Complete one-loop contributions to the muon decay of U(1)$_z$ extensions of the standard model

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The theoretical prediction to the W-boson mass M_W is sensitive to physics beyond the standard model (BSM). Currently, there is a 2σ discrepancy between the standard model (SM) theoretical prediction and the measured value of M_W, obtained from the LEP 2 [1], Tevatron [2] and LHC [3] experiments. Considering also the recent measurement of M_W with the CDF II detector [4], the discrepancy is severely aggravated and the precise determination of theoretical BSM corrections is necessary. The parameter Δr [5], defined in the standard model (SM) as

$$M_W^2 \left(1 - \frac{M_W^2}{M_Z^2}\right) = \frac{\pi\alpha}{\sqrt{2}G_\mathrm{F}}[1 + \Delta r]\,, \tag{1}$$

collects the radiative corrections to the muon decay process. It can be used to predict the mass M_W of the W-boson as a function of fiducial input parameters such as M_Z, α and G_F. We perform the one-loop renormalization of particle physics models with gauge sectors extended by an extra U(1)$_z$ symmetry in the on-shell renormalization scheme in order to compute the radiative corrections to the muon decay process. As a result we obtain – to the best of our knowledge for the first time in the literature a finite, gauge invariant prediction Δr_z. We generalize our findings to the $\overline{\mathrm{MS}}$ scheme and compare our predictions for M_W in U(1)$_z$ extensions to predictions of automated programs, such as `FlexibleSUSY` [6]. In the latter case corrections to the parameter

$$\hat{\rho} = \frac{M_W}{M_Z \hat{c}_\mathrm{W}} \tag{2}$$

are neglected, where the hat denotes $\overline{\mathrm{MS}}$ renormalized quantities and c_W is the cosine of the weak mixing angle. We also explore the parameter space of a U(1)$_z$ extension, the superweak extension of the SM [7] in order to find out whether the neglected terms in $\hat{\rho}$ become relevant.

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