Period 14 High PT Lepton Efficiencies and SF - Blessing

Simona Rolli

Tufts

Electrons ID: Samples

Dataset bhelmj: Runs 252836-254686
MC sample : zektei (March 2008)
GRL :Final GRL for P14

P14 SAM dataset and skim lepton
MC dataset zektei (P14) on SAM

Electron ID: Cuts

CEM Selection Cuts

Variable	Tight (CEM)
Region	== CEM
Fiducial	Fiducial == 1
E_T	$\geq$ 20 GeV
Track Z_0	$\leq$ 60 cm
Track p_T	$\geq$ 10 GeV/c
COT Ax. Seg.	$\geq$ 3
COT St. Seg.	$\geq$ 2
Conversion	$\neq$ 1
Had/em	$\leq (0.055 + (0.00045 \times E))$
Isolation	$\leq$ 0.1
LshrTrk	$\leq$ 0.2
E/P	$\leq$ 2.0 unless $p_T \geq$ 50GeV/c
CES ΔZ	$\leq$ 3.0 cm
Signed CES ΔX	$-3.0 \leq q \times \Delta X \leq 1.5$
CES StripChi2	$\leq$ 10.0

$\mathbb{Z}$ candidates are used to calculate the efficiencies

Plug Selection Cuts

Variable	PHX	PEM
E_T	$\geq$ 20GeV	$\geq$ 20GeV
Pes2dEta	$1.2 \leq \lvert\eta\rvert \leq 2.8$	$1.2 \leq \lvert\eta\rvert \leq 2.8$
Had/Em	$\leq$ 0.05	$\leq$ 0.05
Pem3x3FitTow	$\neq$ 0	$\neq$ 0
Pem3x3Chisq	$\leq$ 10	$\leq$ 10
Pes5by9U	$\geq$ 0.65	$\geq$ 0.65
Pes5by9V	$\geq$ 0.65	$\geq$ 0.65
Isolation	$\leq$ 0.1	$\leq$ 0.1
ΔR	$\leq$ 3.0 cm	$\leq$ 3.0 cm
PhxMatch	TRUE	-
N_{hits}^{Si}	$\geq$ 3	-
$\lvert z_0^{PHX}\rvert$	$\leq$ 60 cm	-

We calculate efficiencies using a set of very loose, or "probe" electrons as the denominator. For each tight electron in the event which passes the trigger, we look for probe electrons which have the opposite sign and which, paired with the tight electron, have an invariant mass in the Z window 76 GeV/c^2 $< M <$ 106 GeV/c^2. (Central-Central)

We calculate Phoenix electron efficiencies using central-plug Z candidates in the mass window 81 GeV/c^2 $< M <$ 101 GeV/c^2. Due to the non-negligible, and η-dependent, Phoenix charge fake rate, there is no opposite-sign requirement.

Period 14 vs P13

	Period 13		Period 14	
	Bhelmi(P13)	zemtjm	Bhelmk(P14)	zektej
CEM Eff	0.784+\-0.004	0.804 +\-0.001	0.805+\-0.010	0.796 +\-0.003
CEM SF	0.975 +\-0.005	N/A	1.011 +\-0.011	N/A
nisoCEM Eff	0.810 +\-0.003	0.829 +\-0.001	0.833 +\-0.009	0.822 +\-0.003
nisoCEM SF	0.984 +\-0.004	N/A	1.014 +\-0.012	N/A
LooseCEM Eff	0.913 +/- 0.003	0.915 +\-0.001	0.924+\-0.007	0.912 +\-0.003
LooseCEM SF	0.998 +\-0.003	N/A	1.014+\-0.008	N/A
nisolooseCEM Eff	0.949+\-0.002	0.945 +\-0.001	0.955+\-0.005	0.944 +\-0.003
nisoloostCEM SF	1.002 +\-0.002	N/A	1.012+\-0.006	N/A

	PHX		PHX	
Eff |Eta| < 2.0	0.681+\-0.006	0.736+\-0.001	0.717+\-0.016	0.753+\-0.004
SF |Eta| < 2.0	0.924+\- 0.008	NA	0.952+\-0.022	NA
	PHX		PHX	
Eff |Eta| < 2.8	0.601+\-0.005	0.644+\-0.001	0.636+\-0.014	0.657+\-0.004
SF |Eta| < 2.8	0.933+\- 0.008	NA	0.968+\-0.022	NA

Results for Period 13 (vs P12)

	Period 12		Period 13	
	Bhelmi(P12)	zewkeh	Bhelmi(P13)	zemtjm
CEM Eff	0.7717+\-0.0052	0.8027 +\-0.0011	0.784+\-0.004	0.804 +\-0.001
CEM SF	0.9613 +\-0.007	N/A	0.975 +\-0.005	N/A
nisoCEM Eff	0.8051 +\-0.0049	0.8286 +\-0.0011	0.810 +\-0.003	0.829 +\-0.001
nisoCEM SF	0.9716 +\-0.006	N/A	0.984 +\-0.004	N/A
LooseCEM Eff	0.9018 +/- 0.0037	0.9136 +\-0.0011	0.913 +/- 0.003	0.915 +\-0.001
LooseCEM SF	0.9869 +\-0.004	N/A	0.998 +\-0.003	N/A
nisolooseCEM Eff	0.9401+\-0.0029	0.9452 +\-0.0011	0.949+\-0.002	0.945 +\-0.001
nisoloostCEM SF	0.9945 +\-0.0033	N/A	1.002 +\-0.002	N/A

	PHX		PHX	
Eff |Eta| < 2.0	0.7016+\-0.008	0.7460+\-0.0015	0.681+\-0.006	0.736+\-0.001
SF |Eta| < 2.0	0.9280+\- 0.0100	NA	0.924+\- 0.008	NA
	PHX		PHX	
Eff |Eta| < 2.8	0.6155+\-0.0066	0.6589+\-0.0015	0.601+\-0.005	0.644+\-0.001
SF |Eta| < 2.8	0.9340+\- 0.0102	NA	0.933+\- 0.008	NA

CEM-PEM

	P12 PEM		P13 PEM	
Eff |Eta| < 2.0	0.8001 +\- 0.0065	0.8609 +\- 0.0012	0.800+\-0.005	0.861+\-0.001
SF |Eta| < 2.0	0.9294+\- 0.0077	NA	0.929+\- 0.006	NA

	PEM		PEM	
Eff |Eta| < 2.8	0.7632 +\- 0.0058	0.8297 +\- 0.011	0.765+\-0.005	0.831+\-0.001
SF |Eta| < 2.8	0.9198 +\- 0.007	NA	0.921+\- 0.005	NA

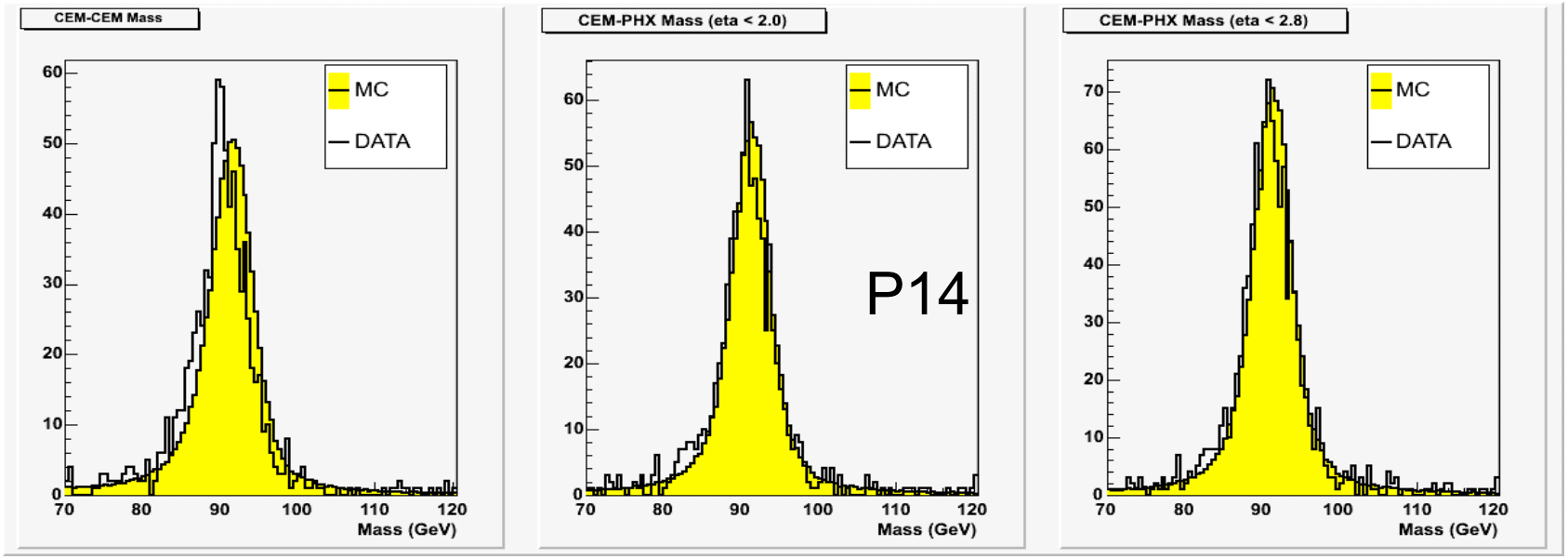
The drop in P13 only concerned Si PHX

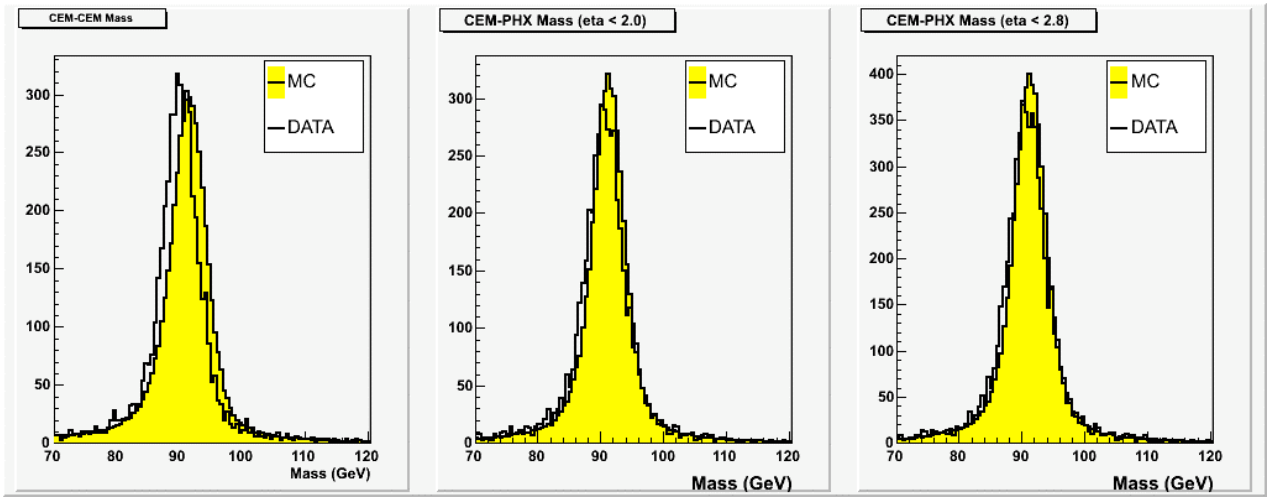
P14

PEM (eta < 2.0)	
0.804+\-0.014	0.862+\-0.004
0.933+\-0.017	NA

PEM (eta<2.8)	
0.776+\-0.012	0.832+\-0.003
0.933+\-0.015	NA

EleID Plots

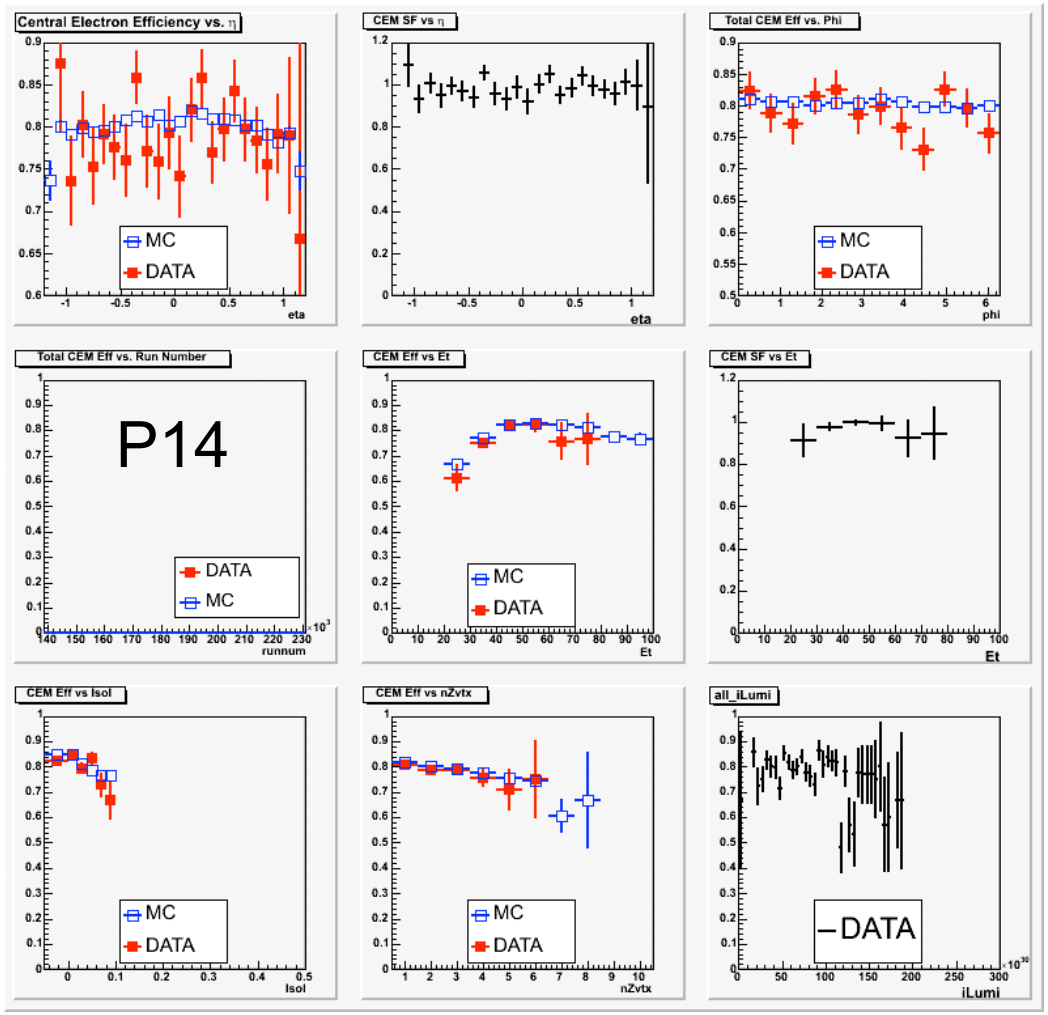




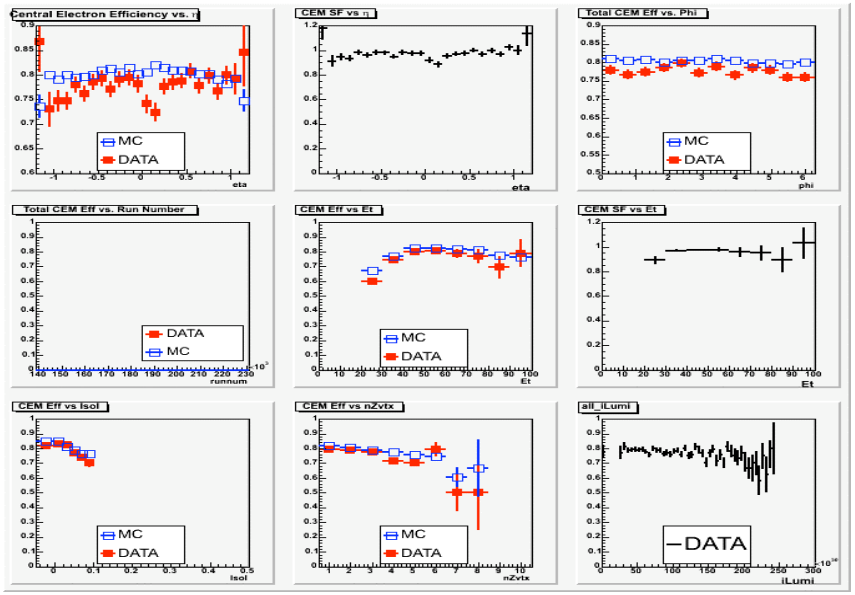
P13

EleID Plots 1

CEM Efficiencies

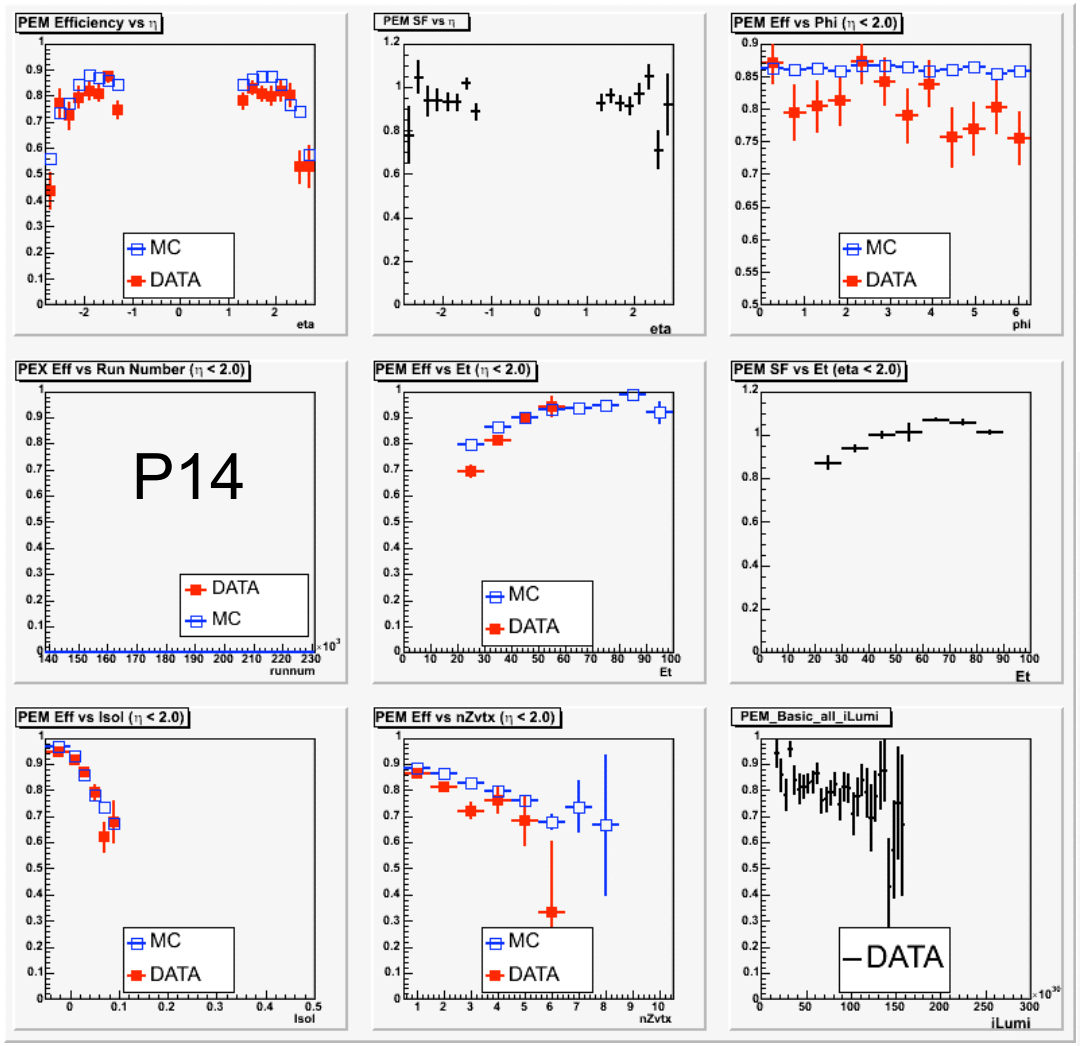


P13

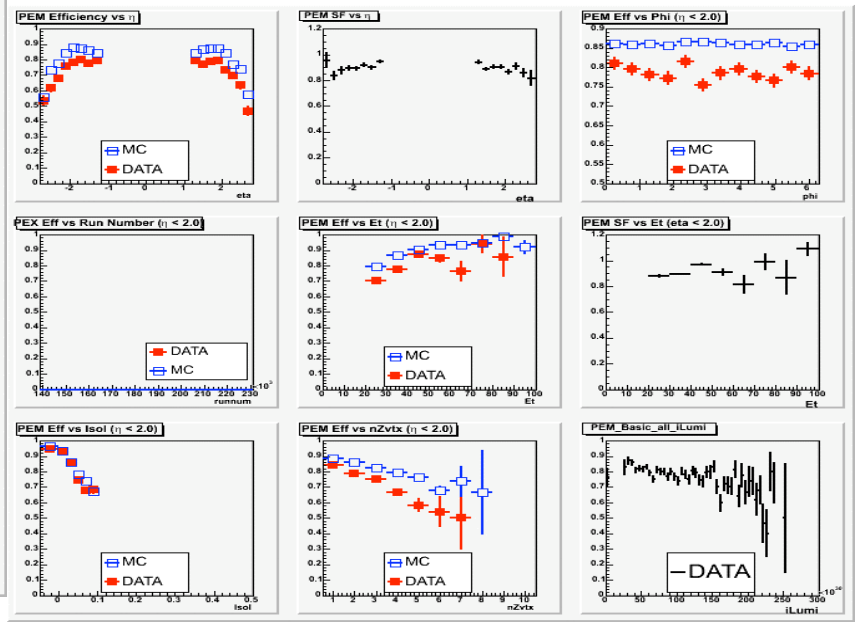


EleID Plots 2

PEM Efficiencies

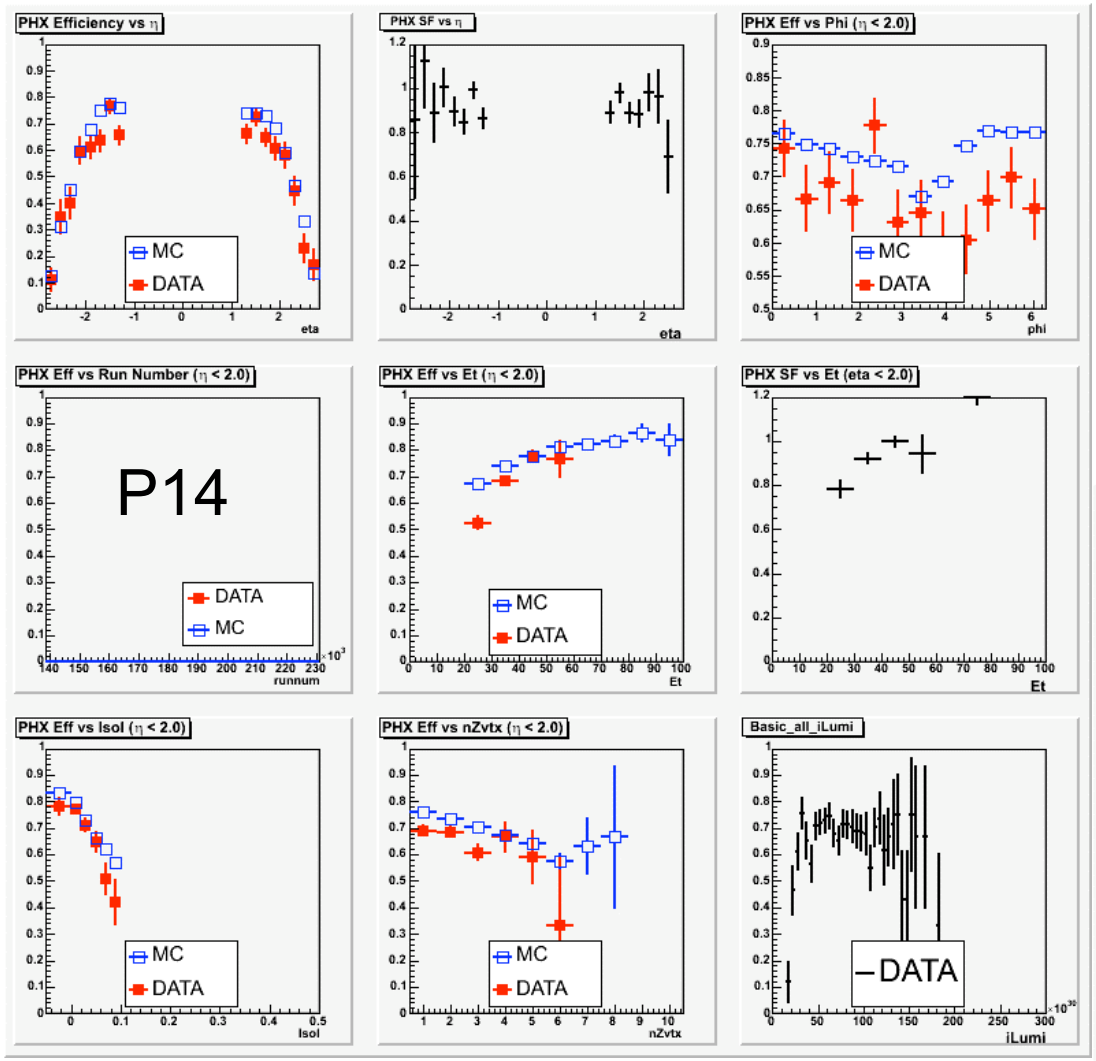


P13

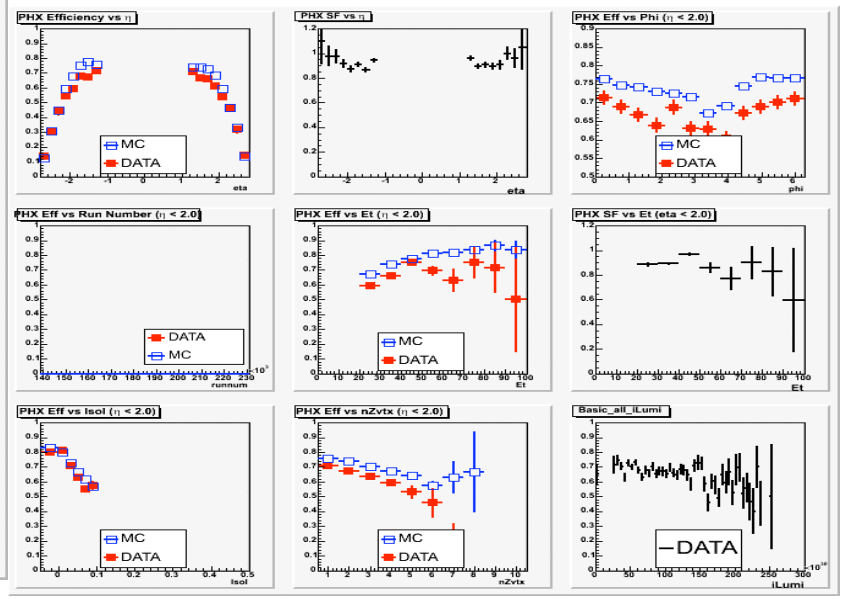


EleID Plots 3

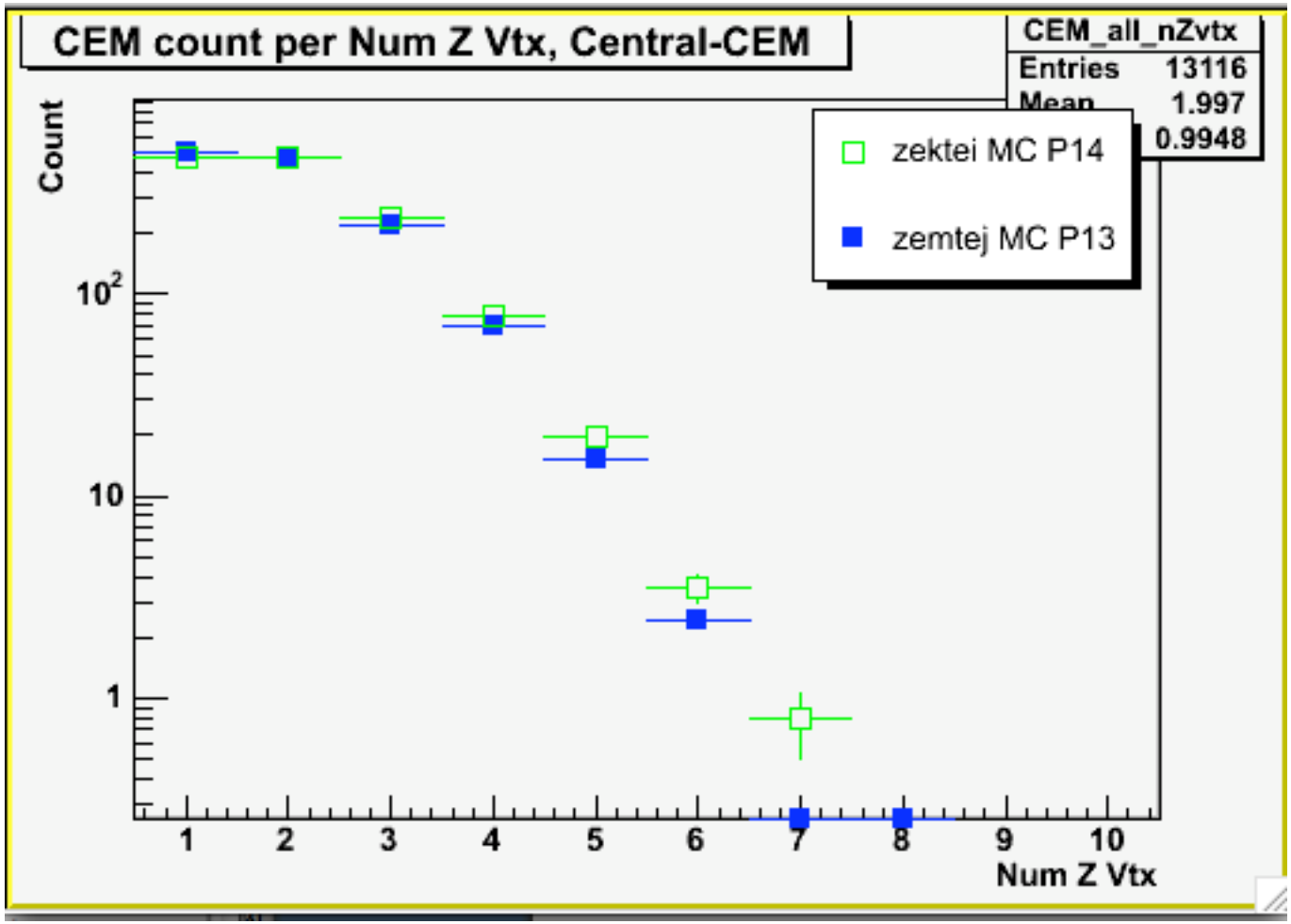
PHX Efficiencies



P13



Nvtx distributions for MC



Electron Trigger: Tracking

1 electron with $E_T > 25GeV$
$\not{E}_T > 25GeV$
reject cosmic events

Table: Offline *W* selection.

Electron Variables	Current baseline cuts
E_T	> 20 GeV
p_T	> 10 GeV/c
N_{SL}^{axial} with 5 hits	≥ 3
N_{SL}^{stereo} with 5 hits	≥ 2
Fiducial	1
Had/Em	$< 0.055 + 0.00045E$
L_{shr}	< 0.2
E/p	< 2 (for $p_T < 50GeV$)
$\lvert Z_{vertex} \rvert$	< 60 cm
$\lvert \Delta X \rvert$	$-3.0 < Q_{trk}\Delta X < 1.5$ cm
$\lvert \Delta Z \rvert$	< 3 cm
χ^2_{strip}	< 10
Conversion	$\neq 1$ (not)

Table: Offline baseline cuts for central electrons.

L1 Tracking Efficiency

$$\epsilon(\text{L1_XFT_PT8}) = \frac{\text{numW \& passed L1_CEM8_PT8}}{\text{numW}}$$

numW means the number of *W* candidates that passed the W-NOTRACK path.

L2 Tracking Efficiency

At L2, there is no additional tracking done except for receiving the XFT information from L1.

$$\epsilon(\text{L2_XFT_PT8}) = \frac{\text{numW \& passed L1_CEM8_PT8 \& passed L2_CEM16_PT8}}{\text{numW \& passed L1_CEM8_PT8}}$$

L3 Tracking Efficiency

$$\epsilon(\text{L3_PT9}) = \frac{\text{numW \& passed L1_CEM8_PT8 \& L2_CEM16_PT8 \& L3_CEM18_PT9}}{\text{numW \& passed L1_CEM8_PT8 \& L2_CEM16_PT8}}$$

Electron Trigger: Calorimeter

L2 Calorimeter Efficiency

- Require at least 1 electron satisfying the baseline cuts and $E_T >$ 18GeV.
- Use ELECTRON_CENTRAL_18_NO_L2 path.
- Efficiency reaches 100% at about 25 GeV.

$$\epsilon(\text{L2_CEM16}) = \frac{\text{numEl \& passed L1_CEM8_PT8 \& L2_PS \& L2_CEM16}}{\text{numEl \& passed L1_CEM8_PT8 \& L2_PS}}$$

L3 Calorimeter Efficiency

- Use the calibration dataset(blpc).
- Use ELECTRON_CENTRAL_8_NO_L2 path.
- Efficiency reaches 100% at about 20 GeV.

$$\epsilon(\text{L3_CEM18}) = \frac{\text{numEl \& passed EL_CENT_8_NO_L2 \& L2_CEM16 \& L3_CEM18}}{\text{numEl \& passed EL_CENT_8_NO_L2 \& L2_CEM16}}$$

Electron Trigger: Results

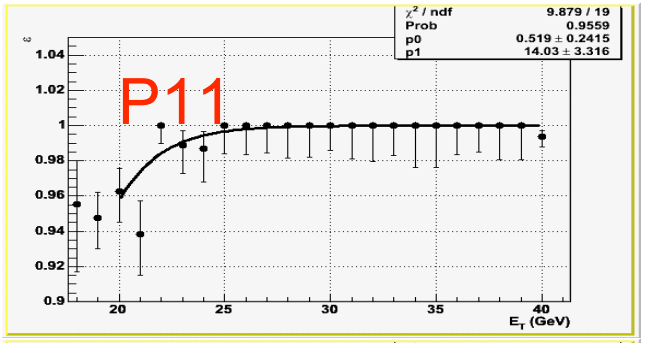
Analyzed all data

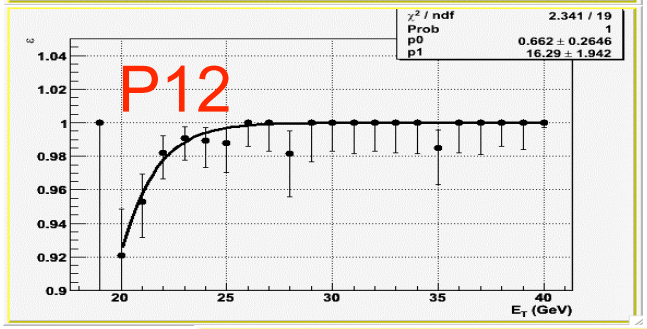
NoffIW	16825
NcemL1	16232
NcemL2	16225
NcemL3	16161

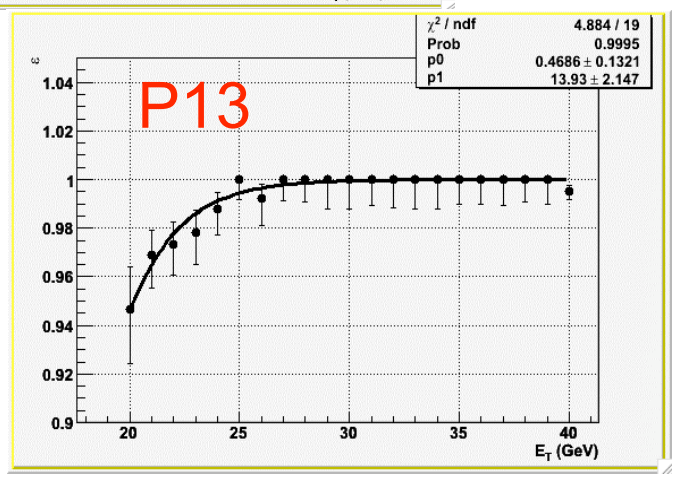
Trigger	Period 9	Period 10A	Period 10B
L1_XFT_PT8	0.9651(6)	0.9673(7)	0.9650(29)
L2_XFT_PT8	0.9992(1)	0.9993(1)	0.9992(5)
L3 tracking	0.9954(2)	0.9932(3)	0.9968(9)
Total Tracking	0.9598(7)	0.9600(8)	0.9611(31)

Trigger	Period 11	Period 12	Period 13	Period 14
L1_XFT_PT8	0.9688(4)	0.96857 ± 0.003	0.963922 ± 0.003	0.964755 ± 0.03
L2_XFT_PT8	0.9988(4)	0.9990 ± 0.003	0.998003 ± 0.003	0.999569 ± 0.03
L3 tracking	0.9935(4)	0.9940 ± 0.003	0.994608 ± 0.003	0.996055 ± 0.03
Total Tracking	0.9614(4)	0.9600 ± 0.003	0.95681 ± 0.003	0.960535 ± 0.03

Electron Trigger : Results

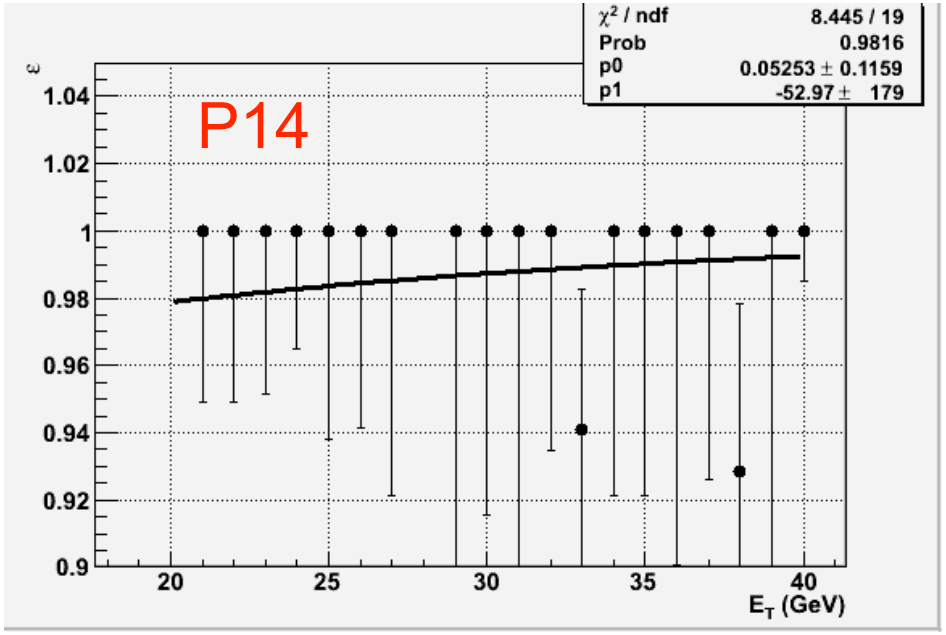






L2_CEM16 calorimeter efficiency

$$\epsilon = \frac{1}{1 + e^{-\beta(E_T - \alpha)}}.$$



Muons

Dataset bhelmi: Runs 252836-254686
MC sample : zektim (Mar 2008)
GRL : Final GRL for P14

Data: P14 Data on SAM and skim lepton
MC: dataset zektim (P14) on SAM

Muon ID Efficiency: ID Cuts

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
$\lvert z_0 \rvert$	$<$	60 cm
Tracks w/ no silicon hits: $\lvert d_0 \rvert$	$<$	0.2 cm
Tracks w/ silicon hits: $\lvert d_0 \rvert$	$<$	0.02 cm

Additionally for tight CMUP muons:

$\lvert \Delta x_{CMU} \rvert$	$<$	7 cm
$\lvert \Delta x_{CMP} \rvert$	$<$	5 cm
No bluebeam muons, run	$<$	154449

Additionally for tight CMX muons:

$\lvert \Delta x_{CMX} \rvert$	$<$	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.

Fiducial cuts

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 $\geq$ 190697 and $\leq$ 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.

ID Efficiency Calculation

- 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.

CMUP ID Efficiency

P13

Cut	Count	Efficiency (%)
No cut	4352	
E_{EM} cut	4222	$97.01^{+0.28}_{-0.26}$
E_{HAD} cut	4282	$98.39^{+0.18}_{-0.21}$
COT hits cut	4352	$100.00^{+0.00}_{-0.04}$
d_0 cut	4338	$99.68^{+0.08}_{-0.11}$
Isolation cut	4206	$96.65^{+0.25}_{-0.28}$
Δx_{CMU} cut	4334	$99.59^{+0.10}_{-0.12}$
Δx_{CMP} cut	4279	$98.32^{+0.20}_{-0.21}$
All above cuts	3928	$90.26^{+0.44}_{-0.49}$
All cuts excl. isol.	4056	$93.20^{+0.38}_{-0.40}$
Sliding isol. cut	4252	$97.70^{+0.23}_{-0.25}$
All cuts (sliding isol.)	3972	$91.27^{+0.41}_{-0.47}$
χ^2 cut	4352	$100.00^{+0.00}_{-0.04}$
All cuts (χ^2)	3928	$90.26^{+0.44}_{-0.49}$
All track cuts	4015	$92.26^{+0.39}_{-0.44}$
All trk cuts excl. isol.	4144	$95.22^{+0.31}_{-0.32}$

P14

Cut	Count	Efficiency (%)
No cut	582	
E_{EM} cut	567	$97.42^{+0.67}_{-0.79}$
E_{HAD} cut	569	$97.77^{+0.62}_{-0.84}$
COT hits cut	582	$100.00^{+0.00}_{-0.32}$
d_0 cut	581	$99.83^{+0.14}_{-0.40}$
Isolation cut	561	$96.39^{+0.73}_{-0.93}$
Δx_{CMU} cut	579	$99.48^{+0.30}_{-0.49}$
Δx_{CMP} cut	568	$97.59^{+0.60}_{-0.77}$
All above cuts	519	$89.18^{+1.35}_{-1.38}$
All cuts excl. isol.	537	$92.27^{+1.19}_{-1.35}$
Sliding isol. cut	562	$96.56^{+0.75}_{-0.91}$
All cuts (sliding isol.)	520	$89.35^{+1.38}_{-1.36}$
χ^2 cut	582	$100.00^{+0.00}_{-0.32}$
All cuts (χ^2)	519	$89.18^{+1.35}_{-1.38}$
All track cuts	534	$91.75^{+1.12}_{-1.23}$
All trk cuts excl. isol.	553	$95.02^{+0.93}_{-1.12}$

TABLE I: Dataset bhmumkP14_SAM: Muon ID efficiencies for CMUP

CMUP ID SF

P13

Cut	Scale Factor
No cut	
E_{EM} cut	$1.0089^{+0.0029}_{-0.0028}$
E_{HAD} cut	$1.0000^{+0.0019}_{-0.0022}$
COT hits cut	$1.0001^{+0.0000}_{-0.0004}$
d_0 cut	$0.9980^{+0.0008}_{-0.0011}$
Isolation cut	$0.9941^{+0.0027}_{-0.0030}$
Δx_{CMU} cut	$0.9960^{+0.0010}_{-0.0012}$
Δx_{CMP} cut	$0.9884^{+0.0020}_{-0.0022}$
All above cuts	$0.9856^{+0.0049}_{-0.0054}$
All cuts excl. isol.	$0.9914^{+0.0041}_{-0.0043}$
Sliding isol. cut	$0.9997^{+0.0024}_{-0.0026}$
All cuts (sliding isol.)	$0.9917^{+0.0045}_{-0.0052}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0004}$
All cuts (χ^2)	$0.9856^{+0.0049}_{-0.0054}$
All track cuts	$1.0023^{+0.0044}_{-0.0048}$
All trk cuts excl. isol.	$1.0077^{+0.0034}_{-0.0035}$

P14

Cut	Scale Factor
No cut	
E_{EM} cut	$1.0122^{+0.0070}_{-0.0082}$
E_{HAD} cut	$0.9942^{+0.0063}_{-0.0086}$
COT hits cut	$1.0001^{+0.0000}_{-0.0032}$
d_0 cut	$1.0012^{+0.0014}_{-0.0040}$
Isolation cut	$0.9963^{+0.0075}_{-0.0097}$
Δx_{CMU} cut	$0.9949^{+0.0030}_{-0.0049}$
Δx_{CMP} cut	$0.9811^{+0.0060}_{-0.0077}$
All above cuts	$0.9800^{+0.0149}_{-0.0152}$
All cuts excl. isol.	$0.9828^{+0.0127}_{-0.0144}$
Sliding isol. cut	$0.9895^{+0.0077}_{-0.0093}$
All cuts (sliding isol.)	$0.9738^{+0.0150}_{-0.0148}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0032}$
All cuts (χ^2)	$0.9800^{+0.0149}_{-0.0152}$
All track cuts	$1.0031^{+0.0123}_{-0.0134}$
All trk cuts excl. isol.	$1.0067^{+0.0099}_{-0.0119}$

CMX ID Efficiencies

P13

Cut	Count	Efficiency (%)
No cut	2662	
E_{EM} cut	2584	$97.07^{+0.32}_{-0.37}$
E_{HAD} cut	2607	$97.93^{+0.28}_{-0.30}$
COT hits cut	2661	$99.96^{+0.03}_{-0.09}$
d_0 cut	2649	$99.51^{+0.13}_{-0.18}$
Isolation cut	2560	$96.17^{+0.39}_{-0.39}$
Δx_{CMX} cut	2653	$99.66^{+0.11}_{-0.16}$
All above cuts	2431	$91.32^{+0.52}_{-0.55}$
All cuts excl. isol.	2515	$94.48^{+0.47}_{-0.46}$
Sliding isol. cut	2589	$97.26^{+0.33}_{-0.36}$
All cuts (sliding isol.)	2458	$92.34^{+0.51}_{-0.56}$
χ^2 cut	2662	$100.00^{+0.00}_{-0.07}$
All cuts (χ^2)	2431	$91.32^{+0.52}_{-0.55}$
All track cuts	2438	$91.59^{+0.55}_{-0.62}$
All trk cuts excl. isol.	2524	$94.82^{+0.42}_{-0.46}$

P14

Cut	Count	Efficiency (%)
No cut	353	
E_{EM} cut	341	$96.60^{+1.01}_{-1.24}$
E_{HAD} cut	349	$98.87^{+0.50}_{-0.87}$
COT hits cut	353	$100.00^{+0.00}_{-0.52}$
d_0 cut	351	$99.43^{+0.35}_{-0.73}$
Isolation cut	346	$98.02^{+0.76}_{-1.09}$
Δx_{CMX} cut	351	$99.43^{+0.35}_{-0.73}$
All above cuts	328	$92.92^{+1.32}_{-1.61}$
All cuts excl. isol.	335	$94.90^{+1.10}_{-1.44}$
Sliding isol. cut	348	$98.58^{+0.59}_{-0.98}$
All cuts (sliding isol.)	330	$93.48^{+1.34}_{-1.59}$
χ^2 cut	353	$100.00^{+0.00}_{-0.52}$
All cuts (χ^2)	328	$92.92^{+1.32}_{-1.61}$
All track cuts	329	$93.20^{+1.43}_{-1.70}$
All trk cuts excl. isol.	336	$95.18^{+1.20}_{-1.34}$

TABLE II: Dataset bhmumkP14_SAM: Muon ID efficiencies for CMX

CMX ID SF

P13

Cut	Scale Factor
No cut	
E_{EM} cut	$1.0080^{+0.0034}_{-0.0039}$
E_{HAD} cut	$1.0014^{+0.0030}_{-0.0031}$
COT hits cut	$0.9997^{+0.0003}_{-0.0009}$
d_0 cut	$0.9960^{+0.0013}_{-0.0018}$
Isolation cut	$0.9882^{+0.0040}_{-0.0041}$
Δx_{CMX} cut	$0.9983^{+0.0011}_{-0.0016}$
All above cuts	$0.9972^{+0.0058}_{-0.0061}$
All cuts excl. isol.	$1.0057^{+0.0051}_{-0.0050}$
Sliding isol. cut	$0.9938^{+0.0034}_{-0.0037}$
All cuts (sliding isol.)	$1.0029^{+0.0057}_{-0.0062}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0007}$
All cuts (χ^2)	$0.9972^{+0.0058}_{-0.0061}$
All track cuts	$0.9982^{+0.0061}_{-0.0068}$
All trk cuts excl. isol.	$1.0075^{+0.0046}_{-0.0049}$

P14

Cut	Scale Factor
No cut	
E_{EM} cut	$1.0035^{+0.0105}_{-0.0129}$
E_{HAD} cut	$1.0104^{+0.0051}_{-0.0089}$
COT hits cut	$1.0001^{+0.0000}_{-0.0052}$
d_0 cut	$0.9967^{+0.0035}_{-0.0073}$
Isolation cut	$1.0107^{+0.0079}_{-0.0113}$
Δx_{CMX} cut	$0.9959^{+0.0035}_{-0.0073}$
All above cuts	$1.0192^{+0.0145}_{-0.0177}$
All cuts excl. isol.	$1.0115^{+0.0117}_{-0.0154}$
Sliding isol. cut	$1.0085^{+0.0060}_{-0.0100}$
All cuts (sliding isol.)	$1.0175^{+0.0146}_{-0.0173}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0052}$
All cuts (χ^2)	$1.0192^{+0.0145}_{-0.0177}$
All track cuts	$1.0207^{+0.0157}_{-0.0186}$
All trk cuts excl. isol.	$1.0129^{+0.0128}_{-0.0142}$

Reconstruction Efficiency

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.

Events Selection
No cosmic tag and 2 tracks passing the following:

- Oppositely charged.
- $|z_0^{(1)} - z_0^{(2)}| < 4$ cm.
- $81\ \mathrm{GeV}/c^2 < m(\mu^+\mu^-) < 101\ \mathrm{GeV}/c^2$
- 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

$$\varepsilon_{Reco} = \frac{\#\text{tracks fiducial and linked to a stub}}{\#\text{ tracks fiducial}}$$

Reconstruction Efficiency

The first leg must pass all the ID and Fid. cuts and must match to the level 1 trigger information. If the second leg is Fiducial, and pass "P_T, E_{EM}, E_{HAD}" cuts, we examine this track to see if is linked to a muon stub or not.

P11

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	3769	3412	$90.53^{+0.46}_{-0.51}$
CMX	2333	2221	$95.20^{+0.43}_{-0.50}$
CMX Arches	1829	1796	$98.20^{+0.32}_{-0.37}$
CMX Miniskirt	422	346	$81.99^{+1.90}_{-2.01}$
CMX Keystone	82	79	$96.34^{+1.90}_{-3.47}$
CMU-only	957	840	$87.77^{+1.04}_{-1.10}$
CMP-only	1120	1015	$90.62^{+0.83}_{-0.93}$

P12

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	2534	2311	$91.20^{+0.55}_{-0.62}$
CMX	1524	1455	$95.47^{+0.57}_{-0.60}$
CMX Arches	1165	1144	$98.20^{+0.41}_{-0.47}$
CMX Miniskirt	283	238	$84.10^{+2.13}_{-2.56}$
CMX Keystone	76	73	$96.05^{+2.19}_{-3.67}$
CMU-only	651	567	$87.10^{+1.28}_{-1.45}$
CMP-only	606	558	$92.08^{+1.18}_{-1.16}$
CMX MiniKey	359	311	$86.63^{+1.75}_{-1.96}$

P13

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	4644	4240	$91.30^{+0.42}_{-0.46}$
CMX	2711	2587	$95.43^{+0.40}_{-0.43}$
CMX Arches	2163	2113	$97.69^{+0.33}_{-0.35}$
CMX Miniskirt	450	382	$84.89^{+1.73}_{-1.98}$
CMX Keystone	98	92	$93.88^{+2.41}_{-3.45}$
CMU-only	1128	1002	$88.83^{+0.97}_{-0.99}$
CMP-only	1284	1184	$92.21^{+0.71}_{-0.85}$
CMX MiniKey	548	474	$86.50^{+1.49}_{-1.63}$

P14

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	625	565	$90.40^{+1.10}_{-1.24}$
CMX	354	343	$96.89^{+0.91}_{-1.24}$
CMX Arches	268	265	$98.88^{+0.58}_{-1.08}$
CMX Miniskirt	66	59	$89.39^{+3.77}_{-5.21}$
CMX Keystone	20	19	$95.00^{+3.83}_{-10.23}$
CMU-only	147	133	$90.48^{+2.30}_{-3.17}$
CMP-only	164	153	$93.29^{+1.92}_{-2.57}$
CMX MiniKey	86	78	$90.70^{+3.25}_{-4.17}$

Reconstruction SF

P11

Category	Scale Factor
CMUP	$0.9276^{+0.0048}_{-0.0053}$
CMX	$0.9557^{+0.0043}_{-0.0050}$
CMX Arches	$0.9840^{+0.0032}_{-0.0037}$
CMX Miniskirt	$0.8277^{+0.0192}_{-0.0203}$
CMX Keystone	$0.9736^{+0.0193}_{-0.0351}$
CMU-only	$0.8991^{+0.0107}_{-0.0114}$
CMP-only	$0.9224^{+0.0085}_{-0.0095}$
CMX MiniKey	$0.8515^{+0.0173}_{-0.0173}$

P13

Category	Scale Factor
CMUP	$0.9371^{+0.0044}_{-0.0047}$
CMX	$0.9577^{+0.0040}_{-0.0043}$
CMX Arches	$0.9785^{+0.0034}_{-0.0035}$
CMX Miniskirt	$0.8567^{+0.0175}_{-0.0200}$
CMX Keystone	$0.9499^{+0.0245}_{-0.0350}$
CMU-only	$0.9100^{+0.0099}_{-0.0102}$
CMP-only	$0.9379^{+0.0072}_{-0.0087}$
CMX MiniKey	$0.8733^{+0.0151}_{-0.0151}$

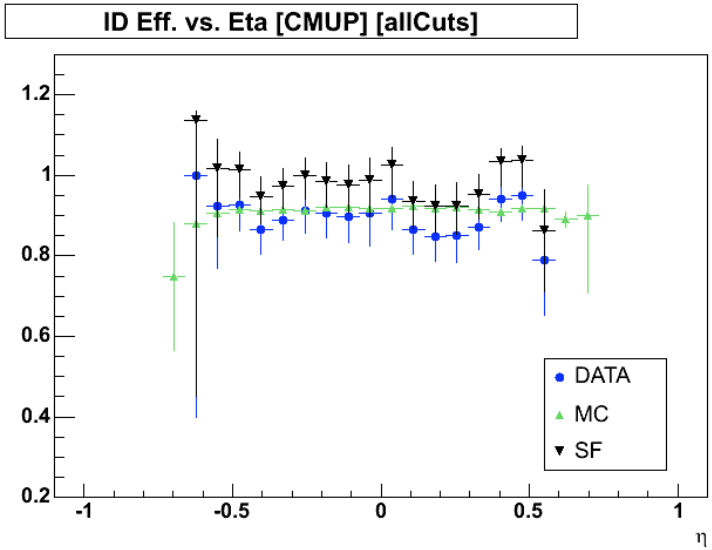
P12

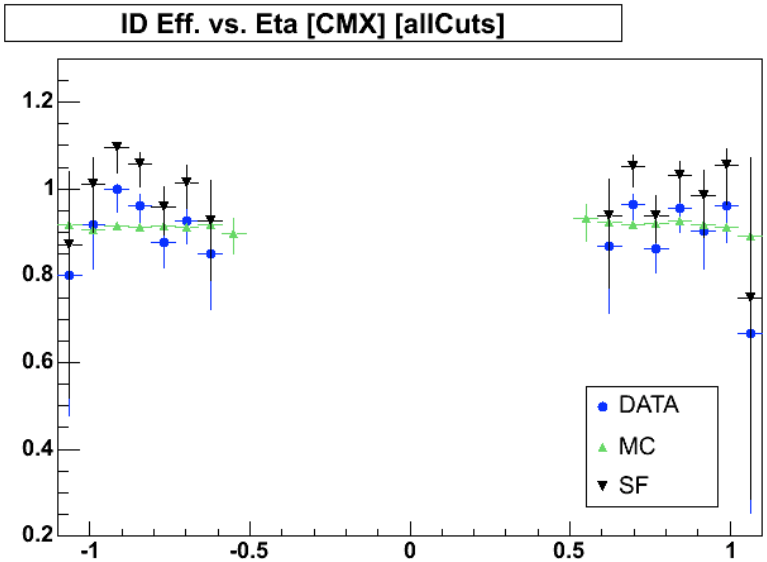
Category	Scale Factor
CMUP	$0.9345^{+0.0056}_{-0.0064}$
CMX	$0.9584^{+0.0058}_{-0.0060}$
CMX Arches	$0.9840^{+0.0041}_{-0.0047}$
CMX Miniskirt	$0.8490^{+0.0215}_{-0.0258}$
CMX Keystone	$0.9706^{+0.0222}_{-0.0372}$
CMU-only	$0.8921^{+0.0132}_{-0.0149}$
CMP-only	$0.9372^{+0.0121}_{-0.0118}$
CMX MiniKey	$0.8747^{+0.0177}_{-0.0177}$

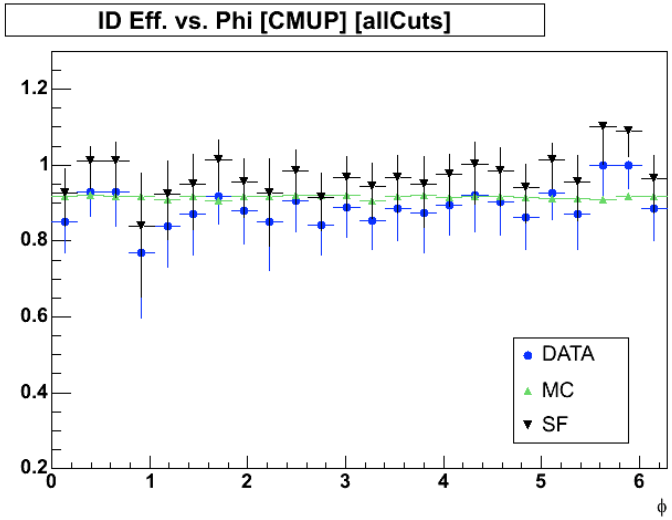
P14

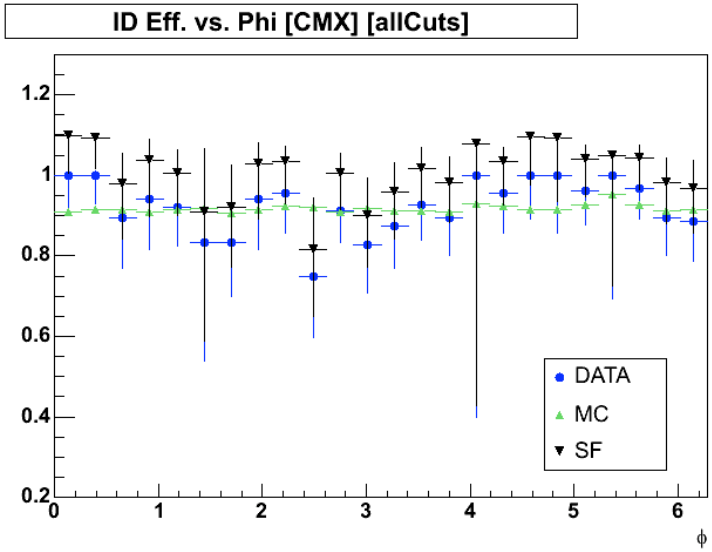
Category	Scale Factor
CMUP	$0.9281^{+0.0113}_{-0.0127}$
CMX	$0.9727^{+0.0091}_{-0.0124}$
CMX Arches	$0.9907^{+0.0058}_{-0.0108}$
CMX Miniskirt	$0.9029^{+0.0381}_{-0.0527}$
CMX Keystone	$0.9617^{+0.0388}_{-0.1036}$
CMU-only	$0.9274^{+0.0236}_{-0.0325}$
CMP-only	$0.9496^{+0.0196}_{-0.0262}$
CMX MiniKey	$0.9165^{+0.0328}_{-0.0328}$

Reco and ID Plots

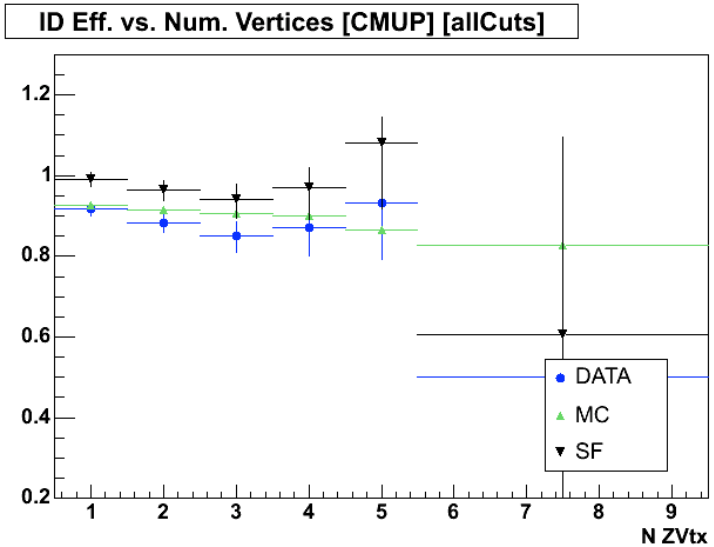


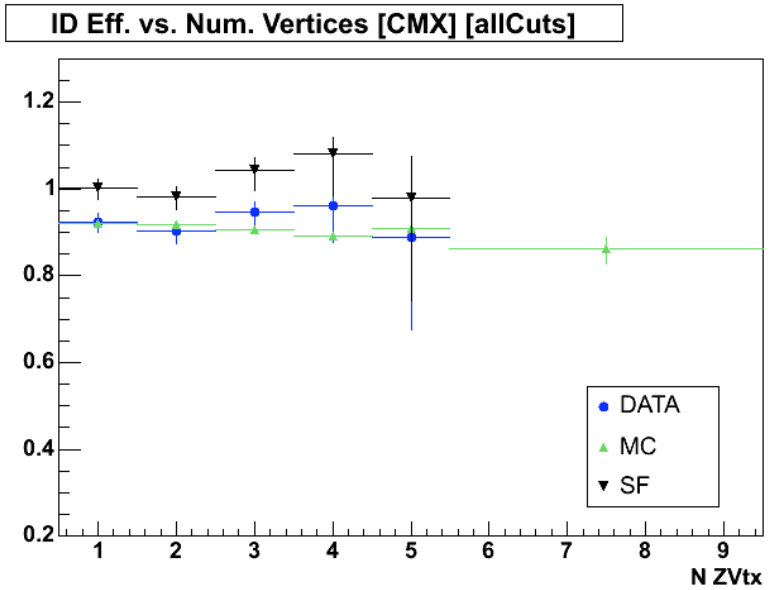


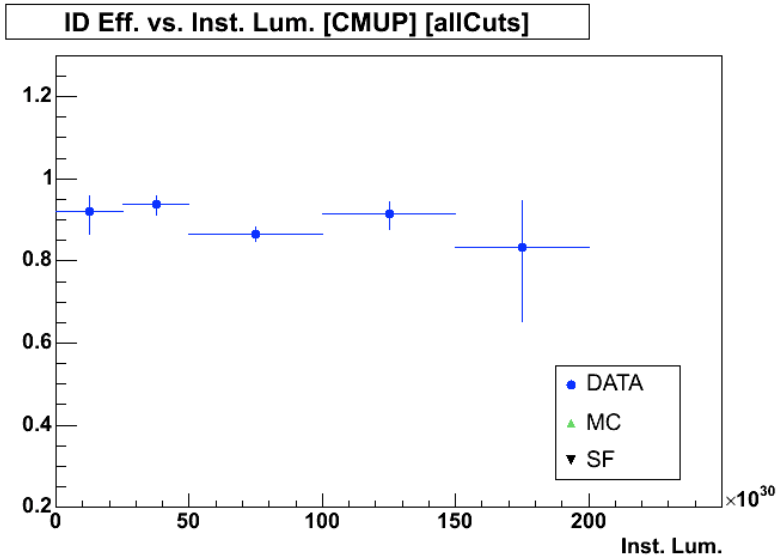


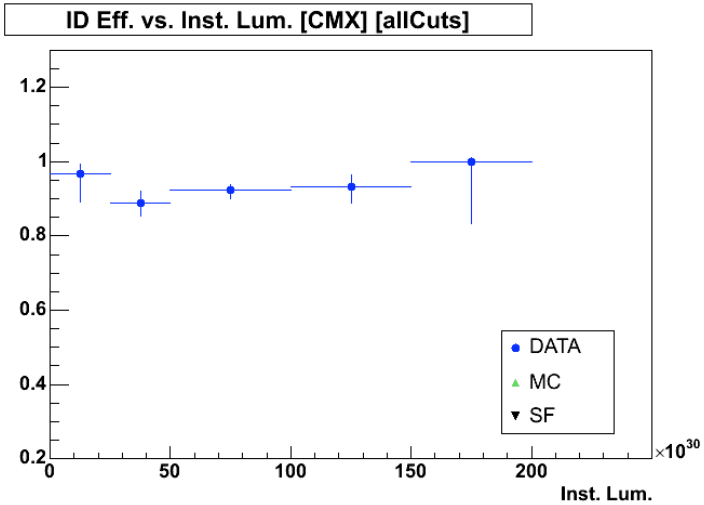


Reco and ID Plots

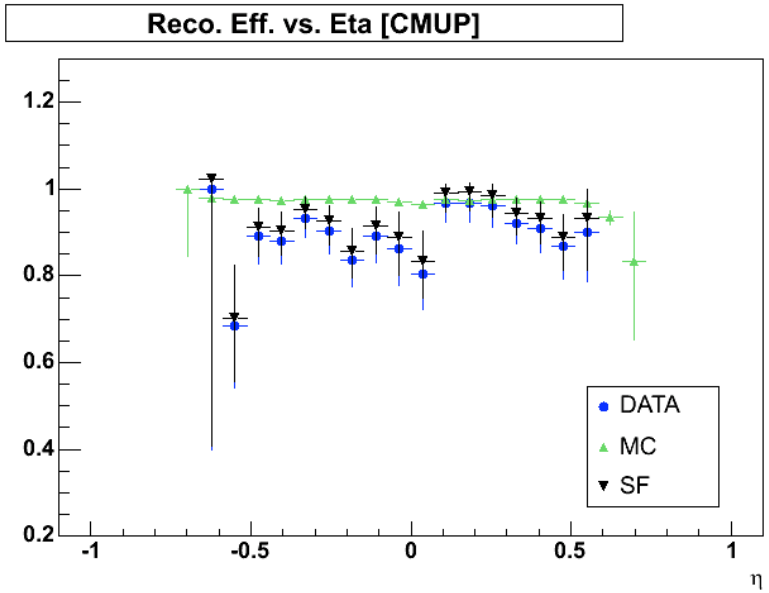


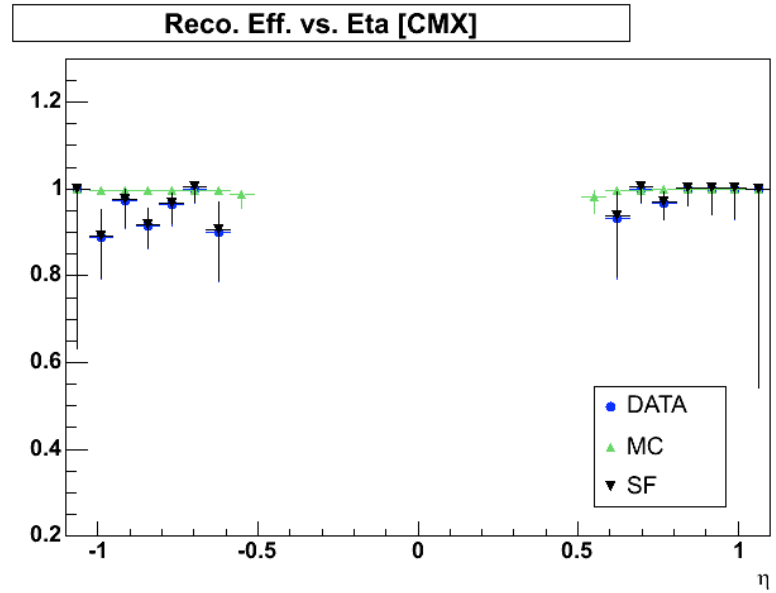


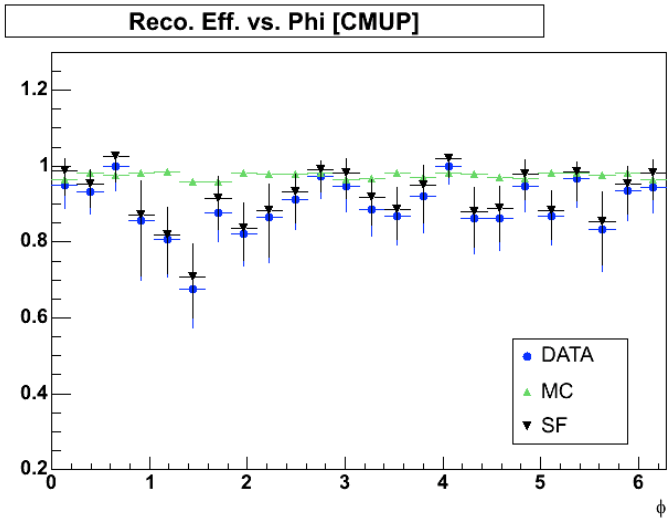


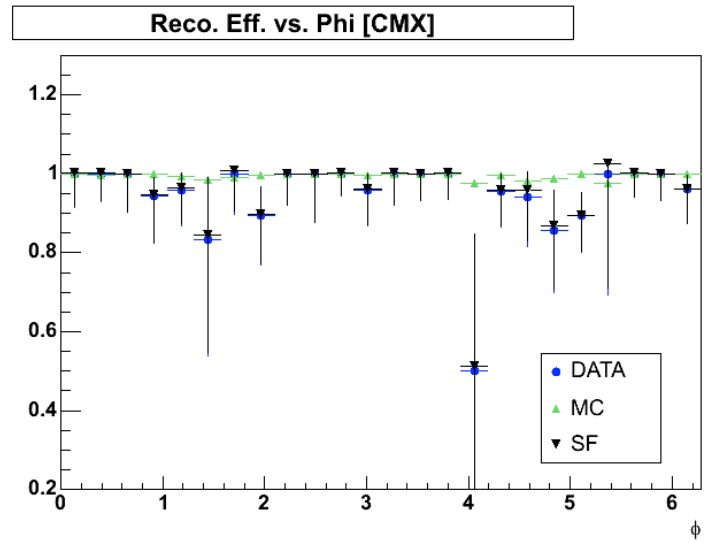


Reco and ID Plots









Trigger Efficiencies

Use the two legs from the reconstructed Z (both legs pass muon ID and fiducial cuts)

Level 1:

ε^{L1}_{CMUP} is calculated from 2 independent samples, using CMUP-CMUP and CMUP-CMX samples:

$$\mathring{a}^{L1(A)}_{CMUP} = \frac{\#\text{ of events with both legs triggered}}{\#\text{ of events with 1 CMX leg triggered}}$$

$$\mathring{a}^{L1(B)}_{CMUP} = \frac{2R}{1+R}$$

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

The final efficiency is an average of $\varepsilon^{L1(A)}_{CMUP}$ and $\varepsilon^{L1(B)}_{CMUP}$ weighted by the errors.

Level 2: (both leg pass L1)

$$\mathring{a}^{L2}_{CMUP} = \frac{\#\text{ of events pass both L2 triggers}}{\#\text{ of events pass L2 CMX trigger}}$$

Level 3: (both leg pass L2)

$$\mathring{a}^{L3}_{CMUP} = \frac{\#\text{ of events pass both L3 triggers}}{\#\text{ of events pass L3 CMX trigger}}$$

CMX trigger efficiency is calculated in similar way.

Efficiencies not corrected for livetimes

1st leg	2nd leg	1st passes	both pass	Efficiency (%)
CMUP	CMUP	191	170	-
CMX	CMUP	217	200	$93.49^{+1.30}_{-1.04}$
CMUP	CMX	230	200	-
CMX	CMX	76	60	$87.42^{+2.14}_{-1.86}$
CMUP	ARCH	180	165	-
CMUP	MK	50	35	-
ARCH	ARCH	44	39	-
ARCH	MK	27	17	-
MK	ARCH	18	17	$92.47^{+2.03}_{-1.58}$
MK	MK	4	4	$82.22^{+5.46}_{-4.41}$

TABLE I: Dataset bhmumkP14_SAM-1: Muon L1 trigger efficiencies

Category	Events Passing	Efficiency (%)
Pass L1	200	-
CMUP	183	$98.37^{+0.90}_{-1.54}$
CMX	184	$98.91^{+0.75}_{-1.40}$
CMUP-CMX	181	-
CMUP-A	150	-
CMUP-MK	33	-
CMUP-CMX-A	148	$98.67^{+0.89}_{-1.74}$
CMUP-CMX-MK	33	$100.00^{+0.00}_{-5.43}$

TABLE II: Dataset bhmumkP14_SAM-1: Muon L2 trigger efficiencies

Category	Events Passing	Efficiency (%)
Pass L1	200	-
CMUP-CMUP$_S$	178	-
CMX-CMX$_S$	179	-
CMUP-CMX-CMUP$_S$	176	$95.65^{+1.52}_{-2.00}$
CMUP-CMX-CMX$_S$	176	$96.17^{+1.38}_{-1.94}$
CMUP-CMX-CMX$_S$-A	143	$95.33^{+1.64}_{-2.46}$
CMUP-CMX-CMX$_S$-MK	33	$100.00^{+0.00}_{-5.43}$

TABLE III: Dataset bhmumkP14_SAM-1: Muon L2 SLAM trigger efficiencies

Trigger Eff

Category	Events Passing	Efficiency (%)
Pass L2	181	-
CMUP	181	$100.00^{+0.00}_{-1.01}$
CMX	181	$100.00^{+0.00}_{-1.01}$
CMUP-CMX	181	-
CMUPA	148	-
CMUPMK	33	-
CMUPARCH	148	$100.00^{+0.00}_{-1.24}$
CMUP-MK	33	$100.00^{+0.00}_{-5.43}$

TABLE IV: Dataset bhmumkP14_SAM-1: Muon L3 trigger efficiencies

<u>Livetimes and correction factors</u>
CMUP 2-D Livetime .953585
CMUP 3-D Livetime 1.000309
CMX 2-D Livetime .947956
CMX 3-D Livetime .956760

CMUP 2-D correction 1
CMX 2-D correction .994096

Category	Efficiency (%)
CMUP	$91.97^{+1.53}_{-2.00}$
CMX	$86.46^{+2.22}_{-2.37}$
CMX A	$91.23^{+2.17}_{-2.51}$
CMX MK	$82.22^{+5.46}_{-7.70}$
CMUP SLAM	$89.43^{+1.89}_{-2.30}$
CMX SLAM	$84.07^{+2.39}_{-2.60}$
CMX SLAM A	$88.15^{+2.46}_{-2.94}$
CMX SLAM MK	$82.22^{+5.46}_{-7.70}$

TABLE V: Dataset bhmumkP14_SAM-1: Muon combined trigger efficiencies

CMX = 86.46 / 0.99 = 87.33 (2.29)
CMX SLAM = 84.07 / 0.99 = 84.91 (2.45)
CMX A = 91.23 / 0.99 = 92.15 (2.39)
CMX SLAM A = 88.15 / 0.99 = 89.04 (2.7)

Comparison with previous periods

Combined (L1+L2+L3) CMUP 2-D Trigger efficiencies

Period	Measured (SR)	Livetime Corr.	Corr. Efficiency
8	0.9130(67)	1.000	0.9130(67)
9	0.9270(67)	1.000	0.9270(67)
10	0.9196(56)	1.000	0.9196(56)
11	0.9198(61)	1.000	0.9198(61)
12	0.9241(78)	1.000	0.9241(78)
13	0.9090(61)	1.0	0.9090(61)
14	0.9197(2.22)	1.0	0.9197 (2.22)

CMUP

Combined (L1+L2+L3) CMUP 3-D Trigger efficiencies

Period	2-D Efficiency	2-D+3-D/2-D (SR)	3-D Efficiency
10	0.9196(56)	0.9265(78)	0.8520(89)
11	0.9198(61)	0.9375(88)	0.8623(98)
12	0.9241(78)	0.9108(105)	0.8417(120)
13	0.9090(61)		0.8284 (91)
14	0.9197(2.22)		0.8943 (2.22)

Comparison with previous periods

Combined (L1+L2+L3) CMX 2-D Trigger efficiencies

Arches-only:

Period	Measured (SR)	Livetime Corr.	Corr. Efficiency
12	0.8923 (118)	0.945	0.944 (125)
13	0.8915 (85)	0.9601	0.9285 (85)
14	0.9123 (2.39)	0.99	0.9215 (2.39)

CMX

Combined (L1+L2+L3) CMX 3-D Trigger efficiencies

Arches-only

Period	2-D Efficiency	3-D Efficiency
12	0.8923 /0.945 = 0.94(125)	0.9002 (140)
13	0.8915 / 0.9601= 0.93 (85)	0.8569 / 0.9601 = 0.8926 (94)
14	0.9123/0.99=0.9215 (2.39)	0.8815/0.99 = .8904 (2.7)

Conclusions

- Efficiencies (ID/Reco and Trigger) for high PT electrons and muons have been derived.
- No substantial difference with previous periods
  - Lower stat so somewhat larger uncertainty