Global Muon Trigger Update

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URL of this presentation:
Outline

- GMT Hardware Status & Plans
- Simulation Results with 2002 Production
  - Low and High Luminosity
  - Single Muon Trigger Rates
  - Di-Muon Trigger Rates & Contributions
  - Possible L1 Working Points
  - Signal Efficiencies
- Example of a Topological Di-Muon Trigger for $B_s \rightarrow \mu^+\mu^-$
Global Muon Trigger Overview

252 MIP bits
252 Quiet bits

4 μ RPC barrel

4 μ DT

4 μ CSC

4 μ RPC fwd

**Inputs:**
- 8 bit \(\phi\), 6 bit \(\eta\), 5 bit \(p_T\),
- 2 bits charge, 3 bit quality,
- 1 bit halo/eta fine-coarse

**Output:**
- 8 bit \(\phi\), 6 bit \(\eta\), 5 bit \(p_T\),
- 1 bit charge, 3 bit quality,
- 1 bit MIP, 1 bit Isolation
GMT Status and Plans

Recently progress
- Logic design completed
  - detailed design document & drawings
- Functionality improved
  - added provision for Beam Halo Trigger during normal operation
- Documentation
  - DT/CSC cancel-out unit
    - improved performance in barrel/endcap overlap region

CMS Note 2002/024: H. Sakulin, "A Robust Solution to the Ghosting Problems of the CMS Level-1 Muon Trigger in the Barrel/Endcap Overlap Region"

Plans for 2002/2003
- continue VHDL simulation of FPGA chips
- VHDL simulation of GMT board
- Synthesis / design of FPGAs

*Milestone Dec. 2001: Logic design done -> Done.*
*Milestone Dec. 2002: FPGA design done -> Delayed to Dec. 2003*
Logic Design: GMT Logic FPGA
2002 Production & Samples

- **Monte Carlo production (Pythia 6.158)**
  - improved weighting of heavy flavor processes
  - improved relative normalization of pt10 and pt4 samples
  - consistent with production in b/τ group

- **CMSIM 125**
- **ORCA 6.0.2 / 6.1.0**
  - digitization for LHC Luminosities
    - \( L = 10^{34} \text{ cm}^{-2}\text{s}^{-1} \) and \( L = 2 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1} \)
  - pile-up without muons

- **ORCA 6.2.2**
  - Trigger Simulation

- **Analysis**
  - assume L1 Trigger only up to \( |\eta| < 2.1 \)

### Sample L \( \text{int} / \text{nb}^{-1} \) | Events in luminosity
---
MB1mu_pt1 | 0.0246 | 150483
MB1mu_pt4 | 0.9908 | 255732
MB1mu_pt10 | 11.4315 | 86914
W_1mu | 3081. | 50000
Z/γ* -> 1mu | 2262. | 50000

+ Special MIX sample that contains in-time pile-up events with muons
  - mixed from pt1, pt4 and pt10
  - used for high luminosity studies
  - (at low luminosity an analytic correction is used)

+ additional signal samples
Generated rates, Min. Bias, W, Z

Generated Rates L=2x10^{33} cm^{-2}s^{-1}

Generated Rates L=10^{34} cm^{-2}s^{-1}

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Global Muon Trigger Update
Single Muon Trigger Efficiency vs. $\eta$

$|\eta| < 2.1$

eff = 96.9 %

(*)efficiency to find muon of any $p_T$ in flat $p_T$ sample
L1 Single Muon Trigger Rates

\[ |\eta| < 2.1 \]

**50 kHz DAQ**

- \( p_T^\mu \geq 14 \text{ GeV}/c: 2.7 \text{ kHz} \)

**100 kHz DAQ**

- \( p_T^\mu \geq 18 \text{ GeV}/c: 7.8 \text{ kHz} \)
- \( p_T^\mu \geq 20 \text{ GeV}/c: 6.2 \text{ kHz} \)

\[ L = 2 \times 10^{33} \text{cm}^{-2}\text{s}^{-1} \]

\[ L = 10^{34} \text{cm}^{-2}\text{s}^{-1} \]
L1 Di-Muon Trigger Rate Contributions
high luminosity (L = 10^{34} cm^{-2} s^{-1})

L1 Di-Muon Trigger Rate, symmetric thresholds

<table>
<thead>
<tr>
<th></th>
<th>Trigger Rate / Hz</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>(10^2)</td>
</tr>
<tr>
<td></td>
<td>(10^3)</td>
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<tr>
<td></td>
<td>(10^4)</td>
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\(|\eta| < 2.1\)

- **important contribution from mix sample at low p_T**
- **low contribution from ghosts**
- **low contribution not related to generated muons**

- Total Di-Muon Trigger Rate GMT
- Two muons (including from in-time PU)
- Two muons from same event
- Two muons from different events (PU)
- One Generated Muon + Ghost
- One Generated Muon + Trigger without Gen \(\mu\)
L1 Single & Di-muon Trigger Rates

trigger rates in kHz

50 kHz DAQ
4 kHz for $\mu$, $\mu\mu$

100 kHz DAQ
8 kHz for $\mu$, $\mu\mu$

| $|\eta| <$ 2.1 |
|---|
| 18, 8;8 |
| $\varepsilon_W$ = 84.9 % |
| $\varepsilon_Z$ = 99.7 % |
| $\varepsilon_{B_s \rightarrow \mu\mu}$ = 7.2 % |

| 20, 5;5 |
| $\varepsilon_W$ = 82.3 % |
| $\varepsilon_Z$ = 99.7 % |
| $\varepsilon_{B_s \rightarrow \mu\mu}$ = 15.1 % |

| 25, 4;4 |
| $\varepsilon_W$ = 74.2 % |
| $\varepsilon_Z$ = 99.5 % |
| $\varepsilon_{B_s \rightarrow \mu\mu}$ = 18.4 % |

Working points compatible with current L1 $p_T$ binning

$L = 2 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$

$L = 10^{34} \text{cm}^{-2}\text{s}^{-1}$

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Global Muon Trigger Update
Example of a Topological Trigger

- Example channel $B_S \rightarrow \mu^+\mu$ (very rare)
  - interesting to continue its study at high luminosity
  - assume L1 working point 20; 5,5
  - assume additional 1 kHz for topological trigger

Combined efficiency from single-$\mu$ and symmetric di-$\mu$ trigger

- starting point
- combined efficiency of single and di-muon trigger
- working points high luminosity
- 100 kHz DAQ
- 8 kHz for $\mu$, $\mu\mu$
- generated muon $p_T$ spectrum
- GMT muon $p_T$ spectrum
- L1 GMT muon $p_T$ spectrum

Example channel $B_S \rightarrow \mu^+\mu$ (very rare)

- interesting to continue its study at high luminosity
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- generated muon $p_T$ spectrum
- GMT muon $p_T$ spectrum
- L1 GMT muon $p_T$ spectrum

- working points high luminosity
- 100 kHz DAQ
- 8 kHz for $\mu$, $\mu\mu$
Topological Di-Muon Trigger

$\Delta \eta$ of highest $p_T$ muons

$B_s \rightarrow \mu \mu$

$MBmixWZ$
Topological Di-Muon Trigger
\(\Delta \phi\) of highest \(p_T\) muons

\[\text{Delta Phi Gen muons}\]

\[\text{Delta Phi GMT muons}\]

\[B_s \rightarrow \mu \mu\]

MBmixWZ

\[\Delta \phi / \text{rad}\]

\[\Delta \phi / \text{rad}\]
Topological Di-Muon Trigger
$\Delta \phi$ between Muon System and Vertex

$\phi_{\text{vextex}} - \phi_{\text{station2}}$

negative charge

Simple correction for bending:

$\phi_{\text{vextex}} = \phi_{\text{station2}} + 0.55 \times \text{charge}$

$\Rightarrow$ Should add conversion of $\phi$ in GMT
Topological Di-Muon Trigger

\( \Delta \phi \) of highest \( p_T \) muons, corrected for bending

- Before correction
- After correction

Generated muons

- GMT muons
- \( B_s \rightarrow \mu \mu \)
- \( B_s \rightarrow \mu \mu \)
- MBmixWZ
Topological Trigger
Gain in Rate and Efficiency at working point 20; 5,5

Additional Rate

muon $p_T$ (GeV/c)

additional rate 1 kHz,

Additional Efficiency

total efficiency = 15.1% + 7.8% = 22.9%

topo trigger:
$|\Delta \phi| < 2$ rad
$|\Delta \eta| < 1.5$

opposite charge

- additional rate 1 kHz
- total efficiency = 15.1% + 7.8% = 22.9%
Conclusion

- GMT design: logic design completed
- Updated Simulation Results with 2002 production
  - single muon trigger rates agree with June CMS Week results
  - we now also understand di-muon trigger rates very well
- Example Study of a Topological Trigger
  - works well for $B_S \rightarrow \mu^+\mu$
  - depending on L1 working point:
    - extra 1 kHz for topological trigger results in large efficiency gain
- Propose to add conversion of $\phi$ at Muon System to $\phi$ at vertex in the Global Muon Trigger