Performance of the FastTracKer in ATLAS

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Tracking in ATLAS Trigger system for Run II

Full tracking information immediately after the first trigger level in Run 2

- selection of events with $b$’s and/or $\tau$’s
  - **tracking**: most powerful separation of signal with $b$ and $\tau$ from QCD
  - $H \rightarrow b\bar{b}$, $H \rightarrow \tau\bar{\tau}$, New Physics
- lepton isolation using tracking

\[ \Downarrow \]

**FastTracKer (FTK)**: global and fast tracking

![Diagram of FastTracKer (FTK) system]

- Run 1: Level 1 <2.5 $\mu$s, Level 2 ~80 ms, Event Filter ~1 s
- Run 2: Level 1 <2.5 $\mu$s, Level 1 ~200 ms, FTK global fast tracking ~100 $\mu$s
- High Level Trigger: 40 MHz, >75 / 100 kHz, 6 / 7 - 17 kHz, 0.4 / 0.5 - 1 kHz
FastTracKer (FTK)

- **custom electronics system**: global track reconstruction ($\sim 100 \mu s$)
- highly **parallel** system organized in 64 $\eta - \phi$ towers
- track reconstruction: $p_T > 1$ GeV, $|\eta| < 2.5$

Performance in $t\bar{t}$ sample

Not matched to truth in $H \to \tau\tau$

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FTK tracks in trigger objects and chains

FTK tracks can help in many ways:

- **Primary Vertices (PV):** reconstructed from FTK tracks, (pileup rejection)
- **jets:**
  - PV energy corrections similar to offline jets
  - Jet Vertex Fraction cuts
  - $b$–tagging with FTK tracks
- **muons and electrons:** track-based isolation
- **$\tau$:** number of FTK tracks in isolation cones (FTK Level-2 $\tau$ trigger), $H \rightarrow \tau\tau$ increase of acceptance of 28% for $\tau_{\text{had}}\tau_{\text{had}}$
- **Missing Transverse Energy (MET):** improve trigger resolution using track and PV information
Missing Transverse Energy with FTK tracks

The challenge of MET triggers:
- **global quantity**: full detector (no RoI)
- high rate of low $p_T$ **background** events
- very important for **New Physics**!

$$\text{MET} = \text{hard term} \ (\text{high } p_T \text{ jets}) + \text{soft term} \ (\text{low } p_T \text{ objects})$$

Run 1 MET triggers: only calorimetric information for soft and hard term → **very sensitive to pileup**

Run 2 global tracking is fundamental. Exploiting **FTK tracks from PV for soft term**:
- better resolution
- reject pileup contribution

More sophisticated combination of calorimetric information with FTK tracks:

**Particle Flow!**

↓

particle flow jets with better resolution for hard term
Particle flow (PFlow) algorithm main idea

1. match tracks (charged particles) to calorimeter energy deposits (clusters)
2. tracks + remaining clusters are used

**Benefits**

1. **better energy, $\eta$ and $\phi$ resolution** than calorimeter one of low momentum particles
2. only tracks coming from Primary Vertex (PV) taken into account
   \[ \Rightarrow \text{pileup contribution reduction} \]

ATLAS on-going studies of application of PFlow to **jets** and **Missing Transverse Energy** with offline tracks

\[ \downarrow \]

improvements in resolution and scale
Application in Trigger of PFlow with FTK tracks

At the HLT:

- **Topological Clusters**
- **Tracks from FTK**
  - $p_T > 1 \text{ GeV} \& p_T < 40 \text{ GeV}$
  - $|z_0|_{BL} < 110 \text{ mm}$ \quad $|d_0|_{BL} < 2 \text{ mm}$
  - implicit good track: at least 9 hits

**Samples (all @ $\langle \mu \rangle = 60$):**

- **Signal**: $ZH \rightarrow \nu \nu bb$
- $t\bar{t} \rightarrow (Wb)(Wb) \rightarrow (l\nu b)(qqb)$
- multi-jet: $20 < p_T^{\text{truth, lead}} < 200 \text{ GeV}$
Anti-$k_T$ R=0.4 Jet resolution comparison

- PFlow jets with FTK tracks
- Standard jets: with calibrated clusters
- PFlow jets with offline tracks

Resolution of PFlow jets is better than Standard jets
MET resolution

\[ ZH \rightarrow \nu\nu bb \]

**ATLAS** Simulation work in progress

ZH→νν bb, \( \mu=60 \)

\( \sqrt{s} = 14 \text{ TeV} \)

Offline PFlow \( E_T^{\text{miss}} \) better resolved than

FTK PFlow \( E_T^{\text{miss}} \) better than FTK+JET

\[ t\bar{t} \]
Performances studied for a trigger chain:
Level 1 MET > 50 GeV $\rightarrow$ HLT MET > 80 GeV

turnon curve = $\frac{\# \text{ events after L1} \& \text{ HLT}}{\# \text{ events after L1}}$ (offline MET)

- cut on HLT MET: **the same bkg rate** (multi-jet) wrt Run1
- HLT MET (only calorimeter) > 80 GeV
- FTK PFlow MET in $|\eta| < 2.5$: steeper turnon curve in truth

MET and lower HLT MET cut
Summary

- FastTracKer (FTK) will provide tracks at trigger level (after L1)
- many trigger chains will take advantage from global FTK track information
- FTK tracks in MET trigger chain and particle flow jets:
  - improvement in pflow jet resolution wrt to standard offline jets
  - steeper turn on curve of PFlow MET wrt Standard jet MET turn on curve
Single Particle Performance

- an emulation mimics the behaviour of FTK hardware and output
- trigger studies can be performed
- to give an idea: reconstruction efficiency of single muons without pileup wrt truth muons

**FTK Efficiency $P_t$**

![Graph showing FTK Efficiency $P_t$.](image)

**FTK Efficiency $\eta$**

![Graph showing FTK Efficiency $\eta$.](image)
Number of events that pass the HLT selection and the truth selection in $L = 122 \text{ fb}^{-1}$

<table>
<thead>
<tr>
<th>Truth MET cut (GeV)</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
<th>160</th>
<th>170</th>
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<tr>
<td>only Truth &amp; L1</td>
<td>1410</td>
<td>1218</td>
<td>1060</td>
<td>930</td>
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<td>676</td>
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<td>Jet MET</td>
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<td>$</td>
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<td>1127</td>
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<td>876</td>
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<td>PFlow MET</td>
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<td>1026</td>
<td>907</td>
<td>777</td>
<td>670</td>
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<tr>
<td>$</td>
<td>\eta^{\text{jet&amp;FTK}}</td>
<td>&lt; 2.5$ PFlow MET</td>
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<td>905</td>
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<td>Jet+FTK</td>
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<td>1176</td>
<td>1033</td>
<td>911</td>
<td>781</td>
<td>669</td>
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<tr>
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<td>1290</td>
<td>1135</td>
<td>1001</td>
<td>883</td>
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**ATLAS** Simulation work in progress
FastTracKer (FTK)

- FTK: custom electronics system for global track reconstruction (≈ 100 μs) after L1
- highly parallel system organized in 64 $\eta - \phi$ towers
- full-resolution hits from Pixel and Silicon strip
- **Associative Memory & Track Fitter**: pattern recognition and first track fitting
- **Second Stage Fit Board**: refines the track quality
- tracks with $p_T > 1$ GeV, $|\eta| < 2.5$
  \[\downarrow\]
  at the beginning of L2