Hidden Higgs Scenarios

new constraints and prospects at the LHC

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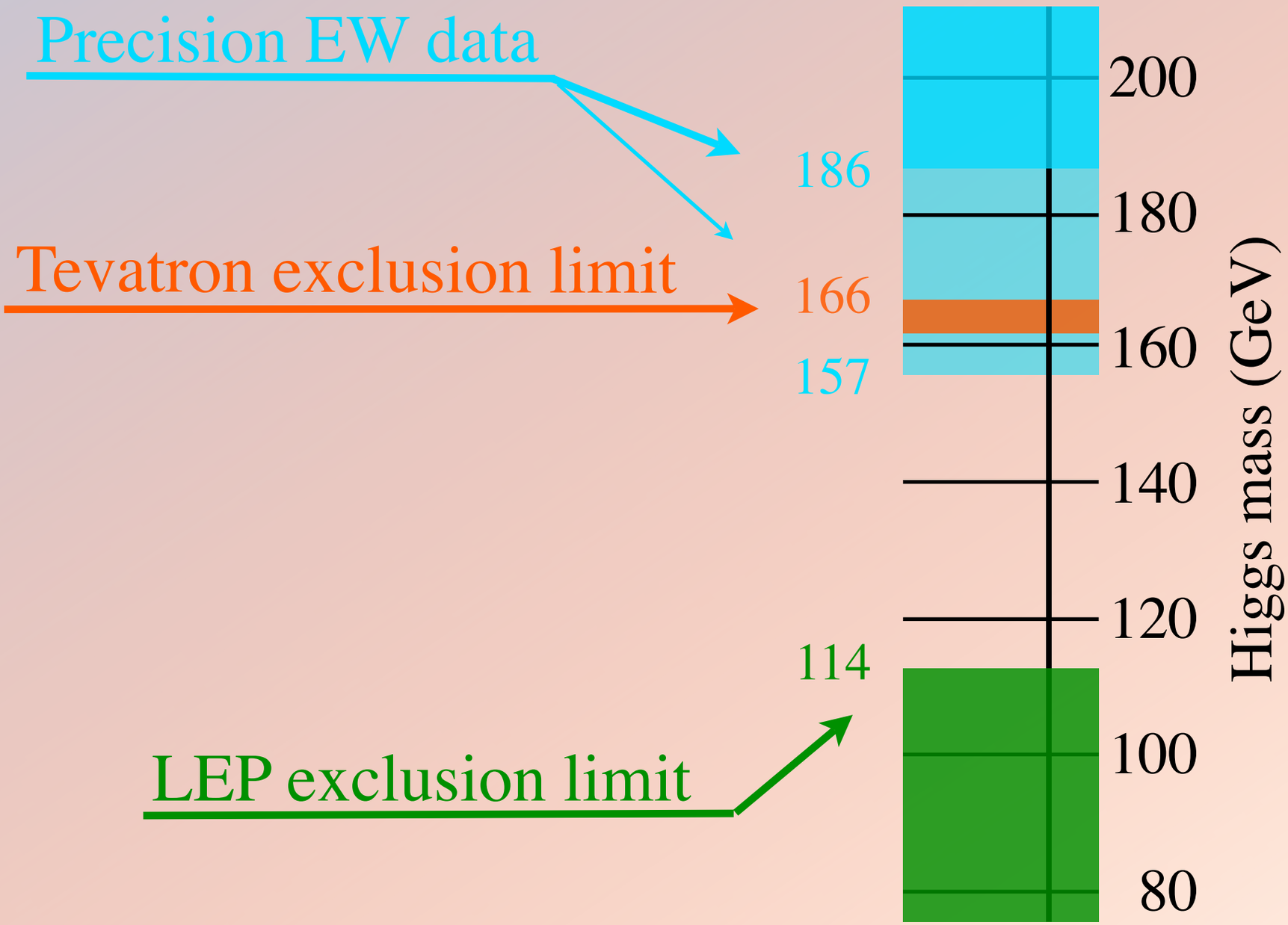
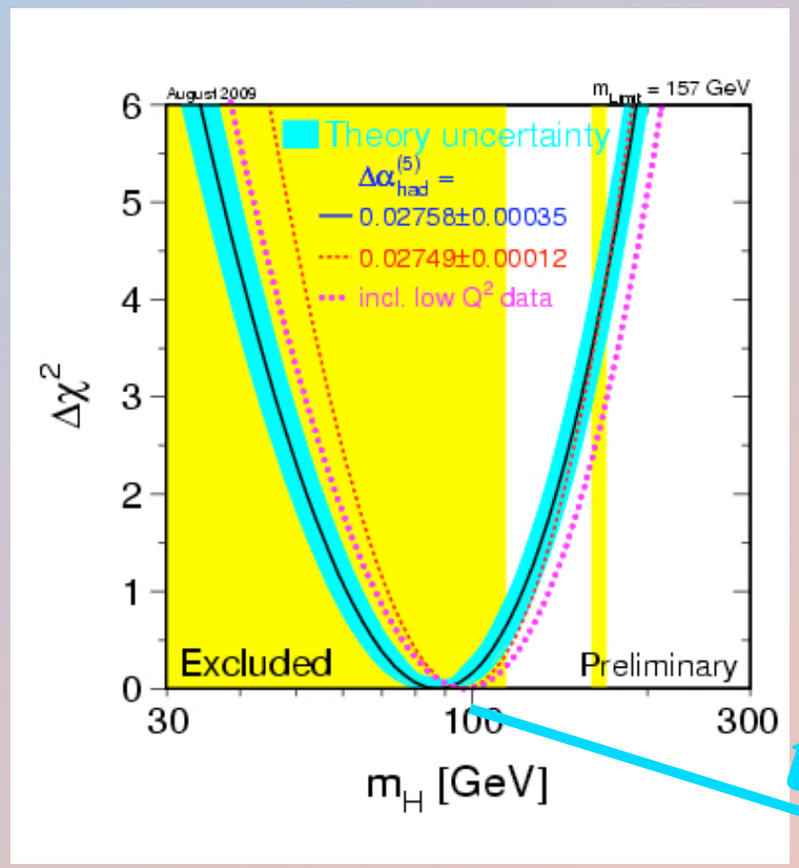
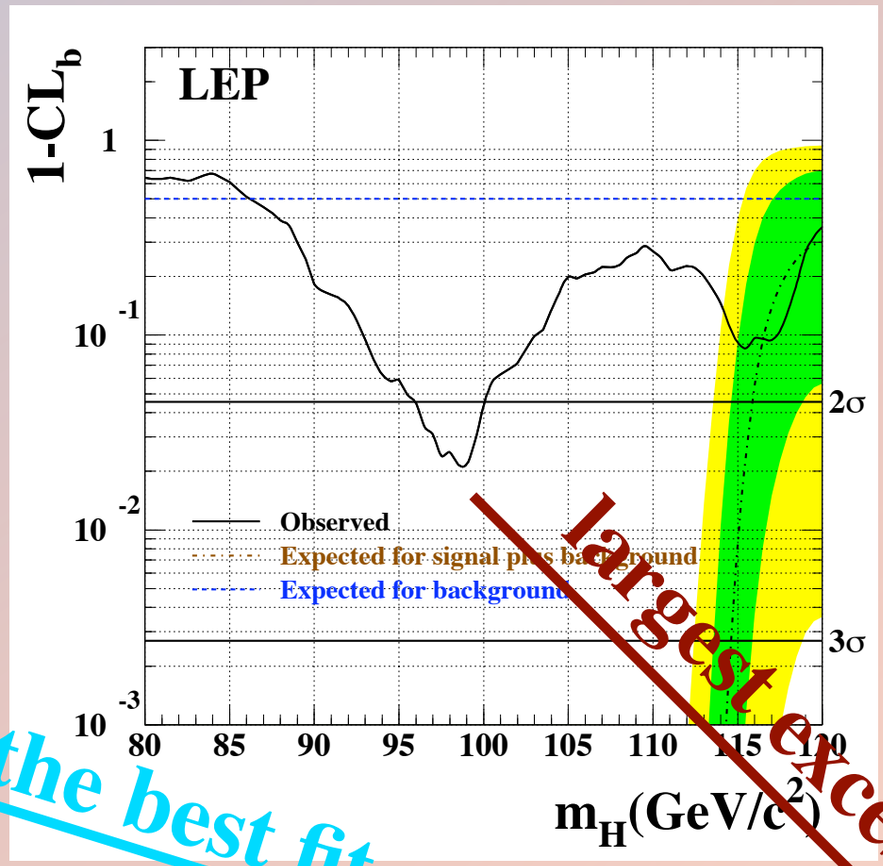
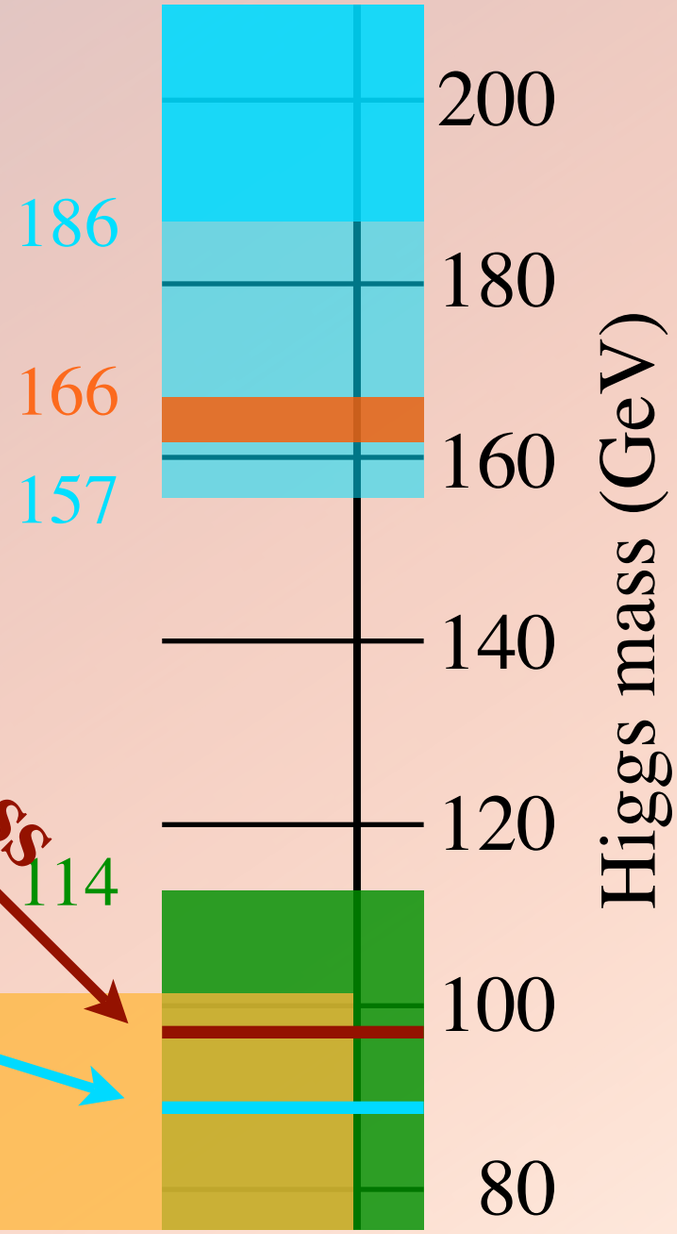
Where is the Higgs?



Where is the Higgs?







the best fit value

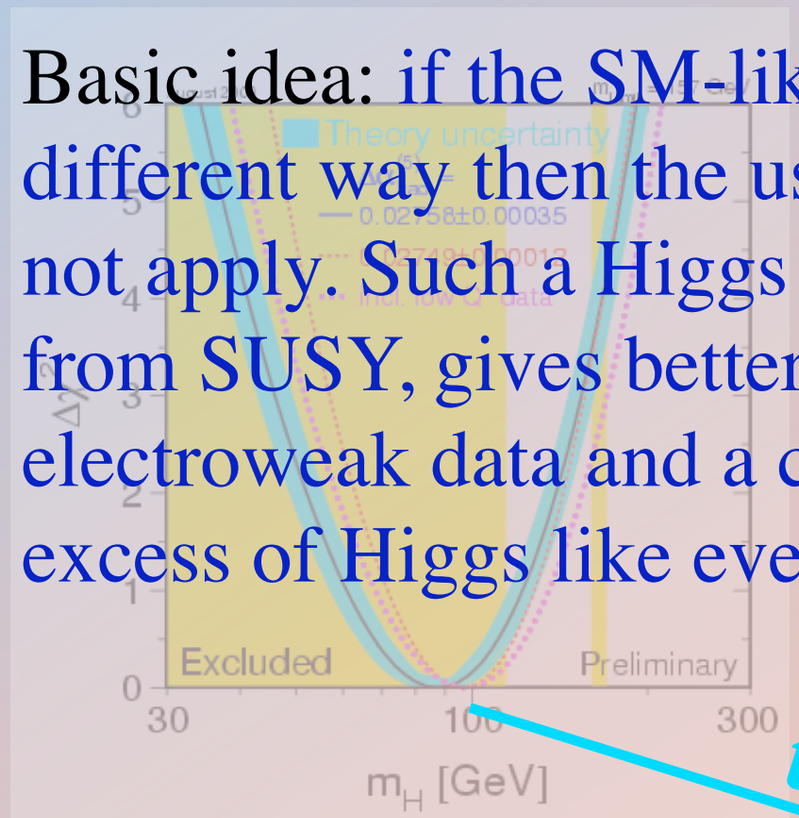
largest excess

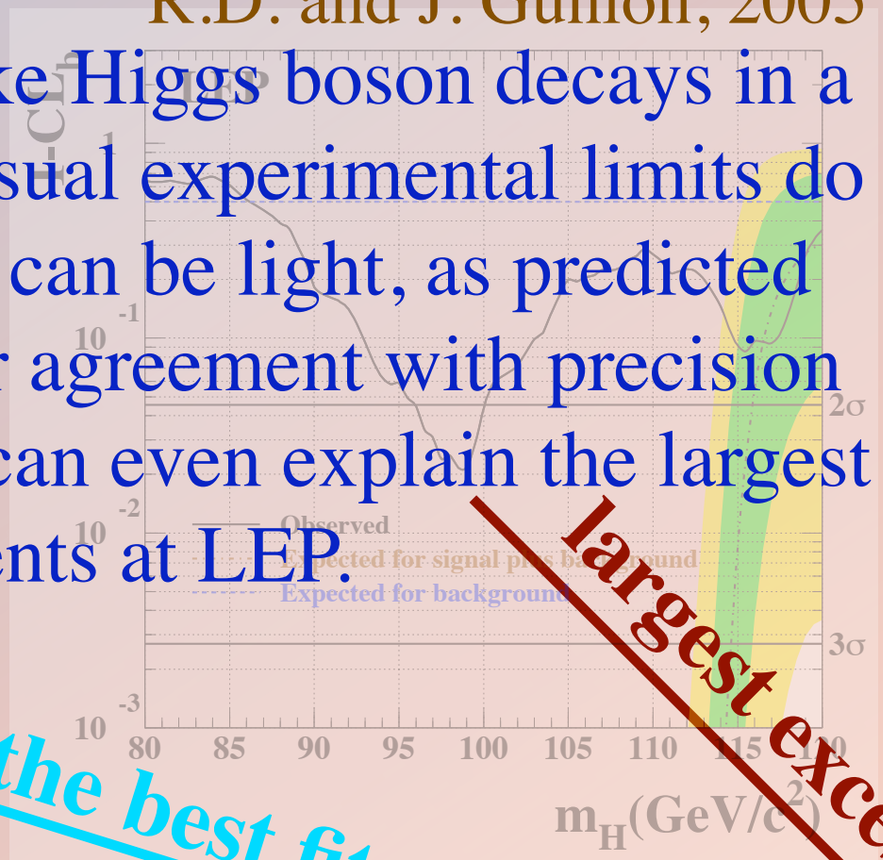
Natural electroweak symmetry breaking in SUSY models is achieved only in this region!

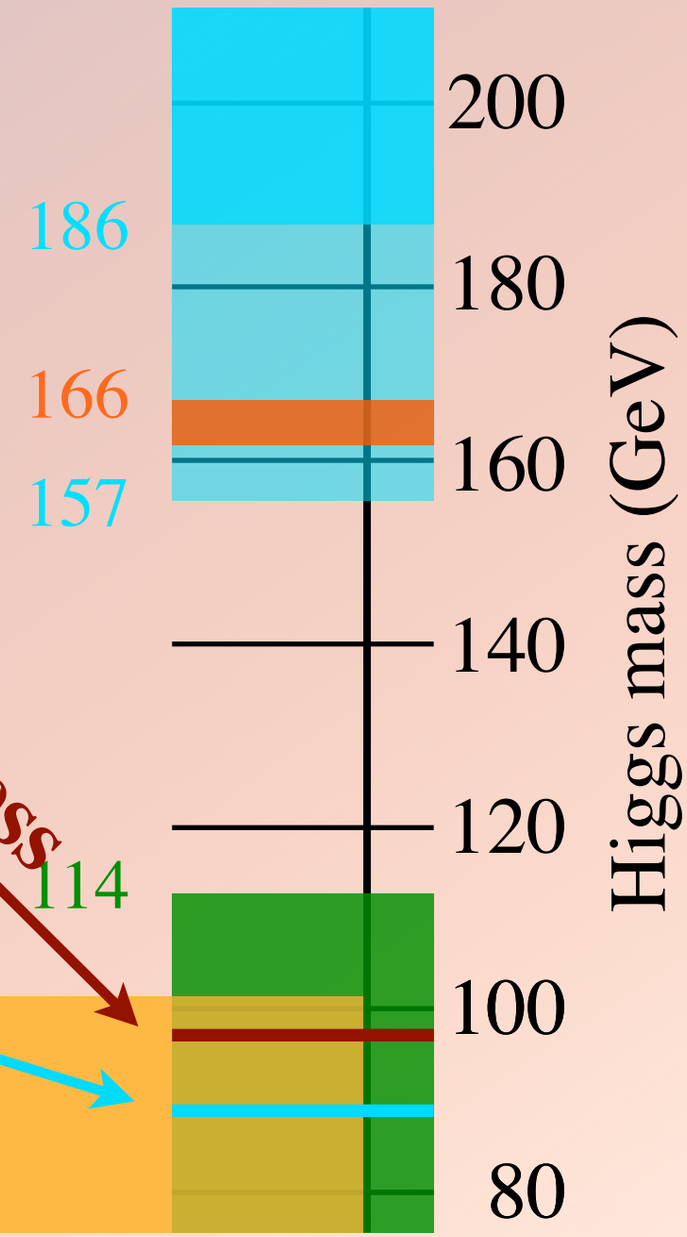
Non-standard Higgs decays

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.

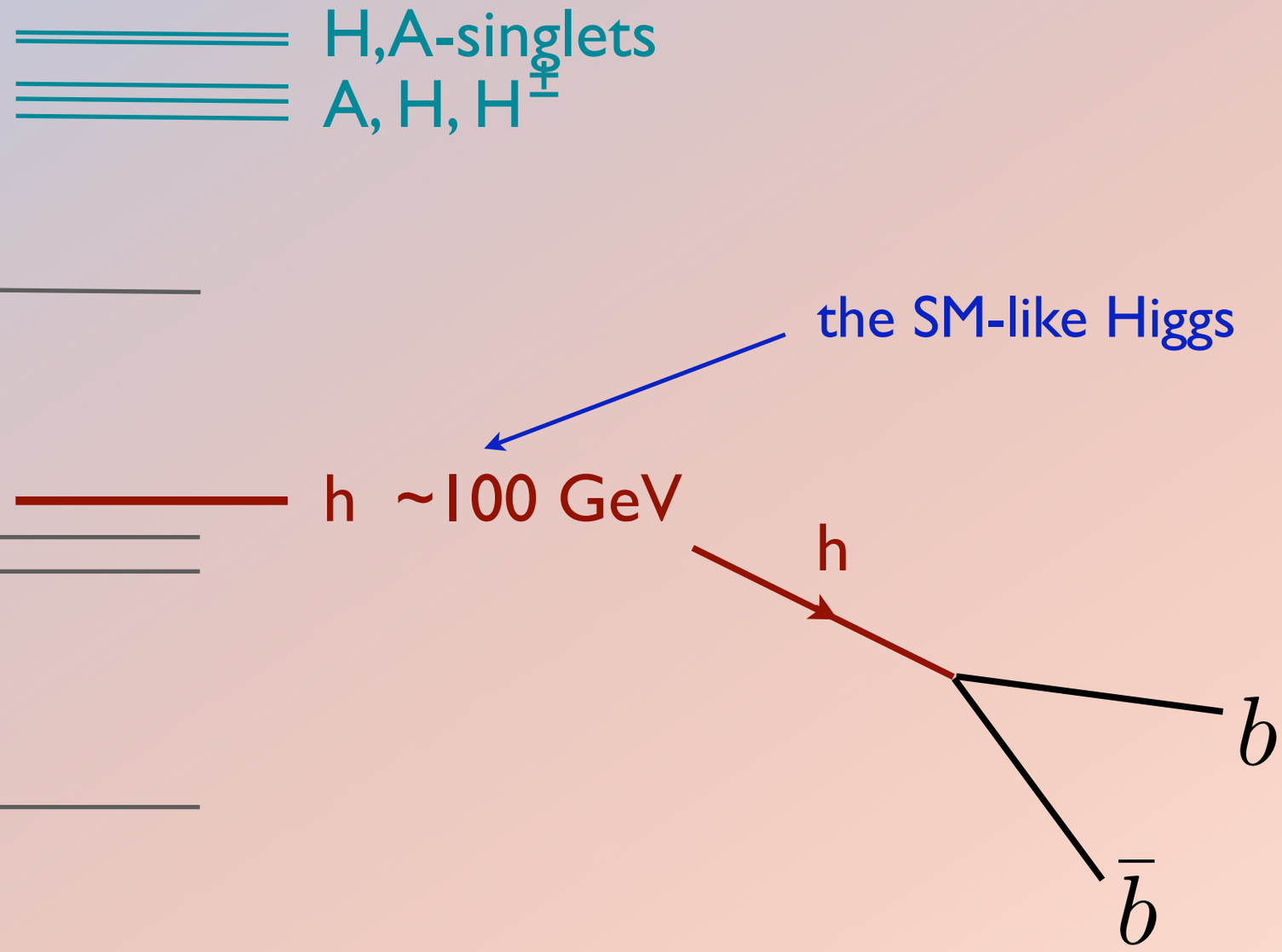






Natural electroweak symmetry breaking in SUSY models is achieved only in this region!

(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

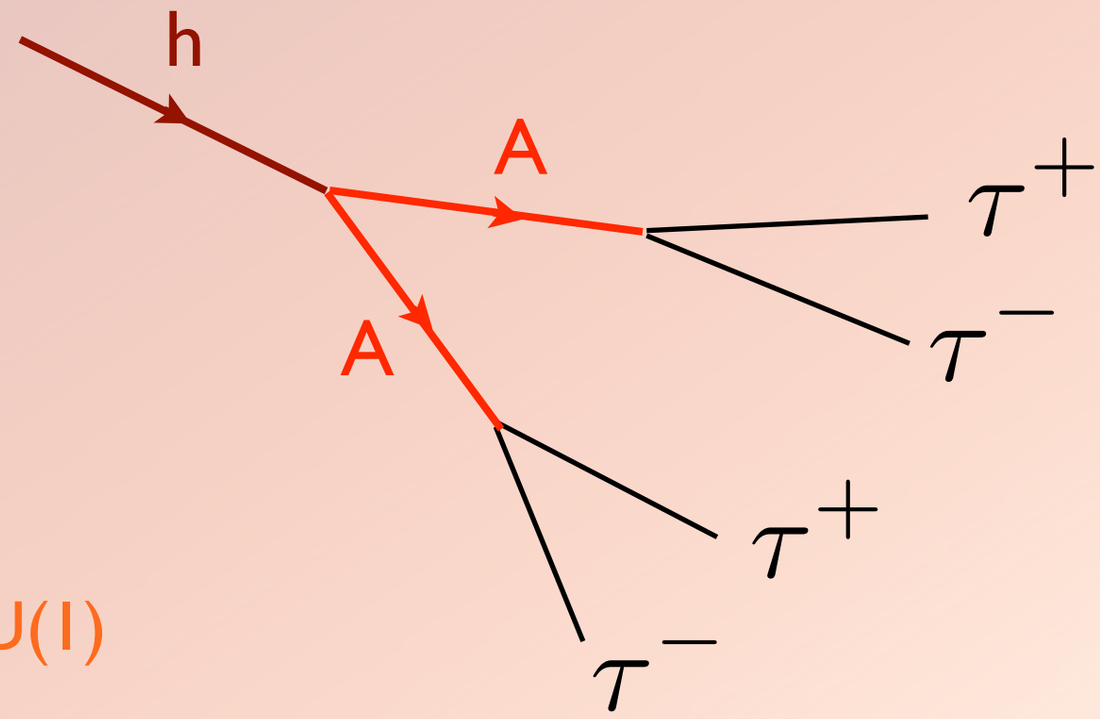
h ~100 GeV

Z
W

10 GeV

A-singlet

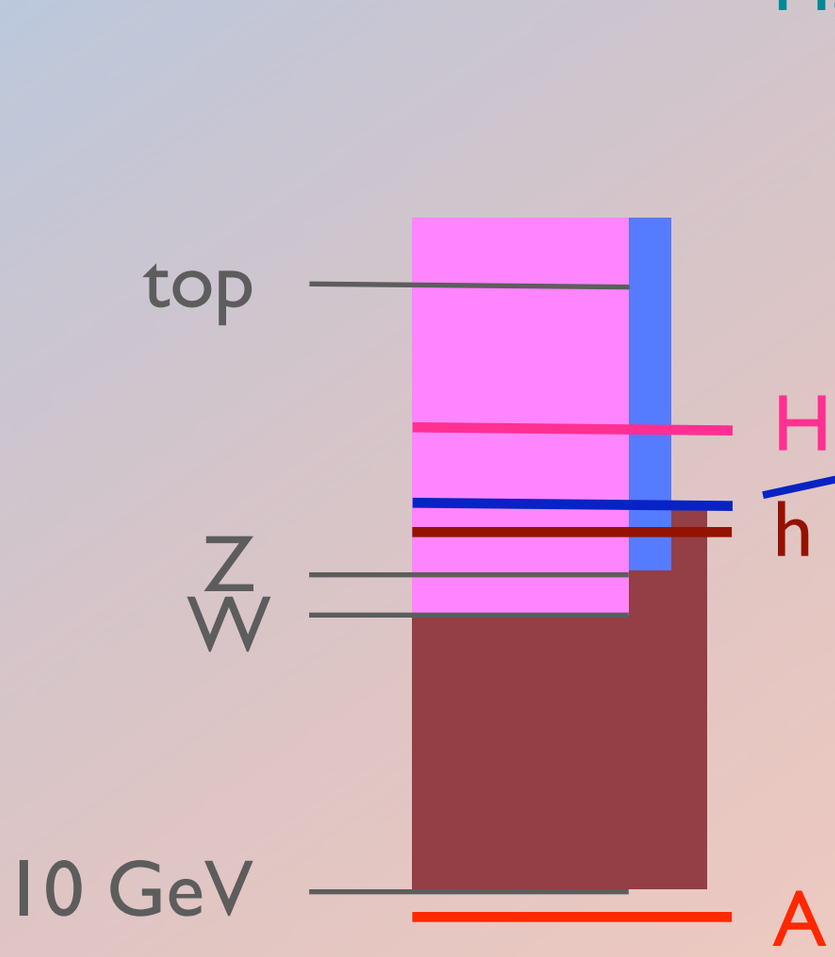
A is light as a result of an approximate global U(1)

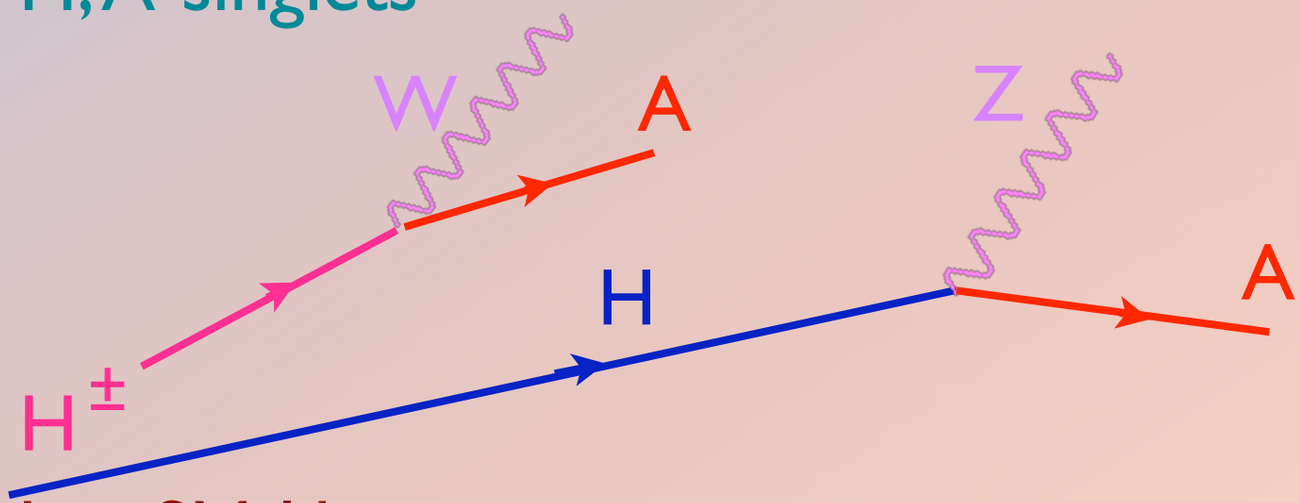


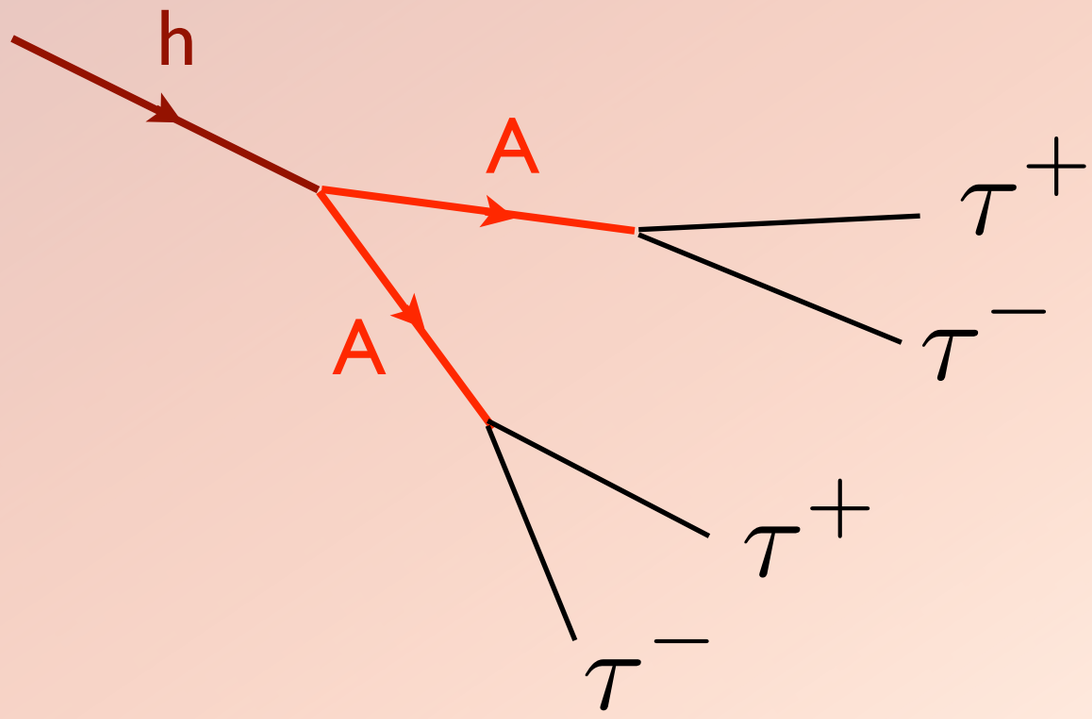
Models with a light doublet-like A

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

H, A-singlets







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 $2m_e$:

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

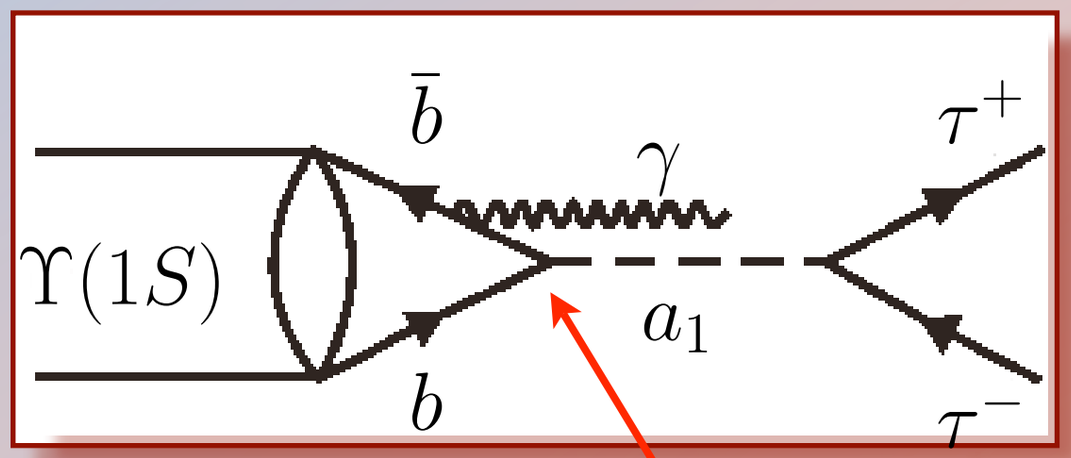
jets of soft particles

Light CP odd Higgs at B factories

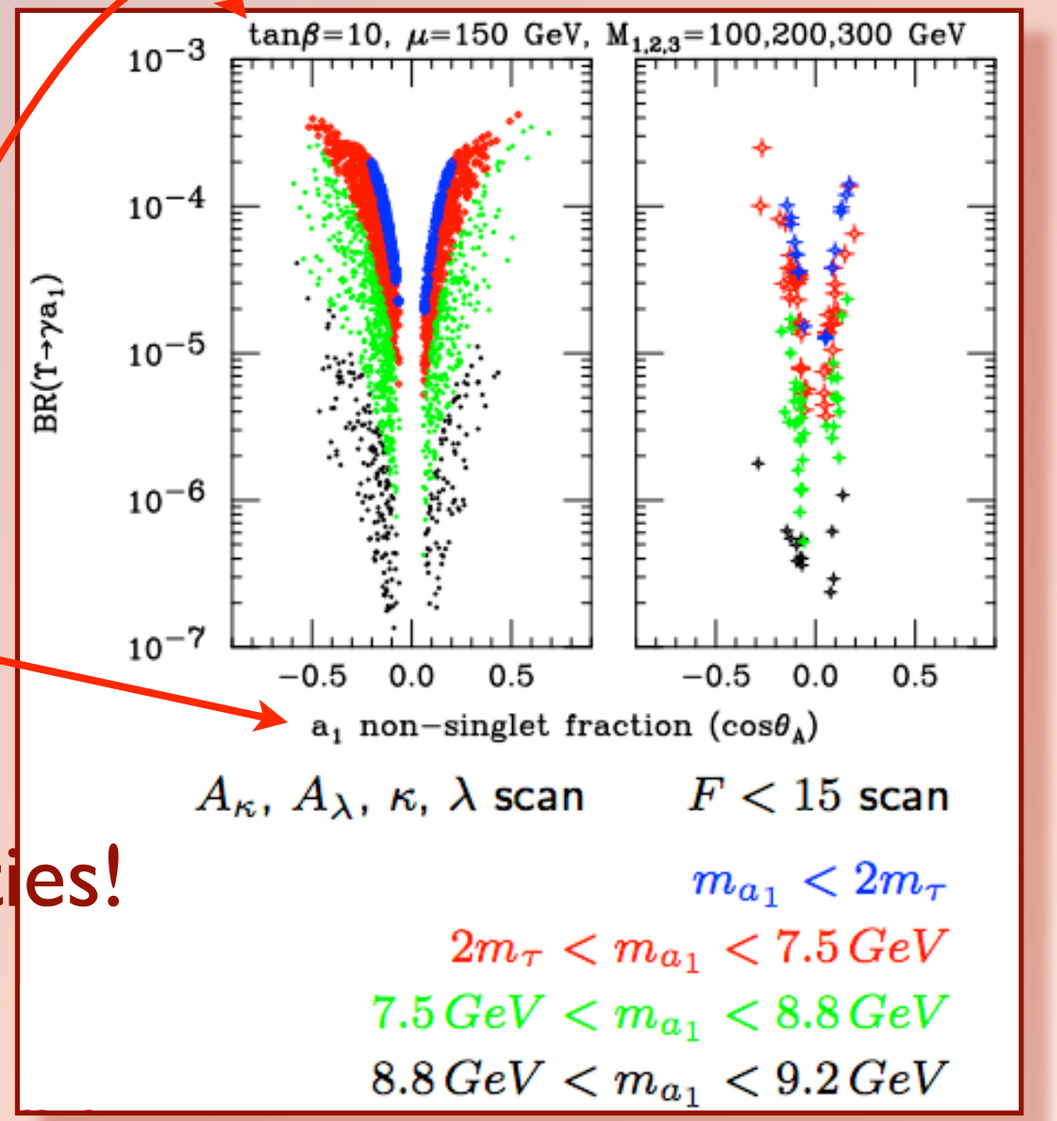
R.D., J. Gunion and B. McElrath, hep-ph/0612031

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

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CLEO, arXiv:0807.1427 [hep-ex]

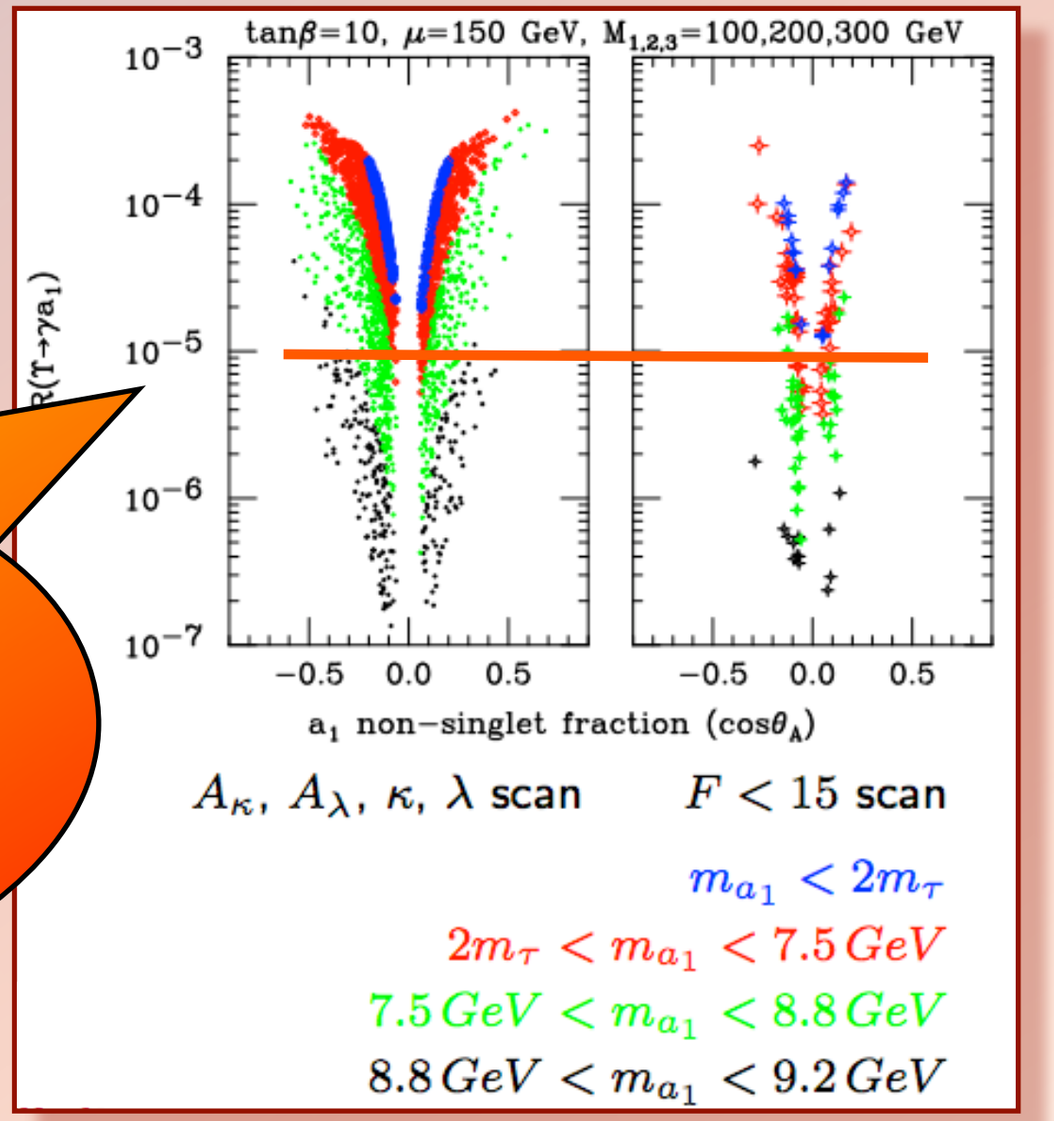
BaBar, arXiv:0902.2176 [hep-ex]

BaBar, arXiv:0906.2219 [hep-ex]

Limits typically require

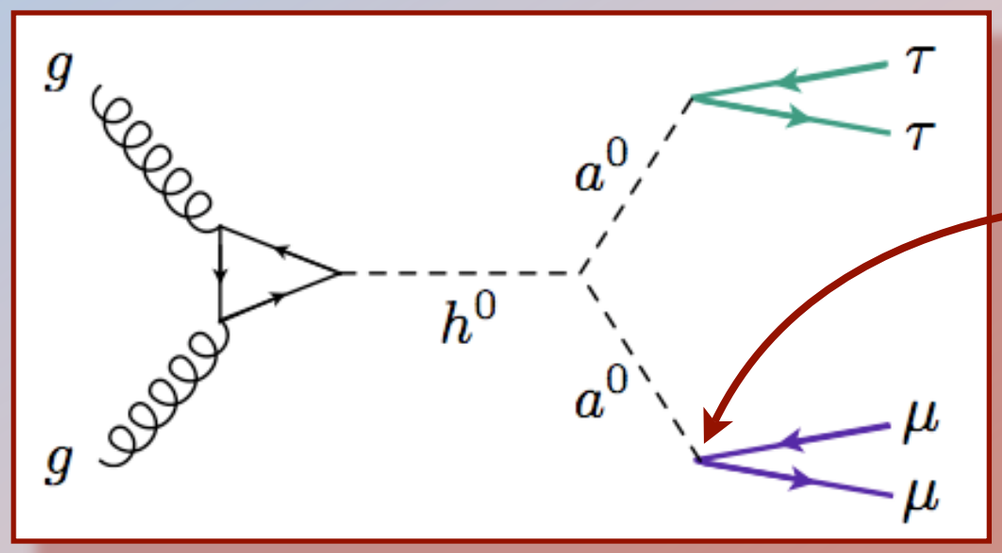
$$m_a \gtrsim 8 \text{ GeV}$$

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]

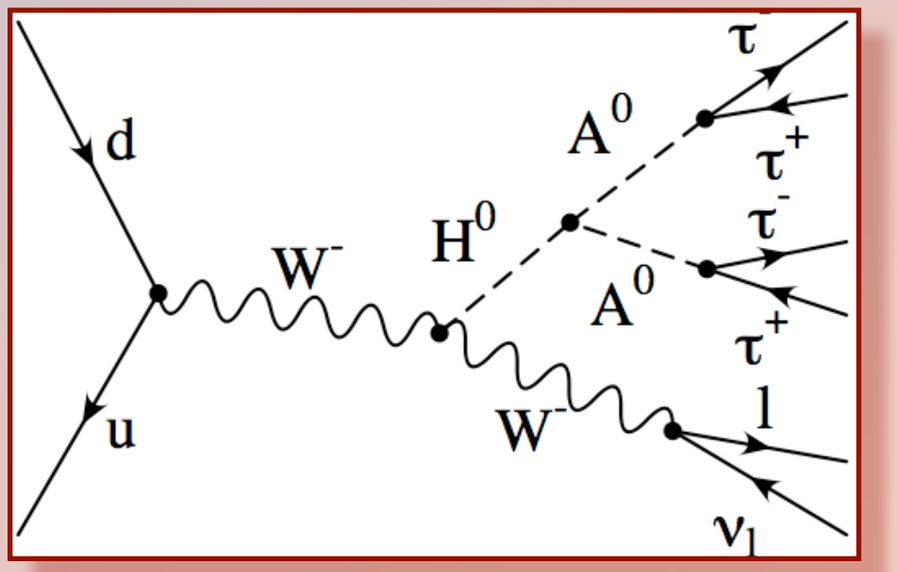
$$\frac{\Gamma(a^0 \to \mu^+\mu^-)}{\Gamma(a^0 \to \tau^+\tau^-)} = \frac{m_\mu^2}{m_\tau^2\sqrt{1-(2m_\tau/m_{a^0})^2}}$$

smaller but cleaner!

DØ search not sensitive yet

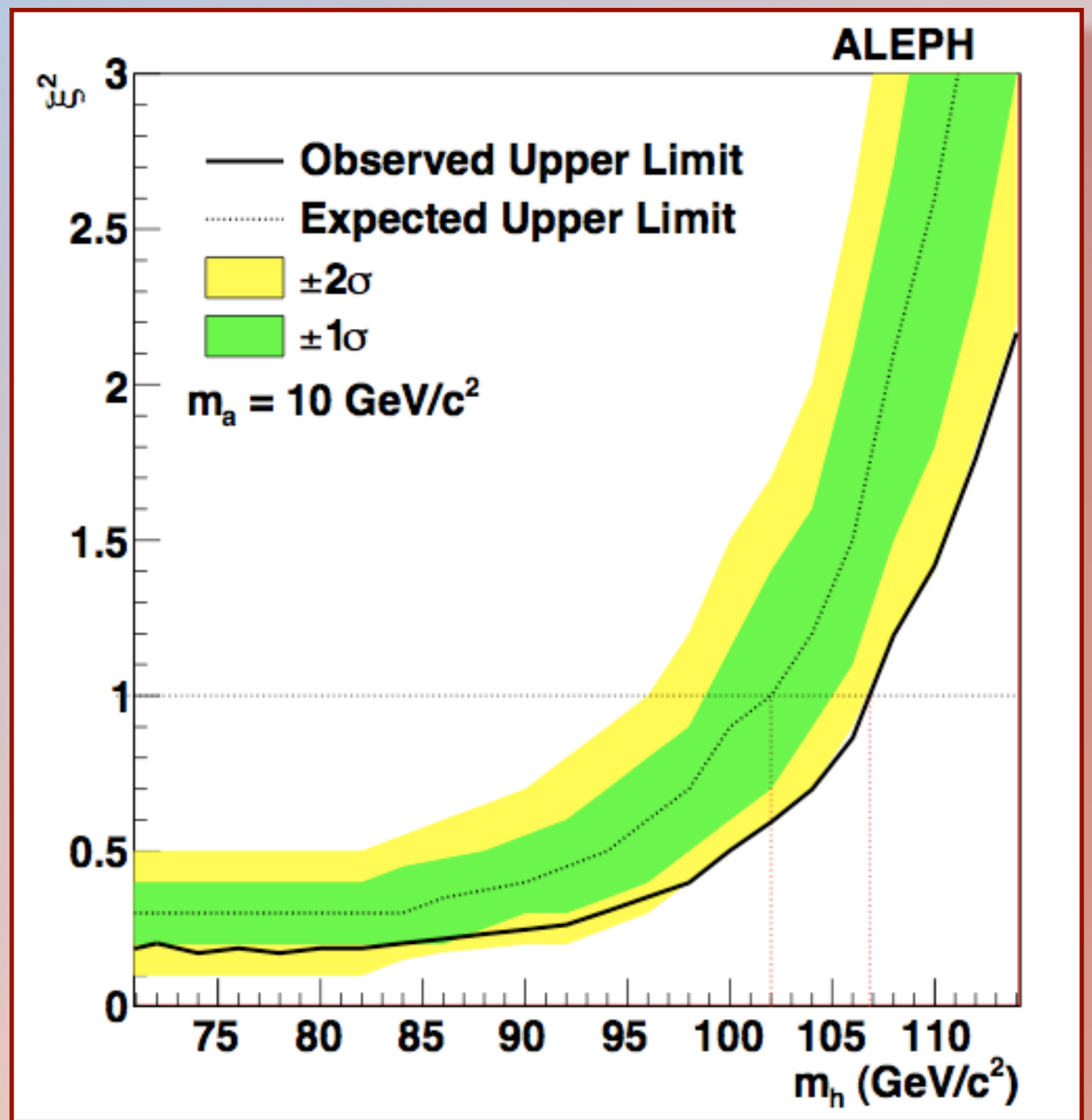
should be relatively easy at the LHC

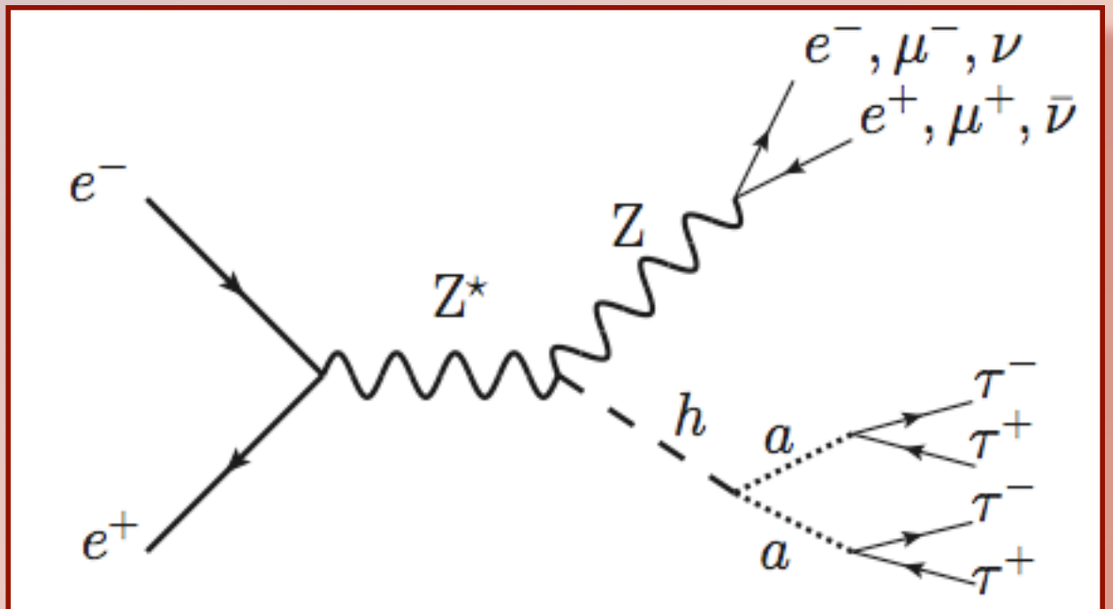
S. Wilbur, CDF, in progress



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

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

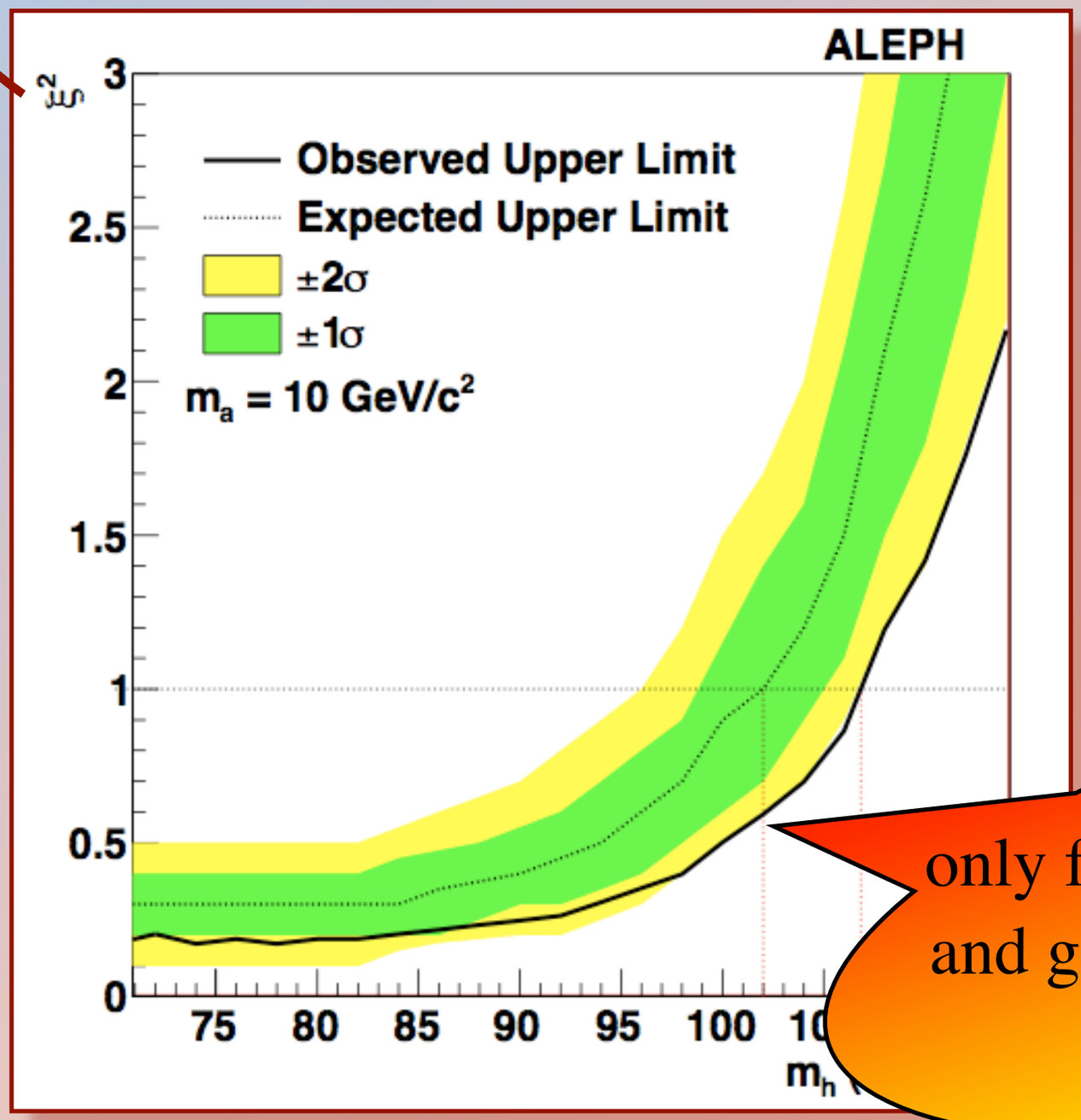


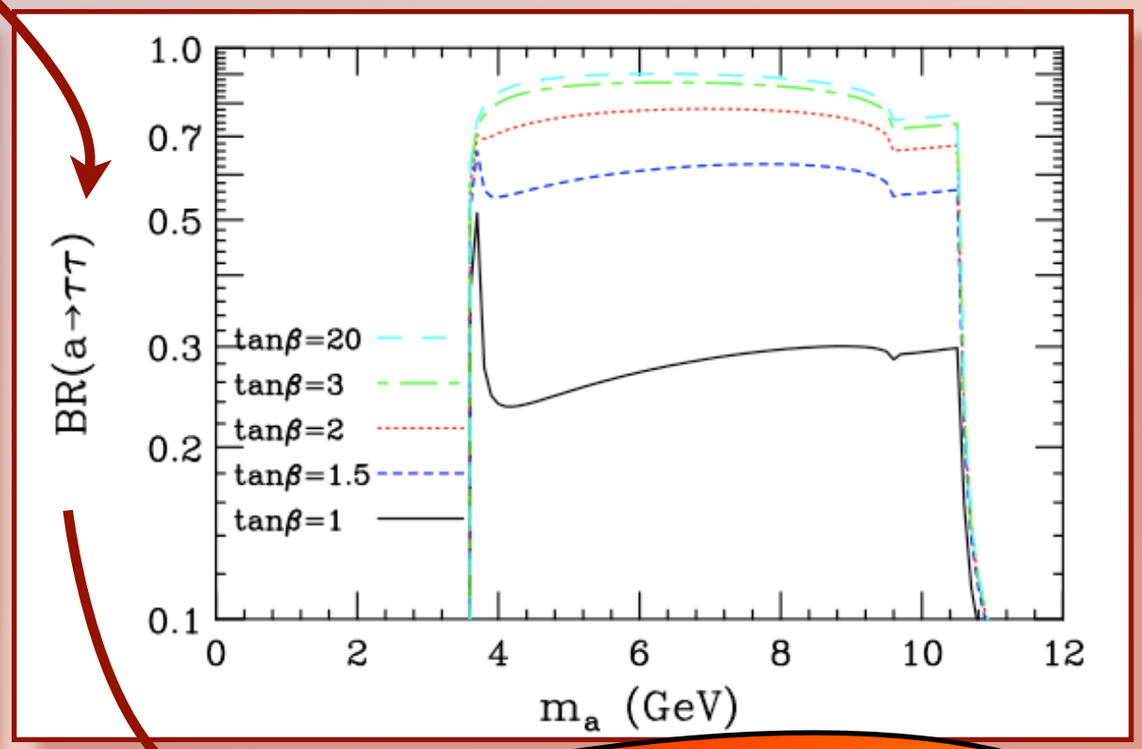


Aleph search for $h \longrightarrow aa \longrightarrow 4\tau$

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

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





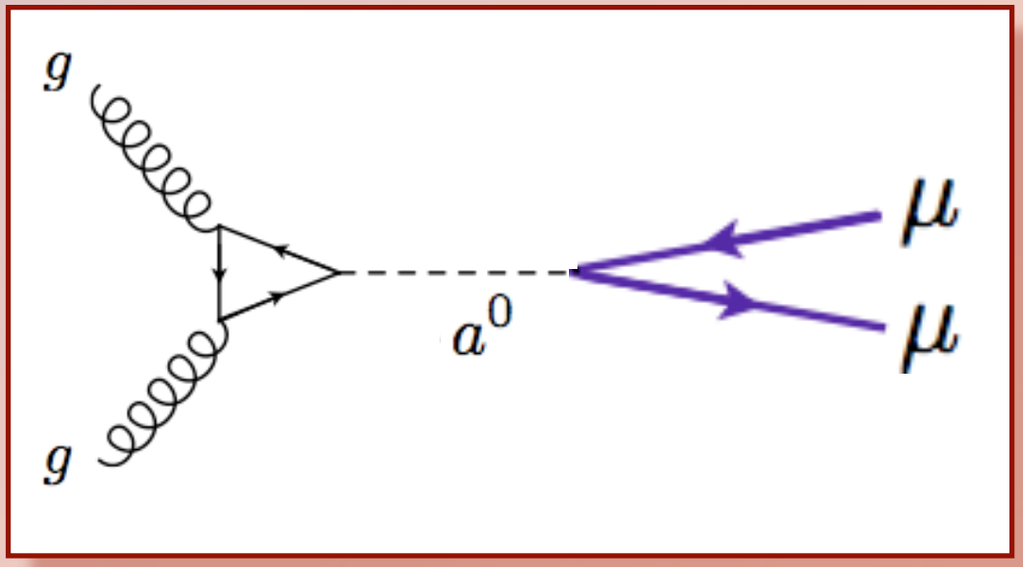
Limits allow
$m_h \simeq 100$ GeV
only for $m_a \simeq 2m_B$ when $\tan\beta > 3$
and generically for $\tan\beta \lesssim 2$

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:

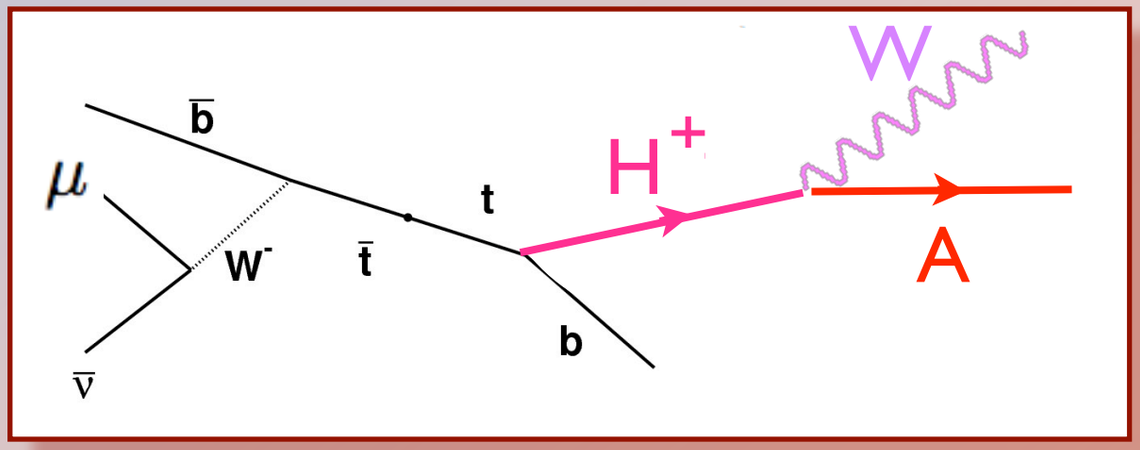
Case	$m_a = 8$ GeV	$m_a = M_{\Upsilon_{1S}}$	$m_a \lesssim 2m_B$
ATLAS LHC7	$17/r^2$	$63/r^2$	$9/r^2$
ATLAS LHC10	$13/r^2$	$48/r^2$	$7/r^2$
ATLAS LHC14	$10/r^2$	$37/r^2$	$5.4/r^2$

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

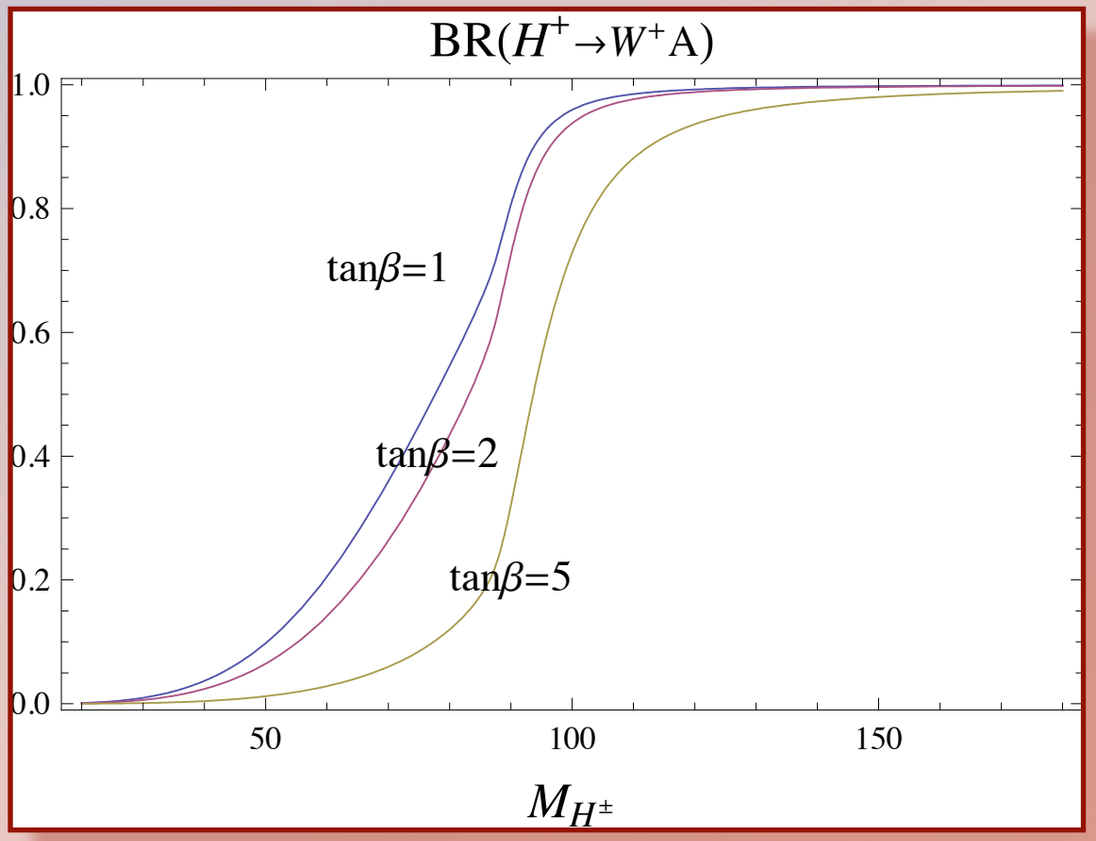
$$\epsilon_{ATLAS} = 0.1 \times r$$

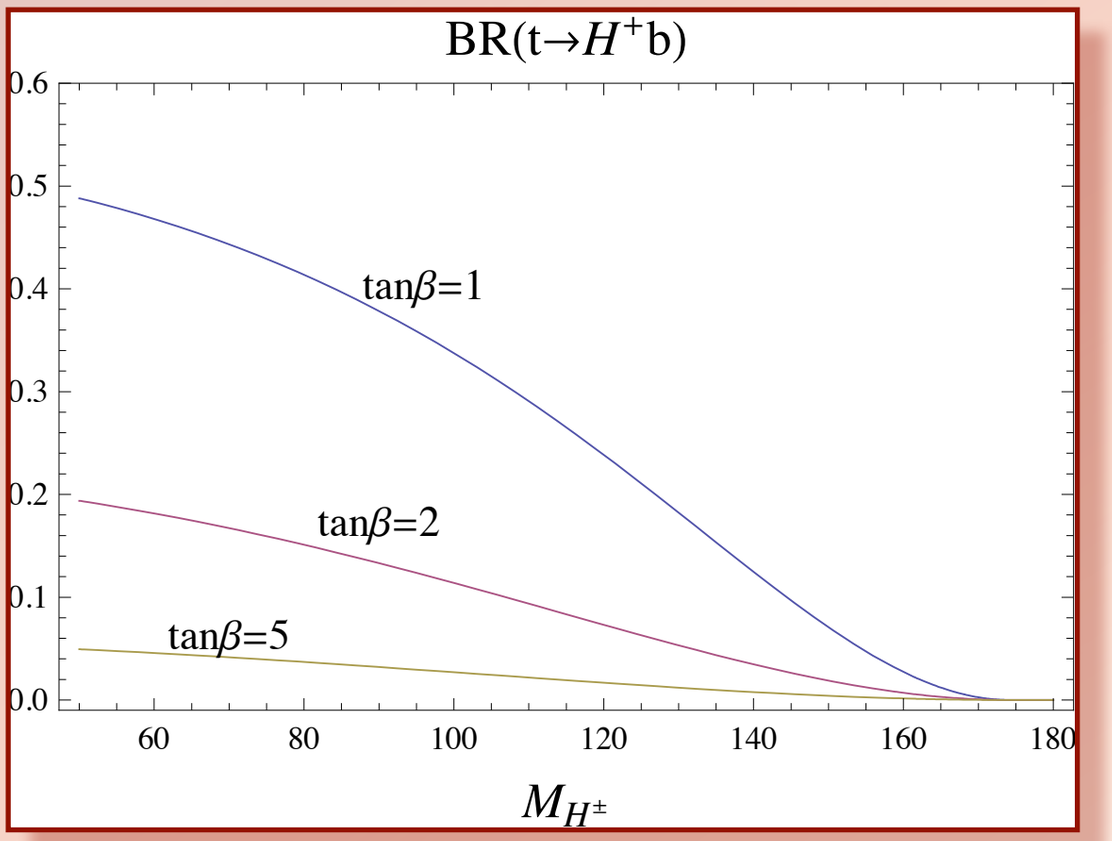
Charged Higgs in Top quark decays

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

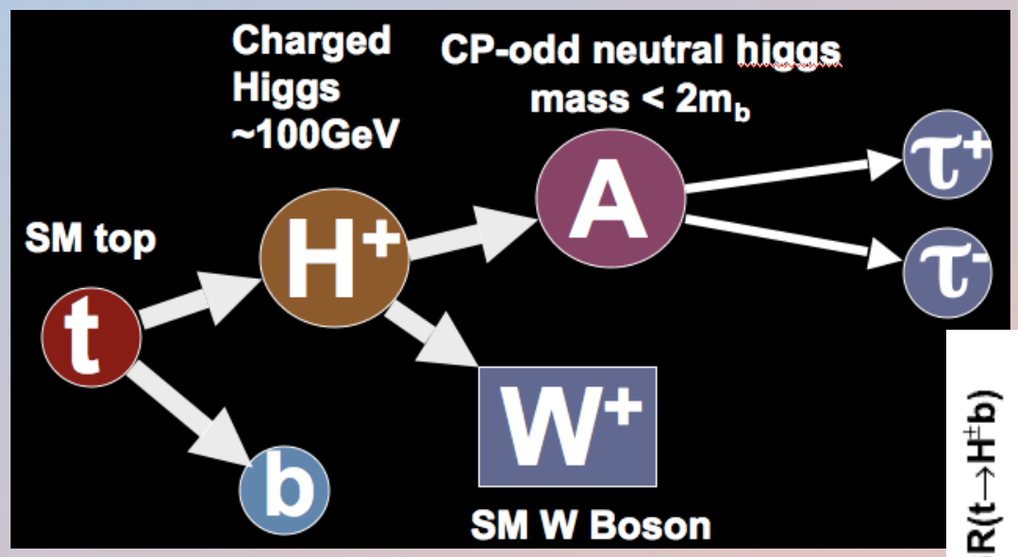


In MSSM:





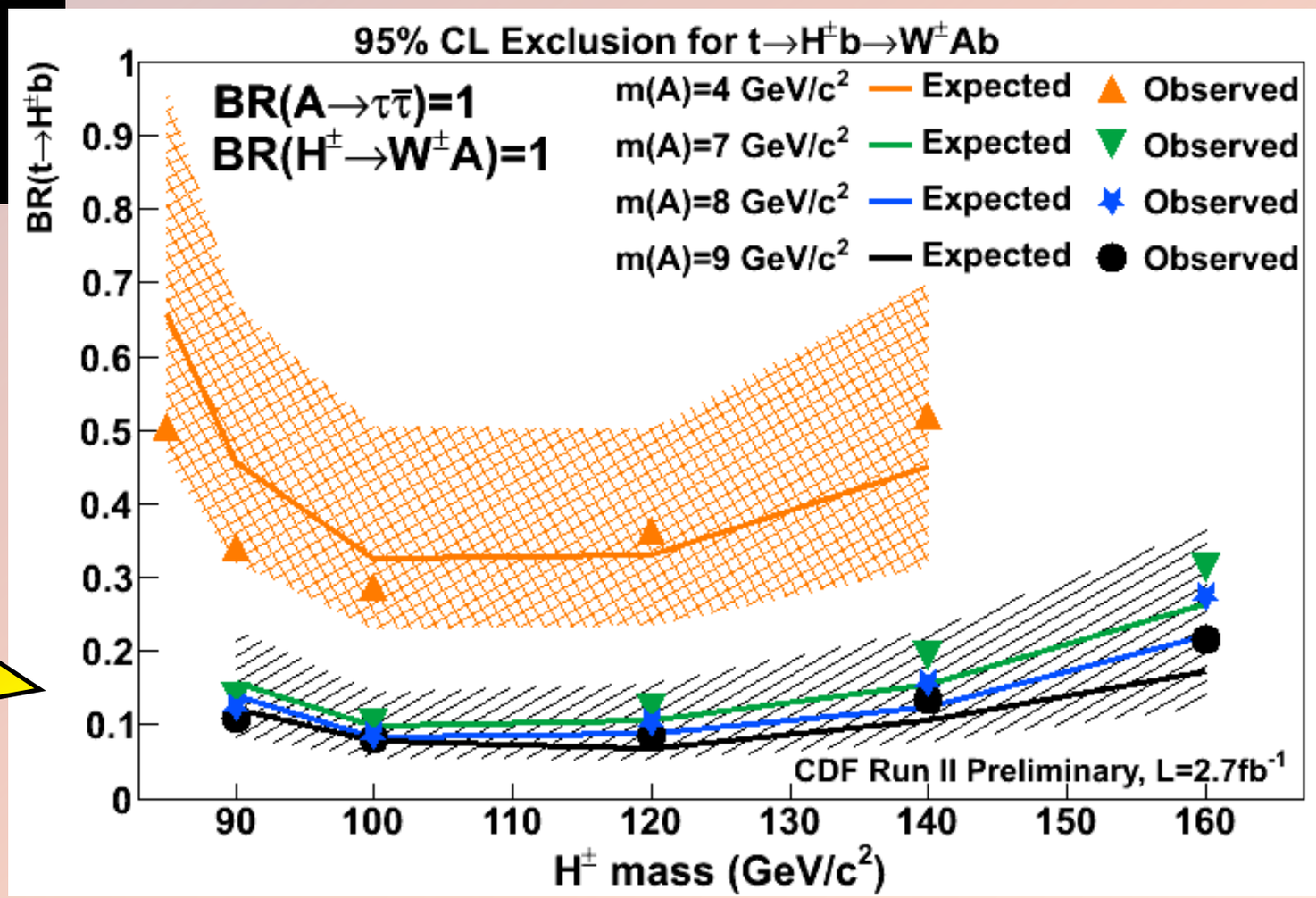
CDF search for charged Higgs



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

Limits allow

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



Charged Higgs at the LHC

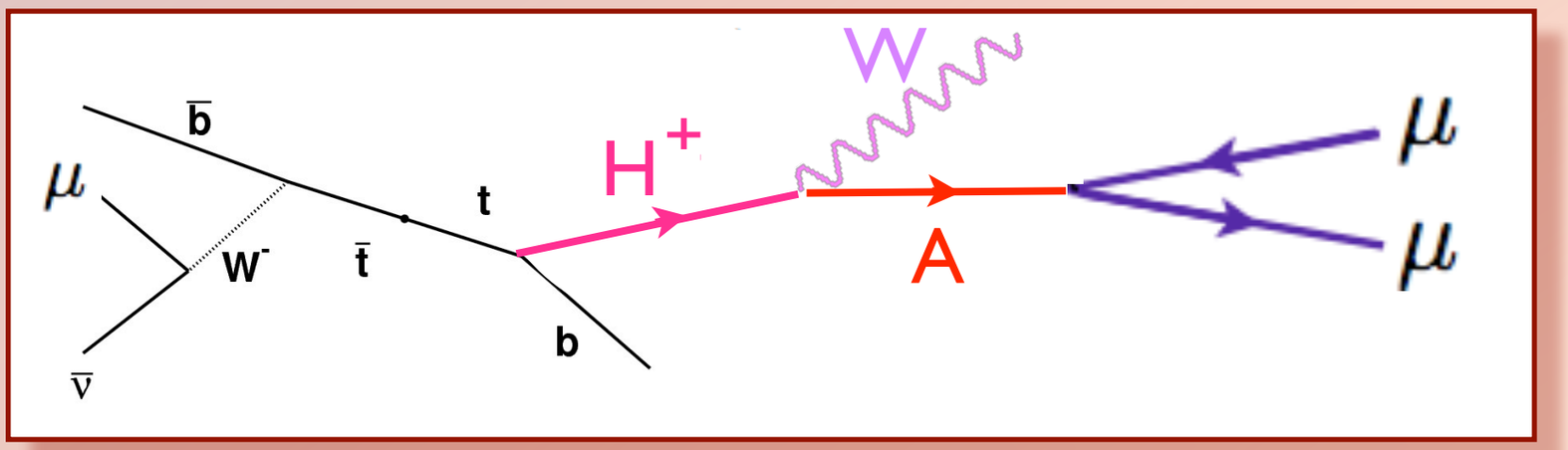
R.D., E. Lunghi and A. Raval, in progress

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

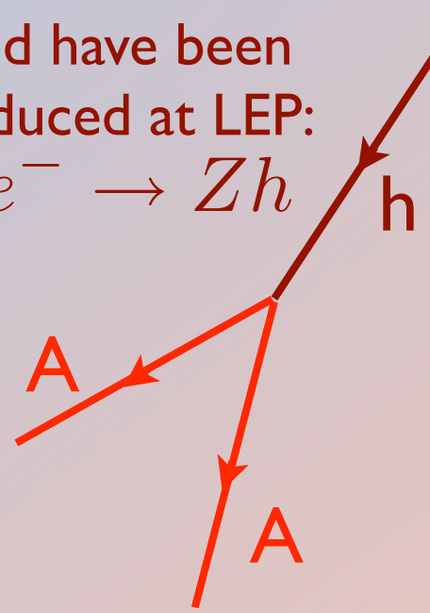
- for $Br(t \to H^+ b) = 10\%$ we have 650 3-muon events



Summary of the Light doublet-like CP odd Higgs scenario

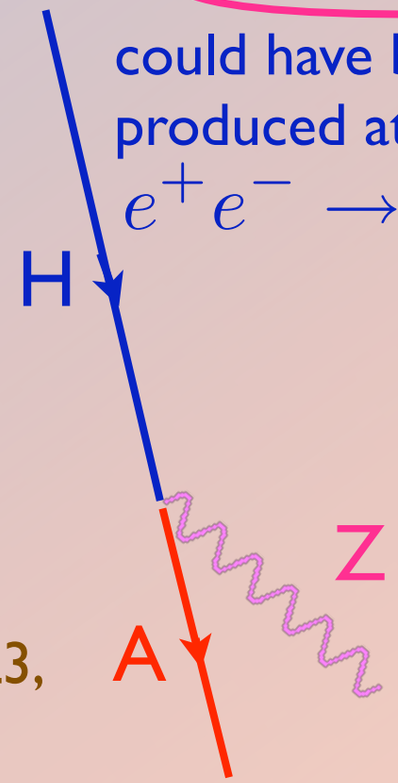
- all the Higgses (from two Higgs doublets) are fairly light
- all the Higgses: h, H, $H^{\pm}$ decay through the CP odd Higgs - A

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



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

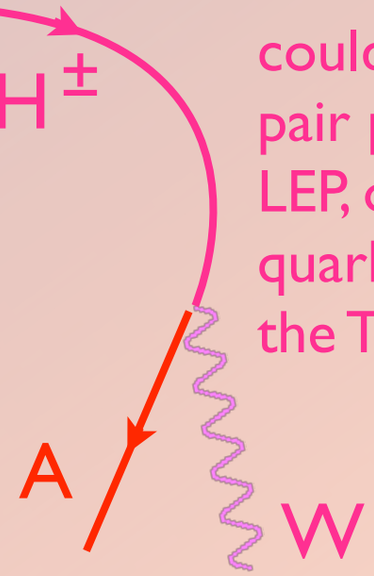
could have been produced at LEP: $e^+e^- \to HA$



no searches or studies

$H^{\pm}$

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



recent search at CDF

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!