Snowmass 2021, Letters of Interest

MSSM Under Higgs Factories

Honglei Li[a], Huayang Song[b], Shufang Su[b], Wei Su[c], and Jin Min Yang[d]

[a]School of Physics and Technology, University of Jinan, Jinan, Shandong 250022, China
[b] Department of Physics, University of Arizona, Tucson, Arizona 85721, USA
[c]ARC Centre of Excellence for Particle Physics at the Terascale, Department of Physics, University of Adelaide, South Australia 5005, Australia
[d]CAS Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China.

August 29, 2020

Thematic Areas:

■ (EF02) EW Physics: Higgs Boson as a portal to new physics
■ (EF01) EW Physics: Higgs Boson properties and couplings
■ (EF08) BSM: Model specific explorations
■ (TF07) Collider phenomenology

Abstract

The future Higgs factories focus on the precision measurements of the Higgs mass and couplings, which are sensitive to the parameter space of the Minimal Supersymmetric Standard Model (MSSM). We study the implication of the Higgs precision measurements on MSSM using multi-variable χ^2 fit. The results show nice complementarity between the indirect searches at Higgs factories and the direct searches at the current LHC Run-II and future HL-LHC.

Direct searches on the extended Higgs sector are extensively explored at the Large Hadron Collider (LHC). Complementary to the direct searches, the Higgs precision measurements provide an alternative way to study the new physics effects. There are several proposals to build Higgs factories in the pursuit of precision Higgs measurements, including the Circular Electron Positron Collider (CEPC) in China [1], the electron-positron stage of the Future Circular Collider (FCC-ee) at CERN [2, 3], and the International Linear Collider (ILC) in Japan [4]. These future Higgs factories will be the frontier of the precision measurements which will be sensitive to the new physics.

As a well-motivated model to solve problems like the naturalness problem, and the origin of dark matter, the MSSM is the simplest extension of the Standard Model with Supersymmetry. Each

*email address: sps_lihl@ujn.edu.cn, shufang@arizona.edu, huayangs@email.arizona.edu, wei.su@adelaide.edu.au, jmyang@itp.ac.cn

SM particle has its supersymmetric partner with spin differed by a half. The Higgs sector of the MSSM follows that of the Type-II two Higgs doublet model with one Higgs doublet couples to the up-type quarks, and the other doublet couples to the down-type quarks and charged leptons. After the electroweak symmetry breaking, there are five physical fields labeled as A, h, H and $H^{\pm}$, in which h and H are CP-even bosons and A is the CP-odd one.

The MSSM Higgs sector at the tree level is described by only two input parameters m_A and $\tan\beta$, the mass of the CP-odd Higgs boson and the ratio of the vacuum expectation of the two Higgs fields. Both the mass and the couplings of the SM-like light CP-even Higgs h receive radiative corrections, which are sensitive to the parameter parameters. In particular, the dominant contribution to the SM-like Higgs mass comes from the stop sector. To capture the dominant effects, we mainly consider four parameters $\tan\beta, m_A, m_{\rm SUSY}, X_t$, with $m_{\rm SUSY}$ being the soft SUSY breaking parameter for stop masses*, and X_t being the left-right mixing in the stop mass matrix: $X_t = A_t - \mu\cot\beta$. To study the sensitivity of MSSM parameters to the Higgs precision measurements at Higgs factories, we use a multi-variable χ^2 fit:

$$\chi^2 = \chi^2_{mass} + \chi^2_{\mu} = \frac{(m_h^{MSSM} - m_h^{obs})^2}{(\Delta m_h)^2} + \sum_{i=f,V..} \frac{(\mu_i^{MSSM} - \mu_i^{obs})^2}{(\Delta\mu_i)^2}. \quad (1)$$

Here χ^2_{mass} and χ^2_{μ} gives contribution to the overall χ^2 from the Higgs mass and signal strength measurements, respectively.

Using the χ^2 analysis, we study the effects of Higgs precision measurements from Higgs factories on the MSSM parameter space. We study the individual constraint from the Higgs mass, loop induced $h\gamma\gamma + hgg$ channels, as well the channels of Higgs decays to a pair of fermions or gauge bosons. Putting all contributions together, we project the constraints onto the two-dimensional planes of $m_{\rm SUSY} - X_t$, $m_A - m_{\rm SUSY}$, $m_A - \tan\beta$, as well as $m_{\rm SUSY} - \tan\beta$. We also compare the sensitivity of indirect search via Higgs precision measurements with direct search limits at current and future LHC runs.

References

[1] **CEPC Study Group** Collaboration, M. Dong and G. Li, *CEPC Conceptual Design Report: Volume 2 - Physics & Detector*, arXiv:1811.10545.

[2] A. Abada et al., *Future Circular Collider: Vol. 1 Physics opportunities*.

[3] A. Abada et al., *Future Circular Collider : Vol. 2 The Lepton Collider (FCC-ee)*.

[4] P. Bambade et al., *The International Linear Collider: A Global Project*, arXiv:1903.01629.

*For simplicity, we assume degenerate mass parameters for $\tilde{t}_L$ and $\tilde{t}_R$.