Research Statement

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After over thirty years of waiting, this summer, the very 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 deviations 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, provide theorists valuable hints in this crucial task. It was a privilege to witness this discovery, and the prospect of contributing to its understanding is very exciting. I will therefore focus my current research on LHC phenomenology, especially that related to Higgs physics, investigating LHC implications of various Higgs models beyond the SM both without and within the framework of supersymmetry (SUSY).

Past research

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 $\sim$125 GeV lightest CP-even Higgs h_1 are able to describe the LHC signal. We found that enhanced $\gamma\gamma$ rates are most natural when the h_1 has mass similar to the second lightest CP-even Higgs, h_2, with enhancement particularly likely if the h_1 and h_2 are degenerate. To experimentally probe this possibility, we developed diagnostic tools that could discriminate whether or not there are two (or more) Higgs bosons versus just one contributing to the LHC signals at 125 GeV. In addition, we studied other interesting multiple Higgs scenarios. Working also with Genevieve Belanger and Ulrich Ellwanger, our team explored the scenario where $m_{h_1} \sim 125$ GeV and $m_{h_2} \sim 136$ GeV. The idea for the latter mass choice is to fit the strong Tevatron signal 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, while the 125 GeV h_1 would be that discovered at the LHC. In a further study with John H. Schwarz, we considered the case where the lightest Higgs h_1 provides a consistent description of 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. Related analyses in the framework of the phenomenological NMSSM, the version of the NMSSM without GUT-scale unification assumptions, are in progress as an extension of the previous studies.

Besides the NMSSM studies, collaborating with Bohdan Grzadkowski, we have been examining the maximum Higgs signal enhancements that can be achieved in the two-Higgs-doublet model (2HDM) in which either a single Higgs or multiple Higgses have mass(es) near 125 GeV. We found that the constraints requiring vacuum stability, unitarity and perturbativity substantially restrict possibilities for signal enhancement. Generically we concluded that the Type II model allows for an enhancement in the $\gamma\gamma$ rate (relative to the SM) of the order of $2-3$, while within the Type I model the enhancement is limited to $\lesssim 1.3$. However, Type II models are disfavored because the substantially enhanced $\gamma\gamma$ signal is automatically associated with an even larger ZZ signal enhancement, which is currently incompatible with the LHC observations. In the case of the Type I model, the maximal value for the $\gamma\gamma$ signal enhancement relative to the SM 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 studies of 2HDM+singlets and 2HDM+triplets with a dark matter candidate extension is under consideration.

Current and future projects

Near future research will include the following. (i) We will consider 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. An initial exploration of the parameter choices in the RS model with the inclusion of Higgs-radion mixing which can describe the LHC signal has been published. Neglected in that study was the phenomenology for the case in which the radion and Higgs are nearly mass-degenerate, a topic we are now pursuing. (ii) It is well known that the SM with a single Higgs boson at 125 GeV is not consistent with four fermion generations. In a second project I will explore the extent to which this inconsistency can be avoided in the context of models having multiple Higgs-doublets plus singlets. (iii) I am part of a collaboration considering the possibility that a heavy axigluon can explain the recent LHC data for the charge asymmetry of the 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 are in the midst of an exciting debate on the nature of the 125 GeV state. I, together with professor Gunion, anticipate that the observed 125 GeV state will provide a key window into theories beyond the SM, and that additional Higgs bosons and SUSY particles may well be found. We are currently waiting to see if the future LHC data supports the various multi-Higgs proposals outlined earlier, or, alternatively, suggests that alternative theories are Nature's choice.

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