$t\bar{t}$ Decay into Six Jets in the First Year of ATLAS@LHC

M. Lambacher, O. Biebel, G. Duckeck, J. Elmsheuser, F. Fiedler, G. Krobath, M. Lamprecht, R. Mameghani, T. Nunnemann, G. Reiter, B. Ruckert, D. Schaile, M. Schott, C. Serfon, and R. Ströhmer

The LHC is a top quark factory. The expected $t\bar{t}$ cross section amounts to 833 pb at NLO, resulting in almost eight million $t\bar{t}$ events[1], already in the first nominal year of the LHC and the ATLAS experiment. 44% of these $t\bar{t}$ pairs decay hadronically, resulting in all-hadronic $t\bar{t}$ events, as illustrated in last year's annual report [1].

The difficulty of this decay channel is, that the all-hadronic $t\bar{t}$ events are superimposed by lots of background events, the QCD multijet background, which comprises 3 to 6 or more final state partons. These QCD events have a cross section many orders of magnitude above the $t\bar{t}$ multijet cross section[2] and show a final state topology very similar to that of the top quark events, which makes it very difficult to distinguish them from the $t\bar{t}$ signals.

The following study describes the analysis and the separation of all-hadronic $t\bar{t}$ events at the very beginning of the LHC and the ATLAS experiment, when the detector is not yet well calibrated nor its components are perfectly aligned.

For the simulation of the $t\bar{t}$ events, which have a cross section proportional to α_s^2, the leading-order (LO) generator PYTHIA 6.2 was used. The 4-vectors of the background events[3] were generated with ALPGEN, version 2.03, which provides multi parton final states in leading order. The generated events were transformed and processed further in the Athena environment with the simulation program ATLFAST 11.0.41. Thereby, the jet reconstruction was performed with the k_T algorithm in exclusive mode with fixed cut-off parameters d_{Cut}. For the reconstruction charged particle tracks as well as calorimeter cell entries were used. ATLFAST also provides detector information simulating the response of the detector's components on the studied events.

In order to separate the background events from the $t\bar{t}$ signal, a cut analysis was developed intending to have a large $t\bar{t}$ sample with small contributions from background events and, therefore, a signal to background (S/B) ratio as large as possible.

Cuts	Tracks & Cells
#0	$\lvert\eta_{jet}\rvert < 3$
#1	$N_{jets} = 6$
#2	$p_{T,jet1} > 115$ GeV , $p_{T,jet2} > 90$ GeV $p_{T,jet3} > 70$ GeV , $p_{T,jet4} > 55$ GeV $p_{T,jet5} > 40$ GeV , $p_{T,jet6} > 30$ GeV
#3	Sum $p_{T,jet} > 140$ GeV
#4	75 GeV $< m_{dijet} <$ 150 GeV
#5	165 GeV $< m_{trijet} <$ 400 GeV
#6	$p_{T,trijet} > 250$ GeV
#7	Aplanarity > 0.1

Table 1: Cuts to separate the $t\bar{t}$ signal from the background

The choice of the optimal selection variables is a crucial factor for the success of a cut analysis. These variables must depend on the physical aspects of the signal events and on the feasibility of the underlying hardware, thus the ATLAS detector. The cuts, used in this study, must also accommodate to the conditions in the start-up period of the experiment.

Table 1 lists the cuts applied to the $t\bar{t}$ and the background events. Among a few kinematic cuts, the reconstructed masses of the two W bosons (m_{dijet}), in which the top quarks decay, and also the reconstructed top-quark masses (m_{trijet}, see Fig. 1) were used to separate the $t\bar{t}$ signal from the QCD multijet background.

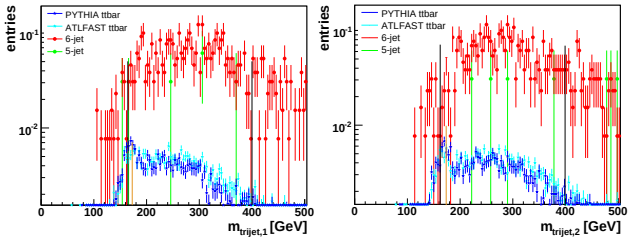

Fig. 1: Reconstructed top quark masses for events reconstructed from calorimeter cell entries. The black vertical lines mark the position of the applied cuts. The orange vertical line shows the "real" mass of the top quark.

The result of the cut analysis, including all the cuts which are listed in Table 1, is illustrated in the first eight bins of the two cut-flow histograms, presented in Fig. 2. Using calorimeter cell entries only, shown in Fig. 2 left, the cut analysis leads to a S/B ratio of 1/16, resulting in a suppression factor of 10000 for the 6-jet background events. Using charged particle tracks only, the S/B ratio amounts to 1/24 also corresponding to a suppression factor of about 10000 for the 6-jet background.

In order to estimate the effect of b-tagging on the S/B ratio, an additional cut on the number of b-tagged jets ($N_{b-\text{jets}} \geq 2$) was added at the end of the cut analysis (see ninth bin in the two cut-flow histograms). The resulting histograms (Fig. 2) show that the S/B ratio gets to 1/2 or unity for track and cell events, respectively. In addition, the 6-jet background events are now suppressed by a factor of 10^6.

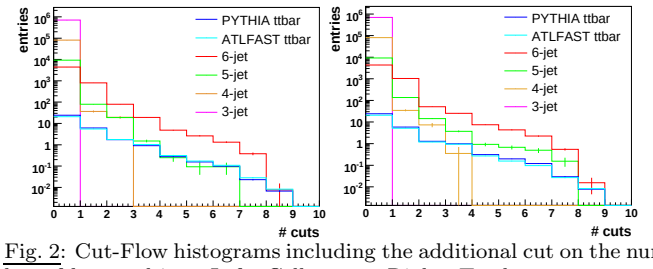

Fig. 2: Cut-Flow histograms including the additional cut on the number of b-tagged jets. Left: Cell events; Right: Track events;

When applying all cuts, presented in Table 1, a number of 4400 (track) and 3400 (cell) all-hadronic $t\bar{t}$ events would remain in the first year at the LHC, respectively. If the additional b-tag cut is included, this number amounts to about 1000 remaining $t\bar{t}$ signal events for tracks and cells with S/B ratio of 1/2 (tracks) or unity (cells), respectively.

References

[1] M. Erlebach *et al.* Annual report 2005, p. 32

[1] This number of events is estimated for an integrated luminosity of 10 fb^{-1}.
[2] The cross section for 5-jet and 6-jet background events amounts to 0.3 μb.
[3] The background events have a cross section proportional up to α_s^6.