Status of PRS/Muon Activities
(including some ME4 re-scoping studies)

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Completed!

528 pages total

nearly 200 pages on HLT design and results
L3 Single and Di-$\mu$ Rate with Isolation

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

\[ L = 10^{34} \text{ cm}^{-2}\text{s}^{-1} \]
Muon HLT Results

Table 15-9  Muon rates and efficiencies for the low luminosity selection. Both absolute and relative efficiencies are shown, where the relative efficiency is with respect to the preceding level (except for Level-3, which is with respect to Level-2).

<table>
<thead>
<tr>
<th>Level</th>
<th>Rate (Hz)</th>
<th>Efficiency for $W \rightarrow \mu\nu$</th>
<th>Efficiency for $t\bar{t} \rightarrow \mu+X$</th>
<th>Efficiency for $Z \rightarrow \mu\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single</td>
<td>Double</td>
<td>Relative</td>
<td>Absolute</td>
</tr>
<tr>
<td>Level-1</td>
<td>2700</td>
<td>900</td>
<td>0.90</td>
<td>0.99</td>
</tr>
<tr>
<td>Level-2</td>
<td>335</td>
<td>25</td>
<td>0.89</td>
<td>0.80</td>
</tr>
<tr>
<td>Calo isolation</td>
<td>220</td>
<td>20</td>
<td>0.97</td>
<td>0.77</td>
</tr>
<tr>
<td>Level-3</td>
<td>100</td>
<td>10</td>
<td>0.93</td>
<td>0.74</td>
</tr>
<tr>
<td>Level-3 + calo + tracker isolation</td>
<td>25</td>
<td>4</td>
<td>0.94</td>
<td>0.69</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td></td>
<td>0.69</td>
<td>0.72</td>
</tr>
</tbody>
</table>

30 Hz output rate

$H \rightarrow ZZ^* \rightarrow \mu\mu\mu\mu \quad \varepsilon \approx 98\%$ for $M=150$ GeV

$H \rightarrow WW^* \rightarrow \mu\mu\nu\nu \quad \varepsilon \approx 92\%$ for $M=160$ GeV

$L=2 \times 10^{33}$ s$^{-1}$cm$^{-2}$
Beyond the TDR

Some of the things to explore post-TDR:

- Loosen the L1 CSC muon quality for di-muon triggers to recover $\eta$ coverage out to 2.4, where we don't have ME1/1. The di-muon L1 thresholds are basically $\approx 0$ anyway for low lumi. Can we live with the rate? Are ghosts under control?

- Further explore showering muons, and make sure our HLT algorithms are optimal. Any way to identify a shower and assign a larger error? Check the efficiency for TeV muons.

- Study the impact of the neutron background in the endcaps.

- Improve upon execution time of GEANE-like propagation.
  - New algorithms that propagate muons with associated errors under development by Tracker group and Geant4 (P.Arce)

- Refine/distinguish HLT tools and offline reconstruction
  - HLT should be fast and robust. Just need to get event to tape, which means reconstructing just one or two muons
  - Offline you want all muons reconstructed (e.g. $H \rightarrow 4\mu$)
  - Need to create muon seeds independently of Level-1

- Further optimize L1 $\rightarrow$ HLT $\rightarrow$ offline for physics
  - Disparity between L1 and L3 inclusive muon thresholds leaves room for more exclusive HLT triggers (correlations) at lower thresholds
  - Some cuts should be relaxed at high $P_T$ (e.g. isolation)
Suggestion by Dick and Richard to study TeV muons: Can ME4/1 help recover loss from muon bremsstrahlung?

Plot Level-1 trigger efficiency for $p_T=300$ GeV ($p \sim 1$ TeV) muons to pass “tight” (3-station) CSC T-F requirement for adequate rate reduction. ME4 does recover efficiency.

**Table:**

| $|\eta|<2.1$ | ME4/1 Efficiency | ME4/2 Efficiency |
|-------------|------------------|------------------|
| 1.6        | $\varepsilon = 64\%$ vs. $60\%$ (6\% effect) |
| 1.8        | $\varepsilon = 81\%$ vs. $74\%$ (10\% effect) |
Plot same CSC T-F efficiency for muons with $50 \text{ GeV} < p_T < 100 \text{ GeV}$ to pass “tight” (3-station) requirement.

Efficiency is 10% higher than TeV muons, same ME4 dependence. Most (7%) of difference is due to bad $p_T$ assignment of TeV muons, not missing segments.

- $1.6 < |\eta| < 2.1$: $\varepsilon = 72\%$ vs. $68\%$ (7% effect)
- $1.8 < |\eta| < 2.1$: $\varepsilon = 90\%$ vs. $82\%$ (10% effect)
Some ME4 conclusions

ME4/1 increases trigger efficiency in that region by 10%

For TeV muons, increase can be greater:

- TeV muon efficiency \textit{without} ME4/1 is 74%
- Lower p_{T} muon efficiency \textit{with} ME4/1 is 90% (20% increase)

Challenge for UF:

- Can we design a Track-Finder that makes use of \textit{four} stations in the p_{T} measurement, so as to identify and remove bad segments?

- Depends on increase in latency, memory size, board complexity, and cost

Challenge for CMS:

- Can we re-scope ME4/1?
Forward-backward asymmetry

\[ A_{FB} = \frac{F - B}{F + B} \]

\[ F = \int_{0}^{1} \frac{d^2\sigma}{dyd(cos\theta^*)} d(cos\theta^*) \]

\[ B = \int_{-1}^{0} \frac{d^2\sigma}{dyd(cos\theta^*)} d(cos\theta^*) \]

\( \theta^* \) is the angle in the di-muon C.M. between the \( \mu^- \) and the quark.

Defining requirements for DC04

2004 CMS Data Challenge (DC04) will consists of off-line processing and analysis of 50 Mevents ($\approx$ 1 month DAQ @ 25 Hz) passed by the L1+HLT chain (which represents filtering by a factor of $10^6$!)

Code must be finalized in next 6 months

Start to think how PRS could profit of such a challenge:

$\Rightarrow$ define possible tasks and datasets (type, size) needed, e.g.:
- calibration / alignment
- benchmark of a few Physics channels
  ( pass them through the full analysis chain, configure and prepare realistic background samples expected at the HLT output)

In the following just one first example.....
So far, in HLT studies, we were looking to “signal” and background rates of 0(10) Hz; Offline analyses will deal with signal rates of 0(10^{-5}) Hz and below (=> 100 events/year)

e.g. : HLT di-muon output stream:

( p_T^{\mu} > 7, 7 GeV/c)

(no off-line cuts:
 e.g. jet veto, \theta_{\mu\mu}^* cut,
 p_T^{\mu} > 20, 10 GeV/c)

H \rightarrow WW \rightarrow 2\mu 2\nu will be 10-10^2 times smaller
Muon
OSCAR validation

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PRS Muon Meeting
3rd December 2002
Geant3 vs. Geant4 Comparisons

Ionisation

\[ G4 \approx G3 \text{ up to 1 TeV (differences expected at higher energies)} \]

Bremsstrahlung

\[ \text{Small differences} \]
\[ \text{Angle of secondaries wrong in GEANT4} \]

Pair Production

\[ \text{Small differences} \]
\[ \text{Angle of secondaries wrong in GEANT4} \]

Multiple scattering

\[ \text{Remarkable differences, increasing with energy} \]
\[ \text{GEANT4 proved to be better than GEANT3 for LEP I 45 GeV muons} \]

Cuts dependency

\[ \text{Affect deviation (multiple scattering)} \]
\[ \text{Step length cannot be bigger than 1mm} \]
\[ \text{GEANT4 have bigger dependencies} \]
Muon Physics: brem gamma energy
Muon Physics: deviation in position

10 GeV

- GEANT3
- GEANT4

100 GeV

- GEANT3
- GEANT4

1000 GeV

- GEANT3
- GEANT4
Two volumes

- Volume I: detector response, physics objects, calibrations, parameterization
- Volume II: high-level analyses, e.g. Higgs, SUSY, extra dims, etc.

Part I: (small) number of full analyses
- Demonstrate how we can do physics

Part II: general physics topics (will be done with full simulation or detector parameterization)
- Demonstrate what physics we can do

Studies should be realistic: backgrounds, misalignments, etc.

Organization of work:

- Volume I maps precisely onto current PRS work/organization
  - Thus, leave responsibility with the current structure
- Volume II is the new, additional work
  - This is the part for which PRS as a project needs to evolve.

Timescale:

- Late 2005
Four new “analysis PRS groups”:

- Higgs (in SM and MSSM)
- SUSY + other Beyond SM (technicolor, extra dims, other exotica)
- Standard Model (Electroweak, Heavy flavors, QCD, diffraction, …)
- Heavy Ions

They are horizontal tasks, running across all existing “detector PRS groups”

- Each group lead by a coordinator, appointed by PRS PM

Sharing of responsibility:

- Detector PRS groups: Volume II (Part 1)
  - Analyses of H→4µ and Z’→2µ by Muon group
- Analysis PRS groups: Volume II (Part 2)
  - Chapter on SUSY Higgs in Higgs group
- Phenomenology group: attract theorists, deliver generators