CDF/ANAL/HEAVY FLAVOR/CDFR/2080
November 1, 1993

Separation of QCD Prompt-γ and π^0 Production in the Conversion Electron Sample

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This note describes the decomposition of the observed conversion electron sample into two sources- QCD prompt photon production, and production of π^0 or η in jets. These provide useful control samples for the inclusive electron analysis. The QCD prompt photons can be used to establish the detector response to single, isolated electrons in the same E_t range as that for b-electrons (W and Z electrons are available for this, but only at much higher E_t.) The π^0conversions can be used to study the HAD/EM response function for electrons in jets. In particular, by isospin we can relate the π^0 conversions to the corresponding charged pion sample, and thereby estimate the the HAD/EM behavior of charged pions in jets; this is important for understanding the fake hadron background rates.

We assume that conversion pairs come from the two sources- QCD prompt photons, and photons from π^0's, η's, etc. The former should be isolated in the surrounding jet cone (eg. in a radius 0.7 around the trigger electron), while the latter should be nonisolated and should have some extra photon energy in the same cell as the electron (from the partner photon in π^0decay.) The extra CEM energy should result in a broader E/p distribution, as compared with the electrons from QCD prompt photon conversions. We first examine the isolation distributions, then the E/p distributions. We compute the calorimeter jet energy in a cone of radius 0.7, *excluding* the electron and positron contributions. Likewise, we compute the sum of charged track momenta in the same cone, again *excluding* the electron and positron. We define an isolation variable by adding these cone sums in quadrature:

$$E_s = \sqrt{E_t^2 + P_t^2}$$

where E_t and P_t are the cone sums. This variable is robust against fragmentation fluctuations (eg, all the E_t is carried by neutrals, hence no P_t) and against calorimeter nonlinearities and phi-cracks (eg, E_t is lost due to calorimeter imperfections, but P_t sum is preserved.) An electron must be very well isolated to have $E_s = 0$, that is both E_t and P_t small.

Figure (1a) shows the E_s distributions for all conversions, after electron quality cuts, and for prompt electrons (shaded inset). We have subtracted residual unseen conversions from the prompt electron sample, and normalized both samples in the region $E_s \geq 6$. The conversions exhibit a pileup at zero isolation. In principle, this could be an artifact of our removal of the partner positron from the E_t and P_t sums. To test this, we use a sample of 'poor' conversions, defined by antiselection on the *sep* and *delta*(*cot*) conversion matching variables. As we have

shown, these pairs are mostly not conversions, but random overlaps of nearby tracks with the electron candidate; they do not have electron-like pulse height in the CES. The comparison of the E_s distributions for good conversions and 'poor' conversions is shown in fig. (1b). The shaded plots in figs. (1a) and (1b) are similar, and we conclude that the peak at $E_s = 0$ in the good conversion sample is not an artifact of the removal of the positron track from the E_t,P_t sums. Figure (2) shows the E_s distribution for W electrons (histogram), and for background-subtracted conversions (using the shaded distribution in (1a) to define the background.) The two isolation distributions are the same. We conclude that the conversions can be characterized by two components- one having an isolation distribution like that of W electrons, the other having a broad E_s distribution similar to the prompt sample.

Next, we examine the E/p distributions for the isolated and nonisolated samples. Figure (3) shows the E/p distributions for the N=1 conversions, cut on $E_s \geq 6GeV$ (points with errors), and $E_s \leq 1.5GeV$ (shaded plot). The $E_s \leq 1.5$ events have an E/p distribution similar to that for W electrons, which are shown in figure (4). The $E_s \geq 6$ conversions have a broad E/p spectrum, as expected for π^0 conversions, due to the nearby second photon.

We define an auxiliary variable, P_{bord}, which is the P_t sum of all tracks within 15 cm of the electron 3-tower cell. This sum excludes the electron and positron tracks in the conversion pair. Charged hadrons in this border region can contribute to the HAD/EM distribution in the 3-tower electron cell, and so is of interest in understanding HAD/EM distributions. We distinguish between events with

$P_{bord} = 0$, typically 70% of electron candidates
$P_{bord} \geq 0$, typically 30% of electron candidates

We can define a fairly clean prompt photon sample by cutting hard on $E_s \leq 4$ and $E/p \leq 1.06$. These events also have zero P_{bord}. The complementary sample is mainly due to π^0, η production. Figures (5a, b) show the E_s distributions for the 12 and 7 GeV electron samples, after requiring $P_{bord} = 0$ and $E/p \leq 1.06$. The shaded plots are estimates of the background shapes, based on the prompt electron sample as in figure (1). The QCD prompt photon signal is enhanced by about a factor of two with these cuts. We will define N1 and N2 to be the number of conversions in the "prompt photon" and "π^0 samples based on these E/p and E_s cuts.

To determine the purity of the two samples, we define

$$\beta(nonisol) = \mathrm{N}(E_s \leq 4)/\mathrm{N}(E_s \geq 4)$$

using the prompt electron sample (unseen conversions subtracted). This ratio should characterize the π^0 conversion sample as well. We further assume that

$$\beta(QCD) = \beta(W \rightarrow e\nu) \simeq \infty$$

for the QCD prompt photon component. Then it is easy to show that the fraction of QCD prompt photons in the sample which we have defined ($E_s \leq 4, E/p \leq 1.06$) is given by

$$\mathrm{F(QCD/all)} = 1 - \beta(nonisol)/\beta(conv) = \text{'F'}$$

where $\beta(conv)$ is the β ratio for the full conversion sample. There is in principle an ambiguity as to whether we should include the $E/p \leq 1.06$ cut or not, in defining $\beta(nonisol)$, since there might be long range correlations between additional CEM energy in the 3-tower cell and jet energy outside the cell. Figure (6a) and (6b) show the measured fraction F(QCD/all), with both definitions of $\beta(nonisol)$, as functions of E_t. Within errors, the two are the same, though $\beta(nonisol)$ is systematically larger with the $E/p \leq 1.06$ cut imposed. Next, we can estimate the overall fraction of QCD prompt photons in the conversion sample:

$$F_{tot} = \frac{N1F}{[N1+N2]\alpha}$$

where α is the probability for QCD prompt photons to satisfy the cuts for sample N1. From the W electron data, we estimate

$$\alpha = 0.90 \pm .02$$

The fraction F_{tot} is around 0.33, and is plotted against E_t in figure (7).

For HAD/EM studies, we are mainly interested in removing the QCD prompt photons, so as to have a "clean" π^0 sample to compare with single electrons. To do this, we have to correct for the statistical cross-talk between the N1 and N2 samples, that is, subtract the (small) QCD contamination in sample N2, and include the (small) π^0 signal in sample N1. After some algebra, we can define the π^0 rate as

$$\mathrm{N}(\pi^0) = N2 + N1(1 - \frac{F}{\alpha})$$

Figure (8) plots the π^0 fraction in the N1 sample, given by (1-F/α), as a function of E_t. We can form a π^0 sample, QCD subtracted, by weighting the N1 and N2 samples as given above. The π^0 fraction in the N1 sample in figure (8) can be parametrized as

$$1 - \frac{F}{\alpha} = 0.20 \pm 0.05, (E_t \geq 10.)$$

By construction, we have forced the π^0 and the single prompt electron samples to have the same E_s distributions (ie same ratio for $E_s \leq 4/E_s \geq 4$.) As a check on the global properties of π^0 and single electron jets, figure (9a,b) shows the calorimeter E_t distributions for the single electron sample (unseen conversion subtracted), and the π^0 sample; we have removed the electron cell and partner positron from the E_t sum. Figures (10a,b) show the same

comparisons for the P_{bord} variable introduced above. In figures (9) and (10) the histograms are the single electron data and the points are the (renormalized) π^0 data. The distributions for the two samples are very similar, so we would expect the π^0 sample to give an accurate reflection of the effect of the nearby jet particles on the HAD/EM distributions for electrons. That is, for a given P_{bord} value, we would expect the effect of these hadrons on HAD/EM to be the same for the two samples. Figure (11) compares the P_{bord} distributions for the single electron data (points) and the b Monte Carlo (histogram). While the b monte carlo predicts a slightly harder spectrum, the results suggest that our monte carlo should be able to predict the jet correlated effects on HAD/EM with reasonable accuracy (recall that only 30% of the events have nonzero P_{bord}.)

We conclude that it is possible to use a statistical weighting procedure to produce a sample of π^0 in jets from the conversion sample, with the 33% prompt photon background removed. This sample has similar isolation properties as the prompt electron and b monte carlo samples. In particular, in subsequent analyses of fake hadron backgrounds, we will use the QCD prompt photon sample to calibrate the calorimeter response to single electrons. We will likewise use the π^0 sample to predict the behavior of charged hadrons that fake electrons, and we use the correlation between border P_t (P_{bord}) and HAD/EM in the different samples to verify the b monte carlo.

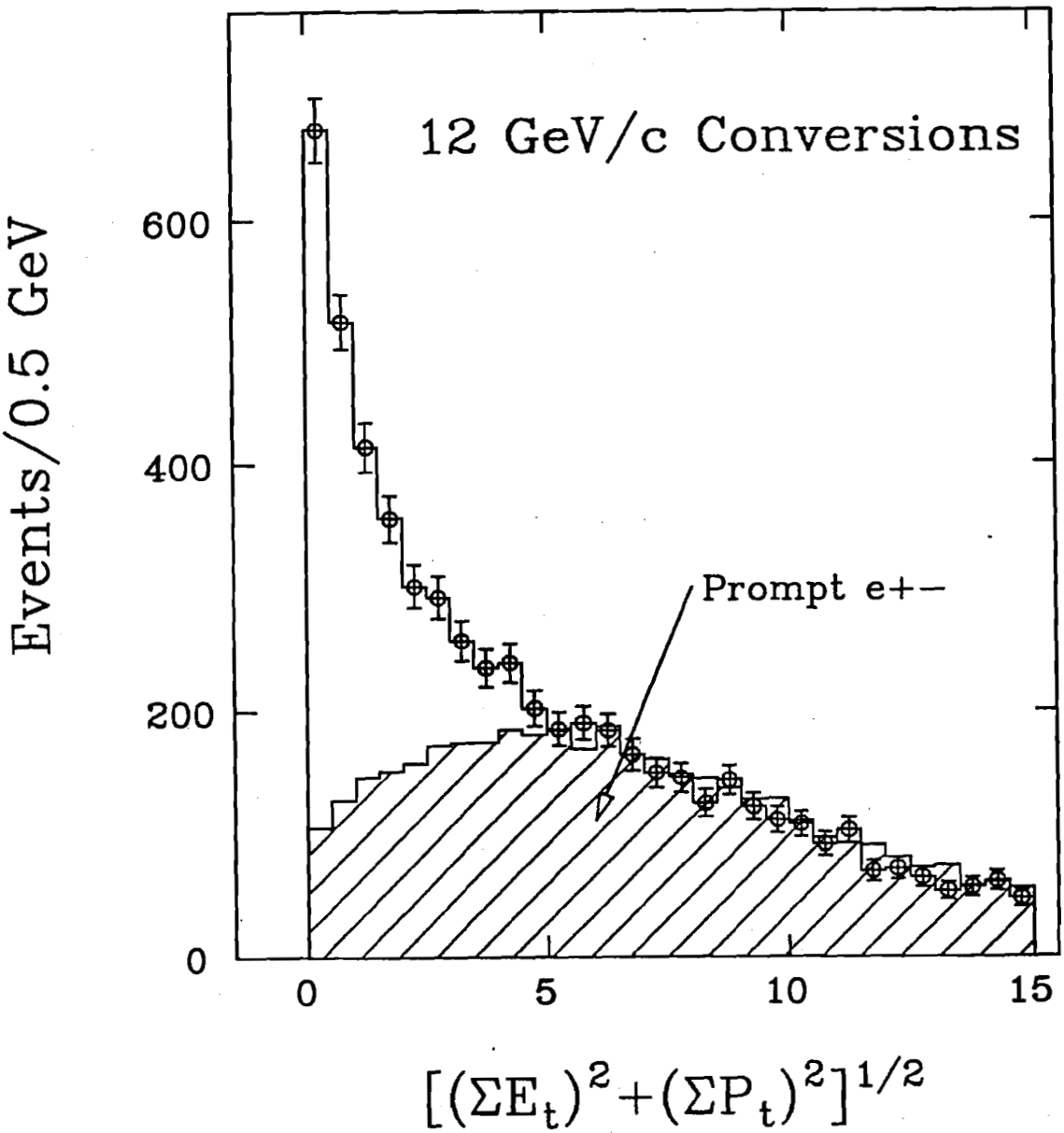
12 GeV/c Conversions
Events/0.5 GeV
600
400
200
0
Prompt e+−
0
5
10
15
$[(\Sigma E_t)^2+(\Sigma P_t)^2]^{1/2}$

Figure (1a)

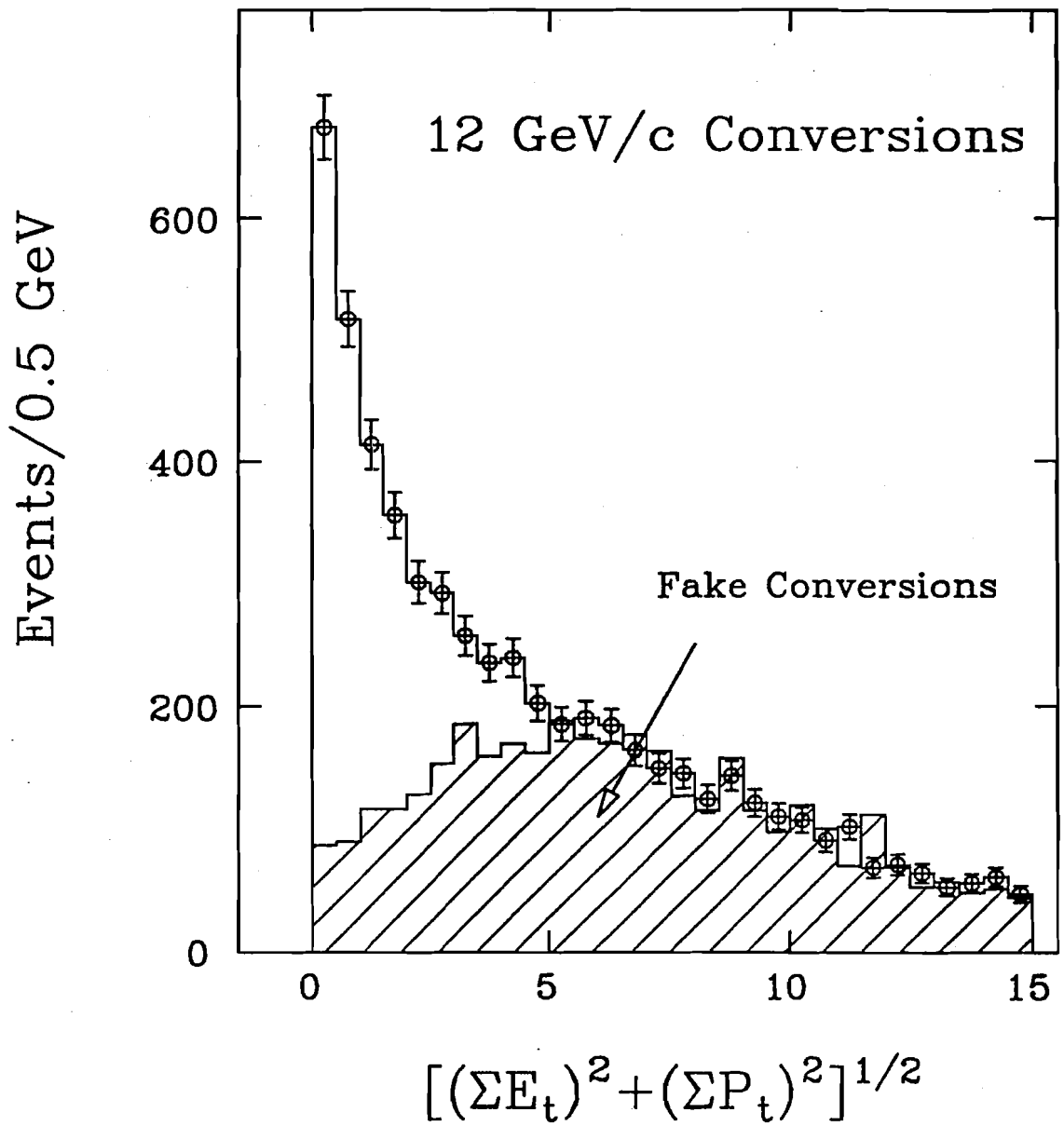
12 GeV/c Conversions
Fake Conversions
Events/0.5 GeV
600
400
200
0
0
5
10
15
$[(\Sigma E_t)^2+(\Sigma P_t)^2]^{1/2}$

Figure (1b)

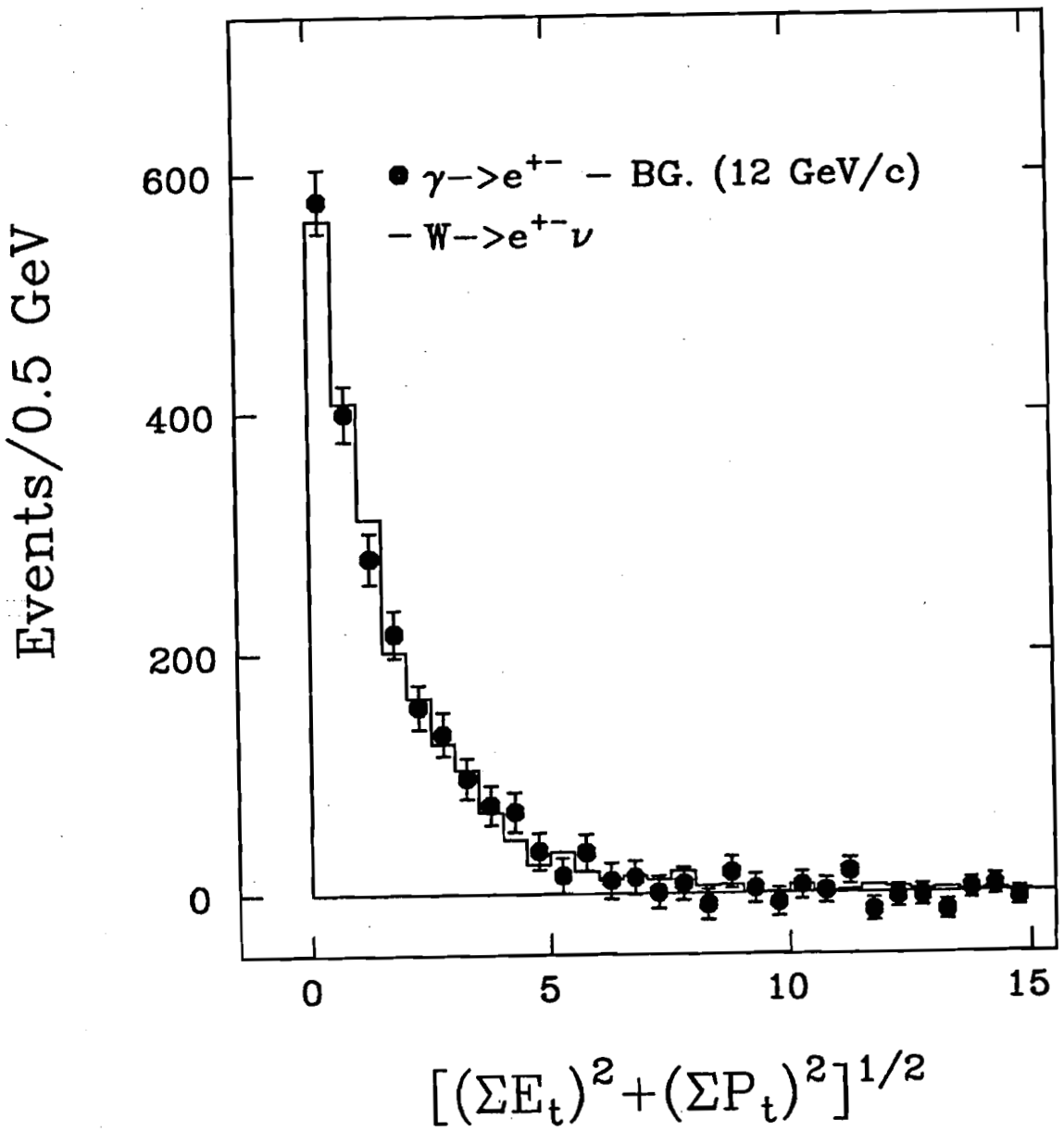
Events/0.5 GeV
600
400
200
0
0
5
10
15
● γ->e+- – BG. (12 GeV/c)
– W->e+-ν
[(ΣEt)2+(ΣPt)2]1/2

Figure (2)

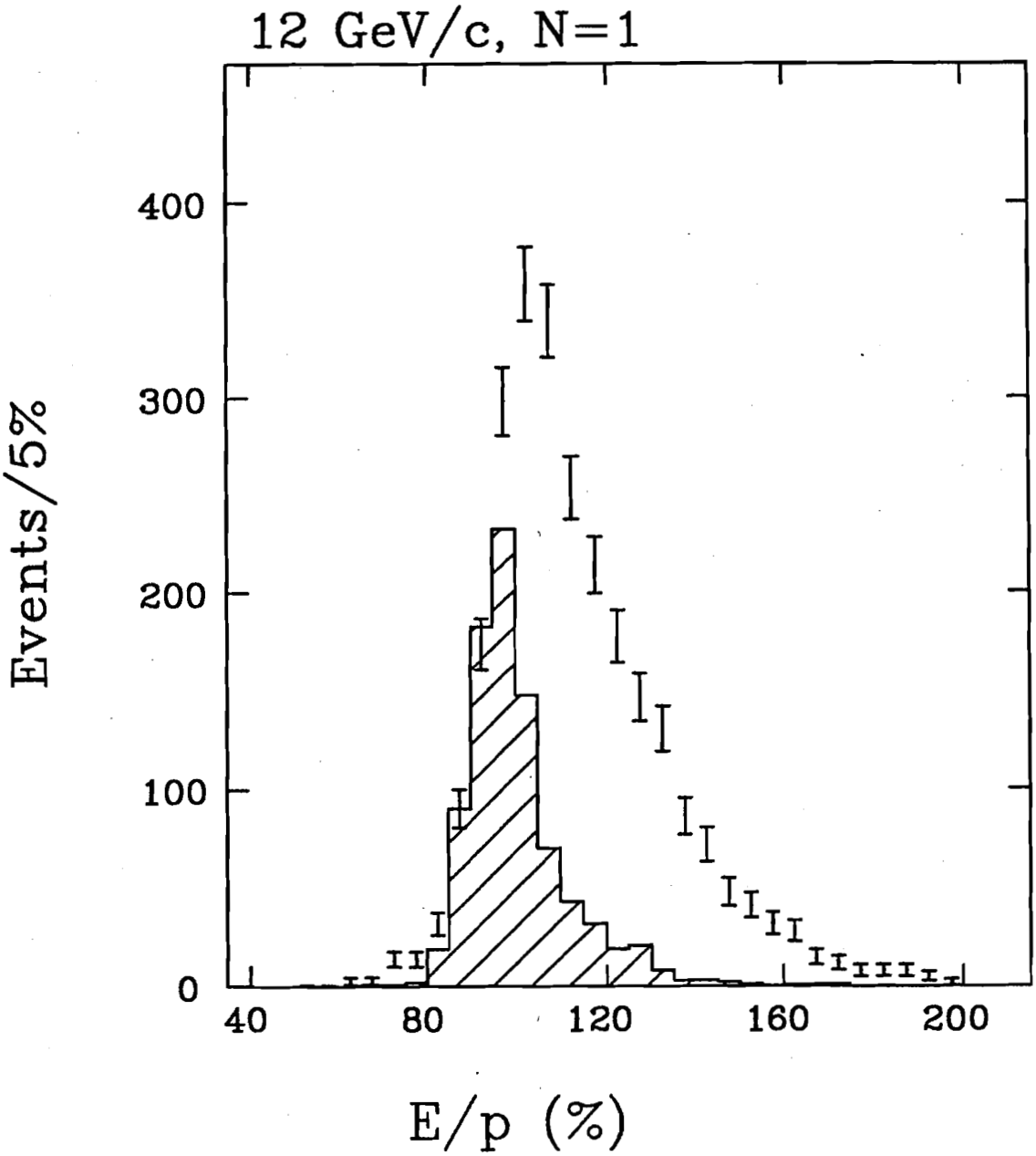

Figure (3)

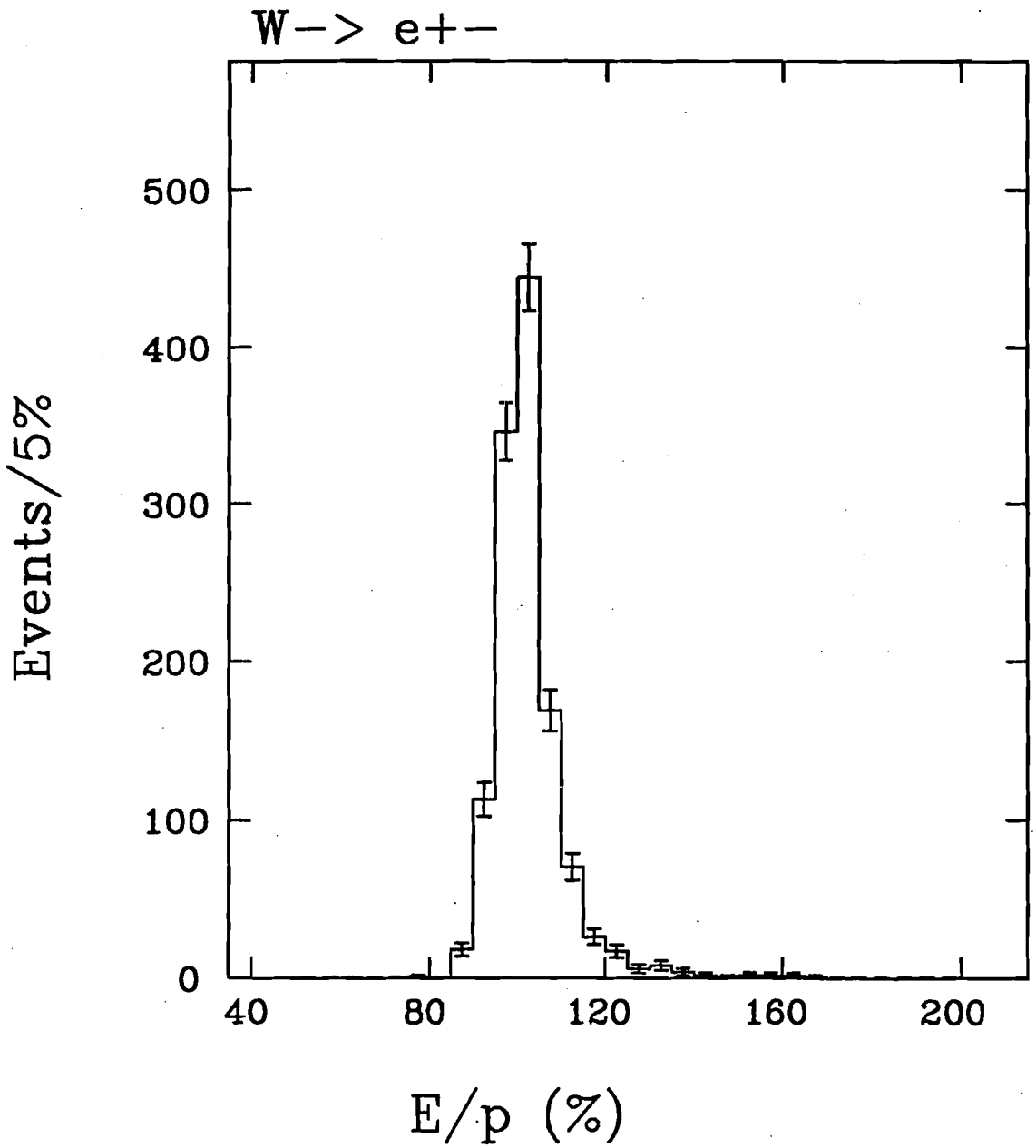

Figure (4)

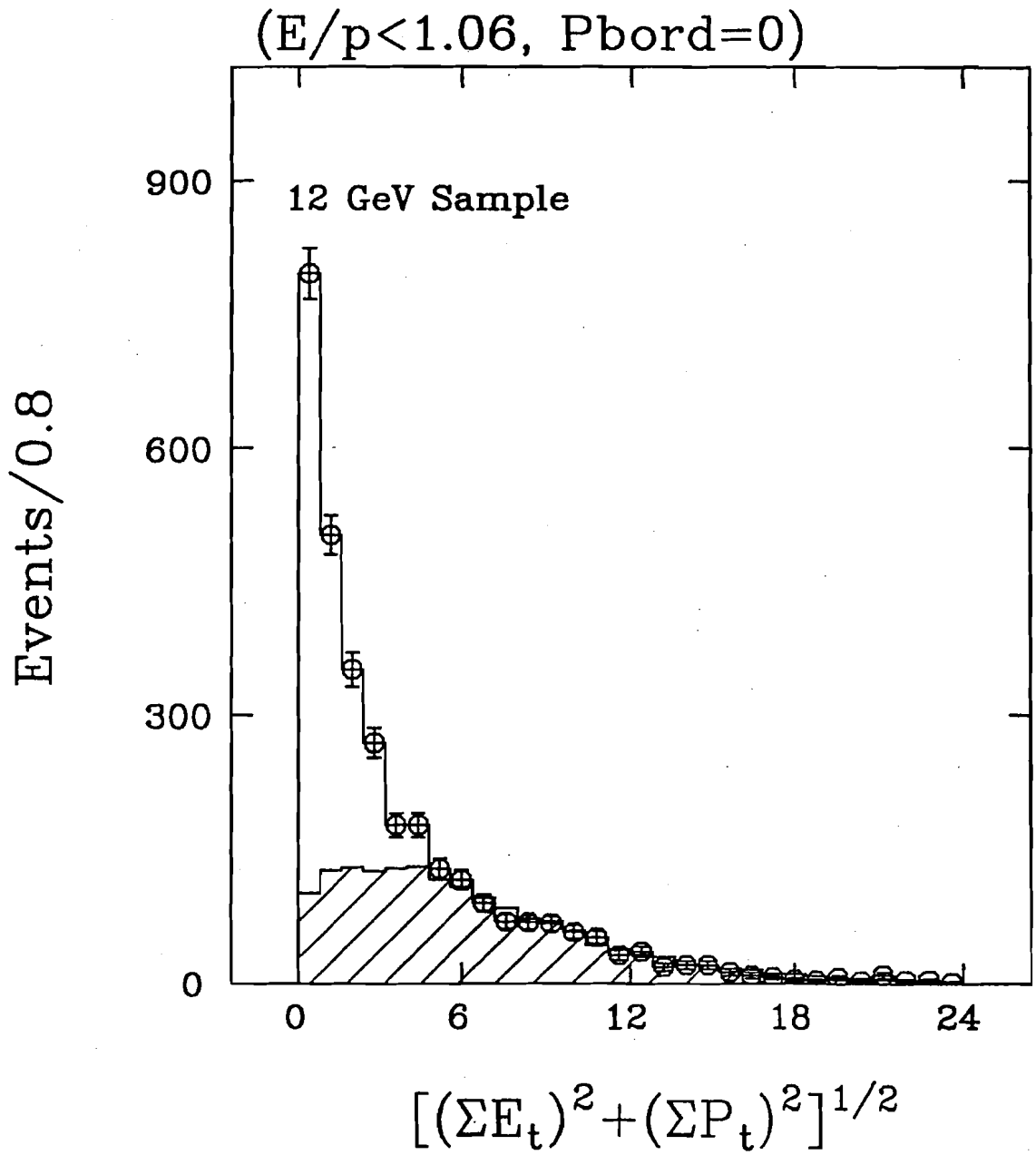
(E/p<1.06, Pbord=0)
12 GeV Sample
Events/0.8
900
600
300
0
0
6
12
18
24
$[(\Sigma E_t)^2+(\Sigma P_t)^2]^{1/2}$

Figure (5a)

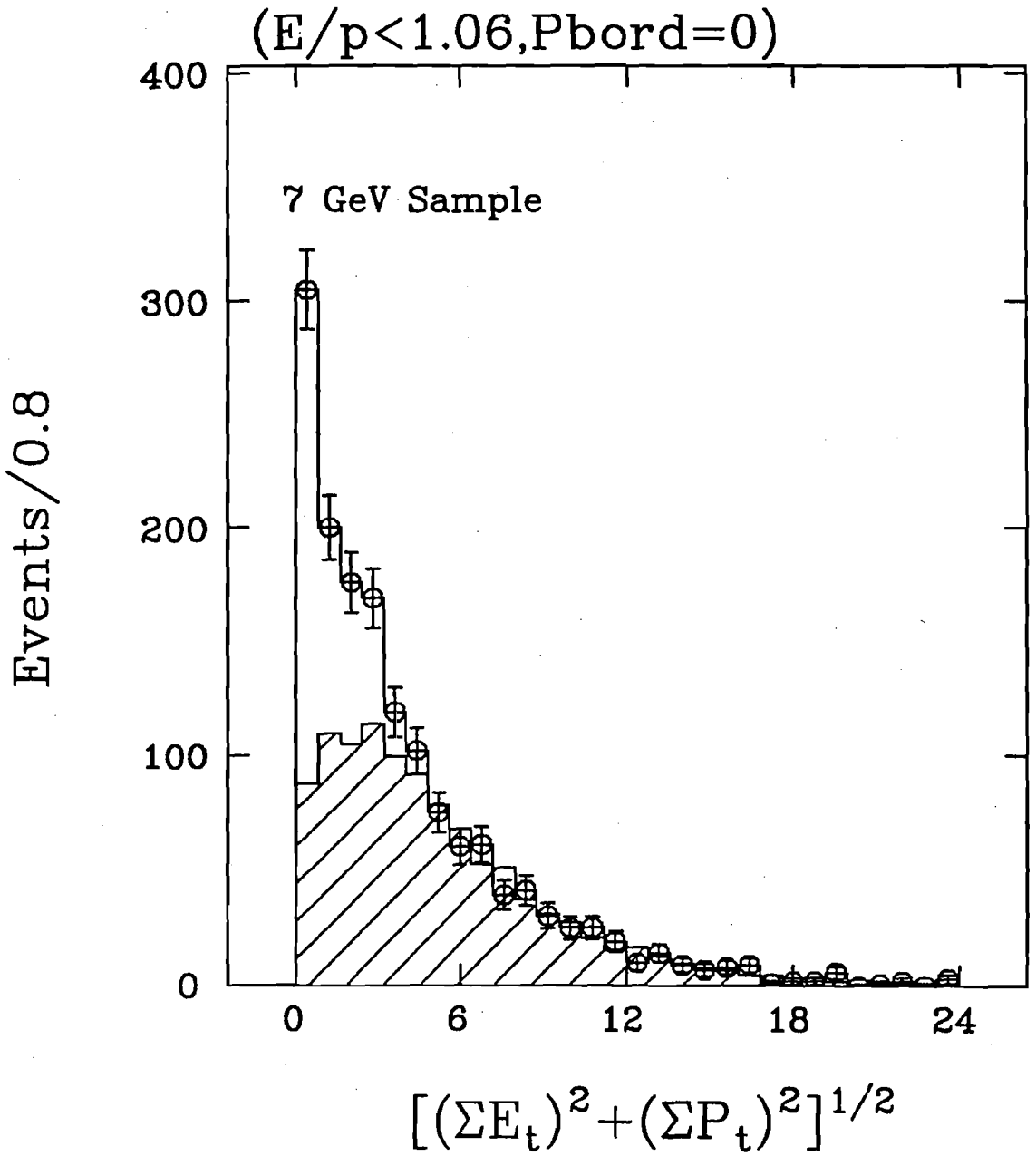
(E/p<1.06,Pbord=0)
7 GeV Sample
Events/0.8
400
300
200
100
0
0
6
12
18
24
$[(\Sigma E_t)^2+(\Sigma P_t)^2]^{1/2}$

Figure (5b)

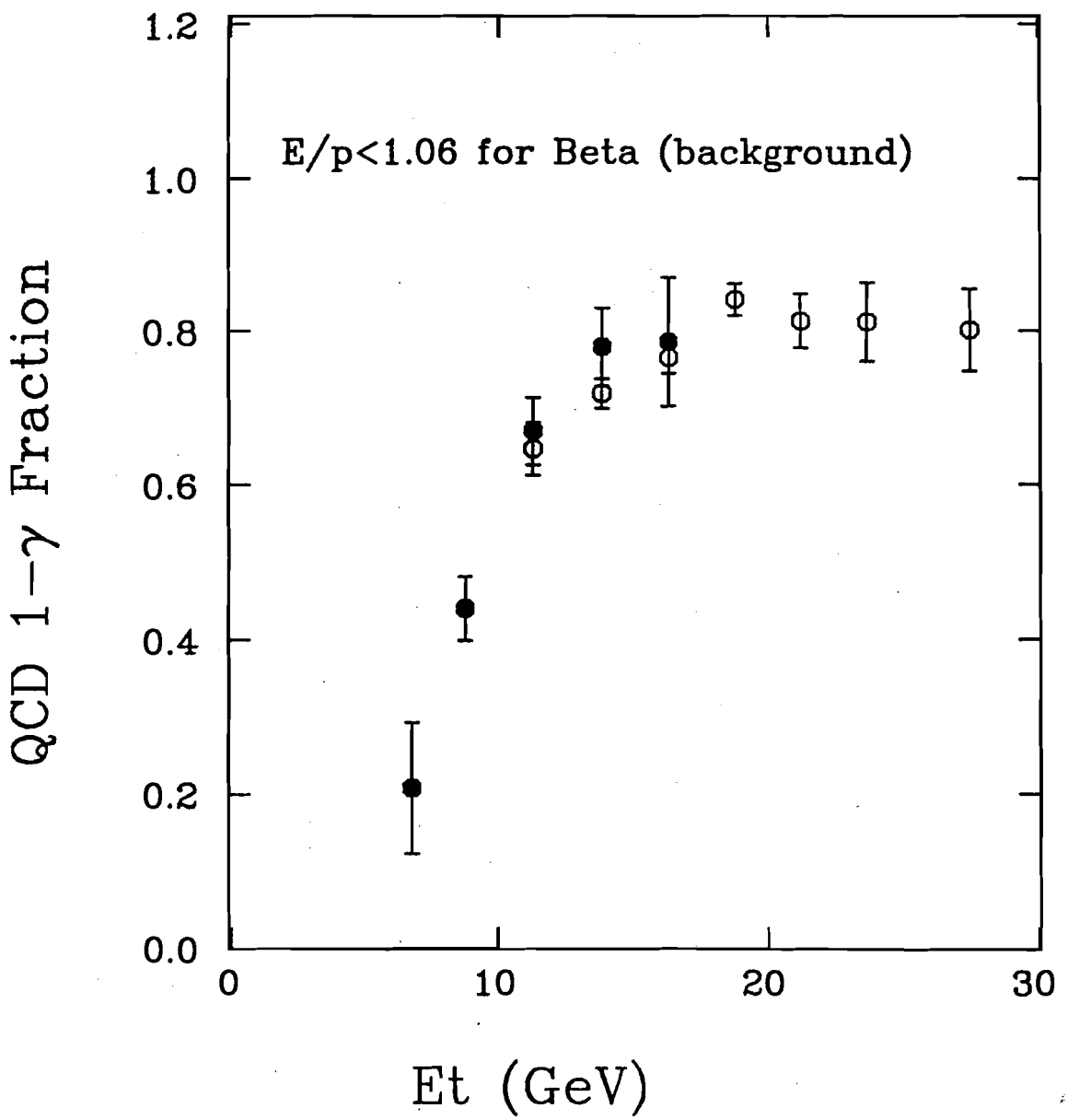
E/p<1.06 for Beta (background)
QCD 1−γ Fraction
Et (GeV)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30

Figure (6a)

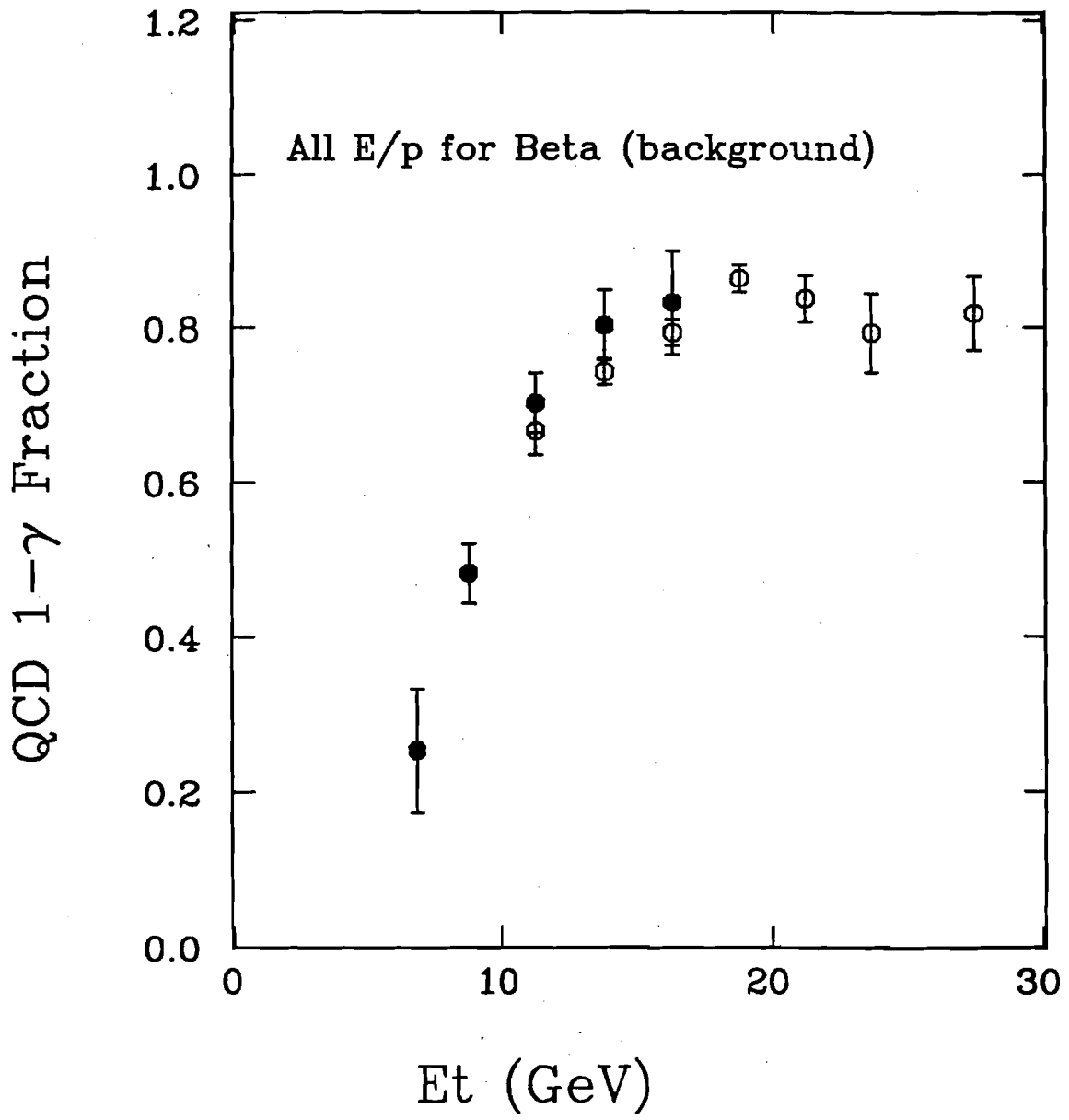
All E/p for Beta (background)
QCD 1−γ Fraction
Et (GeV)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30

Figure (6b)

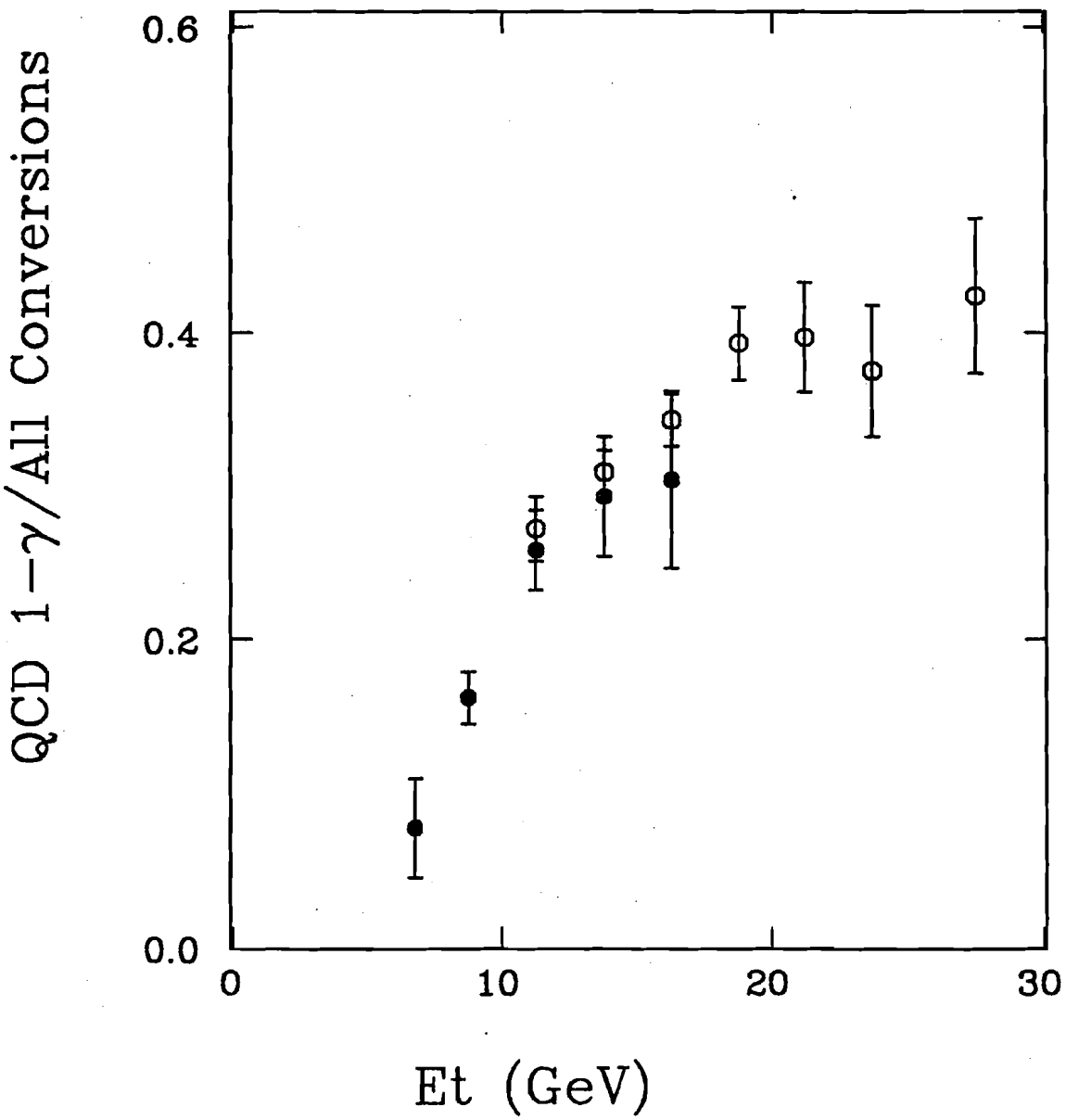

Figure (7)

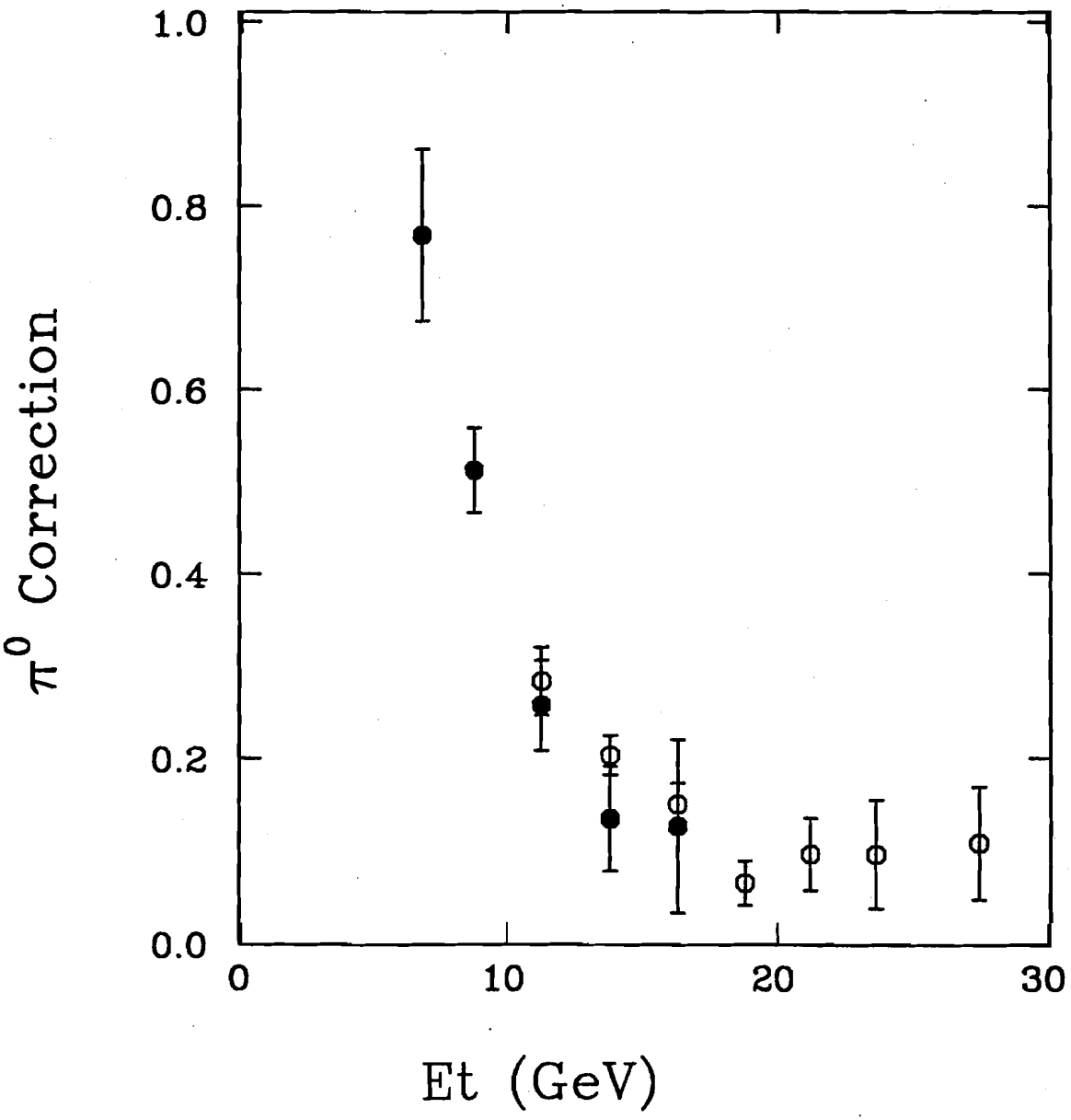

Figure (8)

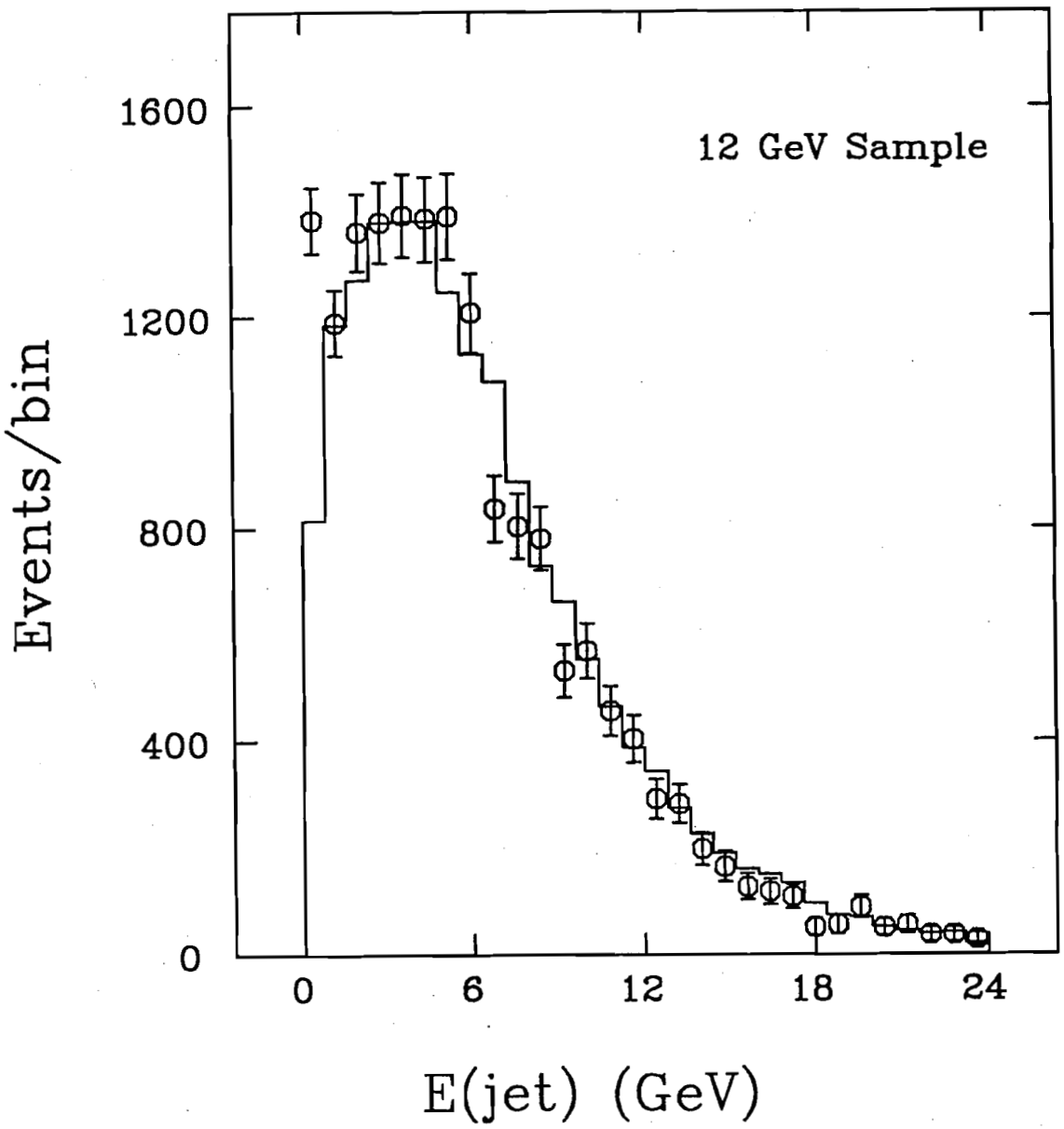
12 GeV Sample
Events/bin
1600
1200
800
400
0
0
6
12
18
24
E(jet) (GeV)

Figure (9a)

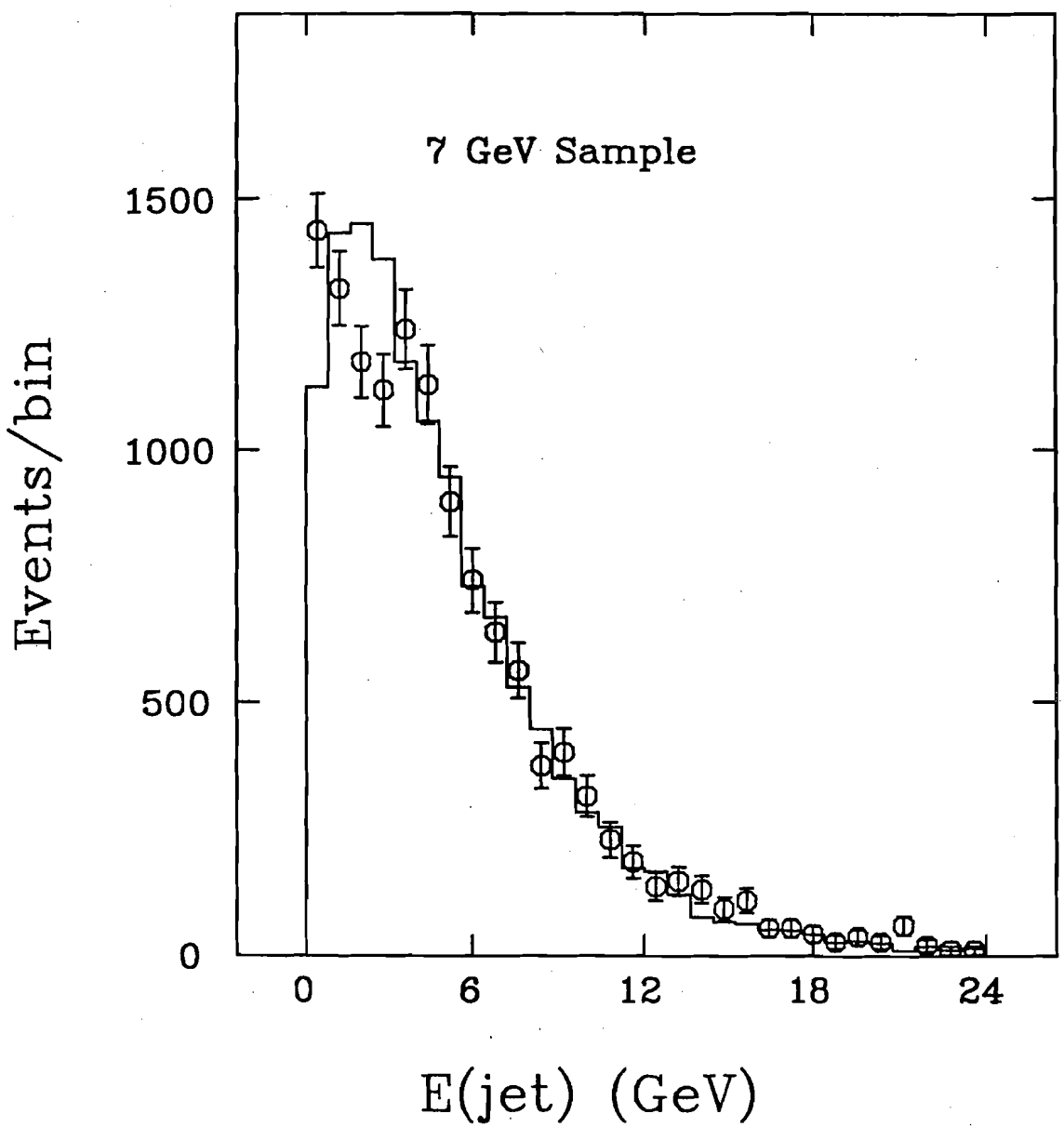

Figure (9b)

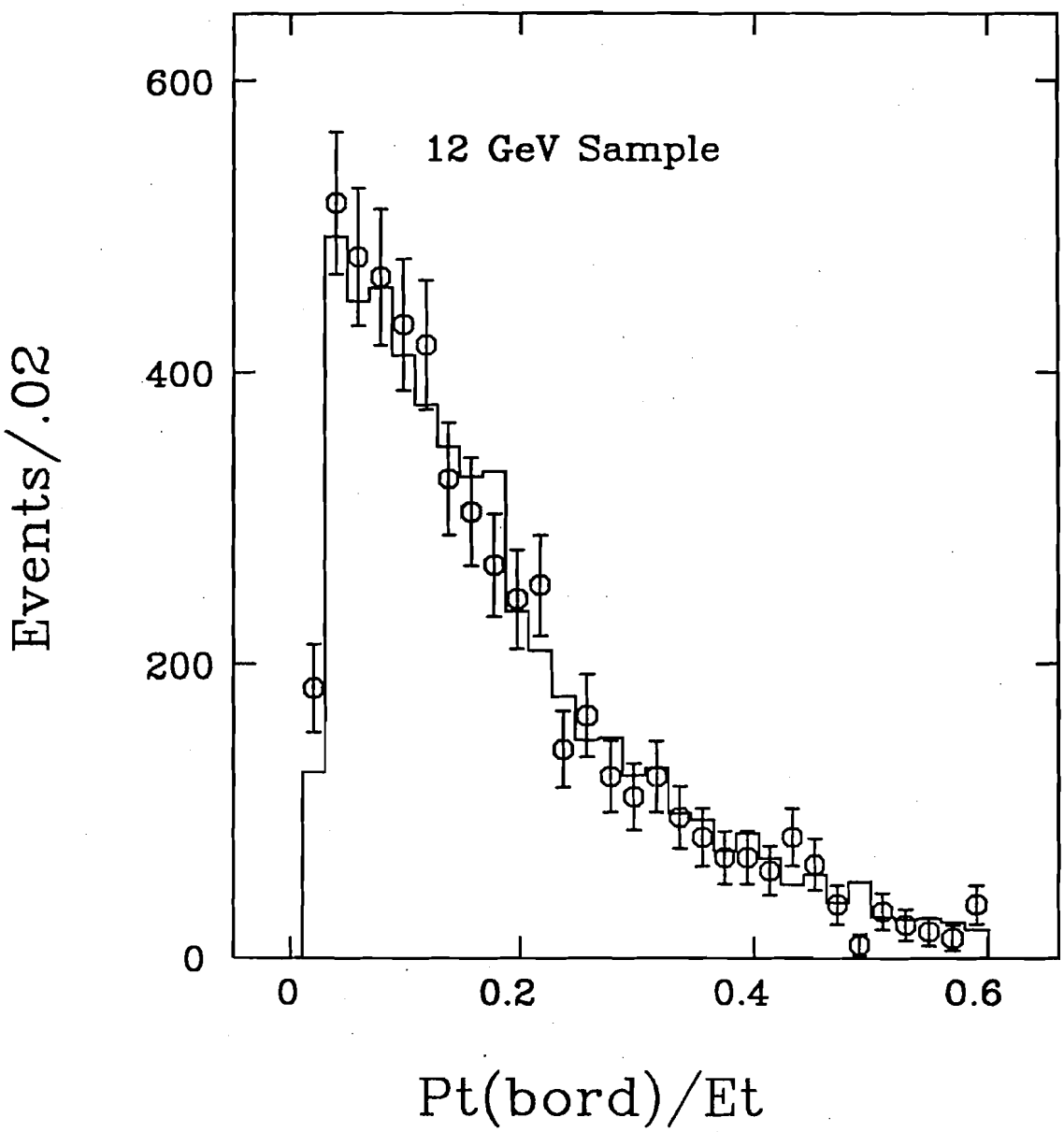

Figure (10a)

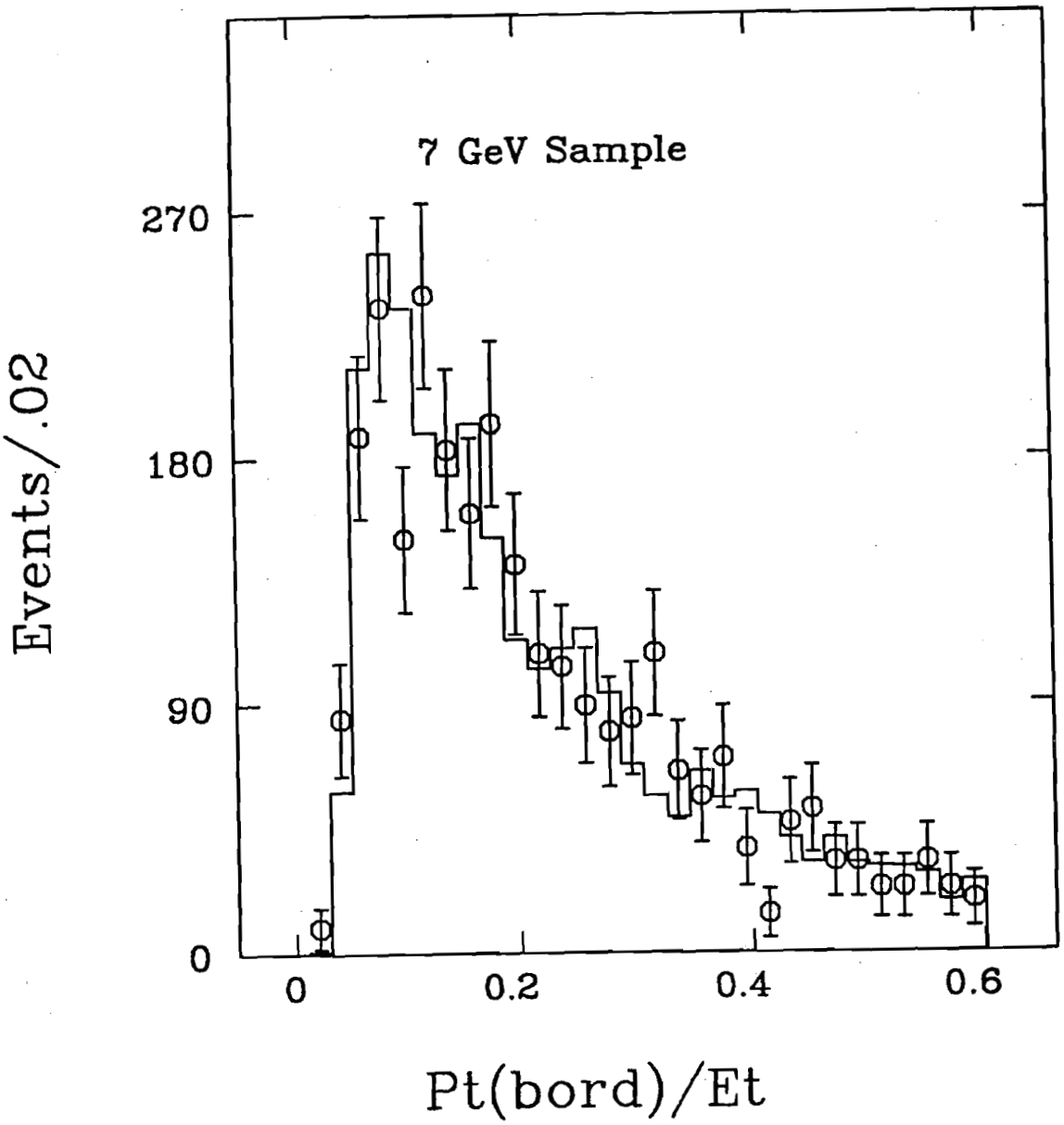

Figure (10b)

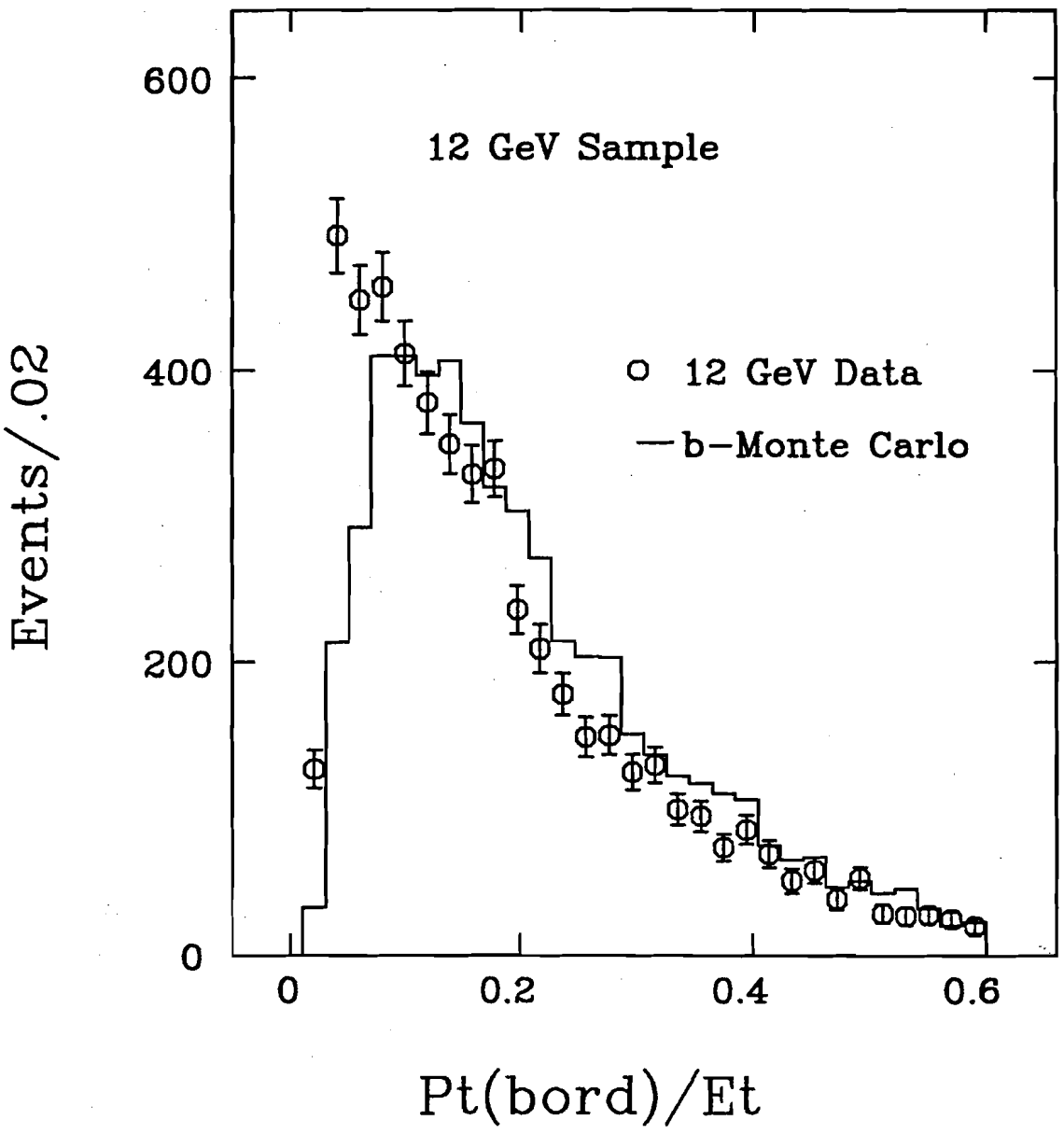
12 GeV Sample
12 GeV Data
b-Monte Carlo
Events/.02
600
400
200
0
0
0.2
0.4
0.6
Pt(bord)/Et

Figure (11)