SEARCH FOR THE STANDARD MODEL $H \to \gamma\gamma$ DECAYS WITH THE ATLAS DETECTOR AT THE LHC

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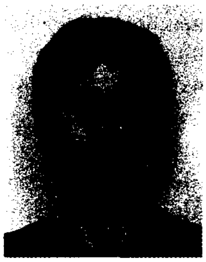


A light Standard Model Higgs boson, with mass between 114.4 and ≈150 GeV, is favored by electroweak fits and direct searches. One of the most important channels to search for this particle in this mass region is the decay $H \to \gamma\gamma$. We investigate the ATLAS discovery potential for a light Higgs boson in the two photon decay mode. In addition to the inclusive analysis we consider also the reconstruction of diphoton systems produced in association with jets, missing E_T or missing E_T plus leptons. The studies are based on a realistic detector simulation of Monte Carlo signal and background events.

Recent 95% Confidence Level exclusion limits from the CDF and D0 experiments [1] (m_H
[160, 170] GeV) together with the LEP limit [2] $m_H > 114.4$ GeV and theory predictions emphasize the importance of the low mass region for the Higgs searches. The $H \to \gamma\gamma$ deca
mode is one of the most promising discovery channels for the Standard Model Higgs boson i
low mass region, between 114.4 and 150 GeV. Despite the small branching ratio ($2.2 \times 10^{-}$
for $m_H = 120$ GeV) this channel has a simple signature and the invariant mass can be reconstructed with a very good mass resolution (≈1.5 GeV). With respect to previous studies severa
new aspects are considered: QCD high order corrections (for inclusive analysis), contribution
of reducible background fragmentation from hard partons to photons and the reconstruction c
diphoton systems produced in association with jets in addition to the inclusive analysis. Finall
significance results computed with a maximum likelihood fit are compared to results obtaine
by event counting. The detector performance issues relevant to the search have been evaluate
using a realistic detector simulation.

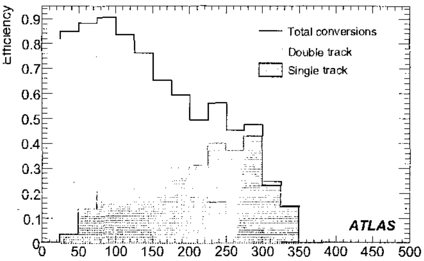
The Higgs boson is mainly produced by the gluon fusion process via a top quark loop and b
Vector Boson Fusion (VBF). The peculiarity of the VBF process is the appearance of forwar

ts, with a large rapidity gap and no activity in the central rapidity region, which can be used) enhance the sensitivity. Production in association with W, Z or $t\bar{t}$ pair is also considered; edicated analyses allow us to increase the signal to background ratio, despite limited statistics.

The decay to two photons proceeds through loops with W bosons or top quarks. The ackground processes can be split into two categories: the irreducible background, coming from ie QCD production of two isolated photons, and the reducible background, coming from events ith at least one fake photon (for instance jets faking photons).

Photons are reconstructed from electromagnetic clusters whose size depends on where the uster is located and whether the photon is converted or not. The cluster position is corrected for nown systematic biases and the energy is reconstructed using calibration constants to correct ı energy loss in front of the calorimeter, longitudinal leakage and energy loss outside the uster. A good photon identification is mandatory to reduce the background from jets faking iotons (reducible background) below the irreducible background. A cut-based method using iower shape parameters is applied: the middle layer of the electromagnetic calorimeter and ie hadronic calorimeter are used to reject jets with high energy pions and wide showers and ie fine segmentation of the first compartment of the electromagnetic calorimeter is used to parate photons from neutral pions. A track based isolation is also used to remove some jets king photons. Details on the electromagnetic calorimeter calibration, photon reconstruction, cluding the conversions and the rejection are presented and discussed in [3,4].

Monte Carlo studies have shown that 57% of $H \to \gamma\gamma$ events have at least one conversion ith a radius below 800 mm (corresponding to the last position where we can reconstruct track in the detector) therefore it is really important to recover converted photons. Two nds of converted photons are used; double track conversions which are reconstructed by a rtexing algorithm using two tracks with opposite charges as input and single track conversions: nversions for which only one of the two tracks has been reconstructed. The separation between primary electron and a conversion electron is done using the first pixel layer. The conversion construction efficiency is almost 66.4% for conversions with radius below 400 mm and with ie reconstruction software used for this analysis (Fig. 1).



gure 1: Conversion reconstruction efficiency as a function of the conversion radius.

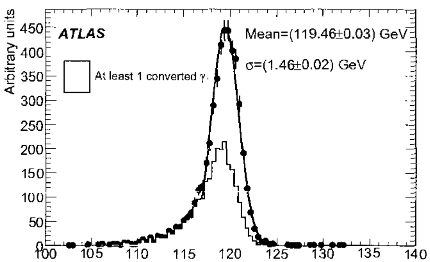


Figure 2: Invariant diphoton mass distribution for a Higgs boson with $m_H = 120$ GeV.

A precise measurement of the photon direction is very important for the accurate Higgs ass reconstruction. The photon direction is measured by an iterative method using a linear fit id exploiting the multi-layer structure of the electromagnetic calorimeter, the position of the nversion vertex and the position of the primary vertex reconstructed by the inner detector ien possible. The addition of the primary vertex gives the best photon angle determination curacy, with a Gaussian width of 0.07 mm (the distribution exhibits large tails with RMS of mm when reconstructed primary vertex is not used) but its identification is not always possible high luminosity.

The invariant mass of photon pairs is determined from an asymmetric Gaussian fit (in the $2\sigma, +3\sigma]$ range, Fig.2). The relative mass resolution σ_m/m is close to 1.2% degrading by a few percent when additional soft proton-proton collisions corresponding to 10^{33}cm^{-2}s^{-1} luminosit are added.

The inclusive analysis refers to the search for a resonance in events with at least two photo candidates in the η region $0 \; o \; |\eta| \; o \; 1.37$ and $1.52 \; o \; |\eta| \; o \; 2.37$, which excludes the transitio region between barrel and end cap. Leading and sub-leading photons candidates are require to have a transverse momentum above 40 and 25 GeV, respectively.

For the Higgs boson plus one jet analysis, at least two photons in the same fiducial regio are required with transverse momenta greater than 45 and 25 GeV and at least one hadroni jet with a transverse momentum higher than 20 GeV in $|\eta| \; o \; 5$ is also required. Finally a cu on the invariant mass of the diphoton and the leading jet is applied ($m_{\gamma\gamma\mathrm{jet}} > 350$ GeV).

For the Higgs boson plus two jets analysis (optimized for VBF processes), the two photon are asked to have transverse momenta higher than 50 and 25 GeV and have to be in the sam fiducial region. At least two hadronic jets are required with transverse momenta higher than 4 and 20 GeV and in $|\eta| \; o \; 5$. As the pseudorapidity gap and invariant mass of signal jets tend t be significantly larger than those expected for background processes, we also apply the followin cuts: $\Delta\eta_{\mathrm{jj}} > 3.6$ and $m_{\mathrm{jj}} > 500$ GeV. The photons are required to be between the tagging je and a central jet veto is applied: $p_{\mathrm{T}} > 20$ GeV, $|\eta| \; o \; 3.2$.

The Higgs boson plus missing E_{T} (plus lepton) requires at least two photons with transvers momenta higher than 60 and 30 GeV in the same detector region. The missing E_{T} must b greater than 80 GeV for the $H + E_{\mathrm{T}}^{\mathrm{miss}}$ analysis and 30 GeV for the $H + E_{\mathrm{T}}^{\mathrm{miss}} + \ell$ analysis. F the latter analysis, the transverse momentum of the most energetic isolated lepton (electron o muon) must be higher than 30 GeV. When an electron is reconstructed, events are rejected the invariant mass of the electron and each of the photons is close to the Z mass ([80, 100] GeV

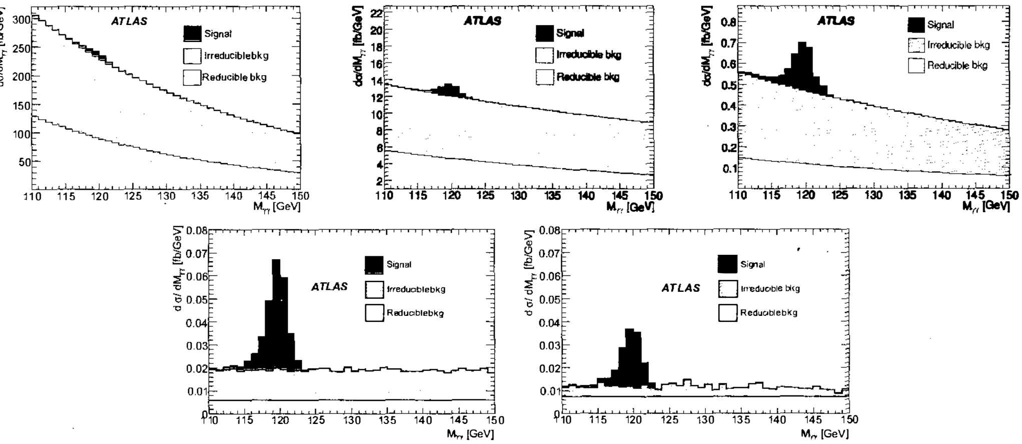
The expected cross-sections after event selection are presented in the Table 1 and the diph ton invariant mass spectra are shown on Fig. 3. Details on the event selection and the result found with these analyses are reported in[4].

	Inclusive	H+1jet	H+2jets	H+$E_{\mathrm{T}}^{\mathrm{miss}}$+1 lepton	H+$E_{\mathrm{T}}^{\mathrm{miss}}$
σ_{sig}	25.4 fb	4.0 fb	0.97 fb	0.126 fb	0.073 fb
σ_{bkg}	947 fb	49 fb	1.95 fb	0.075 fb	0.036 fb

Table 1: Expected cross-sections after event selection for $m_H = 120$ GeV within a mass window of $m_{\gamma\gamma}$ of 1.4 around 120 GeV.

Three η categories and three Higgs production categories (H+0, 1 or 2 jets) are combined u ing an unbinned extended multivariate maximum likelihood fit. Additional discriminating pow is gained considering the difference in the kinematics and topological properties between sign and background events. The transverse momentum of the Higgs boson and the photon dec angle in the Higgs boson rest frame with respect to the Higgs boson lab flight direction, $|\mathrm{c\;s}\theta^{*}$ are used in addition to the invariant diphoton mass. Data are split into different categories order to separate sub-populations of events with different properties. This categorization giv a finer grained description of the data, increases the significance and reduces the biases from t correlation: therefore it improves the accuracy of the likelihood model.

The expected signal significances for 10 fb^{-1} of integrated luminosity are summarized Table 2 using an event counting method. The combined significance (sum in quadrature of H exclusive, H+1jet exclusive and H+2jets) is almost 25% higher than the significance obtain only with the inclusive analysis while the significance increases by 40% with respect to the i



igure 3: Diphoton invariant mass spectrum as obtained after the event selection from the inclusive analysis, H+1jet, H+2jets, H+E_T^{miss}+lepton and H+E_T^{miss} (from top to bottom and from left to right).

	Event counting		Using combined fit	
m_H (GeV)	Inclusive	Combined	Floating mass	Fixed mass
120	2.6	3.3	2.8	3.6
130	2.8	3.5	3.4	4.2
140	2.5	3.0	3.2	4.0

Table 2: Expected signal significances for 10 fb^{-1} of integrated luminosity.

usive analysis using the combined likelihood fit with fixed Higgs mass (see Table 2).

To conclude, the impact of the detector performance on $H \rightarrow \gamma\gamma$ reconstruction has been aluated using a full detector simulation and the feasibility of the search for a Standard Model iggs boson via the $H \rightarrow \gamma\gamma$ channel has been confirmed. The inclusive analysis as well as alyses of diphotons events produced in association with jets have been studied. A combined alysis has been done, improving the significance by ≈25% with respect to inclusive analysis. he use of an unbinned maximum-likelihood fit with additional discriminating variables and tegories has been studied to enhance the sensitivity and the gain is about 40% with respect inclusive analysis. Finally, a 5σ discovery should be possible with integrated luminosity of -30 fb^{-1} but some work will still be needed to understand the detector performance with early ta.

eferences

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