Trigger Overview

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CMS Trigger Project Manager

DOE/NSF Review
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Collision rate  40 MHz  
LV1 Maximum trigger rate  100 kHz  
Average event size  ≈ 1 Mbyte  
Data production  ≈ Tbyte/day  
Event Flow Control  ≈ $10^6$ Mssg/s  
I-O units bandwidth (512+512)  400 MByte/s  
Builder network (512x512 port)  ≥ 500 Gbit/s  
Event filter computing power  ≈ $5 \times 10^6$ MIPS  
High Level Trigger acceptance  1 - 10 %  
Overall dead time  ≤ 2%
### TriDAS Evolution

#### Plans for initial turnon of CMS:

<table>
<thead>
<tr>
<th>Rates (kHz)</th>
<th>Level 1 output</th>
<th>Readout thruput</th>
<th>Ev. Bld. thruput</th>
<th>Ev. Filt. capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Implement.</td>
<td>100</td>
<td>100</td>
<td>75</td>
<td>75*</td>
</tr>
<tr>
<td>Operation</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75*</td>
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</tbody>
</table>

* The final capacity will be determined by the evolution of technology, cost and financial resources

Plan set to exploit funding resources and computing technology advances in the most effective manner
CMS Level 1 Trigger

Level-1. Specialized processors
- Particle identification: high $p_T$ electron, muon, jets, missing $E_T$
- Local pattern recognition and energy evaluation on prompt macro-granular information from calorimeter and muon detectors

High trigger levels.
Network and CPU farms
- Clean particle signature
- Finer granularity precise measurement
- Kinematics, effective mass cuts & event topology
- Track reconstruction and detector matching
- Event reconstruction and analysis

≈ 100 Hz
CMS Level 1 Pipeline

- **Local level-1**
  - Primitive e, γ, jets, μ
  - Pipeline delay (~ 3 μs)
  - LV-1 Accept/Reject

- **Global LVL 1**

- **Trigger**
  - Primitive Generator

- **Front-End Digitizer**
  - Synchronous 40 MHz digital system
    - 160 MHz internal pipeline
    - Readout & processing latency < 1 μs
    - Signal distribution latency ~ 2 μs

- **~ 3 μs latency loop**
Trigger Electronics Locations

In Underground Shielded Room:
- CSC/DT Muon Trigger Track Finder
- RPC Muon Trigger Pattern Logic
- Calorimeter Regional/Global Trigger
- Global L1 Trigger

On Detector:
- CSC/DT Segment Generation
- RPC Muon Hit Generation
- Calorimeter Digitization only
CMS Level 1 Latency

Target is 128 bunch crossings
- 3.2 μs
- set by tracker

Reviewed in detail once/year
- Last Review in November

Number shown are latency budgets
- Units are bunch crossings
- Include contingency

Tracker frontend

RPC frontend

DT frontend

CSC frontend

CALO frontend

RPC PACT

DT TPG

CSC TPG

CALO TPG

link to detector (~ 18 bx)

local clk/control

clk/control

global trigger

66 bx

~ 18 bx

5 bx

$\geq 28$ bx

126 bx

logical units

interconnections btw. logical units

links btw. detector & control room (18 bx)
Calorimeter Trigger Overview

US CMS HCAL: U. Nebraska
US CMS HCAL: FNAL/Maryland
US CMS HCAL: U. Wisconsin
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US CMS HCAL: U. Wisconsin

Calorimeter Regional Trigger
Calorimeter Regional Trigger

Receiver Electron Isolation Jet/Summary
Receiver Electron Isolation Jet/Summary

Copper 40 MHz Parallel
4 Highest $E_t$ isolated & non-isol. e/$\gamma$
4 Highest $\tau$ & std. jets $E_x, E_y$ from each crate

4K 1.2 Gbaud serial links w/ 2 x (8 bits E/H/FCAL Energy + fine grain structure bit) + 5 bits error detection code per 25 ns crossing

US CMS Trigger: U. Wisconsin

CMS ECAL: Lisbon/Palaiseau
CMS ECAL: Lisbon/Palaiseau

72 $\phi$ x 60 $\eta$ H/ECAL Towers ($0.087\phi$ x $0.087\eta$ for $\eta < 2.2$ & $0.174-195\eta$, $\eta > 2.2$)

FCAL: 2x(12 $\phi$ x 12 $\eta$)

E_t sums

Cal. Global Trigger Sorting, $E_t^{\text{Miss}}, \Sigma E_t$

Luminosity Monitor

UK CMS: Bristol

CMS: Vienna

Global Trigger Processor

Muon Global Trigger Iso Mu Minlon Tag

Minlon Tag for each 4$\phi$ x 4$\eta$ region
Data from calorimeter FE on Cu links @ 1.2 Gbaud (ptyp. tstd.)

- Into 133 rear-mounted Receiver Cards (ptyp. tstd. w/ ASICs)

160 MHz point to point backplane (ptyp. tstd.)

- 19 Clock&Control (ptyp. tstd.), 133 Electron ID (ptyp. tstd.)
  19 Jet/Summary, Receiver Cards operate @ 160 MHz
Muon Trigger Overview

- **DT** hits
  - *local trigger*
    - track segments $(\phi, \delta\phi, \eta, \delta\eta)$
  - *regional trigger*
    - Barrel Track Finder
      - $\leq 4$ muon candidates $(p_t, \eta, \phi, \text{quality})$

- **CSC** hits
  - *local trigger*
    - track segments $(\phi, \delta\phi, \eta, \delta\eta)$
  - *regional trigger*
    - Endcap Track Finder
      - $\leq 4$ muon candidates $(p_t, \eta, \phi, \text{quality})$

- **RPC** hits
  - *PAttern Comparator Trigger*
    - $\leq 4$ barrel + $\leq 4$ endcap muon candidates $(p_t, \eta, \phi, \text{quality})$

- **Global Muon Trigger**
  - $\leq 4$ muons $(p_t, \eta, \phi, \text{quality})$
CSC Trigger Layout
(WBS 3.1.1)

60° Sector Layout (x12 Sectors)

Trigger Mother Boards (Rice) in 8 Iron Disk Peripheral Crates

Backplane, Crate Interconnects

5 Muon Port Cards x 12

24 Optical Links x 12

6 Track Finder Crates in Counting Room (total). Sort output (Rice) to Global Muon Trigger (Vienna)
Trigger Status

Muon Trigger

- Construction & test of prototype boards
  - FPGA's, Optical Links, Interfaces
- Integration test of prototype boards
  - Muon Port Card, Sector Receiver, Sector Processor, Backplane, Crate, Clock Board, EMU Prototypes

Calorimeter Trigger

- Produce & test 2nd generation prototype boards
  - Receiver Card, Electron Isolation Card, Backplane
  - Copper high speed serial links
- Produce & test ASICs
  - Phase, Boundary Scan, Sort, Electron ID test on 2nd generation prototype boards

Produce TDR
<table>
<thead>
<tr>
<th>Presentation</th>
<th>Presenter</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMS Trigger Design &amp; Status</td>
<td>W. Smith</td>
<td>11:15 - 11:30</td>
</tr>
<tr>
<td>Trigger Simulation Update</td>
<td>S. Dasu</td>
<td>11:30 - 12:00</td>
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<tr>
<td>Cal. Regional Trigger Status &amp; Plan</td>
<td>W. Smith</td>
<td>12:00 - 12:30</td>
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<td><strong>LUNCH: 12:30 - 1:30 PM</strong></td>
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<tr>
<td>Muon Trigger Overview</td>
<td>J. Hauser</td>
<td>1:30 - 1:50</td>
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<tr>
<td>Muon Trig. Electronics in Cavern</td>
<td>P. Padley</td>
<td>1:50 - 2:10</td>
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<tr>
<td>Muon Trig. Electr. in Counting Room</td>
<td>D. Acosta</td>
<td>2:10 - 2:30</td>
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<tr>
<td>Cost and Schedule: Status</td>
<td>W. Smith</td>
<td>2:30 - 3:00</td>
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