Erratum: Status of negative coupling modifiers for extended Higgs sectors [Phys. Rev. D 105, 035019 (2022)]

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(Received 16 October 2023; published 22 November 2023)

DOI: 10.1103/PhysRevD.108.099901

Upon revisiting this work, we have found that there was critical a mistake in the expression of the fermion coupling modifiers in Eq. (2.16). While the rest of the analysis logic was correct, the mistake in that equation, when propagated through the analysis, substantially changed the conclusions of the paper regarding the experimental status of negative λ_{WZ}. Upon correcting the error, the accidentally custodial (AC) triplets described in Sec. II are still excluded in a model-independent way. The AC quartets can be excluded in a model-independent way by including the weaker bound from $b \to s\gamma$. Unfortunately, all other AC models have vev structures such that it is possible to make the absolute values of coupling modifiers close to the SM prediction, and thus impossible to exclude those additional models using the methodology of our work. This weakens our claims of complete exclusion of negative λ_{WZ} to a softer version where only the minimal models are excluded. On the other hand, this means that there are still models that can have significant coupling modifiers hidden from current data.

To highlight the difference in the analysis we can start by writing the correct coupling modifiers for the fermion-scalar interaction:

$$\kappa_f^\phi = \frac{\nu}{\nu_\phi}. \tag{1}$$

Unlike what is written in the manuscript, the correct formula implies $\kappa_f^\phi \geq 1$. This changes the discussion starting at Eq. (2.21) for the AC triplets. Enforcing $\lambda_{WZ} = -1$:

$$R_3 = -\frac{\nu_\chi}{\nu_\phi}(3\sqrt{2}R_1 + 2R_2). \tag{2}$$

Next, we use this relation into λ_{fZ} and enforce that $|\lambda_{fZ}| = 1$:

$$R_2 = \frac{R_1}{2}\left(\sqrt{2} \mp \frac{\nu^2}{\nu_\chi \nu_\phi}\right). \tag{3}$$

We then check the last coupling modifier κ_{fZ}:

$$\kappa_{fZ} = \pm R_1 \frac{\nu}{\nu_\phi}. \tag{4}$$

The problem now lies in the fact that $\frac{\nu}{\nu_\phi}$ can be larger than one. This implies that Eq. (4) can generate values close to the SM prediction of $\kappa_{fZ} = 1$. We can verify if this is the case by enforcing this condition to be the SM prediction and checking the normalization of the vector $\vec{R}$. This condition reads:

$$\frac{\nu^2}{4\nu_\chi^2} - \frac{5\nu_\chi^2}{\nu^2} = 1, \quad \text{for } \lambda_{fZ} = \kappa_{fZ} = 1, \tag{5}$$

$$\frac{1}{2} + \frac{3\nu^2}{16\nu_\chi^2} - \frac{5\nu_\chi^2}{\nu^2} = 1, \quad \text{for } \lambda_{fZ} = \kappa_{fZ} = -1. \tag{6}$$

In this case, it is clear that this parameter point is excluded, since this condition is only satisfied for values of ν_χ higher than the upper bound of $\nu_\chi \leq \frac{\nu}{2\sqrt{2}}$. This demonstrates that the $\lambda_{WZ} = -1$ scenario with AC triplets are still disfavored.

The situation is different for the AC quartets. Even with the same degree of freedom from $\vec{R}$, the group theory factors change the excluded window. Doing the same analysis we find that the coupling modifiers can be equal to the SM prediction if we have the AC quartet vacuum expectation values (vevs):

$$\nu_\omega \approx 0.198\nu, \quad \text{for } \lambda_{fZ} = \kappa_{fZ} = 1, \tag{7}$$

$$\nu_\omega \approx 0.193\nu, \quad \text{for } \lambda_{fZ} = \kappa_{fZ} = -1. \tag{8}$$

This is inside the allowed range for the vev of $\nu_\omega \lesssim 0.223\nu$. This condition means that the SM limit of the coupling modifiers implies a sizeable contribution from the AC quartets to the EWSB. We can use, in this case, a bound from $b \to s\gamma$ [1] to exclude the higher values of ν_ω in a model-independent way and thus making the wrong-sign SM limit disfavored in the AC quartets model.

For AC pentets and AC sextets, the situation is similar and the analysis becomes model-dependent because it depends on the size of the vevs and the correlation between $\vec{R}$ and the vevs. We can see the difference in the Fig. 1, where we impose the strict bound from $b \to s\gamma$ [1] assuming that all additional scalars are heavy. This bound can be translated to $\sin\theta_h < 0.7$, where $\sin\theta_h$ is the fraction from the extended representations to the EW vev:

$$\sin\theta_H = \begin{cases} \sqrt{8}v_\chi/v & \text{AC triplet} \\ \sqrt{20}v_4/v & \text{AC quartet} \\ \sqrt{40}v_5/v & \text{AC pentet} \\ \sqrt{70}v_6/v & \text{AC sextet} \end{cases}. \tag{9}$$

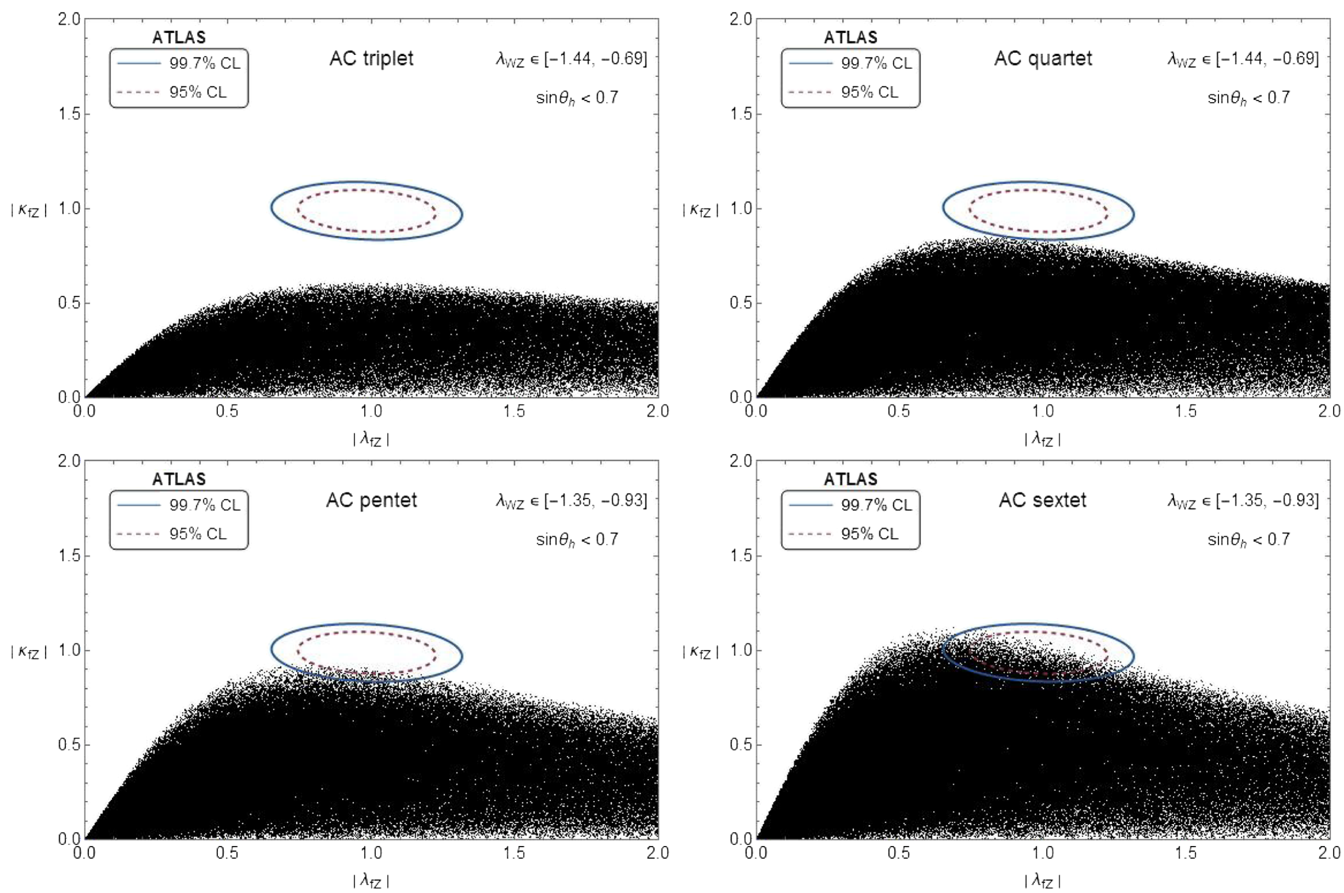

FIG. 1. Updated constraints considering the correct κ_f and including the strict 2σ bound from $b \to s\gamma$ [1].

We can see that both the AC pentet and AC sextet now have points inside the 2σ region. If the model-independent constraints get stronger, then the allowed region from the scan will shrink and it may become possible to extend the exclusion to the AC pentet and AC sextet with our methodology.

The inclusion of small custodial violation allowed by the uncertainty in the measurement of the ρ parameter makes only a small difference. Additionally, the case with multiple AC triplets is still excluded, since the discussion of the individual contributions from each multiplet still holds.

[1] H. E. Logan and V. Rentala, All the generalized Georgi-Machacek models, Phys. Rev. D **92**, 075011 (2015).