Supersymmetry without a light higgs boson at the LHC

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Outline

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   - Motivation
   - A supersymmetric heavy higgs(?)
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3. **heavy higgs**
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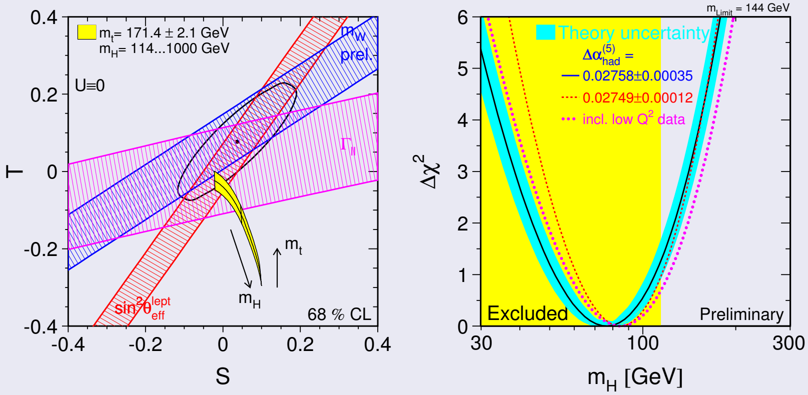
   - Decay
   - λSUSY vs SM
5. **conclusions**

Higgs particle is missing and indirect information about its mass can be obtained under some prior using precision data and, assuming new physics doesn't affect S and T, m_h can be bounded: $76^{+33}_{-24} GeV$



SuSy effect can be quite mild in this analysis, leaving SM results almost untouched, but in this case the lightest CP-even scalar can't be much heavier than m_Z.

What if Nature is supersymmetric and the higgs is heavy?

λSuSy

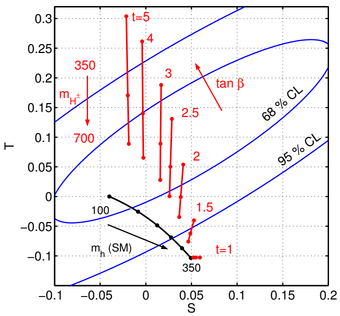
$$W = \lambda S H_u \cdot H_d + W_{MSSM}$$

λ is not bound by unification* but only by calculability of EWPO $\Rightarrow m_h \gg m_h^{MSSM}$

- $\lambda = 2 \Rightarrow m_h \simeq 250 GeV$
- $1.5 \leq \tan\beta \leq 3 \Rightarrow prod. \sim SM$

$$350 GeV \leq m_{H^+} \leq 700 GeV$$

Barbieri Hall Nomura Rychkov hep-ph/0607332



no corrections from heavy $\tilde{t} \Rightarrow$ fully natural

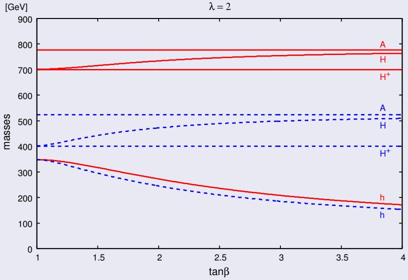
*a unification compatible UV completion exists

$$W = \mu(S) H_1 \cdot H_2 + f(S)$$

$$V = \Sigma_i \mu_i(S) \left|H_i\right|^2 - \mu_3^2(S)\left(H_1 H_2 + h.c.\right) + \lambda^2 \left|H_1 \cdot H_2\right|^2 + V(S) + small$$

We assume the singlet is heavy $\sim 1 TeV$ and nearly not mixed with the other scalars (little correction in any case)

Natural Spectrum



- $m_h > 2m_W$ is natural
- masses are function of only λ, m_{H^+} and $\tan\beta$
- $m_h < m_{H^\pm} < m_H < m_A$

Phenomenology

$\tilde{g}$ and $\tilde{t}$

Naturalness bounds (with 20% FT):

$$m_{\tilde{t}} \lesssim 600 - 800 GeV$$

$$m_{\tilde{g}} \lesssim 1.2 - 1.6 TeV$$

while we can take all other $\tilde{q}, \tilde{l}$ and gaugino to be heavier.

Standard searches for decay chains with jets,leptons and $\not{E}_T$ apply and these particle are detectable with $10 fb^{-1}$ or less.

DM

The lightest neutralino benefits of singlino-higgsino mixing and can be a DM with $m_{\chi_0} \simeq 100 - 200 GeV$

light higgs

Properties

- $m_h \sim 200 - 300 GeV$
- $\Gamma_h \sim 2 - 8 GeV$
- $g_{HVV} \simeq g_{HVV}^{SM}$
- $g_{Htt} \simeq g_{Htt}^{SM}$

$h \to ZZ \to 4l$

- SM studies apply. Mass and width can be measured.
- Precision is not enough to discriminate between SM and λSUSY higgs.

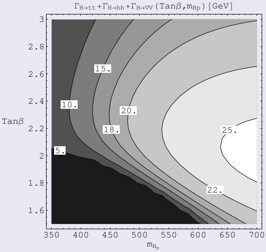
Puzzling Supersymmetry?

This higgs boson is at odds with MSSM, but hints of SUSY from $\tilde{g}$ and $\tilde{t}$ are there. Could be a puzzle, but in λSUSY this is natural.

Heavy Higgs

$$m_H \simeq 400 - 800 GeV$$

$$\Gamma_H \sim few - 20 GeV$$



mostly due to:

- $H \rightarrow hh$ (gray areas)
- $H \rightarrow VV$ (black area)

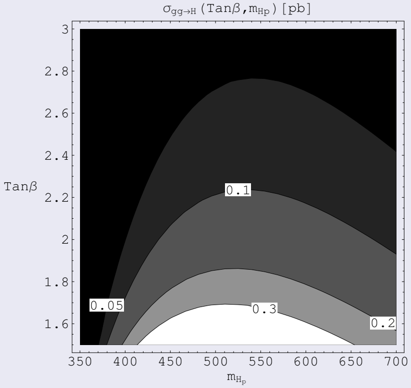
Production is suppressed because

- $g_{HVV} \simeq 0.1 - 0.3 \cdot g^{SM}_{HVV}$
- $g_{Htt} \simeq 0.1 - 0.5 \cdot g^{SM}_{Htt}$

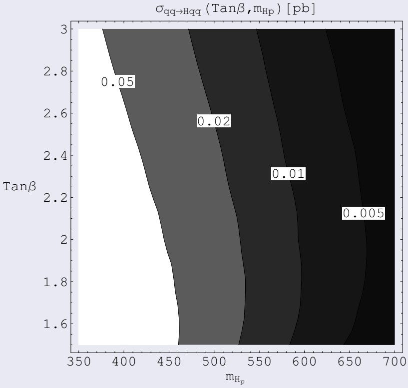
Decay $H \rightarrow hh$ is very natural in λSUSY

Cross Section (HIGLU,VV2H)

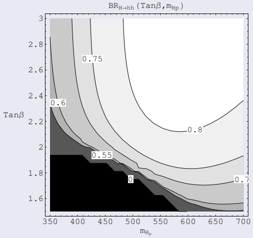
$\sigma_{GF} \simeq 50fb - 300fb$



$\sigma_{VBF} \simeq 5fb - 100fb$

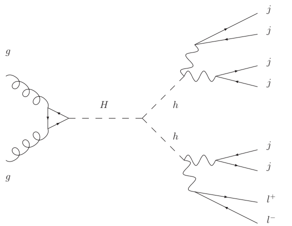


BR($H \to hh$)$\simeq 0.55 - 0.8$



- Can use we use $H \to hh$ to discover H?
- $H \to VV$ otherwise

$H \to hh \to 2Z2V \to 6jl^+l^-$



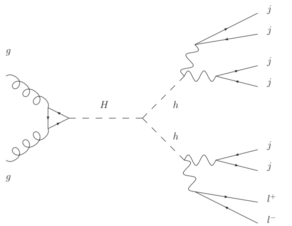
MADGRAPH

Benchmark scenario:
$\tan\beta = 2\ m_{H^\pm} = 500GeV$

$$\sigma_H^{GF} \times BR = 2.4fb$$

$$m_H = 555GeV, \quad \Gamma_H = 21GeV$$

$$m_h = 250GeV, \quad \Gamma_h = 3.8GeV$$



PARTONIC LEVEL

We assume at this time m_h has been measured

Invariant mass requirements

- 2 jets reconstruct a vector if m_{jj} is in $m_V \pm 8GeV$
- 4 fermions reconstruct a higgs if m_{4f} is in $m_h \pm 33GeV$

Event selection

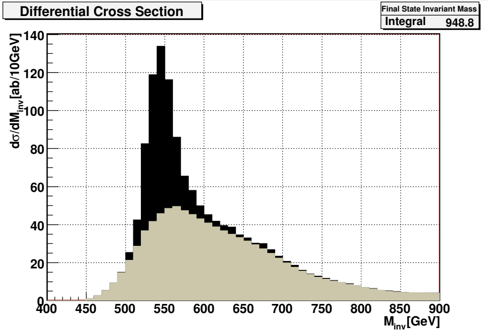
- $\Delta R_{jj} > 0.7$ $p_T^j > 20GeV$
- $\Delta R_{lj} > 0.1$ $p_T^l > 10GeV$
- $\eta_{e,l} < 2.5$
- $80GeV < m_{ll} < 100GeV$

... go through all combinations and ...

Relevant backgrounds

- $Z6j$: $1pb \rightarrow 0.9fb$ (AlpGen)
- $t\bar{t}Z$: $6fb \rightarrow 0.15fb$ (Madgraph)

S+BG vs BG



- Smearing of jets 4-vectors using $\frac{0.5}{\sqrt{E}} + 0.03$ to generate the smearing
- Flavour tagging is not relevant

BG norm. is conservative

PS and HAD are not taken into account

- BG peaks close to signal peak
- Extraction of BG from data could be not simple

$100fb^{-1} \Rightarrow 6.0\sigma$

- Local event excess is very clear
- $g_{Hhh} \sim \lambda^2 \Rightarrow \lambda SUSY$

Pseudoscalar

A

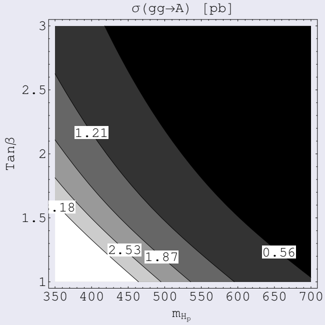
$$m_A = 500GeV - 800GeV$$

$$\Gamma_A \sim 10GeV$$

$$BR(A \to t\bar{t}) = 0.5 - 0.9$$

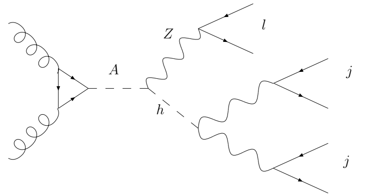
$$BR(A \to hZ) = 0.07 - 0.4$$

Cross Section (HIGLU)



- σ is few pb :-)
- BR is subdominant :-(

$A \to hZ \to ZVV \to 4jl^+l^-$



PARTONIC LEVEL

BS: $\tan\beta = 2$ $m_{H^\pm} = 500GeV$

$$\sigma_A^{GF} \times BR = 5.5fb$$

$$m_A = 615GeV, \quad \Gamma_A = 11GeV$$

$$m_h = 250GeV, \quad \Gamma_h = 3.8GeV$$

Event Selection

- $\Delta R_{jj} > 0.4$ $p_T^j > 20GeV$
- $\Delta R_{lj} > 0.4$ $p_T^l > 10GeV$
- $\eta_{j,l} < 2.5$
- $80GeV < m_{ll} < 100GeV$

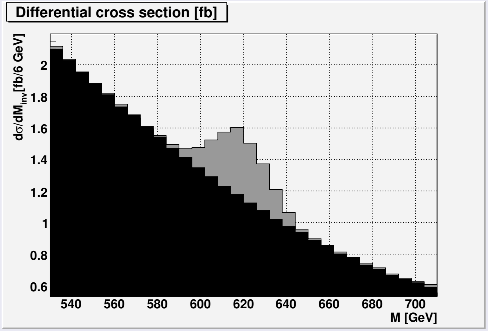
Invariant mass requirements

Same strategy as for H but now $\delta_{m_h} = 18GeV$

Relevant backgrounds

- $Z4j$ (AlpGen)
- $ZW2j$ (AlpGen)

S+BG vs BG



- Smearing of jets 4-vectors using $\frac{0.5}{\sqrt{E}} + 0.03$ to generate the smearing
- Flavour tagging is not relevant

PS and HAD are not taken into account.

$100fb^{-1} \Rightarrow 6.2\sigma$

- Local event excess is very clear
- Peak is very clear
- **A fit of the BG from data seems feasible**

Conclusions

SUSY can be out there even with a heavy higgs

m_h will discriminate between MSSM-like and λSUSY-like

$$A \to hZ \to 2VZ \to 4jl^+l^-$$

and

$$H \to hh \to 4V \to 6jl^+l^-$$

have been studied as possible signature of λSUSY (large g_{Hhh} is very peculiar)

$\tilde{g}, \tilde{t}$ and LSP pheno still available

A and H observable at the LHC in high multiplicity final state

- $100 fb^{-1}$ could be enough to observe A and H
- a large Hhh coupling is natural in λSUSY

$m_h, m_H, m_A \Rightarrow \tan\beta, m_{H^\pm}, \lambda$

- λ allows to estimate the NP scale
- A fourth measuremt like $m_{H^\pm}$ or other decays would be **a test for the theory**