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SOLENOIDAL DETECTOR NOTES

RESOLUTION PARAMETERIZATIONS FOR THE EOI

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Resolution Parameterizations for the EOI*

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Abstract

This document discusses the detector parameters used for simulation of the physics processes shown in the EOI.

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In order to simulate physics processes for the EoI, it was necessaray to estimate the resolutions of the solenoidal detector. In the absence of a complete detector design, such estimates were made using extrapolations from existing detectors (most notibly CDF) and from the design goals stated in the detector subsystem sections of the EoI. In general, the choices made were conservative and represent resolutions we believe are comfortably achievable rather than ultimate goals for the system.

1 Tracking Resolution

We assumed an η-dependent momentum resolution for the tracking system given by

$$\frac{\Delta p_T}{p_T} = a \oplus b p_T \tag{1}$$

with $a = 0.005$ for $|\eta| < 1.0$ and $a = 0.005|\eta|$ for $|\eta| > 1.0$, and with $b = 0.0002$ for $|\eta| < 1.6$ and $b = 0.0002 + 0.00074(|\eta| - 1.6)$ for $1.6 < |\eta| < 2.5$. Momenta are in GeV/c and energies in GeV/c^2 and the symbol $\oplus$ means that the terms are added in quadrature. The resulting values of $\Delta p_t/p_t$ are shown as a function of η for fixed p_t in Figure 1.

2 Muon Resolution

The momentum resolution of the standalone muon system was given by

$$\frac{\Delta p_T}{p_T} = a \oplus b p_T \tag{2}$$

with $a = 0.160\sqrt{\sin\theta}$ for $|\eta| < 1.5$ and $a = 0.035 \tan\theta\sqrt{(7.08 - 10.8\tan\theta)\cos\theta}$ for $1.5 < |\eta| < 2.5$, and with $b = 0.0004 \sin^2\theta$ for $|\eta| < 1.5$ and $b = 0.00025\cos^2\theta$ for $1.5 < |\eta| < 2.5$. The momentum measurement of the reconstructed muon combines the information from both the muon and tracking systems. This combined resolution is shown in Figure 2. The central muon system does not significantly improve upon the measurement from the tracking system alone.

3 Calorimeter Resolution

The calorimeter was segmented into projective towers of size $\Delta\eta \times \Delta\phi = 0.05 \times 0.05$ for $|\eta| < 3$ and 0.10×0.10 for $|\eta| > 3$. The hadron calorimeter energy resolution in these studies was

$$\frac{\Delta E}{E} = \frac{0.50}{\sqrt{E}} \oplus 0.03 \qquad (|\eta| < 3) \tag{3}$$

$$\frac{\Delta E}{E} = \frac{0.80}{\sqrt{E}} \oplus 0.03 \qquad (3 < |\eta| < 5) \tag{4}$$

while the electromagnetic calorimeter resolution was chosen to be

$$\frac{\Delta E}{E} = \frac{0.20}{\sqrt{E}} \oplus 0.01 \tag{5}$$

The degradation of resolution associated with coil support structures ($1.25 \leq |\eta| \leq 1.5$) is incorporated in the parameterization; at the worst point the resolution degrades by a factor of 1.7. This degradation is modeled on that obtained in reference [1]. The values of $\Delta E/E$ are shown in Figures 3 (electromagnetic calorimeter) and 4 (hadronic calorimeter) at fixed E_t as a function of η.

For the measurement of electron energies the better of the tracking and calorimetry measurements was used. Figure 5 shows the boundary in p_t - η space where these resolutions are equal.

All of the resolution functions were assumed to be Gaussian except for the resolution function for jet energies. In studies of background to processes with large missing E_t, the tails of the energy resolution functions are important. This is because jet cross-sections are large and a substantial mismeasurement of jet energies that occurs very rarely can generate a substantial background. Monte Carlo studies performed by the CDF collaboration indicate that there are non-gaussian tails on the jet energy resolution [2]. CDF parameterizes the jet resolution as an exponential convoluted with a Gaussian. First the energies are smeared with an exponential with slope s such that a jet of energy E is measured to have energy E_o in the range $E - s$ to $\pm\infty$ where the sign of the limit at infinity is + (-) for positive (negative) values of s. The distribution in observed energy E_o is:

$$\frac{dN}{dE_o} = \frac{\exp^{(\frac{E_o - E_o - s}{s})}}{s} \tag{6}$$

The resulting value E_o is now smeared with a Gaussian of width ΔE given by the resolutions in Eq. 3. The resulting distribution of measured energies E_m is given by

$$\frac{dN}{dE_m} = \frac{(\frac{|s|}{s} + \mathrm{erf}(\frac{(E_m - E_0)s + s^2 - (\Delta E)^2}{s\Delta E\sqrt{2}})\exp(-\frac{E_m - E_0}{s} - 1 + \frac{(\Delta E)^2}{2s^2})}{2s} \tag{7}$$

In the limit $s \rightarrow 0$, the result is a pure Gaussian of width ΔE.

The non-gaussian tails in CDF result largely from events where one or more stiff tracks pass through the ϕ cracks between calorimeter modules. We expect smaller tails for the more hermetic solenoidal detector; nevertheless, in the intereste of conservatism we use here the CDF parameterizations[2]. In 50% of the cases

$$s = 0.5 - 0.075E,$$

and in the other 50% of cases

$$s = 2.0 + 0.022E$$

The resulting resolution function has a long non-Gaussian tail on both the upper and lower sides as can be seen from Figure 6 which shows the distribution in measured jet energy for a jet of energy 3 TeV at $\eta = 0$. For comparison a Gaussian distribution with the same value of $\Delta E/E$ is shown. Figure 7 shows the fraction of jets that have their energy measured to be below $E - 3\Delta E$ (solid lines), below $E - 4\Delta E$ (dashed lines) or below $E - 5\Delta E$ (dotted lines). It can be seen that these fractions are much larger than the corresponding values (0.135% 0.0032% and 0.000029%) for a pure Gaussian distribution. These tails have the potential to contribute large backgrounds to missing E_t signals.

Electron and muon identification is performed in the region $|\eta| < 2.5$, We took the electron and muon identification efficiency to be 85% for analyses requiring isolated leptons. In the cases where the analysis required two leptons reconstructing to an on-shell Z boson, we have assumed that the lepton identification cuts can be relaxed for the second lepton and have assumed a 95% detection efficiency for it.

References

[1] M. Strovink, W. Wormersley and G. Forden, "Hermeticity in Three Calorimetric Geometries", Workshop on Calorimetry, U. of Alabama, 13-17 March 1989.

[2] T. Hessing and S. Behrends, "Inclusive Jet Spectrum E_t Corrections and Resolution Unsmearing", CDF internal note 1132.

Figure Captions

Figure 1: The resolution of the tracking system $\Delta p_t/p_t$ as a function of rapidity η for fixed p_t

Figure 2: The resolution of the combined tracking and muons systems $\Delta p_t/p_t$ as a function of rapidity η for fixed p_t

Figure 3: The resolution of the electromagnetic calorimeter $\Delta E/E$ as a function of rapidity η for fixed p_t

Figure 4: The resolution of the hadronic calorimeter $\Delta E/E$ as a function of rapidity η for fixed p_t

Figure 5: The boundary in $p_t - \eta$ space where the resolutions of the tracking system and electromagnetic calorimeter are equal. In the region above (below) the line, the calorimeter (tracking system) provides the better measurement of electron energies.

Figure 6: The distribution of reconstructed jet energies for a jet of energy 3 TeV at $\eta = 0$. The solid (dashed) line corresponds to the assumed (pure Gaussian) resolution with non-Gaussian tails. Th curves are normalized to the same area.

Figure 7: The fraction of jet events in percent whose energy is measured to be less than $E - 3\Delta E$ (solid line) $E - 4\Delta E$ (dashed line) and $E - 5\Delta E$ (dotted line) as a function of the jet energy E for jets with $\eta = 0$. If the resolution were purely Gaussian, the values would be 0.135%, 0.0032% and 0.000029%

Figure 1

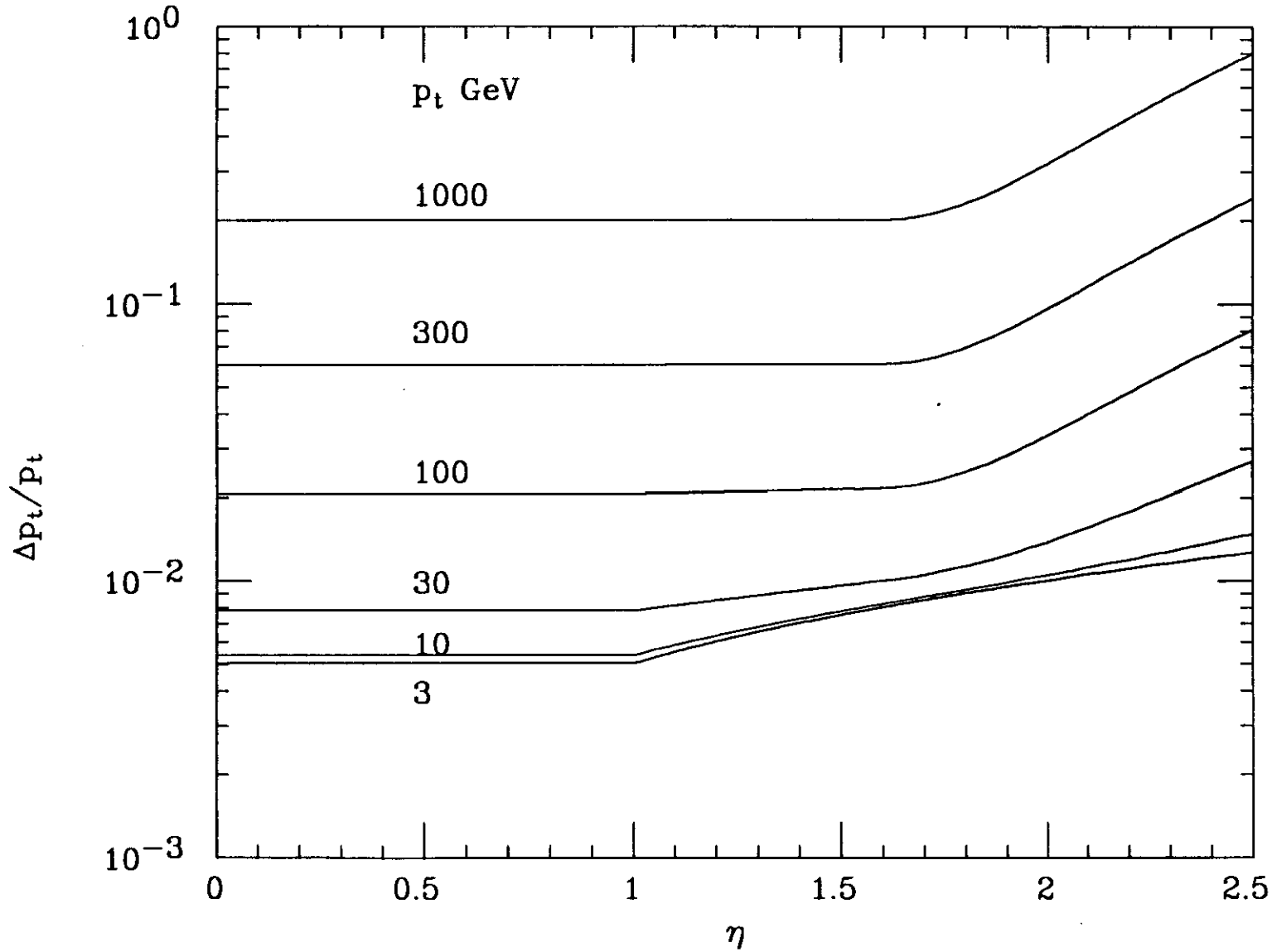

10^0
10^{-1}
10^{-2}
10^{-3}
$\Delta p_t/p_t$
p_t GeV
1000
300
100
30
10
3
0
0.5
1
1.5
2
2.5
η

Figure 2

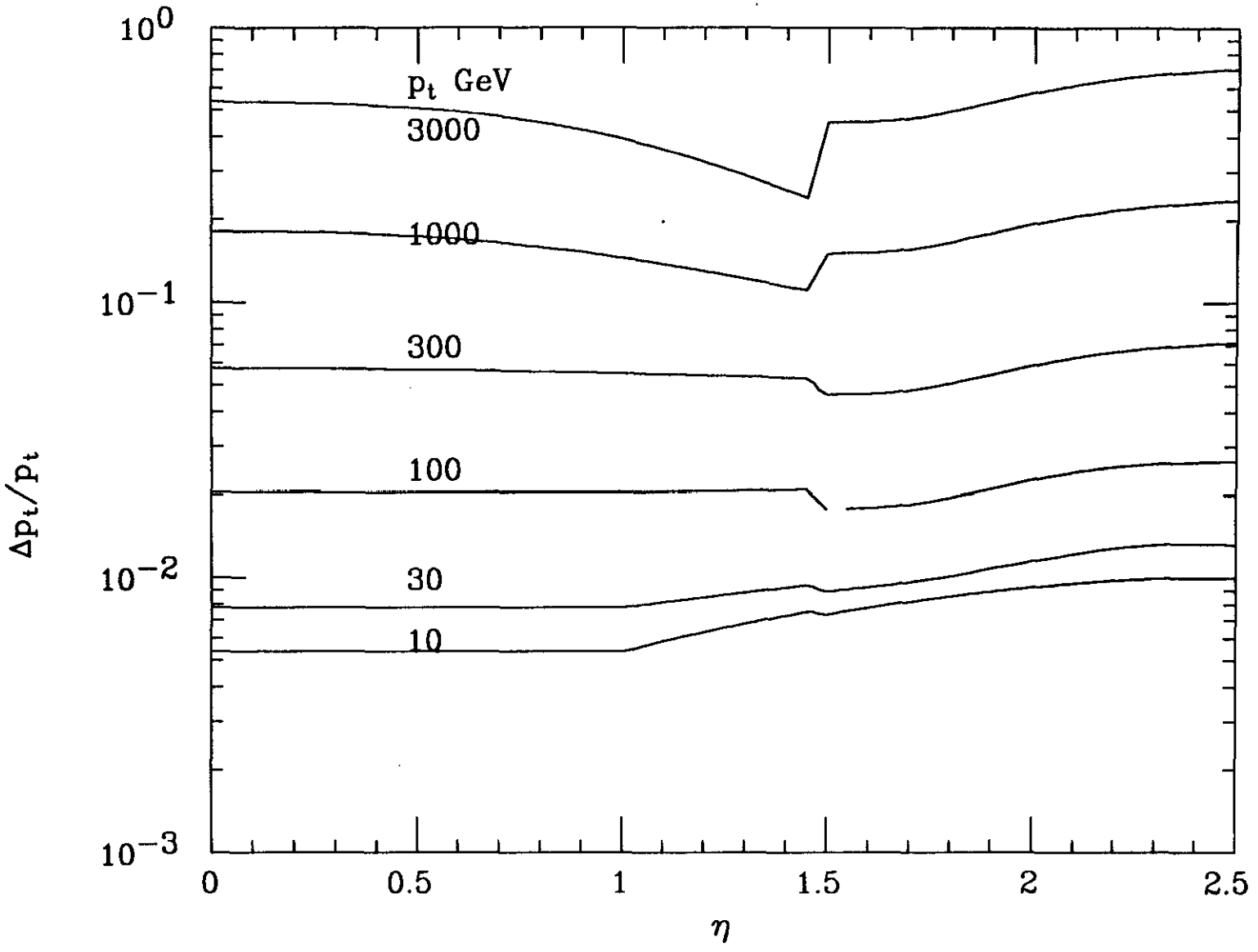

10^0
10^{-1}
10^{-2}
10^{-3}
$\Delta p_t/p_t$
p_t GeV
3000
1000
300
100
30
10
0
0.5
1
1.5
2
2.5
η

Figure 3

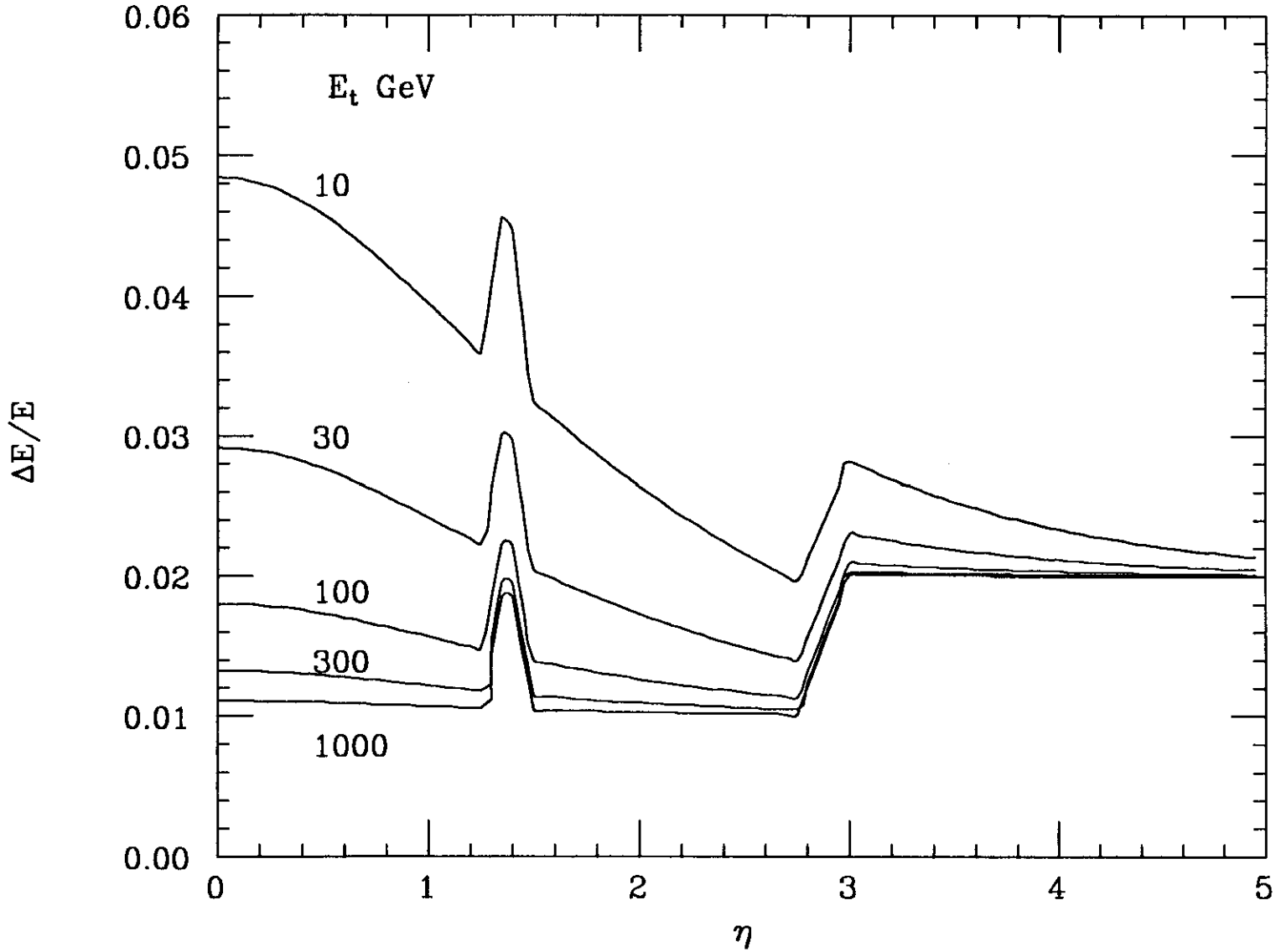

0.06
0.05
0.04
0.03
0.02
0.01
0.00
ΔE/E
E_t GeV
10
30
100
300
1000
0
1
2
3
4
5
η

Figure 4

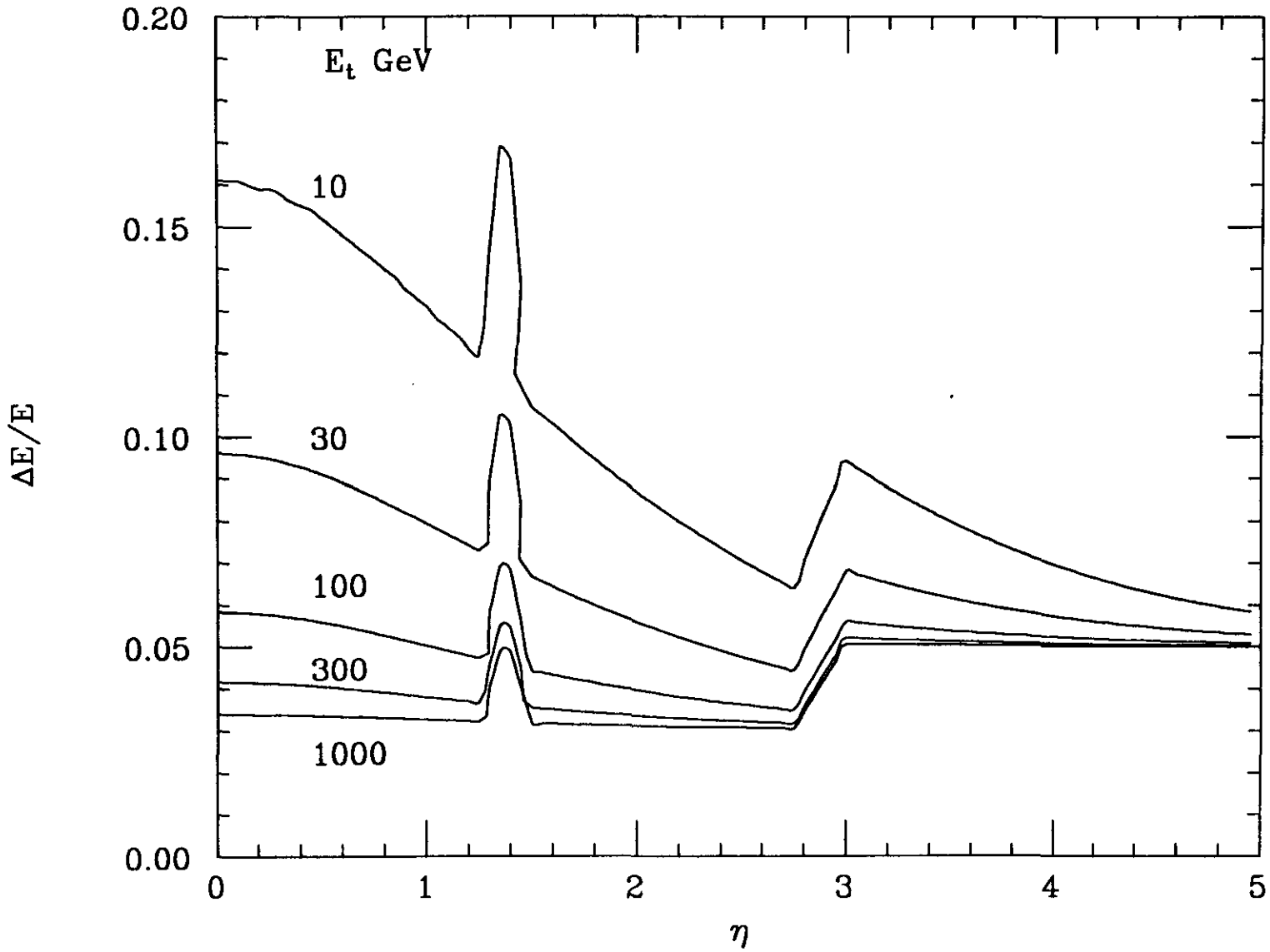


Figure 5

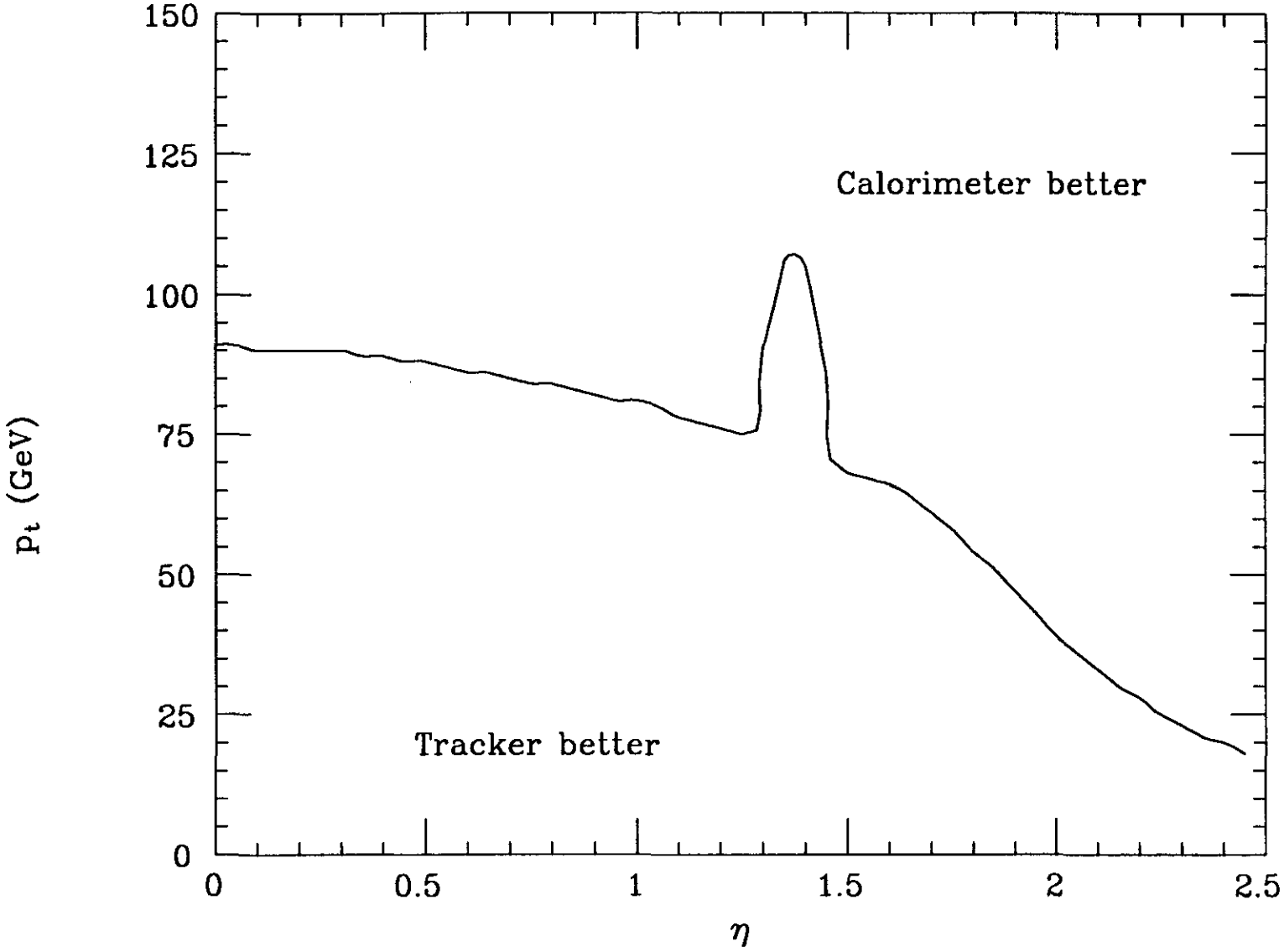

150
125
100
75
50
25
0
0
0.5
1
1.5
2
2.5
p_t (GeV)
η
Calorimeter better
Tracker better

Figure 6a′

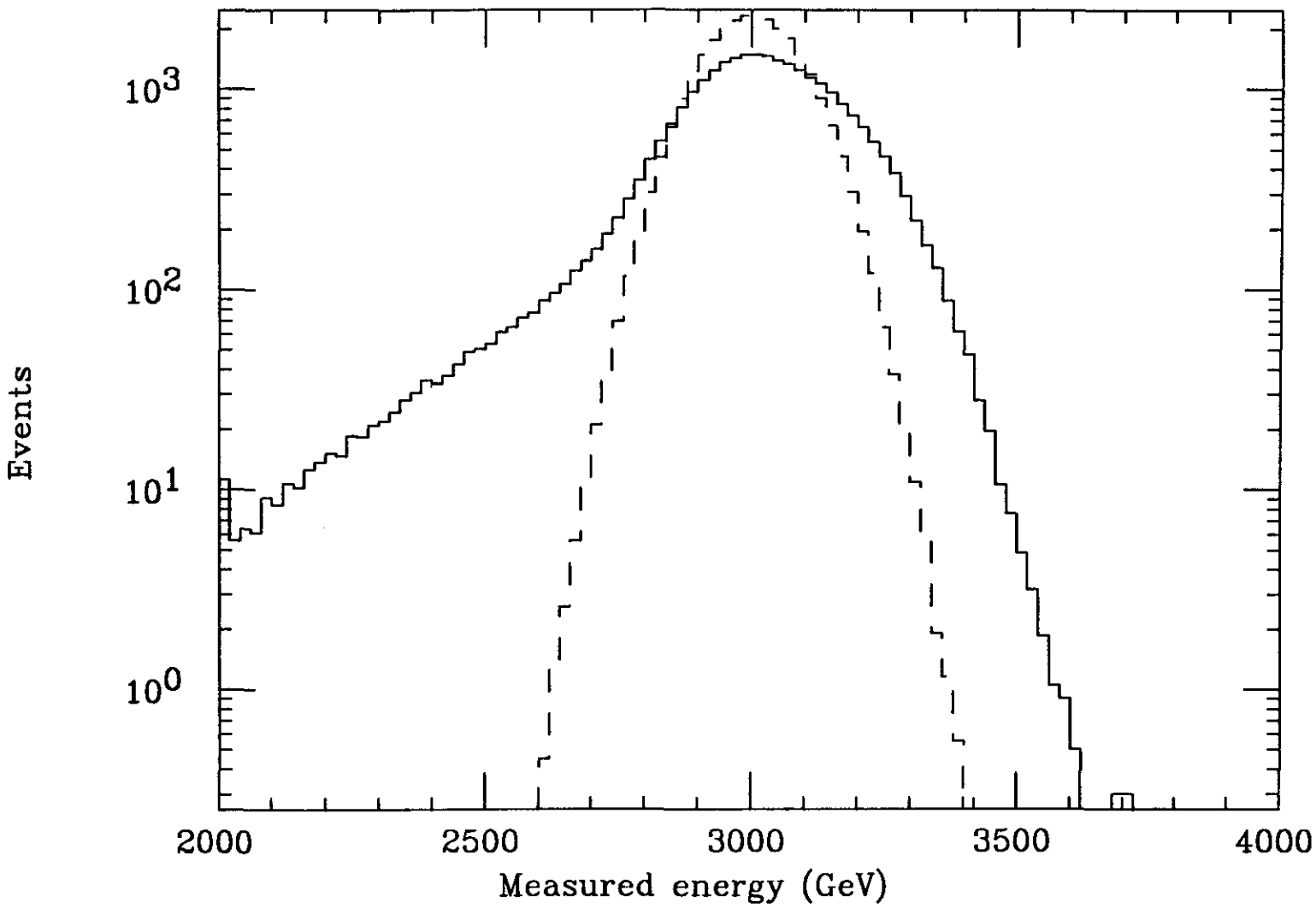
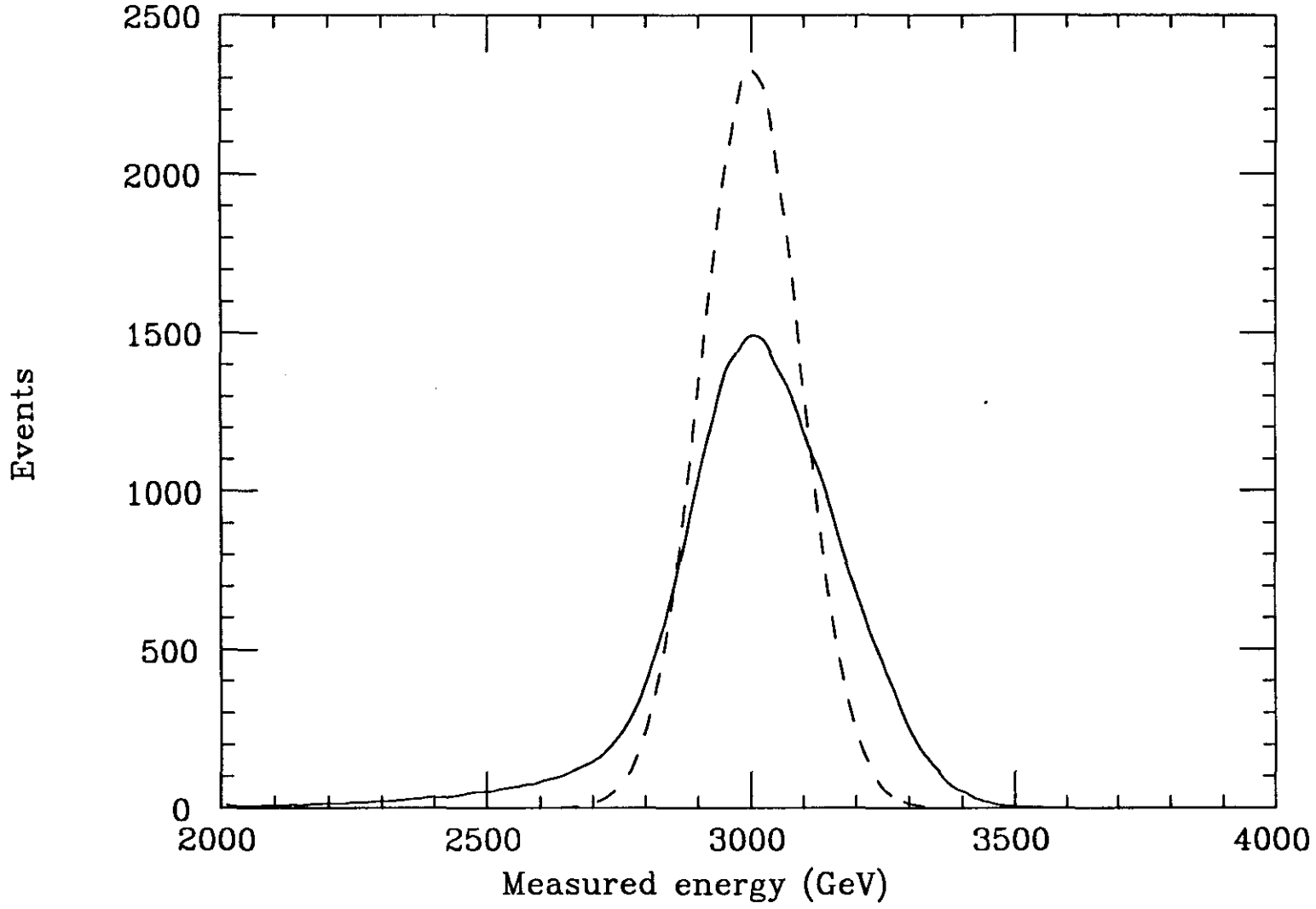

Events
10^3
10^2
10^1
10^0
2000
2500
3000
3500
4000
Measured energy (GeV)

Figure 6b′


2500
2000
1500
1000
500
0
Events
2000
2500
3000
3500
4000
Measured energy (GeV)

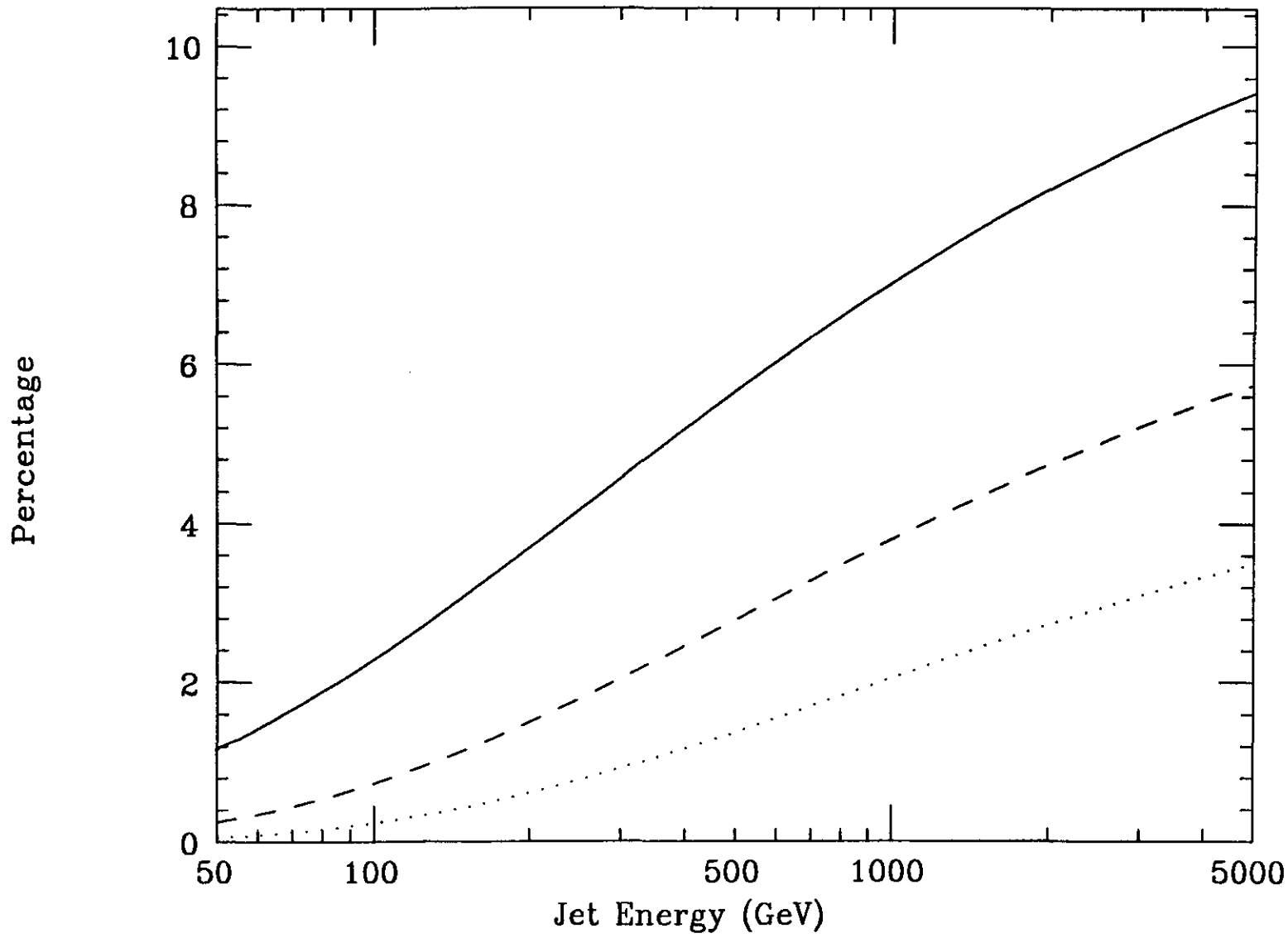



Figure 7