Period 17 High PT Lepton Efficiencies and SF -preblessing

Period16 High PT Lepton Efficiencies and SF -blessing

Simona Rolli
Tufts

Electrons ID: Samples

Dataset bhelmk: Runs 258880-261005 (P17)
MC sample : zektei (Feb 2008)
GRL :GRL for P17 v23

P17 SAM dataset
MC dataset zektei (P14 and onward) on SAM

Dataset bhelmk: Runs 256840-258787 (P16)
MC sample : zektei (Feb 2008)
GRL :GRL for P16 v22

P16 SAM dataset
MC dataset zektei (P14 and onward) 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 16 vs P15

	Period 15		Period 16	
	bhelmk(P15)	zektei	bhelmk(P16)	zektei
CEM Eff	0.792+\-0.005	0.795 +\-0.001	0.790+\-0.006	0.795 +\-0.001
CEM SF	0.996 +\-0.006	N/A	0.994 +\-0.007	N/A
nisoCEM Eff	0.819 +\-0.005	0.825 +\-0.001	0.822 +\-0.005	0.825 +\-0.001
nisoCEM SF	0.993 +\-0.006	N/A	0.996 +\-0.007	N/A
LooseCEM Eff	0.917 +/- 0.003	0.907 +\-0.001	0.914 +/- 0.004	0.907 +\-0.001
LooseCEM SF	1.011 +\-0.004	N/A	1.008 +\-0.005	N/A
nisolooseCEM Eff	0.946+\-0.003	0.943 +\-0.001	0.950+\-0.004	0.943 +\-0.001
nisoloostCEM SF	1.004 +\-0.003	N/A	1.008 +\-0.003	N/A

	PHX		PHX	
Eff |Eta| < 2.0	0.711+\-0.007	0.744+\-0.002	0.702+\-0.009	0.744+\-0.002
SF |Eta| < 2.0	0.956+\-0.010	NA	0.944+\-0.013	NA
	PHX		PHX	
Eff |Eta| < 2.8	0.617+\-0.006	0.645+\-0.002	0.611+\-0.008	0.645+\-0.002
SF |Eta| < 2.8	0.957+\-0.010	NA	0.947+\-0.012	NA

P17 numbers

	Period 16		Period 17	
	bhelmk(P16)	zektei	bhelmk(P16)	zektei
CEM Eff	0.790+\-0.006	0.795 +\-0.001	0.781+\-0.005	0.795 +\-0.001
CEM SF	0.994 +\-0.007	N/A	0.982 +\-0.006	N/A
nisoCEM Eff	0.822 +\-0.005	0.825 +\-0.001	0.815 +\-0.004	0.825 +\-0.001
nisoCEM SF	0.996 +\-0.007	N/A	0.988 +\-0.006	N/A
LooseCEM Eff	0.914 +/- 0.004	0.907 +\-0.001	0.909 +/- 0.003	0.907 +\-0.001
LooseCEM SF	1.008 +\-0.005	N/A	1.002 +\-0.004	N/A
nisolooseCEM Eff	0.950+\-0.004	0.943 +\-0.001	0.945+\-0.0043	0.943 +\-0.001
nisoloostCEM SF	1.008 +\-0.003	N/A	1.003 +\-0.003	N/A

	PHX		PHX	
Eff |Eta| < 2.0	0.702+\-0.009	0.744+\-0.002	0.688+\-0.007	0.744+\-0.002
SF |Eta| < 2.0	0.944+\-0.013	NA	0.925+\-0.010	NA
	PHX		PHX	
Eff |Eta| < 2.8	611.+\-0.007	0.645+\-0.002	0.598+\-0.006	0.645+\-0.002
SF |Eta| < 2.8	0.947+\-0.012	NA	0.934+\-0.009	NA

CEM-PEM

P14

	PEM	
Eff |Eta| < 2.0	0.804+\-0.014	0.847+\-0.002
SF |Eta| < 2.0	0.949+\-0.016	NA

	PEM	
Eff |Eta| < 2.8	0.776+\-0.012	0.810+\-0.001
SF |Eta| < 2.8	0.958+\-0.015	NA

P15

	PEM	
Eff |Eta| < 2.0	0.802+\-0.006	0.847+\-0.002
SF |Eta| < 2.0	0.947+\-0.008	NA

	PEM	
Eff |Eta| < 2.8	0.765+\-0.006	0.810+\-0.001
SF |Eta| < 2.8	0.944+\-0.007	NA

P16

	PEM	
Eff |Eta| < 2.0	0.793+\-0.008	0.847+\-0.002
SF |Eta| < 2.0	0.937+\-0.010	NA

	PEM	
Eff |Eta| < 2.8	0.756+\-0.007	0.810+\-0.001
SF |Eta| < 2.8	0.934+\-0.009	NA

	PEM	
Eff |Eta| < 2.0	0.784+\-0.006	0.847+\-0.002
SF |Eta| < 2.0	0.926+\-0.008	NA

	PEM	
Eff |Eta| < 2.8	0.742+\-0.006	0.810+\-0.001
SF |Eta| < 2.8	0.915+\-0.007	NA

PEM n-1 Eff

Detailed PHX info (eta < 2.0): P17

Hadem N-1 efficiency = 2895/2917 = 0.992458 +/- 0.00160188
Isol N-1 efficiency = 2895/3043 = 0.951364 +/- 0.00389944
DeltaR N-1 efficiency = 2895/2933 = 0.987044 +/- 0.00208808
Pem3x3FitTow N-1 efficiency = 2895/2895 = 1 +/- 0
Pem3x3Chisq N-1 efficiency = 2895/3202 = 0.904122 +/- 0.00520309
Pes2d5by9U N-1 efficiency = 2895/2915 = 0.993139 +/- 0.00152891
Pes2d5by9V N-1 efficiency = 2895/2915 = 0.993139 +/- 0.00152891

Detailed PHX info (eta < 2.0): P16

Hadem N-1 efficiency = 1666/1677 = 0.993441 +/- 0.00197122
Isol N-1 efficiency = 1666/1735 = 0.960231 +/- 0.00469151
DeltaR N-1 efficiency = 1666/1688 = 0.986967 +/- 0.00276052
Pem3x3FitTow N-1 efficiency = 1666/1666 = 1 +/- 0
Pem3x3Chisq N-1 efficiency = 1666/1859 = 0.896181 +/- 0.00707452
Pes2d5by9U N-1 efficiency = 1666/1671 = 0.997008 +/- 0.00133616
Pes2d5by9V N-1 efficiency = 1666/1674 = 0.995221 +/- 0.00168558

Detailed PHX info (eta < 2.0): P15

Hadem N-1 efficiency = 2808/2832 = 0.991525 +/- 0.00172252
Isol N-1 efficiency = 2808/2920 = 0.961644 +/- 0.00355413
DeltaR N-1 efficiency = 2808/2850 = 0.985263 +/- 0.00225713
Pem3x3FitTow N-1 efficiency = 2808/2808 = 1 +/- 0
Pem3x3Chisq N-1 efficiency = 2808/3114 = 0.901734 +/- 0.00533435
Pes2d5by9U N-1 efficiency = 2808/2825 = 0.993982 +/- 0.00145511
Pes2d5by9V N-1 efficiency = 2808/2826 = 0.993631 +/- 0.0014965

PEM N-1 Eff

Detailed PHX info (eta < 2.8): P17

Hadem N-1 efficiency = 3608/3666 = 0.984179 +/- 0.00206091
Isol N-1 efficiency = 3608/3773 = 0.956268 +/- 0.00332924
DeltaR N-1 efficiency = 3608/3650 = 0.988493 +/- 0.0017653
Pem3x3FitTow N-1 efficiency = 3608/3608 = 1 +/- 0
Pem3x3Chisq N-1 efficiency = 3608/4086 = 0.883015 +/- 0.00502805
Pes2d5by9U N-1 efficiency = 3608/3628 = 0.994487 +/- 0.00122927
Pes2d5by9V N-1 efficiency = 3608/3628 = 0.994487 +/- 0.00122927

Detailed PHX info (eta < 2.8): P16

Hadem N-1 efficiency = 2088/2122 = 0.983977 +/- 0.00272575
Isol N-1 efficiency = 2088/2163 = 0.965326 +/- 0.00393379
DeltaR N-1 efficiency = 2088/2110 = 0.989573 +/- 0.00221133
Pem3x3FitTow N-1 efficiency = 2088/2088 = 1 +/- 0
Pem3x3Chisq N-1 efficiency = 2088/2374 = 0.879528 +/- 0.00668078
Pes2d5by9U N-1 efficiency = 2088/2094 = 0.997135 +/- 0.00116809
Pes2d5by9V N-1 efficiency = 2088/2096 = 0.996183 +/- 0.00134686

Detailed PHX info (eta < 2.8): P15

Hadem N-1 efficiency = 3537/3599 = 0.982773 +/- 0.00216891
Isol N-1 efficiency = 3537/3663 = 0.965602 +/- 0.00301125
DeltaR N-1 efficiency = 3537/3580 = 0.987989 +/- 0.00182065
Pem3x3FitTow N-1 efficiency = 3537/3537 = 1 +/- 0
Pem3x3Chisq N-1 efficiency = 3537/4002 = 0.883808 +/- 0.00506557
Pes2d5by9U N-1 efficiency = 3537/3554 = 0.995217 +/- 0.00115735
Pes2d5by9V N-1 efficiency = 3537/3555 = 0.994937 +/- 0.0011904

P16 PEM numbers comments

<u>From Daryl Hare (expert)</u> :

As for the number, when I ran the code, I found a

PEM efficiency = 0.794 +/- 0.008 (simona: 0.793 +\-0.008).

I don't really know if you can say this is a different number than

0.802 +/- 0.006 (simona 0.802 +\- 0.006)

The isolation N-1 efficiency drops slightly, but I think we are mainly looking at statistical fluctuations. When you look at the raw efficiency, period 15 is 0.788 +/- 0.006, and period 16 is 0.783 +/- 0.008. These numbers look even more similar.

The corrected numbers (with background subtraction) use information from the MC. We scale the MC to the size of the data, so while it should be ok to use run independent MC, I have worried that it might cause small effects like this.

P17 All numbers comments

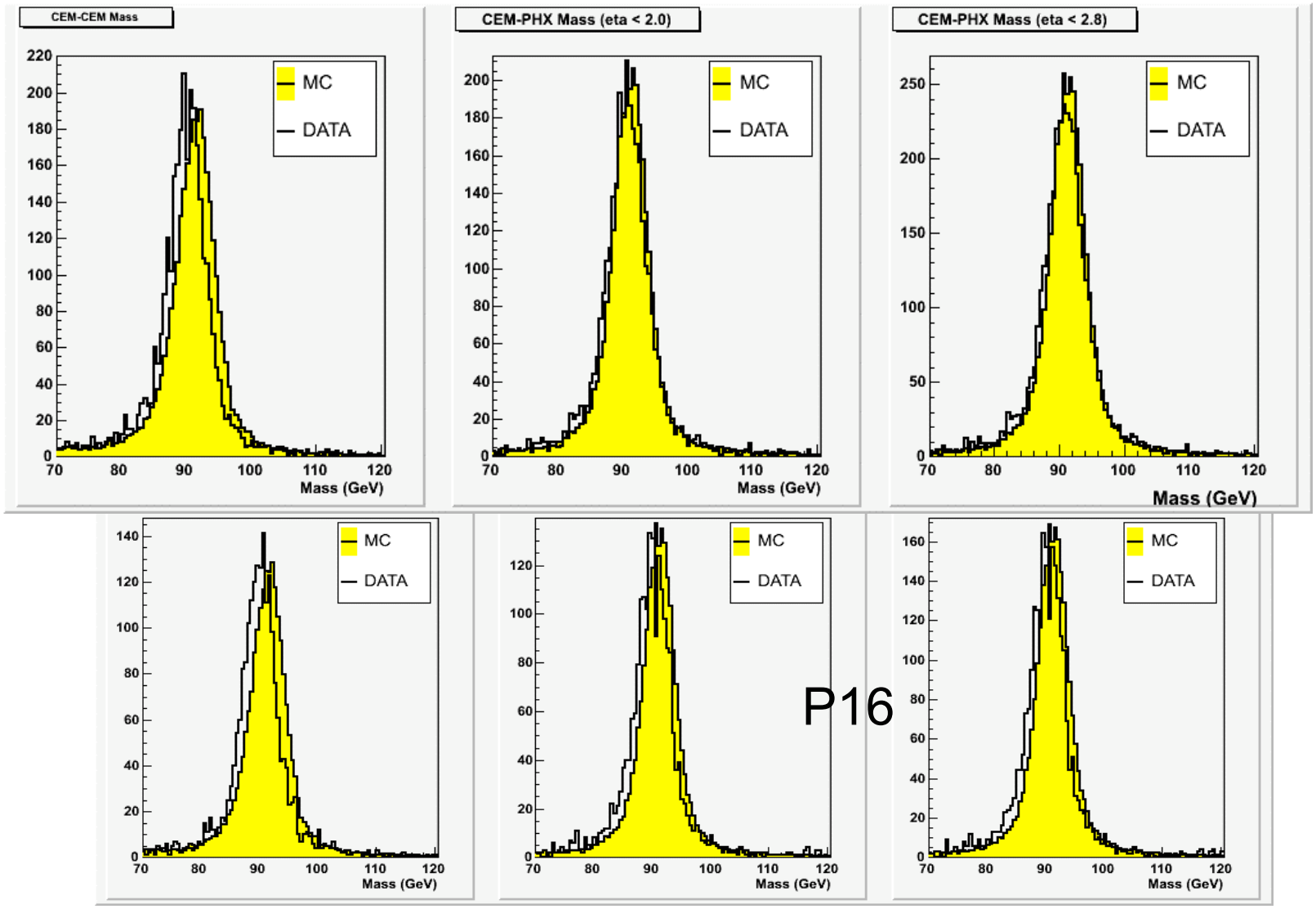
<u>From Daryl Hare (expert)</u> :

It looks like we do have a real drop in the efficiencies this time.
It seems to caused by the isolation cut.

The Isolation N-1 efficiency has dropped 1% since period 15. The raw CEM-CEM efficiency seems to show a similar 1% drop. There appears to be a small drop between period 15 and 16 which is hard to distinguish from statistics. However a 1% difference between period 15 and 17 looks significant.
Period 17 is the first dataset with statistics at luminosities > 250E30. These high luminosity electrons tend to have lower efficiencies as a result of the isolation cut.

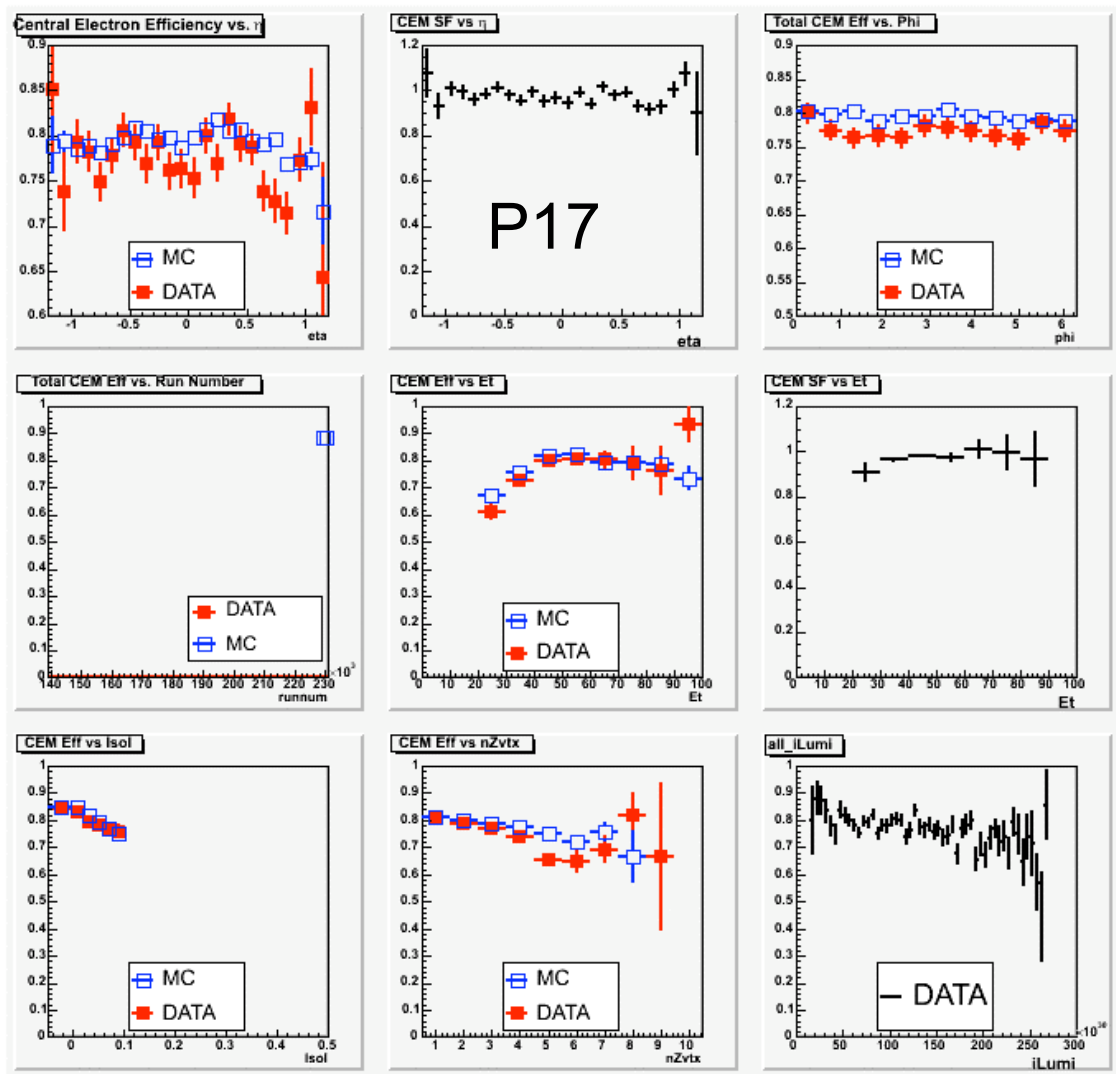
The other smoking gun here is the non-isolated efficiencies.
CEM-CEM and CEM-looseCEM efficiencies have dropped from their previous values.
However, the CEM-nisoCEM and CEM-nisoLooseCEM efficiencies remain the same as before.

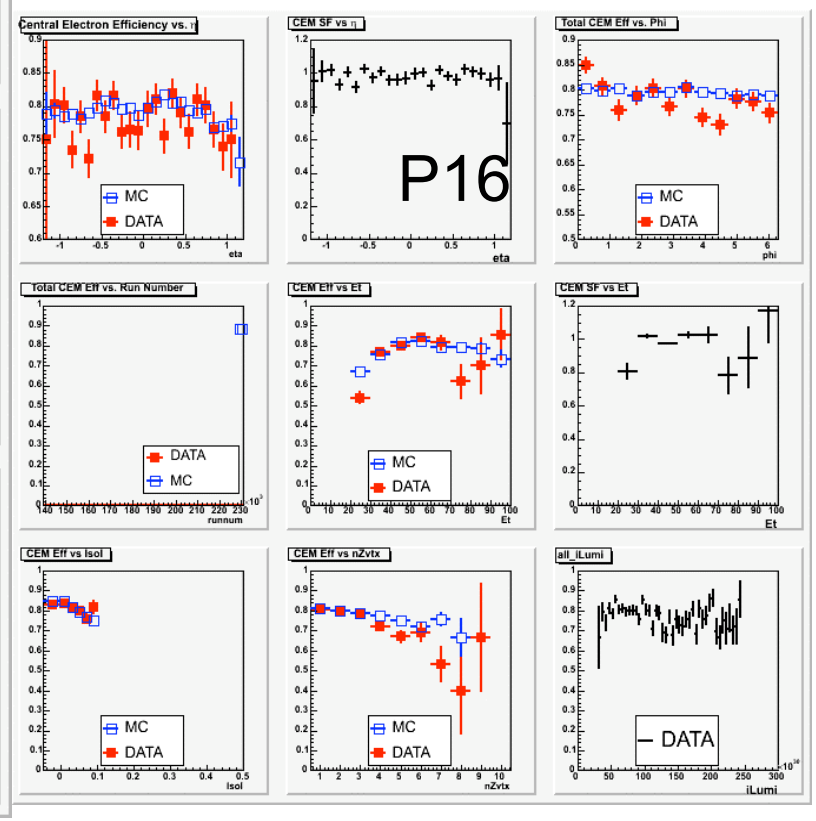
EleID Plots


CEM-CEM Mass
CEM-PHX Mass (eta < 2.0)
CEM-PHX Mass (eta < 2.8)
MC
DATA
Mass (GeV)
P16

EleID Plots 1

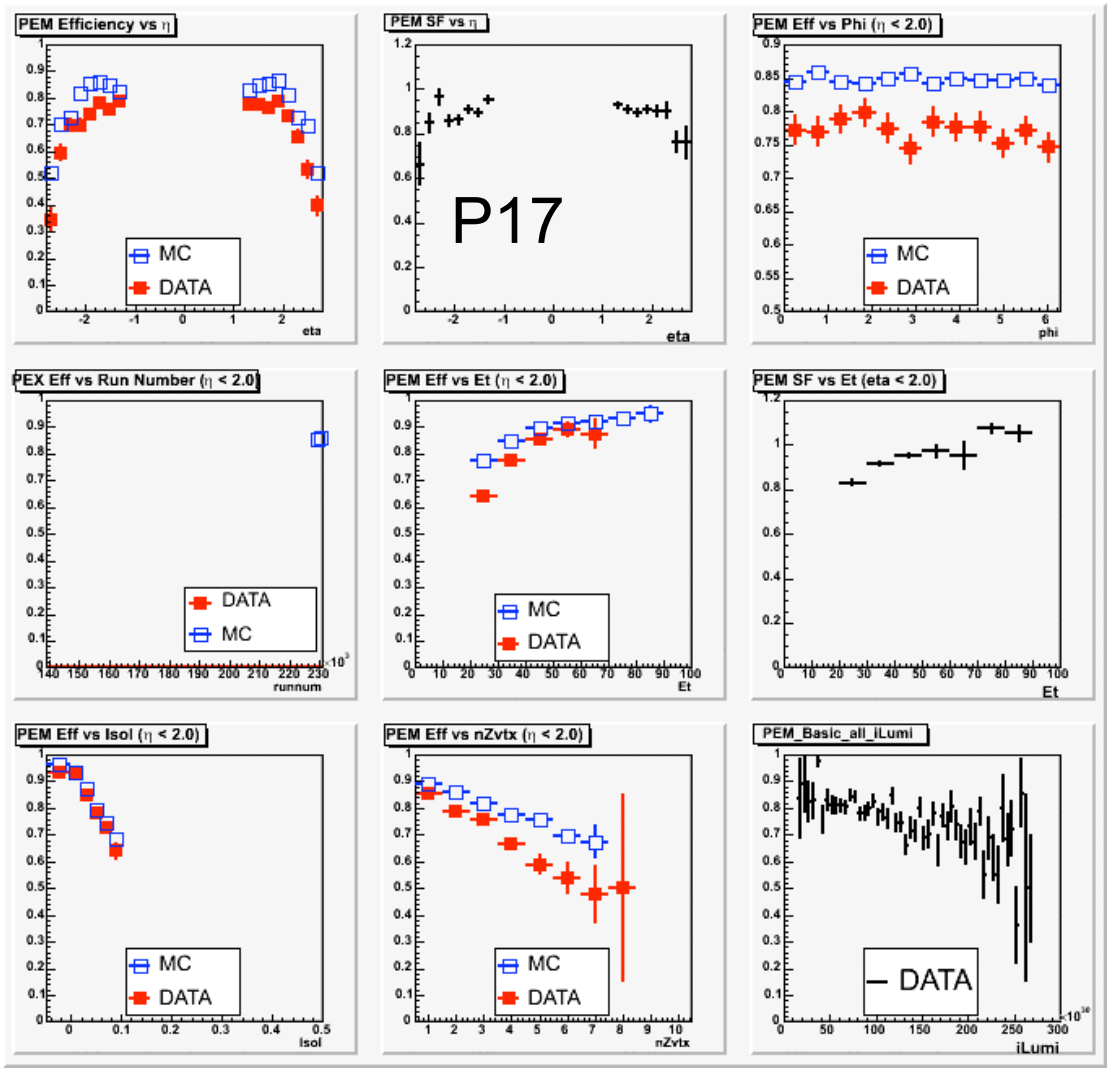
CEM Efficiencies

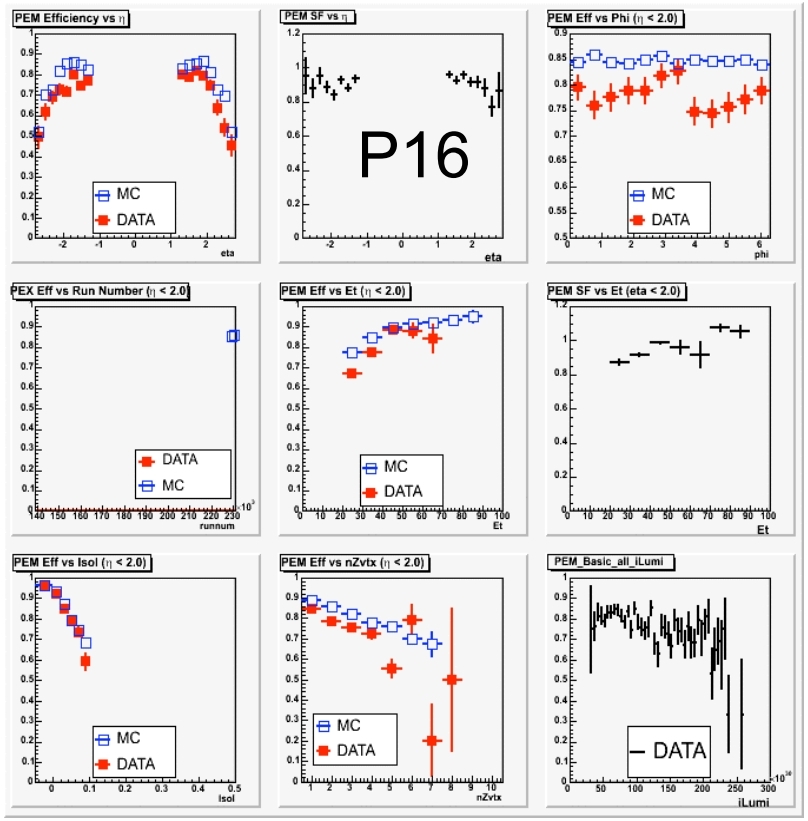




EleID Plots 2

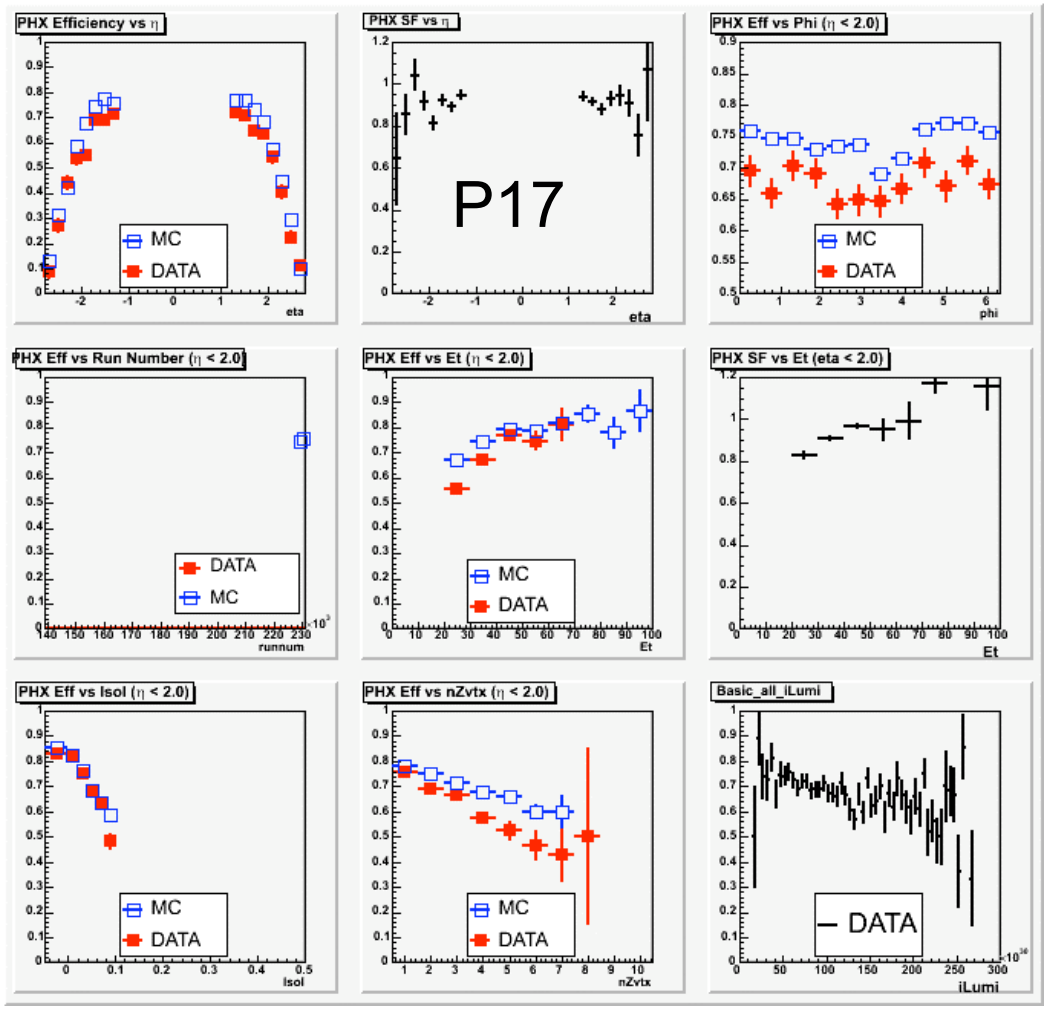
PEM Efficiencies

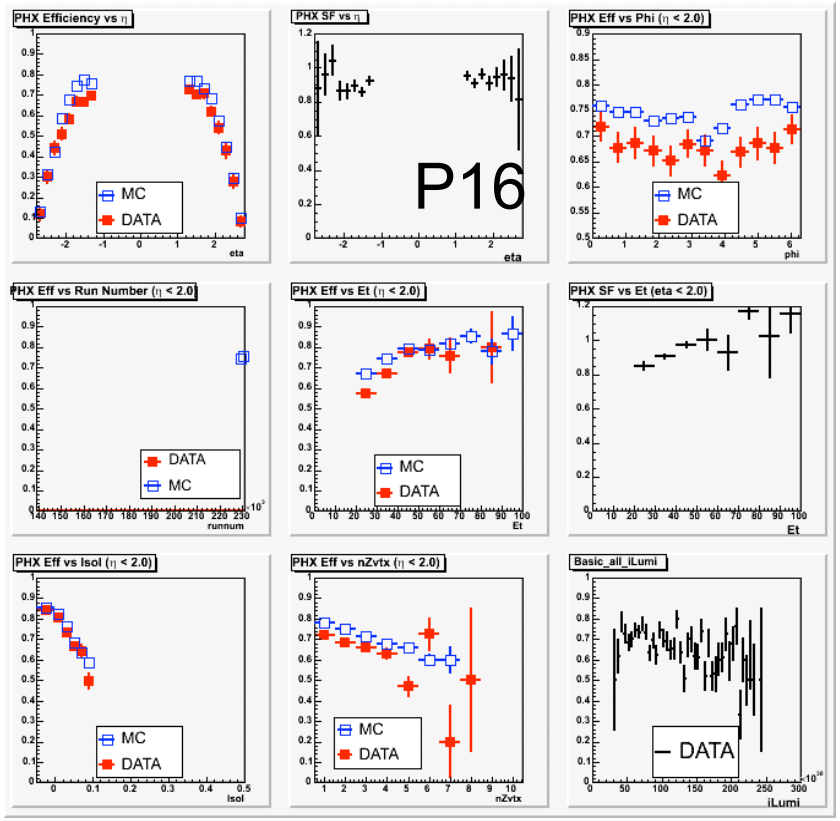




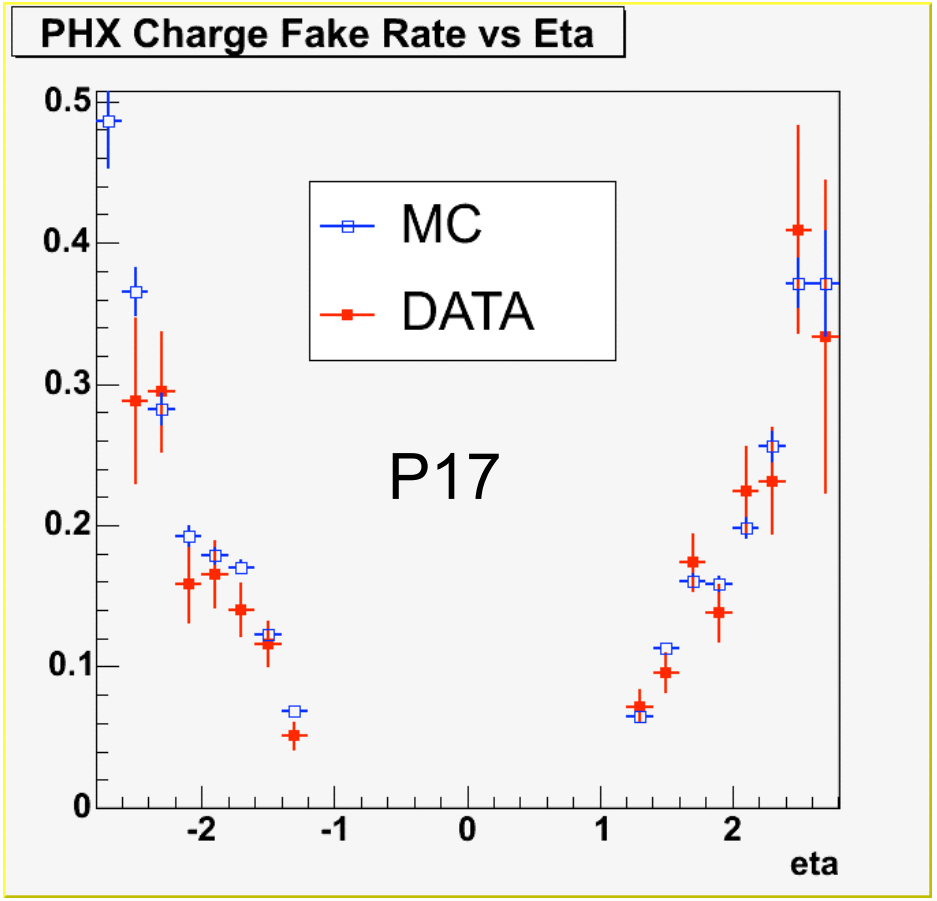
EleID Plots 3

PHX Efficiencies





PHX Fake Charge Rate

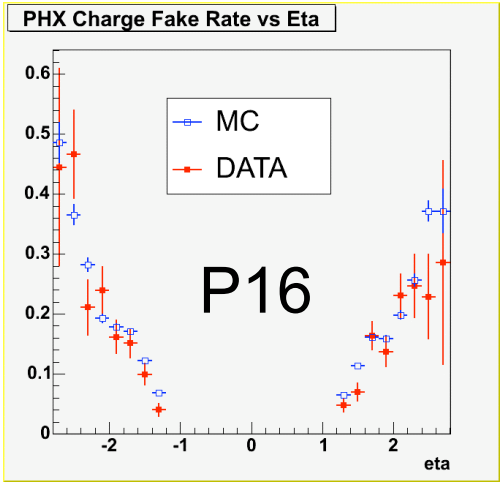


Eta > 2.0
Phoenix charge fake rate =
322/2895 = 0.111226 +/- 0.00584353

Eta < 2.8
Phoenix charge fake rate =
491/3608 = 0.136086 +/- 0.00570833

$\eta < 2$
Phoenix charge fake rate =
0.0984 +/- 0.0072

$\eta < 2.8$
Phoenix charge fake rate =
0.1317 +/- 0.0074



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

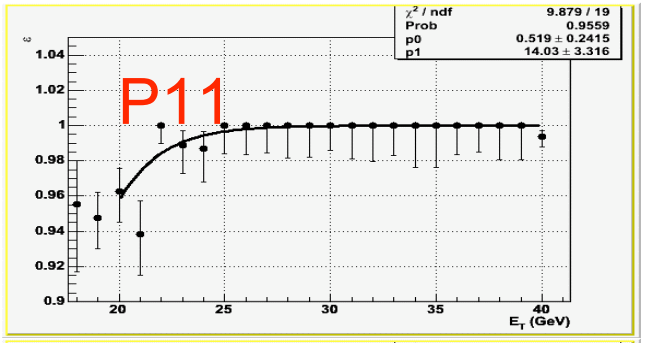
Trigger	Period 9	Period 10A	Period 10B
L1_XFT_PT8	0.9651(6)	0.9673(7)	0.9650(29)
L2_XFT_PT8	0.9992(1)	0.9993(1)	0.9992(5)
L3 tracking	0.9954(2)	0.9932(3)	0.9968(9)
Total Tracking	0.9598(7)	0.9600(8)	0.9611(31)

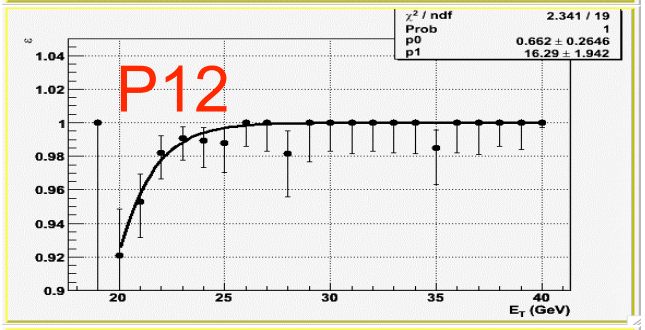
NofflW	95192
NcemL1	92288
NcemL2	92244
NcemL3	91594

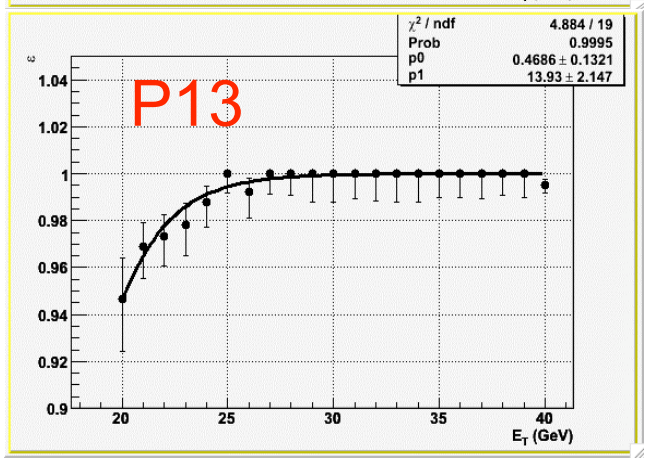
Trigger	Period 11	Period 12	Period 13	Period 14
L1_XFT_PT8	0.9688(4)	0.96857 ± 0.003	0.963922 ± 0.003	0.964755 ± 0.03
L2_XFT_PT8	0.9988(4)	0.9990 ± 0.003	0.998003 ± 0.003	0.999569 ± 0.03
L3 tracking	0.9935(4)	0.9940 ± 0.003	0.994608 ± 0.003	0.996055 ± 0.03
Total Tracking	0.9614(4)	0.9600 ± 0.003	0.95681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

Trigger	Period 15	Period 16	Period 17
L1_XFT_PT8	0.9695 ± 0.005	0.9684 ± 0.005	0.9694 ± 0.003
L2_XFT_PT8	0.9994 ± 0.005	0.9994 ± 0.005	0.9995 ± 0.003
L3 tracking	0.9940 ± 0.005	0.9927 ± 0.005	0.9929 ± 0.003
Total Tracking	0.9633 ± 0.005	0.9609 ± 0.005	0.9622 ± 0.003

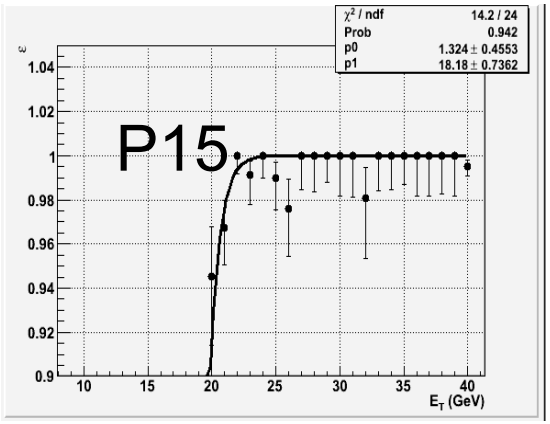
Electron Trigger : Results



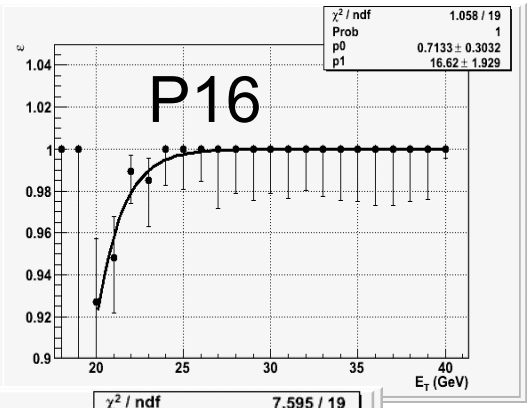


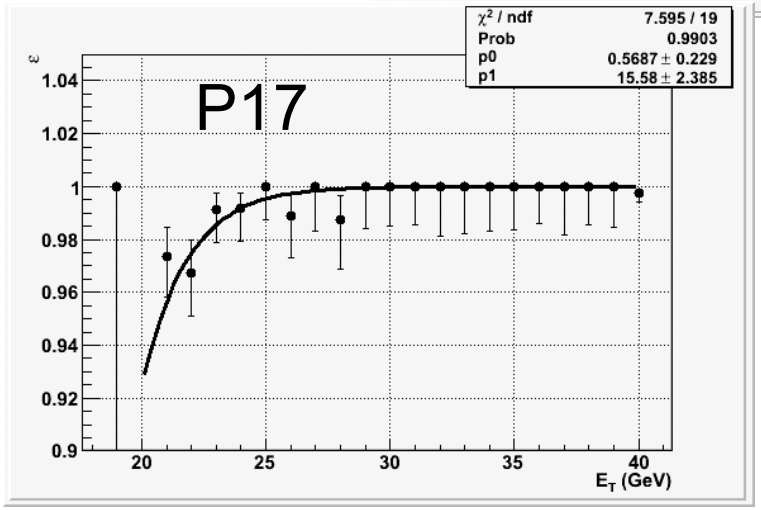


L2_CEM16 calorimeter efficiency



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





Muons

Dataset bhmumk: Runs 258880-261005
MC sample : zektim (Feb 2008)
GRL : GRL for P17 v23

Data: P17 Data on SAM
MC: dataset zektim on SAM

Dataset bhmumk: Runs 256840-258787 (P16)
MC sample : zektim (Feb 2008)
GRL :GRL for P16 v22

P16 SAM dataset
MC dataset zektim (P14 and onward) 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

P16

Cut	Count	Efficiency (%)
No cut	1386	
E_{EM} cut	1341	$96.75^{+0.49}_{-0.54}$
E_{HAD} cut	1359	$98.05^{+0.36}_{-0.47}$
COT hits cut	1385	$99.93^{+0.05}_{-0.17}$
d_0 cut	1379	$99.49^{+0.18}_{-0.26}$
Isolation cut	1327	$95.74^{+0.50}_{-0.58}$
Δx_{CMU} cut	1377	$99.35^{+0.22}_{-0.29}$
Δx_{CMP} cut	1368	$98.70^{+0.30}_{-0.39}$
All above cuts	1231	$88.82^{+0.88}_{-0.88}$
All cuts excl. isol.	1283	$92.57^{+0.74}_{-0.82}$
Sliding isol. cut	1349	$97.33^{+0.45}_{-0.53}$
All cuts (sliding isol.)	1251	$90.26^{+0.80}_{-0.86}$
χ^2 cut	1386	$100.00^{+0.00}_{-0.13}$
All cuts (χ^2)	1231	$88.82^{+0.88}_{-0.88}$
All track cuts	1256	$90.62^{+0.83}_{-0.83}$
All trk cuts excl. isol.	1308	$94.37^{+0.60}_{-0.67}$

TABLE I: Dataset bhmumkP16: Muon ID efficiencies for CMU

P17

Cut	Count	Efficiency (%)
No cut	2643	
E_{EM} cut	2561	$96.90^{+0.34}_{-0.39}$
E_{HAD} cut	2603	$98.49^{+0.23}_{-0.28}$
COT hits cut	2643	$100.00^{+0.00}_{-0.07}$
d_0 cut	2634	$99.66^{+0.11}_{-0.15}$
Isolation cut	2542	$96.18^{+0.38}_{-0.40}$
Δx_{CMU} cut	2635	$99.70^{+0.10}_{-0.16}$
Δx_{CMP} cut	2594	$98.15^{+0.27}_{-0.32}$
All above cuts	2372	$89.75^{+0.63}_{-0.64}$
All cuts excl. isol.	2460	$93.08^{+0.50}_{-0.52}$
Sliding isol. cut	2570	$97.24^{+0.30}_{-0.34}$
All cuts (sliding isol.)	2395	$90.62^{+0.55}_{-0.63}$
χ^2 cut	2643	$100.00^{+0.00}_{-0.07}$
All cuts (χ^2)	2372	$89.75^{+0.63}_{-0.64}$
All track cuts	2422	$91.64^{+0.50}_{-0.57}$
All trk cuts excl. isol.	2513	$95.08^{+0.40}_{-0.48}$

TABLE I: Dataset bhmumkP17: Muon ID efficiencies for CMUP

CMUP ID SF

P16

Cut	Scale Factor
No cut	
E_{EM} cut	$1.0052^{+0.0051}_{-0.0056}$
E_{HAD} cut	$0.9971^{+0.0037}_{-0.0048}$
COT hits cut	$0.9994^{+0.0005}_{-0.0017}$
d_0 cut	$0.9978^{+0.0018}_{-0.0027}$
Isolation cut	$0.9896^{+0.0052}_{-0.0060}$
Δx_{CMU} cut	$0.9936^{+0.0022}_{-0.0029}$
Δx_{CMP} cut	$0.9923^{+0.0030}_{-0.0039}$
All above cuts	$0.9761^{+0.0097}_{-0.0097}$
All cuts excl. isol.	$0.9860^{+0.0079}_{-0.0088}$
Sliding isol. cut	$0.9974^{+0.0046}_{-0.0054}$
All cuts (sliding isol.)	$0.9838^{+0.0088}_{-0.0094}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0013}$
All cuts (χ^2)	$0.9761^{+0.0097}_{-0.0097}$
All track cuts	$0.9907^{+0.0092}_{-0.0091}$
All trk cuts excl. isol.	$0.9999^{+0.0064}_{-0.0071}$

TABLE I: Dataset bhmumkP16_zektimP14: Muon ID Scale

P17

Cut	Scale Factor
No cut	
E_{EM} cut	$1.0067^{+0.0036}_{-0.0041}$
E_{HAD} cut	$1.0015^{+0.0024}_{-0.0029}$
COT hits cut	$1.0001^{+0.0000}_{-0.0007}$
d_0 cut	$0.9995^{+0.0012}_{-0.0015}$
Isolation cut	$0.9941^{+0.0039}_{-0.0042}$
Δx_{CMU} cut	$0.9971^{+0.0010}_{-0.0016}$
Δx_{CMP} cut	$0.9867^{+0.0027}_{-0.0032}$
All above cuts	$0.9863^{+0.0070}_{-0.0070}$
All cuts excl. isol.	$0.9914^{+0.0054}_{-0.0056}$
Sliding isol. cut	$0.9964^{+0.0031}_{-0.0035}$
All cuts (sliding isol.)	$0.9877^{+0.0060}_{-0.0069}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0007}$
All cuts (χ^2)	$0.9863^{+0.0070}_{-0.0070}$
All track cuts	$1.0018^{+0.0055}_{-0.0063}$
All trk cuts excl. isol.	$1.0074^{+0.0043}_{-0.0051}$

TABLE I: Dataset bhmumkP17_zektimP14: Muon ID Scale Factors for CMUP

CMX ID Efficiencies

P16

Cut	Count	Efficiency (%)
No cut	813	
E_{EM} cut	780	$95.94^{+0.69}_{-0.77}$
E_{HAD} cut	793	$97.54^{+0.56}_{-0.71}$
COT hits cut	813	$100.00^{+0.00}_{-0.23}$
d_0 cut	809	$99.51^{+0.22}_{-0.40}$
Isolation cut	786	$96.68^{+0.64}_{-0.73}$
Δx_{CMX} cut	811	$99.75^{+0.16}_{-0.33}$
All above cuts	734	$90.28^{+1.07}_{-1.17}$
All cuts excl. isol.	757	$93.11^{+0.88}_{-0.97}$
Sliding isol. cut	794	$97.66^{+0.53}_{-0.64}$
All cuts (sliding isol.)	740	$91.02^{+1.02}_{-1.13}$
χ^2 cut	813	$100.00^{+0.00}_{-0.23}$
All cuts (χ^2)	734	$90.28^{+1.07}_{-1.17}$
All track cuts	736	$90.53^{+1.02}_{-1.12}$
All trk cuts excl. isol.	759	$93.36^{+0.83}_{-1.02}$

TABLE II: Dataset bhmumkP16: Muon ID efficiencies for CMX

P17

Cut	Count	Efficiency (%)
No cut	1700	
E_{EM} cut	1635	$96.18^{+0.48}_{-0.55}$
E_{HAD} cut	1664	$97.88^{+0.34}_{-0.40}$
COT hits cut	1698	$99.88^{+0.07}_{-0.16}$
d_0 cut	1695	$99.71^{+0.14}_{-0.21}$
Isolation cut	1613	$94.88^{+0.58}_{-0.60}$
Δx_{CMX} cut	1695	$99.71^{+0.14}_{-0.21}$
All above cuts	1512	$88.94^{+0.76}_{-0.81}$
All cuts excl. isol.	1589	$93.47^{+0.62}_{-0.65}$
Sliding isol. cut	1645	$96.76^{+0.43}_{-0.50}$
All cuts (sliding isol.)	1540	$90.59^{+0.67}_{-0.79}$
χ^2 cut	1700	$100.00^{+0.00}_{-0.11}$
All cuts (χ^2)	1512	$88.94^{+0.76}_{-0.81}$
All track cuts	1515	$89.12^{+0.77}_{-0.79}$
All trk cuts excl. isol.	1593	$93.71^{+0.58}_{-0.69}$

CMX ID SF

P16

Cut	Scale Factor
No cut	
E_{EM} cut	$0.9966^{+0.0072}_{-0.0081}$
E_{HAD} cut	$0.9969^{+0.0057}_{-0.0073}$
COT hits cut	$1.0001^{+0.0000}_{-0.0023}$
d_0 cut	$0.9975^{+0.0022}_{-0.0040}$
Isolation cut	$0.9969^{+0.0066}_{-0.0076}$
Δx_{CMX} cut	$0.9991^{+0.0016}_{-0.0033}$
All above cuts	$0.9903^{+0.0118}_{-0.0129}$
All cuts excl. isol.	$0.9924^{+0.0094}_{-0.0104}$
Sliding isol. cut	$0.9991^{+0.0054}_{-0.0066}$
All cuts (sliding isol.)	$0.9907^{+0.0111}_{-0.0123}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0023}$
All cuts (χ^2)	$0.9903^{+0.0118}_{-0.0129}$
All track cuts	$0.9914^{+0.0113}_{-0.0124}$
All trk cuts excl. isol.	$0.9934^{+0.0089}_{-0.0109}$

TABLE II: Dataset bhmumkP16_zektimP14: Muon ID Scale Factors for CMX

P17

Cut	Scale Factor
No cut	
E_{EM} cut	$0.9990^{+0.0050}_{-0.0057}$
E_{HAD} cut	$1.0004^{+0.0035}_{-0.0041}$
COT hits cut	$0.9989^{+0.0007}_{-0.0016}$
d_0 cut	$0.9995^{+0.0014}_{-0.0021}$
Isolation cut	$0.9784^{+0.0060}_{-0.0062}$
Δx_{CMX} cut	$0.9986^{+0.0014}_{-0.0021}$
All above cuts	$0.9755^{+0.0084}_{-0.0089}$
All cuts excl. isol.	$0.9962^{+0.0067}_{-0.0070}$
Sliding isol. cut	$0.9899^{+0.0044}_{-0.0051}$
All cuts (sliding isol.)	$0.9860^{+0.0074}_{-0.0087}$
χ^2 cut	$1.0000^{+0.0000}_{-0.0011}$
All cuts (χ^2)	$0.9755^{+0.0084}_{-0.0089}$
All track cuts	$0.9760^{+0.0085}_{-0.0087}$
All trk cuts excl. isol.	$0.9971^{+0.0062}_{-0.0074}$

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.

P14

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	815	732	$89.82^{+1.05}_{-1.19}$
CMX	487	471	$96.71^{+0.80}_{-1.06}$
CMX Arches	373	367	$98.39^{+0.68}_{-0.98}$
CMX Miniskirt	91	82	$90.11^{+3.05}_{-4.37}$
CMX Keystone	23	22	$95.65^{+3.96}_{-9.13}$
CMU-only	200	179	$89.50^{+2.10}_{-2.68}$
CMP-only	216	199	$92.13^{+1.91}_{-2.19}$
CMX MiniKey	114	104	$91.23^{+2.72}_{-3.53}$

P15

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	2534	2261	$89.23^{+0.67}_{-0.60}$
CMX	1540	1466	$95.19^{+0.56}_{-0.61}$
CMX Arches	1198	1160	$96.83^{+0.49}_{-0.61}$
CMX Miniskirt	261	230	$88.12^{+2.01}_{-2.28}$
CMX Keystone	81	76	$93.83^{+2.46}_{-3.79}$
CMU-only	658	580	$88.15^{+1.21}_{-1.33}$
CMP-only	689	612	$88.82^{+1.12}_{-1.42}$
CMX MiniKey	342	306	$89.47^{+1.64}_{-1.88}$

P16

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	1513	1351	$89.29^{+0.80}_{-0.87}$
CMX	831	789	$94.95^{+0.81}_{-0.85}$
CMX Arches	655	633	$96.64^{+0.67}_{-0.89}$
CMX Miniskirt	149	130	$87.25^{+2.79}_{-3.46}$
CMX Keystone	27	26	$96.30^{+3.12}_{-7.82}$
CMU-only	361	330	$91.41^{+1.46}_{-1.67}$
CMP-only	428	373	$87.15^{+1.62}_{-1.90}$
CMX MiniKey	176	156	$88.64^{+2.57}_{-2.89}$

P17

Category	Fiducial	w/ Stub	Efficiency (%)
CMUP	2893	2574	$88.97^{+0.63}_{-0.64}$
CMX	1727	1643	$95.14^{+0.52}_{-0.56}$
CMX Arches	1355	1305	$96.31^{+0.52}_{-0.56}$
CMX Miniskirt	305	278	$91.15^{+1.72}_{-1.99}$
CMX Keystone	67	60	$89.55^{+3.61}_{-4.98}$
CMU-only	741	656	$88.53^{+1.22}_{-1.32}$
CMP-only	777	688	$88.55^{+1.20}_{-1.34}$
CMX MiniKey	372	338	$90.86^{+1.42}_{-1.70}$

Reconstruction SF

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	$0.9218^{+0.0108}_{-0.0123}$
CMX	$0.9706^{+0.0080}_{-0.0106}$
CMX Arches	$0.9856^{+0.0068}_{-0.0098}$
CMX Miniskirt	$0.9093^{+0.0308}_{-0.0441}$
CMX Keystone	$0.9678^{+0.0401}_{-0.0924}$
CMU-only	$0.9169^{+0.0216}_{-0.0275}$
CMP-only	$0.9371^{+0.0195}_{-0.0223}$
CMX MiniKey	$0.9211^{+0.0274}_{-0.0274}$

P15

Category	Scale Factor
CMUP	$0.9160^{+0.0068}_{-0.0062}$
CMX	$0.9557^{+0.0056}_{-0.0062}$
CMX Arches	$0.9702^{+0.0049}_{-0.0061}$
CMX Miniskirt	$0.8901^{+0.0204}_{-0.0231}$
CMX Keystone	$0.9499^{+0.0250}_{-0.0384}$
CMU-only	$0.9035^{+0.0124}_{-0.0136}$
CMP-only	$0.9041^{+0.0114}_{-0.0145}$
CMX MiniKey	$0.9041^{+0.0166}_{-0.0166}$

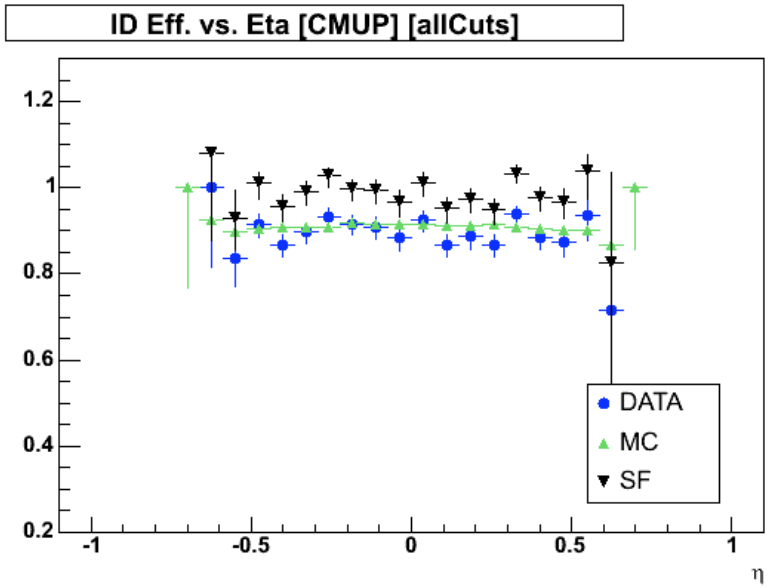
P16

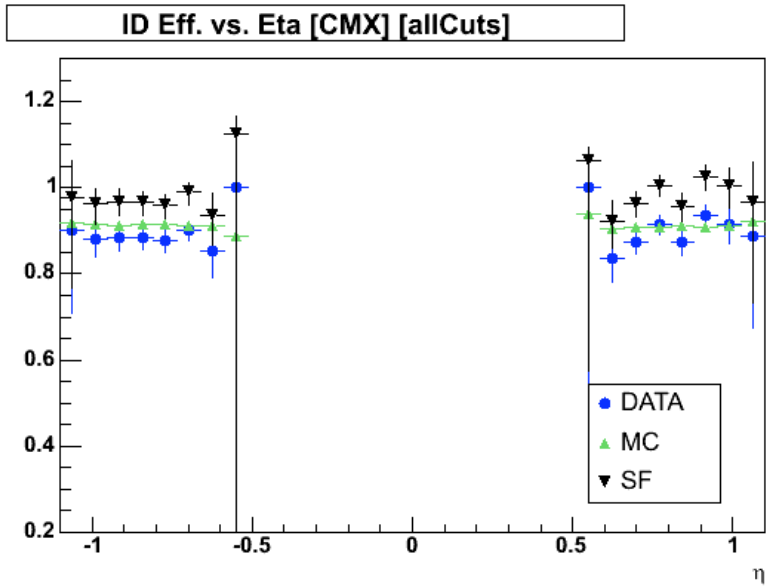
Category	Scale Factor
CMUP	$0.9167^{+0.0082}_{-0.0089}$
CMX	$0.9532^{+0.0081}_{-0.0086}$
CMX Arches	$0.9683^{+0.0067}_{-0.0089}$
CMX Miniskirt	$0.8812^{+0.0282}_{-0.0349}$
CMX Keystone	$0.9749^{+0.0316}_{-0.0792}$
CMU-only	$0.9370^{+0.0150}_{-0.0171}$
CMP-only	$0.8871^{+0.0165}_{-0.0193}$
CMX MiniKey	$0.8956^{+0.0260}_{-0.0260}$

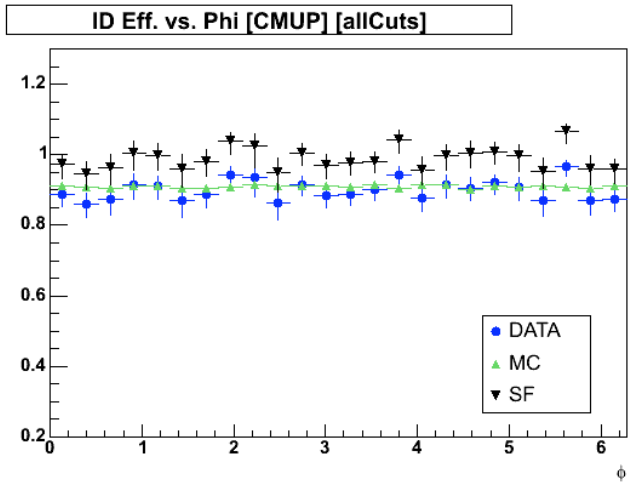
P17

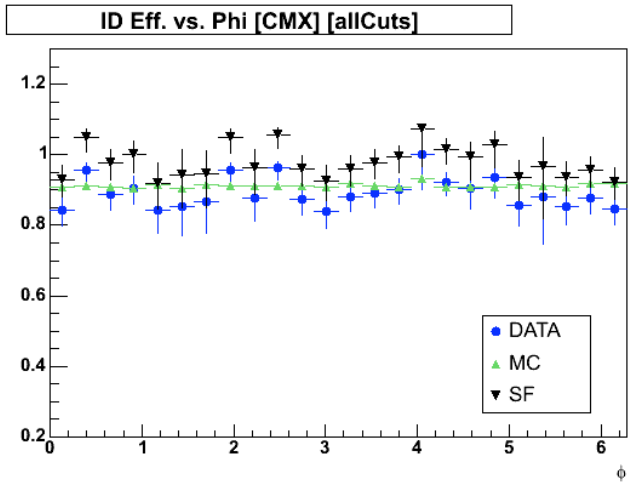
Category	Scale Factor
CMUP	$0.9134^{+0.0064}_{-0.0066}$
CMX	$0.9551^{+0.0052}_{-0.0056}$
CMX Arches	$0.9650^{+0.0052}_{-0.0056}$
CMX Miniskirt	$0.9206^{+0.0174}_{-0.0201}$
CMX Keystone	$0.9066^{+0.0366}_{-0.0505}$
CMU-only	$0.9074^{+0.0125}_{-0.0136}$
CMP-only	$0.9013^{+0.0122}_{-0.0136}$
CMX MiniKey	$0.9181^{+0.0144}_{-0.0144}$

Reco and ID Plots

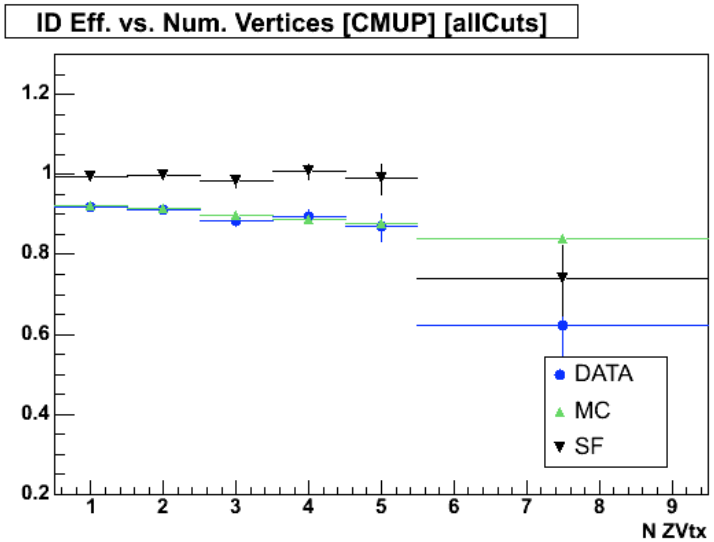


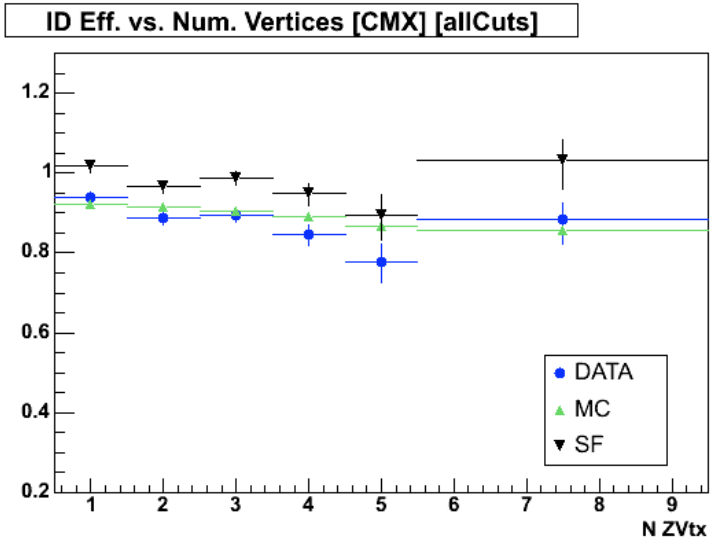


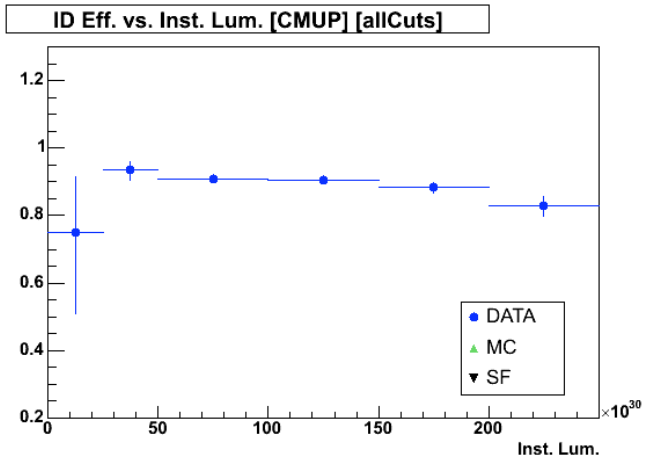


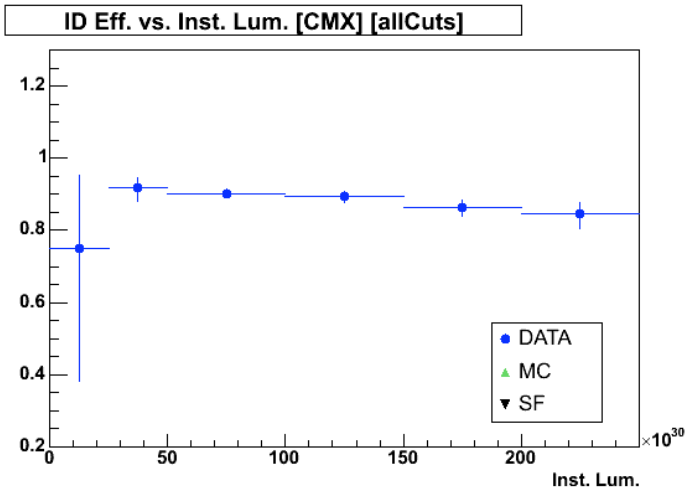


Reco and ID Plots

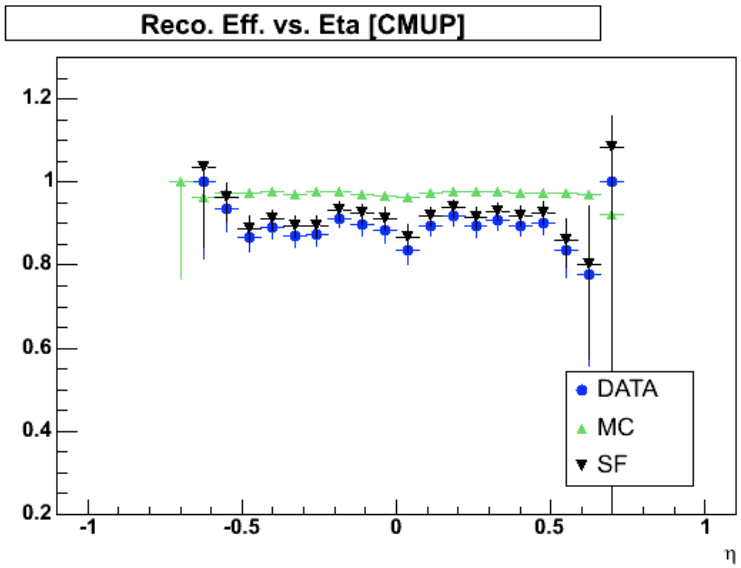


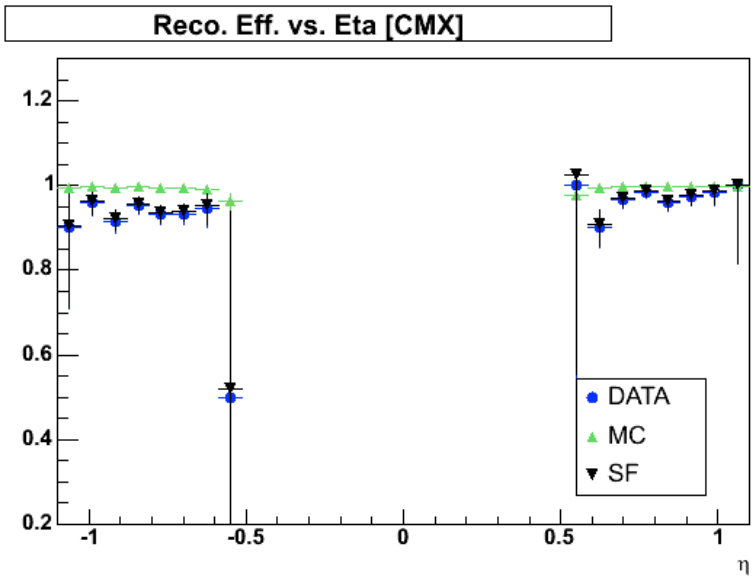


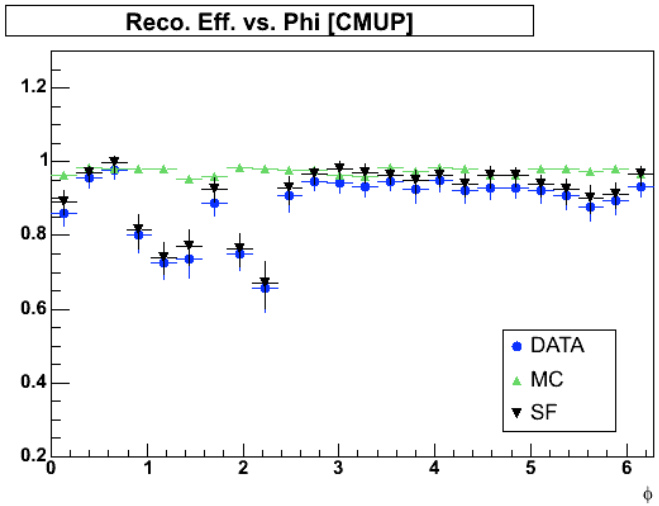


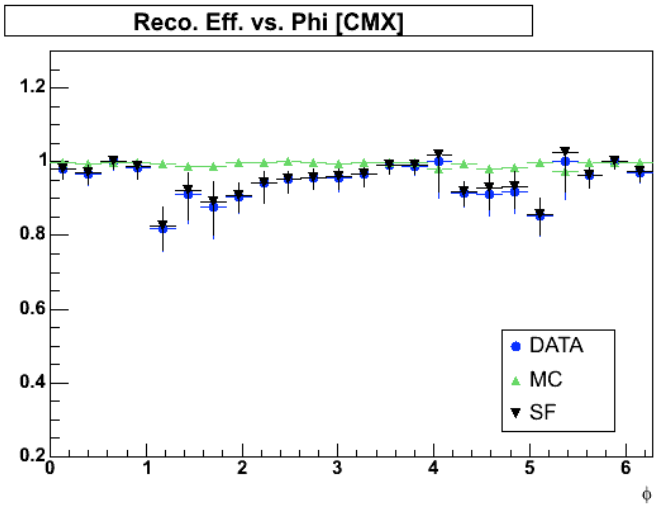


Reco and ID Plots









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:

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

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

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

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)

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

Level 3: (both leg pass L2)

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

CMX trigger efficiency is calculated in similar way.

Efficiencies not corrected for livetimes

P16

1st leg	2nd leg	1st passes	both pass	Efficiency (%)
CMUP	CMUP	489	433	-
CMX	CMUP	477	446	$93.81^{+0.74}_{-0.65}$
CMUP	CMX	498	446	-
CMX	CMX	198	157	$89.15^{+1.25}_{-1.09}$
CMUP	ARCH	395	377	-
CMUP	MK	103	69	-
ARCH	ARCH	138	126	-
ARCH	MK	50	26	-
MK	ARCH	26	26	$95.63^{+1.01}_{-0.79}$
MK	MK	10	5	$77.28^{+3.67}_{-3.59}$

Category	Events Passing	Efficiency (%)
Pass L1	446	-
CMUP	394	$98.33^{+0.64}_{-1.02}$
CMX	360	$89.85^{+1.46}_{-1.66}$
CMUP-CMX	354	-
CMUP-A	332	-
CMUP-MK	62	-
CMUP-CMX-A	296	$89.16^{+1.76}_{-1.95}$
CMUP-CMX-MK	58	$93.55^{+3.13}_{-4.68}$

Category	Events Passing	Efficiency (%)
Pass L1	446	-
CMUP-CMUP$_S$	380	-
CMX-CMX$_S$	350	-
CMUP-CMX-CMUP$_S$	345	$95.83^{+1.14}_{-1.40}$
CMUP-CMX-CMX$_S$	344	$87.31^{+1.66}_{-1.86}$
CMUP-CMX-CMX$_S$-A	287	$86.45^{+1.93}_{-2.17}$
CMUP-CMX-CMX$_S$-MK	57	$91.94^{+3.57}_{-5.02}$

P17

1st leg	2nd leg	1st passes	both pass	Efficiency (%)
CMUP	CMUP	877	775	-
CMX	CMUP	1022	970	$94.27^{+0.52}_{-0.46}$
CMUP	CMX	1087	970	-
CMX	CMX	373	287	$88.57^{+0.84}_{-0.79}$
CMUP	ARCH	859	823	-
CMUP	MK	228	147	-
ARCH	ARCH	257	227	-
ARCH	MK	80	40	-
MK	ARCH	40	40	$95.46^{+0.64}_{-0.55}$
MK	MK	36	20	$73.47^{+2.56}_{-2.45}$

Category	Events Passing	Efficiency (%)
Pass L1	970	-
CMUP	869	$98.00^{+0.49}_{-0.61}$
CMX	799	$90.10^{+1.06}_{-1.09}$
CMUP-CMX	783	-
CMUP-A	734	-
CMUP-MK	135	-
CMUP-CMX-A	658	$89.65^{+1.08}_{-1.27}$
CMUP-CMX-MK	125	$92.59^{+2.13}_{-2.94}$

Category	Events Passing	Efficiency (%)
Pass L1	970	-
CMUP-CMUP$_S$	832	-
CMX-CMX$_S$	772	-
CMUP-CMX-CMUP$_S$	756	$94.62^{+0.84}_{-0.92}$
CMUP-CMX-CMX$_S$	756	$87.00^{+1.19}_{-1.16}$
CMUP-CMX-CMX$_S$-A	632	$86.10^{+1.30}_{-1.44}$
CMUP-CMX-CMX$_S$-MK	124	$91.85^{+2.48}_{-2.98}$

Trigger Eff

Category	Events Passing	Efficiency (%)
Pass L2	354	-
CMUP	352	$99.43^{+0.35}_{-0.77}$
CMX	350	$98.86^{+0.50}_{-0.87}$
CMUP-CMX	348	-
CMUPA	294	-
CMUPMK	58	-
CMUPARCH	291	$98.98^{+0.58}_{-0.98}$
CMUP-MK	57	$98.28^{+1.43}_{-3.84}$

Category	Efficiency (%)
CMUP	$91.72^{+0.99}_{-1.35}$
CMX	$79.19^{+1.75}_{-1.89}$
CMX A	$84.39^{+1.96}_{-2.14}$
CMX MK	$71.05^{+4.25}_{-5.59}$
CMUP SLAM	$89.39^{+1.31}_{-1.60}$
CMX SLAM	$76.95^{+1.86}_{-2.01}$
CMX SLAM A	$81.83^{+2.08}_{-2.31}$
CMX SLAM MK	$69.82^{+4.40}_{-5.70}$

P16

Category	Events Passing	Efficiency (%)
Pass L2	783	-
CMUP	780	$99.62^{+0.20}_{-0.36}$
CMX	781	$99.74^{+0.17}_{-0.34}$
CMUP-CMX	778	-
CMUPA	655	-
CMUPMK	125	-
CMUPARCH	653	$99.69^{+0.20}_{-0.39}$
CMUP-MK	125	$100.00^{+0.00}_{-1.46}$

Category	Efficiency (%)
CMUP	$92.03^{+0.71}_{-0.80}$
CMX	$79.60^{+1.21}_{-1.23}$
CMX A	$85.32^{+1.18}_{-1.35}$
CMX MK	$68.03^{+2.84}_{-3.29}$
CMUP SLAM	$88.85^{+0.95}_{-1.02}$
CMX SLAM	$76.85^{+1.29}_{-1.26}$
CMX SLAM A	$81.95^{+1.36}_{-1.48}$
CMX SLAM MK	$67.48^{+2.98}_{-3.29}$

P17

Comparison with previous periods

CMUP

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

Period	Measured (SR)	Livetime Corr.	Corr. Efficiency
10	0.9196(56)	1.0	0.9196(56)
11	0.9198(61)	1.0	0.9198(61)
12	0.9241(78)	1.0	0.9241(78)
13	0.9090(61)	1.0	0.9090(61)
14	0.9197(2.22)	1.0	0.9197 (2.22)
15	0.9163(77)	1.0	0.9163 (77)
16	0.9172(116)	1.0	0.9172(116)
17	0.9203(76)	1.0	0.9203(76)

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)
15	0.9163(77)		0.8790 (100)
16	0.9172(116)		0.8939(137)
17	0.9203 (76)		0.8885 (97)

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 (239)	0.99	0.9215 (239)
15	0.9013 (117)	0.95	0.9487 (117)
16	0.8439 (204)	0.915	0.9223 (223)
17	0.8532 (127)	0.913	0.9345 (127)

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 (9)
14	0.9123/0.99= 0.9215 (2.39)	0.8815/0.99 = 0.8904 (2.7)
15	0.9013/0.95= 0.9487 (117)	0.8765/0.95 = 0.9226 (128)
16	0.8439/0.915= 0.9223 (223)	0.8183/0.915 = 0.8943 (235)
17	0.8532/0.913= 0.9345 (127)	0.8195/0.913 = 0.8975 (142)

Conclusions

- P17 and P16 high PT electrons and muons analyzed:
  - Electron ID
    - PEM drop in P16 not a concern to the experts
    - General drop in iso-ID in P17 due to high lumi runs
  - Ele Trigger ok
  - Muon ID and Reco ok
  - Muon Trigger ok