INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

In 2012, the ATLAS and CMS collaborations independently observed a new Higgs-like particle with a mass 125 GeV and properties similar to that predicted by the Standard Model (SM) at the Large Hadron Collider (LHC). So far, although the measurements indicate that this Higgs-like boson is compatible with the SM hypothesis, however due to large uncertainties in some of the Higgs detection channels, one still has the possibility of testing this new particle as being a candidate for some beyond the SM (BSM) physics scenarios, for example, the Minimal Supersymmetric Standard Model (MSSM), in the CP-conserving version (CPC-MSSM). We evaluate the modifications of the CPC-MSSM results when CP-violating (CPV) phases are turned on explicitly, leading to the CP-violating MSSM (CPV-MSSM). We investigate the role of the CPV phases in (some of) the soft Supersymmetry (SUSY) breaking terms on both the mass of the lightest Higgs boson h_1, and the rates for some of the gluon gluon fusion (GGF) processes and the vector boson fusion (VBF) processes like,
at the LHC, considering the impact of stringent flavor constraints as well as the constraints coming from electric dipole moment (EDM) measurements.
We obtain that the imaginary part of the top and bottom
Yukawa couplings can take very small but non-zero values even after satisfying all the recent updates from both the ATLAS and CMS collaborations within 1-2_ uncertainties which might be an interesting signature to look for at the future runs of the LHC. Our study shows that the CPV-MSSM provides a potential solution to the recent LHC Higgs data, in fact offering very little in the way of distinction between these two SUSY models (CPC-MSSM and CPV-MSSM) at the 7 and 8 TeV run of the LHC. Improvement in different Higgs coupling measurements is necessary in order to test the possibility of probing any small dependence on these

CPV phases in the MSSM Higgs sector.
In the Next-to-Minimal Supersymmetric Standard Model (NMSSM), it is possible for either one of the additional singlet-like scalar and pseudoscalar Higgs bosons to be almost degenerate in mass with the 125 GeV SM-like Higgs state. In the real NMSSM (rNMSSM), when the mass difference between two scalar states is comparable to their individual total decay widths, the quantum mechanical interference, due to the relevant diagonal as well as o_-diagonal terms in the propagator matrix, between them can become sizable. This possibility invalidates usage of the narrow width approximation (NWA) to compute the cross section for the production of a di-photon pair with a given invariant mass via resonant Higgs boson(s) in the gluon fusion process at the LHC. When, motivated by the baryon asymmetry of the universe, CPV phases are explicitly invoked in the Higgs sector of the NMSSM, all the interaction eigenstates mix to give CP-indefinite physical Higgs bosons. In this scenario, the interference effects due the o_-diagonal terms in the Higgs mass matrix that mix the pseudoscalar-like state with the SM-like one can also become significant, when these two are sufficiently mass-degenerate. We perform a detailed analysis, in both the real and complex NMSSM, of these interference effects, when the full propagator matrix is taken into account, in the production of a photon pair with an invariant mass near 125 GeV through gluon fusion. We find that these effects can account for up to _ 40% of the total cross section for certain model parameter configurations. We also investigate how such mutually interfering states contributing to the 125 GeV signal observed at the LHC can be distinguished from a single resonance.
In the NMSSM, it is possible to have strong mass degeneracies between the new singlet-like scalar and the heavy doublet-like scalar, as well as between the single-tlike and doublet-like pseudoscalar Higgs states. When the difference in masses of such states is comparable to their widths, the quantum mechanical interference between their propagators can become significant. We study these effects by taking into account the full Higgs boson propagator matrix in the calculation of the production process of _+_□ pairs in gluon fusion at the LHC. We find that, while these interference effects are sizable, they are not resolvable in terms of the distributions of differential cross sections, owing to poor detector resolution of the invariant mass. They are, however, identifiable via the inclusive cross sections, which are subject to significant variations with respect to the standard approaches, wherein the propagating Higgs bosons are treated independently from one another. We quantify these effects for several representative benchmark points (BPs), extracted from a large set of points, obtained by numerical scanning of the NMSSM parameter space, that satisfy the most stringent experimental constraints currently available.