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ATLAS Higgs Sensitivity for 1fb^{-1} of data at the LHC running at 7 TeV

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The Standard Model Higgs boson discovery potential of ATLAS for individual final states, such as photon, W and Z boson pairs, as well as for combined channels, is reported. The results are based on re-scaling expectations from detailed analysis at 10 or 14 TeV using cross-section ratios and are presented for an integrated luminosity of 1fb^{-1} at 7 TeV center of mass energy at the Large Hadron Collider. The discovery potential for a pair of charged Higgs bosons and a pseudoscalar Higgs boson introduced by the Minimal Supersymmetric Standard Model is also presented for 1fb^{-1} at 7 TeV.

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1. Standard Model Higgs Search

The Higgs mechanism is a proposed solution to the electroweak symmetry breaking mystery which predicts, in the Standard Model (SM), the existence of an undiscovered scalar particle. LEP results have led to a lower bound on a SM Higgs boson mass of 114.4 GeV [1]. The Tevatron has recently excluded the SM Higgs boson in the mass range between 158 and 175 GeV, and between 100 and 109 GeV [2]. The discovery of the Higgs boson is the key to finding out the origin of mass of fundamental particles. It is the primary physics goal of the LHC physics program. The LHC plan is to deliver 1fb^{-1} of integrated luminosity at 7 TeV center of mass energy before work to increase the energy. The discovery potential of this condition is evaluated based on the detailed 10 TeV and 14 TeV analyses [3, 4, 5] using the cross-section ratio of 7 TeV to 10 or 14 TeV. The cross-sections of signal and background processes are taken at NLO in order to conform to the same perturbative order. In the LHC, The SM Higgs boson is produced via the gluon fusion process whose cross-section is 10 times higher than at the Tevatron and also produced via Vector Boson Fusion (VBF) process. The promising decay modes for the search of the SM Higgs boson are $WW/ZZ(b\bar{b}/\tau\tau/\gamma\gamma)$ in high (low) mass range $\geq(\leq)$ 135 GeV.

One of most promising channels is $H \to WW \to l\nu l\nu$ since the gluon fusion process which has the highest production cross-section can be used due to the relatively clean final state. The analysis for each jet bin (0,1,2 jets) is separately performed to maximize sensitivity. Gluon fusion process is dominant signal in the 0 jet/1 jet analysis and VBF process is dominant in the 2 jet analysis. The dominant background process is SM WW and W+jets where one jet fakes a lepton in the 0 jet analysis and top in 2 jet analysis. The background is estimated from control regions selected with one background dominant in each. Figure 1 (left) shows the expected 95% confidence level (C.L.) upper limit on the Higgs boson production cross-section normalized to the SM cross-section for each integrated luminosity. In the most favourable case of M_H = 160 GeV, a minimum of $\sim$ 250 pb^{-1} is required to be sensitive to the SM Higgs boson. For an integrated luminosity of 1fb^{-1} data, the WW channel can exclude the SM Higgs boson in the mass range of 145-185 GeV at 95% C.L.

Experimentally, the $H \to ZZ \to 4l$ channel has the cleanest signature for the search for the Higgs boson. An excellent energy and momentum resolution for reconstructed electrons and muons leads to a narrow four-lepton invariant mass peak on the top of a smooth background. In the high mass region ($M_H > 180$ GeV), the major background is the irreducible $ZZ^{(*)} \to 4l$ process because the two on-shell Z boson signature strongly suppresses any reducible background, while the irreducible backgrounds from Z+jets and $t\bar{t}$ are more important in low mass region ($M_H <$ 180 GeV). These irreducible backgrounds potentially include leptons from the semileptonic decay of a b-jet. The maximum impact parameter significance is one of the discriminating variables considered in the analysis. Figure 1 (middle) shows the expected 95% C.L. upper limit on this analysis. The most sensitive mass point is about 200 GeV where an upper bound in the cross-section times branching ratio of 2.5 times the SM cross-section is expected.

$H \to \gamma\gamma$ channel also has narrow diphoton invariant mass peak which has $\sim$ 1.1% resolution for m_H = 120 GeV. The major background processes are irreducible background from the Born process $q\bar{q} \to \gamma\gamma$, the bremsstrahlung process $qg \to q\gamma\gamma$ and the box process $gg \to \gamma\gamma$ and redducible background from the inclusive prompt-photon (γ+jet and multi-jet processes with one or more jets mis-reconstructed as photon). Figure 1 (right) shows the expected 95% C.L. upper limit which is estimated by fitting the side-bands of the $M_{\gamma\gamma}$ distribution. The expected upper limit is significantly better than the current limits from each Tevatron experiment [6, 7].

Figure 2 shows the 95% C.L. upper limit combining only three channels, $H \to WW \to l\nu l\nu$, $H \to ZZ \to 4l$ and $H \to \gamma\gamma$. The SM Higgs boson with a mass between 135 and 188 GeV can be excluded with 1fb^{-1} integrated luminosity. This mass range is largely determined by the $H \to WW$ channel. The more recent results indicate the limit is still improved by including other channels such as $H \to b\bar{b}$ and $H \to \tau\tau$ channels in low mass region and $H \to ZZ \to ll(b\bar{b}$ and $\nu\nu)$ channels in high mass region [8].

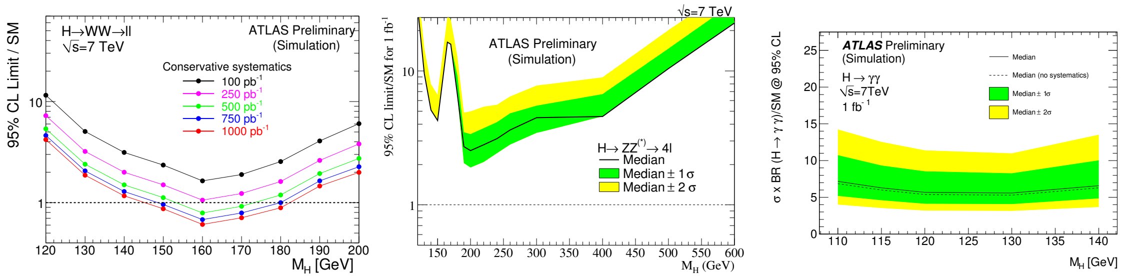

Figure 1: The expected 95% C.L. upper limit of the Higgs boson production cross-section normalised to the SM cross-section. Left: $H \to WW \to l\nu l\nu$ channel. Each line corresponds to different integrated luminosity scenarios. Middle (Left): $H \to ZZ \to 4l$ ($H \to \gamma\gamma$) channel. The solid line means the expected upper limit and the bands indicate the range in which we expect the limit will lie, depending upon the data.

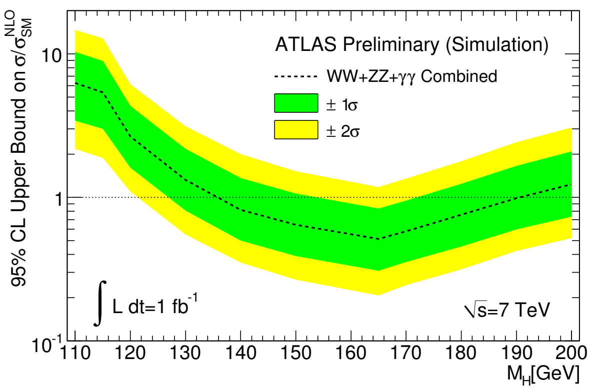

Figure 2: The expected upper bound on the Higgs boson production normalized to the NLO SM cross-section. The green and yellow bands represent the range in which we expect the limit will lie, depending upon the data. Only the $H \to WW \to l\nu l\nu$, $H \to ZZ \to 4l$ and $H \to \gamma\gamma$ channels are combined in this plot.

2. Minimal Supersymmetric Standard Model (MSSM) Search

Five Higgs boson, $h/H/A$ and $H^{\pm}$ are introduced in Minimal Supersymmetric Standard Model (MSSM) considered as a minimal extension of the SM. The discovery of charged Higgs bosons would be a definite signal for new physics beyond the SM. If H^+ is lighter than the top mass, it can appear in the decay of an on-shell top-quark. For $\tan\beta < 1$, the branching ratio $BR(H^+ \to c\bar{s})$ may reach 40%. For $\tan\beta > 1$, $H^+ \to \tau^+\nu$ is dominant decay mode. We discuss the discovery potential for a light charged Higgs boson in an integrated luminosity of 1fb^{-1} at 7 TeV.

$H^+ \to c\bar{s}$ is searched for in the semi-leptonic $t\bar{t}$ events which are the dominant background (95% of the total background). The separation between W and H^+ mass is a key ingredient in this analysis. To improve the dijet mass resolution, we reconstruct entire $t\bar{t}$ events using a kinematic fitter [5]. $H^+ \to \tau\nu$ is also searched for in the dilepton $t\bar{t}$ events. The helicity angle $\cos\theta_l^*$ and the generalised transverse mass $m_{T2}^{H^+}$ after selecting the di-lepton $t\bar{t}$ event topology are good discriminant variables [5]. Figure 3 shows the expected 95% C.L. upper limit as a function of charged Higgs mass assuming either branching ratio $BR(H^+ \to \tau\nu)$=1 or $BR(H^+ \to c\bar{s})$=1. The ATLAS experiment is likely to improve substantially on the current limits from the Tevatron experiments.

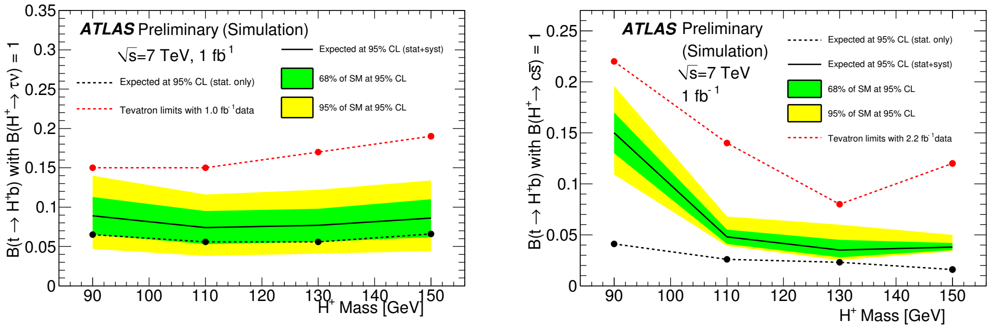

Figure 3: The expected 95% C.L. upper limit versus the charged Higgs boson mass assuming $BR(H^+ \to \tau^+\nu) = 1$ (left) or $BR(H^+ \to c\bar{s}) = 1$ (right).

References

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