Light Charged Higgs
in the NMSSM

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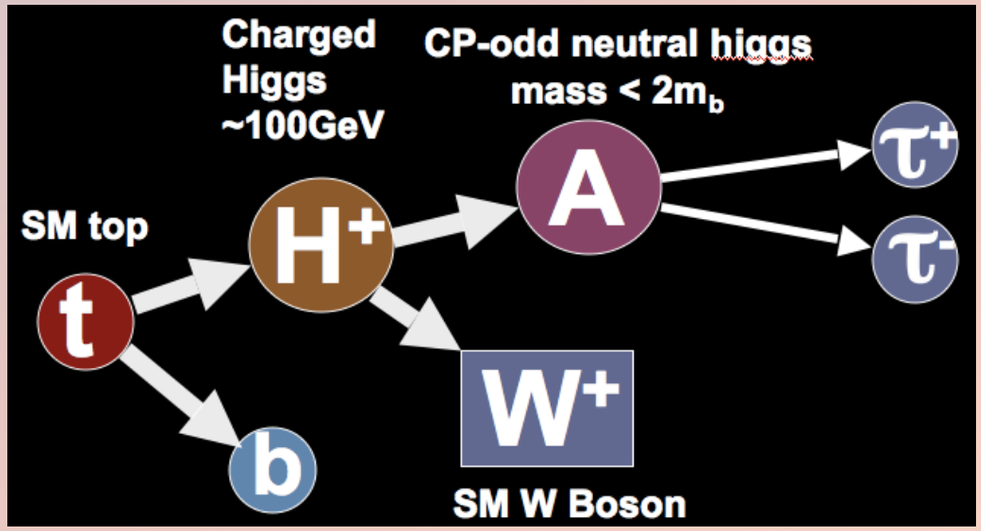
Indiana University, Bloomington

Charged Higgs 2010, Uppsala, Sweden, September 27-30, 2010

Outline

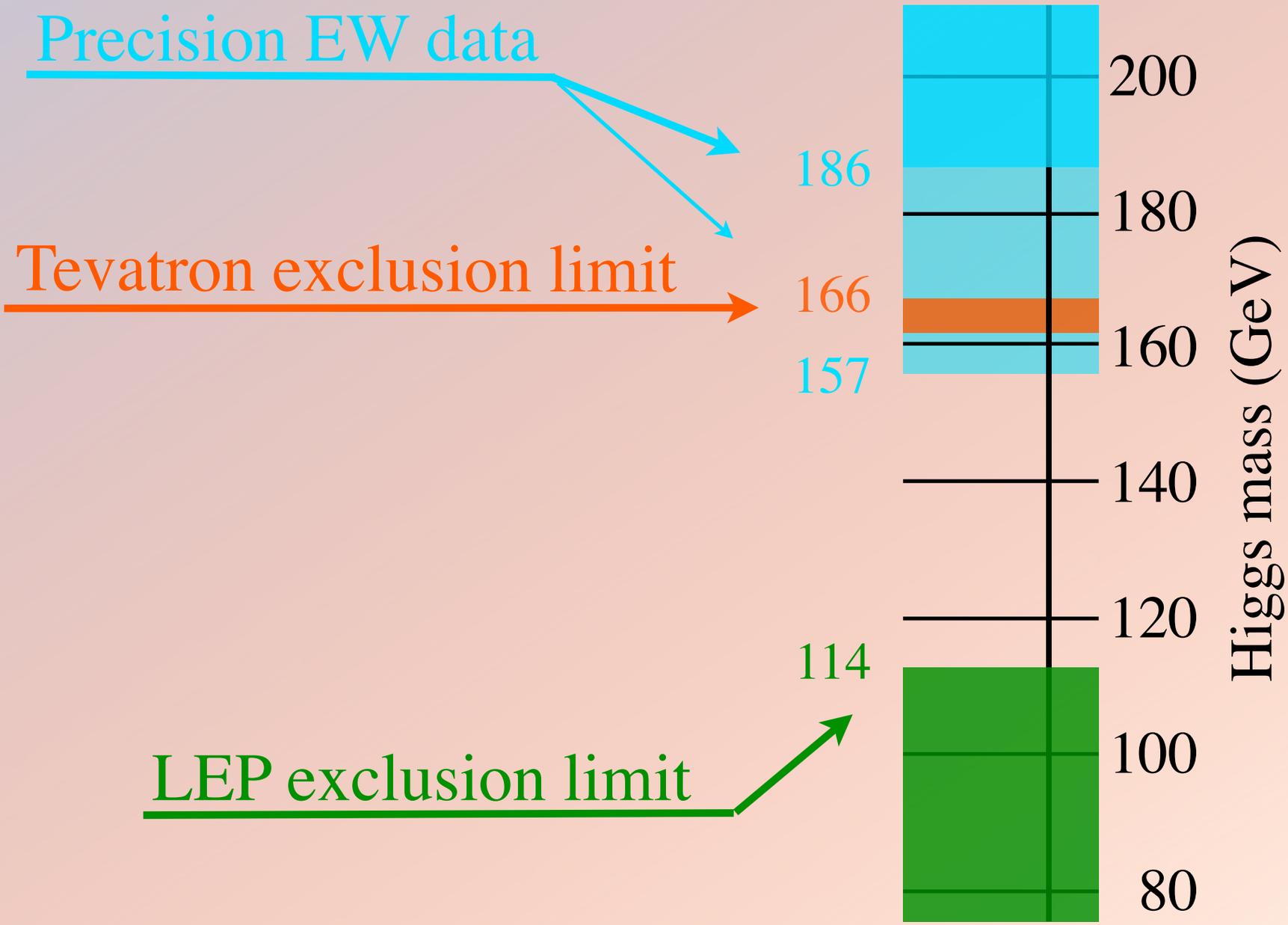


- **motivation for the light charged Higgs scenario**
- **basic features (in the MSSM, NMSSM and BMSSM)**
- **constraints (recent search at CDF)**
- **prospects at the LHC with** $1\ \mathrm{fb}^{-1}$

Motivation

(scenario with a light CP odd Higgs)

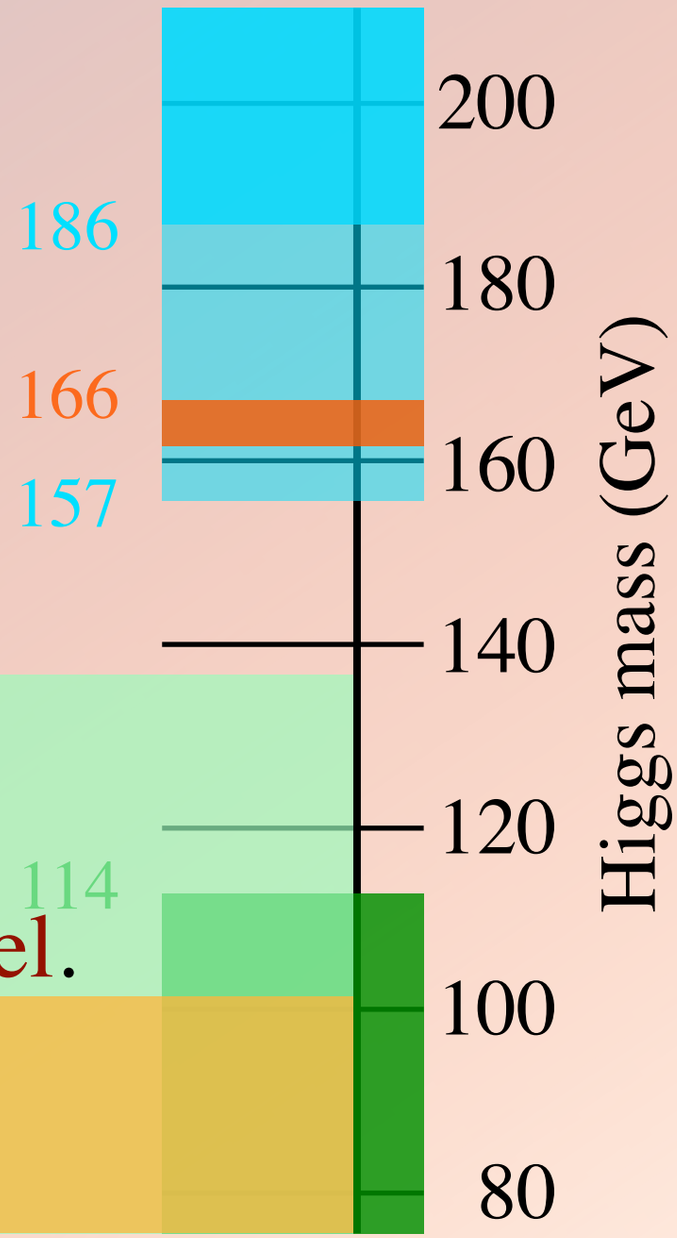
Where is the Higgs?



Interesting coincidences

In the MSSM:

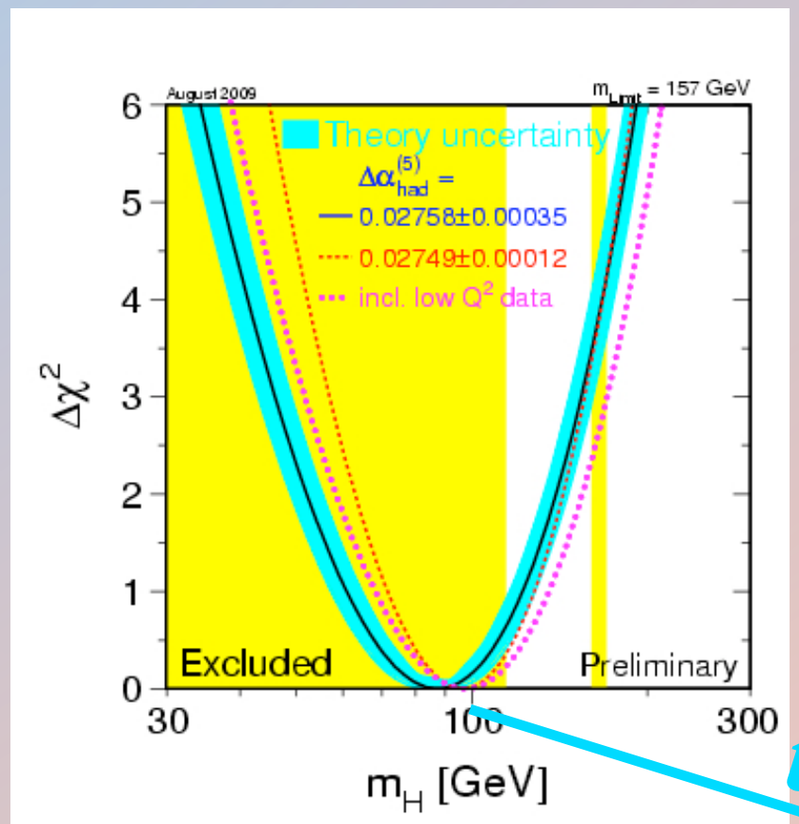
$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + 1 - loop$$

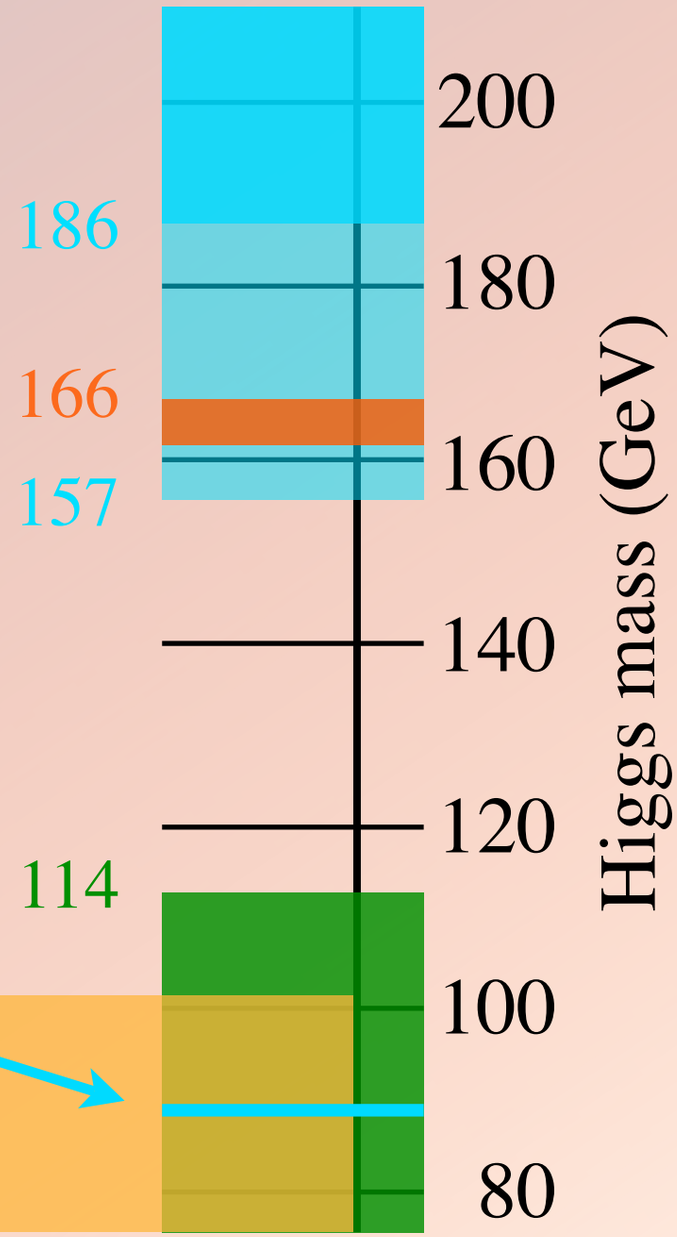


This range corresponds to the Higgs mass predicted in the minimal supersymmetric model.

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

Interesting coincidences

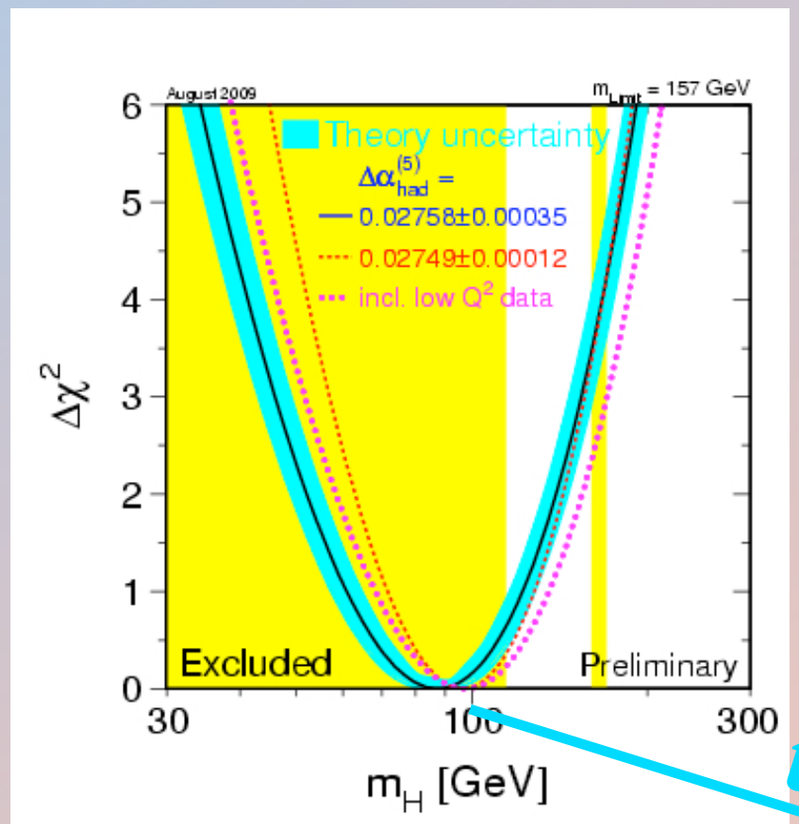


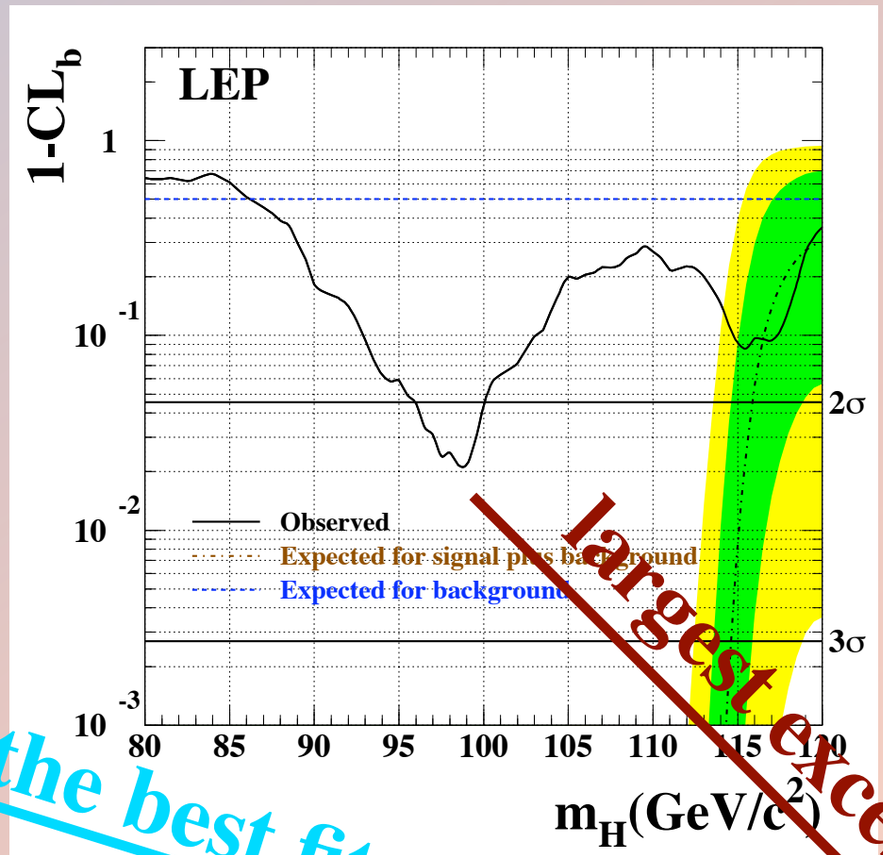


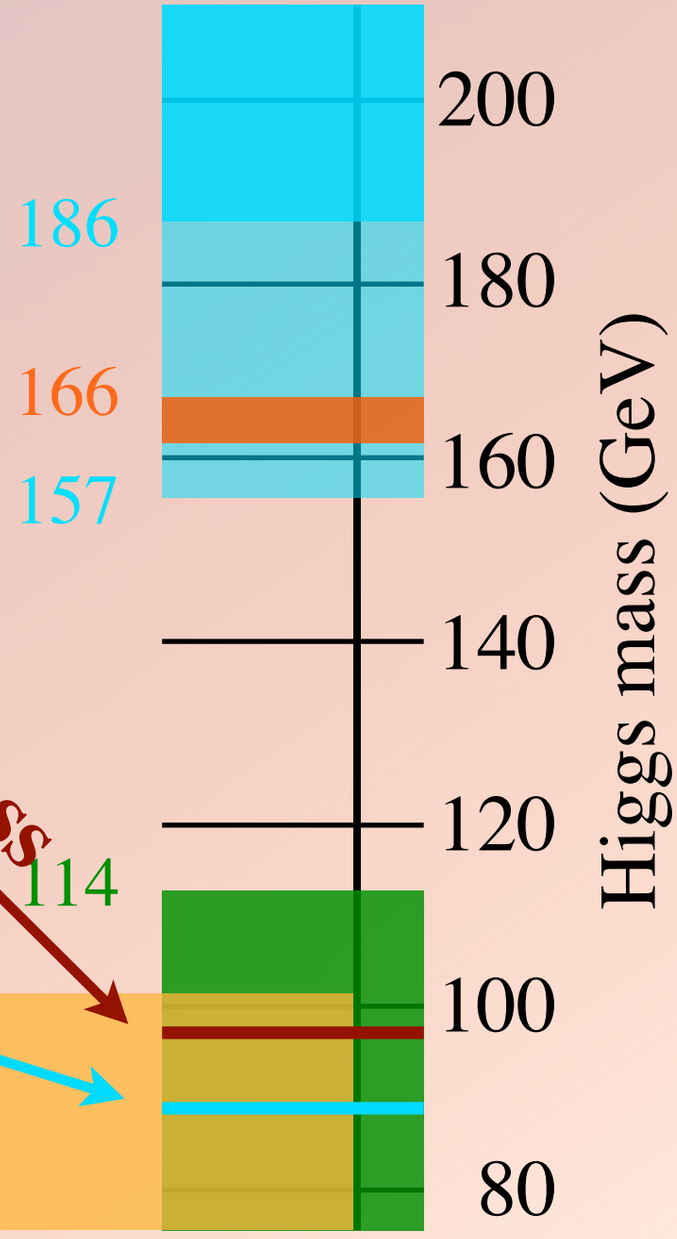
the best fit value

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

Interesting coincidences







largest excess

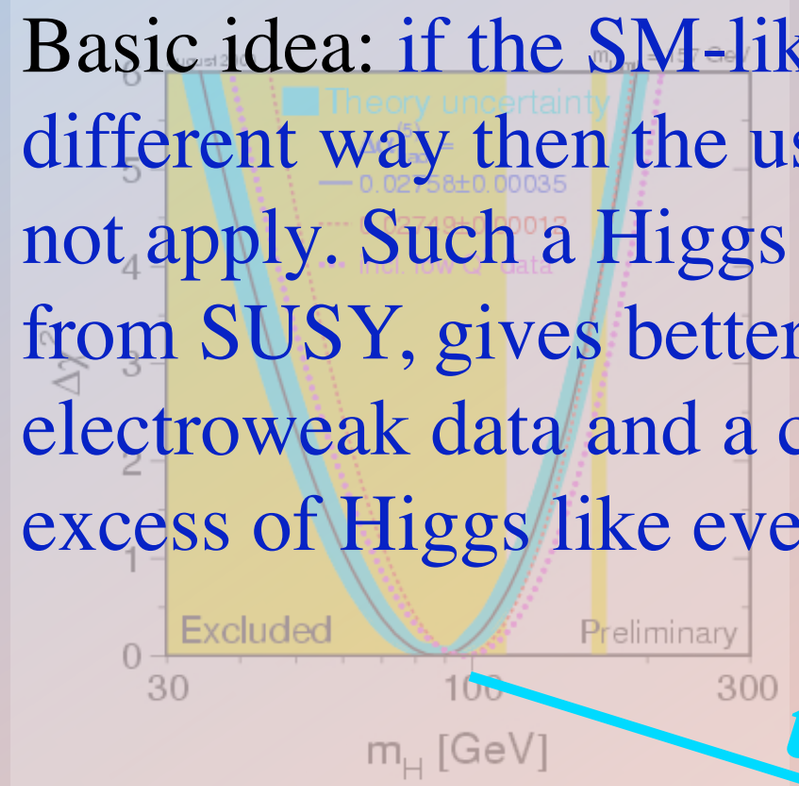
the best fit value

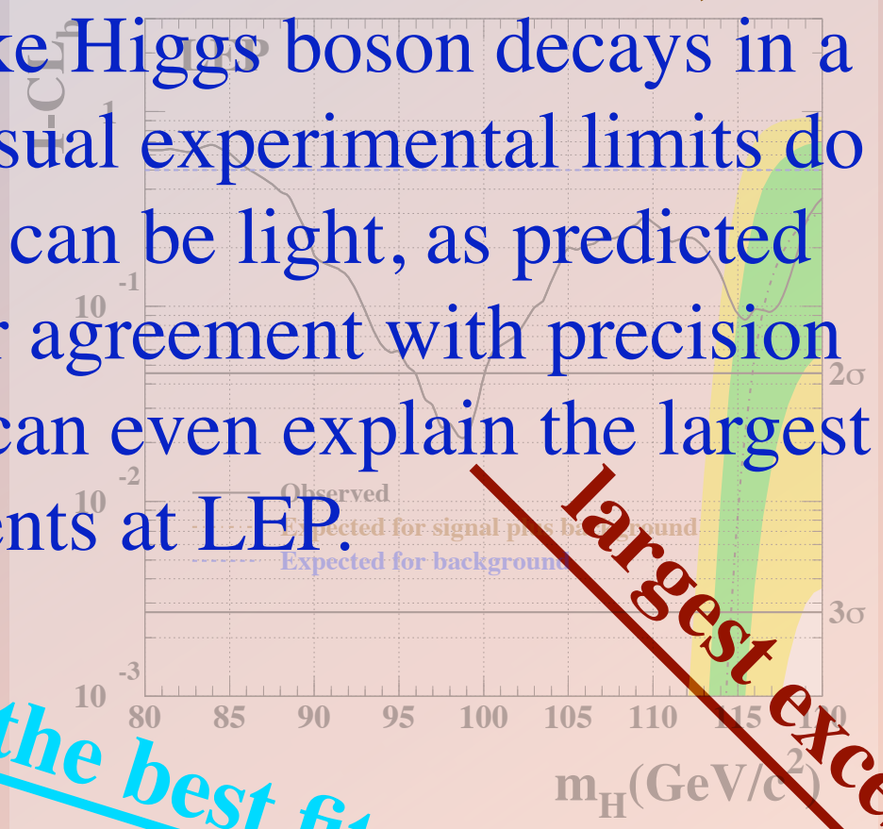
Natural electroweak symmetry breaking in SUSY models is achieved only in this region!

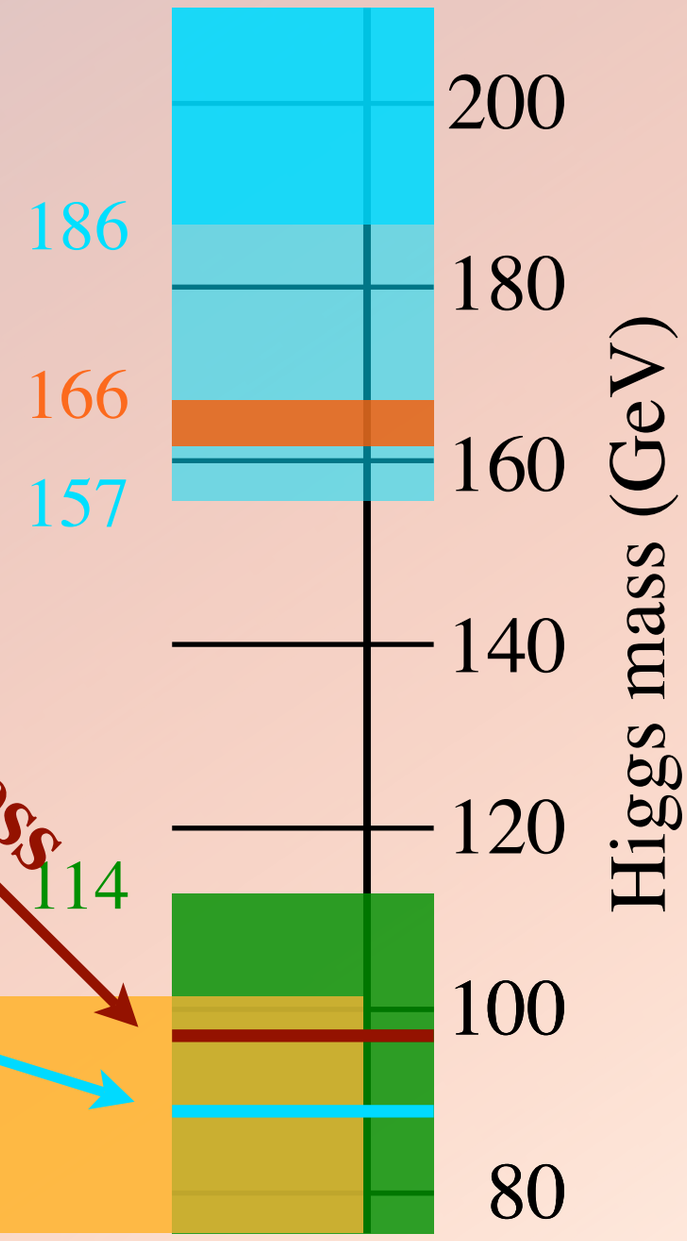
Non-standard Higgs decays

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.

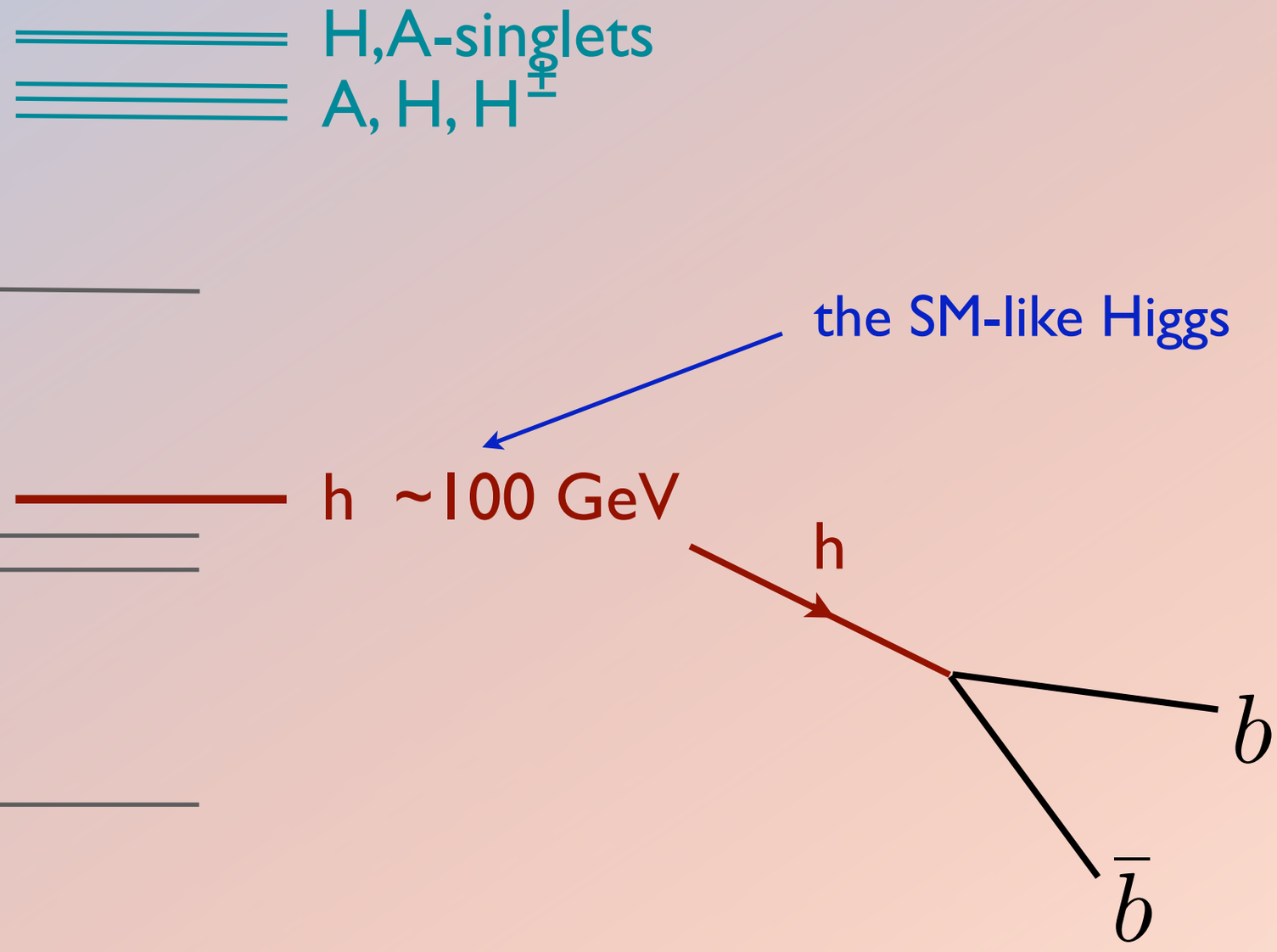






Natural electroweak symmetry breaking in SUSY models is achieved only in this region!

(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

h

A

τ^+

τ^-

A

10 GeV

A-singlet

τ^+

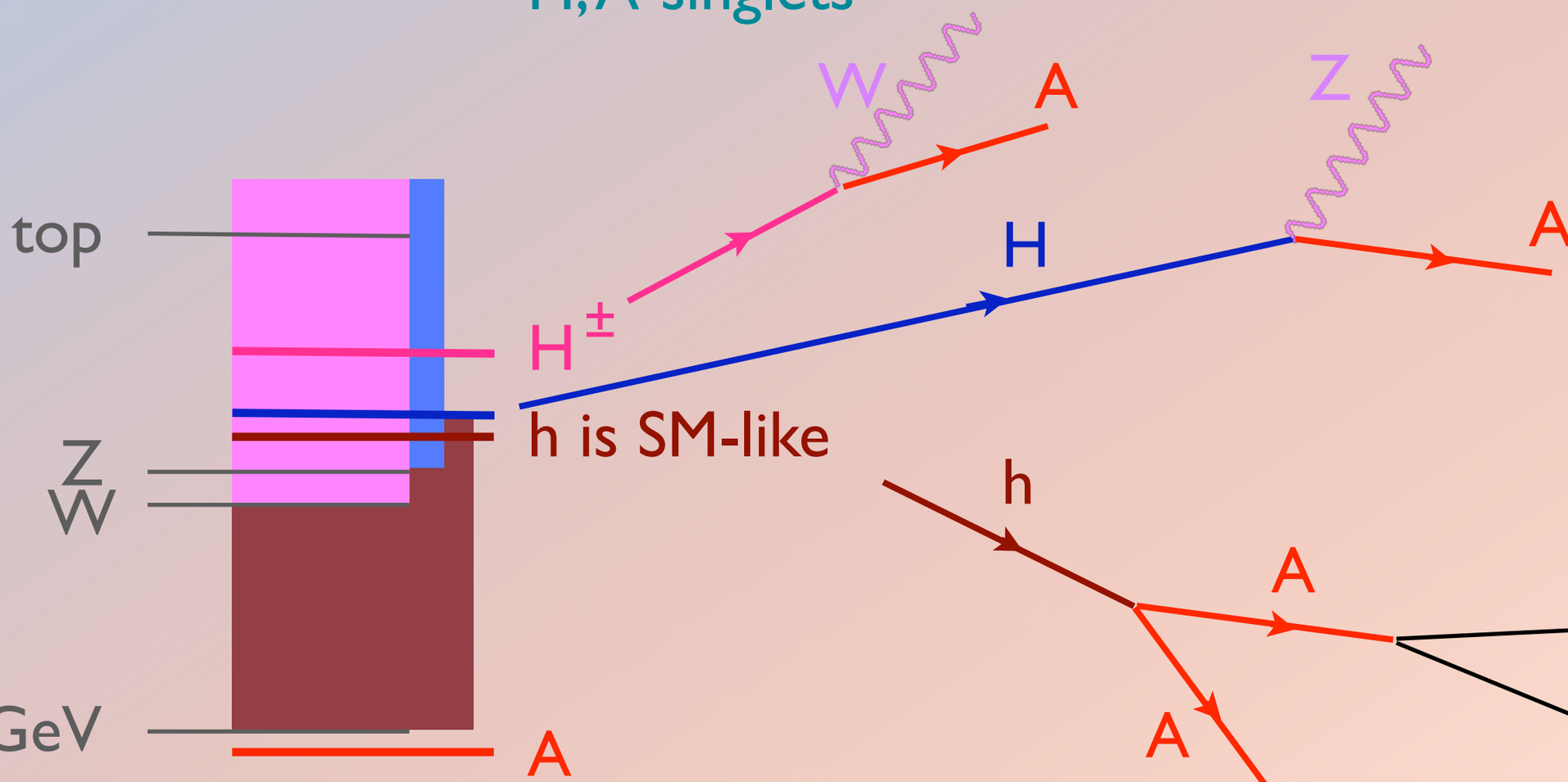
τ^-

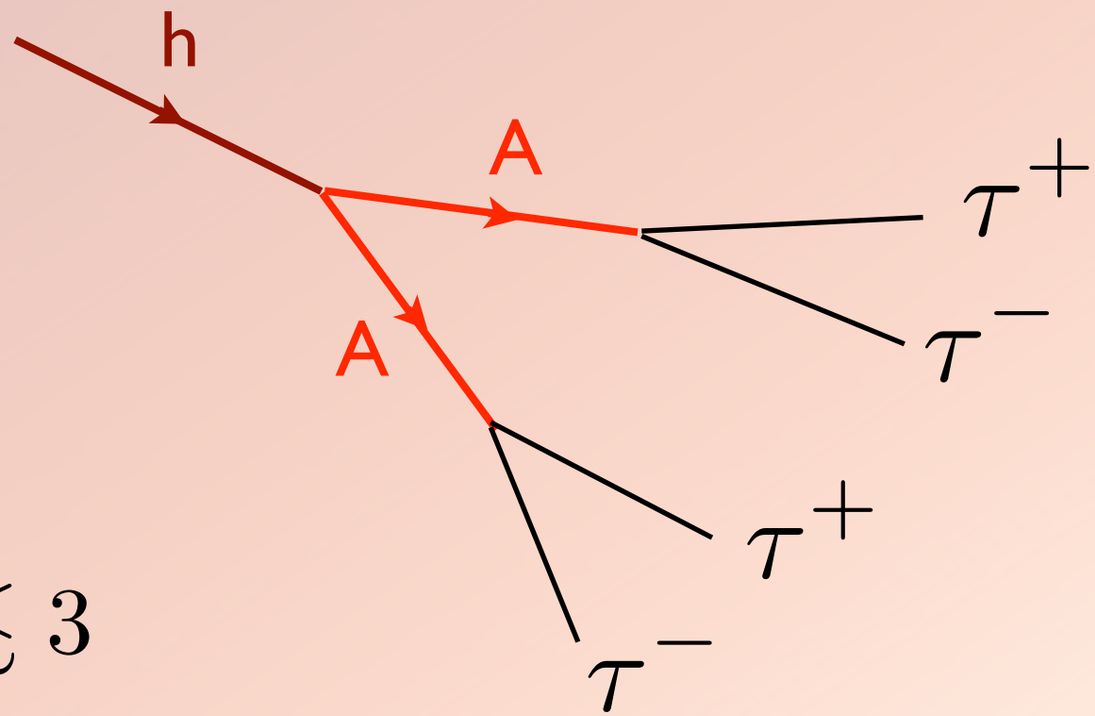
A is light as a result of
an approximate global U(1)

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 $\tan\beta \lesssim 3$

Basic features

Light Charged Higgs in the MSSM

R.D., arXiv:0806.0847 [hep-ph]

Charged Higgs in the MSSM (with light A) is very close to W:

$$m^2_{H^\pm} = m^2_{W^\pm} + m^2_A + (\text{susy loops}) \simeq m^2_{W^\pm}$$

not ruled out by usual searches for the charged Higgs, since

$$H^+ \to W^+ A$$

in the MSSM the scenario is only barely ruled out for $\tan\beta \lesssim 3$
(by decay mode independent search (OPAL) for the SM Higgs)

generically allowed in BMSSM!

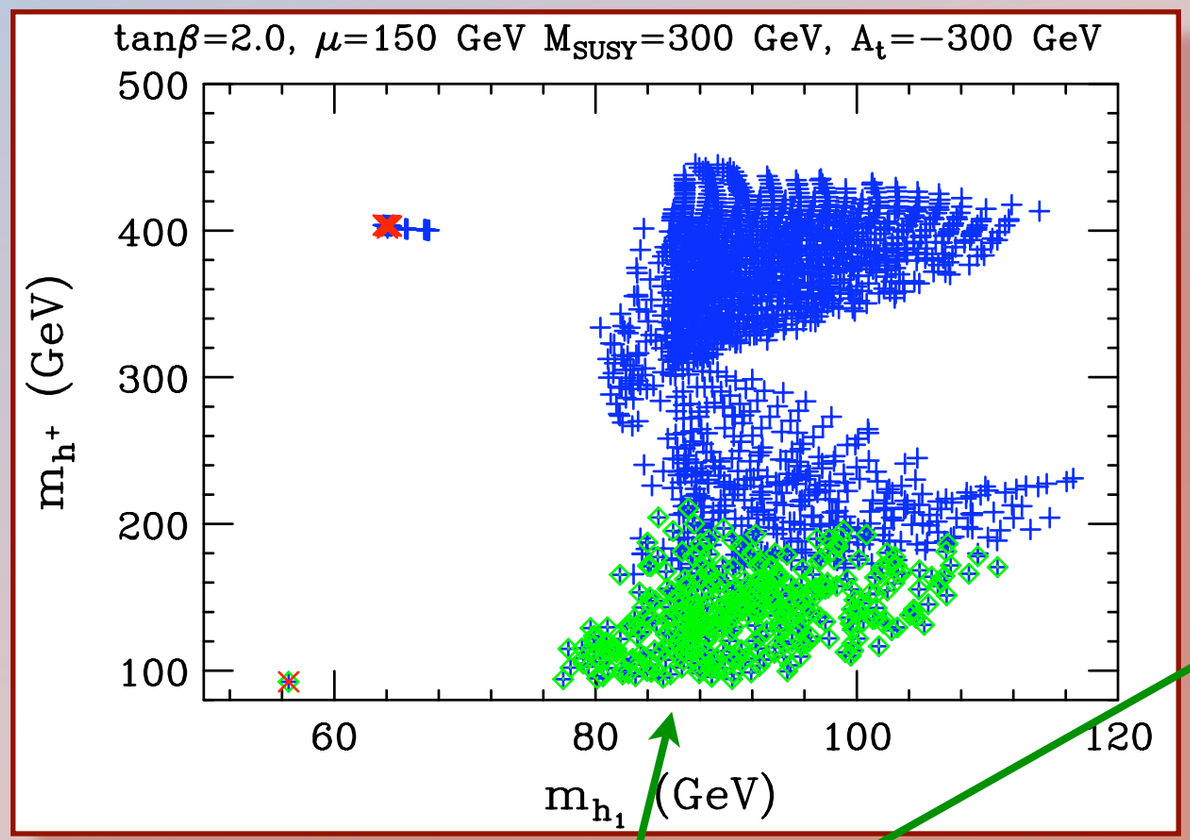
R.D., arXiv:0806.0847 [hep-ph]

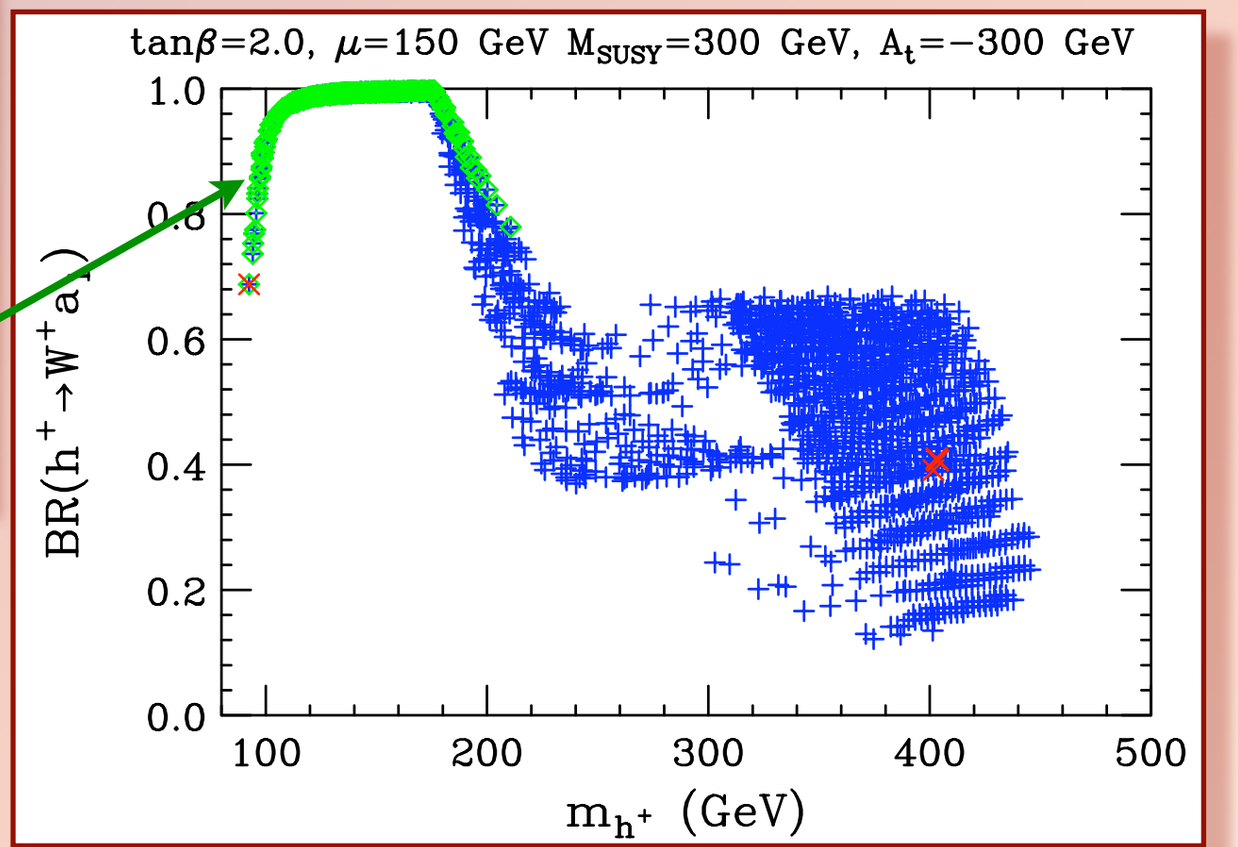
K.J. Bae, R.D., D. Kim, H.D. Kim and J.H. Kim, arXiv:1001.0623 [hep-ph]

Light Charged Higgs in the NMSSM

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

In the NMSSM the scenario is generically viable:





green points indicate scenarios with a doublet-like light CP odd Higgs

Lepton universality in W boson decays

was measured at LEP in $e^+e^- \to W^+W^-$**:** arXiv:hep-ex/0412015

$$B(W \to \mu\nu)/B(W \to e\nu) = 0.994 \pm 0.020$$
$$B(W \to \tau\nu)/B(W \to e\nu) = 1.070 \pm 0.029$$
$$B(W \to \tau\nu)/B(W \to \mu\nu) = 1.076 \pm 0.028$$

$$R_{\tau/l} = 2B(W \to \tau\nu)/(B(W \to e\nu) + B(W \to \mu\nu)) = 1.073 \pm 0.026$$

2.8σ deviation from lepton universality!

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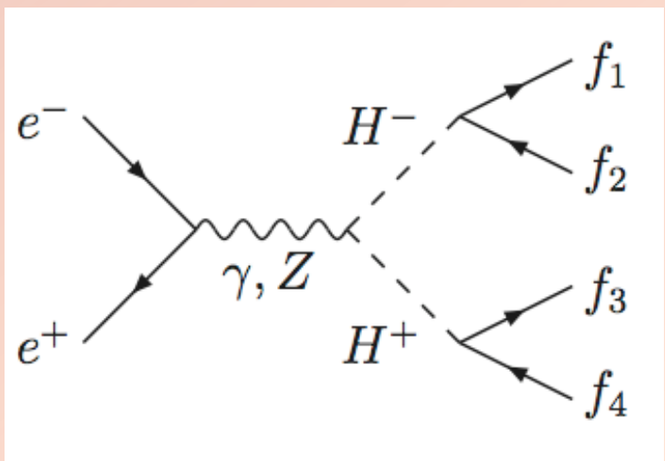
For $m_{H^\pm} \simeq m_{W^\pm}$ **the charged Higgs is expected to contribute:**

$$\frac{\sigma_{H^+H^-} B(H^+ \to \tau^+\nu)^2}{\sigma_{W^+W^-} B(W^+ \to \tau^+\nu)^2} \lesssim \frac{0.16\text{pb} \times 0.3^2}{17\text{pb} \times 0.1^2} \lesssim 0.1$$

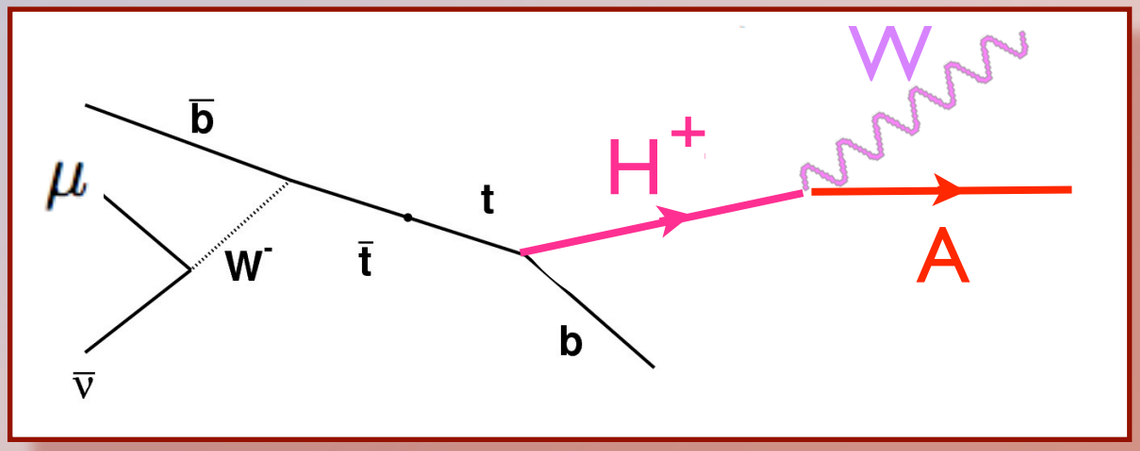


R.D., arXiv:0807.2135 [hep-ph]

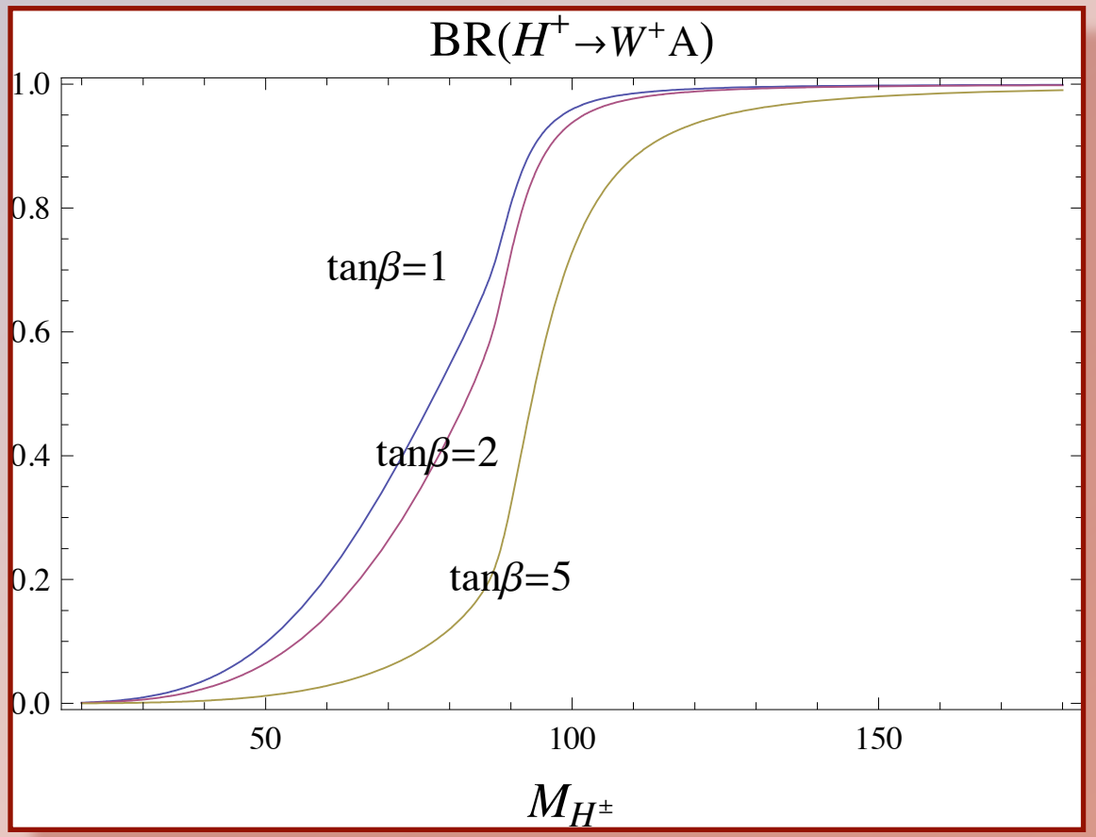
Constraints

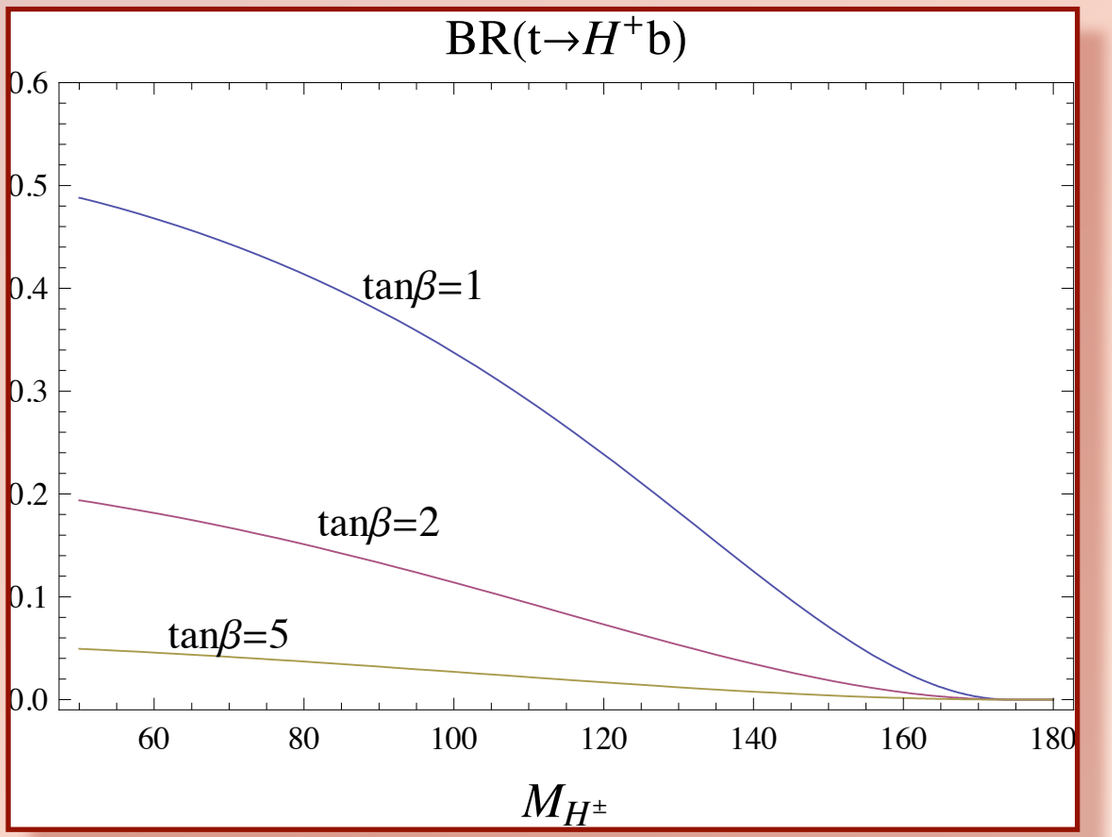
Charged Higgs in Top quark decays

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

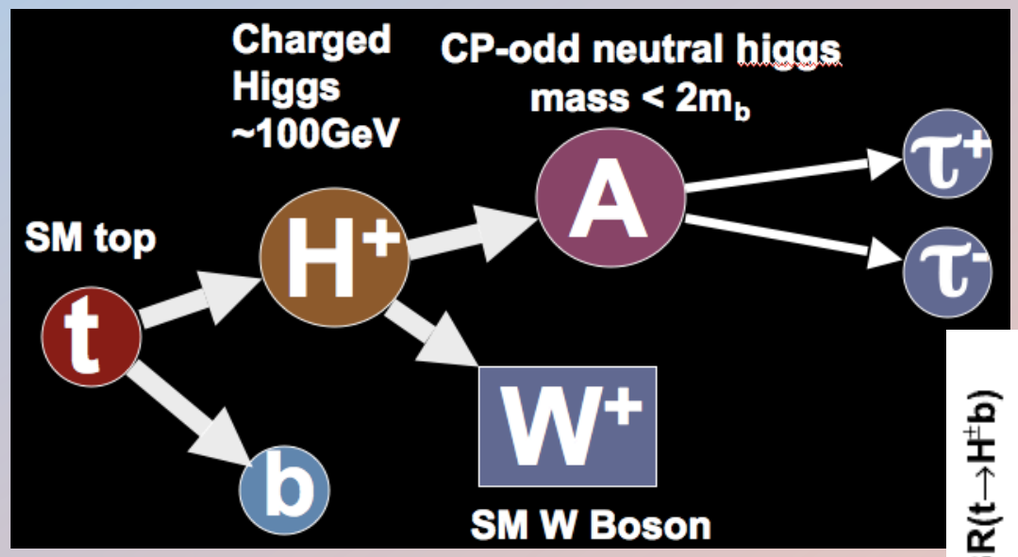


In MSSM:





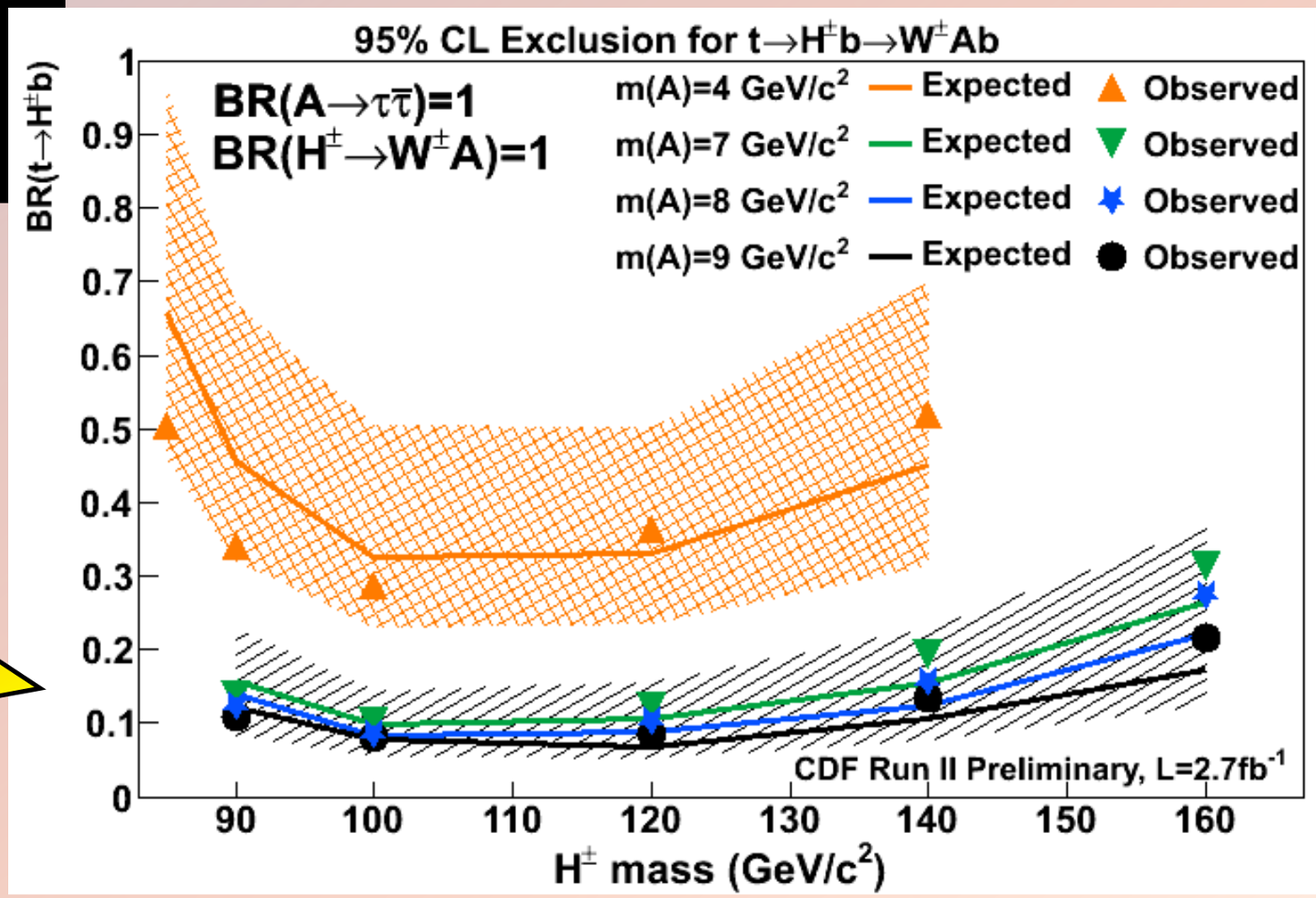
CDF search for charged Higgs



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

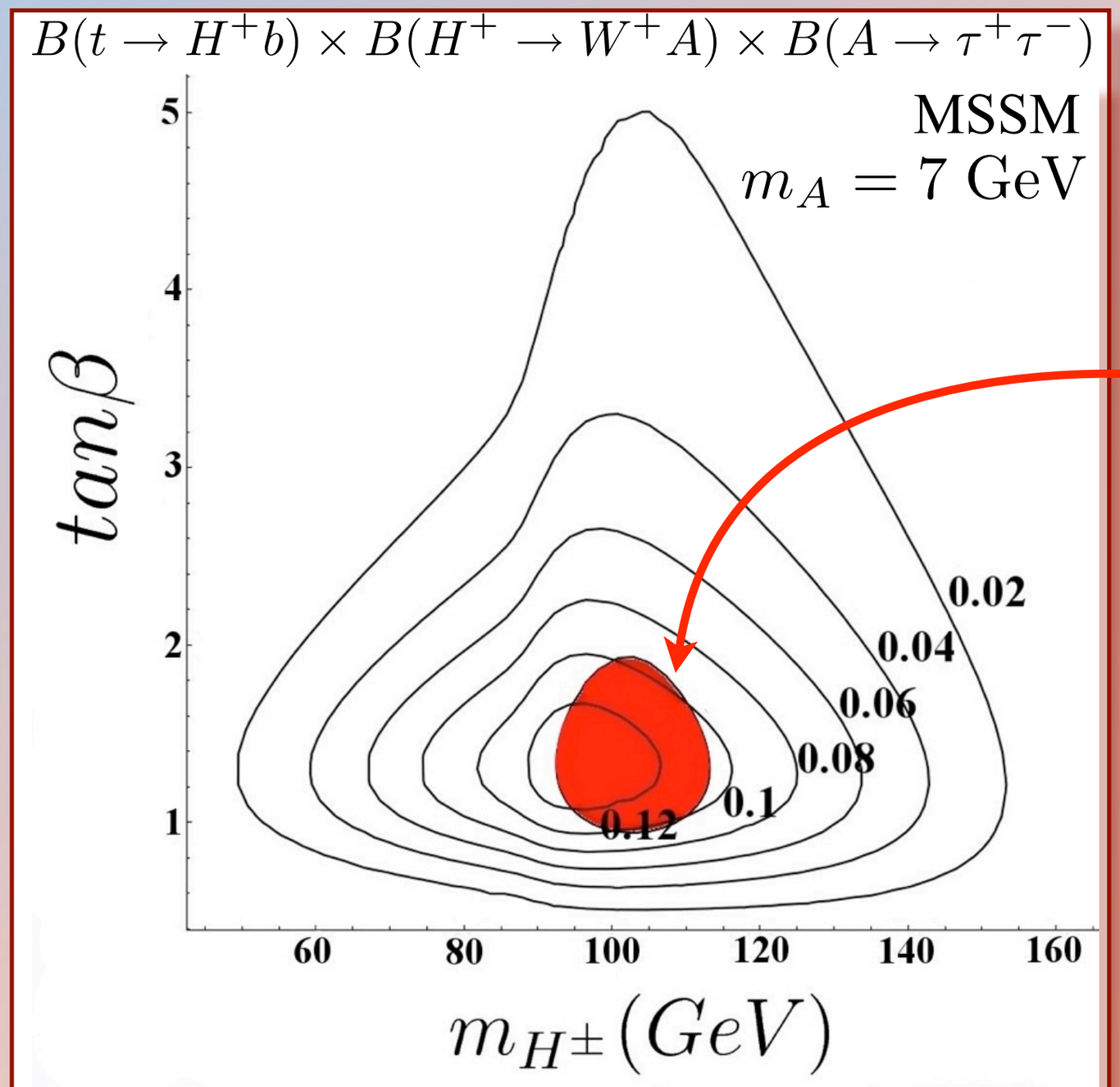
Limits allow

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



Impact of the CDF search

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



Excluded by CDF

(with 2.7 fb^{-1})

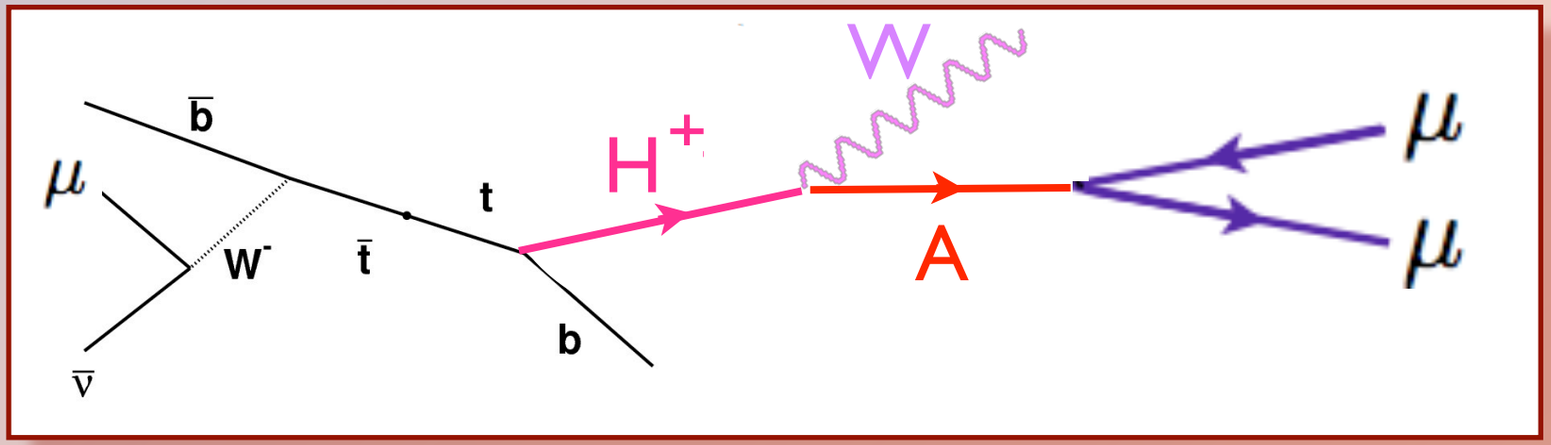
Prospects at the LHC with $1\ \mathrm{fb}^{-1}$.

Charged Higgs at the LHC

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

LHC is a top factory: 200 000 top pairs at 7 TeV with 1 fb^{-1}

it is advantageous to search for a subleading decay mode:

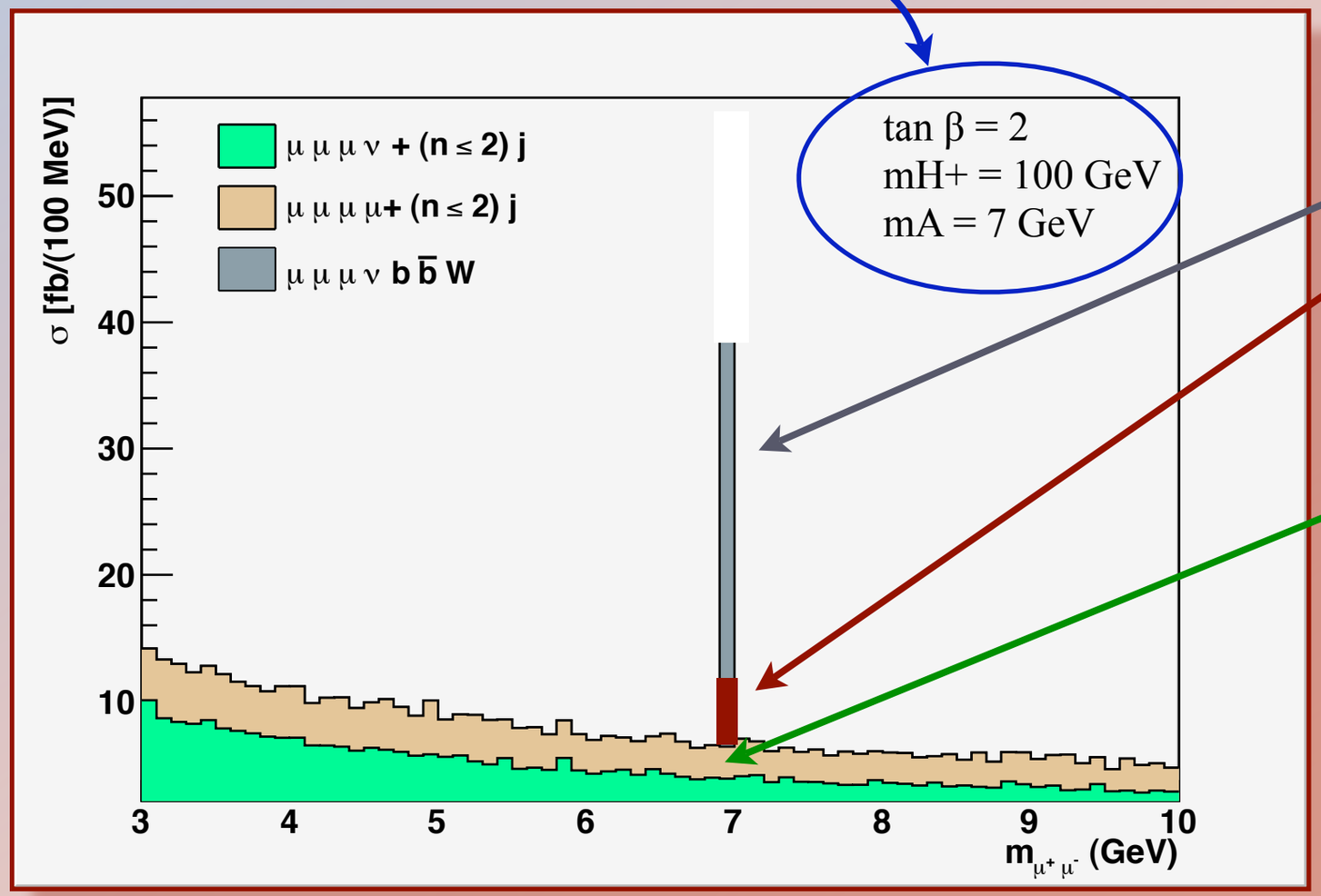


- **one of the two Ws:** $W \to \mu\nu$ **20%**
- **CP-odd Higgs:** $a \to \mu\mu$ **1/250**
- **for** $Br(t \to H^+ b) = 10\%$ **we have ~30 clean 3-muon events!**

Discovery strategy at the LHC

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

Simulation for MSSM with



Signal

Signal after pT cuts

Drell-Yan background highly suppressed by requiring pT of muons > 10 GeV; background from semileptonic b and c decays is manageable - in progress

Further improvements: adding $\mu\mu e$ signal, b-tagging, ...

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

Conclusions

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

In scenarios with a light doublet-like CP odd Higgs boson:

$$B(H^+ \to W^+ A) \geq 70\%$$

and the charged Higgs is typically lighter than the top quark.

For $m_{H^\pm} \simeq m_{W^\pm}$ the charged Higgs is expected to contribute to the measurement of lepton universality in W boson decays.

Searching for sub-leading decay modes is very promising:

$$t \to H^+ b, \quad H^+ \to W^+ a, \quad a \to \mu^+ \mu^-$$

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