Radiative Natural SUSY

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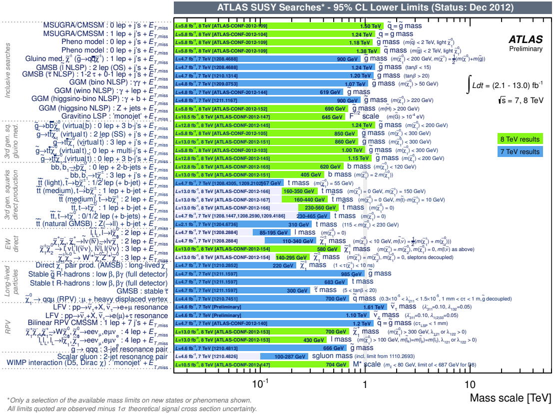
based on work with H. Baer, V. Barger, D. Mickelson, A. Mustafayev and X. Tata

arXiv:1207.3343, 1212.2655

for phenomenology, see Azar Mustafayev's talk at SUSYII section

Outline

What does LHC tell us?



- the little hierarchy problem:
  - *how do multi-TeV values of SUSY model parameters conspire to yield a Z boson(Higgs boson) mass of just 91.2 (125) GeV?*

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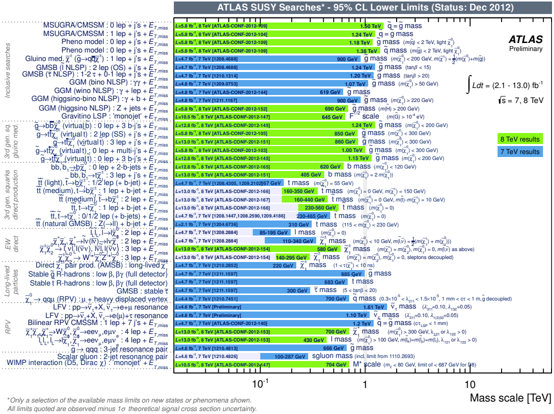
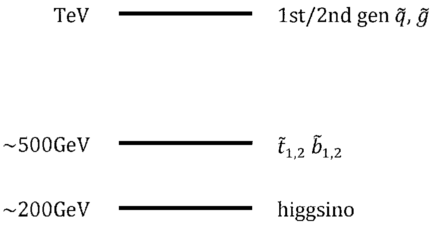


- the little hierarchy problem:
  - *how do multi-TeV scale supersymmetric particles conspire to yield a Z boson(Higgs boson) mass of just 91.2 (125) GeV?*

Natural SUSY



- low electroweak fine-tuning(EWFT)
- sparticles safely beyond LHC search limits
- have great difficulty in accommodating a higgs at 125 GeV

What else does LHC tell us? Higgs !

- Higgs-like resonance at $\sim$ 125 GeV!
- m_h false squarely within the narrow predicted MSSM window!
- $m_{\tilde{t}_1}$, $m_{\tilde{t}_2}$ $\sim$ TeV
- large mixing

- *how does one reconcile low EWFT with such a large value of m_h?*
  - who cares about fine-tuning?
  - compressed spectra: low energy release from the cascade decays to maintain sub-TeV SUSY masses but hide SUSY from LHC
  - add extra fields to the theory. move beyond the MSSM
  - add extra vector-like matter to increase m_h while maintaining the light top squarks.
  - accept some fine-tuning but try to minimize it : effective SUSY
  - **reexamine EWFT and to ascertain if there do indeed exist sparticle spectra within the MSSM that lead to $m_h \sim 125$ GeV while maintaining modest levels of EWFT**

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electroweak fine tuning

- the Z boson mass is given by the minimization of the scalar potential

$$\frac{m_Z^2}{2} = \frac{m_{H_d}^2 + \Sigma_d^d - tan^2\beta(m_{H_u}^2 + \Sigma_u^u)}{tan^2\beta - 1} - \mu^2$$

$$\Sigma_u^u = \left.\frac{\partial \Delta V}{\partial |h_u|^2}\right|_{min}$$

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- Σ_u^u and Σ_d^d include contributions from various particles and sparticles with sizable Yukawa and/or gauge couplings to the Higgs sector

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EWFT definition

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- To obtain a natural value of m_Z, one would expect each term on the RHS C_i to have an absolute value of order $m_Z^2/2$
- define the electroweak fine tuning parameter by

$$\Delta_{EW} \equiv \frac{max_i\,(C_i)}{M_Z^2/2}$$

- low Δ_{EW} means less fine tuning

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Barbieri and Giudice's definition

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$$\Delta_{BG} = max|(a_i/M_Z^2)\partial M_Z^2/\partial a_i|$$

- This measures fractional variation in m_Z^2 due to the fractional variation of a_i
- This measure highly depends on which high-scale parameter set one adopts

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- Δ_{EW} is a purely weak scale relation
- Δ_{EW} measures how well the weak scale SUSY spectra conspire to give a m_Z of 91.2 GeV instead of how well the high scale parameters conspire to do the same thing
- We will impose the Δ_{EW} as a constraint on high scale SUSY models

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How to get low Δ_{EW}?

$$\frac{m_Z^2}{2} \simeq -(m_{H_u}^2 + \Sigma_u^u) - \mu^2$$

- use the two parameter non-universal Higgs mass model (NUHM2) where $m_{H_u}^2(M_{GUT})$ and $m_{H_d}^2(M_{GUT})$ or equivalently, weak scale parameters μ and m_A are chosen independently of matter scalar mass parameters
- the model is completely specified by the following parameter set
  - m_0, $m_{1/2}$, $tan\beta$, μ, m_A and A_0

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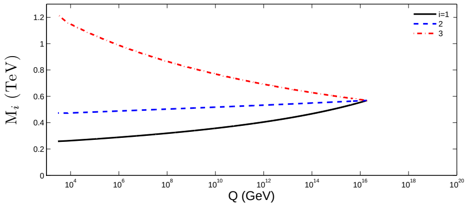

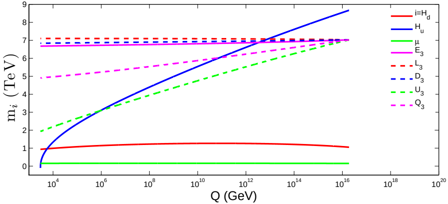

- adjust the GUT scale value of $m^2_{H_u}$ so that it is driven radiatively to $\sim -m^2_Z$ at the weak scale
- Radiative Natural SUSY

radiative corrections from Σ_u^u

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- in the parameter space region where $-m_{H_u}^2 \sim \mu^2 \sim m_Z^2$, the radiative correction terms from Σ_u^u gives the largest contributions to Δ_{EW}
- the largest contribution comes from stop

$$\Sigma_u^u(\tilde{t}_{1,2}) = \frac{3}{16\pi^2} F(m_{\tilde{t}_{1,2}}^2) \times f_t^2$$

$$F(m^2) = m^2(\log(m^2/Q^2) - 1), Q^2 = m_{\tilde{t}_1} m_{\tilde{t}_2}$$

- Natural SUSY requires light stops

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radiative corrections from Σ_u^u and Σ_d^d

- including A_t term

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- as A_t gets large, there is a suppression of $\Sigma_u^u(\tilde{t}_1)$ because of the cancellation
- large A_t also lift up the value of m_h

$$m_h^2 \simeq M_Z^2 \cos^2 2\beta + \frac{3g^2}{8\pi^2}\frac{m_t^4}{m_W^2}[\ln \frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2}(1 - \frac{X_t^2}{12 m_{\tilde{t}}^2})]$$

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- the $\tilde{t}_2$ contribution is suppressed if there is a sizable mass splitting between the two stops

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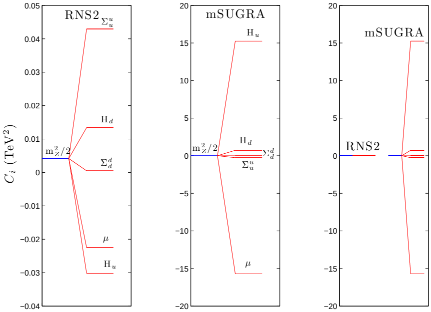
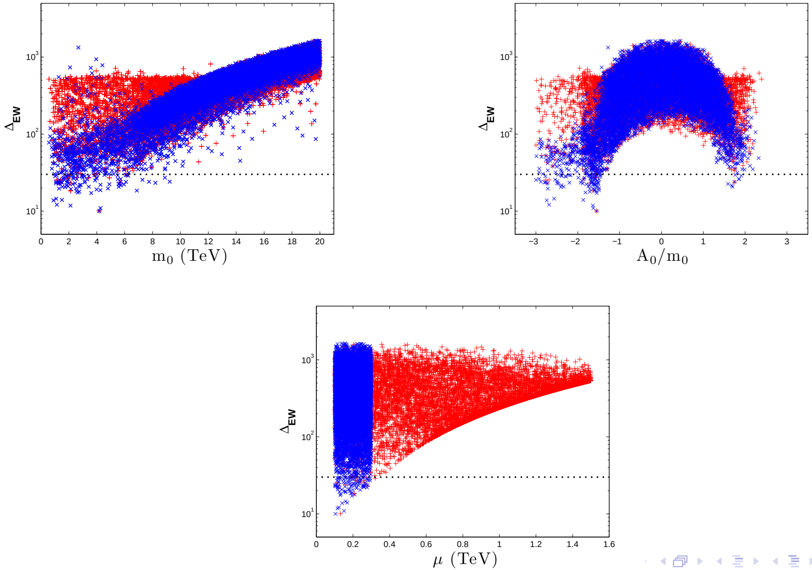
signed contributions to the EWFT

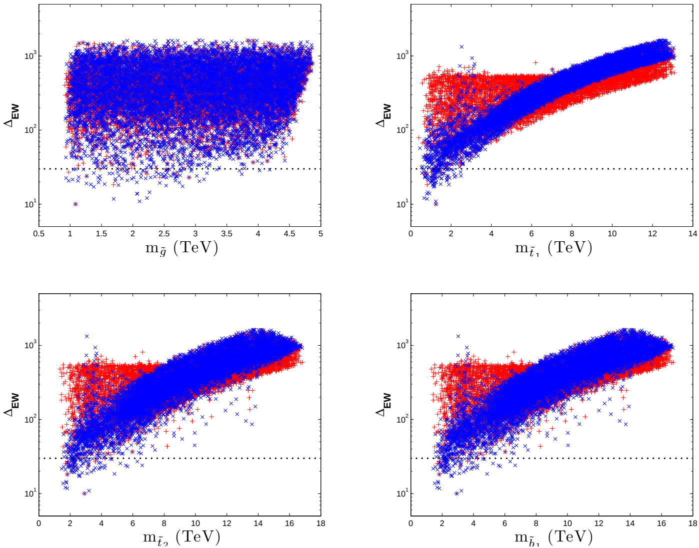
- RNS2 $m_0 = 7025$ GeV, $m_{1/2} = 568.3$ GeV, A_0 = -11426.6 GeV, $tan\beta$ = 8.55, μ = 150 GeV, m_A = 1000 GeV



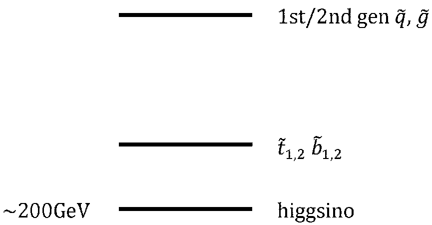
RNS from NUHM2 models



sparticle mass ranges expected from RNS

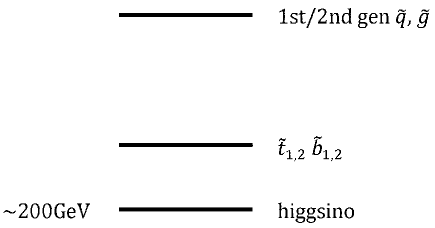


RNS at LHC



- features of radiative natural SUSY
  - light higgsino $\widetilde{W}_1\ \widetilde{Z}_{1,2}$ with masses $\sim |\mu| \sim 100 - 300$ GeV
  - small mass gap of order 10 - 30 GeV, with a possible exception at low $m_{1/2}$ and a larger μ

RNS at LHC



- features of radiative natural SUSY
  - light higgsino $\widetilde{W}_1$ $\widetilde{Z}_{1,2}$ with masses $\sim |\mu| \sim 100 - 300$ GeV
  - small mass gap of order 10 - 30 GeV, with a possible exception at low $m_{1/2}$ and a larger μ

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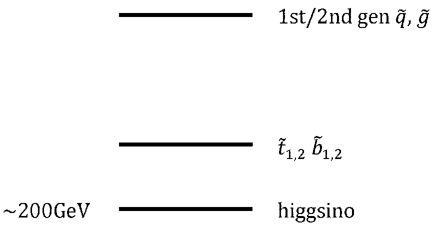

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  - 125 GeV higgs $\surd$
  - low EWFT $\surd$
  - respect LHC search bounds $\surd$
- all you need
  - higgsino like $\tilde{W}_1$ and $\tilde{Z}_{1,2}$, with mass $\sim$ 100 - 300 GeV
  - not too heavy stops : $m_{\tilde{t}_1} \sim$ 1- 2 TeV, $m_{\tilde{t}_2} \sim$ 2-5 TeV
  - large A_t term
  - gluino with mass 1-4 TeV

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