Heavy Higgs from the LHC and LC Precision Data

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based on collaboration with
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1. Introduction
2. The Higgs and scalar top sector
3. Distinguish soft SUSY-breaking scenarios
4. Determination of high energy parameters
5. Conclusions

1. Introduction

What can the LHC measure that is not accessible at the LC ?

What can the LC measure that is not accessible at the LHC ?

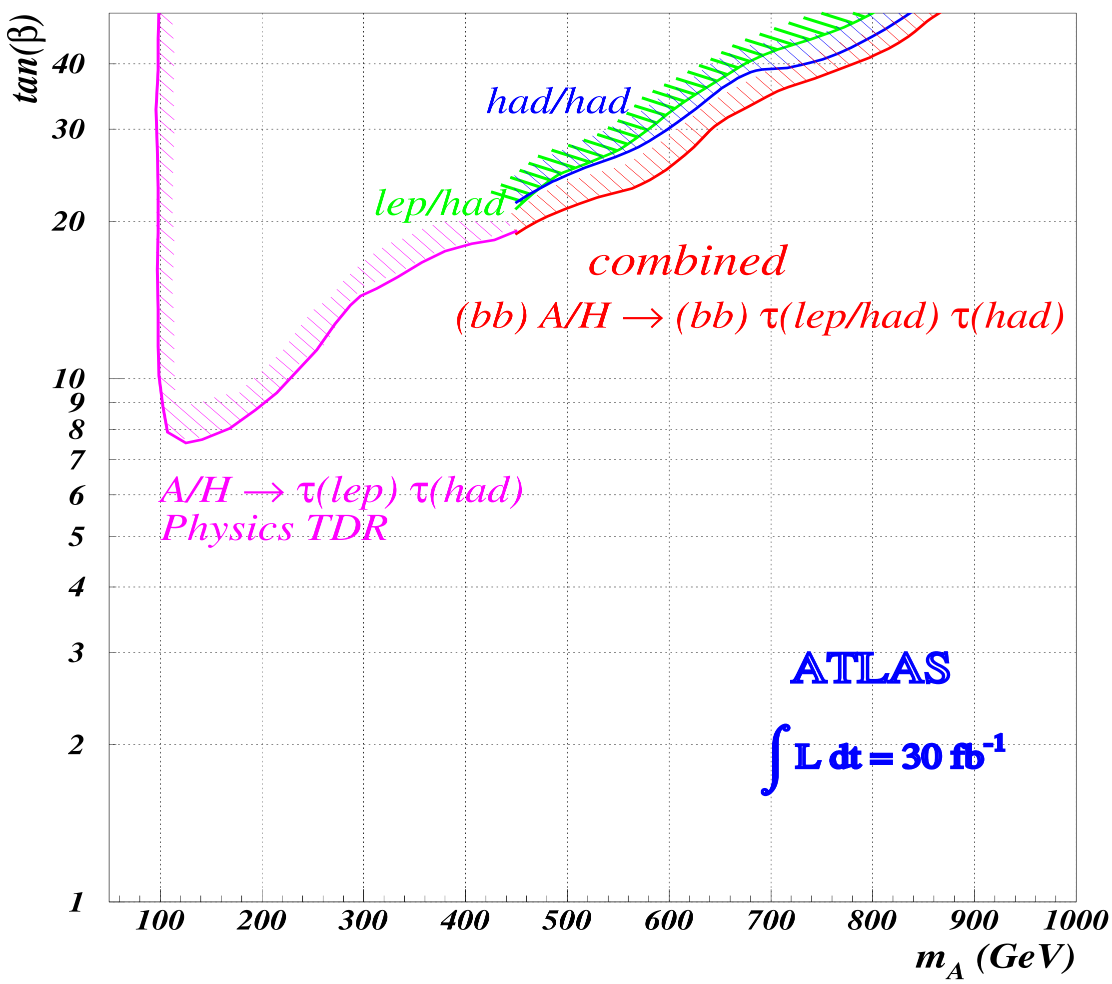
LHC:

– mass of heavy MSSM Higgs bosons,
  M_A, M_H ($M_A, M_H \gtrsim$ 500 GeV)
– $\tan\beta$ (if large) $\rightarrow$ T
– $m_{\tilde{t}}, m_{\tilde{b}}$ ($\Delta m_{\tilde{f}} \lesssim$ 10%)
  (mixing angle ??)

LC:

– $\Delta m_t = 100$ MeV
  necessary to reduce $\Delta m_h^{\text{theo}} \sim \Delta m_t$
  $\Rightarrow$ $\Delta m_h^{\text{theo}} \approx 0.5$ GeV possible
– $\Delta m_h^{\text{exp}} = 0.05$ GeV negligible
– BR($h \to XX$) , ΔBR $= \mathcal{O}$(few %)

[D. Cavalli et al., Les Houches, Higgs working group '02]



$$b\bar{b} \;\to\; b\bar{b}\; H/A \;\to\; b\bar{b}\,\tau^+\tau^-$$

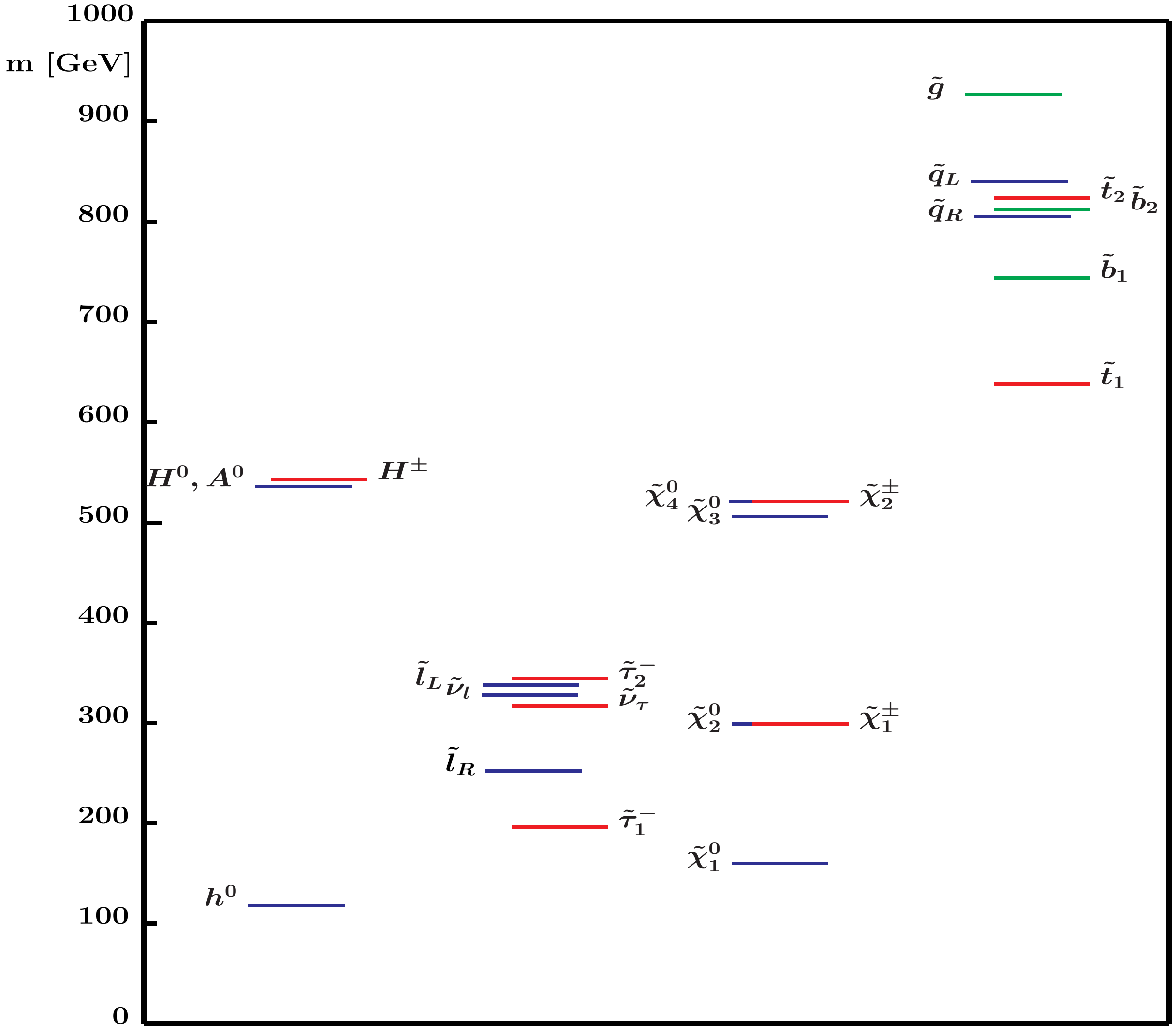
$\Rightarrow$ M_A, M_H and $\tan\beta$ measurable
for $M_A, M_A \gtrsim 500$ GeV and $\tan\beta \gtrsim 20$.

Probably better reach for full Lumi and both detectors.

$\Rightarrow$ $\Delta M_A, M_H \approx 2\%$
$\Delta \tan\beta \approx 15\%$ (??)

2. The Higgs and scalar top sector

Model assumption: SPS 1b



typical mSUGRA point (large $\tan\beta$, $\tan\beta = 30$)

– M_A, M_H, $\tan\beta$ accessible at LHC

– $m_{\tilde{t}}, m_{\tilde{b}}$ accessible at LHC

– h accessible at LHC and LC

Scan over MSSM parameter space:

(*FeynHiggs*)

$$25.5 < \tan\beta < 34.5$$
$$200 \text{ GeV} < M_A < 1000 \text{ GeV}$$
$$400 \text{ GeV} < m_{\tilde{t}_1}, m_{\tilde{t}_2}, m_{\tilde{b}_1}, m_{\tilde{b}_2} < 2000 \text{ GeV}$$
$$\tilde{t}/\tilde{b} \text{ mixing free } (M_{\tilde{t}_L} = M_{\tilde{b}_L} \pm 10\%)$$
$$170 \text{ GeV} < m_t < 180 \text{ GeV}$$
$$M_2 = 310 \text{ GeV}, \ \mu = 500 \text{ GeV}$$

$\tilde{t}$ mass matrix:

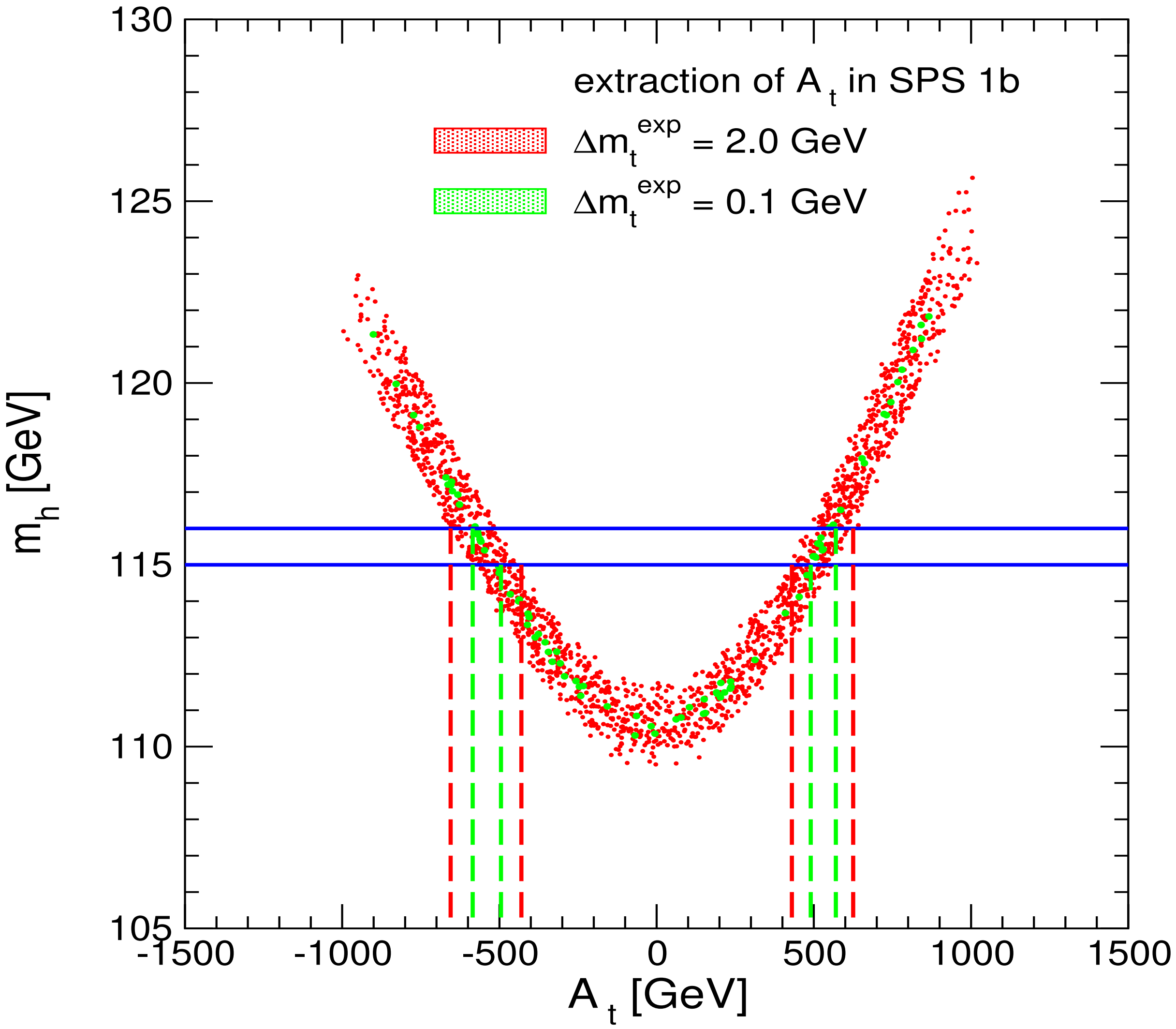
$$\begin{pmatrix} M_{\tilde{t}_L}^2 + m_t^2 & m_t X_t \\ m_t X_t & M_{\tilde{t}_R}^2 + m_t^2 \end{pmatrix} \overset{\theta_{\tilde{t}}}{\longleftrightarrow} \begin{pmatrix} m_{\tilde{t}_1}^2 & 0 \\ 0 & m_{\tilde{t}_2}^2 \end{pmatrix}$$

$m_{\tilde{t}_1}, m_{\tilde{t}_2}$ known, mixing free/$\theta_{\tilde{t}}$ free

$\Rightarrow X_t \ = \ A_t - \mu/\tan\beta$ unknown/not measurable

$\quad \rightarrow |A_t|$ and sign(A_t)

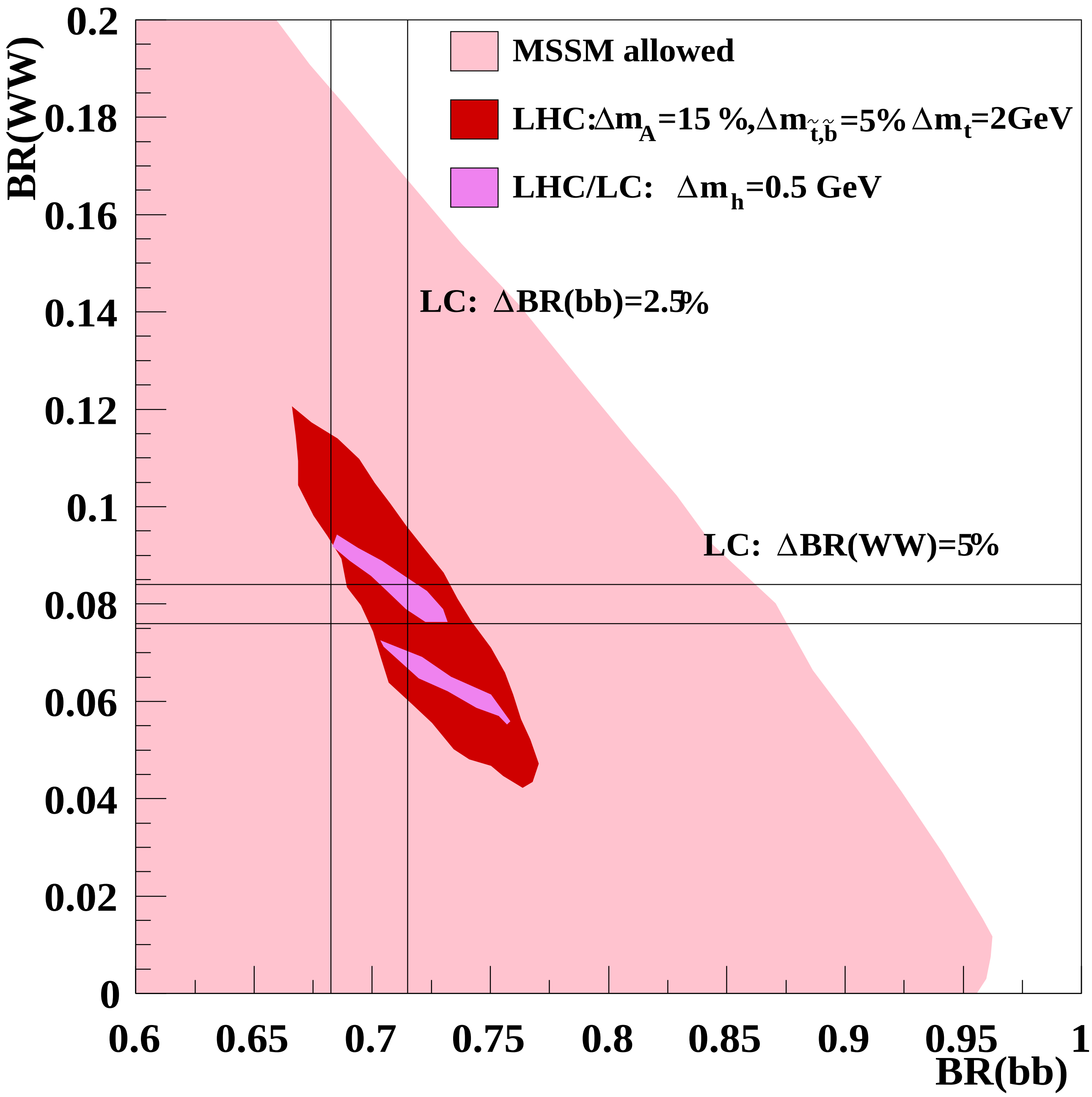
Combine m_h, m_t (LC) and $m_{\tilde{t}}, m_{\tilde{b}}$ (LHC) :



$\Rightarrow$ $|A_t|$ indirectly measurable

(sign unclear)

Use BR($h \to b\bar{b}$), BR($h \to WW^*$):



$\Rightarrow$ Highly sensitive test of theory

$\Rightarrow$ sign(A_t) determined

3. Distinguish soft SUSY-breaking scenarios

Most prominent soft SUSY-breaking scenarios:

- mSUGRA
  minimal SUper GRAvity inspired SUSY break.

- GMSB
  Gauge Mediated Susy Breaking

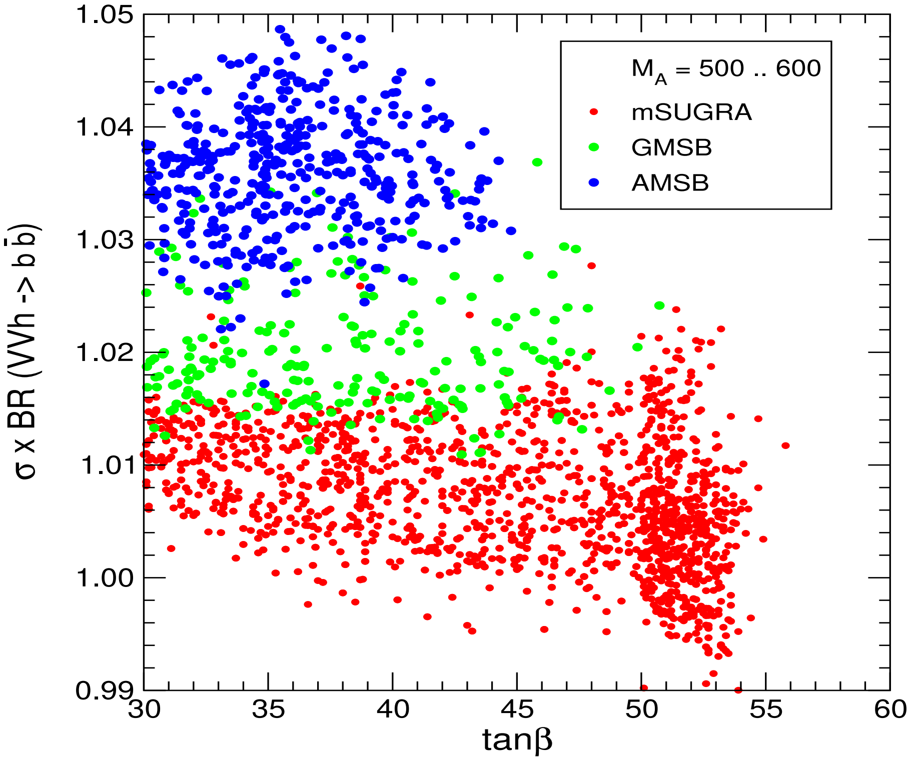
- AMSB
  Anomaly Mediated Susy Breaking

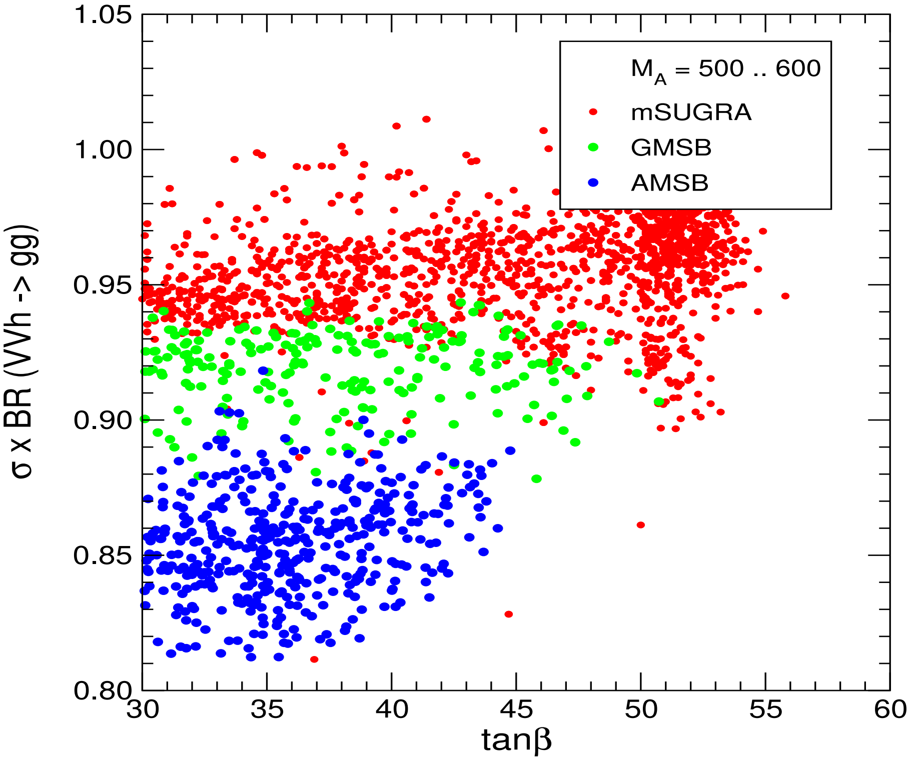
LHC:

– M_A, M_H (500 GeV $< M_A, M_H <$ 600 GeV)
– $\tan\beta$ ($\tan\beta > 30$)

LC:

– BR$(h \to b\bar{b})$, ΔBR $= 1.5\%$
– BR$(h \to gg)$, ΔBR $= 4.0\%$





$\Rightarrow$ distinction between soft SUSY-breaking scenarios possible at the 1-2σ level

(better with more channels . . .)

4. Determination of high energy parameters

mSUGRA:

$$\{m_0, m_{1/2}, A_0\}$$

AMSB:

$$\{m_0, m_{\text{aux}}\}$$

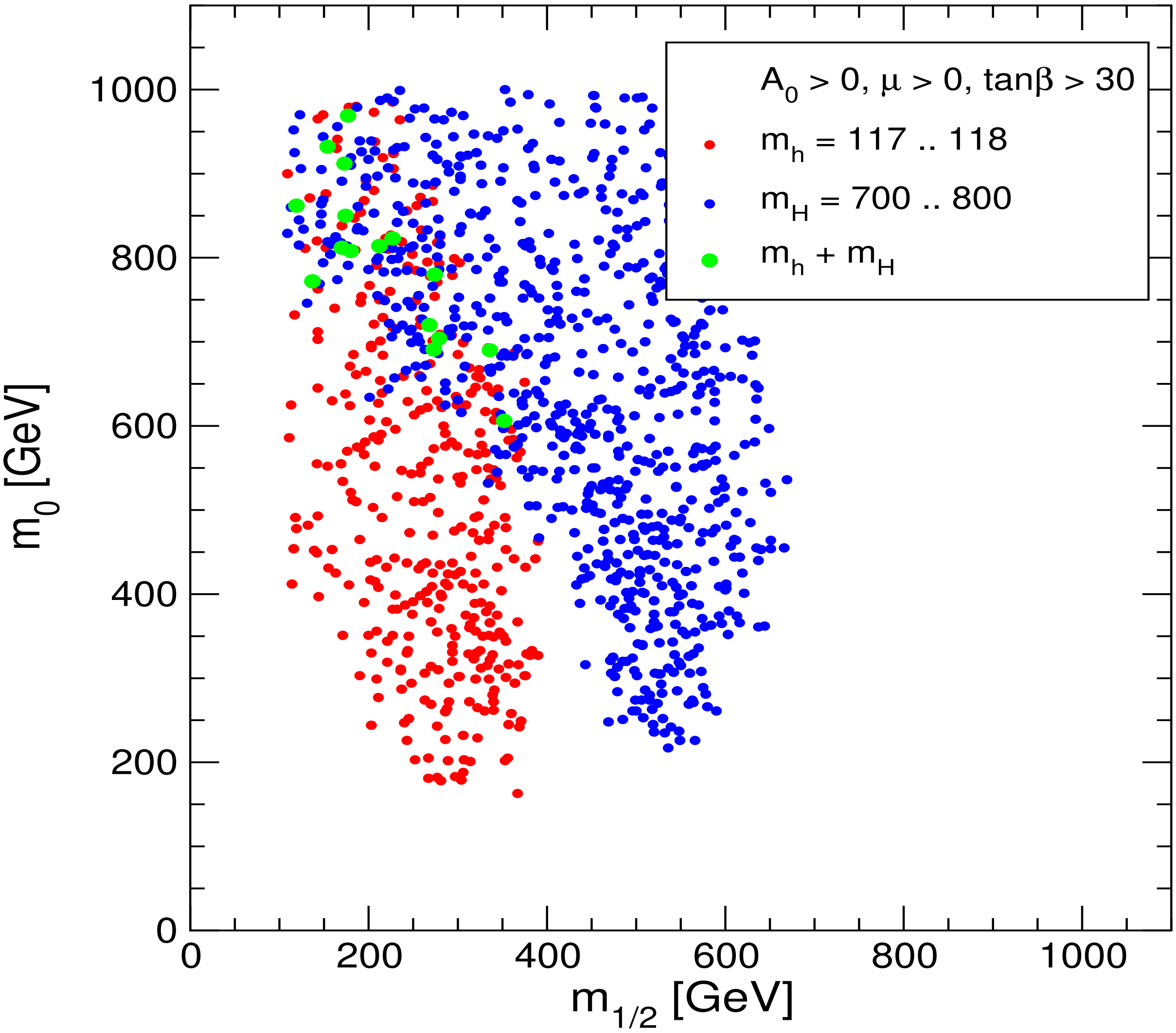
LHC:

- M_A, M_H (700 GeV $< M_A, M_H <$ 800 GeV)
- $\tan\beta$ ($\tan\beta > 30$)

LC:

- $\Delta m_t = 100$ MeV
  necessary to reduce $\Delta m_h^{\text{theo}} \sim \Delta m_t$
  $\Rightarrow \Delta m_h^{\text{theo}} \approx 0.5$ GeV possible
- 117 GeV $< m_h <$ 118 GeV

mSUGRA:



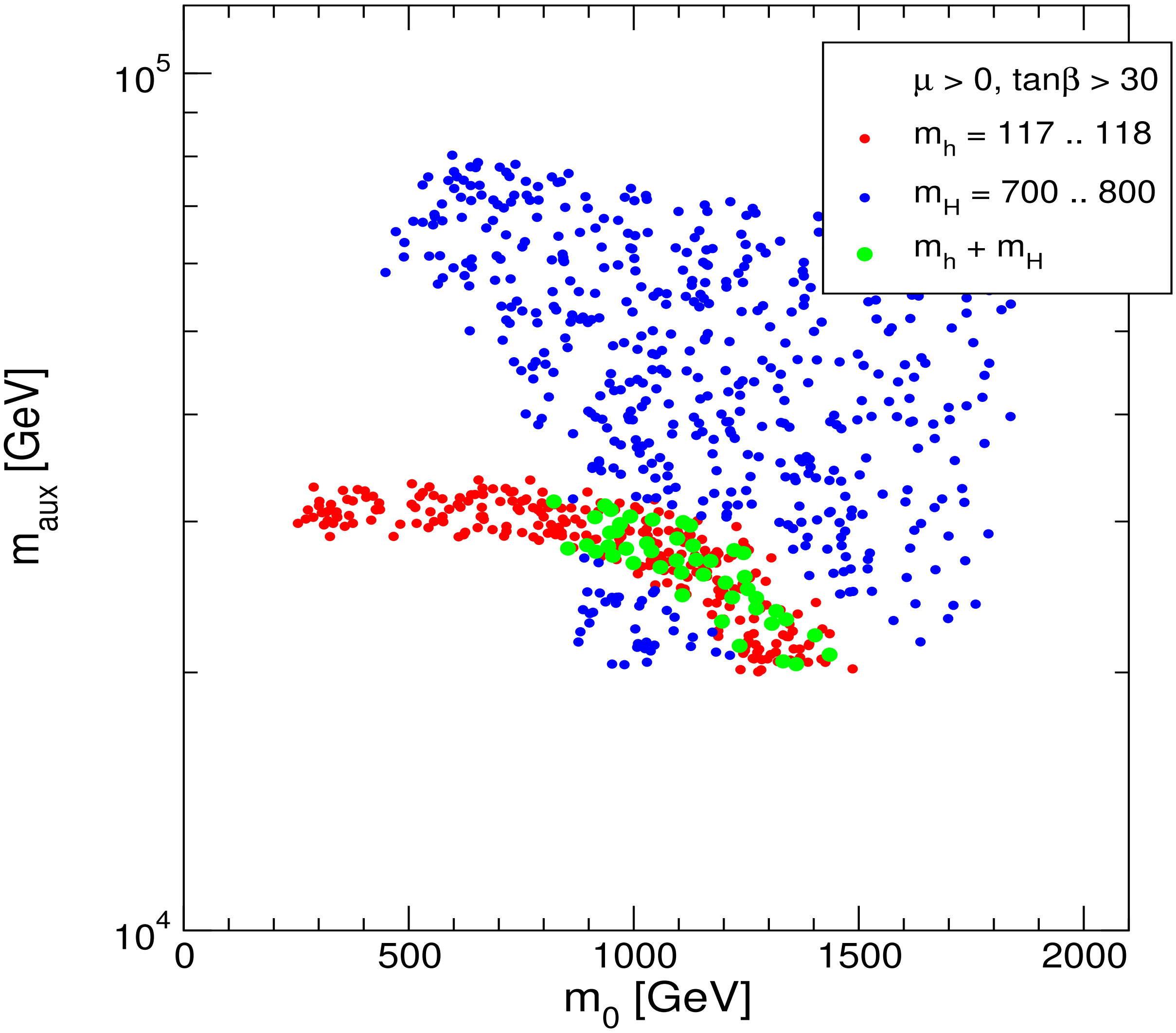
$\Rightarrow$ 150 GeV $\lesssim m_{1/2} \lesssim$ 400

$\Rightarrow$ 600 GeV $\lesssim m_0 \lesssim$ 1000

Determination from Higgs sector alone

$\Rightarrow$ complementary to other methods

AMSB:



$\Rightarrow$ 800 GeV $\lesssim m_0 \lesssim$ 1400

$\Rightarrow$ $2 \cdot 10^4$ GeV $\lesssim m_{\rm aux} \lesssim 3 \cdot 10^4$

Determination from Higgs sector alone

$\Rightarrow$ complementary to other methods

5. Conclusinos

- Assumptions:

  LHC: $M_A, M_H, \tan\beta$

  LC: $\Delta m_t = 100$ MeV $\Rightarrow \Delta m_h \lesssim 0.5$ GeV
  (incl. theory error)
  BR$(h \to XX)$

- Analysis in SPS1b :
  - Determination of $|A_t|$
  - Determination of sign(A_t)
  - Highly sensitive test of MSSM

- Distinction between mSUGRA, GMSB, AMSB possible via BR measurements

- Determination of high energy parameters possible in mSUGRA, AMSB

  $\to$ from Higgs sector alone

  $\Rightarrow$ complementarity to other methods

- Much work remains to be done !!!