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SOLENOIDAL DETECTOR NOTES

MASS RESOLUTION REQUIREMENTS FOR THE HIGGS BOSON

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Mass resolution requirements for the Higgs Boson*

by Daniel D. Pitzl

The mass resolution for Higgs and Z-Bosons achieved in a tracking detector with a given momentum resolution at the SSC was studied.The reaction studied was

pp -> XH -> ZZ -> 4 charged leptons (electrons or muons)

The event simulation was done using PYTHIA4.8 at a beam energy of 20 TeV.The top quark mass was taken to be 120 GeV. The structure functions of Duke-Owens set 1 were used.
Four values for the Higgs mass were assumed (200, 400, 600 and 800 GeV) and about 4000 events were produced for each mass. For reference, Figures 1 to 4 show the transverse momentum and pseudorapidity distributions for the Higgs and the Z bosons in each case. Figures 5 to 8 show the distributions for the leptons. In the further analysis two cuts were applied on each lepton: $p_\perp > 10$ GeV and $|\eta| < 2.5$. Figures 5 to 8 show the minimum lepton-$p_\perp$ and maximum lepton pseudorapidity per event. Figure 9 shows the fraction of Higgs events accepted from all events as a function of the cut parameter in each mass case. The correlation between the two variables is not taken into account in these plots. For the values chosen 54% of all Higgs events are selected after both cuts for a Higgs mass of 200 Gev, increasing to 80% at 800 GeV.
To simulate the detector response the lepton momenta were folded with gaussian resolution functions with standard deviations parametrised as

$$\sigma_{p_\perp} = p_\perp \sqrt{(0.008)^2 + (\alpha \cdot p_\perp)^2} \quad , \quad p_\perp \text{ in TeV}$$

and α was varied from 0.05 to 0.5
The mass resolution was determined from the difference of reconstructed and generated mass values in each event, thus unfolding the natural line width. These distributions are shown in figures 10 to 17 for the Z and Higgs bosons, 4 values of and 4 Higgs masses while the following table gives the full width half maximum for each distribution.

α:	0.05	0.1	0.2	0.3	0.5	natural
FWHM(Z) [GeV]:						
MH = 200 GeV	1.3	1.9	2.7	3.7	4.8	2.4
MH = 400 GeV	1.4	2.1	3.1	4.1	5.7	2.4
MH = 600 GeV	1.7	2.7	4.7	6.2	7.6	2.4
MH = 800 GeV	2.1	3.9	5.3	6.7	9.2	2.4
FWHM(H) [GeV]:						
MH = 200 GeV	2.2	3.3	4.8	6.6	9.3	1.4
MH = 400 GeV	5.1	8.7	14	21	31	30
MH = 600 GeV	10.3	19	34	51	73	107
MH = 800 GeV	17	26	39	57	83	255

Figures 18 to 21 show the reconstructed Higgs-mass distributions.
Conclusions: A momentum resolution of 10% at $p_\perp = 1$ TeV is necessary to achieve a mass resolution for Z-bosons from Higgs decays better than or close to the natural width. The Z-mass constraint is a powerfull cut to reduce the background from semileptonic top decays in $t\bar{t}$ and $t\bar{t}Z$ events.

* Work supported in part by the U.S. Department of Energy.

Above a Higgs mass of 400 GeV the Higgs mass resolution is better than the natural width given by the Minimal Standard Model for all momentum resolutions studied. Below 400 GeV the signal to noise ratio for the Higgs signal improves with the momentum resolution. A detector with better Higgs mass resolution is also sensitive to Higgs bosons with smaller natural width and smaller production rate appearing in extended models.

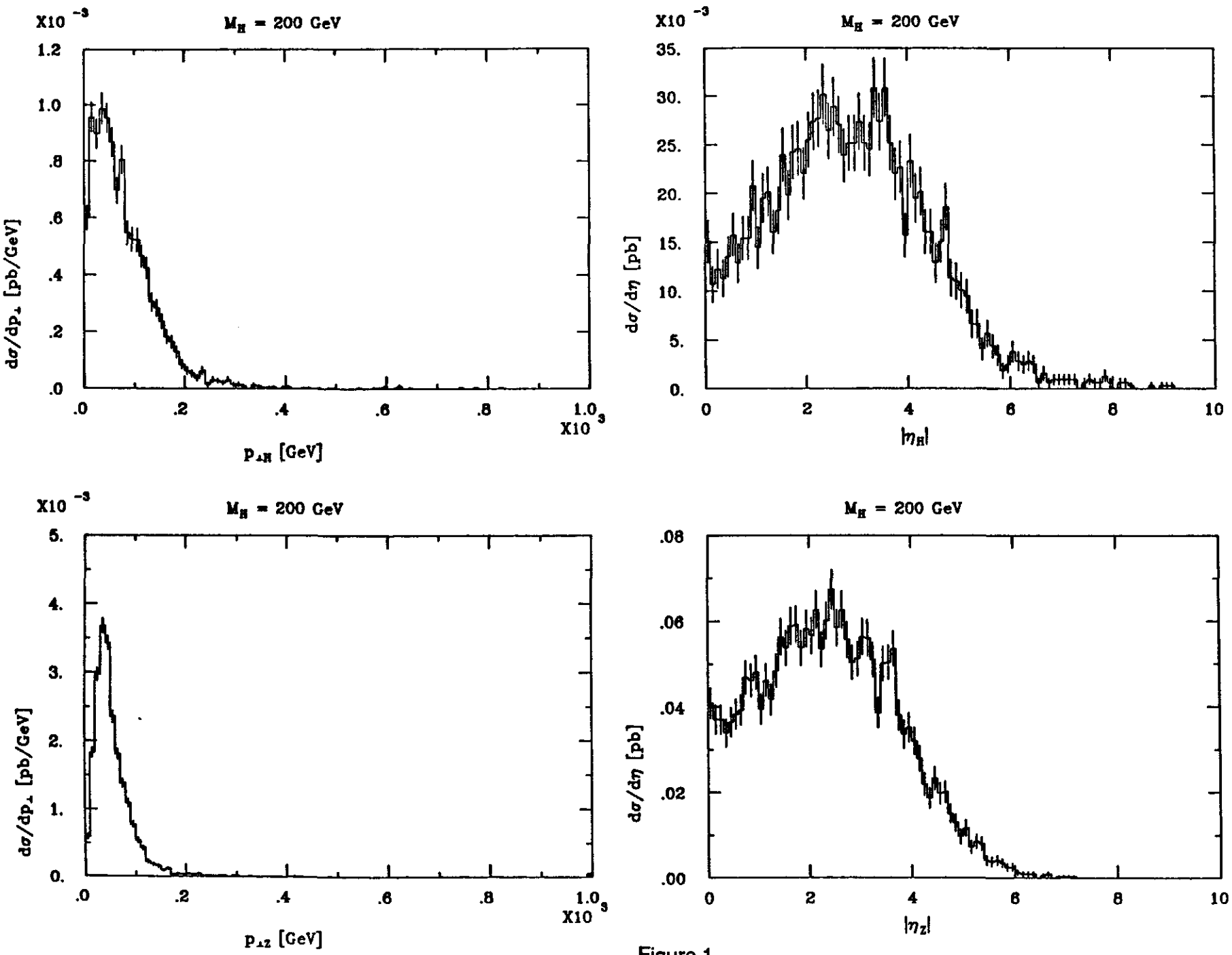

X10 -3
M_H = 200 GeV
dσ/dp⊥ [pb/GeV]
p⊥H [GeV]
X10 3
X10 -3
M_H = 200 GeV
dσ/dη [pb]
|η_H|
X10 -3
M_H = 200 GeV
dσ/dp⊥ [pb/GeV]
p⊥Z [GeV]
X10 3
M_H = 200 GeV
dσ/dη [pb]
|η_Z|

Figure 1

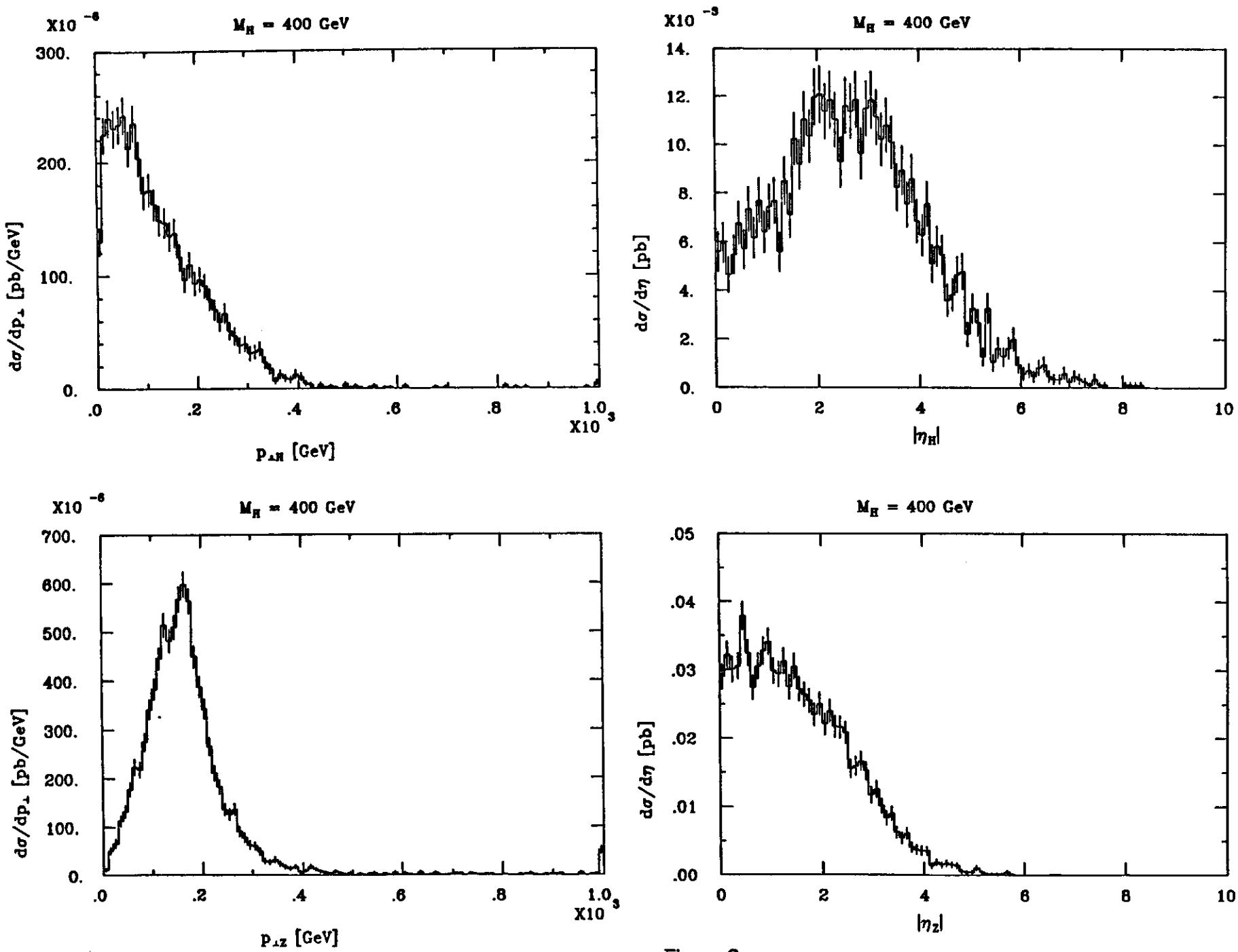

X10 -6
M_H = 400 GeV
300.
200.
100.
0.
dσ/dp⊥ [pb/GeV]
.0
.2
.4
.6
.8
1.0
X10 3
p⊥H [GeV]
X10 -3
M_H = 400 GeV
14.
12.
10.
8.
6.
4.
2.
0.
dσ/dη [pb]
0
2
4
6
8
10
|ηH|
X10 -6
M_H = 400 GeV
700.
600.
500.
400.
300.
200.
100.
0.
dσ/dp⊥ [pb/GeV]
.0
.2
.4
.6
.8
1.0
X10 3
p⊥Z [GeV]
M_H = 400 GeV
.05
.04
.03
.02
.01
.00
dσ/dη [pb]
0
2
4
6
8
10
|ηZ|

Figure 2

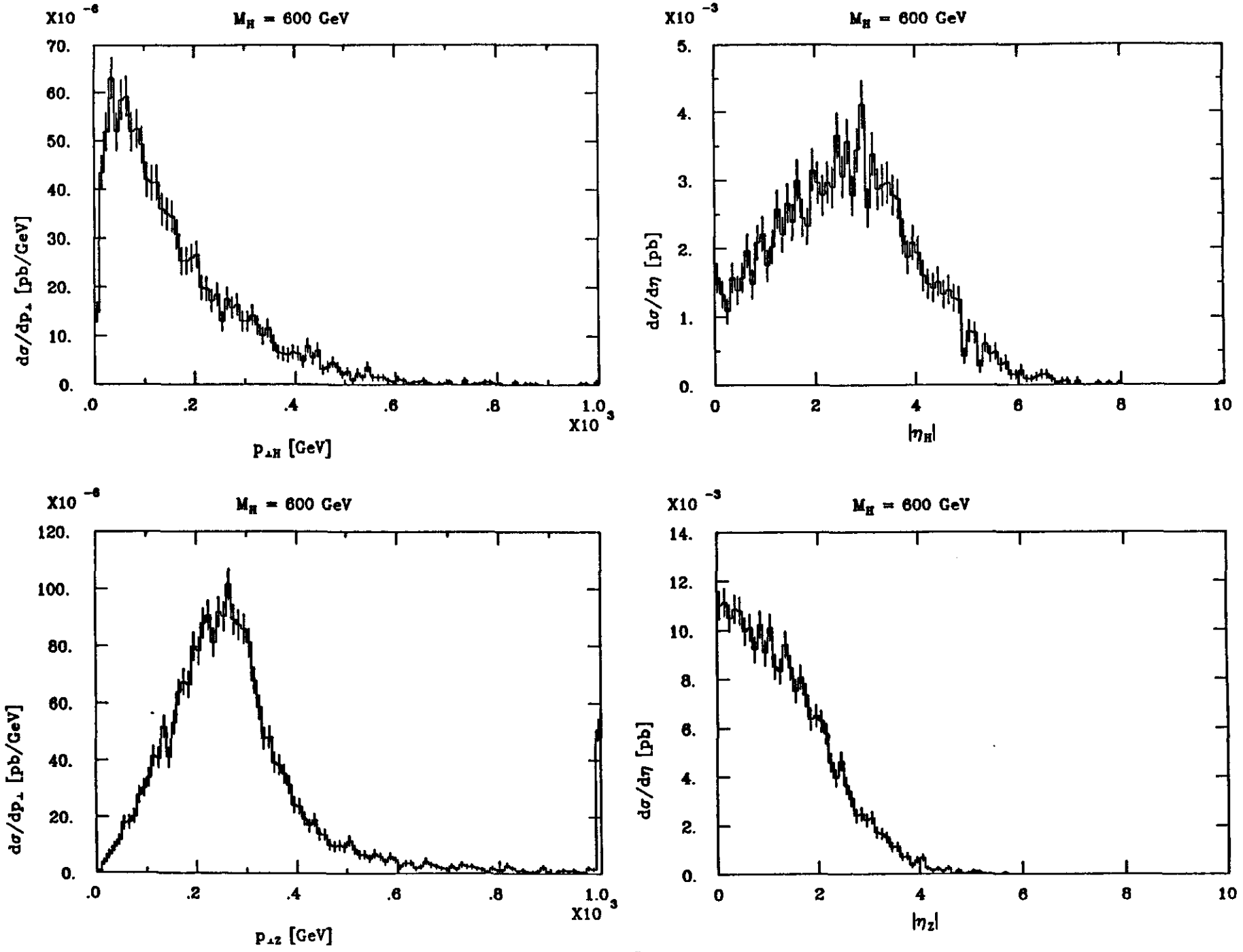
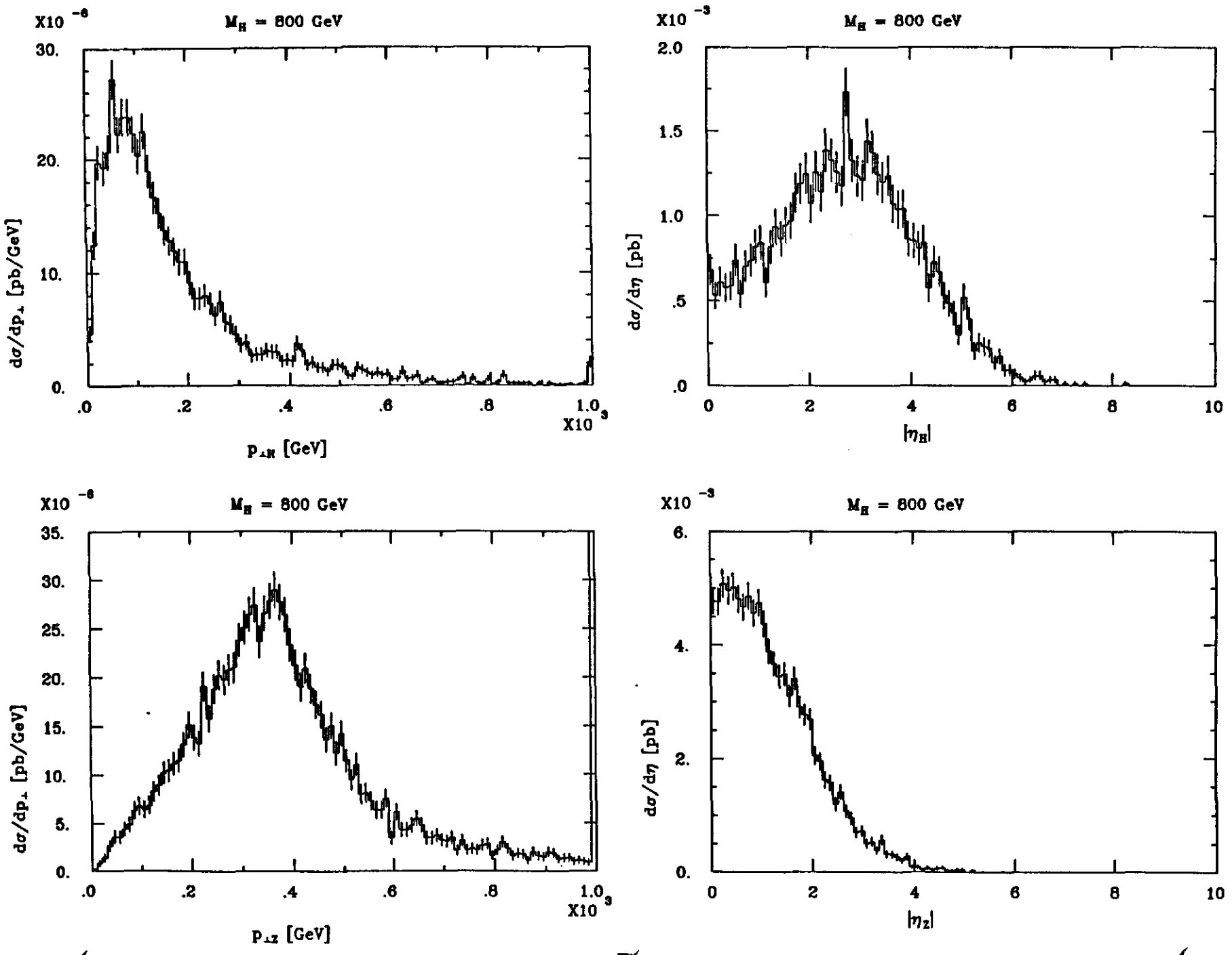

X10 -6
M_H = 600 GeV
dσ/dp⊥ [pb/GeV]
p⊥H [GeV]
X10 -3
M_H = 600 GeV
dσ/dη [pb]
|η_H|
X10 -6
M_H = 600 GeV
dσ/dp⊥ [pb/GeV]
p⊥Z [GeV]
X10 -3
M_H = 600 GeV
dσ/dη [pb]
|η_Z|

Figure 3


X10 -6
M_H = 800 GeV
dσ/dp⊥ [pb/GeV]
p⊥H [GeV]
X10 -3
M_H = 800 GeV
dσ/dη [pb]
|η_H|
X10 -6
M_H = 800 GeV
dσ/dp⊥ [pb/GeV]
p⊥Z [GeV]
X10 -3
M_H = 800 GeV
dσ/dη [pb]
|η_Z|

F 4

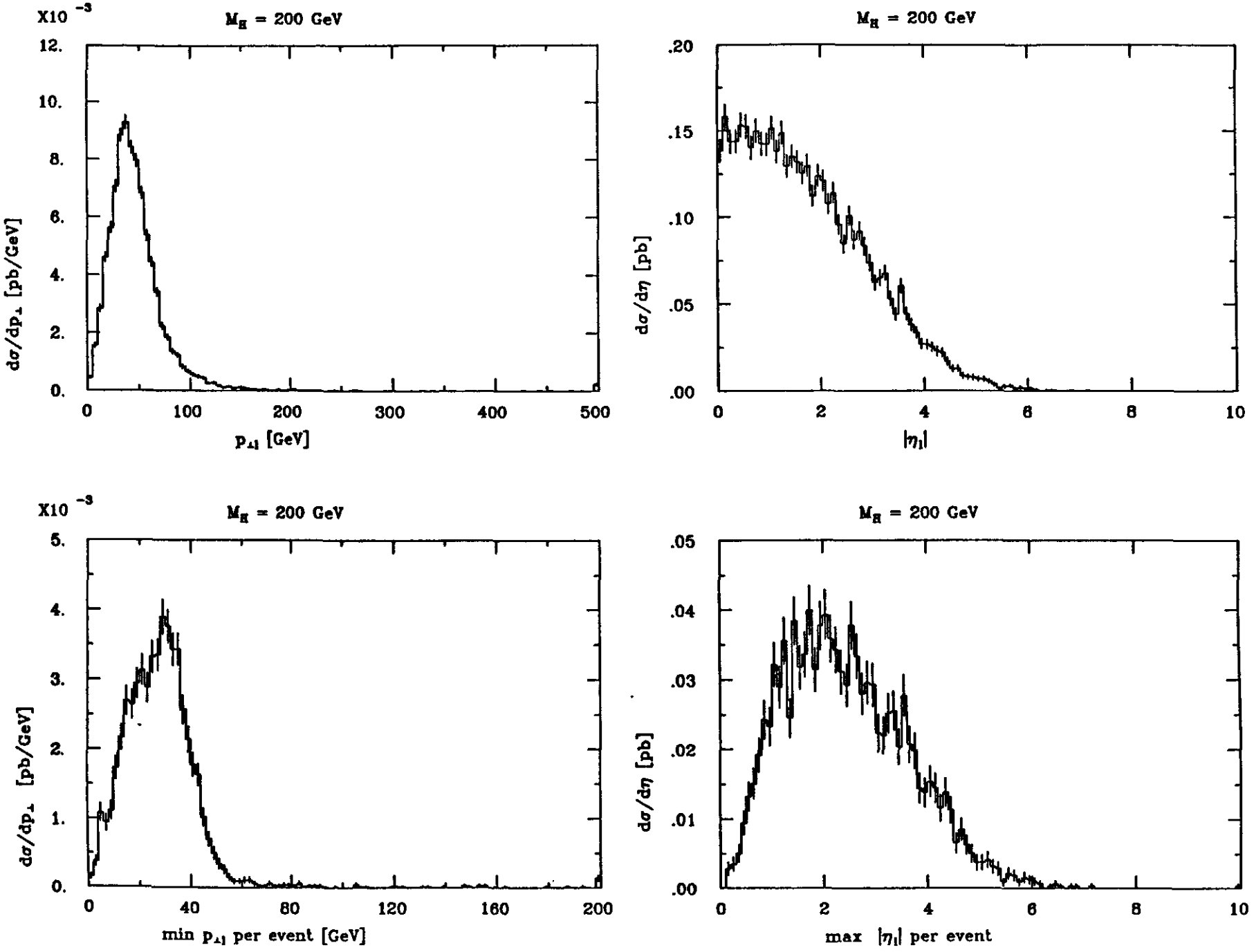
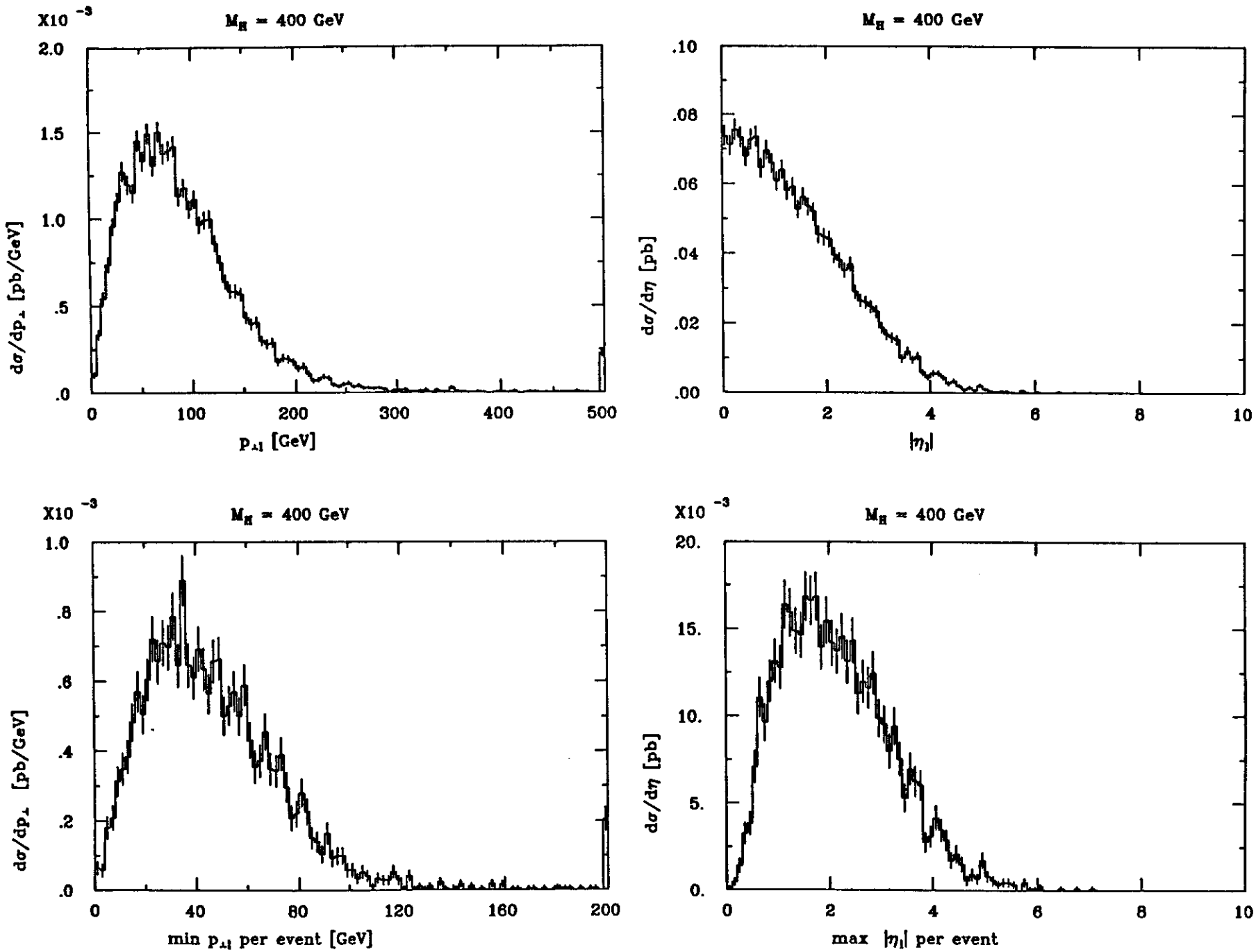

X10 -3
M_H = 200 GeV
dσ/dp⊥ [pb/GeV]
p⊥l [GeV]
M_H = 200 GeV
dσ/dη [pb]
|η_l|
X10 -3
M_H = 200 GeV
dσ/dp⊥ [pb/GeV]
min p⊥l per event [GeV]
M_H = 200 GeV
dσ/dη [pb]
max |η_l| per event

Figure 5


X10 -3
M_H = 400 GeV
dσ/dp⊥ [pb/GeV]
p⊥1 [GeV]
M_H = 400 GeV
dσ/dη [pb]
|η1|
X10 -3
M_H = 400 GeV
dσ/dp⊥ [pb/GeV]
min p⊥1 per event [GeV]
X10 -3
M_H = 400 GeV
dσ/dη [pb]
max |η1| per event

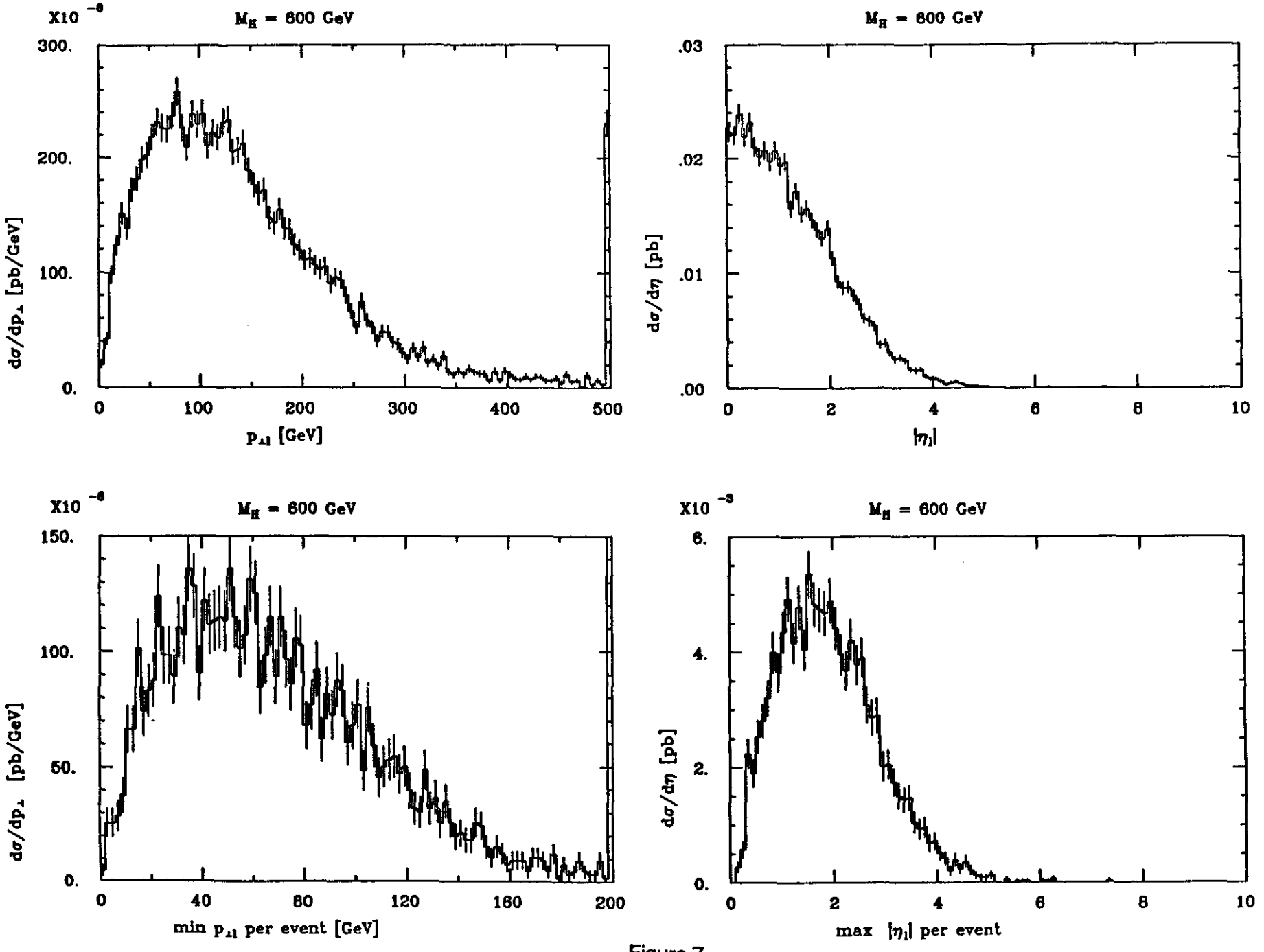

X10 -6
M_H = 600 GeV
300.
200.
100.
0.
dσ/dp⊥ [pb/GeV]
0
100
200
300
400
500
p⊥l [GeV]
M_H = 600 GeV
.03
.02
.01
.00
dσ/dη [pb]
0
2
4
6
8
10
|η_l|
X10 -6
M_H = 600 GeV
150.
100.
50.
0.
dσ/dp⊥ [pb/GeV]
0
40
80
120
160
200
min p⊥l per event [GeV]
X10 -3
M_H = 600 GeV
6.
4.
2.
0.
dσ/dη [pb]
0
2
4
6
8
10
max |η_l| per event

Figure 7

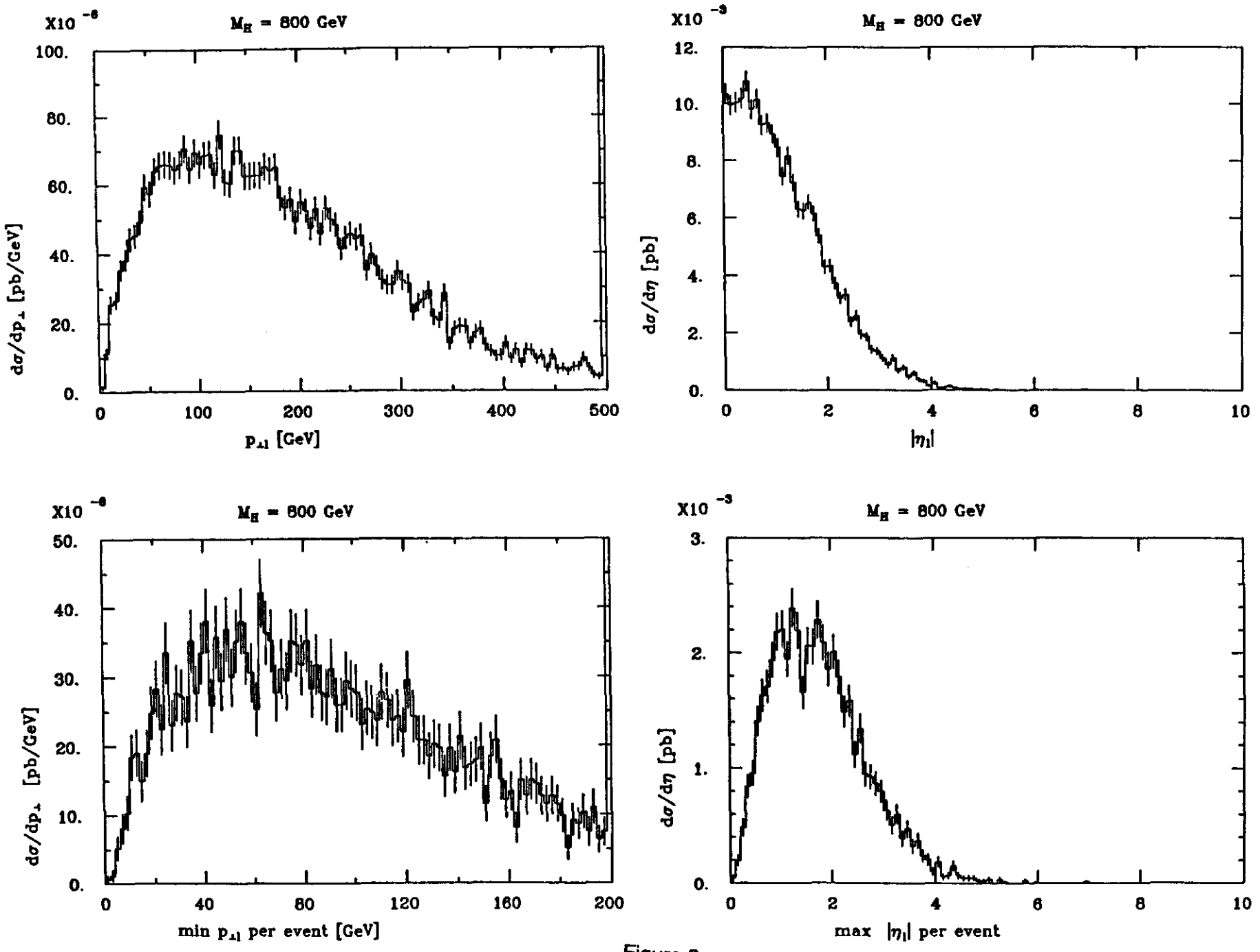

X10 -6
M_H = 800 GeV
dσ/dp⊥ [pb/GeV]
p⊥l [GeV]
X10 -3
M_H = 800 GeV
dσ/dη [pb]
|η_l|
X10 -6
M_H = 800 GeV
dσ/dp⊥ [pb/GeV]
min p⊥l per event [GeV]
X10 -3
M_H = 800 GeV
dσ/dη [pb]
max |η_l| per event

Figure 8

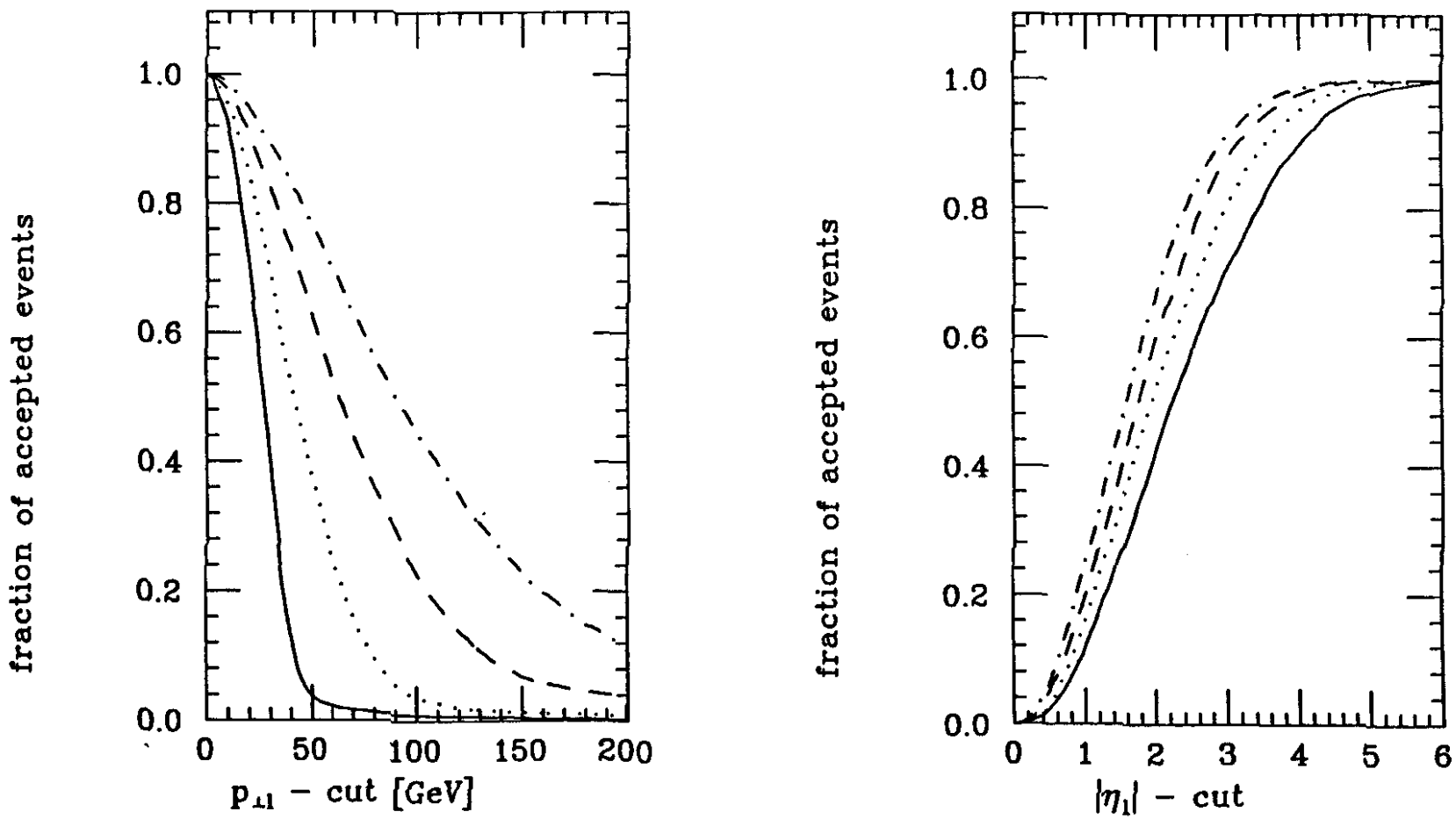


Figure 9: solid: M_H = 200 GeV, dotted: M_H = 400 GeV
dashed: M_H = 600 GeV, dashed-dotted: M_H = 800 GeV

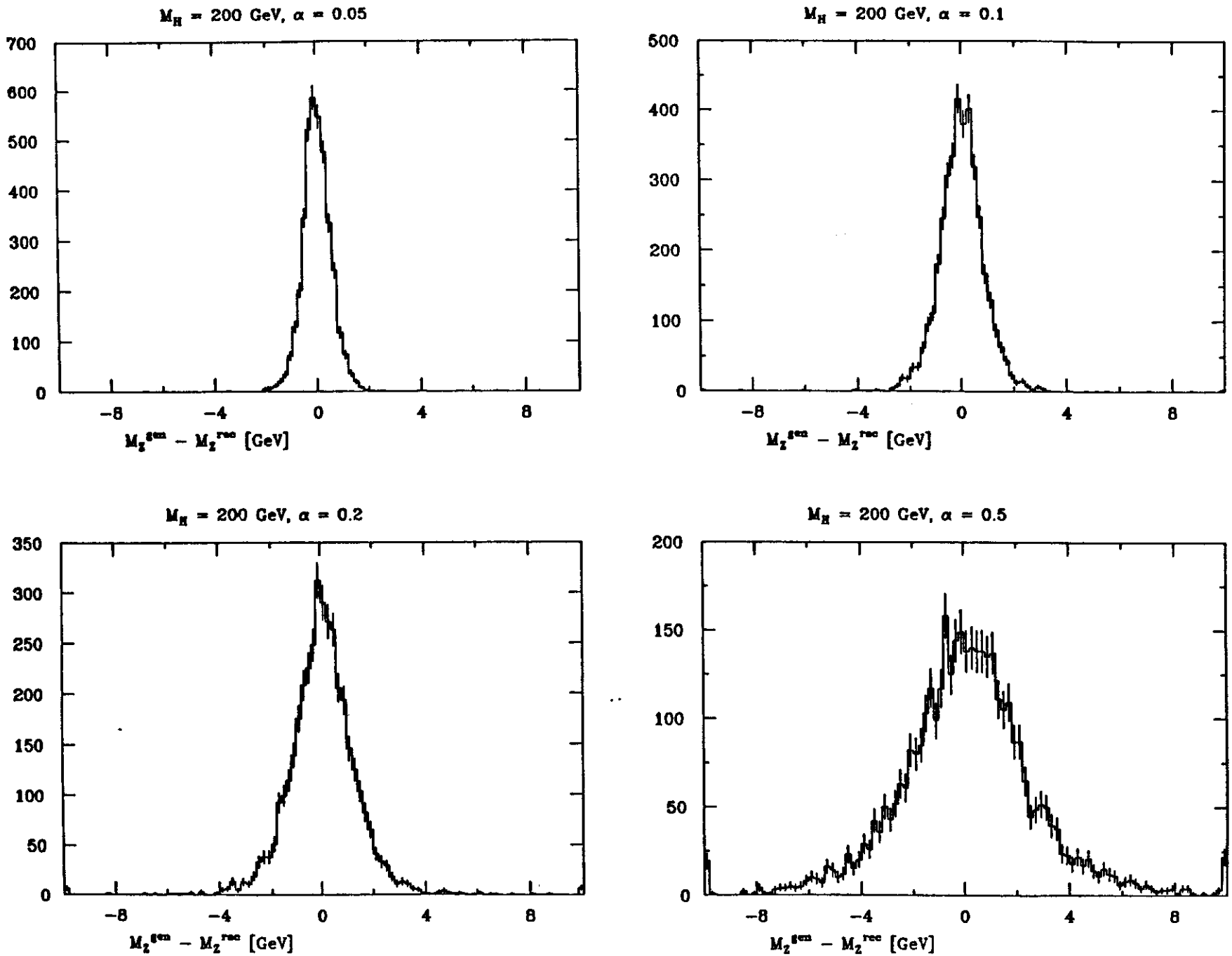

M_H = 200 GeV, α = 0.05
M_H = 200 GeV, α = 0.1
M_H = 200 GeV, α = 0.2
M_H = 200 GeV, α = 0.5
$M_Z^{gen} - M_Z^{rec}$ [GeV]

Figure 10

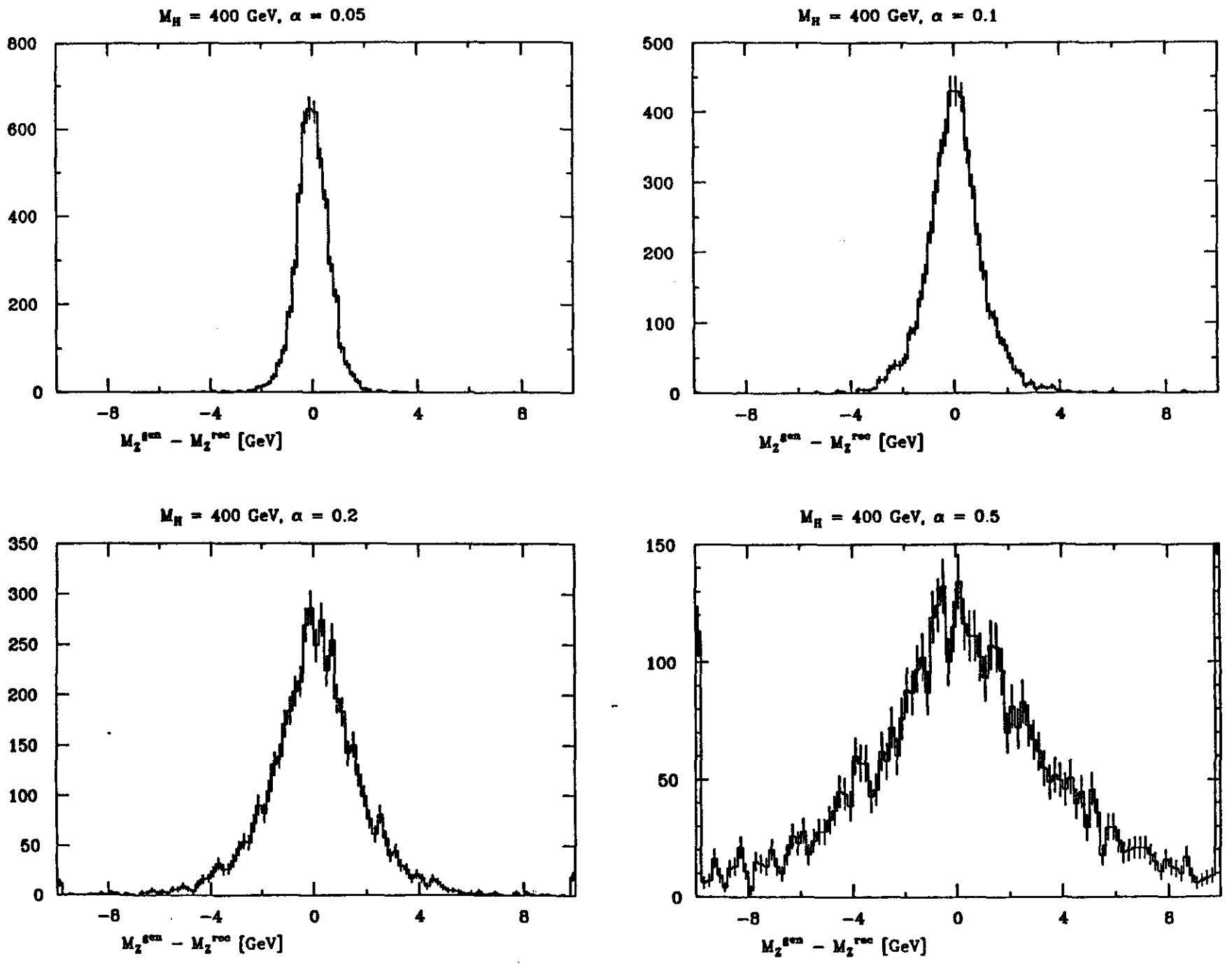

M_H = 400 GeV, α = 0.05
M_H = 400 GeV, α = 0.1
M_H = 400 GeV, α = 0.2
M_H = 400 GeV, α = 0.5
$M_Z^{gen} - M_Z^{rec}$ [GeV]

Figure 11

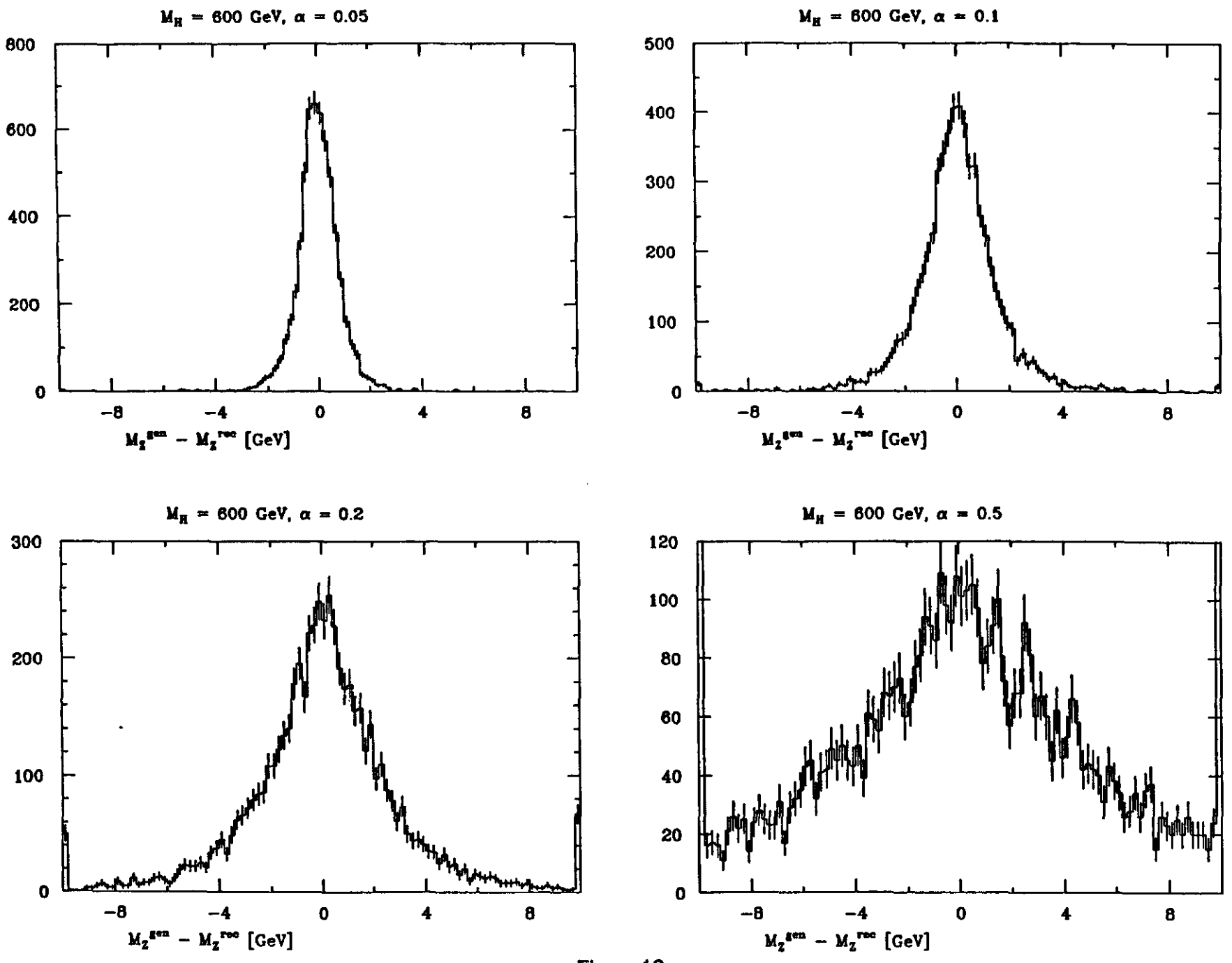

M_H = 600 GeV, α = 0.05
M_H = 600 GeV, α = 0.1
M_H = 600 GeV, α = 0.2
M_H = 600 GeV, α = 0.5
$M_Z^{gen} - M_Z^{rec}$ [GeV]

Figure 12

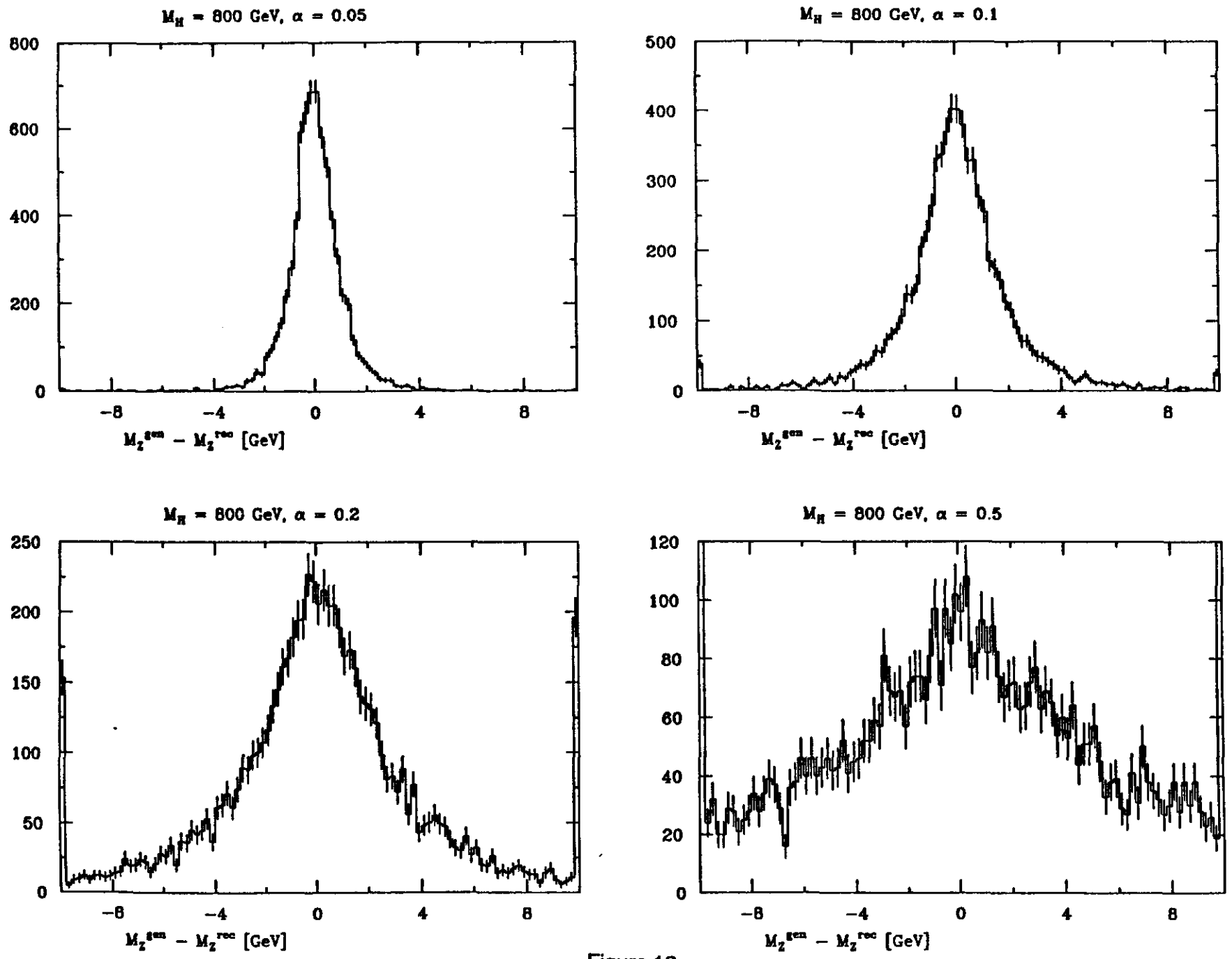

M_H = 800 GeV, α = 0.05
M_H = 800 GeV, α = 0.1
M_H = 800 GeV, α = 0.2
M_H = 800 GeV, α = 0.5
$M_Z^{gen} - M_Z^{rec}$ [GeV]

Figure 13

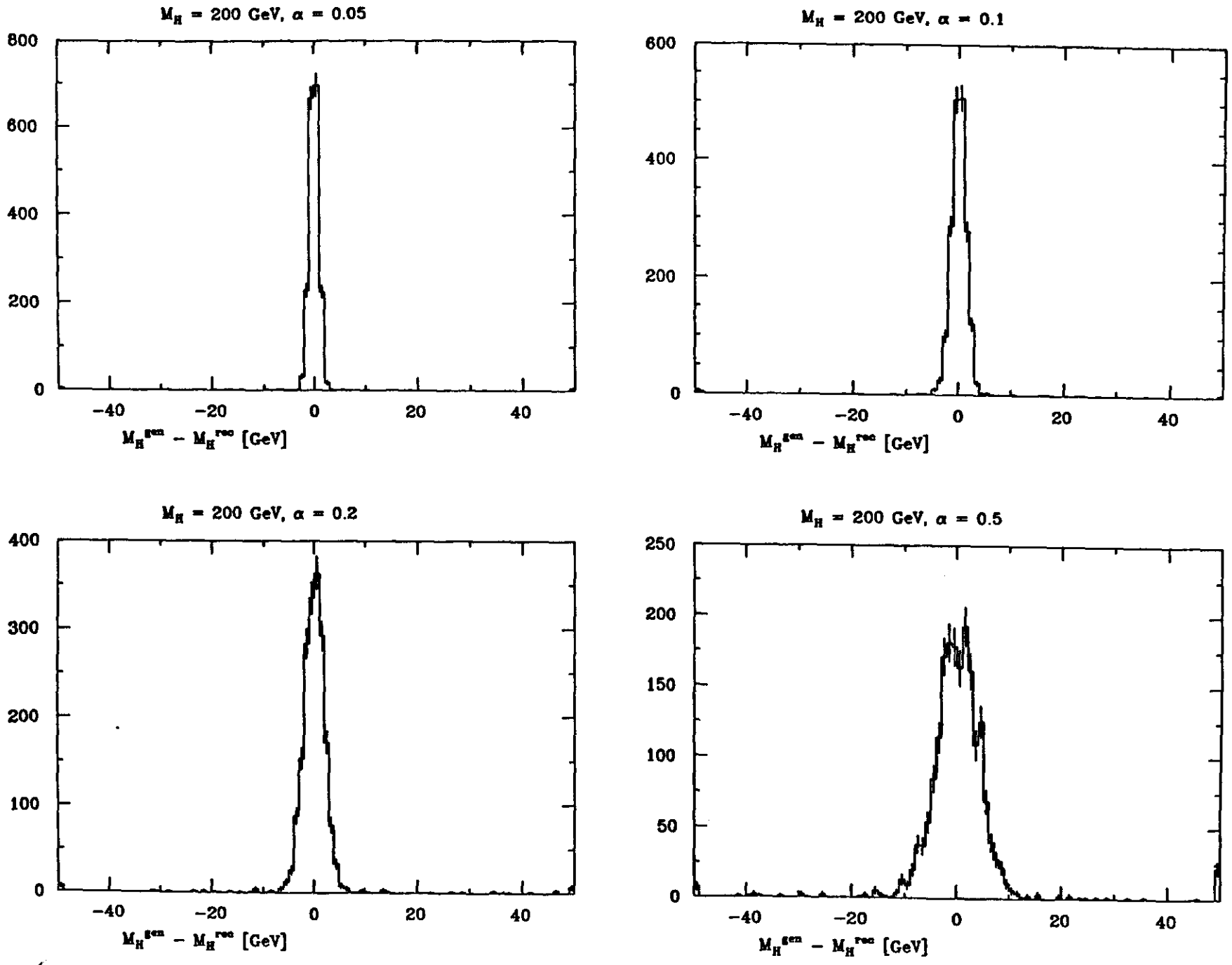

M_H = 200 GeV, α = 0.05
M_H = 200 GeV, α = 0.1
M_H = 200 GeV, α = 0.2
M_H = 200 GeV, α = 0.5
$M_H^{gen} - M_H^{rec}$ [GeV]

Fig. 14

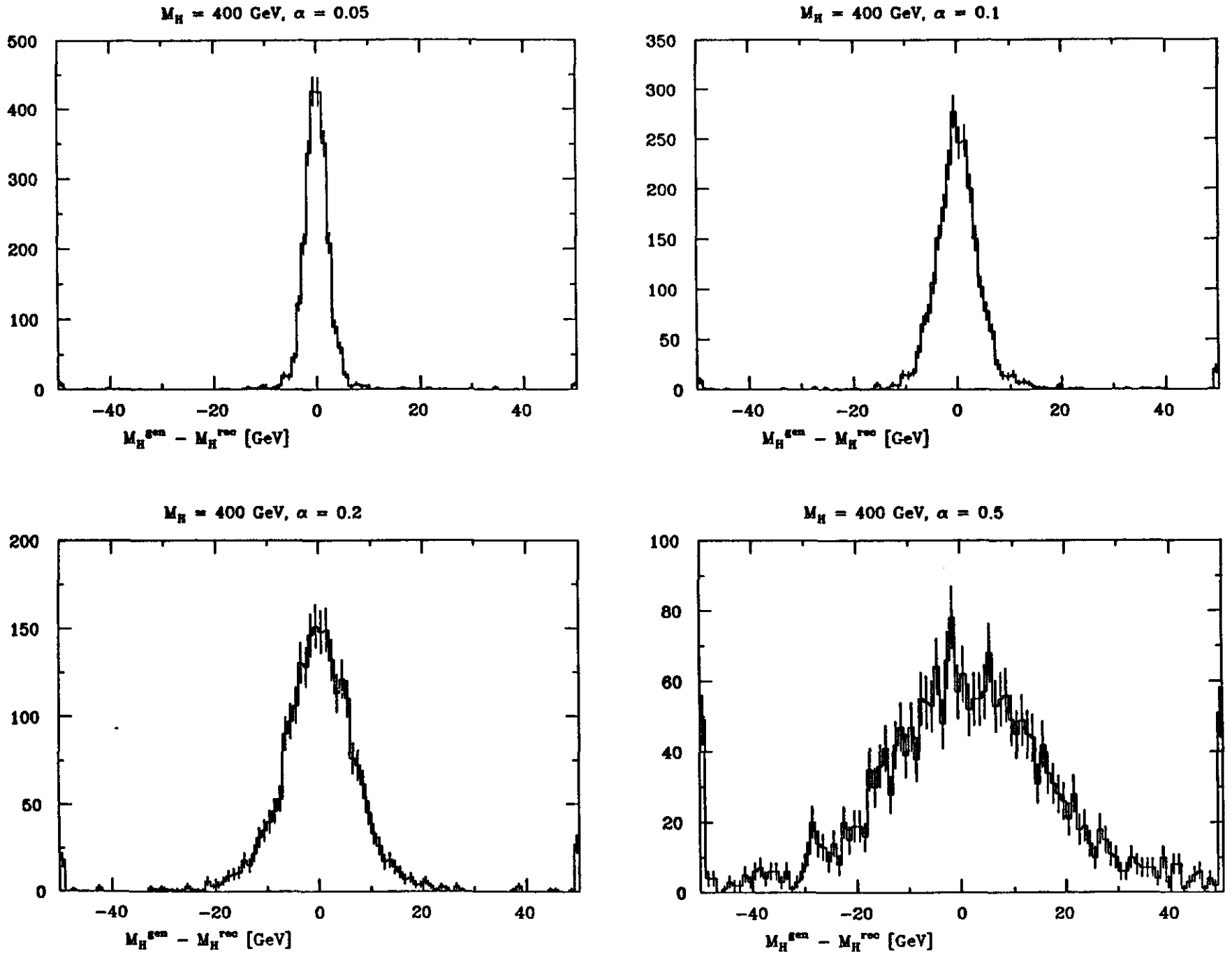

M_H = 400 GeV, α = 0.05
M_H = 400 GeV, α = 0.1
M_H = 400 GeV, α = 0.2
M_H = 400 GeV, α = 0.5
$M_H^{gen} - M_H^{rec}$ [GeV]

Figure 15

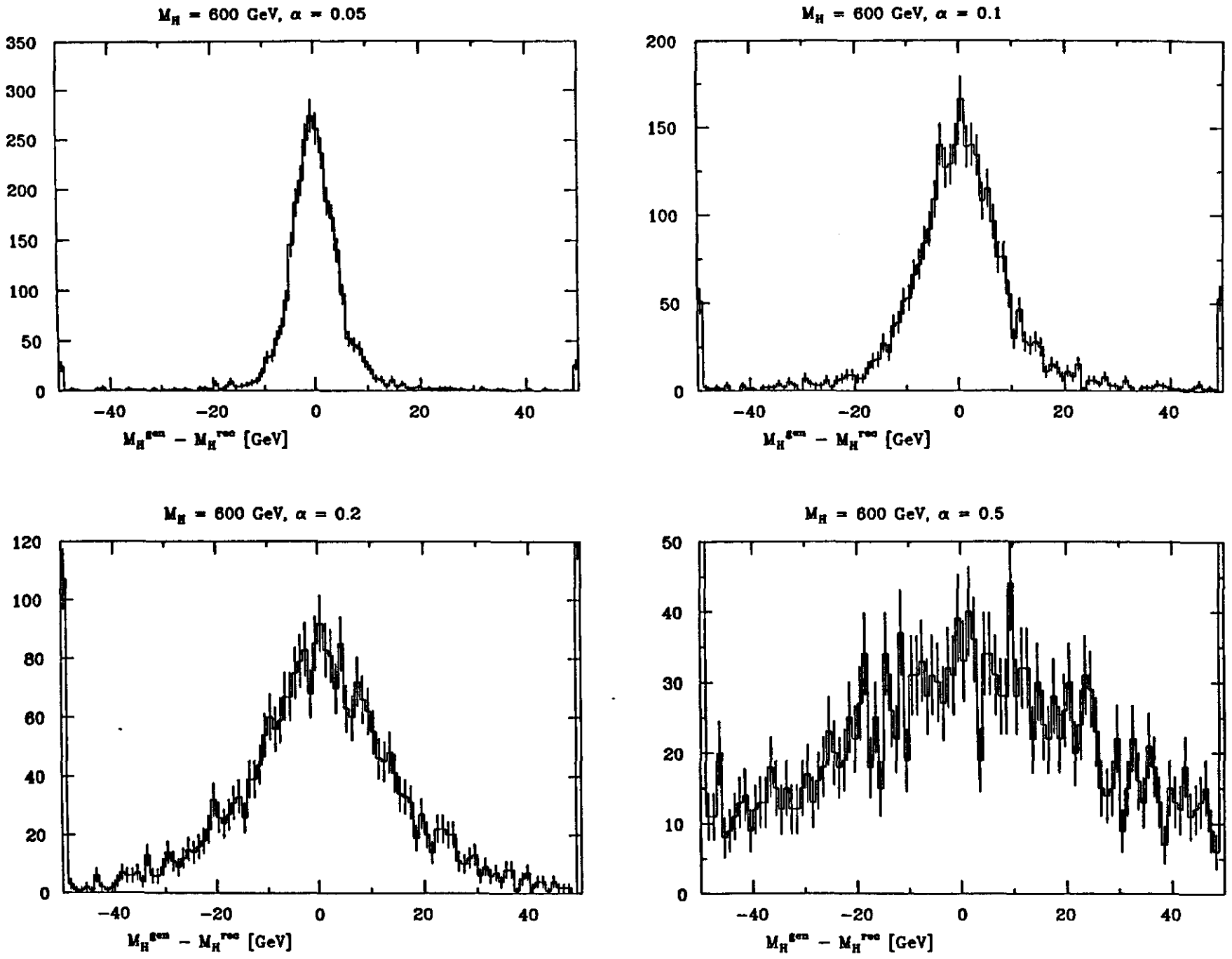

M_H = 600 GeV, α = 0.05
M_H = 600 GeV, α = 0.1
M_H = 600 GeV, α = 0.2
M_H = 600 GeV, α = 0.5
$M_H^{gen} - M_H^{rec}$ [GeV]

Figure 16

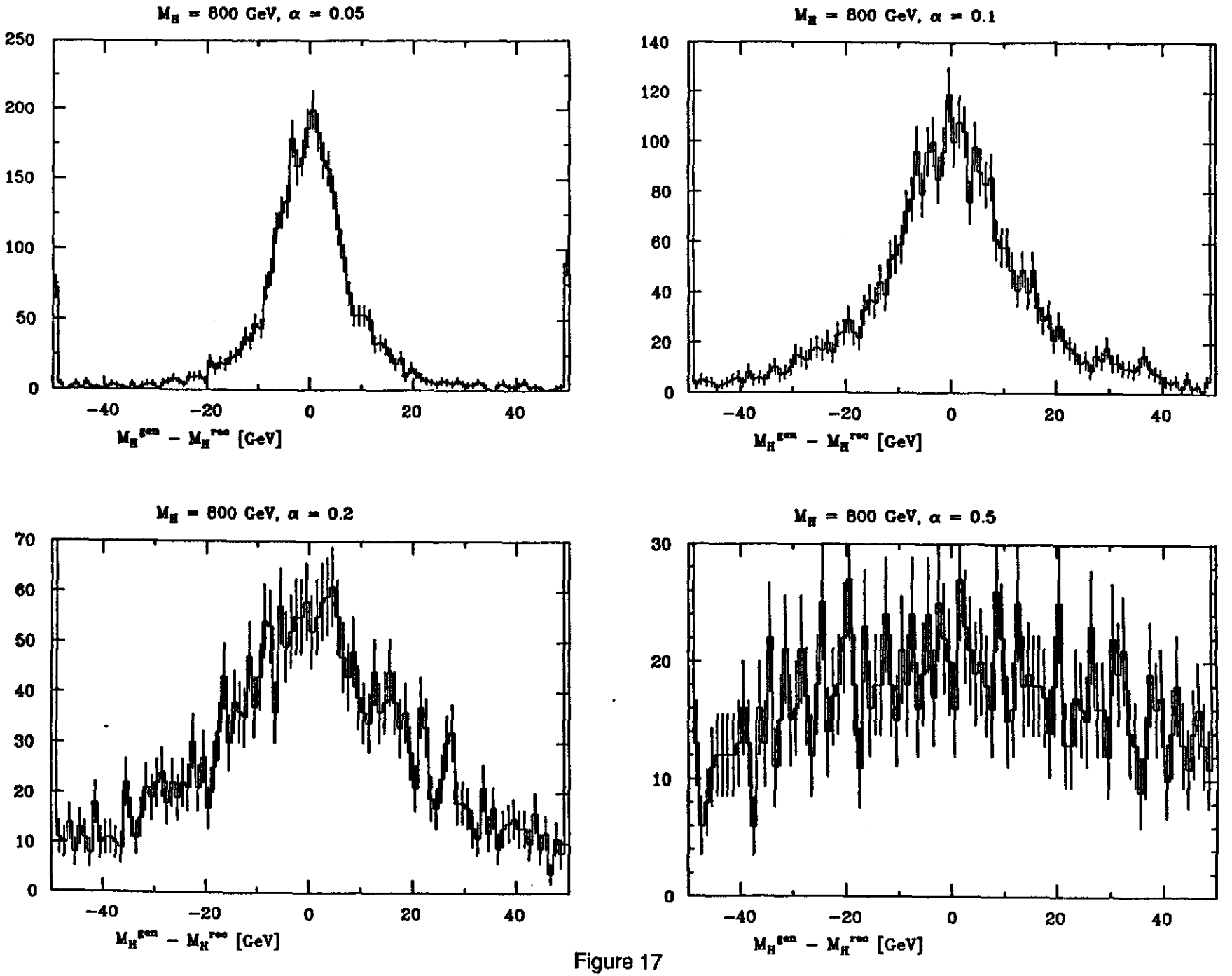

M_H = 800 GeV, α = 0.05
M_H = 800 GeV, α = 0.1
M_H = 800 GeV, α = 0.2
M_H = 800 GeV, α = 0.5
$M_H^{gen} - M_H^{rec}$ [GeV]

Figure 17

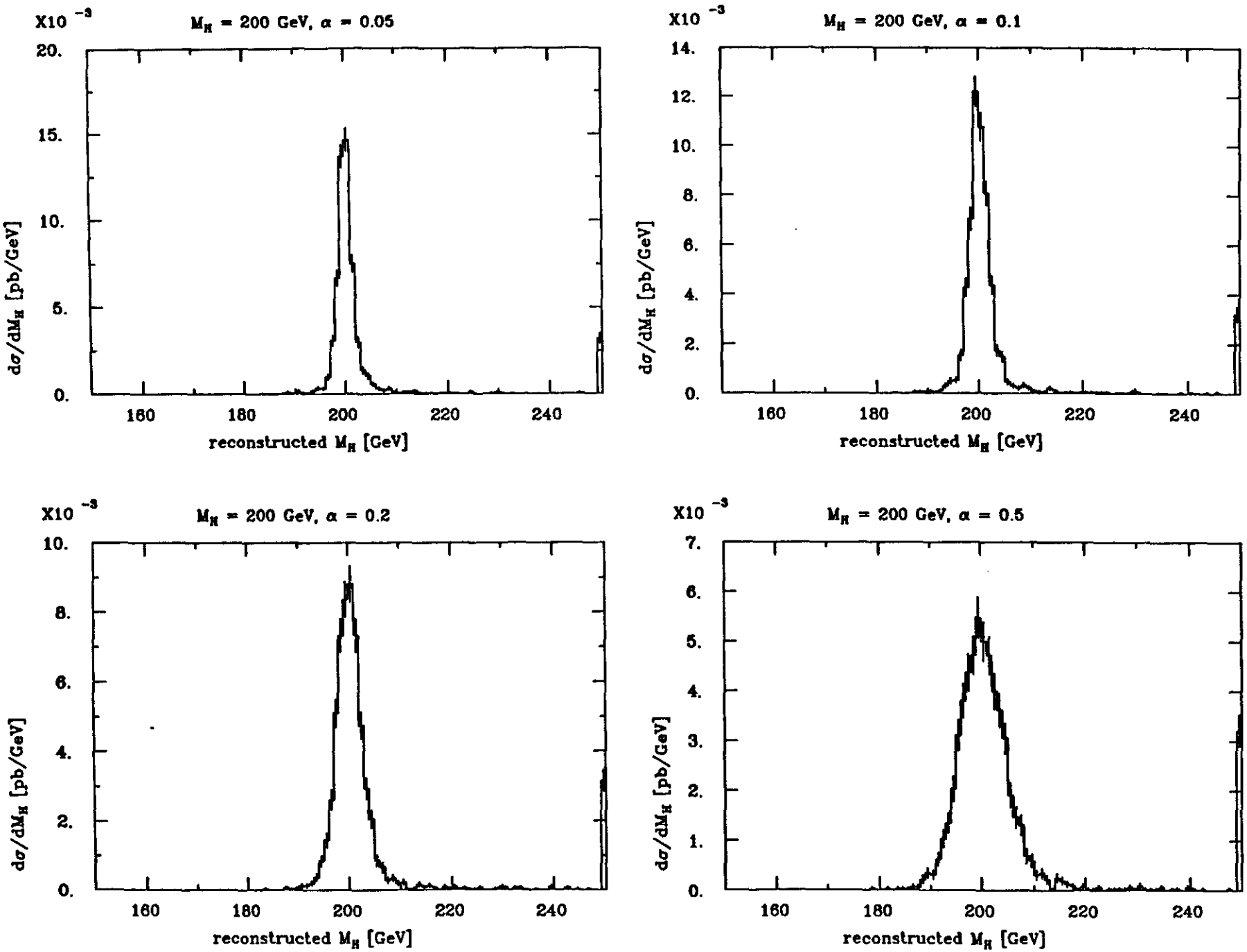

X10 -3
M_H = 200 GeV, α = 0.05
$d\sigma/dM_H$ [pb/GeV]
reconstructed M_H [GeV]
X10 -3
M_H = 200 GeV, α = 0.1
$d\sigma/dM_H$ [pb/GeV]
reconstructed M_H [GeV]
X10 -3
M_H = 200 GeV, α = 0.2
$d\sigma/dM_H$ [pb/GeV]
reconstructed M_H [GeV]
X10 -3
M_H = 200 GeV, α = 0.5
$d\sigma/dM_H$ [pb/GeV]
reconstructed M_H [GeV]

Figure 18

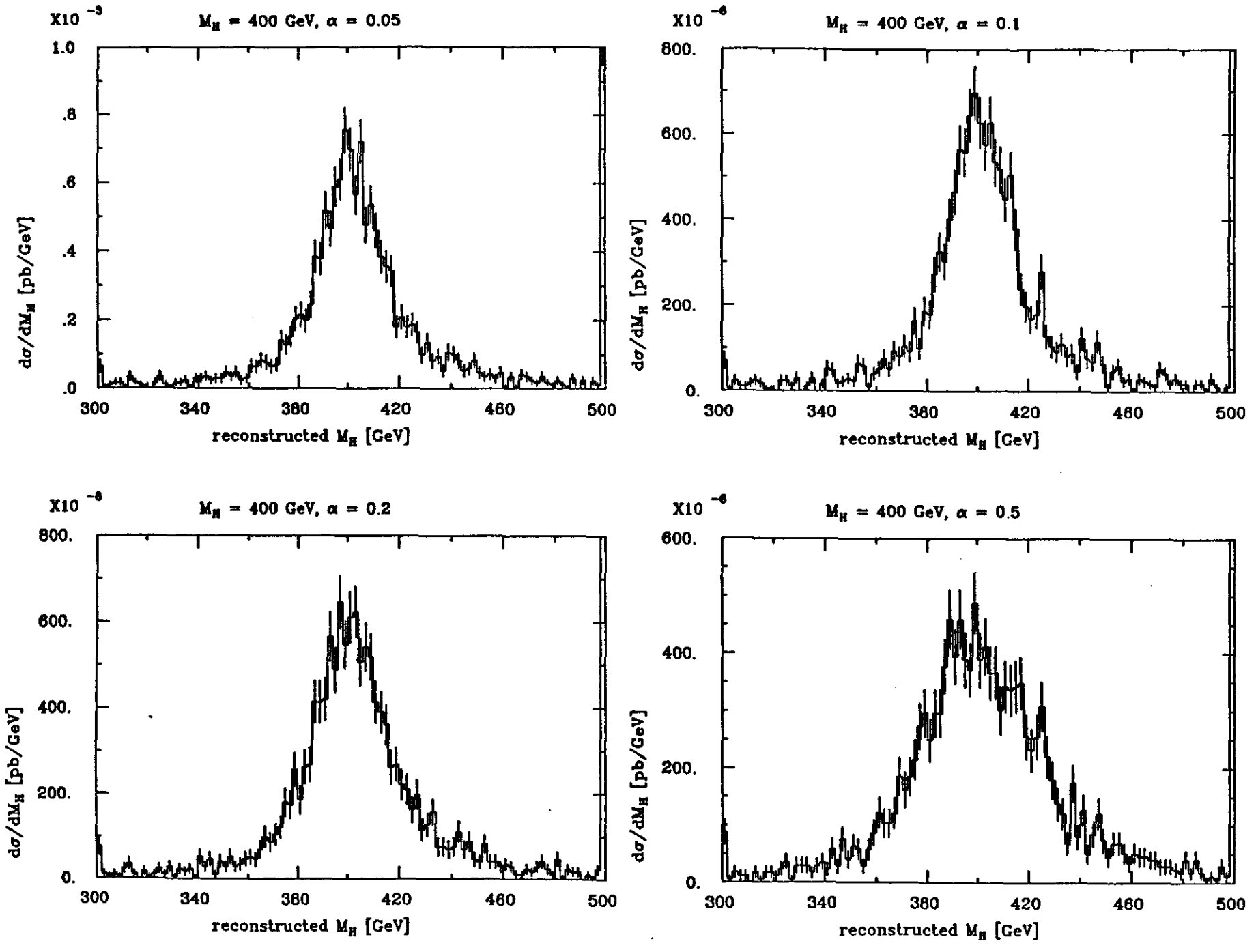
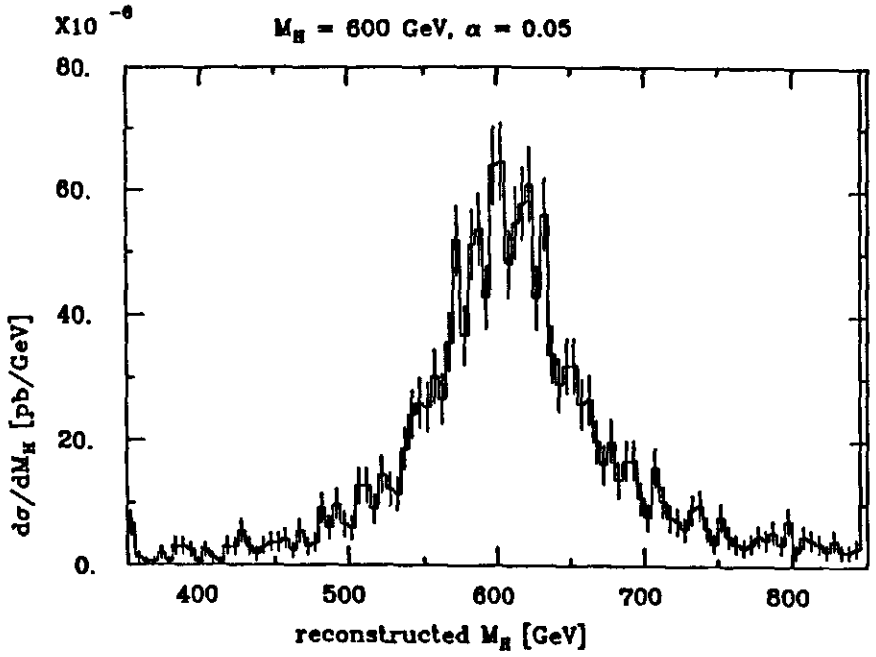
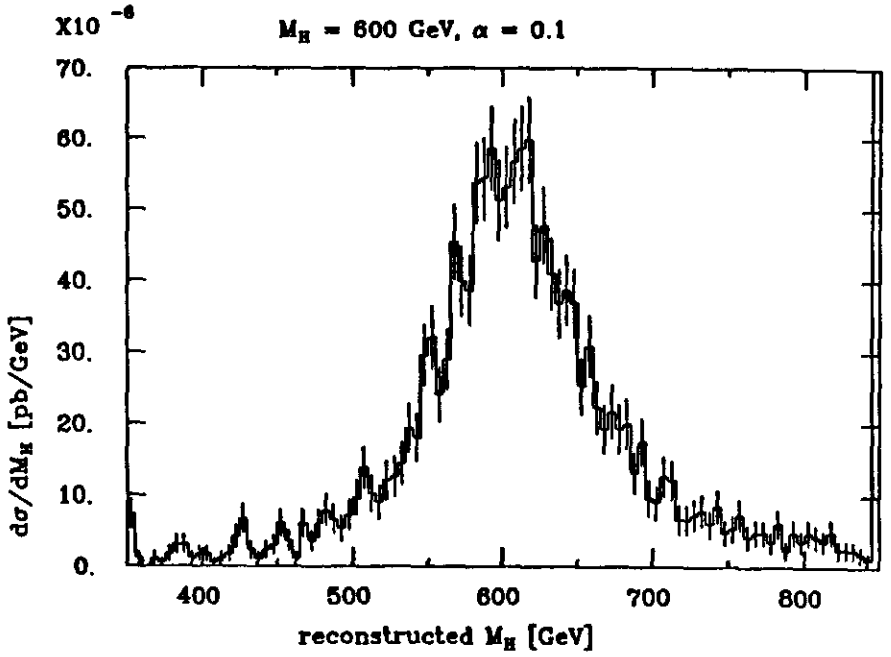
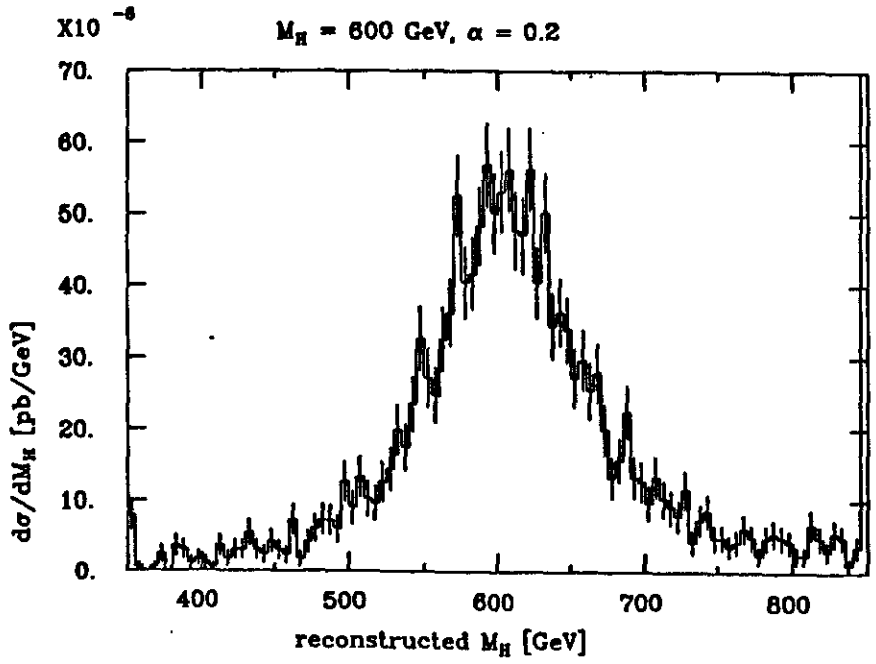
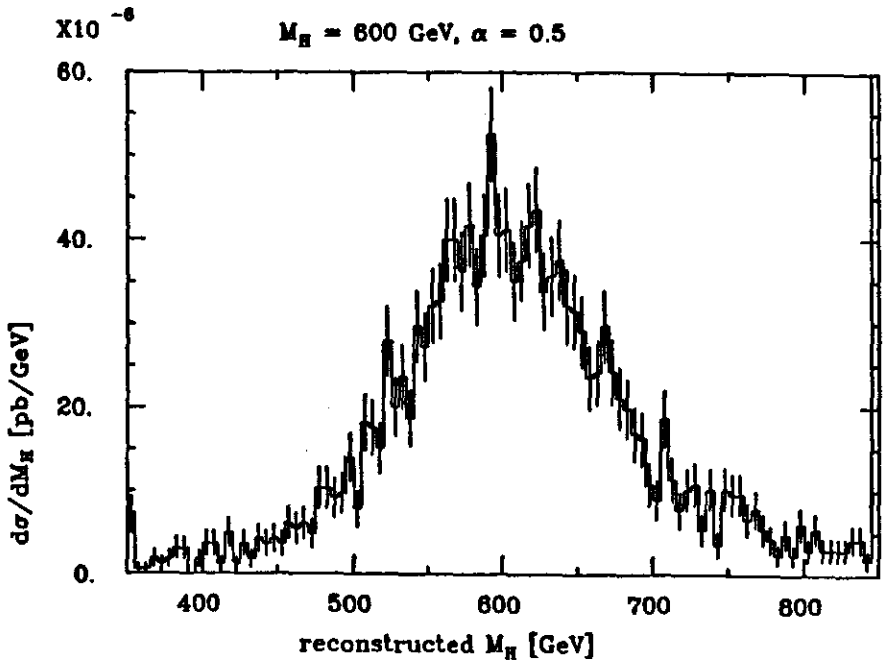

X10 -3
M_H = 400 GeV, α = 0.05
1.0
.8
.6
.4
.2
.0
dσ/dM_H [pb/GeV]
300
340
380
420
460
500
reconstructed M_H [GeV]
X10 -6
M_H = 400 GeV, α = 0.1
800.
600.
400.
200.
0.
dσ/dM_H [pb/GeV]
300
340
380
420
460
500
reconstructed M_H [GeV]
X10 -6
M_H = 400 GeV, α = 0.2
800.
600.
400.
200.
0.
dσ/dM_H [pb/GeV]
300
340
380
420
460
500
reconstructed M_H [GeV]
X10 -6
M_H = 400 GeV, α = 0.5
600.
400.
200.
0.
dσ/dM_H [pb/GeV]
300
340
380
420
460
500
reconstructed M_H [GeV]

Figure 19


X10 -6
M_H = 600 GeV, α = 0.05
80.
60.
40.
20.
0.
400
500
600
700
800
reconstructed M_H [GeV]
$d\sigma/dM_H$ [pb/GeV]


X10 -6
M_H = 600 GeV, α = 0.1
70.
60.
50.
40.
30.
20.
10.
0.
400
500
600
700
800
reconstructed M_H [GeV]
$d\sigma/dM_H$ [pb/GeV]


X10 -6
M_H = 600 GeV, α = 0.2
70.
60.
50.
40.
30.
20.
10.
0.
400
500
600
700
800
reconstructed M_H [GeV]
$d\sigma/dM_H$ [pb/GeV]


X10 -6
M_H = 600 GeV, α = 0.5
60.
40.
20.
0.
400
500
600
700
800
reconstructed M_H [GeV]
$d\sigma/dM_H$ [pb/GeV]

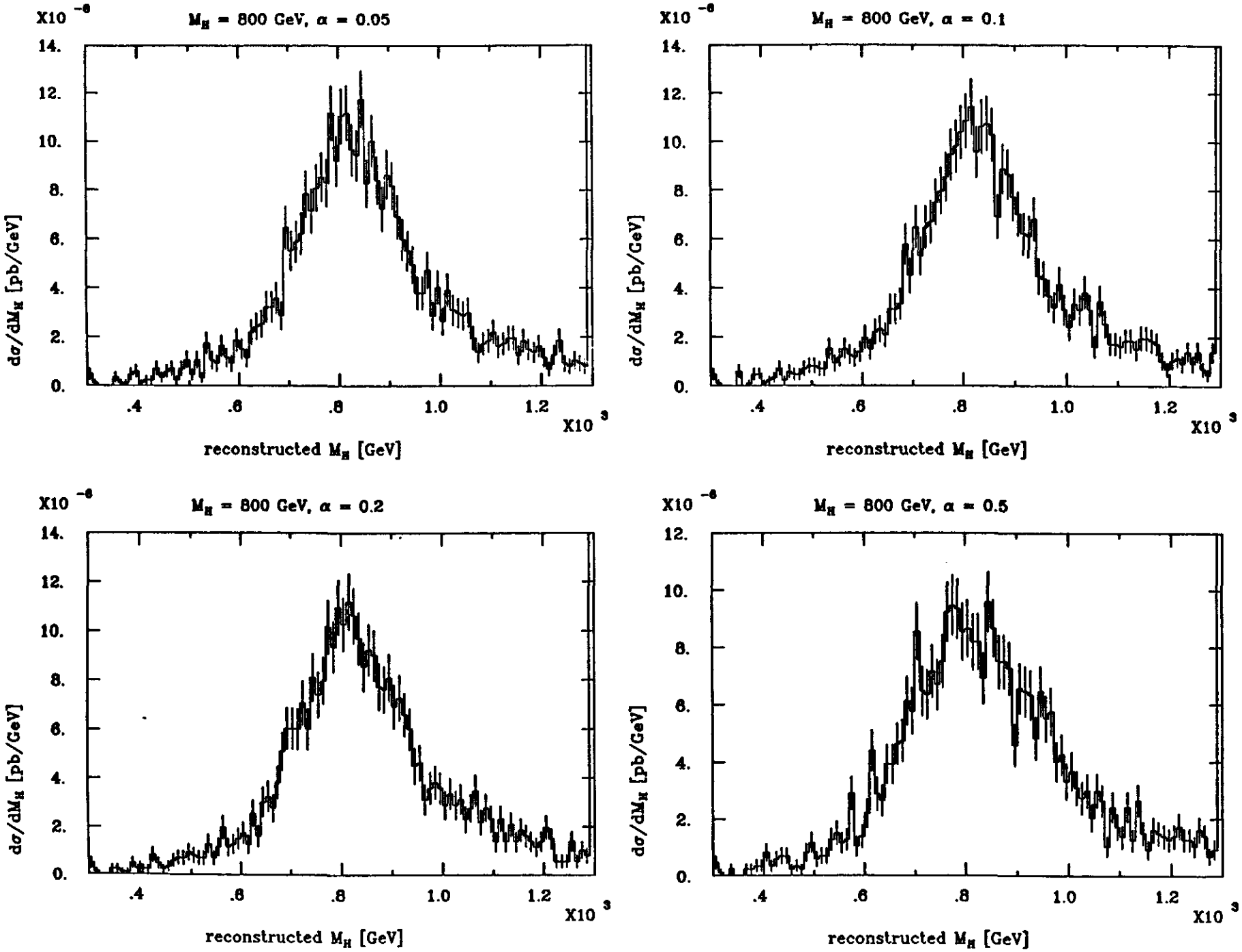

M_H = 800 GeV, α = 0.05
M_H = 800 GeV, α = 0.1
M_H = 800 GeV, α = 0.2
M_H = 800 GeV, α = 0.5
X10 $^{-6}$
$d\sigma/dM_H$ [pb/GeV]
reconstructed M_H [GeV]
X10 ^{3}

Figure 21