# Split Sfermions and the Higgs

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based on:
MB, E. Dudas, M. Olechowski, S. Pokorski, arXiv:1205.1675

# Motivations for Split Sfermion Masses

In the Inverted Hierarchy (IH) scenario, with the first two generations of squarks and sleptons much heavier than the third one, the tension with FCNC constraints is relaxed, without harm for "Natural SUSY".

The LHC SUSY searches pushed up the masses of the 1st generation squarks above 1 TeV.

Stops and sbottoms (which should be light in "Natural SUSY") remains very weakly constrained.

"Natural SUSY" is still viable but only for split sfermion masses.

*e.g. Krippendorf et al. '12*

In fermion mass models based on horizontal symmetries, IH of sfermion masses is linked to the hierarchical fermion masses.

*Dudas et al. '95 '96*
*...*
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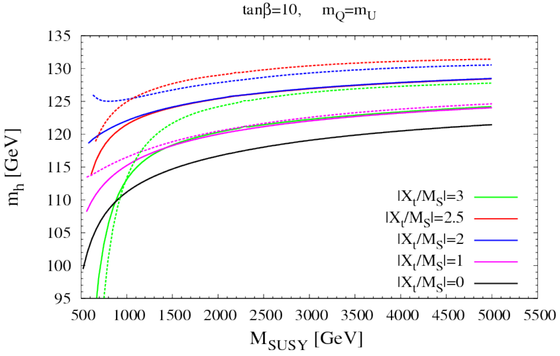
In this talk:

In the IH scenario, large stop-mixing is naturally obtained due to 2-loop RG effects of heavy 1st/2nd generation and the lightest MSSM Higgs is generically heavy

*MB, Dudas, Olechowski, Pokorski, arXiv:1205.1675*

At one loop:

$$m_h^2 \approx M_Z^2 \cos^2 2\beta + \frac{3g^2 m_t^4}{8\pi^2 m_W^2}\left[\ln\left(\frac{M_{\rm SUSY}^2}{m_t^2}\right) + \frac{X_t^2}{M_{\rm SUSY}^2}\left(1 - \frac{X_t^2}{12 M_{\rm SUSY}^2}\right)\right]$$




$M_{\rm SUSY} \equiv \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$

$X_t \equiv A_t - \mu/\tan\beta$

$X_t < 0$ solid lines

$X_t > 0$ dashed lines

The Higgs mass of $\sim 125$ GeV requires:

- Large stop-mixing $|X_t|/M_{\rm SUSY} \sim \mathcal{O}(2-2.5)$ & $M_{\rm SUSY} \gtrsim 1$ TeV

# Maximal stop-mixing from RGEs

At one-loop RGEs:

$$m_Q^2 \approx 3.1M_{1/2}^2 + 0.1A_0M_{1/2} - 0.04A_0^2 + 0.65m_0(3)^2$$
$$m_U^2 \approx 2.3M_{1/2}^2 + 0.2A_0M_{1/2} - 0.07A_0^2 + 0.35m_0(3)^2$$
$$A_t \approx -1.6M_{1/2} + 0.35A_0$$

- Low scale $A_t$ only weakly depends on the GUT scale $A_0$.
- Gluino contribution enhances $A_t$ but also the stop masses.
- Stop-mixing is typically small: $|A_t/M_{\rm SUSY}| \lesssim 1$

## Maximal stop-mixing requires very large $A_0$

e.g. $A_0 \approx -4M_{1/2}$ if $M_{1/2} \approx m_0(3)$

# Maximal stop-mixing from RGEs

At two-loop RGEs:

$$m_Q^2 \approx 3.1M_{1/2}^2 + 0.1A_0M_{1/2} - 0.04A_0^2 + 0.65m_0(3)^2 - 0.03m_0(1,2)^2$$
$$m_U^2 \approx 2.3M_{1/2}^2 + 0.2A_0M_{1/2} - 0.07A_0^2 + 0.35m_0(3)^2 - 0.02m_0(1,2)^2$$
$$A_t \approx -1.6M_{1/2} + 0.35A_0$$

In the IH scenario, $m_0(1,2) \gg m_0(3)$, RG running of $A_t$ can be decoupled from the running of stop masses.

- $A_t$ can be enhanced by gluino contribution without enhancing the stop masses due to the negative contribution from $m_0(1,2)$

**No large initial values of $A_0$ required for maximal stop-mixing**

# Constraints from REWSB

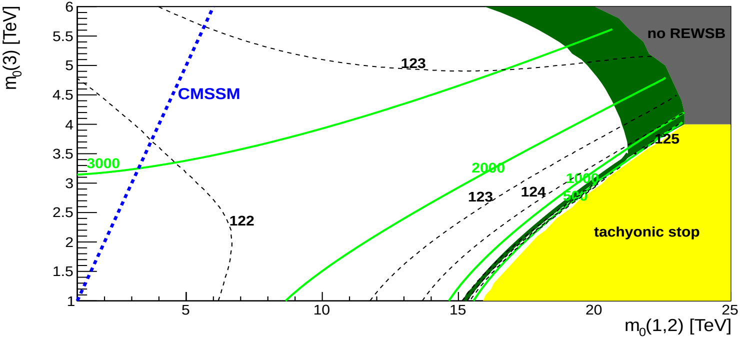
At two-loop RGEs, 1st/2nd generation give positive contribution to $m_{H_u}^2$

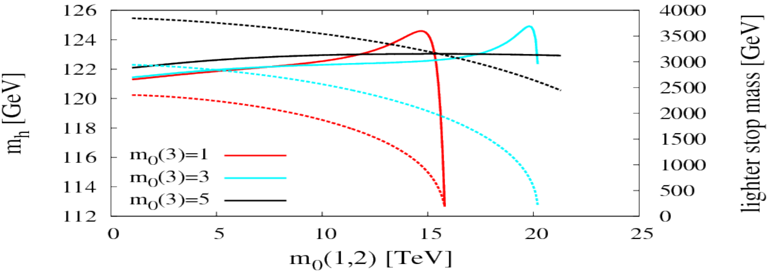
$$\mu^2 \approx -m_{H_u}^2 \approx 1.3M_{1/2}^2+0.1A_0^2-0.35M_{1/2}A_0-0.01m_0(3)^2-0.006m_0(1,2)^2$$

$m_0(1,2)$ too large $\Rightarrow \mu^2 < 0$ and REWSB cannot be realized

**Bigger $\mathbf{M_{1/2}}$ allows for heavier 1st/2nd generation consistent with REWSB**

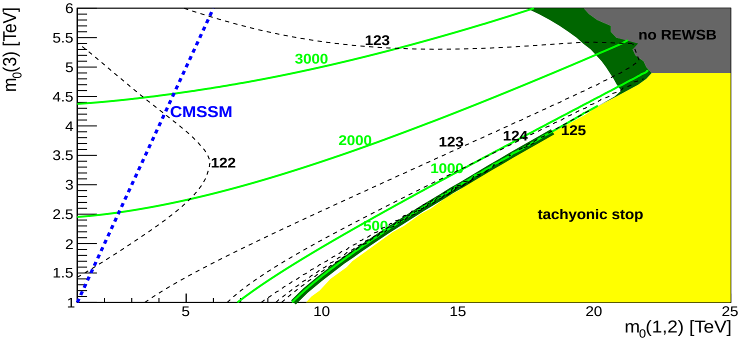
$M_{1/2} = 1.5$ TeV, $\qquad A_0 = 0, \qquad \tan\beta = 10$



For negative $A_0$ smaller $M_{1/2}$ required to obtain a given Higgs mass e.g.:

$$M_{1/2} = 1 \text{ TeV}, \qquad A_0 = -2 \text{ TeV}, \qquad \tan\beta = 10$$



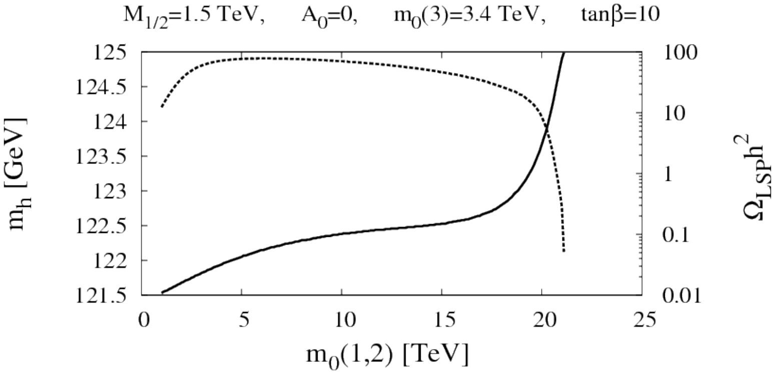

**For heavy 1st/2nd generation the lightest Higgs is generically heavy!**

For instance, $m_0(1,2) > 15$ TeV implies the Higgs mass above 122 GeV

# Inverted Hierarchy and Dark Matter

In the IH scenario LSP can be a good dark matter candidate.

- At smaller $m_0(3)$: light $\tilde{t}_1$ & bino LSP
  Stop-coannihilations may lead to correct $\Omega_{\rm LSP}$
- At larger $m_0(3)$: light higgsino LSP
  $\Omega_{\rm LSP}$ typically too small
- At intermediate $m_0(3)$: light $\tilde{t}_1$ and higgsino & bino-higgsino LSP
  $\Omega_{\rm LSP}$ in agreement with the WMAP data



# Conclusions

Inverted hierarchy of sfermion masses looks like a good bet for the MSSM:

- SUSY FCNC problem can be substantially eased
- It has an interesting link to flavour models
- Maximal stop-mixing without large $A_0$
- Natural SUSY spectrum
- LSP can be a good dark matter candidate
- The lightest Higgs is generically heavy, in the vicinity of 125 GeV