Hidden Higgs Scenarios

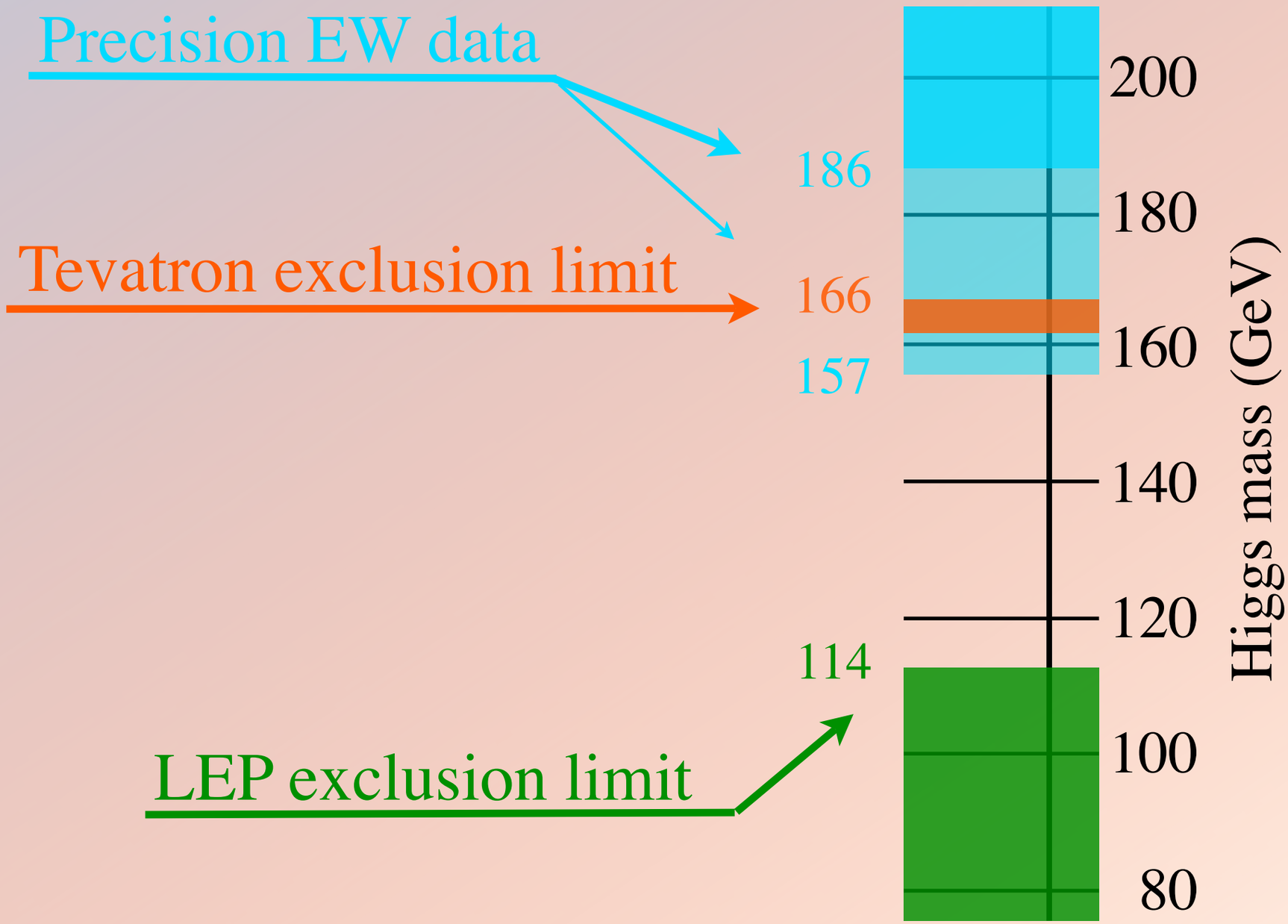
new constraints and prospects at the LHC

Radovan Dermisek

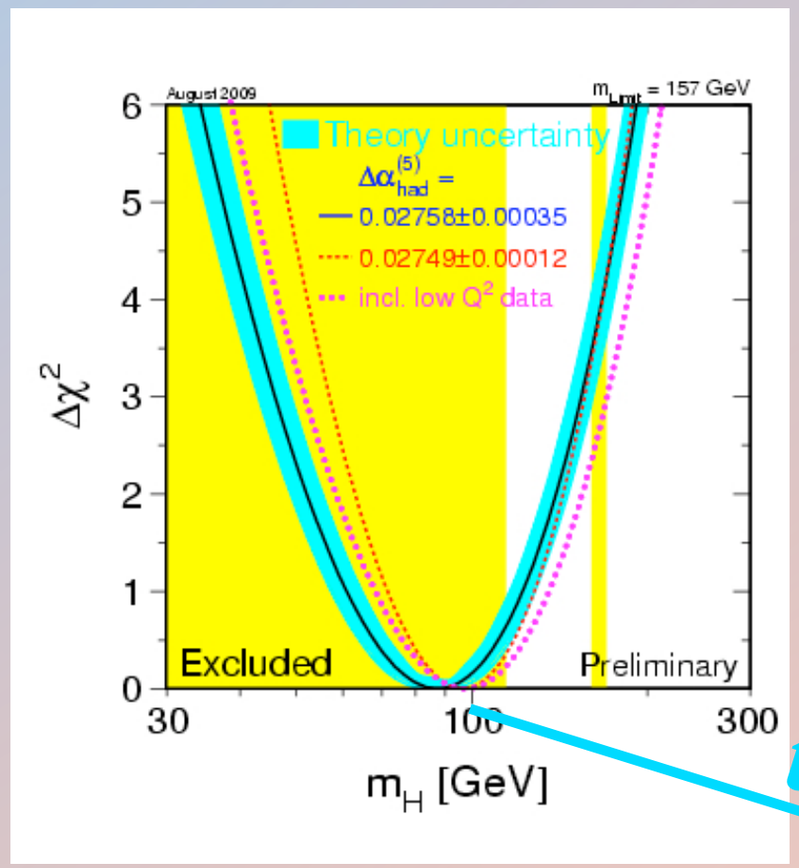
Indiana University, Bloomington

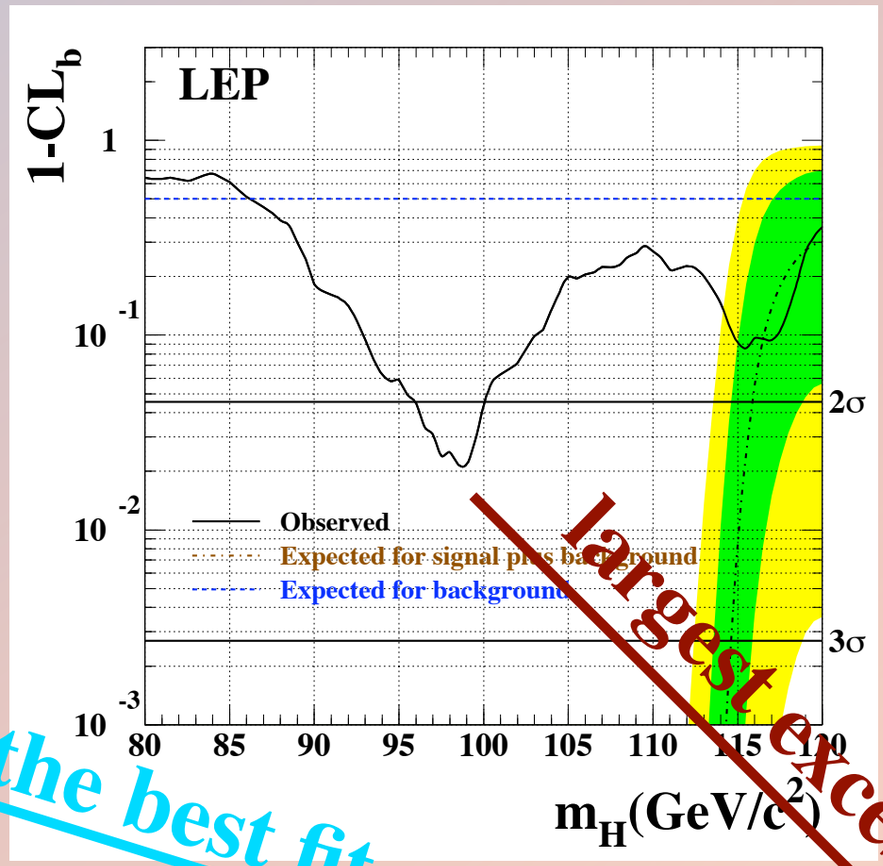
Planck 2010, CERN, May 31 - June 4, 2010

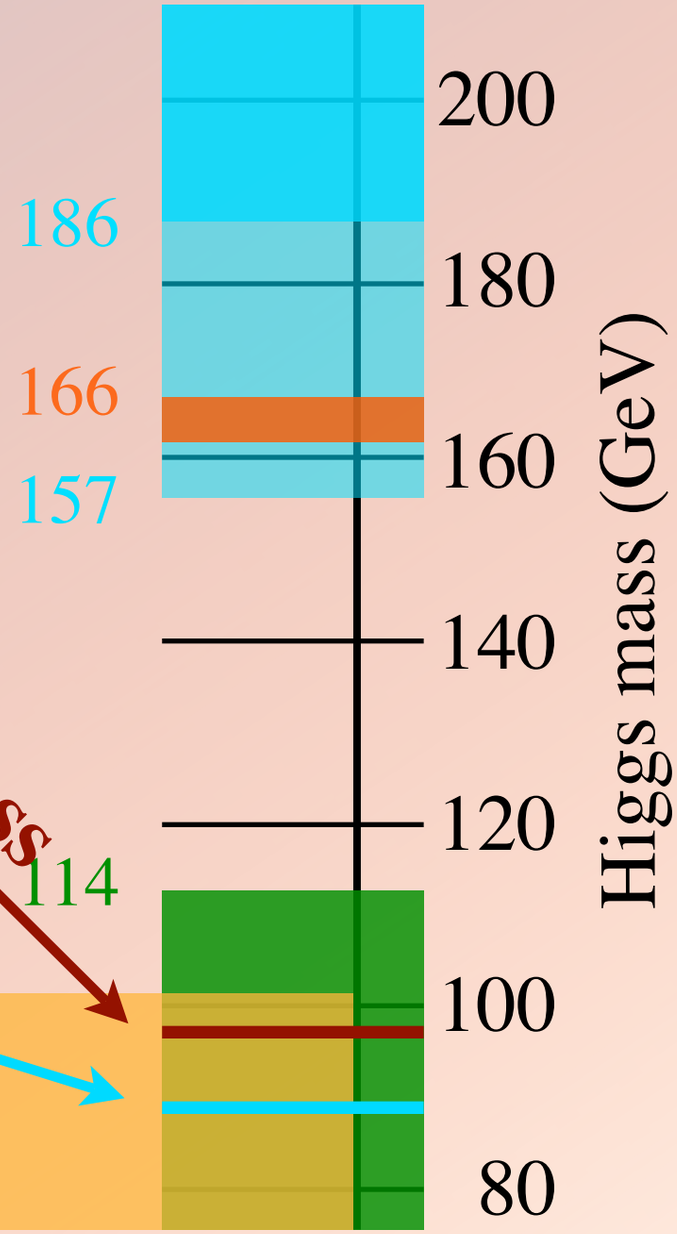
Where is the Higgs?



Where is the Higgs?







the best fit value

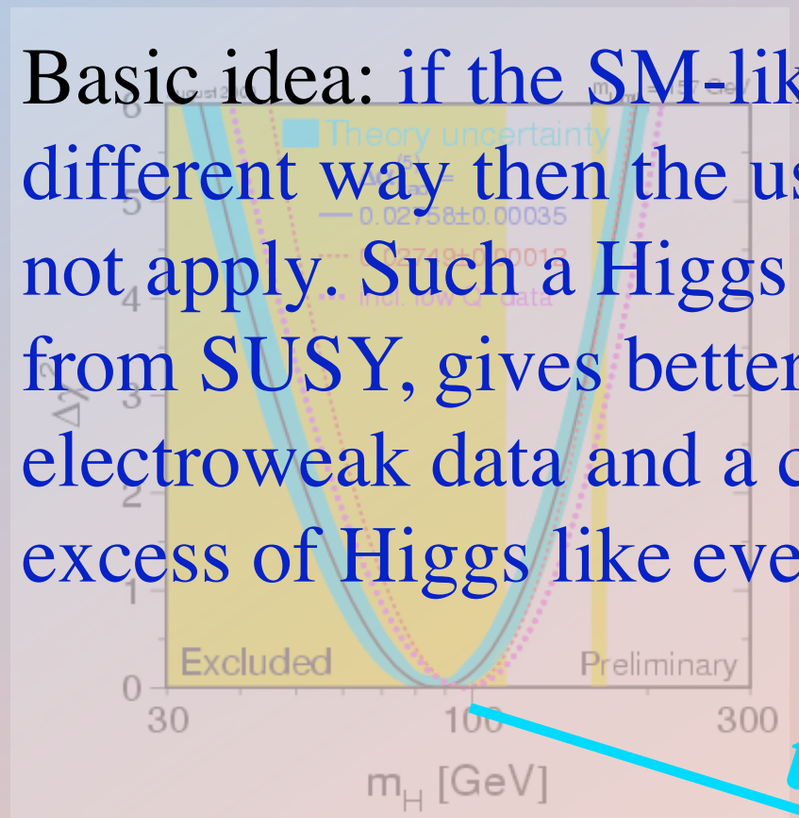
largest excess

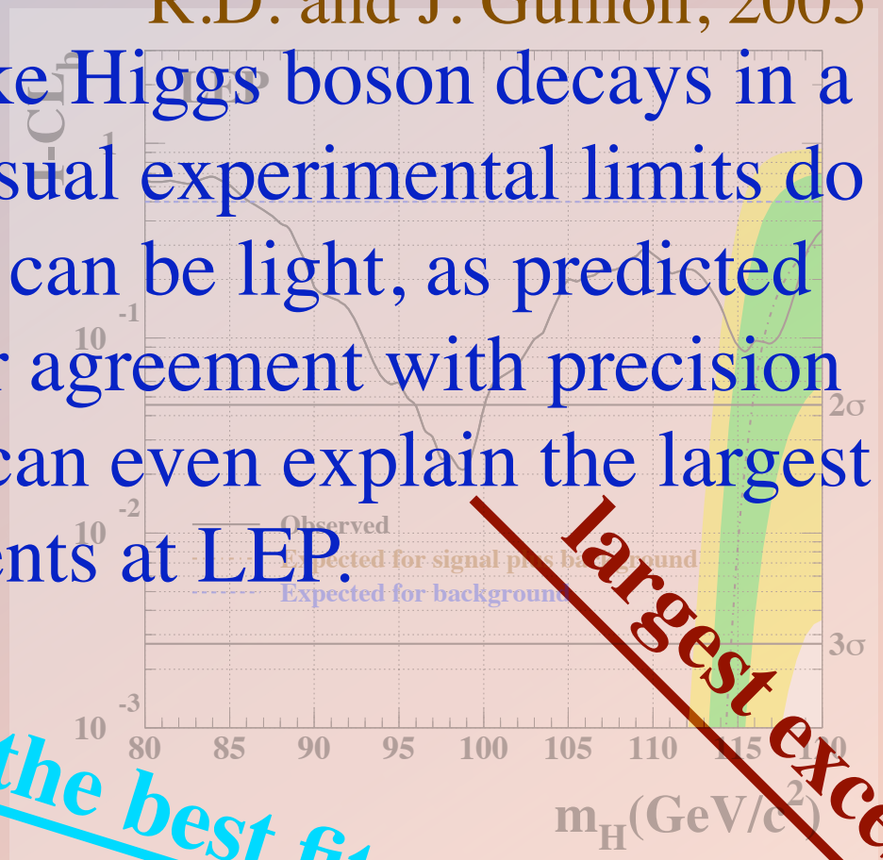
Natural electroweak symmetry breaking in SUSY models is achieved only in this region!

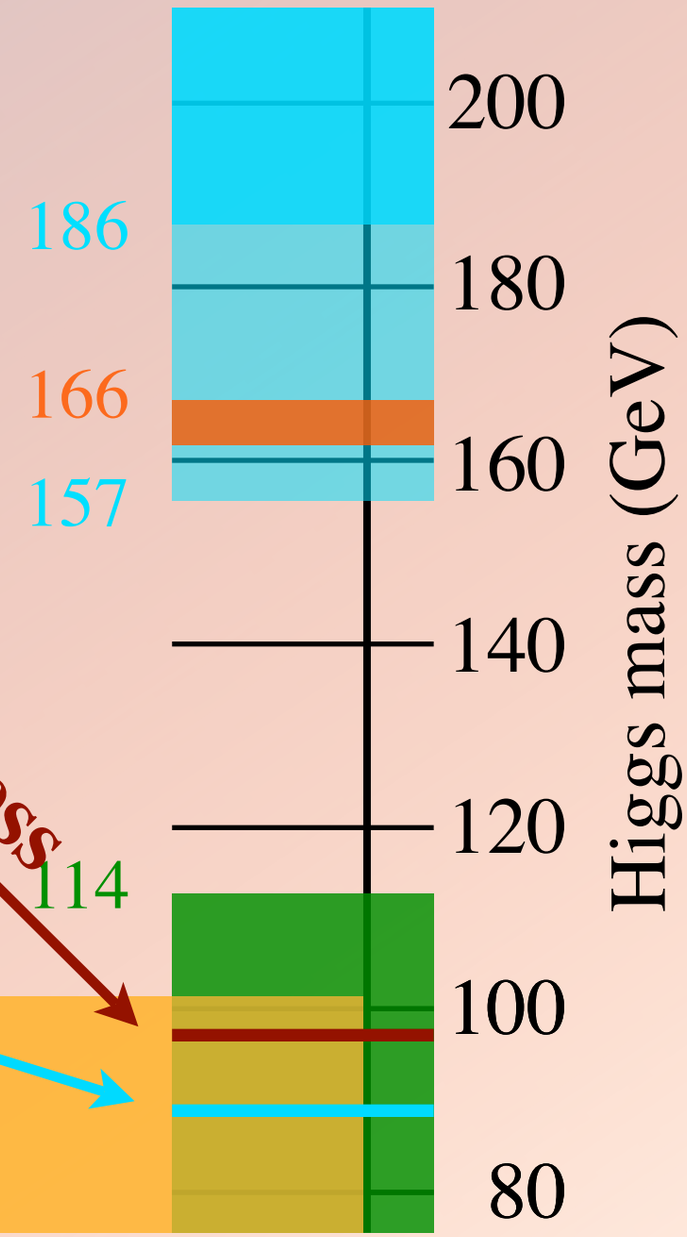
Non-standard Higgs decays

R.D. and J. Gunion, 2005

Basic idea: if the SM-like Higgs boson decays in a different way then the usual experimental limits do not apply. Such a Higgs can be light, as predicted from SUSY, gives better agreement with precision electroweak data and a can even explain the largest excess of Higgs like events at LEP.

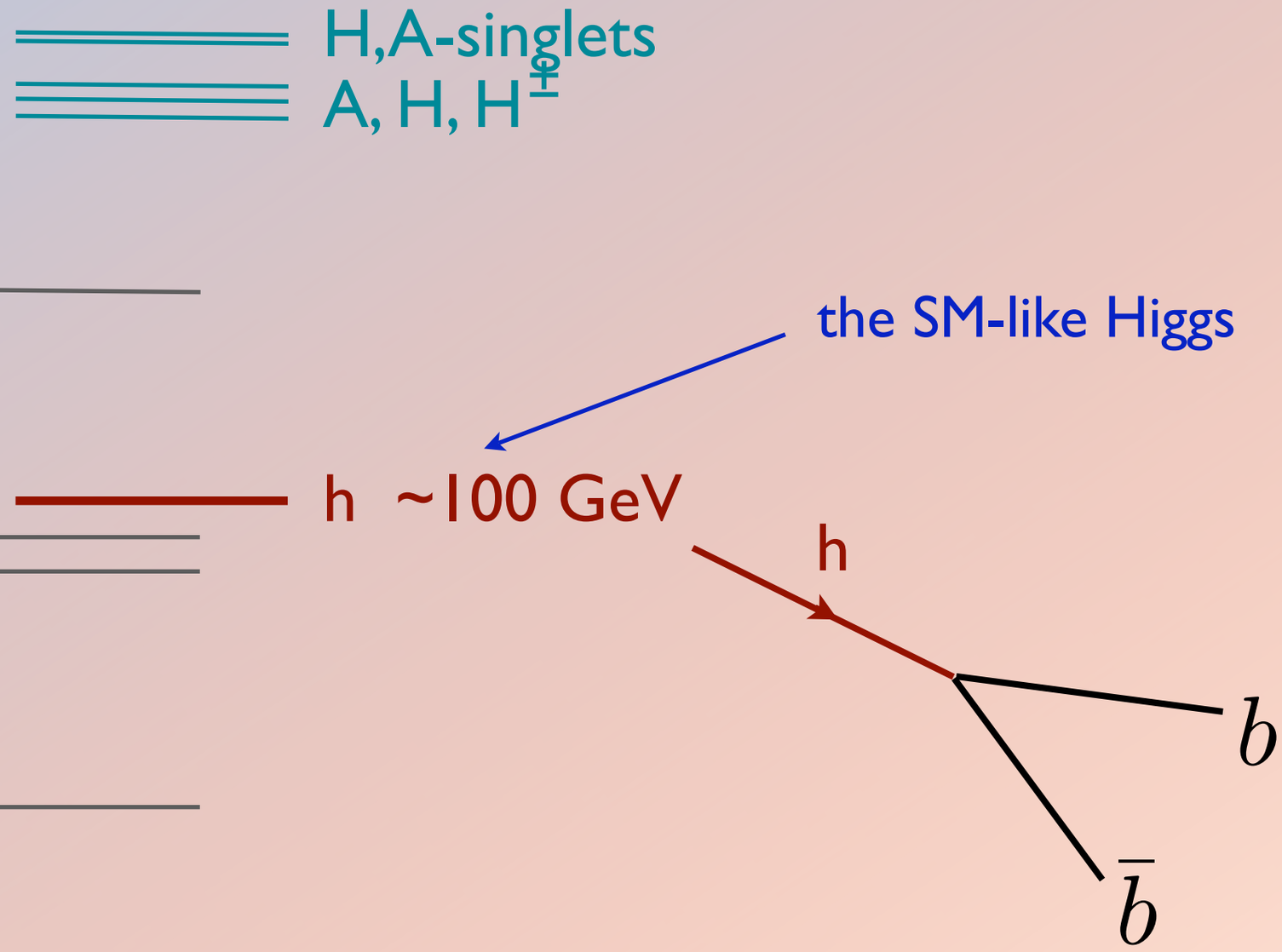






Natural electroweak symmetry breaking in SUSY models is achieved only in this region!

(N)MSSM - the usual story (decoupling)



NMSSM with a light CP odd Higgs

R.D. and J. Gunion, 2005

H-singlet
$A, H, H^{\pm}$

the usual decoupled scenario (for the two Higgs doublet part)

top

the SM-like Higgs

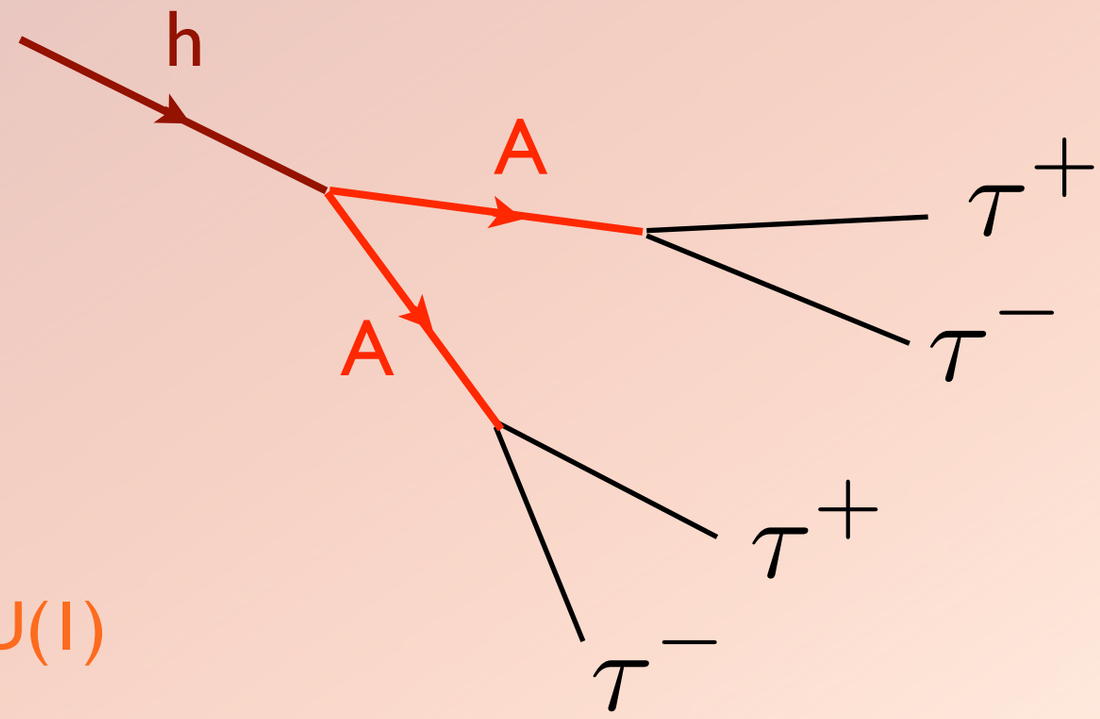
h ~100 GeV

Z
W

10 GeV

A-singlet

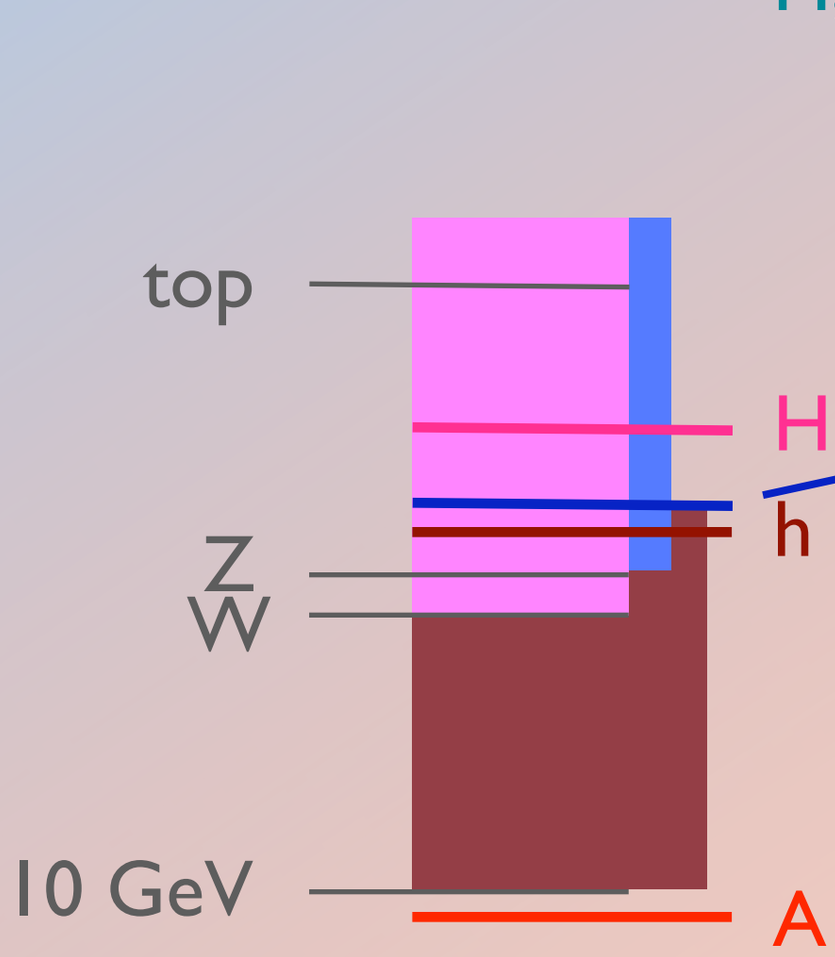
A is light as a result of an approximate global U(1)

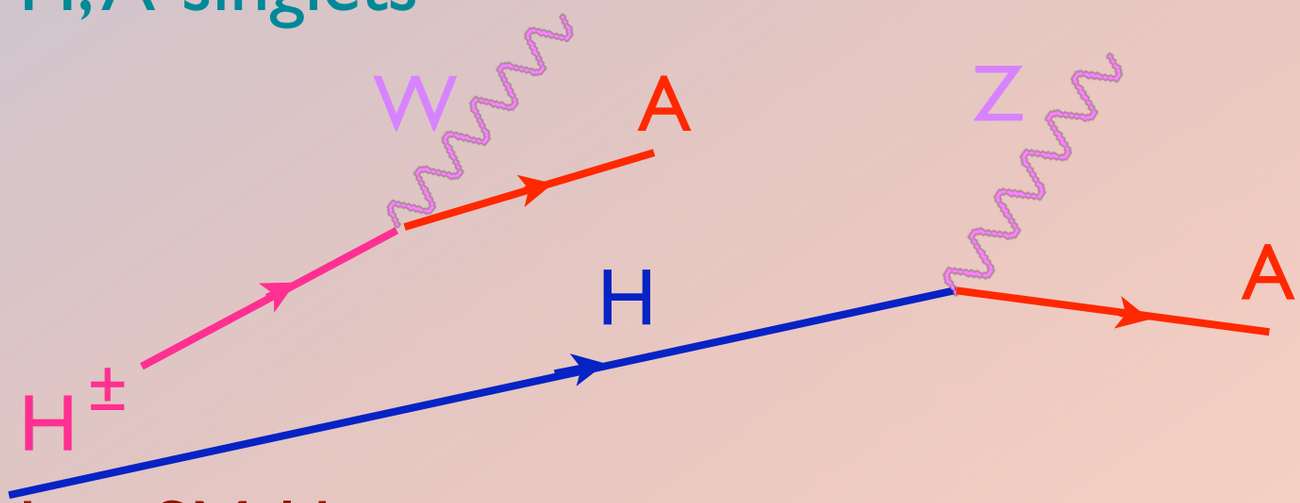


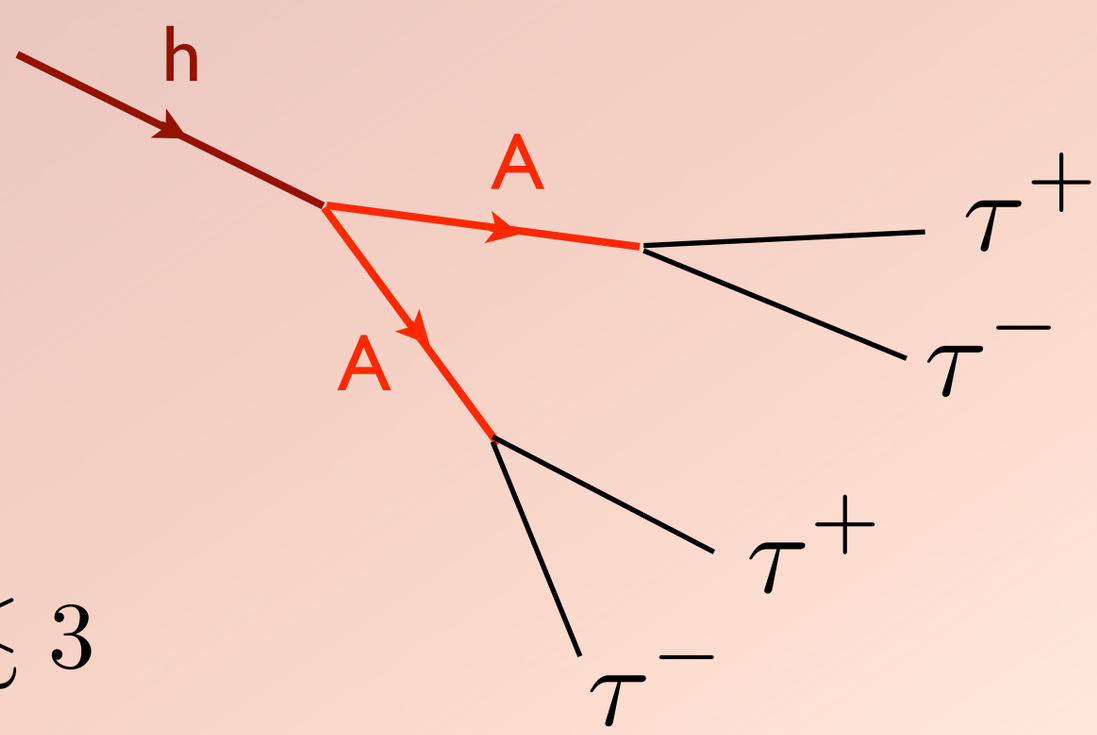
Models with a light doublet-like A

R.D., arXiv:0806.0847 [hep-ph], R.D. and J. Gunion, arXiv:0811.3537 [hep-ph]

H, A-singlets







viable e.g. in NMSSM for $\tan\beta \lesssim 3$

More complex Higgs decays

- $h \to aa \to 4\tau$, 4q, 4g - simplest possibilities allowing $m_h \simeq 100$ GeV
- more complex possibilities:

$$h \to 2\phi_2 \to 4\phi_1 \to 8f$$

$$h \to 2\phi_i \to 4\phi_j \to \cdots \to \text{(large number of) } f$$

if the lightest scalar is lighter than $2m_e$:

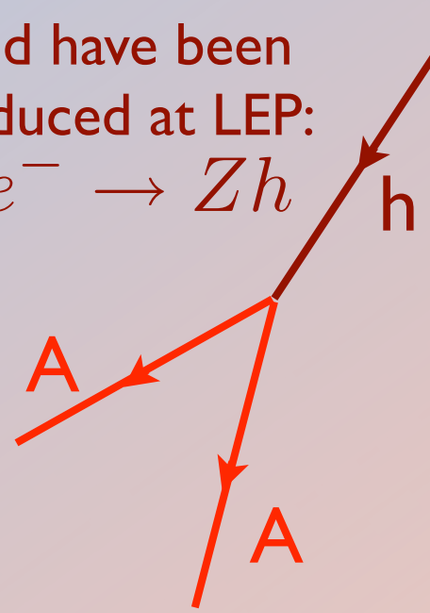
$$h \to \text{(large number of) } \gamma$$

jets of soft particles

Summary of the Light doublet-like CP odd Higgs scenario

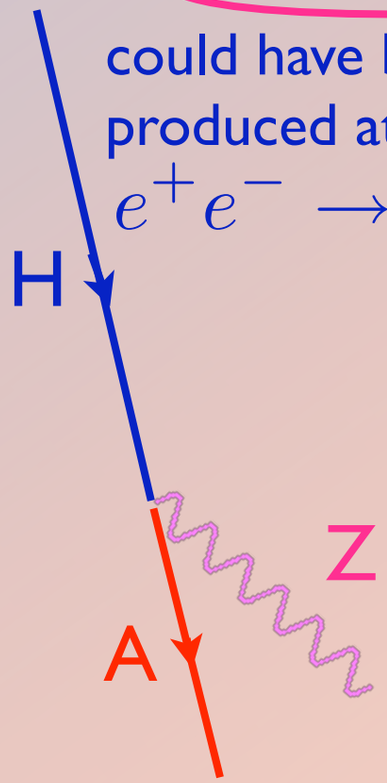
- all the Higgses (from two Higgs doublets) are fairly light
- all the Higgses: h, H, $H^{\pm}$ decay through the CP odd Higgs - A

could have been produced at LEP: $e^+e^- \to Zh$



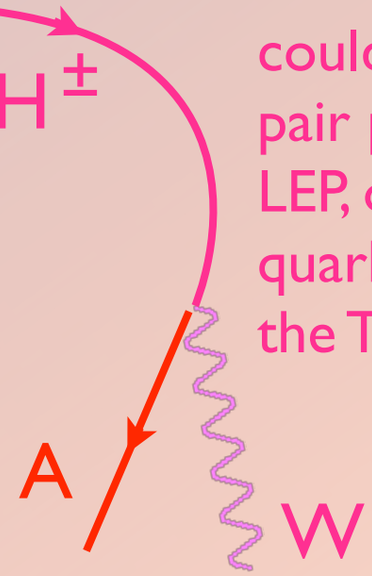
ongoing searches and studies at Aleph, L3, Tevatron, LHC

could have been produced at LEP: $e^+e^- \to HA$



no searches or studies

$H^{\pm}$



recent search at CDF

could have been pair produced at LEP, or in top quark decays at the Tevatron

could have been produced at B factories

$\Upsilon \to A\gamma$

searches at B factories

direct production at Tevatron and LHC

- the extra singlet is not necessary

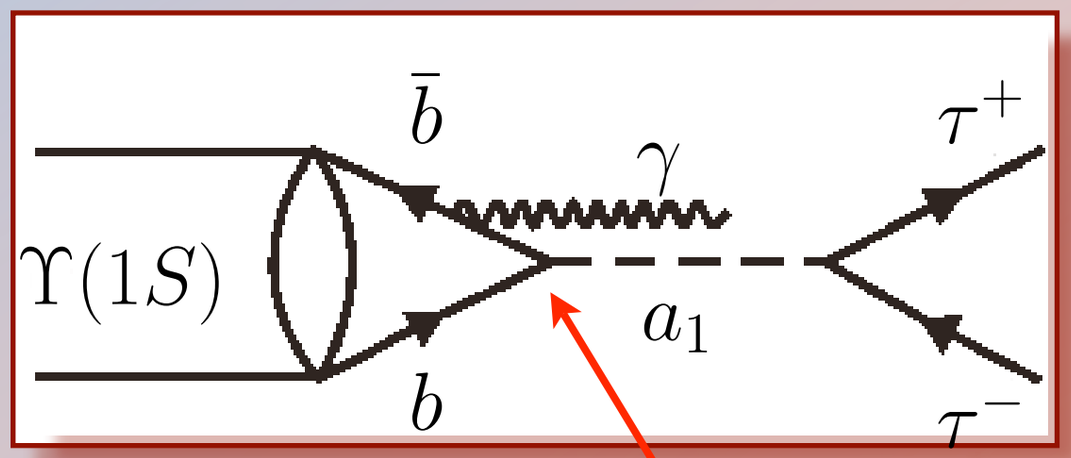
the scenario can be viable in many other models!

Light CP odd Higgs at B factories

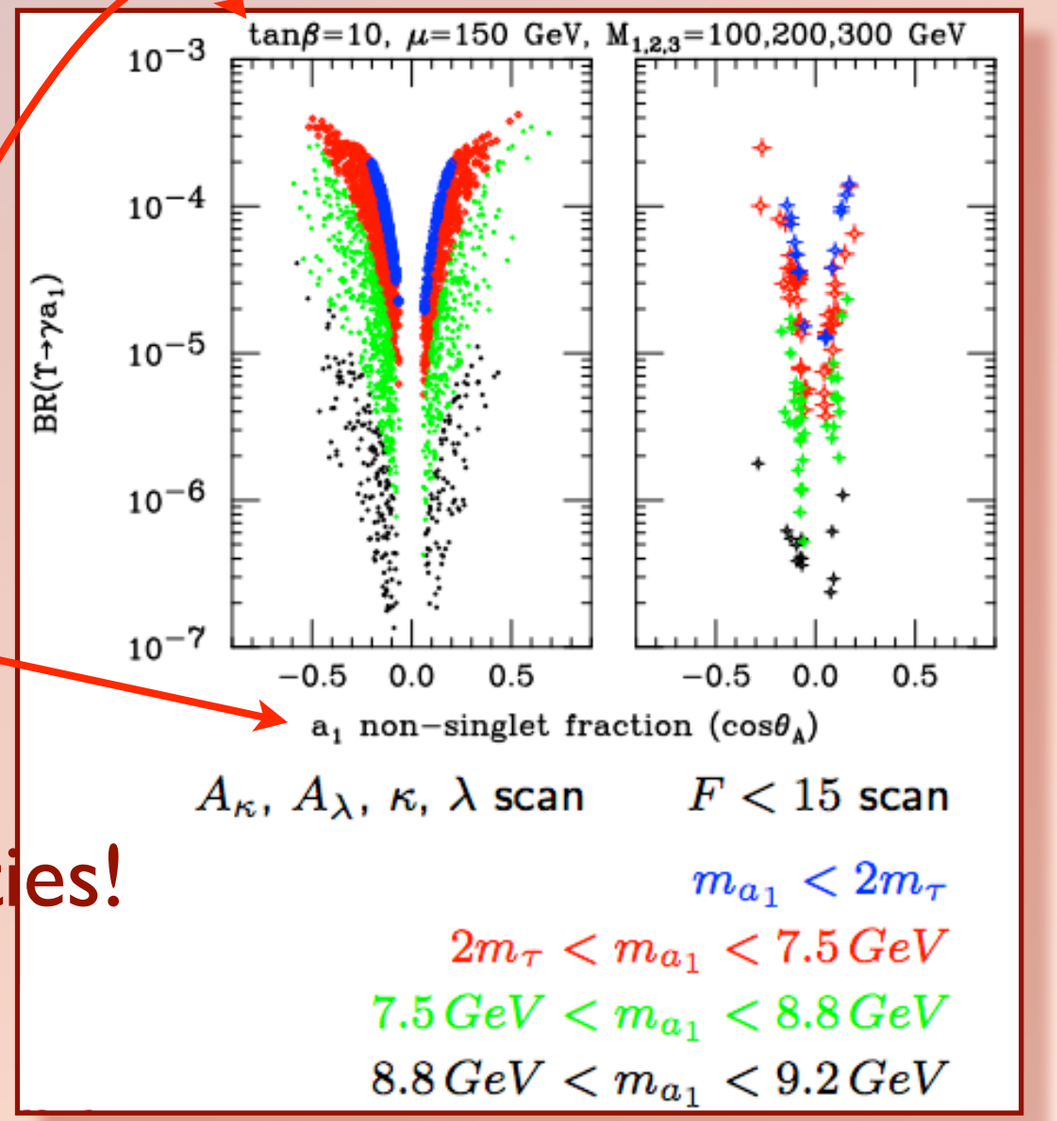
R.D., J. Gunion and B. McElrath, hep-ph/0612031

A could have been produced at B factories: $\Upsilon \to A\gamma$

(it is advantageous to search in $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$ data)



$$C_{a_1 b\bar{b}} = \cos\theta_A \tan\beta$$



Within the reach at existing facilities!

Light CP odd Higgs at B factories

R.D., J. Gunion and B. McElrath, hep-ph/0612031

A could have been produced at B factories: $\Upsilon \to A\gamma$

(it is advantageous to search in $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$ data)

CLEO, arXiv:0807.1427 [hep-ex]

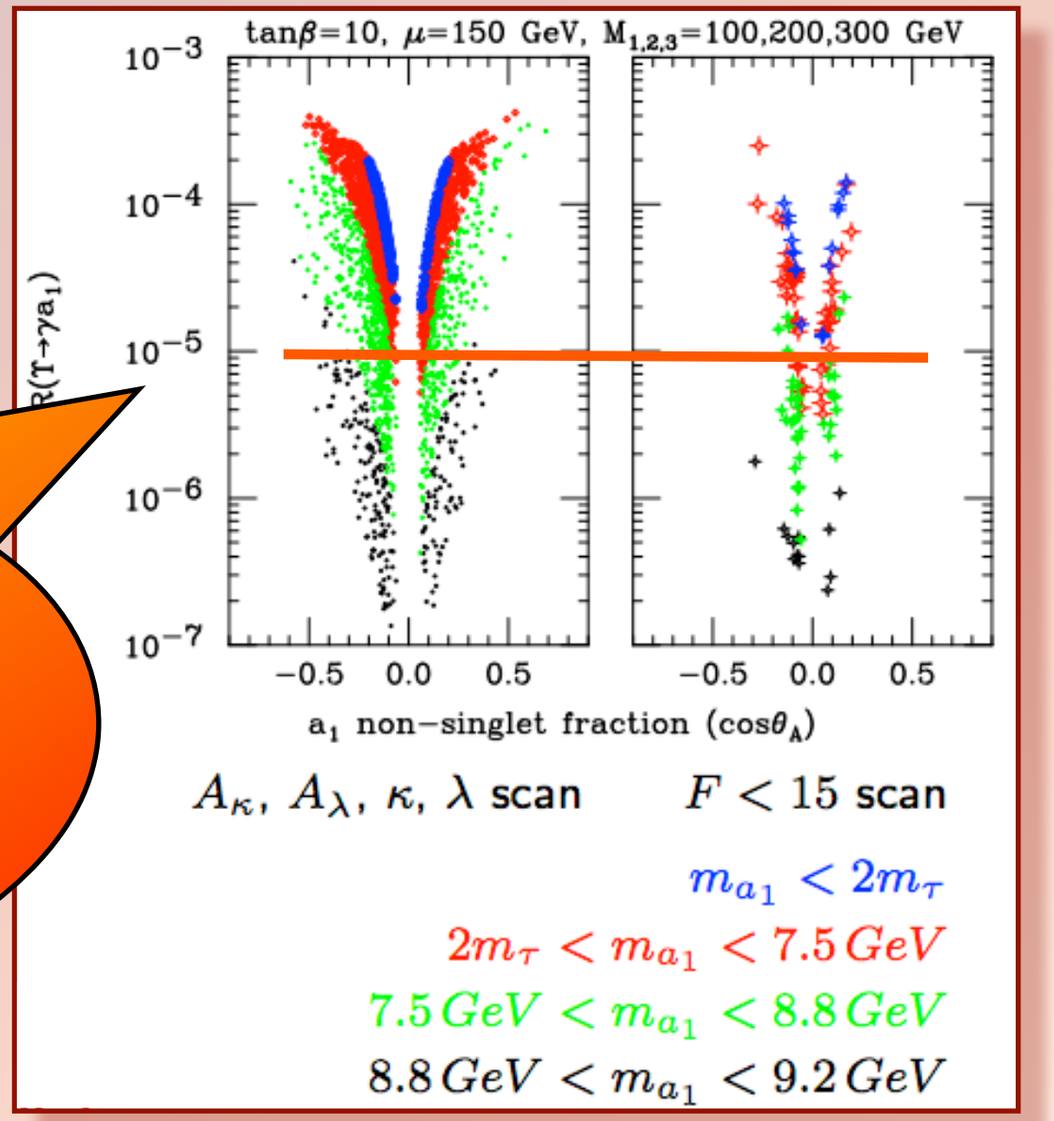
BaBar, arXiv:0902.2176 [hep-ex]

BaBar, arXiv:0906.2219 [hep-ex]

Limits typically require

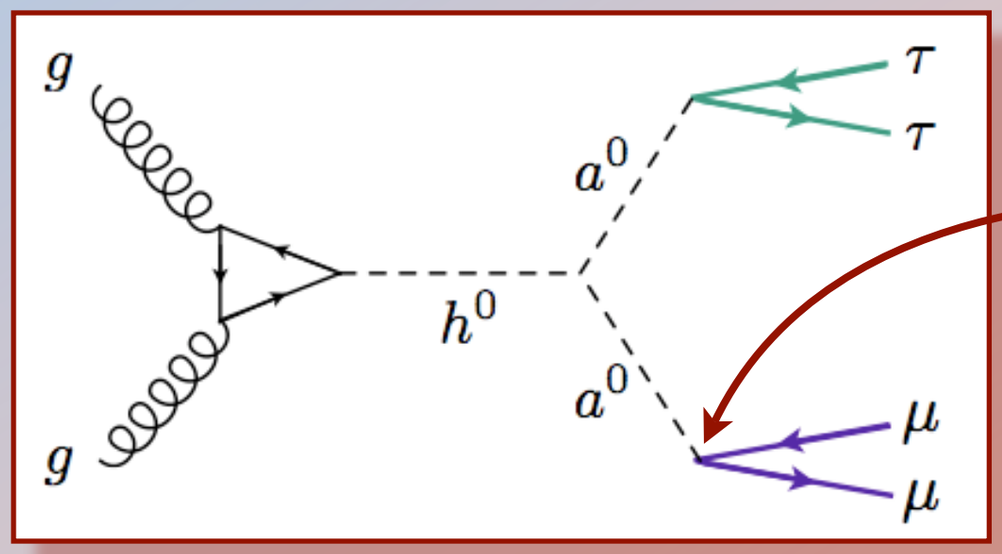
$$m_a \gtrsim 8 \text{ GeV}$$

and are easier to satisfy for smaller $\tan\beta$.



Tevatron searches for $h \longrightarrow aa \longrightarrow 4\tau$

DØ, arXiv:0905.3381 [hep-ex] (PRL)



M. Lisanti and J. Wacker, arXiv:0903.1377 [hep-ph]

$$\frac{\Gamma(a^0 \to \mu^+\mu^-)}{\Gamma(a^0 \to \tau^+\tau^-)} = \frac{m_\mu^2}{m_\tau^2\sqrt{1-(2m_\tau/m_{a^0})^2}}$$

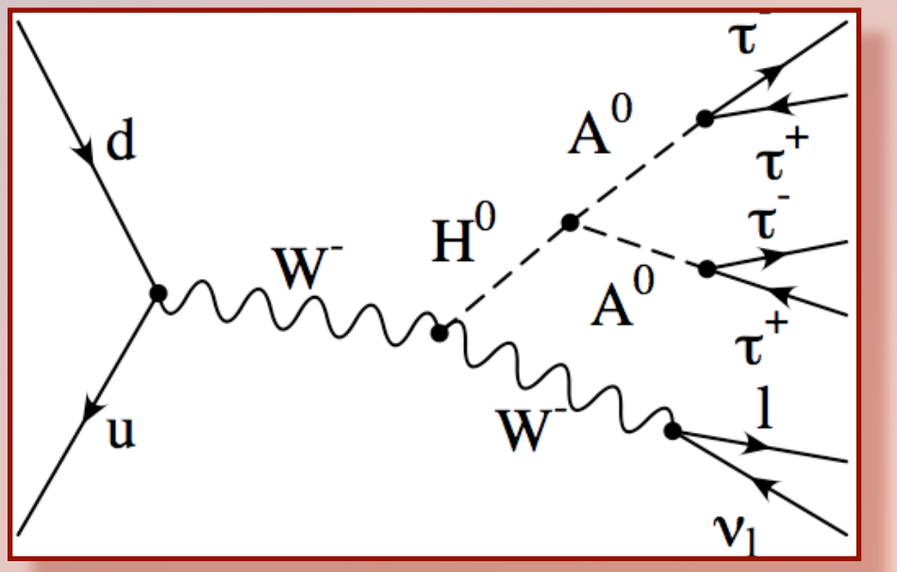
smaller but cleaner!

DØ search not sensitive yet

should be relatively easy at the LHC

~500 events with $1\mathrm{fb}^{-1}$

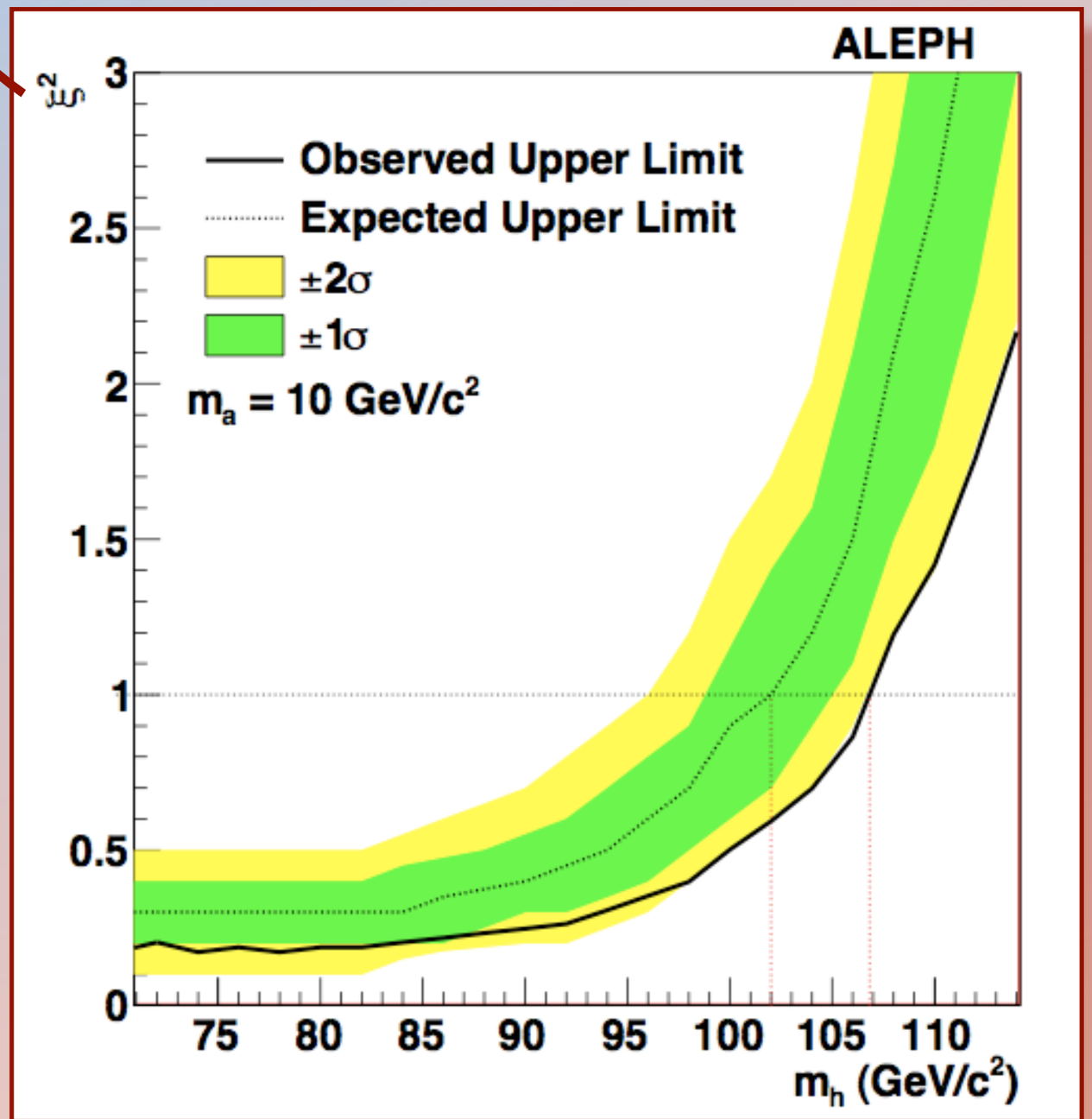
S. Wilbur, CDF, in progress

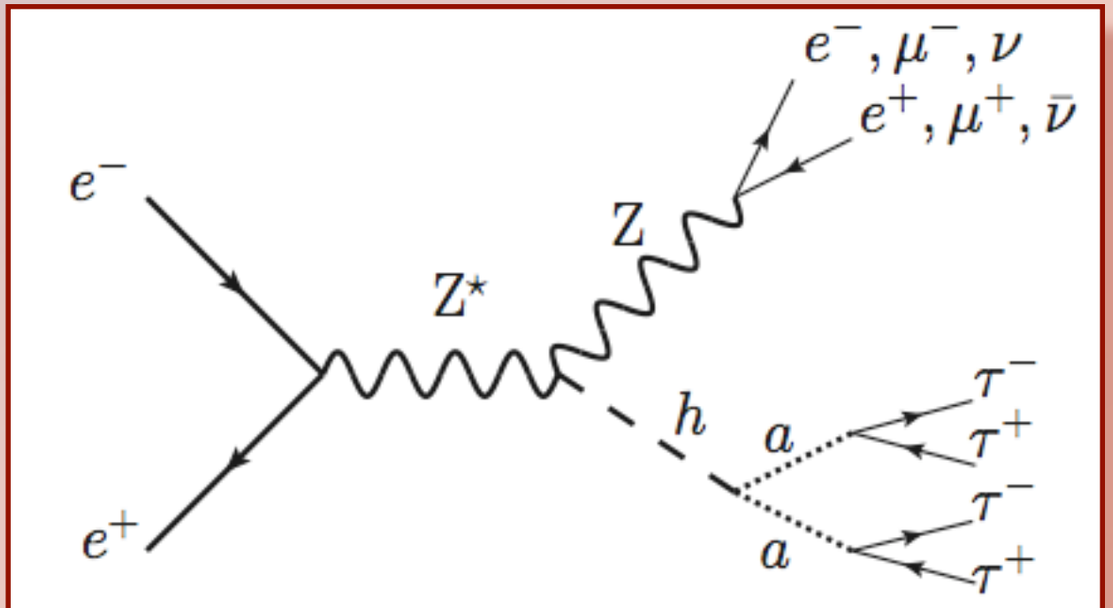


Aleph search for $h \longrightarrow aa \longrightarrow 4\tau$

$$\xi^2 = \frac{\sigma(e^+e^- \to Zh)}{\sigma_{SM}(e^+e^- \to Zh)} \times B(h \to aa) \times B(a \to \tau^+\tau^-)^2$$

K. Cranmer, Aleph, arXiv:1003.0705 [hep-ex]

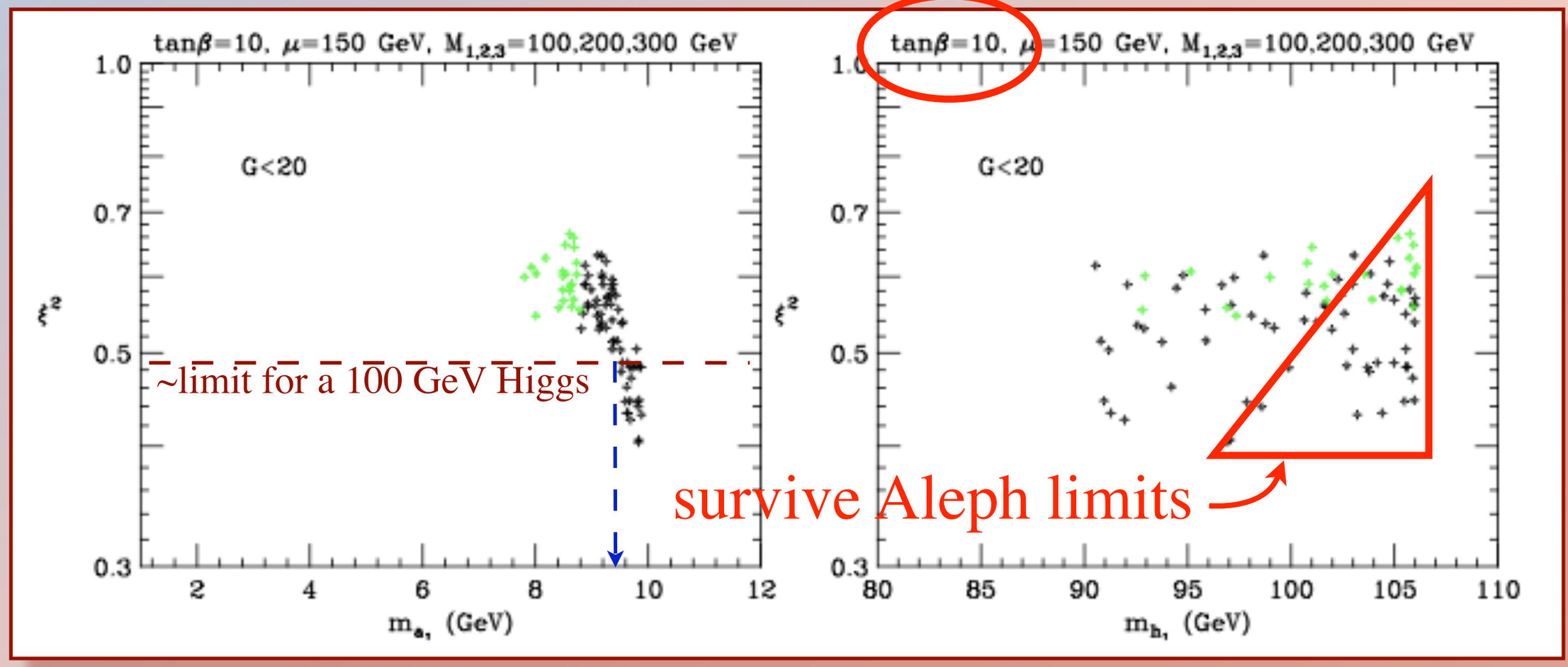




Aleph search for $h \longrightarrow aa \longrightarrow 4\tau$

R.D. and J. Gunion, arXiv:1002.1971 [hep-ph]

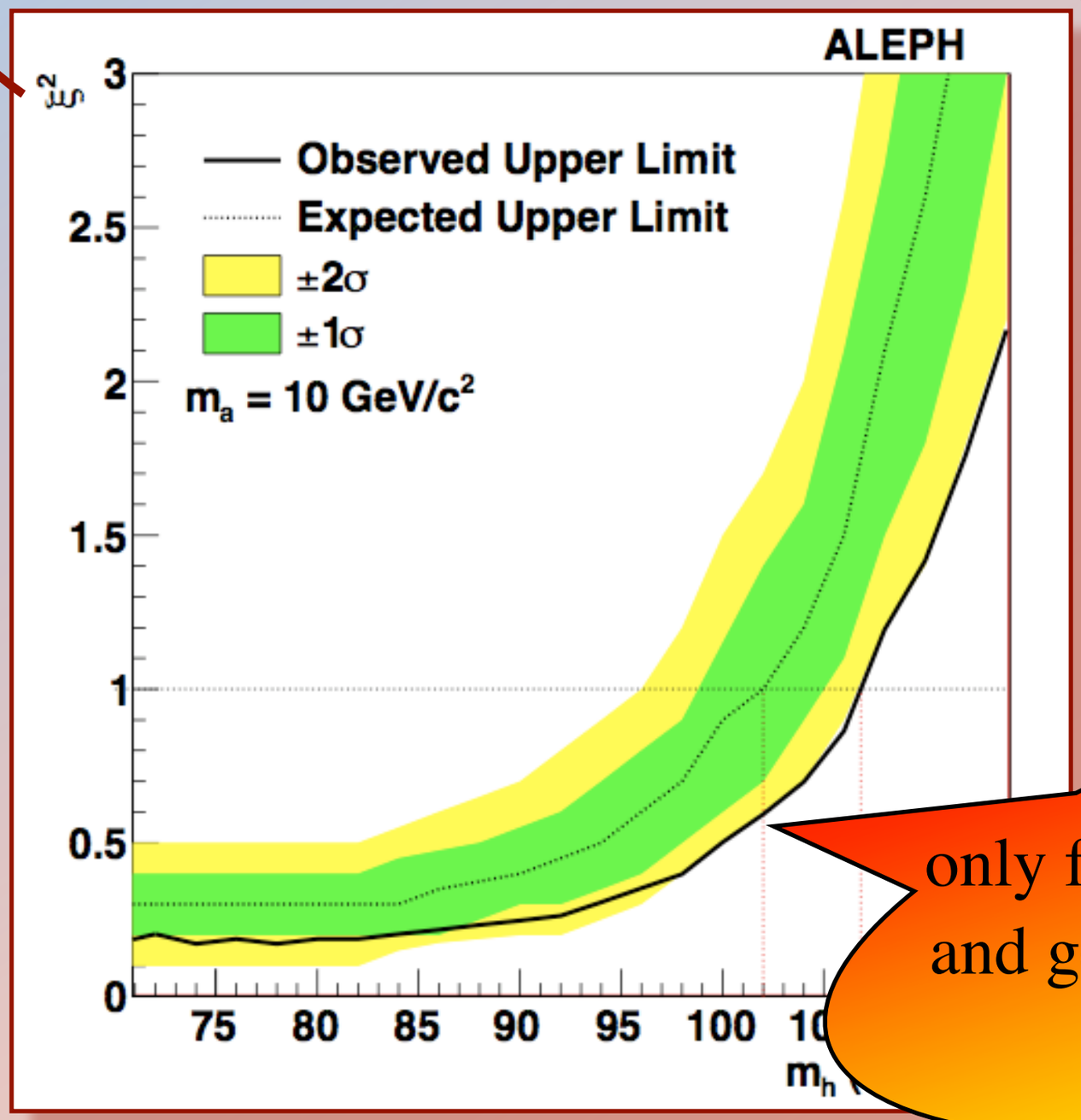
NMSSM scan over trilinear and soft-trilinear couplings, scalars fixed to 300 GeV

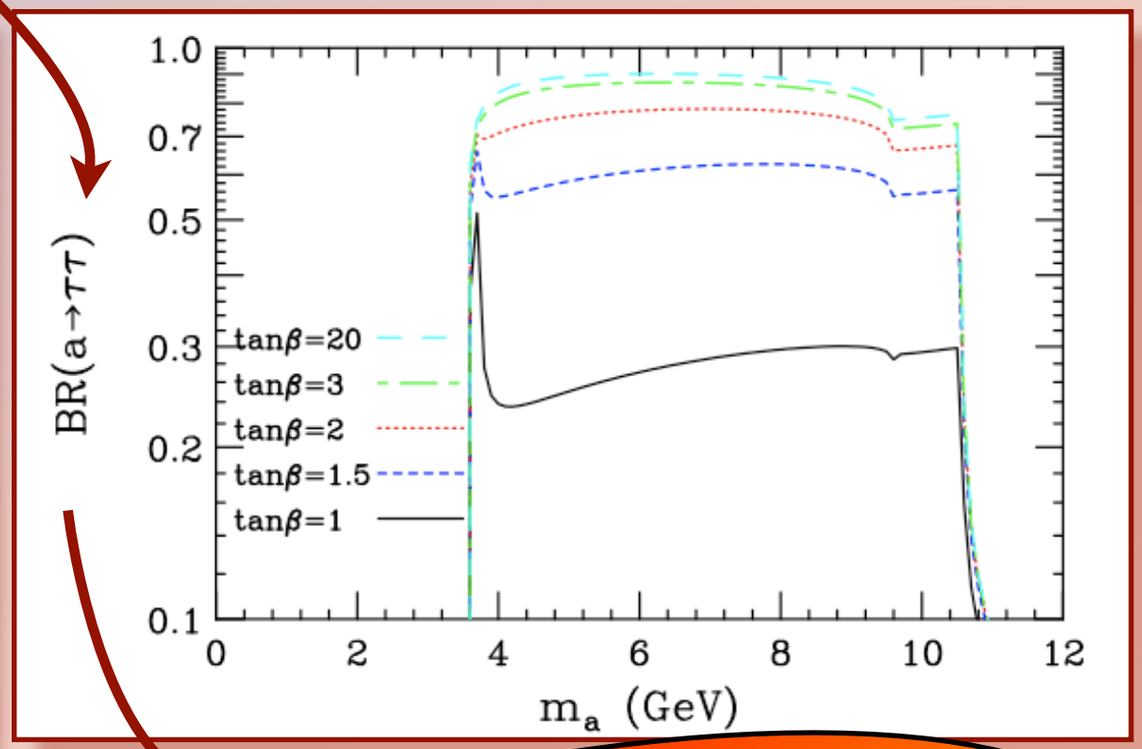


Aleph search for $h \longrightarrow aa \longrightarrow 4\tau$

$$\xi^2 = \frac{\sigma(e^+e^- \to Zh)}{\sigma_{SM}(e^+e^- \to Zh)} \times B(h \to aa) \times B(a \to \tau^+\tau^-)^2$$

R.D. and J. Gunion, arXiv:1002.1971 [hep-ph]





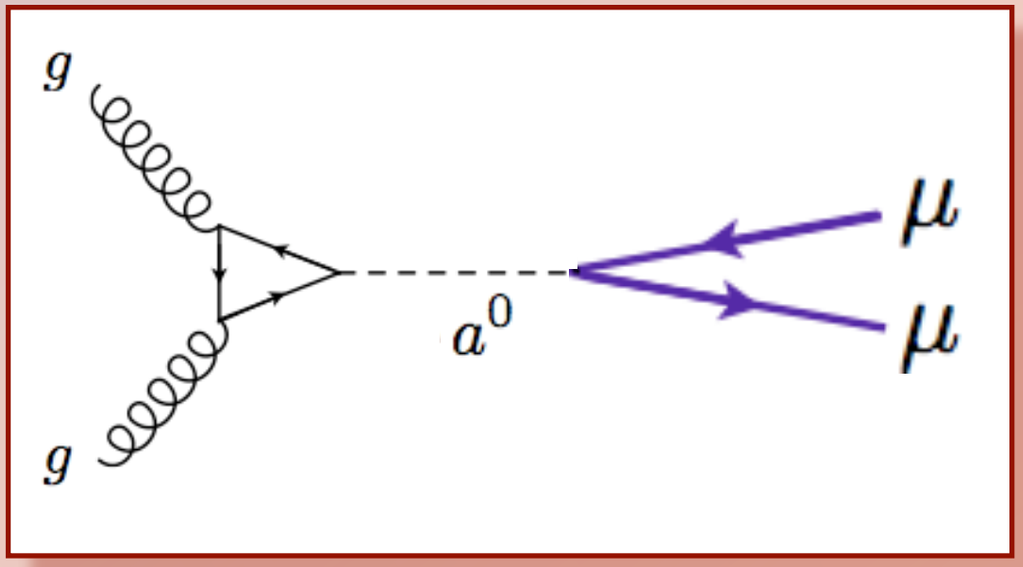
Limits allow
$m_h \simeq 100$ GeV
only for $m_a \simeq 10$ GeV when $\tan\beta > 3$
and generically for $\tan\beta \lesssim 2$

Light CP odd Higgs at Tevatron and LHC

R.D. and J. Gunion, arXiv:0911.2460 [hep-ph]

Looking for direct production of A:

- CDF and DØ can improve on Babar limits especially for heavier CP odd Higgs



- at the LHC we might discover a light CP odd Higgs soon:

integrated luminosity (fb^{-1}) needed for 5σ:

Case	$m_a = 8$ GeV	$m_a = M_{\Upsilon_{1S}}$	$m_a \lesssim 2m_B$
ATLAS LHC7	$17/r^2$	$63/r^2$	$9/r^2$
ATLAS LHC10	$13/r^2$	$48/r^2$	$7/r^2$
ATLAS LHC14	$10/r^2$	$37/r^2$	$5.4/r^2$

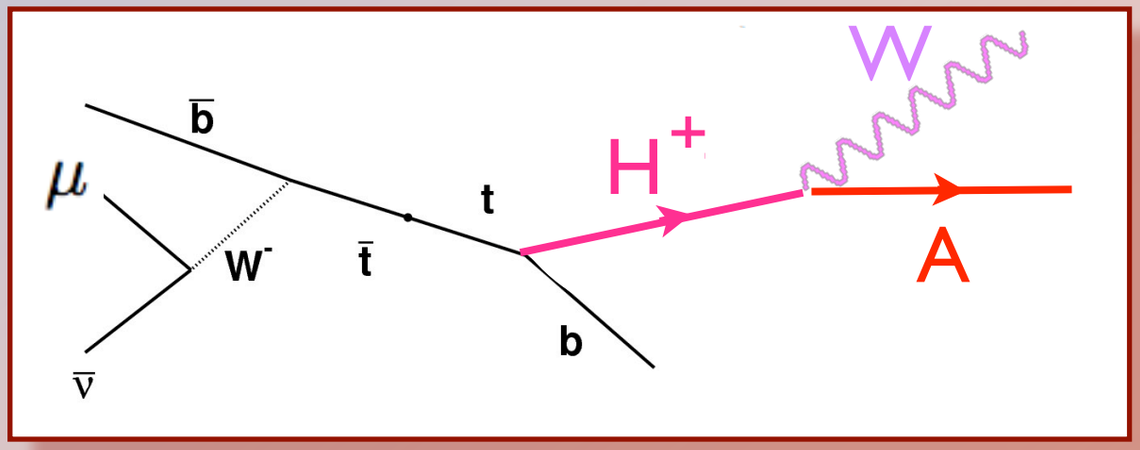
$$\cos\theta_A = 0.1$$
$$\tan\beta = 10$$

$$\epsilon_{ATLAS} = 0.1 \times r$$

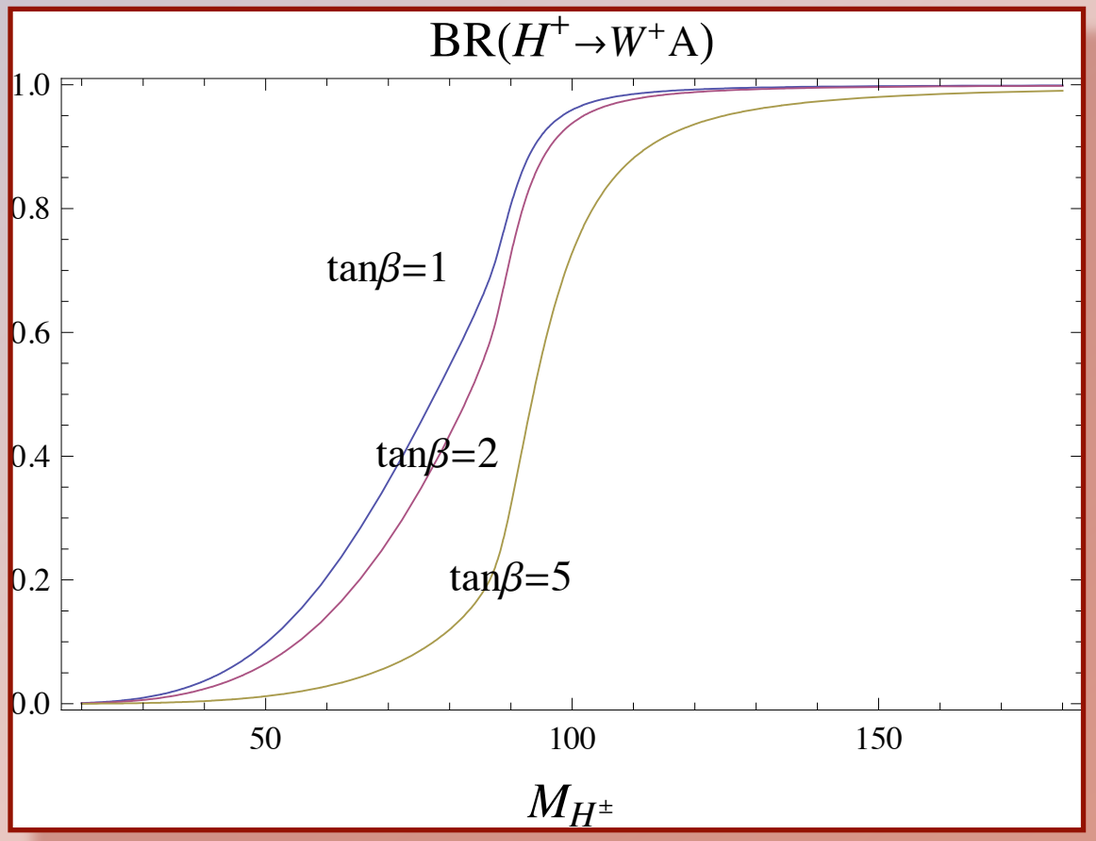
thanks to Yi Yang and Hal Evans

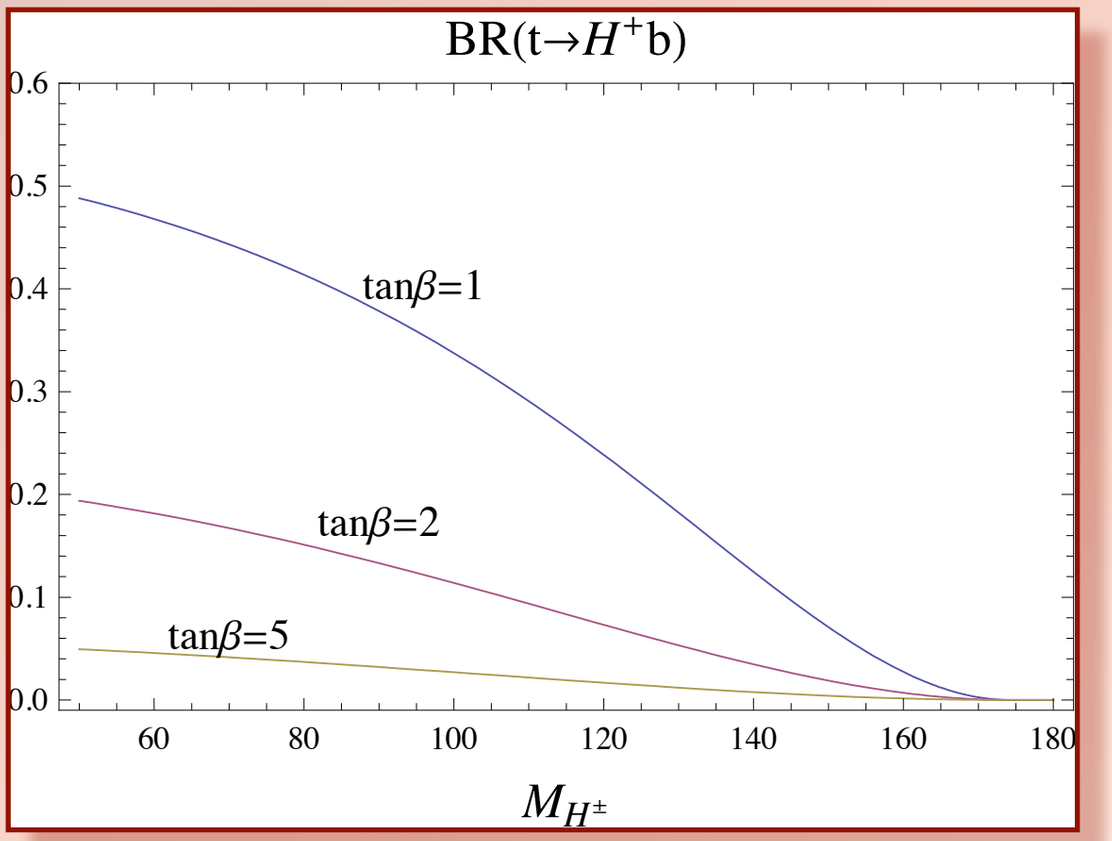
Charged Higgs in Top quark decays

R.D., arXiv:0806.0847 [hep-ph], R.D. and J. Gunion, arXiv:0811.3537 [hep-ph]

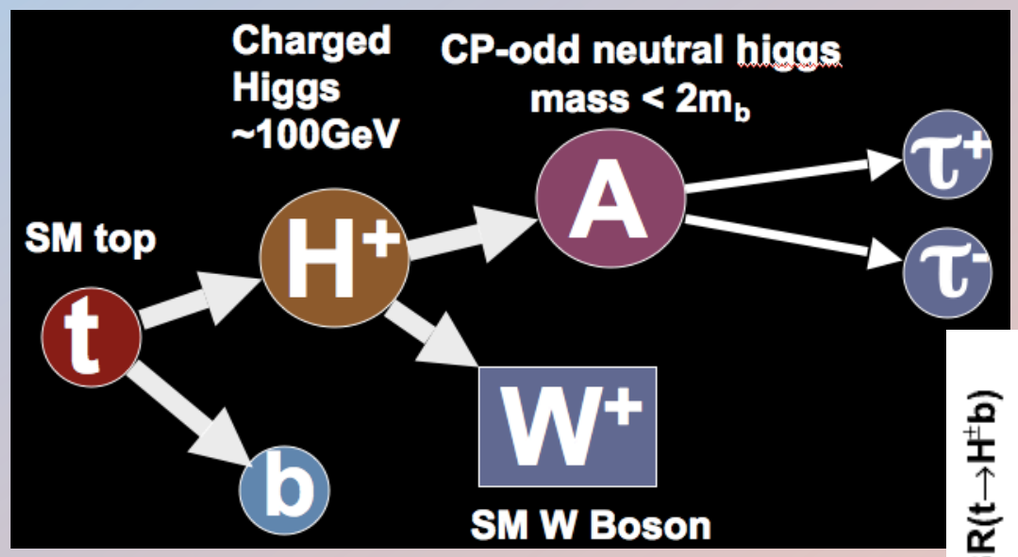


In MSSM:





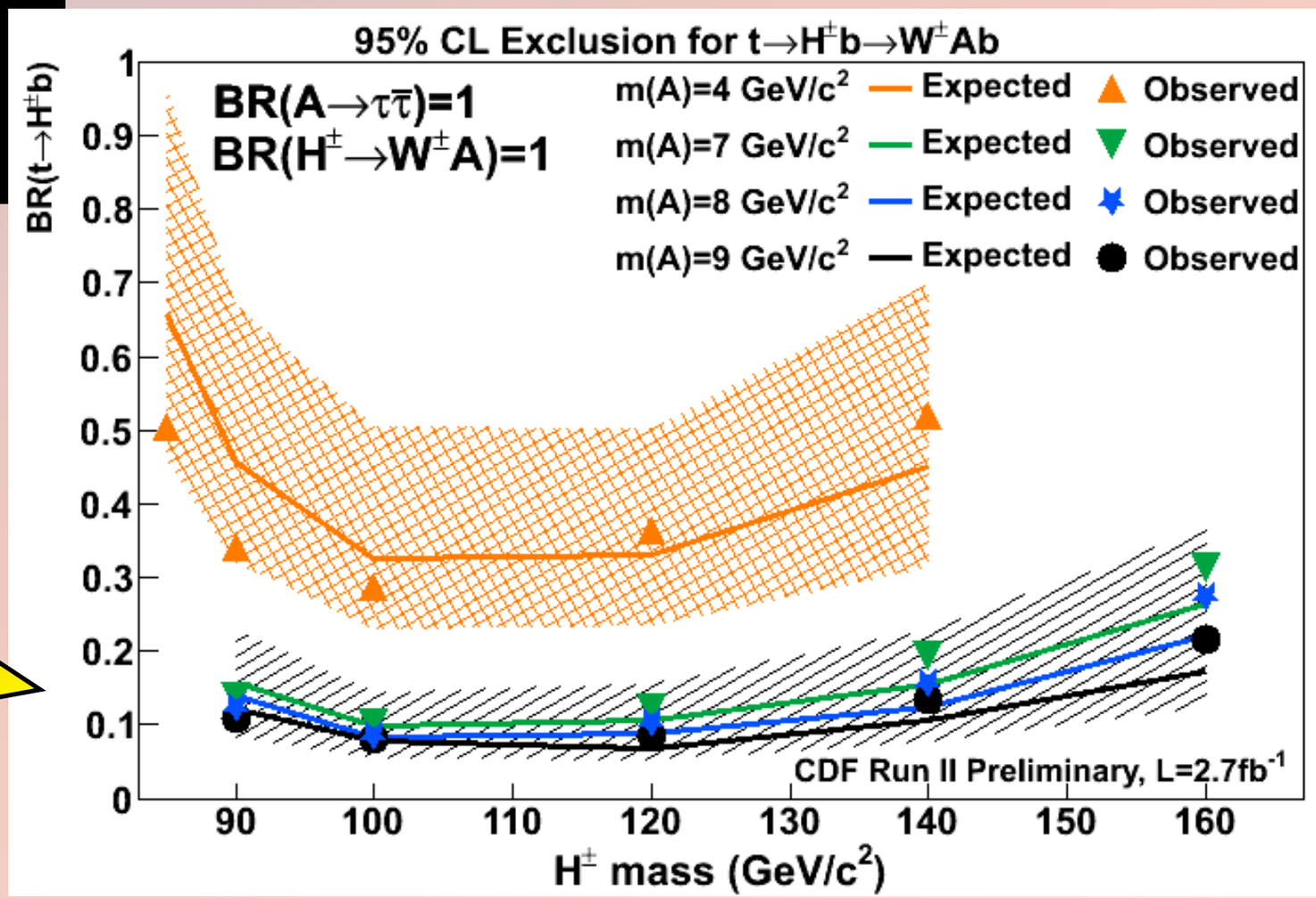
CDF search for charged Higgs



R. Erbacher, A. Ivanov, and W. Johnson, CDF, 2010

Limits allow

$$Br(t \to H^+ b) \sim 10\%$$



Charged Higgs at the LHC

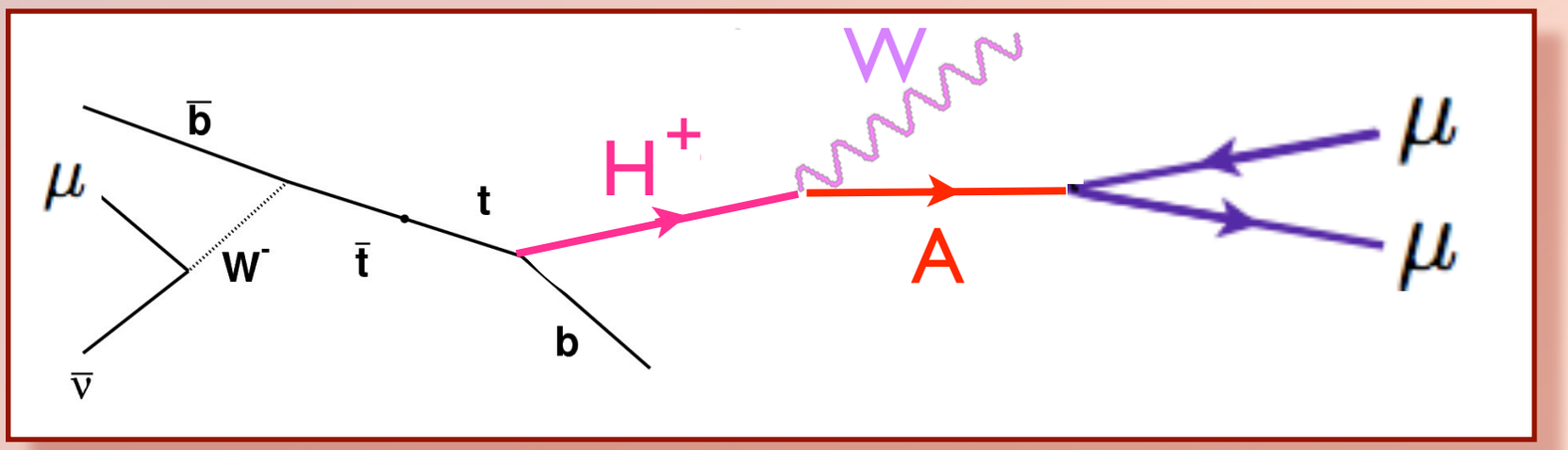
R.D., E. Lunghi and A. Raval, in progress

LHC is a top factory: 4 000 000 top pairs at 10 TeV with 10 fb^{-1}

- one of the two Ws: $W \to \mu\nu$ 20%

- CP-odd Higgs: $a \to \mu\mu$ 1/250

- for $Br(t \to H^+ b) = 10\%$ we have 650 3-muon events



Conclusions

$h \to aa \to 4\tau$, 4q, 4g - simplest possibilities allowing $m_h \simeq 100$ GeV

motivated by naturalness, PEWD, excess of Higgs-like events

dominant decay modes very hard at the LHC (many 100s fb^{-1} needed)

Searching for sub-leading decay modes is very promising:

- $gg \to h \to aa \to 2\tau 2\mu$
- $gg \to a \to 2\mu$
- $t \to H^+ b, \quad H^+ \to W^+ a, \quad a \to \mu^+\mu^-$

possible evidence with $1\,\mathrm{fb}^{-1}$!