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Jet Contributions to $\not{E}_T$ Cross Sections

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ABSTRACT

QCD jets can contribute to missing transverse energy $\not{E}_T$ both because of neutrinos from heavy quarks and because jets are missed at large η or mismeasured. These effects are estimated using a simple model.

Neutrinos from heavy quarks in QCD jets give contributions to to missing transverse energy $\not{E}_T$ signatures which are less than but not negligible compared to those from new physics such as gluinos. QCD jets may also contribute to $\not{E}_T$ by escaping the detector at large η or by being mismeasured. To estimate these contributions to $\not{E}_T$, ISAJET 6.43 was used to generate 4000 events in each of five bins, each a factor of two wide, covering $25\,\mathrm{GeV} < p_T < 800\,\mathrm{GeV}$. Top jets were included assuming $m_t = 140\,\mathrm{GeV}$. An idealized calorimeter with perfect energy resolution and $\Delta\eta = \Delta\phi = 0.10$ for $\eta < 6$ was simulated using CALSIM, and jets with $E_T > 10\,\mathrm{GeV}$ in $\Delta R < 0.7$ were found using GETJET, a simplified version of the UA1 jet algorithm. The jets, leptons, and global event properties were saved in a DST file from which all subsequent analysis was done.

Fig. 1 shows the $\not{E}_T$ cross section calculated with perfect energy resolution. The lower solid curve was obtained by summing all cells of the calorimeter. This cross section is presumably dominated by the effects of the finite cell size and beam hole for small $\not{E}_T$ and by real neutrinos for large $\not{E}_T$. The dashed curve was obtained by summing jets with $\eta_{\mathrm{jet}} < 6$. The agreement between these two indicates that it is sufficient to look at clustered energy for calculating $\not{E}_T$. This probably reduces the effect of pileup and noise, but these have not been included here. The dotted, dot-dashed, and upper solid curves are obtained by summing only jets with $\eta_{\mathrm{jet}} < 5$, $\eta_{\mathrm{jet}} < 4$, and $\eta_{\mathrm{jet}} < 3$ respectively.

Evidently even a hole for $\eta_{\rm jet} < 5$ contributes substantially to the cross section for $\not{E}_T \sim 50\,\mathrm{GeV}$, although it has a small effect for $\not{E}_T > 100\,\mathrm{GeV}$, the region of main interest for the SSC. A hole for $\eta_{\rm jet} > 4$ dominates the missing energy resolution at least up to $\not{E}_T \gtrsim 500\,\mathrm{GeV}$, and a hole for $\eta_{\rm jet} > 3$ is disasterous. The calorimeter coverage must be somewhat greater than the $\eta_{\rm jet}$ limit to insure that the jet is fully contained.

Fig. 2 shows the same distributions after applying to each jet an energy resolution $\Delta E/E = 0.50/\sqrt{E} \oplus 0.02$, a typical good hadronic resolution. Since the sampling term is proportional to $1/\sqrt{E}$, applying it to jets or to individual particles is esentially equivalent. Applying the constant term to jets enhances its importance and is appropriate if there are variations in regions of the calorimeter. Fig. 3 shows the same distributions with $\Delta E/E = 0.70/\sqrt{E} \oplus 0.05$. The three sets of curves are essentially indistinguishable; a comparison of the distributions for $\eta < 6$ is shown in Fig. 4. As long as there are no non-Gaussian tails, energy resolution is not crucial for missing energy.

Fig. 5 shows the same distributions as Fig. 1 with perfect energy resolution but with a cut $p_{T,\rm jet} > 20\,\mathrm{GeV}$. The higher cut worsens the resolution at small $\not{E}_T$ but does not have much effect for $\not{E}_T > 100\,\mathrm{GeV}$. Since the probability for a 20 GeV jet is only about 5% per bunch crossing, this suggests that pileup will not be a major concern. A more detailed study of this is needed.

The transverse momenta of jets in the forward calorimeter will be smeared by angular resolutions produced by transverse shower spreading. This has been studied by Forden using single jets generated with PYTHIA. The preliminary result is that the transverse momentum resolution for jets in the forward calorimeter is better than 10% for jets contained in the calorimeter.* Fig. 6 shows the $\not{E}_T$ cross section with 10% and 20% Gaussian resolutions on p_T applied to jets with $\eta > 3$ compared to that for the full calorimeter with perfect resolution. Evidently a resolution of 10% is adequate and has a amall effect compared to reducing the rapidity coverage. A resolution of 20% significantly increases the cross section for $\not{E}_T \sim 100\,\mathrm{GeV}$.

The background of real neutrinos in QCD jets is significant compared to signatures such as gluinos. Additional cuts besides $\not{E}_T$ are needed to extract such signatures, but

* If PYTHIA uses $Q^2 \sim \hat{s}$ rather than $Q^2 \sim p_T^2$ for the single jet gun, then the multiplicity and hence the angular accuracy would be overestimated.

these cuts do not seem to be correlated with the production of jets at large η. Therefore, the detector should not increase this irreducible background for the total $\not{E}_T$ cross section by a large factor in the interesting region, say $\not{E}_T > 100\,\mathrm{GeV}$. It appears from the simple calculations given here that the calorimeter needs to contain jets with $\eta \lesssim 5$ to achieve this. For very large $\not{E}_T$, $\eta \lesssim 4$ may be adequate. Energy resolution is not crucial. The angular resolution and jet containment of the forward calorimeter need to provide a jet $\Delta p_T/p_T \lesssim 10\%$. Non-Gaussian tails from edges and cracks are of course also important.

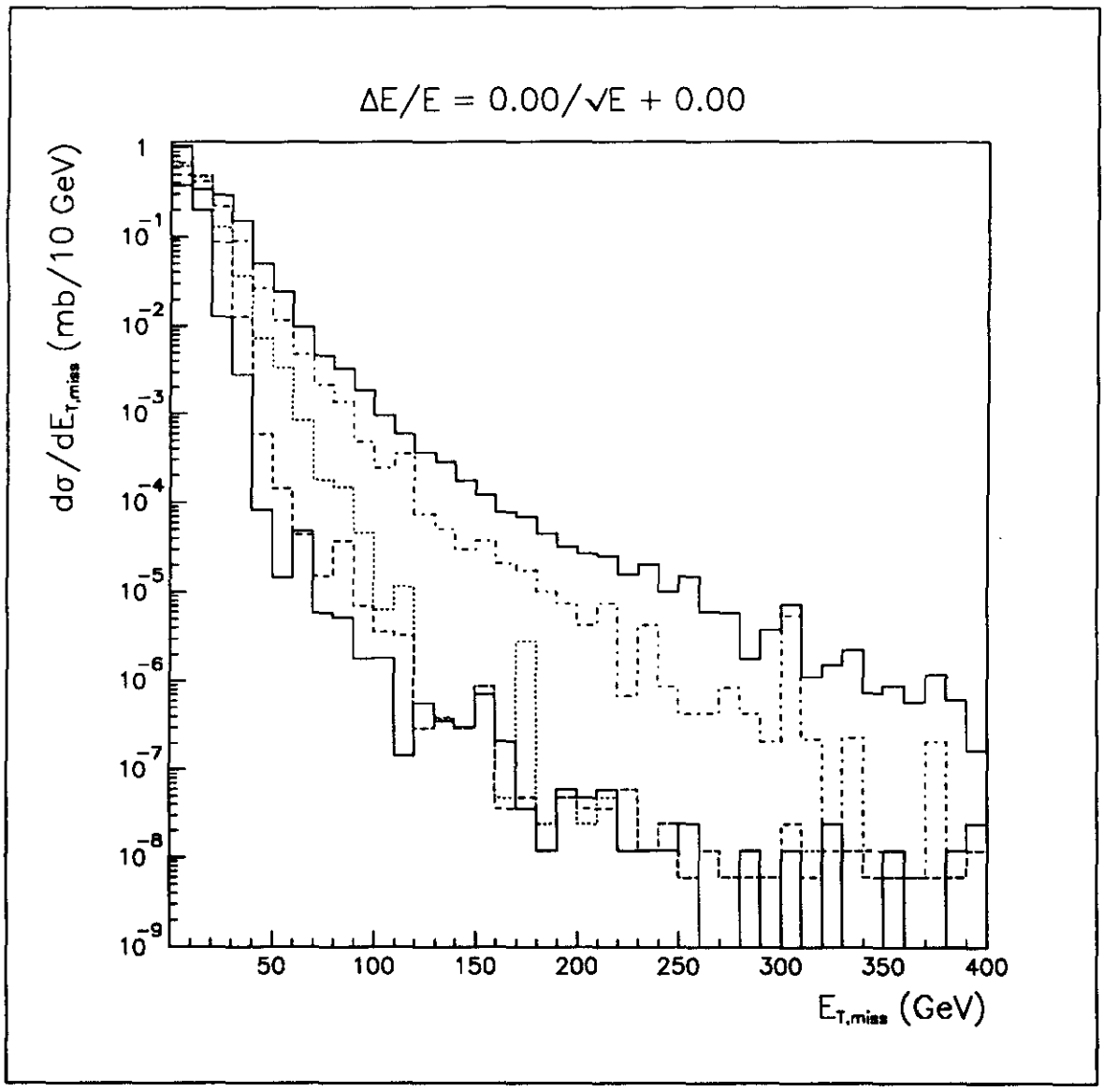

Figure 1: $\not{E}_T$ cross section for perfect energy resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

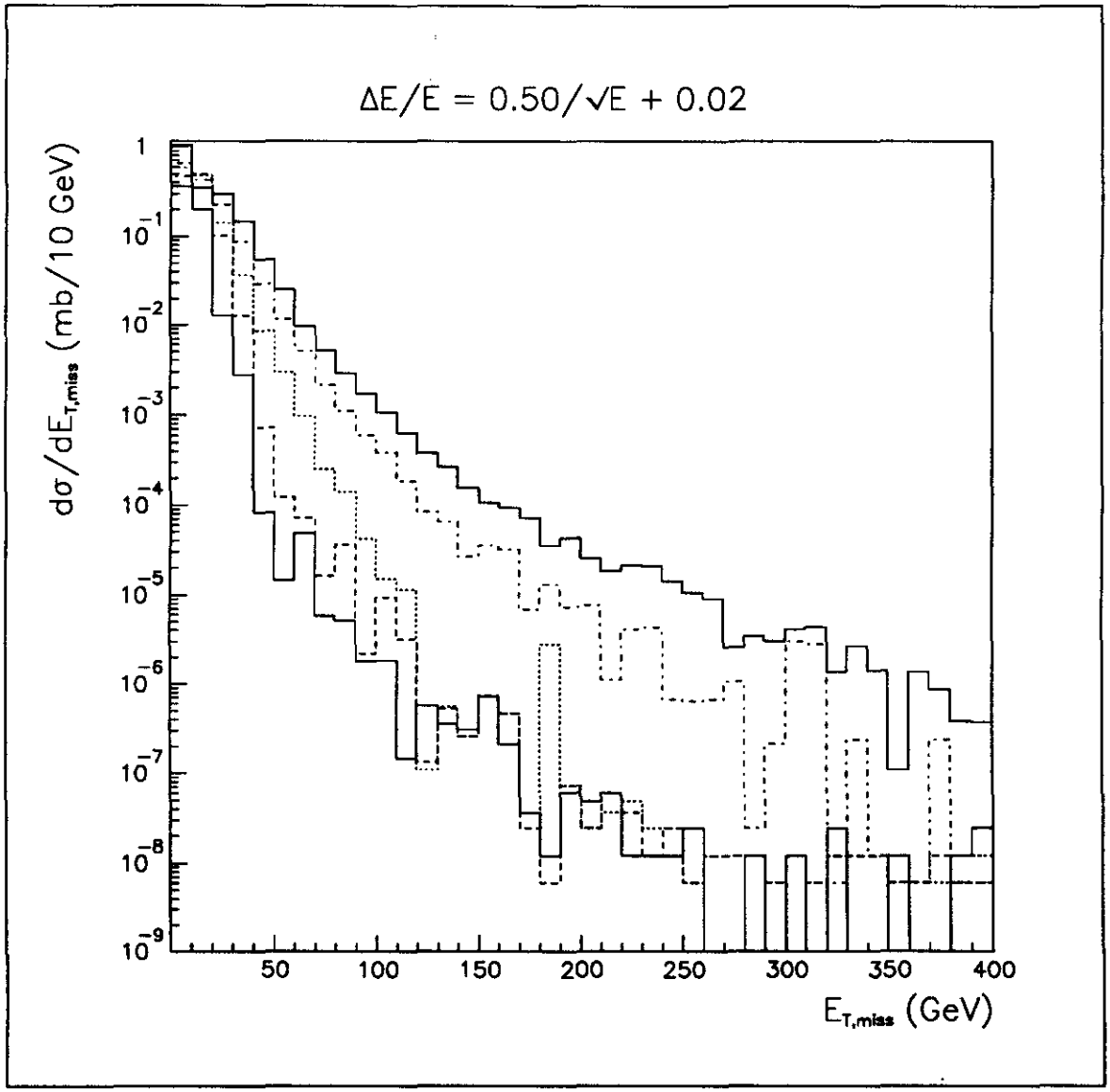

Figure 2: $\not{E}_T$ cross section for good energy resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

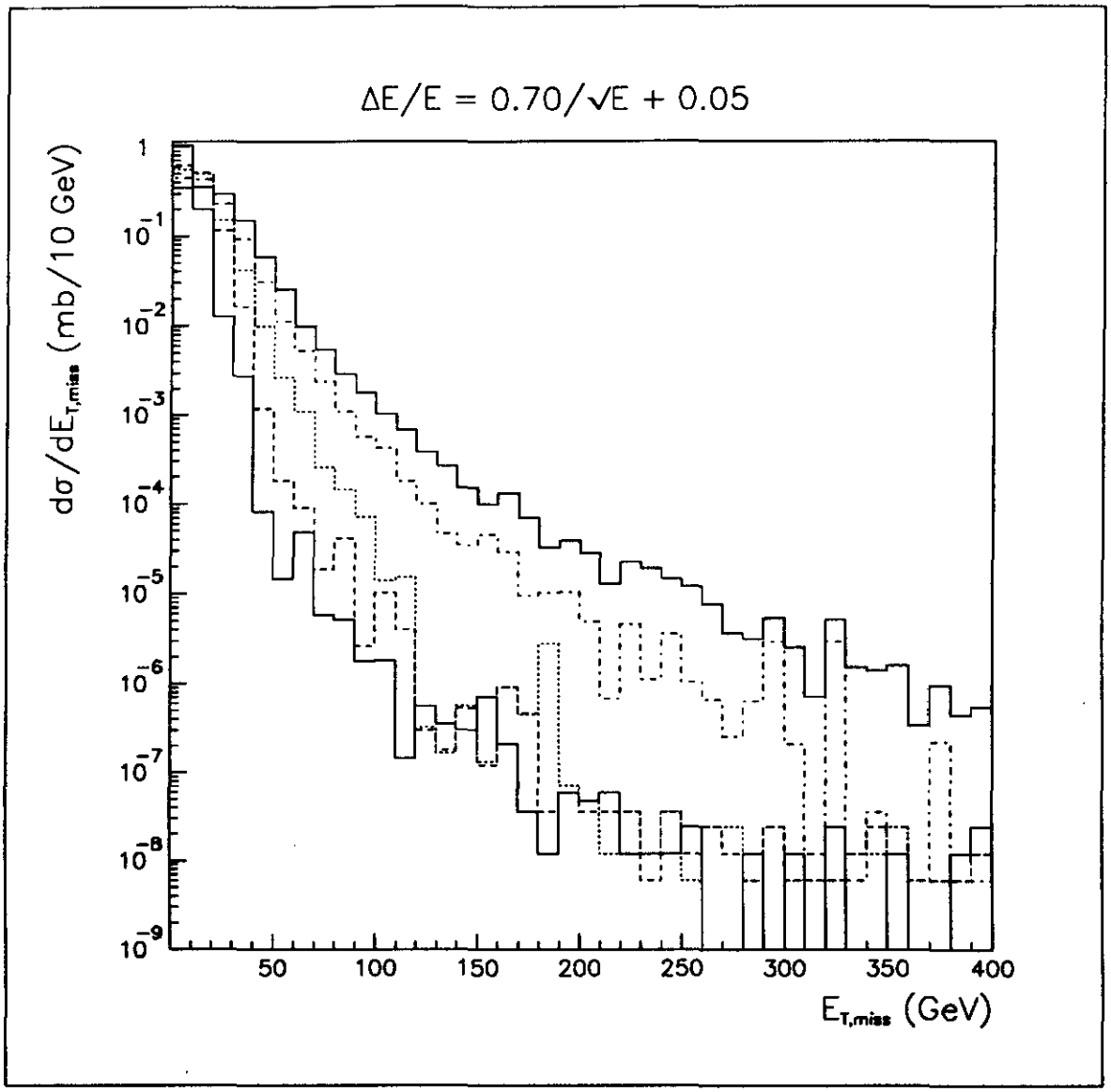

Figure 3: $\not{E}_T$ cross section for mediocre energy resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

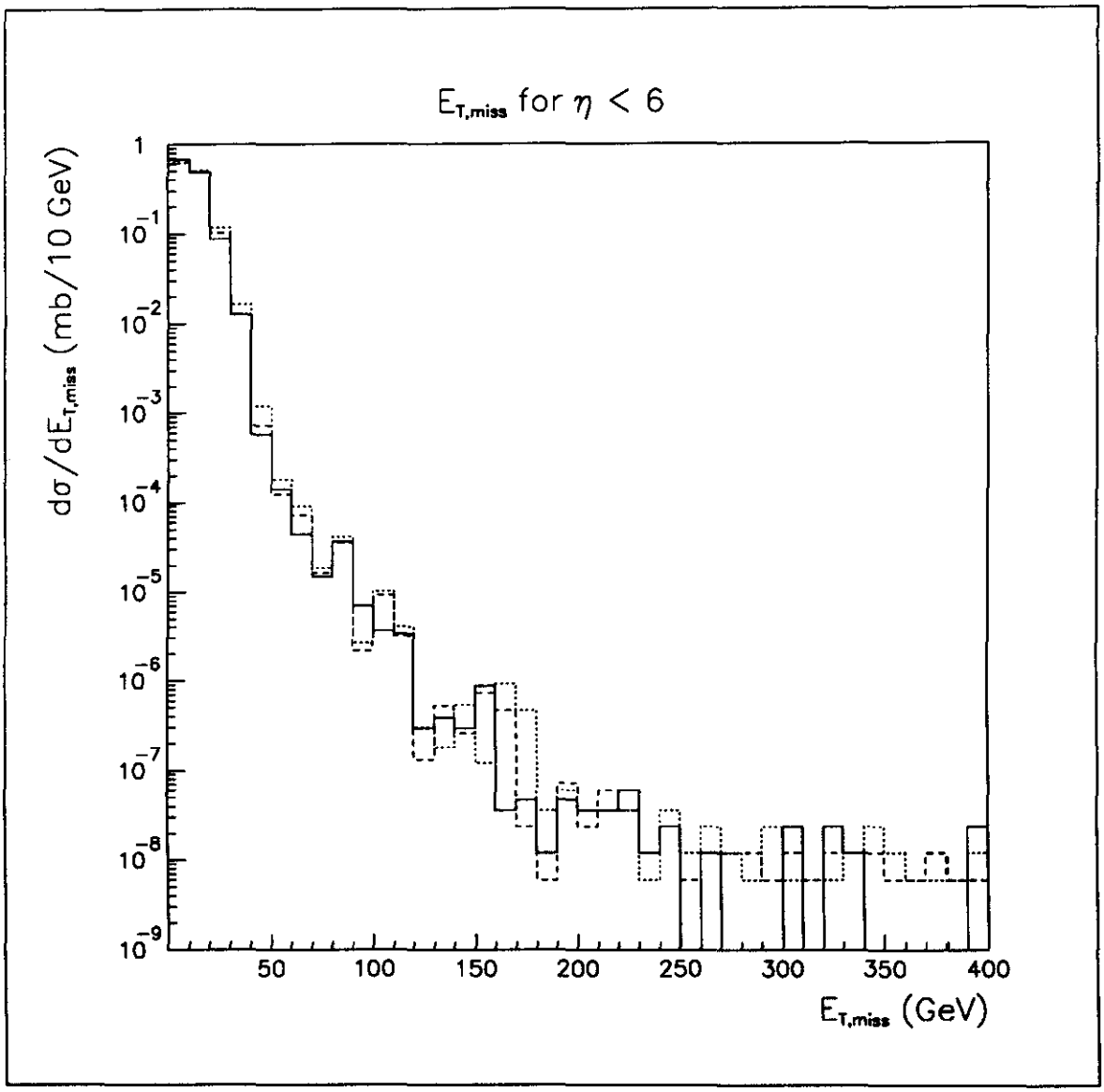

Figure 4: $\not{E}_T$ cross section for perfect resolution. Solid: full calorimeter. Dashed, dotted, dot-dashed, solid: jets with $\eta < 6$, $\eta < 5$, $\eta < 4$, and $\eta < 3$.

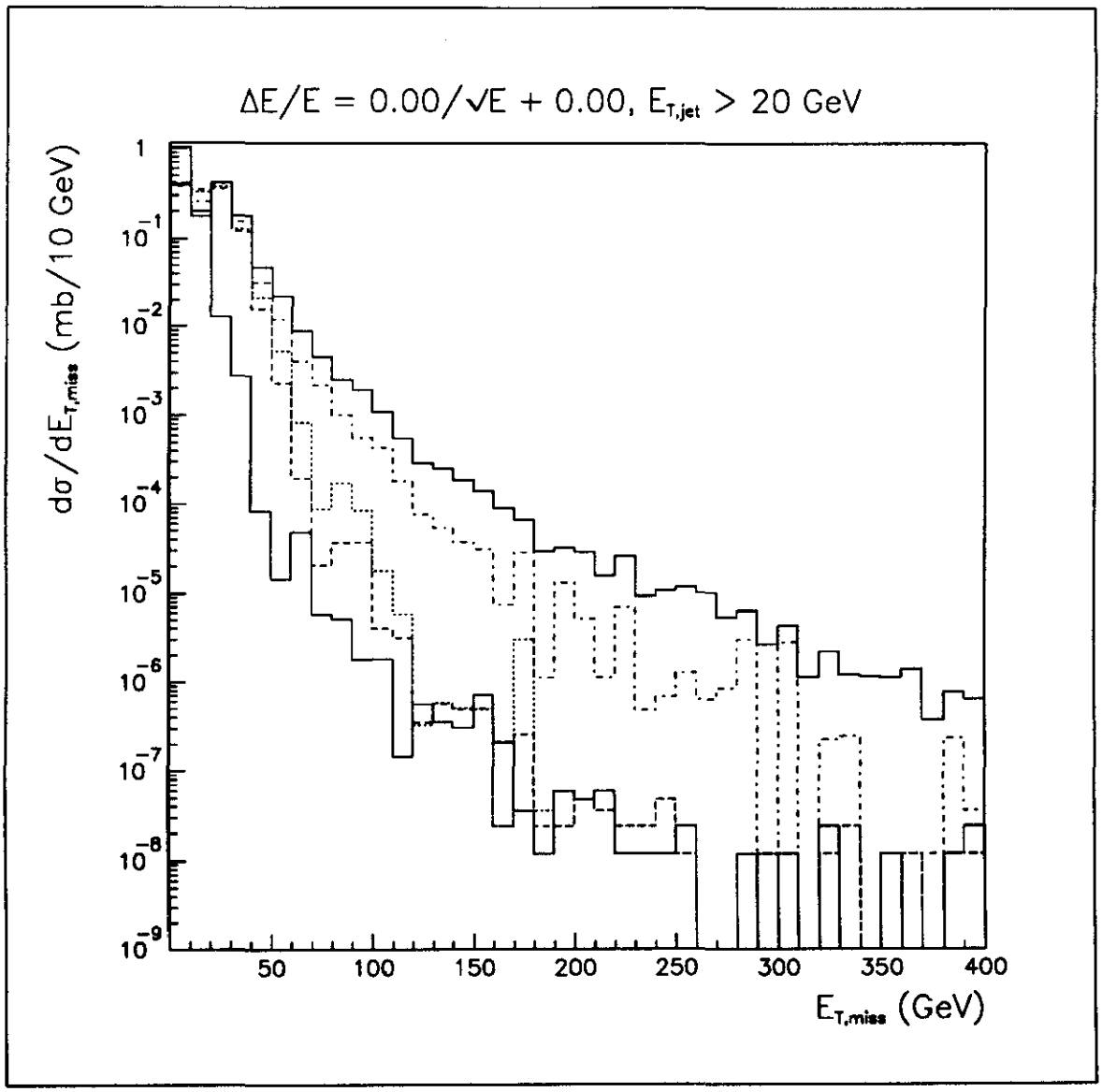

Figure 5: The same as Fig. 1 for $p_{T,\mathrm{jet}} > 20\,\mathrm{GeV}$.

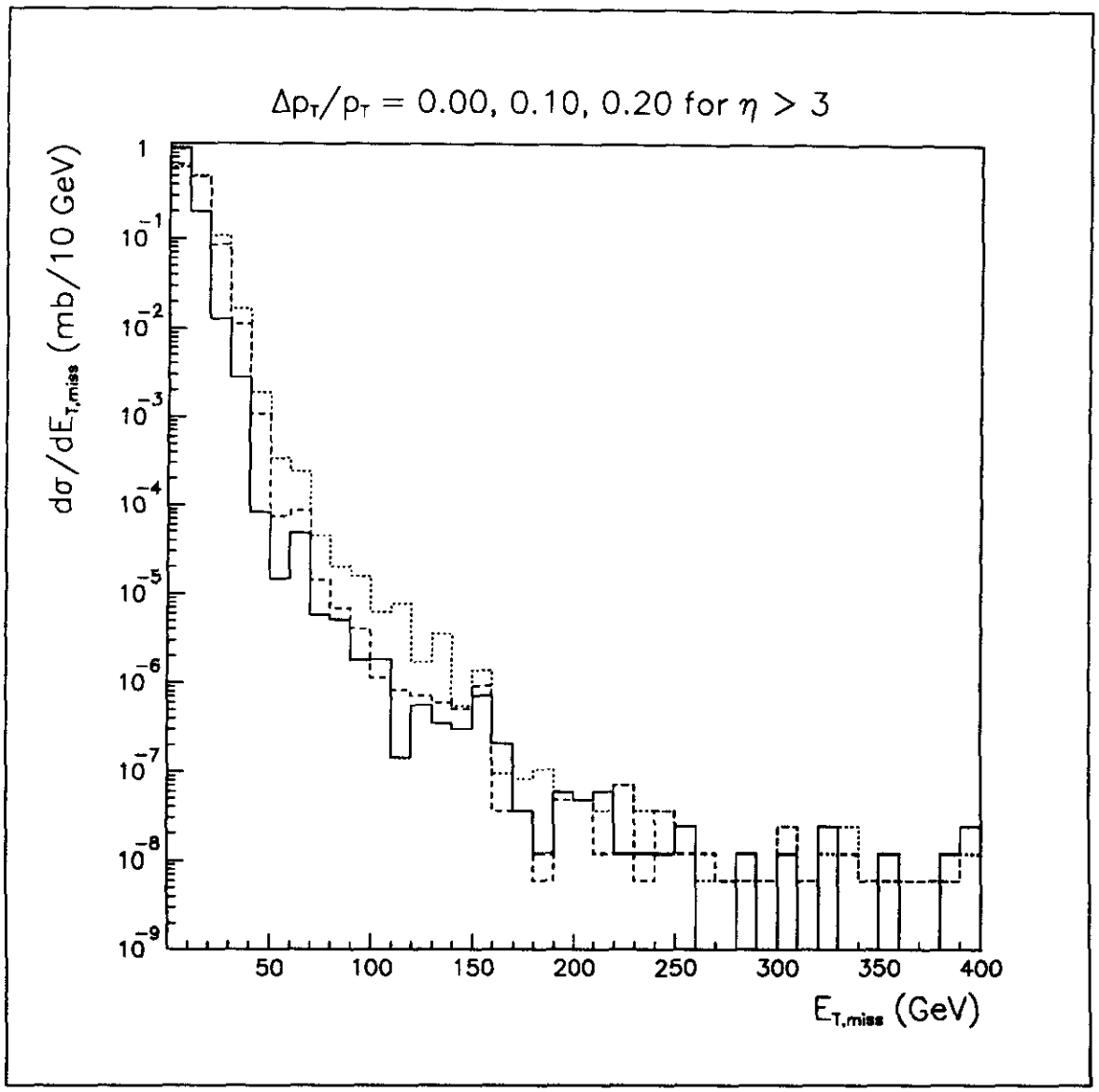

Figure 6: Solid: $\not{E}_T$ cross section for full calorimeter. Dashed: $\not{E}_T$ cross section with $\Delta p_T/p_T = 0.10$ for $\eta > 3$. Dotted: Same, for $\Delta p_T/p_T = 0.20$.