Reply to "Comment on 'Causality-violating Higgs singlets at the LHC'"

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A Reply to the Comment by C. M. Ho and T. J. Weiler.

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Gielen provides an insightful analysis of parts of our published paper [1]. In our paper, we quoted the well-known result that any two-dimensional metric maps into a two-dimensional Minkowski space, and so it is guaranteed that our metric has vanishing curvature (vanishing Riemann tensor) and satisfies all energy conditions. We identified the coordinates $(\tilde{t}, \tilde{u})$ which provide the diagonalized Minkowski metric; these coordinates are repeated in Gielen's Eq. (2). Gielen goes further and finds, via a Lorentz-type boost in the $\bar{u}$ direction, another time variable which he names $\hat{t}$ that is constant across our brane. This provides an explicit demonstration of the inevitable simultaneity of a timelike variable which must exist wherever/whenever closed timelike curves (CTCs) are viable. This simultaneity is demonstrable via a coordinate redefinition that never alters the signature of the metric; no eigenvalue of the metric changes sign, as evidenced by the determinant of the metric never passing through zero (in fact, by our construction the determinant is a constant).

We chose to not exploit the "Minkowski" coordinates because the new times $\tilde{t}$ and $\hat{t}$ are necessarily a mixture of the continuous variable t and the compact variable u. Such times $\tilde{t}$ and $\hat{t}$ are fine when used in theoretical proofs; however, they are not variables that would register on an experimenter's clock. As the title of our paper suggests, our focus is whether causality violation may be observable at experimental facilities such as the LHC. Our affirmative answer remains unchanged.

Gielen gives a simple argument that for the CTC solution to occur in the 5D metric, which we have presented, it must be that the square of the value of the off-diagonal metric coefficient averaged over the extra dimension, $\bar{g}^2$, must exceed the determinant of the metric. Gielen states that we missed this constraint in our paper. He is correct; we missed it. The constraint does not affect any of the phenomenology that we presented. The constraint does change which solution of the somewhat complicated free-field dispersion relation is physical, as we explain in the erratum. Finally, the new constraint requires a redo of our Figs. 1, 2, and 5, which we provide in our erratum.

[1] C. M. Ho and T. J. Weiler, Phys. Rev. D **87**, 045004 (2013).

