DØnote xxxx
Version 1.0
April 10, 2002

Status of PMCS_EM

Junjie Zhu
University of Maryland

Abstract

In this Note, we describe the status of PMCS_EM package, which can be used to do fast simulations of EM objects (electrons, positrons and photons) in DØ detector. We describe in detail how electrons are smeared, how the smearing parameters were obtained from D0reco and also list some results of our fitting methods.

1 Introduction

When we analyze real data, we often need a huge volume of Monte Carlo simulation data. When we follow the normal chain from Generator, D0gstar, D0sim, D0reco to Recoanalyze, each event takes us about two minutes on d0mino, which is too slow. We need a fast simulation program for RunII.

PMCS (Parameterization Monte Carlo Simulation) is a fast simulation of the DØ detector. It contains several packages used to simulate different particle behaviors. Since PMCS goes directly from Generator to Recoanalyze, it is much faster and thus saves us a lot of time. As the name suggests, PMCS_EM is the one that does the fast simulation of EM particles (electrons, positrons and photons). As electrons and photons have almost the same behavior in the electromagnetic calorimeter, we use the same method to smear them. For the following text, we only describe the electron smearing.

2 Smearing Algorithms

We first extrapolate the generator-level electrons from the primary vertex to the EM3 layer of the calorimeter. Depending on the position in EM3, the electrons are divided into different types, and then corresponding parameters are used to smear their energy, detector eta and phi. After the electrons are smeared, we convert detector eta to physics eta and stored them in the root file. Since for DØ the tracker system is better than the calorimeter for angle measurements, if the smeared EM cluster has a track found in pmcs_chprt program, we will use the angle from the tracker system instead of that calculated from the calorimeter.

As we know, the DØ calorimeter system has three components, one central calorimeter and two forward calorimeters. For the central calorimer, there are 32 modules and for each module, the inner 80% is called the fiducial region, the outside 10% is the crack region, in PMCS_EM package the efficiency for finding electrons in the crack region is set to zero, the middle 10% is called the edge region. As the CPS covers almost all of CC region, the FPS only covers a part of EC region. For the region $1.40 < |\eta_{det}| \leq 1.45$, the FPS only has one shower layer; while for the region $1.45 < |\eta_{det}| \leq 2.50$, the FPS has two shower layers, the energy scale and energy resolution of electrons are determined seperately for each of these different regions.

In the PMCS_EM package, by considering the extrapolated position in the calorimer, the electrons are divided into nine types:

1. electrons in the CC region, but not in the CPS;
2. electrons in CC region, in the CPS and in the fiducial region;
3. electrons in the CC region, in the CPS and in the edge region;
4. electrons between $1.17 < |\eta_{det}| \leq 1.40$ that are not in the FPS;

5. electrons between $1.40 < |\eta_{det}| \leq 1.45$, in the region where the FPS has only one shower layer;

6. electrons between $1.45 < |\eta_{det}| \leq 2.46$, in the region where the FPS has two shower layers;

7. electrons between $2.46 < |\eta_{det}| \leq 4.04$, that are not in the FPS

8. electrons in the intercryostat region (ICD);

9. electrons in very forward region (with $|\eta_{det}| > 4.04$).

Electrons with type 4 and type 7 are considered different since for these two regions, DØ detector has different tracker system and thus the detector efficiencies are different. The efficiencies for finding electrons with type 8 and 9 are not set to be zero in PMCS_EM package and also are not stored in the output root file. In order to distinguish electrons in different regions, each electron is given a tag (the variable called pmcs_fid in the root_tuple), as listed in Table 1.

When we get the fitting parameters from D0reco, we use the following formulae to smear electrons at generator-level:
For energy smearing:

$$
\begin{gathered}
E' = a * E_{gen} + b \\
\frac{\sigma_E}{E} = \sqrt{C^2 + \frac{S^2}{E} + \frac{N^2}{E^2}} \\
E_{smear} = E' + x * \sigma_E
\end{gathered}
$$

For η^{det} (as measured in the calorimeter) smearing:

$$\eta^{det}_{smear} = \eta^{det}_{gen} + x * \sigma_{\eta^{det}}$$

For ϕ (as measured in the calorimeter) smearing:

$$\phi_{smear} = \phi_{gen} + x * \sigma_{\phi}$$

Where a and b are scale constants, σ_E is the energy resolution, $\sigma_{\eta^{det}}$ is the detector η resolution and σ_ϕ is the ϕ resolution, x is a random number generated with Gaussian distribution.

3 Analysis Results from D0reco

For now, we get our smearing parameters from the output of the full simulation, we will retune using real data when enough becomes available. We first use mc_runjob (pythia version: p08.13.00; d0gstar, d0sim, d0reco and reco_analyze version: p10.11.00) to generate 15 samples with single energy electrons and positrons: 5, 10, 20, 30, 50, 80, 100, 120, 150, 200, 220, 250, 300, 400, 500 Gev, each sample contains 6000 events, flat in η and ϕ space. We also divide these D0reco electrons into nine types and plot the energy, energy resolution, detector eta and phi distributions for each kind of electrons. For energy, we use a linear function $E' = a * E_{gen} + b$ to fit it, where a and b are energy scale constants; for energy resolution, use $\frac{\sigma_E}{E} = \sqrt{C^2 + \frac{S^2}{E} + \frac{N^2}{E^2}}$ to fit it, where C is the Constant term, S is the Sampling term and N is the Noise term and σ_E is the energy resolution. For Run I, we have $C = 0.003$, $S = 0.13$ and $N = 0.38$ for central calorimeter. For detector eta, we calculate the difference between η^{det} for reconstructed electrons and η^{det} for generated electrons, then use a Gaussian function to fit it. For phi, the method is the same as the detector eta. We first calculate the difference between ϕ for reconstructed electrons and ϕ for generated electrons, then use Gaussian function to fit it. The fitting results are listed on Table 2. As we stated above, we do not find electrons with type 1 and the efficiencies for finding electrons with type 8 and type 9 are set to be zero, so here we only listed the results for the rest six types of electrons.

Figure 1 shows the energy scale for these six different regions, Figure 2, 3 and 4 are the energy resolution, detector eta and phi resolution.

4 Fitting Results from PMCS_EM

We tested PMCS_EM package using two event samples by comparing the results from D0reco and PMCS. The two event samples are: 1. 2000 $Z \to ee$ events with MinBia 2.5. Pythia version: p08.13.00, d0gstar, d0sim, d0reco and reco_analyze version: p10.11.00; 2. 2000 $W \to e\nu$ events also with MinBias 2.5, all versions are the same as those for $Z \to ee$ events.

Since the smearing parameters used in Table 2 are getting from single energy electrons with zero MinBias event, but for the $Z \to ee$ and $W \to e\nu$, we have to consider the effect of underlying events. If we use the parameters in Table 2, the Z peak for CC-CC region is 89.833 Gev, while for EC-EC region the peak is 90.722. For D0reco version p10.11.00, the Z peaks for the two cases are 91.69 and 91.20 Gev, so we rescaled the energy constants by multiplying a and b by 1.0207 in CC and 1.0053 in EC region.

Figure 5 is the invariant mass distribution for all Z events; Figure 6, 7 and 8 are the invariant mass distribution for CC-CC, CC-EC and EC-EC events; Figure 9, 10 and 11 are detector eta, physicss eta and physics pT distributions for electrons in $Z \to ee$ events. Figure 12 is phi distribution for electrons in CC region. Figure 13, 14 and 15 are detector eta, physics eta and physics pT distributions for electrons in $W \to e\nu$ events. Figure 16 is phi distribution for electrons in CC region,

5 Variables stored in the root file

PMCS can produce the root tuple in the same format as EM_Analyze, but it is much slower. For the pmcs_em part, we store the following information:

for each smeared electron:

pmcs_em_eles: energy;
pmcs_em_elpts: physics P_T;
pmcs_em_elptds: detector P_T;
pmcs_em_eletas: physics η;
pmcs_em_eletads: detector η;
pmcs_em_elphis: ϕ.

for each generated electron:

pmcs_em_eleg: energy;
pmcs_em_elptg: physics P_T;
pmcs_em_eletag: physics η;
pmcs_em_elphig: ϕ.

other related variables:

pmcs_em_eledf: energy difference between generated electron and smeared electron;
pmcs_em_elptdf: physics P_T difference between generated electron and smeared electron;
pmcs_em_elpttr: physics P_T from pmcs_chprt;
pmcs_em_eliso: isolation fraction of smeared electron;
pmcs_em_elfid: position tag for generated electron.

6 Conclusions

PMCS_EM package now seems to agrees well enough with D0reco results, but we still need to retune it with real data.

7 Acknowledgements

We would like to thank Florencia Canelli, Dookee Cho and Shawn Kwang for previous work on this package.

References

[1] Improved W boson mass measurement with the DØ detector, version 3.2

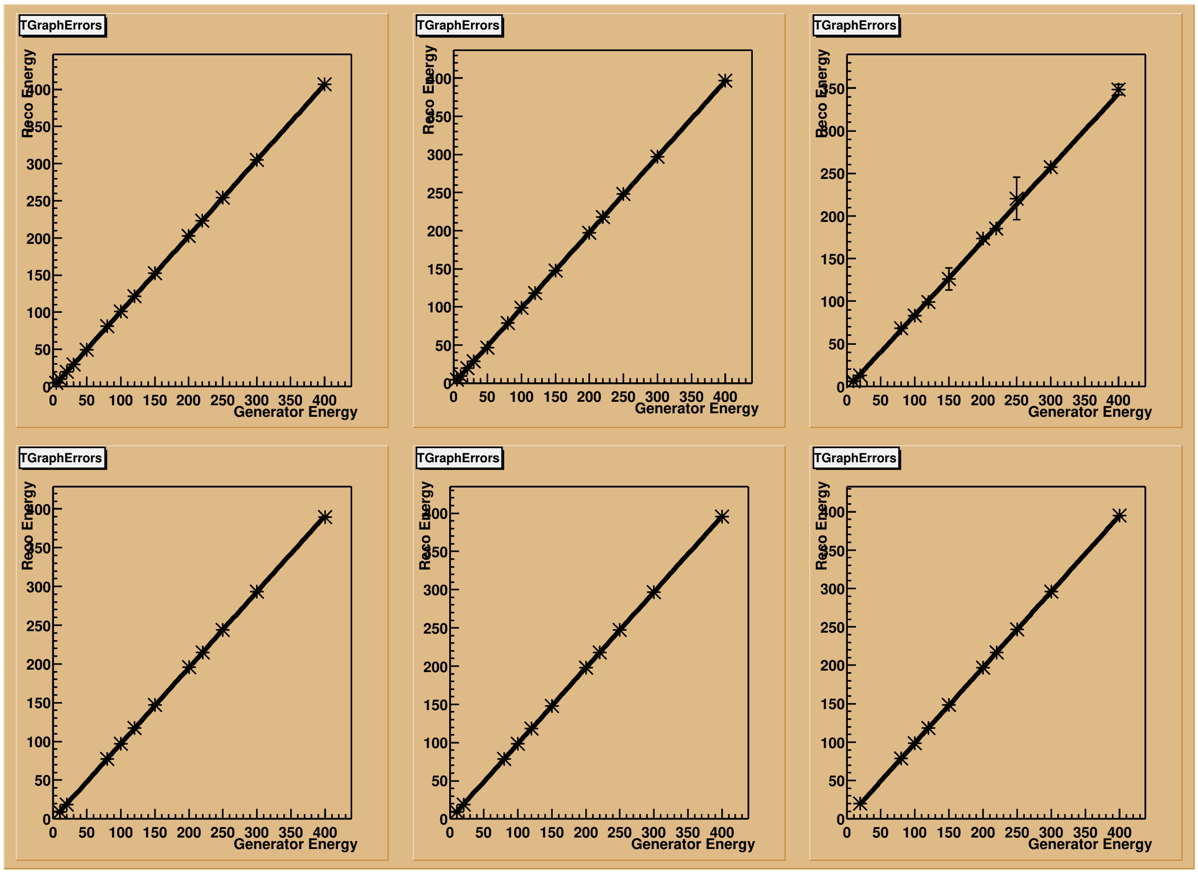

Figure 1: Energy scale for six different regions

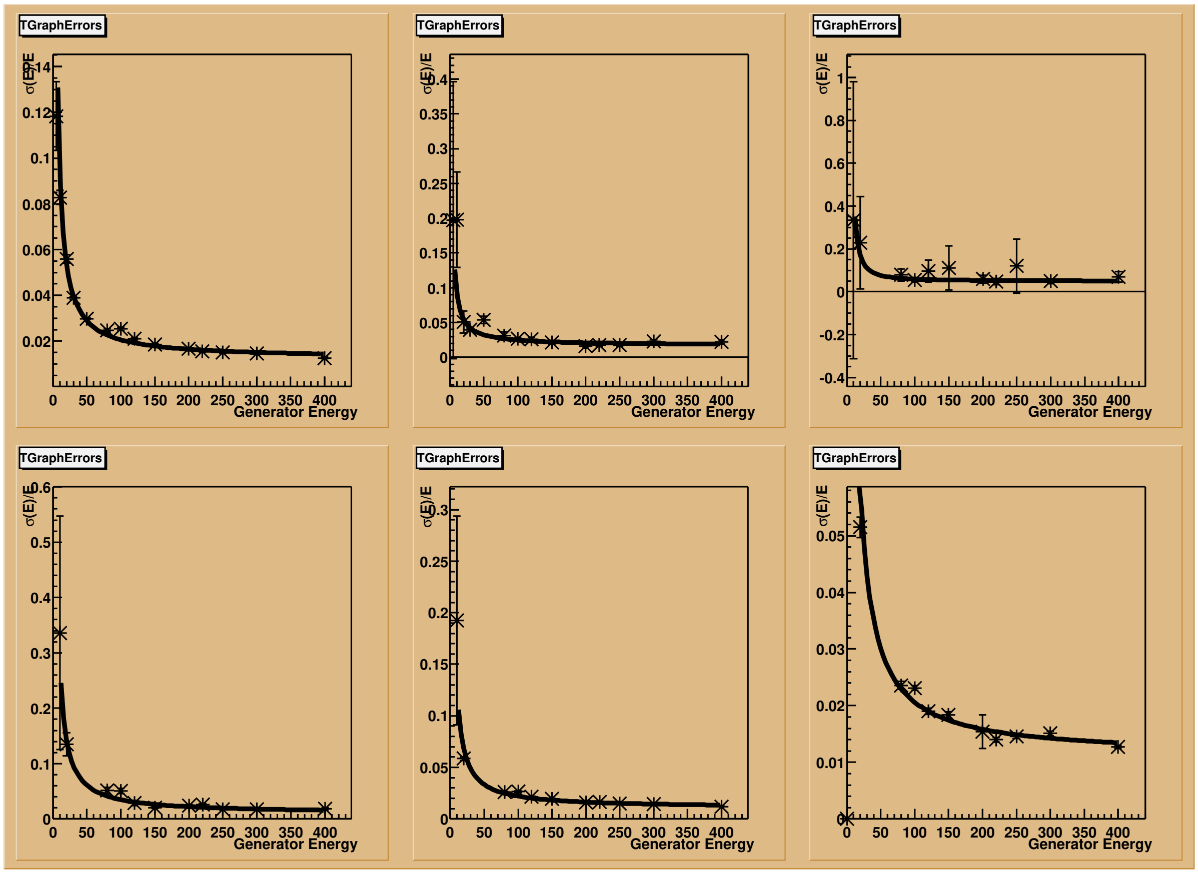

Figure 2: Energy resolution for six different regions

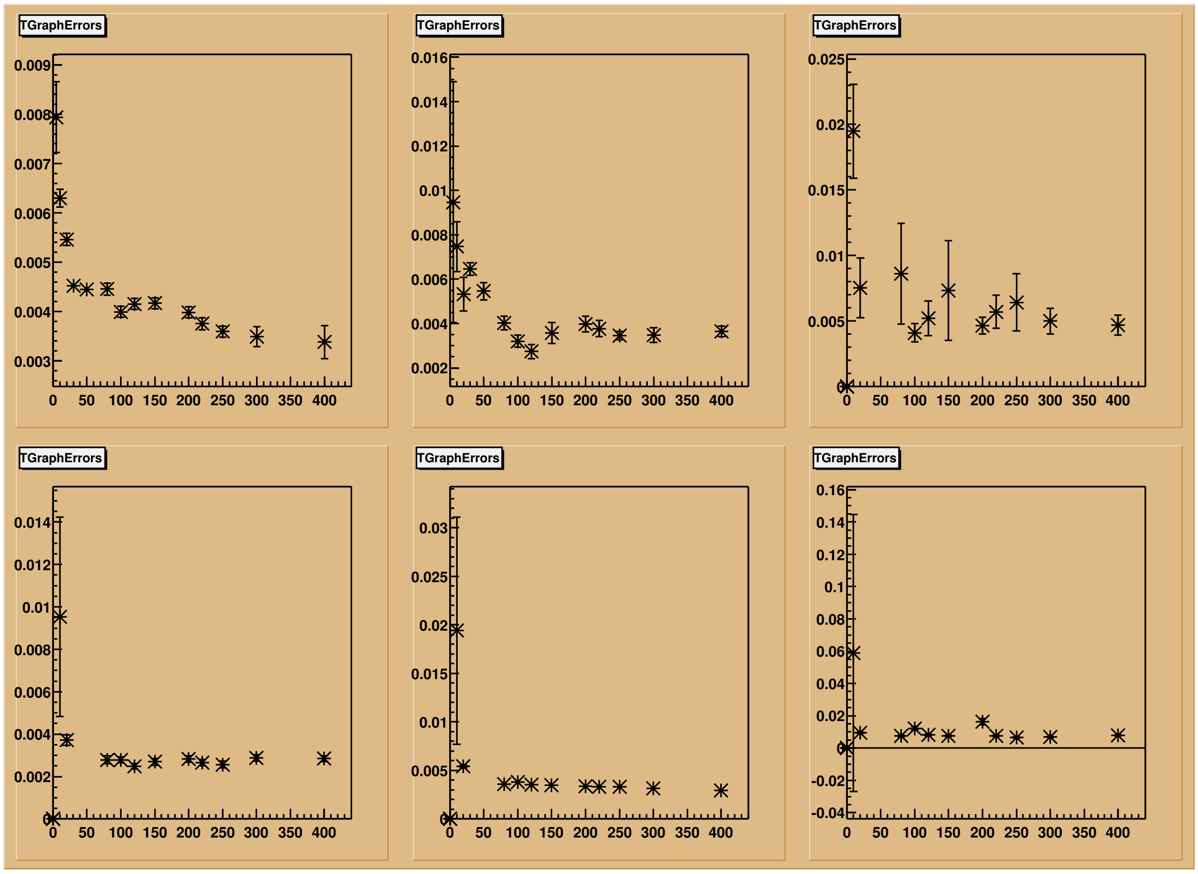

Figure 3: Eta resolution for six different regions

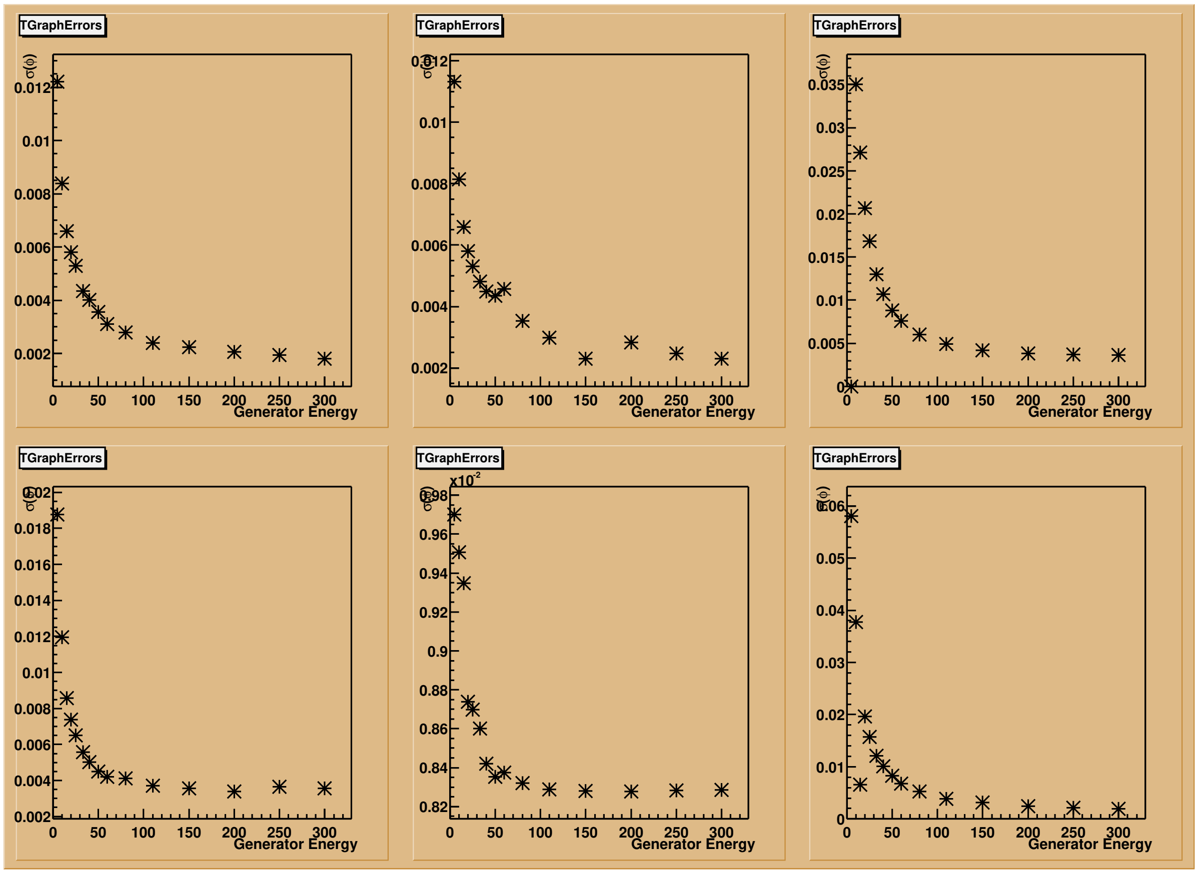

Figure 4: Phi resolution for six different regions

Electron Type	1	2	3	4	5	6	7	8	9
pmcs_fid	1	2	3	4	5	6	7	0	-1

Table 1: Tags for different types of electrons

Electron Type	2	3	4	5	6	7
a	1.0399	1.0133	0.8715	0.9816	0.9971	0.9907
b	-1.0142	-0.8858	-2.9684	-0.6470	-0.8063	0.1705
C	0.0110	0.02819	0.02890	0.00484	0.00765	0.01873
S	0.14398	0.34203	0.46708	0.0002	0.20608	0.18732
N	0.35203	0.0000	-0.00359	0.00484	0.01245	0.50548
$\sigma_{\eta^{det}}$	0.005	0.005	0.004	0.003	0.004	0.006
σ_{ϕ}	0.003	0.003	0.005	0.005	0.008	0.008

Table 2: Different smearing parameters getting from single energy electron samples

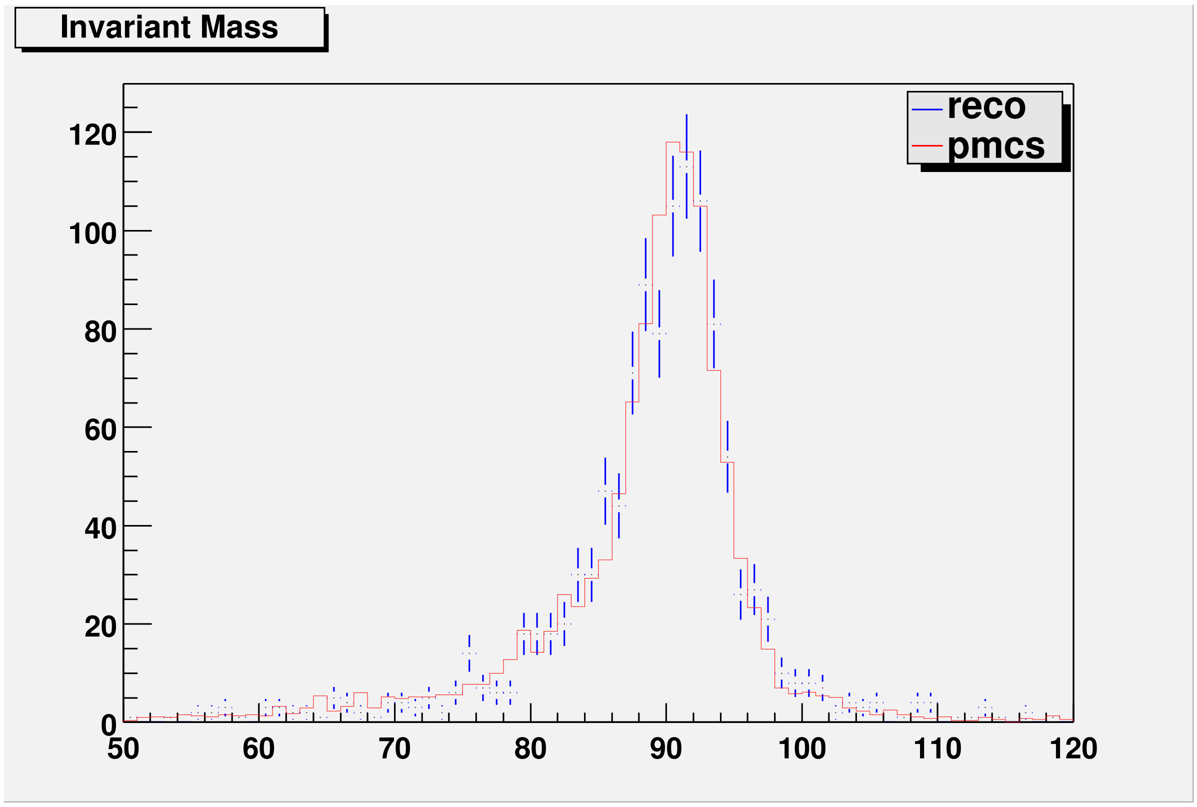

Figure 5: Invariant mass distribution for $Z \to ee$ events, red for pmcs, blue for D0reco

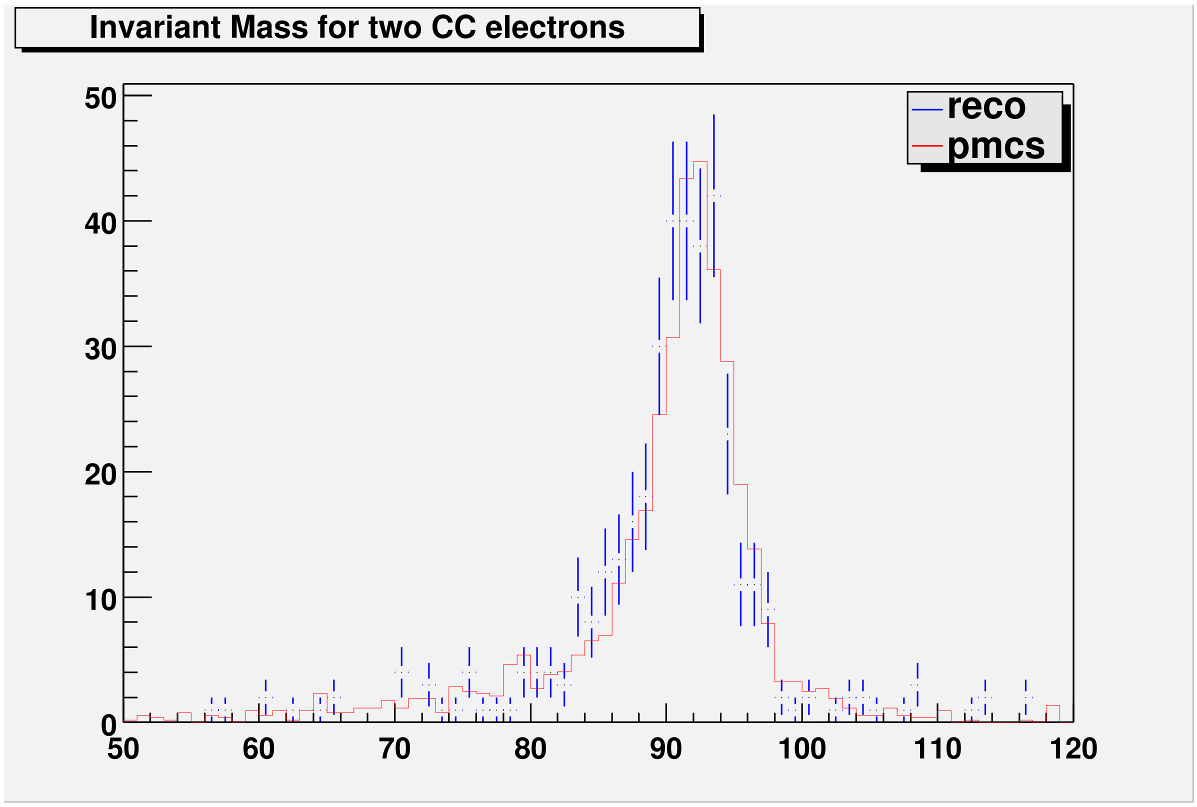

Figure 6: Invariant mass distribution for CC-CC events, red for pmcs, blue for D0reco

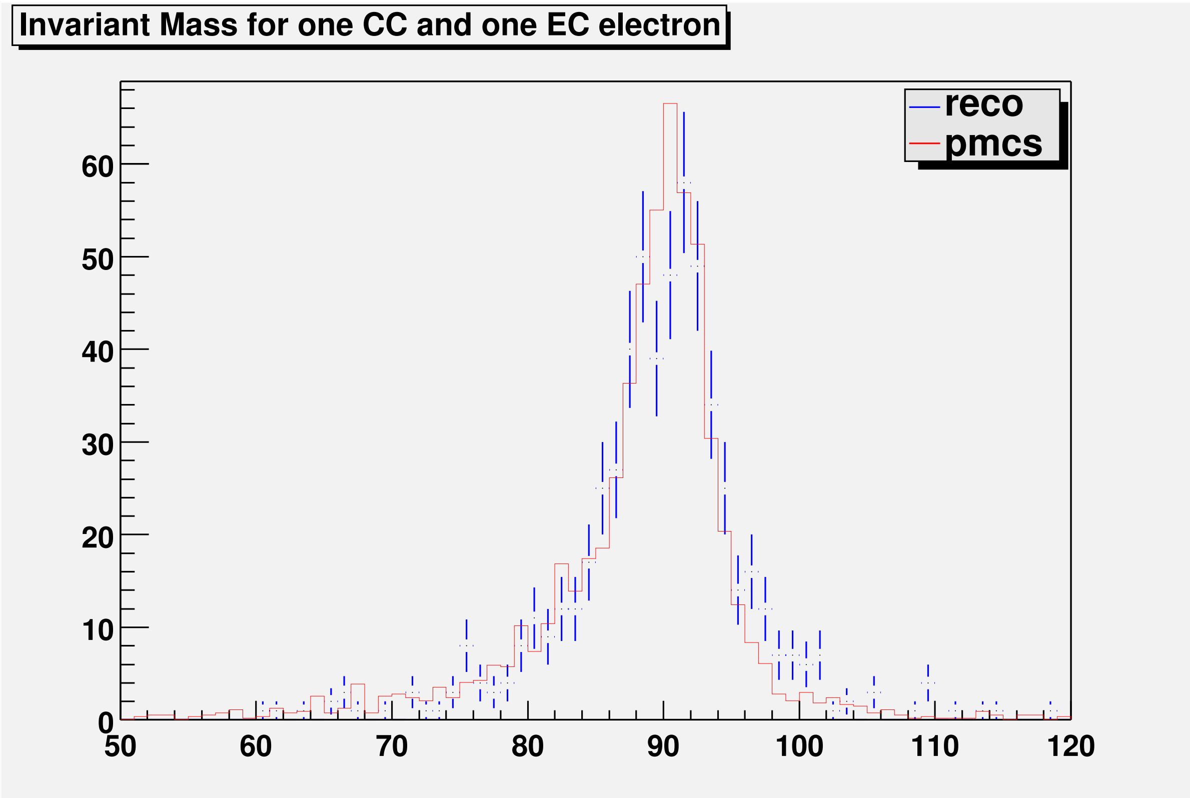

Figure 7: Invariant mass distribution for CC-EC events, red for pmcs, blue for D0reco

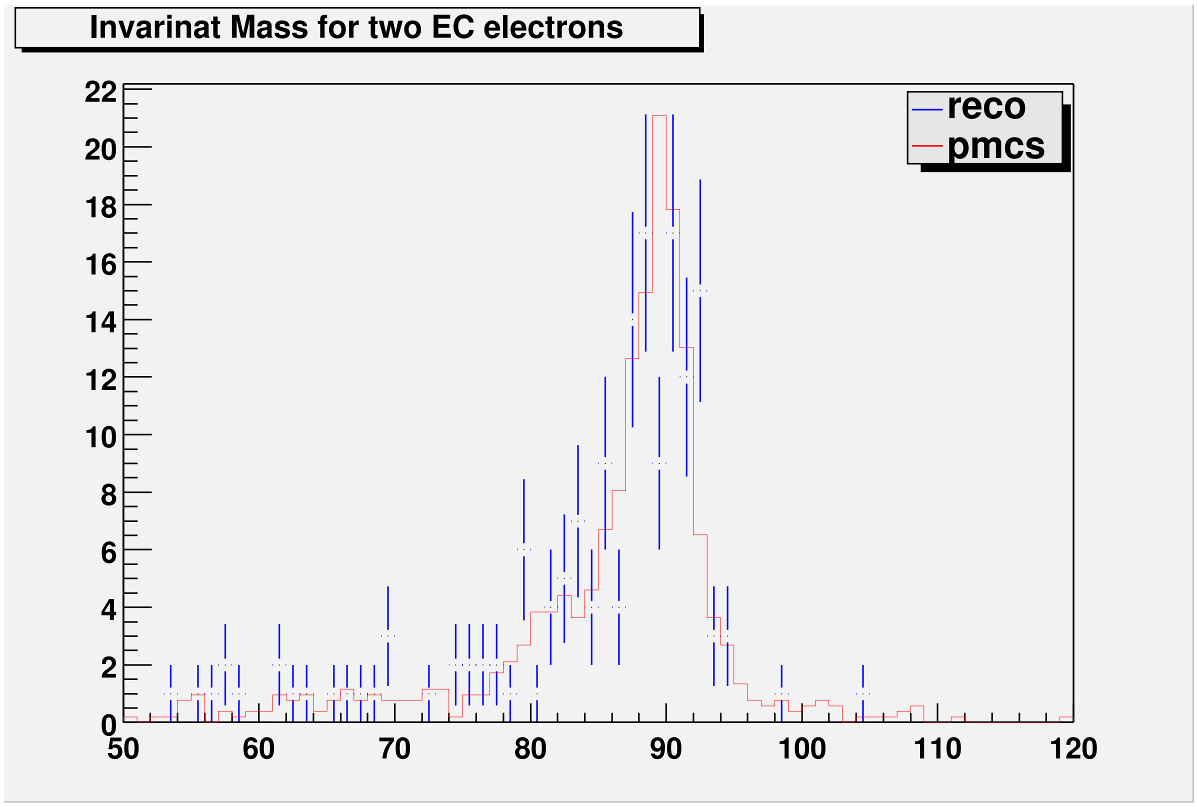

Figure 8: Invariant mass distribution for EC-EC events, red for pmcs, blue for D0reco

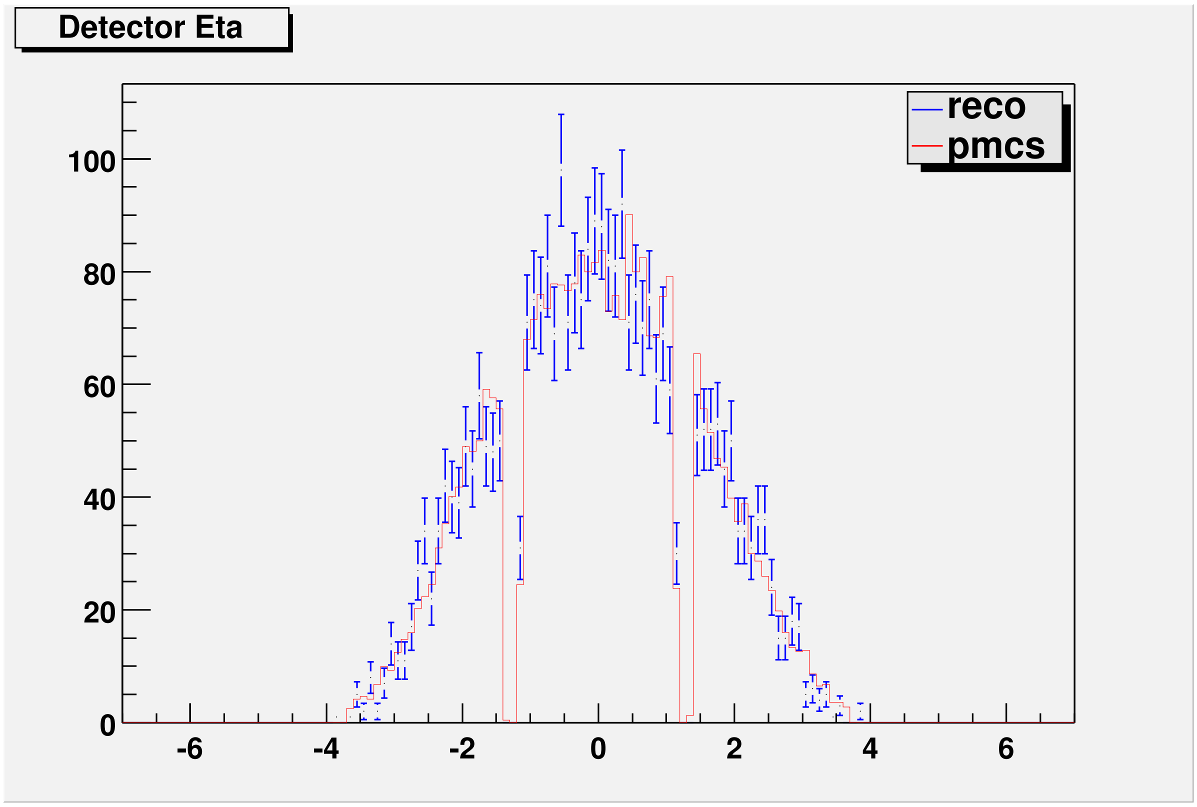

Figure 9: η_{det} distribution for electrons in $Z \rightarrow ee$ events, red for pmcs, blue for D0reco

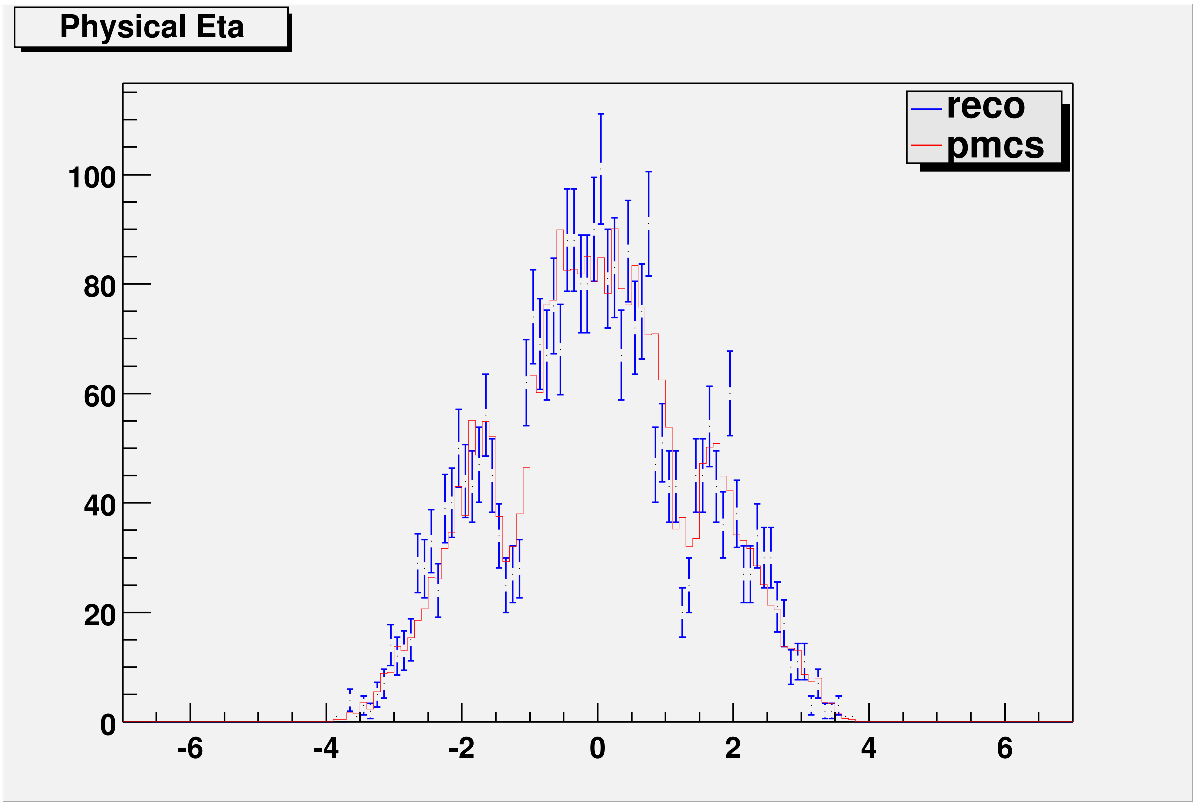

Figure 10: η_{phy} distribution for electrons in $Z \to ee$ events, red for pmcs, blue for D0reco

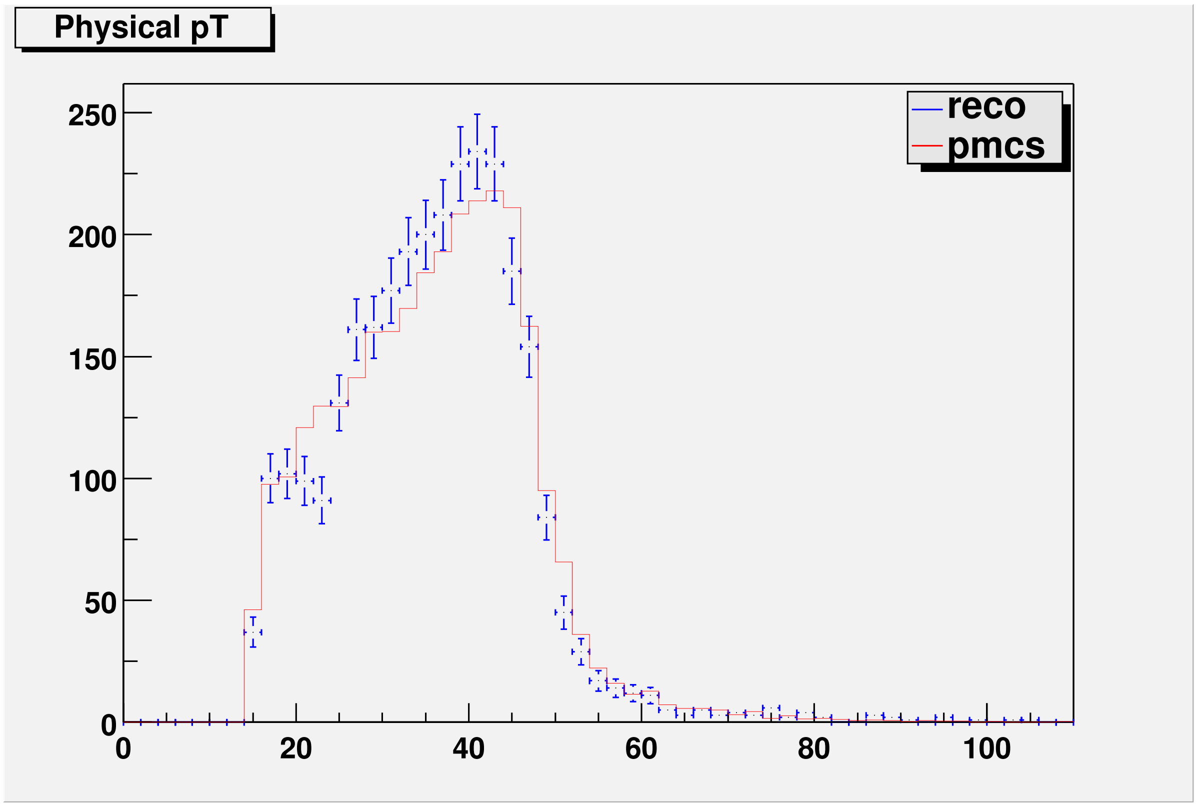

Figure 11: P_T^{phy} distribution for electrons in $Z \to ee$ events, red for pmcs, blue for D0reco

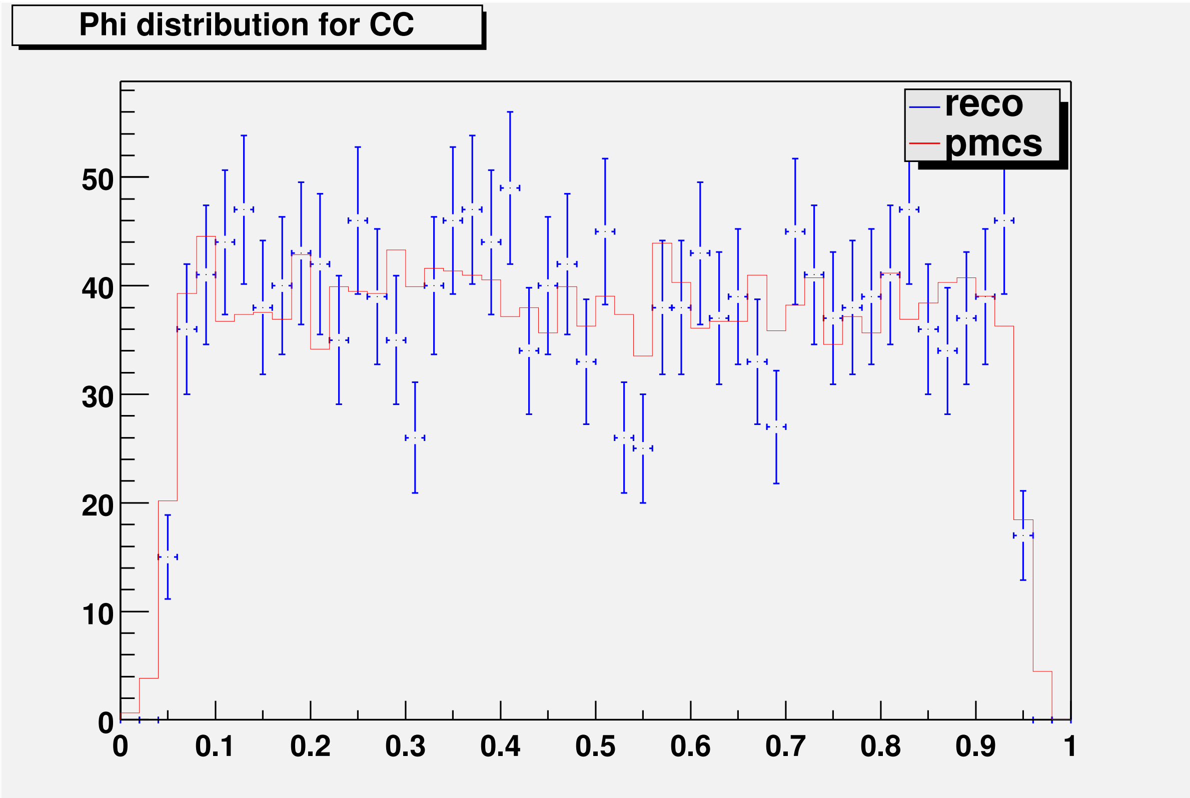

Figure 12: ϕ distribution for CC electrons in $Z \to ee$ events, red for pmcs, blue for D0reco

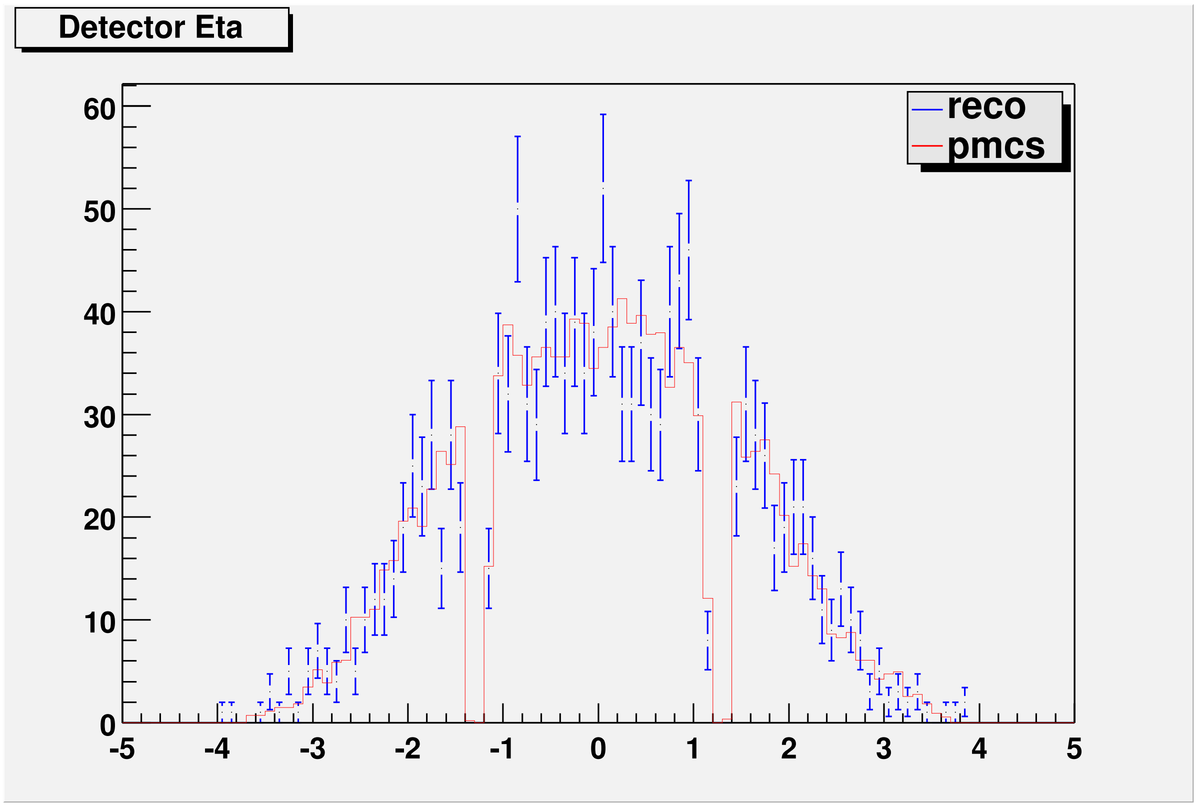

Figure 13: η_{det} distribution for electrons in $W \to e\nu$ events, red for pmcs, blue for D0reco

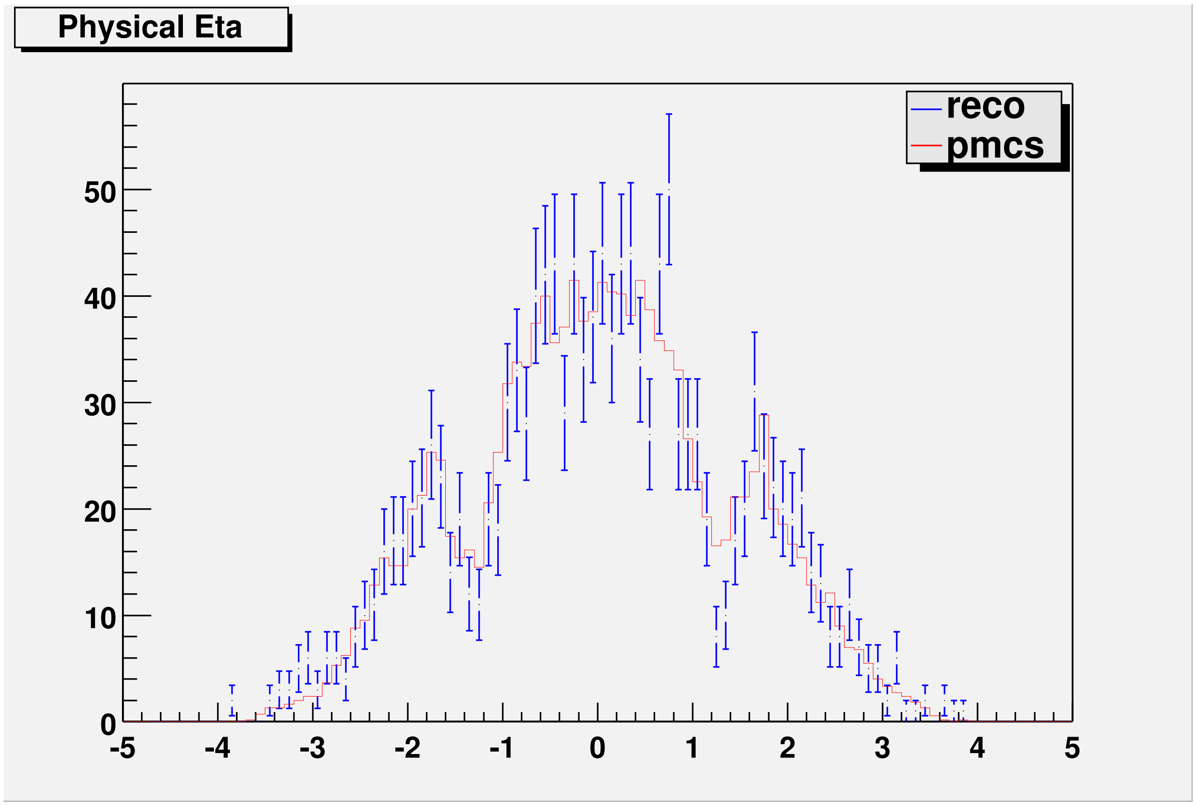

Figure 14: η_{phy} distribution for electrons in $W \rightarrow e\nu$ events, red for pmcs, blue for D0reco

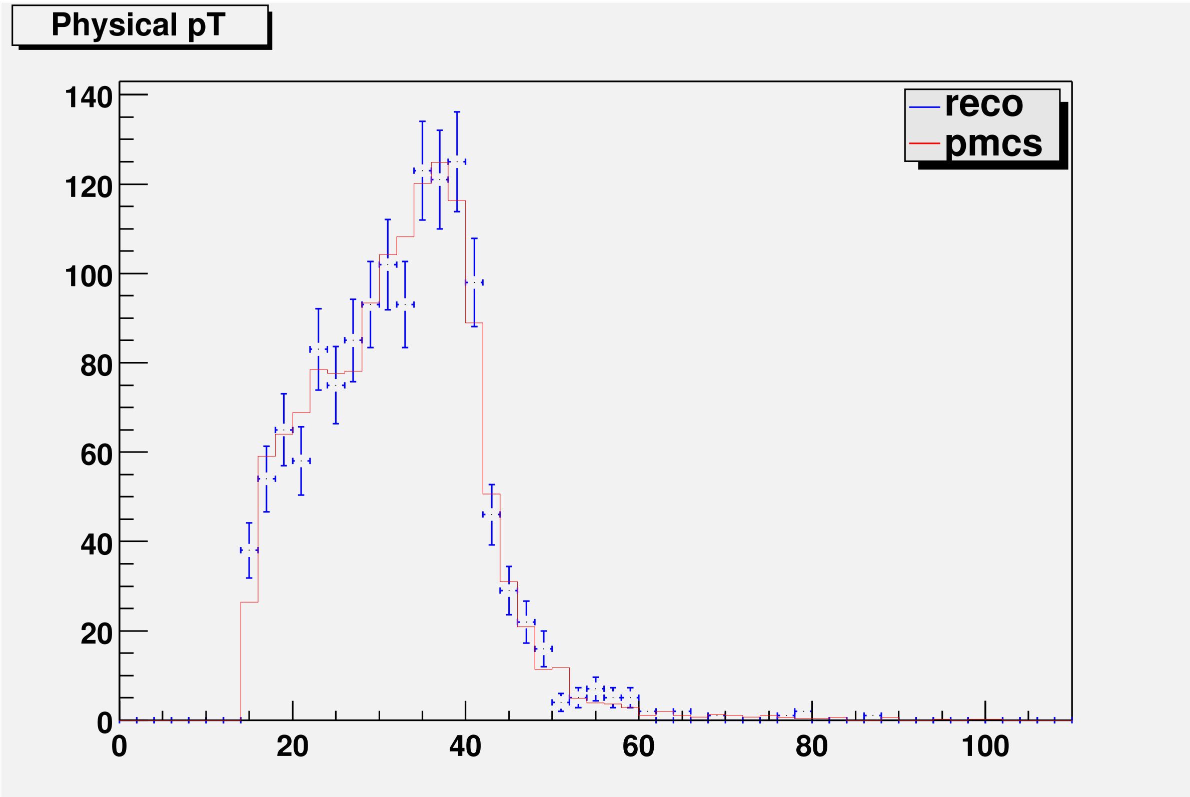

Figure 15: P_T^{phy} distribution for electrons in $W \to e\nu$ events, red for pmcs, blue for D0reco

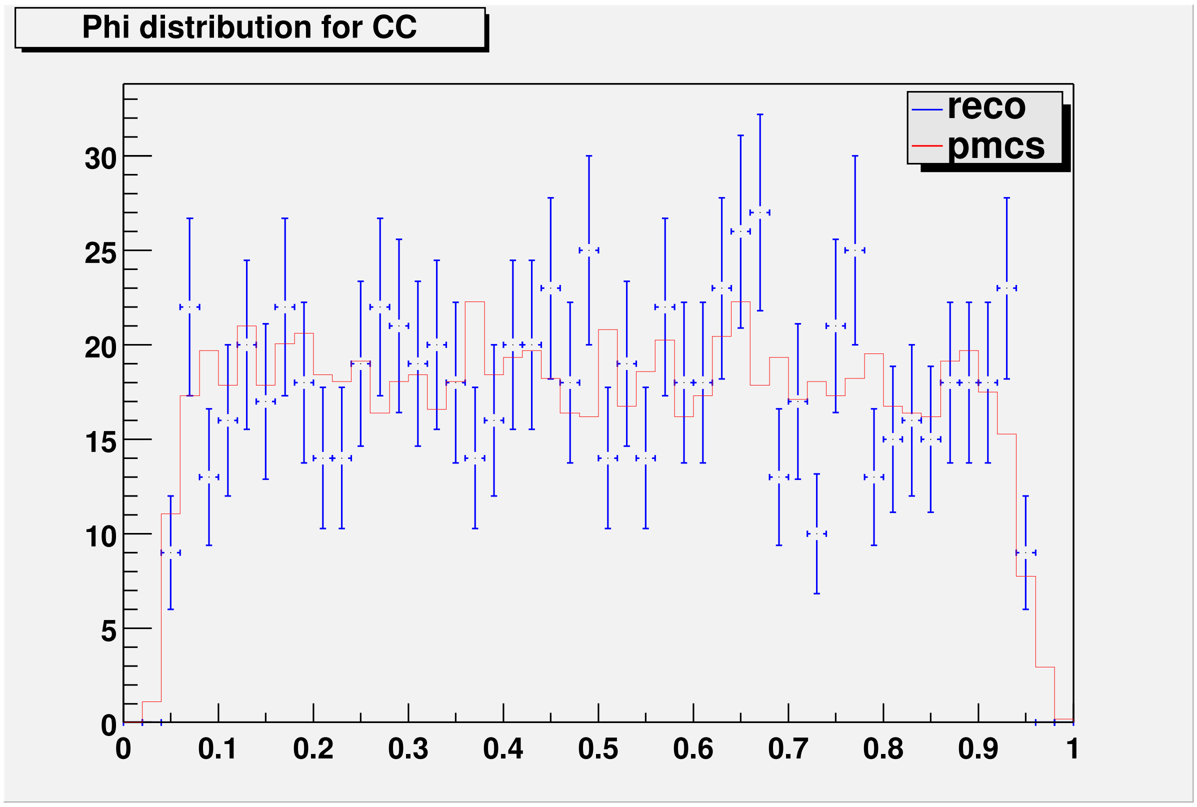

Figure 16: ϕ distribution for electrons in $W \to e\nu$ events, red for pmcs, blue for D0reco