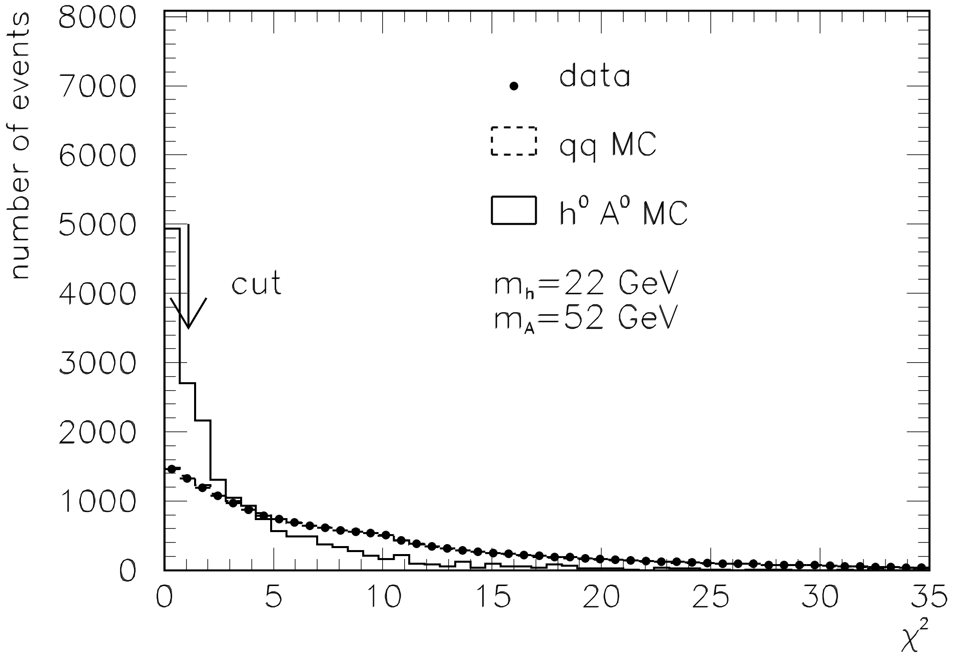
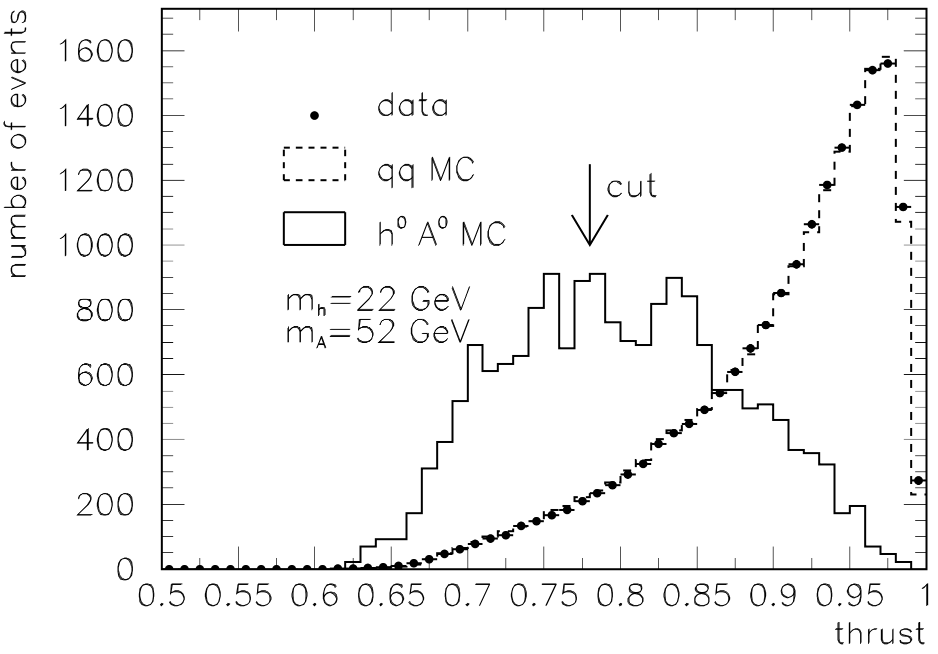
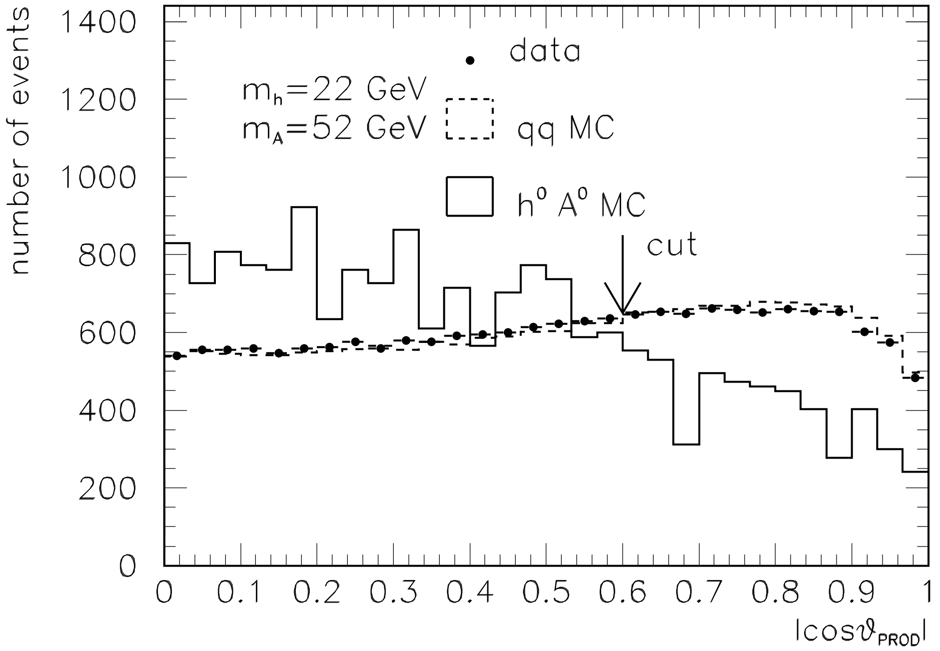
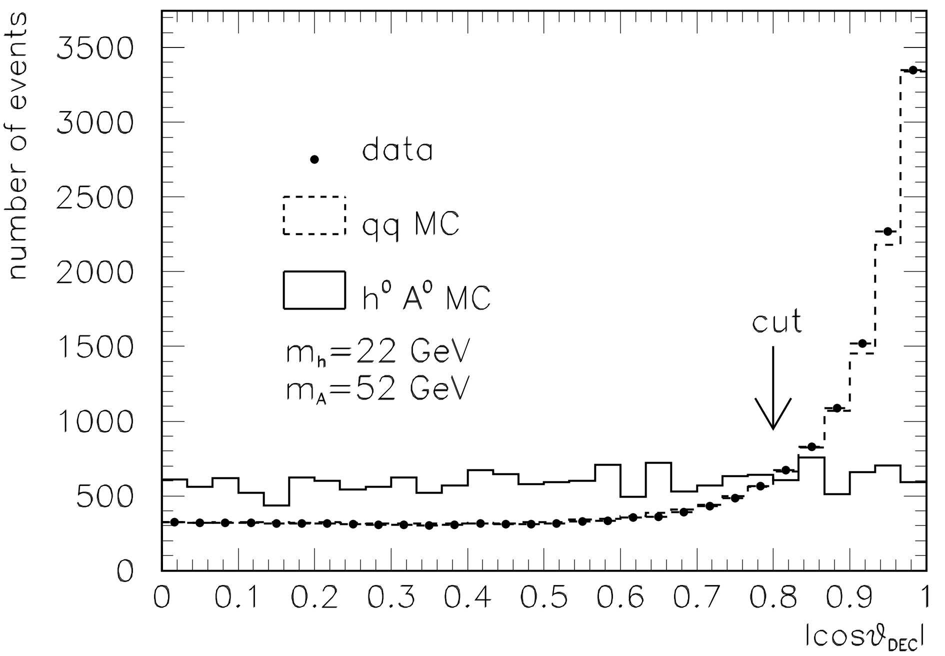
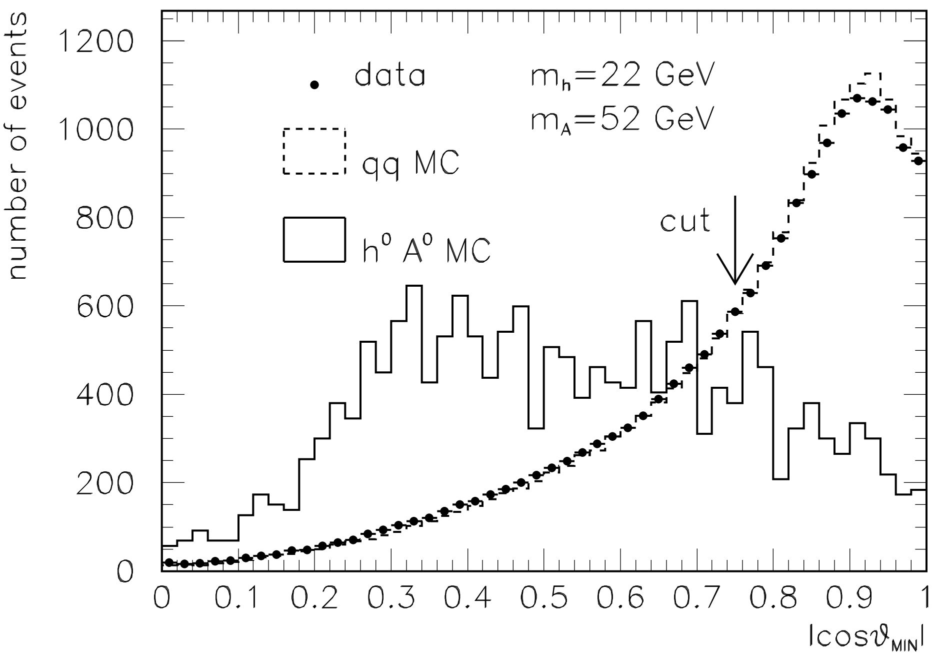

number of events
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
χ^2
data
qq MC
h^0 A^0 MC
cut
m_h=22 GeV
m_A=52 GeV

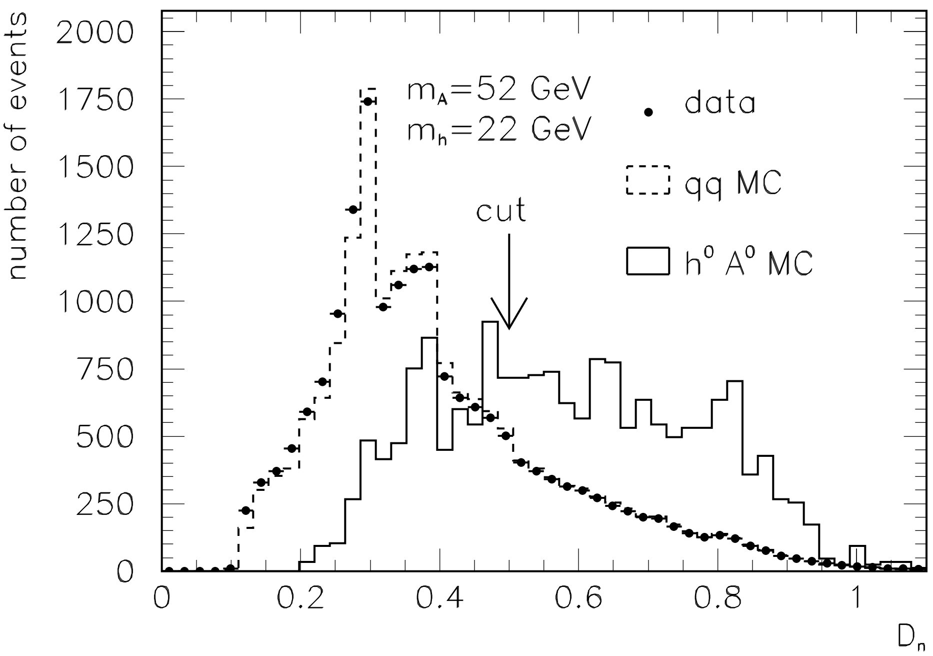

number of events
1600
1400
1200
1000
800
600
400
200
0
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
thrust
data
qq MC
h⁰ A⁰ MC
cut
m_h=22 GeV
m_A=52 GeV

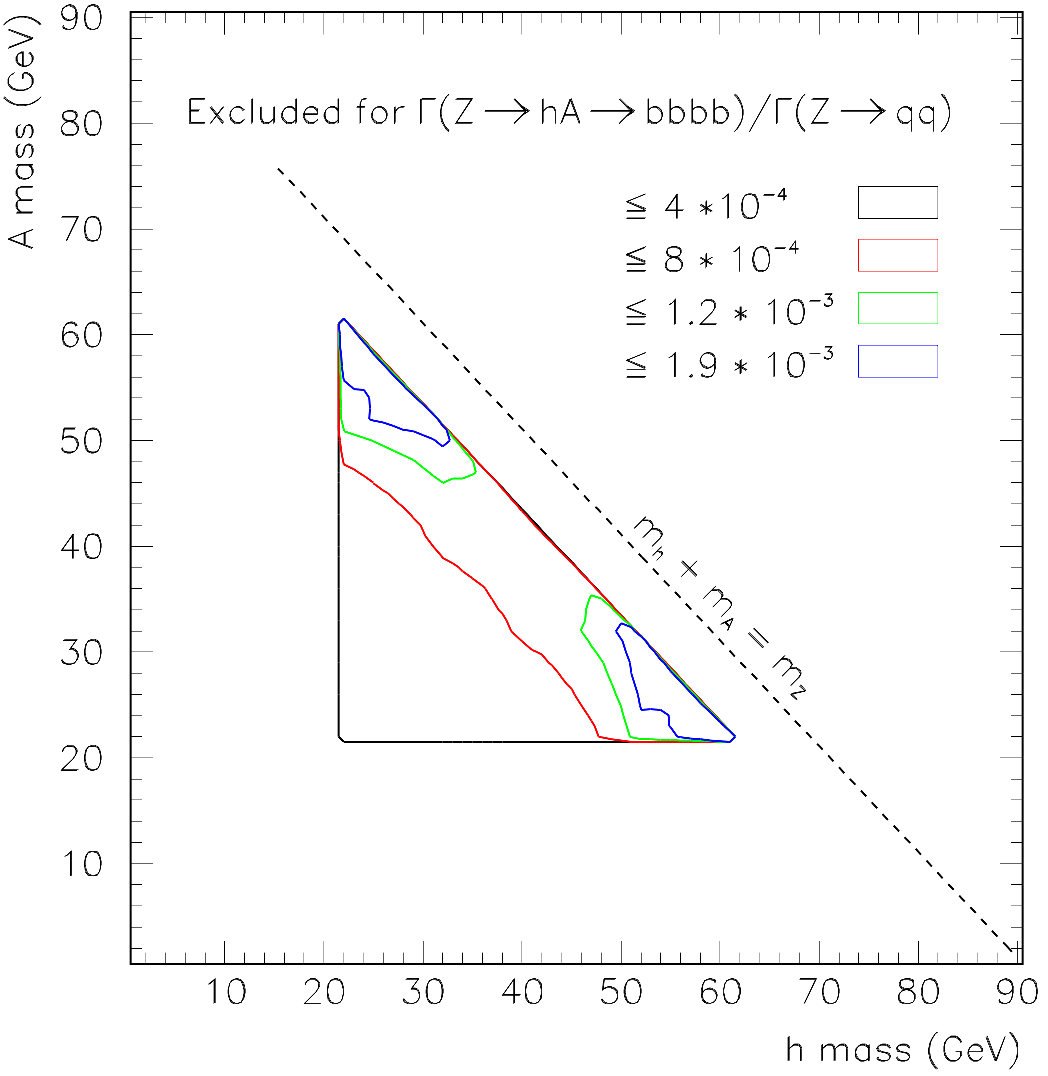

number of events
1400
1200
1000
800
600
400
200
0
data
m_h=22 GeV
m_A=52 GeV
qq MC
h^0 A^0 MC
cut
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
$|\cos\vartheta_{PROD}|$

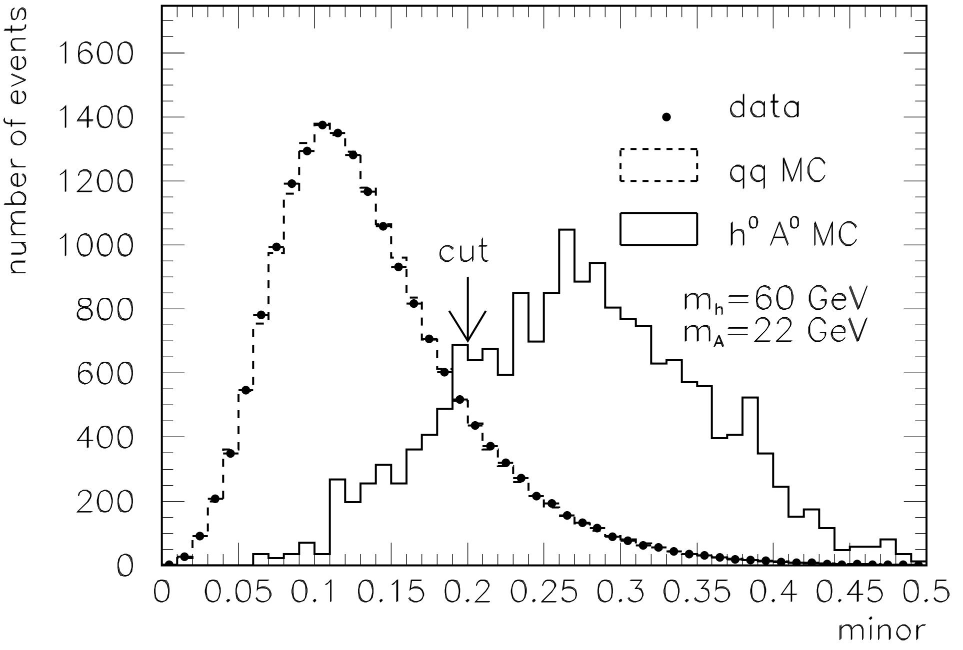


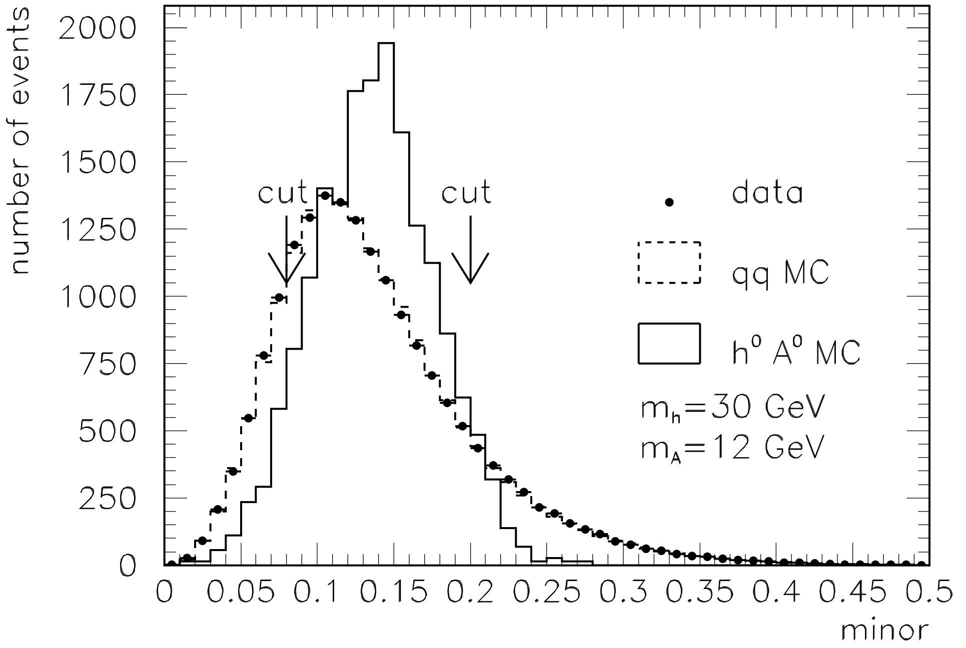
number of events
0
500
1000
1500
2000
2500
3000
3500
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
|cosϑ_DEC|
● data
qq MC
h⁰ A⁰ MC
m_h=22 GeV
m_A=52 GeV
cut

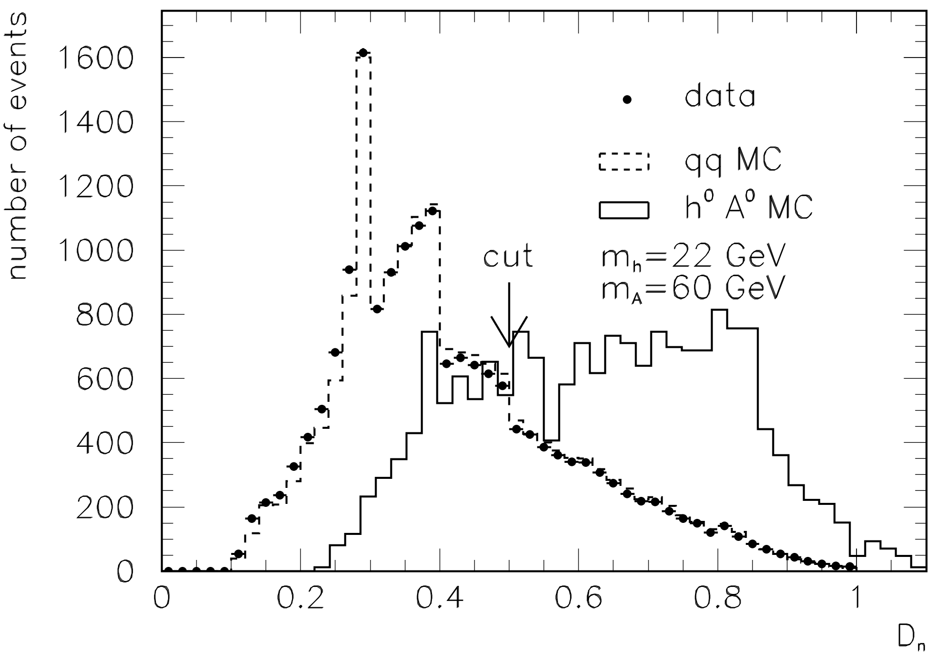

number of events
0
200
400
600
800
1000
1200
data
qq MC
h⁰ A⁰ MC
m_h=22 GeV
m_A=52 GeV
cut
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
|cosϑ_MIN|

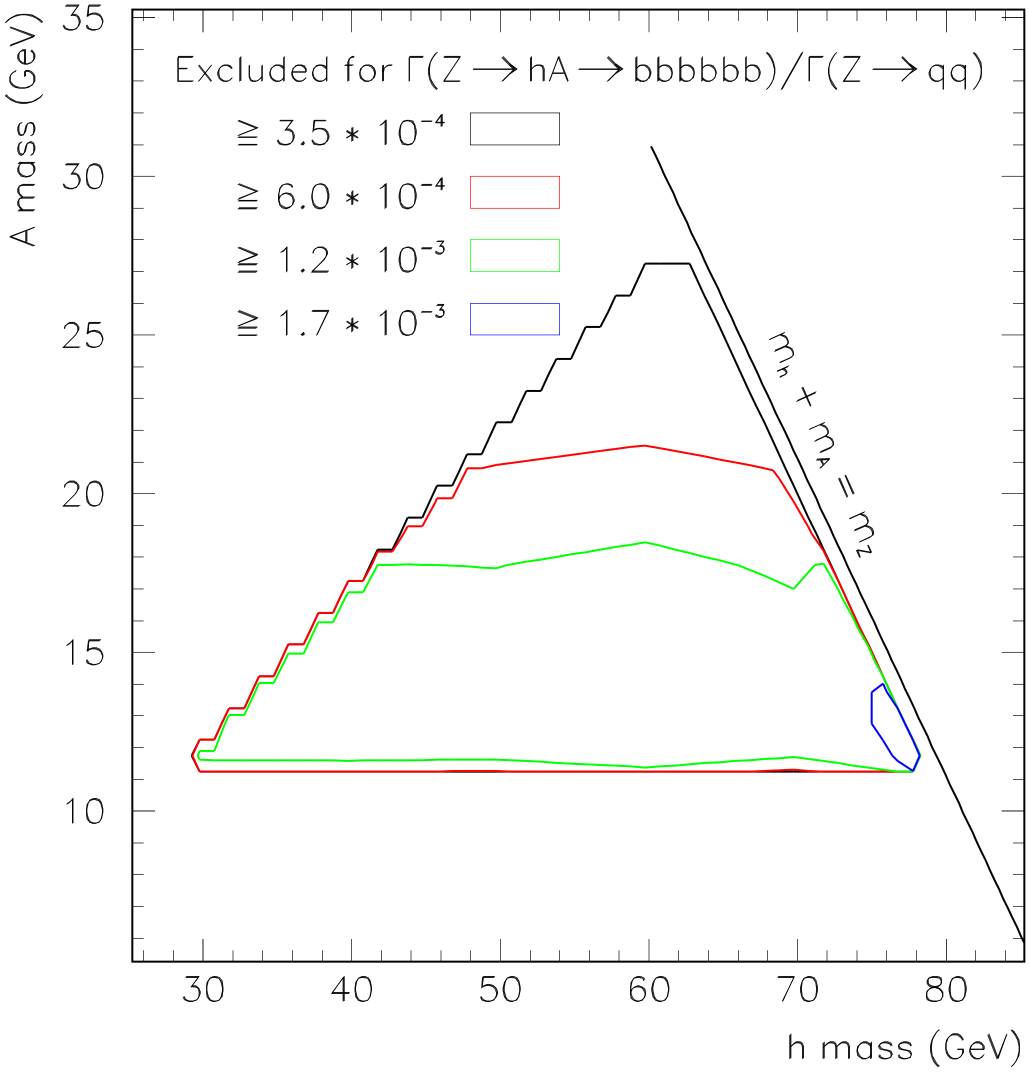

number of events
2000
1750
1500
1250
1000
750
500
250
0
0
0.2
0.4
0.6
0.8
1
D_n
m_A=52 GeV
m_h=22 GeV
● data
qq MC
h^0 A^0 MC
cut


Excluded for $\Gamma(Z \to hA \to bbbb)/\Gamma(Z \to qq)$
$\leqq 4 * 10^{-4}$
$\leqq 8 * 10^{-4}$
$\leqq 1.2 * 10^{-3}$
$\leqq 1.9 * 10^{-3}$
$m_h + m_A = m_Z$
A mass (GeV)
h mass (GeV)
10
20
30
40
50
60
70
80
90

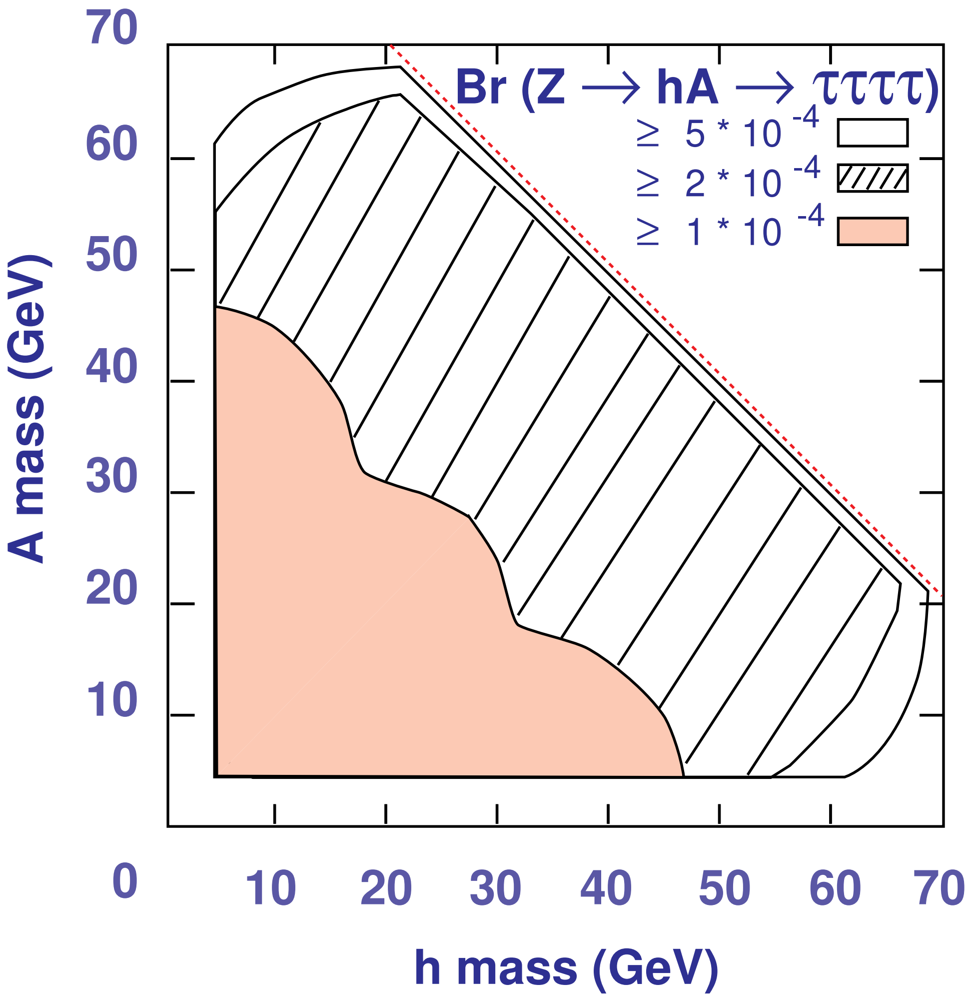

number of events
1600
1400
1200
1000
800
600
400
200
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
minor
cut
data
qq MC
h^0 A^0 MC
m_h=60 GeV
m_A=22 GeV

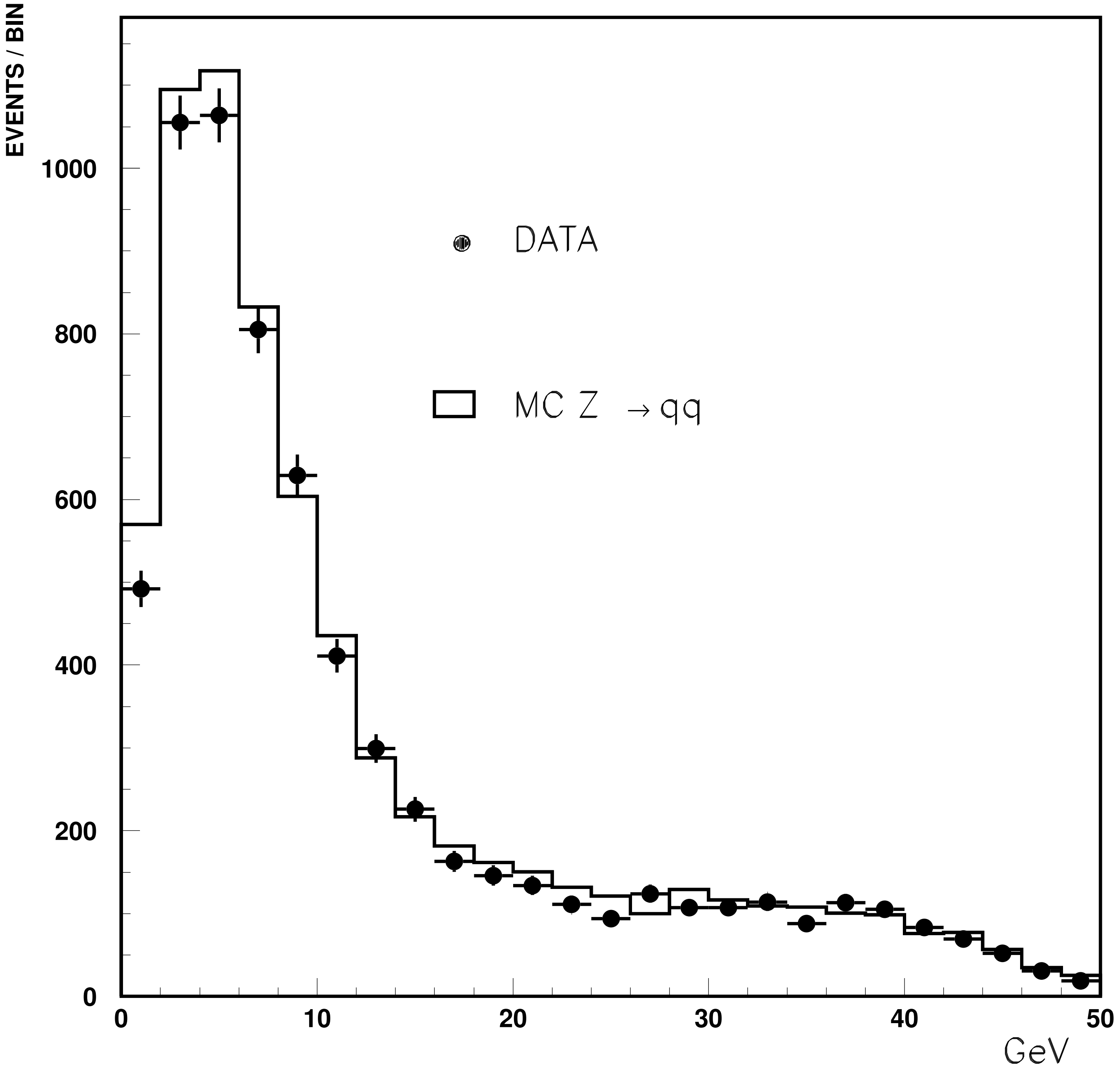

number of events
2000
1750
1500
1250
1000
750
500
250
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
minor
cut
cut
data
qq MC
h⁰ A⁰ MC
m_h=30 GeV
m_A=12 GeV

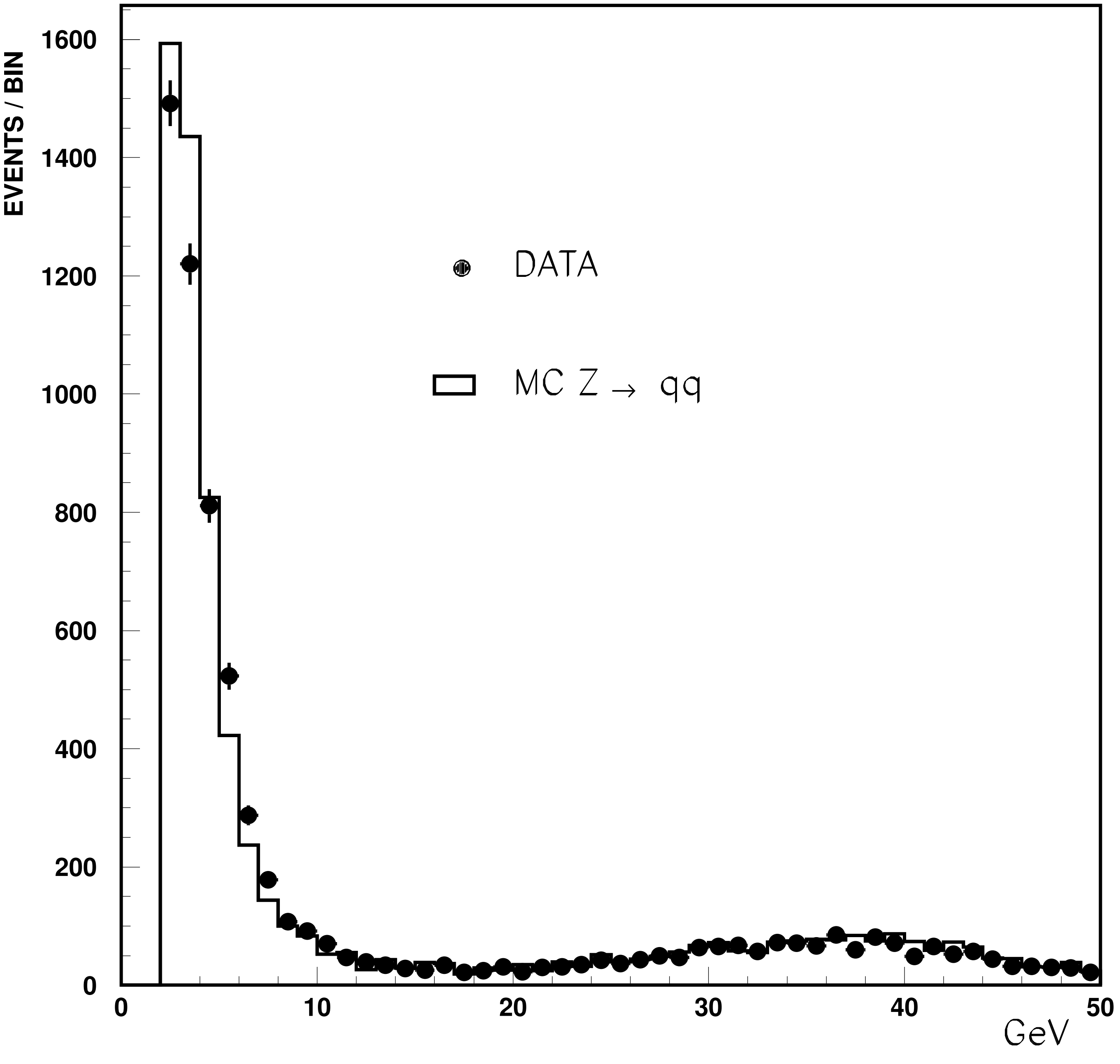

number of events
1600
1400
1200
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1
D_n
● data
qq MC
h^0 A^0 MC
cut
m_h=22 GeV
m_A=60 GeV

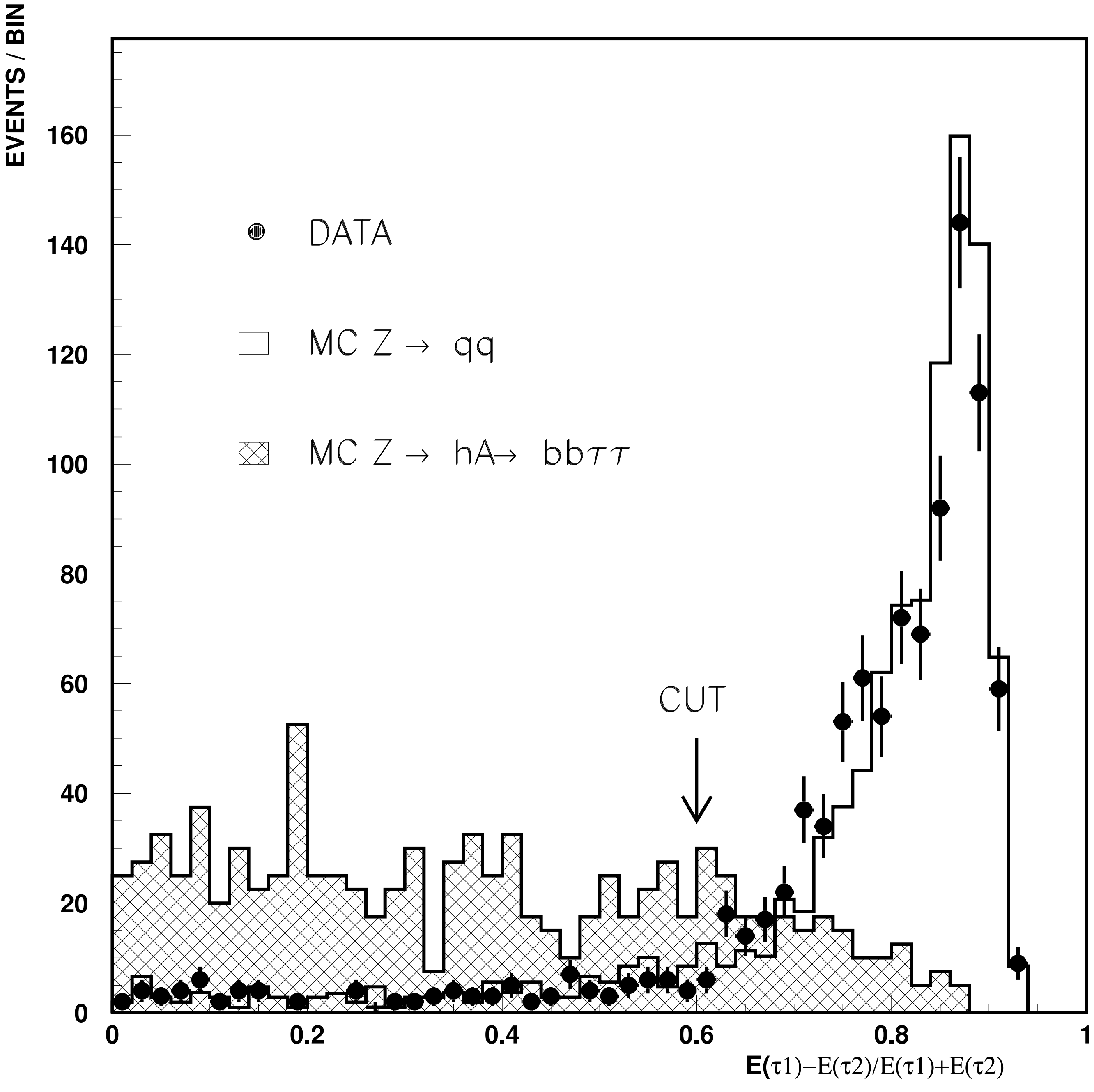


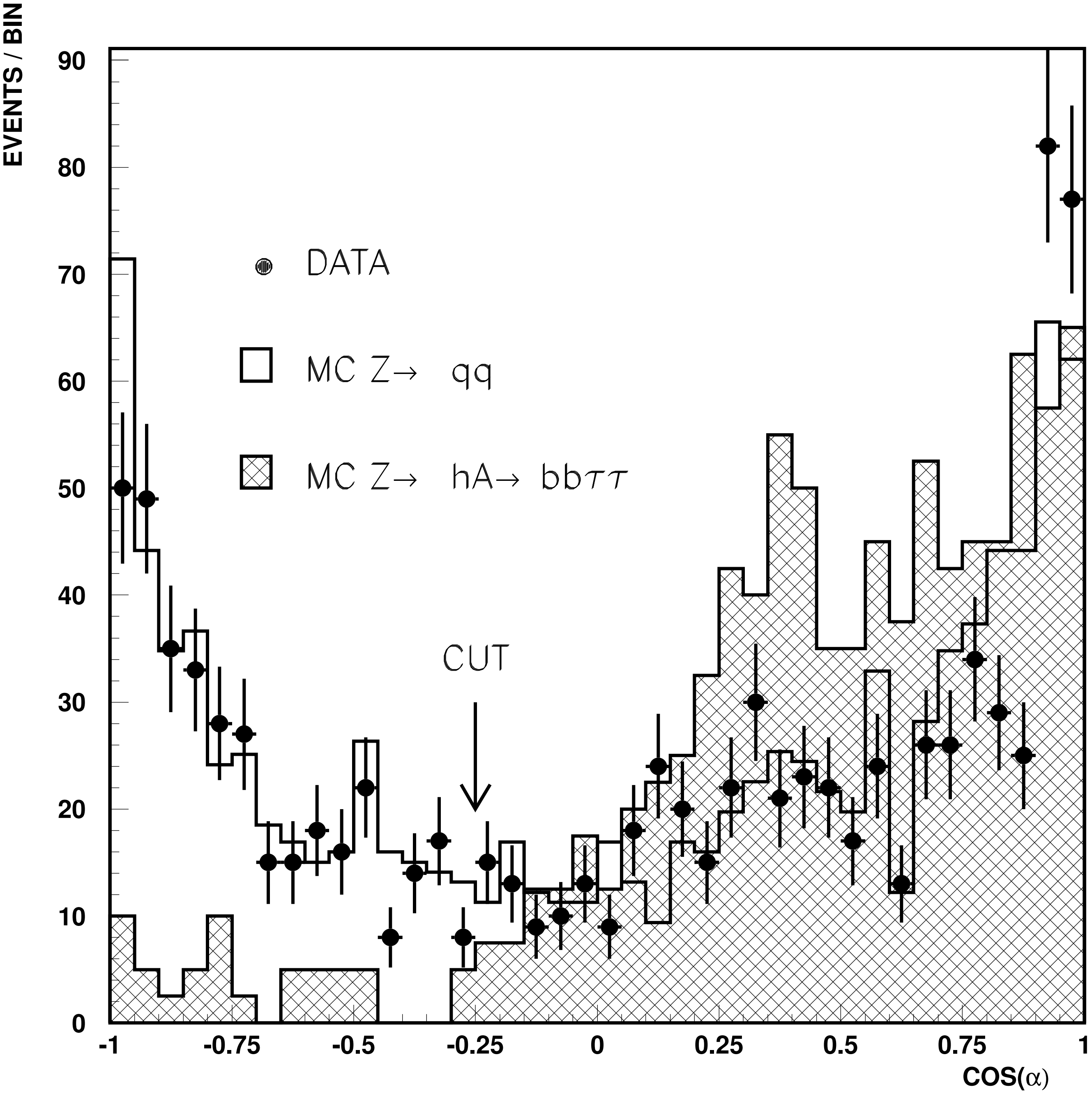
Excluded for $\Gamma(Z \rightarrow hA \rightarrow bbbbbb)/\Gamma(Z \rightarrow qq)$
$\geqq 3.5 * 10^{-4}$
$\geqq 6.0 * 10^{-4}$
$\geqq 1.2 * 10^{-3}$
$\geqq 1.7 * 10^{-3}$
$m_h + m_A = m_Z$
A mass (GeV)
35
30
25
20
15
10
30
40
50
60
70
80
h mass (GeV)

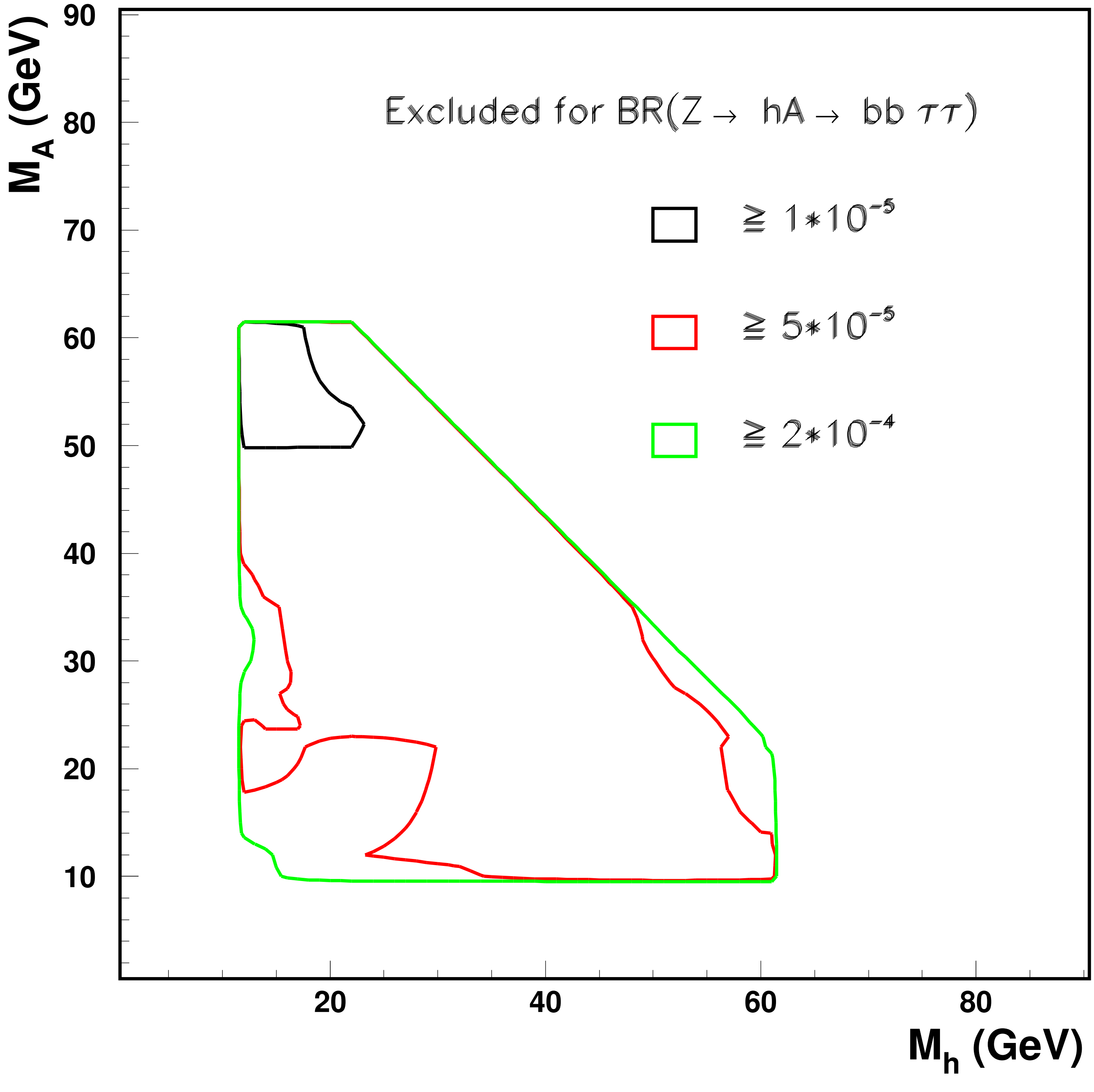

Br (Z ⟶ hA ⟶ ττττ)
≥ 5 * 10 -4
≥ 2 * 10 -4
≥ 1 * 10 -4
A mass (GeV)
h mass (GeV)
0
10
20
30
40
50
60
70

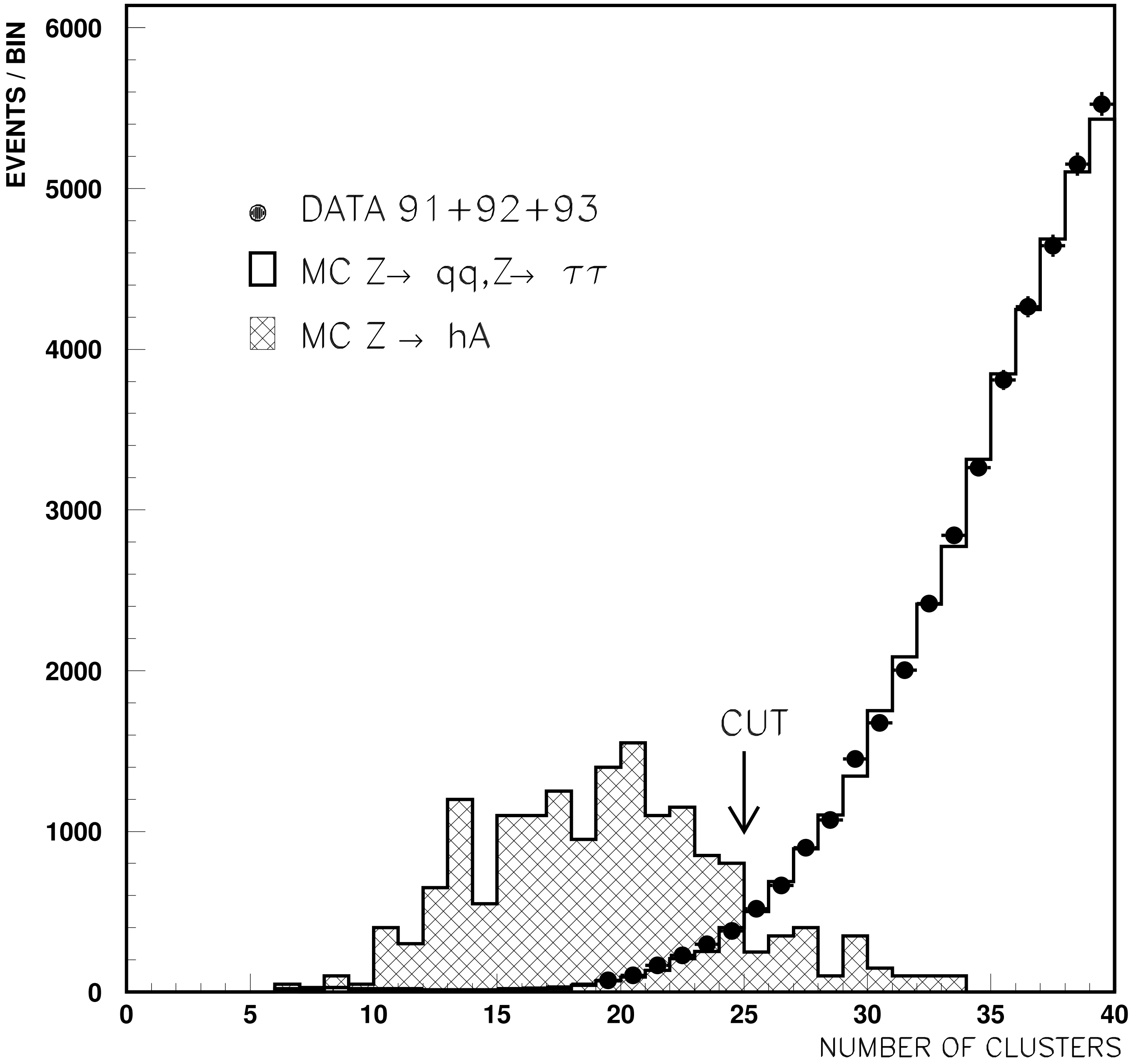

EVENTS / BIN
1000
800
600
400
200
0
0
10
20
30
40
50
GeV
DATA
MC Z → qq

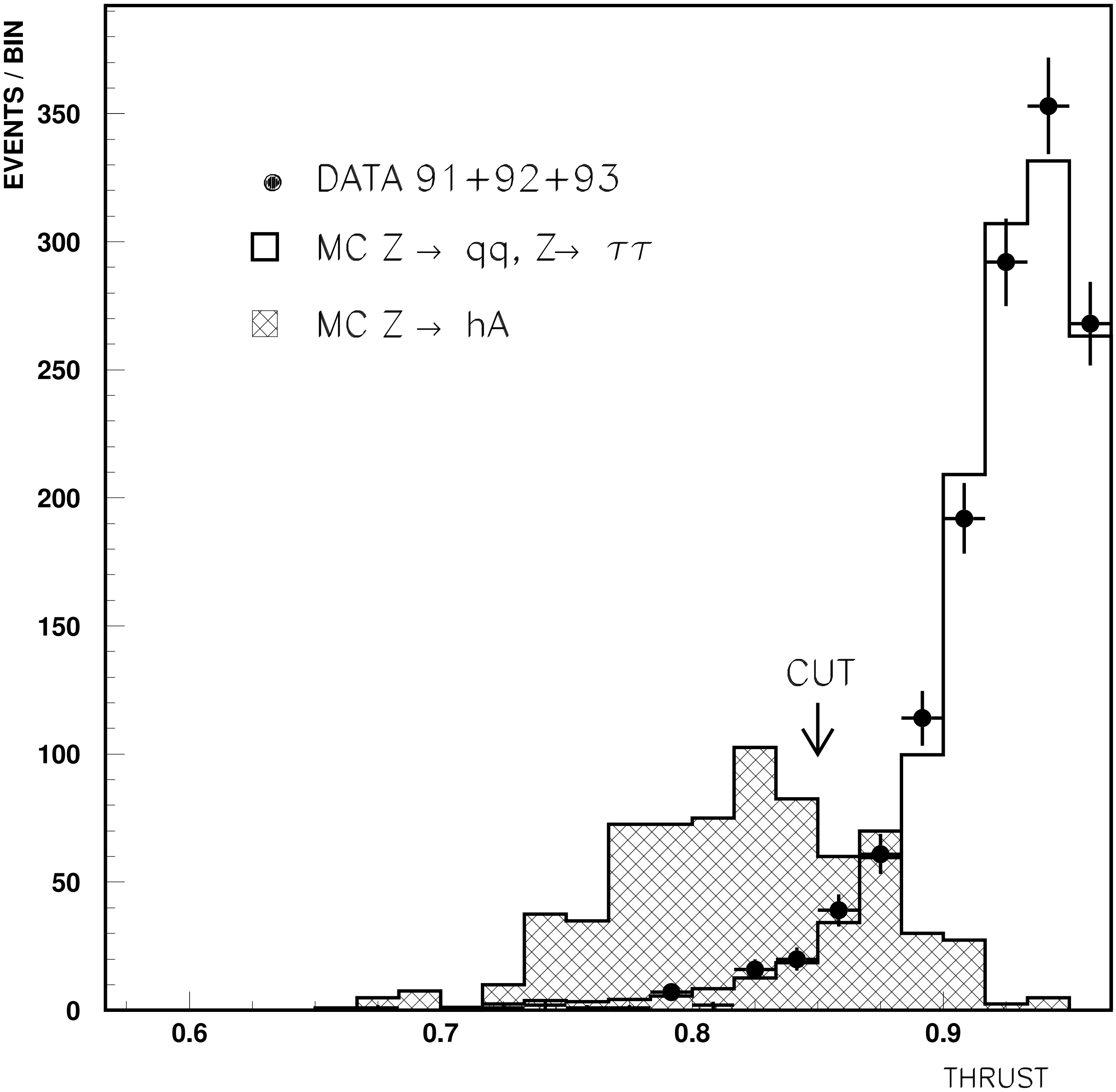

EVENTS / BIN
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
GeV
DATA
MC Z → qq

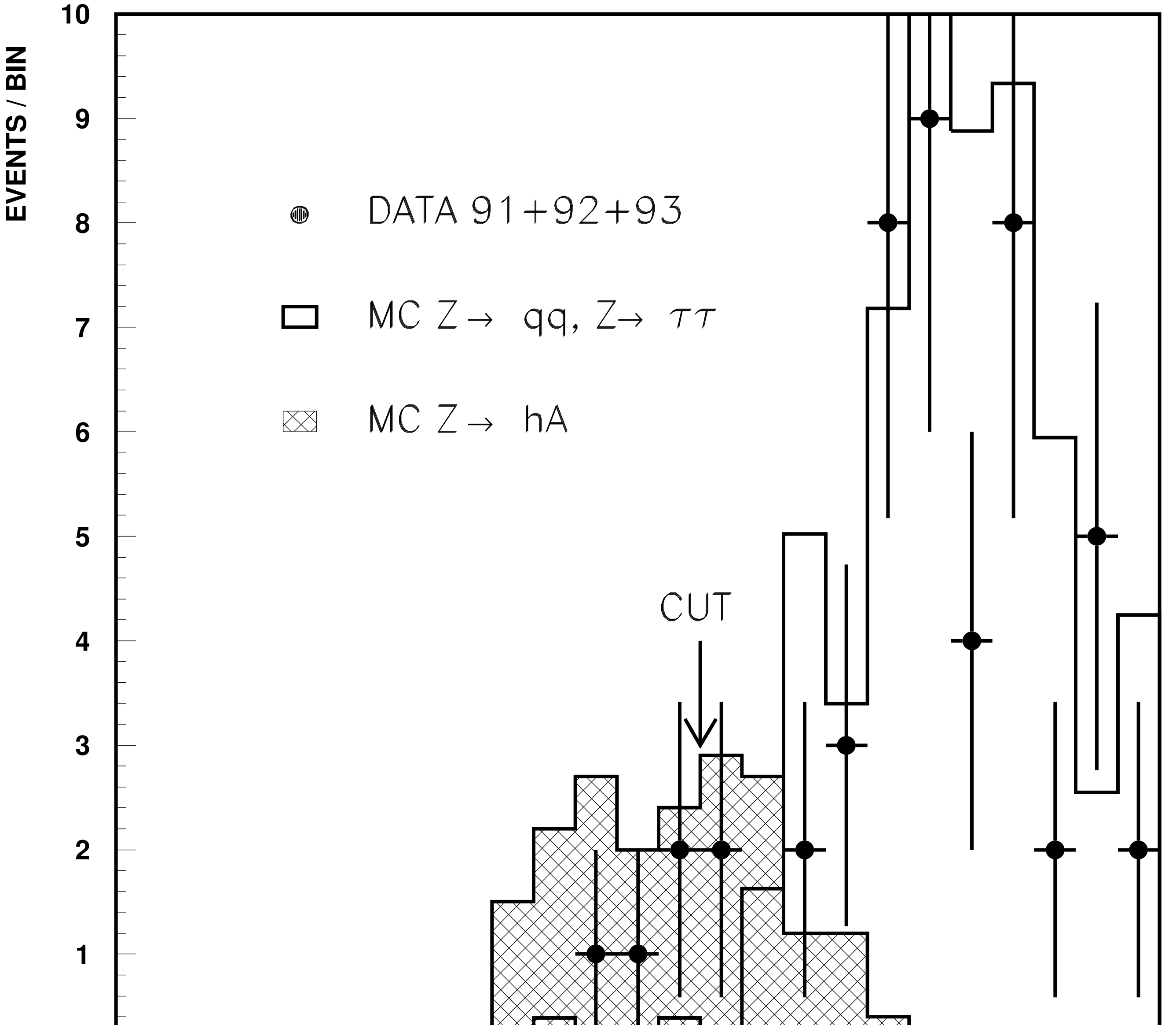

EVENTS / BIN
0
20
40
60
80
100
120
140
160
DATA
MC Z → qq
MC Z → hA→ bbττ
CUT
0
0.2
0.4
0.6
0.8
1
E(τ1)−E(τ2)/E(τ1)+E(τ2)

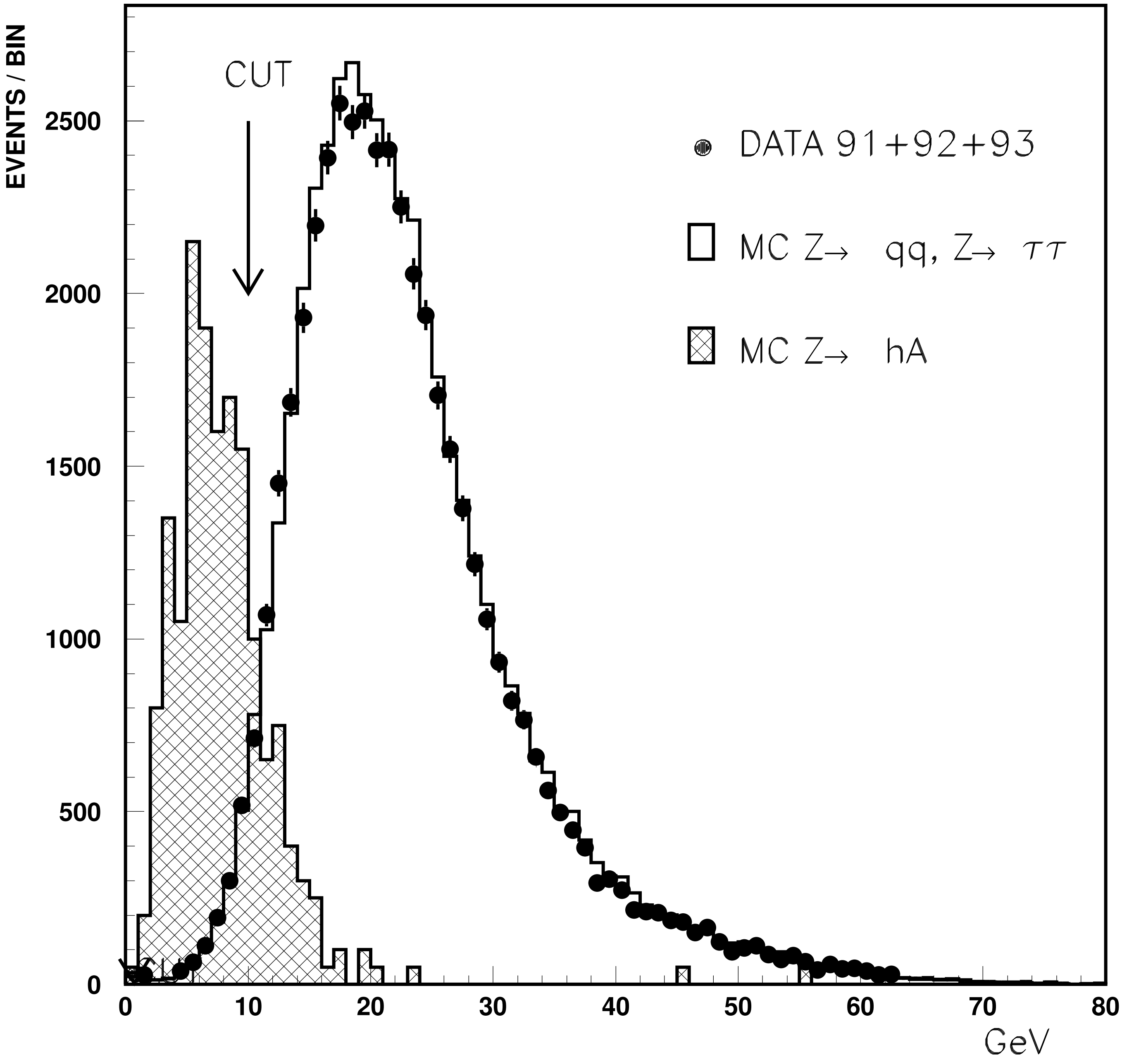

EVENTS / BIN
90
80
70
60
50
40
30
20
10
0
● DATA
MC Z→ qq
MC Z→ hA→ bb$\tau\tau$
CUT
-1
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
COS(α)

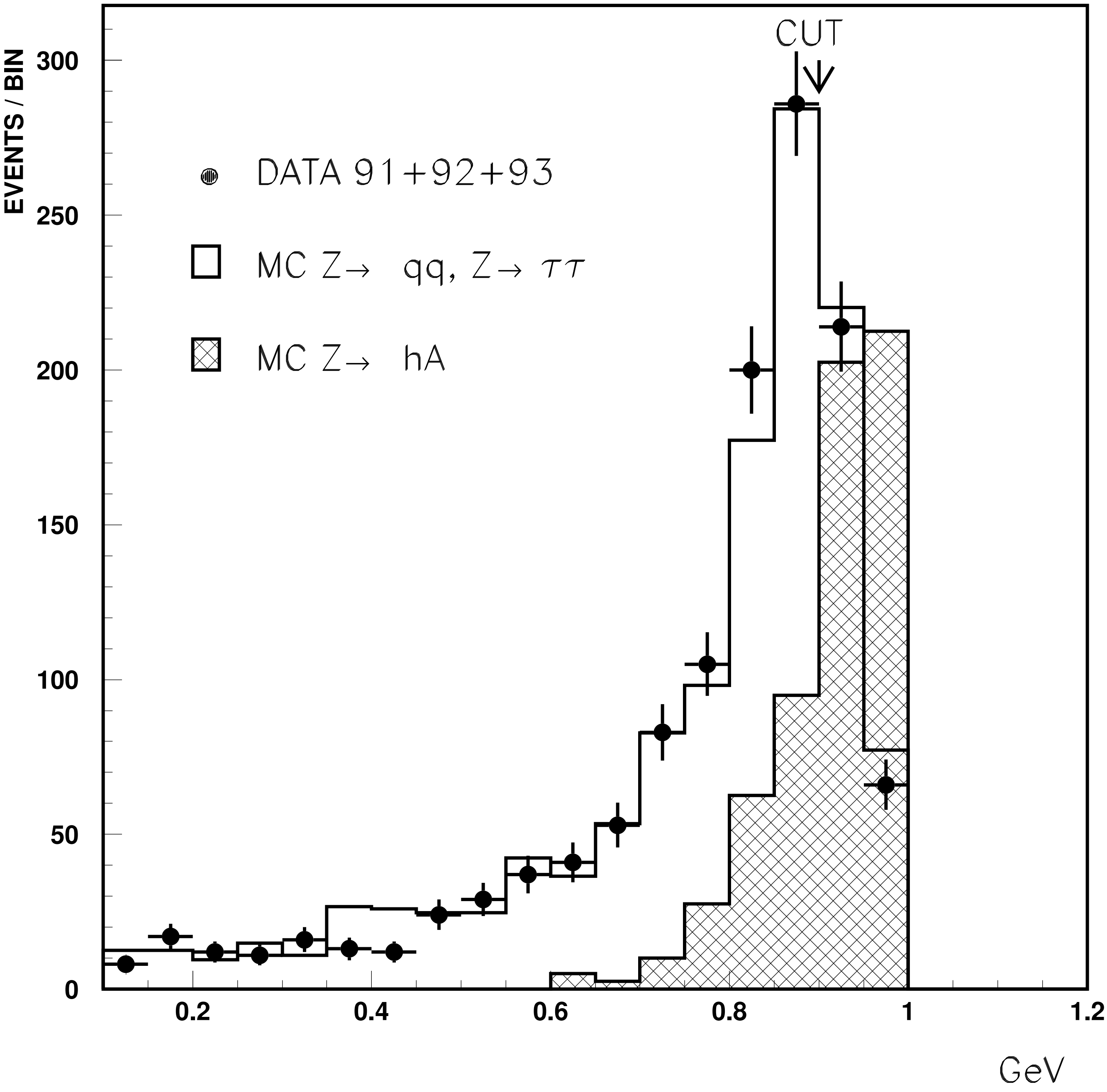

Excluded for BR(Z → hA → bb ττ)
≧ 1∗10⁻⁵
≧ 5∗10⁻⁵
≧ 2∗10⁻⁴
M_A (GeV)
M_h (GeV)
10
20
30
40
50
60
70
80
90
20
40
60
80

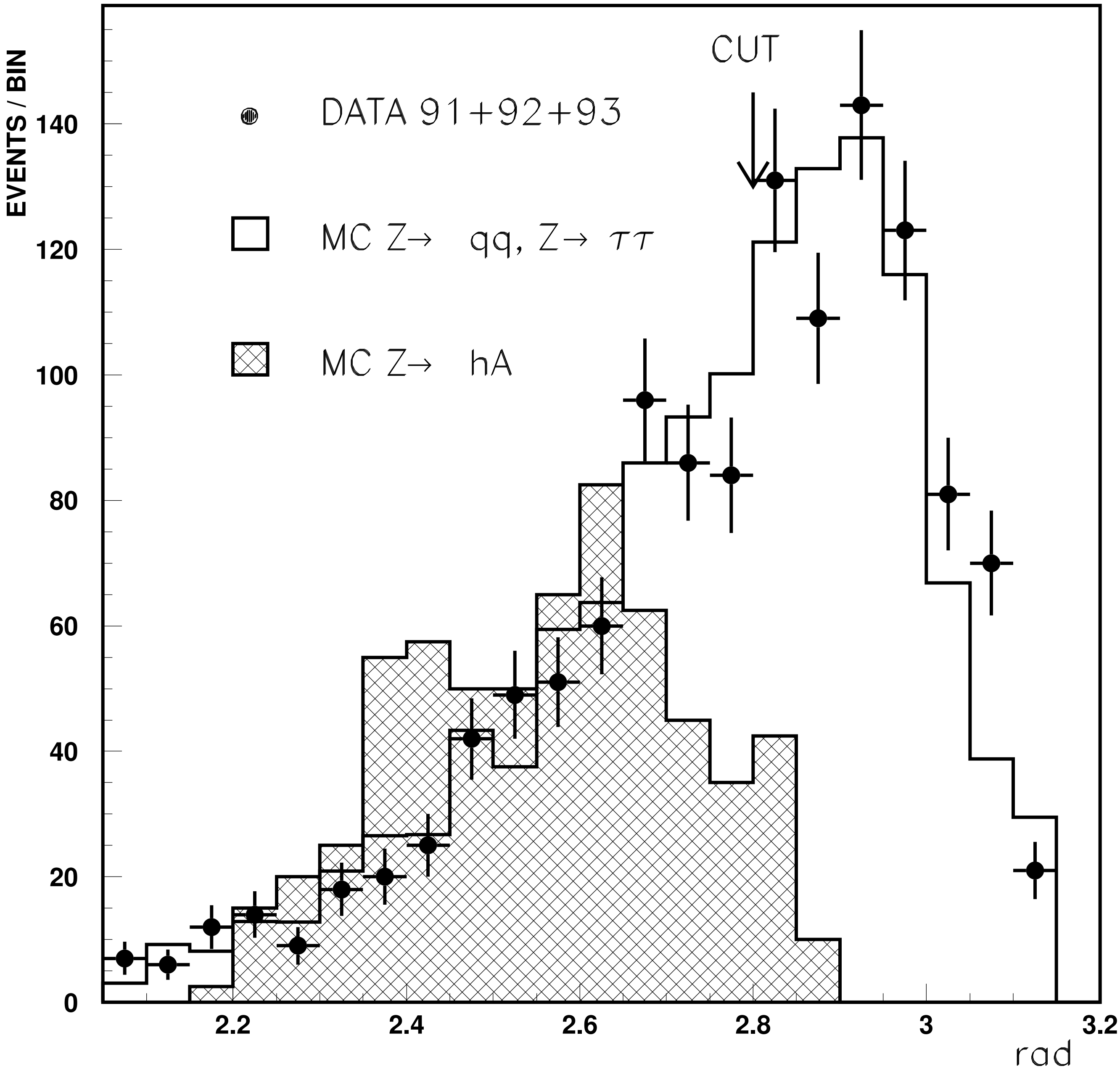

EVENTS / BIN
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
40
NUMBER OF CLUSTERS
DATA 91+92+93
MC Z→ qq,Z→ ττ
MC Z → hA
CUT

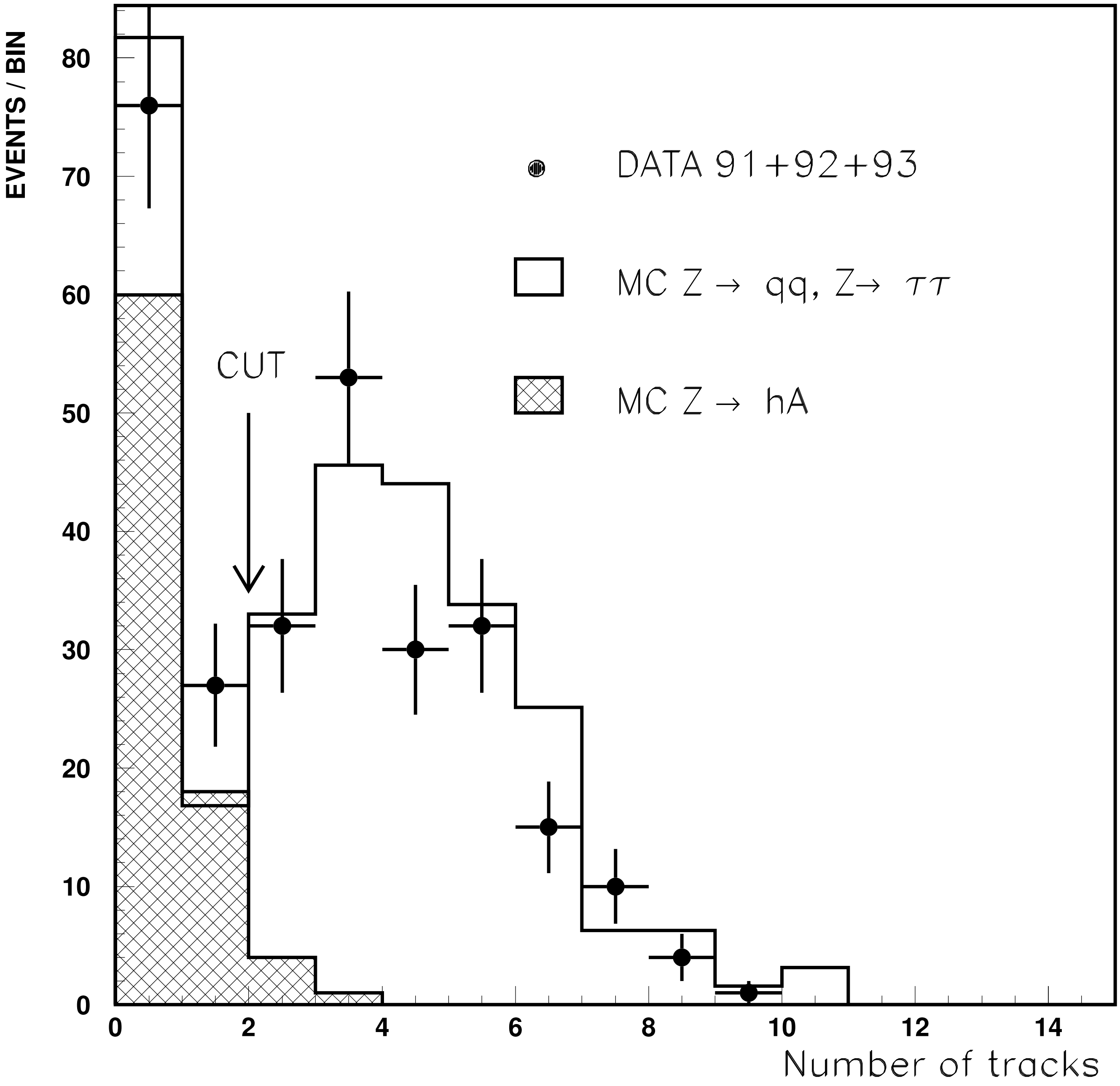

EVENTS / BIN
0
50
100
150
200
250
300
350
DATA 91+92+93
MC Z → qq, Z→ ττ
MC Z → hA
CUT
0.6
0.7
0.8
0.9
THRUST

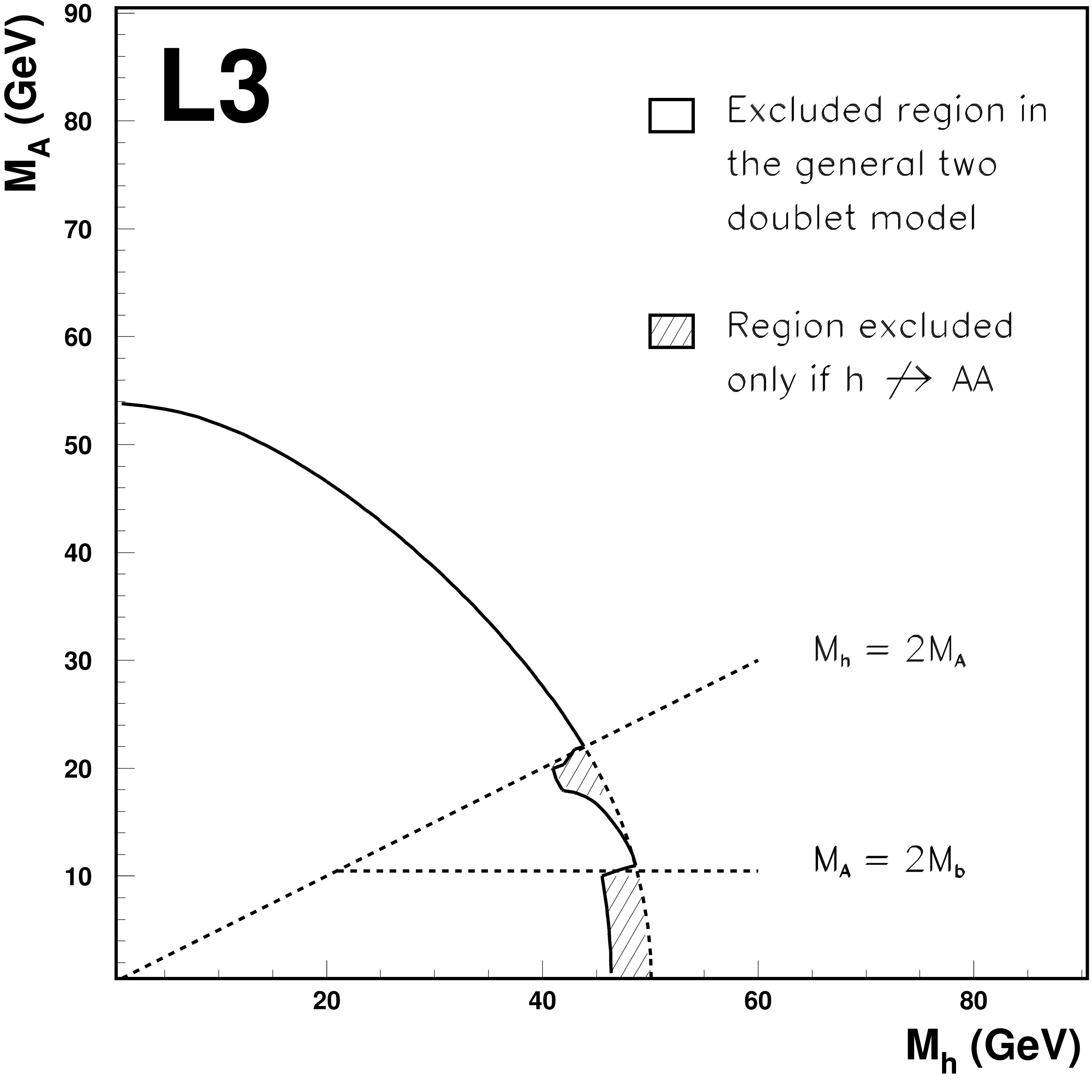

EVENTS / BIN
10
9
8
7
6
5
4
3
2
1
0
0
0.2
0.4
0.6
0.8
1
1.2
VISIBLE ENERGY / ENERGY C.M.
DATA 91+92+93
MC Z→ qq, Z→ ττ
MC Z→ hA
CUT

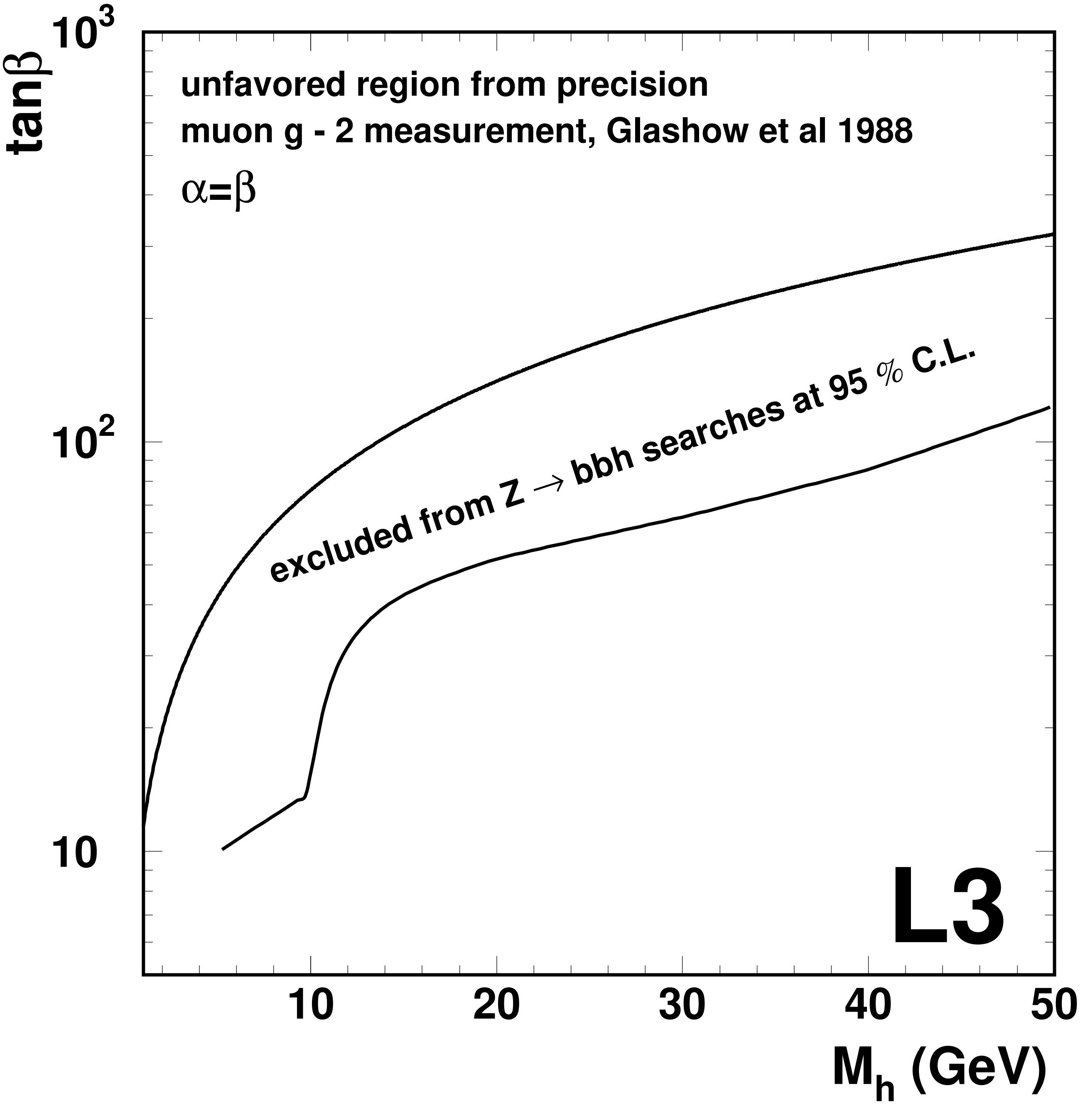

EVENTS / BIN
CUT
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
GeV
DATA 91+92+93
MC Z→ qq, Z→ ττ
MC Z→ hA


EVENTS / BIN
300
250
200
150
100
50
0
0.2
0.4
0.6
0.8
1
1.2
GeV
CUT
DATA 91+92+93
MC Z→ qq, Z→ ττ
MC Z→ hA

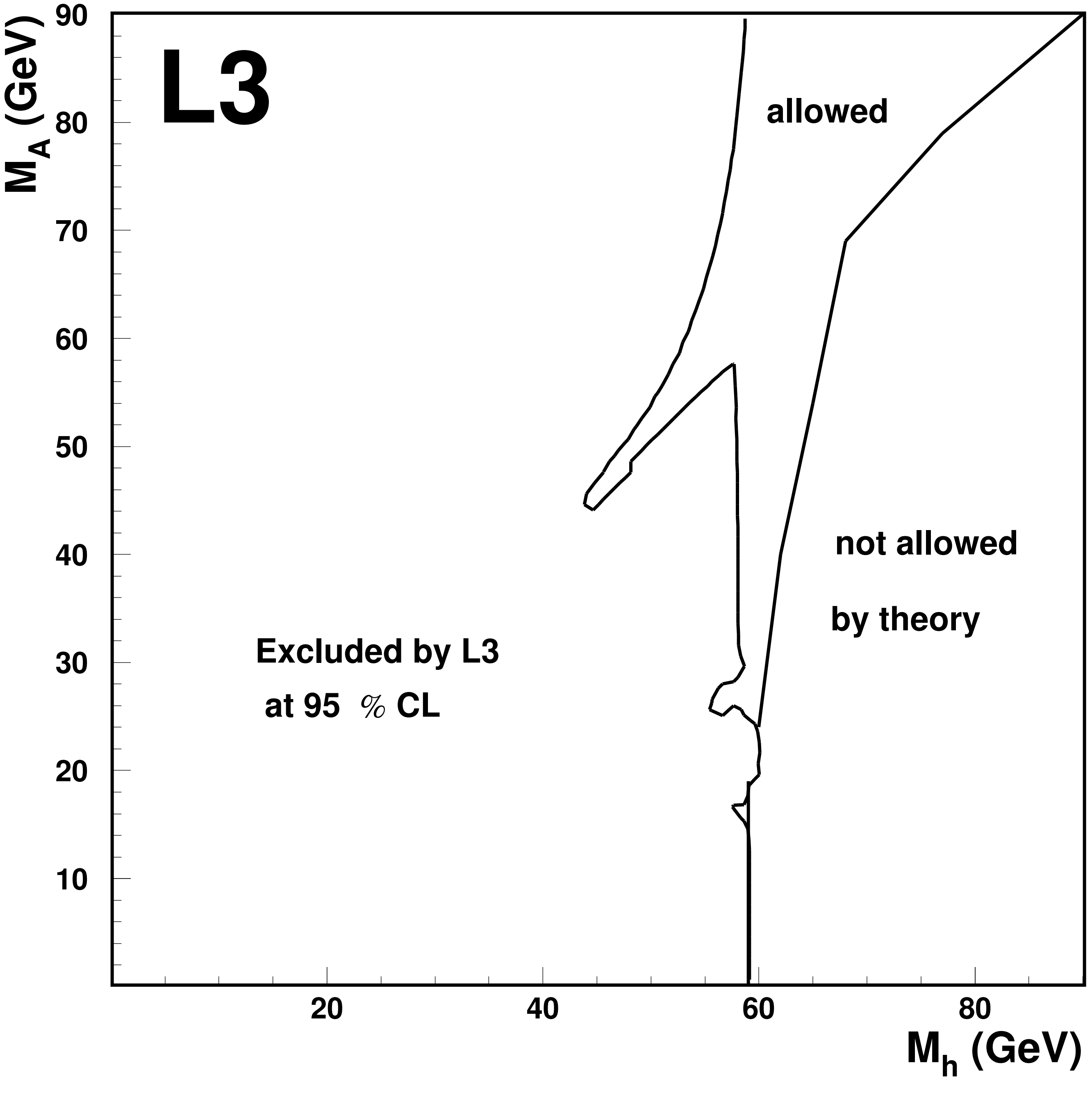

EVENTS / BIN
140
120
100
80
60
40
20
0
2.2
2.4
2.6
2.8
3
3.2
rad
CUT
DATA 91+92+93
MC Z→ qq, Z→ ττ
MC Z→ hA

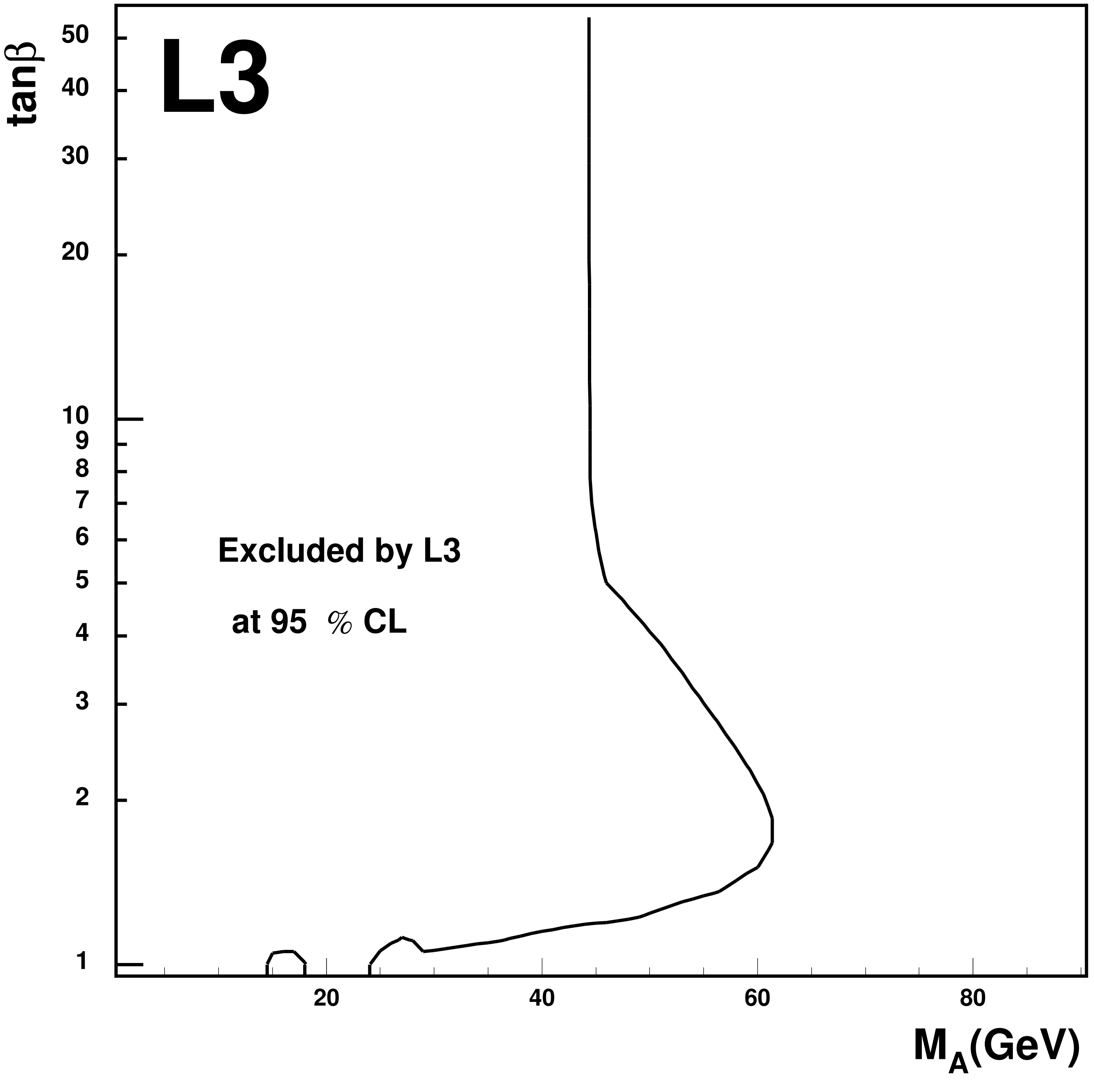

EVENTS / BIN
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
Number of tracks
DATA 91+92+93
MC Z → qq, Z→ ττ
MC Z → hA
CUT

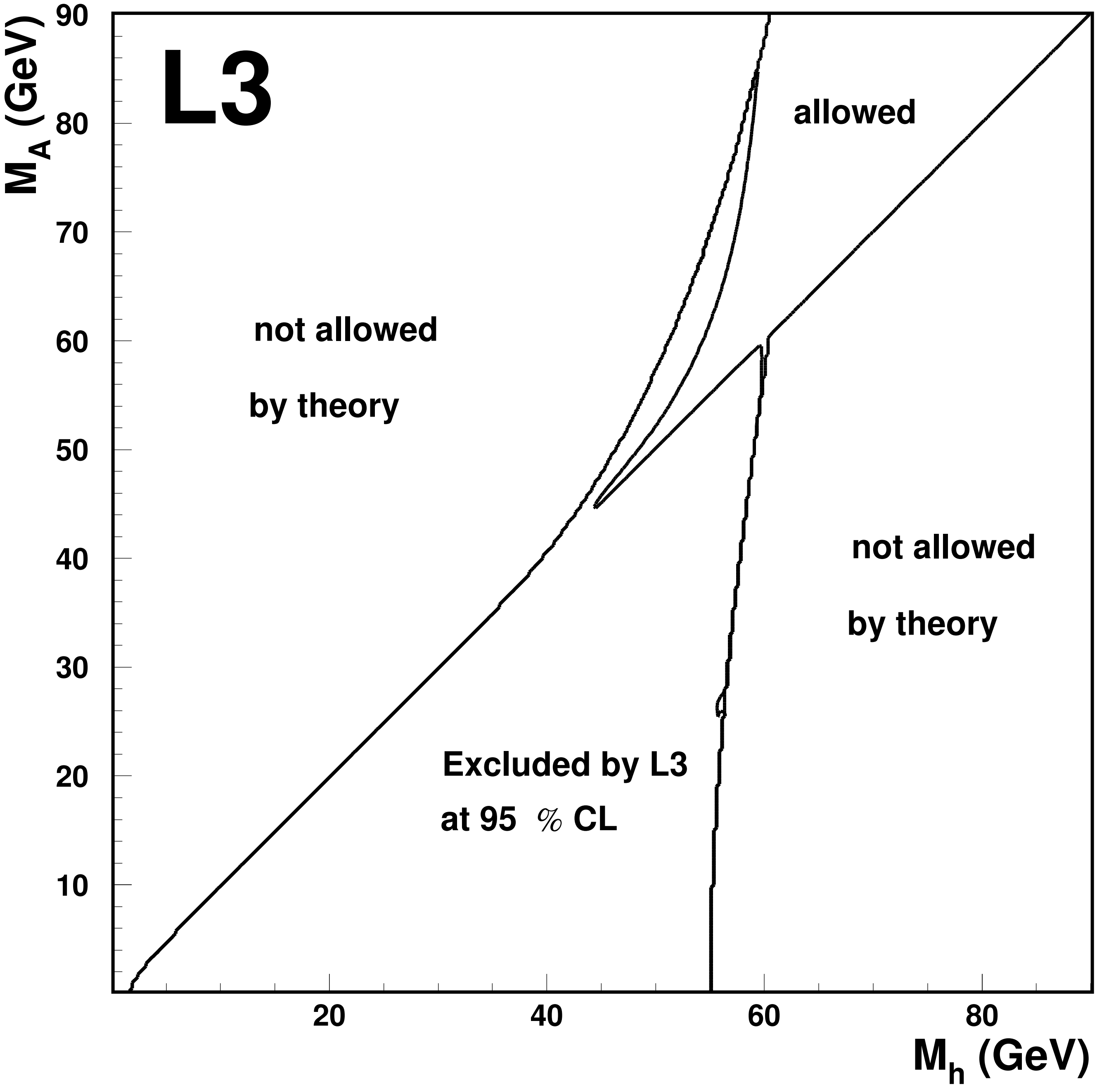

L3
Excluded region in the general two doublet model
Region excluded only if $h \not\to AA$
$M_h = 2M_A$
$M_A = 2M_b$
M_A (GeV)
M_h (GeV)
90
80
70
60
50
40
30
20
10
20
40
60
80

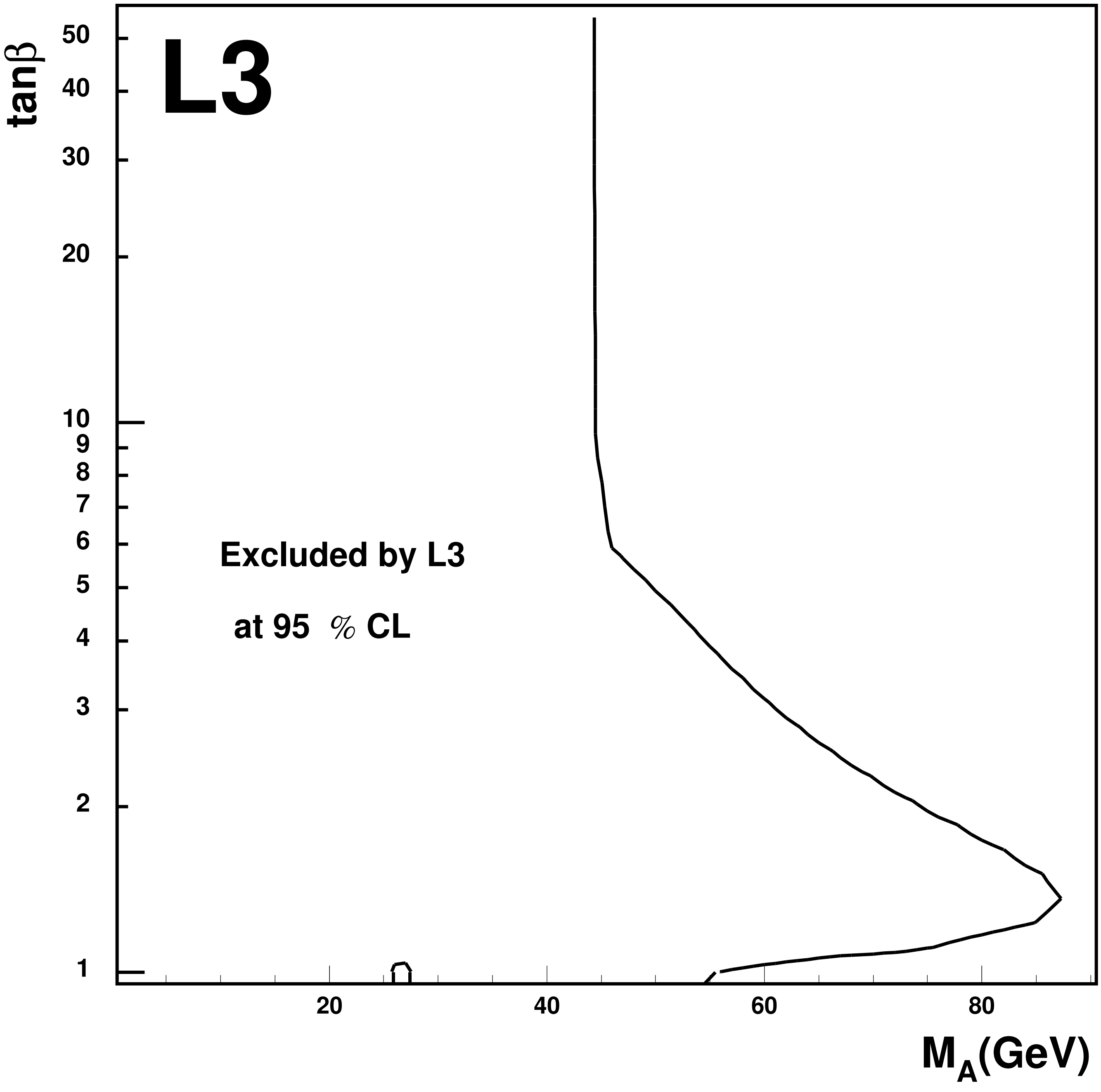


tanβ
10^3
10^2
10
unfavored region from precision
muon g - 2 measurement, Glashow et al 1988
α=β
excluded from Z → bbh searches at 95 % C.L.
L3
10
20
30
40
50
M_h (GeV)

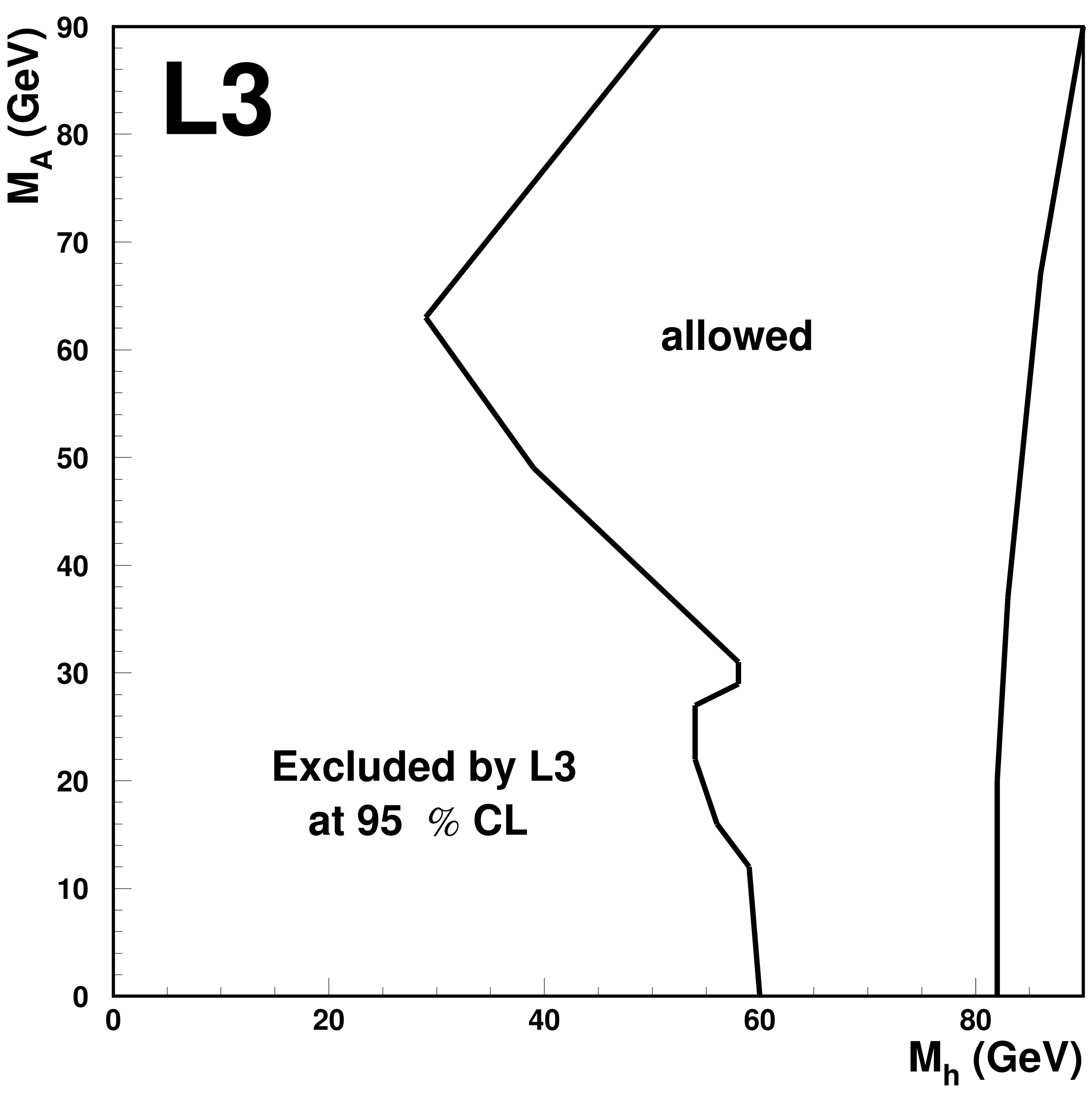

L3
allowed
not allowed
by theory
Excluded by L3
at 95 % CL
M_A (GeV)
90
80
70
60
50
40
30
20
10
20
40
60
80
M_h (GeV)


L3
tanβ
50
40
30
20
10
9
8
7
6
5
4
3
2
1
Excluded by L3
at 95 % CL
20
40
60
80
M_A(GeV)


L3
allowed
not allowed
by theory
not allowed
by theory
Excluded by L3
at 95 % CL
M_A (GeV)
90
80
70
60
50
40
30
20
10
20
40
60
80
M_h (GeV)



L3
tanβ
50
40
30
20
10
9
8
7
6
5
4
3
2
1
Excluded by L3
at 95 % CL
20
40
60
80
M_A(GeV)


L3
allowed
Excluded by L3
at 95 % CL
M_A (GeV)
M_h (GeV)
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80