

Combined searches for light supersymmetry at the LHC with GAMBIT

Pat Scott
on behalf of the GAMBIT Collaboration



Based on GAMBIT Collab, EPJC (2019), [arXiv:1809.02097](https://arxiv.org/abs/1809.02097)

gambit.hepforge.org



GAMBIT: The Global And Modular BSM Inference Tool

gambit.hepforge.org

EPJC 77 (2017) 784

arXiv:1705.07908

- Extensive model database – not just SUSY
- Extensive observable/data libraries
- Many statistical and scanning options (Bayesian & frequentist)
- *Fast* LHC likelihood calculator
- Massively parallel
- Fully open-source
- Fast definition of new datasets and theories
- Plug and play scanning, physics and likelihood packages



Members of:

ATLAS, Belle-II, CLiC, CMS, CTA, *Fermi*-LAT, DARWIN, IceCube, LHCb, SHiP, XENON

Authors of:

DarkSUSY, DDCalc, Diver, FlexibleSUSY, gamlike, GM2Calc, IsaTols, nulike, PolyChord, Rivet, SoftSUSY, SuperISO, SUSY-AI, WIMPSim

Recent collaborators:

Peter Athron, Csaba Balázs, Ankit Beniwal, Sanjay Bloor, Torsten Bringmann, Andy Buckley, José Eliel Camargo-Molina, Marcin Chrzęszcz, Jonathan Cornell, Matthias Danninger, Joakim Edsjö, Ben Farmer, Andrew Fowlie, Tomás E. Gonzalo, Will Handley, Sebastian Hoof, Selim Hotinli, Felix Kahlhoefer, Anders Kvellestad, Julia Harz, Paul Jackson, Farvah Mahmoudi, Greg Martinez, Are Raklev, Janina Renk, Chris Rogan, Roberto Ruiz de Austri, Pat Scott, Patrick Stöcker, Aaron Vincent, Christoph Weniger, Martin White, Yang Zhang

40+ participants in 11 experiments and 14 major theory codes



We are interested in the **electroweakinos**:

neutralinos ($\chi_1^0, \chi_2^0, \chi_3^0, \chi_4^0$) + charginos (χ_1^\pm, χ_2^\pm)

- All other superpartners & new Higgses decoupled
 - SM-like Higgs mass set to 125.09 GeV
- 4 parameters: $M_1, M_2, \mu, \tan\beta$

$$\chi^0 = (\tilde{B}, \tilde{W}^0, \tilde{H}_u^0, \tilde{H}_d^0)$$

$$\chi^\pm = (\tilde{W}^\pm, \tilde{H}^\pm)$$

$$M_N = \begin{bmatrix} M_1 & 0 & -\frac{1}{2}g'v c_\beta & \frac{1}{2}g'v s_\beta \\ 0 & M_2 & \frac{1}{2}g v c_\beta & -\frac{1}{2}g v s_\beta \\ -\frac{1}{2}g'v c_\beta & \frac{1}{2}g v c_\beta & 0 & -\mu \\ \frac{1}{2}g'v s_\beta & -\frac{1}{2}g v s_\beta & -\mu & 0 \end{bmatrix}$$

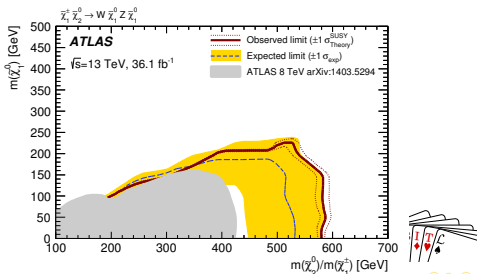
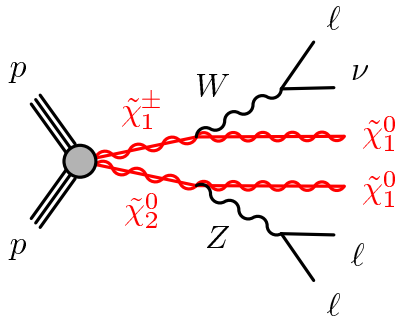
$$M_C = \begin{bmatrix} 0 & X^T \\ X & 0 \end{bmatrix}$$

$$X = \begin{bmatrix} M_2 & \frac{g v s_\beta}{\sqrt{2}} \\ \frac{g v c_\beta}{\sqrt{2}} & \mu \end{bmatrix}$$



Electroweak analyses 36 fb^{-1} included in likelihood:

- ATLAS multi-lepton: $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm \tilde{\chi}_1^\pm, \tilde{\tau}, \tilde{\mu}$; final states with 2–3 leptons + 0–5 jets
- ATLAS 2/3-lepton recursive jigsaw searches for $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$
- ATLAS 4-lepton SUSY search
- ATLAS 4- b Higgsino search
- CMS 1lep(H)bb: single-lepton final states including $H \rightarrow bb$
- CMS 2SFOSlep-soft: $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$, virtual W^* and $Z^* \rightarrow ll$; final state with two same-flav. opp. sign leptons
- CMS 2SFOSlep: as above but with hard leptons (W, Z not virtual)
- CMS multi-lepton: similar to ATLAS, but exclusively $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ production
- Assorted LEP likelihoods & h/Z invisible widths



What chargino and neutralino masses are **excluded**?

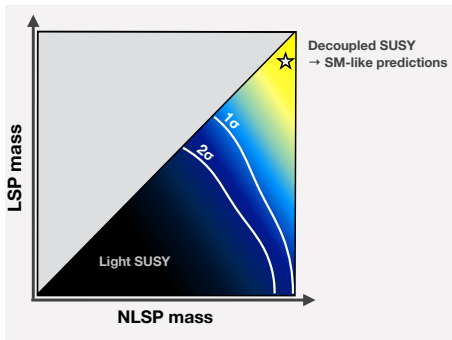
→ Consider only **worse** fits than the SM



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Naive 'SUSY is dead' expectation:



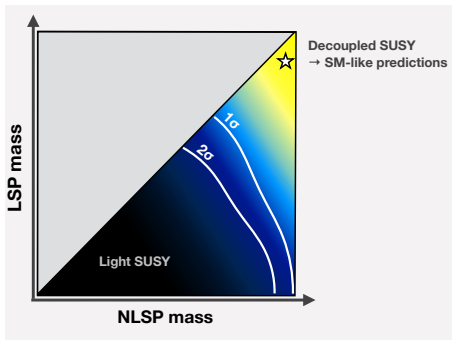
(thanks to Anders Kvellestad)



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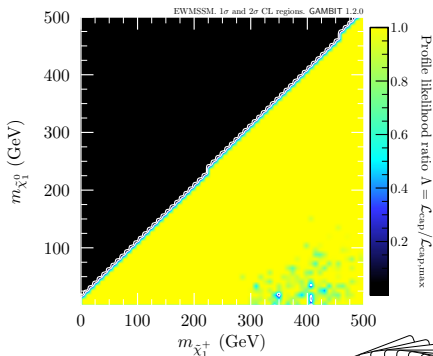
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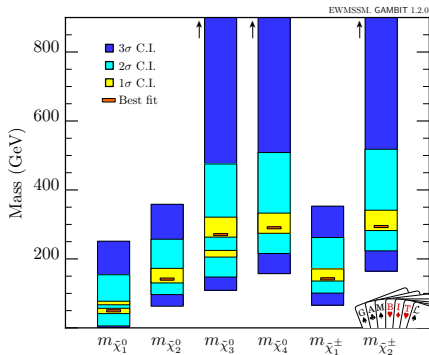
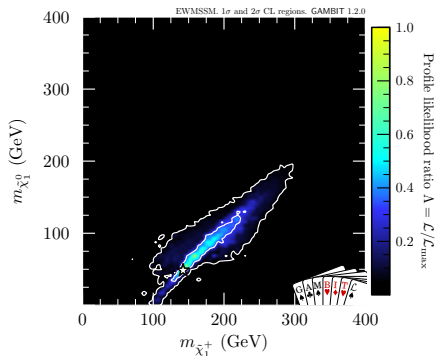
(thanks to Anders Kvellestad)

Actual reality when including all 12 searches:



What chargino and neutralino masses are **preferred**?

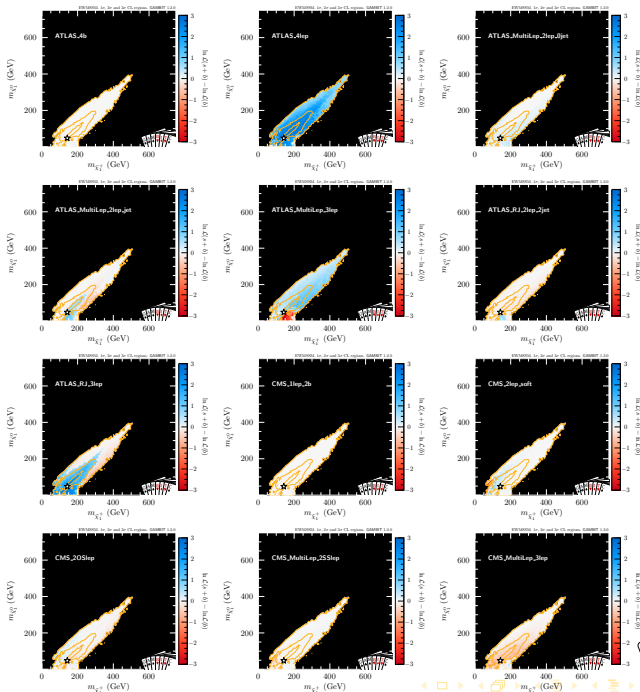
→ Consider also **better** fits than the SM:



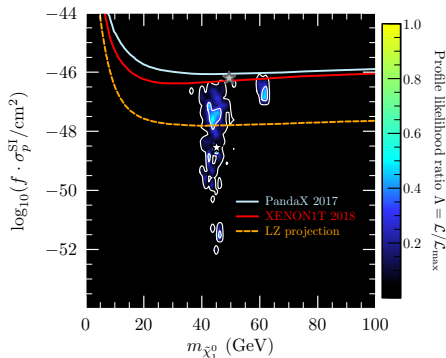
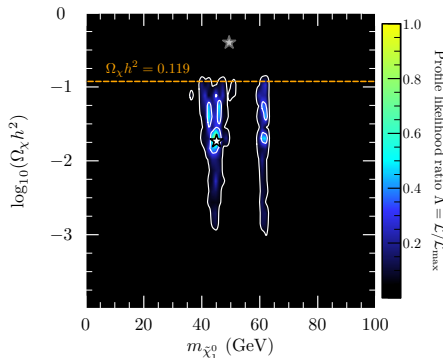
3.3 σ (local) combined signal significance



Likelihood contributions of individual analyses



Just taking the points within our 3σ regions from the LHC fit:

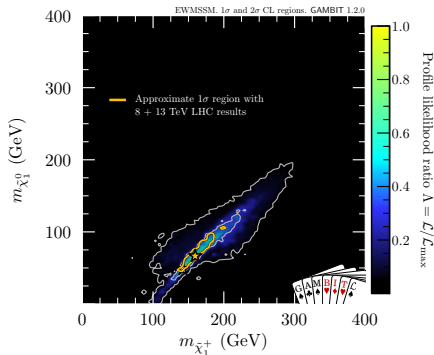


Z and h funnel mechanisms can give sensible relic densities
 \rightarrow models consistent with LHC excesses can also naturally explain dark matter

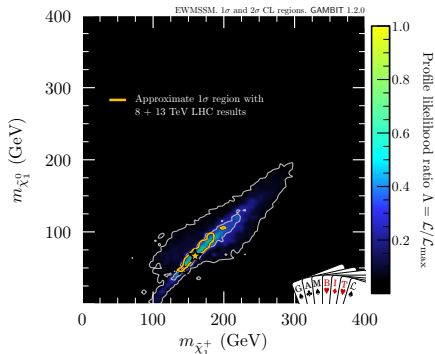


Add $2 \times \text{CMS} + 3 \times \text{ATLAS}$
 8 TeV searches
 \rightarrow best-fit moves higher in mass

 $3.3\sigma \rightarrow 2.9\sigma$ significance



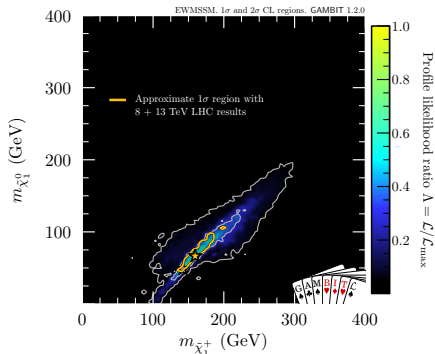
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- Impact of including full covariance matrix for CMS multi-lep search will be greater



- SUSY is not dead
 - In fact the LHC basically doesn't completely exclude any neutralino or chargino mass
 - 3.3σ hint of light SUSY in LHC electroweak searches?
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- GAMBIT global analyses are complete for many other models
 - All GAMBIT results, samples, run files, best fits, benchmarks, etc are *all* available to download from Zenodo:
www.zenodo.org/communities/gambit-official/
 - GAMBIT code is public: gambit.hepforge.org

