Endcap Muon Trigger Simulation Studies

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New since Nov-98 Tridas review:
1. Inclusion of DT primitives for overlap region
2. Misalignment studies
Studies on the Simulation of Muons in the Muon End Cap Chambers of CMS

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Goal: Study reconstruction of Pt of muons in the End Cap chambers at the trigger level, to help in the design of the End Cap Track-Finder.

Simulation:

- use CMSIM 114
  - muon.tz has wrong strip staggering!
    It was corrected for this study.
  - this should be fixed in CMSIM 115.

- produced single muon events at various Pt, in $0.9 < \eta < 2.4$ range

- CMSIM produces ntupple which contains information on the simulation of the CSC trigger primitives ($\phi$, $\eta$, ... of the LCTs).

The information of the trigger primitives in the Barrel Muon chamber was obtained from the Zebra banks.
Simulation of Trigger Primitives (LCTs):

- old Fortran package.
- high Pt patterns only.
- the cathode strips and the anode wires that carry hits caused by the traversing muon, are used to reconstruct the trigger primitives (refer to CMS TN/96-69).
- study $\eta_{\text{rec}}$ as a function of $\eta_{\text{gen}}$ in each station (for different Pt)
- study $\Delta \phi$ as a function of $\eta_{\text{gen}}$ for different Pt.

$\Delta \phi : \Delta \phi_{12} = \phi_1 - \phi_2$
$\Delta \phi_{13} = \phi_1 - \phi_3$
$\Delta \phi_{23} = \phi_2 - \phi_3$
$\eta_{\text{rec}} - \eta_{\text{gen}}$ vs $\eta_{\text{gen}}$ (Pt = 3 GeV)

- Large shift in $\eta_{\text{rec}}$ at low $\eta_{\text{gen}}$
- the “saw-tooth” effect in ME1 is due to the tilt in the anode wires in ME1/1
$\Delta \phi$ vs $\eta_{\text{gen}}$ at different Pt

Extrapolation

<table>
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<tr>
<th>ME1-ME2</th>
<th>ME1-ME3</th>
<th>ME2-ME3 (GeV)</th>
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- the “error” bars are the RMS of the spread.
- $\Delta \phi_{\text{Max}} \sim 9^\circ \; 5^\circ + 2\sigma \; , \; \sigma \sim 2^\circ$.
  $\Delta \phi < 15^\circ \Rightarrow$ drop 2 MSB from 60$^\circ$ range in Track-Finder.
- the jump in $\Delta \phi$ at $\eta_{\text{gen}} \sim 1.6$ for ME1-ME2 and ME1-ME3 is due to ME1/1 being closer to IP compare to ME1/2 and ME1/3.
Reconstruction of Pt

- Pt is obtained from the measured $\Delta \phi$ in two muon stations
- parameterize the $\Delta \phi$ to Pt relation at different fixed $\eta$ ranges

\[
\begin{align*}
1.80 < \eta < 1.95 & : \\
1.95 < \eta < 2.10 & : \\
2.10 < \eta < 2.25 & : \\
2.25 < \eta < 2.40 & : 
\end{align*}
\]

- fit the $\Delta \phi$ as a function of Pt with the relation: $\Delta \phi = a \cdot Pt^{-1}$
- the reconstructed Pt from measurement of $\Delta \phi$ will be:
  \[
  \frac{1}{Pt_{rec}} = \frac{\Delta \phi_{meas}}{a}
  \]

(Note: The inverse relation $\Delta \phi = a \cdot Pt^{-1}$ is not an accurate description of the $\Delta \phi$ to Pt relation due to bending of the magnetic field.)
\[
\frac{1}{P_{t_{\text{rec}}}} - \frac{1}{P_{t_{\text{gen}}}} \quad \text{Distributions}
\]

\begin{align*}
\eta & \quad \text{Pt} \\
1.25-1.30 & \quad 1.70-1.75 & \quad 2.35-2.40 \quad (\text{GeV}) \\
10 & \quad 50 & \quad 100
\end{align*}

- Distributions are Gaussian. No significant tails.
- slight offset from zero may be due to the inaccurate direct inverse relation used in the parameterization
Resolution of Pt as function of $\eta$

- $Pt_{rec}$ obtained from $\Delta \phi$ measured between MB1-ME1 ($0.9 < \eta < 1.2$), and ME1-ME2 ($1.2 < \eta < 2.4$).
• studies of the resolution of Pt by R. Breedon for the case Half-strip Resolution, 1-point staggering. (EMU Meeting, UF Gainesville, 20-21 March 1998)

• Kalman Fit to all 4 stations with estimated LCT resolution.
Without using Barrel Muon Chamber in Over-Lap region

- resolution is poor in the overlap region if only the End Cap Muon Chambers are used.
Effect from the size of the $\eta$ bin on the resolution of $Pt$
(How many bits necessary for $\eta$ ?)

2 cases: parameterize the $\Delta\phi$ vs $Pt$ in

- 8 bins of $\eta$ ($0.9 < \eta < 2.4$) $\Rightarrow$ 3 bits
- 30 bins of $\eta$ ($0.9 < \eta < 2.4$) $\Rightarrow$ 5 bits

- “Saw tooth” effect when a single $\Delta\phi$-$Pt$ parameterization for a large $\eta$ bin is used to reconstruct $Pt$ in finer $\eta$ bins
resolution of Pt is similar in both cases
Pt resolution for $\Delta \phi$ obtained from different sets of Muon Stations

$\Delta \phi$ from:
- ME1 → ME2
- ME1 → ME3
- ME2 → ME3

For Pt=10 GeV, resolution of Pt for ME1-ME3 is slightly worse than ME1-ME2, even though $\Delta \phi_{13}$ is generally larger than $\Delta \phi_{12}$. (due to multiple scattering ... more material to traverse)

For Pt=50 GeV, resolution of Pt is similar for ME1-ME2 and ME1-ME3.
Using bending angle $\Psi$ to improve Pt resolution

- $\Psi$ is the angle between the direction of muon and the normal of the station.
- $\Psi$ can be obtained from the width of the road pattern of the track in the station.

\[\begin{align*}
\Psi &= 5 \\
\Psi &= 4 \\
\Psi &= 3 \\
\Psi &= 2 \\
\Psi &= 1 
\end{align*}\]

**Definition of $\Psi$**

Road pattern of track in the station

*(Plot taken from CMS TN/96-69)*
$\Psi$ vs Pt at different $\eta$

- $\Psi$ is large for low Pt tracks ($Pt \lesssim 5$ GeV) in ME1
- road pattern is almost straight for high Pt tracks and tracks in ME2, ME3
\[ \Phi \downarrow \text{with} \downarrow < \phi \nabla > \bullet \]

\[ \Phi \uparrow \text{with} \downarrow < \phi \nabla > \bullet \]
no improvement in Pt resolution for Pt=50 GeV
marginal improvement in Pt resolution for Pt=100 GeV
Misalignment of the End Cap Chambers

- $\Delta \phi$ from: ME1 $\rightarrow$ ME2
- rotate ME2 by $\pm 0.5$ mrad

- small offset in $\frac{1}{Pt_{rec}}$ at low $Pt_{gen}$, but large offset at high $Pt_{gen}$.
- small effect on the resolution of Pt.
Misalignment Effect

- This simple simulation shows that a 1mm offset of one chamber induces a trigger bias at high Pt
  - This is roughly the expected tolerance on CSC chamber positioning

- Endcap iron disks are expected to be aligned only to 3mm
  - This will have dominant effect on trigger bias

- CSC Track-Finder absolutely must include alignment corrections
  - Natural place is the Sector Receiver, but precision is only needed for $P_T$ assignment
Summary for the End Cap Muon Detector

Preliminary studies show that:

- A coarse resolution of $\eta$ is sufficient for the Track Finder.  
  May ignore tilt of wires in ME1/1.

- The larger bending angle between ME1-ME3 (compared to ME1-ME2) does not help to improve the Pt resolution due to multiple scattering.

- Additional information from $\Psi$ does not contribute much to the improvement of the Pt resolution.

- $\frac{\sigma_{\text{Pt}}}{\text{Pt}} \sim 30\%$

Further studies

- More studies on the misalignment of the End Cap Muon chambers, and its effect on trigger rates and efficiency.

- Study of trigger rates.
All $\mu$

$\mu$ in End Cap

$\mu$ from $\pi K$ decays

$\mu$ from non-$\pi K$ decays