Determining the photon polarization of the radiative B->K1(1270) gamma decay

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PROCEEDINGS OF SCIENCE

Determining the photon polarization of the radiative $B \to K_1(1270)\gamma$ decay

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Recently, the radiative B-decay to the strange axial-vector mesons, $B \to K_1(1270)\gamma$, was observed. This process is particularly interesting as the subsequent K_1-decay into its three body final state allows us to determine the polarization of the γ, which is mostly left- (right-)handed for $\bar{B}$ (B) in the SM while various new physics models predict additional right- (left-)handed components. In order to obtain a theoretical prediction for this polarization measurement, it is important to understand the hadronic effects to this decay channel. We first revisit the strong decays of the K_1 mesons, namely the partial wave amplitudes as well as their relative phases, in the framework of the $^3P_0$ quark-pair-creation model. Then, we present our result on the sensitivity study of the $B \to K_1(1270)\gamma$ process to the photon polarization. The new method we introduced in this work improves the sensitivity by a factor two compared to the standard angular analysis.

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1. Introduction

The $b \to s\gamma$ process, which occurs only through a loop level diagram, plays an important role in understanding the electro-weak interaction of the Standard Model (SM). In the SM, the fact that the W boson couples to left-handed quarks induce the photon polarization to be predominantly left-handed. However, in some extensions of the SM the photon can acquire a significant right-handed component from new possible Dirac structures, induced by new physics effects. This can lead to an excess of right-handed photons without contradicting the measured $Br(B \to X_s\gamma)$. That is why the photon polarization measurement could provide a good test of new physics beyond the SM. Although, there have been several proposals for how to measure this photon polarization, a precise measurement has not been achieved yet. We revisit the method, proposed by Gronau et al. [1], using the exclusive $B \to K_1\gamma$ followed by the three body decay of K_1. Most interestingly, the Belle collaboration recently observed one of these decay channels, $B \to K_1(1270)\gamma$ and found a relatively large branching ratio: $Br(B^+ \to K_1^+(1270)\gamma) = (4.3 \pm 0.9(\text{stat}) \pm 0.9(\text{syst})) \times 10^{-5}$, which dominates over the decay to $K_1(1400)$, previously studied in [1].

2. The $B \to K_1\gamma \to K\pi\pi\gamma$ decay

Due to the angular momentum conservation and the fact that B-meson is a pseudo-scalar meson, helicity is conserved. Hence, in order to determine the photon polarization it is sufficient to measure the polarization of the axial-vector meson $K_1(1^+)$ through its three body decay into $K\pi\pi$ final state. The kinematic distribution of this three body decay carries the information of the K_1 polarization. Using the narrow width approximation for $K_1(1270)$, one can write the total quasi-four body decay width as[1]

$$\frac{d\Gamma(\overline{B} \to \overline{K}\pi\pi\gamma)}{ds\,ds_{13}ds_{23}d\cos\theta} \propto \frac{1}{(s-m_{K_1}^2)^2 + m_{K_1}^2\Gamma_{K_1}^2} \times \left[\frac{1}{4}|\vec{\mathscr{J}}|^2(1+\cos^2\theta) + \lambda_\gamma \frac{1}{2} Im[\vec{n}\cdot(\vec{\mathscr{J}} \times \vec{\mathscr{J}}^*)]\cos\theta\right] \tag{2.1}$$

where $s = (p_1+p_2+p_3)^2$, $s_{ij} = (p_i+p_j)^2$ with p_1, p_2 and p_3 to be the four-momenta of the two pions and kaon respectively. Defining the $-z$ direction in the K_1 rest frame as the photon direction, θ is the angle between the normal to the $K\pi\pi$ plane, $\vec{n} = (\vec{p}_1 \times \vec{p}_2)/|\vec{p}_1 \times \vec{p}_2|$, and the z axis. The function $\mathscr{J}(s, s_{13}, s_{23})$ represents the decay amplitude of the $K_1 \to K\pi\pi$ process. Assuming that this $K\pi\pi$ state comes from the quasi-two body decay through a vector meson, K^* and ρ, $\mathscr{J}$ contains the following hadronic parameters: two couplings, $g_{K^*K\pi}$ and $g_{\rho\pi\pi}$, and four form factors of the $K_1 \to K^*\pi, K\rho$ transitions, which we evaluate using the $^3P_0$ quark model. In the SM the photon polarization parameter λ_γ, defined as

$$\lambda_\gamma \equiv \frac{\Gamma(\overline{B} \to \overline{K}_{1R}\gamma_R) - \Gamma(\overline{B} \to \overline{K}_{1L}\gamma_L)}{\Gamma(\overline{B} \to \overline{K}_{1R}\gamma_R) + \Gamma(\overline{B} \to \overline{K}_{1L}\gamma_L)} \tag{2.2}$$

is equal to $\lambda_\gamma^{SM} = -1(+1) + \mathscr{O}(m_s^2/m_b^2)$ for $\overline{B}(B)$ respectively. Thus, any significant deviation of the measured polarization parameter from predicted λ_γ^{SM} will be the signature of new physics beyond the SM.

[1] More details can be found in [2].

3. Determination of λ_γ using a new method

In our work [2] we use the method, originally proposed by Davier et al. [3] for the τ polarization measurement at LEP, and introduce a new variable, $\omega = \frac{2Im[\vec{n}\cdot(\vec{\mathscr{J}}\times\vec{\mathscr{J}}^*)]\cos\theta}{|\vec{\mathscr{J}}|^2(1+\cos^2\theta)}$. The fact that the decay width (Eq. (2.1)) depends only linearly on the polarization parameter λ_γ allows us to use the variable ω in our study. The simplification in the fit by using ω-distribution makes it easier to include in the fit not only the angular dependence of the polarization parameter but also the three body Dalitz variable dependence, which improves the sensitivity to the polarization parameter as also pointed out in [3].

Performing the "ideal" (i.e. detector and background effects are not taken into account) Monte Carlo simulation, we found that the statistical error on λ_γ in our new method can be reduced by a factor of 2, compared to the case of the angular "up-down" asymmetry studied in [1]. For the naive estimation of the annual yield of data taking at LHCb, 10^4 events, we found the estimated statistical error σ_{λ_γ} to be less than 0.1.

4. Conclusions

We investigated the method of the determination of the photon polarization in the $b \to s\gamma$ process using the decay channel $B \to K_1\gamma \to K\pi\pi\gamma$. We propose a new variable ω to determine the polarization parameter λ_γ. It significantly simplifies the experimental analysis and allows to improve the sensitivity of the λ_γ measurement. Nevertheless, the estimation of the theoretical errors requires a more detailed discussion, which are going to be presented in the forthcoming publication.

References

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