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Interpreting the LHC Higgs Search Results in the MSSM

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Abstract

Recent results reported by the ATLAS and CMS experiments on the search for a SM-like Higgs boson both show an excess for a Higgs mass near 125 GeV, which is mainly driven by the $\gamma\gamma$ and ZZ^* decay channels, but also receives some support from channels with a lower mass resolution. We discuss the implications of this possible signal within the context of the minimal supersymmetric Standard Model (MSSM), taking into account previous limits from Higgs searches at LEP, the Tevatron and the LHC. The consequences for the remaining MSSM parameter space are investigated. Under the assumption of a Higgs signal we derive new lower bounds on the tree-level parameters of the MSSM Higgs sector. We also discuss briefly an alternative interpretation of the excess in terms of the heavy CP-even Higgs boson, a scenario which is found to be still viable.

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1 Introduction

The Higgs boson [1] has for a long time been considered as the only missing piece in the Standard Model (SM) of particle physics. Therefore, finding this particle has been one of the main tasks of experimental high-energy physics. However, the main results from the published searches so far have been exclusion limits (see e.g. the results from LEP [2], the Tevatron [3], and the LHC [4, 5]). Combining the experimental limits, the only allowed region (before the latest results which will be discussed below) a relatively small window for the Higgs mass: 114 GeV $< M_H^{\rm SM} <$ 141 GeV. This low mass region is also the one favoured by electroweak precision tests, see e.g. [6].

A low Higgs mass is predicted in supersymmetric extensions of the SM, where the quartic Higgs couplings are related to gauge couplings. Exclusion of a heavy SM-like Higgs [3, 4, 5] can therefore be considered as being in line with the predictions of supersymmetry (SUSY). Besides predicting a light Higgs boson, SUSY protects scalar masses from the large hierarchy of scales, it allows for gauge coupling unification, and it can provide a dark matter candidate [7]. The *minimal* supersymmetric extension of the SM (MSSM) [8] has two complex Higgs doublets. Following electroweak symmetry breaking, the physical spectrum therefore contains five Higgs bosons. Assuming CP conservation, these are denoted h, H (CP-even), A (CP-odd), and $H^\pm$ (charged Higgs). At the tree-level the MSSM Higgs sector can be described by two parameters (besides the SM parameters), commonly chosen as the mass of the CP-odd Higgs boson, M_A, and $\tan\beta$, the ratio of the two vacuum expectations values. In the decoupling limit, $M_A \gtrsim 2M_Z$ (where M_Z denotes the mass of the Z boson), all MSSM Higgs bosons except the lightest CP-even scalar h become heavy, whereas h has SM-like properties. In this limit it would be difficult to separate hints for a SM Higgs boson from a potential MSSM counterpart. It is also in the decoupling limit where M_h reaches its maximal value, $M_h \simeq 135$ GeV [9].

The LHC experiments recently extended their exclusion regions for a SM-like Higgs boson down to $M_H^{\rm SM} \lesssim 127$ GeV, with the lowest limit coming from CMS ($M_H^{\rm SM} < 131$ GeV for ATLAS). In addition, ATLAS reported exclusion of the range 114 GeV $< M_H^{\rm SM} <$ 115.5 GeV, which is a region where sensitivity was not expected. Most interestingly, both experiments also reported about an excess over the background expectation close to $M_H^{\rm SM} = 125$ GeV [10]. Since this Higgs mass lies in the range compatible with supersymmetry, we report in this letter on a first analysis and interpretation of these results in an MSSM context.

2 Experimental Higgs search results

Both the LHC experiments (ATLAS and CMS) have reported [10] on indications for an excess of Higgs-like events corresponding to a Higgs boson mass[1]

$$M_H^{\rm SM} = 126 \text{ GeV} \qquad \text{(ATLAS)},$$

$$M_H^{\rm SM} = 124 \text{ GeV} \qquad \text{(CMS)}.$$

The result is driven by an observed excess of events over SM background expectations in primarily the $\gamma\gamma$ and ZZ^* channels, which provide relatively good resolution for the Higgs boson mass. The local significance for the combined result is $3.6\,\sigma$ for ATLAS and $2.6\,\sigma$ for CMS. However, when interpreted in a global search containing many mass bins, the local significance is washed out by the look-elsewhere

[1] Another excess at $M_H^{\rm SM} \simeq 119$ GeV was reported by CMS, but not confirmed by ATLAS. Consequently, we will not consider this value in our analysis.

effect (LEE). This effect compensates for the higher probability of random fluctuations generating an excess anywhere when searching in more than one place. Taking this into account, the significance of the reported result is reduced to $2.5\,\sigma$ ($1.9\,\sigma$) for ATLAS (CMS) when interpreted as a SM Higgs search over the mass range from 110 GeV to 146 GeV. On the other hand, one could argue that when interpreting these results in a model where the allowed range for M_h is constrained to a smaller range by the theory (as in the MSSM), the LEE does not apply to the same degree as for the SM interpretation. These new results are therefore even somewhat more interesting in an MSSM context.

For the remainder of this paper, encouraged by the excess reported by ATLAS and CMS, we investigate a scenario where we assume the observation of a state compatible with a SM-like Higgs boson with mass $M_h = (125 \pm 1)$ GeV. We will discuss the implications that such an assumed signal would have for the MSSM. While the current statistical significance does not allow yet to draw firm conclusions on the validity of the above assumption, our analysis is in fact somewhat more general, as possible implications of observing (or excluding) a state compatible with a SM-like Higgs elsewhere in the allowed mass window 115.5 GeV $< M_h <$ 127 GeV [10] can also be inferred.

3 MSSM Interpretation

For calculating the Higgs masses in the MSSM we use the code `FeynHiggs` [9, 11, 12] (v. 2.8.5). The status of higher-order corrections to the masses (and mixing angles) in the neutral Higgs sector is quite advanced.[2] The complete one-loop result within the MSSM is available and has been supplemented by all presumably dominant contributions at the two-loop level, see Ref. [9] for details. Most recently leading three-loop corrections have been presented [14], where the leading term is also included in `FeynHiggs`. Following Ref. [9], we estimate the (intrinsic) theory uncertainty on the lightest Higgs mass from missing higher-order corrections to be $\Delta M_h^{\rm intr} \sim \pm 2$ GeV. The intrinsic M_h uncertainties are also somewhat smaller for a SM-like Higgs than in the general case, which makes this estimate conservative. Concerning the parametric uncertainty from the experimental errors of the (SM-) input parameters, $\Delta M_h^{\rm param}$, the main effect arises from the experimental error of the top-quark mass. We incorporate this uncertainty explicitly in our results below by allowing m_t to vary within the range $m_t = 173.2 \pm 0.9$ GeV [17]. Parametric uncertainties in M_h from α_s are smaller than the m_t uncertainties and will be neglected. Adding the intrinsic theory uncertainty (conservatively) linearly to the assumed experimental uncertainty, we arrive at the allowed interval

$$122 \text{ GeV} < M_h < 128 \text{ GeV}, \tag{1}$$

which will be used for the MSSM interpretation of the assumed Higgs signal. While for most of this paper we investigate the case where the assumed signal is interpreted as the lighter CP-even Higgs boson, h, of the MSSM, we comment below also on the possibility of associating the assumed signal with the *second-lightest* CP-even Higgs boson, H. Since the observed excess includes WW^* and ZZ^* final states, an interpretation in terms of the CP-odd Higgs boson, A, appears to be highly disfavoured.

For our discussions of the possible interpretations of the assumed signal, we use a phenomenological description of the (CP-conserving) MSSM with all parameters given at the electroweak scale. In order to determine the radiative corrections to the Higgs masses it is necessary to specify, besides the tree-level parameters M_A and $\tan\beta$, also the relevant SUSY-breaking parameters entering at higher orders. In particular, the parameters in the stop and sbottom sector have a large impact in this context. Since for the case where we interpret the assumed signal as the lighter CP-even Higgs h we are interested

[2]We concentrate here on the case with real parameters. For the complex case, see Refs. [12, 13] and references therein.

in particular in determining lower bounds on the most relevant parameters, we fix those with smaller impact on M_h to their values in the $m_h^{\max}$ scenario [15],

$$\begin{aligned} M_1 &= 100 \text{ GeV}, \quad M_2 = 200 \text{ GeV} \\ m_{\tilde{g}} &= 0.8 M_{\text{SUSY}}, \quad \mu = 200 \text{ GeV}, \end{aligned} \tag{2}$$

so that conservative lower bounds are obtained for the other parameters. In Eq. (2) $M_{1,2}$ and $m_{\tilde{g}}$ are the soft SUSY-breaking gaugino masses corresponding to the SM gauge group, and μ is the Higgs mixing parameter. This choice ensures that the corresponding contributions to M_h are such that one obtains (approximately) the highest value for M_h. In addition to varying the tree-level parameters, we allow for variation in the overall SUSY mass scale M_{SUSY} and the stop mixing parameter $X_t \equiv A_t - \mu \cot\beta$, where $A_{t,b}$ denotes the trilinear coupling of the Higgs to scalar tops or bottoms. We furthermore set $A_b = A_t$. The scalar top masses will be denoted as $m_{\tilde{t}_1}$ and $m_{\tilde{t}_2}$ below, with $m_{\tilde{t}_1} \leq m_{\tilde{t}_2}$. It should be noted that when we discuss relatively low values of M_{SUSY} this refers only to squarks of the third generation (which give rise to the relevant Higgs mass corrections). The experimental bounds reported from squark searches at the LHC [16], on the other hand, apply only to squarks of the first two generations, which are essentially irrelevant for Higgs phenomenology. We also do not apply a lower bound on the gluino mass, which leads to more conservative lower limits on the parameters from the Higgs sector than e.g. a bound $m_{\tilde{g}} > 700$ GeV [16] would do. We comment further on this point below. As mentioned above, for the top quark mass we use the latest Tevatron combination $m_t = 173.2 \pm 0.9$ GeV [17], taking the uncertainty into account by varying m_t over its $\pm 1\,\sigma$ interval.

Besides constraints from the Higgs sector, which we will discuss shortly, one could also consider indirect constraints on the MSSM parameter space coming from other measurements, such as the anomalous magnetic moment of the muon, $(g-2)_\mu$, or from B-physics observables such as $\text{BR}(b \to s\gamma)$. The former requires in general that $\mu > 0$, while the latter is often in better agreement with experimental data for $\mu X_t \approx \mu A_t < 0$ (for a recent analysis see [18] and references therein). We will not apply any indirect constraints here, but when presenting the results below we sometimes distinguish between positive and negative X_t, where the bounds obtained for $X_t < 0$ could be regarded as experimentally preferred. However, one should keep in mind that a small admixture of non-minimal flavour violation could bring the $\text{BR}(b \to s\gamma)$ results into agreement with experimental data without changing (notably) the Higgs sector predictions [19].

A light CP-even SM-like Higgs boson

We begin the MSSM interpretation by associating the assumed LHC signal with the light CP-even Higgs boson h. By choosing the relevant parameters such that the radiative corrections yield a maximum upward shift to M_h, it is possible to obtain lower bounds on the parameters M_A and $\tan\beta$ governing the tree-level contribution. The situation where the radiative corrections to M_h are maximized in this way is realised in the $m_h^{\max}$ scenario with a stop mixing of $X_t = 2M_{\text{SUSY}}$. In Fig. 1 we show the result of varying the tree-level parameters in this scenario (with $M_{\text{SUSY}} = 1$ TeV as originally defined). Constraints on the parameter space from direct Higgs searches at colliders are taken into account by using `HiggsBounds` [20].[3] Since we are interpreting an assumed signal, we do not include the updated exclusion bounds from [10]. Fig. 1 shows separately the regions excluded by LEP [22] (blue), and the Tevatron/LHC (red). The gray area is the allowed parameter space before

[3] We use `HiggsBounds` v. 3.5.0-beta with a private addition of the latest CMS results on $A/H \to \tau^+\tau^-$ [21]. These new results provide the most stringent Tevatron/LHC limits on the $(M_A, \tan\beta)$ plane at medium or large $\tan\beta$.

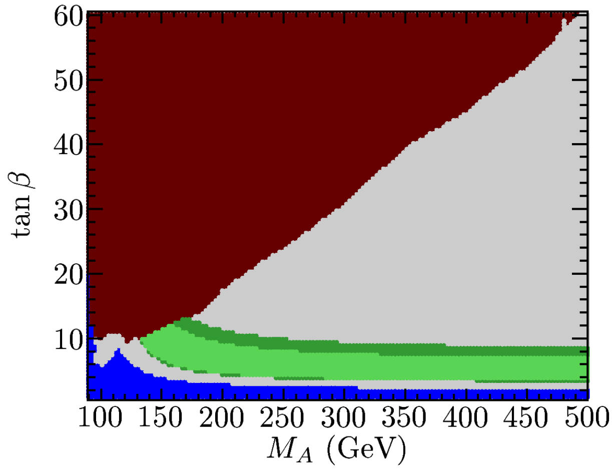

Figure 1: Tree-level Higgs sector parameters (M_A, $\tan\beta$) for the case where the parameters governing the higher-order corrections are chosen such that a maximum value for M_h is obtained ($m_h^{\rm max}$ benchmark scenario). The different colours correspond to the regions excluded by LEP (blue) and Tevatron/LHC (red). The gray area is the allowed parameter space prior to the latest LHC results. The green band shows the region where M_h is compatible with the assumed Higgs signal (see text).

including the bound from Eq. (1), and the green band corresponds to the mass interval compatible with the assumed Higgs signal of 122 GeV $< M_h <$ 128 GeV. The brighter green is for the central value for m_t, while including also the dark green band corresponds to a $\pm 1\,\sigma$ variation of m_t.

The assumed Higgs signal, interpreted as the lighter CP-even MSSM Higgs mass, implies in particular that $M_h > 122$ GeV (including theoretical uncertainties), which is significantly higher than the limit observed for a SM-like Higgs at LEP of $M_h > 114.4$ [2]. From Fig. 1 it is therefore possible to extract lower (one parameter) limits on M_A and $\tan\beta$ from the edges of the green band. As explained above, by choosing the parameters entering via radiative corrections such that those corrections yield a maximum upward shift to M_h, the lower bounds on M_A and $\tan\beta$ that we have obtained are general in the sense that they (approximately) hold for *any* values of the other parameters. To address the (small) residual $M_{\rm SUSY}$ dependence of the lower bounds on M_A and $\tan\beta$, we extract limits for the three different values $M_{\rm SUSY} = \{0.5, 1, 2\}$ TeV. The results are given in Table 1, where for comparison we also show the previous limits derived from the LEP Higgs searches [22], i.e. before the incorporation of the new LHC results reported in Ref. [10]. The bounds on M_A translate directly into lower limits on $M_{H^\pm}$, which are also given in the table. A phenomenological consequence of the bound

	Limits without $M_h \sim 125$ GeV			Limits with $M_h \sim 125$ GeV		
$M_{\rm SUSY}$ (GeV)	$\tan\beta$	M_A (GeV)	$M_{H^\pm}$ (GeV)	$\tan\beta$	M_A (GeV)	$M_{H^\pm}$ (GeV)
500	2.7	95	123	4.5	140	161
1000	2.2	95	123	3.2	133	155
2000	2.0	95	123	2.9	130	152

Table 1: Lower limits on the MSSM Higgs sector tree-level parameters M_A ($M_{H^\pm}$) and $\tan\beta$ obtained with and without the assumed Higgs signal of $M_h \sim 125$ GeV, see Eq. (1). The mass limits have been rounded to 1 GeV.

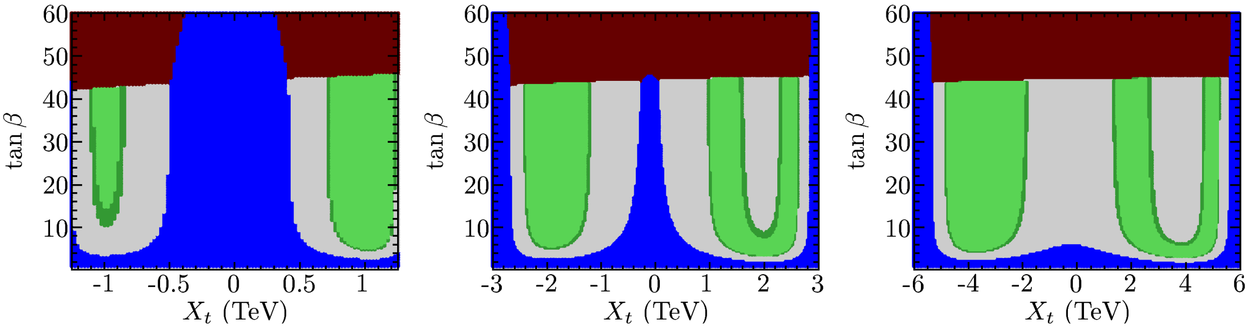

Figure 2: Allowed ranges of $\tan\beta$ for $M_A = 400$ GeV, shown as a function of the stop mixing parameter X_t. The colour coding is as in Fig. 1. The three plots correspond to $M_{\rm SUSY} = 500$ GeV (left), $M_{\rm SUSY} = 1$ TeV (centre), and $M_{\rm SUSY} = 2$ TeV (right).

$M_{H^\pm} \gtrsim 155$ GeV (for $M_{\rm SUSY} = 1$ TeV) is that it would leave only a very small kinematic window open for the possibility that MSSM charged Higgs bosons are produced in the decay of top quarks.

For deriving the conservative lower bounds on M_A and $\tan\beta$ it was unnecessary to impose constraints on the production and decay rates of the assumed Higgs signal in the relevant search channels at the LHC. One might wonder whether it would be possible to improve the bound on M_A by requiring that the rate in the relevant channels should not be significantly suppressed as compared to the SM case. Such an improvement would be scenario-dependent, however, i.e. the result would depend on the specific choice made for the other MSSM parameters. We will therefore not study this issue in further detail.

It might look tempting to extract also an *upper* limit on $\tan\beta$ from the green band in Fig. 1, but in contrast to the lower bound which is scenario-independent, this limit will only apply to the specific case of the $m_h^{\rm max}$ scenario. In fact, the allowed range for $\tan\beta$ depends sensitively on the other parameters, as can be seen from Fig. 2, where we show the $(X_t, \tan\beta)$ plane for $M_A = 400$ GeV, but the results are qualitatively similar for other values of M_A in the decoupling limit. The main difference is the LHC exclusion limit (in red), which goes down to lower values of $\tan\beta$ for lower M_A. On the other hand, for M_A in the non-decoupling regime, even before the new results $\tan\beta$ was already quite restricted, from above by the the LHC limits, and from below by the LEP limits, which can also be seen from Fig. 1. The $m_h^{\rm max}$ value of $X_t = +2M_{\rm SUSY}$ turns out to be quite special, since this parameter region (at least for $M_{\rm SUSY} = 1$ TeV and $M_{\rm SUSY} = 2$ TeV) actually shows the highest sensitivity to variations of $\tan\beta$ when $M_h \sim 125$ GeV. This would result in only a narrow allowed $\tan\beta$ region. For other regions of X_t, however, $\tan\beta$ values all the way up to the LHC bound are compatible with an assumed signal at $M_h \sim 125$ GeV. Further progress could obviously be made if direct information on the stop sector became available from the LHC or a future Linear Collider.

Having established lower limits on the tree-level parameters M_A and $\tan\beta$, we now investigate instead what can be inferred from the assumed Higgs signal about the higher-order corrections in the Higgs sector. Similarly to the previous case, we can obtain an absolute lower limit on the stop mass scale $M_{\rm SUSY}$ by considering the maximal tree-level contribution to M_h. We therefore perform this analysis in the decoupling limit (fixing $M_A = 1$ TeV, $\tan\beta = 20$). The resulting constraints for $M_{\rm SUSY}$ and X_t are shown in Fig. 3 (left) using the same colour coding as before.

Several favoured branches develop in this plane, centred around $X_t \sim -1.5M_{\rm SUSY}$, $X_t \sim 1.2M_{\rm SUSY}$, and $X_t \sim 2.5M_{\rm SUSY}$. The minimal allowed stop mass scale is $M_{\rm SUSY} \sim 300$ GeV with positive X_t

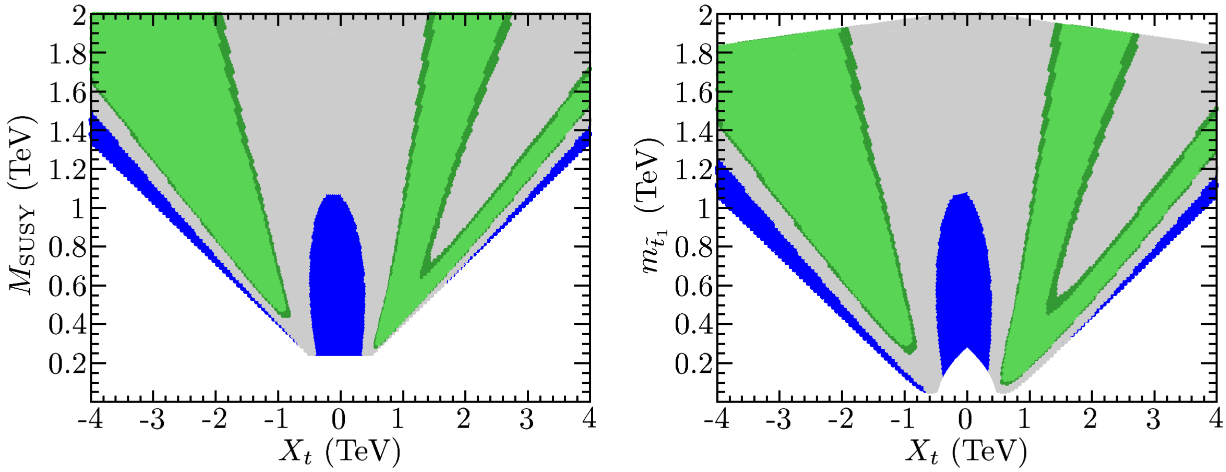

Figure 3: Constraints on the MSSM stop sector from the assumed Higgs signal. The allowed ranges are shown in the (X_t, M_{SUSY}) plane (left) and the (X_t, $m_{\tilde{t}_1}$) plane (right) for $M_A = 1$ TeV, $\tan\beta = 20$. The colour coding is as in Fig. 1.

and $M_{\mathrm{SUSY}} \sim 500$ GeV for negative X_t (which is in general preferred by BR($b \to s\gamma$), see above). The results on the stop sector can also be interpreted as a lower limit on the mass $m_{\tilde{t}_1}$ of the lightest stop squark. This is shown in Fig. 3 (right). It is interesting to note from the figure that without the assumed Higgs signal, there is essentially no lower bound on the lightest stop mass coming from the Higgs sector. Taking the new results into account, we obtain the lower bounds $m_{\tilde{t}_1} > 100$ GeV ($X_t > 0$) and $m_{\tilde{t}_1} > 250$ GeV ($X_t < 0$). These bounds can be compared to those from direct searches, where the LEP limit $m_{\tilde{t}_1} \gtrsim 95$ GeV is still valid [23]. Results from stop searches at the Tevatron can also be found in this reference. No new stop limits have been established so far from the SUSY searches at the LHC [16]. It should be noted that our stop mass bound is rather conservative, since the low mass scales discussed here correspond to a gluino mass $m_{\tilde{g}} = 0.8\,M_{\mathrm{SUSY}} < 300$ GeV, which is experimentally disfavoured [16, 23, 24]. Since the low gluino mass contributes towards a higher value of M_h, a lower bound on $m_{\tilde{g}}$ would lead to a stronger bound on $m_{\tilde{t}_1}$. As an example, in a simplified model consisting just of the gluino, the squarks of the first two generations and a massless lightest supersymmetric particle, the ATLAS Collaboration has inferred a lower bound of about 700 GeV on $m_{\tilde{g}}$ [16]. Imposing such a bound on $m_{\tilde{g}}$ in our analysis would shift the lower limit on $m_{\tilde{t}_1}$ to $m_{\tilde{t}_1} \gtrsim 200$ GeV ($m_{\tilde{t}_1} \gtrsim 350$ GeV) for positive (negative) X_t. It should be noted, however, that in the presence of a light stop decays of the gluino into a top and a scalar top would open up, $\tilde{g} \to \tilde{t}_1 t$, which are expected to weaken the bound on $m_{\tilde{g}}$ as compared to the analysis in the simplified model where this decay mode is assumed to be absent.

A heavy CP-even SM-like Higgs boson

All results presented up until this point apply only if we interpret the assumed signal as corresponding to the light CP-even MSSM Higgs h. We now discuss briefly the alternative possibility that the heavier CP-even H has a mass $M_H \sim 125$ GeV (with the same experimental and theoretical uncertainties as before, see Eq. (1)) and SM-like properties.

In order to investigate whether there is a region in the MSSM parameter space that admits this solution we performed a scan over the relevant free parameters (M_A, $\tan\beta$, M_{SUSY}, X_t), keeping

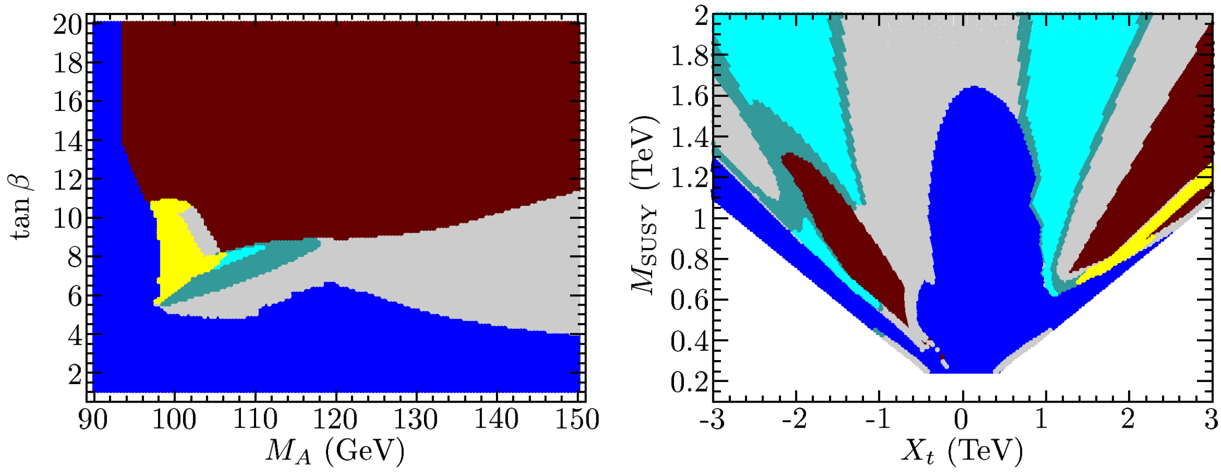

Figure 4: Parameter space in the alternative $M_H \sim 125$ GeV scenario. The colour coding is similar to Fig. 1, with new regions (cyan and yellow) where M_H is in the range compatible with the assumed H signal. In addition, for the yellow region the heavy Higgs has a rate for production times decay into $\gamma\gamma$ of at least 90% of the corresponding SM values. For the plot in the $(M_A, \tan\beta)$ plane (left) we have assumed $M_{\rm SUSY} = 1$ TeV, $X_t = 2.3$ TeV and for the stop parameters (right) we fix $M_A = 100$ GeV, $\tan\beta = 10$. In both cases $\mu = 1$ TeV, and the remaining parameters are given by Eq. (2) with the additional requirement $m_{\tilde{g}} > 700$ GeV.

$\mu = 1$ TeV fixed and the remaining parameters according to Eq.(2). The results are shown in Fig. 4, indicating the region where M_H fulfills Eq. (1) by cyan colour to distinguish it from the case discussed above (similarly to above, the darker region corresponds to the variation of m_t). As we can see from this figure, it is possible to obtain M_H in the right range in a region with low M_A and moderate $\tan\beta$ (left plot) where we have set $M_{\rm SUSY} = 1$ TeV, $X_t = 2.3$ TeV. In the right plot we set $M_A = 100$ GeV, $\tan\beta = 10$ and show the regions compatible with a heavier CP-even Higgs having a mass $M_H \sim 125$ GeV in the plane of the stop sector parameters $M_{\rm SUSY}$ and X_t. We find that such an interpretation is possible over extended regions of the $(M_{\rm SUSY}, X_t)$ parameter plane. Requiring in addition that the production and decay rates into $\gamma\gamma$ and vector bosons are at least 90% of the corresponding SM rates, a smaller allowed region is found (yellow) with large values for the stop mixing ($X_t \gtrsim 1.5$ TeV). In the yellow region enhancements of the rate of up to a factor of three as compared to the SM rate are possible. Concerning the mass of the lighter CP-even Higgs boson h in this kind of scenario we we find in our scan allowed values for M_h only *below* the SM LEP limit of 114.4 GeV [2] (with reduced couplings to gauge bosons so that the limits from the LEP searches for non-SM like Higgs bosons are respected [22]). A particularly intriguing option could be $M_H \simeq 125$ GeV, $M_h \simeq 98$ GeV, in view of the fact that LEP observed a certain excess at $M_h \simeq 98$ GeV [22] (whose interpretation is of course subject to the look–elsewhere effect). This combination of Higgs masses is realized (with H SM-like), for instance, for $M_{\rm SUSY} = 1$ TeV, $X_t = 2.4$ TeV, $\mu = 1$ TeV, $M_A = 106$ GeV, and $\tan\beta = 7$. For this scenario we find a reduced coupling $(g_{hZZ}/g_{HZZ}^{\rm SM})^2 = 0.1$ of the lightest Higgs boson to a pair of Z bosons.

Despite the available parameter space, it should be noted that the scenario where the heavier CP-even Higgs is SM-like and has a mass of $M_H \sim 125$ GeV appears somewhat more contrived than the h interpretation. In particular, we find that simultaneously large values for the μ parameter and a large mixing in the stop sector are required in order to obtain a SM-like rate of production and decay of the heavy CP-even Higgs in the relevant channels. We leave a more detailed investigation of this scenario for future work.

4 Conclusions

An excess in the SM-like Higgs searches at ATLAS and CMS has recently been reported [10] around $M_H^{\rm SM} \simeq 125$ GeV, which within the experimental uncertainties appears to be remarkably consistent between ATLAS and CMS and is supported by several search channels. While it would be premature to assign more significance to this result than regarding it as a possible (exciting) hint at this stage, it is certainly very interesting to note that this excess has appeared precisely in the region favoured by the global fit within the SM, and within the range predicted in the MSSM. Concerning the MSSM, it is remarkable that the mass region above the upper MSSM bound on a light SM-like Higgs is meanwhile ruled out [10]. Observing a state compatible with a SM-like Higgs boson with $M_H^{\rm SM} > 135$ GeV would have unambiguously ruled out the MSSM (but would have been viable in the SM and in non-minimal supersymmetric extensions of it). We therefore regard the reported results as a strong motivation for studying the possible interpretation of an assumed (still hypothetical, of course) signal at 125 GeV $\pm$ 1 GeV. In this paper we have discussed the possible implications of such an assumed signal within the MSSM, where we have investigated both the possibilities that the assumed signal is associated with the light CP-even Higgs boson of the MSSM, h, and the (slightly more exotic) possibility that the assumed signal in fact corresponds to the heavier CP-even Higgs boson H.

Investigating the interpretation $M_h = 125 \pm 1$ GeV first, we have demonstrated that there is a significant parameter space of the MSSM compatible with the interpretation that the assumed signal corresponds to the lighter CP-even MSSM Higgs boson. While it would not be appropriate to assign any physical significance to point densities in MSSM parameter space, our scans nevertheless do not seem to indicate a strong case for going from the MSSM to non-minimal SUSY models even though the reported excess is not very far away from the upper bound on the lightest Higgs mass in the MSSM. It should be noted that the question to what extent the scenarios discussed in this paper can be realized in constrained GUT-based models of SUSY breaking is of a very different nature. We do not pursue this any further here, besides mentioning that it has already been shown to be rather difficult to get to such high M_h values in models such as the CMSSM, mGMSB, mAMSB, or NUHM1 [25].

We performed two kinds of complementary investigations of the implications of an assumed Higgs signal at $M_h = 125 \pm 1$ GeV. Setting the parameters that enter via the (in general) numerically large higher-order corrections in the MSSM Higgs sector to their values in the $m_h^{\rm max}$ benchmark scenario, which maximizes the upward shift in M_h as compared to the tree-level value, we have obtained conservative lower limits on the parameters governing the M_h prediction at tree level, M_A and $\tan\beta$. We have found that an assumed signal of $M_h = 125 \pm 1$ GeV (when including conservatively estimated intrinsic theoretical uncertainties from unknown higher orders, and taking into account the most important parametric uncertainties arising from the experimental error on the top-quark mass) yields the lower bounds $M_A > 133$ GeV and $\tan\beta > 3.2$ (for $M_{\rm SUSY} = 1$ TeV). The bound on M_A translates directly into a lower limit $M_{H^\pm} > 155$ GeV, which restricts the kinematic window for MSSM charged Higgs production in the decay of top quarks.

Choosing values for M_A and $\tan\beta$ in the decoupling region, in a second step we have investigated the constraints on the scalar top and bottom sector of the MSSM from an assumed signal at $M_h = 125 \pm 1$ GeV. In particular, we have found that a lightest stop mass as light as $m_{\tilde{t}_1} \sim 100$ GeV is still compatible with the assumed Higgs signal. The bound on $m_{\tilde{t}_1}$ raises to $m_{\tilde{t}_1} \gtrsim 250$ GeV if one restricts to the negative sign of the stop mixing parameter $X_t \equiv A_t - \mu/\tan\beta$, which in general yields better compatibility with the constraints from BR($b \to s\gamma$).

As an alternative possibility, we have investigated in how far it is possible to associate the assumed Higgs signal with the heavier CP-even Higgs boson H. Performing a scan over M_A, $\tan\beta$, $M_{\rm SUSY}$ and X_t we have found an allowed area at low M_A and moderate $\tan\beta$. A SM-like rate for production and decay of the heavier CP-even Higgs in the relevant search channels at the LHC is possible for large values of μ and large mixing in the stop sector. It is interesting to note that in the scenario where the assumed Higgs signal is interpreted in terms of the heavier CP-even Higgs boson H the mass of the lighter Higgs, M_h, always comes out to be *below* the SM LEP limit of 114.4 GeV (with reduced couplings to gauge bosons so that the limits from the LEP searches for non-SM like Higgs bosons are respected). The fact that scenarios like this are in principle viable should serve as a strong motivation for extending the LHC Higgs searches, most notably in the $\gamma\gamma$ final states, also to the mass region below 100 GeV.

Needless to say, an MSSM interpretation of the observed excess would of course gain additional momentum if the searches for the scalar quarks of the third generation and the direct searches for the colour-neutral SUSY states, which so far have resulted in only very weak limits, would soon give rise to a tantalising excess (or more than one) as well.

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