SUSY BENCHMARKS FOR SNOWMASS 2013

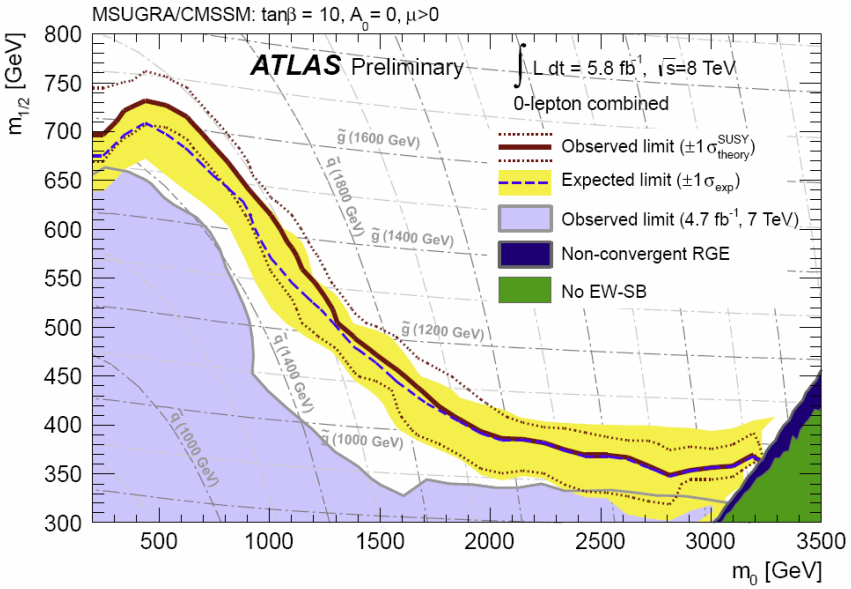
Jonathan Feng with Patrick Draper, Jamie Gainer, Philipp Kant, Konstantin Matchev, Stefano Profumo, David Sanford, and others

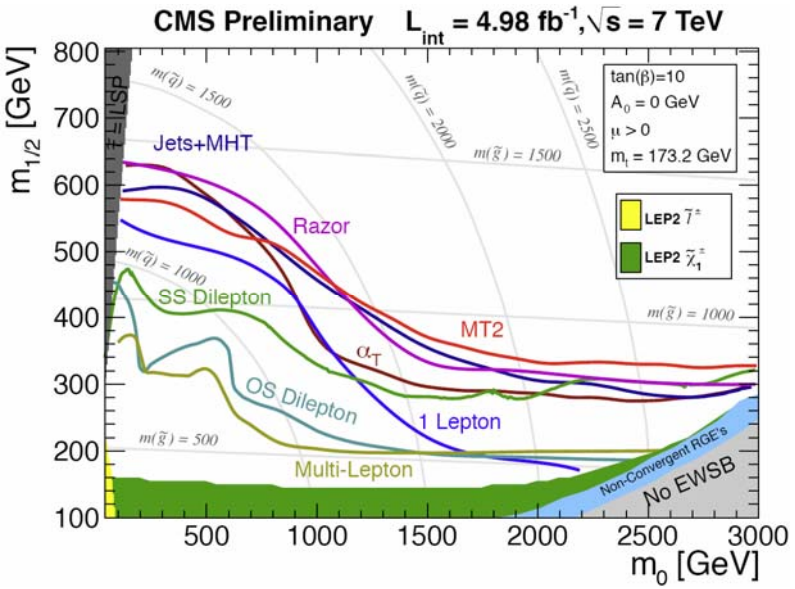
Energy Frontier BSM Meeting, UC Irvine, 14 January 2013

MINIMAL SUPERGRAVITY

- Limitations
  - Includes many unjustified assumptions
  - Does not include important cases
- Virtues
  - Accommodates key motivations for SUSY: radiative EWSB, gauge coupling unification, dark matter
  - Additional assumptions are reasonable if not taken too literally (e.g., scalar unification)
  - Simple: m_0, $M_{1/2}$, $\tan\beta$, A_0, sign(μ)
  - Easy to characterize points
  - Easy to characterize slopes, these end, important for comparing current and far future colliders
  - Widely used previously and currently; facilitates comparisons to other studies, avoids re-inventing the wheel

EXPERIMENTAL STATUS

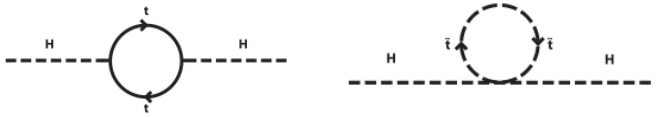




- $m_{\tilde{g}} = m_{\tilde{q}}$: m > 1.5 TeV ; $m_{\tilde{g}} \ll m_{\tilde{q}}$: $m_{\tilde{g}}$ > 1 TeV
- LHC has made tremendous progress in excluding regions of mSUGRA parameter space; at the same time, these regions were already disfavored for other reasons

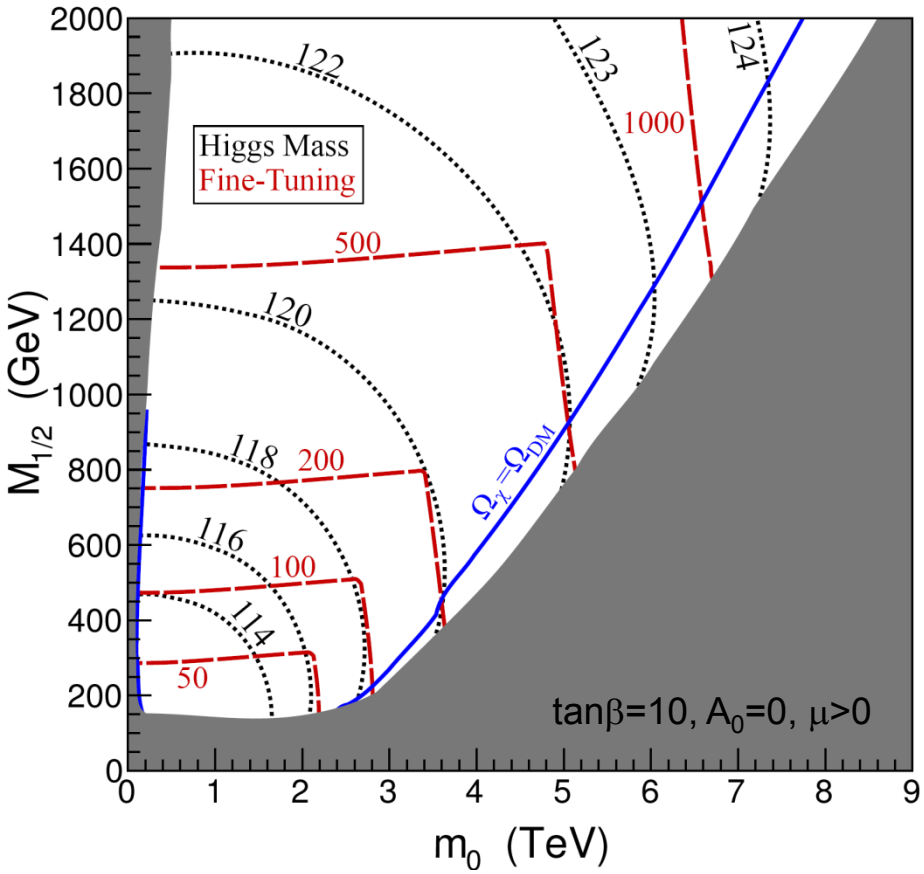
HIGGS BOSON

- 40,000 foot view: great for SUSY
- Closer view: challenging for SUSY: need large radiative corrections



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

  - Expt. uncertainties ~ 1 GeV
  - Theory uncertainties ~ few GeV
- Many regions excluded by LHC were already excluded by (even the LEP 2!) Higgs mass bound



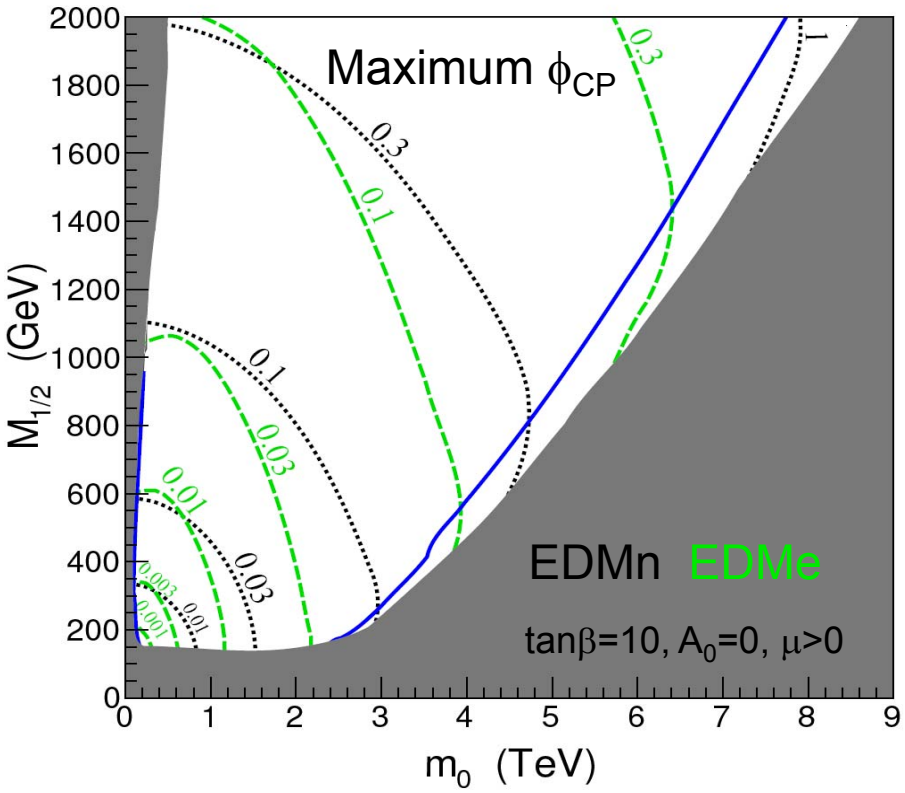
Feng, Matchev, Sanford (2011)

ELECTRIC DIPOLE MOMENTS

- Low-energy constraints are famous problems for new physics
- Flavor violation eliminated by fiat in mSUGRA, but EDMs are flavor-conserving, CP-violating, not eliminated by scalar degeneracy
- Stringent bounds on electron and neutron EDMs

  Regan et al. (2002); Baker et al. (2006)
- O(1) phases → multi-TeV scalars
- Many regions excluded by LHC were already disfavored by EDMs

$$d_f = \frac{1}{2} e\, m_f\, g_2^2\, |M_2 \mu|\, \tan\beta\, \sin\phi_{\rm CP}\, K_C(m^2_{\tilde{f}_L}, |\mu|^2, |M_2|^2)$$



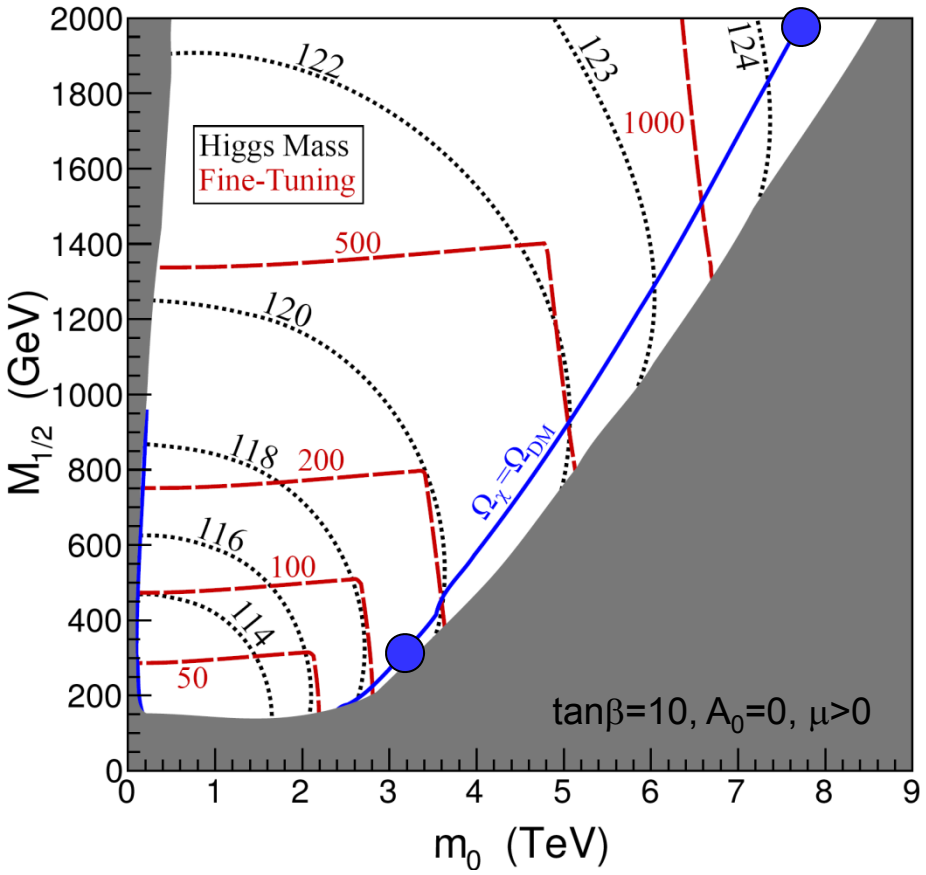
Feng, Matchev, Sanford (2011)

FOCUS POINT POINTS AND SLOPE

- Includes
  - 150 GeV Bino-Higgsino DM (near FP region)
  - 1 TeV pure Higgsino DM (far FP region)
  - And interpolates between these

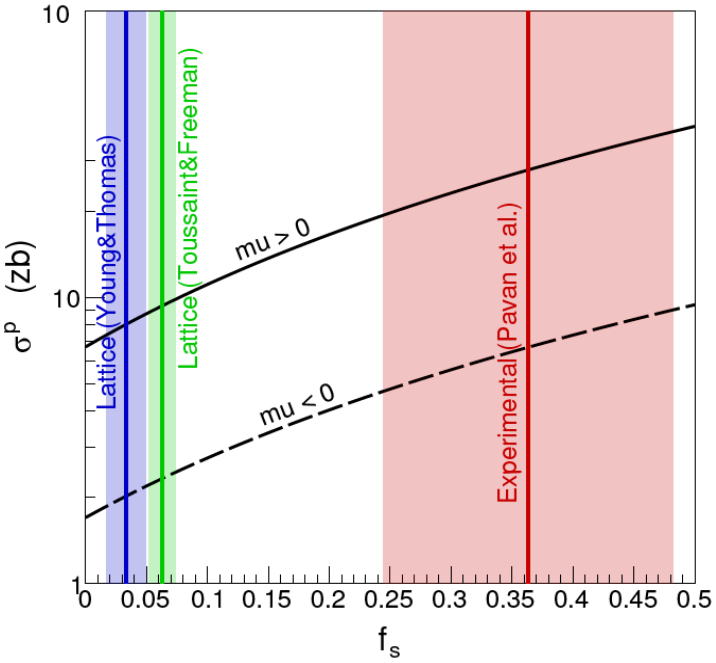
- $A_0 = 0 \rightarrow m_h \sim 120\text{-}126$ GeV. Refine this: for fixed tanβ , vary $M_{1/2}$, use (Ω_{DM}, m_h) to determine (m_0, A_0)

- sign(μ) free or determined by σ_{DM}



FOCUS POINT STATUS

- Reports of death of FP SUSY are greatly exaggerated, result from
  - Redefining mSUGRA to have fewer free parameters
  - Assuming a large strange quark content of the proton
  - Considering only $\mu > 0$
  - Requiring SUSY to fix $(g-2)_\mu$
  - Combinations of the above



- In fact, FP SUSY is more motivated now than ever before as a simple representative of theories with all scalars hierarchically heavy

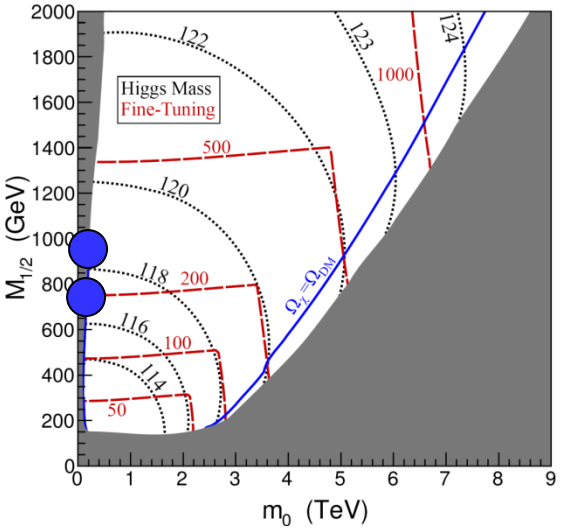
BINO-STAU CO-ANNIHILATION POINTS AND SLOPE

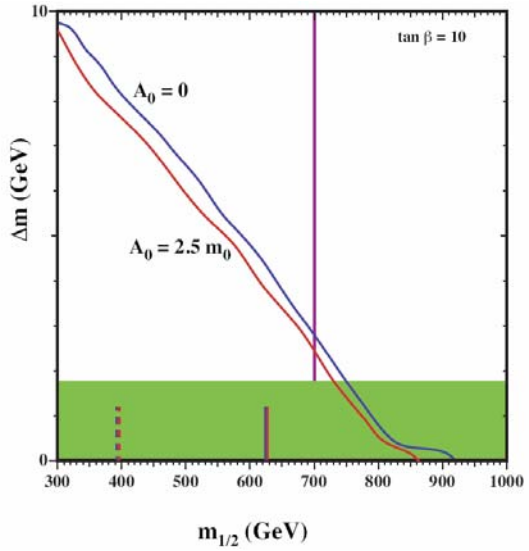
- Includes
  - 1.4 TeV squarks (near co-annihilation region)
  - 2 TeV squarks (far co-annihilation region)
  - And interpolates between these

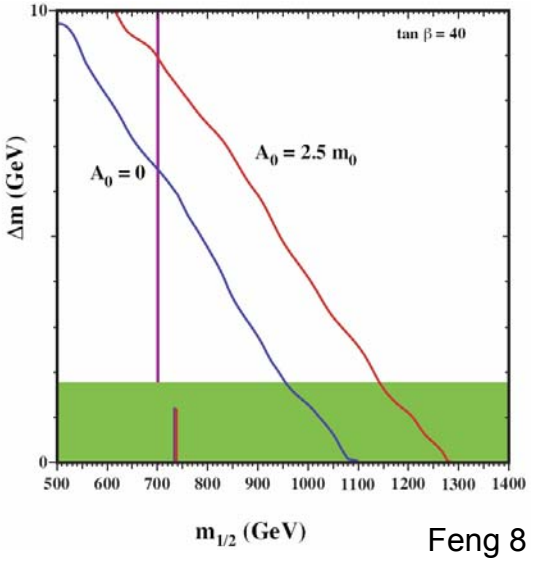
- Far co-annihilation region has metastable sleptons

- Region pinches off; LHC will be sensitive to this whole region

Citron, Ellis, Lou, Marrouche, Olive, de Vries (2012)





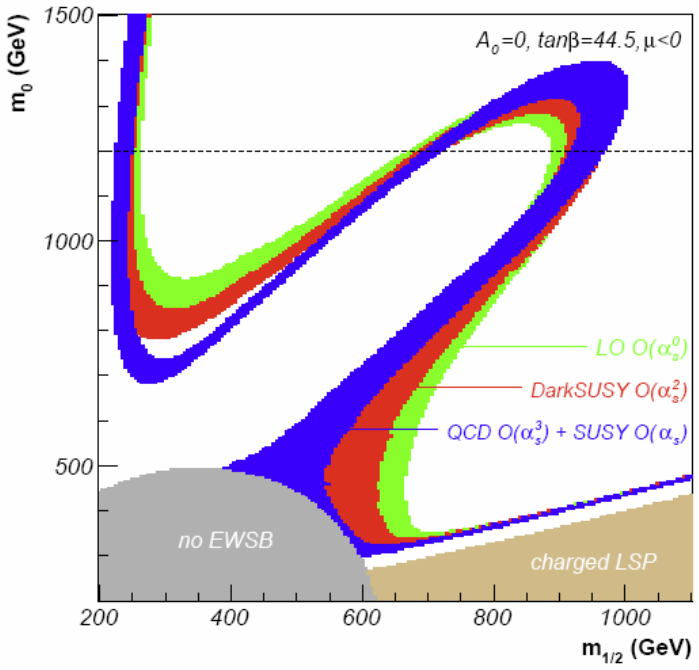


OTHER POINTS AND SLOPES

- mSUGRA also accommodates other cosmologically-motivated models

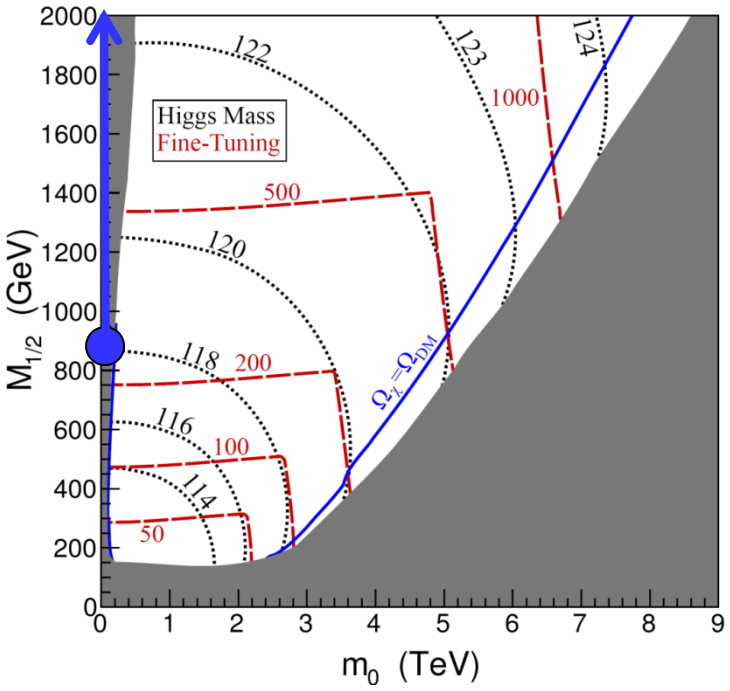
A funnel (large tanβ)

Herrmann, Klasen (2007)



superWIMP $\tilde{G}$ DM (m_0 = 0)

Feng, Rajaraman, Smith (2005)



FUTURE WORK

- Discuss mSUGRA, pMSSM, other benchmarks, and their projected implications; not all benchmarks serve all purposes
- Determine which qualitative features merit further work (Bino-Higgsino DM, Higgsino DM, Bino-stop co-annihilation, Bino-squark co-annihilation, superWIMP with slepton NLSP, superWIMP with sneutrino NLSP, compressed spectra,…)
- Determine where mSUGRA and other benchmarks are similar, avoid duplicating work
- For the mSUGRA benchmarks deemed worthy of further work, agree on the format for defining points and slopes (high energy vs. low energy, etc.)