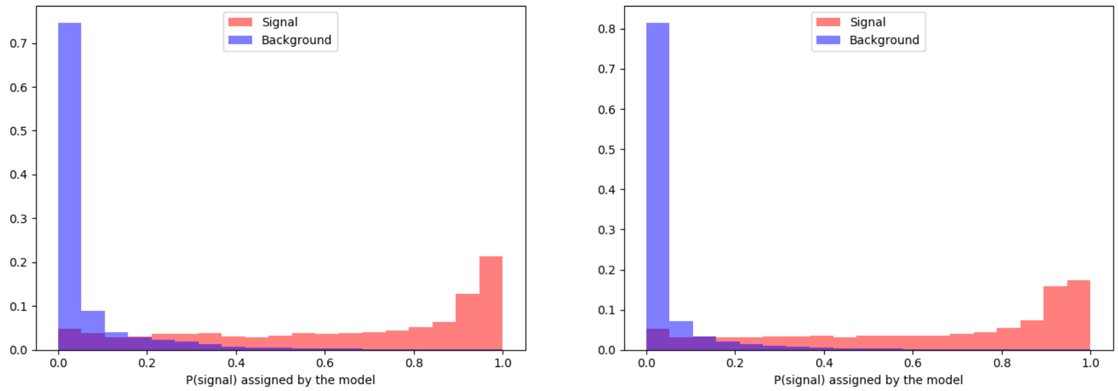
Progress Report

Using the ATLAS experiment at the Large Hadron Collider (LHC) a search for rare top quark decays in proton-proton collisions, with center of mass energy $\sqrt{s}$ = 13 TeV is ongoing by Professor James Brau and graduate student Jason Barkeloo. This search follows a similar search done at $\sqrt{s}$= 8 TeV which was able to set new limits on the branching ratio of the rare top quark flavor-changing neutral current (FCNC) decay modes where a top quark decays to an up-type quark (up or charm) and a photon.

Within the Standard Model (SM) of particle physics the top quark decays to a W boson and a bottom quark (t $\rightarrow$ bW) almost 100% of the time. A neutral current decay though which the top quark decays to a neutral boson (photon, Z quark or Higgs boson) and an up-type quark (e.g. t $\rightarrow q\gamma$) is heavily suppressed within the SM. Various suppression occurs to these processes leaving their branching ratios on the order of 10^{-17} to 10^{-12} [**?**], such as the GIM-Mechanism [**?**] and being off-diagonal in the CKM-Matrix [**?**]. These FCNC processes can still occur in the SM through higher-order loop processes. These SM ratios are significantly beyond current expiermental reach as well as being so far suppressed they are out of future experimental reach for any reasonable timeframe. Many beyond the standard model theories exist which predict large enhancements to the top sector of the SM (e.g. various models of supersymmetry, Randall-Sundrum models, 2 Higgs Doublet models). Observation of any of these FCNC decays would require a very large enhancement, eight to twelve orders of magnitude, to the SM Branching ratio and would be an absolute indication of new physics. Current upper limits on the branching ratio BR(t $\rightarrow q\gamma$) from the production mode search using the ATLAS experiment at the LHC are BR($t \rightarrow c\gamma$) < 1.8x10^{-4} and BR($t \rightarrow u\gamma$) < 2.8x10^{-5}, with the 81fb^{-1} of 13 TeV data[**?**].

We are preforming a search for the FCNC in the $t\bar{t} \rightarrow bWq\gamma$ channel at ATLAS, using the entire Run 2 data set of 139fb^{-1} of $\sqrt{s}$ = 13 TeV pp collisions. Specialized Monte Carlo simulation events for this process have been created after validation with the ATLAS collaboration's top quark group. MadGraph was used to force the decays of the top quark to this specific final state. These simulated events are reconstruced using a model of the ATLAS detector and have been created for all of the decay channels of the FCNC process for top-quark pair events including the top or antitop undergoing FCNC decay while the other goes through the SM typical decay. The W boson decays are included as well and large signal samples have been produced for the leptonic mode (W $\rightarrow l\nu$) final state. Working with the Monte Carlo production team to debug issues with the grid sites and Mad Graph samples were produced for each of the three Monte Carlo campaigns to correspond with different run parameters of Run 2 at the LHC.

There are many SM processes that can mirror the final state of our signal processes including $t\bar{t}$, W+jets, Z+jets, including processes that have an associated photon as well. Machine learning techniques have been employeed for signal-background separation, the



(a) e+jets

(b) μ+jets

Figure 1: Neural network output used for signal-background separation for both analysis channels.

outputs for both signal channels are shown in Figure **??**. In addition to this metric being used to separate out our signal region from the various backgrounds various validation regions orthogonal to the signal region have been produced to check Monte Carlo modeling of background samples in comparison to the data. We are using these orthogonal regions to ensure accuracy of our background modeling while our signal region is blinded. After background studies have ensured a well modeled system we will move to unblind the study and search for any excesses in the signal region. Any excess would imply some new physics otherwise a new branching ratio can be set which will help restrict current and future theoretical models.

References

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[3] M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973). doi:10.1143/PTP.49.652

[4] ATLAS Collaboration, "Search for flavour-changing neutral currents in processes with one top quark and a photon using 81 fb^{-1} of pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS experiment," arXiv:1908:08461 [hep-ex].

[5] LHCtopWG, LHC Top Working Group Summary Plots `https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCTopWGSummaryPlots`