ATLAS NOTE

ATLAS-CONF-2011-071

May 8, 2011

Update of Background Studies in the Search for the Higgs Boson in the Diphoton Channel with the ATLAS detector at $\sqrt{s} = 7\,\text{TeV}$

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Abstract

This note presents an update of the study of the backgrounds in the search for the Higgs boson decaying into a pair of photons. The analysis done with 38 pb^{-1} of pp collision data collected in 2010 with the ATLAS detector at a centre-of-mass energy of $\sqrt{s} = 7$ TeV is complemented with 94 pb^{-1} of data collected in 2011. The dominant background components are measured and found to be in agreement with the Standard Model predictions, both in terms of overall yield and invariant mass distribution. No excess is observed.

At this early stage of LHC operation an important question in the search for the Higgs boson in the diphoton decay channel is the relative contributions of the different background processes. The predominant background components are the irreducible prompt diphoton production, the reducible γ-jet and dijet backgrounds where one or more jets are misidentified as photons, and Drell-Yan events where both electrons are misidentified as photons. The measurement of these backgrounds is essential to accurately assess the performance of the search and to ascertain that all background processes are well modeled. This note presents an update of the study of backgrounds in the search for the Higgs boson in the $H \rightarrow \gamma\gamma$ channel, using a data sample corresponding to an integrated luminosity of 94 pb^{-1} recorded in 2011 with the ATLAS detector at a centre-of-mass energy of 7 TeV. This luminosity estimate is based on a preliminary calibration; a 7% uncertainty is assigned in the normalization calculation. The computation of the expected backgrounds and the details of the data-driven background measurements follow closely the procedure described in [1, 2]. The two data sets of 2010 and 2011 are analyzed independently as the acceptance has changed due to the repair of faulty optical links in the calorimeter readout during the winter shutdown and because of the different running conditions.

Since the end of 2010 the LHC has been running with beams structured in bunch trains, with the number of bunches per train varying from 8 to more than 70. The bunch spacing also varied from 150 ns in fall 2010 to 75 ns in March 2011 and down to 50 ns in April 2011. The changing beam patterns, in conjunction with the increasing beam intensities, have resulted in a variety of in-time and out-of-time pile-up conditions. An average number of interactions per bunch crossing of up to ~ 8 was reached. In this analysis a full Monte Carlo simulation, taking into account both the effects of in-time and out-of-time pile-up, was used. The efficiency of the photon identification and in particular that of the isolation cut are estimated using this simulation with high pile-up conditions.

The event selection is unchanged with respect to [1, 2], except for the trigger thresholds where the transverse energy requirement for the two loosely selected photons has been raised from 15 GeV in 2010 to 20 GeV in 2011. Diphoton candidates are required to pass tight identification criteria, to be within the inner detector and calorimeter acceptance ($|\eta| < 2.37$ excluding $1.37 < |\eta| < 1.52$), to have transverse momenta larger than 40 GeV for the leading photon and 25 GeV for the sub-leading photon, and to have an invariant mass between 100 and 150 GeV. The photon isolation used in this analysis is calorimeter-based; it is corrected for underlying event and pile-up effects on an event-by-event basis, and for out-of-cone showering as described in [3]. Similarly to what was done in [1, 2] the Monte Carlo isolation efficiency is corrected for differences between the simulation and the data using electrons from W decays collected in 2011.

The numbers of expected events for all background processes estimated for the 2011 running conditions are summarized in Table 1. The total expected background amounts to 301 ± 72 events. The main sources of uncertainties in these predictions are the jet fragmentation (into a photon or a leading π^0), the parton density functions and the variations of renormalization and factorization scales in the next-to-leading order predictions [1].

Altogether 291 diphoton candidate events are selected in the 2011 data, in good agreement with the overall Monte Carlo expectation. The number of prompt diphoton ($N_{\gamma\gamma}$), photon-jet ($N_{\gamma j}$) and dijet (N_{jj}) events in the 2011 data sample are measured using the double sideband method described in [1, 2]. This method applies the sideband procedure of [3] to each photon sequentially. The sidebands are defined in terms of photon isolation and identification criteria using the fine-grained first sampling of the electromagnetic calorimeter. Since electrons from Drell-Yan events have a shower profile similar to that of isolated prompt photons, the $N_{\gamma\gamma}$ component estimated using the double sideband method contains most Drell-Yan dielectron events. The number of these events (N_{DY}) is independently measured, and subsequently subtracted from $N_{\gamma\gamma}$, using Z decays to two electrons of which at least one is reconstructed as a photon. Systematic uncertainties in the background decomposition arise from the asymmetry between the photon and the jet transverse energies in photon-jet events, the correlations between isolation and

Table 1: Summary of the number of measured and expected prompt diphoton ($N_{\gamma\gamma}$), Drell-Yan (N_{DY}), photon-plus-jet ($N_{\gamma j}$), and dijet (N_{jj}) background events with a diphoton invariant mass between 100 and 150 GeV.

	$N_{\gamma\gamma}$	N_{DY}
Measured	219 ± 25 (stat.) $^{+8}_{-9}$ (syst.)	6.7 ± 0.3 (stat.) ± 1.8 (syst.)
Expected (MC)	214 ± 59	7.1 ± 0.5
	$N_{\gamma j}$	N_{jj}
Measured (Reducible)	59 ± 12 (stat.) ± 9 (syst.)	6 ± 4 (stat.) $^{+4}_{-1}$ (syst.)
Expected (MC)	77 ± 42	2.5 ± 2.6

identification variables, and the uncertainty in the contribution of diphoton events to the isolation and identification sideband regions. A summary of the main background components, estimated in the 2011 data, is given in Table 1 and illustrated in Figure 1 (a). A reasonable agreement between each measured component and its prediction is observed.

In order to reconstruct the invariant mass of the diphoton system as precisely as possible, two essential ingredients are the photon energy calibration and the reconstruction of the longitudinal position of the primary vertex of the interaction. The calibration of the reconstructed photon energy is based on precise test-beam data as well as on a simulation of the calorimeter and an accurate description of the amount of material upstream of it. This calibration scheme is further completed by an additional correction for energy scale variations as a function of pseudorapidity estimated with electrons from Z decays. As in the 2010 data analysis, for events with more than one reconstructed primary vertex, the vertex associated with tracks having the largest sum of transverse momenta-squared is used to estimate the position of the hard scattering interaction. This method does not use the full ATLAS capabilities to select the primary vertex such as the ability of the calorimeter to determine the photon direction and the reconstruction of converted photons. An improvement in the $\gamma\gamma$ invariant mass resolution of about 10%, in the 2011 data running conditions, compared to the data taken in 2010 [1, 2], could be achieved with a refined primary vertex reconstruction method.

The invariant mass distributions of the events selected in the 2011 data (b) and for the combined 2010 and 2011 data set corresponding to an integrated luminosity of 131 pb^{-1} (c) are shown in Figure 1 along with the absolute background predictions. The expected full width at half maximum (FWHM) of the invariant mass distribution of a narrow resonance decaying into two photons amounts to $\sim$ 4.5 GeV [1, 2]. Given the bin size of 5 GeV in the histograms of Figure 1, if produced at a sufficiently high rate, such a resonance would manifest itself as an excess of events mostly in two bins with respect to their neighboring sidebands. No excess is observed, neither with the analysis criteria described in this note nor with other selections studied.

Conclusion

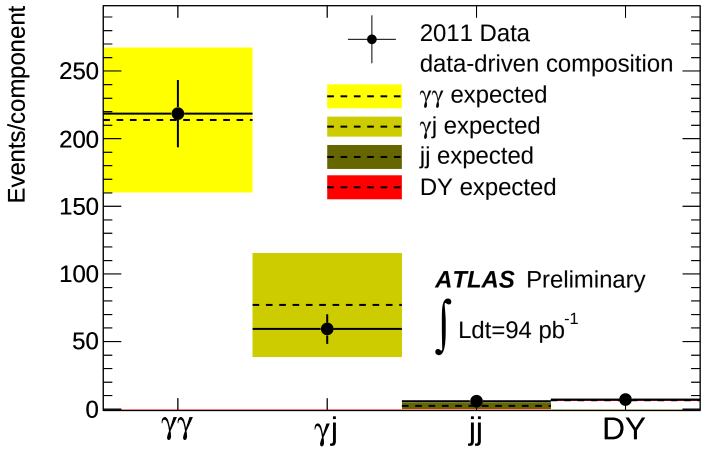
The estimate of the background composition in the search for the Higgs boson in the diphoton channel has been updated using a sample of 94 pb^{-1} of data collected in 2011. The main background components are measured and found to be in good agreement with their Standard Model predictions. No excess with respect to the expected backgrounds is observed in the diphoton invariant mass distribution.

References

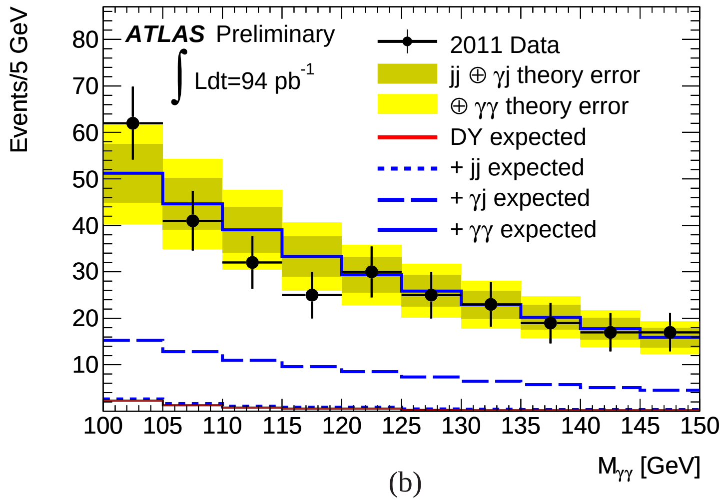
[1] ATLAS Collaboration, *Measurement of the backgrounds to the $H \rightarrow \gamma\gamma$ search and reappraisal of its sensitivity with 37 pb^{-1} of data recorded by the ATLAS detector*, ATLAS-CONF-2011-004.

[2] ATLAS Collaboration, *Search for the Higgs boson in the diphoton final state with 38 pb^{-1} of data recorded by the ATLAS detector in proton-proton collisions at $\sqrt{s}$=7 TeV*, ATLAS-CONF-2011-025.

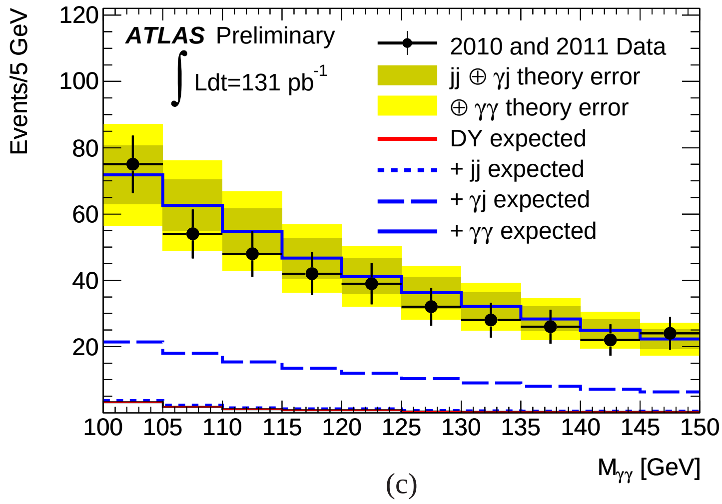
[3] ATLAS Collaboration, *Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector*, Phys. Rev. D **83**, 052005 (2011).



(a)



(b)



(c)

Figure 1: (a) Measured number of events for each background component (points with error bars), compared with the corresponding Monte Carlo predictions (color bands). (b) and (c) Diphoton invariant mass distributions for data and the cumulative predictions of the Drell-Yan (red solid), dijet (blue dotted), photon-jet (blue dashed) and diphoton (blue solid) components of the background for the 2011 data only (b) and the combined 2010 and 2011 data (c). The two yellow bands depict the total uncertainty on the prediction and the uncertainty on the reducible background component only.