Background Ionization Behavior For Combined dE/dx And Disappearing Track Analysis

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Introduction And Goals

The Standard Model of particle physics describes all the ordinary matter we observe and three of the four fundamental forces. Despite its high accuracy and predictive power, numerous lines of experimental evidence and theoretical considerations indicate that the Standard Model is incomplete. For instance, dark matter is very well motivated and yet the Standard Model offers no explanation for it. One extension to the Standard Model that would address these issues is Supersymmetry. Under Supersymmetry, each particle has a partner, and with specific models, the lightest symmetric particle could be a dark matter candidate. We are seeking to develop methods to understand particle collisions that will be used in a full analysis such as:

- What are the main sources of background that contribute high dE/dx and high momentum tracklets?
- What is the ionization behavior of tracklets?

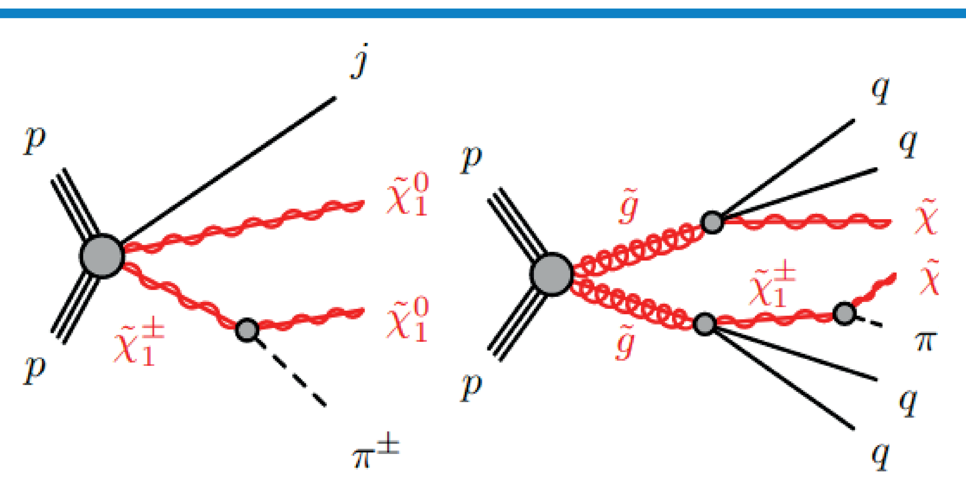


Fig 1: Electroweak (left) and Strong (right) production channels of the chargino[1]

Disappearing Track + dE/dx

At the Large Hadron Collider (LHC), protons are accelerated and then collided with a center of mass energy of $\sqrt{s} = 13$ TeV within the ATLAS detector. Then, analysis teams that are a part of the ATLAS experiment begin to analyze the data using numerous experimental techniques.

Our analysis will be focusing on looking for high dE/dx signatures and disappearing track signatures. The chargino, the target of the analysis, is potentially heavy and long-lived. Consequently, it could travel a short distance in the detector before decaying into non-interacting products. This leaves a unique signature within the detector.

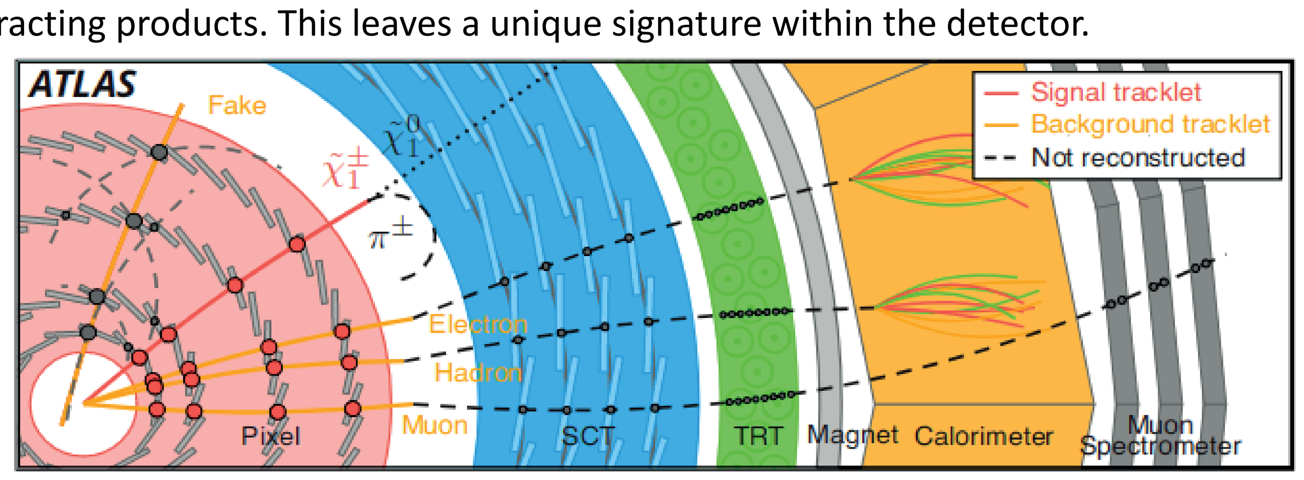


Fig 2: An example event within the ATLAS detector showing both background and signal events[1]

Because the chargino would be charged and potentially high mass, we can look at the ionization energy it leaves behind as it moves through the detector. This value, normalized by path length, is called dE/dx. A slow moving, massive particle moving through the detector would have an anomalously high dE/dx. The chargino this search is looking for would be produced with the right conditions such that it would produce both signatures.

A serious challenge for all analyses is background. Background is anything that isn't our signal, and it can be challenging to remove. The most difficult form of background to remove are events that look like our signal, such as multiple slow-moving particles being reconstructed as a single high momentum particle.

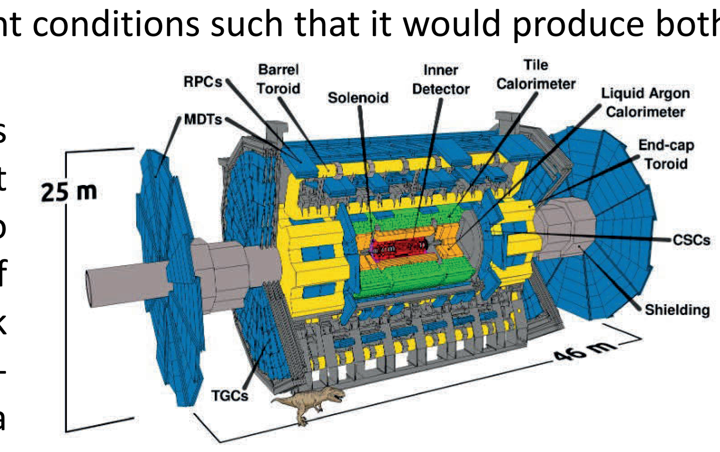
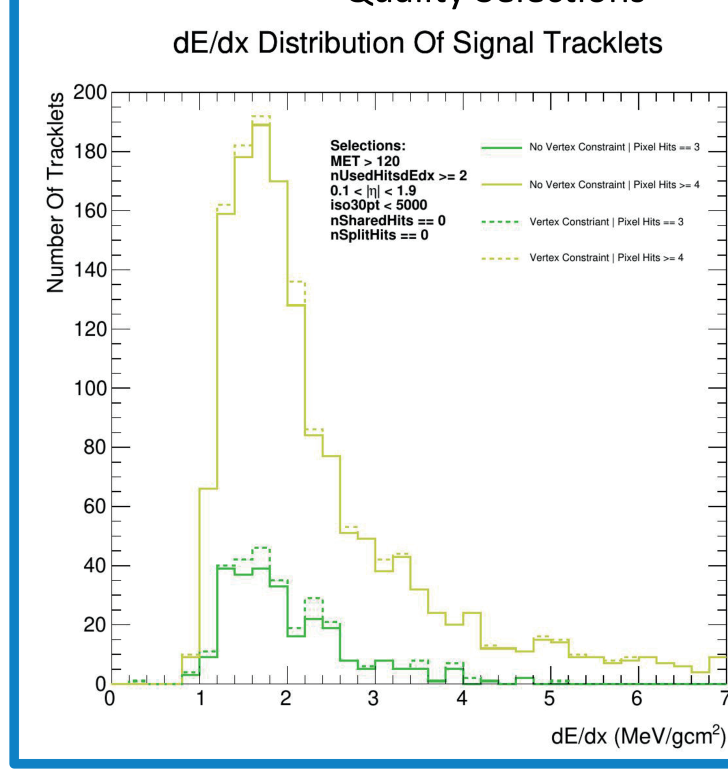


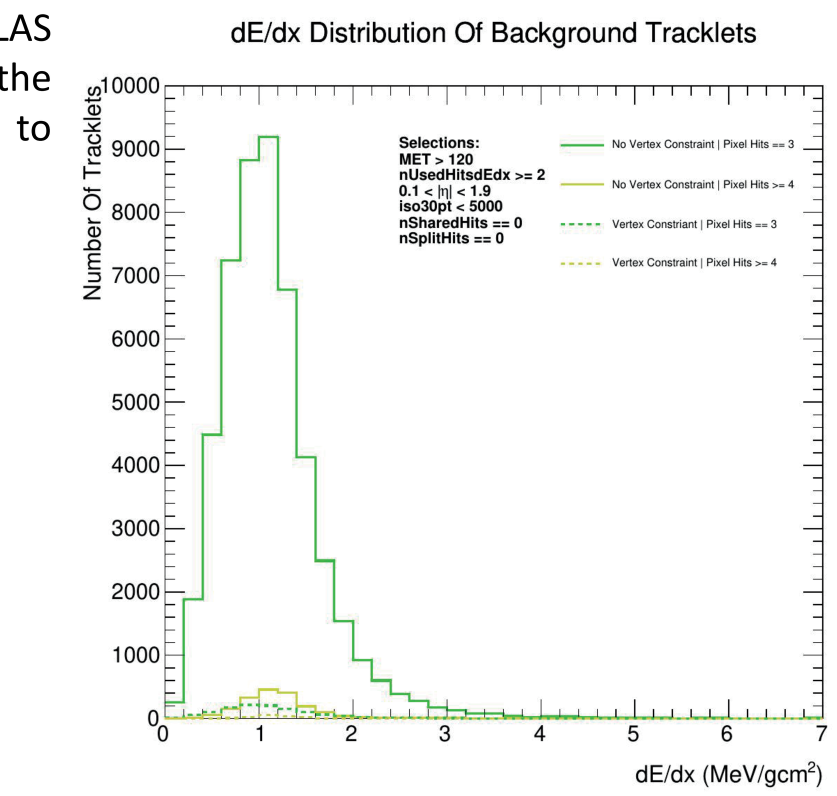
Fig 3: The ATLAS detector with a T-Rex for scale[3]

Data Selection Criteria

Most of the processes that occur in the ATLAS detector are not of interest to us. To isolate the potential signal, we use a series of selections to reduce background. These include:

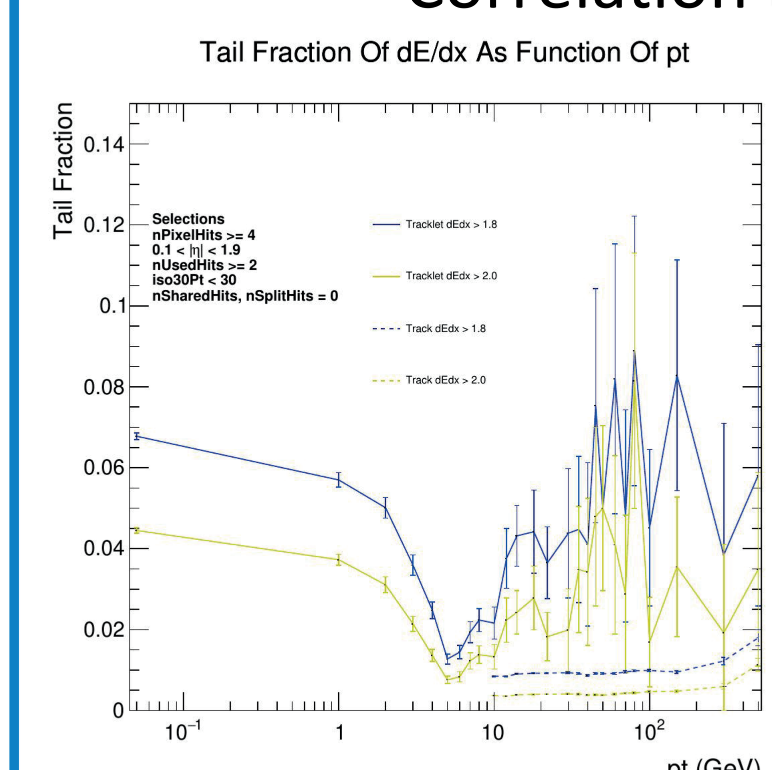
- A missing energy threshold
- Pseudorapidity (η) selections
- Tracklet isolation requirements
- Momentum requirements
- Quality Selections





In addition, we tested the way two additional requirements would affect the number of simulated background and signal events. A vertex constraint, where we assume that a tracklet came from the primary vertex, and a requirement that a tracklet contains a certain number of hits. The use of the vertex constraint and a requirement that there are 4 or more hits in a tracklet reduced the background greatly while not having a large effect on the number of signal events.

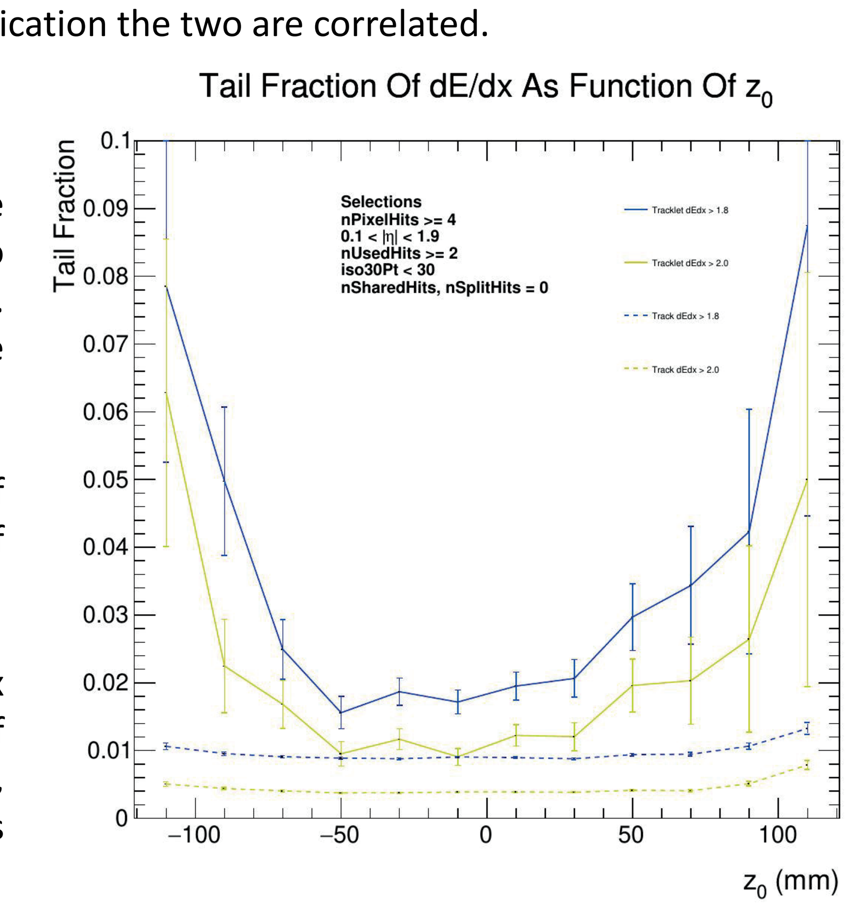
Correlation Between Variables



One potential way to estimate the number of background events is via an ABCD method. Two variables are chosen and, if they are uncorrelated, we can use regions defined by them to estimate the number of signal events in our signal region.

One well motivated combination of variables are ionization energy (dE/dx), and transverse momentum (pt). One way to measure the correlation of a pair of variables is to analyze the distribution of one variable as a function of another. If the shape of the distribution of one variable changes as a function of the other, that is indication the two are correlated.

The distribution of dE/dx as a function of transverse momentum is not consistent, and there appears to be a correlation at low momentum scales. Conclusions about higher momentum scales are limited by statistics.

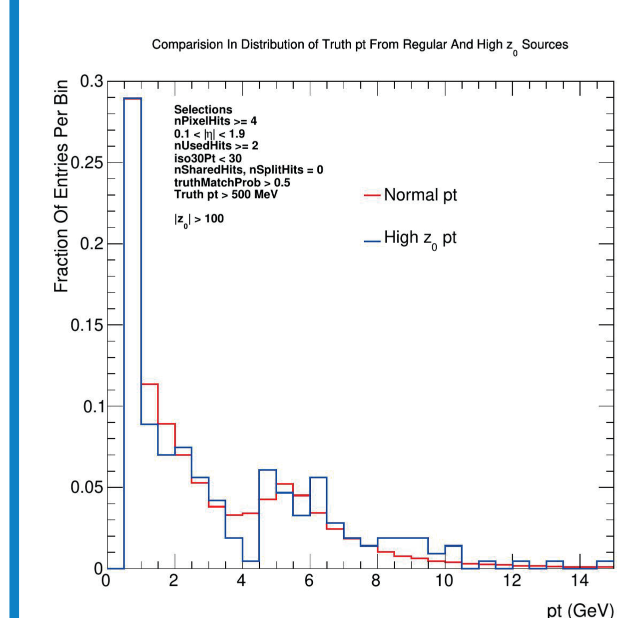


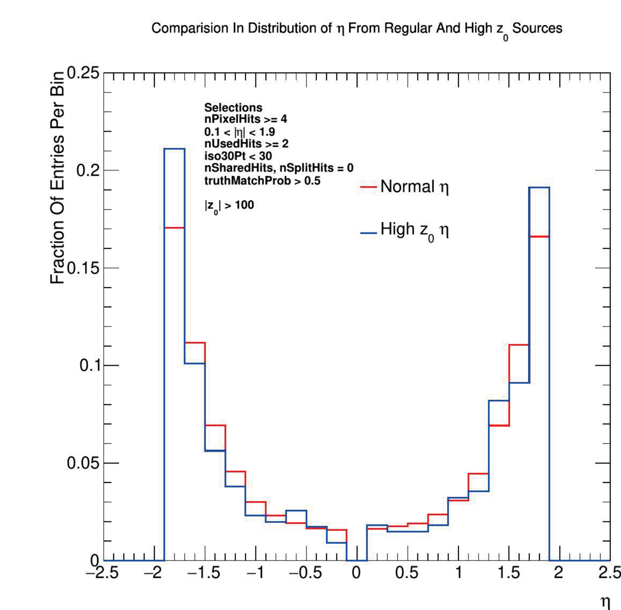
Another potential pair of uncorrelated pair of variables was dE/dx and z_0, a measurement of position for a tracklet.

At low values of z_0, the distribution of dE/dx tracklets is consistent. However, at higher values of z_0, the dE/dx distribution widens considerably, indicating a strong correlation. This behavior was unexpected and warranted further investigation.

High z_0 Regime Behavior

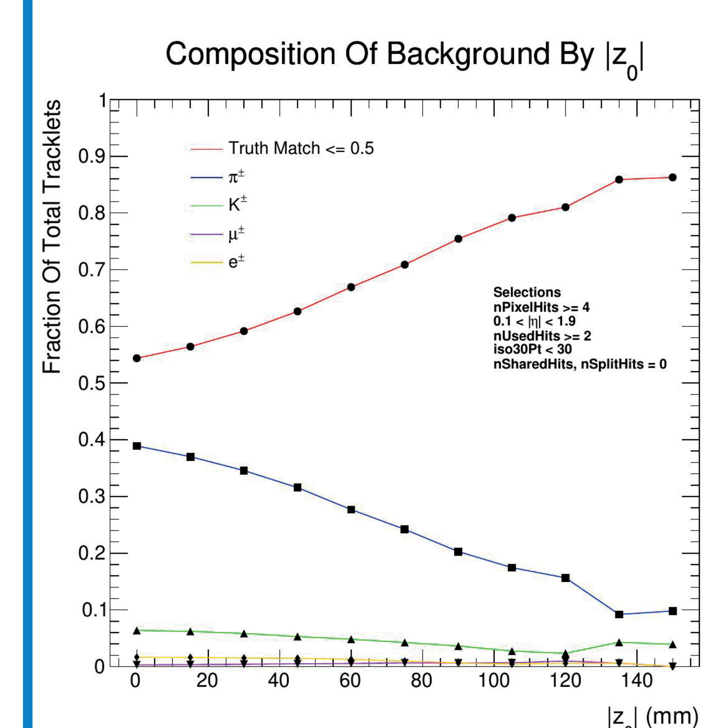
One potential explanation of the strange behavior was that there was some additional effect from either momentum or angle within the detector. To investigate this, the transverse momentum and pseudorapidity of the background were plotted in both the low z_0 and high z_0 regime.





There is some discrepancy between the low and high z_0 regimes, but it isn't enough to attribute the extreme degree of the behavior.

An alternative hypothesis was that the low and high z_0 regimes are constructed of different backgrounds. This would be the case if the portion of fake tracklets increases as a function of z_0.



As can be seen, there is an increase in the number of fake tracklets along with a corresponding decrease in the number of charged pion tracklets. There are negligible decreases in the number of charged kaon and lepton tracklets that also contribute to the trend. This is strong evidence that the source of the changing dE/dx distribution is a different source of background at high z_0.

References

1. ATLAS Collaboration, "Search for long-lived charginos based on a disappearing-track signature using 136 fb^{-1} of pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector.
2. ATLAS Collaboration, "Search for heavy, long-lived, charged particles with large ionisation energy loss in *pp* collisions $\sqrt{s}$=13 TeV using the ATLAS experiment and the full run 2 dataset."
3. R. Carney, *Silicon Tracking and a Search for Long-lived Particles*. PhD thesis, Stockholm University
4. L. Lee, C. Ohm, A. Soffer, and T.-T. Yu, "Collider searches for long-lived particles beyond the standard model," vol. 106, pp. 210–255.

Acknowledgments

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