Research Statement

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After over thirty years of waiting, this summer, the most exciting news that a Higgs-like boson was discovered with mass around 125 GeV came from the Large Hadron Collider (LHC) and also from the Tevatron. Extensive searches are ongoing to measure the properties of the new boson and to construct the nature of the underlying theory that has given rise to it. The deviation of the signal rates relative to the Standard Model (SM) predictions in many channels, particularly in $\gamma\gamma$, ZZ^* and $b\bar{b}$ decay modes, provides theorists valuable hints in this tedious task. It is a privilege to witness this discovery, and a fascinating prospect to possibly contribute to its understanding. I therefore focus my current research on the LHC phenomenology mainly related to Higgs physics. My PhD work in UC Davis High Energy Physics program involves investigating LHC implications of new physics scenarios, –particularly supersymmetry (SUSY)–, that predict a Higgs boson, and also of dark matter.

What we have done in the past

The phenomenology of the 125 GeV Higgs-like signal in the next-to-minimal supersymmetric standard model (NMSSM) has constituted the main part of my work in the past few months. Together with my supervisor John F. Gunion and with Sabine Kraml, we first assessed the extent to which various semi-constrained NMSSM (scNMSSM) scenarios with a ∼125 GeV lightest CP-even Higgs h_1 are able to describe the LHC signal. In light of the fact that the broadened mass peaks are natural, we next proposed a novel idea — "degenerate Higgs" — which states that not merely one Higgs has mass near 125 GeV, but there could be other Higgs states with mass close to that value. For the purpose of verifying our idea, we again examined the scNMSSM scenarios in which both the lightest Higgs h_1 and the second lightest Higgs h_2 have masses near 125 GeV. As expected, we saw that substantially enhanced $\gamma\gamma$ and other signals are possible. Furthermore, we developed diagnostic tools that would provide incontrovertible evidence for the presence of more than one Higgs state near 125 GeV at the LHC. In addition, we studied other interesting multiple Higgs scenarios within the NMSSM perspective: Working also with Genevieve Belanger and Ulrich Ellwanger, our team showed that for the 125 GeV+136 GeV LHC-Tevatron scenario, the best fit to the Tevatron results in the $b\bar{b}$ channel and the mild excesses in CMS data 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, alongside the lightest one at 125 GeV discovered at the LHC. In a further study with John H. Schwarz, we saw that for the 98+125 LEP-LHC scenario, the lightest Higgs h_1 is consistent with the small LEP excess at 98 GeV whereas the heavier Higgs h_2 possesses the primary features of the LHC Higgs-like signals at 125 GeV, including an enhanced $\gamma\gamma$ rate. Both scenarios 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 in progress as an extension of the previous study.

Besides the phenomenological studies in the NMSSM, together with A. Drozd and G. Grzadkowski, we have also been examining the maximum Higgs signals that can be achieved in the two-Higgs-doublet model (2HDM) in which

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either a single Higgs or multiple Higgses can have mass(es) near 125 GeV (to appear on arXiv.). We found that the constraints requiring vacuum stability, unitarity and perturbativity substantially restrict possibilities of the signal enhancement. Generically we concluded that the Type II model allows for an enhancement of the order of $2-3$, while within the Type I model the enhancement is limited to $\lesssim 1.3$. However, Type II models have a high possiblity 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 the $\gamma\gamma$ signal can reach the order of 1.3 for which the ZZ signal is of order 1, both being consistent with the current data. The follow-up study of 2HDM+singlets or 2HDM+triplets with a dark matter candidate extension is under consideration.

What we are doing now or are going to do in the near future

The scope of our future studies will expand to other new physics scenarios. We intend to investigate the scalar sector in the Randall-Sundrum (RS) model in which a single warped extra dimension is introduced to alternatively resolve the hierarchy problem of the SM: The parameter choices in the RS model with the inclusion of Higgs-radion mixing which can describe the LHC signal have already been explored. We are now studying the phenomenology for the case in which the radion and Higgs are nearly mass-degenerate. Next, enlightened by a number of recent papers on the multi-Higgs fourth generation models within and outside the SUSY framework, I am now thinking about some idea that is worth 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 being employed in a collaboration applying a heavy axigluon to interpret the LHC data for the charge asymmetry of top quark.

Instead of being the end of story, the recent discovery of the 125 GeV Higgs-like signal has brought particle physics research into the start of a new era. We will shortly be in the midst of another wild debate on spin-0 physics. I, together with my advisor professor Gunion, anticipate that Higgs bosons and SUSY particles will be either confirmed or found. We are currently waiting for the future LHC data to verify our work, however, the data may, of course, suggest that alternative theories are Nature's choice.