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Effects of Limited Calorimeter Coverage on $\not{E}_T$

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Abstract:

Due to limited calorimeter acceptance QCD jets produced at large η will miss the calorimeter, contributing to the measured $\not{E}_T$ cross-section. A simple calorimeter model is used to estimate this effect.

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ABSTRACT

Due to a limited calorimeter acceptance QCD jets produced at large η will miss the calorimeter, contributing to the measured $\not{E}_T$ cross-section. A simple calorimeter model is used to estimate this effect.

1. Introduction

Missing transverse energy ($\not{E}_T$) is a useful signature for a variety of processes at the SSC. The standard model backgrounds come from production of heavy quarks and of W and Z bosons at high p_T. In addition there are detector induced backgrounds from the energy resolution of the calorimeter, including non-Gaussian tails, from the angular resolution of the forward calorimeter, and from leakage through the beam hole. Previous analyses have usually put in real physics backgrounds and detector resolution, but they have not treated the response of the forward calorimeter in much detail. Recently a full GEANT shower simulation of the p_T resolution of a tungsten/liquid argon forward calorimeter for GEM has been performed.[1] This gave a resolution

$$\begin{aligned} \frac{\Delta p_T}{p_T} &\approx 10\% \quad \text{for} \quad 3 < \eta < 5\,, \\ &\approx 30\% \quad \text{for} \quad \eta = 5.5\,, \end{aligned}$$

for single hadrons in the forward calorimeter. This result is used here to make an improved estimate the detector contribution to the $\not{E}_T$ cross section. It is found that a coverage $\eta_{\max} \geq 5$ is required to prevent the detector contribution to dominating the inclusive standard model contribution for $\not{E}_T \gtrsim 100\,\text{GeV}$, which is the interesting range for SSC physics.

It may not be essential to measure the inclusive $\not{E}_T$ contribution. Some missing energy processes, e.g. Higgs, top, technicolor, new gauge bosons and WW interactions, have an isolated lepton as an additional signature to $\not{E}_T$. Such a lepton in the event will reduce the $\not{E}_T$ background from QCD jet leakage. Other processes, including the production of gluinos and other SUSY particles, in general do not have isolated leptons, but they require making additional multi-jet and topology cuts in the event selection. Such cuts also reduce the $\not{E}_T$ background from QCD jet leakage. Nevertheless, measuring the inclusive $\not{E}_T$ cross section is clearly desirable to have another handle on understanding the standard model background, and sufficient forward calorimeter coverage to do so should be a design goal.

2. $\not{E}_T$ Cross Sections

ISAJET[2] was used to generate about 50K TWOJET events in each of ten p_T bins covering the range p_T = 50–1600 GeV in increasing steps: 50–75, 75–100, 100–150, 150–200, ..., 800–1200, 1200–1600 GeV. The sample includes both neutrinos from heavy quarks (m_t = 140 GeV) and light quark and gluon jets, which can contribute to the observed $\not{E}_T$ cross section through mismeasurement. These events were put into an idealized calorimeter simulation based on CALSIM with $\Delta\eta = \Delta\phi = 0.10$ for $\eta < 6$. The energy resolution for $\eta < 3$ was similar to the GEM LOI Liquid Argon Calorimeter option (Table 1). No transverse smearing was performed, but the $\Delta p_T/p_T$ resolution calculated in Ref. 1 was taken into account by including an additional constant term in the energy resolution:

$$\begin{aligned} \frac{\Delta E_T}{E_T} &= 10\%\,, & 3 < \eta < 5 \\ &= 10\% + 30\%\,(\eta - 5)\,, & 5 < \eta < 6 \end{aligned}$$

All resolutions were assumed to be Gaussian. It is obviously important to calculate the complete resolution function for the forward calorimeter to determine whether there are significant non-Gaussian tails.

Table 2.1: Calorimeter Resolution Parameters

Calorimeter section	stochastic	constant
electromagnetic	$0.075/\sqrt{E}$	0.005
hadronic	$0.63/\sqrt{E}$	0.02

Fig. 2.1 shows the $\not{E}_T$ cross section calculated by summing all neutrinos with $|\eta| < 6$. This "true" $\not{E}_T$ cross section represents the irreducible background in search of new particles. High $\not{E}_T$ values are due to a heavy quark neutrino decays.

The $\not{E}_T$ measured by summing the energy deposition in each calorimeter cell within the limited coverage has an additional background from an escaping high p_T QCD jets. Fig. 2.2 shows the ratio

$$\mathcal{R} = \frac{\left.\dfrac{d\sigma}{d\not{E}_T}\right|_{\mathrm{obs},\,\eta<\eta_{\mathrm{max}}}}{\left.\dfrac{d\sigma}{d\not{E}_T}\right|_{\nu}}$$

of the measured $\not{E}_T$, calculated within the assumed calorimeter coverage of $\eta_{\mathrm{max}} = 6, 5, 4$ or 3, to the true $\not{E}_T$ cross section of Fig. 2.1. At low $\not{E}_T$ the contribution of QCD jets missing the calorimeter acceptance increases the cross section, and hence the potential background for new physics, by up to several orders of magnitude. The effect of the finite calorimeter acceptance becomes small by $\not{E}_T \approx 70$ GeV for $\eta_{\mathrm{max}} = 6$, but it remains important up to $\not{E}_T \approx 500$ GeV, well beyond the interesting range, for $\eta_{\mathrm{max}} = 4$.

Any additional event selection which forces a harder scattering or a more central event reduces the $\not{E}_T$ background from QCD jet leakage. Fig. 2.3 shows the ratio $\mathcal{R}$ of the

observed $\not{E}_T$ cross section with $\eta_{\max} = 6$, 5, 4, and 3 to the true $\not{E}_T$ cross section for events having an isolated lepton with $p_T^\ell > 25\,\mathrm{GeV}$. The requirement of a 25 GeV isolated lepton in event almost presumably selects mainly $t\bar{t}$ jets. It almost eliminates the missing QCD jet background and makes appropriate smaller values of $\eta_{\max}$. The absence of the missing QCD jet background in the events with an isolated lepton is the reason why the GEM LOI simulation of the fourth generation 400 GeV quark search was insensitive to the calorimeter coverage.[3]

Another example of such a cut is provided by the GEM LOI gluino analysis.[3] To reduce background for gluinos in the 300 GeV mass range at least 5 jets with $p_T > 75$ GeV and $|\eta| < 3$ were required. Fig. 2.4 shows the ratio $\mathcal{R}$ of the observed to the true $\not{E}_T$ cross section with $\eta_{\max} = 6$, 5, 4, and 3 with this multi-jet cut applied. It also reduces the background from the events with escaping QCD jets and makes smaller values of $\eta_{\max}$ appropriate.

For some processes QCD jet events are not the dominant background source. For $H \to ZZ \to \ell^+\ell^-\nu\bar{\nu}$, for example, the dominant background comes from $Z + jets$ production. The SDC LOI[4] found $\eta_{\max} = 4$ to be sufficient to reduce the $Z + jets$ background.

If one does observe any nonstandard signal, particularly something like the gluino signal which does not have a reconstructable mass peak, it will be important to verify that all the calculated standard model backgrounds to $\not{E}_T$ are correct. The Z contribution can be checked with $Z \to \ell^+\ell^-$. The $t\bar{t}$ and W contributions can be checked by measuring isolated leptons. The $b\bar{b}$ and $c\bar{c}$ contributions are best checked by measuring high-p_T muons in jets; GEM should do this particularly well. Beyond this, one would like to verify that the inclusive $\not{E}_T$ cross section without additional cuts to select heavy particle production is described by the standard model.

3. Conclusions

Measuring of the inclusive $\not{E}_T$ spectrum at the SSC for $\not{E}_T \gtrsim 100\,\mathrm{GeV}$ is the most demanding task and requires calorimeter coverage of $\eta_{\max} \approx 5.5$. This coverage is also needed to implement a simple $\not{E}_T$ trigger.

Searches for new particles usually requires additional cuts besides the $\not{E}_T$ cut. These additional cuts reduce the contributions to $\not{E}_T$ from missing QCD jets and make the calorimeter coverage requirements less demanding. For example:

(1) The requirement of a $p_T > 25\,\mathrm{GeV}$ isolated lepton in the event almost eliminates the $\not{E}_T$ background from missing jets.

(2) The search for gluinos in the range $m \approx 300\,\mathrm{GeV}$ requires $\eta_{\max} = 4.5$ if one uses the multi-jet selection from the GEM LOI.

Unfortunately those additional cuts complicate trigger and reduce the flexibility of the search, and they increase the systematic error in the calculated trigger efficiency. Even more important, they eliminate the possibility of using the inclusive $\not{E}_T$ distribution as a handle on the standard model and detector backgrounds. For these reasons, it seems important to design the forward calorimeter so that missing QCD jets do not dominate the inclusive $\not{E}_T$ cross section in the region relevant for SSC physics. The present GEM forward calorimeter appears to meet this goal.

Acknowledgements

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References

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2. F.E. Paige and S.D. Protopopescu, ISAJET 6.43 (1991).
3. GEM Collaboration, *Letter of Intent*, GEM TN-92-49 (1992).
4. SDC Collaboration, *Letter of Intent*, SDC-90-00151 (1990).

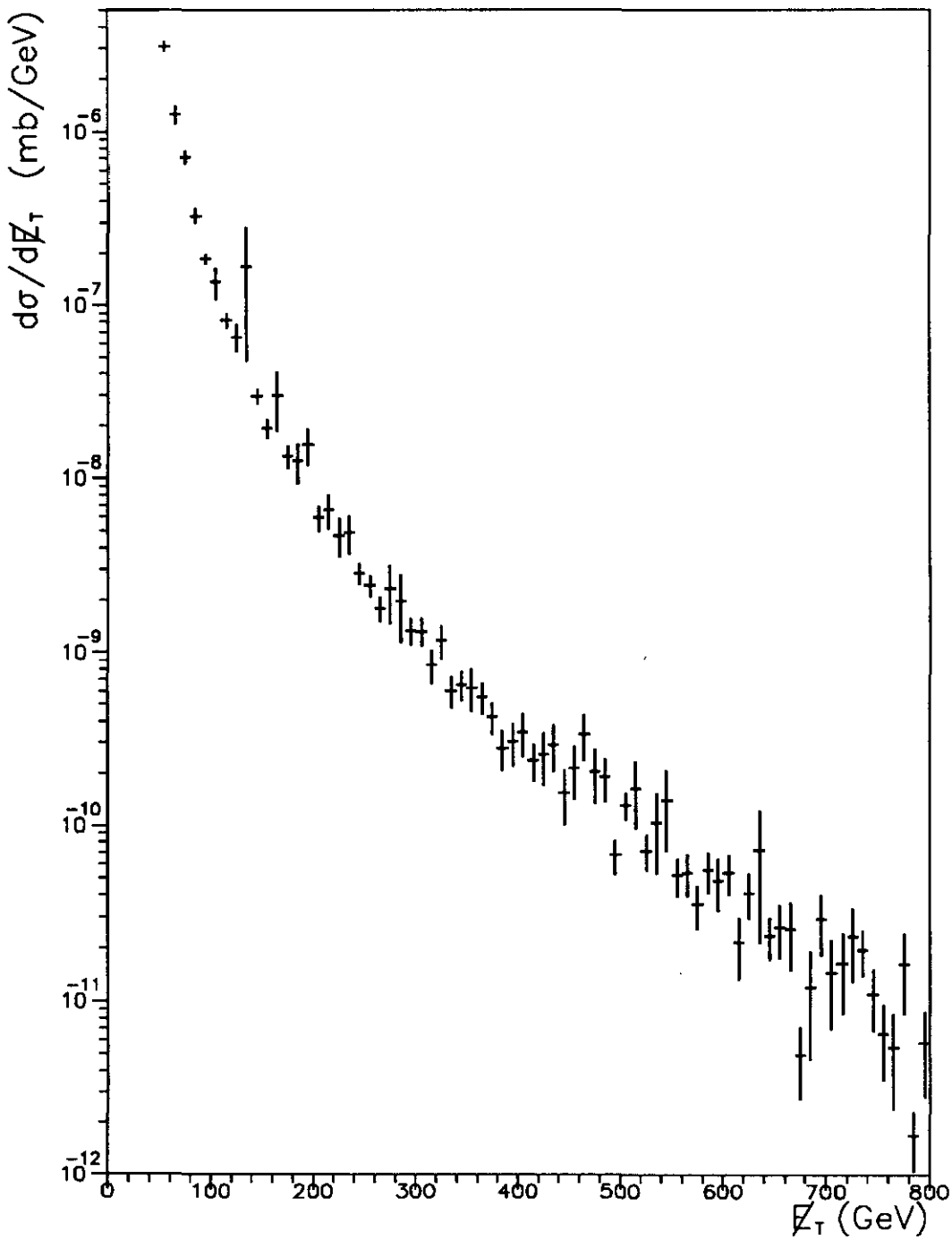

Figure 2.1: True $\not{E}_T$ cross section from neutrinos from heavy quark decays.

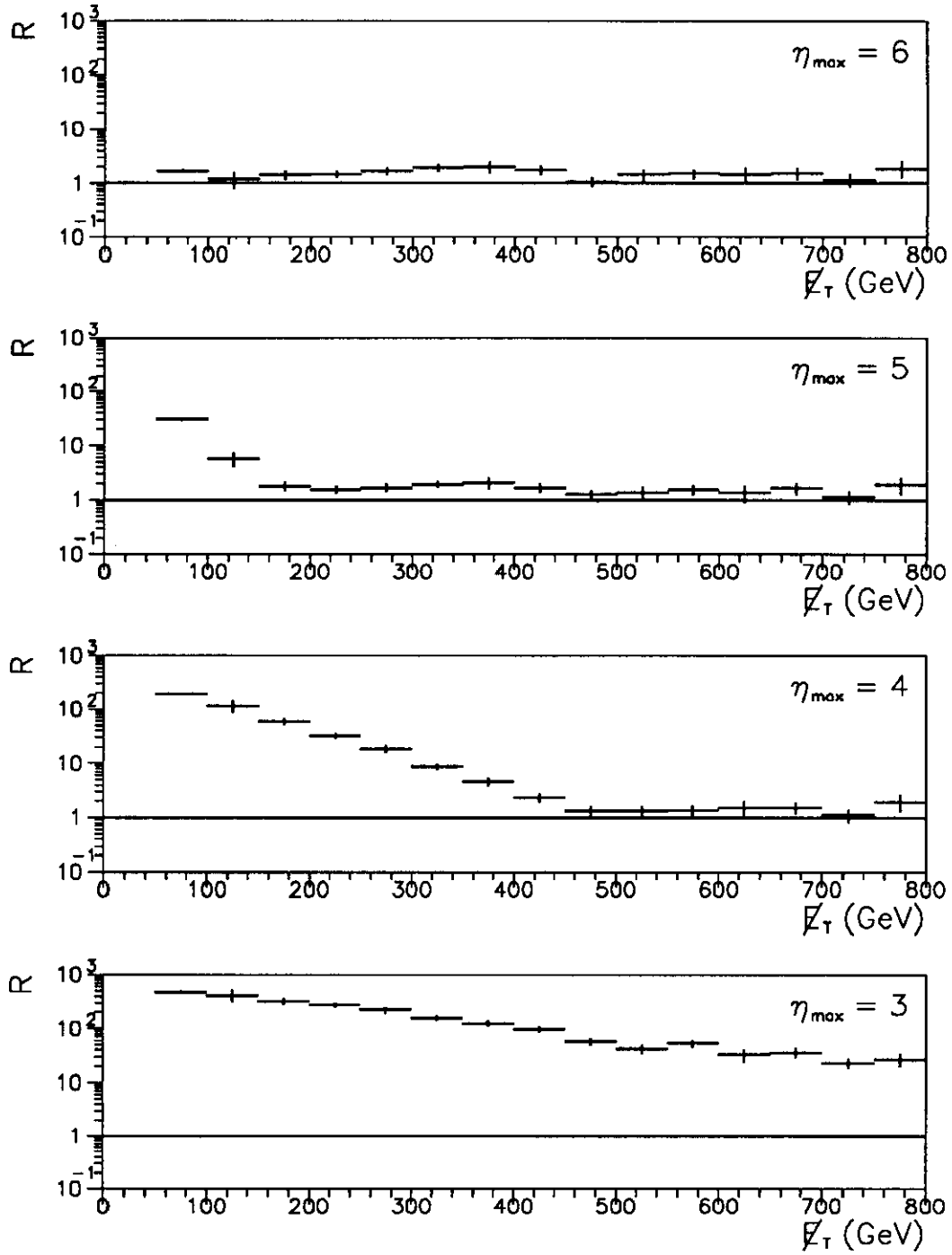

Figure 2.2: Ratio $\mathcal{R}$ of $\not{E}_T$ cross section observed for various $\eta_{\max}$ to true cross section, Fig. 2.1.

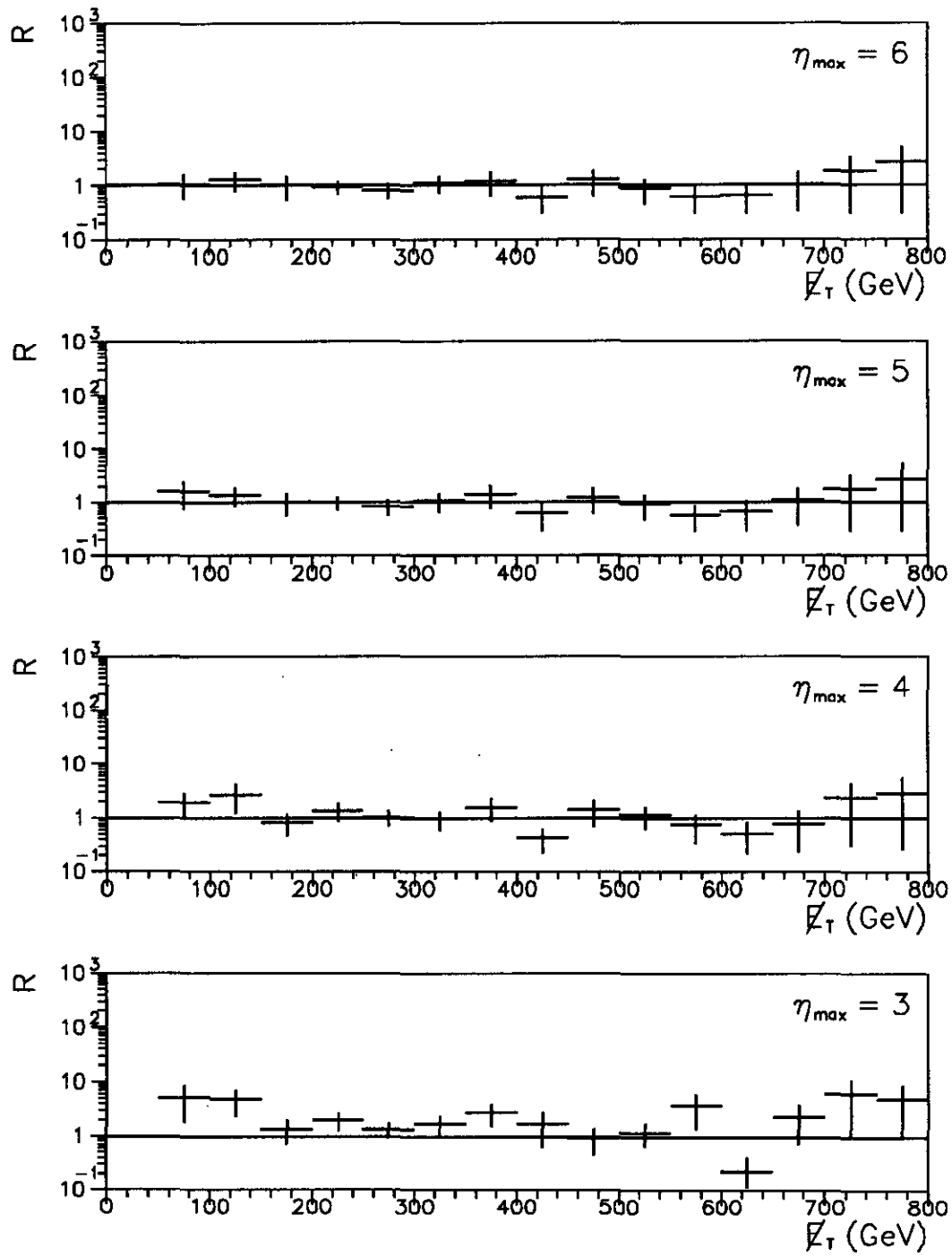

Figure 2.3: Same as Fig. 2.2, but with additional requirement of an isolated lepton with $p_T > 25\,\mathrm{GeV}$ and $|\eta| < 3$.

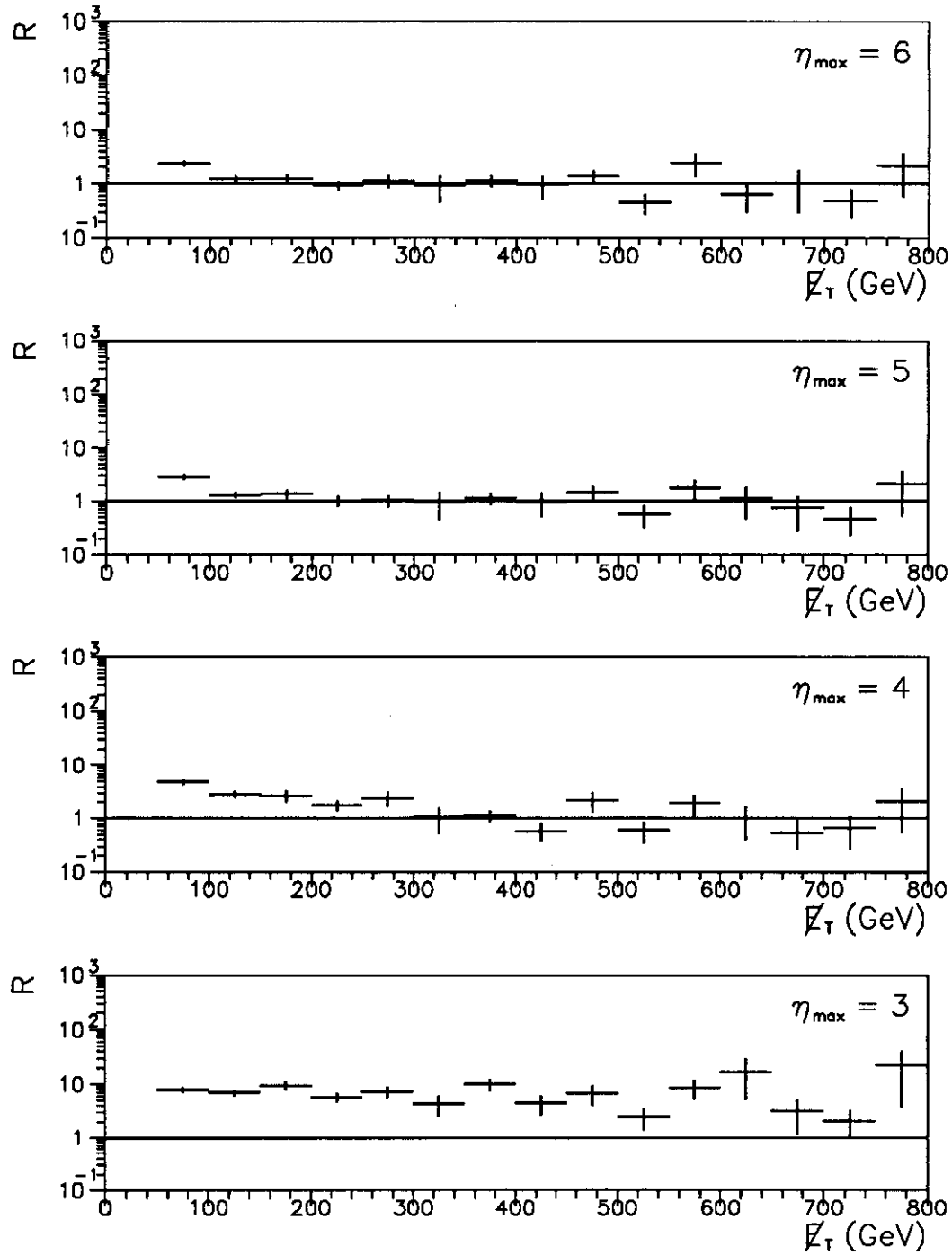

Figure 2.4: Same as Fig. 2.2, but with additional requirement of 5 jets with $p_T > 75\,\mathrm{GeV}$ and $|\eta| < 3$.