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The $W\ell\nu$-vertex corrections to W-boson mass in the R-parity violating MSSM

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Abstract

Inspired by the astonishing 7σ discrepancy between the recent CDF-II measurement and the standard model prediction on the mass of W-boson, we investigate the λ'-corrections to the vertex of $\mu \to \nu_\mu e \bar{\nu}_e$ decay in the context of the R-parity violating minimal supersymmetric standard model. These corrections can raise the W-boson mass independently. Combined with recent Z-pole and kaon decay measurements, $m_W \lesssim 80.37$ GeV can be reached. We find that these vertex corrections cannot explain the CDF result entirely at the 2σ and even 3σ levels. However, these corrections together with the oblique contributions can be accordant with the CDF-II result and relevant bounds at the 3σ level.

1 Introduction

In the past decades, the observation of striking agreement between the standard model (SM) predictions and the experimental results in a vast number of particle interactions has shown up the powerful predicted capacity of the SM. However, the SM is not the final answer to the particle physics, as it is unable to explain several phenomena, including the matter-antimatter asymmetry, the origin of neutrino mass, the hierarchy problem, and the candidate of dark matter. These strongly call for some new physics (NP) beyond the SM. Although no up-to-date direct evidence shows that the NP exists, there are still indirect ways, e.g., studying the loop-effects of NP on low-energy processes or electroweak observables, like the precision measurement of the W-boson mass.

Recently, the Collider Detector at Fermilab (CDF) collaboration at Tevatron reported a high precision measurement on the mass of W-boson with the CDF-II detector. The measured value is given by $m_W^{\rm CDF} = 80.4335 \pm 0.0094$ GeV [1] with better precision than all other previous measurements and is 7σ from the SM prediction $m_W^{\rm SM} = 80.357 \pm 0.006$ GeV [2]. If the measurement is confirmed in the future, such an astonishing tension will undoubtedly be a strong challenge to the SM. After this exciting $m_W^{\rm CDF}$ reported, plentiful theoretical researches [3–38] have emerged in a short time.

Before this profound result, there are already some anomalies indicating the clues of NP, e.g., the recent average values of the observables $R_{D^{(*)}}$, reported by the Heavy Flavor Averaging Group [39–41], are about 3.2σ away from the corresponding SM predictions [42–50], considering the R_D and R_{D^*} total correlation -0.29. To explain these anomalies, there are numerous phenomenological studies combined with the $m_W^{\rm CDF}$ measurement in different models (e.g., see Refs. [34, 51–55]). In this work, we utilize the minimal supersymmetric standard model (MSSM) extended by the R-parity violation (RPV), especially including the $\lambda' \hat{L}\hat{Q}\hat{D}$ superpotential term, which can explain the B-physics anomalies in the neutral current[1] or/and the charged

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[1] Some anomalies are observed in the $b \to s\mu^+\mu^-$ decays include P_5' [56], the branching fraction of $B_s \to \phi\mu^+\mu^-$ [57], etc. The ratios $R_{K^{(*)}}$ in the $b \to s\ell^+\ell^-$ ($\ell = e, \mu$) processes, have been reported recently by the LHCb Collaboration [58] that they are in agreement with the SM predictions, and this new result overturns the previous ones which show anomalies in $R_{K^{(*)}}$ [59–61].

one (see, e.g., Refs. [62–65]). Thus, further investigations on this framework for the $m_W^{\rm CDF}$ explanation are necessary. Although it is found that the MSSM can provide some parameter points which can raise m_W into the 2σ accordance region [9], mainly through bosonic self-energy contributions relevant to the oblique corrections [66, 67], the stop mass in the solution with $m_{\tilde{t}} \lesssim 1$ TeV is not suit for general collider search scenarios. Thus, it is also worth studying other corrections to m_W in the extended MSSM framework, considering the general bounds for colored sparticle masses at the Large Hadron Collider (LHC). Above all, we will study corrections to the vertex $W\ell\nu$ from the R-parity violating interaction $\lambda'\hat{L}\hat{Q}\hat{D}$ and get an enhancement to m_W, which is independent of the oblique corrections.

This paper is organized as follows. In Section 2, we introduce the vertex corrections to the W-boson mass in the MSSM framework extended by RPV. Then, we show the numerical results and discussions in Section 3. Our conclusions are presented in Section 4.

2 The contribution to m_W from the R-parity violating MSSM

As we know, the W-boson mass can be determined from the muon decay with the relation (see, e.g., Refs. [68–70])

$$\frac{m_W^2}{m_Z^2} = \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\pi\alpha}{\sqrt{2}G_\mu m_Z^2}(1+\Delta r)}, \tag{1}$$

which comprises the three precise inputs, the Z-boson mass m_Z, the Fermi constant G_μ, and the fine structure constant α. Here the one-loop corrections to Δr can be expressed as

$$\Delta r = \Delta r^{\rm SM} + h^s + h^v + h^b, \tag{2}$$

where the SM part $\Delta r^{\rm SM}$ is derived first in Refs. [71, 72]. Within the NP part, the self-energy of the renormalized W-boson is denoted by h^s, and the vertex and box corrections to the $\mu \to \nu_\mu e \bar{\nu}_e$ decay are denoted by h^v and h^b, respectively. In the MSSM, the pure squarks (sleptons) only engage the self-energy sector at the one-loop level. The corrections to the vertex and box involve charginos and neutralinos. Among these one-loop contributions in the MSSM, the dominant contribution to m_W is the one-loop diagrams involving pure squarks. This dominant part in h^s can be expressed by [68]

$$\begin{aligned}(h^s)_{\rm dom} = -\frac{3G_\mu \cos\theta_W^2}{8\sqrt{2}\sin\theta_W^2\pi^2}\Big[&-\sin^2\theta_{\tilde{t}}\cos^2\theta_{\tilde{t}}F_0(m_{\tilde{t}_1}^2, m_{\tilde{t}_2}^2) - \sin^2\theta_{\tilde{b}}\cos^2\theta_{\tilde{b}}F_0(m_{\tilde{b}_1}^2, m_{\tilde{b}_2}^2) \\ &+ \cos^2\theta_{\tilde{t}}\cos^2\theta_{\tilde{b}}F_0(m_{\tilde{t}_1}^2, m_{\tilde{b}_1}^2) + \cos^2\theta_{\tilde{t}}\sin^2\theta_{\tilde{b}}F_0(m_{\tilde{t}_1}^2, m_{\tilde{b}_2}^2) \\ &+ \sin^2\theta_{\tilde{t}}\cos^2\theta_{\tilde{b}}F_0(m_{\tilde{t}_2}^2, m_{\tilde{b}_1}^2) + \sin^2\theta_{\tilde{t}}\sin^2\theta_{\tilde{b}}F_0(m_{\tilde{t}_2}^2, m_{\tilde{b}_2}^2)\Big],\end{aligned} \tag{3}$$

where θ_W is the Weinberg angle and the definition of mixing angle $\theta_{\tilde{q}}$ is referred to Ref. [68] and the function $F_0(x,y) = x + y - \frac{2xy}{x-y}\log\frac{x}{y}$ with the extra properties $F_0(m^2, m^2) = 0$ and $F_0(m^2, 0) = m^2$. Thus, one can see that h^s is sensitive to the mass splitting between the isospin partners due to the factor $\cos^2\theta_{\tilde{t}}\cos^2\theta_{\tilde{b}}$. Obviously, h^s can be negligible when the soft breaking masses $M_{\tilde{Q}_i}$ are sufficiently heavy compared to the chiral mixing. In this work, we focus on the vertex corrections h^v affected by the λ'-coupling in the R-parity violating MSSM (RPV-MSSM) and can omit h^s and h^b in the particular scenario.

In RPV-MSSM, the λ'-superpotential term $\mathcal{W} = \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}_k$ leads to the related Lagrangian in the mass basis

$$\begin{aligned}\mathcal{L}^{\rm LQD} =& \lambda'_{ijk}\left(\tilde{\nu}_{Li}\bar{d}_{Rk}d_{Lj} + \tilde{d}_{Lj}\bar{d}_{Rk}\nu_{Li} + \tilde{d}_{Rk}^*\bar{\nu}_{Li}^c d_{Lj}\right) \\ &- \tilde{\lambda}'_{ijk}\left(\tilde{l}_{Li}\bar{d}_{Rk}u_{Lj} + \tilde{u}_{Lj}\bar{d}_{Rk}l_{Li} + \tilde{d}_{Rk}^*\bar{l}_{Li}^c u_{Lj}\right) + \text{h.c.},\end{aligned} \tag{4}$$

where the generation indices $i,j,k = 1,2,3$, while the color ones are omitted, and "c" indicates the charge conjugated fermions. In this paper, all the repeated indices are defaulted to be summed over unless otherwise stated. The relation between λ' and $\tilde{\lambda}'$ is $\tilde{\lambda}'_{ijk} = \lambda'_{ij'k}K_{jj'}^*$ with K being the Cabibbo-Kobayashi-Maskawa (CKM) matrix. In this work, we restrict the index k of the superfield $\hat{D}_k$ to the single value 3.

Including the one-loop contribution from the RPV-MSSM, the $W\ell_l\nu_i$-vertex is described by the following Lagrangian

$$\mathcal{L}_{\rm eff}^W = \frac{g}{\sqrt{2}}\bar{\ell}_l\gamma^\mu P_L(\delta_{li} + h_{li})\nu_i W_\mu^- + \text{h.c.}, \tag{5}$$

where g is the $SU(2)_L$ gauge coupling, and the correction part h_{li} from the λ'-contributions is given by (as the analogy to the formula in Ref. [73])

$$h'_{li} = -\frac{3}{64\pi^2}x_t f_W(x_t)\tilde{\lambda}'^*_{l33}\tilde{\lambda}'_{i33}, \tag{6}$$

where $x_t \equiv m_t^2/m_{\tilde{b}_R}^2$ and the loop function $f_W(x) \equiv \frac{1}{x-1} + \frac{(x-2)\log x}{(x-1)^2}$ and other non-dominant parts are eliminated. This dominant contribution is from the vertex engaged by the right-handed sbottom $\tilde{b}_R$ (Fig. 1a) while the vertex involving left-handed squarks (Fig. 1b) provides non-dominant effects and can be eliminated. Then, we

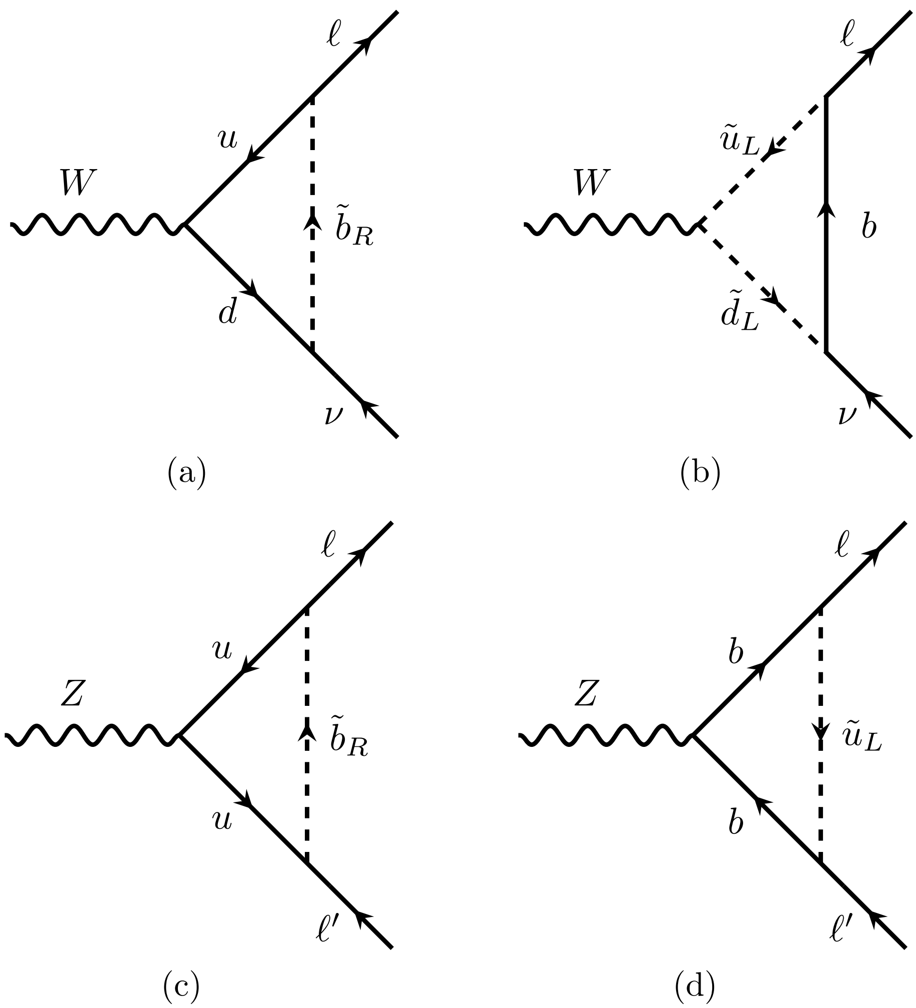

Fig. 1 The diagrams of the $W\ell\nu$-vertex and $Z\ell\ell^{(\prime)}$-vertex (shown as examples) in the RPV-MSSM

consider the λ'-correction only to the $W\mu\nu$-vertex or to the $We\nu$-vertex at a time. This can be easily achieved by setting one of the couplings $(\tilde{\lambda}'_{133}, \tilde{\lambda}'_{233})$ dominant while neglecting the rest. Given this "single coefficient dominance" scenario, the λ'-corrections to the $\mu \to \nu_\mu e \bar{\nu}_e$ box also vanish,[2] then the one-loop λ'-contribution to Δr only comes from h'_{aa} (the index a here is restricted to 1 or 2 at a time).

Given the purpose of this work is to investigate that to what degree, the pure λ' contribution, h'_{aa}, can accommodate the new W-boson mass data. We can further write down the prediction of the W-boson from the pure-λ' contributions[3] as

$$(m_W^{\lambda'}/\mathrm{GeV}) = 80.357 - 15.6387 h'_{aa} = 80.357 + 0.0743 x_t f_W(x_t) \left|\tilde{\lambda}'_{a33}\right|^2 \quad (7)$$

with Eqs. (1) and (6). It is clear from Eq. (7) that the right-handed sbottom mass $m_{\tilde{b}_R}$ and the coupling $\tilde{\lambda}'_{a33}$ are related to λ'-correction of m_W.

3 Numerical results and discussions

In this section, we investigate the explanation of m_W^{CDF} combined with the relevant constraints. At first, we concentrate on the pure λ'-effects assuming the soft breaking masses of gauginos and left-handed squarks (sleptons) are sufficiently heavy, and then, only the model parameters $(\tilde{\lambda}'_{a33}, m_{\tilde{b}_R})$ are involved. If the pure λ'-contribution (see Eq. (7)) can explain the new W-boson mass at the 2σ level, we need h'_{aa} to fulfill $-6.34 < h'_{aa} \times 10^3 < -3.47$. With Eq. (6), this bound provides

$$0.7313 < x_t f_W(x_t) \left|\tilde{\lambda}'_{a33}\right|^2 < 1.3357. \quad (8)$$

[2] In this scenario, the λ'-contributions to the $\mu \to \nu_i e \bar{\nu}_i$ through Z penguin vanish as well.

[3] There are always contributions from the original MSSM framework, while we can set sufficiently heavy masses of left-handed squarks, sleptons, and gauginos in soft breaking terms to screen these effects.

Also, $-6.34 < h'_{aa} \times 10^3 < -3.47$ let the ratio

$$R^W_{\rm NP/SM} \equiv \Gamma(W \to \ell_a \nu_a)_{\rm NP}/\Gamma(W \to \ell_a \nu_a)_{\rm SM} \quad (9)$$

stay in the region

$$-12.7 < (R^W_{\rm NP/SM} - 1) \times 10^3 < -6.9, \quad (10)$$

because $R^W_{\rm NP/SM}$ can be calculated as $1 + 2h'_{aa}$, with Eq. (5). Then, we compare Eq. (10) with the W-boson partial width ratios $R^W_{l/l'} \equiv \Gamma(W \to l\nu)/\Gamma(W \to l'\nu)$, and their experimental results are given as $R^W_{\mu/e} = 0.996 \pm 0.008$, $R^W_{\tau/\mu} = 1.008 \pm 0.031$, and $R^W_{\tau/e} = 1.043 \pm 0.024$ [74]. It is found that the m_W explanation demands much stronger bounds, whenever the NP exists in the μ or e channel (the τ flavor is assumed decoupled with the NP for simplicity).

As shown in Fig. 1c and d, the NP effects on the $W\ell\nu$-vertex will also inevitably affect the Z-vertex. The Z-boson partial width ratios $R^Z_{l/l'} \equiv \Gamma(Z \to ll)/\Gamma(Z \to l'l')$ are measured as $R^Z_{\mu/e} = 1.0001 \pm 0.0024$, $R^Z_{\tau/\mu} = 1.0010 \pm 0.0026$, and $R^Z_{\tau/e} = 1.0020 \pm 0.0032$ [74], which all constrain the coupling g_{ℓ_L} in the effective Lagrangian

$$\mathcal{L}^Z_{\rm eff} = \frac{g}{\cos\theta_W} \bar{\ell}_i \gamma^\mu \left[g^{ij}_{\ell_L} P_L + g^{ij}_{\ell_R} P_R\right] \ell_j Z_\mu, \quad (11)$$

where $g^{ij}_{\ell_L} = \delta^{ij} g^{\rm SM}_{\ell_L} + \delta g^{ij}_{\ell_L} + \delta g'^{ij}_{\ell_L}$ and $g^{ij}_{\ell_R} = \delta^{ij} g^{\rm SM}_{\ell_R}$, with $g^{\rm SM}_{\ell_L} = -\frac{1}{2} + \sin^2\theta_W$ and $g^{\rm SM}_{\ell_R} = \sin^2\theta_W$. The formulas of $\delta g^{ij}_{\ell_L}$ and $\delta g'^{ij}_{\ell_L}$ are [75]

$$\begin{aligned}(32\pi^2)\delta g^{ij}_{\ell_L} =& 3\tilde{\lambda}'_{j33}\tilde{\lambda}'^*_{i33}\Bigg\{-x_t(1+\log x_t) + \frac{m_Z^2}{18 m^2_{\tilde{b}_R}}\Bigg[(11 - 10\sin^2\theta_W) \\ &+ (6 - 8\sin^2\theta_W)\log x_t + \frac{1}{10}(-9 + 16\sin^2\theta_W)\frac{m_Z^2}{m_t^2}\Bigg]\Bigg\}, \\ (32\pi^2)\delta g'^{ij}_{\ell_L} =& \tilde{\lambda}'_{j33}\tilde{\lambda}'^*_{i33}\frac{m_Z^2}{m^2_{\tilde{t}_L}}\left[\left(-\frac{2}{3}\sin^2\theta_W\right)\left(\log\left(\frac{m_Z^2}{m^2_{\tilde{t}_L}}\right) - i\pi - \frac{1}{2}\right) + \left(-\frac{1}{6} + \frac{1}{9}\sin^2\theta_W\right)\right].\end{aligned} \quad (12)$$

Given that the mass of $\tilde{t}_L$ is set sufficiently heavy, the $\delta g'^{ij}_{\ell_L}$ part can be eliminated.

As to the invisible Z-decay, this model can also make loop-level contributions to the $Z \to \nu\bar{\nu}$, i.e., ℓ exchanged with ν and $u(\tilde{u}_L)$ exchanged by $d(\tilde{d}_L)$ in Fig. 1c, d. Then, the effective number of light neutrinos N_ν, which is defined by $\Gamma_{\rm inv} = N_\nu \Gamma^{\rm SM}_{\nu\bar{\nu}}$ [76], will constrain the couplings via

$$N_\nu = \left|1 + \frac{\delta g^{aa}_\nu + \delta g'^{aa}_\nu}{\delta g^{\rm SM}_\nu}\right|^2 + 2, \quad (13)$$

where the coupling $\delta g^{\rm SM}_\nu = \frac{1}{2}$ and the formulas of $\delta g^{(\prime)ij}_\nu$ is given by

$$\begin{aligned}(32\pi^2)\delta g^{ij}_\nu =& \lambda'_{j33}\lambda'^*_{i33}\frac{m_Z^2}{m^2_{\tilde{b}_R}}\left[\left(-1 + \frac{2}{3}\sin^2\theta_W\right)\left(\log\left(\frac{m_Z^2}{m^2_{\tilde{b}_R}}\right) - i\pi - \frac{1}{3}\right) + \left(-\frac{1}{12} + \frac{4}{9}\sin^2\theta_W\right)\right], \\ (32\pi^2)\delta g'^{ij}_\nu =& \lambda'_{j33}\lambda'^*_{i33}\frac{m_Z^2}{m^2_{\tilde{b}_L}}\left[\left(\frac{1}{3}\sin^2\theta_W\right)\left(\log\left(\frac{m_Z^2}{m^2_{\tilde{b}_L}}\right) - i\pi - \frac{1}{2}\right) + \left(-\frac{1}{6} + \frac{4}{9}\sin^2\theta_W\right)\right].\end{aligned} \quad (14)$$

Then, the measurement $N^{\rm exp}_\nu = 2.9840(82)$ [76] will make constraints.

Except the purely leptonic decays of W/Z boson, the $\mu \to e\bar{\nu}_e\nu_\mu$ and $\tau \to \ell\bar{\nu}_\ell\nu_\tau$ decays, which contain the $W\ell\nu$-vertex, should also be considered. The fraction ratios $\mathcal{B}(\tau \to \mu\bar{\nu}_\mu\nu_\tau)/\mathcal{B}(\tau \to e\bar{\nu}_e\nu_\tau)$, $\mathcal{B}(\tau \to e\bar{\nu}_e\nu_\tau)/\mathcal{B}(\mu \to e\bar{\nu}_e\nu_\mu)$, and $\mathcal{B}(\tau \to \mu\bar{\nu}_\mu\nu_\tau)/\mathcal{B}(\mu \to e\bar{\nu}_e\nu_\mu)$ make the bounds [77] as

$$\begin{aligned}\frac{1 + \delta^{a2} h'_{\mu\mu}}{1 + \delta^{a1} h'_{ee}} =& 1.0018(14), \\ \frac{1}{1 + \delta^{a2} h'_{\mu\mu}} =& 1.0010(14), \\ \frac{1}{1 + \delta^{a1} h'_{ee}} =& 1.0029(14).\end{aligned} \quad (15)$$

Here we can define $B^{ij} \equiv (32\pi^2)(\delta g^{ij}_{\ell_L} + \delta g'^{ij}_{\ell_L})$ and further get the bound $|B^{aa}| < 0.35(0.53)$ at the $2(3)\sigma$ level.

Due to that $h'_{aa} \leqslant 0$, Eq. (15) induces the $2(3)\sigma$ bounds $-4.6(-6.0) < h'_{ee} \times 10^3 \leqslant 0$ or

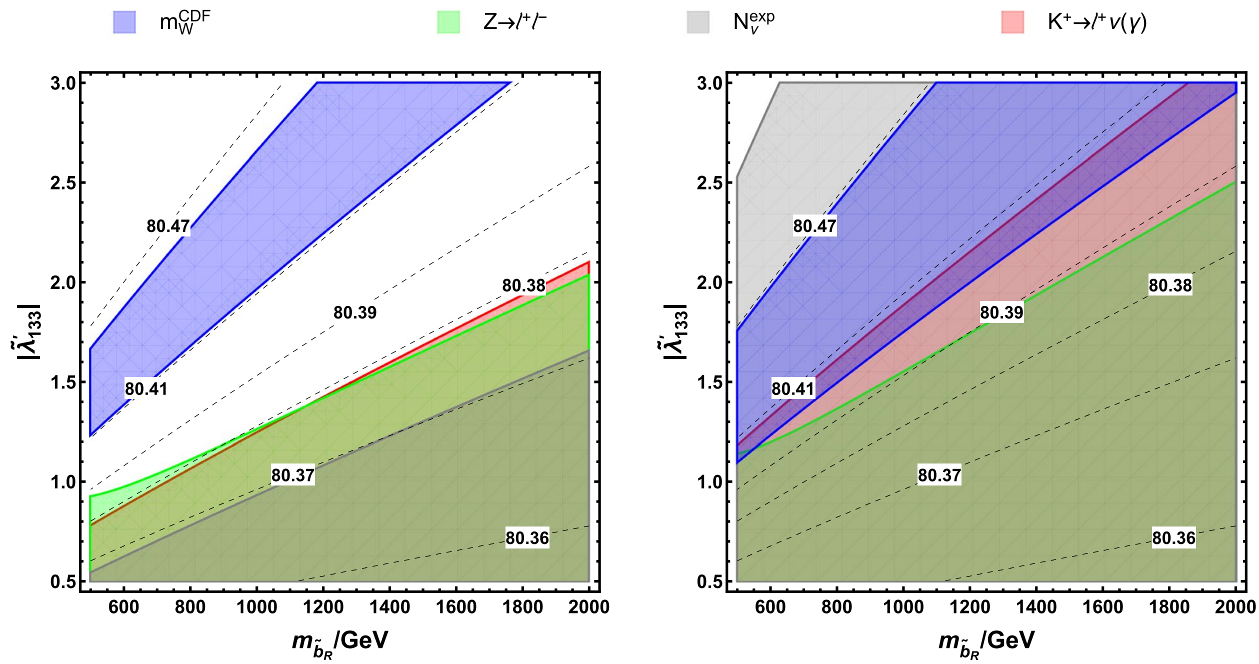

Fig. 2 The regions of $(m_{\tilde{b}_R}, |\tilde{\lambda}'_{133}|)$ at the 2σ (left) and 3σ (right) levels. The pure λ'-contributions to the $m_W^{\rm CDF}$ explanation are denoted by the blue. The areas allowed by $R^Z_{\ell/\ell'}$ and $N_\nu^{\rm exp}$ are shown by the green and gray, respectively. The areas filled by the red are allowed by the data of $K^+ \to \ell^+\nu(\gamma)$ decay. The dashed lines express the $m_W^{\lambda'}$ value (GeV) enhanced by vertex corrections

$-1(-2.4) < h'_{\mu\mu} \times 10^3 \leqslant 0$ for a restricted to 1 or 2, respectively. Similarly, the decays of kaons and pions also make the bounds, and the most stringent ones [77] induce $-1.4(-3.2) < h'_{ee} \times 10^3 \leqslant 0$ or $-0.8(-1.7) < h'_{\mu\mu} \times 10^3 \leqslant 0$ at the 2(3)σ level, which are provided by the constraints in the $K^+ \to \ell^+\nu(\gamma)$ and $\pi \to \ell\nu(\gamma)$ decays, respectively. However, the 2σ-level $m_W^{\rm CDF}$ explanation demands $-6.34 < h'_{aa} \times 10^3 < -3.47$ as mentioned before, and thus, one can see exactly the 2σ-level explanation is already excluded by these decays of kaons and pions, while we can still investigate the degree of the NP raising m_W. Given that $h'_{\mu\mu}$ is constrained more strongly than h'_{ee}, in the following we focus the NP in the e flavor. Thus, we set λ'_{133} dominant and other λ' couplings negligible. Then with the CKM rotation, $\tilde{\lambda}'_{ijk} = \lambda'_{ij'k}K^*_{jj'}$, the nonzero $\tilde{\lambda}'$ couplings $|\tilde{\lambda}'_{133}| \approx |\lambda'_{133}|$, $|\tilde{\lambda}'_{123}| \approx 0.04|\lambda'_{133}|$, and $|\tilde{\lambda}'_{113}| \approx 10^{-3}|\lambda'_{133}|$. As we consider the real number λ'_{133} varying in $0 \leqslant \lambda'_{133} \leqslant 3$, it is checked that the effects on the $m_W^{\rm CDF}$ explanation and constraints from the couplings $\tilde{\lambda}'_{123}$ and $\tilde{\lambda}'_{113}$ are negligible. It is worth to mention that all the model parameters are set at the scale of around TeV. Given that only (axial-)vector currents are involved in relevant processes discussed before, the couplings of these currents are kept nearly the same when the scale runs down to the electroweak scale.

Combining the bounds introduced above with the W mass explanation, the allowed regions are shown in Fig. 2. The two areas allowed by $Z \to \ell\ell$ and kaon decays overlap almost entirely at the 2σ level, while the $Z \to \ell\ell$ bound is stronger at the 3σ level. The bounds of $N_\nu^{\rm exp}$ is more stringent than the former two at the 2σ level, but the loosest at the 3σ level. In the common region of these three observables at the 2σ level, $m_W^{\lambda'}$ can be raised to around 80.37 GeV at most, while it cannot reach the value to explain $m_W^{\rm CDF}$ as predicted. Even at the 3σ level, there are still none common areas for $m_W^{\rm CDF}$ and bounds besides the one when $m_{\tilde{b}_R} \lesssim 600$ GeV, but this mass scale is already excluded by LHC searches [78–80]. Therefore, we find that the pure λ' contributions cannot fully solve the m_W problem unless with other effects, e.g., the oblique corrections [9, 81]. Thus, we will further study

Table 1 The sets of parameters in the MSSM part. Parameters with mass dimension are given in GeV. The lower limits of squark masses refer to Ref. [78]

Parameters	Sets	Parameters	Sets
$\tan\beta$	15	$M_{\tilde{L}_{1,2,3}} = M_{\tilde{E}_{1,2,3}}$	2000
μ	1000	$M_{\tilde{Q}_{1,2}} = M_{\tilde{U}_{1,2}} = M_{\tilde{D}_{1,2}}$	10^4
M_1	500	$M_{\tilde{Q}_3}$	$1500 \sim 3000$
M_2	1000	$M_{\tilde{U}_3}$	$1500 \sim 10^4$
M_3	5000	$M_{\tilde{D}_3}$	$1300 \sim 3000$
M_A	2000	$A_{u,c} = A_{d,s} = A_l$	1500
m_t	173.3	A_t, A_b	$-5000 \sim 5000$

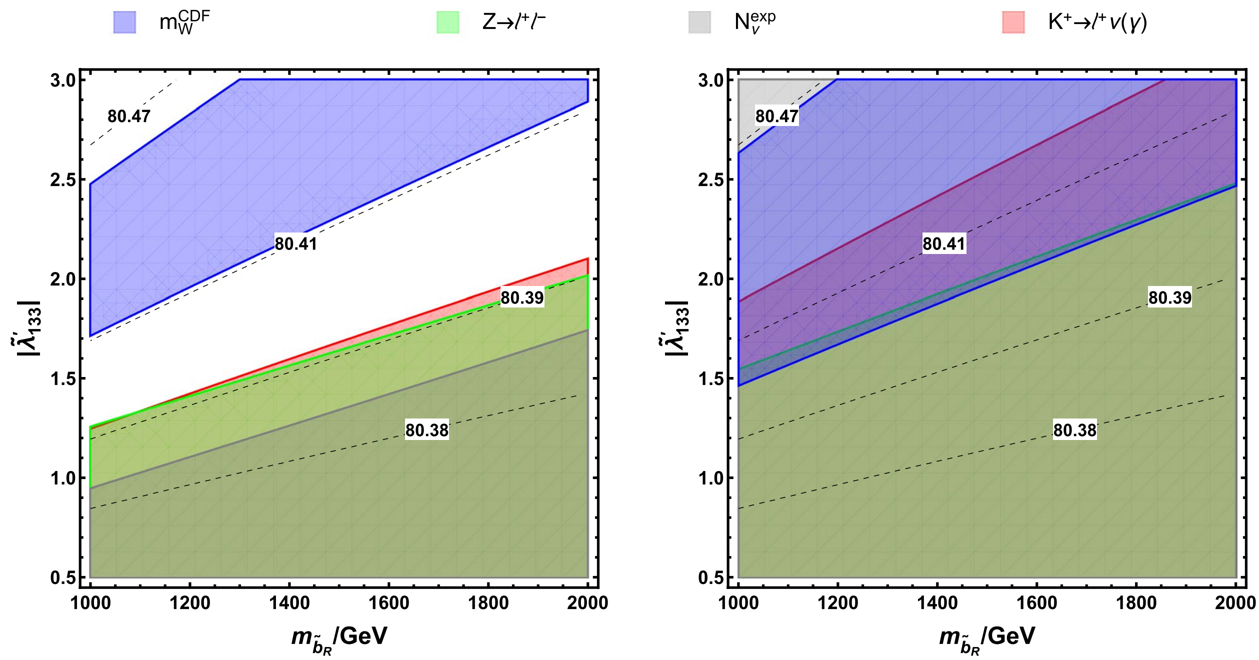

Fig. 3 Same as Fig. 2 but the dashed lines express the m_W^{NP} value (GeV) enhanced by both vertex corrections and oblique ones of the MSSM

the combination explanation with the λ'-contributions and the oblique ones of the MSSM framework.

Different from the pure-RPV case that only parameters $(\tilde{\lambda}'_{133}, m_{\tilde{b}_R})$ are focused on, in the following we further consider non-decoupled masses of stops and gauginos, and the parameters are collected in Table 1. Then, we utilize `FeynHiggs-2.18.1` [82–89] to calculate the loop correction of MSSM part, i.e., h^s, which is given as the nearly fixed value $h^s \approx -8 \times 10^{-4}$ for the parameters $M_{\tilde{Q}_3}$, $M_{\tilde{U}_3}$, $M_{\tilde{D}_3}$, A_t, and A_b varying in the ranges shown in Table 1, also keeping the mass of Higgs-like boson in $122 < m_H < 128$ GeV. Then, we can further set $M_{\tilde{Q}_3} = 2.1$ TeV, $M_{\tilde{U}_3} = 10$ TeV, and $A_t = A_b = 1.5$ TeV as the benchmark point, and write down the prediction of m_W from combined contributions as

$$(m_W^{NP}/\text{GeV}) = 80.370 - 15.622h'_{aa} = 80.370 + 0.0742x_t f_W(x_t)\left|\tilde{\lambda}'_{a33}\right|^2. \tag{16}$$

Then, the allowed regions are shown in Fig. 3. One can see that m_W can be raised to around 80.38 GeV in the 2σ -level allowed region of the Z and kaon decays, and explaining the W-mass anomaly at 2σ is still unachievable. However, the 3σ-level explanation is allowed by all the bounds, within the narrow overlap near the edge of m_W^{CDF} region.

4 Conclusions

In this paper, inspired by the astonishing 7σ discrepancy between the CDF-II measurement and the SM prediction on the mass of W-boson, we performed a phenomenological analysis on the muon decay that is relevant to the W mass under the framework of RPV-MSSM, to access whether such a deviation can be accommodated by this NP model. We focused on the one-loop corrections to the vertex of $\mu \to \nu_\mu e \bar{\nu}_e$ decay, assuming that the vertex correction is only affected by a single λ' coupling in the RPV-MSSM. The numerical results shown in Fig. 2 imply that pure λ'-contributions in the RPV-MSSM are hard to accommodate the CDF measurement entirely. However, the λ'-corrections can help raise the prediction of W mass to be accordant with m_W^{CDF} at the 3σ level when combined with the oblique corrections, which is shown in Fig. 3.

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Authors' contributions

M.D. contributed to the study conception and design. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
The authors declare they have upheld the integrity of the scientific record.

Consent for publication
The authors give their consent for publication of this article.

Competing interests
The authors declare that they have no competing interests.

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