LHC Implications for SUSY: Light Stops?

Maxim Perelstein, Cornell U.

LCWS 11, Granada, Spain

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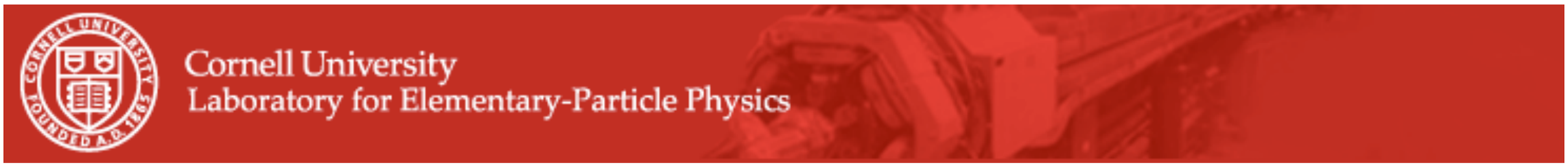

BBC NEWS

SCIENCE & ENVIRONMENT

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LHC results put supersymmetry theory 'on the spot'

By Pallab Ghosh
Science correspondent, BBC News

Results from the Large Hadron Collider (LHC) have all but killed the simplest version of an enticing theory of sub-atomic physics.

Researchers failed to find evidence of so-called "supersymmetric" particles, which many physicists had hoped would plug holes in the current theory.

How Does One Kill the MSSM?

- MSSM makes no firm predictions: large number (~100) of free parameters, with uncertain ranges: e.g. no upper limit for sparticle masses
- Fewer parameters in specific models of SUSY breaking, but no fully compelling model emerged after ~30 years of effort* ⇨ ignore them and learn from data
- In my view, fine-tuning provides the only useful measure on the MSSM parameter space: "kill MSSM" = "show that it must be very finely tuned if realized in Nature"
- Z mass at the tree level in the MSSM:

$$m_Z^2 = -m_u^2 \left(1 - \frac{1}{\cos 2\beta}\right) - m_d^2 \left(1 + \frac{1}{\cos 2\beta}\right) - 2|\mu|^2$$

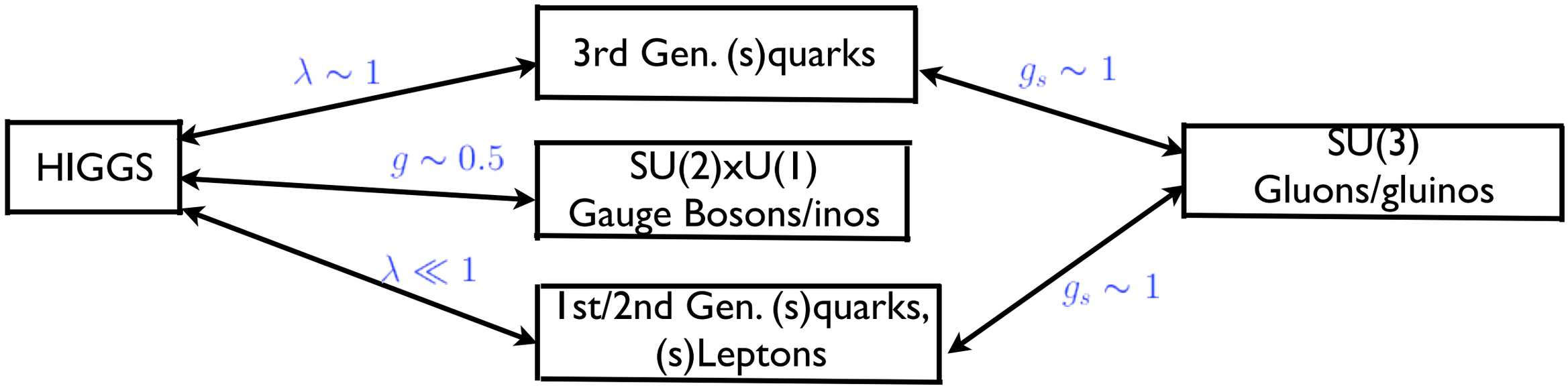
- Unless all terms on the r.h.s. are of order 100 GeV, cancellations are required to make this work
- Light Higgsinos (chargino and 2 neutralinos): <400 GeV if ~1% tuning is allowed

* - mSUGRA is among the least compelling, due to FCNC problems

- At loop level, the Higgs mass par's. receive quadratically divergent corrections, cut off by superpartner masses ("SUSY solves the hierarchy problem")

$$\delta m_h^2 \sim \frac{g_p^2}{16\pi^2}\Lambda^2 \quad \text{(SM)} \qquad \Rightarrow \qquad \delta m_h^2 \sim \frac{g_p^2}{16\pi^2} m_{\tilde{p}}^2 \log \frac{\Lambda^2}{m_{\tilde{p}}^2} \quad \text{(SUSY)}$$

- While a large number of parameters enter, the "hierarchy of couplings" in the SM/MSSM simplifies the problem:

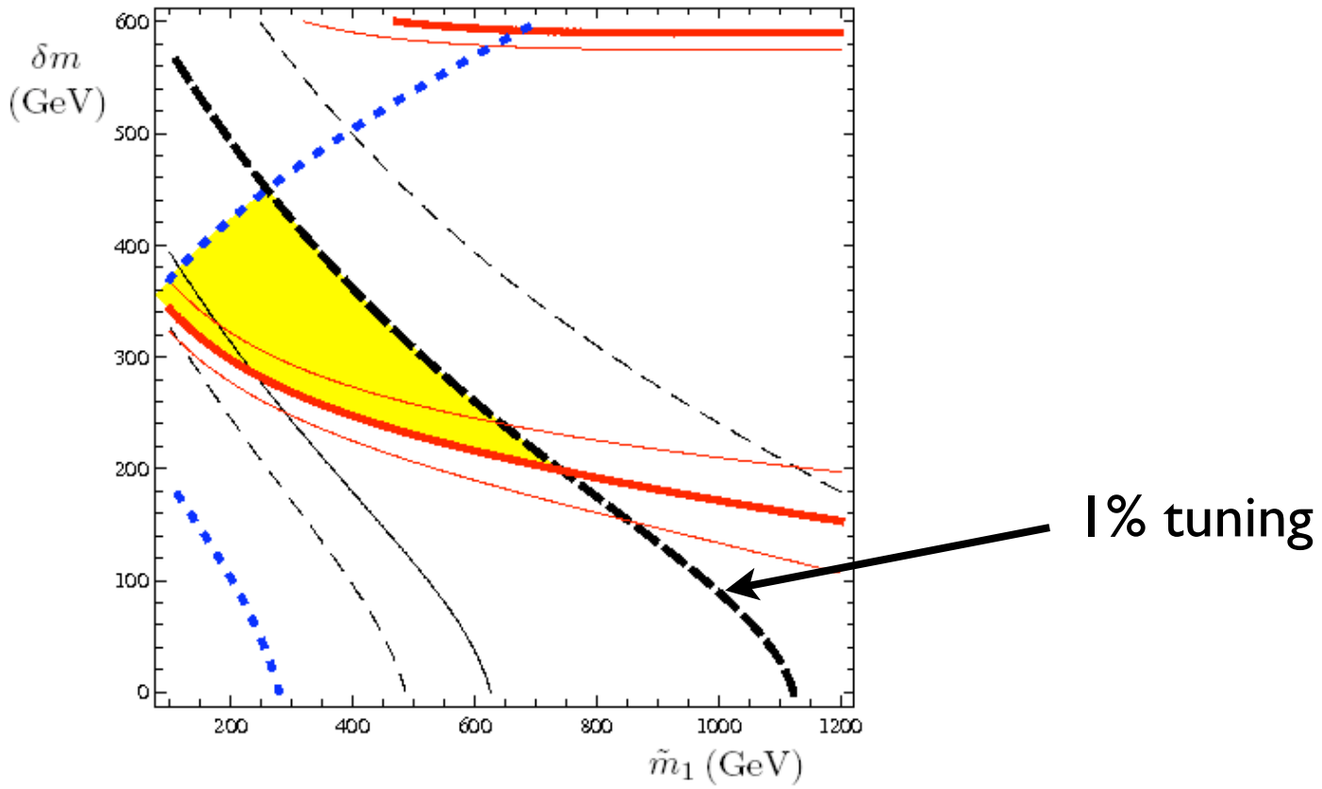


- So: 3rd gen. squark loops are the most important, other squarks/sleptons may be a factor of 5 or more heavier than the 3rd gen squarks with no effect on fine-tuning

- Gluino first appears at 2 loops, suppressing its effect on fine-tuning

- 1% tuning (with low messenger scale ~100 TeV) implies stops (and one sbottom) below ~1 TeV

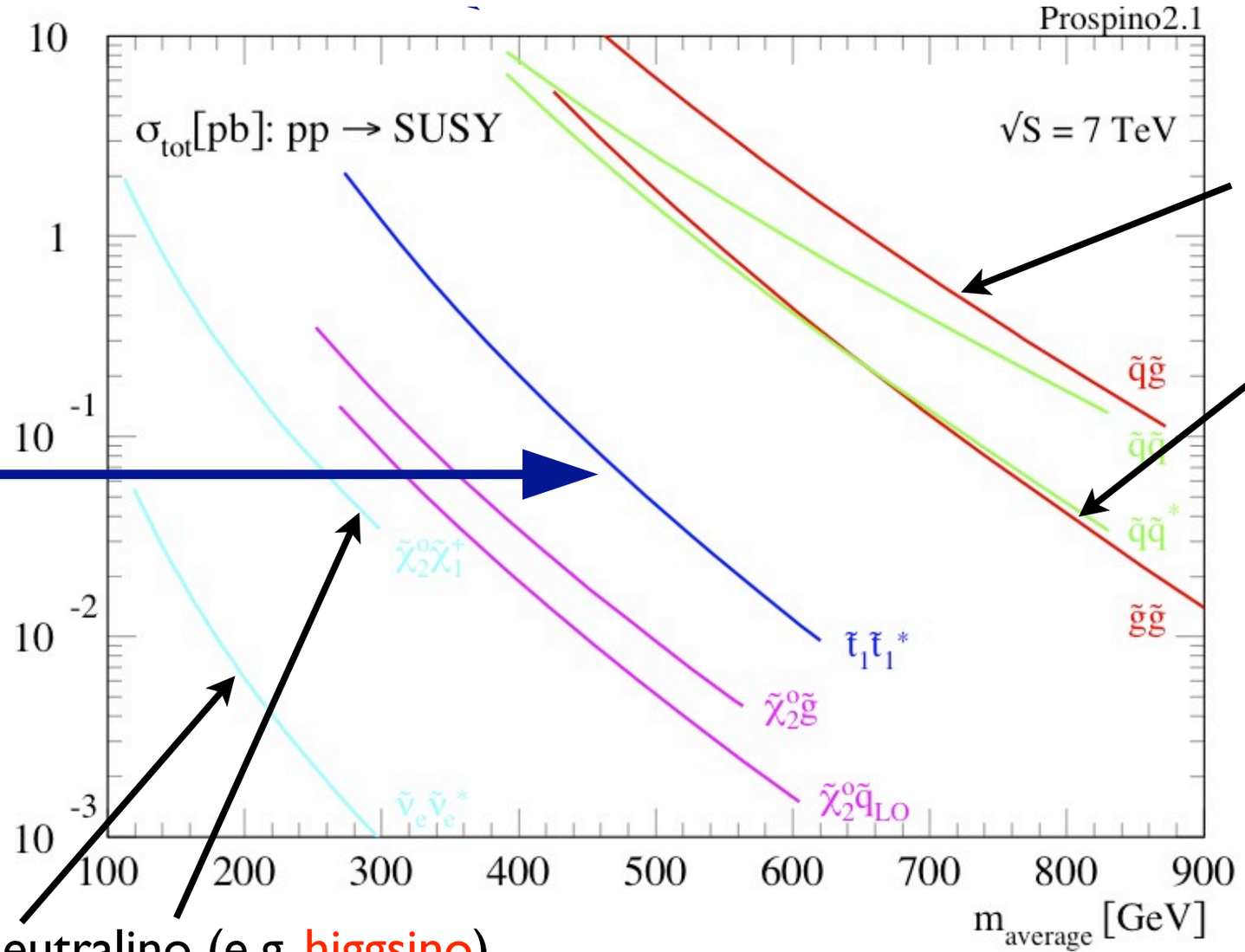
- Other squarks, sleptons may well be at 5 TeV, no problems with tuning



$$\Lambda = 100 \text{ TeV}, \quad \theta_t = \pi/4, \quad \tan\beta = 10$$

[plot from MP, Spethmann, hep-ph/0702038]

What About the LHC?



All searches so far rely on producing gluinos and/or 1st, 2nd gen. squarks, different decay channels

Stops have small cross sections:

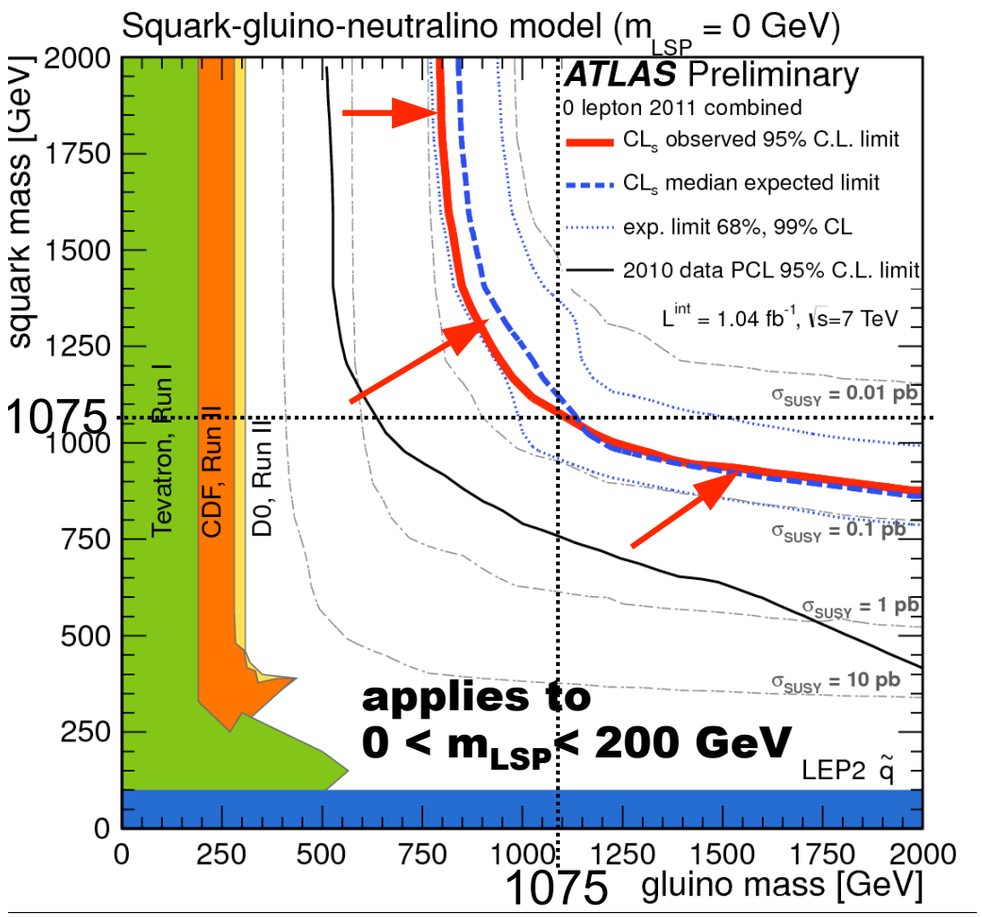
$\sigma(\tilde{t}\tilde{t}^*) \approx 30$ fb

at 500 GeV

Chargino/neutralino (e.g. higgsino) cross sections are even smaller

Plot credit: H. Bachacou talk at LP-11

LHC Searches



Plot credit:
H. Bachacou
talk at LP-11

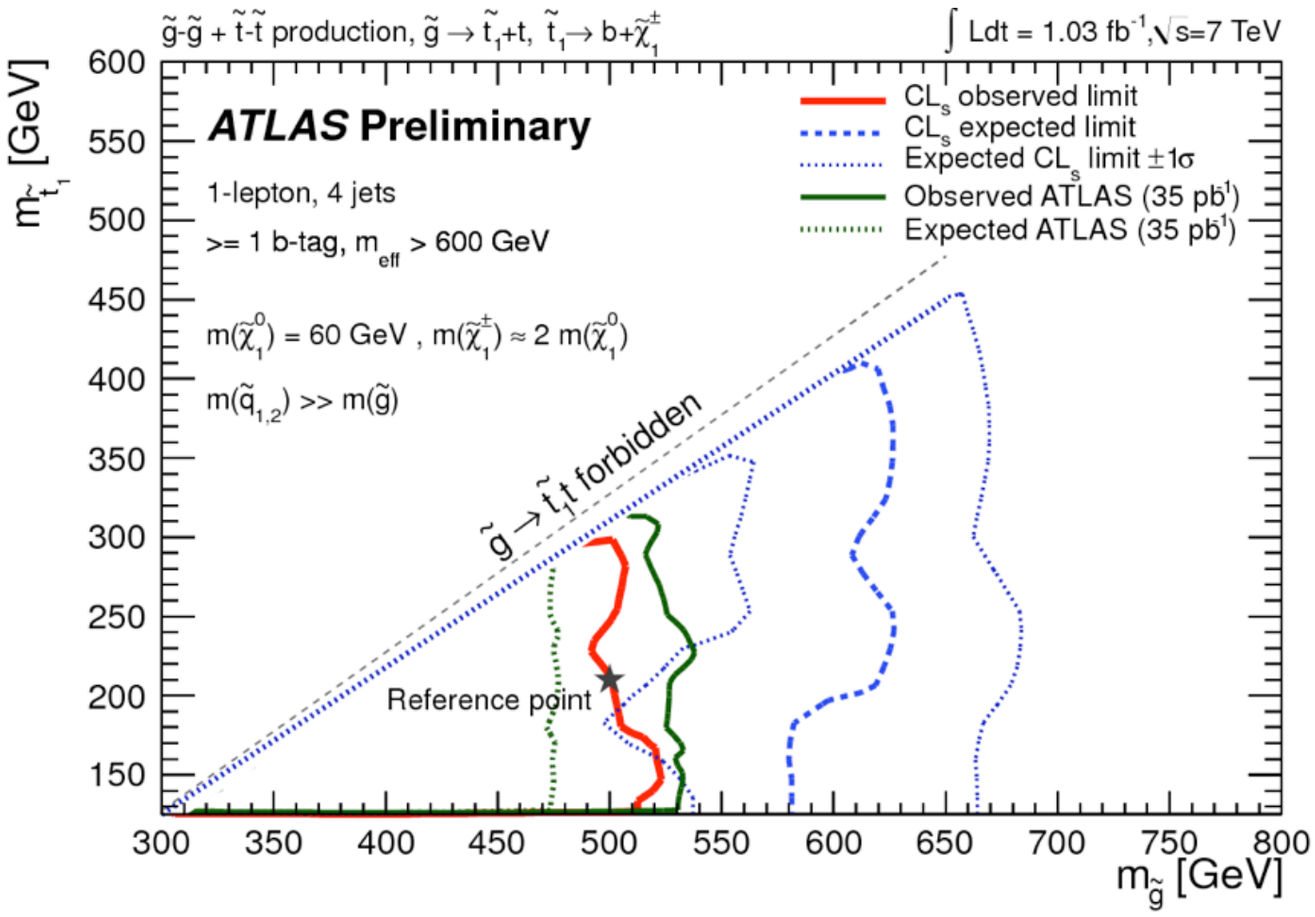
BOTTOM LINE: 1st/2nd gen. squark/gluino bounds have essentially NO impact on fine-tuning in the MSSM

[Not so in specific SUSY breaking models, e.g. where three gen. of squarks have common mass term at some scale]

LHC Searches

Don't they search for stops?

ATLAS-CONF-2011-130 17 August 2011

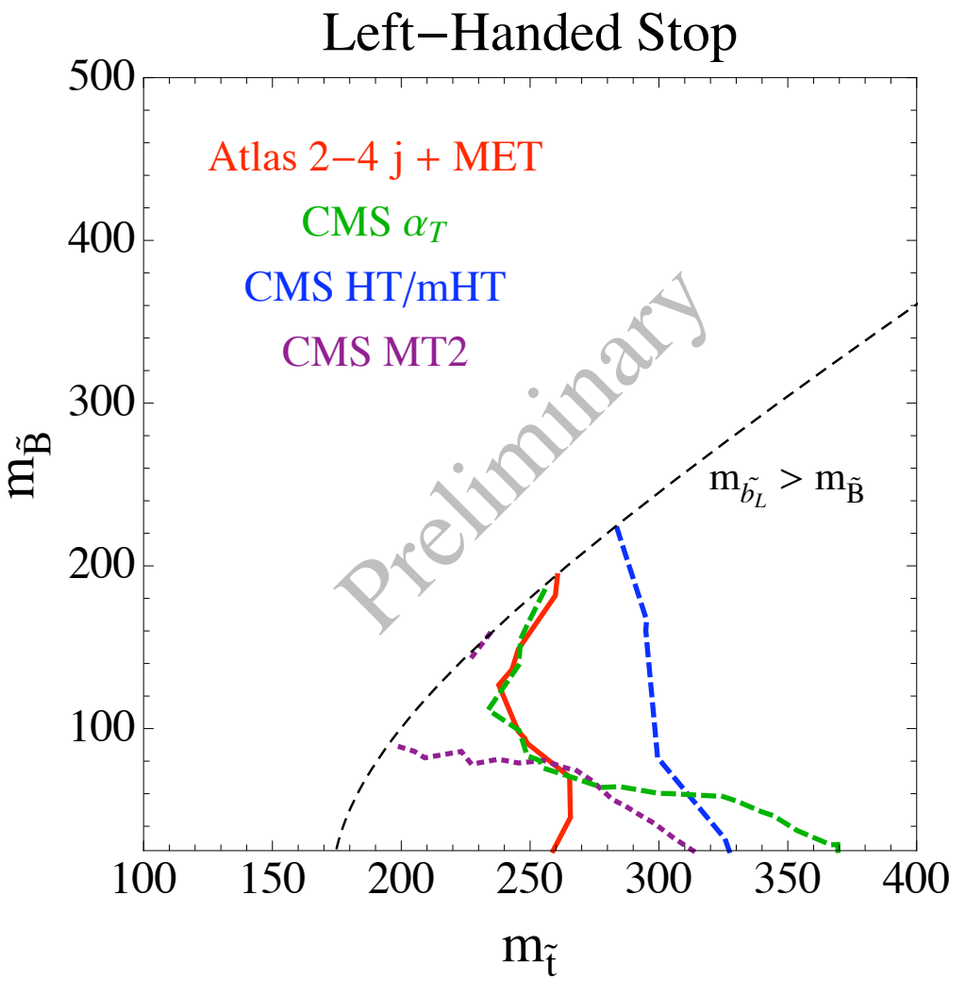


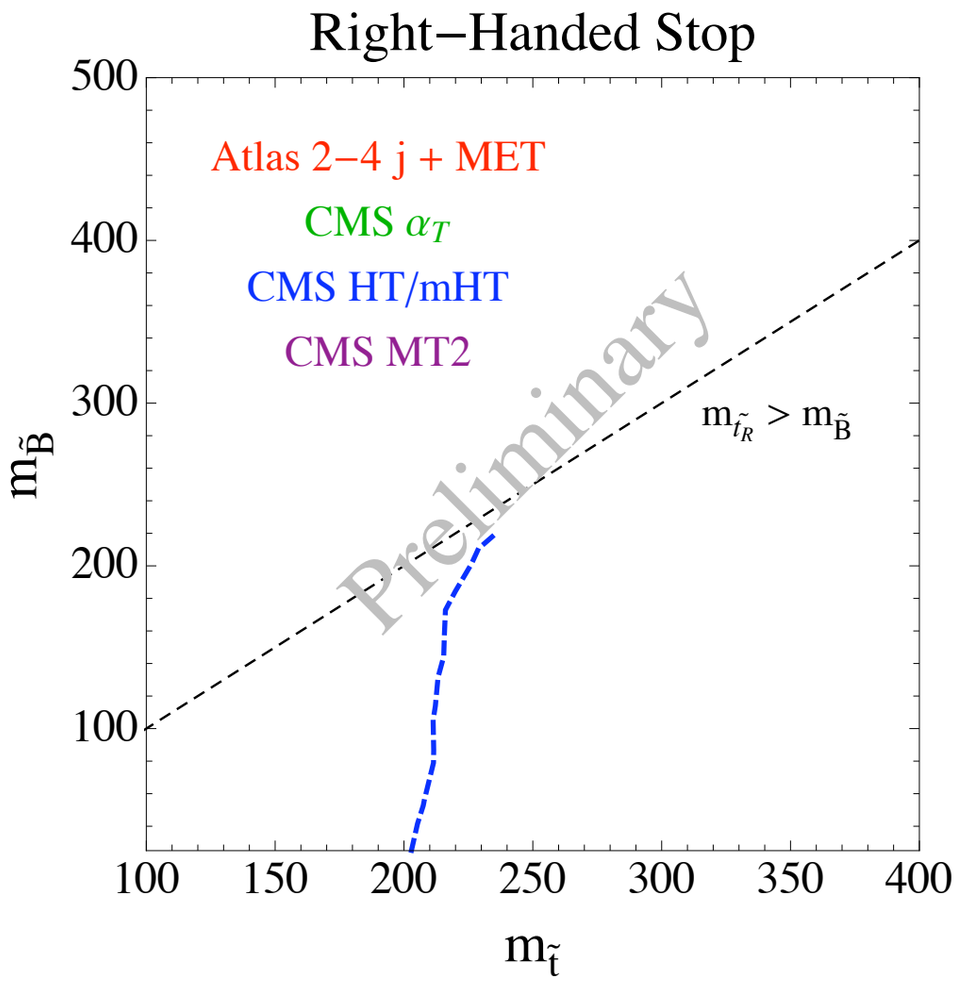
$m_{\tilde{g}} \gtrsim 500\,\mathrm{GeV}$ $\qquad$ $m_{\tilde{t}} \gtrsim ?$

This search relies on gluino pair-production to make stops, and has no impact on fine-tuning so far

LHC Searches

Wouldn't stops show up in other channels? Yes, but the limits so far are not strong enough to impact fine-tuning

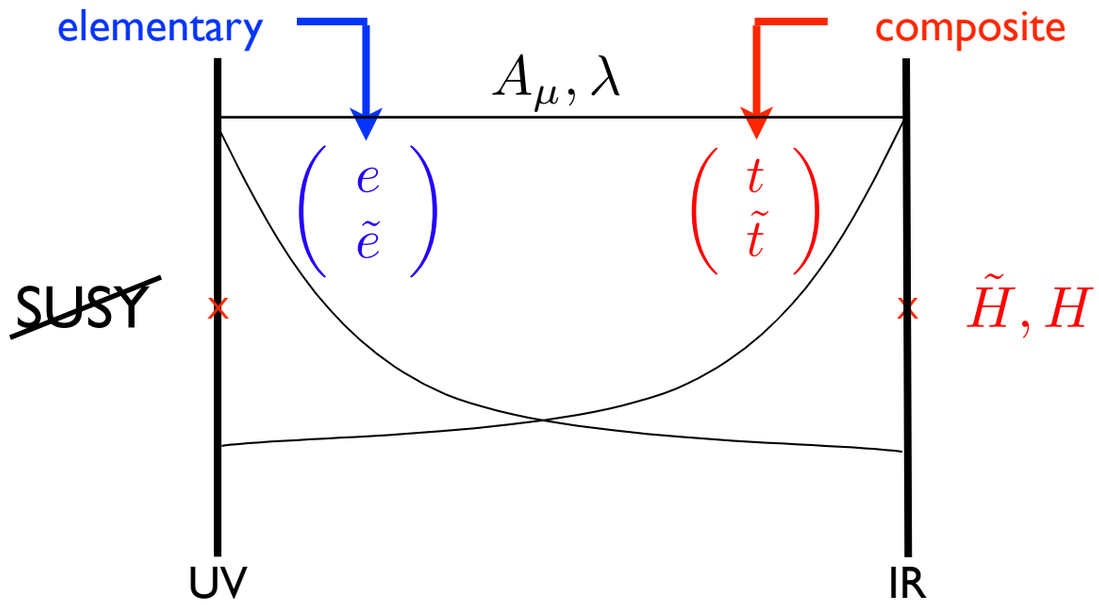




[Re-interpretation of 1 fb-1 searches presented at summer conferences, by Papucci, Ruderman, Toro and Weiler]

Partial SUSY [TG, Pomarol, hep-ph/0302001]

SUSY broken at UV scale



bulk mass parameter

$$\begin{pmatrix} \psi \\ \tilde{\phi} \end{pmatrix} \propto e^{(\frac{1}{2}-c)ky}$$

Fermion mass spectrum
determines sparticle spectrum!

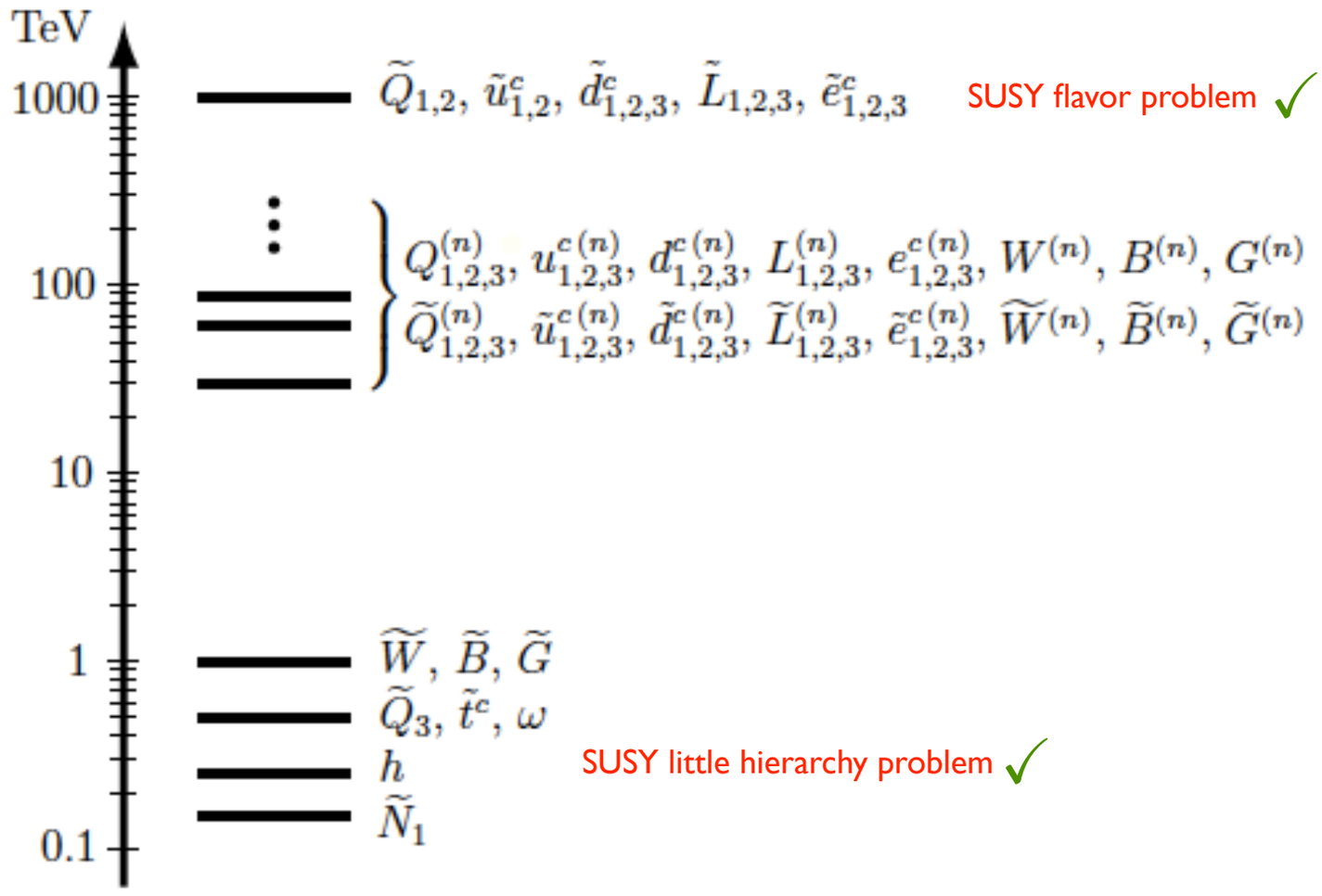
Low-energy SUSY spectrum $\tilde{t}, \tilde{H}$ $(\tilde{f}_{1,2}, \lambda$ decouple)

KK spectrum $m_f^{(n)} \simeq m_{\tilde{f}}^{(n)}$ $n = 1, 2, \ldots$

[From Tony Gherghetta's talk at PACIFIC-2011]

Accidental SUSY spectrum:

$(\Lambda_{IR} = 40\,\mathrm{TeV}, m_{IR} = 10\,\mathrm{TeV})$



SUSY flavor problem ✓

RS flavor problem ✓

SUSY little hierarchy problem ✓

[From Tony Gherghetta's talk at PACIFIC-2011]

Conclusions

- Good news: SUSY, as a solution to the hierarchy problem, is alive and well despite lack of LHC discovery so far
- Spectrum below 1 TeV may be minimal required by naturalness: 3rd gen squarks + Higgsino (+ perhaps bino for dark matter?)
- Stops/sbottoms within the ILC-1000 reach will soon be discovered or ruled out
- Weak-inos are not being probed yet, including regions within ILC-500 reach