PROCEEDINGS OF SCIENCE

SM Higgs search in the 4-lepton final state with ATLAS

Alessia D'ORAZIO*on behalf of the ATLAS Collaboration
Max Planck Institute for Physics, Munich
E-mail: alessia.d'orazio@cern.ch

The sensitivity of the ATLAS experiment to a possible discovery of the Standard Model Higgs boson through its observation in the four lepton final state is presented. The analysis strategy for selecting the signal and rejecting the backgrounds and the discovery potential over Higgs masses ranging from 120 to 600 GeV are discussed.

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*Speaker.

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1. Introduction

The search for the Higgs boson and the source of electroweak symmetry breaking is a primary task of the Large Hadron Collider (LHC). The Higgs boson mass is a free parameter in the Standard Model (SM) but direct searches at LEP set a lower bound at 114.4 GeV and precision electroweak data lead to un upper bound of $m_H < 182$ GeV at 95 % confidence level. Furthermore, Tevatron experiments excluded a mass for the Higgs of 170 GeV with a 95% CL.

The studies reported here are performed on Monte Carlo samples, using an up-to-date detector simulation, and summarizes the expected potential of ATLAS in the search of the Higgs boson decaying into four leptons [1].

2. The $H \to ZZ^{(*)} \to 4\ell$ channel

At LHC energies, the main SM Higgs production processes are the gluon-fusion, accounting for approximately 80% depending on the Higgs mass, and the Weak Boson Fusion.

The decay mode $H \to ZZ^{(*)} \to 4\ell$ is one of the most promising processes for the discovery of the SM Higgs boson at LHC over a wide mass range, from 120 to 600 GeV. The combination of a narrow reconstructed mass peak and a relatively low backgrounds makes this channel the golden one for the discovery above 180 GeV when the cross section for two Z bosons on-shell opens up.

The dominant source of background for this process is due to the continuum $ZZ \to 4\ell$ over the full mass range. In the most challenging low mass region, where one of the Z bosons is off-shell giving low p_T leptons, also backgrounds from $Zb\bar{b} \to 4\ell$ and $t\bar{t} \to 4\ell$ are significant and tight lepton isolation cuts are required to reduce them.

3. Analysis strategy

Crucial for this channel are the efficiency and the resolution on the lepton reconstruction, so the event selection is mainly based on the lepton quality and kinematics. The analysis selection requires at least four isolated high p_T leptons passing the quality criteria from the interaction vertex.

The different topology of the $Zb\bar{b}$ and $t\bar{t}$ backgrounds with respect to the signal has been exploited to reject them. The leptons originating from the Higgs boson decay are expected to be significantly more isolated that the ones originating from the heavy quarks leptonic decays

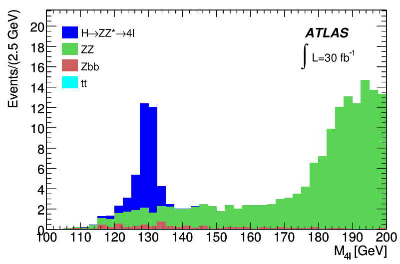

Figure 1: Reconstructed 4-lepton mass for signal and background processes, in the case of a 130 GeV Higgs mass, normalized to a luminosity of 30 fb^{-1}.

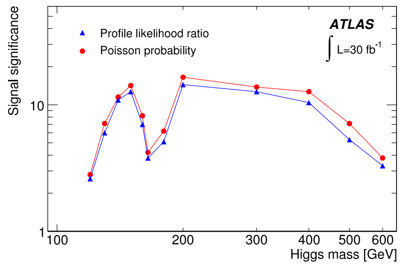

Figure 2: Signal significances as function of the Higgs mass obtained from the profile likelihood ratio method compared to the one calculated without including the systematic uncertainties using the Poisson statistic.

and compatible with a single vertex hypothesis, while for the $Zb\bar{b}$ and $t\bar{t}$ backgrounds the leptons from the b and t decay tree come from secondary vertices. Therefore, through the use of impact parameter and lepton isolation requirements the $Zb\bar{b}$ and $t\bar{t}$ background contributions, which are important only at low m_H, can be significantly reduced. A further reduction of the backgrounds is achived by applying a Z-mass constraint to the oppositely charged leptons pair with an invariant mass closest to the Z invariant mass. For Higgs masses greater than 200 GeV, for which both Z bosons are on-shell, the Z-mass constraint is applied to both lepton pairs. The distribution of the reconstructed four leptons mass after the full selection, in case of m_H =130 GeV hypothesis and for an integrated luminosity of 30 fb^{-1} is shown in Fig. 1.

Systematic uncertainties on quantities associated with the background estimation and the signal efficiency are taken into account. The main systematic effect on the signal significance is related to the knowledge of the continuum ZZ background rate in the signal region and the uncertainty on this knowledge. Various methods to extract the background from experimental data, to evaluate the background uncertainties and to include them in the significance calculation, based on a profile likelihood ratio statistical approach have been considered. The expected signal significances as function of the Higgs mass are shown in Fig. 2.

4. Conclusion

The Standard Model Higgs boson in the mass range $130 < m_H < 500$ GeV could be observable at ATLAS with greater than 5σ significance through the channel $H \to ZZ^{(*)} \to 4\ell$ with an integrated luminosity of 30 fb^{-1}. The channel is highly sensitive in the high mass region (200 - 400 GeV) and for $m_H = 150$ GeV, where an Higgs discovery could be possible with 5 fb^{-1}. Some exclusion limits can be also set with a very modest integrated luminosity.

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References

[1] ATLAS Collaboration, *Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics*, `arXiv:0901.0512`.