

## REFeree REPORT

Authors: Spyros Argyropoulos and Ulrich Haisch  
Title: Benchmarking LHC searches for light 2HDM+a pseudoscalars  
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I recommend publication of this paper in SciPost Physics after a minor revision of the manuscript following the points outlined below.

In general the analysis in Section 3 appears to be comprehensive while providing useful benchmarks for future LHC studies. I would have preferred a slightly more detailed presentation in Section 2 to make the paper more self-contained. The authors should at least provide a little more information on the relevant model parameters. For example, eq. (2) depends on a number of scalar potential parameters whose definitions are provided in a previously published paper. It would not have taken much space to present the relevant scalar potential prior to exhibiting eq. (2), so that the reader can immediately see the origin of the relevant parameters. The parameter  $\theta$  is also introduced as a mixing angle, which again is related to the scalar potential parameters. To summarize, the relevant parameters (especially those used to define the benchmark scenarios) should be more explicitly defined in Section 2.

I also note that the authors denote the fermionic dark matter by  $\chi$ , although this symbol does not show up until the bottom of page 2. For clarity, this symbol should be introduced earlier. Finally, the statement at the top of page 3 on the lower limit of 100 GeV for  $m_a$  is quite mysterious, as the authors associate this with the latest searches for invisible Higgs decay. However, for  $a$  masses above half the Higgs boson mass (62.5 GeV), the invisible Higgs decay limits are irrelevant. Thus, it is hard to understand where the 100 GeV limit is coming from. (This point has also been echoed by one of the other referees.)

Finally, above eq. (3), the authors state that the total Higgs decay width predicted by the SM is 4.07 GeV, which is much smaller than the LHC sensitivity on  $\Gamma_h$ . The authors then impose  $\Gamma_h < 1.1$  GeV. However, an indirect determination of the Higgs width at the LHC using off-shell Higgs production (admittedly with some caveats), concludes that the observed Higgs width is quite close to its Standard Model value. See arXiv:2202.06923 for further details. Presumably, this would lead to a significant reduction of the bound quoted in eq. (4). The authors should comment on this and indicate how the results of Section 3 would be affected by imposing the stricter bound.

Once these points are adequately addressed, I would be happy to support the publication of this work in SciPost Physics.