RPV SUSY effects in $\tau^- \to e^- (\mu^-) K \bar{K}$ Decays

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In this paper, we investigate $\tau^- \to e^- (\mu^-) K \bar{K}$ ($K \bar{K} = K^+ K^-, K^0 \bar{K}^0$) decays in the framework of the RPV SUSY model. We discuss the tree level contribution of the sparticles $\tilde{\nu}$ and $\tilde{u}$ to these decay branching ratios. In the two channels, the $\tilde{\nu}$-mediated channel is more sensitive to the parameter product $|\lambda_{122}^i \lambda_{31(2)}| \lambda_{31(2)}^j|$ than the $\tilde{u}$-mediated channel to $|\lambda_{12}^i \lambda_{23}^j|$. And the parameter product $|\lambda_{122}^i \lambda_{31(2)}|$ is severely constrained to the order of $O(10^{-5})$ by the experiment data with $m_{\tilde{\nu}} = 100 GeV$, which is one order of magnitude more stringent than before. In the calculation of hadronic matrix elements, the resonant effects are large than those of non-resonant terms. Especially, the resonant contribution of scalar meson $f_{(980)}$ plays a dominate role in $\tilde{\nu}$-mediated channel.

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I. INTRODUCTION

Tau lepton physics has been on focus in particle physics and gets steady development in experiment[1]. Currently, the measurement of $\theta_{13}$ in Daya Bay experiment[2-3], as well as the neutrino oscillation, show the existence of lepton flavor violating(LFV) in the lepton sector. Now the $\tau$ LFV decays have been one of most interesting topics. While these LFV processes are strongly suppressed in the Standard Model(SM). Hence the study of $\tau$ LFV decays can provide a stage to the new physics beyond the SM.

Recently, tau pairs production has reached the sample events of $10^9$ at the B factories. The LFV decays of $\tau^- \to e^- (\mu^-) K \bar{K}$ ($K \bar{K} = K^+ K^-, K^0 \bar{K}^0$) are relative clean channels to investigate strong interaction. And their latest experimental upper limits are [4]:

$$B(\tau^- \to e^- K^+ K^-) < 3.4 \times 10^{-8}, \; 90\% CL$$
$$B(\tau^- \to e^- K^0 \bar{K}^0) < 7.1 \times 10^{-8}, \; 90\% CL$$
$$B(\tau^- \to \mu^- K^+ K^-) < 4.4 \times 10^{-8}, \; 90\% CL$$
\[ B(\tau^- \rightarrow \mu^- K^0\bar{K}^0) < 8.0 \times 10^{-8}, \ 90\% CL \]

where the values of \( B(\tau^- \rightarrow e^- (\mu^-) K^0\bar{K}^0) \) have been got by using 4.79 fb\(^{-1}\) of data collected from the CLEO II detector at CESR.

The LFV decays of \( \tau \) have made rapid progress in scores of years. The recent studies show that, in some extended scenarios beyond the SM, LFV process could occur and their ratios could even be largely enhanced by new particle/new flavor violating resource [5–13]. Among these extensions, the R-parity violating supersymmetry (RPV SUSY) model is the interested one, where the R-parity odd interactions could violate the lepton and baryon number and couple the different generations or flavors of leptons and quarks [14, 15]. Moreover, it is interested that non-zero neutrino masses are included naturally. So we are going to focus on the RPV effects of these LFV decays, and will calculate their branching ratios in this work. For the hadronic effects in the decay final states, some calculating methods are proposed. One argument suggest, the mass of \( \tau \) is 1 \( \sim \) 2 GeV and therefore the energy scale of \( \tau \) decays belongs to low energy region. A non-perturbative method, the Resonance Chiral Theory (R\( \chi \)T) [16, 17], is adopted to deal with these decays. E. Arganda et al. have studied these processes in two constrained MSSM-seesaw scenarios with \( R\chi T \), where the vector resonance effects play a vital role. Similarly, M.Herrero et al., and Yue’s group have made discussions on these decays in the SUSY-seesaw models and the topcolor-assisted technicolor model and the littlest Higgs model with T-parity (LHT) model, respectively. Recently, Petrov et al. have found that the gluonic operators have large contributions to these decays in RPV SUSY model [18]. Daub et al. have studied \( \pi\pi \) channel in this model with a more appropriate method to express the form factors of the scalar and vector currents, and got the limits of parameter products at the order of \( \mathcal{O}(10^{-4}) \) [19]. Besides, although the relevant hadronic performance for \( \tau^- \rightarrow e^- (\mu^-) K\bar{K} \) decays are difficult to settle, one could rely on the hadronic information of \( B \rightarrow KKK \) decay, where both the resonant and non-resonant effects are considered [20]. For the \( \tau^- \rightarrow \mu^- K^+ K^- \) decays in the framework of the supersymmetric seesaw mechanism with nonholomorphic terms, Chen et al. have studied the contribution of scalar meson to by means of this scheme [11]. Then, Cheng et al. pointed out that, although the resonant term is linked to the form factor, the form factor should be away from the resonant region, and the polar contributions from resonant term are ignored [21, 22]. In this paper, we will only consider the case of \( s\bar{s} \) production in final states and discuss the RPV SUSY effects in these decays by this improved method.

Our paper is structured as follows: in Section 2 we present the RPV SUSY scenario and the calculating method we will work with. We dedicate Section 3 to the numerical results of LFV \( \tau^- \rightarrow e^- (\mu^-) K\bar{K} \) decay rates in RPV SUSY model, analyzing the roles of the resonant and non-resonant terms to these rates. Our conclusions are contained in Section 5.
II. $\tau^{-}\to e^{-}(\mu^{-})K\bar{K}$ DECAY BRANCHING RATIOS IN R-PARITY VIOLATING MSSM

SuperSymmetry model is one of compelling candidates favored by theorists. In this scenario, the lepton number or baryon number violating are permitted and hence the proton decays are induced. To avoid this case, R parity, defined as $R \equiv (-1)^{3B+2S+L}$, is introduced. However, there have the possibilities of R parity violating in experiment and theory. Moreover, one could avoid the problem of proton lifetime by keeping the lepton number and baryon number not be violated simultaneously. Therefore, LFV decay could occur in minimal supersymmetry model with R parity violating(RPV MSSM). More details could refer to literature[1 4, 15].

The $R$ superpotential and the relevant Lagrangian could be expressed as $[14]$

\[ W_R = \sum_{i,j,k} \left( \frac{1}{2} \lambda_{ijk} L_i L_j E_i^c + \lambda'_{ijk} L_i Q_j D_k^c + \lambda''_{ijk} U_i^c D_j^c D_k^c \right) + \sum_i \mu_i L_i H_u, \]

\[ L_R = \sum_{i,j,k} \left\{ \frac{1}{2} \lambda_{ijk} \left[ \tilde{\nu}_i L \tilde{e}_k R e_j L + \tilde{e}_j L \tilde{e}_k R \nu_i L + \tilde{e}_k R \tilde{\nu}_i R e_j L - (i \rightarrow j) \right] \right. \]

\[ + \left. \lambda'_{ijk} \left[ \tilde{\nu}_i L \tilde{d}_k R d_j L + \tilde{d}_j L \tilde{d}_k R \nu_i L + \tilde{d}_k R \tilde{\nu}_i R d_j L - \tilde{\nu}_i L \tilde{d}_k R e_j L - \tilde{e}_j L \tilde{d}_k R \nu_i L - \tilde{d}_k R \tilde{\nu}_i R u_j L \right] \right\}, \]

where the indices $i, j, k(=1, 2, 3)$ label quark and lepton generations. $L_i$ and $Q_i$ are the SU(2)-doublet lepton and quark superfields, respectively. $U_i^c, D_i^c, E_i^c$ are the singlet superfields. $\lambda'_{ijk}$ is antisymmetric in '$ij$', while $\lambda''_{ijk}$ is antisymmetric in '$jk'$. In Eq. $[2]$, the first two terms are involved in lepton flavor/number violating, and the third term is relevant to baryon number violating. The final term comes from the bilinear coupling between the higgsinos and the leptons.

In this work, we only focus on the channels with $s\bar{s}$ production. From Eq. $[3]$, one can know that these channels can be mediated by sparticles $\tilde{\nu}$ and $\tilde{u}$. So the effective Hamilton of these decays reads as:

\[ \mathcal{H} = \sum_{k=1}^{3} C_k^l O_k^l, \]

\[ O_1^l = (\tilde{l}_R \tau_L) \otimes (\tilde{s}_R s_L), \quad O_2^l = (\tilde{l}_L \tau_R) \otimes (\tilde{s}_L s_R), \quad O_3^l = (\tilde{l}_L \gamma^\mu \tau_L) \otimes (\tilde{s}_R \gamma^\mu s_R), \]

\[ C_1^l = C_2^l = \frac{\lambda'_{22} \lambda_{31(2)}}{m_{\tilde{\nu}_i}^2}, \quad C_3^l = \frac{\lambda'_{1(2)j2} \lambda_{3j2}}{m_{\tilde{u}_j}^2}, \]

where $O_k^l$ and $C_k^l (l = e, \mu, k = 1, 2, 3)$ denote the operators and the related operator coefficients, respectively. And the operator $O_1^l (O_3^l)$ are from the $\tilde{\nu} (\tilde{u})$-mediated process. $m_{\tilde{\nu}_i(\tilde{u}_j)}$ is the mass of sparticle $\tilde{\nu}_i (\tilde{u}_j)$. The decay matrix for $\tau^{-} \to l^{-}K\bar{K}$ channel could be expressed as the product of leptonic vertex and hadronic matrix elements. During the calculation, the key problem is how to deal with the hadronic matrix elements $\langle \bar{K}K | \bar{q}q \rangle_{V(S)} |0\rangle$. Although the associated hadronic effects are complicated and not so well understood, we could still get the support from the knowledge of hadronic matrix elements in $B \to KKK$ decay $[21, 22]$. The work of Cheng $[21]$ shows that the form
And the parameters $\sigma$ be referred to \[21\]:

Among the $f$ like a role. We consider the scalar meson mainly from two aspects. One is dominated by $\bar{f} S$ of scalar(vector) meson $c$ parameter $T$ respectively.

Consequently, the expression of branching ratio could be written as:

$$\langle K(p_1)K(p_2)|\bar{s}s|0 \rangle = f_s^R + \sum_i f_{s,i}^{NR}, (i = 1, 2)$$

where $F_s^{R(NR)}$ and $f_s^{R(NR)}$ signify the relevant resonant(non-resonant) term. $Q = (p_1 + p_2)$, where $p_{1(2)}$ is the momentum of $K(K)$ meson. $\phi$ and $S_i$ denote the vector meson $\phi(1680)$ and scalar mesons $f_0(980), f_0(1530),...$ The parameter $c_\phi$ could be fitted from the kaon e.m form factor. $m_{S_i(\phi)}$ and $\Gamma_{S_i(\phi)}$ denote the mass and the decay width of scalar(vector) meson $S_i(\phi)$. $g^{S_i \to KK}$ indicates the strong coupling of $S_i \to KK$ and $\tilde{f}_S$ means the associated scalar decay constant. As far as the resonant term $f_s^R$ concerned, the pole contributions of scalar meson perform a role. We consider the scalar meson mainly from two aspects. One is dominated by $\bar{s}s$ content and the other, like $f_0(980)$ and $f_0(1530)$ mesons, has large coupling to $\bar{K}K$ \[22\]. So $f_0(980)$ and $f_0(1530)$ mesons are preferred among the $f_0$ mesons. The term $\sigma_{NR} e^{-\alpha Q^2}$ could keep the non-resonant form factor apart from resonant area. And the parameters $\sigma_{NR}$ and $\alpha$ could be determined by the experimental data \[24\]. The relevant parameters could be referred to \[21\]:

$$c_\phi = 0.363, \quad m_\phi = 1.02GeV, \quad \Gamma_\phi = 4.26GeV,$$

$$x_1 = -3.26GeV^2, \quad x_1^\prime = 5.02GeV^2, \quad x_2 = 0.47GeV^2, \quad x_2^\prime = 0, \quad \tilde{\Lambda} = 0.3GeV,$$

$$g_{f_0(980) \to KK} = 4.3GeV, \quad g_{f_0(1530) \to KK} = 3.18GeV, \quad \Gamma_{f_0(980)} = 0.08GeV, \quad \Gamma_{f_0(1530)} = 1.16GeV,$$

$$m_{f_0(980)} = 0.980GeV, \quad m_{f_0(1530)} = 1.16GeV, \quad \tilde{f}_{f_0(980)} \approx \tilde{f}_{f_0(1530)} \approx 0.33GeV,$$

$$v = 2.87GeV, \quad \sigma_{NR} = e^{i\pi/4} (3.36^{+1.11}_{-0.96})GeV^2, \quad \alpha = (0.14 \pm 0.02)GeV^{-2}. \quad (9)$$

Consequently, the expression of branching ratio could be written as:

$$\text{Br}(\tau^- \to l^- K \bar{K}) = T_\tau \int_{m_{\tau^-} - m_\mu}^{m_{\tau^-} + m_\mu} \frac{1}{8\pi^2} \cdot \frac{1}{16m_\tau^2} \cdot |\mathcal{M}|^2 \cdot |\vec{p}_K| \cdot |\vec{p}_l| \cdot dQd\Omega_l^*,$$

$$|\vec{p}_K| = \frac{1}{2Q}[(Q^2 - 2m_\tau^2)Q^2]^\frac{1}{2}, \quad |\vec{p}_l| = \frac{1}{2m_\tau}[(m_\tau^2 - (Q + m_\ell)^2)(m_\tau^2 - (Q - m_\ell)^2)]^\frac{1}{2},$$

where $T_\tau$ is the lifetime of $\tau$ lepton, $\Omega_l^*$ and $|\vec{p}_l|$ are the energy and momentum of lepton in the final state, respectively.
all of these branching ratios could reach to the experimental upper limits. For Fig.1(a), when the numerical parameters are fixed, the contributions of sparticle masses $m_{\tilde{u}(i_j)}$. For the sake of decreasing the number of parameters, we assume that only one sfermion contributes one time with universal mass $m_{\tilde{u}(i_j)} = \tilde{m} = 100 GeV$. Using the model parameters list in Eq. (9), we could get the branching ratios of $\tau^- \rightarrow e^- (\mu^-) K^+ K^- (K^0 \bar{K}^0)$ decays. The relation of branching ratios versus model parameter products $|\lambda_{122}^i \lambda_{312}^j| (|\lambda_{122}^{i*} \lambda_{312}^{j*}|)$ are given in Fig.2, where (a) is for $\tilde{u}$-mediated process and (b) for $\tilde{u}$-mediated process, respectively. The solid(dash, dot and dot dash) curve denotes the branching ratio of $\tau^- \rightarrow \mu^- K^+ K^- (K^0 \bar{K}^0)$ decay, and the horizon lines denote their experimental upper limits. From Fig.1(a) and Fig.1(b), one could see that the curves of branching ratios rise with the increasing of the parameter products. And when the values of $|\lambda_{122}^i \lambda_{312}^j| (|\lambda_{122}^{i*} \lambda_{312}^{j*}|)$ are at the order of $O(10^{-5}) (O(10^{-4}))$, all of these branching ratios could reach to the experimental upper limits. For Fig.1(a), when the numerical value of parameter product $|\lambda_{122}^{i*} \lambda_{312}^{j*}|$ fixed, the contributions of $K^+ K^-$ final states are a little larger than those of $K^0 \bar{K}^0$ final state. When $|\lambda_{122}^i \lambda_{312}^j| = 1.0 \times 10^{-5}$, the relation of these branching ratios is $Br(\tau^- \rightarrow \mu^- K^0 \bar{K}^0) < Br(\tau^- \rightarrow e^- K^0 \bar{K}^0) < Br(\tau^- \rightarrow \mu^- K^+ K^-) < Br(\tau^- \rightarrow e^- K^+ K^-)$. While, for the $\tilde{u}$-mediated channel in Fig.1 (b), when the value of $|\lambda_{122}^{i*} \lambda_{312}^{j*}|$ fixed, the contributions of $e^-$ channel are a little larger than those of $\mu^-$ channel. When $|\lambda_{122}^{i*} \lambda_{312}^{j*}| = 3.0 \times 10^{-4}$, the relation of these branching ratios is

III. NUMERICAL VALUES AND DISCUSSION

In the following, we will calculate the branching ratios of $\tau^- \rightarrow e^- (\mu^-) K^+ K^- (K^0 \bar{K}^0)$ decays and use the experimental results to constrain the parameter space.

From Eq. (10), we know that the branching ratio is proportional to the coefficients $C_1^{(i*), C_3}$ and the form factors. These coefficients involve the parameter products $|\lambda_{122}^i \lambda_{312}^j| (|\lambda_{122}^{i*} \lambda_{312}^{j*}|)$ and the sparticle masses $m_{\tilde{u}(i_j)}$. For the sake of decreasing the number of parameters, we assume that only one sfermion contributes one time with universal mass $m_{\tilde{u}(i_j)} = \tilde{m} = 100 GeV$. Using the model parameters list in Eq. (9), we could get the branching ratios of $\tau^- \rightarrow e^- (\mu^-) K^+ K^- (K^0 \bar{K}^0)$ decays. The relation of branching ratios versus model parameter products $|\lambda_{122}^i \lambda_{312}^j| (|\lambda_{122}^{i*} \lambda_{312}^{j*}|)$ are given in Fig.2, where (a) is for $\tilde{u}$-mediated process and (b) for $\tilde{u}$-mediated process, respectively. The solid(dash, dot and dot dash) curve denotes the branching ratio of $\tau^- \rightarrow \mu^- K^+ K^- (\mu^- K^0 \bar{K}^0, e^- K^+ K^-, e^- K^0 \bar{K}^0)$ decay, and the horizon lines denote their experimental upper limits. From Fig.1(a) and Fig.1(b), one could see that the curves of branching ratios rise with the increasing of the parameter products. And when the values of $|\lambda_{122}^i \lambda_{312}^j| (|\lambda_{122}^{i*} \lambda_{312}^{j*}|)$ are at the order of $O(10^{-5}) (O(10^{-4}))$, all of these branching ratios could reach to the experimental upper limits. For Fig.1(a), when the numerical value of parameter product $|\lambda_{122}^{i*} \lambda_{312}^{j*}|$ fixed, the contributions of $K^+ K^-$ final states are a little larger than those of $K^0 \bar{K}^0$ final state. When $|\lambda_{122}^i \lambda_{312}^j| = 1.0 \times 10^{-5}$, the relation of these branching ratios is $Br(\tau^- \rightarrow \mu^- K^0 \bar{K}^0) < Br(\tau^- \rightarrow e^- K^0 \bar{K}^0) < Br(\tau^- \rightarrow \mu^- K^+ K^-) < Br(\tau^- \rightarrow e^- K^+ K^-)$. While, for the $\tilde{u}$-mediated channel in Fig.1 (b), when the value of $|\lambda_{122}^{i*} \lambda_{312}^{j*}|$ fixed, the contributions of $e^-$ channel are a little larger than those of $\mu^-$ channel. When $|\lambda_{122}^{i*} \lambda_{312}^{j*}| = 3.0 \times 10^{-4}$, the relation of these branching ratios is
FIG. 2: The relation of branching ratio $Br(\tau^+ \rightarrow \mu^- K^+ K^-)$ versus model parameter product $|\lambda'_{i22} \lambda_{i32}|$ with $m_\phi = 100\text{GeV}$. The horizon line presents the current experimental upper limit.

$Br(\tau^- \rightarrow \mu^- K^0 \bar{K}^0) < Br(\tau^- \rightarrow \mu^- K^+ K^-) < Br(\tau^- \rightarrow e^- K^0 \bar{K}^0) < Br(\tau^- \rightarrow e^- K^+ K^-)$. Moreover, it is noted that the experimental results restrict the parameter product $|\lambda'_{i22} \lambda_{i31(2)}|$ at the value of $1.08 \times 10^{-5}$ for $\tilde{\nu}$-mediated channel, which is one order of magnitude more stringent than those in [19]. While for $\tilde{u}$-mediated channel, $|\lambda'_{j2(1)} \lambda_{3j2}|$ is constrained at the value of $2.31 \times 10^{-4}$. Therefore, the $\tilde{\nu}$-mediated channel is more sensitive to the variation of the parameter product than that of $\tilde{u}$-mediated channel.

| decay mode | $f_R^n(980)$ | $f_{R,1}^{NR}(1530)$ | $f_{R,2}^{NR}$ | $F_R^n$ | $F_{R,1}^{NR}$ | $F_{R,2}^{NR}$ |
|------------|--------------|-------------------|--------------|--------|-------------|-------------|
| $e^- K^+ K^-$ | 90.13 | 3.05 | 2.68 | 31.18 | 59.81 | 34.73 |
| $e^- K^0 \bar{K}^0$ | 91.08 | 3.58 | 2.79 | 36.28 | 61.15 | 32.50 |
| $\mu^- K^+ K^-$ | 91.13 | 3.04 | 2.77 | 34.21 | 61.15 | 34.37 |
| $\mu^- K^0 \bar{K}^0$ | 92.12 | 3.55 | 2.86 | 36.40 | 63.15 | 32.10 |

TABLE I: The ratios of $Br^{R(NR)}$ to the value of total branching ratio $Br$ with $|\lambda'_{i22} \lambda_{i31(2)}|(|\lambda'_{j2(1)} \lambda_{3j2}|) = 1 \times 10^{-5}$.

Next, we will analyze the roles of these form factors in the decay branching ratios. From Eq. (7), (8), one could know that these form factors include the resonant term $F_{R}^s(f_R^s)$ and the non-resonant term $F_{R}^{NR}(f_{R,1}^{NR})$, where $F_{R}^s$ and $f_R^s$ mainly manifests the resonant effects of vector meson $\phi$ and scalar mesons $f_{980}(f_{1530})$, respectively. For the non-resonant term, besides the $G_{NR}^{(s)}$ term, $\tilde{\nu}$-mediated channel has an additional term $f_{R,2}^{NR}$.

We list the rate of these resonant(non-resonant) contributions to total branching ratio $Br^{R(NR)}/Br$ in Tab.1 with $|\lambda'_{i22} \lambda_{i31(2)}|(|\lambda'_{j2(1)} \lambda_{3j2}|) = 1 \times 10^{-5}$, where (from left to right) the first column denotes the decay mode. Comparing the second to the fifth column in Tab.1, we could find, for the resonant part of $\tilde{\nu}$-mediated channel, the percentage
of \( f_{(980)} \) contributions could reach 90% \(-\) 92% and is much larger than those of \( f_{(1530)} \) meson. While, for the non-resonant part, \( f_{s,2}^{NR} \) even could hold 31% \(-\) 36% effects and \( f_{s,1}^{NR} \) only accounts for less of 3%. So we could get the relation of these parts \( f_{s,f(980)}^{R} > f_{s,f(1530)}^{NR} > f_{s,f(980)}^{R} \) for \( \tilde{\nu} \)-mediated channel. For \( \tilde{\nu} \)-mediated channel, the contributions of \( F_{s}^{R} \) account for 59% \(-\) 63%. And the contributions of \( F_{s}^{NR} \) are smaller and occupy about 32% \(-\) 35%, which is similar to the case of \( f_{s,2}^{NR} \) in \( \tilde{\nu} \)-mediated channel.

Obviously, the uncertainties of these branching ratios mainly come from hadron matrix elements. Here, we will focus on the uncertainties caused by the non-resonant term \( f_{s,2}^{NR} \) in \( \tilde{\nu} \)-mediated channel. There are two parameters \( \sigma = e^{i \pi/4} (3.36^{+1.12}_{-0.96}) \) and \( \alpha = (0.14 \pm 0.02) \text{GeV}^{-2} \) in the term \( f_{s,2}^{NR} \). We take \( \tau^{-} \rightarrow \mu^{-}K^{+}K^{-} \) decay as an example, and present the relation of its branching ratio versus parameter product \( |\lambda_{12}^{*} \lambda_{32}| \) in Fig.2, where the dot line denotes the branching ratio with parameter \( \sigma = e^{i \pi/4} 3.36 \) and \( \alpha = 0.14 \pm 0.02 \text{GeV}^{-2} \), and the triangle line denotes the branching ratio with the parameter \( \sigma = e^{i \pi/4} 3.36^{+1.12}_{-0.96} \) and \( \alpha = 0.14 \text{GeV}^{-2} \), respectively. As one could see, although the two curves grow with the increasing of parameter product \( |\lambda_{12}^{*} \lambda_{32}| \), the uncertainties induced by the parameter \( \sigma \) are so much larger than those induced by the parameter \( \alpha \).

### IV. SUMMARY

In this work, we discuss the R-Parity violation effects of LFV \( \tau^{-} \rightarrow e^{-}(\mu^{-})K\bar{K}(K\bar{K} = K^{+}K^{-}, K^{0}\bar{K}^{0}) \) decays in RPV SUSY model. Since the hadronic behaviour of these decays is known a little by us, we calculate the hadronic matrix elements \( < K\bar{K}|(\bar{q}q)_{V(S)}|0> \) in light of the hadron performance of \( B \rightarrow KKK \) decay. The result shows that the RPV effects could improve the decay branching ratios to the experimental measurement range. The experimental data permit firmly the model parameter product \( |\lambda_{12}^{*} \lambda_{31(2)}| \) to the order of \( \mathcal{O}(10^{-5}) \) with \( \tilde{m} = 100 \text{GeV} \), which is more stringent than those in literatures. The resonant and non-resonant terms from vector(scalar) mesons are considered. The effects of resonant term are larger than those of the non-resonant term. For \( \tilde{\nu} \)-mediated channel, the resonant contribution of \( f_{(980)} \) meson occupies the leading resonant position. And the contributions of non-resonant term are as much as the case of \( \tilde{u} \)-mediated channel. Finally, the uncertainties are mainly induced by the non-resonant term \( f_{s,2}^{NR} \).

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[1] Antonio Pich, Prog. Part. Nucl. Phys. **75**, 41-85(2014), hep-ph/1310.7922.
[2] Daya Bay Collaboration, Phys. Rev. Lett. **108**, 171803(2012).
[3] Daya Bay Collaboration, Chin. Phys. **C37**, 011001(2013), hep-ex/1310.6732.
[4] Y. Miyazaki, et al., (The Bell Collaboration), Lett. **B682**, 355(2010), hep-ex/1206.5595.
[5] A. Ilakovac, Phys. Rev. **D62**:036010(2000).
[6] Z. H. Li, Y. Li and H. X. Xu, Phys. Lett. **B677**, 150(2009).
[7] E. Arganda, M. J. Herrero and J. Portolés, JHEP, **0806**:079(2008).
[8] M. Herrero, J. Portoles and A. Rodriguez-Sanchez, AIP Conf. Proc., **1200**:908-911,(2010), hep-ph/0909.0724.
[9] Wei Liu, Chong-Xing Yue, Jiao Zhang, Eur. Phys. J. **C68**:197-207(2010).
[10] W. J. Li et al., Int. J. Mod. Phys. **A25**, 4827(2010).
[11] Chuan-Hung Chen, Chao-Qiang Geng, Phys. Rev. **D74**:035010(2006).
[12] H. K. Dreiner, M. Kramer, Ben O’Leary, Phys. Rev. **D75**:114016(2007), hep-ph/0612278.
[13] Wen-jun Li, Ya-dong Yang, Xiang-dan Zhang, Phys. Rev. **D73**:073005-073023(2005).
[14] R. Barbier et al., Phys.Rept. **420**, 1-202 (2005), hep-ph/0406039.
[15] M. Chemtob, Prog. Part. Nucl. Phys. **54**, 71(2005), hep-ph/0406029.
[16] G. Ecker, J. Gasser, A. Pich, E. de Rafael, Nucl. Phys. **B321**, 311(1989).
[17] G. Ecker, et al., Phys. Lett. **B223**, 425(1989).
[18] Alexey A. Petrov, Dmitry V. Zhuridov, Phys. Rev. **D89**: 033005 (2014), hep-ph/1308.6561.
[19] J. T. Daub, H. K. Dreiner, C. Hanhart, B. Kubis and U. G. Meissner, JHEP **1301**, 179(2013), hep-ph/1212.4408.
[20] Hai-Yang Cheng et al., Phys. Rev. **D72**:094003-094013(2005).
[21] Hai-Yang, Cheng et al., Phys. Rev. **D76**:094006-094046(2007).
[22] Hai-Yang Cheng, Chun-Khiang Chua, Phys. Rev. **D88**:114014(2013).
[23] V.V. Anisovich et al., Yad. Fiz. **65**, 1583(2002)[Phys. At. Nucl. **65**, 1545(2002)].
[24] B. Aubert et al., (BaBar Collaboration), Phys. Rev. Lett. **99**:161802(2007).