# Research Statement

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After over thirty years of waiting, the most exciting news that the Higgs-like signal was discovered around 125 GeV came out from the Large Hadron Collider (LHC) and the Tevatron as well this summer. The deviation of signal rates relative to the standard model (SM) predictions in many channels, particularly the $\gamma\gamma$, $ZZ^*$ and $b\bar{b}$ decay modes, provides theorists some hints to reveal the relevant theoretical structures. LHC phenomenology and its theoretical implications beyond the SM is thus the emphasis of work in my Ph.D. program at UC Davis High Energy Frontier Theory Initiative. In particular, I mainly focus on the theories or topics related to Higgs boson physics, supersymmetry and dark matter.

The phenomenology of this 125 GeV Higgs-like signal in the next-to-minimal supersymmetric standard model (NMSSM) is the main work of ours in the last few months. We first assessed the extent to which various semi-constrained NMSSM (scNMSSM) scenarios with a $\sim$125 GeV lightest $CP$-even Higgs $h_1$ are able to describe this LHC signal. In light of the fact that broadened mass peaks are natural, we next proposed a novel idea — "degenerate Higgs" — not merely one Higgs has mass near 125 GeV. For the purpose of verifying our idea, we again examined scNMSSM scenarios in which both the lightest Higgs $h_1$ and the second lightest Higgs $h_2$ have mass near 125 GeV. As what we expected, very substantially enhanced $\gamma\gamma$ and other signals are possible. Afterwards we developed diagnostic tools that would provide incontrovertible evidence for the presence of more than one Higgs near 125 GeV in the LHC data. In addition, we also studied interesting multiple Higgs scenarios in the NMSSM perspective. In the case of the 125+136 LHC-Tevatron scenario, the best fit to the Tevatron results in the $b\bar{b}$ channel and the mild excesses at CMS in the $\gamma\gamma$ channel at 136 GeV and in the $\tau\tau$ channel above 132 GeV can be explained by a second lightest Higgs state in this mass range, in addition to the lightest one at 125 GeV discovered at the LHC. Concerning the 98+125 LEP-LHC scenario, the lightest Higgs $h_1$ is consistent with the small LEP excess at 98 GeV and the heavier Higgs $h_2$ has the primary features of the LHC Higgs-like signals at 125 GeV, including an enhanced $\gamma\gamma$ rate. Both two ones can be consistent with practically all available signal rates, including a reduced rate in the $b\bar{b}$ ($\tau\tau$) channel around 98 GeV (125 GeV) in the former (latter) scenario. A similar analysis in the framework of phenomenological NMSSM is working in progress as an extension of previous work.

Besides the phenomenological study in the NMSSM, we also examined the maximum Higgs signals that can be achieved in the two-Higgs-doublet model (2HDM) in which either a single Higgs or multiple Higgses has mass near 125 GeV. We found that the constraints requiring vacuum stability, unitarity and perturbativity substantially restrict possibilities of the signal enhancement. Generically we concluded that Type II model allows for an enhancement of order of $2-3$ while within Type I model the enhancement is limited to $\lesssim 1.3$. However, Type II models are highly possible to be disfavored because the substantially enhanced $\gamma\gamma$ signal in the Type II model yields a larger $ZZ$ signal, and thus, making it incompatible with the LHC observation. In the case of the Type I model, the maximal value for $\gamma\gamma$ signal can be reached the order of 1.3 for which $ZZ$ signal is of order 1, both consistent with current data. The follow-up study of 2HDM+singlets or 2HDM+triplets with a dark matter candidate implementation is under consideration.

In addition to employing the supersymmetry (SUSY), the hierarchy problem of the SM can be alternatively solved by introducing one or more warped extra dimensions. The first model to resolve this problem was proposed by Randall and Sundrum (RS). The parameter choices in the RS model with the inclusion of Higgs-radion mixing that can describe the LHC signal have been already explored. We are now studying the phenomenology for the case in which the radion and Higgs are nearly degenerate in mass. Motivated by a number of recent papers on the multi-Higgs fourth generation models without and within SUSY framework, I am now thinking about some idea that worths studying in this topic under a general model setup though the SM with four fermion generations (SM4) is strongly disfavored, essentially excluding the SM4 Higgs with masses up to 600 GeV. Besides, I am also employed in a collaboration applying a heavy axigluon to interpret the LHC data for the charge asymmetry of top quark.

Anyway, the recent 125 GeV "Higgs-like" signal discovery is not the end of story. Instead, research on particle physics has already entered into a new era and we will shortly be in the midst of another huge debate on spin-0 physics. I, together with my advisor Prof. Gunion, anticipate that Higgs bosons and supersymmetric particles will be either confirmed or found, but future LHC data may suggest that alternative theories are natures choice.

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