Study of Fully Hadronic $t\bar{t}$ Decays and their Separation from QCD Multijet Background Events in the First Year of the ATLAS Experiment

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The LHC is a top quark factory, resulting in almost eight million $t\bar{t}$ events already in the first nominal year of the LHC and the ATLAS experiment. 44% of these $t\bar{t}$ pairs decay into fully hadronic final states. These decays, however, are overwhelmed by QCD multijet background, in particular final state with six or more partons. These QCD events have a cross section many orders of magnitude above the $t\bar{t}$ multijet cross section 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.

An analysis [1] was developed which allows to separate $t\bar{t}$ events from QCD multijet background events at the very beginning of the LHC and the ATLAS experiment, when the detector is neither well calibrated nor its components are perfectly aligned. For the simulation of the $t\bar{t}$ events the PYTHIA 6.2 generator was used. The QCD background events were generated with the Monte Carlo generator ALPGEN, which provides multiparton final states. Jets of particles were reconstructed with the k_T jet algorithm in exclusive mode using a fixed cut-off parameter d_{Cut}. A fast parametrized simulation of ATLAS provided the response of the detector on the events studied.

In order to separate the background events from the $t\bar{t}$ signal, a cut based analysis was developed striving for large background reduction while maintaining an reasonable signal. The variables chosen accommodate to the conditions of the ATLAS detector in the start-up phase of the experiment.

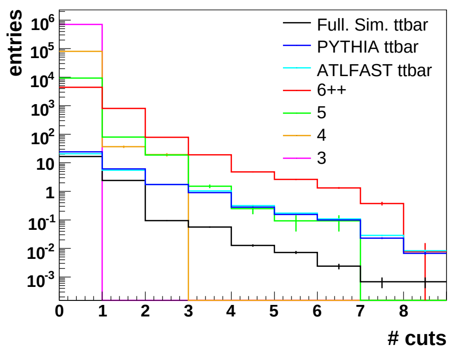

Fig. 1: Cut-Flow histogram. The distribution includes also an additional cut on the number of b-tagged jets (last bin).

Kinematic cuts were applied on (#0) the pseudorapidity of the jets, (#1) the number of reconstructed jets, (#2) the transverse momenta of the jets, (#3) the vectorial sum of transverse momenta, (#4) the reconstructed masses of the two W bosons, in which the top quarks decay, and also on (#5) the reconstructed top quark masses. Due to the high c.m.-energy of LHC, (#6) the top quarks typically have large transverse momenta, but still (#7) $t\bar{t}$ events look less planar than the QCD multijet background.

The result of the cut analysis is illustrated in the cut-flow histogram, presented in Figure 1. It leads to a signal-over-backgroun ratio of 1/16, resulting in a suppression factor of greater than 10000 for the 6-jet background events while a $t\bar{t}$ selection efficiency of about one permill was maintained. Thus, about 3300 fully hadronic $t\bar{t}$ events would remain in 10 fb^{-1} of the first nominal year of the LHC.

In order to estimate the effect of b-tagging on the signal-over-background ratio, an additional cut (#8) on the number of b-tagged jets ($N_{b-\text{jets}} \geq 2$) was employed after all other cuts. This yields a total suppression of 6-jet background events by a factor of 10^6, while the signal-over-background achieves unity. The number of $t\bar{t}$ events amounts to about 1000 in this case.

In addition to this cut analysis, a top-mass peak was reconstructed from the fully hadronic $t\bar{t}$ event using looser cuts. The corresponding distribution is represented in Figure 2(top). The remaining QCD 6-jet background distribution was parameterized by a Landau function.

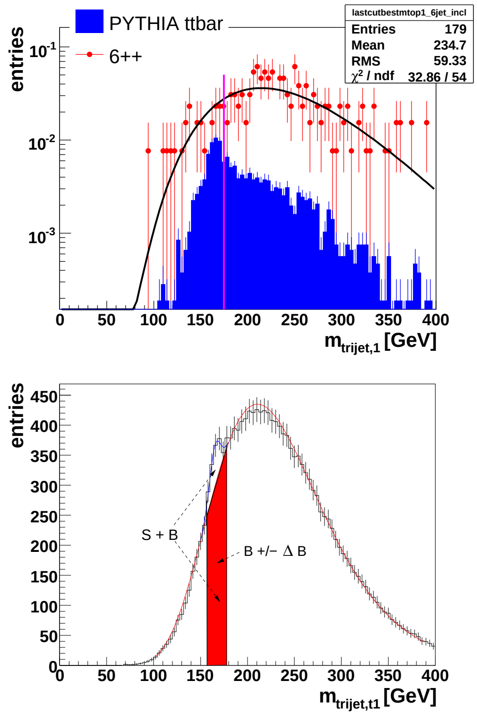

Fig. 2: Top: Reconstructed mass of the top quark according to simulated statistics. The residual QCD 6-jet events have been fitted with a Landau function. Bottom: Distribution for the $t\bar{t}$ and 6-jet background events scaled for an assumed integrated luminosity of 1560 pb^{-1}. S corresponds to the signal events and B stands for the number of QCD 6-jet events in the signal region. $S + B$ is the total number of remaining events.

For demonstrating the expected top-mass peak at a larger integrated luminosity, signal and background were scaled appropriately with keeping the parametrized background shape. The corresponding distribution was then fitted with a Gauss function for the signal plus a Landau function for the background in order to assess from the signal S the statistical uncertainty for a cross section measurement for any integrated luminosity (Figure 2 bottom). Assuming an integrated luminosity of 10 fb^{-1} for the first nominal year of LHC and ATLAS a statistical accuracy of about 4 % can be obtained for the determination of the cross section for the production of fully hadronic $t\bar{t}$ events.

References

[1] M. Lambacher, Ph.D. thesis, LMU München, 2007