New tensor interaction as the source of the observed CP asymmetry in

$$\tau \rightarrow K_S \pi \nu_\tau.$$  

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Abstract

Babar collaboration has reported an intriguing opposite sign in the integrated decay rate asymmetry $A_{cp}(\tau \rightarrow K_S \pi \nu_\tau)$ than that of SM prediction from the known $K^0 - \bar{K}^0$ mixing. Babar’s result deviate from the SM prediction by about 2.7σ. If the result stands with higher precision in the future experiments, the observed sign anomaly in the $A_{cp}(\tau \rightarrow K_S \pi \nu_\tau)$ can most likely come only from some new physics occurring possibly in both hadronic as well as leptonic sectors. In this work, we will give an improved analysis of our previous work where we have illustrated that, while non-standard scalar or vector/axial-vector interactions will not contribute to the observed asymmetry in the integrated decay rate, a new tensor interaction can explain the observed anomaly. Assuming the real part of the new tensorial coupling is negligible compared to its imaginary part and with $A_{cp}(\tau \rightarrow K_S \pi \nu_\tau)$ and $Br(\tau \rightarrow K_S \pi \nu_\tau)$ as data points to fit the imaginary part of the NP coupling, we have been able to fit the result within 1σ of the experimental values.

1 Introduction

The study of CP violation in tau decays has always been of much interest for beyond the Standard Model studies in the past two decades. In SM, the only source of CP violation is the one phase in the Kobayashi Maskawa (KM) matrix. While the Kobayashi Maskawa ansatz for CP violation within the Standard Model in the quark sector has been clearly verified by the plethora of data from the B factories, this is unable to account for the observed baryon asymmetry of the Universe. Hence, one needs to look for other sources of CP violation, including searches in the leptonic sector. Apart from the CP phases that may arise in the neutrino mixing matrix, the decays of the tau lepton may allow us to explore nonstandard CP-violating interactions. Various experimental groups have been involved in exploring CP violation in tau decays in the...
last decade or more. The BABAR collaboration for the first time reported a sign anomaly in the integrated
decay rate asymmetry $A_{\text{cp}}(\tau \to K_s\pi\nu_\tau)$ of

$$A_{\text{cp}} = (-0.36 \pm 0.23 \pm 0.11)\%.$$  

(1)

However for $\tau^\pm \to K_s^0\pi^\pm\nu_\tau \to [\pi\pi]^0_{K}^{\pm}\pi^\pm\nu_\tau$, Babar has predicted the SM integrated decay-rate asymmetry to be

$$A_{\text{cp}}^{SM} = (0.33 \pm 0.01)\%.$$  

(2)

Comparing the rate asymmetries for decays to neutral kaons of the taus with that of D mesons, Grossman
and Noir have pointed out that since $\tau^+(\tau^-)$ decays initially to a $K^0(\bar{K}^0)$ whereas $D^+(D^-)$ decays initially
to $K^0(\bar{K}^0)$, the time-integrated decay-rate CP asymmetry (arising from oscillations of the neutral kaons) of
$\tau$ decays must have a sign opposite to that of D decays. The observation of a CP asymmetry in $\tau$ decays
to $K_s$ having the same sign as that in D decays, and moreover of the same magnitude but opposite in sign
to the SM expectation, implies that this asymmetry cannot be accounted for by the CP violation in $K^0\bar{K}^0$
mixing.

1. Naively one may expect that the simplest way to account for the observed anomaly would be to
introduce a direct CP violation via a new CP violating charged scalar exchange. However, it turns out
that the charged scalar type of exchange may contribute in the angular distributions, but its mixing
with SM term in the integrated decay rate goes to zero.

2. Now the next candidate of NP would be a new CP violating charged vector exchange, but CP violation
from vector type NP will be observable only if both vector current and axial vector currents contributes
to the same final states. Since in two pseudo scalar meson final states only vector current can contribute
due to parity conservation of strong interaction, vector type of NP can contribute in general to CP
violation in three or more pseudo scalar meson final states but not in two pseudo scalar meson final
states such as $K_s\pi$.

3. Now the only possibility left is tensor type of NP.

In this presentation, we will give the results the materials contianed in the references [1] and [2].

2 Results

With taking the approximation of $A_{\text{cp}}^{K}A_{\text{cp}}^{\tau} \approx 0$ we can express the Eqs(29,30) of [2] as:

$$A_{cp}(\tau \to K_s\pi\nu_\tau) = A_{cp}^{K} + A_{cp}^{\tau}$$  

(3)
\[ Br(\tau \rightarrow K_s\pi\nu_\tau) = \frac{(\Gamma^{+} + \Gamma^{-})}{2}\tau_\tau = (\Gamma_{SM} + \Gamma_T)\tau_\tau \] (4)

where \( A^k_{cp} \) is the known SM CPV from the \( K - \bar{K}^0 \) mixing, \( \Gamma_{SM} \) is the SM decay rate corresponding to fitted form factors from Belle fits, \( \Gamma_T \) is the decay rate due to purely tensor term and \( \tau_\tau \) is the life time of \( \tau \) lepton. From Eqs(9,10) and using \( F_T^a \) from Eqs(7) the best fitted value of the complex parameter \( Im(C_T^\tau) \) to the two data points gives at \( \chi^2 \approx 4.5 \)

\[ Im(C_T^\tau) = -0.071, \] (5)

which gives

\[ Br(\tau \rightarrow K_0\pi\nu_\tau)^{(Th)} = 2Br(\tau \rightarrow K_s\pi\nu_\tau)^{(Th)} = (0.756 \pm 0.085)\% \] (6)

and

\[ A_{cp}^{\tau(Th)} = (-0.703 \pm 0.54)\% \] (7)

whereas the experimental values of these observables are given as

\[ A_{cp}^{(Exp-SM)} = A_{cp}^{\tau(Exp)} - (A^k_{cp})^{SM} = (-0.69 \pm 0.26)\%, \] (8)

and

\[ Br(\tau \rightarrow K_0\pi\nu_\tau)^{(Exp)} = 2Br(\tau \rightarrow K_s\pi\nu_\tau)^{(Exp)} = (0.84 \pm 0.04)\%. \] (9)

Comparing Eqs(7,8) and Eqs(6,9) we see that the theoretical predicted values fit with the experimental values within 1\( \sigma \).

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**References**

[1] H.Z. Devi, L.dhargyal, Nita Sinha, *Phys. Rev. D* 90, 013016 (2014)

[2] Lobsang Dhargyal, arXiv:1605.00629 [hep-ph]