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Higgs Physics at Future Colliders: recent theoretical developments.

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I. A very brief introduction.

II. Higgs boson decays in the SM and in the MSSM.

III. Higgs boson production at hadron colliders.

- The production processes in the SM.
- Possible measurements at the LHC.
- What is different in the MSSM.
- New scenarii and analyses for detection:
  - The intense coupling regime.
  - Cascade decays of strongly interacting SUSY particles.

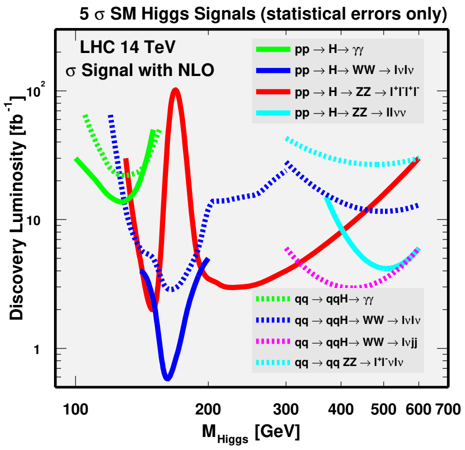
IV. Higgs boson production at e^+e^- colliders

- The production processes in the SM.
- What is different in the MSSM.
- Precision measurements at the LC.

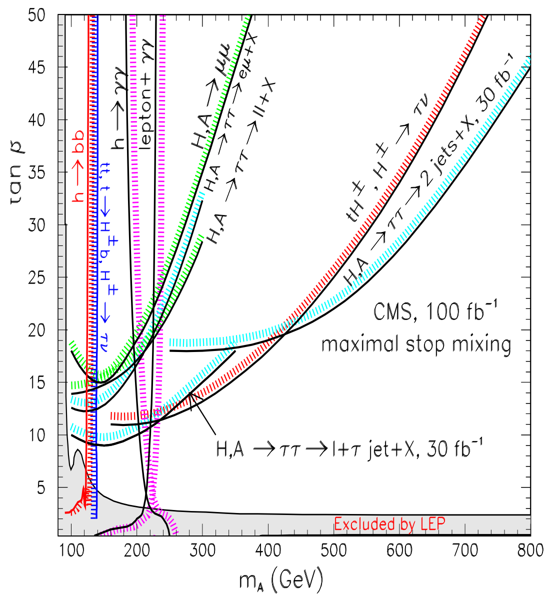
V. A very brief conclusion...

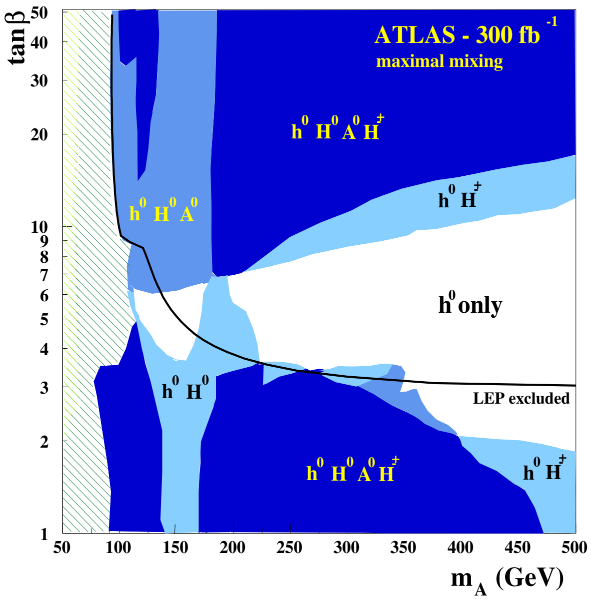
I. Introduction

LHC (Tevatron?) will find a SM Higgs. ATLAS+CMS analyses show that:



Also in the MSSM, a light Higgs boson cannot escape detection and in large areas of the parameter space, more than one Higgs can be found.





Next step: to do high precision physics and check Higgs properties.

– Probe new (non-dominant) production channels.

– Measure σ, BR, masses, couplings, spin-parity, ...

$\longrightarrow$ needs precise predictions and involved theory+experiment analyses!

$\longrightarrow$ needs also complementary detailed studies at e^+e^- machines.

II. Higgs decays in the SM and MSSM

Higgs decays in the SM

- "Low mass" range, $M_H \lesssim 130$ GeV:
  - $H \to b\bar{b}$ dominant, BR = 60 to 90% ,
  - $H \to \tau^+\tau^-, c\bar{c}, gg$, BR = a few percent,
  - $H \to \gamma\gamma, \gamma Z$, BR = a few permille.
- "High mass" range, $M_H \gtrsim 130$ GeV:
  - $H \to WW^*, ZZ^*$ (BR $\sim 2/3$ and $1/3$ for $M_H \gtrsim 200$ GeV).
  - $H \to t\bar{t}$ for $M_H \gtrsim 350$ GeV (but BR $\lesssim 20\%$).
- Total width: $\mathcal{O}(10$ MeV) to $\mathcal{O}(100$ GeV) for $M_H \sim 100 - 700$ GeV.

Higgs decays in the MSSM

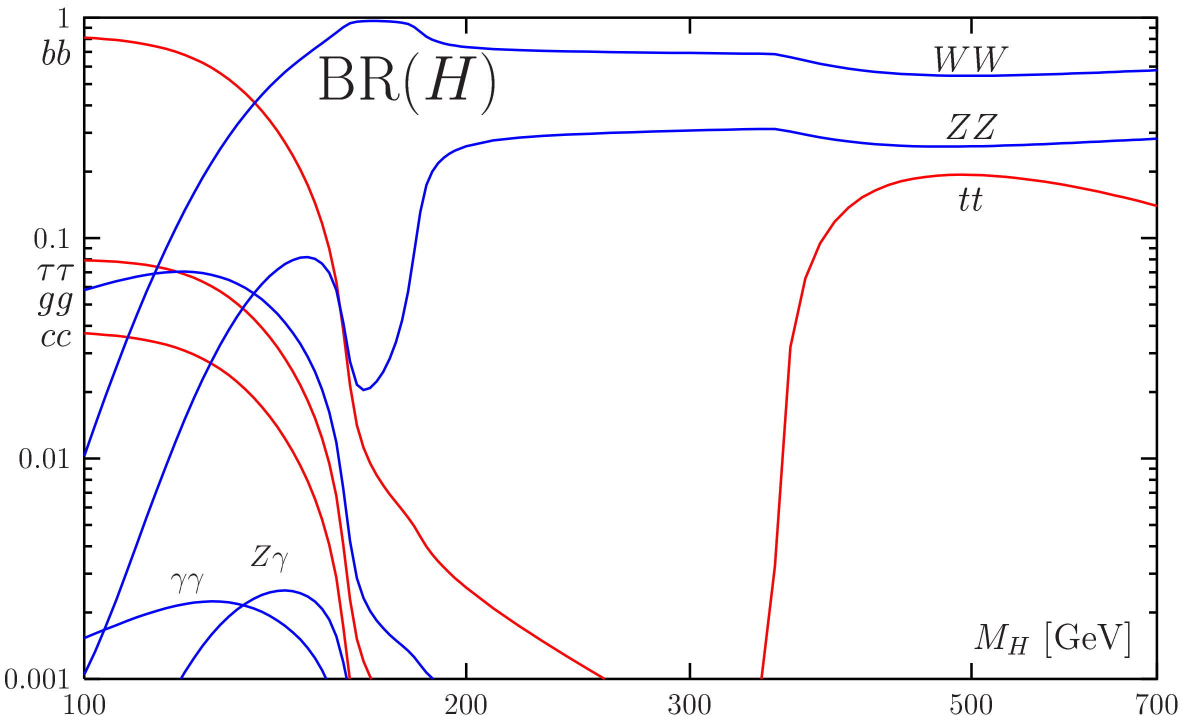
- h: same as $H_{\rm SM}$ in general (in particular in decoupling limit)
  $h \to b\bar{b}$ and $\tau^+\tau^-$ potentially enhanced ($\tan\beta \gtrsim 3$).
- A: only $b\bar{b}, \tau^+\tau^-$ and $t\bar{t}$ decays (no VV, hZ suppressed).
- H: same as A in general (WW, ZZ, hh decays suppressed).
- $H^\pm$: $\tau\nu$ and tb decays (depending if $M_{H^\pm} <$ or $> m_t$).

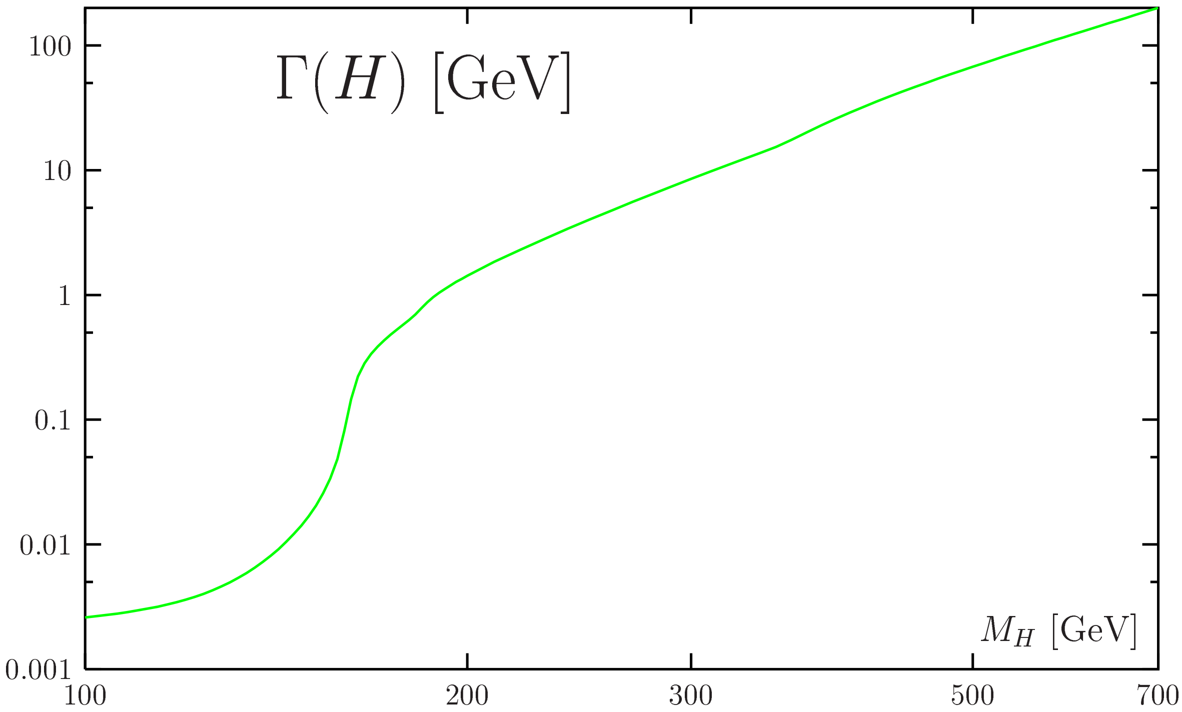
Possible new effects

- Although suppressed, decays into $V\Phi$ and/or VV states possible.
- 3–body decays important ($h \to WW^*, H/A \to tt^*, H^+ \to tb^*$...)
- Loops of SUSY particles might be important ($h/A/H \to b\bar{b}, h \to gg$).
- Decays into SUSY particles if kinematically allowed can be significant:
  $h \to \chi_1^0\chi_1^0$ still possible in non universal MSSMs.
  $H, A \to \chi_i^+\chi_j^-, \chi_i^0\chi_j^0$ and $H^\pm \to \chi_i^0\chi_j^\pm$ important for low $\tan\beta$.

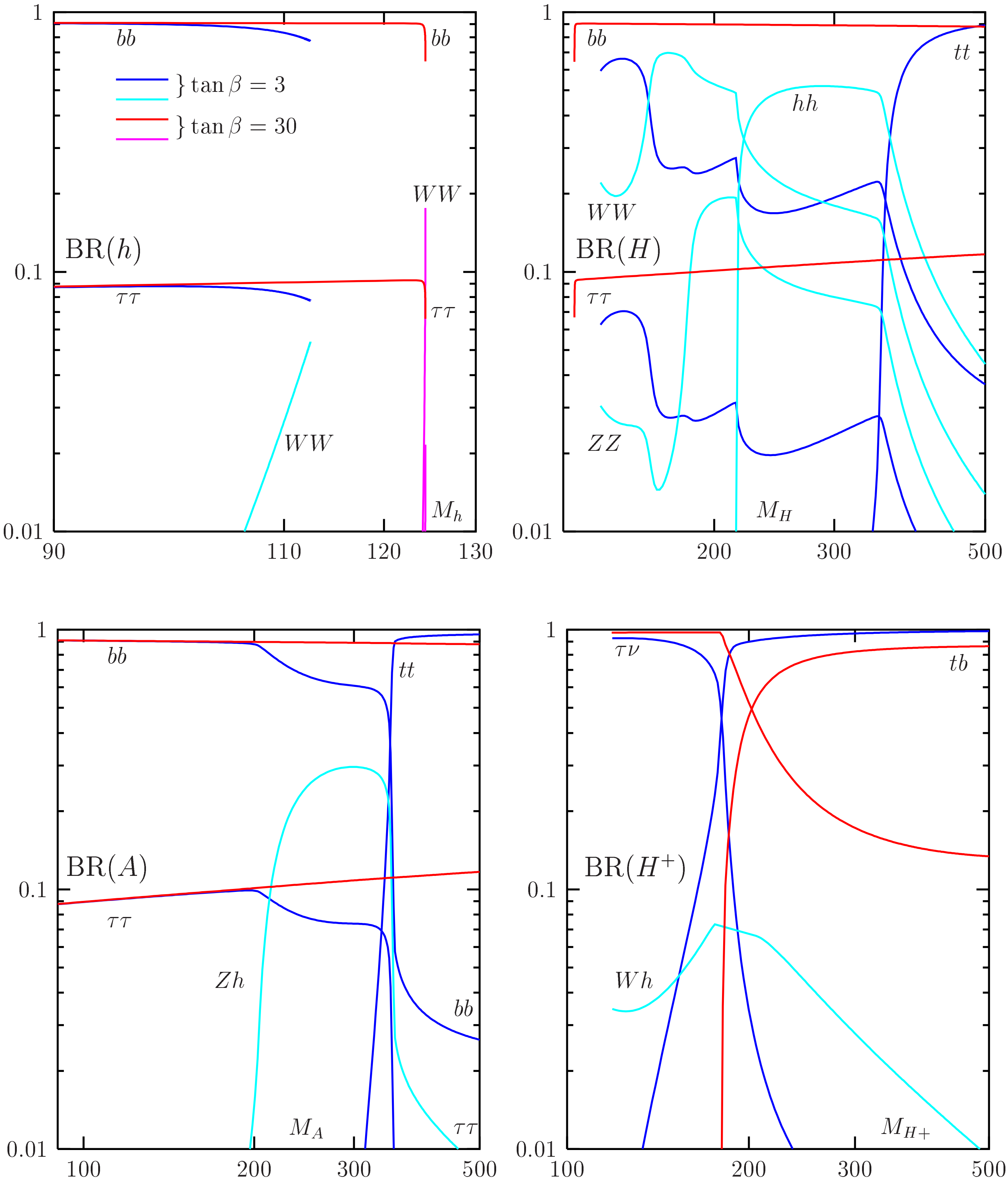
Total decay widths:

- Small for the SM–like Higgs bosons (h or H if $M_A \gtrsim (\lesssim) M_h^{\rm max}$).
- Large for A, H and $H^\pm$ ($\propto M_\Phi \tan^2\beta$) but not as in SM.

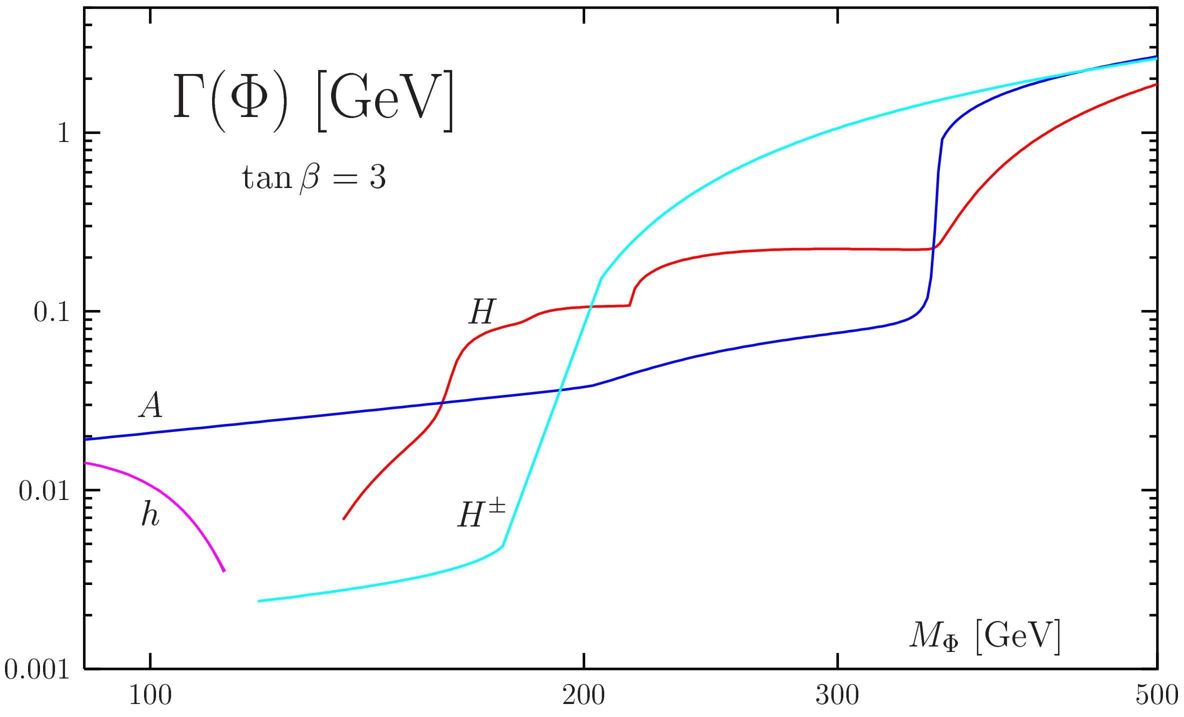




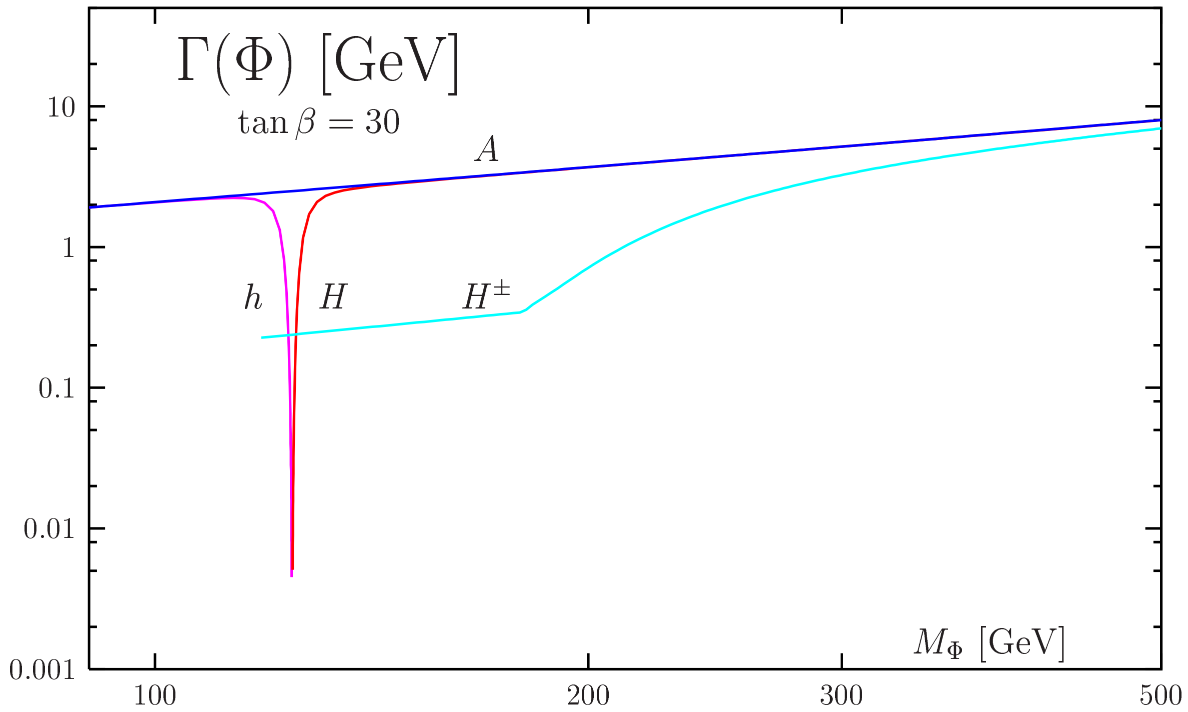
AD, Kalinowski, Spira



1
0.1
0.01
bb
bb
} tan β = 3
} tan β = 30
WW
BR(h)
ττ
ττ
WW
M_h
90
110
120
130
bb
tt
hh
WW
BR(H)
ττ
ZZ
M_H
200
300
500
bb
tt
BR(A)
ττ
Zh
bb
M_A
ττ
100
τν
tb
BR(H^+)
Wh
M_{H+}



Γ(Φ) [GeV]
tan β = 3
1
0.1
0.01
0.001
A
h
H
H±
M_Φ [GeV]
100
200
300
500



Γ(Φ) [GeV]
tan β = 30
10
1
0.1
0.01
0.001
A
h
H
H±
M_Φ [GeV]
100
200
300
500

New development: a new version of `HDECAY`

`HDECAY`: a Fortran program for Higgs boson decay widths and branching ratios in the Standard Model and in its Supersymmetric extensions

AD, Kalinowski and Spira; hep-ph/9704448

It includes all important features:

– All the decay channels allowed and with BR $\gtrsim 10^{-5}$.
– All QCD corrections to the fermionic and gluonic decay modes.
– Below–threshold three–body decays with off–shell particles.
– Double off–shell decays: $H_{SM}, h, H, \rightarrow W^*W^*, Z^*Z^* \rightarrow 4f$.
– In the MSSM, the radiative corrections are fully incorporated.
– All the decays into SUSY particles $\chi_i^+\chi_j^-, \chi_i^0\chi_j^0, \tilde{l}_i\tilde{l}_j, \tilde{q}_i\tilde{q}_j$.
– SUSY loops in decays into $\gamma\gamma, \gamma Z, gg$ with QCD included.
– Many other features....

The version `HDECAY3.0` has appeared two months ago.

Major changes compared to the previous version:

– SUSY-QCD corrections to $h, H, A \rightarrow b\bar{b}$ including resummation.
– Links to more routines for MSSM Higgs boson mass calculations: subh, subhpole, hmsusy, FeynHiggsFast.
– Extension of 2-loop RGE approach to Higgs self–interactions.
– Addition of decays into gravitino + gaugino.
– Reorganization of subroutines and main program.
– Renaming of subroutines, functions and commons to allow for simpler links to other programs (all names have extension `_HDEC` now).

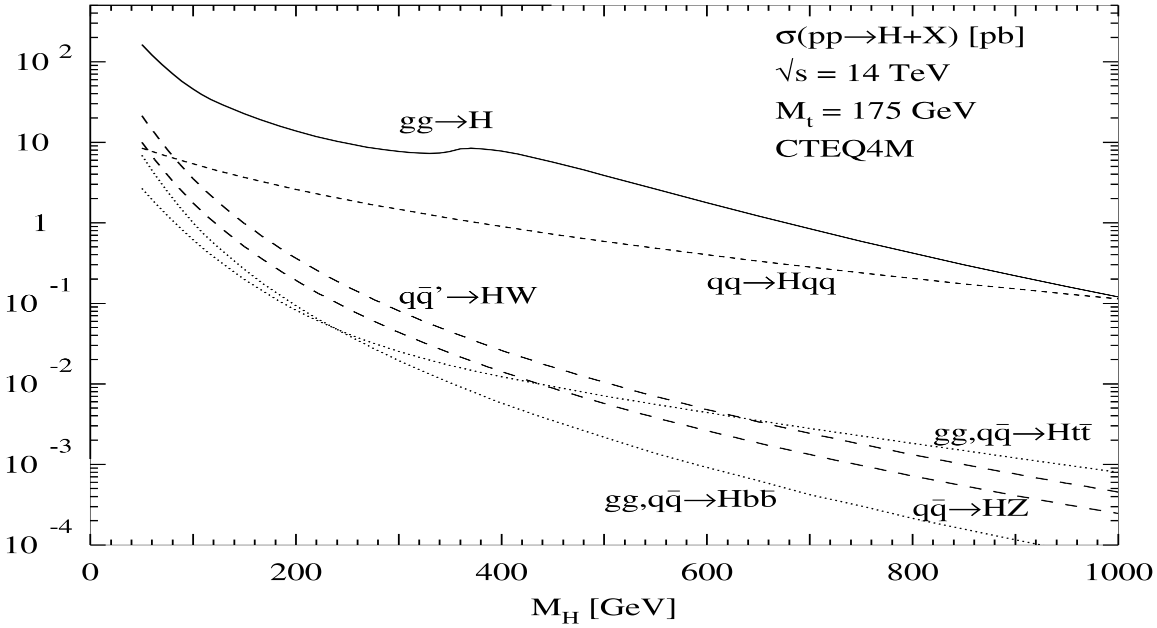
Please update by taking the new routine at the `HDECAY` site:

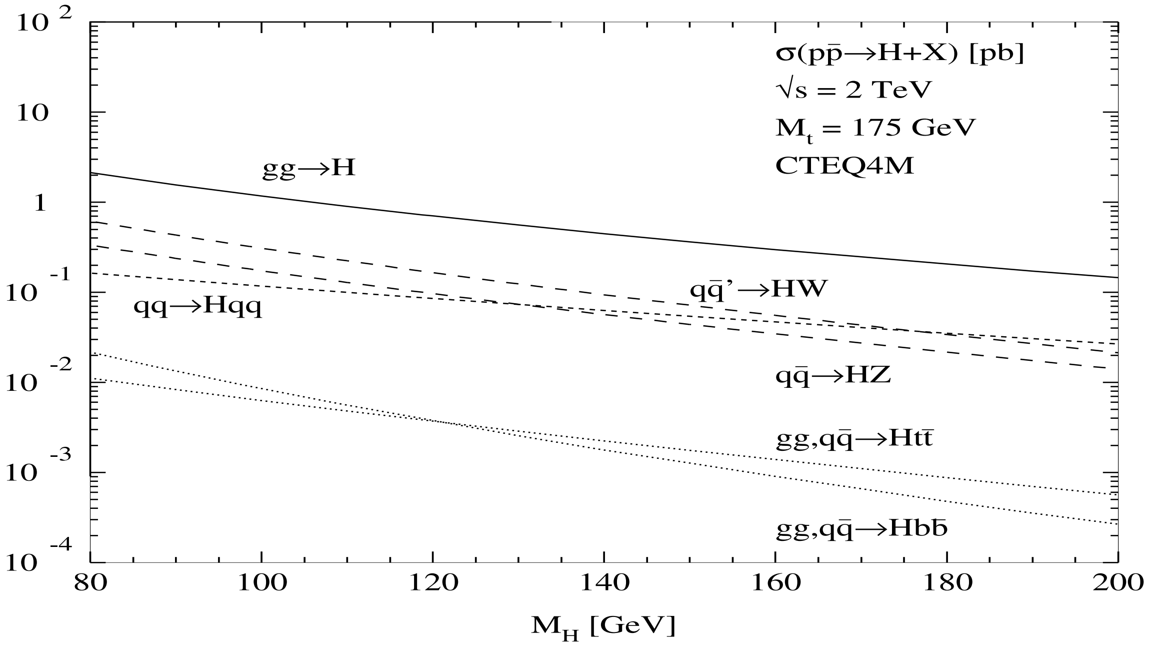
http://www.desy.de/~ spira/

III. Higgs Production at hadron colliders

Production processes and cross sections at LHC/Tevatron in the SM:

(a)	gluon – gluon fusion	gg	$\rightarrow$	H
(b)	association with W/Z	$q\bar{q}$	$\rightarrow$	$V+H$
(c)	WW/ZZ fusion	VV	$\rightarrow$	H
(d)	association with $Q\bar{Q}$	$gg, q\bar{q}$	$\rightarrow$	$Q\bar{Q}+H$





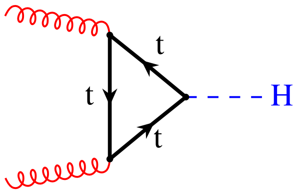
Spira

(a) $gg \to H$: NNLO QCD corrections

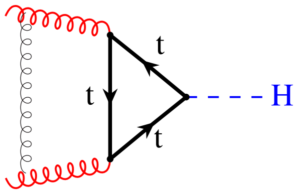
The dominant production mechanism for SM Higgs production at LHC.

– $M_H \lesssim 130$ GeV: $H \to \gamma\gamma$.
– $M_H \gtrsim 130$ GeV: $H \to WW^*, ZZ^* \Rightarrow \ell^\pm \ell^\pm jj$.

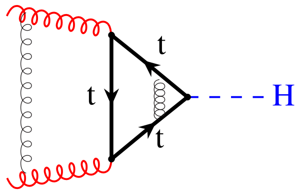
In the very heavy top quark limit (valid for $M_H \lesssim 2m_t$):



LO: 1978
Georgi, Glashow+
Machacek, Nanopoulos



NLO: 1991
AD, Spira, Zerwas
Dawson

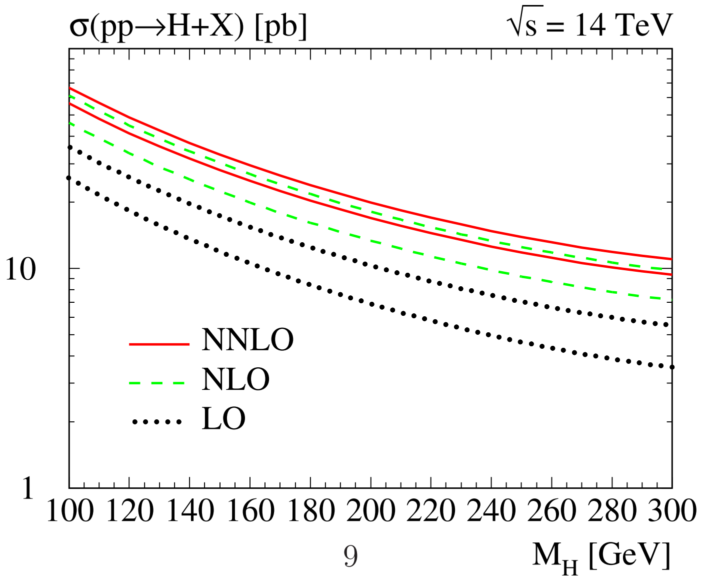


NNLO: 2002
Harlander, Kilgore
Anastasiou, Melnikov

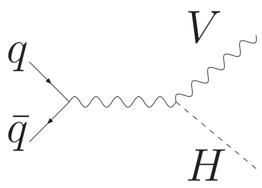
For the exact calculation (any M_H value and extension to MSSM) only the NLO is known: Spira, AD, Graudenz, Zerwas (1995).

$$K_{\rm tot} = \sigma_{\rm tot}/\sigma_{\rm LO} \sim 1 + 0.7 + 0.3 \sim 2$$

– Large correction but nice convergence of the perturbative series.
– Scale dependence (the measure of higher orders) strongly reduced.
– Large corrections also to $d\sigma/dP_T dy$ Ravindran et al.



(b) $q\bar{q} \to HW, HZ$: the Tevatron channel



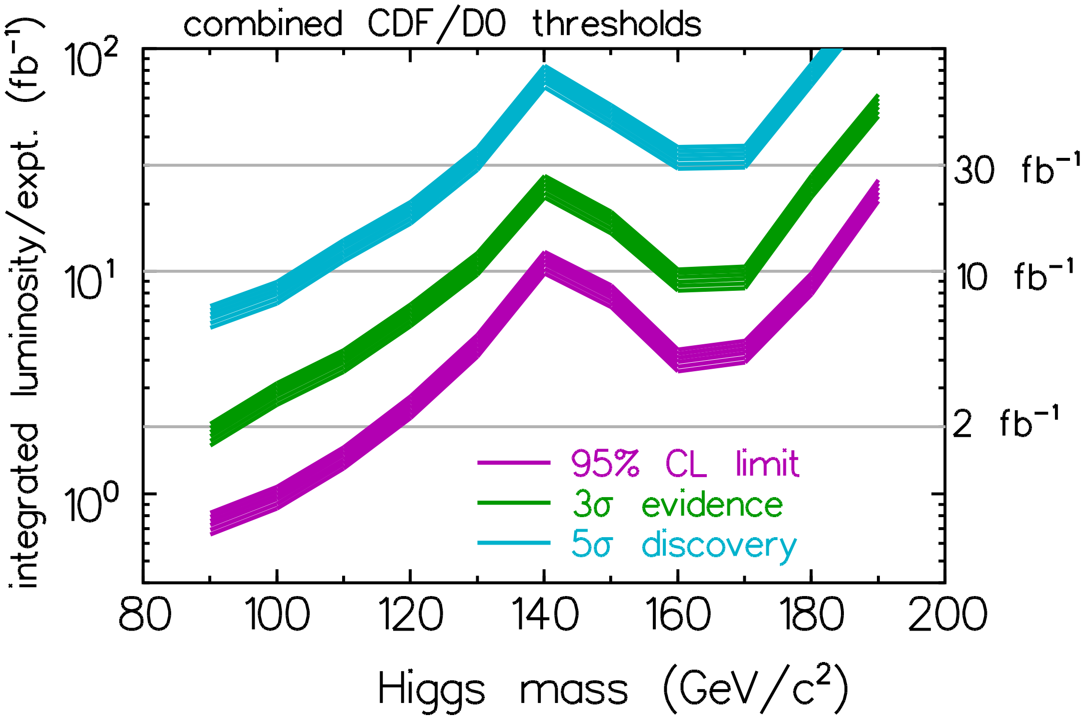
LO (1978)
Glashow+
Nanopoulos+
Yildiz

NLO (DY K$\sim$ 1.3)
Han, Willenbrock
AD, Spira (SM+SUSY)

This production channel is the most important one at the Tevatron:

– $M_H \lesssim 130$ GeV: $H \to b\bar{b}$ $\Rightarrow \ell\nu b\bar{b}, \nu\bar{\nu}b\bar{b}, \ell^+\ell^- b\bar{b}$.

– $M_H \gtrsim 130$ GeV: $H \to WW^*$ $\Rightarrow \ell^\pm\ell^\pm jj$.



Up-to-now, it only plays a marginal role at the LHC (small rates etc...).

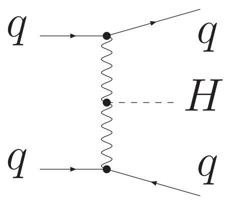
Only few analyses made after Les Houches (LHC/Tevatron comparison).

The process might be important to detect an invisible Higgs boson:

$pp \to HW, HZ$ with $H \to$ invisible ($\chi_1^0\chi_1^0$, majorons, etc...)

Choudhury+DP Roy, Godbole+Guchait+Mazumdar+Moretti+DP Roy

(c) $qq \to qqH$: plenty of new analyses for LHC



LO (1985)
Cahn, Dawson
Altarelli, Mele, Pitolli
Hikasa

NLO (PDF K$\sim$ 1.1)
Han, Valencia+
Willenbrock
AD, Spira (SM+SUSY)

D. Zeppenfeld and collaborators are discussing this issue since ten years

Barger, Cheung, Han, Ohnemus, Zeppenfeld, Phys. Rev. D44 (1991) 1426

and now it became the most experimentally studied channel. Why?

- Large enough rates, $\sigma(qq \to qqH) \sim \mathcal{O}(\text{pb})$ for $M_H \lesssim 200$ GeV.
- Rather small backgrounds, $S/B \sim \mathcal{O}(1)$, allowing measurements.
- Forward jet tagging or mini-jet veto for low $\mathcal{L}$.
- Central Higgs decay products on which one can trigger.

In the past few years, it has been shown that $H \to \tau^+\tau^-$ can be seen

see Zeppenfeld et al. in Les Houches Workshop for a summary.

Recently other channels have been discussed and shown to work:

- $H \to WW^*$ possible for $M_H \sim 125$–180 GeV.

  Kauer, Plehn, Rainwater, Zeppenfeld
- $H \to \gamma\gamma, ZZ^*$ for coupling measurements.

  Kinnunen, Richter–Was, Nikitenko, Zeppenfeld
- $H \to \mu^+\mu^-$ for second generation fermion couplings.

  Plehn, Rainwater and Han, McElrath
- $H \to$ invisible if forward jet–trigger.

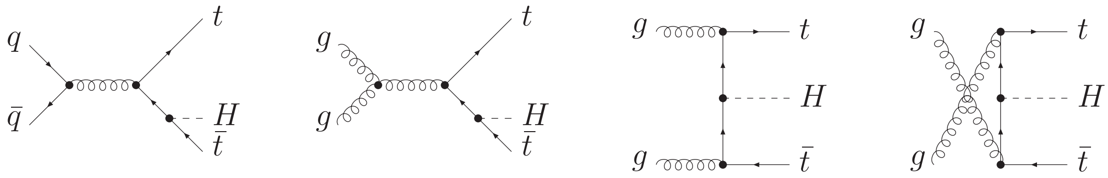
  Eboli, Zeppenfeld
- $H \to b\bar{b}$ to measure the $b\bar{b}H$ Yukawa couplings.

  Mangano, Moretti, Piccinini, Pittau and Polosa

But more detailed simulations/experimental analyses are needed!

$(d)\ gg \to t\bar{t}H$: NLO QCD corrections

The most complicated Higgs production channel at hadron colliders:

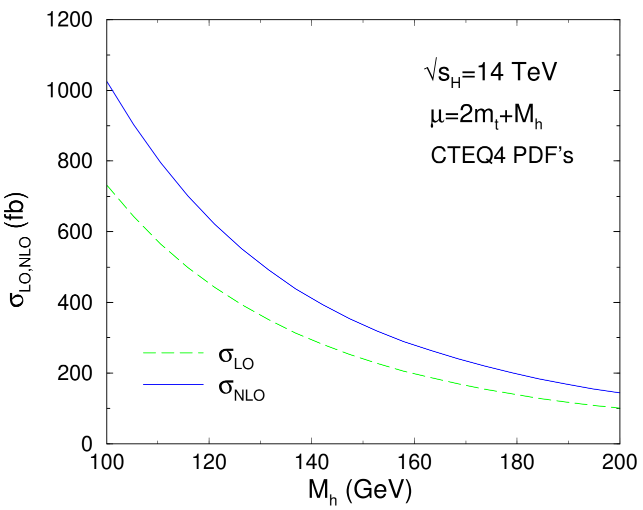


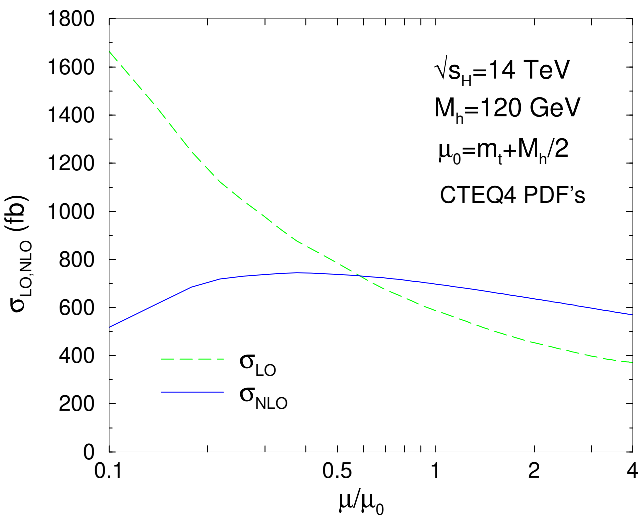
The LO cross section available since 1984 (Kunszt).
The only SM Higgs process which did not have the NLO corrections.
Calculation rather involved:

– pentagon diagrams with several non-zero masses for loops.
– four particle final state corrections for real parton emission.

Full NLO calculation available only since one year:
US Ladies: Dawson, Orr, Reina, Wackeroth.
DESY Gents: Beenakker, Dittmaier, Kramer, Plumper, Spira, Zerwas.
Main results:

– K–factors $\sim$ 1.2 at the LHC and 0.8 at the Tevatron!
– scale dependence drastically reduced $\sim 10-20\%$.
– needs some more work to deal with the $b\bar{b}$+Higgs case.
– NLLO in 2020? Maybe not needed...





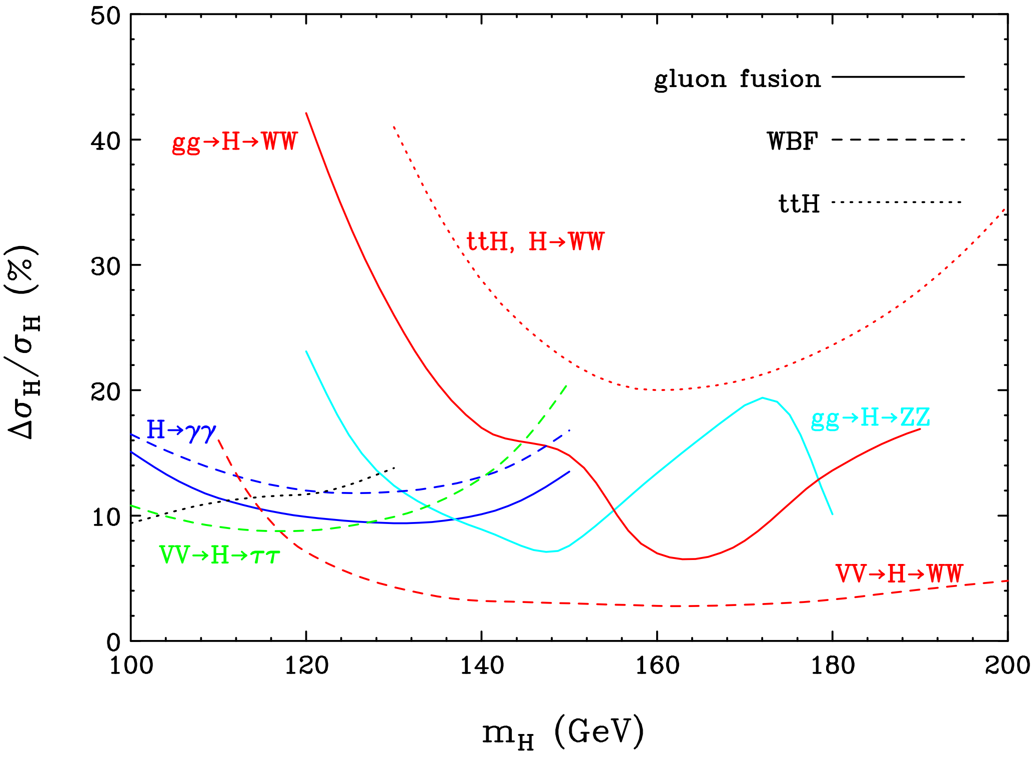
Measurements to be made at the LHC

- $\Delta M_H/M_H \sim 0.1\%$ in $H \to \gamma\gamma$ or $H \to ZZ \to 4\ell^\pm$.
- $\Delta\Gamma_H/\Gamma_H \sim \mathcal{O}(10\%)$ with $H \to ZZ \to 4\ell^\pm$ for $M_H \gtrsim 300$ GeV.
- Higgs spin in correlations in $H \to ZZ \to 4\ell^\pm$.
- Measurement of Higgs couplings in ratios of cross sections times BRs

(no direct measure due to errors: PDF, higher orders, systematics, bkgs..).

Process	Measurement quantity	Error	Mass range
$\frac{(t\bar{t}H+WH)\to\gamma\gamma+X}{(t\bar{t}H+WH)\to b\bar{b}+X}$	$\frac{\mathrm{BR}(H\to\gamma\gamma)}{\mathrm{BR}(H\to b\bar{b})}$	$\sim 15\%$	$80-120$ GeV
$\frac{H\to\gamma\gamma}{H\to 4\ell^+}$	$\frac{\mathrm{BR}(H\to\gamma\gamma)}{\mathrm{BR}(H\to ZZ^*)}$	$\sim 7\%$	$120-150$ GeV
$\frac{t\bar{t}H\to\gamma\gamma,b\bar{b}}{WH\to\gamma\gamma,b\bar{b}}$	$(g_{Htt}/g_{HWW})^2$	$\sim 15\%$	$80-120$ GeV
$\frac{H\to ZZ^*\to 4\ell^+}{H\to WW^*\to 2\ell^\pm 2\nu}$	$(g_{HZZ}/g_{HWW})^2$	$\sim 10\%$	$130-190$ GeV

Kinnunen, Richter–Was, Nikitenko, Zeppenfeld



What is different in the MSSM:

For neutral Higgses: same production channels as in SM but rates enhanced/suppressed by the different couplings to fermions and gauge bosons.

In particular, for $\tan\beta \gg 1$ and $M_A \gtrsim 130$ GeV:

– b–loops dominant in the $gg \to H/A$ processes ($g_{\Phi bb} \propto \tan\beta$).

– $b\bar{b}$ final states dominant in $pp \to Q\bar{Q} + H/A$ ($\sigma \propto \tan^2\beta$).

– no VV fusion or $V\Phi$ production for A (CP) and H (suppressed).

Note that BR($H/A \to \gamma\gamma, ZZ$) are small and BR($H/A \to \tau^+\tau^-$) $\sim 10\%$.

For the h boson: same as in SM (in particular in the decoupling limit).
Since $M_h \lesssim 130$ GeV, one has to rely on $h \to \gamma\gamma$ (with $gg \to h$ e.g.).

For the charged Higgs: the processes, depending on the mass, are:

– $M_{H^\pm} \lesssim m_t$: $gg/q\bar{q} \to t\bar{t} \to H^\pm + X \to \tau^\pm\nu_\tau + X$ (easy).

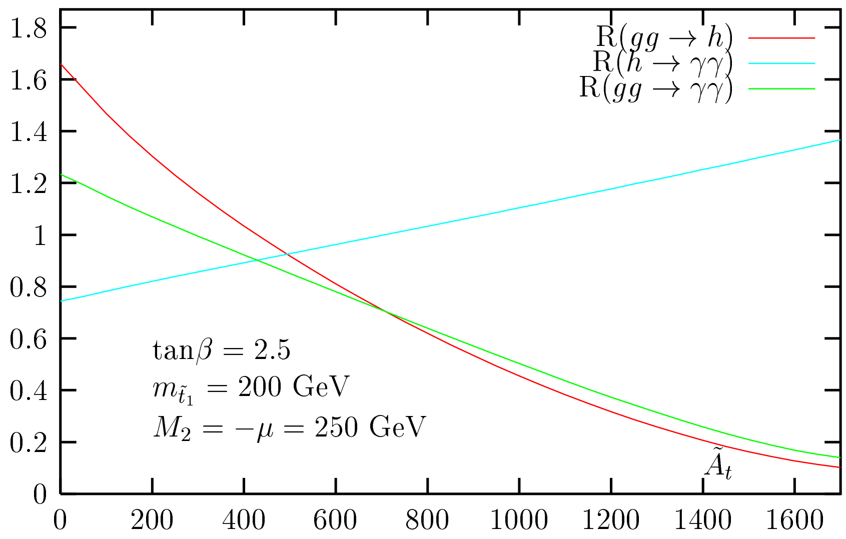
– $M_{H^\pm} \gtrsim m_t$: $gb \to H^- t$ and $gg/q\bar{q} \to H^- t\bar{b} \to \tau\nu$ or tb (tricky).

DP Roy et al.

But, watch out:

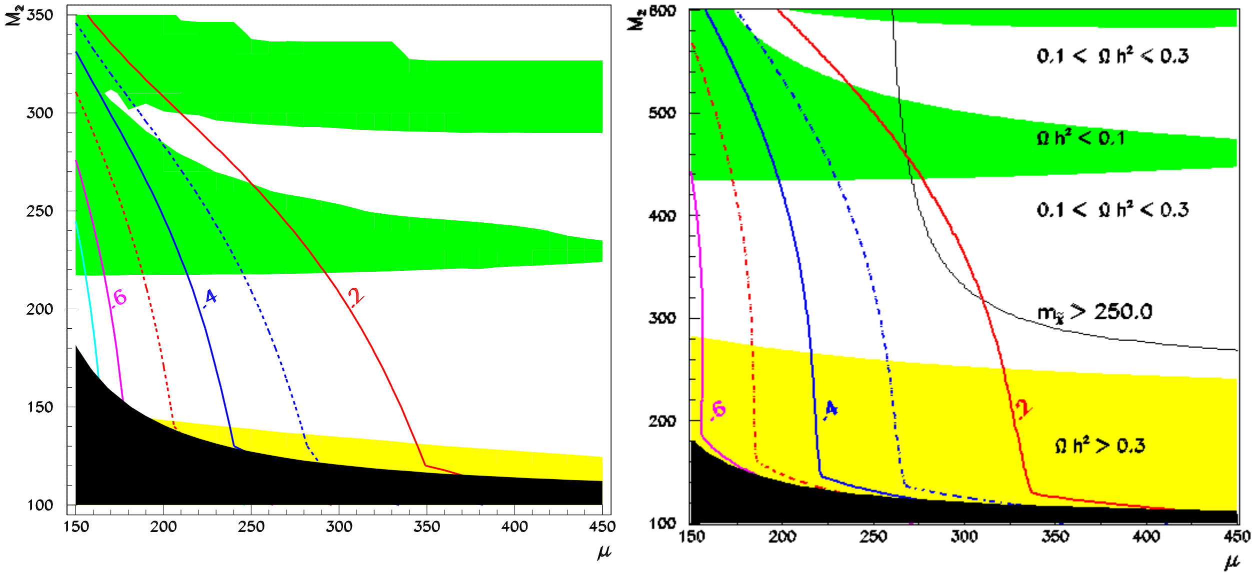
• SUSY loops might play an important role in production/decay: ex: light $\tilde{t}$ loops might make $\sigma(gg \to h) \times$ BR($h \to \gamma\gamma$) much smaller than in SM.

AD, Bélanger+Boudjema+Sridhar



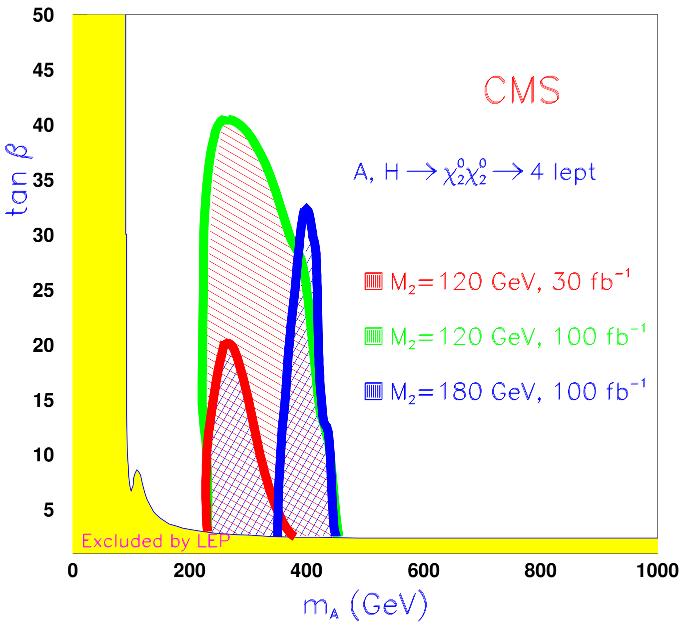
- SUSY decays, if allowed, might alter the search strategies:
  - $h \to \chi_1^0\chi_1^0, \tilde{\nu}\tilde{\nu}$ are still possible in non universal models...

Bélanger+Boudjema+Cottrant+Godbole+Semenov



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

Abdullin, Denegri, Moortgat



- There are scenarii where searches are different from the SM case:
  - The intense coupling regime. Boos, AD, Mühlleitner, Vologdin
  - Cascade decays of SUSY particles. Datta, AD, Guchait, Moortgat

The intense coupling regime:

In (constrained)MSSM, most of the time: decoupling regime, $M_A \gg M_Z$:

$\rightarrow$ SM Higgs physics with a light 100 GeV $\lesssim M_h \lesssim$ 130 GeV Higgs
if $M_A \lesssim$ 700 GeV, $A, H, H^{\pm}$ physics and searches well separated.

A much more interesting possible scenario (think pink!):

$M_A \sim \mathcal{O}(M_Z) \rightarrow M_h \sim M_H \sim M_A \sim$ 100–130 GeV and $\tan\beta$ large

- One CP–even Higgs is SM–like (Φ_H) and one is A–like (Φ_A)
- Φ_H (Φ_A) couples strongly to W, Z, t but not quite as in SM (b, τ).

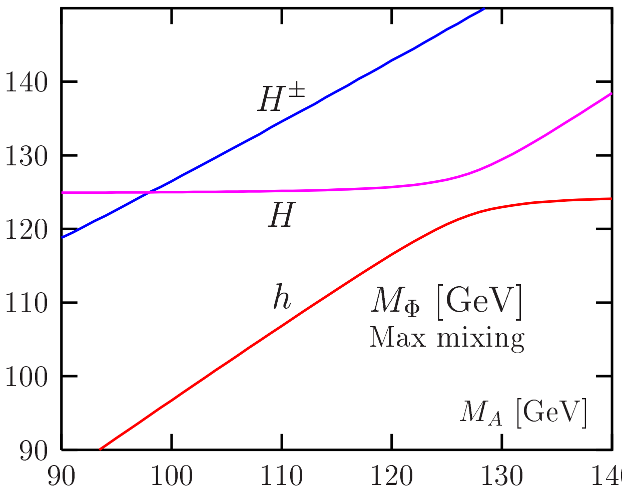
New and/or interesting features

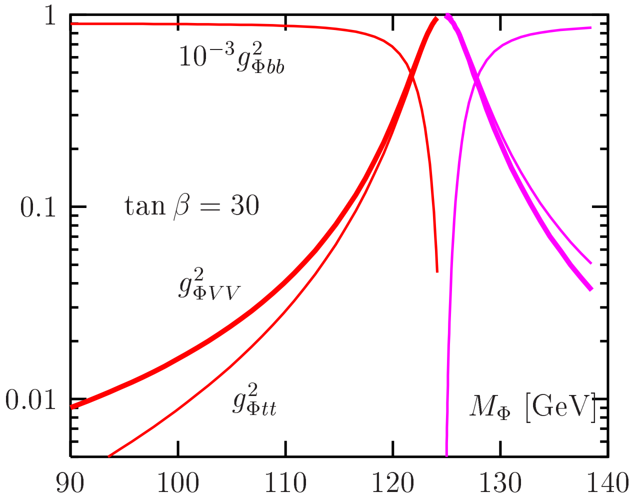
- A, H, A light, all processes are in principle accessible.
- Cross sections rather large for many channels.
- Complete coverage of the MSSM is theoretically possible.
- Plenty of couplings to measure and probe of EWSB.

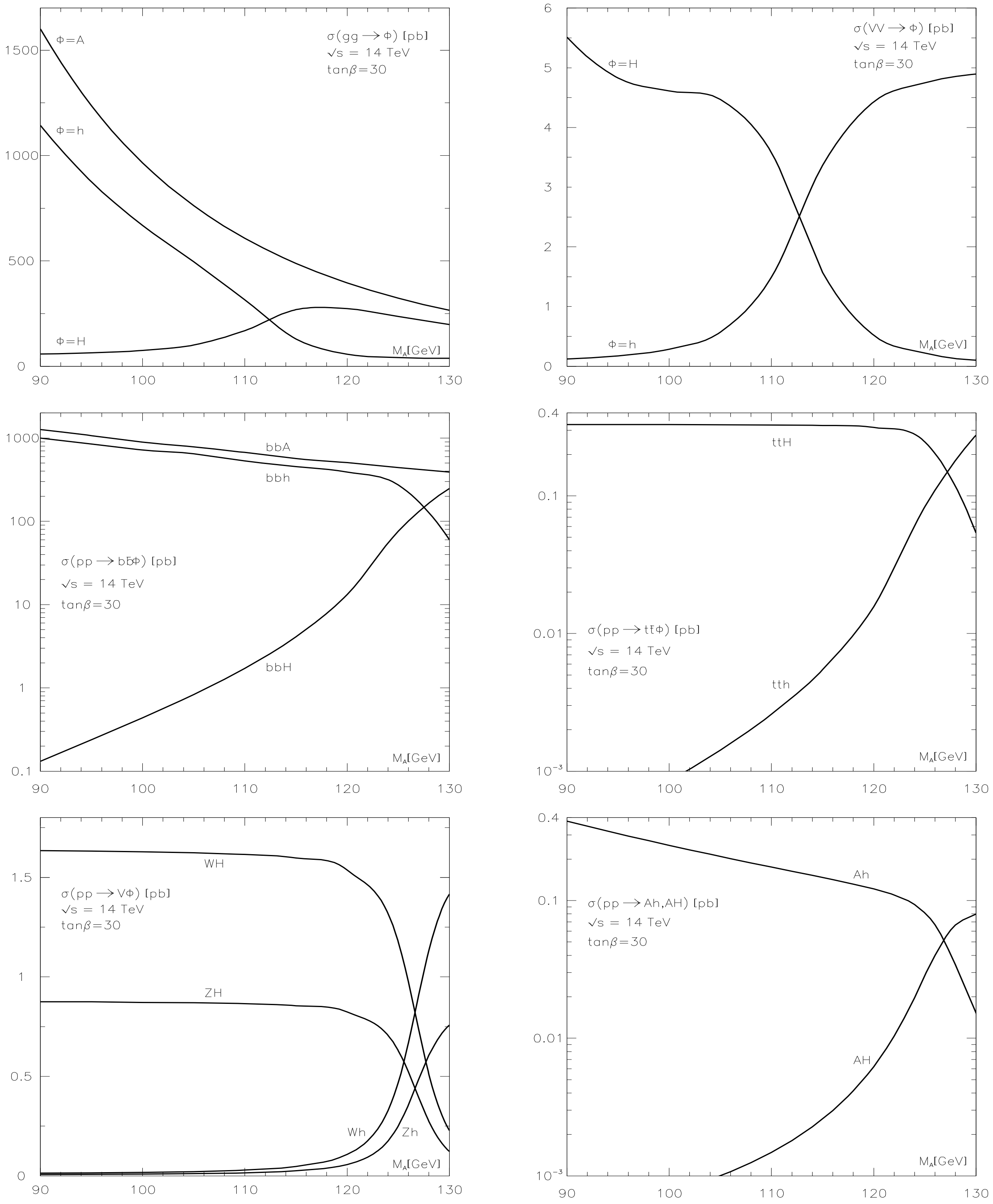
But many problems challenges too:

- The signal for one process is a background for the other!!
- Some interesting BRs suppressed v.s. SM for both h and H!
- Pathological regions where $g_{\Phi\tau\tau}, g_{\Phi bb}$ suppressed.
- The widths are large and must be taken into account.

Detailed analysis and simulation needed!






σ(gg → Φ) [pb]
√s = 14 TeV
tanβ=30
Φ=A
Φ=h
Φ=H
M_A[GeV]
σ(VV → Φ) [pb]
√s = 14 TeV
tanβ=30
Φ=H
Φ=h
M_A[GeV]
σ(pp → bb̄Φ) [pb]
√s = 14 TeV
tanβ=30
bbA
bbh
bbH
M_A[GeV]
σ(pp → tt̄Φ) [pb]
√s = 14 TeV
tanβ=30
ttH
tth
M_A[GeV]
σ(pp → VΦ) [pb]
√s = 14 TeV
tanβ=30
WH
ZH
Wh
Zh
M_A[GeV]
σ(pp → Ah,AH) [pb]
√s = 14 TeV
tanβ=30
Ah
AH
M_A[GeV]

Cascade decays of SUSY particles:

$\tilde{q}, \tilde{g}$ are copiously produced at the LHC (strongly interacting)!
Possible large branching ratios for cascades into MSSM Higgs bosons?

- In the past, the "little cascade" has been analyzed for the h boson:

$$pp \to \tilde{g}\tilde{g}, \tilde{q}\tilde{q}, \tilde{q}\tilde{q}^*, \tilde{q}\tilde{g} \to \chi_1^\pm, \chi_2^0 + X \to \chi_1^0 + h(H^\pm, H, A) \ + X$$

- One can also look at the "big cascade" processes for all Higgsses:

$$pp \to \tilde{g}\tilde{g}, \tilde{q}\tilde{q}, \tilde{q}\tilde{q}^*, \tilde{q}\tilde{g} \to \chi_2^\pm, \chi_{3,4}^0 + X \to \chi_1^\pm, \chi_{1,2}^0 + h, H, A, H^\pm \ + X$$

- Also possible in some areas of the MSSM parameter space: direct decays of $\tilde{t}, \tilde{b}$ and for a light $H^\pm$, new decays through top quarks:

$$\begin{aligned} pp &\to \tilde{t}_2\tilde{t}_2^*, \tilde{b}_2\tilde{b}_2^* \ \text{ with } \ \tilde{t}_2(\tilde{b}_2) \to \tilde{t}_1(\tilde{b}_1) + h/H/A \text{ or} H^\pm \\ pp &\to \tilde{g}\tilde{g}, \tilde{q}\tilde{q}, \tilde{q}\tilde{q}^*, \tilde{q}\tilde{g} \to t/\bar{t} + X \to H^\pm + X \end{aligned}$$

These processes are particularly suited for the intense coupling regime!

Motivations to look for these channels:

- New and possibly large source of Higgs bosons...
- Measurement of couplings and reconstruction of $\mathcal{L}_{\rm Soft}$.
- Fill the hole for $M_A \sim 150$ GeV and $\tan\beta \sim 5$.

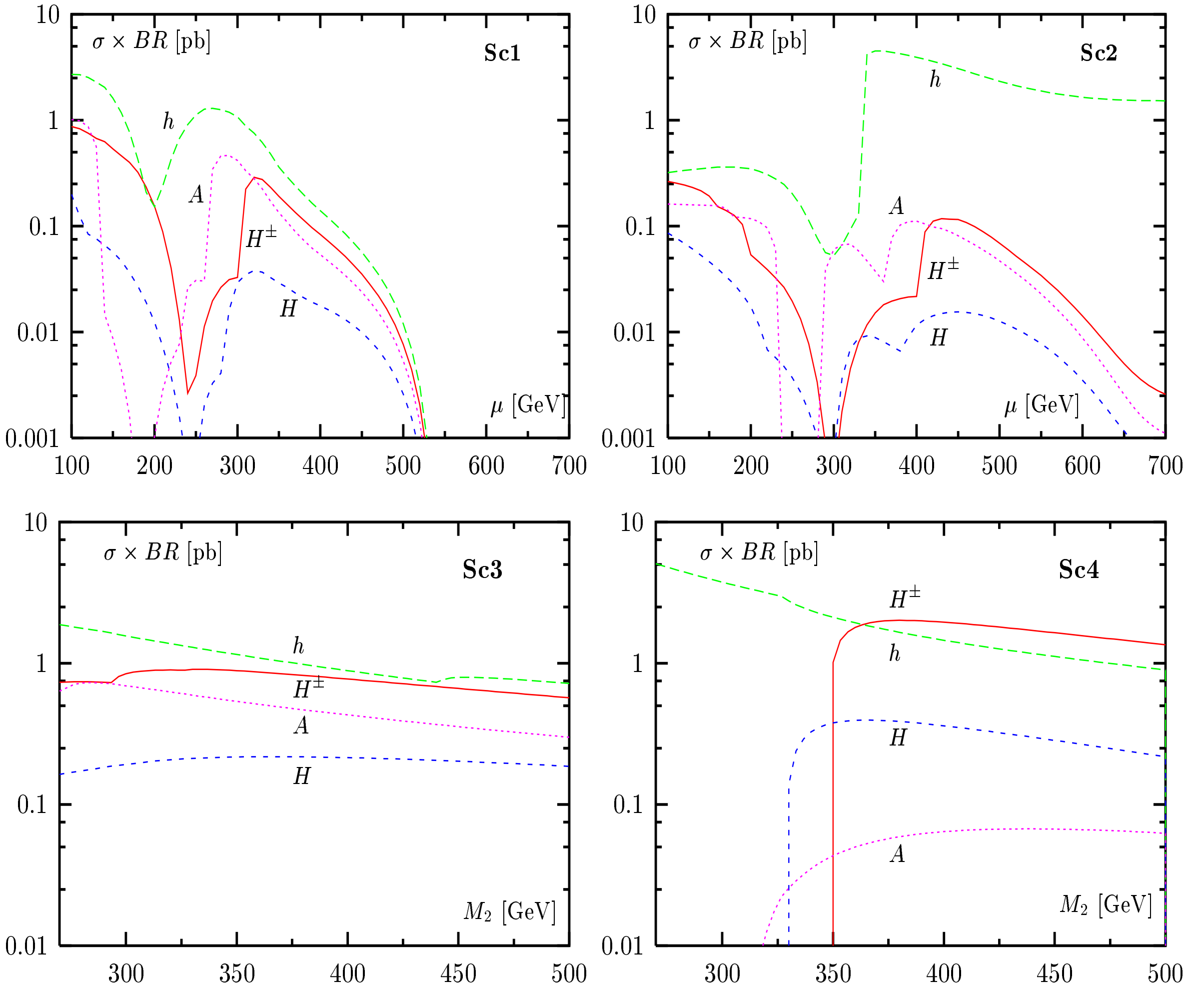
Problem: complete analysis not that trivial!

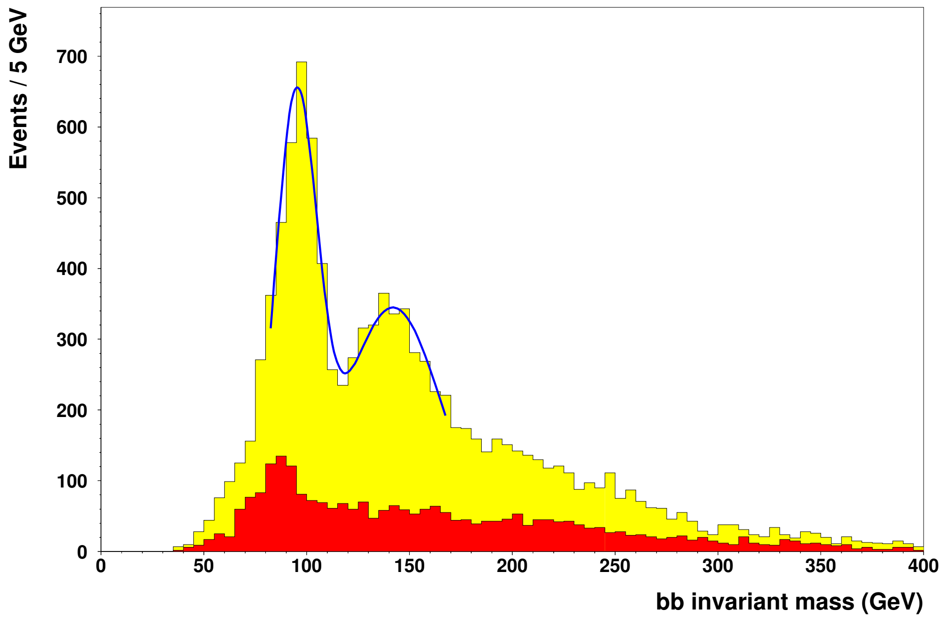
Openning the Pandora box: quick analysis in few representative scenarii:
Sc 1: $m_{\tilde{q}} > m_{\tilde{t}_1} > m_{\tilde{g}}$, $m_{\chi_1^\pm, \chi_2^0} - m_{\chi_1^0} < M_\Phi \to$ big cascade.
Sc 2: $m_{\tilde{q}} > m_{\tilde{t}_1} > m_{\tilde{g}}$, $m_{\chi_1^\pm, \chi_2^0} - m_{\chi_1^0} > M_\Phi \to$ small+big cascade.
Sc 3: $m_{\tilde{q}} > m_{\tilde{t}_1} < m_{\tilde{g}}$, small μ (higgsino): $\tilde{q} \to$ big cascade.
Sc 4: $m_{\tilde{q}} > m_{\tilde{t}_1} < m_{\tilde{g}}$, large μ (gaugino): $\tilde{q} \to$ small cascade.

and it looks very promising!!

Many more studies will be needed in future (next LHC favorite sport?!).

Datta, AD, Guchait, Moortgat



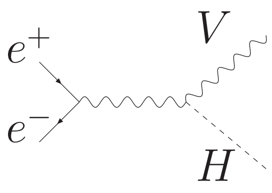


IV. Higgs production at e^+e^- Colliders

1. The Higgs production processes in the SM

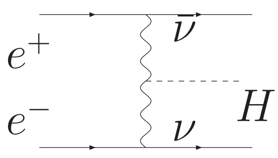
There are two main production channels with large cross sections:

The H–strahlung process: Bjorken, Lee+Quigg+Thacker, Ellis..., Ioffe..., Barger...



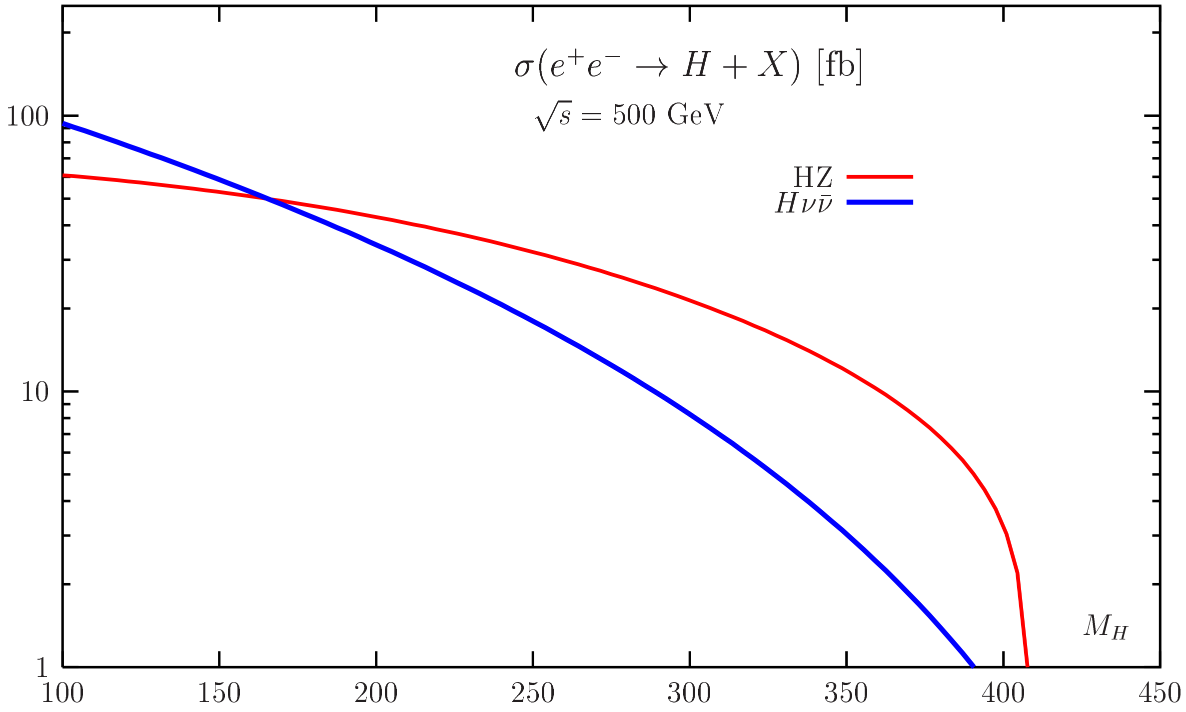
- Scales like $1/s$, dominant for small s.
- Peak in the missing mass in $e^+e^- \to Z + X$.
- Sensitive to the g_{HZZ} coupling.
- Very clean channel with low bckgs...
- NLO small: Bohm+Denner+Kubelbeck, Kniehl

The WW fusion process: Jones+Petcov, Altarelli..., Cahn..., Hikasa, Kramer...



- Scales like $\mathrm{Log}(s/M_W^2)$, dominant for large s.
- Larger backgrounds but still manageable.
- Sensitive to the g_{HWW} coupling.
- NLO recently calculated (EW contr. small)

Bélanger et al., hep-ph/0212261



There are also higher order processes which are useful for measurements:

The ZZ fusion process: Jones+Petcov, Altarelli..., Cahn..., Hikasa, Kramer...

- Cross section 10 times small than in WW fusion.
- Cleaner channel, smaller backgrounds.
- Sensitive to the g_{HZZ} coupling.

The $t\bar{t}H$ process: AD+Kalinowski+Zerwas, Dawson et al., Zerwas et al. (NLO)

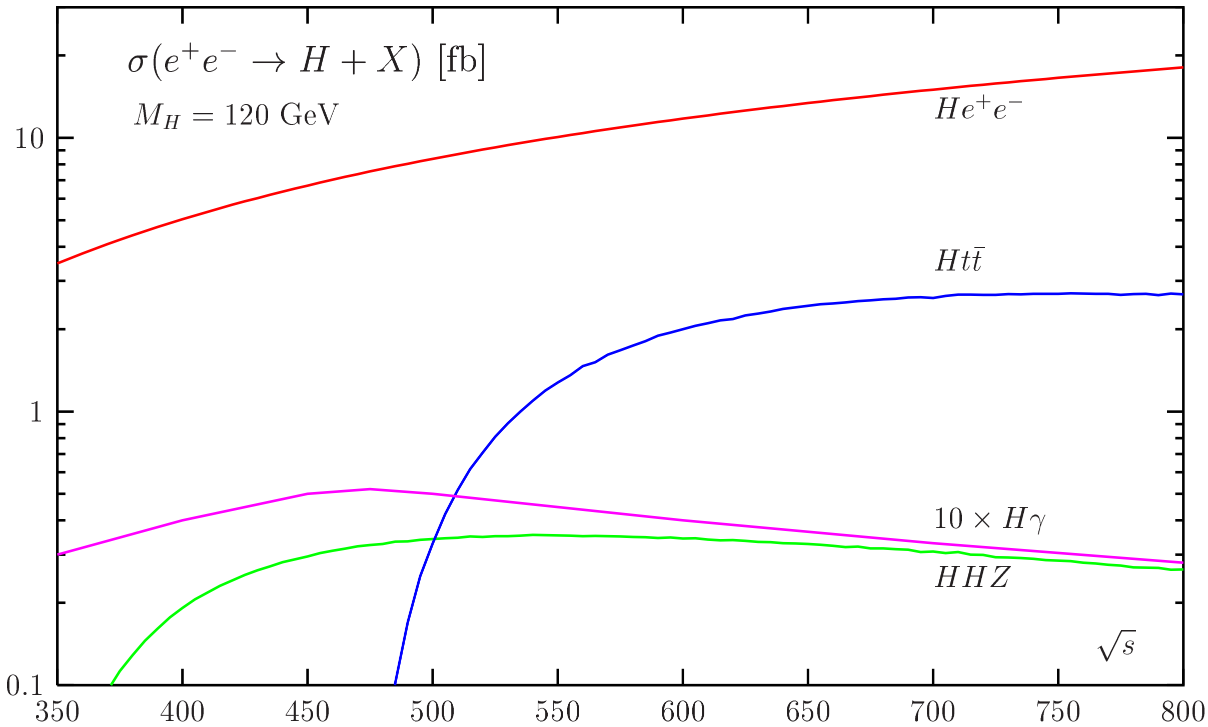
- Small cross section, better probed at higher energies.
- Sensitive to the important g_{Htt} Yukawa coupling.

The HHZ process: AD, Haber, Kilian, Mühlleitner, Zerwas

- Even smaller cross section, and at higher energies $WW \to HH$.
- Sensitive to the triple Higgs coupling needed to reconstruct $V_{\rm Higgs}$.

The $H\gamma$ process: Romao+Pulido, AD+Driesen+Hollik+Rosiek

- Extremely small cross section, only a few ten events with $\mathcal{L} \sim 1$ ab^{-1}.
- Sensitive to the loop induced $H\gamma\gamma$ coupling (similar to $\gamma\gamma \to H$).



2. What is different in the MSSM:

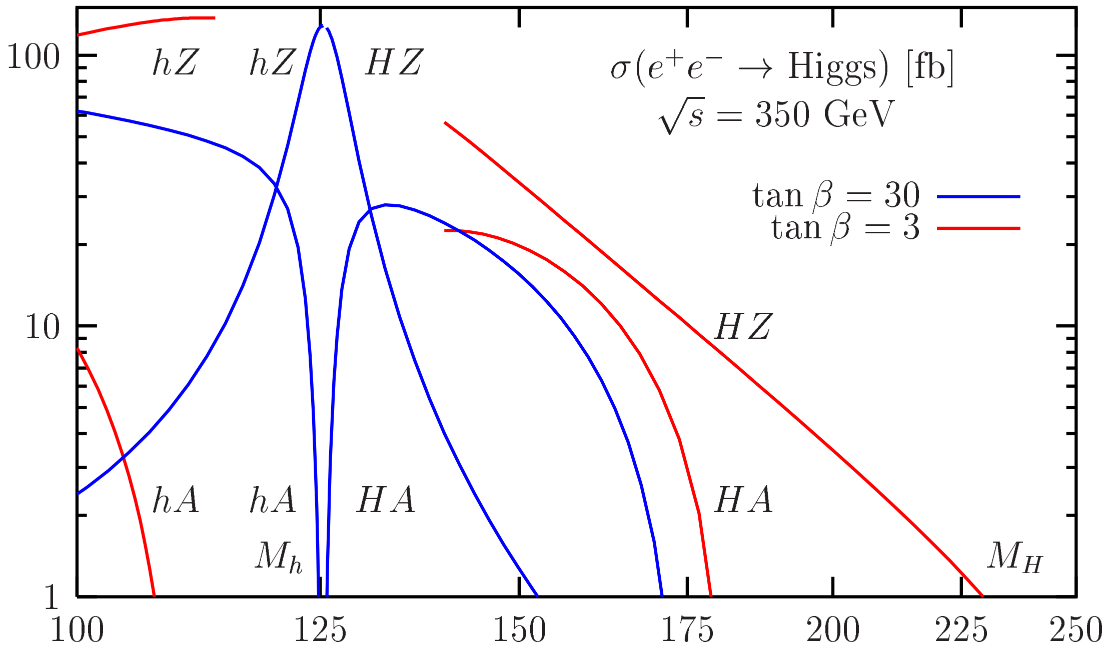
In the MSSM, the main Higgs production processes are:

- Bremsstrahlung processes: $e^+e^- \to (Z) \to Z + h/H$
- VV fusion processes: $e^+e^- \to \bar{\nu}\nu\ (e^+e^-) + h/H$
- Pair production processes: $e^+e^- \to (Z) \to A + h/H$
- $H^\pm$ pair production process: $e^+e^- \to (\gamma, Z) \to H^+H^-$

Main features and points:

- $\sigma(hZ),\ \sigma(h\bar{\nu}\nu),\ \sigma(he^+e^-)$ and $\sigma(AH) \sim \sin^2(\beta-\alpha) \to 1$
  $\sigma(HZ),\ \sigma(H\bar{\nu}\nu),\ \sigma(He^+e^-)$ and $\sigma(Ah) \sim \cos^2(\beta-\alpha) \to 0$
  $\Rightarrow$ Complementarity: always one process/Higgs with large σ.
- Decoupling limit, produce: hZ, $h\bar{\nu}\nu$, he^+e^- and HA, H^+H^-
  Production possible if: $\sqrt{s} \gtrsim 250$ GeV $\sqrt{s} \gtrsim 2M_A$.
- If kinematically accessible: production and detection guaranteed.

TESLA TDR



3. Precision Measurements at the LC

Because of the clean environment and high–luminoisty, $\int \mathcal{L} \sim 500$ fb^{-1}, very high precision measurements are possible at a future LC:

- From the recoil mass in $e^+e^- \to ZH \to He^+e^-$ or $H\mu^+\mu^- \Rightarrow M_H$.
- From the angular distribution of the Z/H ($\sim \sin^2\theta$) $\Rightarrow$ zero–spin.
- Correlations in $e^+e^- \to HZ \to 4f$ or $H \to WW \to 4f \Rightarrow J^P = 0^+$.
- Unambiguous test of the CP nature in $e^+e^- \to t\bar{t}H$ or $\gamma\gamma \to H$.
- The g_{HZZ} and g_{HWW} couplings measured from $\sigma(HZ)$ and $\sigma(H\nu\nu)$.
- From the measurement of the Higgs BRs, one checks the prediction that couplings are proportional to masses (Higgs mechanism!) and distinguishes a SM Higgs from possible extensions:
  - $b\bar{b}$, $c\bar{c}$ and $\tau^+\tau^- \Rightarrow$ check relative Higgs couplings to fermions.
    ex: BR($H \to \tau^+\tau^-$) $\sim m_\tau^2/3\bar{m}_b^2$ allows such a test.
  - The gg branching ratio is sensitive to the $t\bar{t}H$ Yukawa coupling.
  - BR(WW) significant for $M_H \gtrsim 120$ GeV and allows to measure g_{HWW}.
  - BR($\gamma\gamma$) is sensitive to new charged particles.
- The Higgs Yukawa coupling to top quarks, g_{Htt}, from $e^+e^- \to t\bar{t}H$.
- The trilinear Higgs self–coupling, λ_{HHH} from $e^+e^- \to ZHH$.
- The total decay width Γ_H from $\sigma(H\nu\nu)$ and BR($H \to WW$).

Full simulation for ($\sqrt{s} \sim 500$ GeV and $\mathcal{L} \sim 500$ fb^{-1})   TESLA TDR

M_H	ΔM_H	ΔCP	$\Gamma_{\rm tot}$	g_{HWW}	g_{HZZ}	g_{Htt}	g_{Hbb}	g_{Hcc}	$g_{H\tau\tau}$	g_{HHH}
120	±0.033	±3.8	±6.1	±1.2	±1.2	±3.0	±2.2	±3.7	±3.3	±17
140	±0.05	–	±4.5	±2.0	±1.3	±6.1	±2.2	±10	±4.8	±23

Interpretation in the MSSM

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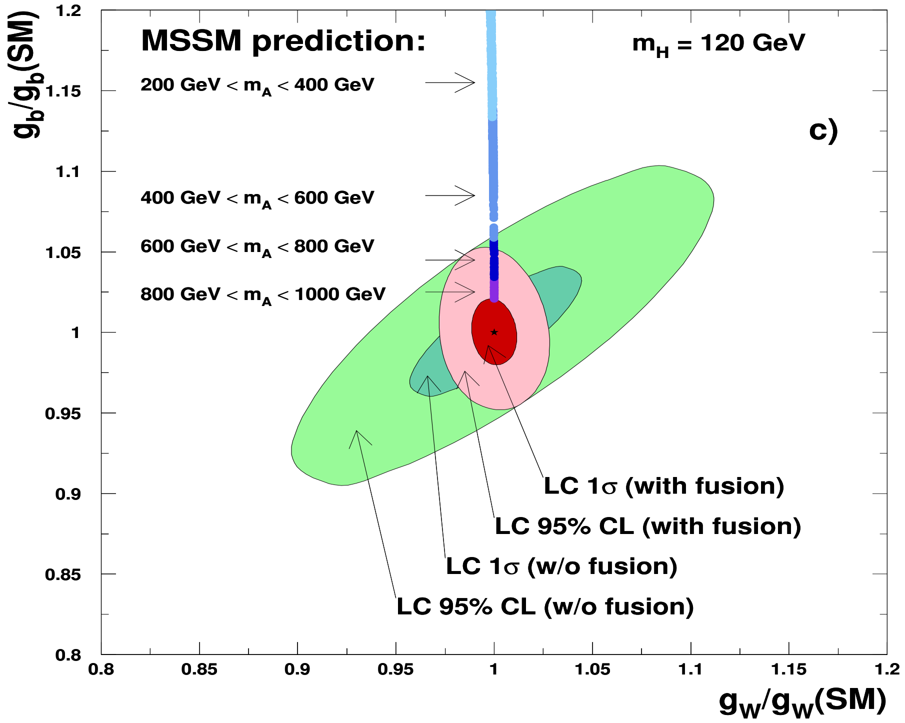

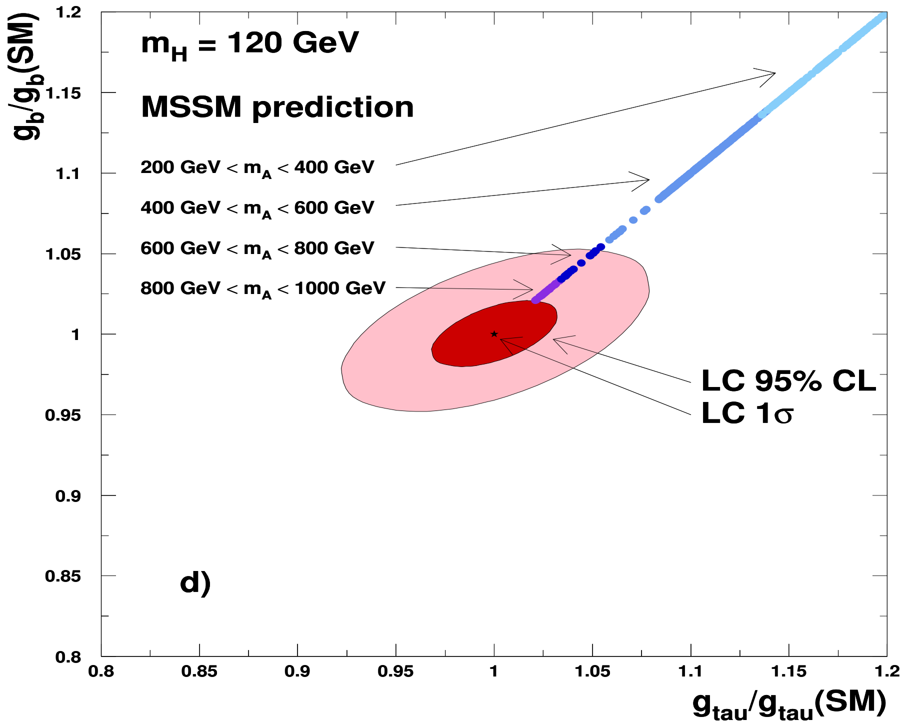

V. Conclusions

This decade, with Tevatron and the LHC, will be the Higgs decade.
The next one, with LHC and the LC, will allow deep tests of EWSB.