Probing unparticle theory via lepton flavor violating process

\( J/\psi \rightarrow ll' \) at BESIII

Zheng-Tao Wei, Ye Xu, and Xue-Qian Li

Department of Physics, Nankai University, Tianjin 300071, China

Abstract

The lepton flavor violating process \( J/\psi \rightarrow ll' \ (l \neq l') \) serves as an ideal place to probe the unparticle theory. Such process can only occur at loop level in the Standard model (SM), so that should be very suppressed, by contrast in unparticle scenario, it happens at tree level and its contribution may be sizable for practical measurement. Moreover, the BESIII will offer the largest database on \( J/\psi \) which makes more accurate measurements possible. Furthermore, for such purely leptonic decays background is relatively low and signal would be cleaner. Our work carefully investigates the possibility of observing such processes from both theoretical and experimental aspects.
I. INTRODUCTION

Violation of the lepton flavor symmetry plays an important role for exploring new physics beyond the standard model (SM). Neutrino oscillations which are observed in many experiments, indicate that lepton flavor symmetry is broken and the minimal SM must be extended to accommodate non-zero neutrino masses. Up to present, the lepton flavor violation (LFV) has only been observed in the neutrino sector. This violation is induced by the neutrino masses and existence of the right-handed neutrinos. By contrast, for the charged lepton sector, there is no any evidence for such a violation. Many studies have been devoted to explore the LFV through $\mu$, $\tau$ and $Z$ decays [1]. In Ref. [2], it was suggested to look for LFV via charmonium $J/\psi$ decays. In terms of the database of $5.8 \times 10^7$ $J/\psi$ data at BES processes $J/\psi \to e\mu$ [4], $J/\psi \to \mu\tau$, $e\tau$ [5] have been explored and upper limits for their branching fractions were set. New hope is raised that the forthcoming upgraded BESIII will accumulate up to $10^{10}$ $J/\psi$ per year [6], which makes it possible to test LFV with a much higher precision. It is well known that the SM contribution to such violation can only occur via loops and are very suppressed, so that cannot produce observable effects even with so large database of $J/\psi$. Therefore it is time to investigate possibility of discovering such violation in terms of the theoretical models beyond SM.

Recently, Georgi proposed an interesting idea that a scale invariant stuff may exist in our world. The scale invariant stuff contains no particle, but the so-called unparticle [7]. To be consistent with the present experimental observations, in the effective theory about the unparticle, the coupling of unparticle to the ordinary Standard Model (SM) matter must be sufficiently weak. The scale dimension of unparticle is in general fractional rather than an integral number. The interactions between the unparticle and the SM particles in low energy effective theory can lead to various interesting phenomenology. There have been many phenomenological and theoretical explorations related to unparticles in literature. Since interaction between unparticle and ordinary SM matter is rather weak, we can expect that its participation cannot produce observable effects for the processes (production and decays) which have large rates, but definitely may play important roles in the rare processes where the SM contribution are suppressed.

In unparticle physics, the unparticle can couple to different flavors of the SM leptons and thus induce LFV even at tree level. There have been several studies of LFV in unparticle physics, for instance, $\mu \to 3e$ in [8]; $\mu \to e+U$, 3e in [9]; $M^0 \to ll'$, $e^+e^- \to ll'$ in [10]; $\mu \to e\gamma$, $e\gamma$ conversion in [11]; muonium and antimuonium oscillation in [12]; $r \to ll'$, $l \to l'\gamma\gamma$ in [13]. In this work, we propose to study LFV in unparticle physics via $J/\psi \to ll'$ decays. There are several advantages of exploring LFV in $J/\psi \to ll'$ decays, in particular the $J/\psi \to e\mu$ process. On the experimental side, the final states contain only leptons which are easy to detect. Compared to $e^+e^- \to ll'$ processes which occur due to non-resonance contribution, a large database of $J/\psi$ is expected at BESIII which will begin running very soon. From the
theoretical point of view, the processes $J/\psi \rightarrow ll'$ are free of hadronic uncertainties after the parameter related to the binding effect of $J/\psi$ is experimentally determined by measuring $J/\psi \rightarrow e^+e^- (\mu^+\mu^-)$.

Anyway, an observation of $J/\psi \rightarrow ll'$ ($l \neq l'$) would be a clear indication of new physics beyond SM. In our case, $c\bar{c}$ in $J/\psi$ annihilate into a virtual unparticle which later converts into two leptons $ll'$ with different flavors. As we will show that the theoretical prediction on the branching ratio of $J/\psi \rightarrow e\mu$ can reach about $10^{-8}$ order, which is absolutely possible to be observed at BESIII. To help or experimental colleagues, on the basis of BESIII environments, we carry out an investigation on the possibility of search for $J/\psi \rightarrow e\mu$ in terms of a Monta Carlo simulation.

II. $J/\psi \rightarrow ll'$ IN UNPARTICLE PHYSICS

We start with a brief review about the unparticle physics which is relevant to this study. The scale invariant unparticle fields emerge below an energy scale $\Lambda_{U}$ which is assumed to be at the order of TeV. The interactions of the unparticle with the SM particles are described by a low energy effective theory. The coupling of unparticle to SM fermions (quarks and leptons) is generally given by the following effective operators as

$$
\frac{c_{SS}^{ff}}{\Lambda_{U}^{d_{U}-1}}\bar{f}_{i}^{\gamma_{5}}f O_{U}^{a}, \quad \frac{c_{SP}^{ff}}{\Lambda_{U}^{d_{U}-1}}\bar{f}_{i}^{\gamma_{5}}f O_{U}^{a}, \quad \frac{c_{SV}^{ff}}{\Lambda_{U}^{d_{U}-1}}\bar{f}_{i}^{\gamma_{5}}f \partial^{\mu}O_{U}^{a}, \quad \frac{c_{SA}^{ff}}{\Lambda_{U}^{d_{U}-1}}\bar{f}_{i}^{\gamma_{5}}f \partial^{\mu}O_{U}^{a},
$$

where $O_{U}$ and $O_{U}^{a}$ denote the scalar and vector unparticle fields, respectively. Tensor unparticle does not contribute in our case. The $c_{ij}$ are dimensionless coefficients. Because $J/\psi$ is a vector, only the vector current $\bar{f}_{i}^{\gamma_{5}}f$ couples to $J/\psi$. For a scalar unparticle coupling $\bar{f}_{i}^{\gamma_{5}}f \partial^{\mu}O_{U}$, it is proportional to the momentum of the unparticle. Using the equations of motion, one can immediately show that this part is proportional to the lepton masses in decays of $J/\psi \rightarrow ll'$ and thus is suppressed. Consequently, we will only consider the effective interaction $\frac{c_{ij}^{ff}}{\Lambda_{U}^{d_{U}-1}}\bar{f}_{i}^{\gamma_{5}}f O_{U}^{a}$ which dominates in the decays of $J/\psi \rightarrow ll'$.

For the vector unparticle field, the propagator is given by

$$
\int d^{4}x e^{iP \cdot x} \langle 0|TO_{U}^{a}(x)O_{U}^{a}(0)|0 \rangle = \frac{i}{2\sin(d_{U}\pi)} \frac{A_{d_{U}}}{(P^{2} + i\epsilon)^{2-d_{U}}} e^{i(d_{U}-2)\pi}.
$$

where

$$
A_{d_{U}} = \frac{16\pi^{5/2}}{(2\pi)^{2d_{U}}} \frac{\Gamma(d_{U} + 1/2)}{\Gamma(d_{U} - 1)\Gamma(2d_{U})}.
$$

The function $\sin(d_{U}\pi)$ at the denominator implies that the scale dimension $d_{U}$ cannot be integers except $d_{U} = 1$. The peculiar unparticle propagator and the phase factor $e^{i(d_{U}-2)\pi}$ which
provides a CP conserving phase produces novel effects in high energy scattering processes [14], CP violation [15], neutral meson mixing [16] and neutrino processes [17].

\[ \bar{c} c \rightarrow J/\psi \]

\[ J/\psi \rightarrow l l' \]

FIG. 1: The diagram for the decay of $J/\psi \rightarrow ll'$. The double dashed lines represent the unparticle.

The lowest order contribution to decays of $J/\psi \rightarrow ll'$ is a simple tree diagram, which is depicted in Fig. 1. From the diagram, the exchange of vector unparticle is analogous to a photon exchange unless photon cannot couple to flavor changing currents. By using the effective operators and unparticle propagator, it is straightforward to write out the decay amplitude as

$$\mathcal{M}(J/\psi(P) \rightarrow l(k)l'(k')) = \frac{c_{VV}c_{VV}'}{A_{d_U}} A_{d_d} \frac{m_{\psi}f_{\psi}}{2\sin d_U \pi} \epsilon_{\psi}^{\mu} \bar{u}(k) \gamma_{\mu} v(k').$$  (4)

where $s = m_{\psi}^2$. The decay constant $f_{\psi}$ is derived from the pure-leptonic process $J/\psi \rightarrow e^+e^-$. In principle, unparticle can also contribute to $J/\psi \rightarrow e^+e^-$, but compared with the QED contribution, its fraction in $BR(J/\psi \rightarrow e^+e^-) \sim 6\%$ and $BR(J/\psi \rightarrow e^+\mu^-) < 1.1 \times 10^{-6}$ [4] is completely negligible.

The decay width of $J/\psi \rightarrow ll'$ is given by

$$\Gamma(J/\psi \rightarrow l^+l^-) = \frac{|\vec{p}_k|}{8\pi m_{\psi}^2} \cdot \frac{1}{3} \sum_{\text{spins}} |\mathcal{M}|^2,$$  (5)

with

$$\frac{1}{3} \sum_{\text{spins}} |\mathcal{M}|^2 = \frac{1}{3} \left( \frac{c_{VV}c_{VV}'}{A_{d_U}^2 \sin d_U \pi} \frac{m_{\psi} f_{\psi}}{s^2 - d_U} \right)^2 \left[ 2(P \cdot k)(P \cdot k') + k \cdot k' \right].$$  (6)

For $J/\psi \rightarrow e\mu$, where the final lepton masses are both small compared to mass of $J/\psi$, we have the simplified form for the decay ratio as

$$\frac{\Gamma(J/\psi \rightarrow e^+\mu^-)}{\Gamma(J/\psi \rightarrow e^+e^-)} = \left| \frac{c_{VV}c_{VV}'}{4\pi \alpha e_c} \frac{A_{d_d}}{2\sin d_U \pi} \left( \frac{s}{A_{d_U}^2} \right)^{d_U-1} \right|^2.$$  (7)

with $e_c = 2/3$. Noting that $\Gamma(J/\psi \rightarrow e^-\mu^+) = \Gamma(J/\psi \rightarrow e^+\mu^-)$ due to CP symmetry, we have

$$\Gamma(J/\psi \rightarrow e\mu) \equiv \Gamma(J/\psi \rightarrow e^-\mu^+) + \Gamma(J/\psi \rightarrow e^+\mu^-) = 2\Gamma(J/\psi \rightarrow e^+\mu^-).$$  (8)
We would like to present several comments as follows: (1) The relation of Eq. (7) can be applied to other vector meson whose mass is larger than that of \( J/\psi \), such as \( \Upsilon \), etc.. (2) The decay width of \( V \to e\mu \) depends on the invariant mass squared \( s \), and is proportional to \((s/\Lambda_U)^{d_U-1}\). When \( d_U > 1 \), the decay width decreases as a power function. (3) For \( 1 < d_U < 2 \), the decay width decreases faster as \( d_U \) increases. The dependence of the branching ratio of \( J/\psi \to e\mu \) on dimension \( d_U \) is shown in Fig. 2.

An important constraint on the unparticle interaction which is related to \( J/\psi \to ll' \) processes comes from the invisible decay of \( J/\psi \). In SM, the invisible final states are neutrinos. The \( J/\psi \to \nu\bar{\nu} \) decays are highly suppressed and can be neglected. In unparticle physics, the unparticle \( \Upsilon \) cannot be detected by experimental apparatus and if \( J/\psi \) decays into an unparticle pair, \( \Upsilon \)'s would correspond to missing energy. Moreover, the \( J/\psi \to \Upsilon \) decay is possible because the mass of \( \Upsilon \) is not fixed, and \( \Upsilon \) also escapes from our detector. It provides a constraint on the the coupling of unparticle to \( c\bar{c} \) quark pair. The rate of the \( J/\psi \to \Upsilon \) decay are derived using the same effective interactions as that in \( J/\psi \to ll' \), and it is straightforwardly to obtain

\[
\frac{\Gamma(J/\psi \to \Upsilon)}{\Gamma(J/\psi \to e^+e^-(\mu^+\mu^-))} = \frac{3A_{d_U}|\epsilon_{VV}|^2}{8\pi\alpha^2e_c^2}\left(\frac{s}{\Lambda_U^2}\right)^{d_U-1}.
\]

Our result is in agreement with [18] except a factor of 4 difference due to different conventions. Another constraint on the coupling of unparticle to \( e\mu \) may come from \( \mu \to e+\Upsilon \) and \( \mu \to 3e \). In [9], the scale dimension for vector unparticle \( d_U > 2 \) is used. We will follow [7] and assume \( 1 < d_U < 2 \). If \( d_U > 2 \) as in [9], the branching ratio of \( J/\psi \to e\mu \) will be so small that it cannot be observed at BESIII only if \( d_U \) is close to 2 (other integers are also possible).

![FIG. 2: The branching ratio for \( J/\psi \to e\mu \) with scale dimension \( d_U \). The dashed line represents the present experimental upper bound.](image)

The BESII collaboration recently sets an upper limit for the invisible decay ratio \( \frac{\Gamma(J/\psi \to \Upsilon)}{\Gamma(J/\psi \to \mu^+\mu^-)} < 1.2 \times 10^{-2} \) [20]. It determines the upper bound on the coupling coefficient of unparticle to \( c\bar{c} \) quarks. If choosing \( \Lambda_U = 1 \) TeV and \( d_U = 1.35 \), then we obtain \(|\epsilon_{VV}| < 0.01\).
The present experimental upper bounds on the branching fractions are given in [4, 5]: 

\[ BR(\psi^J \rightarrow e\mu) < 1.1 \times 10^{-6}, \quad BR(\psi^J \rightarrow e\tau) < 2.0 \times 10^{-6}, \quad BR(\psi^J \rightarrow \mu\tau) < 8.3 \times 10^{-6}. \]

Among them, the upper bound on \( \psi^J \rightarrow e\mu \) is the lowest which may provide the most stringent constraint on the coupling. If we adopt the constraints from invisible decay to fix the unparticle parameters, i.e. \( d_\lambda = 1.35, \Lambda_\lambda = 1 \text{ TeV} \) and choose \( c_{VV}^{e\mu} = 0.01 \), the branching fraction is predicted to be \( BR(\psi^J \rightarrow e\mu) = 7 \times 10^{-8} \). We may further constrain the unparticle parameters by the upper bound on \( BR(\psi^J \rightarrow e\mu) \). When \( \Lambda_\lambda \) and \( c_{VV}^{e\mu} \) are fixed, for instance, choosing \( \Lambda_\lambda = 1 \text{ TeV} \) and \( c_{VV}^{e\mu} = 0.01 \), we obtain \( d_\lambda > 1.26 \). This result is consistent with the constraint achieved from \( D^0 - \bar{D}^0 \) mixing within 1\( \sigma \) error tolerance [12]: \( d_\lambda = (0.21 + n) \pm 0.07 \) where \( n \) is an arbitrary integer (note that uncertainty is still large). We will discuss the possibility of observing fractions of order \( 10^{-8} \) at BESIII in the next section.

In [2], the authors obtain a bound \( BR(\psi^J \rightarrow e\mu) < 8.3 \times 10^{-6} \) based on a model-independent approach which introduces an effective four-fermion contact interaction. By considering the strong bounds from three body LFV processes, such as \( \mu \rightarrow 3e \) and using the ”unitarity inspired” relation between two and three-body LFV decays, it is found that the upper bound is constrained to be very small \( BR(\psi^J \rightarrow e\mu) < 4 \times 10^{-13} \) [3]. However, it is noted that such serious bound can be avoided due to some possible kinematical suppression or cancelations [2]. Our predicted value lies a range between [2] and [3]. The precise prediction is difficult because of the unknown model parameters, especially the scale dimension \(^1\).

### III. ESTIMATING POSSIBILITY OF THE DETERMINATION OF \( BR(\psi^J \rightarrow e\mu) \)

BESIII is a spectrometer which will begin operation in 2008 at the upgraded Beijing Electron-Positron Collider (BEPCII) whose designed luminosity is approximately 100 times higher than that of BEPC [6]. With this high luminosity, the BESIII detector will be able to collect over 10 billion \( \psi^J \) events in one year of running. The performance of the BESIII [6] will be much more effective in comparison with the BESII [21], so that we can expect that BESIII would perform a more precise and clear particle identification (PID) than BESII. It helps to accurately analyze rare decay channels, such as the concerned lepton-flavor violating processes.

The upper bound on \( BR(\psi^J \rightarrow e\mu) \) was achieved with the the BESII data [4] a long while ago. Before BESIII begins running, we would roughly pre-estimate the upper bound with

\(^1\) For scale dimension of the vector unparticle, it is pointed out that conformal symmetry puts a lower bound \( d \geq 3 \) in [19]. If we take this constraint, the fraction of \( BR(\psi^J \rightarrow ll') \) will be decreased by more than two orders and it is impossible to observe them in experiment except \( d_\lambda \) is very close to 3. One may avoid this problem by taking a point of view that scale symmetry is different from conformal symmetry. The discussion of this controversial topic is beyond this study.
the BESIII data, if signals are still not observed. For BESIII, ten billion $J/\psi$ events can be used for our analysis. The main backgrounds to our signal channel $J/\psi \rightarrow e\mu$ are the nearly back-to-back tracks in $J/\psi \rightarrow e^+e^-, \mu^+\mu^-, K^+K^-, \pi^+\pi^-$ and $e^+e^- \rightarrow e^+e^-(\gamma), \mu^+\mu^-(\gamma)$. Since the BESIII experiment has not begun running yet, some detailed information about BESIII environment is not available, therefore we adopt relevant parameters for BESII to estimate $BR(J/\psi \rightarrow e\mu)$ and the corresponding backgrounds, except the number of available $J/\psi$ events.

The method of determining the selection efficiency for $J/\psi \rightarrow e\mu$ and the rate of misidentifying the background as a signal is the same as the one used in [4]. The overall selection efficiency for the signal channel (or rate of misidentifying the background channel as the signal channel) includes the $\mu$ and $e$ particle identification (PID) efficiency and the geometric efficiency. Indeed, the geometric efficiency of BESIII is only slightly different from BESII, thus in this work we set the same geometric efficiency as that for the previous BESII experiments. The PID efficiency and contamination rate which refer to identifying other particles as electrons or muons in BESIII are taken from [4]. In order to discriminate muons to reject other particles as much as possible, a very rigorous criterion of the $\mu$ identification has to be performed while selecting signal event $J/\psi \rightarrow e\mu$. The geometric and the PID efficiency are listed in Tables I and II respectively.

**TABLE II: The particle identification/misidentification efficiency.**

| identified as $e$ | identified as $\mu$ |
|------------------|------------------|
| $e$ | 98.0% | — |
| $\mu$ | — | 19.0% |
| $\pi$ | 0.1% | 0.46% |
| $K$ | 0.1% | 0.38% |
The overall selection efficiency for the signal $J/\psi \rightarrow e\mu$ (or rate of misidentifying the background as the signal $J/\psi \rightarrow e\mu$) can be calculated with the PID (or misidentification) and geometric efficiency given in the tables. For the signal channel $J/\psi \rightarrow e\mu$, the total selection efficiency is then

$$\epsilon_{J/\psi \rightarrow e\mu} = \epsilon_{e\mu-MC} \times \epsilon_{e \rightarrow e} \times \epsilon_{\mu \rightarrow \mu},$$

(10)

where $\epsilon_{e\mu-MC}$ is the geometric efficiency, $\epsilon_{e \rightarrow e}$ is the electron PID efficiency, and $\epsilon_{\mu \rightarrow \mu}$ is the muon PID efficiency. With the number given in Tables I and II, we obtain the selection efficiency for $J/\psi \rightarrow e\mu$ as about 10%. One can evaluate the misidentification rate of the background channels $J/\psi \rightarrow XX$ or $e^+e^- \rightarrow XX$, where $X = e, \mu, \pi, K$, (i.e. the background channels are misidentified as the signal channel) as

$$\epsilon_{XX} = \epsilon_{XX-MC} \times \epsilon_{X \rightarrow e} \times \epsilon_{X \rightarrow \mu} \times 2.$$

(11)

where $\epsilon_{XX-MC}$ is the Monte-Carlo geometric efficiency, shown in Table I, and $\epsilon_{X \rightarrow e}$ and $\epsilon_{X \rightarrow \mu}$ are the contamination rate for X being identified as an electron or a muon.

Because electrons and muons cannot be misidentified with each other, the only background which should be taken into account in the estimation is the hadronic channels. The misidentification rate and the number of background from hadronic channels are estimated in terms of the methods given in [4], and the results are listed in Table III.

**TABLE III: The misidentification rate and the number of background from hadronic channel.**

| decays     | misidentification rate | number of background |
|------------|-------------------------|----------------------|
| $J/\psi \rightarrow \pi\pi$ | $4.85 \times 10^{-6}$ | 7.13                 |
| $J/\psi \rightarrow KK$      | $1.85 \times 10^{-6}$ | 4.38                 |
| total       |                         | 11.5                 |

Now, we can set an upper limit for $BR(J/\psi \rightarrow e\mu)$ if there only few events are observed in BESIII and they are consistent with the background estimation. For an illustration, we discuss a case similar to that we did for BESII where there were four $J/\psi \rightarrow e\mu$ candidates observed by the detector [4]. Although our real case may be different, the analysis should provide a useful reference. With the four observed events which are supposed to be the signal and 11.5 background events from hadronic channels in BESIII, we gave an upper limit for $BR(J/\psi \rightarrow e\mu)$ as

$$BR < \lambda(N_{OB}, N_{BG})/[N_T \times \epsilon_{J/\psi \rightarrow e\mu}].$$

(12)
where $\lambda$ is calculated using the method of [23] to be $\lambda=2.31$ is obtained at 90% C.L.. Therefore, we obtain $BR(J/\Psi \rightarrow e\mu) < 2.3 \times 10^{-9}$ in the BESIII experiment, which is more precise than the BESII by two orders.

Now let us discuss the case with branching ratio being about $BR(J/\psi \rightarrow e\mu) = 7 \times 10^{-8}$ as the unparticle physics predicts. If the total selection efficiency for $J/\psi \rightarrow e\mu$ is 10%, then, about 70 events are passed through the selection criterion of $J/\psi \rightarrow e\mu$ in 10 billion $J/\psi$ events collected by BESIII during one year of running. From Table 3, there are 11.5 background events as estimated. Then, the signal to noise ratio reaches about 7:1. It is possible to determinate the branching ratio of $J/\psi \rightarrow e\mu$ since the signal significance is enough.

In fact, the electron and muon identification is very important in the analysis of the concerned channels. The muon identification in BESIII is better than the one in BESII. Certainly, the contamination rate for kaons being misidentified as muons should be lower than the one for pions [21]. In the work, however, the contamination rate for kaons being misidentified as muons has to be set to the same as the contamination rate for pions being misidentified as muons, because of lack of precise information about kaons. So the background for $J/\psi \rightarrow e\mu$ is overestimated in this work. In fact, the background in BESIII should be less than that estimated in the work. Therefore, the real signal to noise ratio for $J/\psi \rightarrow e\mu$ is higher in real BESIII experiments.

**IV. CONCLUSIONS**

The lepton flavor violating decays of $J/\psi \rightarrow ll'$ provide an ideal probe to explore new physics beyond the minimal standard model. In this study, we have presented a detailed analysis on the contribution of unparticle physics to $J/\psi \rightarrow ll'$ decays. The coupling of unparticle to different flavors of leptons cause the LFV processes at tree level.

Even though the scaling factor $(m^2_{\psi}/\Lambda^2_{U})^{d \epsilon -1}$ which is sensitive to the scale dimension of the unparticle field suppresses LFV, one still hopes to observe such rare processes at experiments with very high luminosity and precision. Within a reasonably chosen parameter space, the branching fraction of $J/\psi \rightarrow e\mu$ can reach about an order of $10^{-8}$ which is possible to be observed at the forthcoming BESIII.

Indeed, the BESIII is planning to produce $10^{10} J/\psi$ per year. These huge data samples guarantee an exploration of LFV with a high precision. As a moderate estimation, the upper limit of measuring $BR(J/\psi \rightarrow e\mu)$ is obtained as $2 \times 10^{-9}$ at BESIII. If so, the unparticle theory indeed predicts a production rate within this range and LFV should be observed. As discussed above, the background for such lepton-flavor violating processes is relatively clean and the signal-to-noise is high, so that observation would be more optimistic.

As we know, to judge validity of a new physics model, usually one cannot decide its
existence only by a unique experiment, but needs a combination of data from various measurements. Such a synthesis analysis may help to confirm a new model. Phenomenological analysis on effects induced by unparticle physics has been carried out for various production and decay processes and even the cosmology. In general, the concerned parameters, such as its coupling to SM matter, scale dimension $d_U$ and other characteristics are constrained by earlier analysis, therefore it seems to be the time to let experiment tell us the validity of the whole theory. Thus our conclusion is that observation of the lepton-flavor violating decays may provide an important test of the unparticle scenario. If the observation confirms the predicted value, the unparticle theory would be greatly supported (even though relatively large uncertainty still remains), by contrary, if the reaction is not seen at BESIII, one may set a more stringent constraint on the parameters which would be applied to other experiments for further tests.

Acknowledgments

This work was supported in part by National Natural Science Foundation of China (NSFC) under contract Nos. 10475042, 10745002, 10705015, 10605014 and the special foundation of the Education Ministry of China.

[1] For a review, see J.L. Feng, arXiv:hep-ph/0101122.
[2] X. Zhang, arXiv:hep-ph/0010105.
[3] S. Nussinov, R. D. Peccei and X. M. Zhang, Phys. Rev. D 63, 016003 (2001) arXiv:hep-ph/0004153.
[4] BES Collaboration (J.Z. Bai et al.), Phys. Lett. B 561, 49-54 (2003) arXiv:hep-ex/0303005.
[5] BES Collaboration (M. Ablikim et al.), Phys. Lett. B 598, 172-177 (2004) arXiv:hep-ex/0406018.
[6] F.A. Harris, Nucl. Phys. Proc. Suppl. 162, (2006) 345 arXiv:physics/0606059.
[7] H. Georgi, Phys. Rev. Lett. 98, 221601 (2007) arXiv:hep-ph/0703260; Phys. Lett. B 650, 275-278 (2007) arXiv:0704.2457 [hep-ph].
[8] T.M. Aliev, A.S. Cornell, N. Gaur, Phys. Lett. B 657, 77-80 (2007) arXiv:0705.1326 [hep-ph].
[9] D. Choudhury, D.K. Ghosh, Mamta, Phys. Lett. B 658, 148-154 (2008) arXiv:0705.3637 [hep-ph].
[10] C.-D. Lu, W. Wang, Y.-M. Wang, Phys. Rev. D 76, 077701 (2007) arXiv:0705.2909 [hep-ph].
[11] G.-J. Ding, M.-L. Yan, Phys. Rev. D 77, 014005 (2008).
[12] S.-L. Chen, X.-G. He, X.-Q. Li, H.-C. Tsai and Z.-T. Wei, arXiv:0710.3663 [hep-ph].
[13] E.O. Itlan, arXiv:0711.2744 [hep-ph]; arXiv:0801.0301 [hep-ph].
[14] K. Cheung, W.-Y. Keung, T.-C. Yuan, Phys. Rev. Lett. 99, 051803 (2007) [arXiv:0704.2588 [hep-ph]].
[15] C.-H. Chen, C.-Q. Geng, Phys. Rev. D 76, 115003 (2007) [arXiv:0705.0689 [hep-ph]].
[16] M. Luo, G. Zhu, Phys. Lett. B 659, 341-344 (2008) [arXiv:0704.3532 [hep-ph]]; X.-Q. Li, Z.-T. Wei, Phys. Lett. B 651, 380-383 (2007) [arXiv:0705.1821 [hep-ph]]; X. Liu, H.-W. Ke, Q.-P. Qiao, Z.-T. Wei, X.-Q. Li, Phys. Rev. D 77, 035014 (2008) [arXiv:0710.2600 [hep-ph]]; Z.T. Wei, Int. J. Mod. Phys. A 23, 3339 (2008).
[17] S. Zhou, Phys. Lett. B 659, 336-340 (2008) [arXiv:0706.0302 [hep-ph]]; X.-Q. Li, Y. Liu, Z.-T. Wei, L. Tang, [arXiv:0707.2285 [hep-ph]].
[18] S.-L. Chen, X.-G. He, H.-C. Tsai, JHEP 0711, 010 (2007) [arXiv:0707.0187 [hep-ph]].
[19] B. Grinstein, K. A. Intriligator and I. Z. Rothstein, Phys. Lett. B 662, 367 (2008) [arXiv:0801.1140 [hep-ph]].
[20] BES Collaboration (M. Ablikim et al.), Phys. Rev. Lett. 100, 192001 (2008) [arXiv:0710.0039 [hep-ex]].
[21] BES Collaboration (J.Z. Bai, et al.), Nucl. Instr. and Meth. A 458, (2001) 627.
[22] G. Qin, et al., Chinese Physics C 32, 1-8 (2008).
[23] S. Jin and P. McNamara, Nucl. Instr. and Meth. A 462, 561 (2001).