

Quy Nhon, Vietnam July 15 - 21, 2012

# **Higgs and SUSY in Vietnam**

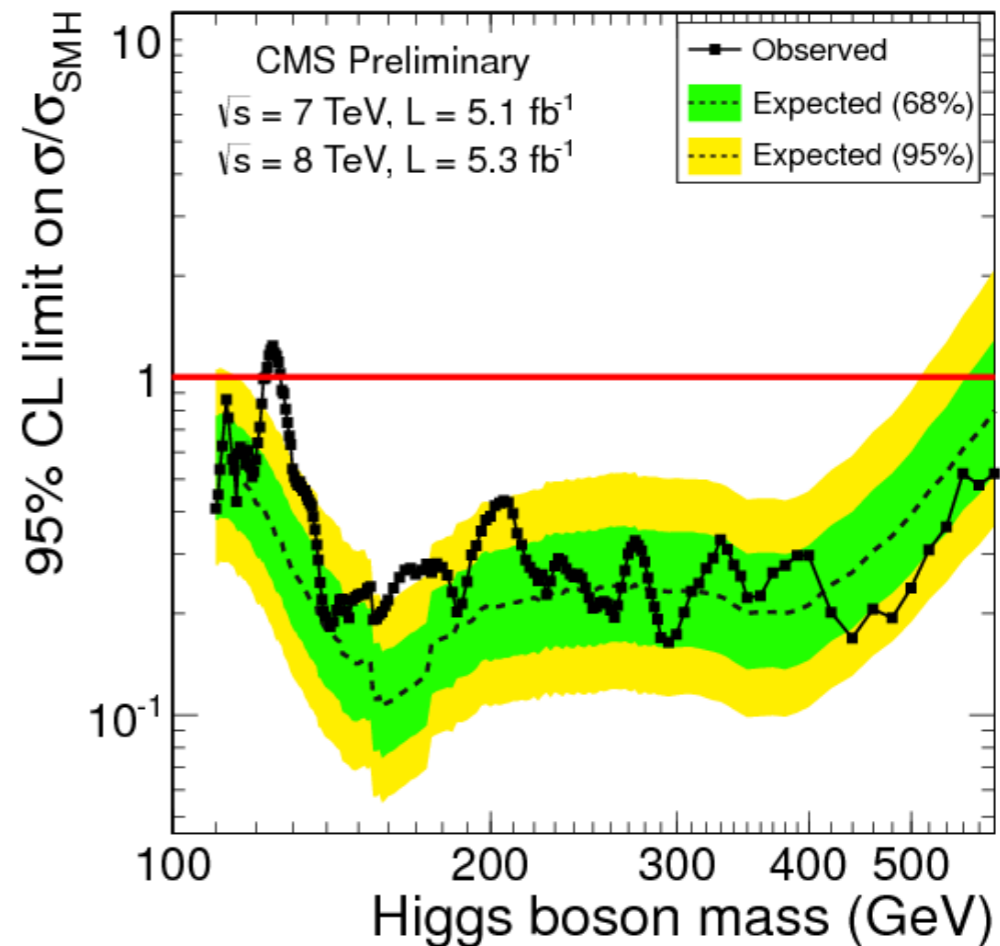
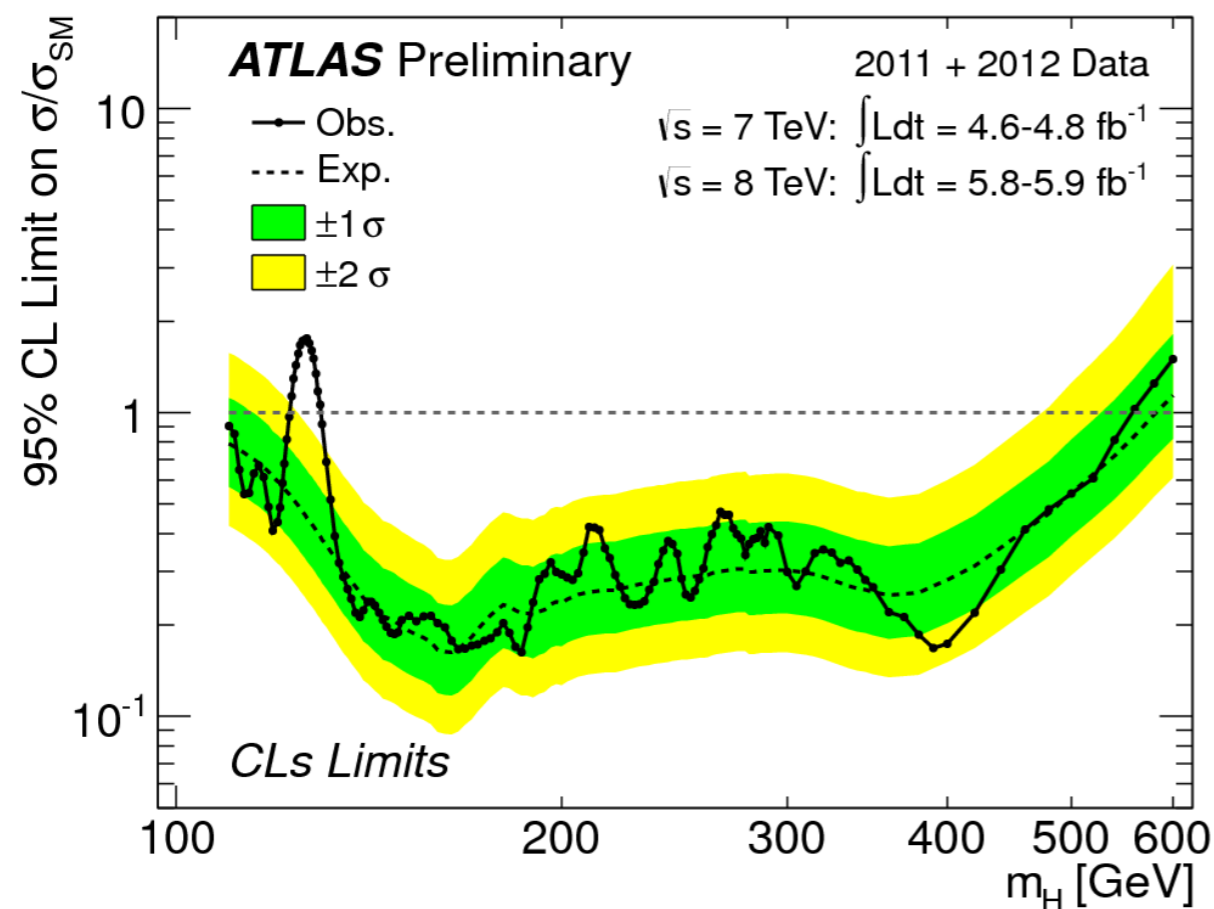
## **Some 2012 Highlights**

Edmond L Berger

Argonne National Laboratory

# SM Higgs – We know where it is NOT

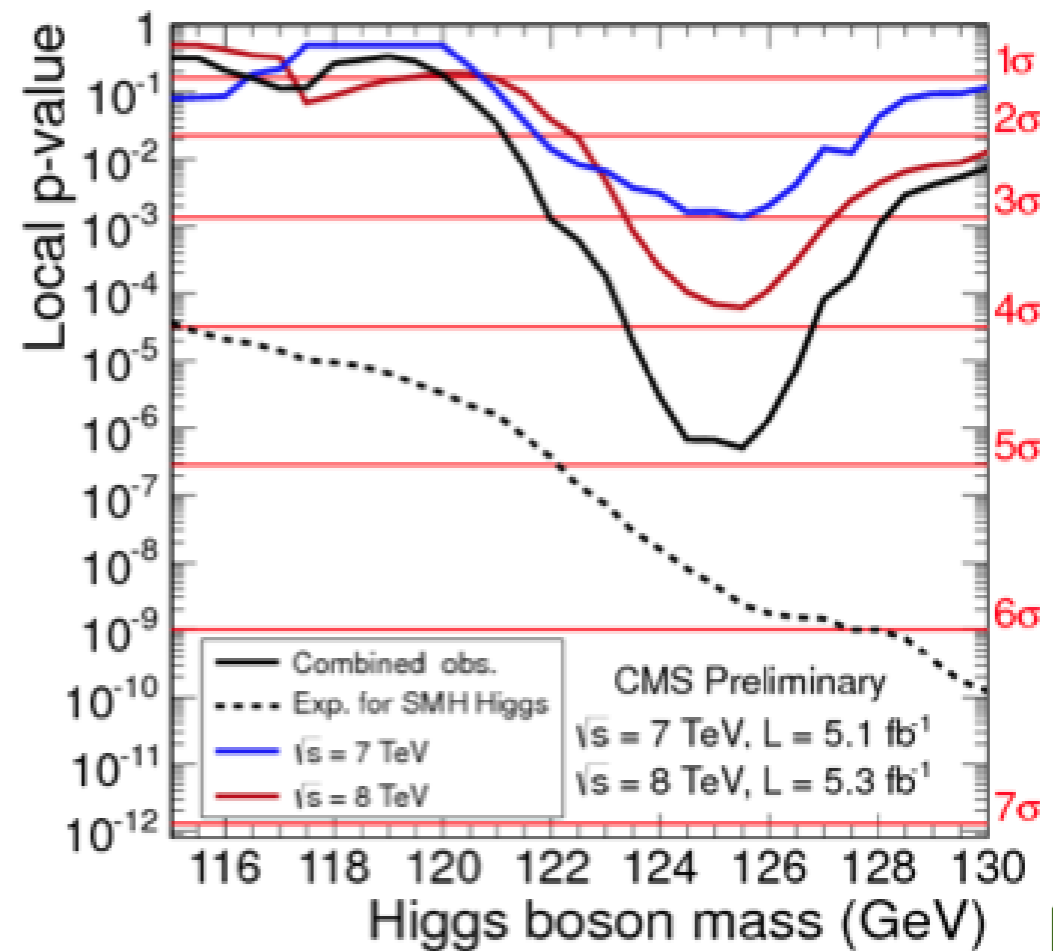
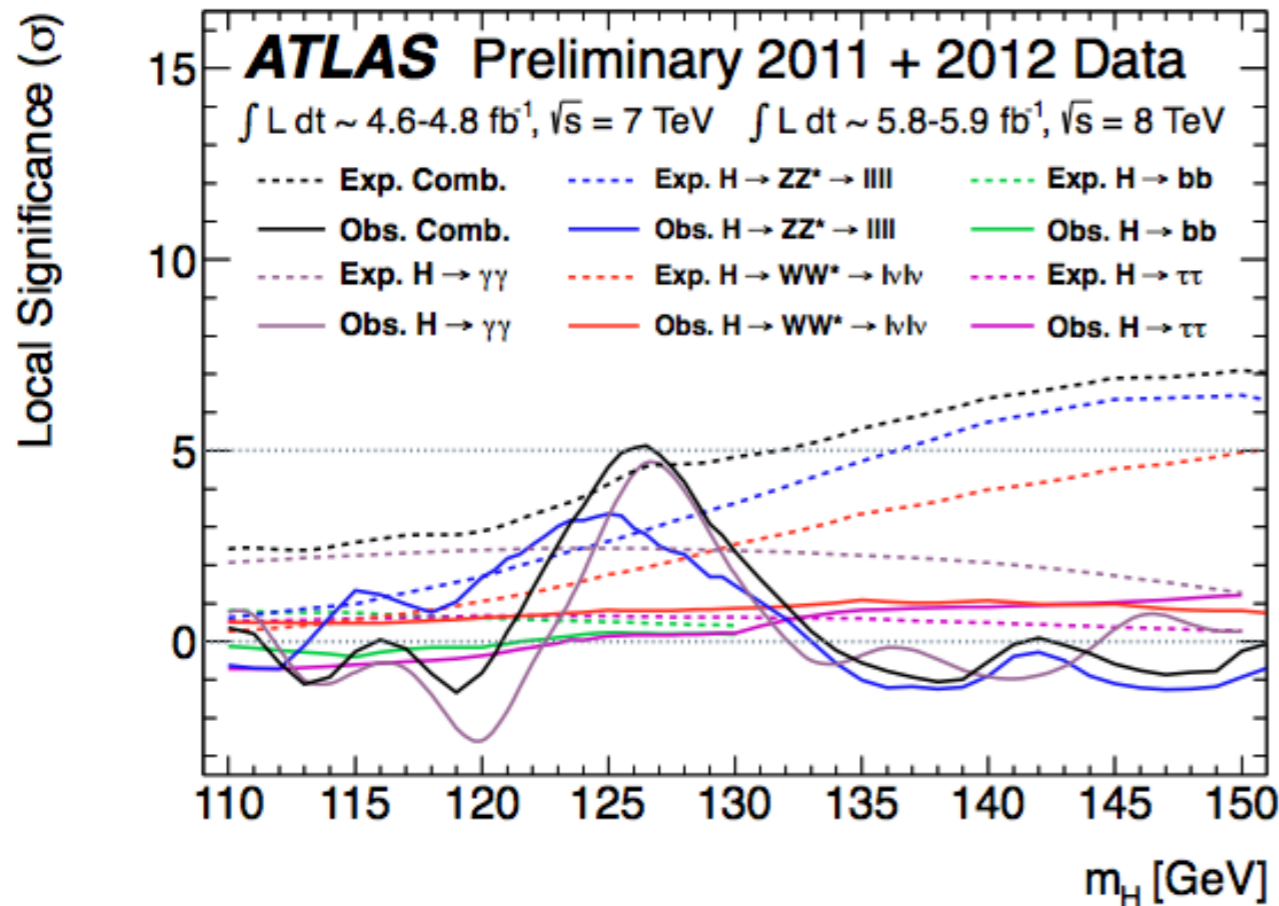
## Exclusion of a SM Higgs boson



The full range up to 500+ GeV is excluded by ATLAS and CMS, except for the window near 125 GeV

# SM Higgs?

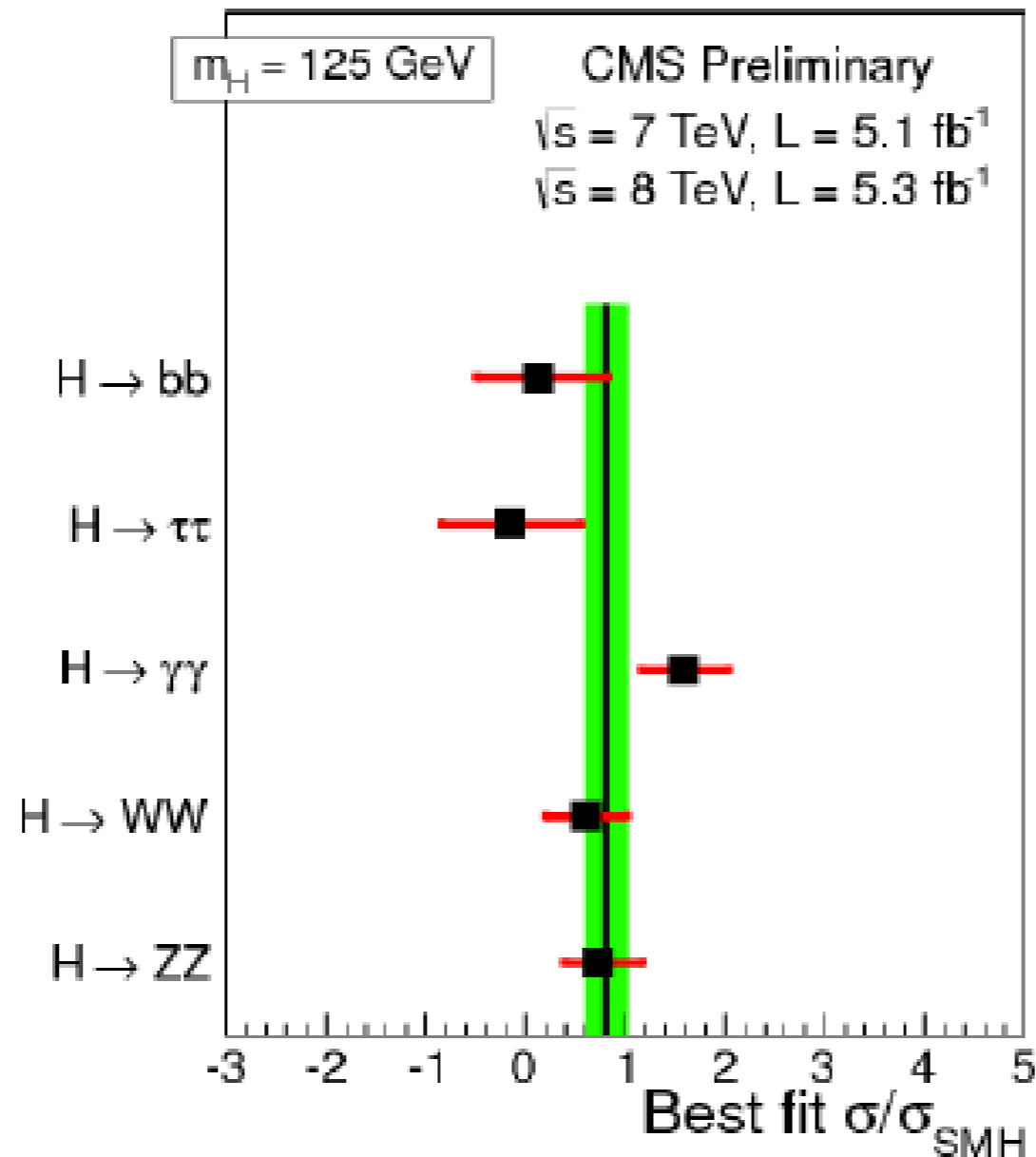
**Higgs-like particle OBSERVED** near 125 – 126 GeV at 5 sigma significance – same mass in two experiments; same at 7 and 8 TeV; same mass in 2011 and 2012 data, ...



# SM Higgs?

- **Era of exclusion is over.** There is now a signal in a very interesting range of masses where several decay channels are open: vectors:  $\gamma\gamma$ ,  $ZZ$ ,  $WW$ , and fermions:  $b\bar{b}$ ,  $\tau\tau$
- It could be the SM Higgs (that serves both as the mechanism of EWSB AND the agent of fermion mass generation), or a two-Higgs doublet; or a SUSY Higgs (decoupling limit), ...
- Theorists have a new sense of direction; also mass scale established for new facilities (ILC, CLIC, ...)
- Focus has changed to identification of the properties of the signal; measure spin and parity using angular distributions in  $ZZ$ ,  $WW$ , and  $\gamma\gamma$ ; measurement of branching fractions is critical –

May be tantalizing hints of deviations in branching fractions, but some low (fermions) and some high (gamma gamma) could also be temporary – stay tuned



# SUSY?

- What is beyond the Higgs boson?
- BSMs: extra Z-primes, extra W-primes; extra dimensions; supersymmetry; ....
- SUSY is well motivated – unification of couplings; dark matter candidate (if R parity is good); stabilize Higgs scalar mass; .... However, **BROKEN SYMMETRY**
- Many searches but no direct evidence at 7 TeV or at 8 TeV yet for SUSY at level of 5 inverse fb (Nakahama, Gesce, Paramesvaran). Limits are model dependent.
- BUT, a Higgs-like boson exists at 125 – 126 GeV!!!
- Higgs boson mass is an important guide for the future of SUSY – strong constraint --- the generation of SUSY mass spectra by evolution from some high mass scale to the real world, has to get the right Higgs boson mass

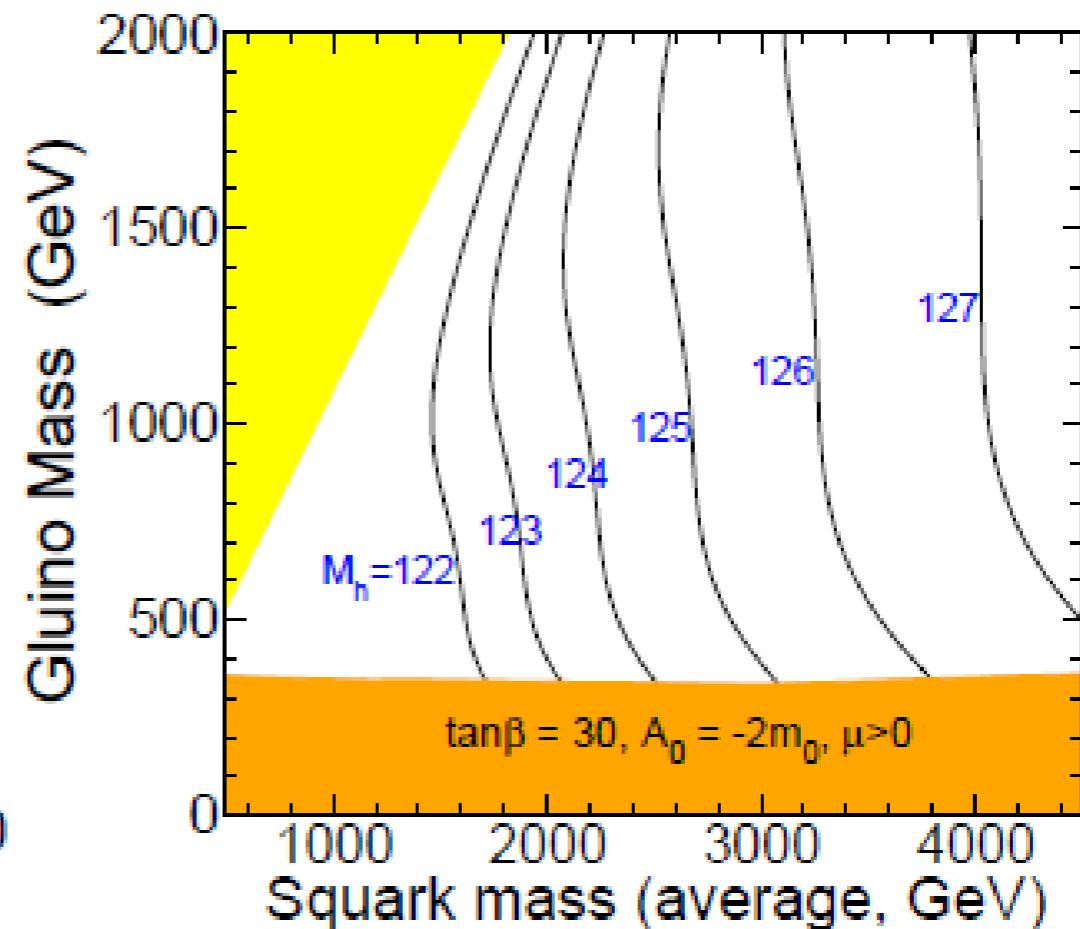
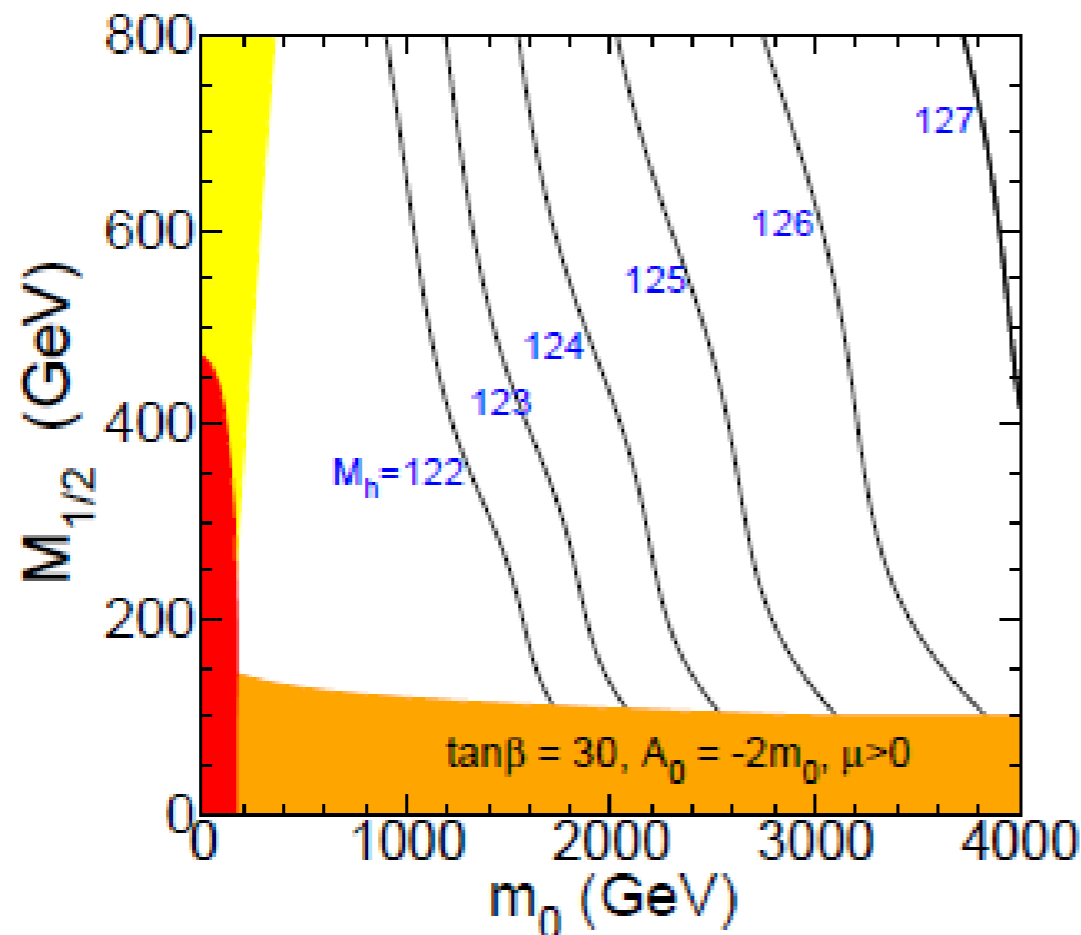
# SUSY?

- Ways to accommodate Higgs mass near 125 – 126 GeV (c.f. Hyung D Kim, here)
  - Larger stop mixing (for example, in mSUGRA,  $A_0 = -2m_0$  rather than  $A_0 = 0$ .)
  - NMSSM: add a singlet, increases Higgs quartic coupling
  - Extra vector-like quarks increase  $M_h$

# SUSY?

Slide borrowed from Steve Martin

$M_h$  in mSUGRA with  $\tan\beta = 30$  and  $A_0 = -2m_0$ :



Features:

- $122 < M_h < 128$  (taking into account experimental and theoretical uncertainties) compatible with **any** gluino mass.
- Average squark mass as light as 1500 GeV; stops much lighter



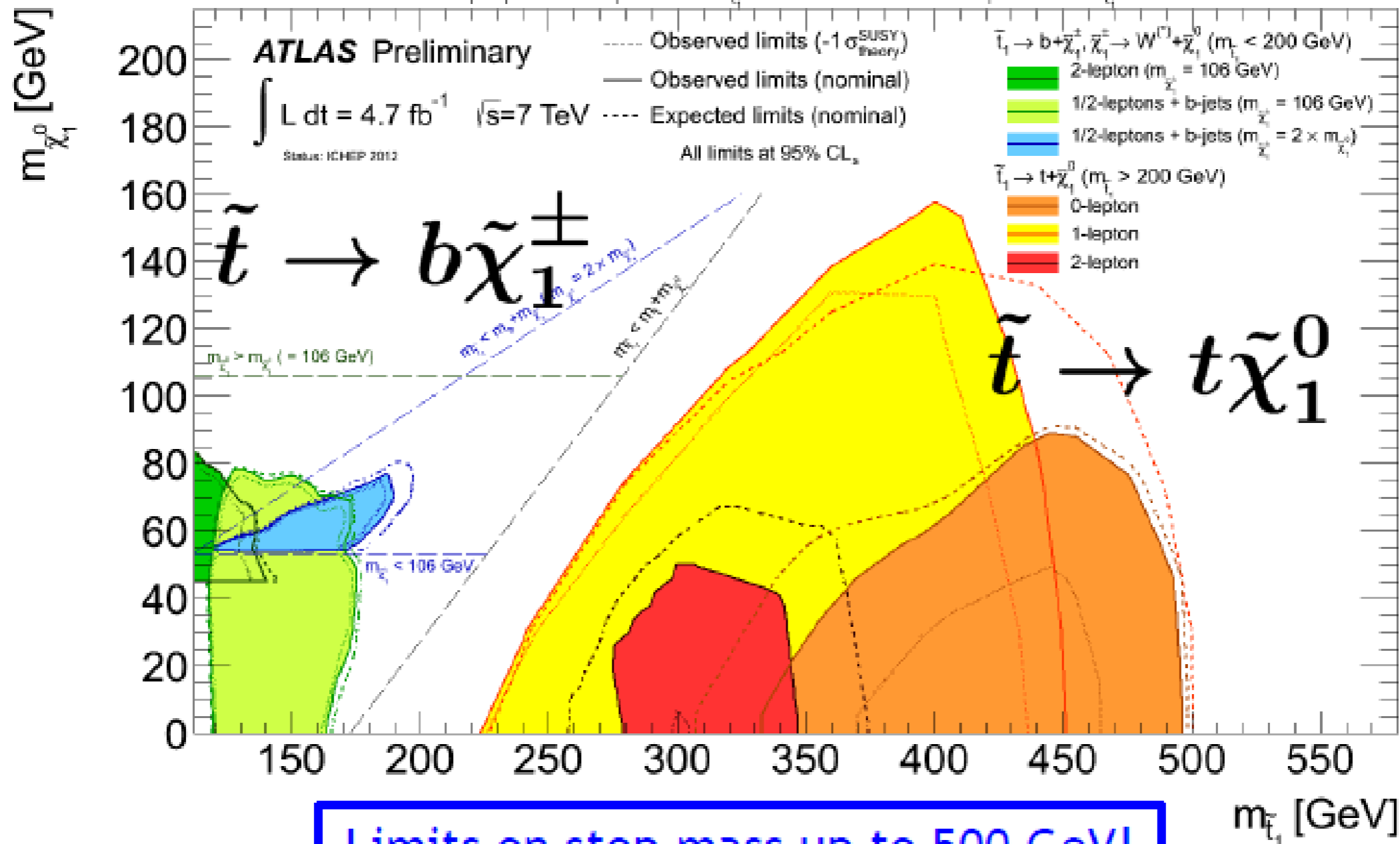
# SUSY?

- Ways to accommodate Higgs mass near 125 – 126 GeV; light top squark
  - From the hierarchy problem point of view, the scalar top should not be too heavy in order to cancel a large loop contribution from SM top. Strong reason to search for scalar top (stop) in dedicated searches!
  - The search strategy varies depending on its mass
    - Heavy stop [ $>m(\text{top})$ ]  
Signal:  $\tilde{t}\tilde{t} \rightarrow (t\tilde{\chi}_1^0)(t\tilde{\chi}_1^0)$   
Leptonic or hadronic top decays with extra MET
    - Light stop [ $<m(\text{top})$ ]:  
Signal: Top like decays via chargino.  
 $\tilde{t}\tilde{t} \rightarrow (b\tilde{\chi}_1^\pm)(b\tilde{\chi}_1^\pm) \rightarrow (bW^{(*)}\tilde{\chi}_1^0)(bW^{(*)}\tilde{\chi}_1^0)$   
Low  $p_T$  leptons, and subsystem mass below  $2m(\text{top})$

# SUSY?

## Search for light top squarks – ATLAS results so far

$\tilde{t}_1, \tilde{t}_1$  production:  $\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^{(\prime)} + \tilde{\chi}_1^0$  (BR=1,  $m_{\tilde{t}_1} < 200$  GeV);  $\tilde{t}_1 \rightarrow t + \tilde{\chi}_1^0$  (BR=1,  $m_{\tilde{t}_1} > 200$  GeV)



Limits on stop mass up to 500 GeV!  
 (Strongly depend on LSP mass)

# L'Envoi sur SUSY

- \*Exclusions establish lower limits within the context of models of SUSY breaking
- \*Would like to abstract from all these studies some SUSY mass scale – how high is it?
- \*We are still in the “exclusion” mode – just as we were for the Higgs boson one year ago. SUSY is harder – not as one-dimensional
- \*Phenomenology: not sure the Higgs mass value has been fully digested in SUSY breaking models – mass spectra, branching fractions, cross sections, decay chains, expected signals, search strategies, ....
- \* **Come back in 2013 – one BSM or another, and maybe even SUSY**

# Appreciation

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Want to express heartfelt appreciation for all the efforts by **Marc Besancon** in the organization of the scientific program.

Quiet, self-effacing dedication. Great equanimity in the face of last minute changes.

Felicitations, Marc!