From the LHC to Terascale Physics: How to go ahead

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Hamburg, 02/2012

1. How to go ahead?
2. LHC2TSP and WG1
3. How to go ahead!

1. How to go ahead?

Why do we not construct the ILC tomorrow?

- "overall" strategy is needed
- the ILC is not really cheap (but also not absurdly expensive!)
- at least Europe has to to ahead united

European Strategy of Particle Physics

- "European Strategy Update" (group)
- decision in $\sim$ September/October 2012
- ILC needs endorsement to go ahead

Encouraging development in Japan!!

- but this talk will not depend on it

Early LHC results: a possible window of opportunity

- Exciting results from the early LHC data could open up a window of opportunity for securing a long-term future of the field: possibility to bring a new major facility on the way

- The particle physics community will have to act quickly and speak with a unanimous voice:

  We will need to come up with a convincing and
  scientifically solid conclusion on how to proceed

⇒ The particle physics community (WE!) should
interpret the LHC data on the road to future experiments

First Workshop:
'The LHC early phase for the ILC' (April 12–14, 2007, Fermilab)

Focus was on implications for the ILC

workshop charge:

- What could be the impact of early LHC results on the choice of the ultimate ILC energy range and the ILC upgrade path?

  Could there be issues that would need to be implemented into the ILC machine and detectors design from the start?

- Could there be cases that would change the consensus about the physics case for an ILC with an energy of about 500 GeV?

- What are the prospects for LHC / ILC interplay based on early LHC data?

CERN Theory Institute: "From the LHC to Future Colliders"

(February 9–27, 2009, at CERN)

Organizers:
Albert De Roeck, John Ellis, Christophe Grojean, S.H., Karl Jakobs, Georg Weiglein, James Wells

Goals:

- Discuss recent physics developments
- Anticipate near-term capabilities of Tevatron, LHC and other experiments
- Have discussions on the most effective ways to be prepared for giving science input to plans of the post-LHC era

Considered future options for accelerator-based facilities at the TeV scale beyond the first phase of the LHC:
SLHC, ILC, CLIC, LHeC, Muon Collider, . . .

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– "Dry run" for early LHC data

– assumptions: $10\,\text{fb}^{-1}$ @ 14 TeV

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But now we really have LHC data!

What to do now?

New workshop series: From the LHC to Terascale Physics (LHC2TSP)

2. LHC2TSP and WG1

LHC2TSP:

- Workshop series
- Organizers: O. Buchmüller, P. De Jong, A. De Roeck, J. Ellis, C. Grojean, S.H., J. Hewett, K. Jakobs, M. Mangano, F. Teubert, G. Weiglein
- First meeting: 28.08. - 02.09. 2011
- one intermediate working group meeting 11/2011
- next general meeting: 03/2012

WG1: Signals of electroweak symmetry breaking
(S.H., M.Kado, C.Mariotti, G.Weiglein, A.Weiler)

WG2: Signatures with missing energy
(R.Cavenaugh, J.Hewett, S.Kraml, G.Polesello)

WG3: Other signatures of possible BSM physics
(C.Grojean, D.Martinez, J.Santiago Perez, P.Savard, S.Worm)

From the LHC2TSP charge:

- "... to evaluating the implications of recent results from the LHC, and elsewhere, for TeV-scale physics, and to discuss the impact of these results on the future strategy for particle physics."

- WG1: Signals of electroweak symmetry breaking

- The task of the working groups is to assess the possible interpretations of the experimental results in view of their implications for the future strategy of particle physics.

- The charge for the first meeting:
  - to summarize the experimental situation at this time
  - to start the discussion of possible interpretations
  - to define the lines of work that should be carried out

- final document will be ready in time for the Orsay-type meeting of the European Strategy update

Possible scenarios for WG1

– observation of a state compatible with
– non-exclusion of

A: non-SM-like Higgs with $M_H \lesssim 115$ GeV

B: SM-like Higgs with 115 GeV $\lesssim M_H \lesssim 140$ GeV

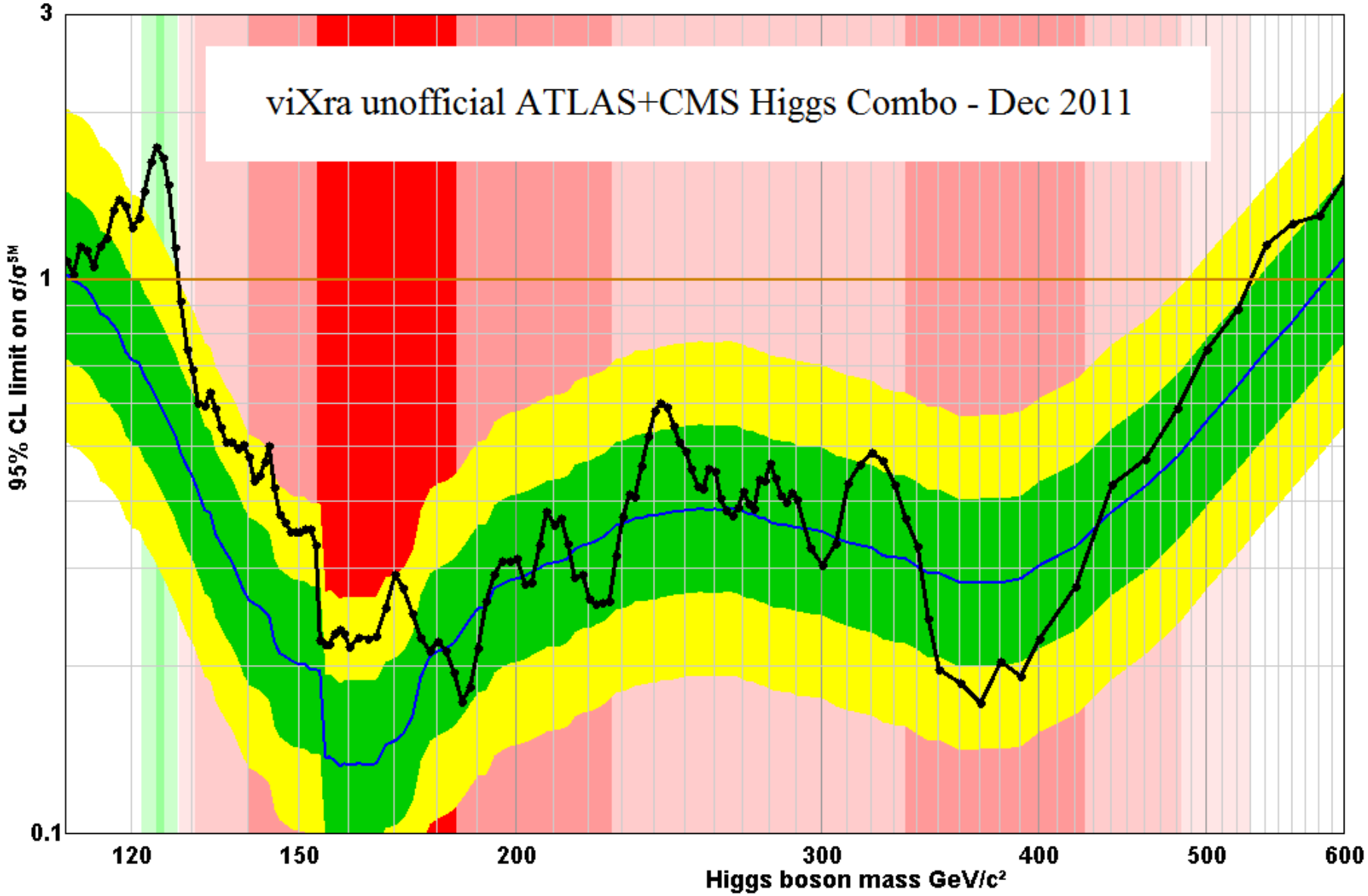
C: non-SM-like Higgs with ... GeV $\lesssim M_H \lesssim$ ... GeV

D: a "very heavy" Higgs

E: "nothing" (weak signal?)

Right now: B looks "most probable"

Unofficial(!) LHC combination:



Data assumptions

Right now: $\mathcal{L} \sim 4 - 5\,\text{fb}^{-1}$ @ 7 TeV

analyzed: up to $\sim 2\,\text{fb}^{-1}$

End of 2012: $\mathcal{L} \sim 15\,\text{fb}^{-1}$ @ 8 TeV

For our analysis/write-up: $\mathcal{L} \lesssim 10\,\text{fb}^{-1}$ @ 7/8 TeV ?

(at best: right after ICHEP 2012)

$\oplus$ combination of ATLAS and CMS !?

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Right now:

- prepare ourselves for "our" data set
- discussion of how results are presented:
  p_0, "cyan band", channel by channel, ...
- interpretation of results (TH $\leftrightarrow$ EXP)

The tasks:

(according to the WG1 Twiki page)

1. Theorist should try to interpret the existing (and/or anticipated) LHC results (on Higgs/EWSB/other) searches in their favorite model. Which models are still allowed, which are excluded? How do they differ in their LC phenomenology? How does this compare to the HL-LHC expectations?

2. For particular models of specific interest it can be possible to put data (XS, BR, ...) on a web page so that it can be used by experimental groups/analyses (this will be WG1 convenor moderated) $\rightarrow$ TH

3. Experimental expectations for Higgs searches (for 2011/2012 data), what are the expectations on the determination of Higgs properties of a possible signal?

4. How can/should experimental results are presented? sigma x BR, channel by channel, ... $\rightarrow$ TH $\oplus$ EXP

5. Insert the assumption of a SM-like Higgs and the LHC measurements assuming 10/fb at 7 TeV into your Higgs analysis (in the 'favored' mass rang of 115 - 135 GeV). What can be measured? $\rightarrow$ TH $\oplus$ EXP

6. The same as task 5, but for the assumption of reduced couplings (or other deviations from a SM-like Higgs). $\rightarrow$ TH $\oplus$ EXP

7. Insert the assumption of a Higgs signal and some evidence of SUSY (or another favored model) into your analysis/fits. What can we learn? $\rightarrow$ TH $\oplus$ EXP

8. Assume large M_H, prepare an analysis in the M_H–Γ_H plane. $\rightarrow$ TH $\oplus$ EXP

9. VV scattering at 7 TeV: what is the status? What can be done? $\rightarrow$ TH $\oplus$ EXP

Guessing for 10-20 fb^{-1}

Assume factor 10 in luminosity, ~ factor 3-4 in sensitivity

- **Can be better because of improved analysis, tighter cuts, ...**
- **Can be worse because of systematics, high pileup, ...**
- **Worse for couplings: should also treat ggH, VBF, … independent**

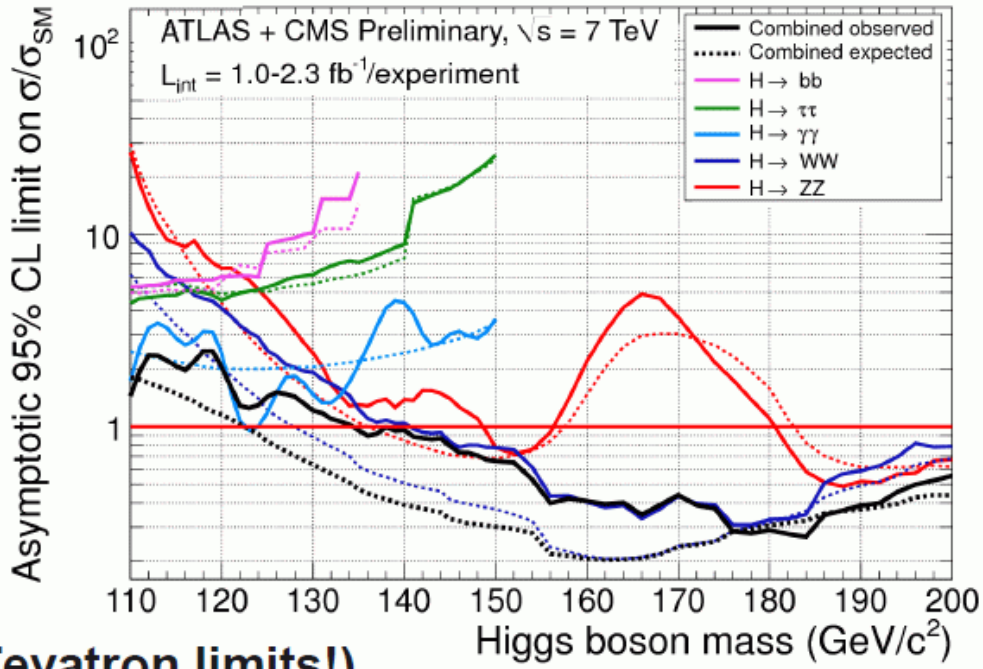
Guesses of measurement precisions for a SM Higgs:

m_H ~ 120 GeV

gg→H→γγ	: O(25%)
gg→H→WW	: O(50%)
gg→H→ZZ	: O(100%)
gg/VBF H→ττ	: O(75%)

m_H ~ 135 GeV

gg→H→γγ	: O(25%)
gg→H→WW	: O(15%)
gg→H→ZZ	: O(20%)
gg/VBF H→ττ	: O(75%)



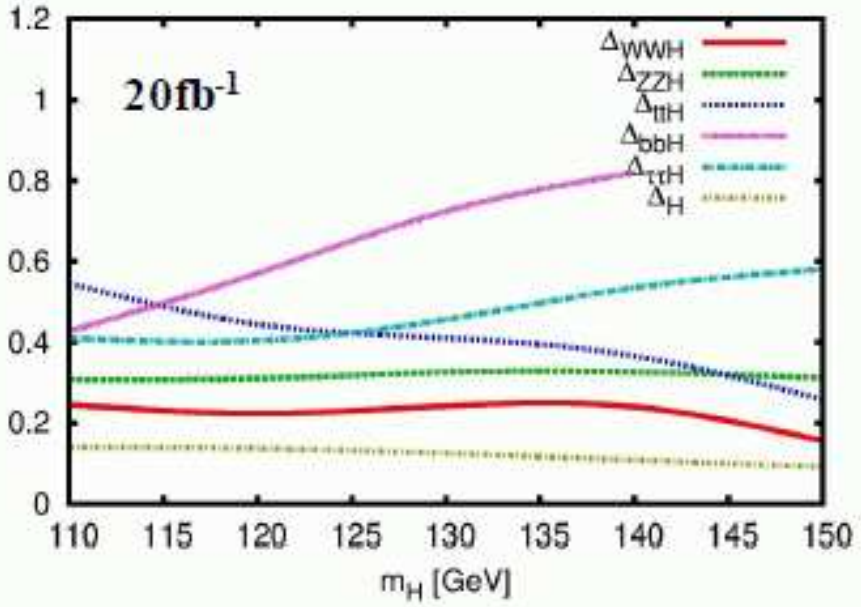
(ignoring H→bb for now: Tevatron limits!)

Michael Duehrssen LHC2TSP 5

Example for first results at the intermediate WG1 meeting:

[*D. Zerwas, SFitter '11*]

Conclusions



- 2012: Higgs between 115-140GeV
- couplings known to better than 0.5 ☺

3. How to go ahead!

To be kept in mind for the LHC2TSP:

a) How well do the observed signatures in the early LHC data constrain the possible physics scenario?

b) What could be the impact of early LHC results on the choice of the next facility and its (ultimate) energy reach and luminosity?

c) What would be the possible implications for the machine and the detector design?

$\Rightarrow$ skeleton draft very soon

$\rightarrow$ hopefully with some names assigned

$\Rightarrow$ Document about the LHC physics implications from "US"!

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Finding a particle that is compatible with
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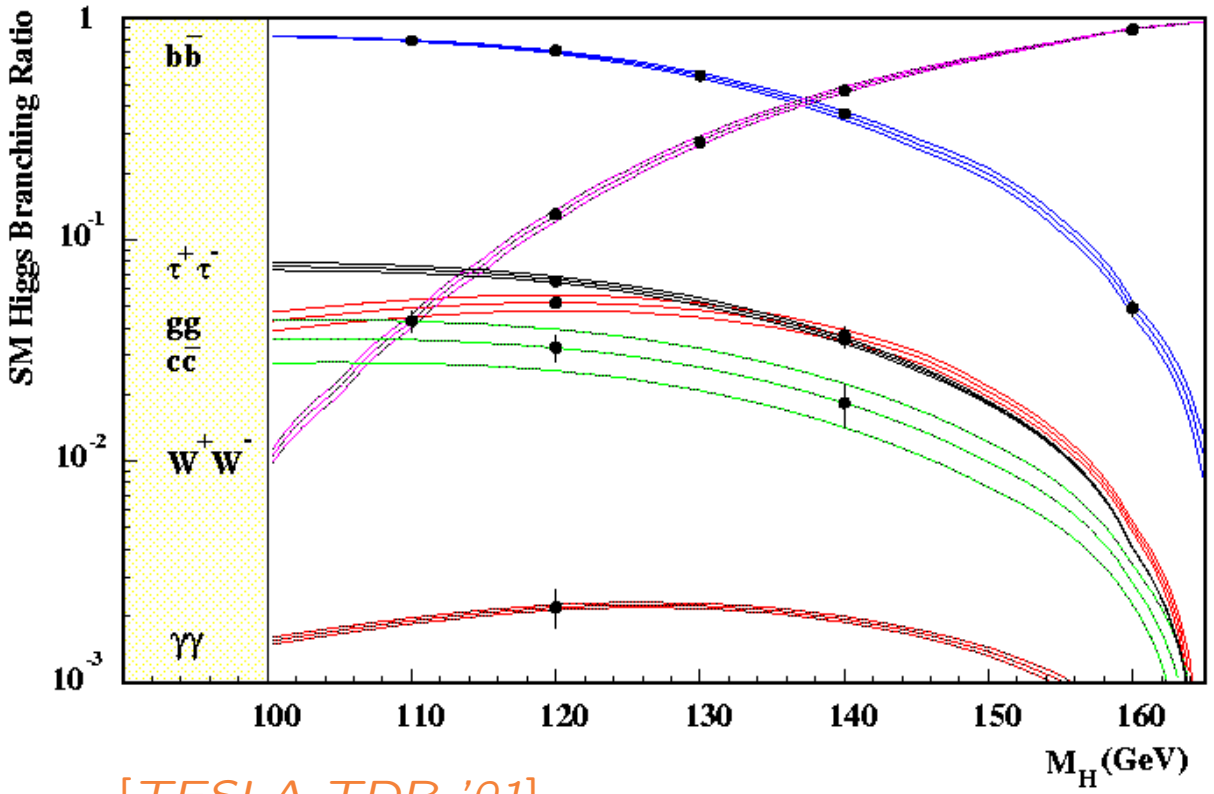
Higgs physics at the ILC:

SM Higgs @ ILC:

Precise measurement of:

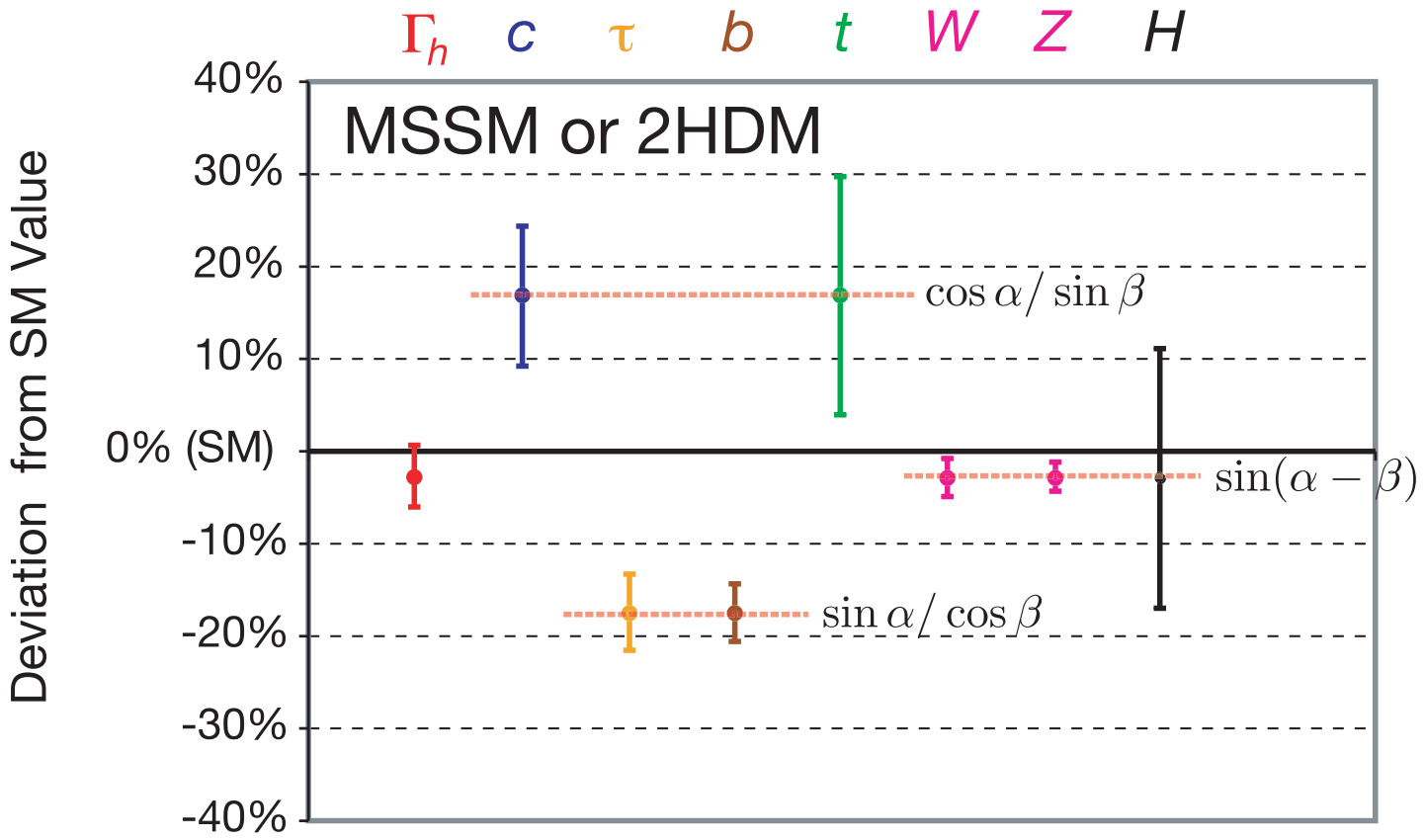
1. Higgs boson mass,
   $\delta M_H \approx 50$ MeV
2. Higgs boson width
   (direct/indirect)
3. Higgs boson couplings,
   $\mathcal{O}$ (few%) $\Rightarrow$
4. Higgs boson quantum
   numbers: spin, ...



[*TESLA TDR '01*]

Example: Higgs couplings in the MSSM:

"Normal(?)" MSSM scenario:



⇒ measurable deviations (at least in some parts of the parameter space)

The decoupling limit:

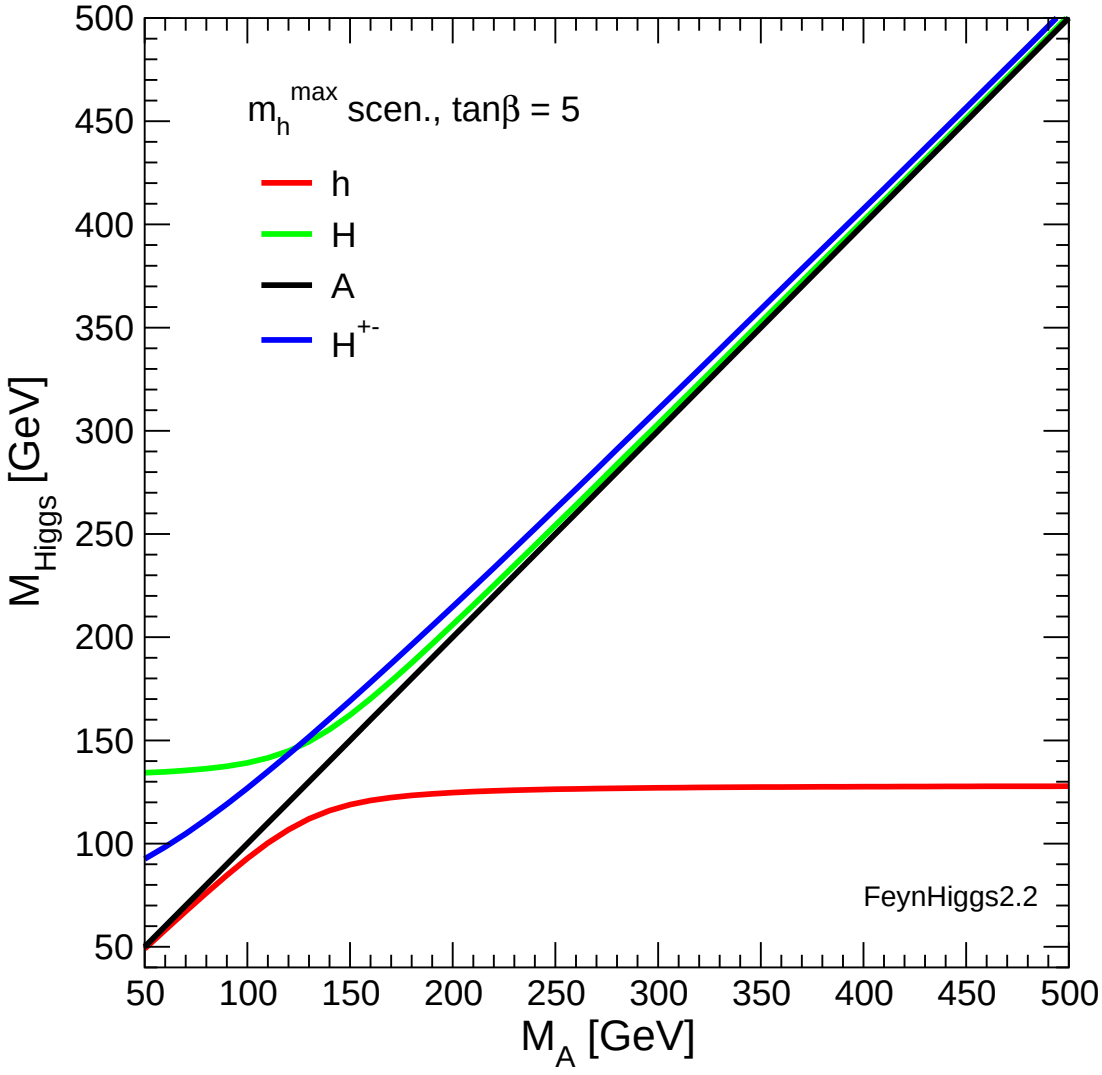
For $M_A \gtrsim 150$ GeV:

The lightest MSSM Higgs
is SM-like
$\Rightarrow$ SM analysis applies!

The heavy MSSM Higgses:
$M_A \approx M_H \approx M_{H^\pm}$

$\longrightarrow$ coupling to gauge bosons ~ 0

$\Rightarrow$ no decay $H \to WW^{(*)}, \ldots$



Indirect determination of unknown Higgs sector parameters

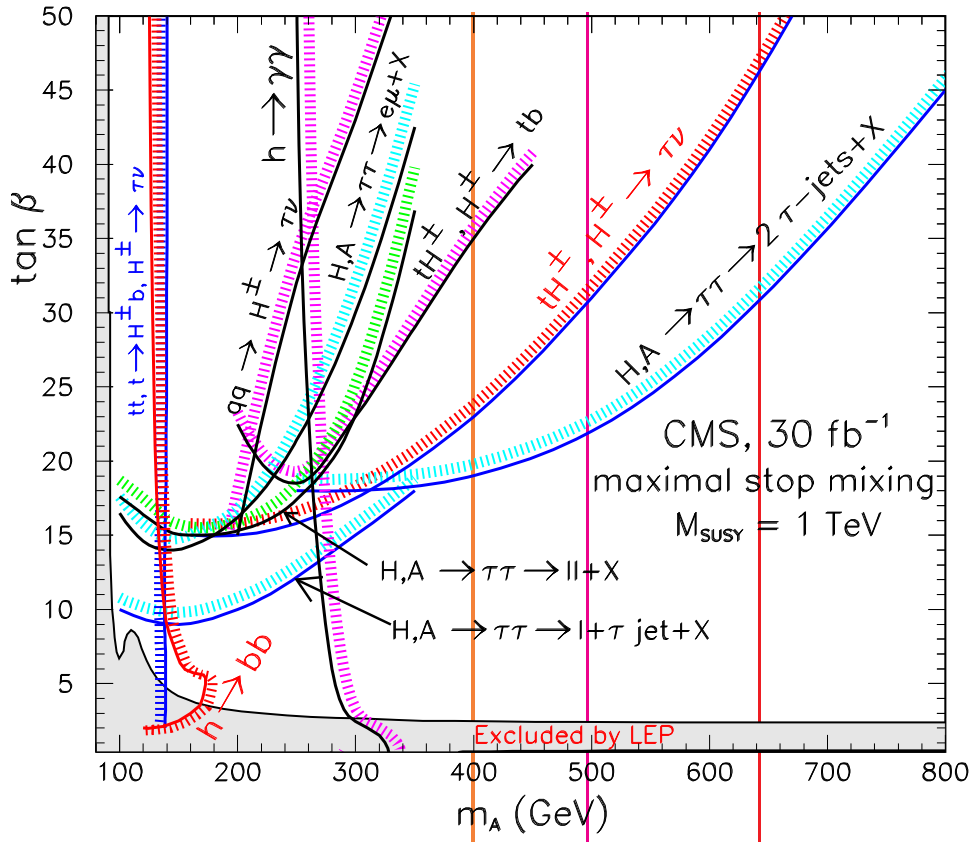
LHC/ILC reach for MSSM Higgs bosons:

LHC:

h : all $M_A - \tan\beta$ plane

H, A : unreachable parts

CMS, 30 fb^{-1}, m_h^{max} scenario: $\Rightarrow$



ILC: $\sqrt{s} = 800$ GeV

$\sqrt{s} = 1000$ GeV

$\gamma\gamma$:

kinematic limit: $M_A \lesssim 0.8\sqrt{s}$

$\gamma\gamma$: $\sqrt{s} = 800$ GeV

ILC:

kinematic limit: $M_A \lesssim \sqrt{s}/2$

$\rightarrow$ $\sqrt{s} = 800$ GeV

$\rightarrow$ $\sqrt{s} = 1000$ GeV

Q: Is it possible to extend the reach for heavy Higgs bosons ?

A: Yes, by direct and indirect measurements

Tricky scenario:

The LHC finds only a SM-like Higgs and nothing else

Q: Do we still need the ILC with GigaZ?

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A: Of course!

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Q: Do we still need the ILC with GigaZ?

A: Of course! Or better: even more!

The ILC+GigaZ provides:

– precise Higgs coupling measurements (ILC)

– precision observable measurements (GigaZ)

⇒ Only the ILC+GigaZ can find deviations from the SM predictions via the various precision measurements

⇒ Only the ILC+GigaZ can point towards extensions of the SM

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- ILC as a Higgs (and top) factory
- Staged approach?
  - start at lower energies to produce $\mathcal{O}\left(10^5\right)$ Higgs bosons
  - go to higher energies for top physics
  - go to higher energies for TeV scale exploration
- go to other options: GigaZ, $\gamma\gamma$, . . .

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$\Rightarrow$ We have to speak unanimously in favor of the ILC!

$\Rightarrow$ We have to act **THIS YEAR**

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Do you think this is a worthwhile effort?

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We can have a positive impact on our own future! :-)