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Top Physics at ATLAS

GEORGIOS STAVROPOULOS
Physics Department, U.C. Berkeley, 1 Cyclotron Road, Berkeley, CA-94720, U.S.A.

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The large number of $t\bar{t}$ events that will be produced at LHC, will allow very precise measurements of the properties of the top quark, which may also reveal New Physics. The mass of the top quark will be measured with a precision of about one GeV. Rare decays of the top quark can be probed for branching ratios as small as 10^{-4}. Finally, the detailed study of three different mechanisms of electroweak single top production will allow precise measurements of the CKM matrix element V_{tb}.

Keywords: Top; LHC; ATLAS.

1. Introduction

The Large Hadron Collider (LHC) at CERN will be a proton-proton collider with a centre-of-mass energy of 14 TeV and a design luminosity of 10^{34} cm^{-2}s^{-1}, providing four experiments with 100 fb^{-1} of integrated luminosity in one year of data taking. During its first three years of operation, LHC is expected to run in lower luminosity up to $2 \times 10^{33} cm^{-2}s^{-1}$ delivering 10 fb^{-1} of integrated luminosity per year. The cross-section for producing $t\bar{t}$ pairs has been determined[1] to Next to Leading Order (NLO) to be $\simeq$ 830 pb^{-1}, which means that there will be over 8×10^6 $t\bar{t}$ events at low luminosity and ten times that quantity at high luminosity; the LHC will be considered a top factory. This paper summarizes studies of the top mass measurement, of the top quark decays and couplings, and of single top production, obtained using ATLFAST[2], the parametrized ATLAS (A Toroidal LHC Apparatus) detector simulation, and confirmed by the detailed simulation of the ATLAS detector.

2. Measurement of the Top Quark Mass

A precise measurement of the top mass is highly desirable both within the Standard Model (SM) and the Minimal Supersymmetric Stadard Model (MSSM) framework. In the SM, an improved accuracy on the measurement of the top and W masses would help to provide a rigorous consistency check and to constrain some parameters of the model such as the mass of the Higgs boson. In the MSSM, it would put constraints on the parameters of the scalar top sector and would therefore allow sensitive tests of the model by comparing predictions with direct observations.

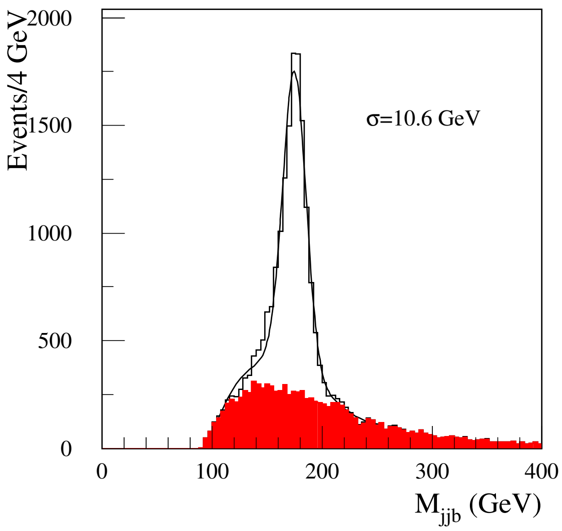

Fig. 1. Invariant mass of the bjj system after 10 fb^{-1} of integrated luminosity. The shaded area is the combinatorial background

According to the SM, the top quark decays almost exclusively to Wb. At the LHC, the top mass will best be measured in $t\bar{t}$ events, where one W decays leptonically and the other W hadronically into two jets. The following criteria will be typical of the cuts used to select this type of events: an isolated lepton (e or μ) with $p_T > 20$ GeV, $E_T^{miss} > 20$ GeV, and at least four jets with $p_T > 40$ GeV two of which should be tagged as b-jets. After imposing these criteria in ATLAS the resulting signal-to-background ratio was found to be $\simeq 78$. For accepted events, the invariant mass of the W decaying into two jets was reconstructed from among the non-b-tagged jets. The events with all combinations having $|m_{jj} - m_W| > 20$ GeV were rejected. In the remaining events the two jet combination which gave the smallest $|m_{jj} - m_W|$ value was combined with the b-jet which gave the highest p_T for the three-jet combination. The invariant mass, m_{bjj}, of the three-jet system is shown in Figure 1. The statistical uncertainty in m_t after 10 fb^{-1} of integrated luminosity[3] will be 0.070 GeV.

The largest systematic uncertainty in m_t will arise from the jet energy scale and final state radiation. If the jet energy scale will be known to 1%, then the systematic uncertainty in m_t will be $\simeq 1$ GeV.

3. Flavor Changing Neutral Current Decays (FCNC)

Within the SM and MSSM, FCNC decays of the top quark are highly suppressed, and so any observation of FCNC top decays at the LHC would be a very good validity check of these models. In ATLAS the $t \to Zq$, $t \to \gamma q$, and $t \to gq$ FCNC decays were studied, for which the SM and MSSM predict branching ratios of order 10^{-12} and 10^{-8} respectively. These studies[4] showed that in ATLAS branching ratios as low as 10^{-4} could be discovered at the 5σ level with an integrated luminosity of 100 fb^{-1}. From this we can conclude that the branching ratios predicted by SM and MSSM are too small to be observable at LHC. However ATLAS will be able to set more stringent limits than the existing ones, and check the predictions of other theoretical models, which allow branching ratios for these FCNC decays of the order of 10^{-3} - 10^{-2}.

4. Single Top Production

The precise determination of the properties of the $W - t - b$ vertex, and the associated coupling strengths, will more likely be obtained from measurements of the electroweak production of single top quarks. Single top quarks can be produced via three different reactions: Wg fusion, Wt production, and the W^* production. In order to select single top events against the enormous QCD multi-jet backgrounds and to provide a high $p_T > 20$ GeV lepton for trigger purposes, single top production with $t \to Wb$ followed by a leptonic decay $W \to l\nu (l = e, \mu)$ has been considered. Additional selection criteria were imposed depending on the process of interest. Assuming an integrated luminosity of 30 fb^{-1}, ATLAS studies[4] showed that the CKM matrix element V_{tb} could be measured with a statistical uncertainty of 0.4%. However the errors in the measurement of V_{tb} are dominated by uncertainties in the parton distribution functions of the proton and cross sections of background processes, and by the uncertainty in the m_t.

5. Conclusions

The large production cross-sections at the LHC for $t\bar{t}$ pair production and electroweak single top production imply that over the lifetime of the ATLAS experiment, samples of many millions of top quark events will be selected. The mass of the top quark will be measured with a precision of about one GeV, dominated entirely by systematic errors. Rare decays of the top quark can be probed down to branching ratios as low as of order of 10^{-4}. The detailed study of different mechanisms of electroweak single top production will allow the measurement of V_{tb} with a statistical uncertainty as low as 0.4%.

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