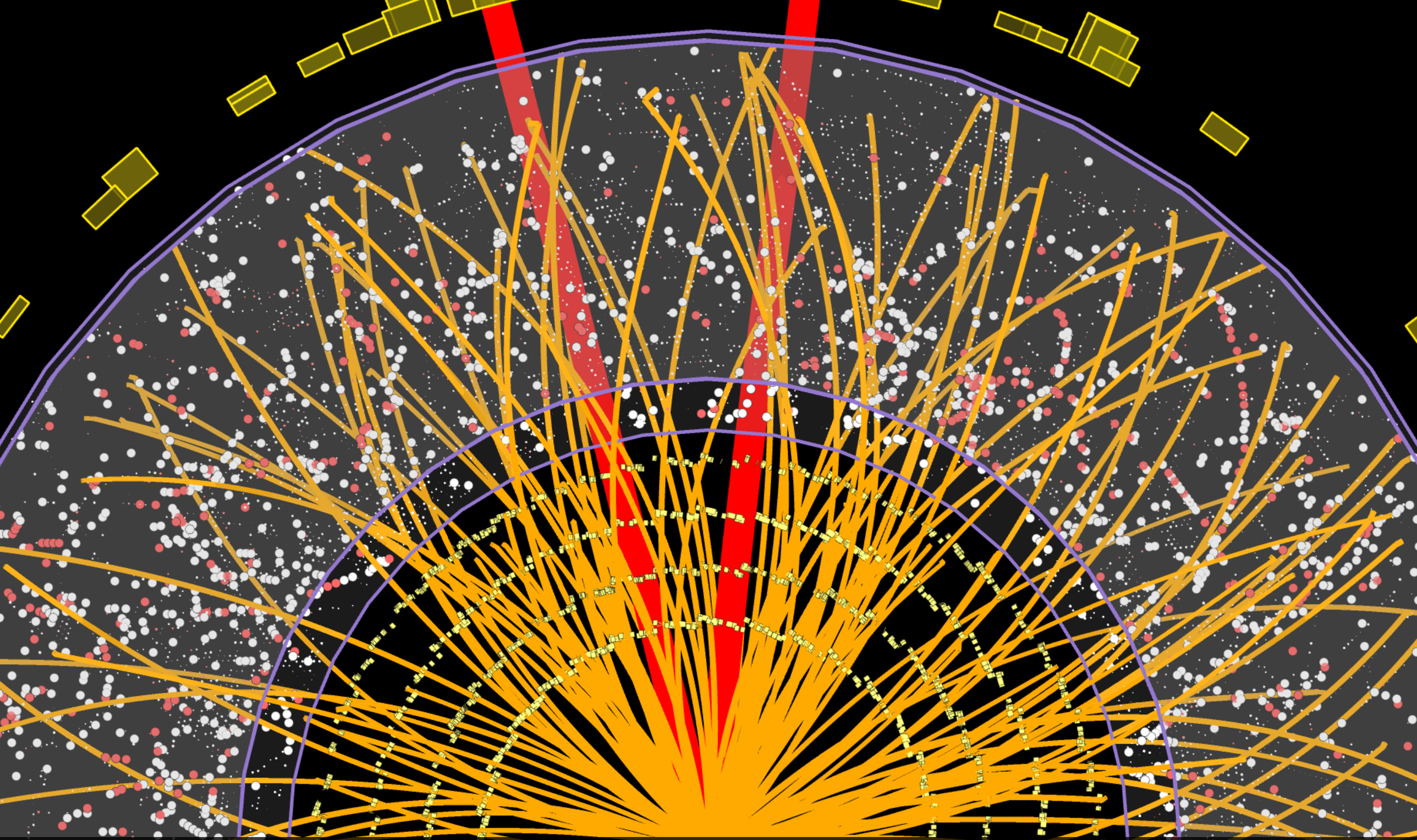


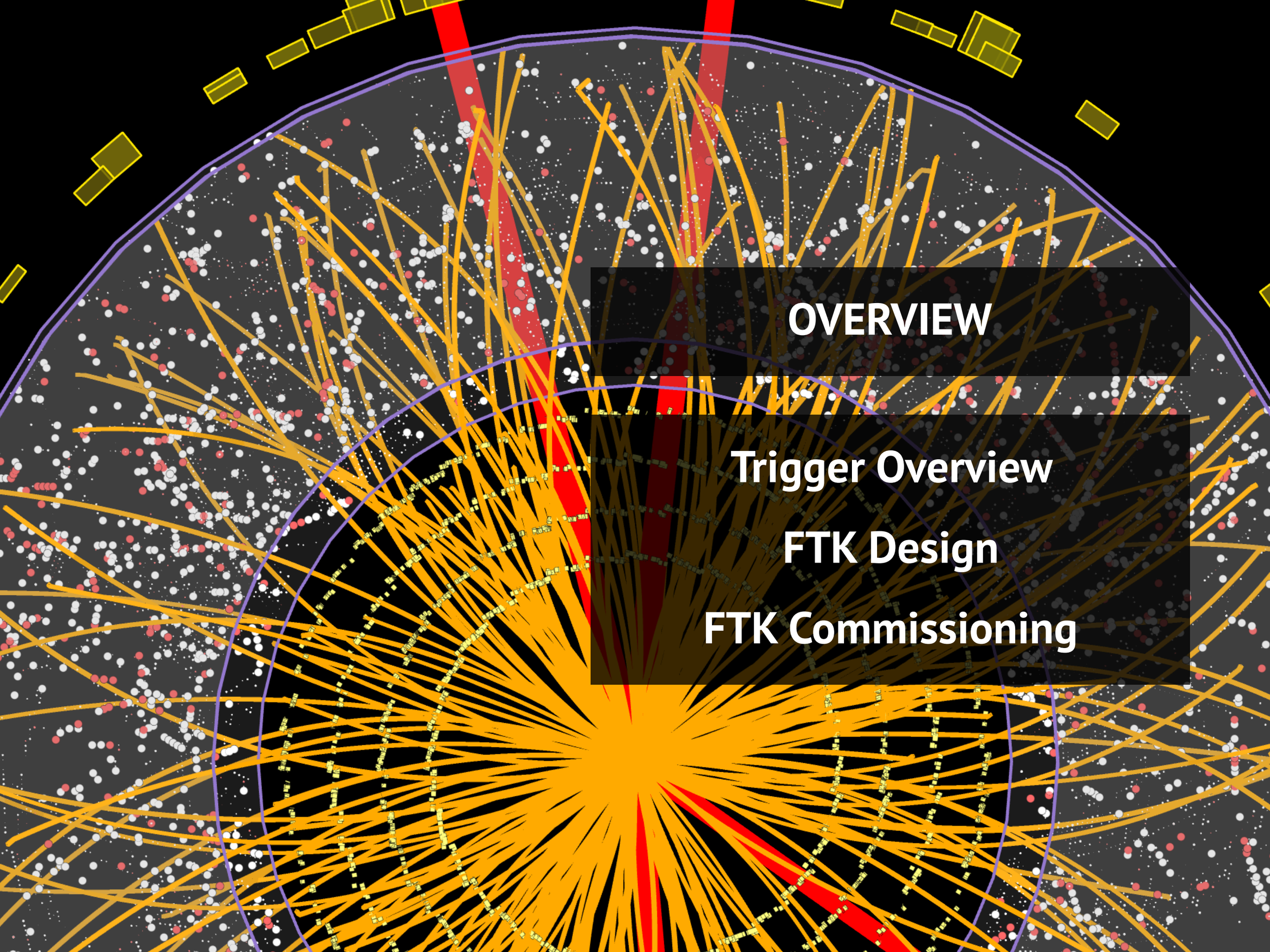
ATLAS EXPERIMENT

Physics on the Fast TracK

Incorporating global tracking into the ATLAS trigger

Tova Holmes,
University of Chicago

DPF Meeting
July 30, 2019



OVERVIEW

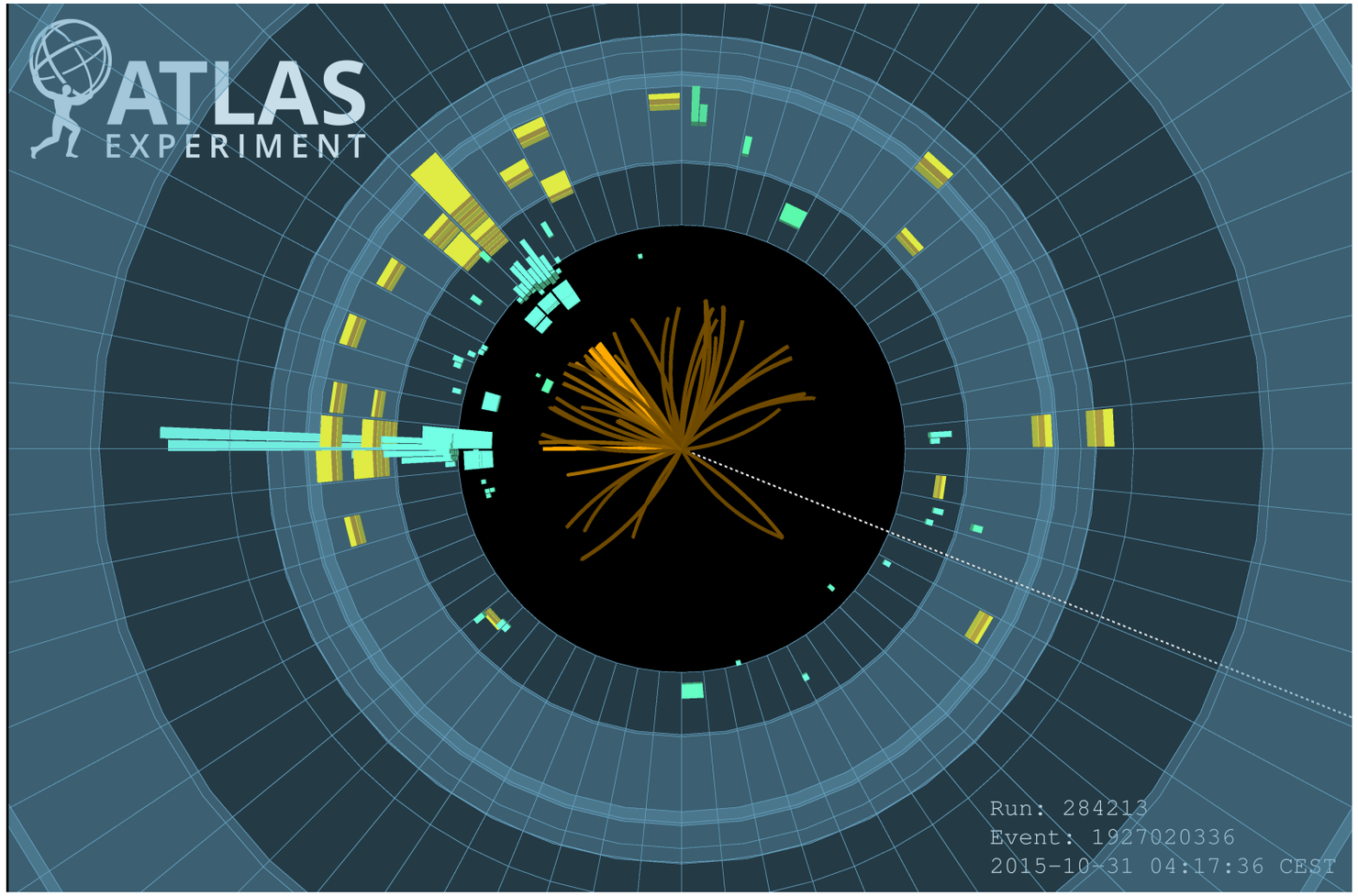
Trigger Overview

FTK Design

FTK Commissioning

The ATLAS Trigger

ATLAS **rejects** more than 99.99% of collisions



ATLAS public event displays

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

How do we decide if this event is worth keeping?

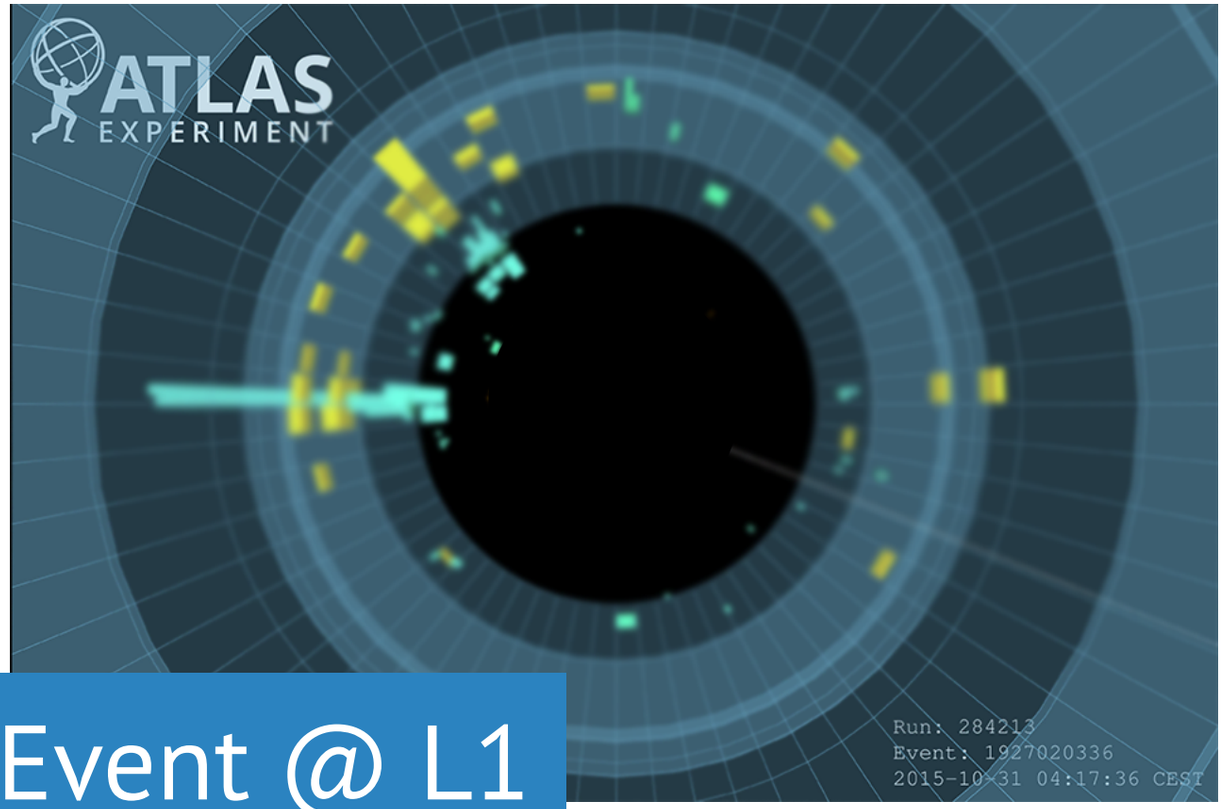
(image of an event with analysis-level “offline” reconstruction)

Level 1 trigger decisions are made with rough **calorimeter** and **muon** information

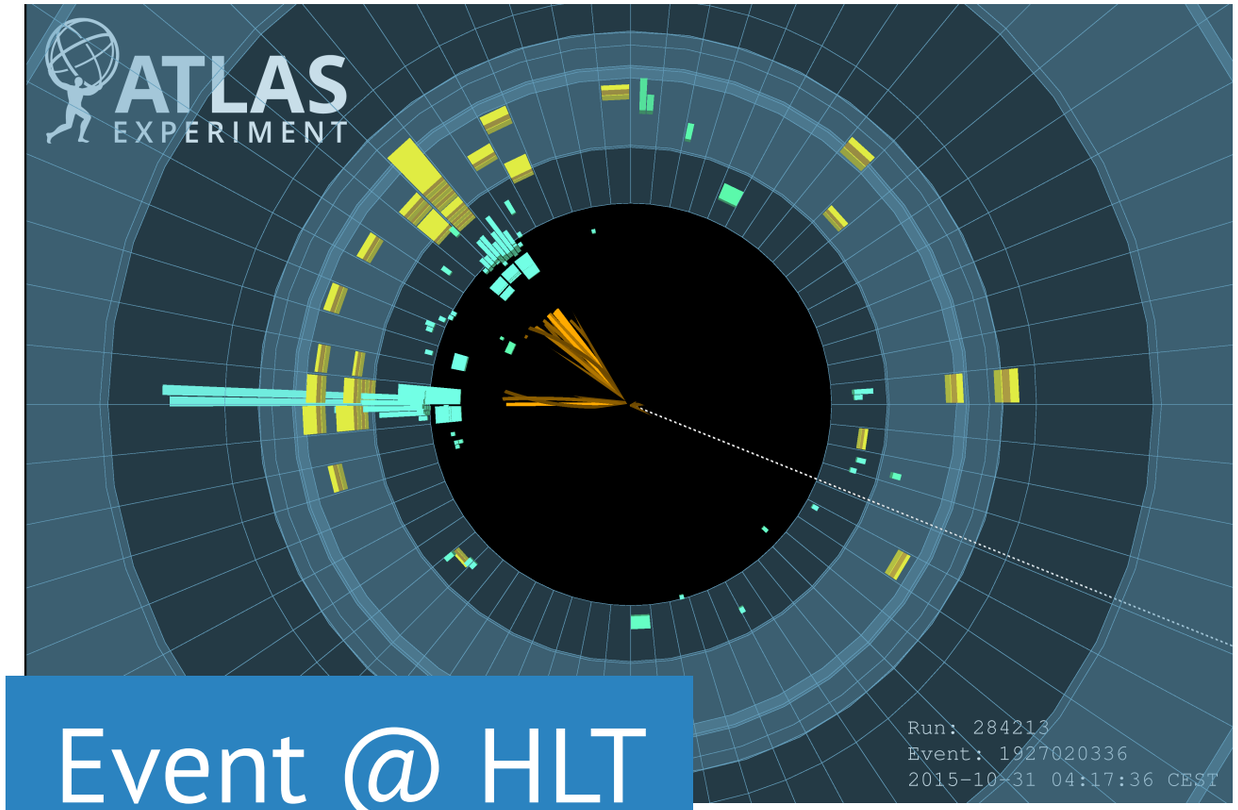
40 MHz → 100 kHz

High Level Trigger uses **full precision** information in **small regions**

100 kHz → 1 kHz



Event @ L1

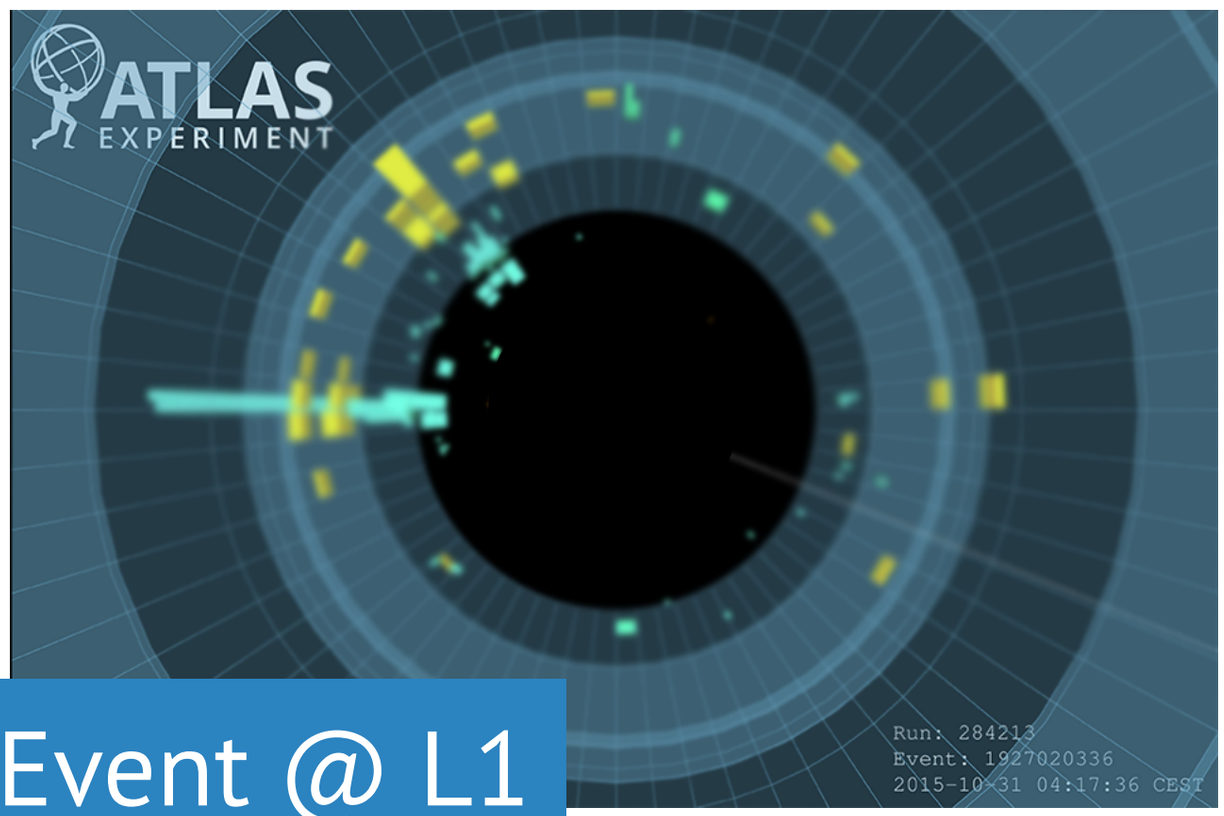


Event @ HLT

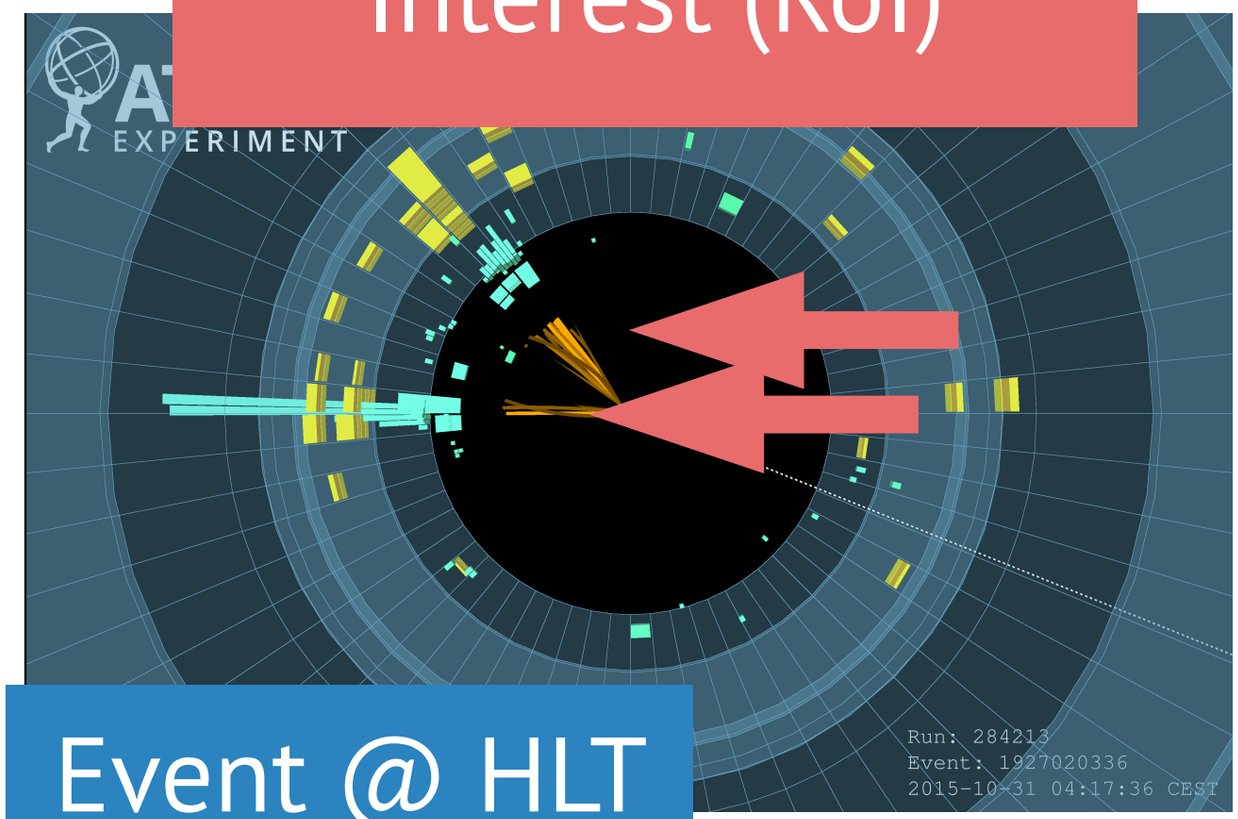
Level 1 trigger decisions are made with rough **calorimeter** and **muon** information

High Level Trigger uses **full pre** information in **small regior**

tracking performed in Regions of Interest (RoI)



Event @ L1

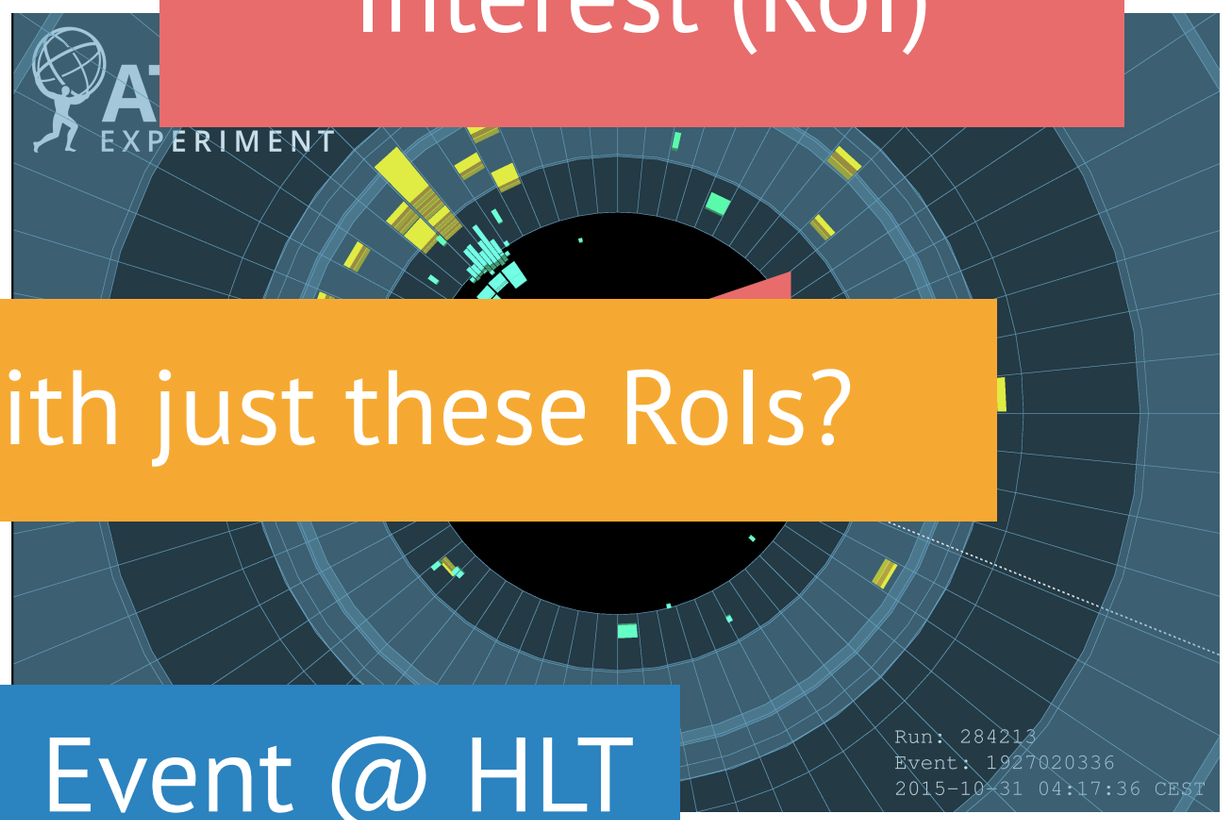


Event @ HLT

Level 1 trigger decisions are made with rough **calorimeter** and **muon** information

High Level Trigger uses **full pre** information in **small regior**

tracking performed in Regions of Interest (RoI)



What do we miss with just these RoIs?

Event @ L1

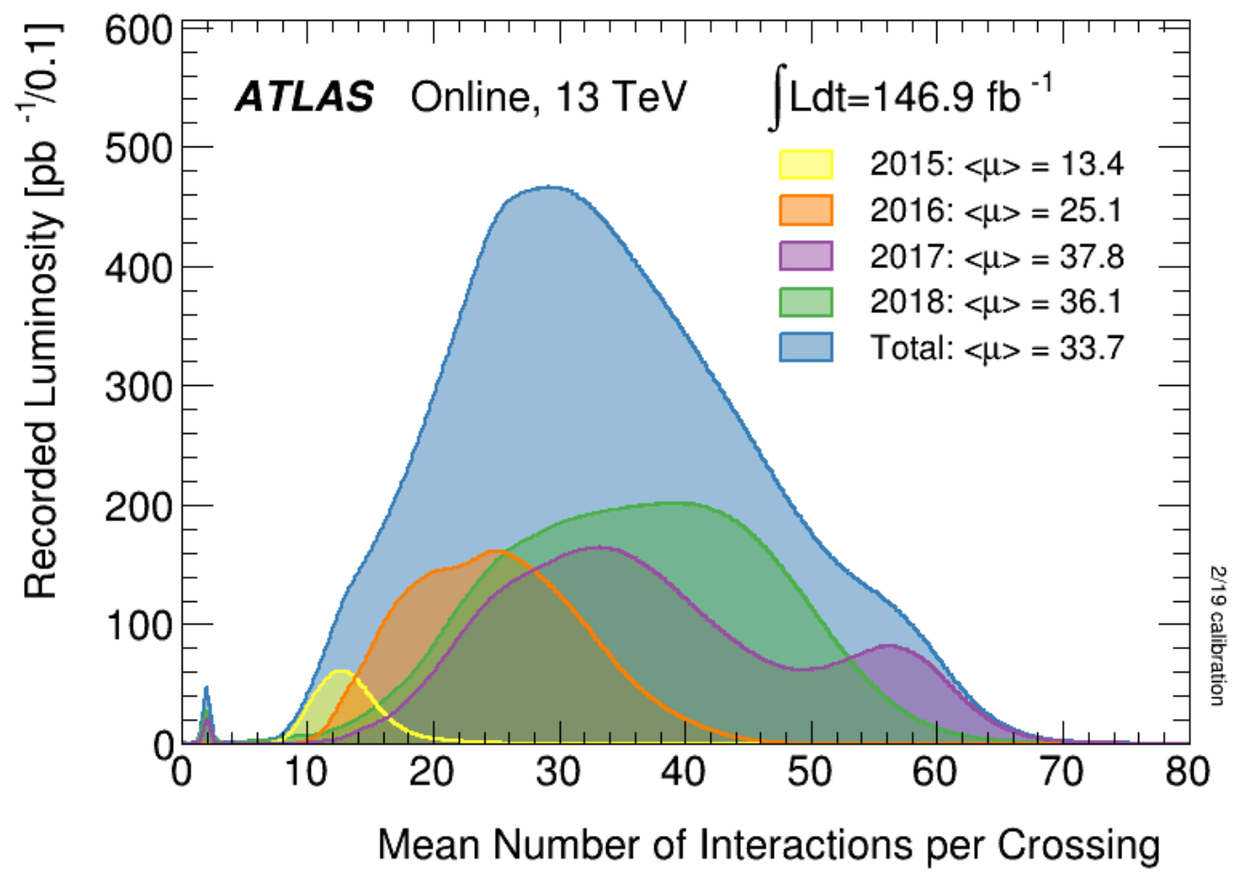
Event @ HLT

Pileup

up to 60 simultaneous *pp* interactions per event

tracks let us identify objects from the **primary vertex** (and **ignore** everything else)

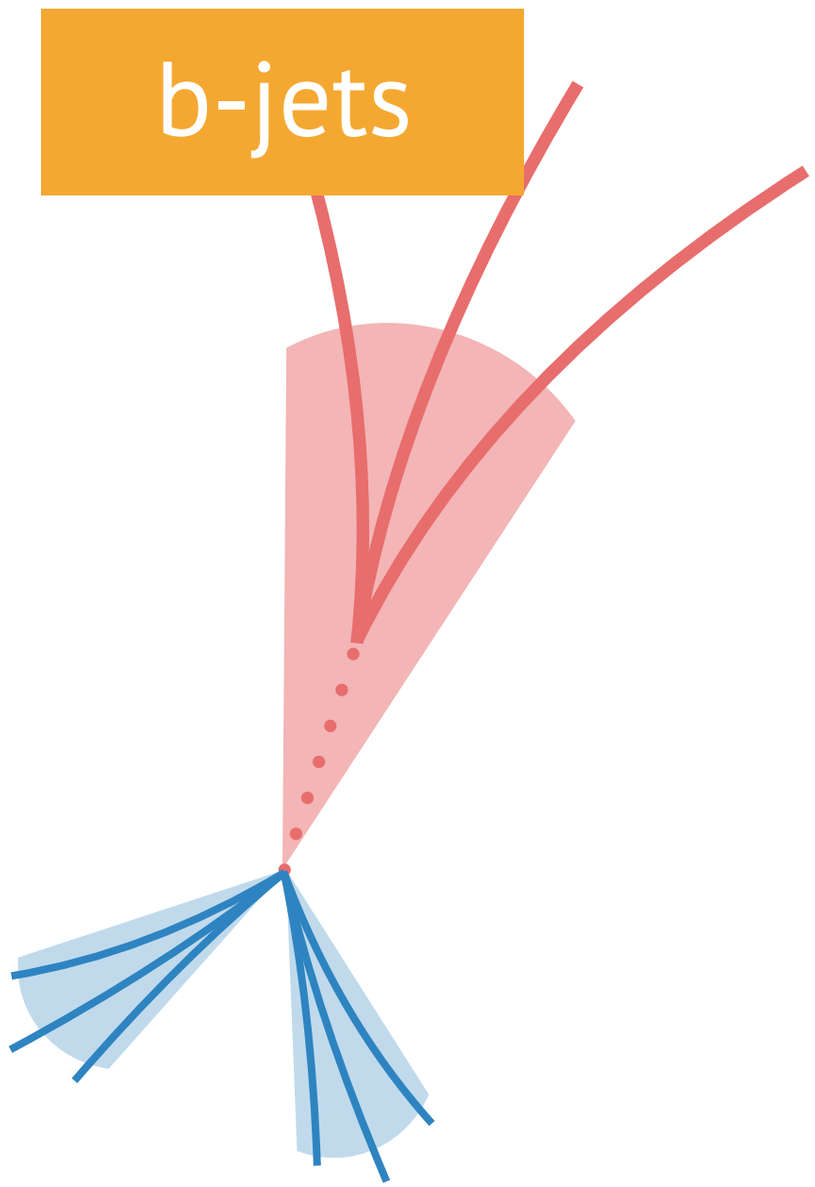
need global tracking to do this for the full event!

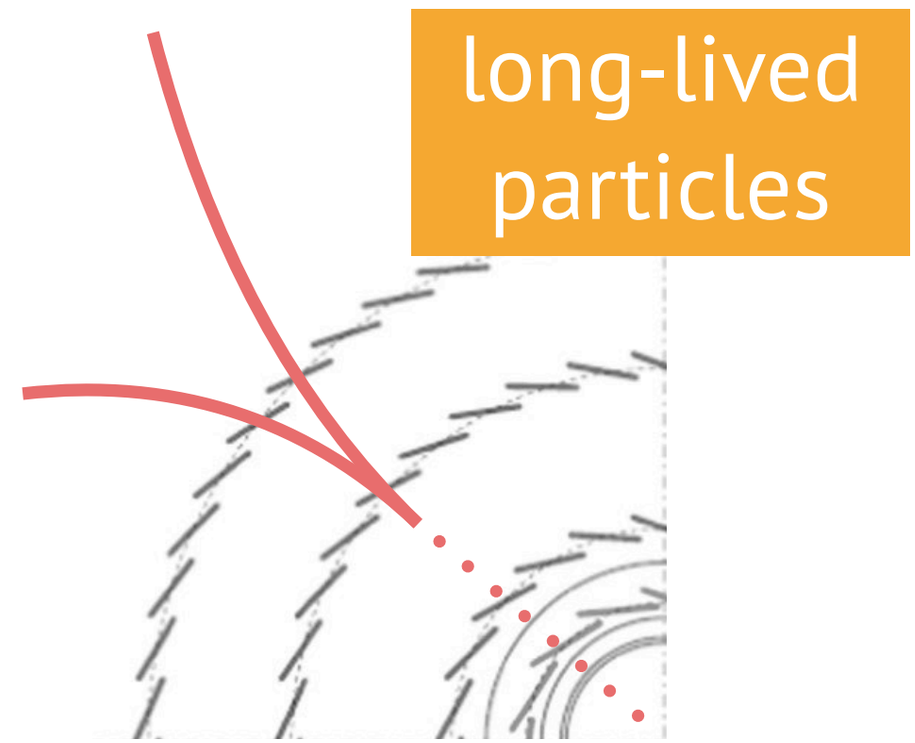


crucial for jet and missing E_T triggers

ATLAS Luminosity Plots

Global tracking can help identify any object with **track-based signatures**





Plus: if tracking is already available, **frees up CPU** at HLT for other tasks

The **Fast TracKer** gives us global tracking

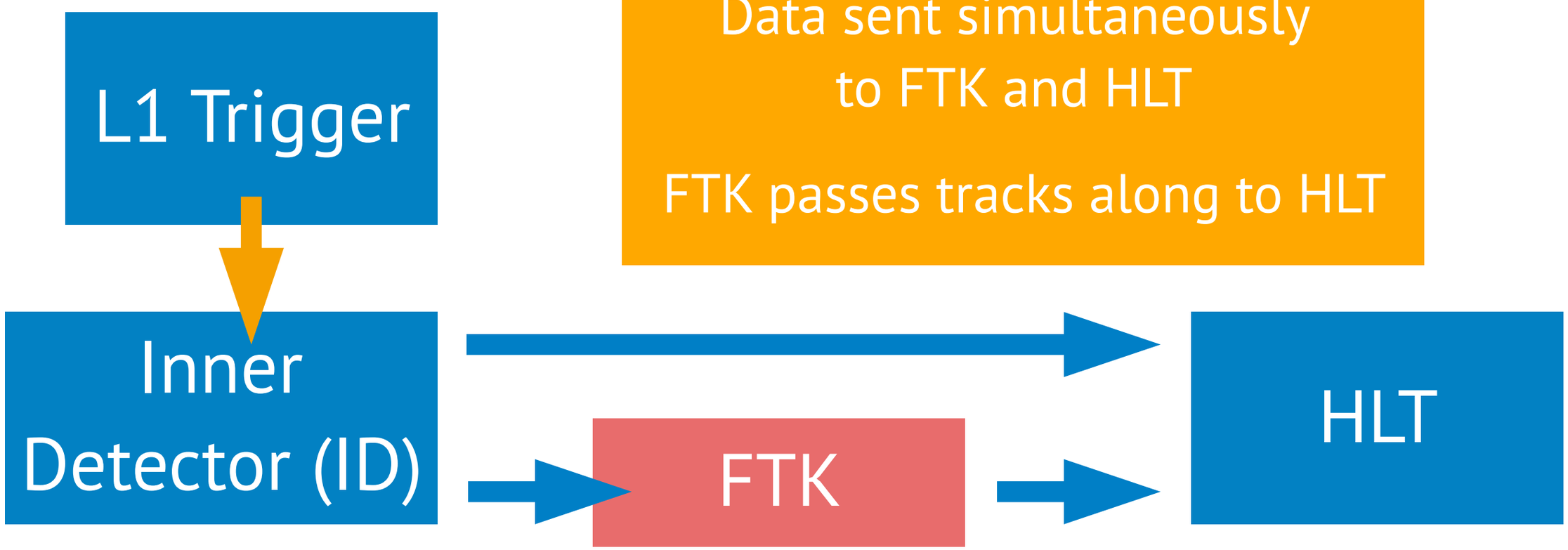
FTK performs **hardware-based** tracking on silicon hits

provides HLT with >1 GeV tracks in ID acceptance (|η|<2.5)

Data from the ID is read out when a L1 trigger is fired

Data sent simultaneously to FTK and HLT

FTK passes tracks along to HLT



Time constraints

Offline track reconstruction for the full tracking volume requires about 10 s / event

To keep up with L1 rates, FTK must do tracking for the full event in ~.1 ms

Requires time reduction of ~5 orders of magnitude

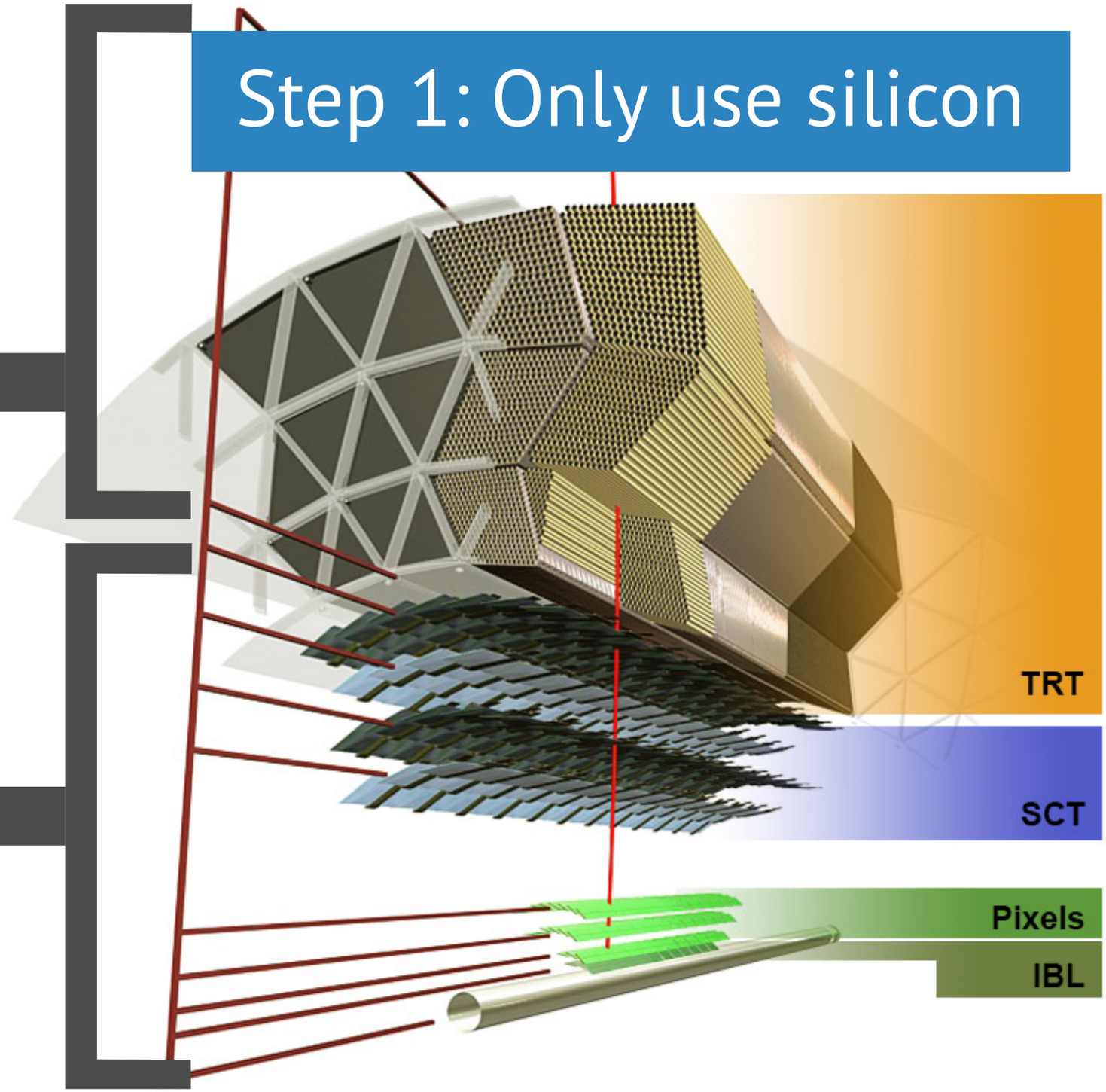
How can we track so fast?

Making tracking a simpler problem

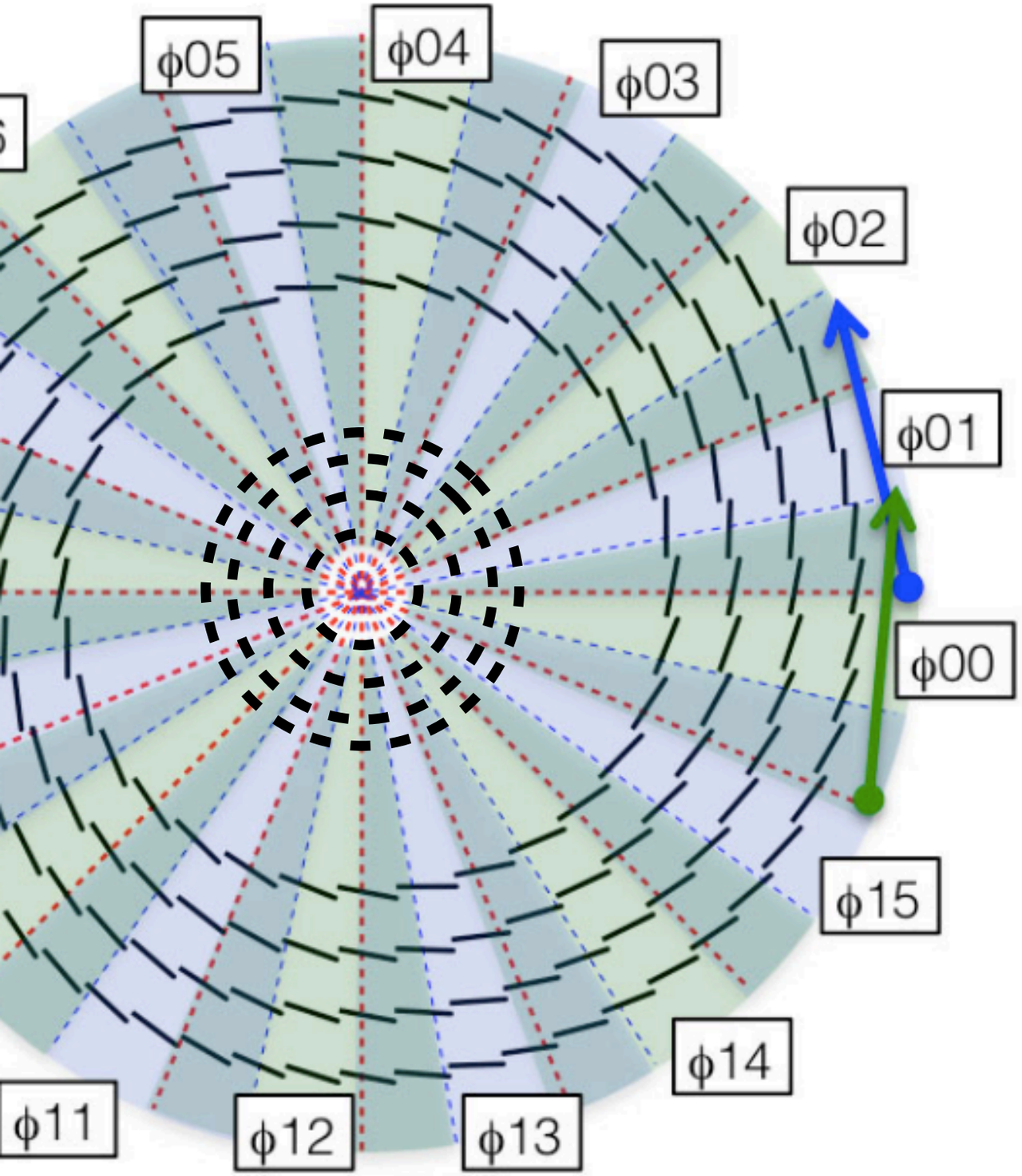
Step 1: Only use silicon

Straight to HLT

Split signals go to HLT and FTK



Making tracking a simpler problem



Step 2: Parallelize

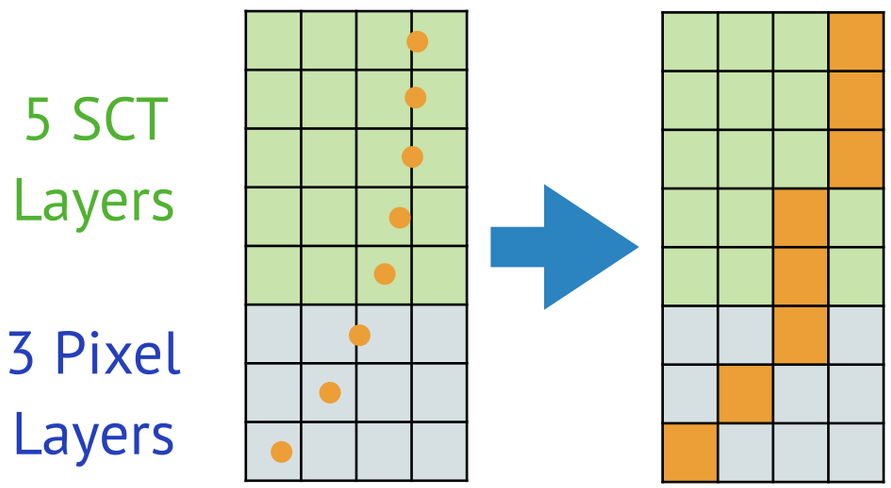
Divide the detector into 64 overlapping **towers**

32 input boards **share data** and categorize into towers

Data from each tower sent to separate processing units

Making tracking a simpler problem

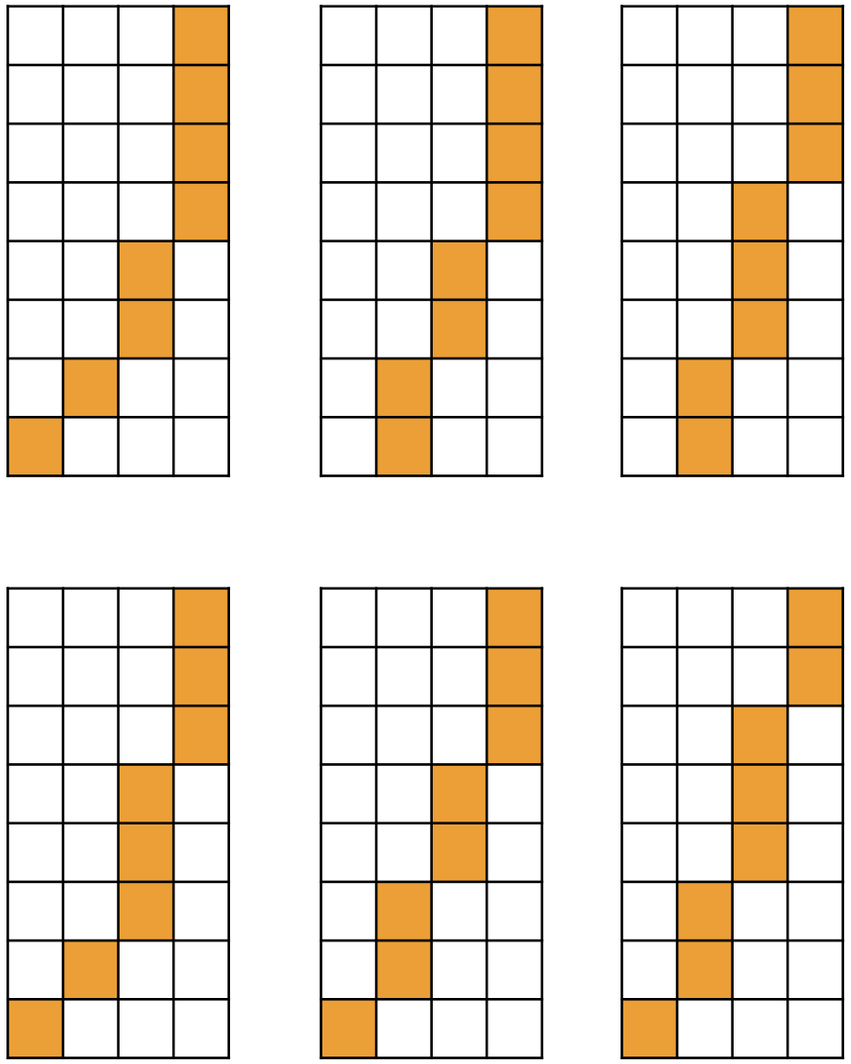
Start with 8/12
silicon layers of ATLAS



Step 3: Pattern Match

Divide each layer into
coarse chunks

Making tracking a simpler problem

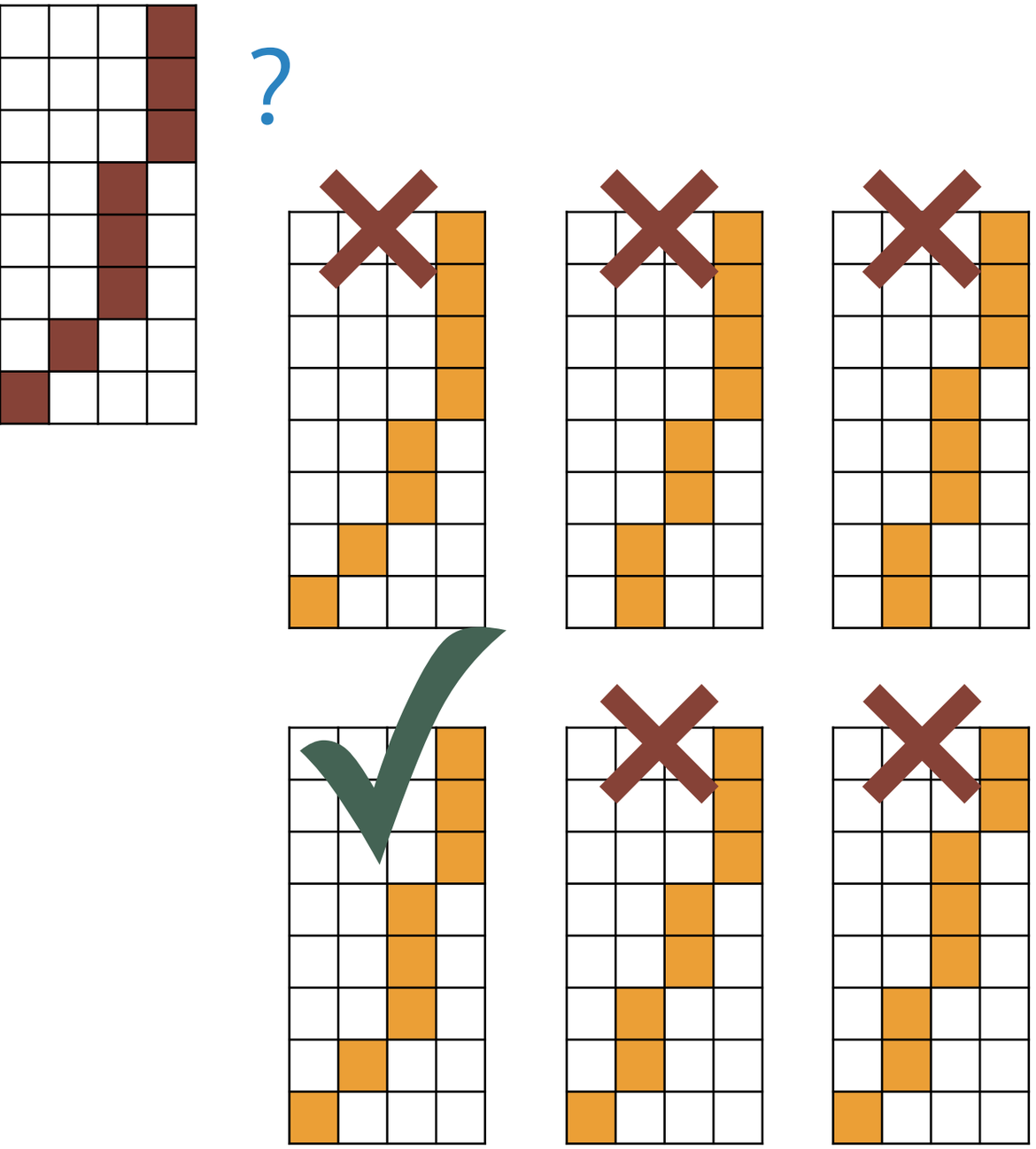


Step 3: Pattern Match

Divide each layer into **coarse chunks**

Define **patterns** of these chunks that correspond to tracks

Making tracking a simpler problem



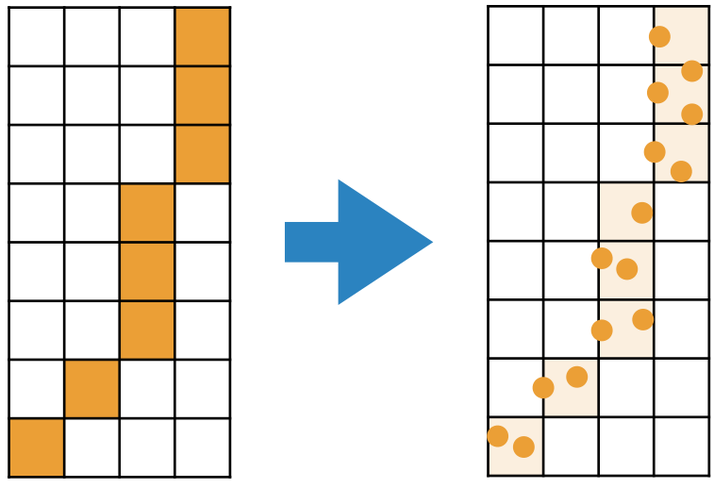
Step 3: Pattern Match

Divide each layer into **coarse chunks**

Define **patterns** of these chunks that correspond to tracks

Compare fired pattern **simultaneously** to full bank of patterns

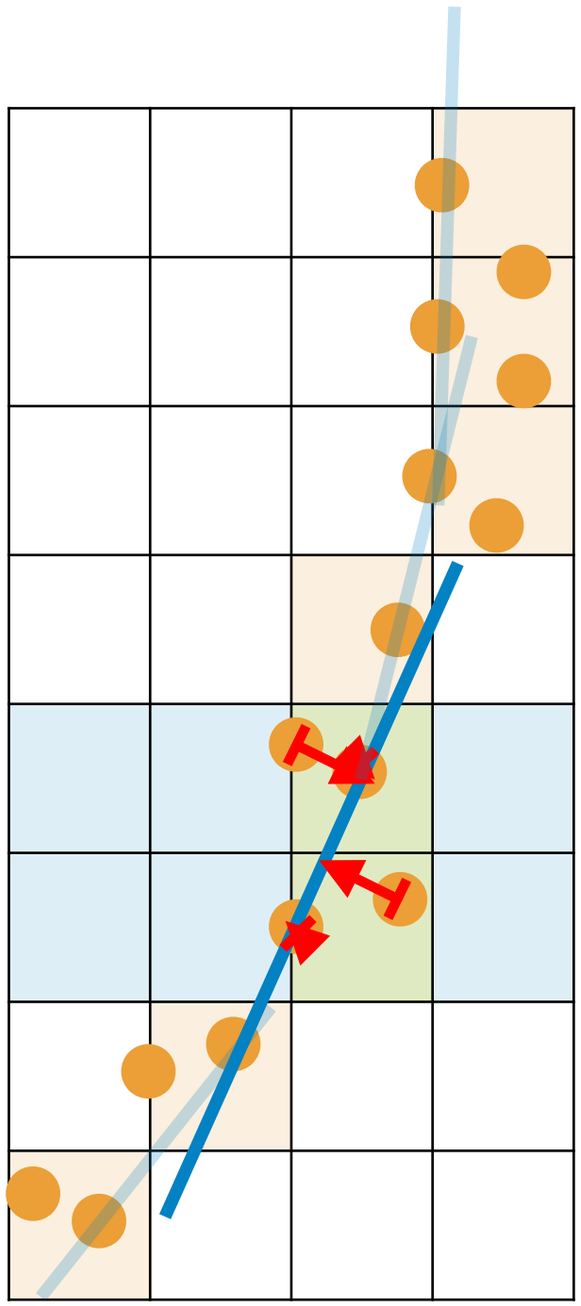
Making tracking a simpler problem



Step 4: Fit a Subset

For matched patterns,
retrieve all **full resolution** hits

Making tracking a simpler problem



Step 4: Fit a Subset

For matched patterns,
retrieve all **full resolution** hits

Perform a **linearized fit**
on the hits in 8 layers

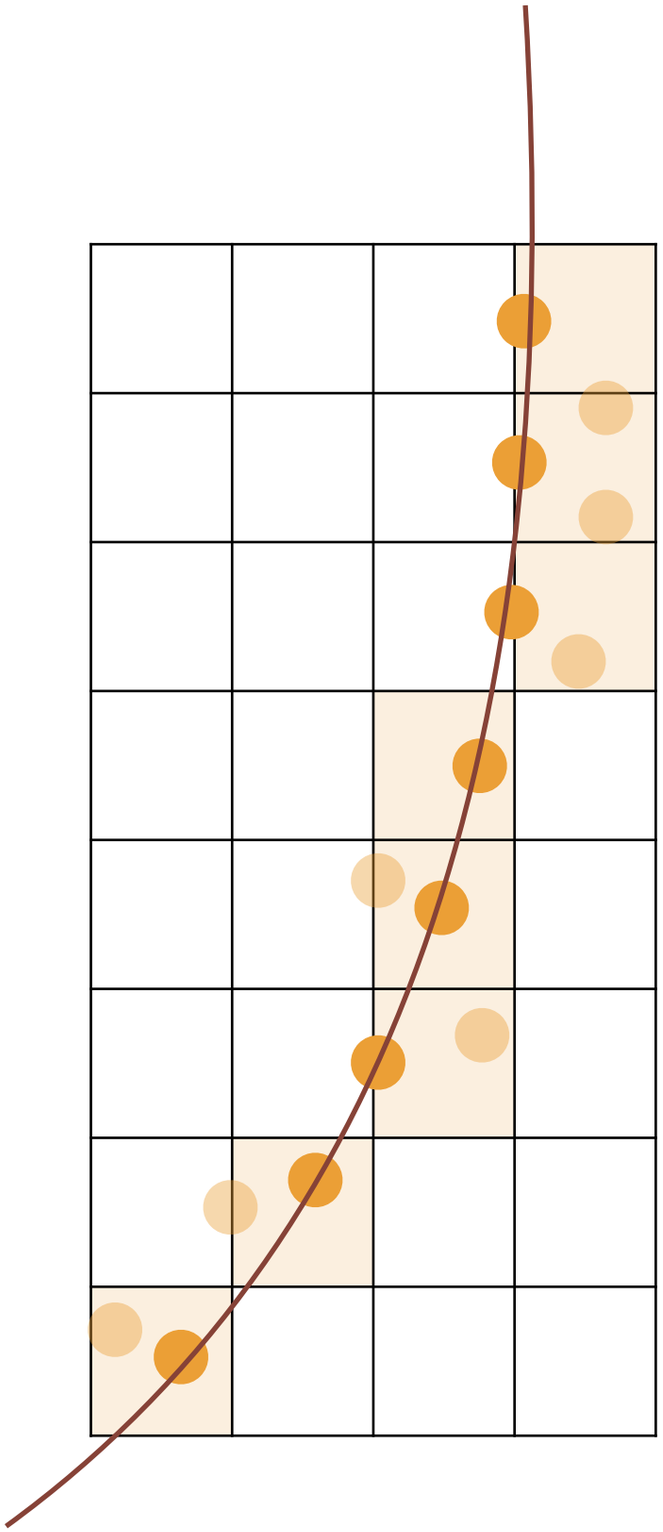
constants pre-defined
per detector region

line: $y = mx + b$

each hit has a distance from the line: $\Delta x, \Delta y$

X^2 of fit: $\chi^2 = \sum_i^8 \sqrt{\Delta x_i^2 + \Delta y_i^2}$

Making tracking a simpler problem



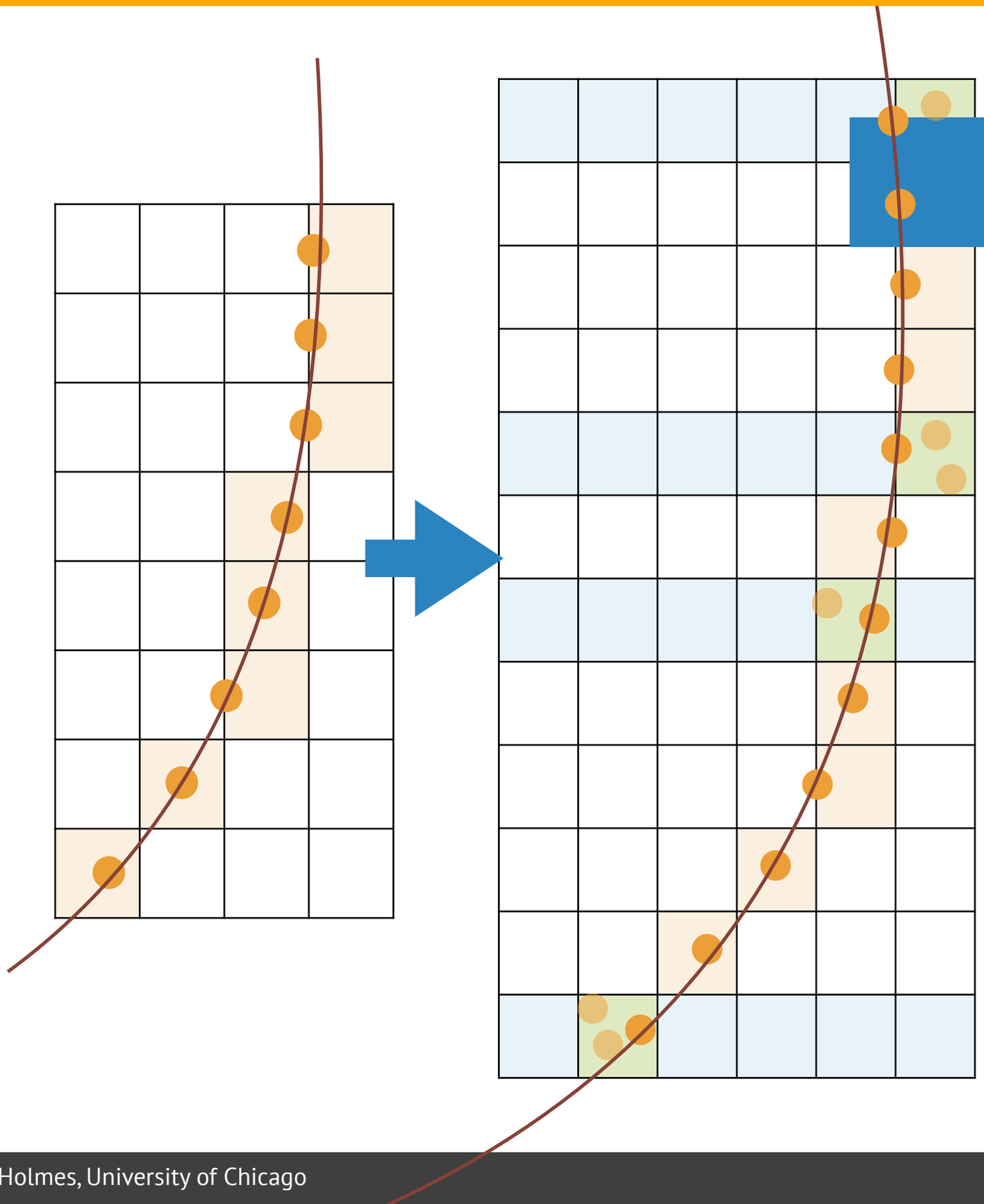
Step 4: Fit a Subset

For matched patterns,
retrieve all **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

Look for nearby hits in remaining layers and perform a **full fit**

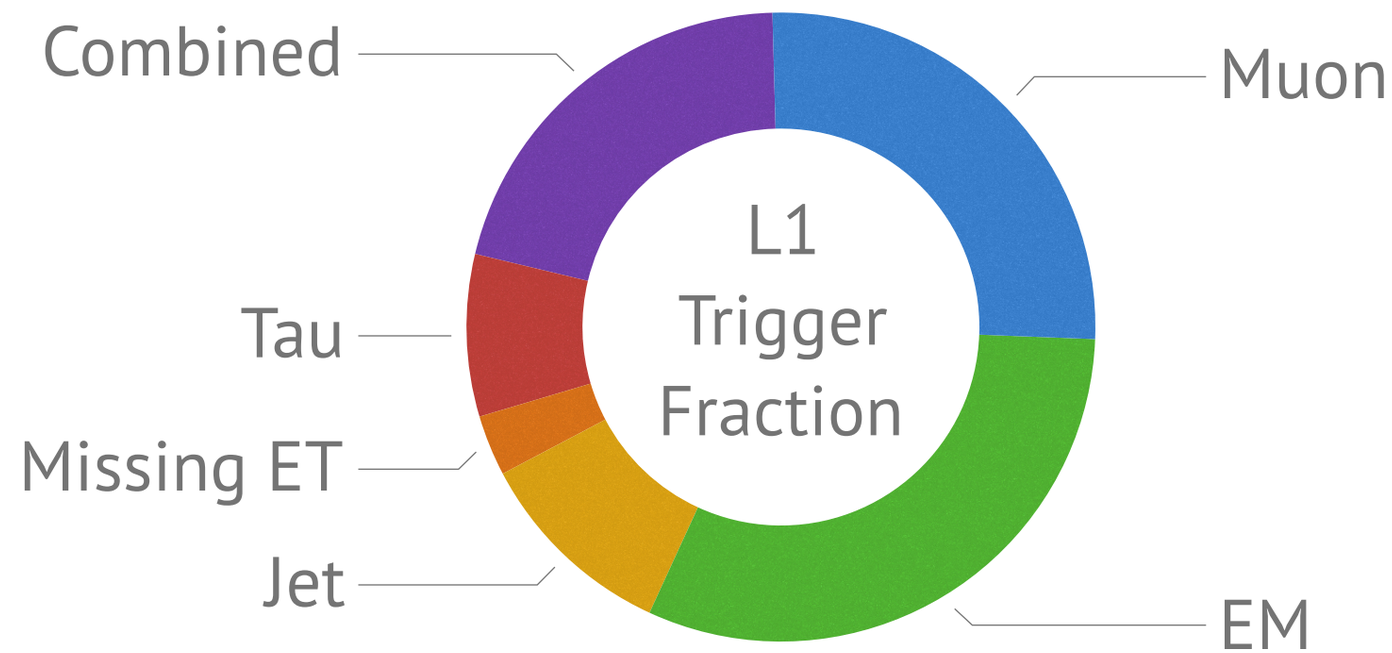
Send tracks passing a linear χ^2 cut

FTK Expected Performance

Total L1 rate is 100 kHz;
FTK will run at **35 kHz**

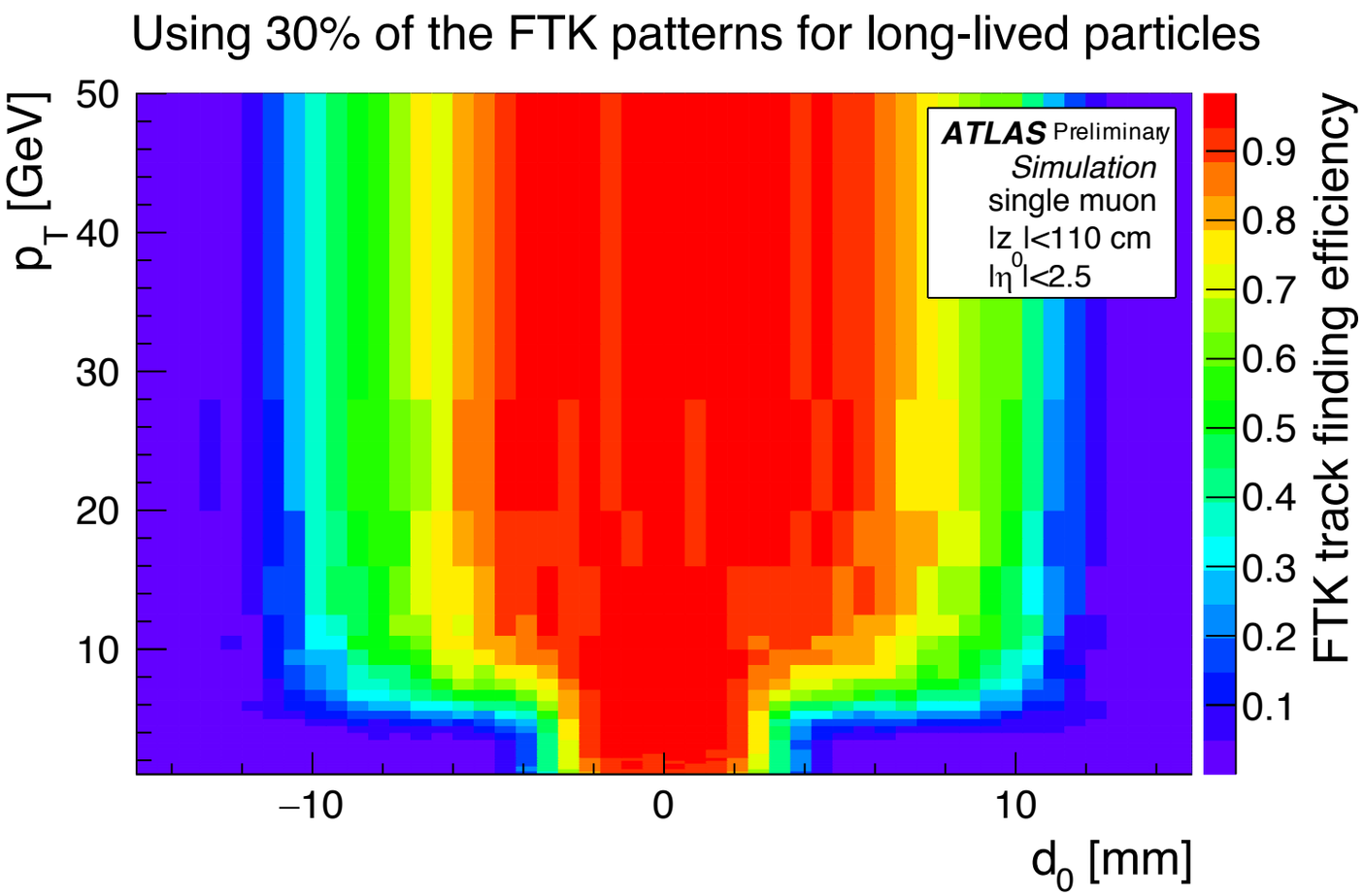
includes all
jet, missing E_T,
EM+jets

with ~10 kHz
remaining for
other use cases



Remaining rate mostly lepton and photon triggers— well handled by current HLT

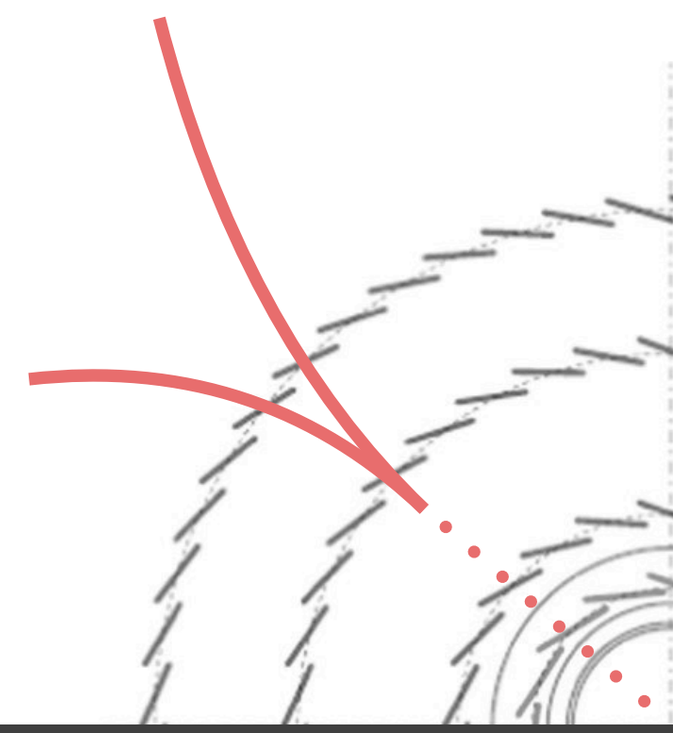
FTK Expected Performance



new: exploring reconstruction of displaced tracks from **long-lived particles**

pattern banks with **extended d_0 range**
minimal impact on prompt efficiency

allows for identification of displaced particles in the trigger!



FTK Public Plots

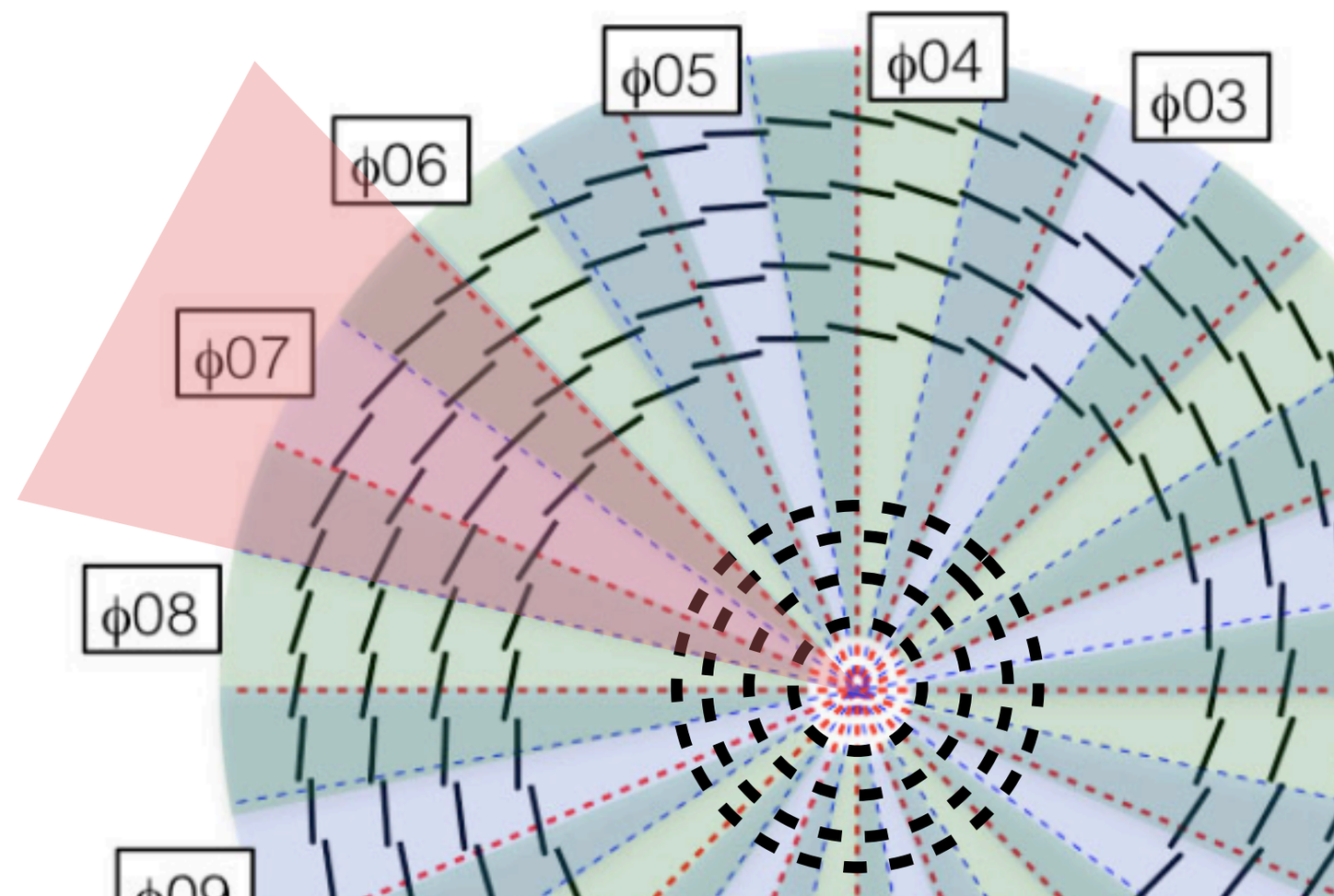
FTK Commissioning

very complex system

almost **2000 FPGAs** across
six different types of boards
+ **8000 custom ASICs**

commissioning
began with
one of each board
type in a tower

a "**slice**"

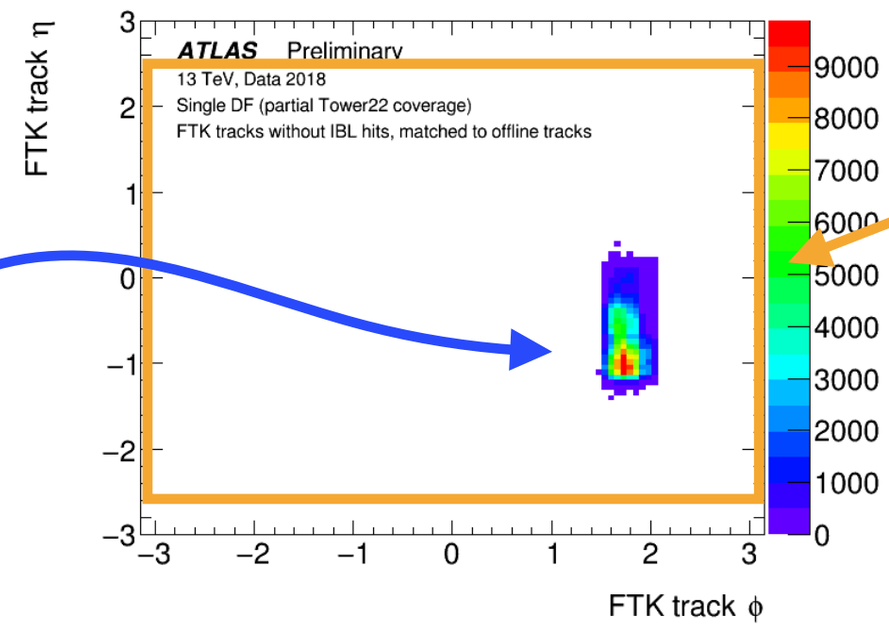


FTK Commissioning

excellent progress commissioning with beam in 2018

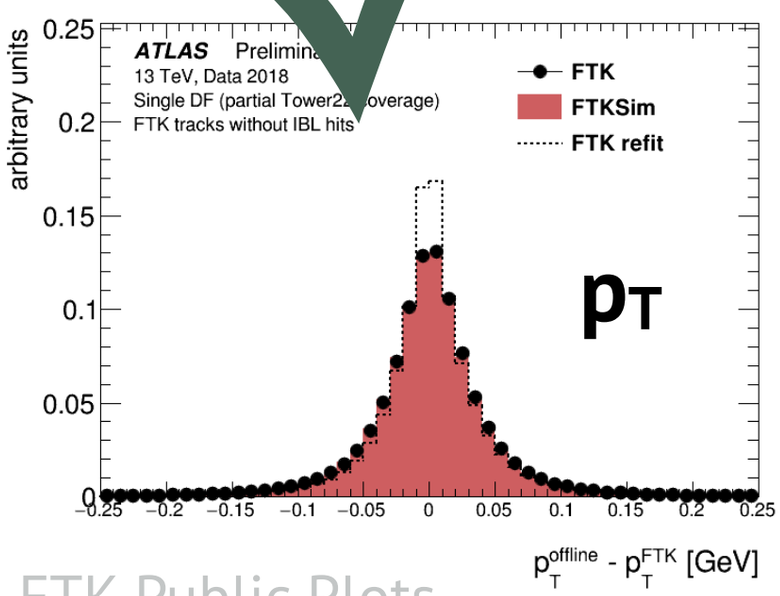
✓ **ran one slice of FTK** in ATLAS

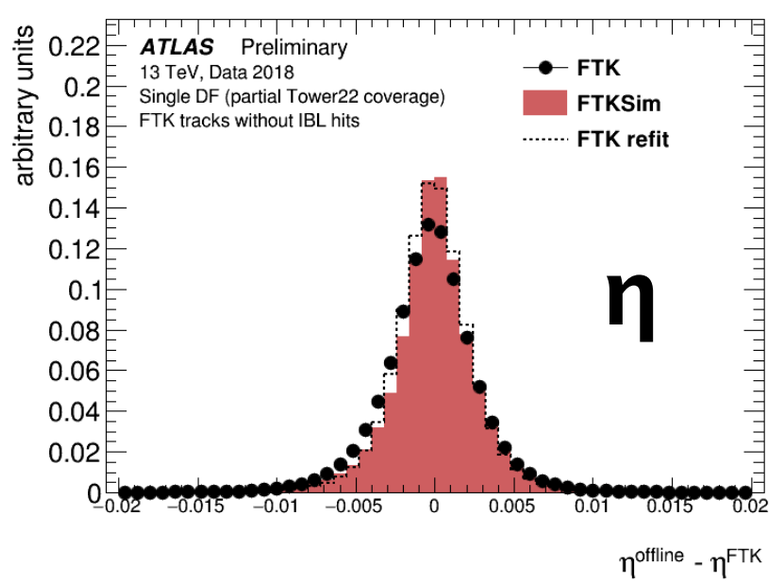
single tower coverage

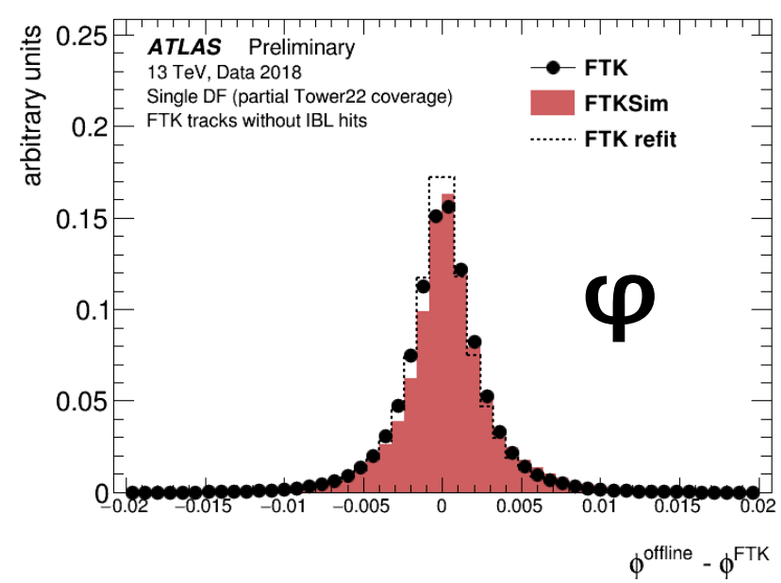


coverage of full FTK

✓ demonstrated good **agreement with simulation**







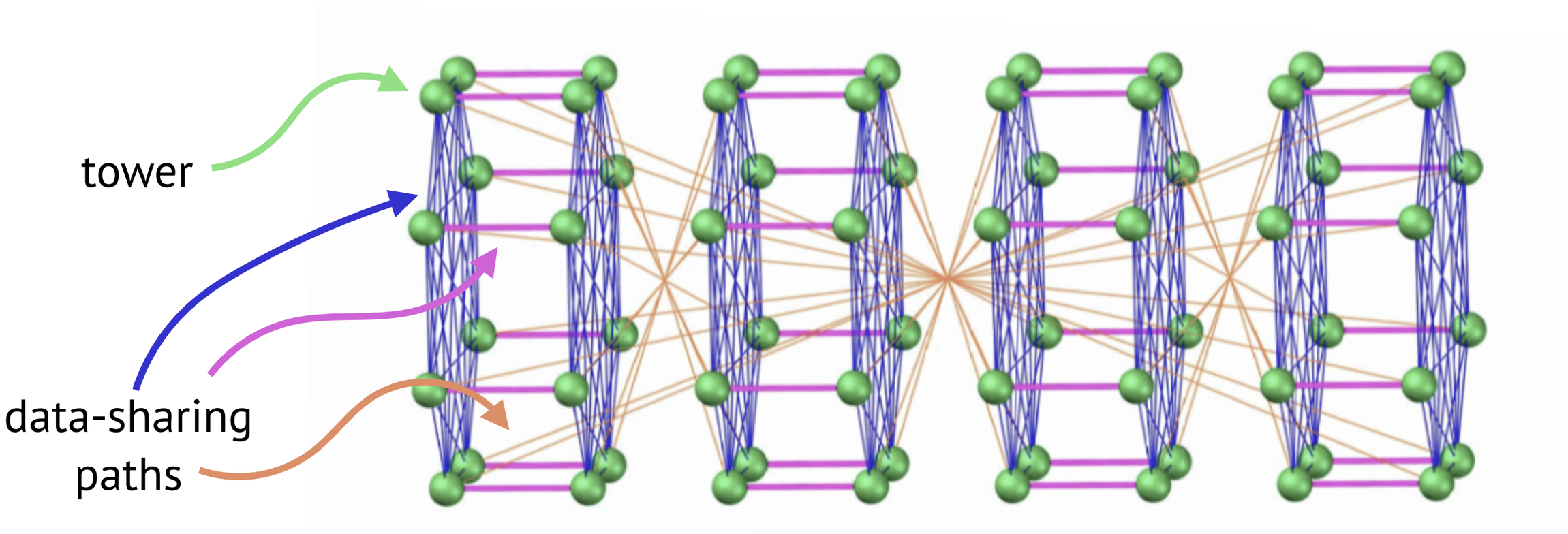
FTK Public Plots

FTK Commissioning

much more to do!

scaling up to the full system

- **data-sharing** in the full system
- increasing **speed** to handle more dataflow
- improving **robustness** to data errors
- **installing** remaining hardware

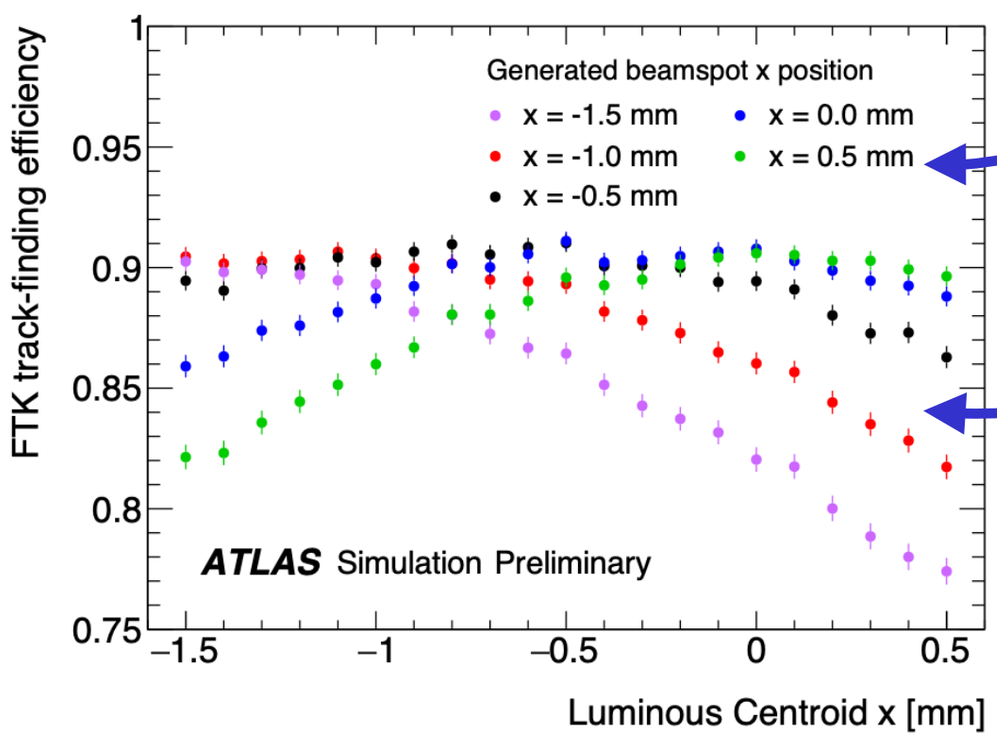


FTK Commissioning

much more to do!

integrating with ATLAS

- improving **monitoring** and communication to HLT
- testing and iterating on the FTK **trigger menu**
- joining **cosmic runs** to validate performance
- develop methods to adjust FTK for **changing conditions**

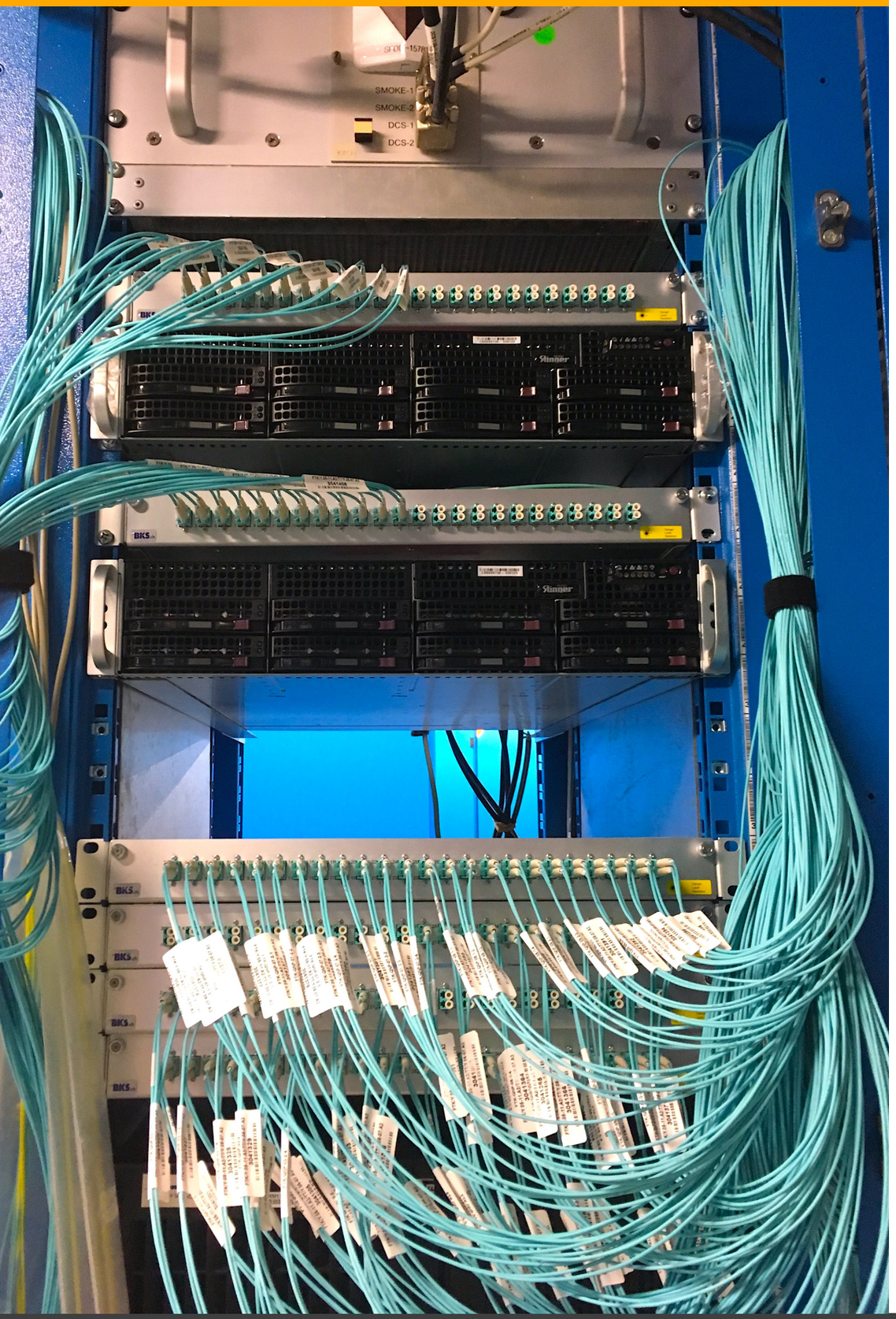


FTK choice of **beam spot** position

FTK **efficiency** vs. actual position

FTK Public Plots

FTK Commissioning



plus… a new system

QuestNP:

15 cards that allow for **data playback** with ATLAS-like conditions

lets FTK commission as if there were still beam

Conclusions

LHC Run 3 is a lot like Run 2

No large jumps in luminosity or energy

FTK will open up **new opportunities**

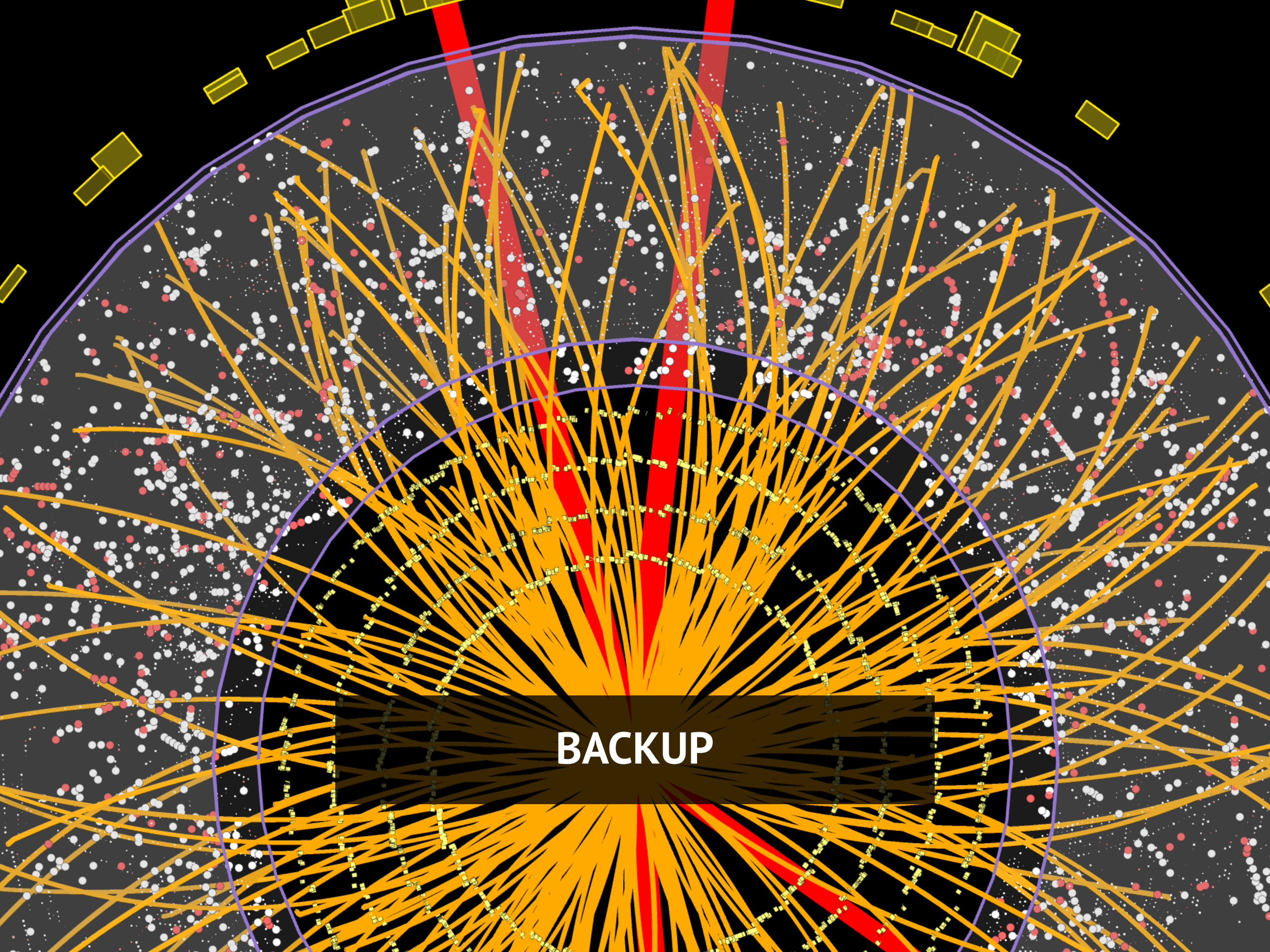
Lots of commissioning **progress** already in Run 2

FTK team is **very busy** during the long shutdown

First hardware track trigger of LHC: gives us **experience** for future upgrades

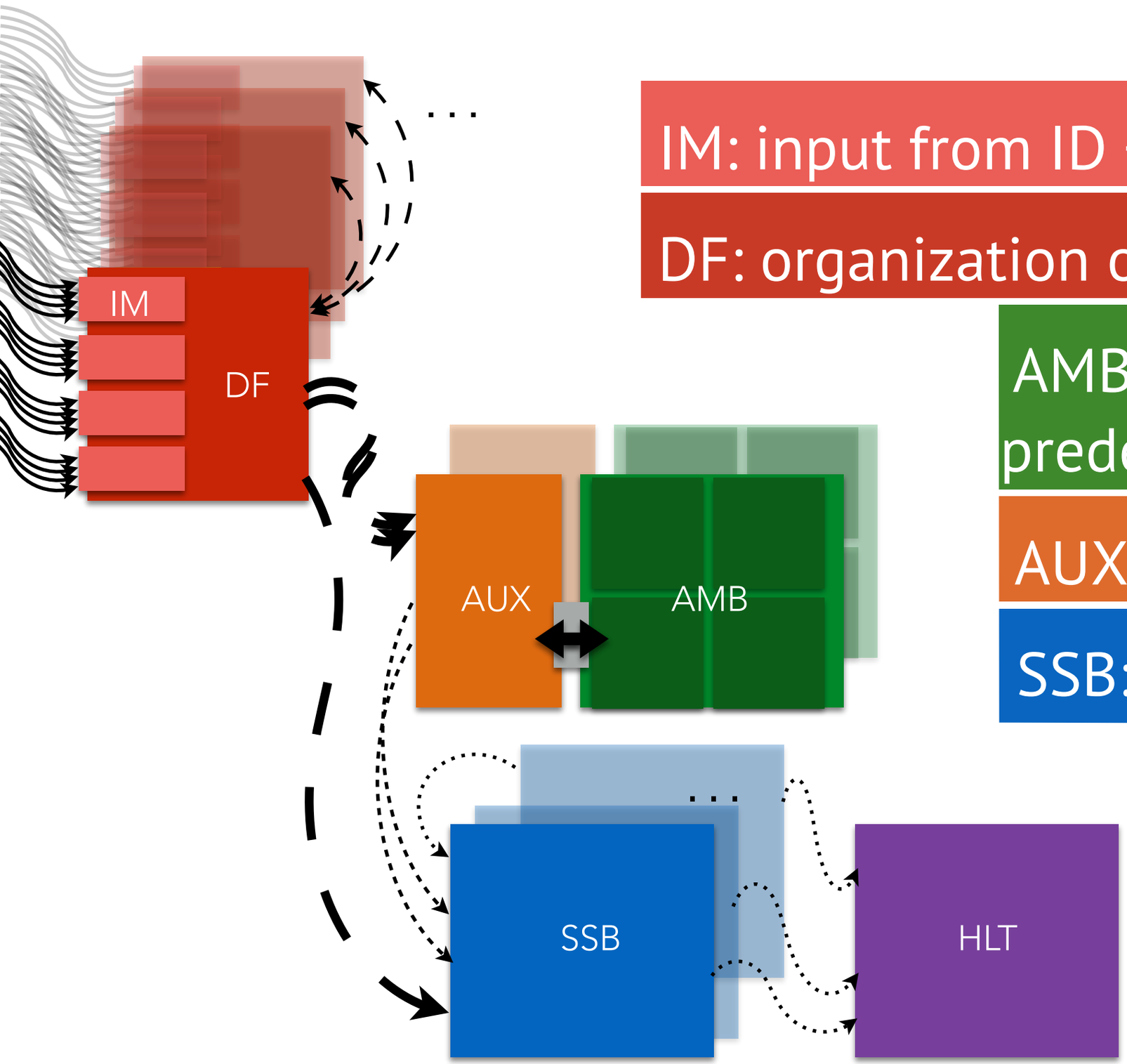
Still **rate available** for creative triggers using FTK!

THANK YOU!



BACKUP

FTK Boards



IM: input from ID + hit clustering

DF: organization of data into towers

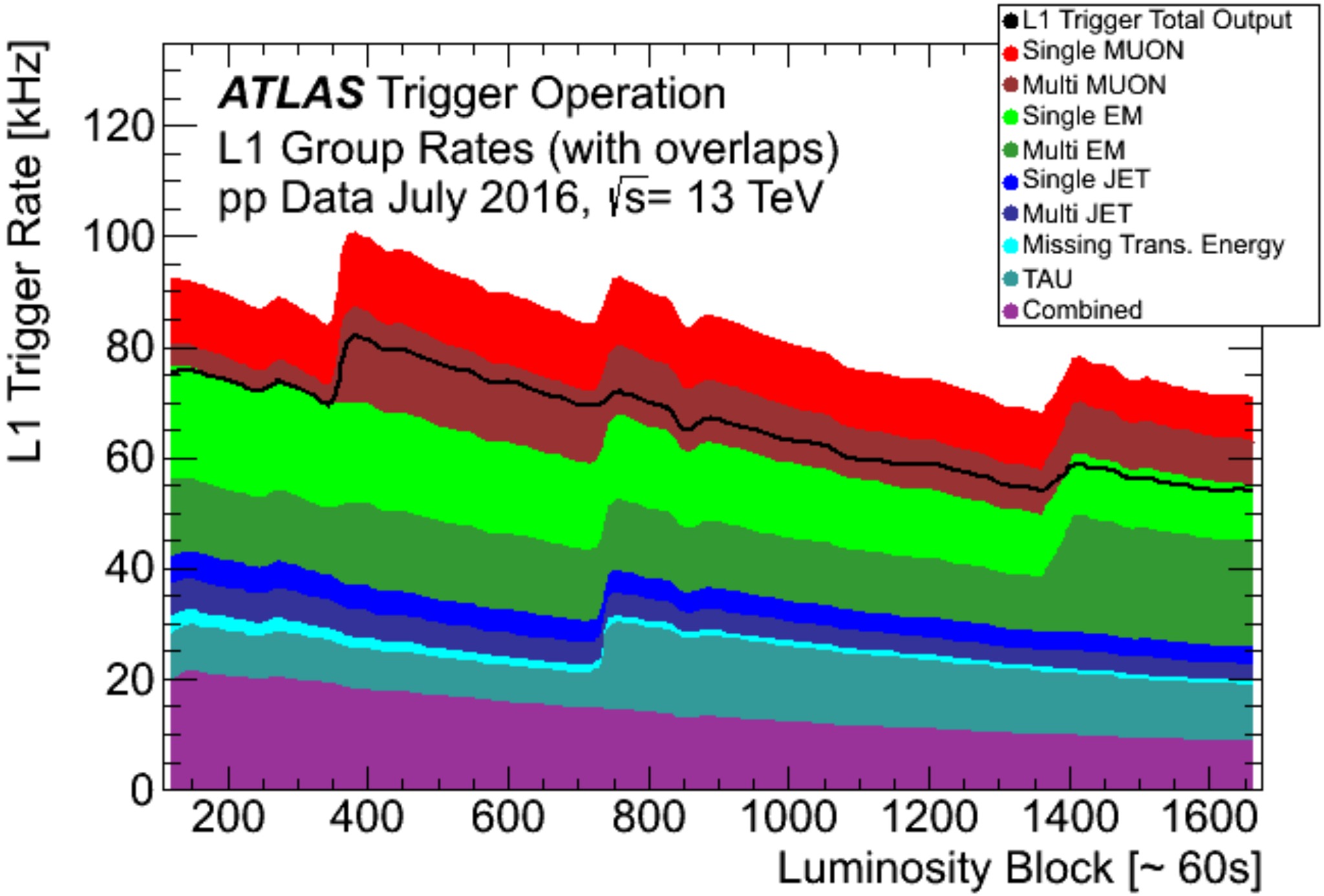
AMB: matching clusters to predefined patterns

AUX: 8-layer track fitting

SSB: 12-layer track fitting

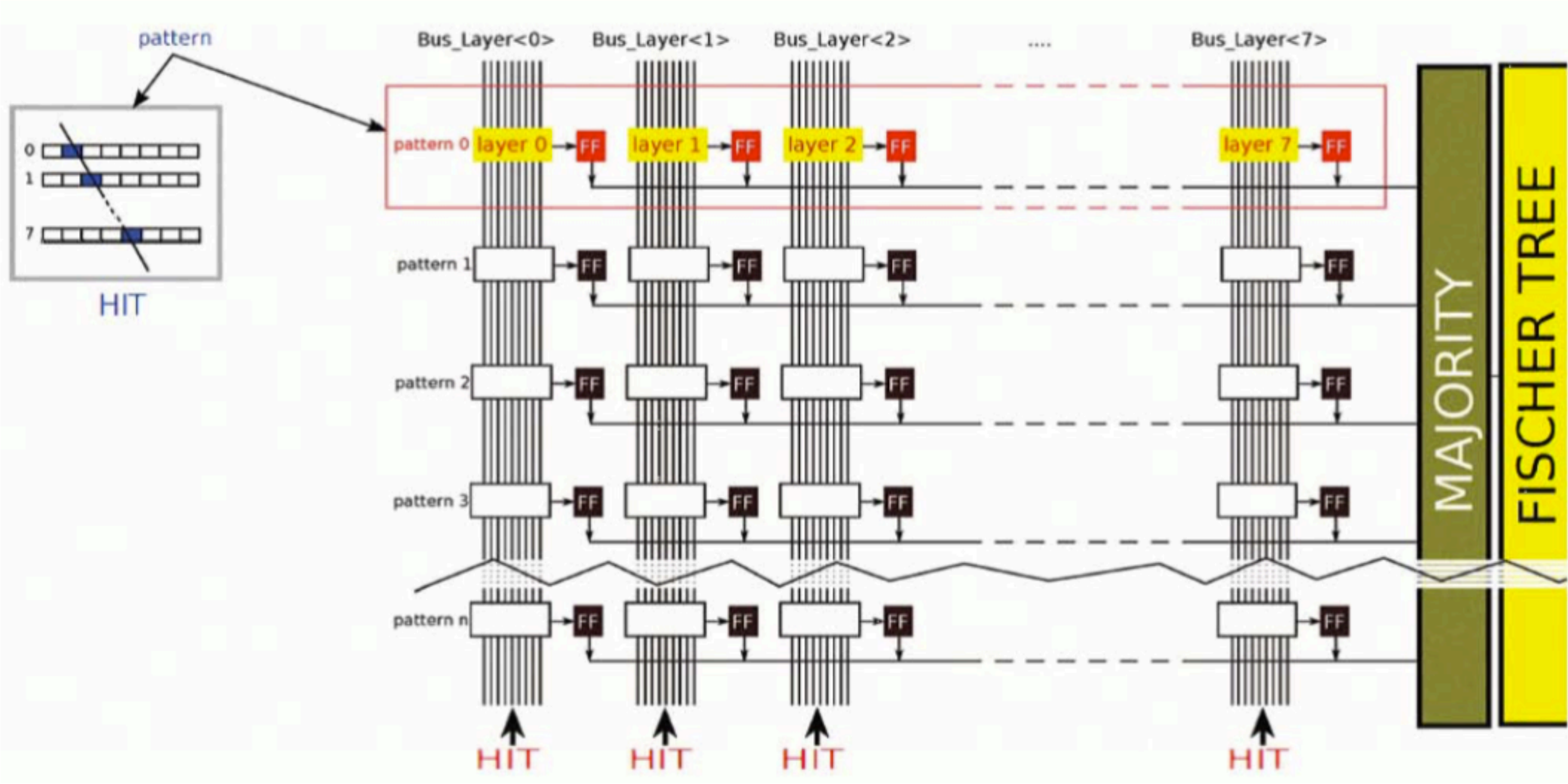
raw hits
clusters
8-layer tracks
12-layer tracks

L1 Trigger Rates

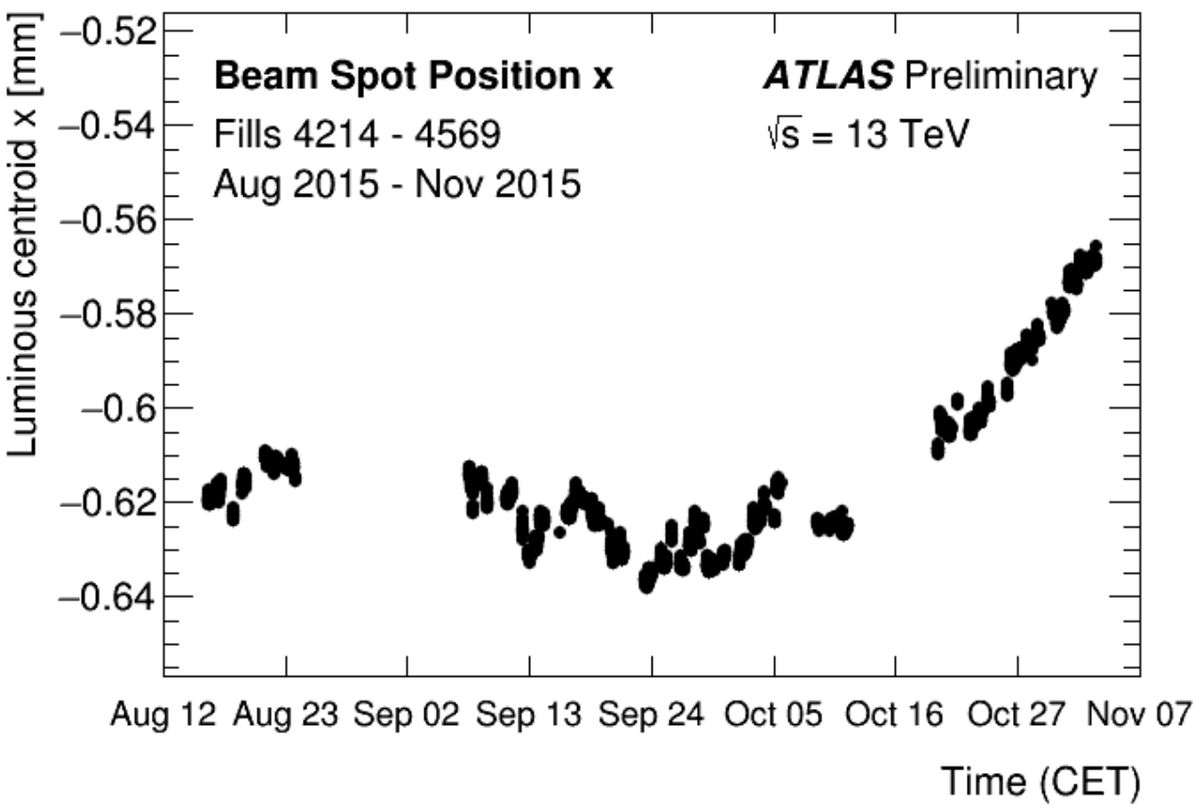


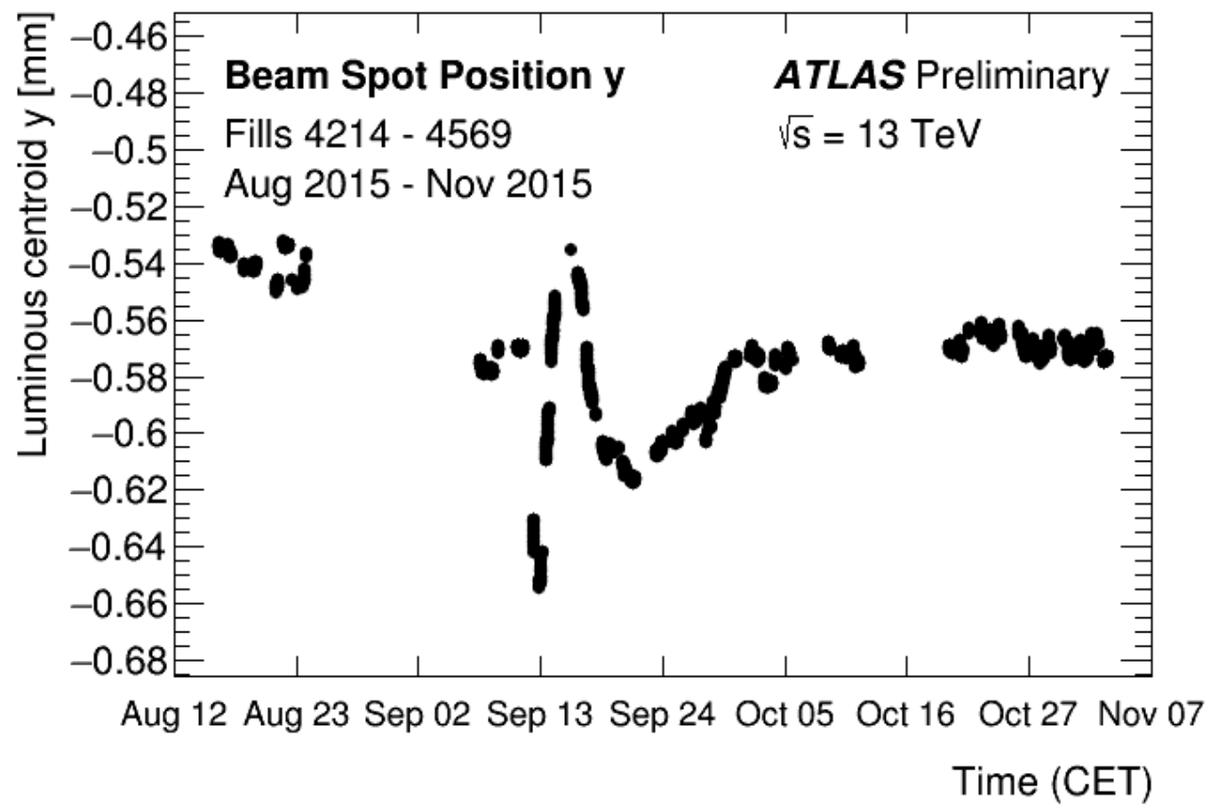
Trigger Public Plots

AM Logic


pattern
0
1
7
HIT
Bus_Layer<0>
Bus_Layer<1>
Bus_Layer<2>
....
Bus_Layer<7>
pattern 0
layer 0
layer 1
layer 2
layer 7
FF
pattern 1
pattern 2
pattern 3
pattern n
HIT
HIT
HIT
HIT
MAJORITY
FISCHER TREE

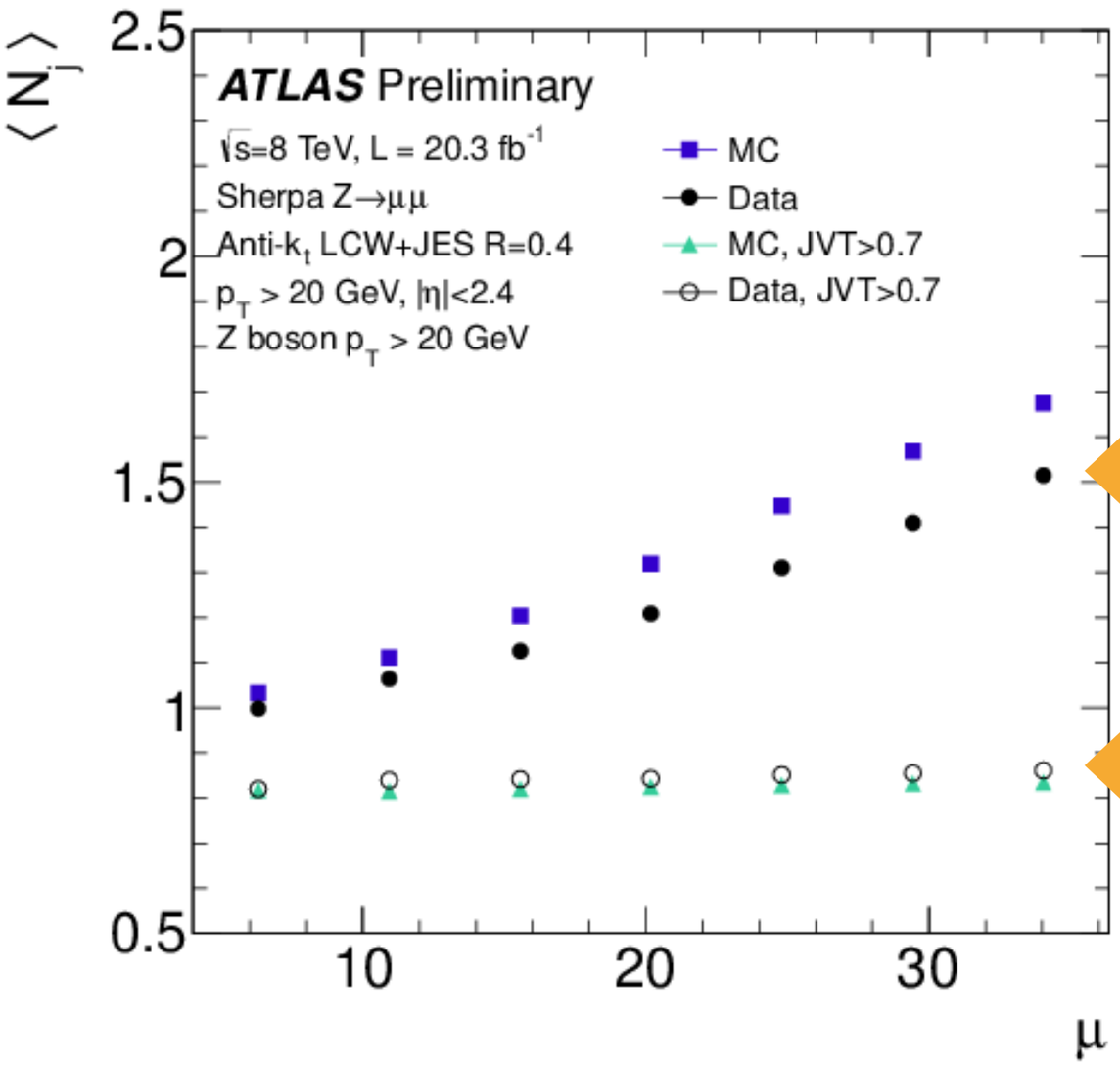
Beamspot Positions





Beam Spot Public Results

Pileup @ the LHC



Tracking at the trigger level is essential to maintaining low trigger thresholds

njets selected without tracking

njets selected with tracking

ATLAS-CONF-2014-018