Using Initial State Radiation (ISR) Jets for SUSY Search

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Introduction

Atoms are small particles that make up the world around us. The word "atom" came from the Greek word "atomos", which means indivisible. However, atoms are not the smallest particle that we know of today. For example, atoms are all made up of neutrons, protons, and electrons, which then consist of smaller subatomic particles called elementary particles - shown on the left side of Figure 1.1.

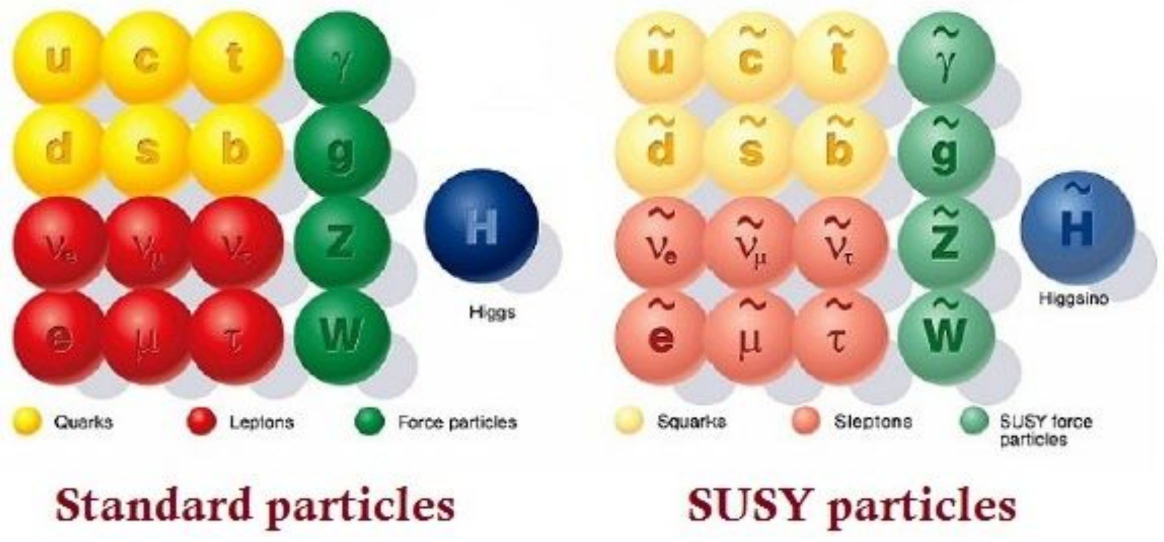

Figure 1.1. Visualization of the elementary particles of the Standard Physics Model to the left, and the theorized SUSY counterparts to the right, from Charitos (2016).

Physicists have been searching for proof of even more elementary particles. 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.

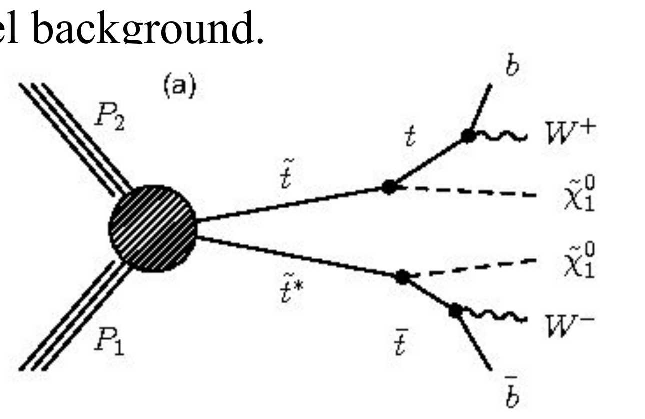

Figure 1.2. Diagram of the T2tt signal from Duarte (2015).

Particle interactions, like the one shown in Figure 1.2, are often depicted through Feynman diagrams. Feynman diagrams are meant to be read left to right. The horizontal axis represents space and the vertical axis represents time, as explained in Figure 1.3. Figure 1.4 is a Feynman diagram that depicts an Initial State Radiation (ISR) jet decaying off of an incoming particle.

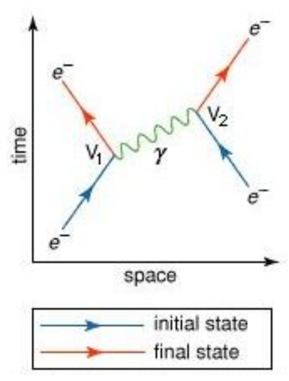

Figure 1.3. Basic Feynman Diagram from Sutton (n.d.).

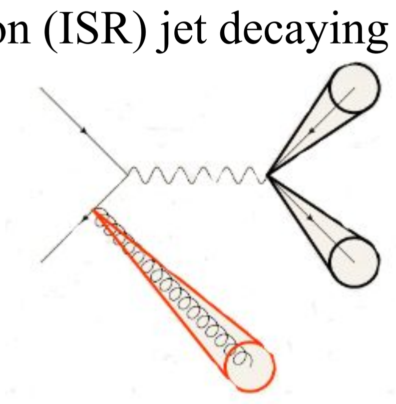

Figure 1.4. Feynman Diagram depicting the release of an ISR jet in the red conical shape from Krohn (2010).

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, physicists first 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 1.5 (Webber, n.d.).

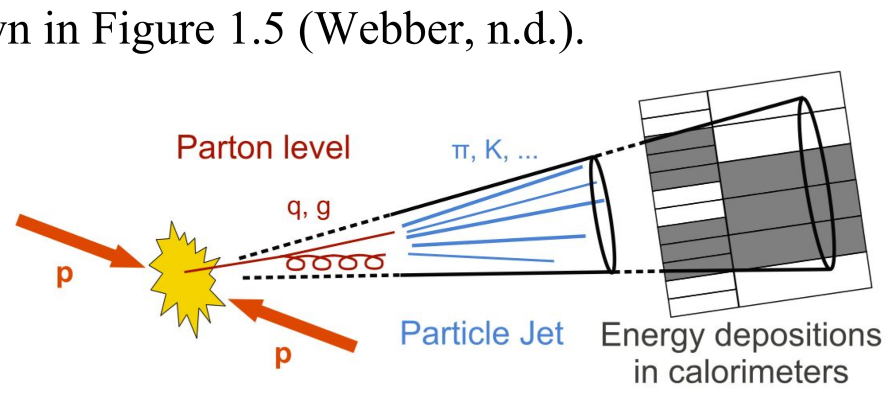

Figure 1.5. Sketch of pp-collision and resulting collimated spray of particles, a jet, from Kirschenmann (2012).

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.

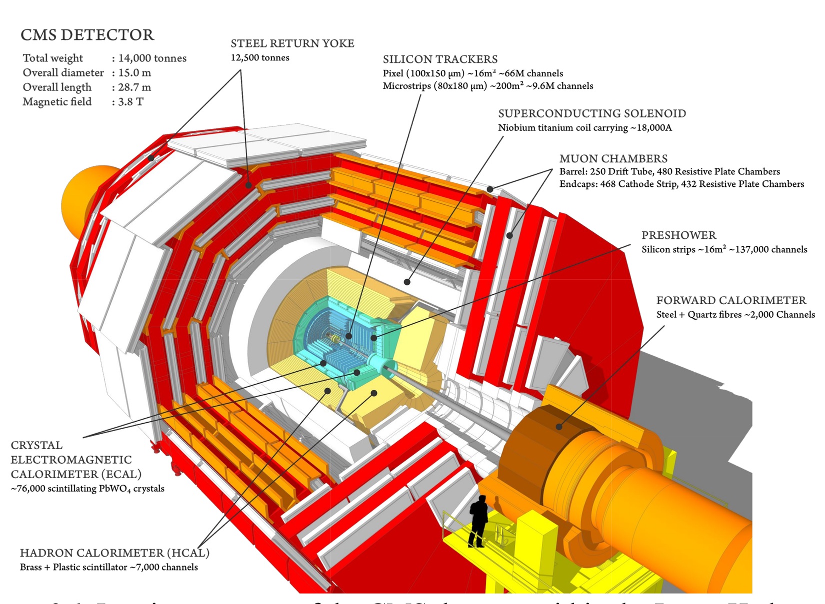

Figure 2.1. Interior structure of the CMS detector within the Large Hadron Collider from Taylor (2012).

The momentum perpendicular to the z-axis, also known as "Pt" or the transverse momentum, is also important to study and is shown in Figure 2.2. 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, shown in Figure 2.3, 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, 2019).

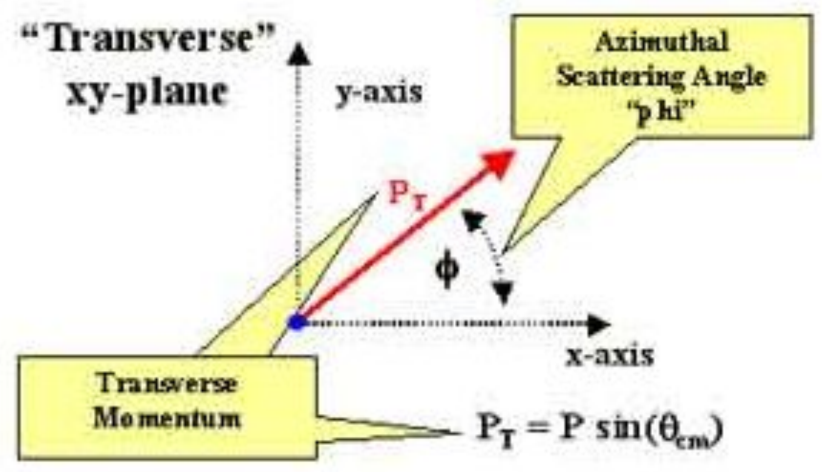

Figure 2.2. Diagram explaining what the Pt value is in relation to the transverse plane, the z-axis. by FNAL (n.d.).

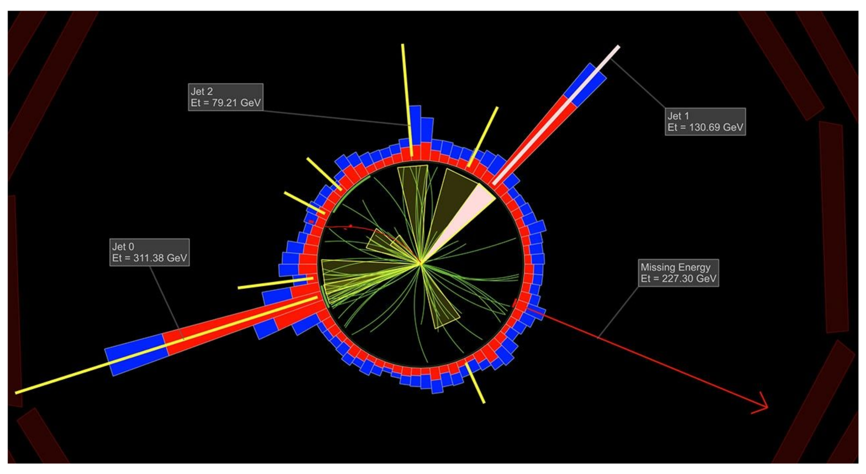

Figure 2.3. Diagram depicting a collision in which missing energy is released from Pandolfi (2017).

Pseudorapidity, represented by the Greek letter "eta"(η), is another important measurement to analyze while observing ISR jet decay. Pseudorapidity, as shown in Figure 2.4, is the measure of the forward direction on the positive z-axis.

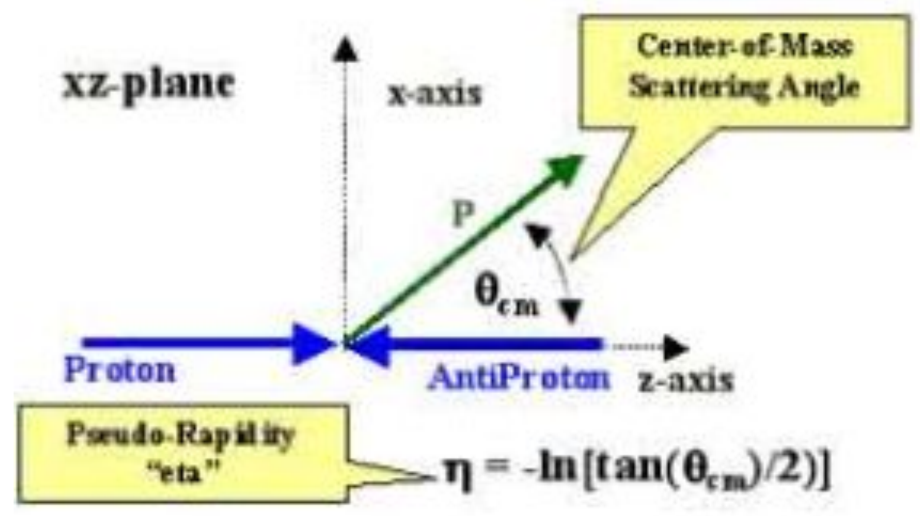

Figure 2.4. Visualization of pseudorapidity in relation to the transverse plane, the z-axis. by FNAL (n.d.).

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.

Results and Discussion

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.

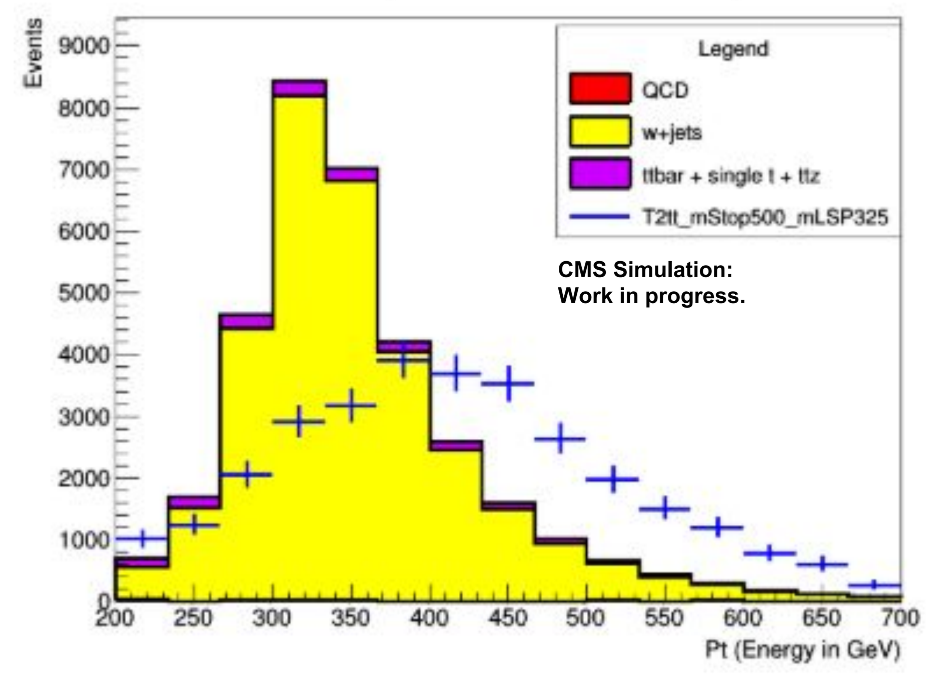

Figure 3. Graph of ISR jet Pt per event. The graph includes: QCD, W+ jets, and ttbar (the unwanted background data), and the T2tt signal (the top squarks). The graph was normalized by efficiency before SUSY baseline cuts were applied. The baseline cuts, Pt less than 200 cut, and mtb less than 175 cut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

Conclusion

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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