The Higgs at the LHC

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1. The Higgs spectrum in the SM and the MSSM

2. Higgs decay and production at the LHC

3. Difficult scenarios in the conventional MSSM

4. Beyond the conventional MSSM

5. Conclusion

1. The Higgs in the SM

To generate particle masses in an $\mathrm{SU(2)_L \times U(1)_Y}$ gauge invariant way:

Spontaneous Electroweak Symmetry Breaking or Higgs mechanism:

$\Rightarrow$ **introduce a doublet of complex scalar fields** $\Phi = \binom{\phi^+}{\phi^0}$ **with** $\mathrm{Y}_\Phi = 1$

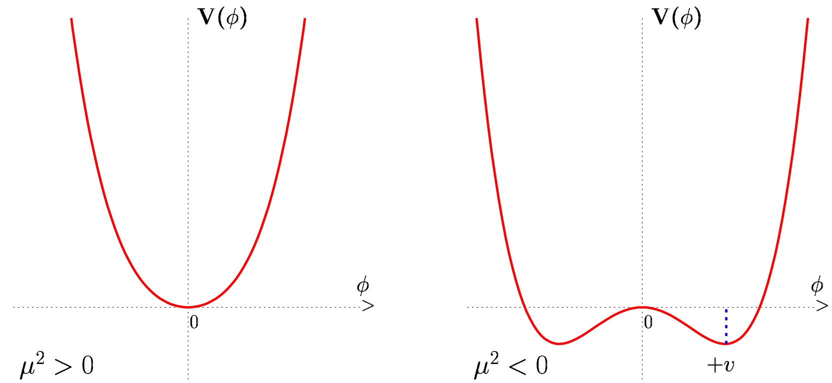
$$\mathcal{L}_\mathrm{S} = (\mathrm{D}^\mu \Phi)^\dagger (\mathrm{D}_\mu \Phi) - \mu^2 \Phi^\dagger \Phi - \lambda (\Phi^\dagger \Phi)^2$$

$\mu^2 > 0$: **4 scalar particles.**

$\mu^2 < 0$: Φ **develops a vev:**

$$\langle 0 | \Phi | 0 \rangle = \binom{0}{\mathrm{v}/\sqrt{2}}$$

$$\mathrm{v} = \left(-\frac{\mu^2}{\lambda}\right)^{\frac{1}{2}} = 246 \ \mathrm{GeV}$$



$\Rightarrow$ **3 degrees of freedom for** $\mathrm{W_L^\pm, Z_L}$ **and thus** $\mathrm{M_{W^\pm}, M_Z; M_\gamma = 0}$

For fermion masses, use <u>same</u> doublet field Φ **and its <u>conjugate</u> field**

$$\mathcal{L}_\mathrm{Yuk} = -\mathrm{f_e} (\bar{\mathrm{e}}, \bar{\nu})_\mathrm{L} \Phi \mathrm{e_R} - \mathrm{f_d} (\bar{\mathrm{u}}, \bar{\mathrm{d}})_\mathrm{L} \Phi \mathrm{d_R} - \mathrm{f_u} (\bar{\mathrm{u}}, \bar{\mathrm{d}})_\mathrm{L} \tilde{\Phi} \mathrm{u_R} + \cdots$$

The residual degree corresponds to the spin–zero Higgs particle, H.

1. The Higgs in the SM

- The Higgs boson: $J^{PC} = 0^{++}$ quantum numbers
- Masses and self–couplings from $\mathcal{L}_S \propto \mu^2 \Phi^\dagger \Phi + \lambda (\Phi^\dagger \Phi)^2$

$$M_H^2 = 2\lambda v^2 = -2\mu^2 , \; g_{H^3} = 3i\, M_H^2/v \; , \; g_{H^4} = 3iM_H^2/v^2$$

- Higgs couplings derived the same way as the particle masses:

$$\mathcal{L}_{M_V} \sim M_V^2 (1 + H/v)^2 \; , \; \mathcal{L}_{m_f} \sim -m_f (1 + H/v)$$

$$\Rightarrow g_{Hff} = im_f/v \; , \; g_{HVV} = -2iM_V^2/v \; , \; g_{HHVV} = -2iM_V^2/v^2$$

Since v is known, the only free parameter in SM is M_H or λ.

However, there are theoretical constraints:

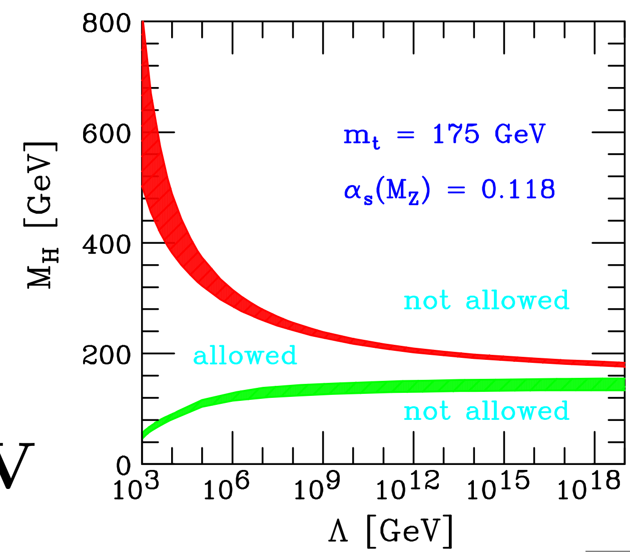
– Very heavy Higgs: strong W/Z interactions

perturbative unitarity $\Rightarrow M_H \lesssim 1$ TeV

– Triviality and stability bounds

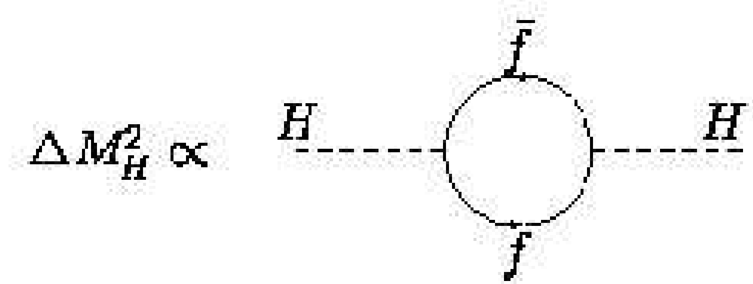
$\Lambda \sim 1$ TeV $\Rightarrow 70 \lesssim M_H \lesssim 700$ GeV

$\Lambda \sim 10^{16}$ GeV $\Rightarrow 130 \lesssim M_H \lesssim 180$ GeV



1. The Higgs in the SM: problems

A big problem in the SM: the hierarchy/naturalness problem

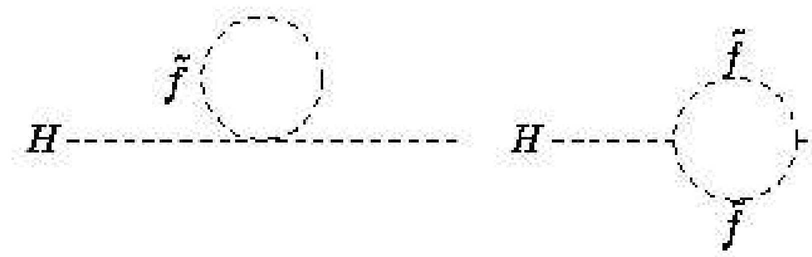


- **Radiative corrections to M_H^2 in SM**

with a cut–off $\Lambda = M_{NP} = M_{GUT}$

$$\Delta M_H^2 = N_f \frac{\lambda_f^2}{8\pi^2}\left[-\Lambda^2 + 6 m_f^2 \log\frac{\Lambda}{m_f} - 2 m_f^2\right] + \mathcal{O}(1/\Lambda^2)$$

M_H prefers to be close to the high scale than to the EWSB scale.



- **In SUSY, add spartner contribution:**

$N_S = N_f, \lambda_f^2 = -\lambda_S, m_1 = m_2 = m_S$

$$\Delta M_H^2|^{\rm tot} = \frac{\lambda_f^2 N_f}{4\pi^2}\left[(m_f^2 - m_S^2)\log(\frac{\Lambda}{m_S}) + 3 m_f^2 \log(\frac{m_S}{m_f})\right]$$

Symmetry fermions–scalars $\Rightarrow$ no divergence in Λ^2

But if $M_S \gg 1$ TeV the problem is back again $\Rightarrow$ low energy SUSY.

At least two other attractive features of low energy SUSY models:

solutions to the gauge coupling unification and dark matter problems

1. The MSSM Higgses: the framework

Up to now, the focus was mainly on the Higgs sector of the

Minimal Supersymmetric Standard Model (MSSM):

- **minimal gauge group: SU(3)$\times$SU(2)$\times$U(1),**
- **minimal particle content: 3 fermion families and 2 Φ doublets,**
- **R=$(-1)^{(2s+L+3B)}$ parity is conserved,**
- **minimal set of terms (masses, couplings) breaking "softly" SUSY.**

To reduce the number of the (too many in general) free parameters:

– impose phenomenological constraints: O(20) free parameters,

– unified models, O(5) parameters (mSUGRA: $m_0, m_{\frac{1}{2}}, A_0, \tan\beta, \epsilon_\mu$),

– in general sparticles assumed to be heavy: decouple from Higgs.

First summarize Higgs phenomenology in this (rather simple) model.

- **there are still tricky scenarios which need further analyses....**
- **the impact of light SUSY particles might be important...**
- **the impact of relaxing some MSSM assumptions can be huge...**

1. The MSSM Higgs sector

In MSSM with two Higgs doublets: $H_1 = \binom{H_1^0}{H_1^-}$ and $H_2 = \binom{H_2^+}{H_2^0}$,

- to cancel the chiral anomalies introduced by the new $\tilde{h}$ field,
- give separately masses to d and u fermions in SUSY invariant way.

After EWSB (which can be made radiative: more elegant than in SM):

Three dof to make $W_L^\pm, Z_L \Rightarrow$ 5 physical states left out: $h, H, A, H^\pm$

Only two free parameters at the tree level: $\tan\beta, M_A$; others are:

$$M^2_{h,H} = \frac{1}{2}\left[M_A^2 + M_Z^2 \mp \sqrt{(M_A^2+M_Z^2)^2 - 4M_A^2 M_Z^2 \cos^2 2\beta}\right]$$

$$M^2_{H^\pm} = M_A^2 + M_W^2$$

$$\tan 2\alpha = \tan 2\beta \,(M_A^2 + M_Z^2)/(M_A^2 - M_Z^2)$$

We have important constraint on the MSSM Higgs boson masses:

$$M_h \leq \min(M_A, M_Z) \cdot |\cos 2\beta| \leq M_Z,\; M_{H^\pm} > M_W, M_H > M_A \ldots$$

$M_A \gg M_Z$: decoupling regime, all Higgses heavy except for h.

$$M_h \sim M_Z |\cos 2\beta| \leq M_Z!\;,\; M_H \sim M_{H^\pm} \sim M_A\;,\; \alpha \sim \frac{\pi}{2} - \beta$$

1. The Higgs spectrum: Higgs masses

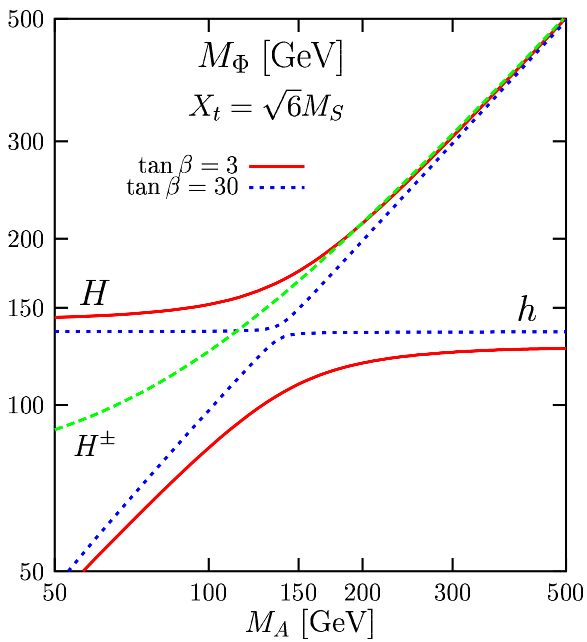
Radiative corrections very important in the MSSM Higgs sector.

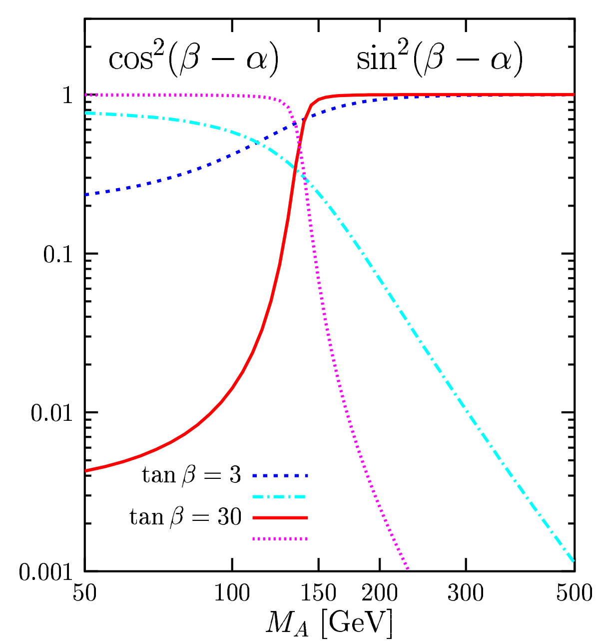
- **Dominant corrections are due to top (s)quark at one-loop level**

$$\Delta M_h^2 = \frac{3g^2}{2\pi^2}\frac{m_t^4}{M_W^2}\log\frac{m_{\tilde{t}}^2}{m_t^2} \text{ large: } \xrightarrow{M_h^{max} \to M_Z + 40\,\text{GeV}} \gtrsim 115\,\text{GeV}$$

- **Full one–loop corrections available: μ, A_t, A_b enter the game**
- **Approximate dominant two–loop corrections in EPA approach:**
- **Using full 1–loop and the 2–loop RC in effective potential approach:**

Carena ea, Haber ea, Heinemeyer ea, Espinosa ea, Slavich ea, Martin





1. MSSM Higgs couplings

Higgs decays and cross sections strongly depend on couplings.

Couplings in terms of $\mathrm{H_{SM}}$ and their values in decoupling limit:

Φ	$g_{\Phi \bar{u} u}$	$g_{\Phi \bar{d} d}$	$g_{\Phi VV}$
h	$\frac{\cos\alpha}{\sin\beta} \to 1$	$\frac{\sin\alpha}{\cos\beta} \to 1$	$\sin(\beta-\alpha) \to 1$
H	$\frac{\sin\alpha}{\sin\beta} \to 1/\tan\beta$	$\frac{\cos\alpha}{\cos\beta} \to \tan\beta$	$\cos(\beta-\alpha) \to 0$
A	$1/\tan\beta$	$\tan\beta$	0

– The couplings of $\mathrm{H^{\pm}}$ have the same intensity as those of A.

– Couplings of $\mathrm{h, H}$ to VV are suppressed; no AVV couplings (CP)

– For $\tan\beta > 1$: couplings to d enhanced, couplings to u suppressed.

– For $\tan\beta \gg 1$: couplings to b quarks ($\mathrm{m_b} \tan\beta$) very strong.

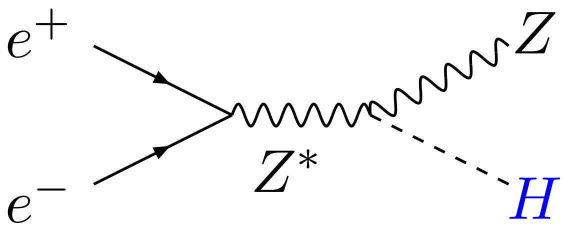
– For $\mathrm{M_A} \gg \mathrm{M_Z}$: h couples like the SM Higgs boson and H like A.

In decoupling limit: MSSM reduces to SM but with a light Higgs.

1. The Higgs spectrum: SM limit and constraints

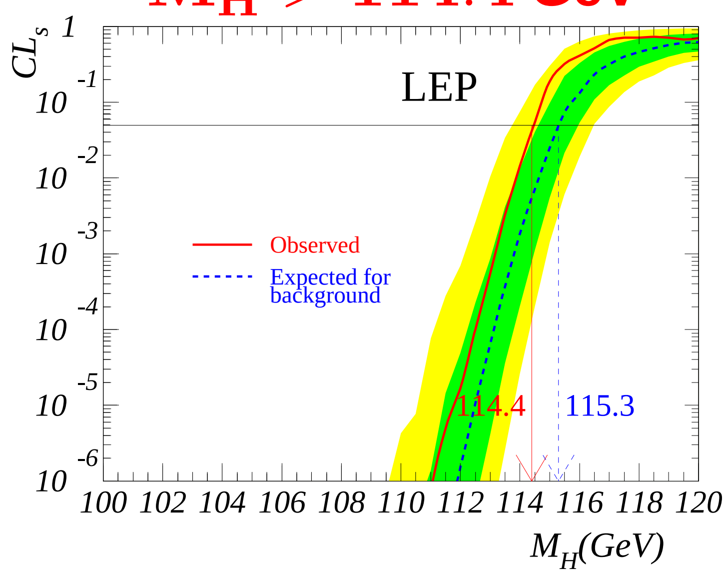
Direct searches at LEP:

H looked for in $e^+e^- \to ZH$



We have a limit at 95% CL:

$M_H > 114.4$ **GeV**

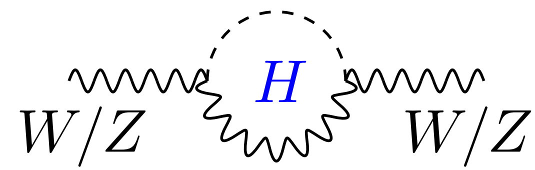


Absolute mass bound in MSSM:

$M_h, M_A \gtrsim M_Z$

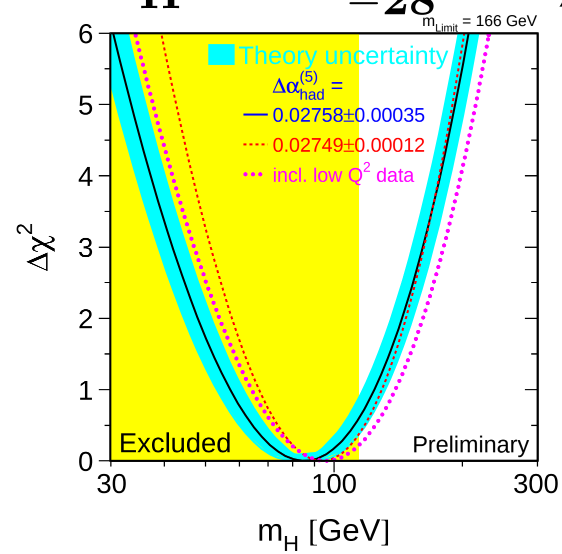
Indirect Higgs searches:

H contributes to RC to W/Z masses:



Fit the EW precision measurements:

we obtain $M_H = 85^{+39}_{-28}$ **GeV, or**

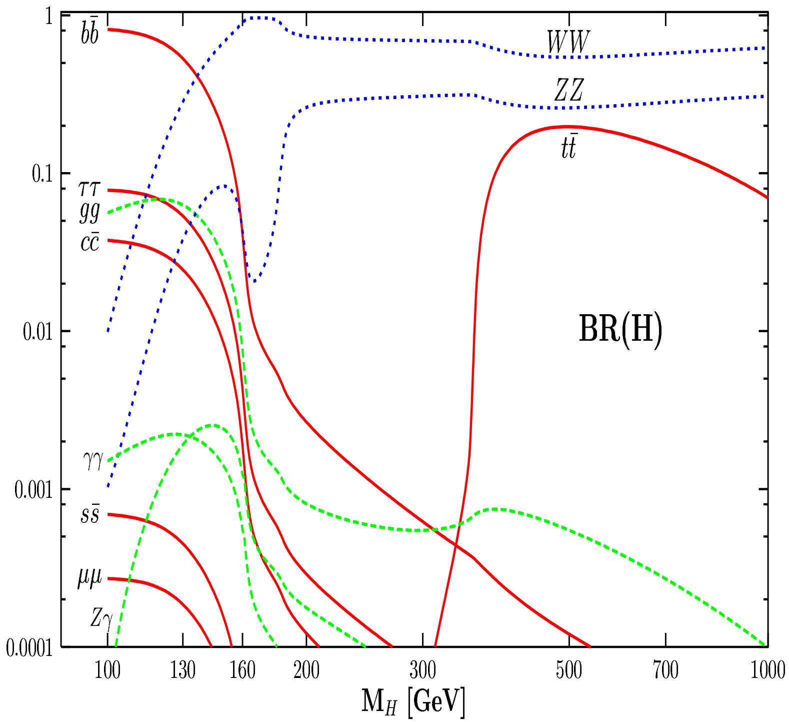


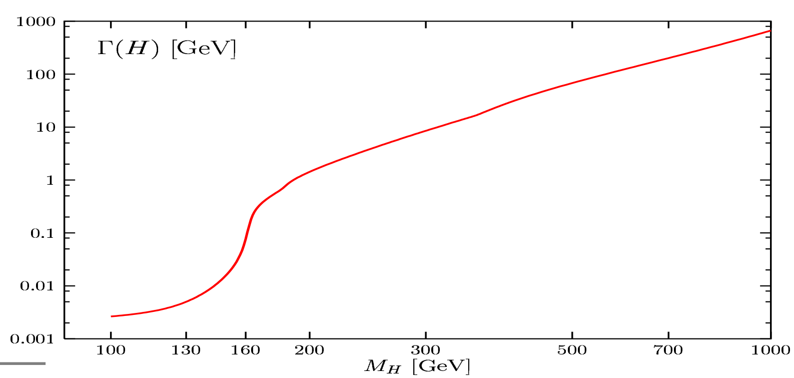
$M_H \lesssim 166$ **GeV at 95% CL**

MSSM: $M_h \lesssim 140$ **GeV**

2. Higgs decays: summary in SM

Higgs decays in the SM:





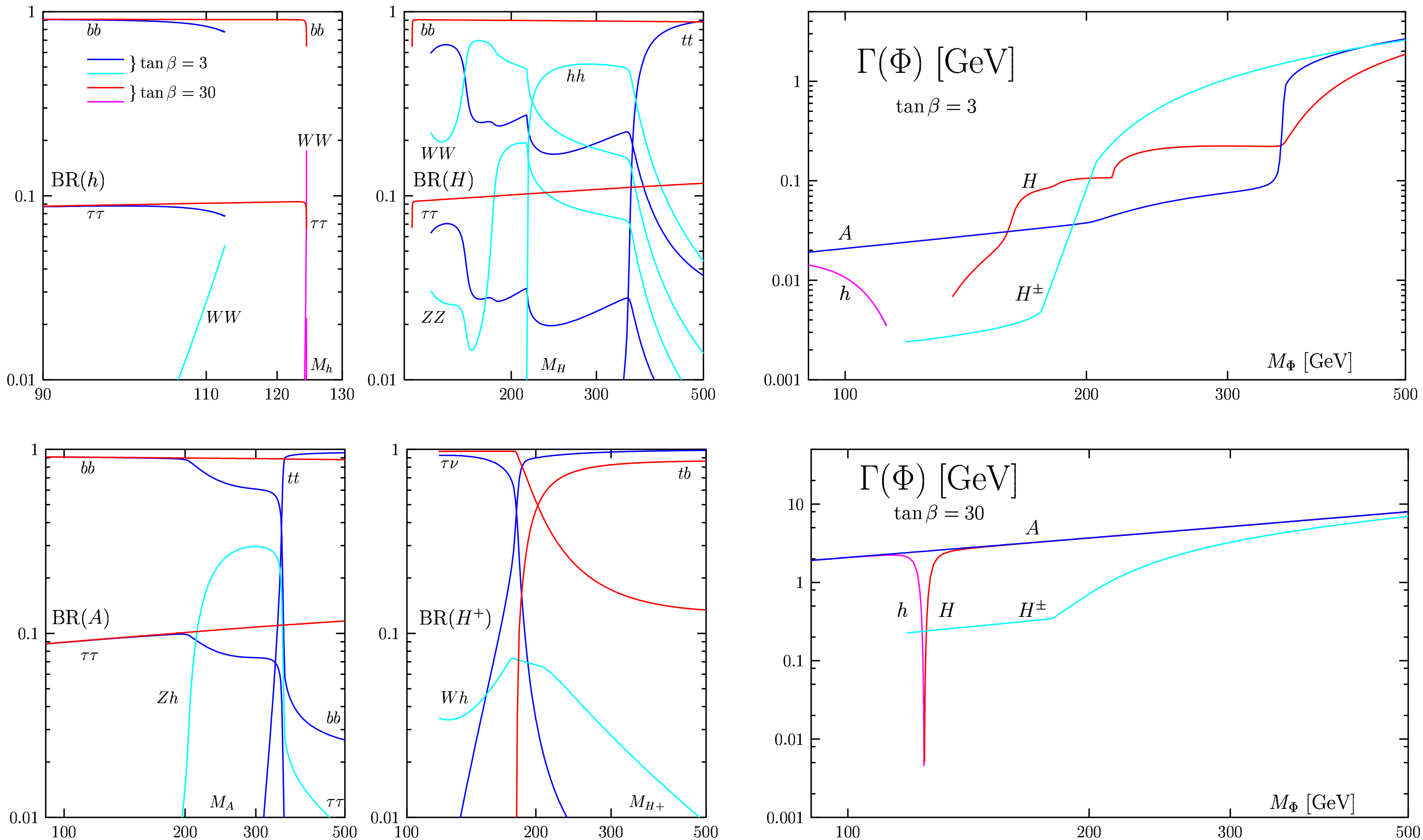
Higgs decays in the MSSM:

General features:

- h: same as $\mathrm{H_{SM}}$ in general (in particular in decoupling limit) $\mathrm{h \to b\bar{b}}$ and $\tau^+\tau^-$ same or enhance
- A: only $\mathrm{b\bar{b}}, \tau^+\tau^-$ and $\mathrm{t\bar{t}}$ decays (no VV decays, hZ suppressed).
- H: same as A in general $(\mathrm{WW}, \mathrm{ZZ}, \mathrm{hh}$ decays suppressed).
- $\mathrm{H^\pm}$: $\tau\nu$ and tb decays (depending if $\mathrm{M_{H^\pm}} <$ or $> \mathrm{m_t}$).

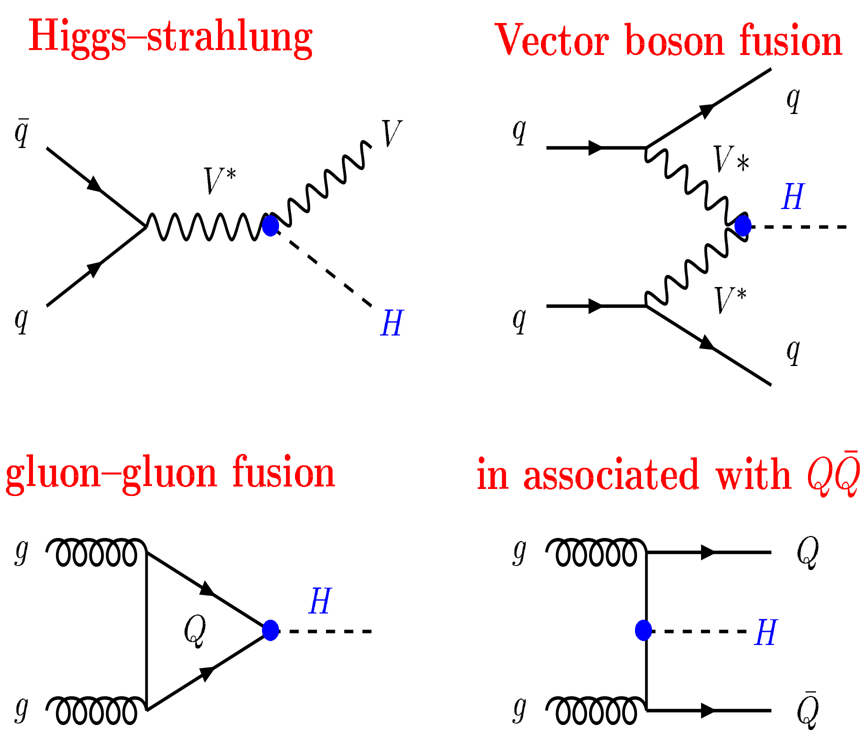
Possible new effects from SUSY

2. Higgs decays: BRs and widths

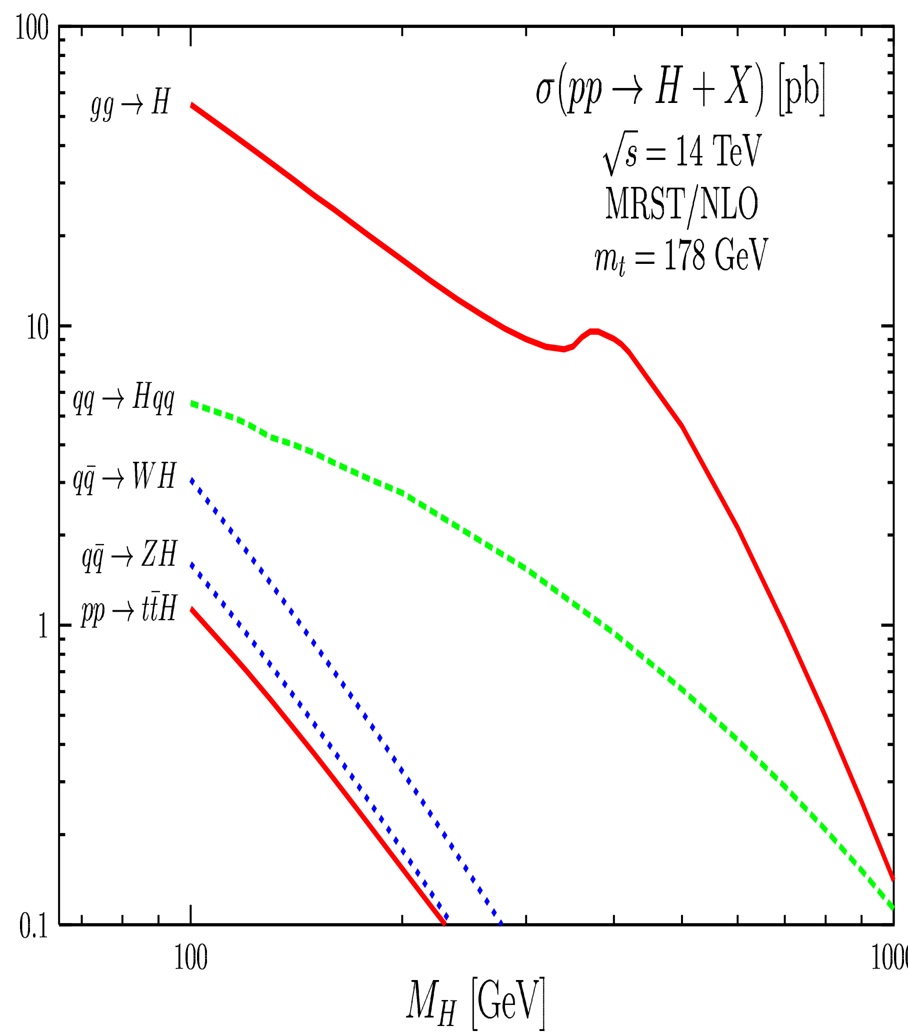


2. Production at the LHC: SM case

SM production mechanisms



Cross sections at the LHC



There are also subleading processes, $gg \to HH$, etc...

2. Production at LHC: cross sections

Summary of higher order calculations for production in the SM:

- **Very large corrections to the process $\mathrm{gg} \to \mathrm{H}$:**

+70% at NLO: Spira et al (exact case); Dawson ($\mathrm{m_t} \to \infty$);

+30% at NNLO: Harlander et al; Melnikov et al; Ravindran et al;

+5% with gluon resumation: Catani et al, Spira et al.

10% for EW corrections: Degrassi et al.

- **Moderate corrections to the process $\mathrm{VV} \to \mathrm{H}$:**

+10% at NLO: Han+Valencia

also corrections to the various distributions (MC): Zeppenfeld et al;

- **Small corrections to $\mathrm{pp} \to \mathrm{t\bar{t}} + \mathrm{H}$**

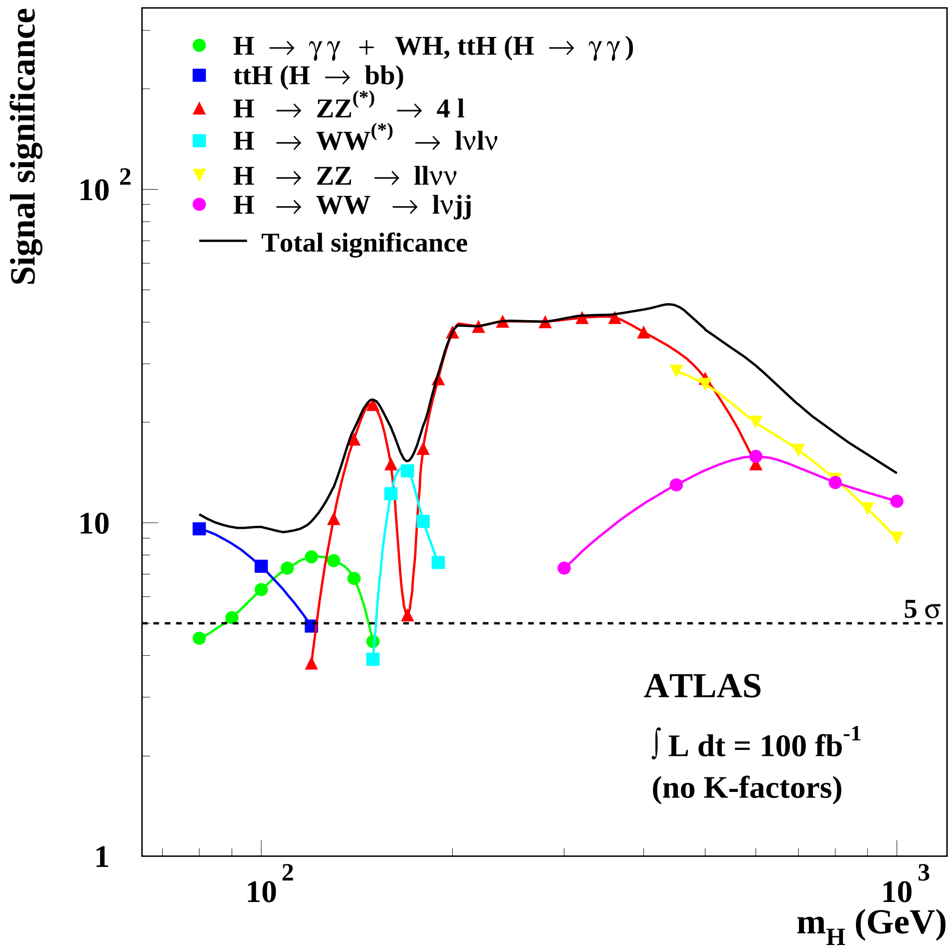
+20% at NLO: Spira ea; Zerwas ea; Dawson ea.

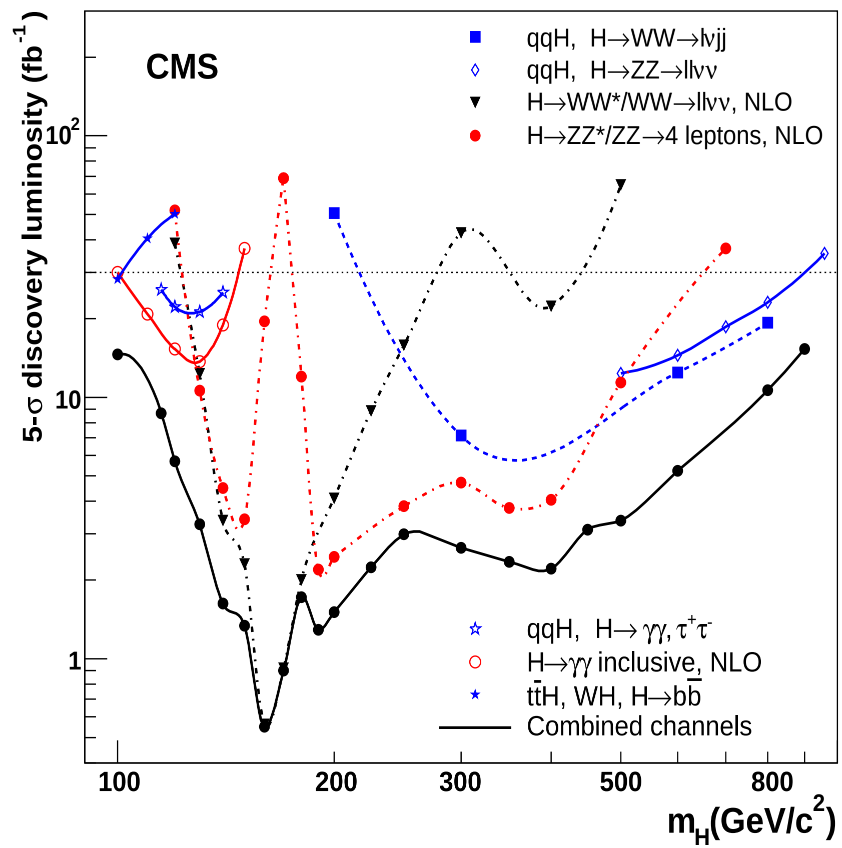
- **Moderate corrections to $\mathrm{pp} \to \mathrm{VH}$**

+30% at NLO: Han ea; 5% at NNLO: Brein ea; also EW: Dittmaier ea.

H decays: QCD+EW under control in general/summarized in HDECAY.

2. Production at the LHC: detection

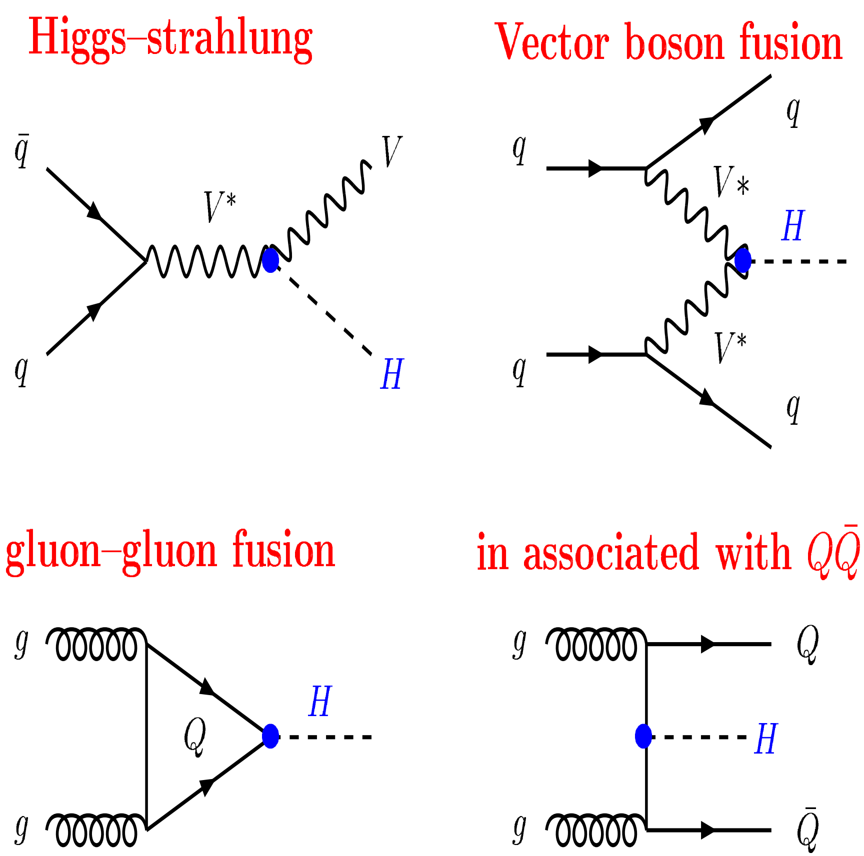




2. Production at the LHC: MSSM case

SM production mechanisms

[assuming heavy sparticles]



What is different in MSSM

- **All work for CP–even h,H bosons.**

– in ΦV, $qq\Phi$ h/H complementary

– $\sigma(h) + \sigma(H) = \sigma(H_{SM})$

– aditionnal mechanism: qq $\to$ A+h/H

- **For** $gg \to \Phi$ and $pp \to tt\Phi$

– include the contr. of b–quarks

– dominant contr. at high tanβ!

- **For pseudoscalar A boson:**

– CP: no ΦA and qqA processes

– $gg \to A$ and $pp \to bbA$ dominant.

- **For charged Higgs boson:**

– $M_H \lesssim m_t$: $pp \to t\bar{t}$ with $t \to H^+ b$

– $M_H \gtrsim m_t$: continuum $pp \to t\bar{b}H^-$

2. Production at LHC: cross sections

Summary of higher order calculations in MSSM (for SM see earlier)

For h/H: same processes as for SM Higgs (esp. for $\mathrm{M_A \gg M_Z}$) but:

- Include b–loop contributions to $\mathrm{gg \to h/H}$ and new $\mathrm{gg \to A}$

K–factors only at NLO ($\sim$ 1.5–2) AD+Graudenz+Spira+Zerwas

- Include b–final states in $\mathrm{pp \to b\bar{b} + h/H}$ (dominant at high $\tan\beta$)

large K–factors at NLO (50%) Spira ea; Zerwas ea; Dawson ea

- Additional SUSY–QCD corrections in $\mathrm{pp \to V + h/H; qq + h/H}$:

rather small at NLO (a few %) for heavy $\mathrm{\tilde{q}/\tilde{g}}$ AD+Spira

For A: rates including K–factors approx the same as above for h/H

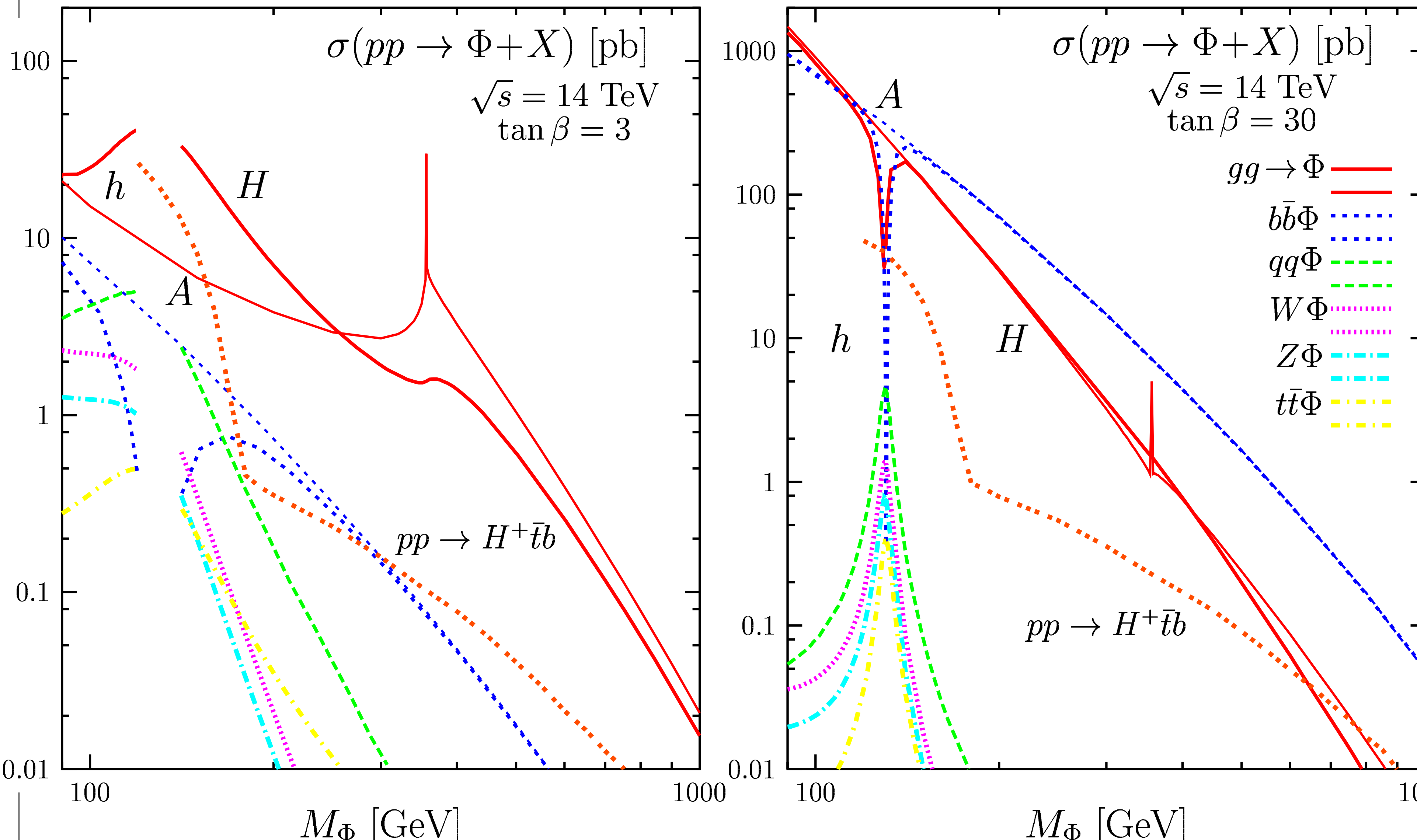
For $\mathrm{H^\pm}$: main process is $\mathrm{pp \to tt^{(*)} \to tbH^\pm}$ in general

relevant corrections known exactly at NLO Plehn; Zhou; Kidonakis

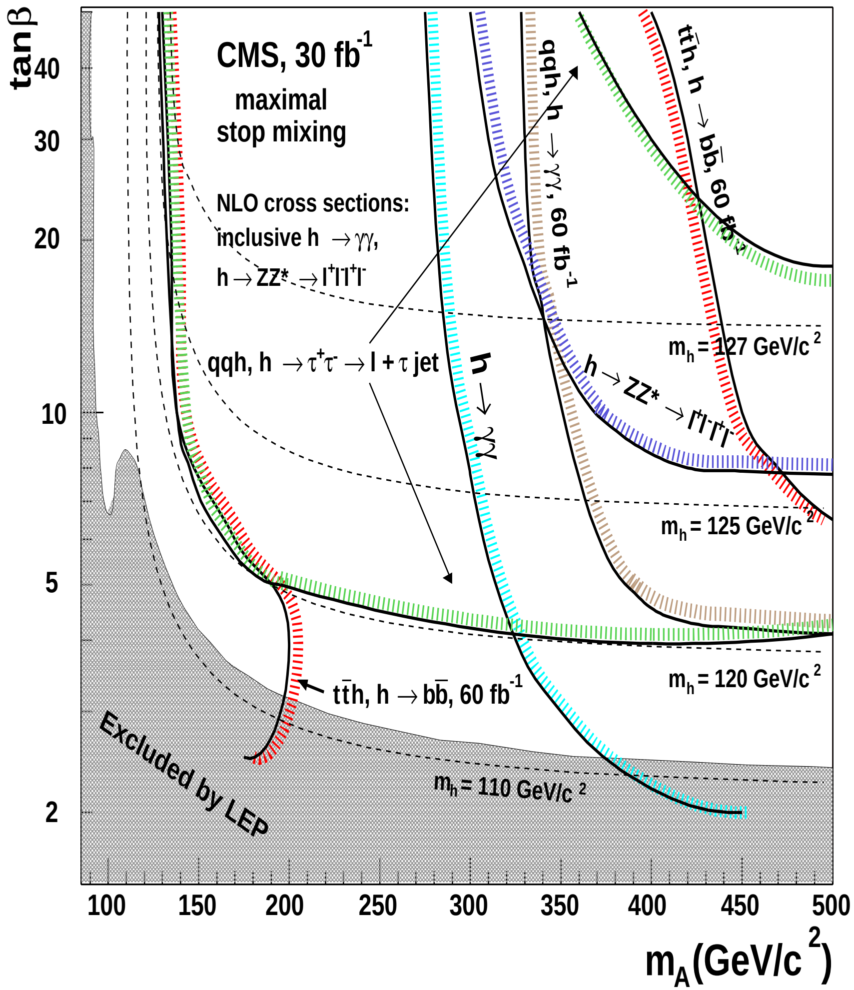
h,H,A,H$^\pm$ decays: well under control including SUSY+NL0 corrections

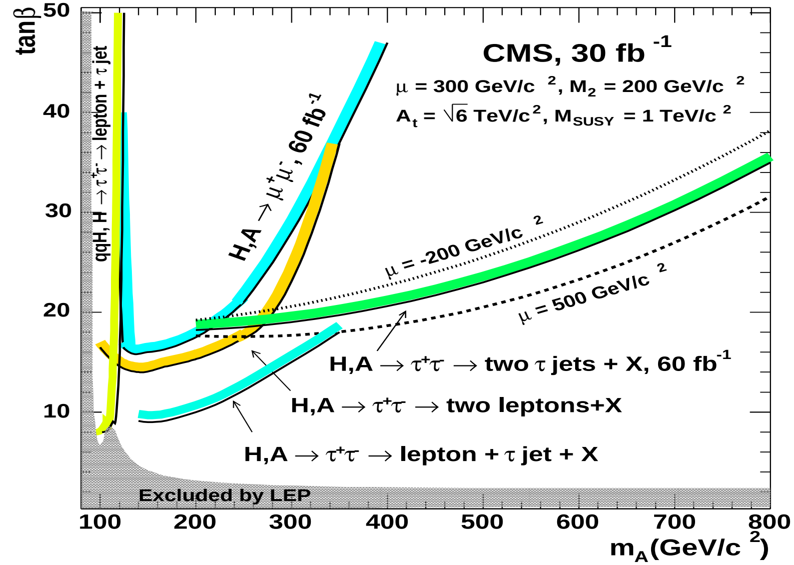
summarized in the program HDECAY AD+Kalinowski+Spira

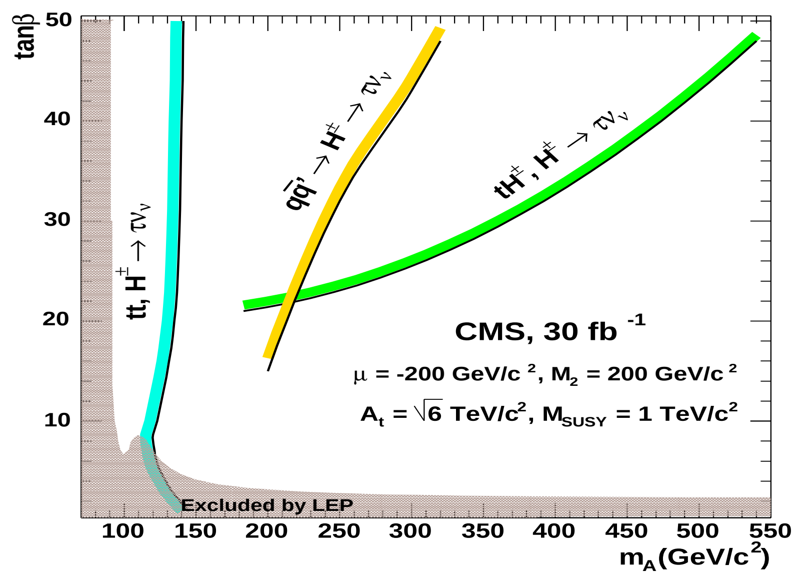
2. Production at LHC: cross sections



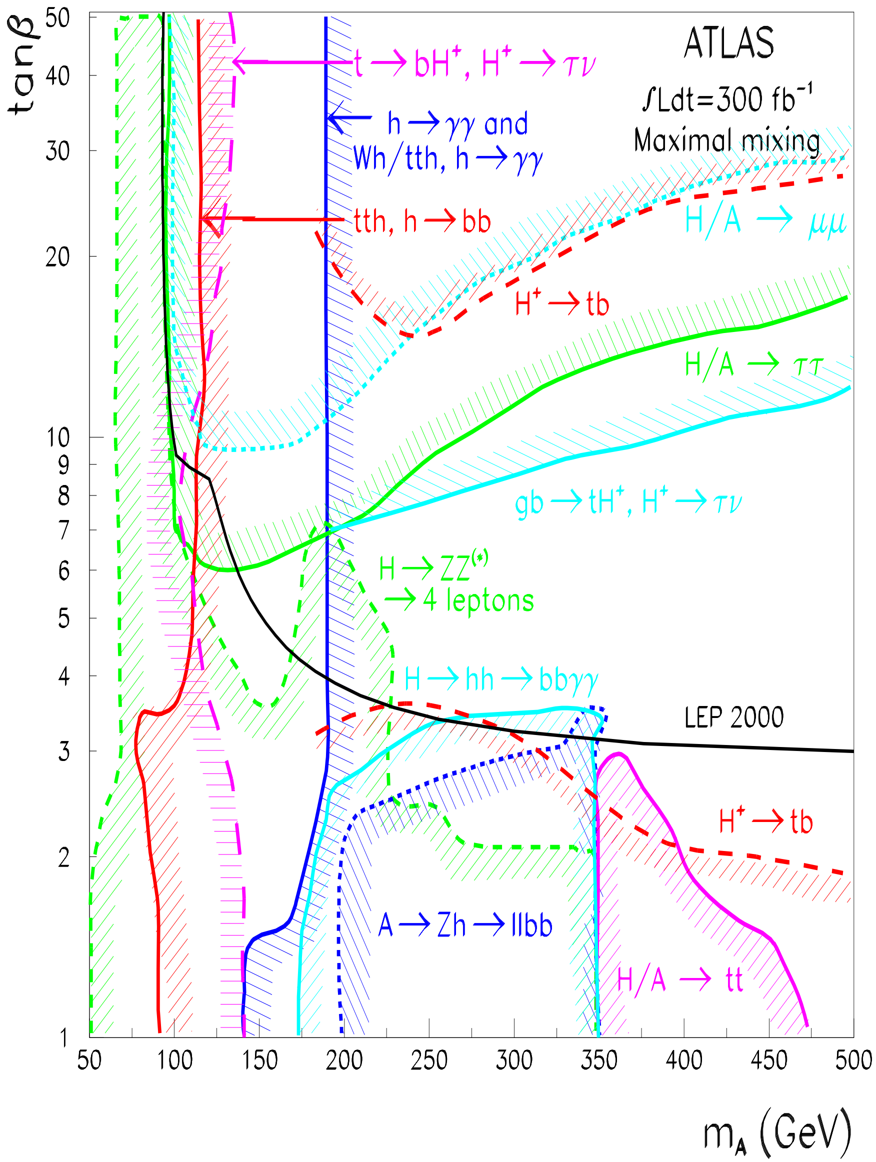
2. Production at LHC: detection

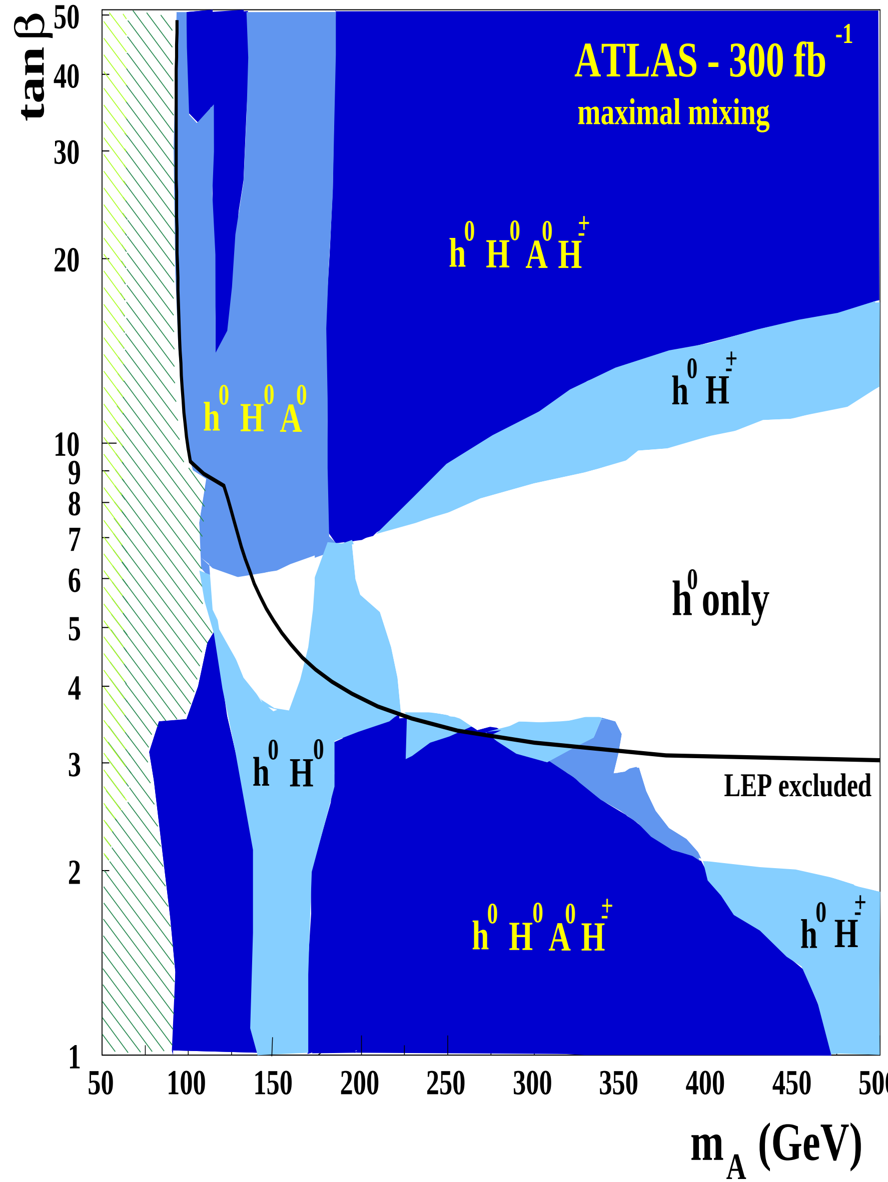






2. Production at LHC: detection





3. Difficult scenarios in the MSSM

However: life can be much more complicated even in this MSSM

- **There is the "bad luck" scenario in which only h is observed:**

– looks SM–like at the 10% level (and $M_{SUSY} \gtrsim 3$ TeV...): SM

- **There are scenarii where searches are different from standard case:**

– The intense coupling regime: h,H,A almost mass degenerate....

- **SUSY particles might play an important role in production/decay:**

– light $\tilde{t}$ loops might make $\sigma(gg \to h \to \gamma\gamma)$ smaller than in SM.

– Higgsses can be produced with sparticles ($pp \to \tilde{t}\tilde{t}^* h$,..).

– Cascade decays of SUSY particles into Higgs bosons....

- **SUSY decays, if allowed, might alter the search strategies:**

– $h \to \chi_1^0 \chi_1^0, \tilde{\nu}\tilde{\nu}$ are still possible in non universal models...

– Decays of $A, H, H^\pm$ into $\chi_i^\pm, \chi_i^0$ are possible but can be useful...

Be prepared for the unexpected!

3. Difficult scenarios: intense coupling regime

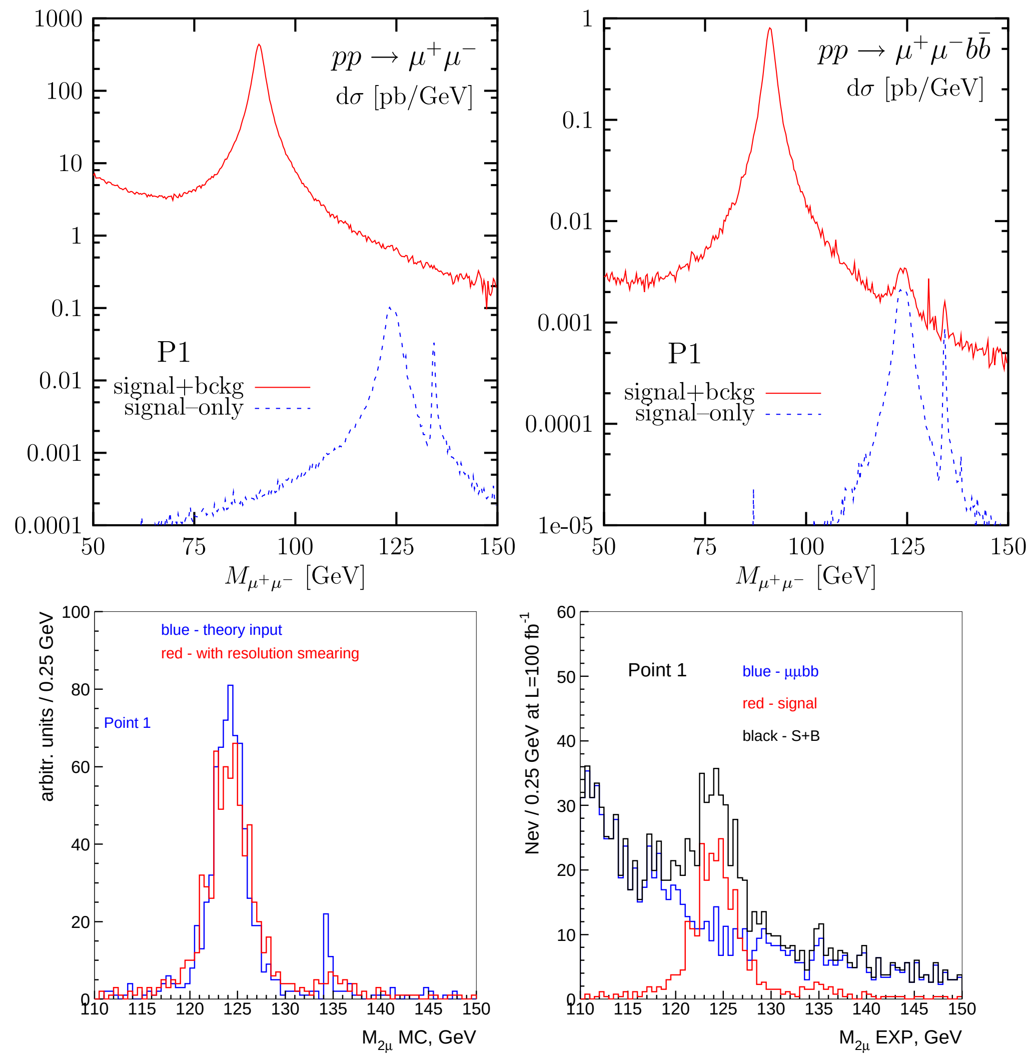
- **There are scenarii where searches are different from standard case:**

– The intense coupling regime: h,H,A almost mass degenerate....

E. Boos,

A. Nikitenko,

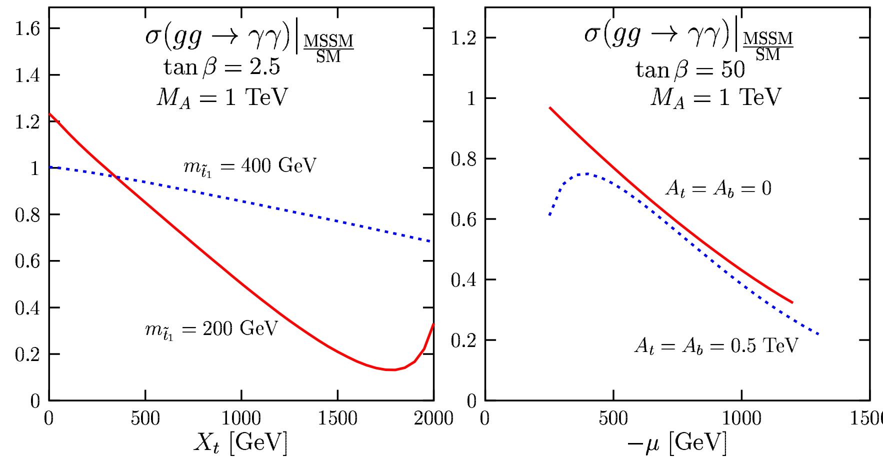
....



3. Difficult scenarios: light stops

- **SUSY particles might play an important role in production/decay:**

– light $\tilde{t}$ loops might make $\sigma(gg \to h \to \gamma\gamma)$ smaller than in SM.



– Higgsses can be produced with sparticles ($pp \to \tilde{t}\tilde{t}^* h$,..).

JL. Kneur,

G.Moultaka,

S.Moretti,

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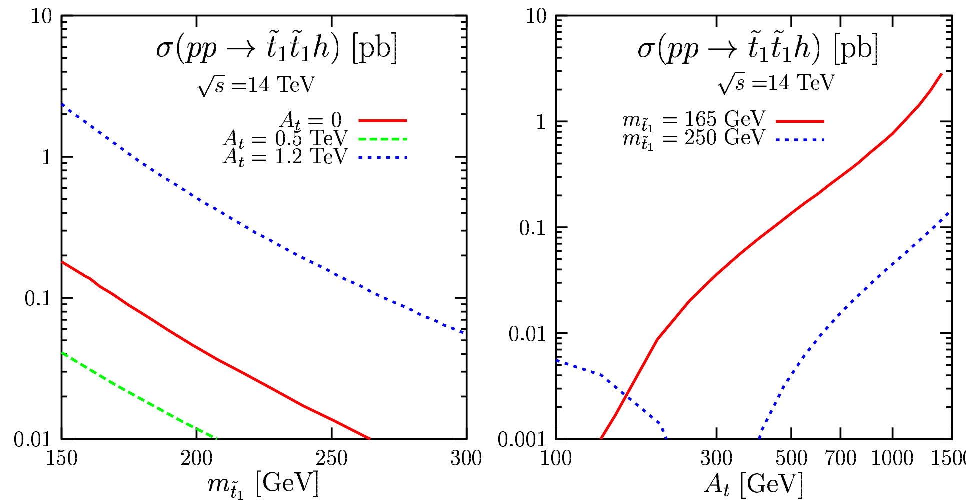
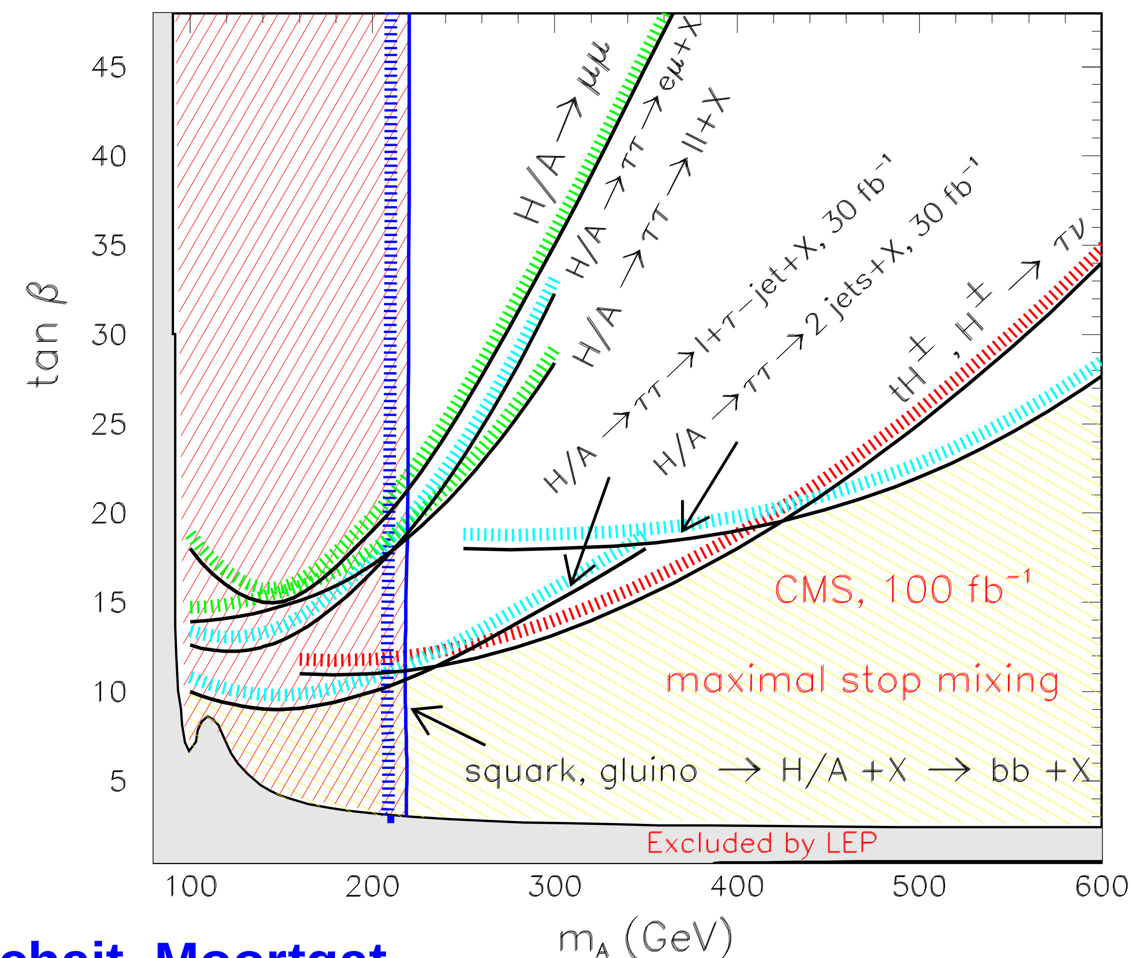


3. Difficult scenarios: SUSY cascade decays

- **SUSY particles might play an important role in production/decay:**

– Cascade decays of SUSY particles into Higgs bosons....

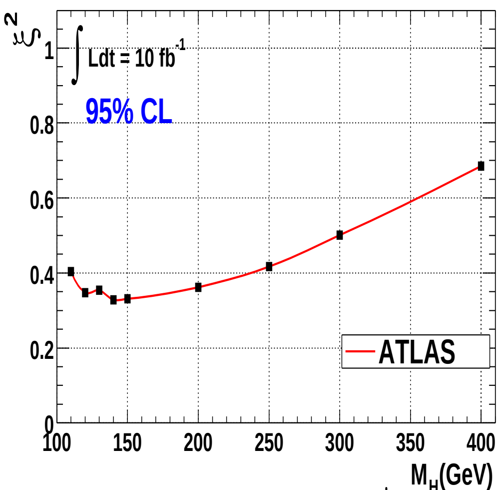


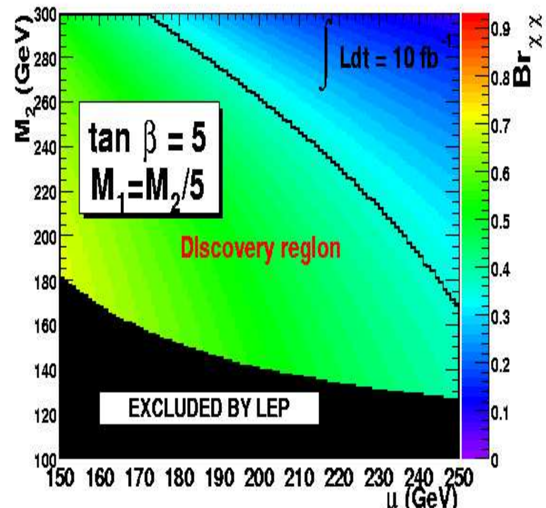
Datta, Guchait, Moortgat, ...

3. Difficult scenarios: decays into SUSY

- **SUSY decays, if allowed, might alter the search strategies:**

– $\mathbf{h} \to \chi_1^0 \chi_1^0, \tilde{\nu}\tilde{\nu}$ **are still possible in non universal models...**

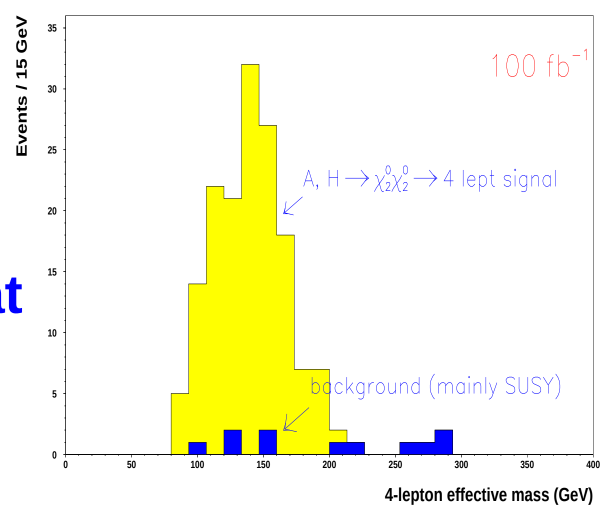


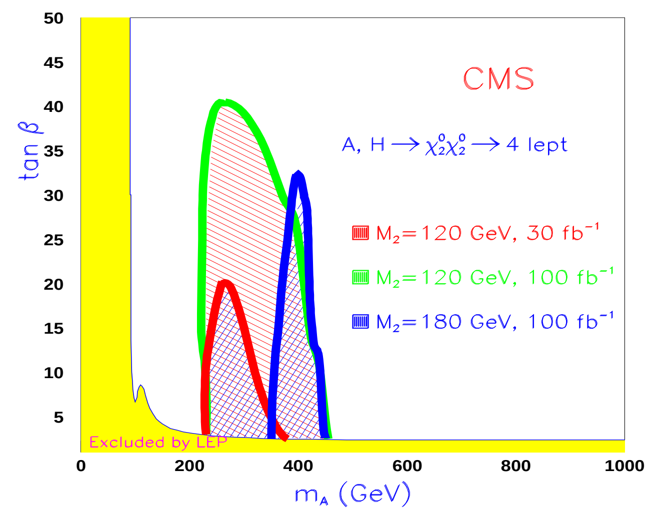


Bélanger, Boudjema, Donato Godbole, Rosier Lee

– **Decays of** $\mathbf{A, H, H^\pm}$ **into** $\chi_i^\pm, \chi_i^0$ **are possible but can be useful...**

Moortgat





4. Beyond the conventional MSSM: CP–violation

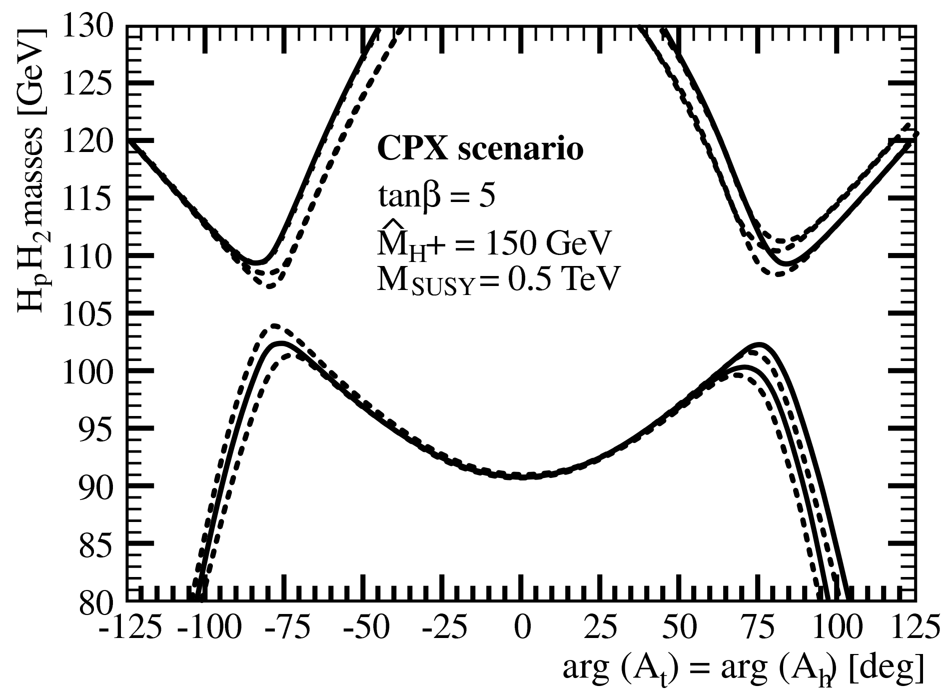
Life can be even more complicated in extensions of the MSSM

We can allow for some amount of CP–violation in eg. M_i, μ and A_f

Higgs sector: CP–conserving at tree level $\Rightarrow$ CP–violating at one–loop

Good to address the issue of baryogenesis at the electroweak scale....

- **h, H,A are not CP definite states and h_1, h_2, h_3 CP mixtures**
- **determination of Higgs spectrum slightly more complicated,**
- **possibility of a light h_1 that has escaped detection at LEP2.**



Carena et al, Choi+Drees et al, Pilaftsis et al, Ellis et al, Haber+Gunion, Krawczyk et al, Osland et al, Heinemeyer et al, Moretti et al, ...

4. Beyond the conventional MSSM: CP–violation

The CPX scenario:

(Carena et al, Ellis et al,)

h_1 light but weak cplgs to W,Z

$h_2 \to h_1 h_1$ decays allowed

h_3 couplings to VV reduced...

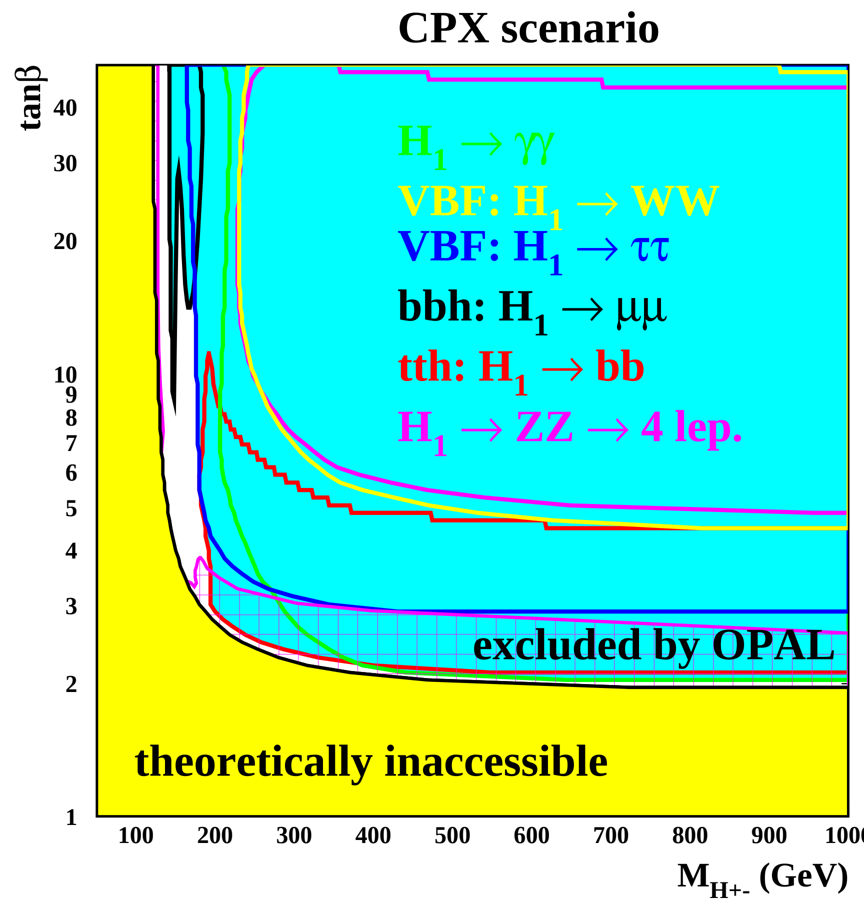
All Higgses escape detection

Still, there is the possibility

$t \to H^+ b$ with $H^+ \to hW^*$

(Godbole, Guchait, Roy).

M. Schumacher $\longrightarrow$



Regions of MSSM parameter space not covered by ATLAS/CMS:

more work is still needed....

4. Beyond the conventional MSSM: the NMSSM

The next-to-minimal SSM is becoming the "standard" MSSM these days..

MSSM problem: μ is SUSY-preserving but $\mathcal{O}(\mathrm{M_Z})$; a priori no reason

Solution, μ related to the vev of singlet field, $\langle \mathrm{S} \rangle \propto \mu$ Kim+Nilles

NMSSM: introduce a gauge singlet in Superpotential: $\lambda \hat{\mathrm{H}}_1 \hat{\mathrm{H}}_2 \hat{\mathrm{S}} + \frac{1}{3}\hat{\mathrm{S}}$

Nilles et al, Frere et al, Ellis et al, Drees, Ellwanger et al, King et al, ...

SUSY spectrum extended by χ_5^0 and two neutral Higgs particles $\mathrm{h_3, a_2}$

- **additional parameters enter in Higgs masses and couplings**

  less constrained model, more flexibility, ...

- **the bound on lightest Higgs boson mass is higher than in MSSM**

  less fine-tuning is needed to cope with LEP..

- **possibility of a light Higgs which has escaped detection at LEP2**

possibility of a light Higgs which has escaped detection at LEP2

  rich phenomenology: low energy constraints, DM, ...

- **Note: constrained NMSSM, less freedom than in mSUGRA ...**

4. Beyond the conventional MSSM: the NMSSM

The NMSSM with universal boundary conditions at GUT scale:

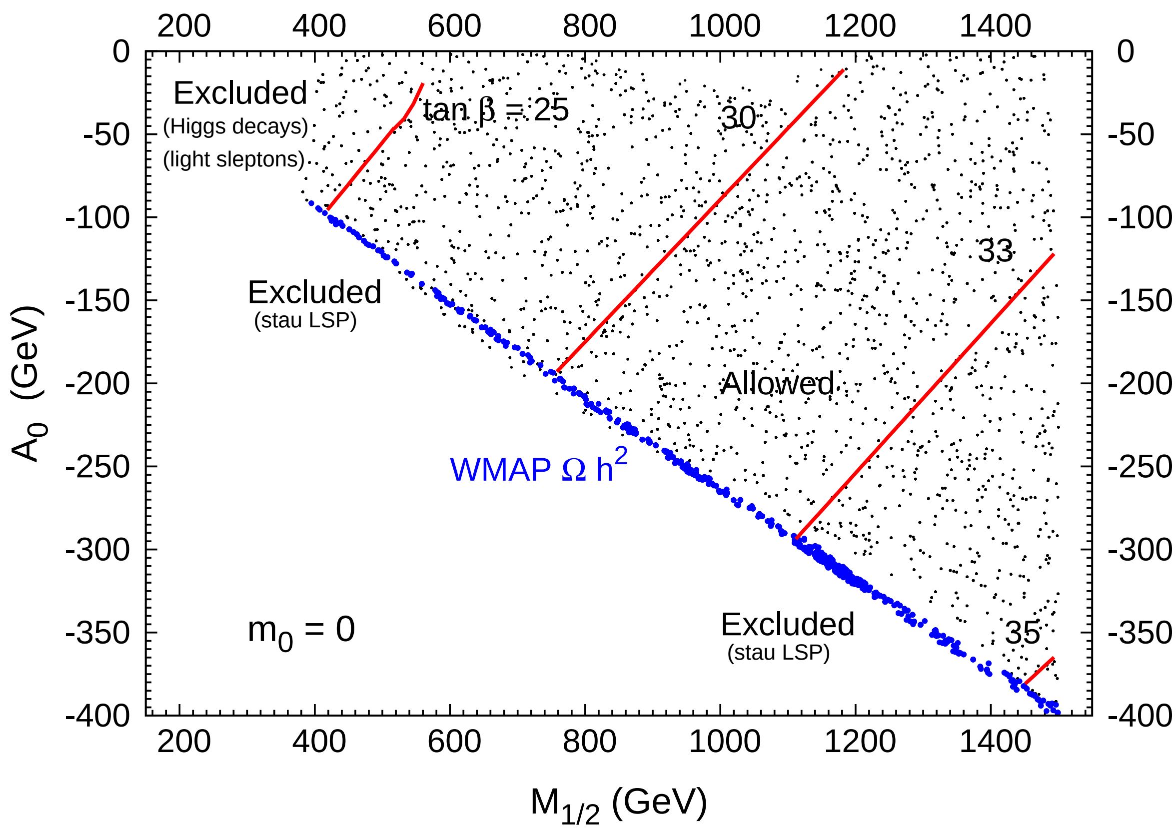
In principle: $\mathbf{M_{1/2}, m_0, A_0}, \lambda, \tan\beta$ **as free parameters**

With constraints: proper EWSB+LEP Higgs+low energy+ WMAP

only one cNMSSM free parameter: $\mathbf{m_0 \sim 0}$ **and** $\lambda \lesssim \mathbf{0.01}$

The parameters $\mathbf{A_0}$ **and** $\tan\beta$ **are related to** $\mathbf{M_{1/2}}$

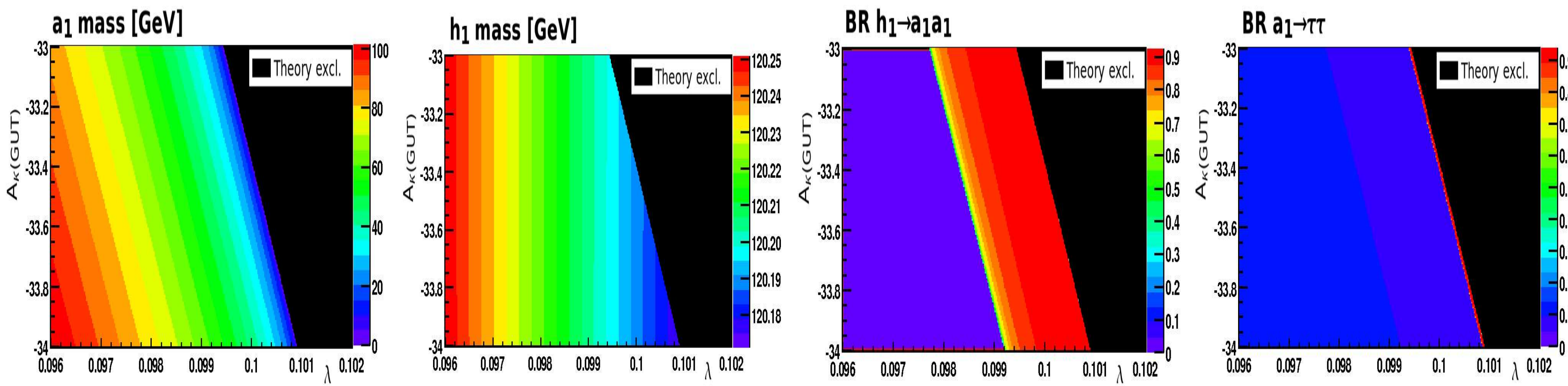
Ellwanger, Teixeira, AD (2008)



4. Production in NMSSM

But life can be even more complicated with LHC Higgs searches:

the possibility of missing all Higgs bosons is not yet ruled out!
(Ellwanger, Hugonie, Gunion, Moretti; King..., Nevzorov..., Barger...)



Recently, some benchmark scenarios for NMSSM Higgs searches

have been proposed: AD, Drees, Rottlander, M. Schumacher, et al., ...

- h_1 **is SM–like and** a_1 **light:** $h_1 \to a_1 a_1$ **with** $a_1 \to b\bar{b}$ **and/or** $\tau^+\tau^-$
- h_2 **is SM–like and** h_1 **light:** $h_2 \to h_1 h_1$ **with** $h_1 \to b\bar{b}$
- **All Higgs are light (NMSSM ICR): reduced couplings to VV, etc...**

4. Production in NMSSM

Higgs $\rightarrow$ Higgs+Higgs $\rightarrow$ $4\mathrm{b}, 2\mathrm{b}2\tau$

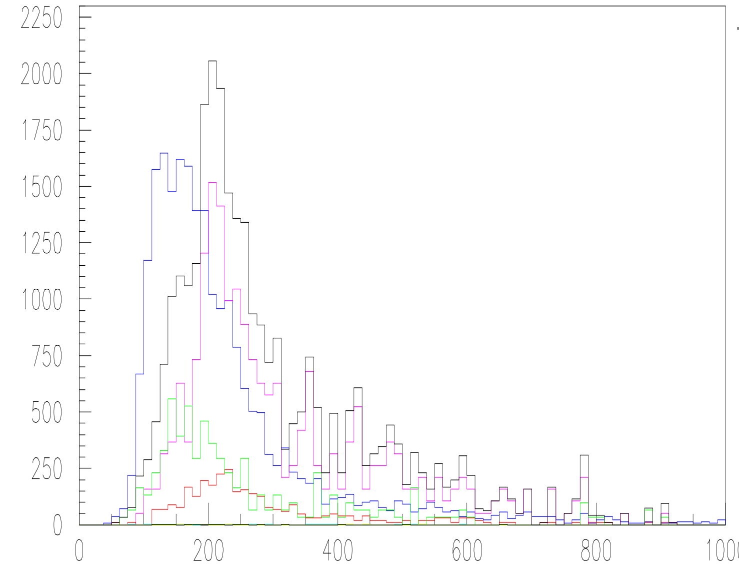
searches very difficult at the LHC:

$pp \rightarrow qq \rightarrow\rightarrow W^*W^*qq \rightarrow h_1 qq$

——– $h_1 \rightarrow a_1 a_1 \rightarrow b\bar{b}\tau\tau \times 500$.

——– total background.

(Ellwanger..., Baffioni+D.Zerwas)



Higgs $\rightarrow$ Higgs+Higgs $\rightarrow$ $4\tau \rightarrow 4\ell\mathrm{X}$

also difficult but detection possible

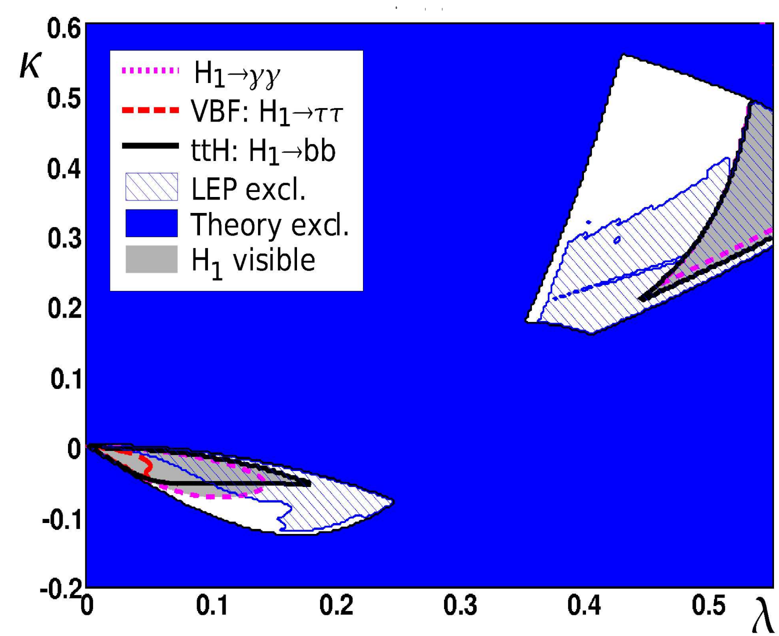
(Nikitenko .., Schumacher+Rottlander)

Example of scan for light h_1

using VBF + all h_1 decay channels

(same for all Higgsses can be done)

(Schumacher+Rottlander)

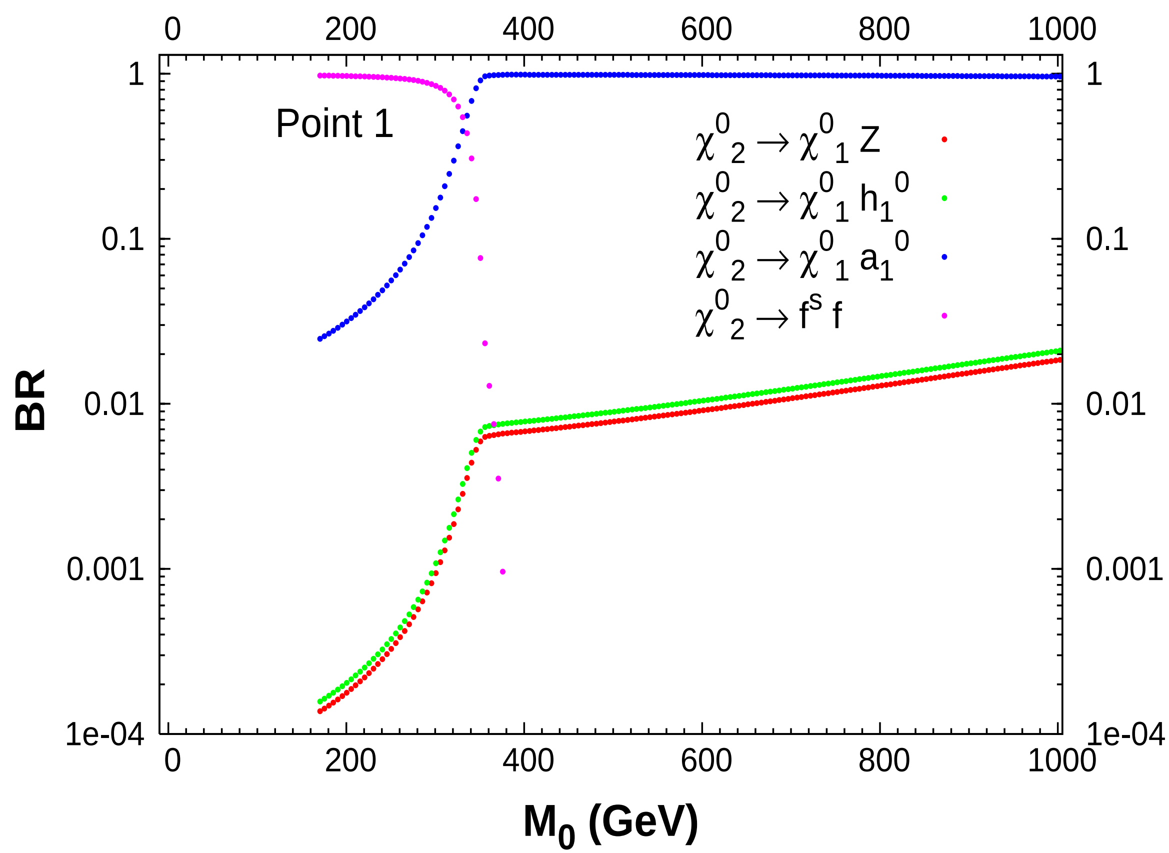


4. Higgs decays of SUSY particles

A possible rescue in both the CPV MSSM and NMSSM might come from SUSY particle cascade decays into Higgs bosons. In particular:

$$\mathbf{pp \to \tilde{q}\tilde{q}, \tilde{g}\tilde{g}, \tilde{g}\tilde{q} \to \chi + X \text{ with } \chi_2^0 \to \chi_1^0 + Higgs}$$

Example for one of the NMSSM benchmark points with light a_1:



Ellwanger ea

4. Invisible Higgs??

There are many scenarios in which a Higgs boson would decay invisibly

- **In MSSM, Higgs $\rightarrow \chi_1^0\chi_1^0, \tilde{\nu}\tilde{\nu},$ etc.. as already discussed.**
- **In MSSM with $\mathrm{R}\!\!\!/_{\mathrm{p}}$: Higgs $\rightarrow \mathrm{JJ}$ could be dominant.** **Valle ea**
- **The SM when minimaly extended to contain a singlet field (which decouples from f/V), $\mathrm{H} \rightarrow \mathrm{SS}$ can be dominant** **Bij, Wells ea,..**
- **In large extra dimensions H mixing with graviscalars.** **Gunion ea**

... or very different couplings to fermions and bosons...

- **Radion mixing in warped extra dimension models: supressed f/V couplings and Higgs decays to radions** **Hewett+ Rizzo, Gunion ea**
- **Presence of new quarks which alter production** **Moreau ea**

... Many possible surprises/difficult scenarios.......

5. Conclusion?

Probably in 2-3 years we will find the Higgs (and maybe nothing else):

we celebrate, shake hands, drink champagne, take care of our bets, ...

and should we declare Particle Physics closed and go home or fishing?

No! We need to check that it is indeed responsible of spontaneous EWSB!

Measure its fundamental properties in the most precise way:

- **its mass and total decay width and chek $\mathrm{J^{PC}} = 0^{++}$,**
- **its couplings to fermions and gauge bosons and check that they are indeed proportional to the particle masses (fundamental prediction!),**
- **its self–couplings to reconstruct the potential $\mathrm{V_H}$ that makes EWSB.**
- **If SUSY is there, plenty of other very important things to do...**

A very ambitious and challenging program!

which is even more difficult to achieve than the Higgs discovery itself...

5. Measurements at the LHC

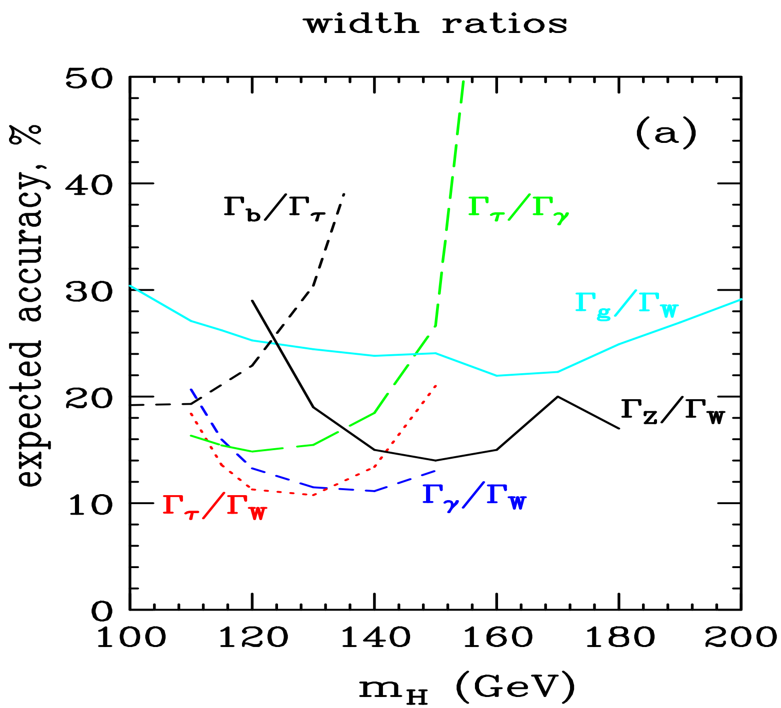
Lightest Higgs: as in SM

Higgs mass $\mathrm{h} \to \gamma\gamma, \mathrm{ZZ}^*$

Higgs spin/CP numbers

Higgs couplings from $\sigma\times$ **BR**

Higgs self couplings hopeless...



M. Dührssen et al. (2004).

Heavy Higgsses

Masses from $\mathrm{H/A} \to \mu^+\mu^-$

$\tan\beta$ **in** $\mathrm{pp} \to \mathrm{H/A} + \mathrm{b\bar{b}}$

H/A separation difficult