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Search for neutral MSSM Higgs bosons at CMS

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Summary. — Results on the search for neutral Higgs bosons, in the context of the Minimal Supersymmetric extension of the Standard Model (MSSM), are presented. Different decay channels and final states are considered, including the production of the bosons in association with additional b-quarks and their decay into tau, muon, and b-quark pairs. The exclusion limits are presented in the MSSM m_A *vs.* $\tan\beta$ parameter space. The searches are performed on data samples collected with the Compact Muon Solenoid (CMS) detector at the Large Hadron Collider (LHC) during the 2011 and 2012 data taking periods, in proton-proton collisions at the center-of-mass energy of 7 TeV and 8 TeV, respectively.

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1. – Introduction

The recent discovery of a boson in the search for Standard Model (SM) Higgs by the CMS [1] and ATLAS [2] collaborations at the LHC is possibly the last missing stone of the SM. However, the SM is known to have some open issues, and numerous extensions have been proposed; the Minimal Supersymmetric Standard Model (MSSM) is a minimal extension of the SM involving SuperSymmetry (SUSY). In this document a summary of the searches of MSSM Higgs boson signals in a variety of final states with the CMS experiment [3] is provided.

2. – Search for $\Phi \to \mu^+\mu^-$

The search of the $\Phi \to \mu^+\mu^-$ process [4], where Φ denotes collectively the three neutral Higgs bosons, has been so far performed on the 2011 data sample, consisting of $4.96\,\text{fb}^{-1}$ of data at $\sqrt{s} = 7\,\text{TeV}$. Candidates are experimentally characterized by the presence of two isolated, oppositely-charged muons, whose invariant mass would correspond to the mass of the boson. Events are assigned to three exclusive categories, motivated by the two main production modes: *Category 1* collects events with at least one jet identified by an appropriate tagging algorithm; such events are candidates for the Higgs associated

production with b-quarks. *Category 2* events have a third additional soft muon, a possible signature of a b-quark semileptonic decay. Events that do not belong to the previously described cases fall into *Category 3*, enhancing the sensitivity to the gluon-gluon fusion production process.

The search for a Higgs signal and the exclusion limit calculation is performed for *Category 1*, *2*, and *3* by independently fitting the di-muon invariant mass distribution. The limit on the rate is interpreted as a limit on the cross section times branching ratio, and projected on the MSSM m_A-tan β parameter space in the m_h-max benchmark scenario [5], where m_A is the mass of the pseudoscalar boson and tan β the ratio of the vacuum expectation values of the two Higgs doublets. For the combination of the three categories, a region above $\tan\beta \approx 20$ can be excluded for $m_A \lesssim 180\,\text{GeV}$.

3. – Search for $\Phi \to b\bar{b}$

The search of low-mass MSSM Higgs bosons in the *all-hadronic* [6] channel is based on a data sample of $2.7\,\text{fb}^{-1}$ collected in 2011, and makes use of jet triggers with an online b-tagging algorithm; an additional sample ($L = 4.0\,\text{fb}^{-1}$) with higher jet thresholds aims at Higgs masses above 180 GeV. The *semi-leptonic* [7] channel exploits the frequent presence of a soft muon in the event to lower the trigger thresholds on jets. Both analysis require at least three jets b-tagged with a combined secondary vertex algorithm in the offline selections, in order to enhance the sensitivity to the b-quark associated production process.

The *all-hadronic* analysis derives a background model from templates built from the different combinations of the three jets being tagged, where the signal yield is small; then, the b-tagging probabilities of the selected jets are determined for each flavor as a function of the jets kinematic variables. The signal fraction is extracted from a two-dimensional fit to the invariant mass distribution of the two leading jets and an additional variable that takes into account the number of tagged jets.

In order to estimate the large QCD background, the *semi-leptonic* analysis requires the two leading jets to be tagged, and b-tagging probability matrices for the third jet are

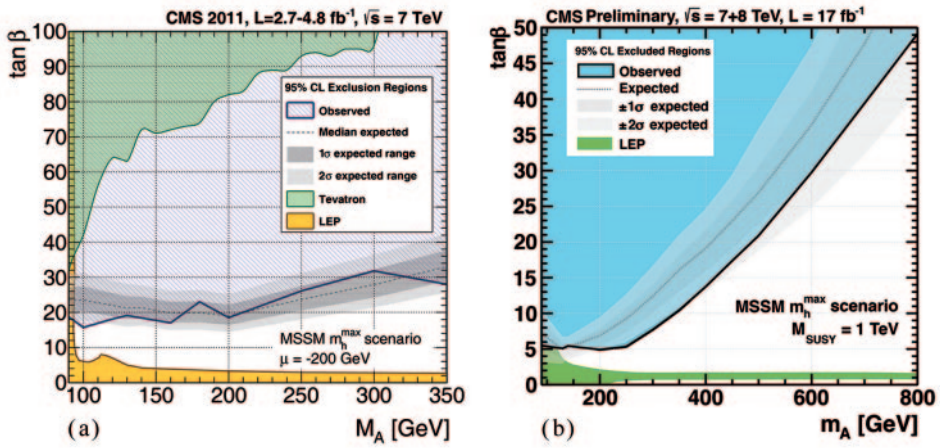

Fig. 1. – Exclusion limit at 95% CL for the $\Phi \to b\bar{b}$ (left) and $\Phi \to \tau\tau$ channels (right) in the MSSM m_A-tan β parameter space in the m_h-max scenario.

built fitting two discriminating variables. This procedure allows to reweigh the double-tagged data spectrum to predict the three-tagged distribution. Another independent data-driven method, based on a customized nearest-neighbor algorithm, predicts the background shape in the three-tagged sample using events with one b-tag.

The limits of the two channels are combined [8], taking into account the small overlap ($\sim 2\%$) of events. Results are reported in fig. 1(a); no significant deviation is observed, not confirming the excess seen by Tevatron for m_A values around 150 GeV [9].

4. – Search for $\Phi \to \tau\tau$

The MSSM $\Phi \to \tau\tau$ search [10] uses the 2011 data sample ($4.9\,\text{fb}^{-1}$ at $\sqrt{s} = 7\,\text{TeV}$) plus additional $12.1\,\text{fb}^{-1}$ collected at $\sqrt{s} = 8\,\text{TeV}$ in 2012. Four different final states are considered ($e\tau_h$, $\mu\tau_h$, $e\mu$, $\mu\mu$) each divided into two categories depending on the presence of at least one additional b-tagged jet in the event. The offline event selection requires one isolated lepton (e, μ), an hadronically-decaying τ or an additional lepton (e, μ); in order to reduce electroweak backgrounds a veto is set for additional leptons. The τ-pair mass is reconstructed using a maximum likelihood technique which computes the most compatible mass with the visible τ momenta and the reconstructed missing transverse energy. The algorithm yields a τ-pair mass distribution consistent with the true value and a width of 15-20%. To search for the presence of a Higgs boson signal, a fit to the τ-pair invariant mass spectrum is performed simultaneously for the two categories and the four final states. Figure 1(b) shows the resulting exclusion region in the m_A-$\tan\beta$ plane; no excess over the SM backgrounds is found.

5. – Summary

The analysis of the three considered channels shows no evidence of MSSM Higgs bosons. The $\tau\tau$ channel has proven to be the most sensitive, the other channels being penalized by overwhelming QCD backgrounds ($b\bar{b}$) and the low rate ($\mu\mu$). New interesting results are expected once the full 2012 dataset is analyzed, but a definitive answer whether the MSSM is the model chosen by Nature or not will have to wait after the resuming of LHC operations in 2015.

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