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High-P_T muons recommended cuts and efficiencies for Summer 2006

U. Grundler, A. Taffard, X. Zhang
University of Illinois - Urbana-Champaign

Abstract

We summarize the high p_T muon ID cuts and efficiencies using data up to the February 2006 shutdown and 6.1.4 MC samples with minimum bias.

1 Introduction

We have examined high p_T muons using all the data up to the February 2006 shutdown. This updates the results found in [1] for use with the `1invfb` TopNtuples made in version `6.1.4`. The following list summarizes some changes since posting the above mentioned note:

1. Use v13 good run list, **Top/EWK/Exoticselectron/muonsnosilicon**$(\mathbf{1}, \mathbf{0}, \mathbf{4}, \mathbf{1})$.
2. Run on TopNtuples rather than Vicoria Martin's ntuple.
3. Use updated `MuonFiducialTool` and other packages necessary to update the fiducial tool for CMP and CMX. These packages are applied at the TopNtuple level and not during MC generation. `http://www-cdf.fnal.gov/tiki/tiki-index.php?page=TopCodePrescriptions`
4. Removed some of the ϕ cuts and use them primarily to distinguish parts of the CMX detector when determining the reconstruction efficiencies.
5. Change in the CMU dx cut to 7 cm. (3 cm is still used for comparison with previous results).

It is important to measure the high p_T muon efficiencies for the new data in the new release. It provides the efficiencies needed in many analyses. Moreover, it provides a good cross-check on the running of relevant sub-detectors. We will report three muon efficiencies: trigger, ID and reconstruction efficiencies. We discuss the data sample in section 2, and the muon ID and fiducial cuts in section 3 and 4. Event selection is discussed in section 5. Muon trigger efficiencies are discussed in section 6. Muon ID and reconstruction efficiencies are discussed in sections 7 and 8. A summary is given in the last section.

2 Samples

- **Data Sample**
  The latest inclusive high p_T triggered muon sample, `bhmu0i`, is the primary dataset for this analysis. This sample, along with `bhmu0h` were made with the `6.1.2` production. An older dataset, `bhmu0d`, was made with the `5.3.1` production. All three of these samples have been made into TopNtuples using version `6.1.4` of the code. The sample is based on MUON_CMUP18 and MUON_CMX18 trigger. We are using version 13 of the good run list given on `http://www-cdf.fnal.gov/internal/dqm/goodrun/v13/goodv13.html`. Please refer to "List for Top/EWK/Exotics electron/muons no silicon" (cmx bit ignored for run < 150145). The `bhmu0i` sample corresponds to about 270 pb^{-1} of data and the combination of it and the older data comes to about 1030 pb^{-1}.

- **Monte Carlo Sample**
  The `zewkam` and `zewk9m` Monte Carlo samples are used in this analysis. They are PYTHIA $Z \to \mu^+\mu^-$ samples generated with `6.1.4`, are run dependent, and cover the run range for the `0d` and `0h + 0i` datasets, respectively.

2.1 Combining Samples

In addition to calculating the efficiencies and scale factors for the individual data samples, we have also calculated the same for the combined samples `0h + 0i` and `0d + 0h + 0i`. For `0h + 0i`, which were made in the same production, we have added the event counts together and treated the combination as if it was one large dataset. For the combination of `0d + 0h + 0i` we have taken a weighted average of `0d` and the combination `0h + 0i` based on the luminosity of these samples. We use the luminosities from the electron/muon good run list with no silicon. We then add a systematic error to the combination equal to the difference between the two individual efficiencies or scale factors.

3 Muon Identification Cuts

The suggested muon identification cuts for high-P_T muons for the combination of `6.1.4` data and Monte Carlo are summarized in Table 1. Figures 4 and 5 show the distribution of each of the variables used in identifying muons. We should note that P_T is defined as the standard track P_T unless there are no COT hits, in which case the track P_T is beam constrained. In either case the Larry Corrections are applied [4].

We also continue to provide efficiencies for cuts on a sliding definition of isolation. This sliding isolation corrects the isolation for the number of vertices in an event and is defined as follows: $(E_T^{isol.} - 0.35 \cdot (N_{vtx} - 1))/P_T$. This definition of isolation will always be referred to as 'sliding' to differentiate it from the standard definition of isolation.

4 Muon Fiducial Cuts

Some analyzers 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 a low number of events such cuts may not be advantageous. We list the recommended cuts in Table 2 with ϕ cuts used in the determination of reconstruction efficiencies in Table 3.

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`. This includes the removal of muons from the bluebeam, keystone, and miniskirt regions for run periods where these detectors were not operating and/or triggering in a stable fashion.

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
$E_T^{isol.}/P_T$	$<$	0.1
Number of axial SL with $\geq$ 5 hits	$\geq$	3
Number of stereo SL with $\geq$ 5 hits	$\geq$	2
$\|z_0\|$	$<$	60 cm
Tracks w/ no silicon hits: $\|d_0\|$	$<$	0.2 cm
Tracks w/ silicon hits: $\|d_0\|$	$<$	0.02 cm

Additionally for tight CMUP muons:

$\|\Delta x_{CMU}\|$	$<$	7 cm (we also look at 3 cm)
$\|\Delta x_{CMP}\|$	$<$	5 cm
No bluebeam muons, run	$<$	154449

Additionally for tight CMX muons:

$\|\Delta x_{CMX}\|$	$<$	6 cm
Run	$>$	150144
No miniskirt or keystone muons, run	$<$	190697
No muons in wedge 14 west, runs	$\geq$	190697 and $\leq$ 209760

Table 1: Standard muon ID cuts for 6.1.4 data MC.

2. A cut on the COT exit radius of the track associated to the muon.

3. Cuts to differentiate the CMX arches from the miniskirt and keystone. These cuts are used to allow measurement of the CMX reconstruction efficiency with and without the keystone and miniskirt regions.

Please note that the cuts in ϕ to define the fiducial area of different parts of the CMX, have changed since the last iteration of this measurement in [1]. The cuts have been simplified because a newer version of the `MuonFiducialTool` has information on whether individual wedges and chambers are dead or otherwise not fiducial for a given run. This means that the cuts used to remove non-existent regions in the Miniskirt, for example, are no longer necessary.

The ϕ cuts have not been removed entirely, however, because they are still the only way we have to determine which region of the CMX a track is fiducial to and so provide us with a way to separate the Arches and Miniskirt/Keystone areas if we wish. Wedge information is available, however, for muon stubs, so the phi cuts are only used for the determination of the reconstruction efficiency, whereas for the ID and trigger efficiencies we use stub information to distinguish parts of the detector.

4.1 Keystone and Miniskirt Regions

The main motivation to apply these cuts is to allow users to differentiate between the CMX Arches and Miniskirt/Keystone if needed. Muons from the CMX arches should only be used from run 150145. Starting with run 190697 both the keystone and miniskirt have been reliably on all the time, so we recommend not using these regions before that run. The updated `MuonFiducialTool` should take care of removing these regions for the proper run periods.

5 $Z \to \mu\mu$

To calculate the muon trigger, ID and reconstruction efficiencies, we use $Z \to \mu\mu$ events, requiring the two muons have opposite charges. For trigger efficiency, we require both Z legs pass all the cuts given in Table 1 and 2. Next we require that one muon pass a required trigger and call it the "triggered leg". We then look for another muon in the event, which we call the "probe leg". If the invariant mass of the two legs is in the range 81 GeV/c^2 to 101 GeV/c^2, we test the probe leg to see if it passed the cut in question.

In addition, the cuts used to select $Z \to \mu^+\mu^-$ events are summarized below:

- 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: 81 $GeV/c^2 < m(\mu^+\mu^-) <$ 101 GeV/c^2.

For CMUP muons:

Fiducial distance from CMU:		
x-fid	$<$	0 cm
z-fid	$<$	0 cm
Fiducial distance from CMP:		
x-fid	$<$	0 cm
z-fid	$<$	-3 cm
No muons from 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 keystone region for run < 190697		
No muons from miniskirt region for run < 190697		
No muons wedge 14 west for runs ≥ 190697 and ≤ 209760		

Table 2: Suggested muon fiducial cuts for tight muons in release 6.1.4.

Arches:
$0^\circ \leq \phi \leq 75^\circ$ or $105^\circ \leq \phi \leq 225^\circ$ or $315^\circ \leq \phi < 360^\circ$
Additionally, for runs 190697 - 209760, remove:
$210^\circ < \phi \leq 225^\circ$ if $\eta < 0$
Keystone:
$75^\circ < \phi < 105^\circ$ and $\eta < 0$
Miniskirt:
$225^\circ < \phi < 315^\circ$

Table 3: Cuts on ϕ for distinguishing parts of the CMX detector when determining reconstruction efficiencies.

6 Trigger Efficiencies

In this section we calculate the trigger efficiencies in the MUON_CMUP18 and MUON_CMX18 trigger path. The two trigger paths (obtained from the section of "runs for triggers" from "All DataSets" in CDF navigation webpage) are shown in Table 4 and Table 5. Run numbers have been corrected to reflect the valid runs in the good run list (no silicon requirement).

	CMUP18 trigger path
Level 1	L1_CMUP6_PT4
Level 2	L2_AUTO_L1_CMUP6_PT4 (run≤152949)
	L2_TRK8_L1_CMUP6_PT4(152949<run≤179056)
	L2_CMUP6_PT8(181013≤run≥202717)
	L2_CMUP6_PT15(run≥198428)
Level 3	L3_MUON_CMUP18

Table 4: The trigger path for L3_MUON_CMUP18. The overlap of run range found above is due to one trigger is in the high luminosity trigger table, the other in the low luminosity table. There should never be a run with two L2 triggers in one trigger path.

	CMX18 trigger path
Level 1	L1_CMX_PT8_PS1 (run≤152949)
	L1_CMX_PT8_CSX(_PS1) (run>152949)
Level 2	L2_AUTO_L1_CMX6_PT8(run≤152949)
	L2_AUTO_L1_CMX6_PT8_CSX(152525≤run≤179056)
	L2_AUTO_L1_CMX6_PT10(181013≤run≤202717)
	L2__L1_CMX6_PT15(run≥198428)
Level 3	L3_MUON_CMX_18

Table 5: The trigger path for L3_MUON_CMX18. The overlap in the run range is due to the same reason mentioned above

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Based on the muon types, there are three combinations, CMUP-CMUP, CMX-CMX, CMUP-CMX. The CMUP-CMUP (CMX-CMX) and CMUP-CMX events have been used in the calculation of L1 CMUP (CMX) trigger efficiency. There is no significant difference in the L1 trigger efficiency between the two sets of events. Therefore, we only use CMUP-CMX in the calculation of L3 trigger efficiencies.

6.1 Level 1 Trigger Efficiency

The efficiency of events passing the selection criteria for $Z \to \mu^+\mu^-$ are shown in Table 6. As mentioned above, the efficiency for the level 1 CMUP trigger (ϵ^{L1}_{CMUP}) is calculated from two independent samples. First, using the CMX-CMUP sample (the triggered leg is CMX muon, the probe leg is CMUP muon):

$$\epsilon^{L1(A)}_{CMUP} = \frac{\text{number of events with both legs triggered}}{\text{number of events with 1 CMX trigger leg}} \tag{1}$$

Second, using the CMUP-CMUP trigger sample:

$$R = \frac{\text{number of events with both legs triggered}}{\text{number of events with } \geq 1 \text{ CMUP triggered leg}} \tag{2}$$

$$\epsilon^{L1(B)}_{CMUP} = \frac{2R}{1+R} \tag{3}$$

	Efficiency (%)		
	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMUP	89.29 ± 0.41	93.00 ± 0.30	92.87 ± 0.39
CMX	97.12 ± 0.30	88.88 ± 0.46	89.41 ± 0.57
Arches	97.12 ± 0.30	95.54 ± 0.34	95.49 ± 0.43
Mini./Key.		76.83 ± 1.30	74.83 ± 1.77

Table 6: Level 1 muon trigger efficiencies.

6.2 Level 3 Trigger Efficiency

This time around, we have dropped the calculation of the level 2 trigger efficiency due to difficulties we have had in getting these triggers. Without the level 2 trigger efficiencies, the level 3 trigger efficiency we calculate is from a level 1 starting point. To calculate L3 trigger efficiency, candidate CMUP-CMX event is required to pass both L1 corresponding triggers. The level 3 CMUP18 trigger efficiency (ϵ^{L3}_{CMUP}) is calculated as:

$$\epsilon^{L3}_{CMUP} = \frac{\text{number of events pass both L3 triggers}}{\text{number of events pass L3 CMX trigger}} \tag{4}$$

and level 3 CMX18 trigger efficiency (ϵ^{L3}_{CMX})

$$\epsilon^{L3}_{CMX} = \frac{\text{number of events pass both L3 triggers}}{\text{number of events pass L3 CMUP trigger}} \tag{5}$$

The efficiency of events passing the L3 trigger requirement is shown in Table 7.

	Efficiency (%)		
	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMUP	99.56 ± 0.15	98.78 ± 0.21	98.95 ± 0.25
CMX	99.62 ± 0.14	99.44 ± 0.14	99.81 ± 0.11
Arches	99.62 ± 0.14	99.36 ± 0.17	99.85 ± 0.11
Mini./Key.		99.79 ± 0.21	99.62 ± 0.38

Table 7: Combined level 2 and level 3 muon trigger efficiencies.

6.3 Trigger Efficiency Summary

The overall efficiency of the MUON_CMUP18 and MUON_CMX18 triggers is the product of the level 1 and level 3 efficiencies. The result is shown in Table 8 and the results for the combined datasets are shown in Table 9.

	Efficiency (%)		
	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMUP	88.90 ± 0.43	91.86 ± 0.36	91.89 ± 0.45
CMX	96.75 ± 0.33	88.39 ± 0.48	89.25 ± 0.58
Arches	96.75 ± 0.33	94.94 ± 0.37	95.35 ± 0.44
Mini./Key.		76.67 ± 1.31	74.55 ± 1.78

Table 8: Overall trigger effiiciencies. These are the products of efficiencies in Tables 6 and 7.

	Efficiency (%)	
Category	`0h + 0i`	`0d + 0h + 0i`
CMUP	91.87 ± 0.28	90.46±0.25±2.97
CMX	88.67 ± 0.37	
Arches	95.08 ± 0.29	95.87±0.22±1.67
Mini./Key.	75.86 ± 1.06	

Table 9: Overall (L1*L2*L3) trigger efficiencies for the combinations `0h + 0i` and `0d + 0h + 0i`. See Sec. 2.1 for details on the combinations. With large systematic uncertainties it may be unwise to use the combined efficiencies.

7 Muon ID cut efficiencies

To calculate the muon 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 81 GeV/c^2 to 101 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.

7.1 Event selection

Events used for this measurement are selected as follows:

- A first leg must be a CMUP or CMX muon passing all the cuts given in Tables 1 and 2.
- A second leg must be a muon with a CMUP or CMX stub and satisfy:
  - $P_T > 20$ GeV.
  - fiducial requirements in Table 2.
- 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: $81 < m(\mu^+\mu^-)$ GeV/$c^2 < 101$.

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

7.2 Applicability of these efficiencies

The trigger requirement on the first leg ensures that the second leg is free of any trigger bias. Therefore the efficiencies reported are independent of any trigger bias. We have made fiduciality requirements on the second leg and so the efficiencies are only valid for muons with these requirements.

7.3 Results for CMUP and CMX muons

Results for CMUP muons are shown in Tables 10 and 11 and those for CMX muons are given in Tables 12 and 13. We also have results for the arches and miniskirt/keystone separately in Tables 14, 15 and 16. Efficiencies for all of the cuts combined, and of some different combinations of the cuts, are also reported. The resulting scale factors - ratio of ID efficiencies for data and MC - are given in Table 17 and those of the combined datasets are given in Table 18.

We have again measured the efficiency of a cut on the χ^2 of the track in the data. Continuing with what we did previously in [1] we make a different cut in **bhmu0d** than in **bhmu0h** and **bhmu0i**. Table 19 shows the efficiencies of these cuts.

	Efficiency (%)		
	bhmu0d	**bhmu0h**	**bhmu0i**
E_{EM} cut	97.18 ± 0.21	97.49 ± 0.18	96.85 ± 0.26
E_{HAD} cut	98.11 ± 0.17	98.37 ± 0.15	98.05 ± 0.21
COT hits cut	99.59 ± 0.08	100.00 ± 0.00	100.00 ± 0.00
d_0 cut	99.28 ± 0.11	99.71 ± 0.06	99.78 ± 0.07
Isolation cut	97.70 ± 0.19	97.39 ± 0.18	96.58 ± 0.27
Δx_{CMU} cut	99.51 ± 0.09	99.60 ± 0.07	99.60 ± 0.09
Δx_{CMP} cut	98.29 ± 0.17	97.97 ± 0.16	98.09 ± 0.20
All above cuts	90.52 ± 0.37	90.97 ± 0.33	89.88 ± 0.45
All cuts excl. isol.	92.44 ± 0.34	93.36 ± 0.29	92.77 ± 0.39
Sliding isol. cut	97.89 ± 0.18	97.85 ± 0.17	97.31 ± 0.24
All cuts (sliding isol.)	90.68 ± 0.37	91.37 ± 0.32	90.57 ± 0.44
All track cuts	92.49 ± 0.34	93.26 ± 0.29	91.88 ± 0.41
Track cuts excl. isol.	94.44 ± 0.29	95.66 ± 0.24	94.85 ± 0.33
Using $\Delta x_{CMU} < 3$ cm			
Δx_{CMU} cut	95.78 ± 0.26	95.95 ± 0.23	96.08 ± 0.29
All cuts	87.33 ± 0.43	87.55 ± 0.38	86.74 ± 0.51
All cuts excl. isol.	89.08 ± 0.40	89.85 ± 0.35	89.52 ± 0.46
All cuts (sliding isol.)	87.50 ± 0.43	87.94 ± 0.38	87.38 ± 0.50

Table 10: Efficiencies of the muon ID cuts for CMUP muons.

7.4 Dependencies

We have checked to see if any of the efficiencies depend on time, position, muon momentum, isolation, instantaneous luminosity, and the number of vertices in the event. The efficiencies of the ID cuts as a function of run number are shown in Figs. 6 and 7. No significant dependence is seen. Figure 8 shows the efficiencies of all the cuts as a function of η and ϕ for **bhmu0i**.

Any dependence on P_T may be obscured by the kinematics of the $Z \to \mu^+\mu^-$ sample: the momentum of muons with $81 < m(\mu^+\mu^-)/\mathrm{GeV}/c^2 < 101$ is highly peaked around 45GeV/c. Therefore to study the P_T dependence of the ID efficiencies, high and low momentum for this we have expanded the mass range to $50 < m(\mu^+\mu^-)/\mathrm{GeV}/c^2 < 130$ to pick up more statistics at high and low momentum. We find that most of the P_T-dependence of the ID cuts is described by the isolation and E_{EM} cuts. Figures 9, 10, and 11 show the results of this study for **bhmu0i**.

	Efficiency (%)	
	`zewkam`	`zewk9m`
E_{EM} cut	96.37 ± 0.06	96.29 ± 0.04
E_{HAD} cut	98.41 ± 0.04	98.34 ± 0.03
COT hits cut	100.00 ± 0.00	100.00 ± 0.00
d_0 cut	99.91 ± 0.01	99.91 ± 0.01
Isolation cut	98.00 ± 0.04	97.73 ± 0.03
Δx_{CMU} cut	99.99 ± 0.00	99.99 ± 0.00
Δx_{CMP} cut	99.43 ± 0.02	99.47 ± 0.02
All above cuts	92.44 ± 0.08	92.12 ± 0.06
All cuts excl. isol.	94.22 ± 0.07	94.10 ± 0.05
Sliding isol. cut	98.13 ± 0.04	98.00 ± 0.03
All cuts (sliding isol.)	92.56 ± 0.08	92.36 ± 0.06
All track cuts	92.96 ± 0.08	92.61 ± 0.06
Track cuts excl. isol.	94.75 ± 0.07	94.61 ± 0.05
Using $\Delta x_{CMU} < 3$ cm		
Δx_{CMU} cut	99.89 ± 0.01	99.88 ± 0.01
All cuts	92.41 ± 0.08	92.08 ± 0.06
All cuts excl. isol.	94.19 ± 0.07	94.06 ± 0.05
All cuts (sliding isol.)	92.53 ± 0.08	92.32 ± 0.06

Table 11: Efficiencies of the muon ID cuts for CMUP muons in Monte Carlo.

	Efficiency (%)		
	`bhmu0d`	`bhmu0h`	`bhmu0i`
E_{EM} cut	97.60 ± 0.28	96.82 ± 0.26	96.72 ± 0.33
E_{HAD} cut	98.00 ± 0.26	98.25 ± 0.19	98.12 ± 0.25
COT hits cut	99.83 ± 0.07	99.98 ± 0.02	99.97 ± 0.03
d_0 cut	99.63 ± 0.11	99.77 ± 0.07	99.73 ± 0.10
Isolation cut	97.60 ± 0.28	97.14 ± 0.24	97.99 ± 0.26
Δx_{CMX} cut	99.73 ± 0.09	99.47 ± 0.11	99.62 ± 0.11
All above cuts	92.75 ± 0.47	91.88 ± 0.40	92.39 ± 0.49
All cuts excl. isol.	94.88 ± 0.40	94.46 ± 0.33	94.30 ± 0.43
Sliding isol. cut	97.84 ± 0.27	97.72 ± 0.22	98.29 ± 0.24
All cuts (sliding isol.)	92.95 ± 0.47	92.41 ± 0.39	92.70 ± 0.48
All track cuts	93.01 ± 0.47	92.26 ± 0.39	92.73 ± 0.48
Track cuts excl. isol.	95.14 ± 0.39	94.91 ± 0.32	94.64 ± 0.42

Table 12: Efficiencies of the muon ID cuts for CMX muons.

	Efficiency (%)	
	`zewkam`	`zewk9m`
E_{EM} cut	96.42 ± 0.08	96.42 ± 0.05
E_{HAD} cut	97.62 ± 0.07	97.85 ± 0.04
COT hits cut	100.00 ± 0.00	100.00 ± 0.00
d_0 cut	99.93 ± 0.01	99.92 ± 0.01
Isolation cut	98.06 ± 0.06	97.77 ± 0.04
Δx_{CMX} cut	99.85 ± 0.02	99.86 ± 0.01
All above cuts	92.21 ± 0.12	92.18 ± 0.07
All cuts excl. isol.	93.92 ± 0.11	94.14 ± 0.06
Sliding isol. cut	98.18 ± 0.06	98.02 ± 0.04
All cuts (sliding isol.)	92.33 ± 0.12	92.41 ± 0.07
All track cuts	92.34 ± 0.12	92.30 ± 0.07
Track cuts excl. isol.	94.06 ± 0.10	94.28 ± 0.06

Table 13: Efficiencies of the muon ID cuts for CMX muons in Monte Carlo.

	Efficiency (%)		
	`bhmu0d`	`bhmu0h`	`bhmu0i`
E_{EM} cut	97.60 ± 0.28	97.11 ± 0.28	96.86 ± 0.36
E_{HAD} cut	98.00 ± 0.26	98.30 ± 0.21	98.11 ± 0.28
COT hits cut	99.83 ± 0.07	100.00 ± 0.00	99.96 ± 0.04
d_0 cut	99.63 ± 0.11	99.73 ± 0.09	99.70 ± 0.11
Isolation cut	97.60 ± 0.28	97.36 ± 0.27	98.15 ± 0.28
Δx_{CMX} cut	99.73 ± 0.09	99.37 ± 0.13	99.66 ± 0.12
All above cuts	92.75 ± 0.47	92.22 ± 0.44	92.68 ± 0.54
All cuts excl. isol.	94.88 ± 0.40	94.64 ± 0.37	94.40 ± 0.48
Sliding isol. cut	97.84 ± 0.27	97.83 ± 0.24	98.45 ± 0.26
All cuts (sliding isol.)	92.95 ± 0.47	92.66 ± 0.43	92.98 ± 0.53
All track cuts	93.01 ± 0.47	92.72 ± 0.43	92.98 ± 0.53
Track cuts excl. isol.	95.14 ± 0.39	95.22 ± 0.35	94.71 ± 0.46

Table 14: Efficiencies of the muon ID cuts for CMX muons in the arches.

	Efficiency (%)	
	`zewkam`	`zewk9m`
E_{EM} cut	96.42 ± 0.08	96.44 ± 0.06
E_{HAD} cut	97.62 ± 0.07	97.86 ± 0.05
COT hits cut	100.00 ± 0.00	99.99 ± 0.00
d_0 cut	99.93 ± 0.01	99.92 ± 0.01
Isolation cut	98.06 ± 0.06	97.76 ± 0.05
Δx_{CMX} cut	99.85 ± 0.02	99.85 ± 0.01
All above cuts	92.21 ± 0.12	92.17 ± 0.08
All cuts excl. isol.	93.92 ± 0.11	94.14 ± 0.07
Sliding isol. cut	98.18 ± 0.06	98.01 ± 0.04
All cuts (sliding isol.)	92.33 ± 0.12	92.40 ± 0.08
All track cuts	92.34 ± 0.12	92.31 ± 0.08
Track cuts excl. isol.	94.06 ± 0.10	94.29 ± 0.07

Table 15: Efficiencies of the muon ID cuts for CMX muons in the arches in Monte Carlo.

	Efficiency (%)		
	`bhmu0h`	`bhmu0i`	`zewk9m`
E_{EM} cut	95.82 ± 0.62	96.22 ± 0.77	96.36 ± 0.11
E_{HAD} cut	98.10 ± 0.42	98.19 ± 0.54	97.85 ± 0.08
COT hits cut	99.91 ± 0.09	100.00 ± 0.00	100.00 ± 0.00
d_0 cut	99.91 ± 0.09	99.84 ± 0.16	99.93 ± 0.02
Isolation cut	96.39 ± 0.57	97.37 ± 0.65	97.81 ± 0.08
Δx_{CMX} cut	99.81 ± 0.13	99.51 ± 0.28	99.90 ± 0.02
All above cuts	90.69 ± 0.90	91.28 ± 1.14	92.20 ± 0.15
All cuts excl. isol.	93.83 ± 0.74	93.91 ± 0.97	94.15 ± 0.13
Sliding isol. cut	97.34 ± 0.50	97.70 ± 0.61	98.08 ± 0.08
All cuts (sliding isol.)	91.55 ± 0.86	91.61 ± 1.12	92.44 ± 0.15
All track cuts	90.69 ± 0.90	91.78 ± 1.11	92.29 ± 0.15
Track cuts excl. isol.	93.83 ± 0.74	94.41 ± 0.93	94.24 ± 0.13

Table 16: Efficiencies of the muon ID cuts for CMX muons in the miniskirt/keystone.

	Scale Factor		
Category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMUP	0.9792 $\pm$ 0.0041	0.9875 $\pm$ 0.0037	0.9757 $\pm$ 0.0049
Excl. isol.	0.9812 $\pm$ 0.0037	0.9921 $\pm$ 0.0031	0.9858 $\pm$ 0.0041
Sliding isol.	0.9798 $\pm$ 0.0041	0.9893 $\pm$ 0.0036	0.9806 $\pm$ 0.0048
CMX	1.0058 $\pm$ 0.0053	0.9967 $\pm$ 0.0044	1.0023 $\pm$ 0.0054
Excl. isol.	1.0102 $\pm$ 0.0044	1.0033 $\pm$ 0.0036	1.0017 $\pm$ 0.0046
Sliding isol.	1.0067 $\pm$ 0.0052	1.0001 $\pm$ 0.0043	1.0032 $\pm$ 0.0053
Arches	1.0058 $\pm$ 0.0053	1.0005 $\pm$ 0.0049	1.0055 $\pm$ 0.0059
Excl. isol.	1.0102 $\pm$ 0.0044	1.0053 $\pm$ 0.0040	1.0028 $\pm$ 0.0051
Sliding isol.	1.0067 $\pm$ 0.0052	1.0029 $\pm$ 0.0048	1.0064 $\pm$ 0.0058
Mini./Key.		0.9836 $\pm$ 0.0098	0.9900 $\pm$ 0.0125
Excl. isol.		0.9966 $\pm$ 0.0080	0.9975 $\pm$ 0.0104
Sliding isol.		0.9903 $\pm$ 0.0094	0.9910 $\pm$ 0.0123
Using $\Delta x_{CMU} < 3$ cm			
CMUP	0.9450 $\pm$ 0.0047	0.9507 $\pm$ 0.0042	0.9420 $\pm$ 0.0056
Excl. isol.	0.9458 $\pm$ 0.0043	0.9551 $\pm$ 0.0038	0.9517 $\pm$ 0.0049
Sliding isol.	0.9456 $\pm$ 0.0047	0.9526 $\pm$ 0.0042	0.9465 $\pm$ 0.0054

Table 17: Scale factors - ratio of efficiencies for data and MC - for all muon identification cuts, all cuts excluding the isolation cut, and all cuts with the sliding isolation.

	Scale Factor	
Category	`0h + 0i`	`0d + 0h + 0i`
CMUP	0.9830 $\pm$ 0.0030	0.9817$\pm$0.0034$\pm$0.0038
Excl. isol.	0.9897 $\pm$ 0.0025	0.9867$\pm$0.0029$\pm$0.0085
Sliding isol.	0.9860 $\pm$ 0.0029	0.9838$\pm$0.0033$\pm$0.0062
CMX	0.9989 $\pm$ 0.0035	1.0013$\pm$0.0041$\pm$0.0069
Excl. isol.	1.0027 $\pm$ 0.0029	1.0053$\pm$0.0034$\pm$0.0075
Sliding isol.	1.0012 $\pm$ 0.0034	1.0031$\pm$0.0040$\pm$0.0055
Arches	1.0025 $\pm$ 0.0038	1.0037$\pm$0.0043$\pm$0.0033
Excl. isol.	1.0043 $\pm$ 0.0032	1.0064$\pm$0.0036$\pm$0.0059
Sliding isol.	1.0042 $\pm$ 0.0037	1.0051$\pm$0.0042$\pm$0.0025
Mini./Key.	0.9860 $\pm$ 0.0078	
Excl. isol.	0.9969 $\pm$ 0.0064	
Sliding isol.	0.9906 $\pm$ 0.0075	

Table 18: Scale factors - ratio of efficiencies for data and MC - for the combinations `0h + 0i` and `0d + 0h + 0i`. See Sec. 2.1 for details on the combinations.

	Efficiency (%)		
	bhmu0d $\chi^2 < 2.75$	bhmu0h $\chi^2 < 2.3$	bhmu0i $\chi^2 < 2.3$
CMUP	98.34 ± 0.16	98.84 ± 0.12	98.69 ± 0.17
CMX	98.70 ± 0.21	98.74 ± 0.16	98.87 ± 0.19

Table 19: Efficiencies of a χ^2 cut which can be applied to the data.

Figure 12 shows the efficiencies of all cuts (except the isolation requirement) as a function of muon isolation for `bhmu0i`.

The efficiencies of all cuts as a function of instantaneous luminosity are shown in Fig. 13. Figure 14 shows the same thing as a function of the number of vertices in the event.

8 Muon Reconstruction Efficiencies

The reconstruction efficiency is defined as the probability to find a muon stub and link it to a track. First, to know whether we should find a stub or not we have to know that the muon is fiducial in any of the muon chambers. We use the `MuonFiducialTool` class for this purpose. We define a track as being fiducial in a given muon system if it passes the cuts defined in Tables 2 and 3 for that system.

To calculate the reconstruction efficiency we select events with no cosmic tag and two tracks passing the following cuts:

- Oppositely charged.
- $|z_0^{(1)} - z_0^{(2)}| < 4$ cm.
- 81 GeV/$c^2 < m(\mu^+\mu^-) < 101$ GeV/c^2
- The first leg must be a reconstructed `CdfMuon` passing all the ID and fiducial cuts given in Tables 1 and 2. It must also match to the level 1 trigger information.
- The second leg must be fiducial in both the CMU and CMP sub-detectors (or the CMX sub-detector) and satisfy:
  - $P_T > 20$ GeV.
  - $E_{EM} < 1.5 \cdot (2+\max(0, (p - 100) \cdot 0.0115))$ GeV
  - $E_{HAD} < 1.5 \cdot (6+\max(0, (p - 100) \cdot 0.028)$ GeV

We then examine these tracks to see if they are linked to a muon stub. The reconstruction efficiency is defined as the number of tracks that are both fiducial and linked to a stub divided by the number of tracks that are fiducial. It is in determining the reconstruction efficiency that the ϕ cuts defined in Table 3 are needed. The ϕ cuts help us define where the CMX sub-regions are so we can determine any differences in the reconstruction efficiencies between them.

The results of this study can be found in Tables 20 and 21. The resulting reconstruction efficiency scale factors are given in Table 22. The scale factors of combined samples are given in Table 23.

The CMX reconstruction efficiency is higher in `bhmu0d` than in `bhmu0h` or `bhmu0i`. This is due to the lower reconstruction efficiencies of the keystone and miniskirt which are not part of the `bhmu0d` number. We see that if we consider only the arches, then the efficiencies are similar.

	Efficiency (%)		
Category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMUP	92.47 ± 0.33	91.73 ± 0.31	91.72 ± 0.40
CMX	99.12 ± 0.17	97.24 ± 0.24	97.46 ± 0.29
Arches	99.12 ± 0.17	98.82 ± 0.18	98.77 ± 0.23
Miniskirt		92.10 ± 0.89	92.49 ± 1.16
Keystone		92.42 ± 1.88	94.31 ± 2.09

Table 20: Efficiencies of muon reconstructions.

	Efficiency (%)	
Category	`zewkam`	`zewk9m`
CMUP	97.52 ± 0.05	97.56 ± 0.03
CMX	99.81 ± 0.02	99.61 ± 0.02
Arches	99.81 ± 0.02	99.79 ± 0.01
Miniskirt		99.04 ± 0.06
Keystone		99.02 ± 0.13

Table 21: Efficiencies of muon reconstructions in Monte Carlo.

	Scale Factor		
Category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMUP	0.9482 ± 0.0034	0.9403 ± 0.0032	0.9401 ± 0.0041
CMX	0.9931 ± 0.0017	0.9762 ± 0.0024	0.9784 ± 0.0029
Arches	0.9931 ± 0.0017	0.9903 ± 0.0018	0.9898 ± 0.0023
Mini./Key.		0.9305 ± 0.0082	0.9374 ± 0.0103

Table 22: Scale factors - ratio of efficiencies for data and MC - for muon reconstruction.

	Scale Factor	
Category	`0h + 0i`	`0d + 0h + 0i`
CMUP	0.9402 ± 0.0025	0.9430±0.0028±0.0080
CMX	0.9771 ± 0.0019	
Arches	0.9901 ± 0.0014	0.9912±0.0015±0.0030
Mini./Key.	0.9330 ± 0.0064	

Table 23: Scale factors - ratio of efficiencies for data and MC - for the combinations `0h + 0i` and `0d + 0h + 0i`. See Sec. 2.1 for details on the combinations.

9 Identification and Reconstrucion Scale Factors 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 24 and those of the combined datasets are summarized in Table 25.

	Scale Factor		
Category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMUP	0.9285 ± 0.0051	0.9285 ± 0.0046	0.9173 ± 0.0061
Excl. isol.	0.9303 ± 0.0048	0.9328 ± 0.0043	0.9268 ± 0.0056
Sliding isol.	0.9290 ± 0.0051	0.9302 ± 0.0046	0.9220 ± 0.0060
CMX	0.9988 ± 0.0055	0.9730 ± 0.0049	0.9807 ± 0.0060
Excl. isol.	1.0032 ± 0.0047	0.9795 ± 0.0043	0.9801 ± 0.0054
Sliding isol.	0.9997 ± 0.0055	0.9763 ± 0.0048	0.9815 ± 0.0059
Arches	0.9988 ± 0.0055	0.9908 ± 0.0052	0.9952 ± 0.0063
Excl. isol.	1.0032 ± 0.0047	0.9955 ± 0.0044	0.9925 ± 0.0056
Sliding isol.	0.9997 ± 0.0055	0.9931 ± 0.0051	0.9960 ± 0.0062
Mini./Key.		0.9153 ± 0.0122	0.9280 ± 0.0155
Excl. isol.		0.9273 ± 0.0110	0.9351 ± 0.0142
Sliding isol.		0.9215 ± 0.0119	0.9290 ± 0.0154
Using $\Delta x_{CMU} < 3$ cm			
CMUP	0.8957 ± 0.0055	0.8935 ± 0.0050	0.8877 ± 0.0065
Excl. isol.	0.8964 ± 0.0052	0.8977 ± 0.0047	0.8968 ± 0.0060
Sliding isol.	0.8963 ± 0.0055	0.8953 ± 0.0050	0.8919 ± 0.0064

Table 24: Summary of the overall scale factors for the high-P_T muon ID and reconstruction efficiencies. Overall scale factors are products of the numbers found in Tables 17 and 22.

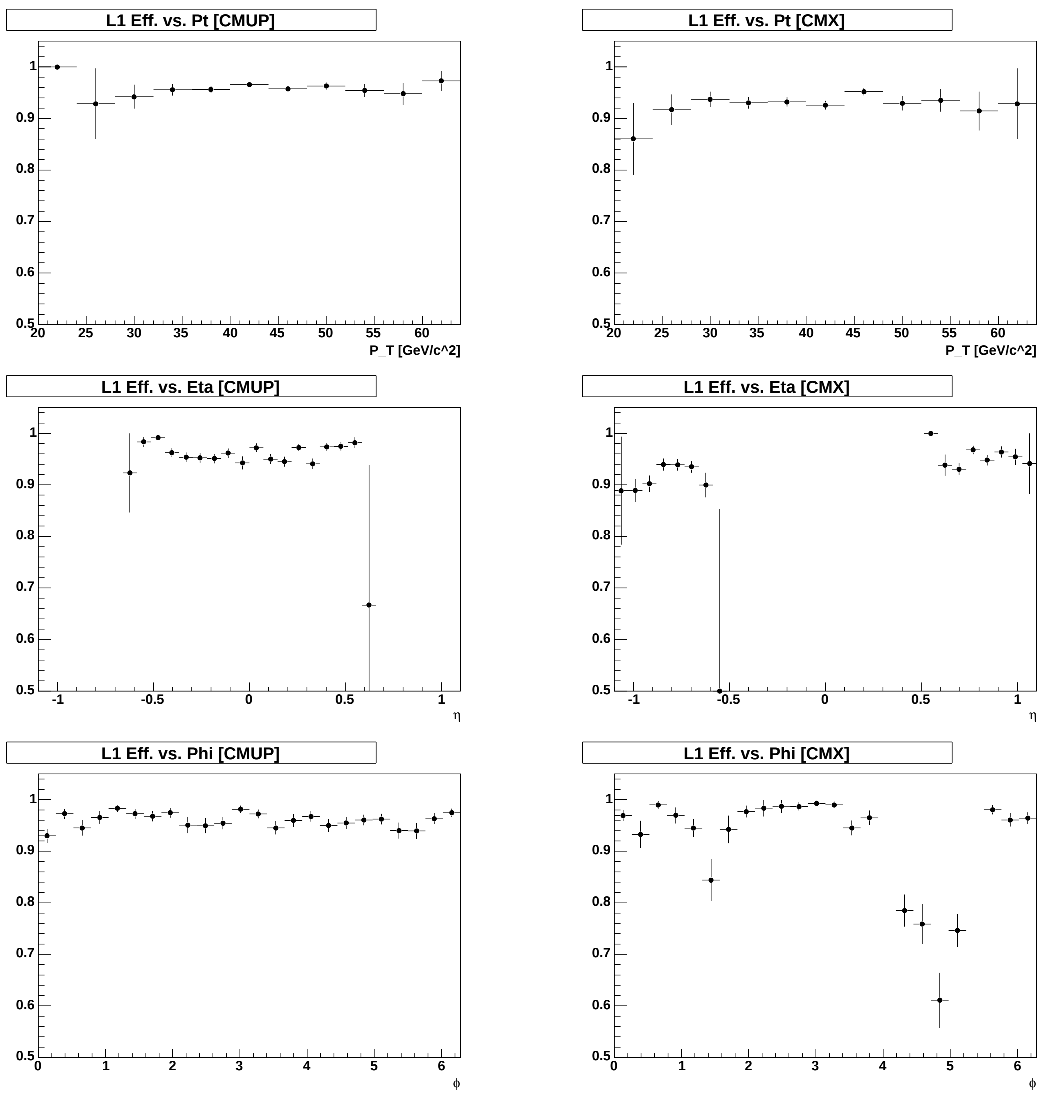

Figure 1: The L1 CMUP and L1 CMX trigger efficiency as a function of p_T, η, and ϕ for `bhmu0i`.

Category	Scale Factor	
	`0h + 0i`	`0d + 0h + 0i`
CMUP	0.9242±0.0037	0.9257±0.0042±0.0086
Excl. isol.	0.9305±0.0034	0.9305±0.0039±0.0112
Sliding isol.	0.9270±0.0037	0.9278±0.0042±0.0098
CMX	0.9760±0.0039	
Excl. isol.	0.9797±0.0034	
Sliding isol.	0.9783±0.0038	
Arches	0.9926±0.0040	0.9948±0.0045±0.0044
Excl. isol.	0.9944±0.0035	0.9975±0.0039±0.0066
Sliding isol.	0.9943±0.0039	0.9962±0.0045±0.0039
Mini./Key.	0.9199±0.0096	
Excl. isol.	0.9301±0.0087	
Sliding isol.	0.9242±0.0094	

Table 25: Summary of the overall scale factors for the high-P_T muon ID and reconstruction efficiencies of combined data samples. Overall scale factors are products of the numbers found in Tables 18 and 23. See Sec. 2.1 for details on the combinations.

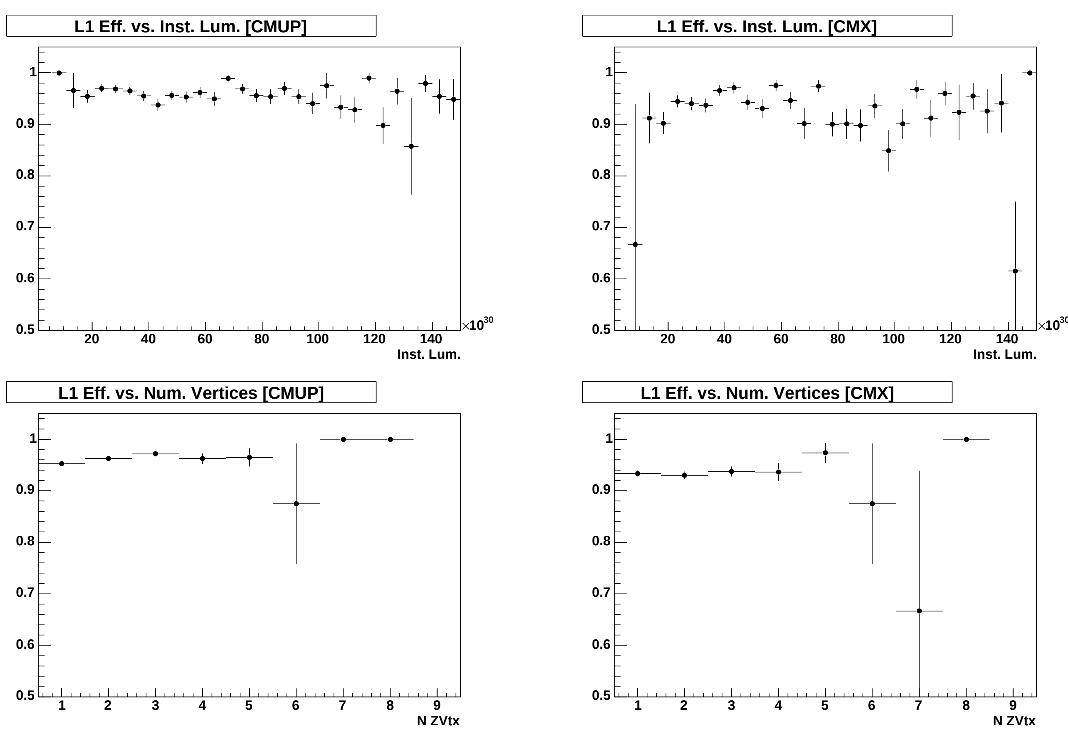

Figure 2: The L1 CMUP and L1 CMX trigger efficiency as a function of the instantaneous luminosity and number of z vertex for `bhmu0i`.

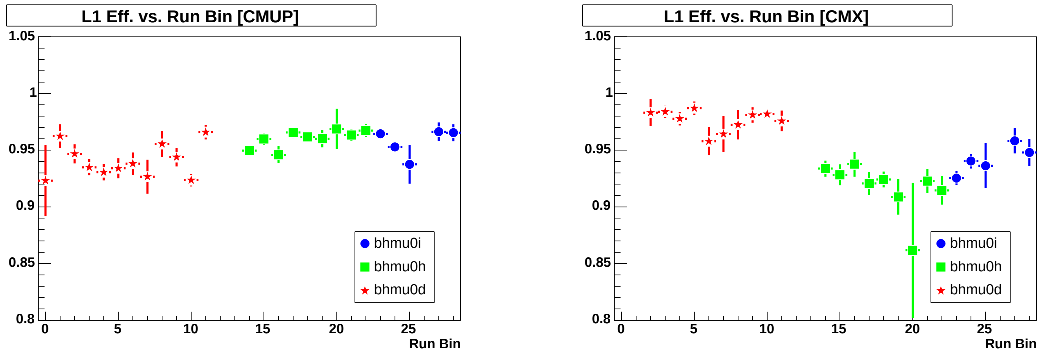

Figure 3: The L1 CMUP and L1 CMX trigger efficiency as a function of run bin. The drop in efficiency in the CMX between the `bhmu0d` and `bhmu0h` datasets is due to the inclusion of the miniskirt and keystone starting at the beginning of the `bhmu0h` data.

A Efficiencies in CMX arches with no ρ cut

Upon request we have calculated the ID efficiencies for muons in the CMX arches after dropping the cut on ρ. All other cuts remain unchanged. The results of this study are found in Tables 26 and 27 with the corresponding scale factors given in Table 28. We found no significant difference in the reconstruction efficiencies upon dropping the ρ cut, so the reader should refer back to Tables 20, 21 and 22 for those.

	Efficiency (%)		
	`bhmu0d`	`bhmu0h`	`bhmu0i`
E_{EM} cut	97.47 ± 0.26	97.24 ± 0.25	97.07 ± 0.32
E_{HAD} cut	98.06 ± 0.23	98.13 ± 0.20	98.18 ± 0.25
COT hits cut	98.32 ± 0.21	99.62 ± 0.09	99.46 ± 0.14
d_0 cut	99.28 ± 0.14	99.73 ± 0.08	99.61 ± 0.12
Isolation cut	97.34 ± 0.26	97.49 ± 0.23	98.11 ± 0.26
Δx_{CMX} cut	99.71 ± 0.09	99.41 ± 0.11	99.68 ± 0.11
All above cuts	91.08 ± 0.46	92.07 ± 0.41	92.50 ± 0.50
All cuts excl. isol.	93.40 ± 0.41	94.31 ± 0.35	94.21 ± 0.44
Sliding isol. cut	97.60 ± 0.25	97.97 ± 0.21	98.39 ± 0.24
All cuts (sliding isol.)	91.35 ± 0.46	92.46 ± 0.40	92.78 ± 0.49

Table 26: Efficiencies of the muon ID cuts for muons in the CMX arches with no ρ cut applied.

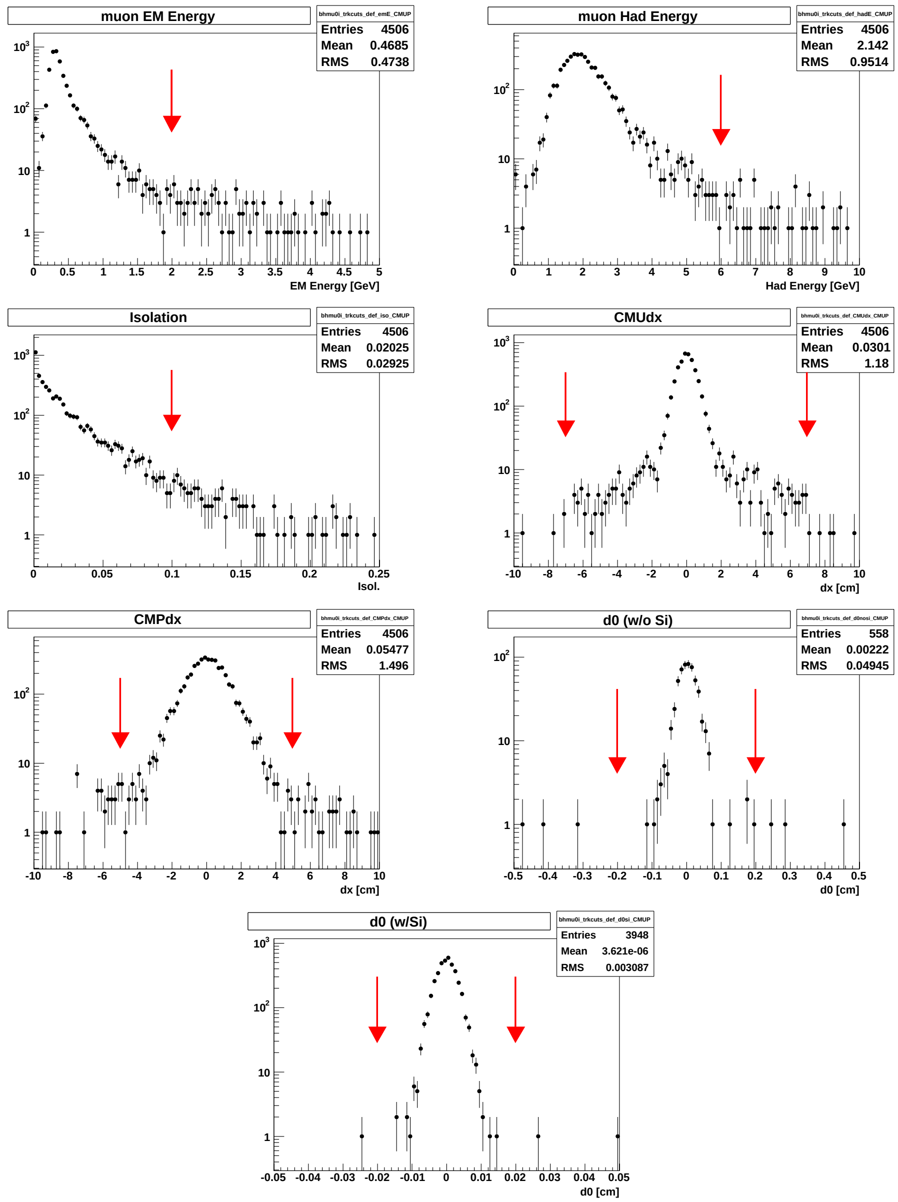

Figure 4: Distributions of the cut variables for CMUP muons. The position of the recommended cut is shown with an arrow.

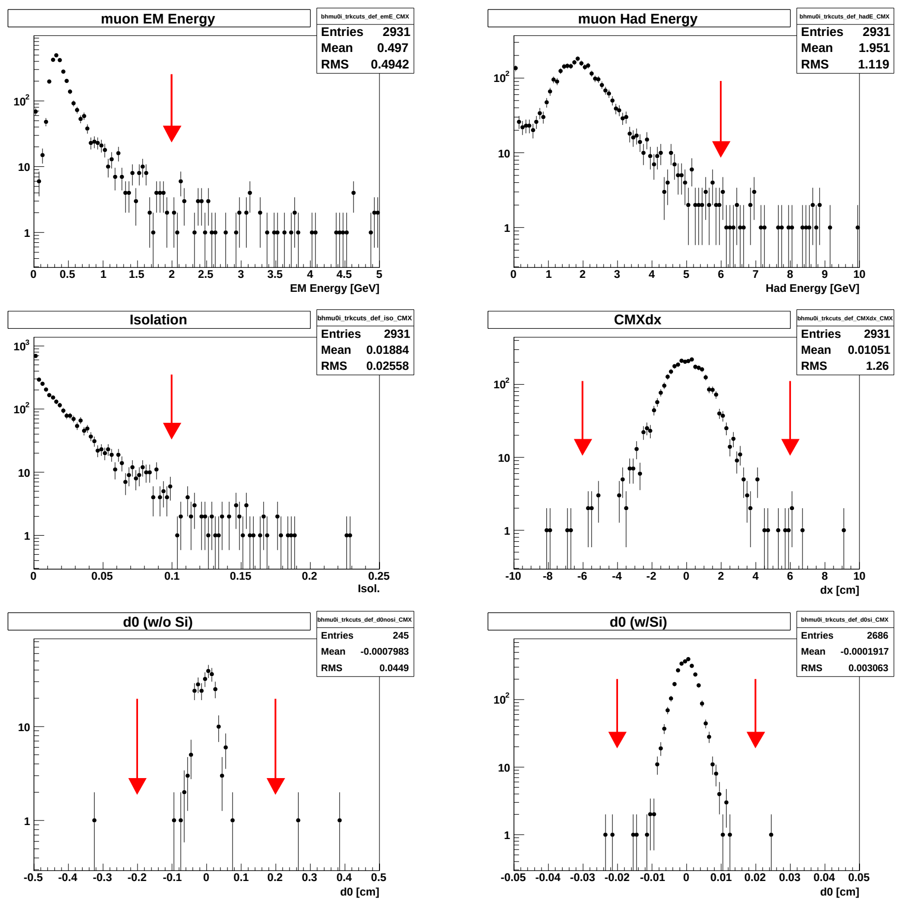

Figure 5: Distributions of the cut variables for CMX muons. The position of the recommended cut is shown with an arrow.

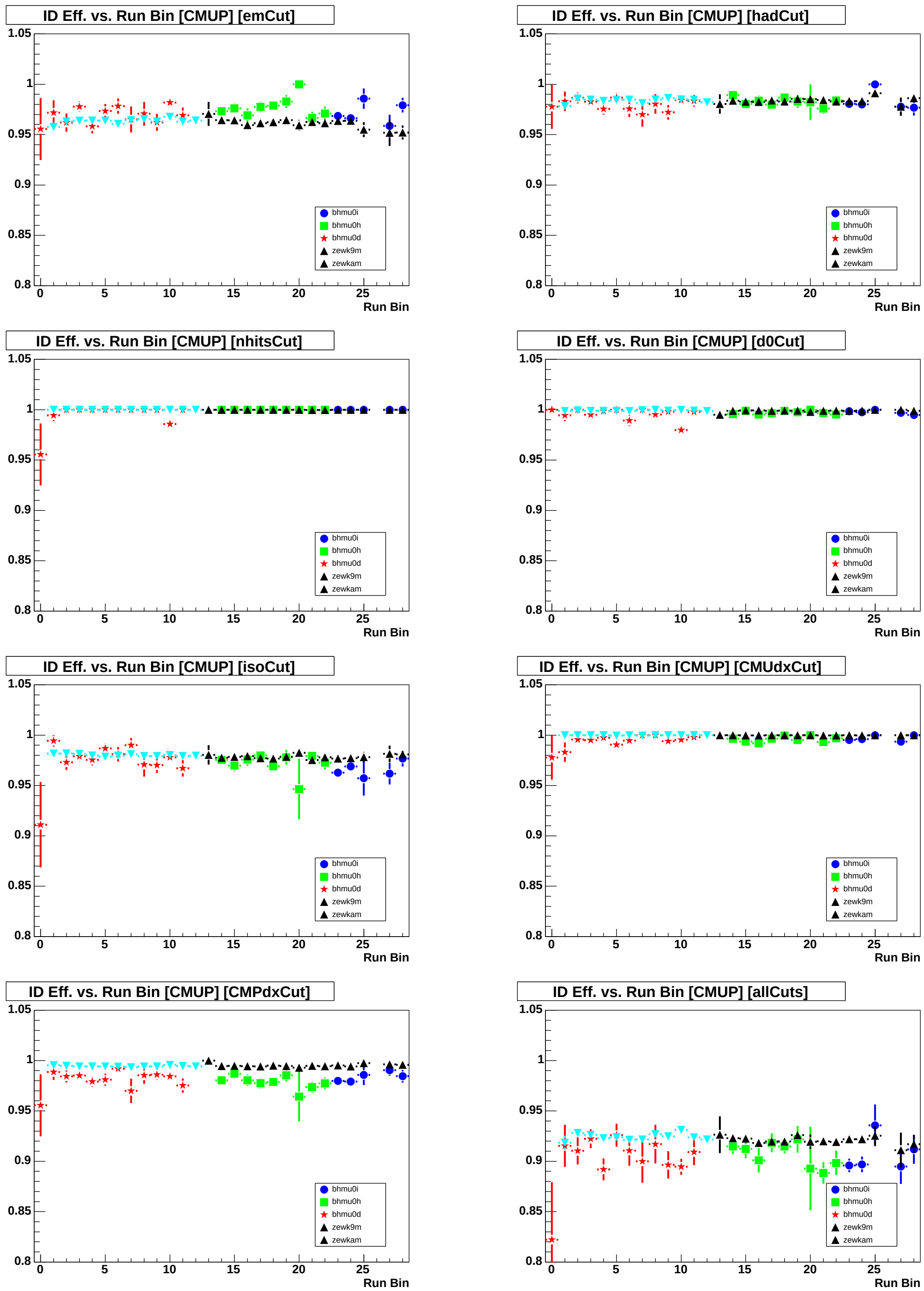

Figure 6: Efficiency of the cuts for CMUP muons as a function of run bin. This covers all three (`0d`, `0h`, and `0i`) run ranges.

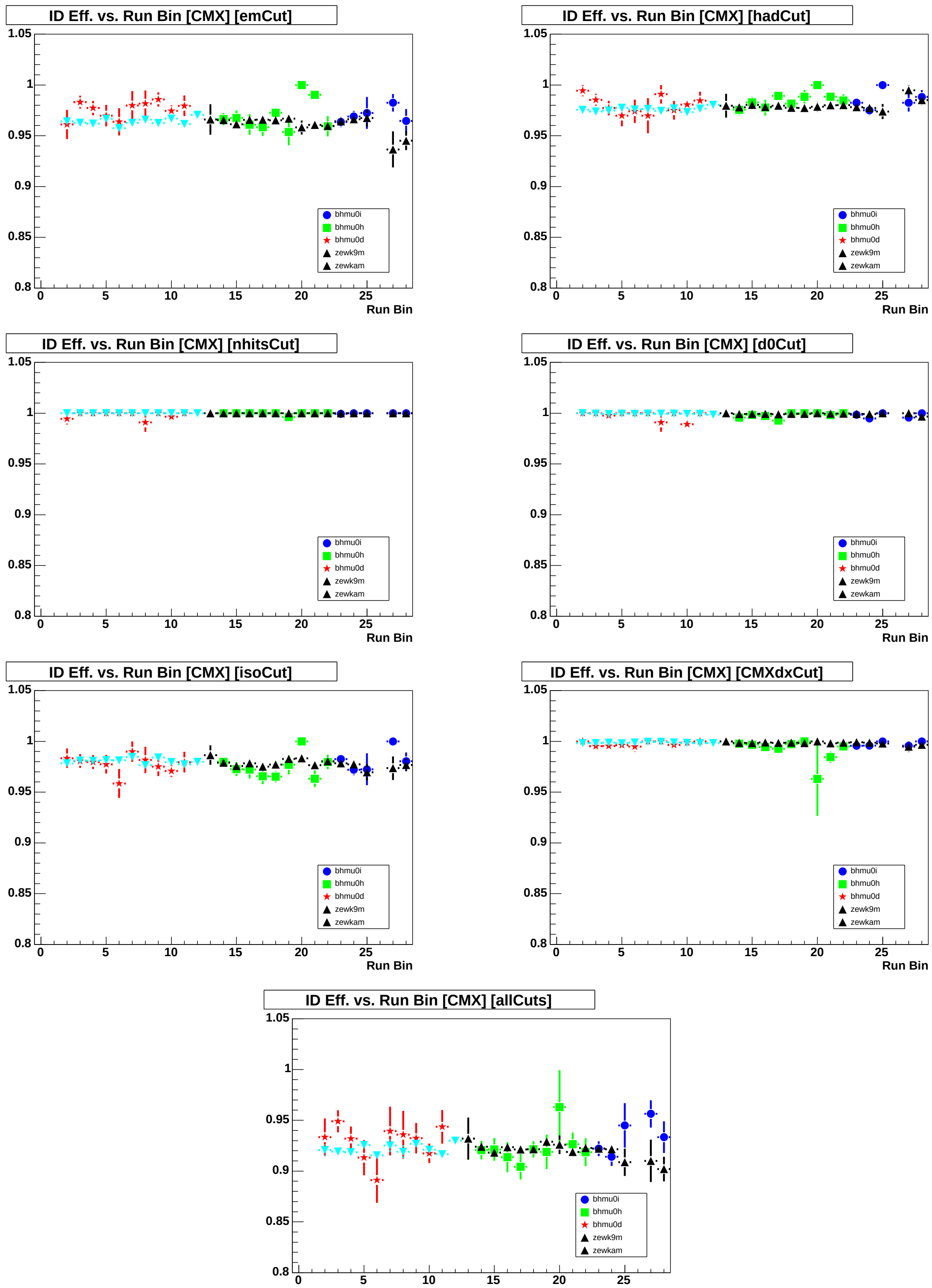

Figure 7: Efficiency of the cuts for CMX muons as a function of run bin. This covers all three (`0d`, `0h`, and `0i`) run ranges.

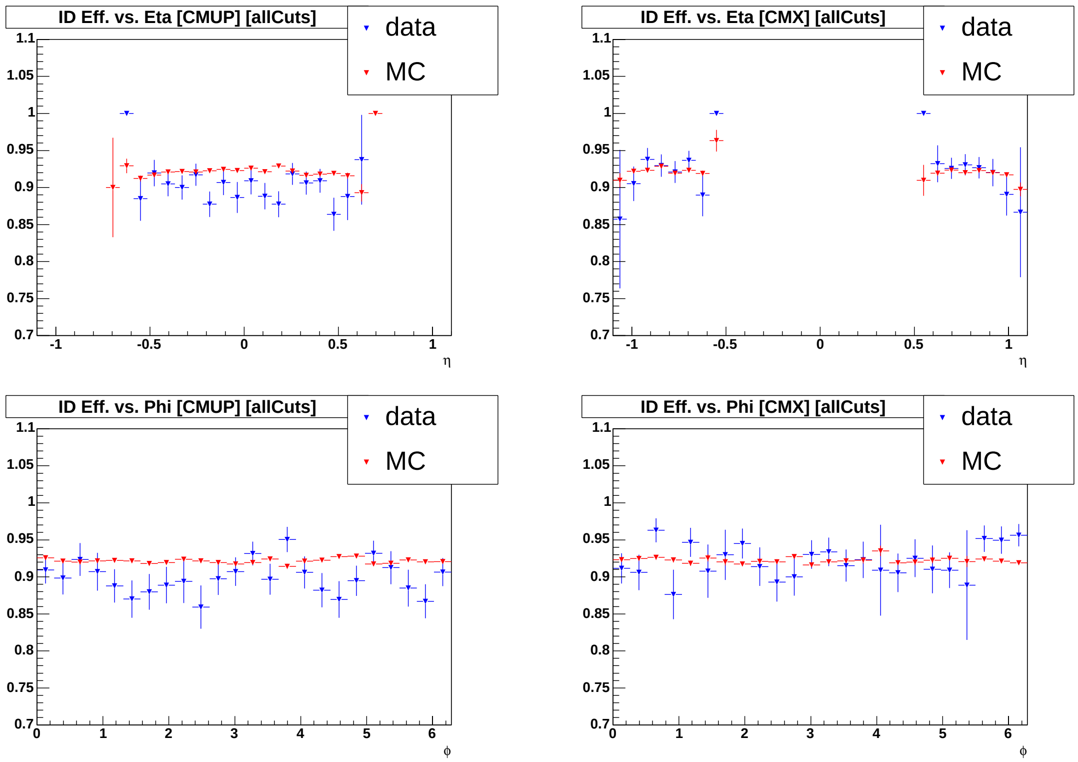

Figure 8: Efficiency of the CMUP and CMX ID cuts as a function of η and ϕ for **bhmu0i**.

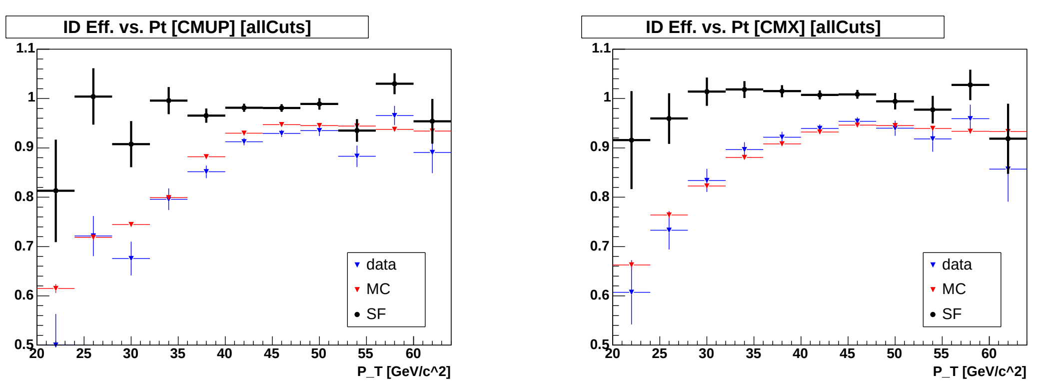

Figure 9: Efficiency of the CMUP and CMX for all ID cuts as a function of P_T for **bhmu0i**. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range to $50 < m(\mu^+\mu^-)/\mathrm{GeV}/c^2 < 130$.

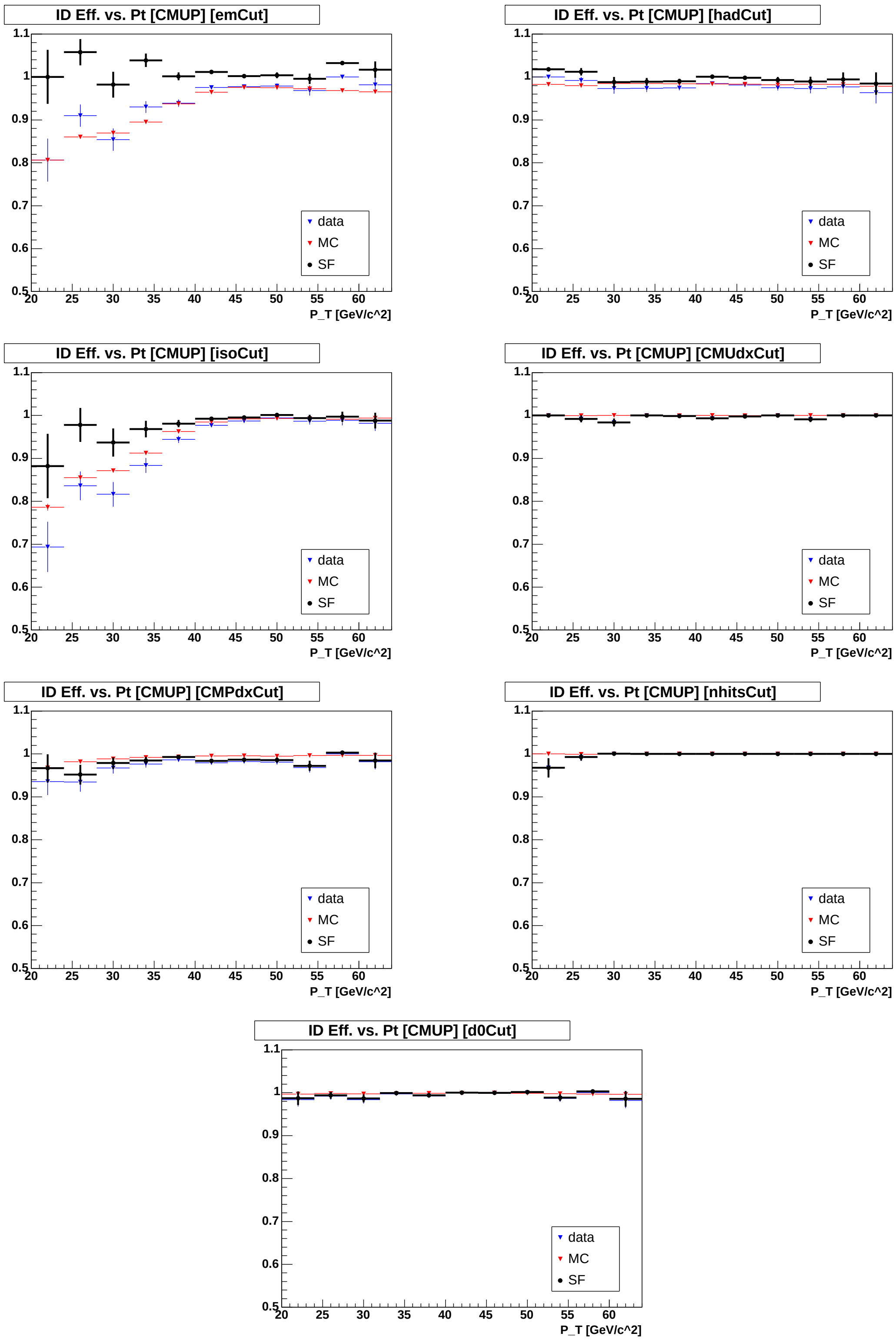

Figure 10: Efficiency and scale factor for each of the CMUP ID cuts for `bhmu0i`. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range to $50 < m(\mu^+\mu^-)/\mathrm{GeV}/c^2 < 130$.

	Efficiency (%)	
	`zewkam`	`zewk9m`
E_{EM} cut	96.59 ± 0.07	96.54 ± 0.05
E_{HAD} cut	97.59 ± 0.06	97.80 ± 0.04
COT hits cut	99.52 ± 0.03	99.58 ± 0.02
d_0 cut	99.88 ± 0.01	99.88 ± 0.01
Isolation cut	98.03 ± 0.05	97.73 ± 0.04
Δx_{CMX} cut	99.86 ± 0.01	99.85 ± 0.01
All above cuts	91.89 ± 0.11	91.79 ± 0.08
All cuts excl. isol.	93.62 ± 0.09	93.81 ± 0.07
Sliding isol. cut	98.16 ± 0.05	97.99 ± 0.04
All cuts (sliding isol.)	92.01 ± 0.11	92.03 ± 0.07

Table 27: Efficiencies of the muon ID cuts for muons in the CMX arches with no ρ cut applied in Monte Carlo.

	Scale Factor		
	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMX Arches	0.9912 ± 0.0052	1.0030 ± 0.0045	1.0077 ± 0.0055
Excl. isol.	0.9977 ± 0.0044	1.0054 ± 0.0038	1.0043 ± 0.0048
Sliding isol.	0.9928 ± 0.0051	1.0046 ± 0.0044	1.0082 ± 0.0054

Table 28: Scale factors - ratio of efficiencies for data and MC - for muon identification cuts with no ρ cut applied.

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

Following Victoria's lead from Gen. 5 [3], we have calculated efficiencies for CMU-only and CMP-only muon samples using Gen. 6 data.

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 in Table 2.
- It is not fiducial in the CMP, as defined in Table 2.
- It passes all the stubless muon cuts in Table 1.
- $|\Delta x_{CMU}| < 3$ 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 in Table 2.
- It is not fiducial in the CMU, as defined in Table 2.
- It passes all the stubless muon cuts in Table 1.
- $|\Delta x_{CMP}| < 5$ cm.

Finally, we report values for the CMIO sample. In addition to the standard CMIO sample, we look at the efficiencies of 'stubbed' CMIO muons. We stress that no study has been made on these samples to determine the backgrounds in the samples, and hence no background subtractions have been made.

Definition of CMIO muon sample. The CMIO sample is defined as:

- There is no stub in the CMU, CMP, CMX, or BMU detectors.
- It is not fiducial in the CMU, CMP, CMX, or BMU. That is, it does not pass x-fid < 0 cm and z-fid < 0 cm in any of these systems.

- It passes all the stubless muon cuts in Table 1.
- It passes minimum energy cut: $E_{EM} + E_{HAD} > 0.1\text{GeV}$.

Definition of SCMIO muon sample. The 'stubbed' CMIO sample is defined as:

- There is a stub in some muon detector.
- It does not meet the requirements of any other stubbed muon category.
- It passes all the stubless muon cuts in Table 1.
- It passes minimum energy cut: $E_{EM} + E_{HAD} > 0.1\text{GeV}$.

B.1 Results

The reconstruction efficiencies and scale factors for CMU-only and CMP-only muons can be found in Tables 29-31.

	Efficiency (%)		
Second leg category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMU-only	89.82 ± 0.73	88.00 ± 0.75	87.81 ± 0.94
CMP-only	93.45 ± 0.59	93.71 ± 0.52	93.39 ± 0.68

Table 29: Efficiencies of muon reconstructions.

	Efficiency (%)	
Second leg category	`zewkam`	`zewk9m`
CMU-only	97.83 ± 0.09	97.73 ± 0.07
CMP-only	98.31 ± 0.07	98.21 ± 0.05

Table 30: Efficiencies of muon reconstructions in Monte Carlo.

	Scale Factor		
Second leg category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMU-only	0.9233 ± 0.0074	0.9005 ± 0.0077	0.8985 ± 0.0096
CMP-only	0.9506 ± 0.0060	0.9542 ± 0.0053	0.9509 ± 0.0070

Table 31: Efficiencies of muon reconstructions.

The ID efficiencies for the samples defined above can be found in Tables 32-39. The ID cut scale factors are presented in Table 40. Finally, the overall scale factors of these samples can be found in Table 41.

	Efficiency (%)		
Cut	`bhmu0d`	`bhmu0h`	`bhmu0i`
E_{EM} cut	97.57 ± 0.39	97.00 ± 0.41	97.35 ± 0.49
E_{HAD} cut	98.02 ± 0.35	98.12 ± 0.33	97.63 ± 0.46
COT hits cut	99.74 ± 0.13	99.94 ± 0.06	100.00 ± 0.00
d_0 cut	99.49 ± 0.18	99.71 ± 0.13	99.73 ± 0.16
Isolation cut	97.64 ± 0.38	96.18 ± 0.46	97.08 ± 0.51
Δx_{CMU} cut	95.92 ± 0.50	96.36 ± 0.45	96.44 ± 0.56
All cuts	89.66 ± 0.77	88.48 ± 0.77	88.77 ± 0.95
All (w/o isol.) cuts	91.32 ± 0.71	91.83 ± 0.66	91.60 ± 0.84

Table 32: Efficiencies of the muon ID cuts for the CMU-only sample. The Δx_{CMU} cut for CMU-only muons is at 3 cm.

	Efficiency (%)	
Cut	`zewkam`	`zewk9m`
E_{EM} cut	96.14 ± 0.12	96.23 ± 0.08
E_{HAD} cut	97.99 ± 0.09	97.96 ± 0.06
COT hits cut	100.00 ± 0.00	100.00 ± 0.00
d_0 cut	99.95 ± 0.01	99.95 ± 0.01
Isolation cut	97.85 ± 0.09	97.51 ± 0.07
Δx_{CMU} cut	99.81 ± 0.03	99.86 ± 0.02
All cuts	92.13 ± 0.17	91.86 ± 0.12
All (w/o isol.) cuts	94.01 ± 0.15	94.07 ± 0.10

Table 33: Efficiencies of the muon ID cuts for the CMU-only sample in Monte Carlo. The Δx_{CMU} cut for CMU-only muons is at 3 cm.

	Efficiency (%)		
Cut	`bhmu0d`	`bhmu0h`	`bhmu0i`
E_{EM} cut	97.49 ± 0.38	98.35 ± 0.28	97.46 ± 0.44
E_{HAD} cut	99.22 ± 0.21	98.89 ± 0.23	98.89 ± 0.30
COT hits cut	99.52 ± 0.17	99.95 ± 0.05	99.92 ± 0.08
d_0 cut	99.28 ± 0.21	99.56 ± 0.14	99.60 ± 0.18
Isolation cut	97.43 ± 0.39	97.10 ± 0.37	96.83 ± 0.49
Δx_{CMP} cut	97.61 ± 0.37	96.95 ± 0.38	98.17 ± 0.38
All cuts	91.09 ± 0.70	91.43 ± 0.62	91.59 ± 0.78
All (w/o isol.) cuts	93.36 ± 0.61	93.76 ± 0.53	94.05 ± 0.67

Table 34: Efficiencies of the muon ID cuts for the CMP-only sample.

	Efficiency (%)	
Cut	`zewkam`	`zewk9m`
E_{EM} cut	97.73 ± 0.09	97.82 ± 0.06
E_{HAD} cut	98.73 ± 0.07	98.83 ± 0.04
COT hits cut	99.94 ± 0.01	99.94 ± 0.01
d_0 cut	99.91 ± 0.02	99.86 ± 0.01
Isolation cut	97.75 ± 0.09	97.44 ± 0.06
Δx_{CMP} cut	99.45 ± 0.04	99.49 ± 0.03
All cuts	93.80 ± 0.14	93.68 ± 0.10
All (w/o isol.) cuts	95.80 ± 0.12	96.02 ± 0.08

Table 35: Efficiencies of the muon ID cuts for the CMP-only sample in Monte Carlo.

	Efficiency (%)		
Cut	`bhmu0d`	`bhmu0h`	`bhmu0i`
E_{EM} cut	96.40 ± 0.43	95.79 ± 0.48	96.63 ± 0.54
E_{HAD} cut	98.28 ± 0.30	97.81 ± 0.35	98.14 ± 0.40
COT hits cut	99.84 ± 0.09	99.77 ± 0.12	99.73 ± 0.15
d_0 cut	99.63 ± 0.14	99.48 ± 0.17	99.47 ± 0.22
Isolation cut	96.87 ± 0.40	96.25 ± 0.46	96.19 ± 0.57
Min. Energy cut	96.29 ± 0.43	95.61 ± 0.49	95.21 ± 0.64
All cuts	88.98 ± 0.72	87.24 ± 0.80	87.94 ± 0.97
All (w/o isol.) cuts	91.12 ± 0.65	89.55 ± 0.74	90.25 ± 0.88

Table 36: Efficiencies of the muon ID cuts for CMIO muons. No study has been made to determine and correct for backgrounds in this sample.

	Efficiency (%)	
Cut	`zewkam`	`zewk9m`
E_{EM} cut	96.44 ± 0.09	96.87 ± 0.08
E_{HAD} cut	97.82 ± 0.07	98.01 ± 0.06
COT hits cut	99.99 ± 0.00	100.00 ± 0.00
d_0 cut	99.92 ± 0.01	99.91 ± 0.01
Isolation cut	97.71 ± 0.08	97.61 ± 0.07
Min. Energy cut	93.14 ± 0.13	91.27 ± 0.13
All cuts	85.84 ± 0.18	84.38 ± 0.17
All (w/o isol.) cuts	87.57 ± 0.17	86.25 ± 0.16

Table 37: Efficiencies of the muon ID cuts for CMIO muons in Monte Carlo. No study has been made to determine and correct for backgrounds in this sample.

	Efficiency (%)		
Cut	`bhmu0d`	`bhmu0h`	`bhmu0i`
E_{EM} cut	95.78 ± 0.56	94.58 ± 0.71	93.94 ± 0.94
E_{HAD} cut	96.09 ± 0.54	94.38 ± 0.72	95.34 ± 0.83
COT hits cut	99.69 ± 0.15	99.90 ± 0.10	100.00 ± 0.00
d_0 cut	98.85 ± 0.30	99.31 ± 0.26	100.00 ± 0.00
Isolation cut	96.32 ± 0.52	94.97 ± 0.69	92.86 ± 1.01
Min. Energy cut	98.47 ± 0.34	99.11 ± 0.29	99.53 ± 0.27
All cuts	89.26 ± 0.86	89.05 ± 0.98	87.73 ± 1.29
All (w/o isol.) cuts	90.80 ± 0.80	90.43 ± 0.92	91.46 ± 1.10

Table 38: Efficiencies of the muon ID cuts for stubbed CMIO muons. No study has been made to determine and correct for backgrounds in this sample.

	Efficiency (%)	
Cut	`zewkam`	`zewk9m`
E_{EM} cut	96.00 ± 0.21	96.61 ± 0.13
E_{HAD} cut	98.09 ± 0.15	98.18 ± 0.10
COT hits cut	99.95 ± 0.02	99.99 ± 0.01
d_0 cut	99.81 ± 0.05	99.79 ± 0.03
Isolation cut	97.77 ± 0.16	97.63 ± 0.11
Min. Energy cut	97.88 ± 0.16	97.41 ± 0.12
All cuts	90.09 ± 0.32	89.98 ± 0.22
All (w/o isol.) cuts	91.95 ± 0.29	92.12 ± 0.20

Table 39: Efficiencies of the muon ID cuts for stubbed CMIO muons in Monte Carlo. No study has been made to determine and correct for backgrounds in this sample.

	Scale Factor		
Category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMU-only	0.9729 ± 0.0086	0.9626 ± 0.0086	0.9684 ± 0.0104
Excl. isol.	0.9712 ± 0.0077	0.9757 ± 0.0072	0.9759 ± 0.0089
CMP-only	0.9711 ± 0.0076	0.9760 ± 0.0067	0.9776 ± 0.0084
Excl. isol.	0.9746 ± 0.0065	0.9764 ± 0.0056	0.9795 ± 0.0070
CMIO	1.0366 ± 0.0086	1.0340 ± 0.0097	1.0423 ± 0.0117
Excl. isol.	1.0405 ± 0.0077	1.0382 ± 0.0087	1.0463 ± 0.0104
SCMIO	0.9909 ± 0.0102	0.9897 ± 0.0112	0.9750 ± 0.0146
Excl. isol.	0.9874 ± 0.0093	0.9816 ± 0.0102	0.9928 ± 0.0121

Table 40: Scale factors - ratio of efficiencies for data and MC - for muon identification cuts.

	Scale Factor		
Category	`bhmu0d`	`bhmu0h`	`bhmu0i`
CMU-only	0.8984 ± 0.0107	0.8704 ± 0.0107	0.8740 ± 0.0132
Excl. isol.	0.8967 ± 0.0101	0.8823 ± 0.0099	0.8807 ± 0.0123
CMP-only	0.9231 ± 0.0093	0.9313 ± 0.0082	0.9297 ± 0.0105
Excl. isol.	0.9264 ± 0.0085	0.9317 ± 0.0075	0.9314 ± 0.0095
CMIO	1.0366 ± 0.0086	1.0340 ± 0.0097	1.0423 ± 0.0117
Excl. isol.	1.0405 ± 0.0077	1.0382 ± 0.0087	1.0463 ± 0.0104
SCMIO	0.9909 ± 0.0102	0.9897 ± 0.0112	0.9750 ± 0.0146
Excl. isol.	0.9874 ± 0.0093	0.9816 ± 0.0102	0.9928 ± 0.0121

Table 41: Overall scale factors for muon ID and reconstruction efficiencies. Overall scale factors are products of the scale factors found in Tables 29 and 40.

	Scale Factor	
Category	`0h + 0i`	`0d + 0h + 0i`
CMU-only	0.8718 ± 0.0083	0.8811±0.0091±0.0266
Excl. isol.	0.8817 ± 0.0077	0.8870±0.0085±0.0150
CMP-only	0.9307 ± 0.0065	0.9280±0.0075±0.0076
Excl. isol.	0.9316 ± 0.0059	0.9298±0.0068±0.0052
CMIO	1.0372 ± 0.0076	1.0370±0.0080±0.0006
Excl. isol.	1.0414 ± 0.0068	1.0411±0.0071±0.0009
SCMIO	0.9840 ± 0.0090	0.9864±0.0094±0.0069
Excl. isol.	0.9860 ± 0.0080	0.9865±0.0085±0.0014

Table 42: Overall scale factors for muon ID and reconstruction efficiencies of combined data samples. Overall scale factors are products of the numbers found in Tables 29 and 40. See Sec. 2.1 for details on the combinations. With a large systematic uncertainties it may be unwise to combine scale factors.

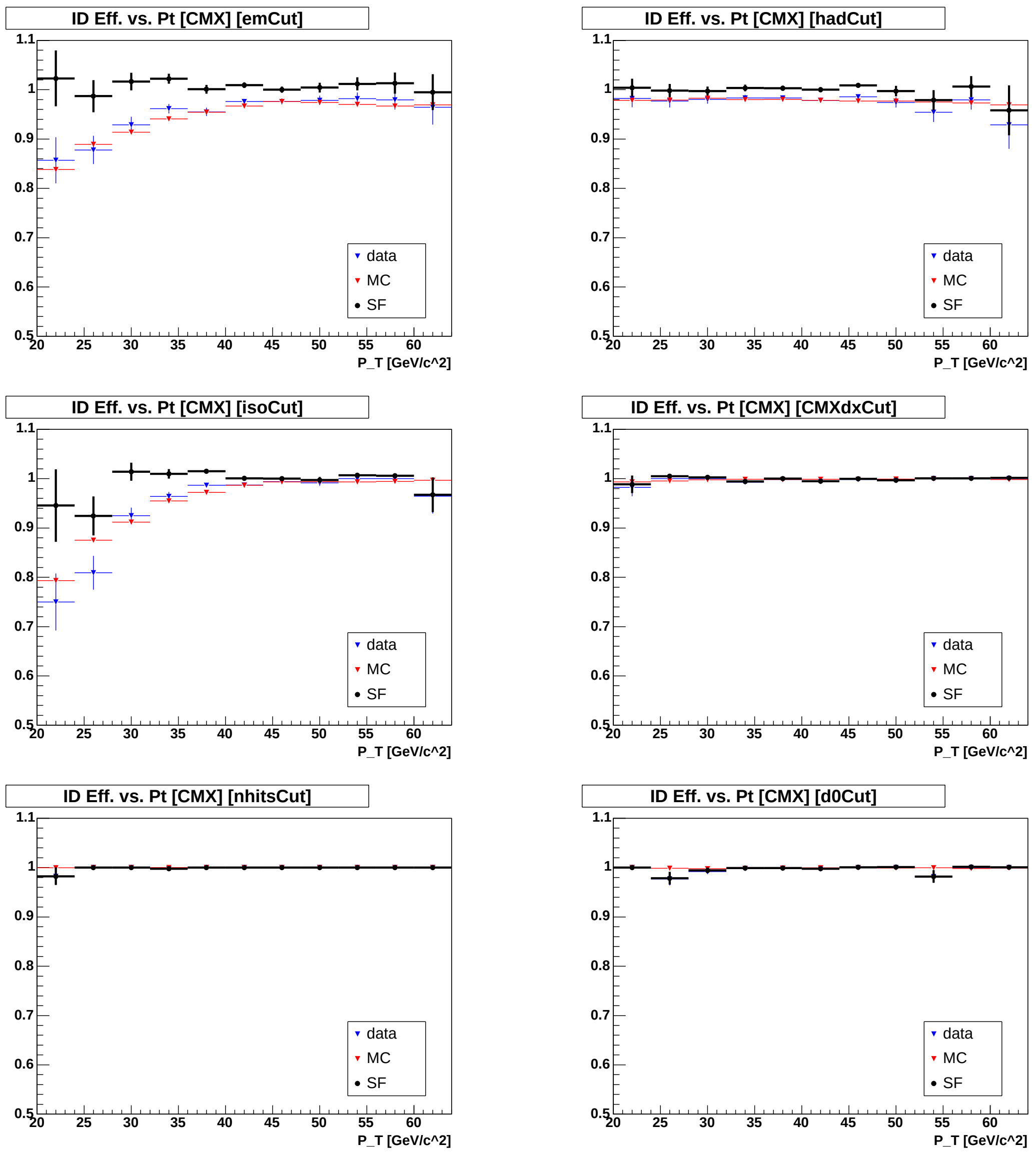

Figure 11: Efficiency and scale factor for each of the CMX ID cuts for `bhmu0i`. In order to pick up more statistics at low and high momenta, we have expanded the allowed mass range to $50 < m(\mu^+\mu^-)/\mathrm{GeV}/c^2 < 130$.

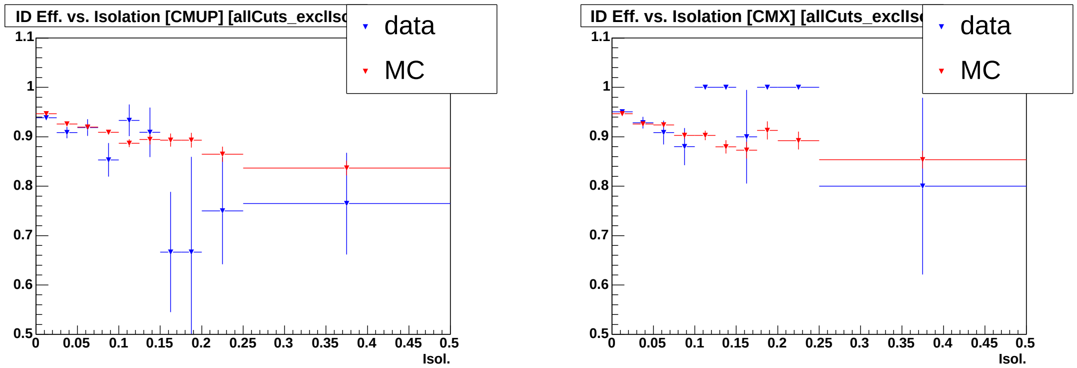

Figure 12: Efficiency and scale factor for the ID cuts for `bhmu0i`, excluding the isolation cut, as a function of isolation.

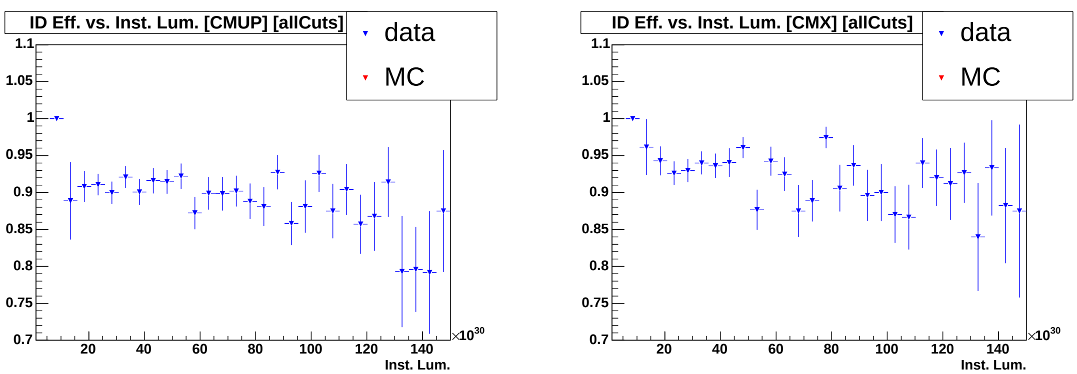

Figure 13: Efficiency for the ID cuts as a function of instantaneous luminosity for `bhmu0i`.

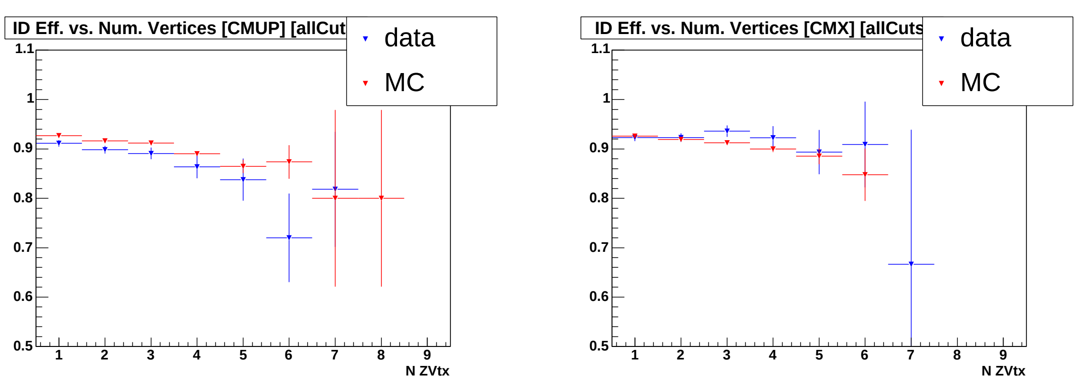

Figure 14: Efficiency for the ID cuts as a function of the number of vertices in the event for `bhmu0i`.

References

[1] CDF 7956 U. Grundler, A. Taffard, and X. Zhang, *High-p_T muons, recommended cuts and efficiencies for Winter 2006.*

[2] CDF 7031 V. Martin, *High-p_T muons, recommended cuts and efficiencies for release 5.3.*

[3] CDF 7367 V. Martin, *High-p_T Muon ID Cuts and Efficiencies for use with 5.3.1 Data and 5.3.3 MC.*

[4] CDF 6971 L. Nodulman, *Curvature Corrections for 5.3.1 and 6.1.1.*

[5] CDF 6711 D. 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.*