FastTracKer Commission: Second Stage Board Parsing

WONG HIU WING, DEPARTMENT OF PHYSICS, CUHK

SUPERVISED BY STEFANIA XELLA, ALESSANDRA CAMPLANI

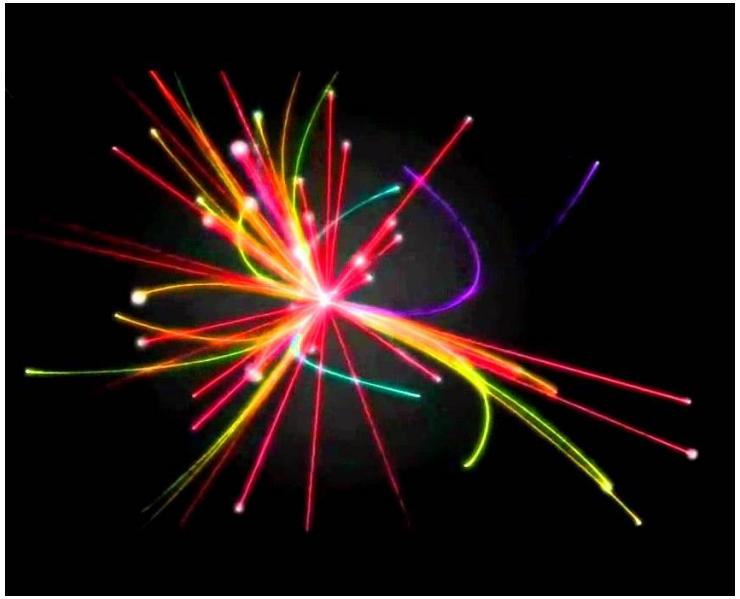
Motivation

- High Luminosity LHC will be up soon
- Increase the number of collisions by a factor of 10 (to 40M collision per second)
- More data → More new physics !

Motivation

- Why we need so many collision?
- 99.99% of the data is “not interesting”,

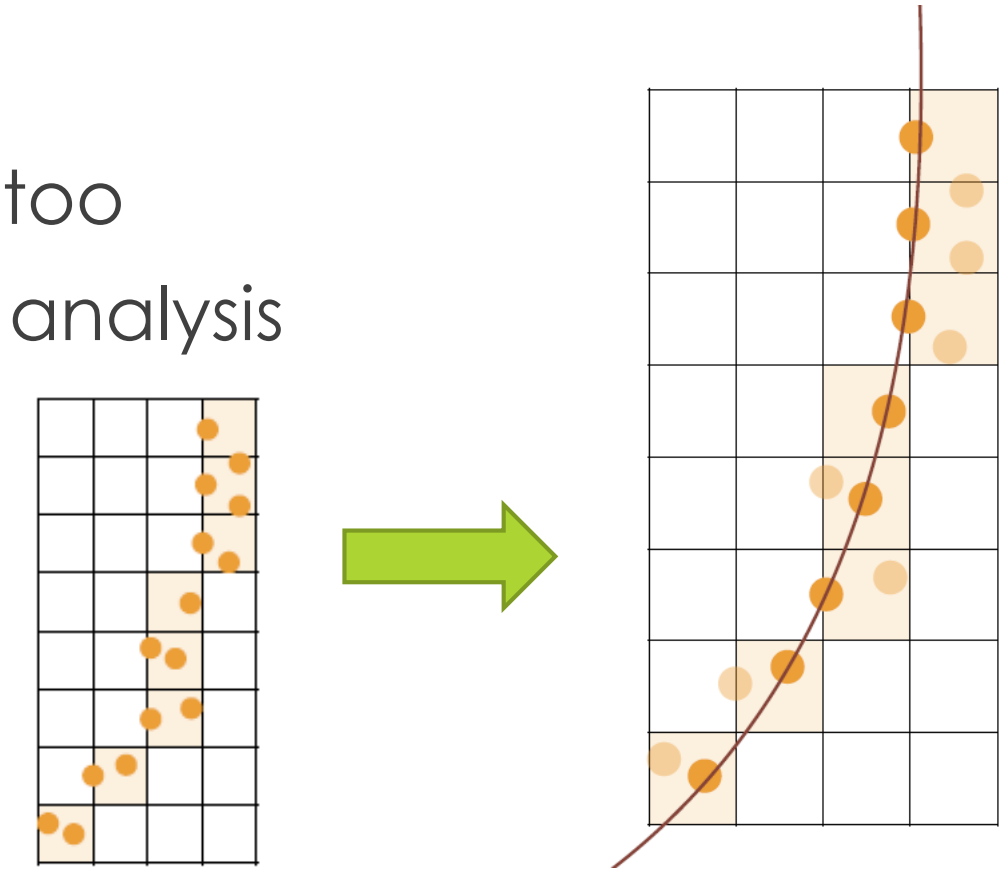
  We just throw them away!
- Decide about whether to keep the event (Level 1 trigger)



Motivation

- Besides looking at the raw hit,

  the track of the particles is need too
- Decide if this event need further analysis (High Level Trigger HLT)

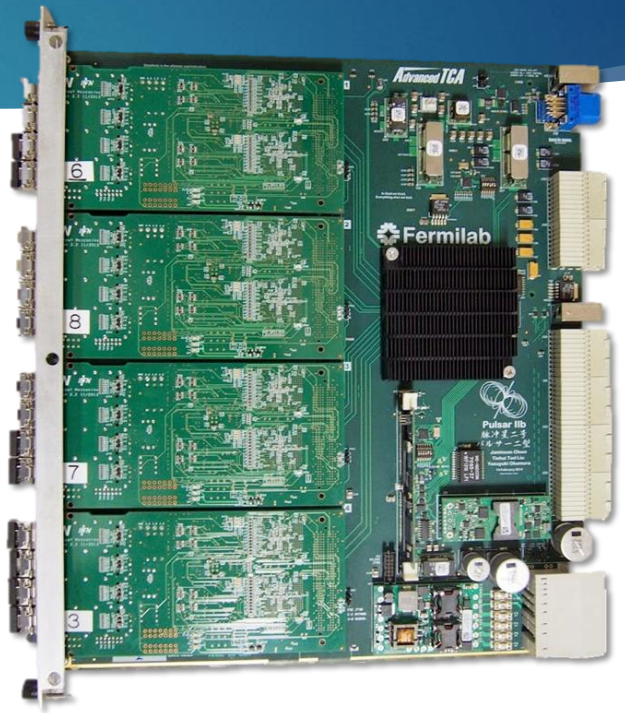


Motivation

- However, the system for reconstructing the tracks cannot handle such data flow!
- We have to make tracking faster!

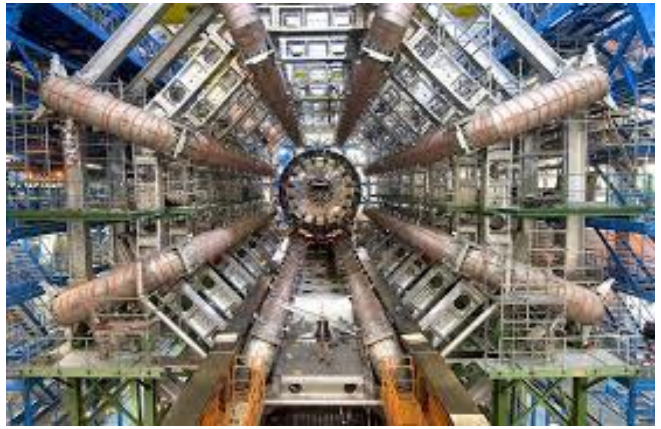
What is FastTracKer (FTK)?

Current Track fitting system:
CPU-based
Slow, ~10s an event
One track at a time



FastTracKer (FTK) :
hardware-based (FPGAs)
Fast, ~0.1ms an event
Parallel processing

40MHz



100kHz

Level 1 Trigger system (L1)

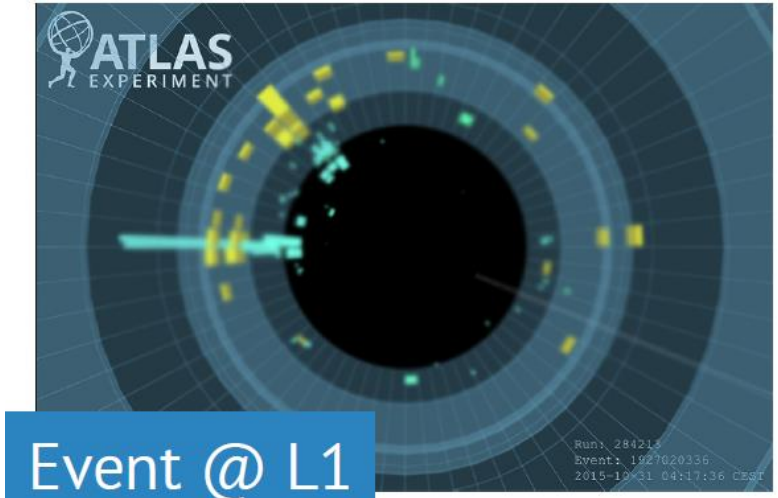
1kHz

High Level Trigger system (HLT)

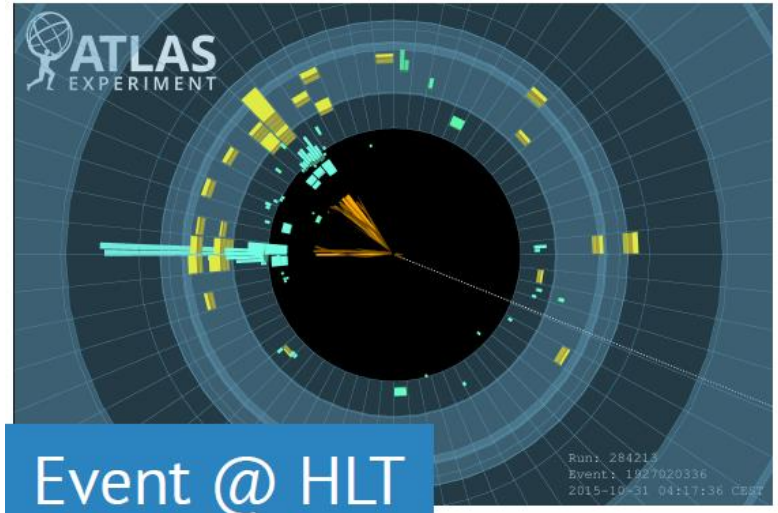
Getting raw hits from L1

Providing the tracks that HLT needed

FastTracKer (FTK)



Event @ L1

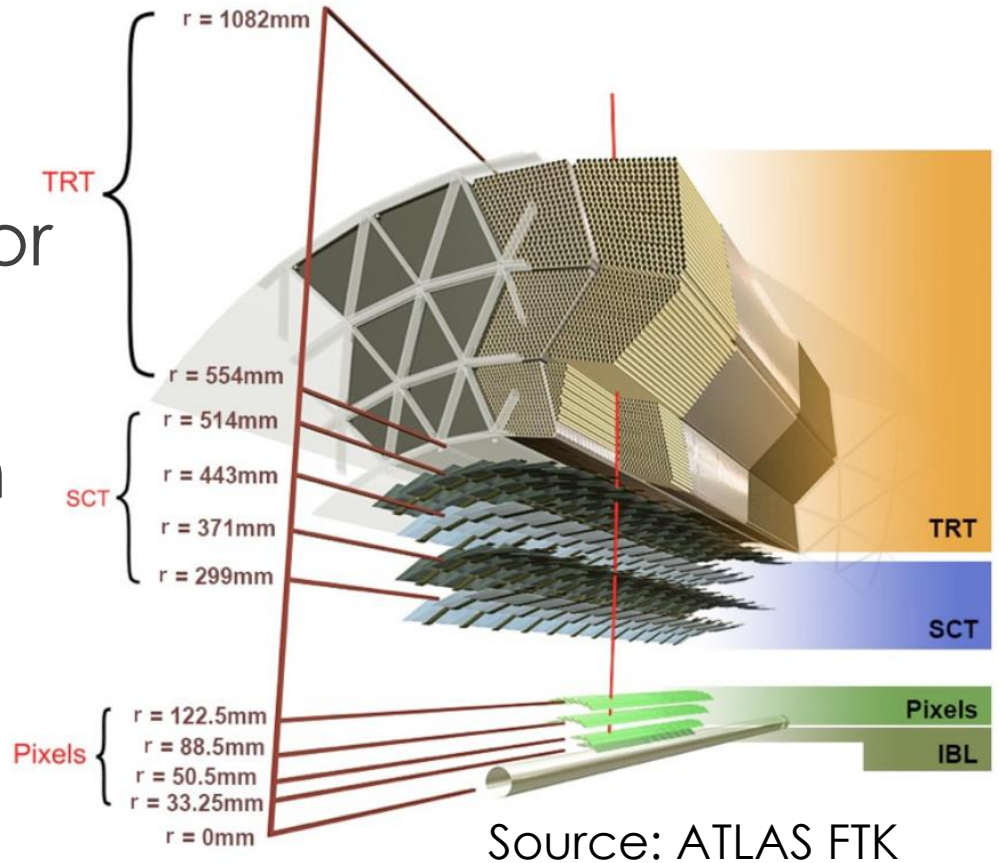


Event @ HLT

How can FTK track so fast?

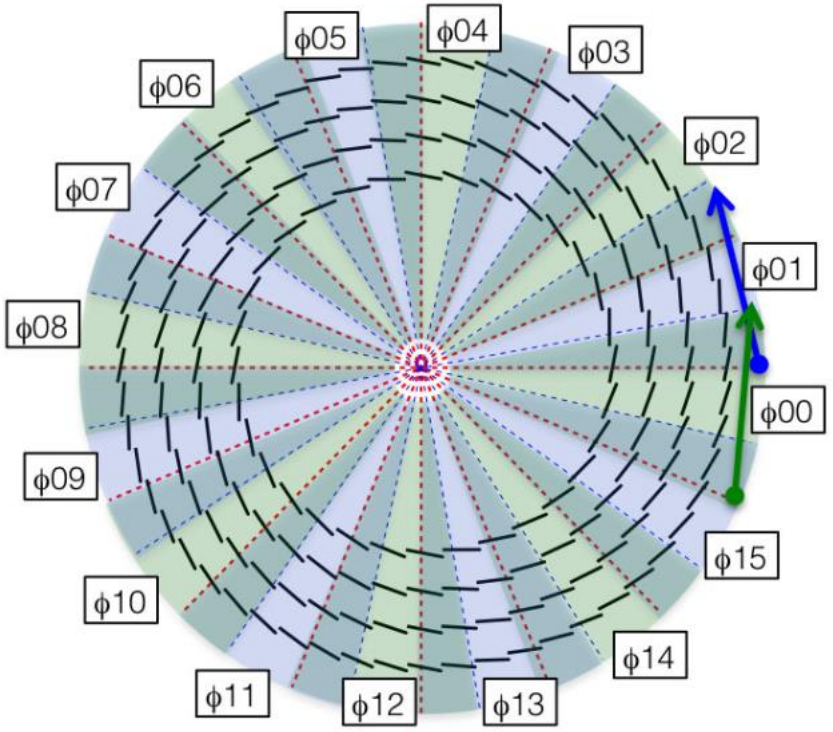
Track with smaller data set

- Only use the silicon part of the detector (i.e. Pixel and SCT)
- Track with only 12 layers of information



Source: ATLAS FTK Technical Design Report

How can FTK track so fast?

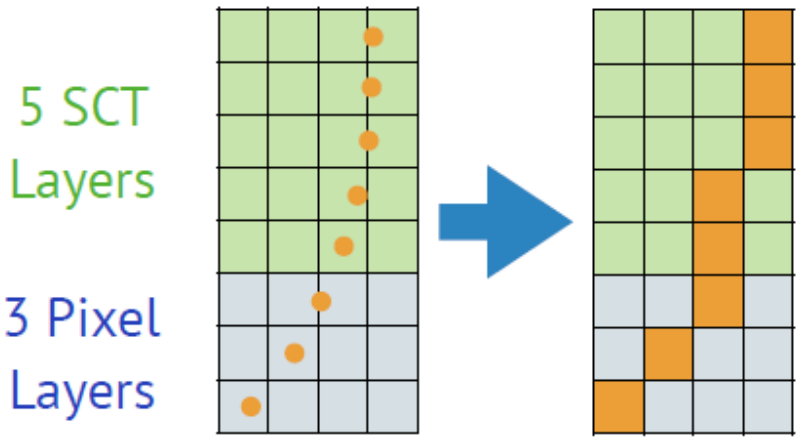


Source: ATLAS FTK Technical Design Report

Parallelize

- FTK divide the detector into 64 towers
- Send data from each tower to separate Processor Unit in FTK
- Reconstruct multiple track at once

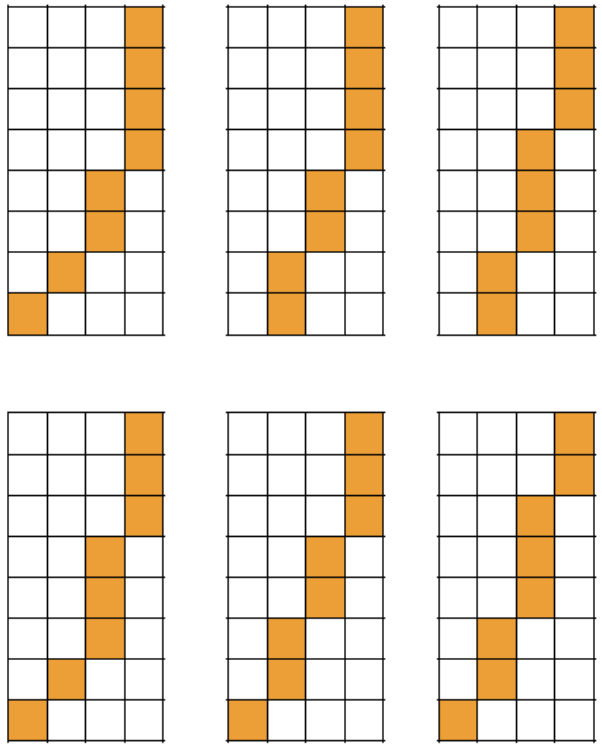
How can FTK track so fast?



Pattern Matching

- Look at each layer with lower resolution

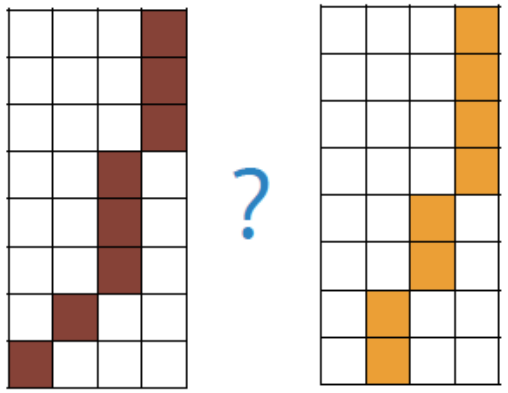
How can FTK track so fast?



Pattern Matching

- Look at each layer with lower resolution
- Define different patterns correspond to tracks

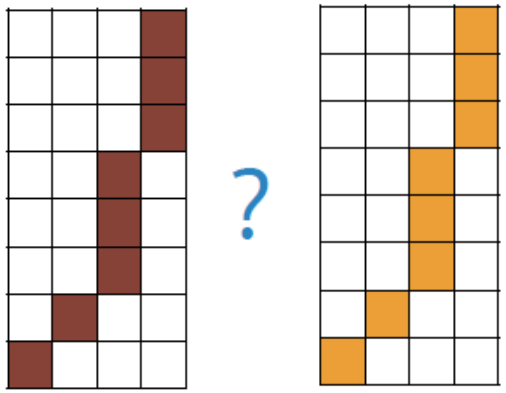
How can FTK track so fast?



Pattern Matching

- Compare the collected patterns with the bank defined patterns

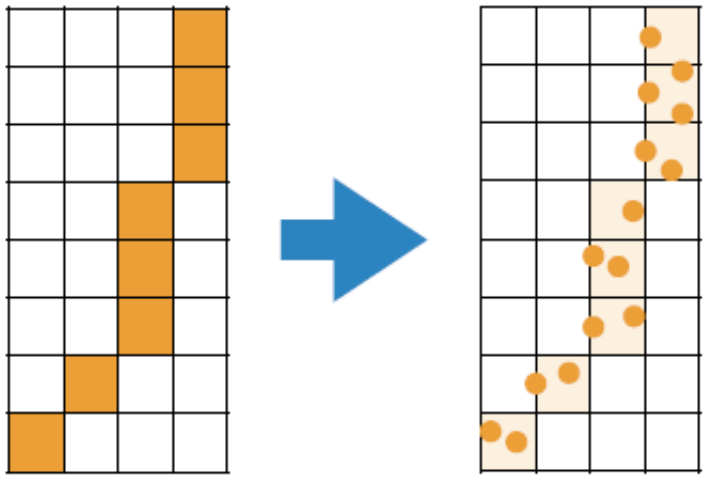
How can FTK track so fast?



Pattern Matching

- Compare the collected patterns with the bank defined patterns

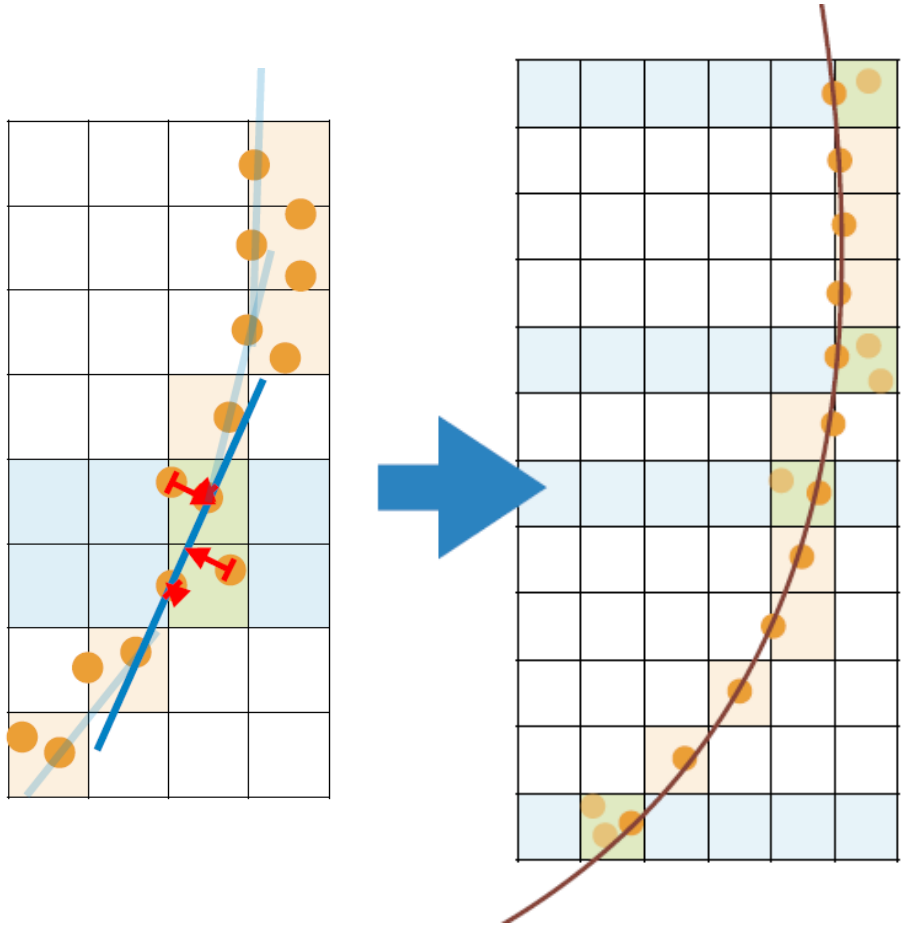
How can FTK track so fast?



Pattern Matching

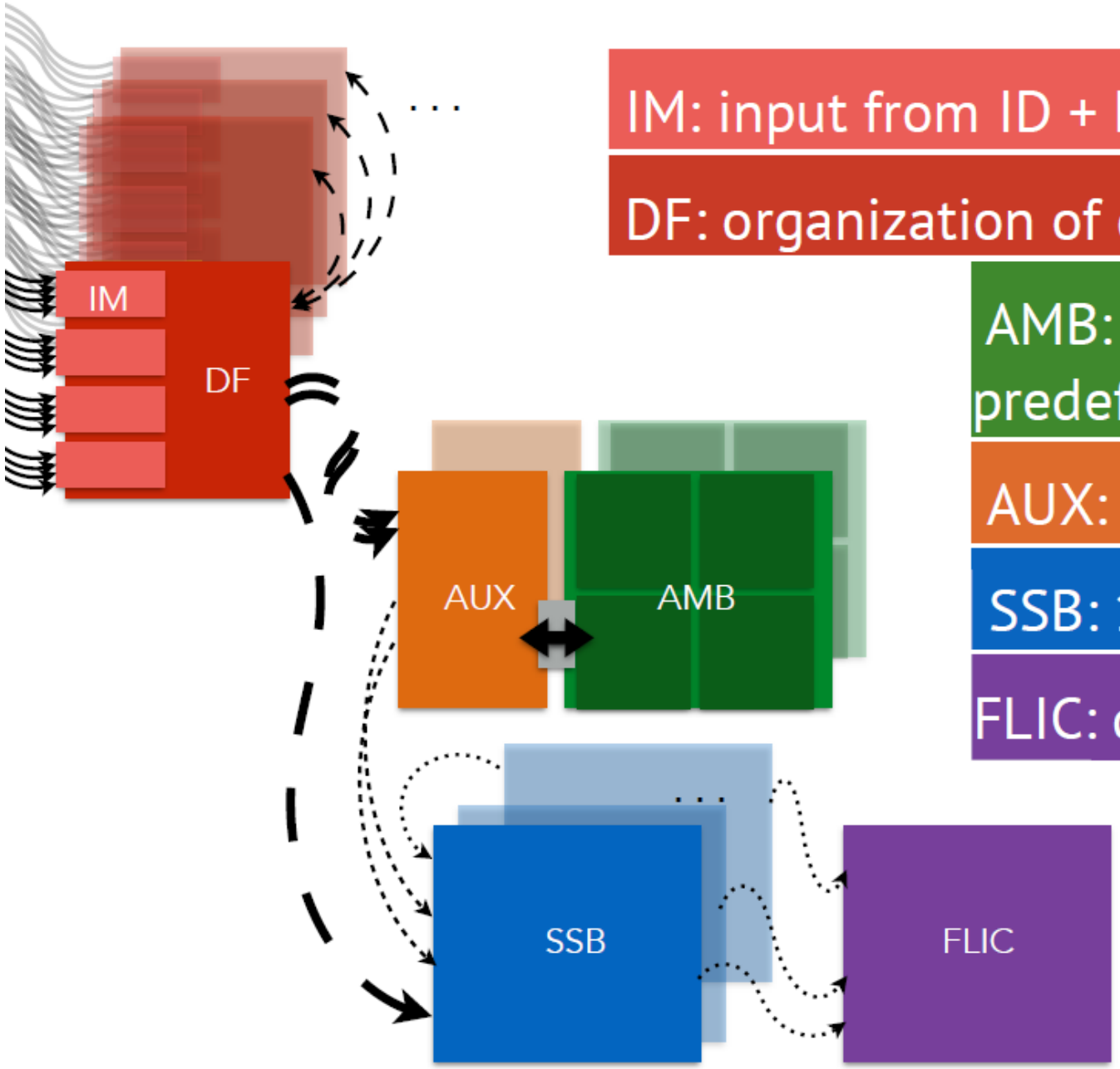
- Compare the collected patterns with the bank defined patterns
- If a pattern matched, retrieve full resolution

How can FTK track so fast?



Fitting the tracks

- Using linearized fit on 8 layers
- Look for nearby hits in remaining layers and refit in 12 layers



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

FLIC: data formatting for HLT

Source:
The ATLAS FastTracKer
ATL-DAQ-SLIDE-2018-468

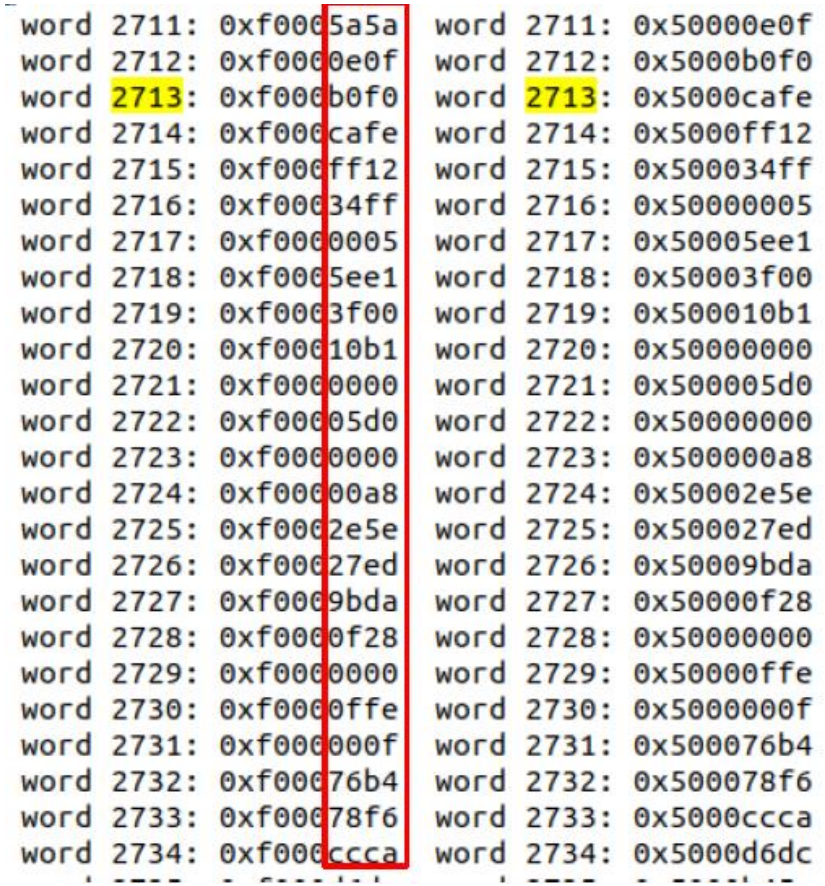
Second Stage Board Parsing

AUX+AMB run3 cooling tests

New SSB testing and commissioning

- FTK is still on commissioning
- Our team needed to debug or calibrate different boards
- Often we use a circular memories called Spybuffer to monitor the output of the boards

Second Stage Board Parsing



```
word 2711: 0xf0005a5a  word 2711: 0x50000e0f
word 2712: 0xf0000e0f  word 2712: 0x5000b0f0
word 2713: 0xf000b0f0  word 2713: 0x5000cafe
word 2714: 0xf000cafe  word 2714: 0x5000ff12
word 2715: 0xf000ff12  word 2715: 0x500034ff
word 2716: 0xf00034ff  word 2716: 0x50000005
word 2717: 0xf0000005  word 2717: 0x50005ee1
word 2718: 0xf0005ee1  word 2718: 0x50003f00
word 2719: 0xf0003f00  word 2719: 0x500010b1
word 2720: 0xf00010b1  word 2720: 0x50000000
word 2721: 0xf0000000  word 2721: 0x500005d0
word 2722: 0xf00005d0  word 2722: 0x50000000
word 2723: 0xf0000000  word 2723: 0x500000a8
word 2724: 0xf00000a8  word 2724: 0x50002e5e
word 2725: 0xf0002e5e  word 2725: 0x500027ed
word 2726: 0xf00027ed  word 2726: 0x50009bda
word 2727: 0xf0009bda  word 2727: 0x50000f28
word 2728: 0xf0000f28  word 2728: 0x50000000
word 2729: 0xf0000000  word 2729: 0x50000ffe
word 2730: 0xf0000ffe  word 2730: 0x5000000f
word 2731: 0xf000000f  word 2731: 0x500076b4
word 2732: 0xf00076b4  word 2732: 0x500078f6
word 2733: 0xf00078f6  word 2733: 0x5000ccca
word 2734: 0xf000ccca  word 2734: 0x5000d6dc
```

- SSB dumps data with hexadecimal digit
- Contains header, track info and trailer
- Obey certain format to ensure the packet is intact

Second Stage Board Parsing: Motivation

```
word 2711: 0xf0005a5a  word 2711: 0x50000e0f
word 2712: 0xf0000e0f  word 2712: 0x5000b0f0
word 2713: 0xf000b0f0  word 2713: 0x5000cafe
word 2714: 0xf000cafe  word 2714: 0x5000ff12
word 2715: 0xf000ff12  word 2715: 0x500034ff
word 2716: 0xf00034ff  word 2716: 0x50000005
word 2717: 0xf0000005  word 2717: 0x50005ee1
word 2718: 0xf0005ee1  word 2718: 0x50003f00
word 2719: 0xf0003f00  word 2719: 0x500010b1
word 2720: 0xf00010b1  word 2720: 0x50000000
word 2721: 0xf0000000  word 2721: 0x500005d0
word 2722: 0xf00005d0  word 2722: 0x50000000
word 2723: 0xf0000000  word 2723: 0x500000a8
word 2724: 0xf00000a8  word 2724: 0x50002e5e
word 2725: 0xf0002e5e  word 2725: 0x500027ed
word 2726: 0xf00027ed  word 2726: 0x50009bda
word 2727: 0xf0009bda  word 2727: 0x50000f28
word 2728: 0xf0000f28  word 2728: 0x50000000
word 2729: 0xf0000000  word 2729: 0x50000ffe
word 2730: 0xf0000ffe  word 2730: 0x5000000f
word 2731: 0xf000000f  word 2731: 0x500076b4
word 2732: 0xf00076b4  word 2732: 0x500078f6
word 2733: 0xf00078f6  word 2733: 0x5000ccca
word 2734: 0xf000ccca  word 2734: 0x5000d6dc
```

- To debug or even discover a bug, we often need to read through this
- My summer's work is to create a program that analysis this dump

Second Stage Board Parsing: Goal

```
word 2711: 0xf0005a5a
word 2712: 0xf0000e0f
word 2713: 0xf000b0f0
word 2714: 0xf000cafe
word 2715: 0xf000ff12
word 2716: 0xf00034ff
word 2717: 0xf0000005
word 2718: 0xf0005ee1
word 2719: 0xf0003f00
word 2720: 0xf00010b1
word 2721: 0xf0000000
word 2722: 0xf00005d0
word 2723: 0xf0000000
word 2724: 0xf00000a8
word 2725: 0xf0002e5e
word 2726: 0xf00027ed
word 2727: 0xf0009bda
word 2728: 0xf0000f28
word 2729: 0xf0000000
word 2730: 0xf0000ffe
word 2731: 0xf000000f
word 2732: 0xf00076b4
word 2733: 0xf00078f6
word 2734: 0xf000ccca
```

SSB raw output

```
------------------------------------
Event: 85 line: 2683
ECR: 63
L1A: 4272
GOOD!
------------------------------------
Event: 86 line: 2713
ECR: -1
L1A: 16777215

WARNING:
L1ID not match!

------------------------------------
Event: 87 line: 2799
ECR: 63
L1A: 4089

WARNING:
L1ID Skip Happen Here!

------------------------------------
```

Packet integrity

```
------------------------------------
Event: 69 line: 2090
Track Parameter:

Track 1
chisq = 69.625
d0    = 0.38794
z0    = 1.6865
cotth = -0.66846
phi0  = 1.5645
curv  = -0.0002383

Track 2
chisq = 39840.0
d0    = -6.9922
z0    = -74.5
cotth = 0.13696
phi0  = 1.7529
curv  = -0.0005455
------------------------------------
```

Track information

The SSB parser: packet integrity

- Check the packet length, and the key words (and their relative position)
- Example:

  The beginning of the header is always,

  b0f0, cafe, ff12, 34ff
- Do the same thing with track frame and trailer

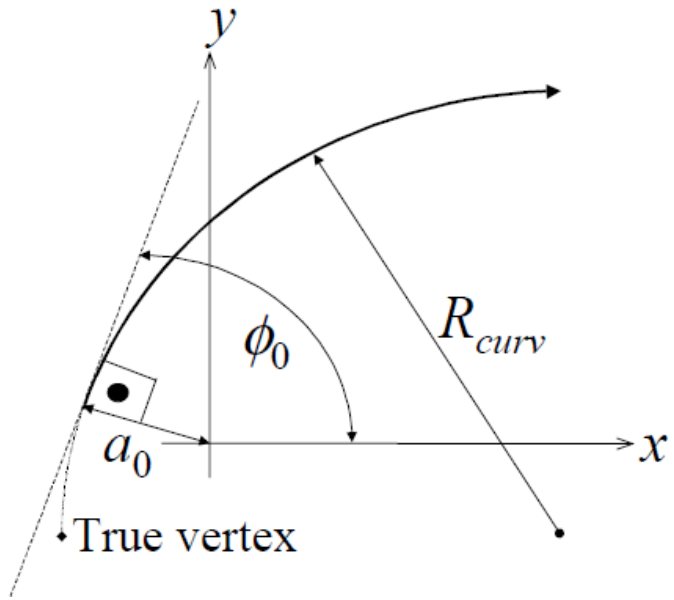
```
word 2711: 0xf0005a5a
word 2712: 0xf0000e0f
word 2713: 0xf000b0f0
word 2714: 0xf000cafe
word 2715: 0xf000ff12
word 2716: 0xf00034ff
word 2717: 0xf0000005
word 2718: 0xf0005ee1
word 2719: 0xf0003f00
word 2720: 0xf00010b1
word 2721: 0xf0000000
word 2722: 0xf00005d0
word 2723: 0xf0000000
word 2724: 0xf00000a8
word 2725: 0xf0002e5e
word 2726: 0xf00027ed
```

The SSB parser: L1ID

```
------------------------------
Event: 85 line: 2683
ECR: 63
L1A: 4272
GOOD!
------------------------------
Event: 86 line: 2713
ECR: -1
L1A: 16777215

WARNING:
L1ID not match!

------------------------------
Event: 87 line: 2799
ECR: 63
L1A: 4089

WARNING:
L1ID Skip Happen Here!

------------------------------
```

- Every event accepted by L1 Trigger will have an L1ID
- L1ID may not match in header and trailer, which may case different problem
- Consecutive event should have consecutive L1ID

The SSB parser: Helix parameter



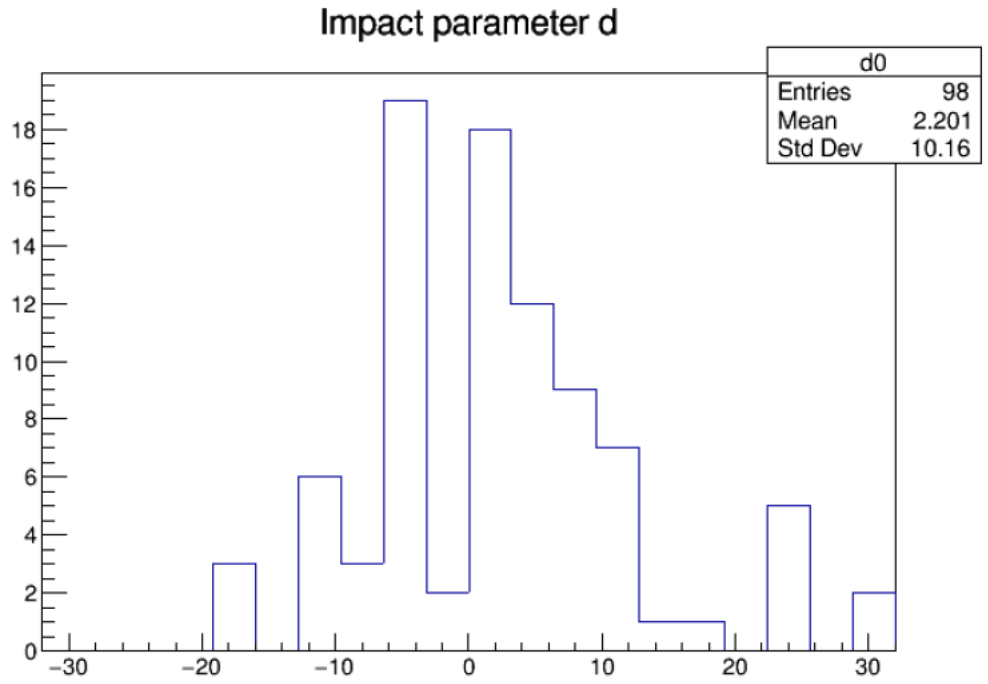

```
Event: 43 line: 1281
Track Parameter:

Track 1
chisq = 4.33984375
d0    = 0.497314453125
z0    = 15.9921875
cotth = -1.208984375
phi0  = 1.6533203125
curv  = -0.000293016433716
--------------------------------
```

- 6 different parameters is used to characterize the path
- Chisq: χ^2 is a measure of the goodness of fit
- z0, d0 : impact parameter
- cotth: $\cot\theta$

The SSB parser: Helix parameter

```
--------------------------------
Event: 69 line: 2090
Track Parameter:

Track 1
chisq = 69.625
d0    = 0.38794
z0    = 1.6865
cotth = -0.66846
phi0  = 1.5645
curv  = -0.0002383

Track 2
chisq = 39840.0
d0    = -6.9922
z0    = -74.5
cotth = 0.13696
phi0  = 1.7529
curv  = -0.0005455
--------------------------------
```

Easy!



Thank you for your attention!

Any question?