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Electron ID Efficiency and Scale Factor with TopNtuple 6.1.4 for Summer 2006

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Abstract

We derive identification efficiencies and scale factors for central (CEM) and plug (PHX) electrons. We also evaluate the Phoenix electron charge fake rate, study the plug energy scale, and evaluate electron identification systematics.

1 Introduction

We have measured electron identification efficiencies for central and plug electrons, in data and Monte Carlo. This is done using Z candidates observed in a small mass window, so that the data sample is relatively free of background. To reduce the influence of background on the data counts as much as possible, additional selections are made to increase the sample purity and the estimated background is subtracted from the counts of Z candidates where appropriate. Data/Monte Carlo scale factors to be used in analysis are calculated, along with the statistical and systematic uncertainty on those scale factors. The Monte Carlo used is from version 6.1.4 of the offline software, and the data have been processed in either the 5.1.0 or 6.1.4 version of offline. We also study the Phoenix electron charge fake rate. These studies are largely based on work done in the Gen 5 version of offline, and efforts are made to keep the selection, and analysis the same, see [1, 2]. The plug energy scale factor is also measured and presented. This note will be defining the plug electron energy differently than in the past [1]. See Section 7 for details.

2 Samples Used

There are three data samples consisting of all CDF RunII data to be compared in this analysis, bhel0d, bhel0h and bhel0i. The newest data, bhel0i, is the main data sample for this note. The bhel0h and bhel0i data samples have been processed using the official Summer 2006 version of the offline software, 6.1.4, using calibration pass 17. The early dataset bhel0d was processed using offline version 5.3.0 and calibration pass 13A. This note will use data in TopNtuple format 6.1.4v5. This is not the final version of the TopNtuple format, and this note will be updated when the final pass of the TopNtuples are ready.

The bhel0d dataset includes all data taken until September 2004, up to and including run number 186598, approximately 350pb^{-1}in total. The bhel0h dataset includes all data from runs 190697 - 203799, which spans 7 December 2004 to 4 September 2005. This is approximately 400pb^{-1}. The bhel0i dataset includes data taken between 5 September 2005 to 22 February 2006, up to the shutdown. This dataset is approximately 300pb^{-1}.

Currently, tracks with silicon hits are not beam-constrained. Events in the data are required to have fired the central high-p_T electron trigger, and specifically, the tight central electron of the Z is required to be matched in η-φ space to a L2 calorimeter cluster. All data runs used are required to be on the good run list for electrons. The good run list is DQM version 13, which includes all of the data up to the 2006 shutdown, excluding the "Compromised COT period"[1]. For the Phoenix electron studies we also require that the run be marked good for silicon.

For Monte Carlo we use the electroweak Pythia $Z \to ee$ (dataset zewkad) sample which has been processed with version 6.1.4 of the offline software and the final version, *6.1.4_1invfb* of TopNtuple. There are 6.9 million events in the sample. This MC sample covers the bhel0h - bhel0i range of run numbers, and therefore running conditions, in runs 190697 -

[1]See a previous iteration of the note, Ref. [2], for a study of the electron efficiencies during this period

212133. A dataset that covers the run range up to 186598 is presently being generated. In a major change from previous studies of the electron identification we switch to electroweak MC samples following the advice of the top group. The electroweak samples include extra min bias events overlaid with the primary interaction in order to better model the higher instantaneous luminosity environment of CDF.

3 Selection

3.1 Central-Central $Z \to ee$ candidates

The Zs used to calculate CEM electron efficiencies are central-central, where at least one of the two electrons is tight and passes the trigger, to the extent that it matches to a L2 calorimeter cluster in η and φ. Currently, tracks with silicon hits are not beam-constrained. Events in the data are required to have fired the central high-p_T electron trigger, and specifically, the tight central electron of the Z is required to be matched in η-φ space to a L2 calorimeter cluster. 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.

We use five distinct CEM selection criteria for the central efficiency studies. CEM electrons pass all the standard tight cuts. Non-isolated CEM electrons ("nisoCEM") pass all tight cuts except for isolation. Loose CEM electrons ("looseCEM") which are still acceptable for some analyses have a number of the standard cuts relaxed. Non-isolated looseCEM electrons ("nisolooseCEM") pass all the loose cuts except for isolation. Finally we have very loose, or "probe" electrons ("LCEM") which pass only minimal kinematic cuts and are used only as a denominator for the efficiency calculations. The selection defining all of these categories is enumerated in Table 1. For each distinct electron pair, we count each electron according to the criteria they pass[2]. All electron candidates in this note are labeled by the criteria they pass (for example, LCEM electrons form the denominator of all of the efficiencies.)

3.2 Central-Plug $Z \to ee$ candidates

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. The central electron is selected with one extra-tight central leg (the extra Tight ("TCEM") selection detailed in Table 1). The various cuts used for the plug leg are defined in Table 2. The baseline tight Phoenix cuts ("PHX") are essentially those recommended by the original Electron Task Force [3]. Efficiencies and scale factors for PHX electrons up to $|\eta| <$2.0 and $|\eta| <$2.8 are provided. The loose plug selection ("LPEM") is a kinematic selection only, used as the denominator for the plug electron efficiencies.

[2]The CEM, nisoCEM, looseCEM, nisolooseCEM and LCEM cuts are hierarchical, meaning that if an electron passes the CEM selection, by definition it also passes looser selections.

Variable	Loose (LCE)	Tight (CEM)	extra Tight (TCEM)
Region	== CEM	== CEM	== CEM
Fiducial	TrkFiducial == 4	Fiducial == 1	Fiducial == 1
	OR Fiducial == 1		
E_T	$\geq$ 20 GeV	$\geq$ 20 GeV	$\geq$ 20 GeV
Track Z_0	$\leq$ 60 cm	$\leq$ 60 cm	$\leq$ 60 cm
Track p_T	$\geq$ 10 GeV/c	$\geq$ 10 GeV/c	$\geq$ 10 GeV/c
COT Ax. Seg.	-	≥ 3	≥ 3
COT St. Seg.	-	≥ 2	≥ 2
Conversion	-	$\neq 1$	$\neq 1$
Had/em	-	$\leq (0.055 + (0.00045 \times E))$	$\leq (0.055 + (0.00045 \times E))$
Isolation	-	≤ 0.1	≤ 0.05
LshrTrk	-	≤ 0.2	≤ 0.1
E/P	-	≤ 2.0 unless $p_T \geq$ 50GeV/c	≤ 2.0 unless $p_T \geq$ 50GeV/c
CES ΔZ	-	≤ 3.0 cm	≤ 3.0 cm
Signed CES ΔX	-	$-3.0 \leq q \times \Delta X \leq 1.5$	$-3.0 \leq q \times \Delta X \leq 1.5$
CES StripChi2	-	≤ 10.0	≤ 10.0

Table 1: *CEM selection cuts. Both axial and stereo COT segments are required to have* ≥ 5 *hits each. There are no changes between Gen 5 and Gen 6 selections. Nonisolated CEM electrons ("nisoCEM") pass all of the tight cuts except for isolation. Loose CEM electrons for analysis ("looseCEM") are required to pass only the cuts above the line. Nonisolated loose CEM electrons (nisolooseCEM) pass all of the looseCEM cuts except isolation. Note the change in the fiducial selection for loose (LCE) electrons from Gen 5.*

The Phoenix track matching requirement, as implemented in the StdPemElectron and TopNtuple, is the requirement that a high-quality 2D Phoenix track is associated with the electron. In more detail, the tracks associated with the EmObject are retrieved and the 2D Phoenix silicon track with the lowest χ^2/DOF for the silicon fit is chosen as the matched track. The only restriction to that matching is that the χ^2/DOF is required to be less than 10 to avoid low quality tracks. No p_T or $|\eta|$ restrictions are made, so that all Phoenix tracks are considered for the match (However, such restrictions are typically given as an input to the PhoenixTrackingModule; the current settings used by the Top group, which are typical, are $p_T > 10$ GeV and $|\eta| < 2.8$.

The total number of Z or electron candidates of each type is listed in Table 3. Plots of the invariant mass of the CEM-CEM and TCEM-PHX tight electron pairs are shown in Figures 1 and 2.

3.3 Tracking Efficiency

We measure the central tracking efficiency, as a separate quantity from the electron identification efficiency in the region $1.0 < |\eta| < 1.5$, the fiducial region of the BMU. We define two

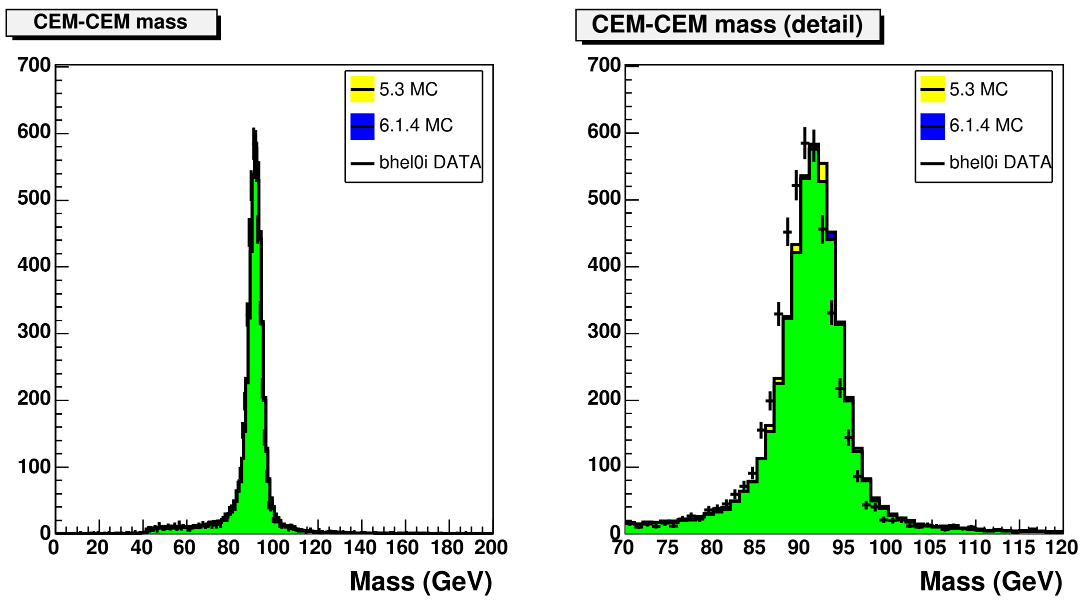

Figure 1: *Invariant mass of CEM-CEM electron pairs. See text for selection definitions. Green is the overlap between 5.3 Monte Carlo (yellow) and 6.1.4 MC (blue).*

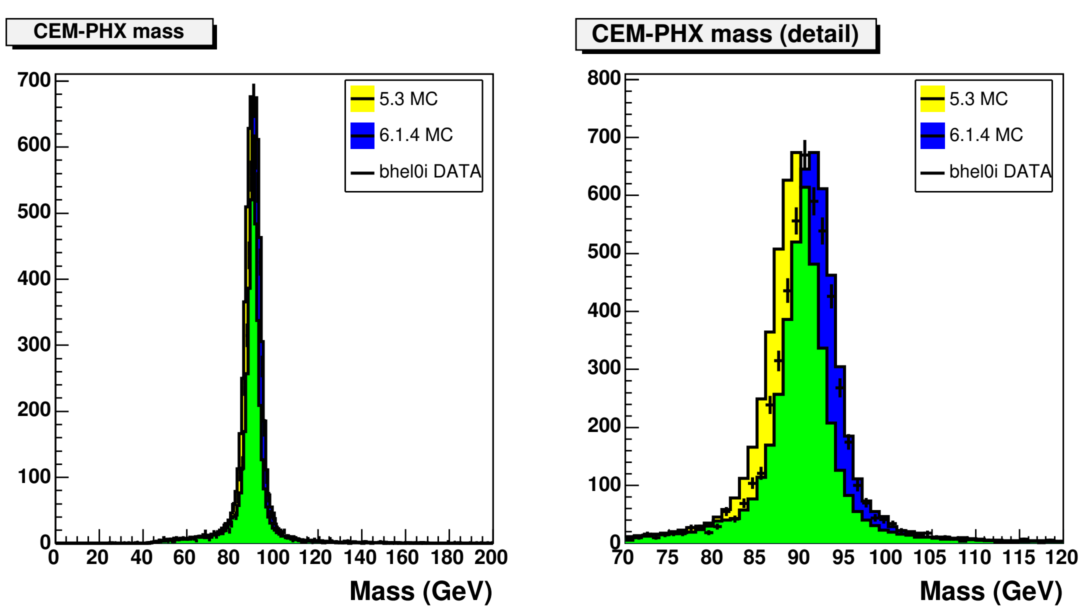

Figure 2: *Invariant mass of TCEM-PHX electron pairs. See text for selection definitions. Green is the overlap between 5.3 MC (yellow) and 6.1.4 MC (blue). There is a clear difference in the plug energy scale between the two MC datasets. This is due to the change in PHX energy definition, we are now adding the PPR and leakage energy, with the associated corrections. See Section 7 for plug electron energy scale factors.*

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

Table 2: *Definitions of plug electron types. Please refer to the main text for the definition of PhxMatch.*

tracking efficiencies as the efficiency for finding a track "defTrk" or "COTTrk" pointing at a cluster of energy passing minimal kinematic cuts. Table 4 defines the selection cuts. We select the calorimeter clusters and tracks by first finding a CEM electron, then looking for a calorimeter cluster whose invariant mass falls in the Z mass window. The calorimeter clusters are denoted $N_{CEMClus}$ and form the denominator of the efficiency. We then look through all *defTracks* type tracks in the *offltrack* collection. We take the highest p_T track that matches within a cone of 0.1 in η and ϕ to the $N_{CEMClus}$. We reject tracks that have p_T greater than 20% over the cluster E_T. We also consider the efficiency for "COT tracks". This is calculated in the same way, except we also require the track to have at least 2 Axial and 2 Stereo COT segements of 5 hits each. At no time for either the "defTrk" or "COTTrk" efficiency do we require opposite charge of the track and the CEM leg, or same charge of the calorimeter cluster and track. This implicitly requires there to be a track associated with calorimeter, thereby biasing the result.

4 Background Subtraction

One reason the $Z \rightarrow ee$ data sample works well for electron identification studies is that it is quite pure, but some background remains at the level of a few percent, depending on the mass window and lepton selection criteria chosen. Background in the data tends to decrease the efficiency measured in data and therefore the scale factor as well. We subtract background from all of the data Z samples used in these studies, using different methods for the central-central and central-plug Zs.

Type	bhel0d data	bhel0h data	bhel0i data	6.1.4 MC
CEM	12614	15331	9372	482990
ssCEM	21	18	10	454
LCEM	15834	19417	11967	597507
ssLCEM	244	311	170	4626
nisoCEM	12918	15759	9626	495923
ssnisoCEM	22	22	12	518
looseCEM	14490	17695	10860	549283
sslooseCEM	42	38	26	917
TCEM-PHX	6242	7596	4873	140651
TCEM-LPEM	8879	10711	6860	183998

Table 3: *Number of electron candidates in the data and Monte Carlo used for this analysis. "SS" means same-sign. PHX electron counts only extend to* $\eta < 2.0$.

Variable	defTrack	COTTrack	CEM cluster
DefEmObject Region	-	-	== CEM
E_T	-	-	$\geq$ 20GeV
Had/Em	-	-	$\leq (0.055 + (0.00045 \times E))$
Isolation	-	-	≤ 0.1
matched defTrack	TRUE	TRUE	-
COT Ax. Seg	-	2	-
COT St. Seg	-	2	-

Table 4: *Tracking efficiency cuts.*

4.1 Central-Central Zs

For central-central Z candidates the sign information can be used to estimate the backgrounds. The dominant background for $Z \to ee$ is W+jets events where one jet fakes a lepton [4]. A generic jet has equal probability of faking either sign of lepton, so a first approximation to the background in $N_{\rm OS}$ Z events where an opposite-sign cut has been applied is $N_{\rm OS}^{\rm bg} = N_{\rm SS}$. There are two corrections to this. One is that a fraction of same-sign events are actual Z candidates in which one electron undergoes a "trident" conversion. This fraction can be estimated using the fraction of same-sign events in the Monte Carlo. Then $N_{\rm bg}$ becomes $N_{\rm OS}^{\rm bg} = N_{\rm SS}^{\rm data} - N_{\rm SS}^{\rm MC} \times (N^{\rm data}/N^{\rm MC})$ The other correction is that the inclusive Z sample is predominantly zero jet events, and the same-sign fraction in W+jets fakes of zero-jet Zs is actually about 40% [5]. Because of this OS/SS asymmetry we need to scale up the number of SS fakes by a factor of 0.6 / 0.4. Therefore the number of background events in a central-central Z sample is

$$N_{\rm OS}^{\rm bg} = (0.6/0.4) \times \{N_{\rm SS}^{\rm data} - N_{\rm SS}^{\rm MC} \times \frac{N_{\rm OS}^{\rm data}}{N_{\rm OS}^{\rm MC}}\}$$

Background is subtracted from both the numerator and the denominator. If this estimate is less than zero, the background is said to be less than the sensitivity of this method, and is assigned to be zero. Using this method we found following background fractions for our bhel0i Z samples: CEM-CEM, (0.020 ± 0.015) %; CEM-nisoCEM, (0.030 ± 0.018) %; CEM-looseCEM, (0.109 ± 0.032) %; CEM-nisolooseCEM, (0.195 ± 0.042) %; CEM-LCE, (0.970 ± 0.090) %.

4.2 Central-Plug Zs

Same-sign subtraction is not an option for central-plug efficiencies due to the non-negligible Phoenix charge fake rate, and the fact that no sign information at all is available for PEM electrons. For Z cross-section analyses using plug electrons the background is usually computed using QCD lepton fake rate information derived from jet data (see for example CDF note 6642) [6]. Since this is not a background estimate for a physics analysis, we sought to keep our method simpler. In an earlier note we explored three methods of deriving the background from the shape of the invariant mass distribution around the Z peak in data and Monte Carlo [2]. Here we describe only the method that was chosen.

The background in the data is estimated using the height of the sidebands, in data and in Monte Carlo, relative to the Z peak. The data and Monte Carlo histograms are normalized to the same area in the signal-dominated invariant mass window $76~\mathrm{GeV}/c^2 < M < 106~\mathrm{GeV}/c^2$. The difference between the data and Monte Carlo is found on a bin-by-bin basis for all bins outside of that signal window but inside of $70~\mathrm{GeV}/c^2 < M < 120~\mathrm{GeV}/c^2$. The average difference per bin is taken to be the amount of background per bin. Assuming that the background is constant in invariant mass, the calculated background per bin is multiplied by the number of bins in the mass window used for counting Z candidates to estimate the number of background events in those Z candidates. If this estimate is less than zero, the background is said to be less than the sensitivity of this method, and is assigned to be zero. Using this method, we find the background in the bhel0i dataset for CEM-CEM and CEM-LCE Z's to be (0.000 ± 0.975)% and (0.755 ± 1.429)%, which, within their considerable uncertainty, agree with the numbers quoted in the previous subsection. In the mass window $81~\mathrm{GeV}/c^2 < M < 101~\mathrm{GeV}/c^2$, which is used to derive the PHX scale factor, the background fractions for CEM-PHX Zs is (0.000 ± 0.594)%, for CEM-PHX Zs is (0.000 ± 0.632)%, and for CEM-LPEM Zs is (0.995 ± 0.895)%.

5 Efficiencies and Scale Factors

We define the following CEM efficiency:

$$\epsilon_{\mathrm{CEM}} = \frac{N_{\mathrm{T}}}{N_{\mathrm{L}}}$$

where N_{T} is the number of probe electrons that pass the CEM/nisoCEM/looseCEM/nisolooseCEM cuts, and where N_{L} is the inclusive number of probe electrons.

For Phoenix electrons, we calculate the efficiencies of the PHX selection, using TCEM-PEM Zs as the denominator. The efficiency is defined:

$$\epsilon_{\rm PHX} = \frac{N_{\rm TCEM\text{-}PHX}}{N_{\rm TCEM\text{-}LPEM}} \ .$$

In the past, we separately calculated the tracking efficiency (using TCEM-PEM Zs as the denominator) and the plug calorimeter (PEM) efficiency (using TCEM-LPHX Zs, where LPHX electrons are like LPEM with a matched PHX track), and multiplied them to find the total efficiency. This method avoids relaxing all of the cuts at once, which allows less background into the sample. But, the tracking and calorimeter efficiencies are correlated in this method. The tracking efficiency is about 10% higher when measured after the PEM cuts are applied than if it is measured before. This has a minimal impact on the scale factor relative to the size of the current uncertainties, but as we have background subtraction there is no reason not to do this correctly, so we have changed our method to give the total PHX efficiency as $\epsilon_{\rm PHX}$ as given above.

The total CEM efficiency and the PHX efficiency efficiency are shown as a function of η, ϕ, and run number in Figures 9 through 14. The total CEM efficiency as a function of E_T is shown in Figure 15. Figures 16 to 18 shows the efficiency versus isolation, the number of Z vertices, and instantaneous luminosity.

The CEM and PHX efficiencies vs η are shown in Figures 9 to 10. These figures show that the scale factors are not constant for all values of η. Table 19 gives the scale factor for various η ranges.

For both CEM and PHX electrons, the scale factor defined as $\epsilon^{\rm data}/\epsilon^{\rm MC}$ is used in analysis to correct the acceptance calculated from Monte Carlo. The efficiencies and scale factors, after background subtraction has been applied, for CEM and PHX electrons are all collected in Table 5. Efficiencies and scale factors derived using all available data and MC are presented in Table 6. We also present efficiencies and data/MC scale factors for six short data taking periods, see Tables 7.

The CEM efficiencies continue their trend of lower efficiencies with higher average instantaneous luminosity, as can be seen by the decreasing efficiency going from dataset bhel0d, bhel0h and bhel0i. The CEM efficiency falls by 1.5% over these three data taking periods. CEM scale factors are improved by 0.5% for bhel0d data and 0.8% for bhel0h data using the new electroweak MC samples with extra min bias events. The PHX tracking efficiencies have not significantly changed with the new definition of the plug energy or the reprocessing of the data in the new version of TopNtuple.

We also find N-1 efficiencies for all of the identification variables for both CEM and PHX electrons. These are calculated using the same formula as the total efficiencies, except that the "probe" electron passes all selection criteria except the one in question. For the sake of simplicity, we do not subtract background, since the background is likely to be very small anyways. All of the N-1 efficiencies for CEM electrons are given in Table 8 and for PHX in Table 9. The reader should also keep in mind that many of these quantities are correlated. All quantities used for selection, for both CEM and PHX, are shown in Figures 19 through 23. In those plots, a line is drawn at the value of the constant cut (linear terms and cutoffs are ignored).

CEM				
efficiency	bhel0d Data	bhel0h Data	bhel0i Data	6.1.4 MC
ϵ_{CEM}	0.801±0.003	0.796±0.003	0.786 ± 0.004	0.808 ± 0.001
scale factor	0.991 ± 0.004	0.983 ±0.004	0.972 ± 0.005	N/A
$\epsilon_{\mathrm{nisoCEM}}$	0.825±0.003	0.821±0.003	0.812 ± 0.004	0.830±0.001
scale factor	0.993 ± 0.006	0.989 ±0.003	0.978 ± 0.004	N/A
$\epsilon_{\mathrm{looseCEM}}$	0.924±0.002	0.922±0.002	0.916 ± 0.003	0.919 ±0.001
scale factor	1.005 ± 0.002	1.002 ±0.002	0.995 ± 0.003	N/A
$\epsilon_{\mathrm{nisolooseCEM}}$	0.949±0.002	0.949±0.002	0.942 ± 0.002	0.945 ±0.001
scale factor	1.004 ± 0.002	1.003 ±0.002	0.996 ± 0.002	N/A
PHX				
efficiency	bhel0d Data	bhel0h Data	bhel0i Data	6.1.4 MC
$\epsilon_{\mathrm{PHX}} \lvert\eta\rvert < 2.0$	0.712 ± 0.005	0.716 ± 0.004	0.714 ± 0.005	0.764 ± 0.001
scale factor	0.932 ±0.006	0.937 ±0.006	0.934 ± 0.007	N/A
$\epsilon_{\mathrm{PHX}} \lvert\eta\rvert < 2.8$	0.637 ± 0.004	0.635 ± 0.004	0.630 ± 0.005	0.670 ± 0.001
scale factor	0.951 ±0.006	0.947 ±0.006	0.953 ± 0.007	N/A

Table 5: *Total data and Monte Carlo efficiencies and scale factors, for both tight electron types. Background subtraction is done for both data sets. Uncertainties are statistical only.*

	Data	MC
ϵ_{CEM}	0.793 ± 0.002	0.808 ± 0.001
scale factor	0.981 ± 0.003	
$\epsilon_{\mathrm{nisoCEM}}$	0.818 ± 0.002	0.830 ± 0.001
scale factor	0.986 ± 0.002	
$\epsilon_{\mathrm{looseCEM}}$	0.920 ± 0.001	0.919 ± 0.001
scale factor	1.001 ± 0.002	
$\epsilon_{\mathrm{nisolooseCEM}}$	0.946 ± 0.001	0.945 ± 0.001
scale factor	1.001 ± 0.001	
$\epsilon_{\mathrm{PHX}} \lvert\eta\rvert < 2.0$	0.715 ± 0.003	0.764 ± 0.001
scale factor	0.935 ± 0.004	
$\epsilon_{\mathrm{PHX}} \lvert\eta\rvert < 2.8$	0.638 ± 0.002	0.671 ± 0.001
scale factor	0.951 ± 0.004	

Table 6: *Data and Monte Carlo efficiencies and scale factors, using all data and MC available. PHX tracks extend out to $\lvert\eta\rvert$ <2.8. Background subtraction is done for both data sets. Uncertainties are statistical only.*

Time Period	Efficiency	Scale Factor
"initial 200/pb"	0.804 ± 0.004	0.995 ± 0.005
"Year 2004"	0.797 ± 0.005	0.987 ± 0.006
"Early 2005"	0.799 ± 0.004	0.989 ± 0.005
"Summer 2005"	0.791 ± 0.004	0.978 ± 0.006
"Fall 2005"	0.788 ± 0.005	0.975 ± 0.006
"Winter 2006"	0.784 ± 0.005	0.969 ± 0.007

Table 7: *CEM efficiencies and data/MC scale factors for the six short data taking time periods. Uncertainties are statistical only.*

efficiency	bhel0d Data	bhle0h Data	bhle0i Data	6.1.4 MC
Conversion	0.974 ± 0.001	0.970 ± 0.001	0.969 ± 0.002	0.9729 ± 0.0002
Fiducial	0.983 ± 0.001	0.987 ± 0.001	0.984 ± 0.001	0.9894 ± 0.0001
TrkAxSeg	0.9991 ± 0.0003	0.9988 ± 0.0003	0.9990 ± 0.0003	0.9997 ± 0.0000
TrkStSeg	0.9998 ± 0.0001	1 ± 0	1 ± 0	1 ± 0
Hadem	0.993 ± 0.001	0.992 ± 0.001	0.9921 ± 0.001	0.9884 ± 0.0002
Isol	0.976 ± 0.001	0.973 ± 0.001	0.974 ± 0.002	0.9739 ± 0.0002
LshrTrk	0.993 ± 0.001	0.9924 ± 0.0007	0.992 ± 0.001	0.9905 ± 0.0001
EP	0.933 ± 0.002	0.932 ± 0.002	0.933 ± 0.002	0.9279 ± 0.0004
DeltaZ	0.9980 ± 0.0004	0.9982 ± 0.0003	0.9981 ± 0.0005	0.99925 ± 0.0000
QxDeltaX	0.9978 ± 0.0004	0.9984 ± 0.0003	0.9978 ± 0.0005	0.9985 ± 0.0001
StripChi2	0.967 ± 0.002	0.965 ± 0.001	0.962 ± 0.002	0.9812 ± 0.0002

Table 8: *CEM N-1 efficiencies. No background subtraction is done, errors are statistical only.*

It is also important to check for changes in the efficiencies as a function of time in the data, since the data in the Gen 5 (bhel0d) and Gen 6 (bhel0h) era have already been validated, and there are possible problems with the increased luminosity in the detector. We divide the data into six separate time periods for the purposes of comparison: "initial 200pb^{-1}" is run numbers 141544-168889, and is approximately 200pb^{-1}of data. "Year 2004" is run numbers 175066-186598, up to the shutdown in August 2004, and is approximately 155pb^{-1}of data. "Early 2005" consists of runs 190697 - 198379 and is about 200pb^{-1}of data. "Summer 2005" comprises the data taken from June - September 2005, and is about 200 pb^{-1}. "Fall 2005" consists of run numbers 203819 - 206989 and is about 134pb^{-1}, taken between 5 September - 9 November 2005. "Winter 2006" is the most recent data, runs 206990 - 212133, taken 10 November 2005 - 22 February 2006. This is 135pb^{-1}of data. All CEM efficiencies are shown separately for these six time periods in Table 10.

The efficiency for def tracks matching a CEM calorimeter cluster is

$$\epsilon_{\text{deftrk}} = \frac{N_{\text{deftrk}}}{N_{\text{CEM clusters}}}$$

efficiency	bhel0d Data	bhel0h MC	bhel0i Data	6.1.4 MC
Hadem	0.993 ± 0.001	0.993 ± 0.001	0.991 ± 0.001	0.9922 ± 0.0006
Isol	0.981 ± 0.002	0.974 ± 0.002	0.975 ± 0.002	0.984 ± 0.001
DeltaR	0.986 ± 0.001	0.987 ± 0.001	0.986 ± 0.002	0.9885 ± 0.0007
Pem3x3FitTow	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Pem3x3Chisq	0.915 ± 0.003	0.913 ± 0.003	0.912 ± 0.004	0.943 ± 0.001
Pes2d5by9U	0.991 ± 0.001	0.993 ± 0.001	0.992 ± 0.001	0.9930 ± 0.0005
Pes2d5by9V	0.989 ± 0.001	0.996 ± 0.001	0.989 ± 0.001	0.9948 ± 0.0004

Table 9: *Phoenix N-1 efficiencies. No background subtraction is done, errors are statistical only. This table selects PHX tracks up to* $|\eta| < 2.0$.

efficiency	initial 200pb^{-1}	Year 2004	Early 2005	Summer 2005	Fall 2005	Winter 2006
Conversion	0.974 ± 0.002	0.973 ± 0.002	0.971 ± 0.002	0.969 ± 0.002	0.968 ± 0.002	0.969 ± 0.003
Fiducial	0.986 ± 0.001	0.980 ± 0.002	0.987 ± 0.001	0.988 ± 0.001	0.986 ± 0.002	0.983 ± 0.002
TrkAxSeg	0.9994 ± 0.0003	0.9985 ± 0.0005	0.9989 ± 0.0003	0.9988 ± 0.0004	0.9990 ± 0.0005	0.9991 ± 0.0004
TrkStSeg	0.9997 ± 0.0002	0.9998 ± 0.0002	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Hadem	0.993 ± 0.001	0.993 ± 0.001	0.993 ± 0.001	0.991 ± 0.001	0.992 ± 0.001	0.992 ± 0.001
Isol	0.976 ± 0.002	0.978 ± 0.002	0.972 ± 0.002	0.973 ± 0.002	0.974 ± 0.002	0.974 ± 0.004
LshrTrk	0.994 ± 0.001	0.992 ± 0.001	0.991 ± 0.001	0.994 ± 0.001	0.991 ± 0.001	0.9983 ± 0.0006
EP	0.934 ± 0.003	0.933 ± 0.003	0.933 ± 0.003	0.930 ± 0.003	0.937 ± 0.003	0.9981 ± 0.0006
DeltaZ	0.9983 ± 0.0005	0.9976 ± 0.0007	0.9979 ± 0.0005	0.9986 ± 0.0004	0.9979 ± 0.0007	0.961 ± 0.003
QxDeltaX	0.9976 ± 0.0006	0.9980 ± 0.0006	0.9986 ± 0.0004	0.9980 ± 0.0005	0.9975 ± 0.0007	0.9981 ± 0.0006
StripChi2	0.968 ± 0.002	0.966 ± 0.002	0.967 ± 0.002	0.962 ± 0.002	0.962 ± 0.003	0.961 ± 0.003
total	0.804 ± 0.004	0.797 ± 0.005	0.799 ± 0.004	0.791 ± 0.004	0.788 ± 0.005	0.784 ± 0.005

Table 10: *CEM N-1 efficiencies for the six data taking time periods. See the end of Section 5 for the exact definitions of the data-taking time periods. Background subtraction is applied to total efficiencies only, uncertainties are statistical only.*

efficiency	initial 200pb^{-1}	Year 2004	Early 2005	Summer 2005	Fall 2005	Winter 2006
Hadem	0.994 ± 0.001	0.991 ± 0.002	0.994 ± 0.002	0.993 ± 0.001	0.993 ± 0.002	0.989 ± 0.002
Isol	0.981 ± 0.002	0.980 ± 0.003	0.973 ± 0.002	0.975 ± 0.003	0.976 ± 0.003	0.974 ± 0.003
DeltaR	0.988 ± 0.002	0.986 ± 0.002	0.987 ± 0.002	0.987 ± 0.002	0.986 ± 0.002	0.986 ± 0.002
Pem3x3FitTow	1 ± 0	1 ± 0	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Pem3x3Chisq	0.923 ± 0.004	0.905 ± 0.005	0.916 ± 0.004	0.910 ± 0.005	0.917 ± 0.005	0.907 ± 0.006
Pes2d5by9U	0.990 ± 0.002	0.993 ± 0.002	0.992 ± 0.001	0.993 ± 0.001	0.991 ± 0.002	0.993 ± 0.002
Pes2d5by9V	0.990 ± 0.002	0.988 ± 0.002	0.993 ± 0.001	0.992 ± 0.001	0.962 ± 0.003	0.992 ± 0.002
tracking	0.856 ± 0.006	0.864 ± 0.006	0.872 ± 0.005	0.871 ± 0.005	0.879 ± 0.006	0.878 ± 0.006
PEM	0.849 ± 0.005	0.821 ± 0.006	0.834 ± 0.005	0.824 ± 0.006	0.819 ± 0.007	0.811 ± 0.007
total	0.727 ± 0.008	0.709 ± 0.009	0.728 ± 0.007	0.718 ± 0.008	0.721 ± 0.009	0.712 ± 0.009

Table 11: *PHX N-1 efficiencies for the six data taking periods. PHX tracks extend to $|\eta|$ <2.0. See the end of Section 5 for the exact definition of the time periods. Background subtraction is applied to tracking, PEM, and total efficiencies only, uncertainties are statistical only.*

The COT efficiency is given by a similar expression.

6 Phoenix Charge Fake Rate

Analyses which use the charge information for Phoenix electrons must consider not only the identification efficiency but also the probability of charge misidentification. We measure the Phoenix electron charge fake rate using the same samples and TCEM-PHX Z candidates that are the numerator in the efficiencies. The charge fake rate is defined as

$$\mathrm{CFR} = \frac{N_{\text{wrong-sign}}}{N_{\text{right-sign}} + N_{\text{wrong-sign}}}$$

where $N_{\text{wrong-sign}}$ is the number of Z candidates where the tight CEM electron and the Phoenix electron have the same sign, and $N_{\text{right-sign}}$ is the number where they have the opposite sign. For now we assume that the charge fake rate for CEM electrons and the background contamination in the TCEM-PHX Z candidate sample are both negligible. Charge fake rates for Phoenix electrons with $|\eta|$ ranges out to 2.0 and 2.8 are shown in Tables 13 and 12.

For analyses which use the Phoenix electron charge information, it is important to note that the charge fake rate is highly dependent on η, as shown in Figure 3. The average charge fake rate can be used to construct a scale factor correcting for the effect of requiring the Phoenix electron to be a particular sign, but the average should be weighted by the pseudorapidity distribution of plug electrons generated by the physics process in question. The charge fake rate as a function of pseudorapidity is provided for this purpose in Table 14. As an illustration, the charge fake rate re-weighted by the pseudorapidity distribution of Phoenix electrons in $t\bar{t}$ dilepton events (using tracks up to $|\eta| < 2.0$ only) is 0.100 ± 0.004 for data and 0.105 ± 0.002 for Monte Carlo. This is noticeably lower than the numbers in Table 13 because the

bhel0d Data	0.142 ± 0.004
bhel0h Data	0.134 ± 0.003
bhel0i Data	0.141 ± 0.004
6.1.4 MC	0.1481 ± 0.0006
"initial 200pb^{-1}"	0.150 ± 0.005
"Year 2004"	0.133 ± 0.006
"Early 2005"	0.135 ± 0.005
"Summer 2005"	0.133 ± 0.005
"Fall 2005"	0.142 ± 0.006
"Winter 2006"	0.139 ± 0.006

Table 12: *Phoenix electron charge fake rates for PHX tracks with* $|\eta| < 2.8$.

bhel0d Data	0.112 ± 0.004
bhel0h Data	0.105 ± 0.004
bhel0i Data	0.111 ± 0.004
6.1.4 MC	0.1191 ± 0.0006
"initial 200pb^{-1}"	0.117 ± 0.005
"Year 2004"	0.105 ± 0.006
"Early 2005"	0.105 ± 0.005
"Summer 2005"	0.106 ± 0.005
"Fall 2005"	0.112 ± 0.006
"Winter 2006"	0.109 ± 0.006

Table 13: *Phoenix electron charge fake rates for PHX tracks with* $|\eta| < 2.0$.

charge fake rate is lower at lower $|\eta|$ and $t\bar{t}$ events are more central than Z events. The charge fake rate dilutes the acceptance for Phoenix events, so a scale factor must be applied to any Monte Carlo acceptance for Phoenix electrons where an opposite sign requirement is made. That scale factor is:

$$\frac{1 - F_{\mathrm{data}} \cdot N_{\mathrm{OS}} + F_{\mathrm{data}} \cdot N_{\mathrm{SS}}}{1 - F_{\mathrm{MC}} \cdot N_{\mathrm{OS}} + F_{\mathrm{MC}} \cdot N_{\mathrm{SS}}}$$

$F_{\mathrm{data(MC)}}$ is the charge fake rate in data(Monte Carlo) and $N_{\mathrm{OS(SS)}}$ is the expected fraction of same-sign events. For top and Z events, where N_{OS} is essentially 100%, this expression gives scale factors of 1.001 ± 0.006 and 1.001 ± 0.005, respectively for PHX tracks up to $|\eta| <2.0$. For PHX tracks up to $|\eta| < 2.8$ the scale factor for Z events is 1.014 ± 0.003.

7 The Plug Electron Energy Scale

The plug is calibrated to make central-plug Z invariant mass distribution have the correct peak. To obtain the correct plug electron energy, the end user must apply a series of corrections

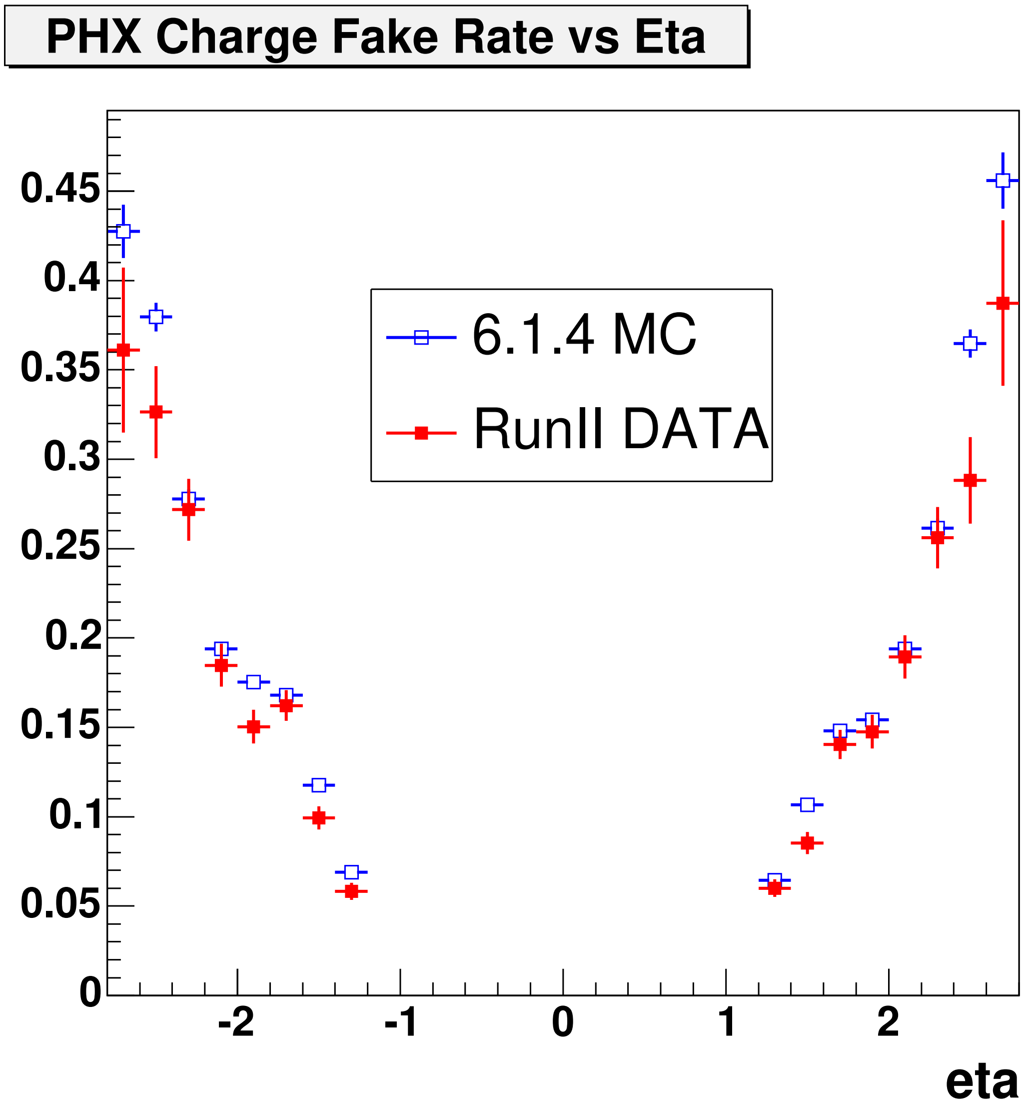

Figure 3: *The charge fake rate for Phoenix electrons as a function of electron η.*

Range	Run II Data	6.1.4 Monte Carlo
2.8< $\|\eta\|$ <2.6	0.374 $\pm$ 0.033	0.438 $\pm$ 0.009
2.6< $\|\eta\|$ <2.4	0.307 $\pm$ 0.018	0.371 $\pm$ 0.005
2.4< $\|\eta\|$ <2.2	0.264 $\pm$ 0.012	0.272 $\pm$ 0.003
2.2< $\|\eta\|$ <2.0	0.187 $\pm$ 0.008	0.194 $\pm$ 0.002
2.0< $\|\eta\|$ <1.8	0.149 $\pm$ 0.007	0.168 $\pm$ 0.002
1.8< $\|\eta\|$ <1.6	0.151 $\pm$ 0.006	0.157 $\pm$ 0.001
1.6< $\|\eta\|$ <1.4	0.092 $\pm$ 0.005	0.113 $\pm$ 0.001
1.4< $\|\eta\|$ <1.2	0.059 $\pm$ 0.003	0.066 $\pm$ 0.001

Table 14: *Phoenix electron charge fake rates, as a function of pseudorapidity.*

to the energy, along with a final scale factor calculated to bring the central-plug Z mass peak to 91 GeV/c^2. In the most recent (6.1.4) version of TopNtuple these corrections are all done for the end user and stored as the default values of the electron energy, E_T, etc., but we discuss the corrections made in detail here for reference. The definitions and procedure used here are based on the discussion in [11].

The components of the corrected plug electron energy (except the final scale factor) are as follows:

Baseline Energy
- `PemBaseEnergy` in the TopNtuple electron
- Raw energy from 2x2 ("BF_PEM") clustering

PPR Energy
- `PprEn` in the TopNtuple electron
- from `emobj_alg::PPREnergy` by way of `StdPEMElectron::pprEnergy`
- PPR (Plug pre-radiatior) energy (not included in default energy)

2x2 Leakage
- `LeakE*(PemBaseEnergy/EmEt)` in the TopNtuple electron
- from `IsoCorrAlg::GetIsoCorr` by way of `StdPEMElectron::calIsoEt`
- Leakage energy (energy leaking over the eta/phi boundaries of the cluster and not included in the 2x2 cluster) **Note:** LeakE actually contains the transverse leakage energy, so it must be corrected as above to recover the full leakage energy.

Face Correction
- `PemFaceCorrFactor` in the TopNtuple electron
- from `PemCorrAlg::GetPemCorr`
- Corrects for irregularities in the response of individual calorimeter towers (Also known as map corrections)

3x3 Leakage
- `Pem3by3LeakageCorr` in the TopNtuple electron
- from `PemCorrAlg::PEMfid3by3` using the PEM detector eta and `StdPEMElectron::vertexZ()` as inputs, with additional low-eta leakage correction where applicable
- Additional leakage correction accounting for leakage outside of the 3x3 area of the cluster. *Applies to data only.*

The corrected energy is assembled according to the prescription:

$$E = \frac{\text{Baseline Energy} + \text{PPR Energy} + \text{2x2 Leakage}}{\text{Face Correction} \times \text{3x3 Leakage}} \times (\text{Energy Scale Factor}) \qquad (1)$$

Even after all these corrections, the central-plug Z mass peak is still not at 91 GeV/c^2. Following the prescription in [11], we fit the CEM-PHX Z peak in the window 86 - 98 GeV/c^2. We find scale factors via

$$E^{CEM}_{scale} = \frac{91}{M_{CC}}$$

$$E^{PEM}_{scale} = (\frac{91}{M_{CP}})^2 \times \frac{1}{E^{CEM}_{scale}}$$

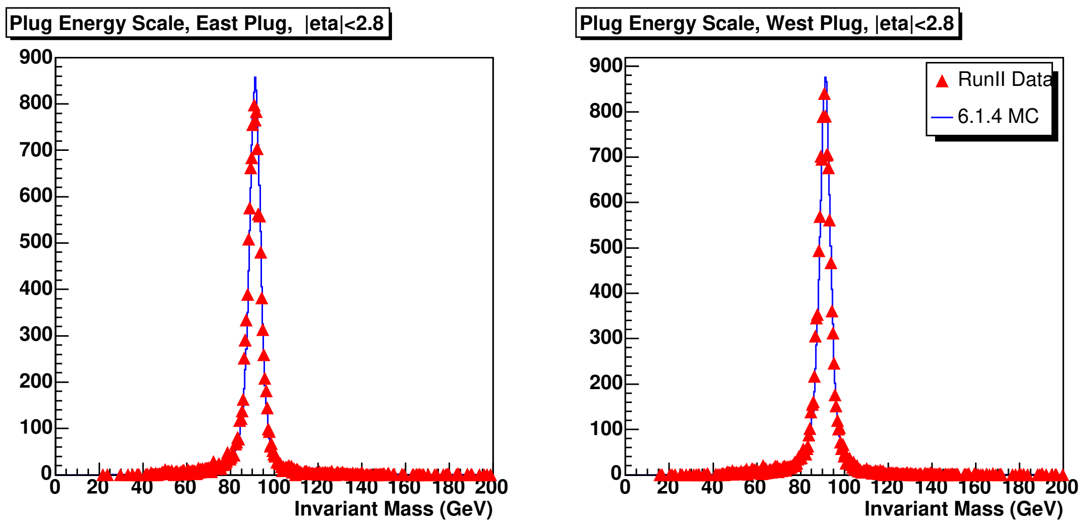

Figure 4: *Reconstructed CEM-PHX mass in 1fb^{-1}of data and MC for the east and west plugs. All plug electron corrections are applied, including the energy scale factors from Table 15. PHX tracks extend out to $|\eta|$ <2.8.*

We find and apply different scale factors for each of the east ($|\eta| > 0$) and west ($|\eta| < 0$) plugs, and for data and MC. We then apply these energy scale factors to the data, and MC. The scale factors found for all the data under consideration are shown in Table 15. Note that there is no significant difference between the scale factors calculated using PHX electrons up to $|\eta| < 2.0$ and $|\eta| < 2.8$, nor any significant difference between the different datasets.

Figure 4 shows the reconstructed Z peak for both 1fb^{-1}of data, and MC, with all the corrections described above, including the scale factor, applied. The fits shown are give the results: Fitting the Z peak with a Gaussian in the invariant mass range 86 GeV$/c^2 < M <$ 98 GeV$/c^2$ gives mean values of 90.95 ± 0.04 GeV$/c^2$ for the east plug and 90.95 ± 0.03 GeV$/c^2$ for the west plug for the entire 1fb^{-1}of data with $|\eta| < 2.0$ and 91.22 ± 0.01 GeV$/c^2$ for the east plug and 91.22 ± 0.01 GeV$/c^2$ for the west plug for the Monte Carlo.

8 Systematic Uncertainties

There are three potentially significant sources for systematic uncertainty in the scale factors. The first is trigger bias. Central-central Zs where both electrons are tight are more likely to have fired the trigger, and are expected to be very slightly overrepresented in the high-p_T electron sample relative to Zs where one central electron fails some of the criteria. That in principle could artificially enhance the efficiency in the data. This concerns only the central electron results because the trigger defining the sample under study does not include plug electrons. The second potential source of a systematic bias is inaccuracy in the background estimate. For example, underestimating the background deflates the efficiency measured in the data and therefore the scale factor. This systematic is a concern for both central and plug

$\|\eta\| < 2.0$					
		First Pass		Second Pass	
DataSet	E^{CEM}	E^{east}	E^{west}	E^{east}	E^{west}
bhel0d Data	1.0000±0.0004	1.015 ± 0.002	1.011 ± 0.002	1.003 ± 0.002	0.999 ± 0.001
bhel0h Data	1.0025±0.0003	1.014 ± 0.002	1.018 ± 0.002	1.001 ± 0.001	1.005 ± 0.001
bhel0i Data	1.0042±0.0004	1.012 ± 0.002	1.016 ± 0.002	1.000 ± 0.002	1.004 ± 0.002
6.1.4 MC	0.9948±0.0001	0.9971 ± 0.0003	0.9976 ± 0.0003	1.0003 ± 0.0003	1.0002 ± 0.0003
$\|\eta\| < 2.8$					
bhel0d Data	1.0000±0.0004	1.013 ± 0.002	1.001 ± 0.001	1.0001 ± 0.0004	0.998 ± 0.001
bhel0h Data	1.0025±0.0003	1.014 ± 0.001	1.016 ± 0.001	1.001 ± 0.001	1.004 ± 0.001
bhel0i Data	1.0042±0.0004	1.010 ± 0.002	1.012 ± 0.002	0.998 ± 0.002	1.001 ± 0.002
6.1.4 MC	0.9948±0.0001	0.9962 ± 0.0003	0.9969 ± 0.0003	0.9994 ± 0.0003	0.9995 ± 0.0003
In Ntuple - Data	-	1.013	1.012	1.0005	1.002
In Ntuple - MC	-	0.9966	0.9972	0.9999	0.9999

Table 15: *Central and plug electron energy scale factors, derived from 6.1.4v5 TopNtuples in data and 6.1.4 MC. These values were the "first pass" and "second pass" plug energy scale factors used in the final TopNtuple processing. TopNtuple users* should not *apply these factors by hand, as they are already included in the default energy values.*

electrons. The third source of systematic bias is the application of the first pass plug energy scale factor to scale up the plug energies. The final plug energies are only known as well as the first pass energy scale factors, which can vary over η and ϕ across the plug face. This systematic bias only affects the plug electrons. The fourth source of systematic bias is a small bug in defintion of the leakage energy in the *6.1.4_1invfb* version of TopNtuple.

8.1 Trigger Bias Systematic

To measure the trigger bias in the central electron efficiency,[3] we examined the efficiency in the data using only events where both electrons fired the trigger and events where only one electron is required to have fired the trigger. For this study only, we say that an electron fired the trigger if it matches a Level 2 calorimeter cluster in η and φ ($\Delta R < 0.4$) and an XFT track in ϕ (within 5 degrees). We do not require XFT track matching for any other study in this note because the XFT track information is missing from a block of runs in the ntuples used, but what is there is adequate for the purposes of this study. If only one electron is required to fire the trigger, there are 3326 CEM-CEM Zs and 4878 CEM-LCEM Zs, resulting in a (background-subtracted) efficiency of 0.819 ± 0.006. If both electrons are required to fire the trigger, there are 3126 CEM-CEM Zs and 4611 CEM-LCEM Zs, giving an efficiency of 0.816 ± 0.006. Now, the uncertainties on those efficiencies are highly correlated,

[3] This study is unchanged from version 2.0 of CDF note 7309 [2] because the XFT track information was not stored in the official Top Group Ntuples. The results from 5.3.1 should still apply.

since the numerator and denominator of the second efficiency are each subsamples of the numerator and denominator of the first efficiency. Given that all of the numbers involved are highly correlated, it is extremely difficult to extract the uncorrelated part of the uncertainty, and therefore difficult to state from these numbers whether this is a statistically significant discrepancy. Because there is no significant effect, we do not include a systematic error for the trigger efficiency. The reasoning is that one could arbitrarily inflate the systematic error on a measurement by thinking of every possible factor that could change the answer, measuring the effect of changing that factor, and then taking the difference between the original and altered measurements as a systematic uncertainty, regardless of whether the effect was statistically significant (Thanks to Pasha Murat for pointing this out).

8.2 Z mass window systematic

Because the percentage background in a sample of Zs depends on the width of the invariant mass window, the change in the efficiencies as the mass window is varied can be used to estimate the effect of the residual background. The mass window is varied from 66 GeV/c^2 $< M <$ 116 GeV/c^2 to 86 GeV/c^2 $< M <$ 96 GeV/c^2 in increments of 10 GeV/c^2. Both the data and Monte Carlo efficiencies increase as the mass window is narrowed. Therefore the change in the scale factor is used to calculate the systematic, to cancel out effects from true Zs. The systematic uncertainty is the full difference between the nominal scale factor and the most discrepant scale factor from any other window. The background-subtracted data efficiencies, Monte Carlo efficiencies, and resulting scale factors are shown in Table 16 for central electrons and in Table 17 for plug electrons. The resulting systematic uncertainties for bhel0i data are 0.6% for CEM electrons, 0.5% for nisoCEM electrons, 0.5% for looseCEM electrons, 0.4% for nisolooseCEM electrons, and 1.3% for PHX electrons. The systematic uncertainties using all 1fb^{-1}of data are 0.3% for CEM electrons, 0.3% for nisoCEM electrons, 0.2% for looseCEM electrons, 0.2% for nisolooseCEM electrons, and 0.9% for PHX electrons.

8.3 Plug Energy Scale Systematic

We use plug energies that have been arbitrarily scaled up by the first pass plug energy scale factor to 91 GeV. The first pass scale factor is the average of the different data taking periods, and over all η and ϕ of the plug. So after the application of the first pass energy scale factor, we only know the plug energies as well as we know the scale factor. To estimate the systematic associated with this limited knowledge we find the fit value of the Z-peak as a function of η and ϕ, in both east and west plugs. and take the RMS of the difference between the data and MC fits. The reconstructed Z mass peak in both data and MC for each η and ϕ slice for the east and west plugs are found in Figures 5 - 8.

$$systematic = \sqrt{(\Sigma(\frac{Data - MC}{Data})^2)}$$

We find the systematic variation in η is 0.54% for the east plug, and 0.52% for the west plug. The systematic variation in ϕ is 0.42% for the east plug, and 0.41% for the west plug. Since the

Background-subtracted CEM efficiencies (data)					
	66-116	71-111	**76-106**	81-101	86-96
CEM	0.788±0.002	0.790±0.002	**0.793±0.002**	0.798±0.002	0.807±0.002
nisoCEM	0.816±0.002	0.817±0.002	**0.818±0.002**	0.821±0.002	0.826±0.002
looseCEM	0.916±0.001	0.917±0.001	**0.920±0.001**	0.923±0.001	0.932±0.001
nisolooseCEM	0.945±0.001	0.946±0.001	**0.946±0.001**	0.947±0.001	0.951±0.001
Monte Carlo efficiencies					
	66-116	71-111	**76-106**	81-101	86-96
CEM	0.806±0.001	0.807±0.001	**0.809±0.001**	0.813±0.001	0.820±0.001
nisoCEM	0.828±0.001	0.829±0.001	**0.831±0.001**	0.833±0.001	0.836±0.001
looseCEM	0.917±0.001	0.919±0.001	**0.920±0.001**	0.923±0.001	0.930±0.001
nisolooseCEM	0.945±0.001	0.946±0.001	**0.946±0.001**	0.947±0.001	0.949±0.001
Scale factors					
	66-116	71-111	**76-106**	81-101	86-96
CEM	0.979±0.003	0.979±0.003	**0.980±0.003**	0.981±0.003	0.984±0.003
nisoCEM	0.985±0.002	0.985±0.002	**0.985±0.002**	0.986±0.003	0.988±0.003
looseCEM	0.999±0.002	0.999±0.002	**0.999±0.002**	1.000±0.002	1.002±0.002
nisolooseCEM	1.000±0.001	1.000±0.001	**1.000±0.001**	1.001±0.001	1.002±0.001

Table 16: *Efficiencies and scale factors for CEM electrons using all RunII data and 6.1.4 MC. The mass window used for the central value is in boldface. Uncertainties are statistical only.*

Background-subtracted PHX efficiencies (data)					
	66-116	71-111	76-106	**81-101**	86-96
PHX	0.705 ± 0.003	0.709 ± 0.003	0.712 ± 0.003	**0.715 ± 0.003**	0.724 ± 0.003
Monte Carlo efficiencies					
	66-116	71-111	76-106	**81-101**	86-96
PHX	0.761 ± 0.001	0.762 ± 0.001	0.763 ± 0.001	**0.764 ± 0.001**	0.769 ± 0.001
Scale factors					
	66-116	71-111	76-106	**81-101**	86-96
PHX	0.926 ± 0.004	0.931 ± 0.004	0.933 ± 0.004	**0.935 ± 0.004**	0.942 ± 0.004

Table 17: *Efficiencies and scale factors for Phoenix electrons using all RunII data and 6.1.4 MC. The mass window used for the central value is in boldface. Uncertainties are statistical only.*

variation over η is greater, we take the average of the east and west plugs as our systemtatic, and find 0.5% as the final value.

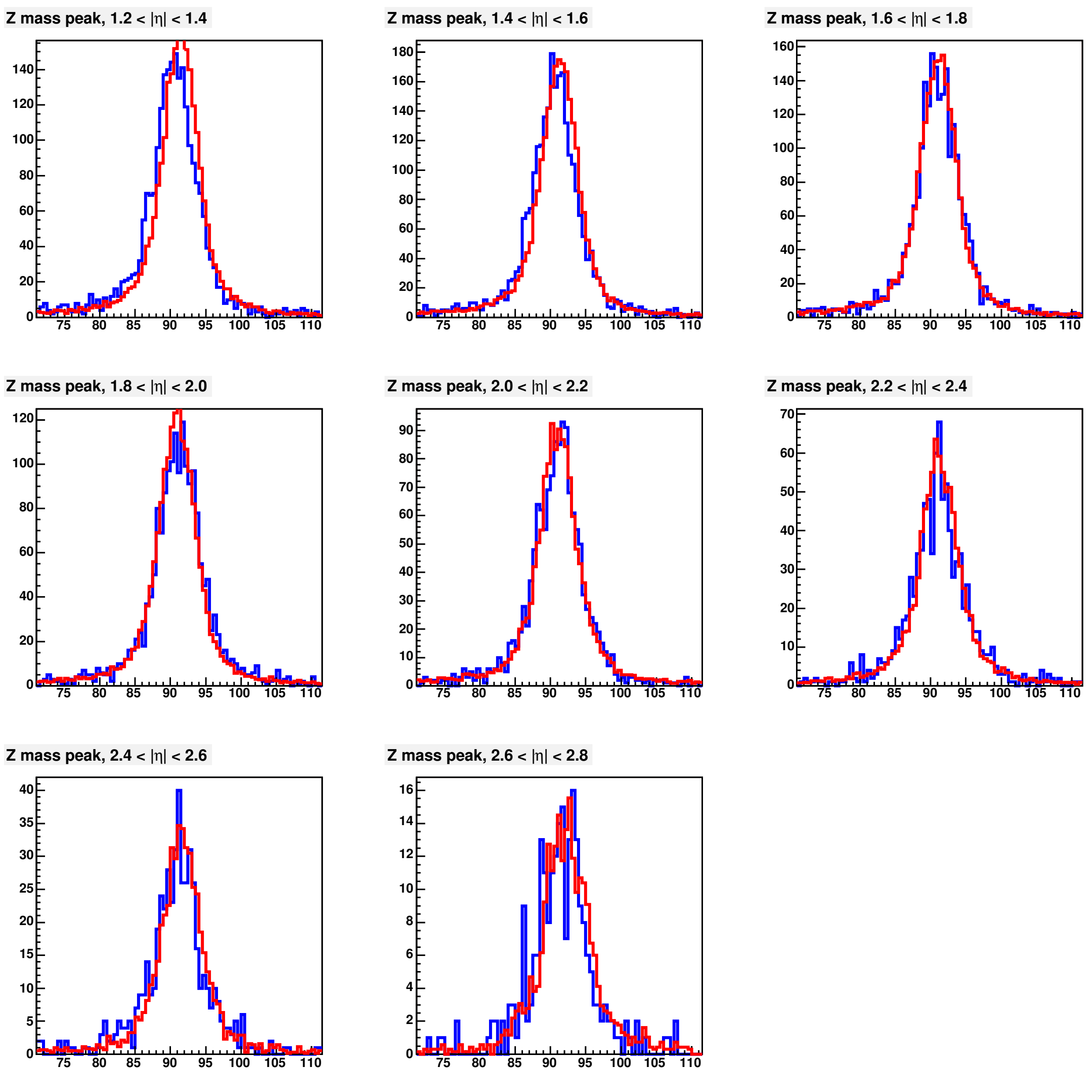

Figure 5: *Reconstructed TCEM-PHX mass in 1fb^{-1}of data (blue) and 6.1.4 MC (red) over the η range of the east plug.*

9 Conclusion

We have measured electron efficiencies for CEM and Phoenix electrons, in data and Monte Carlo, using the official Top Group ntuples. The data used span the full range of datataking through to the March 2006 shutdown. The Monte Carlo samples are run-dependent and simulate runs from parts of the datataking period covering dataset bhel0h and bhel0i. We

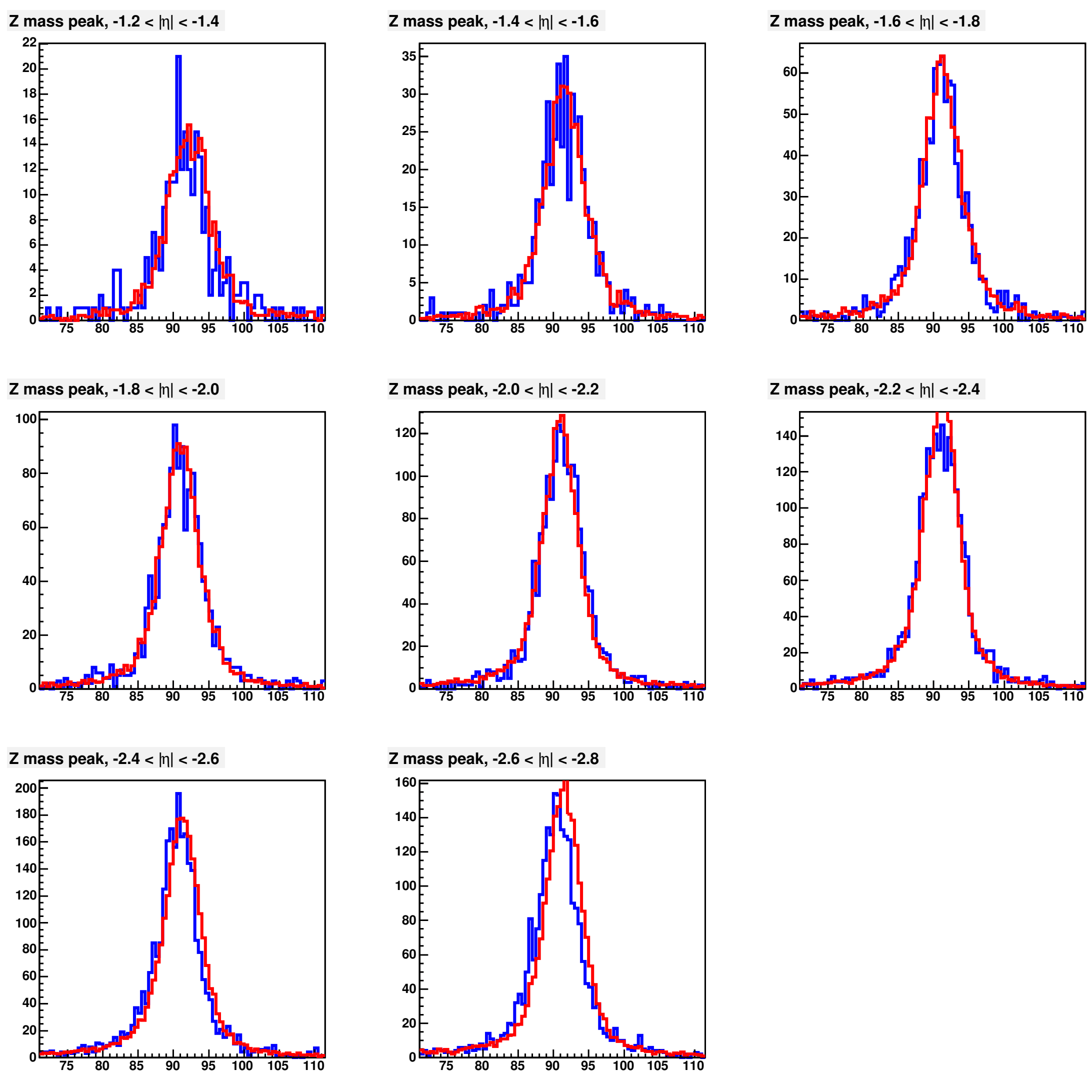

Figure 6: *Reconstructed TCEM-PHX mass in 1fb*$^{-1}$*of data (blue) and 6.1.4 MC (red) over the* η *range of the west plug.*

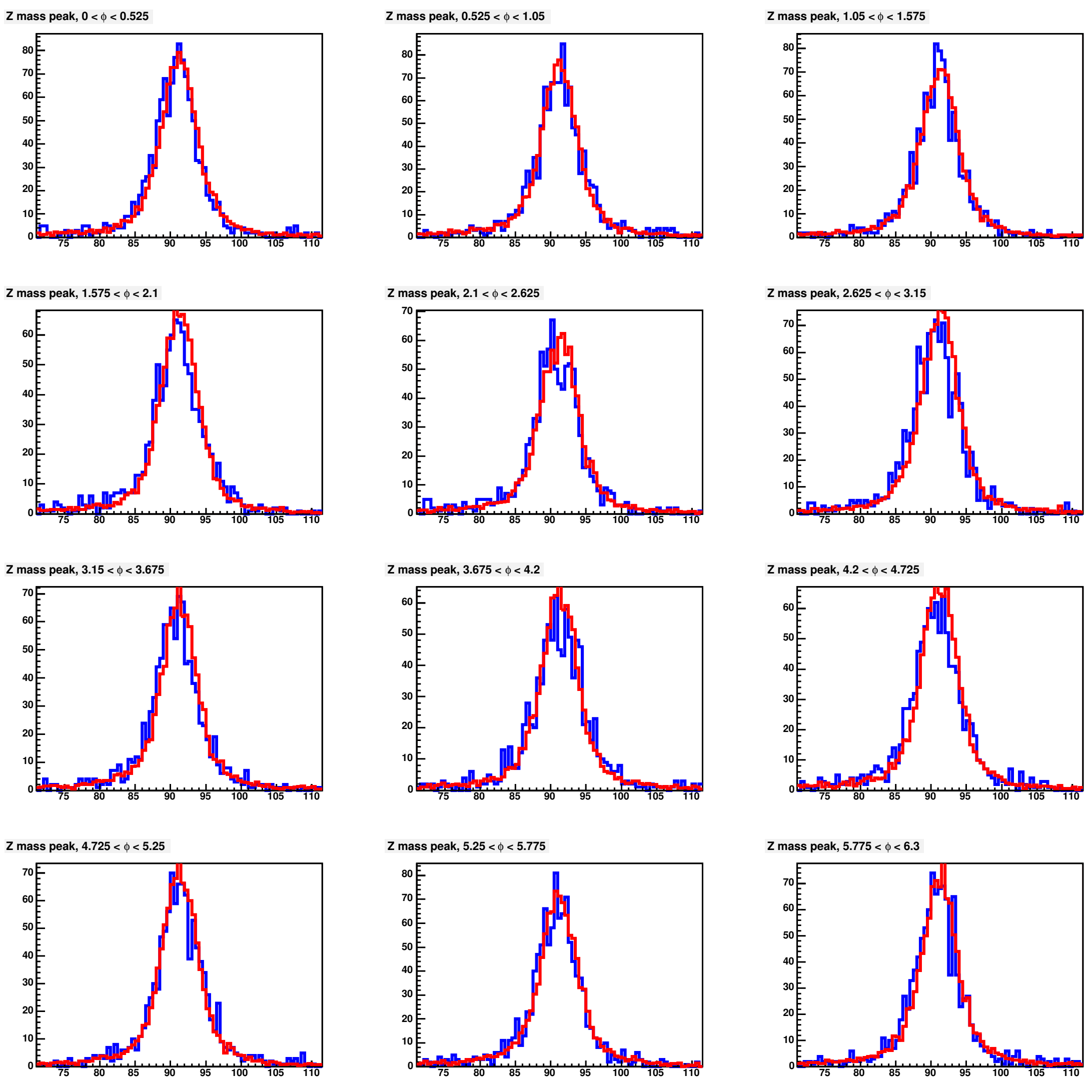

Figure 7: *Reconstructed TCEM-PHX mass in 1fb^{-1}of data (blue) and 6.1.4 MC (red) over the ϕ range of the east plug.*

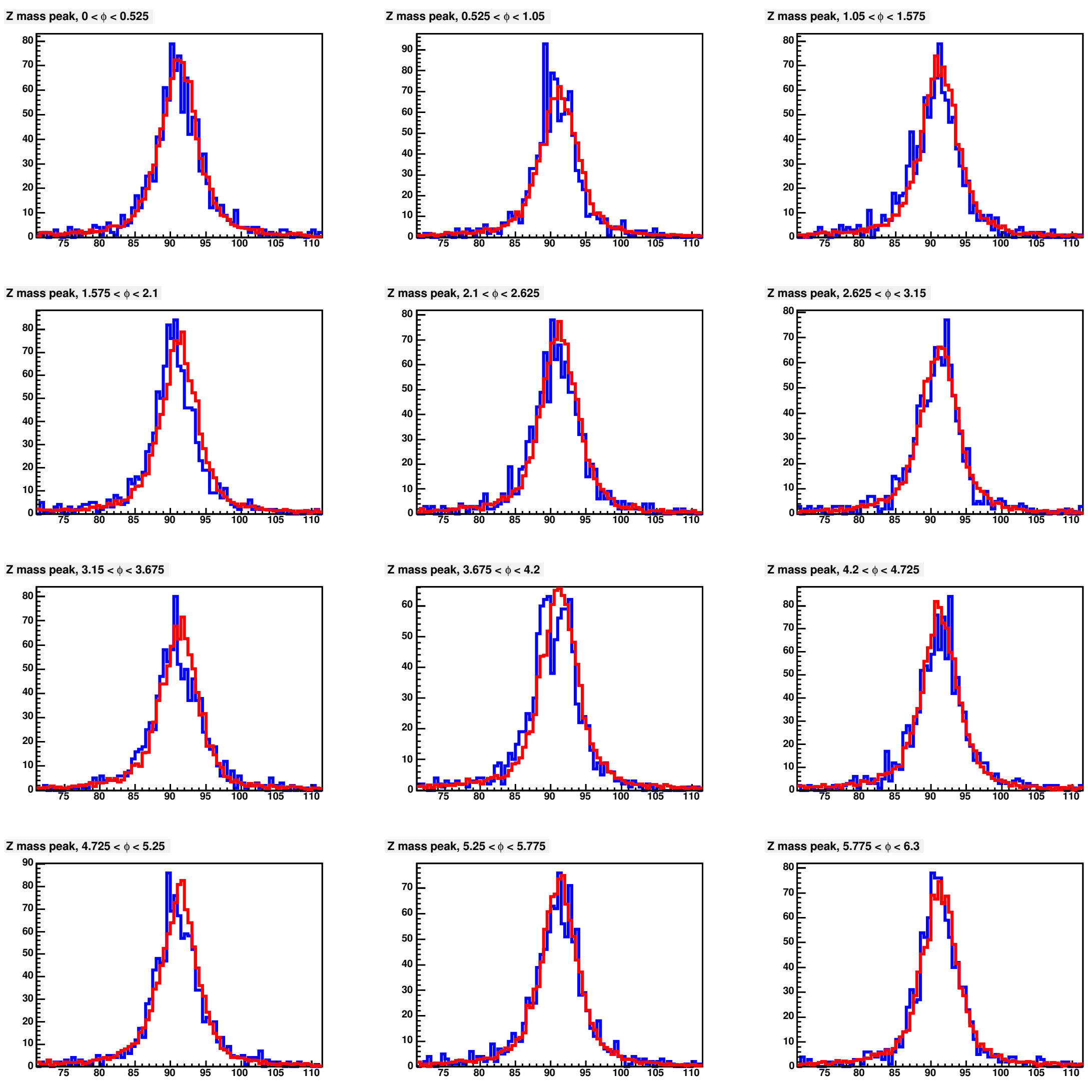

Figure 8: *Reconstructed TCEM-PHX mass in 1fb^{-1}of data (blue) and 6.1.4 MC (red) over the ϕ range of the west plug.*

	ϵ(Data)	ϵ(MC)	Scale Factor
CEM	0.793 ± 0.002	0.808 ± 0.001	0.981 ±0.003(stat) ±0.003(syst)
Nonisolated CEM	0.818 ± 0.002	0.830 ± 0.001	0.986 ±0.002(stat) ±0.003(syst)
Loose CEM	0.920 ± 0.001	0.919 ± 0.001	1.001 ±0.002(stat) ±0.002(syst)
Nonisolated Loose CEM	0.946 ± 0.001	0.945 ± 0.001	1.001 ±0.001(stat) ±0.002(syst)
PHX	0.715 ± 0.003	0.764 ± 0.001	0.935 ±0.004(stat) ±0.009± 0.005

Table 18: *Efficiencies and scale factors recommended for use in 1fb^{-1}analysis with PHX tracks extended to $|\eta|$ <2.0.*

have derived scale factors for use in analysis which correct the efficiency found in the Monte Carlo for the efficiency in the data, which are shown in Table 18. This note also measures the charge fake rate for Phoenix electrons. The corrections to the plug energy scale are defined and a scale factor to bring the central-plug Z peak up to 91 GeV is derived. In the process we estimate a systematic uncertainty quantifying how well we understand the plug electron energy scale.

10 Acknowledgments

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A Methods of Calculating Efficiencies

There are two basic methods for calculating the single-lepton identification efficiency given a sample of Z candidates where both leptons are in the same detector. One is based on counting Zs and one is based on counting individual leptons. Both methods produce the same answer if used correctly, but there are some advantages to the lepton counting method. Previous iterations of this note have used the Z counting method, at times incorrectly. In this note we use the lepton-counting method, and in this appendix we attempt to elucidate the similarities, differences, and potential pitfalls in the methods.

The lepton counting method looks for probe leptons which make an opposite-sign Z with a tight lepton which passes the trigger requirements, usually within some mass window. All possible pairs in the event are considered, so that if the two leptons forming such a Z are tight and pass the trigger, both are counted as probe leptons. If only one passes all the criteria and passes the trigger, only the probe lepton it makes a Z with is counted. Since all leptons in the event are considered, and the other lepton is required to have passed the trigger requirements, the set of probe leptons is considered to be an unbiased set of leptons. Then, if $N_{\rm L}$ is the number of probe leptons and $N_{\rm T}$ the number which pass the tight selection (or any other criteria), the efficiency ϵ for the tight selection is

$$\epsilon = N_{\rm T}/N_{\rm L} \ .$$

The Z counting method looks for pairs of leptons which make an opposite-sign Z, usually within some mass window, where one lepton is tight and passes the trigger requirement, and the other lepton is required only to pass the probe lepton selection. The second lepton is then studied to measure the effciency. This is distinct from the lepton counting method in that the first, tight lepton is ignored after it is used to tag the event as a Z. This can introduce a bias in the probe lepton sample, depending on how the tight leptons are chosen. For example, if the highest-E_T tight lepton is always chosen as the tight lepton for the event, leptons with E_T above about $1/2M_Z$ will only ever be the probe lepton if they fail the tight cuts, so that there are very few probe leptons above that E_T the efficiency measured in that range is very low.

The single-lepton efficiency ϵ in the Z counting method can be recovered by considering the relationships among $N_{\rm TT}$ (the number of Z where both leptons pass the tight cuts), $N_{\rm TL}$ (the number of Zs where at least one lepton passes the tight cuts), and $N_{\rm LL}$ (the number of Zs where both leptons pass at least the probe cuts).

$$N_{\rm TT} = \epsilon^2 \cdot N_{\rm LL}$$

and

$$N_{\rm TL} = (1 - (1-\epsilon)^2) \cdot N_{\rm LL}$$

where $(1-\epsilon)^2$ is the probability for neither lepton to be tight. A little algebra to eliminate $N_{\rm LL}$ from the picture leads to the formula

$$\epsilon = \frac{2N_{\rm TT}}{N_{\rm TT} + N_{\rm TL}}.$$

The two methods, used in the same Z sample, are actually equivalent. Each tight-tight Z contributes two probe leptons and each tight-loose Z *which is not a tight-tight* Z contributes one Only those probe leptons from the tight-tight Zs pass all the cuts. Therefore:

$$\begin{aligned} N_{\rm T} &= 2N_{\rm TT} \\ N_{\rm L} = 2N_{\rm TT} + (N_{\rm TL} - N_{\rm TT}) &= N_{\rm TT} + N_{\rm TL} \end{aligned} \tag{2}$$

Another equivalent formula counts the number of Z where the second leg passes the probe cuts but not the tight cuts. Let the number of such Zs be $(N_{\rm TF})$. Noting that $N_{\rm TL} = N_{\rm TF} + N_{\rm TT}$, so

$$\epsilon = \frac{2N_{\rm TT}}{N_{\rm TT} + N_{\rm TL}} = \frac{2N_{\rm TT}}{2N_{\rm TT} + N_{\rm TF}} \ .$$

There is one subtlety in relating the numbers of Zs to the number of leptons, which arises from the trigger requirement in the data. $N_{\rm T} = 2N_{\rm TT}$ is not exactly true because of the requirement that the tight leg fired the trigger. $N_{\rm TT}$ can include events where only one of the two fired the trigger but such events can only contribute one probe lepton to N_T, not two. $N_{\rm L}$

is affected similarly. The size of this effect is only about as big as the trigger inefficiency for tight leptons. In the CEM-CEM Z sample this affects about half a percent of the Zs.

There are two disadvantages to the Z counting method. One is the potential bias in the probe lepton sample mentioned earlier. The other is that to calculate efficiencies for selections other than the tight one, the efficiency formula must be based on $N_{\rm OO}$ and $N_{\rm OL}$ (O for "Other" selection, which is typically somewhere between tight and loose in efficiency). This allows more background into the sample, which is undesirable but not a crucial problem. What does not work is

$$\epsilon_{\rm O} = \frac{2N_{\rm TO}}{N_{\rm TO} + N_{\rm TL}} \quad \text{this is wrong!}$$

This formula was used in previous iterations of the note to calculate the loose CEM, nonisolated CEM, and CEM N-1 efficiencies, so those numbers were incorrect. However, the formula above is approximately correct to the extent that $N_{\rm TO} \approx N_{\rm TT}$. The biggest change observed in correcting this mistake was in the loose CEM efficiencies. For example, the loose CEM efficiency decreased from 0.930 to 0.922. The scale factors for any selection, in data or Monte Carlo, changed by at most 0.001, so the final conclusions of the studies were correct.

References

[1] T. Spreitzer et al, *Electron Identification in Offline Release 6.1.2*, CDF note 7950.

[2] C. Hill et al, *Electron Identification in Offline Release 5.3*, CDF note 7309.

[3] C. Issever et al, *Plug Electron Baseline Cuts as defined in Summer 2003 and their Efficiencies*, CDF note 6789.

[4] D. Amidei et al, *First Measurements of Inclusive W and Z Cross Sections from Run II of the Tevatron Collider*, CDF note 7332.

[5] P. Merkel et al, *WW Cross Section Measurement using the Tight Lepton and Isolated Track Sample*, CDF note 6872.

[6] A. Robson et al, *A Measurement of* $\sigma \times Br(Z \to ee)$ *using Run 2 Central and Plug Electrons in 72* pb^{-1}, CDF note 6642.

[7] M. Coca and E. Halkiadakis, *Central Electron Identification Efficiencies for the 200* pb^{-1} *Run 2 Dataset*, CDF note 6580.

[8] http://www-cdf.fnal.gov/internal/silicon/scc.html

[9] W.K. Sakumoto *Event* $|Zvtx| < 60$ *Cut Acceptance for Run II (to Sep05)* CDF note 7935.

[10] D. Goldstein et al, *A New PEM Clustering Algorithm for Run II*, CDF note 5682.

[11] S. Harper et al, *Reconstructing the Plug Electron Energy in 5.3.3*, CDF note 7687.

$\|\eta\|$ range	Scale Factor
-2.8< η <-2.6	1.084 $\pm$ 0.091
-2.6< η <-2.4	0.955 $\pm$ 0.041
-2.4< η <-2.2	1.009 $\pm$ 0.027
-2.2< η <-2.0	1.010 $\pm$ 0.018
-2.0< η <-1.8	0.933 $\pm$ 0.014
-1.8< η <-1.6	0.933 $\pm$ 0.011
-1.6< η <-1.4	0.917 $\pm$ 0.010
-1.4< η <-1.2	0.937 $\pm$ 0.010
2.8< η <2.6	0.924 $\pm$ 0.010
2.6< η <2.4	0.910 $\pm$ 0.010
2.4< η <2.2	0.919 $\pm$ 0.011
2.2< η <2.0	0.933 $\pm$ 0.013
2.0< η <1.8	0.969 $\pm$ 0.018
1.8< η <1.6	1.032 $\pm$ 0.027
1.6< η <1.4	0.989 $\pm$ 0.042
1.4< η <1.2	1.023 $\pm$ 0.088

Table 19: *PHX tracking scale factor as a function of* $|\eta|$.

[12] D. Glenzinski et al, *Results from the Top Dilepton Analysis of the Tight Lepton and Isolated Track Sample*, CDF note 6562.

[13] D. Glenzinski et al, *Addition of PHX Electrons to the Dilepton Analysis using the Tight Lepton and Isolated Track Sample*, CDF note 6787.

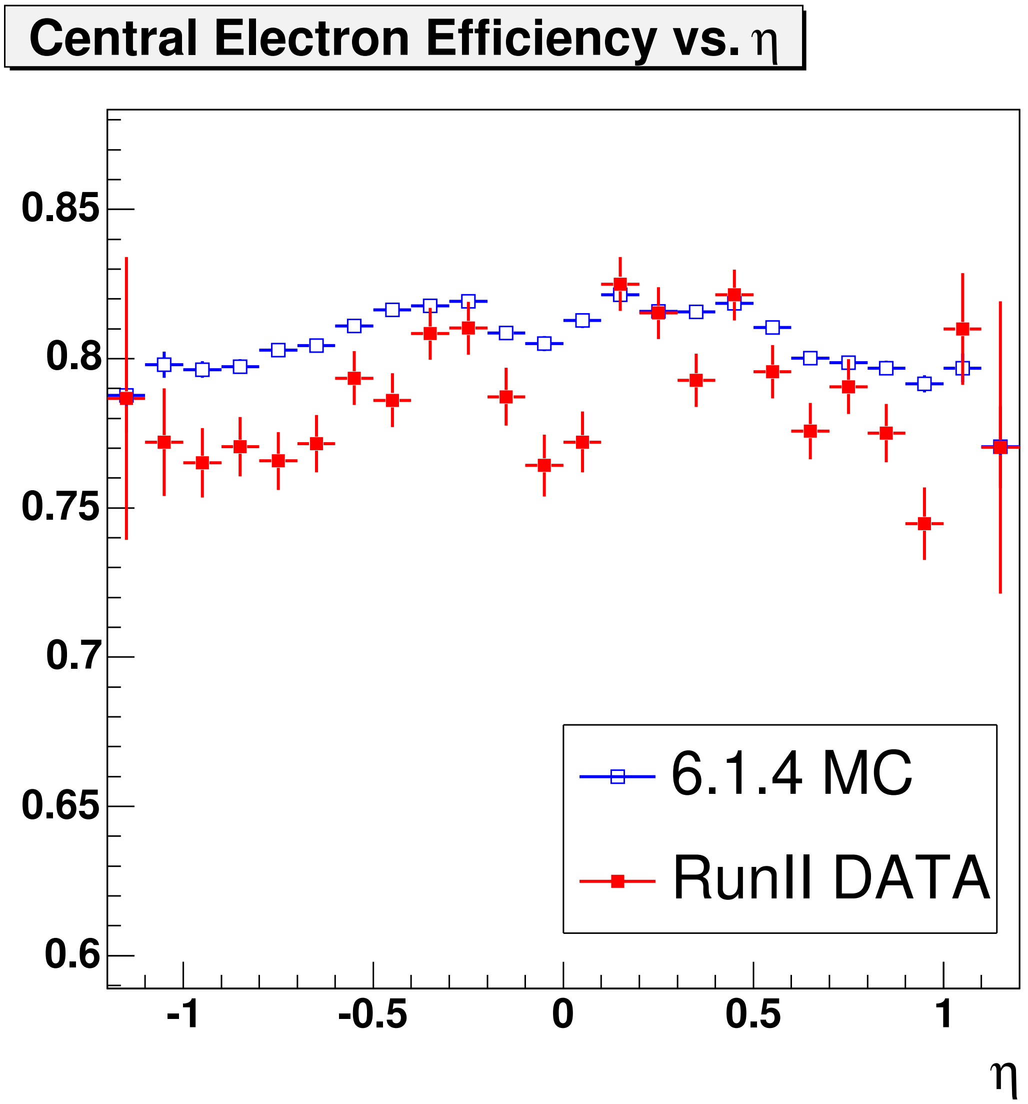


Figure 9: *CEM total ID efficiency vs η.*

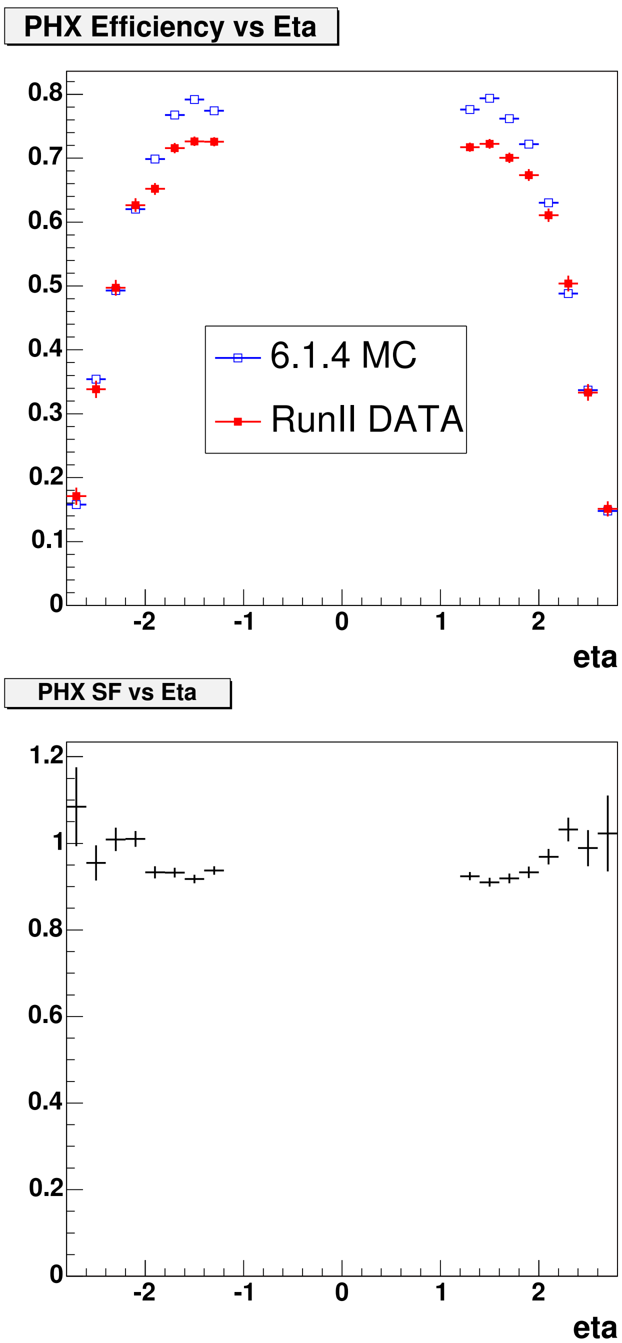


Figure 10: *PHX efficiency vs η (upper plot), and the scale factor (lower plot).*

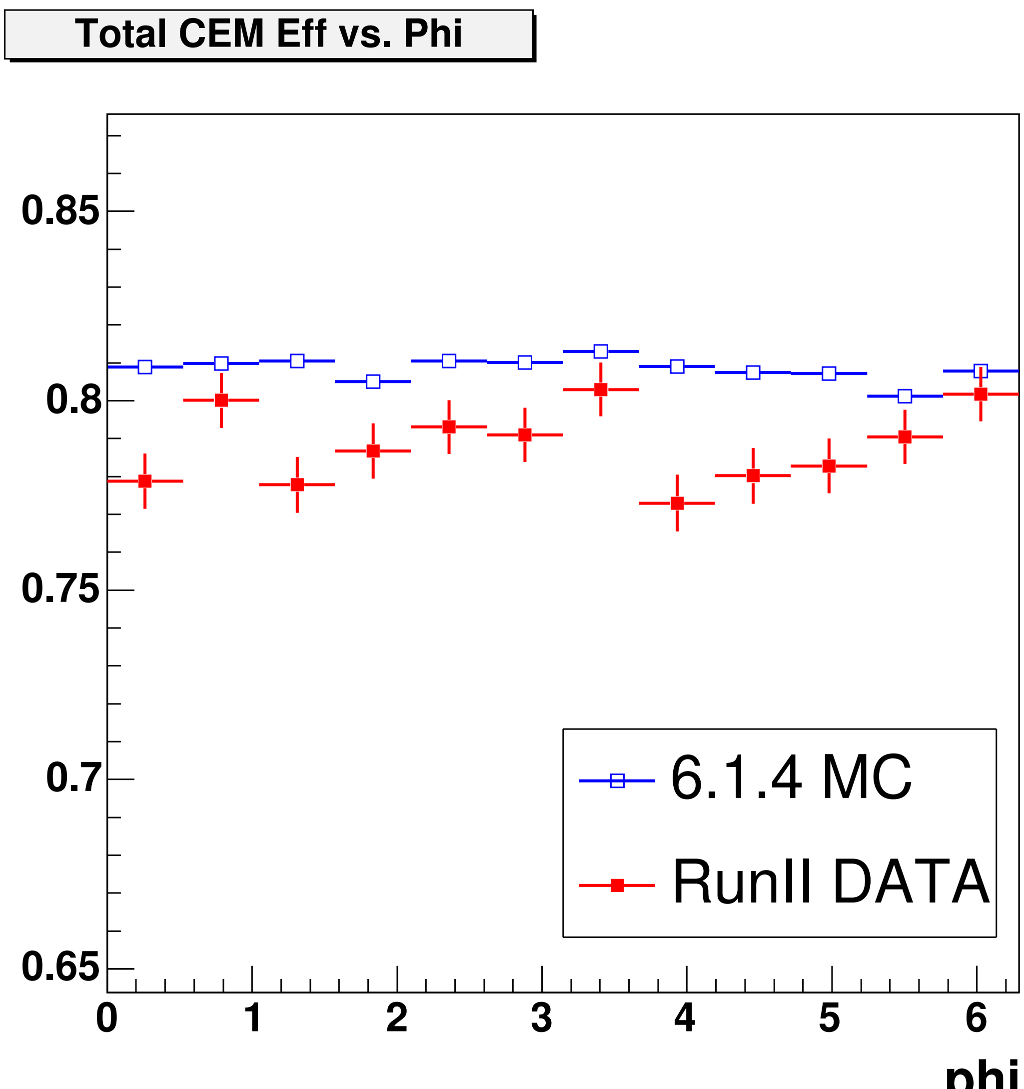


Figure 11: *CEM total ID efficiency vs ϕ.*

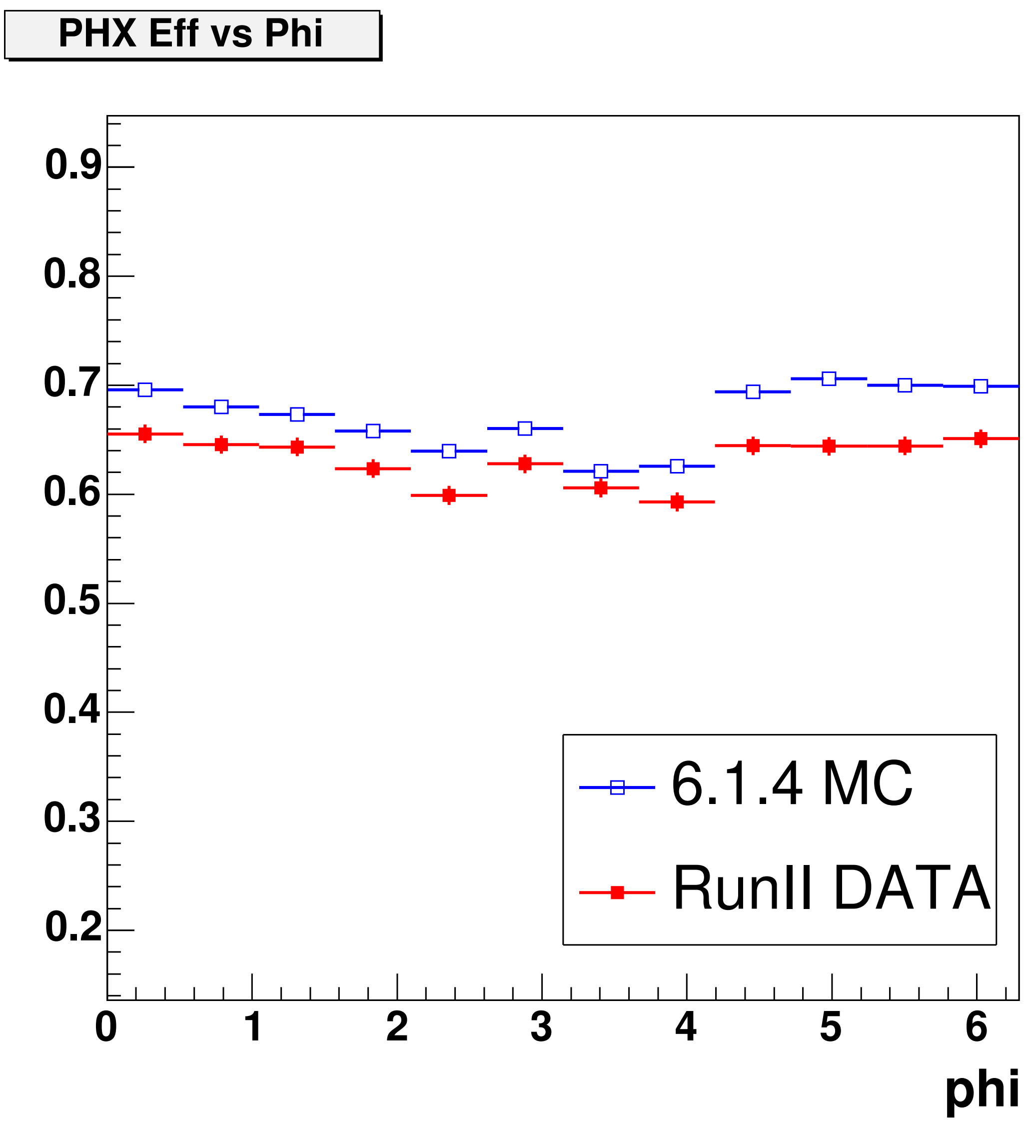


Figure 12: *PHX efficiency vs ϕ. PHX tracks extend out to $|\eta| < 2.8$.*

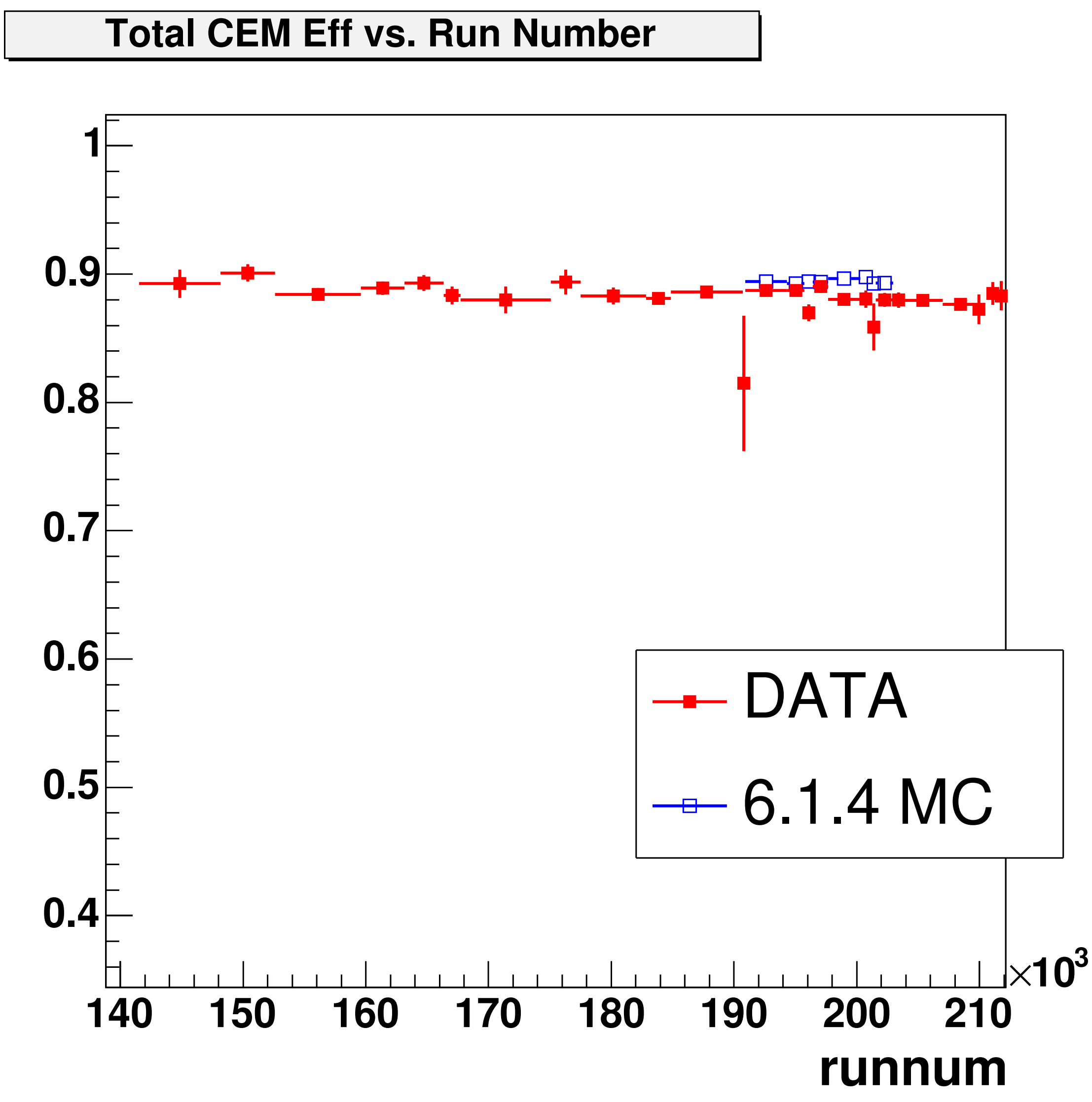


Figure 13: *CEM total ID efficiency vs run number.*

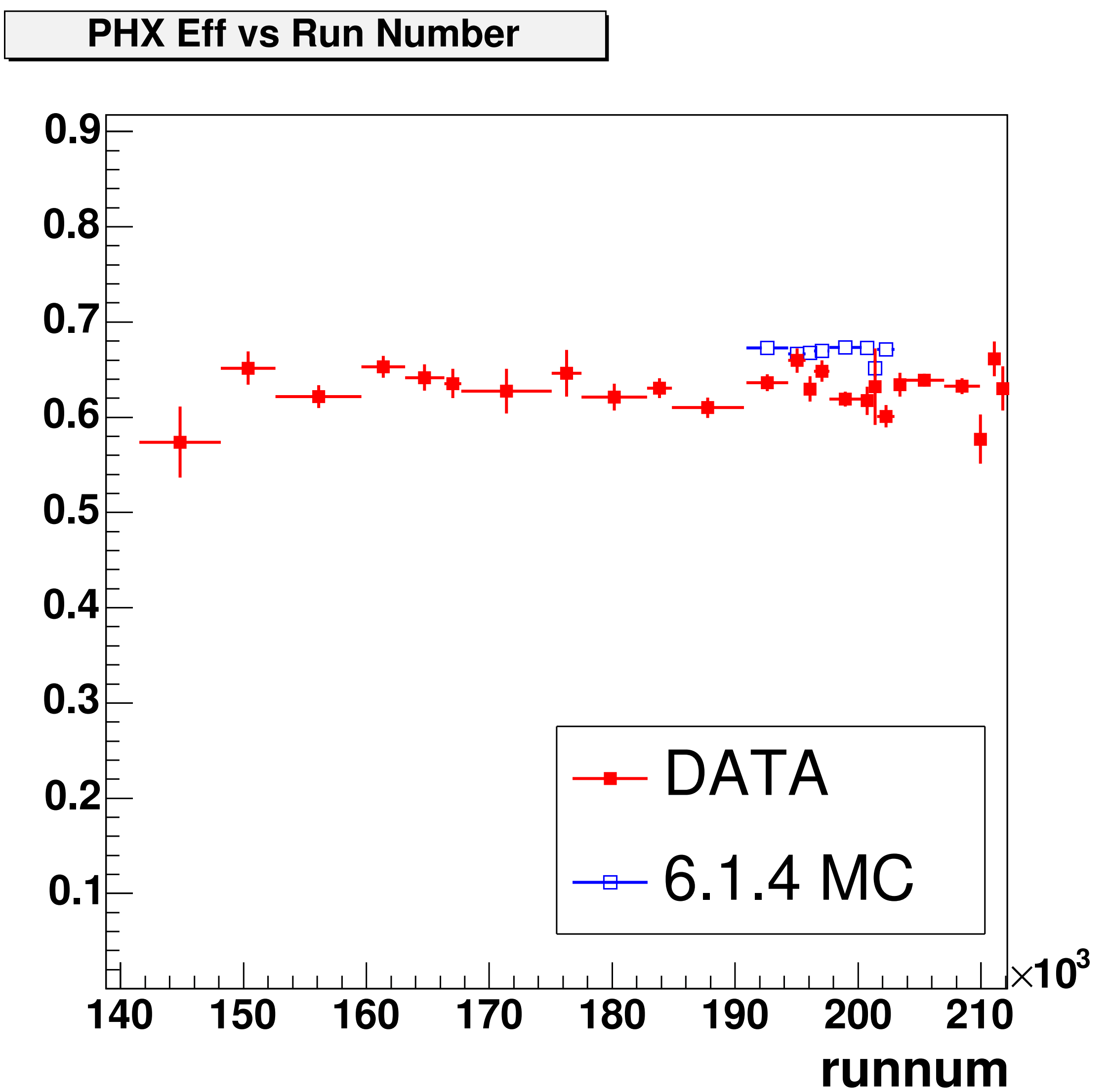


Figure 14: *PHX efficiency vs run number.*

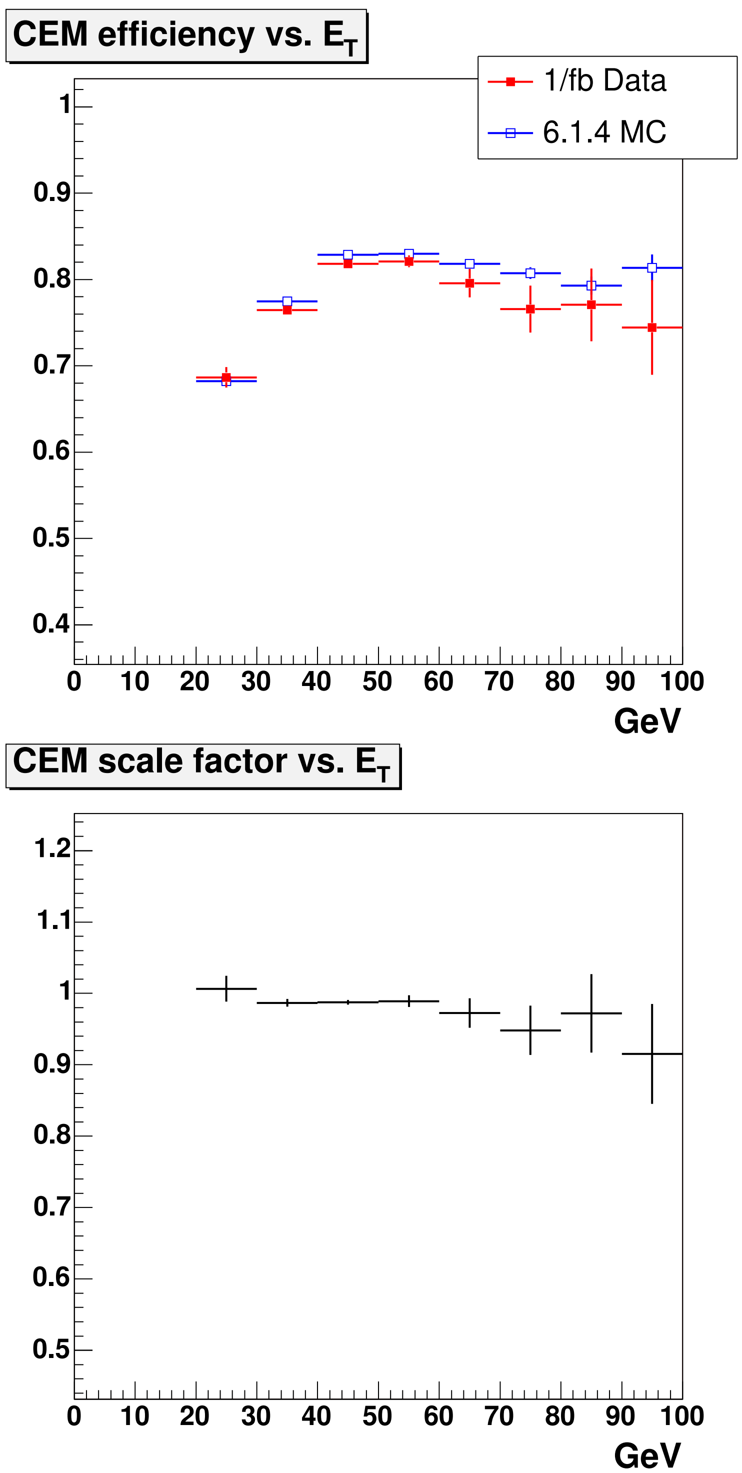


Figure 15: *CEM efficiency vs E_T bin-by-bin background subtraction (above) and the scale factor (below).*

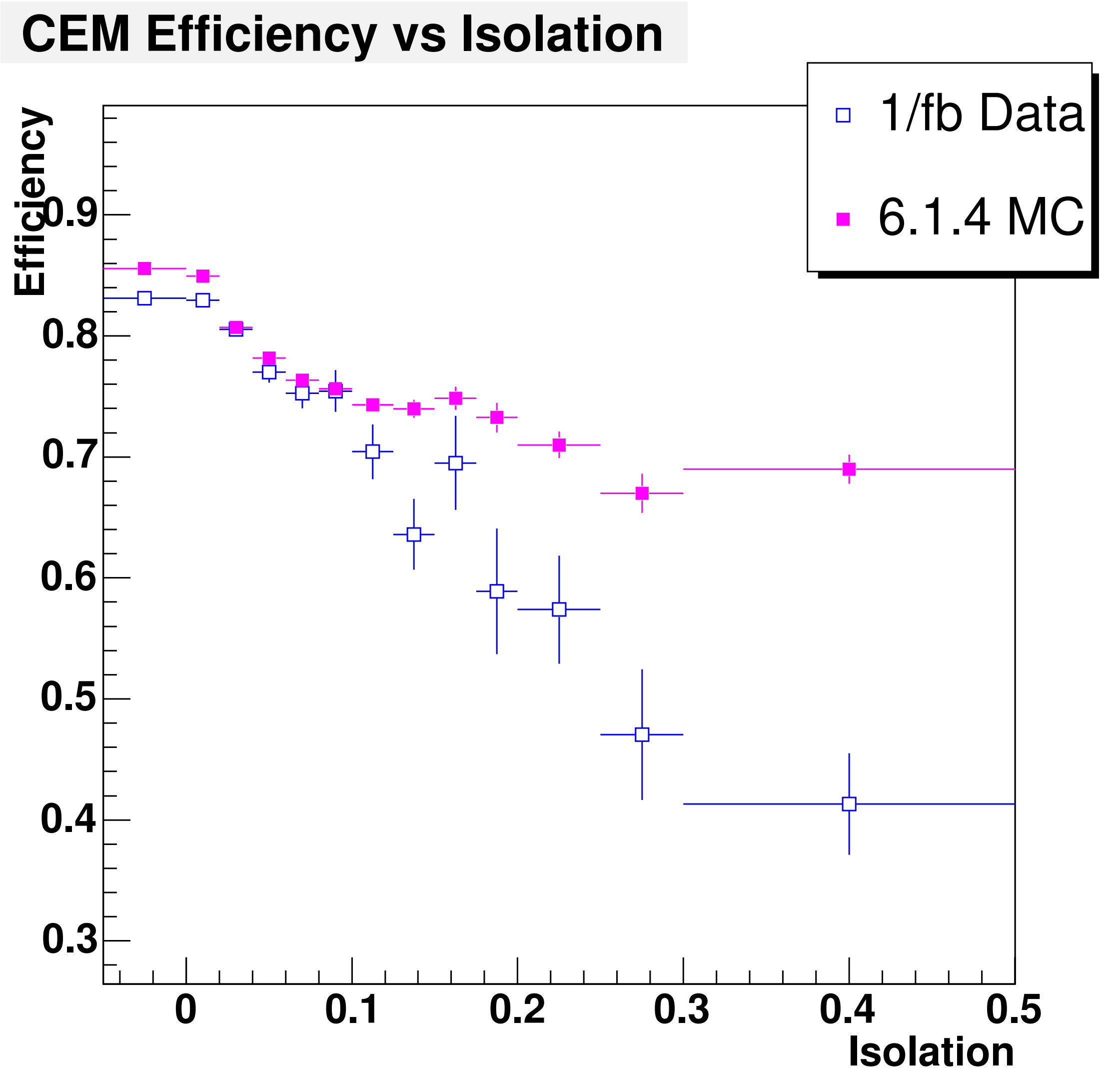


Figure 16: *CEM efficiency vs isolation.*

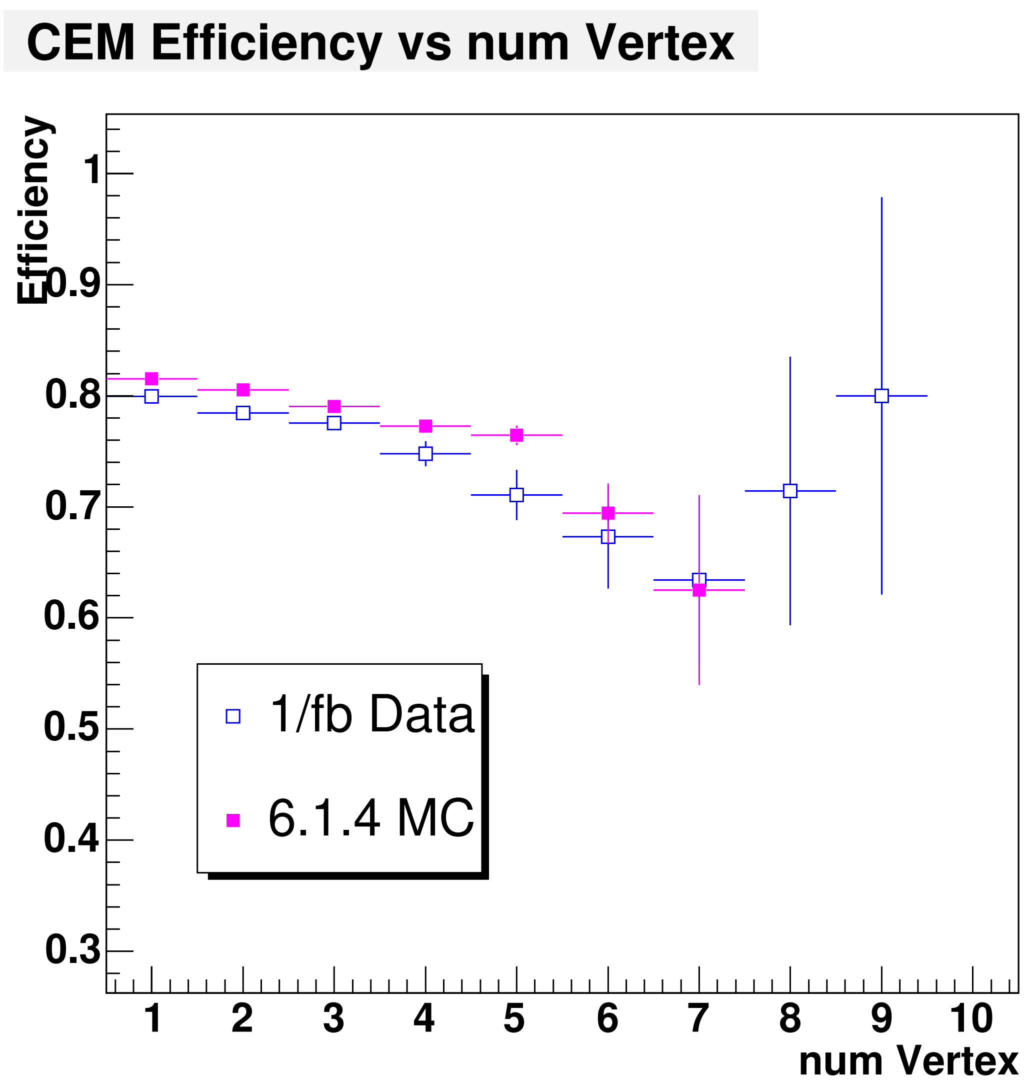


Figure 17: *CEM efficiency vs number of vertices.*

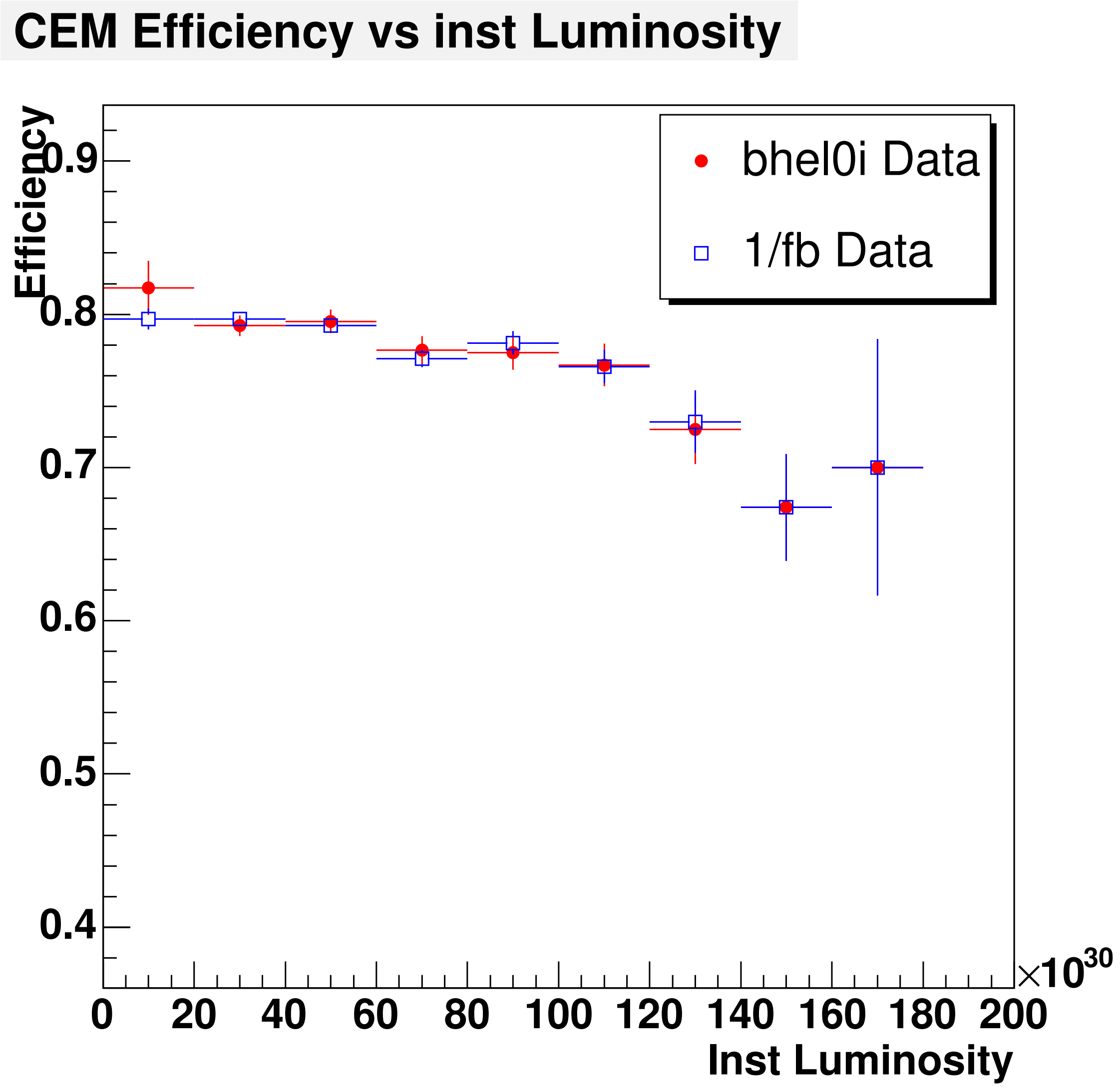
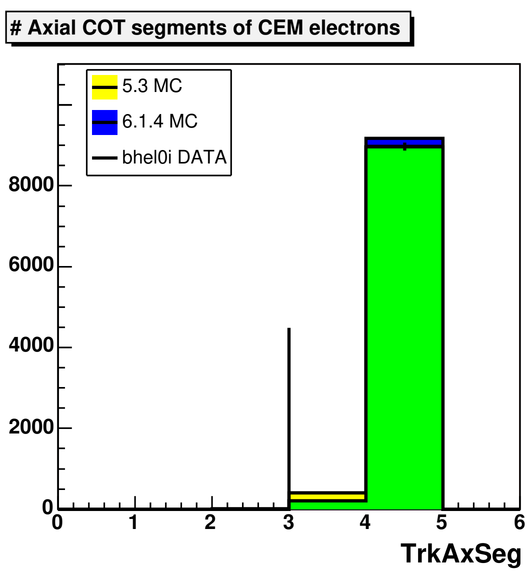


Figure 18: *CEM efficiency vs instantaneous Luminosity.*



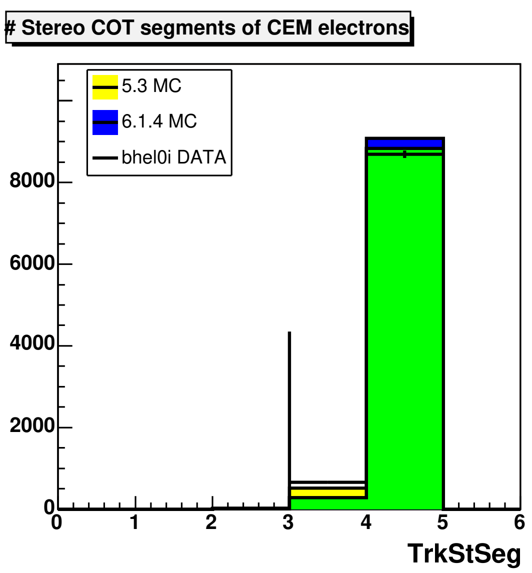


Figure 19: *CEM electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

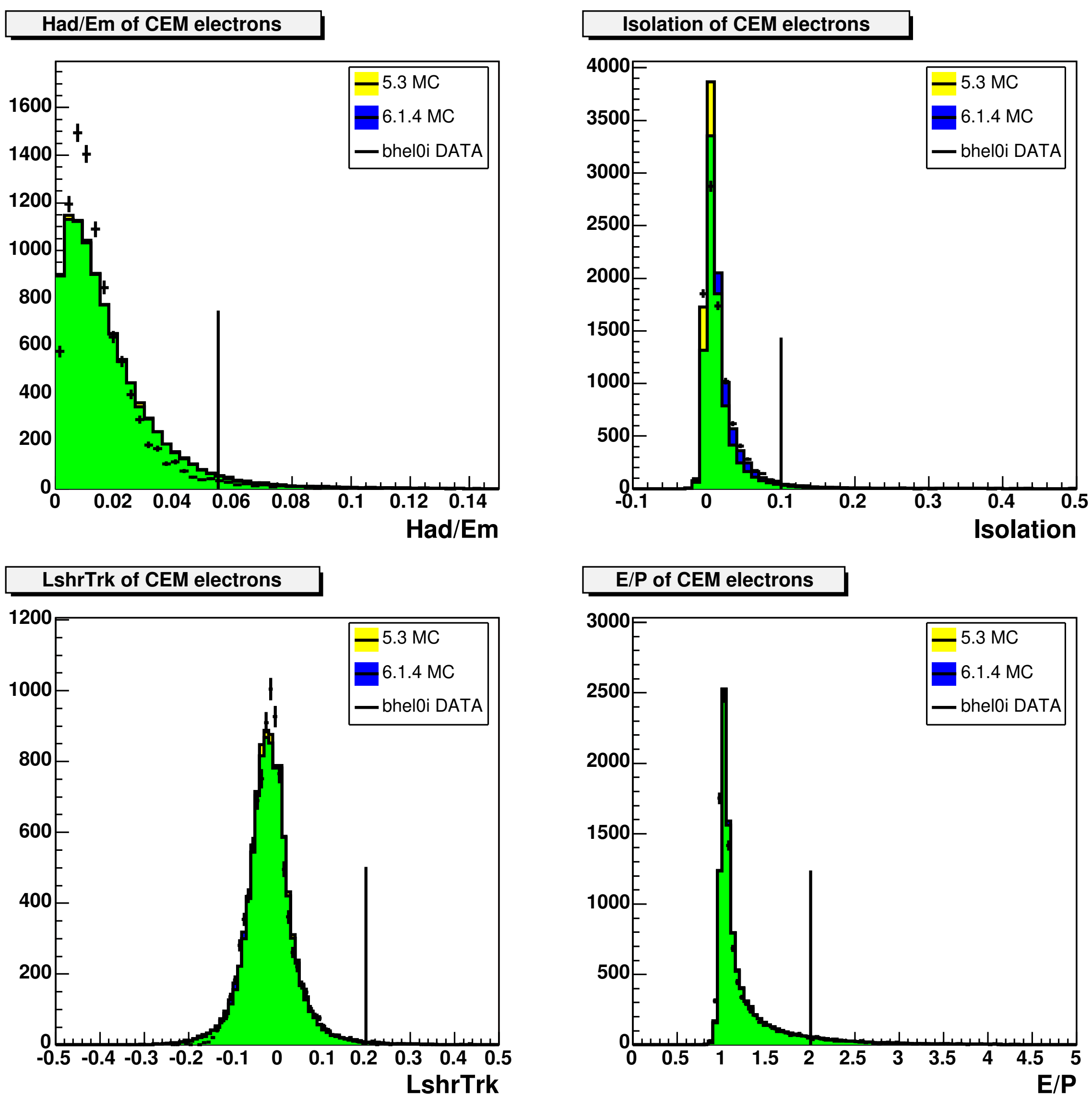


Figure 20: *CEM electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

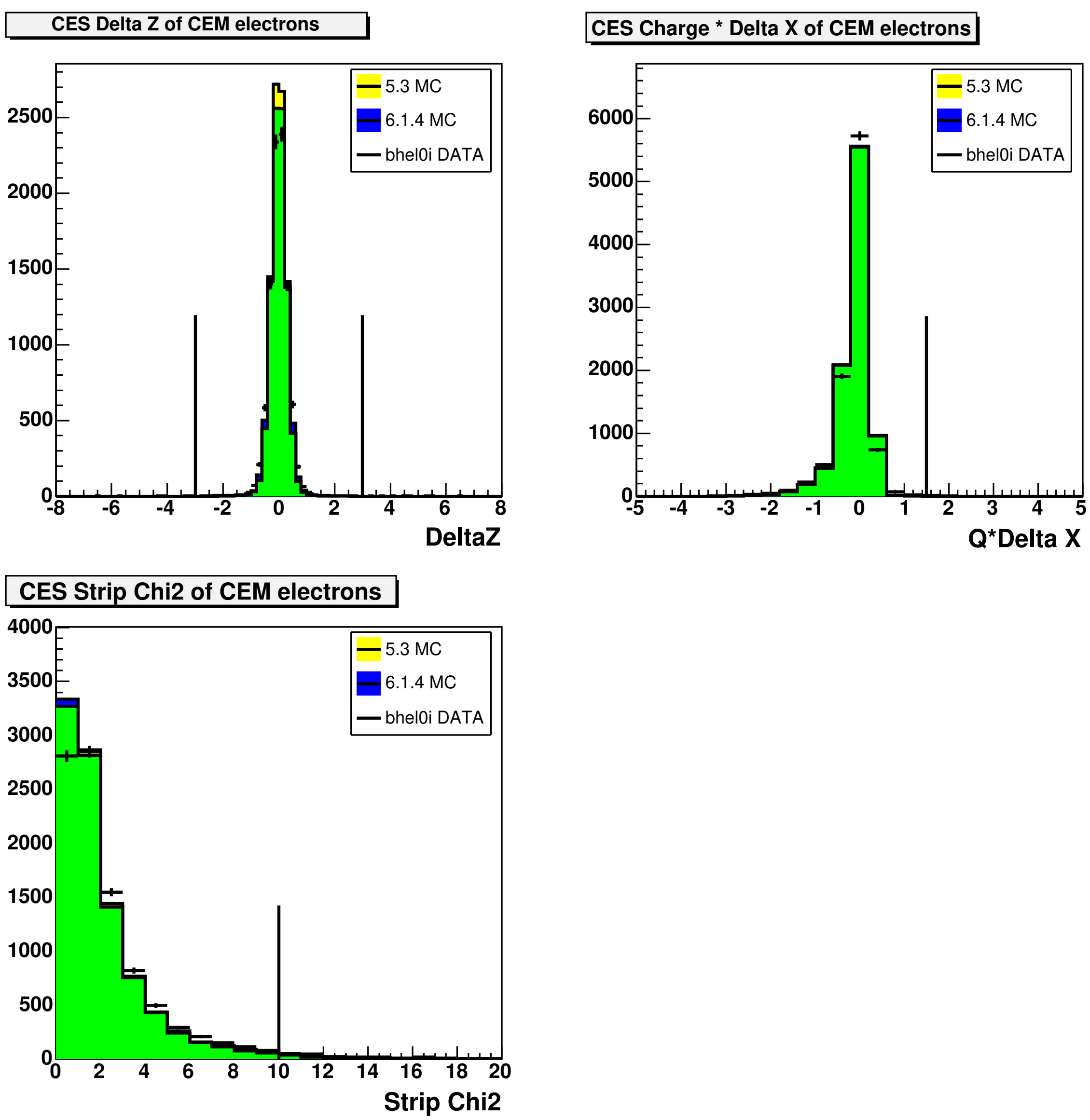


Figure 21: *CEM electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

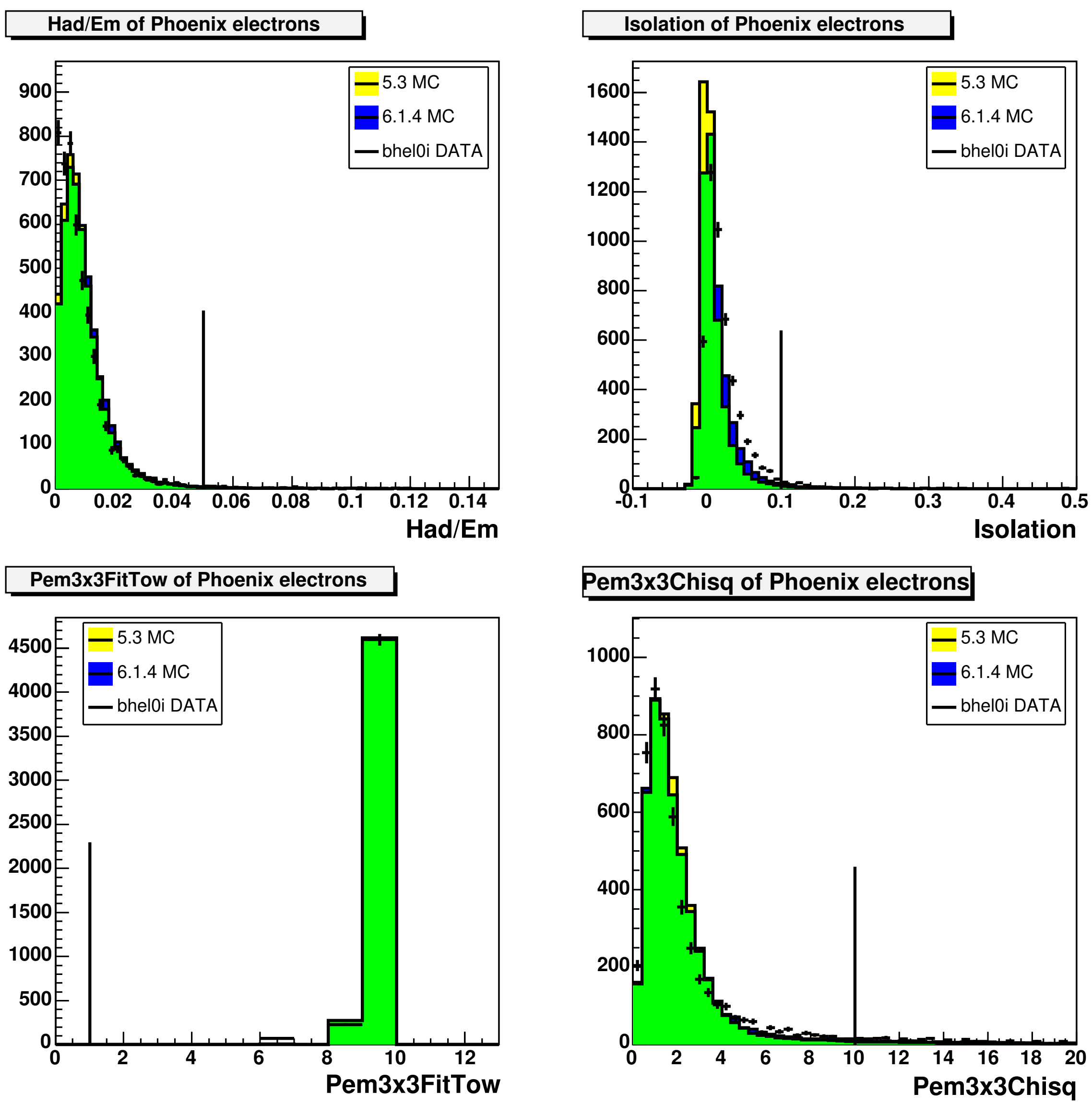


Figure 22: *PHX electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

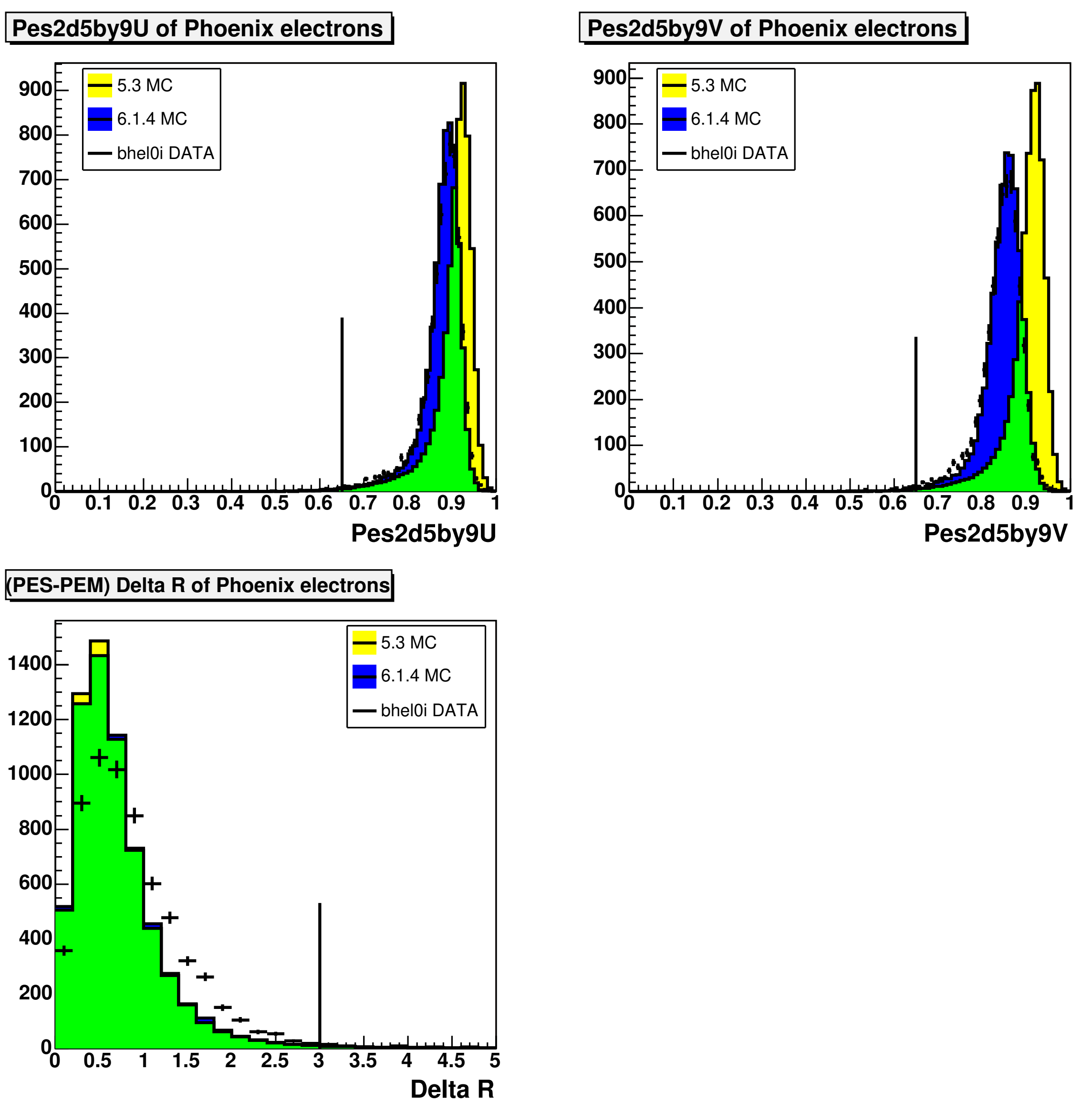


Figure 23: *PHX electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*