

Improved dE/dx Evaluation for Background Suppression In Searches for Low- β New Particles

ICEPP D2 Okumura-lab
Yoshifumi Narukawa

Target of this analysis

- Long-lived O (0.1 ~ 10.0 ns), massive O(100 ~ 1000 GeV), charged particles

- LSP and NLSP :
- Motivation :
- Long lived due to :
- Target lifetime :
- Target mass :

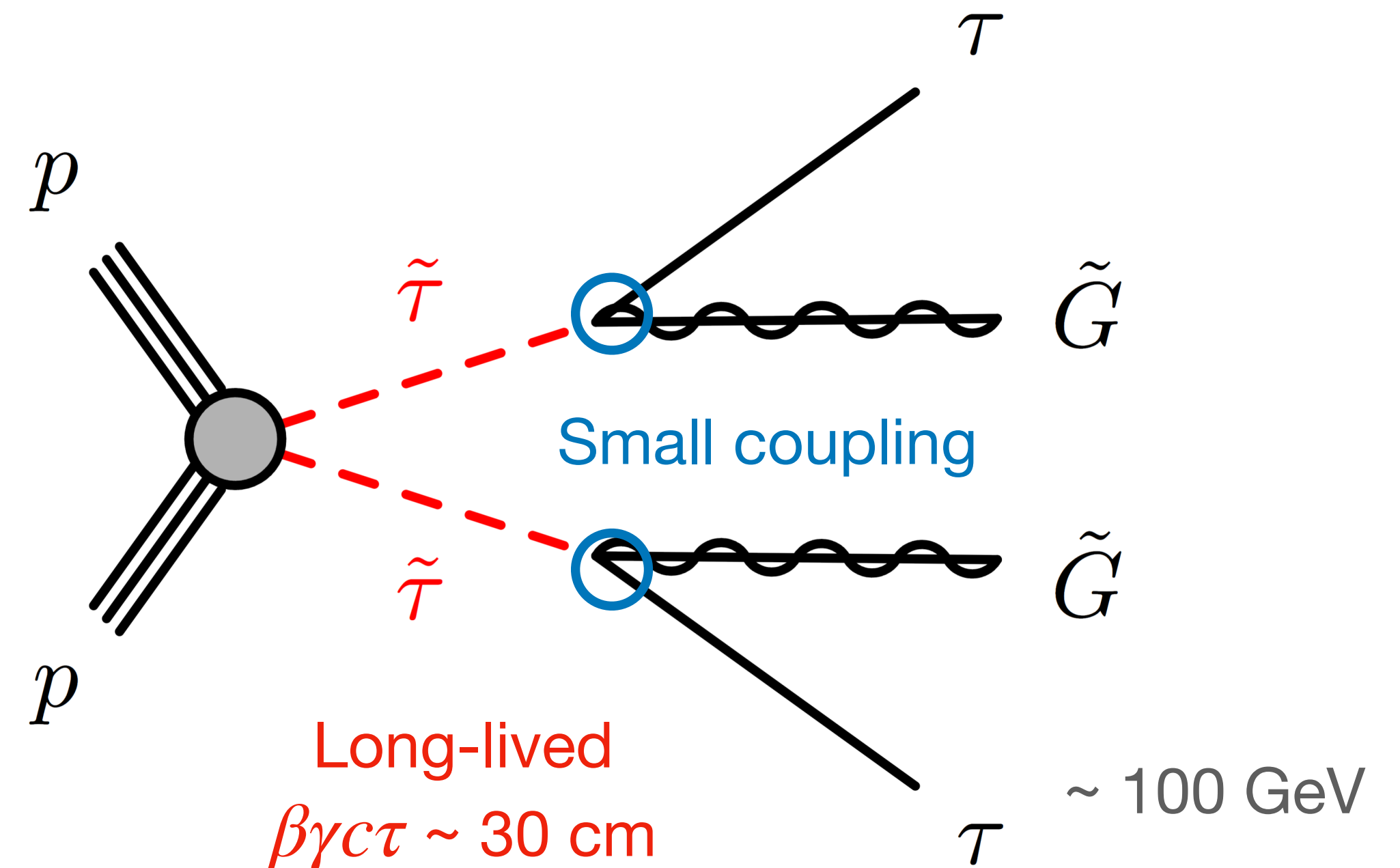
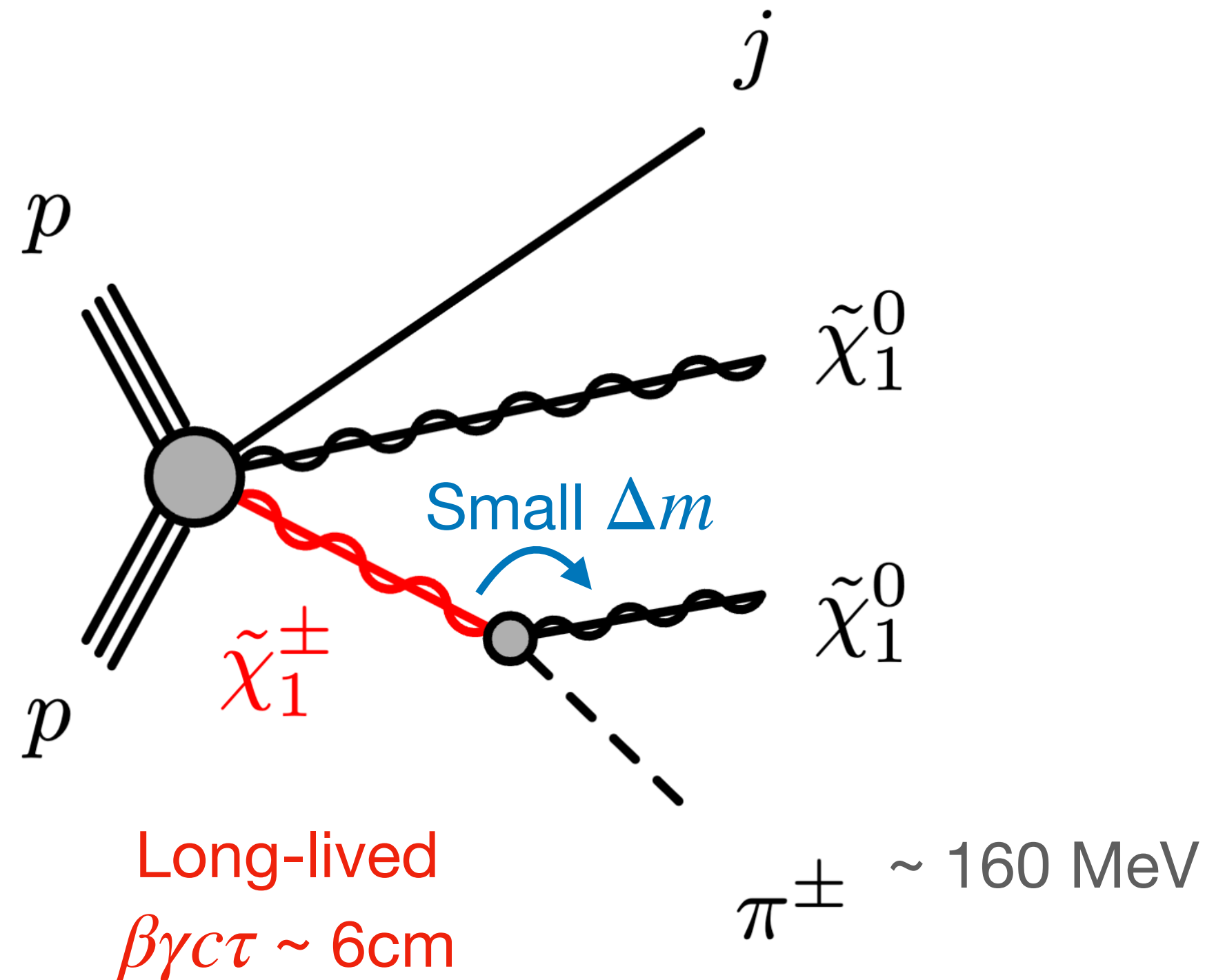
Chargino (Wino-LSP)

Chargino - Neutralino
 DM thermal relic
 Small Δm
 0.2 ns (Theory-driven)
 700 GeV* ~ 3 TeV

GMSB Stau

Stau - Gravitino
 Flavor problem free
 Small coupling
 1 ns*
 300 GeV* ~

*Defined as not covered
 by previous search



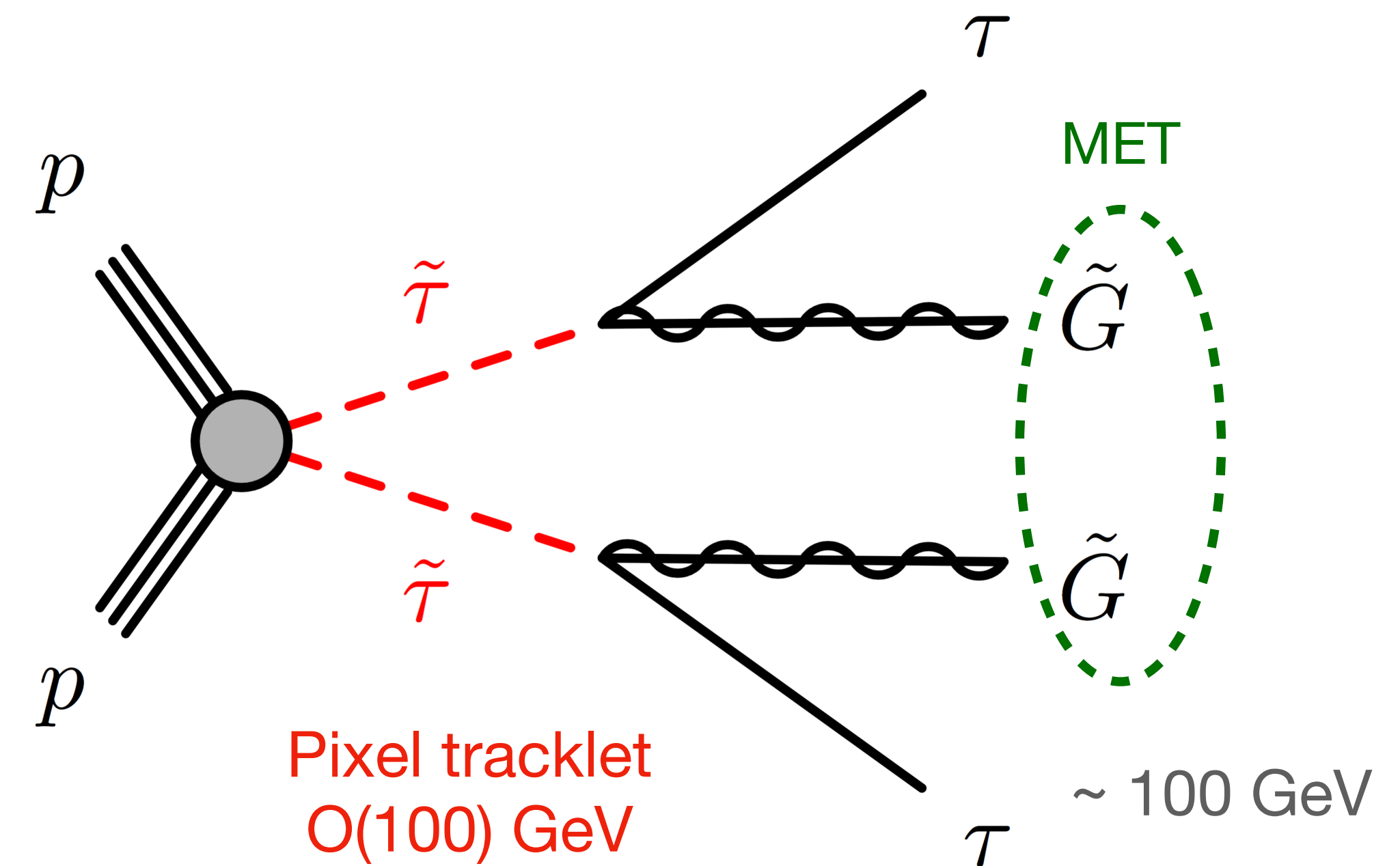
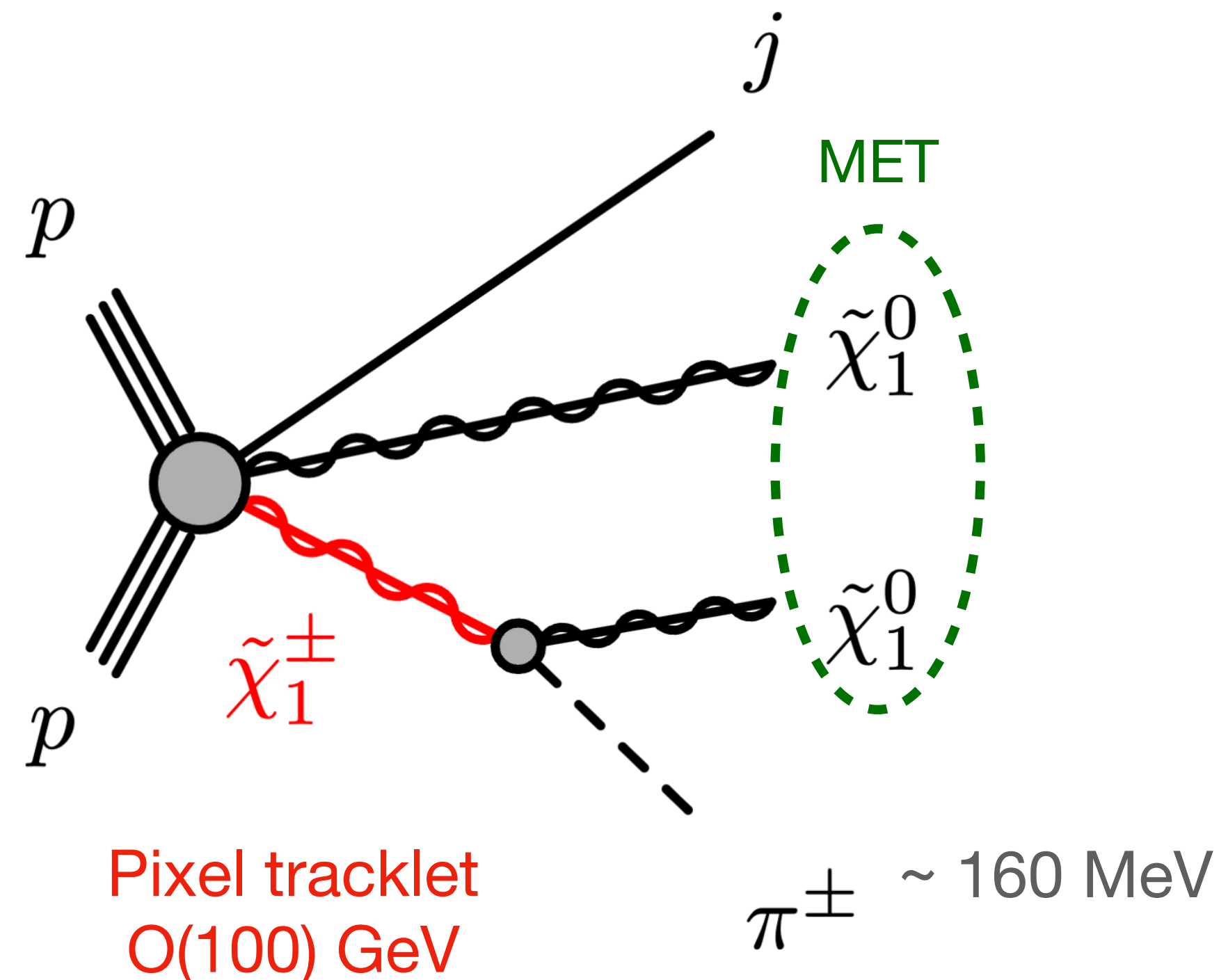
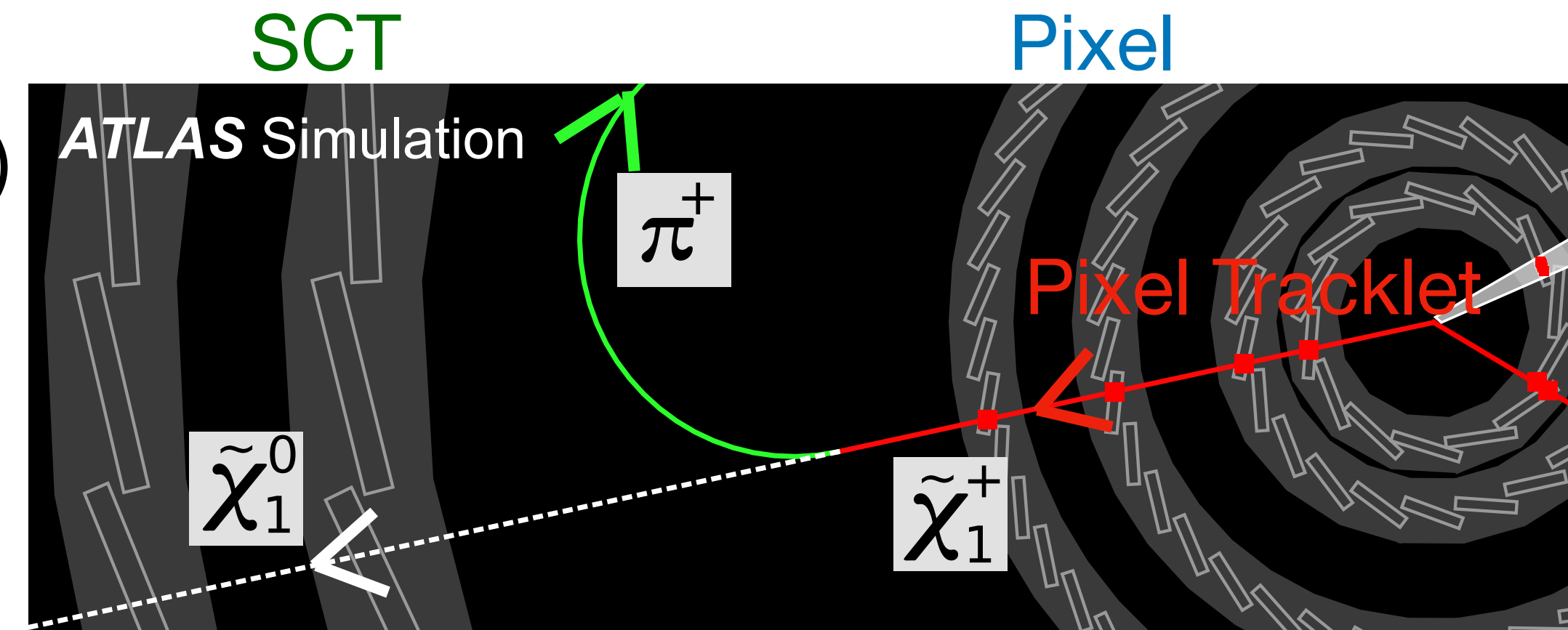
Analysis strategy 1/2

Signature to tag signal event

- Pixel tracklets with high ionization energy loss (high dE/dx)

Selection

- High MET, High tracklet p_T , Large pixel dE/dx
 - Signal $m \sim O(100 \text{ GeV}) \rightarrow$ small β (0.2 ~ 1.0)
 - \rightarrow Larger dE/dx than standard model bkg (MIP)



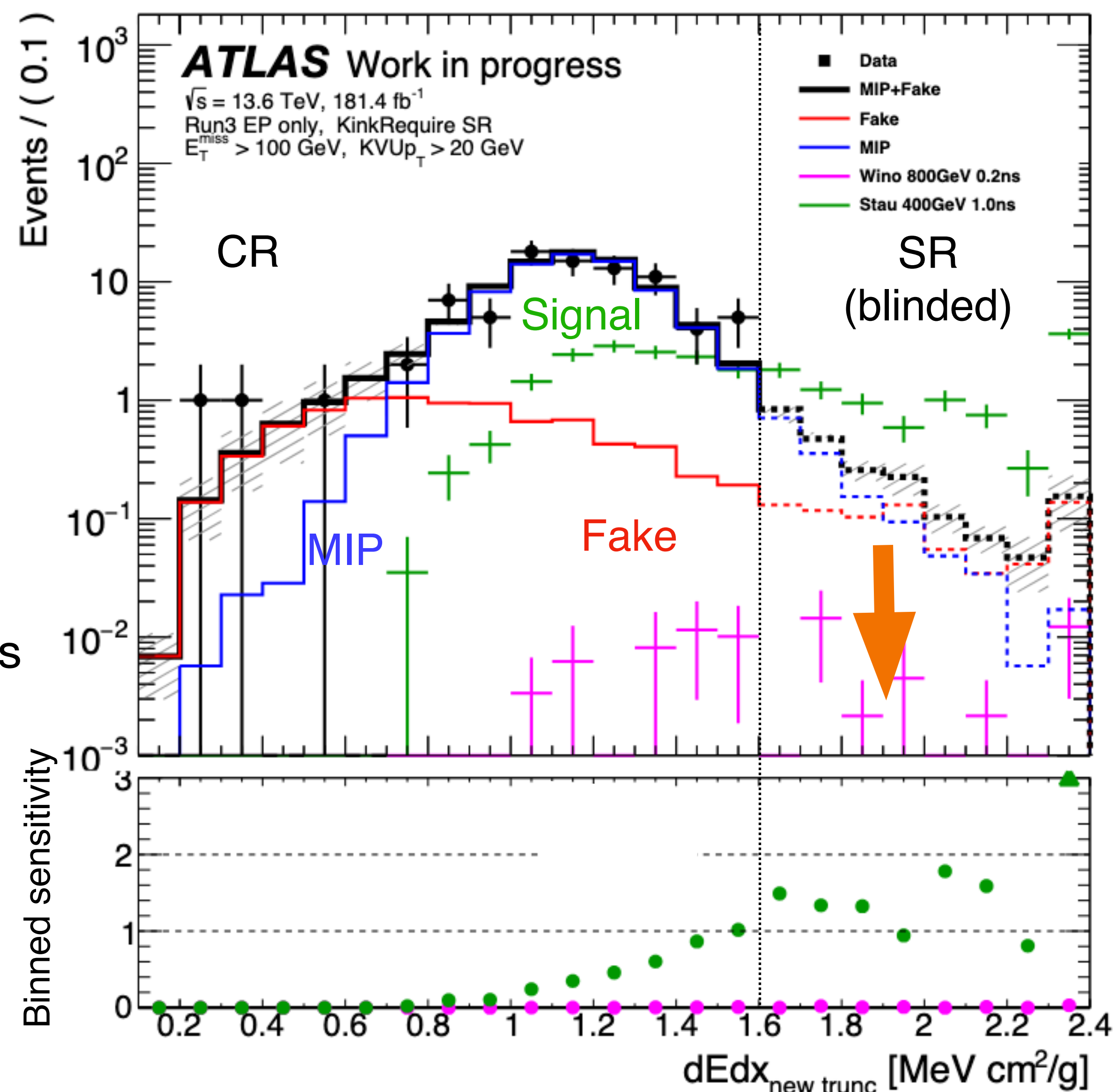
Analysis strategy 2/2

Full-data driven background estimation

- Use pixel dE/dx as the final discriminant for signal extraction
 - Simultaneous shape fit to determine background and signals yields
- (A) **MIP**: charged particle scattered by material
– Regardless of particle type (μ , e, hadron)
- (B) **Fake**: mis-combination of hits from multiple particles
- ❖ Detailed discussion on the Poster

Today's topic

- To improve the sensitivity, reducing the high- dE/dx fraction of the background is the key



Per-layer dE/dx

Per-layer dE/dx

- dE/dx is measured in each of four pixel layers

dE : Collected charge calculated from the Time-over-Threshold

dx : Path length estimated from the thickness of the silicon sensor and the track's incident angle α

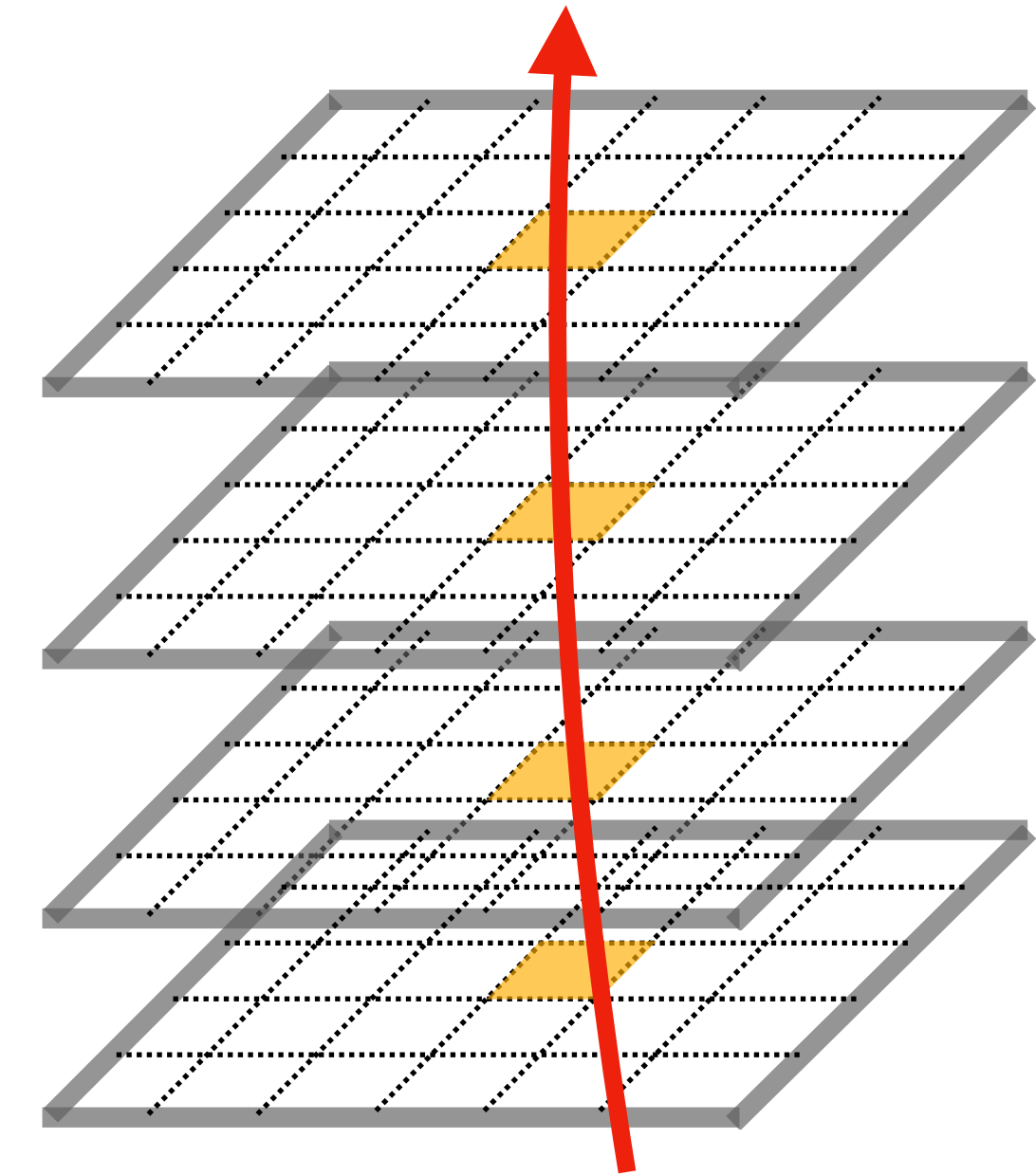
$$\frac{1}{\rho} \frac{dE}{dx} = \frac{1}{\rho [\text{g/cm}^3]} \frac{q_i(\text{ToT}) [e^-] W [\text{eV}/e^-]}{\frac{d}{\cos \alpha} [\text{cm}]} [\text{eV cm}^2 / \text{g}]$$

Layer-2

Layer-1

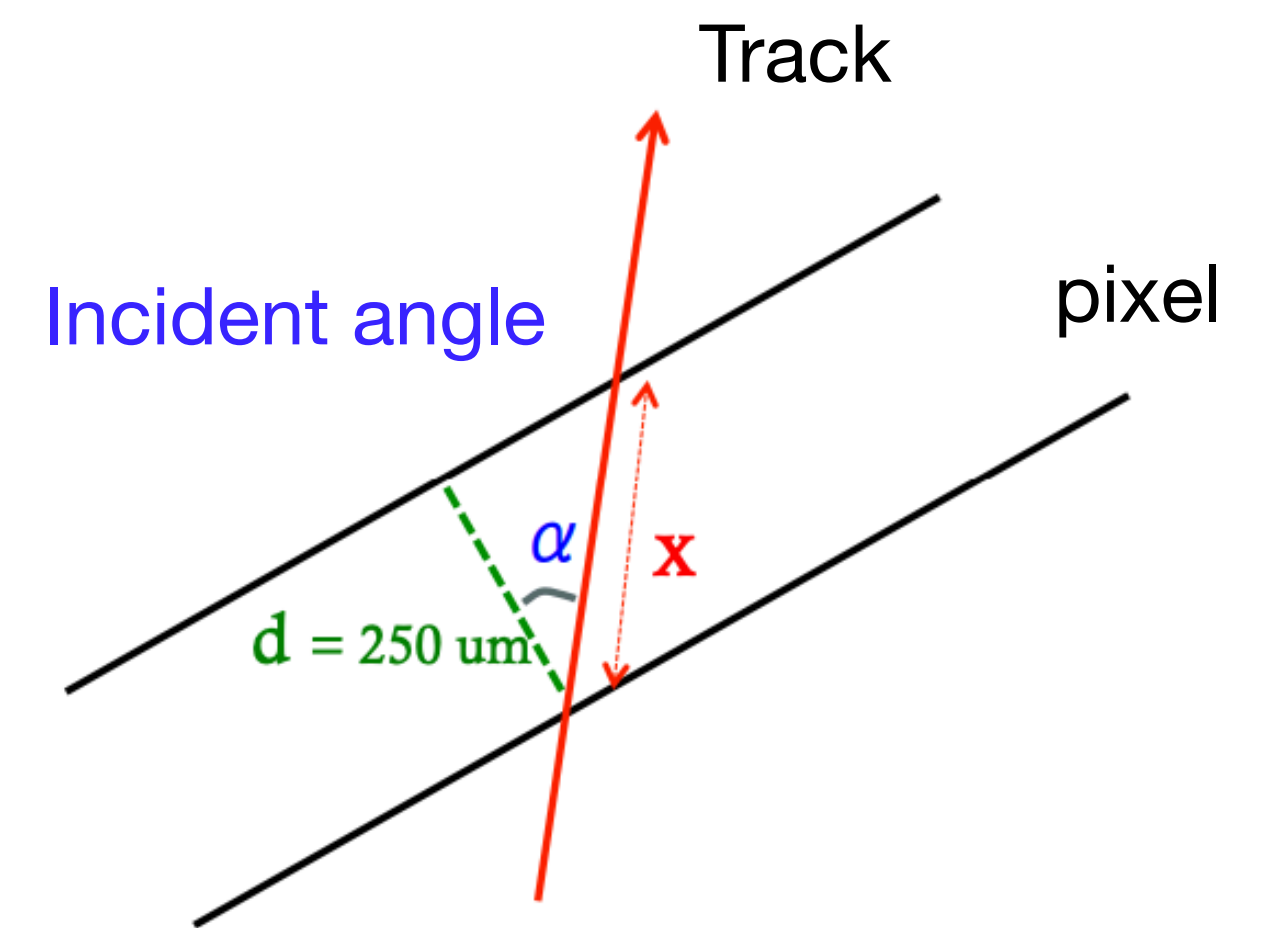
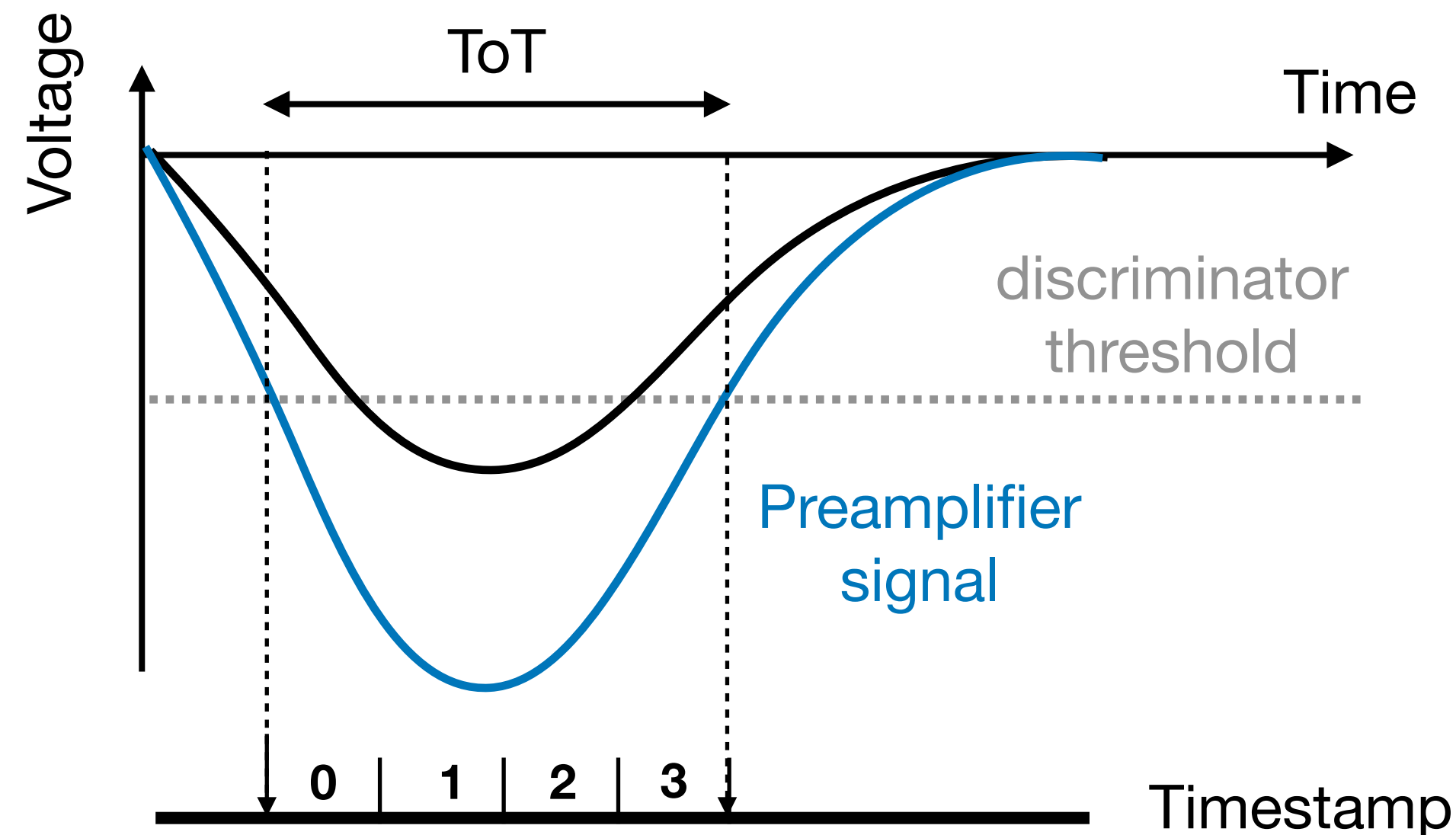
Blayer

IBL



dE/dx correction

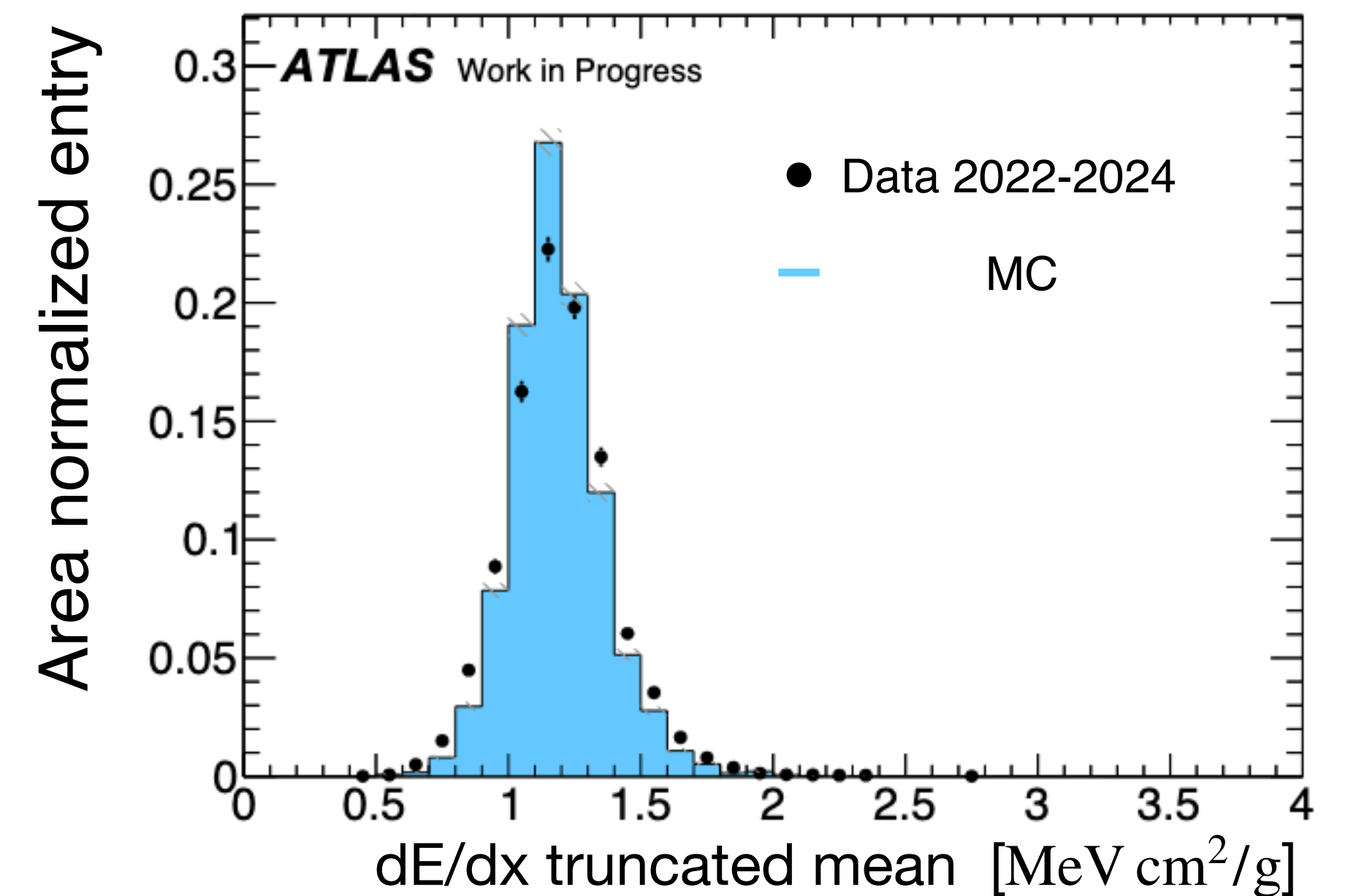
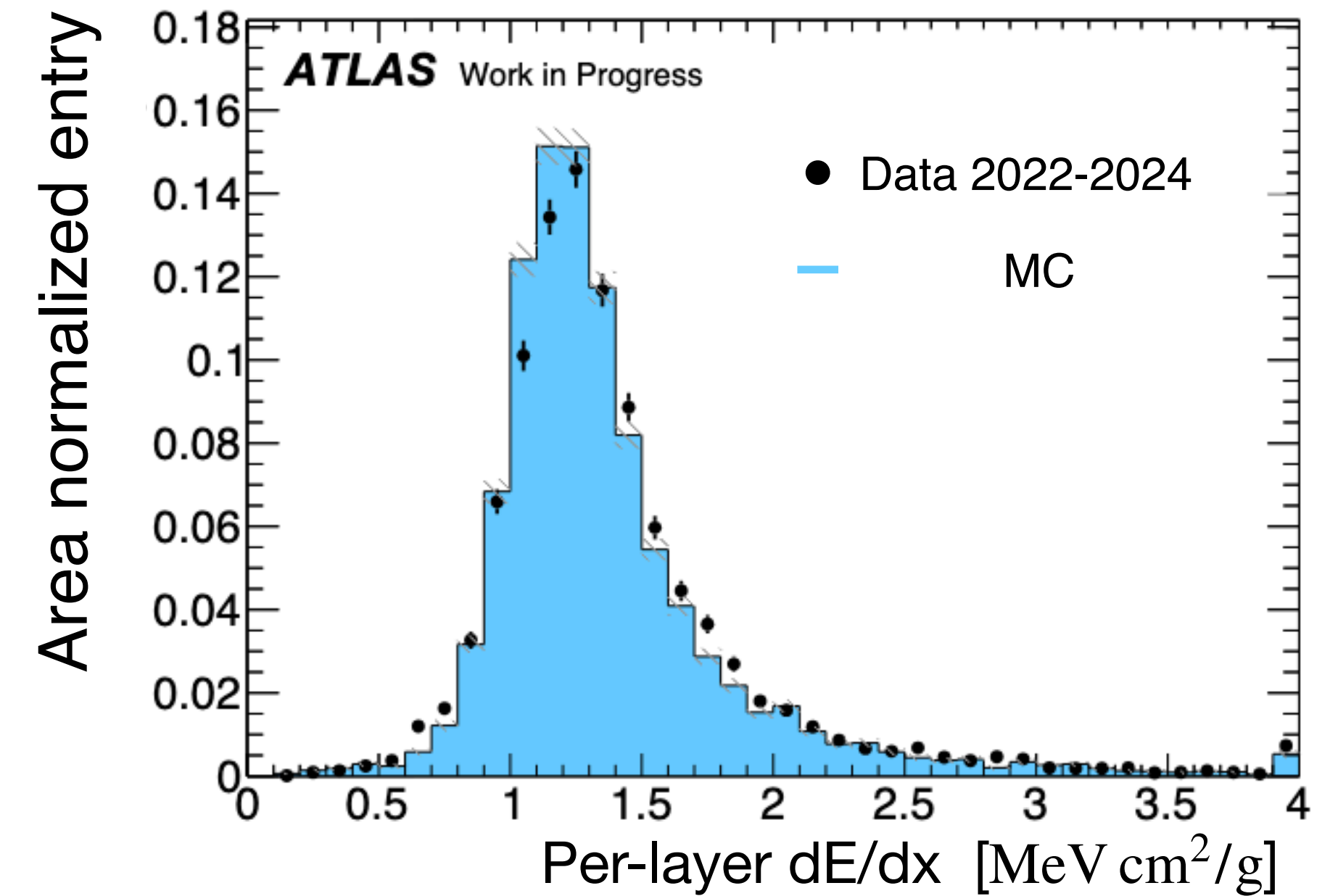
- Radiation damage correction
 - Run by run
 - η -dependent
 - Layer-dependent
- Data-MC correction



Per-track dE/dx

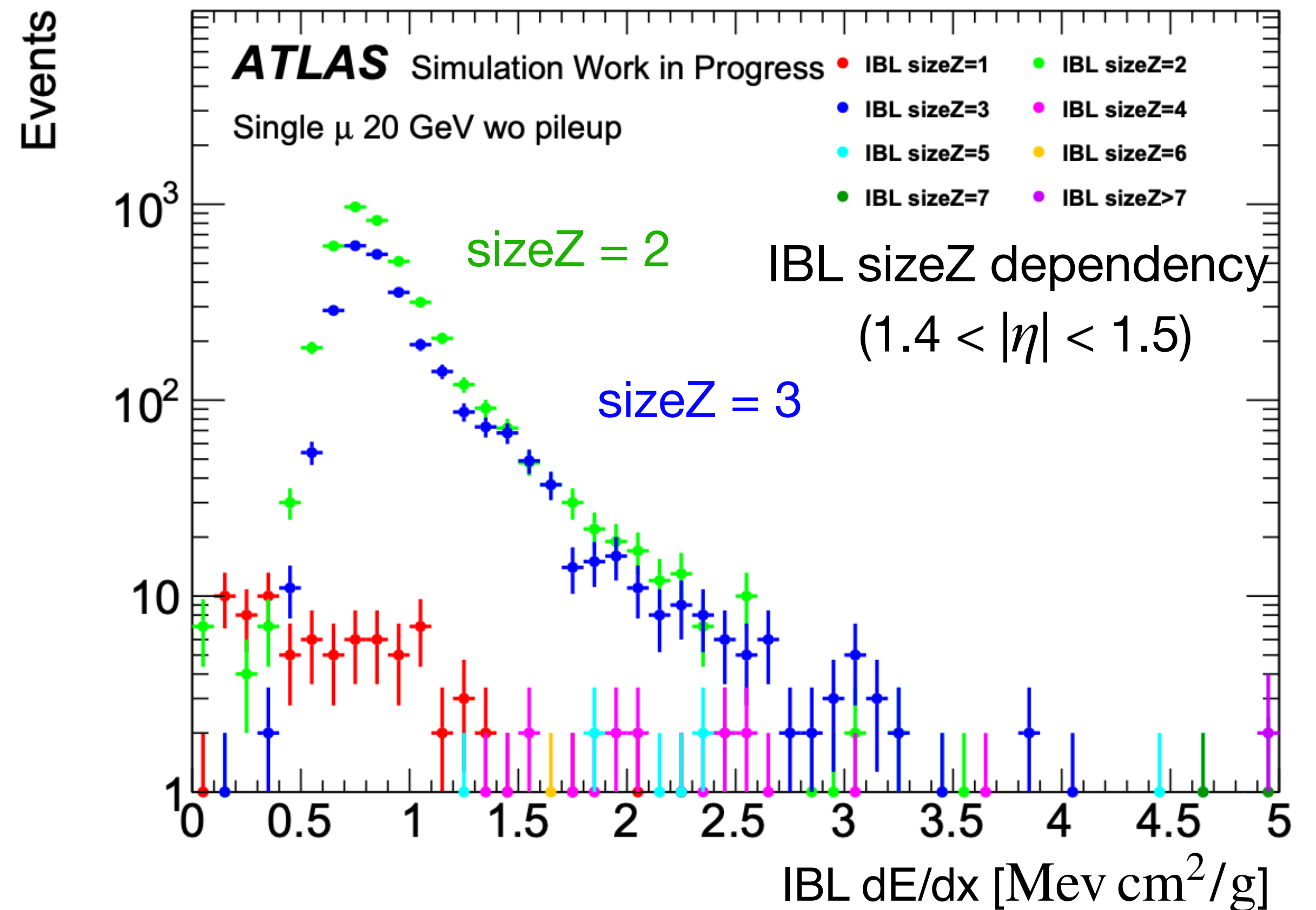
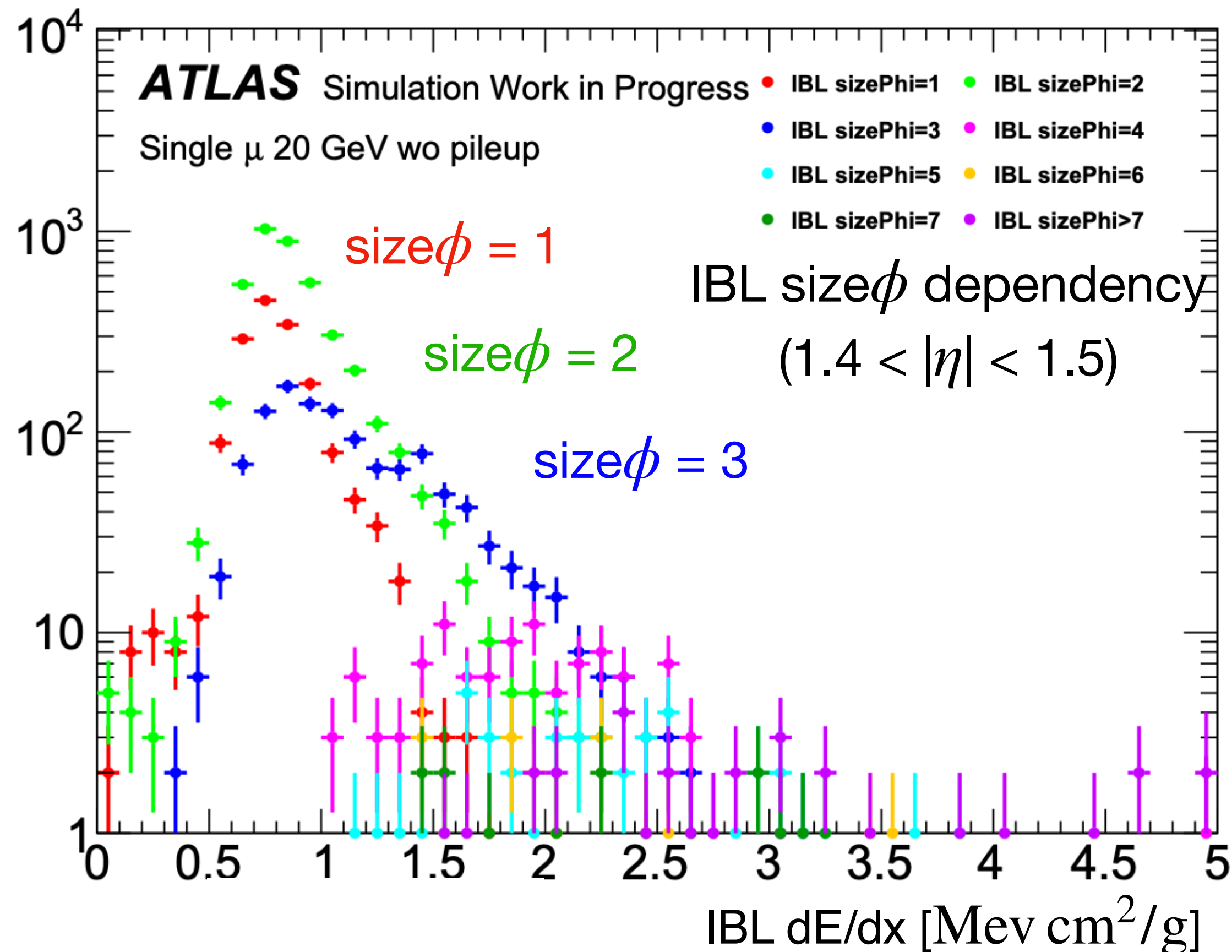
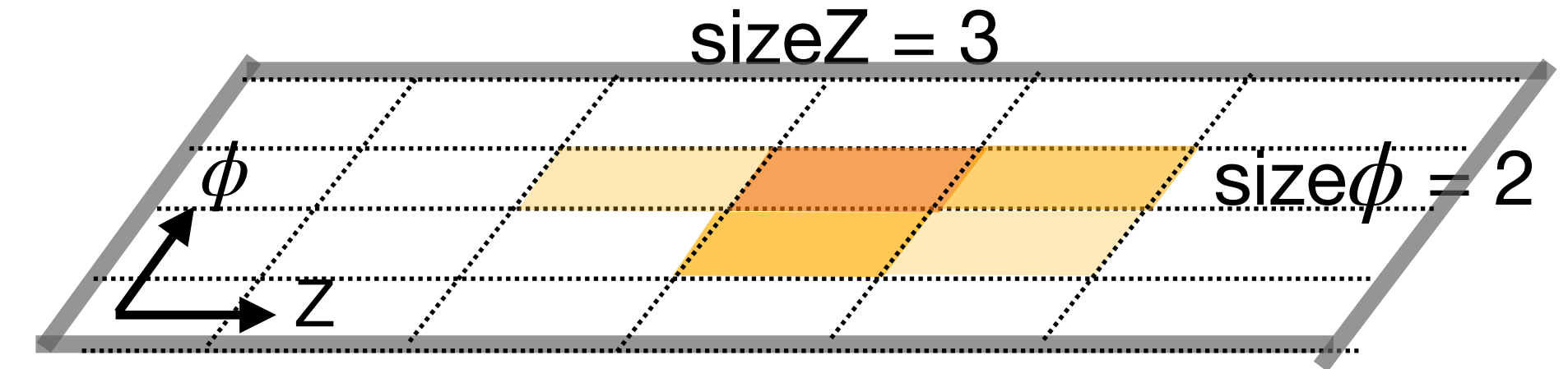
Per-track dE/dx

- Defined by averaging the individual layers' dE/dx
- To suppress the Landau tail component caused by δ -ray, the “truncated mean” is used
 - A δ -ray causes a large dE/dx in a single pixel layer
 - ▶ By excluding the maximum dE/dx cluster as an “outlier” from the averaging, the dE/dx tail is suppressed
- Improved method for per-track dE/dx definition
 - dE/dx + cluster size



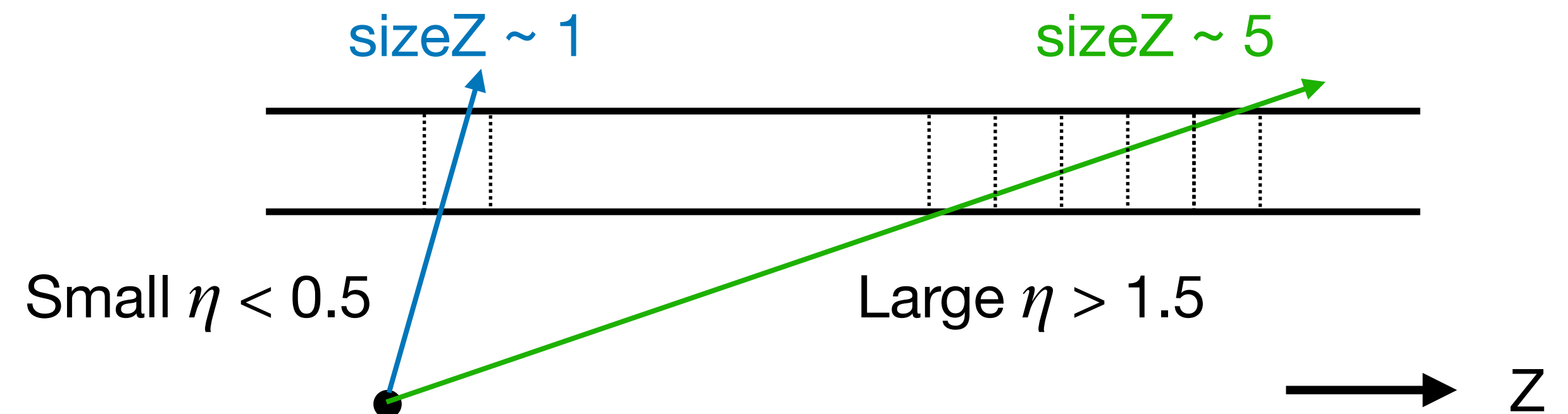
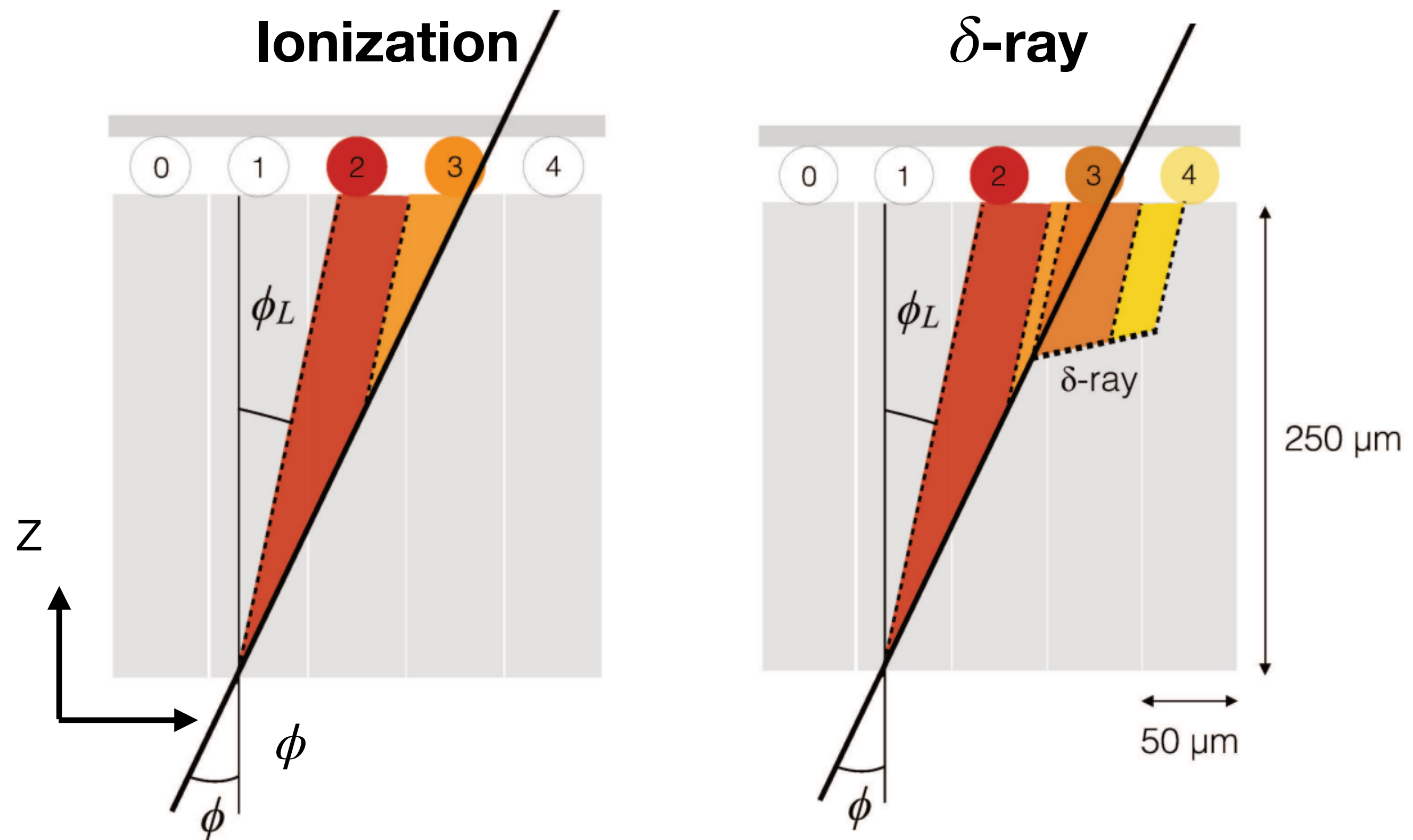
Per-layer dE/dx and Cluster size

- Check correlation of pixel dE/dx and cluster size
- Single muon ($p_T = 20$ GeV) without pileup sample



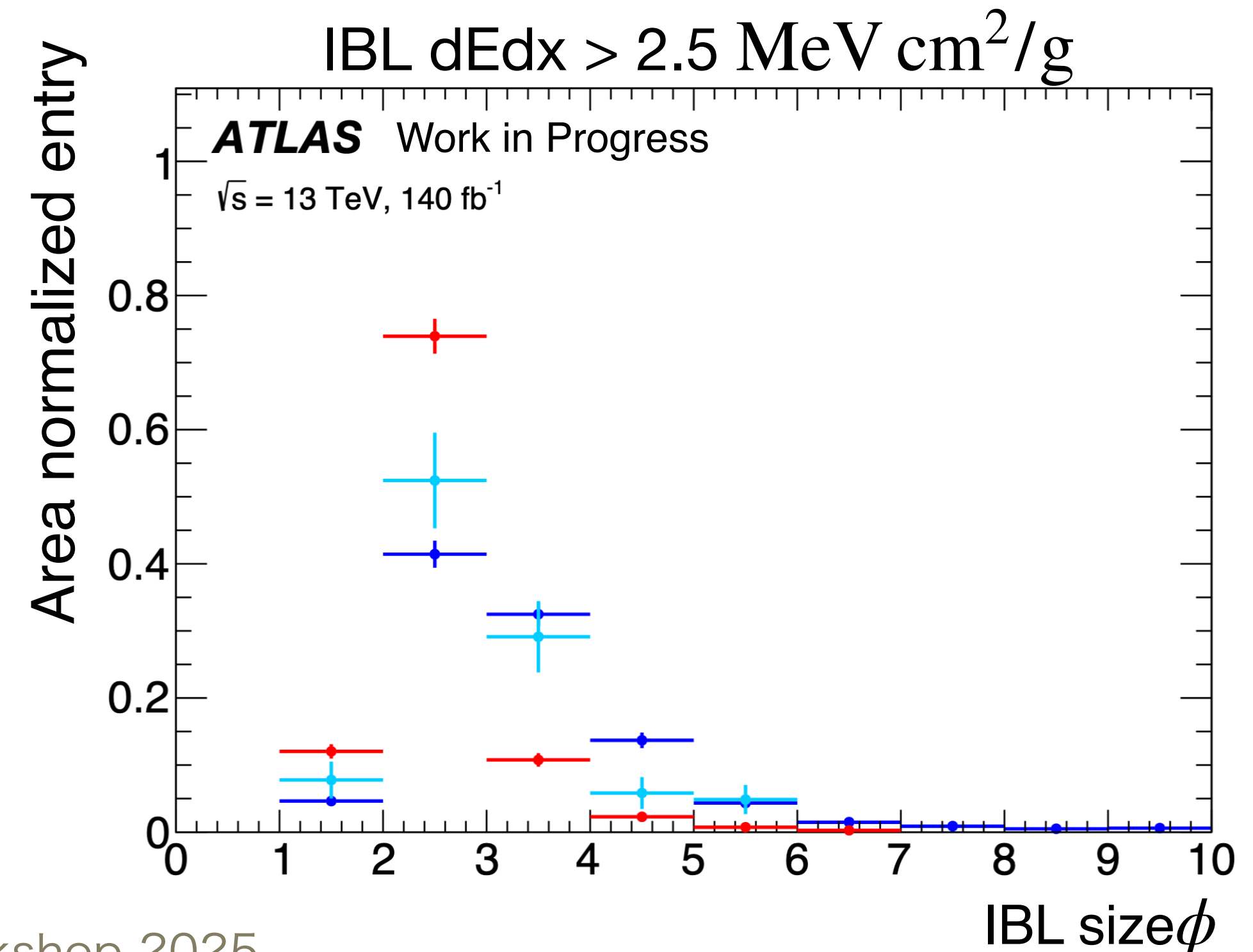
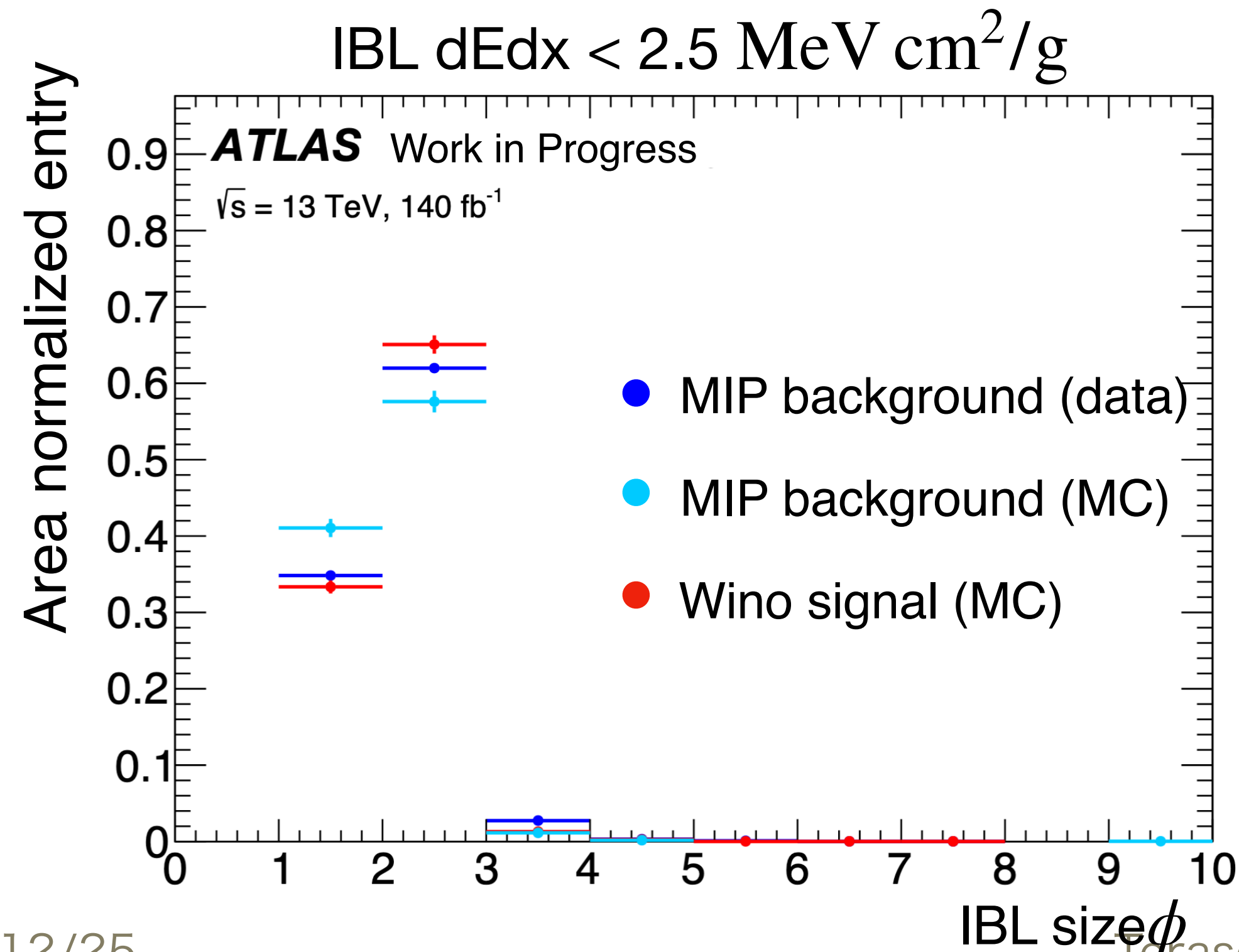
Interpretation of the large size ϕ cluster

- Caused by δ -ray
 - For standard ionization process, cluster typically extend 1-2 pixels
 - Secondary electrons can spread over more than three pixels
- size ϕ is more sensitive than size Z
 - Pixel size is smaller \rightarrow better resolution
 - The size Z has a wide spread due to differences in the incident angle across different η regions



Signal and background comparison

- The physics process leading to high dE/dx are different
 - MIP background : δ -ray \rightarrow large size ϕ
 - Signal : Ionization at low β
- By treating clusters with large size ϕ (≥ 3) as delta-ray-like outliers,
 \Rightarrow MIP background can be selectively suppressed



New per-track dE/dx

New per-track dE/dx definition

1. Cluster with sizePhi ≥ 3 is excluded
2. Take the remaining layer's average excluding the largest cluster

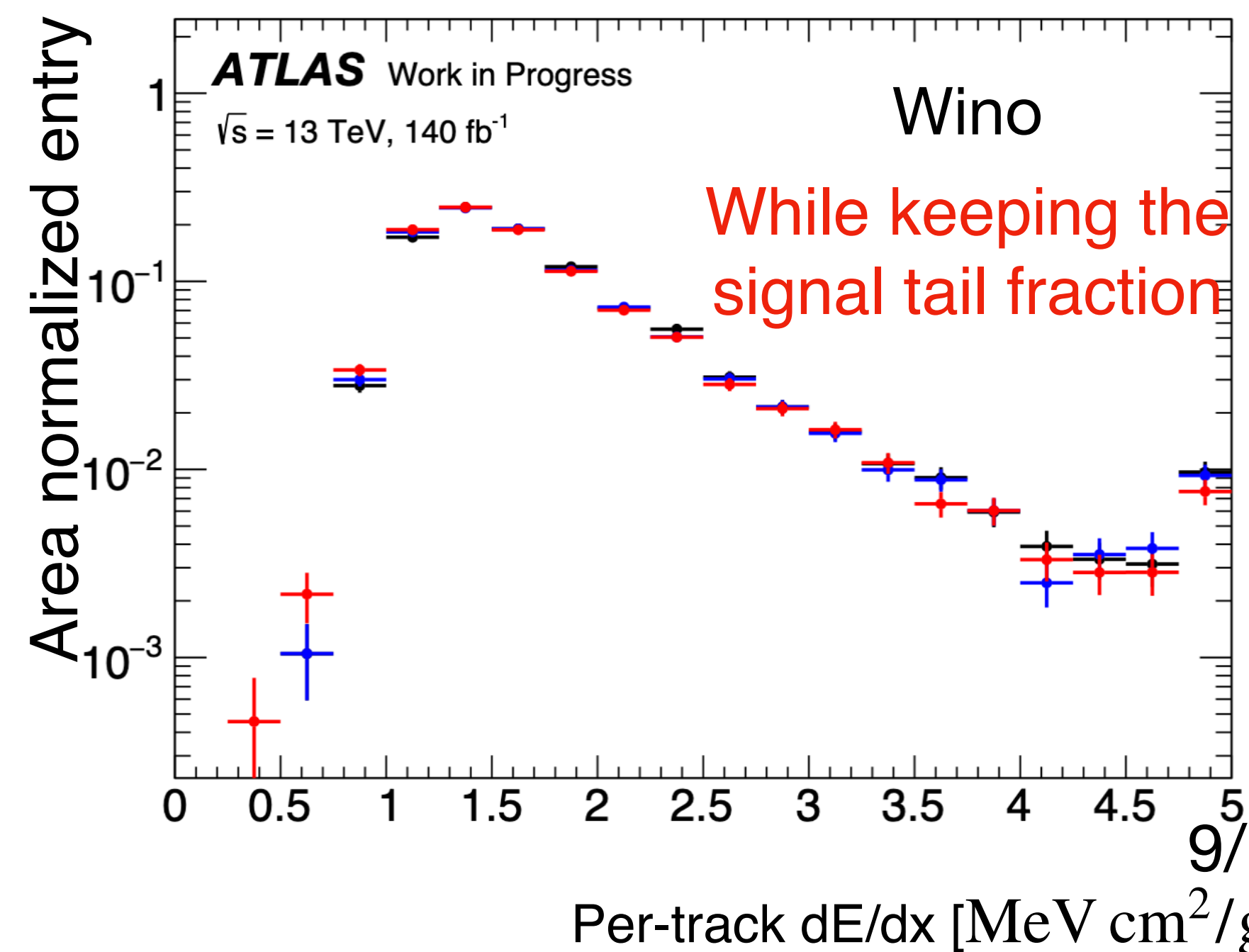
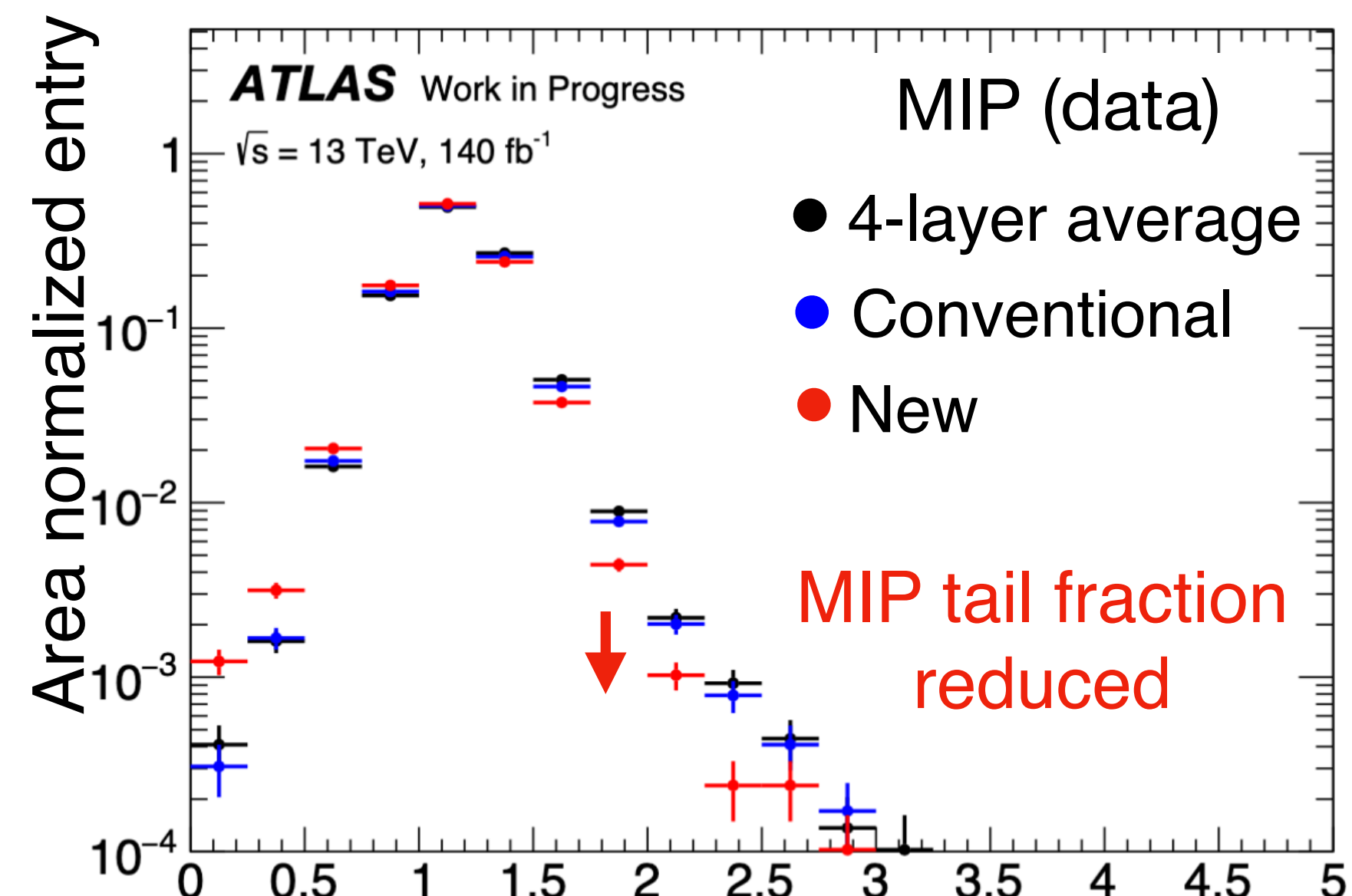
ex)

Conventional New

Layer	sizePhi	dEdx
0	1	+ 1.0758 +
1	<u>4</u>	3.9441
2	<u>3</u>	+ 3.6240
3	2	+ 2.6409

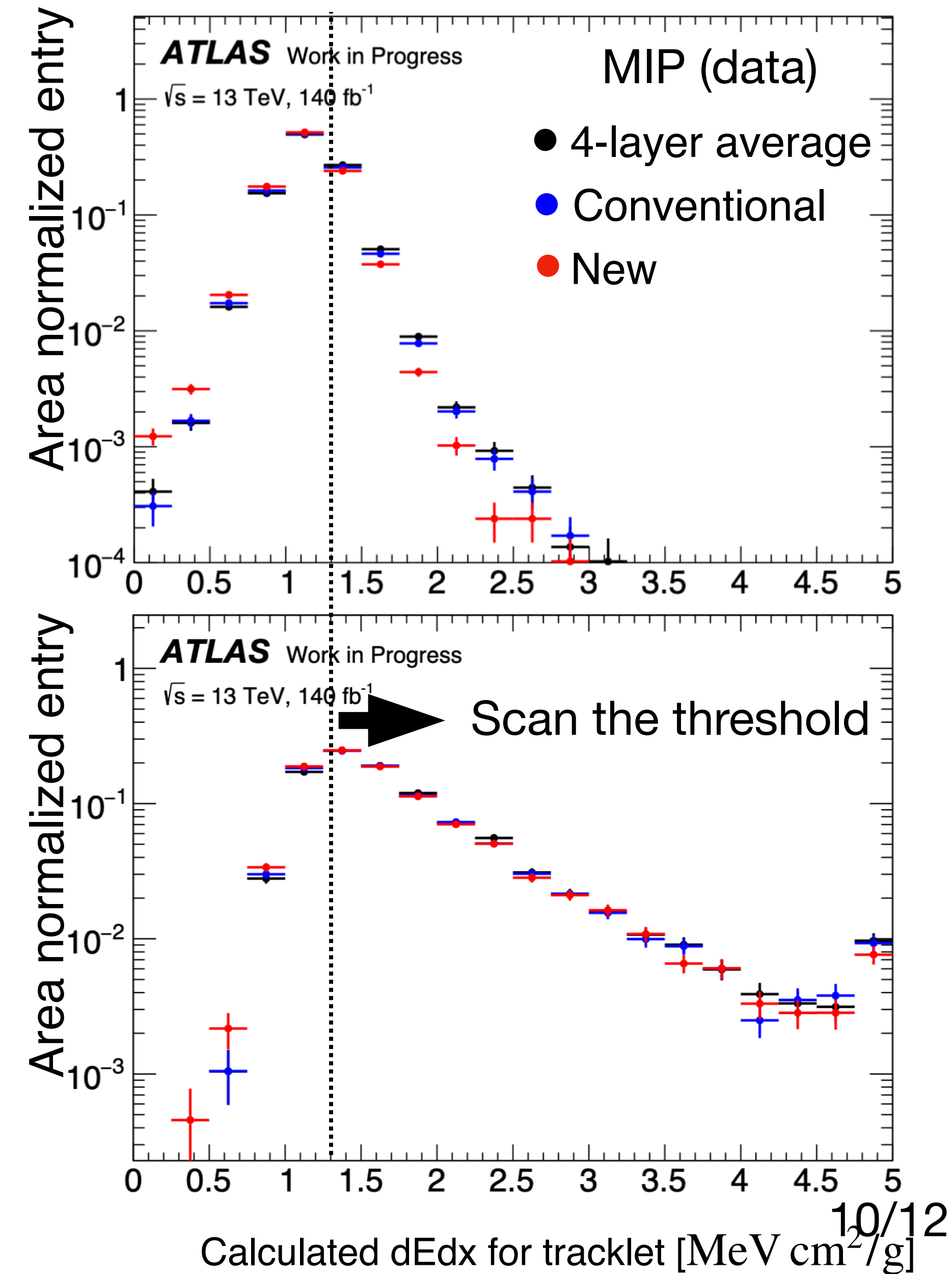
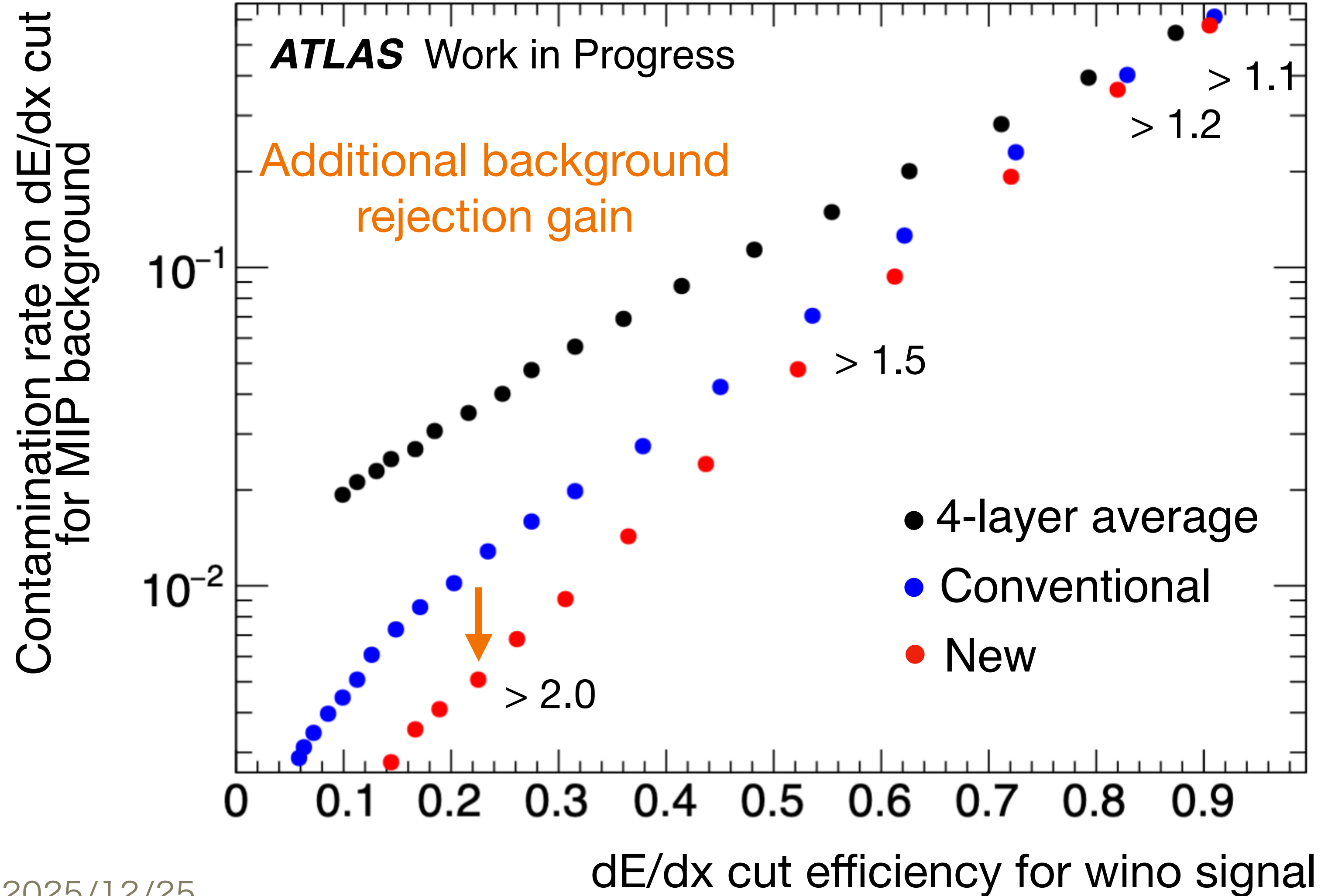
=> 2.44 => 1.07

- Tried several truncation pattern and compared the background rejection performance



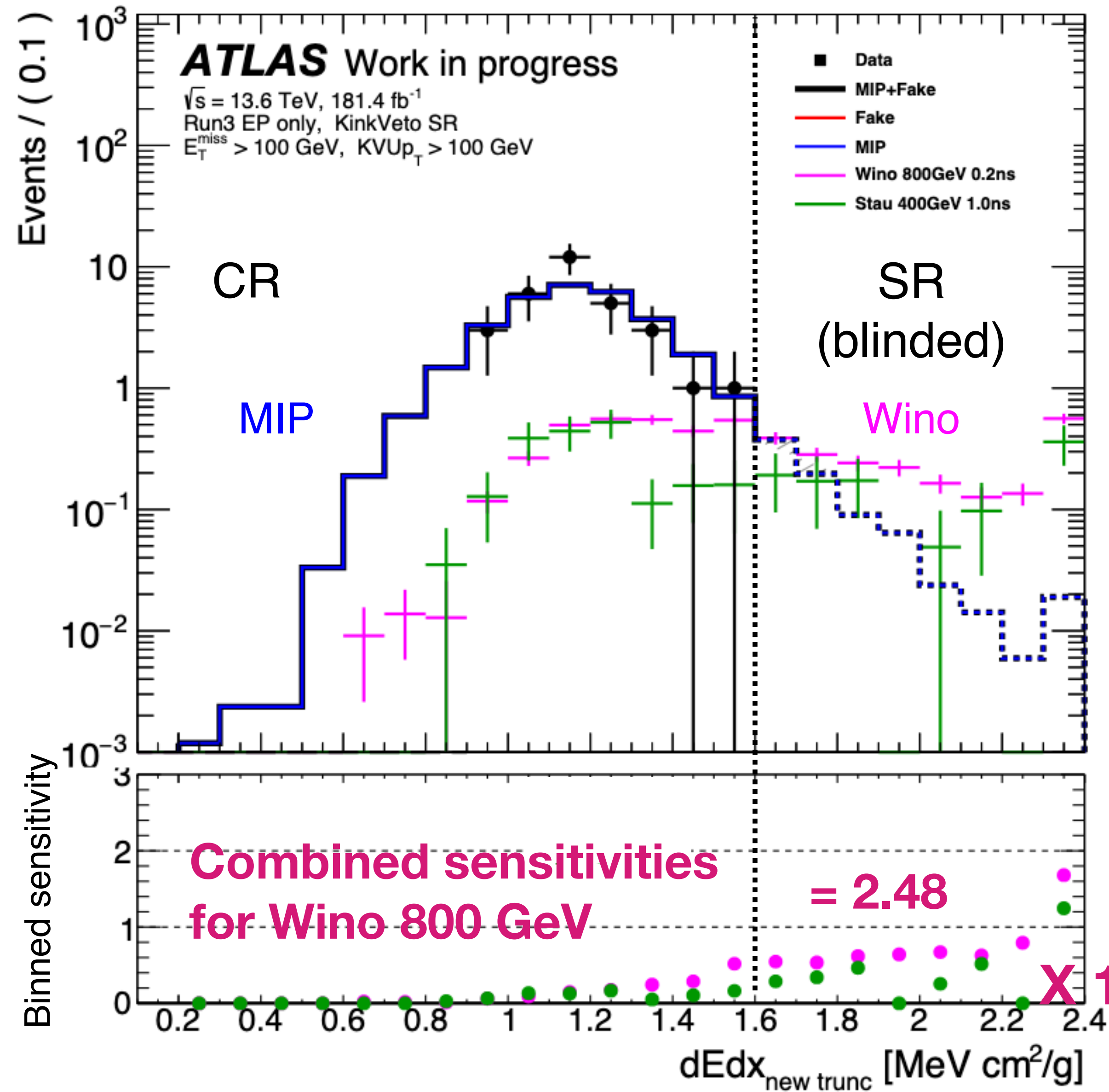
New per-track dE/dx

- RoC curve obtained by varying the dE/dx threshold value

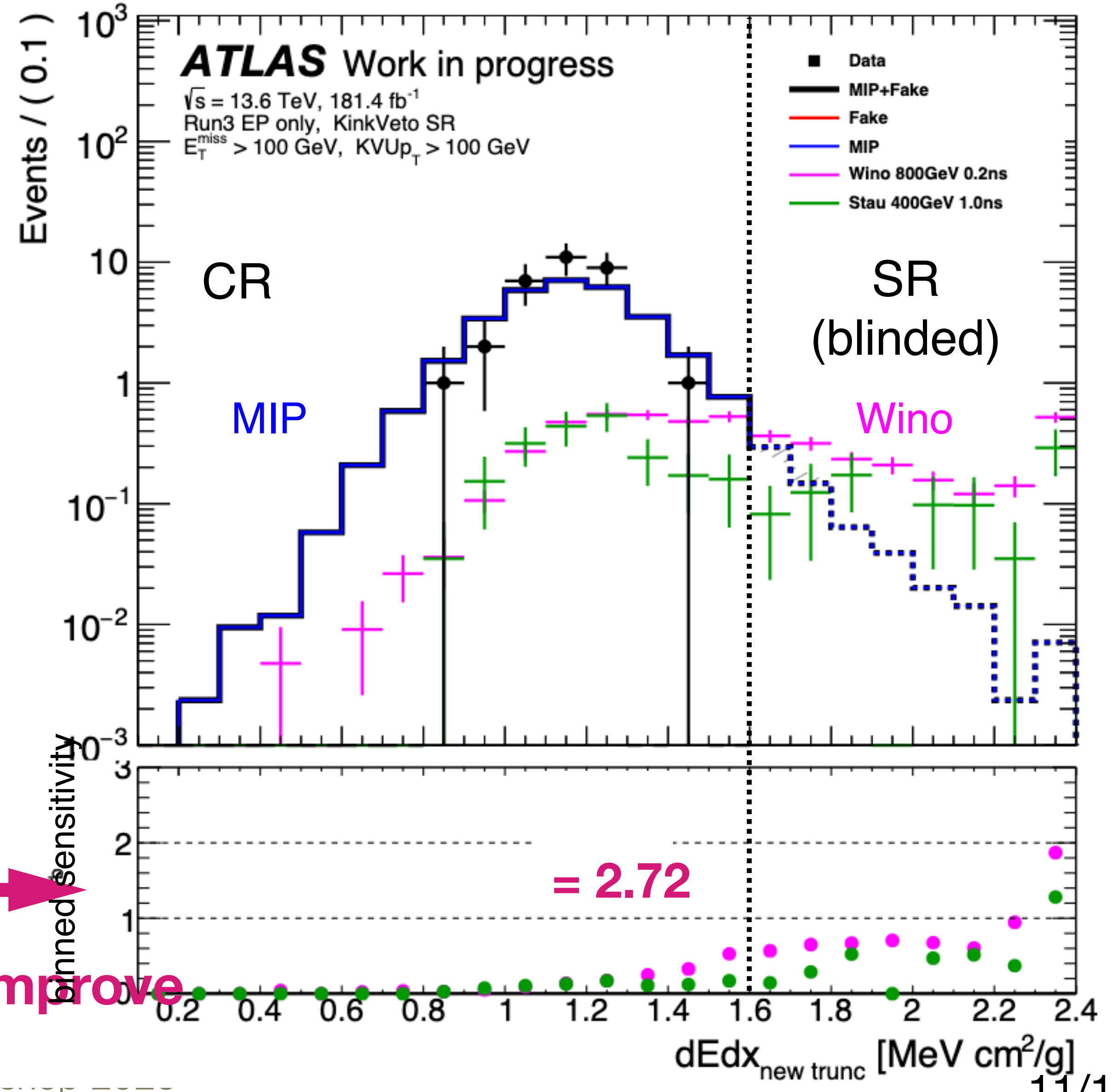


Impact for sensitivity

Conventional method



New method



X 1.1 improve

Summary

- In the long-lived low- β new particle searches, reducing the MIP dE/dx tails is crucial to extract signals in the high dE/dx tail region
- Detailed study of the phenomena to create high dE/dx in the MIP background, a new way of estimating “tracklet dE/dx” is established using the cluster size information

➡ Results in a 1.1 x improvement in sensitivity

✿ Welcome to my poster

- Signal region definition strategy
- Full data-driven background estimation
- Sensitivity expectation for wino and stau