Searches for Non-Standard Model Higgs Bosons at CMS

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These proceedings report the results on the Higgs Searches beyond the Standard Model at the CMS experiment with data collected during the 2011 LHC run at 7 TeV, corresponding to an integrated luminosity of about 5 fb^{-1}. Many analyses performed by the CMS collaboration are reviewed and results for several models are shown. Most of these analyses are based on the same signature, like a resonance in the invariant mass of two b-quarks, muons or taus or an excess in the $\gamma\gamma$ spectrum. No significant deviation from the Standard Model is found and limits on the Higgs mass are set for each physics scenario.

1 Introduction

The Standard Model (SM) of Particle Physics describes very precisely the experimental measurements up to now but one of its key ingredients has not yet been observed: the Higgs boson, which is at the source of the electro-weak symmetry breaking and provides a mechanism to assign mass to particles. It is clear, however, that the SM theory breaks at larger scales and some major open points are the unification of couplings, hierarchy problem, dark matter issue and neutrino masses. Theories have been proposed that attempt to answer to some of these open questions such as supersymmetry (SUSY) or other Beyond Standard Model (BSM) scenarios and are currently under experimental test. The CMS experiment, a multi-purpose detector [1] operating at the CERN LHC pp collider, has been designed to investigate a wide range of physical phenomena. In these proceedings, the latest BSM Higgs searches at the CMS experiment will be briefly described. These results are achieved by the CMS collaboration with datasets collected in 2011 with a corresponding luminosity of about 5 fb^{-1}.

2 The MSSM Higgs

In the Minimal Supersymmetric Standard Model, the standard scalar Higgs boson is substituted by three neutral ϕ = (h,H,A) and two charged ($H^{\pm}$) Higgs particles. Neutral MSSM Higgs

bosons are searched in the ditau final state. In the MSSM, all decays to "down-type" fermions are enhanced by a factor of tanβ. For relatively high tanβ the BR ($\phi \rightarrow \tau^+\tau^-$) is about 10% which is much lower then the corresponding branching ratio of the b-decay mode. The ditau channel is however preferred for its clear signature in the two leptons final states (electrons or muons) and in the lepton plus an hadronic decaying τ final state. The signature is an isolated high p_T lepton and a hadronic τ or an opposite sign lepton. The dilepton channel was searched in dimuons and in electron-muon final states. The hadronic τ is reconstructed in 1 and 3 prongs (+N π^0). The background is mostly due to Z decays, W+jets and $t\bar{t}$ with a lower contribution of WW and ZZ decays. A kinematic fit is applied on the reconstructed Higgs mass, in order to take into account the missing energy, with an improvement of about 20% on the measured mass [2]. In fig. 1 is shown the exclusion plot for the neutral MSSM Higgs mass versus tanβ. For tanβ = 20 Higgs masses up to 300 GeV/c^2 are excluded.

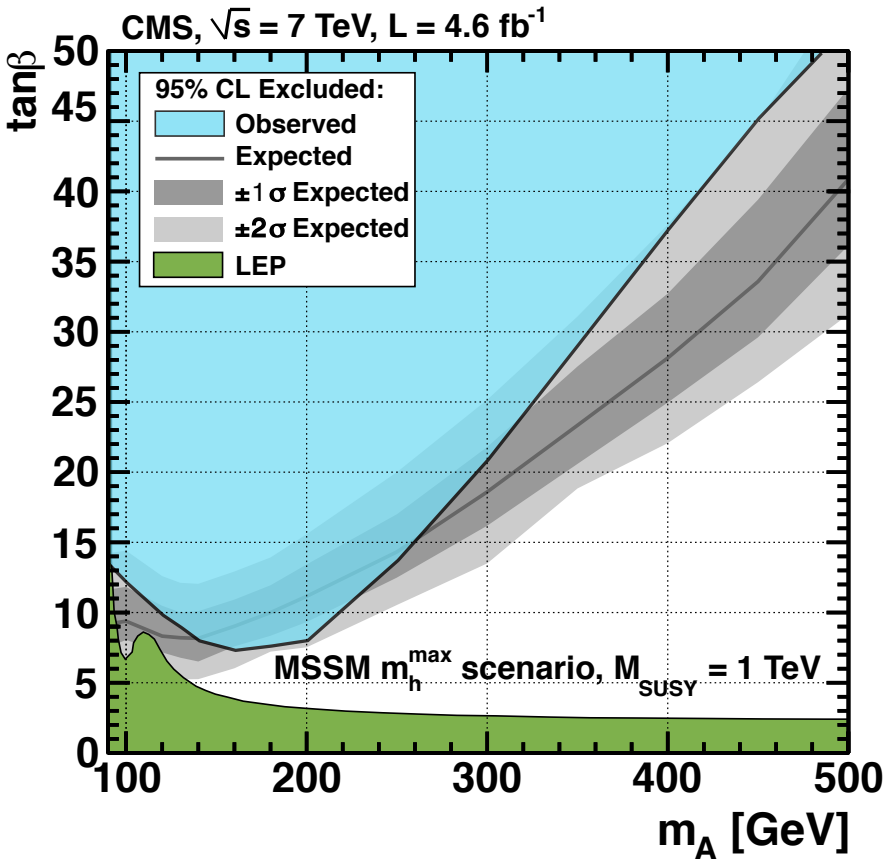

Figure 1: Region in the parameter space of tanβ versus m_A excluded at 95% CL in the context pf the MSSM scenario. The expected one- and two-standard-deviation ranges and the observed 95% CL upper limits are shown together with the observed excluded region.

The charged MSSM Higgs bosons are searched in the top decays $t \rightarrow H^+$ with the tau final states a $H^+ \rightarrow \tau^+\nu$. The $t\bar{t}$ production yields with tau final states are modified by Higgs diagrams if the Higgs mass is lower than the top mass. The Higgs particle is searched in isolated τ decays plus b-jets and possibly an isolated lepton in the final state, depending on the second top decay chain in the $t\bar{t}$ events. The analysis is described here [3] and results on BR($t \rightarrow H^+$) are shown in fig. 2 and fig. 3 together with the mass limits. Values of BR($t \rightarrow H^+$) $> 4\%$ are excluded for all the possible Higgs mass values.

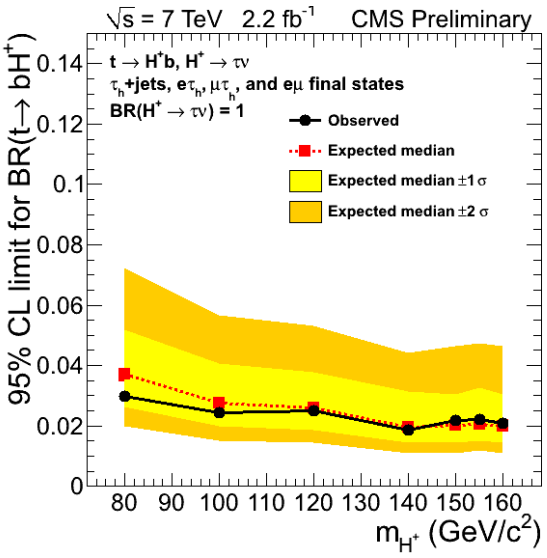

Figure 2: Upper limit on BR(t $\rightarrow$ H$^+$) assuming BR($H^+ \rightarrow \tau^+\nu$)=1 as a function of m(H$^+$). The yellow bands show the one and two sigma bands around the expected limit.

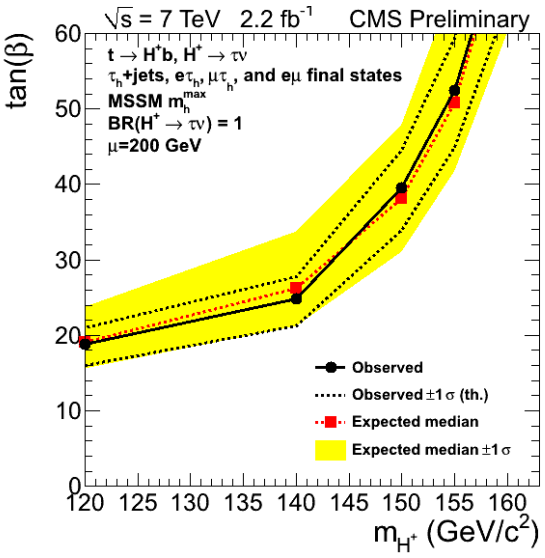

Figure 3: Exclusion plot of the H$^+$ mass vs tanβ obtained for the MSSM scenario.

3 Doubly charged H$^{\pm\pm}$

These exotic Higgs bosons are predicted within the "type II" see-saw model and are related to the presence of a light neutrino mass. H$^{\pm\pm}$ decay to two same charged resonant leptons and obviously do not have any physical background in the Standard Model. They are produced in pairs or together with a single charged Higgs through the processes: Z/$\gamma^* \rightarrow H^{++}H^{--}$ and W$^+$ $\rightarrow H^{++}H^-$ (charge conjugates included), giving a final states with four or three leptons, same charge resonant. No excess is observed in the CMS data. In fig. 4 the invariant mass of the same charge leptons is shown for the 3 leptons analysis. Fig. 5 shows the mass limits for the different leptonic final states and four benchmark points of the see-saw mechanism described in [4].

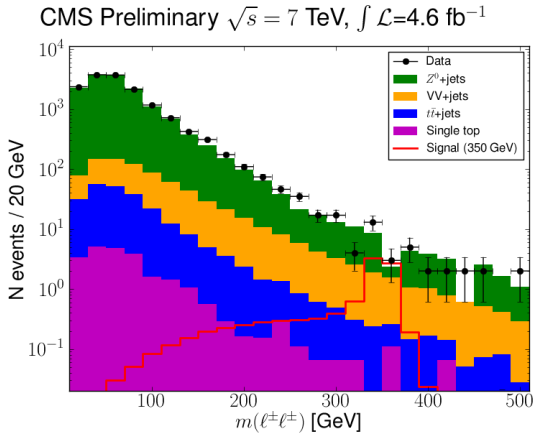

Figure 4: Invariant mass distribution from three lepton final state for backgrounds and data. We also show the expected contribution of a H^{++} with a mass of 350 GeV

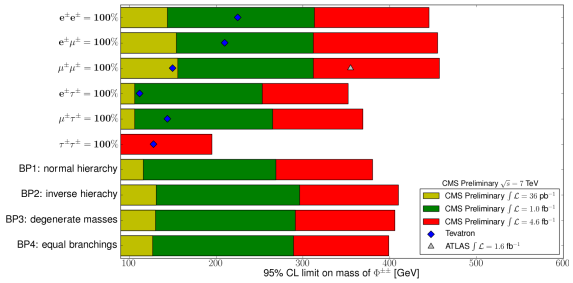

Figure 5: Limits on the mass of the doubly charged Higgs bosons for different final states

4 Light pseudoscalar Higgs boson

The presence of a light pseudoscalar CP-odd Higgs a is predicted within the Next to Minimal Supersymmetric extension to the Standard Model. This search [5] has been performed in the sidebands of the $\Upsilon \rightarrow \mu^+\mu^-$ dimuon decays, namely $5.5 < M(\mu\mu) < 9$ GeV/c^2 and $11.5 < M(\mu\mu) < 14$ GeV/c^2. A special high level trigger conceived for charmonium states studies was set up and this analysis was performed with a data sample corresponding to a luminosity of 1.3 fb^{-1}. Results are shown in fig. 6 with no excess found in the dimuon spectrum. An upper limit on the cross-section $\sigma(pp \rightarrow a \rightarrow \mu^+\mu^-)$ below 5 pb is set for all the masses in the two search intervals.

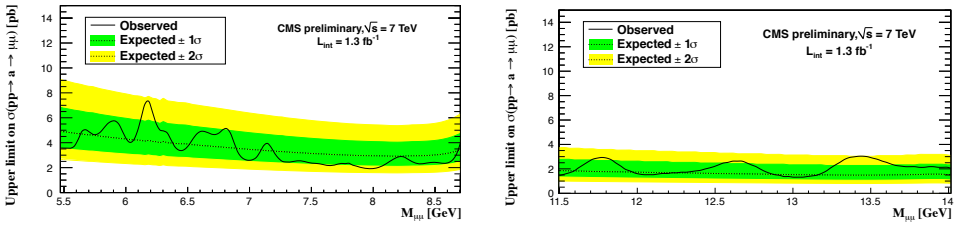

Figure 6: Limits on the cross-section $\sigma(pp \rightarrow a \rightarrow \mu^+\mu^-)$ for the two mass intervals in the Υ sidebands

5 Fermiophobic Higgs boson decays

In the Fermiophobic model the gluon-gluon process of Higgs production is forbidden and the production cross-section is suppressed by an order of magnitude with the Vector Boson Fusion (VBF) and the Higgs-strahlung (VH) that become the two most important contributions to Higgs production. On the other hand, the diphoton decay $H \rightarrow \gamma\gamma$ is enhanced by another order of magnitude, with the result of a total $\sigma\times$ BR that is of the same size of the standard Higgs diphoton decays . This analysis is based on the selection of two high p_T photons and three tag classes with electron, muon or dijets in the final states [6] corresponding to different decays in the associate production. Furthermore four inclusive samples based on different Ecal regions and leading to four different Higgs mass resolutions are taken into account. The results are presented in fig. 7 and show a small excess at 126 GeV/c^2 corresponding to 2.7σ of local significance, reducing to 1.2σ of global significance taking into account of the "Look Elsewhere" effect. Two intervals of Higgs mass are excluded @95% of C.L.: $110 < M_H < 124$ GeV/c^2 and $128 < M_H < 136$ GeV/c^2. The excess at 126 GeV/c^2 is even more diluted when the diphoton channel is combined[7] with $H \rightarrow WW, ZZ$ as shown in fig. 8.

6 Other results

Other results to be mentioned here are the analysis of the long lived neutrals [8] where the Higgs particle is searched in exotic neutral particles decaying at long distance from the beam-line and Standard Model SM4 extensions searches obtained including a fourth quark generation [7] that significantly increase the Higgs bosons production rate. The SM4 model is excluded @95% CL from 120 up to 600 GeV/c^2 of Higgs masses.

7 Conclusions

A broad program of BSM Higgs bosons searches with CMS has been presented in this talk. Model independent inclusive searches together with well defined new physics scenarios have

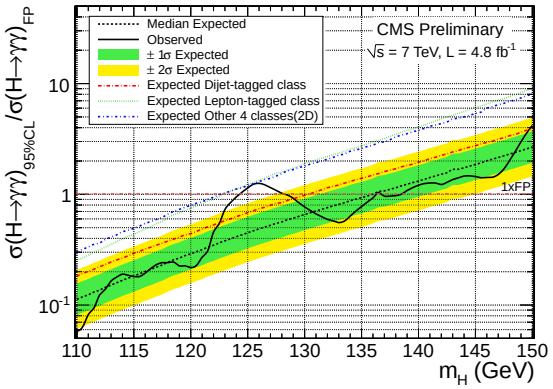

Figure 7: The 95% CL upper limits on the signal strength parameter $\mu = \sigma/\sigma_{FP}$ for the fermiophobic Higgs boson hypothesis as function of the Higgs boson mass for the di-photon channel. The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The limits are obtained with the asymptotic CLs approximation.

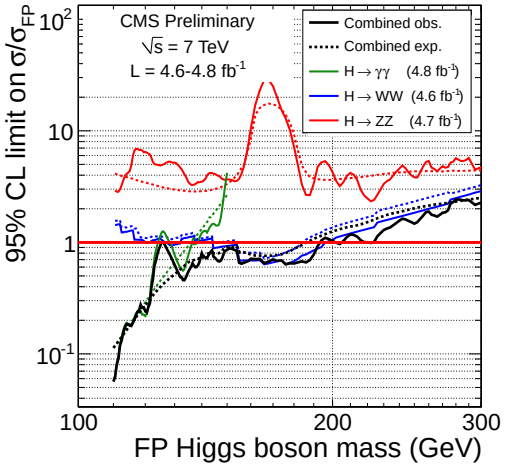

Figure 8: The 95% CL upper limits on the signal strength parameter $\mu = \sigma/\sigma_{FP}$ for the fermiophobic Higgs boson hypothesis as function of the Higgs boson mass for the three explored Higgs boson decay modes and their combination. Observed limits are shown with solid lines, while expected limits are shown with dashed lines. The limits are obtained with the asymptotic CLs approximation.

been probed during 2011 with a luminosity of about 5 fb^{-1}. A large fraction of the MSSM Higgs parameters are constrained by the $H \to \tau^+\tau^-$ analyses. A small excess on the $H \to \gamma\gamma$ is registered, compatible with a statistical fluctuation. No evidence for new BSM Higgs bosons is observed. The 2012 run, with about 15 fb^{-1} of data collected, will help to improve these searches.

References

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