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Discriminating New Physics in $b \to s\mu^+\mu^-$ via Transverse Polarization Asymmetry of K^* Meson

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A global fit to current $b \to s\ell^+\ell^-$ data suggests several new physics solutions. Considering either only one operator or a pair of similar operators at a time and new physics only in the muon sector, it has been shown that the three scenarios (I) $C_9^{\rm NP} < 0$, (II) $C_9^{\rm NP} = -C_{10}^{\rm NP}$, (III) $C_9^{\rm NP} = -C_9^{\prime\rm NP}$ can account for all the data. In order to discriminate between these scenarios one needs to have a handle on additional observables in $b \to s\mu^+\mu^-$ sector. In this work, we study the transverse polarization asymmetry of K^* polarization in $B \to K^*\mu^+\mu^-$ decay, A_T, to explore its sensitivity to discriminate between the three scenarios. We show that a measurement of this asymmetry with an accuracy of one percent can pick out which new physics scenario is the true solution, at better than 3σ C.L.

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1. Introduction

A number of measurements in decays induced by the quark level transition $b \to s\ell^+\ell^-$ ($\ell = e, \mu$) exhibit tension with the Standard Model (SM). By assuming new physics (NP) only in the muon sector, several groups performed global fits to all available data in the $b \to s\mu^+\mu^-$ sector to identify the Lorentz structure of possible NP. Most of these analyses suggested NP solutions in the form of vector and axial-vector operators. In the simplest approach, only one NP operator or two related NP operators are considered. There are three NP scenarios which provide a very good fit to all $b \to s\mu^+\mu^-$ data. These scenarios are (I) $O_9 = (\bar{s}\gamma^\alpha P_L b)(\bar{\mu}\gamma^\alpha \mu)$, (II) a combination of O_9 and $O_{10} = (\bar{s}\gamma^\mu P_L b)(\bar{\mu}\gamma^\mu\gamma^5\mu)$ and (III) a combination of $O_9' = (\bar{s}\gamma^\mu P_R b)(\bar{\mu}\gamma^\mu\mu)$ (the chirality flipped counterpart of O_9) and O_9. These scenarios along with the fit values of Wilson coefficients (WCs) are listed in Table 1.

Therefore one of the key open problems is to uniquely identify the Lorentz structure of new physics in $b \to s\mu^+\mu^-$ decay. This can be achieved by either analyzing new decay modes/new observables [1] or precision measurements of the already measured quantities in the decays mediated by $b \to s\mu^+\mu^-$ [2]. In this work we investigate the discrimination capability of transverse polarization asymmetry of K^* in $B \to K^*\mu^+\mu^-$ decay.

2. Calculations, Results and Discussions on Transverse polarization asymmetry

The sum of three polarization fractions of K^* should be unity, $F_L + F_T^+ + F_T^- = 1$. Hence only two of them should be independent. As the longitudinal polarization fraction can be a very good discriminant only for the tensor and scalar NP interactions [3], we study the discriminating capability of transverse polarization. An asymmetry between the two transverse polarizations of K^* meson can be defined as

$$A_T = F_T^+ - F_T^- = \frac{|H_+|^2 - |H_-|^2}{|H_0|^2 + |H_+|^2 + |H_-|^2} = \frac{2\,\mathrm{Re}\left(A_\parallel A_\perp^*\right)}{|A_\parallel|^2 + |A_\perp|^2 + |A_0|^2}\,. \tag{2.1}$$

Here $H_{0,+,-}$ are the helicity amplitudes for the three helicity components of K^* meson. However, we make use of the transversity amplitudes [4]. We have, $A_i A_j^* = A_{iL}A_{jL}^* + A_{iR}A_{jR}^*, (i, j = 0, \perp, \parallel)$. The expressions for these transversity amplitudes are given in Ref. [4]. The numerical values of these form factors are taken from Ref. [5] which are calculated by performing a combined fit to lattice QCD (LQCD) and light cone sum rule (LCSR) approaches. We obtain predictions for A_T within the SM as well as for various new physics scenarios.

The plots of q^2 distribution of the transverse polarization asymmetry of K^* in $B \to K^*\mu^+\mu^-$ decay , $A_T(q^2)$, are shown in Fig. 1, for the SM as well as for the three allowed new physics solutions listed in Table 1. These predictions are calculated for the low-q^2 region which corresponds to 1 GeV$^2 \le q^2 \le 6$ GeV^2. Within the SM, $A_T(q^2)$ is negative in the entire low-q^2 region. Further, the peak value of $A_T(q^2)$ in the SM is -0.13 which is at $q^2 \simeq 2.2$ GeV^2.

The new physics scenarios I and III make the values of $A_T(q^2)$ even lower than those of SM and scenario I in the entire low-q^2 region. The change is largest for the new physics scenario III. The peak value of $A_T(q^2)$ for scenarios I and III are -0.19 and -0.22, respectively. Thus we see that scenarios I and III can provide large deviations in $A_T(q^2)$, the deviation being largest for

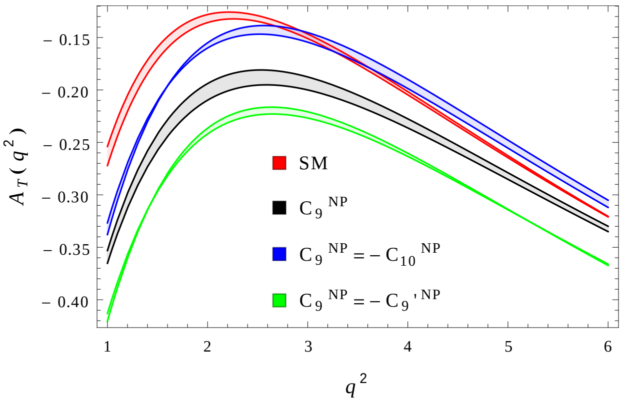

Figure 1: The SM and NP predictions of the transverse asymmetry $A_T(q^2)$ as a functions of q^2 in GeV^2.

the scenario III. For scenario II, $A_T(q^2)$ prediction is similar to that of the SM for $q^2 \geq 3$ GeV^2. For $q^2 \leq 3$ GeV^2, $A_T(q^2)$ is suppressed. However the suppression is less as compared to that of scenarios I and III. An accurate measurement of q^2 distribution of the transverse polarization asymmetry of K^* in $B \to K^* \mu^+ \mu^-$ decay can therefore discriminate between all the three allowed new physics solutions in the $b \to s \mu^+ \mu^-$ sector.

NP scenarios	Best fit value	pull	$\langle|A_T|\rangle$ in %
SM	0	0	20.7 ± 0.48
(I) $C_9^{\rm NP}$	-1.09 ± 0.18	6.24	24.9 ± 0.57
(II) $C_9^{\rm NP} = -C_{10}^{\rm NP}$	-0.53 ± 0.09	6.40	21.3 ± 0.50
(III) $C_9^{\rm NP} = -C_9^{\prime\rm NP}$	-1.12 ± 0.17	6.43	28.4 ± 0.66

Table 1: The predictions of A_T, averaged over the q^2 range of $1-6$ GeV^2 for the SM and for the three NP solutions taken from Ref. [6].

This is also evident from the integrated values of $A_T(q^2)$, A_T, within q^2 range of $1-6$ GeV^2 which are given in Table 1. The uncertainty in $\langle|A_T|\rangle$ is calculated taking into account the uncertainties in both the new physics Wilson coefficients and the form factors. From this table it can be seen that the prediction of $\langle|A_T|\rangle$ for each new physics solution is substantially different from that of the other two NP solutions. Hence, an accurate measurement of this transverse asymmetry, at the level of a percent, can uniquely identify the new physics solution at better than 3σ.

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