

CMS Performance Note

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27 March 2013

Single Muon efficiencies in 2012 Data

CMS Collaboration

Abstract

Muon identification, isolation and single-muon trigger efficiencies from 2012 data are presented. The results are obtained from $Z \rightarrow \mu^+ \mu^-$ events by the Tag-and-Probe technique.

Single Muon Efficiencies in 2012 Data

CMS Collaboration

Muon ID and Isolation Efficiencies in 2012 Run ABCD

Outline

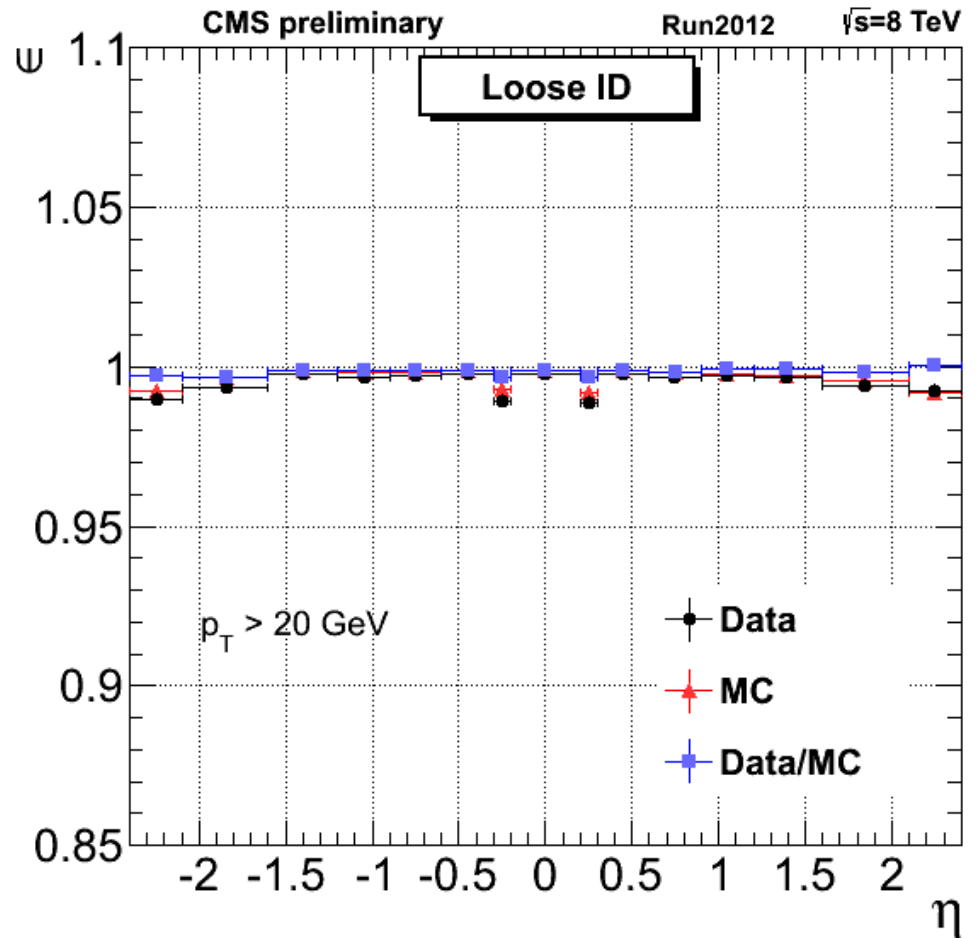
- Muon ID efficiencies:
 - **Tight**
 - global muon
 - PF muon
 - `globalTrack.normalizedChi2 < 10`
 - `globalTrack.numberOfValidMuonHits > 0`
 - `numberOfMatchedStations > 1`
 - `|dxy| < 0.2 cm, |dz| < 0.5 cm`
 - `numberOfValidPixelHits > 0`
 - `trackerLayersWithMeasurement > 5`
 - **Loose**
 - PF muon
 - global or tracker muon
- Isolation efficiencies for tight muons:
 - **tracker relative isolation** ($(\sum p_T(\text{TRK}))/p_T < 0.1$ (cone $\Delta R=0.3$)
 - **combined relative PF isolation** ($(\sum E_T(\text{chHad from PV}) + \sum E_T(\text{neutHad}) + \sum E_T(\text{photons}))/p_T < 0.12$ and < 0.20 with **dBeta correction** for pile up (cone $\Delta R = 0.4$). DeltaBeta: Correction to the neutral component of the combined isolation, taking into account the charged particles in the cone of interest but with particles not originating from the primary vertex, and the average of neutral to charged particles as measured in jets
- Plot efficiencies for Data, MC and scale factors vs eta, pt (barrel, overlap, endcap), number of vertices

Method

- Method: Tag and Probe Selection on $Z \rightarrow \mu^+ \mu^-$
 - Tag muon:
 - Tight Muon
 - $p_T > 15$ GeV
 - matched to a single muon trigger
 - Probe muon:
 - General Track (for ID efficiencies)
 - Tight Muon (for Isolation efficiencies)
 - Z mass window: 70 -130 GeV
 - PDF shape:
 - signal = sum of 2 Voigtians
 - background = exponential

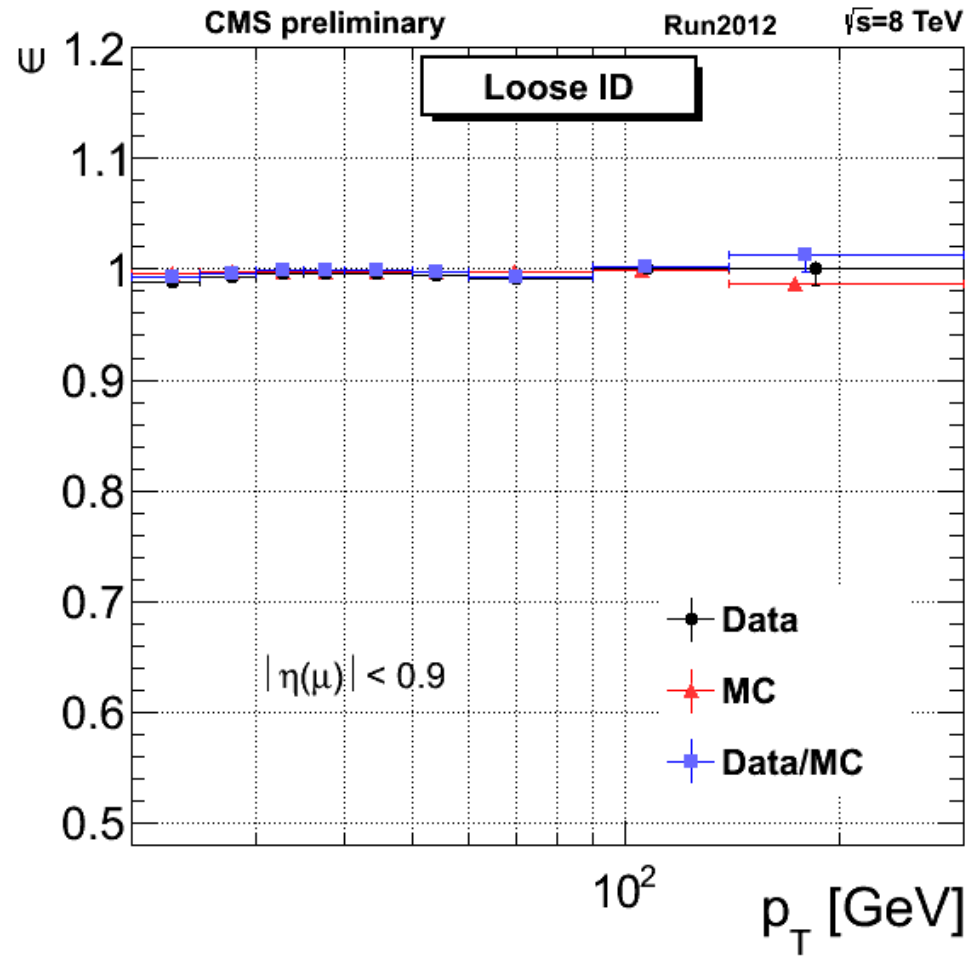
ID efficiency

- Loose Selection Efficiency (Data and MC) and scale factors vs eta
- TnP method used on Zs
- Probes general tracks



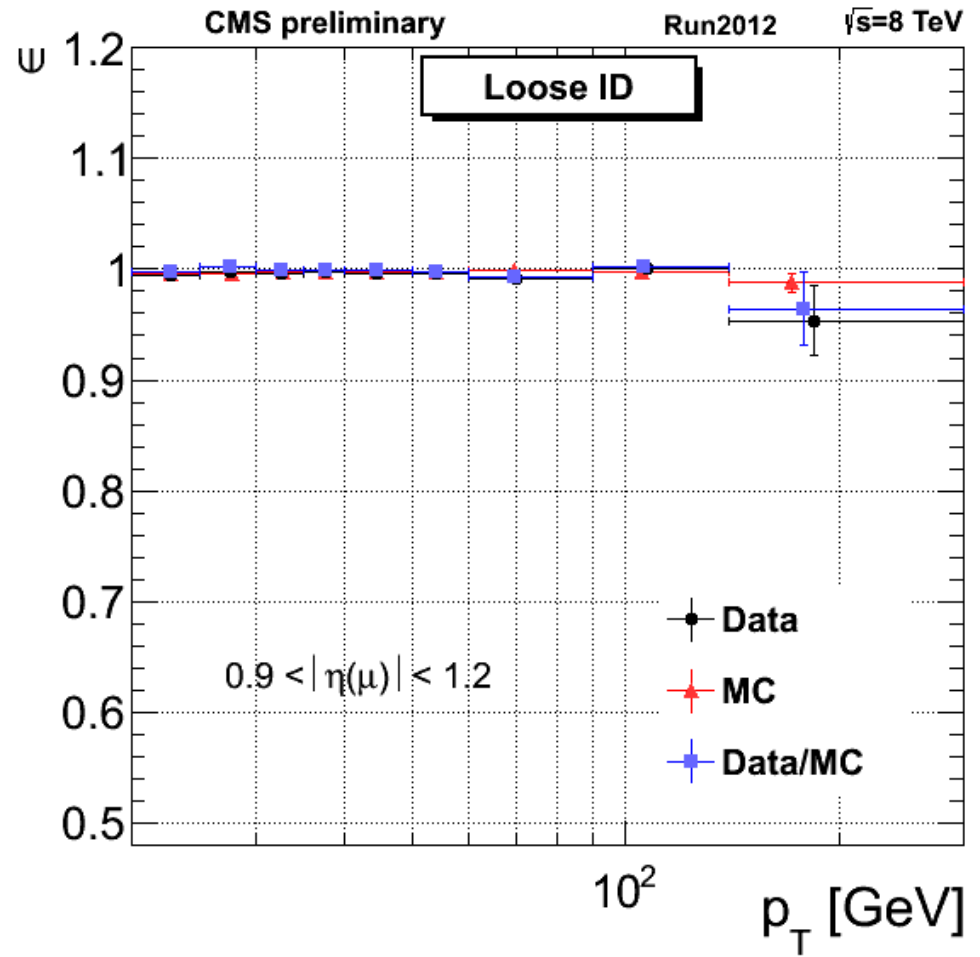
ID efficiency

- Loose Selection Efficiency (Data and MC) and scale factors vs p_T in the barrel
- TnP method used on Zs
- Probes general tracks



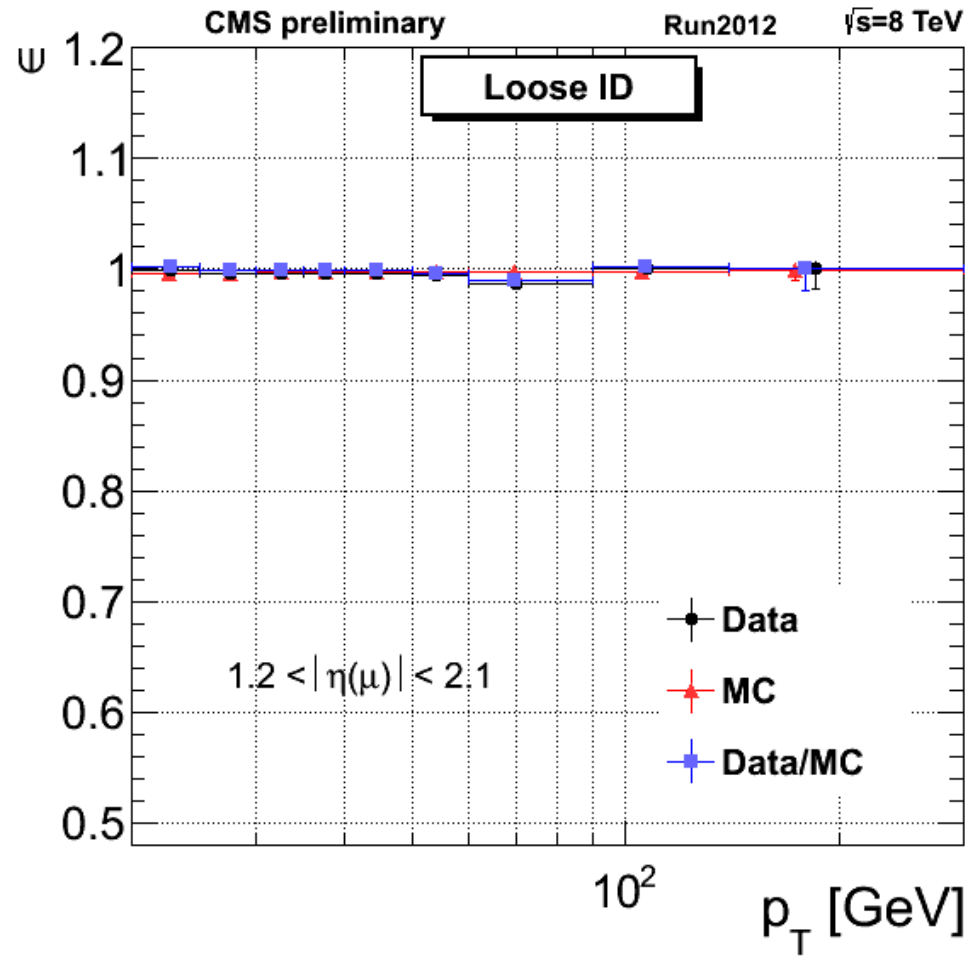
ID efficiency

- Loose Selection Efficiency (Data and MC) and scale factors vs p_T in the overlap
- TnP method used on Zs
- Probes general tracks



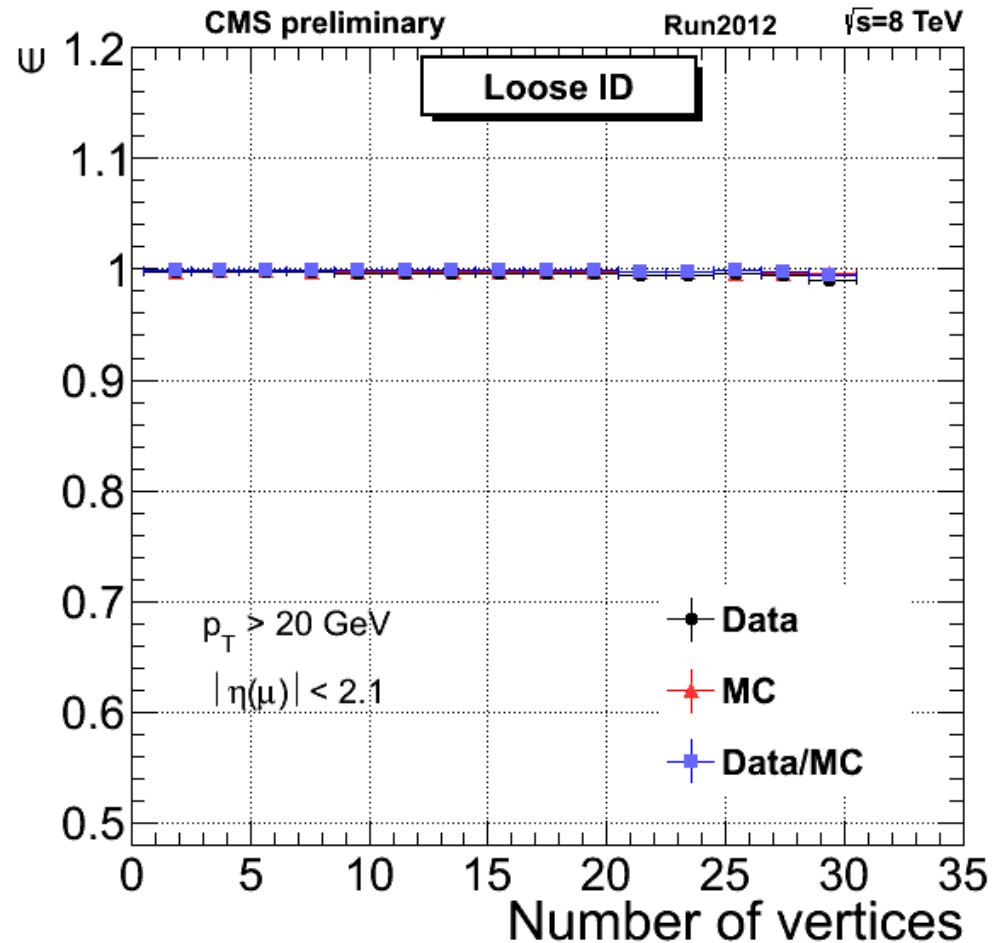
ID efficiency

- Loose Selection Efficiency (Data and MC) and scale factors vs p_T in the endcap
- TnP method used on Z_s
- Probes general tracks



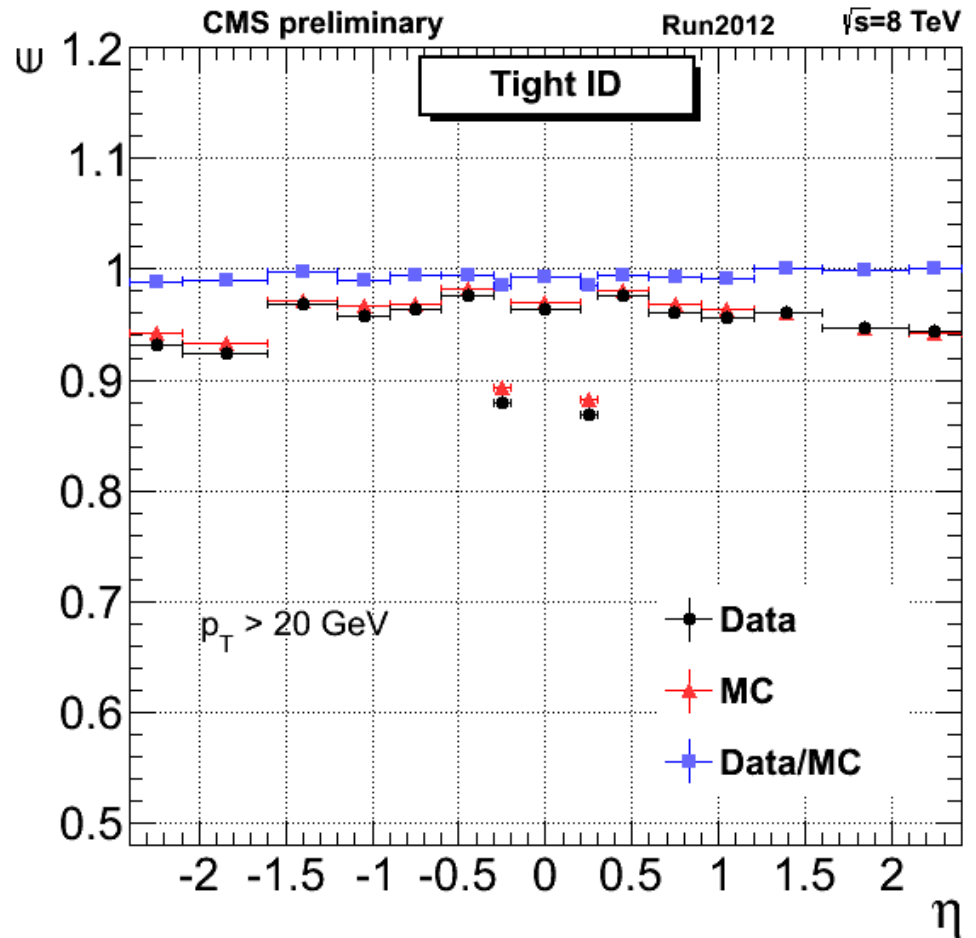
ID efficiency

- Loose Selection Efficiency (Data and MC) and scale factors vs Number of Vertices
- TnP method used on Zs
- Probes general tracks



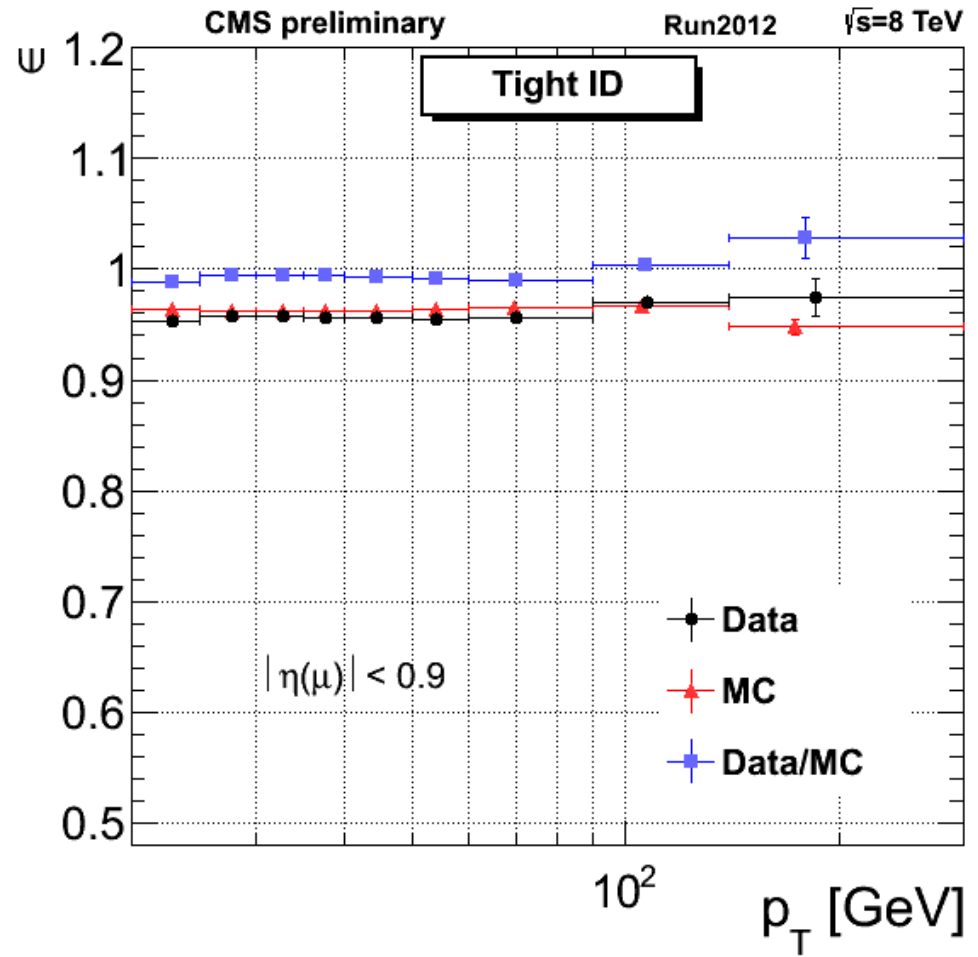
ID efficiency

- Tight Selection Efficiency (Data and MC) and scale factors vs eta
- TnP method used on Zs
- Probes general tracks



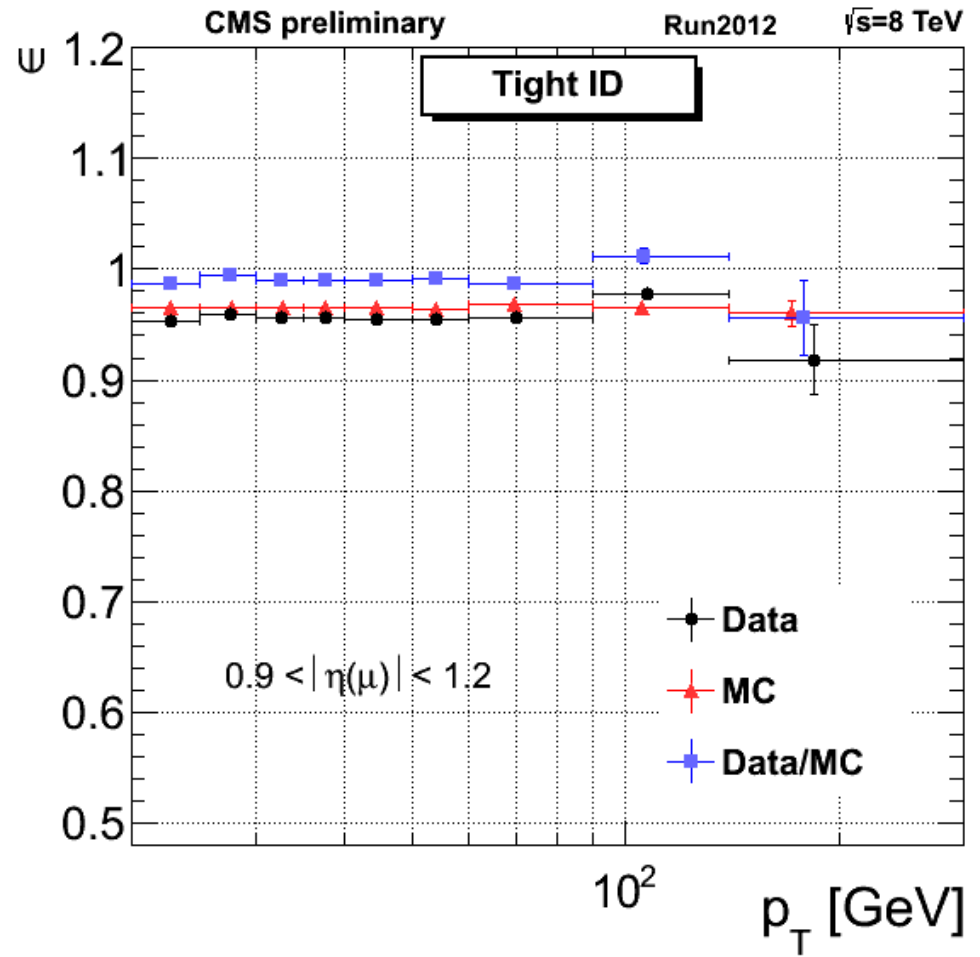
ID efficiency

- Tight Selection Efficiency (Data and MC) and scale factors vs p_T in the barrel
- TnP method used on Z_s
- Probes general tracks



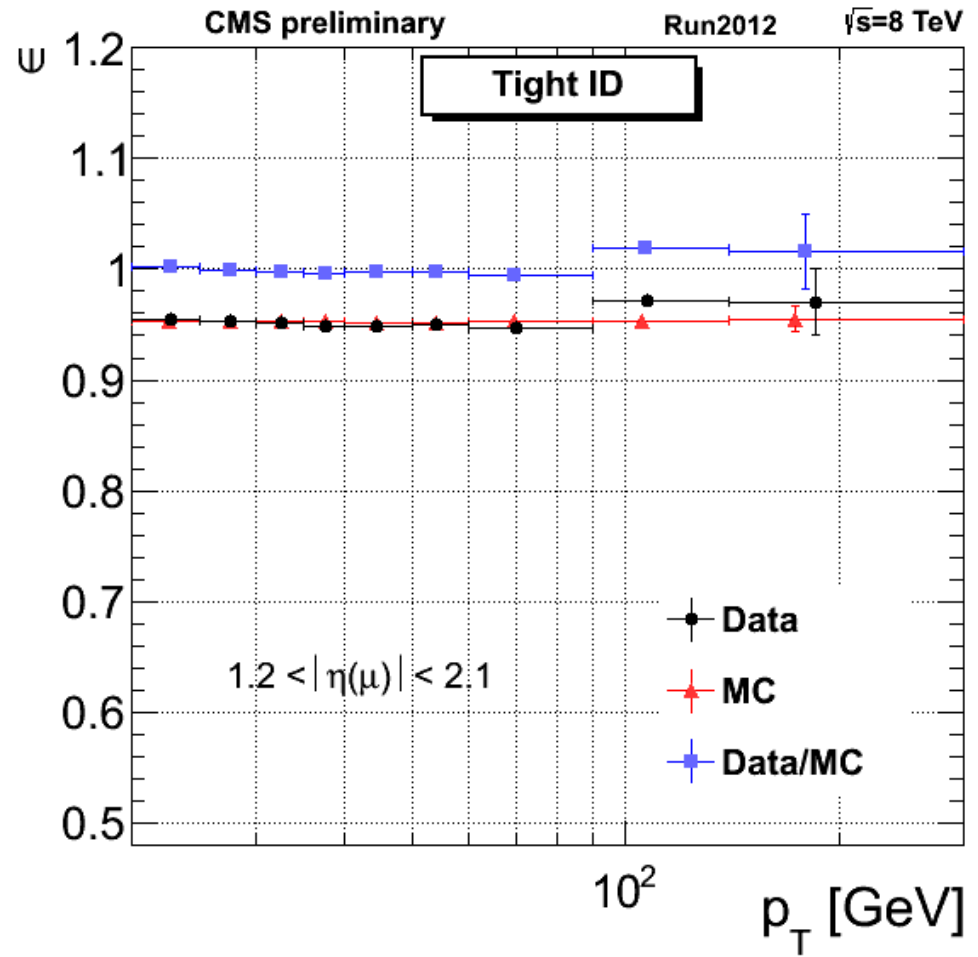
ID efficiency

- Tight Selection Efficiency (Data and MC) and scale factors vs p_T in the overlap
- TnP method used on Z_s
- Probes general tracks



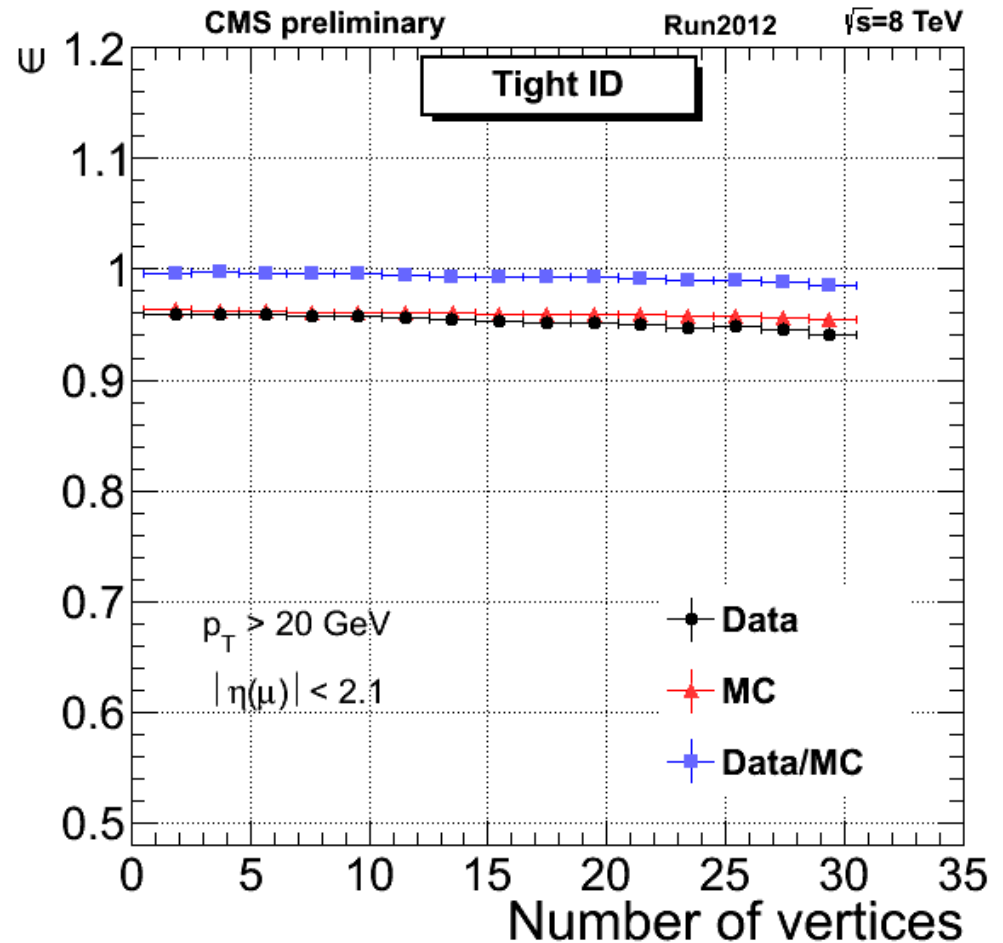
ID efficiency

- Tight Selection Efficiency (Data and MC) and scale factors vs p_T in the endcap
- TnP method used on Z_s
- Probes general tracks



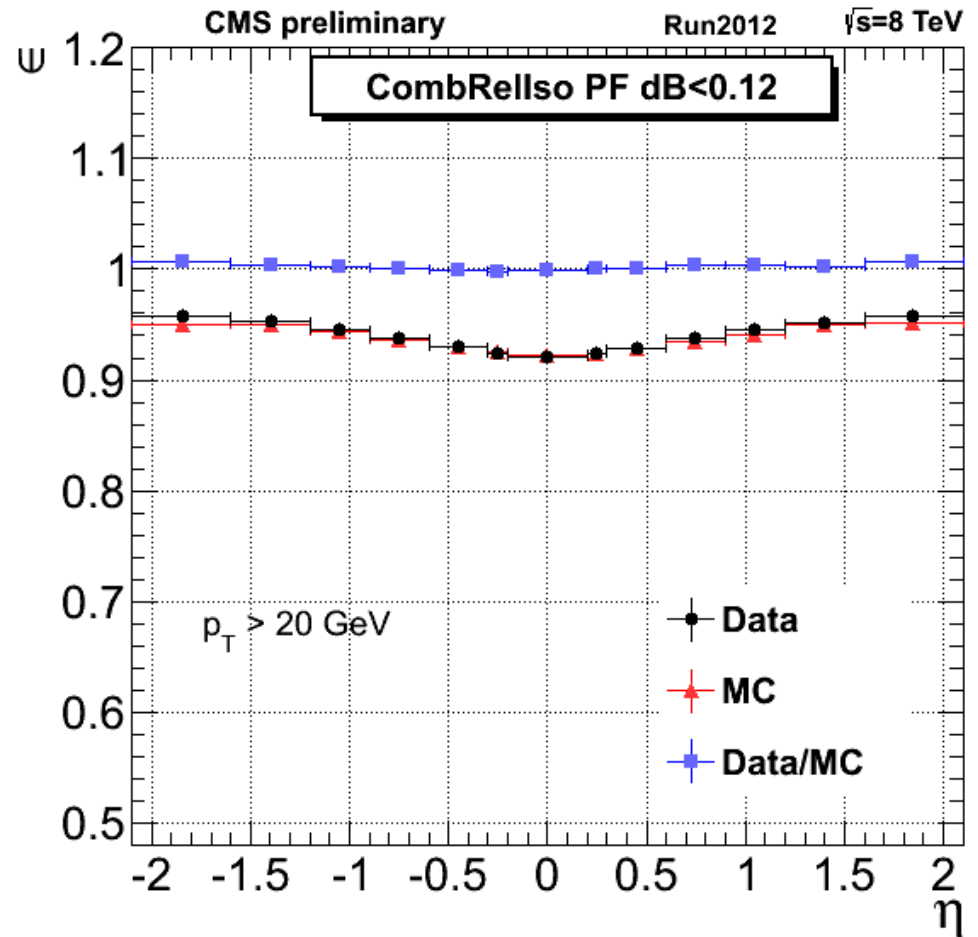
ID efficiency

- Tight Selection Efficiency (Data and MC) and scale factors vs Number of Vertices
- TnP method used on Zs
- Probes general tracks



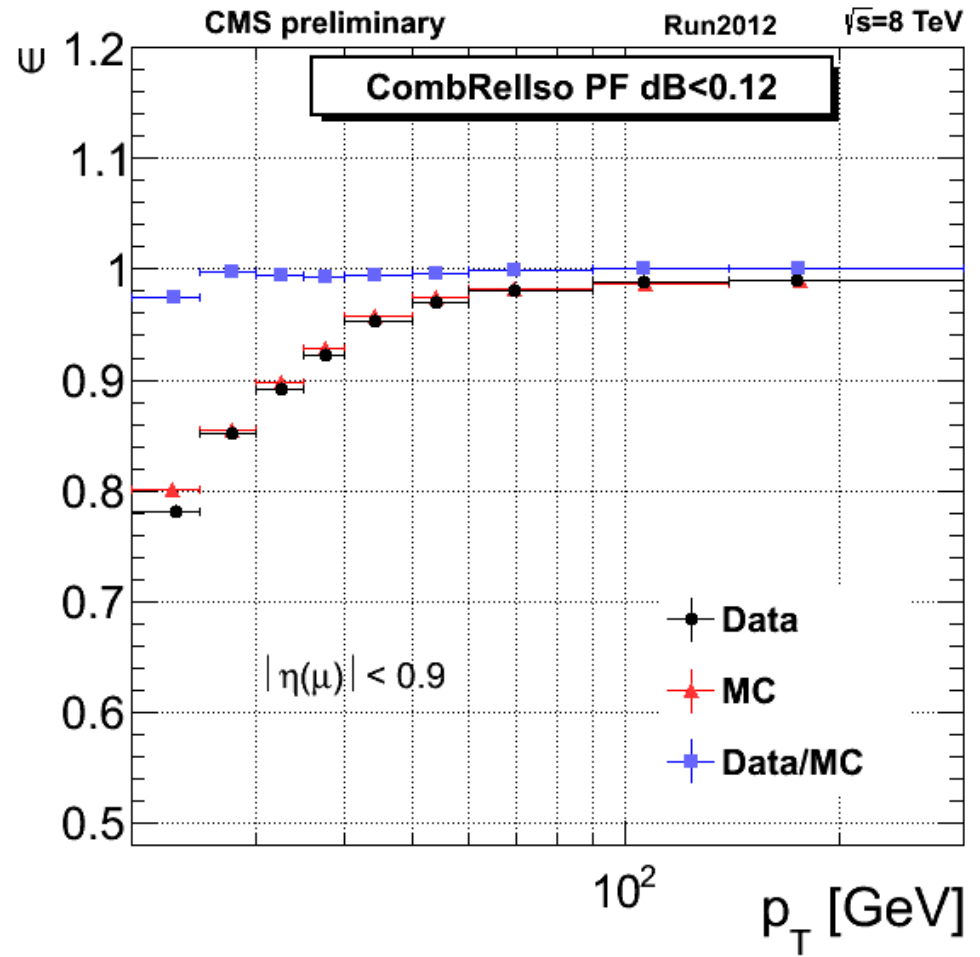
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.12 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs eta
- TnP method used on Zs
- Probes Tight Muons



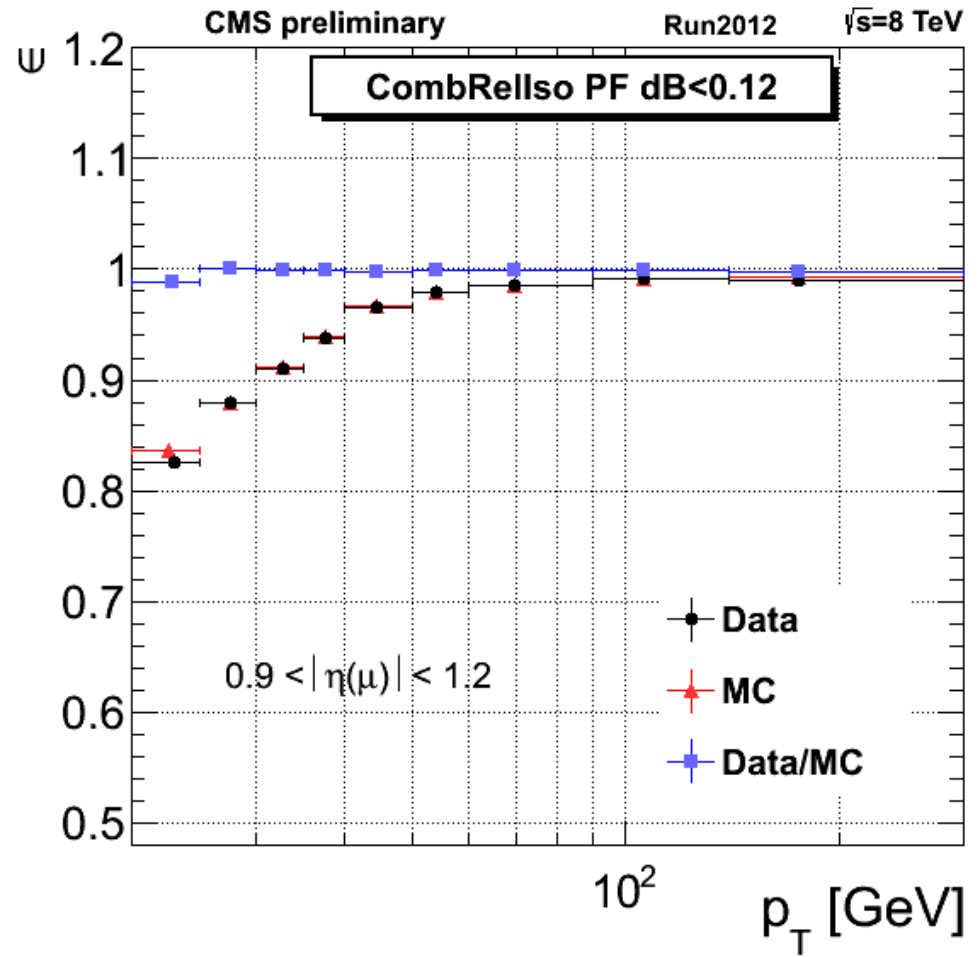
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.12 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs p_T in the barrel
- TnP method used on Zs
- Probes Tight Muons



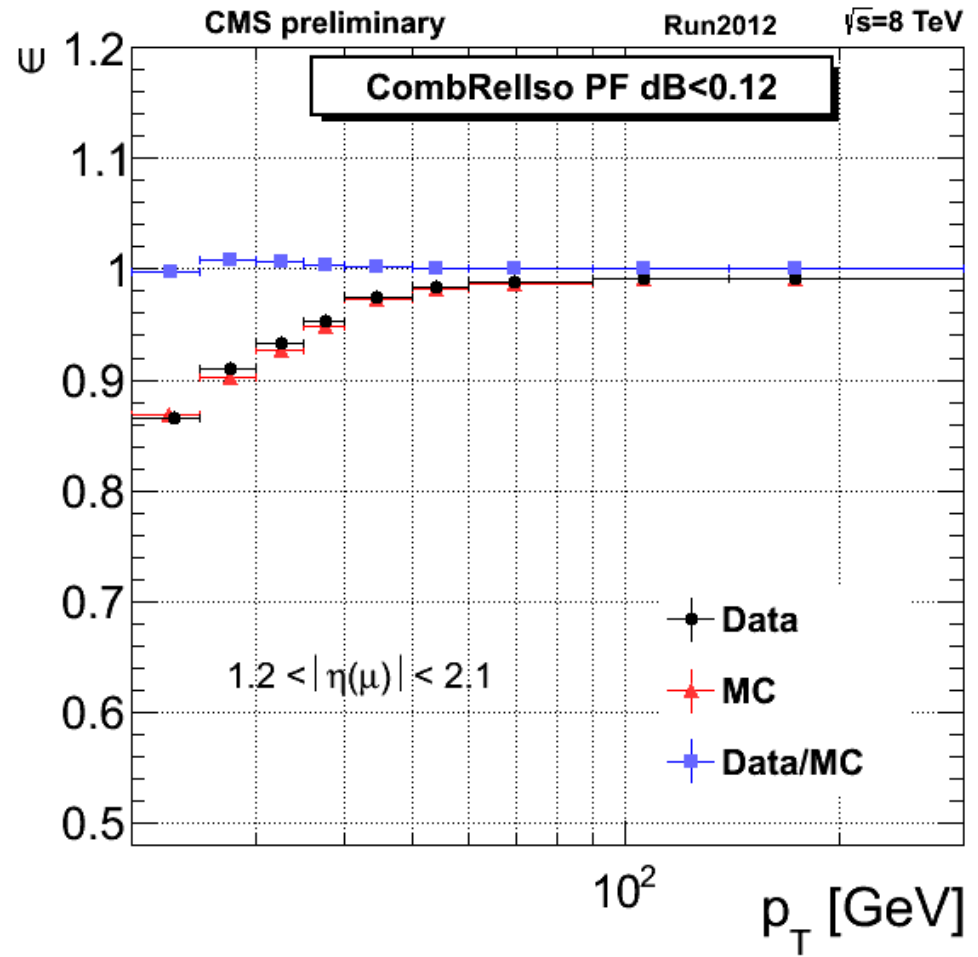
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.12 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs p_T in the overlap
- TnP method used on Zs
- Probes Tight Muons



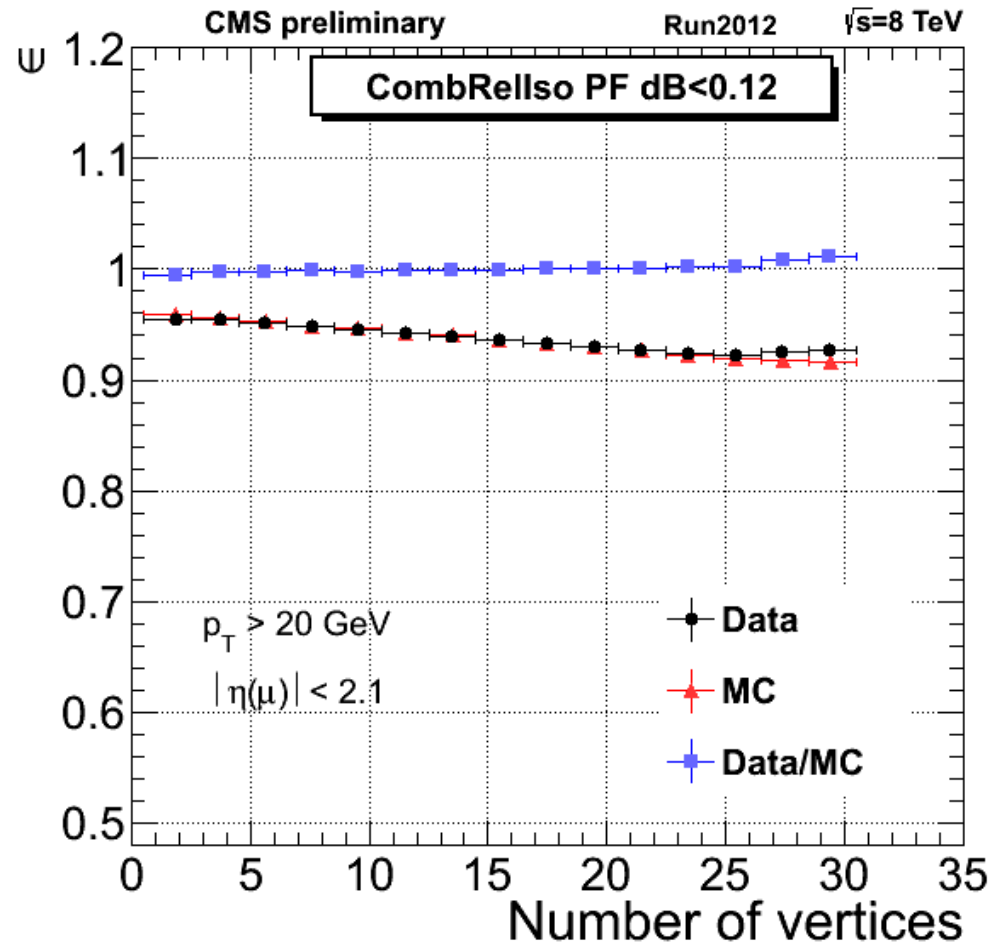
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.12 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs p_T in the endcap
- TnP method used on Zs
- Probes Tight Muons



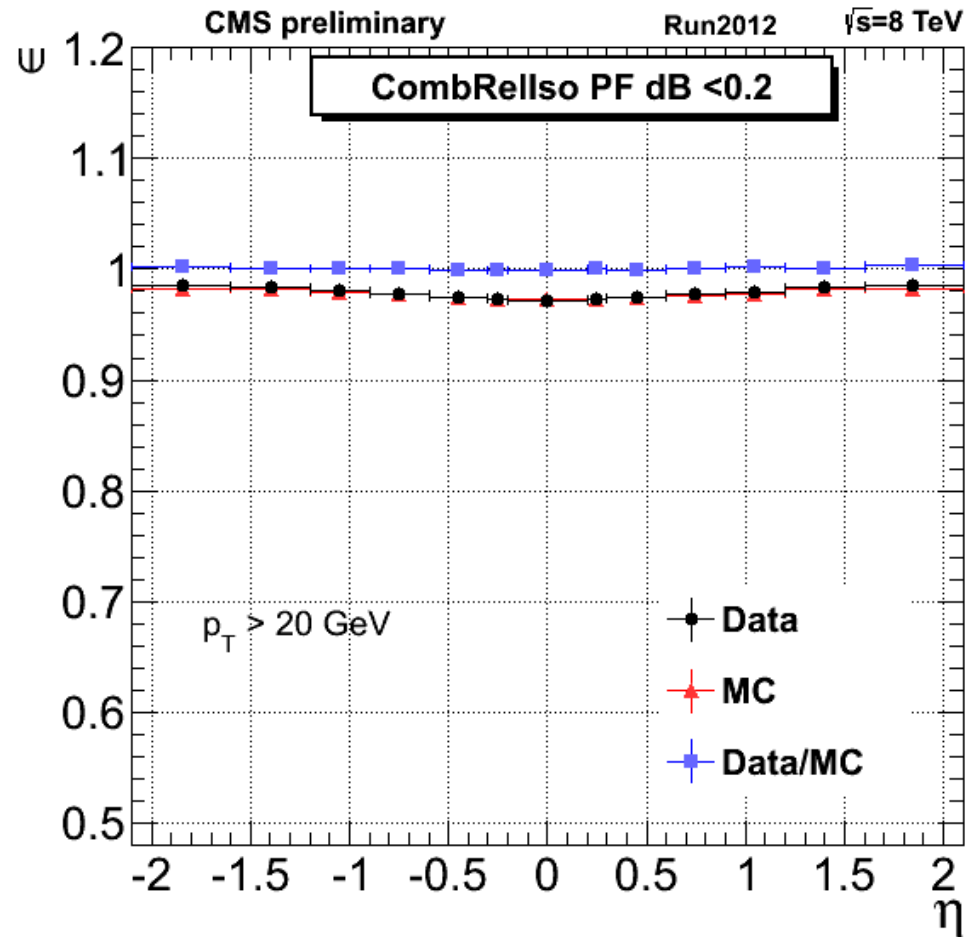
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.12 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs Number of Vertices
- TnP method used on Zs
- Probes Tight Muons



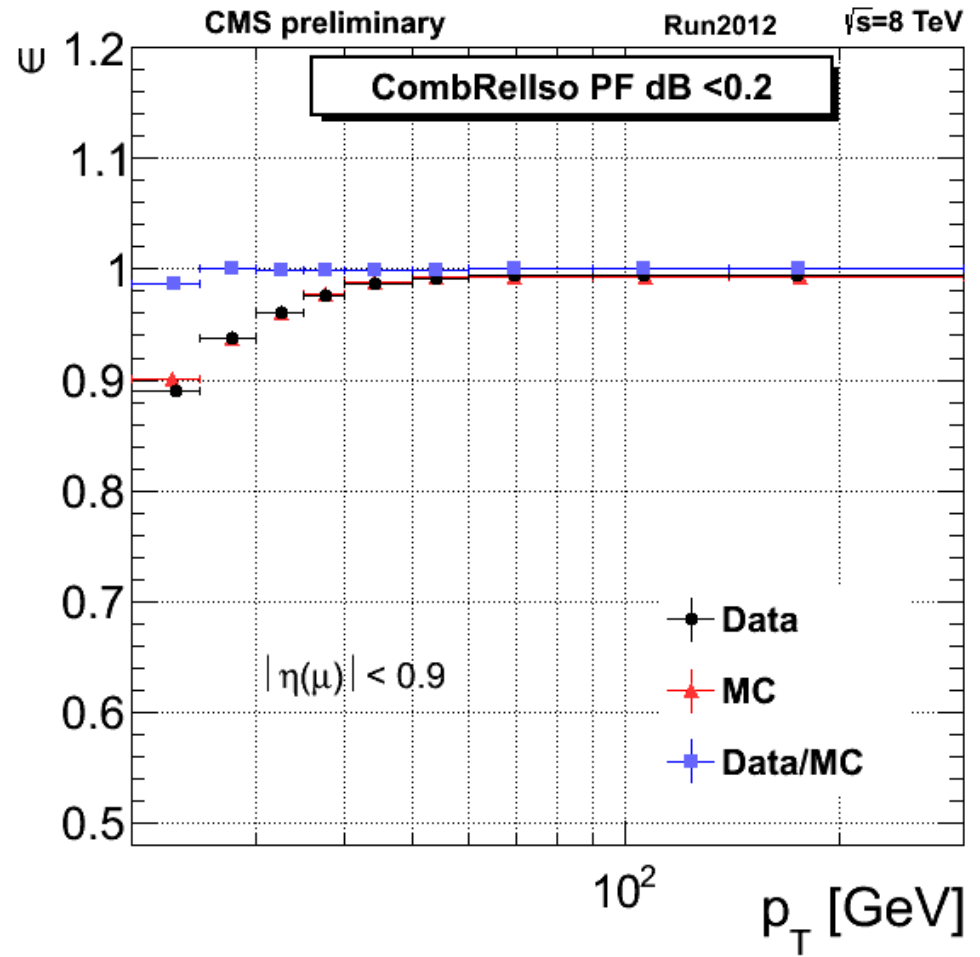
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.20 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs Eta
- TnP method used on Zs
- Probes Tight Muons



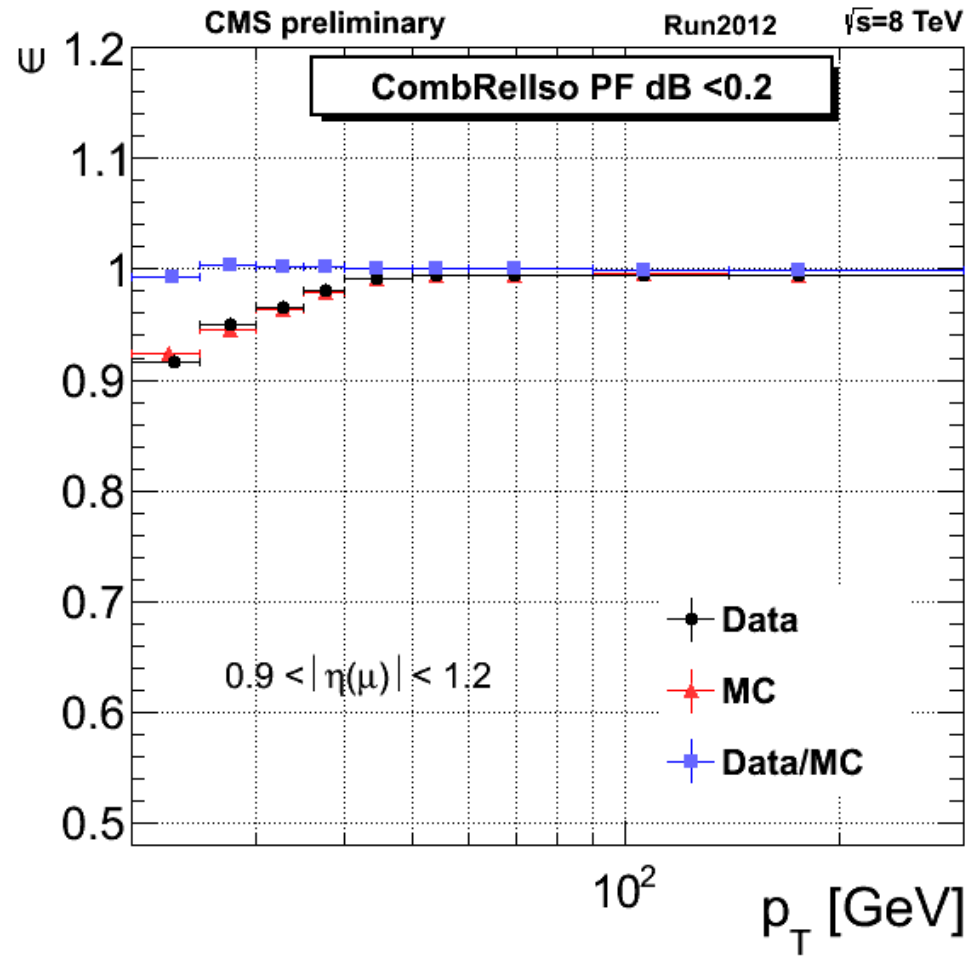
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.20 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs p_T in the barrel
- TnP method used on Zs
- Probes Tight Muons



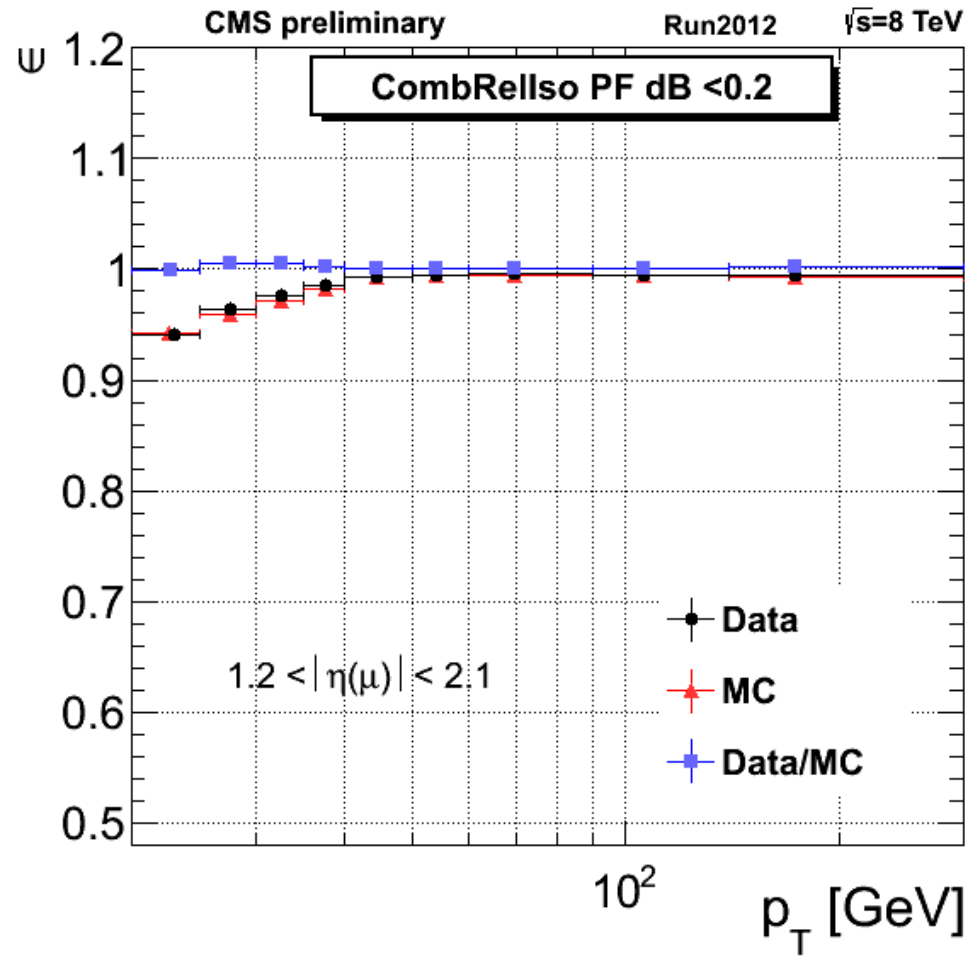
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.12 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs pt in the overlap
- TnP method used on Zs
- Probes Tight Muons



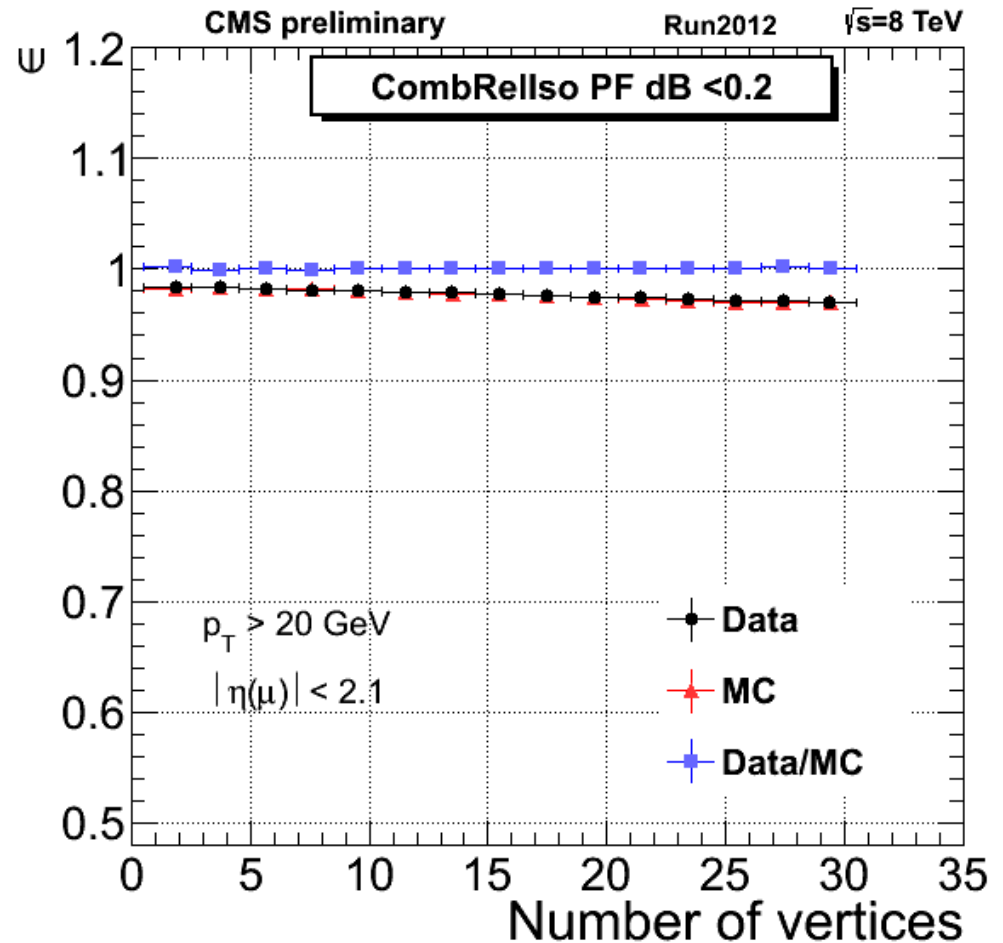
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.20 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs p_T in the endcap
- TnP method used on Zs
- Probes Tight Muons



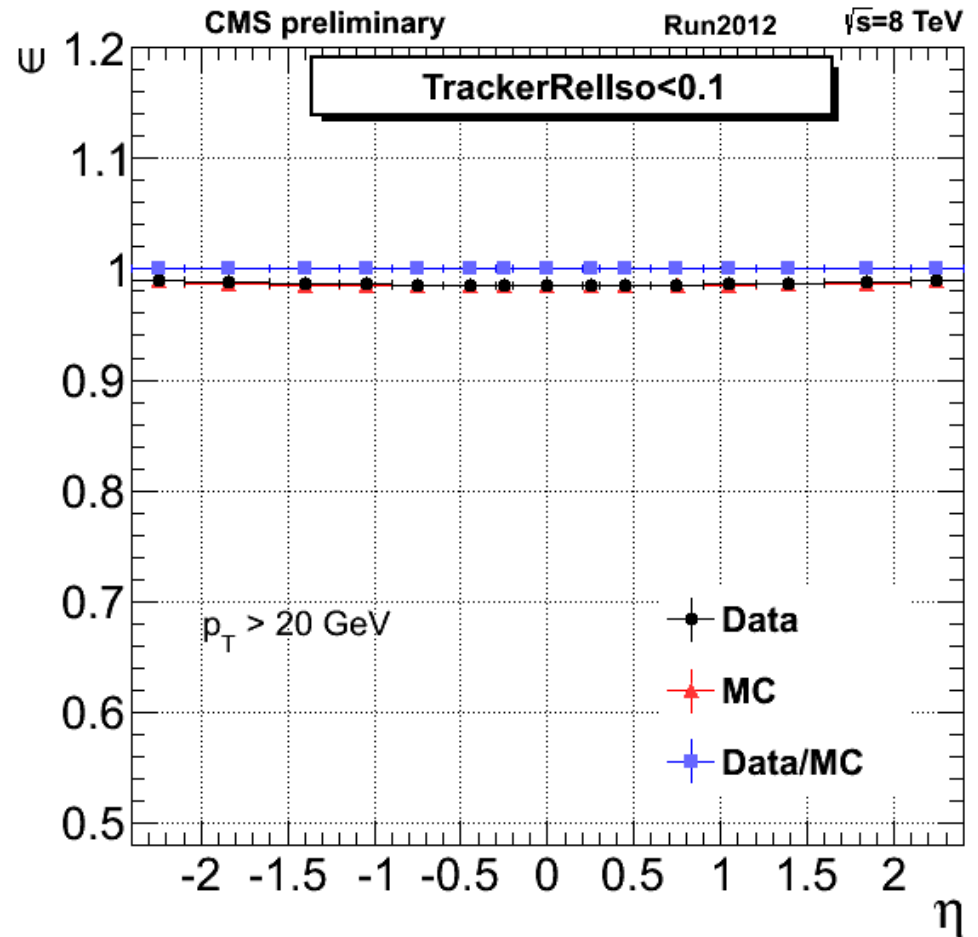
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.20 for PF Combined Relative Isolation with DeltaBeta correction for pile up vs Number of Vertices
- TnP method used on Zs
- Probes Tight Muons



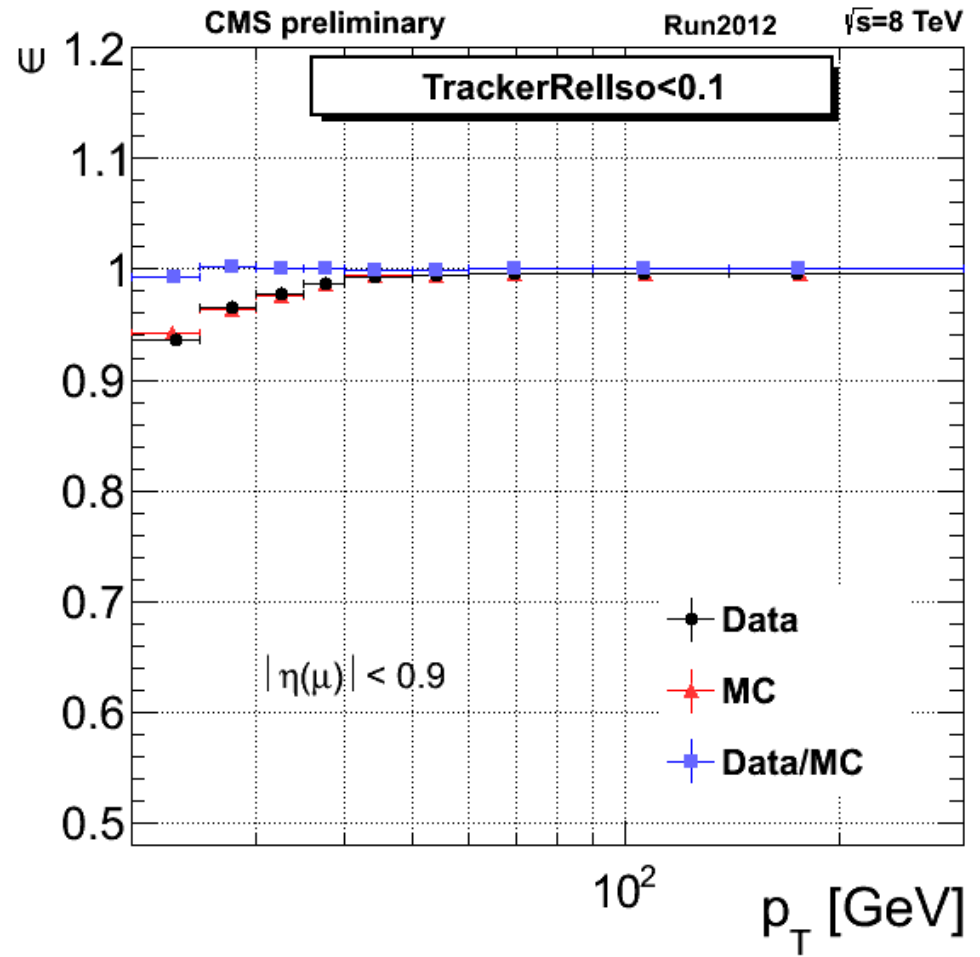
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.1 for Tracker Relative Isolation vs eta
- TnP method used on Zs
- Probes Tight Muons



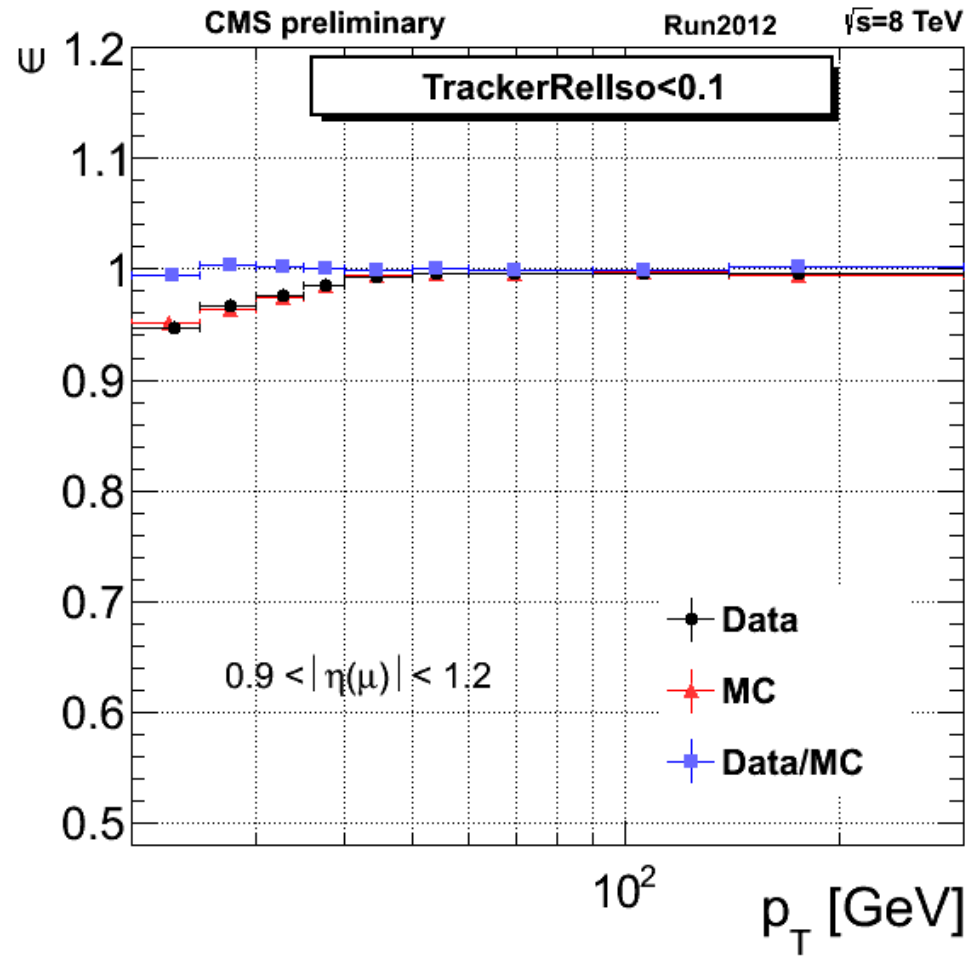
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.1 for Tracker Relative Isolation vs p_T in the barrel
- TnP method used on Zs
- Probes Tight Muons



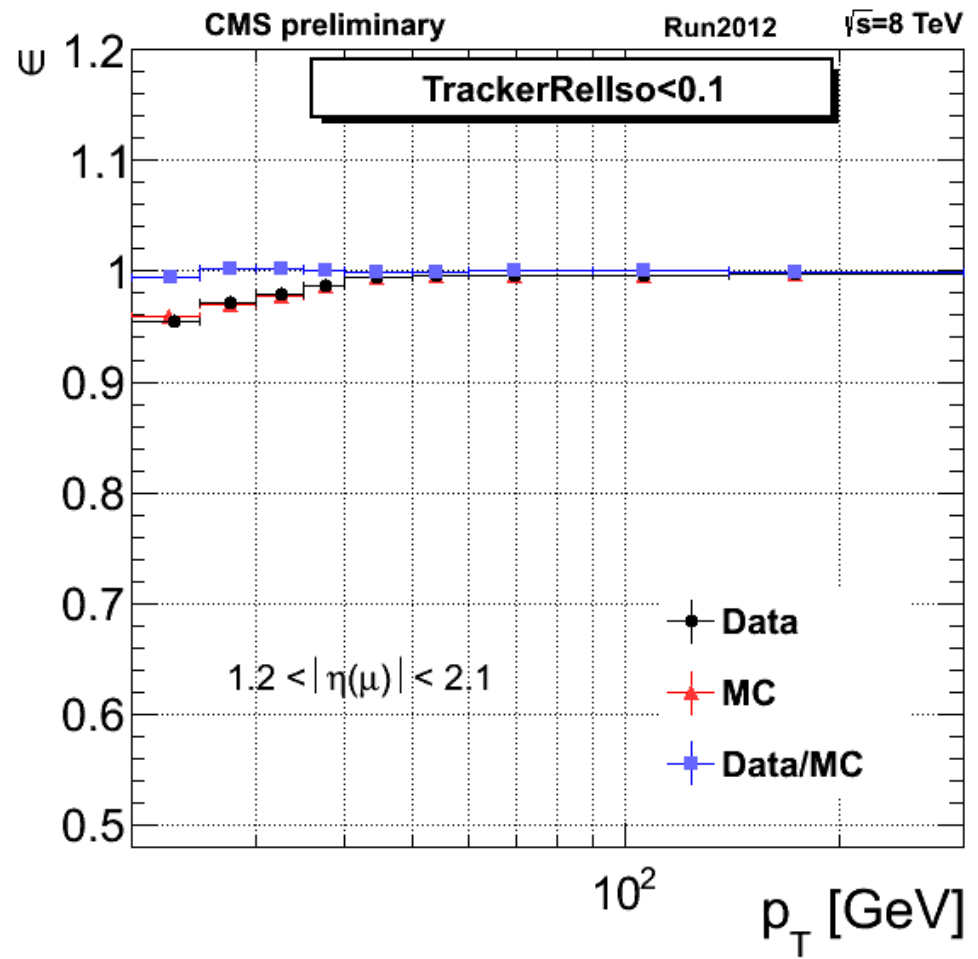
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.1 for Tracker Relative Isolation vs p_T in the overlap
- TnP method used on Zs
- Probes Tight Muons



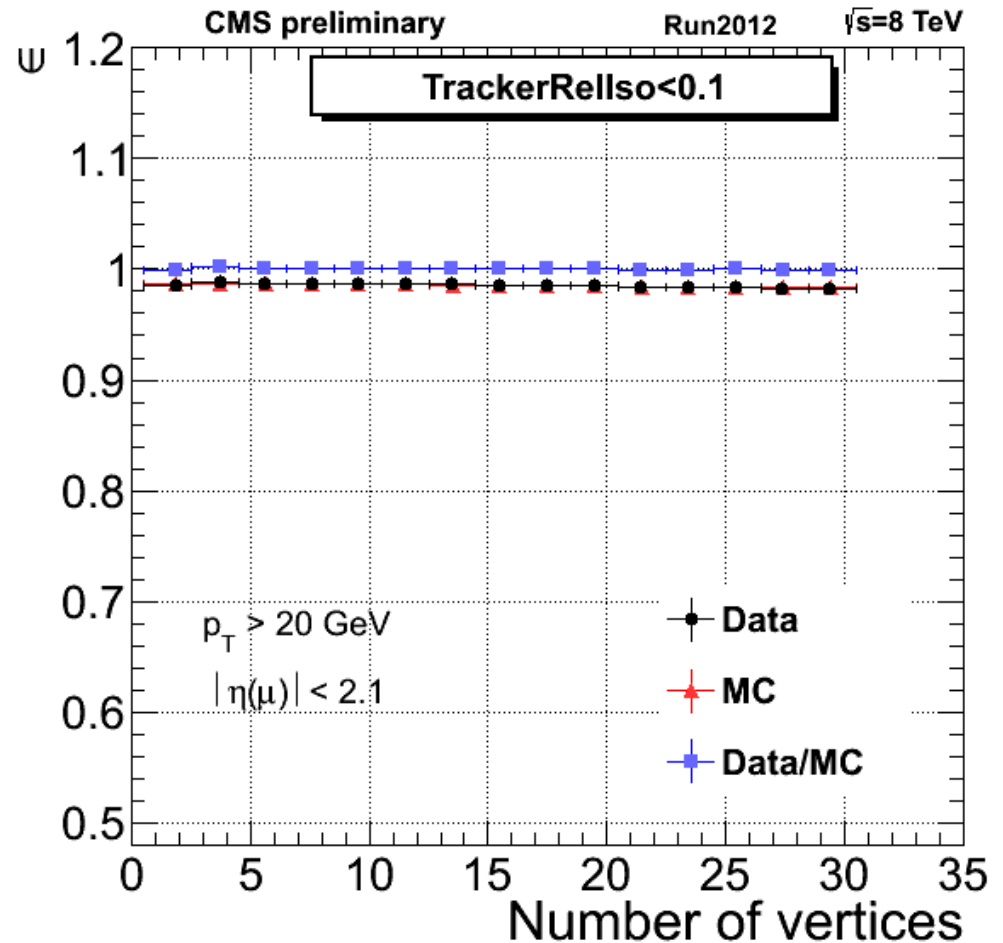
Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.1 for Tracker Relative Isolation vs p_T in the endcap
- TnP method used on Zs
- Probes Tight Muons



Isolation efficiency

- Efficiency (Data and MC) and scale factors for a cut at < 0.1 for Tracker Relative Isolation vs number vertices
- TnP method used on Zs
- Probes Tight Muons



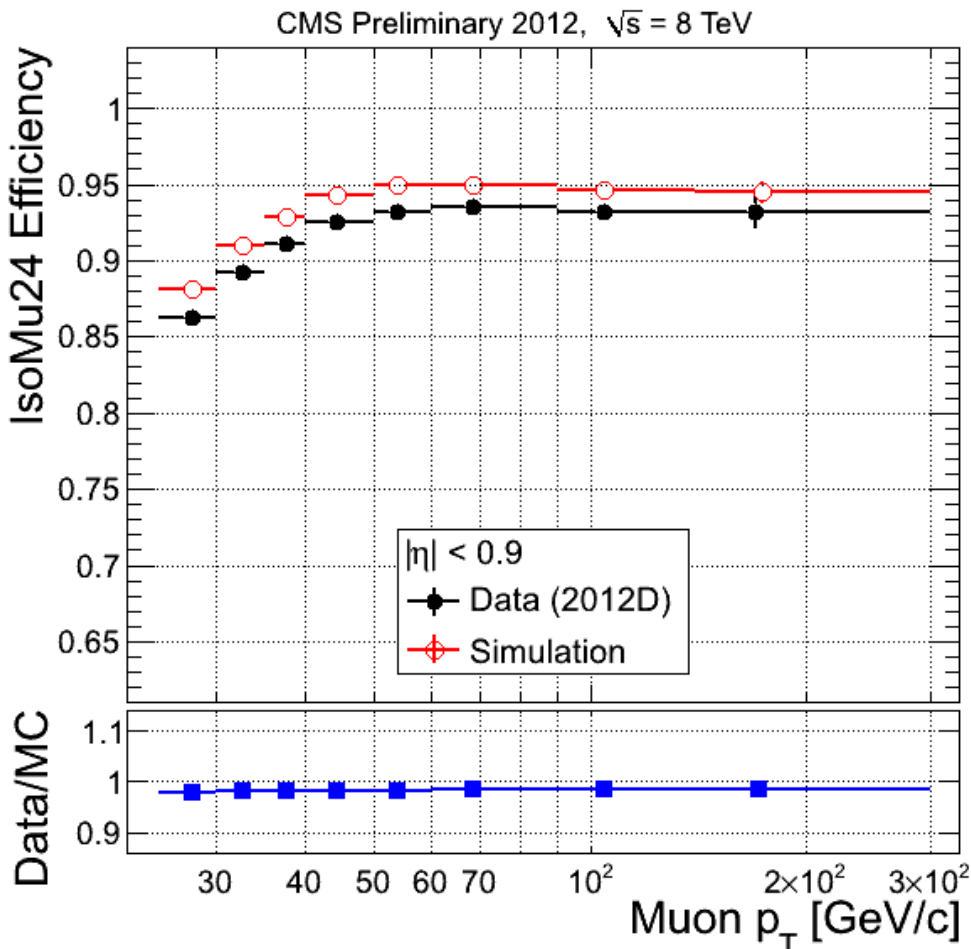
Single Muon Trigger Efficiencies in 2012 Run D

Method

- Efficiency of triggers `HLT_Mu40`, `HLT_IsoMu24` vs p_T , η , vertex multiplicity w.r.t. **tight muon ID**
 - tight muon ID:
 - Particle Flow (PF) && Global Muon ID
 - Global track's $\chi^2_{\text{GLB}} / \text{dof} < 10$
 - # valid muon hits > 0 , # matched muon stations > 1
 - Impact parameters of tracker track w.r.t. primary vertex: $|d_{xy}| < 0.2 \text{ cm}$, $|d_z| < 0.5 \text{ cm}$
 - # valid pixel hits > 0 , # tracker layers with measurements > 5
- Method: **tag-and-probe** with Z resonance
 - **tag**:
 - tight muon ID, $p_T > 15 \text{ GeV}/c$
 - matched with `HLT_IsoMu24(_eta2p1)`
 - **probe**:
 - tight muon ID
 - (only for IsoMu24 efficiency) Loose combined-relative PF isolation:
$$[\sum E_T(\text{ch-hadr from PV}) + \sum E_T(\text{neutr-hadr}) + \sum E_T(\text{phot})] / p_T^\mu < 0.2 \quad (\Delta R = 0.4)$$

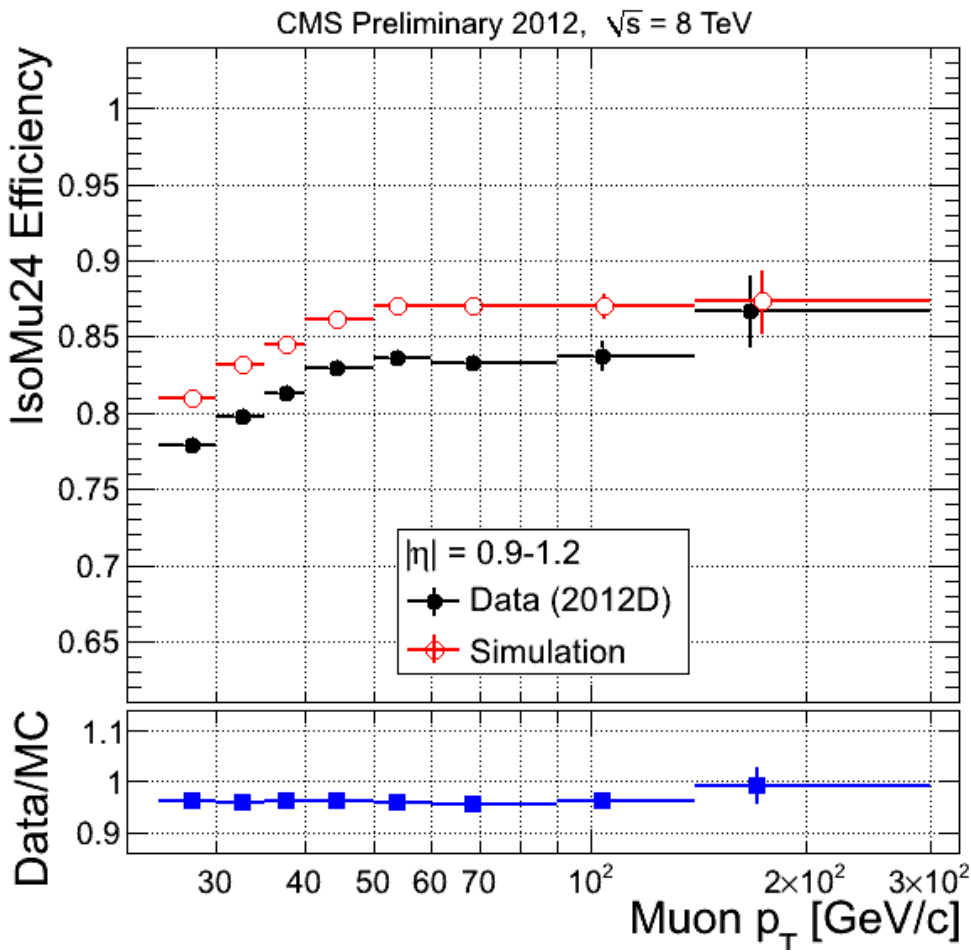
“ $\Delta\beta$ correction” on neutral component, estimated using the charged particles in the isolation cone originating from non-primary vertexes, and the neutral-to-charged ratio
- MC: $Z \rightarrow \mu\mu$, with pileup reweighting to observed number of reconstructed vertices

HLT_IsoMu24: Efficiency VS p_T ($|\eta| < 0.9$)



- HLT_IsoMu24 efficiency vs muon p_T
 - data (2012 D)
 - MC
 - data/MC scale factors
- Probe:
 - tight muon
 - combined relative PF isolation
 - $p_T > 25$ GeV/c
 - $|\eta| < 0.9$ (muon barrel, DT only)

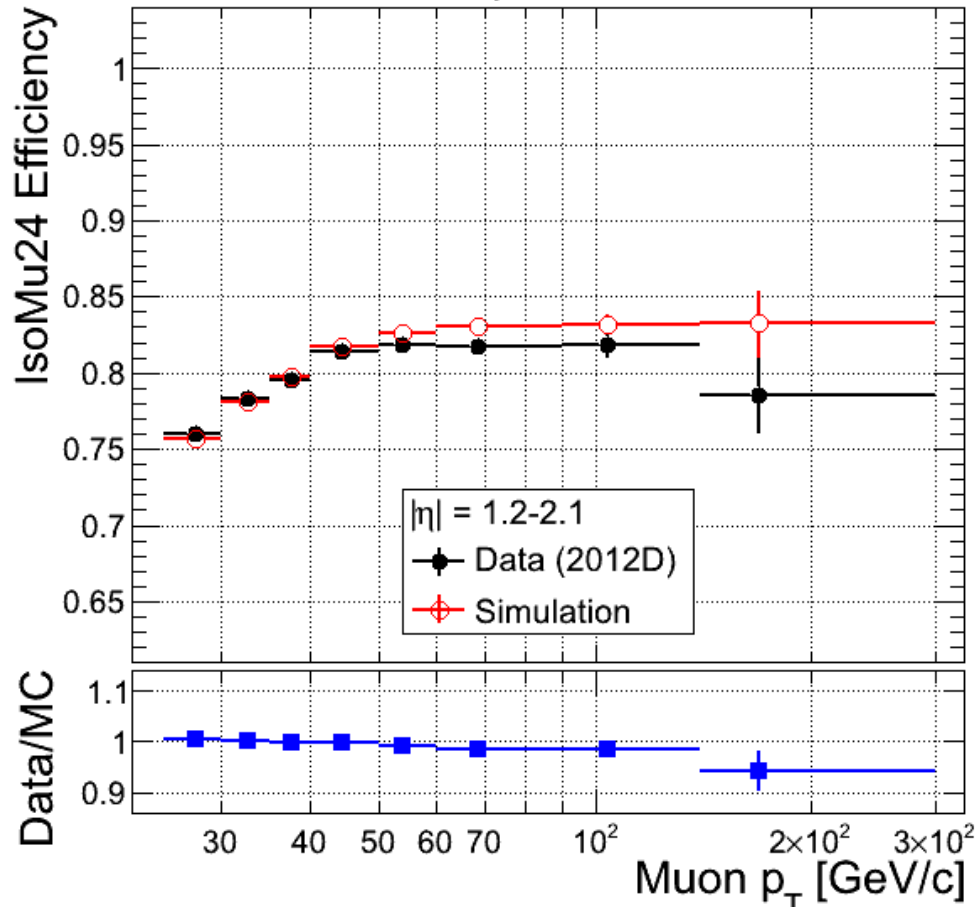
HLT_IsoMu24: Efficiency VS p_T ($|\eta| = 0.9-1.2$)



- HLT_IsoMu24 efficiency vs muon p_T
 - data (2012 D)
 - MC
 - data/MC scale factors
- Probe:
 - tight muon
 - combined relative PF isolation
 - $p_T > 25$ GeV/c
 - $0.9 < |\eta| < 1.2$ (DT-CSC overlap)

HLT_IsoMu24: Efficiency VS p_T ($|\eta| = 1.2-2.1$)

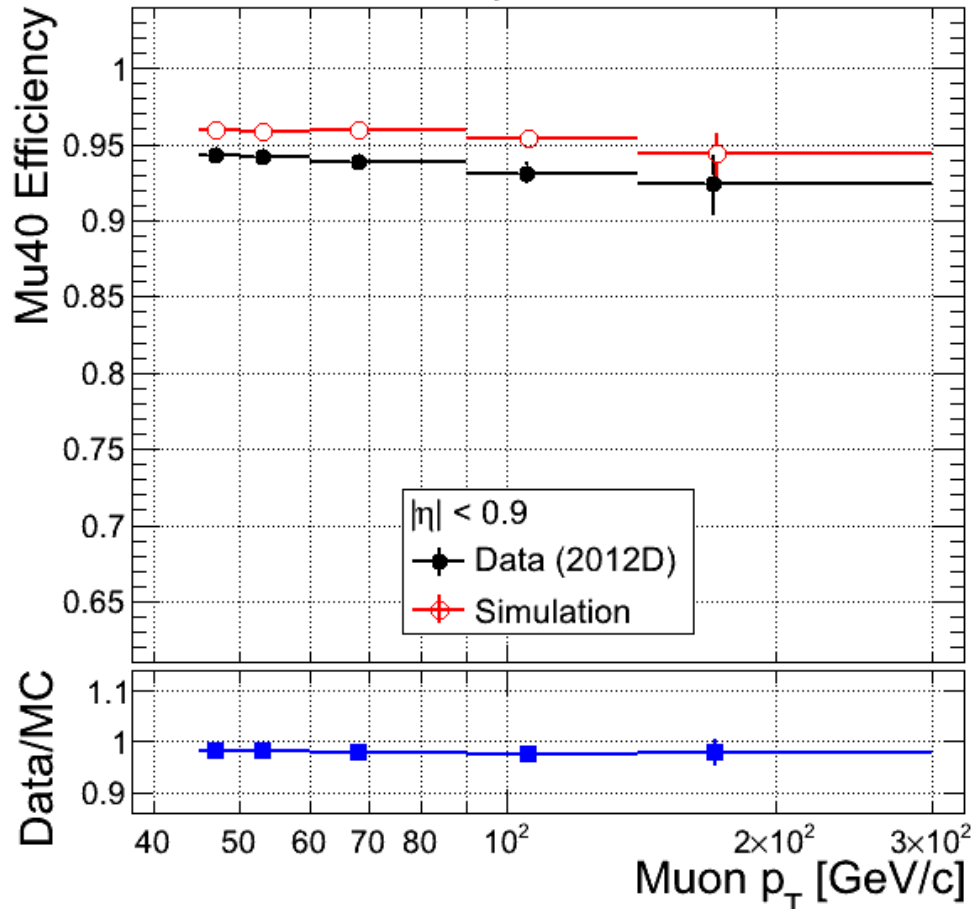
CMS Preliminary 2012, $\sqrt{s} = 8$ TeV



- HLT_IsoMu24 efficiency vs muon p_T
 - data (2012 D)
 - MC
 - data/MC scale factors
- Probe:
 - tight muon
 - combined relative PF isolation
 - $p_T > 25$ GeV/c
 - $1.2 < |\eta| < 2.1$ (muon endcaps, CSC only)

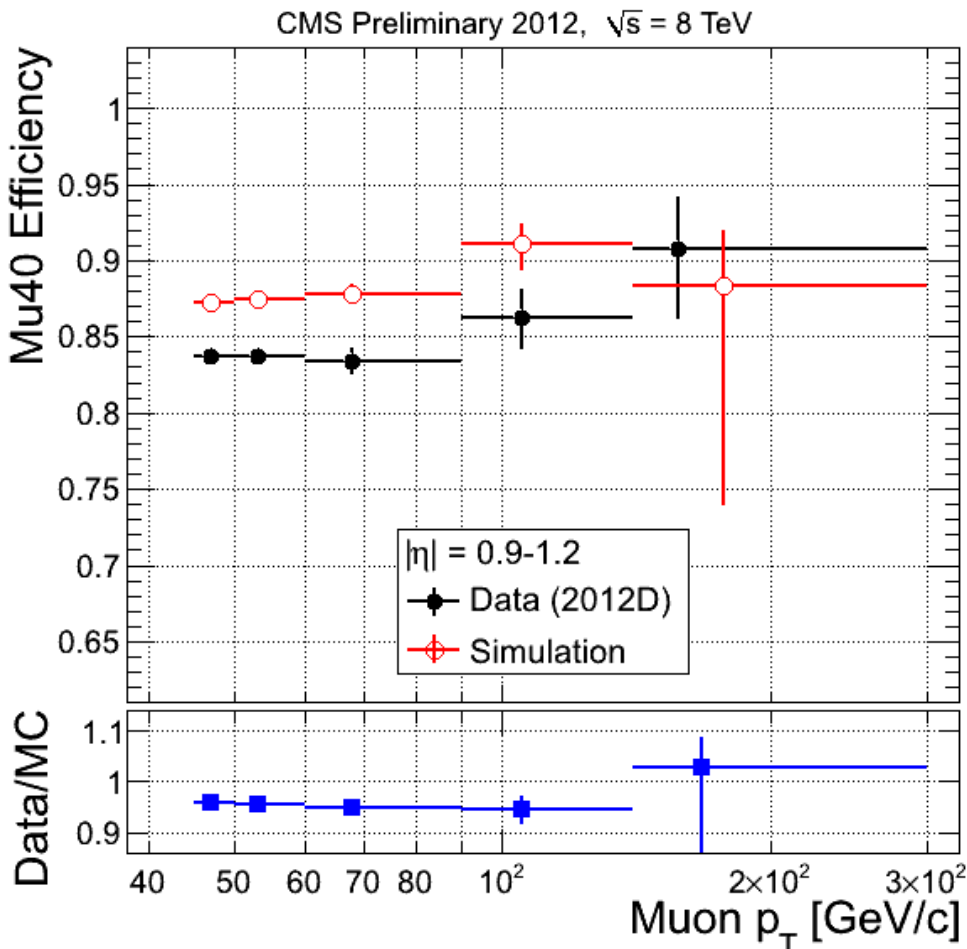
HLT_Mu40: Efficiency VS p_T ($|\eta| < 0.9$)

CMS Preliminary 2012, $\sqrt{s} = 8$ TeV



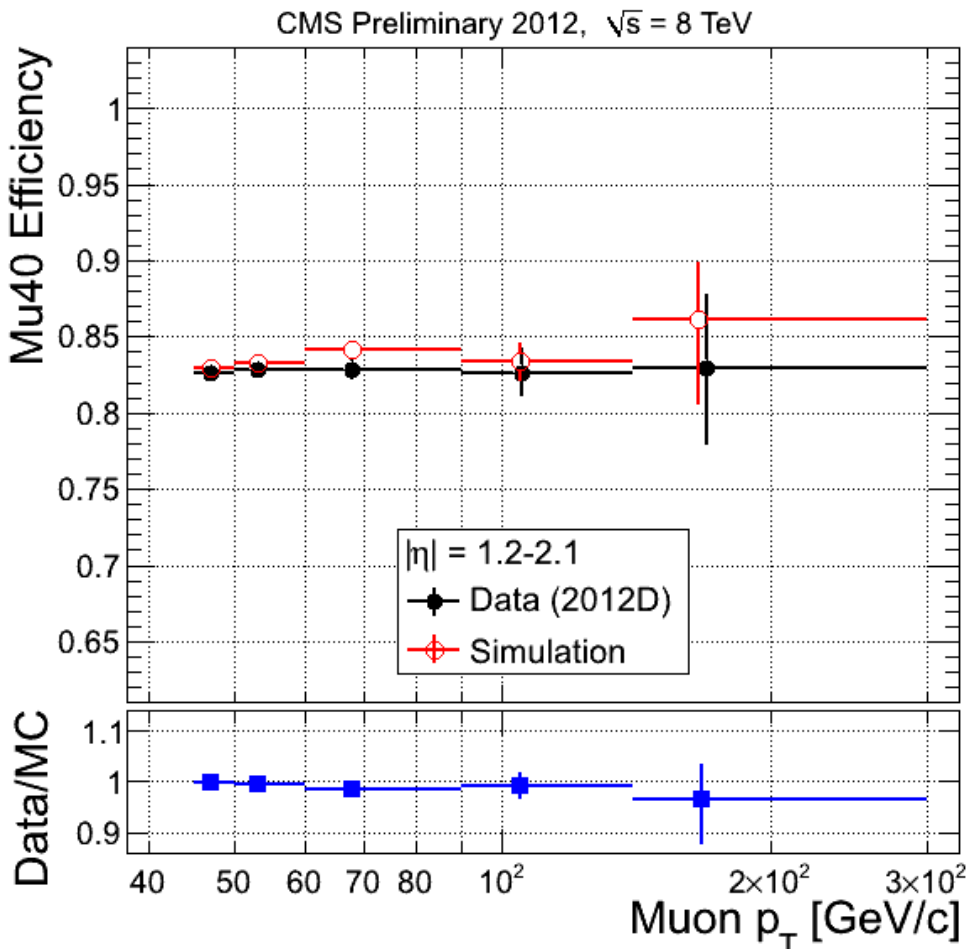
- HLT_Mu40 efficiency vs muon p_T
 - data (2012 D)
 - MC
 - data/MC scale factors
- Probe:
 - tight muon
 - $p_T > 45$ GeV/c
 - $|\eta| < 0.9$ (muon barrel, DT only)

HLT_Mu40: Efficiency VS p_T ($|\eta| = 0.9-1.2$)



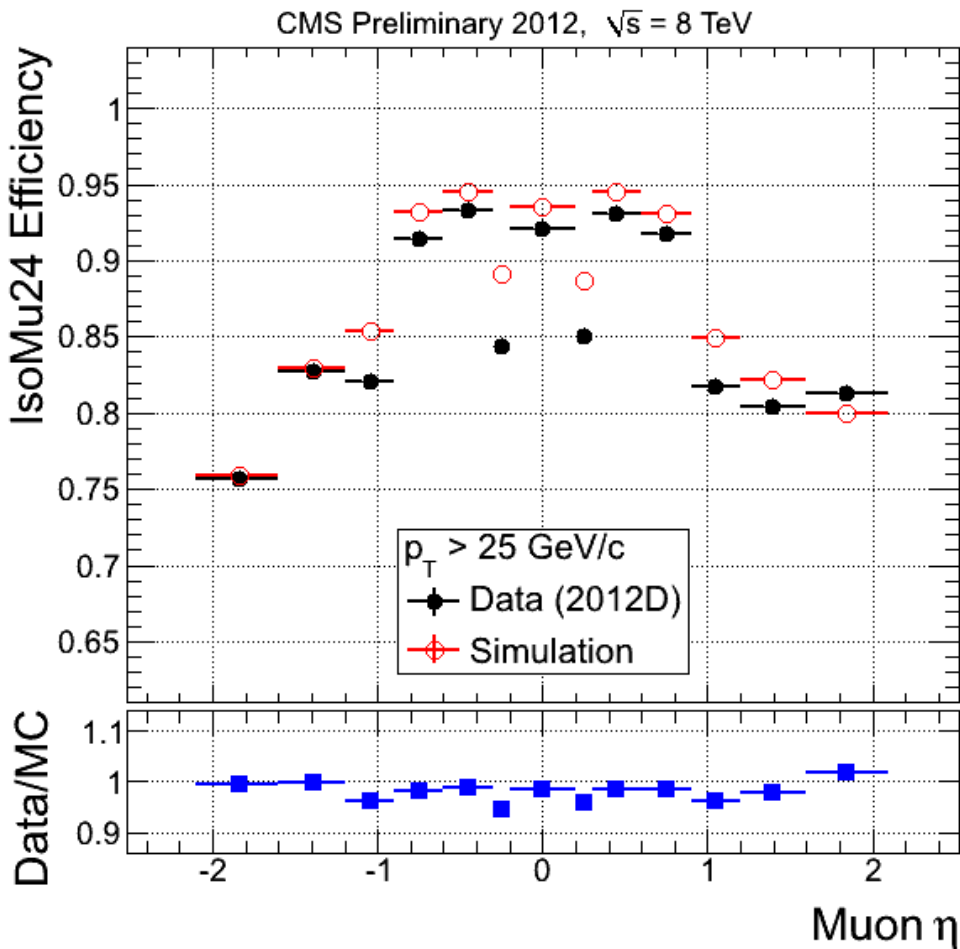
- HLT_Mu40 efficiency vs muon p_T
 - data (2012 D)
 - MC
 - data/MC scale factors
- Probe:
 - tight muon
 - $p_T > 45$ GeV/c
 - $0.9 < |\eta| < 1.2$ (DT-CSC overlap)

HLT_Mu40: Efficiency VS p_T ($|\eta| = 1.2-2.1$)



- HLT_Mu40 efficiency vs muon p_T
 - data (2012 D)
 - MC
 - data/MC scale factors
- Probe:
 - tight muon
 - $p_T > 45$ GeV/c
 - $1.2 < |\eta| < 2.1$ (muon endcaps, CSC only)

HLT_IsoMu24: Efficiency VS η ($p_T > 25$ GeV/c)



- HLT_IsoMu24 efficiency vs muon η

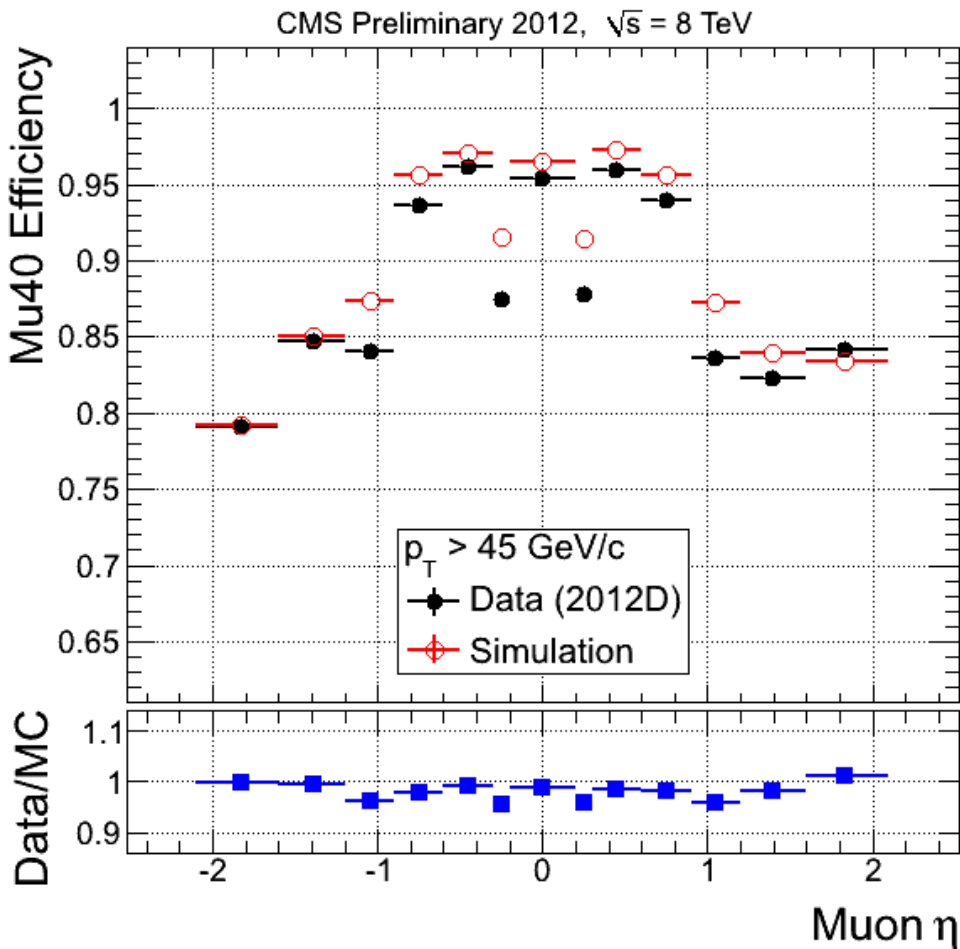
- data (2012 D)
- MC
- data/MC scale factors

- Probe:

- tight muon
- combined relative PF isolation
- $p_T > 25$ GeV/c

- $|\eta| = 0.2-0.3$: dips due to cracks b/w DT wheels 0 and ± 1
- $|\eta| > 1.2$: asymmetry due to CSC bad (non-operational) chambers

HLT_Mu40: Efficiency VS η ($p_T > 45$ GeV/c)



- HLT_Mu40 efficiency vs muon η

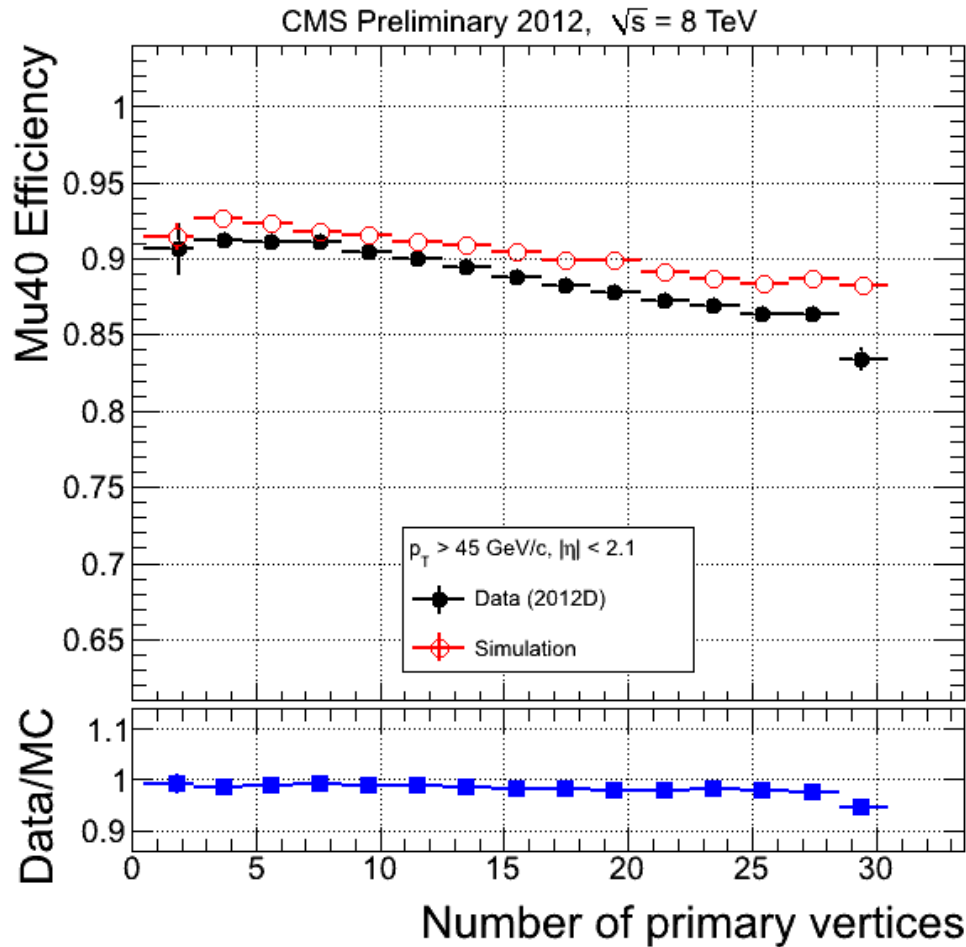
- data (2012 D)
- MC
- data/MC scale factors

- Probe:

- tight muon
- $p_T > 45$ GeV/c

- $|\eta| = 0.2-0.3$: dips due to cracks b/w DT wheels 0 and ± 1
- $|\eta| > 1.2$: asymmetry due to CSC bad (non-operational) chambers

HLT_Mu40: Efficiency vs N.Vertices ($p_T > 45$ GeV/c, $|\eta| < 2.1$)



- HLT_Mu40 efficiency vs number of reconstructed primary vertices
 - data (2012 D)
 - MC
 - data/MC scale factors
- Probe:
 - tight muon
 - $p_T > 45$ GeV/c
 - $|\eta| < 2.1$