Grant Title: Exotic Physics with the Top Quark at the LHC
PI: Assistant Professor Kevin Black (summer supported by this grant)
DOE Grant Number : DE-SC0007899 Graduate Students: Clare Bernard (supported by this grant)
Post-Doc: Lidia Dell'Asta (supported with startup funds)
Undergraduates: Alice Sady and Kelsey Bilsback

1 Introduction

Boston University has been involved in the ATLAS experiment since the early 1990s. The PI of this grant, Kevin Black, joined Boston University in the fall of 2010 as an assistant professor. This grant was funded starting in the spring of 2012 and initially was to support the PI summer salary, one graduate student (Clare Bernard), and travel and expenses. After one year the Boston University grant was submitted along with PIs Steve Ahlen and John Butler and it was decided to merge this standalone grant to a joint grant and hence support for this grant ended after only one year (with continued support for the new grant beginning in 2013). The grant supported two main activities : searching for new physics with the top quark at the LHC and development of the ATLAS muon trigger.

2 ATLAS Muon Trigger

The ATLAS online event selection or trigger system is built upon three logical layers which make increasing precise decisions about which events to record. The process reduces the event rate from the collision frequency from the MHz rate to more manageable rate of several hundred Hz. The ATLAS trigger is divided into a hardware based trigger called Level-1 (L1) and the High Level Trigger (HLT) which is further divided into Level-2 and Event Filter (EF). In the spring of 2012 , Black was appointed the convener of the ALTAS Muon Trigger Studies group. This group has the responsibility of developing the HLT trigger algorithms for the muon spectrometer, designing the muon trigger items, and measuring and monitoring the performance of the trigger.

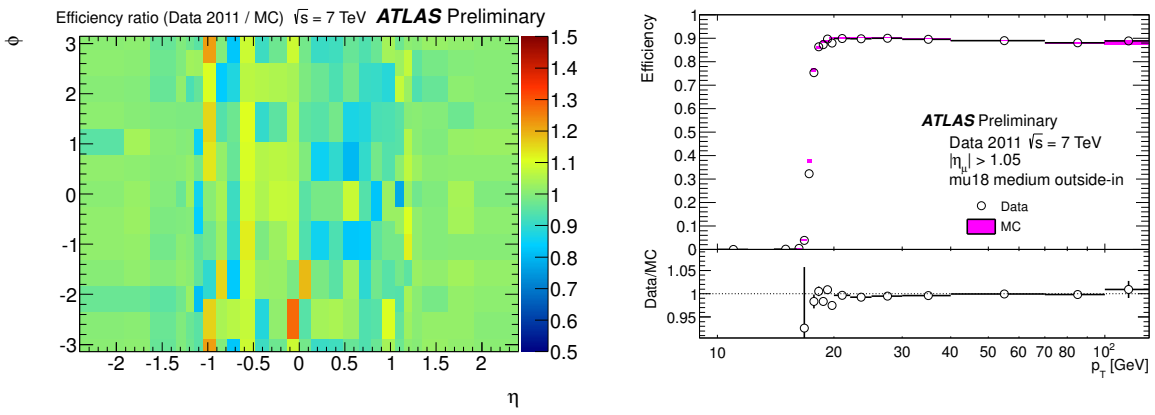

Figure 1: The ratio of the trigger efficiency in data and simulation as a function of η and ϕ (left) and the efficiency as a function of the p_T for a single muon trigger with a requirement of a $p_T > 18$ GeV muon as measured in the 7 TeV data from [1] .

2.1 Muon Trigger Performance

Our group contributed to the measurement of the performance of the ATLAS muon trigger in both the 7 and 8 TeV run. We measured the efficiency of the ATLAS muon trigger by identifying events from the Z $\rightarrow \mu\mu$ and measuring the efficiency over the detector as seen in Figure 1.Since the summer of 2012 we have been working to update with the full dataset and to measure the isolation efficiency, performance with high pileup, and finalize the systematic uncertainties. That project is now almost completed and will be published in a more comprehensive paper on the performance of the ATLAS muon trigger in the fall.

2.2 Level 2 Muon Trigger

A major activity during this period was the rewrite of the ATLAS level two muon trigger. The project was undertaken at the request of ATLAS management as the previous version of the L2 trigger algorithm had been written over ten years ago in legacy code which was no longer supported by the standard ATLAS framework. We worked with a group from Japan to produce a completely rewritten version of the level 2 muon code. The main improvements made were:

- Use of Common Offline and Trigger Framework Code allowing easier maintenance and extendability - in particular to the upgrade project
- Decreased Processing Time

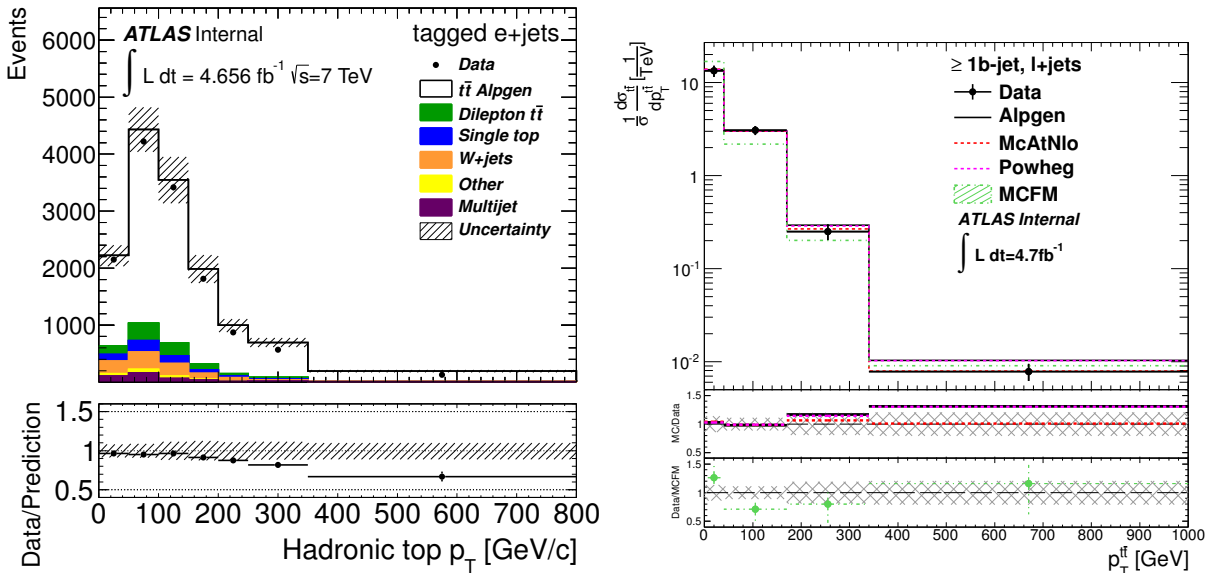

Figure 2: Top Pt Distribution of selected $t\bar{t}$ events in data and simulation (left) and the measured $t\bar{t}$ system p_T (right) .

- Increased Efficiency from improved algorithms - in particular recovery sectors for which the L1 trigger data is lost (previously also lost at L2 but now recovered with the new algorithm)

The work was completed in time for a preliminary version of the algorithm to run for the entire 8 TeV dataset. Continued testing has been taking place and this will form the basis for future work intreating the new small wheel into the L2 algorithms.

3 Physics Analysis

3.1 Top Differential Cross-Section and Searches With the Top Quark

Black and Bernard have worked for over a year to measure the top quark differential cross-section as a function of top quark p_T, top quark pair p_T , and top quark pair rapidity y. The measurement is a precise measurement using the complete ATLAS 7 TeV dataset. Preliminary results using first 2 fb^{-1} of data were published in [2]. Preliminary results from the entire dataset are shown in Figure 2. The analysis is is in final collaboration review and submission to a journal will happen in the next month. Black was co-editor of both the internal note and paper in publication.

Vector-like quarks (VLQs) are a general prediction of a wide class of beyond the Standard Model theories, as extra dimensions, composite Higgs models. Building on our institutional knowledge of the top quark final state

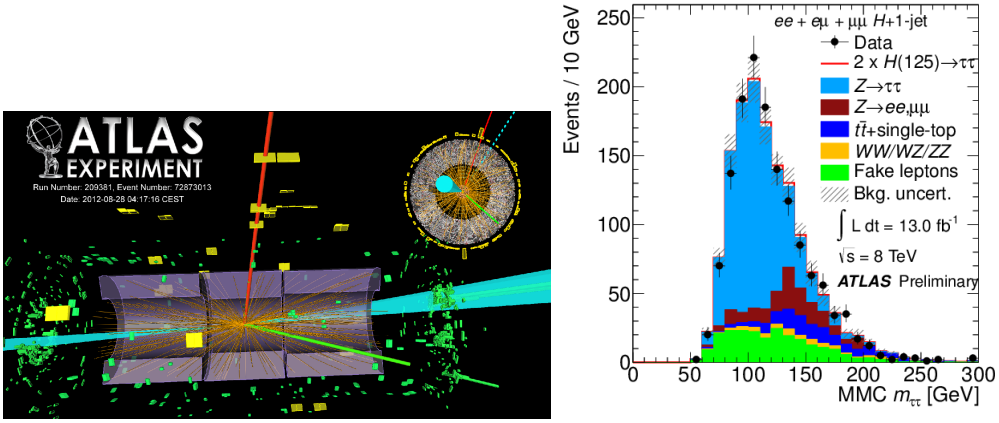

Figure 3: Higgs candidate mass (left) and Higgs candidate event dispay

from the work on the top differential cross-section - Bernard and Black have set about to search for the existence of vector like quarks. The existence of these types of quarks could provide important cancelation to the quantum corrections to the Higgs boson mass helping explain the heirachy and fine tuning problem of the Standard Model. The analysis will be done with the full 8 TeV dataset and also provided as an input to Snowmass using a fast simulation.

3.2 Higgs to $\tau\tau$

The discovery of the Higgs Boson in the summer of 2012 started a new area of research for our group. We became interested in the observation of the Higgs boson by observing its direct coupling to fermions and τ's. Building on Dell'Asta's experience with tau particle identification from her graduate student work we began to look for evidence of tau production in our data. The first measurement [3] was based on the 7 TeV and partial 8 TeV dataset. The BU group contributed by understanding the background contribution to a difficult search channel by producing so called 'embedded' samples. The largest background to the two lepton channel is the Z + jets channel. This is a difficult channel to model in MC so we take Z to dimuon events from data removing the muon candidates and replacing them with simulated tau particles. This is at technically challenging analysis and provides a much better understanding of the large and difficult to model backgrounds. In addition we provided the measurements of the muon trigger efficiency for this channel.

Since the preliminary result a major thrust of our research has been to update that result to the complete 8 TeV dataset. Dell Asta served as the analysis organizer and we expect final results to be published in the next few months.

4 Editorial Boards

Black has served on over 10 editorial boards of papers and conference notes including the 4 lepton discovery of the Higgs Boson and chairing 3 editorial boards.

5 Invited Talks and Conference Presentations

- 'Standard Model Backgrounds in the Search for the Higgs' , The Next Stretch of the Higgs Magnificent Mile, May 2012
- 'Prospects for Top Quark Properties at the LHC', LHC Workshop 2012
- ATLAS Muon and Tau Triggers, ACAT 2013, China

6 Publications

Members of the BU group are authors on all ATLAS papers published to date. A complete list of publications, over 250 and counting, can be found at https://twiki.cern.ch/twiki/bin/view/AtlasPublic/Publications.

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