NATURALNESS AND THE STATUS OF SUPERSYMMETRY

Jonathan Feng
University of California, Irvine

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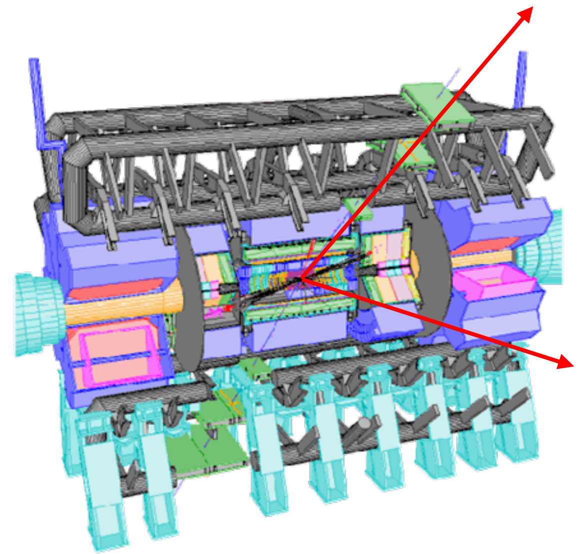
SUPERSYMMETRY

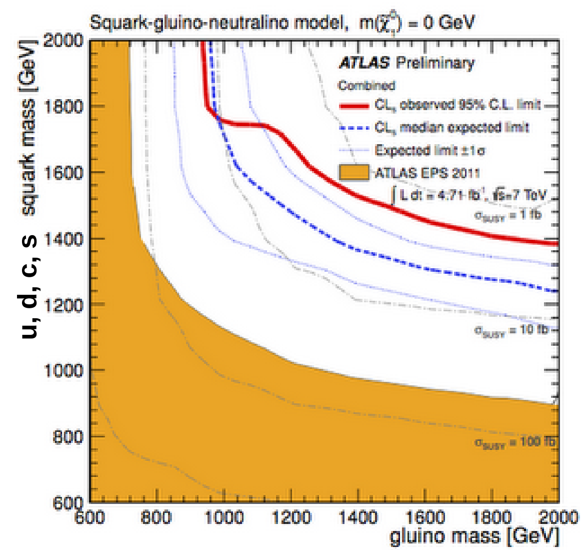
- Weak-scale SUSY has long been the dominant paradigm for new particle physics
- Longstanding and strong motivations
  - A natural solution to the gauge hierarchy problem
  - Gauge coupling unification
  - An excellent DM candidate
- This is now being challenged by the LHC
  - Null results from superpartner searches
  - Results from Higgs boson searches

SUPERPARTNER SEARCHES

- An example: squark and gluino searches
  - $pp \rightarrow \tilde{g}\tilde{g}\ \ \tilde{g}\tilde{q}\ ,\ \tilde{q}\tilde{q}$
  - Each squark and gluino instantaneously cascade decays, ending in a neutralino χ
  - The 2 χ's escape the detector and are seen as missing momentum



- In tens (hundreds?) of analyses, no excess over predicted background → bounds
  - u, d, c, s squarks > 1400 GeV
  - gluinos > 900 GeV
  - top squarks > 350 GeV
  - Winos > 200 GeV
  - sleptons > 150 GeV



- Significant variations possible for other decay possibilities

REACTIONS

- These LHC results have led to many interesting statements that I disagree with. The Top 10:

  10. SUSY is now excluded
  9. Weak-scale SUSY is now excluded
  8. The CMSSM is now excluded
  7. Naturalness requires light top squarks
  6. It’s time to stop thinking about naturalness
  5. The 125 GeV Higgs requires physics beyond the MSSM
  4. Particle physics is in trouble
  3. We should all be depressed
  2. We shouldn’t be depressed, but we should start preparing to be depressed
  1. String theory predicts a 125 GeV Higgs

MOTIVATIONS

- Recall the three primary motivations for SUSY
  - A natural solution to the gauge hierarchy problem

    Maiani (1981); Witten (1981); Veltman (1981); Kaul (1982); …
  - Gauge coupling unification

    Dimopoulos, Raby, Wilczek (1981); Ibanez, Ross (1981); Einhorn, Jones (1982); …
  - An excellent DM candidate

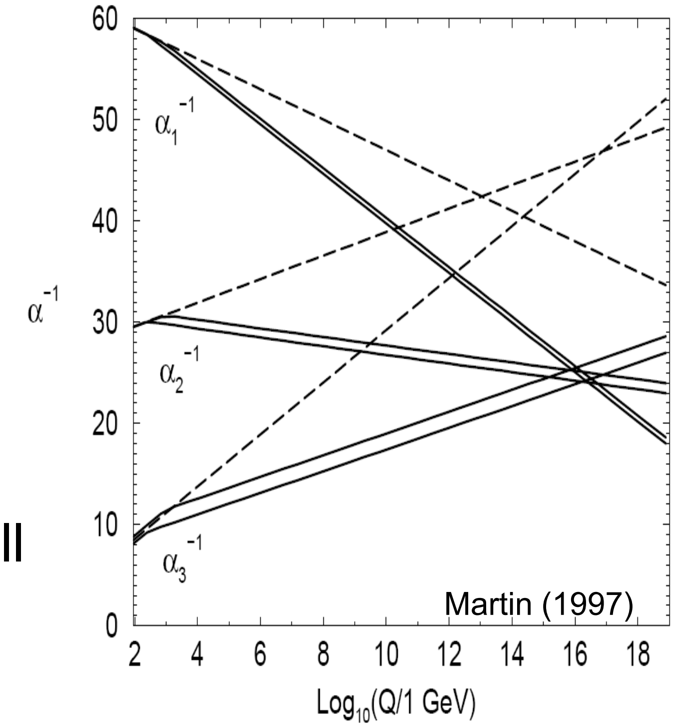
    Goldberg (1983); Ellis, Hagelin, Nanopoulos, Olive, Srednicki (1984); …
- These motivations have been explored and developed by many people over time, but they have persisted in more or less their original form for three decades
- What do they require of the superpartner masses?

GAUGE COUPLING UNIFICATION

- The SM particles beautifully unify in SU(5) multplets, but the SU(3), SU(2), and U(1) gauge couplings do not meet at any scale

$$\begin{pmatrix} \bar{d}_R \\ \bar{d}_B \\ \bar{d}_G \\ e^- \\ \nu_e \end{pmatrix}_L \qquad \begin{pmatrix} 0 & \bar{u}_G & -\bar{u}_B & -u_R & -d_R \\ -\bar{u}_G & 0 & \bar{u}_R & -u_B & -d_B \\ \bar{u}_B & -\bar{u}_R & 0 & -\bar{u}_G & -d_G \\ u_R & u_B & \bar{u}_G & 0 & -e^+ \\ d_R & d_B & d_G & e^+ & 0 \end{pmatrix}_L$$

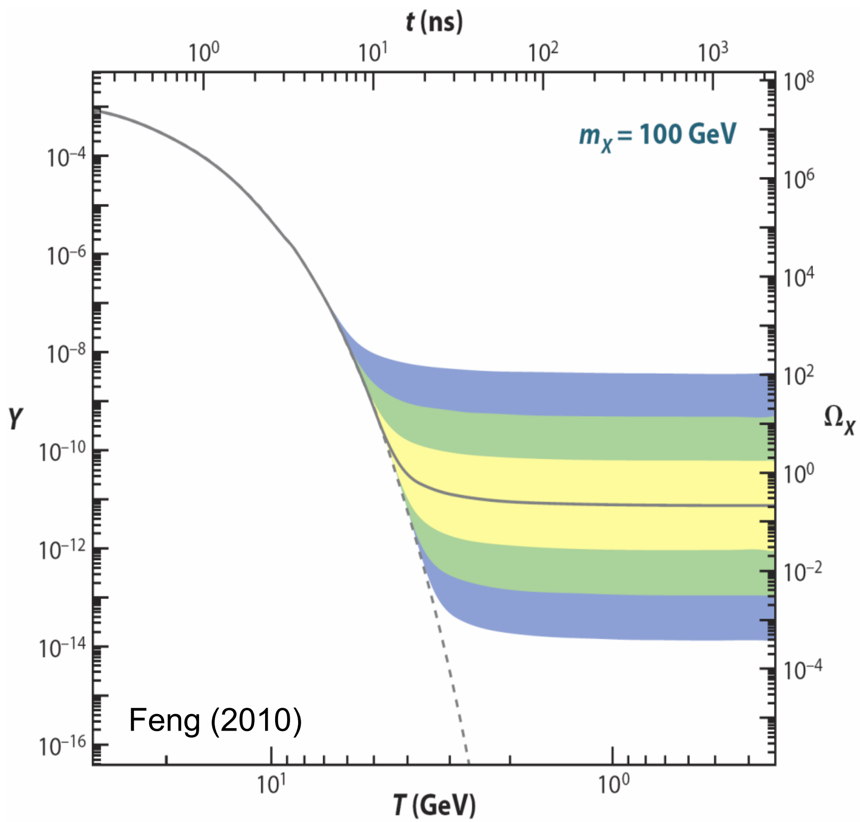
- They do unify in the MSSM
  - At a value ($\alpha < 1$) that is perturbative
  - At a scale high enough (> 10^{16} GeV) to suppress proton decay
  - At a scale low enough (< 10^{18} GeV) to avoid strong gravity



- This is, however, only logarithmically sensitive to the superpartner mass scale

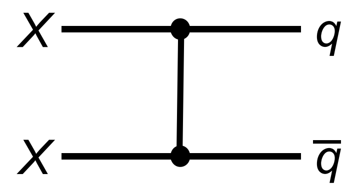
- Also, it has been known for decades that full SU(5) multiplets (e.g., all squarks/sleptons) can decouple without impacting unification

DARK MATTER



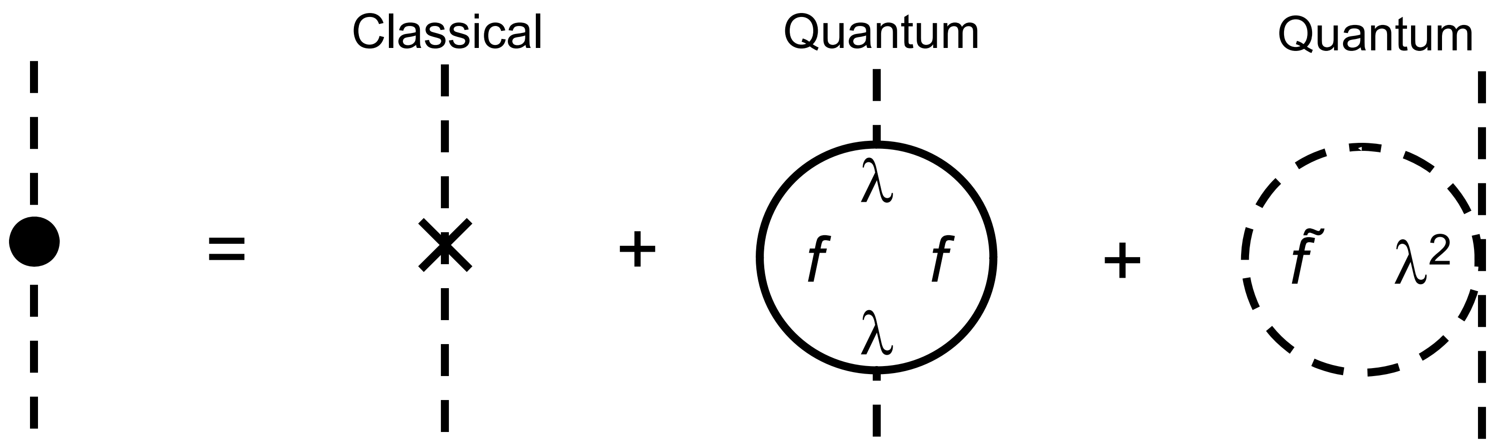
- SUSY contains an excellent thermal relic candidate, the neutralino
- Ω_X and annihilation strength are inversely related, so overclosure → upper bound on DM mass

$$\Omega_X \propto \frac{1}{\langle \sigma v \rangle} \sim \frac{m_X^2}{g_X^4}$$



- Unfortunately, for Wino (Higgsino) DM, this bound is 3 TeV (1 TeV)
- Also, DM bound doesn't tell us anything about collider signals

NATURALNESS



$$m_h^2 = (m_h^2)_0 - \frac{1}{16\pi^2}\lambda^2\Lambda^2 + \frac{1}{16\pi^2}\lambda^2\Lambda^2$$

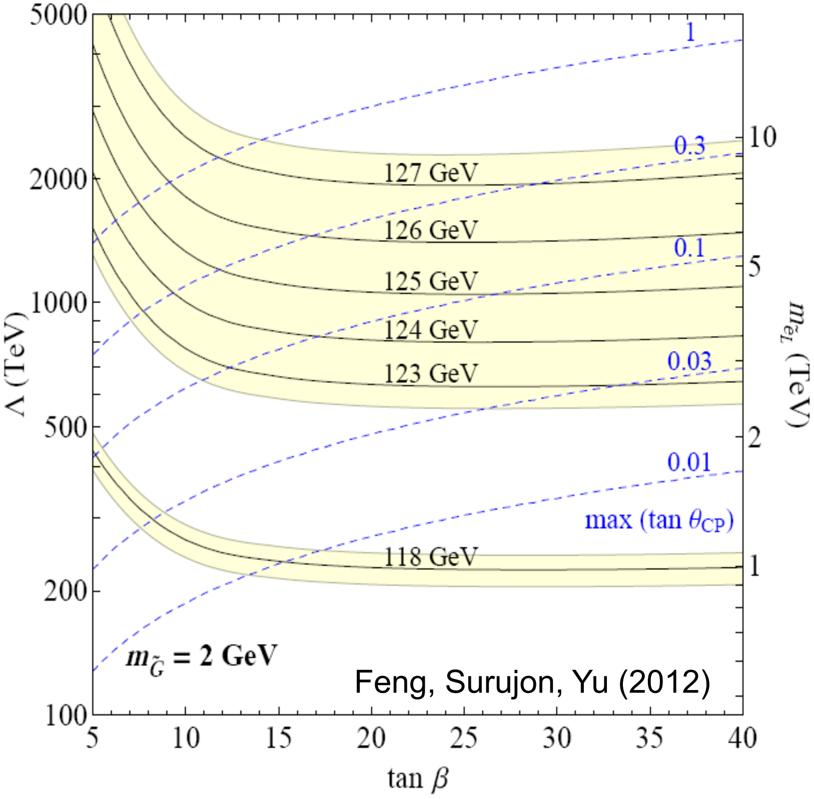
$$+ \frac{2N_f}{16\pi^2}\lambda^2(m_{\tilde{f}}^2 - m_f^2)\ln(\Lambda/m_h)$$

- For $\Lambda \sim m_{GUT}$ (m_W), f = top, $N_f = 6$, 1% fine-tuning → $m_{\tilde{t}} < 1$ (5) TeV
- Also, bounds on other sfermions are much weaker: $m_{\tilde{f}} < 10$ (50) TeV

Drees (1986); Dimopoulos, Giudice (1995); Pomoral, Tomasini (1996)

FLAVOR AND CP CONSTRAINTS

- Grand unification, dark matter, and naturalness do not forbid super-TeV superpartners
- But there are also strong reasons to expect them: flavor and CP violation
- My personal favorites: electron and neutron electric dipole moments. These violate CP, but not flavor, are so are generically large even in GMSB, AMSB



- Bottom line: so far, null results from superpartner searches do not lessen the appeal of SUSY (note that this is a relative statement); those who were surprised simply haven't appreciated these constraints

EFFECTIVE SUSY, 2-1 SUSY, SUPERHEAVY SUSY

Drees (1986); Dine, Kagan, Samuel (1990); Dimopoulos, Giudice (1995); Pomoral, Tomasini (1996); Cohen, Kaplan, Nelson (1996); Dvali, Pomarol (1996); Mohapatra, Riotto (1997); Zhang (1997); Bagger, Feng, Kolda, Polonsky (1999); Agashe, Graesser (1999); Hisano, Kurosawa, Nomura (1999); …

Transparencies from Fermilab Wine & Cheese Seminar, October 1999

NATURALNESS RE-EXAMINED

Implications for SUSY

at the

Tevatron and Beyond

Jonathan Feng
Institute for Advanced Study, Princeton

October 1999

CONCLUSIONS

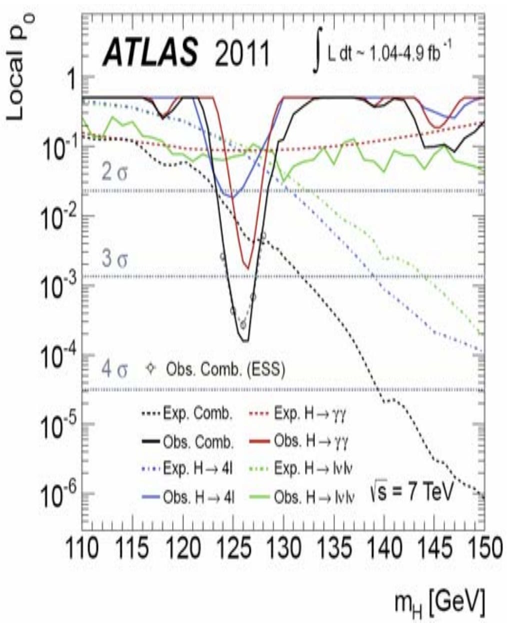
mSUGRA has a H_u focus point at the weak scale. Robust to variations in $M_{1/2}$, A, $\tan\beta$, m_t, Q_0.

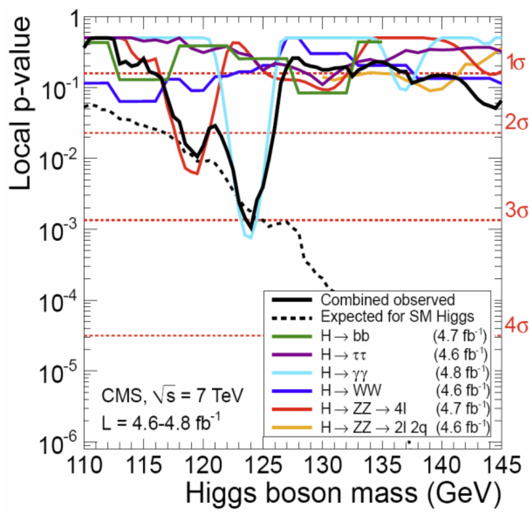
Naturalness limits on all scalars are greatly relaxed. Gauginos/Higgsinos still bounded by TeV. (Note: multi-TeV scalars are favored by EDMs, proton decay, gauge coupling unification. . .)

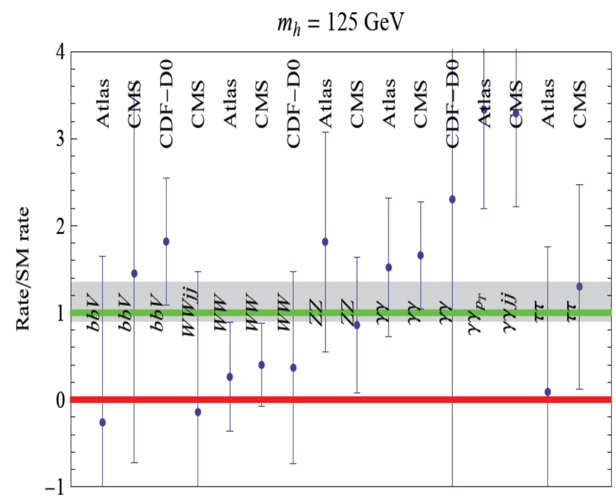
The discovery of all superpartners at LHC, NLC may be extremely challenging. Muon collider, VLHC?

HIGGS BOSONS

- Higgs results from the LHC and Tevatron are more challenging
- Searches for gg → h → $\gamma\gamma$ at the LHC and many other channels







Giardino, Kannike, Raidal, Strumia (2012)

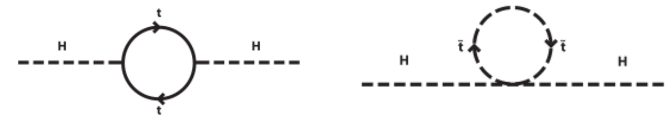
- ~3σ (local significance) signals at 126 GeV (ATLAS), 124 GeV (CMS)
- Light Higgs windows: 117.5 – 118.5 GeV and 122.5 – 127.5 GeV
- No strong hints for non-SM Higgs couplings

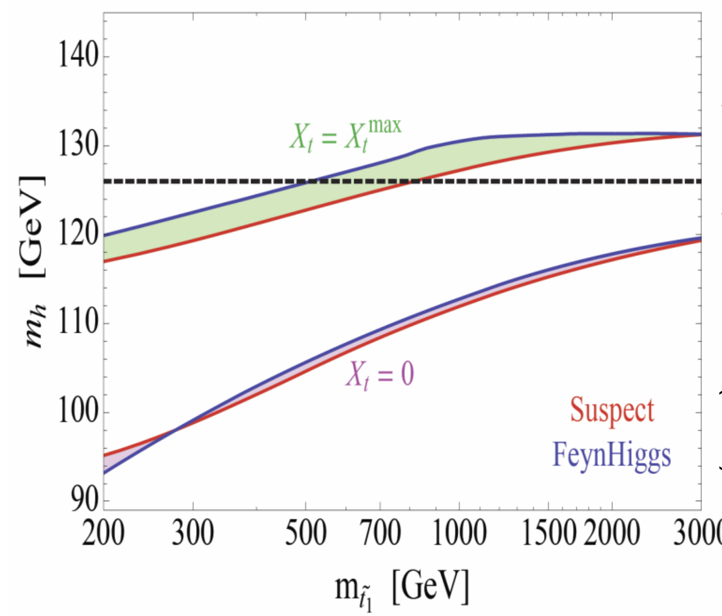
HIGGS RESULTS AND SUSY

- 30,000 foot view: great for SUSY
- Closer view: challenging for SUSY
  - Tree-level: $m_h < m_Z$
  - Higgs mass requires large loop-level corrections from heavy top squarks

Tree-level ↓ $\sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$ ↓ Left-right mixing ↓

$$m_h^2 = m_Z^2 c_{2\beta}^2 + \frac{3m_t^4}{4\pi^2 v^2}\left(\log\left(\frac{M_S^2}{m_t^2}\right) + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right)$$



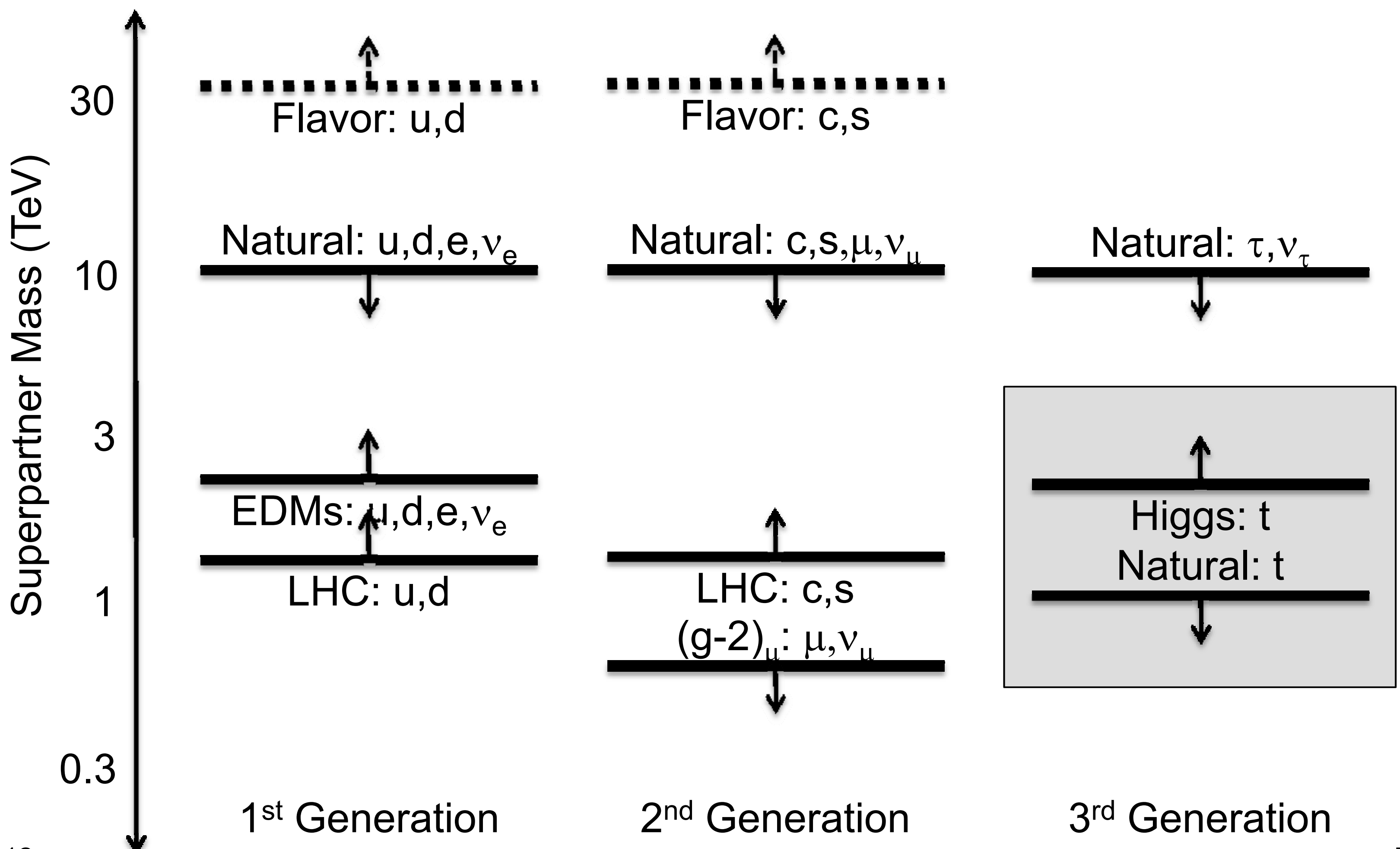


Hall, Pinner, Ruderman (2011)

- But naturalness requires light top squarks. This tension is much more direct than the tension created by bounds from superpartner searches
- *Note*: expt, theory, and parametric uncertainties are each ~ 2 GeV or more

CONSTRAINTS ON SUSY

[Assumes gaugino and Higgsino masses at 1 TeV or below;
rough, incomplete, other assumptions, some of which I will try to clarify]



NATURALNESS

- To understand the Higgs implications, must delve into naturalness a bit more. Two approaches:
- Option 1: “I know it when I see it.” Justice Potter Stewart
- Option 2: Quantify with some well-defined naturalness prescription
- Option 1 acknowledges that naturalness is subjective, but is a non-starter. Option 2 provides an opportunity for discussion and insights, as long as its limitations are appreciated.

A NATURALNESS PRESCRIPTION

- Step 1: Choose a framework with input parameters. E.g., mSUGRA with

$$\left\{P_{\text{input}}\right\} = \left\{m_0, M_{1/2}, A_0, \tan\beta, \text{sign}(\mu)\right\}$$

- Step 2: Fix all remaining parameters with RGEs, low energy constraints. E.g., at the weak scale, tree-level,

$$\frac{1}{2}m_Z^2 = \frac{m_{H_d}^2 - m_{H_u}^2 \tan^2\beta}{\tan^2\beta - 1} - \mu^2$$

- Step 3: Choose a set of parameters as free, independent, and fundamental. E.g., mSUGRA with

$$\{a_i\} = \{m_0, M_{1/2}, A_0, B_0, \mu_0\}$$

- Step 4: Define sensitivity parameters

$$c_i \equiv \left|\frac{\partial \ln m_Z^2}{\partial \ln a_i^2}\right|$$

Ellis, Enqvist, Nanopoulos, Zwirner (1986)
Barbieri, Giudice (1988)

- Step 5: Define the fine-tuning parameter

$$c = \max\{c_i\}$$

COMMENTS AND CAVEATS

- Step 1: Choose a framework with input parameters. E.g., mSUGRA/CMSSM with

$$\left\{P_{\text{input}}\right\} = \left\{m_0, M_{1/2}, A_0, \tan\beta, \text{sign}(\mu)\right\}$$

This is absolutely crucial. Generic SUSY-breaking is excluded, and there must be structure leading to correlated parameters. But the correlations impact naturalness; there is no model-independent measure of naturalness.

- Step 2: Fix all remaining parameters with RGEs, low energy constraints. E.g., at the weak scale

$$\frac{1}{2}m_Z^2 = \frac{m_{H_d}^2 - m_{H_u}^2 \tan^2\beta}{\tan^2\beta - 1} - \mu^2$$

Important to refine this to include 2-loop RGEs, 1-loop threshold corrections, decouple superpartners at their mass, and minimize the potential at some appropriate scale (typically, the geometric mean of stop masses) so that quadratic contributions are included.

COMMENTS AND CAVEATS

- Step 3: Choose a set of parameters as free, independent, and fundamental. E.g., mSUGRA with $\{a_i\} = \{m_0, M_{1/2}, A_0, B_0, \mu_0\}$

  A popular choice is $\{a_i\} = \{\mu_0\}$, which leads to $c = 2\mu^2/m_Z^2$. This is a simple, but completely deficient and misleading, measure of naturalness.

  Should we include other parameters, like y_t?
  - No – Ellis, Enqvist, Nanopoulos, Zwirner (1986); Ciafaloni, Strumia (1996), Bhattacharyya, Romanino (1996); Chan, Chattopadhyay, Nath (1997); Barbieri, Strumia (1998); Giusti, Romanino, Strumia (1998); Chankowski, Ellis, Olechowski, Pokorski (1998); …
  - Yes – Barbieri, Giudice (1988); Ross, Roberts (1992); de Carlos, Casas (1993); Anderson, Castano (1994); Romanino, Strumia (1999); …

  No – we are trying understand the naturalness of the superpartner mass "cutoff," so include only dimensionful SUSY breaking parameters. Fine-tuning with respect to the top mass is better viewed as non-genericity.

  Note: this is not an issue of what is measured and what isn't: with our current understanding, if μ were measured to be 1 PeV ± 1 eV, it will be precisely measured, but completely unnatural.

COMMENTS AND CAVEATS

- Step 4: Define sensitivity parameters $c_i \equiv \left| \frac{\partial \ln m_Z^2}{\partial \ln a_i^2} \right|$.

Ellis, Enqvist, Nanopoulos, Zwirner (1986)
Barbieri, Giudice (1988)

Why not $c_i \equiv \left| \frac{\partial \ln m_Z^2}{\partial \ln a_i} \right|$ (original definition) or $c_i \equiv \left| \frac{\partial \ln m_Z}{\partial \ln a_i^2} \right|$?

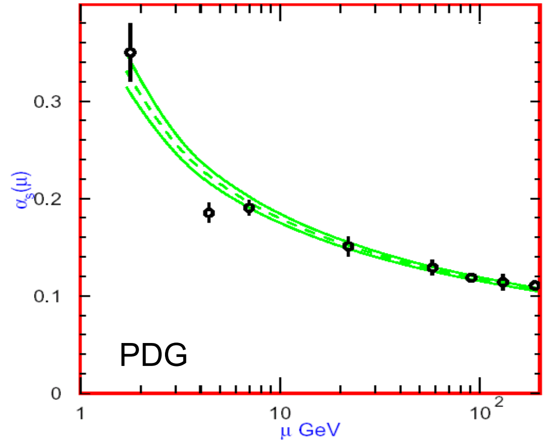
m^2 is more fundamental than m (it can be negative), but in any case, factors of 2 or 4 are insignificant.

COMMENTS AND CAVEATS

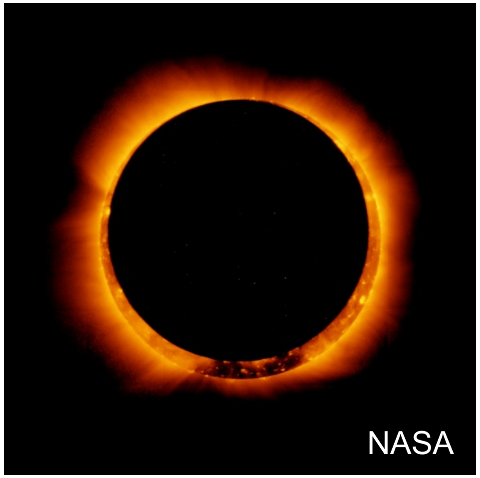
- Step 5: Define the fine-tuning parameter $c = \max\{c_i\}$
  .

  Why not add in quadrature? What if c is large for all possible parameter choices (cf. Λ_{QCD})?

  De Carlos, Casas (1993)
  Anderson, Castano (1994)



And finally, what is the maximal natural value for c: 10, 100, 1000, … ? Some studies impose c < 10, but this is extreme. If SUSY is found and reduces c from 10^{32} to 100 or 1000, will we still be looking for a solution to the gauge hierarchy problem?



WAYS FORWARD

- Explore Higgs boson predictions, non-SM Higgs properties

  Carena, Gori, Shah, Wagner (2011); Heinemeyer, Stal, Weiglein (2011); Christensen, Han, Su (2012); …

- Light SUSY with Exotic Decays: Introduce new decay modes to make light superpartners compatible with collider constraints

  Strassler, Zurek (2006), Fan, Reece, Ruderman (2011), Csaki, Grossman, Heidenreich (2011); …

- Hidden Higgs, Buried Higgs: Make m_h < 115 GeV compatible with collider constraints

  Dermisek, Gunion (2005); Bellazzini, Csaki, Falkowski, Weiler (2009); …

- Beyond the MSSM (NMSSM, Effective SUSY, …): Increase particle content to raise m_h naturally, accommodate non-SM Higgs properties

  Hall, Pinner, Ruderman (2011); Ellwanger (2011); Arvanitaki, Villadoro (2011);

  Gunion, Jiang, Kraml (2011); Perez (2012); King, Muhlleitner, Nevzorov (2012); Kang, Li, Li (2012);…

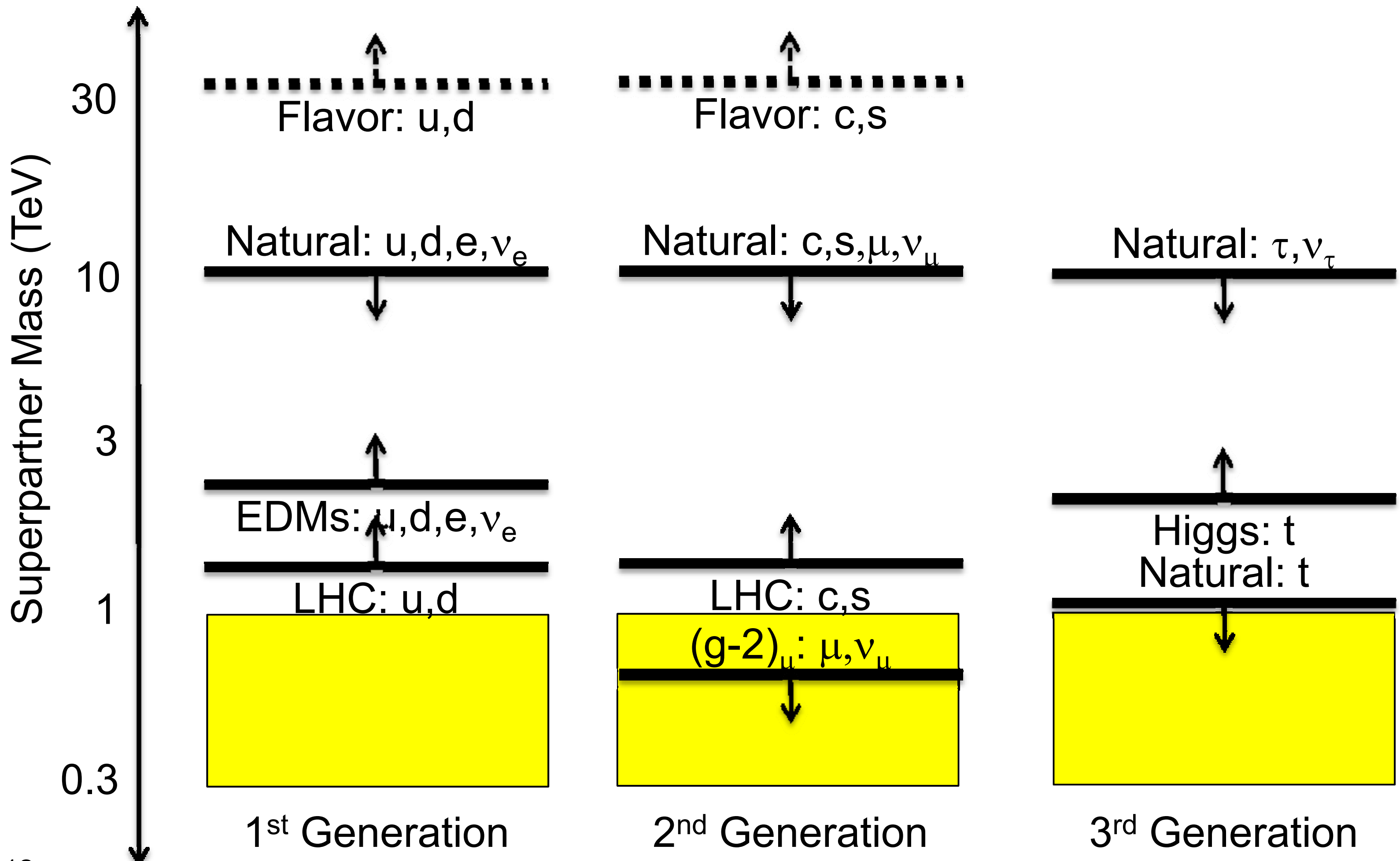
- Focus Point SUSY: Dynamically generated naturalness

  Feng, Matchev, Moroi (1999); Feng, Matchev, Wilczek (2000); Kitano, Nomura (2005); Abe, Kobayashi, Omura (2007);

  Horton, Ross (2009); Asano, Moroi, Sato, Yanagida (2011); Akula, Liu, Nath, Peim (2011); Younkin, Martin (2012); …

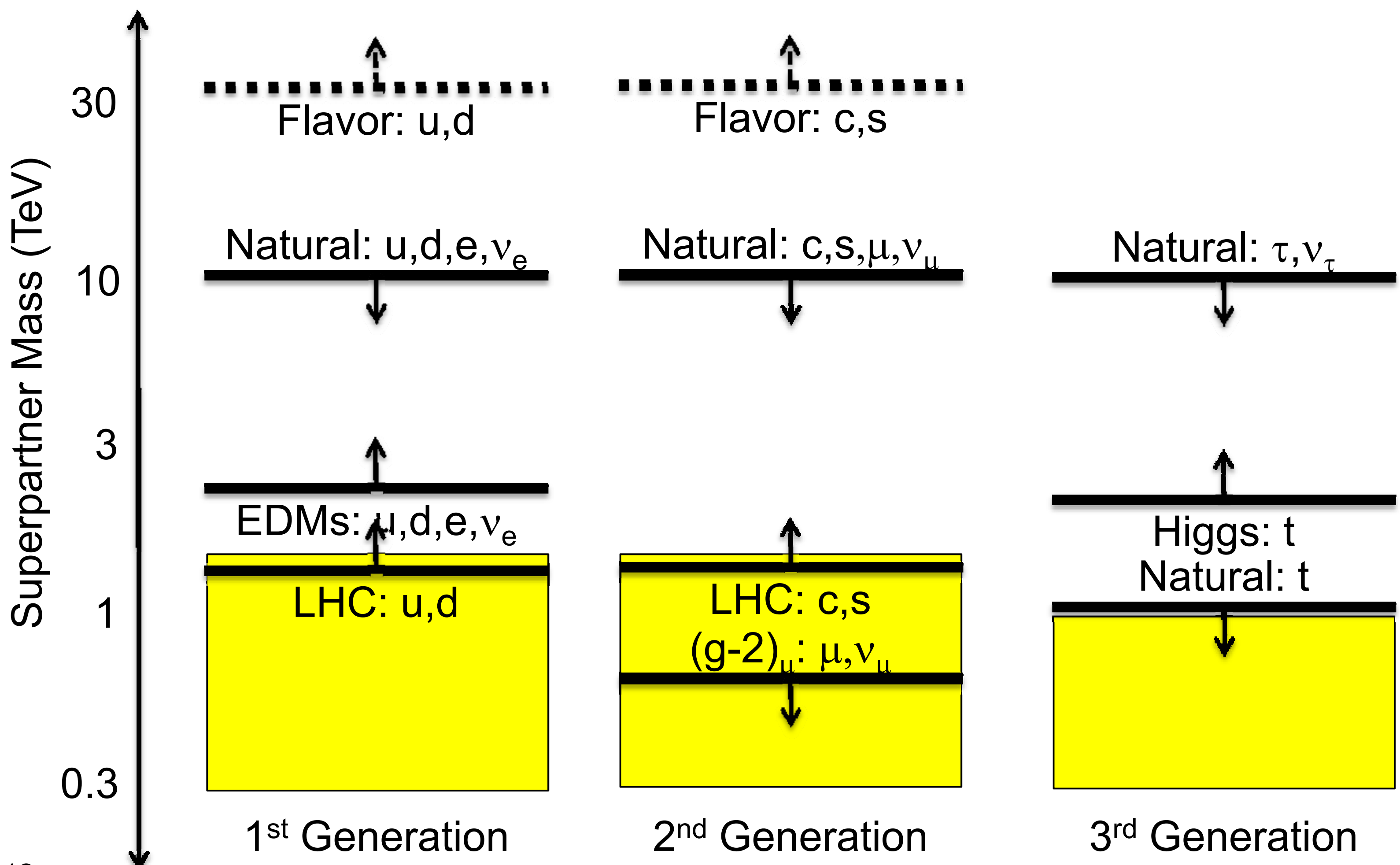
LIGHT SUSY WITH EXOTIC DECAYS

New decays (R-parity, hidden sectors, …) soften LHC constraints



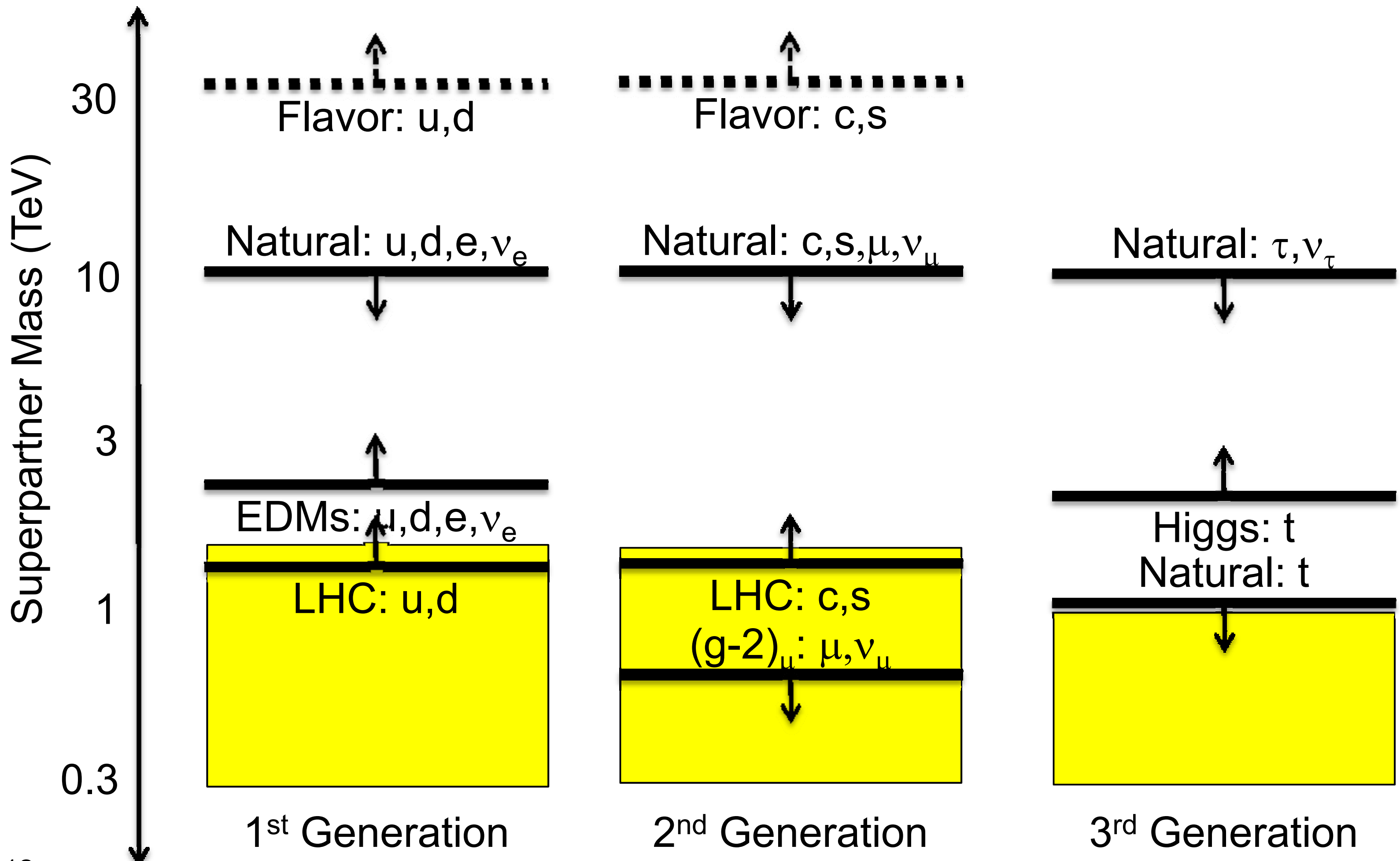
HIDDEN HIGGS, BURIED HIGGS

Exotic Higgs decays ($h \rightarrow aa \rightarrow bbbb$, …) allow $m_h < 115$ GeV



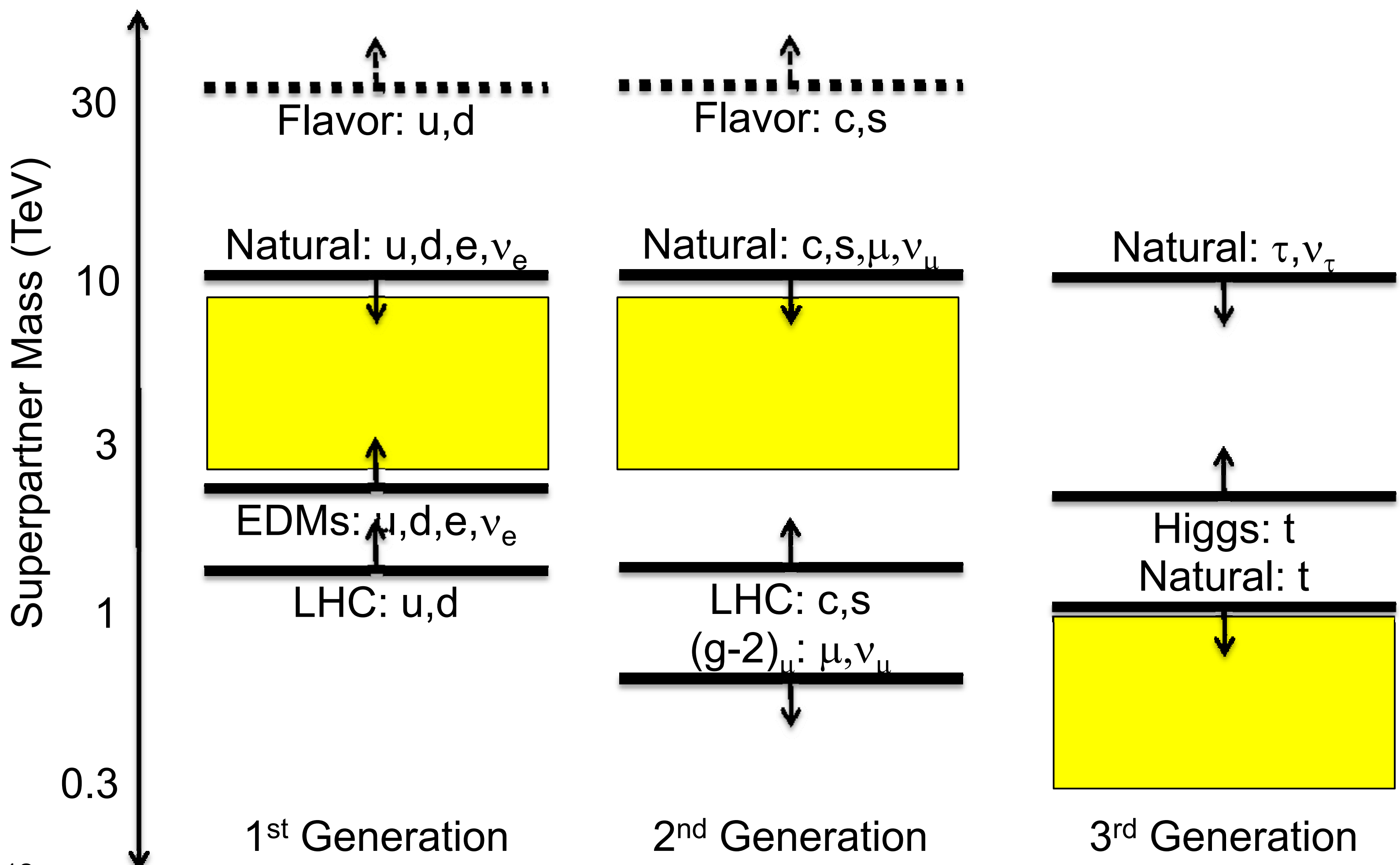
BEYOND THE MSSM: NMSSM,…

Introduce new particles to raise m_h



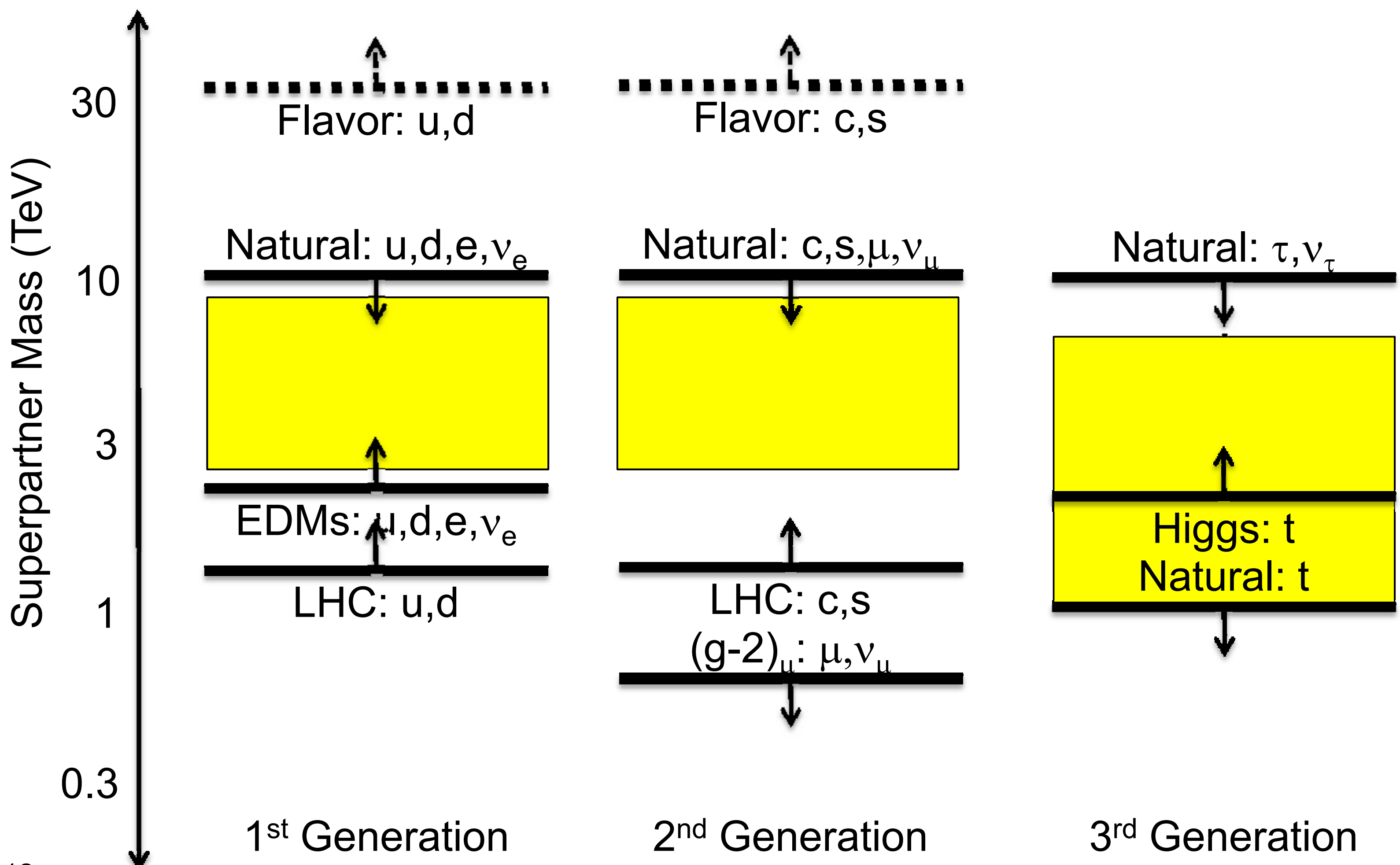
BEYOND THE MSSM: EFFECTIVE SUSY

Like old Effective SUSY, but introduce new particles to raise m_h



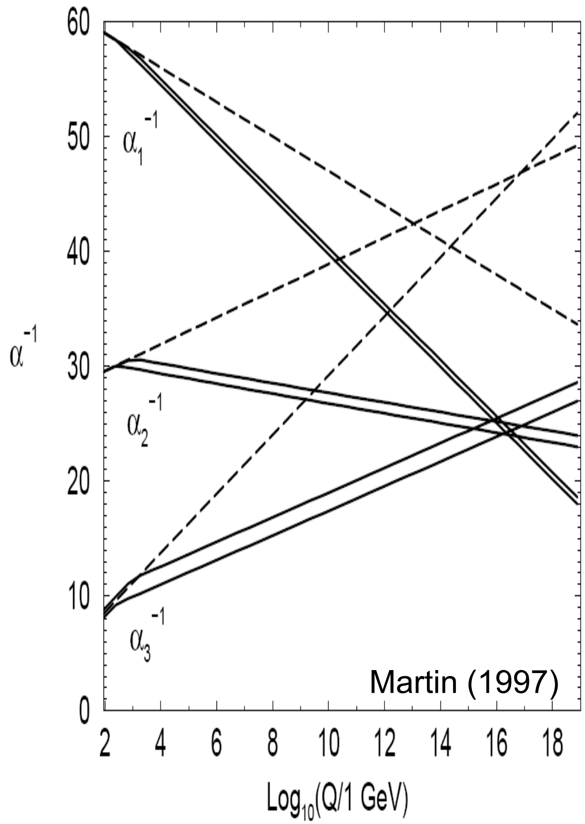
FOCUS POINT SUSY

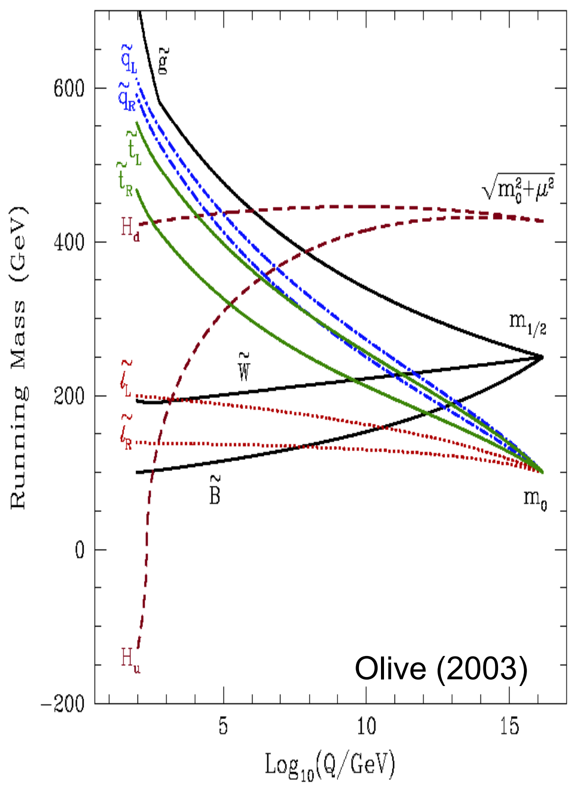
Correlations make large stop masses natural

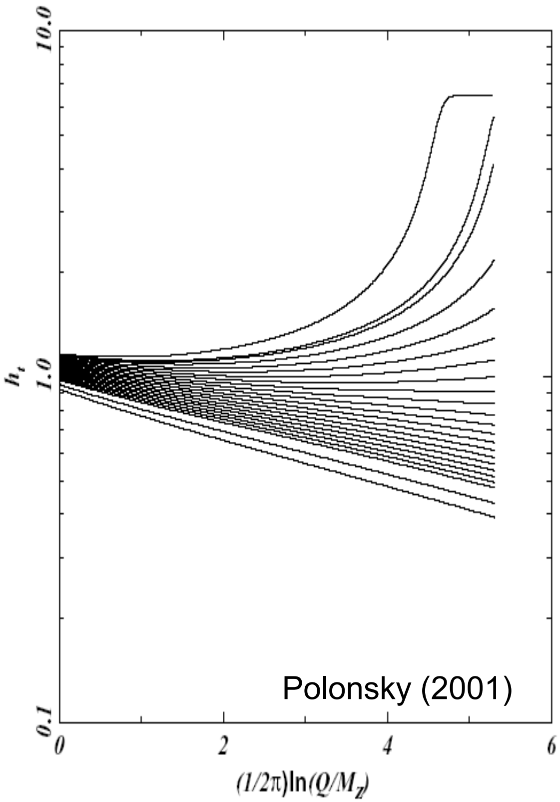


FOCUS POINT SUSY

- RGEs play a crucial role in almost all of the main motivations for weak-scale SUSY: coupling constant unification, radiative EWSB, neutralino DM, top quark quasi-fixed point. What about naturalness?







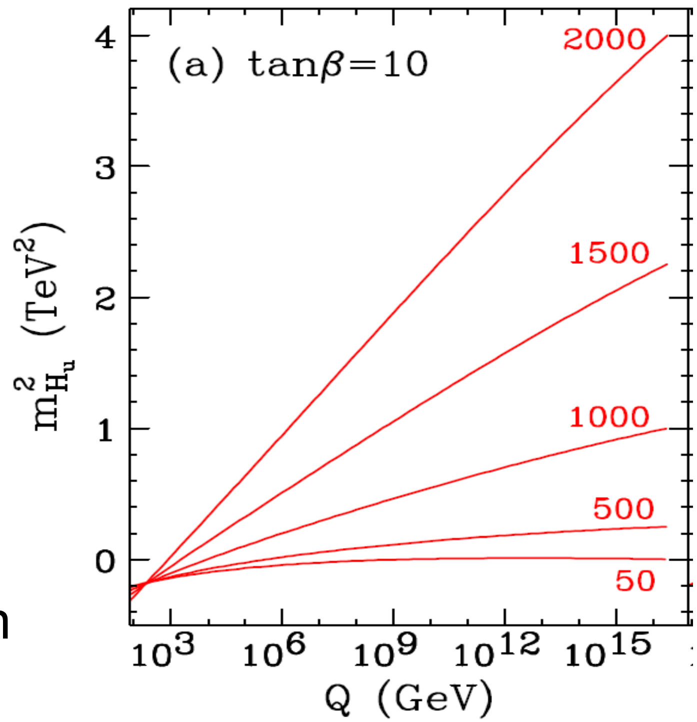
FP SUSY: GRAPHICAL EXPLANATION

- Focus on m_{Hu} :

$$\frac{1}{2}m_Z^2 = -\mu^2 + \frac{m_{H_d}^2 - m_{H_u}^2 \tan^2\beta}{\tan^2\beta - 1}$$
$$\approx -\mu^2 - m_{H_u}^2$$

- Insensitivity to GUT-scale parameters
  → a family of RG trajectories focus to a point at the weak scale

- Dynamically-generated hierarchy between the stop masses and the weak scale



- Removes large log-enhanced contributions: $\frac{2N_f}{16\pi^2}\lambda^2(m_{\tilde{f}}^2 - m_f^2)\ln(\Lambda/m_h)$
- Recall: Λ ~ m_{GUT} (m_W), and f = top, 1% fine-tuning → $m_{\tilde{t}}$ < 1 (3) TeV

- Theories with heavy stops are natural if they are focus point theories

FP SUSY: ANALYTIC EXPLANATION

- Schematic form of the RGEs:

$$\frac{dg}{d\ln Q} \sim -g^3$$
$$\frac{dy}{d\ln Q} \sim -g^2 y + y^3$$
$$\frac{dM}{d\ln Q} \sim -g^2 M$$
$$\frac{dA}{d\ln Q} \sim g^2 M + y^2 A$$
$$\frac{dm^2}{d\ln Q} \sim -g^2 M^2 + y^2 A^2 + y^2 m^2$$

- Assume m, A >> $M_{1/2}$

$$\frac{d}{d\ln Q}\begin{bmatrix} m_{H_u}^2 \\ m_{\bar{U}_3}^2 \\ m_{Q_3}^2 \\ A_t^2 \end{bmatrix} = \frac{y_t^2}{8\pi}\begin{bmatrix} 3 & 3 & 3 & 3 \\ 2 & 2 & 2 & 2 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 12 \end{bmatrix}\begin{bmatrix} m_{H_u}^2 \\ m_{\bar{U}_3}^2 \\ m_{Q_3}^2 \\ A_t^2 \end{bmatrix}$$

$$\begin{bmatrix} m_{H_u}^2(Q) \\ m_{\bar{U}_3}^2(Q) \\ m_{Q_3}^2(Q) \\ A_t^2(Q) \end{bmatrix} = \kappa_{12}\begin{bmatrix} 3 \\ 2 \\ 1 \\ 6 \end{bmatrix} e^{12I(Q)} + \kappa_6 \begin{bmatrix} 3 \\ 2 \\ 1 \\ 0 \end{bmatrix} e^{6I(Q)} + \kappa_0 \begin{bmatrix} 1 \\ 0 \\ -1 \\ 0 \end{bmatrix} + \kappa_0' \begin{bmatrix} 0 \\ 1 \\ -1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} m_{H_u}^2(m_{\rm GUT}) \\ m_{\bar{U}_3}^2(m_{\rm GUT}) \\ m_{Q_3}^2(m_{\rm GUT}) \\ A_t^2(m_{\rm GUT}) \end{bmatrix} = m_0^2 \begin{bmatrix} 1 \\ 1+x-3y \\ 1-x \\ 9y \end{bmatrix} \to \begin{bmatrix} m_{H_u}^2(m_W) \\ m_{\bar{U}_3}^2(m_W) \\ m_{Q_3}^2(m_W) \\ A_t^2(m_W) \end{bmatrix} = m_0^2 \begin{bmatrix} 0 \\ \frac{1}{3}+x-3y \\ \frac{2}{3}-x \\ y \end{bmatrix}$$

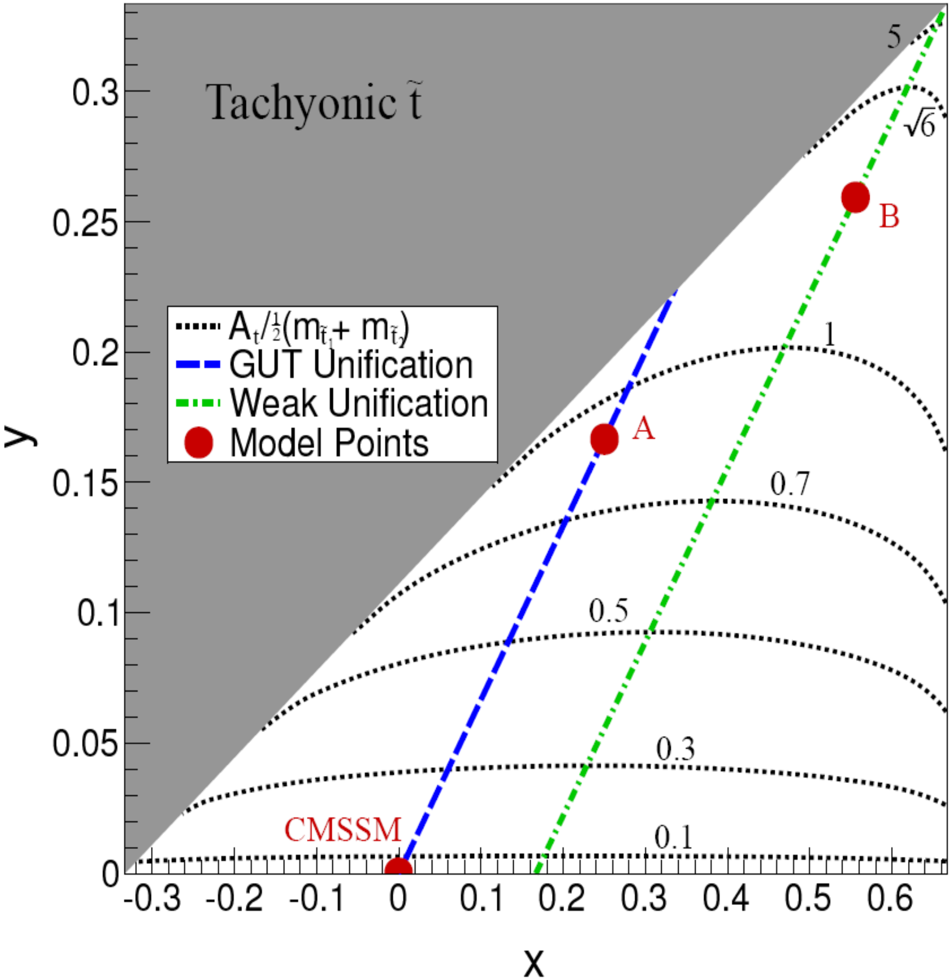
- Focus point if $m_{H_u}^2 : m_{U_3}^2 : m_{Q_3}^2 : A_t^2 = 1 : 1+x-3y : 1-x : 9y$ for any x, y, independent of all other SUSY breaking parameters
- CMSSM is x=y=0: this generalizes CMSSM to other natural possibilities

FP SUSY PARAMETER SPACE

- This analysis contains
  - CMSSM: (x,y) = (0,0)
  - Previous work: y=0
  - GUT models: blue line

- Provides new FP SUSY models with large stop mixing, possibly light stops within reach of LHC

Feng, Sanford (2012)



FP SUSY: NUMERICAL EXPLANATION

- By dimensional analysis, can write m_{Hu} in the following form and see the FP numerically:

$$\begin{aligned} -2m_{Hu}^2(M_z) &= 5.45M_3^2 + 0.0677M_3M_1 - 0.00975M_1^2 \\ &+0.470M_2M_3 + 0.0135M_1M_2 - 0.433M_2^2 \\ &+0.773A_tM_3 + 0.168A_tM_2 + 0.0271A_tM_1 \\ &+0.214A_t^2 \boxed{- 1.31m_{Hu}^2 + 0.690m_{Q_3}^2 + 0.690m_{U_3}^2} \end{aligned}$$

Abe, Kobayashi, Omura (2007)

- In fact, special cases of FP SUSY can be seen in the results of some early (pre-top quark) studies

Alvarez-Gaume, Polchinski, Wise (1983); Barbieri, Giudice (1988)

- The underlying structure is obscured by the numerical calculations, but this is also a way forward to find new FP possibilities, e.g., involving non-universal gaugino masses

Abe, Kobayashi, Omura (2007); Horton, Ross (2009); Younkin, Martin (2012)

IMPLICATIONS

- All scalars may be heavy, but naturalness is preserved
- Naturalness is useful if it leads us toward theories that describe data. Let's assume all scalars are heavy and at the same scale. How does such a theory fare?
- FP SUSY fits all the data so far
  - Higgs boson mass
  - Coupling constant unification and proton decay
  - Natural suppression of EDMs
  - LHC: gluinos with top- and bottom-rich decays
  - Excellent dark matter candidate (mixed Bino-Higgsino)

Feng, Matchev (2000); Feng, Matchev, Wilczek (2000)

OTHER HEAVY STOP MODELS

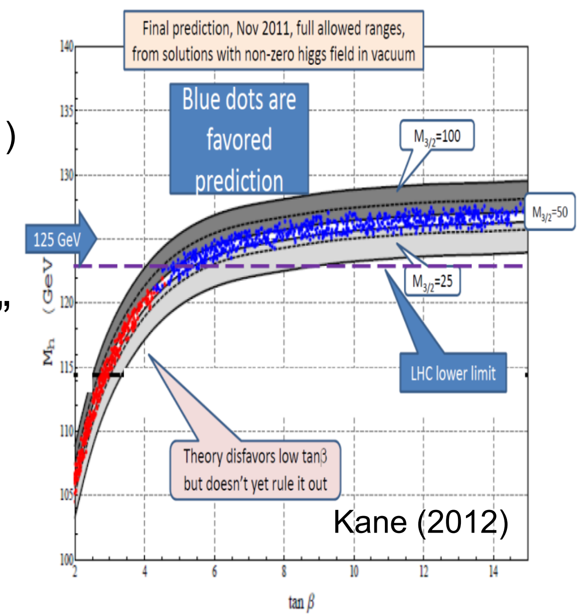
- FP SUSY has naturally heavy stops; they can also be unnaturally heavy
- Split SUSY

  Arkani-Hamed, Dimopoulos (2004); Giudice, Romanino (2004)

  - Extremely heavy scalars; if above 1 PeV, possibly long-lived gluinos, otherwise, phenomenology essentially identical to FP SUSY
  - Manifestly unnatural, motivated by the anthropic principle
- String-inspired Models

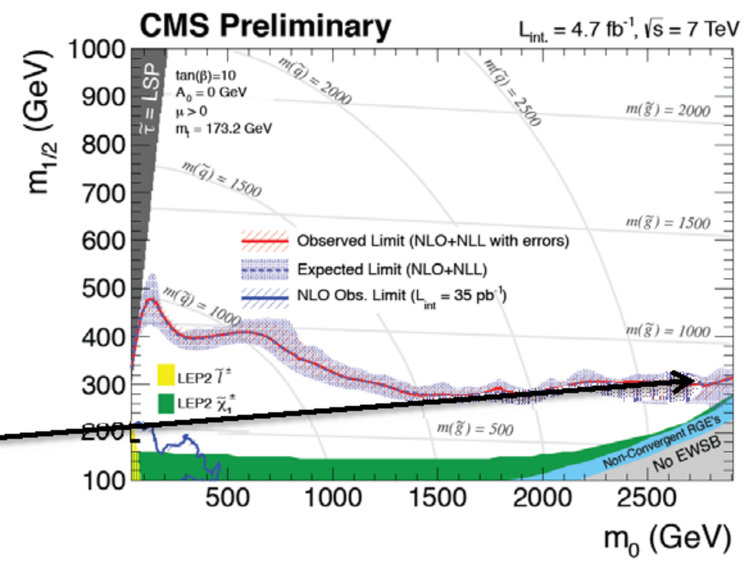
  Feldman, Kane, Kuflik, Lu (2011); Kane, Kumar, Lu, Zheng (2011)

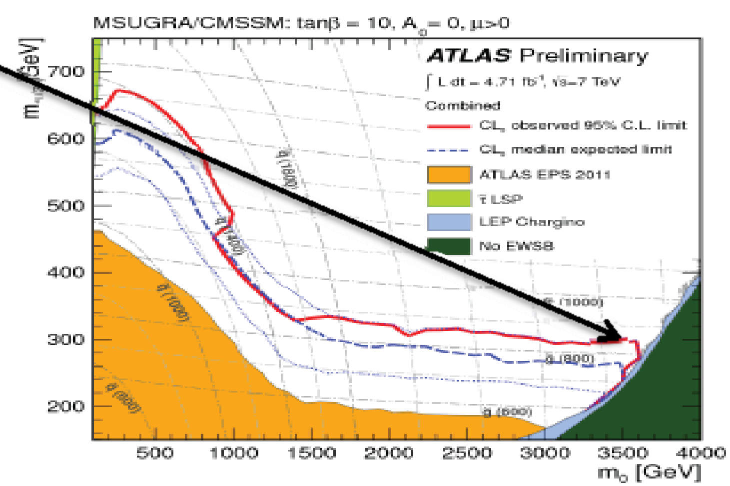
  - "String theory is already or soon being tested in several ways, including correctly predicting the recently observed Higgs boson properties and mass"
  - 30 TeV squarks, phenomenology essentially identical to FP SUSY, but extremely fine-tuned: low μ, but large fine-tuning in m_{Hu}
  - For $\tan\beta > 2$, m_h = 100-127 GeV



LHC

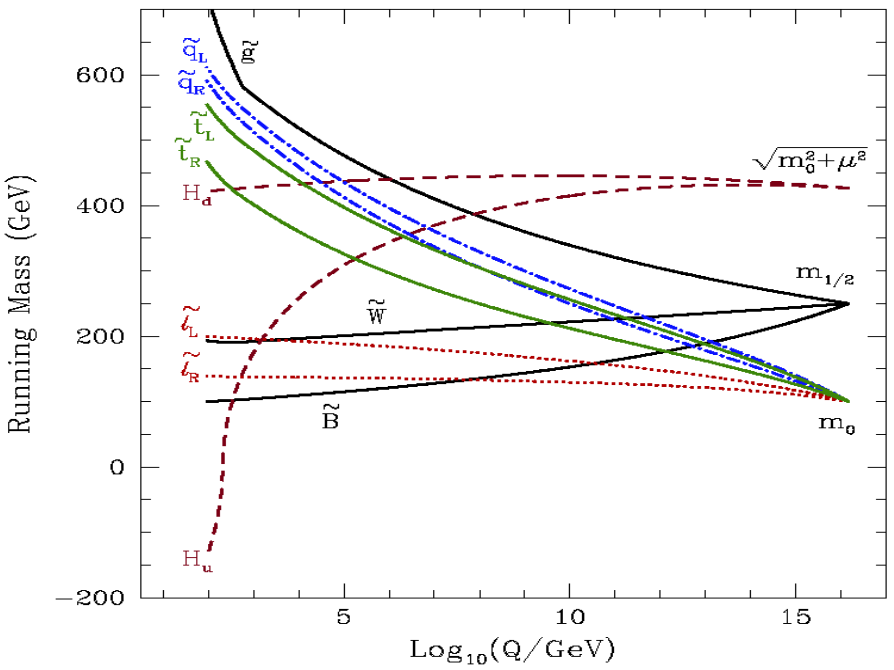
- Commonly heard statements: SUSY is in trouble, CMSSM is excluded
- Actually, the CMSSM has never been more useful and likely to be *effectively* correct
- The region of interest
- Custom-built for analysis: Higgs results, etc. suggest that SUSY is already a simplified model, with just a few parameters (μ, $M_{1/2}$, $\tan\beta$)
- Generalize to (μ, M_1, M_2, M_3, $\tan\beta$); may use Ω to removes one, collider results probably insensitive to $\tan\beta$





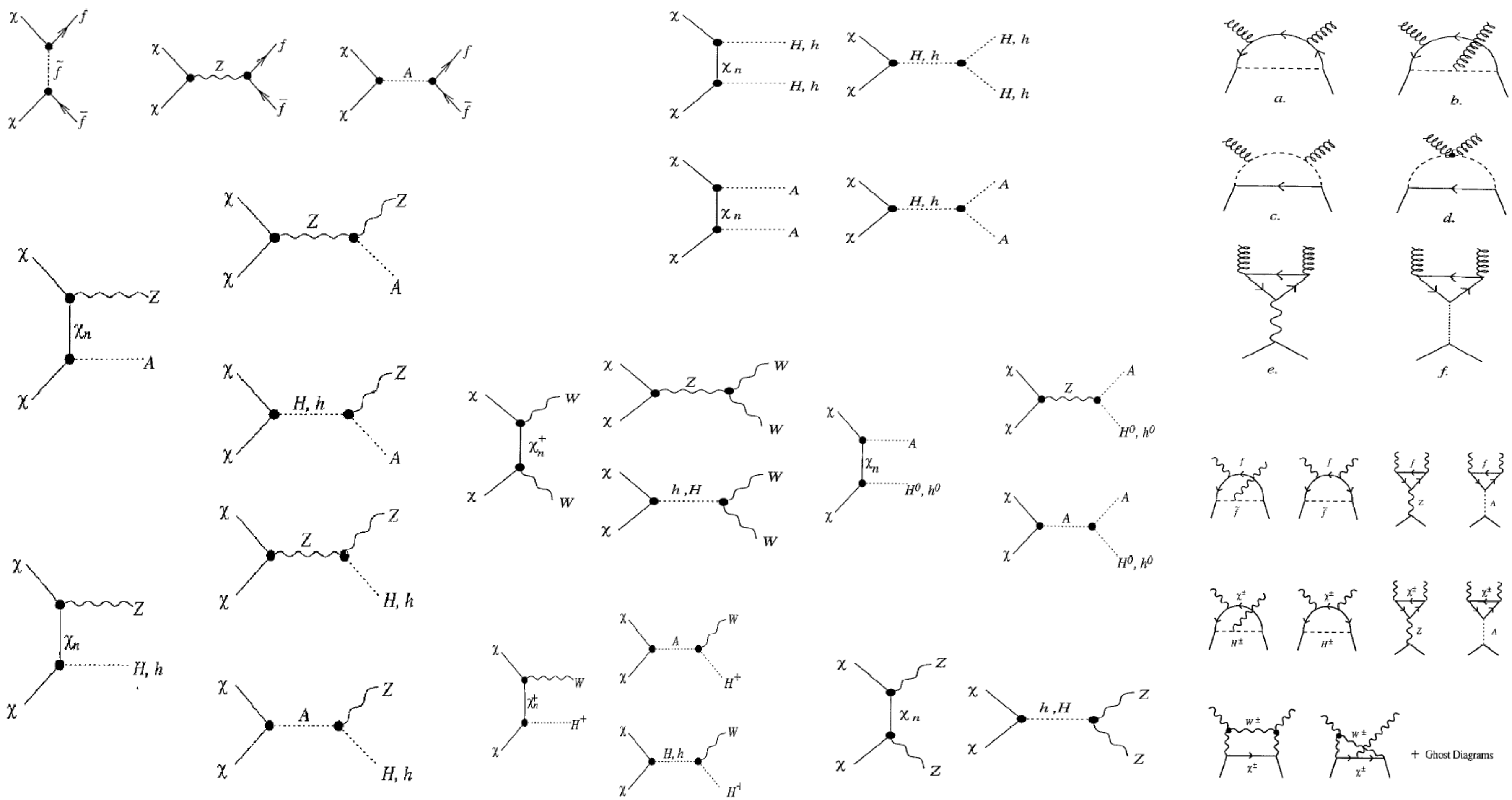
DARK MATTER

- The neutralino is the classic WIMP
  - ~ 50 GeV – 1 TeV
  - weakly-interacting
  - Naturally the lightest standard model superpartner in many models



- So many SUSY models and parameters. Can we say anything interesting? Generically, no.

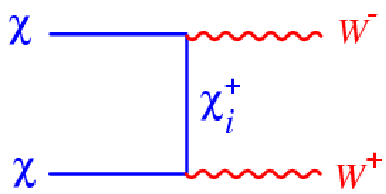
NEUTRALINO DM

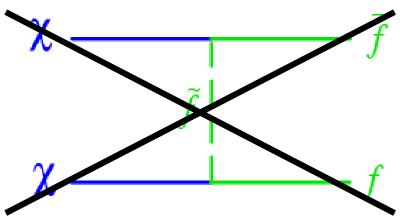


Jungman, Kamionkowski, Griest (1995)

NEUTRALINO DM SIMPLIFIED

- But there essentially two classes of diagrams:

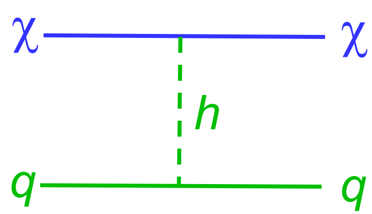




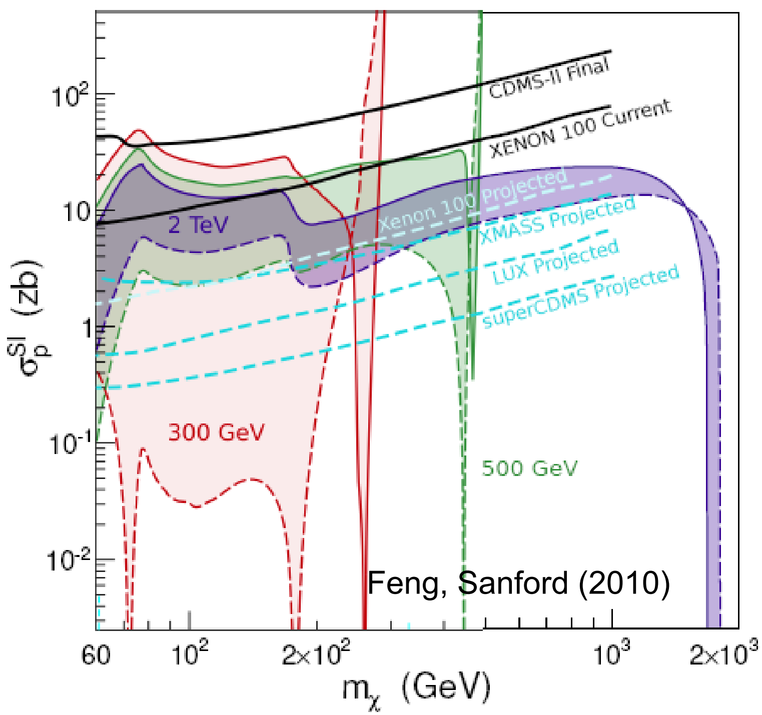
If all scalars are at the same scale, the LHC has eliminated the 2nd one.

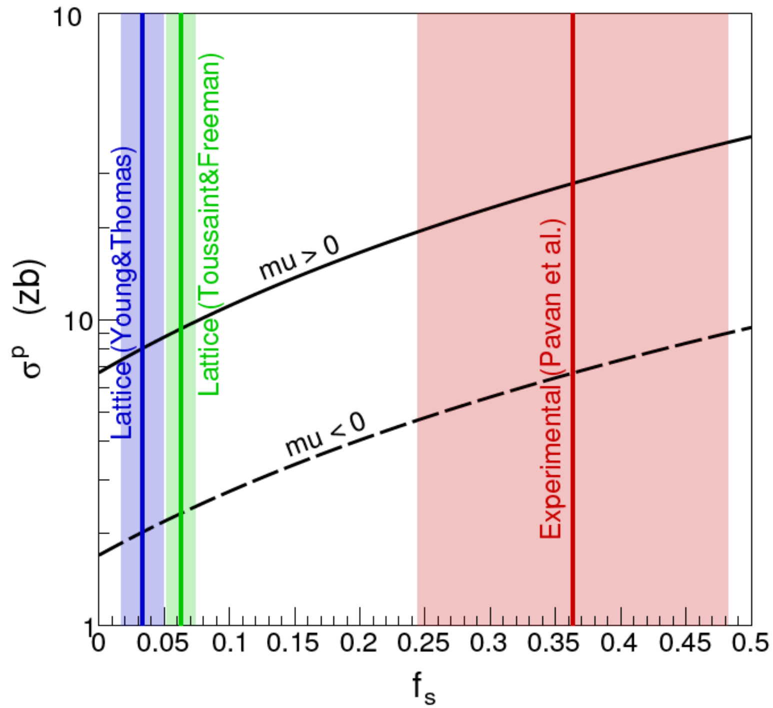
- If $M_2 > M_1$, no special cases (co-annihilation, resonances), this fixes the neutralino's coupling to Ws as a function of its mass.

- But this also fixes the DM scattering cross section as a function of its mass, predictions collapse to a band.



NEUTRALINO DETECTION PROSPECTS





- Direct detection cross section: strong dependence on strange content
- Predicted cross sections not excluded, but very close to current bounds; a signal should be seen soon (e.g., this summer at IDM2012)

SUMMARY

- LHC superpartner null results do not exclude weak-scale SUSY; the main motivations remain intact
  - Naturalness
  - Gauge coupling unification
  - Dark matter
- Higgs boson results are more challenging for naturalness
- Straightforward interpretation of all data so far: multi-TeV scalars, most naturally realized in focus point theories
  - Simple: minimal field content, standard decay modes
  - Expect discovery of SM-like 125 GeV Higgs soon
  - LHC: promising signals include gluinos with t- and b-rich cascade decays, chargino and neutralino searches, stop searches
  - EDMs very promising
  - DM: neutralino WIMPs with large scattering cross section, exciting prospects for direct and indirect detection