapter IV of the textbook by D.Griffiths “Introduction to Elementary Particles J.Wiley)

Solve Problem 4.17

Solve Problem 4.18

Solve Problem 4.20

Solve Problem 4.21

Solve Problem 4.24

Solve Problem 4.25

Solve Problem 4.26

Solve Problem 4.28

Solve Problem 4.29

Solve Problem 4.30