Search for Higgs Bosons at the LHC with the ATLAS Muon System ◇

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Introduction

Spontaneous symmetry breaking and the Higgs mechanism in particle physics give rise to one or more fundamental massive neutral or charged particles, the Higgs bosons. In the standard model with one neutral scalar Higgs boson, its couplings to fermions and vector bosons are known, but the Higgs mass is not specified. Higgs searches have been performed at LEP. So far the results of the searches have been negative, and the symmetry breaking mechanism remains mysterious. The current lower mass limit is 95 GeV. It is expected that LEP2 can reach the Higgs search limit up to $M_H \sim 105$ GeV. The Higgs search will remain a central topic of experimental high energy physics during the coming decade. The continuation of the search for the Higgs particle will be one of the main objectives of the LHC physics program.

Much work has been carried out to understand the Higgs discovery potential of the ATLAS detector [1] for the LHC. This note reports the results of a study of the detection sensitivity for the intermediate mass Higgs (130 GeV$< M_H <$ 180 GeV) with the ATLAS detector through four muon final state. This study has been performed using a full detector simulation and event reconstruction with the ATLAS muon spectrometer [2].

The ATLAS Muon System

The muon system has to fulfill three basic tasks: (i) identification, (ii) momentum measurement and (iii) triggering. The latter is very challenging in hadron collider experiments. The possibility to trigger on and identify muons down to low p_T increases the acceptance for important physics processes like $H \to ZZ^* \to \mu^+\mu^-\mu^+\mu-$.

The ATLAS superconducting air-core toroid system is optimised for stand-alone measurements. The Muon-spectrometer consists of precision chambers (monitored drift tubes and cathode strip chambers) which require a high-accuracy tracking (50 μm/chamber), which have to be aligned to 30 μm. Resistive plate chambers and thin-gap chambers are used for triggering. The expected resolution ranges from about 2 - 3% at p_T^μ=100 GeV to about 11% at p_T^μ=1 TeV.

$H \to ZZ^* \to \mu^+\mu^-\mu^+\mu-$

For the most demanding mass range (130 GeV$< M_H <$ 180 GeV), typical muon momenta lie in the range 5$<$ p_T^μ $<$50 GeV. As the natural Higgs width in this mass range is very narrow and the physics backgrounds are severe, a mass resolution at the level of a few percent is needed for adequate signal sensitivity. The 'intrinsic' momentum resolution of the spectrometer, governed by the combination of bending power and tracking accuracy, meets this requirement. However multiple scattering in chamber material and magnet structures, as well as energy loss fluctuations in the calorimeters, limit the effective momentum resolution to 2 - 3% in this kinematical range. The rapidity range $|\eta|$ $<$2.7 covers more than 85% of the muons with p_T $>$6 GeV from H(150 GeV)$\to 4\mu$ decays, yielding a kinematical acceptance of 62% for the Higgs itself. Satisfactory trigger acceptance at a tolerable rate is achieved by requiring at least one high-p_T muon (p_T $>$20 GeV). This threshold, combined with a trigger coverage of $|\eta|$ $<$2.4 captures 99.5% of the H(150 GeV)$\to 4\mu$ events that decay within the tracking acceptance ($|\eta < 2.7|$). The typical reconstruction efficiences are 80 - 85% for masses up to 200 GeV (fig.1a). The four-muon mass resolution σ_M/M as a function of the four-muon invariant mass $M_{4\mu}$ is shown in fig. 1b, using only the muon spectrometer. It ranges from 1.8% to 2.1% for the mass range 100 to 500 GeV.

The reducible backgrounds, $Zb\bar{b}$ and $t\bar{t}$, can be reduced by using an isolation cut in a cone of radius 0.2 around the muon track and an impact parameter cut. One is left with the irreducible ZZ^* continuum. After the first three years of LHC running ($\mathcal{L}_{int} = 30$ fb^{-1}) the expected number for Higgs events is 10 - 40, and S/B $\sim$10. This channel allows to observe a Higgs in the whole mass range (120 GeV $< M_H < 2M_Z$), with a difficult region near $2M_W$. Fig.1c shows the signal ($M_H = 150$ GeV) and background events after the first three years of data taking.

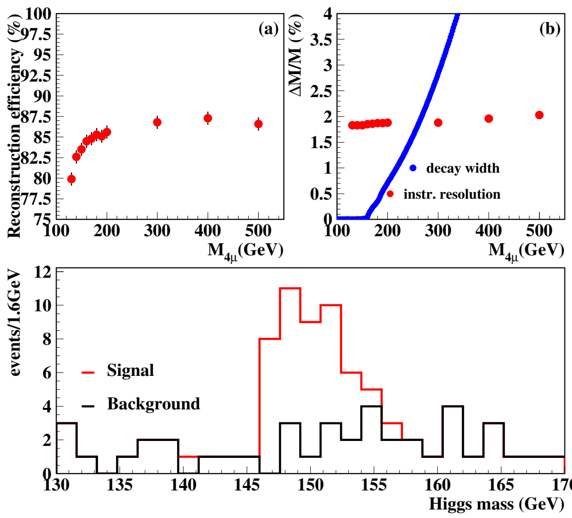

Fig. 1: Reconstruction efficiency (a), mass resolution (b) for different Higgs masses. Signal (M_H=150 GeV) and background events after the first three years of LHC running ($\mathcal{L}_{int} = 30$ fb^{-1}).

References

[1] ATLAS Technical proposal, CERN/LHCC/P2, 1994
[2] T. Trefzger *et al.*, ATLAS-PHYS-NO 116, 1997

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