OVERVIEW

Trigger Overview

FTK Design

FTK Commissioning
ATLAS **rejects** 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?

ATLAS public event displays

(image of an event with analysis-level “offline” reconstruction)
Level 1 trigger decisions are made with rough calorimeter and muon information.

High Level Trigger uses full precision information in small regions.

40 MHz → 100 kHz

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 precision** information in **small regions** of interest (RoI)
Level 1 trigger decisions are made with rough **calorimeter** and **muon** information.

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

What do we miss with just these RoIs?
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
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
FTK performs **hardware-based** tracking on silicon hits provides HLT with >1 GeV tracks in ID acceptance (|\(\eta\)|<2.5)

Data sent simultaneously to FTK and HLT

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

FTK passes tracks along to HLT

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*The Fast Tracker gives us global tracking*
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
Start with 8/12 silicon layers of ATLAS

Step 3: Pattern Match

Divide each layer into coarse chunks
Making tracking a simpler problem

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

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For matched patterns, retrieve all full resolution hits

Perform a linearized fit on the hits in 8 layers

line: \( y = mx + b \)

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

\[ X^2 \text{ of fit: } \chi^2 = \sum_{i}^{8} \sqrt{\Delta x_i^2 + \Delta y_i^2} \]
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 $\chi^2$ 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 $\chi^2$ cut
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
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 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**”

T. Holmes, University of Chicago
FTK Commissioning

excellent progress commissioning with beam in 2018

✓ ran one slice of FTK in ATLAS

✓ demonstrated good agreement with simulation

single tower coverage

coverage of full FTK

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

![Diagram showing data-sharing paths and towers]
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!
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**

*ATLAS* Trigger Operation

L1 Group Rates (with overlaps)

pp Data July 2016, $\sqrt{s}=13$ TeV

**Trigger Public Plots**
AM Logic
Beamspot Positions

Beam Spot Position x
Fills 4214 - 4569
Aug 2015 - Nov 2015

ATLAS Preliminary
\( \sqrt{s} = 13 \) TeV

Beam Spot Position y
Fills 4214 - 4569
Aug 2015 - Nov 2015

ATLAS Preliminary
\( \sqrt{s} = 13 \) TeV

Beam Spot Public Results

T. Holmes, University of Chicago
Pileup @ the LHC

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

ATLAS Preliminary

\(<N_{\text{jets}}^->\)

- $\sqrt{s} = 8$ TeV, $L = 20.3$ fb$^{-1}$
- Sherpa $Z \rightarrow \mu \mu$
- Anti-$k_t$, LCW+JES R=0.4
- $p_T > 20$ GeV, $|\eta| < 2.4$
- Z boson $p_T > 20$ GeV

njets selected without tracking

njets selected with tracking

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