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Phenomenological MSSM interpretation of the CMS 2011 7 TeV 5 fb^{-1} results

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Abstract. We interpret within the phenomenological MSSM (pMSSM) results obtained by CMS using a *pp* data set collected in 2011 at 7 TeV, corresponding to an integrated luminosity of 5 fb^{-1}. The pMSSM is a 19-parameter realization of the MSSM defined at the SUSY scale, that captures most of the features of the general R-parity conserving weak-scale MSSM. A global Bayesian analysis is performed that yields posterior probability densities of model parameters, masses and observables. We provide conclusions that are more generic, and therefore more robust, than those derived in more constrained setups, including simplified models and models that impose particular SUSY breaking schemes, such as the CMSSM. Our results also comprise implications for the MSSM Higgs sector, as well as for dark matter searches. Furthermore, we discuss which scenarios currently escape detection despite a high production cross section. Our study thus gives a coherent global picture of how the current CMS searches constrain SUSY in general.

1 Introduction

We interpret a set of 7 TeV CMS [1] searches within a 19-dimensional realization of the R-parity conserving MSSM called the *phenomenological MSSM* (pMSSM) [2], defined at the SUSY scale, $M_{\text{SUSY}} \equiv \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$. Assuming no new sources of CP violation or flavor changing neutral currents, and that the first two generations of sfermions are mass-degenerate and their A-terms negligible, the model has 19 free parameters This model captures most of the phenomenological features of the R-parity conserving MSSM, thus allowing very general conclusions about SUSY, conclusions that are more generic, and therefore more robust, than those derived in more constrained setups, including simplified models and models that impose particular SUSY breaking schemes, such as the CMSSM. Our study represents the first global analysis of how the 7 TeV CMS results constrain the MSSM in general, while aiming to make as few assumptions as possible. For a detailed description of this study we refer to its original documentation [3].

2 Analysis

We derive posterior $p(\theta|D)$ densities for pMSSM parameters, masses and other observables:

$$p(\theta|D) \propto L(D^{\text{CMS}}|\theta) L(D^{\text{preCMS}}|\theta) p(\theta).$$

In this formula,

- θ denotes the free parameters in our analysis, namely the 19 pMSSM parameters and 3 Standard Model parameters m_t, $m_b(m_b)$ and $\alpha_s(M_Z)$,
- $p(\theta)$ is the initial prior, which we choose to be flat,
- $L(D^{\text{preCMS}}|\theta)$ is the "preCMS" likelihood, based on theoretical constraints and preCMS data, D^{preCMS}, from measurements of flavor physics observables, the muon anomalous magnetic moment, the masses of the top and bottom quark, the strong coupling constant and sparticle mass limits from LEP. The likelihood is set to zero if the Higgs mass is not between 120 and 130 GeV, if the LSP is not the lightest neutralino or, for technical reasons, if the lightest chargino is long-lived, such that it would lead to a heavy charged particle track.
- $L(D^{\text{CMS}}|\theta)$ is the CMS likelihood, based on data D^{CMS}, from various CMS searches for new physics, listed in Table 1. The considered searches use the CMS *pp* data set collected in 2011 at 7 TeV, corresponding to an integrated luminosity of 5 fb^{-1}. These searches all consist of one or more count experiments, for each of which we construct an approximative likelihood, based on the observations and background predictions documented in the measurements' papers and based on signal predictions obtained from simulation. For each analysis, signal regions are combined if they are exclusive by multiplying the individual likelihoods.

We obtain a discrete representation of the preCMS likelihood by sampling points from $L(D^{\text{preCMS}}|\theta)$ using a Markov Chain Monte Carlo method. The pMSSM parameters are sampled within a 19-D cube in which sparticle masses can go as high as about 3 TeV. The parameters m_t, $m_b(m_b)$ and $\alpha_s(M_Z)$ are constrained only by the preCMS likelihood. About 20 million points are sampled using multiple MCMC chains, from which a random sub-sample of 7205 points are selected for further analysis. The poste-

Table 1. List of implemented CMS analyses, which are used for building the CMS likelihood $L(D^{\text{CMS}}|\theta)$.

Hadronic $H_T + H_T^{miss}$ search	[4]
Hadronic $H_T + E_T^{miss} + b$-jets search	[5]
Hadronic $H_T + E_T^{miss} + \tau$s search	[6]
Hadronic monojet $+E_T^{miss}$ search	[7]
Leptonic same sign (SS) 2ℓ search	[8]
Leptonic opposite sign (OS) 2ℓ search	[9]
Leptonic electroweakino (EWKino) search	[10]

rior density $p(\theta|D)$ is approximated by weighting each of the 7205 selected pMSSM point by $L(D^{\text{CMS}}|\theta)$.

To study which regions in pMSSM parameter space are probed by the considered CMS searches, we define a significance measure $Z(\theta)$,

$$Z(\theta) = \text{sign}\,(\ln \text{B}_{10}(\theta))\,\sqrt{2|\ln B_{10}(\theta)|}, \quad (1)$$

with $B_{10}(\theta)$ the local Bayes factor,

$$B_{10}(\theta) = L(D^{\text{CMS}}|\theta, H_1)/L(D^{\text{CMS}}|H_0), \quad (2)$$

where H_1 denotes the signal plus background hypothesis and H_0 the background only hypothesis. $Z(\theta)$ is a signed Bayesian analog of the frequentist "n-sigma". Values above (below) zero indicate the data favors (disfavors) the background plus signal hypothesis with respect to the background only hypothesis. Small absolute values for $Z(\theta)$ indicate the considered data is insensitive to the signal. The significance of searches is combined by taking the best significance as follows:

$$\begin{aligned} l_{best}(\theta) &\equiv \arg\max_l(|Z_l(\theta)|), \\ Z_{best(\theta)} &= Z_{l_{best}(\theta)}(\theta), \end{aligned} \quad (3)$$

with l running over the indices of the considered searches. We consider a point θ unexplored if: $|Z_{\text{best}}(\theta)| < 2$.

3 Results

Fig. 2 shows the 1D posterior density for the $\tilde{g}$ mass, comparing the preCMS distributions (shown as filled blue histograms) to the distributions after incorporating the results of various CMS analyses (shown as line histograms). Solid curves represent the posterior densities obtained from likelihoods calculated using the central values of predicted signal counts $s(\theta)$, whereas dashed and dotted lines represent the posterior densities obtained from likelihoods calculated using $s - 0.5s$ and $s + 0.5s$, respectively. A 50% uncertainty in s is a conservative estimate of the overall statistical, systematic and theoretical uncertainties. More 1D and 2D posterior distributions for the pMSSM parameters, sparticle masses and several observables were derived for each of the considered CMS analyses, and scrutinized.

In Fig. 1, we plot marginalized probability distributions of the best significance, Z_{best}. The left histogram depicts the preCMS distribution of this quantity[1]. According to our definition, about 63% of the points remain unexplored. The right plot shows the preCMS distribution of Z_{best} for points with cross section greater than 10 fb, which are much more likely to be accessible for the considered data. In this subset, about 45% of the points remains unexplored.

Fig. 3 shows marginalized 1D posterior densities for points with $|Z_{best}| < 2$, compared with the preCMS distributions for selected sparticle masses and the total sparticle production cross section. More 1D and 2D posterior distributions for the pMSSM parameters, other sparticle masses and several observables were derived and scrutinized [3].

[1] In other words, Z_{best} is plotted for the 7205 radomly selected pMSSM points, without weighting with $L(D^{\text{CMS}}|\theta)$.

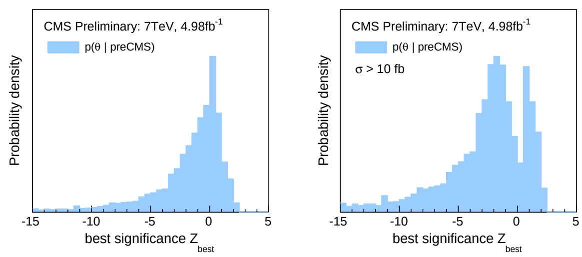

Figure 1. Marginalized probability distributions for the best significance Z_{best}. The left histogram depicts the preCMS distribution of this quantity, the right plot shows the preCMS distribution for points with cross section greater than 10 fb.

4 Conclusions

We have investigated the impact of a subset of the 7 TeV CMS SUSY searches on a potentially accessible sub-space of the pMSSM. The sub-space has been chosen to cover sparticle masses up to about 3 TeV. The implemented analyses span a variety of final states, which, in principle, permit a broad exploration of the pMSSM and by association the MSSM in general.

The hadronic 2011 CMS analyses have a significant impact on the allowed values of the gluino and light-flavor squark masses, but third-generation squarks are much less affected. The leptonic analyses do not have a noticeable effect, largely because the region of the pMSSM parameter space to which they could be sensitive is limited.

We characterized the region in pMSSM parameter space that remains unexplored despite high cross sections, through signal decomposition into Simplified Model Spectra, as described in the original documentation of this study [3]. Moreover we discussed the consequences for the SUSY Higgs sector and for dark matter.

References

[1] S. Chatrchyan *et al.* [CMS Collaboration], JINST **3**, S08004 (2008).

[2] A. Djouadi *et al.* [MSSM Working Group Collaboration], hep-ph/9901246.

[3] [CMS Collaboration], CMS-PAS-SUS-12-030 (2013).

[4] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. Lett. **109**, 171803 (2012)

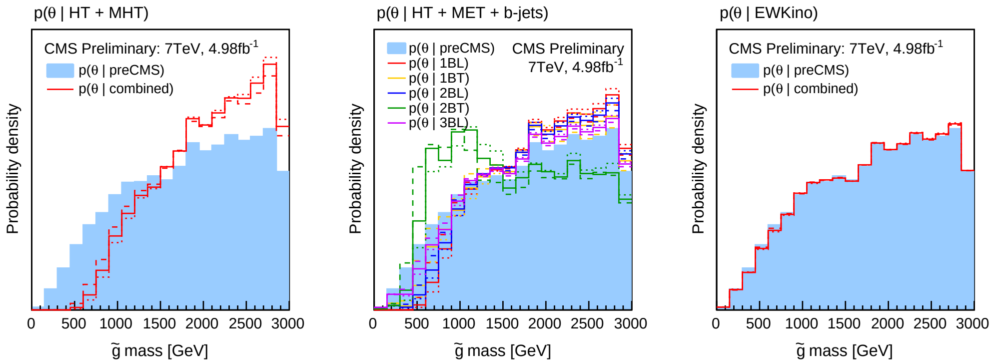

Figure 2. Marginalized 1D posterior probability distributions for $\tilde{g}$ mass. The line histograms in the three plots show posterior densities after including the three of the seven implemented CMS analyses: $H_T + H_T^{miss}$, $H_T + E_T^{miss} + b$-jets and EWKino. Within each analysis, different search regions are combined if they are exclusive, or shown separately otherwise. Solid curves show the posterior densities obtained from likelihoods calculated using the central values of estimated signal counts s, whereas the dashed and dotted lines show the posterior densities obtained from likelihoods calculated using $s - 0.5s$ and $s + 0.5s$ respectively.

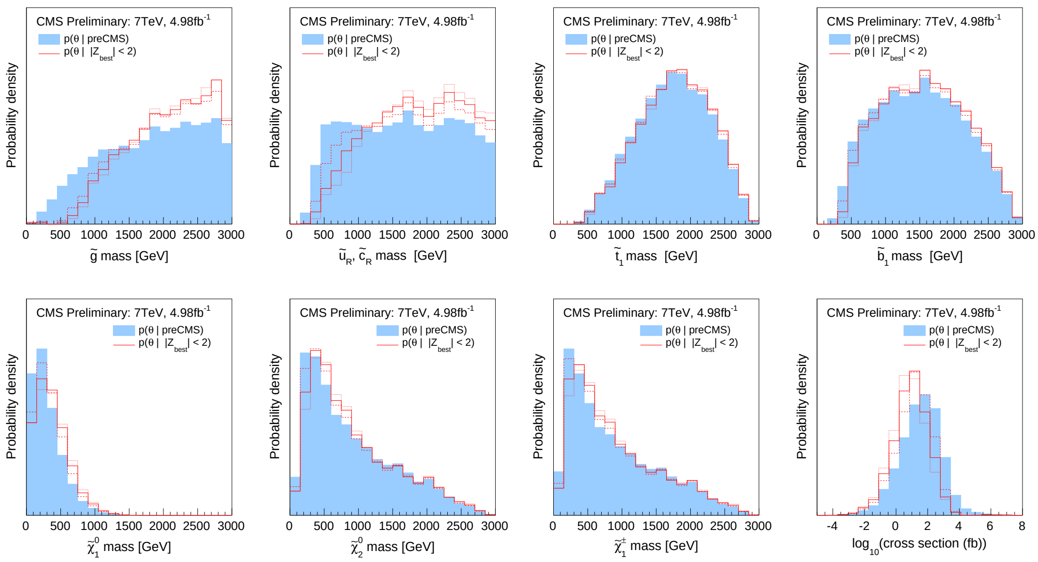

Figure 3. Marginalized 1D posterior densities for selected sparticle masses and total sparticle production cross section. The filled blue histograms in each plot show the posterior densities after preCMS measurements. The line histograms show the normalized distributions of points that have best significance $|Z_{best}| < 2$, i.e., points that are not excluded. The solid curves show the distributions obtained from likelihoods (and significances) calculated using the central values of estimated signal counts s, while the dashed and dotted lines show the distributions obtained from likelihoods (and significances) calculated using $s - 0.5s$ and $s + 0.5s$, respectively.

[5] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. D **86**, 072010 (2012)

[6] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1301.3792 [hep-ex].

[7] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1209**, 094 (2012)

[8] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. Lett. **109**, 071803 (2012)

[9] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Lett. B **718**, 815 (2013)

[10] S. Chatrchyan *et al.* [CMS Collaboration], JHEP **1211**, 147 (2012)