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 ntuple which contains information on the simulation of the CSC trigger primitives (ϕ, η, ... of the LCTs).
  The information of the trigger primitives in the Barrel Muon chamber was obtained from the Zebra banks.

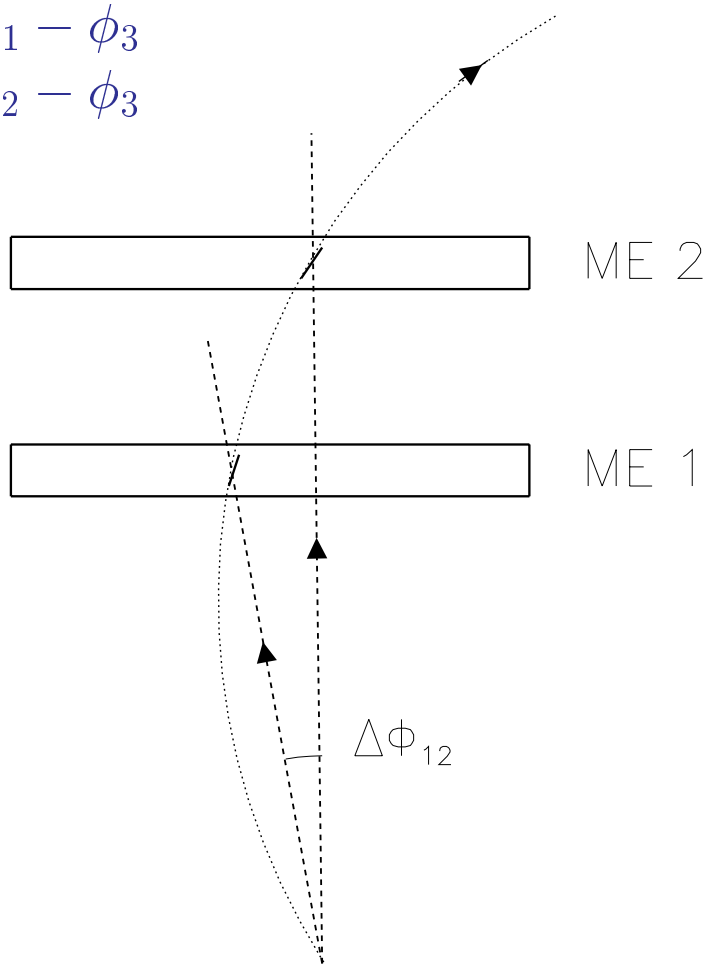
Simulation of Trigger Primitives (LCTs):

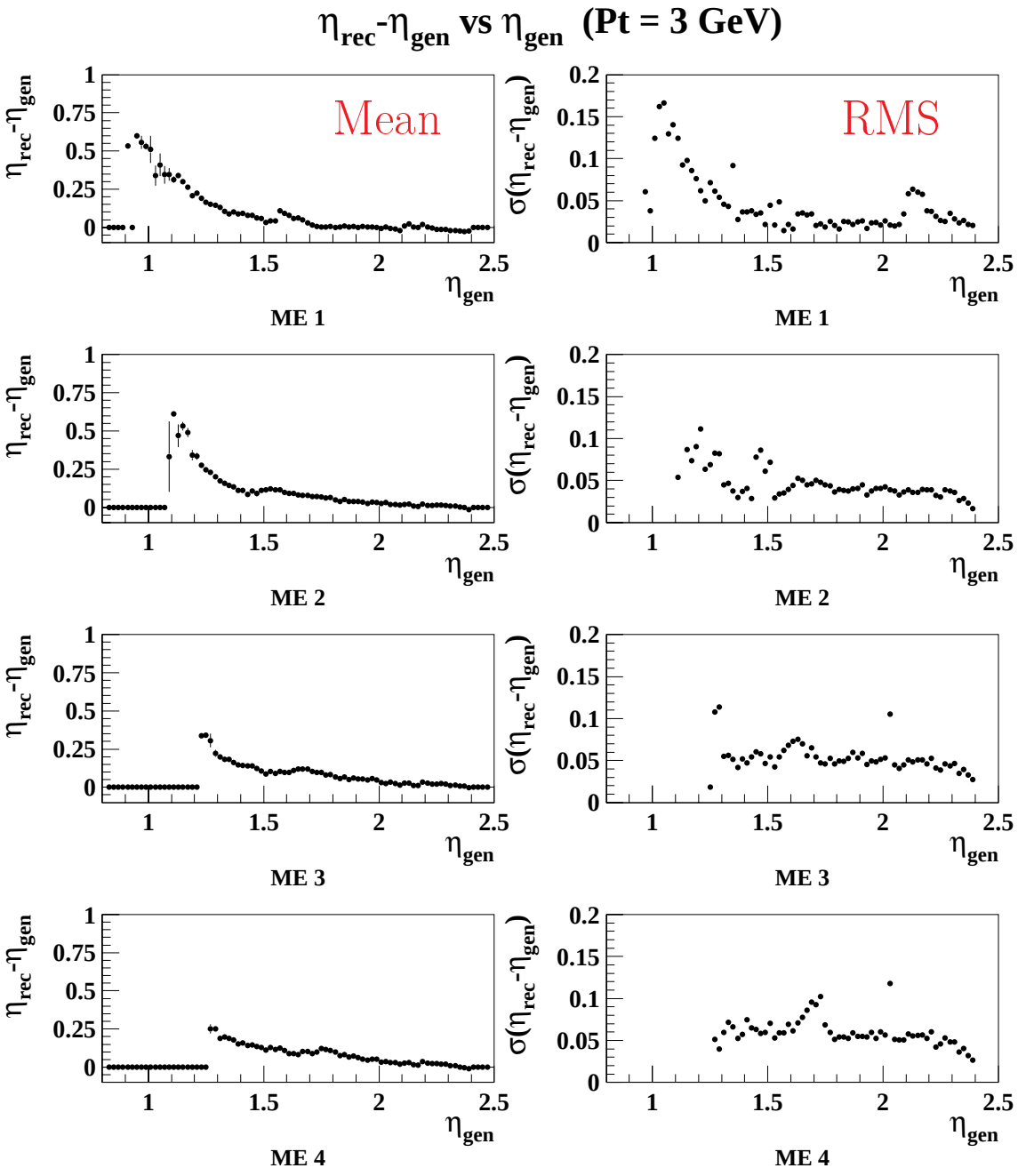
- old Fortran package.
- high Pt patterns only.
- the cathode strips and the anode wires that carry hits caused by the traversing muon, are used to reconstruct the trigger primitives (refer to CMS TN/96-69).
- study $\eta_{\rm rec}$ as a function of $\eta_{\rm gen}$ in each station (for different Pt)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

  $\Delta\phi$: $\Delta\phi_{12} = \phi_1 - \phi_2$

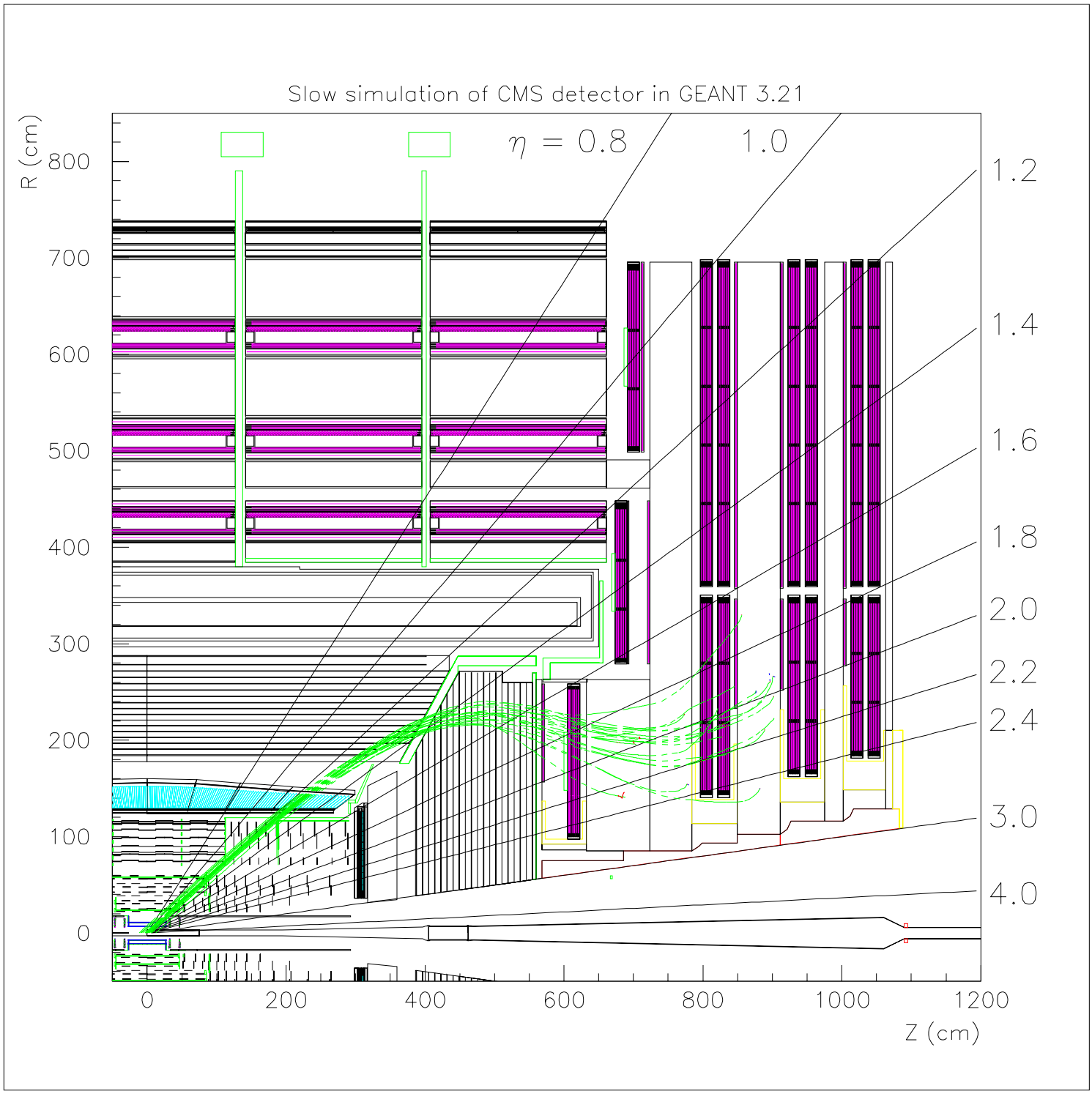
  $\Delta\phi_{13} = \phi_1 - \phi_3$

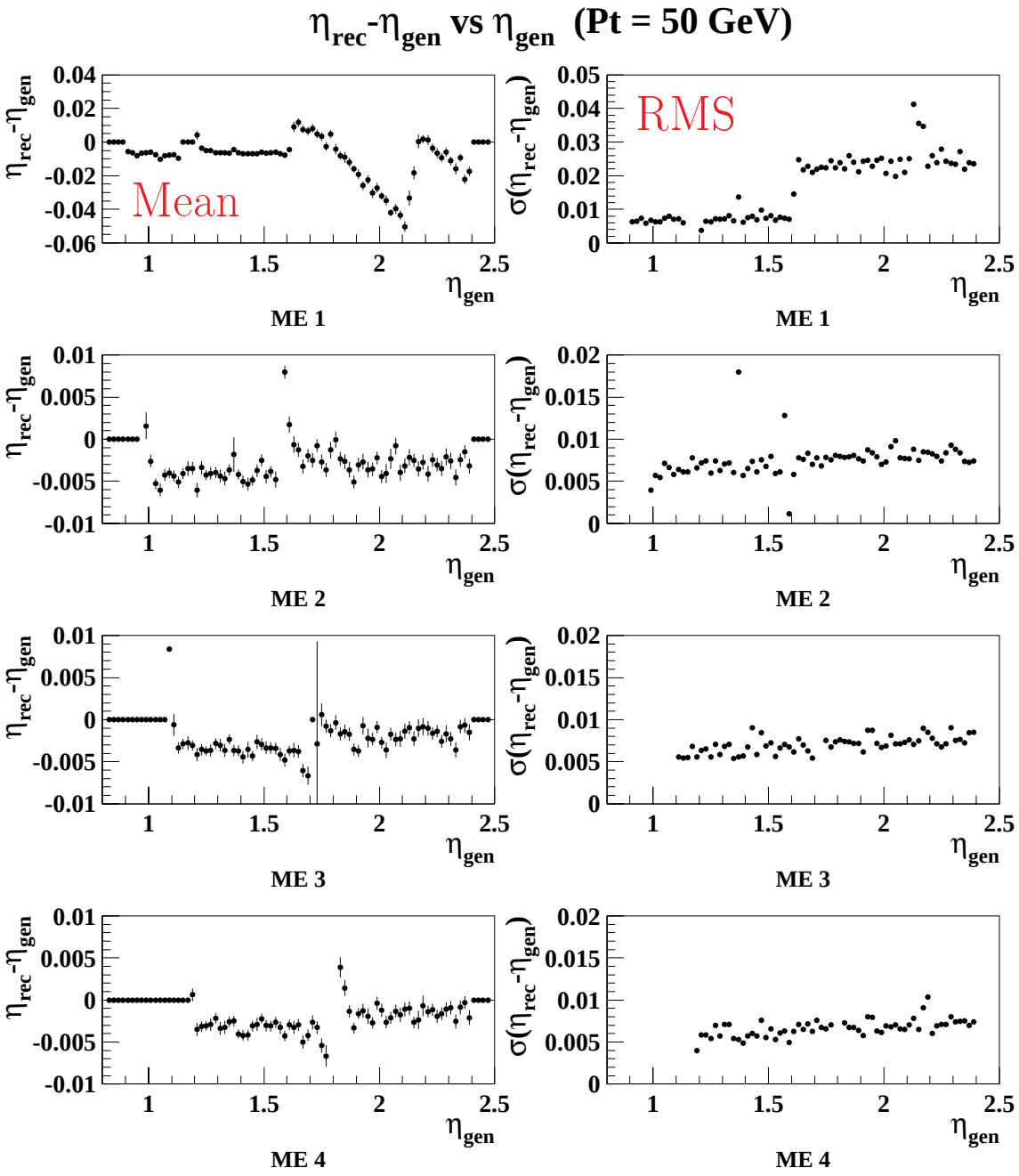
  $\Delta\phi_{23} = \phi_2 - \phi_3$



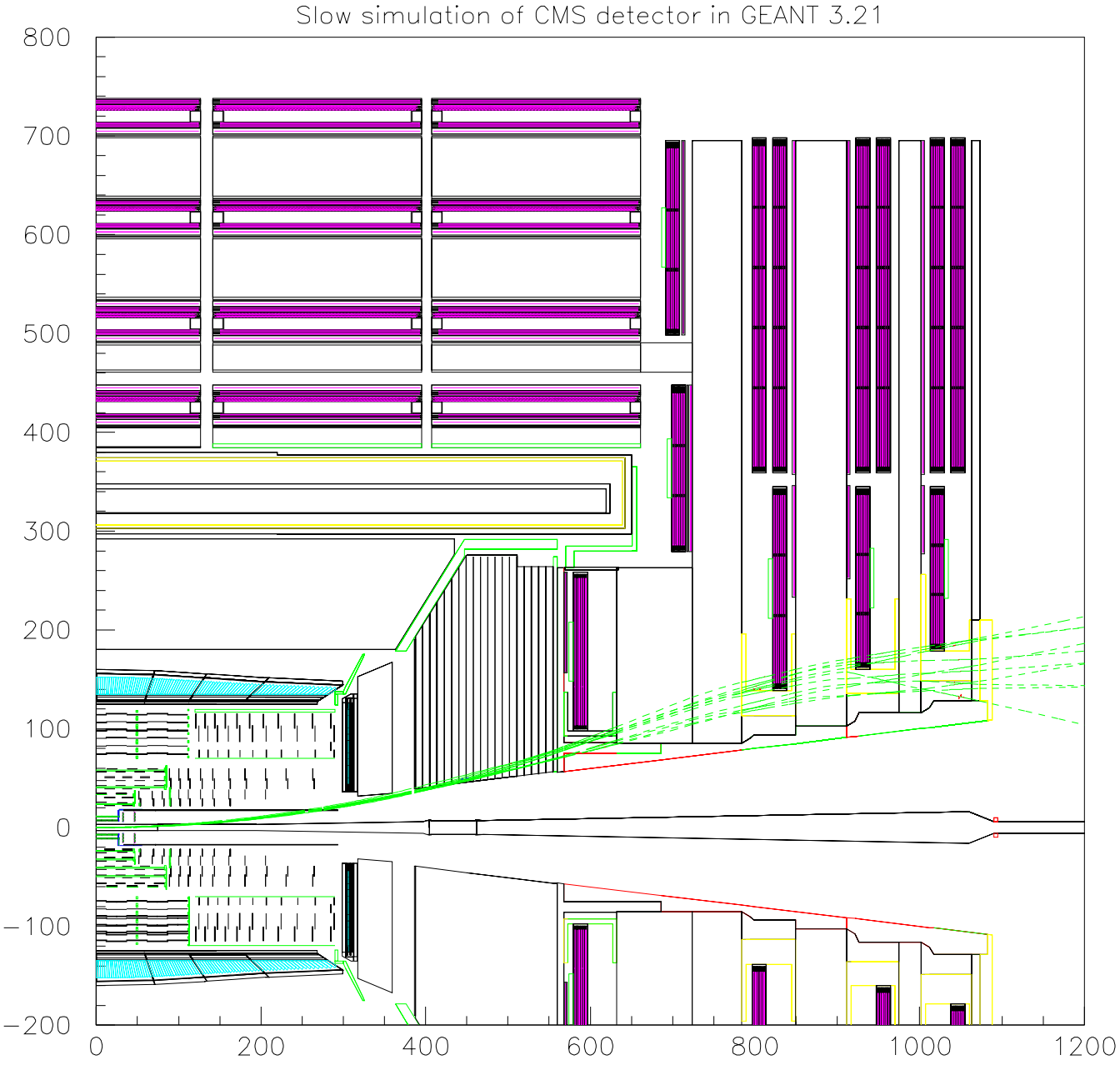


- large shift in $\eta_{\rm rec}$ at low $\eta_{\rm gen}$

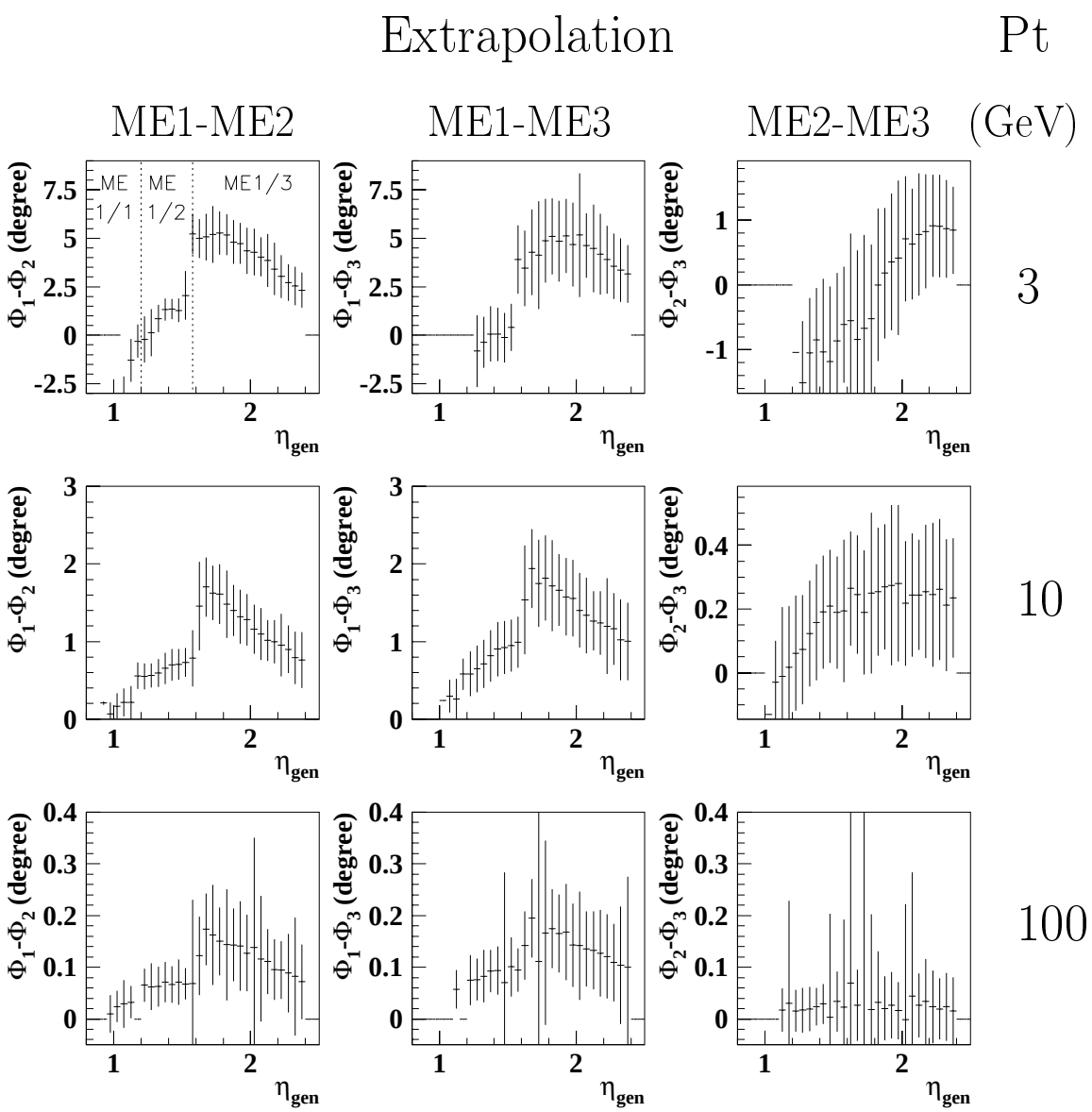

Slow simulation of CMS detector in GEANT 3.21
R (cm)
800
700
600
500
400
300
200
100
0
η = 0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
3.0
4.0
0
200
400
600
800
1000
1200
Z (cm)



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


Slow simulation of CMS detector in GEANT 3.21
800
700
600
500
400
300
200
100
0
−100
−200
0
200
400
600
800
1000
1200

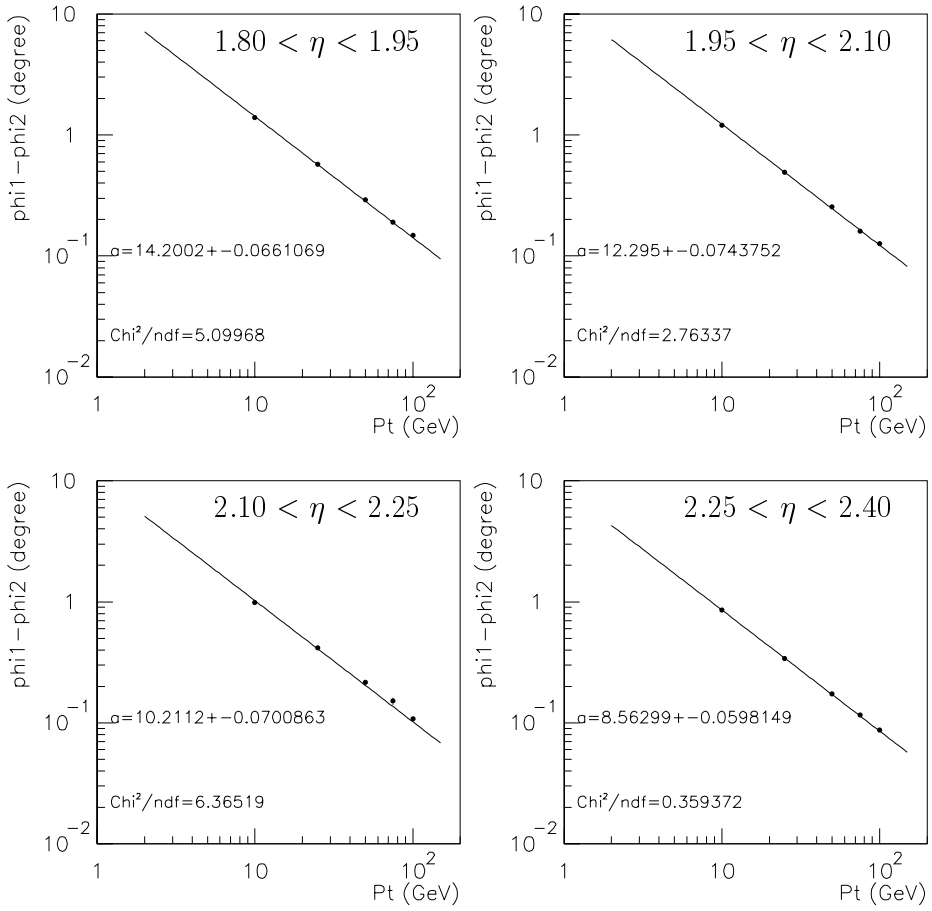
$\Delta\phi$ vs $\eta_{\rm gen}$ at different Pt



- the "error" bars are the RMS of the spread.
- $\Delta\phi_{\rm Max} \lesssim 9^\circ \quad 5^\circ + 2\sigma \;\;,\;\; \sigma \approx 2^\circ$.
  $\Delta\phi < 15^\circ \Rightarrow$ drop 2 MSB from 60° range in Track-Finder.
- 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

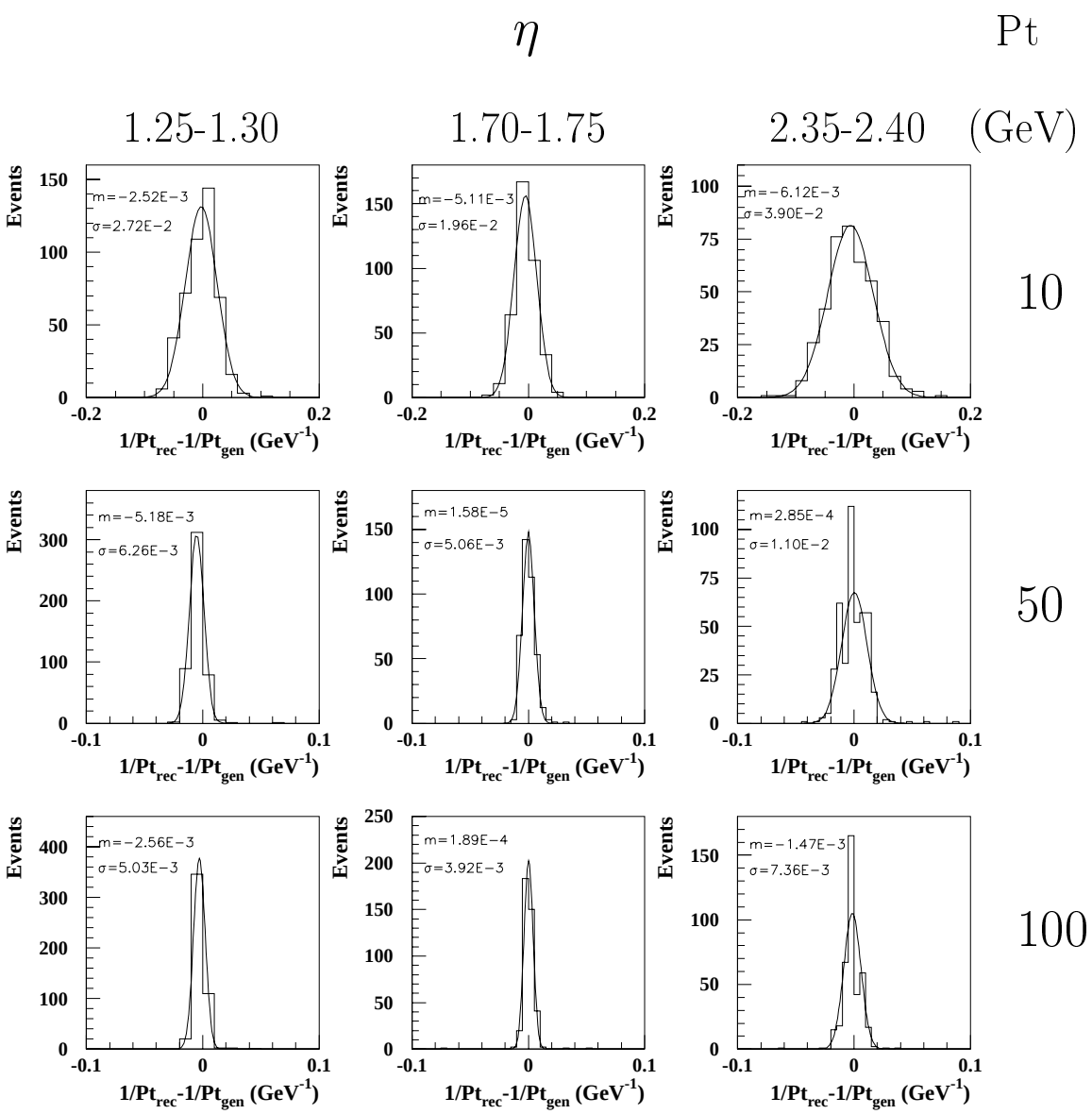
- Pt is obtained from the measured $\Delta\phi$ in two muon stations
- parameterize the $\Delta\phi$ to Pt relation at different fixed η ranges



- 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 : $\frac{1}{\mathrm{Pt}_{rec}} = \frac{\Delta\phi_{meas}}{a}$

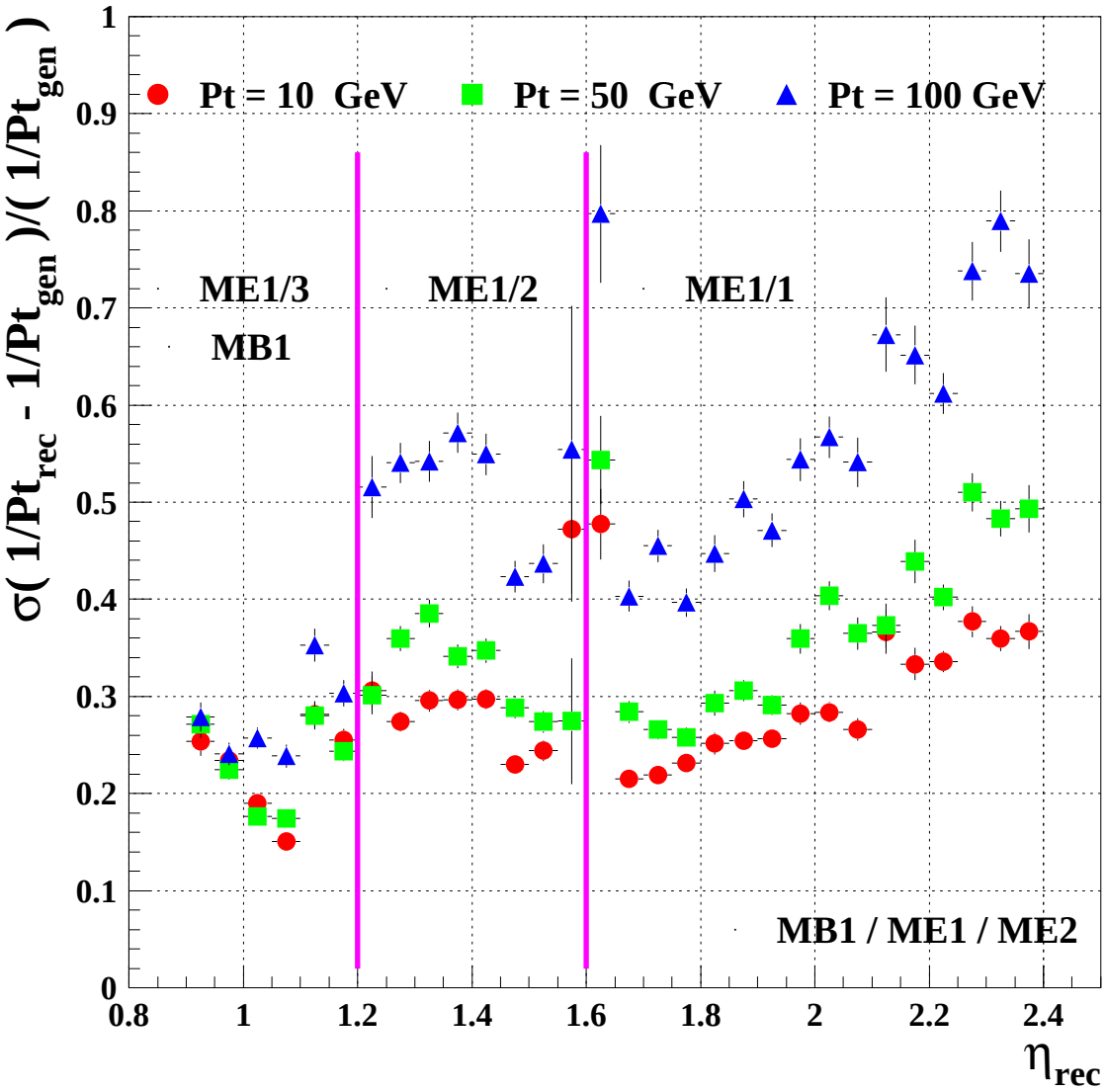
(Note: The inverse relation $\Delta\phi = a \cdot \mathrm{Pt}^{-1}$ is not an accurate description of the $\Delta\phi$ to Pt relation due to bending of the magnetic field.)

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



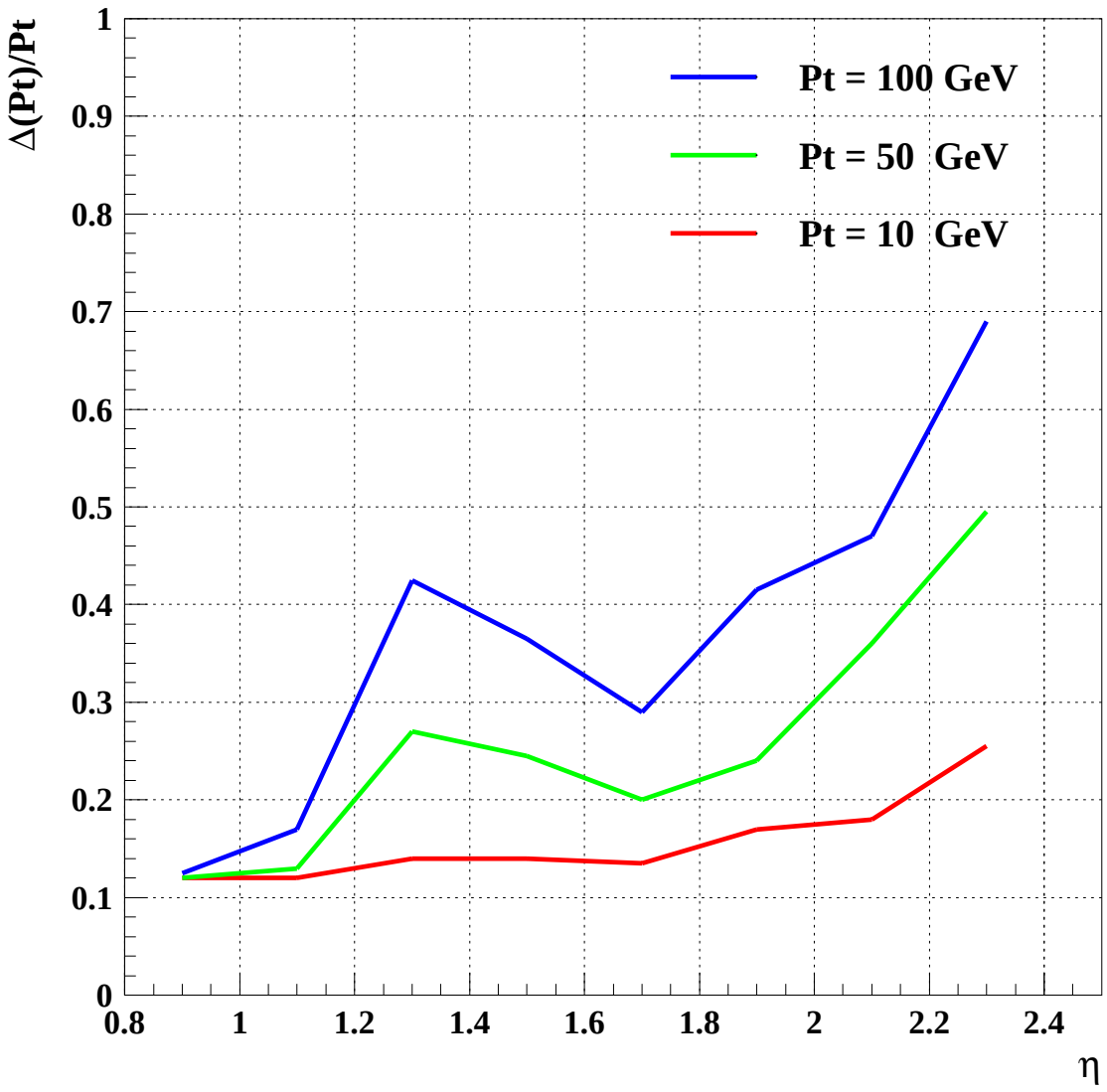
- Distributions are Gaussian. No significant tails.
- slight offset from zero may be due to the inaccurate direct inverse relation used in the parameterization

Resolution of Pt as function of η



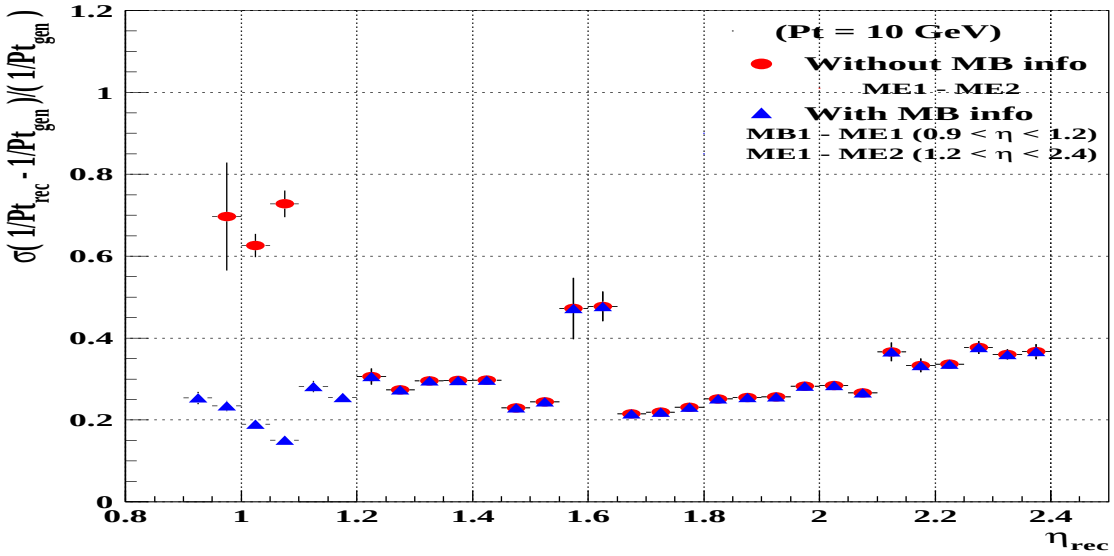
- Pt_{rec} obtained from $\Delta\phi$ measured between MB1-ME1 ($0.9 < \eta < 1.2$), and ME1-ME2 ($1.2 < \eta < 2.4$).

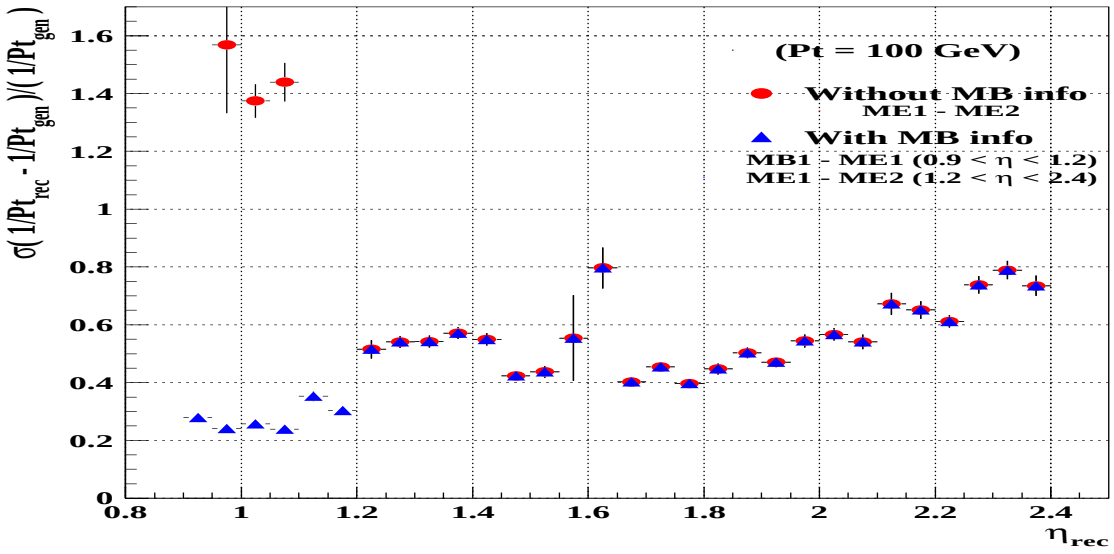
Resolution of Pt as function of η



- 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)
- Kalman Fit to all 4 stations with estimated LCT resolution.

Without using Barrel Muon Chamber in Over-Lap region



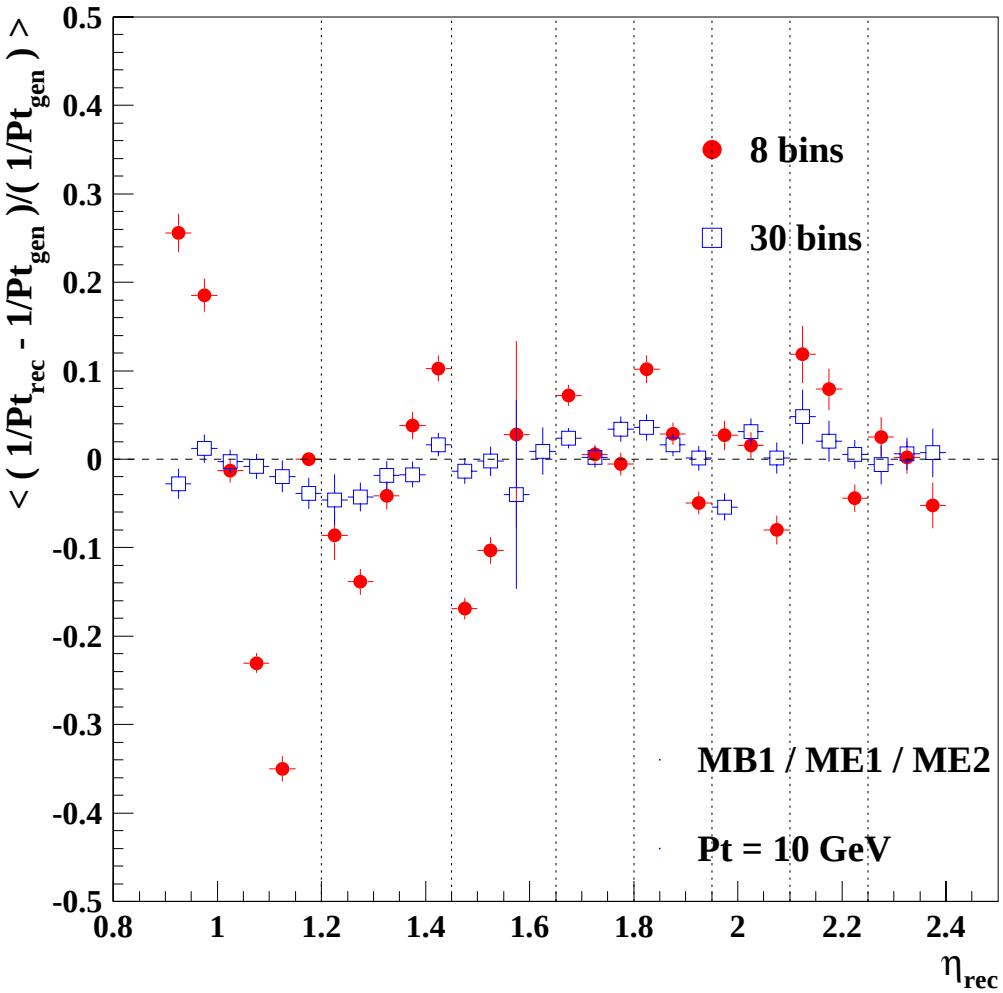


- resolution is poor in the overlap region if only the End Cap Muon Chambers are used.

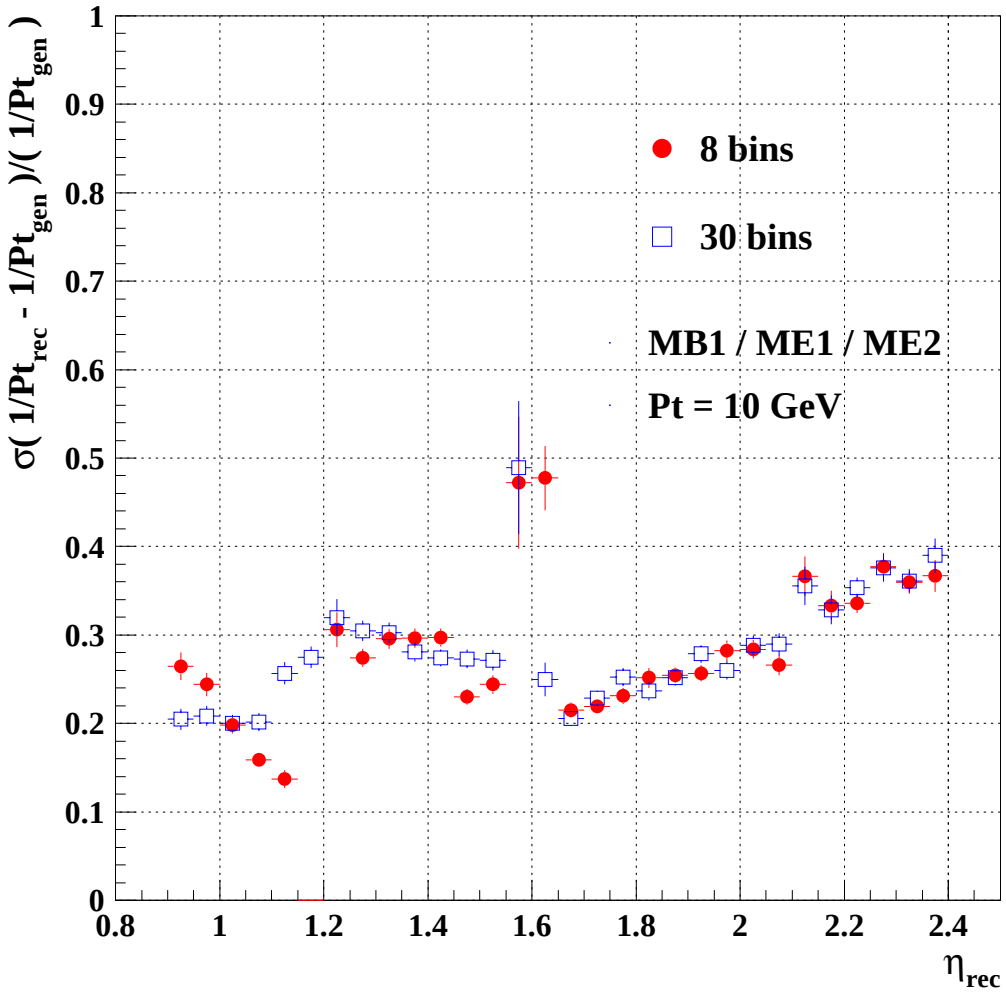
Effect from the size of the η bin on the resolution of Pt (How many bits necessary for η ?)

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

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



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

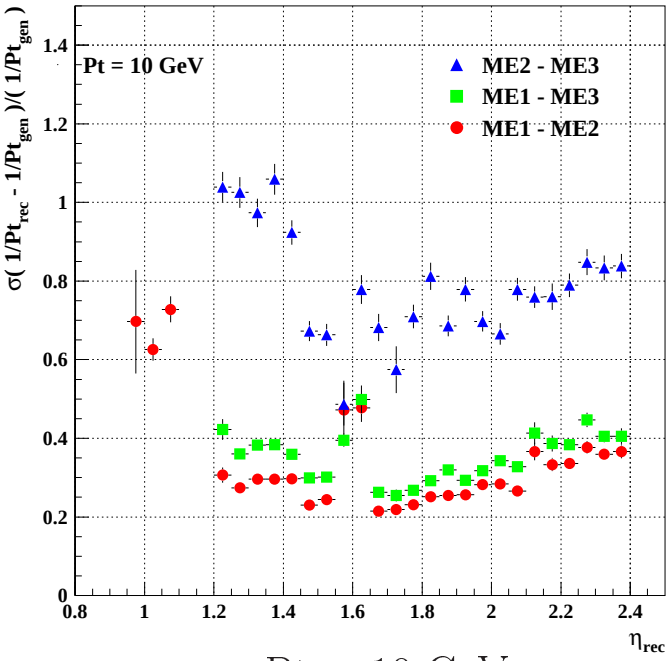


- resolution of Pt is similar in both cases

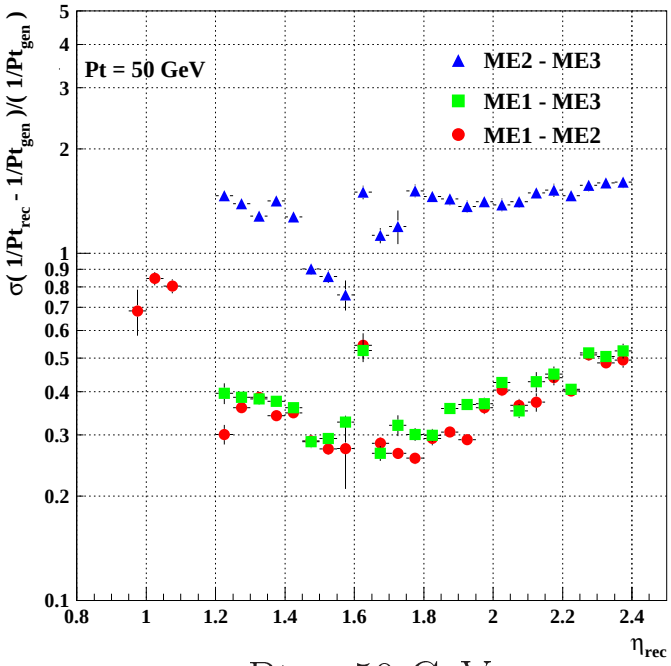
Pt resolution for $\Delta\phi$ obtained from different sets of Muon Stations

$\Delta\phi$ from :

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



Pt = 10 GeV

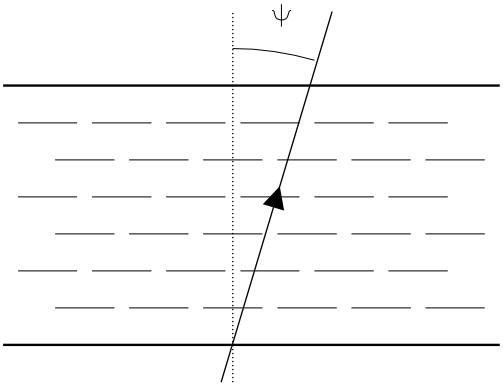


Pt = 50 GeV

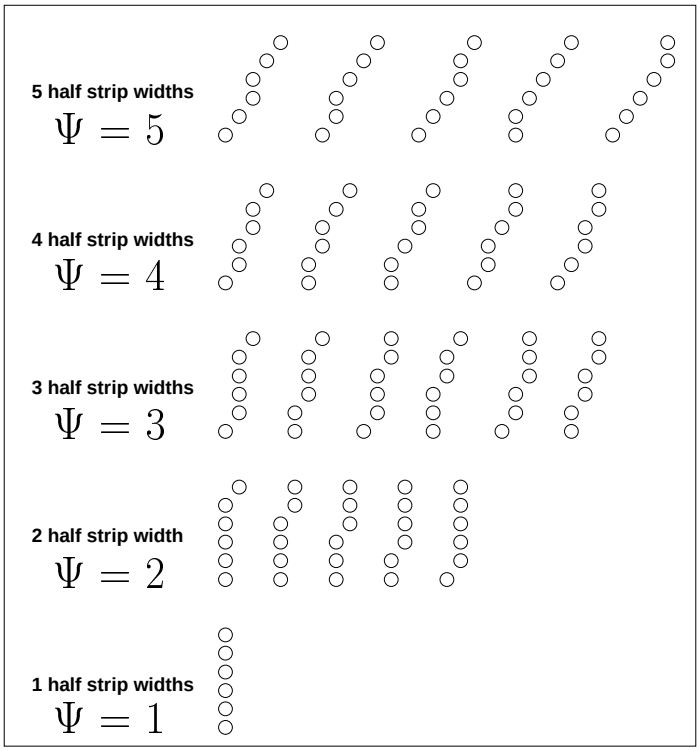
- For Pt=10 GeV, resolution of Pt for ME1-ME3 is slightly worse than ME1-ME2, even though $\Delta\phi_{13}$ is generally larger than $\Delta\phi_{12}$. (due to multiple scattering ... more material to traverse)
- For Pt=50 GeV, resolution of Pt is similar for ME1-ME2 and ME1-ME3.

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



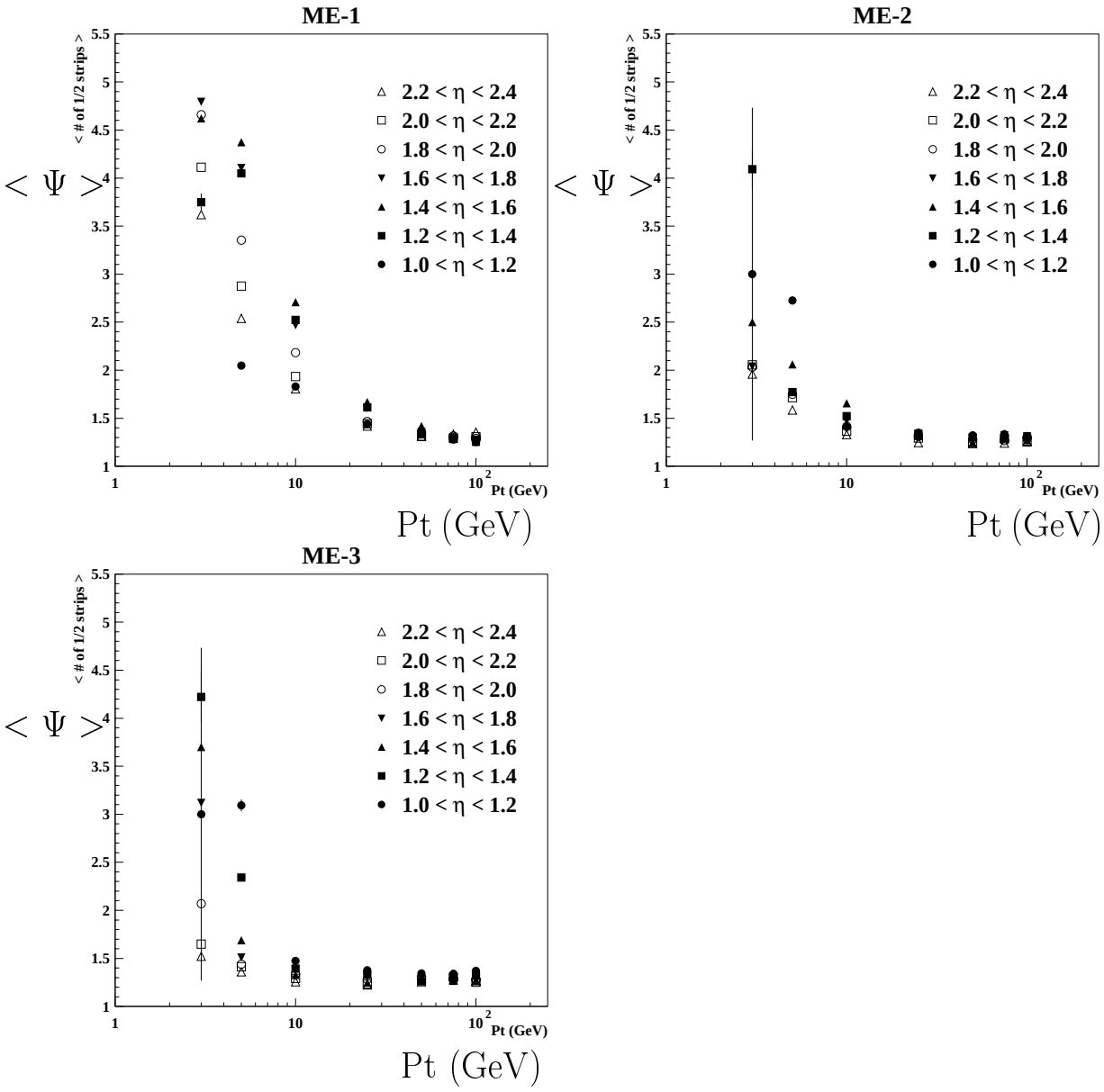
Definition of Ψ



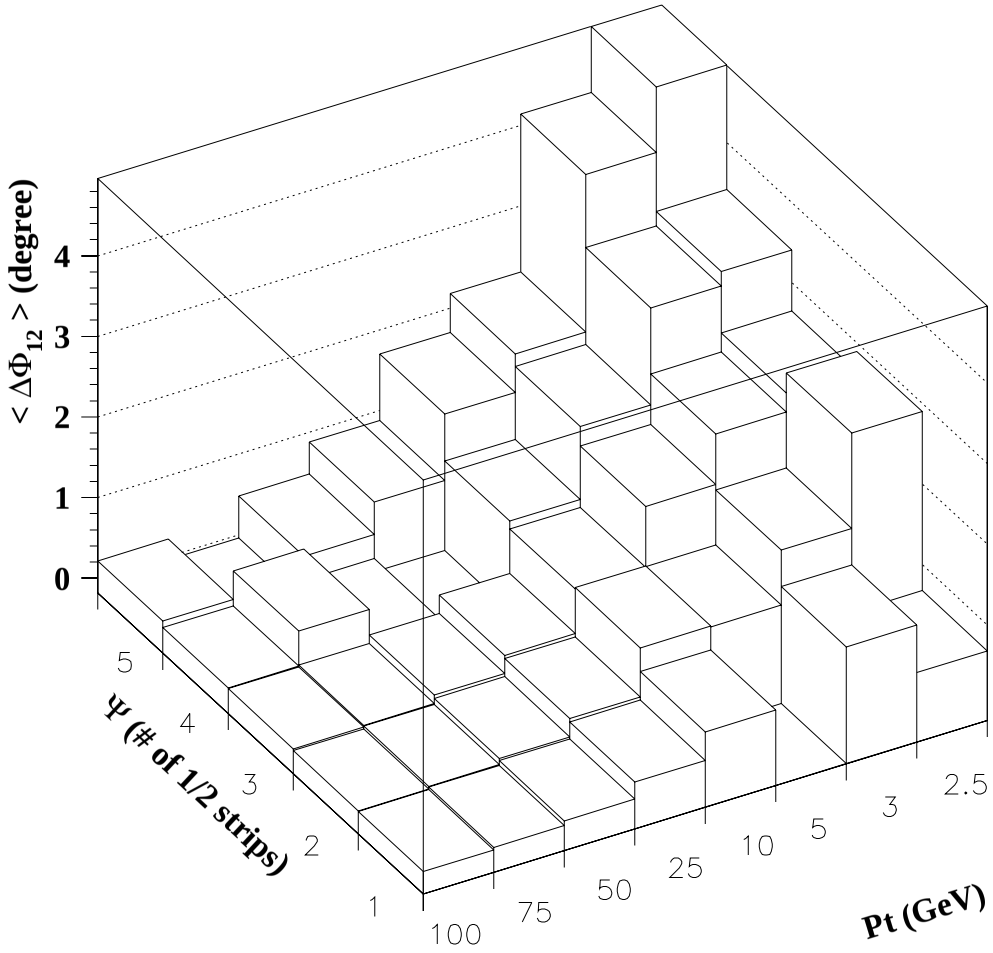
Road pattern of track in the station

(Plot taken from CMS TN/96-69)

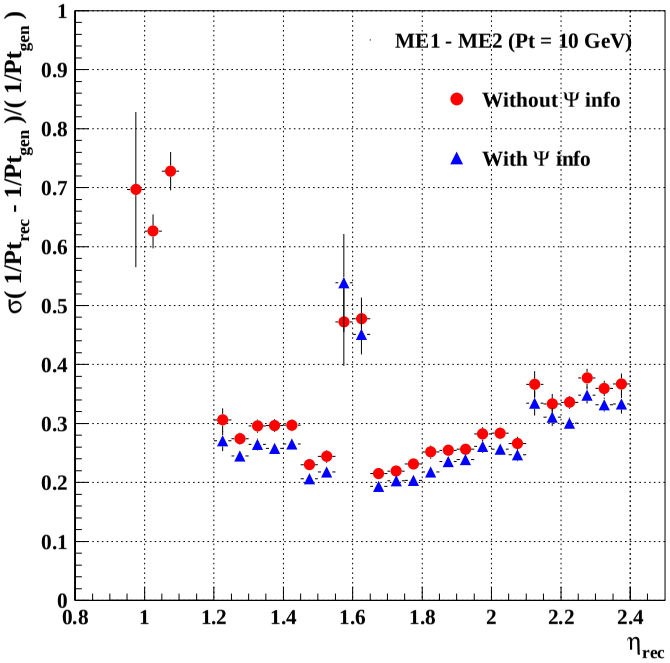
Ψ vs Pt at different η



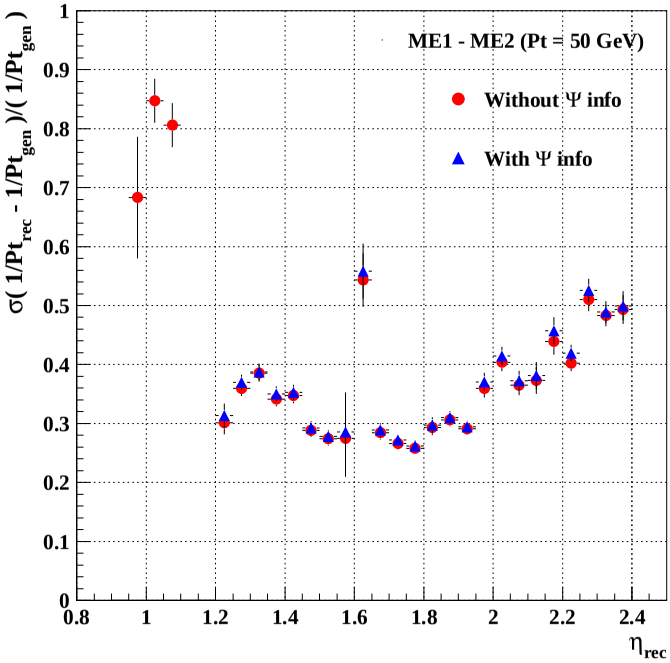
- Ψ is large for low Pt tracks (Pt$\lesssim$5 GeV) in ME1
- road pattern is almost straight for high Pt tracks and tracks in ME2, ME3



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



Pt=10 GeV

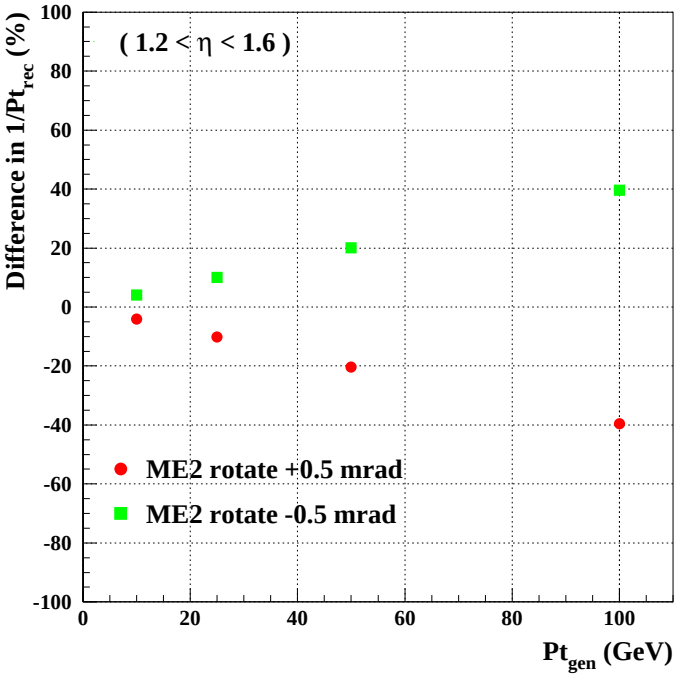


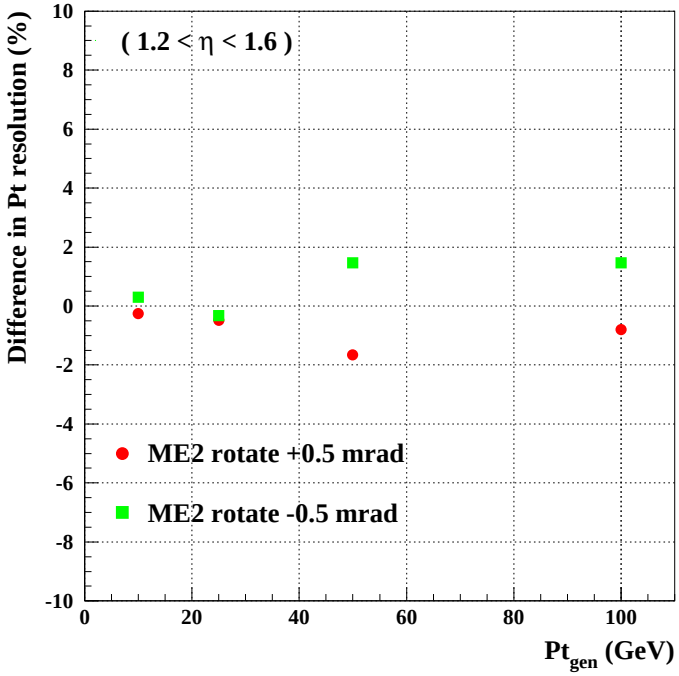
Pt=50 GeV

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

Misalignment of the End Cap Chambers

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





- small offset in $\frac{1}{\mathrm{Pt_{rec}}}$ at low $\mathrm{Pt_{gen}}$, but large offset at high $\mathrm{Pt_{gen}}$.
- 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

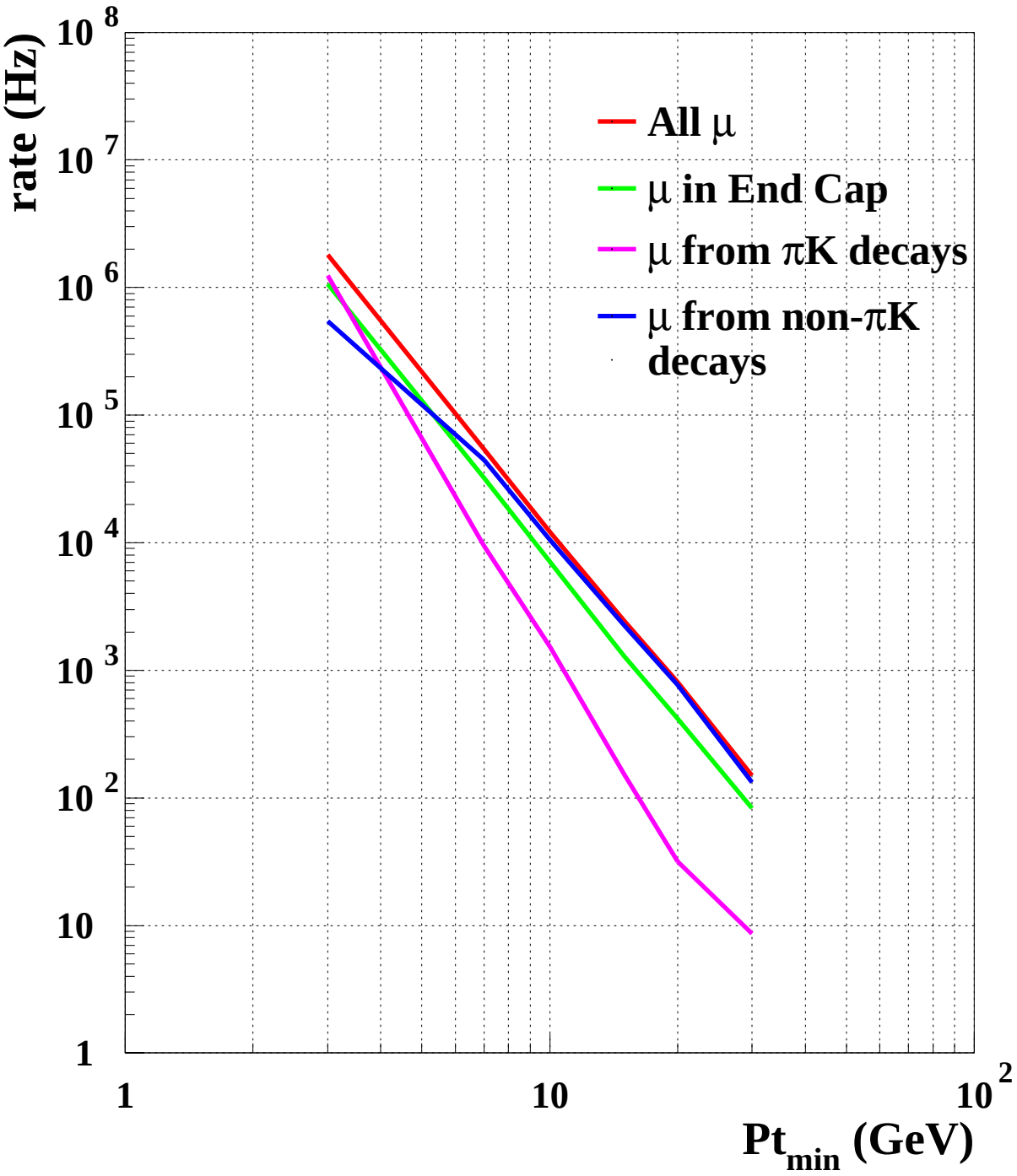
Summary for the End Cap Muon Detector

Preliminary studies show that :

- A coarse resolution of η 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 Ψ does not contribute much to the improvement of the Pt resolution.
- $\frac{\sigma_{\mathrm{Pt}}}{\mathrm{Pt}} \sim 30\%$

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.


rate (Hz)
10 8
10 7
10 6
10 5
10 4
10 3
10 2
10
1
1
10
10 2
Pt min (GeV)
All μ
μ in End Cap
μ from πK decays
μ from non-πK decays