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Systematic Uncertainties Associated with Jet Corrections for Winter 2003 Conferences

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Abstract

We present an estimate of the systematic uncertainties on the jet energy corrections used for Winter 2003 Conferences. Systematics on data and Monte Carlo for corrected jets, as well as for raw jets are given.

1 Introduction

In order to convert the jet E_T measured in the calorimeter to a quantity which can be compared to physics predictions, one has to apply many corrections. Each correction have associated systematic uncertainties. In addition, the current Monte Carlo simulation of the calorimeter does not adequately reproduce the $p\bar{p}$ data, instead the simulated response differs from the one observed in collider data as a function of η. Furthermore, photon-jet balancing results suggest that, after applying all corrections, the calorimeter jet energy in simulated data may not be the same as in collider data. These discrepancies and our general lack of understanding of some of the observed effects, lead to undesirable large systematic uncertainties associated with the jet corrections described in our previous CDF note [1]. Here we discuss in details of the systematic uncertainties to be assigned to those corrections.

The following expression includes all the corrections applied to jets in Run I. We start out with the raw energy measured in the calorimeters and obtain a corrected energy. As discussed in Ref [1], one additional correction has been applied to the raw jets in Run II, due to disagreement between the raw jet energies in Run I and Run II observed in the γ-jet balance analysis. Each of these terms has an uncertainty associated with it, which we will discuss in this note.

$$P_T(R) = (P_T^{raw}(R) \times f_{rel} - UEM(R)) \times f_{abs}(R) - UE(R) + OC(R) + SPLO$$

The parameter R=$\sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$ is the cone radius chosen for the jet measurement; R=0.4 for the top analyzes, typically 0.7 for the QCD analyzes. The cone algorithm for jet reconstruction is assumed here. The corrections are described below.

- f_{rel}, the relative energy scale, corrects for non-uniformities in the η response.
- $UEM(R)$ takes into account energy due to multiple interactions in the event.
- $f_{abs}(R)$, is the absolute energy scale correction.
- $UE(R)$ takes into account the energy due to the underlying event.
- $OC(R)$, corrects for the energy expected to be outside the cone radius of 0.4.
- $SPLO$ is the splash-out correction, which takes into account the energy lost outside a cone with R=1.0. This correction is 0.0 with an uncertainty of ± 1 GeV, as in Run I.

2 Relative Jet Energy Corrections

The relative jet corrections are designed to make the calorimeter response flat as a function of detector η. The detector configuration is shown in Fig. 1. The response in each η bin is normalized to the response in the $0.2 \leq |\eta| \leq 0.6$ range. This region of the central calorimeter is away from detector cracks and is expected to have a stable response.

As discussed in Ref [1], collider data and simulation do not agree at this time, so we have provided corrections for both. Fig. 2 (top) shows the di-jet balance versus η for the Jet_20 sample, after correction for the time dependence of the plug calorimeter gains as applied by Currat et al [2] according to the prescription of Ref [3]. Fig. 2 (bottom) shows the Electromagnetic Fraction (EMF) of the jet as a function of η. Fig. 3 shows the difference of the di-jet balance obtained with the data and the Monte Carlo. See Ref. [2] for more details.

The current detector simulation does not describe the data accurately especially in the WHA region and at large $|\eta|$ values in the plug calorimeter.

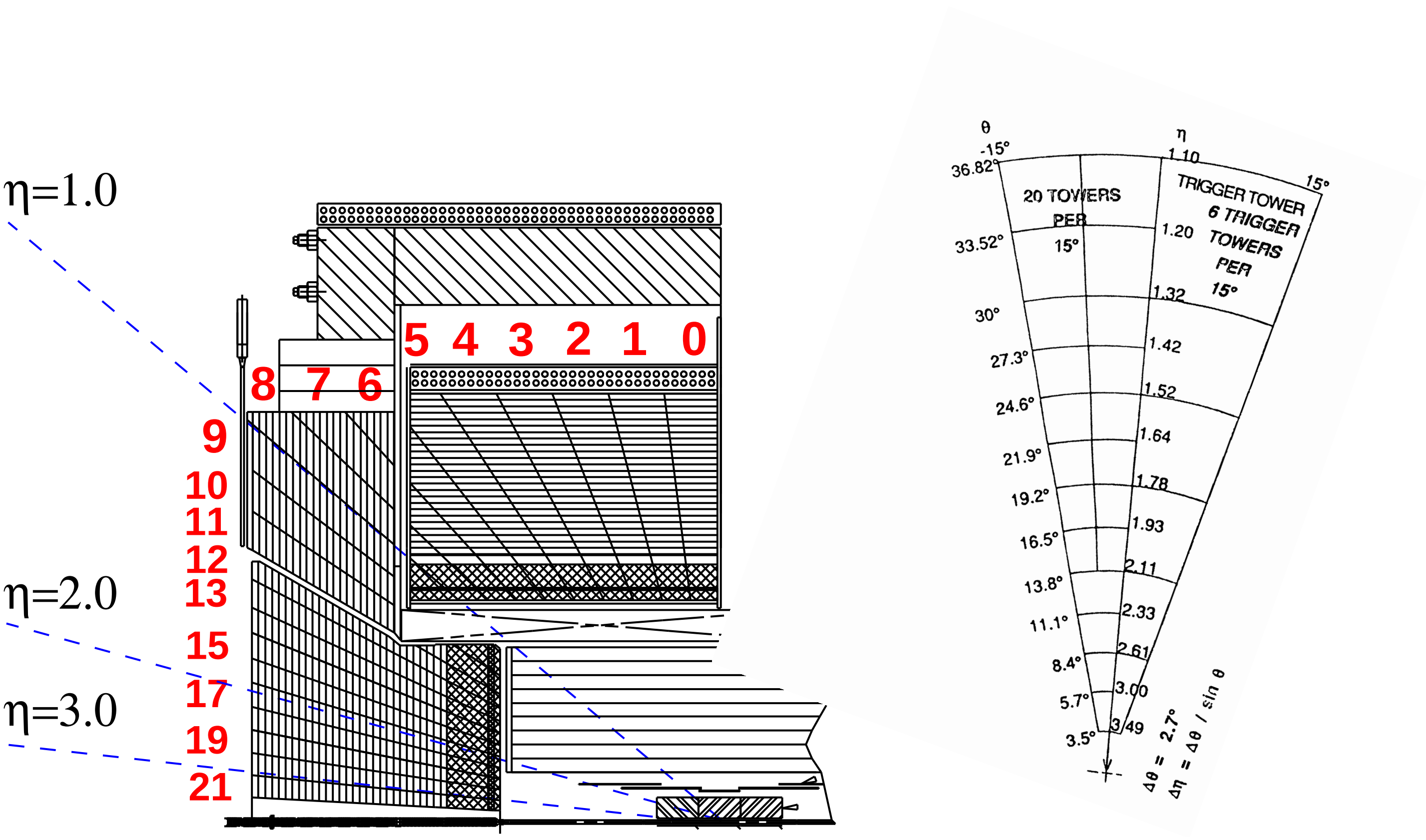

Figure 1: The run II CDF detector calorimeters. Left: one quarter section. The central (CEM, CHA) and WHA calorimeters have not changed, whereas the plug calorimeters (PEM, PHA) are new. The numbers refer to the nomenclature for the towers. Right: the plug wedge configuration. Both the angle to the beam axis and the η values are given.

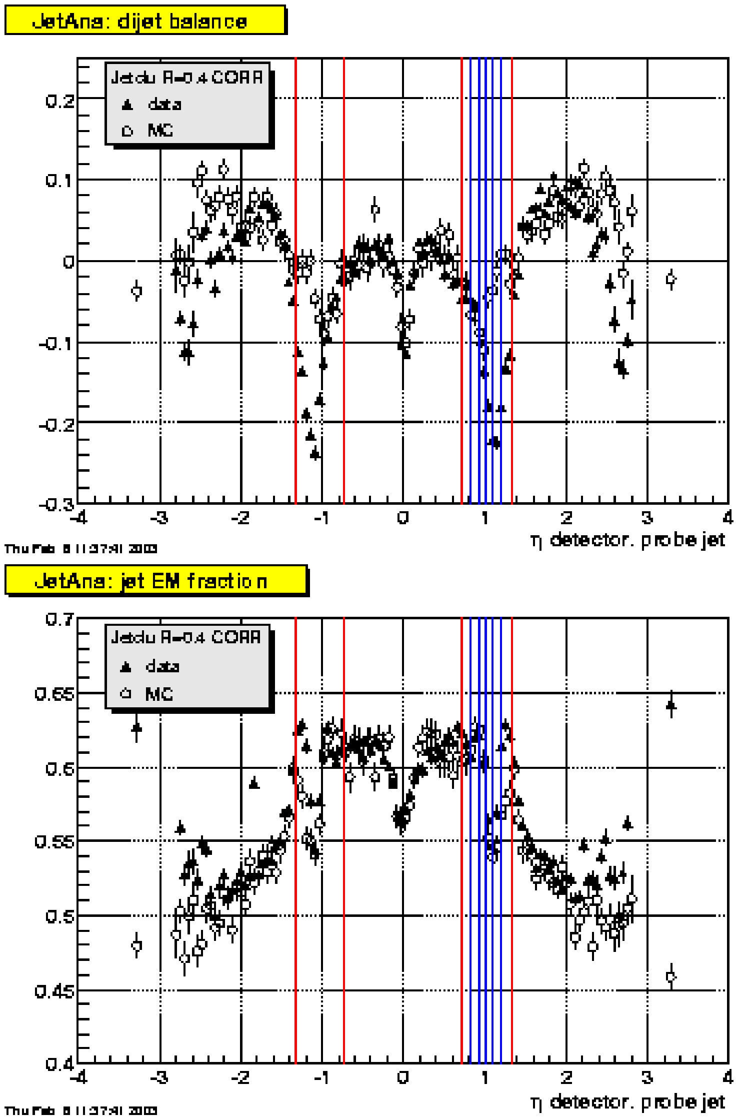

Figure 2: Difference between data and Monte Carlo as a function of η for the Jet_20 sample using a jet cone of radius R=0.4. The plug data has been corrected for time dependent gains. Data between Feb. 4-2002 and Nov. 2002 is used.

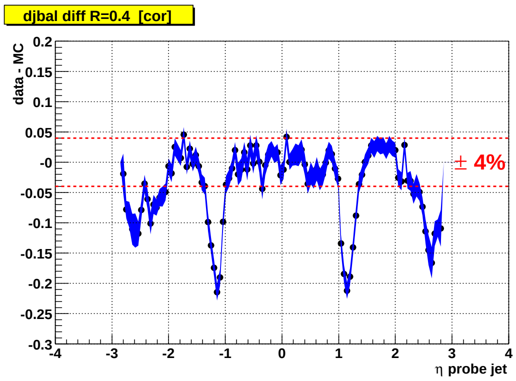

Figure 3: Difference between data and Monte Carlo as a function of η for the Jet_20 sample shown in Fig.3. The plug data has been corrected for time dependent gains.

Table 1: Uncertainties associated with Relative Corrections

Detector η	Real Data	Simulated Data
0.0-0.2	2%	2%
0.2-0.8	0.2%	0.2%
0.8-1.4	4%	15%
1.4-2.0	4%	4%
2.0-3.6	7%	7%

There are clear problems with the di-jet balance and the EMF in the WHA region: the crack position seems to be displaced and the simulation seems to have a higher response than the data. The response from the Monte Carlo seems to indicate a smaller EMF then expected (i.e. larger hadronic contribution). The data may have some E-scale problems as well, as pointed out in Ref. [1]. At the time of determination of the corrections and systematics (Feb. 2003) there was an indication [4] that the WHA scale may be about 10% too low, This however, would only raise the jet response in Fig. 2 by about 3% at most in the data, i.e. not enough to explain the discrepancy. Therefore, at this point we assign a 15% uncertainty to the simulation in this region, which is basically the difference in the response in simulated and real data. It is assumed that this difference is mostly a problem with the WHA simulation.

For the $|\eta| > 2.0$ region, the simulated data are above the real data. In this region, it is not clear where the problem lies and thus we assign a large systematic uncertainty to both data and MC corrections.

The uncertainties, given in Table 1, include any residual spline-interpolation effects, any biases in the di-jet balancing procedure specially in the crack region and variation of plug calorimeter response with time.

The corrections and the associated systematic uncertainties, depend on the jet clustering cone size (there is evidence that the disagreement between data and Monte Carlo increase with cone size, see Ref [2], and the jet transverse momenta. However, for simplicity, we provide systematic uncertainties which are the same for all cone sizes and valid for all transverse momenta of jets.

3 Raw Jet Energy Scale

Uncertainties on the jet energy scale are determined by using the γ-jet balance technique: we measure the photon very well, so we can study the jet energies by comparing the P_T components of the jet and the photon. Collider data and Monte Carlo are used to establish the systematic uncertainties. Since we will be applying the relative corrections, only the central part of the detector is used to set the energy scale and its uncertainty.

3.1 $p\bar{p}$ Collider Data

The Run II raw energy scale is set to Run I raw energy scale comparing photon-jet balancing results obtained in Run II with those obtained in Run I. As shown in Ref. [1] there is a discrepancy of $\sim$ 5% in the raw jet energy of the central calorimeter, which is jet cone size dependent. Source of this scale change is not understood. Without much studies made at this point, the correction factor is assumed to be independent of jet P_T. Again, for simplicity, we assign a common systematic uncertainty of 5%, independent of P_T and jet cone sizes, as shown in Table 2.

3.2 Monte Carlo Data

A comparison of photon-jet balancing in simulated and collider data shows that the difference between photon and jet transverse momenta observed in the simulated data does not agree with that observed in collider data. In Fig. 4 the di-jet balance for raw jets in data and Monte Carlo shows a discrepancy of about 5% for jet cone of 0.4 and almost no discrepancy for jet cone of 1.0.

Once the jet corrections of Ref. [1] are applied to data and Monte Carlo, we again notice a difference of about 5% in the R=0.4 case with the Monte Carlo being higher that the collider data. See Fig. 5. The situation reverses when we compare data and Monte Carlo for a cone radius of 1.0. Another comparison of data and Monte Carlo for corrected jets is shown in Fig. 6. Here we notice a P_T dependence of the discrepancy for R=0.4.

The simulated data is pure photon-jet sample whereas the collider data includes background from jet-jet events where one of the jet passes photon identification criteria. We conclude this study with a decision to apply no scaling factor to the

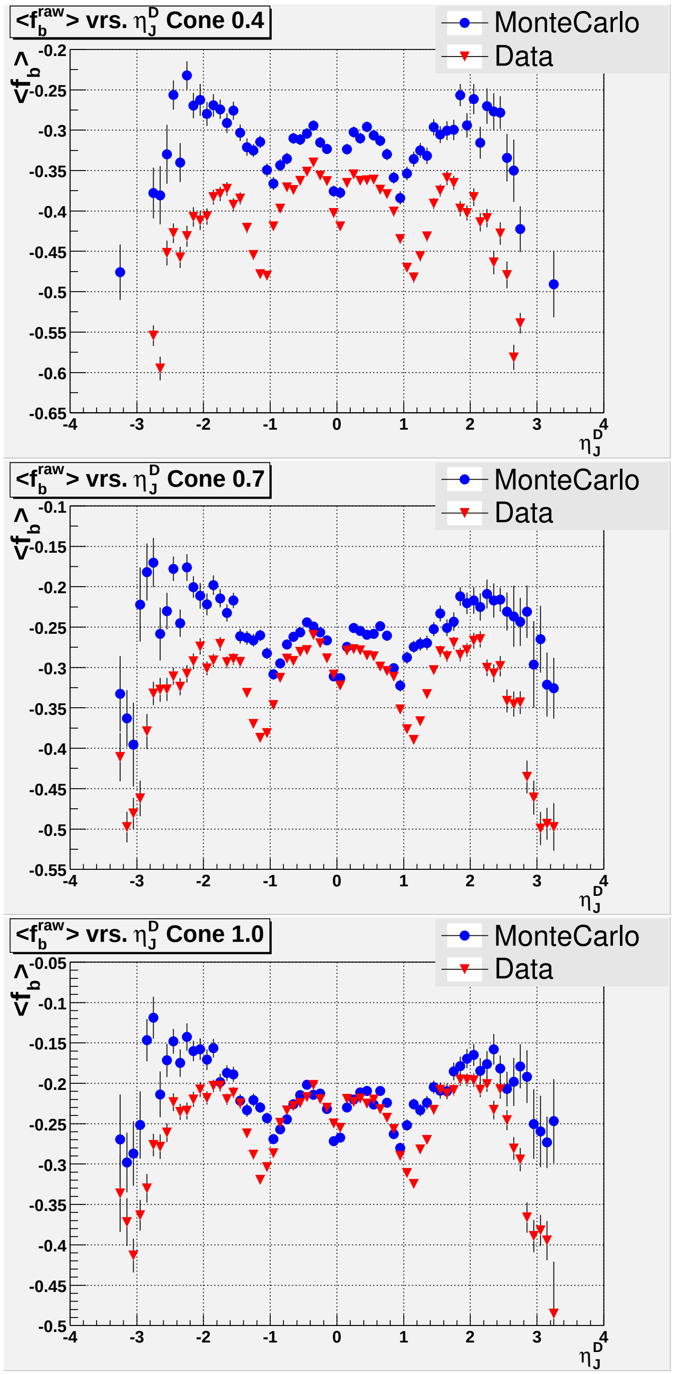

Figure 4: Gamma-jet balance as a function of detector η of the γ. Raw jet energies for collider and simulation data are shown. No corrections have been applied in the central and in the plug calorimeters. Jet cone sizes are R=0.4 (top), R=0.7 (center), R=1.0 (bottom). The data sample used for these plots included 102 pb^{-}1 of integrated luminosity.

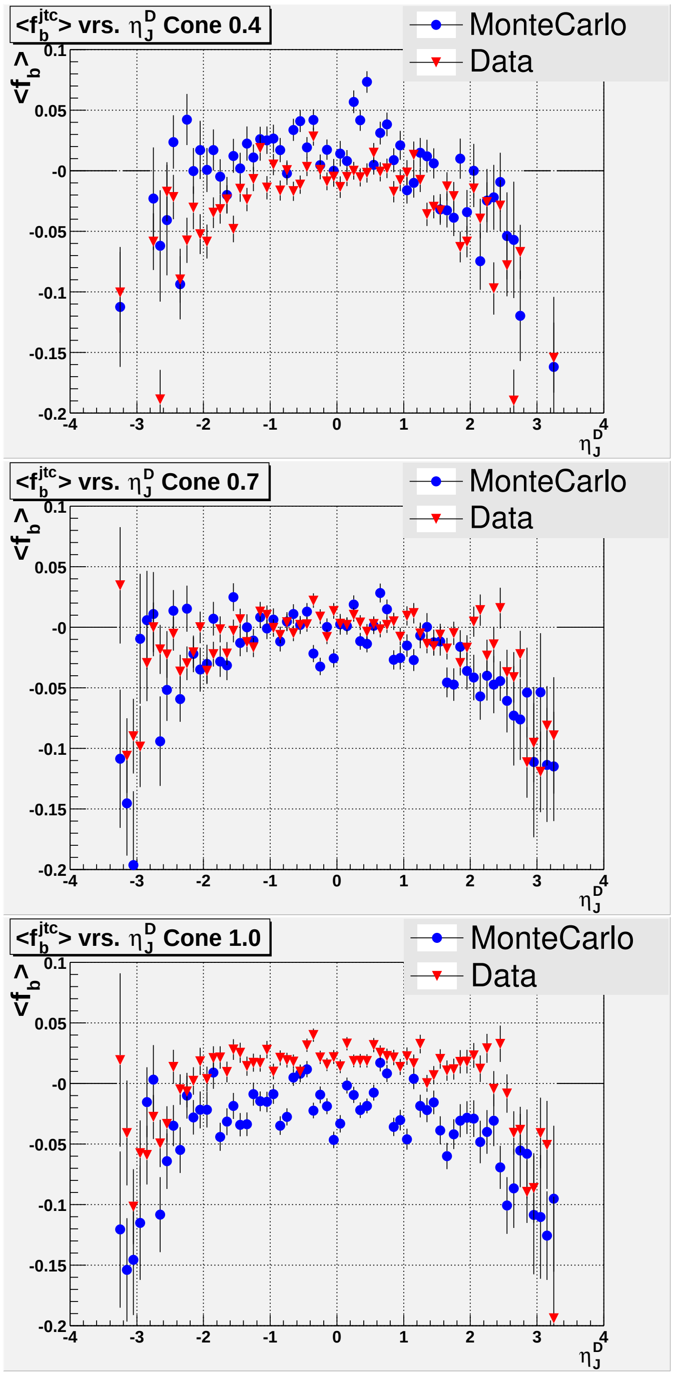

Figure 5: γ-jet balance as a function of detector η of the γ, compared with Monte Carlo. All known corrections have been applied [1]. Jet cone sizes are R=0.4 (top), R=0.7 (center), R=1.0 (bottom). The data sample used for these plots included 102 pb^{-}1 of integrated luminosity.

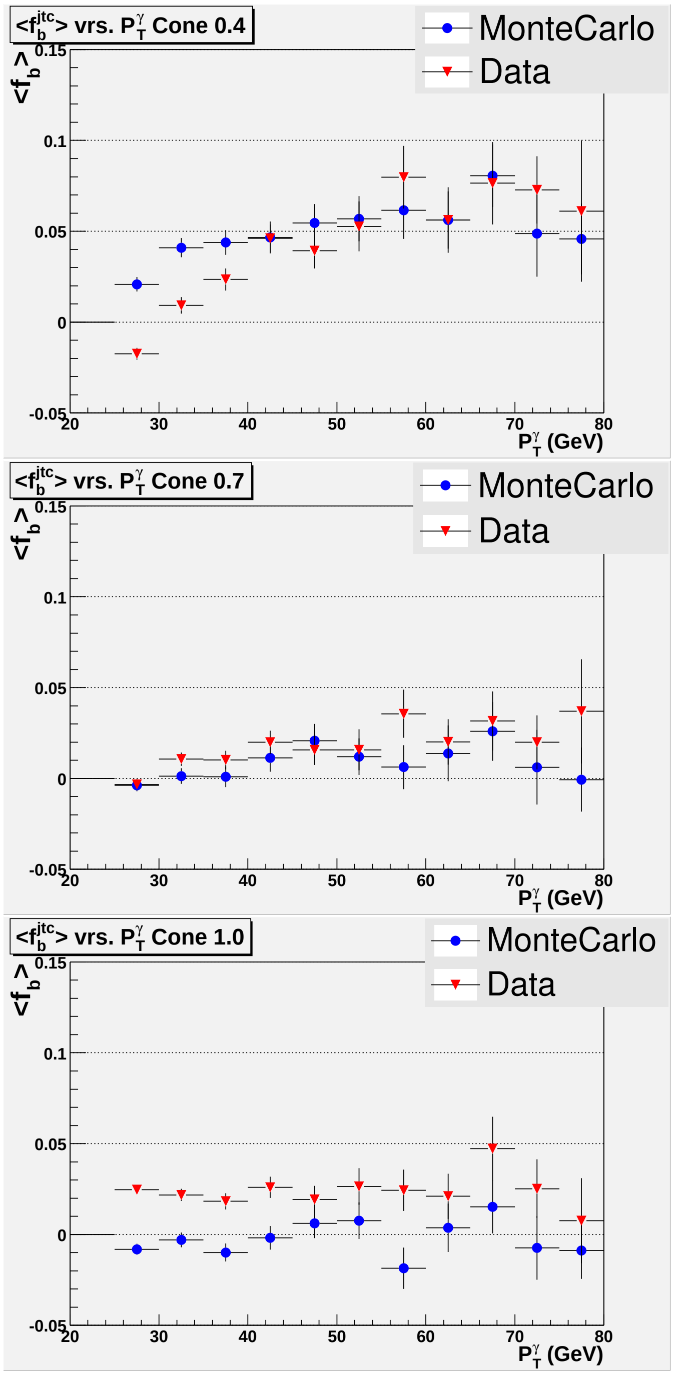

Figure 6: γ-jet balance as a function of P_T of γ, compared with Monte Carlo. All known corrections have been applied [1] to both data and Monte Carlo. Jet cone sizes are R=0.4 (top), R=0.7 (center), R=1.0 (bottom). The data sample used for these plots included 102 pb^-1 of integrated luminosity.

Table 2: Uncertainty of raw calorimeter energy scale

Real Data	Simulated Data
±5%	±5%

simulation energy scale, but we assign a ±5% uncertainty to the simulated data. The uncertainty on the jet energies in data and Monte Carlo are shown in Table 2.

4 Absolute, Multiple Interactions, underlying event and out-of-cone and Splash-out Corrections

We have not reevaluated the absolute and out of cone corrections for the Run II detector configuration. We use the same corrections and uncertainties as those used in Run I [5]. They are shown in Fig. 7.

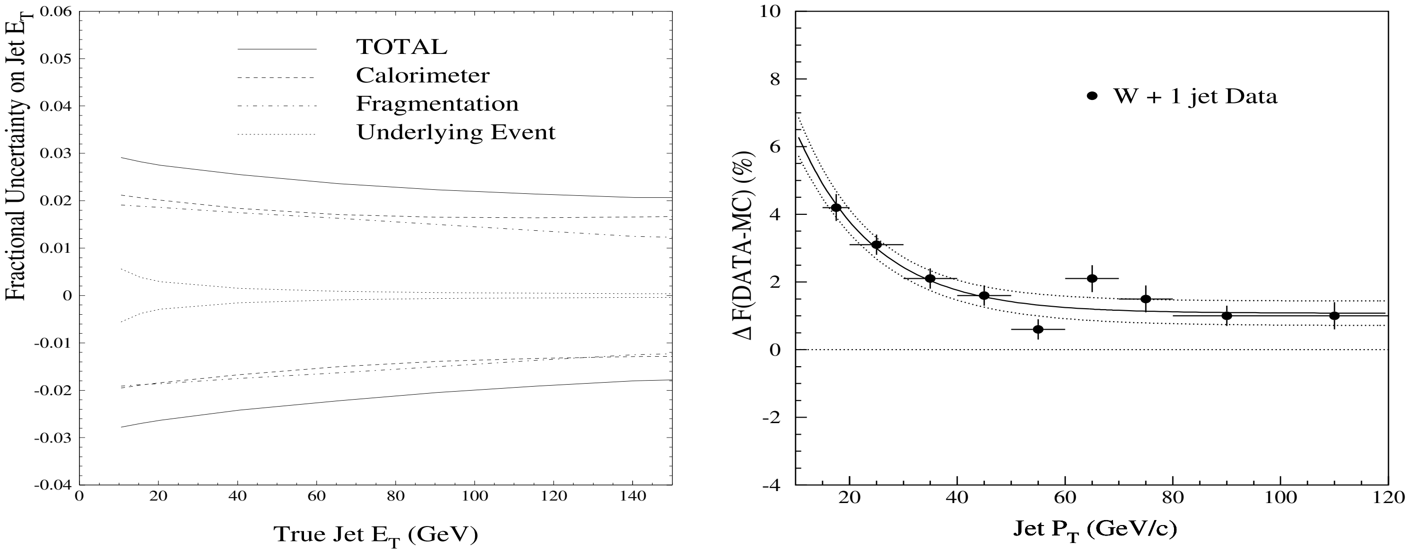

Figure 7: Absolute energy correction systematic uncertainty as a function of P_T (left) [6] and out of cone correction systematics as a function of corrected jet P_T (right) [7].

We have reevaluated the underlying event and multiple interaction corrections, but we assign to them the same systematic errors as in Run I.
Table 3 contains a summary of all the systematic errors on the jet energies, including the uncertainty from the splash-out term (same as in Run I). In summary we are using the same corrections as in Run I, except for new uncertainties on the raw jet energy scale (Table 2) and the relative corrections (Table 1.)

Table 3: Systematic Uncertainties on jet energies

	Effect	Real Data	Simulated Data	Where applied
1	calor. stability	1%	-	raw P_T
2	raw jet P_T	5%	5%	raw P_T
3	relative corr.	Table 1	Table 1	after f_{rel}
4	UEM	100 MeV/vertex	-	after f_{rel}
5	Absolute Cor.	$\sim$ 2.5%, Fig. 7	-	after f_{abs}
	includes UE	(30% of cor.)	-	
6	soft gluon(OC)	Fig. 7	-	after OC
7	splash-out	1 GeV	-	after OC

5 Corrections for Analyzes that use Cuts on Raw Jet P_T

Some of the analyzes select events using uncorrected jets. In this case the systematics of both the data and the Monte Carlo raw jets have to be applied. For example, for the top cross section measurement event selection was done by using uncorrected jets and the acceptance was calculated using uncorrected jets in Monte Carlo. Therefore both systematic uncertainties have to be applied.

The data and Monte Carlo comparison of the di-jet balance analysis for uncorrected jets is shown in Fig. 8 for a cone of 0.4. The bottom curve shows the difference between the two sets of data.

We can obtain the same information from γ-jet balance. This is expected to show a larger difference because the balance is done against the photon which is well measured and not against the central jets. The data and Monte Carlo as a function of η were shown in Fig 4. Clearly the difference between the two sets of data is larger then in Fig. 8, as expected, because of the 5% discrepancy between data and Monte Carlo in the central calorimeter. This difference has been used in the code to assess the jet systematic uncertainty for those analysis that cut on raw jet energies.

6 Conclusions

We have done a honorable job of determining the jet correction and associated uncertainties and we feel proud of our accomplishments.

http://www-cdf.fnal.gov/internal/physics/top/jets/corrections.html

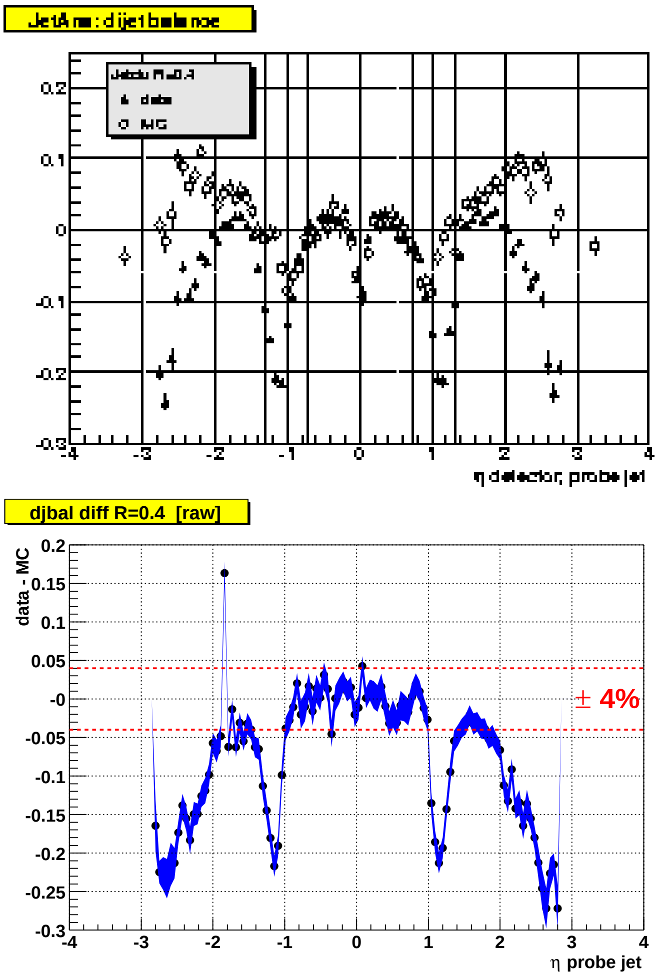

Figure 8: Comparison of data and Monte Carlo as a function of η for the Jet_20 sample for a jet cone R=0.4. Raw jet energies have been used. The plug data has not been corrected for time dependent gains. Data between Feb. 4-2002 and Nov. 2002 is used. The bottom plot shows the difference between the two sets of data.

References

[1] J-F. Arguin et al., (Jet Correction Group), *Generic Jet Energy Corrections for Run II data used for the Winter Conferences*, CDF-6280 (rev. May 2003).

[2] C. Currat, L. Galtieri, J. Lys, *Comparison of uncorrected jet P_T in data and Monte Carlo after time dependent corrections in the plug calorimeters*, CDF-6420 (May 2003).

[3] H.S. Budd, W.K. Sakumoto, *Determining Gains of Plug Towers using Plug Laser and Source Data*, CDF-6433 (April 2003).

[4] H. Kim *MIP Energy Scale Comparisons of CHA/WHA between Run I and Run II*, CDF-6392, in preparation. The high P_T E scale check was shown in a talk at the Jet Correction meeting of Sept. 4, 2002.

[5] L. Galtieri, J. Lys, *How well do we understand jets in Run I? Study of the Jet E-scale for raw jet $E_T > 8$ GeV*, CDF-3983 (March 1997).

[6] S. Behrends, *A plot of the systematic uncertainties on jet P_T*, CDF-3550 (February 1996).

[7] L. Galtieri, M. Garcia-Sciveres, J. Lys, W-M Yao, S. Rolli, *Gluon Radiation Studies in W+jets data*, CDF-3253 (February 1996).