Higgs physics

(For more info, see Carena, Haber, Prog.Part.Nucl.Phys., 50 (2003) 63-152.)

Higgs search=search for dynamics of SU(2) x U(1) breaking.

To identify the correct model of electroweak symmetry breaking:

- find the Higgs boson
- measure the couplings to fermions
- measure the couplings to gauge bosons
- Note that WWH and ZZH couplings are generated only after symmetry breaking – thus they probe the very existence of VEV

Lightest neutral Higgs mass in MSSM:

Brignole, Degrassi, Slavich, Zwirner, NPB 631 (2002)195.

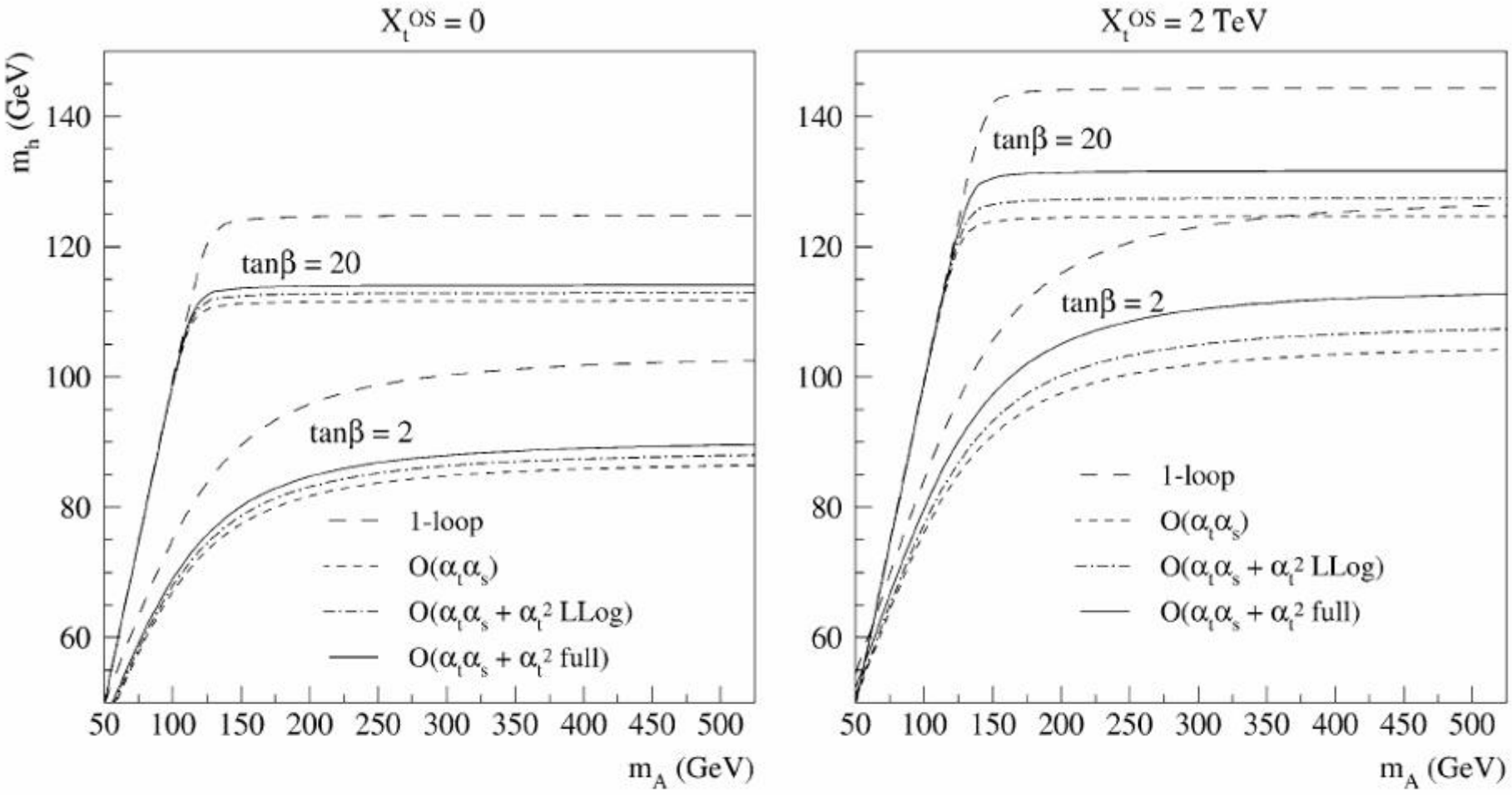
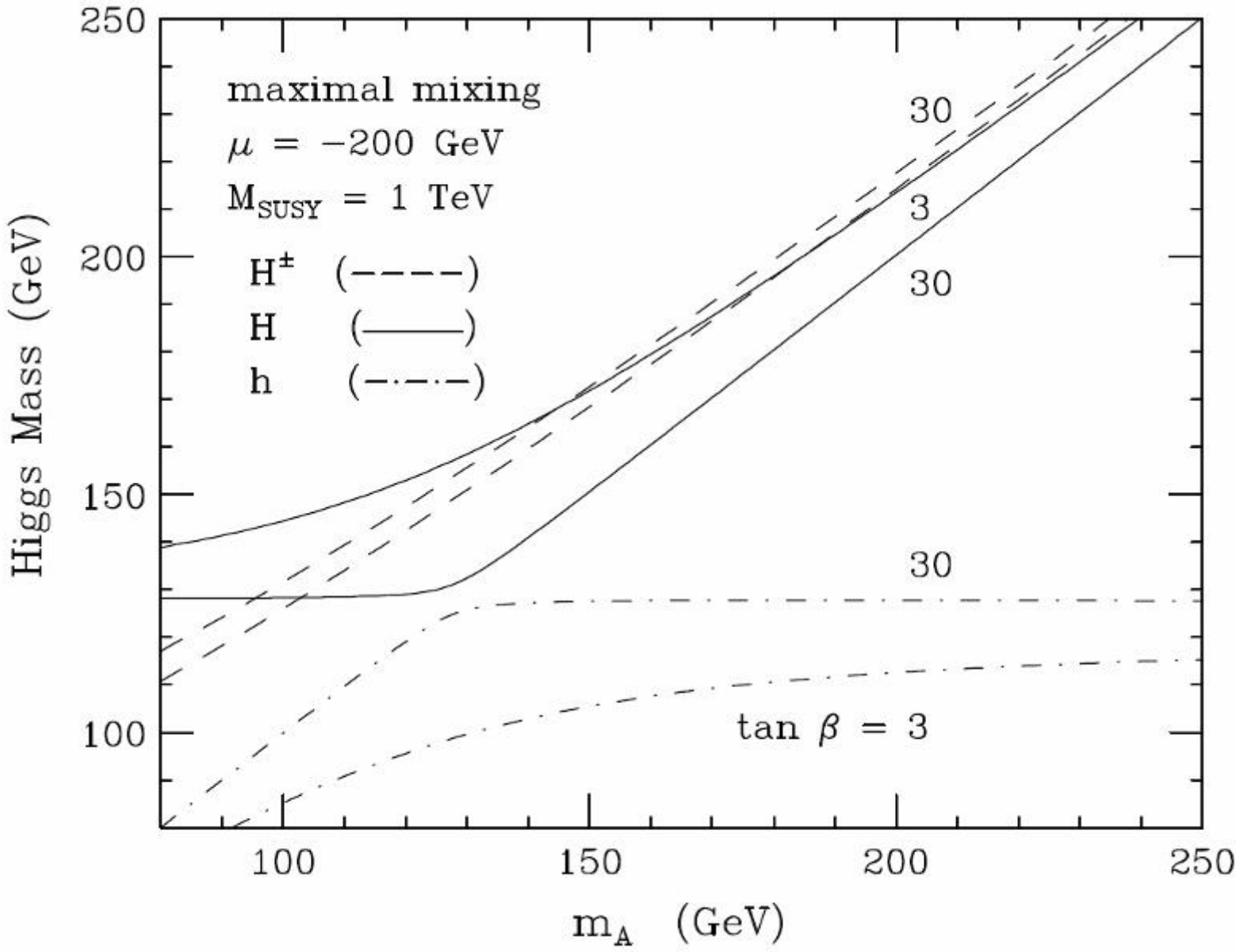
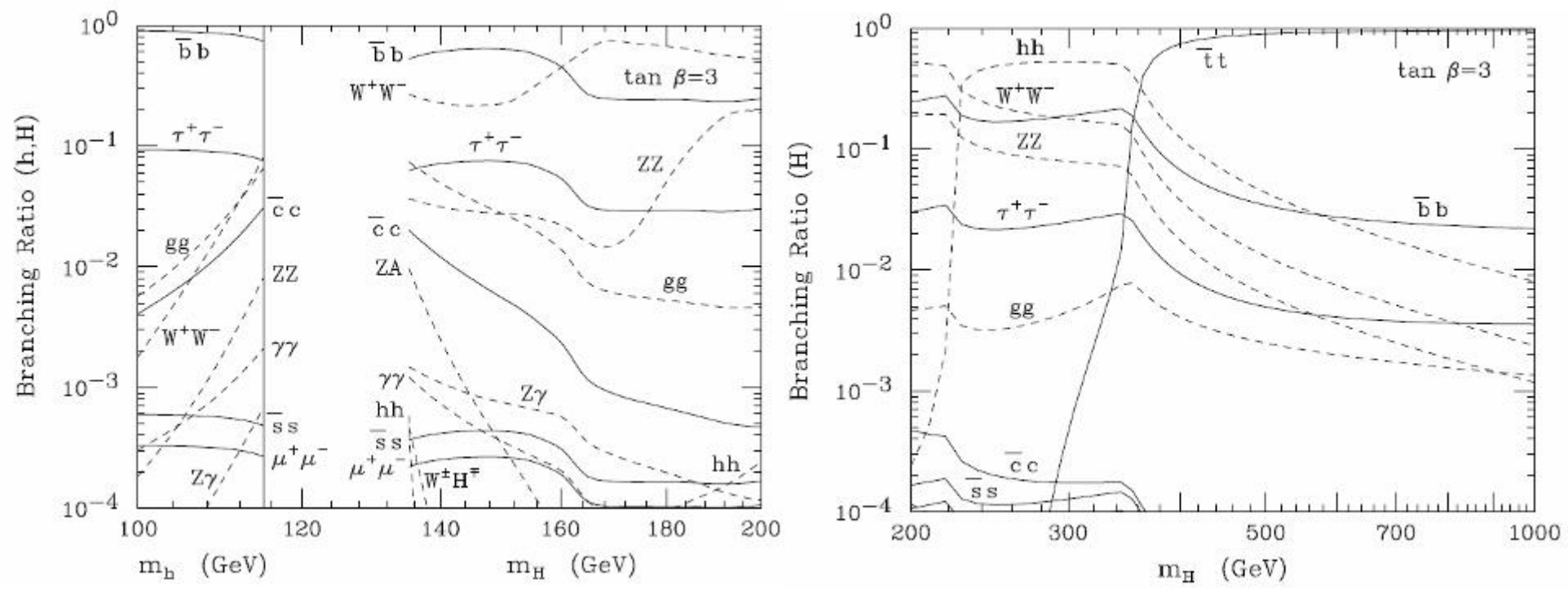


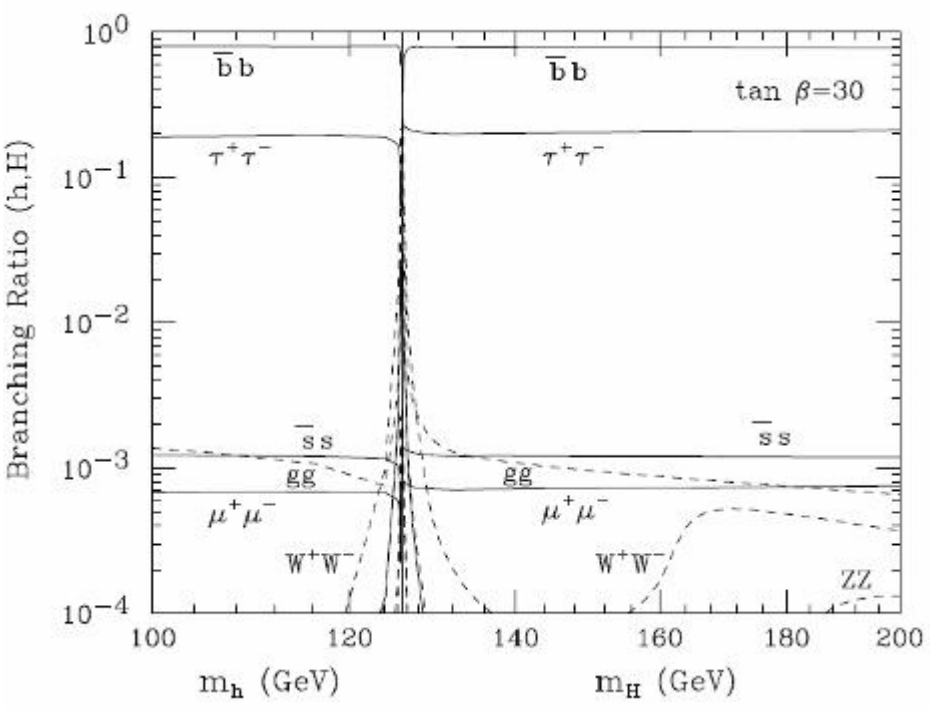
Fig. 2. The mass m_h as a function of m_A, for $\tan\beta = 2$ or 20 and $X_t^{OS} = 0$ or 2 TeV. The other parameters are $m_Q^{OS} = m_U^{OS} = 1$ TeV, $\mu = 200$ GeV, $m_{\tilde{g}} = 800$ GeV. The meaning of the different curves is explained in the text.

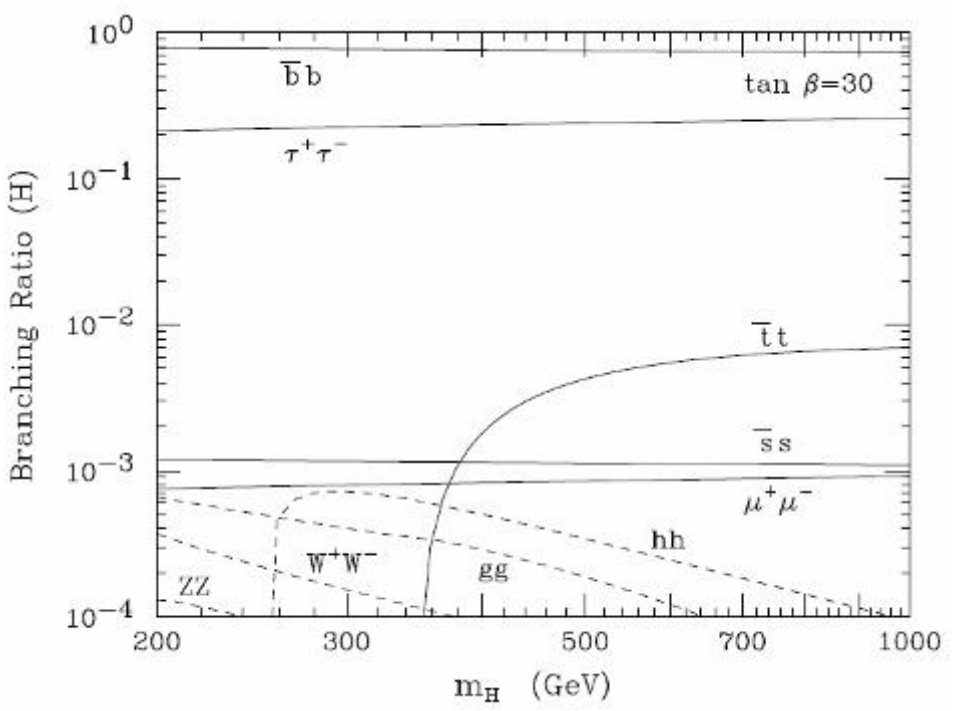
Compare with heavy neutral and charged Higgs:

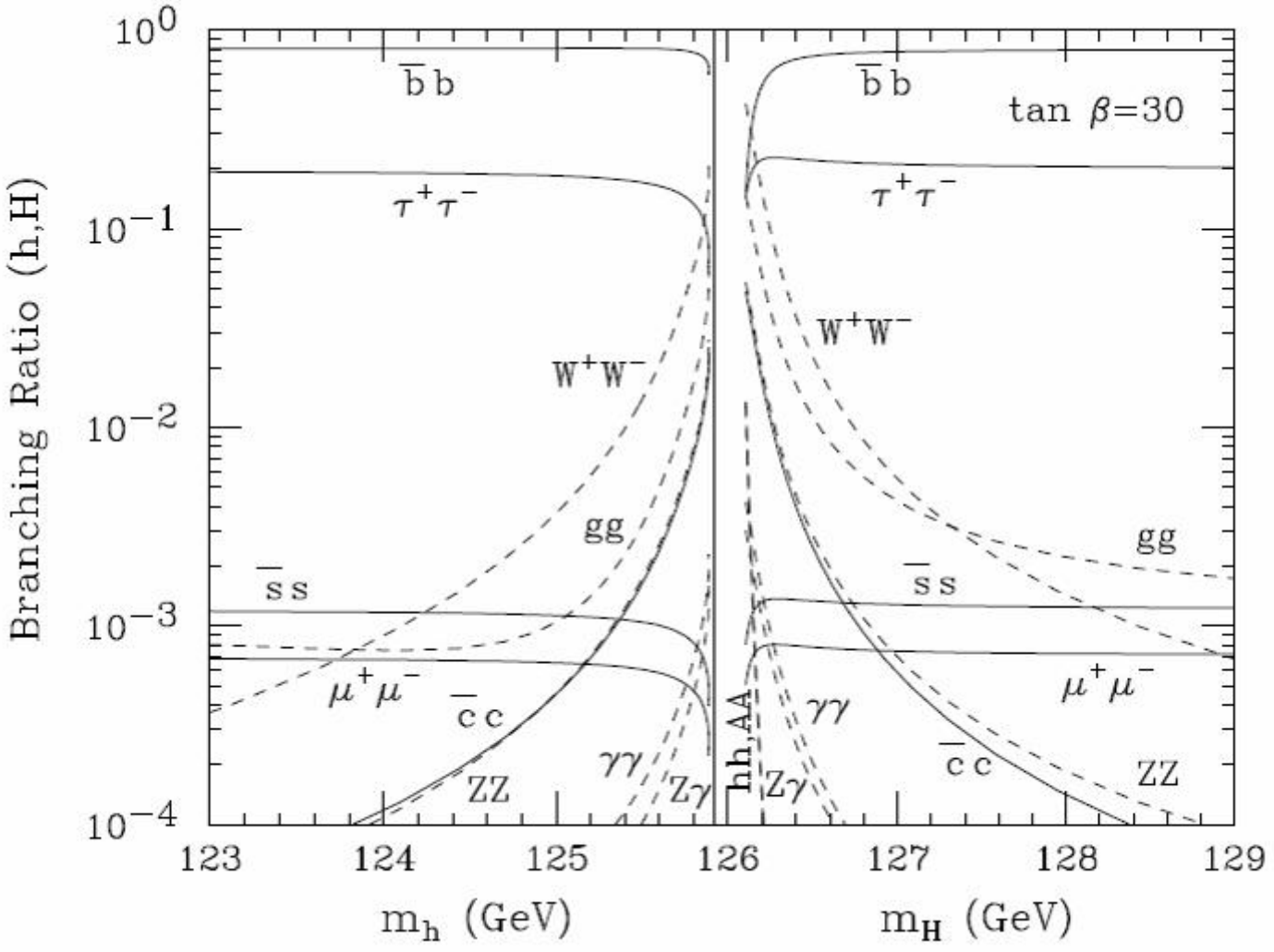


Branching ratios of CP even neutral Higgses:

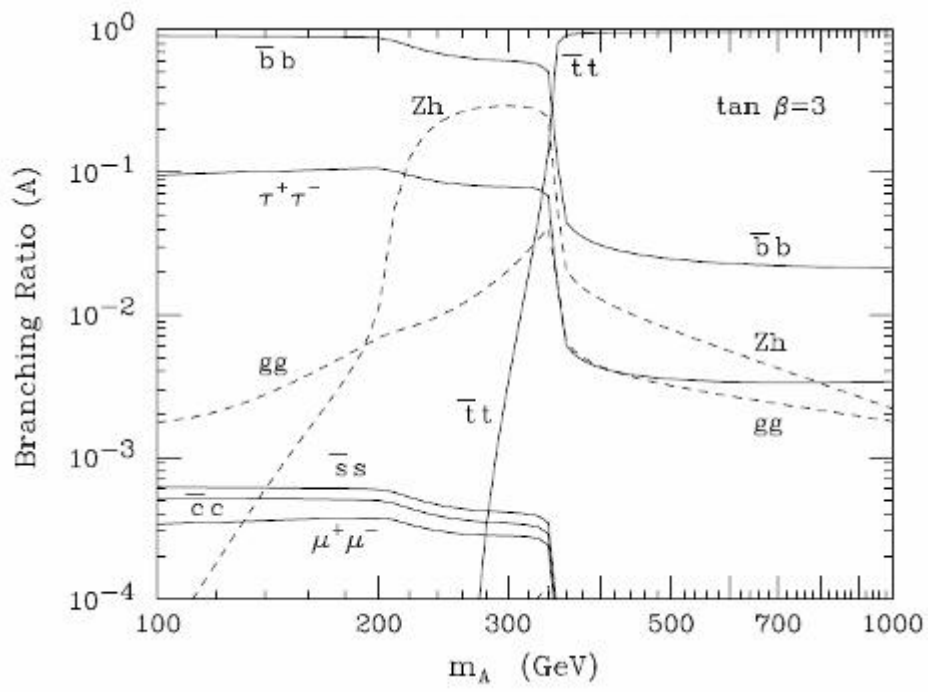


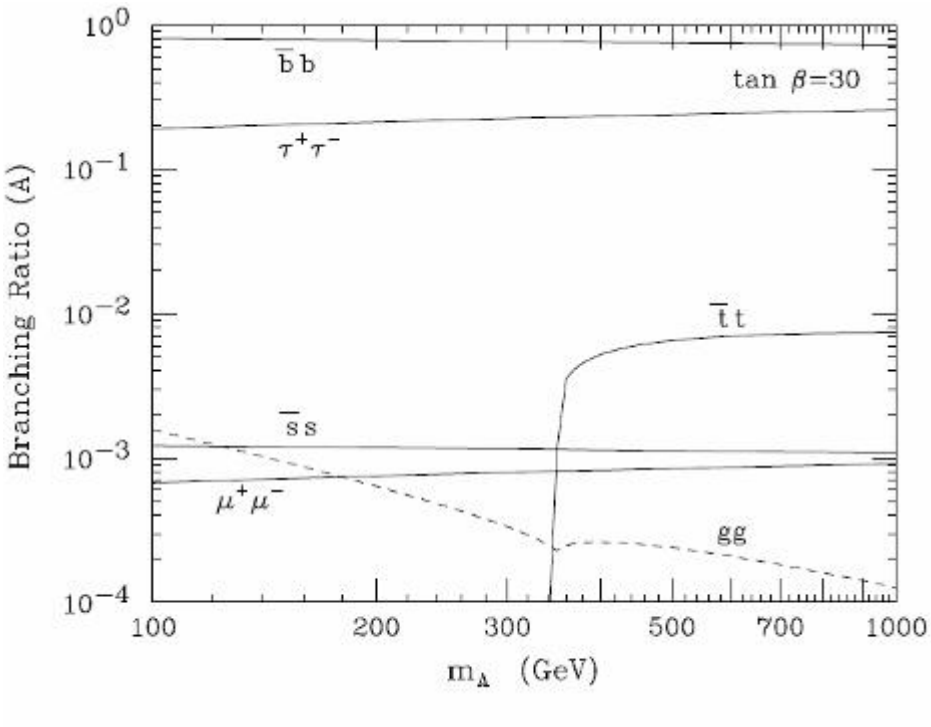

Branching Ratio (h,H)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\bar{b}b$
$\bar{b}b$
tan β=30
$\tau^+\tau^-$
$\tau^+\tau^-$
$\bar{s}s$
$\bar{s}s$
gg
gg
$\mu^+\mu^-$
$\mu^+\mu^-$
W^+W^-
W^+W^-
ZZ
100
120
140
160
180
200
m_h (GeV)
m_H (GeV)


Branching Ratio (H)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\bar{b}b$
tan β=30
$\tau^+\tau^-$
$\bar{t}t$
$\bar{s}s$
$\mu^+\mu^-$
hh
W^+W^-
gg
ZZ
200
300
500
700
1000
m_H (GeV)

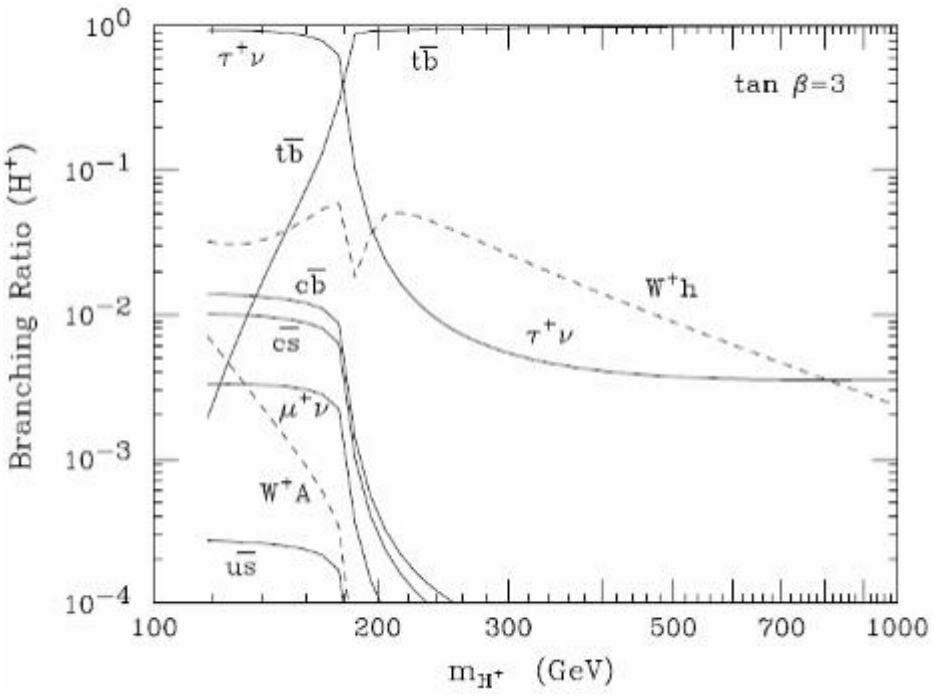

Branching Ratio (h,H)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\bar{b}\,b$
$\tau^+\tau^-$
W^+W^-
gg
$\bar{s}\,s$
$\mu^+\mu^-$
$\bar{c}\,c$
ZZ
$\gamma\gamma$
$Z\gamma$
hh,AA
tan β=30
123
124
125
126
127
128
129
m_h (GeV)
m_H (GeV)

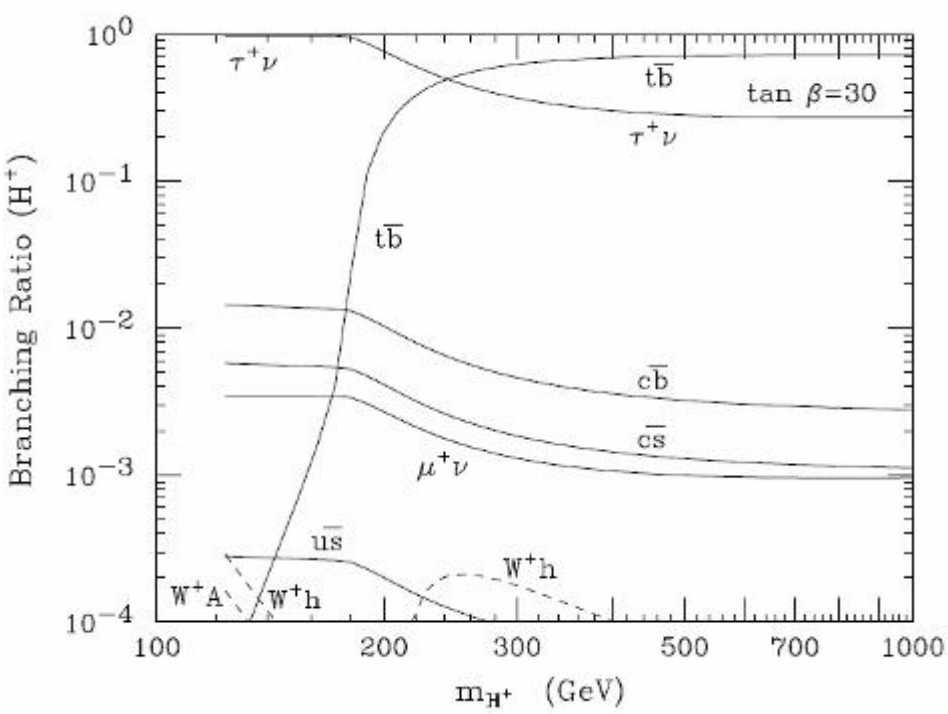
Branching ratios of CP odd neutral Higgs (A):





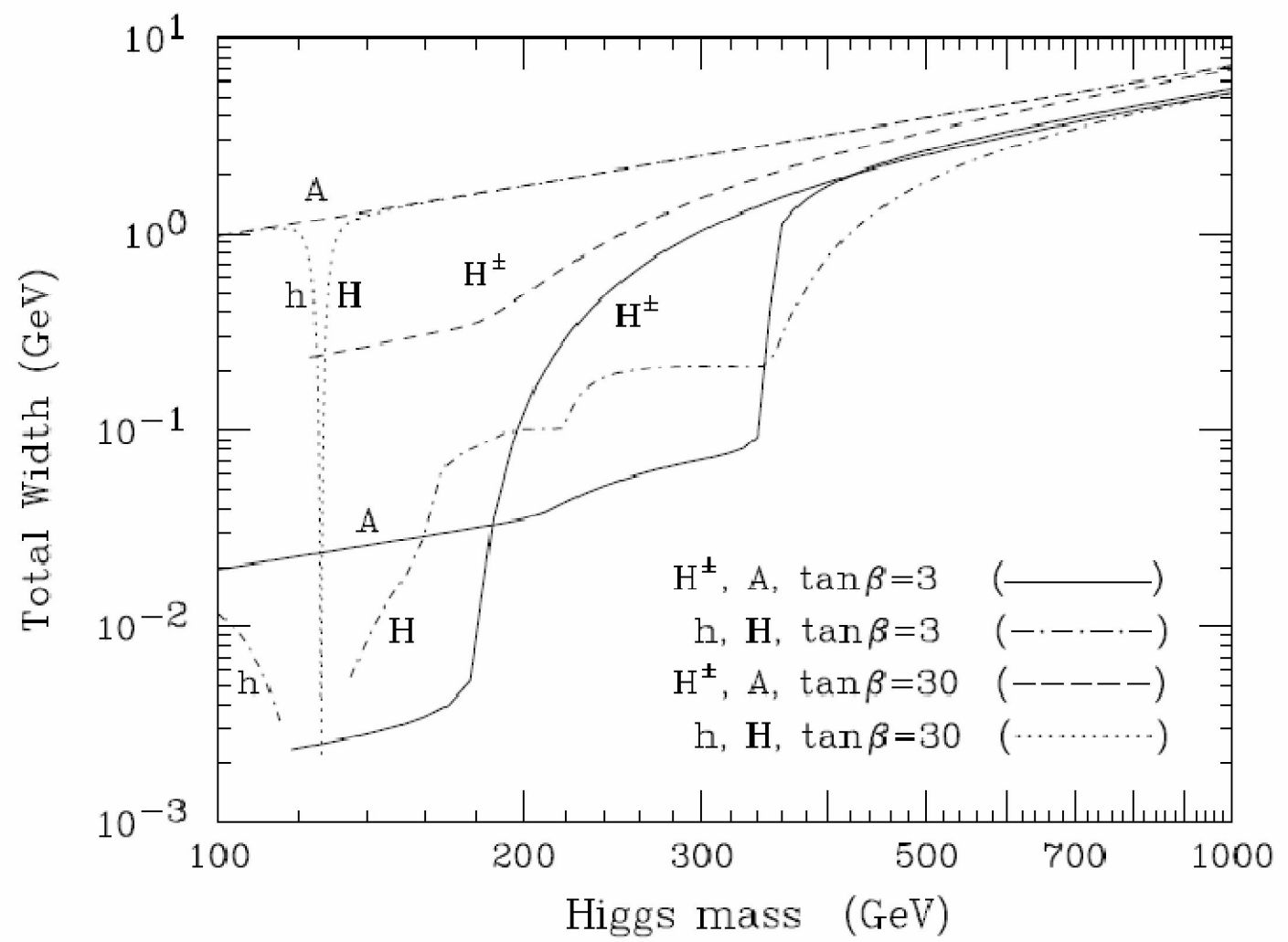
Branching ratios of charged Higgs ($H^{+/-}$):



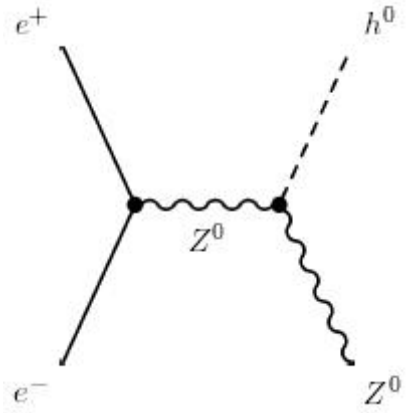


A charged Higgs signal (unlike a neutral one) is always a signal of (whatever) BSM physics !

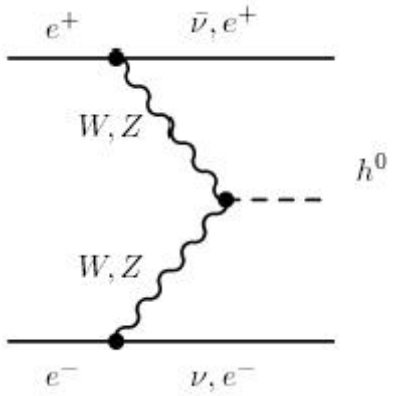
Width of the MSSM Higgses



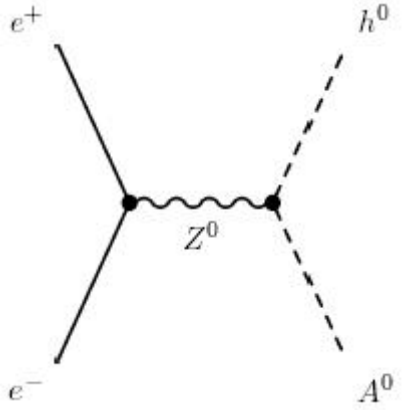
Production at e+e- machines:



Higgsstrahlung



Fusion (small)

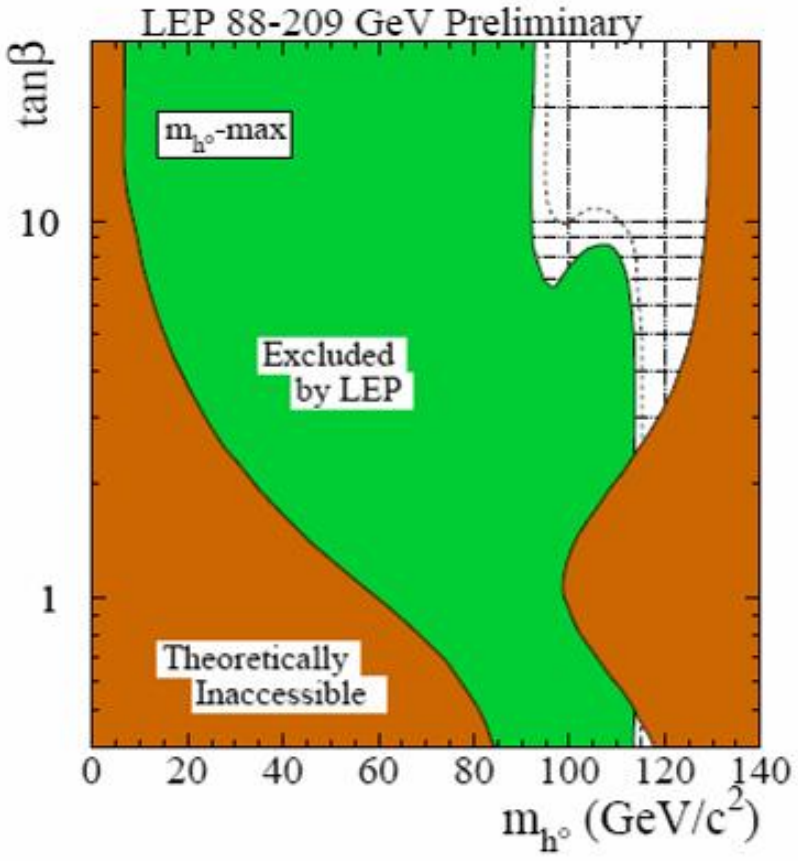


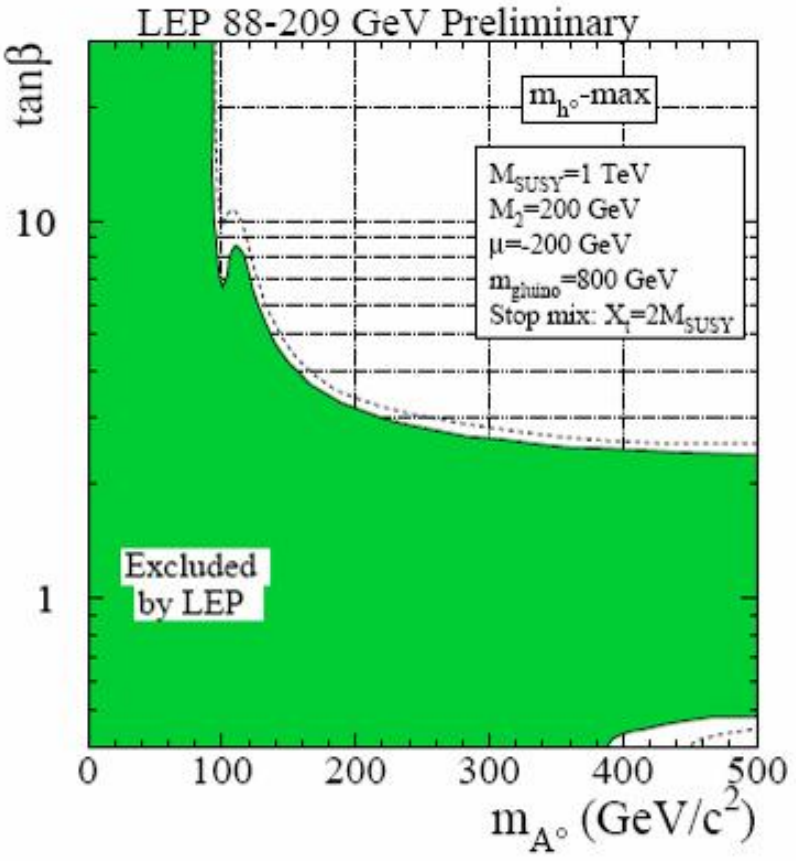
Associated production

$$e^+e^- \to h^0 Z, \quad \sigma \propto \sin^2(\beta - \alpha)$$
$$e^+e^- \to h^0 A, \quad \sigma \propto \cos^2(\beta - \alpha)$$

α is mixing angle of h^0 and H^0

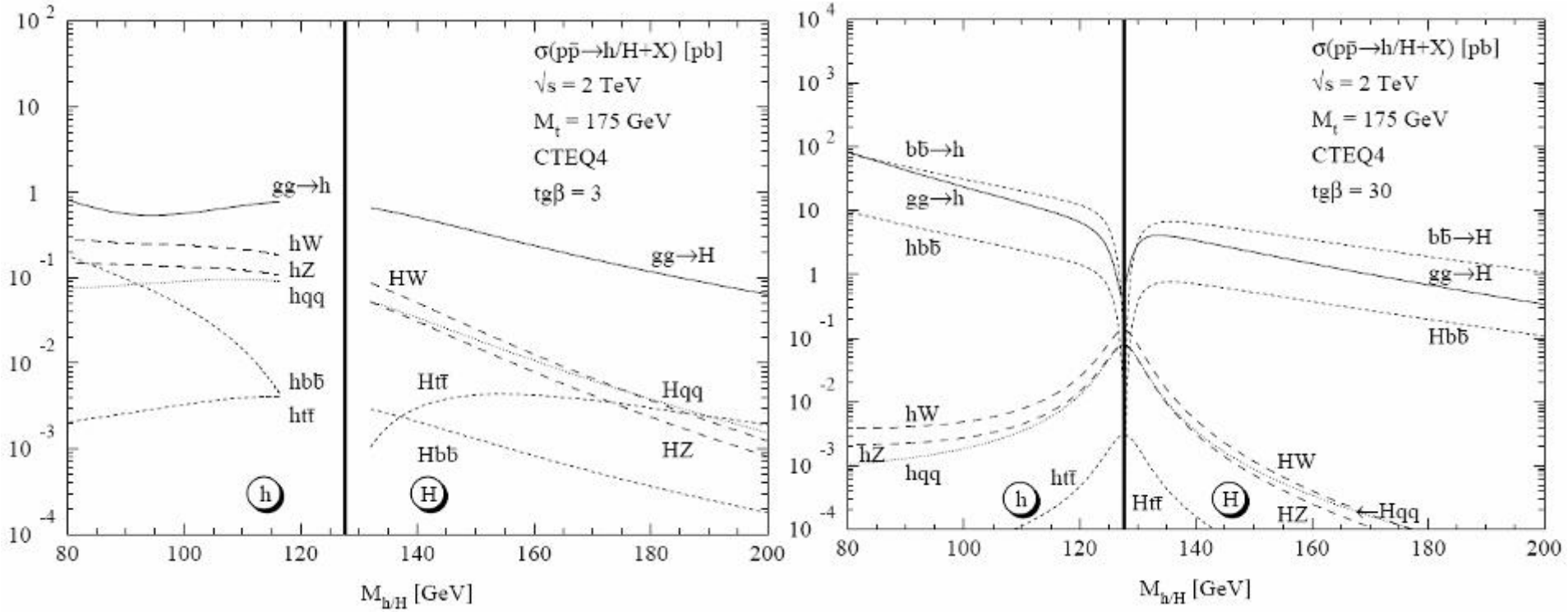
The processes are complementary

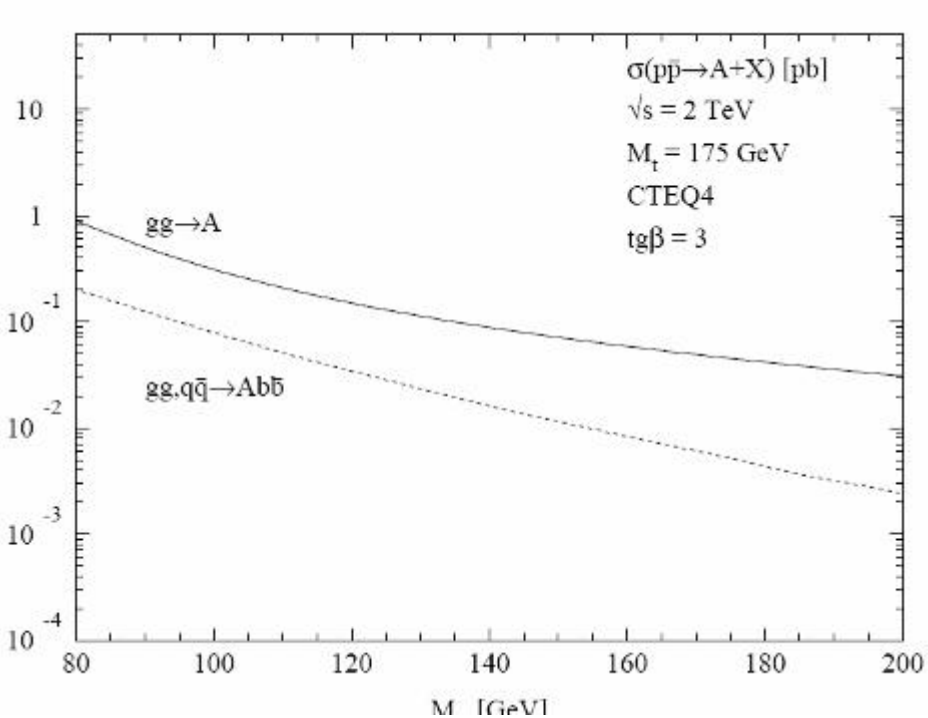


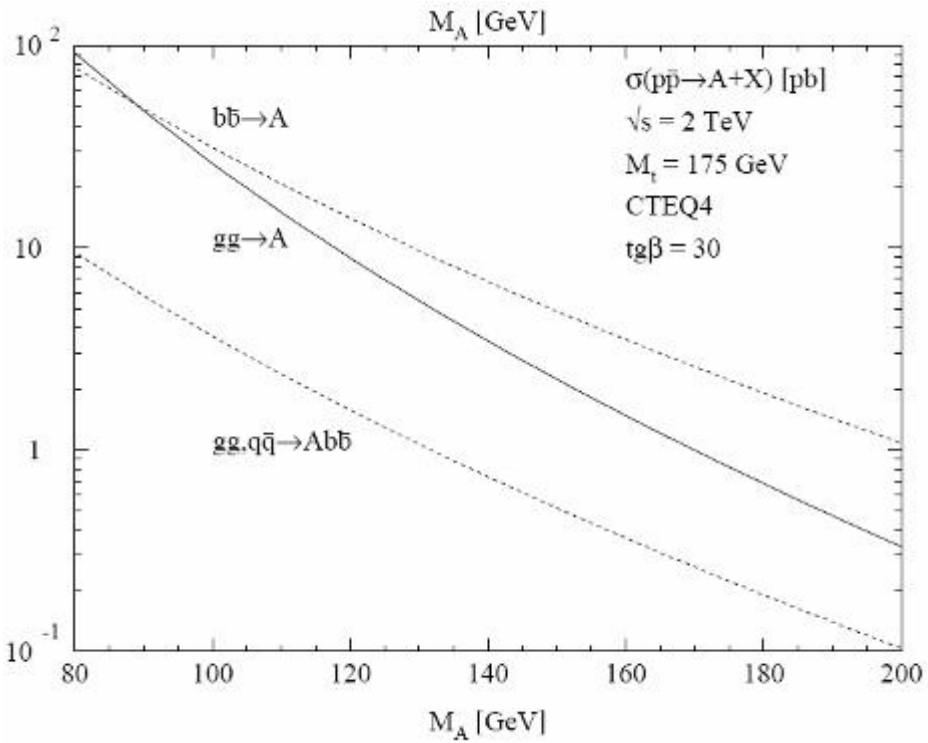


m_h>91.0 GeV
m_A>91.9 GeV
$m_{\text{charged H}}$>78.6 GeV

Production cross sections at Tevatron




σ(pp̄→A+X) [pb]
√s = 2 TeV
M_t = 175 GeV
CTEQ4
tgβ = 3
gg→A
gg,qq̄→Abb̄
10
1
10^-1
10^-2
10^-3
10^-4
80
100
120
140
160
180
200


M_A [GeV]
σ(pp̄→A+X) [pb]
√s = 2 TeV
M_t = 175 GeV
CTEQ4
tgβ = 30
bb̄→A
gg→A
gg,qq̄→Abb̄
10^2
10
1
10^-1
80
100
120
140
160
180
200
M_A [GeV]

Tevatron Run – III?

Carena et al, arXiv: 1011.5304

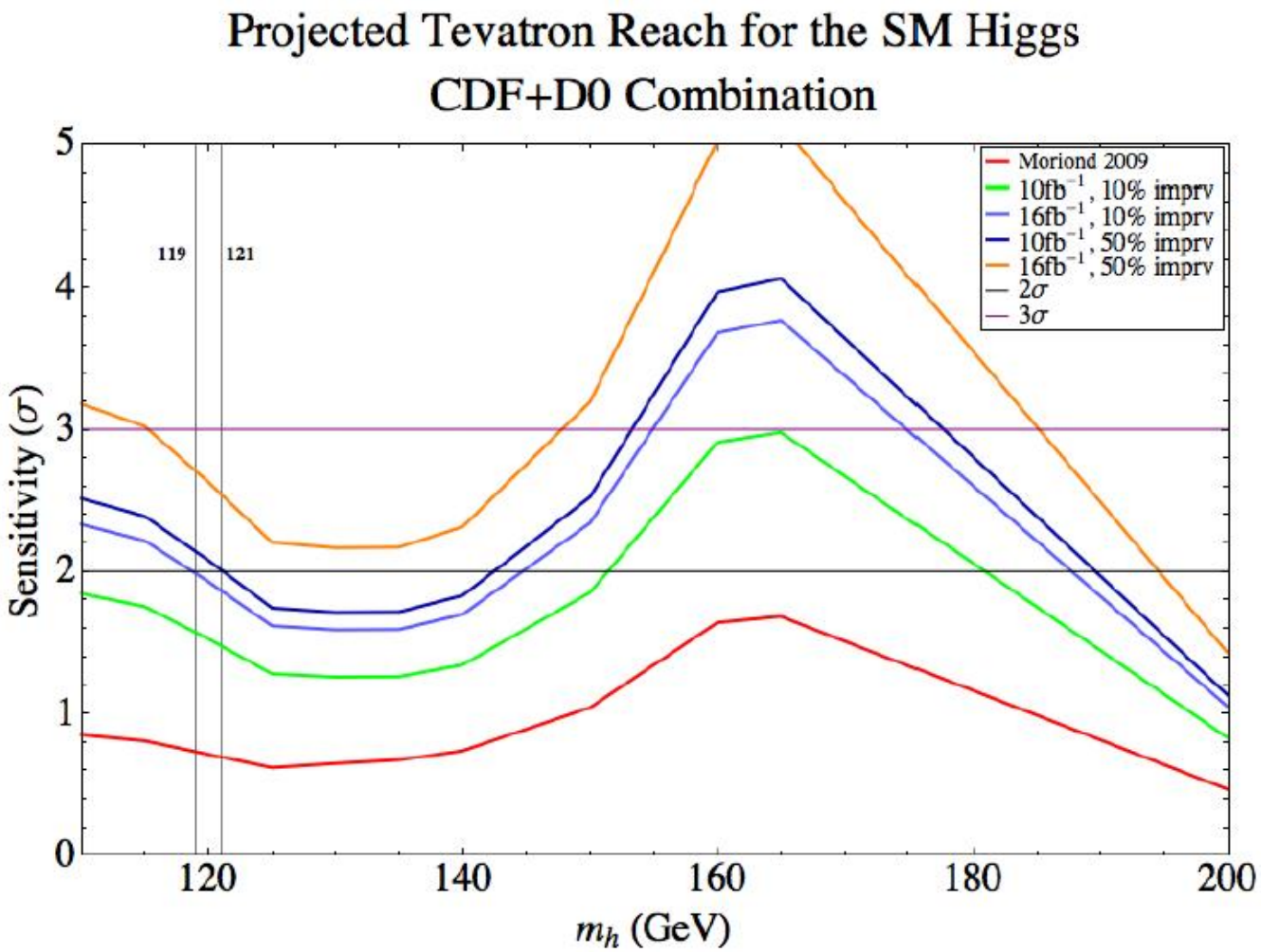
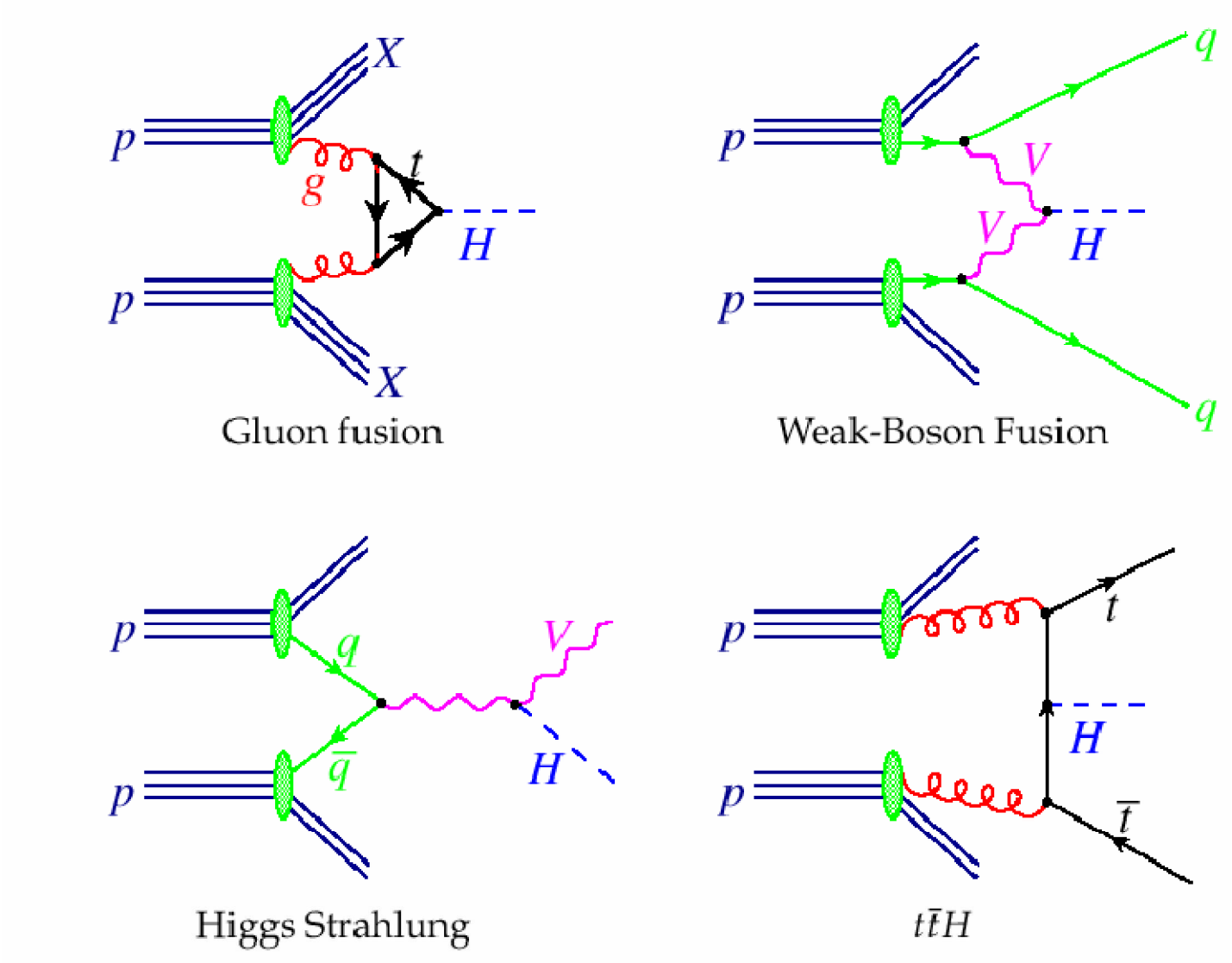
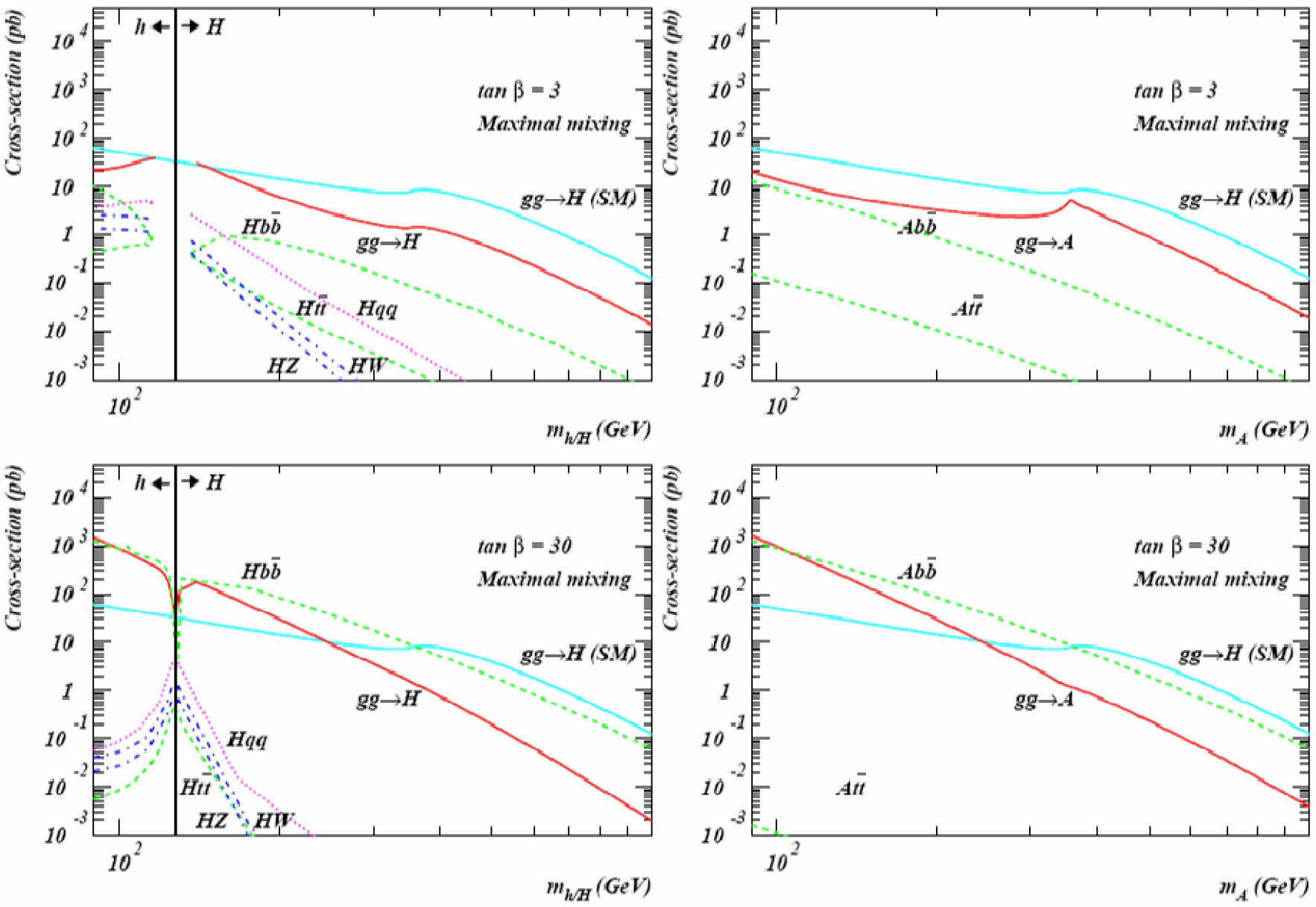


FIG. 1. Projected Tevatron coverage of SM Higgs masses for a range of final luminosities and efficiency curve labelled "Moriond 2009" indicates the March 2009 expected limits.

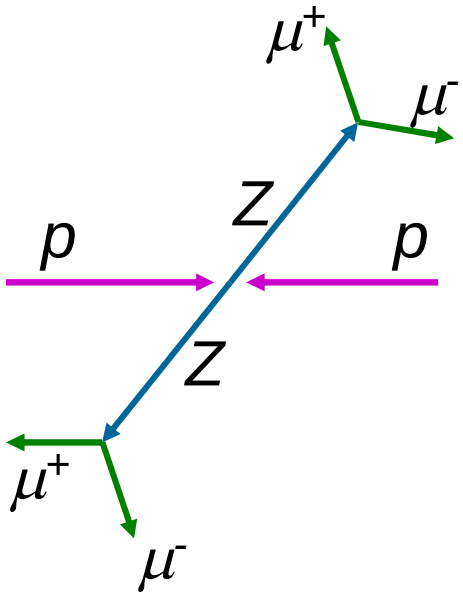
Production modes at the LHC:



Production cross sections at the LHC



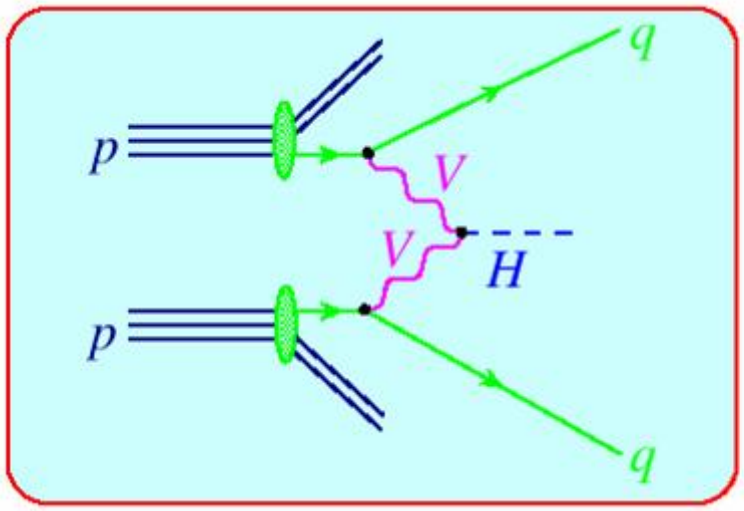
Golden mode: $H \rightarrow ZZ \rightarrow l^+l^-l'^+l'^-$

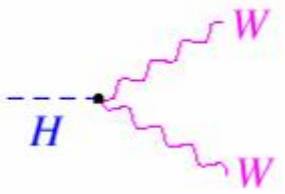


- invariant mass fully reconstructed

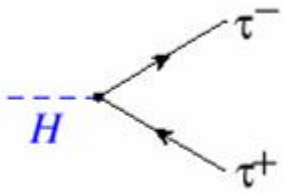
Weak boson fusion

Eboli,Hagiwara,Kauer, Rainwater,Zeppenfeld;
Mangano,Moretti,Piccinnini,Pittau,Polosa (2003)

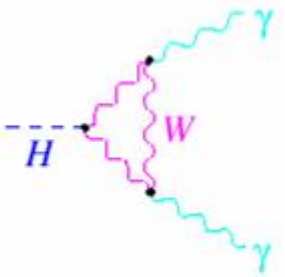




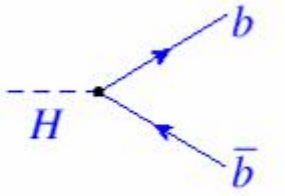
$m_H > 120$ GeV



$m_H < 140$ GeV

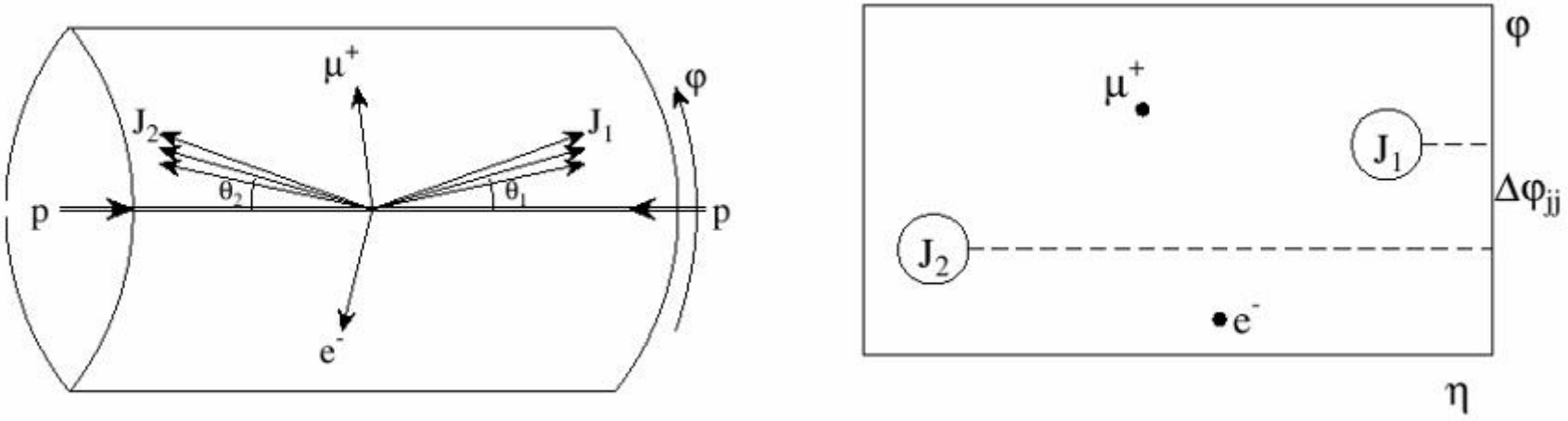


$m_H < 150$ GeV



$m_H < 140$ GeV

WBF signature

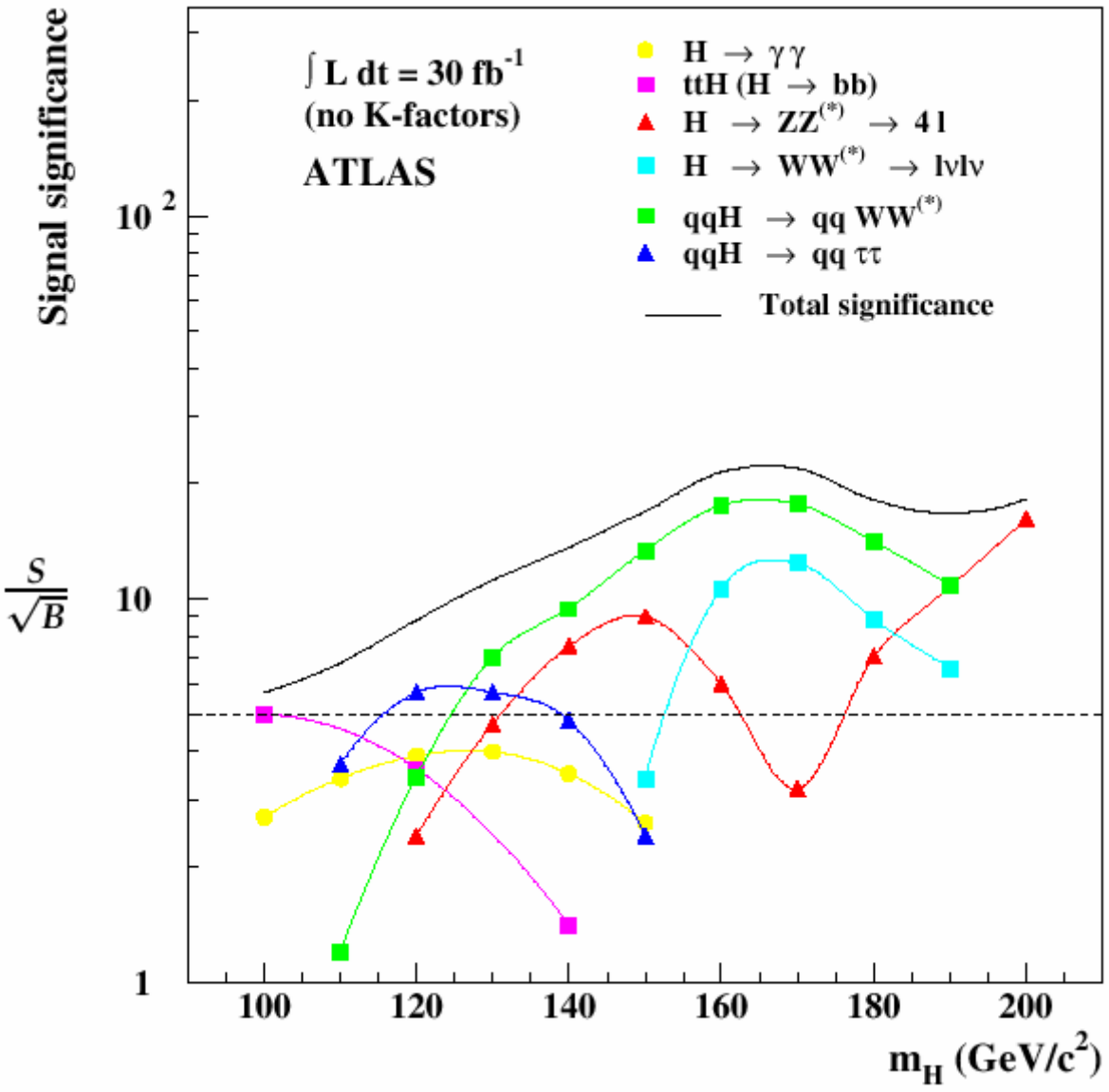


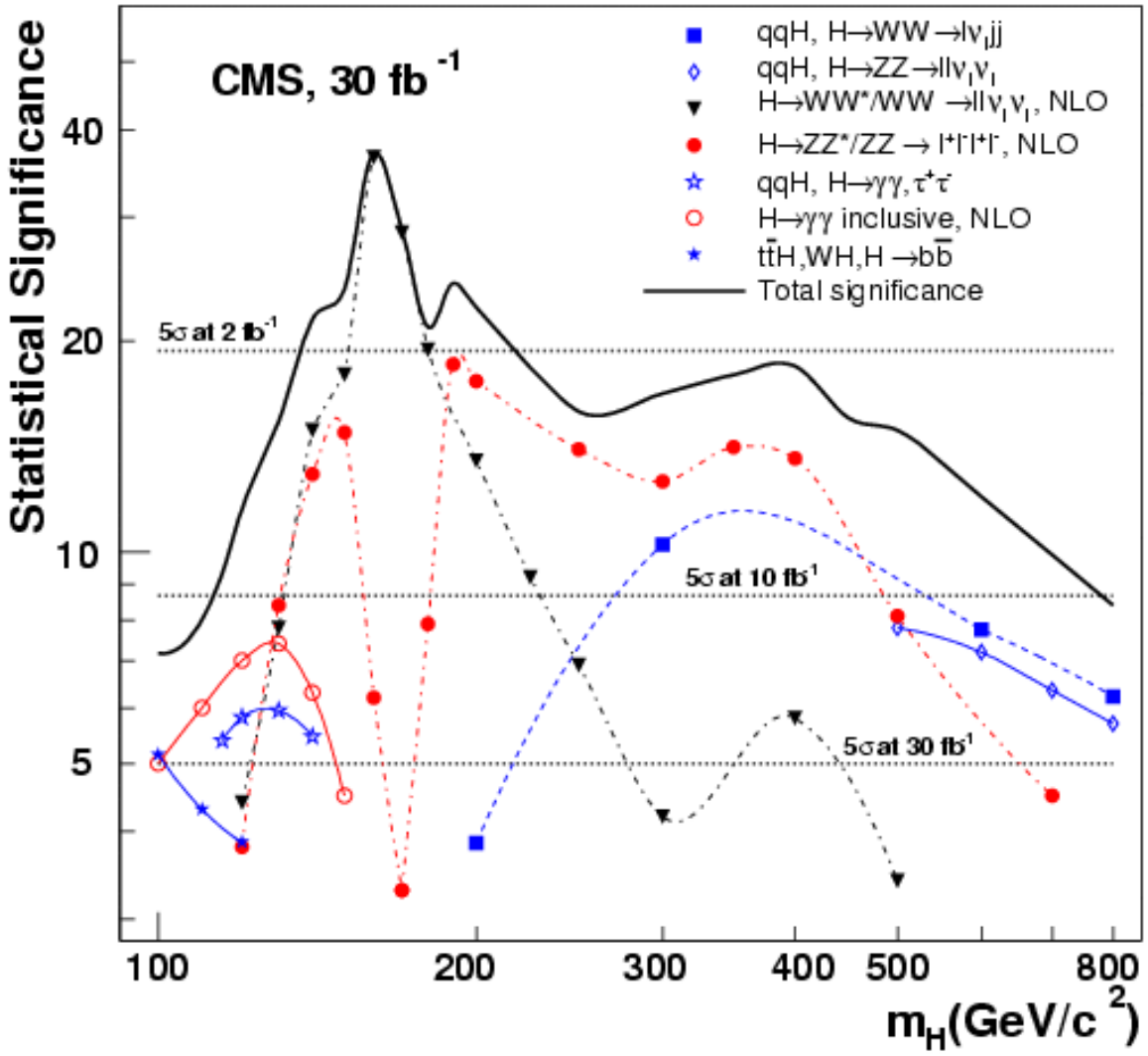
$$\eta = \frac{1}{2} \log \frac{1 + \cos\theta}{1 - \cos\theta}$$

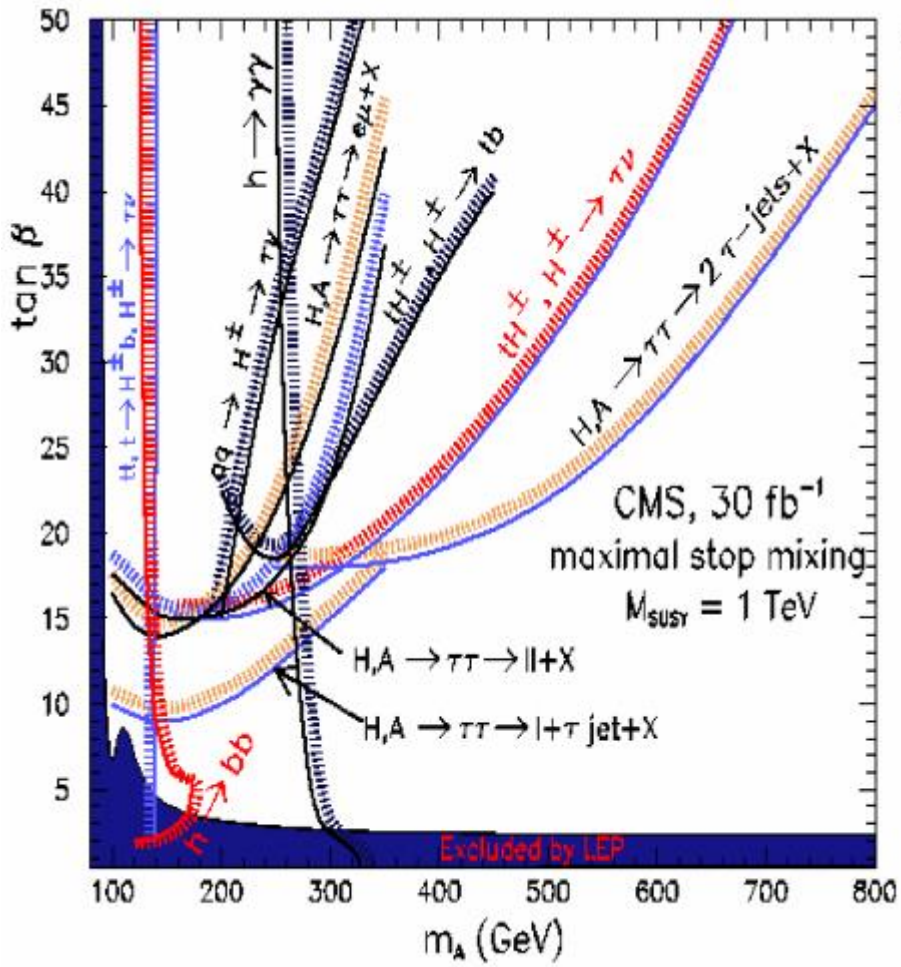
Characteristics:

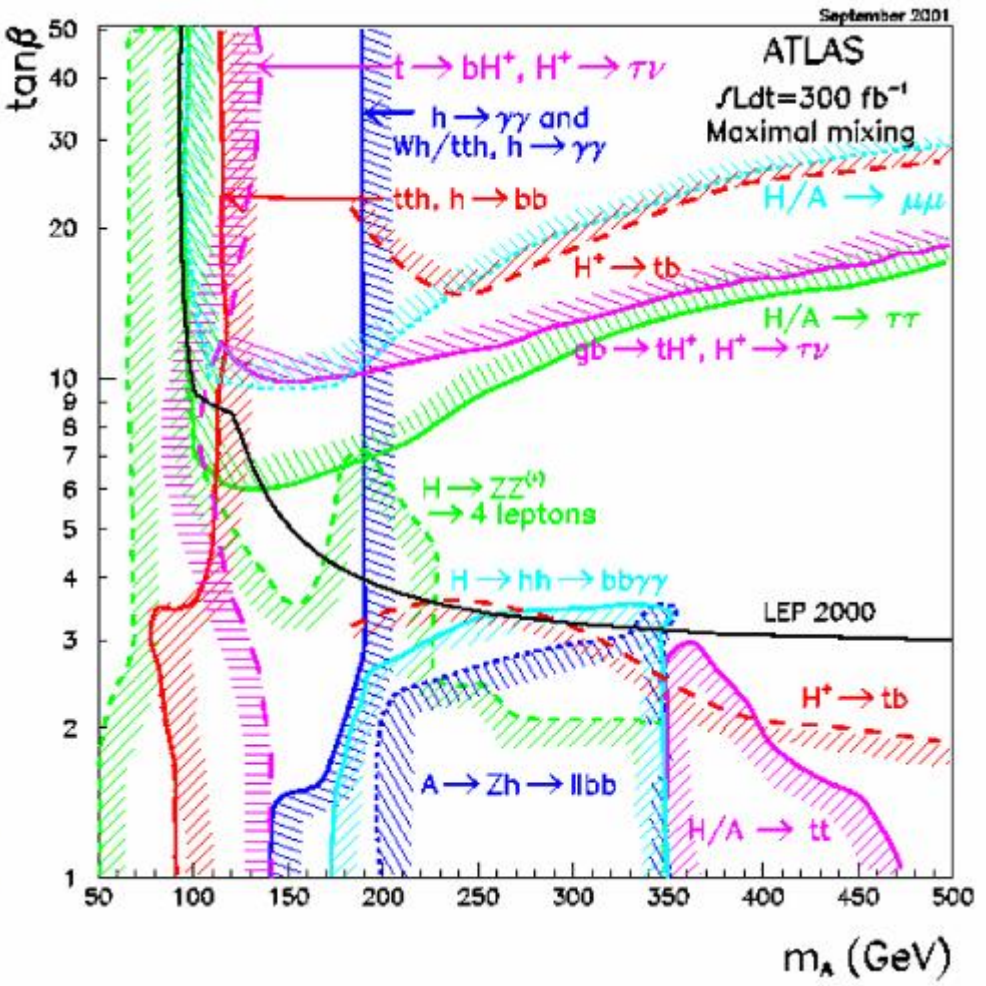
- energetic jets in the forward and backward directions ($p_T > 20$ GeV)
- Higgs decay products between tagging jets
- Little gluon radiation in the central-rapidity region, due to colorless W/Z exchange (central jet veto: no extra jets with $p_T > 20$ GeV and $|\eta| < 2.5$)

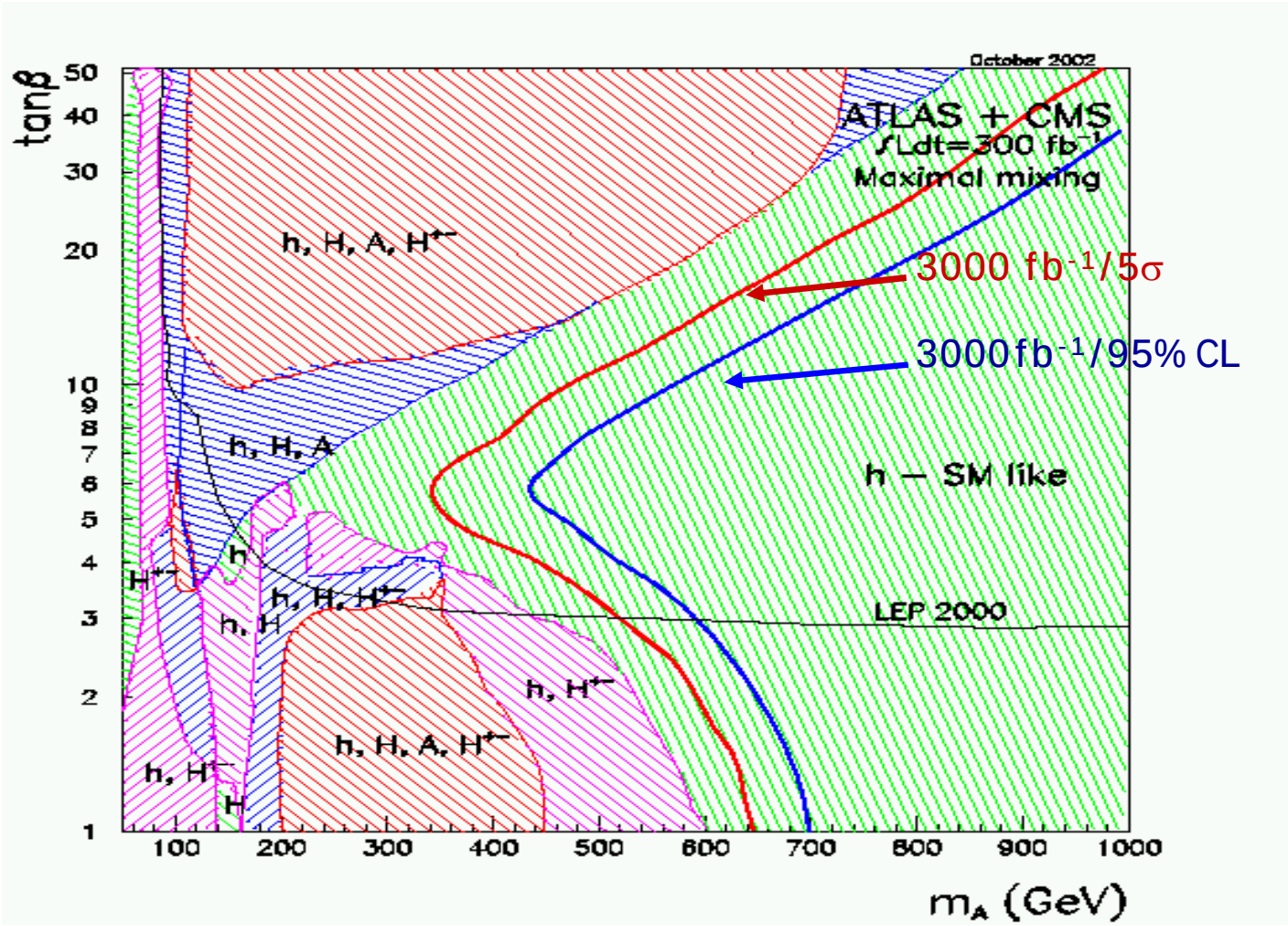
Higgs discovery potential:




CMS, 30 fb -1
qqH, H→WW→lν_l jj
qqH, H→ZZ→llν_l ν_l
H→WW*/WW →llν_l ν_l, NLO
H→ZZ*/ZZ → l+l-l+l-, NLO
qqH, H→γγ, τ+τ-
H→γγ inclusive, NLO
tt̄H,WH,H →bb̄
Total significance
5σ at 2 fb-1
5σ at 10 fb-1
5σ at 30 fb-1
Statistical Significance
40
20
10
5
100
200
300
400
500
800
m_H(GeV/c 2)


tan β
m_A (GeV)
CMS, 30 fb⁻¹
maximal stop mixing
M_SUSY = 1 TeV
H,A → ττ → ll+X
H,A → ττ → l+τ jet+X
H,A → ττ → 2 τ−jets+X
tH±, H± → τν
tH±, H± → tb
H,A → ττ → eμ+X
h → γγ
qq → H± → τν
h → bb
Excluded by LEP


September 2001
ATLAS
∫Ldt=300 fb⁻¹
Maximal mixing
tanβ
m_A (GeV)
t → bH⁺, H⁺ → τν
h → γγ and Wh/tth, h → γγ
tth, h → bb
H/A → μμ
H⁺ → tb
H/A → ττ
gb → tH⁺, H⁺ → τν
H → ZZ^(*) → 4 leptons
H → hh → bbγγ
LEP 2000
H⁺ → tb
A → Zh → llbb
H/A → tt


October 2002
ATLAS + CMS
∫Ldt=300 fb⁻¹
Maximal mixing
3000 fb⁻¹/5σ
3000fb⁻¹/95% CL
h – SM like
LEP 2000
h, H, A, H±
h, H, A
h
H±
h, H, H±
h, H
h, H±
h, H, A, H±
h, H±
H
tanβ
m_A (GeV)
50
40
30
20
10
9
8
7
6
5
4
3
2
1
100
200
300
400
500
600
700
800
900
1000