Top-Higgs Associated Production to a Four Lepton Final State with the ATLAS Detector at the LHC

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Abstract

We investigate potential sensitivity to the associated production process $t\bar{t}H$ in the four lepton channel at ATLAS with 20.7fb^{-1} of data and collected at a centre of mass energy of 8 TeV. The signal is broken into 3 channels: 4 electrons or muons, 3 electrons or muons and 1 hadronic tau and 3 electrons or muons and 1 isolated track. We find similar expected event rates for hadronic tau channels and isolated track channels, with the former having better background rejection. The combined estimated sensitivity of the 4 lepton and 3 lepton + 1 hadronic tau channels is 0.587 ± 0.035.

1 Introduction

The standard model Higgs boson is predicted to couple proportionally to mass. An important test of the standard model is measuring the strength of the interaction between the top quark, the heaviest fundamental particle, and the newly discovered Higgs. Although the dominant Higgs production mode at the LHC is gluon-gluon fusion and the gluons fuse through a loop of virtual particles dominated by top quarks [1], its cross section is sensitive to quantum corrections from undiscovered, massive particles and is therefore only an indirect measurement of the top-Higgs Yukawa coupling [2] . In comparison, associated top-Higgs production, henceforth abbreviated to $t\bar{t}H$, can uniquely provide a direct measurement of this important standard model parameter.

This report focuses on $t\bar{t}H$ sensitivity estimates in the four lepton channel. Mutlileptonic final states are attractive potential channels because they are well understood and have low expected background rates. However, the more leptons required in the final state, the smaller the multiplicative branching ratio becomes and therefore the expected number of signal events decreases significantly.

1.1 ATLAS Detector and Coordinate System

The ATLAS detector is massive; stretching 45m long and 25m wide, it weighs approximately 7,000 tons [3]. The proton beam runs through the length of the detector, with the sensitive detector components surrounding it cylindrically. There are three major parts of the detector: the inner detector, which measures particle momenta; the calorimeter, which measures particle energy; the muon spectrometer, which measures the momenta of muons.

The direction of the beam is defined to be the $\hat{z}$ direction in the ATLAS coordinate system, with the $\hat{x}$ and $\hat{y}$ directions defining the plane transverse to the beam. The transverse momentum of a particle (p_T) and the angle of the particle in the transverse plane (ϕ) are both Lorentz invariant with respect to boosts in the $\hat{z}$ direction. However, the angle of the particle (θ) with the $\hat{z}$ axis is not; therefore, a particle is more commonly described by its pseudorapidity (η), which is defined as $-2\ln(\tan\theta/2)$. The difference in two pseudorapidities is Lorentz invariant for boosts in the $\hat{z}$ direction in the relativistic limit.

An additional spatial coordinate, ΔR, is defined to be the distance between two objects in $\phi - \eta$ space: $\sqrt{\Delta\phi^2 + \Delta\eta^2}$.

1.2 Beam Luminosity and Pile-up

The LHC collides bunches of protons, each bunch consisting of approximately 10^{11} protons. This greatly increases the chances of multiple collision events between partons, resulting in final state particles which were created at multiple spatial points. Pile-up occurs when the detector has information on multiple collisions in a single event. The collision point that is deemed most interesting is referred to as the primary vertex of the event.

2 Analysis Overview

For the $t\bar{t}H$ final state to produce 4 leptons, the Higgs needs to decay into either two W bosons, two taus or two Z bosons. MC samples from all three decay modes are included in this analysis.

Experimentally, electrons and muons are well understood. They have a high detection efficiency and a low fake rate. Therefore, we expect the cleanest signal when requiring four electrons or muons in the event, which I will henceforth refer to as the 4 lepton channel.

Taus have a mean lifetime of $\sim 2.9 * 10^{-13}s$ and cannot directly be detected. No effort is made to differentiate electrons and muons from leptonically decaying taus and prompt electrons and muons. Consequently, leptonically decaying taus are included in the previous 4 lepton signal region. For similar efficiencies, hadronic tau objects have a higher fake rate; therefore the efficiency for hadronic tau detection is set lower than the electron or muon detection efficiency in order to reduce the fake rate to an acceptable level. Due to the fact that we expect different backgrounds when including hadronic taus, we created another channel with three electrons or muons and one hadronic tau, henceforth called the 3 lepton + 1 hadronic tau channel.

Since the low number of expected events is the major difficulty with the $t\bar{t}H\rightarrow 4l$ channel, we also investigated the possibility of detecting one prong hadronic taus as isolated tracks, creating the 3 lepton + 1 isolated track channel. We choose to impose the same isolation requirements for these isolated tracks as we do for electron tracks and muon tracks. Even though we decrease the signal to background ratio when loosening the requirements on reconstructed tau candidates, we hope to overall increase our expected sensitivity by increasing our signal acceptance. The 3 lepton + 1 isolated track channel and the 3 lepton + 1 hadronic tau channel are partially overlapping and can both accept the same event.

2.1 Object Definition

- Electrons must be of "medium" quality. They must also have a p_T greater than 10 GeV, an $|\eta|$ less than 2.47 (excluding a crack region of 1.37 to 1.52) and be sufficiently isolated.

- Muons must pass a "tight" ID requirement. In addition, selected muons also require a p_T greater than 10 GeV, an $|\eta|$ less than 2.5 and must be sufficiently isolated.

- Hadronic taus must pass a set of "medium" quality cuts, have a p_T of at least 15 GeV and be sufficiently central with an $|\eta|$ less than 2.5. This analysis also requires that selected hadronic tau objects have a reconstructed charge of $\pm$1e and either 1 or 3 tracks associated with the reconstructed hadronic tau object, corresponding to a 1 or 3 prong tau decay.

- Isolated tracks require at least 15 GeV of p_T, an $|\eta|$ of less than 2.5, a minimum number of pixel hits and semiconductor tracker hits, and they must be sufficiently isolated. A track's isolation is calculated by summing the p_T of all tracks that fall within a ΔR of 0.2, provided this second track also came from the primary vertex of the event.

- Jets are reconstructed with the anti-kt algorithm with a cone parameter ΔR of 0.4. In addition, they also must have a p_T greater than 20 GeV. In order to be classified as a b-jet, the jet must go through a multivariate analysis to determine its flavour composition and its final flavour weight must be above the set threshold. In this analysis this threshold was computed so that 80% of b-jets will pass.

2.2 Overlap Removal

In order to ensure that we do not accidentally double count a single object as two different reconstructed objects, we perform overlap removal on all reconstructed object collections. The overlap removal algorithm is defined as follows:

- Electrons and muons: reject electron if $\Delta R(e, \mu) < 0.1$
- Electrons: reject lower p_T electron if $\Delta R(e, e) < 0.1$
- Electrons and jets: reject jet if $\Delta R(e, jet) < 0.3$
- Muons and jets: reject muon if $\Delta R(\mu, jet) < 0.3$
- Hadronic taus and electrons: reject hadronic tau if $\Delta R(\tau, e) < 0.2$
- Hadronic taus and muons: reject hadronic tau if $\Delta R(\tau, \mu) < 0.2$
- Hadronic taus and jets: reject hadronic tau if jet is b-tagged and reject jet otherwise if $\Delta R(\tau, jet) < 0.3$
- Isolated tracks and electrons: reject isolated track if $\Delta R(track, e) < 0.2$
- Isolated tracks and muons: reject isolated track if $\Delta R(track, \mu) < 0.2$

2.3 Major Backgrounds

There are two major backgrounds for this channel: $ZZ^* \to 4l$ and $t\bar{t}Z/\gamma^* \to 4l$. The ZZ^* background is a reducible background; we reject events with a lepton pair with opposite sign and same flavour, with an invariant mass between 81 and 101 GeV. We also impose a requirement of at least one reconstructed b-jet. Finally, this background has been studied in detail at ATLAS because it is a major background for the $H \to ZZ^* \to 4l$ analysis [4].

The other major background, $t\bar{t}Z/\gamma^* \to 4l$, is only reducible when two of the leptons come from an on-shell Z boson. There is also a huge theoretical uncertainty on the cross section of ttZ/γ^*. Finally, there is no published experimental measurement of the cross section of this background.

This analysis also considers the following backgrounds: $t\bar{t}W$, $t\bar{t}WW$, $t\bar{t}b\bar{b}$, $t\bar{t}c\bar{c}$, $t\bar{t}$, WZ and $W\gamma$. The contribution from these backgrounds is expected to be very small. The cross section for $t\bar{t}WW$ is approximately an order of magnitude smaller than the cross section for $t\bar{t}H$. All of the other backgrounds require at least one fake lepton to enter the 4 lepton signal region.

2.4 List of Cuts

For a candidate event to be preselected it must have exactly four electrons or muons or three electrons or muons and either one hadronic tau or one isolated track. The net charge of these four reconstructed objects must equal zero. Finally, preselected events must pass a single lepton trigger.

To further increase sensitivity to $t\bar{t}H$ this analysis defines the following additional cuts:

- Drell-Yan Veto: vetos any event with an opposite sign, same flavour lepton pair that has an invariant mass less than 10 GeV.

- # B-Jets ≥ 1: requires that selected events have at least one b-jet.
- Z Veto: rejects events that have an opposite sign, same flavour lepton pair with an invariant mass within 10 GeV of the Z mass.
- # Jets or E_T^{miss}: selected events must have either two or more jets or at least 100 GeV of E_T^{miss}.

2.5 Definition of Signal Regions

Leptonic Z boson decay is the largest standard model source of multileptonic final states. Consequently, final states with different numbers of opposite sign, same flavour pairs have very different expected backgrounds. To maximize sensitivity, each channel is further subdivided into signal regions based on how many Z bosons could have contributed background events. The 4 lepton channel is divided into three signal regions:

- Z depleted: $e^{\pm}e^{\pm}\mu^{\mp}\mu^{\mp}$
- Z enriched: $eee\mu$ or $e\mu\mu\mu$
- ZZ enriched: $eeee$, $\mu\mu\mu\mu$ or $e^{\pm}e^{\mp}\mu^{\pm}\mu^{\mp}$

The 3 lepton + 1 hadronic tau channel is divided into two signal regions:

- Z depleted: $e^{\pm}e^{\pm}\mu^{\mp}\tau^{\mp}$ or $\mu^{\pm}\mu^{\pm}e^{\mp}\tau^{\mp}$
- Z enriched: $eee\tau$, $\mu\mu\mu\tau$, $e^{\pm}e^{\mp}\mu^{\pm}\tau^{\mp}$ or $\mu^{\pm}\mu^{\mp}e^{\pm}\tau^{\mp}$

The 3 lepton + 1 isolated track channel is also divided into two signal regions:

- Z depleted: $e^{\pm}e^{\pm}\mu^{\mp}t^{\mp}$ or $\mu^{\pm}\mu^{\pm}e^{\mp}t^{\mp}$
- Z enriched: $eeet$, $\mu\mu\mu t$, $e^{\pm}e^{\mp}\mu^{\pm}t^{\mp}$ or $\mu^{\pm}\mu^{\mp}e^{\pm}t^{\mp}$

Z depleted signal regions are very clean and therefore only need the Drell-Yan and b-jet cuts. Z/ZZ enriched signal regions apply all cuts listed in the previous section. However, the 4 lepton Z enriched signal region does not gain any sensitivity by applying the # Jets or E_T^{miss} cut and therefore it is not used.

2.6 Sensitivity Estimate

We calculate the expected sensitives for each channel using the low statistics formula, given in Equation 1. All uncertainties quoted are assumed to be Gaussian and uncorrelated.

$$\sigma = \sqrt{2} * \sqrt{(S+B) * \ln\left(1 + \frac{S}{B}\right) - S} \tag{1}$$

3 Results

The fractional expected signal contribution from each Higgs decay mode per signal region is documented in Figure 1. The 4 lepton channel is predominantly composed of signal events where the Higgs decays into two W bosons. The 3 lepton + 1 hadronic tau channel and the 3 lepton + 1 isolated track channel have a much larger fraction of expected signal events where the Higgs decayed into two taus.

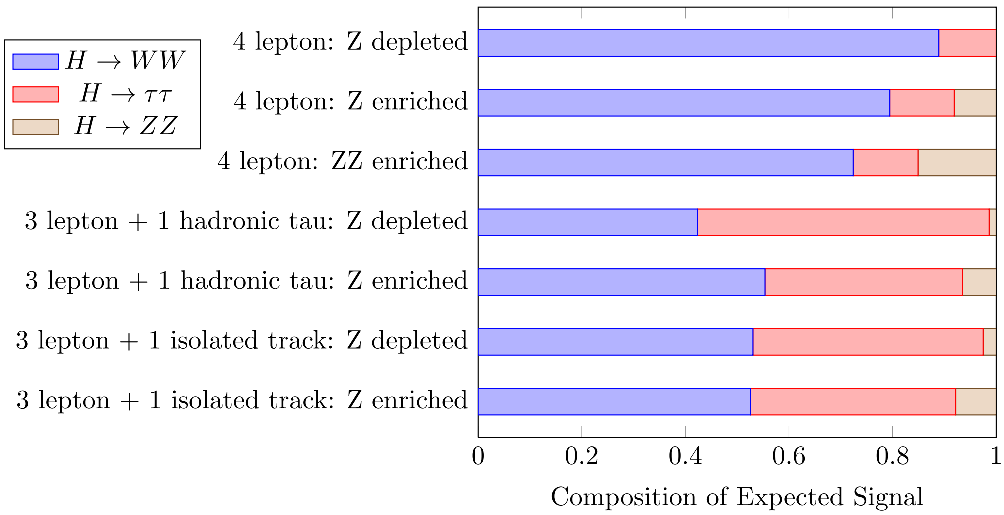

Figure 1: Fraction of Higgs decay mode that is expected to compose the signal in each one of the seven signal regions defined in this analysis.

Figures 2-8 contain p_T, η and ϕ distributions and the expected jet multiplicity for each signal region in this analysis, respectively. Additionally, tables 1-7 contain cut flows for each signal region. Expected event rates, signal to background ratios, and sensitivities for each signal region are displayed in Table 8.

Even though the 4 lepton channel has the best signal to background ratio of all the channels, the low expected event rate means that it is less sensitive to $t\bar{t}H$ than the 3 lepton + 1 hadronic tau channel.

Since the 3 lepton + 1 hadronic tau channel has a lower fake rate than the 3 lepton + 1 isoalted track channel, the former has a better expected sensitivity. However, since a significant portion of the isolated tracks are matched to true electrons and muons in the MC which failed ID requirements, future efforts may still opt to include this channel, albeit with a lesser priority than the 3 lepton + 1 hadronic tau channel. Unfortunately, we were missing the necessary truth information to do detailed studies of the efficiency of detecting one-prong taus as isolated tracks.

The combined estimated sensitivity for the 4 lepton and 3 lepton + 1 hadronic tau channels is 0.587 ± 0.035.

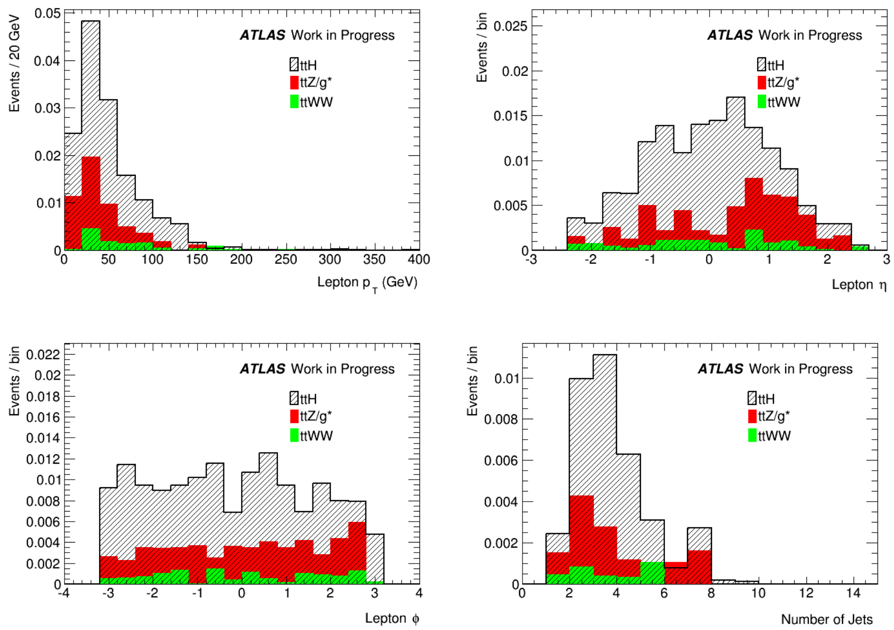

Figure 2: The p_T, η and ϕ of leptons and the jet multiplicity for events in the Z depleted signal region for the 4 lepton channel after cuts.

	Preselection	Drell-Yan Veto	# B-Jets ≥ 1
ttH	0.042 ± 0.004	0.042 ± 0.004	0.037 ± 0.003
Total **bkg**	0.032 ± 0.010	0.032 ± 0.010	0.014 ± 0.004
ttW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ttZ/γ^*	0.011 ± 0.004	0.011 ± 0.004	0.010 ± 0.003
ttWW	0.005 ± 0.001	0.005 ± 0.001	0.003 ± 0.001
ttqq	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
tt	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZ	0.009 ± 0.009	0.009 ± 0.009	0.000 ± 0.000
ZZ	0.007 ± 0.002	0.007 ± 0.002	0.000 ± 0.000
Wγ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
S/B	1.334 ± 0.432	1.334 ± 0.432	2.713 ± 0.765
Est σ	0.202 ± 0.028	0.202 ± 0.028	0.242 ± 0.028

Table 1: Cut flow for the Z depleted signal region in the 4 lepton channel.

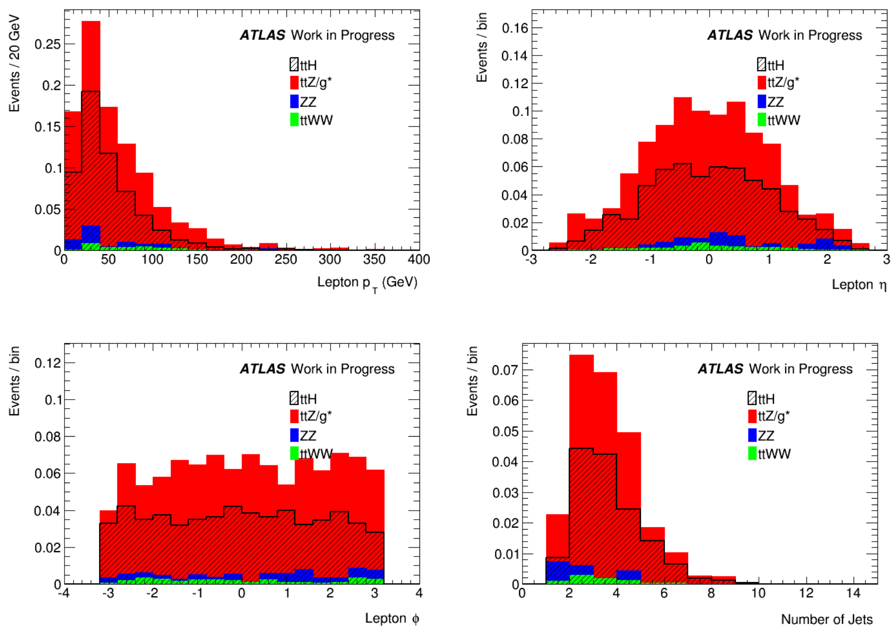

Figure 3: The p_T, η and ϕ of leptons and the jet multiplicity for events in the Z enriched signal region for the 4 lepton channel after cuts.

	Preselection	Drell-Yan Veto	# B-Jets ≥ 1	Z Veto
ttH	0.225 ± 0.009	0.219 ± 0.009	0.191 ± 0.008	0.144 ± 0.007
Total **bkg**	4.615 ± 0.120	4.513 ± 0.119	1.455 ± 0.041	0.250 ± 0.017
ttW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ttZ/γ^*	1.567 ± 0.041	1.544 ± 0.041	1.362 ± 0.039	0.230 ± 0.016
ttWW	0.011 ± 0.002	0.011 ± 0.002	0.010 ± 0.002	0.008 ± 0.002
ttqq	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
tt	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZ	0.109 ± 0.069	0.109 ± 0.069	0.000 ± 0.000	0.000 ± 0.000
ZZ	2.928 ± 0.089	2.849 ± 0.088	0.084 ± 0.015	0.013 ± 0.005
Wγ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
S/B	0.049 ± 0.002	0.049 ± 0.002	0.131 ± 0.007	0.574 ± 0.047
Est σ	0.104 ± 0.004	0.102 ± 0.004	0.155 ± 0.007	0.265 ± 0.014

Table 2: Cut flow for the Z enriched signal region in the 4 lepton channel.

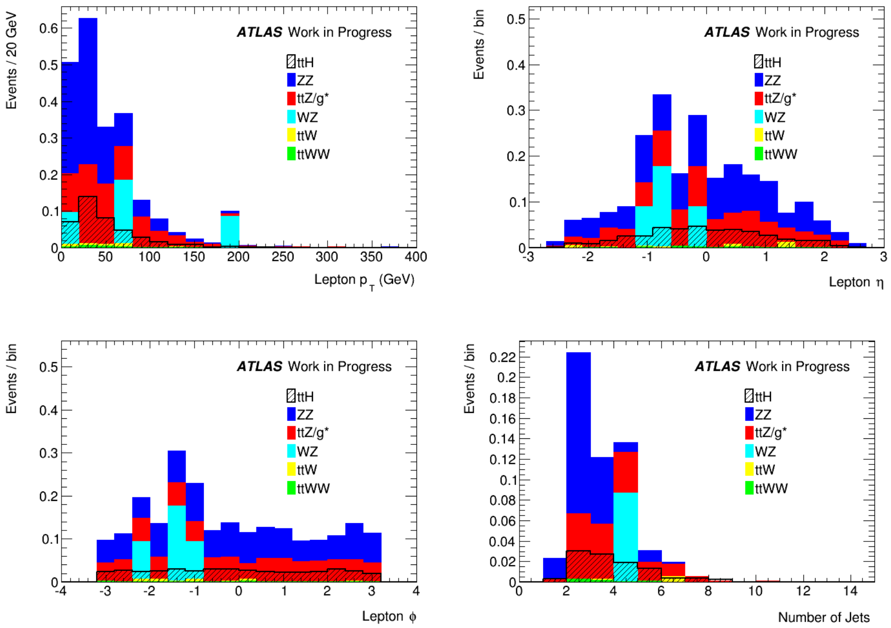

Figure 4: The p_T, η and ϕ of leptons and the jet multiplicity for events in the ZZ enriched signal region for the 4 lepton channel after cuts.

	Preselection	Drell-Yan Veto	# B-Jets ≥ 1	Z Veto	# Jets or E_T^{miss}
ttH	0.176 ± 0.008	0.170 ± 0.008	0.151 ± 0.007	0.107 ± 0.006	0.103 ± 0.006
Total **bkg**	208.943 ± 0.678	192.238 ± 0.650	7.875 ± 0.150	0.791 ± 0.095	0.564 ± 0.092
ttW	0.007 ± 0.006	0.007 ± 0.006	0.007 ± 0.006	0.007 ± 0.006	0.007 ± 0.006
ttZ/γ^*	1.550 ± 0.041	1.512 ± 0.041	1.341 ± 0.038	0.205 ± 0.015	0.198 ± 0.015
ttWW	0.014 ± 0.002	0.013 ± 0.002	0.011 ± 0.002	0.007 ± 0.001	0.007 ± 0.001
ttqq	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
tt	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZ	0.212 ± 0.110	0.212 ± 0.110	0.087 ± 0.087	0.087 ± 0.087	0.087 ± 0.087
ZZ	207.160 ± 0.668	190.494 ± 0.639	6.430 ± 0.116	0.485 ± 0.033	0.266 ± 0.025
Wγ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
S/B	0.001 ± 0.000	0.001 ± 0.000	0.019 ± 0.001	0.135 ± 0.018	0.182 ± 0.031
Est σ	0.012 ± 0.001	0.012 ± 0.001	0.054 ± 0.003	0.118 ± 0.009	0.133 ± 0.013

Table 3: Cut flow for the ZZ enriched signal region in the 4 lepton channel.

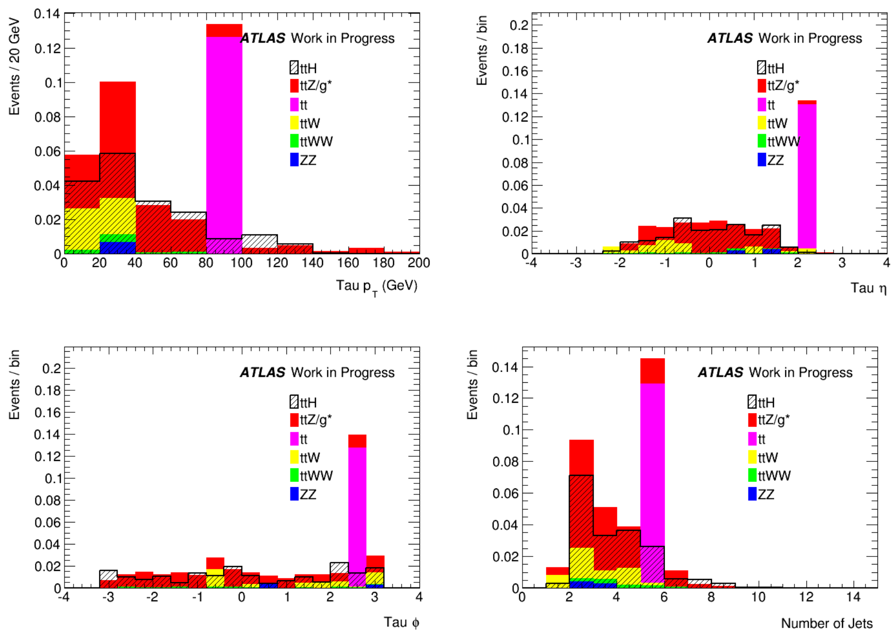

Figure 5: The p_T, η and ϕ of the hadronic tau and the jet multiplicity for events in the Z depleted signal region for the 4 lepton channel after cuts.

	Preselection	Drell-Yan Veto	# B-Jets ≥ 1
ttH	0.220 ± 0.022	0.220 ± 0.022	0.192 ± 0.021
Total **bkg**	1.116 ± 0.333	1.116 ± 0.333	0.375 ± 0.128
ttW	0.051 ± 0.017	0.051 ± 0.017	0.045 ± 0.017
ttZ/γ^*	0.198 ± 0.015	0.198 ± 0.015	0.181 ± 0.014
ttWW	0.010 ± 0.002	0.010 ± 0.002	0.010 ± 0.002
ttqq	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
tt	0.431 ± 0.330	0.431 ± 0.330	0.126 ± 0.126
WZ	0.082 ± 0.028	0.082 ± 0.028	0.005 ± 0.005
ZZ	0.344 ± 0.029	0.344 ± 0.029	0.009 ± 0.006
Wγ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
S/B	0.197 ± 0.062	0.197 ± 0.062	0.511 ± 0.183
Est σ	0.202 ± 0.034	0.202 ± 0.034	0.291 ± 0.052

Table 4: Cut flow for the Z depleted signal region in the 3 lepton + 1 hadronic tau channel.

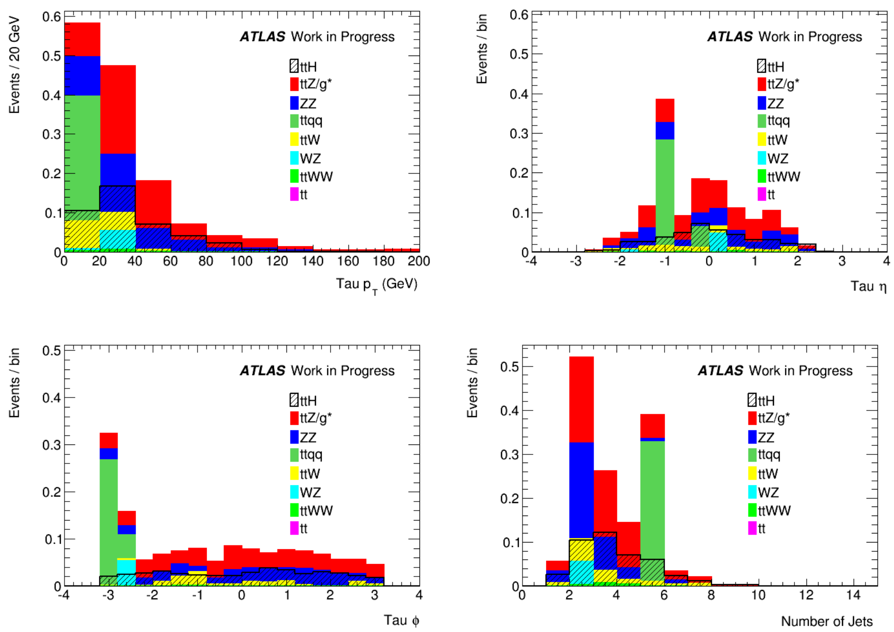

Figure 6: The p_T, η and ϕ of the hadronic tau and the jet multiplicity for events in the Z enriched signal region for the 4 lepton channel after cuts.

	Preselection	Drell-Yan Veto	# B-Jets ≥ 1	Z Veto	# Jets or E_T^{miss}
ttH	0.585 ± 0.030	0.583 ± 0.030	0.494 ± 0.027	0.429 ± 0.026	0.422 ± 0.026
Total **bkg**	123.261 ± 1.317	118.685 ± 1.294	6.811 ± 0.529	2.422 ± 0.489	1.440 ± 0.279
ttW	0.182 ± 0.033	0.182 ± 0.033	0.163 ± 0.031	0.134 ± 0.028	0.121 ± 0.026
ttZ/γ^*	1.882 ± 0.045	1.864 ± 0.045	1.634 ± 0.042	0.591 ± 0.025	0.565 ± 0.025
ttWW	0.029 ± 0.003	0.029 ± 0.003	0.026 ± 0.003	0.023 ± 0.003	0.023 ± 0.003
ttqq	0.317 ± 0.271	0.317 ± 0.271	0.317 ± 0.271	0.317 ± 0.271	0.317 ± 0.271
tt	0.724 ± 0.410	0.724 ± 0.410	0.562 ± 0.399	0.562 ± 0.399	0.000 ± 0.000
WZ	22.945 ± 1.113	21.961 ± 1.090	0.859 ± 0.194	0.089 ± 0.060	0.053 ± 0.048
ZZ	97.020 ± 0.474	93.446 ± 0.465	3.250 ± 0.087	0.706 ± 0.041	0.362 ± 0.029
Wγ	0.161 ± 0.161	0.161 ± 0.161	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
S/B	0.005 ± 0.000	0.005 ± 0.000	0.073 ± 0.007	0.177 ± 0.037	0.293 ± 0.060
Est σ	0.053 ± 0.003	0.053 ± 0.003	0.187 ± 0.012	0.268 ± 0.030	0.337 ± 0.036

Table 5: Cut flow for the Z enriched signal region in the 3 lepton + 1 hadronic tau channel.

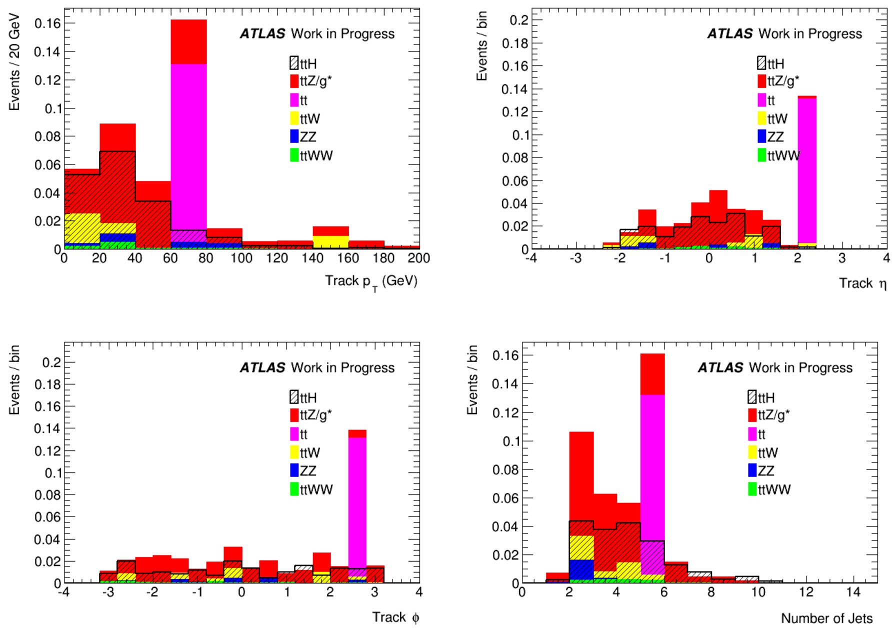

Figure 7: The p_T, η and ϕ of the isolated track and the jet multiplicity for events in the Z depleted signal region for the 4 lepton channel after cuts.

	Preselection	Drell-Yan Veto	# B-Jets $\geq$ 1
ttH	0.211 ± 0.018	0.211 ± 0.018	0.192 ± 0.017
Total **bkg**	1.188 ± 0.340	1.188 ± 0.340	0.440 ± 0.128
ttW	0.040 ± 0.014	0.040 ± 0.014	0.037 ± 0.014
ttZ/γ^*	0.261 ± 0.017	0.261 ± 0.017	0.241 ± 0.016
ttWW	0.013 ± 0.002	0.013 ± 0.002	0.011 ± 0.002
ttqq	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
tt	0.440 ± 0.338	0.440 ± 0.338	0.126 ± 0.126
WZ	0.010 ± 0.007	0.010 ± 0.007	0.000 ± 0.000
ZZ	0.424 ± 0.033	0.424 ± 0.033	0.025 ± 0.009
Wγ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
S/B	0.178 ± 0.053	0.178 ± 0.053	0.437 ± 0.133
Est σ	0.188 ± 0.030	0.188 ± 0.030	0.272 ± 0.042

Table 6: Cut flow for the Z depleted signal region in the 3 lepton + 1 isolated track channel.

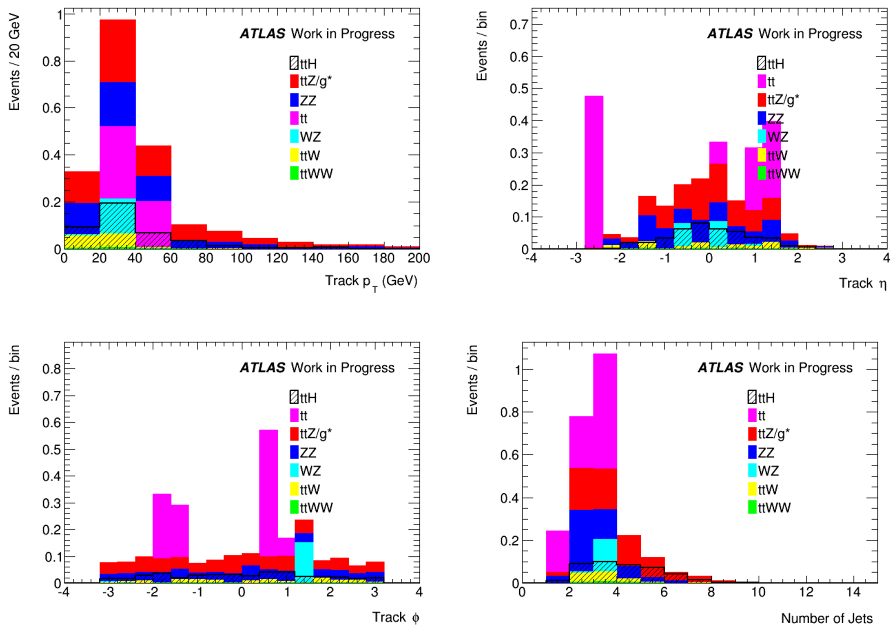

Figure 8: The p_T, η and ϕ of the isolated track and the jet multiplicity for events in the Z enriched signal region for the 4 lepton channel after cuts.

	Preselection	Drell-Yan Veto	# B-Jets ≥ 1	Z Veto	# Jets or E_T^{miss}
ttH	0.611 ± 0.031	0.604 ± 0.031	0.515 ± 0.028	0.430 ± 0.025	0.424 ± 0.025
Total **bkg**	120.629 ± 1.113	116.541 ± 1.095	8.718 ± 0.660	3.003 ± 0.583	2.548 ± 0.580
ttW	0.139 ± 0.031	0.139 ± 0.031	0.134 ± 0.030	0.112 ± 0.028	0.112 ± 0.028
ttZ/γ^*	2.069 ± 0.047	2.054 ± 0.047	1.814 ± 0.044	0.748 ± 0.028	0.729 ± 0.028
ttWW	0.033 ± 0.003	0.033 ± 0.003	0.029 ± 0.003	0.026 ± 0.003	0.026 ± 0.003
ttqq	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
tt	1.301 ± 0.616	1.301 ± 0.616	1.200 ± 0.611	0.974 ± 0.568	0.974 ± 0.568
WZ	12.085 ± 0.790	11.474 ± 0.769	1.045 ± 0.222	0.232 ± 0.119	0.157 ± 0.106
ZZ	105.003 ± 0.482	101.540 ± 0.474	4.496 ± 0.099	0.910 ± 0.046	0.549 ± 0.035
Wγ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
S/B	0.005 ± 0.000	0.005 ± 0.000	0.059 ± 0.005	0.143 ± 0.029	0.166 ± 0.039
Est σ	0.056 ± 0.003	0.056 ± 0.003	0.173 ± 0.011	0.243 ± 0.027	0.259 ± 0.032

Table 7: Cut flow for the Z enriched signal region in the 3 lepton + 1 isolated track channel.

Channel	Signal Region	# of Events	S/B	Estimated σ
4 lepton	Z depleted	0.037 ± 0.003	2.713 ± 0.765	0.242 ± 0.025
	Z enriched	0.144 ± 0.007	0.574 ± 0.047	0.265 ± 0.014
	ZZ enriched	0.103 ± 0.006	0.182 ± 0.031	0.133 ± 0.013
3 lepton + 1 hadronic tau	Z depleted	0.192 ± 0.021	0.511 ± 0.183	0.291 ± 0.052
	Z enriched	0.422 ± 0.026	0.293 ± 0.060	0.337 ± 0.036
3 lepton + 1 isolated track	Z depleted	0.192 ± 0.017	0.437 ± 0.133	0.272 ± 0.042
	Z enriched	0.424 ± 0.025	0.166 ± 0.039	0.259 ± 0.032

Table 8: MC estimates for the expected event rates, signal to background ratios and expected sensitivities for each $t\bar{t}H \rightarrow 4l$ signal region.

4 Conclusions

Multileptonic final states provide exciting handles in the search for $t\bar{t}H$ at the LHC. Although we expect low event rates for the 4 lepton channel with $\sqrt{s}$ = 8 TeV and 20.7fb^{-1}, we also expect very clean signal regions; the 4 lepton channel will be useful in combination with other $t\bar{t}H$ analyses. Finally, with $\sqrt{s}$ = 14 TeV and 300fb^{-1} we have discovery potential for $t\bar{t}H$ in the 3 and 4 lepton channels alone [5].

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