

# Muon Efficiency for Lepton Charge Asymmetry

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# Muon Efficiency Study

- Muon efficiency study for lepton charge asymmetry analysis

- Lepton charge asymmetry is defined as

$$A(\eta) = \frac{d\sigma/d\eta(W^+ \rightarrow \ell^+ \nu) - d\sigma/d\eta(W^- \rightarrow \ell^- \bar{\nu})}{d\sigma/d\eta(W^+ \rightarrow \ell^+ \nu) + d\sigma/d\eta(W^- \rightarrow \ell^- \bar{\nu})}$$

- We measure  $A(\eta)$  from the number of events for  $W^+$  and  $W^-$
- It is important to measure the efficiency for  $\mu^+$  and  $\mu^-$ , respectively
- Muon efficiency is estimated as a function of  $p_T$ ,  $\eta$ , and charge
  - Efficiency is estimated using Tag & Probe method using Z events
  - Efficiency scale factor of data to MC in  $p_T$  and  $\eta$  is applied in MC
  - Efficiency scale factor in charge is used for the systematic study
  - Efficiency for 2011A data set
    - Data : 2011A data set ( IsoMu\_24 and IsoMu\_15),  $\int L dt = 2 \text{ fb}^{-1}$
    - MC : Madgraph (inclusive Drell-Yan MC :  $Z \rightarrow l^+ l^-$ )
    - Muon Id : VBTF standard selection excluding isolation cut

- Muon selection :
  - $p_T > 25$  GeV with  $|\eta| < 2.4$
  - Muon is identified as both “GlobalMuon” and “TrackerMuon”
  - Normalized global track fitting  $\chi^2 < 10$
  - At least 11 valid silicon hits
  - At least 1 valid muon chamber hit
  - At least 1 valid pixel hit
  - At least 2 number of muon chamber matches
  - $|d_{xy}| < 2$  mm
- Additional requirement on the second muon to remove Z contamination
  - $p_T > 15$  GeV with  $|\eta| < 2.4$
  - Combined relative isolation,  $\text{Iso}_{\text{rel}} = (\text{Iso}_{\text{trk}} + \text{Iso}_{\text{calo}})/p_T < 0.2$  (not finalized)
- Many W related analyses use PF variable, but we keep GlobalMuon so far...
  - For isolation cut, PF isolation is one of our option

# Tag and Probe Method

- The efficiencies are measured using Tag and Probe method (T&P)
  - Internal package is used for the efficiency measurement
    - Working on the official T&P package for cross-check (Samir Guragain)
  - Tagged leg is required to pass all muon selection
  - The probe leg is used to estimate the efficiency
  - The efficiency is estimated for tracking, global, ID, trigger, and  $\text{Iso}_{\text{rel}} < 0.2$

$$\epsilon_{\text{tot}} = \epsilon_{\text{tracking}} \times \epsilon_{\text{global}} \times \epsilon_{\text{ID}} \times \epsilon_{\text{HLT}}$$

- The background is estimated using Z mass fitting
  - Separate the events for cut passed and non-passed events
  - Estimate the background separately
    - non-passed events has higher background contamination
- Z mass window:
  - Estimated efficiency for both  $60 < M < 120$  and  $80 < M < 100$ , mass window
  - The efficiency estimated in  $80 < M < 100$  is used for  $2 \text{ fb}^{-1}$  analysis

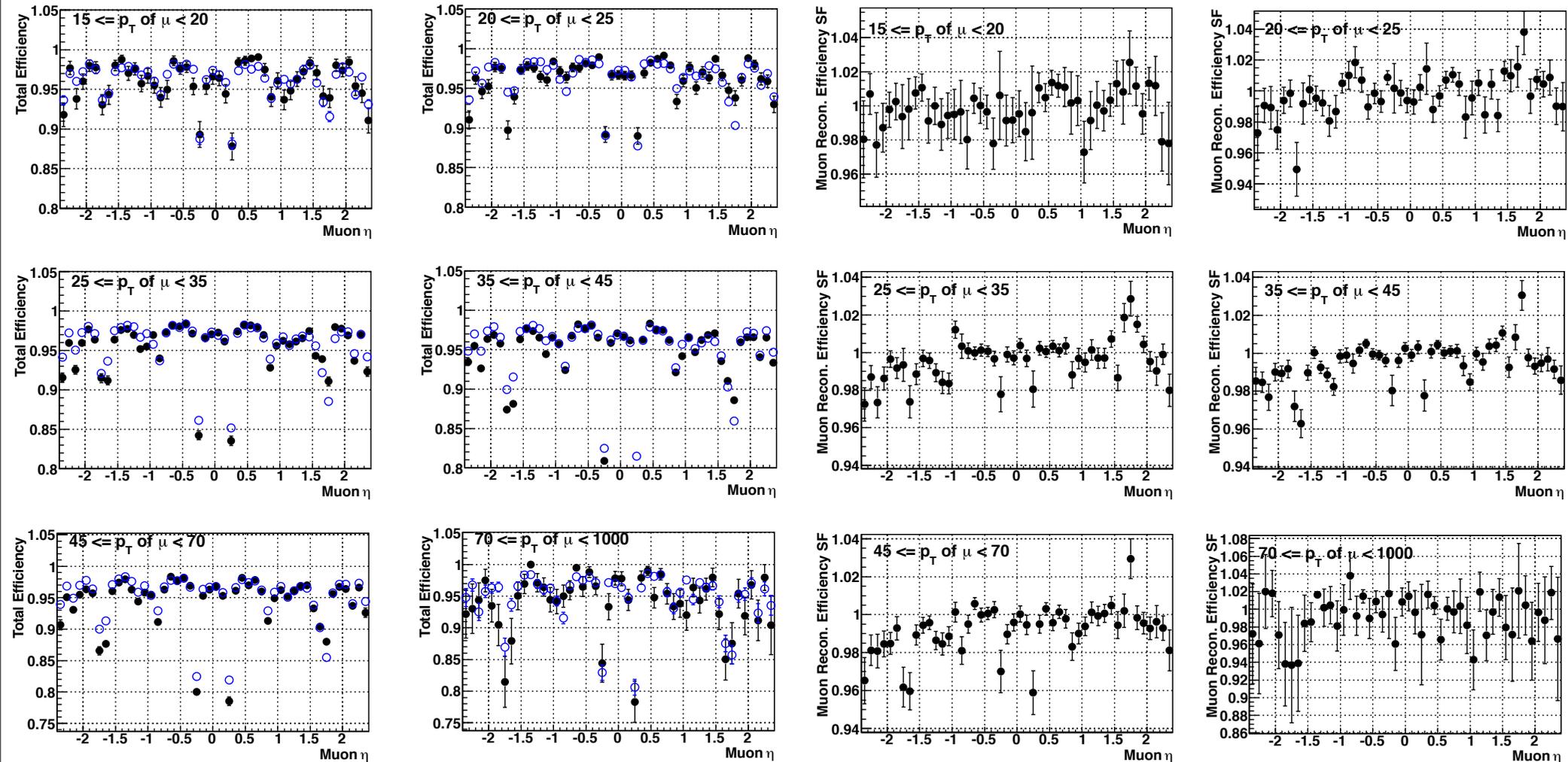
- Efficiency as a function of  $\eta$  and  $p_T$ 
  - For  $234 \text{ pb}^{-1}$ , the efficiency is estimated in  $|\eta|$  (11 bins) and  $p_T$  (5 bins)
  - For  $2 \text{ fb}^{-1}$ , we make finer bins for  $\eta$  and  $p_T$  (22x6 and 48x6 bins)
    - The efficiency is estimated for  $-\eta$  and  $+\eta$  region, respectively
    - The efficiency tables for both bins are provided
      - The efficiency in data, MC and the scale factor of the efficiency
      - The efficiency scale factor of data to MC is applied into MC
- Charge dependence of the efficiency
  - The efficiency and the scale factor are estimated for  $\mu^+$  and  $\mu^-$
  - The scale factor (data/MC) ratio of  $\mu^+$  and  $\mu^-$  is measured and used to assign the systematic uncertainty ( close to be 1.0 )

# Efficiency in Data and MC

- Total efficiency ( $\epsilon_{tot} = \epsilon_{tracking} \times \epsilon_{global} \times \epsilon_{ID} \times \epsilon_{HLT}$ ) and scale factor

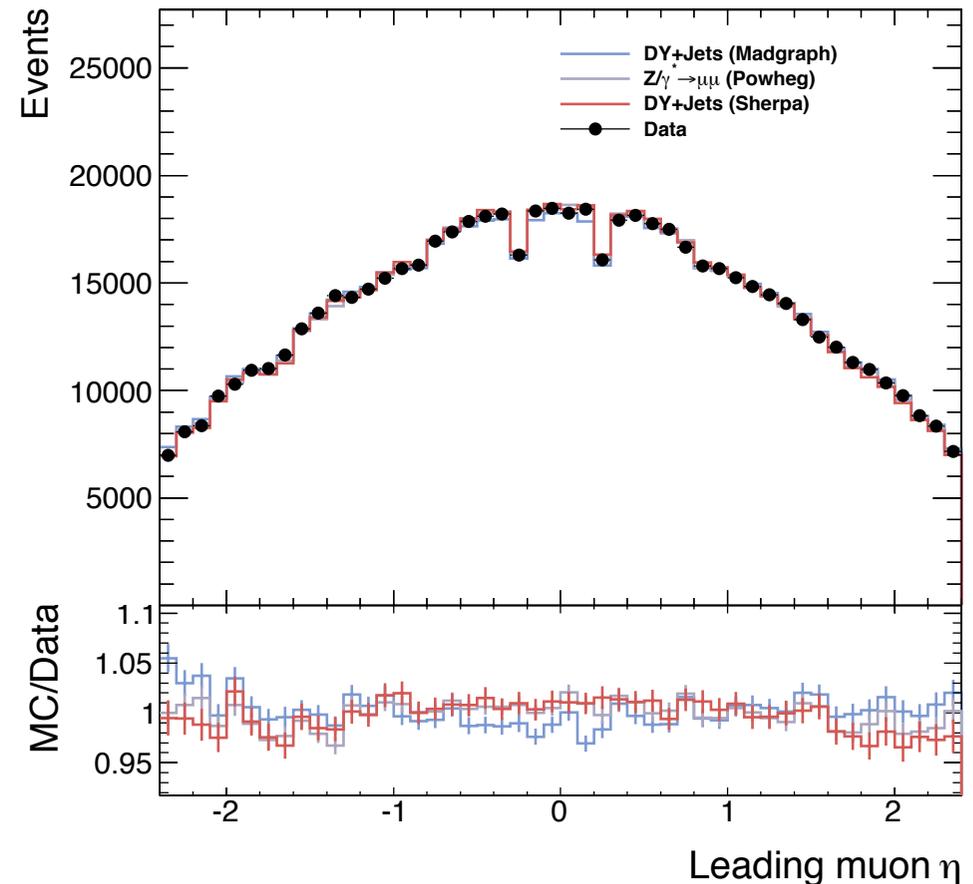
Efficiency in  $(\eta, p_T)$ : Data vs. MC

Efficiency scale factor in  $(\eta, p_T)$



# Muon $\eta$ Distribution After Correction

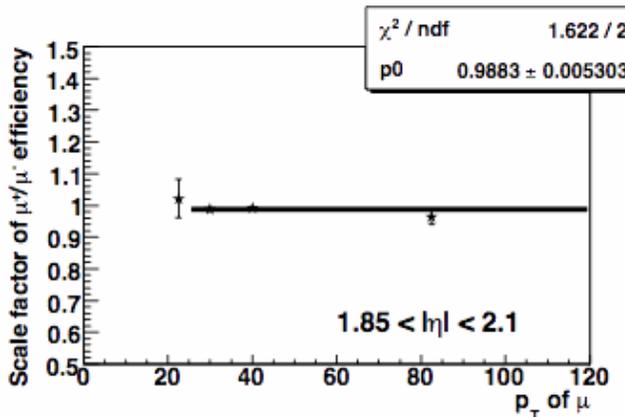
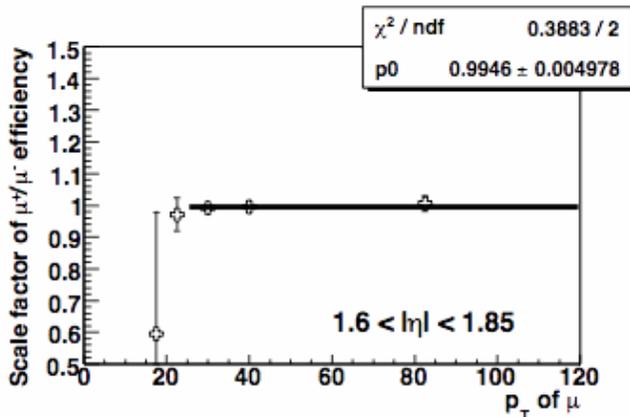
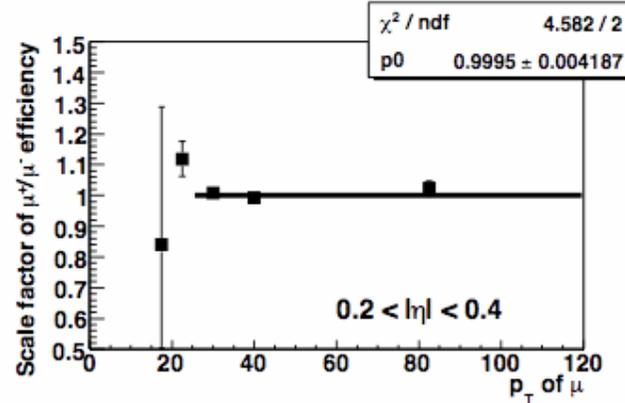
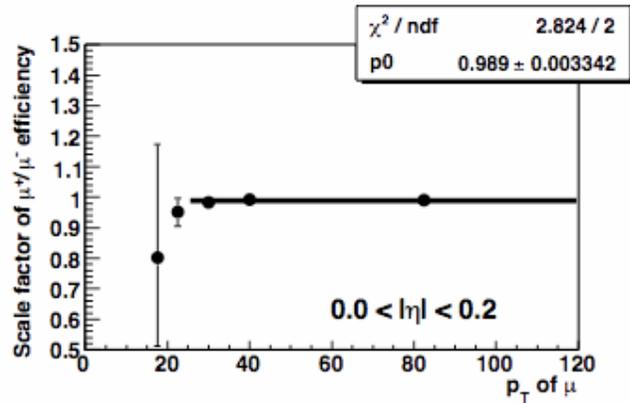
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- After efficiency correction,
  - Data and MC has better agreement
  - Muon  $\eta$  agrees within  $\sim 2\%$  level

# Efficiency Ratio of $\mu^+$ to $\mu^-$

- We measure the efficiency ratio of  $\mu^+$  to  $\mu^-$  for the systematic study



Plots for old binning  
(also checking with new bins)

Muon  $p_T$  for lepton charge  
asymmetry is  $p_T > 25$  GeV

Fit the scale factor of  $\mu^+/\mu^-$   
in  $p_T > 25$  GeV  
 $\Rightarrow$  close to 1.0

The scale factor of  $\mu^+/\mu^-$   
is used for the systematic  
study

$ \eta $ Bin	Fit Result (Data)	$ \eta $ Bin	Fit Result (Data)
0.00 - 0.20	$0.9890 \pm 0.0033$	1.20 - 1.40	$1.0034 \pm 0.0045$
0.20 - 0.40	$0.9995 \pm 0.0042$	1.40 - 1.60	$1.0007 \pm 0.0047$
0.40 - 0.60	$0.9967 \pm 0.0031$	1.60 - 1.85	$0.9946 \pm 0.0050$
0.60 - 0.80	$0.9976 \pm 0.0033$	1.85 - 2.10	$0.9883 \pm 0.0053$
0.80 - 1.00	$1.0046 \pm 0.0047$	2.10 - 2.40	$0.9962 \pm 0.0080$
1.00 - 1.20	$1.0027 \pm 0.0044$		

# Summary and Plan

- We keep working on the efficiency study for lepton charge asymmetry
  - The efficiency study is using  $2 \text{ fb}^{-1}$  data (IsoMu HLT trigger used)
  - **Consider  $p_T$ ,  $\eta$ , and charge dependence**
  - Total efficiency includes tracking, muon recon., ID, trigger efficiency
  - The efficiency scale factor of data to MC is applied into MC
  - The charge dependence is used for the systematic study
    - **The scale factor of  $\mu^+$  to  $\mu^-$  is closed to be 1.0** within stat. uncertainty
- Need to improve and consider ....
  - CMS official T&P package is also studied for the cross check
  - Tag( $\eta_1, p_{T1}$ ) & Tag( $\eta_2, p_{T2}$ ) events is counted once
    - Ignore the correlation of two legs for the efficiency now
    - Will consider this correlation  $\Rightarrow$  both legs are used for the efficiency

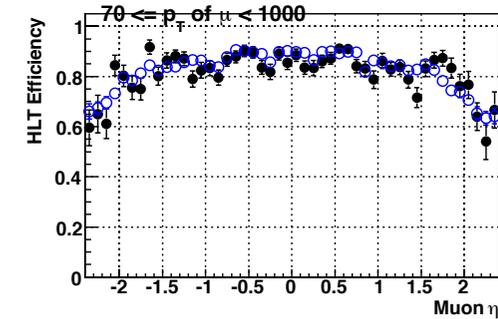
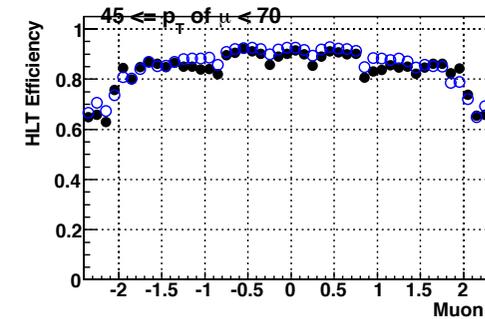
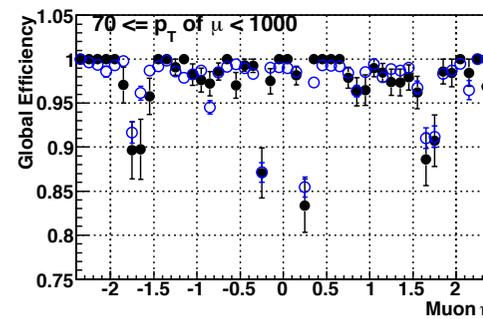
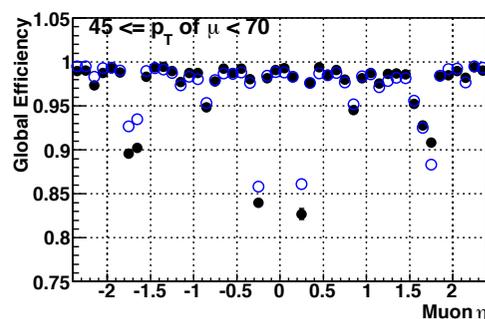
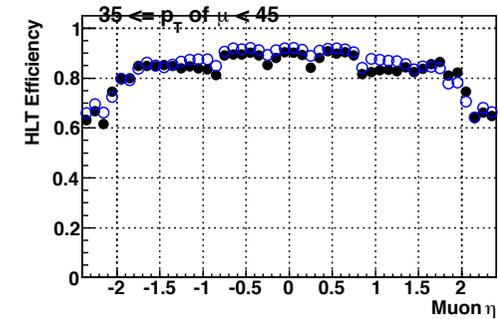
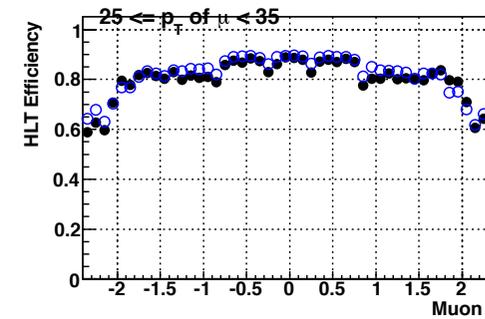
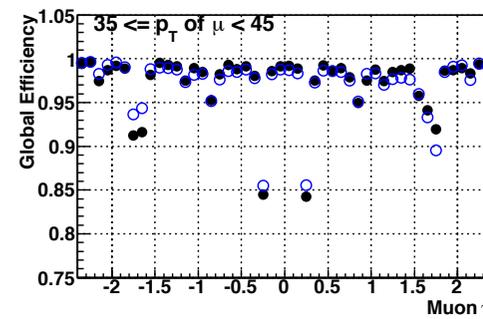
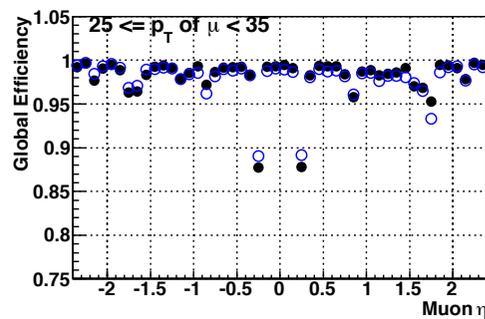
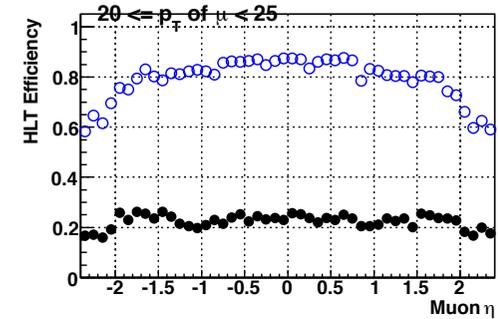
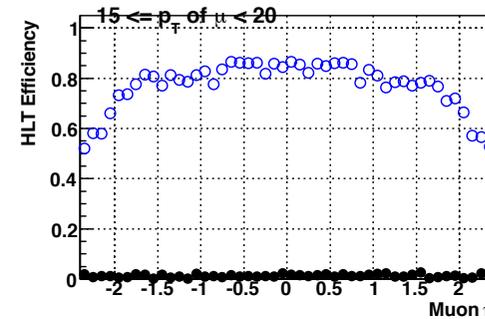
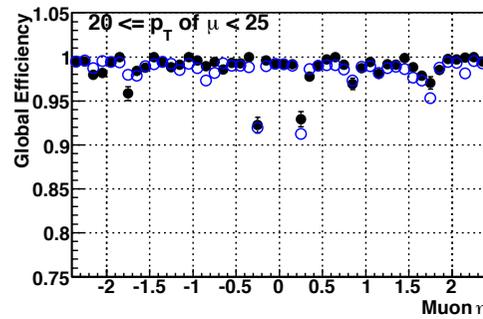
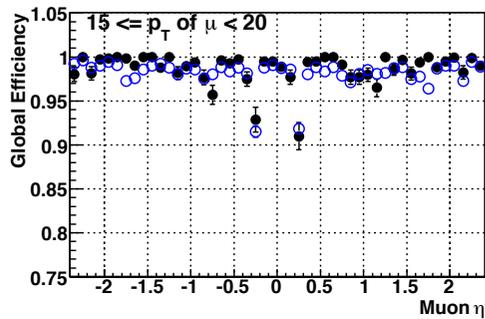
# Back-Up Slides

# Global and HLT Efficiency

- Global and HLT efficiency

Global effi. in  $(\eta, p_T)$  : Data vs. MC

HLT effi. in  $(\eta, p_T)$  : Data vs. MC



# Isolation Efficiency

- Isolation cut ( $\text{Iso}_{\text{rel}} = (\text{Iso}_{\text{trk}} + \text{Iso}_{\text{calo}})/p_T < 0.2$ ) efficiency and scale factor

Efficiency in  $(\eta, p_T)$ : Data vs. MC

Efficiency scale factor in  $(\eta, p_T)$

