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High-p_T Muon ID Cuts and Efficiencies for use with 5.3.1 Data and 5.3.3 MC.

Victoria Martin, Northwestern University

Abstract

We summarise the muon ID cuts and efficiencies that should be used with 5.3.1 data and 5.3.3 MC. This combination is being used by the top and exotic groups. This note should be read in conjunction with CDF note 7031, which describes the main features of high-p_T muons in Gen 5.

Version History

Version 2.0 of the note updates the data number for version 7.0 of the good run list.

1 Introduction

1.1 Data sample

For this analysis we use the inclusive muon sample `bhmu0d`. This sample is based on `MUON_CMUP18` and `MUON_CMX18` trigger, and has been reprocessed using `5.3.1`. We are using version 7.0 of the good run list given on:
`http://www-cdf.fnal.gov/internal/dqm/goodrun/v7/goodv7.html`. Please refer to "List for Top/EWK/Exotics electron/muons no silicon" (cmx bit ignored for run < 150145). This samples corresponds to about 330 pb^{-1} of data. The analysis is made using my own ntuple, not the top ntuple.

1.2 Monte Carlo Sample

The zewk3m MC sampled is used. It is generated with 5.3.3, and is run dependent with minimum bias events. Please note this an EWK MC sample, and not a Top MC sample.

1.3 Track corrections

For the all CMUP and (most) CMX muons in this note we are using COT-only beam-constrained tracking. That is, we have looked for the COT-parent track of the track associated to the muon (`muon.bestTrack()`). Then using the hits on this track we have rerun the track fitting constraining the track to come from the beamline as described by the `CotBeam` class.

For the momentum variables we have applied the so-called "Larry Correction" [1]:

$$\begin{aligned}
pinv &= \frac{Q}{|Q|} \cdot \frac{1}{p_T} \\
pinv &\to pinv + 0.00020 \cdot \sin(\phi_0 + 3.4) \\
pinv &\to pinv + 0.00022 \cdot \sin(3\,\phi_0 + 0.9) \\
pinv &\to pinv - 0.000026 - 0.000072 \cdot \cot + 0.00024 \cdot \cot^2 \\
pinv &\to pinv - 0.0002 \cdot \cot \cdot \sin(\phi_0 - 0.9) - 0.0002 \cdot \cot^2 \cdot \sin(\phi_0 - 4.1)
\end{aligned}$$

$$p_T \quad = \quad 1/pinv \tag{1}$$

Where ϕ_0, cot and p_T are the track helix parameters from the COT-only beam constrained track.

We use this corrected tracking for all of the kinematic variables that we cut on (p_T, z_0, ...), except for the impact parameter d_0. For d_0 we take it from track associated to the muon and correct it to for the beamline position. If the track has silicon hits we correct d_0 with respect to the `SvxBeam`. If the track has no silicon hits we correct d_0 with respect to the `CotBeam`. As shown in table 1 we make a different cut on d_0 depending on whether we have used the `SvxBeam` or `CotBeam`.

In the appendix we present result for `defTracks`.

2 Muon Identification Cuts

The suggested muon identification cuts for high-p_T muons for the combination of `5.3.1` data and `5.3.3` are summarized in table 1.

2.1 Track χ^2 cut

The track χ^2 cut is poorly modeled in the `5.3.3` data release. Therefore we do not apply any cut on the track-χ^2 in either the data or MC when we use this set of data and MC releases.

3 Suggested Muon Fiducial Cuts

Some analysers may wish to apply fiducial cuts to select *tight* muons. The main motivation to apply such cuts is to select only the muons that are best understood, therefore minimizing systematic errors associated with the selection of muons. However, for analyses that have have a low number of events such cuts may not be advantageous. We list the recommended cuts in table 2.

Where applying these cuts makes a difference to the efficiencies reported here we have added a comment to this effect.

There are three classes of fiducial cuts we use:

1. Cuts on the fiducial distances of tracks from the chambers as calculated by the `MuonFiducialTool`.

For all events:

No cosmic tag.

For all muon types (including stubless muons):

p_T	$>$	20 GeV/c
E_{EM}	$<$	$2 + \max(0, (p - 100) \cdot 0.0115)$ GeV
E_{HAD}	$<$	$6 + \max(0, (p - 100) \cdot 0.028)$ GeV
$isolation/p_T$	$<$	0.1
Number of axial SL with ≥ 5 hits	$\geq$	3
Number of stereo SL with ≥ 5 hits	$\geq$	3 (tight cuts)
	$\geq$	2 (loose cuts)
$\lvert z_0 \rvert$	$<$	60 cm
Tracks with no silicon hits attached: $\lvert d_0 \rvert$	$<$	0.2 cm
Tracks with silicon hits attached: $\lvert d_0 \rvert$	$<$	0.02 cm

Additionally for tight CMUP muons:

$\lvert \Delta x_{\mathrm{CMU}} \rvert$	$<$	3 cm
$\lvert \Delta x_{\mathrm{CMP}} \rvert$	$<$	5 cm
No bluebeam muons, run $<$ 154449		

Additionally for tight CMX muons:

run	$>$	150144
$\lvert \Delta x_{\mathrm{CMX}} \rvert$	$<$	6 cm

Table 1: Standard muon ID cuts for `5.3.1` data and `5.3.3` MC.

For CMUP muons:

fiducial distance from CMP:		
x-fid	$<$	0 cm
z-fid	$<$	-3 cm
No muons from the bluebeam region for run $<$ 154449		

For CMX muons:

ρ_{COT}	$>$	140 cm
fiducial distance from CMX:		
x-fid	$<$	0 cm
z-fid	$<$	-3 cm
No muons from the keystone region for run $<$ 186598		
No muons from the miniskirt region for run $<$ 186598		

Table 2: Suggested muon fiducial cuts for tight muons in release `5.3`.

2. A cut on the COT exit radius of the track associated to the muon.
3. Cuts to remove any muons from the bluebeam, keystone and miniskirts regions of the muon detectors for certain runs ranges. These ranges correspond to periods where these detectors were not operating and/or triggering in a stable fashion.

3.1 Miniskirt, Keystone and Bluebeam Rejection

The main motivation to apply these cuts is to simplify any acceptance calculation from the MC, while also maximizing the number of muons available to your analysis.

3.1.1 CMP bluebeam region

The CMP bluebeam region (top of CMP, stacks 6–12) has been operating stably since run number 154449. For earlier runs the bluebeam region was either noisy or turned off. We recommend that you reject any tight muons with stubs in the bluebeam region for run $<$ 154449.

Muons from the CMX arches should only be used from run 150144. For simplicity we recommend that you only use muons from the CMX keystone and miniskirt after the October 2004 shutdown. (If you are careful, wedge 5 of the keystone is usable from run 175008.)

4 Muon Cut ID Efficiencies

To calculate the trigger and ID efficiencies we use $Z \to \mu^+\mu^-$ events. We look for a CMUP or CMX muon passing all the cuts given in tables 1 and 2. We define this muon as the 'first leg'. We then look for an oppositely charged track in the event, which we call the 'second leg'. If the invariant mass of the two legs is in the range 80 GeV/c^2 to 100 GeV/c^2, we test the second leg to see if it passed the cut in question.

The exact details of the efficiency calculations are given in the sections below.

There is known to be very little background in the $Z \to \mu^+\mu^-$ sample [2]. Therefore we do not make any correction for background whilst calculating these efficiencies.

5 Muon ID cut efficiencies

In this section we report the efficiencies for applying the ID cuts given in table 1.

5.1 Event selection

- A first leg must be a CMUP or CMX muon passing all the (tight) cuts given in tables 1 and 2. In addition this muon must match to the level 1 trigger information. (See [3] for more information.)
- A second leg must be a muon with a CMUP or CMX stub. In addition this second leg must satisfy the following cuts:
  - $p_T > 20$ GeV
  - fiducial requirements given in table 2.
  - $\rho_{\mathrm{COT}} > 140$ cm
- The event must not have a cosmic tag.
- The z_0 of the two legs must pass: $|z_0^{(1)} - z_0^{(2)}| < 4$ cm.
- The invariant mass of the two tracks must pass: $80 < m(\mu^+\mu^-)$ GeV/c$^2 < 100$.

We then test the second leg to see if it passes each of the muon ID cuts given in table 1.

5.2 Applicability of these efficiencies

We make the trigger requirement on the first leg to ensure the second leg is free of any trigger bias. Therefore the efficiencies reported are independent of any trigger bias. As we have made fiduciality requirements on the second leg the efficiencies are technically only valid for muons with these requirements. However we have looked at the efficiencies for muons not passing the fiducial cuts and they agree with the values reported here.

5.3 Results for CMUP muons

The results for CMUP muons are shown in table 3 and 5. We also report the efficiencies for all of the cuts combined (taking into account any correlations), and of some different combinations of the cuts.

The resulting scale factor, ratio of ID efficiencies for data and MC is: 0.9295 ± 0.0051 for tight cuts, and 0.9485 ± 0.0048 for loose cuts. If one neglects the isolation cut (which may be different for different samples) the scale factors are: 0.9290 ± 0.0049 (tight), 0.9488 ± 0.0046 (loose).

5.4 Results for CMX muons

The results for CMX muon are shown in tables 4 and 6. The resulting scale factor, ratio of ID efficiencies for data and MC is 1.0020 ± 0.0056 for tight cuts, and 1.0123 ± 0.0052 for loose cuts. If one neglects the isolation cut (which may be different for different samples) the scale factor is: 1.0001 ± 0.0050 (tight), 1.0111 ± 0.0044 (loose).

5.5 Dependences

We have check to see if any of the efficiencies depend on muon momentum and isolation. Efficiency dependences on time and position are examined in [3].

Any dependence on p_T may be obscured by the kinematics of the $Z \to \mu^+\mu^-$ sample: the momentum of muon with $80 < m(\mu^+\mu^-)/\mathrm{GeVc}^{-2} < 100$ is highly peaked around 45 GeV/c^2. Therefore to study the p_T dependence of the ID efficiencies, high and low momentum for this we have expanded the mass range to $50 < m(\mu^+\mu^-)/\mathrm{GeVc}^{-2} < 130$ to pick up more statistics at high and low momentum. Figures 2, 3, 4 and 5 show the results of this study.

Figure 6 show the efficiencies of all cuts (except the isolation requirement) as a function of muon isolation.

Cut	data		MC	
	events	efficiency	events	efficiency
Total CMUP second legs	4883		123559	
E_{EM} cut	4732	0.9691 ± 0.0025	118929	0.9625 ± 0.0005
E_{HAD} cut	4785	0.9799 ± 0.0020	121506	0.9834 ± 0.0004
number of COT hits cut	4770	0.9769 ± 0.0022	123346	0.9983 ± 0.0001
d_0 cut	4863	0.9959 ± 0.0009	123410	0.9988 ± 0.00001
isolation cut	4773	0.9775 ± 0.0021	120941	0.9788 ± 0.0004
Δx_{CMU} cut	4659	0.9541 ± 0.0030	123390	0.9986 ± 0.0001
Δx_{CMP} cut	4799	0.9828 ± 0.0019	122868	0.9944 ± 0.0002
All above cuts	4173	0.8546 ± 0.0050	113603	0.9194 ± 0.0008
All track cuts (excl. isol)	4520	0.9257 ± 0.0038	116620	0.9438 ± 0.0006
All track cuts (incl. isol)	4433	0.9078 ± 0.0041	114299	0.9251 ± 0.0007
All cuts excl. isol	4255	0.8714 ± 0.0048	115900	0.9380 ± 0.0007

Table 3: Efficiencies of the tight muon ID cuts for CMUP muons.

Cut	data		MC	
	events	efficiency	events	efficiency
Total CMX second legs	2396		56353	
E_{EM} cut	2336	0.9750 ± 0.0032	54305	0.9637 ± 0.0008
E_{HAD} cut	2349	0.9804 ± 0.0028	55161	0.9788 ± 0.0006
number of COT hits cut	2362	0.9858 ± 0.0024	56206	0.9974 ± 0.0002
d_0 cut	2393	0.9987 ± 0.0007	56322	0.9995 ± 0.00001
isolation cut	2346	0.9791 ± 0.0029	55177	0.9791 ± 0.0006
Δx_{CMX} cut	2390	0.9975 ± 0.0010	56264	0.9984 ± 0.0002
All above cuts	2210	0.9224 ± 0.0055	51871	0.9205 ± 0.0011
All track cuts (excl. isol)	2255	0.9411 ± 0.0048	52995	0.9404 ± 0.0010
All track cuts (incl. isol)	2215	0.9245 ± 0.0054	51951	0.9219 ± 0.0011
All cuts (excl. isol)	2250	0.9391 ± 0.0049	52913	0.9390 ± 0.0010

Table 4: Efficiencies of the tight muon ID cuts for CMX muons.

Cut	data		MC	
	events	efficiency	events	efficiency
Total CMUP second legs	4883		123559	
E_{EM} cut	4732	0.9691 ± 0.0025	118929	0.9625 ± 0.0005
E_{HAD} cut	4785	0.9799 ± 0.0020	121506	0.9834 ± 0.0004
number of COT hits cut	4882	0.9998 ± 0.0002	123558	0.999992 ± 0.000008
d_0 cut	4863	0.9959 ± 0.0009	123410	0.9988 ± 0.00001
isolation cut	4773	0.9775 ± 0.0021	120941	0.9788 ± 0.0004
Δx_{CMU} cut	4659	0.9541 ± 0.0030	123390	0.9986 ± 0.0001
Δx_{CMP} cut	4799	0.9828 ± 0.0019	122868	0.9944 ± 0.0002
All above cuts	4266	0.8736 ± 0.0048	113793	0.9210 ± 0.0008
All track cuts (excl. isol)	4626	0.9474 ± 0.0032	116820	0.9455 ± 0.0006
All track cuts (incl. isol)	4534	0.9285 ± 0.0037	114489	0.9266 ± 0.0007
All cuts excl. isol	4353	0.8915 ± 0.0045	116100	0.9396 ± 0.0007

Table 5: Efficiencies of the loose muon ID cuts for CMUP muons.

Cut	data		MC	
	events	efficiency	events	efficiency
Total CMX second legs	2396		56353	
E_{EM} cut	2336	0.9750 ± 0.0032	54305	0.9637 ± 0.0008
E_{HAD} cut	2349	0.9804 ± 0.0028	55161	0.9788 ± 0.0006
number of COT hits cut	2394	0.9992 ± 0.0006	56348	0.99991 ± 0.00004
d_0 cut	2393	0.9987 ± 0.0007	56322	0.9995 ± 0.00001
isolation cut	2346	0.9791 ± 0.0029	55177	0.9791 ± 0.0006
Δx_{CMX} cut	2390	0.9975 ± 0.0010	56264	0.9984 ± 0.0002
All above cuts	2239	0.9345 ± 0.0051	51997	0.9227 ± 0.0011
All track cuts (excl. isol)	2286	0.9541 ± 0.0043	53126	0.9427 ± 0.0010
All track cuts (incl. isol)	2244	0.9366 ± 0.0050	52077	0.9241 ± 0.0011
All cuts (excl. isol)	2281	0.9520 ± 0.0043	53044	0.9413 ± 0.0010

Table 6: Efficiencies of the loose muon ID cuts for CMX muons.

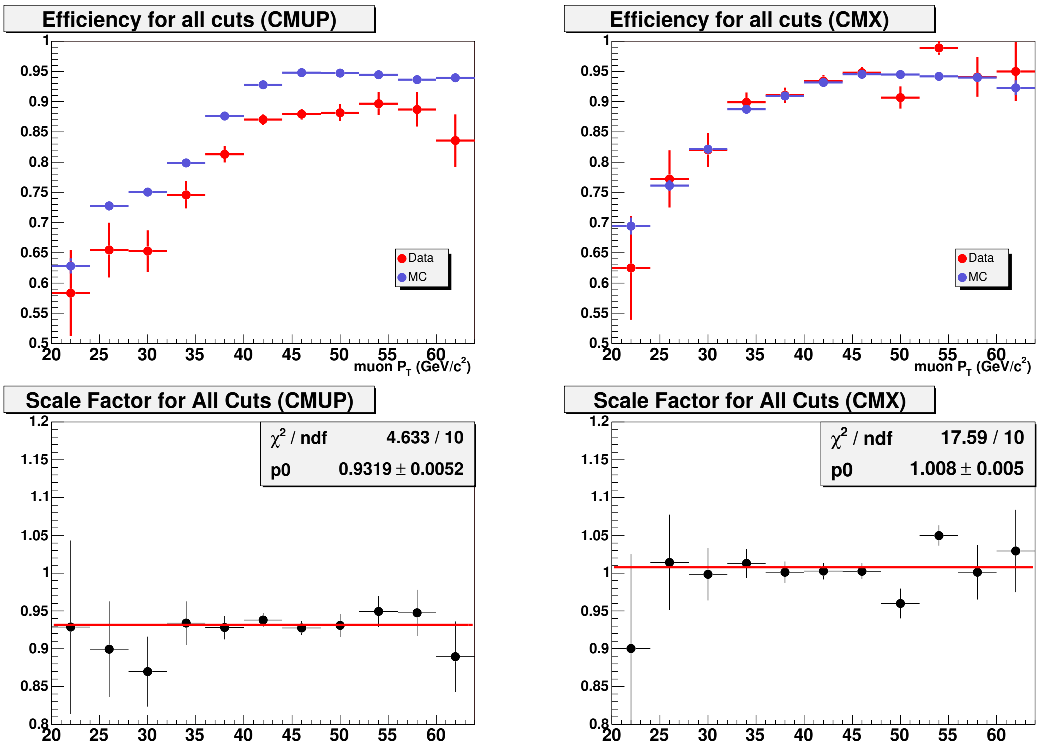

Figure 1: Top: efficiency of the CMP and CMX for all ID cuts as a function of p_T. Bottom: scale factor as a function of scale factor. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range for to $50 < M(\mu^+\mu^-) < 130$. Tight cuts have been for the number of COT hits cuts.

6 Reconstructions efficiencies

The reconstruction efficiency is defined as the probability to find a muon stub and link it to a track. The method for finding the trigger efficiency is described in note 7031. Table 7 gives the numbers of events used to calculate the reconstruction efficiency. The results we obtain are:

$$\begin{aligned}
\epsilon^{\texttt{CMUP}}(data) &= 5205/5691 &= 0.9146 \pm 0.0037 \\
\epsilon^{\texttt{CMUP}}(MC) &= 122386/125919 &= 0.9719 \pm 0.0005 \\
\epsilon^{\texttt{CMX}}(data) &= 2585/2623 &= 0.9855 \pm 0.0023 \\
\epsilon^{\texttt{CMX}}(MC) &= 55794/55880 &= 0.9986 \pm 0.0002
\end{aligned} \tag{2}$$

$$\begin{aligned}
\text{CMUP reconstruction efficiency scale factor} &= 0.9410 \pm 0.0037(stat) \pm 0.0070(sys) \\
\text{CMX reconstruction efficiency scale factor} &= 0.9869 \pm 0.0023(stat) \pm 0.0020(sys)
\end{aligned}$$

Second leg category	Number in data	Number in $Z \to \mu^+\mu^-$ MC
fiducial in the CMUP	5691	122386
fiducial in the CMUP with CMU and CMP stubs	5205	125919
fiducial in the CMX	2623	55794
fiducial in the CMX with a CMX stub	2585	55880

Table 7: Numbers used in the calculation of the reconstruction efficiency.

7 Trigger Efficiencies

The derivation of the trigger efficiencies is described in cdf note 7031. The numbers used to calculate the trigger efficiencies are results are given in this section.

7.1 Level 1

Table 8 gives the number of $Z \to \mu^+\mu^-$ events in different trigger categories. Using these numbers we obtain:

$$\epsilon^{\mathrm{L1}}_{\mathrm{CMUP}} = 0.9106 \pm 0.0045 \tag{3}$$

$$\epsilon^{\mathrm{L1}}_{\mathrm{CMX}} = 0.9657 \pm 0.0039 \tag{4}$$

The trigger efficiencies reported here are for the case when the COT exit radius cut $\rho_{\mathrm{COT}} > 140$ cm is being applied. If this cut is not applied then the appropriate value for the CMX trigger efficiency is:

$$\epsilon^{\mathrm{L1}}_{\mathrm{CMX}}(\text{no } \rho_{\mathrm{COT}} \text{ cut}) = 0.8747 \pm 0.0065 \tag{5}$$

7.2 Level 3

We calculate the efficiency of the level 3 CMUP muon trigger ($\epsilon^{\mathrm{L3}}_{\mathrm{CMUP}}$) as:

$$\epsilon^{\mathrm{L3}}_{\mathrm{CMUP}} = \frac{\text{Number of events with CMUP and CMX triggers}}{\text{Number of events with CMX triggers}}, \tag{6}$$

and similarly for the level 3 CMX trigger.

Using the number given in table 9, the results we obtain are:

$$\begin{array}{rcccl} \epsilon^{\mathrm{L3}}_{\mathrm{CMUP}} & = & 1295/1299 & = & (99.69 \pm 0.15)\% \\ \epsilon^{\mathrm{L3}}_{\mathrm{CMX}} & = & 1295/1296 & = & (99.92 \pm 0.07)\% \end{array} \tag{7}$$

CMUP–CMUP events	
No trigger requirements	1488
At least one level 1 match	1486
Two level 1 matches	1250

CMX–CMX events	
No trigger requirements	451
At least one level 1 match	451
Two level 1 matches	416

CMUP–CMX events	
No trigger requirements	1479
CMUP level 1 trigger match	1342
CMX level 1 trigger match	1437
CMUP and CMX level 1 trigger matches	1300

Table 8: Events used in the calculation of the level 1 muon trigger efficiency.

No Level 3 trigger requirement	1300
CMUP level 3 trigger requirement	1296
CMX level 3 trigger requirement	1299
CMUP and CMX level 3 trigger requirements	1295

Table 9: Events used in the calculation of the level 3 muon trigger efficiency.

7.3 Overall Trigger Efficiencies

The overall trigger efficiencies is the product of the level 1 and level 3 trigger efficiencies:

$$\begin{aligned} \epsilon_{\mathrm{CMUP}}^{\mathrm{trigger}} &= (90.78 \pm 0.47)\% \\ \epsilon_{\mathrm{CMX}}^{\mathrm{trigger}} &= (96.49 \pm 0.40)\% \end{aligned} \tag{8}$$

8 Summary

The overall scale factors to be applied to Monte Carlo should be the product of the ID scale factor and the reconstruction scale factor. The overall scale factors are summarized in table 10.

loose CMUP	0.8921 ± 0.0088
loose CMX	0.9990 ± 0.0060
tight CMUP	0.8738 ± 0.0086
tight CMX	0.9889 ± 0.0063

Table 10: Summary of the scale factors for high-p_T muon ID and reconstruction efficiencies for analysis using `5.3.1` data and `5.3.3` MC.

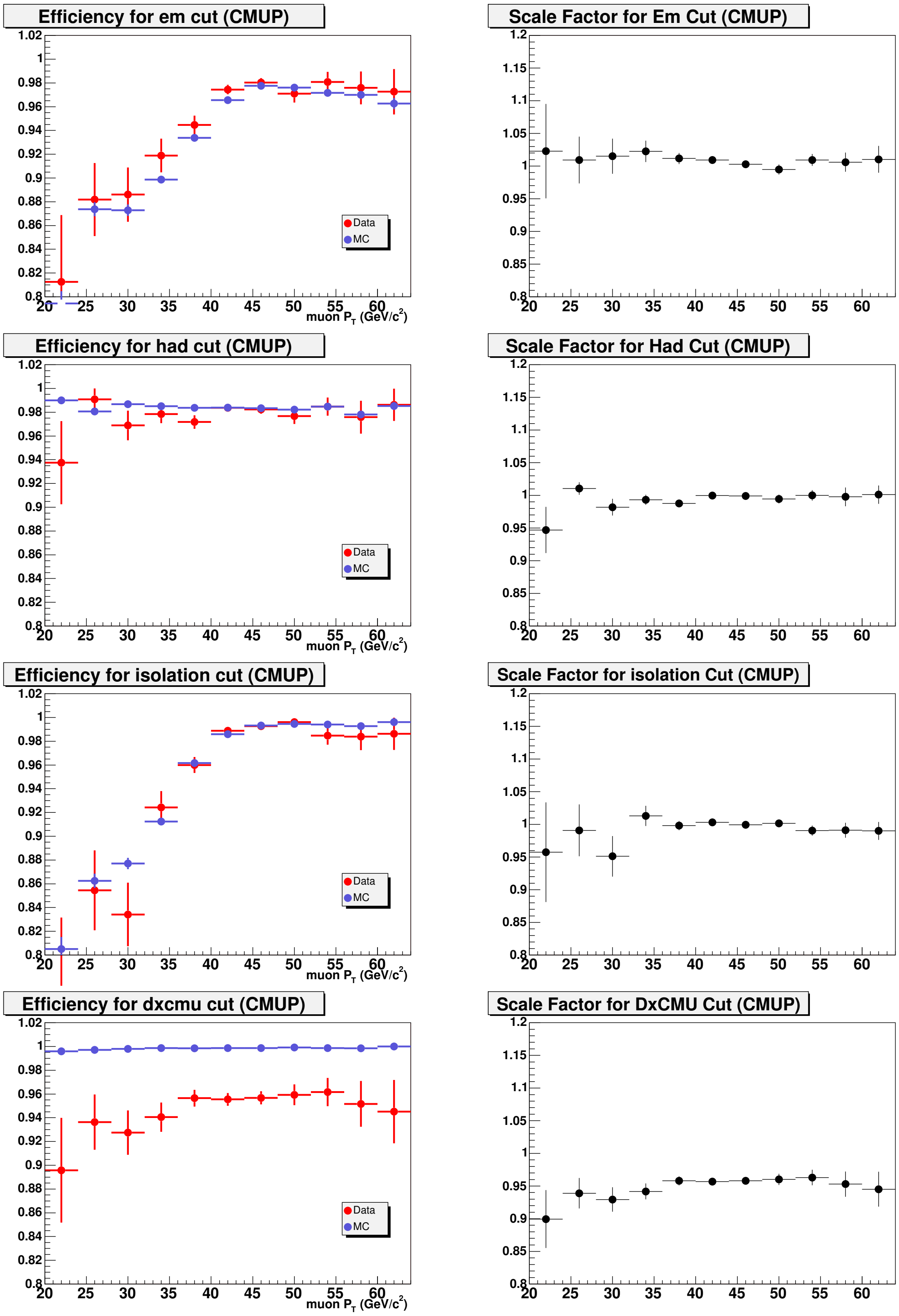

Figure 2: Efficiency and scale factor for each of the CMUP ID cuts. Most of the p_T-dependence of the ID cuts is described by the isolation and $E_{\rm EM}$ cuts. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range for to $50 < M(\mu^+\mu^-) < 130$. Tight cuts have been for the number of COT hits cuts.

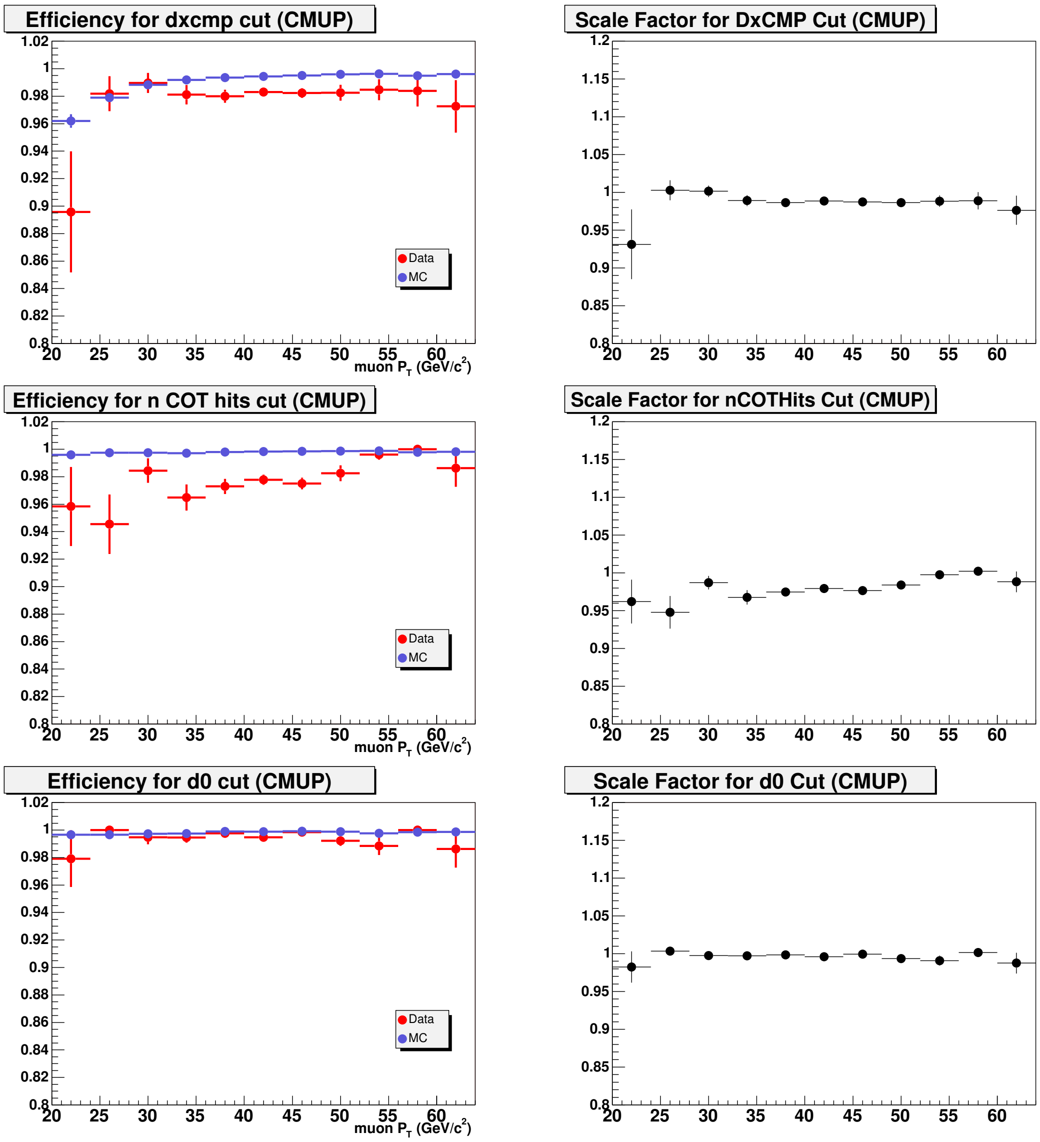

Figure 3: Efficiency and scale factor for each of the CMUP ID cuts. Most of the p_T-dependence of the ID cuts is described by the isolation and E_{EM} cuts. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range for to $50 < M(\mu^+\mu^-) < 130$. Tight cuts have been for the number of COT hits cuts.

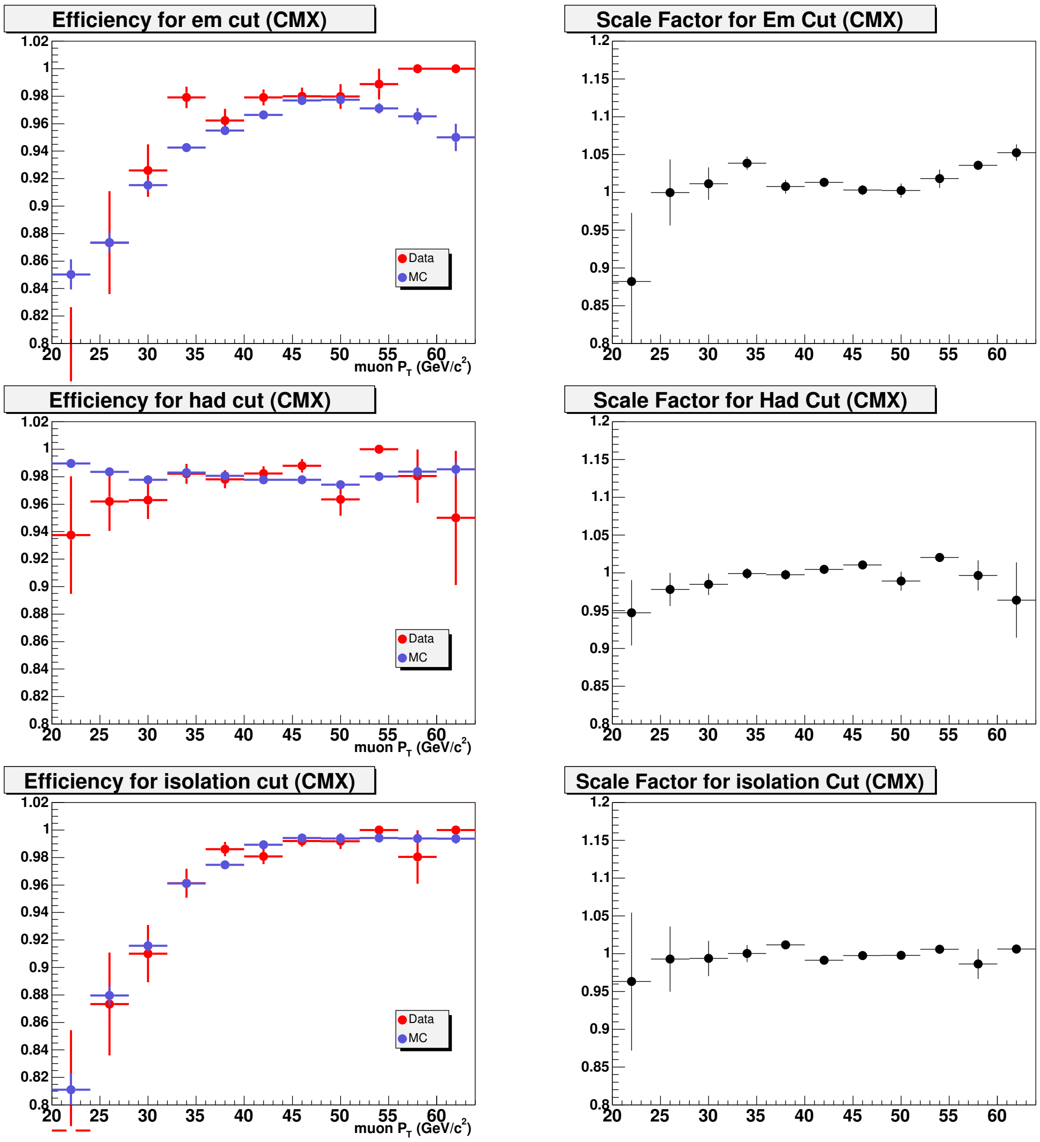

Figure 4: Efficiency and scale factor for each of the CMX ID cuts as a function of muon p_T. Most of the p_T-dependence of the ID cuts is described by the isolation and $E_{\rm EM}$ cuts. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range for to $50 < M(\mu^+\mu^-) < 130$. Tight cuts have been for the number of COT hits cuts.

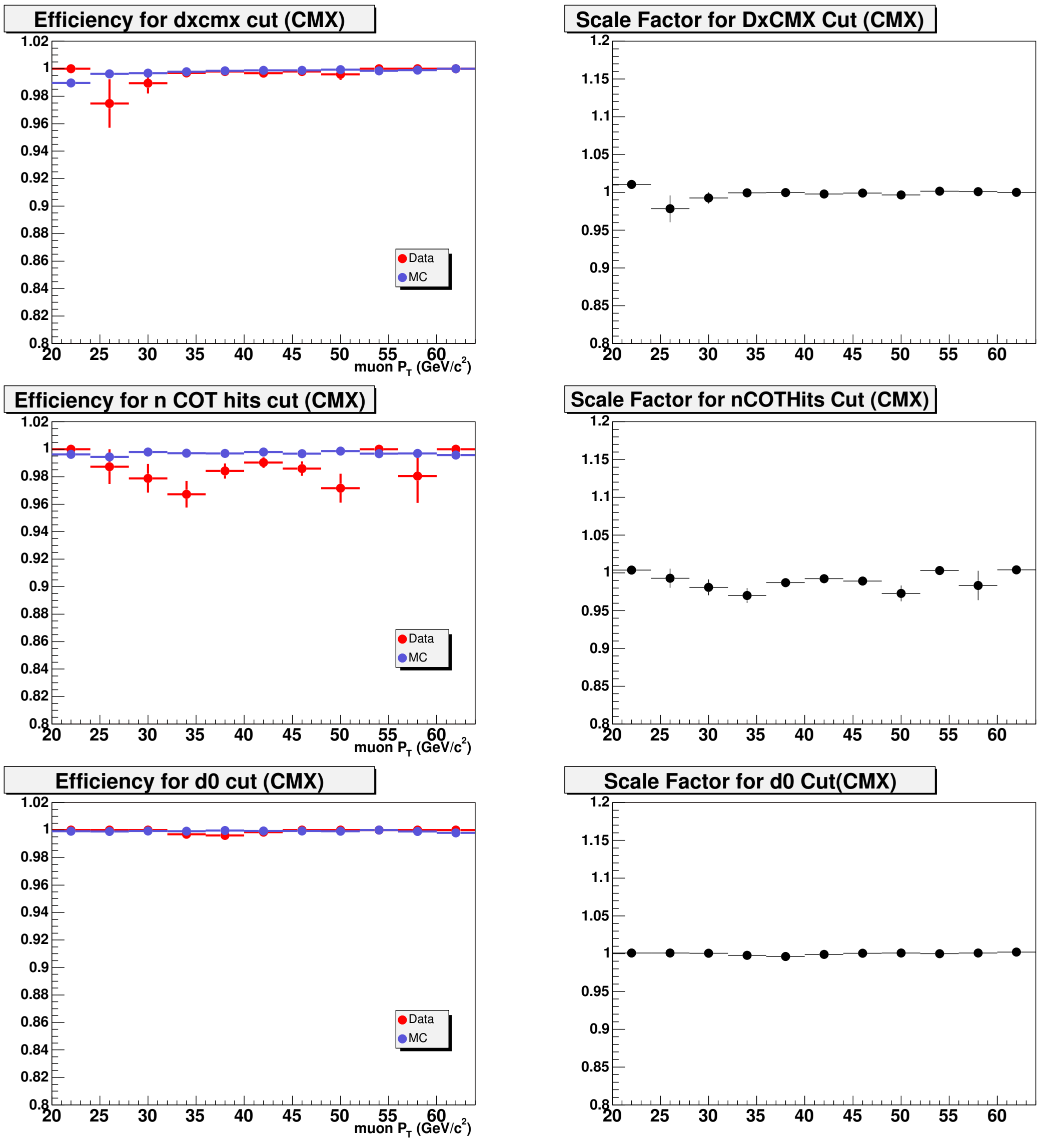

Figure 5: Efficiency and scale factor for each of the CMX ID cuts. Most of the p_T-dependence of the ID cuts is described by the isolation and $E_{\rm EM}$ cuts. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range for to $50 < M(\mu^+\mu^-) < 130$. Tight cuts have been for both the number of COT hits cuts.

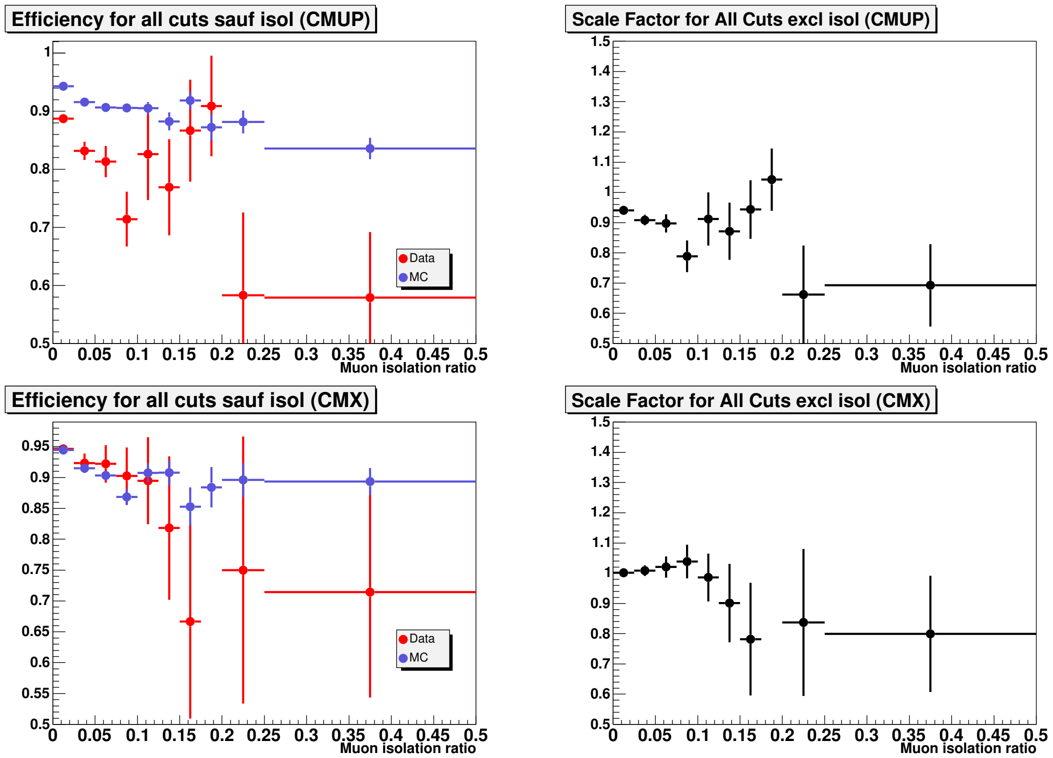

Figure 6: Efficiency and scale factor for the overall muon ID cuts as a function of isolation.

A ID efficiencies using defTracks

All the results in this appendix use the version 6 good run list. (Not the version 7 good run list used in the rest of this note.)

Tables 11, 12, 13 and 14, show the efficiencies of the ID cuts using defTracks for muons with silicon hits. For muons without silicon hits we follow the COT-only track refitting procedure as described in section 1.3.

The relevant change for the tracks with silicon hit are:

- p_T, z_0 is taken directly from `muon.bestTrack()`, which is a member of the `defTrack` collection.
- Invariant mass of the muon pairs is calculated with p_T η and ϕ^0 of `muon.bestTrack()`.
- The appropriate Larry Correction [1] is applied.
- The number of COT hits is taken from the COT-refitted tracks.[1] However we don't expect any difference between the number of COT hits on the defTrack and the refitted track.
- Fiducial distances are calculated using `muon.bestTrack()`.

Table 15 summarises the difference between the efficiencies calculated with `defTracks` and COT-only beam constrained tracks. The differences are small, however the efficiency using `defTracks` is consistently 0.2% higher than the efficiency using COT-only beam constrained tracking. As the difference is small, using the efficiencies reported in the main section of the note for samples using `defTracks` is ok.

[1] This is the only thing I have in my ntuple.

Cut	data events	data efficiency	MC events	MC efficiency
Total CMX second legs	1751		56066	
E_{EM} cut	1711	0.9772 ± 0.0036	54016	0.9634 ± 0.0008
E_{HAD} cut	1715	0.9794 ± 0.0034	54896	0.9791 ± 0.0006
number of COT hits cut	1727	0.9863 ± 0.0028	55915	0.9973 ± 0.0002
d_0 cut	1748	0.9983 ± 0.0010	56039	0.9995 ± 0.00001
isolation cut	1711	0.9771 ± 0.0036	54907	0.9793 ± 0.0006
Δx_{CMX} cut	1746	0.9971 ± 0.0013	55979	0.9984 ± 0.0002
All above cuts	1611	0.9200 ± 0.0065	51620	0.9207 ± 0.0011
All track cuts (excl. isol)	1650	0.9423 ± 0.0056	52729	0.9405 ± 0.0010
All track cuts (incl. isol)	1616	0.9229 ± 0.0064	51700	0.9221 ± 0.0011
All cuts (excl. isol)	1645	0.9395 ± 0.0057	52646	0.9390 ± 0.0010

Table 11: Efficiencies of the tight muon ID cuts for CMX muons. `defTracks` have been used for muons with no silicon hits.

Cut	data events	data efficiency	MC events	MC efficiency
Total CMUP second legs	3546		122293	
E_{EM} cut	3439	0.9698 ± 0.0029	117745	0.9628 ± 0.0005
E_{HAD} cut	3470	0.9786 ± 0.0024	120264	0.9834 ± 0.0004
number of COT hits cut	3466	0.9774 ± 0.0025	122084	0.9983 ± 0.0001
d_0 cut	3532	0.9961 ± 0.0011	122161	0.9989 ± 0.00001
isolation cut	3469	0.9783 ± 0.0024	119730	0.9790 ± 0.0004
Δx_{CMU} cut	3376	0.9521 ± 0.0036	122127	0.9986 ± 0.0001
Δx_{CMP} cut	3490	0.9842 ± 0.0021	121610	0.9944 ± 0.0001
All above cuts	3015	0.8503 ± 0.0060	112514	0.9200 ± 0.0008
All track cuts (excl. isol)	3281	0.9253 ± 0.0044	115473	0.9442 ± 0.0007
All track cuts (incl. isol)	3217	0.9072 ± 0.0049	113201	0.9256 ± 0.0008
All cuts excl. isol	3074	0.8669 ± 0.0057	114760	0.9384 ± 0.0007

Table 12: Efficiencies of the tight muon ID cuts for CMUP muons. `defTracks` have been used for muons with no silicon hits.

Cut	data		MC	
	events	efficiency	events	efficiency
Total CMX second legs	1751		56066	
E_{EM} cut	1711	0.9772 ± 0.0036	54016	0.9634 ± 0.0008
E_{HAD} cut	1715	0.9794 ± 0.0034	54896	0.9791 ± 0.0006
number of COT hits cut	1749	0.9989 ± 0.0008	56061	0.99991 ± 0.00004
d_0 cut	1748	0.9983 ± 0.0010	56039	0.9995 ± 0.0001
isolation cut	1711	0.9772 ± 0.0036	54907	0.9793 ± 0.0006
Δx_{CMX} cut	1746	0.9971 ± 0.0013	55979	0.9984 ± 0.0002
All above cuts	1630	0.9309 ± 0.0061	51750	0.9230 ± 0.0011
All track cuts (excl. isol)	1671	0.9543 ± 0.0050	52864	0.9429 ± 0.0010
All track cuts (incl. isol)	1635	0.9338 ± 0.0059	51830	0.9244 ± 0.0011
All cuts (excl. isol)	1666	0.95145 ± 0.005	52781	0.9414 ± 0.0010

Table 13: Efficiencies of the loose muon ID cuts for CMX muons. `defTracks` have been used for muons with no silicon hits.

Cut	data		MC	
	events	efficiency	events	efficiency
Total CMUP second legs	3546		122293	
E_{EM} cut	3439	0.9698 ± 0.0029	117745	0.9628 ± 0.0005
E_{HAD} cut	3470	0.9786 ± 0.0024	120264	0.9834 ± 0.0004
number of COT hits cut	3544	0.9994 ± 0.0004	122291	0.9999 ± 0.00001
d_0 cut	3532	0.9961 ± 0.0011	122161	0.9989 ± 0.0001
isolation cut	3469	0.9783 ± 0.0024	119730	0.9790 ± 0.0004
Δx_{CMU} cut	3376	0.9521 ± 0.0036	122127	0.9986 ± 0.0001
Δx_{CMP} cut	3490	0.9842 ± 0.0021	121610	0.9944 ± 0.0002
All above cuts	3084	0.8697 ± 0.0057	112701	0.9216 ± 0.0008
All track cuts (excl. isol)	3358	0.9470 ± 0.0038	115669	0.9458 ± 0.0006
All track cuts (incl. isol)	3290	0.9278 ± 0.0043	113388	0.9272 ± 0.0007
All cuts excl. isol	3147	0.8875 ± 0.0053	114956	0.9400 ± 0.0007

Table 14: Efficiencies of the loose muon ID cuts for CMUP muons. `defTracks` have been used for muons with no silicon hits.

	COT-only bc tracking	defTracks
Tight CMX cuts	0.9200 ± 0.0065	0.9222 ± 0.0063
Tight CMUP cuts	0.8503 ± 0.0060	0.8519 ± 0.0059
Loose CMX cuts	0.9309 ± 0.0061	0.9319 ± 0.0060
Loose CMUP cuts	0.8697 ± 0.0057	0.8712 ± 0.0056

Table 15: Using version 6 good run list: comparison of the overall ID efficiencies using COT-only beam constrained tracking and defTracks. The errors on these quantities cannot be directly compared, as the event samples overall significantly.

B Efficiencies for CMU-only, CMP-only and CMIO muons

At the request of several people, we have calculated efficiencies for CMU-only and CMP-only muon samples.

Definition of CMU-only muon sample. For the purposes of this analysis, a muon is defined as a "CMU-only" muon if:

- It has a stub in the CMU detector.
- It does not have a stub in the CMP detector.
- It is fiducial in the CMU, as defined by the following cuts:
  - fiducial distance from CMU:
    x-fid < 0 cm
    z-fid < 0 cm
- It is not fiducial in the CMP, as defined by the following cuts:
  - fiducial distance from CMP:
    x-fid ≥ 0 cm
    z-fid ≥ -3 cm
- It passes all the stubless muon cuts in table 1.
- $|\Delta x_{\mathrm{CMU}}| < 3$ cm

Definition of CMP-only muon sample A muon is defined as a "CMP-only" muon if:

- It has a stub in the CMP detector.
- It does not have a stub in the CMU detector.
- It is fiducial in the CMP, as defined by the following cuts:
  - fiducial distance from CMP:
    x-fid < 0 cm
    z-fid < -3 cm
- It is not fiducial in the CMU, as defined by the following cuts:

- fiducial distance from CMU:
  x-fid ≥ 0 cm
  z-fid ≥ 0 cm

- It passes all the stubless muon cuts in table 1.
- $|\Delta x_{\text{CMP}}| < 5$ cm

B.1 Definition of all-CMU muon sample

A muon is defined to be part of the "all-CMU" sample if:

- It has a stub in the CMU detector. (There may or may not also be an associated stub in the CMP detector.)
- It is fiducial in the CMU, as defined by the following cuts:
  - fiducial distance from CMU:
    x-fid < 0 cm
    z-fid < 0 cm
- It passes all the stubless muon cuts in table 1.
- $|\Delta x_{\text{CMU}}| < 3$ cm

B.2 Definition of all-CMP muon sample

Similarly, a muon is defined to be part of the "all-CMP" sample if:

- It has a stub in the CMP detector. (There may or may not also be an associated stub in the CMU detector.)
- It is fiducial in the CMP, as defined by the following cuts:
  - fiducial distance from CMP:
    x-fid < 0 cm
    z-fid < -3 cm
- It passes all the stubless muon cuts in table 1.
- $|\Delta x_{\text{CMP}}| < 5$ cm

Finally we report values for the CMIO and "all-muon" sample. We stress than no study has been made on these samples to determine the background in the sample, and hence no background subtractions have been made.

B.3 Definition of CMIO muon sample

The CMIO sample is defined as:

- There is no stub in the CMU, CMP or CMX detector.
- It is not fiducial in the CMU, CMP or CMX (as defined by the fiducial cuts described above).
- It passes all the stubless muon cuts in table 1.
- passes minimum energy cut: $E_{\text{EM}} + E_{\text{HAD}} > 0.1$ GeV

B.4 Definition of all-muon sample

The 'all-muon' sample is defined as any second leg (with or without a stub), passes all the stubless muon cuts in table 1. Most importantly the cut on COT exit radius $\rho_{\text{COT}} > 140$ cm has been applied.

B.5 Results

Please note that the numbers in this section are not blessed. We have performed the same level of checks as we have for the numbers presented in the main section of the note. In particular, for the reconstruction SF presented here we have not evaluated a systematic error, and we have made no corrections for potential backgrounds which may occur especially in the "all-muon" sample.

The overall scale factors are presented in table 22.

The reconstruction efficiencies and scale factors for CMU-only, CMP-only, all-CMU and all-CMP muons are calculated as below.

$$\begin{array}{rcccl} \epsilon^{\texttt{CMU-only}}(data) & = & 1266/1406 & = & 0.9004 \pm 0.0080 \\ \epsilon^{\texttt{CMU-only}}(MC) & = & 29624/30375 & = & 0.9753 \pm 0.0009 \\ \epsilon^{\texttt{CMP-only}}(data) & = & 882/945 & = & 0.9311 \pm 0.0064 \\ \epsilon^{\texttt{CMP-only}}(MC) & = & 36163/36903 & = & 0.9799 \pm 0.0007 \end{array} \quad (9)$$

The resulting reconstruction efficiency scale factors are:

$$\text{reconstruction efficiency scale factor for CMU-only} = 0.9232 \pm 0.0081 \quad (10)$$

$$\text{reconstruction efficiency scale factor for CMP-only} = 0.9500 \pm 0.0064 \quad (11)$$

	data		MC	
No cuts applied	1153		28271	
Em Cut	1126	0.9766 ± 0.0044	27203	0.9622 ± 0.0011
Had Cut	1131	0.9809 ± 0.0040	27654	0.9782 ± 0.0009
Cot Cut	1128	0.9783 ± 0.0043	28226	0.9984 ± 0.0002
d0 Cut	1150	0.9974 ± 0.0015	28254	0.9994 ± 0.0001
isol Cut	1126	0.9766 ± 0.0045	27692	0.9795 ± 0.0008
dxcmu Cut	1114	0.9662 ± 0.0053	28228	0.9985 ± 0.0002
all Cuts	1022	0.8864 ± 0.0093	26025	0.9206 ± 0.0016
all (w/o isol) Cuts	1044	0.9055 ± 0.0086	26523	0.9382 ± 0.0014

Table 16: ID efficiencies for the CMU-only sample. Tight COT cuts have been used.

	data		MC	
No cuts applied	1343		34121	
Em Cut	1308	0.9739 ± 0.0043	33315	0.9764 ± 0.0008
Had Cut	1332	0.9918 ± 0.0025	33752	0.9892 ± 0.0006
Cot Cut	1302	0.9695 ± 0.0047	33999	0.9964 ± 0.0003
d0 Cut	1337	0.9955 ± 0.0018	34079	0.9988 ± 0.0002
isol Cut	1308	0.9739 ± 0.0043	33387	0.9785 ± 0.0008
dxcmp Cut	1317	0.9806 ± 0.0038	33951	0.9950 ± 0.0004
all Cuts	1202	0.8950 ± 0.0084	31973	0.9370 ± 0.0013
all (w/o isol) Cuts	1232	0.9173 ± 0.0075	32634	0.9564 ± 0.0011

Table 17: ID efficiencies for the CMP-only sample.Tight COT cuts have been used.

	data		MC	
No cuts applied	6319		155138	
Em Cut	6119	0.9683 ± 0.0022	149287	0.9623 ± 0.0005
Had Cut	6186	0.9790 ± 0.0018	152409	0.9824 ± 0.0003
Cot Cut	6172	0.9767 ± 0.0019	154874	0.9983 ± 0.0001
d0 Cut	6296	0.9964 ± 0.0008	154969	0.9989 ± 0.0001
isol Cut	6167	0.9759 ± 0.0019	151857	0.9789 ± 0.0004
dxcmu Cut	6065	0.9598 ± 0.0025	154937	0.9987 ± 0.0001
all Cuts	5526	0.8745 ± 0.0042	143202	0.9231 ± 0.0007
all (w/o isol) Cuts	5630	0.8910 ± 0.0039	146089	0.9417 ± 0.0006

Table 18: ID efficiencies for the all-CMU sample. Tight COT cuts have been used.

	data		MC	
No cuts applied	6396		159853	
Em Cut	6204	0.9700 ± 0.0021	154344	0.9655 ± 0.0005
Had Cut	6287	0.9830 ± 0.0016	157400	0.9847 ± 0.0003
Cot Cut	6235	0.9748 ± 0.0020	159513	0.9979 ± 0.0001
d0 Cut	6367	0.9955 ± 0.0008	159657	0.9988 ± 0.0001
isol Cut	6243	0.9761 ± 0.0019	156452	0.9787 ± 0.0004
dxcmp Cut	6284	0.9825 ± 0.0016	158963	0.9944 ± 0.0002
all Cuts	5708	0.8924 ± 0.0039	147633	0.9236 ± 0.0007
all (w/o isol) Cuts	5831	0.9117 ± 0.0035	150640	0.9424 ± 0.0006

Table 19: ID efficiencies for the all-CMP sample.Tight COT cuts have been used.

	data		MC	
No cuts applied	619		15888	
Em Cut	599	0.9677 ± 0.0071	15318	0.9641 ± 0.0015
Had Cut	612	0.9887 ± 0.0043	15531	0.9775 ± 0.0012
Minimum Energy Cut	596	0.9628 ± 0.0076	15136	0.9527 ± 0.0017
Cot Cut	603	0.9742 ± 0.0064	15831	0.9964 ± 0.0005
d0 Cut	619	1 ± 0	15871	0.9989 ± 0.0003
isol Cut	597	0.9645 ± 0.0074	15538	0.9780 ± 0.0012
all Cuts	539	0.8708 ± 0.0135	13906	0.8753 ± 0.0026
all (w/o isol) Cuts	557	0.8998 ± 0.0121	14178	0.8924 ± 0.0025

Table 20: ID efficiencies for CMIO muons using tight COT cuts. No study has been made to study and correct for backgrounds in this sample.

	data		MC	
No cuts applied	12681		301418	
Em Cut	12197	0.9618 ± 0.0017	290380	0.9634 ± 0.0003
Had Cut	12365	0.9751 ± 0.0014	295570	0.9806 ± 0.0003
Cot Cut	12385	0.9767 ± 0.0013	300686	0.9976 ± 0.0001
d0 Cut	12630	0.9960 ± 0.0006	301081	0.9989 ± 0.0001
isol Cut	12252	0.9662 ± 0.0016	294526	0.9771 ± 0.0003
all Cuts	11439	0.9021 ± 0.0026	278610	0.9243 ± 0.0005
all (w/o isol) Cuts	11688	0.9217 ± 0.0024	284254	0.9431 ± 0.0004

Table 21: ID efficiencies for all second legs (CMUP, CMX, CMU-only, CMP-only and stubless muons) using tight COT cuts. No study has been made to study and correct for backgrounds in this sample.

Category	ID Scale Factor	Reconstruction SF	Overall SF
CMU only	0.9628 ± 0.0094	0.9232 ± 0.0081	0.8889 ± 0.0099
CMP only	0.9552 ± 0.0084	0.9500 ± 0.0064	0.9074 ± 0.0088
CMU all	0.9474 ± 0.0043	0.9695 ± 0.0025	0.9185 ± 0.0052
CMP all	0.9662 ± 0.0040	0.9568 ± 0.0027	0.9245 ± 0.0050
CMIO	0.9949 ± 0.0137	-	0.9949 ± 0.0137
All second legs	0.9760 ± 0.0026	-	0.9760 ± 0.0026

Table 22: Resulting ID and reconstruction scale factors for CMU-only, CMP-only, all-CMU, all-CMP, CMIO and all muon categories. Tight COT cuts have been used, and no systematic errors have been evaluated.

$$\begin{array}{rcccl} \epsilon^{\texttt{all-CMU}}(data) & = & 4183/4383 & = & 0.9511 \pm 0.0025 \\ \epsilon^{\texttt{all-CMU}}(MC) & = & 163369/165513 & = & 0.9810 \pm 0.0003 \\ \epsilon^{\texttt{all-CMP}}(data) & = & 4179/4438 & = & 0.9446 \pm 0.0027 \\ \epsilon^{\texttt{all-CMP}}(MC) & = & 169965/167790 & = & 0.9872 \pm 0.0003 \end{array} \tag{12}$$

The resulting reconstruction efficiency scale factors are:

$$\text{reconstruction efficiency scale factor for all-CMU} = 0.9695 \pm 0.0025 \tag{13}$$

$$\text{reconstruction efficiency scale factor for all-CMP} = 0.9568 \pm 0.0027 \tag{14}$$

References

[1] CDF Note 6971 Larry Nodulman. *Curvature Corrections for 5.3.1*

[2] CDF Note 6711. Dan Ameidi et. al. *Measurements of* $\sigma \cdot B(W \to \mu\nu)$, $\sigma \cdot B(Z \to \mu^+\mu^-)$ *and* $R = \frac{\sigma \cdot B(W \to \mu\nu)}{\sigma \cdot B(Z \to \mu^+\mu^-)}$ *using CDF run II data.*

[3] CDF Note 7031. Victoria Martin.