DØ Note #2922

W Mass Analysis - Run 1A
Underlying Event Corrections:
Summary of Previous Studies and Results of Study of Minimum Bias Data

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1 Introduction

For the determination of the W and Z mass, the electron and neutrino momenta are modelled in the fast Monte Carlo. The electron and W transverse momenta (and therefore the neutrino momentum as well) are corrected for zero suppression effects and the underlying event contribution to match the data, which is not corrected for these effects. In this note, we discuss the method for correcting the data, the previous studies used to determine the corrections, new results from a detailed study of minimum bias events, and, finally, the corrections adopted.

The momenta used to determine the W and Z mass are modelled in the fast Monte Carlo as

$$\vec{P}_T(e) = \vec{P}_T^{ss}(e) + \vec{u}_{mb}(e) - \vec{u}_{zs}$$

$$\vec{P}_T(W) = \vec{P}_T^{s}(W) + C\vec{u}_{mb}(tot) - \vec{u}_{mb}(e).$$

$\vec{P}_T^{ss}(e)$ is the electron transverse momentum scaled down by the electron energy scale to match the data and smeared using the energy and angular resolutions. $\vec{P}_T^{s}(W)$ is the W transverse momentum scaled by the electron and hadronic energy scales and smeared by the jet energy resolution. The neutrino is then inferred using

$$\vec{P}_T(\nu) = \vec{P}_T(W) - \vec{P}_T(e).$$

The extra energy added to the electron due to the underlying event and zero suppression effects is $\vec{u}_{mb}(e) - \vec{u}_{zs}$. These quantities are both vectors in the electron direction and are constant in η. The value of $\vec{u}_{mb}(e)$ is the energy under the electron due to the underlying event. The quantity $\vec{u}_{zs}$ includes electron energy lost below the zero suppression 2σ threshold, and a correction for the towers that are always occupied and therefore not affected by zero suppression. This last effect is not modelled by the minimum bias events. The extra energy added to the $\vec{P}_T(W)$ due to the underlying event is $C\vec{u}_{mb}(tot) - \vec{u}_{mb}(e)$. The value of $\vec{u}_{mb}(tot)$ is the total $\vec{P}_T$ of a (zero-suppressed) minimum bias event and is obtained from a lookup table. The number of minimum bias events needed to give the observed spread in recoil momentum about the value obtained from the electrons in Z events fixes the constant C.

2 Summary of Corrections to the Electron Momenta - Study #1

Minimum bias events that are not zero-suppressed, W events, and single electron Monte Carlo data were used to determine the corrections to the electron momenta used in the fast

Monte Carlo [1]. There were only two unsuppressed minimum bias runs that were available for use in this study and the results from higher luminosity run were taken since its luminosity more closely matched that in the W event sample.

The average energy per tower (EM plus FH1) in the central calorimeter (CC) in these unsuppressed minimum bias events was measured to be 6.128 MeV at $\theta = 90\,\text{deg}$. After offline zero suppression, the energy was 13.683 MeV. The underlying E_T is flat in η. Therefore the effect of zero suppression was measured to add $13.683 - 6.128 = 7.555$ MeV E_T per tower. Using W events and rotating away in azimuth from the electron, the average E_T per tower was measured to be 16.784 MeV. Subtracting zero suppression effects, the average E_T per tower due to the underlying event in W events is $16.784 - 7.555 = 9.23$ MeV. We note that the E_T per tower in W events is a factor of 1.5 larger than that from minimum bias events. Using single electron Monte Carlo data, it was determined that 152 MeV is lost due to the tails of the electron being below the zero suppression cut. Although a clustering algorithm is used to define the electron, the difference in underlying energy obtained using the 5×5 window (25 towers) and the cluster is negligible. On average, 8 towers in the electron cluster always contain energy, and therefore do not need to be corrected for zero suppression effects. From these results, the underlying event corrections for the electron quantities are:

$$\vec{u}_{mb}(e) = 25(9.23 + 7.555)\ \text{MeV}\ (E_T)$$

and

$$\vec{u}_{zs} = 152 + 8(7.555)\ \text{MeV}\ (E_T).$$

3 Summary of Corrections to the $P_T(W)$ - Study #2

Minimum bias events and Z events were used to determine corrections to the $P_T(W)$ in the fast Monte Carlo [2]. Zero-suppressed minimum bias events were used to generate a lookup table containing the total $\vec{P}_T$ in the event. This lookup table is binned in luminosity with the same luminosity distribution as the W data sample. The correction from the minimum bias events must be scaled so that the it corresponds to the underlying event E_T per tower in W and Z events. From measurements of the $P_T(W)$ resolution in Z events, this scale factor was determined to be 1.0. This result does not correlate with the above result obtained for the correction to the electron energy in which the scale factor would be 1.5. From these results, we get

$$C = 1$$

and

$$\vec{u}_{mb}(tot) = \text{ total } \vec{P_T} \text{ of a (zerosuppressed) minimum bias event.}$$

4 Results of Analysis of Minimum Bias Data to Determine Underlying Event Corrections - Study #3

Zero-suppressed minimum bias data was used to measure the average energy per tower as another check on the results of the previous studies. Three 8mm tapes of minimum bias data ($\approx$ 13,000 events) were used and the instantaneous luminosity and the energy averaged over ϕ for each η was recorded for the sum of the EM layers, the FH1 layer and the sum of the HAD layers in a tower. The energy per tower includes contributions from the underlying event and zero-suppression. Figure 1a shows the z-vertex distribution from RECO and figure 1b shows the instantaneous luminosity with the requirement that the z-vertex was not equal to 0 (meaning no vertex was found for the event). All subsequent figures also have this requirement. There was no requirement on the multiple interaction flag. Figures 2 and 3 show the average energies per tower averaged over the CC and full calorimeter versus the instantaneous luminosity. The energy increases slightly as the luminosity increases.

The average energy in the towers for the CC and full calorimeter is shown in figures 4 and 5 for the EM, FH1 and HAD layers separately. Figure 6 shows the average energy per tower versus η. The energy is relatively constant in CC, but gets larger as η increases. The distribution of the average transverse energy, E_T, in the CC towers is shown in figure 7. These values are shown versus η in a profile plots in figure 8. In figure 9, the E_T is plotted versus η for $|\eta| \leq .9$ and $|\eta| \leq 1.1$. The distribution is fit to a line in the first plot and is seen to be flat (slope ≈ 0) and constant at 15.3 MeV per tower. At the edge of the CC, the E_T is lower by a few MeV. The average E_T per tower is slightly lower than that from W events obtained in study #1 (16.784 MeV), leading to a value for C of 1.09. It is consistent with study #2 which found that the energy per tower for Z events should be the same as in minimum bias events.

5 Results and Conclusions

From the results of the current study of minimum bias data (study #3) we determine that the underlying event contribution is the same for W and Z events as it is for minimum bias events which is consistent with the results from Z data. The average EM + FH1 E_T per tower from minimum bias zero-suppressed data is $\approx$ 15.3 MeV and is constant in η in the CC out to $\eta \leq 0.9$.

In the fast Monte Carlo, we use the values:

$$\vec{u}_{mb}(e) = 25(9.23 + 7.555) \text{ MeV } (E_T) \rightarrow \text{ along electron direction,}$$

$$\vec{u}_{zs} = 152 + 8(7.555) \text{ MeV } (E_T) \rightarrow \text{ along electron direction,}$$

$$C = 1 \rightarrow \text{ scale factor to relate minimum bias to } W \text{ \& } Z \text{ events,}$$

and

$$\vec{u}_{mb}(tot) \rightarrow \text{ total } \vec{P_T} \text{ of minimum bias event from lookup table}$$

to correct the Monte Carlo quantities to model the data.

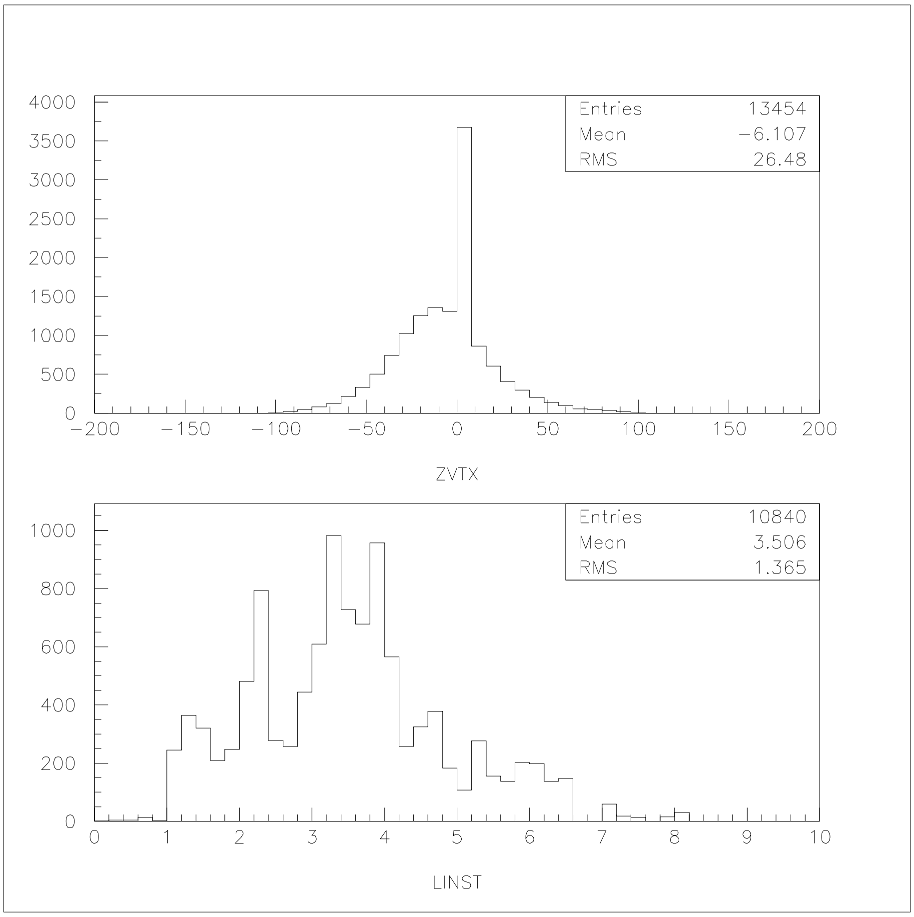

Figure 1: Distribution of z-vertex and instantaneous luminosity from minimum bias events

References

[1] Ian Adam, "Underlying Event Correction to the Electron Energy in $W \rightarrow e\nu$ Decays at DØ ", DØ note #?.

[2] Marcel Demarteau, John Sculli, Kathleen Streets, "The Measurement of the W Mass", DØ note #?.

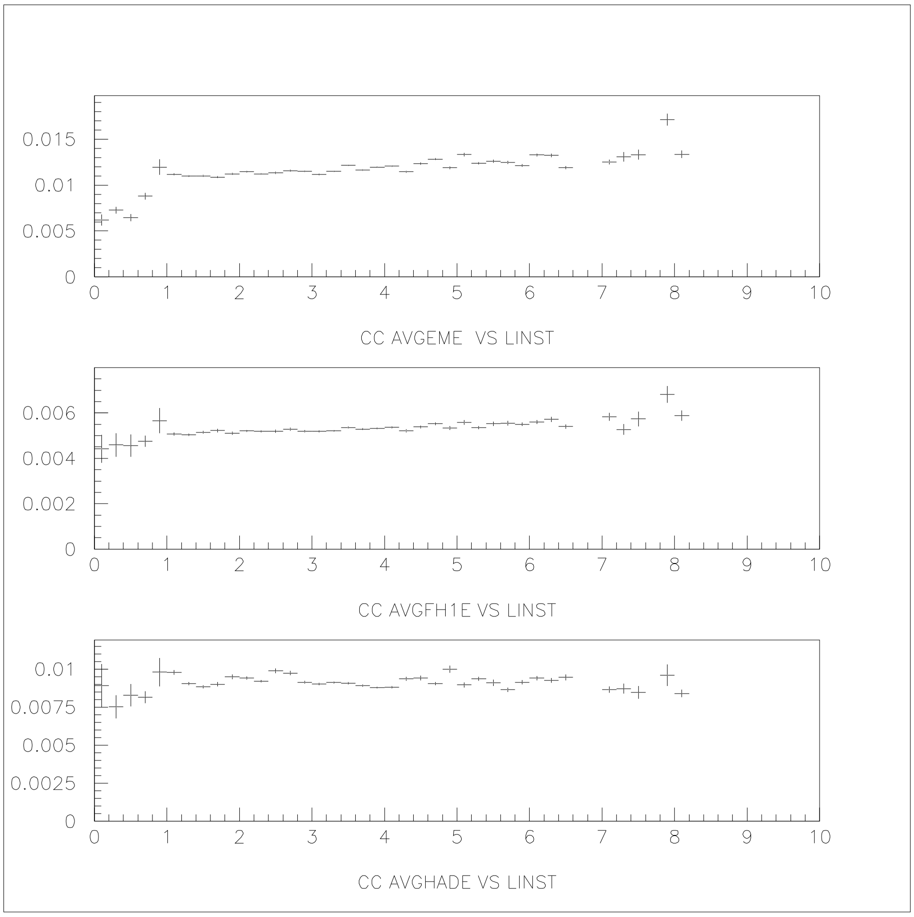

Figure 2: Average energy per tower for EM, FH1 and HAD layers in the CC versus luminosity

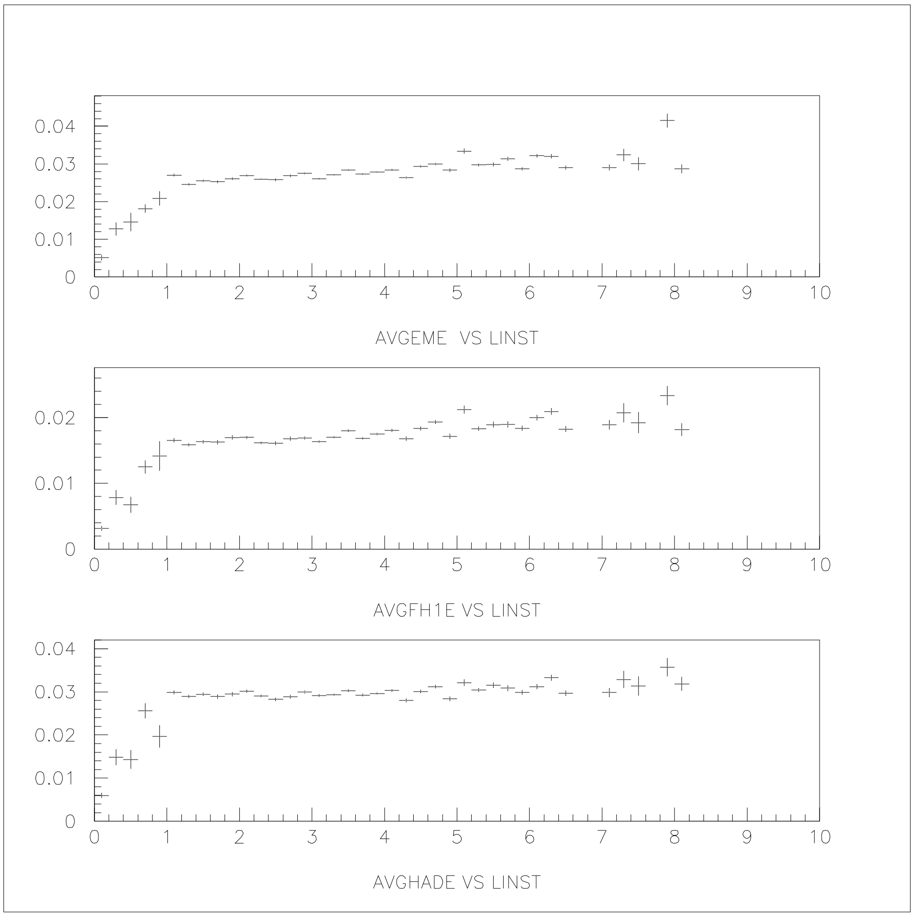

Figure 3: Average energy per tower for EM, FH1 and HAD layers versus luminosity

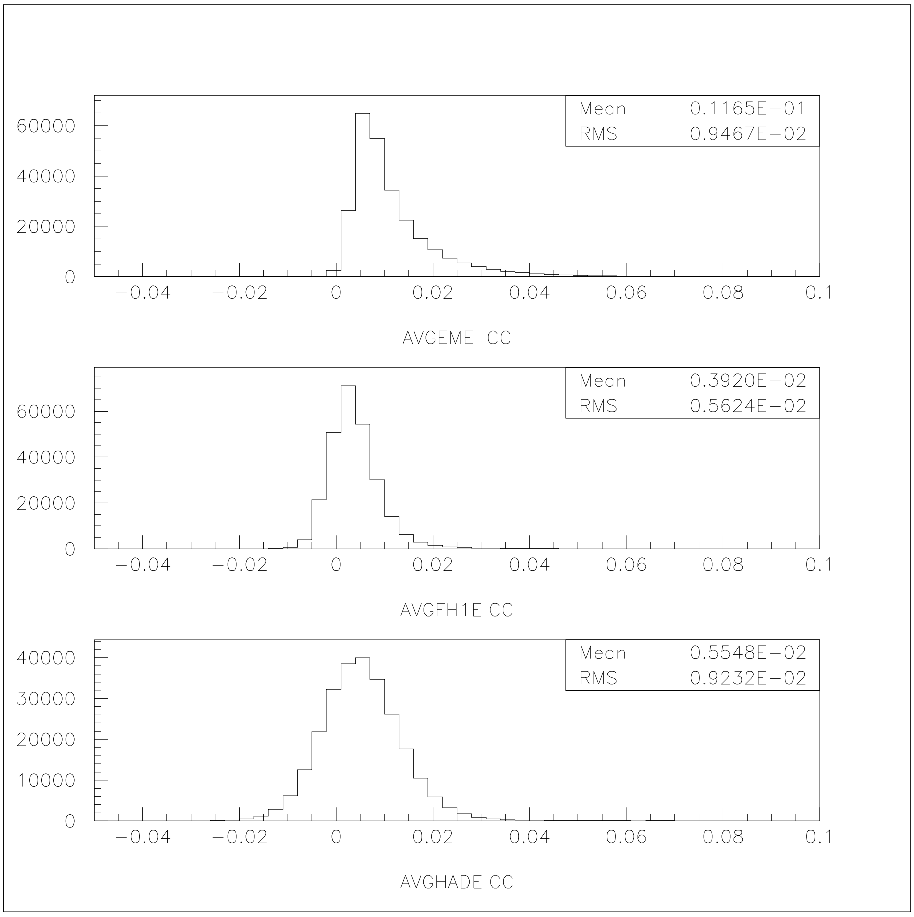

Figure 4: Distribution of average energy per tower for EM, FH1 and HAD layers in the CC

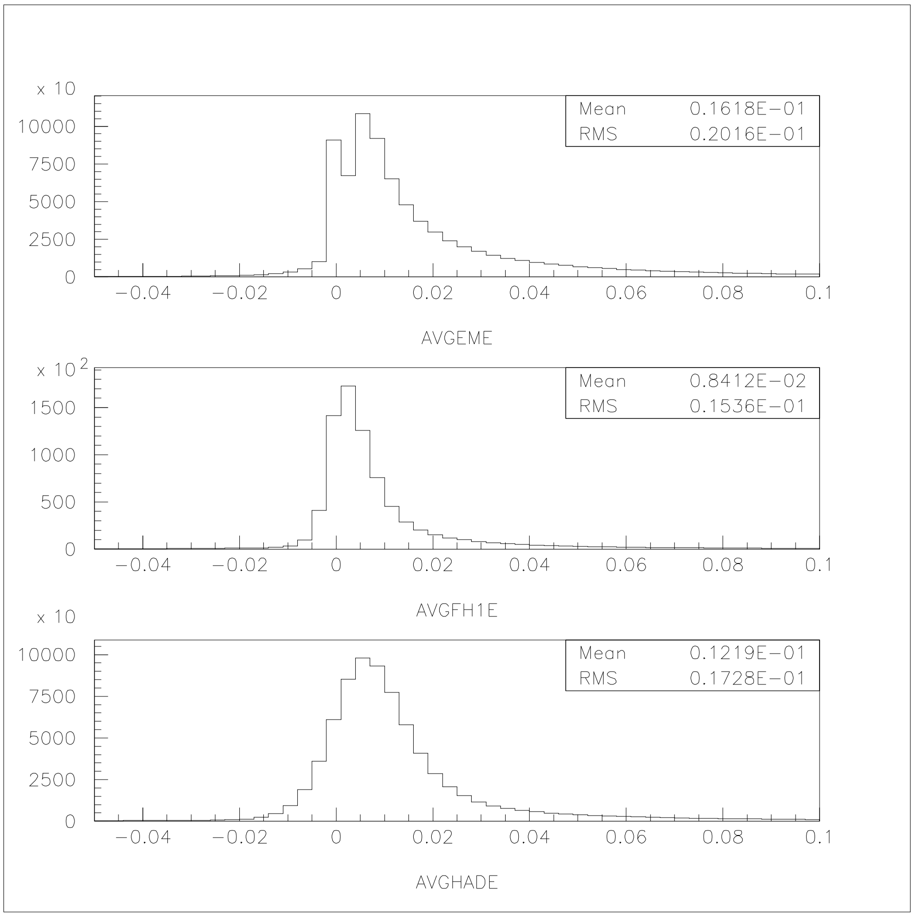

Figure 5: Distribution of average energy per tower for EM, FH1 and HAD layers

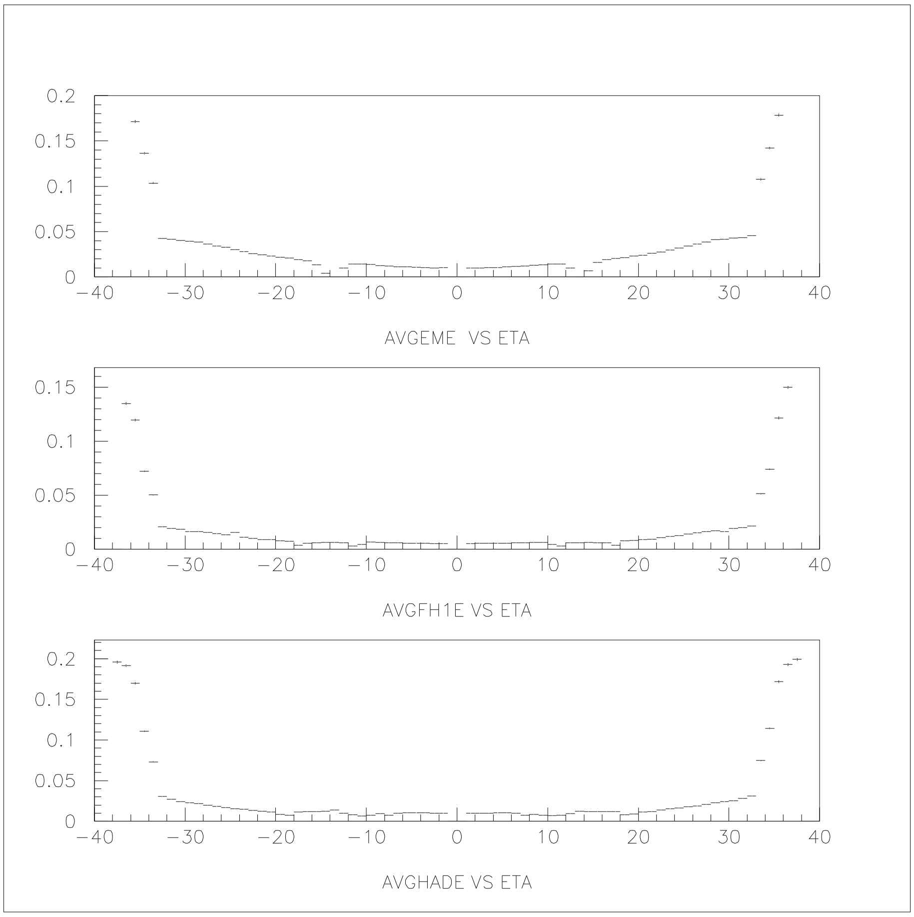

Figure 6: Average energy per tower for EM, FH1 and HAD layers versus η

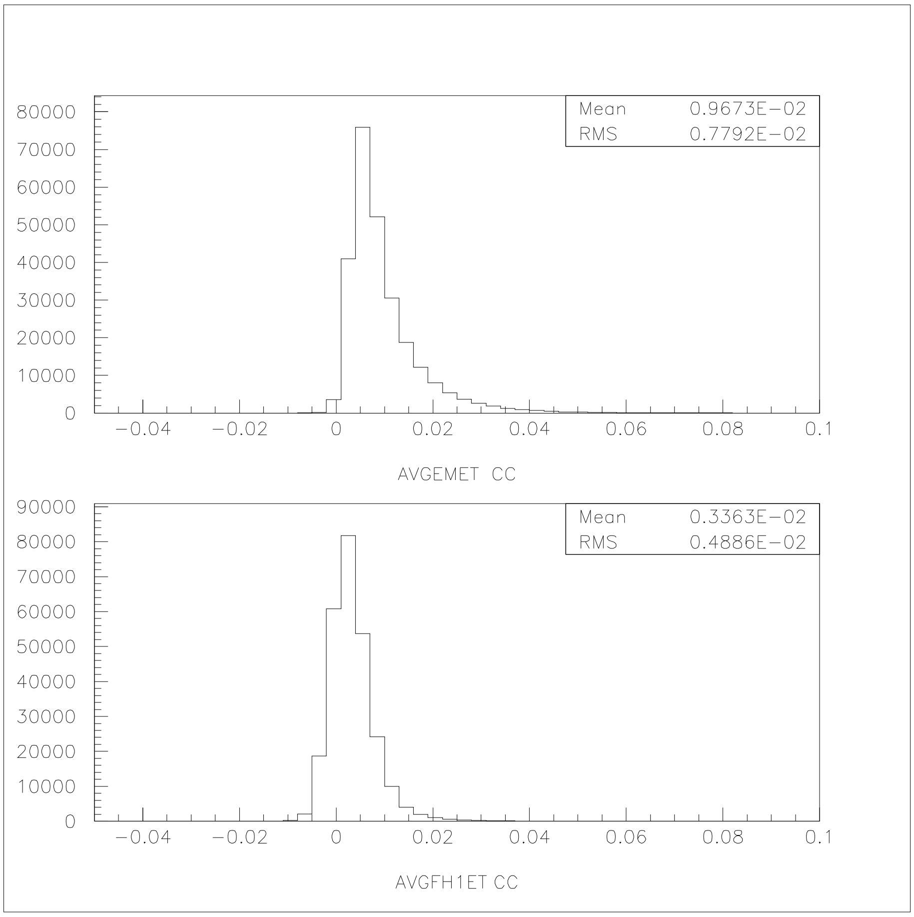

Figure 7: Distribution of average E_T per tower for EM and FH1 layers

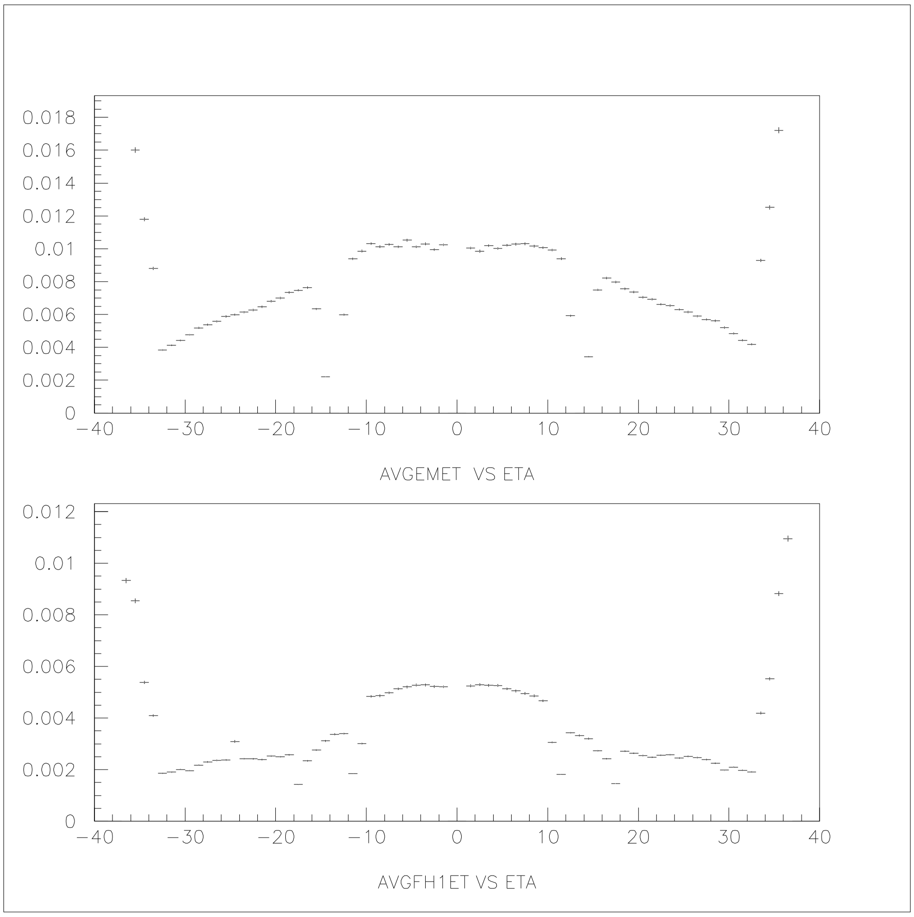

Figure 8: Average E_T per tower for EM and FH1 layers versus η

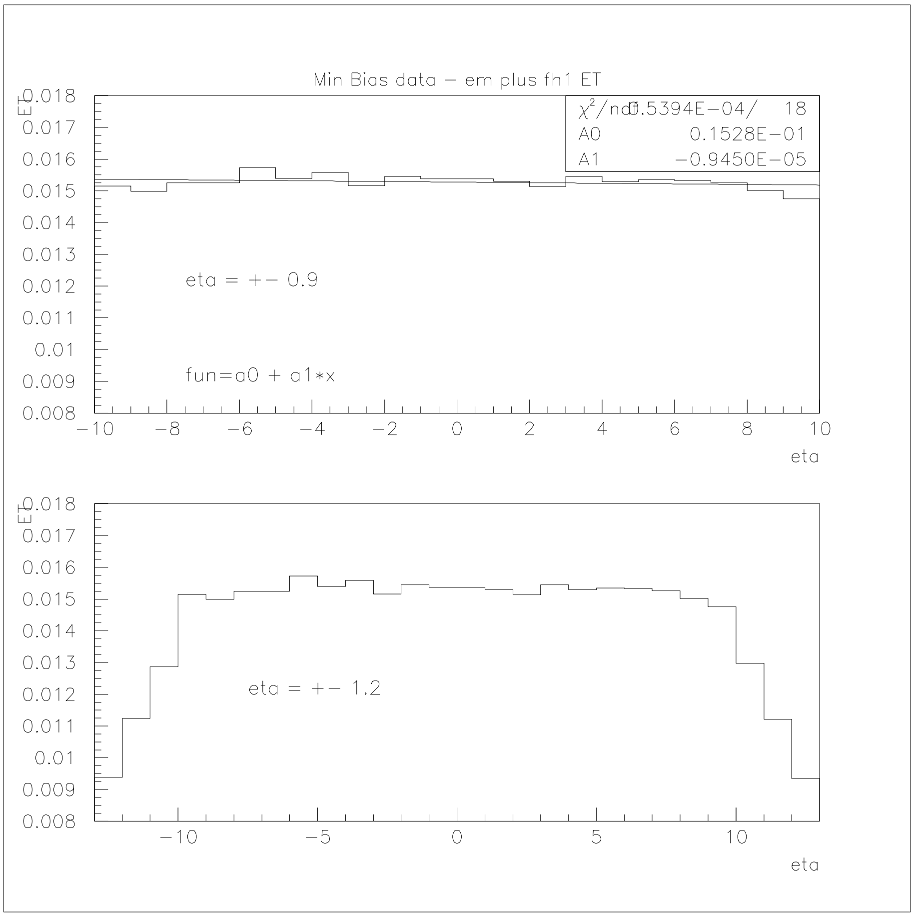

Figure 9: Average E_T per tower for EM + FH1 layers versus η.