Lepton flavor violation two-body decays of quarkoniums

Wu-Jun Huo

Department of Physics, Peking University, Beijing 100871, P. R. China

Tai-Fu Feng

Institute of High Energy Physics, Chinese Academy of Sciences, P.O. Box 918(4),
Beijing 100039, P. R. China

Chong-Xing Yue

College of Physics and Information Engineering, Henan Normal University,
Xinxiang 453002, P. R. China

Abstract

In this paper we firstly study various model-independent bounds on lepton flavor violation (LFV) in processes of $J/\Psi$, $\Psi'$ and $\Upsilon$ two-body decays, then calculate their branch ratios in models of the leptoquark, $R$ violating MSSM and topcolor assisted technicolor(TC2) models.
1 Introduction

At present, Standard model (SM) not only has theoretical shortcoming but also must face to the experimental difficulties. The recent measurement of the muon anomalous magnetic moment by the experiment E821 \[1\] disagrees with the SM expectations and there are also convincing evidences that neutrinos are massive and oscillate in flavor \[2\]. It seems to indicate the presence of new physics just round the corner will be in the leptonic part. As probing new physics, lepton flavor violation (LFV) processes have as natural consequence an increased interest experimentally and theoretically. Several experiments that may considerably improve on lepton flavor violating processes, such as the two-body LFV of bosons, $\mu$ and $\tau$ LFV decays, are under consideration. For example, the TESLA Linear Collider project will work at the $Z$ resonance, reaching a $Z$ production rate of $10^9$ per year \[3\]. A number of theoretical studies are devoted to these LFV decays to investigate the new physics effects \[4, 5, 6, 7\]. For $J/\Psi$ meson, BES \[8\] has accumulated about $10^7 - 10^8$ $J/\Psi$ events which can be available to probe lepton flavor violation of $J/\Psi$ \[9\]. In this note, we study the LFV processed of the heavy vector bosons, $J/\Psi$, $\Psi'$ and $\Upsilon$ with some models beyond SM.

The LFV decays of $J/\Psi$, $\Psi'$ and $\Upsilon$, such as $J/\Psi, \Psi', \Upsilon \rightarrow \mu e, \tau l$, are absent in SM at tree level because of the strong GIM suppression. They are strongly suppressed by powers of small neutrino masses and have very small branching ratios. Experimentally, there are no clear bounds of these decays. Then, such decays give therefore existence room of new physics. Ref. \[9\] discuss these flavor decays by using the simple ”unitarity inspired” relations and get rather strong model-independent constraints on these two-body LFV processes

\[
\begin{align}
\text{Br}(J/\Psi \rightarrow \mu e) & \leq 4 \times 10^{-13} \\
\text{Br}(J/\Psi \rightarrow \tau l) & \leq 6 \times 10^{-7} \\
\text{Br}(\Upsilon \rightarrow \mu e) & \leq 2 \times 10^{-9} \\
\text{Br}(\Upsilon \rightarrow \tau l) & \leq 10^{-2}
\end{align}
\]

From the above constraints, we can see perhaps BES could observe some of these processes.
In fact, in many models beyond SM, there exist many bosons (scalars or vectors), such as leptoquarks in GUTs, sleptons in SUSY and $Z'$ in technicolor models, which can induce the LFV decays at tree level and contribute large branching ratios. In many GUTs, the existence of leptoquarks is predicted, which has been actively searched in many collider experiments [10]. These new particles, which carry both the lepton and quark numbers, can couple to a current comprising of a lepton and a quark [11, 12]. Thus, they can lead to the vertices $J/\Psi \mu e$, $J/\Psi \mu \tau$, and so on. Recently, Refs. [13, 14] investigate the muon anomalous magnetic moment with the leptoquarks and get the restricting parameter space. Leptoquarks can induce the quarknioums decay to $ll'$ through $t$-channel.

The similar situation is in SUSY models without lepton number conservation and R-parity which the squarks play the same role as leptoquarks in GUTs [13, 14, 17, 18]. Although the present experiment constraint those couplings in various ways, the R-parity violating coupling may give large contribution to $J/\Psi \mu e$, $J/\Psi \mu \tau$, and so on.

In topcolor assisted technicolor (TC2) models [19], when the non-universal interactions, topcolor interactions are written in the mass eigenstates, it may lead to the flavor changing coupling vertices of the new gauge boson $Z'$, such as $Z'\mu e$, $Z'\mu \tau$. Thus, the $Z'$ has significant contributions to the lepton flavor changing process, like $\mu \to 3e$, and may have severe bound on the mass $M_{Z'}$ [7]. $Z'$ can also, but different from leptoquarks and sleptons, induce the decays of quarknioums to $ll'$ through $s$-channel.

We investigate the bounds of $J/\Psi, \Psi', \Upsilon \to ll'$ with model-independent analysis in sec. 2. Then, in sec.3, we study these bounds with model-dependent analysis in three models, leptoquarks, SUSY and technicolor, respectively. We give our conclusion in the last section.
2 Bounds of $V_i \rightarrow ll'$ with model independent analysis

Considering that a vector boson $V_i$, such as $J/\Psi$, $\Psi'$ and $\Upsilon$, couples to $\bar{ll}'$, the effective coupling between the vector boson $V_i$ and $\bar{ll}'$ as

$$\mathcal{L}_{\text{eff}} = g'_{V\nu\nu} \bar{l}l' V^\alpha + \text{h.c.}$$  \hspace{1cm} (5)$$

and $[4]$

$$\Gamma_\alpha = \left( \gamma_\alpha A_1^L + i\sigma_{\alpha\beta} \frac{q_\beta}{M} A_2^L + \frac{q_\beta}{M} A_3^L \right) P_L + (L \leftrightarrow R),$$ \hspace{1cm} (6)

where mass scale $M$ is introduced to make the form factors $A_{2,3}^{L,R}$ dimensionless. For on-shell vector mesons, the $A_3^{L,R}$ form factors do not contribute. With this lagrangian, we can calculate the decay $\tau \rightarrow ll'\bar{l}'$ (see Fig. 1). In the limit $m_e \rightarrow 0$, we can obtain

$$\Gamma(\tau \rightarrow ll'\bar{l}') = \frac{g_{V\tau l}^2 g_{V\nu\nu}^2 m_\tau^5 Q^2 \alpha^2}{192\pi^3 M_V^3} \left( |A_1^L - \frac{m_\tau A_2^R}{2M}|^2 + |A_1^R - \frac{m_\tau A_2^L}{2M}|^2 + \frac{3}{20} \frac{m_\tau^2 A_2^L}{M} \right)$$

$$+ (L \leftrightarrow R),$$ \hspace{1cm} (7)

where $Q$ is the charge of quark in the quarkoniums, $Q = 2/3$ for $J/\Psi$ and $\Psi'$ and $Q = -1/3$ for $\Upsilon$. $g_{V\nu\nu}$ is the vector meson decay constants and no relate to the effective coupling $g'_{V\tau l}$.

Similarly, we can get LFV decay width

$$\Gamma(V \rightarrow l\nu l') = \frac{g_{V\tau l}^2 m_\tau^2}{24\pi M_V} \left( 1 + 2 \frac{M_V^2}{m_\tau^2} \right) \left( 1 - \frac{m_\tau^2}{M_V^2} \right)^2 \left( |A_1^L|^2 + \frac{1}{2} \frac{m_\nu A_2^L}{M} \right)^2 + (L \leftrightarrow R) \right) \right).$$ \hspace{1cm} (8)

Using above equations and compared to the standard decays $\tau \rightarrow \nu_\tau l\nu_l$

$$\Gamma(\tau \rightarrow \nu_\tau l\nu_l) = \frac{G_F^2 m_\tau^5}{192\pi^3}$$ \hspace{1cm} (9)

and

$$\Gamma(V \rightarrow l'') = \frac{4\pi^2 Q^2 g_{V\nu\nu}^2}{3} \frac{m_\nu^2}{M_V^3},$$ \hspace{1cm} (10)
we obtain
\[
\frac{\text{Br}(\tau \to ll')}{\text{Br}(V \to \tau l) \cdot \text{Br}(V \to ll')} = \frac{\Gamma(\tau \to ll')}{\Gamma(\tau \to \nu_\tau l'\bar{\nu}_\tau)} \cdot \frac{\Gamma_V^2}{\Gamma(V \to \tau l) \cdot \Gamma(V \to ll')} \times \text{Br}(\tau \to \nu_\tau l'\bar{\nu}_\tau) = \frac{18\Gamma_V^2 \cdot \text{Br}(\tau \to \nu_\tau l'\bar{\nu}_\tau)}{C^2_V m^2_V M^4_V (1 + 2 \frac{M^2_V}{m^2_\tau})(1 - \frac{m^2_\tau}{M^2_V})^2} \times A,
\]
where \(\Gamma_V\) is the total decay width of the vector bosons \(V\) and
\[
A = \frac{(|A^L_1 - \frac{m_\tau A^R_1}{2M^2_V}|^2 + |A^R_1 - \frac{m_\tau A^L_1}{2M^2_V}|^2 + \frac{3}{25} |\frac{m_\nu A^L_1}{M^2_V}|^2)}{(|A^L_1|^2 + \frac{1}{2} |\frac{m_\nu A^L_1}{M^2_V}|^2)} \times (L \leftrightarrow R).
\]

By using the experimental bounds of \(\text{Br}(\tau \to ll')\) and the experimental values of \(\text{Br}(V \to ll')\) and \(\text{Br}(\tau \to \nu_\tau ll')\) \[20\], we could obtain the bounds of \(V \to \tau l\). For discussing the bounds, as like doing in \[4\], we consider two limiting cases:

- **When** \(|A^L_1|, |A^R_1| \gg \frac{m^2_\tau}{M^2_V}|A^{L,R}_2|, A \approx 1\). From eq.(7), we get
  \[
  \text{Br}(J/\Psi \to \tau l) < 1.0 \times 10^{-7}
  \]
  \[
  \text{Br}(\Psi' \to \tau l) \leq 0.7 \times 10^{-7}
  \]
  \[
  \text{Br}(\Upsilon \to \tau l) < 8.0 \times 10^{-5}
  \]

  Similarly, by using \(\text{Br}(\mu \to e^- e^+ e^-) \leq 10^{-12}\) and the experimental values of \(\text{Br}(V \to e^- e^+)\) and \(\text{Br}(\mu \to \nu_\mu e\bar{\nu}_e)\) \[20\]

  \[
  \text{Br}(J/\Psi \to \mu e) < 2 \times 10^{-13}
  \]
  \[
  \text{Br}(\Psi' \to \mu e) \leq 1.2 \times 10^{-13}
  \]
  \[
  \text{Br}(\Upsilon \to \mu e) < 1.7 \times 10^{-9}
  \]

- **When** \(|A^L_1|, |A^R_1| \ll \frac{m^2_\tau}{M^2_V}|A^{L,R}_2|, A \approx \frac{13 m^2_\tau}{10 M^2_V}\). We get
  \[
  \text{Br}(J/\Psi \to \tau l) < 3.6 \times 10^{-7}
  \]
  \[
  \text{Br}(\Psi' \to \tau l) \leq 2.5 \times 10^{-7}
  \]
  \[
  \text{Br}(\Upsilon \to \tau l) < 2.9 \times 10^{-4}
  \]
Similarly,

\[
\text{Br}(J/\Psi \to \mu e) < 5.3 \times 10^{-13} \tag{22}
\]
\[
\text{Br}(\Psi' \to \mu e) \leq 3.6 \times 10^{-13} \tag{23}
\]
\[
\text{Br}(\Upsilon \to \mu e) < 1.5 \times 10^{-8} \tag{24}
\]

From the above equations, we find some of them (Eqs. (13) and (19)) can reach the current experimental level of BES.

3 Bounds of \( J/\Psi \to ll' \) with model-dependent analysis

3.1 In leptoquark model

Many models beyond SM, like GUTs, naturally contain leptoquarks which can couple to a lepton-quark pair. This can induce the LFV two-body decays of \( J/\Psi \) and \( \Upsilon \) through \( t \)-channel (see Fig. 2).

The Leptoquarks contributing to these diagrams are \( \Phi_1 \) and \( \Phi_3 \). Their couplings are

\[
\Phi_1 : \ [\lambda^{(1)}_{ij} Q_{Lj} e_{Ri} + \tilde{\lambda}^{(1)}_{ij} \bar{u}_{Rj} L_{Li}] \Phi_1,
\]
\[
\Phi_3 : \ [\lambda^{(3)}_{ij} \bar{Q}_{Lj} L_{Li} + \tilde{\lambda}^{(3)}_{ij} \bar{u}_{Rj} e_{Ri}] \Phi_3.
\]

Confining ourselves to terms involving the \( \mu \) and \( \tau \), \( J/\Psi \) and \( \Phi_1 \), the relevant part of the interaction Lagrangian can be parametrized as

\[
\mathcal{L}_{\text{eff}}^{\text{Leptoquark}} = \bar{c}(\lambda^A_L P_L + \lambda^A_R P_R)\mu \Phi_A \\
+ \bar{c}(\lambda^A_L P_L + \lambda^A_R P_R) \tau \Phi_A + h.c. \tag{25}
\]

where \( \Phi \) is one of the above two leptoquarks, \( \lambda_{L,R} \) is the structure of the chiral couplings and \( P_{L,R} = (1 \mp \gamma^5)/2 \).
The decay width is
\[
\Gamma(J/\Psi \to \mu \tau) = \frac{|p|}{32\pi^2 M_{J/\Psi}} \int |\mathcal{M}|^2 d\Omega
\]
\[
= \frac{g_{J/\Psi}^2 m_\tau^2}{96\pi M_{J/\Psi}} (1 + 2 \frac{M_{J/\Psi}^2}{m_\tau^2}) \left(1 - \frac{m_\tau^2}{M_{J/\Psi}^2}\right)^2 \frac{|\lambda_L^{\mu \tau} \lambda_L^{\tau \mu}|^2 + |\lambda_R^{\mu \tau} \lambda_R^{\tau \mu}|^2}{M_\Phi^4}, \tag{26}
\]
where \(g_{J/\Psi}\) is \(J/\Psi\) decay constant. Compared to electromagnetic decay \(J/\Psi \to e^+e^-\) through \(\gamma\),
\[
\Gamma(J/\Psi \to e^+e^-) = \frac{16\pi}{27} \alpha^2 \frac{g_{J/\Psi}^2}{M_{J/\Psi}^3}, \tag{27}
\]
we get
\[
\text{Br}(J/\Psi \to \mu \tau) = \frac{9}{2^9 \pi^2 \alpha^2} \frac{m_\tau^2 M_{J/\Psi}^2}{2} \left(1 + 2 \frac{M_{J/\Psi}^2}{m_\tau^2}\right) \left(1 - \frac{m_\tau^2}{M_{J/\Psi}^2}\right)^2 \frac{|\lambda_L^{\mu \tau} \lambda_L^{\tau \mu}|^2 + |\lambda_R^{\mu \tau} \lambda_R^{\tau \mu}|^2}{M_\Phi^4} \times \text{Br}(J/\Psi \to e^+e^-) \tag{28}
\]
We take the experimental value, \((\text{Br}(J/\Psi \to e^+e^-) = (6.02 \pm 0.19)\%)\) \cite{20}. To get the constraints of \(|\lambda_L^{\mu \tau} \lambda_L^{\tau \mu}|^2 + |\lambda_R^{\mu \tau} \lambda_R^{\tau \mu}|^2}/M_\Phi^4\), we consider another lepton flavor decay \(\tau \to \mu \gamma\) through leptoquarks (see Fig. 3). Compared to electroweak decay \(\tau \to \mu \nu_\tau \bar{\nu}_\mu\), this gives a branching ratio of
\[
\text{Br}(\tau \to \mu \gamma) = \frac{3}{2^9 \pi^2 G_F^2} \frac{\alpha^2}{M_\Phi^4} \frac{|\lambda_L^{\mu \tau} \lambda_L^{\tau \mu}|^2 + |\lambda_R^{\mu \tau} \lambda_R^{\tau \mu}|^2}{M_\Phi^4} \times \text{Br}(\tau \to \mu \nu_\tau \bar{\nu}_\mu), \tag{29}
\]
where \(G_F\) is the effective electroweak couplings. By using the experimental values, \(\text{Br}(\tau \to \mu \gamma) < 1.1 \times 10^{-6}\) and \(\text{Br}(\tau \to \mu \nu_\tau \bar{\nu}_\mu) = (17.37 \pm 0.09) \times 10^{-6}\), we can obtain
\[
\frac{|\lambda_L^{\mu \tau} \lambda_L^{\tau \mu}|^2 + |\lambda_R^{\mu \tau} \lambda_R^{\tau \mu}|^2}{M_\Phi^4} < 1.5 \times 10^{-10} \tag{30}
\]
Then, we can obtain the bound of \(\text{Br}(J/\Psi \to \mu \tau)\) with a scalar leptoquark is
\[
\text{Br}(J/\Psi \to \mu \tau) < 3.0 \times 10^{-8}. \tag{31}
\]
Similarly, we get
\[
\text{Br}(J/\Psi \to \mu e) < 3.5 \times 10^{-15}, \tag{32}
\]
\[
\begin{align*}
\text{Br}(\Psi' \to \mu\tau) &< 9.3 \times 10^{-9}, \\
\text{Br}(\Psi' \to \mu\tau) &< 1.1 \times 10^{-15}, \\
\text{Br}(\Upsilon \to \mu\tau) &< 1.3 \times 10^{-7}, \\
\text{Br}(\Upsilon \to \mu\tau) &< 1.6 \times 10^{-14}.
\end{align*}
\]

### 3.2 In SUSY model

In the supersymmetry model without R-parity and lepton number conservation, rare processes \(J/\Psi \Upsilon \to ll'\) is induced by squark through \(t\)-channel, (see Fig. 2).

The superpotential for the lepton number violation supersymmetry can be written as:

\[
W = W_{\text{MSSM}} + W_L.
\]

The \(W_{\text{MSSM}}\) represents the R-parity conservation sector supersymmetry and can be found in literatures[13]. The R-parity violation sector superpotential is

\[
W_L = \epsilon_{ij} \lambda'_{1jk} \hat{L}_i \hat{L}_j \hat{R}_K + \epsilon_{ij} \lambda'_{1jk} \hat{L}_i \hat{Q}_j \hat{D}_K
\]

with \(\hat{L}'\) represents the \(I\)-th generation lepton superfields and \(\hat{Q}'\) represents the \(I\)-th generation quark superfields, which are all the doublet of \(SU(2)\) group. The \(\hat{R}', \hat{D}'\) are the \(I\)-th generation \(SU(2)\) singlet lepton- and quark- superfields. Here, we have ignore the bilinear lepton number violation terms in the superpotential[14]. Although there are 36 trilinear R-parity couplings in the superpotential Eq.(38), our computation involve only two trilinear couplings \(\lambda'_{222}\) and \(\lambda'_{223}\).

The calculation is similar to that of leptoquarks. The relative effective Lagrangian can be written as

\[
\mathcal{L}_{\text{eff}}^{\text{SUSY}} = \frac{\lambda'_{222} \lambda'_{223}}{4M^2_\Phi} (\bar{c}_P \mu \bar{\tau}_P R_C + \bar{c}_P \tau \bar{\mu}_P R_C),
\]

where \(M^2_\Phi\) is the mass of squark.

From this Lagrangian, we can get decay width with squark \(\Phi\) is

\[
\Gamma(J/\Psi \to \mu\tau) = \left(\frac{(\lambda'_{222} \lambda'_{223})^2 g^2}{3 \times 16^2 \pi M^4_\Phi}\right) \frac{m^2_\tau}{M^2_{J/\Psi}} \left(1 + 2 \frac{M^2_\Psi}{m^2_\tau}(1 - \frac{m^2_\tau}{M^2_{J/\Psi}})\right)^2.
\]
Comparing to ordinary decay $J/\Psi \rightarrow e^+e^-$ (Eq. (8)), we obtain

$$
\text{Br}(J/\Psi \rightarrow \mu\tau) = \frac{9}{8 \times 16^2 \pi^2 \alpha^2} \left( \frac{\lambda'_{222} \lambda'_{223}}{M^4_\Phi} \right) m^2_\tau M^2_{J/\Psi} (1 + 2 \frac{M^2_{J/\Psi}}{m^2_\tau})(1 - \frac{m^2_\tau}{M^2_{J/\Psi}})^2 \times \text{Br}(J/\Psi \rightarrow e^+e^-) \quad (41)
$$

As for tribilinear coupling constants, we adopt the single coupling hypothesis, where a single coupling constant is assumed to dominate over all the others, so that each of the coupling constants contributes once at a time\[17\]. The analysis of tree level $R_\nu$ contributions to the D-mesons three body decays, $D \rightarrow K + l + \nu; D \rightarrow K^* + l + \nu$ yields the bounds\[18\]

$$
\lambda'_{22K} < 0.18, \quad K = 1, 2, 3.
$$

If the supersymmetry is weak-scale theory with $M_\Phi = 100\text{GeV}$, we can obtain the bound of $\text{Br}(J/\Psi \rightarrow \mu\tau)$ with sleptons is

$$
\text{Br}(J/\Psi \rightarrow \mu\tau) < 5.0 \times 10^{-9}. \quad (42)
$$

Similarly, we get

$$
\begin{align*}
\text{Br}(J/\Psi \rightarrow \mu e) &< 5.7 \times 10^{-16}, \quad (43) \\
\text{Br}(\Psi' \rightarrow \mu\tau) &< 1.8 \times 10^{-9}, \quad (44) \\
\text{Br}(\Psi' \rightarrow \mu e) &< 1.9 \times 10^{-16}, \quad (45) \\
\text{Br}(\Upsilon \rightarrow \mu\tau) &< 2.2 \times 10^{-8}, \quad (46) \\
\text{Br}(\Upsilon \rightarrow \mu e) &< 2.5 \times 10^{-15}. \quad (47)
\end{align*}
$$

### 3.3 In TC2 models

To solve the phenomenological difficulties of traditional technicolor theory, TC2 theory\[19\] was proposed by combing technicolor interactions with topcolor interactions for the third generation at the energy scale of about 1 TeV. TC2 models predict the existence of the new gauge boson $Z'$, which lead to the LFV coupling vertices, $Z'\ell\ell'\ell$. Thus, it can give
significant contributions to some LFV processes. In TC2 models, the contributions of $Z'$ to the LFV process $J/\Psi \rightarrow \mu \tau$ can be induced through s-channel, (see Fig. 4).

The couplings of the new gauge boson $Z'$ to ordinary fermions, which are related to the LFV process $J/\Psi \rightarrow \mu \tau$, can be written as:

$$L_{Z'}^{\text{eff}} = -\frac{g_1 \tan \theta'}{6} Z'_\mu [\bar{c}_L \gamma^\mu c_L + 2 \bar{c}_R \gamma^\mu c_R + ...] - \frac{g_1}{2} Z'_\mu [k_{\tau\mu}(\bar{\mu}_L \gamma^\mu \tau_L + 2 \bar{\mu}_R \gamma^\mu \tau_R) + ...],$$

(48)

where $g_1$ is the $U(1)$ coupling constant at the scale $\Lambda_{TC}$, $k_{\tau\mu}$ is the flavor mixing factor, and $\theta'$ is the mixing angle. With the above Lagrangian, we can obtain the decay width contributed by the new gauge boson $Z'$:

$$\Gamma(J/\Psi \rightarrow \mu \tau) = \left(\frac{\pi k_1 \tan^4 \theta'}{12 M_{Z'}^2}\right)^2 \frac{g^2 (k_{L}^2 + 4 k_{R}^2) m_{\tau}^2}{12 \pi M_{J/\Psi}^2} \left(1 + 2 \frac{M_{J/\Psi}^2}{m_{\tau}^2}\right)(1 - \frac{m_{\tau}^2}{M_{J/\Psi}^2})^2$$

(49)

Compared to ordinary decay $J/\Psi \rightarrow e^+e^-$, we obtain

$$\text{Br}(J/\Psi \rightarrow \mu \tau) = \frac{9}{32 \times 12^2 \alpha^2} \left(\frac{k_1 \tan^4 \theta'}{M_{Z'}^2}\right)^2 \frac{(k_{L}^2 + 4 k_{R}^2) m_{\tau}^2 M_{J/\Psi}^2}{12 \pi} \left(1 + 2 \frac{M_{J/\Psi}^2}{m_{\tau}^2}\right)$$

$$\times (1 - \frac{m_{\tau}^2}{M_{J/\Psi}^2})^2 \text{Br}(J/\Psi \rightarrow e^+e^-)$$

(50)

Using the results of Ref. [4], we can obtain the bound of $\text{Br}(J/\Psi \rightarrow \mu \tau)$ with $Z'$ is

$$\text{Br}(J/\Psi \rightarrow \mu \tau) < 3.3 \times 10^{-8}.\quad (51)$$

Similarly, we get

$$\text{Br}(J/\Psi \rightarrow \mu e) < 3.8 \times 10^{-15},\quad (52)$$
$$\text{Br}(\Psi' \rightarrow \mu \tau) < 1.0 \times 10^{-8},\quad (53)$$
$$\text{Br}(\Psi' \rightarrow \mu e) < 1.2 \times 10^{-15},\quad (54)$$
$$\text{Br}(\Upsilon \rightarrow \mu \tau) < 1.3 \times 10^{-7},\quad (55)$$
$$\text{Br}(\Upsilon \rightarrow \mu e) < 1.6 \times 10^{-14}.\quad (56)$$

4 Conclusions

we have investigated the bounds of lepton flavor violation processes of $J/\Psi$ and $\Upsilon$ two-body decays in leptoquarks, SUSY and TC2 models, respectively. We used the constraints
of couplings from other ways to obtain the indirect bounds of \( \text{Br}(J/\Psi, \Upsilon \rightarrow ll') \) with model independent. It is interesting that some results would get the experimental level. And it is shown that these new particles perhaps can be seen or ruled out by the near future experiments.

**Acknowledgments**

We thank Professor Xinmin Zhang for suggestions on this project. One of the authors (W. J. Huo) acknowledges supports from the Chinese Postdoctoral Science Foundation and CAS K.C. Wong Postdoctoral Research Award Fund. The work of C. X. Yue was supported by the National Natural SScience Foundation of China(I9905004), the Excellent Youth Foundation of Henan Scientific Committee(9911), and Foundation of Henan Educational Committee.

**References**

[1] Muon g-2 Collaboration, H.N. Brown *et al.*, Phys. Rev. Lett. **86**, 2227 (2001).

[2] Y. Fukuda *et al.*, Phys. Lett. **B436** 33 (1998); Phys. Rev. Lett. **81**, 1562 (1998).

[3] R. Hawkings and K. Monig, Eur. Phys. J. **C8**, 1 (1999); J. Erler, S. Heinemeyer, W. Hollik, G. Weiglein and P.M. Zerwas, Phys. Lett. B486, 125 (2000).

[4] D. Delépine and F. Vissani, [hep-ph/0106287](http://arxiv.org/abs/hep-ph/0106287).

[5] W. Buchmüller, D. Delepine and F. Vissani, Phys. Lett. **B459**, 171 (1999).

[6] S. Nussinov, R.D. Peccei and X.M. Zhang, Phys. Rev. **D63**, 016003 (2000).

[7] C.X. Yue, G.L. Liu and J.T. Li, Phys. Lett. **B496**, 89 (2000); C. X. Yue, Q. J. Xu, G. L. Liu, [hep-ph/0106213](http://arxiv.org/abs/hep-ph/0106213).
[8] BES Collaboration, J. Z. Bai et al. Nucl. Instrum. Methods in Phys. Res. Sect. A344 319 (1994).

[9] X. Zhang, hep-ph/0010105, A. Datta, P. J. O’Donnell, S. Pakvasa, and X. Zhang, Phys. Rev. D60, 014011 (1999).

[10] CDF Collaboration, F. Abe et al., Phys. Rev. Lett. 79, 4327 (1997); 81, 4806 (1998); DØ Collaborations, B. Abbott et al., 79, 4321 (1997);84, 2088 (2000); H1 Collaboration, C. Adloff et al., Eur. Phys. J. C11, 447 (1999); C14, 553 (2000); ZEUS Collaboration, J. Breitweg et al., 16, 253 (2000).

[11] A.J. Davies and X.G. He, Phys. Rev. D43, 225 (1991).

[12] J. Hewett and T. G. Rizzo, Phys. Rev. D56, 5709 (1997).

[13] K. Cheung, Phys. Rev. D64, 033001(2001).

[14] D. Chakraverty, D. Choudhury and A. Datta, Phys.Lett. B506, 103 (2001).

[15] H. E Haber and G. L. Kane, Phys. Rep. 117, 75(1985); J. F. Gunion and H. E. Haber, Nucl. Phys. B272, 1(1986).

[16] M. A. Diaz, J. C. Romao, J. W. F. Valle, Nucl. Phys. B524, 23(1998); C. H. Chang, Tai-Fu Feng, Eur. Phys. J. C12, 137(2000).

[17] S. Dimopoulous and L. J. Hall, Phys. Lett. B207,210(1987); V. Barger, G. F. Giudice and T. Han, Phys. Rev. D40,2987(1989).

[18] G. Bhattacharyya and D. Choudhury, Mod. Phys. Lett. A10, 1699(1995).

[19] C. T. Hill, Phys.Lett. B345, 483(1995); K. Lane and E. Eichten, Phys. Lett. B352, 383(1995); K. Lane, Phys. Lett. B433, 96(1998); G. Cvetic, Rev. Mod. Phys. 71, 513(1999).

[20] Particle Data Group, K. Hagiwara et al., Phys. Rev. D66, 010001 (2002).
Figure 1: Diagram of LFV decays $\tau \to l\bar{l}l'$ through vector mesons, $J/\Psi, \Upsilon$.

Figure 2: Diagram $J/\Psi \to \mu\tau$ through letoquarks or sleptons.

Figure 3: Diagram of $\tau \to \mu\gamma$ through letoquarks.
Figure 4: Diagram of $J/\Psi \rightarrow \mu \tau$ in TC2 models.