

FTK: A Global Tracker for the ATLAS Trigger

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Long-Lived Particle Workshop
10.18.2017

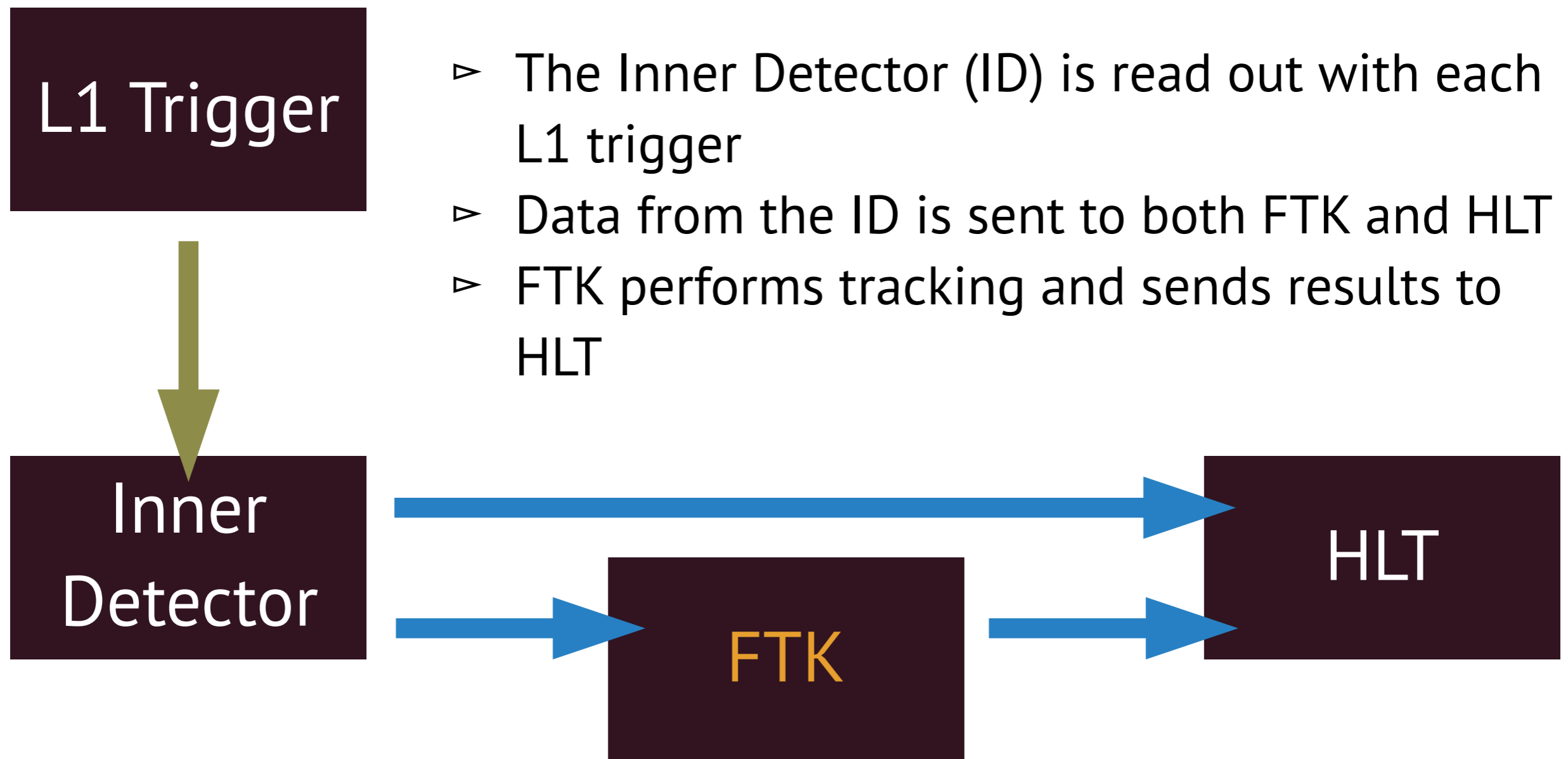


OVERVIEW

- ▷ What was FTK designed for?
- ▷ How does FTK work?
- ▷ When will FTK provide tracks?

What is the FastTracker (FTK)?

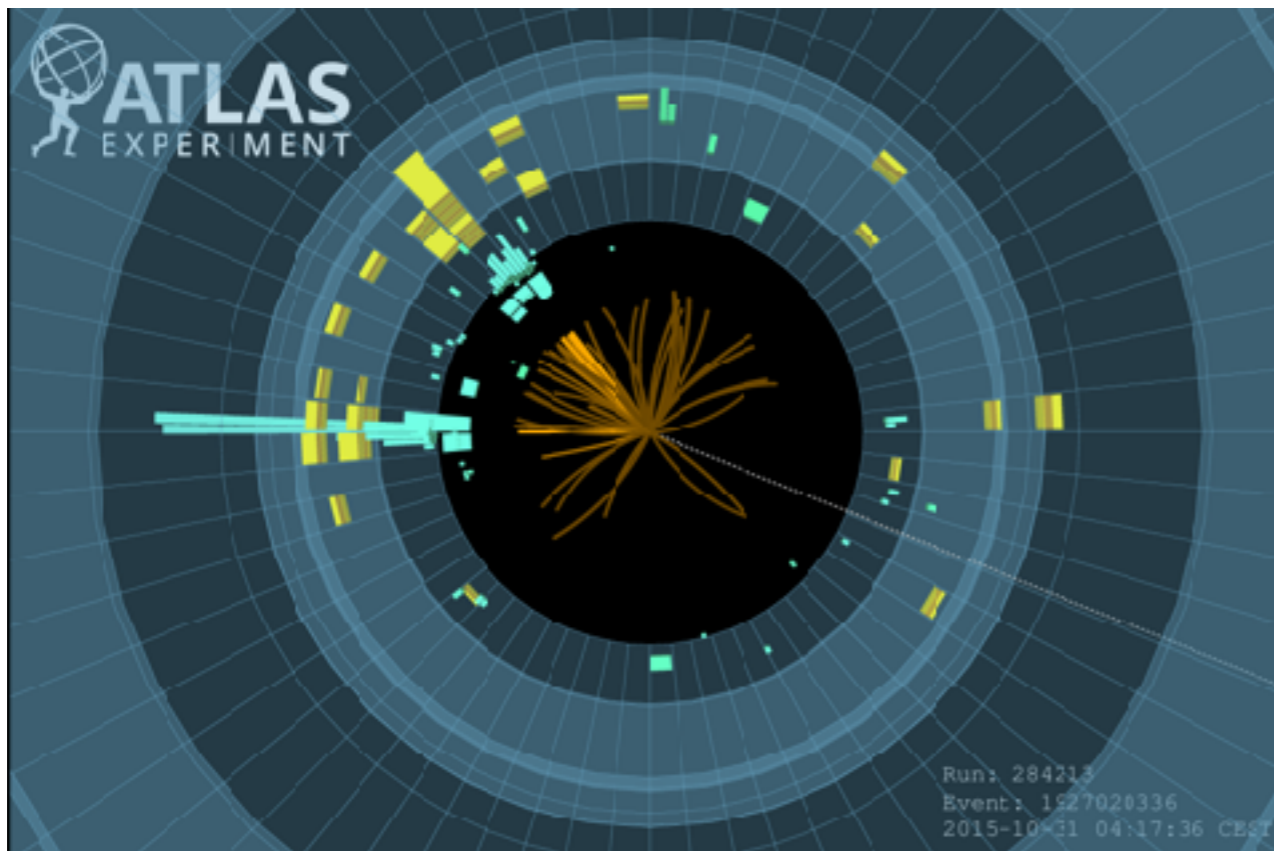
FTK provides **full tracking information to HLT** for tracks with $|\eta| < 2.5$, $p_T > 1$ GeV



Why do we need FTK?

ATLAS tosses more than 99.99% of collisions

Final decision on what to keep is made in around 250 ms



How do we decide if this event is worth keeping?

(image of an event with analysis-level “offline” reconstruction)

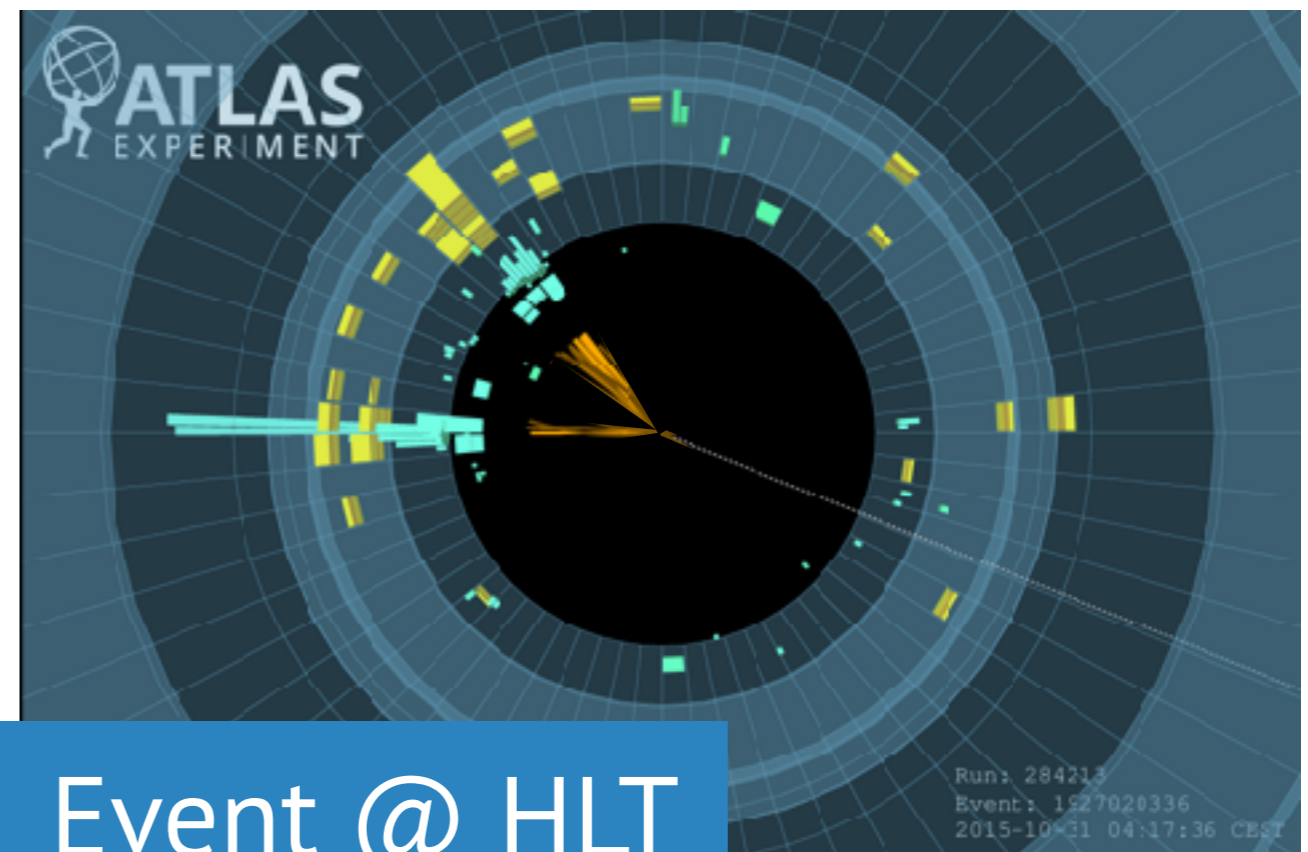
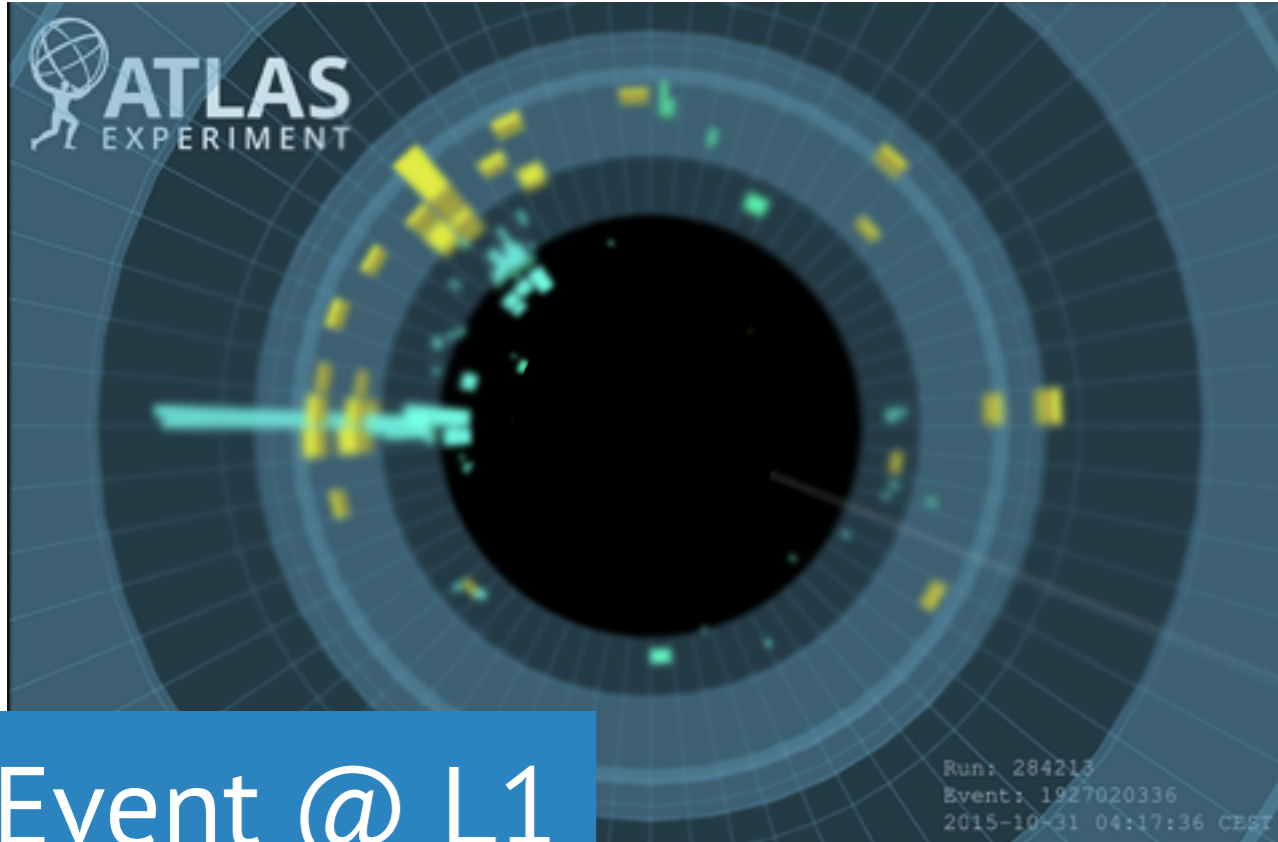
Why do we need FTK?

Level 1 trigger decision are made with rough calorimeter and muon information

High Level Trigger uses full precision information around objects identified at L1

40 MHz →
100 kHz

100 kHz →
1 kHz



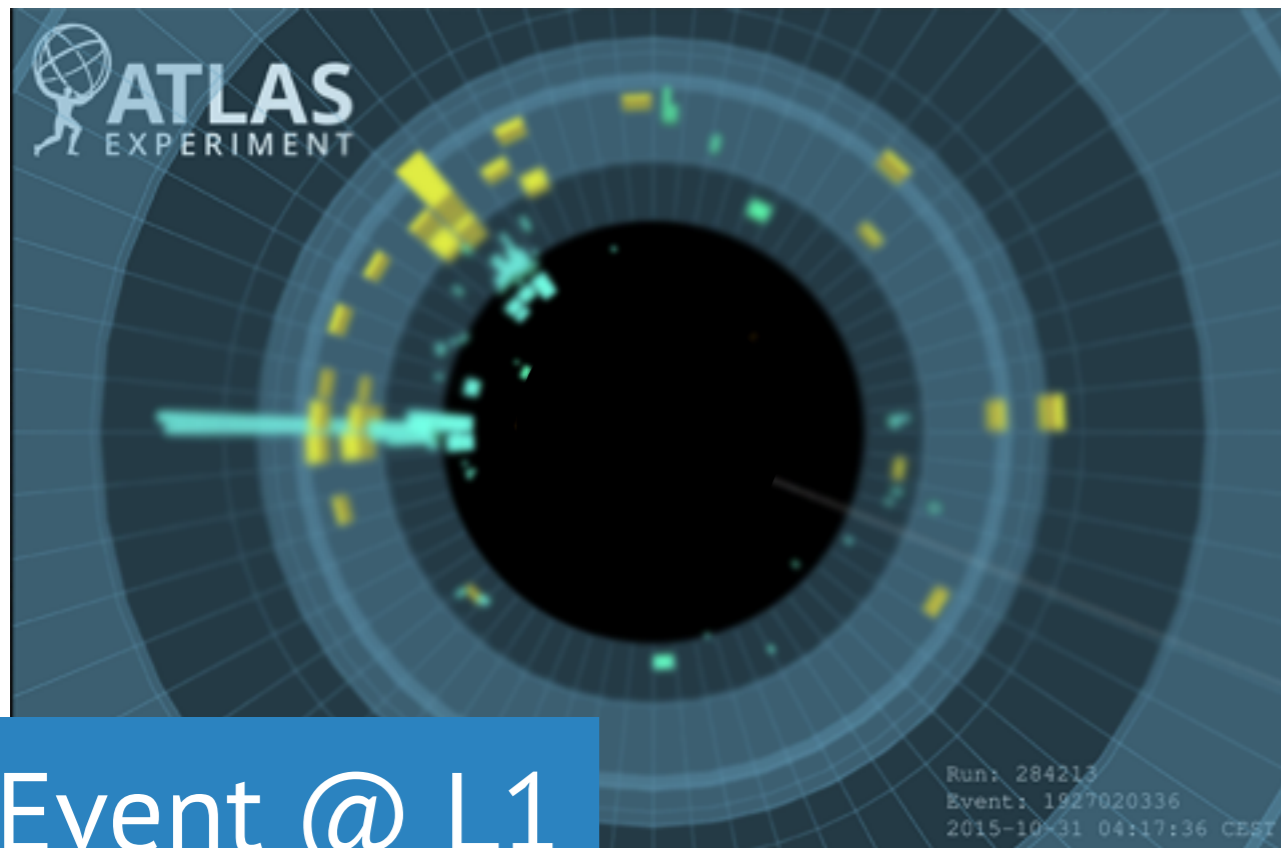
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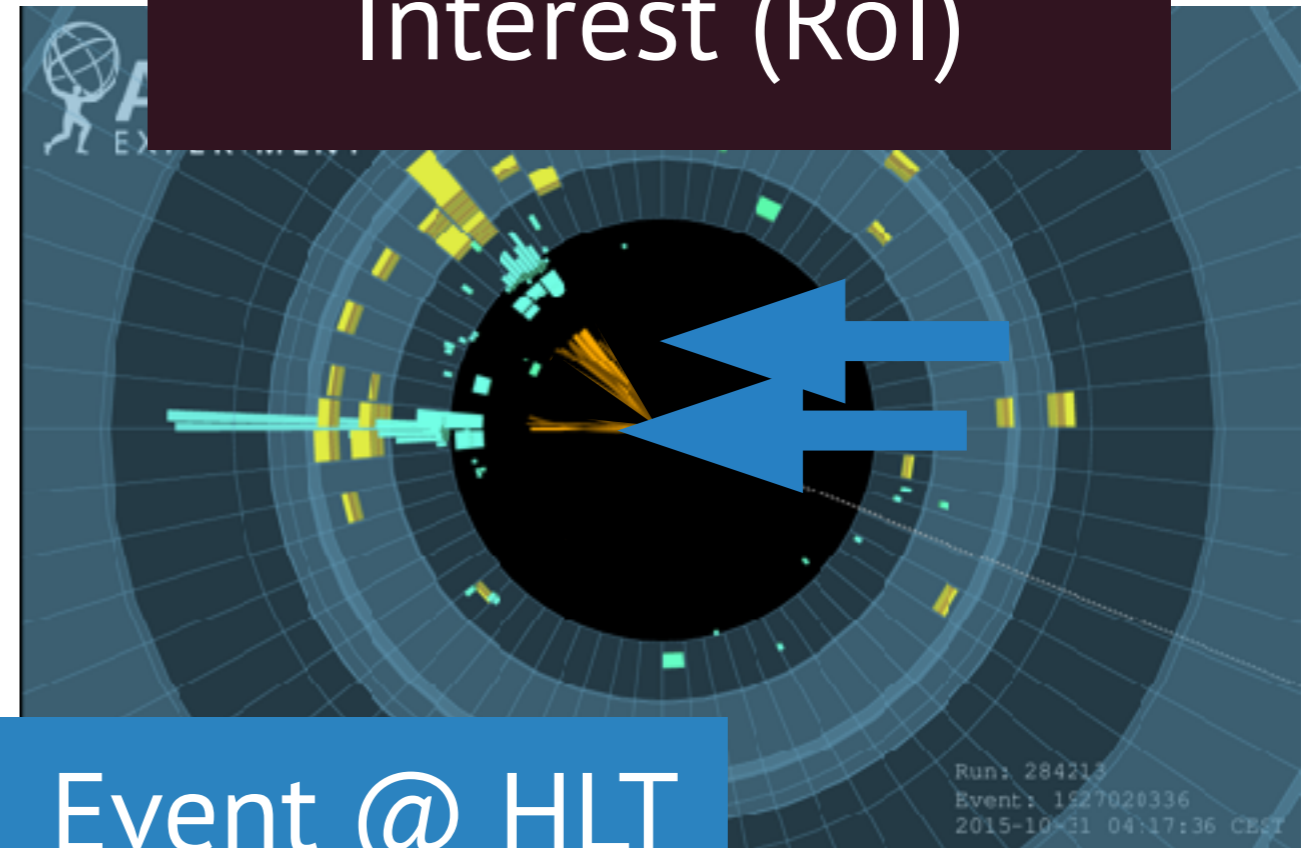
High Level Trigger uses full pre

information around objects identi

Tracking performed
only in Regions of
Interest (RoI)



Event @ L1



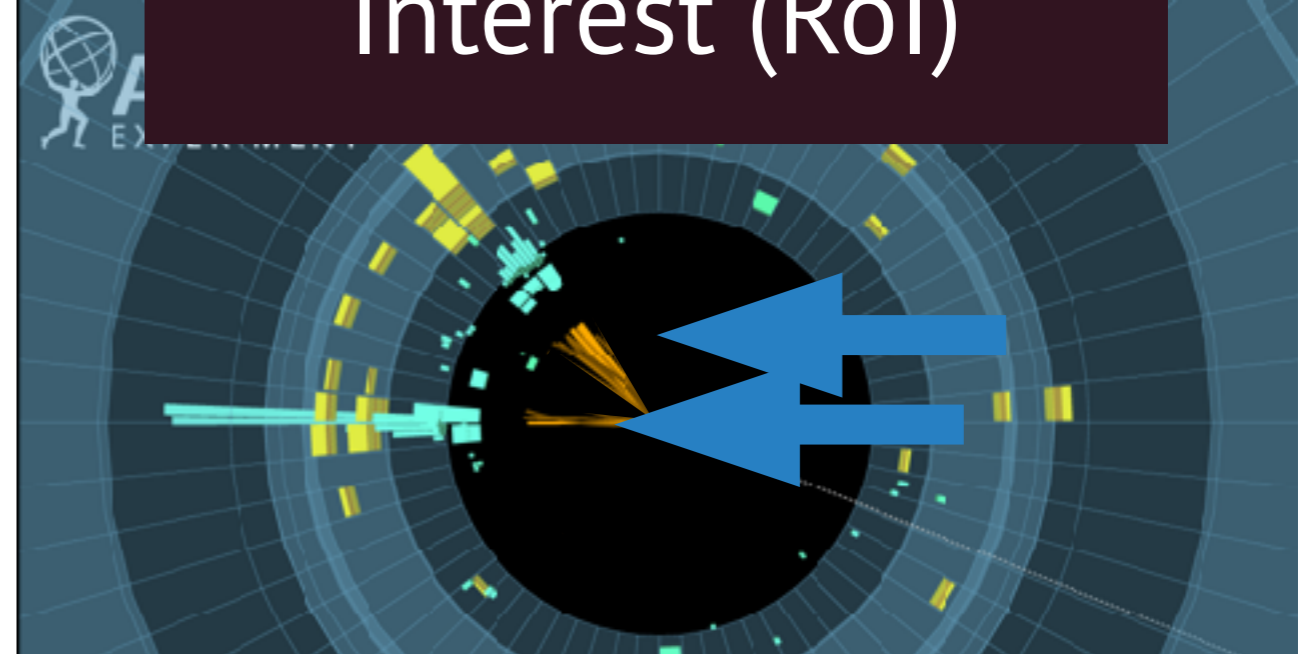
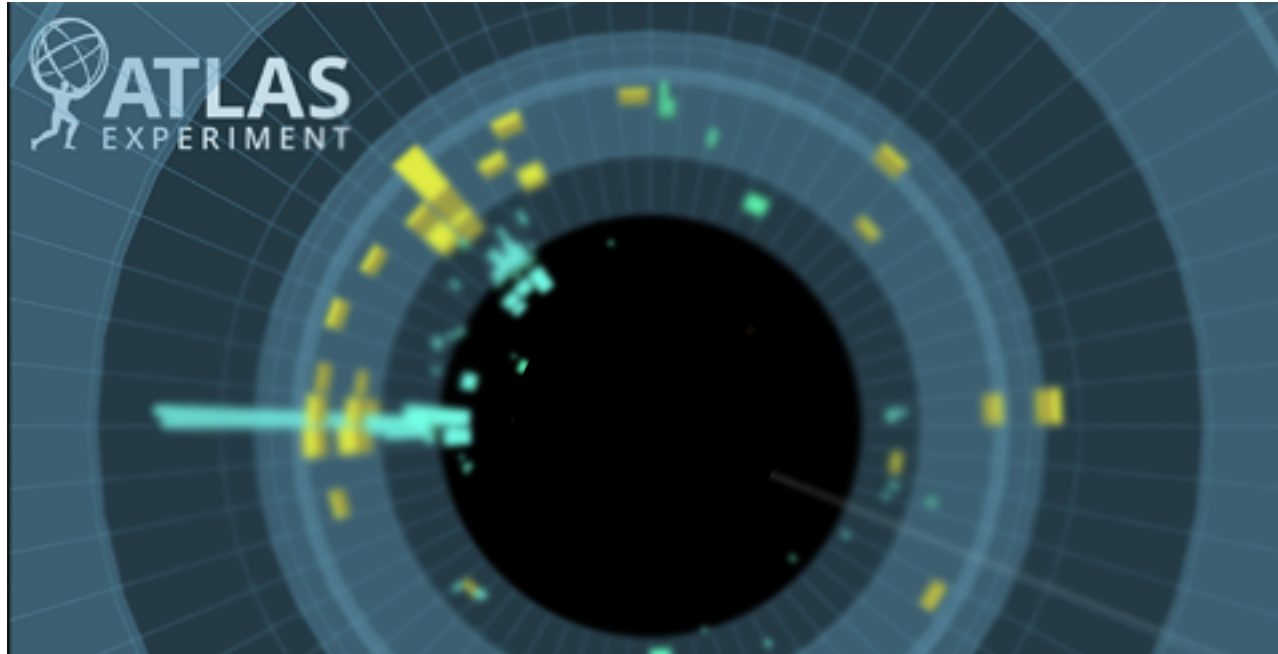
Event @ HLT

Why do we need FTK?

Level 1 trigger decision are made with rough calorimeter and muon information

High Level Trigger uses full pre-tracker information around objects identified

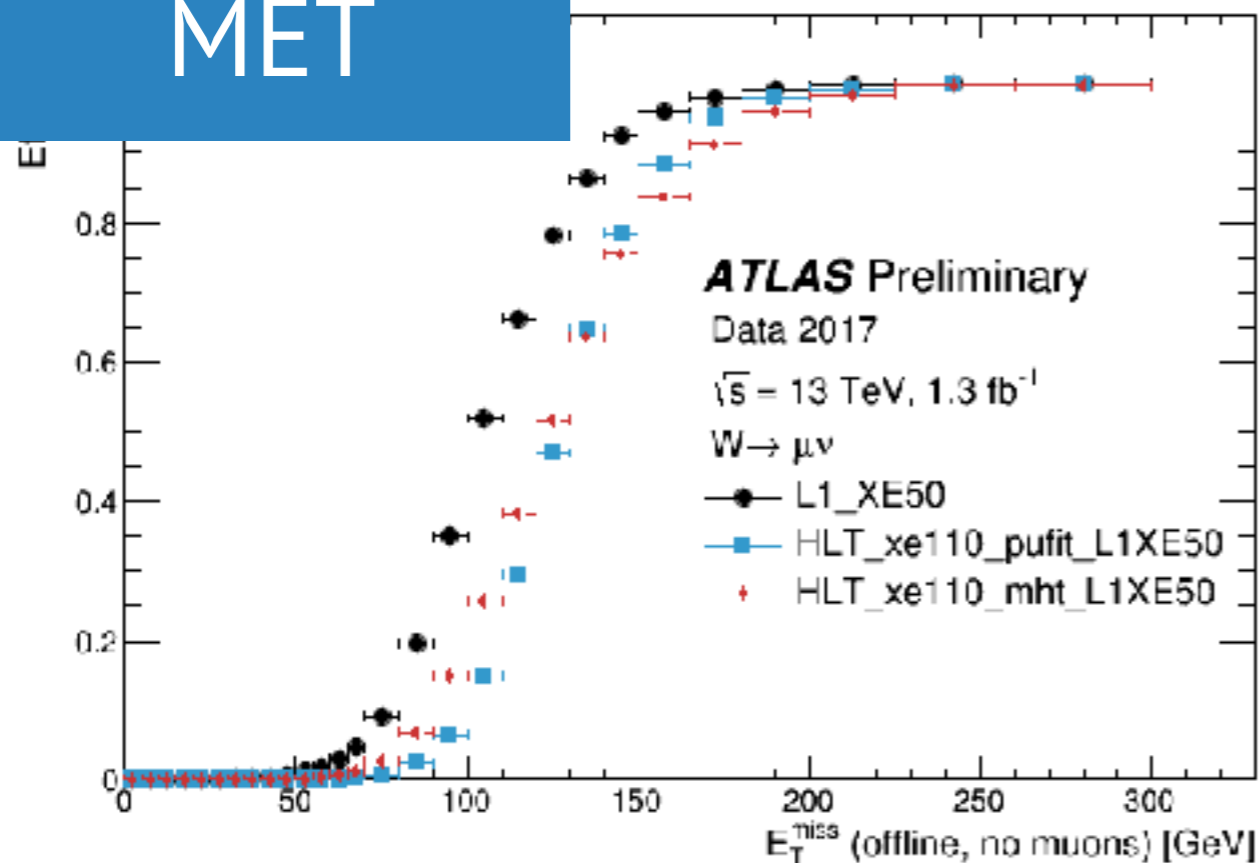
Tracking performed only in Regions of Interest (RoI)



FTK removes the limitation of these Rols

What was FTK designed to look at?

MET



Lowest unscaled MET trigger is at 110 GeV, but **takes until ~200 GeV to become fully efficient**

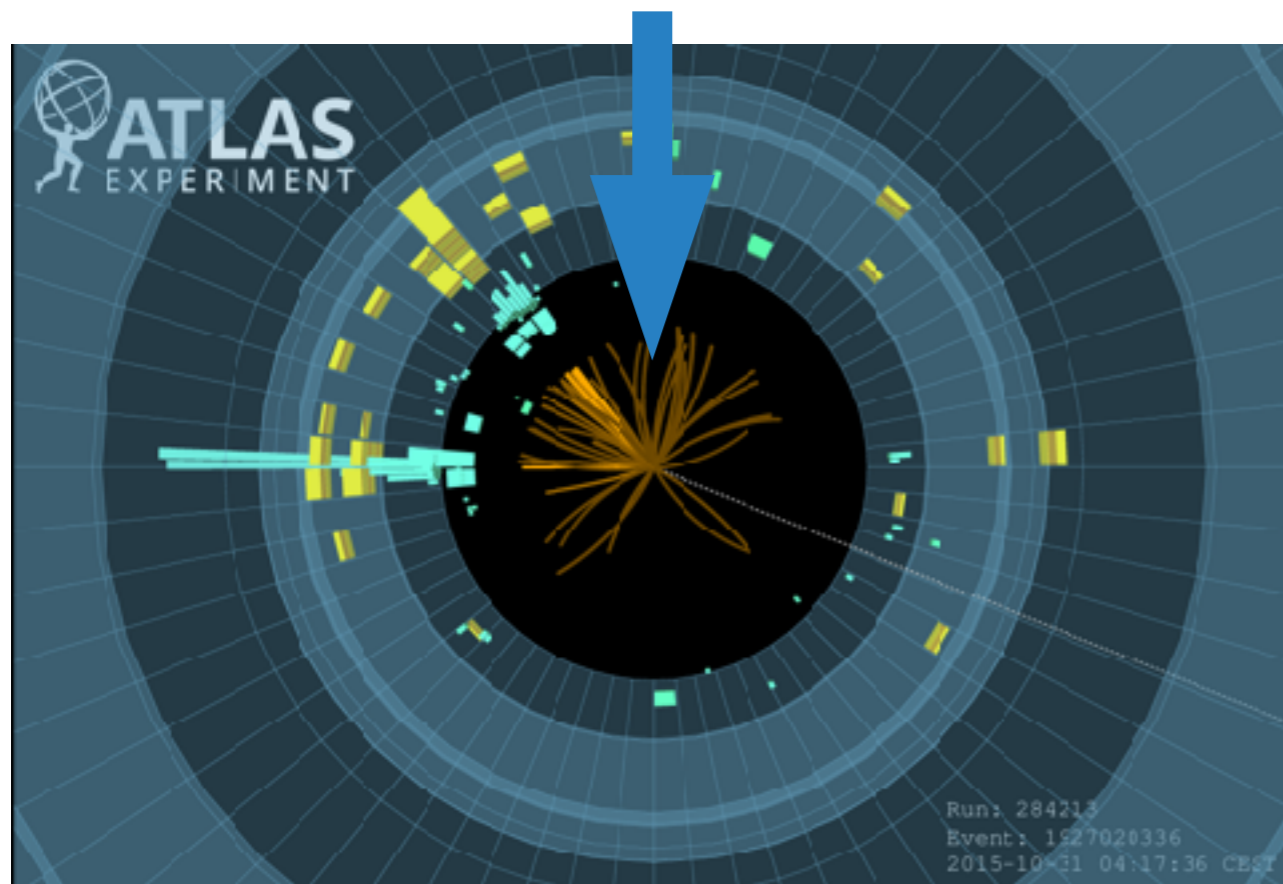
- ▷ high threshold partially due to pile-up
 - ▷ additional hadronic activity contributes to MET soft term (energy unassociated with other objects)
- ▷ tracking lets us identify objects from the primary vertex (and ignore everything else)

What was FTK designed to look at?

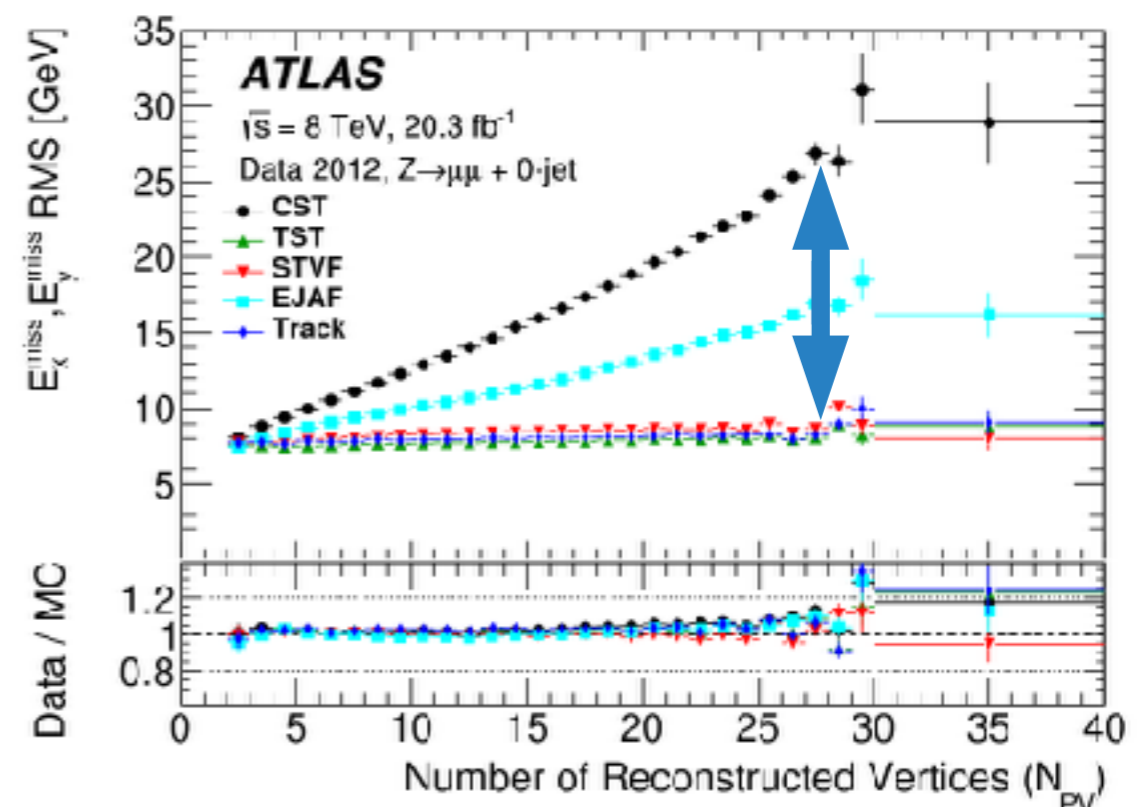
MET

- Offline, tracks are used to construct the MET soft term, nearly eliminating its dependence on pile-up
- FTK can make this possible for the trigger

need this in every event

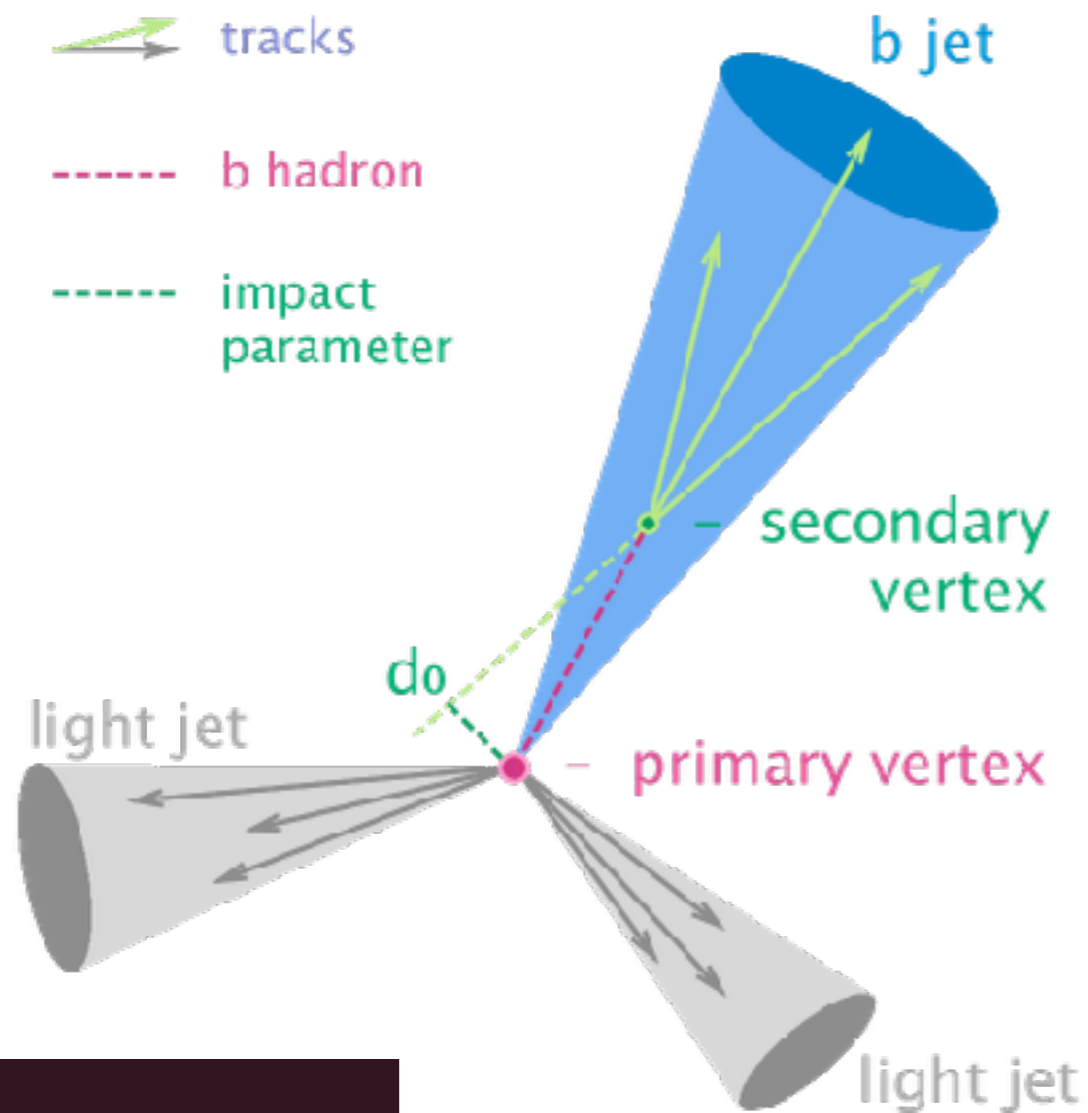


to make an improvement
similar to this

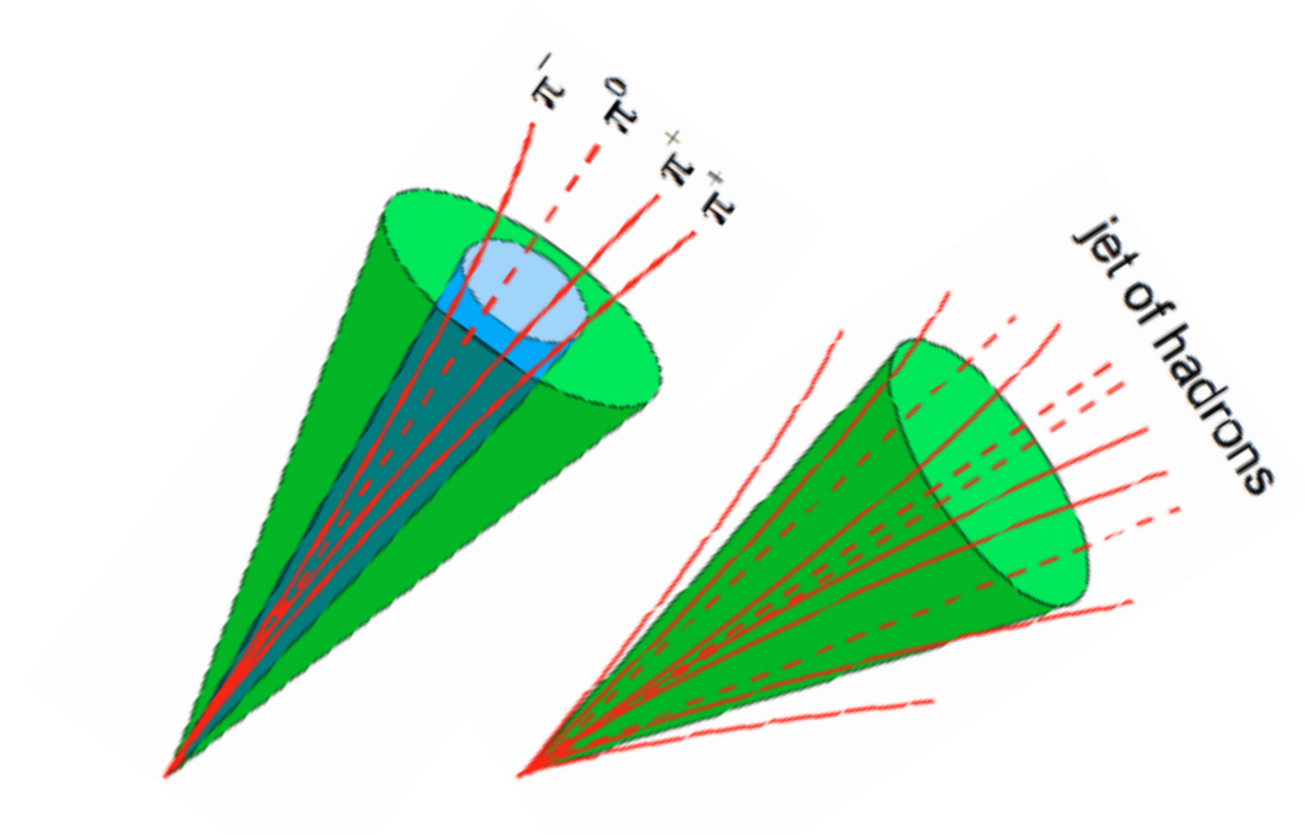


What was FTK designed to look at?

b-jets and τ s



b-jets



hadronic τ s

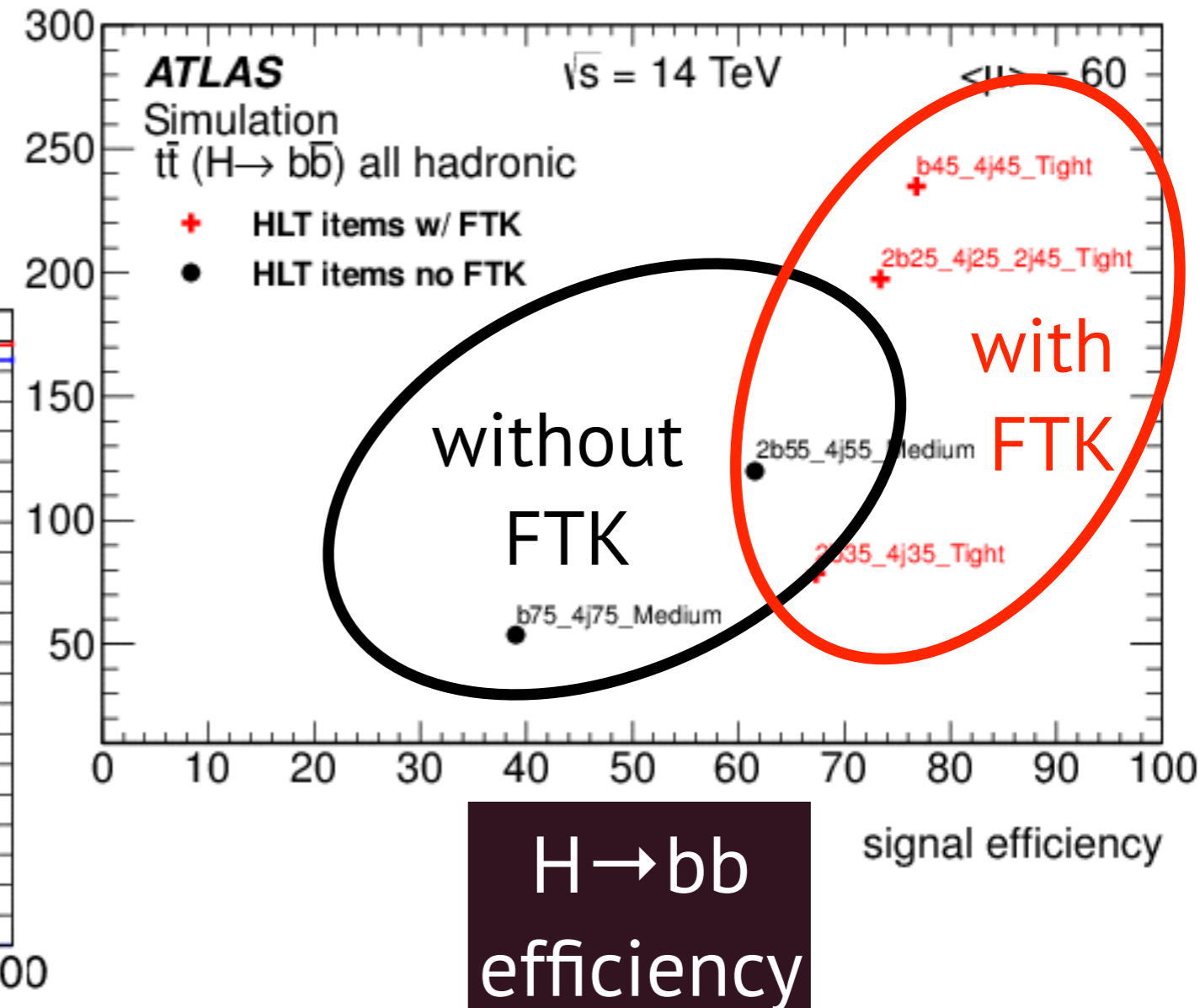
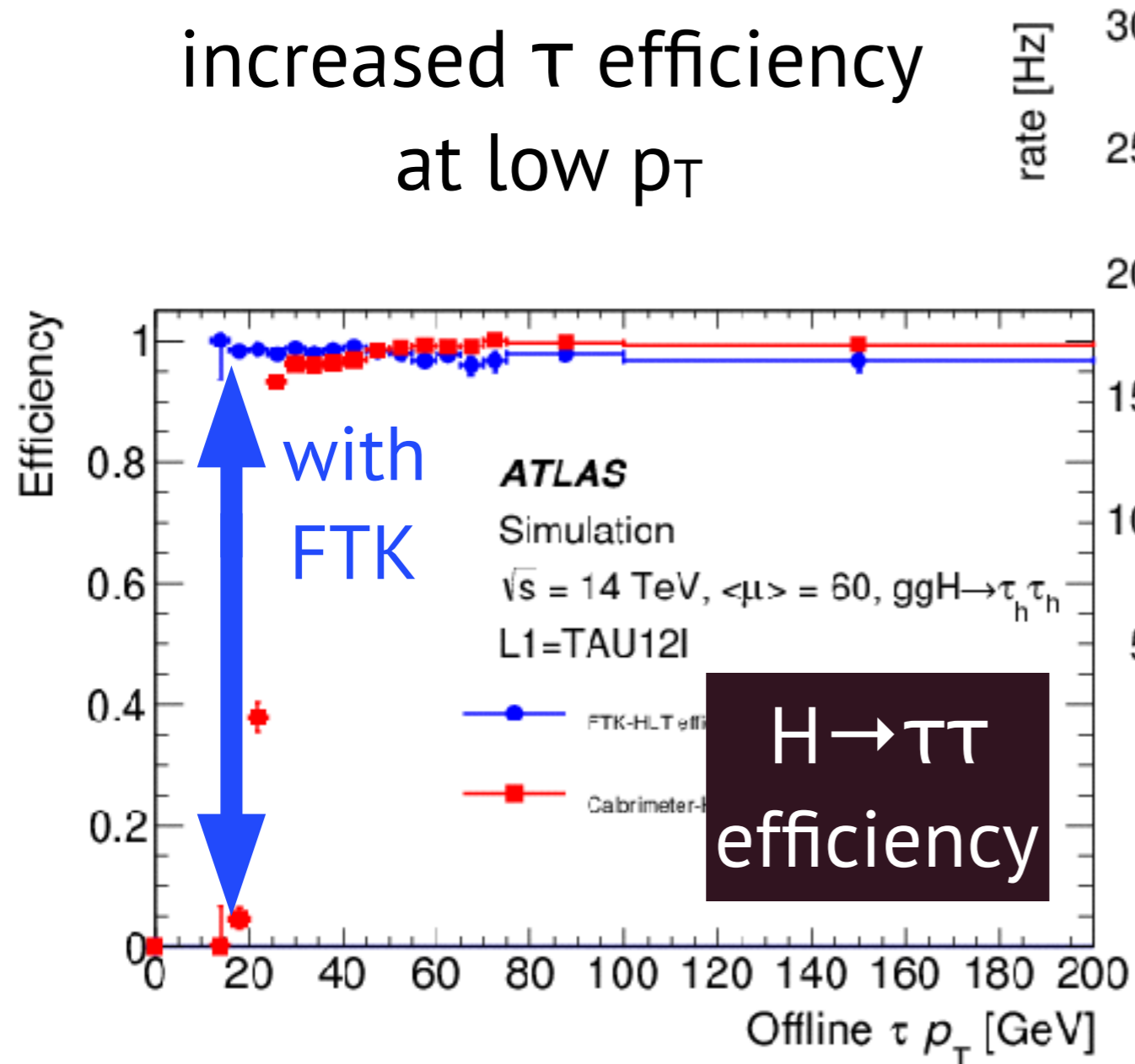
efficient identification of these particles requires tracks

What was FTK designed to look at?

b-jets and τ s

large improvement in
b-tag working points

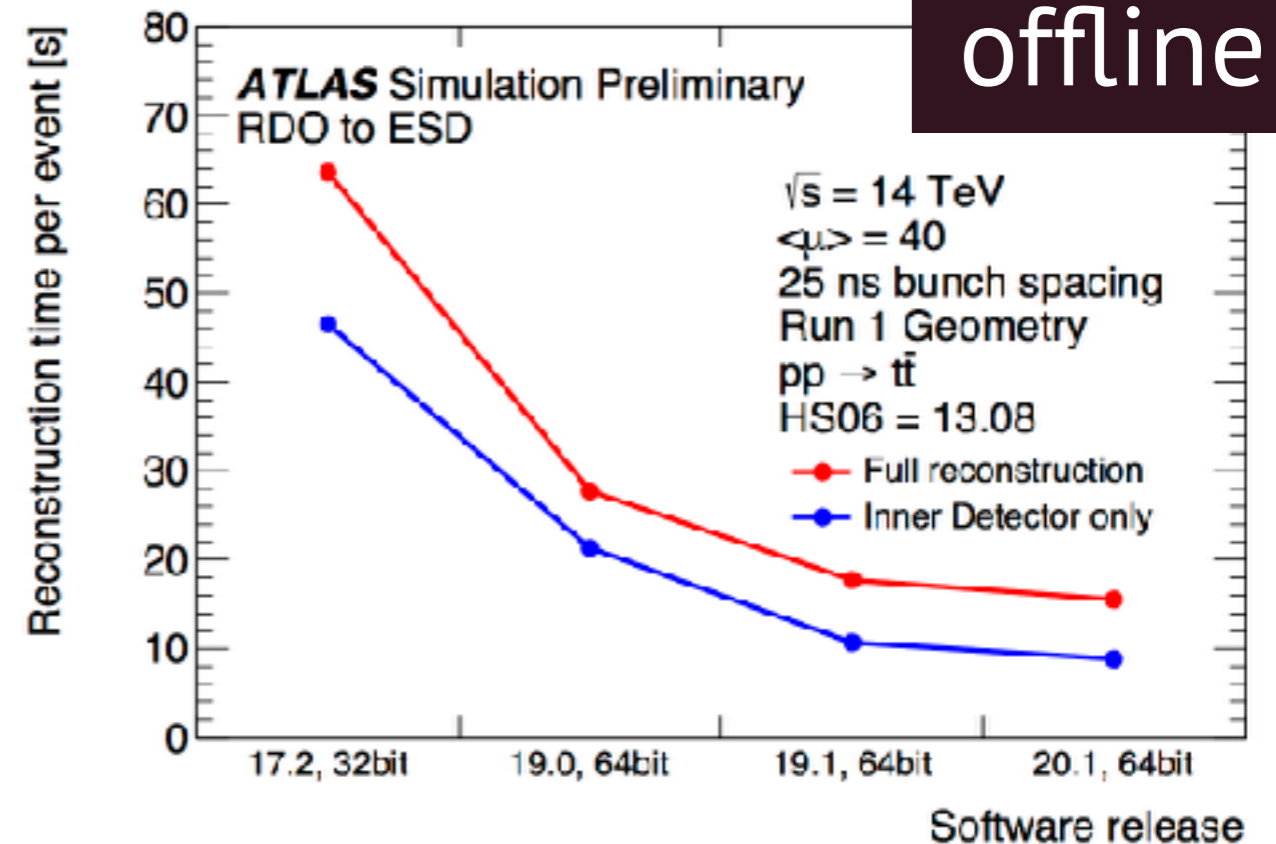
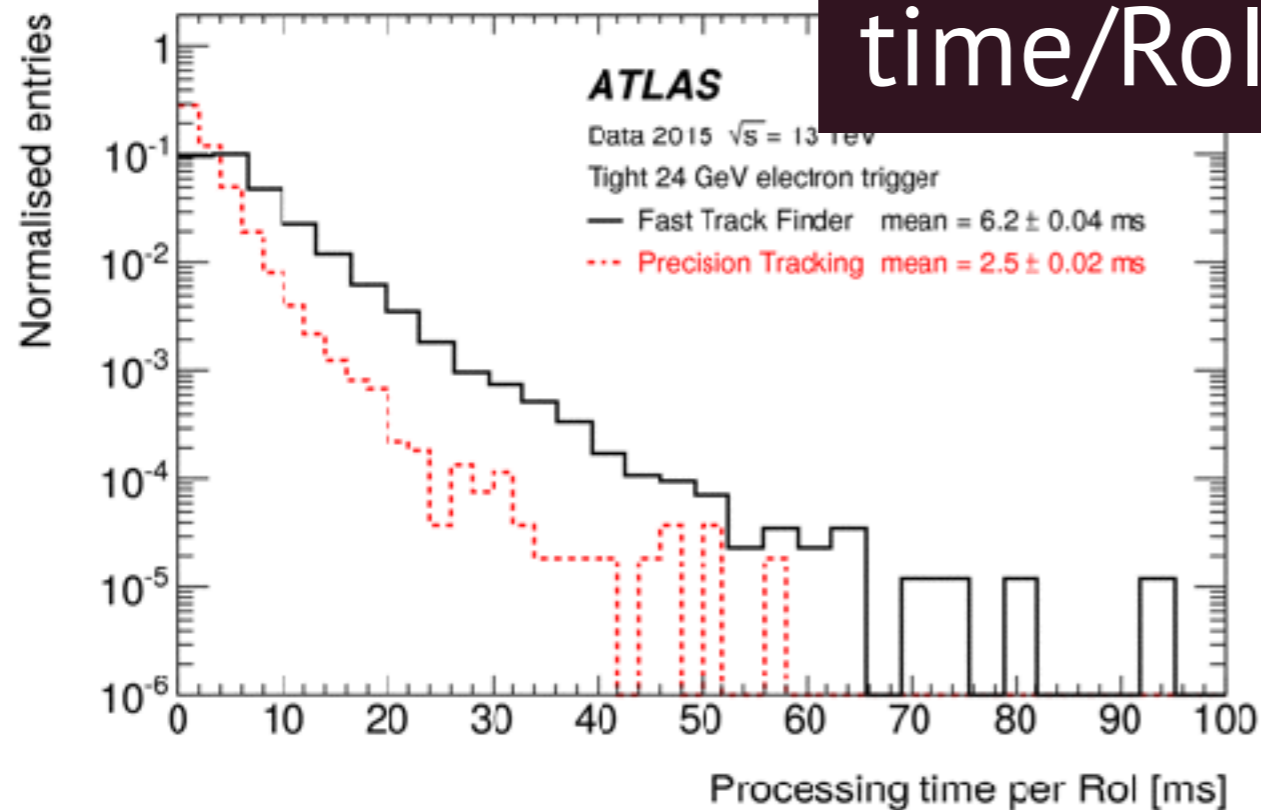
increased τ efficiency
at low p_T



Time constraints

Tracking in an RoI takes on order 10 ms

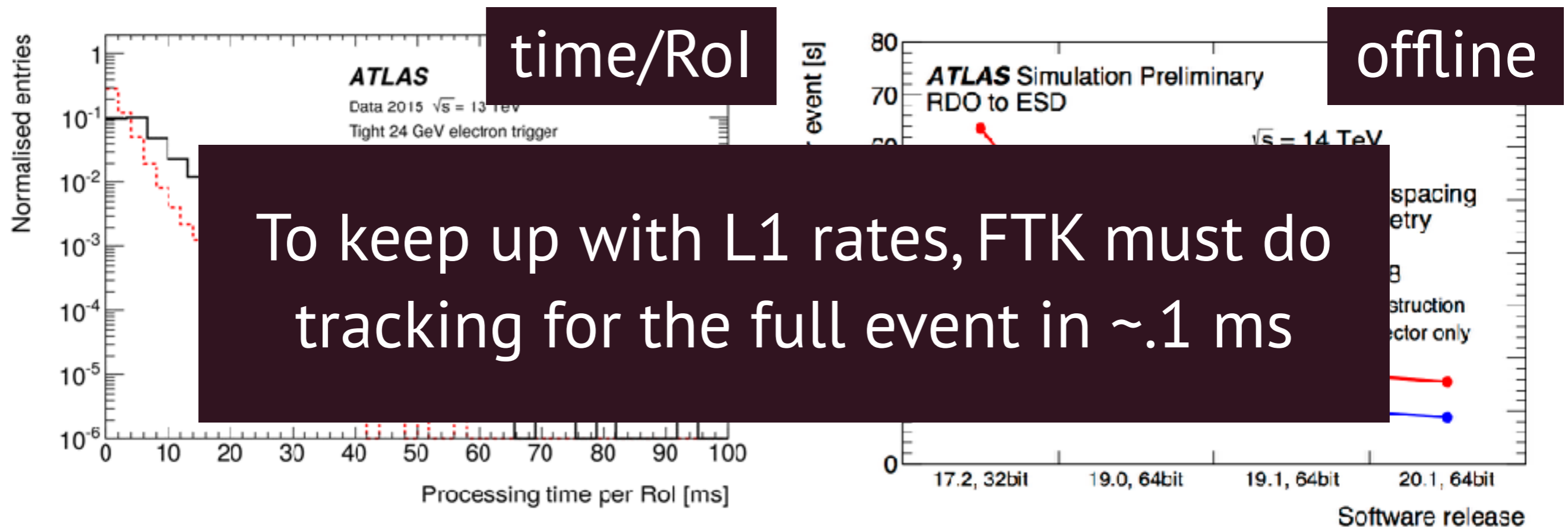
Offline track reconstruction (analysis level) for the full tracking volume requires about 10 s / event



Time constraints

Tracking in an RoI takes on order 10 ms

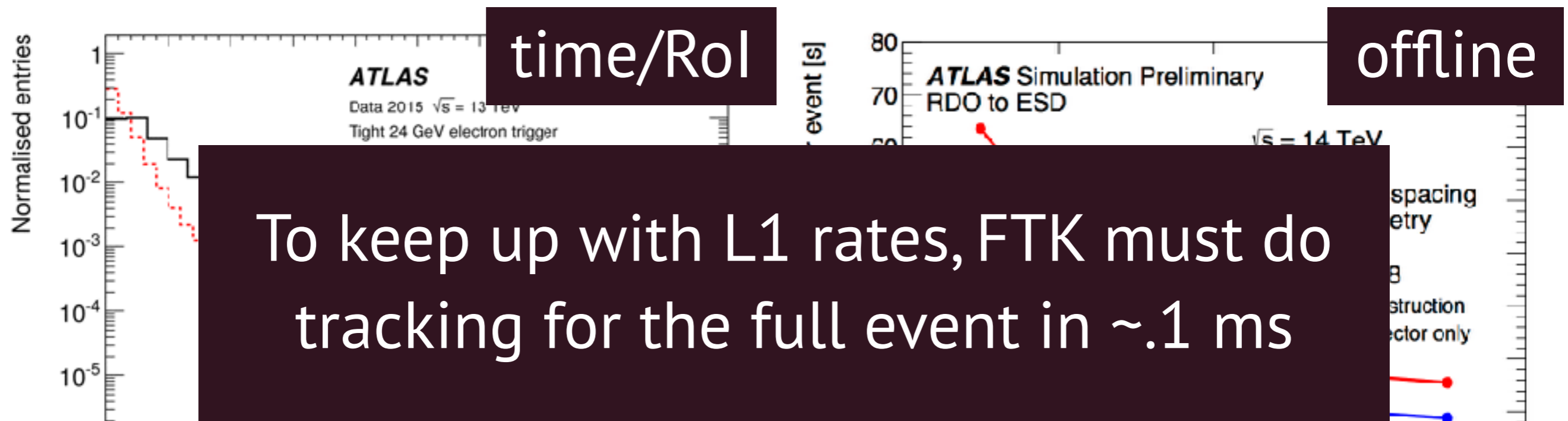
Offline track reconstruction (analysis level) for the full tracking volume requires about 10 s / event



Time constraints

Tracking in an RoI takes on order 10 ms

Offline track reconstruction (analysis level) for the full tracking volume requires about 10 s / event



Requires time reduction of ~ 5 orders of magnitude



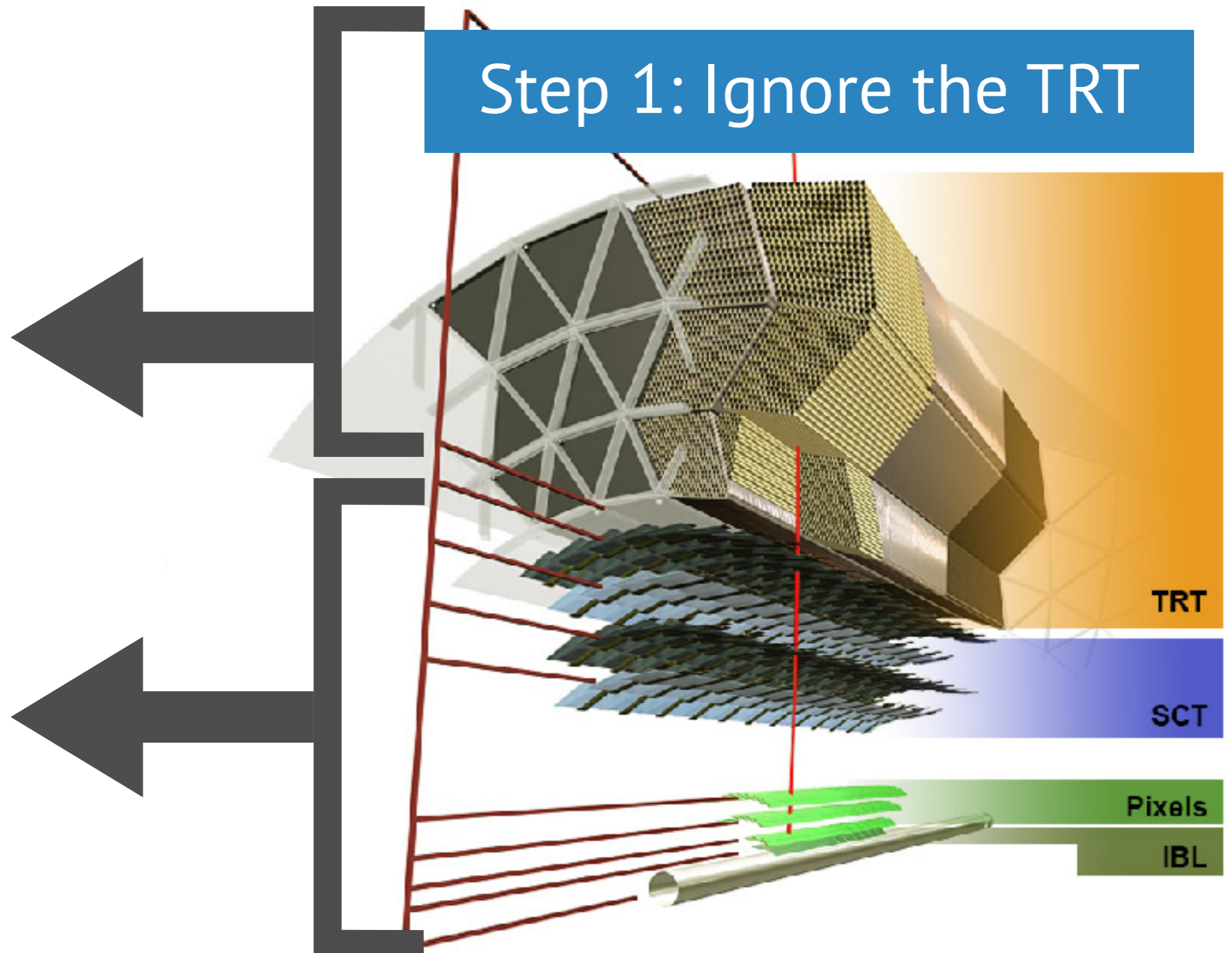
**HOW CAN WE TRACK
THAT FAST?**

Making Tracking a Simpler Problem

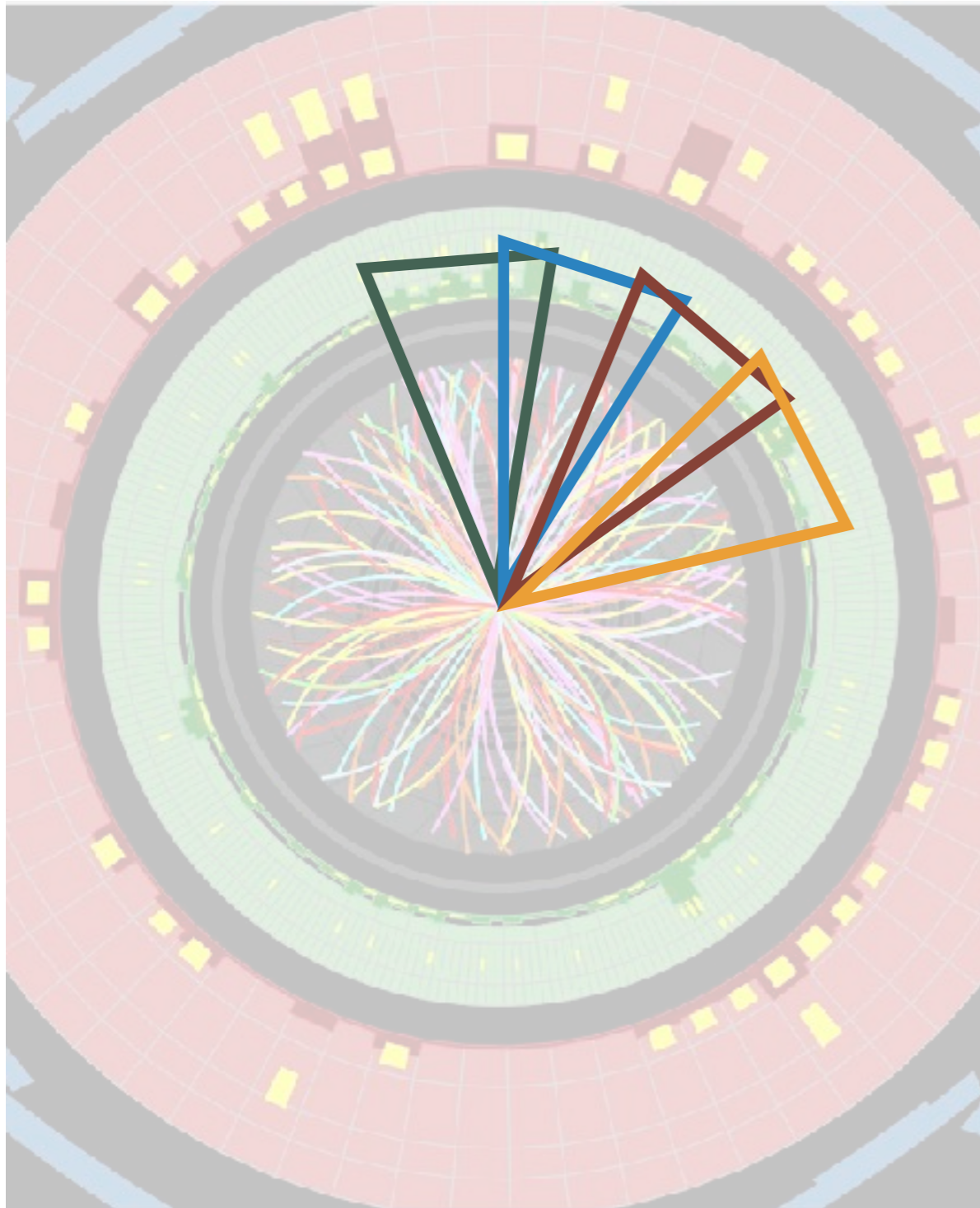
Step 1: Ignore the TRT

Straight to
HLT

Split signals
go to HLT
and FTK



Making Tracking a Simpler Problem



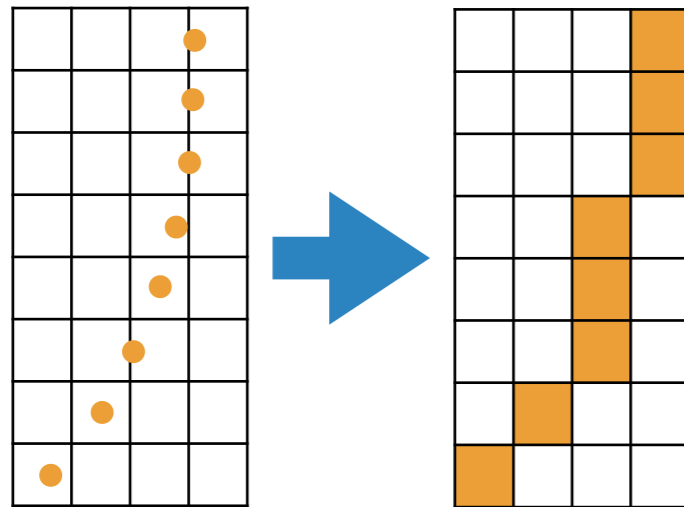
Step 2: Parallelize

Divide the barrel into
64 overlapping towers

Send data from each tower
to separate processing units

Making Tracking a Simpler Problem

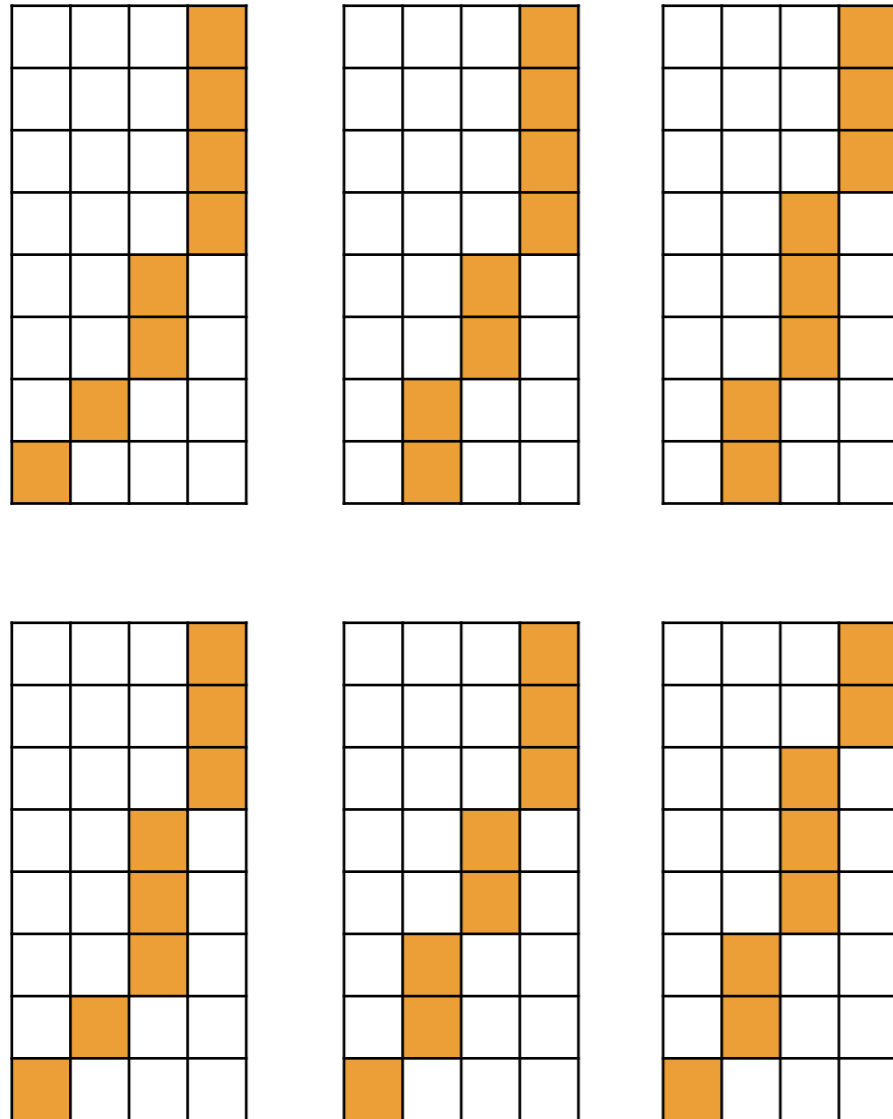
Step 3: Pattern Match



Divide each layer into
coarse chunks

Making Tracking a Simpler Problem

Step 3: Pattern Match

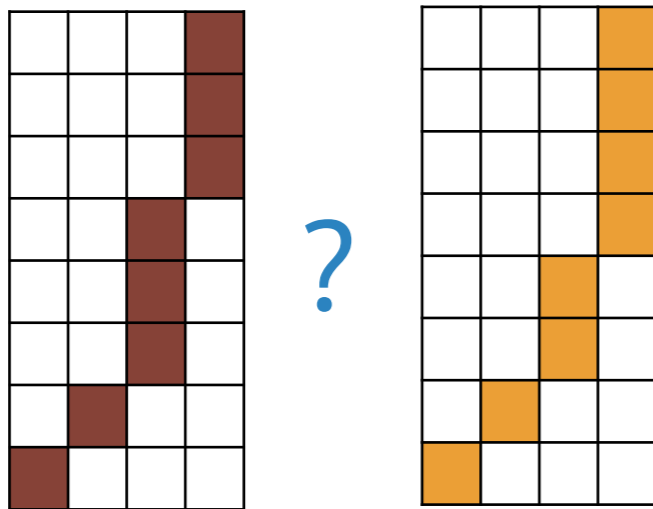


Divide each layer into
coarse chunks

Define patterns of these
chunks that correspond
to tracks

Making Tracking a Simpler Problem

Step 3: Pattern Match



Divide each layer into coarse chunks

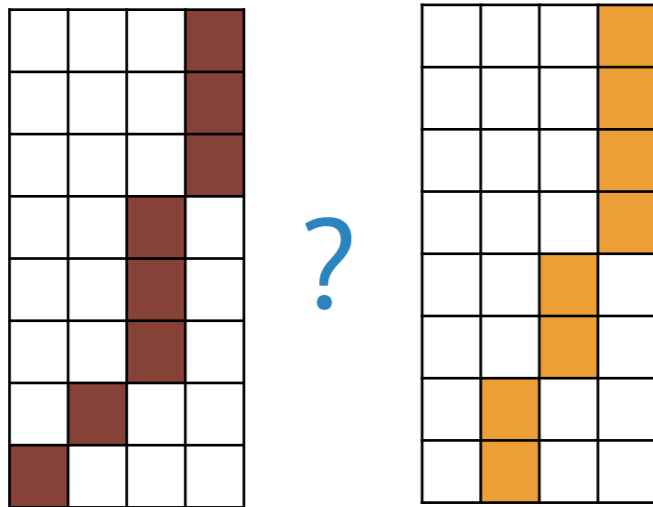
Define patterns of these chunks that correspond to tracks

Compare fired patterns to a stored bank of track-like patterns



Making Tracking a Simpler Problem

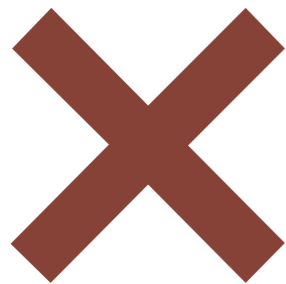
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Divide each layer into coarse chunks

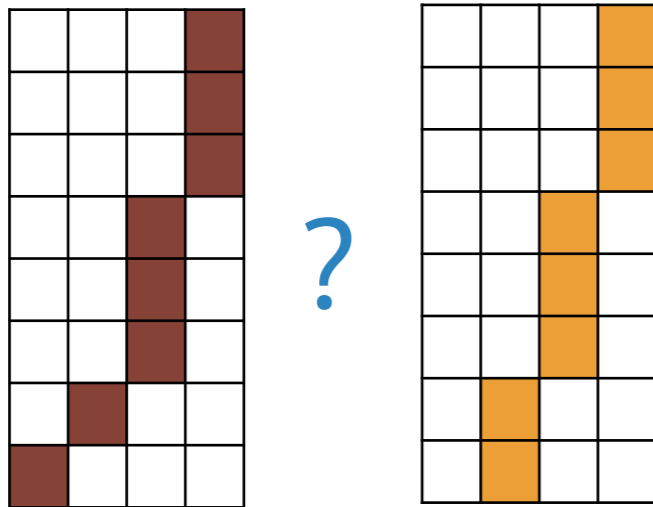
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Making Tracking a Simpler Problem

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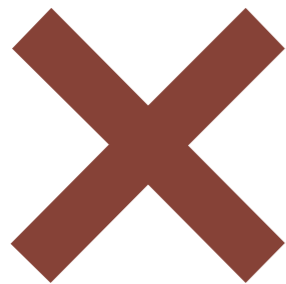
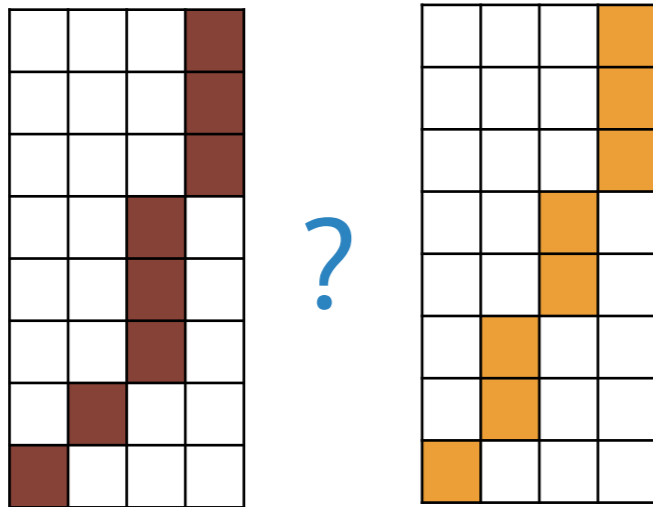
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Making Tracking a Simpler Problem

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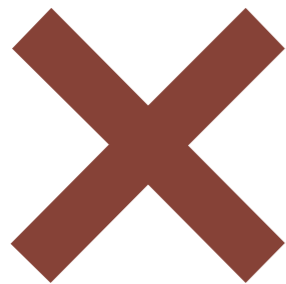
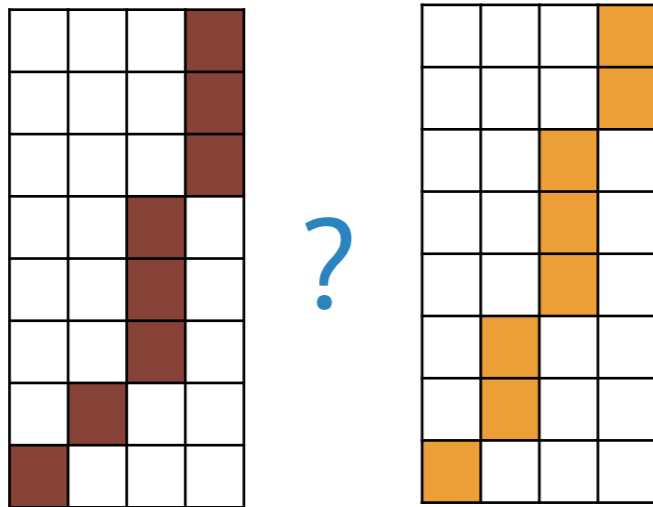
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Making Tracking a Simpler Problem

Step 3: Pattern Match



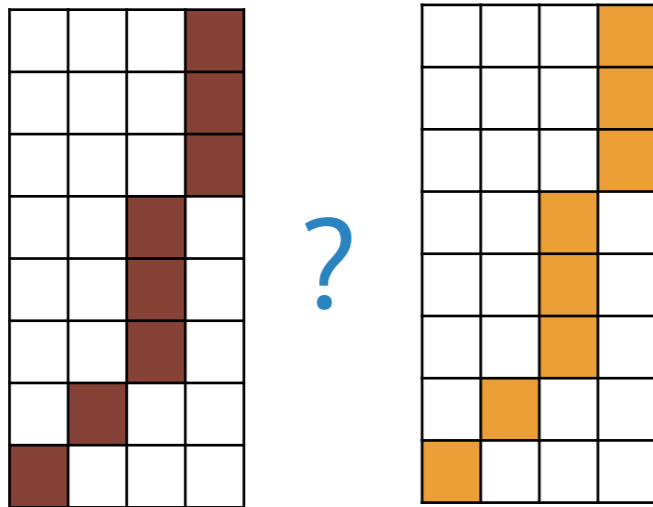
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Making Tracking a Simpler Problem

Step 3: Pattern Match

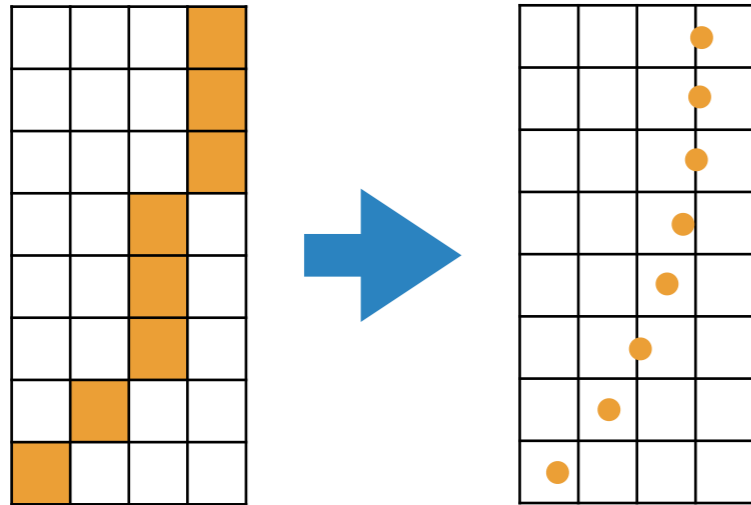


Divide each layer into coarse chunks

Define patterns of these chunks that correspond to tracks

Compare fired patterns to a stored bank of track-like patterns

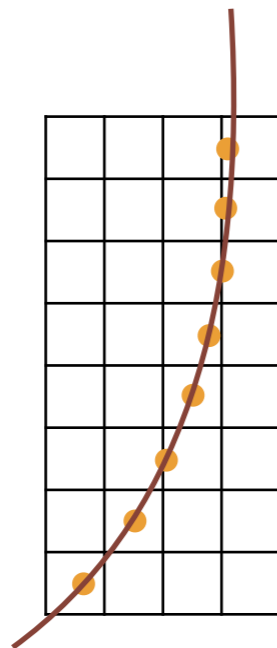
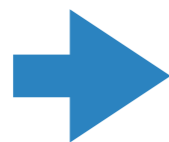
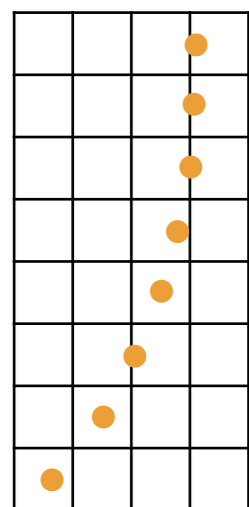
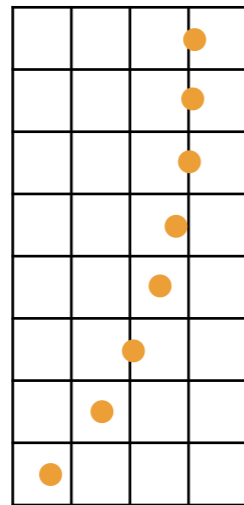
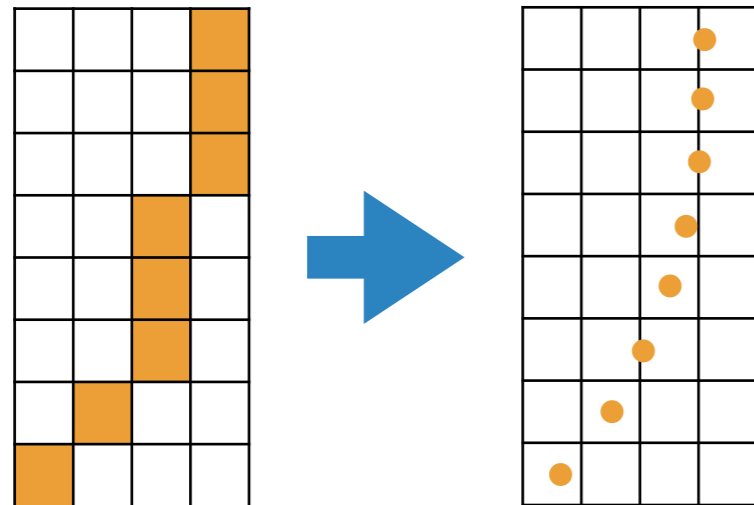
Making Tracking a Simpler Problem



Step 4: Fit a Subset

For matched patterns,
retrieve the full resolution hits

Making Tracking a Simpler Problem



Step 4: Fit a Subset

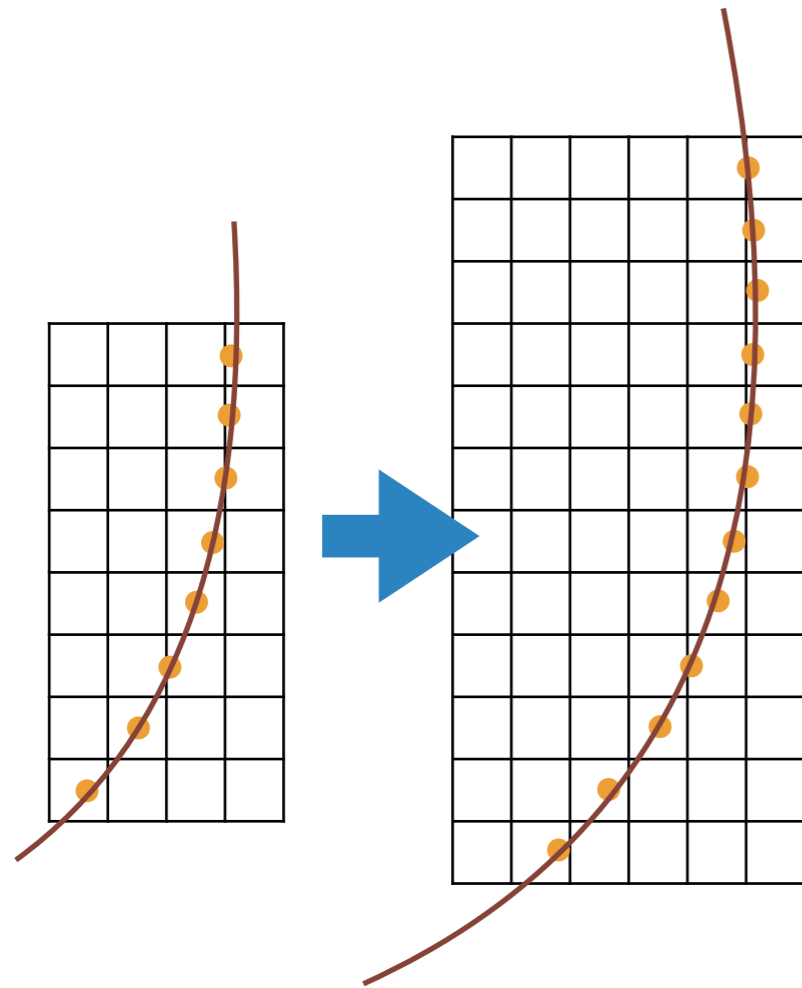
For matched patterns,
retrieve the full resolution hits

Perform a linearized fit
on the hits in 8 layers

Keep tracks passing a χ^2 cut

Making Tracking a Simpler Problem

Step 4: Final Fit

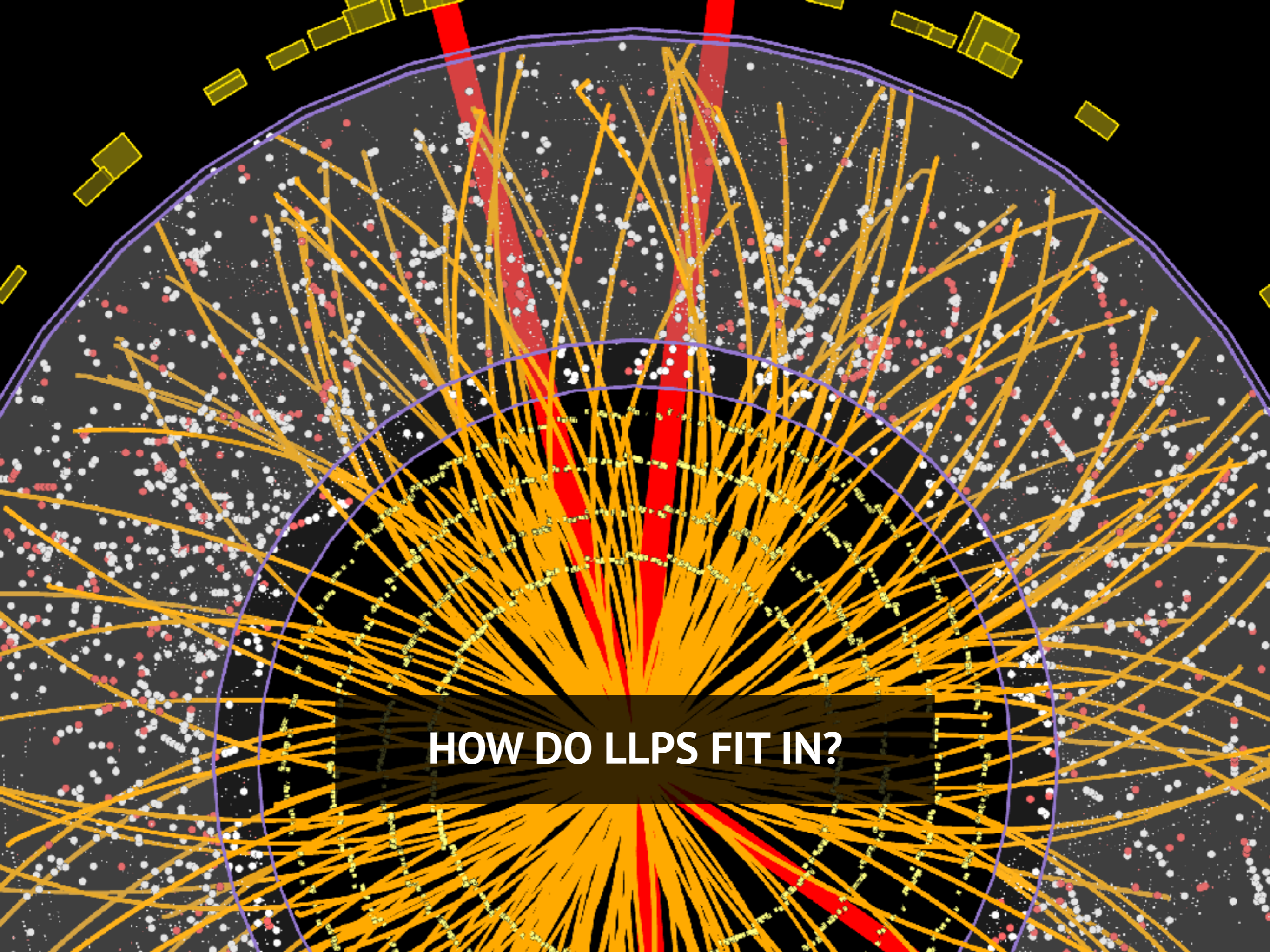


Extrapolate the 8-layer tracks to find additional hits

Refit in all 12 layers

Keep tracks passing a χ^2 cut

Send the resulting tracks to HLT

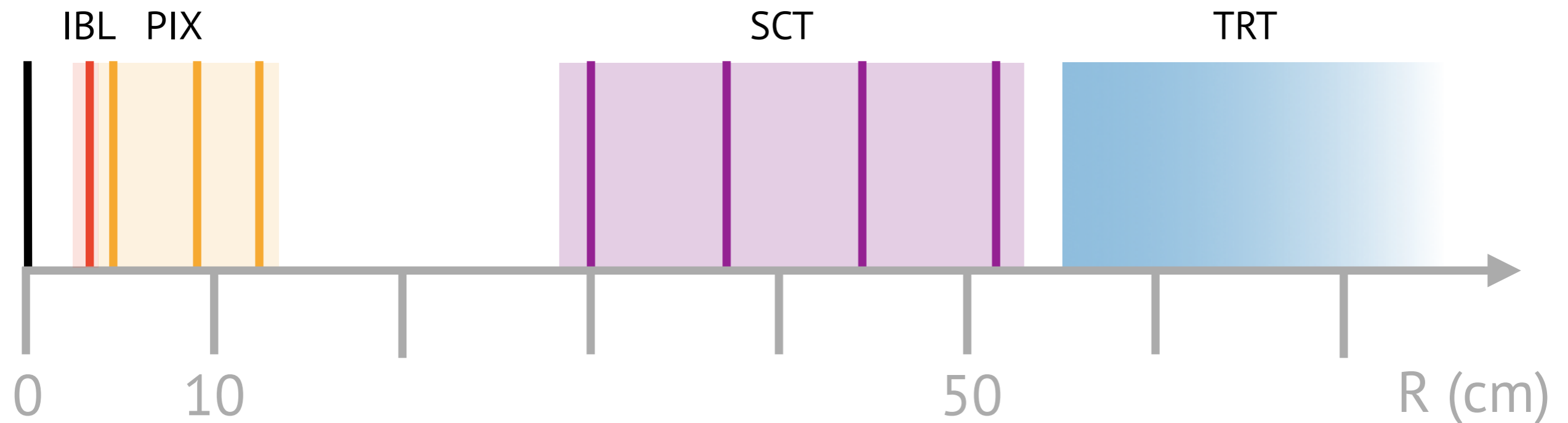


HOW DO LLPS FIT IN?

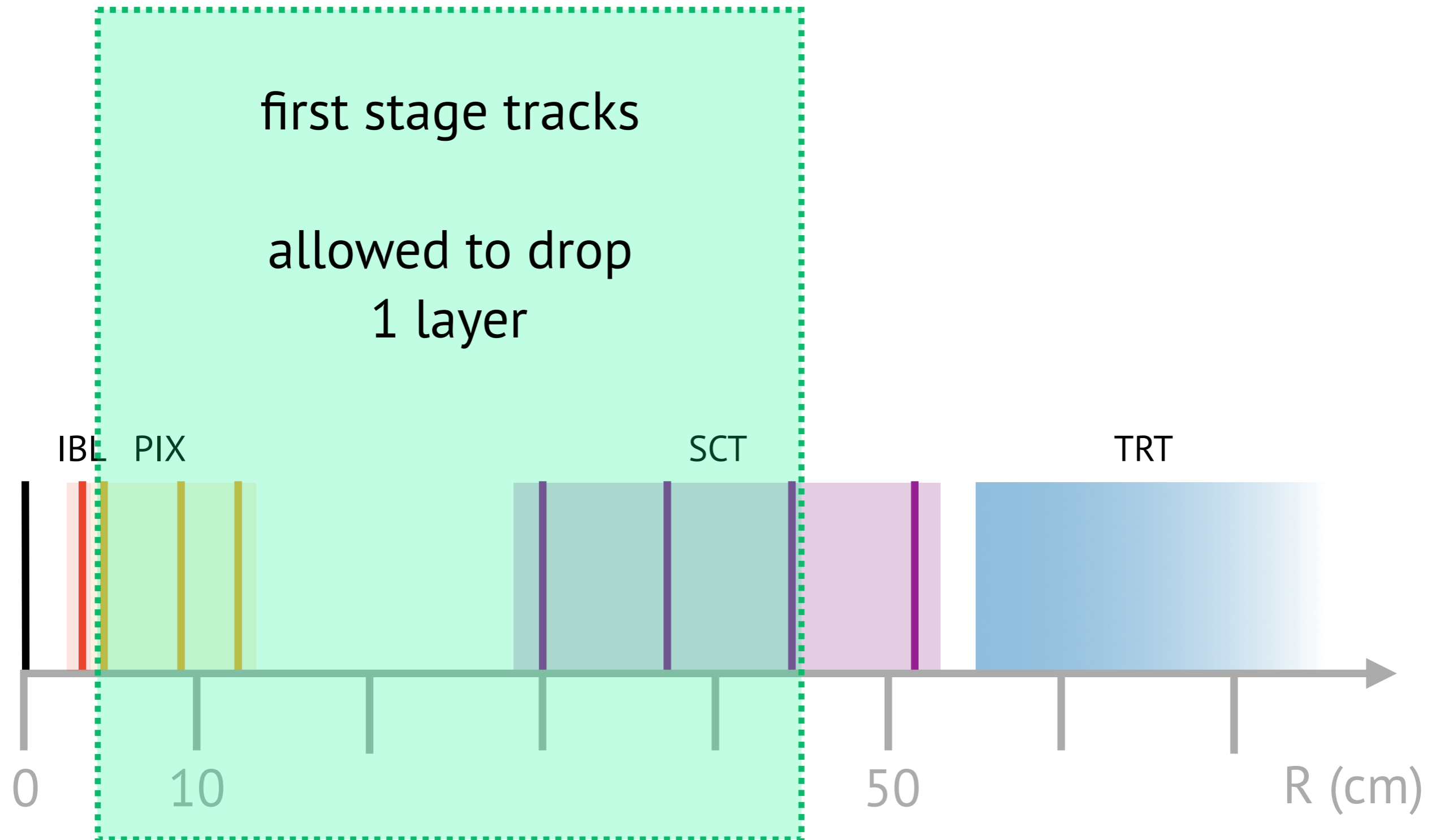
Can this work for LLPs?

Looking directly at LLPs

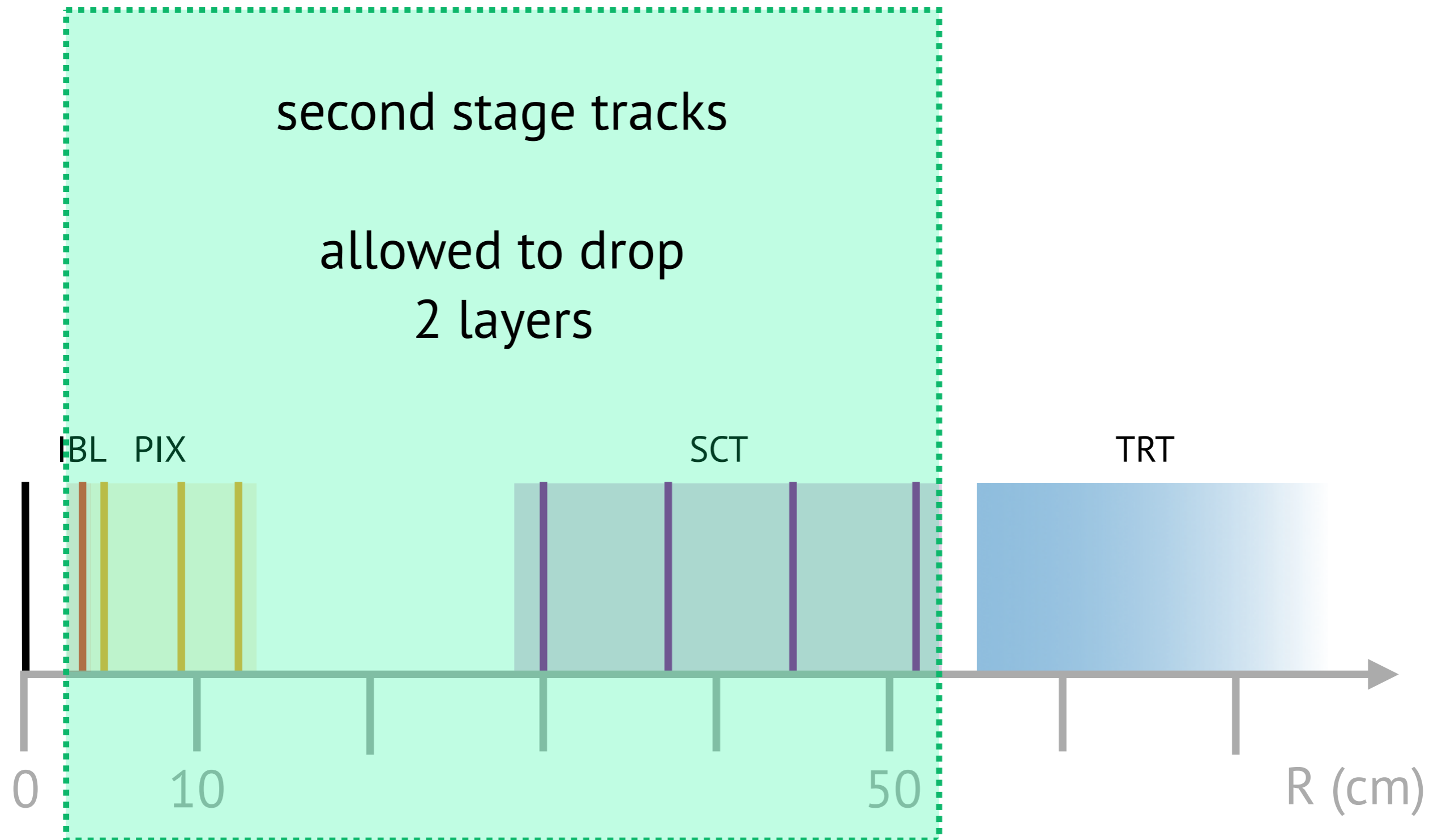
What are the physical limitations of FTK?



Can this work for LLPs?



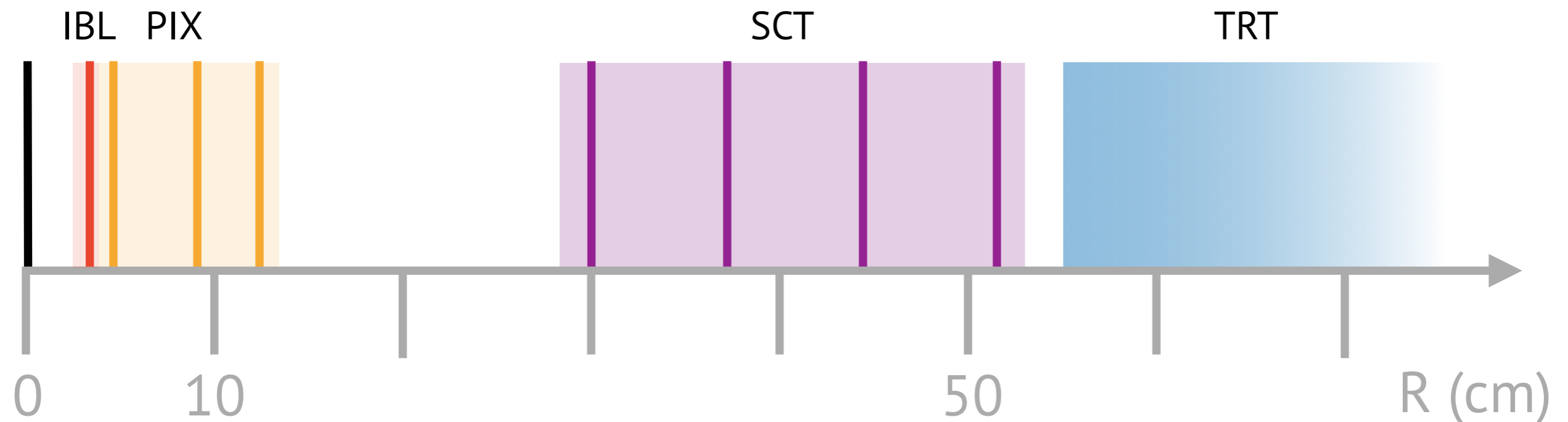
Can this work for LLPs?



Can this work for LLPs?

disappearing tracks

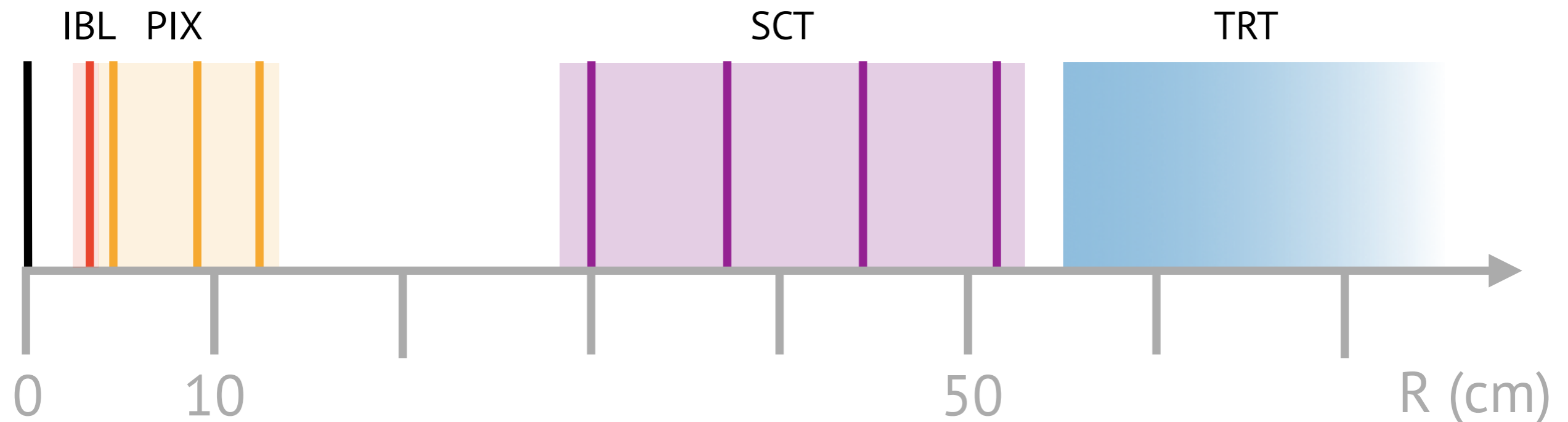
- ▷ anything that decays outside SCT is fine (> 55 cm)
- ▷ reduced efficiency down to ~ 44 cm
- ▷ impossible for decays before that



Can this work for LLPs?

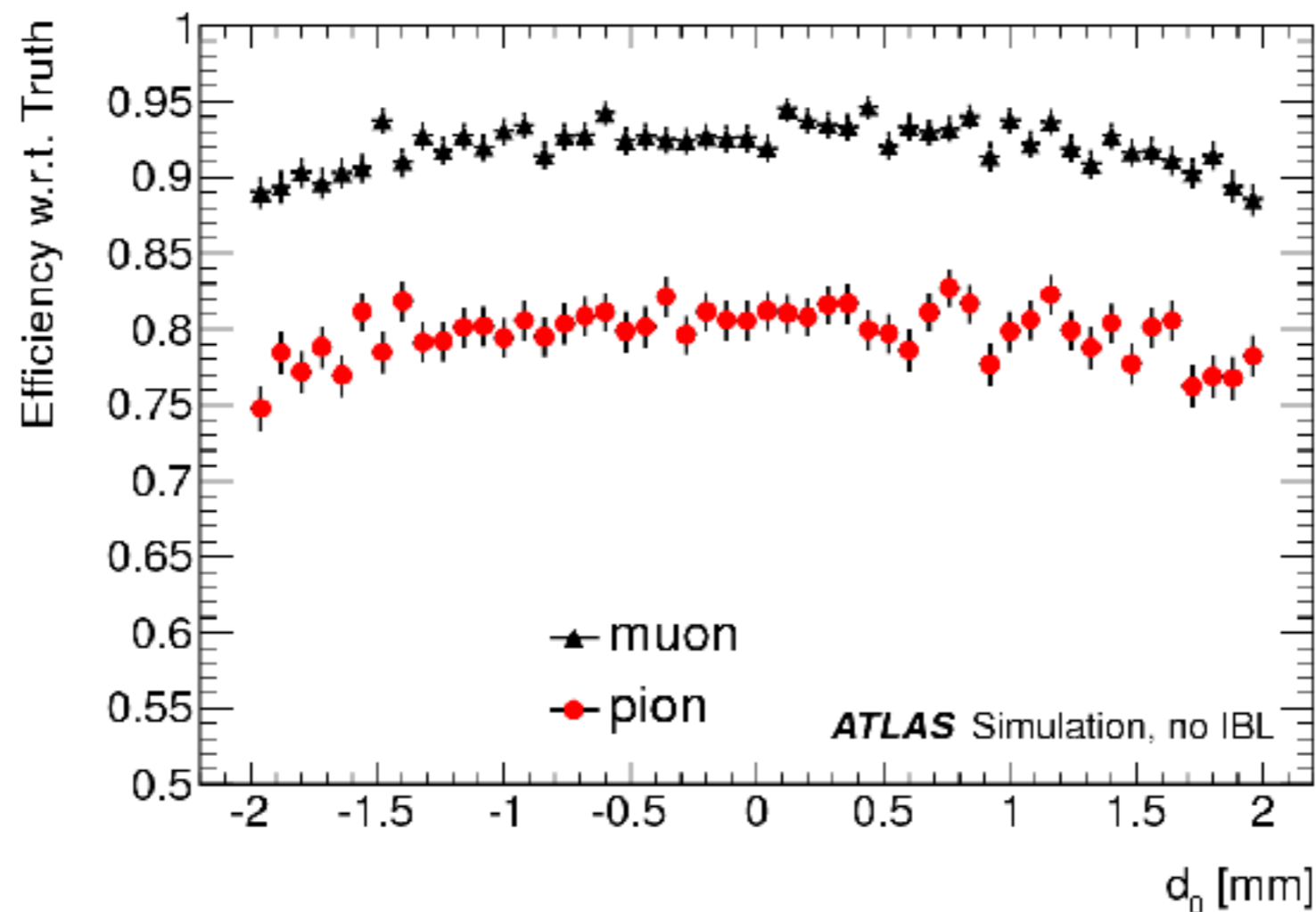
displaced tracks

- ▷ no necessary loss for tracks starting within 3 cm
- ▷ drops in efficiency at 5 cm and 9 cm
- ▷ impossible after 12 cm



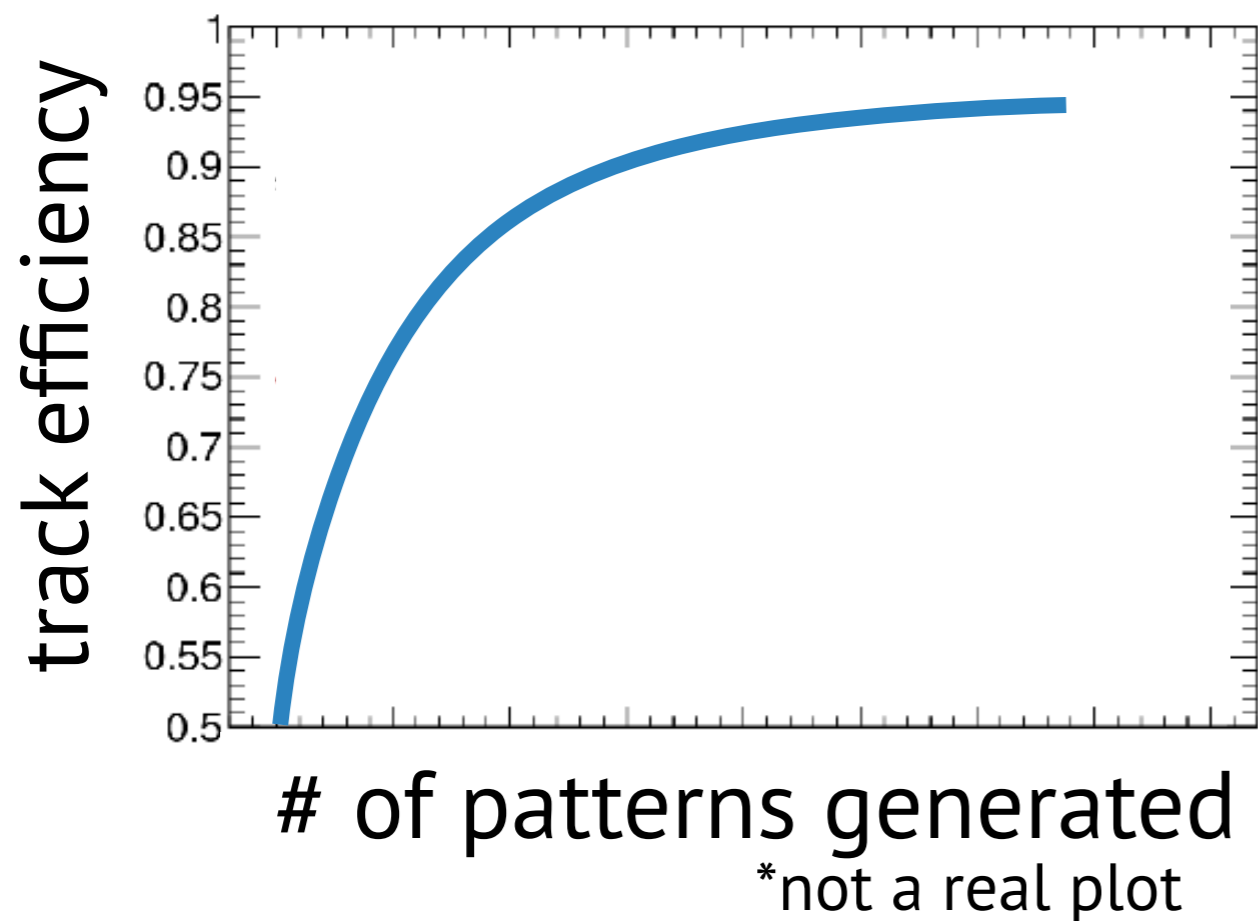
Can this work for LLPs?

What about pattern bank efficiency?



- ▷ pattern banks are generated to have b-jet-like coverage, optimized for $d_0 < 2\text{mm}$

Can this work for LLPs?



- ▷ this is not set in stone
- ▷ very small gains in coverage from the last 10% of patterns
 - ▷ discussions of using this for special signatures
- ▷ if we want it for ourselves, we need to push for it!

Can this work for LLPs?

To answer the question – YES!



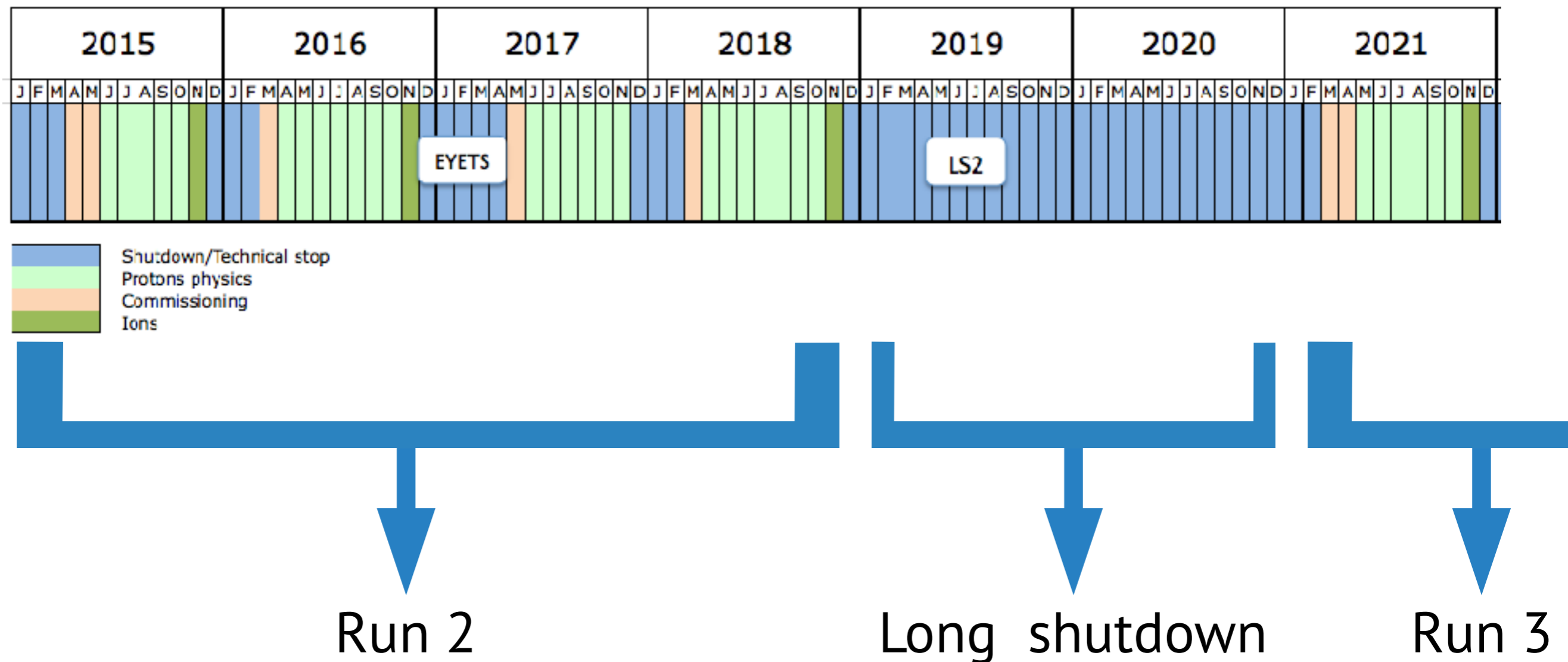
We just need to get everyone excited about it!



**WHEN WILL FTK BE
AVAILABLE?**

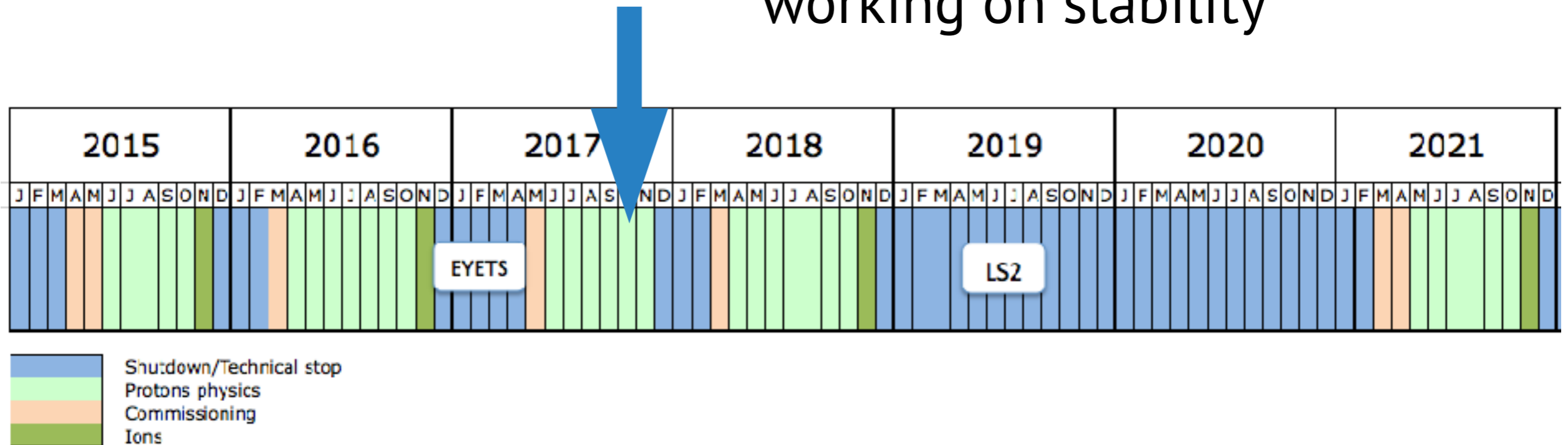
Timescale goals

This is the LHC's plan:



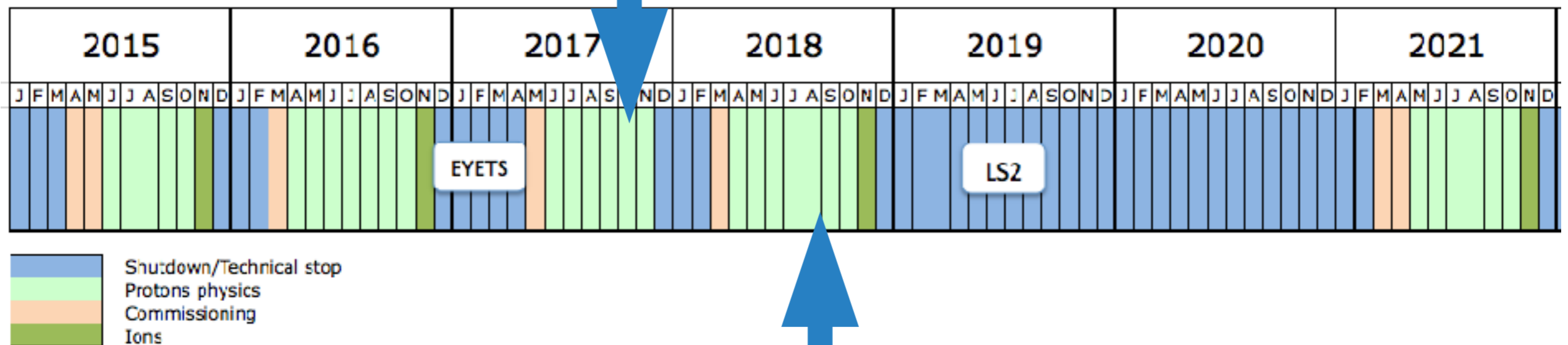
Timescale goals

now: FTK commissioning,
working on stability



Timescale goals

now: FTK commissioning,
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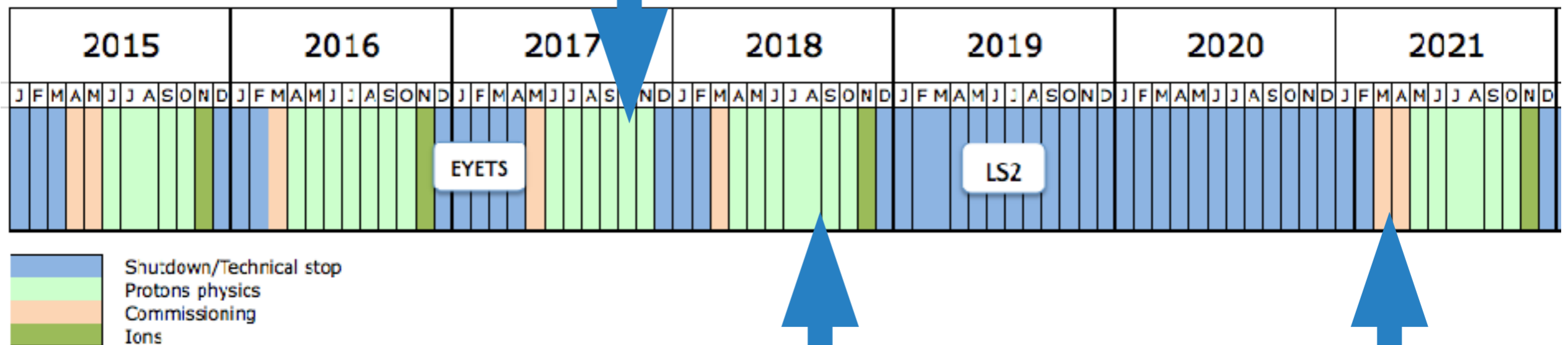
2018:

installation of full system

partial integration (limited coverage)

Timescale goals

now: FTK commissioning,
working on stability

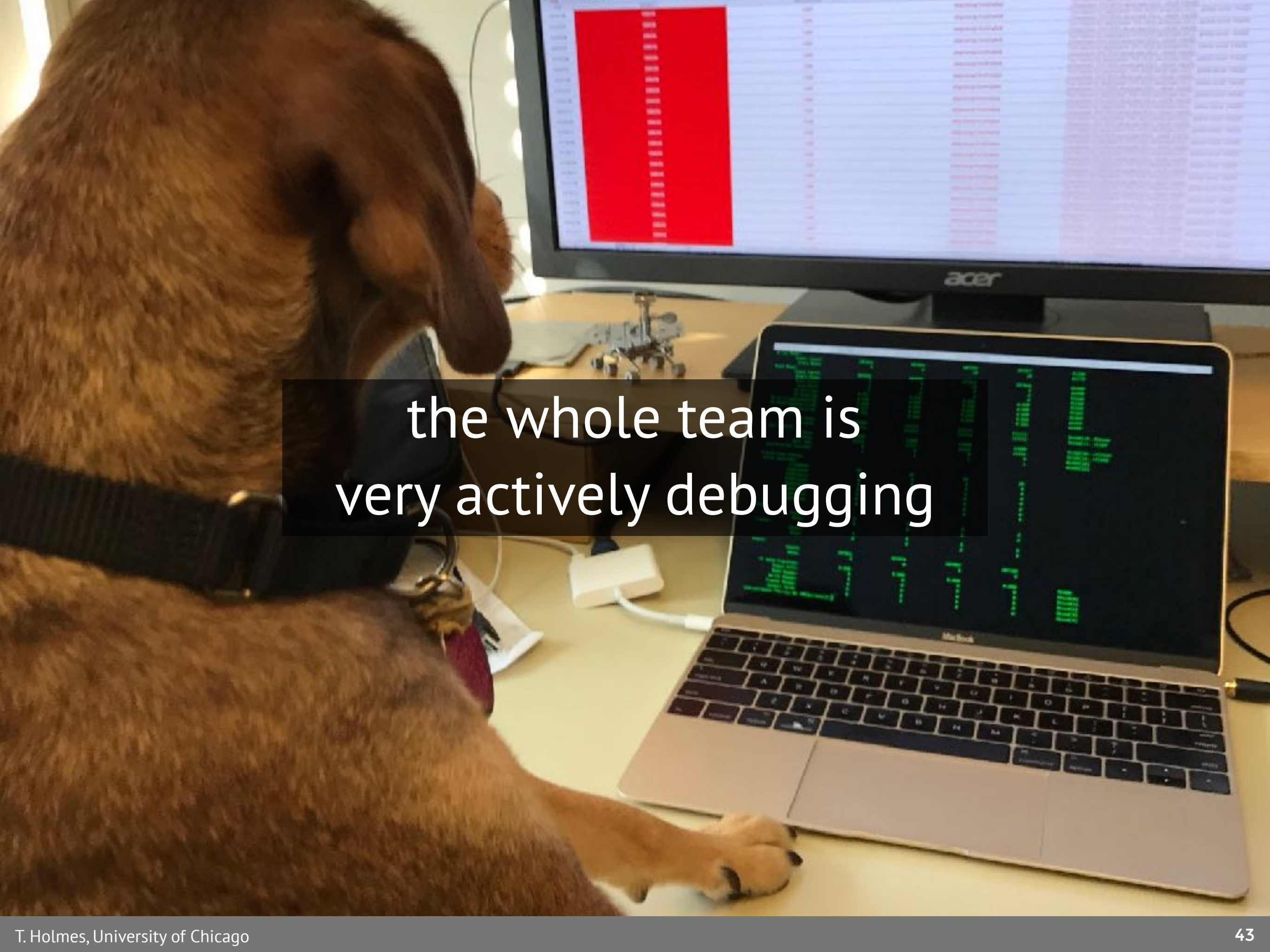


2018:

installation of full system
partial integration (limited coverage)

Run 3:

full FTK
available



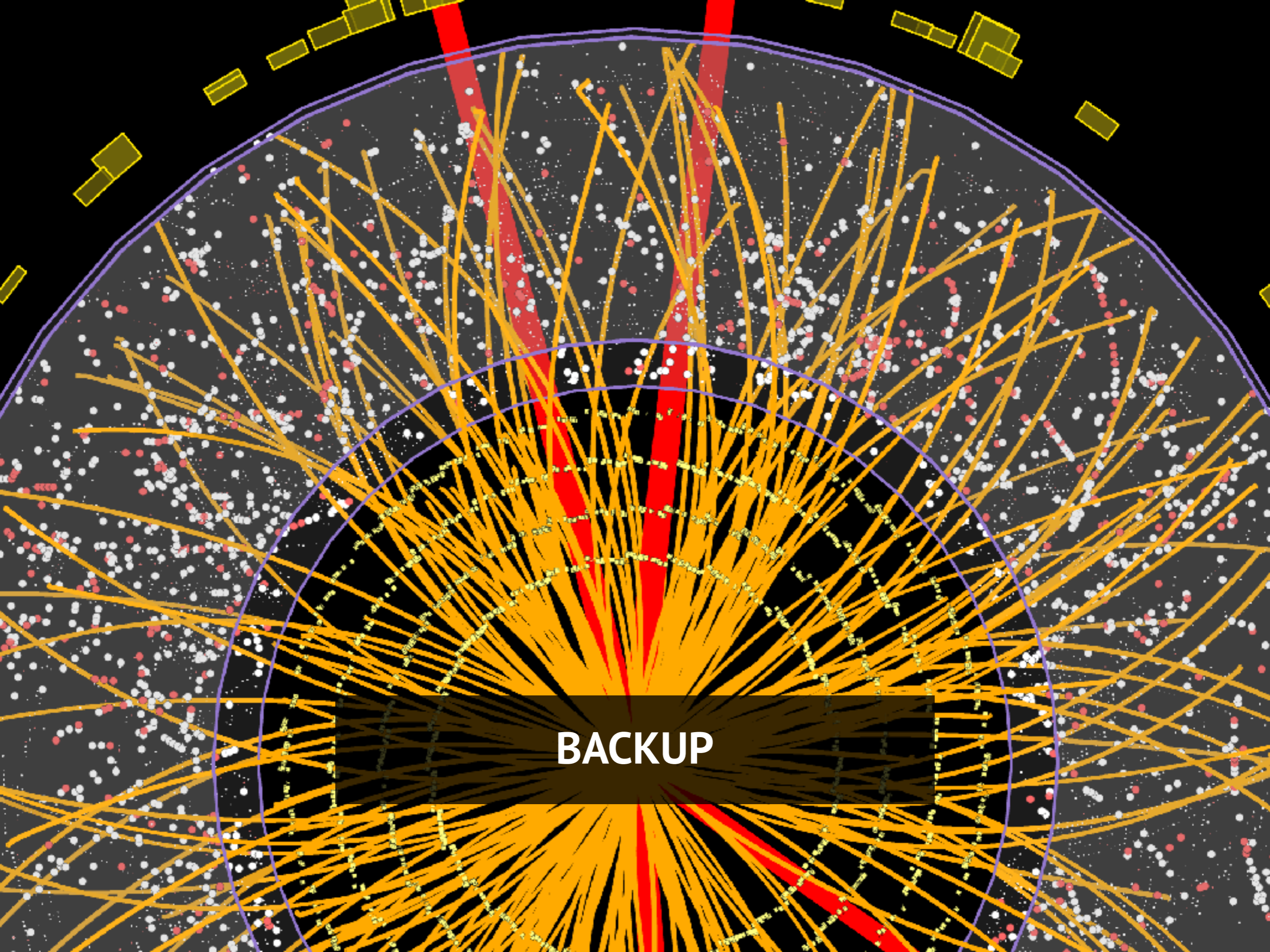
the whole team is
very actively debugging

Conclusions

The FTK is actively integrating into the ATLAS detector and will soon be available to provide full event tracking at HLT

FTK has the potential to help identify LLPs – but much work needs to be done to study efficacy

Up next, Lesya will explain more about how we can use FTK to get gains in the LLP triggers

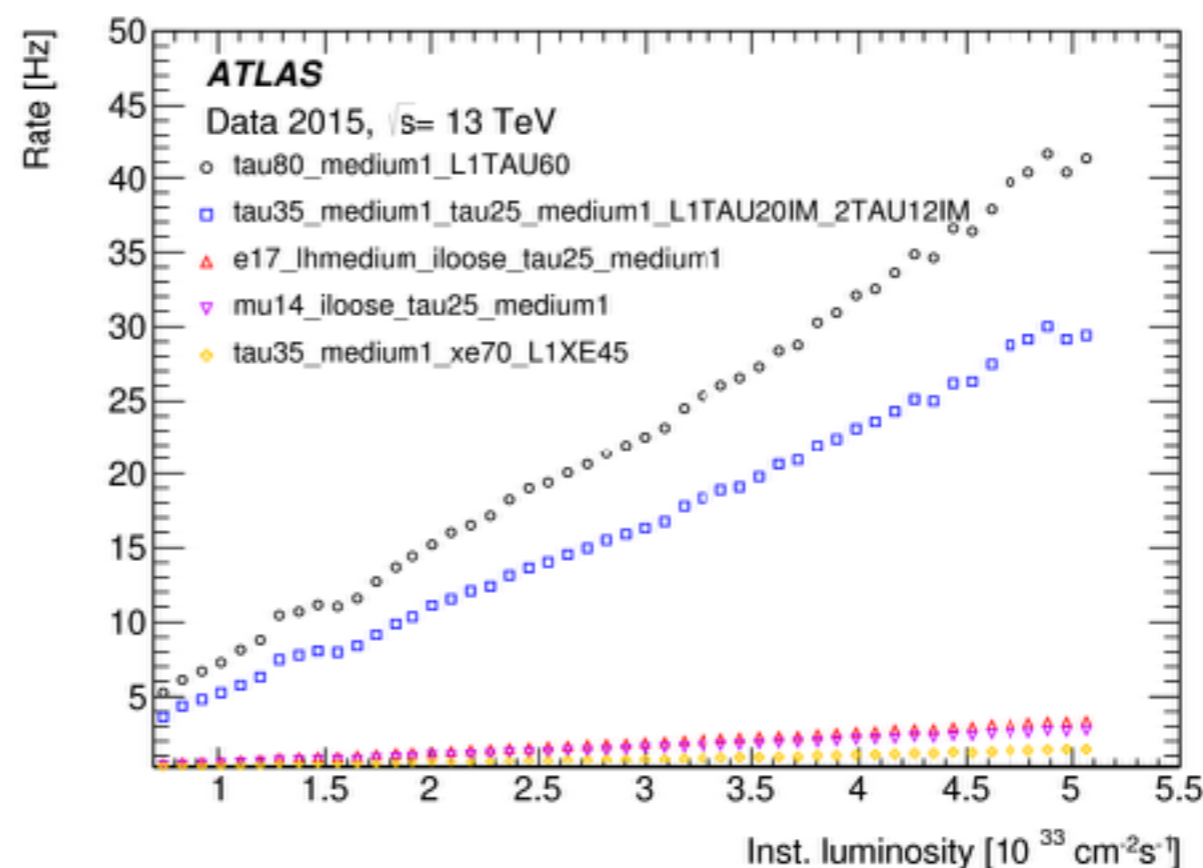
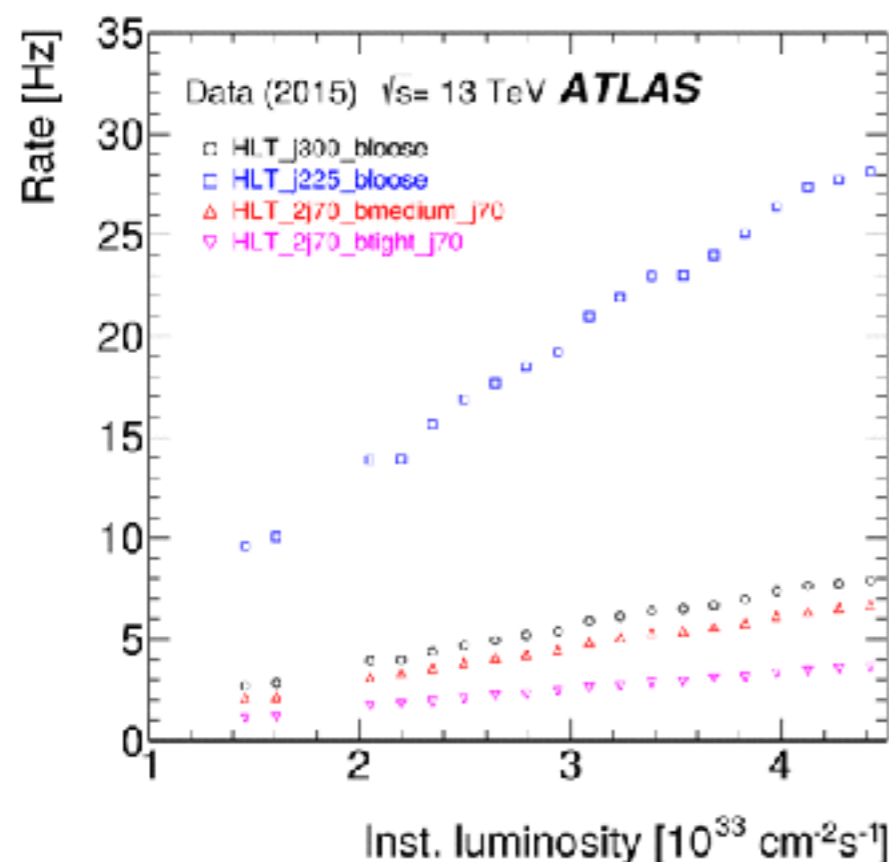


BACKUP

How good are we at triggering on b-jets and τ s?

Rate limitations

as instantaneous luminosity climbs,
trigger rates for these objects increase untenably

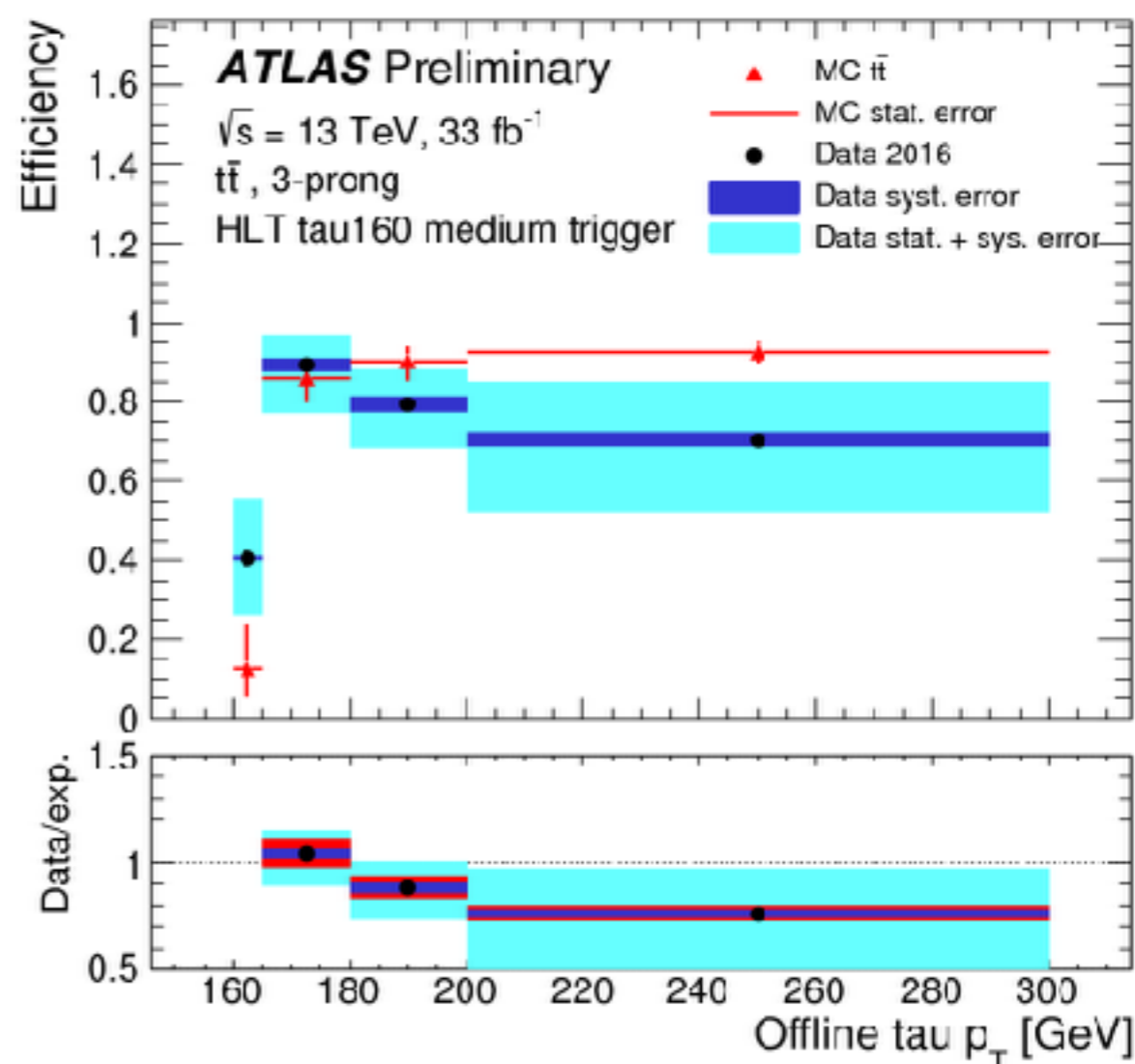
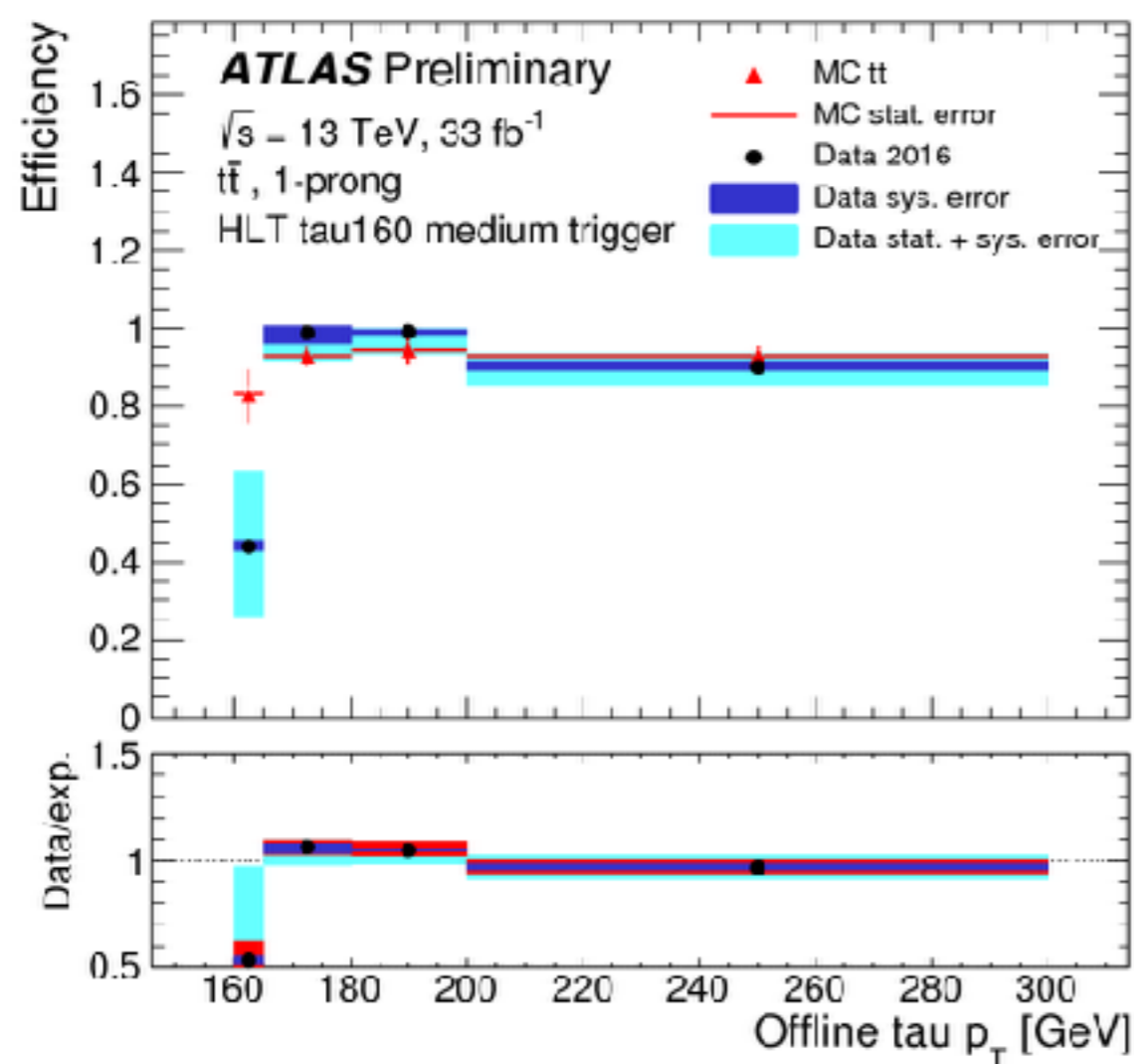


we're at $1.5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ now!

How good are we at triggering on b-jets and τ s?

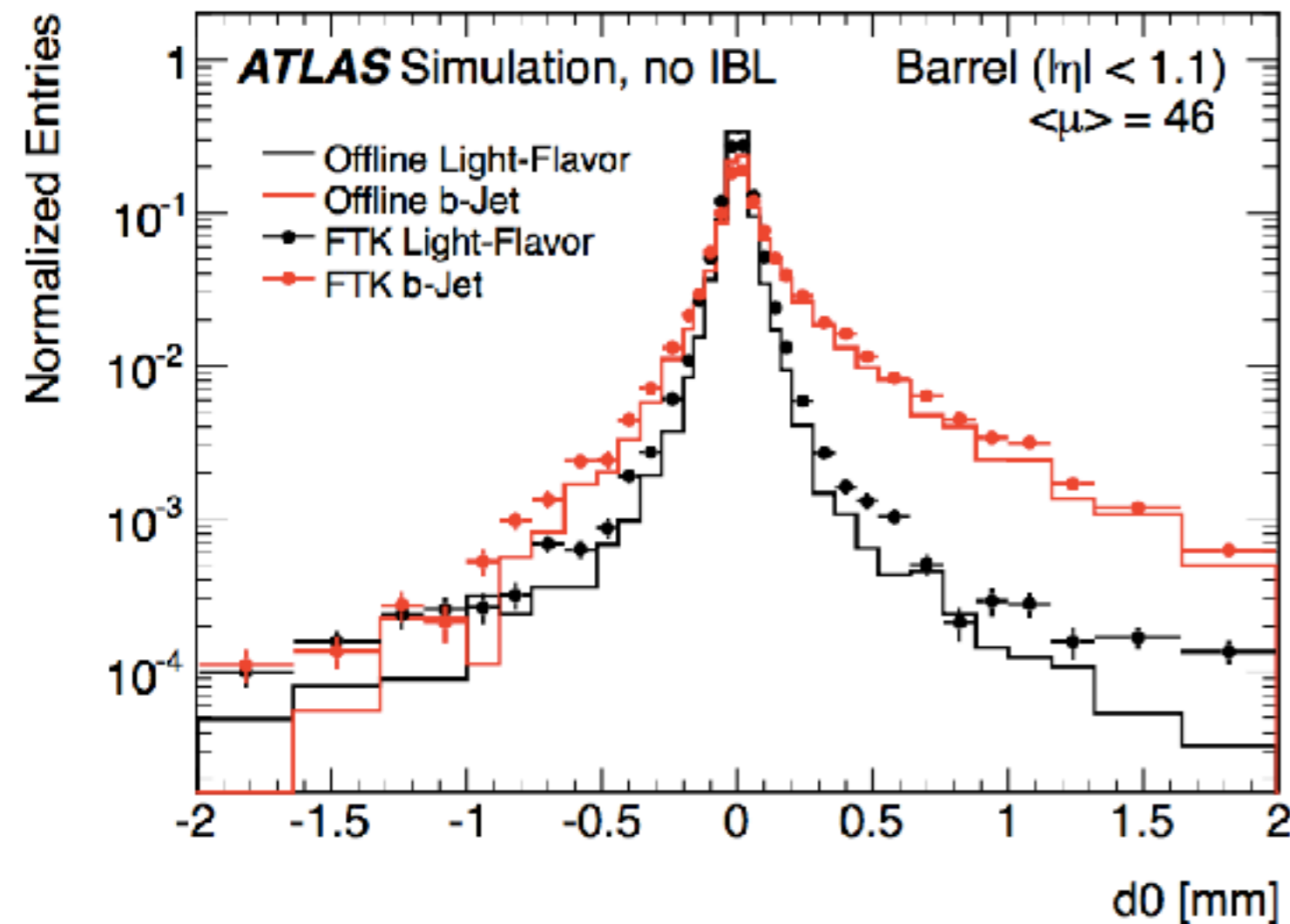
Currently the lowest unprescaled triggers ATLAS can support are:

- 160 GeV for τ
- ~ 200 GeV for b-jets



Improvement from FTK

b-jets



b-jet tagging already done at the trigger level, but only in Rols near high- p_T jets

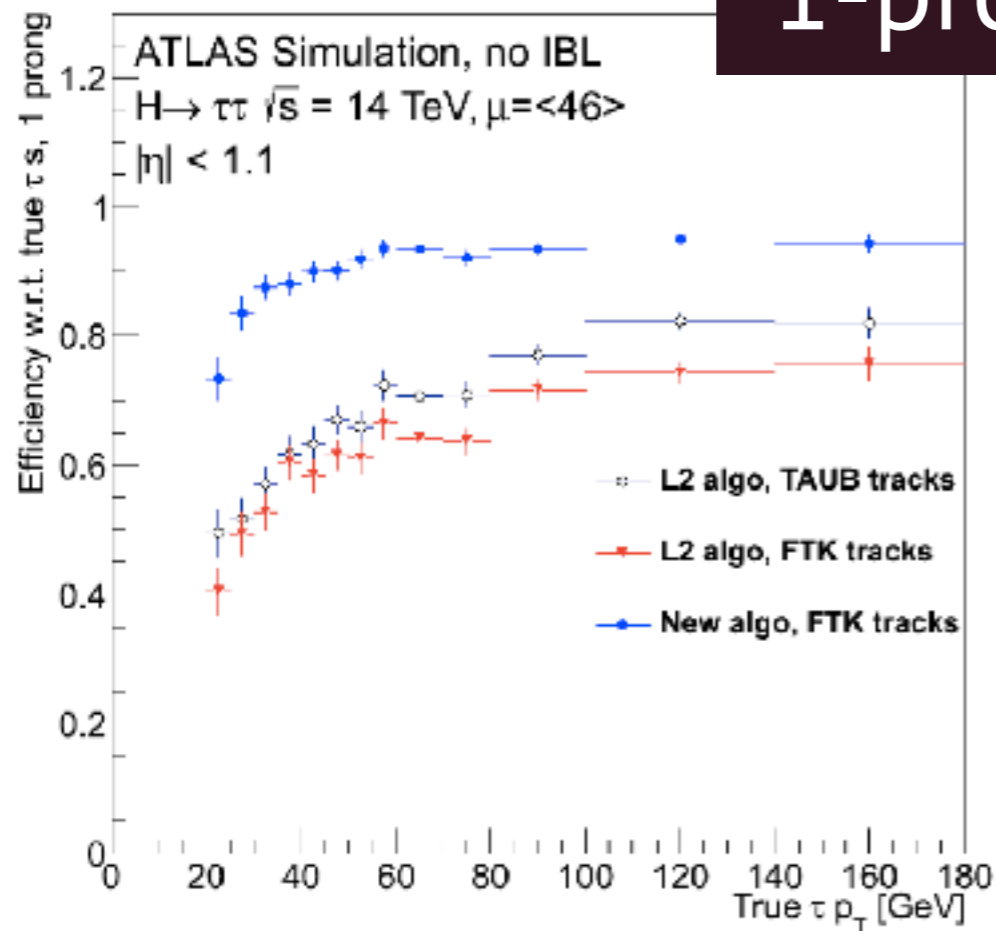
FTK is very successful at replicating the offline d_0 measurements for b-jets

Improvement from FTK

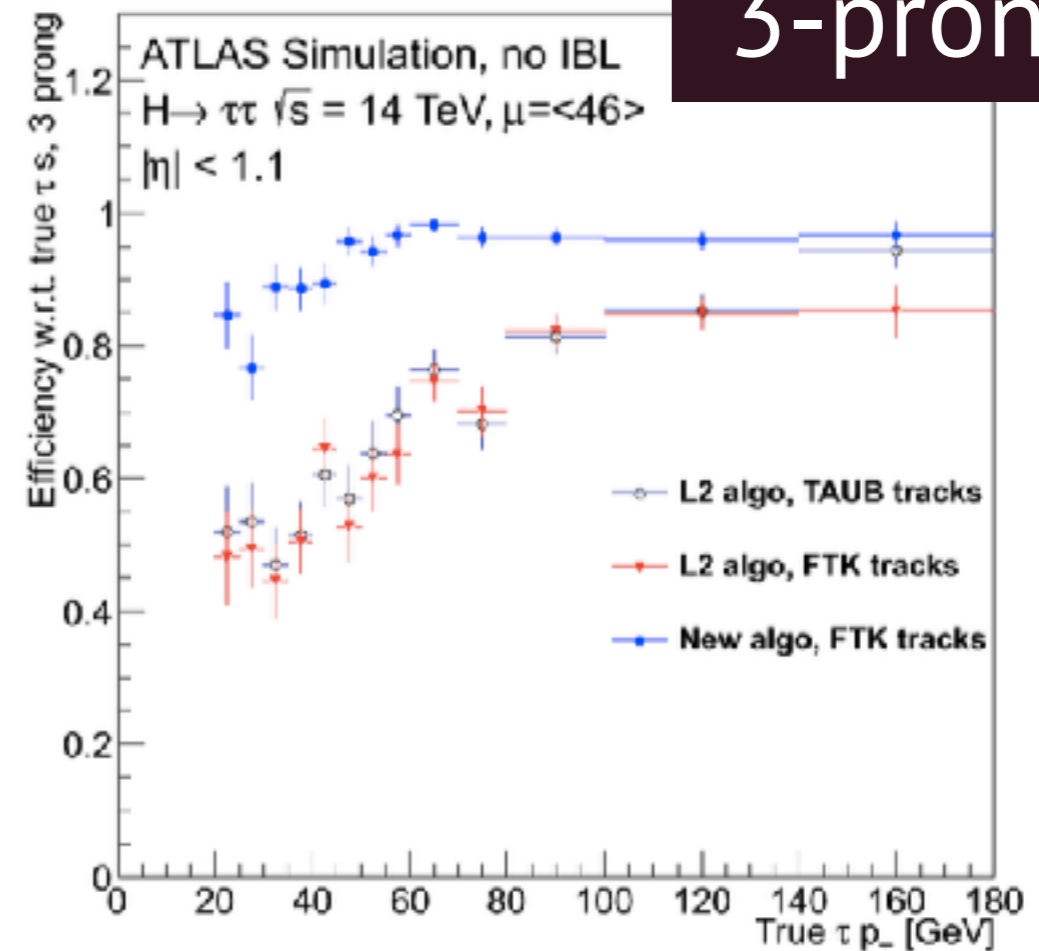
τ leptons

FTK-based algorithms show great improvement over the current HLT efficiencies

1-prong



3-prong



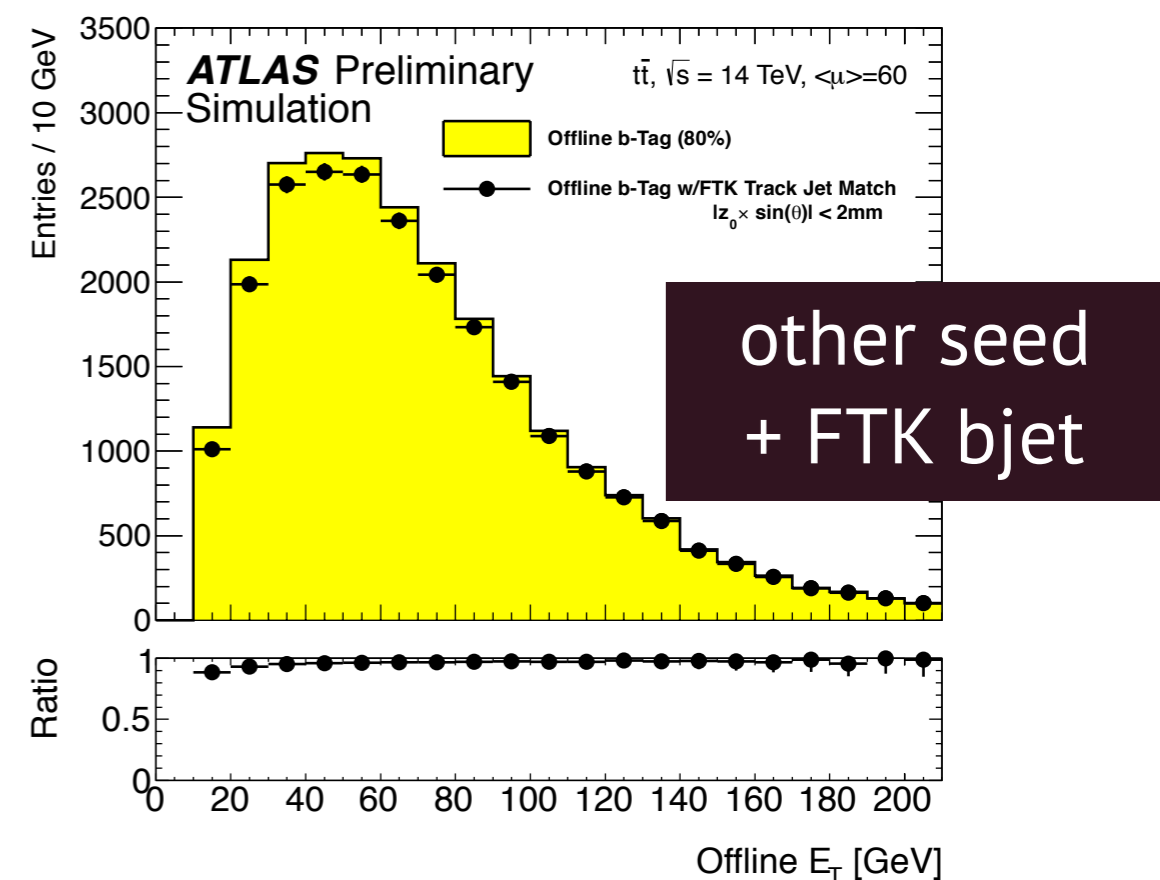
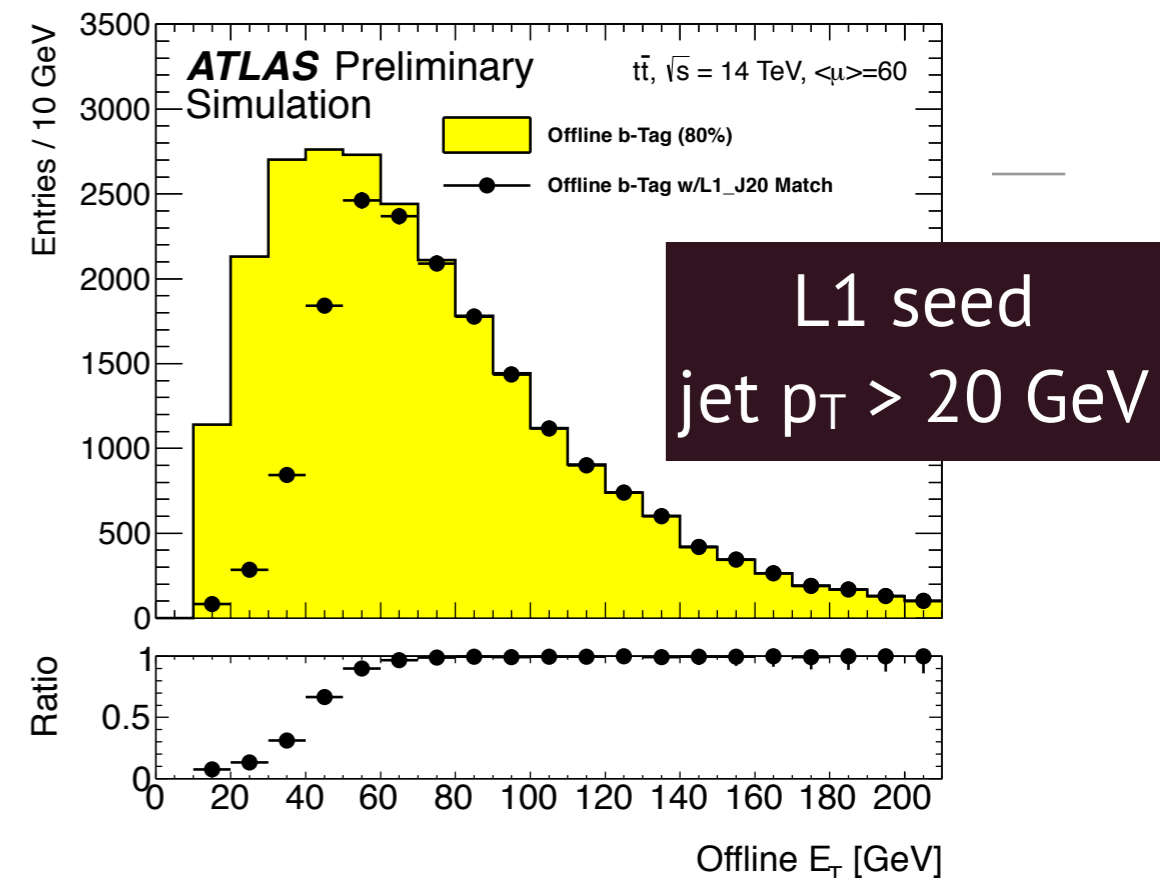
(caveat: this working point comes with a slightly higher fake-rate)

Improvement from FTK

b-jets

Another improvement comes from additional tracking around jets that are lower p_T

To trigger, need another interesting object in the event to provide the L1 seed

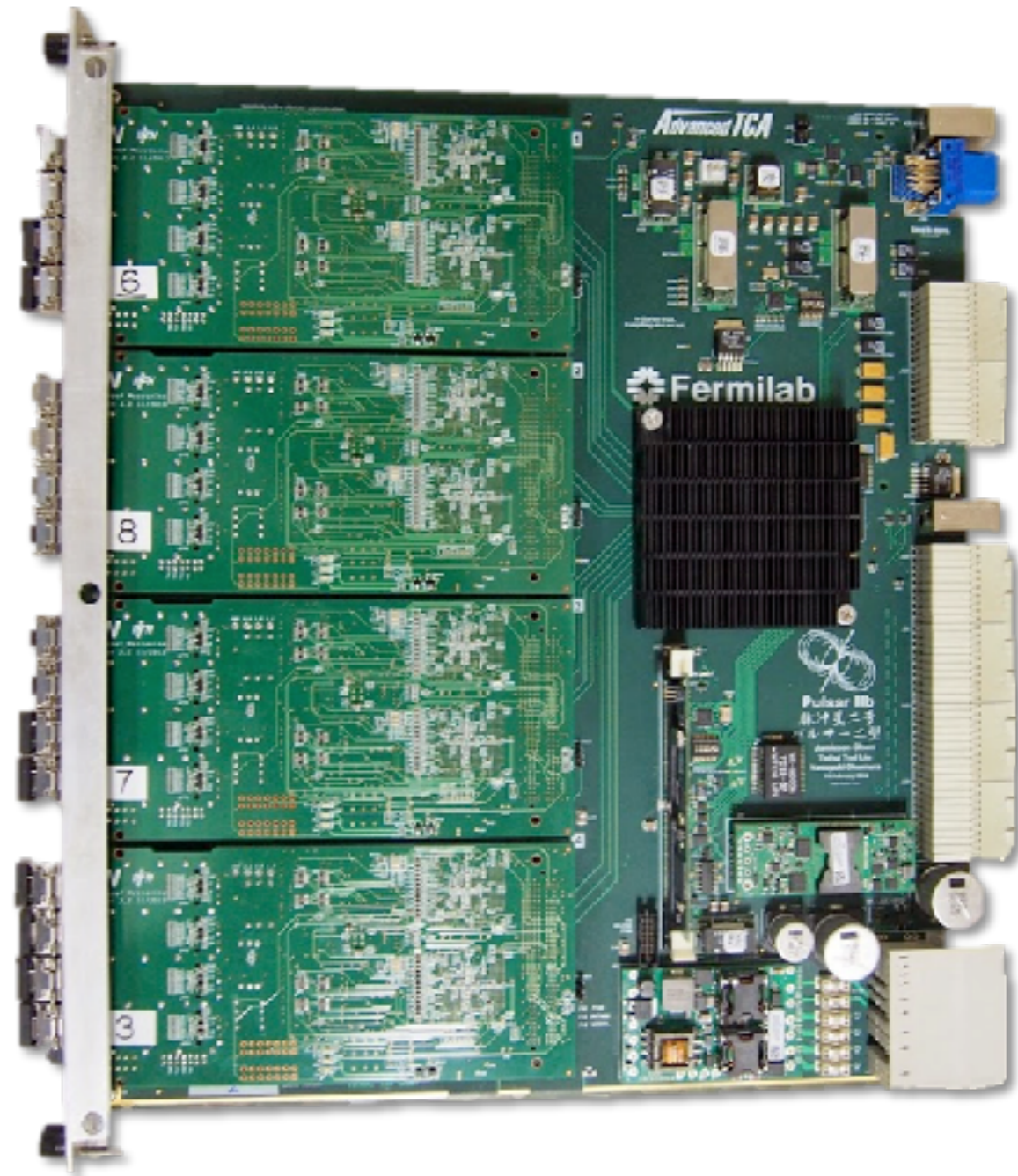


Implementation

Input Mezzanine & Data Formatter

IM receives data from the ID, clusters adjacent silicon hits to form the “hits” used in FTK

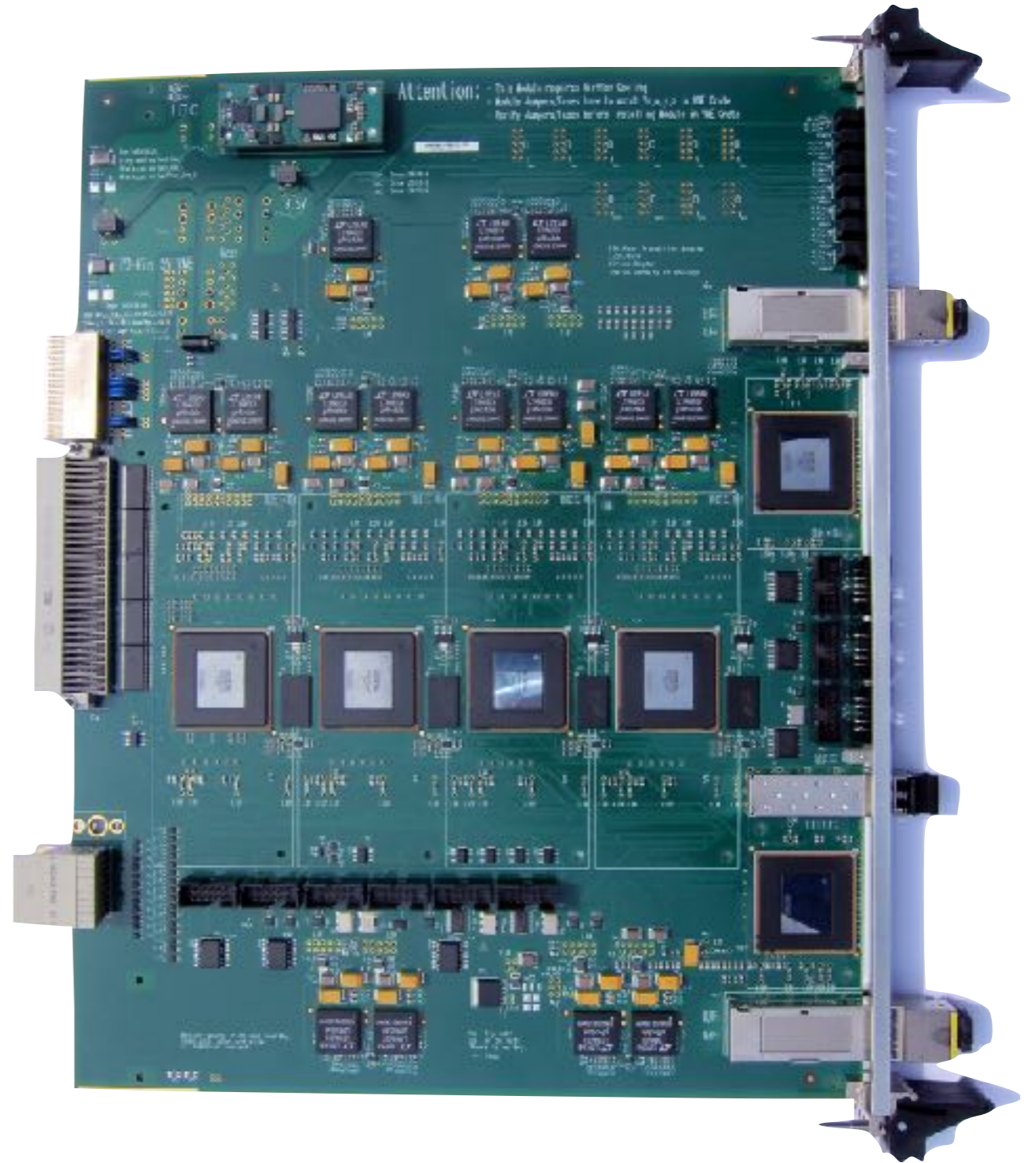
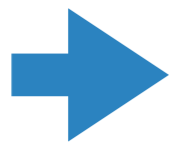
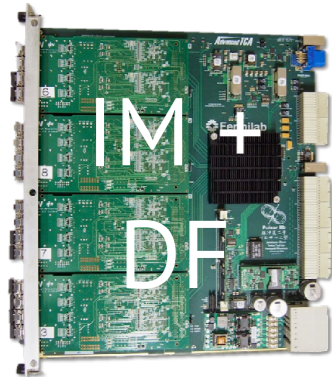
DF divides hits into towers and sends to the appropriate boards



Implementation

Auxiliary Card

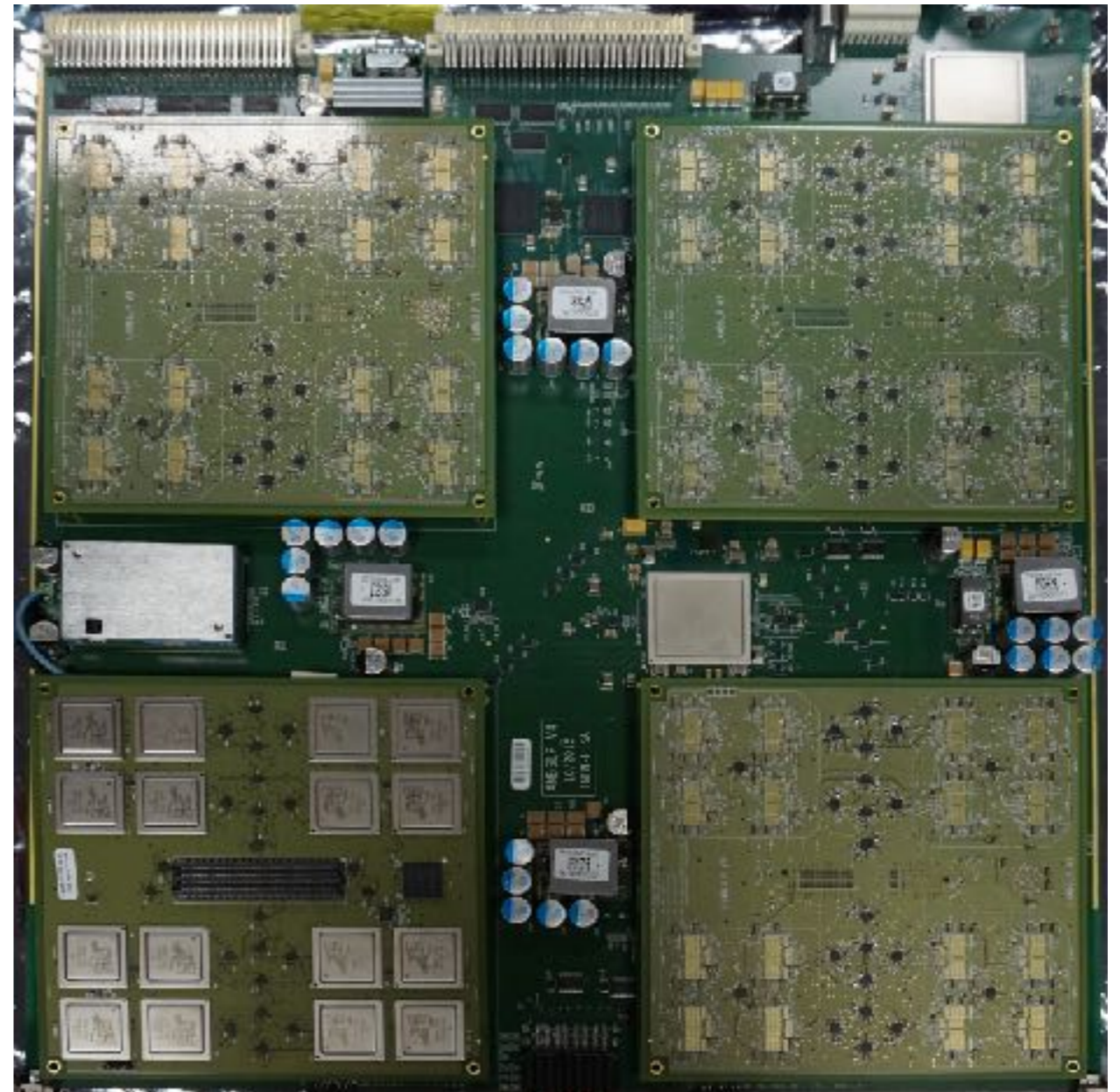
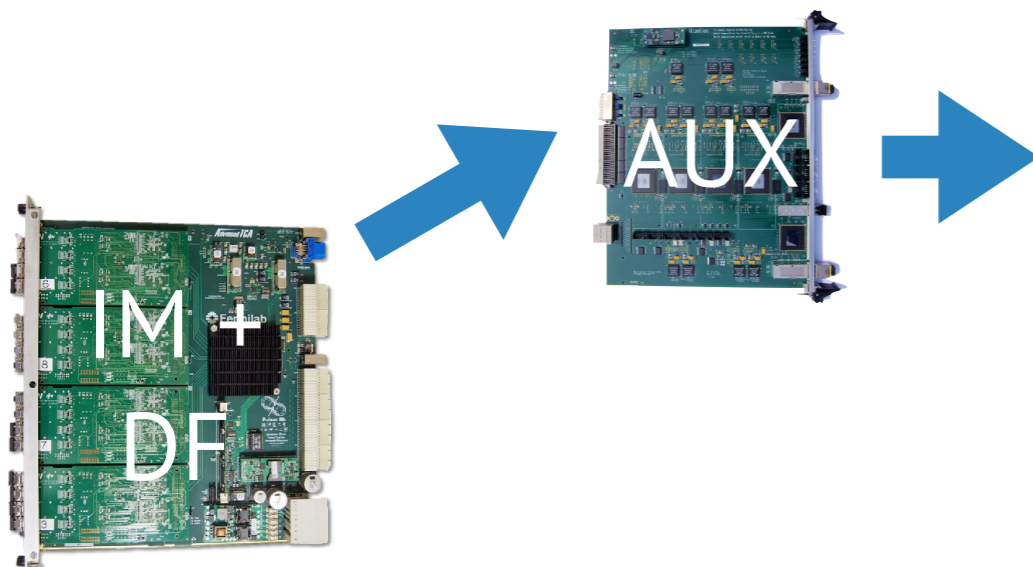
AUX converts hits to coarse resolution “super-strips”



Implementation

Associated Memory Board

AMB performs the pattern matching, returns “roads” representing matched patterns to the AUX

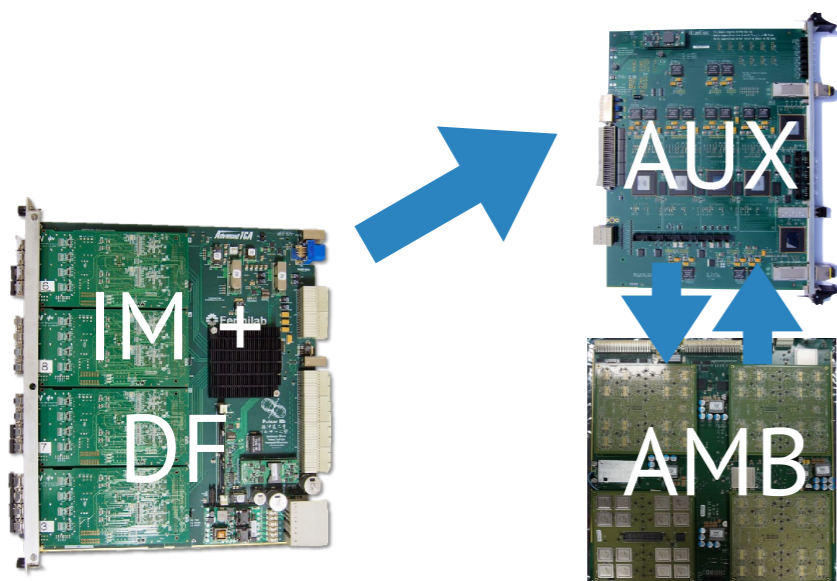
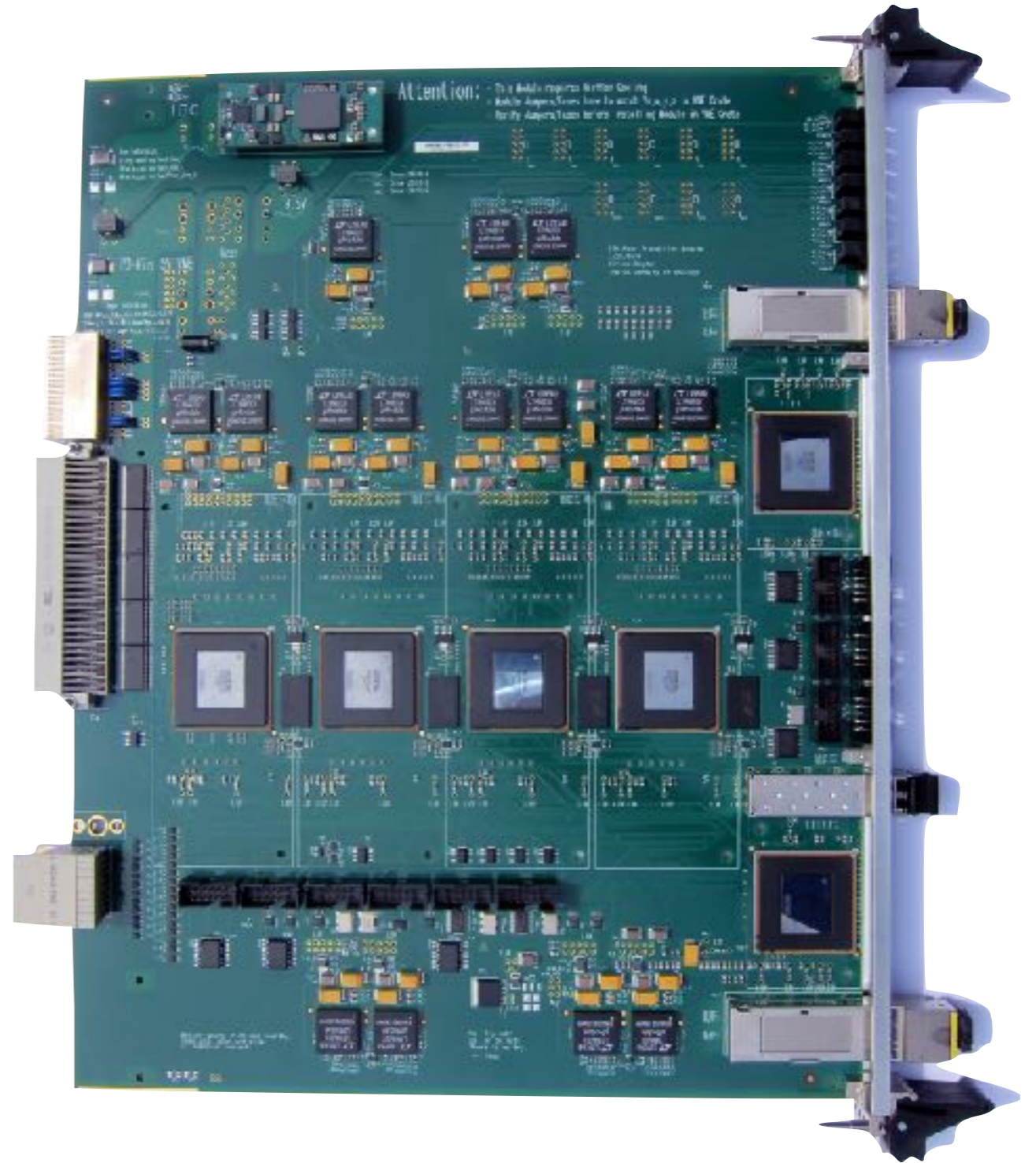


Implementation

Auxiliary Card

Retrieves the full-resolution
hit information for hits
matched to roads

Performs the 8-layer track fit

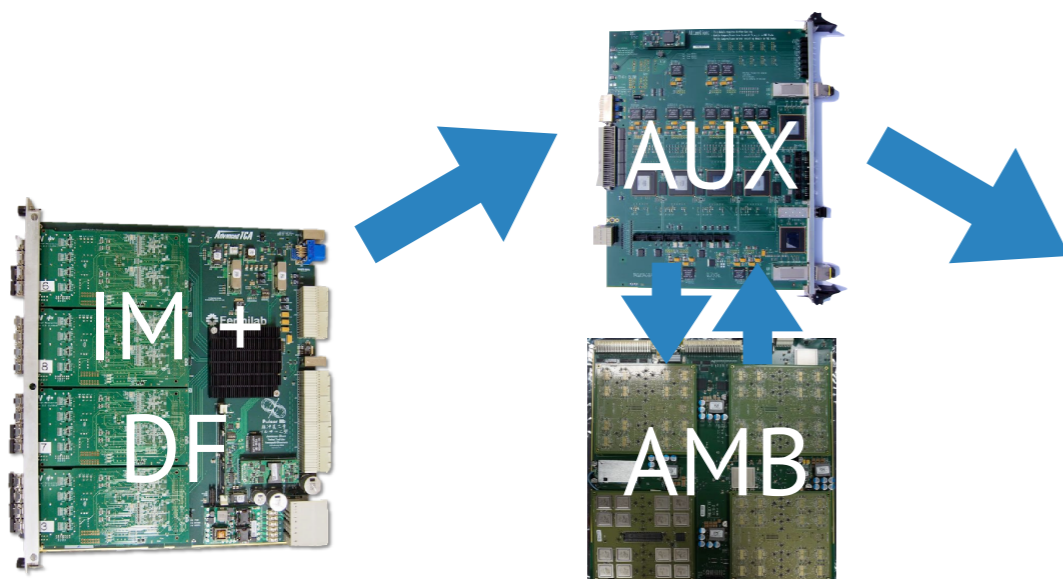
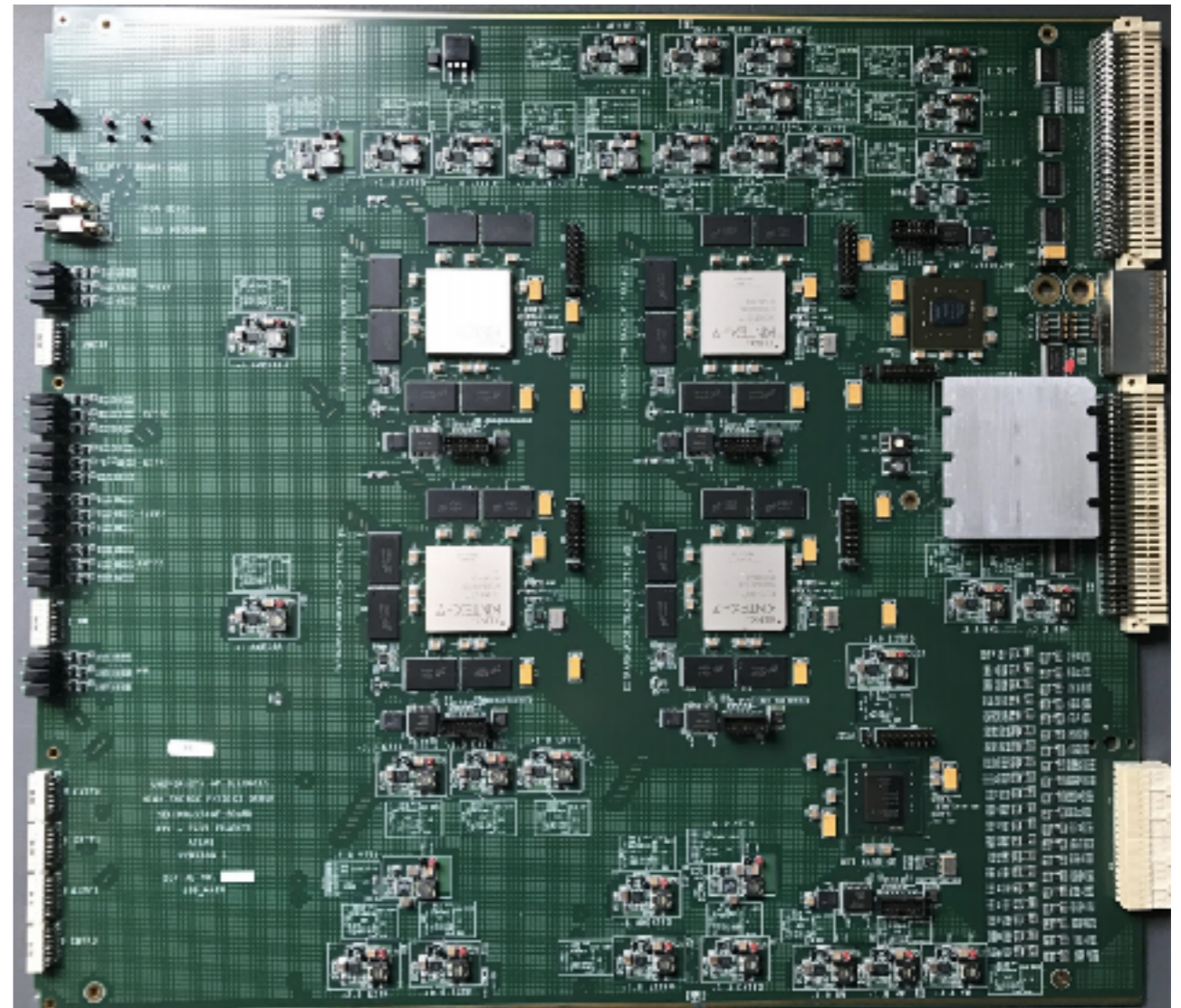


Implementation

Second Stage Board

SSB Extrapolates 8-layer fit to remaining 4 layers

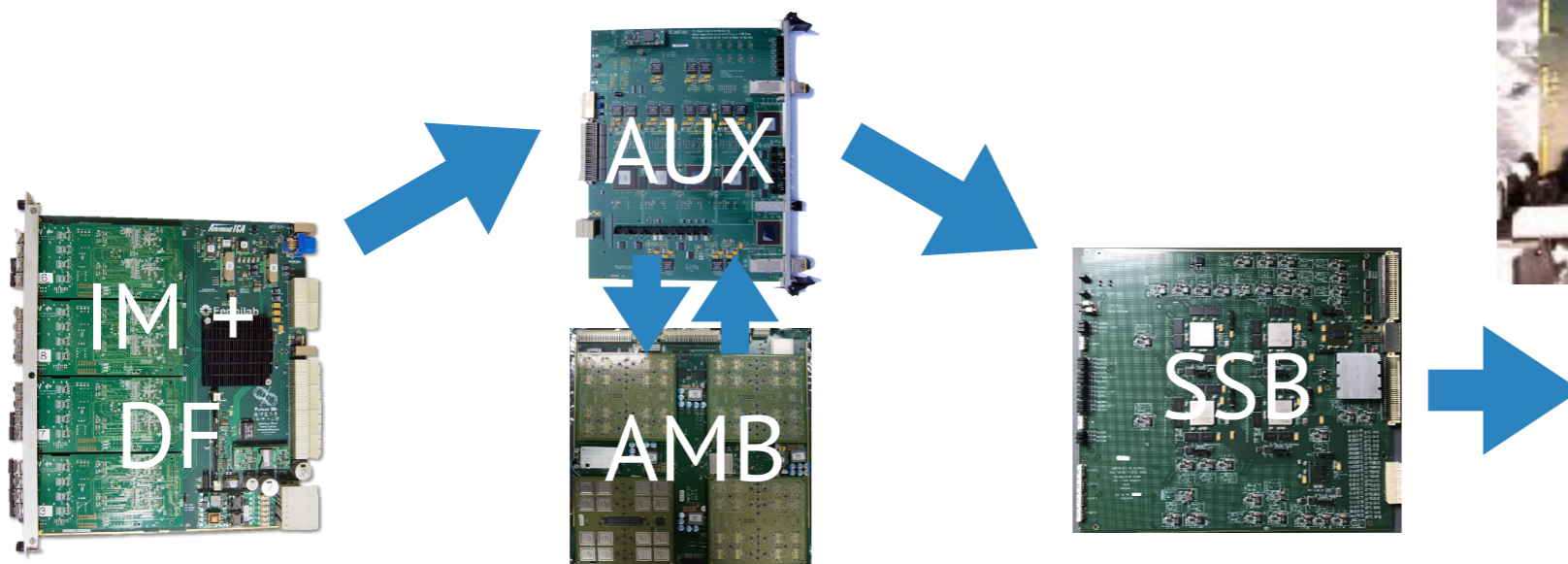
Performs a fit on all 12 silicon layers



Implementation

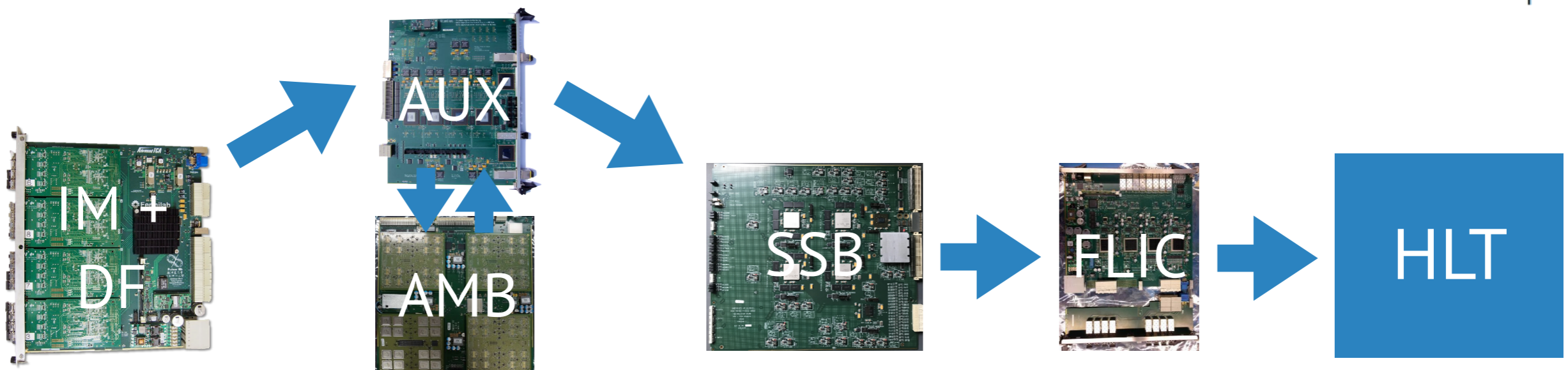
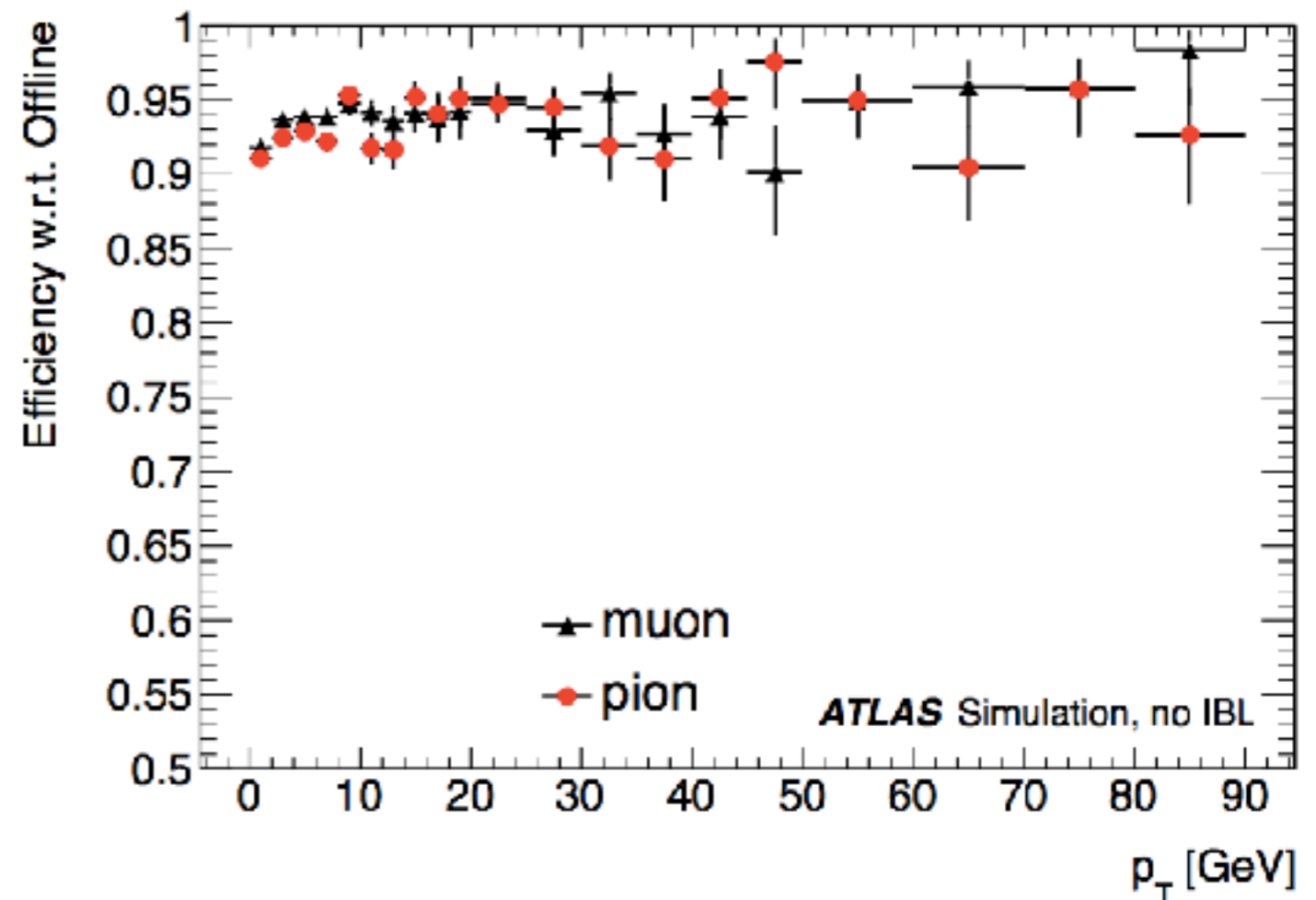
FTK-to-L2 Interface Card

Sends tracks passing
all cuts to be processed
by High Level Trigger

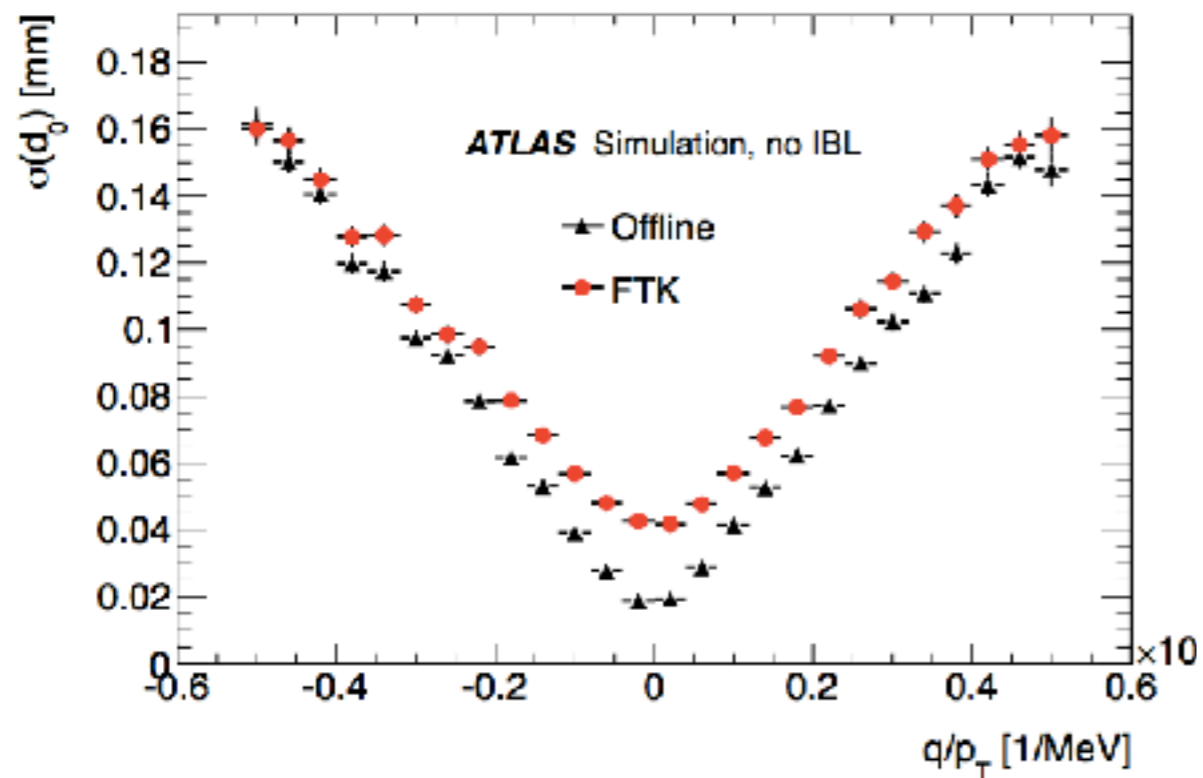


Implementation

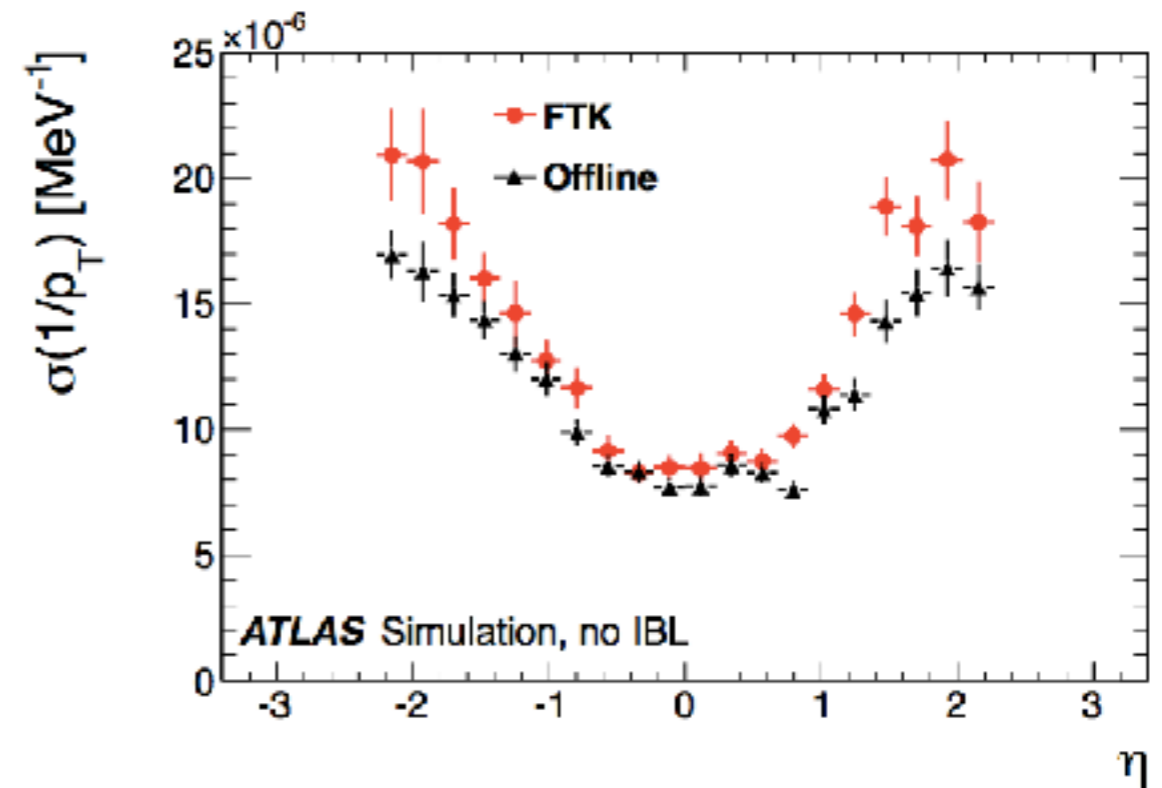
The full chain should send tracks to HLT that are >90% efficient relative to offline



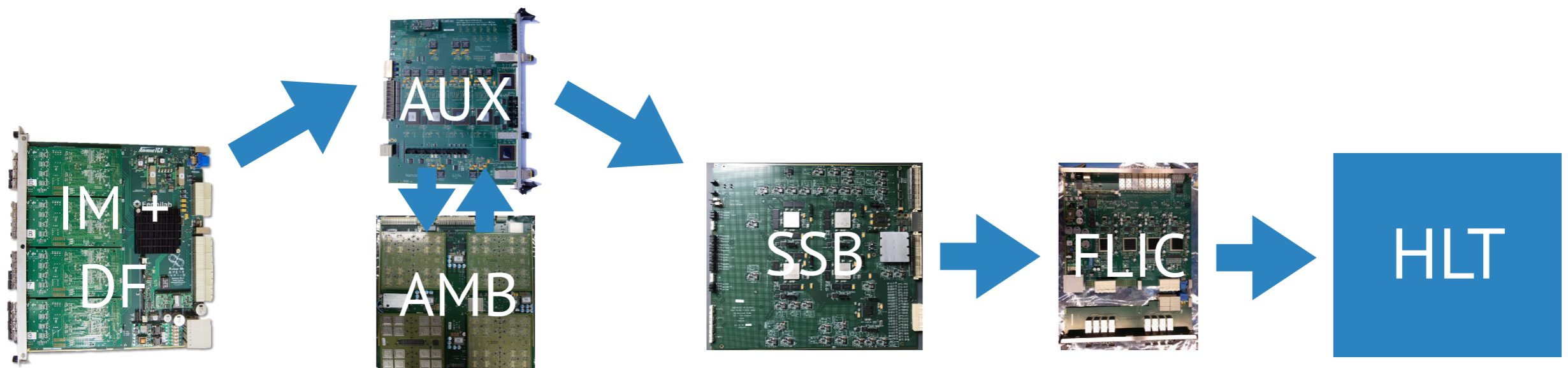
Implementation



d_0 values similar to offline
at low p_T

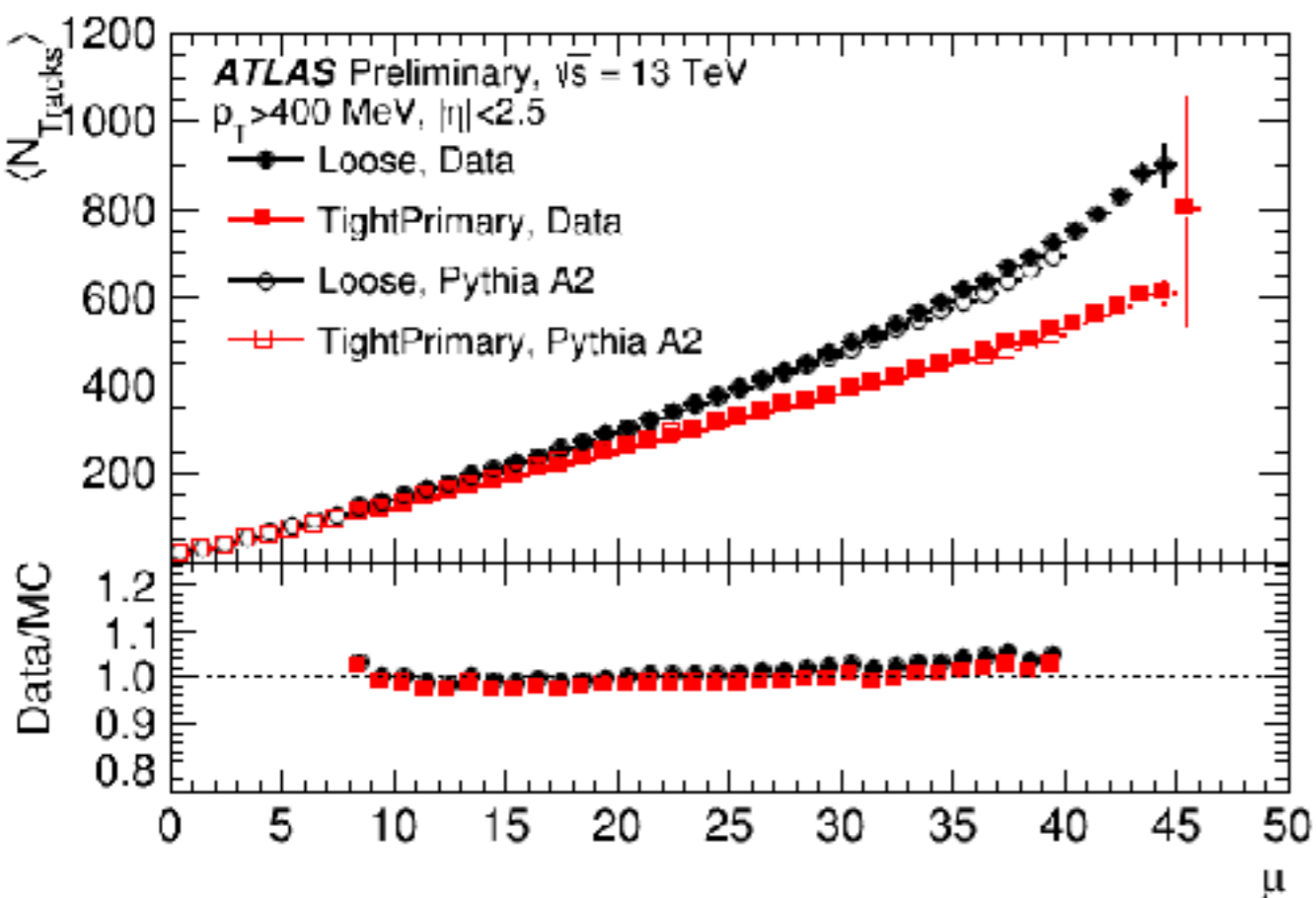


p_T resolutions close
to offline values

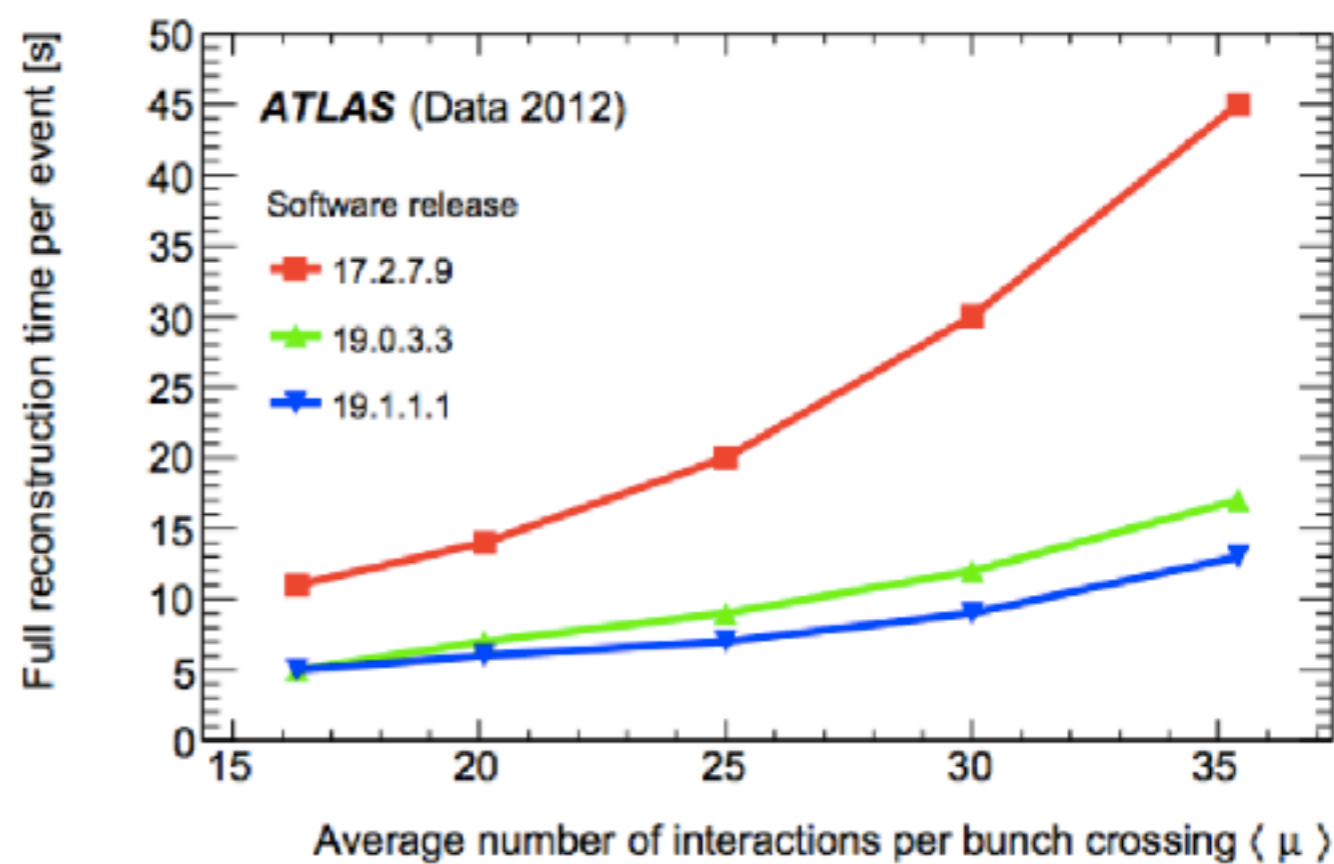


Time constraints

number of tracks



time to reconstruct



Only gets harder with more pile-up