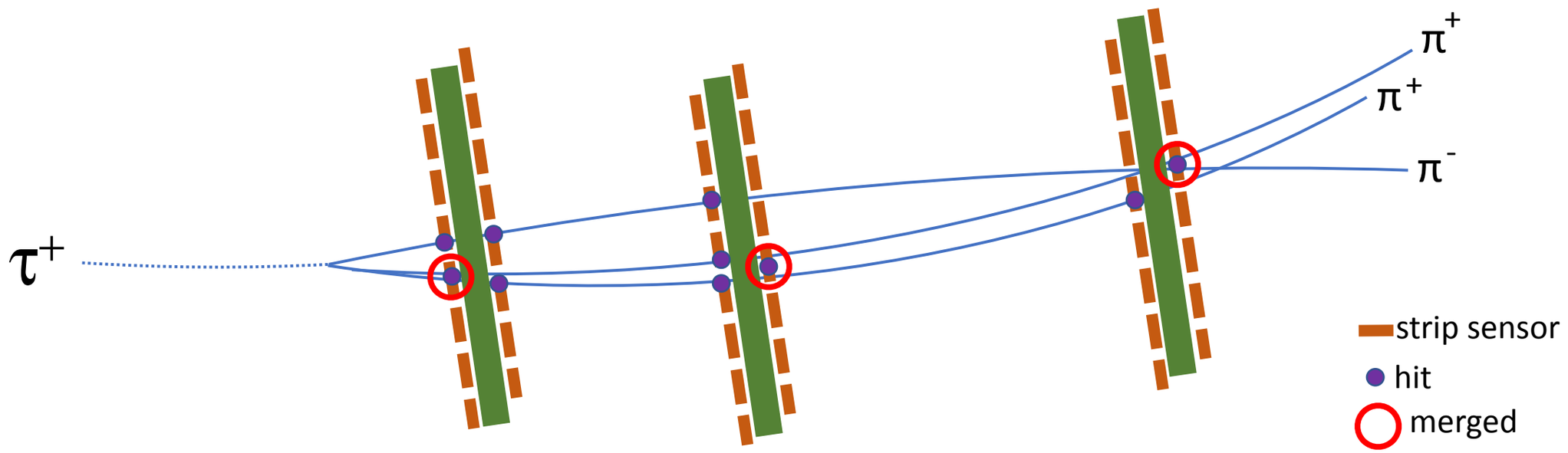
Splitting Strip Detector Clusters in Dense Environments

BERKELEY LAB



Ben Nachman, Wm. Patrick McCormack, Maurice Garcia-Sciveres

LBNL/UC Berkeley

ATLAS EXPERIMENT

On behalf of the ATLAS Collaboration

March 21, 2018 Connecting the Dots

Image inspired from:
Journal of Physics:
Conference Series 119
(2008) 032014

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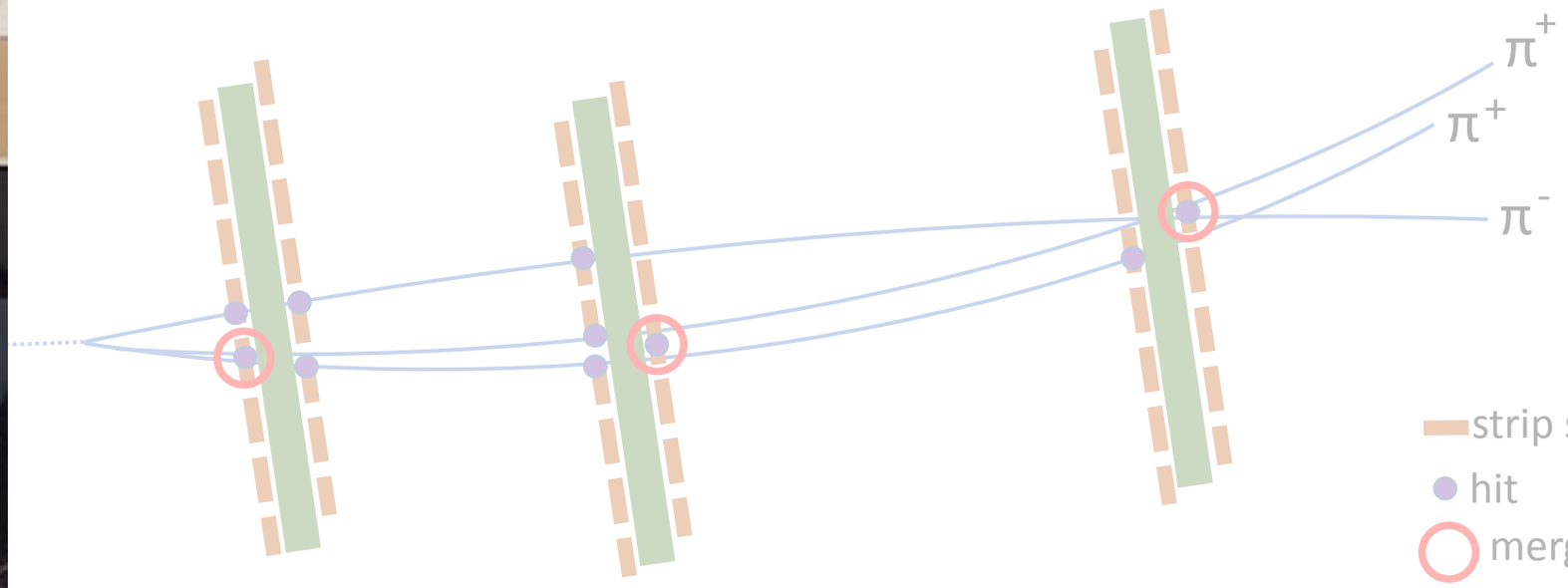

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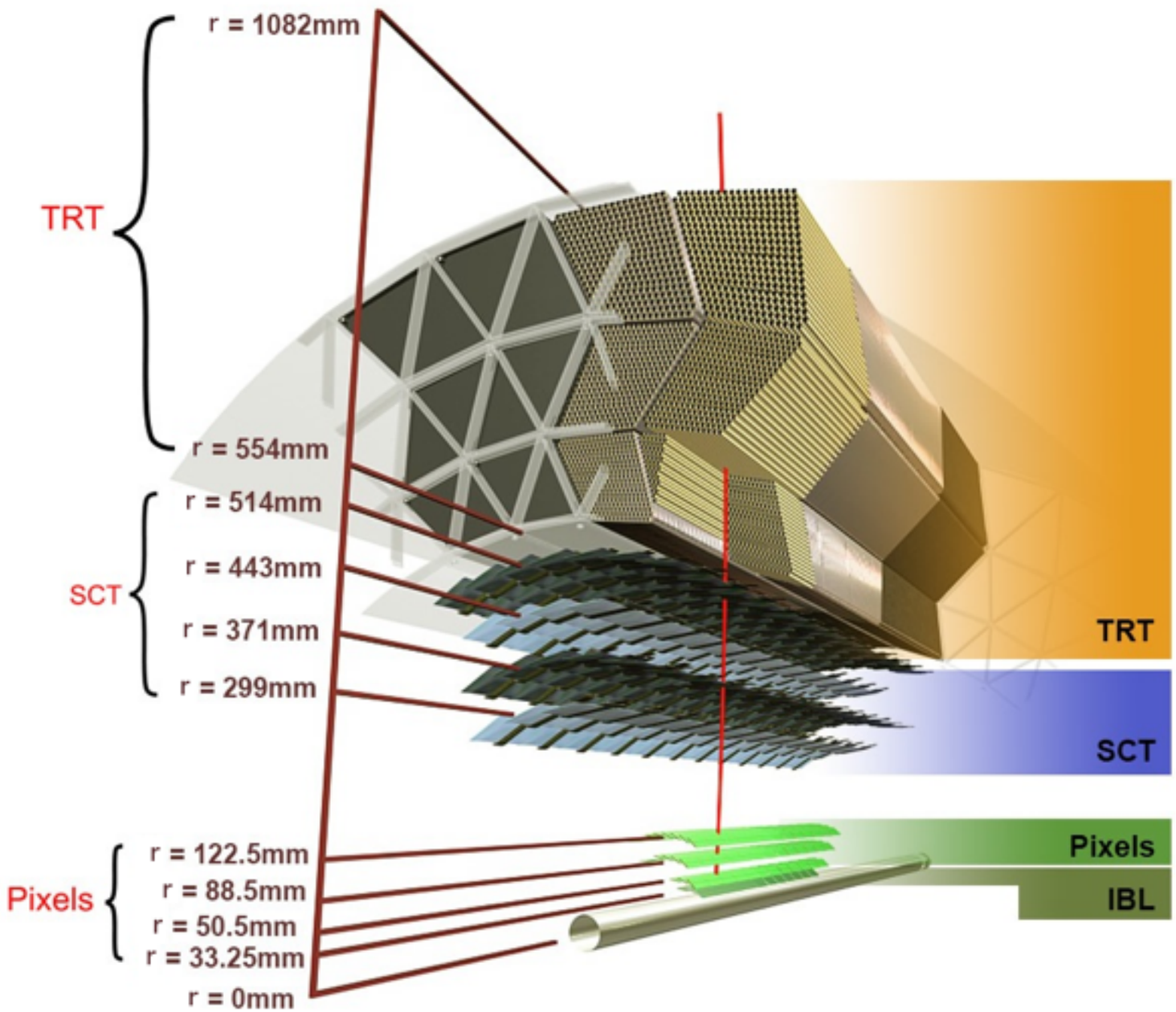
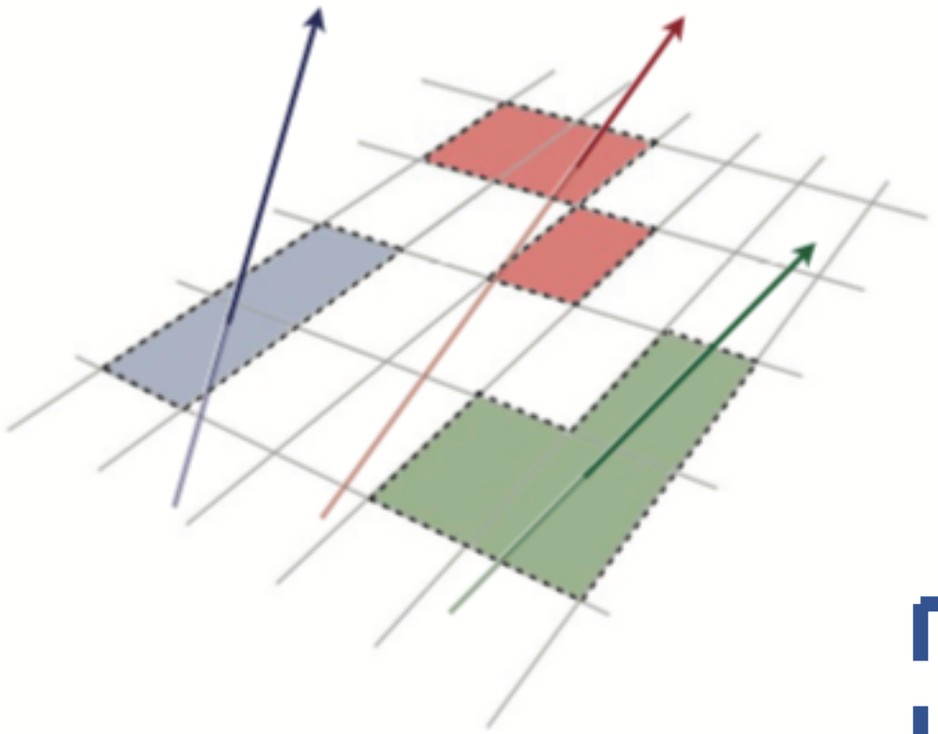
Tracking in ATLAS

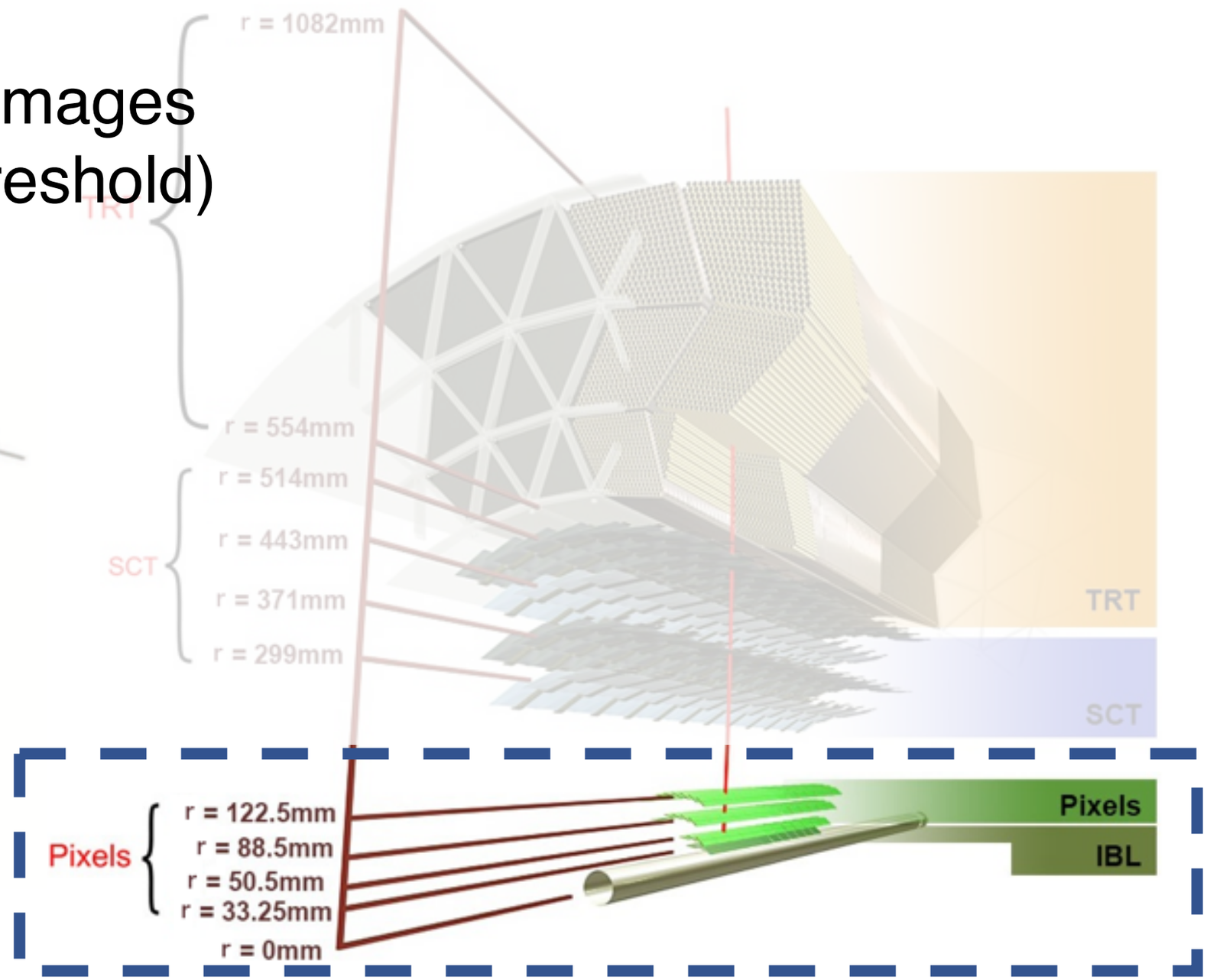
ATLAS Inner Detector



Tracking in ATLAS - Pixels

Clusters are gray-scale images
(intensity = time-over-threshold)

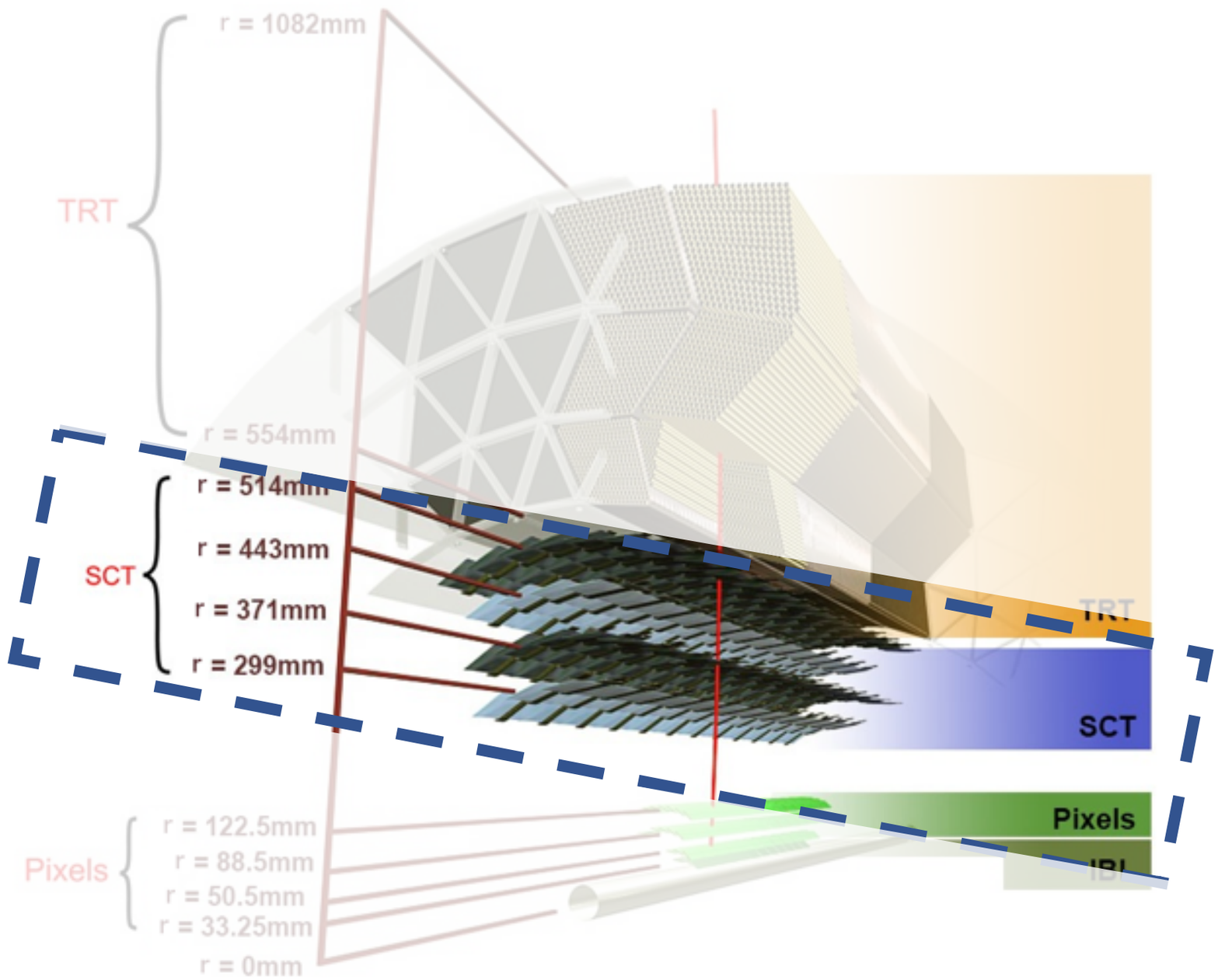




Tracking in ATLAS - Strips

Binary readout

No charge information



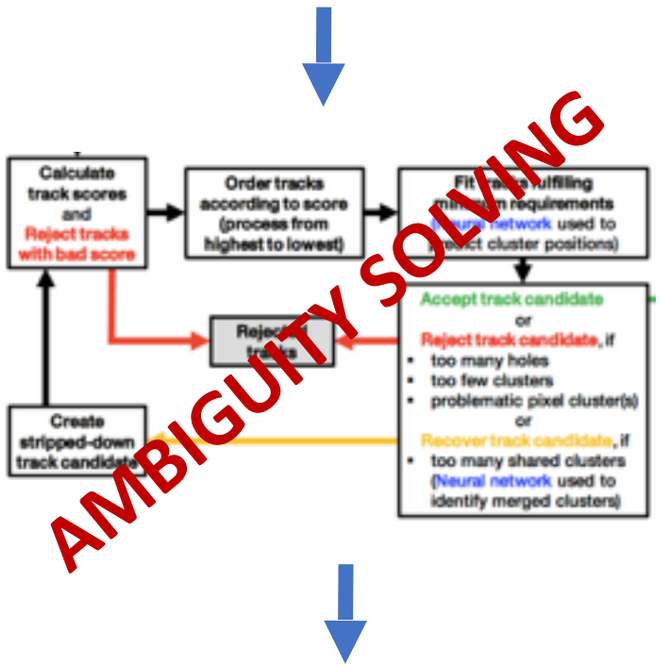
Strip dimensions – not to scale!

Tracking in ATLAS - Track finding

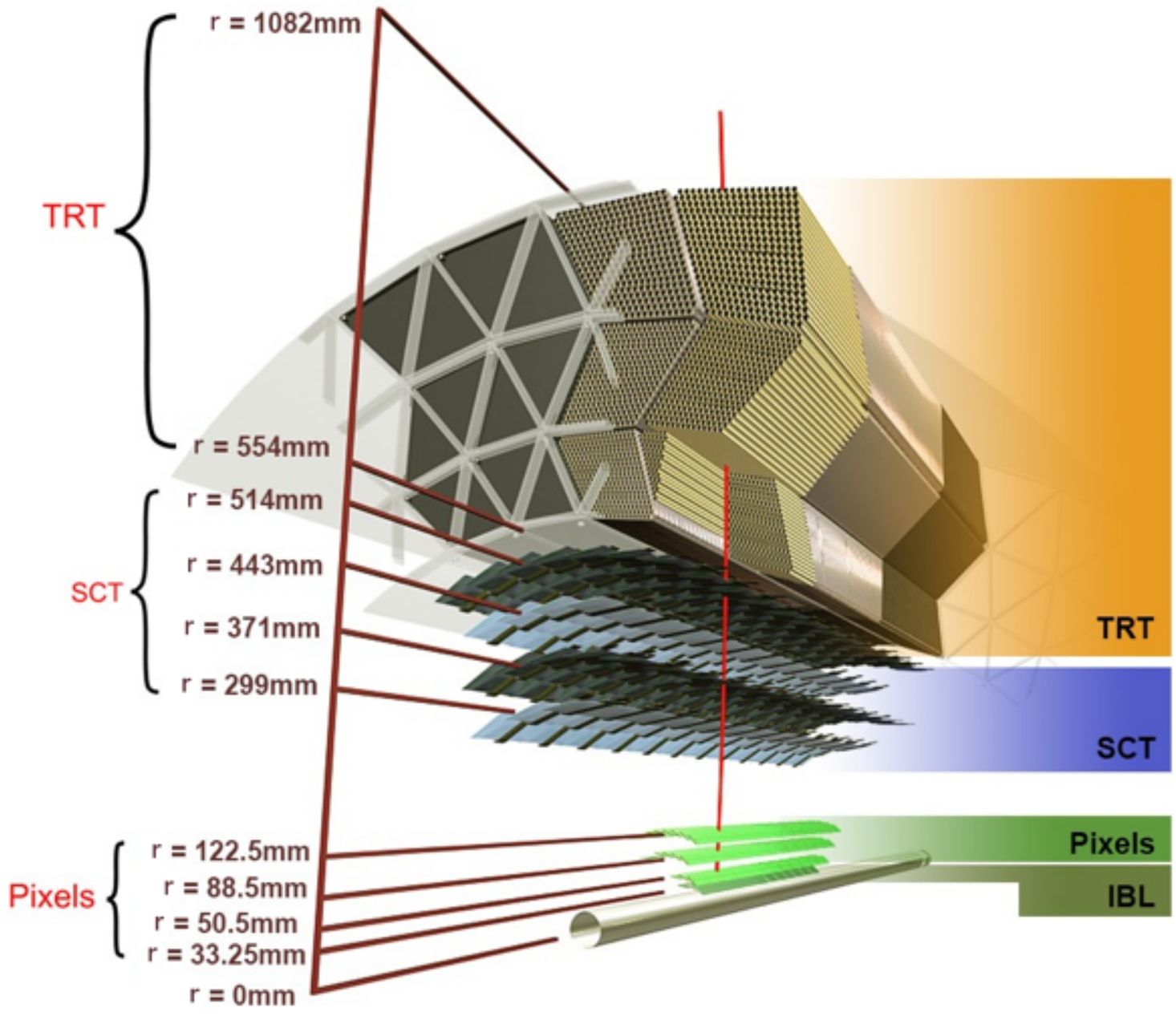
Space Points

Seeds

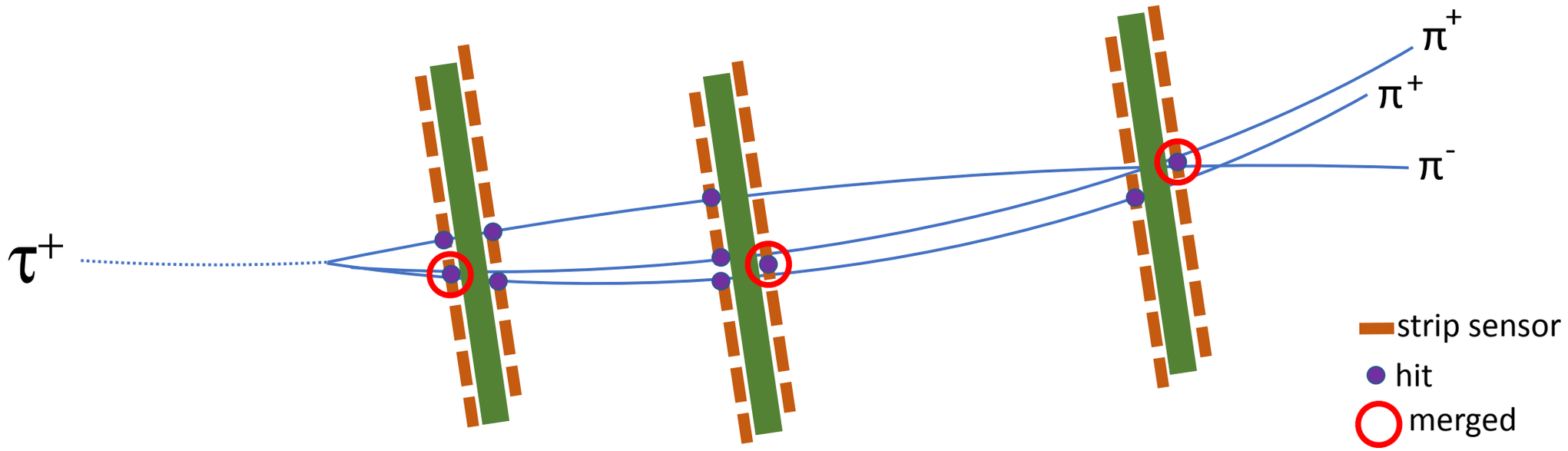
Track Candidates



Output Tracks



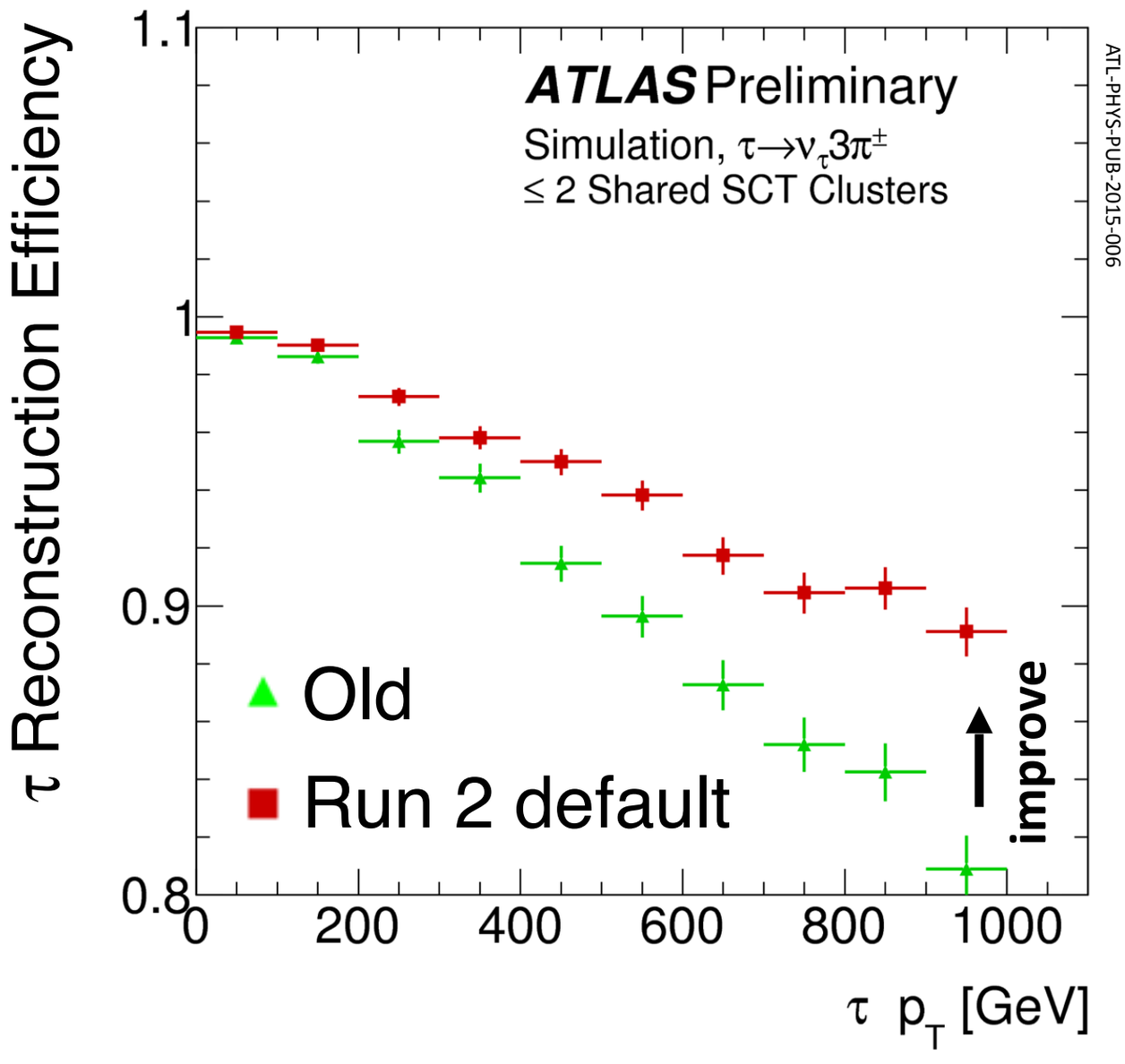
Dense Environments



High p_T, three-prong taus are a good “lab” for high-density tracking – distance scales as $1/p_T$

Dense Environments

- In dense environments, merged clusters can dramatically affect tracking
- Cluster-splitting for pixels has been effective at improving reconstruction
- Strip clusters are important for momentum measurements due to lever-arm



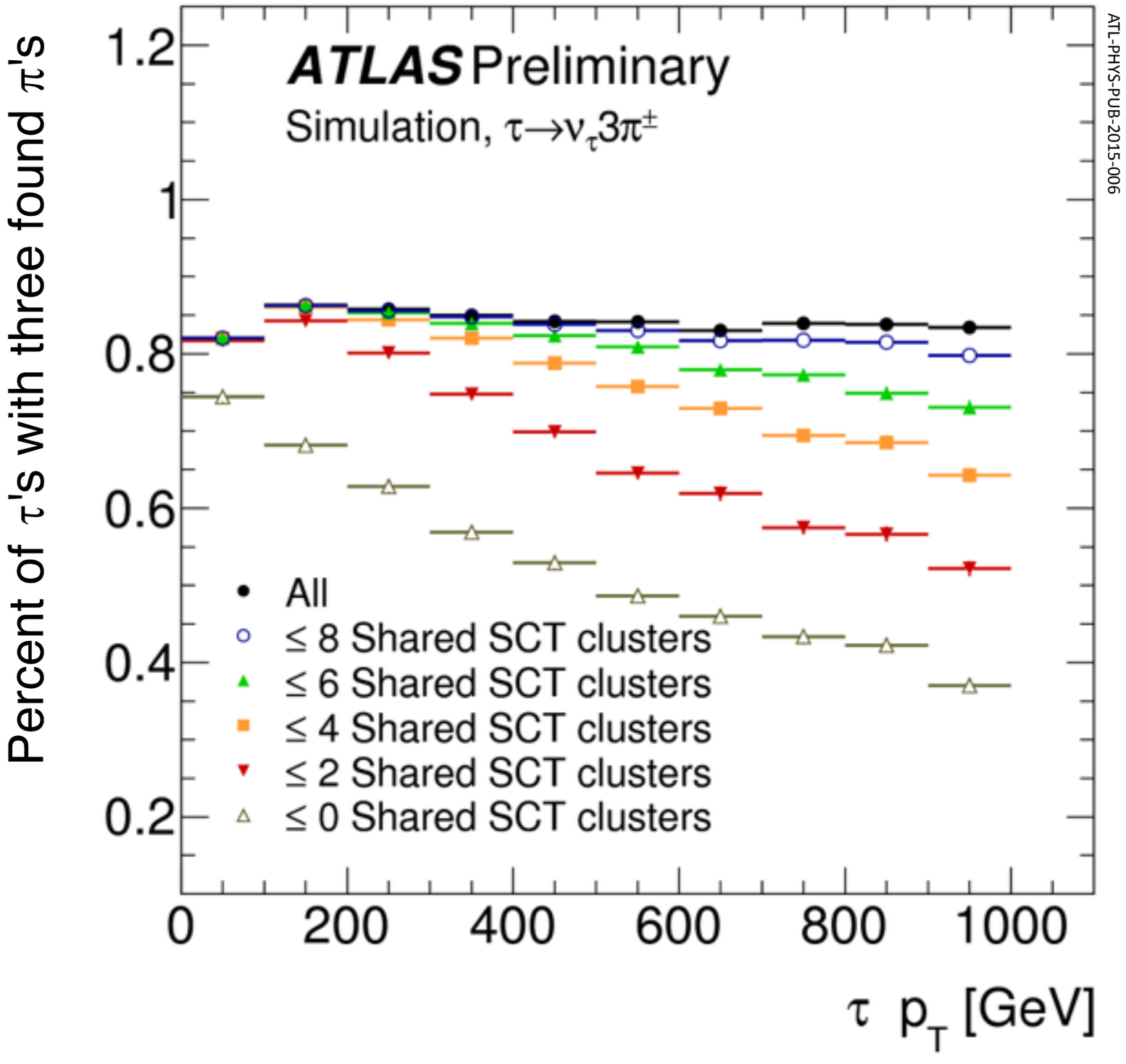
Current algorithm: no SCT-cluster splitting

Pixel NN papers

JINST, Vol. 9, (2014);
Eur. Phys. J. C 77 (2017) 673;
ATL-PHYS-PUB-2015-006

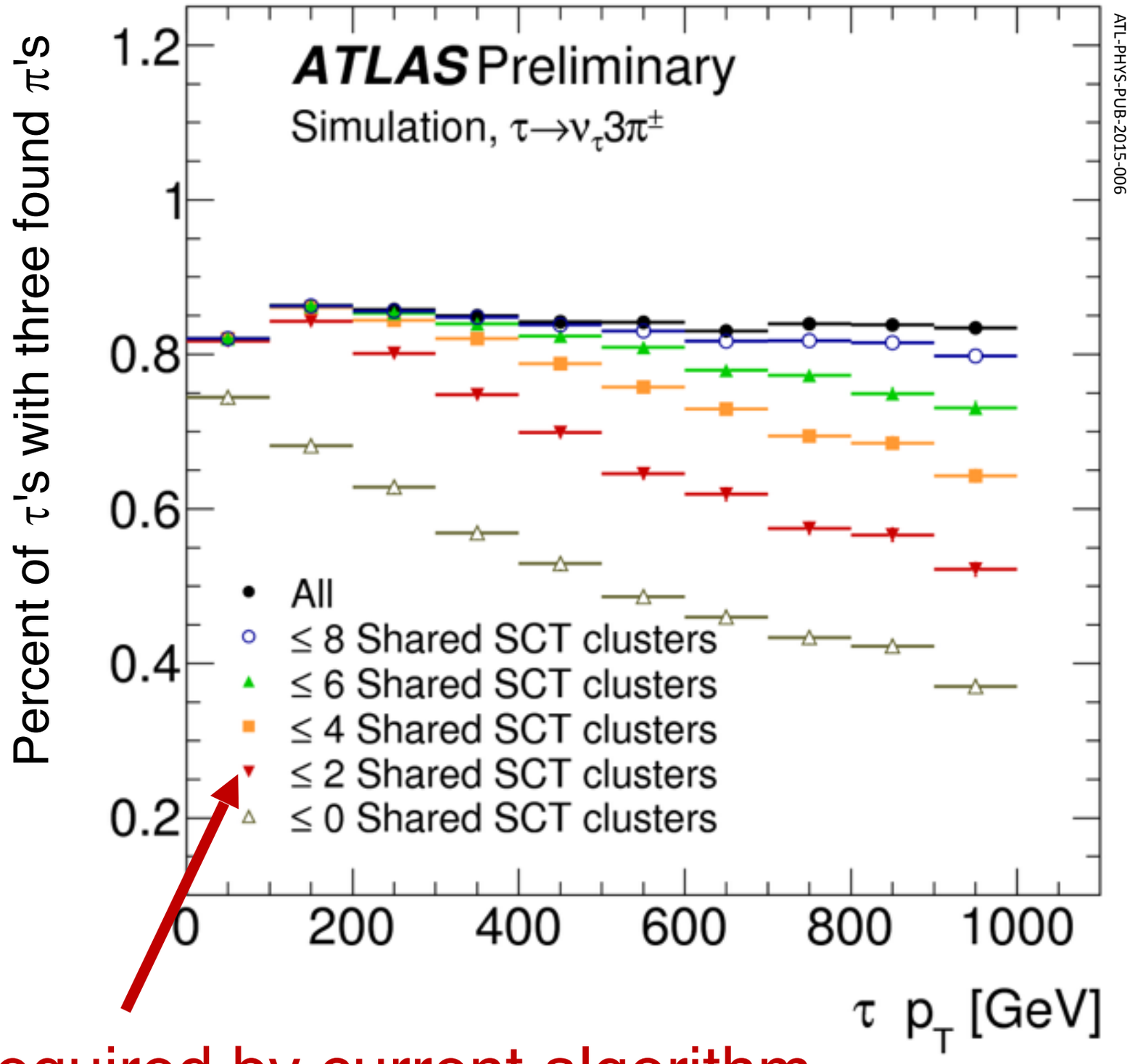
Another CTD talk!
"Implementation and performance of the ATLAS pixel clustering neural networks" by Louis-Guillaume Gagnon

What can strip cluster-splitting do for you?



Definition:
"**Shared**" cluster = cluster used by more than track

What can strip cluster-splitting do for you?

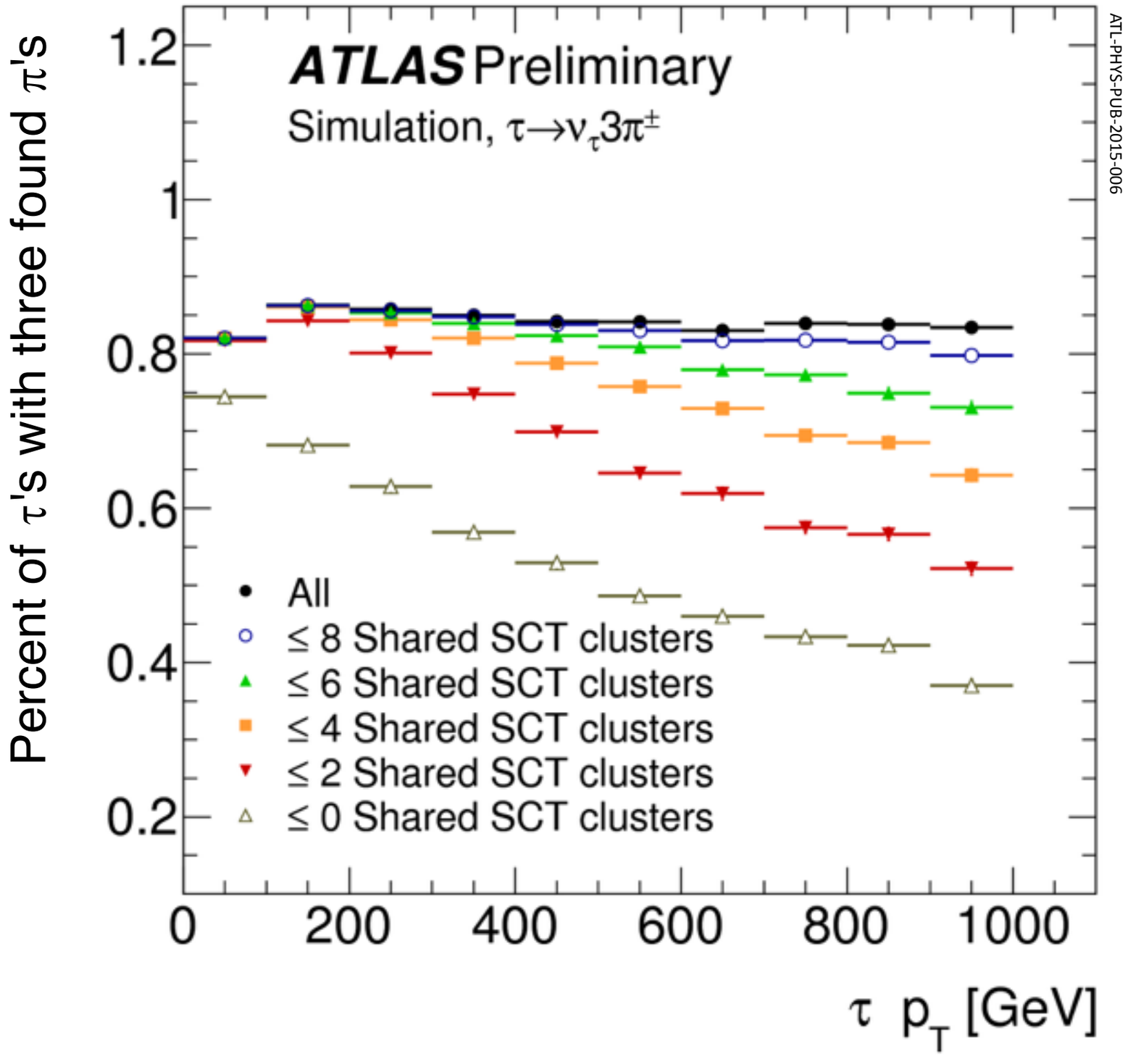


Large loss in efficiency for high p_T τ's

Note: plot on previous slide required ≤ 2 shared clusters on truth tracks, meaning an artificially under-dense system

Required by current algorithm

What can strip cluster-splitting do for you?



The key question:
Can we improve efficiency without dramatically increasing fake rate?

Merged clusters **should be shared** without penalty!

How can we split strip clusters?

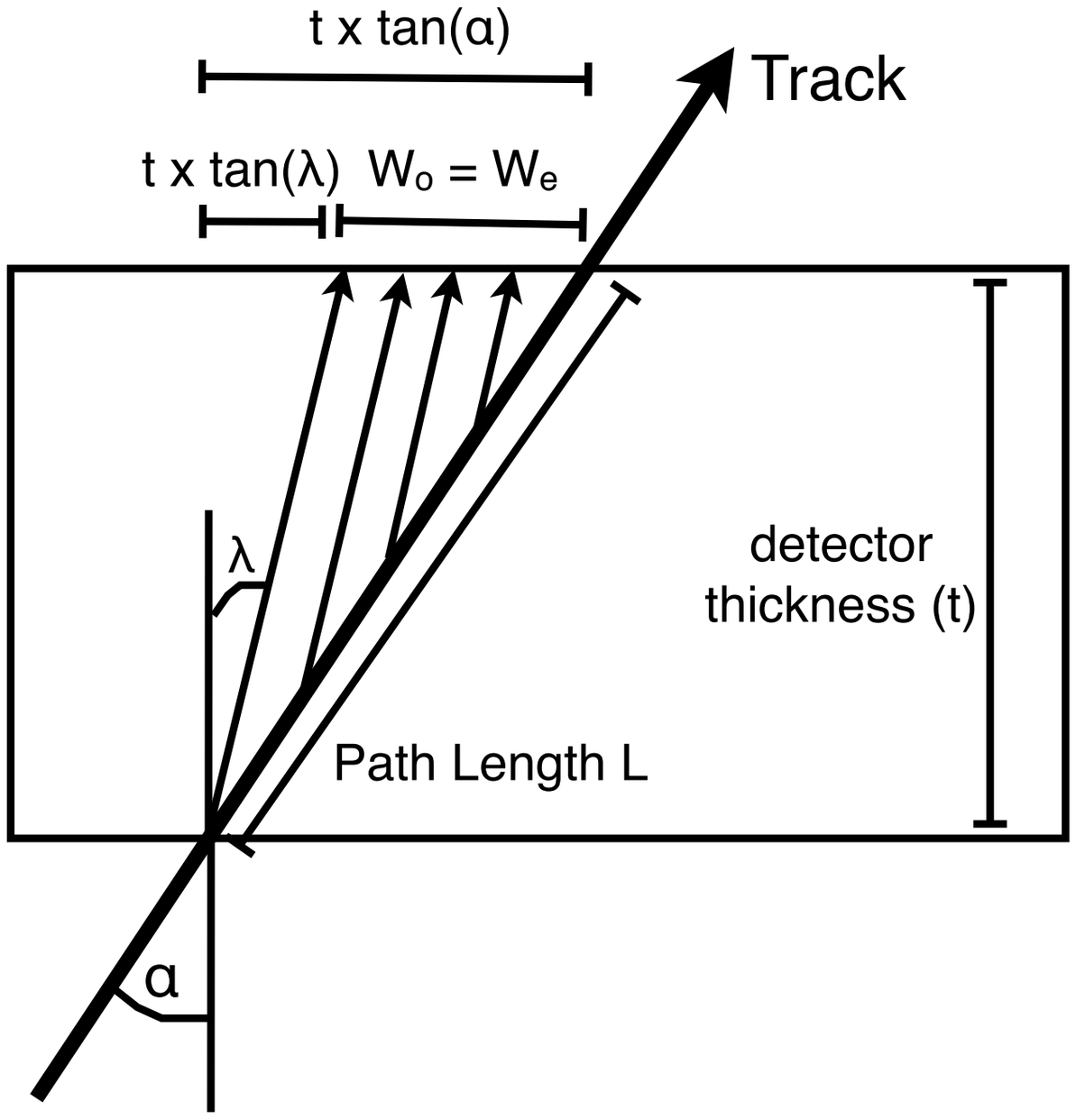
Pixels can use charge to split merged clusters.

… but strips do not have charge information!

Use idea from ATLAS study of δ-rays:

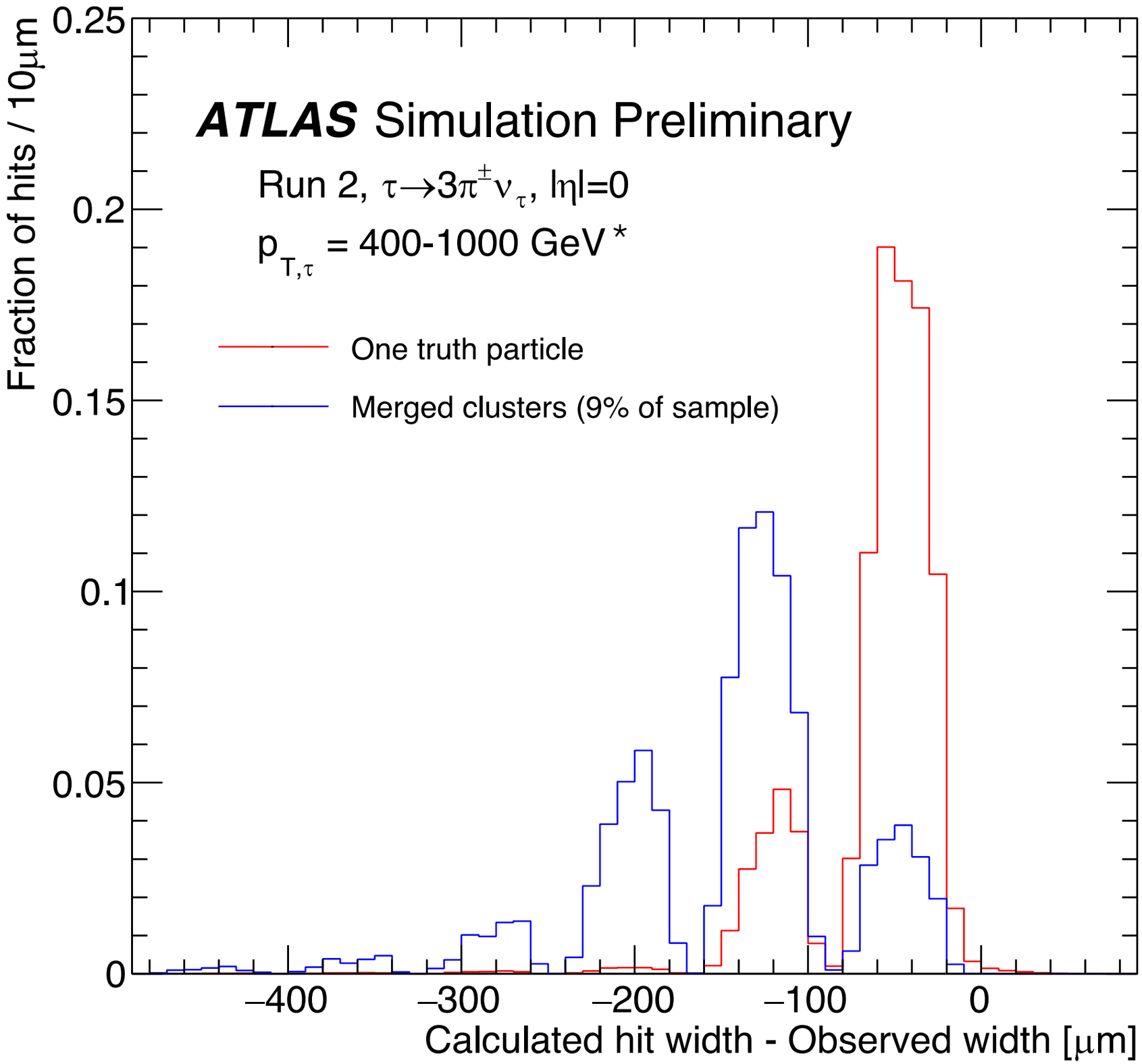
- Determine cluster expected width W_e from geometry

- Merged clusters are wider than expected



Delta Ray CONF Note:
ATLAS-CONF-2013-005

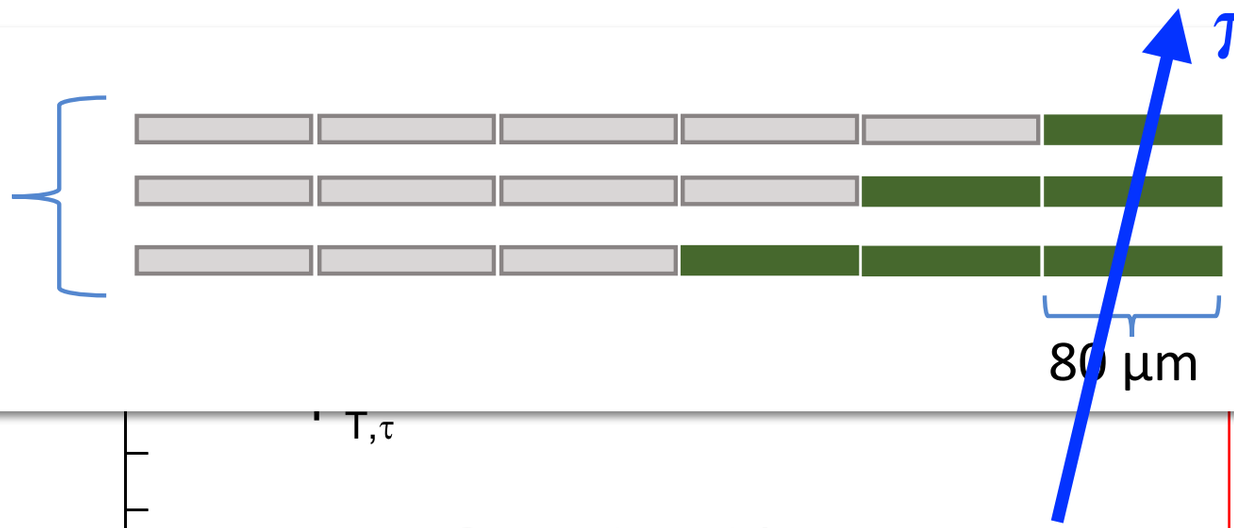
Discrimination power



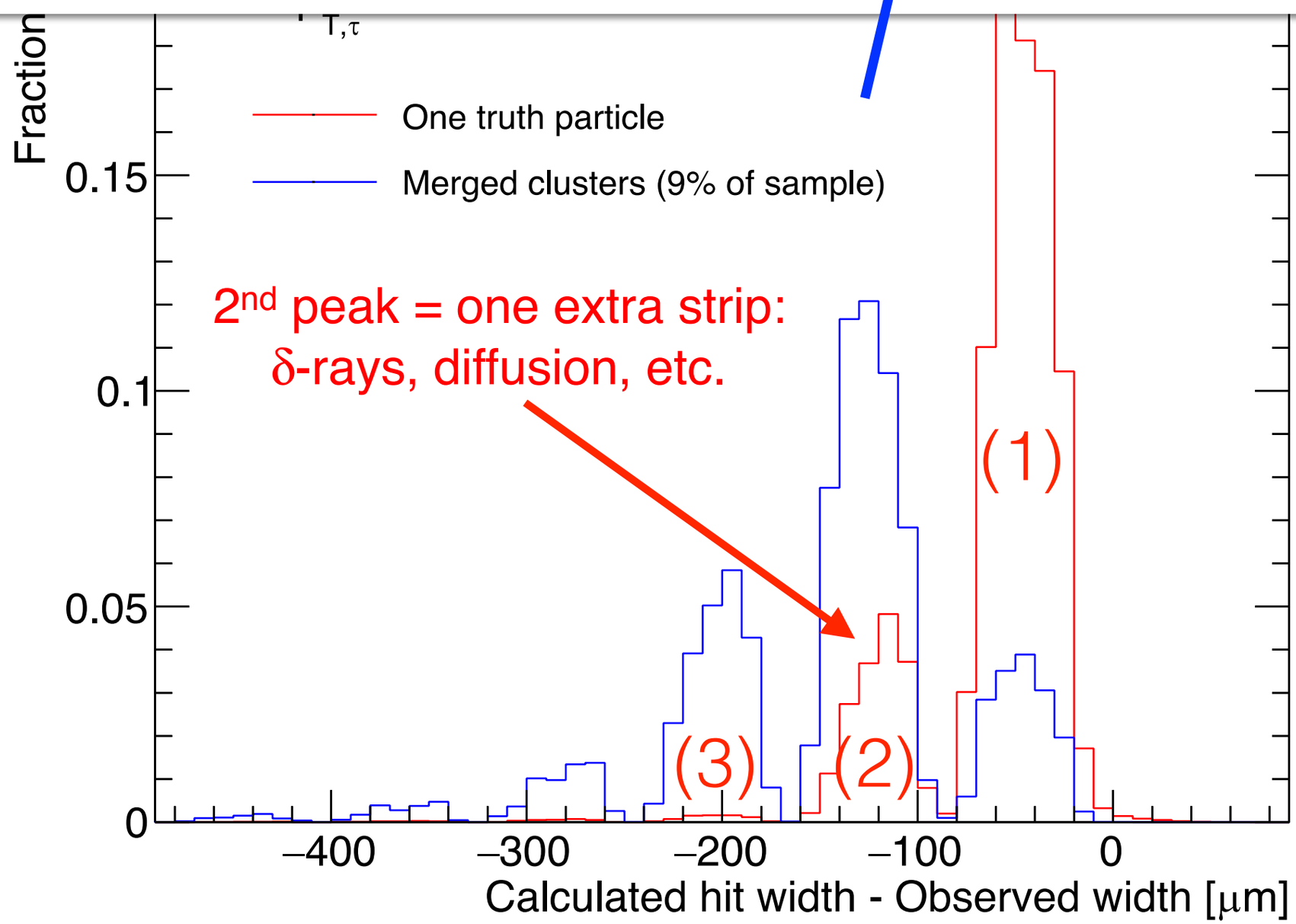
*uniform p_T distribution

Discrimination power

Example if you expect 1 strip!

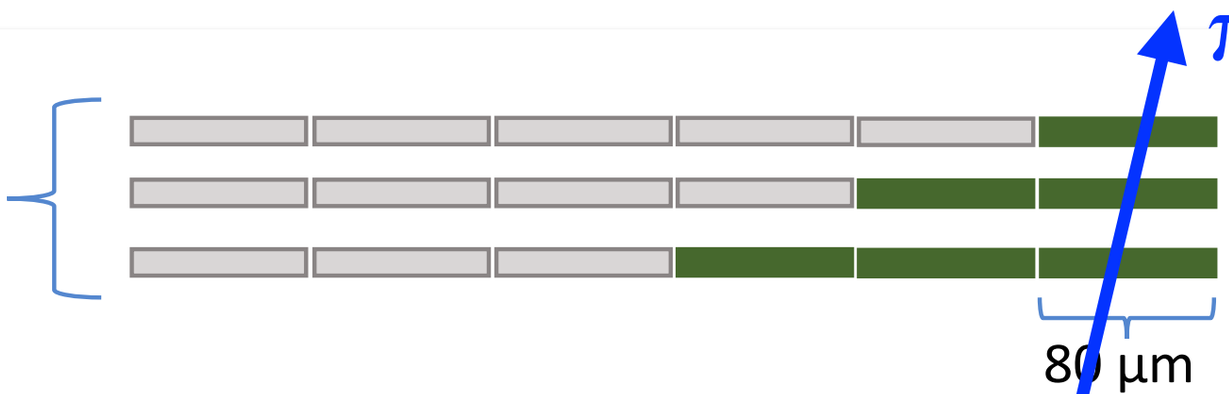


(1)
(2)
(3)

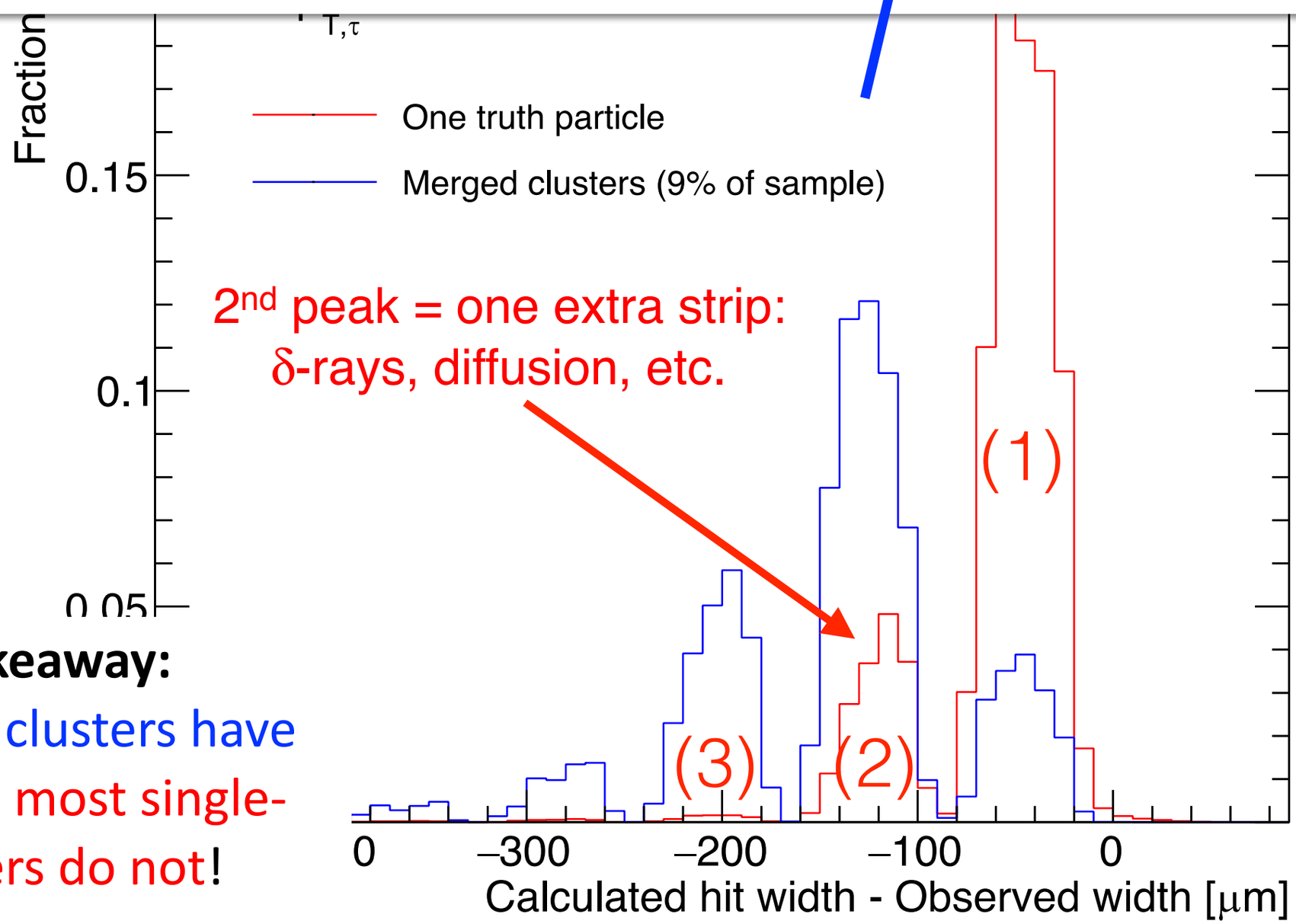


Discrimination power

Example if you expect 1 strip!



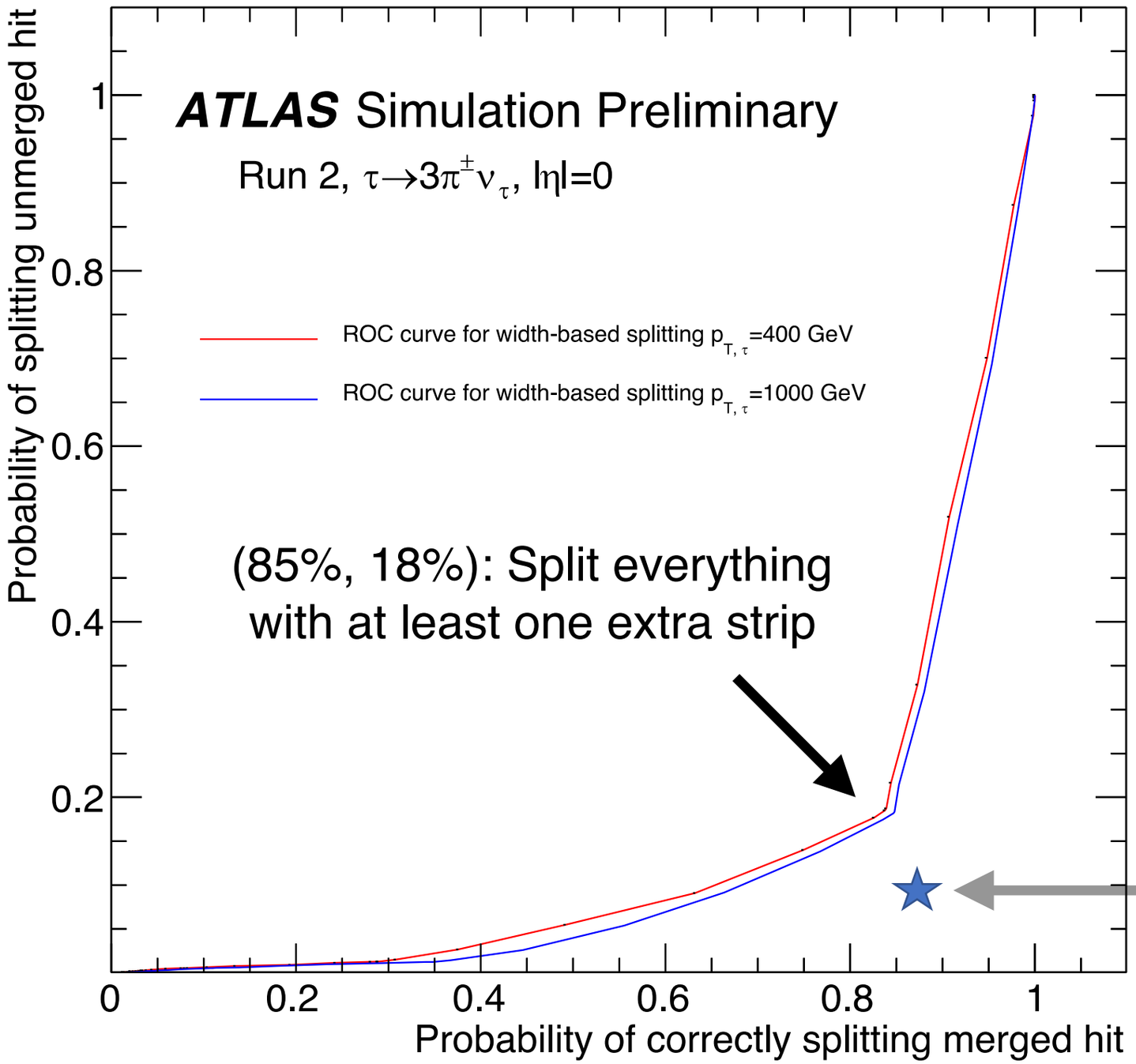
(1)
(2)
(3)



Important takeaway:

Most merged clusters have an extra strip; most single-particle clusters do not!

Watching the ROC



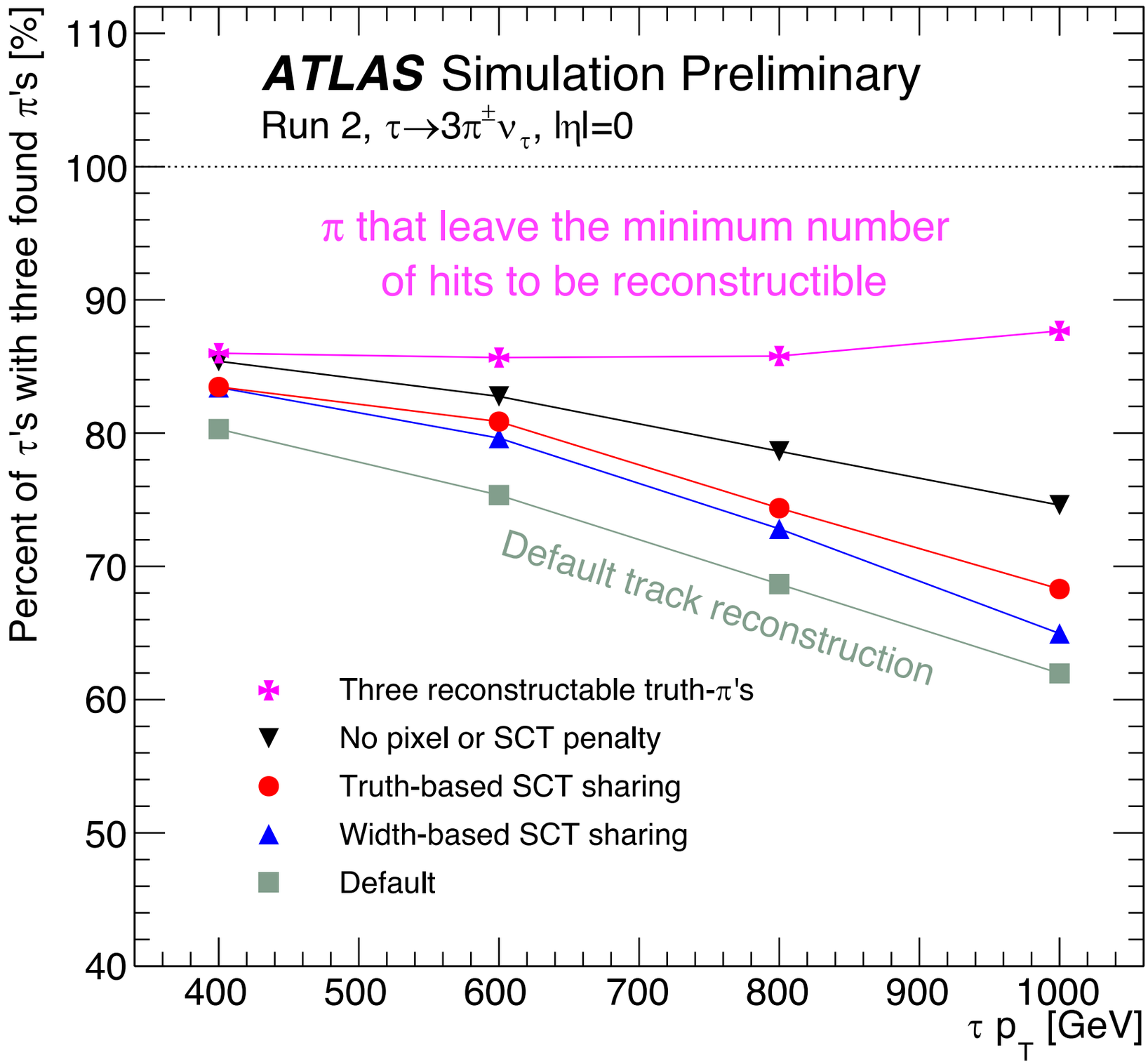
ROC curve mostly independent of τ p_T

(merging rate increases with p_T)

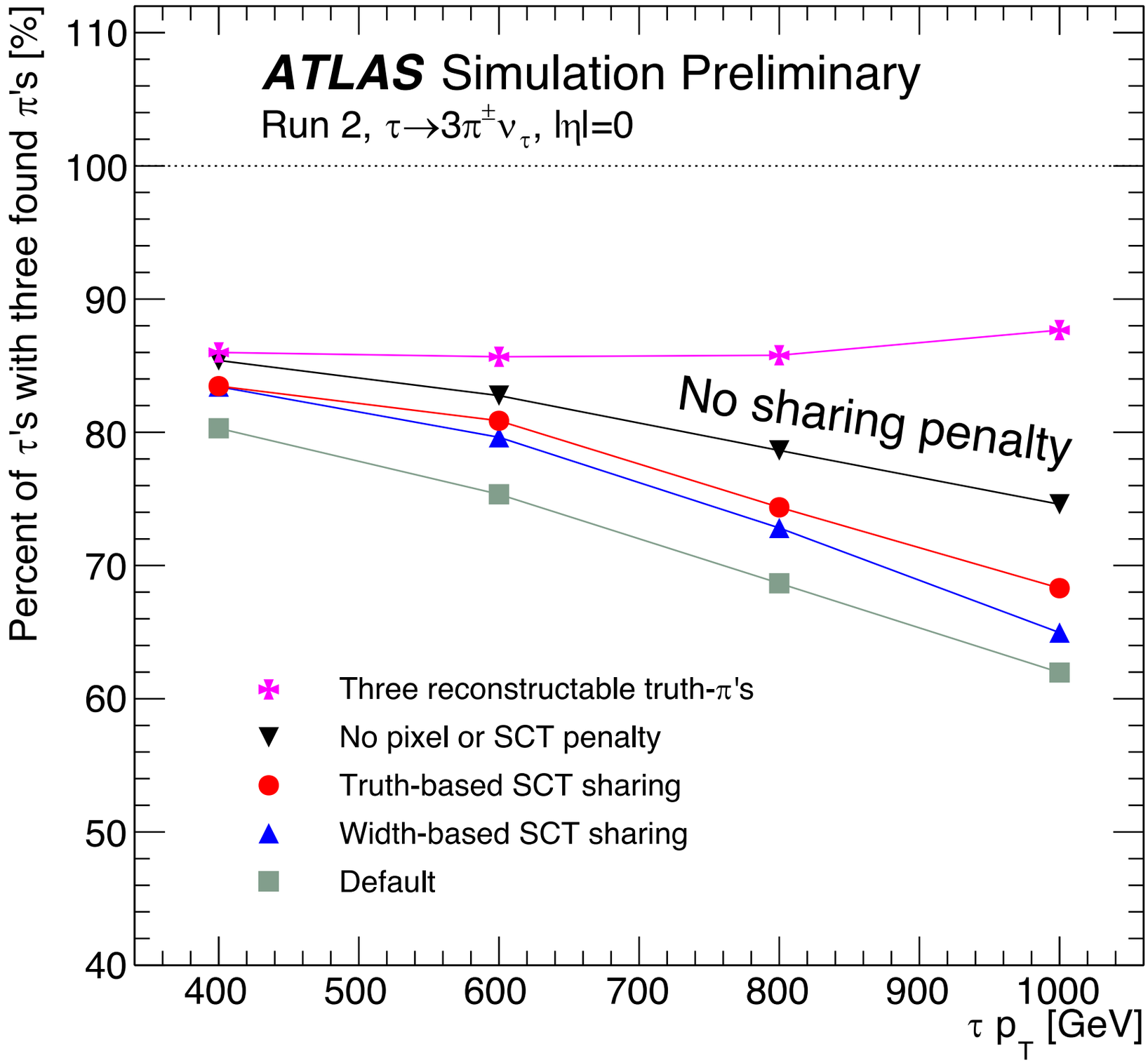
The pixel NN correctly splits 85-90% of clusters, and incorrectly splits <10%

Eur. Phys. J. C 77 (2017) 673

Let's Split!


ATLAS Simulation Preliminary
Run 2, τ→3π±ντ, |η|=0
π that leave the minimum number of hits to be reconstructible
Default track reconstruction
Three reconstructable truth-π's
No pixel or SCT penalty
Truth-based SCT sharing
Width-based SCT sharing
Default
Percent of τ's with three found π's [%]
τ pT [GeV]
110
100
90
80
70
60
50
40
400
500
600
700
800
900
1000

Let's Split!


ATLAS Simulation Preliminary
Run 2, τ→3π±ν_τ, |η|=0
No sharing penalty
Three reconstructable truth-π's
No pixel or SCT penalty
Truth-based SCT sharing
Width-based SCT sharing
Default
Percent of τ's with three found π's [%]
τ p_T [GeV]
110
100
90
80
70
60
50
40
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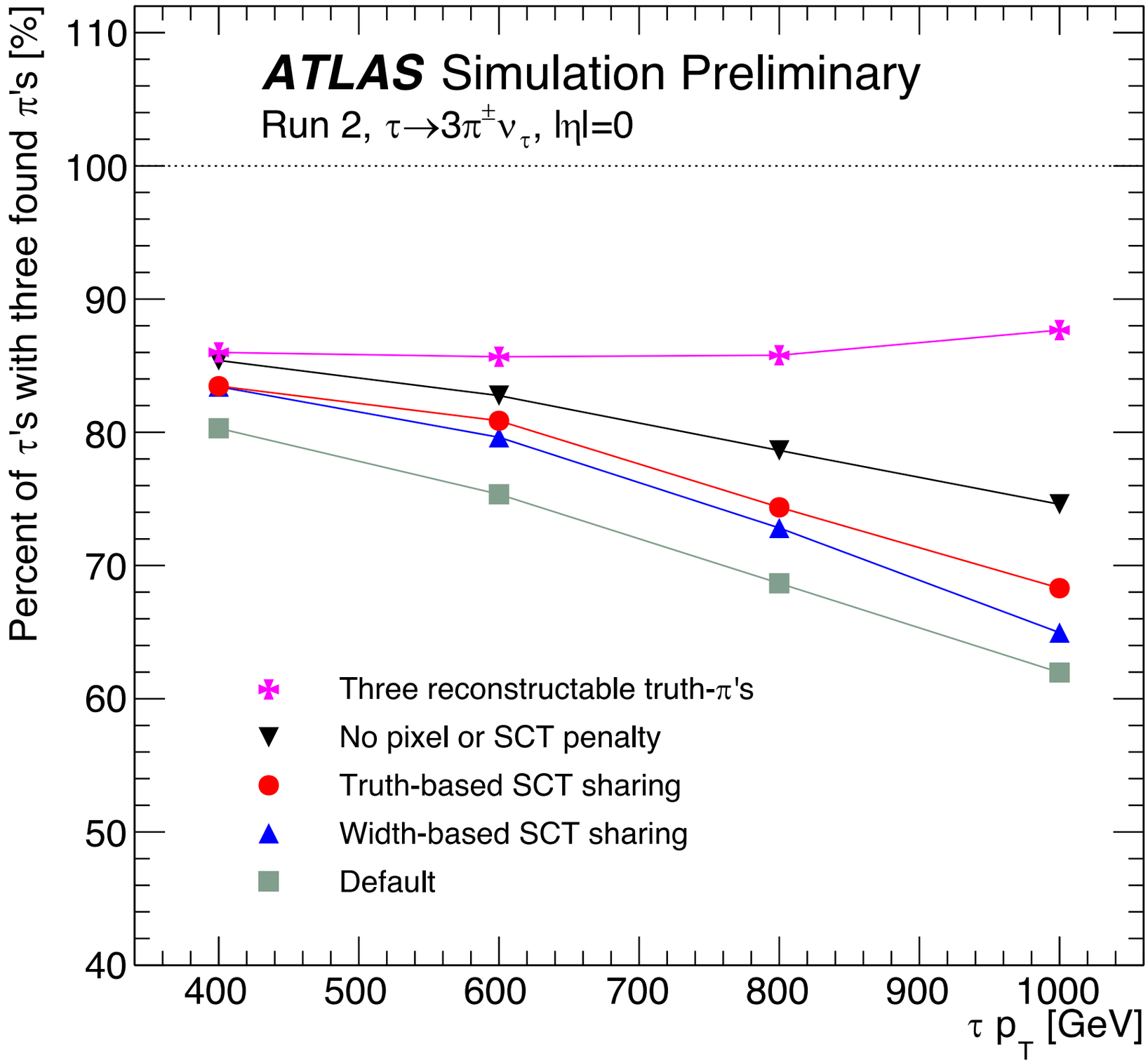
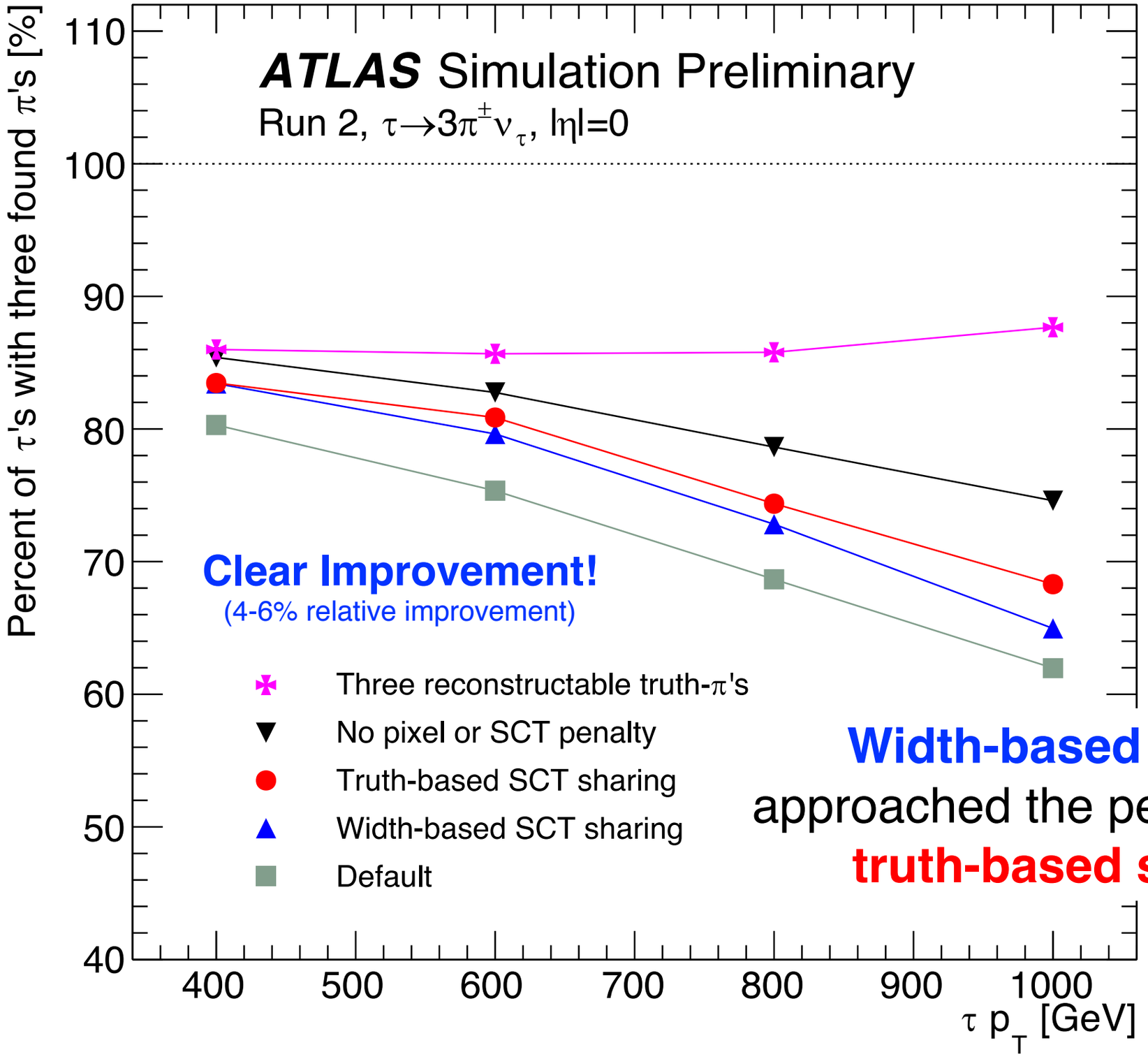
Let's Split!



Split when merged

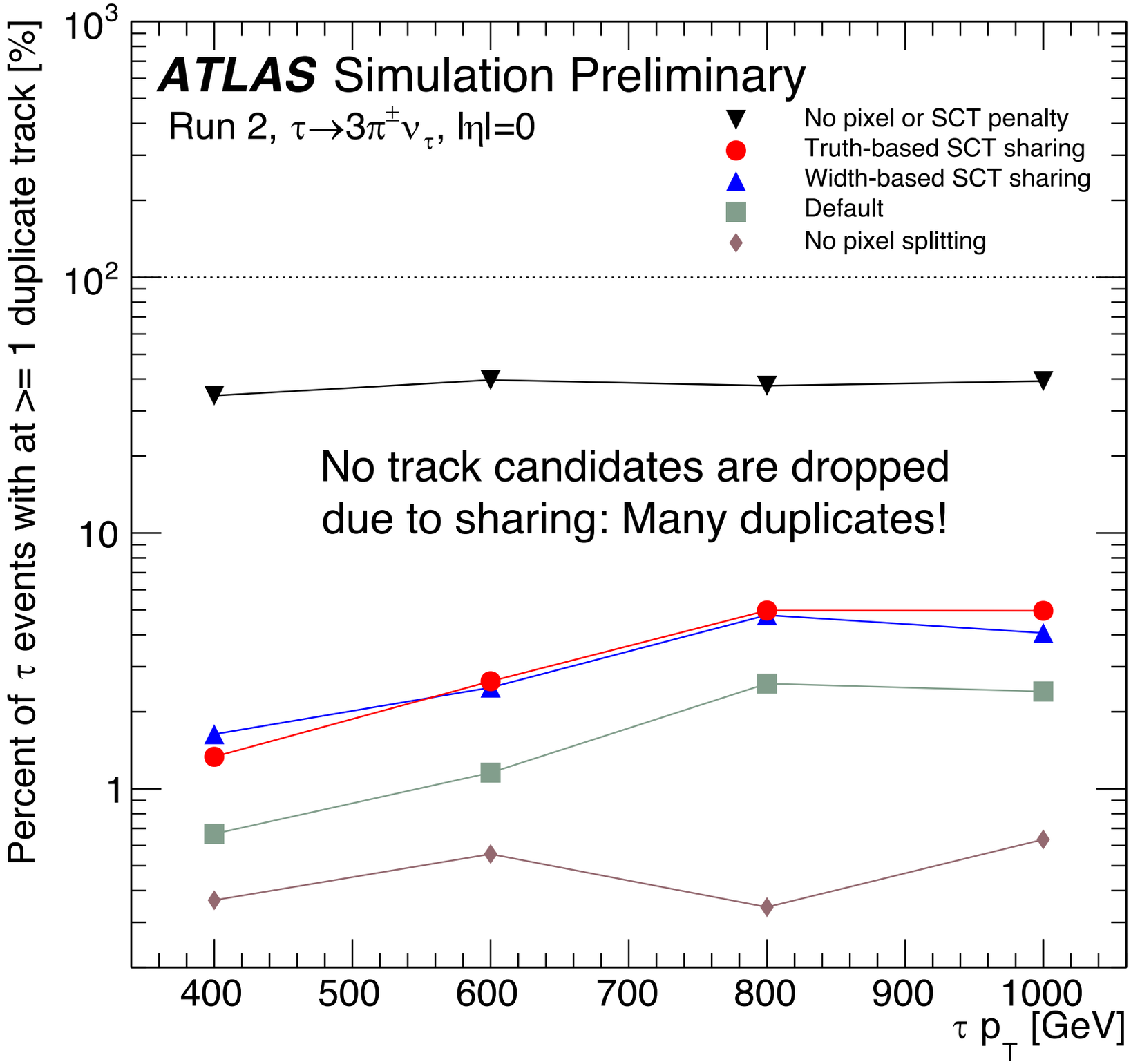
(theoretical limit - requires truth info)

Let's Split!



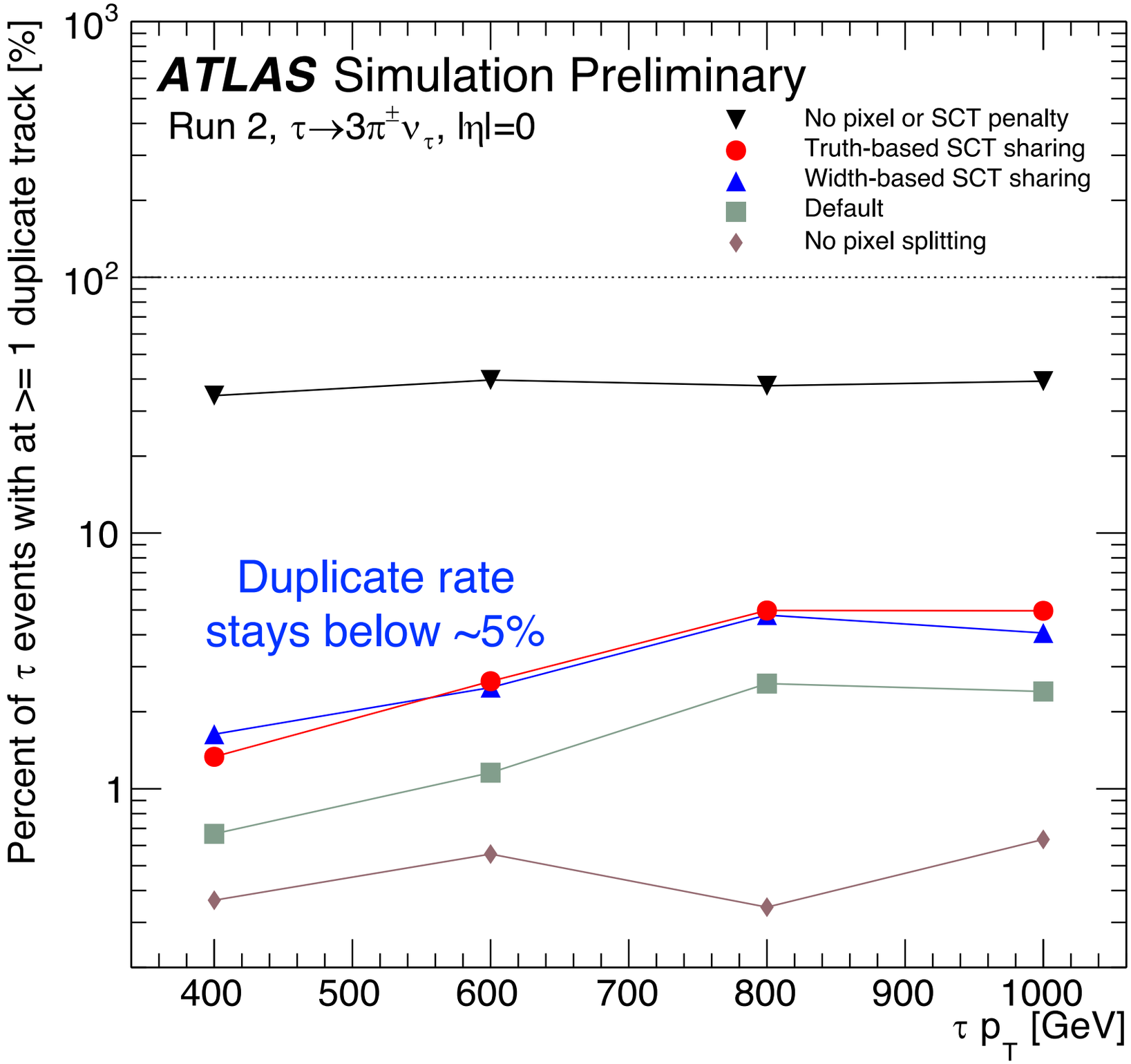
Width-based splitting approached the performance of **truth-based splitting**!

Don’t be too accepting!



Duplicate: when > 1 reconstructed track is truth-matched to the same π

Don’t be too accepting!



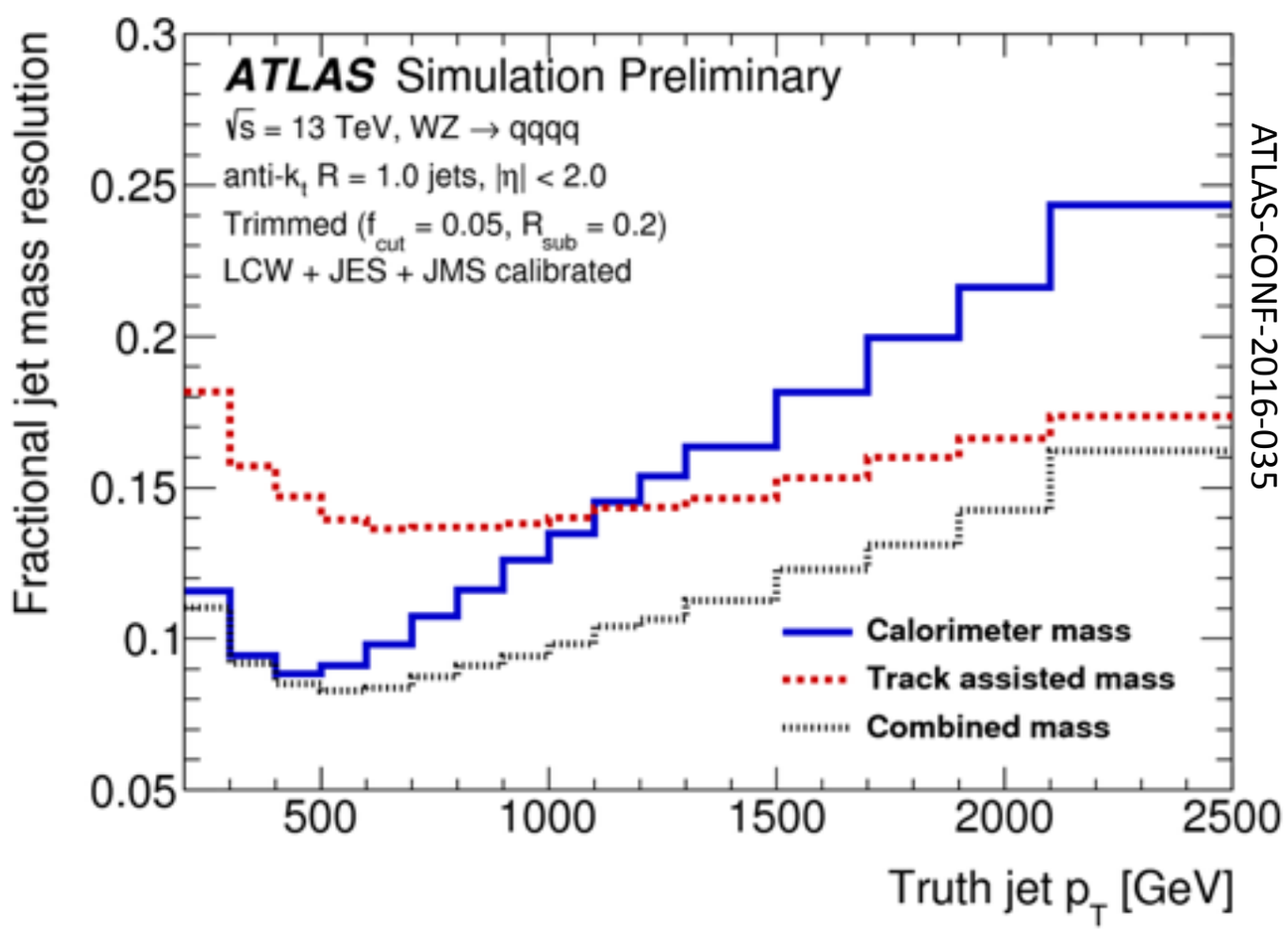
Duplicate: when > 1 reconstructed track is truth-matched to the same π

N.B.: there is no pile-up in these samples. Duplicate rate in high-μ samples needs to be studied.

Conclusions and Outlook

- Comparing **expected cluster widths** to the **observed width** is effective for splitting **strip clusters**
- Allowing tracks to share strip clusters with 1 extra strip **increases efficiency** in dense environments, without increasing duplicate rate
- Will **improve searches & measurements** using tracks inside τ's & jets

strip-cluster splitting will improve **red** and **black** lines



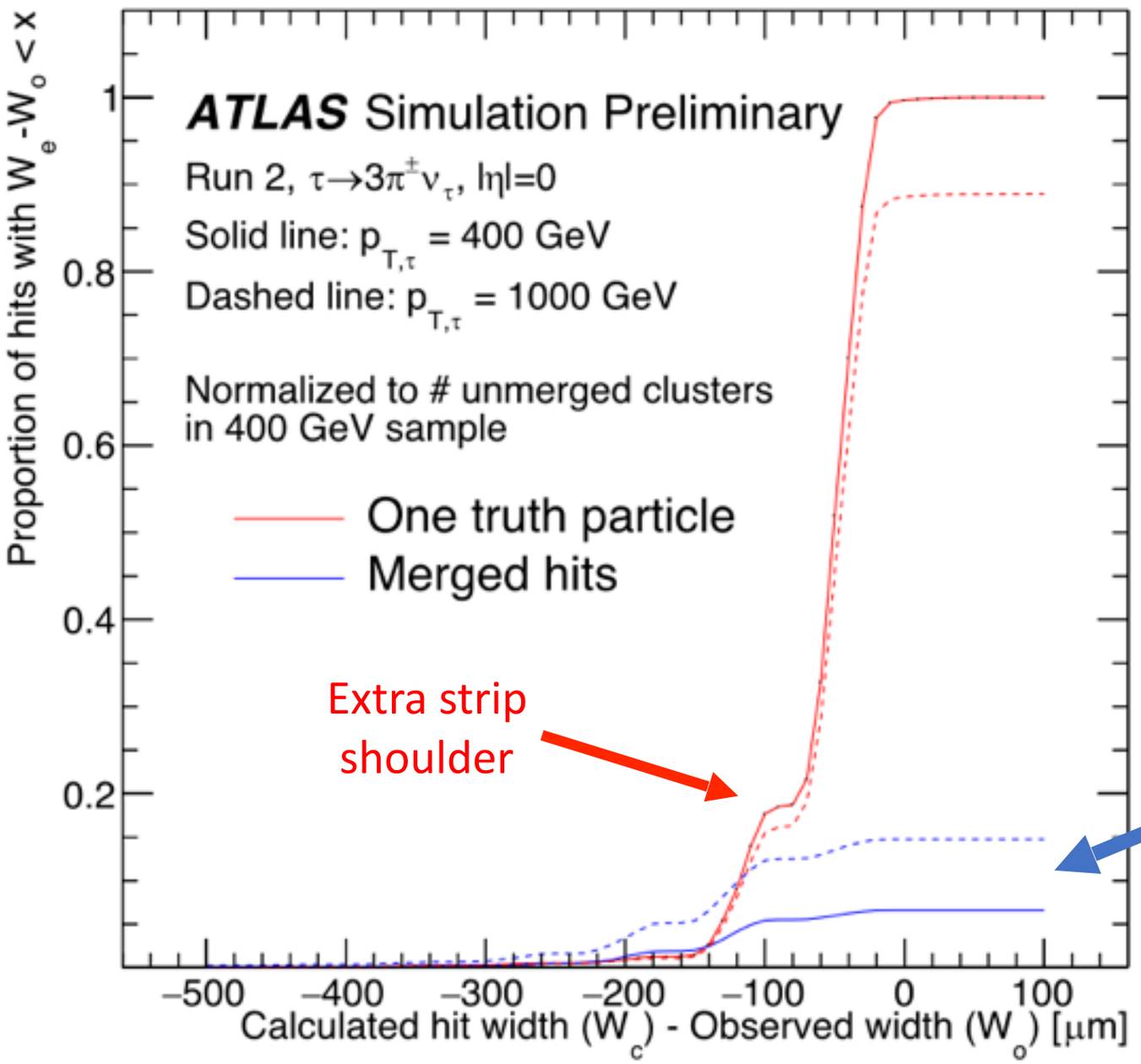
Questions?

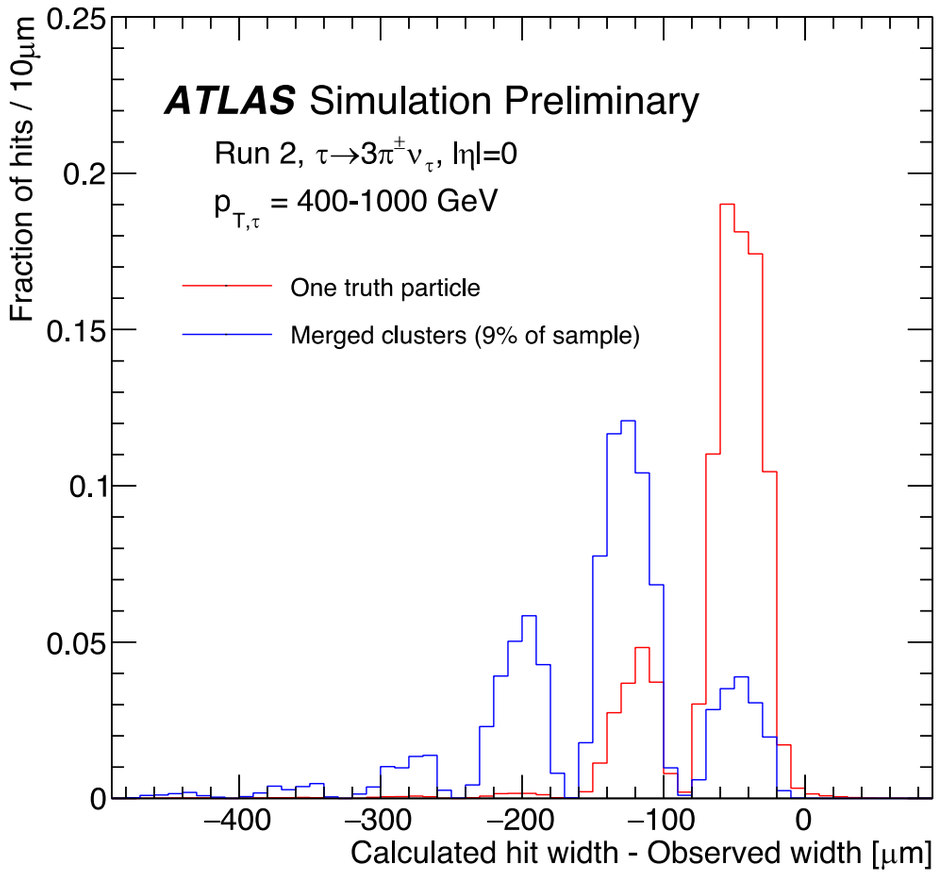
← **Ask this guy**

Backup

Cumulative distribution function

Integrate this from the left to get CDF





Higher p_T = more merging

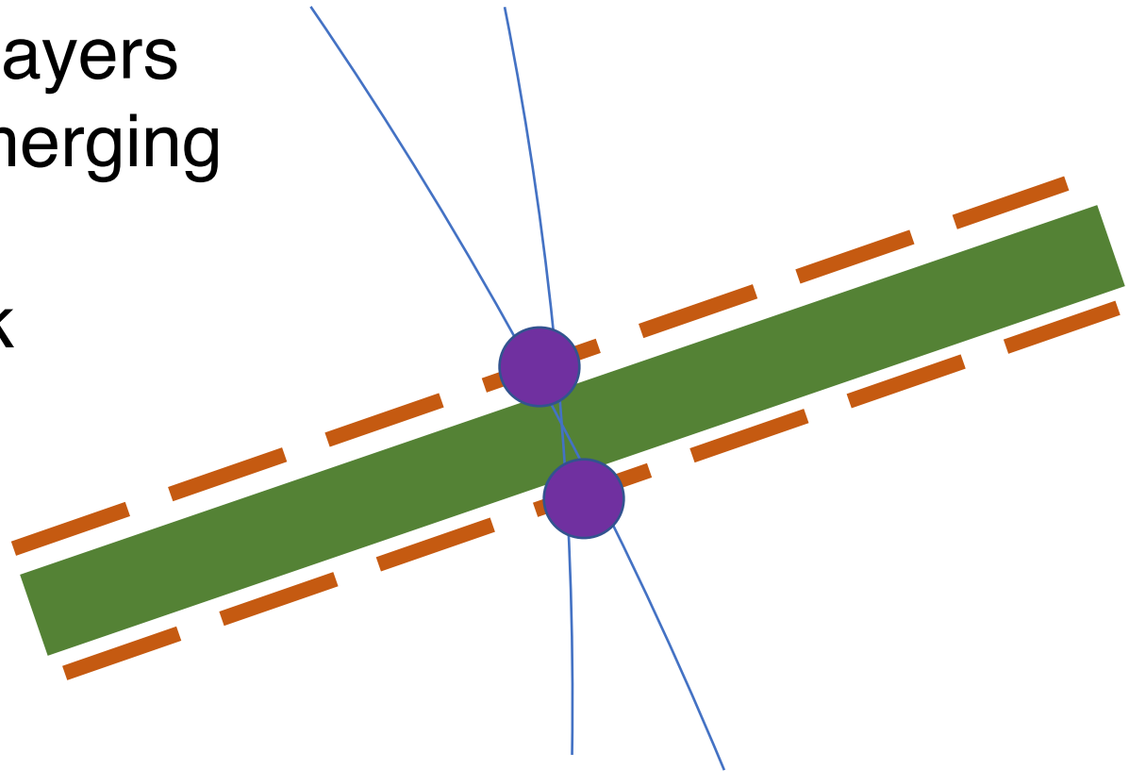
Additional Variables?

We can consider multiple variables to improve efficiency

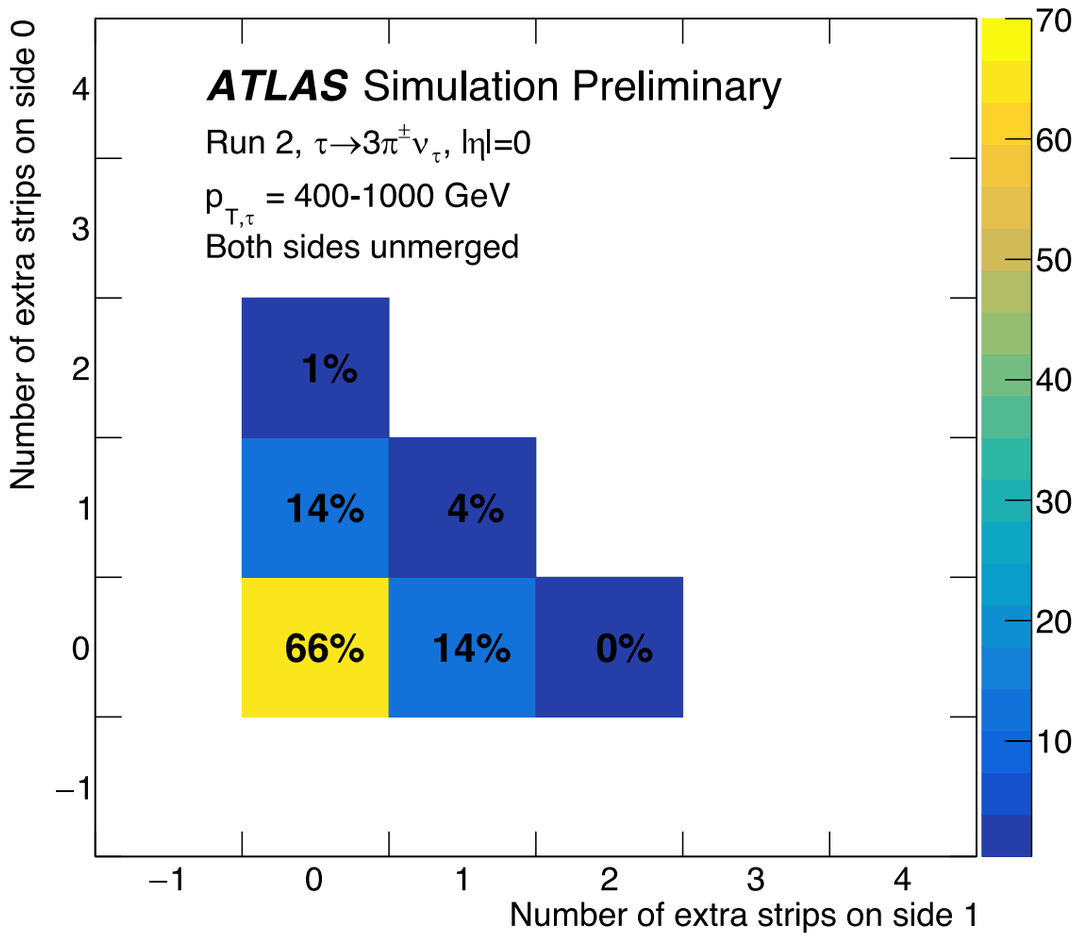
Can we recover marginal truth vs width splitting loss at high p_T'? (and check jets)

Example input variables:

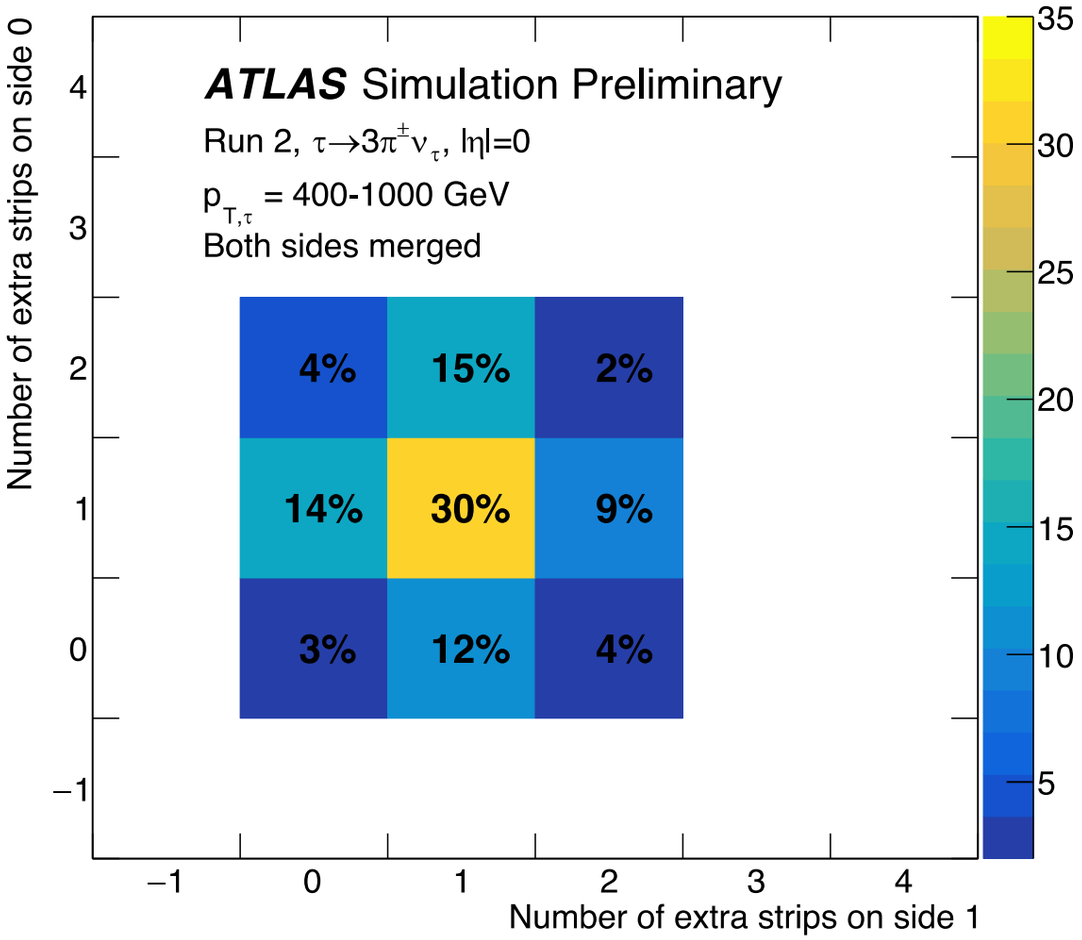
1. W_e-W_o (of course)
2. Cluster layer, more merging in inner layers
3. Track p_T; higher p_T can mean more merging
4. τ p_T
5. Number of split pixel clusters on track
6. W_e-W_o of cluster on other strip layer



For example: use two sides

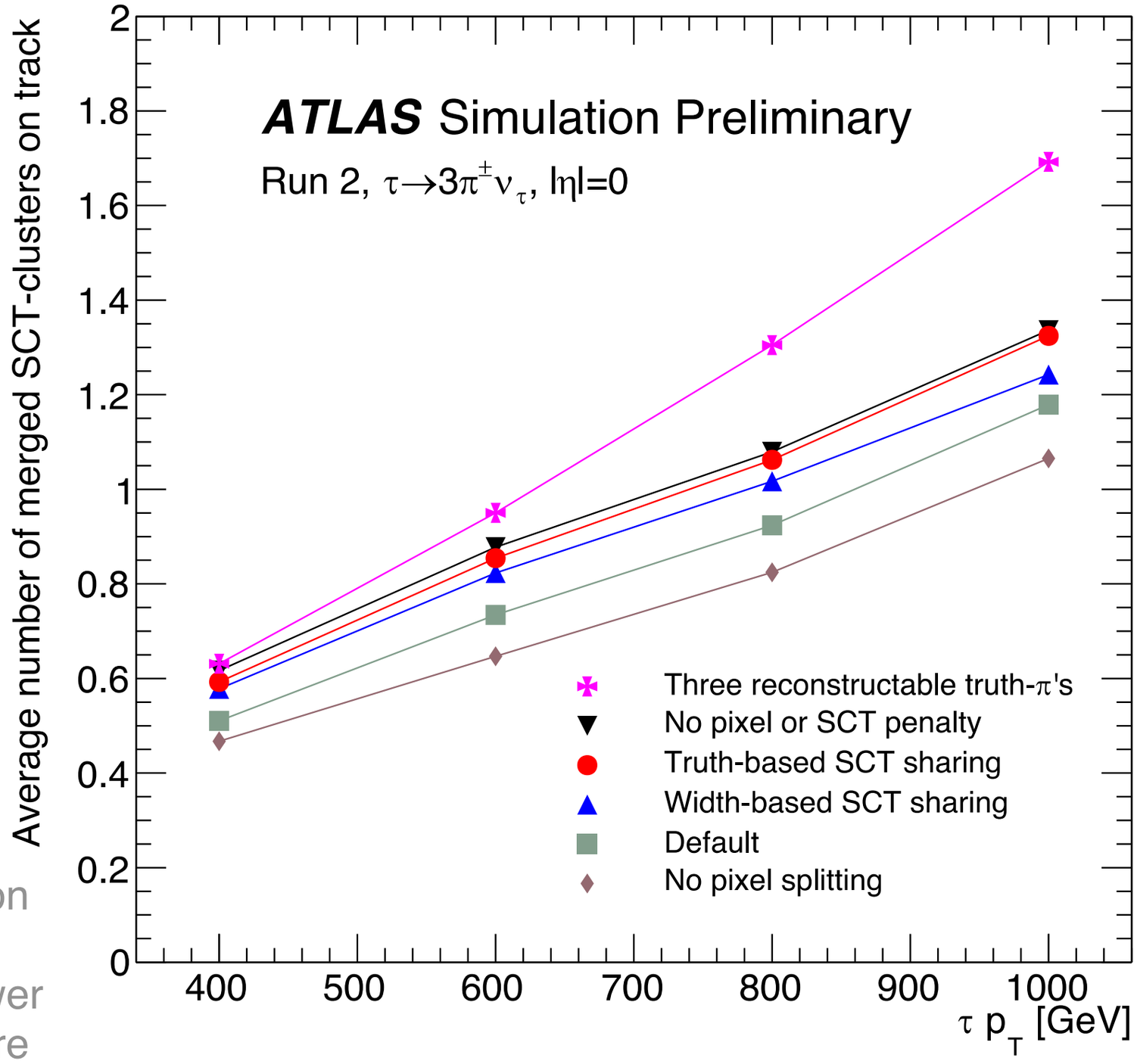


If both sides are not merged, both will most likely not have an extra strip



If both sides are merged, both will most likely have an extra strip

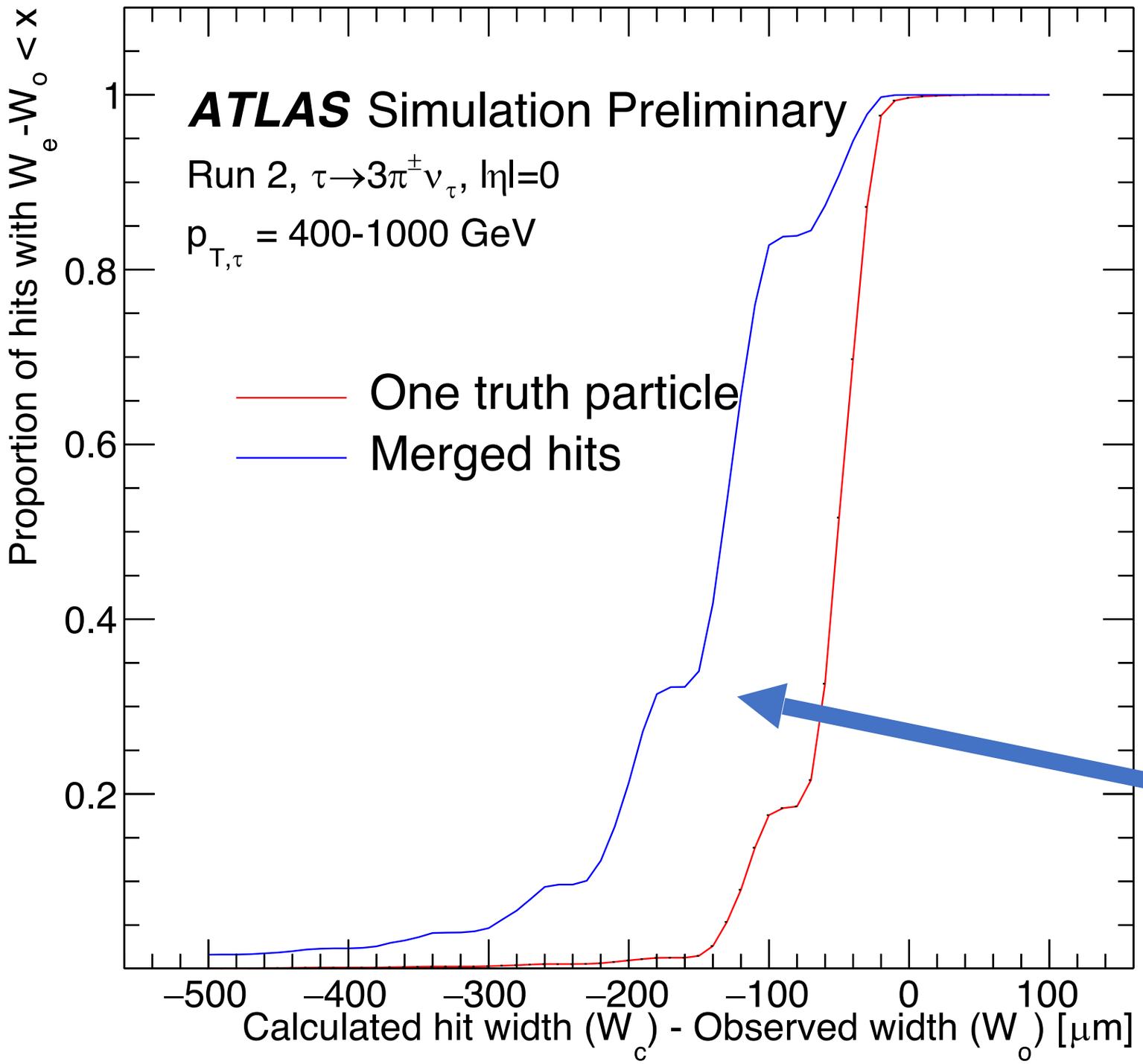
Getting a sense of the merging rate



The average pion is almost at the allowed limit for default sharing!

Merging is based on truth, so a higher average means fewer track candidates are rejected when they shouldn't be

Renormalized CDF



A cut in this area would make sense!