# Combinatorial Fake Discrimination Studies For Combined dE/dx and Disappearing Track Search

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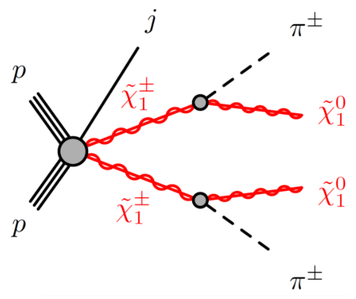
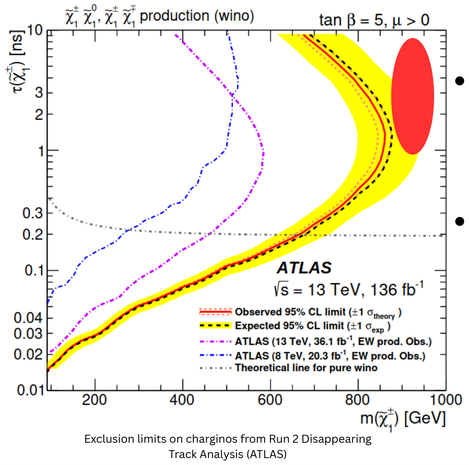
## Introduction

- The Standard Model is a highly accurate theory of physics
- Search for long-lived, massive, charged particles that decay into a dark matter candidate
- Interested in a way to select against background in favor of signal



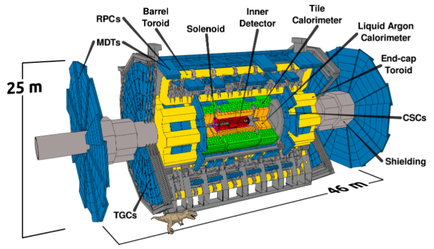

Example signal Process: charginos decaying into pions and neutralinos (N. Young)




Exclusion limits on charginos from Run 2 Disappearing Track Analysis (ATLAS)

- Previous analyses have limited charginos up to masses of 850 GeV
- We seek to combine two analysis strategies to gain further senstivity

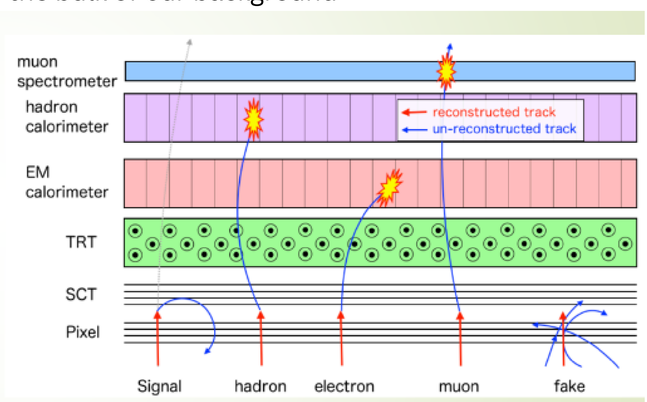
## Disappearing Track + dE/dx




ATLAS detector with a T.Rex for scale (Goodson)

- Analysis uses data collected from the ATLAS experiment innner detector at the Large Hadron Collider

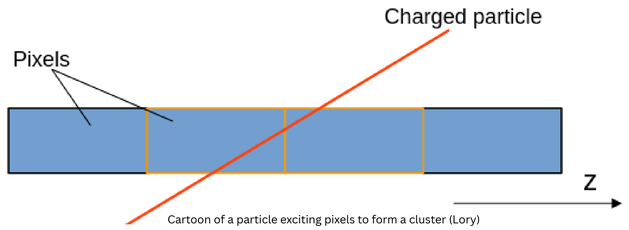
- Using a combination disappearing track and high ionization energy loss (dE/dx) signature
- Much of the background that dominated the Run 2 disappearing track analysis will be suppressed by ionization energy requirements
- Many fake tracklets are expected to remain, forming the bulk of our background




Disappearing track signature, a particle decays in between Pixel and SCT detectors. Also pictured are possible background processes that produce similar looking signatures (ATLAS)

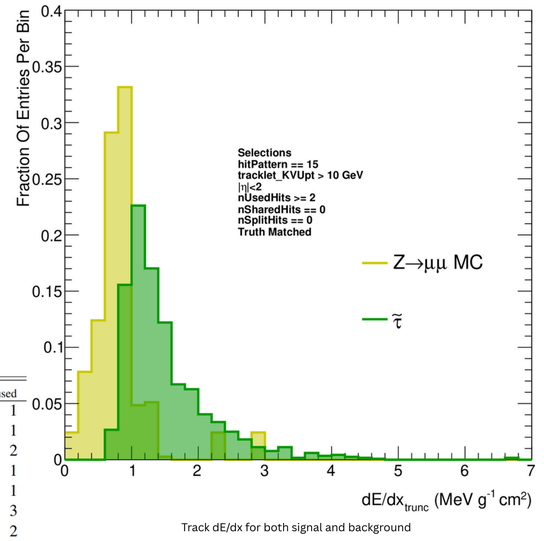
## Clusters + dE/dx

- Tracks formed up of individual clusters
  - Grouped excitations of pixel detectors
- Ionization energy loss is recorded in these




Cartoon of a particle exciting pixels to form a cluster (Lory)

- Comparision of the calculated dE/dx value indicates a good discrimantory power between background and signal
- Searching for a selection that maximizes the strength of a signal we would observe.



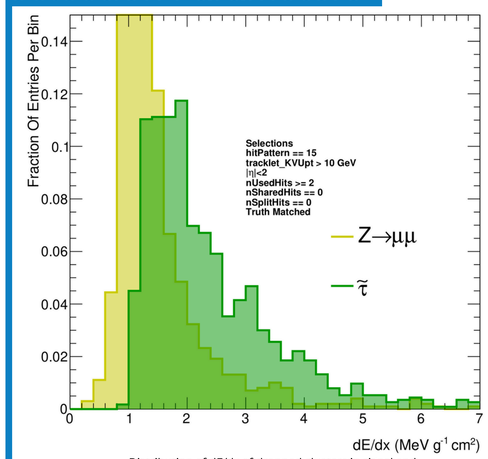

Track dE/dx for both signal and background

| $N_c$ | Cluster pattern | $n_{OF}^{IBL}$ | Truncation pattern | | $n_{used}$ |
|---|---|---|---|---|---|
| 1 | X | 0 or 1 | X | \|N/A | 1 |
| 2 | X,X | 0 or 1 | X | \|X | 1 |
| 3 | C,C,X | 0 or 1 | C,C | \|X | 2 |
| 3 | C,0,X | 1 or 2 | C | \|0,X | 1 |
| 3 | 0,X,X | 1,2,3 | 0 | \|X,X | 1 |
| 4 | C,C,C,X | 0 or 1 | C,C,C | \|X | 3 |
| 4 | C,C,0,X | 1 or 2 | C,C | \|0,X | 2 |
| 4 | C,0,X,X | 1,2,3 | C,0 | \|X,X | 2 |
| 4 | 0,X,X,X | $1,\cdots,4$ | 0,X | \|X,X | 2 |
| $\geq 5$ | X,X,X,X,X,$\cdots$ | $0,\cdots,N_c$ | X,X,X,$\cdots$ | \|X,X | $N_c-2$ |

Truncation pattern lookup table for track dE/dx average. Truncation pattern is based on number of clusters and the number of IBL overflow hits a track has. C=Normal Hits, 0=IBL overflow hit, X=Either (ATLAS)

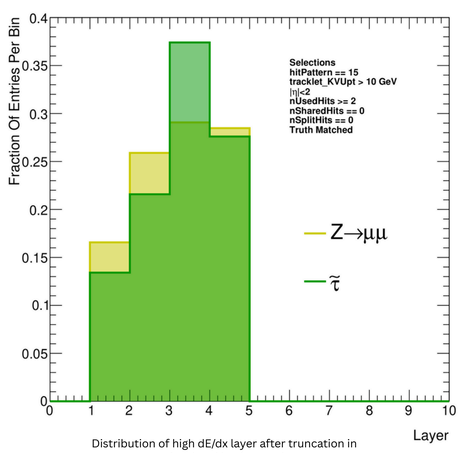
- Can convert a tracks cluster's dE/dx values into a truncated dE/dx via an algorithm
- What information can we use from the full set of dE/dx values?

## Selection Parameters

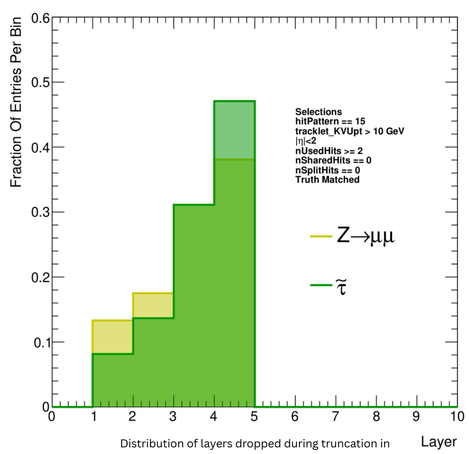



Distribution of dE/dx of dropped clusters in signal and background

- With the additional parameters we can now look to select on, want to investigate distribution of several parameters in order to see which might offer the best discriminatory power
- Looking at many different parameters
  - dE/dx of dropped hits
  - Layer in which high hit occurs
  - Layer that gets dropped during truncation
  - RMS of all cluster dE/dx values




Distribution of high dE/dx layer after truncation in signal and background

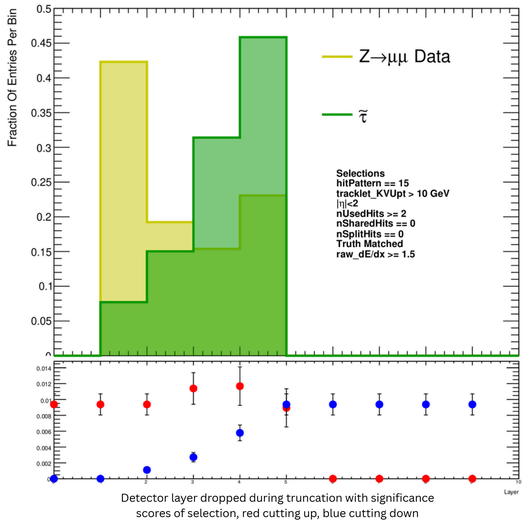



Distribution of layers dropped during truncation in signal and background

## Preliminary Significance Studies

- We can identify an optimal parameter to select on by seeing which gives the best significance score for a selection in the high dE/dx regime

$$Z_A = \sqrt{2\left((s+b)\log\left(1+\frac{s}{b}\right)-s\right)}$$




Detector layer dropped during truncation with significance scores of selection, red cutting up, blue cutting down

- Preliminary results indicate that the dropped layer of a tracklet could be a potentially powerful discriminant
- This may suggest that low momentum tracklets are adding to the energy deposited in the first layers

## Conclusion/Next Steps

- Searching for long-lived, massive, charged particles in the ATLAS detector
- Identified potential selection criteria to optimize discovery for further study using cluster level information
- Want to better understand behavior of high dE/dx regime
  - How does cluster size relate to high dE/dx hits in innermost layers of detector?

## References


- ATLAS Collaboration. Search for long-lived charginos based on a disappearing-track signature using 136 fb-1 of pp collisions at √s = 13 TeV with the ATLAS detector.
- ATLAS Collaboration. Search for heavy, long-lived, charged particles with large ionisation energy loss in *pp* collisions at √s = 13 TeV using the ATLAS experiment and the full Run 2 dataset.
- Lory, Alexander. Search for new physics in signatures of soft unclustered energy patterns within the ATLAS detector
- J.J. Goodson. "Search for Supersymmetry in States with Large Missing Transverse Momentum and Three Leptons including a Z-Boson". Presented 17 Apr 2012. PhD thesis. Stony Brook University, 2012.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