Using Initial State Radiation (ISR) Jets in the SUSY Search

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ABSTRACT

To search for the hypothesized SUSY particles, physicists have to create algorithms or cuts to separate signals from the unwanted background events. Cuts are easy to apply to a dataset, but are not always very efficient at selecting the signal being analyzed. In this study, we analyzed the plausibility and effectiveness of using ISR jet pseudorapidity and ISR jet Pt cuts on the T2tt signal sample from the CMS detector to separate the signal from the background. After graphing the Pt and pseudorapidity per event graphs, we concluded that an ISR jet Pt cut would be an effective cut, but and ISR pseudorapidity cut would not be effective. We determined that an ISR jet Pt cut around 350 GeV would be effective at increasing the ratio of signal events to background events because below 350 GeV, there are significantly more background events than signal events. ISR jets appear in a large amount of particle interactions, so although our findings only are for the T2tt signal, it is highly likely that these findings could be applied to other signals that are being analyzed for the search for supersymmetry.

INTRODUCTION

According to the Standard model of physics, particles are composed of subatomic particles called elementary particles - shown on the left side of Figure 1.1, according to the Standard model of physics. However, the Standard model has failed to fully explain observed phenomena, resulting in the search for new models of physics. The Supersymmetry Model, or SUSY model, proposes that each of the Standard Model particles have a corresponding SUSY particle (Murayama, n.d.). One of the signals that SUSY researchers are currently studying is called the T2tt signal. This signal has a top squark pair, which has yet to be identified (Duarte, 2015). In this study, we are searching for the production of theorized top squark pairs only; therefore, we must be able to separate out the signal from the Standard Model background. In most particle physics experiments, physicists analyze either simulated data or real data collected from collisions within a particle collider. To properly analyze and find patterns in these collisions, we must design an algorithm to collect only the interesting data through triggers, and then they identify and "tag" each particle (Lajoie, 2009). Jets are a group of particles created by the decay of gluons or quarks, through a process called hadronization as shown in Figure 1.2 (Webber, n.d.). In this study, we analyzed ISR jets and how ISR jets can be used to better identify signals, specifically the T2tt signal, in the future.

METHODOLOGY

Before beginning the analysis, we had to collect a large amount of data. The data is collected through one of the four detectors within the Large Hadron Collider, the CMS detector. After protons collide, the produced particles then pass through layers of detectors, leaving signatures, as depicted in Figure 2.1. The CMS detector alone receives around 600 MB per second of data (CERN, 2012). The data is passed through triggers, which cut out the uninteresting events, and is then further separated into different files. In this study, we used Monte Carlo simulated events that passed through the detector and triggers. The momentum perpendicular to the z-axis, also known as "Pt" or the transverse momentum, is also important to study. The Law of Conservation of Energy states that no energy can be lost within an isolated system, which means that there should be no resulting missing energy from a collision in the detector; however, missing energy is identified. Missing energy is energy released by particles that the detector fails to detect, such as neutralinos. Since the T2tt signal releases neutralinos, we have to account for a large amount of missing energy in this study (Murayama). Pseudorapidity, represented by the Greek letter "eta"(n), is another important measurement to analyze while observing ISR jet decay. Pseudorapidity, is the measure of the forward direction on the positive z-axis. By analyzing both ISR jets' transverse momentum and pseudorapidity, and the difference between the background and the signal events, we can determine how to make better signal cuts, or selections, in the future.

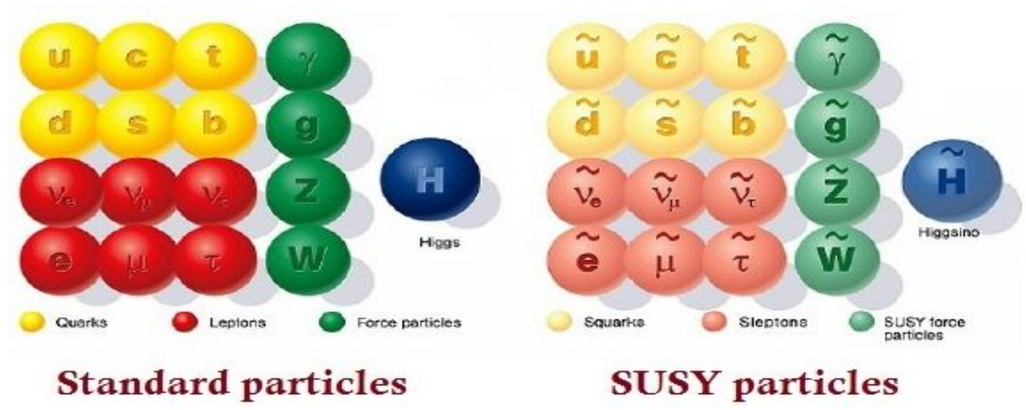

Figure 1.1. Visualization of the elementary particles of the Standard Physics Model to the left, and the theorized SUSY counterparts to the right, from Charitos (2016).

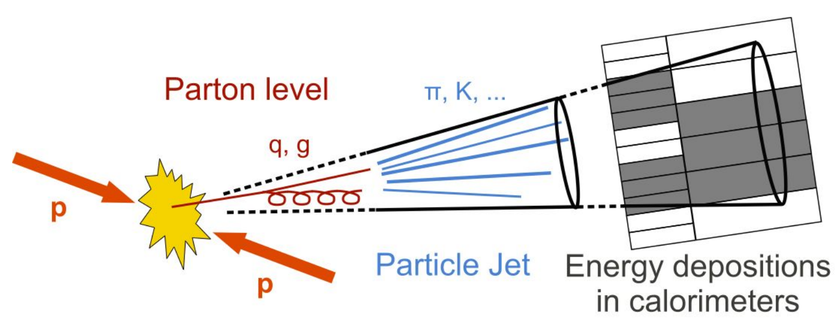

Figure 1.2. Sketch of pp-collision and resulting collimated spray of particles, a jet, from Kirschenmann (2012).

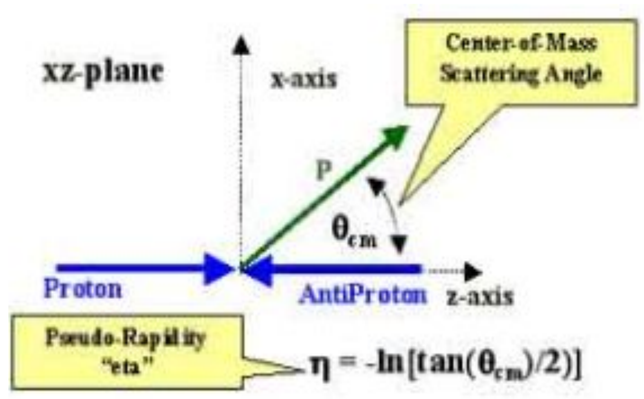

Figure 2.1. Visualization of pseudorapidity in relation to the transverse plane, the z-axis. by FNAL (n.d.).

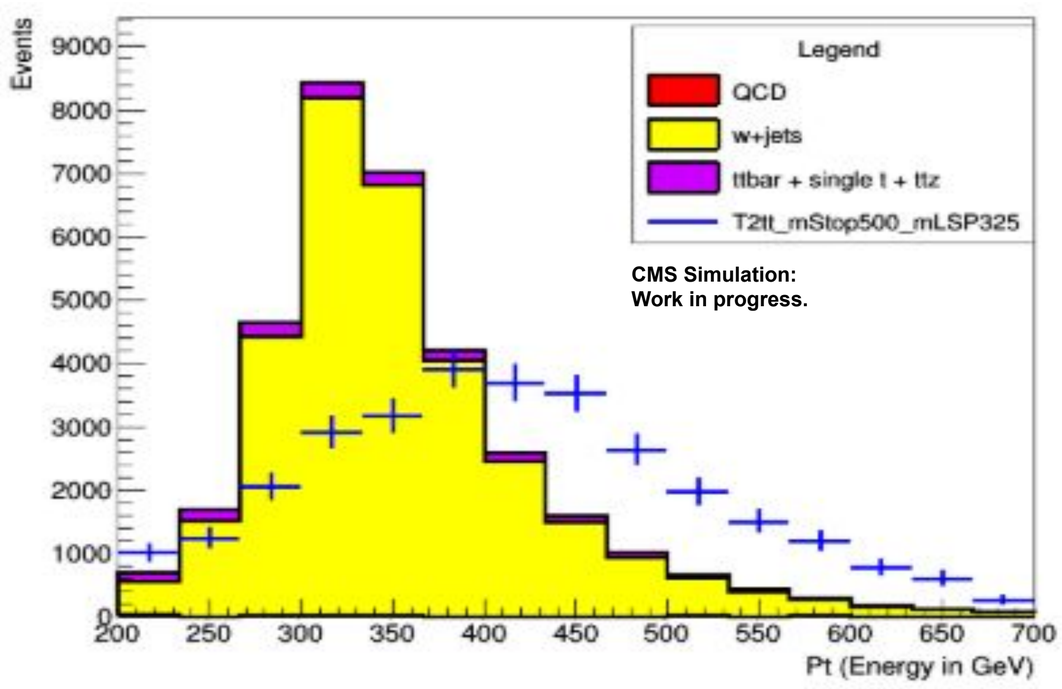

Figure 3. Graph of ISR jet Pt per event. The graph includes: QCD, W+ jets, and ttbar (the unwanted background data), and the T2tt signal (the top squarks). The graph was normalized by efficiency before SUSY baseline cuts were applied. The baseline cuts, Pt less than 200 cut, and mtb less than 175 cut were all applied. The signal was increased by a factor of 500 to make it more visible on the graph.

CONCLUSIONS

We graphed both ISR jet pseudorapidity and ISR jet Pt with the T2tt signal and background. The ISR jet pseudorapidity shows a similar distribution between the signal and the background, which means that ISR jet pseudorapidity would not be an efficient cut to use to select a signal. The ISR jet Pt graph, shown in Figure 3, shows that the signal and background have different distributions. Since there is a far larger amount of background events than signal events below the 350-400 GeV mark, that means that applying a cut there would successfully increase the ratio of signal event to background event. We have found that in respect to the T2tt signal, cuts based on ISR jet pseudorapidity would not be effective in finding the signal, but ISR jet Pt cuts would be effective. By applying this cut, the top squarks will be less overpowered by the background events. ISR jets provide a channel that will aid in future particle searches.

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