## Erratum: Off-Shell Higgs Probe of Naturalness [Phys. Rev. Lett. 120, 111801 (2018)]

Dorival Gonçalves, Tao Han, and Satyanarayan Mukhopadhyay

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Subsequent to our recent publication, we have noted an inadvertent numerical error in the computation of the corrections from the singlet scalar sector to the off-shell Higgs production process. The corrected differential distributions of the four-lepton invariant mass observable are presented in Fig. 1 (left). In view of this correction, the sensitivity reach at the 14 and 27 TeV LHC runs are also modified by a small margin, as seen in Fig. 1 (right). Our primary conclusions remain unaltered and we summarize them as follows.

(1) The  $2\sigma$  ( $5\sigma$ ) reach at the 27 TeV LHC using the off-shell probe is  $m_S \sim 120$  GeV (100 GeV), for values of the portal coupling dictated by the naturalness relation.

(2) The off-shell analysis is found to have better sensitivity compared to realistic projections for the singlet pair production in the vector-boson fusion (VBF) channel, over the entire singlet mass range of interest  $m_s > m_h/2$ .

One additional interesting feature observed is that there is an enhancement of sensitivity of the off-shell channel for values of  $m_s$  close to  $m_t$ . This is because of the opening of two different thresholds close to each other, namely, the  $2m_t$  threshold in the triangle and box diagrams for  $ZZ^*$  production and the  $2m_s$  threshold in the radiative correction from the scalar singlet to the same process.

In view of the revised differential distributions, we note in passing that for a typical parameter point with  $5\sigma$  reach at the 14 TeV HL-LHC, e.g.,  $m_S = 70$  GeV and  $\lambda_S(m_h^2) = 4.5$ , we obtain around 425 signal events for  $180 < m_{4\ell} < 200$  GeV, while the standard model (SM) background ( $q\bar{q}$  and gg induced) event number is around 14800.



FIG. 1. Left: Four-lepton invariant mass distribution for the  $gg \rightarrow 4\ell$  process at the 14 TeV LHC: in the SM (black line) and in the presence of an additional gauge singlet scalar (red line), including the one-loop electroweak effects from the singlet scalar sector. We show the signal ratio between the scalar singlet model and the SM in the bottom panel. Right:  $2\sigma$  (red line) and  $5\sigma$  (blue line) sensitivity on the singlet-Higgs coupling  $\lambda_s$  at the scale  $m_h^2$  as a function of the singlet scalar mass  $m_s$  from the off-shell Higgs analysis at the 14 TeV LHC with  $\mathcal{L} = 3 \text{ ab}^{-1}$  (dashed line) and at the 27 TeV LHC with  $\mathcal{L} = 15 \text{ ab}^{-1}$  (solid line). For comparison, we also show the reach from the weak-boson fusion production of Higgs above its threshold, assuming the high-luminosity LHC  $2\sigma$  confidence level projections of  $\mathcal{BR}(h \rightarrow \text{invisible}) < 20\%$  (green dotted line) and 5% (green dashed line), which correspond to a realistic projection and an idealistic limit of the systematic uncertainties on the background prediction, respectively.

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