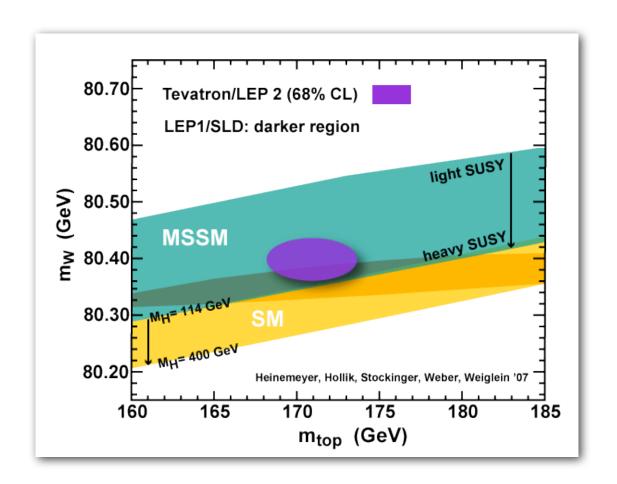
# No Higgs at the LHC?

John Conway
UC Davis
LHC Early for the ILC

#### Latest billion dollar plot...



My view: significant chance of non-SM Higgs at LHC ...or no Higgs at all

I knew exactly where it was, I just couldn't find it.

- Yogi Berra

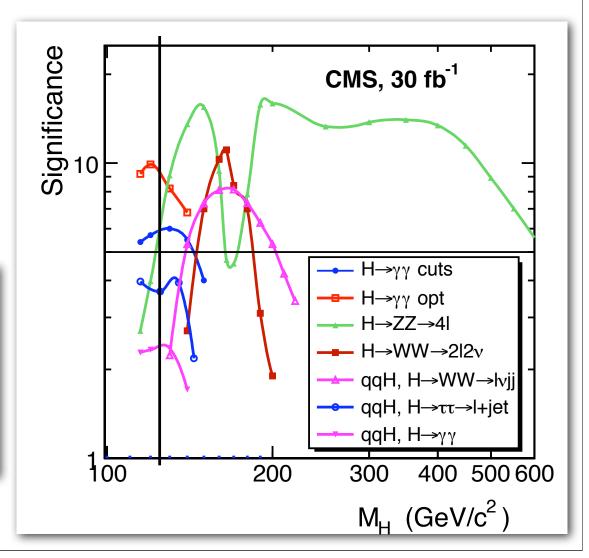
#### It's 2009. What is it we are not seeing?

main signals for SM-like Higgs at the LHC

I. 
$$gg \rightarrow H \rightarrow \gamma\gamma$$

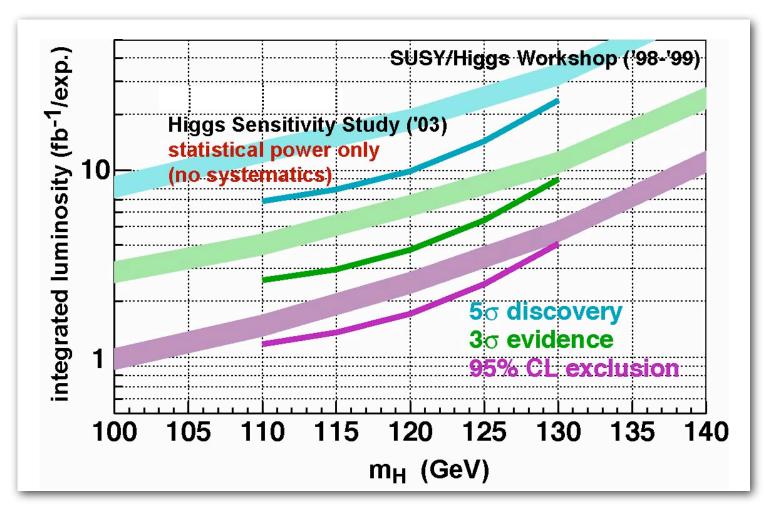
- 2. VBF: qqH,  $H \rightarrow TT$
- 3.  $gg \rightarrow H \rightarrow ZZ$

If we are not seeing it at the LHC, will we already have not seen it at the Tevatron?



#### Tevatron reach

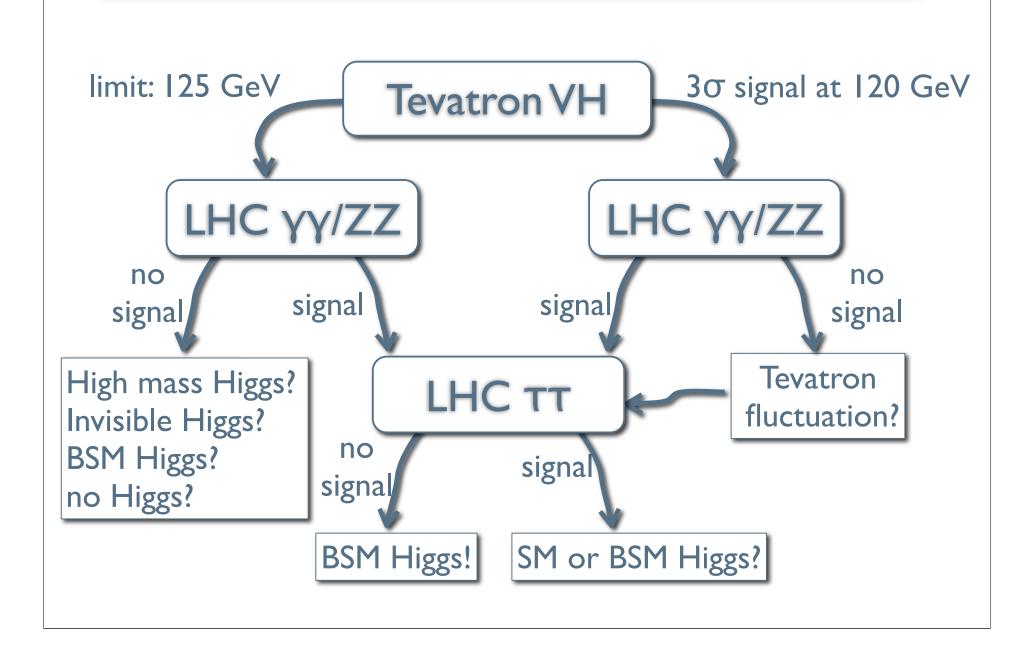
people love to hate 'em, but still our best guess!



When you come to a fork in the road, take it.

- Yogi Berra

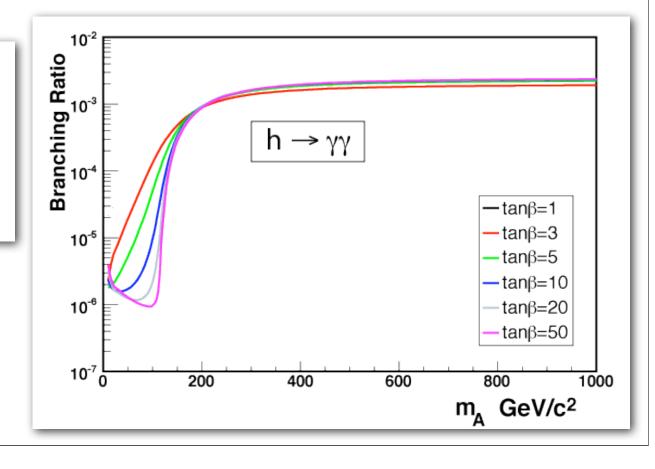
#### What will the situation be two years from now?



### First scenario: missing/suppressed $H \rightarrow \gamma \gamma$

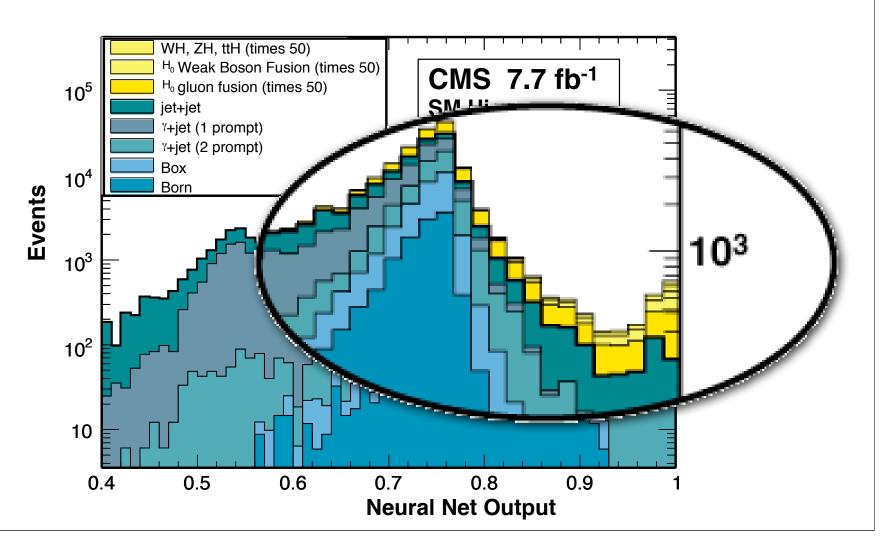
- Tevatron limit at 125 GeV would put us in the regime where γγ and ZZ have similar sensitivity
- Could be our first real hint of non-SM-like Higgs

In MSSM, if  $m_A$  is not > 250 GeV, then  $h \rightarrow \gamma \gamma$  is significantly less than the SM rate



### First scenario - missing/reduced yy

• CMS has optimized NN analysis for  $\gamma\gamma$  - we'll know well within 10 fb<sup>-1</sup> if this is the case!



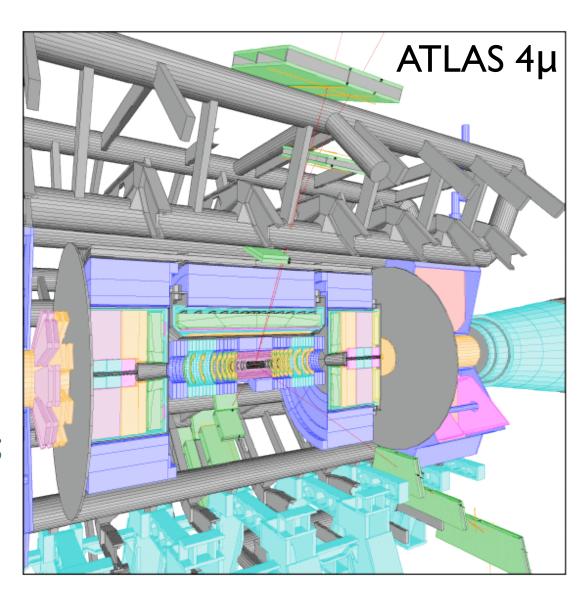
#### Confirmation? $h \rightarrow ZZ \rightarrow 4\ell$

eeee, eeμμ, μμμμ

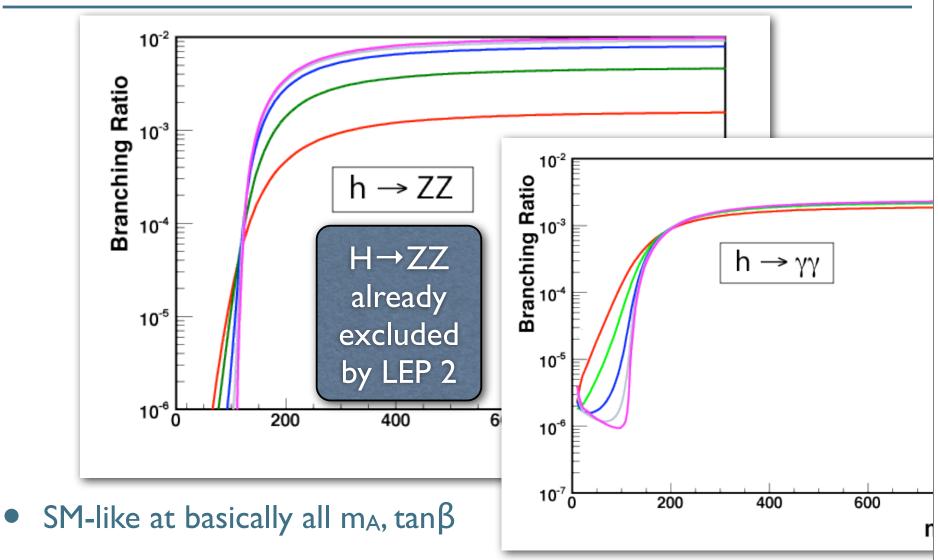
Excellent Higgs mass resolution

Relevant if h mass above ~125 GeV

Compare with SM rate for this process; can help with mass?

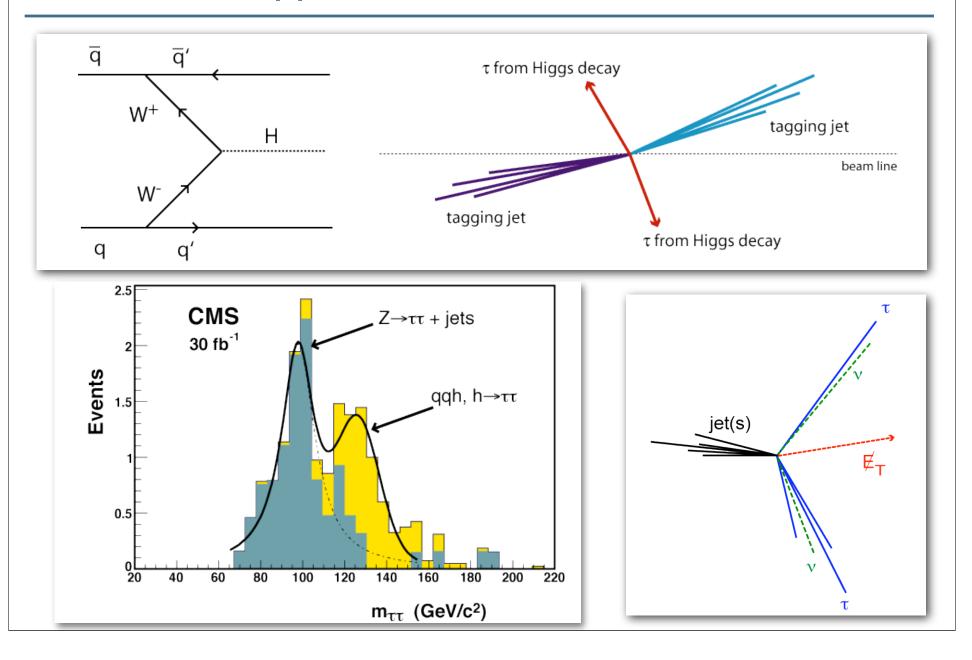


### Second signal: $h \rightarrow ZZ \rightarrow 4\ell$



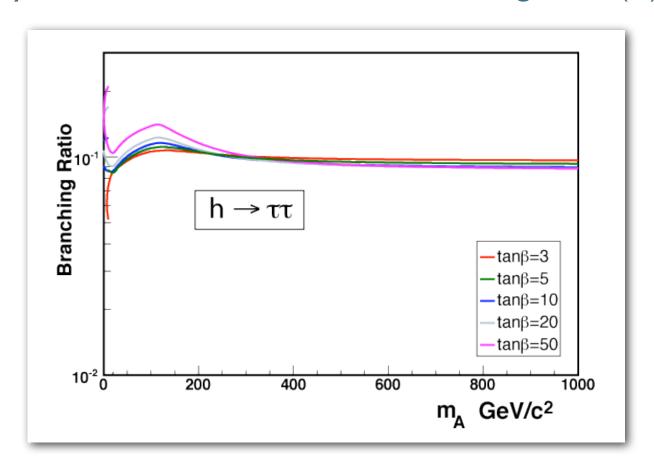
BR tracks that of SM:"confirming mode"

### What about $qqH, H \rightarrow TT$ ?



#### h→TT branching ratio in MSSM

very stable at around 10% over wide range of m(A)

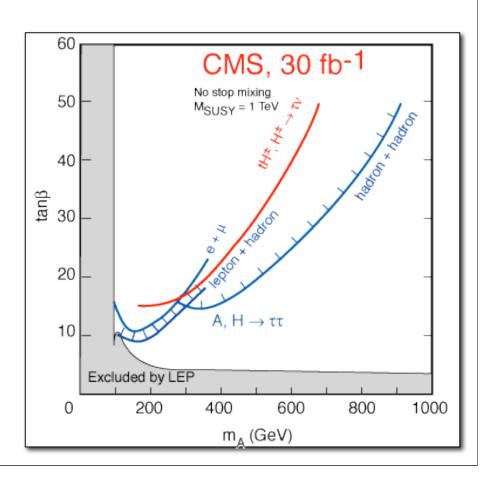


(Are high tan beta curves right? Disagrees with FeynHiggs...)

#### cross section for WW→h versus m(A)

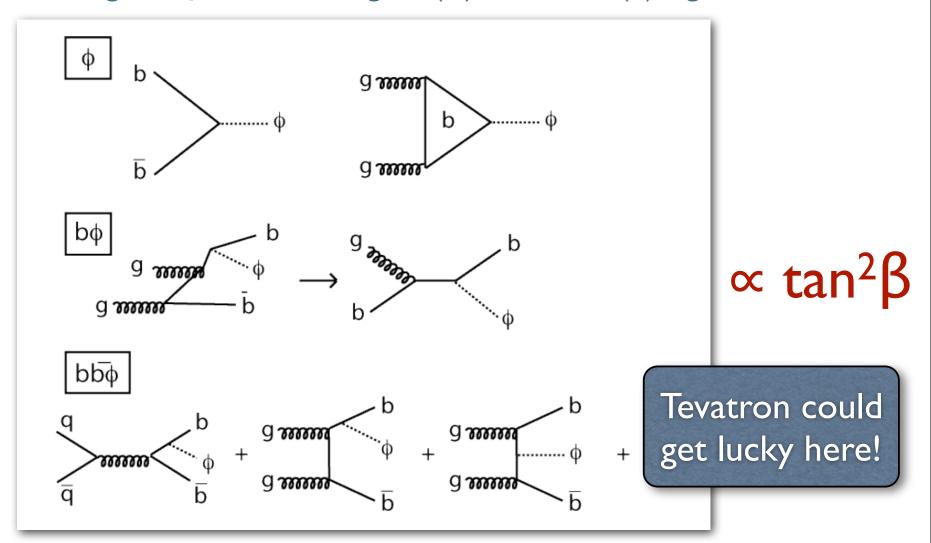
- it's not just the branching ratio of course
- if m(A) is large, then h has SM-like hVV couplings and we'll see the tau pair mode with ~25-20 fb<sup>-1</sup>

 meanwhile we need to look for enhanced production (lower m(A), high tanβ) in tau pair modes

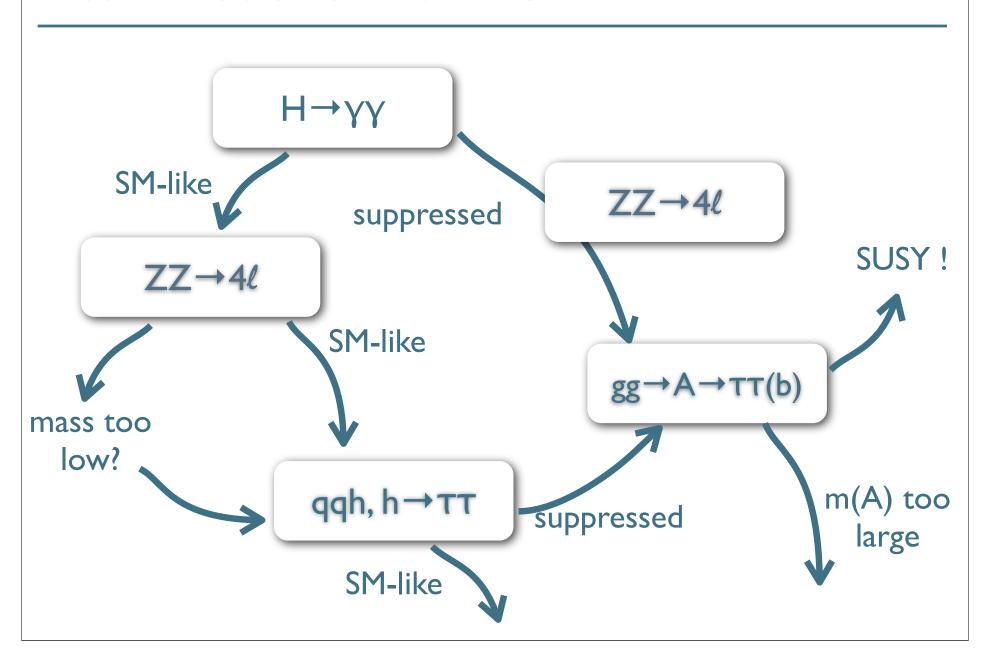


### enhanced production

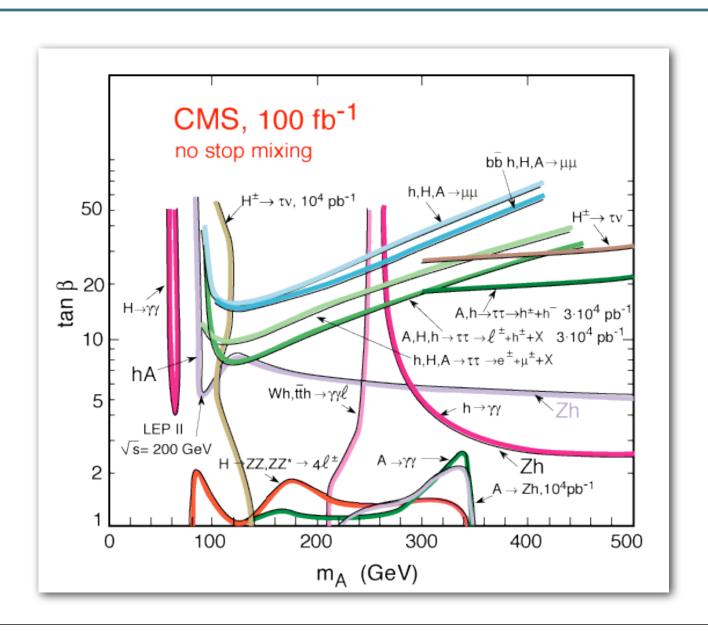
• large  $tan\beta$ , not too large m(A): TT, TTb(b) signals



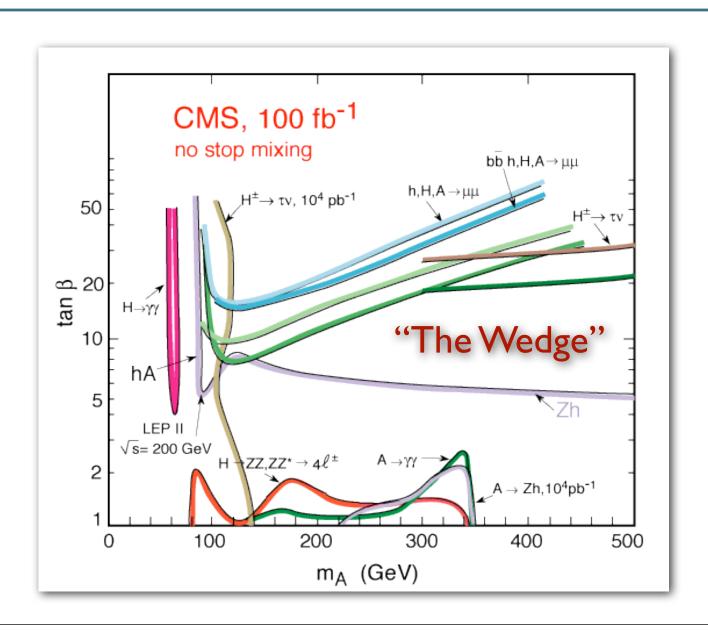
#### MSSM decision tree at LHC



### "Tokyo subway plot" (5σ discovery reach)



## "Tokyo subway plot" (5σ discovery reach)



#### Implication for Linear Collider

- <u>absence</u> of a  $h \rightarrow \gamma \gamma$  signal means we are in an interesting world...but is it explorable with a 500 GeV machine?
- <u>suppressed</u>  $h \rightarrow \gamma \gamma$  is very interesting and could mean that A/H are reachable with a 500 GeV machine
  - \*\* an early LHC signal of enhanced, high tanβ SUSY would be a powerful argument for a 500 GeV machine
- <u>SM-like</u>  $h \rightarrow \gamma \gamma$  means we may be in a situation where only independent evidence of SUSY can help...or a TeV LC

see Tim Tait's talk for more...

Not enough experimental work so far on non-SM, non-MSSM Higgs searches!

#### **CPNSH** workshop report out:

CP 2HDM MSSM with CP phases NMSSM (MSSM+singlet) **RPV MSSM** extra gauge groups Little Higgs models Large extra dimensions Warped extra dimensions Higgsless Models Strongly interacting Higgs Technicolor Higgs Triplets

CERN 2006-009 31 July 2006

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH



#### Workshop on CP Studies and Non-Standard Higgs Physics

May 2004 - December 2005

Sabine Kraml 1, Georges Azuelos 2,3, Daniele Dominici 4, John Ellis 1, Gerald Grenier 5. Howard E. Haber 6. Jae Sik Lee 7. David J. Miller 8. Apostolos Pilaftsis 9 and Werner Porod 10

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- University of California, Santa Cruz, USA.
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http://kraml.web.cern.ch/kraml/cpnsh/

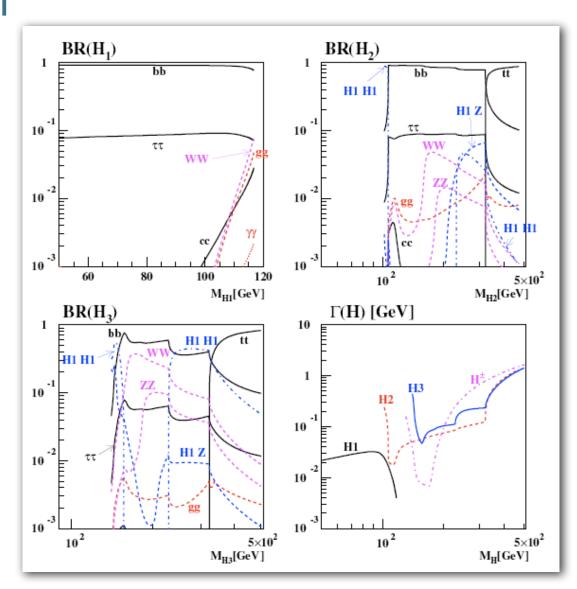
"Higgs Hunters Guide to non-standard Higgs"

If this was easy it wouldn't be so hard. - Yogi Berra One example: MSSM with CP phases

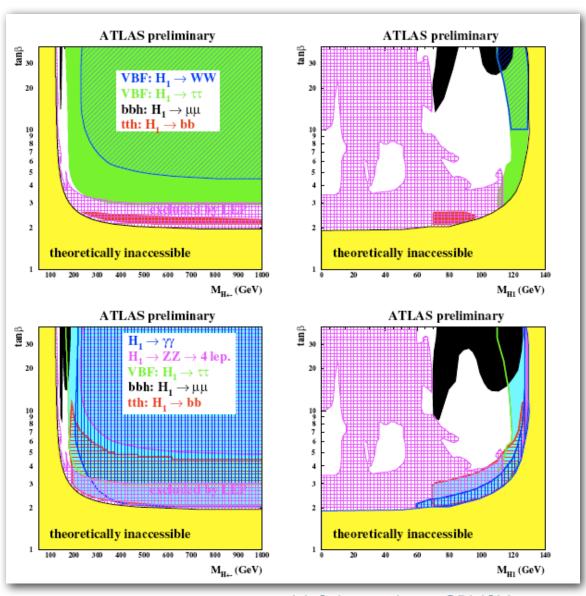
Three Higgs bosons H<sub>1</sub>, H<sub>2</sub>, H<sub>3</sub>

Branching ratios look somewhat familiar!

Use SM, MSSM searches to probe the model

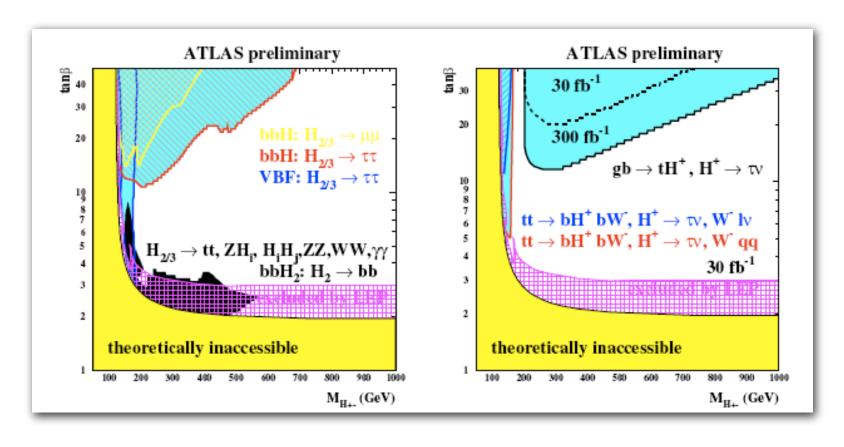


#### ATLAS reach for H<sup>±</sup>, H<sub>1</sub>



M. Schumacher, CPNSH report

#### ATLAS reach for H<sub>2</sub>, H<sub>3</sub>



#### what about <u>really</u> no Higgs signals?

- no gamma gamma signal
- no  $Z \rightarrow 4\ell$  signal
- no tau pairs (qqH,  $H \rightarrow \tau\tau$ , gg $\rightarrow \tau\tau$ , gb $\rightarrow \tau\tau$ b...)
  - Little Higgs
  - Technicolor
  - UED
  - extra gauge groups

These might give observable signals at the LHC eventually but could be difficult to justify a 500 GeV

You give 100% for the first half of the game, and if that's not enough, in the second half you give what's left.

- Yogi Berra

### Our parallel program

- J. Gunion Introduction
  - G. Cacciapaglia No-Higgs scenarios
  - T. Tait MSSM scenarios
  - J. Reuter Little Higgs
  - J. Gunion Extra/exotic decay channels
- discussion

You can observe a lot just by watching. - Yogi Berra