Prospect for Higgs searches in CMS with 1 fb^{-1} at 7 TeV and CMS performance validation with early data

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We overview the prospects for Higgs boson searches with a data sample of 1 fb^{-1} to be collected in pp-collisions at 7 TeV. We present sensitivity projections for SM-like decay modes $H \to WW \to 2\ell 2\nu$, $H \to ZZ \to 4\ell$, $H \to \gamma\gamma$ (including their combination), the MSSM-like signature $pp \to bb\Phi \to bb(\tau\tau)$ and we discuss a few other possible models/searches.

1 Introduction

The search for the Higgs boson is one of the main goals of the CMS experiment at the Large Hadron Collider. Limits on its mass have been set: LEP excluded the region $m_H < 114.4$ GeV at 95% C.L. and TeVatron recently did the same in the range $162 < m_H < 166$ GeV. Moreover, unitarity constraints require the Higgs mass to be lower than 1 TeV. The whole m_H range will therefore be explored at the LHC.

The discovery and exclusion sensitivities for Higgs searches with CMS had already been shown in a $\sqrt{s} = 14$ TeV, $L = 1 \div 30$ fb^{-1} scenario. The results presented here (see also [1]) are obtained by projecting those calculations to $\sqrt{s} = 7$ TeV, $L = 1$ fb^{-1}. Details on how this projection was performed are given.

2 Projections to $\sqrt{s} = 7$ TeV

Projections from 14 TeV to 7 TeV have been performed according to the following prescriptions.

The event yields for both the signal and the backgrounds have been rescaled by the ratio of the corresponding cross sections, $\frac{\sigma(7\ TeV)}{\sigma(14\ TeV)}$, and projected to an integrated luminosity of $L = 1$ fb^{-1}. No corrections have been applied to take into account the (up to $\sim 20\%$) higher acceptance of the detector at 7 TeV, due to the fact that particles are less forward-boosted at 7 TeV than at 14 TeV. The improvements in the detector simulation and in the reconstruction performances achieved after the 14 TeV analysis was published have not been considered either.

The systematic errors obtained from control samples have been rescaled by $1/\sqrt{N}$, where N is the number of events in the sample. Some other uncertainties, like the theoretical ones, have been left unchanged, whereas other ones have been inflated because of poorer statistics in the datasets.

The statistical analysis uses the re-evaluated event counts and uncertainties. The 95% C.L. exclusion studies have been carried out by applying the Modified Frequentist method [4], while the significances have been calculated with the Profile Likelihood method [5].

3 Projections for each search channel

3.1 Results for $H \to WW \to 2\ell 2\nu$

The signature of this channel is given by 2 isolated high-p_T leptons, along with missing E_T and the absence of jets in the central rapidity region. No Higgs mass peak can be looked for, because of the missing E_T, therefore one has to use counting experiments and the transverse mass M_T of the $2\ell 2\nu$ system.

The most important backgrounds for this channel are WW, Wt, $t\bar{t}$, WZ, ZZ and Drell-Yan processes. The WW background can be reduced by cutting on $\Delta\Phi_{\ell\ell}$, the angle between the 2 isolated leptons in the transverse plane. This angle tends to be larger for WW events than for signal ones. The Drell-Yan, WZ and ZZ backgrounds can be identified by checking if the invariant mass of the di-lepton pair is close to the Z mass peak. The $t\bar{t}$ background can be rejected by applying a 'central jet veto'.

The projection is derived using results published in [2]. Figure 1 shows the sensitivity for Higgs exclusion at 95% C.L. in this channel. The excluded m_H range is $150 < m_H < 185$ GeV. As shown in Fig. 2, a 5σ discovery is expected to be reached in the mass range $160 < m_H < 170$ GeV.

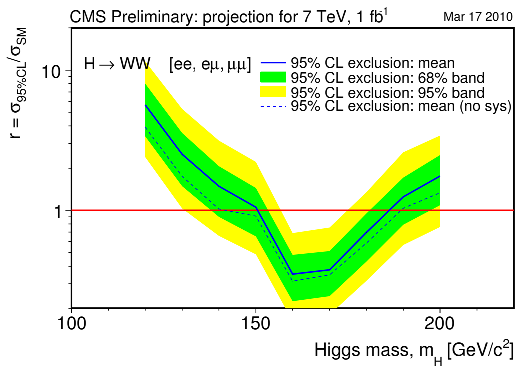

Figure 1: Exclusion plot for the $H \to WW \to 2\ell 2\nu$ channel, for $\sqrt{s} = 7\ TeV$ and $L = 1\ fb^{-1}$, assuming absence of signal.

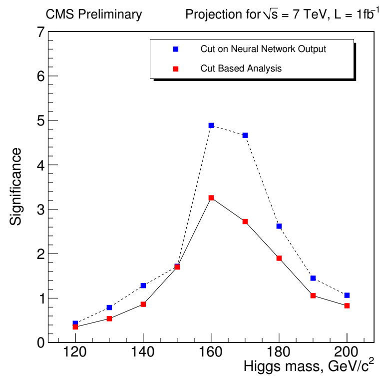

Figure 2: Expected significance for the $H \to WW \to 2\ell 2\nu$ channel as a function of m_H, for $\sqrt{s} = 7\ TeV$ and $L = 1\ fb^{-1}$.

3.2 Results for $H \to ZZ \to 4\ell$

This is the *'golden channel'* since its signature is very clear: two pairs of opposite-charge, same-flavour, high-p_T isolated leptons. Moreover, the invariant mass of the lepton pairs tends to be close to m_Z.

The main backgrounds are ZZ, $Zb\bar{b}$, $t\bar{t}$, W/Z+jets, QCD. The invariant mass $m(4\ell)$ in ZZ events does not peak around any value, therefore it is a good discriminant. The $Zb\bar{b}$ and $t\bar{t}$ backgrounds can be reduced by cutting on isolation variables and on the impact parameter significance of the leptons.

The projection is derived using results published in [3]. The plot in Fig. 3 shows that the SM Higgs exclusion is out of reach in the whole m_H range. However, in case a fourth generation of quarks exists, the Higgs boson could be excluded in the region $m_H \lesssim 420$ GeV.

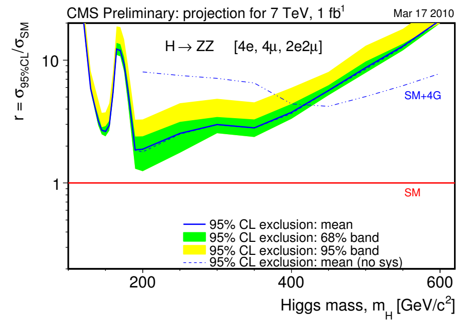

Figure 3: Exclusion plot for the $H \to ZZ \to 4\ell$ channel, for $\sqrt{s} = 7\ TeV$ and $L = 1\ fb^{-1}$.

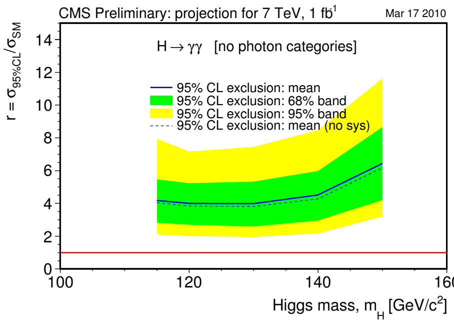

Figure 4: Exclusion plot for the $H \to \gamma\gamma$ channel, for $\sqrt{s} = 7\ TeV$ and $L = 1\ fb^{-1}$.

3.3 Results for $H \to \gamma\gamma$

The analyses in this channel require two isolated photons. The projection presented here is for a generic search for a narrow $\gamma\gamma$resonance, since nothing specific to the SM Higgs boson was used in this study. The large QCD background is estimated from sidebands.

In Fig. 4 one can see the m_H exclusion limits for this channel. The exclusion is not possible anywhere in the mass range, However, if the Higgs is *fermiophobic*, it can be ruled out in the region $m_{hf} < 110$ GeV.

3.4 Combination of the SM channels

By combining the results shown in the previous paragraphs 3.1, 3.2, 3.3 about SM Higgs, one gets the plot in Fig. 5. The expected exclusion mass range is $145 < m_H < 190$ GeV.

3.5 Results for $pp \to bb\Phi \to bb\tau^+\tau^-$

In this MSSM channel, isolated pairs of τ leptons are looked for, namely (τ_μ, τ_e), (τ_{had}, τ_e), (τ_{had}, τ_μ). The collinear approximation is applied to calculate $m(\tau\tau)$: the ν's are supposed to be collinear to the τ's. If missing E_T is there, one checks if a tagged b-jet is present and vetoes any other jets. The events are counted in a sliding $m(\tau\tau)$ window and the main backgrounds, which are $t\bar{t}$, $Zb\bar{b}$, $Zc\bar{c}$, are estimated in a data-driven way.

The plot in Fig. 6 shows the projected discovery and exclusion contours in the $(m_A,\ tan\beta)$ plane. At low m_A values, such as $m_A \sim 90$ GeV, the discovery is expected to be possible for $tan\beta > 20$ and the exclusion for $tan\beta \sim 15$.

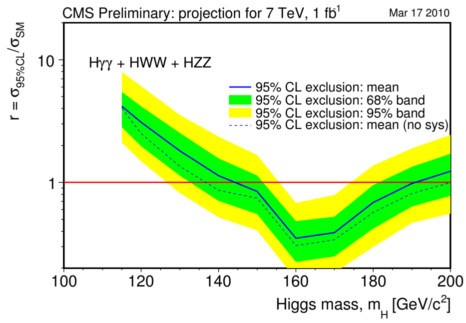

Figure 5: Expected exclusion limits for the combination of the channels, assuming absence of signal, for $\sqrt{s} = 7\ TeV$ and $L = 1\ fb^{-1}$.

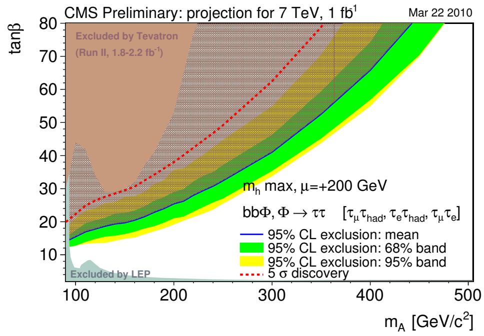

Figure 6: Expected exclusion limits for the $H \to \gamma\gamma$ channel, for $\sqrt{s} = 7\ TeV$ and $L = 1\ fb^{-1}$.

4 Conclusions

The prospects for Higgs searches with CMS have been presented in the $\sqrt{s} = 7$ TeV, $L = 1\ fb^{-1}$ scenario. A brief description of the analysis strategies in the different channels has been given and the expected reach for both exclusion and discovery has been outlined.

References

[1] The CMS Collaboration, CMS Note 2010-008

[2] The CMS Collaboration, *"Search Strategy for a Standard Model Higgs Boson Decaying to Two W Bosons in the Fully Leptonic Final State"*, CMS PAS-HIG-08-006.

[3] The CMS Collaboration, *"Search strategy for the Higgs boson in the $ZZ^{(*)}$ decay channel with the CMS experiment"*, CMS PAS-HIG-08-003.

[4] A. L. Read, "Modified frequentist analysis of search results (the CLs method)", CERN-OPEN-2000-205; also, J. Phys. G 28, 2693 (2002).

[5] e.g., Thomas Alan Severini, Likelihood methods in statistics (Oxford University Press, 2000).