The High Luminosity HL-LHC upgrade to the Large Hadron Collider will allow an ultimate integrated luminosity of 3000 fb\(^{-1}\) to be collected in the decade following 2023. At the HL-LHC proton bunches will cross each other every 25 ns, producing up to an average of 200 collisions per bunch crossing (BX). To work in such an environment the CMS experiment will be upgraded (CMS Phase II Upgrade). In particular, for the first time, data coming from the Outer Tracker will be used in the L1 Trigger. The new tracker will adopt double sensor modules. Making use of the correlation between hits in two sensors consistent with a high-p\(_T\), track (stubs), it will be possible to reject tracks under certain p\(_T\) threshold. The architecture that will be used to handle the tracker data is still under discussion. Our proposal is based on a Time Multiplexed approach.

### Results show a generally good algorithm efficiency (>95%), except for electrons. This loss is mainly due to the Bremsstrahlung effect, which changes the electron’s trajectory the that which is expected.

#### Track Filtering

To build track candidates an approach based on the 

\[ \text{Hough Transform (HT)} \]

has been proposed. The HT sorts stubs into track candidates before the selection and the final fitting stages.

Stubs are collected into \(\beta\) segments and then binned into the track finder array based on a HT (m,c) using the \(r,\phi\) projection. A track is found where there is a local peak in the 2-d histogram.

### The Time Multiplexed Trigger

**L1 Track Finding for a Time Multiplexed Trigger**

Davide Cieri - davide.cieri@bristol.ac.uk

**Algorithm Efficiency vs. PU (ttbar sample)**

<table>
<thead>
<tr>
<th>PU</th>
<th>RMS (charged)</th>
<th>Hits (charged)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.75</td>
<td>0.8</td>
</tr>
<tr>
<td>20</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>30</td>
<td>0.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Filter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R Filter</td>
<td>High p(_T) tracks should leave hits in all track layers, only cells with &gt;5 stubs belonging to 5+ tracker layers/disk are marked for readout.</td>
</tr>
<tr>
<td>Eta Filter</td>
<td>Tracks should have a physical r-z trajectory, stubs in a cell are binned in (\eta), find the most populated (\eta) bin, remove from the cell stubs with (\Delta\eta &gt; 0.5), R Filter applied again.</td>
</tr>
</tbody>
</table>

**Array Readout**

After filtering ~1.5 cells per \(\beta\) segment are marked for readout in a PU140 event, in most cases the stubs present in a HT cell are not consistent with real tracks. Indeed they are usually due to random combinations of hits belonging to pile-up tracks. In order to remove those false, filter stages can be applied to each cell in the array.

**Track Parameters in HT**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>m (mm)</th>
<th>c (mm)</th>
<th>RMS x (mm)</th>
<th>RMS y (mm)</th>
<th>Entries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stubs</td>
<td>0.001</td>
<td>0.0005</td>
<td>0.0015</td>
<td>0.0006</td>
<td>1000</td>
</tr>
<tr>
<td>Pions</td>
<td>0.002</td>
<td>0.001</td>
<td>0.0025</td>
<td>0.0012</td>
<td>2000</td>
</tr>
<tr>
<td>Muons</td>
<td>0.003</td>
<td>0.0015</td>
<td>0.0035</td>
<td>0.0018</td>
<td>3000</td>
</tr>
</tbody>
</table>

**References**

[4] Track Tracker Integration group, Use of tracking in the CMS L1 trigger for the phase-2 upgrade

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**Authors & References**

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**Funding**

This project has received funding from the European Union's Seventh Framework Programme for research, technological development & demonstration under grant agreement n. 317446

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**Firmware Implementation**

**ALGORITHM PERFORMANCE**

**Data Ordering**

**The CMS Phase II Upgrade**

**track ordering**

**track finding**

**Track Filter stages**

**time multiplexed trigger**

**The Time Multiplexed Trigger**

**Track Parameters**

**array content**

**Track Candidates**

**Array Concept**

- **Eastbound Traffic**
- **Two entry points (W-N)**
- **Cells resident when stub entries with 5+ different r values**

The algorithm has been implemented in a **systolic array**, operating at 250 MHz. A standalone 20x20 array is currently being implemented within the MP7, for online data processing.