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RECONSTRUCTING MSSM PARAMETERS FROM HIGGS SEARCHES

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Abstract

We present some highlights on the complementarity of the Higgs and SUSY searches at the LHC, using the 8 and 13 TeV results. In particular, we discuss the constraints that can be obtained on the MSSM parameters by the determination of the Higgs boson mass and couplings. In addition, we investigate the interplay with heavy Higgs searches, and evaluate how higher LHC luminosities and a future linear collider can help probing the pMSSM Higgs sector and reconstructing the underlying parameters.

1 Introduction

The discovery of the Higgs boson at the LHC has marked a major step for our understanding of particle physics, and for the construction of the Higgs sector of new physics scenarios. Direct searches for new particles are currently actively pursued at the LHC, in particular in the context of supersymmetry (SUSY). No new physics signal has been discovered so far, implying that new physics should be subtle or heavy. Therefore, indirect constraints are at the moment of utmost importance. The measurements of the properties of the Higgs boson can provide in this respect very strong constraints on new physics scenarios. The measurement of its mass at 125 GeV [1] is very constraining for supersymmetry, because the Higgs mass can receive large corrections from the stop sector, and has a large impact on the SUSY parameter space [2]. In the following, we will discuss the status of the Higgs sector of the phenomenological MSSM. To do so, we perform random scans on the 19 parameters of the pMSSM, following the procedures detailed in [3]. In particular, we use a master program based on SuperIso [4], generate the MSSM spectra with SOFTSUSY [5] and compute the Higgs boson decay widths and couplings with HDECAY [6]. We keep only the parameter points for which the lightest supersymmetric particle is a neutralino (constituting a dark matter candidate) and with a light Higgs mass of 125 ± 3 GeV.

2 Higgs coupling measurements and SUSY direct searches

We first study the interplay of the measurement of the Higgs boson properties and of the results of the SUSY direct searches. We impose the LEP constraints on the SUSY masses [1]. To assess the constraints from SUSY searches at the LHC, we generate events with PYTHIA [7], simulate the detector with Delphes [8] and obtain constraints from ATLAS and CMS results with a luminosity between 36 and 139 fb^{-1} [9], for gluino and squark, neutralino and chargino, stop and sbottom, and monojet searches. For the Higgs measurements, we consider that there are 6 independent effective Higgs couplings, to the photons κ_γ, gluons κ_g, vector bosons κ_V, tops κ_t, bottoms κ_b and taus κ_τ. We use the combined ATLAS measurements of the Higgs couplings at 7, 8 and 13 TeV [10]. In order to verify whether a point is consistent with these measurements, we use a χ^2 test and keep only the points which are in agreement with the data at 95% C.L. In Figure 1, we present the photon, gluon and bottom squared coupling distributions as a function of M_A, applying different sets of constraints: First we apply the Higgs mass constraint, then the LEP constraints on superpartner masses, followed by the LHC direct search constraints, and finally the constraints from Higgs coupling measurements. We can see that all the shown couplings are sensitive to M_A, in addition to other SUSY parameters which modify the couplings

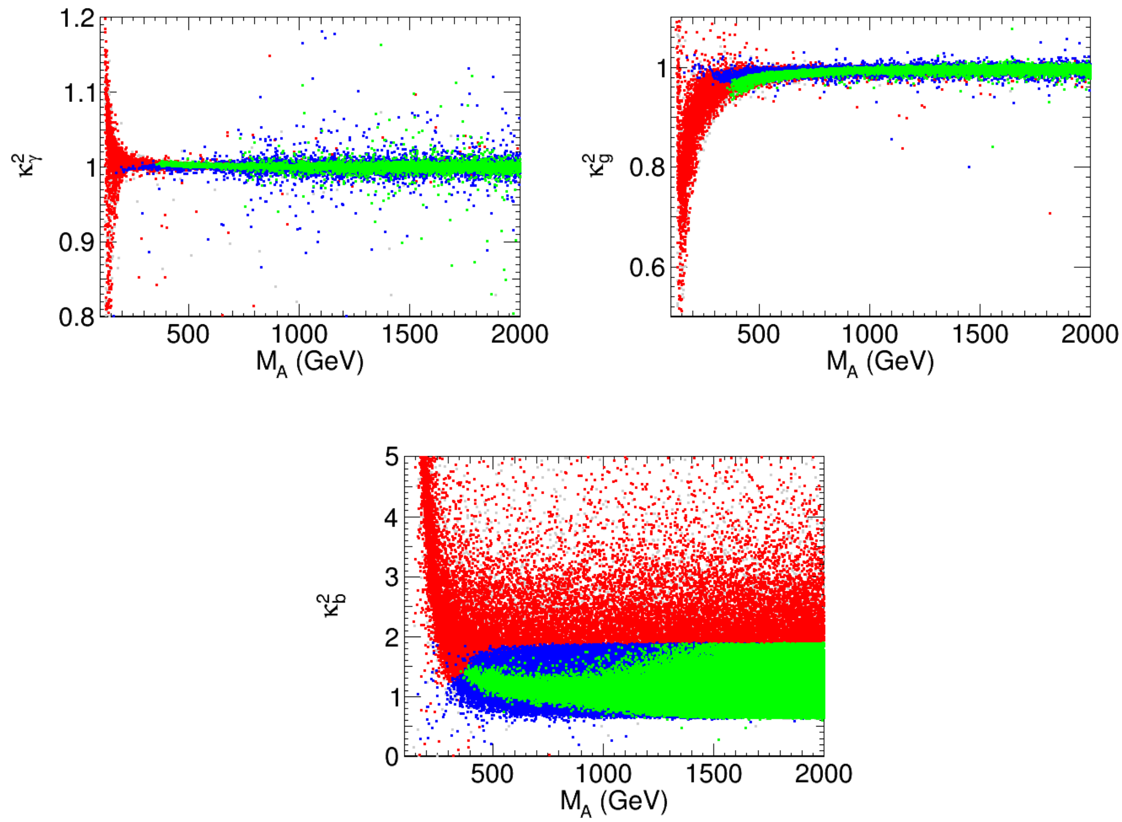

Figure 1: *Distributions of the squared light scalar Higgs couplings to photons (upper left), gluons (upper right) and bottoms (lower), as a function of M_A in the pMSSM. The gray points correspond to all points with $M_h \sim 125$ GeV, the red points pass in addition the constraints from LEP, the blue points are also consistent with LHC SUSY direct searches and the green points are compatible with Higgs coupling measurements.*

at loop level. In particular, the photon and gluon couplings are sensitive to the stop and sbottom masses. The bottom coupling is modified by the Δ_b corrections [11]. It is clear that the combination of the direct searches and Higgs measurements strongly restricts the coupling values to be close to 1. Since the different couplings are related to SUSY masses, these results can be used to obtain constraints on the pMSSM parameters.

3 Heavy Higgs direct searches and Higgs coupling measurements

The Higgs sector can be constrained directly through searches for heavier Higgs states and the light Higgs coupling measurements. To compute the Higgs decay rates and production cross-sections we use HDECAY [6] and SusHi [12], respectively, and apply ATLAS and CMS heavy Higgs search limits [13]. We compare the exclusion from the Higgs coupling measurements to the one from heavy Higgs searches in Figure 2, which reveals the important interplay between the light Higgs coupling measurements and the heavy Higgs search limits. We consider three parameter planes: $(M_A, \tan\beta)$ which are the two main parameters for the couplings of the Higgs bosons; $(M_{\tilde{b}_1}, X_b)$ which can enter the Higgs mass calculation and can affect Δ_b; (M_2, μ) which are the main parameters for the electroweakino sector. As can be expected the $(M_A, \tan\beta)$ parameter plane is constrained by both the Higgs coupling measurements and very strongly by heavy Higgs searches, and in particular the $H/A \to \tau^+\tau^-$ searches. The $(M_{\tilde{b}_1}, X_b)$ and (M_2, μ) parameter planes are rather uniformly probed by heavy Higgs searches with a small exclusion power, as these parameters only weakly affect the heavy Higgs production cross-sections. On the contrary, the Higgs couplings are sensitive to light charginos, neutralinos and sbottoms, leading to strong exclusions in some regions of both parameter planes.

4 Prospects for the MSSM Higgs sector

As we have seen in the previous sections, the Higgs couplings are affected by pMSSM parameters, and an important question is whether it can be possible to determine these parameters indirectly through the exploitation of Higgs coupling measurements and direct searches. While it is now impossible with the data at hand, we study here the prospects for the high-luminosity LHC (HL-LHC) run and ILC [14], by considering the possibility of reconstructing specific scenarios using the Higgs coupling measurements. We test two categories of scenarios: the first one where only M_A and $\tan\beta$ are varied, and the second one where $\mu\tan\beta$ is modified. We assume the accuracy reached when the ILC collects 1 ab^{-1} of luminosity at energies between 350 and 800 GeV. We consider the following method: Within our large sample of pMSSM parameter points, we choose a particular scenario in agreement with the current data. We then use, as prospective central experimental values, the Higgs decay rates and cross-sections of this specific point considering the prospective experimental uncertainties for HL-LHC and ILC. We finally search in our sample for the points that are compatible with those data, and find the mean values and standard deviations for M_A and $\tan\beta$, or $\mu\tan\beta$. Table 1 summarizes our results for several example scenarios (some at the limit of being excluded by current searches). We can conclude that the HL-LHC alone would allow us to reconstruct CP-odd Higgs masses up to 500 GeV. For higher masses, or for scenarios with modified $\mu\tan\beta$, the ILC will be necessary to identify the underlying parameters of the scenario.

5 Conclusions

In this study, we have considered the MSSM Higgs sector, and demonstrated how it can be probed by both the light Higgs coupling measurements and heavy Higgs searches. We showed that indirect signals

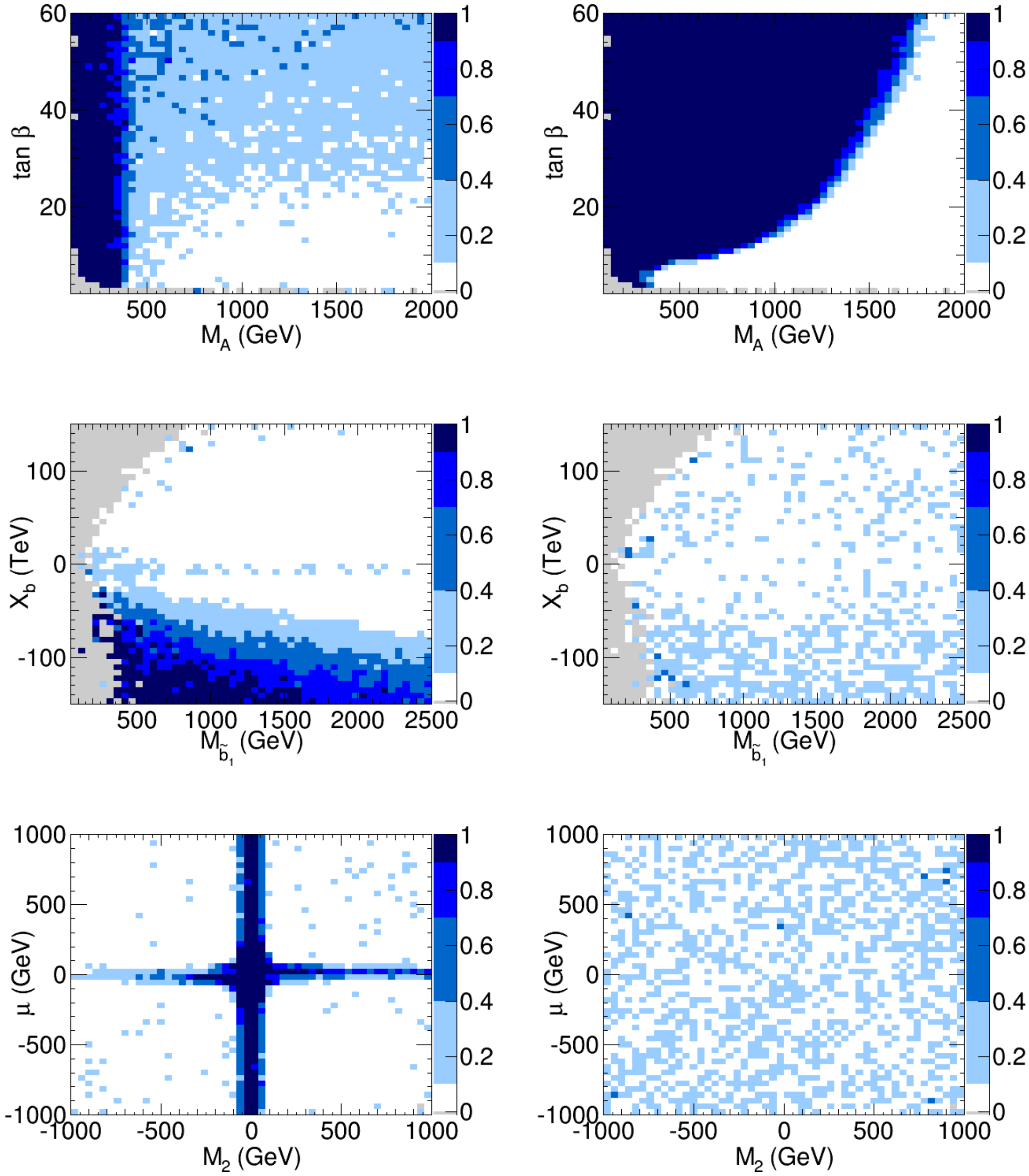

Figure 2: *Fraction of points excluded by Higgs coupling measurements (left) and heavy Higgs searches (right), in the* $(M_A, \tan\beta)$ *(top),* $(M_{\tilde{b}_1}, X_b = A_b - \mu \times \tan\beta)$ *(middle) and* (M_2, μ) *(bottom) parameter planes.*

	M_A(GeV)	$\tan\beta$	M_A(GeV)	$\tan\beta$	M_A(GeV)	$\tan\beta$
Original parameters	334.9	9.9	427.3	5.7	657.2	12.7
HL-LHC reconstruction	394±40	9.6±4.0	471^{+341}_{-56}	-	-	-
ILC reconstruction	351±23	9.2±1.9	460^{+54}_{-45}	10.4^{+6}_{-4}	747.7^{+302}_{-97}	10.2^{+20}_{-4}

Original $\mu\tan\beta$ (TeV)	-149.9	-86.6	0	79.6	108.6
ILC reconstruction	-76.3^{+28}_{-39}	-124.6^{+46}_{-60}	-2.2 ± 22	67.2^{+39}_{-22}	82.5^{+40}_{-22}

Table 1: *Reconstruction potential of different pMSSM scenarios with HL-LHC and ILC projections.*

of supersymmetry can be revealed at the LHC, even in the case no superparticle is directly observed. In addition, precision measurements of the light Higgs properties enables the extraction of the relevant SUSY parameters, if deviations from the SM are observed.

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