Updates & Rates in the Level-1 CSC Trigger Primitive code in ORCA

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New requirements implemented:

- **Hardware changes**
  - Elimination of cards in the LCT Processors.
  - Change of keylayer in chamber from 3\textsuperscript{rd} layer from interaction to 4\textsuperscript{th} layer in chamber.

- **Better trigger emulation**
  - Fix centering of phi for high momentum to the middle of a halfstrip.
  - More exact treatment of the pretrigger to emulate the hardware electronics.
  - More accurate treatment of distrip staggering.
  - Increase from 2 to 7 CLCT patterns. – thanks to Benn Tannenbaum and Jay Hauser
  - More accurate description of the data delivered from ALCT (CLCT) to TMB, MPC, SR and SP. – thanks to Benn Tannenbaum
  - Bunch-cross time is defined as the time of the pretrigger.

- **Improved software structure**
  - LCT Processor parameters such as min bx-time, and patterns are easier to modify. New file, L1MuCSCChamberConstants, has also been added for easy maintenance of detector constants.
  - Increased debug, assert, and output statements for easier debugging, including particle types for the simHits.
Updates in Trigger Primitives since ORCA_4_5_0

Fixed problems:

- Array size mismatch in CathodeLCTProcessor.
- Wrong implementation of reassignment of ‘=’ operator in L1MuCorrelatedLCT.
- Wrong implementation of reassignment of ‘>’ operator in L1MuCathodeLCT.
- Wire counting error in AnodeLCTProcessor.
- Strip counting error in CathodeLCTProcessor.
- Mistake in counting the number of distrips from 0-40. This gave 41 distrips instead of 40.
- Error in buffer region between cards in AnodeLCTProcessor and CathodeLCTProcessor. Now cards have been completely eliminated.
- Strip offset in wrong direction for low-momentum hits in SectorReceiverLUT.
- Hard coded correction for wire tilt in station 1 in SectorReceiverLUT. There was an assumption of 80 strips for both inner rings.
- Mismatch between SectorReceiver and CSCTrackStub values. Eta and phi values could be negative in SectorReceiver, but then converted to unsigned int in the CSCTrackStub.
- Because of sectorOffset, stubphivalue was mismatched with simPhi at the 2PI edge.
- Stagger removal of keystrip in CathodeLCTProcessor was done for wrong layer.
- Distrip stagger dysfunctional in CathodeLCTProcessor. The result was a loss of hits.
- Artificial phi corrections in SectorReceiverLUT due to misunderstanding of halfstrip centering for high momentum.
- The L1CSCAnodeLCTProcessor favored lower wire groups for LCTs that had the same quality. There was an additional error in the same logic that shifted the LCT values of one wire to the next wire.
- Sector size in ME 1/3 fixed from 60.68 degrees to 60 degrees.
Remaining problems:

- Phi can be miscalculated for a small fraction of events due to the sector offset being the same for both rings in a given sector. There is in fact a difference in phi for the rings for the real sector.
- The removal of all hard-coded corrections in phi has revealed a minor resolution problem in ME1/3.
- The sector offset calculation done in the SectorReceiverLUT always uses strips 40 and 41 to calculate a halfstrip width. In reality every strip may have a slightly different halfstrip width.
- Emulation of SectorReceiverLUT is still imperfect because of recent hardware design changes.
Reconstructed Values from LCTs

**Anode LCT**

- Reconstructed track made by a particle crossing the wires of several layers in a chamber.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Wires</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
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<tr>
<td>2</td>
<td></td>
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<tr>
<td>1</td>
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</tbody>
</table>

**Cathode LCT**

- Same as anode LCT except created with strips.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Strips</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
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<tr>
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</table>

Local Charged Track (LCT)
- Provides reconstructed info.
- Anode LCT gives eta measurement.
- Cathode LCT gives phi measurement.
Improvements in $\phi$ Resolution (for Single Muons)

OLD

NEW

Plot is cleaner

Large gap removed

- 5% more CLCTs found
- Mean centered closer to zero
- Less Underflow and Overflow
- More symmetric
- Slightly bigger RMS

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Improvements in $\langle |\phi_{\text{rec}} - \phi_{\text{sim}}| \rangle$ vs $\phi$

(for Single Muons)

New Features
- More entries
- Mean values closer to zero

Method of measurement of resolution can still be improved!
Improvements in $\eta$ Resolution (for Single Muons)

- 3% more ALCTs found
- Mean centered closer to zero
- Less underflow and overflow
- Smaller RMS
- More symmetric

Cleaner plots
Improvements in $|\eta_{rec} - \eta_{sim}|$ vs $\phi$
(for Single Muons)

New Features
- More entries
- Mean values closer to zero

Method of measurement of resolution can still be improved!
Efficiency vs Pt Improvement in L1CSCTrackFinder (for Single Muons)

Plots courtesy of Darin Acosta and Bobby Scurlock

10% Increase
Efficiency vs $\eta$ Improvement in L1CSCTrackFinder (for Single Muons)

Plots courtesy of Darin Acosta and Bobby Scurlock

Average increase of 10%

Loose: 2 or more stations including ME1 in endcap but any two in DT/CSC overlap region
Tight: 3 or more stations including ME1 in endcap and MB1 in DT/CSC overlap
Efficiency vs $\eta$ Improvement In Global Muon Trigger (for Single Muons)

Plots courtesy of Hannes Sakulin

CSC Region is more level and closer to 100%
Global Muon Trigger Rates

Plots courtesy of Hannes Sakulin

PT cut = 16 GeV/c

PT cut = 25 GeV/c
SimHit

- Simulation of particle showers and energy deposited in CSC.
- Contains entry point, exit point, and energy deposition.

Wire and Strip Digi

- Electric pulse caused by one or more SimHits in the CSCs.
- Wire digis are used for finding anode LCTs.
- Strip digis are processed into rec digis.

Reconstructed Digi (Rec Digi)

- Precise reconstruction which determines the halfstrip a particle passed through in a CSC layer.
- Made with information from several strip digis.
- Used for finding cathode LCTs.

Local Charged Track (LCT)

- The coincidence of digis on at least 4 CSC layers within one of several pre-defined 6-layer templates.
Job Parameters

• **CMSIM 121 and ORCA 5_2_0**
• **Un-weighted minimum bias events**
  - 17.3 events/bx corresponding to 55.2 mb at a luminosity of \(10^{34} \text{cm}^{-2} \cdot \text{s}^{-1}\)
  - 5,750 piled-up bx’s without neutrons.
  - 6,000 piled-up bx’s with neutrons simulated with MC_JUNK.
  - W decays, top quark decays, Higgs decays, cosmic muons, and beam halo muons are not included.
• Sample at the University of Florida.
SimHits per BX
(No Neutrons)

Summed over both endcaps

Peak at 6 from particles traversing all 6 CSC layers

Electromagnetic showers
Wire Digis per BX (No Neutrons)

Summed over both endcaps

Number of Wire Digis, station 1

Number of Wire Digis, station 2

Number of Wire Digis, station 3

Number of Wire Digis, station 4
Rec Digits per BX
(No Neutrons)

Summed over both endcaps
SimHit Rates

Points of Interest
- Can be compared to background particle flux rates in TDR
  - Our rates are higher in all stations except ME4.
- Highest rate is \( \sim 10^3 \) Hz/cm\(^2\) in ME1.
- Rate is highest near beamline.
- Neutron rate drops then rises near outer edge.
- Gaps seen in ring boundaries.
- Significant increase in rates with neutrons in outer edge of ME4.
- Lowest overall rate is in ME3.
LCT Rates
(No Neutrons)

Summed over both endcaps

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Points of Interest

1. CLCT rate is lower than ALCT rate in ME1
2. ME1/3 has lowest rate
3. ME4/2 has higher rate than ME3/2
LCT Rates (With Neutrons)

Points of Interest

- Neutrons cause a rate increase of ~30% except in ME4.
- ME4/2 has a higher neutron rate than all stations.
- Highest rate is ~13 MHz which corresponds to ~200 kHz/chamber.
Portcard Rate

Number of LCTs in portcard, endcap 1 station 1

Points of Interest
- For 5,750 bx minbias without neutrons, mean values range from $1.30 \times 10^{-2}$ to $2.04 \times 10^{-2}$ in ME1.
- There are 5 bxs with more than 2 LCTs/portcard.

Portcard selects 2 (ME1) or 3 (ME2, ME3, ME4) out of 18 LCTs from 9 chambers.
Conclusions

- New ORCA trigger primitive code.
  - Improvements in phi, eta resolution, and efficiency in L1CSCTrackFinder and GlobalMuonTrigger.
  - Upgraded code is more maintainable and makes optimization of hardware electronics easier.

- SimHit, digi, and LCT rate studies are available.
  - For the first time Digi/SimHit/LCT rates measured using the full collaboration software.
  - Rates are available for both the trigger path and DAQ path.

- Memo on rates is in preparation.

Special thanks

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