Studies on the Simulation of Muons in the Muon End Cap Chambers of CMS

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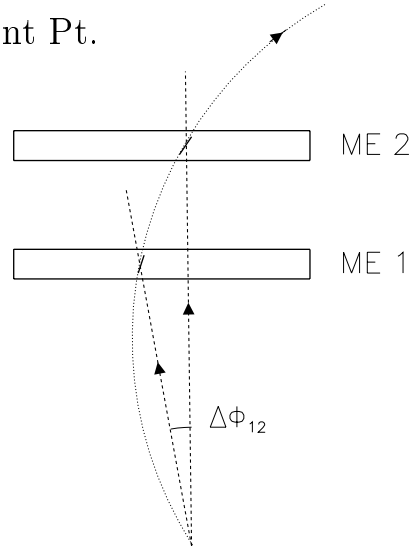
Goal: Study reconstruction of Pt of muons in the End Cap chambers at the online level, to help in the design of the End Cap muon trigger.

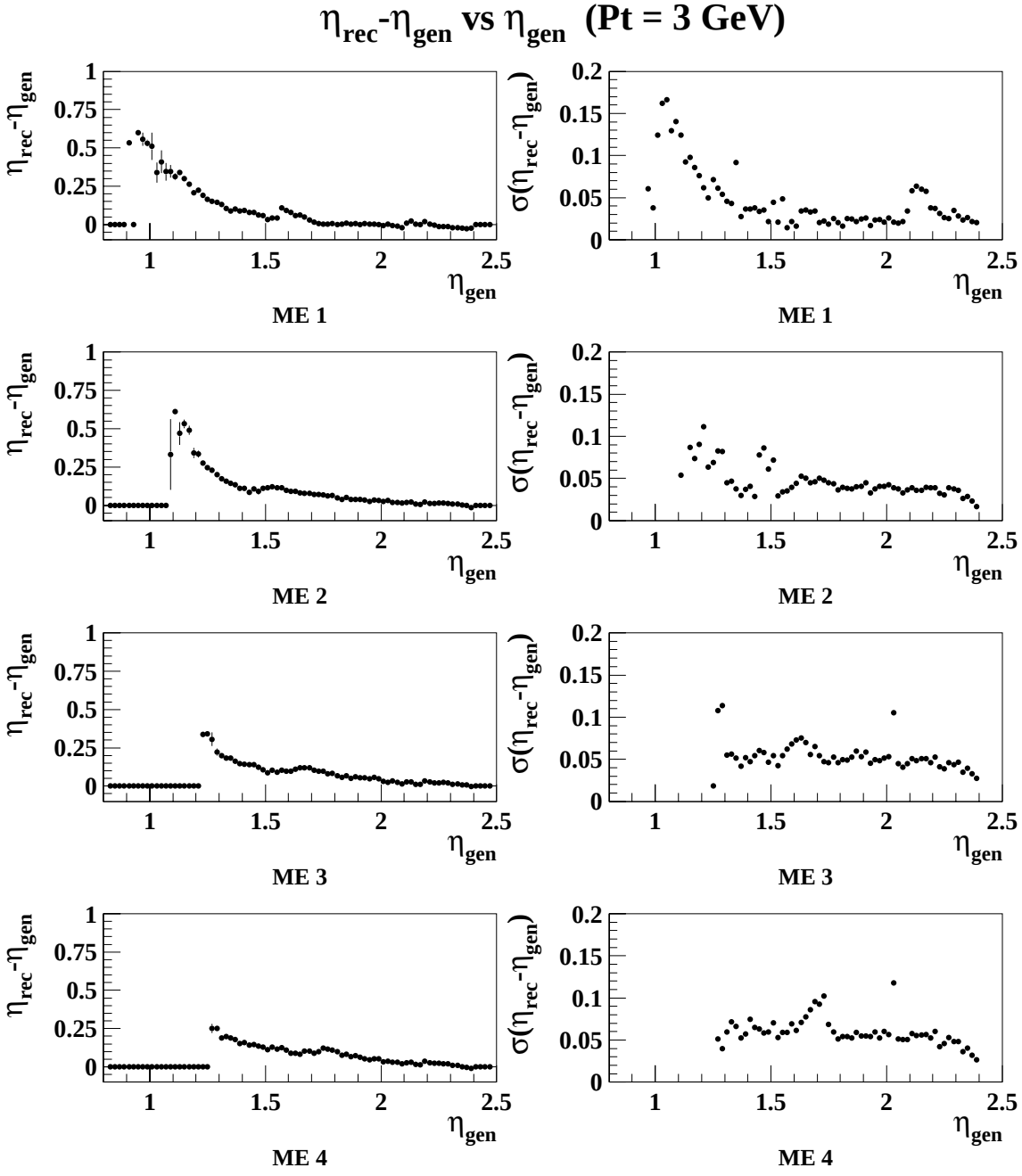
Simulation:

- use CMSIM 114
- produced single muon events at various Pt, in $0.9 < \eta < 2.4$ range
- CMSIM produces ntuple which contains informations on the simulation of the CSC trigger primitives (ϕ, η, ... of the LCTs).

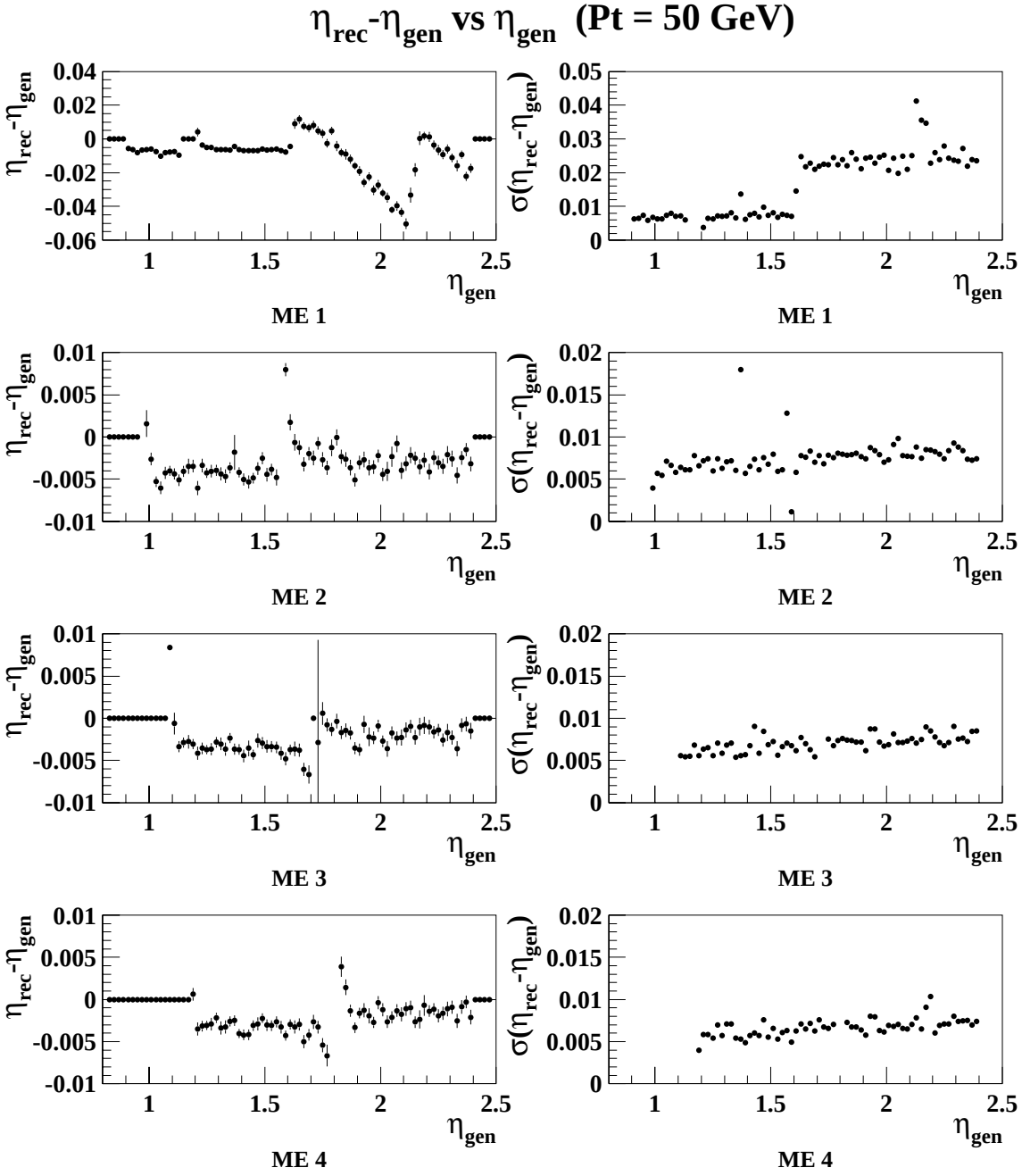
Simulation of Trigger Primitives (LCTs):

- 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 $\eta_{\rm rec}$ as a function of $\eta_{\rm gen}$ in each station (for different Pt)
- study $\Delta\phi$ as a function of $\eta_{\rm gen}$ for different Pt.
  $\Delta\phi$: $\Delta\phi_{12} = \phi_1 - \phi_2$
  $\Delta\phi_{13} = \phi_1 - \phi_3$
  $\Delta\phi_{23} = \phi_2 - \phi_3$



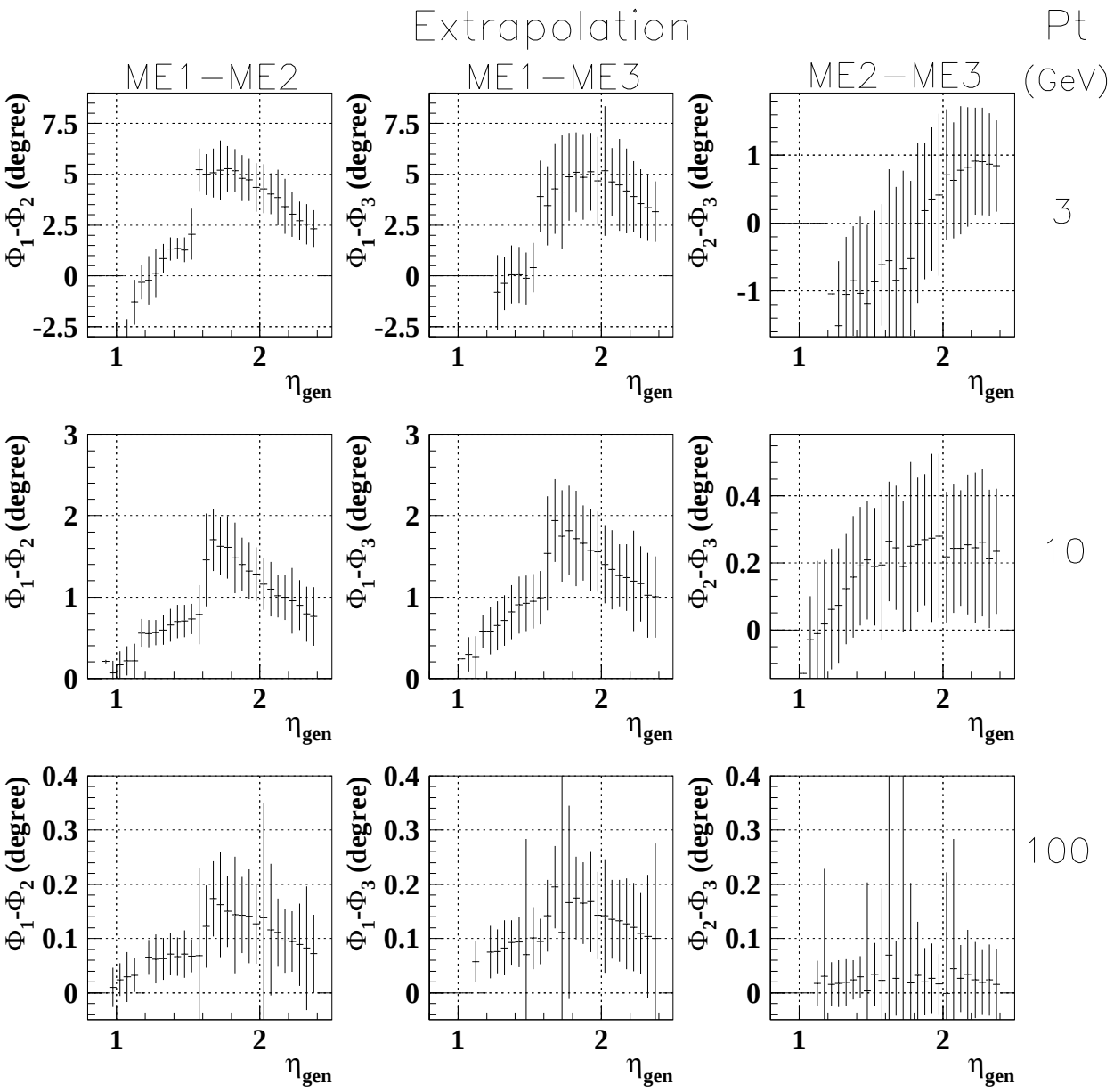


- large shift in η_{rec} at low η_{gen}



- the "saw-tooth" effect in ME1 is probably due to the tilt in the anode wires in ME1/1

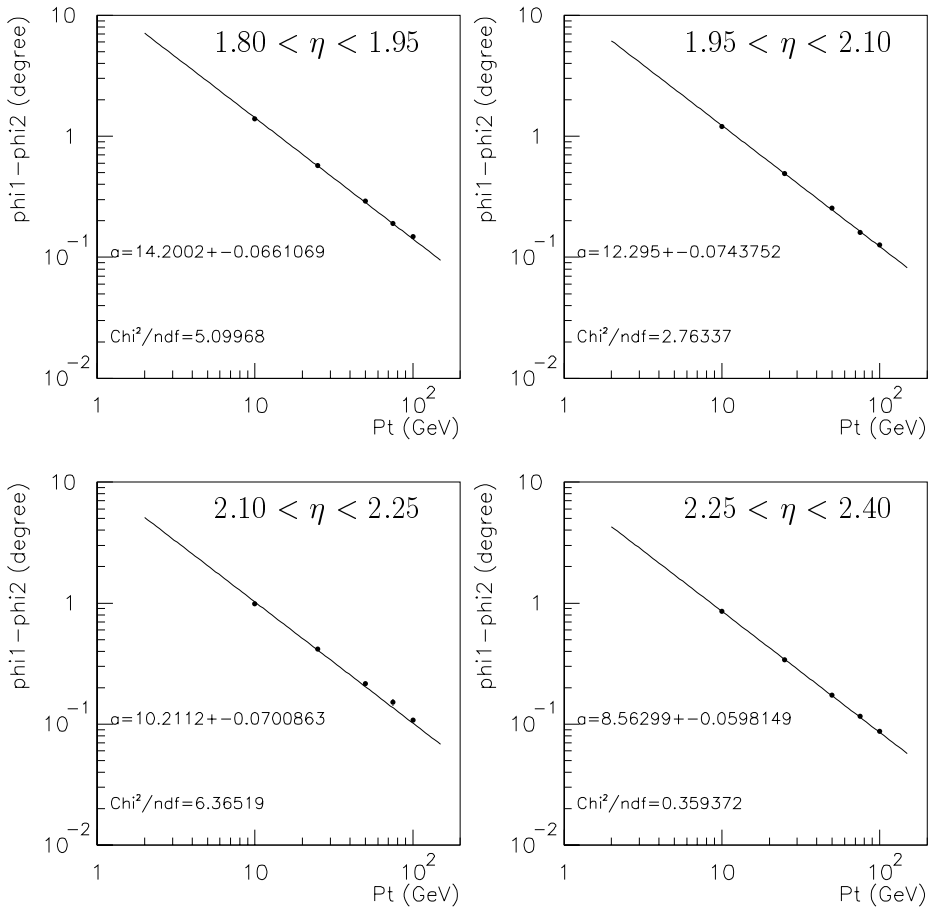
$\Delta\phi$ vs $\eta_{\rm gen}$ at different Pt



- the "error" bars are the RMS of the spread.
- $\Delta\phi_{\rm Max} \lesssim 9°$.
- the jump in $\Delta\phi$ at $\eta_{\rm gen} \sim 1.6$ 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

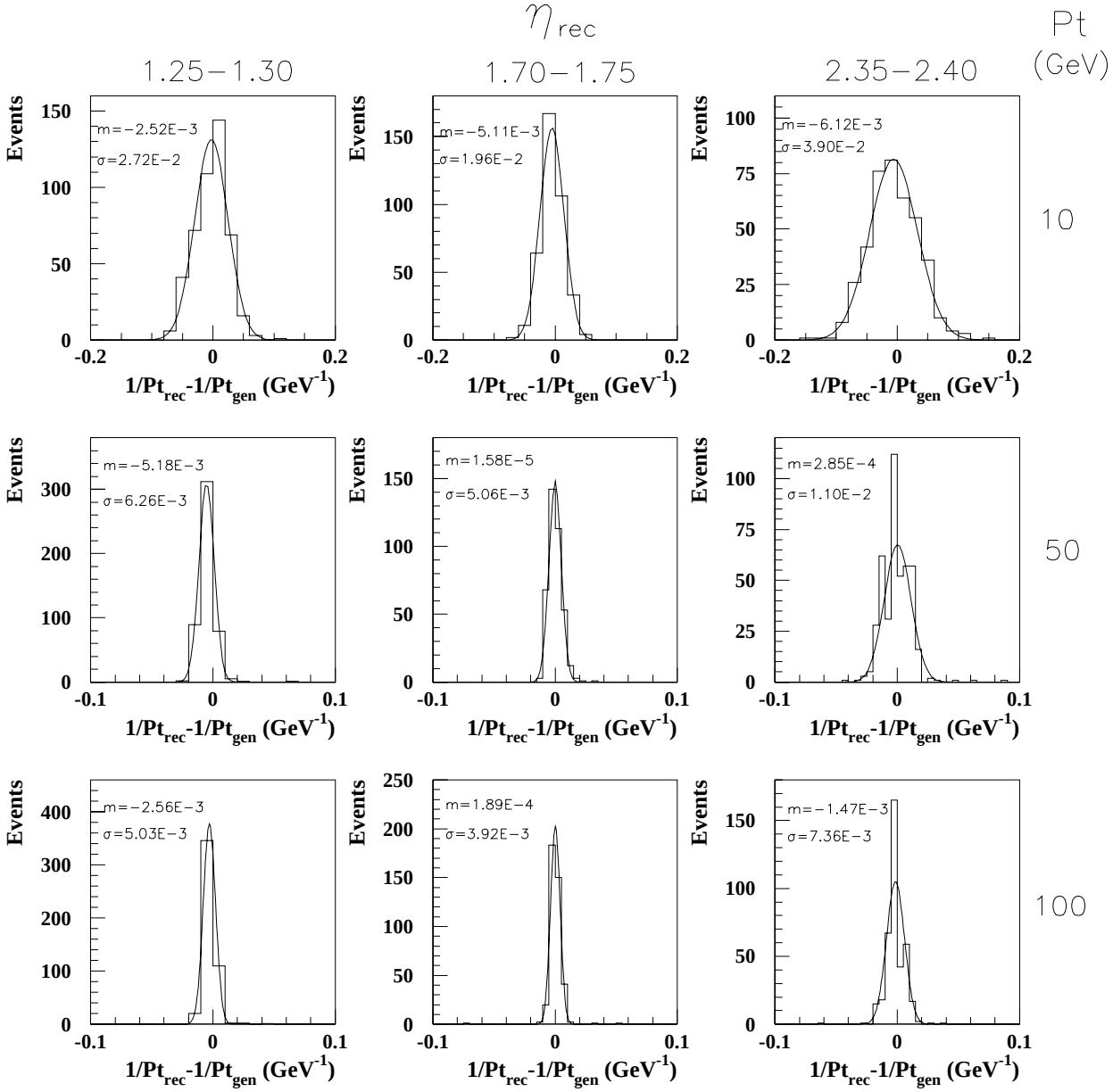
- Pt is obtained from the measured $\Delta\phi$ in two muon stations
- parameterize the $\Delta\phi$ to Pt relation at different fixed η ranges



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

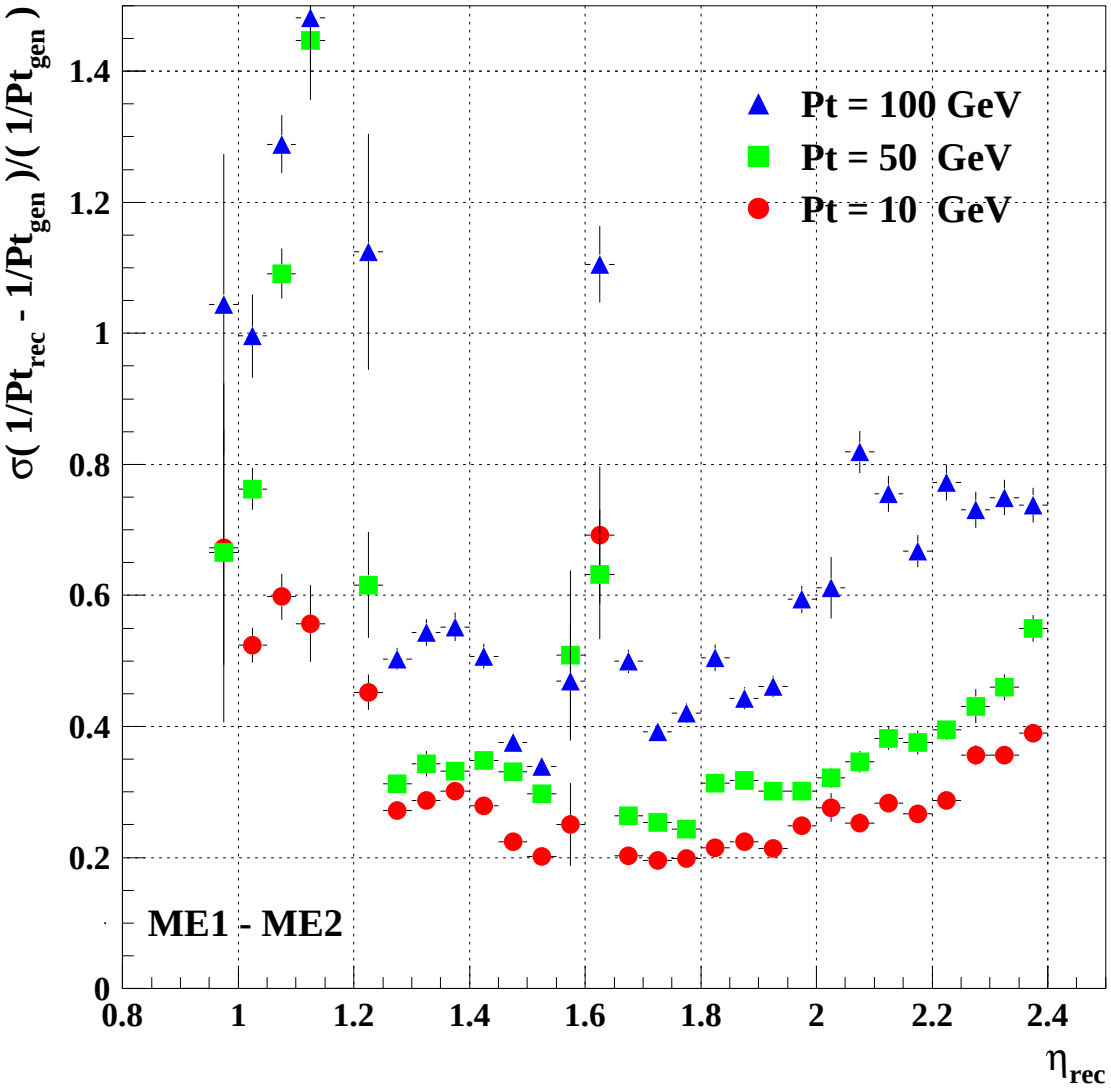
(Note: The inverse relation $\Delta\phi = a \cdot \mathrm{Pt}^{-1}$ is not an accurate description of the $\Delta\phi$ to Pt relation due to bending of the magnetic field.)

$\frac{1}{\mathrm{Pt_{rec}}} - \frac{1}{\mathrm{Pt_{gen}}}$ Distributions



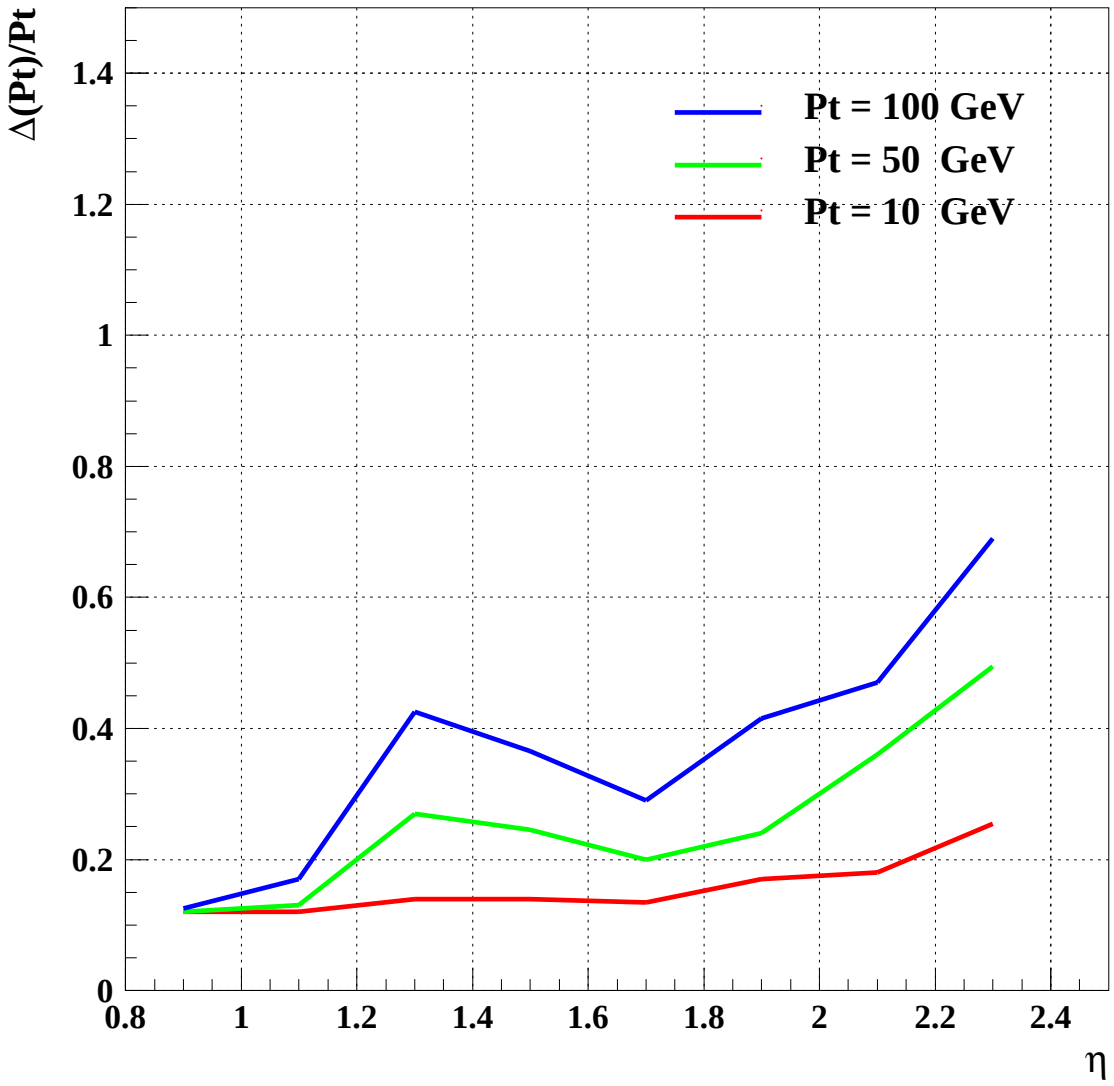
- distributions are quite symmetric
- slight offset from zero may be due to the inaccurate direct inverse relation used in the parameterization

Resolution of Pt as function of η



- Pt_{rec} obtained from $\Delta\phi$ measured between ME1 and ME2
- resolution is minimum at $\eta \sim 1.6 - 1.8$
- resolution degrades with increase in Pt
- resolution from this simulation study has the same shape as that obtained by Richard Breedon (for $\eta \gtrsim 1.2$), however the results from this study are $\sim 5\% - 10\%$ higher (probably due to multiple scattering when traversing through the detector)
  (Refer to Breedon's talk at EMU meeting, UF Gainesville, 20-21 March 1998)

Resolution of Pt as function of η

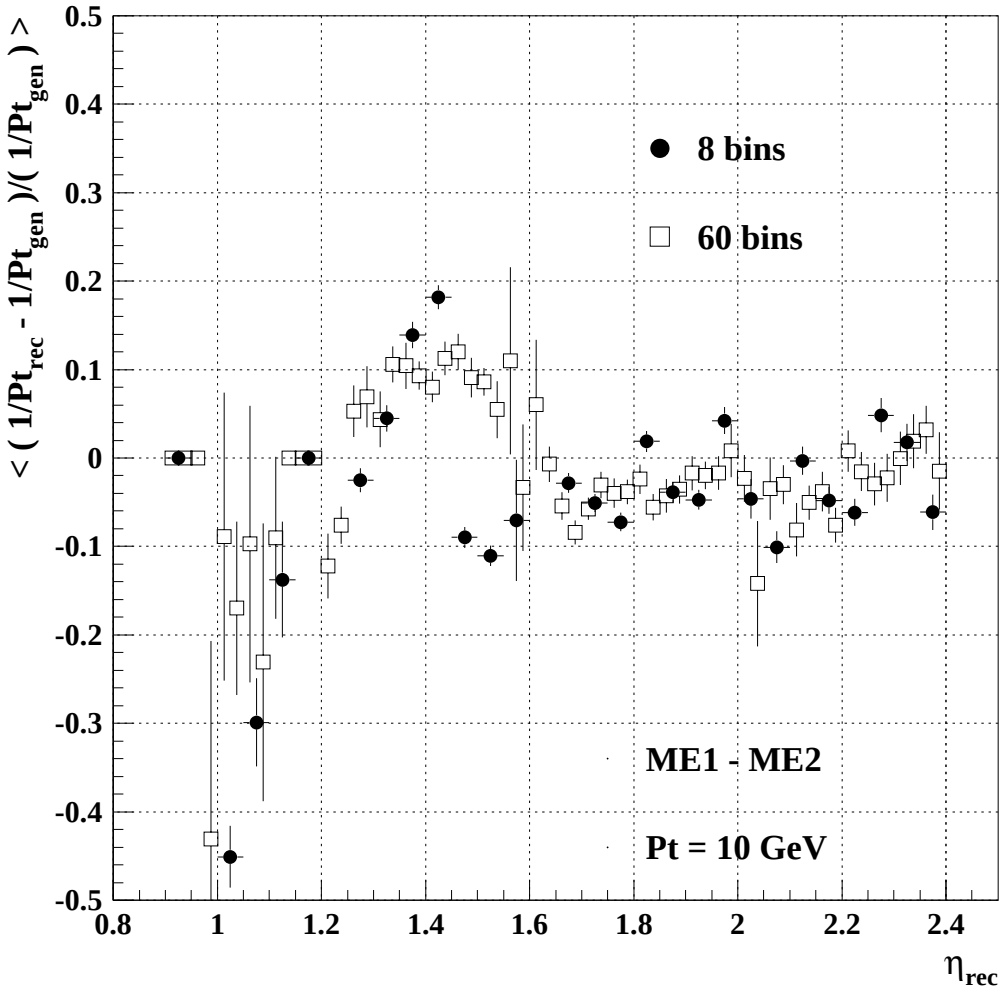


- studies of the resolution of Pt by R. Breedon for the case Half-strip Resolution, 1-point staggering.
  (EMU Meeting, UF Gainesville, 20-21 March 1998)

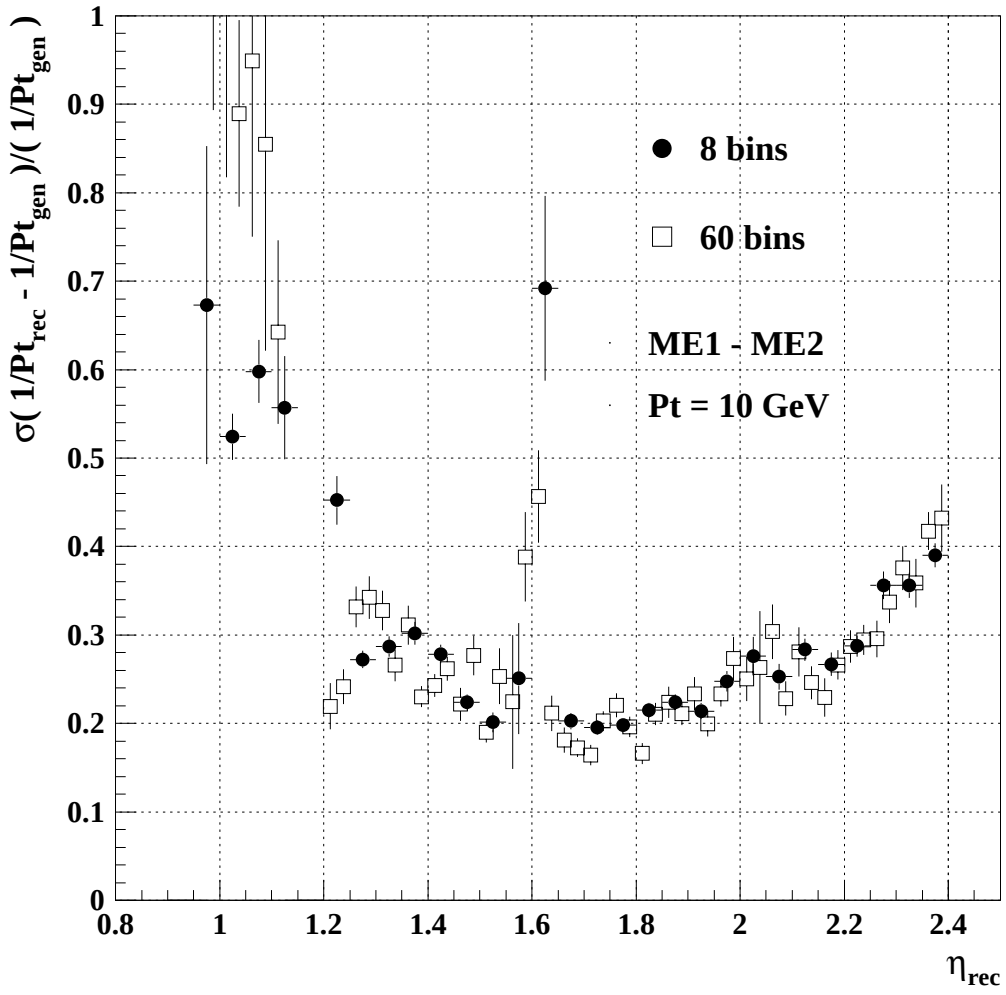
Effect from the size of the η bin on the resolution of Pt

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

- 8 bins of η $(0.9 < \eta < 2.4)$
- 60 bins of η $(0.9 < \eta < 2.4)$



- "Saw tooth" effect when a single $\Delta\phi$-Pt parameterization for a large η bin is used to reconstruct Pt in finner η bins

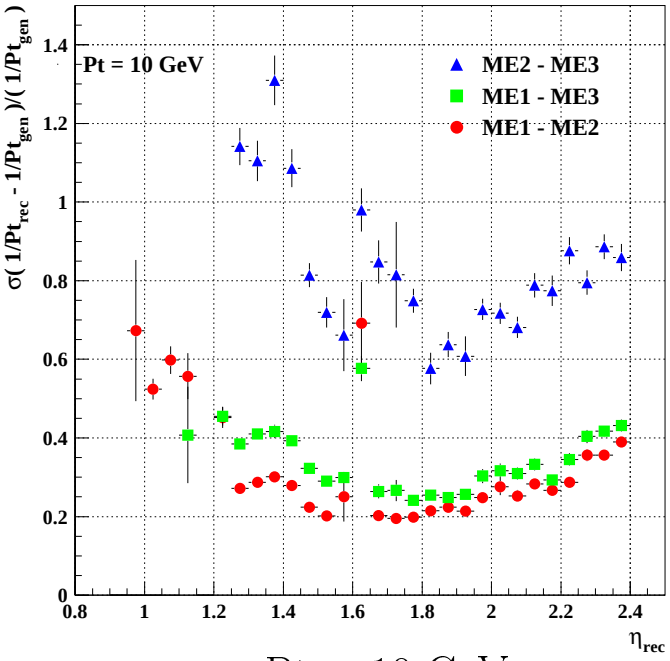


- resolution of Pt is similar in both cases

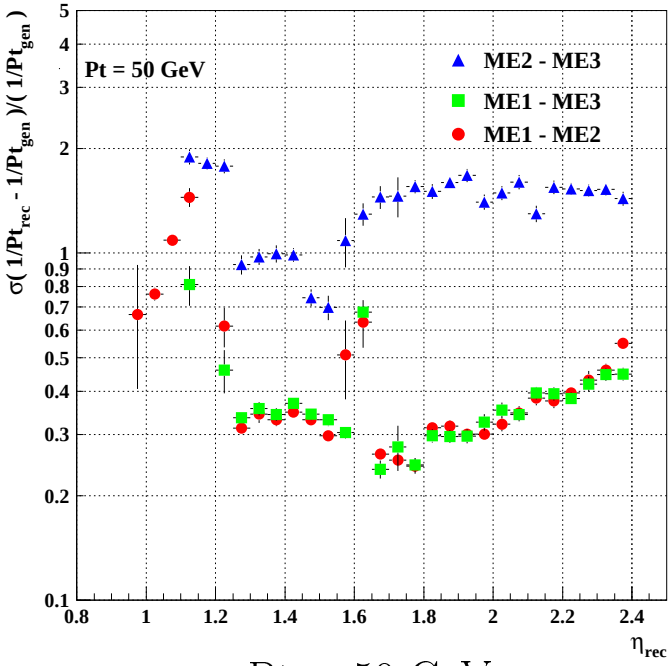
Pt resolution for $\Delta\phi$ obtained from different sets of Muon Stations

$\Delta\phi$ from :

- ME1 $\rightarrow$ ME2
- ME1 $\rightarrow$ ME3
- ME2 $\rightarrow$ ME3



Pt = 10 GeV

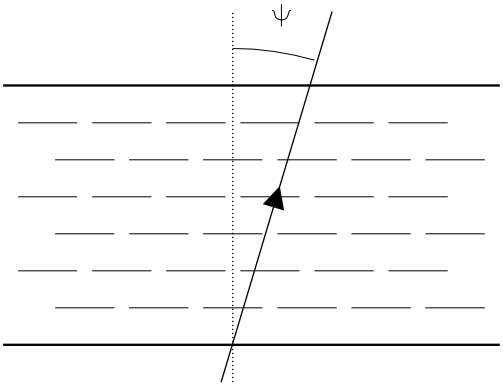


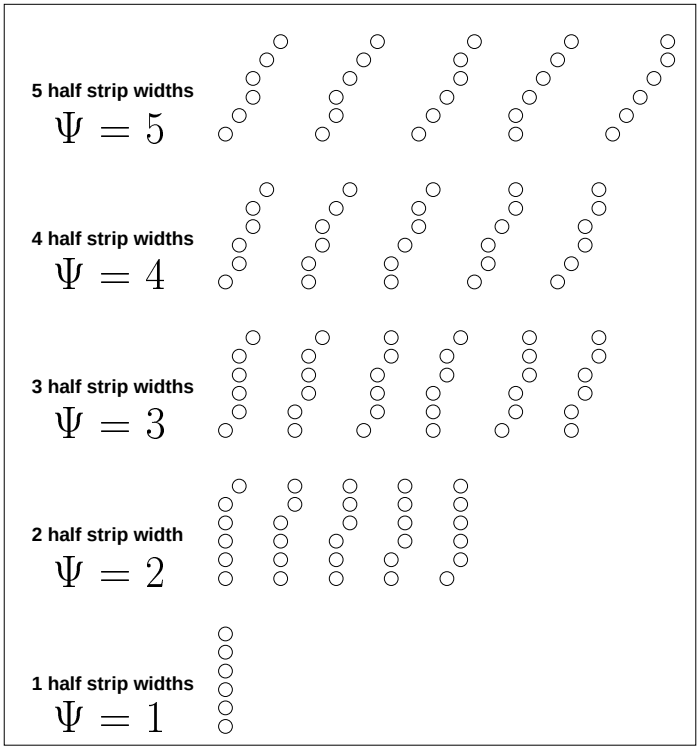
Pt = 50 GeV

- 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 $\Delta\phi_{12}$. (probably 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 Ψ to improve Pt resolution

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

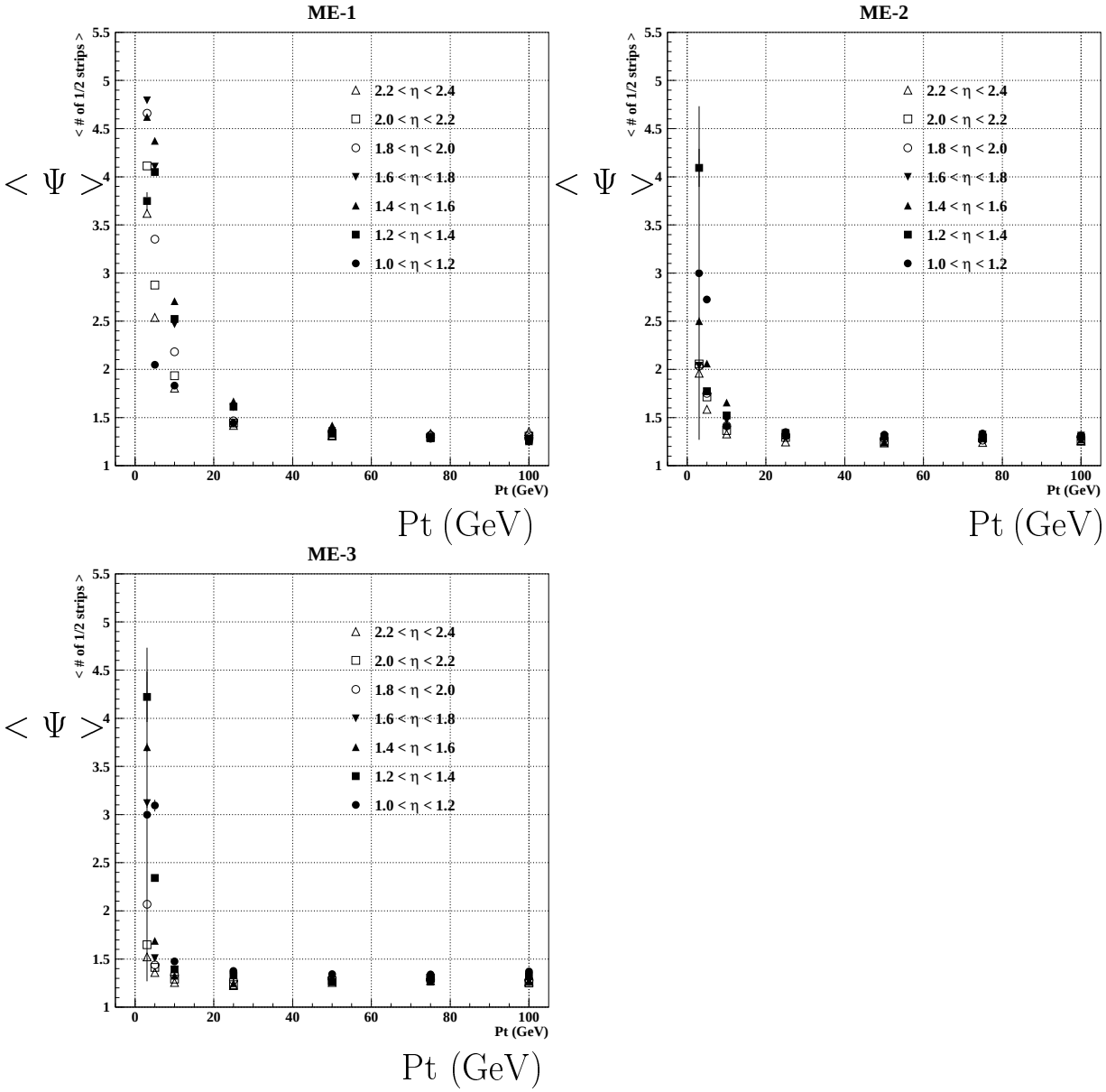




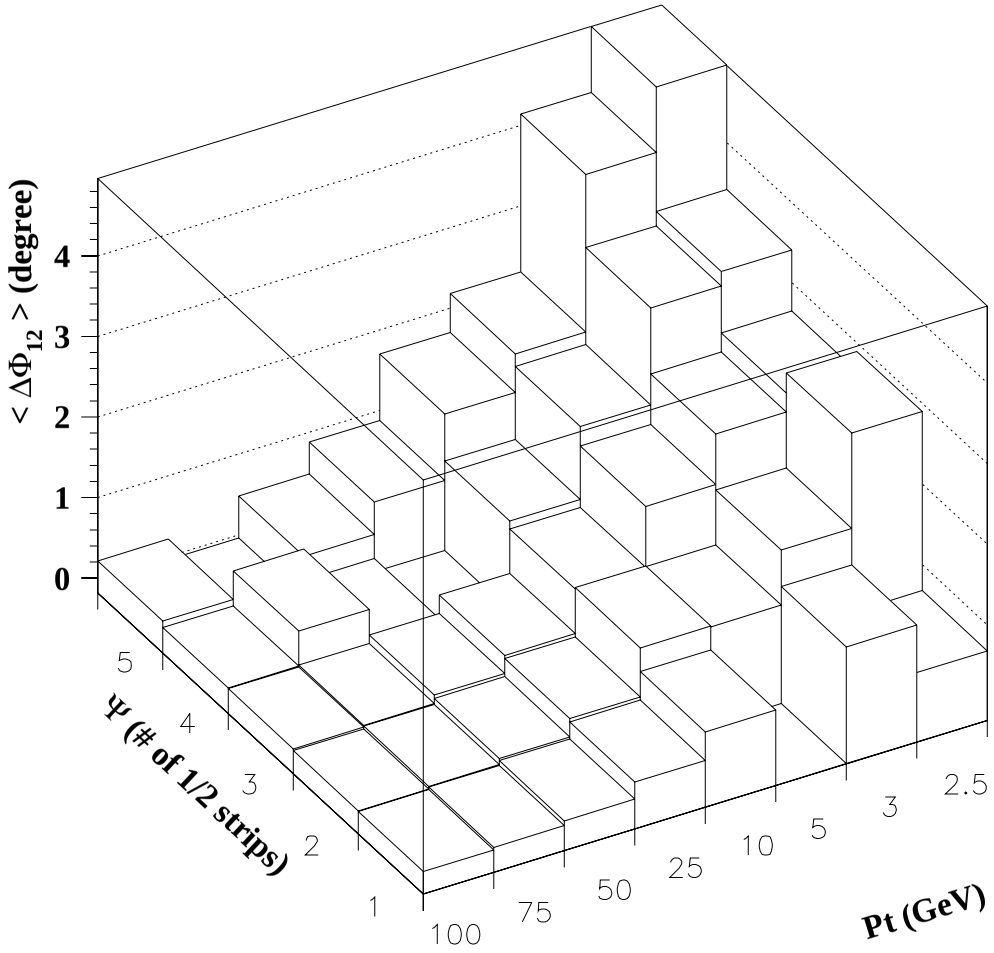
Road pattern of track in the station

(Plot taken from CMS TN/96-69)

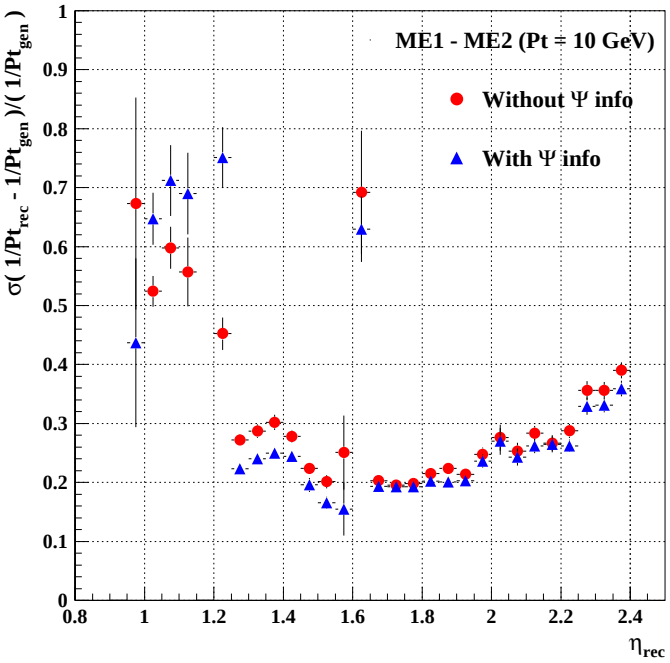
Ψ vs Pt at different η



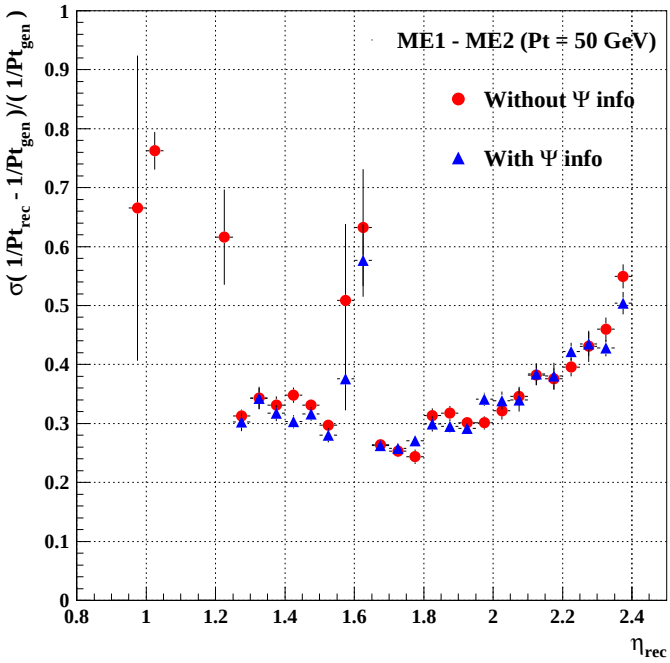
- Ψ is large for low Pt tracks (Pt$\lesssim$5 GeV) in ME1
- road pattern is almost straight for high Pt tracks and tracks in ME2, ME3



- $< \Delta\phi > \uparrow$ with $\downarrow$ Pt
- $< \Delta\phi > \uparrow$ with $\uparrow \Psi$
- parameterize $\Delta\phi$ as function of Pt for each value of Ψ



Pt=10 GeV



Pt=50 GeV

- marginal improvement in Pt resolution for Pt=10 GeV
- no improvement in Pt resolution for Pt=50 GeV

Summary for the End Cap Muon Detector

Preliminary studies show that :

- The selection of wider η bins in the parameterization of $\Delta\phi$-vs-Pt does not have much effect on the Pt resolution. Thus a coarse resolution of η is sufficient for the Track Finder.
- 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 Ψ does not contribute much to the improvement of the Pt resolution.