Disappearing track trigger in ATLAS for Run 3 searches

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DESY Summer student presentation

4th September 2024

Content

Introduction

- Dark matter candidate in SUSY
- Trigger system

Dataset- 2022, ATLAS experiment

pp collisions $\sqrt{s} = 13.6\ TeV, integrated\ luminosity$: $29\ fb^{-1}$

Study efficiency of disappearing track trigger

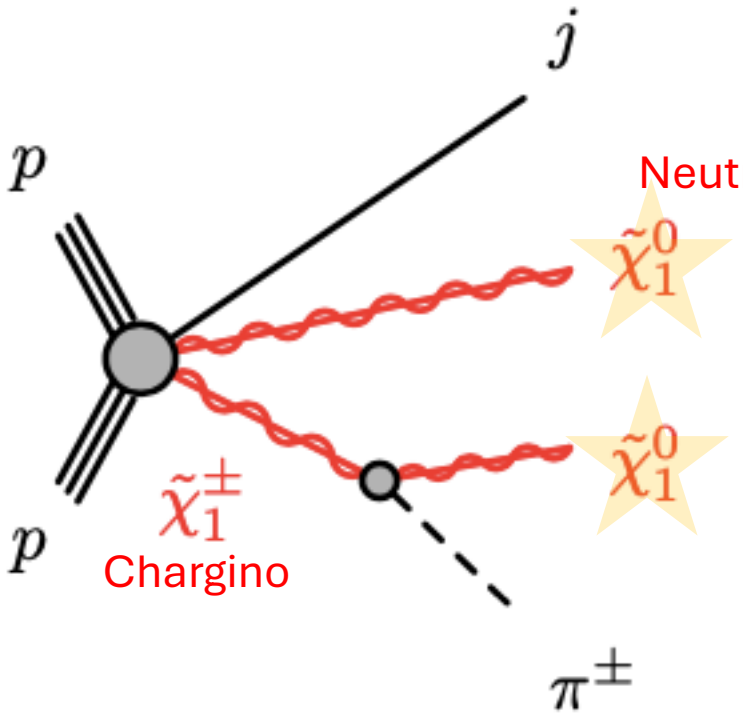
Generated events- MadGraph5 ver.3.5.4, Pythia8 ver.8.311, generate signal events

pp collisions $\sqrt{s} = 13.6\ TeV, integrated\ luminosity$: $137 fb^{-1}$

Study gained signal events with disappearing track trigger

Introduction

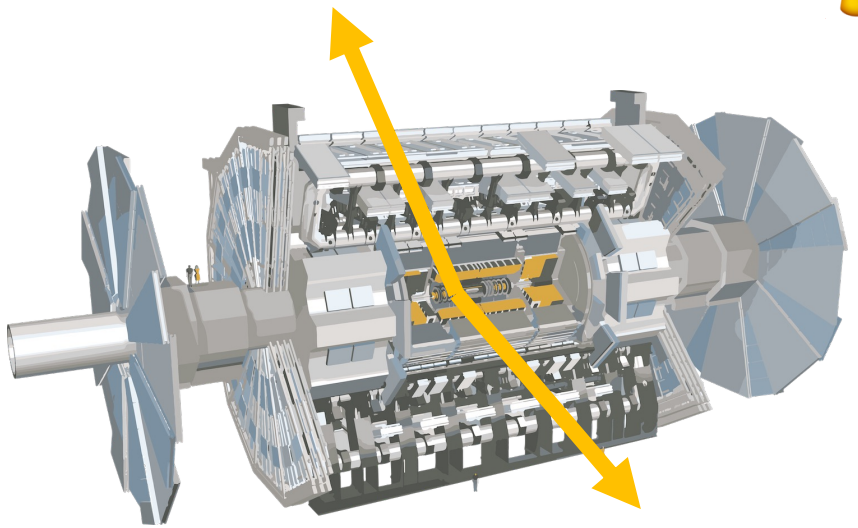
- Target: SUSY model – LSP(Neutralino) Dark matter candidate



$$E_{\mathrm{T}}^{\mathrm{miss}} = \left| \sum_{c} \vec{p}_{T,c} \right|$$

Pass through detector
→ Use momentum imbalance
→Missing Transverse Energy (MET or $\mathrm{E}_{\mathrm{T}}^{\mathrm{miss}}$)

Collision (event) every 25ns ! 😱



→ Trigger system

L1 (Hardware) – process all input
→ HLT (Software) – run event reconstruction algorithm
→ Store

Adjust the triggers to see new signal candidates

Aad, G., Abbott, B., Abbott, D.C. *et al.* Search for long-lived charginos based on a disappearing-track signature using 136 fb of *pp* collisions at = 13 TeV with the ATLAS detector. *Eur. Phys. J. C* **82**, 606 (2022).

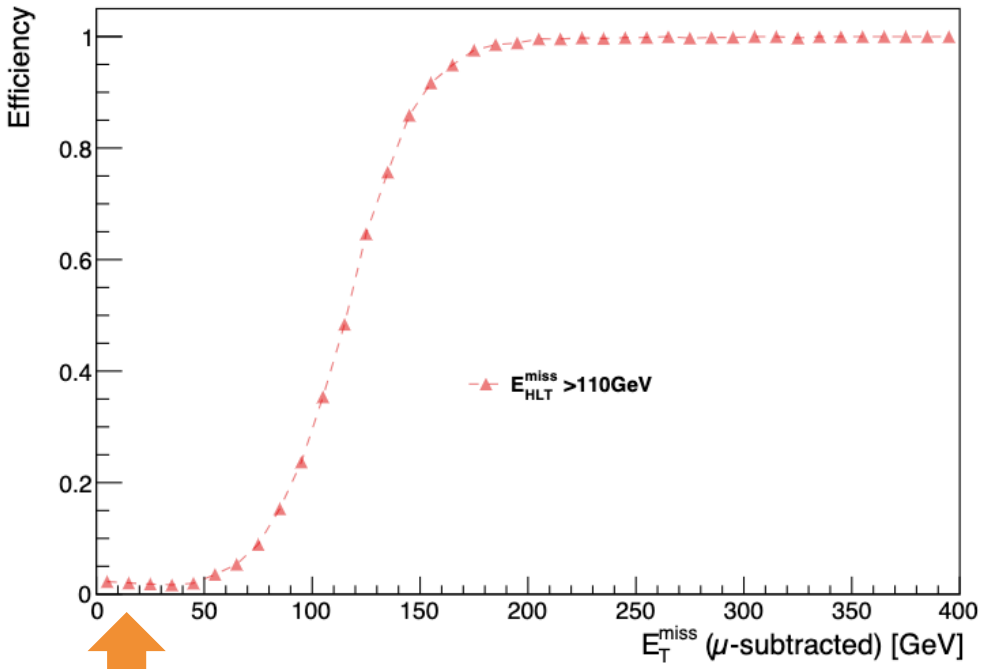
MET trigger L1 + HLT Trigger

L1: $E_T^{miss} > 50GeV$

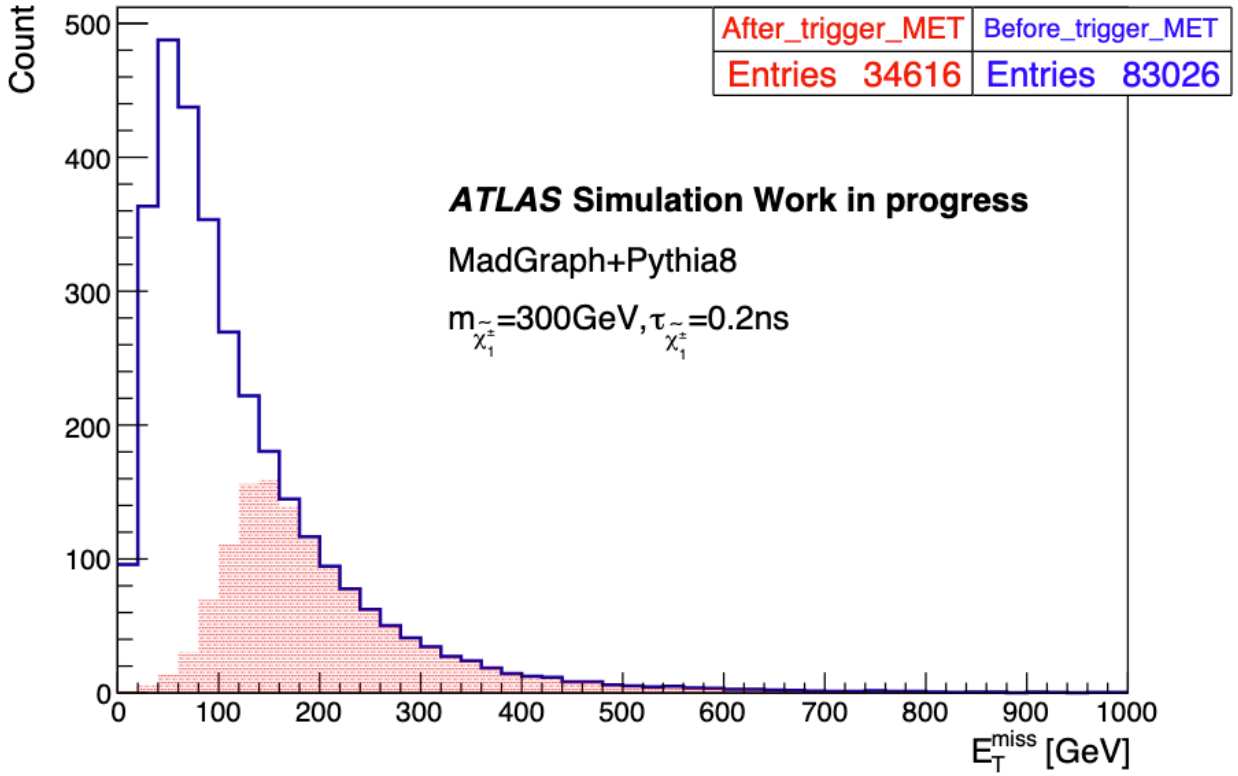
HLT: $E_T^{miss} > 110GeV$

keep data take-in managable → Cut

MET trigger efficiency plot



E_T^{miss} before and after MET trigger



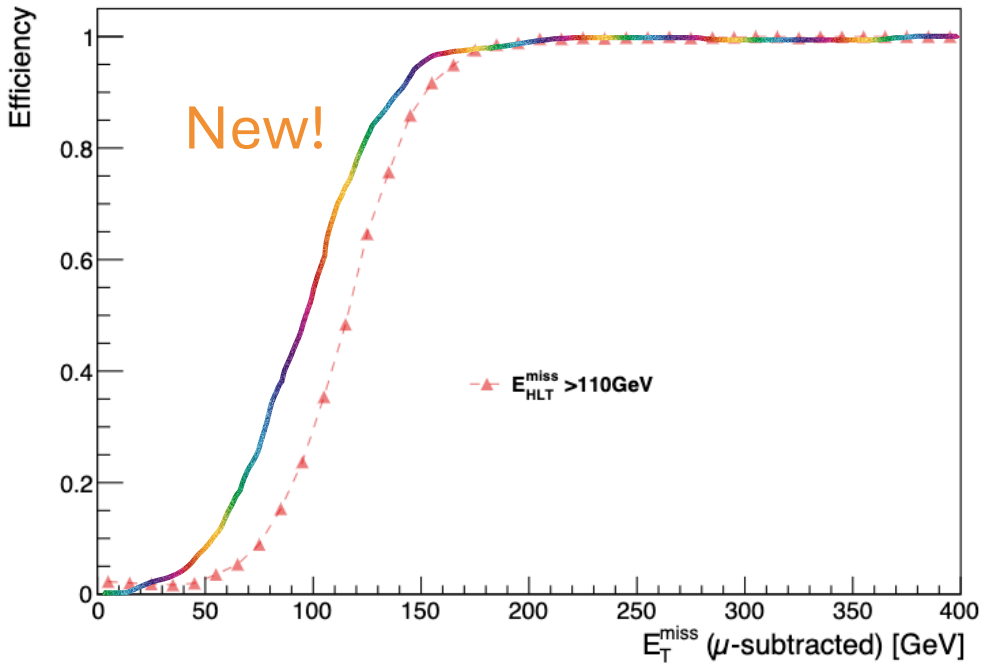
Low E_T^{miss}: higher bkg & difficult to reconstruct

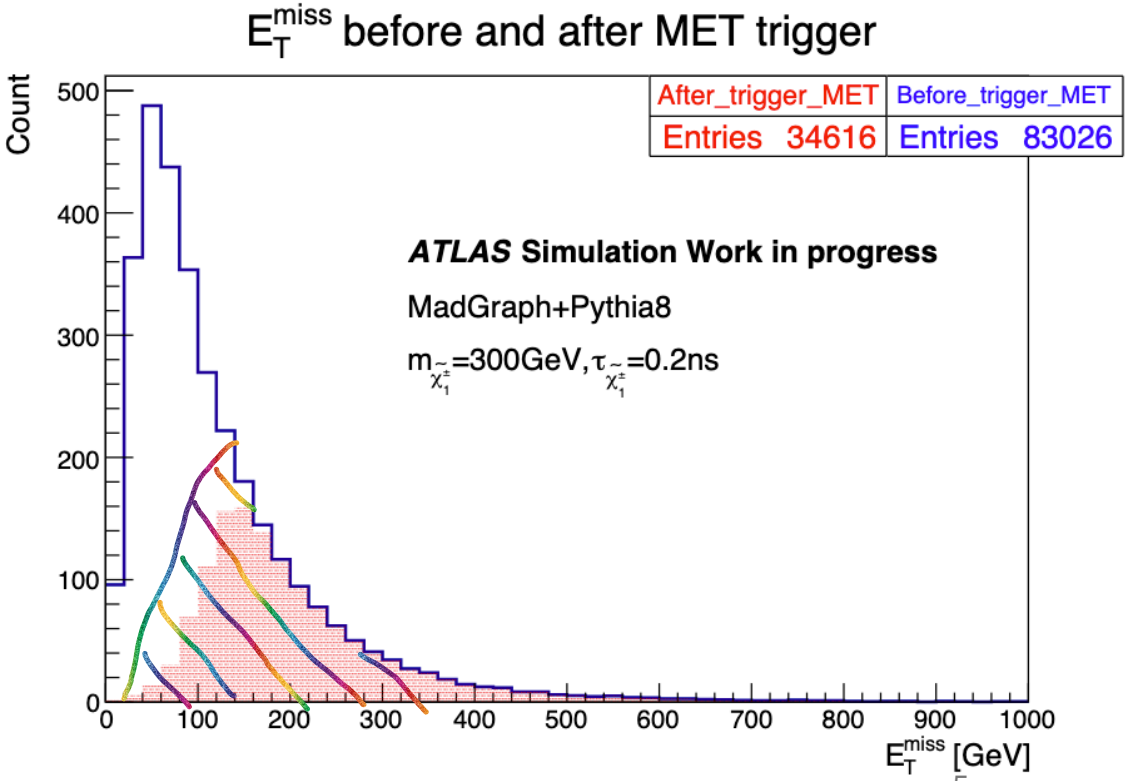
Aaboud, Morad, et al. "Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in s= 13 TeV pp collisions with the ATLAS detector." *Physical review D* 97.5 (2018): 052012

Objective - Upgrade trigger!

L1 + HLT Trigger + Disappearing track Trigger

- Gain new signal region candidates at low MET
- Lower bkg rate → lower MET requirement

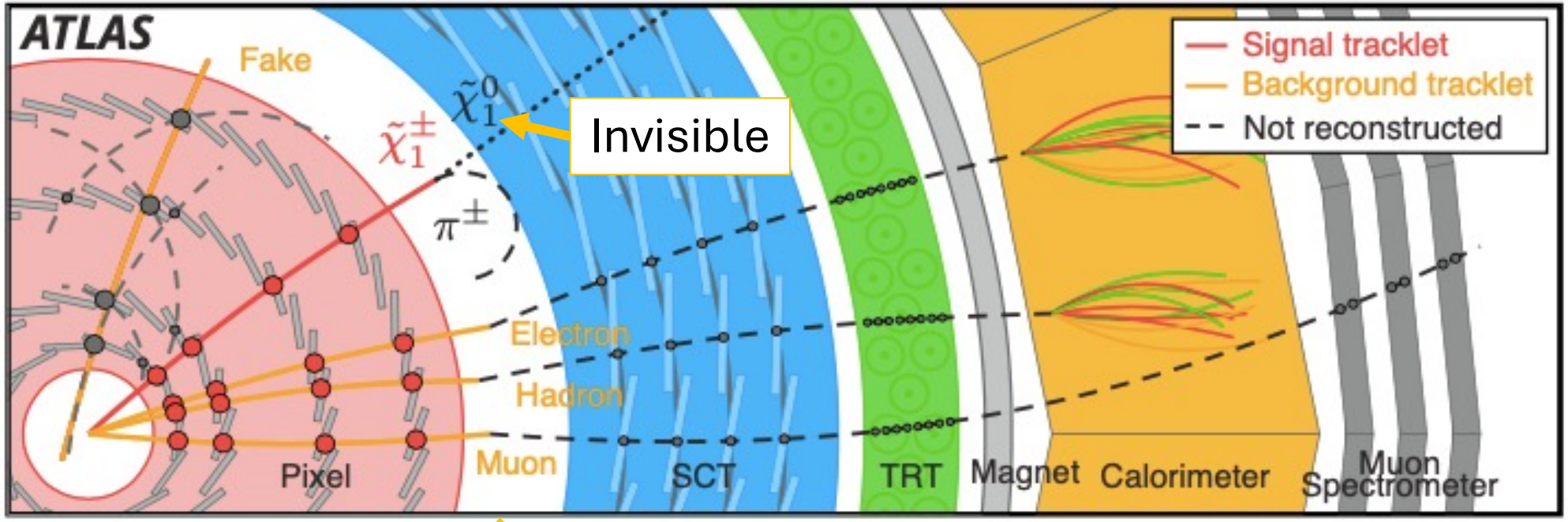


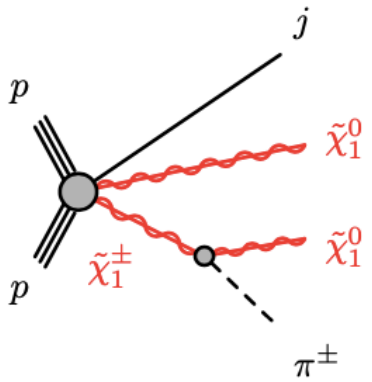


Upgraded trigger –Disappearing track trigger

'tracklet' = only Pixel hits

Detector view





'Decay'

Aad, G., Abbott, B., Abbott, D.C. *et al.* Search for long-lived charginos based on a disappearing-track signature using 136 fb of *pp* collisions at = 13 TeV with the ATLAS detector. *Eur. Phys. J. C* **82**, 606 (2022).

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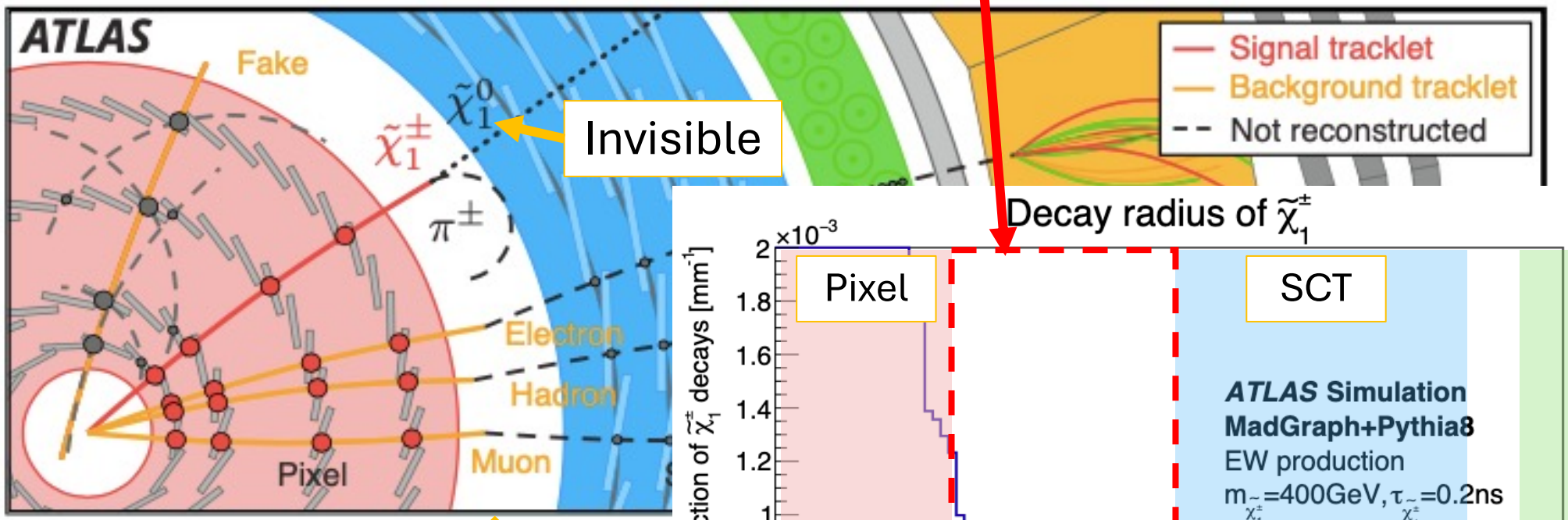
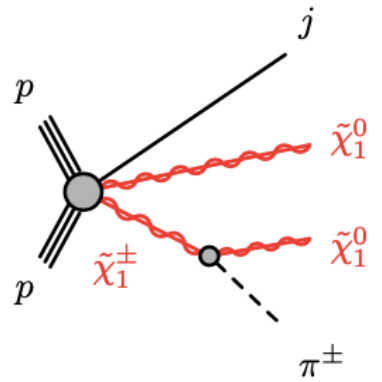
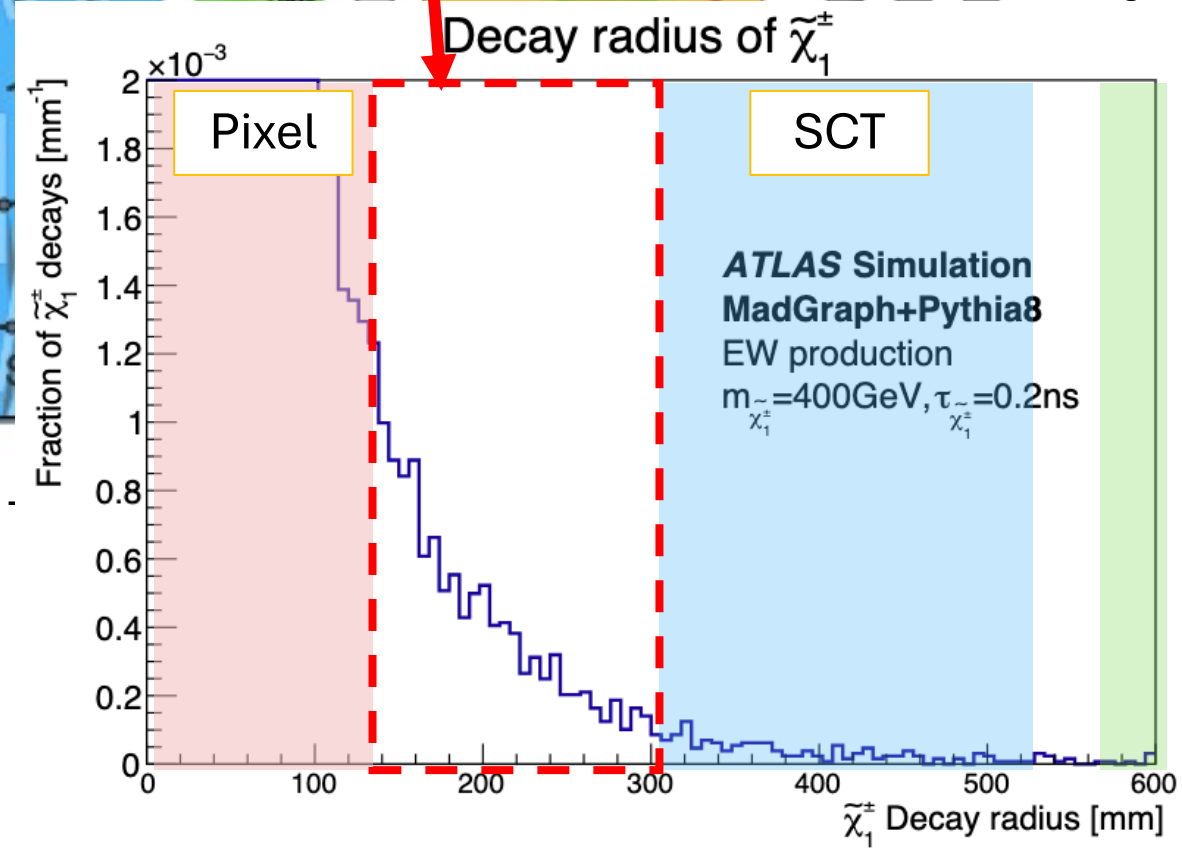




'Decay'



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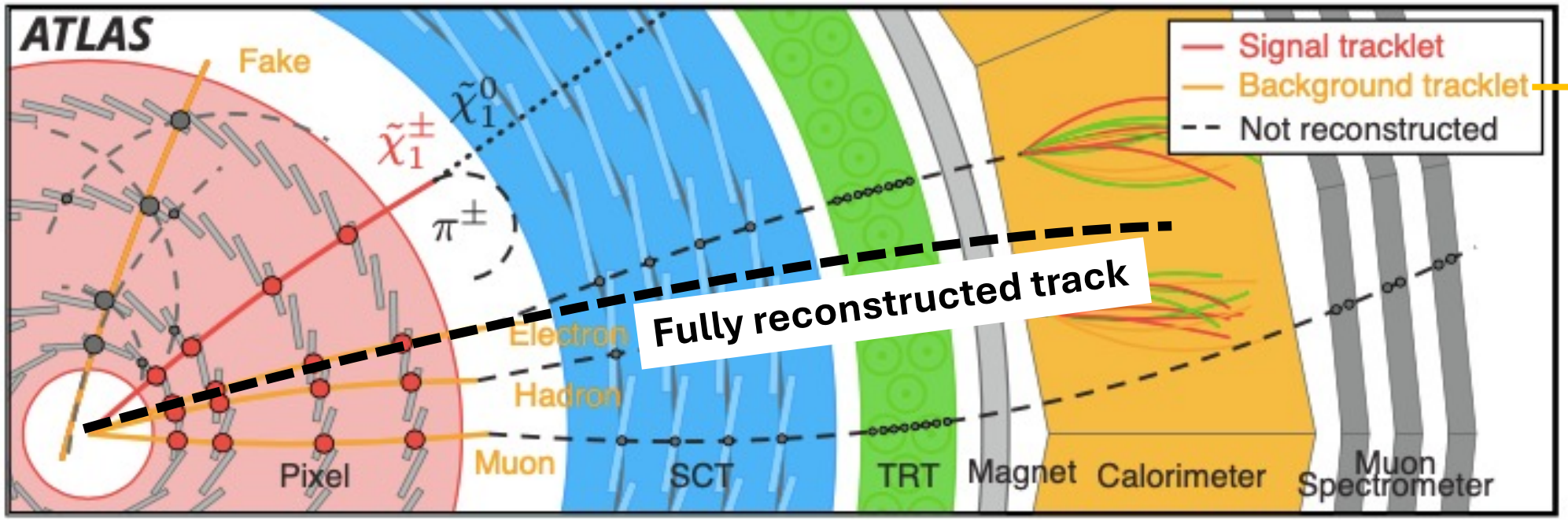
Upgraded trigger –Disappearing track trigger

'tracklet' = only Pixel hits

Detector view



Fake
Electron & Hadron
Muon

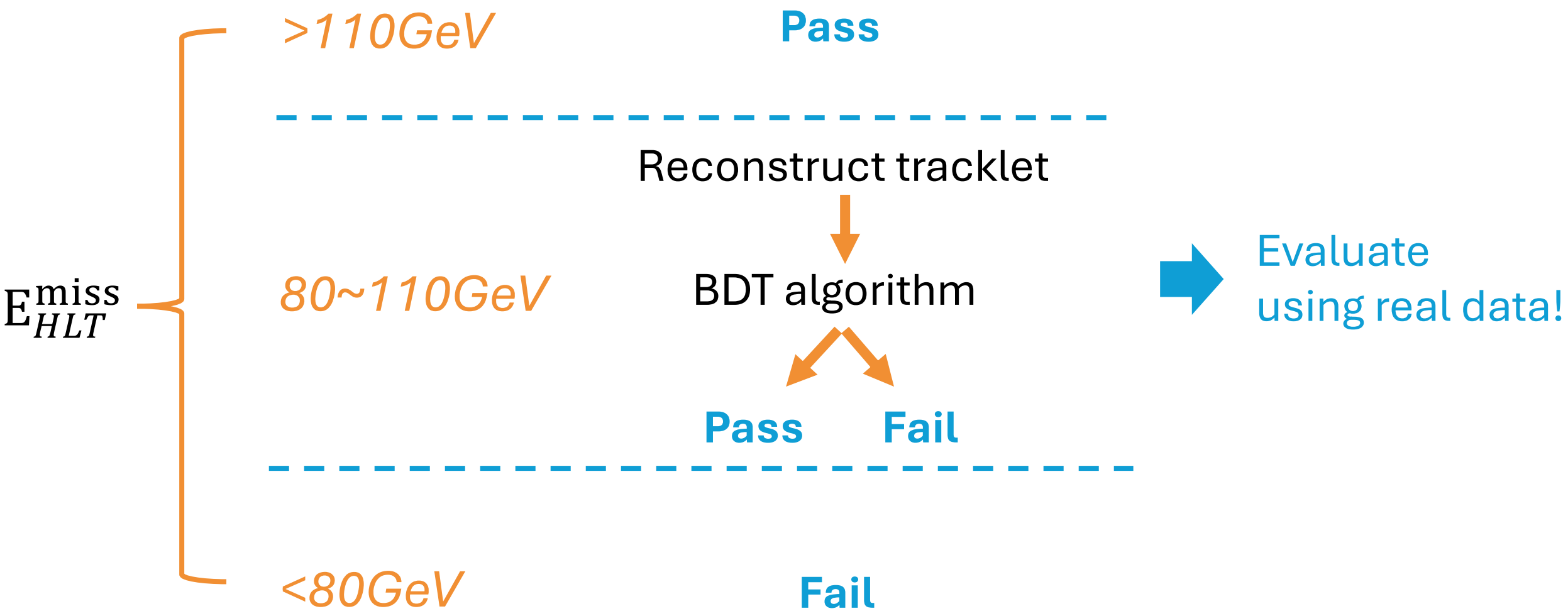
BDT (Boosted Decision Tree)

-Separate bkg (fake) & signal tracklet

-12 variables (track parameters, quality of fit, number of Pixel hits etc)

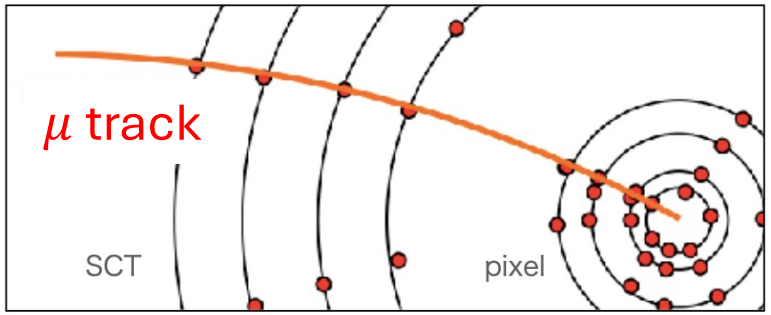
Aad, G., Abbott, B., Abbott, D.C. *et al.* Search for long-lived charginos based on a disappearing-track signature using 136 fb of *pp* collisions at = 13 TeV with the ATLAS detector. *Eur. Phys. J. C* **82**, 606 (2022).

Upgraded trigger –Disappearing track trigger

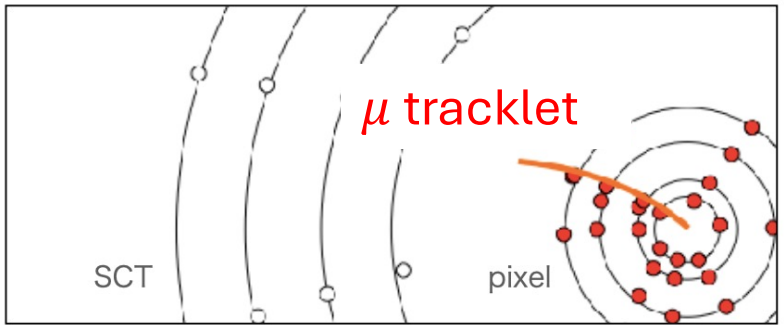


Real Data-Evaluate performance of MET trigger

Offline (after collecting data)

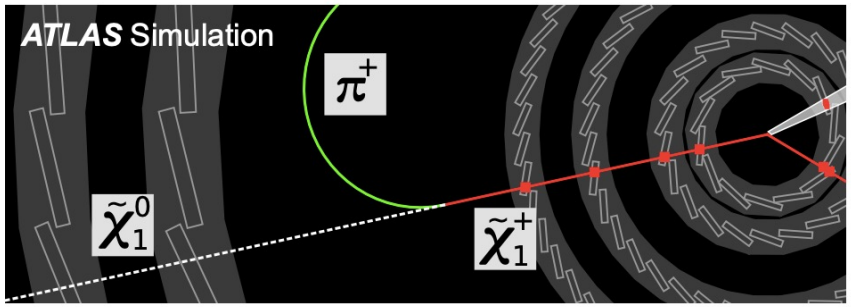


Online (while collecting data)



$\approx$

Event we are interested in



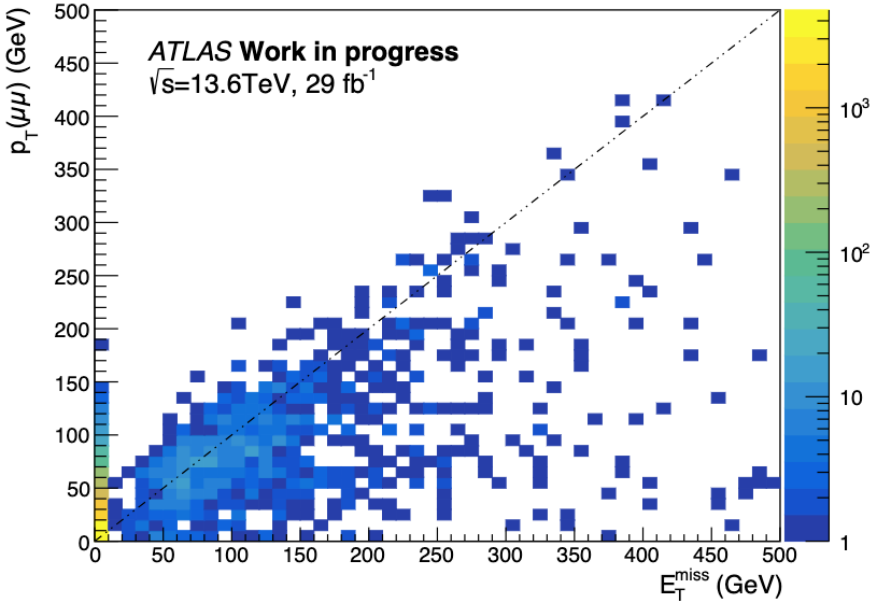
μ info not used at online-level!

μ: proxy for MET

Data: $Z \rightarrow \mu\mu$ events (well-understood)

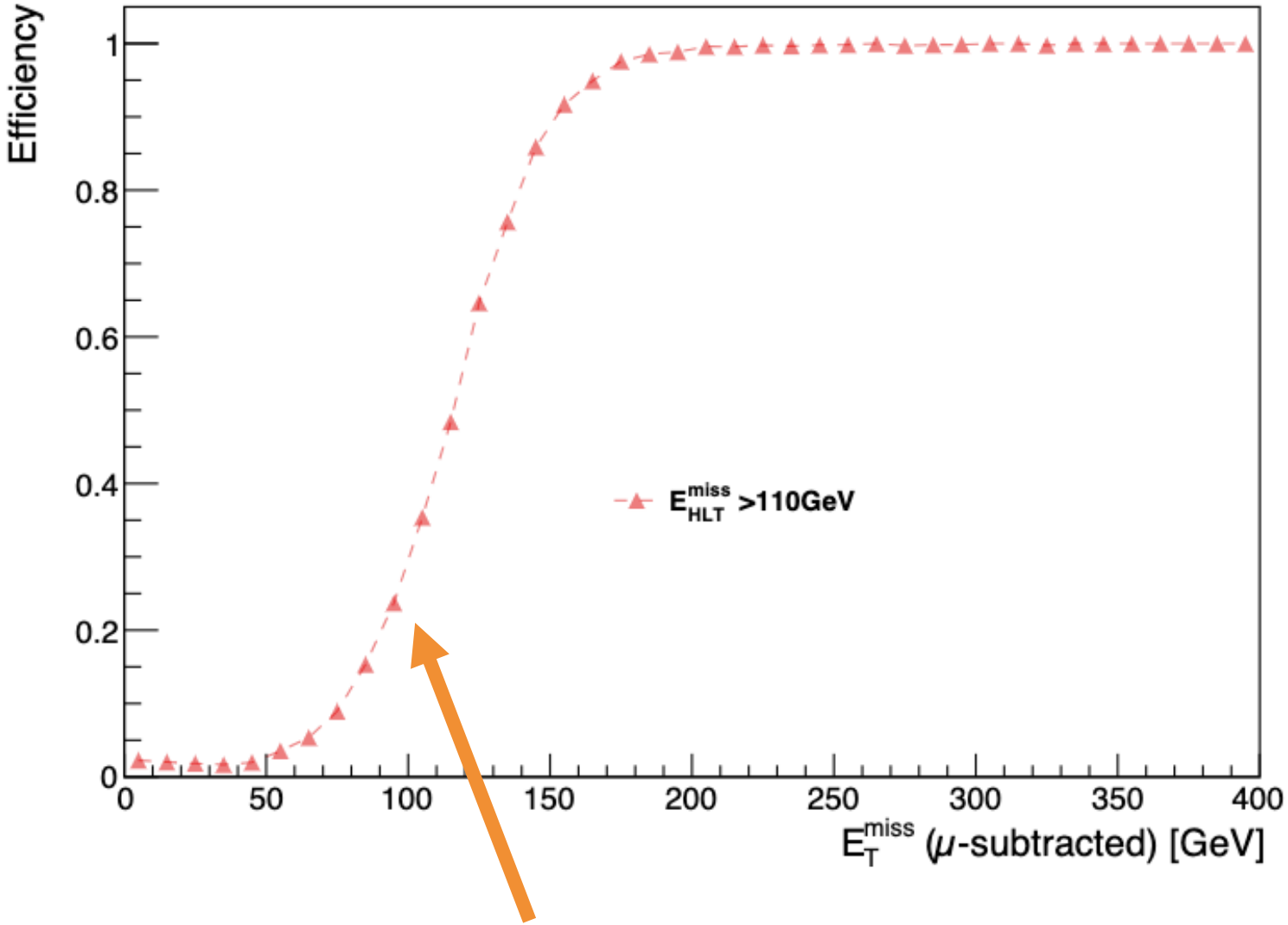
- Select good events:

1) Good quality muons
2) $0.1 < |\eta| < 1.9$
3) Offline Pixel hit ≥ 3
4) $81 < m_{\mu\mu} < 101\ GeV$
5) Isolated



Aaboud, Morad, et al. "Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in s= 13 TeV pp collisions with the ATLAS detector." *Physical review D* 97.5 (2018): 052012

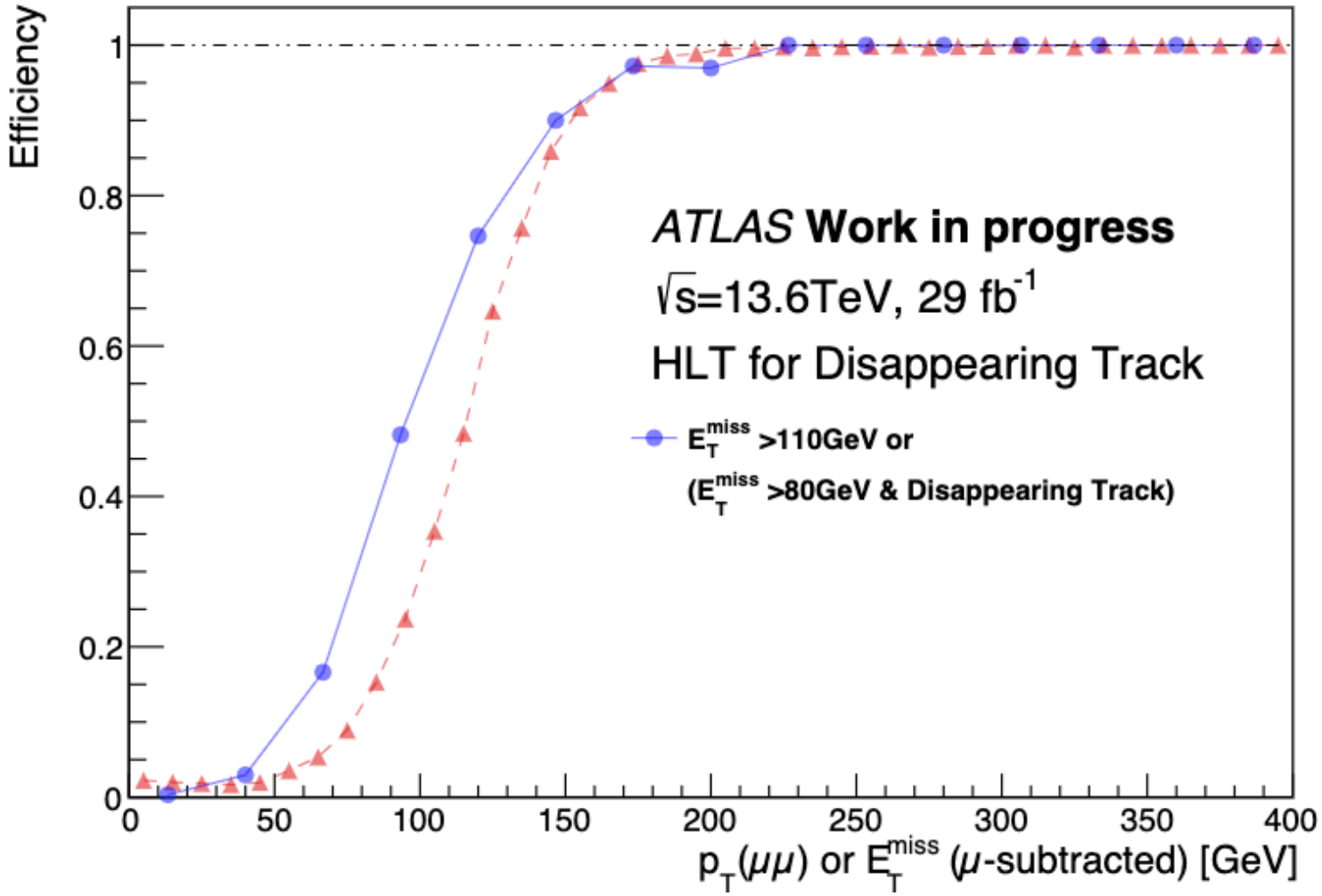
Efficiency of upgraded trigger



Original Efficiency used in 2018

Aaboud, Morad, et al. "Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in s= 13 TeV pp collisions with the ATLAS detector." *Physical review D* 97.5 (2018): 052012

Efficiency of upgraded trigger



Accept more events with Potential candidates!

Apply this new efficiency to generated events!

Aaboud, Morad, et al. "Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum in s= 13 TeV pp collisions with the ATLAS detector." *Physical review D* 97.5 (2018): 052012

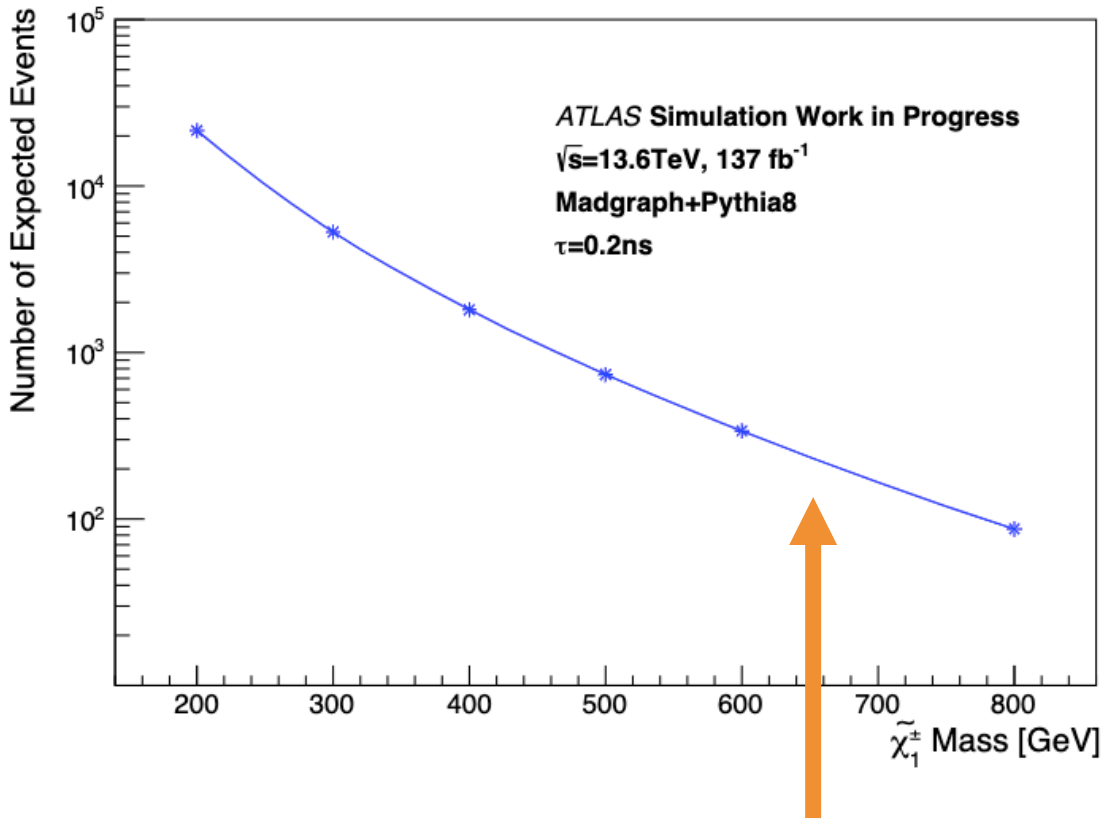
Generated events

Analyze

Simple Analysis

Signal events! $p\,p \rightarrow \widetilde{\chi_1^{\pm}} + \widetilde{\chi_2^0} + jet$

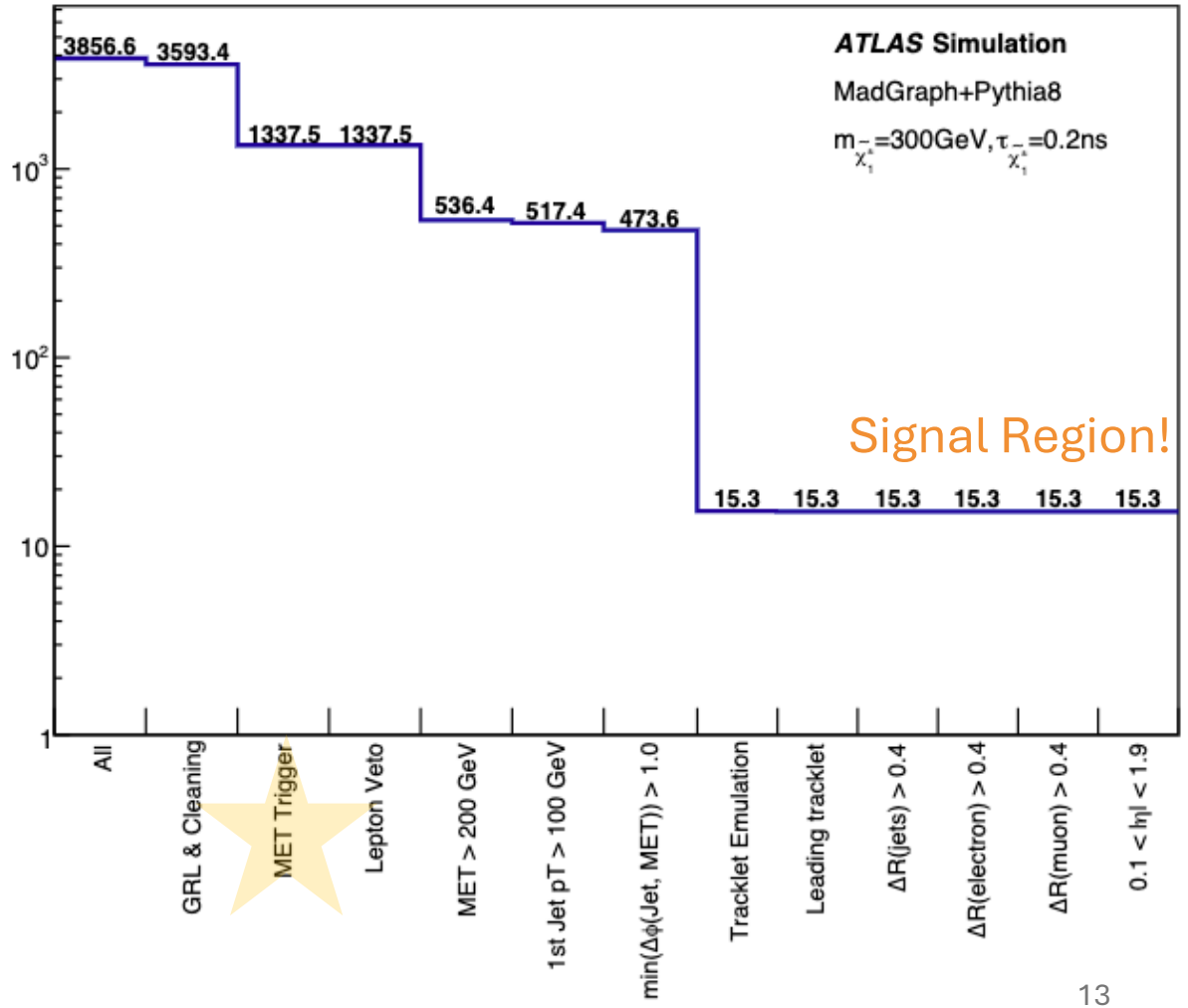
Number of Events generated for different masses



Need higher efficiency for large mass!

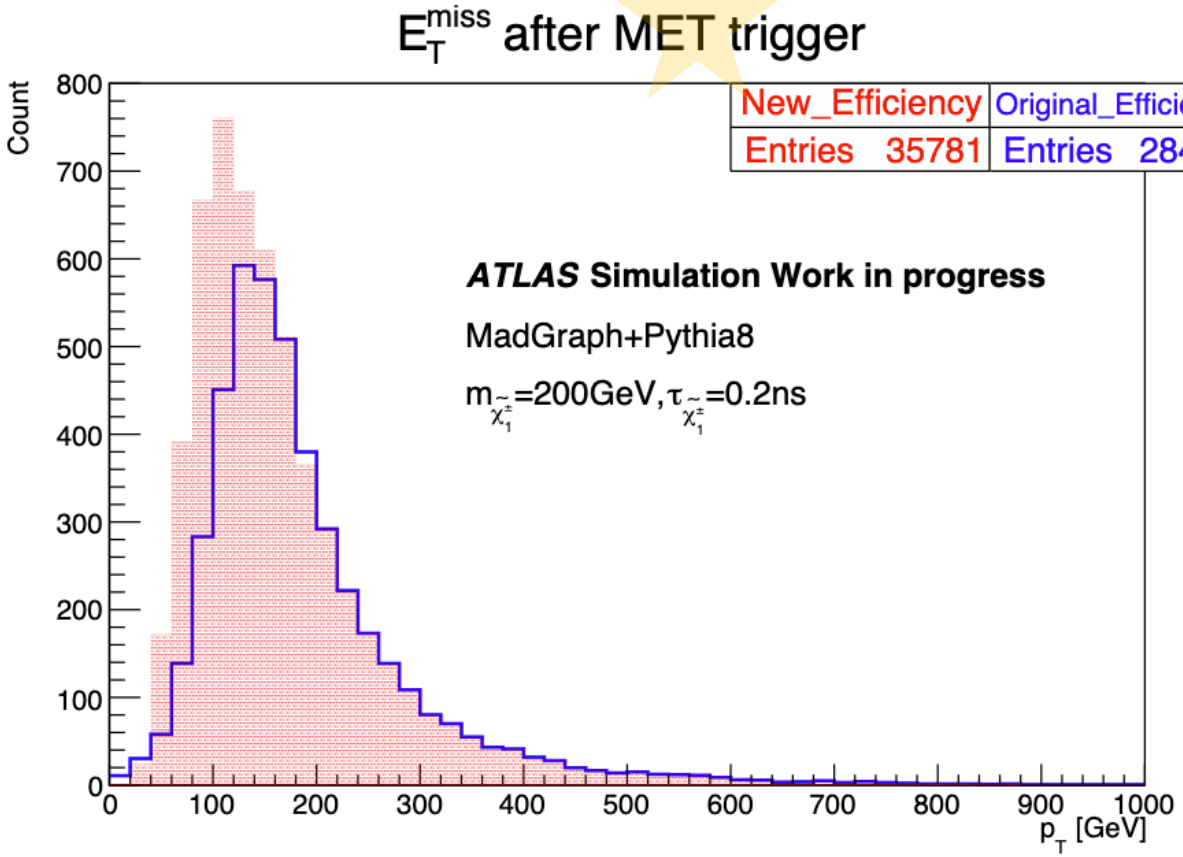
Online + Offline

Get Signals that we are interested in!

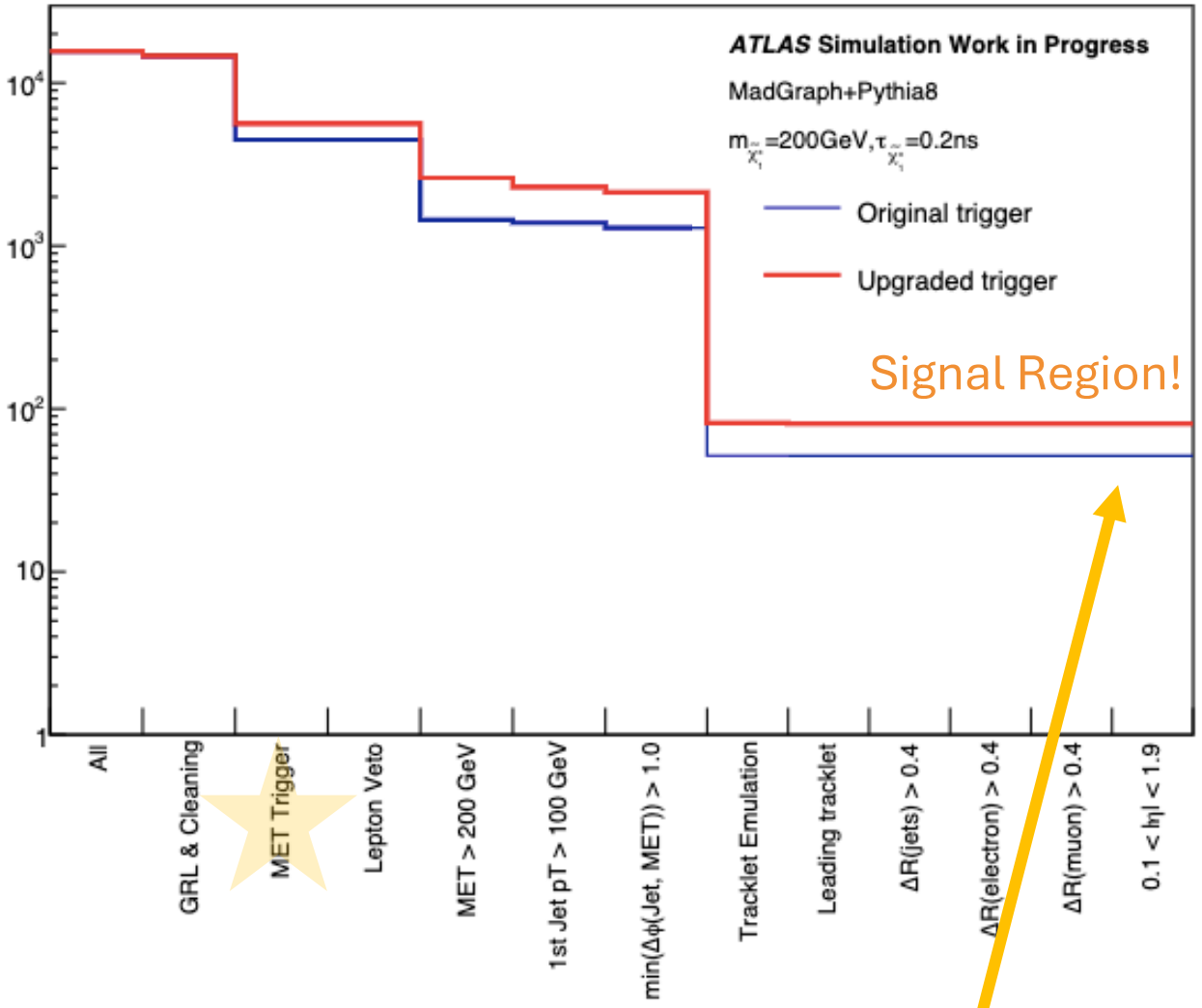


Result - Apply disappearing track trigger

- Replace efficiency curve



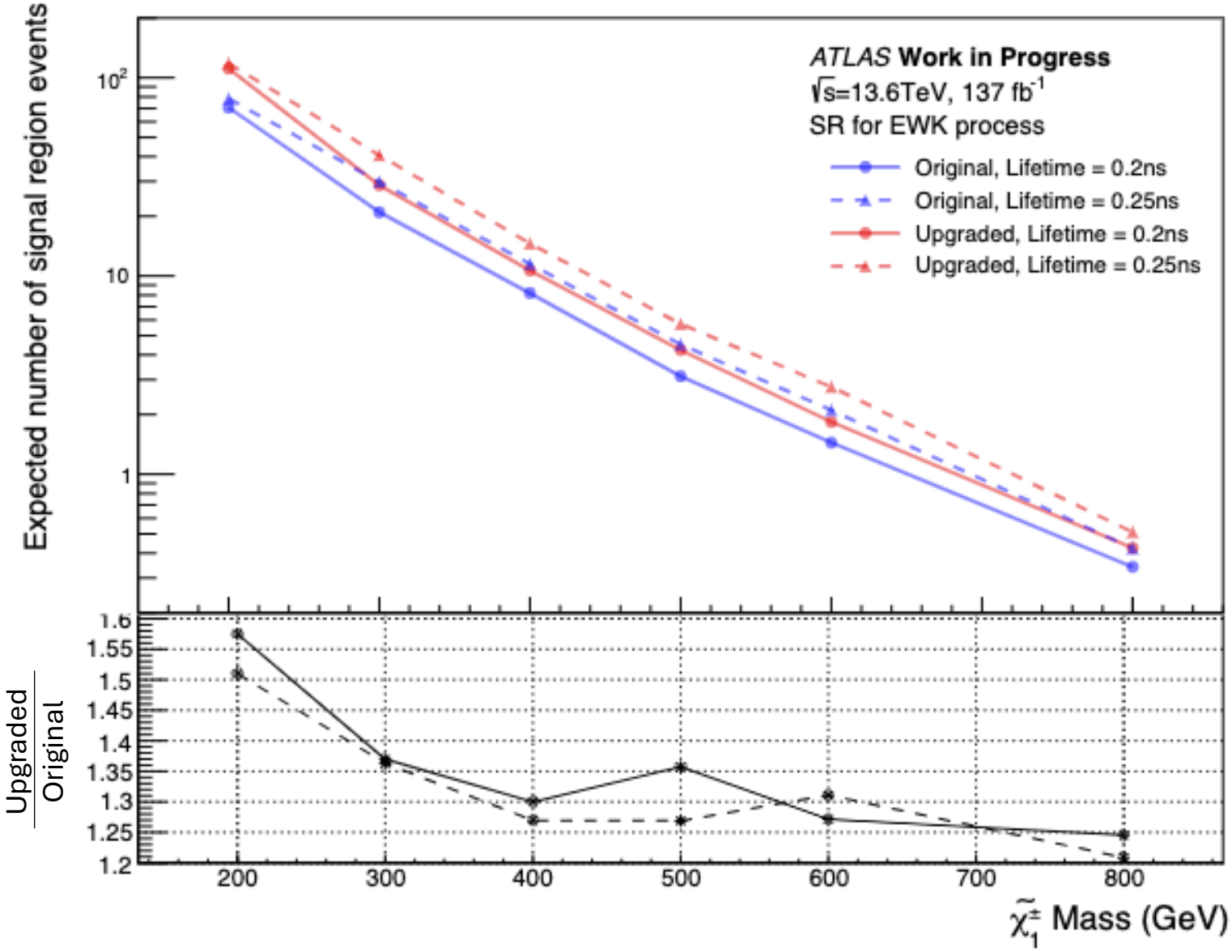
Increase in candidate events!



Increase in signal region events!

Result - Apply disappearing track trigger

Number of Signal Region events for differing chargino mass



After Upgraded trigger, SR events:

- ~1.35 times increase
- Less increase for higher mass

Summary

Motivation

Search for dark matter candidate predicted by SUSY

Method

Implement disappearing track trigger (BDT)
-Lower momentum threshold for MET
-Increase acceptence of signals

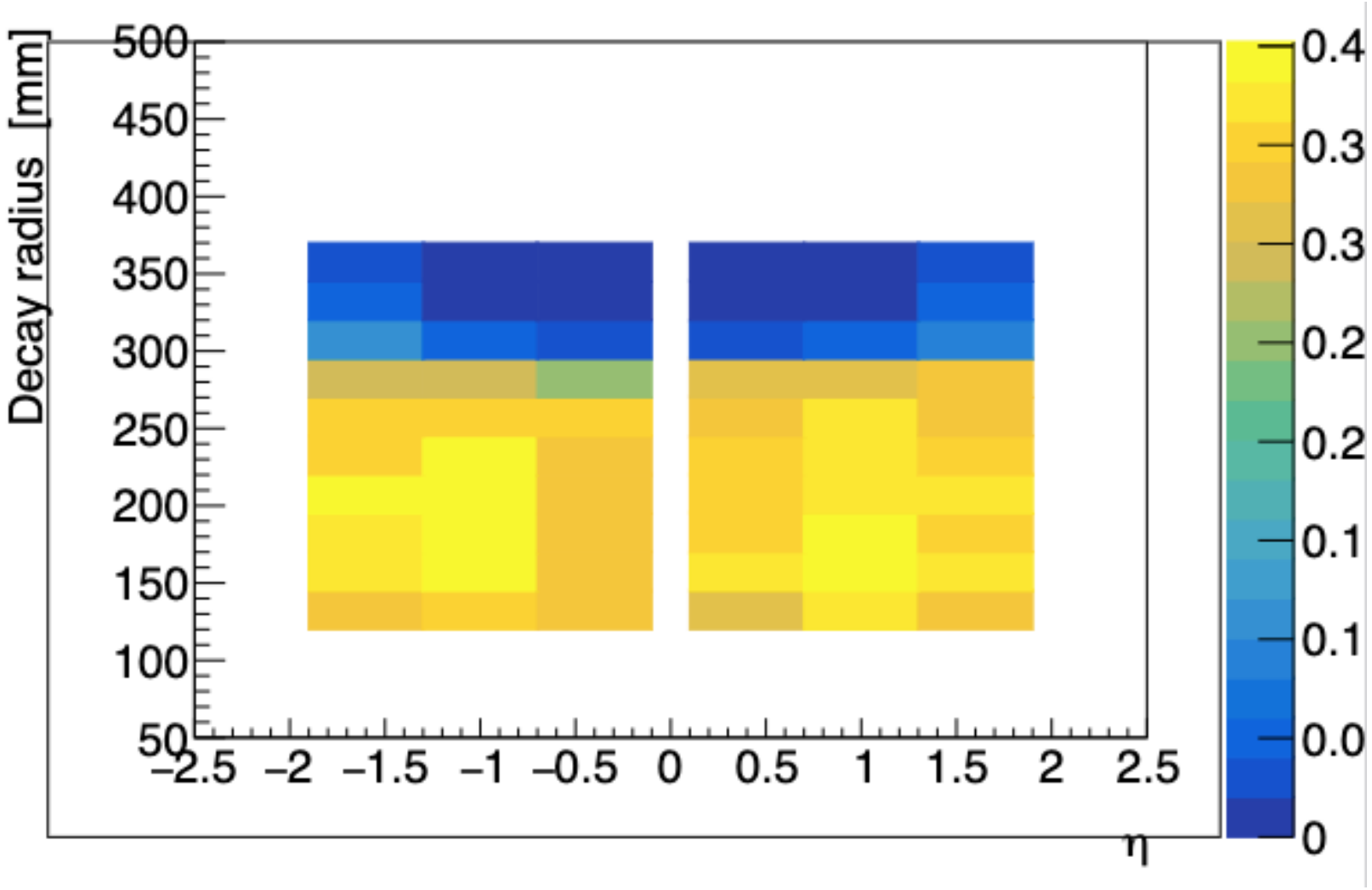
Results

- Signal region improved ~ 35%

Further improvments

Thank you for your attention

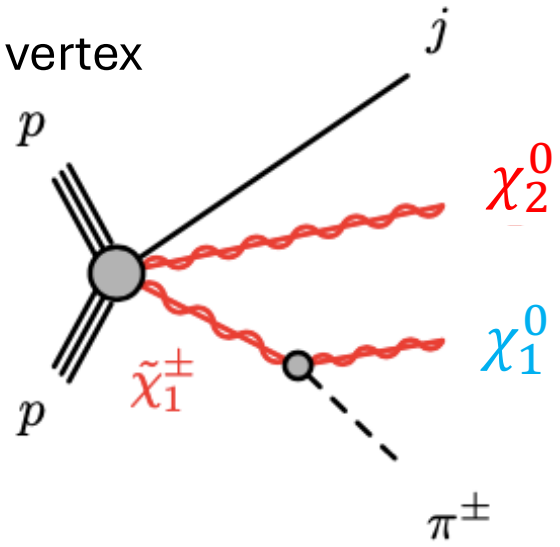
Track Emulation



Decay radius

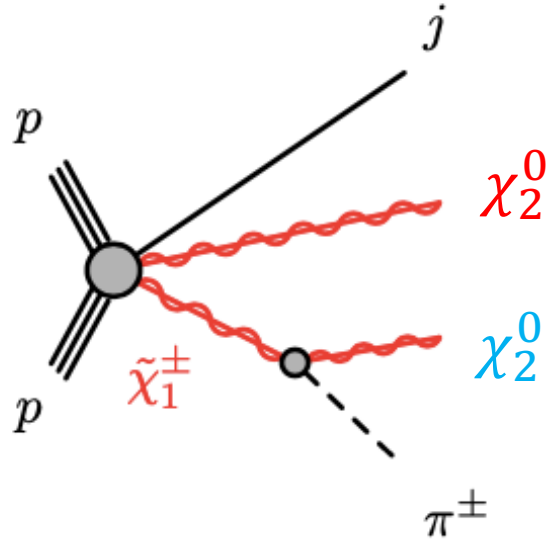
Set production vertex of χ_1^0, χ_2^0 as decay vertex

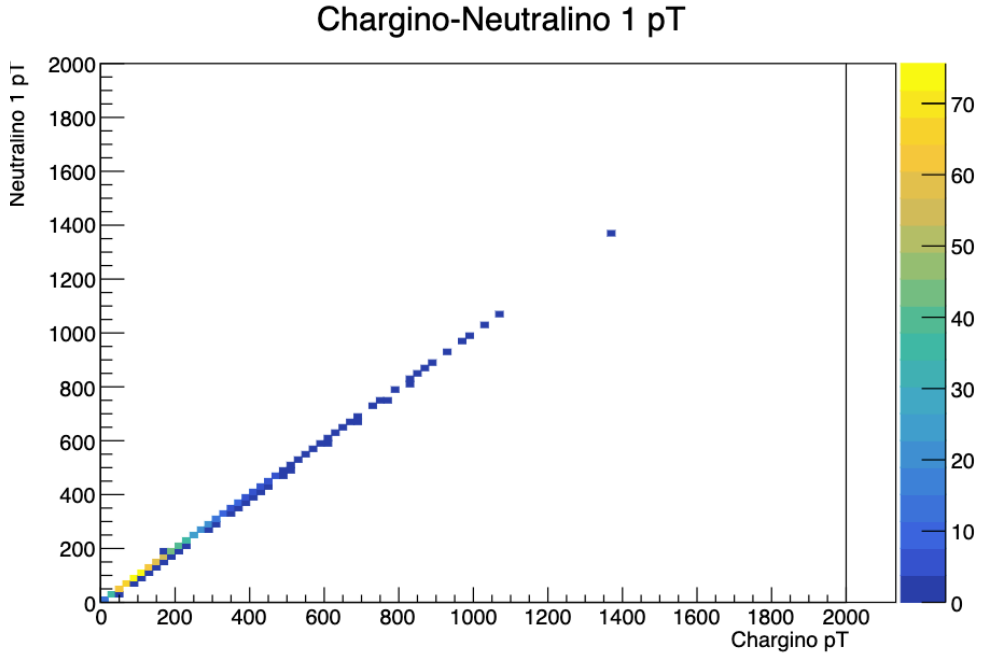
$$p_T^{\chi_1^0} = p_T^{\chi_1^\pm}$$

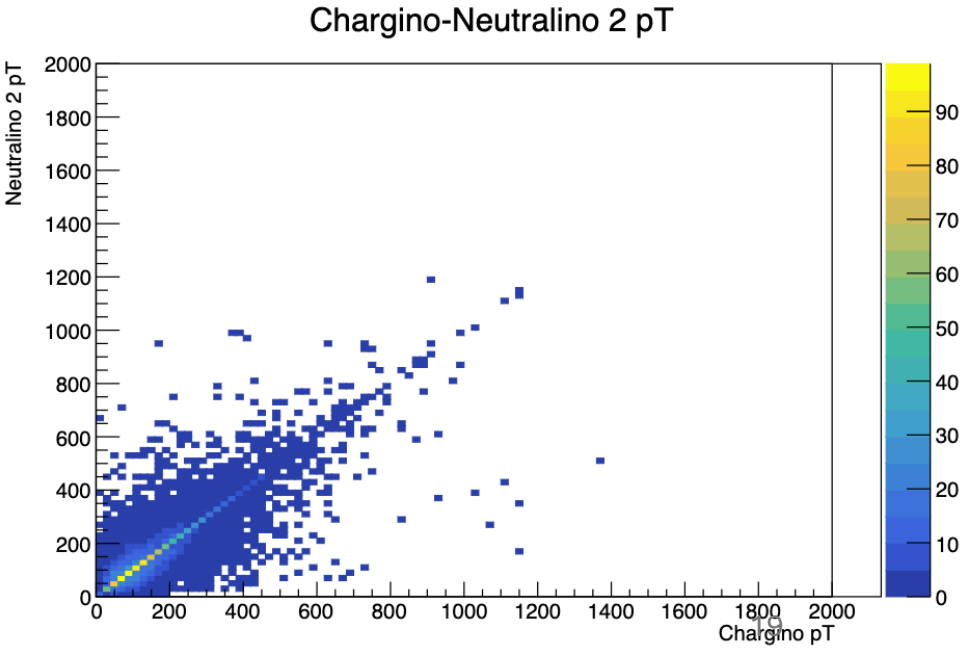


Chargino decay 50%

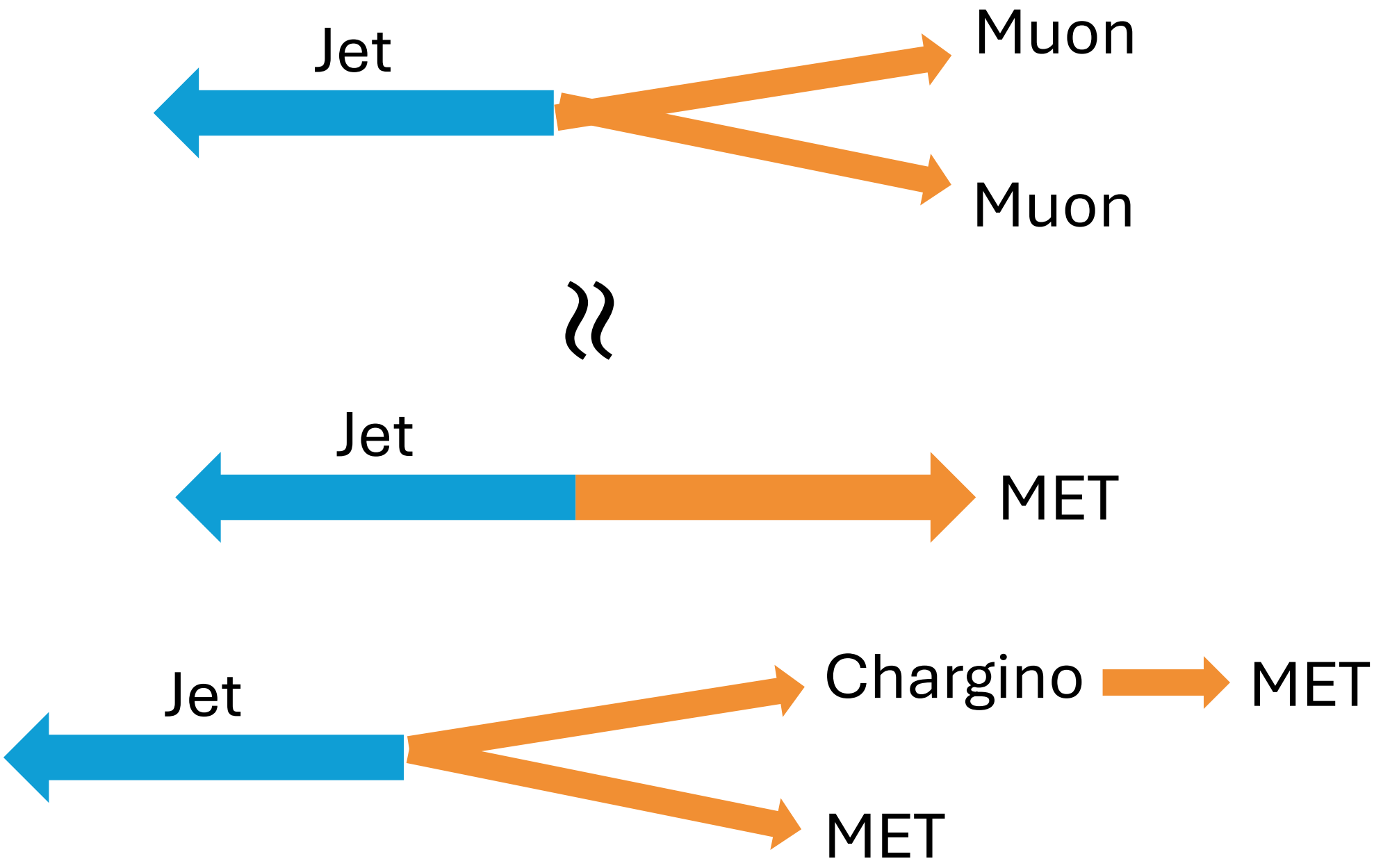
χ_2^0 not the only one



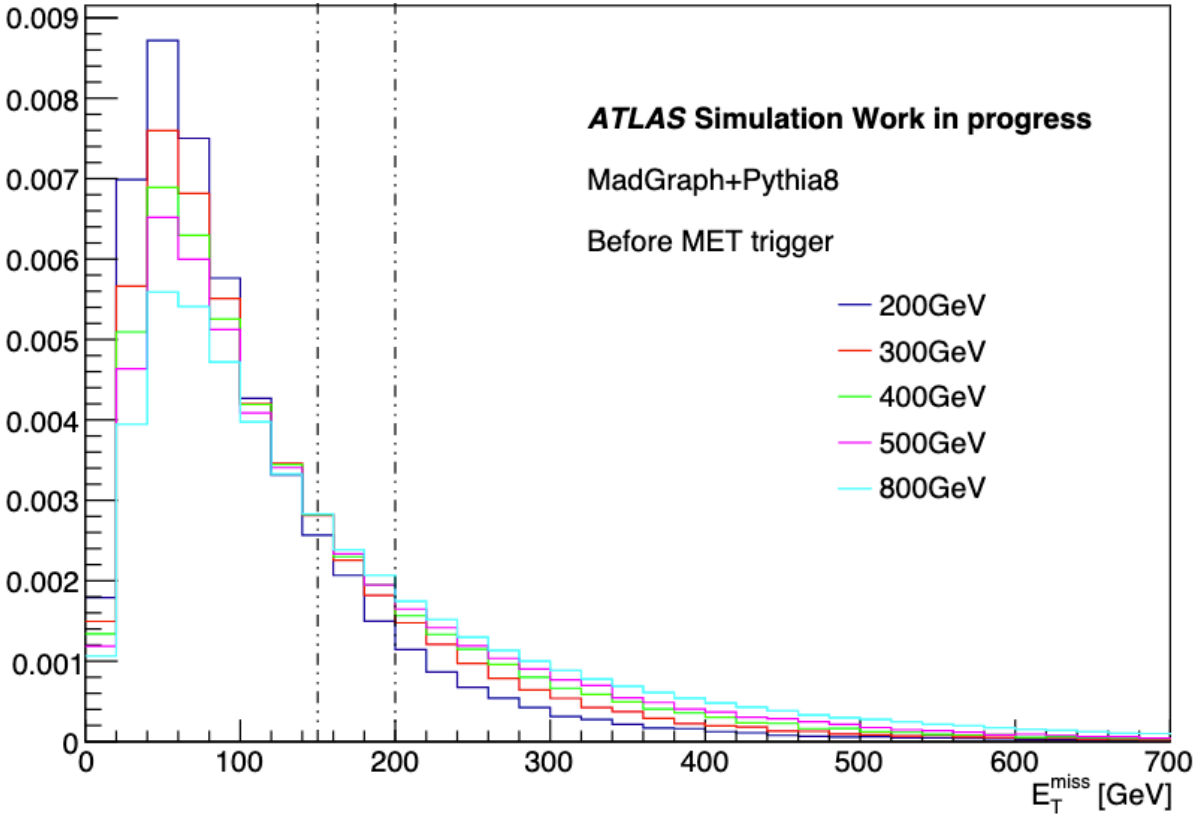


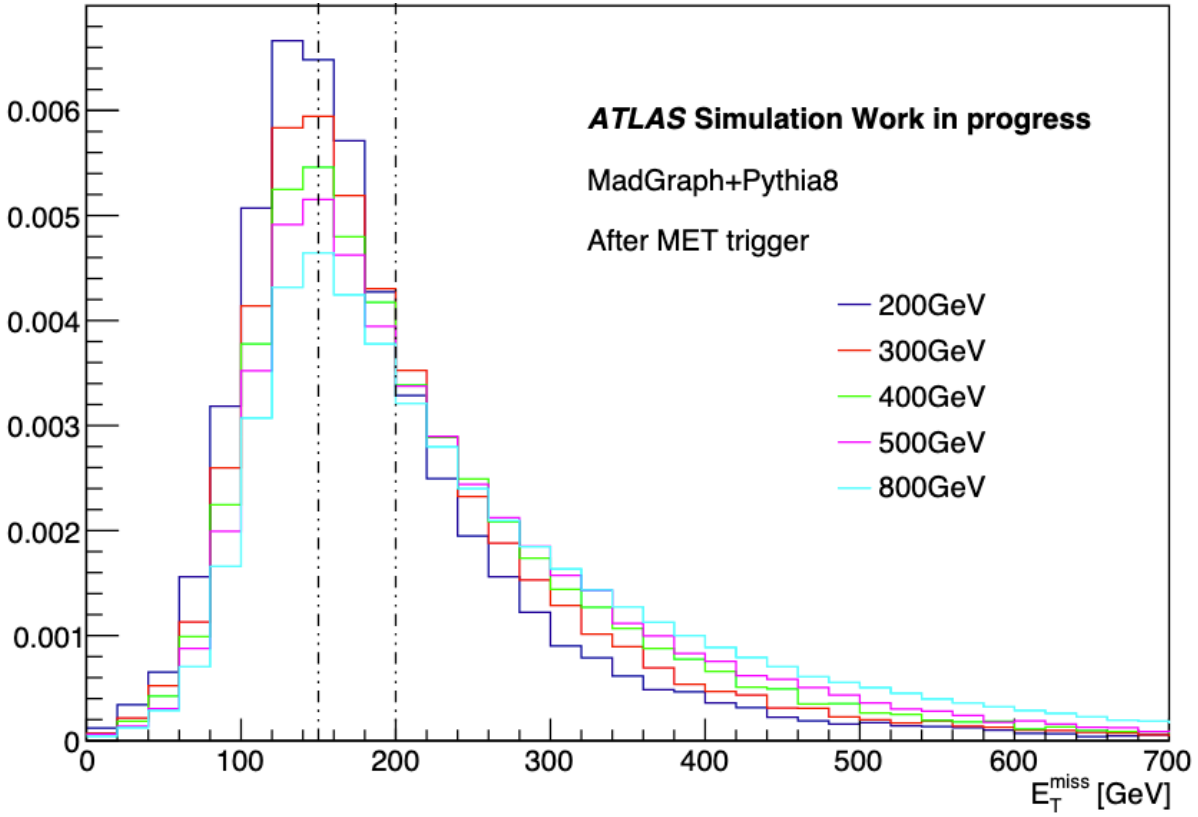


Diagram

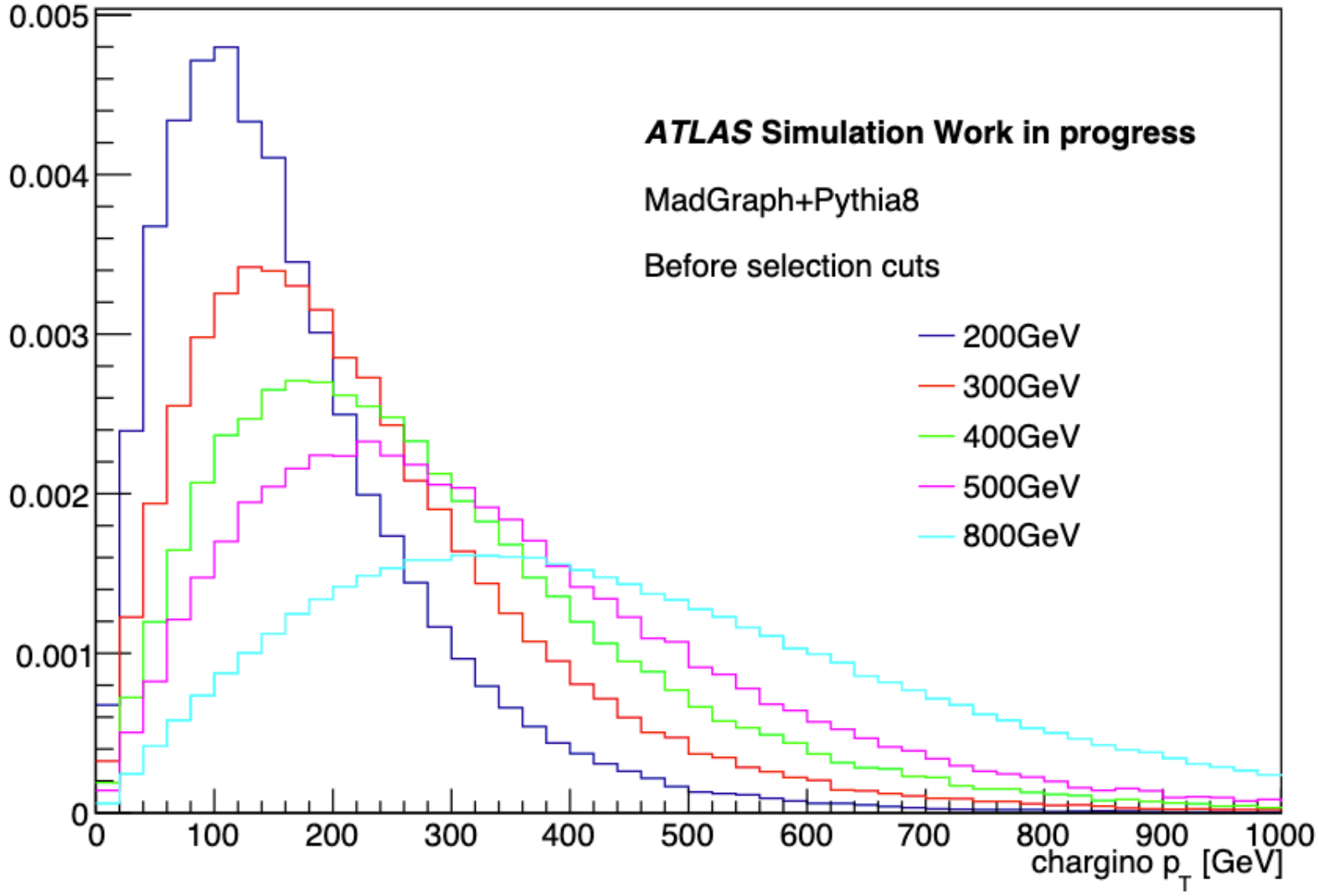


MET in different chargino masses

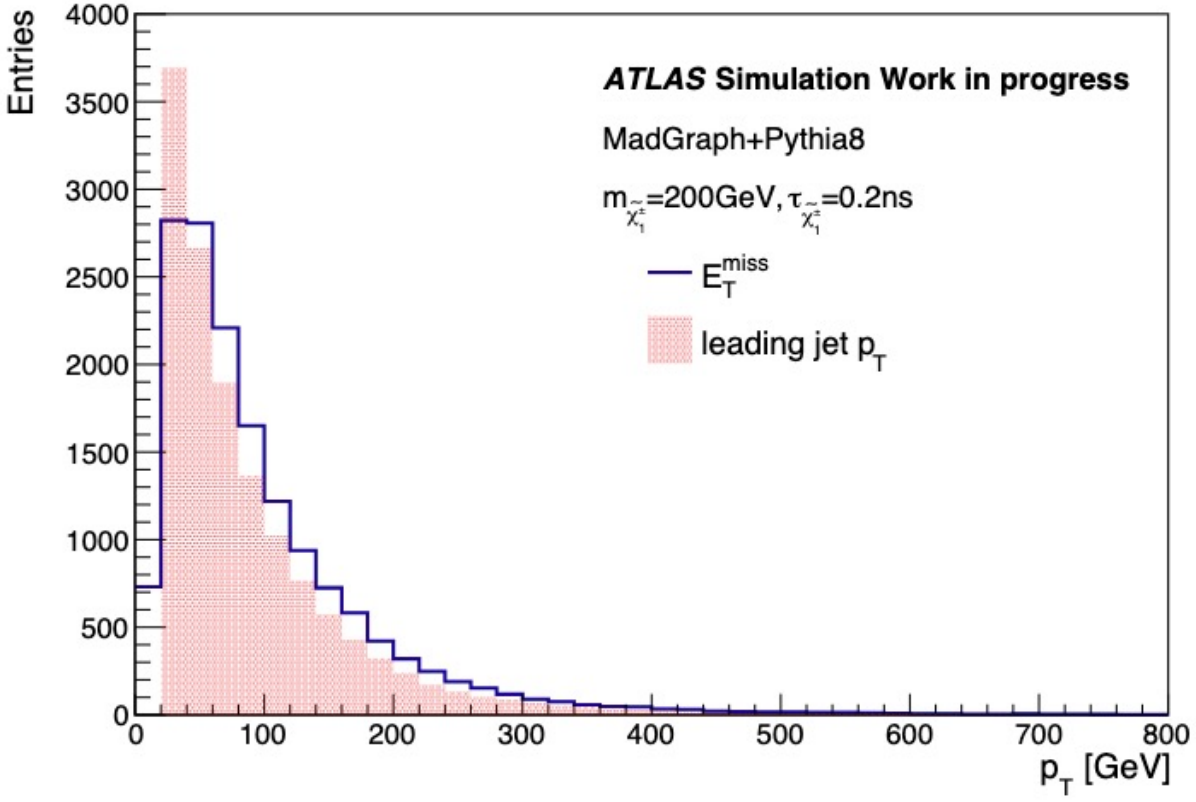


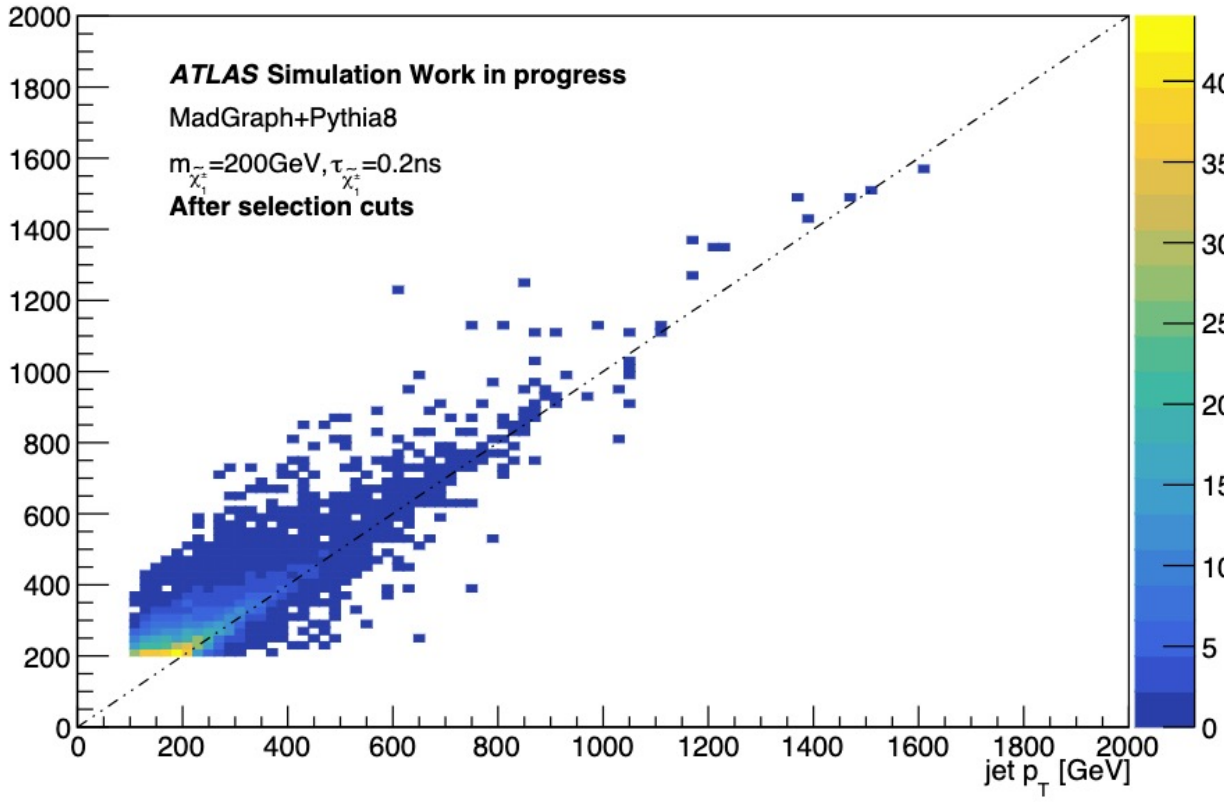


Chargino p_T in different chargino masses



Kinematic distribution of MET and leading jet





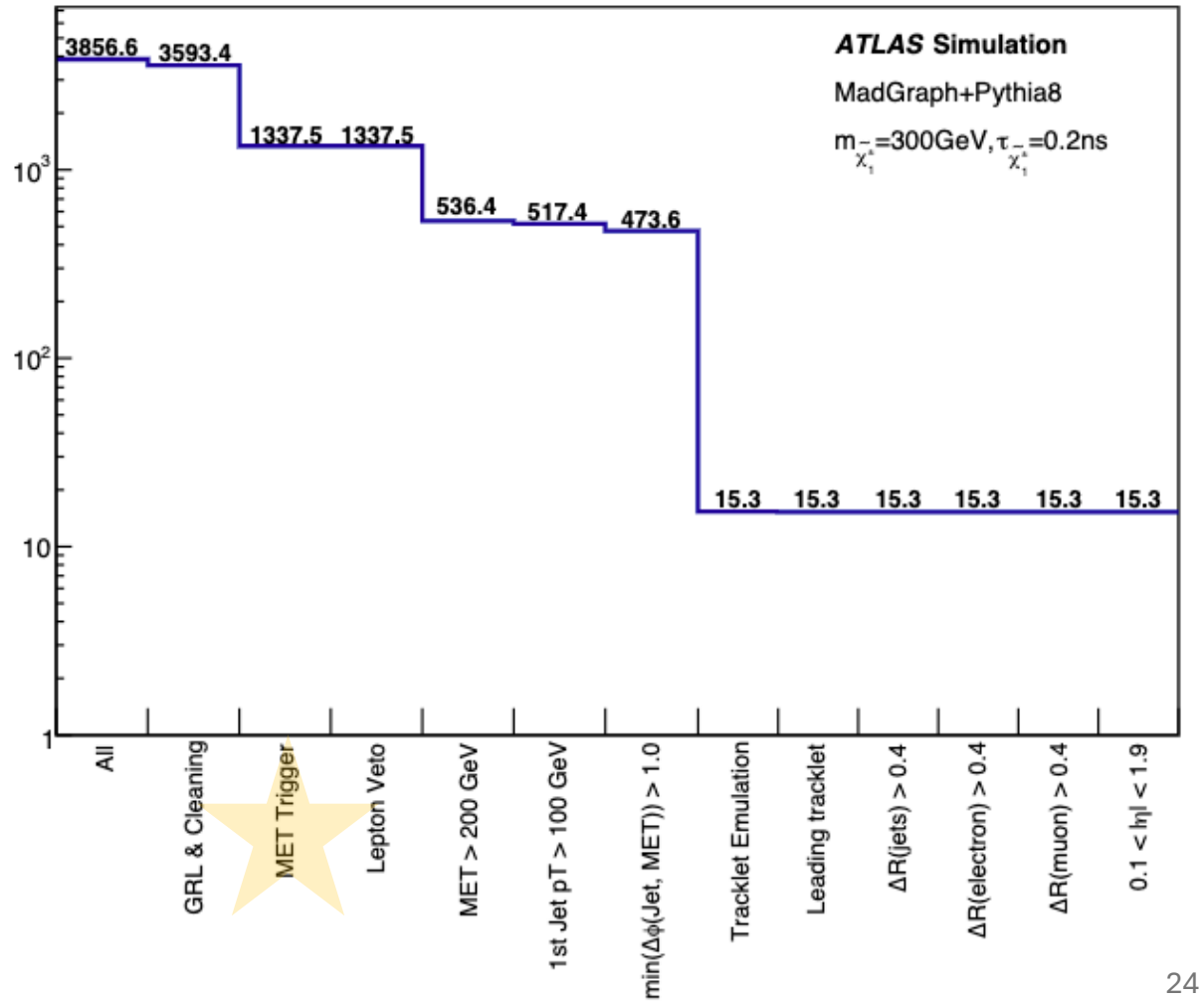
Data Analysis

Analysis of generated data → Get Signals that we are interested in!

SimpleAnalysis

- online + offline

1) Overlap removal
2) Smear pT
3) Object reconstruction
4) Signal region selection



Expected number of events

- Number of events generated

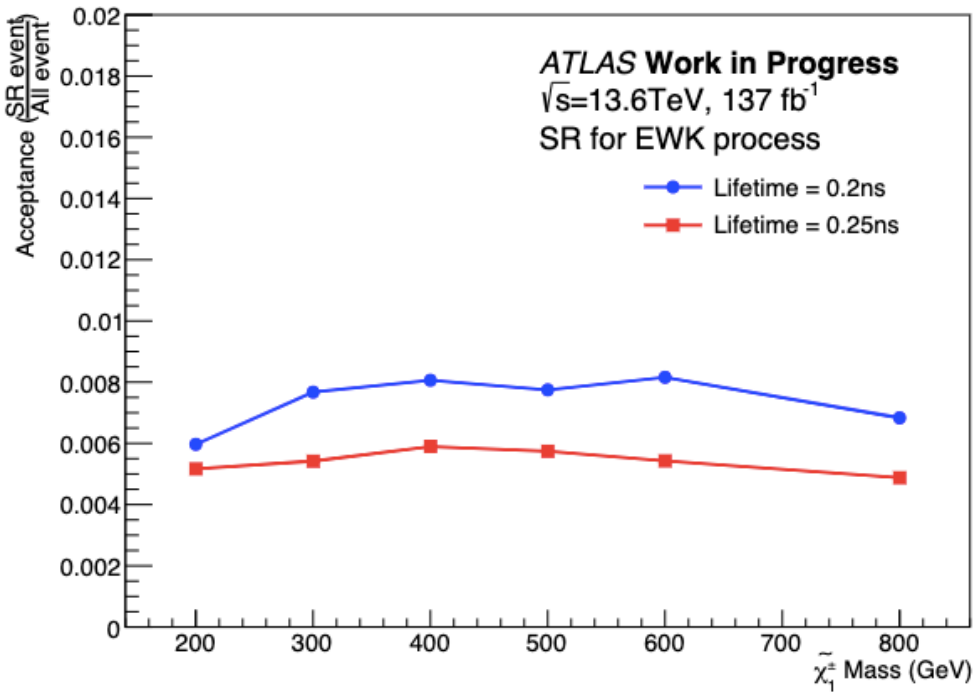
$$Cross\ section \times integrated\ luminosity = expected\ number\ of\ events$$

Where, $integrated\ luminosity = 137 fb^{-1}$

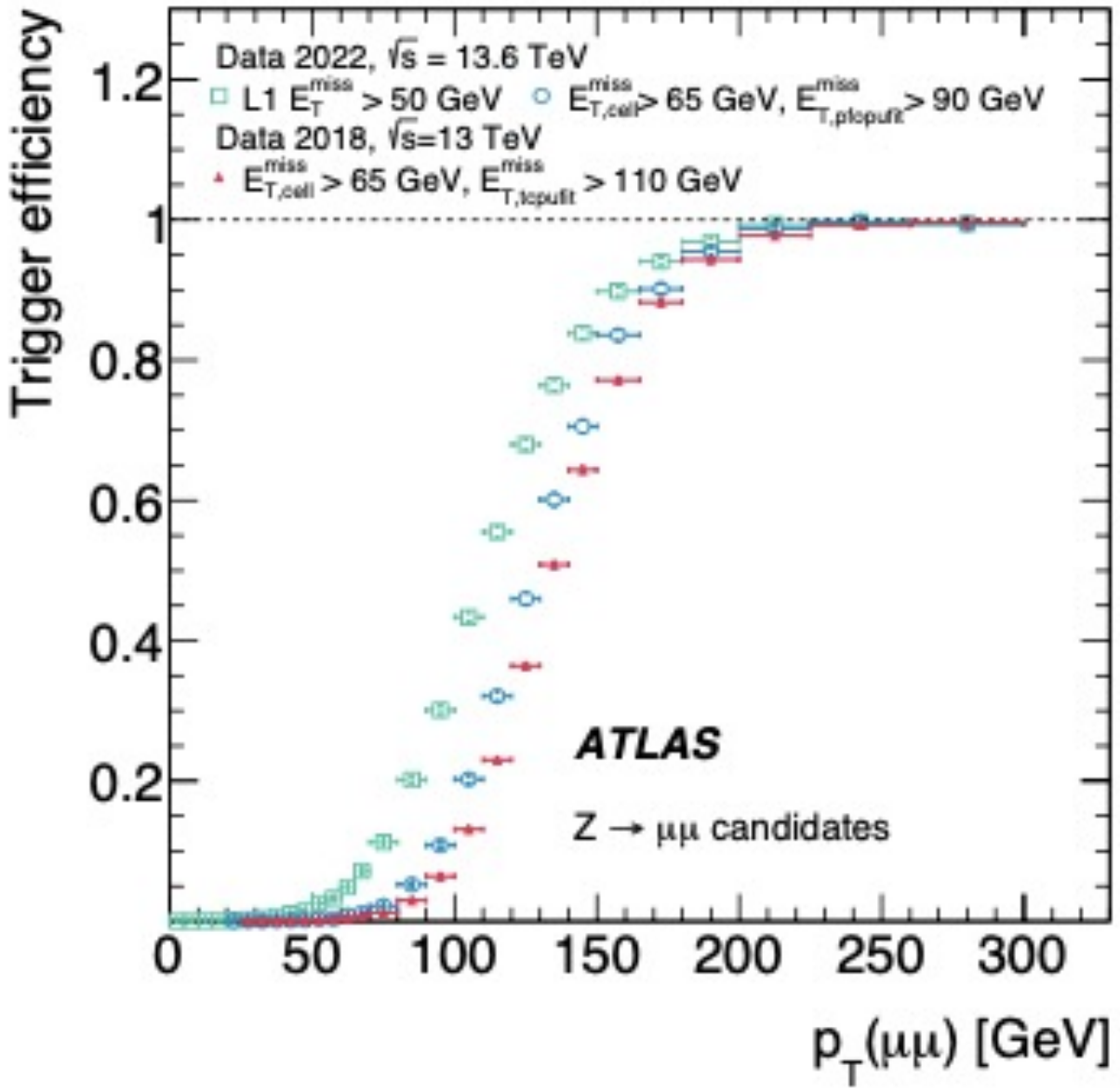
- Binning

Rescaled to: $Cross\ section \times \#Event\ generated$

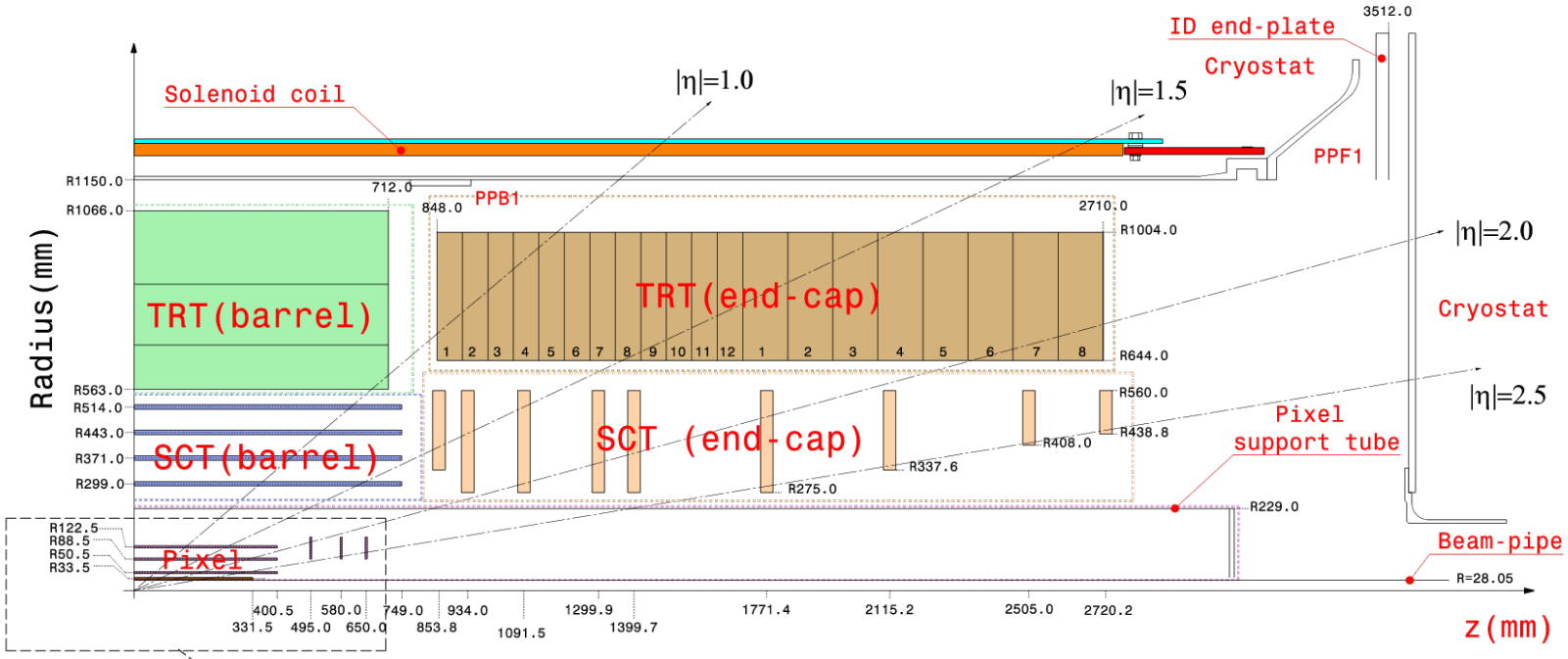
Acceptance times Efficiency

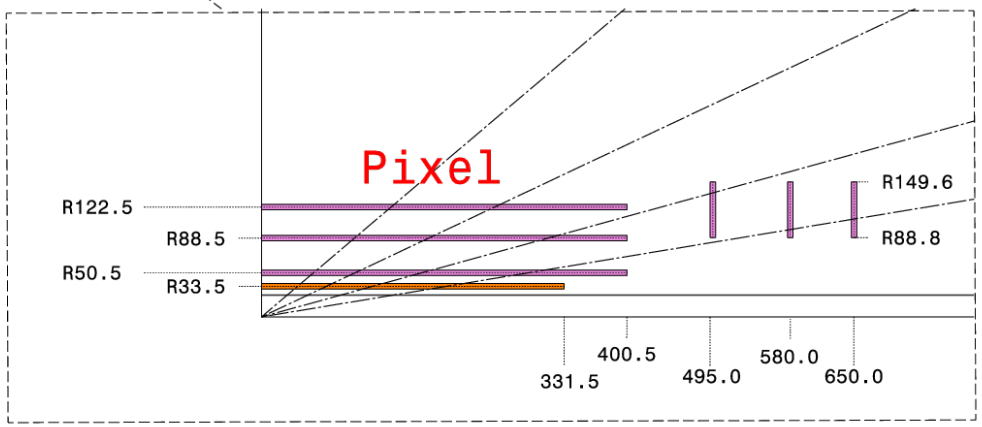


How HLT was improved



ATLAS Detector





Envelopes

Pixel		31<R<242 (mm)
SCT barrel		255<R<549 (mm)
SCT end-cap		251<R<610 (mm)
TRT barrel		554<R<1082 (mm)
TRT end-cap		617<R<1106 (mm)

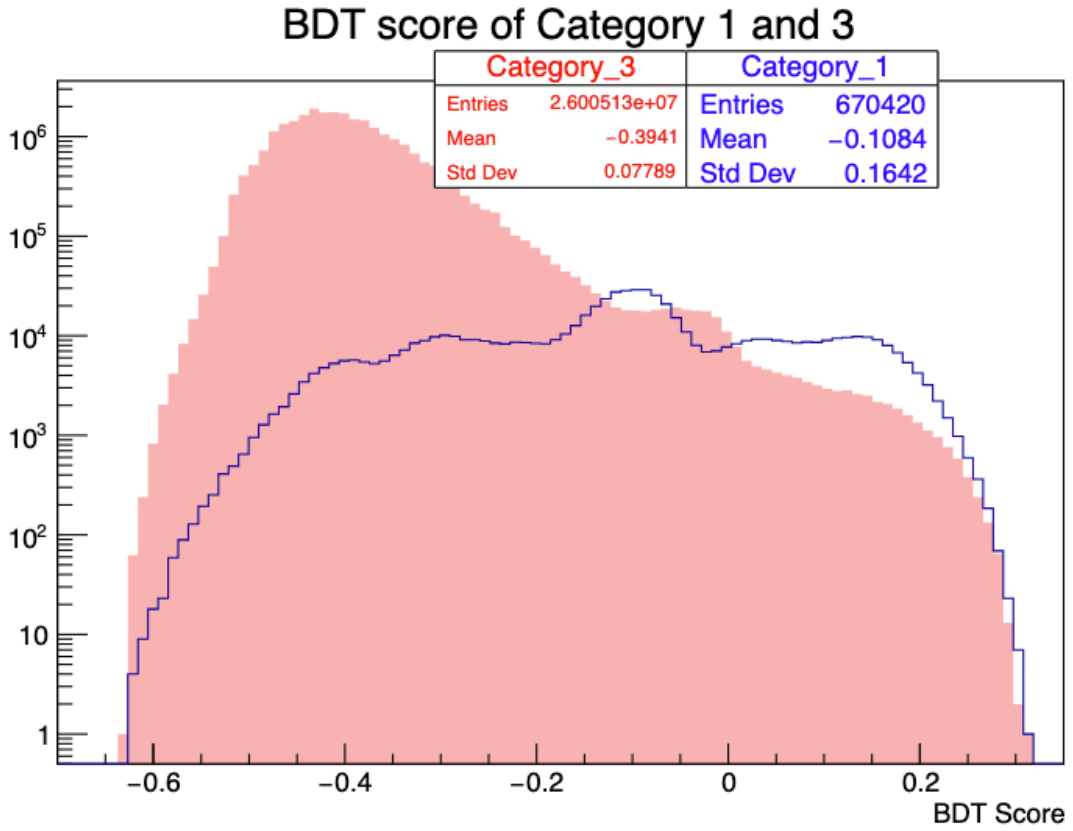
BDT Variables

category	number of pixel hits	number of sct hits
pix4lsct0	4	0
pix4lsct1+	4	> 0
pix3lsct0	3	0
pix3lsct1+	3	> 0

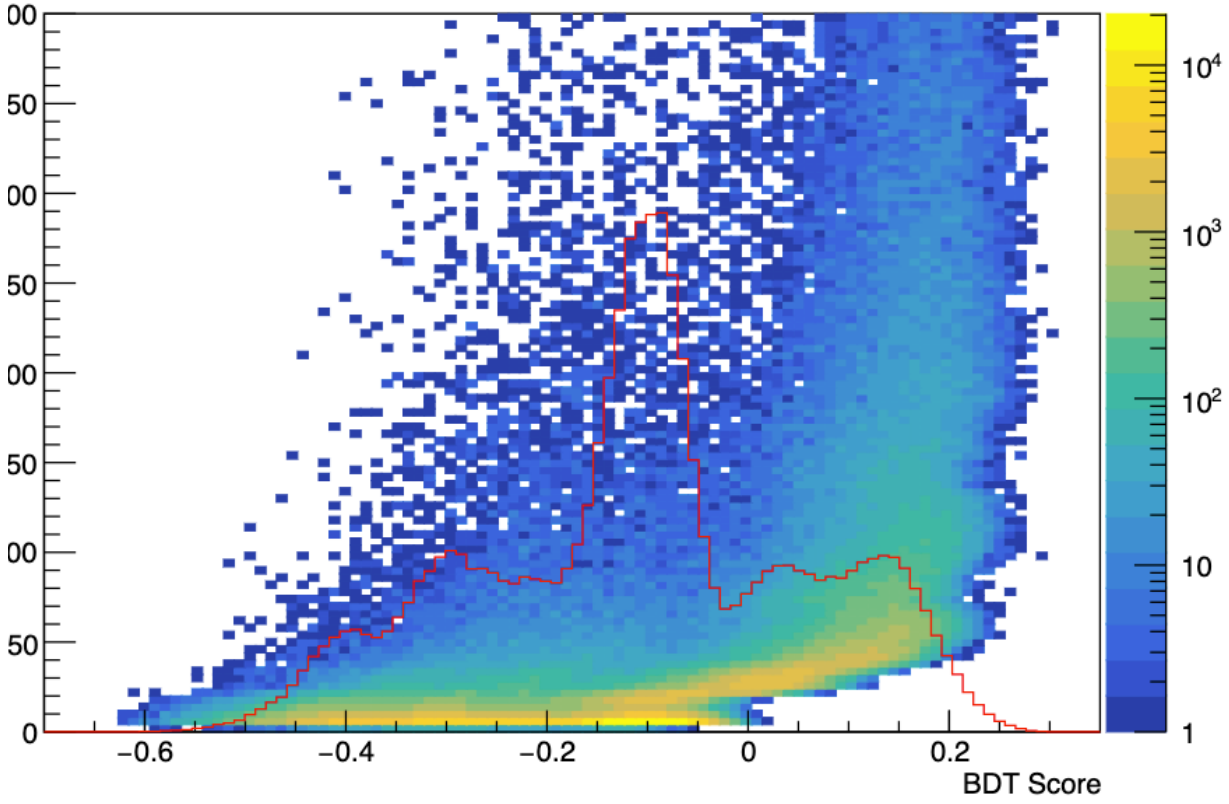
BDT variables	pix4lsct0	pix4lsct1+	pix3lsct0	pix3lsct1+
p_T	○	○	○	○
$\|z_0\|$	○		○	○
$\|d_0\|$	○		○	○
χ^2/ndof	○		○	○
χ^2/ndof pix	○	○	○	
p_T(refit w/o SCT)	○	○	○	○
$\|z_0\|$(refit w/o SCT)		○	○	○
$\|d_0\|$(refit w/o SCT)		○	○	○
χ^2/ndof(refit w/o SCT)				○
refit p_T/p_T	○	○		○
refit $(\chi^2/\text{ndof})/(\chi^2/\text{ndof})$	○	○		
Nr of Pixel hits	○	○	○	○
Nr of SCT hits		○		○
Nr of Barrel hits	○		○	○
Isolation($\Delta R < 0.1$)	○	○	○	○
Isolation($0.1 < \Delta R < 0.2$)	○	○	○	○
Fail or success(Combinatorial tracking)		○		○
Nr of BDT variables	12	12	12	15

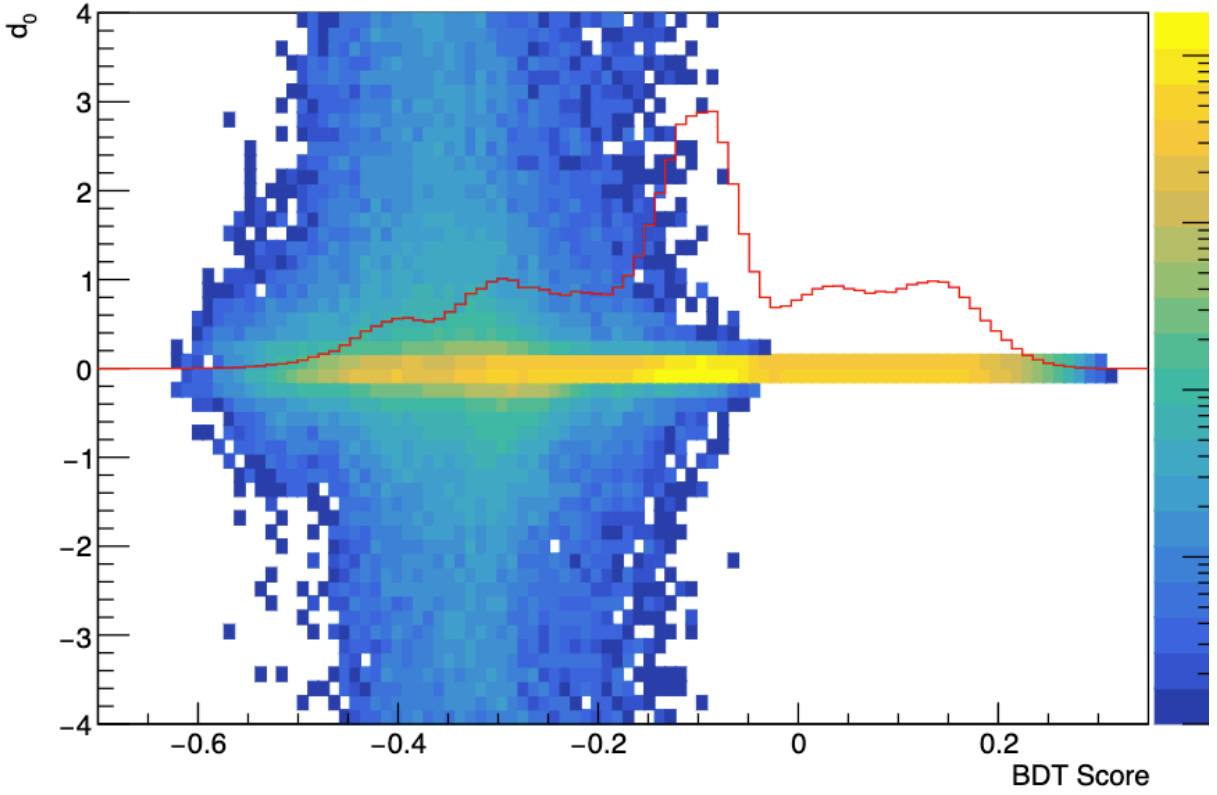
BDT distribution & cut

	Number of contributing pixel hits	BDT cut score
Category 1	4-layer tracklet	-0.1
Category 3	3-layer tracklet	0.04

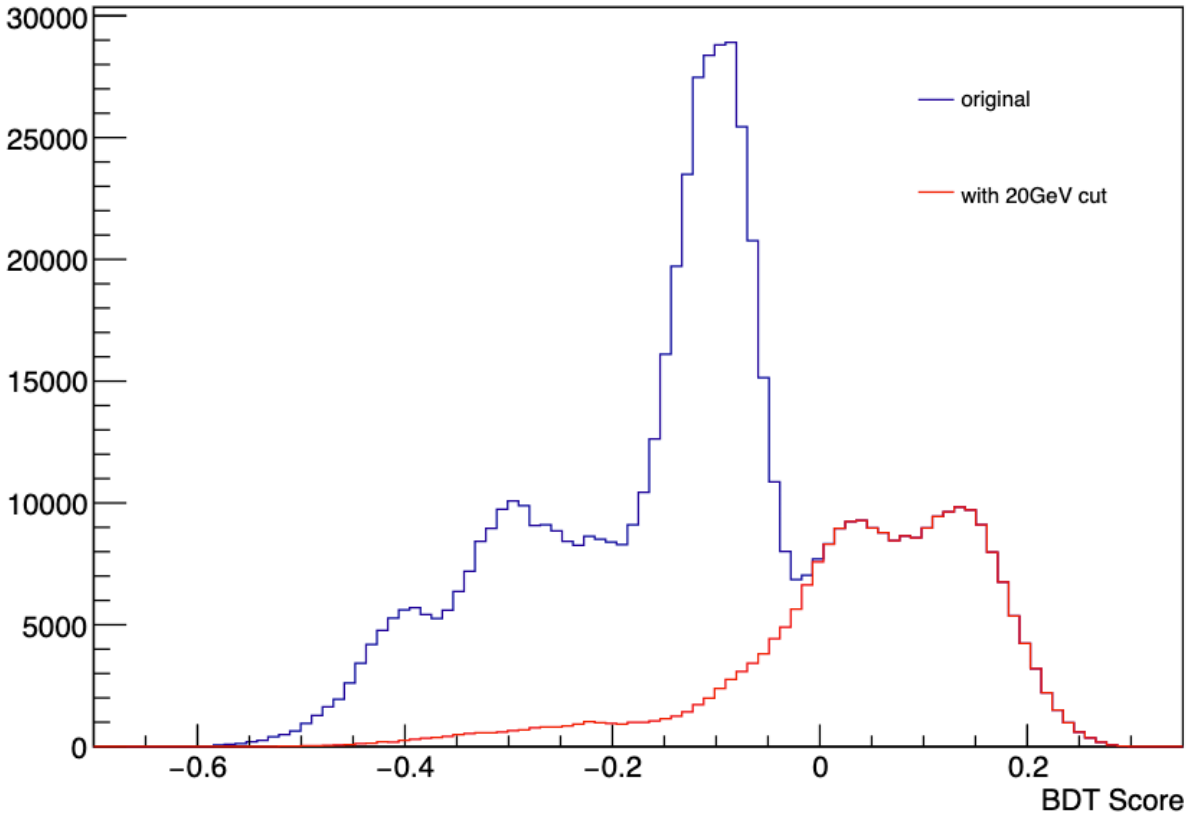


BDT distribution

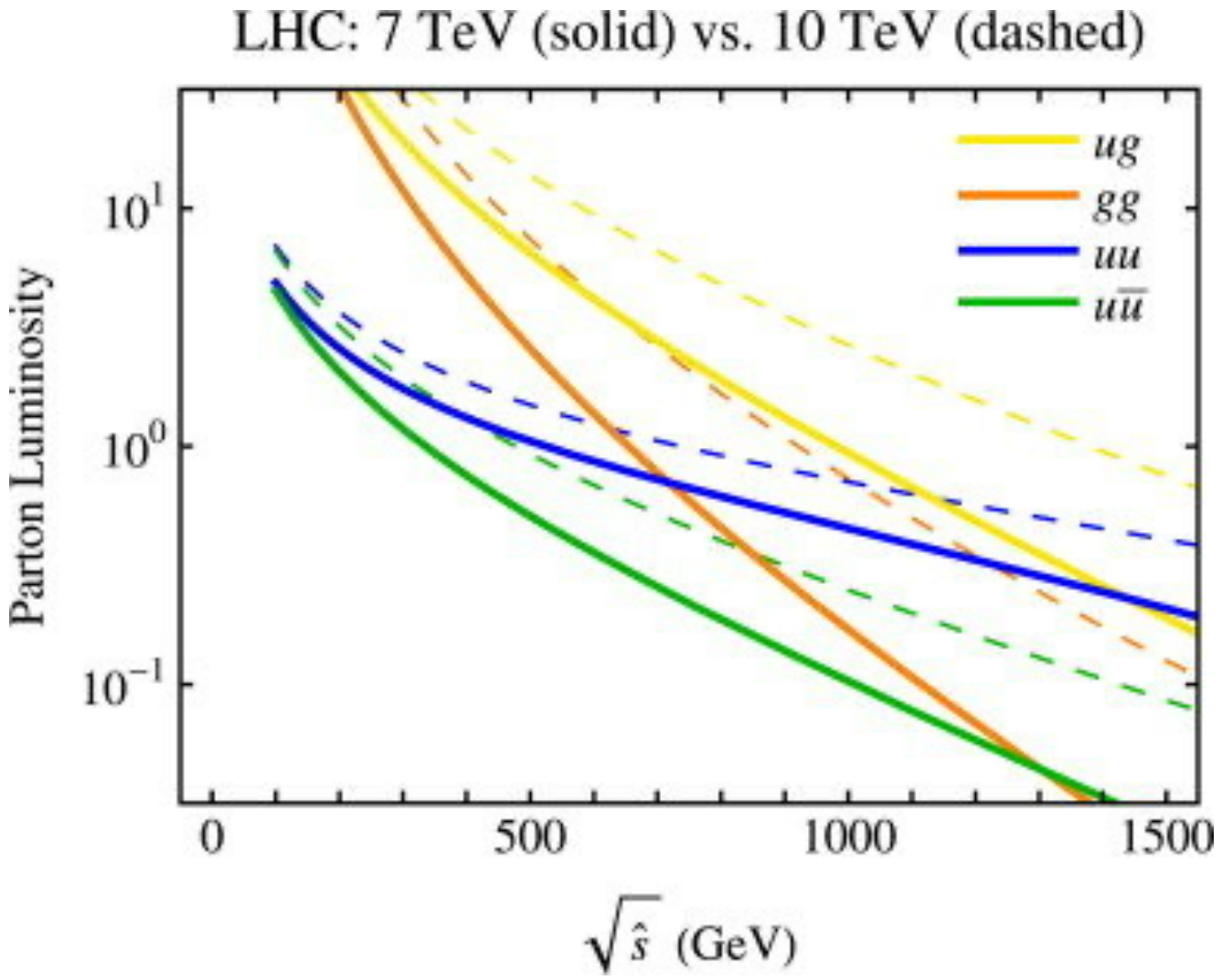




Renewed BDT distribution

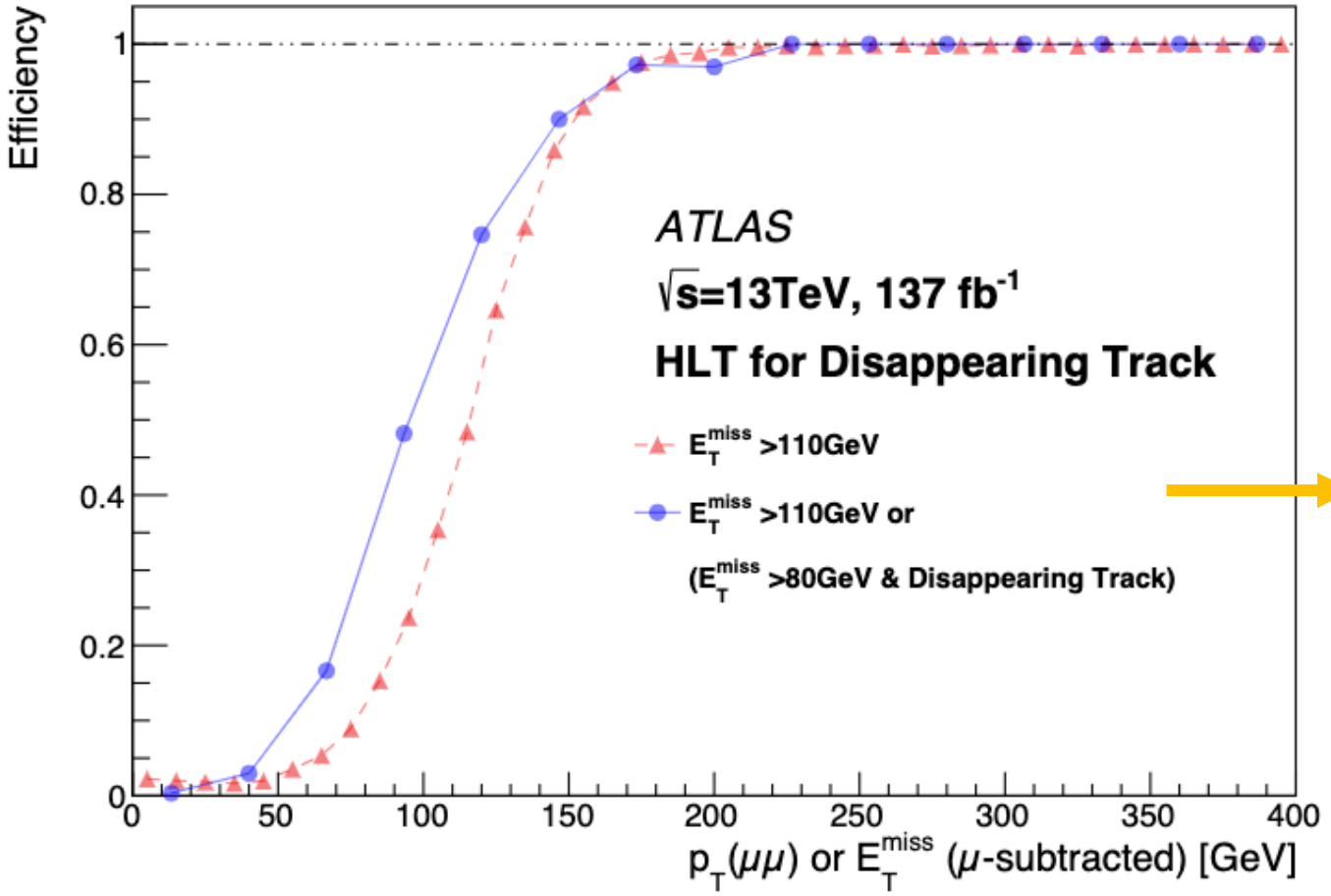


Parton Luminosity



Efficiency of new trigger

$$Efficiency = \frac{\#\ Events\ passed\ ('CUT' + BDT\ score)}{\#\ Events\ passed\ 'CUT'}$$



Original (L1+HLT)

New (Loosned HLT + BDT algorithm)