L1 and L2 Triggers for MSP’s and τ’s

Yu. Gershtein
Brown U
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Outline

- Introduction
  - why trigger with tracker
- What makes it difficult
- Changes to \textit{L1} terms
  - track isolation
  - estimate of number of interactions at \textit{L1}
    (total occupancy)
  - local occupancy
- New features of \textit{L2CTT}
- Summary
Why Tracker?

- Sometimes it is all we have
  - Massive Stable Particles
    - can be too slow or decay before the muon system

- More efficient
  - $\tau$ leptons
    - recover low $E_t (\approx 10 \text{ GeV})$
      - taus which often do not give a triggerable jet

- Just because
  - Stiff isolated track is always interesting!!
    - flavor blind lepton trigger
    - physics we don’t know about
Why Is It Difficult?

* Only 8 axial fiber layers in L1 track finder -> fakes!!!
Fake L1 Tracks

Tracks with $p_t > 11 \text{ GeV/c}$

- huge rate at high $N_{\text{int}}$ comes from fake tracks
  - check occupancy near high $p_t$ track
  - suppress high $N_{\text{int}}$ events
**Track Isolation**

- **L1 track is isolated** if it is the only track in the home and both adjacent sectors (3 sectors out of 80)

**Two tracks above 5 GeV**

- no isolation
- one of tracks isolated
- both isolated

2 tracks, one isolated, \( N_{int} \leq 4 \)
**Total Occupancy**

- Occupancy in CFT is determined by the number of soft (untriggerable) tracks and strongly correlated with the number of interactions.

- Count hits in each of 80 FE and set bit if the number of hits is over a threshold (29 = 12%).

- OBC counts sectors with set bits and reports the number to FBC.
  - 0 → 0, 1 → 0, 2 → 1, 3 → 2, 4 → 3, 5 → 4, 6 → 5, 7 → 6, 8 → 7, 9 → 7, 10 → 7

- FBC adds 8 OBC reports and sets “high number of interactions” bit if the sum is greater than 15.
Total Occupancy

Event Acceptance

\[ \varepsilon = 85\% \]

for  \( \mu = 1.98 \)

\begin{itemize}
  \item Note, that this is signal efficiency.
  \item The background rejection can be much higher.
  \item No way to simulate at the moment 😞
\end{itemize}

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Local Occupancy

- One step further:
  - probability to have a fake track is a very steep function of occupancy in the home sector
  - Cut on it!

- Note: Inefficient for tau decays...
L1 Strategy

- If not for the fake tracks one could trigger, for example, just on a pair of tracks with $p_T > 5$ GeV.

- Most of the fake tracks come from low $E_T$ events with high number of interactions $\Rightarrow$
  - Suppress very high $N_{\text{interactions}}$
  - Suppress very low $E_T$ events

```
<table>
<thead>
<tr>
<th>Rate, Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^2$</td>
</tr>
<tr>
<td>$10^3$</td>
</tr>
<tr>
<td>$10^4$</td>
</tr>
</tbody>
</table>

$\pi\pi(2,5)\pi\pi(5)$

Require L1 jet seeds of
- 3 GeV,
- 5 GeV,
- 6 GeV
L1/L2 Strategy

Level 1

<table>
<thead>
<tr>
<th>MIXED--LEPTON TRIGGERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 TRIGGERS</td>
</tr>
<tr>
<td>ELE_TAU_A</td>
</tr>
<tr>
<td>DITAU_5C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRACK-MINBIAS TRIGGERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 TRIGGERS</td>
</tr>
<tr>
<td>LL_TEL</td>
</tr>
<tr>
<td>TIS_MSP</td>
</tr>
<tr>
<td>TTK2_THT</td>
</tr>
<tr>
<td>TTK2H_TLO</td>
</tr>
</tbody>
</table>

Level 2

- Confirmation of tracks in the silicon should kill most of the fakes
- Many other handles
  - dE/dx in silicon
  - dE/dx in CPS
  - Calorimeter tau tool
  - ...
  - more sophisticated isolation in CFT

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Isolation at L2

- At L2 one can examine the event topology in more detail.
- Things we look for have a common feature: they are narrow isolated objects.
- One prong
  - track with $p_T > 5$ GeV and in $\Delta \phi < 0.5$ there is no more than one track with $p_T < 2$ GeV and no tracks with $p_T > 2$ GeV.
- Three prong
  - as one prong, but allow up to two additional tracks in $\Delta \phi < 0.1$ around the track.
Isolation at L2

Can have more elaborate isolation at L2

* One-prong:
  - no tracks over $P_0$ GeV in ±0.5 rad
  - one or no tracks below $P_0$ GeV

* Three-prong:
  - allow one or two tracks within ±0.1
  - less pure object but still factor of $\approx 5$

$$\text{TTK}(2,5)*\text{TIS}(5)$$

- $P_0 = 3$ GeV
- $P_0 = 2$ GeV
- $P_0 = 0$ GeV

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L2CTT

- Receives a list of tracks from L1FT or L2STT
- Recalculates $p_T$
- Sorts tracks in $p_T$
- Has some spare time for low track multiplicity events
Algorithm

- Only one pass through the track list
- As the tracks are uploaded from the input buffers they are:
  - tagged as a one/three prong candidate if $p_T > 5$ GeV
  - two 160-bit bitmaps are filled for tracks with $p_T > P_0$ and for $p_T < P_0$, making a "histogram" of track azimuth angle
  - for all one/three prong candidates (usually a very short list) bit sums are performed, giving a track count "almost" in wedges $\Delta \phi < 0.5$ and $\Delta \phi < 0.1$
- The L2CTT output words format has enough spares to accommodate two bits for one and three prong tags
Run optimized code on do2ka for 20-40 GeV QCD and for ttbar + 2 minbias

Before

After

Increase
The Efficiency

Study efficiency on $Z \rightarrow \text{tau}^+ \text{tau}^-$

- select events with two taus $|\eta| < 1.5 \ p_T > 10$
- Require $\text{TTK}(2.5) \cdot \text{TIS}(5)$ at $L1$
- $L2$ loose means $P_e = 2 \text{ GeV}$, tight $\rightarrow P_e = 0$

$\text{MC events}$

- $L1$
- $1-1$ loose
- $1-1$ tight
- $1-3$ loose
- $1-3$ tight

$\text{Eff}(L1) = 72\%$

$\text{Eff}(L1 \cdot L2) = 40-60\%$

$\text{85\%/tau}$

NOTE that THT efficiency of 85-90% is not included
Summary

- The improvements of the tracking system in Run II gives new opportunities
- New L1 terms are included in the design
- Modifications to L2CTT algorithms are coded and timed
- New items in the trigger menu