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Lepton Triggers at the SSC

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Abstract:

The dominant sources of prompt leptons at the SSC are decays of c and b quarks in QCD jets, W decays, and top decays. It is important to be able to set the trigger thresholds low enough to be able to study physics just beyond the reach of the Tevatron.

Lepton Triggers at the SSC

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Leptons are an important signature for a wide range of physics at the SSC. It is important to be able to set the trigger thresholds low enough to be able to study physics just beyond the reach of the Tevatron. For example, it now seems likely that the top quark will only be studied in detail at the SSC even if it is discovered first at the Tevatron. Since the top quark has a large cross section, it can easily be discovered using two-lepton decays,

$$t\bar{t} \to e^{\pm}\mu^{\mp}X.$$

But one would like to trigger on a single semileptonic decay and then study the decays of the other t. This requires a single lepton trigger with

$$p_{T,\,\mathrm{lepton}} \gtrsim 40\,\mathrm{GeV}.$$

for good efficiency.

The dominant sources of prompt leptons at the SSC are decays of c and b quarks in QCD jets, W decays, and top decays. The rates for leptons from Drell-Yan and Z^0 decays are smaller by an order of magnitude, and other standard-model sources such as W^+W^- pairs are smaller still. Muons from π and K decays and fake electrons from overlaps of electromagnetic showers and charged tracks are not considered here.

To study lepton trigger cross sections three samples of events have been generated with ISAJET 6.22 giving leptons with $p_T > 10\,\mathrm{GeV}$

- QCD jets, $20\,\mathrm{GeV} < p_T < 200\,\mathrm{GeV}$. For this sample, each hard scattering event was evolved 10 times, and each evolved event containing a c, b, or t quark was fragmented 10 times, and only events containing leptons were saved.
- $W \to \ell\nu$, $10 < p_{T,W} < 200\,\mathrm{GeV}$, using the $\mathcal{O}(\alpha_s)$ Drell-Yan graphs.

- $t\bar{t}$ events, $m_t = 140\,\mathrm{GeV}$.

In the $W^{\pm}$ sample the $\mathcal{O}(\alpha_s)$ graphs are used to obtain the correct high-p_T tail; the lower limit on $p_{T,W}$ is chosen to give the right total $W^{\pm}$ cross section. For c and b decays it is known that there are large higher order QCD corrections to the lowest order processes,

$$g + g \to Q + \bar{Q}, \quad q + \bar{q} \to Q + \bar{Q}.$$

These higher order corrections change both the normalization of the cross section and the topology of the events. ISAJET does not contain a correct treatment of higher order QCD, but it does approximate to these effects by including the gluon splitting process, $g \to Q\bar{Q}$. A special version of ISAJET has been used to generate the gluon splitting process more efficiently in the QCD jet sample.

Fig. 1 shows the inclusive single lepton p_T distributions summed over $e^{\pm}$ and $\mu^{\pm}$ for these samples. The cross sections for $p_T > 40\,\mathrm{GeV}$ are:

c, b	87 nb
$W^{\pm}$	12 nb
t	4 nb

The $W^{\pm}$ and t cross sections give a plausible trigger rate, but the contribution from c and b decays in QCD jets is an order of magnitude larger. Thus it is important to be able to reduce c and b decays in the trigger.

Fig. 2 shows the η distribution for $p_T > 40\,\mathrm{GeV}$ for the top sample. While the leptons for this light system extend out to $\eta \approx 4.0$, the cross section is large enough that one can afford some loss in efficiency. For heavy particles it is typically sufficient to cover leptons with $|\eta| \lesssim 2.5$.

Leptons from c and b decays should be less isolated than those from heavier particles. Fig. 3 shows for each sample the total transverse energy of all hadrons contained in a cone

$$\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < 0.2$$

around each lepton. Fig. 4 shows the same quantity for $\Delta R < 0.4$. The optimal value of ΔR is not precisely known but is in this range. Smaller values miss too much of the E_T from the c and b decays, while larger values pick up too much from the beam jets.

Fig. 5 shows the single lepton distributions for the three samples with a cut

$$E_T < 2\,\mathrm{GeV} \quad \text{in a cone} \quad \Delta R < 0.2$$

Note that with this cut the c and b rates are greatly reduced, giving a viable trigger in the range $p_T \gtrsim 40\,\mathrm{GeV}$.

The isolation cuts described here assumes a perfect measurement of the associated hadronic energy. In a real calorimeter, some of the hadronic energy will be deposited in the electromagnetic part of the calorimeter. Furthermore, electronic noise and pileup will add E_T to all the samples and so decrease the rejection of the c and b sample. On the other hand, extra photons near the lepton can be detected and will provide some additional rejection. A better simulation is needed.

For dileptons the threshold should be lower to be able to see cascade leptons. A reasonable value is set by the requirement of seeing Z^0 decays efficiently for calibration purposes:

$$p_{T,\,\mathrm{lepton\,1}} = p_{T,\,\mathrm{lepton\,2}} \gtrsim 20\,\mathrm{GeV}.$$

$Z^0 \to \ell^+\ell^-$ has a cross section of about 4 nb and dominates the rate for this trigger. Multilepton thresholds need to be in a similar range to detect, e.g.

$$H \to Z^0 Z^0 \to \ell^+\ell^-\ell^+\ell^-$$

with $m_H \approx 2m_Z$.

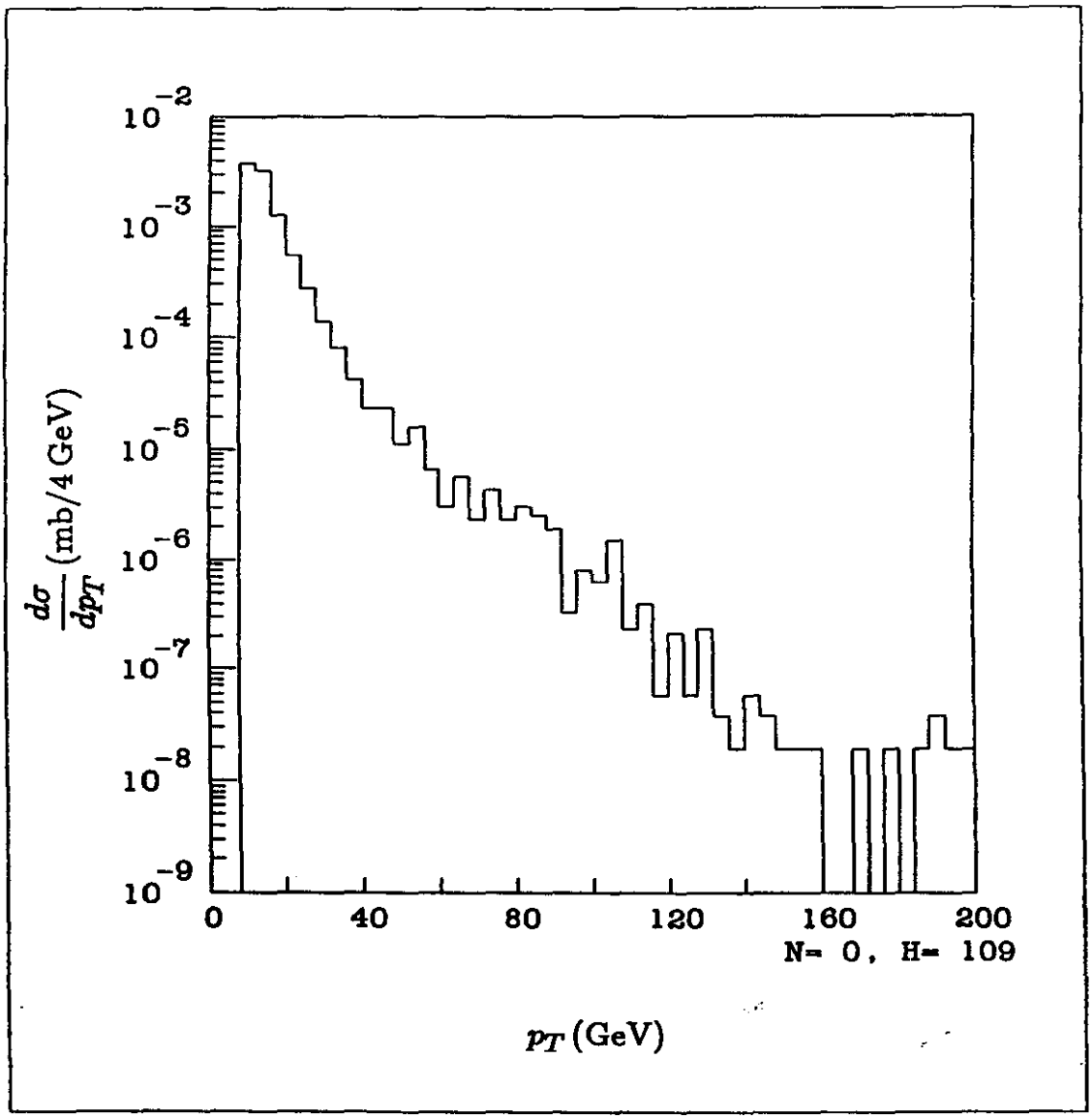

Figure 1a: Single lepton p_T distribution from c and b decays in QCD jets.

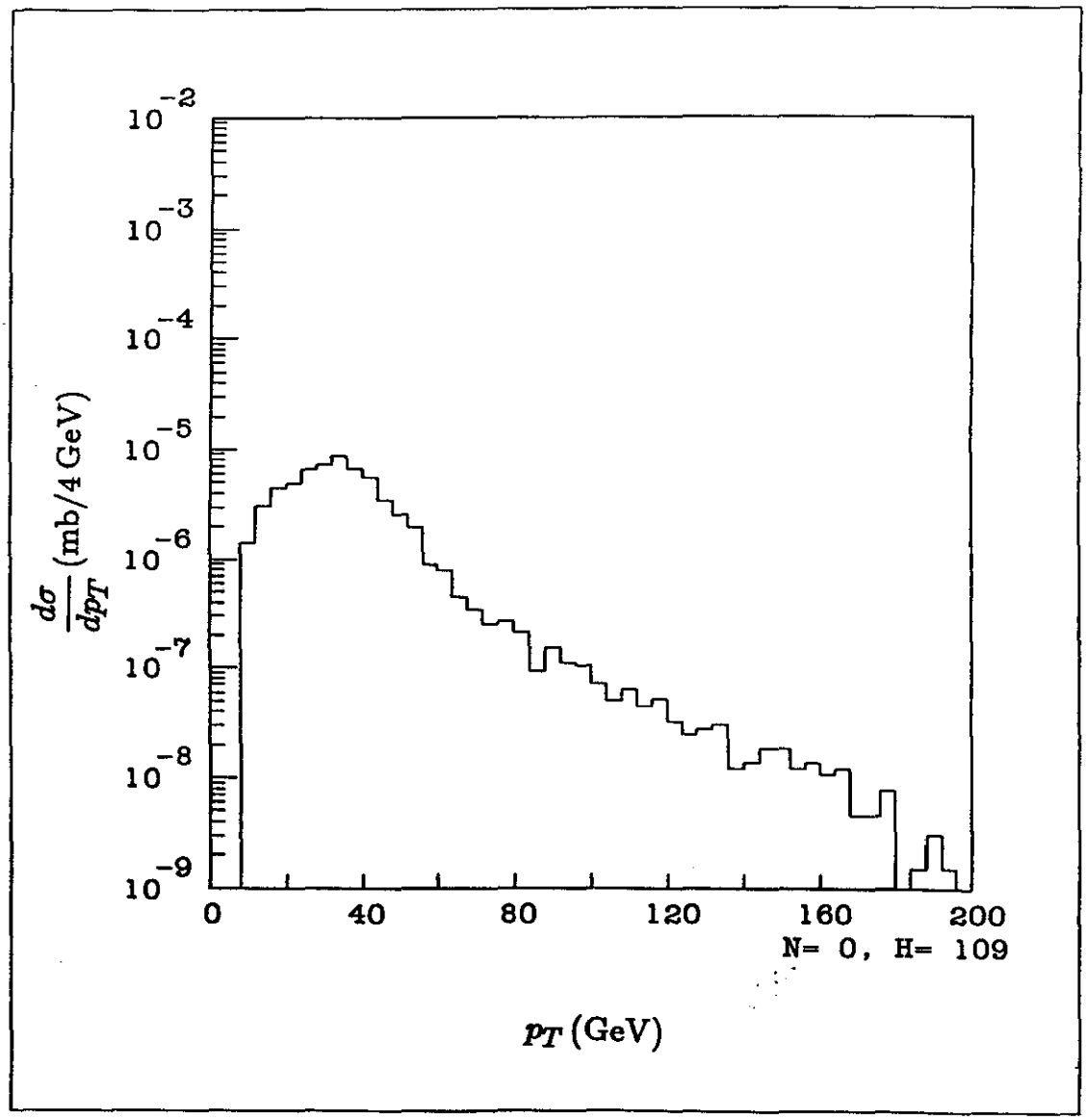

Figure 1b: Single lepton p_T distribution from $W^{\pm}$ decays.

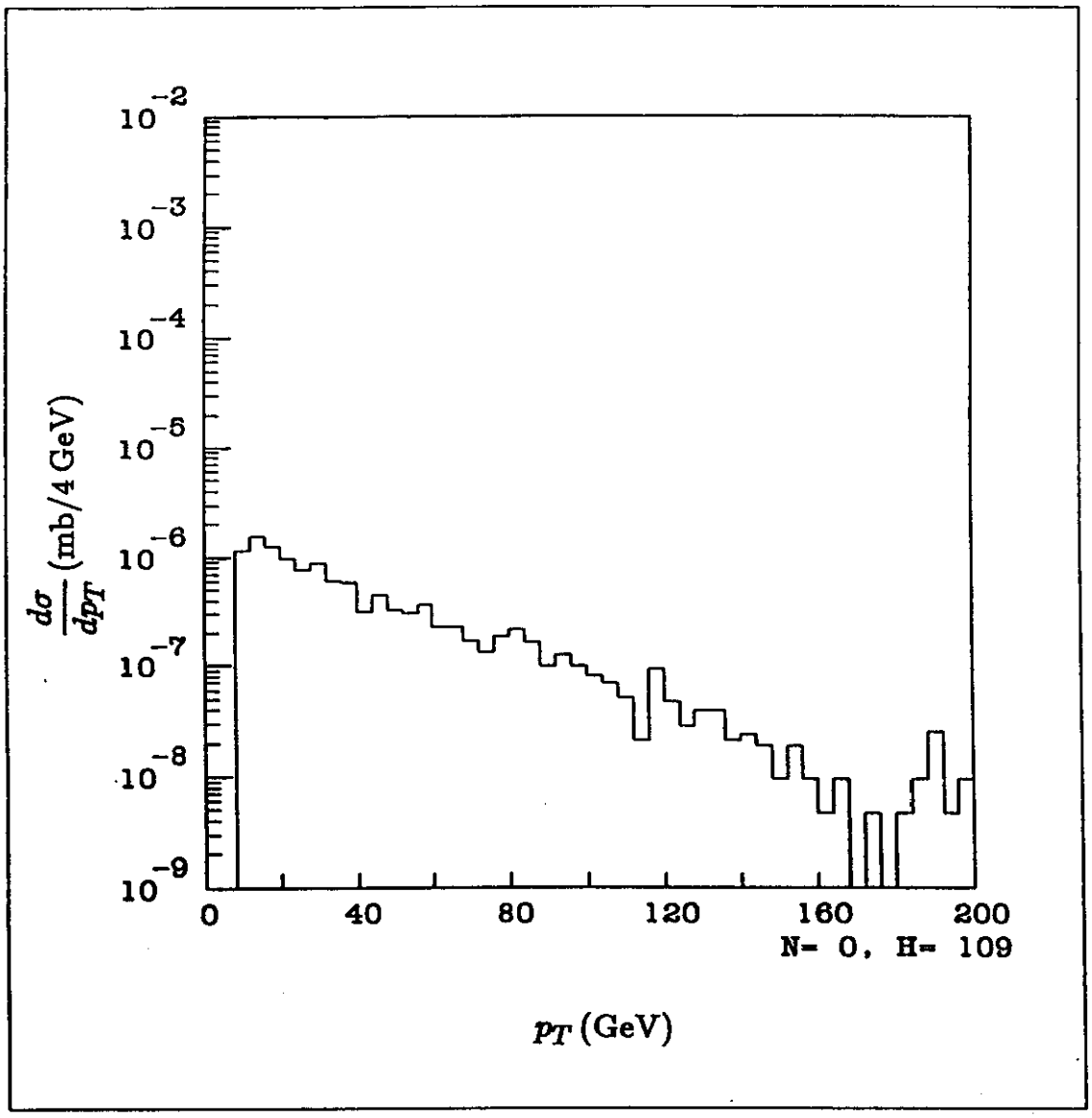

Figure 1c: Single lepton p_T distribution from top decays with m = 140 GeV.

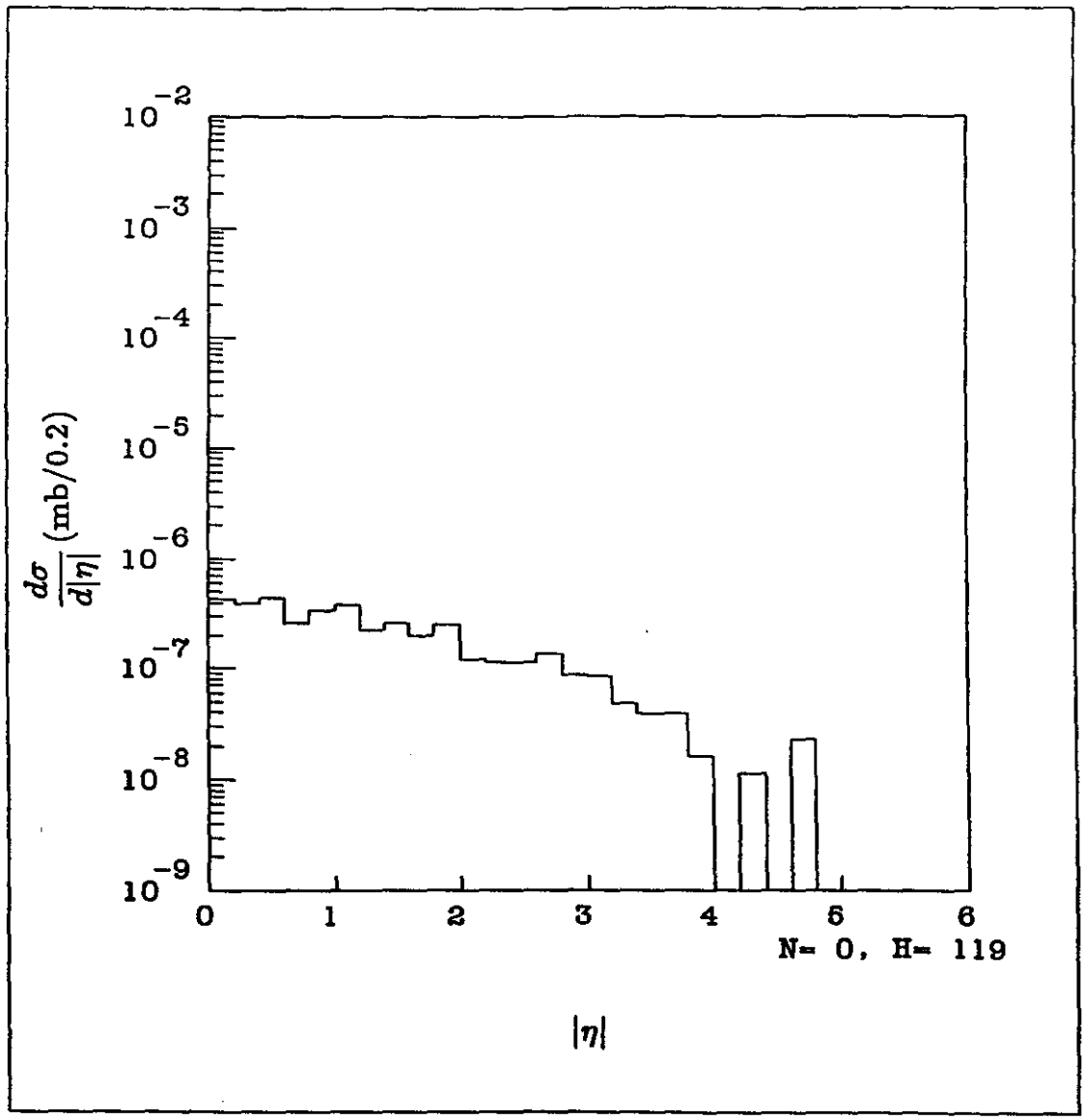

Figure 2: Single lepton η distribution for $p_T > 40\,GeV$ from top decays with $m = 140\,\mathrm{GeV}$.

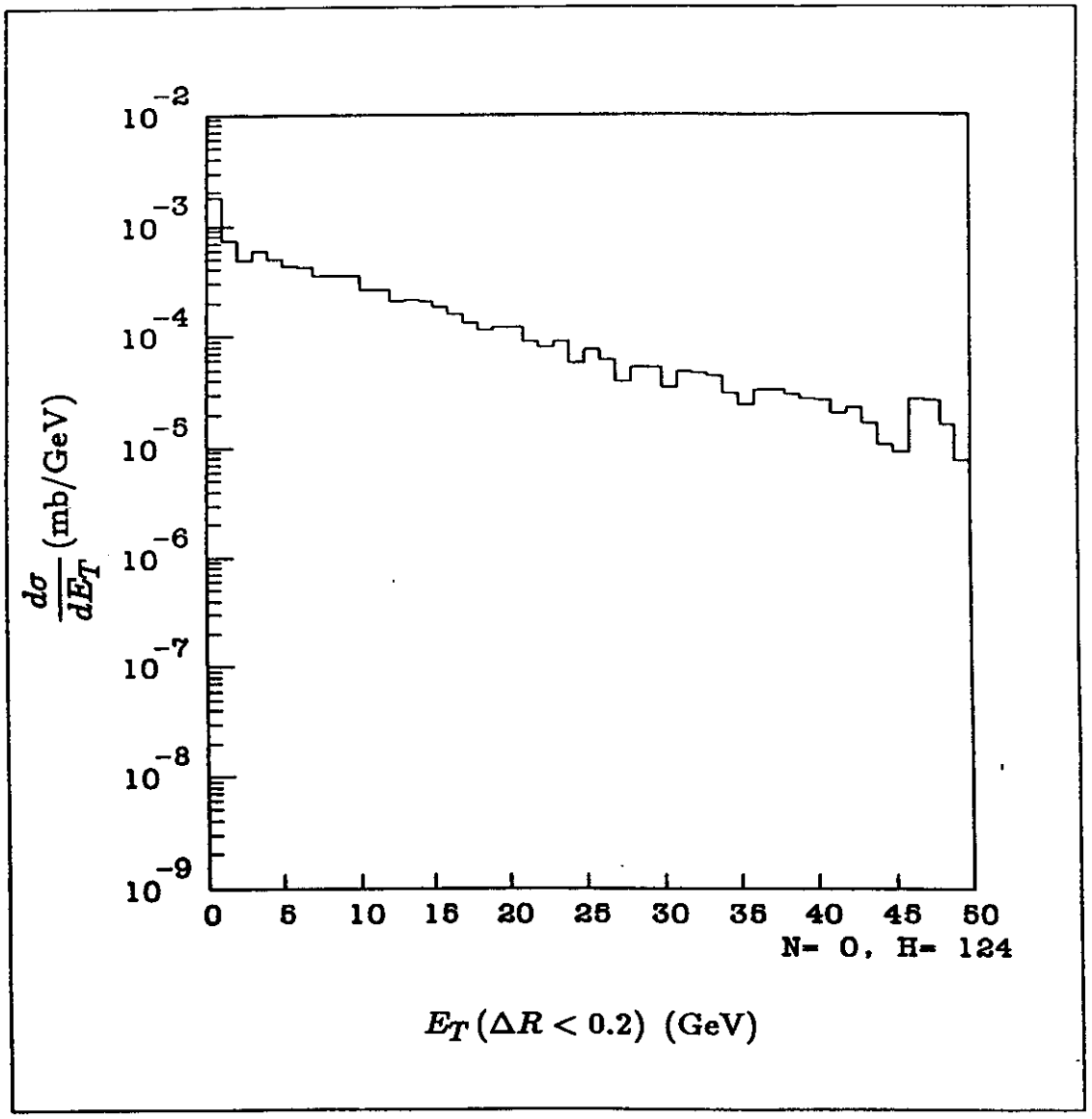

Figure 3a: E_T distribution in $\Delta R < 0.2$ from c and b decays in QCD jets.

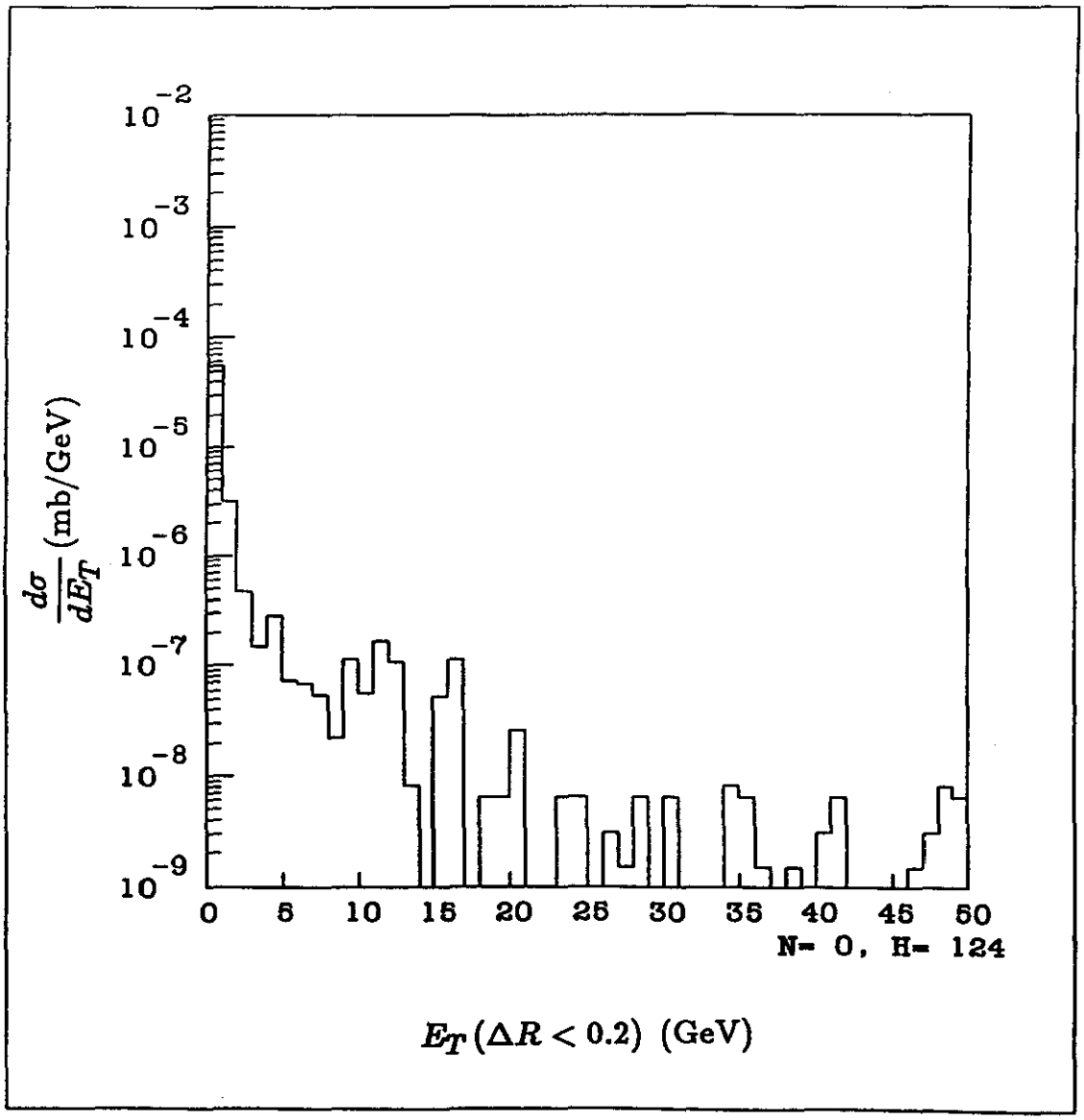

Figure 3b: E_T distribution in $\Delta R < 0.2$ from $W^{\pm}$ decays.

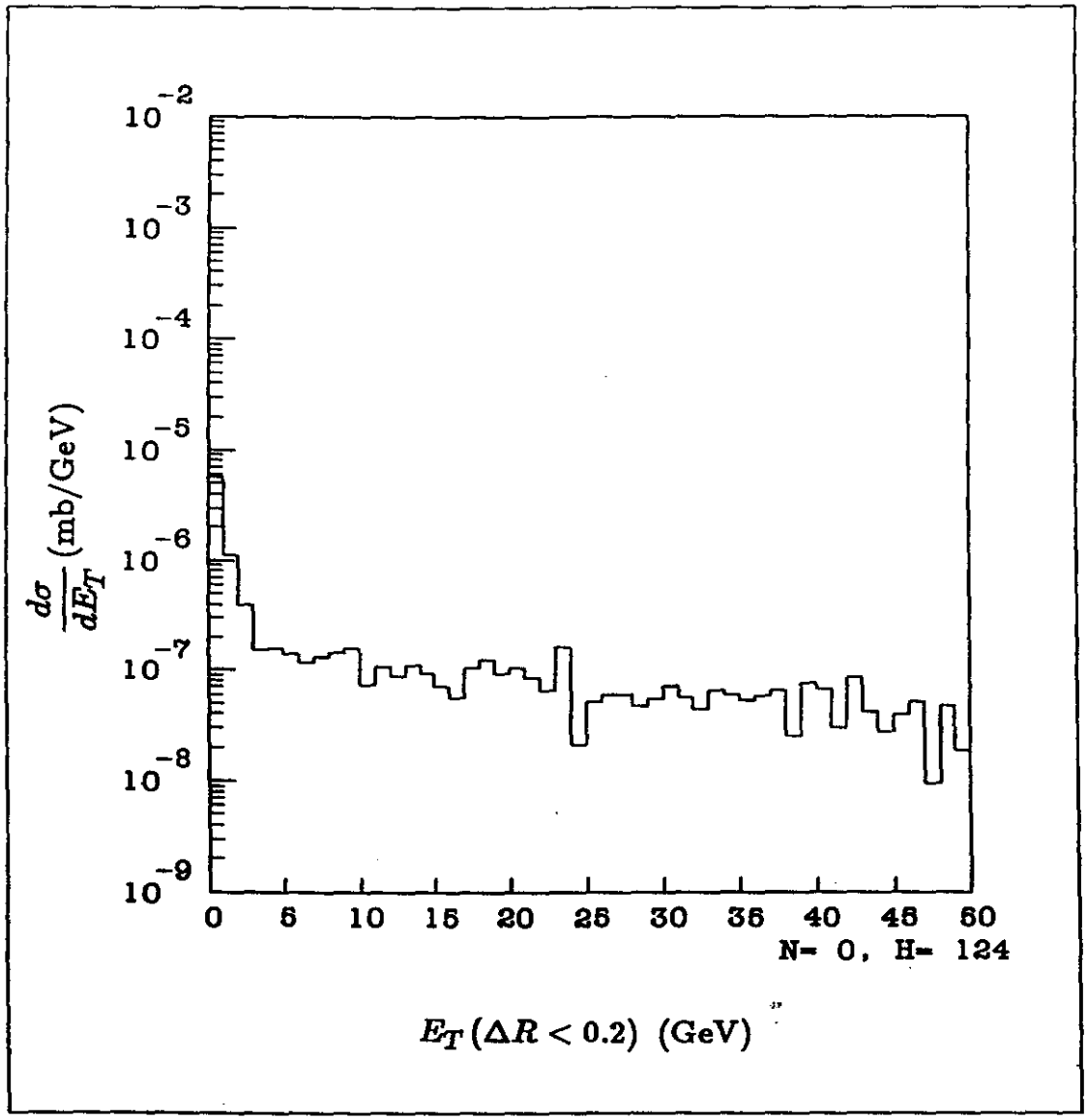

Figure 3c: E_T distribution in $\Delta R < 0.2$ from top decays with $m =$ 140 GeV.

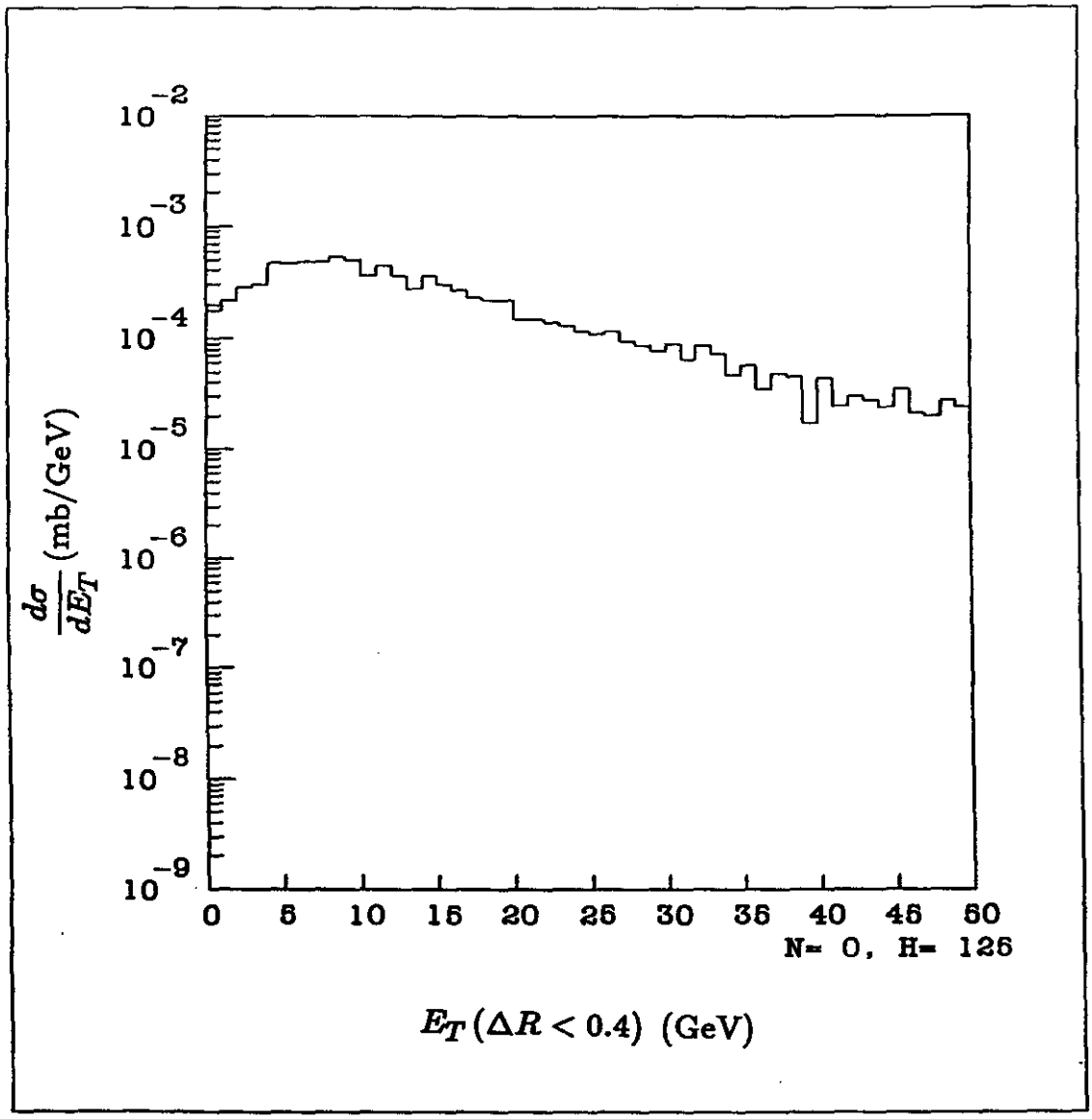

Figure 4a: E_T distribution in $\Delta R < 0.4$ from c and b in QCD jets.

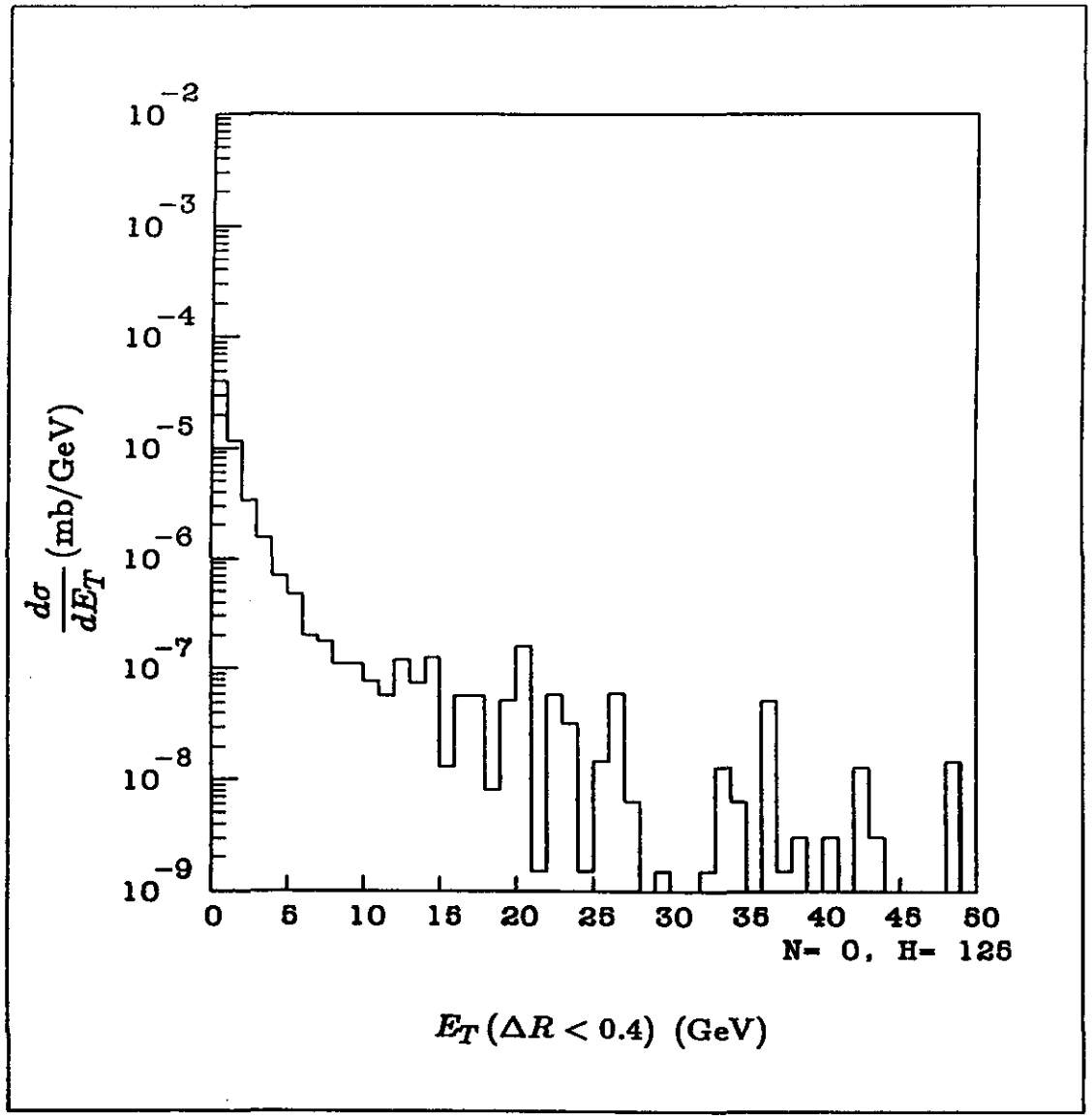

Figure 4b: E_T distribution in $\Delta R < 0.4$ from $W^{\pm}$ decays.

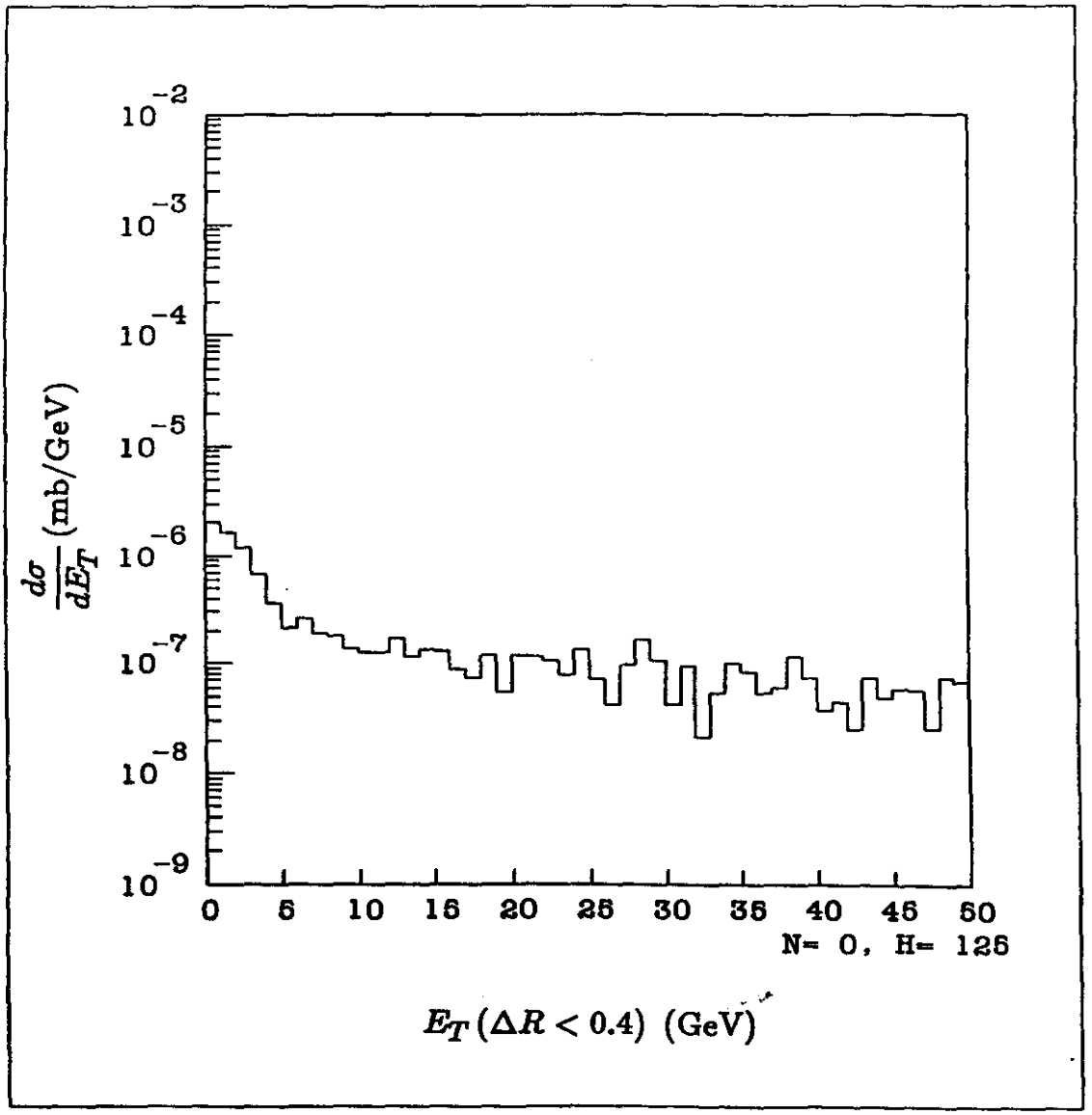

Figure 4c: E_T distribution in $\Delta R < 0.4$ from top decays with $m =$ 140 GeV.

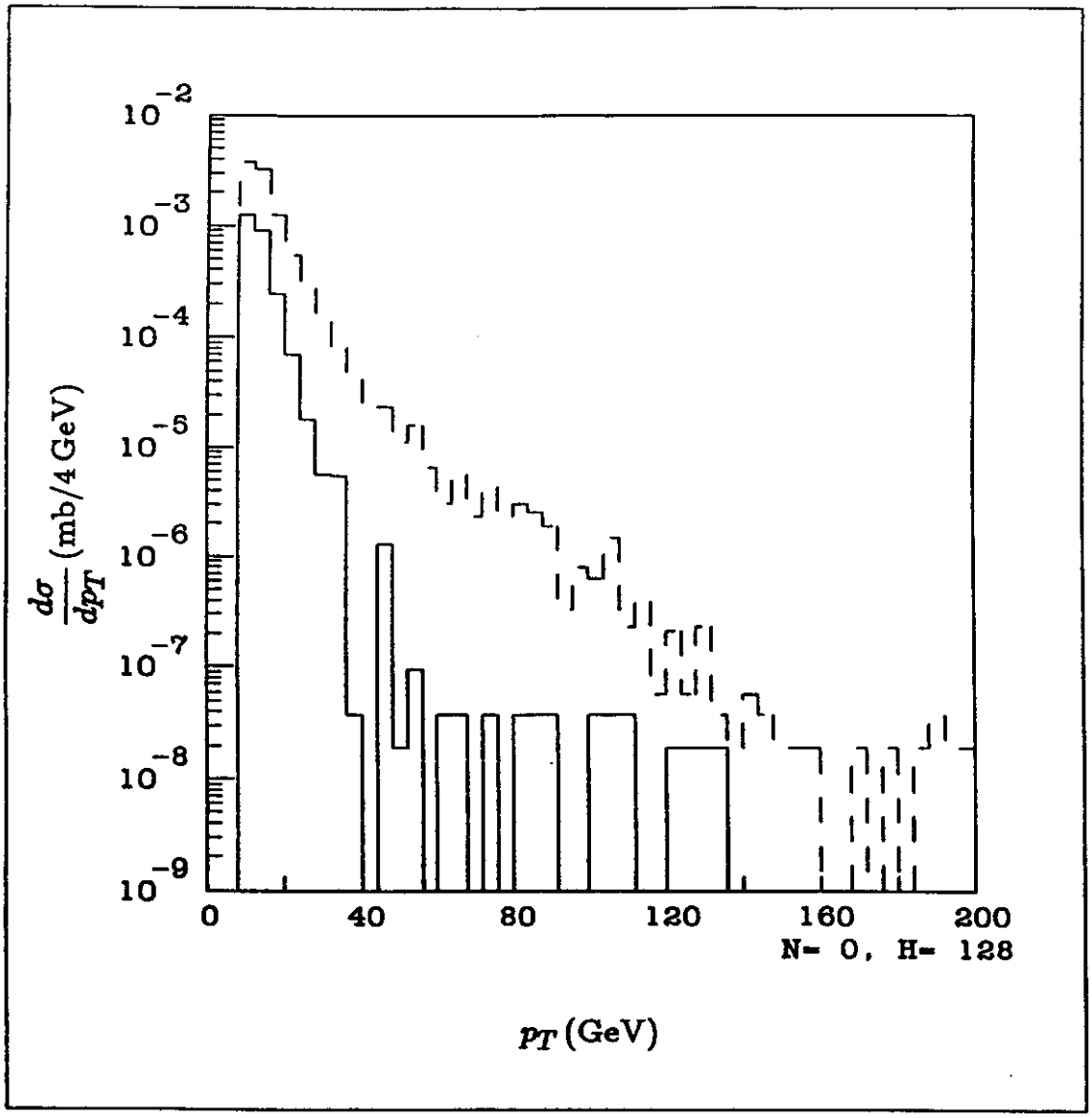

Figure 5a: p_T distribution for $E_T < 2\,\mathrm{GeV}$ in $\Delta R < 0.2$ from c and b decays in QCD jets.

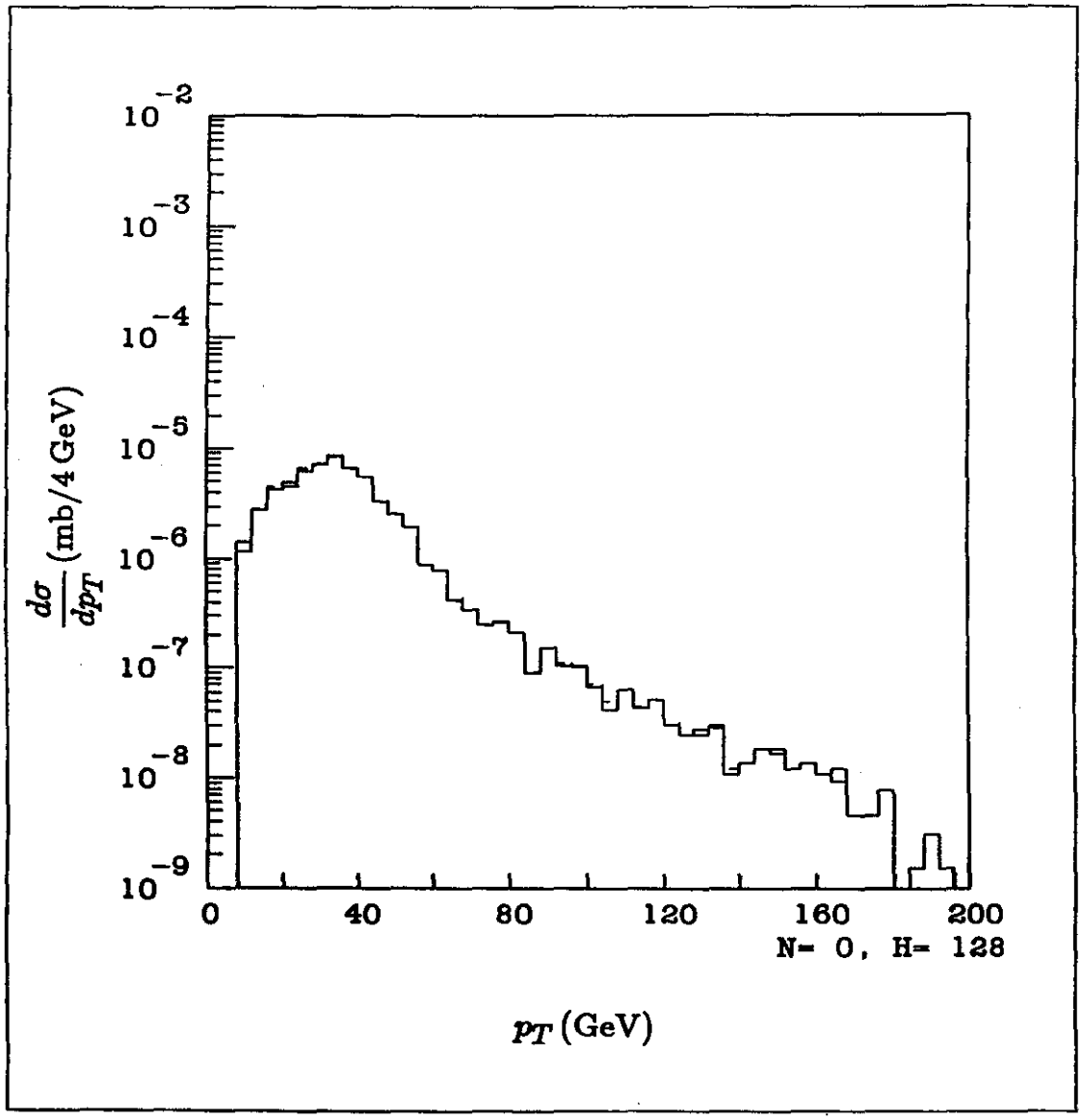

Figure 5b: p_T distribution for $E_T < 2\,\mathrm{GeV}$ in $\Delta R < 0.2$ from $W^{\pm}$ decays.

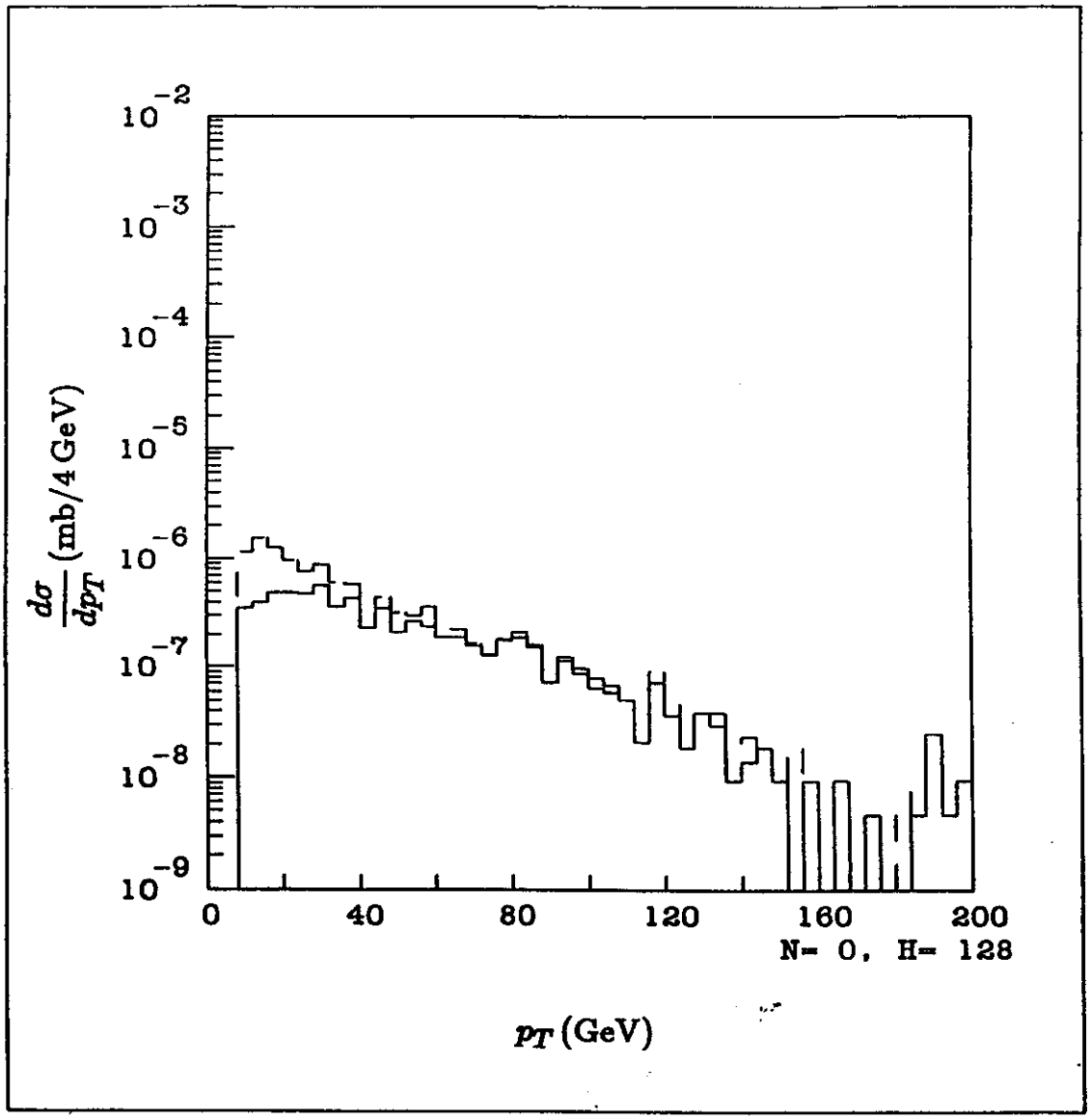

Figure 5c: p_T distribution for $E_T < 2\,\mathrm{GeV}$ in $\Delta R < 0.2$ from top decays with $m = 140\,\mathrm{GeV}$.