Compressed EWinos: a SUSY scenario*

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*For recent review of SUSY in light of theory/experiment developments see arXiv:2002.03013

Compressed EWinos are (IMO) the most highly motivated avenue to SUSY discovery at LHC!

Practical naturalness: an observable O is natural if
all independent contributions to O are comparable to or less than O

$$\text{unnatural} \equiv \text{implausible}$$

[This is how naturalness was used e.g. by Gaillard and Lee to predict m(c) based on Delta m(K)]

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

radiatively driven to small negative

suppressed by loop factors

μ-term:

- SUSY conserving MSSM μ term comes from sol'n to SUSY μ problem
- feeds mass to W, Z, h and higgsinos
- $\mu \sim 100 - 350$ GeV

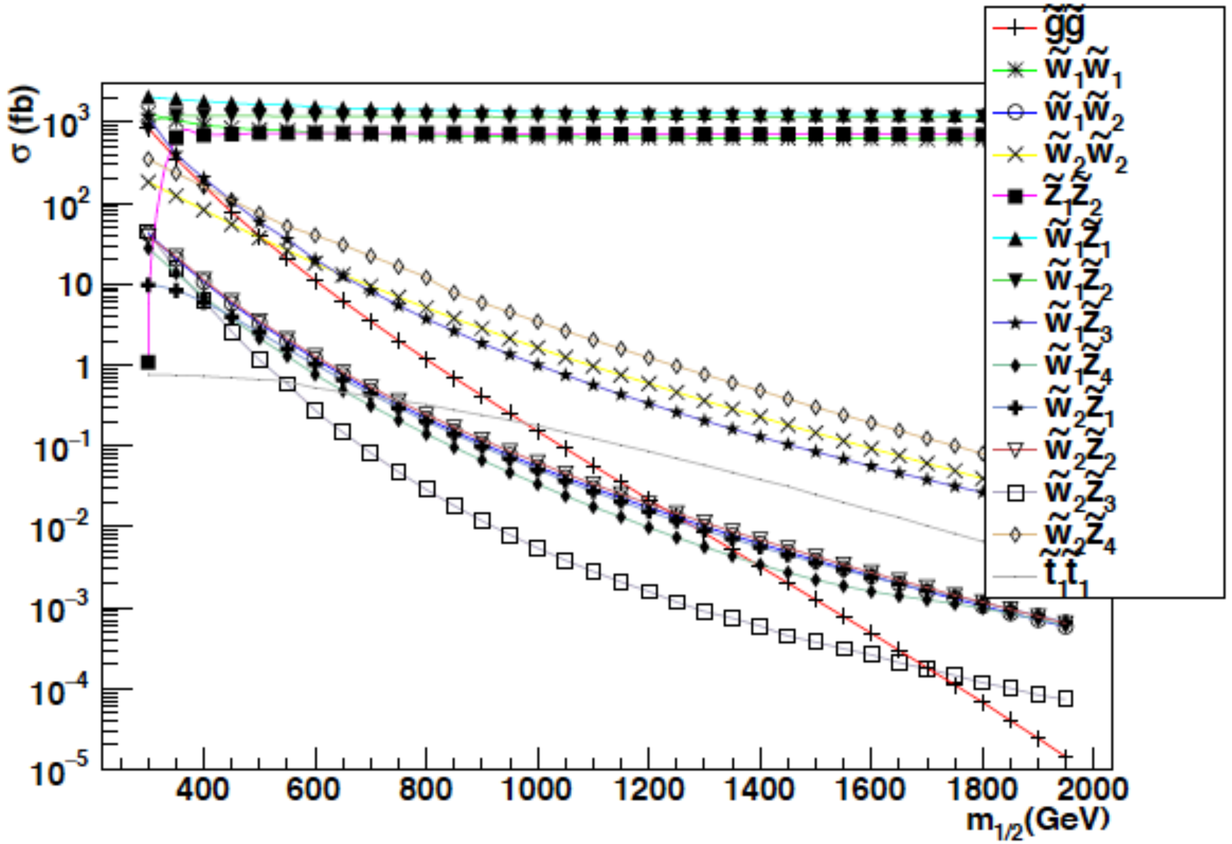
$$m_{\tilde{\chi}_{1,2}^0},\ m_{\tilde{\chi}_1^\pm} \sim \mu \sim 100 - 350 \text{ GeV}$$

While mu~100-300 GeV, soft breaking terms generally selected to large values (string theory landscape)

Thus, light compressed higgsinos may be only SUSY particles accessible to LHC searches

compressed higgsinos

$$pp \rightarrow \tilde{\chi}_1^0\tilde{\chi}_2^0,\ \tilde{\chi}_1^\pm\tilde{\chi}_2^0$$
$$\tilde{\chi}_2^0 \rightarrow \ell^+\ell^-\tilde{\chi}_1^0$$



seems most promising?

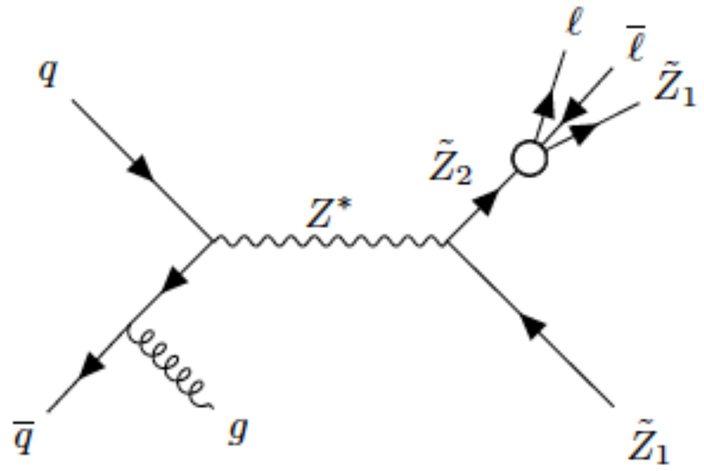
HB, Barger, Huang, arXiv:1107.5581;
HB, Barger, Huang, Mickelson, Mustafayev, Tata
arXiv:1310:4858

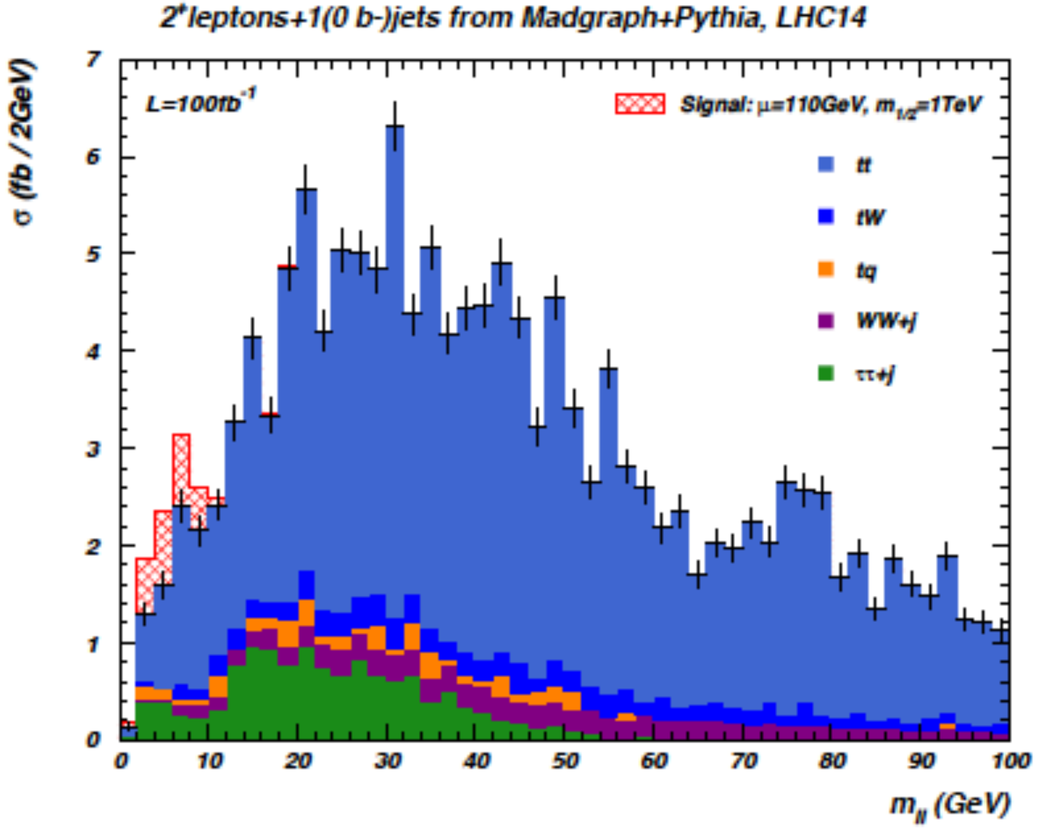
OS/SF dileptons, MET very soft, most reaction energy -> 2m(LSP)

Can ATLAS, CMS create a soft dilepton trigger?

Can gain harder leptons, harder MET by requiring ISR hard jet radiation

Z. Han, Kribs, Martin, Menon, arXiv:1401.1235
HB, Mustafayev, Tata, arXiv:1409.7058
C. Han, D. Kim, Munir, Park, arXiv:1502.03734
HB, Barger, Savoy, Tata,arXiv:1604.07438



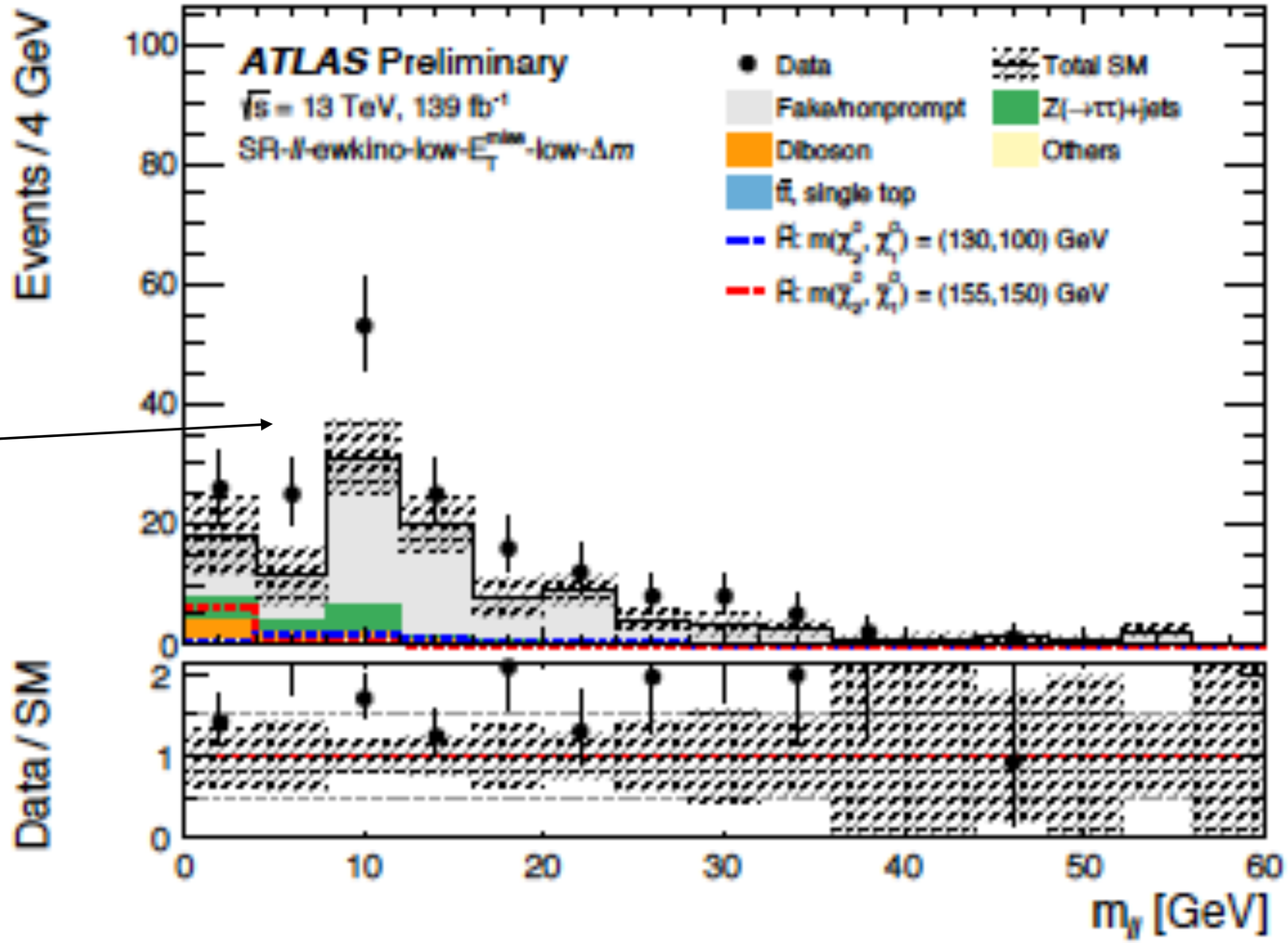


After $m^2_{\tau\tau} < 0$ cut:

b-jet rejection

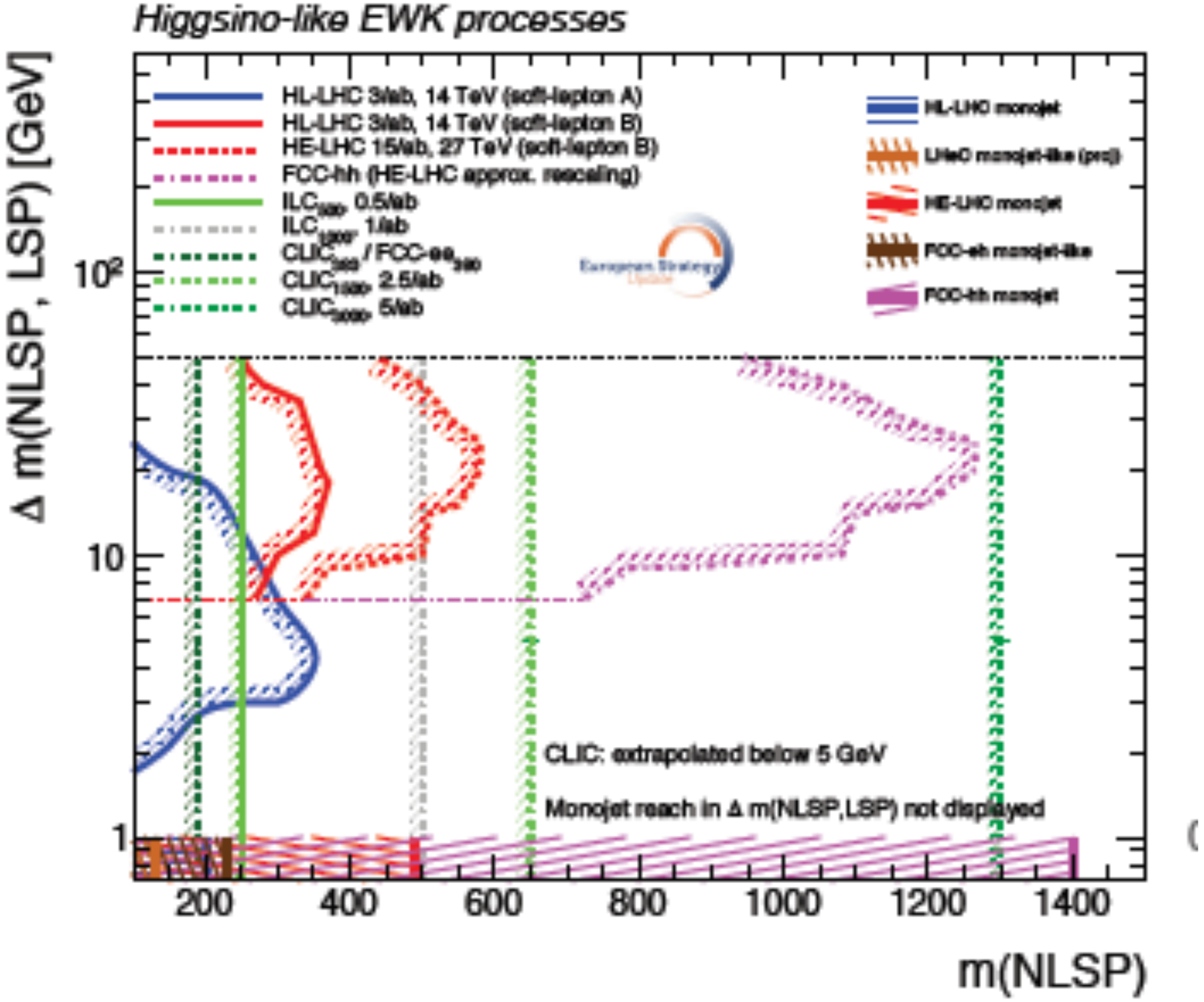
What does data say?

expect excess here



*will this excess build with more data?
*what does CMS have?
*how to improve?

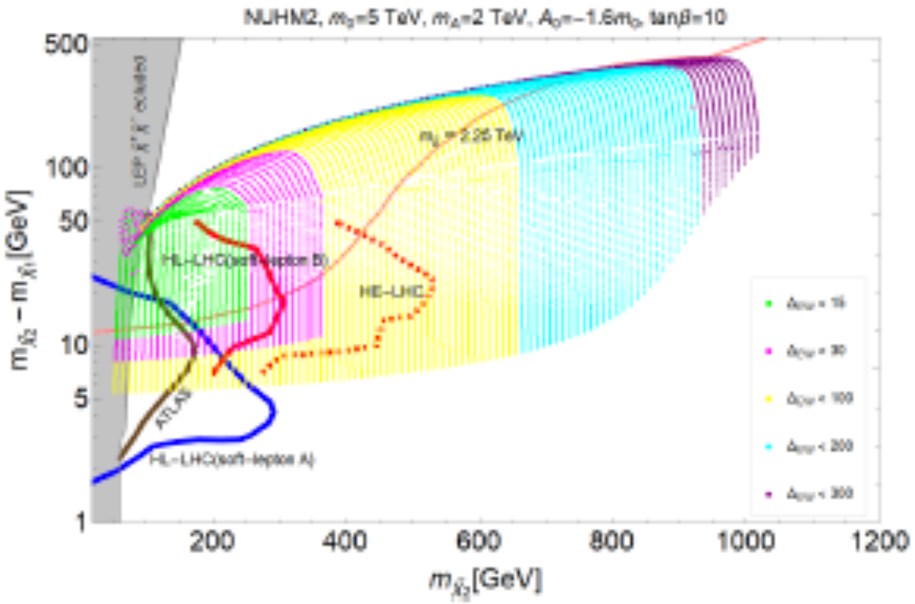
ATLAS-CONF-2019-014

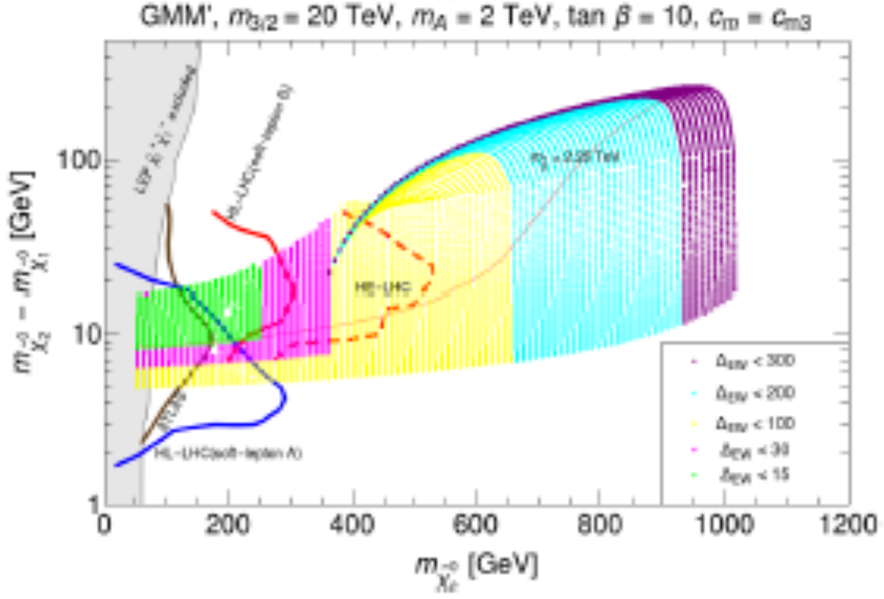


projected reach ATLAS (blue), CMS (red) at HL-LHC: can they do better?

Expected region of discovery plane from naturalness:

HB, Barger, Salam, Sengupta, Tata, arXiv:2007.09252





gravity-mediation, NUHM2

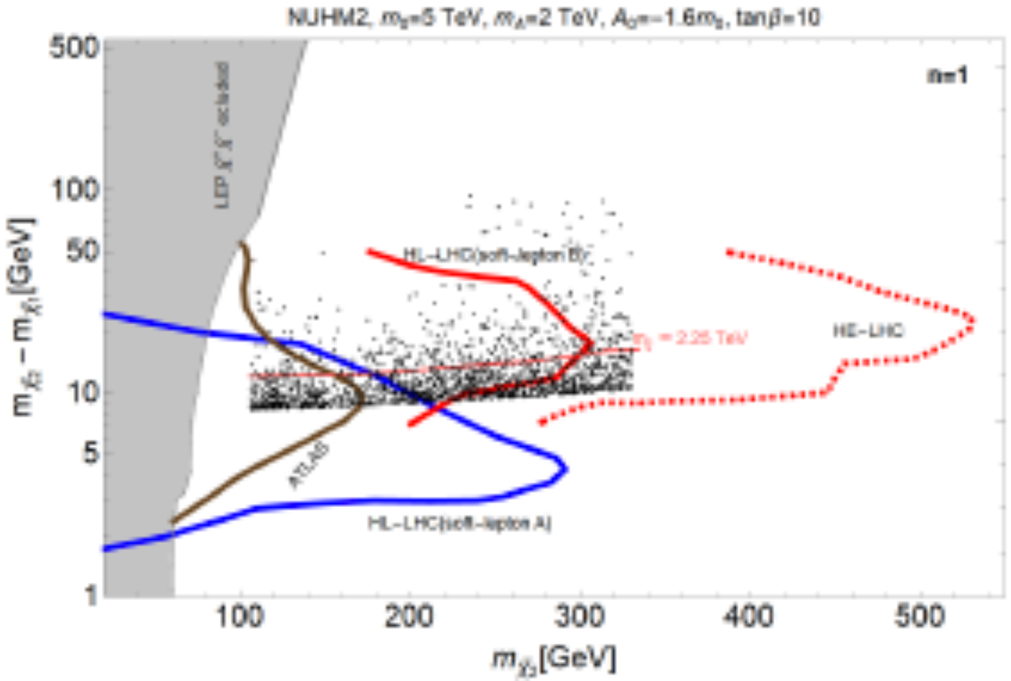
favored:

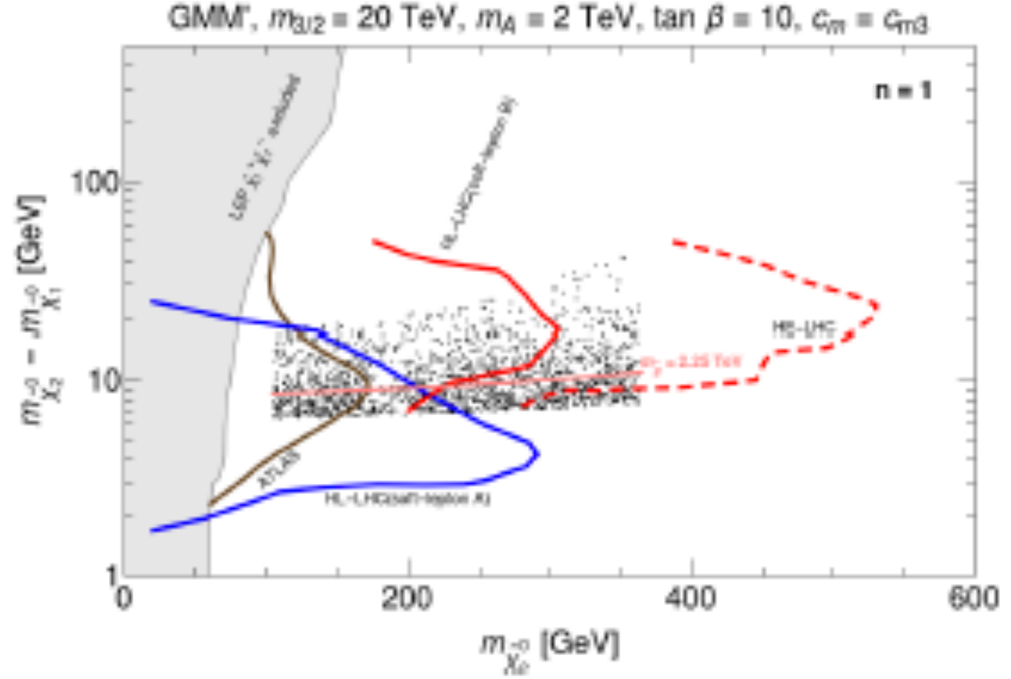
$$m_{\tilde{\chi}_2^0} \sim 100 - 350 \text{ GeV with } \Delta m \sim 5 - 10 \text{ GeV}$$

For mass gaps <5 GeV, then m(gauginos) becomes very high: violates naturalness

natural mirage mediation

green, magenta are natural





Expected region from string landscape:
high density of dots is more stringy natural

landscape statistical pull on m(gaugino) to large values
but not so large that weak scale becomes
too big in pocket universes

$$m_{\tilde{\chi}_2^0} \sim 100 - 350 \text{ GeV with } \Delta m \sim 5 - 10 \text{ GeV}$$

For mass gaps decreasingly below 5 GeV,
motivation becomes weaker:
(but one never knows)

Conclusions from theory side

1. Compressed higgsino search is most lucrative avenue towards SUSY discovery at LHC

2. Most promising parameter space:

$$m_{\tilde{\chi}_2^0} \sim 100 - 350 \text{ GeV with } \Delta m \sim 5 - 10 \text{ GeV}$$

3. Smaller mass gaps worth doing (but less motivated)

4. Is signal already emerging? (ATLAS excess)

5. What can we do to improve?
   - Examine all distributions
     - Soft dimuon trigger?

6. Need more data: excellent target for Run 3/HL-LHC!