EMU Trigger Simulations

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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
  - mf.tz has wrong strip staggering!
    It was corrected for this study
  - For CMSIM 115,
    * staggering was not fixed
    * ME4 is not in the geometry file
    * MB chambers have similar efficiency as in CMSIM 114

- Produced single muon events at various Pt, in $0.9 < \eta < 2.4$ range with no backgrounds

- Cathode strips and anode wires that carry hits caused by traversing muon are used to reconstruct the trigger primitives (high Pt patterns only) (refer to CMS TN/96-69)
Study the dependence of $\Delta \phi$ on $\eta$ and Pt

$\Delta \phi$:
- $\Delta \phi_{12} = \phi_1 - \phi_2$
- $\Delta \phi_{13} = \phi_1 - \phi_3$
- $\Delta \phi_{23} = \phi_2 - \phi_3$
**Δφ vs. η_{gen} at different Pt**

<table>
<thead>
<tr>
<th>Extrapolation</th>
<th>Pt</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME1-ME2</td>
<td>3</td>
</tr>
<tr>
<td>ME1-ME3</td>
<td>10</td>
</tr>
<tr>
<td>ME2-ME3</td>
<td>100</td>
</tr>
</tbody>
</table>

- "Error" bars are the RMS of the spread
- \( Δφ_{\text{Max}} \approx 9° \ 5° + 2\sigma \), \( σ \approx 2° \).
  \( Δφ < 15° \Rightarrow \) drop 2 MSB from 60° range in Track-Finder
- Jump in Δφ at \( η_{\text{gen}} \sim 1.6 \) for ME1-ME2 and ME1-ME3 is due to ME1/1 and ME1/A being closer to IP compare to ME1/2 and ME1/3
Parameterize $\Delta \phi$ vs. Pt and $\eta$

- Fit to $\Delta \phi = A(\eta)/\text{Pt}$
- Invert relation to obtain Pt
\[ \frac{1}{P_{\text{rec}}} - \frac{1}{P_{\text{gen}}} \]

Distributions

\( \eta \)

\( \text{Pt} \)

\( 1.25-1.30 \)

\( 1.70-1.75 \)

\( 2.35-2.40 \) (GeV)

- \( \frac{1}{P_{\text{rec}}} - \frac{1}{P_{\text{gen}}} \) for single muon events, with no background
- Distributions are Gaussian. No significant tails
Resolution of $1/Pt$ as function of $\eta$

- $Pt_{rec}$ obtained from $\Delta\phi$ measured between MB1-ME1 ($0.9 < \eta < 1.2$), and ME1-ME2 ($1.2 < \eta < 2.4$).
- Resolution $\sim 30\%$ at low $Pt$
- Resolution in $2.2 < \eta < 2.4$ may be poorer since in CMSIM 114 there are 65 cathode strips in ME1/A instead of 48
- Expected to be improved as Track-Founder design evolves
1/Pt Resolution with and without Measurements in MB1 or ME1

- 1/Pt resolution $\sim 70\%$ without MB1 in overlap region, or without ME1 in endcap
- Cannot satisfy single muon rate requirement without ME1 in the End Cap region, or without MB1 in the overlap region
Study of Single Muon Rate in CSC

Estimated Muon Flux

- Estimate muon flux at $L = 10^{34}$ from QCD events
  - Parameterization based on Pythia (CMS Note 1997/096)
  - Includes $\pi/K$ which decay before calorimeter
- Fold in probability to punch through calorimeter in endcap region (determined from CMSIM)
- Assume 100% chamber efficiency
Trigger Efficiency Curves

- Assume Gaussian errors for $1/Pt$ resolution
- Convolute muon flux with trigger efficiency curve to determine trigger rate
Single Muon Trigger Rates in CSC

- Single $\mu$ rate from Pythia, convoluted with efficiency curve
- Threshold set for 90% efficiency
- Require rates $< 1$ kHz per unit rapidity
- Not satisfied for Pt resolution worse than 30%

$L = 10^{34} \text{cm}^2\text{s}^{-1}$
Parameterize Resolution as Function of $\eta$

- For $Pt = 10$ GeV (end cap region only)

\[ \sigma(\frac{1}{Pt_{rec}} - \frac{1}{Pt_{gen}}) = (\frac{1}{Pt_{gen}}) \]

\[ \sigma = p1(\eta + p2)^2 + p3 \]

Chi$^2$/ndf = 2.60796

$p1 = 0.384386 \pm 0.024932$

$p2 = -1.70685 \pm 0.0113638$

$p3 = 0.239374 \pm 0.00321547$
\[ \Delta \phi_{23} \text{ vs. } \Delta \phi_{12} \]

- Using the relation between $\Delta \phi_{23}$ and $\Delta \phi_{12}$ to improve resolution at low Pt
Effect of Misalignment of CSC on Track-Finder

- Estimate overall accuracy of station placement \( \approx 3 \text{ mm} \) (from Dick Loveless)
- \( \Rightarrow \) relative misalignment between 2 stations \( \lesssim 6 \text{ mm} \)
- Simulate effect by misaligning ME1 by \( \Delta x = +3, +8 \text{ mm} \)

\[
\frac{\sin(|\delta\phi|)}{\Delta x} = \frac{\sin(\phi - |\delta\phi|)}{R}
\]

\[
|\delta\phi| \approx \frac{\Delta x}{R} \sin(\phi)
\]

- Different values of \( \delta\phi_1 \) at different locations in ME1
- \( \phi_1 \rightarrow \phi_1' = \phi_1 + \delta\phi_1 \)
\[ \delta \phi_1 \text{ vs. } \phi_1 \text{ for } \Delta x = +8 \text{ mm in ME1} \]

- \( | \delta \phi_1 | \) is larger for the trigger primitives located in the chambers closer to the beam pipe
- \( \delta \phi_1 \) has opposite signs for trigger primitives in opposite halves of the station
Effect on the Reconstruction of $1/P_t$

- $1/P_t$ obtained from $\Delta \phi$ measured between MB1-ME1 ($0.9 < \eta < 1.2$), and ME1-ME2 ($1.2 < \eta < 2.4$)
- Difference in $1/P_t = \frac{1/P_{t\text{misaligned}} - 1/P_{t\text{aligned}}}{1/P_{t\text{aligned}}}$

**MB1-ME1-ME2  +8mm ME1  Pt=50 GeV**

- 0.9 eta 1
- 1 eta 1.1
- 1.1 eta 1.2
- 1.2 eta 1.3
- 1.3 eta 1.4
- 1.4 eta 1.5
- 1.5 eta 1.6
- 1.6 eta 1.7
- 1.7 eta 1.8
For +3 mm:

- $| \text{Difference in } 1/Pt | \lesssim 20\%$ (for $Pt = 10$ GeV)
  $\lesssim 100\%$ (for $Pt = 50$ GeV)

For +8 mm:

- $| \text{Difference in } 1/Pt | \lesssim 50\%$ (for $Pt = 10$ GeV)
  $\lesssim 200\%$ (for $Pt = 50$ GeV)
Correction on $\phi$ due to Misalignment

- Perform an average correction in each detector (e.g. ME1/A, ME1/1, ME1/2, ME1/3)
- Perform corrections in 15 bins of $\eta$ ($0.9 < \eta < 2.4$)

![Graph showing corrections in 15 bins of $\eta$ for different detectors.](image-url)
**MB1-ME1-ME2 +8mm ME1 Pt=50 GeV Ave Corr/det**

- **Average correction per detector**
  - For +3 mm | \(| \text{Diff in 1/Pt} | \lesssim 2\% \) (for Pt = 10 GeV resolution \( \sim 30\% \))
    - \( \lesssim 10\% \) (for Pt = 50 GeV resolution \( \sim 30-40\% \))
  - For +8 mm | \(| \text{Diff in 1/Pt} | \lesssim 5\% \) (for Pt = 10 GeV)
    - \( \lesssim 20\% \) (for Pt = 50 GeV)

- **Corrections in 15 bins of \( \eta \) (for +8 mm)**
  - | \(| \text{Diff in 1/Pt} | \lesssim 10\% \) (for Pt = 50 GeV)
**Summary**

Preliminary studies show that:

- $1/P_t$ resolution $\sim 30\%$ for low $P_t$
- Single muon trigger rate will be too high if resolution worse than $30\%$, or without station ME1, and MB1 (for overlap)
- Corrections of $\phi$ of the LCTs in small number of $\eta$ bins is sufficient to reduce the effect on the reconstruction of $1/P_t$ due to misalignment (for MB1-ME1-ME2)

**Further studies**

- Improve on the $1/P_t$ resolution for low $P_t$ muons using the relation between $\Delta\phi_{12}$ and $\Delta\phi_{23}$
- Further studies on the station misalignments for ME2-ME3 (... expect greater effect due to smaller $\Delta\phi_{23}$), and its effect on trigger rates and efficiencies
- Write Track-Finder simulation program to test the Track Finding algorithm, its efficiency and rejection power on background
- Use more realistic LCT simulation (from UCLA) in CSC and DT (e.g. CMSIM 116)