HIGGS BOSONS AT LHC

- Tantalizing hints in the 2011 data

- \( \sim 3\sigma \) (local significance) signals at 126 GeV (ATLAS), 124 GeV (CMS)

- Light Higgs windows: 117.5 – 118.5 GeV and 122.5 – 127.5 GeV

- Consistent with 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

\[ m_h^2 = m_Z^2 v^2 \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}} + \frac{3 m_t^4}{4 \pi^2 v^2} \left( \log \left( \frac{M_S^2}{m_t^2} \right) + \frac{X_t^2}{M_S^2} \left( 1 - \frac{X_t^2}{12 M_S^2} \right) \right) \]

• But naturalness requires light top squarks. This tension motivates reconsideration of many SUSY models
GOLDILOCKS SUSY

Let’s reconsider gauge-mediated supersymmetry breaking: a beautiful framework that suppresses flavor violation

In GMSB, Higgs is a special problem: $X_t$ is small $\rightarrow$ heavy top squarks

But GMSB also has other difficulties:

EDMs
- GMSB suppresses flavor, but not CP violation (e.g., from $\mu$, $M_{1/2}$ phase difference)
- Electron EDM $\rightarrow$ selectrons $> 2$ TeV, GMSB relations $\rightarrow$ squarks $> 5$ TeV

Dark Matter
- No WIMP miracle: neutralinos decay to gravitinos
- keV gravitino DM not viable: $\Omega_G h^2 \approx 0.1 \ (m_G / 80 \text{ eV}),$ but Lyman-$\alpha \rightarrow m_G > 2$ keV

Feng, Smith, Takayama (2007); Feng, Surujon, Yu (2012)
Kitano, Low (2005); Ibe, Kitano (2007)

Draper, Meade, Reece, Shih (2011); Evans, Ibe, Shirai, Yanagida (2012)

Viel et al. (2006); Seljak et al. (2006)
MINIMAL GMSB

• Let’s simply close our eyes, take all the data at face value, and see where it leads us. For simplicity, consider minimal GMSB

• 5 parameters: $m_\tilde{G}$, $\Lambda$, $\tan\beta$, $N_5$, $\text{sign}(\mu)$; set $N_5 = 1$, $\mu > 0$

$$m_\tilde{G} = \frac{F}{\sqrt{3} M_\ast}$$

$$\Lambda = \frac{F}{M_m}$$

$$m_j^2(M_m) = 2 N_5 \Lambda^2 \sum_{a=1}^{3} C_a^f \left[ \frac{\alpha_a(M_m)}{4\pi} \right]^2$$

$$M_a(M_m) = N_5 \Lambda \frac{\alpha_a(M_m)}{4\pi}$$
HIGGS AND EDMS

- Higgs Mass

- Electron EDM

- The Higgs and EDM constraints both point to the same region of parameter space

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Feng 6
• Such large masses $\rightarrow$ TeV neutralinos are vastly over-produced in the early universe with $\Omega h^2 \sim 100$. But then they decay to GeV gravitinos that have the right relic density!

**Neutralino $\Omega$**

- $\Omega h^2 = 300$
- $\Omega h^2 = 100$
- $\Omega h^2 = 30$
- $\tan \beta = 10$
- $m_h = 125$ GeV

**Gravitino $\Omega$**

- $0.01, 0.1, 0.2$ Mpc
- $0.4, 0.8$ Mpc

• Why “Goldilocks”:
  - Gravitinos are light enough to solve the flavor problem
  - Gravitinos are heavy enough to be all of DM
GOLDILOCKS COSMOLOGY

• Dark matter is non-thermal gravitinos from late decays

• Several constraints
  – Relic density
    \[ \Omega \tilde{G} h^2 = \left( \frac{m_{\tilde{G}}}{m_\chi} \right) \Omega_\chi h^2 \]
  – Decays before BBN (1 s)
    \[ \tau_\chi \approx \frac{48\pi m_{\tilde{G}}^2 M_\mu^2}{m_\chi^3} \approx 0.02 \sec \left( \frac{m_{\tilde{G}}}{1 \text{ GeV}} \right)^2 \left( \frac{2 \text{ TeV}}{m_\chi} \right)^5 \]
  – Cold enough (\( \lambda_{FS} < 0.5 \text{ Mpc} \))
    \[ \lambda_{FS} \approx 1.0 \text{ Mpc} \left[ \frac{u_\tau^2 \tau}{10^6 \text{ s}} \right]^{1/2} \left[ 1 - 0.07 \ln \left( \frac{u_\tau^2 \tau}{10^6 \text{ s}} \right) \right] \]

• All constraints point to the same region of parameter space
• Naturalness? Perhaps focus point SUSY

Agashe (1999)
SUMMARY

• LHC Higgs results motivate a re-analysis of BSM models

• If the Higgs signal persists, Goldilocks SUSY will be among the simplest explanations
  – Minimal field content, standard cosmology
  – Simultaneously fits Higgs mass, flavor, EDMs
  – Cosmology: non-thermal GeV gravitino DM from late decays

• Implications
  – SM-like Higgs will be discovered at ~ 125 GeV
  – No superpartners at the LHC; no direct, indirect DM detection
  – EDMs just around the corner
  – Warm DM with $\lambda_{FS} \sim 0.1 – 0.5$ Mpc