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Second Thoughts about the τ-θ Puzzle

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ABSTRACT

The new parity value of π^0 was determined according to the hypothesis of conservation of particle number. The theoretical pentaquark proton's parity value was also determined, and it was found that the conservation of parity is account nicely for the τ-θ puzzle.

Keywords: Conservation of Parity; Parity of Pion; Parity of Pentaquark Proton; Parity of Deuteron; τ-θ Puzzle; Conservation of Particle Number

1. Introduction

In 1951, Panofsky *et al.* [1] reported on the parities of pions from the reaction of $p+\pi^-$ and $D+\pi^-$. The reaction between proton (p) and charged pion (π^-) is

$$p+\pi^- \to n+\pi^0$$

In the general two-body system, the parity formula is

$$P_a \cdot P_b \cdot (-1)^l$$

where P_a and P_b are the intrinsic parities, l is the angular momentum. The traditional proton, neutron, and meson's parity values in common use are +1, +1, and –1, respectively. The parity is a multiplicative quantum number. Since the initial state ($p+\pi^-$) is S state (l = 0) and the angular momentum is 0, the initial state's parity is

$$P_{\pi^-} \cdot P_p \cdot (-1)^0 = P_{\pi^-} \cdot (+1) \cdot (-1)^0 = P_{\pi^-}$$

The final state's parity is

$$P_{\pi^0} \cdot P_n \cdot (-1)^0 = P_{\pi^0} \cdot (-1) \cdot (-1)^0 = P_{\pi^0}$$

It was considered that the two parities are same by the conservation of parity.

$$P_{\pi^-} = P_{\pi^0}$$

In 1954, Chinowsky and Steinberger [2] obtained the parity value (–1) of π^- from the absorption of negative pions in deuterium. In 1959, Plano *et al.* [3] determined the parity value (–1) of neutral pion (π^0). However the quark numbers by the traditional formula are not add up between the initial state and the final state. It is thought of as a serious problem.

By the way, the two different decays were found for the positively charged strange mesons [3]:

$$\theta^+ \to \pi^+ + \pi^0$$

$$\tau^+ \to \pi^+ + \pi^+ + \pi^-$$

The charged kaon (K^+) [4] used to be called τ^+ and θ^+. Both the τ^+ and θ^+ particles were supposed to be two different particles, but they are the same particles. The two final states have different parities, and it is known as the τ-θ puzzle [5-8].

In this paper, the parities of the pentaquark proton, deuteron, and neutral pion are re-searched based on the hypothesis of conservation of particle number [9]. It is attested to the conservation of parity for the τ-θ puzzle.

2. Results and Discussion

2.1. The Parity of π^0 for the $p+\pi^-$ Reaction

The traditional formula and quark contents by experiment [1,3] are

$$\{u,u,d\}+\{\bar{u},d\} \to \{u,d,d\}+\{u,\bar{d},\bar{u},d\}$$

The numbers of down and anti-down quarks, d and *d-bar*, are not add up between the left-hand member and the right-hand member. It is necessary for the adjustment of particle numbers. To adjust their member, the pentaquark proton (p') is adopted [9]. According to the hypothesis of conservation of particle number, the above formulae for $p+\pi^-$ are as indicated below.

$$p'+\pi^- \to n+\pi^0$$

$$\{(\pi^+),(n)\}+\pi^- \to n+\pi^0$$

$$\{u,\bar{d}\}\{u,d,d\}+\{\bar{u},d\} \to \{u,d,d\}+\{u,\bar{d},\bar{u},d\}$$

where the {(π^+), (n)} is a pentaquark proton (p'), the quark content is {u, d-bar} {u, d, d} [9]. The pentaquark proton's parity ($P_{p'}$) is –1, since the parity formula is

$$P_{p'} = P_{\pi^+} \cdot P_n \cdot (-1)^0 = (-1)\cdot(+1)\cdot(-1)^0 = -1$$

The initial state's parity is

$$P_{\pi^0} \cdot P_n \cdot (-1)^0 = P_{\pi^0} \cdot (+1)\cdot(-1)^0 = P_{\pi^0}$$

By the conservation of parity,

$$P_{\pi^0} = P_{\pi^-} \cdot (-1) = (-1)\cdot(-1) = +1$$

The new parity value of π^0 is +1, not –1 in common use.

2.2. The Parity of π^0 for the $D+\pi^-$ Reaction

The numbers of down and anti-down quarks are not add up between the left-hand member and the right-hand member by experiment [1].

$$D + \pi^- \to n + n + \pi^0$$
$$\{u,u,d\}\{u,d,d\} + \{\overline{u},d\} \to$$
$$\{u,d,d\} + \{u,d,d\} + \{u,\overline{d},\overline{u},d\}$$

It is necessary for the adjustment of particle numbers. To adjust their member, the pentaquark proton (p') is adopted [9]. According to the hypothesis of conservation of particle number, the above formulae for $D+\pi^-$ are as indicated below. The reaction between the deuteron (D') and charged pion (π^-) is

$$D' + \pi^- \to n + n + \pi^0$$
$$\{(p'),(n)\} + \pi^- \to n + n + \pi^0$$
$$\{u,\overline{d}\}\{u,d,d\}\{u,d,d\} + \{\overline{u},d\} \to$$
$$\{u,d,d\} + \{u,d,d\} + \{u,\overline{d},\overline{u},d\}$$

where the {(p'),(n)} is the deuteron(D') [9].

The deuteron's parity ($P_{D'}$) is –1, since the parity formula is

$$P_{D'} = P_{p'} \cdot P_n \cdot (-1)^0 = (-1)\cdot(+1)\cdot(-1)^0 = -1$$

The initial state's parity is

$$P_{\pi^-} \cdot P_{D'} \cdot (-1)^0 = P_{\pi^-} \cdot (-1)\cdot(-1)^0 = P_{\pi^-} \cdot (-1)$$

The final state's parity is

$$P_{\pi^0} \cdot \left\{P_n \cdot P_n \cdot (-1)^0\right\}\cdot(-1)^0 = P_{\pi^0}$$

By the conservation of parity,

$$P_{\pi^0} = P_{\pi^-} \cdot (-1) = (-1)(-1) = +1$$

The new parity value of π^0 in this reaction is also +1.

2.3. The Parity of $\pi^- + D \leftrightarrow p + p$ Reaction

The reaction between the $\pi^+ + D$ and $p+p$ by experiment [10] is

$$\pi^- + D \leftrightarrow p + p$$

This reaction was not considered by Aoki [9]. The formula for the quark content $\{u,u,d\}$ of the traditional proton is

$$\{u,\overline{d}\} + \{u,u,d\}\{u,d,d\} \leftrightarrow \{u,u,d\} + \{u,u,d\}$$

However the numbers of down and anti-down quarks are not add up between the left-hand member and the right-hand member. The parity is not conserved. The formula of the left-hand parity is

$$P_{\pi^+} \cdot P_D \cdot (-1)^0 = -1$$

The formula of the right-hand parity is:

$$\left\{P_p \cdot P_p \cdot (-1)^0\right\}\cdot(-1)^0 = +1$$

To adjust their member, the pentaquark proton (p') is adopted [9].

$$\{u,\overline{d}\} + \{u,\overline{d}\}\{u,d,d\}\{u,d,d\} \leftrightarrow$$
$$\{u,\overline{d}\}\{u,d,d\} + \{u,\overline{d}\}\{u,d,d\}$$

The formula of the left-hand parity is

$$P_{\pi^+} \cdot P_{D'} \cdot (-1)^0 = +1$$

The formula of the right-hand parity is

$$P_{p'} \cdot P_{p'} \cdot (-1)^0 = +1$$

The parity is conserved by the hypothesis of conservation of particle number.

2.4. The Validation of Conservation of Parity for the τ-θ Puzzle

In the τ-θ puzzle [5-8], the two parities of θ^+ and τ^+ have same value (–1), since the positively charged Kaon (K^+) is a meson. The K^+ was shown as follows by Aoki [9].

$$K^+ = \{u,\overline{s}\} = \left\{\left(u,\overline{d}\right),\oplus_{e\mu}\right\} = \left\{\left(\pi^+\right),\oplus_{e\mu}\right\}$$

where the anti-strange quark (s-bar) is the composite particle consisting of the anti-down quark(d-bar) and $\oplus_{e\mu}$, the $\oplus_{e\mu}$ is the $\oplus_e$ and $\oplus_\mu$ pair, the $\oplus_e$ is the neutrino-antineutrino pair, and the $\oplus_\mu$ is the muonneutrino-antimuonneutrino pair. The parity of $\oplus_{e\mu}$ is +1. The $\oplus_{e\mu}$ may be the two photons.

$$P_{K^+} = P_{\pi^+} \cdot P_{\oplus_{e\mu}} \cdot (-1)^0$$
$$(-1) = (-1)\cdot P_{\oplus_{e\mu}} \cdot (+1)$$
$$P_{\oplus_{e\mu}} = +1$$

The θ^+ and τ^+ masses, lifetimes, and spins are no difference with each other. In the traditional expression, the parities are

$$P_{\theta^+} \neq P_{\pi^+} \cdot P_{\pi^0} \cdot (-1)^0 = (-1)^2 = +1$$

$$P_{\tau^+} = P_{\pi^+} \cdot P_{\pi^+} \cdot P_{\pi^-} \cdot (-1)^{l+L} = (-1)^3 \cdot (-1)^{\text{even}} = -1$$

where l is the angular momentum between π^+ and π^+, L is the angular momentum between π and the center of π^+, π^+.

The two final states have the different parities, +1 and –1. The parity for θ^+ is not conserved. It is considered as the parity violation in weak interactions. However the parity is conserved as follows by the new parity value (+1) of π^0.

$$\theta^+ + \pi^0 \rightarrow \pi^+ + \pi^0 + \oplus_{e\mu}$$

$$\left\{\left(u,\bar{d}\right),\oplus_{e\mu}\right\} + \left\{u,\bar{d},\bar{u},d\right\} \rightarrow \left\{u,\bar{d}\right\} + \left\{u,\bar{d},\bar{u},d\right\} + \oplus_{e\mu}$$

$$\left\{\left(u,\bar{d}\right),\oplus_{e\mu}\right\} + \left\{u,\bar{d},\bar{u},d\right\} \rightarrow \left\{u,\bar{d}\right\} + \left\{u,\bar{d}\right\} + \left\{\bar{u},d\right\} + \oplus_{e\mu}$$

The neutral pions of both initial states were added by the hypothesis of conservation of particle number. The π^0 for τ^+ is corresponding to the $\pi^+ + \pi^-$. The initial state's parities for $\theta^+ + \pi^0$ and $\tau^+ + \pi^0$ are –1.

$$P_{\theta^+} \cdot P_{\pi^0} \cdot (-1)^0 = (-1)\cdot(+1)\cdot(-1)^0 = -1$$

$$P_{\tau^+} \cdot P_{\pi^0} \cdot (-1)^0 = (-1)\cdot(+1)\cdot(-1)^0 = -1$$

The final state's parity for θ^+ is –1.

$$\left\{P_{\pi^+} \cdot P_{\pi^0} \cdot (-1)^0\right\} \cdot P_{\oplus_{e\mu}} \cdot (-1)^0 = -1$$

The final state's parity for τ^+ is –1.

$$\left\{P_{\pi^+} \cdot P_{\pi^+} \cdot P_{\pi^-} \cdot (-1)^{l+L}\right\} \cdot P_{\oplus_{e\mu}} \cdot (-1)^0 = (-1)^3 \cdot (-1)^{\text{even}} = -1$$

3. Conclusions

The new parity values of the the pentaquark proton (p'), deuteron (D'), and neutral pion (π^0), are –1, –1, and +1, respectively.

It was attested to the conservation of parity for the τ-θ puzzle.

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