ATLAS FTK a - very complex - custom parallel supercomputer

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on behalf of the ATLAS Collaboration

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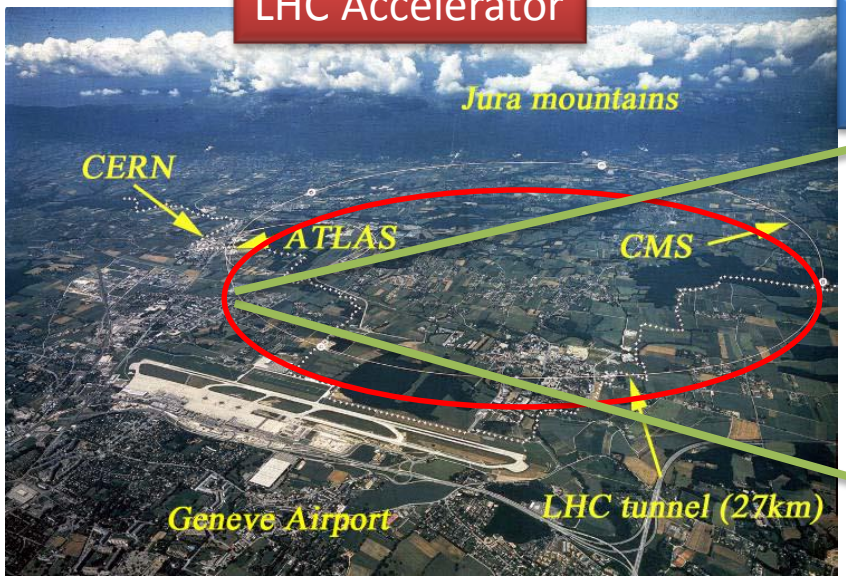
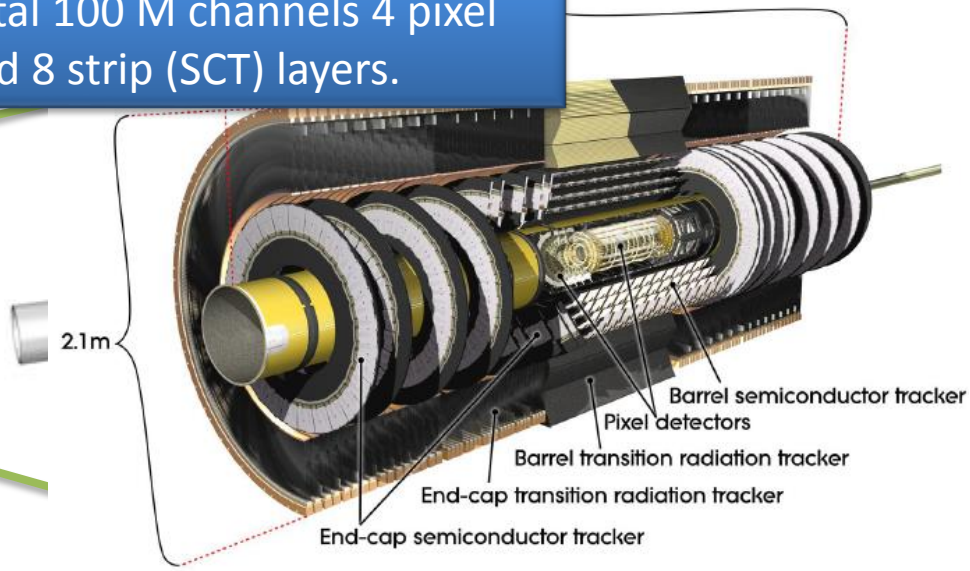
LHC and ATLAS

LHC Accelerator

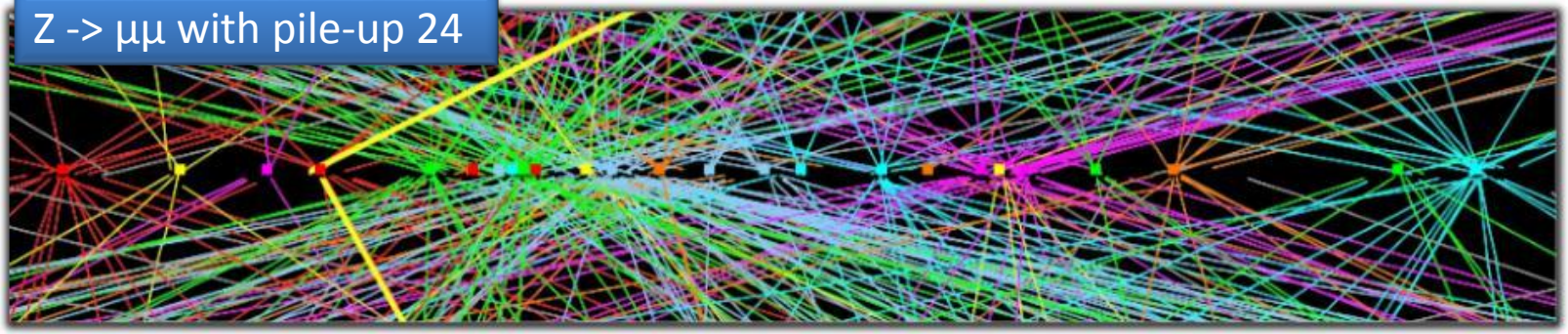


ATLAS SCT and Pixel silicon Detector

Total 100 M channels 4 pixel and 8 strip (SCT) layers.



Z -> μμ with pile-up 24

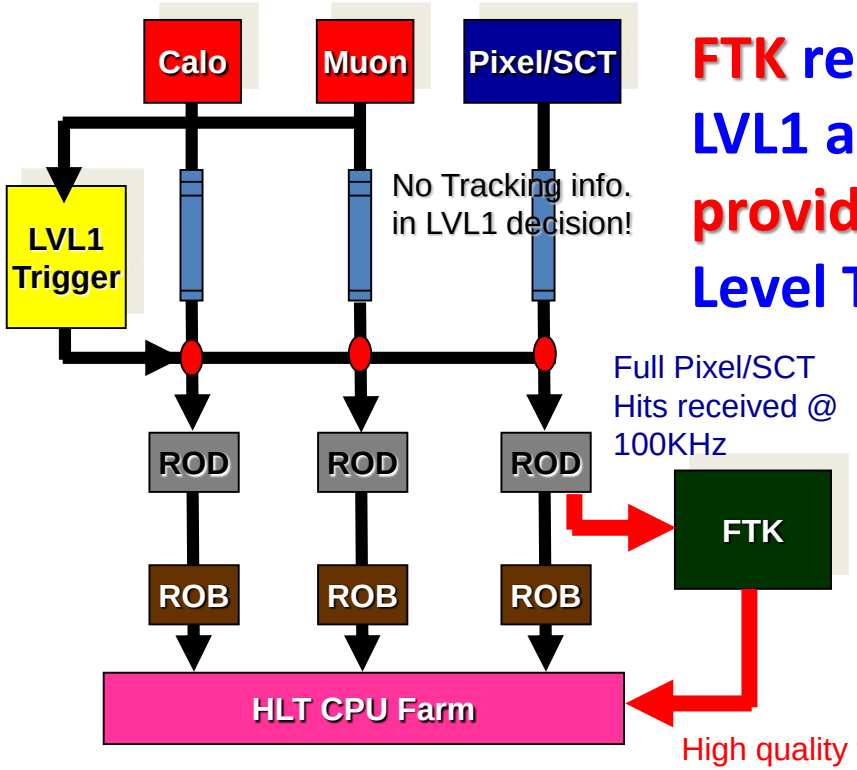


Atlas event with a Z boson decaying to two muons and 24 additional interaction vertices.

~80 interactions per bunch crossing in Run III (2019-...)

- **Increased difficulty of real time data selection at the trigger level**

What is FTK



FTK reconstructs all tracks (P_T >1 GeV) for all LVL1 accepted events (100 kHz). And provides track information to the High-Level Trigger (HLT) before trigger decision.

FTK uses only silicon detector information.

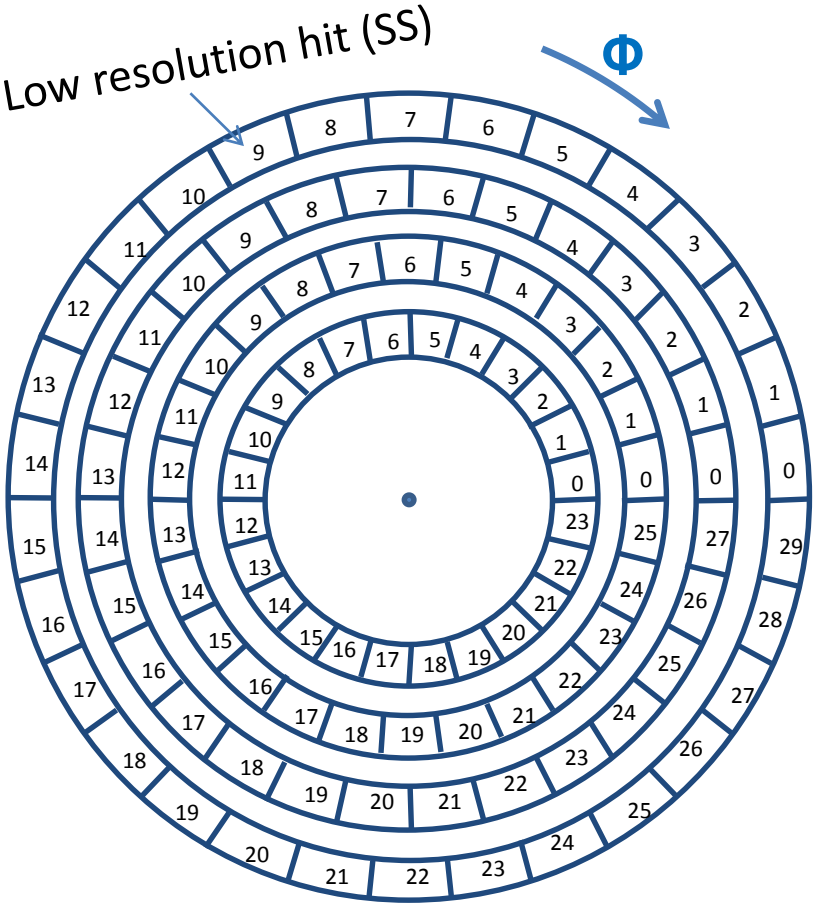
FTK provides further information that is useful for trigger.

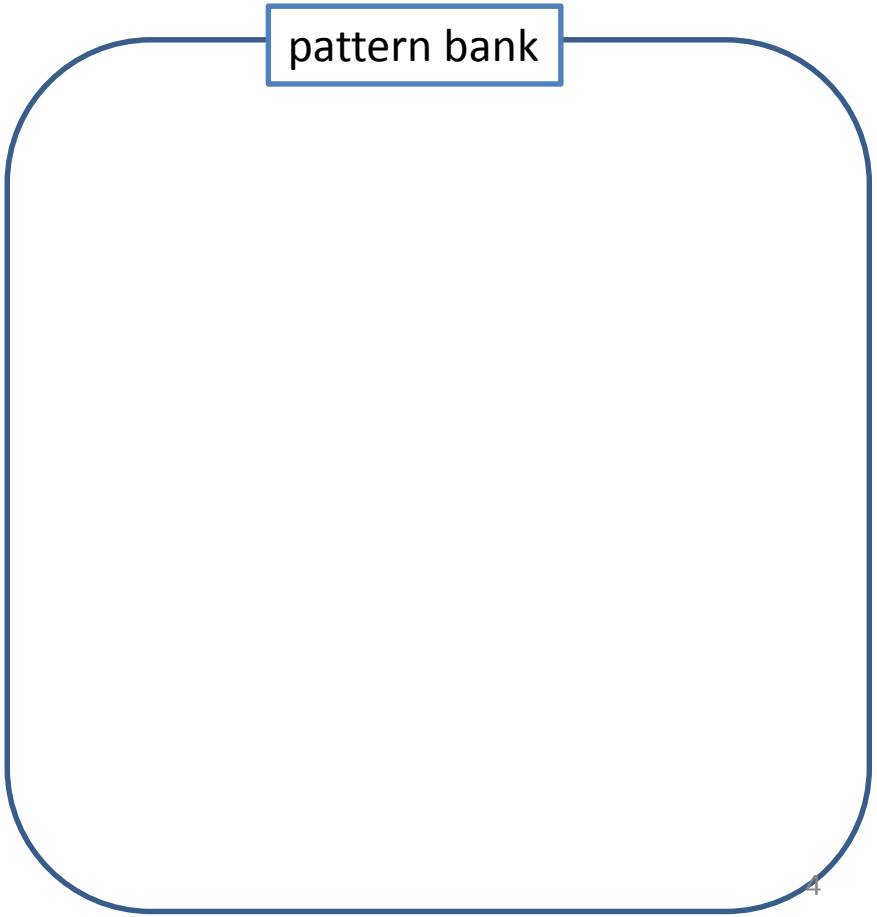
Key point of FTK: Speed and Quality

We need to reconstruct track information (Pt, D0, Z0, eta, phi) from 12 layers, 100 M ch silicon detector in ~100 micro second at 100 kHz.

FTK principle : Pattern Recognition

Find low resolution track called “pattern”.

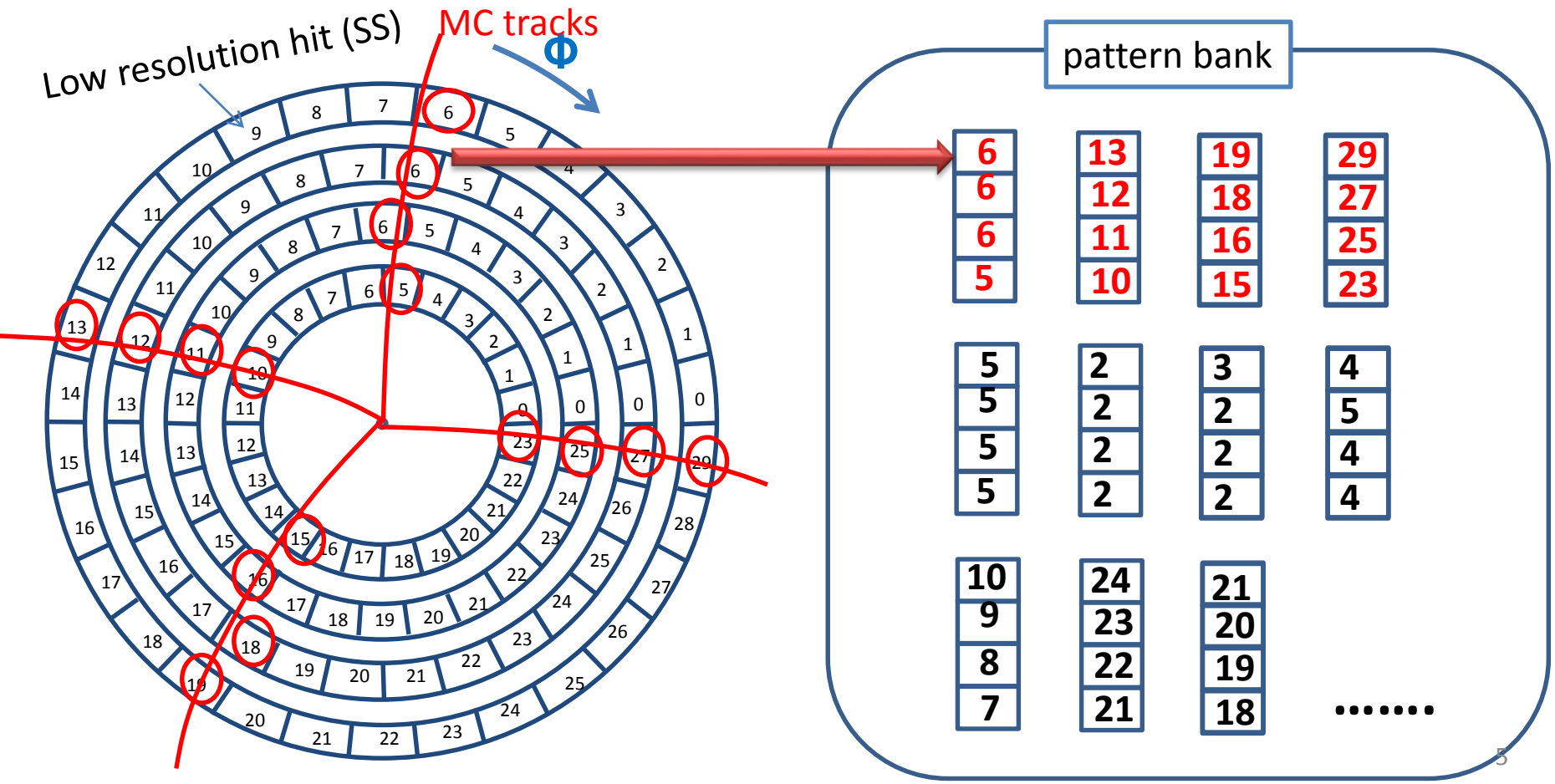




FTK principle : Pattern Recognition

Find low resolution track called “pattern”.

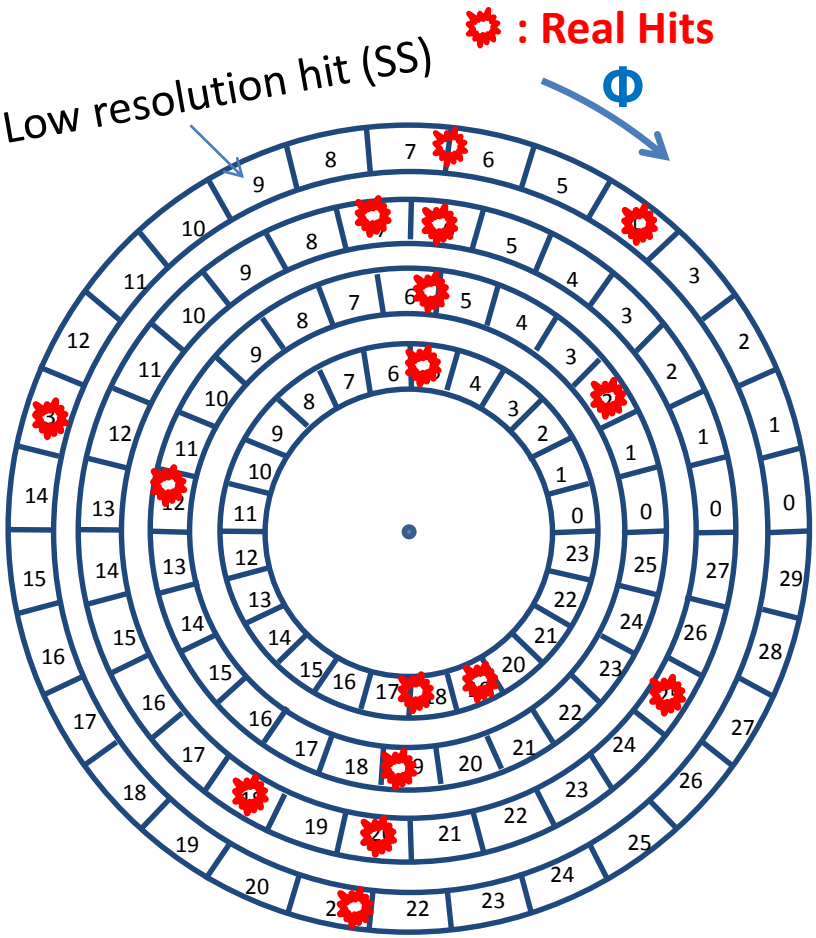
1. Generate all possible patterns using **MC simulation**.
   More than 50 billion tracks are used for pattern generation.

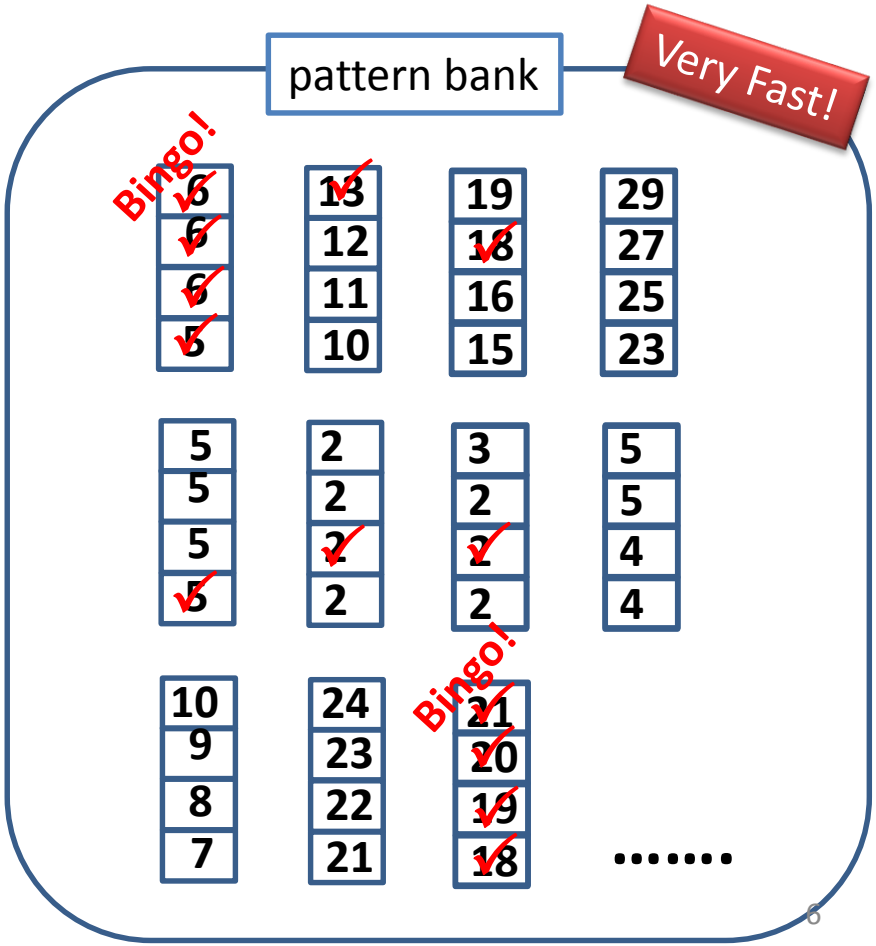


FTK principle : Pattern Recognition

Find low resolution track called as "pattern".

2. Find the pattern in real data using **pattern recognition**
   For real data, detector hits sent to pattern bank sequentially, and patterns are recognized like a bingo game. All patterns are found when all hits have arrived.





FTK principle : Track Fitting

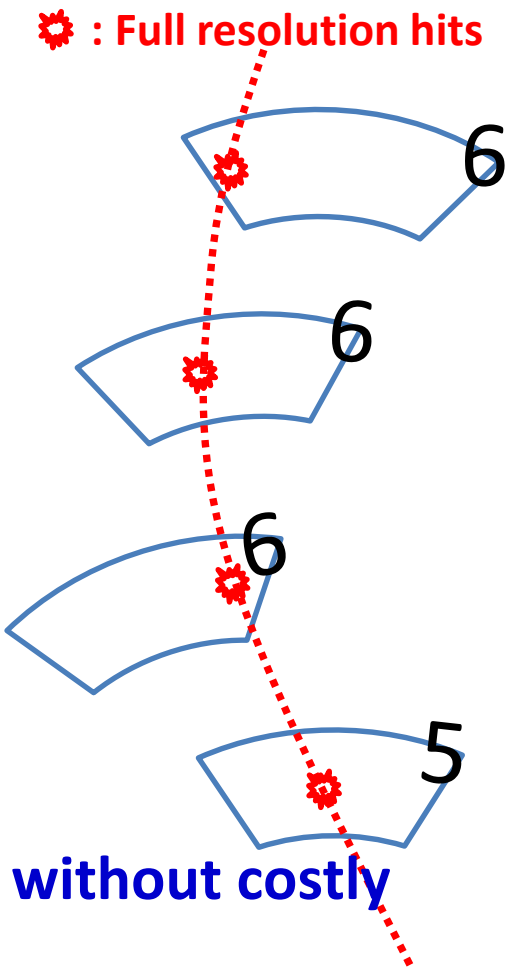
Estimate track parameters using full resolution hit information in a linearized fit approximation.

5 parameters
d0, z0, eta, phi, P_T

1. Pre-Calculate the constants for the 5 parameter's linear approximation as a function of hit coordinates using MC simulation.

2. Estimate the track parameters using linear **approximation** equation with pre-calculated constant and **full resolution** hits coordinates.

$$\tilde{p_i} = \sum_{l=1}^{N} C_{il} x_l + q_i$$



Parameters

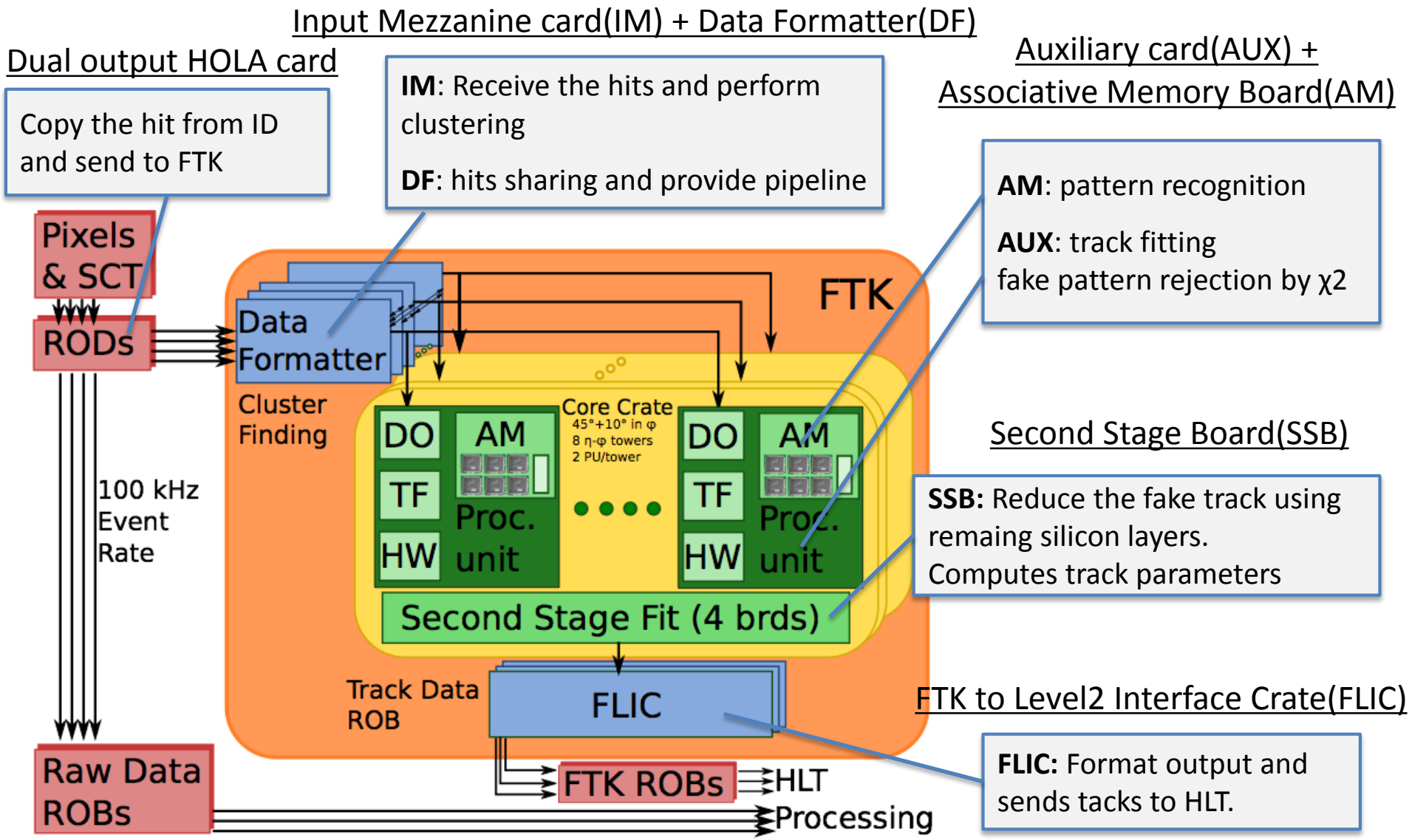
$\tilde{p_i}$: Track Parameters (i=0-4)

x_i : Hit Coordinate

$\vec{C_i}\ q_i$: Constant

FTK estimates track information very quickly without costly looping in minimalization.

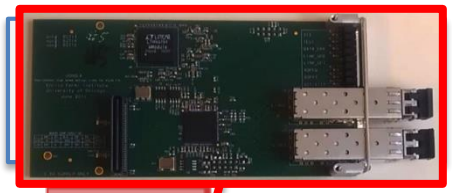
FTK System and Boards

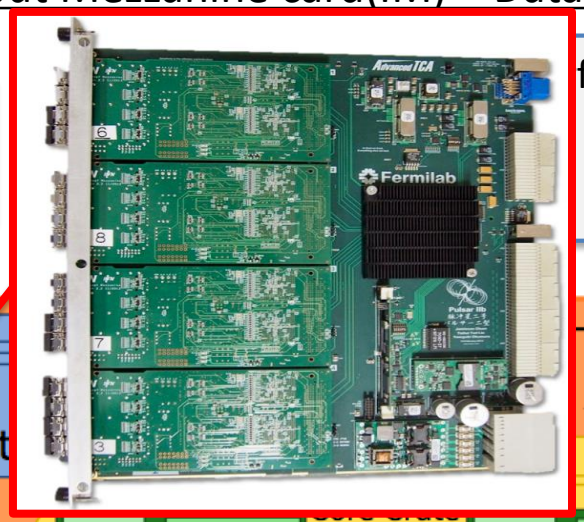


FTK System and Boards

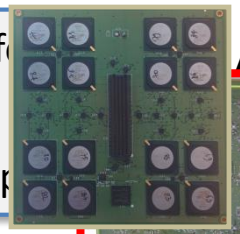
Input Mezzanine card(IM) + Data Formatter(DF)

Dual HOLA card

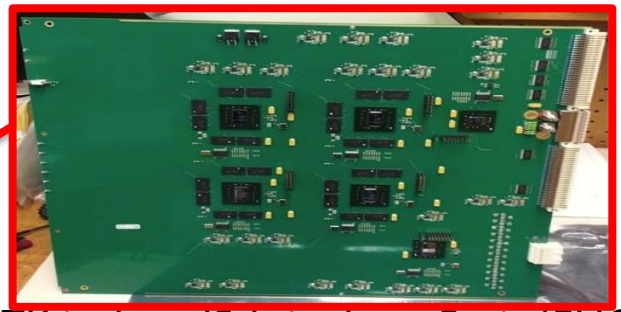




Auxiliary card(AUX) +
Associative Memory Board(AM)

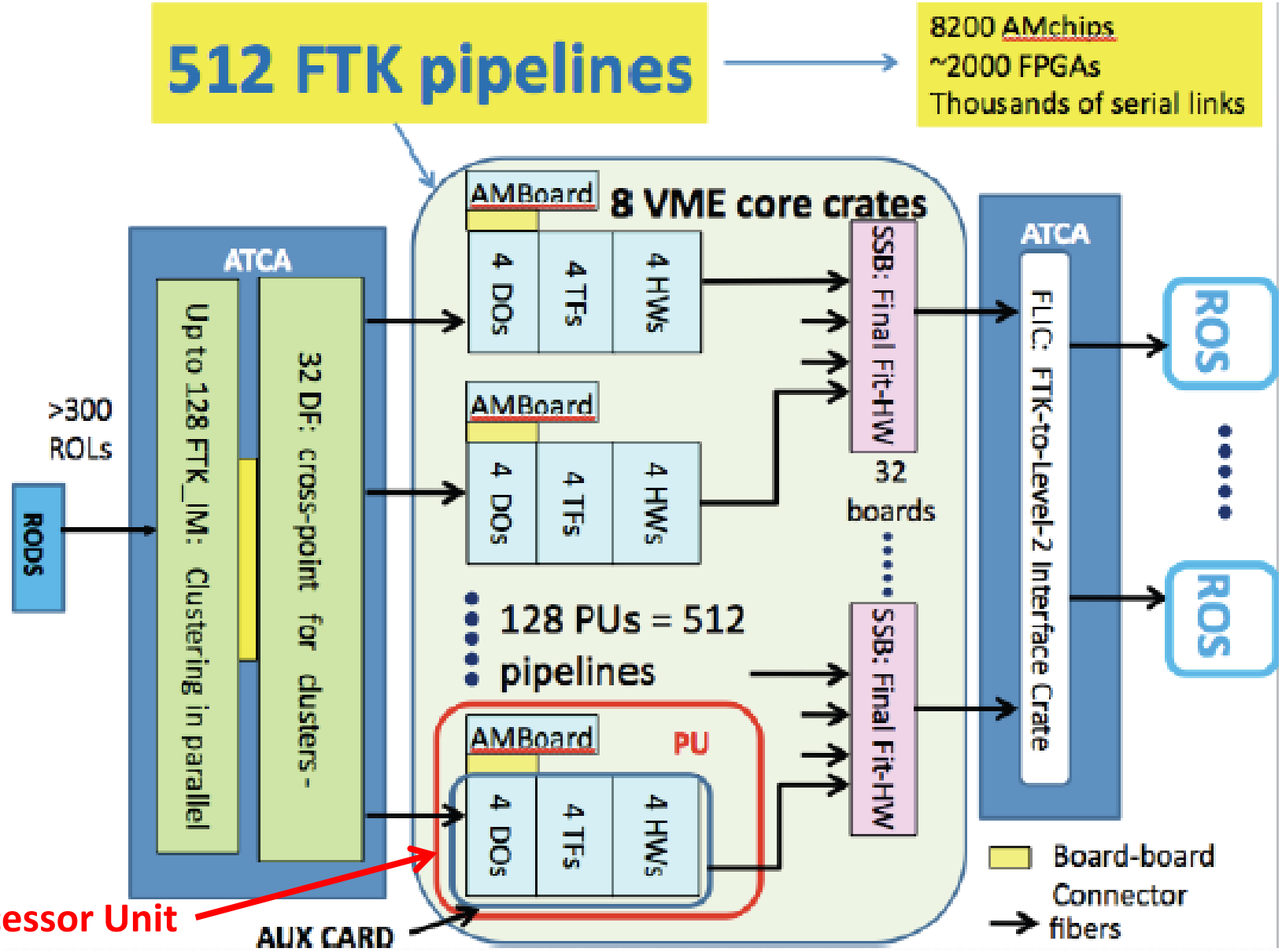


Second Stage Board(SSB)



FTK to Level2 Interface Crate(FLIC)

Parallelization of FTK System

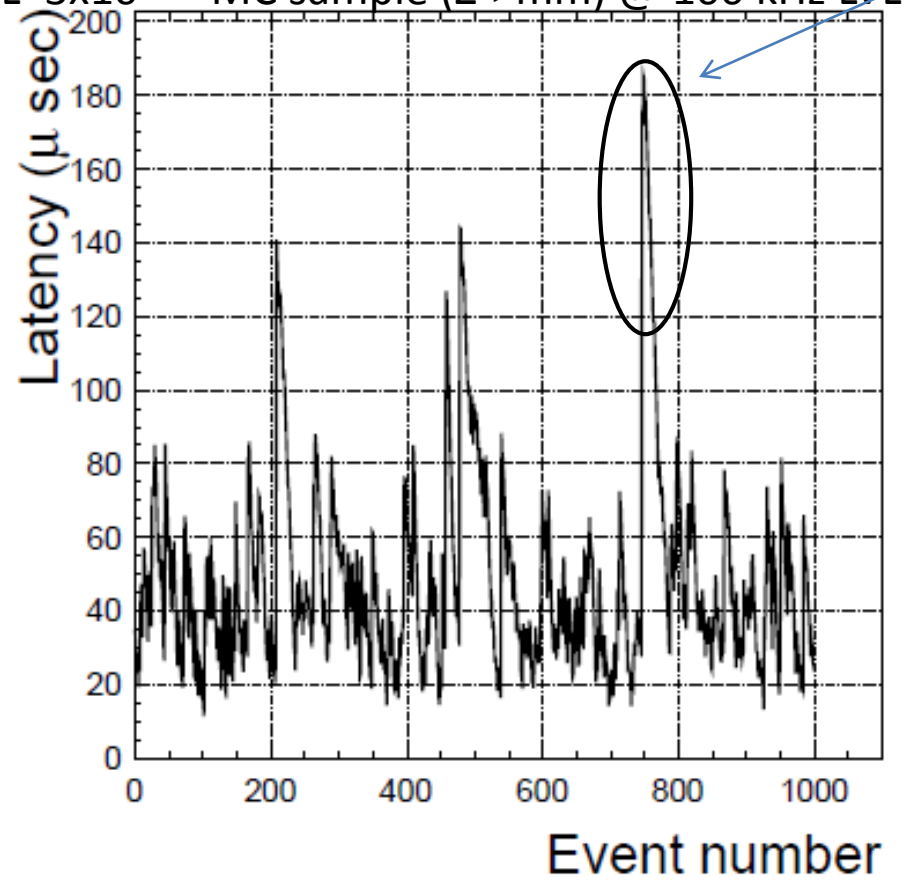


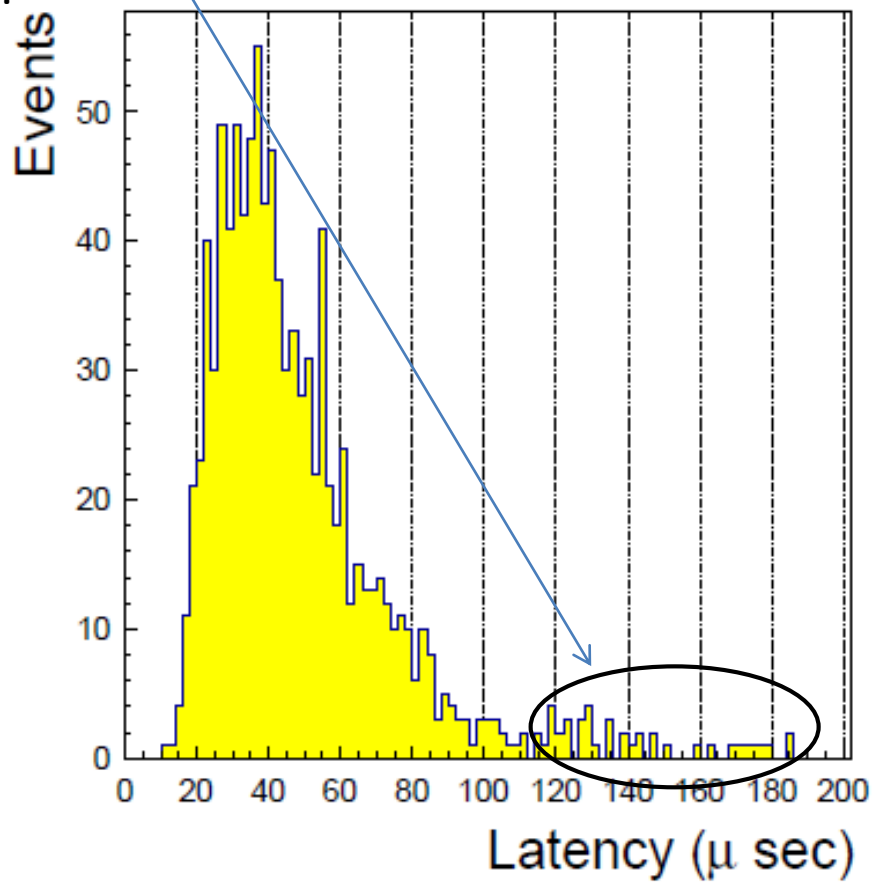
FTK Latency

FTK system has enough processing power at L=3x10^{34}cm^{-2}s^{-1}

Latency was increased by high occupancy event, but after such an event the latency quickly returns to the typical range.

L=3x10^{34} MC sample (Z->mm) @ 100 kHz LVL1 rate.





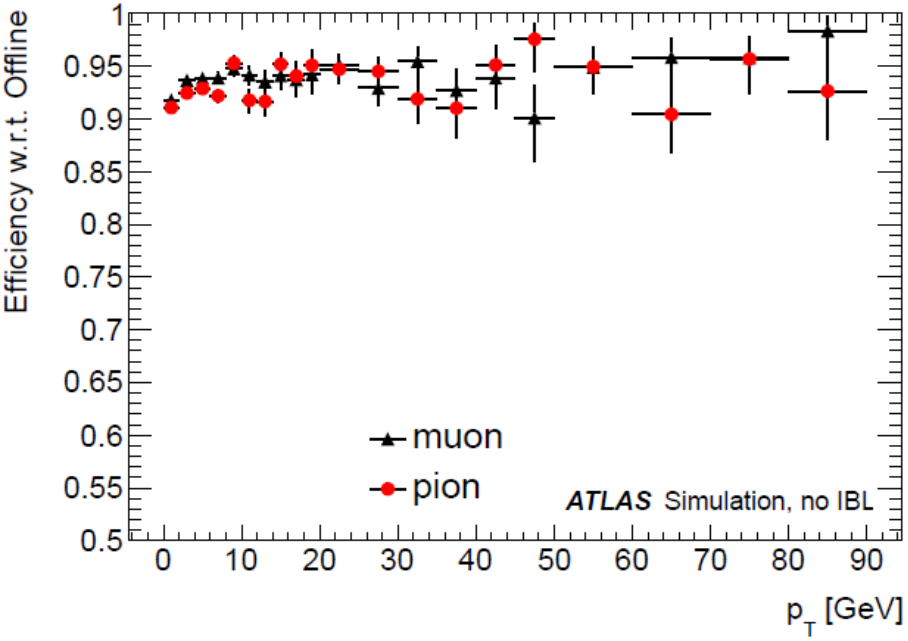
Average latency is ~50 μsec and maximum is ~ few hundred μsec. It meets HLT speed requirements.

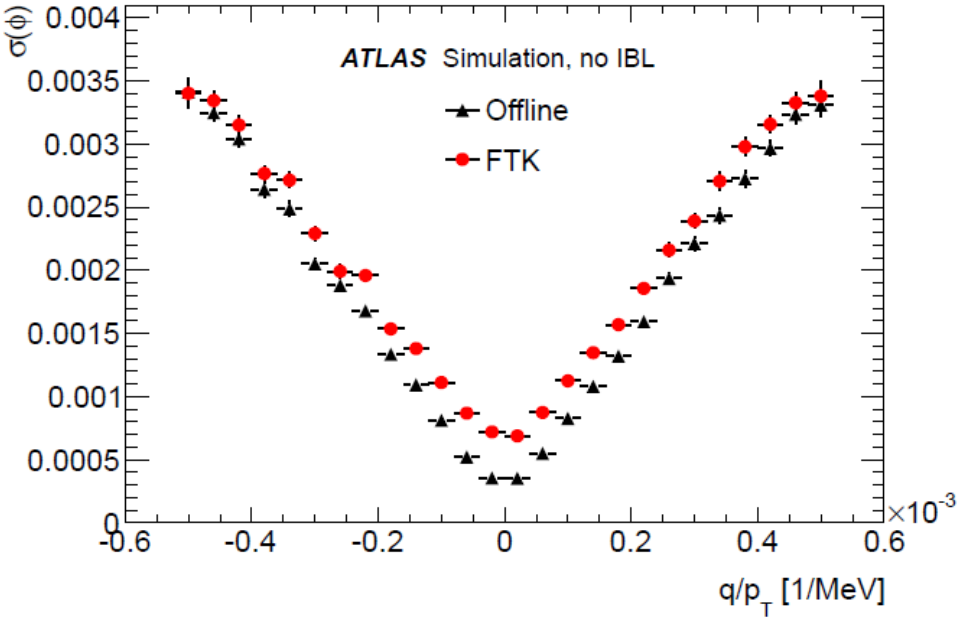
FTK Track performance

FTK tracking algorithm differs from offline:

- Simple hit clustering
- Lack of Low P_T patterns
- Only linear track parameters approximation.
- No TRT, no δray correction, etc

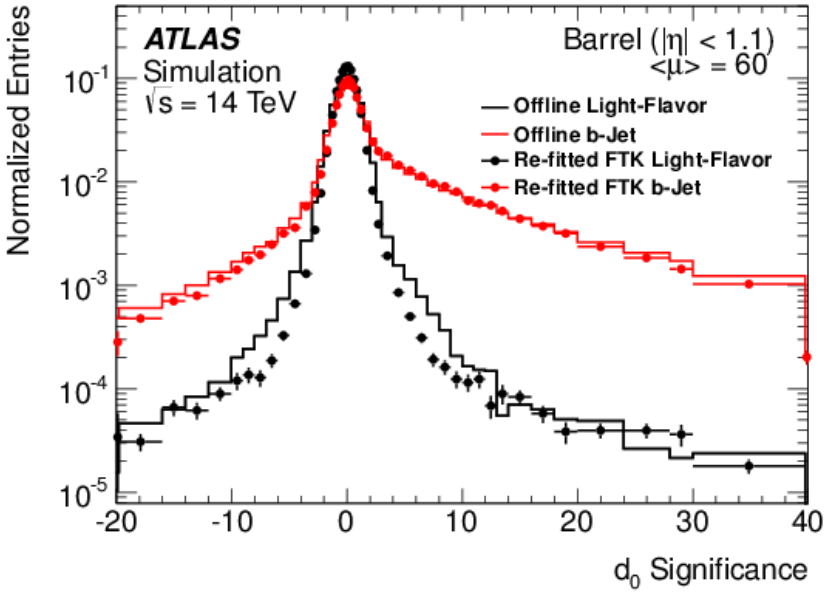
Nevertheless the performance of it is comparable:

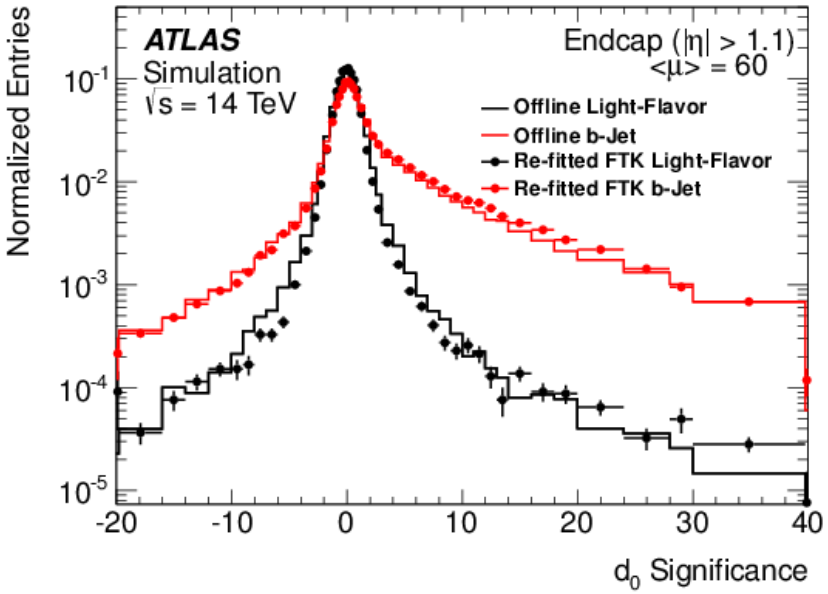




More than 90 % efficient with respect to offline.

Advantage in b-jet triggering

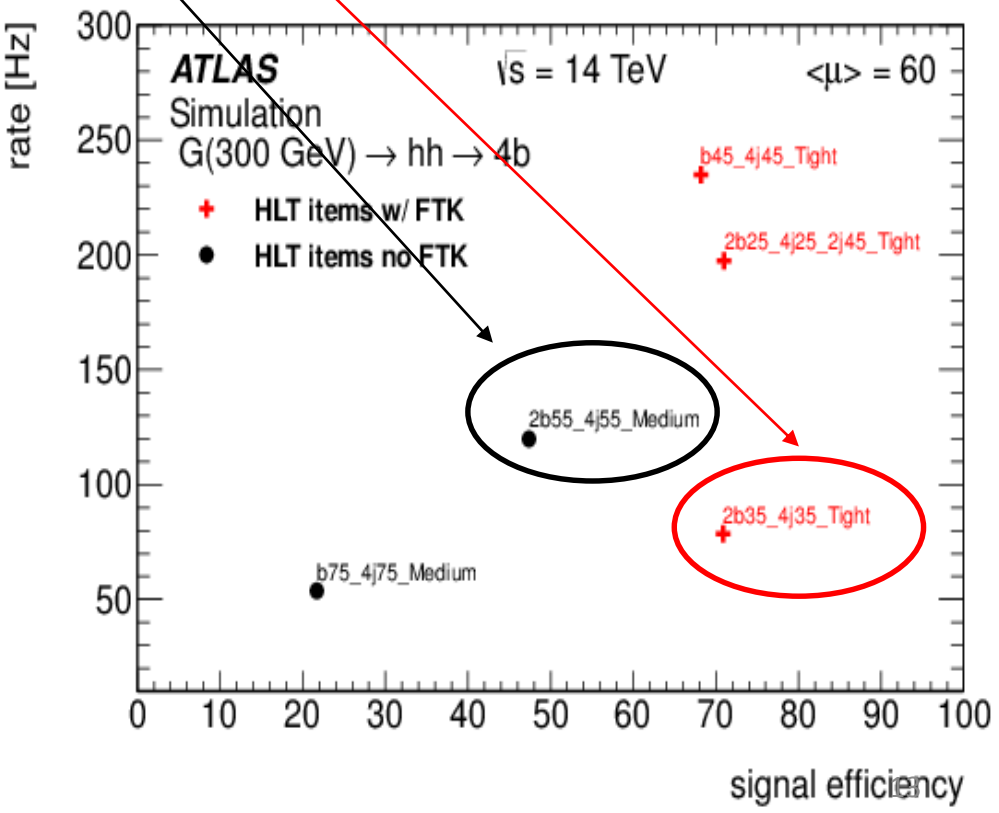




- FTK allows b-jet algorithms to be run with Looser HLT jet pT thresholds.

55 GeV Medium 2b-tag with 55 GeV 4th jet

35 GeV Tight 2b-tag with **35 GeV** 4th jet



Commissioning at CERN

2013 2014 2015 2016 2017

Test room integration

Boards get moved to ATLAS once stable data flow is achieved.

Start operation in limited region

Vertical Slice Test (VS Test)

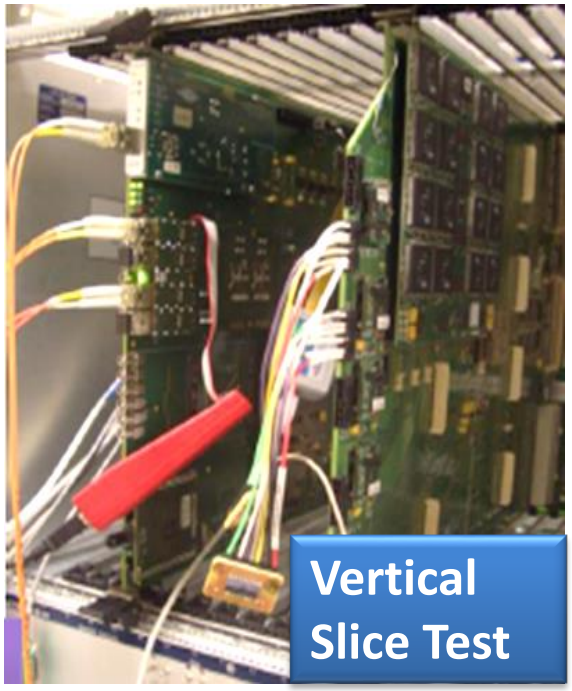
Only SCT, test inputs with simulated 70 kHz L1 data

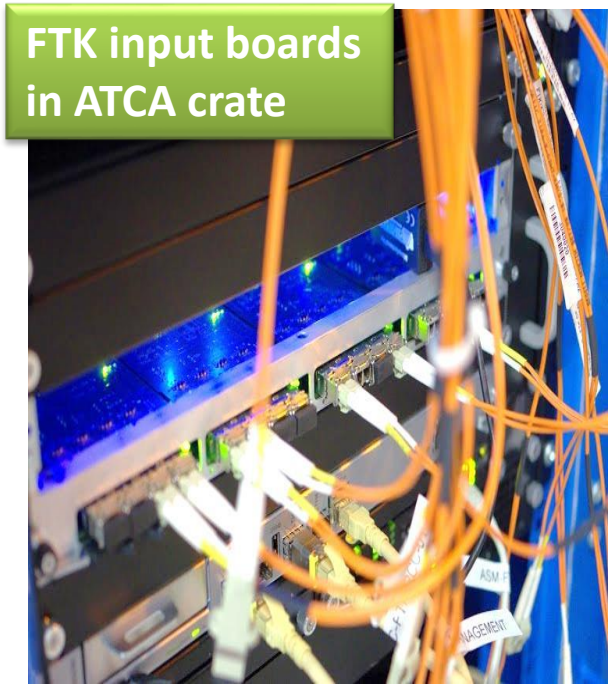
Global Integration Test

SCT and Pixel, real inputs with Cosmic or test data with maximum 100 kHz Test trigger.

Commissioning in ATLAS

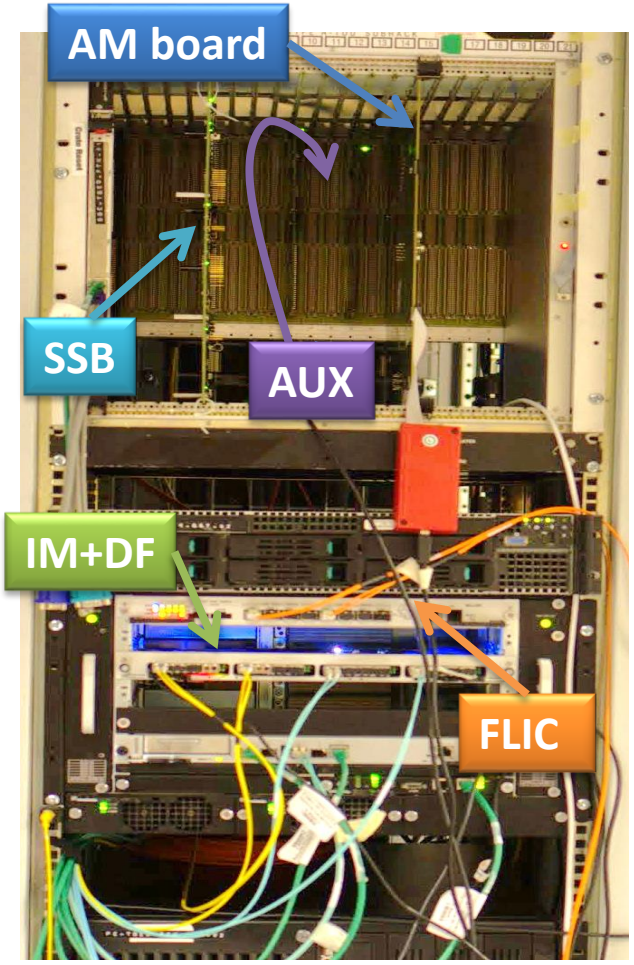
SCT, Pixel and IBL with Real pp and HI Collision data with ~ 50 kHz





Current Commissioning status

- Data flow test in both test stand and ATLAS are ongoing.
- Gaining feedback through operational experience leading to Firmware improvement.



All boards test in same rack

- Installation of inputs board (IM, DF) has started.

Installed DF and IM boards

Integration to ATLAS Run control & monitoring

Integration test of FTK control, monitoring to ATLAS global control system.

We **succeeded in integrating FTK, processed data and wrote FTK hits into the ATLAS event data output stream!**

FTK Plan

2015

Dec — Debug input dataflow with Heavy Ion collisions

2016

Jan — Install FTK input system (128 IM and 32 DF) to ATLAS. **All FTK inputs boards**

Feb — Continue to debug on data flow with additional boards.

Mar — Install full FTK chain with **1 Processor unit** with final version's AM chip

Apr — Commissioning of full FTK chain with single processor

May

Jun

July — mu ~= 40, FTK covers **full barrel**. **16 Processor units**

Aug — Test of full barrel FTK processing and start providing track information to HLT

Sep

Oct

Nov

Dec — mu ~= 40, FTK covers **full detector**. **32 Processor units**

Full spec FTK with **128 Processor units** (2018)

Summary

- FTK provides full track information above P_T> 1 GeV to the HLT. HLT can use track information as needed.
- Board development, FW development, installation and commissioning are progressing well.
- Start data taking in middle of Run II with limited detector coverage and full coverage by the end of 2016.
- FTK TDR

http://cds.cern.ch/record/1552953/files/ATLAS-TDR-021.pdf

- FTK Public Results:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/FTKPublicResults