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Electron Identification in Offline Release 6.1.2

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Abstract

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

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 5.3 of the offline software, and some of the data has been processed in the 5.1.0 version, and some in the 6.1.2 version, so that we can use the full amount of data available. Efficiencies are compared among four different data-taking periods, two periods using the 5.3 data, and two with the 6.1.2 data. 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].

Notes on version 2.0 There are three major changes from version 1.0. First, a change has been made to the fiducial requirement for probe CEM electrons to ensure that the numerator of the efficiency is a proper subset of the denominator. See the note at the beginning of Section 3 for more detailed discussion. Second, the method of counting electrons has been changed, so that we now count individual electrons, not Z pairs. See Section 5 and Appendix A for a full discussion of the implications of this change. This version also extends the PHX electron selection to $|\eta| < 2.8$. Where possible, results are presented for both electrons with $|\eta| < 2.0$ and $|\eta| < 2.8$ since both are useful for different analyses, depending on the physics being studied.

2 Samples Used

The 5.3 data is processed using offline version 5.3.1 and calibration pass 13A, and includes all data taken until September 2004, up to and including run number 186598, approximately 350pb^{-1}in total. The 6.1.2 data is processed using offline version 6.1.2 and calibration pass 17. The 6.1.2 data includes all data from runs 190697 - 203799, which started in November 2004, approximately 400pb^{-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 10, which includes all of the data through the end of August 2005 (run 203799), excluding the "Compromised COT period"[1]. For the Phoenix electron studies we also require that the run be marked good for silicon.

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

For 5.3 Monte Carlo we use the Pythia $Z \to ee$ (dataset ztop2i) sample which has been processed with the 5.3.3_nt5 version of TopNtuple. It covers the full range of run numbers, and therefore running conditions, up to 186598 We also use an extended run range of the same MC processed in 5.3.3 MC (dataset ztop1f, runs 190753 - 195408, hereafter called 5.3 ERR MC) to simulate the detector configuration during the 2004 - 2005 data taking period.

3 Selection

3.1 Central-Central $Z \to ee$ candidates

Notes on version 2.0 In this version we have moved to a new method of accounting for calculating the efficiencies. We now count single electrons, and not the electron pairs that make up a Z. This does not change the selection criteria, only the bookkeeping. Appendix A discusses the various methods for calculating efficiencies, and the effect of this change, in some detail. We have also changed the fiduical requirements of probe CEM (aka LCEM) electrons. Previously, probe electrons were required to be track fiducial, meaning that the electron track, extrapolated to the plane of the CES, is fiducial to the CES (TrkFiducial == 4 for TopNtuple electrons, emobj_alg::fidEle(emObject , "TRACK") == emobj_alg::FIDUCIAL_CEM_TRACK in the offline) . Tight electrons were required to be fiducial to the CES chambers using the actual cluster (Fiducial == 1 for TopNtuple electrons, emobj_alg::fidEle(emObject) == emobj_alg::FIDUCIAL_CEM in the offline). A small fraction of electrons are track-fiducial to the CEM but also have a CES cluster which is not in the fiducial region of the CES. So the numerator of the efficiency (N_T) was not a strict subset of the denominator (N_L). The selection was thus changed to correct the situation.

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. We calculate efficiencies using a set of very loose, or "probe" electrons as the denominator. For each tight electrons 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 which are still acceptable for some analyses ("looseCEM") have a number of the standard cuts relaxed, and very loose, or "probe" electrons ("LCEM") 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.)

[2]The CEM, nisoCEM, looseCEM 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	-	$\leq$ 2.0 unless $p_T \geq$ 50GeV/c	$\leq$ 2.0 unless $p_T \geq$ 50GeV/c
CES ΔZ	-	$\leq$ 3.0 cm	$\leq$ 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. Note the change in the fiducial selection for loose electrons.*

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 [2]. Efficiencies and scale factors for PHX electrons up to $|\eta|$ <2.0 and $|\eta|$ <2.8 are provided. The loose Phoenix selection ("LPHX") is a kinematic selection only, plus the requirement of a Phoenix track to reduce background. The PEM selection is all of the standard cuts, without a Phoenix track requirement.

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.

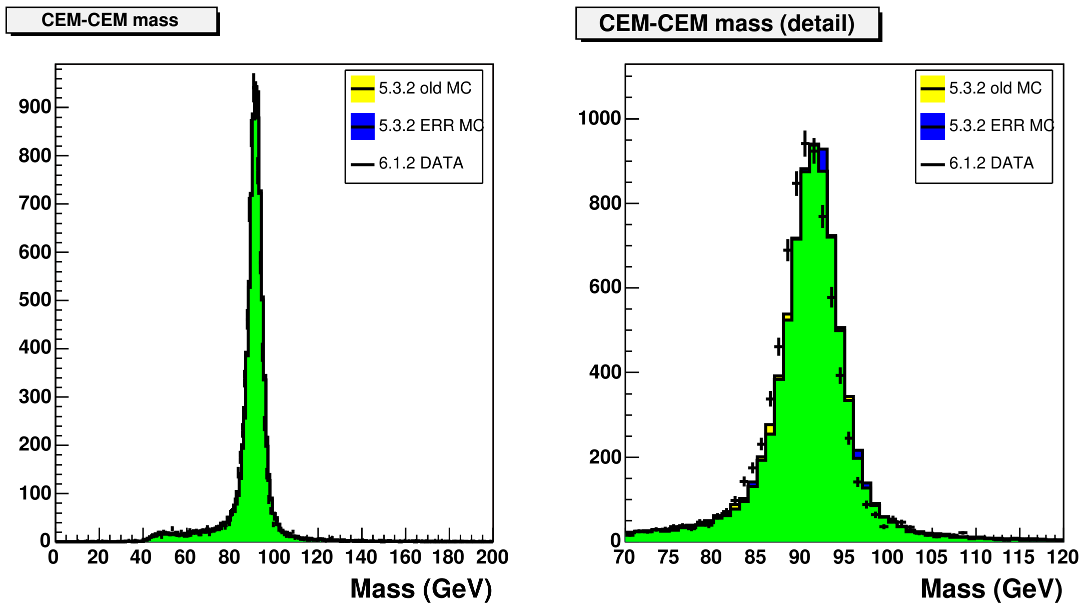

Figure 1: *Invariant mass of CEM-CEM electron pairs. See text for selection definitions. Green is the overlap between 5.3 old Monte Carlo (yellow) and 5.3 ERR MC (blue).*

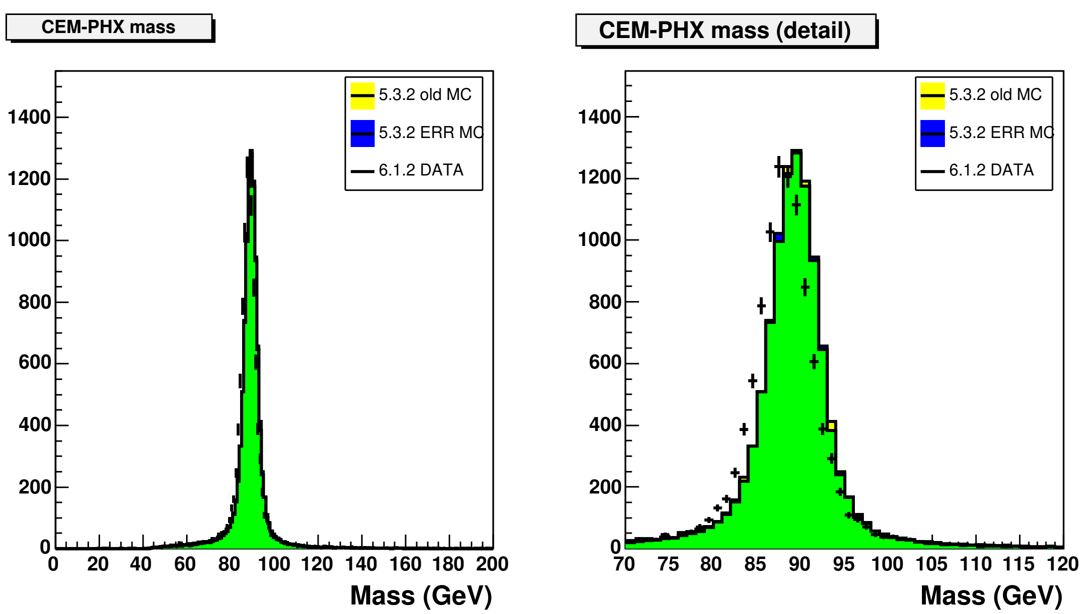

Figure 2: *Invariant mass of TCEM-PHX electron pairs. See text for selection definitions. Green is the overlap between 5.3 old MC (yellow) and 5.3 ERR(blue). There is a clear difference in the energy scale from the expected 91 GeV. See Section 10 for plug electron energy scale factors.*

Variable	Tight (PHX)	Loose (LPHX)	Loose (PEM)
E_T	$\geq$ 20GeV	$\geq$ 20GeV	$\geq$ 20GeV
Pes2dEta	$1.2 \leq \lvert\eta\rvert \leq 2.8$	$1.2 \leq \lvert\eta\rvert \leq 2.8$	$1.2 \leq \lvert\eta\rvert \leq 2.8$
Had/Em	≤ 0.05	≤ 0.125	≤ 0.05
Pem3x3FitTow	$\neq 0$	-	$\neq 0$
Pem3x3Chisq	≤ 10	-	≤ 10
Pes5by9U	≥ 0.65	-	≥ 0.65
Pes5by9V	≥ 0.65	-	≥ 0.65
Isolation	≤ 0.1	-	≤ 0.1
ΔR	$\leq$ 3.0 cm	-	$\leq$ 3.0 cm
PhxMatch	`TRUE`	`TRUE`	-
N_{hits}^{Si}	≥ 3	≥ 3	-
$\lvert z_0^{PHX}\rvert$	$\leq$ 60 cm	$\leq$ 60 cm	-

Table 2: *The baseline cuts (leftmost) are essentially the baseline ETF tight plug electron cuts. Note that the $|\eta|$ requirement has changed in version 2.0 of this note.*

4 Background Subtraction

One reason the $Z \to ee$ data sample works well for lepton 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.

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 [3]. 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% [4]. 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

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

Type	5.3 data	6.1.2 data	5.3 old MC	5.3 ERR MC
CEM	13043	15323	100038	48896
ssCEM	21	18	74	54
LCEM	16374	19397	123018	59879
ssLCEM	256	310	924	476
nisoCEM	13361	15751	102107	49918
ssnisoCEM	22	22	87	54
looseCEM	14979	17676	123018	55604
sslooseCEM	43	38	924	96
TCEM-PHX	8060	9422	75150	31485
TCEM-PEM	10348	11877	98571	39814
TCEM-LPHX	9623	11412	83872	35026

Table 3: *Number of electron candidates in the data and Monte Carlo, in 5.3 and 6.1.2. "SS" means same-sign.*

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 Z samples: CEM-CEM, (0.073 ± 0.016)%; CEM-nisoCEM, (0.079 ± 0.016) %; CEM-looseCEM, (0.169 ± 0.023) %; CEM-LCE, (1.225 ± 0.058) %.

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) [5]. 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 [1]. 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 GeV/$c^2 < M <$ 106 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 GeV/$c^2 < M <$ 120 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 the estimate should come out to be less than zero, the background is said to be zero. Using this method, we find the background for CEM-

CEM and CEM-LCE Z's to be (0.027 $\pm$ 1.014)% and (0.966 $\pm$ 1.474)%, which, within their considerable uncertainty, agree with the numbers quoted in the previous subsection. In the mass window 81 GeV/c^2 $< M <$ 101 GeV/c^2, which is used to derive the PHX scale factor, the background fractions for CEM-PHX Zs is (0.257 $\pm$ 0.733)%, for CEM-PEM Zs is (0.254 $\pm$ 0.744)%, and for CEM-LPHX Zs is (0.907 $\pm$ 0.874)%.

5 Efficiencies and Scale Factors

Note on version 2.0 In version 1.0 of this note, and previous notes [1, 6] the central electron efficiency was calculated by counting the number of Zs, which necessitated an unintuitive definition of the efficiency and introduced a bias into some of the calculationsi (but not the main result). See Appendix A for a full explanation.

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 cuts, and where N_{L} is the inclusive number of probe electrons.

For Phoenix electrons, we calculate separately the tracking efficiency (the efficiency to find a track given a well-identified plug cluster) and the plug calorimeter (PEM) efficiency (the efficiency to pass all of the plug selection given an electron with a track passing the kinematic cuts). The denominator for the tracking efficiency is then TCEM-PEM Zs, and the denominator for the calorimeter selection efficiency is TCEM-LPHX Zs. This method avoids relaxing all of the cuts at once, which would admit more background. The tracking efficiency is then

$$\epsilon_{\mathrm{tracking}} = \frac{N_{\mathrm{TCEM\text{-}PHX}}}{N_{\mathrm{TCEM\text{-}PEM}}} ,$$

the plug calorimeter selection efficiency is

$$\epsilon_{\mathrm{PEM}} = \frac{N_{\mathrm{TCEM\text{-}PHX}}}{N_{\mathrm{TCEM\text{-}LPHX}}} ,$$

and the total efficiency for Phoenix electrons is the product of the two:

$$\epsilon_{\mathrm{PHX}} = \epsilon_{\mathrm{PEM}} \times \epsilon_{\mathrm{tracking}}$$

The total CEM efficiency, the Phoenix tracking efficiency, and the PEM efficiency are shown as a function of η, ϕ, and run number in Figures 10 through 18. The total CEM efficiency as a function of E_T is shown in Figure 19 for both the biased and unbiased selection methods The significant efficiency drop which was present in the biased counting method is now gone. Table 24 gives CEM the scale factor as a function of E_T to account for the residual shape. Figure 20 shows the efficiency versus isolation.

The CEM and PHX efficiencies vs η shown in These figures show that the scale factors are not constant for all values of η. Tables 25 - 27 give the scale factor for various η ranges.

CEM				
efficiency	5.3 Data	5.3 old MC	6.1.2 Data	5.3 ERR MC
$\epsilon_{\rm CEM}$	0.802±0.003	0.813±0.001	0.796 ± 0.003	0.817 ± 0.002
scale factor	0.986 ± 0.004		0.975 ±0.004	
$\epsilon_{\rm nisoCEM}$	0.825±0.003	0.830±0.001	0.822 ± 0.003	0.834±0.002
scale factor	0.994 ± 0.004		0.986 ±0.004	
$\epsilon_{\rm looseCEM}$	0.924±0.002	0.925±0.001	0.922 ± 0.002	0.929 ±0.002
scale factor	0.999 ± 0.003		0.993 ±0.003	
PHX				
efficiency	5.3 Data	5.3 old MC	6.1.2 Data	5.3 ERR MC
$\epsilon_{\rm tracking}$	0.778 ± 0.004	0.762 ± 0.001	0.794 ± 0.004	0.791 ± 0.002
$\epsilon_{\rm PEM}$	0.844 ± 0.004	0.896 ± 0.001	0.830 ± 0.004	0.899 ± 0.002
$\epsilon_{\rm PHX}$	0.657 ± 0.006	0.683 ± 0.002	0.659 ± 0.005	0.711 ± 0.003
scale factor	0.962 ±0.008		0.927 ±0.008	

Table 4: *Total data and Monte Carlo efficiencies and scale factors, for both tight electron types. PHX tracks accepted out to $|\eta| < 2.8$. Background subtraction is done for both data sets. Uncertainties are statistical only.*

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 4. Efficiencies and scale factors for PHX tracks with $|\eta| < 2.0$ are provided in Table 5. Efficiencies and scale factors derived using all available data and MC are presented in Tables 6 and 7.

The CEM data efficiencies for both 5.3 and 6.1.2 versions of the offline are lower now than they were previously. This is because we have now loosened the fiducial cut on the probe electron (i.e., the denominator) without changing the cuts on the tight electron.

The 6.1.2 CEM efficiencies and scale factors are lower than those measured in 5.3 data due to the efficiency drop as the detector environment gets busier with increased luminosity. See Section 6 for more discussion and a method to recover some lost efficiency.

The 6.1.2 PHX tracking efficiency both in data and MC are higher than in 5.3. There are two main contributions to this, narrower z_0 distribution of events due to different beam optics, and an increased number of active silicon ladders in the ISL. These issues will be discussed in Section 7.

We also present data/MC scale factors using combinations of data and MC from various data periods, see Tables 8 and 9.

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 "loose" 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 10 and for PHX in

PHX				
efficiency	5.3 Data	5.3 old MC	6.1.2 Data	5.3 ERR MC
$\epsilon_{\rm tracking}$	0.858 ± 0.004	0.853 ± 0.001	0.873 ± 0.004	0.884 ± 0.002
$\epsilon_{\rm PEM}$	0.846 ± 0.004	0.896 ± 0.001	0.840 ± 0.004	0.901 ± 0.002
$\epsilon_{\rm PHX}$	0.726 ± 0.005	0.764 ± 0.002	0.733 ± 0.005	0.797 ± 0.003
scale factor	0.947 ± 0.008		0.920 ± 0.007	

Table 5: *Total data and Monte Carlo efficiencies and scale factors, for PHX electrons up to $|\eta| < 2.0$. Background subtraction is done. Uncertainties are statistical only.*

	Data	MC
$\epsilon_{\rm CEM}$	0.799 ± 0.002	0.814 ± 0.001
scale factor	0.981 ± 0.003	
$\epsilon_{\rm nisoCEM}$	0.823 ± 0.002	0.831 ± 0.001
scale factor	0.990 ± 0.003	
$\epsilon_{\rm looseCEM}$	0.923 ± 0.001	0.926 ± 0.001
scale factor	0.996 ± 0.002	
$\epsilon_{\rm tracking}$	0.787 ± 0.003	0.771 ± 0.001
$\epsilon_{\rm PEM}$	0.837 ± 0.003	0.897 ± 0.001
$\epsilon_{\rm PHX}$	0.658 ± 0.004	0.691 ± 0.001
scale factor	0.952 ± 0.006	

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

	Data	MC
$\epsilon_{\rm tracking}$	0.866 ± 0.003	0.862 ± 0.001
$\epsilon_{\rm PEM}$	0.843 ± 0.003	0.899 ± 0.001
$\epsilon_{\rm PHX}$	0.730 ± 0.004	0.775 ± 0.001
scale factor	0.942 ± 0.005	

Table 7: *Data and Monte Carlo efficiencies and scale factors, using all data and MC available. PHX tracks extend out to $|\eta| < 2.0$. Background subtraction is done for both data sets. Uncertainties are statistical only.*

	Gen 5		Gen 6	
CEM	initial 200pb^{-1}	Year 2004	Early 2005	Summer 2005
5.3 Old MC	0.981 ± 0.003	0.982 ± 0.003	0.983 ± 0.003	0.983 ± 0.003
5.3 ERR MC	0.977 ± 0.003	0.978 ± 0.003	0.978 ± 0.003	0.978 ± 0.003

Table 8: *CEM Data/MC scale factors using various combinations of data and MC.*

	Gen 5		Gen 6	
PHX	initial 200pb^{-1}	Year 2004	Early 2005	Summer 2005
5.3.2 Old MC	0.963 ± 0.006	0.964 ± 0.006	0.963 ± 0.006	0.962 ± 0.006
5.3.2 ERR MC	0.926 ± 0.006	0.927 ± 0.006	0.926 ± 0.006	0.925 ± 0.006

Table 9: *Total PHX Data/MC scale factors using various combinations of data and MC.*

Table 11. The reader should also keep in mind that many of these quantities are correlated (we hope to examine the correlations in a future study). All quantities used for selection, for both CEM and PHX, are shown in Figures 21 through 25. In those plots, a line is drawn at the value of the constant cut (linear terms and cutoffs are ignored).

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 era has already been validated, and there are possible problems with the increased luminosity in the detector. We divide the data into four 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}. All CEM (PHX) efficiencies are shown separately for these four time periods in Table 12(13).

6 Recovering Efficiency at high luminosity

Note on version 2.0 This study was done in version 1.0 of the note to see how much efficiency could be recovered using this technique. Since the difference between the resulting scale factors is smaller than their statistical uncertainties, this study has not been updated with the new definition of fiducial CEM electrons.

The 6.1.2 CEM efficiencies and scale factors are lower than those measured in 5.3 data due to the efficiency drop as the detector environment gets busier with increased luminosity. Figure 3 shows spectra of the number of z vertices and instantaneous luminosity in the 5.3.3 and 6.1.2 data taking eras showing the increased number of interactions per crossing and higher average luminosity in 6.1.2 data.

At higher luminosity there are additional interactions which deposit energy in the calorimeter. This extra energy increases the value of measured isolation. A correction to the isolation

efficiency	5.3 Data	5.3 old MC	6.1.2 Data	5.3 ERR MC
Conversion	0.974 $\pm$ 0.001	0.9740 $\pm$ 0.0005	0.970 $\pm$ 0.001	0.9753 $\pm$ 0.007
Fiducial	0.984 $\pm$ 0.001	0.9884 $\pm$ 0.0003	0.987 $\pm$ 0.001	0.9886 $\pm$ 0.0004
TrkAxSeg	0.999$\pm$ 0.003	0.9994 $\pm$ 0.0001	0.9988 $\pm$ 0.0002	0.9994 $\pm$ 0.0001
TrkStSeg	0.9998$\pm$0.0001	1 $\pm$ 0	1 $\pm$ 0	1 $\pm$ 0
Hadem	0.993$\pm$ 0.001	0.9883 $\pm$ 0.0003	0.9921 $\pm$ 0.0007	0.9894 $\pm$ 0.005
Isol	0.977$\pm$ 0.001	0.9797 $\pm$ 0.0004	0.973 $\pm$ 0.001	0.9795 $\pm$ 0.0006
LshrTrk	0.993$\pm$0.001	0.9910 $\pm$ 0.0003	0.9924 $\pm$ 0.007	0.9911 $\pm$ 0.0004
EP	0.933 $\pm$ 0.002	0.9270 $\pm$ 0.0008	0.932 $\pm$ 0.002	0.927 $\pm$ 0.001
DeltaZ	0.9980$\pm$0.0003	0.9993 $\pm$ 0.0001	0.9982 $\pm$ 0.0003	0.9992 $\pm$ 0.0001
QxDeltaX	0.9977$\pm$0.0004	0.9987 $\pm$ 0.0001	0.9984 $\pm$ 0.0003	0.9988 $\pm$ 0.0002
StripChi2	0.968$\pm$0.001	0.9816 $\pm$ 0.0004	0.966 $\pm$ 0.001	0.9808 $\pm$ 0.0006

Table 10: *CEM N-1 efficiencies. No background subtraction is done, errors are statistical only.*

efficiency	5.3 Data	5.3 old MC	6.1.2 Data	5.3 ERR MC
Hadem	0.988 $\pm$ 0.001	0.9892 $\pm$ 0.0003	0.985 $\pm$ 0.001	0.9903 $\pm$ 0.0006
Isol	0.985 $\pm$ 0.002	0.9917 $\pm$ 0.0003	0.980 $\pm$ 0.001	0.9913 $\pm$ 0.0005
DeltaR	0.990 $\pm$ 0.001	0.9910 $\pm$ 0.0003	0.990 $\pm$ 0.001	0.9915 $\pm$ 0.0005
Pem3x3FitTow	1 $\pm$ 0	1 $\pm$ 0	1 $\pm$ 0	1 $\pm$ 0
Pem3x3Chisq	0.912 $\pm$ 0.003	0.9452 $\pm$ 0.0008	0.905 $\pm$ 0.003	0.950 $\pm$ 0.001
Pes2d5by9U	0.993 $\pm$ 0.001	0.9966 $\pm$ 0.0002	0.993 $\pm$ 0.001	0.9963 $\pm$ 0.0003
Pes2d5by9V	0.992 $\pm$ 0.001	0.9970 $\pm$ 0.0002	0.994 $\pm$ 0.001	0.9971 $\pm$ 0.0003

Table 11: *Phoenix N-1 efficiencies. No background subtraction is done, errors are statistical only. This table selects PHX tracks up to* $|\eta| < 2.8$.

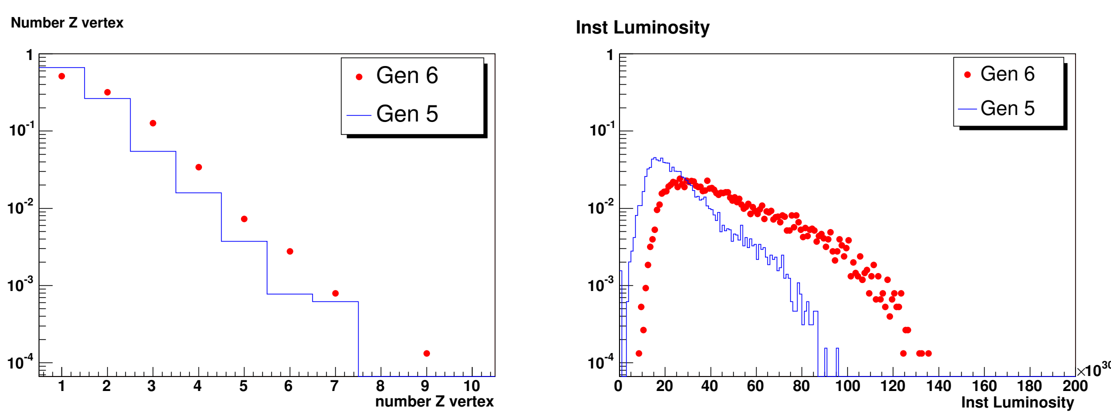

Figure 3: *The spectra of the number of* z *vertices and the instantaneous luminosity for both the 5.3 and 6.1.2 data taking eras. Plots are normalized to unit area.*

efficiency	initial 200pb^{-1}	Year 2004	Early 2005	Summer 2005
Conversion	0.974 ± 0.002	0.973 ± 0.002	0.971 ± 0.001	0.969 ± 0.002
Fiducial	0.986 ± 0.001	0.980 ± 0.002	0.987 ± 0.001	0.988 ± 0.001
TrkAxSeg	0.9995 ± 0.0003	0.9986 ± 0.0005	0.9989 ± 0.0004	0.9988 ± 0.0004
TrkStSeg	0.9997 ± 0.0002	0.9998 ± 0.0002	1 ± 0	1 ± 0
Hadem	0.993 ± 0.001	0.993 ± 0.001	0.993 ± 0.001	0.991 ± 0.001
Isol	0.975 ± 0.002	0.977 ± 0.002	0.973 ± 0.002	0.973 ± 0.002
LshrTrk	0.993 ± 0.001	0.992 ± 0.001	0.991 ± 0.001	0.994 ± 0.001
EP	0.933 ± 0.003	0.934 ± 0.003	0.934 ± 0.003	0.930 ± 0.003
DeltaZ	0.9982 ± 0.0005	0.9979 ± 0.0006	0.9979 ± 0.0005	0.9986 ± 0.0004
QxDeltaX	0.9980 ± 0.0005	0.9973 ± 0.0007	0.9986 ± 0.0004	0.9982 ± 0.0005
StripChi2	0.968 ± 0.002	0.966 ± 0.002	0.967 ± 0.002	0.962 ± 0.002
total	0.797 ± 0.002	0.798 ± 0.02	0.799 ± 0.002	0.799 ± 0.002

Table 12: *CEM N-1 efficiencies in both the 5.3 and 6.1.2 data. See the end of Section 5 for the exact definitions of the data-taking time periods. Background subtraction is applied to total efficiencies, uncertainties are statistical only.*

efficiency	initial 200pb^{-1}	Year 2004	Early 2005	Summer 2005
Hadem	0.991 ± 0.001	0.986 ± 0.002	0.985 ± 0.002	0.986 ± 0.002
Isol	0.985 ± 0.002	0.985 ± 0.002	0.981 ± 0.002	0.980 ± 0.002
DeltaR	0.991 ± 0.001	0.989 ± 0.002	0.990 ± 0.001	0.990 ± 0.002
Pem3x3FitTow	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Pem3x3Chisq	0.922 ± 0.004	0.901 ± 0.005	0.908 ± 0.004	0.902 ± 0.004
Pes2d5by9U	0.992 ± 0.001	0.994 ± 0.001	0.994 ± 0.001	0.994 ± 0.001
Pes2d5by9V	0.993 ± 0.001	0.990 ± 0.002	0.995 ± 0.001	0.993 ± 0.001
tracking	0.785 ± 0.003	0.788 ± 0.003	0.787 ± 0.003	0.787 ± 0.003
PEM	0.838 ± 0.003	0.837 ± 0.003	0.836 ± 0.003	0.835 ± 0.003
total	0.658 ± 0.004	0.659 ± 0.004	0.658 ± 0.004	0.657 ± 0.004

Table 13: *PHX efficiencies in both the 5.3 and 6.1.2 data, divided by time period. PHX tracks extend to $|\eta|$ <2.8. See the end of Section 5 for the exact definition of the time periods. Background subtraction is applied to tracking, PEM, and total efficiencies, uncertainties are statistical only.*

CEM				
	Uncorrected		Corrected	
efficiency	5.3 Data	6.1.2 Data	5.3 Data	6.1.2 Data
ϵ_{CEM}	0.815 ± 0.004	0.803 ± 0.004	0.813 ± 0.004	0.807 ± 0.004
$\epsilon_{\mathrm{nisoCEM}}$	0.835 ± 0.004	0.829 ± 0.004	0.834 ± 0.004	0.829 ± 0.004
$\epsilon_{\mathrm{looseCEM}}$	0.936 ± 0.003	0.930 ± 0.002	0.934 ± 0.003	0.934 ± 0.002
PHX				
	Uncorrected		Corrected	
efficiency	5.3 Data	6.1.2 Data	5.3 Data	6.1.2 Data
$\epsilon_{\mathrm{tracking}}$	0.858 ± 0.004	0.873 ± 0.004	0.858 ± 0.004	0.873 ± 0.004
ϵ_{PEM}	0.846 ± 0.004	0.840 ± 0.004	0.850 ± 0.004	0.846 ± 0.004
ϵ_{PHX}	0.726 ± 0.006	0.733 ± 0.005	0.729 ± 0.006	0.738 ± 0.005

Table 14: *Total data efficiencies for both tight electron types, nominal isolation and using the isolation correction. Background subtraction is done for both data sets. Uncertainties are statistical only.*

CEM				
	Uncorrected		Corrected	
scale factor	Gen 5	Gen 6	Gen 5	Gen 6
SF_{CEM}	0.995 ± 0.005	0.981 ± 0.005	0.997 ± 0.005	0.986 ± 0.005
SF_{nisoCEM}	0.999 ± 0.005	0.989 ± 0.005	0.999 ± 0.005	0.988 ± 0.005
SF_{looseCEM}	1.001 ± 0.003	0.994 ± 0.003	1.002 ± 0.003	0.998 ± 0.003
SF_{PHX}	0.946 ± 0.008	0.920 ± 0.007	0.950 ± 0.008	0.920 ± 0.007

Table 15: *Total scale factors for both tight electron types, nominal isolation and using the isolation correction. Background subtraction is done for both data sets. Uncertainties are statistical only.*

to compensate for this extra energy has been proposed as:

$$(E_T^{isol} - 0.35GeV \times (N_{vtx} - 1)/E_T^l) \leq 0.1$$

which is derived from the average energy in a randomly oriented cone [7]. The correction factor is the same for central and plug electrons. For MC, the correction factor is 0.27GeV. Using this modified version of the isolation variable we calculate the CEM and PHX efficiencies. The results are found in Tables 14 and 15. Figures 4 and 5 show the CEM efficiency (nominal, non-isolated, and corrected versions) as a function of the number of primary vertices in the event, and the instantaneous luminosity. These figures show that the corrected isolation recovers more efficiency than the standard measure of isolation, but is not as efficient as totally removing the isolation cut. Studies are currently underway to determine how much additional background is admitted with this modified version of the efficiency.

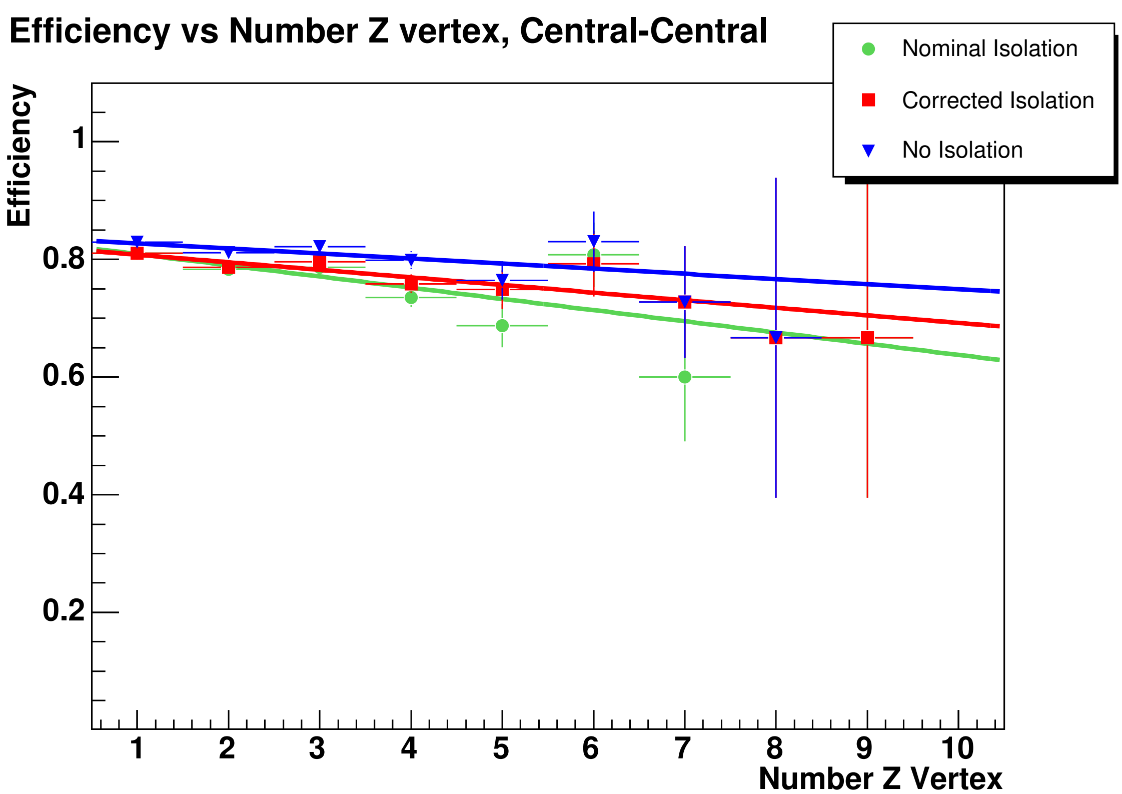

Figure 4: *CEM, corrected CEM, and niso CEM efficiencies in 6.1.2 data as a function of the number of primary vertices of quality 12 and above. The lines are linear fits with slopes of* $(-1.9 \pm 0.3) \times 10^{-2}$, $(-1.3 \pm 0.3) \times 10^{-2}$, $(-0.9 \pm 0.3) \times 10^{-2}$ *for CEM, corrected CEM and niso CEM respectively.*

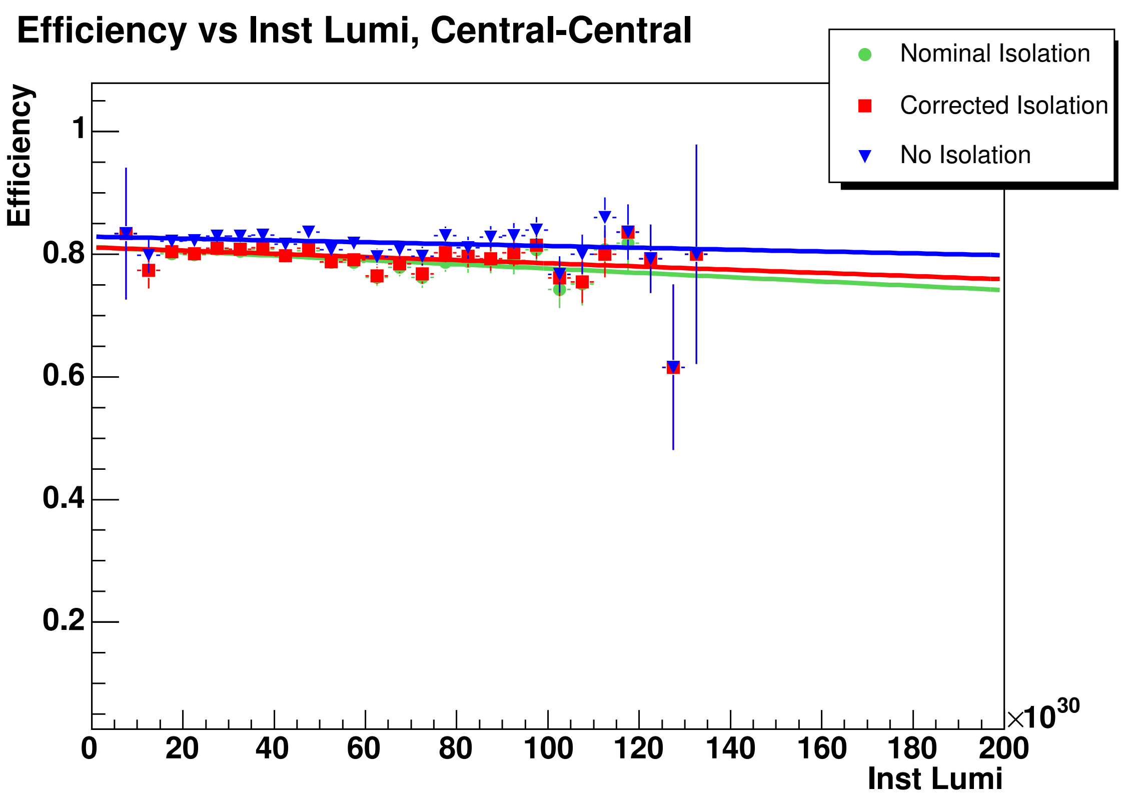

Figure 5: *CEM, corrected CEM, and niso CEM efficiencies in 6.1.2 data as a function of the instantaneous luminosity. The lines are linear fits with slopes of* $(-3.5 \pm 1.3) \times 10^{-34}$, $(-2.6 \pm 1.2) \times 10^{-34}$, *and* $(-1.5 \pm 1.2) \times 10^{-34}$ *for CEM corrected CEM, and niso CEM respectively.*

7 Increased PHX tracking efficiency

Note on version 2.0 This study was done in version 1.0 of the note to find the cause of the increased PHX tracking efficiency compared to the 5.3 old MC and 5.3 data. This study has not been repeated using tracks with $|\eta| < 2.8$.

Over the course of Run II, parts of the silicon detector have gone offline (due to beam incidents and other troubles) and come back online (through the efforts of the silicon group). In particular, the fraction of ladders online increased significantly between the start of running and run 160000 (the silicon detector group keeps a running tally in the figure at [8]). Importantly 8 ladders in layer 6 of ISL central west were recovered during the August 2004 shutdown [10]. More of the detector being online means that tracks have a higher probability of crossing 3 or more active silicon layers, and therefore the PHX tracking efficiency. This effect is also seen in the run-dependent Monte Carlo, since CDF simulation retrieves the silicon configuration on a run-by-run basis from the database.

Starting with run 182580 the Tevatron changed the beam optics, resulting in a narrower z_0 distribution in the CDF detector [9]. This change was incorporated into the MC simulation[3] The narrower distribution of event z_0 also increases the chances of a PHX track hitting more silicon layers and increasing the PHX tracking efficiency.

To estimate the magnitude of the impact of the new z_0 distribution for each data/MC sample we re-weight tracking efficiency as a function of event z_0 with the actual event z_0 measured in that data sample. The event z_0 for data and MC in both 5.3 data and 6.1.2 data are shown in Figure 6.

$$\epsilon_{tracking} = \sum_{i}^{nbins} \frac{z_{0i} \times \epsilon_i}{nEvents}$$

Where ϵ_i is the efficiency as a function of z_0, and is shown in Figure 7. The PHX tracking efficiency has increased by 1.7% and 3.6% in data and MC respectively in going from Gen 5 to Gen 6. And re-weighting the tracking efficiency estimates efficiency increases of 1.2% and 2.3%. The tracking efficiency re-weighting does not account for the entire increase in efficiency, but this exercise shows that the increase is approximately the right size, and the remainder of the increase can probably be attributed to the increased number of active silicon ladders.

8 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

[3]The 5.3.3 Monte Carlo (i.e., all of the MC used in this note) models the beam shape as a Gaussian, using the beam width as the Gaussian width. In Gen 6 the MC models the beam using a function more representative of the actual beam shape. Work is ongoing in measuring the difference between these models.

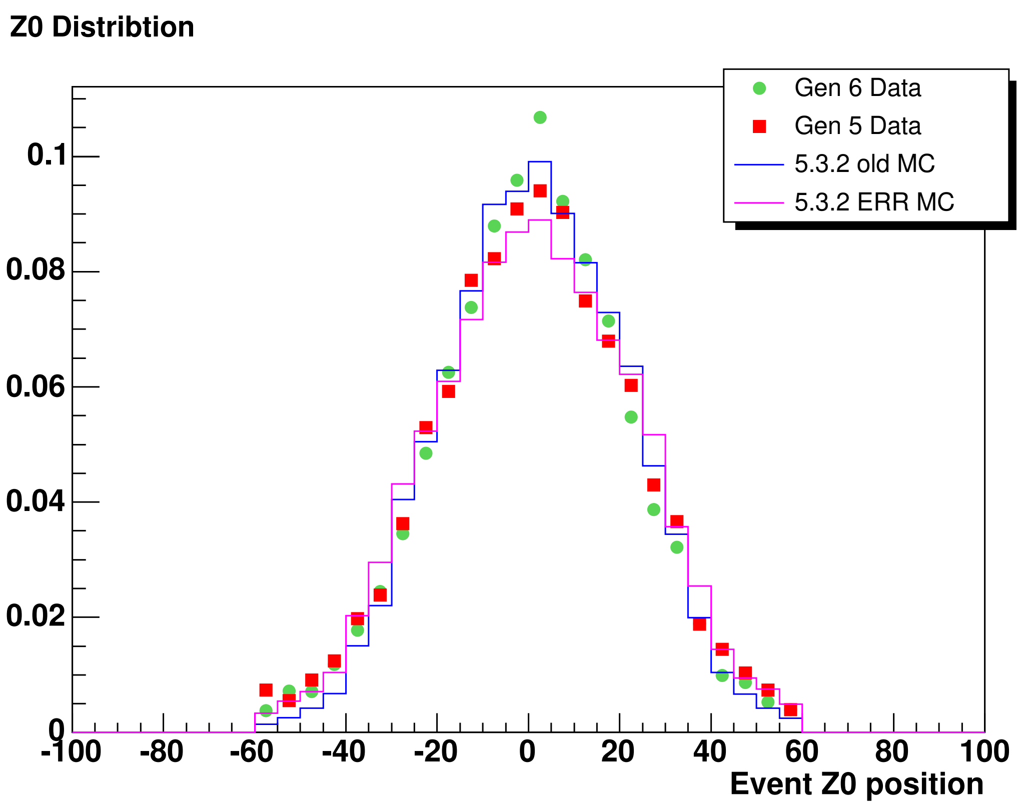

Figure 6: *Event z_0 distributions for data and MC. All distributions are normalized to unit area.*

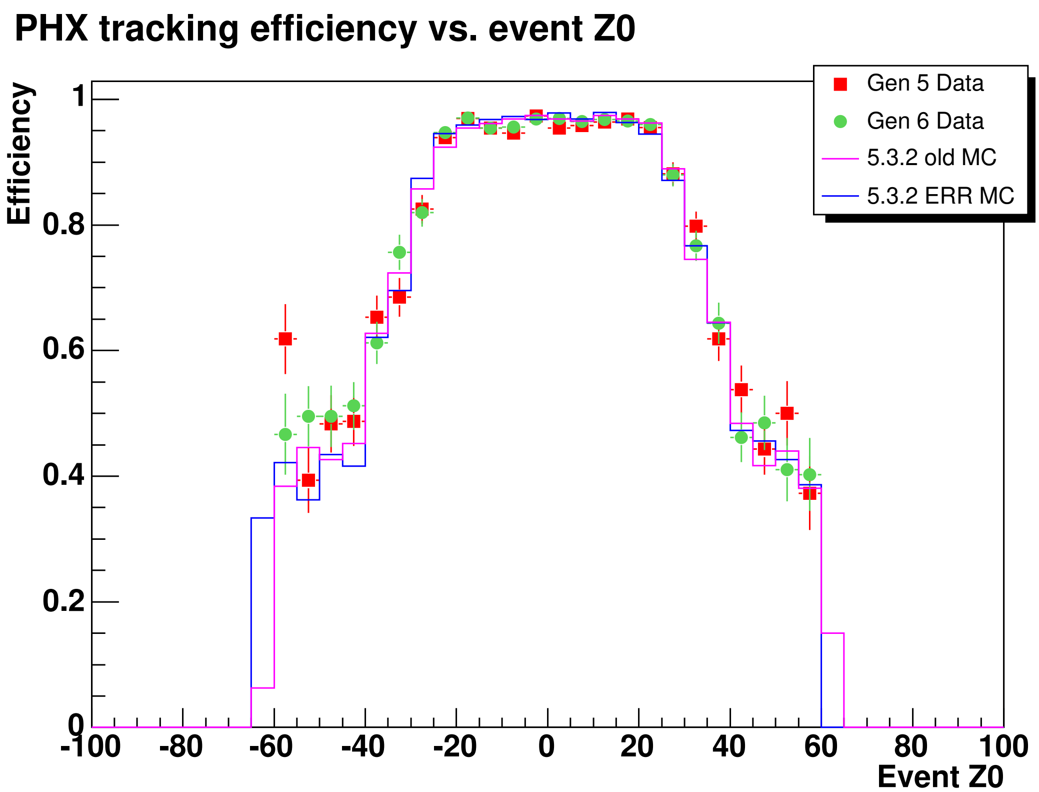

Figure 7: *The PHX tracking efficiency as a function of event* z_0*, as measured in all data samples. Note that it is approximately the same in the new and old Monte Carlo, and in the old and new data.*

5.3 old MC	0.125 ± 0.001
5.3 ERR MC	0.123 ± 0.002
5.3 Data	0.141 ± 0.004
6.1.2 Data	0.134 ± 0.004
5.3 data "initial 200pb^{-1}"	0.147 ± 0.005
5.3 data "Year 2004"	0.135 ± 0.006
6.1.2 data "Early 2005"	0.134 ± 0.005
6.1.2 data "Summer 2005"	0.134 ± 0.005

Table 16: *Phoenix electron charge fake rates for PHX tracks with* $|\eta| < 2.8$.

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 17 and 16. The improvement in the charge fake rate after the "initial 200 pb^{-1}" is correlated with, and likely attributable to, the increased number of active silicon layers [8].

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 8. 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 18. 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 0.094 ± 0.003 for data and 0.094 ± 0.002 for Monte Carlo. This is noticeably lower than the numbers in Table 17 because the 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:

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

$F_{\text{data(MC)}}$ is the charge fake rate in data(Monte Carlo) and $N_{\text{OS(SS)}}$ 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 0.999 ± 0.004 and 0.996 ± 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 0.987 ± 0.005.

5.3 old MC	0.105 ± 0.001
5.3 ERR MC	0.102 ± 0.002
5.3 Data	0.112 ± 0.004
6.1.2 Data	0.109 ± 0.003
5.3 data "initial 200pb^{-1}"	0.116 ± 0.005
5.3 data "Year 2004"	0.109 ± 0.006
6.1.2 data "Early 2005"	0.106 ± 0.005
6.1.2 data "Summer 2005"	0.107 ± 0.005

Table 17: *Phoenix electron charge fake rates for PHX tracks with* $|\eta| < 2.0$.

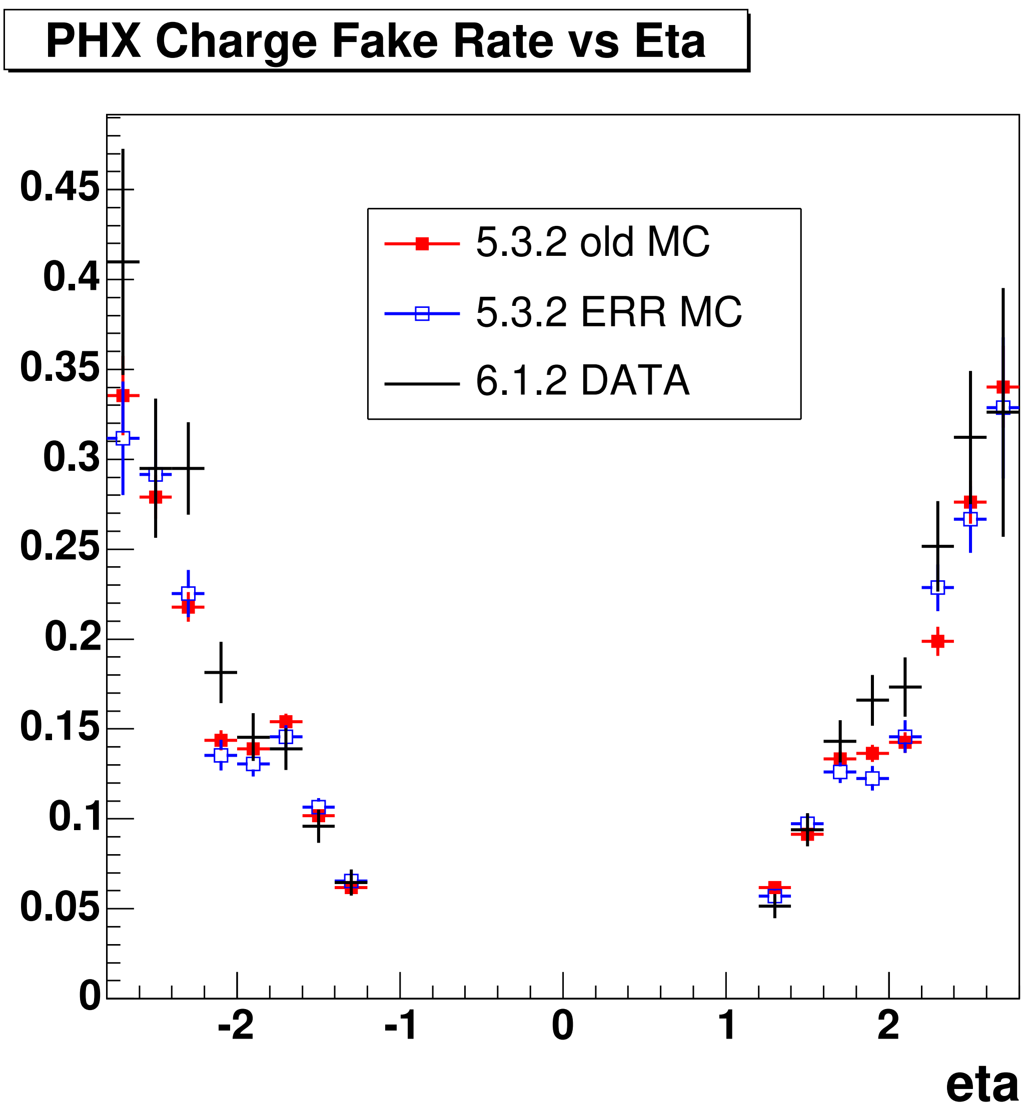

Figure 8: *The charge fake rate for Phoenix electrons as a function of electron* η.

Range	Data	Monte Carlo
2.8< $\lvert\eta\rvert$ <2.6	0.374 ± 0.047	0.318 ± 0.025
2.6< $\lvert\eta\rvert$ <2.4	0.304 ± 0.027	0.279 ± 0.013
2.4< $\lvert\eta\rvert$ <2.2	0.274 ± 0.018	0.227 ± 0.009
2.2< $\lvert\eta\rvert$ <2.0	0.177 ± 0.012	0.140 ± 0.006
2.0< $\lvert\eta\rvert$ <1.8	0.155 ± 0.010	0.127 ± 0.005
1.8< $\lvert\eta\rvert$ <1.6	0.141 ± 0.008	0.136 ± 0.005
1.6< $\lvert\eta\rvert$ <1.4	0.095 ± 0.007	0.102 ± 0.004
1.4< $\lvert\eta\rvert$ <1.2	0.058 ± 0.005	0.061 ± 0.002

Table 18: *Phoenix electron charge fake rates, as a function of pseudorapidity.*

9 Systematic Uncertainties

There are two 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 electrons.

To measure the trigger bias in the central electron efficiency,[4] 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, 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

[4] This study is unchanged from version 2.0 of CDF note 7309 [1] because the XFT track information was not stored in the official Top Group Ntuples. The results from 5.3.1 should still apply.

Background-subtracted CEM efficiencies (data)					
	66-116	71-111	**76-106**	81-101	86-96
CEM	0.792 ± 0.003	0.795 ± 0.003	**0.796 ± 0.003**	0.800 ± 0.003	0.810 ± 0.003
nisoCEM	0.820 ± 0.003	0.822 ± 0.003	**0.822 ± 0.003**	0.825 ± 0.003	0.830 ± 0.003
looseCEM	0.918 ± 0.002	0.920 ± 0.002	**0.922 ± 0.002**	0.925 ± 0.002	0.934 ± 0.002
Monte Carlo efficiencies					
	66-116	71-111	**76-106**	81-101	86-96
CEM	0.813 ± 0.002	0.814 ± 0.002	**0.817 ± 0.002**	0.820 ± 0.002	0.828 ± 0.002
nisoCEM	0.831 ± 0.002	0.832 ± 0.002	**0.834 ± 0.002**	0.836 ± 0.002	0.840 ± 0.002
looseCEM	0.925 ± 0.002	0.927 ± 0.002	**0.929 ± 0.002**	0.931 ± 0.002	0.937 ± 0.002
Scale factors					
	66-116	71-111	**76-106**	81-101	86-96
CEM	0.975 ± 0.004	0.976 ± 0.004	**0.975 ± 0.004**	0.976 ± 0.004	0.979 ± 0.004
nisoCEM	0.986 ± 0.004	0.987 ± 0.004	**0.986 ± 0.004**	0.987 ± 0.004	0.989 ± 0.004
looseCEM	0.993 ± 0.003	0.993 ± 0.003	**0.993 ± 0.003**	0.993 ± 0.003	0.997 ± 0.003

Table 19: *Efficiencies and scale factors for CEM electrons using 6.1.2 data and 5.3 ERR MC. The mass window used for the central value is in boldface. Uncertainties are statistical only.*

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).

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 19 for central electrons and in Table 20 for plug electrons. The resulting systematic uncertainties are 0.4% for CEM electrons, 0.3% for nisoCEM electrons, and 0.4% for looseCEM electrons, and 1.15% for PHX electrons.

The final systematic uncertainties are 0.4% for CEM electrons, 0.3% for nisoCEM electrons, and 0.4% for looseCEM electrons, and 1.15% for PHX electrons.

Background-subtracted PHX efficiencies (data)					
	66-116	71-111	76-106	**81-101**	86-96
TRK	0.791 ± 0.004	0.791 ± 0.004	0.792 ± 0.004	**0.794 ± 0.004**	0.795 ± 0.004
PEM	0.823 ± 0.003	0.824 ± 0.003	0.825 ± 0.003	**0.830 ± 0.004**	0.842 ± 0.004
TOT	0.650 ± 0.005	0.652 ± 0.005	0.653 ± 0.005	**0.659 ± 0.005**	0.669 ± 0.006
Monte Carlo efficiencies					
	66-116	71-111	76-106	**81-101**	86-96
TRK	0.791 ± 0.002	0.791 ± 0.002	0.791 ± 0.002	**0.791 ± 0.002**	0.790 ± 0.002
PEM	0.897 ± 0.002	0.897 ± 0.002	0.898 ± 0.002	**0.899 ± 0.002**	0.905 ± 0.002
TOT	0.710 ± 0.003	0.710 ± 0.003	0.711 ± 0.003	**0.711 ± 0.003**	0.714 ± 0.003
Scale factors					
	66-116	71-111	76-106	**81-101**	86-96
TRK	0.999 ± 0.005	1.000 ± 0.005	1.001 ± 0.005	**1.004 ± 0.005**	1.007 ± 0.006
PEM	0.917 ± 0.004	0.919 ± 0.004	0.919 ± 0.004	**0.924 ± 0.004**	0.931 ± 0.005
TOT	0.916 ± 0.008	0.918 ± 0.008	0.919 ± 0.008	**0.927 ± 0.008**	0.937 ± 0.009

Table 20: *Efficiencies and scale factors for Phoenix electrons using 6.1.2 data and 5.3 ERR MC. The mass window used for the central value is in boldface. Uncertainties are statistical only.*

10 The Plug Energy Scale

The plug is calibrated to make central-plug Zs have the correct Z mass when the energy from the PPR is added to the energy reconstructed from the calorimetry towers. For this note, we have used the default energy as calculated in the TopNtuple, which is from 2x2 tower clusters formed by the BF_PEMClustering algorithm [11], which is then corrected using `PemCorrAlg::GetPemCorr`, which includes the "PEM face corrections". As can clearly be seen in Figure 2, the Z peak in Monte Carlo and especially data is not centered at 91. Incorporating the PPR energy into the total electron energy moves the Z peak closer to the nominal value, as can be seen in Figure 9. Fitting the peak with a Gaussian in the invariant mass range 86 GeV/c^2 $< M <$ 98 GeV/c^2 gives mean values of 91.46 ± 0.05 GeV/c^2 for the data and 92.60 ± 0.02 GeV/c^2 for the Monte Carlo. We find scale factors using the standard technique [12] to give plug energies of $91 GeV/c^2$.

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

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

Because not all top analyses use the PPR energy, we provide here the scale factor (E^{PPR}_{scale}) where the PPR energy has been added, and the scale factor (E^{PEM}_{scale}) where only the PEM energy from the top ntuple has been used. Plug energy scale factors for both data and MC are found in Tables 21 and 22

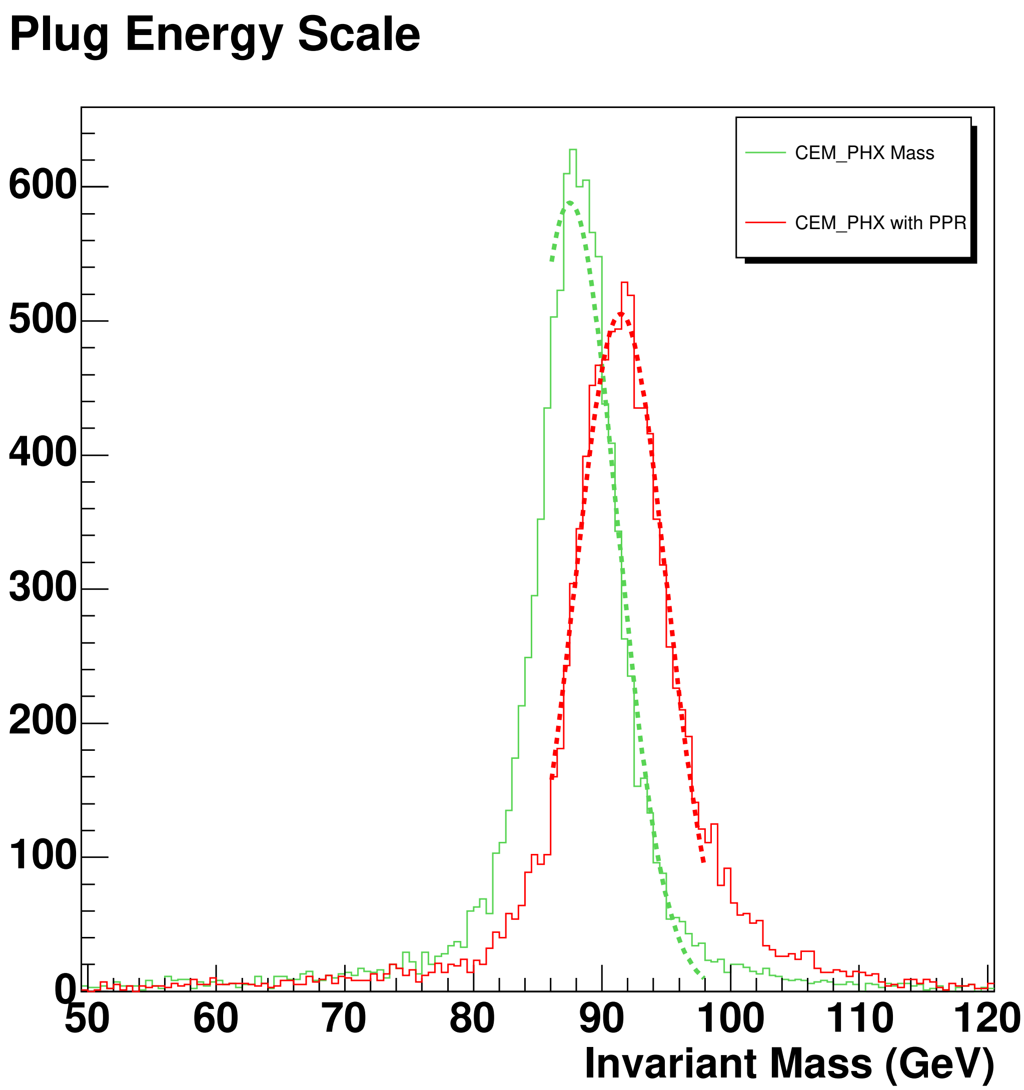

Figure 9: *Reconstructed CEM-PHX mass in data with and without the PPR energy included in the plug electron energy. PHX tracks extend out to* $|\eta| < 2.8$.

Range	Data	Monte Carlo
E^{CEM}	1.002 $\pm$ 0.0005	0.995 $\pm$ 0.0003
E^{PPR}	1.08 $\pm$ 0.03	1.04 $\pm$ 0.02
E^{PHX}	0.99 $\pm$ 0.02	0.97 $\pm$ 0.02

Table 21: *Plug energy scale factors in data and MC for PHX tracks with $|\eta| < 2.8$.*

Range	Data	Monte Carlo
E^{CEM}	1.002 $\pm$ 0.0005	0.995 $\pm$ 0.003
E^{PPR}	1.08 $\pm$ 0.03	1.04 $\pm$ 0.02
E^{PHX}	1.00 $\pm$ 0.02	0.96 $\pm$ 0.01

Table 22: *Plug energy scale factors in data and MC for PHX tracks with $|\eta| < 2.0$.*

11 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 run 203799, and the Monte Carlo samples are run-dependent and simulate runs from the full datataking period. We observe some effects in the data (and in the Monte Carlo!) which are dependent on run number, and have investigated them. Further studies are underway to see where it may be possible to correct for inefficiencies due to the higher instantaneous luminosity running conditions. That noted, we 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 23. This note also measures the charge fake rate for Phoenix electrons and presents the plug energy scale factors.

12 Acknowledgments

The authors would like to thank (in no particular order) Beate Heinemann, Eva Halkiadakis, Steve Levy, Marcel Stanitzki, Anyes Taffard, and Monica Tecchio.

	ϵ(Data)	ϵ(MC)	Scale Factor
CEM	0.799 $\pm$ 0.002	0.814 $\pm$ 0.001	0.981 $\pm$0.003(stat) $\pm$0.004(syst)
Nonisolated CEM	0.823 $\pm$ 0.002	0.831 $\pm$ 0.001	0.990 $\pm$0.003(stat) $\pm$0.003(syst)
Loose CEM	0.923 $\pm$ 0.001	0.926 $\pm$ 0.001	0.996 $\pm$0.002(stat) $\pm$0.004(syst)
PHX	0.658 $\pm$ 0.004	0.691 $\pm$ 0.001	0.952 $\pm$0.006(stat) $\pm$0.012(syst)

Table 23: *Efficiencies and scale factors recommended for use in 700pb^{-1}analysis with PHX tracks extended to $|\eta|$ <2.8.*

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 passes 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_{L} is the number of probe leptons and N_{T} the number which pass the tight selection (or any other criteria), the efficiency ϵ for the tight selection is

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

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_{TT} (the number of Z where both leptons pass the tight cuts), N_{TL} (the number of Zs where at least one lepton passes the tight cuts), and N_{LL} (the number of Zs where both leptons pass at least the probe cuts).

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

and

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

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

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

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:

$$\begin{aligned} N_{\mathrm{T}} &= 2N_{\mathrm{TT}} \\ N_{\mathrm{L}} = 2N_{\mathrm{TT}} + (N_{\mathrm{TL}} - N_{\mathrm{TT}}) &= N_{\mathrm{TT}} + N_{\mathrm{TL}} \end{aligned} \tag{1}$$

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_{TF}). Noting that $N_{\mathrm{TL}} = N_{\mathrm{TF}} + N_{\mathrm{TT}}$, so

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

There is one subtlety in relating the numbers of Zs to the number of leptons, which arises from the trigger requirement in the data. $N_{\mathrm{T}} = 2N_{\mathrm{TT}}$ is not exactly true because of the requirement that the tight leg fired the trigger. N_{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_{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_{OO} and N_{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

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

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 $N_{\mathrm{TO}} \approx N_{\mathrm{TT}}$. 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] C. Hill et al, *Electron Identification in Offline Release 5.3*, CDF note 7309.

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

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

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

E_T range	Scale Factor
20< E_T <30	0.849 $\pm$ 0.019
30< E_T <40	0.969 $\pm$ 0.006
40< E_T <50	0.987 $\pm$ 0.004
50< E_T <60	0.975 $\pm$ 0.009
60< E_T <70	0.976 $\pm$ 0.022
70< E_T <80	0.917 $\pm$ 0.040
80< E_T <90	0.972 $\pm$ 0.062
90< E_T <100	0.885 $\pm$ 0.085

Table 24: *CEM scale factor as a function of E_T.*

CEM SF	$\|\eta\| < 0.5$	$\|\eta\| > 0.5$
Gen 5	1.003 $\pm$ 0.007	0.966 $\pm$ 0.007
Gen 6	0.992 $\pm$ 0.007	0.946 $\pm$ 0.007

Table 25: *The CEM scale factor for different regions of η.*

[5] 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.

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

[7] B. Heinemann *Isolation Cut Efficiency*, in preparation.

[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] M. Stanitzki (and others), private communication.

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

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

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

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

$\lvert\eta\rvert$ range	Scale Factor
2.8< $\lvert\eta\rvert$ <2.6	1.120 $\pm$ 0.215
2.6< $\lvert\eta\rvert$ <2.4	0.998 $\pm$ 0.098
2.4< $\lvert\eta\rvert$ <2.2	1.034 $\pm$ 0.058
2.2< $\lvert\eta\rvert$ <2.0	1.040 $\pm$ 0.038
2.0< $\lvert\eta\rvert$ <1.8	0.983 $\pm$ 0.027
1.8< $\lvert\eta\rvert$ <1.6	0.985 $\pm$ 0.020
1.6< $\lvert\eta\rvert$ <1.4	0.984 $\pm$ 0.015
1.4< $\lvert\eta\rvert$ <1.2	0.994 $\pm$ 0.014

Table 26: *PHX tracking scale factor as a function of* $\lvert\eta\rvert$.

$\lvert\eta\rvert$ range	Scale Factor
2.8< $\lvert\eta\rvert$ <2.6	0.741 $\pm$ 0.102
2.6< $\lvert\eta\rvert$ <2.4	0.807 $\pm$ 0.053
2.4< $\lvert\eta\rvert$ <2.2	0.891 $\pm$ 0.036
2.2< $\lvert\eta\rvert$ <2.0	0.942 $\pm$ 0.024
2.0< $\lvert\eta\rvert$ <1.8	0.930 $\pm$ 0.019
1.8< $\lvert\eta\rvert$ <1.6	0.933 $\pm$ 0.019
1.6< $\lvert\eta\rvert$ <1.4	0.920 $\pm$ 0.018
1.4< $\lvert\eta\rvert$ <1.2	0.926 $\pm$ 0.019

Table 27: *PHX PEM scale factor as a function of* $\lvert\eta\rvert$.

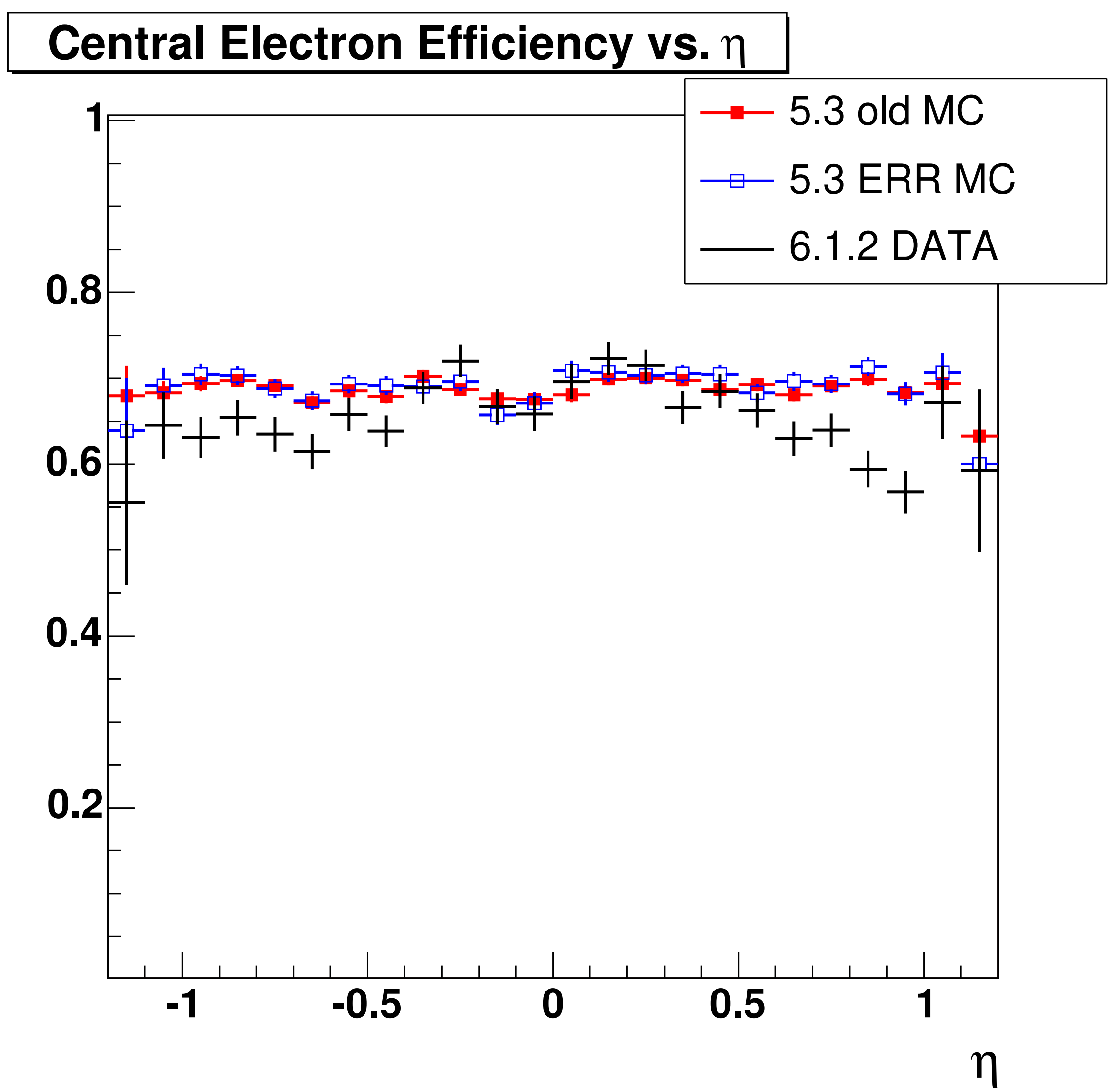

Figure 10: *CEM total ID efficiency vs η.*

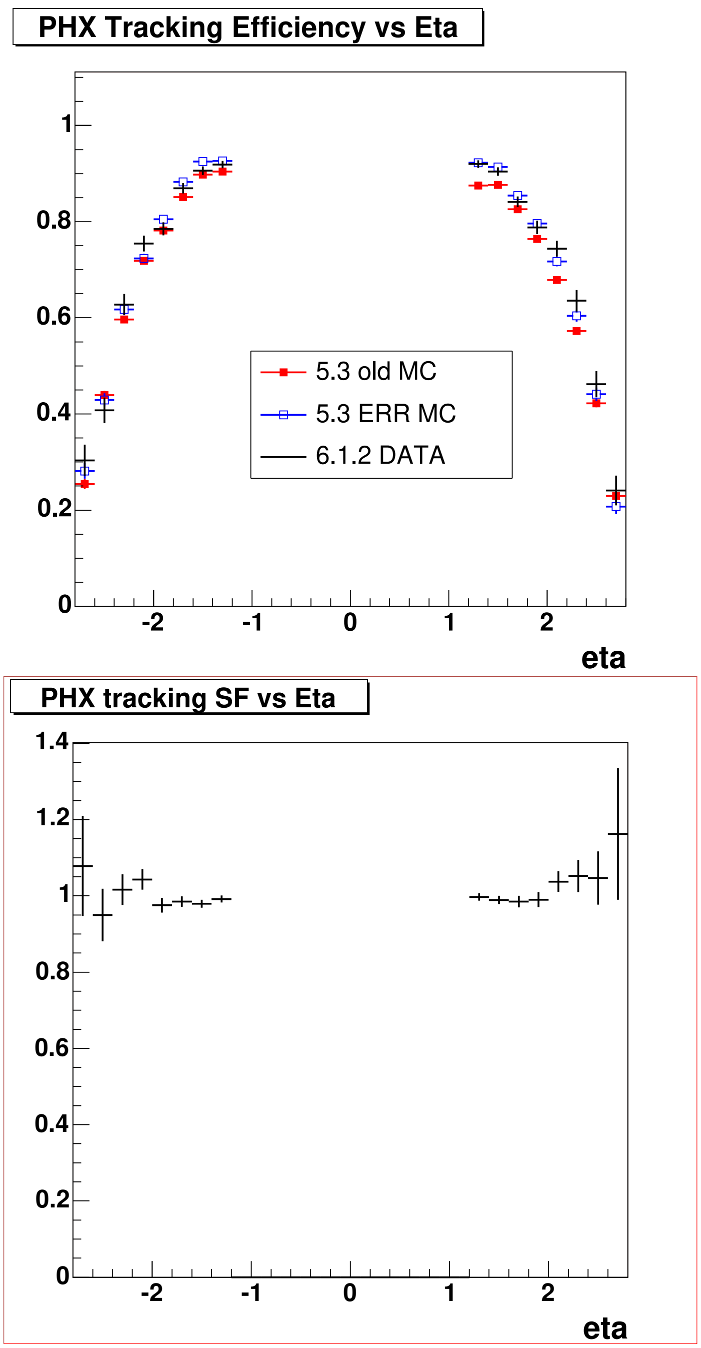

Figure 11: *PHX tracking efficiency vs η (upper plot), and the scale factor (lower plot).*

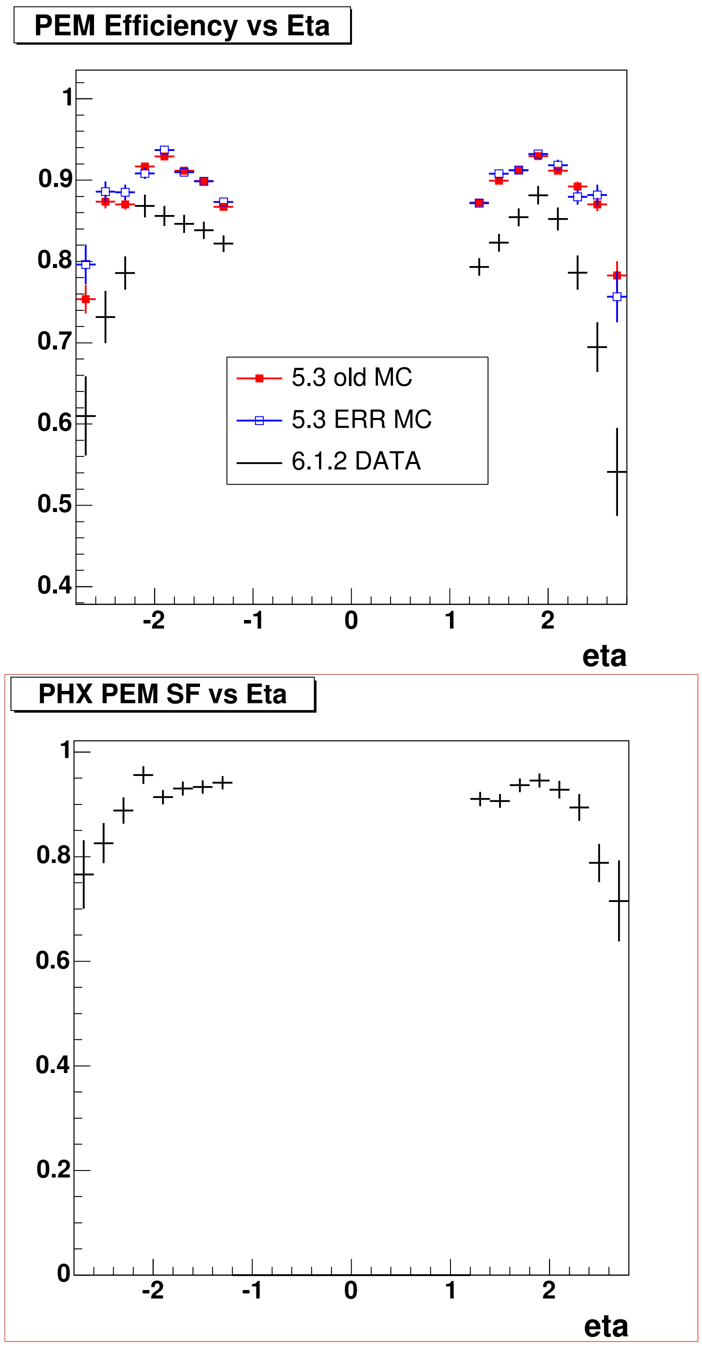

Figure 12: *PEM efficiency (plug cluster ID variables) vs* η *(upper plot) and the scale factor (lower plot).*

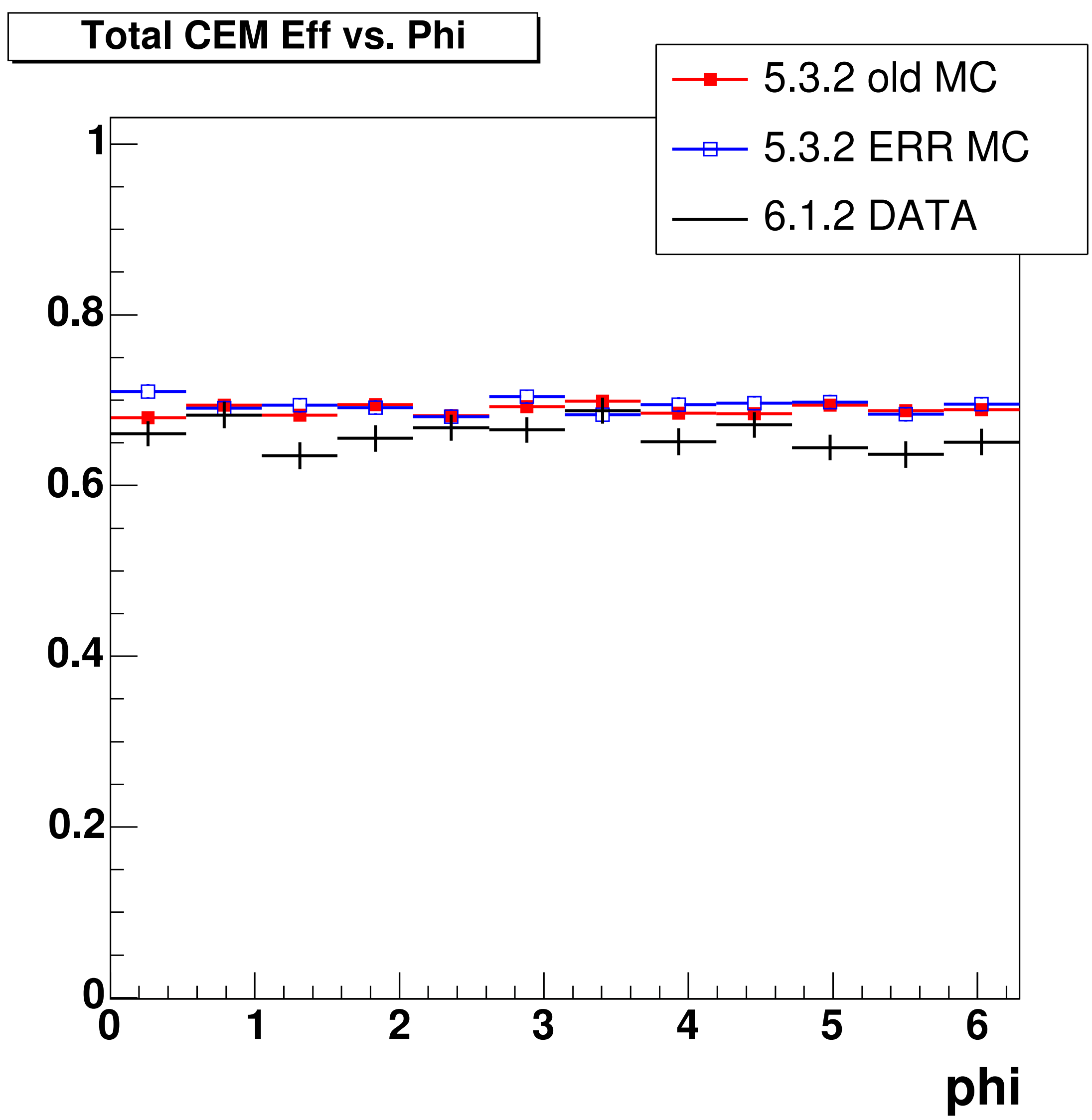

Figure 13: *CEM total ID efficiency vs* ϕ.

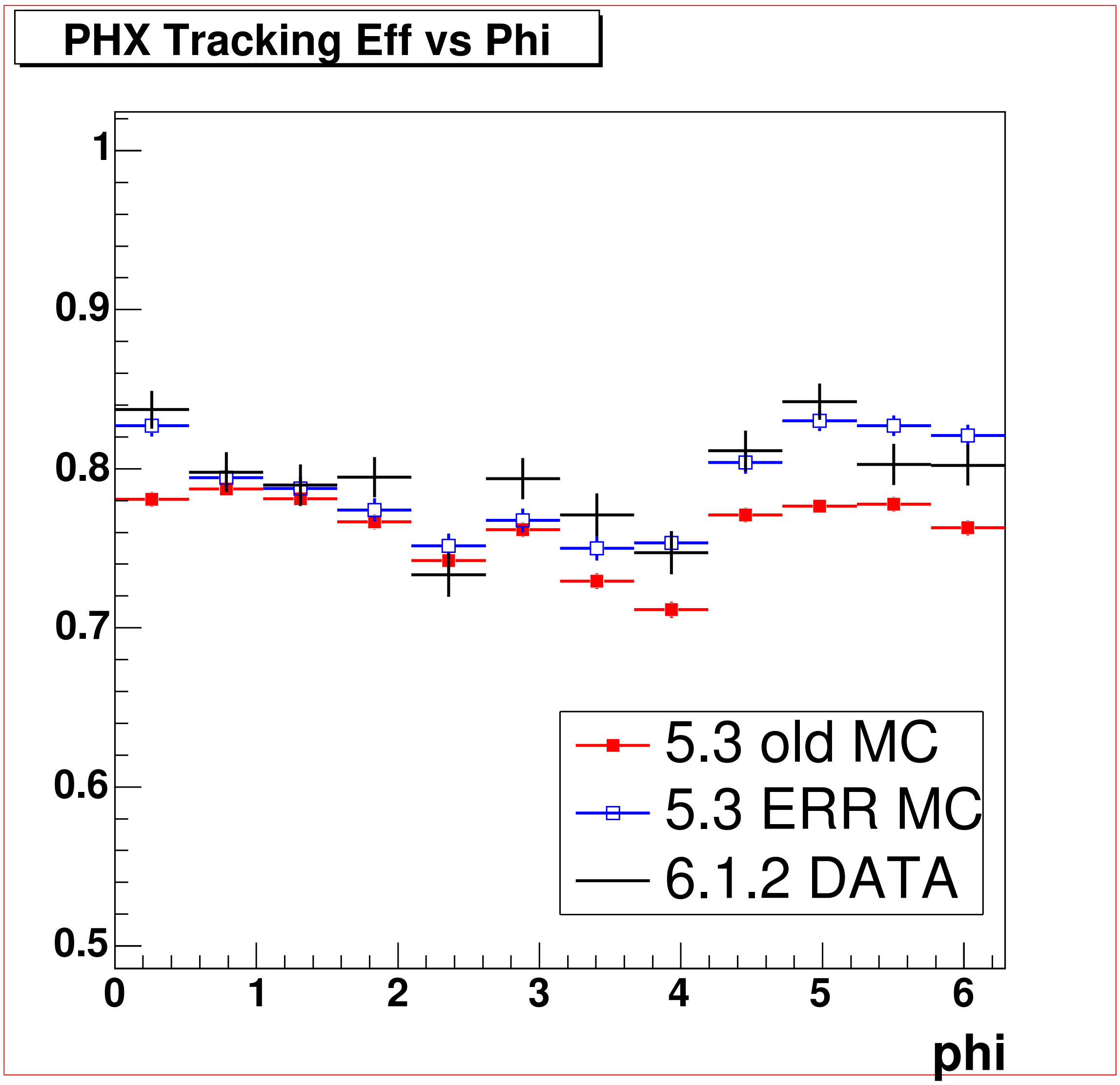

Figure 14: *PHX tracking efficiency vs* ϕ.

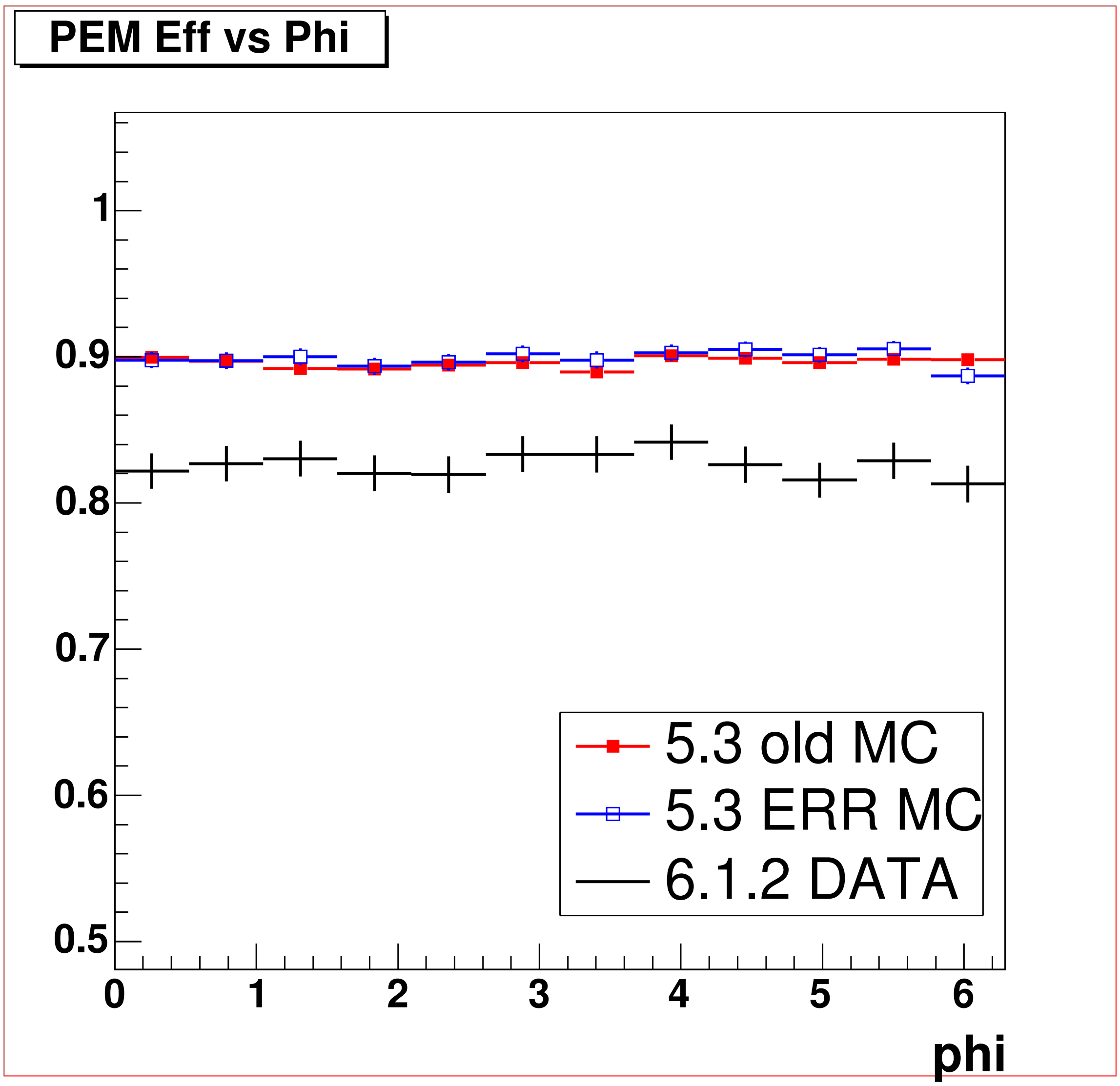

Figure 15: *PEM efficiency (plug cluster ID variables) vs* ϕ.

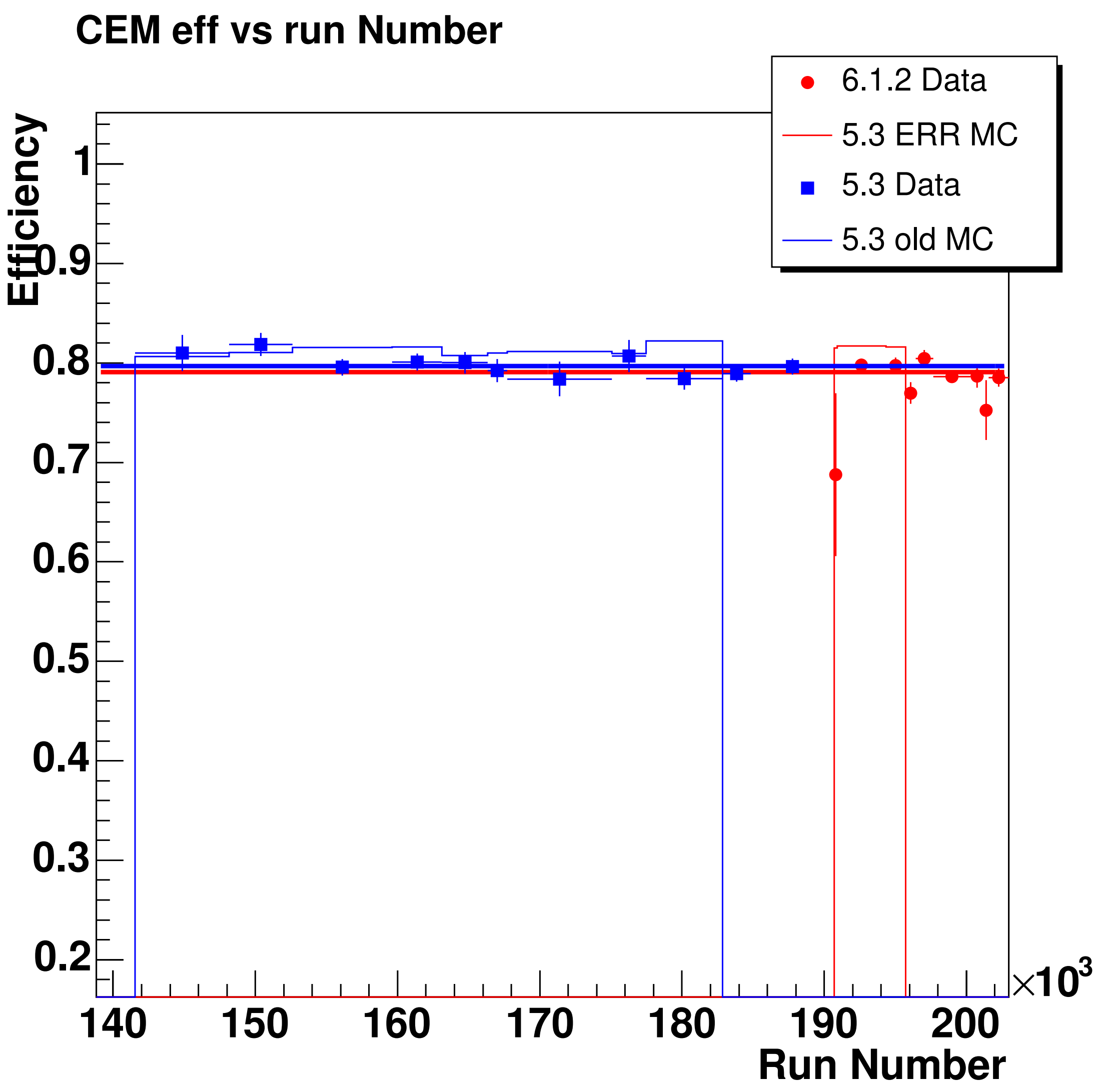

Figure 16: *CEM total ID efficiency vs run number. The thick lines are zeroth order polynomial fits (flat lines) to the data and MC. The fits are data: 0.791 ± 0.003 and MC: 0.797 ± 0.003.*

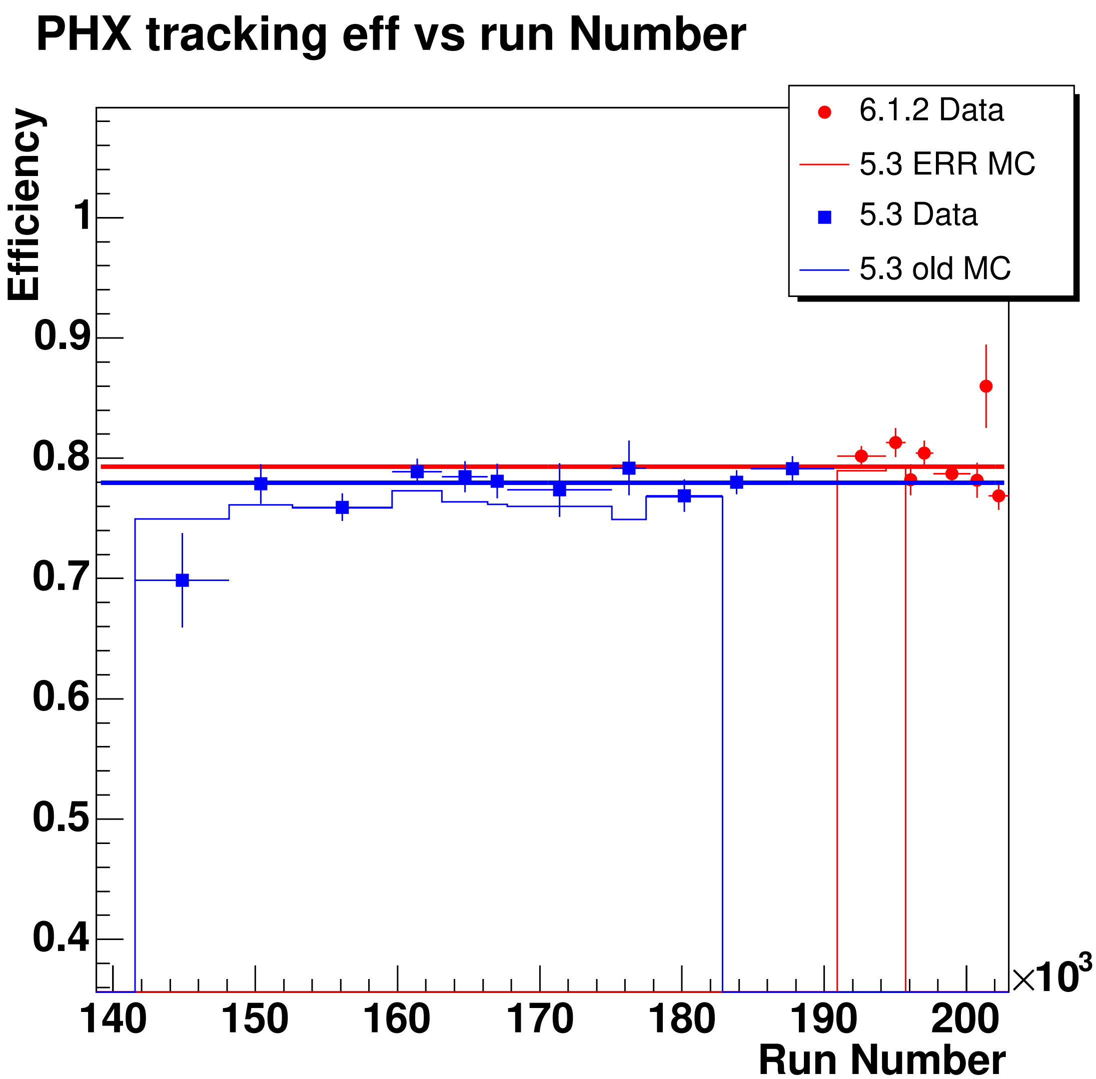

Figure 17: *PHX tracking efficiency vs run number. The thick lines are zeroth order polynomial fits (flat lines) to the data and MC. The fits are data: 0.793 ± 0.004 and MC: 0.779 ± 0.004.*

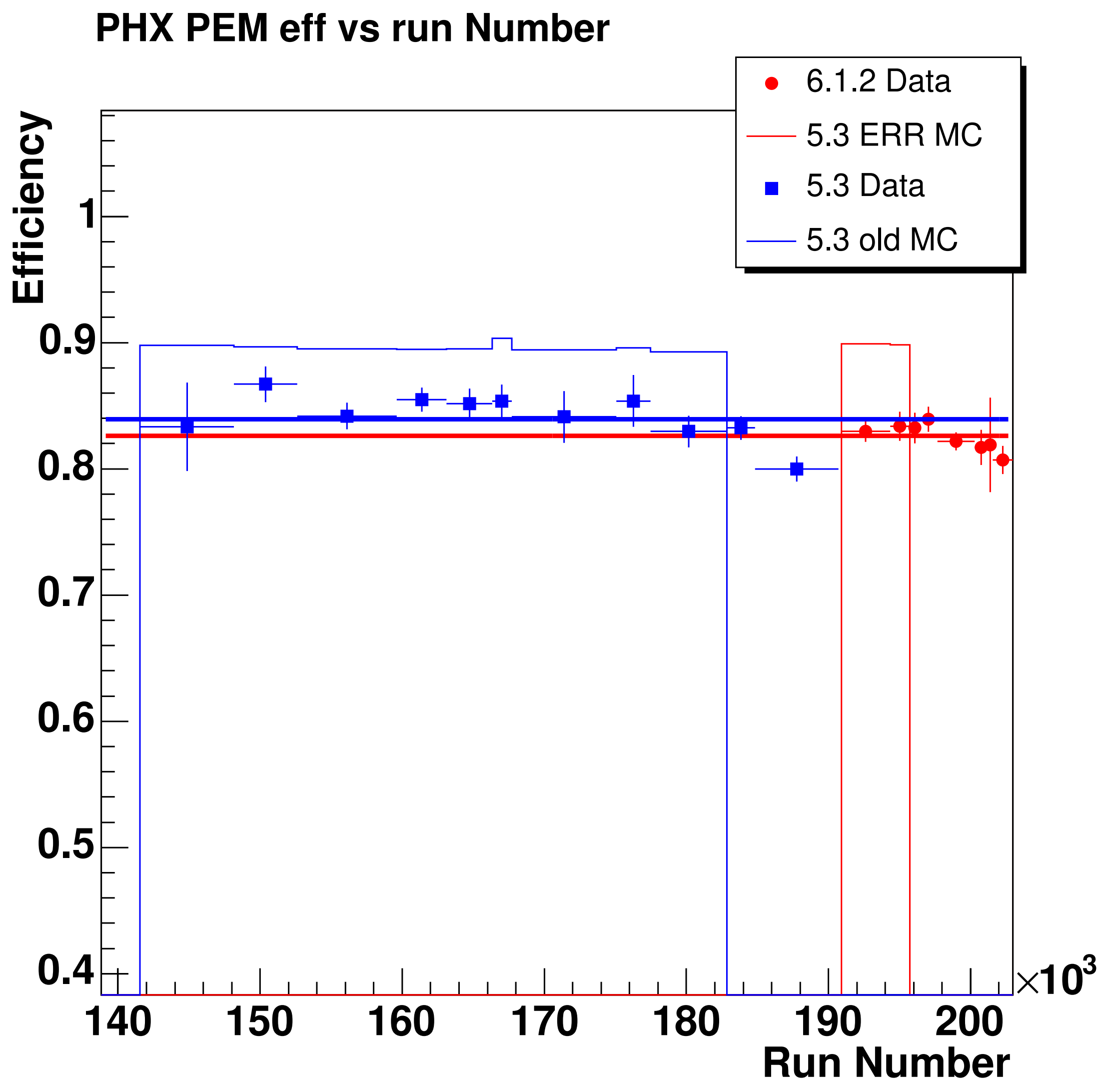

Figure 18: *PEM efficiency (plug cluster ID variables) vs run number. The thick lines are zeroth order polynomial fits (flat lines) to the data and MC. The fits are data: 0.826 $\pm$ 0.004 and MC: 0.839 $\pm$ 0.004.*

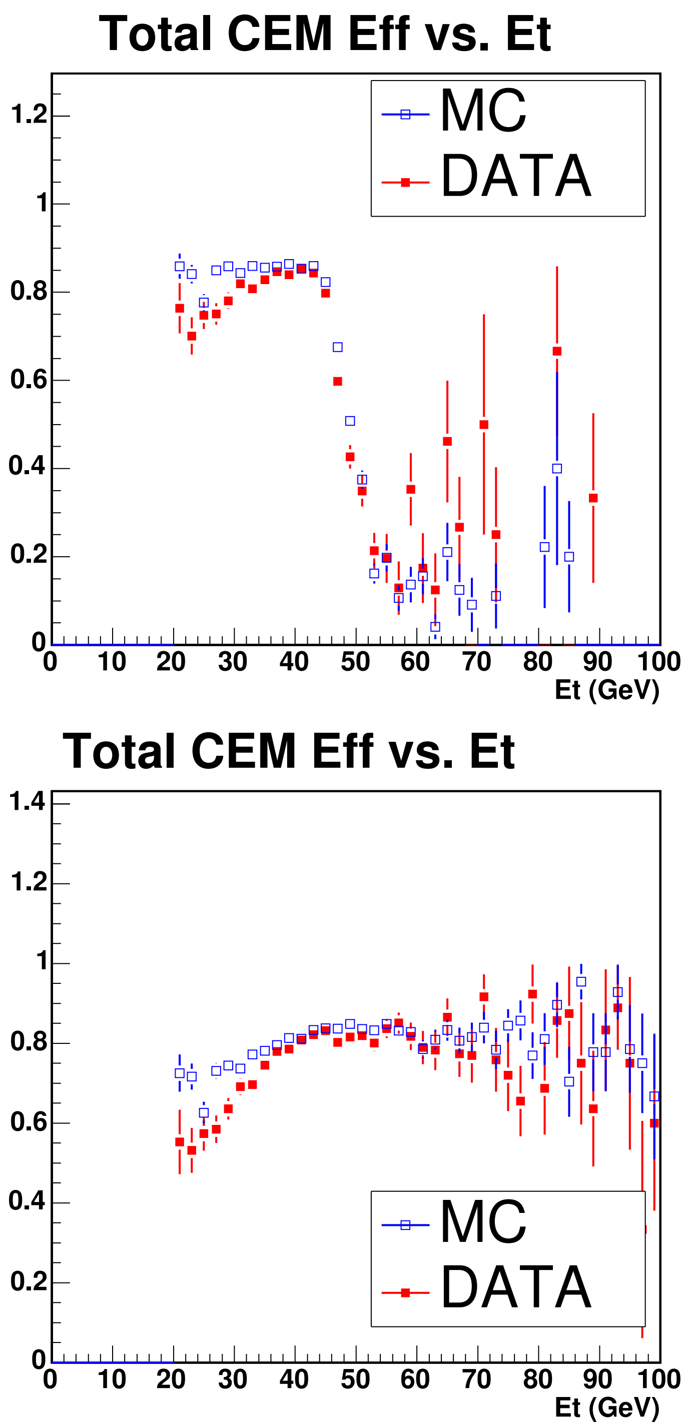

Figure 19: *CEM efficiency vs* E_T *with the biased counting method (top plot) and with the unbiased counting (bottom).*

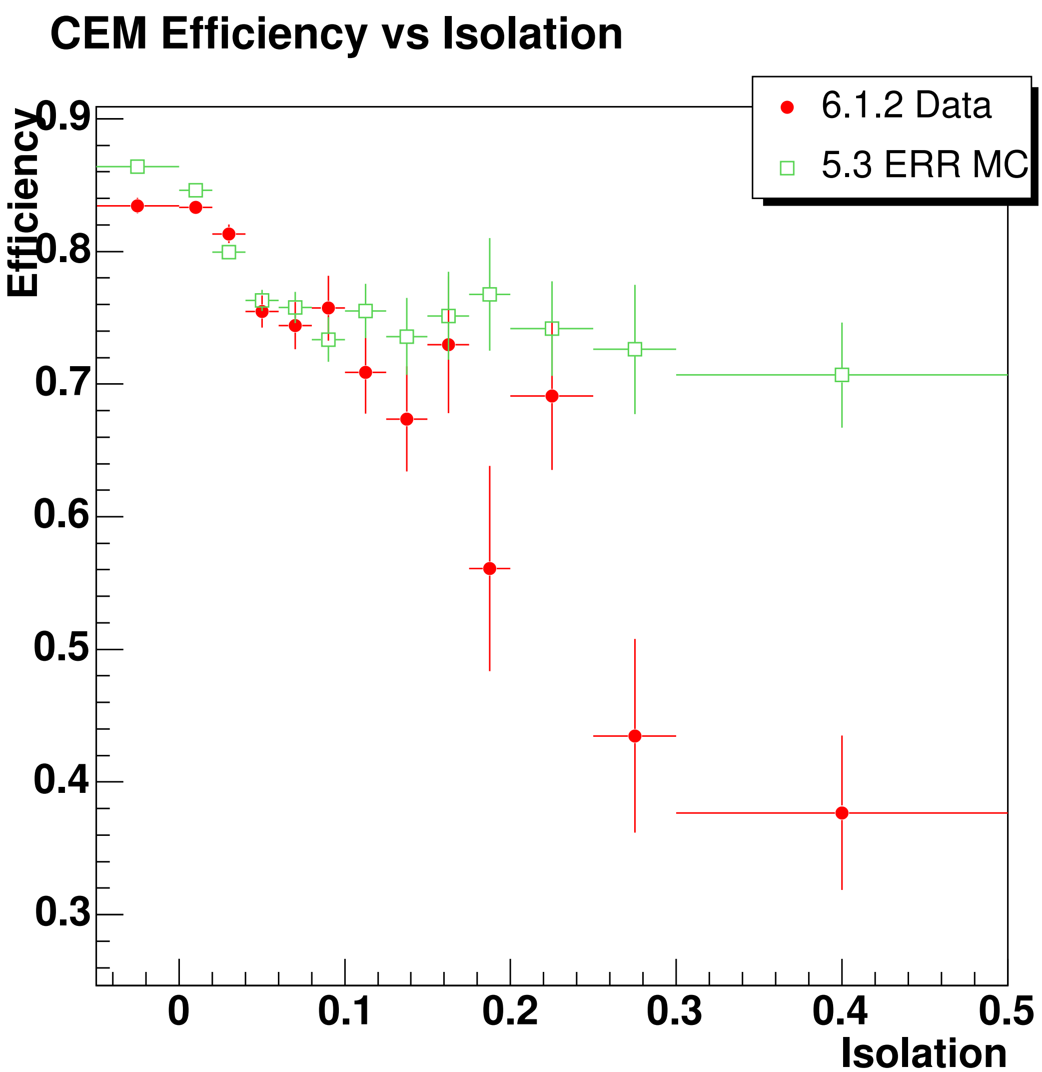

Figure 20: *CEM efficiency vs isolation.*

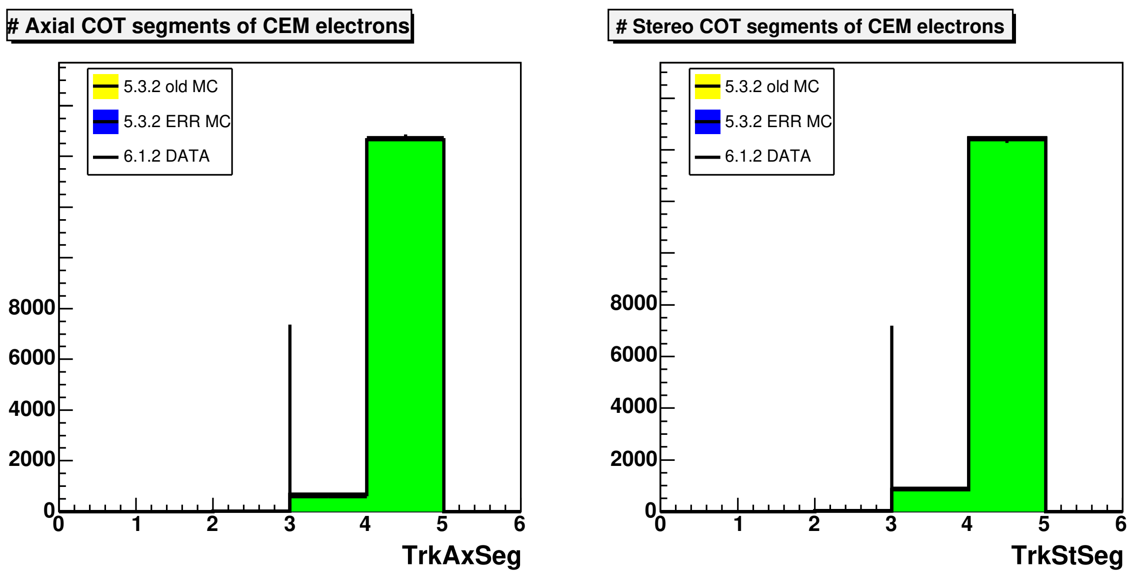

Figure 21: *CEM electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

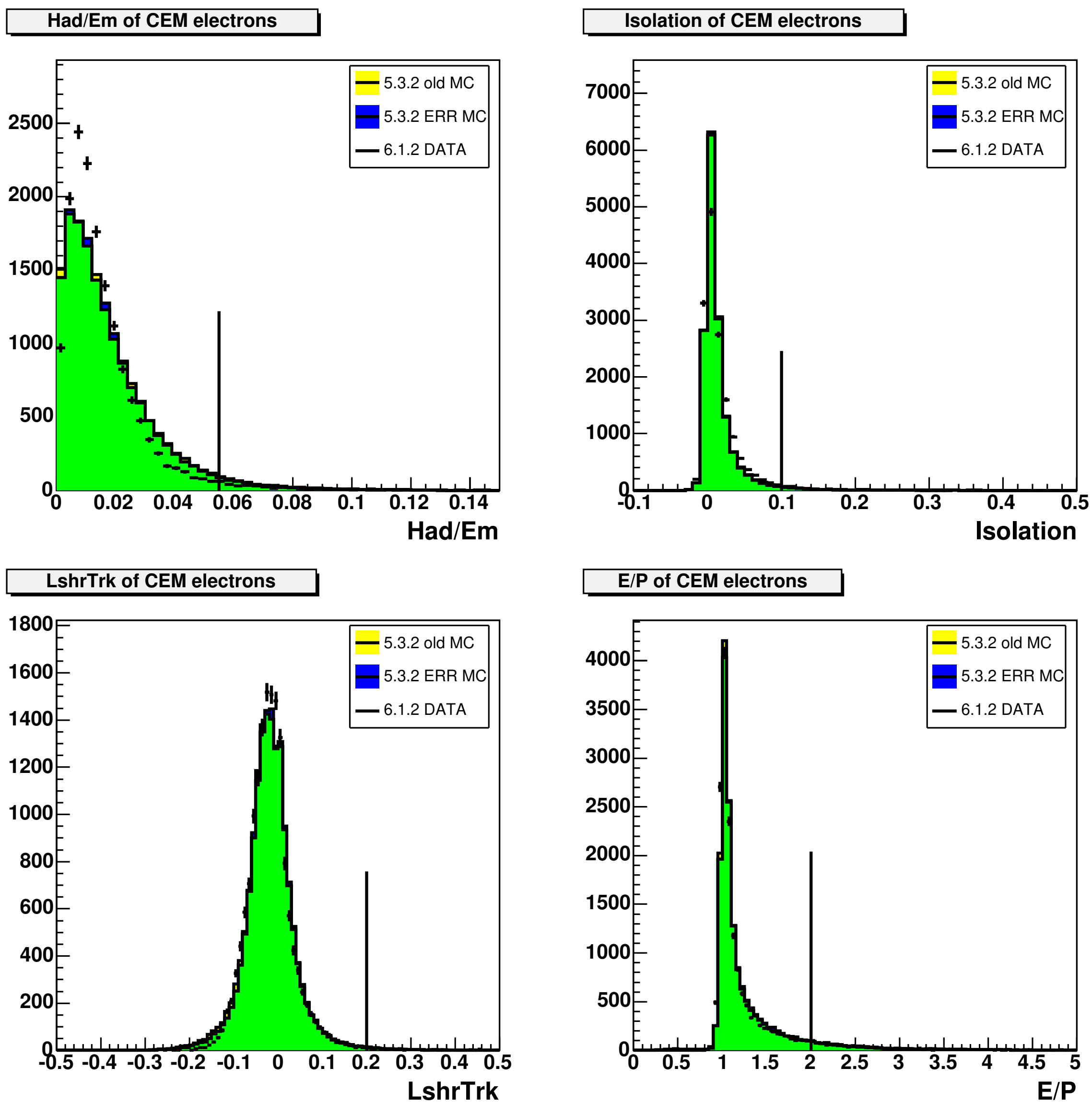

Figure 22: *CEM electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

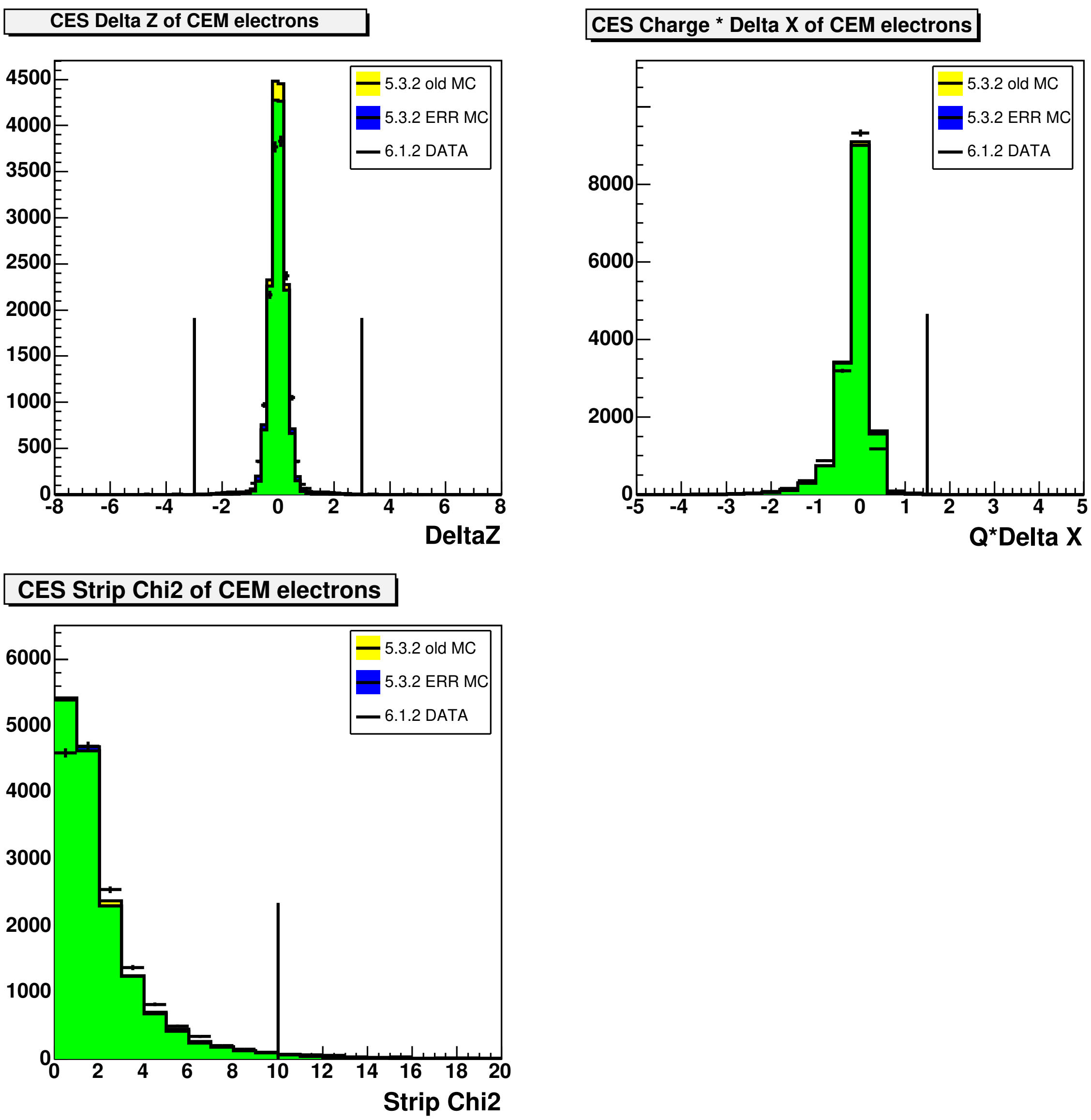

Figure 23: *CEM electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

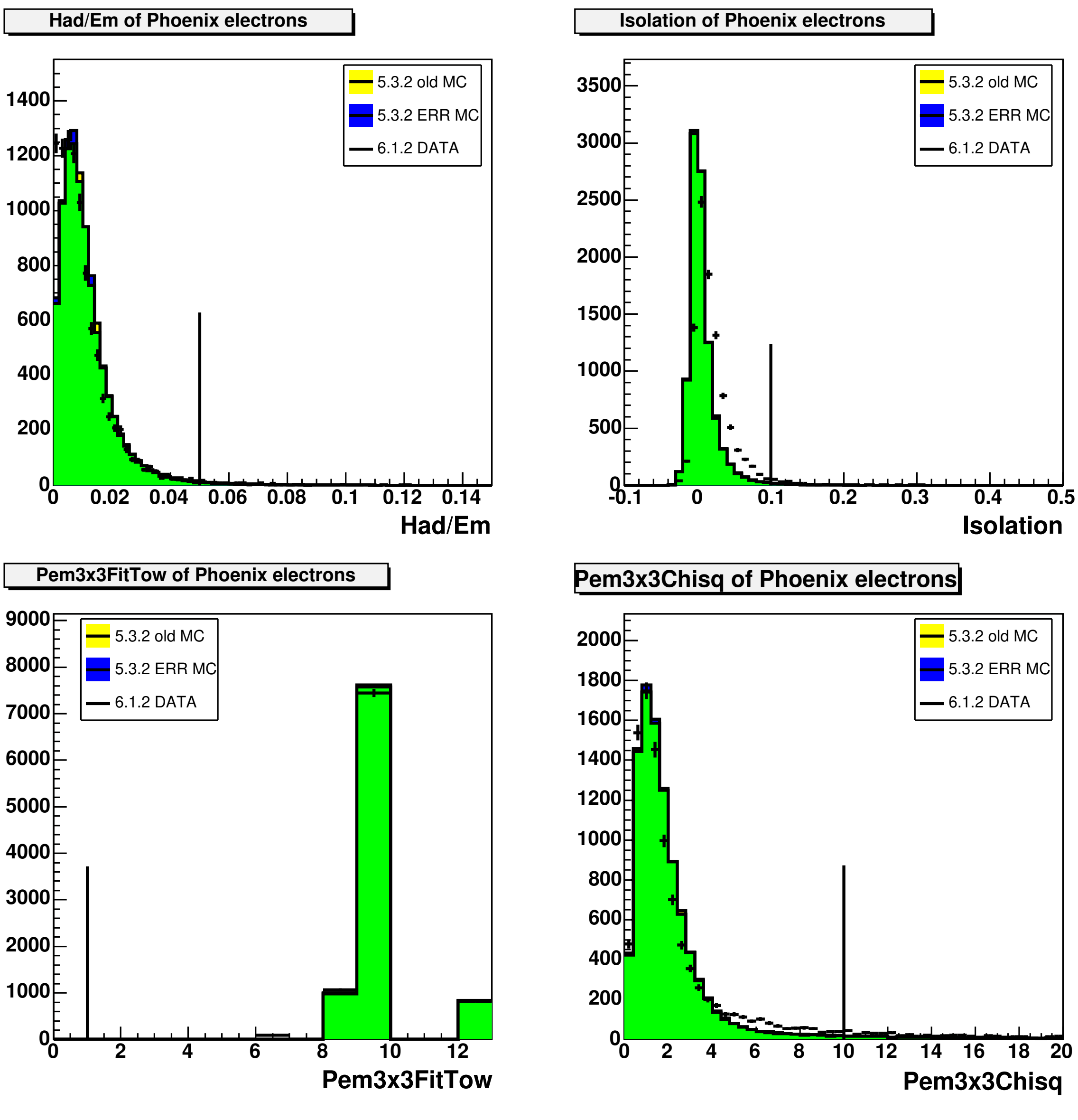

Figure 24: *PHX electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*

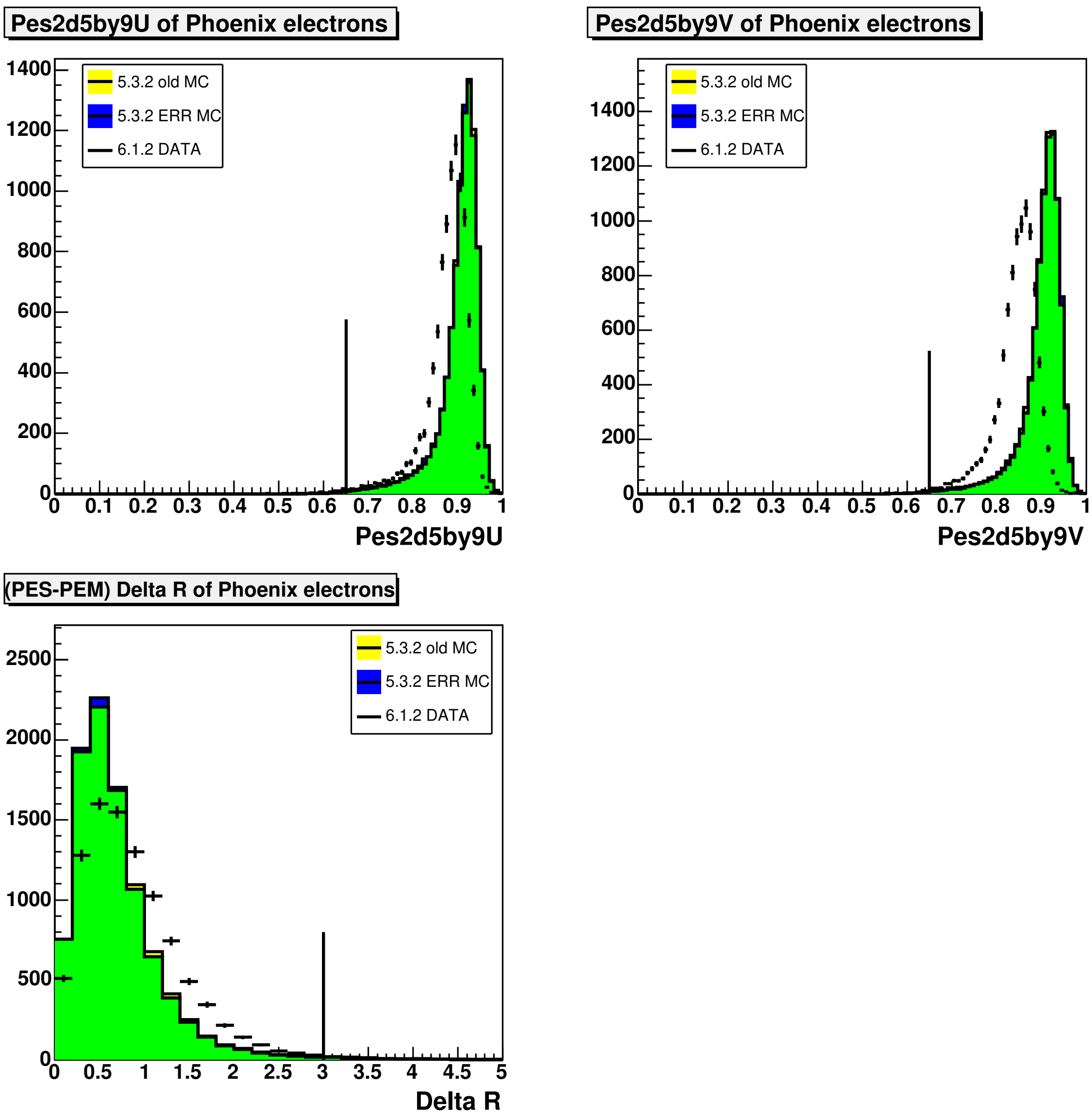

Figure 25: *PHX electron identification variables. Green is the overlap between the original 5.3.3 Monte Carlo (yellow) and the extended run range Monte Carlo (blue).*