



Summary of my CDMPP Research

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Brief summary of my CDMPP research

- General hep-ph papers on DM-relevant models, e.g.
 - primordial black hole dark matter (arXiv:1907.06485)
 - composite Higgs scenarios (1907.06485)
 - multicomponent DM (arXiv:1709.01945, arXiv:1804.08437, arXiv:1809.06881)
- GAMBIT collaboration: Global and Modular Beyond-SM Inference Tool
 - WIMP theories
 - axion-like particle theories
 - cosmology
- New methods for discovering DM-like particles at the LHC
 - unsupervised machine learning for model-independent searches (arXiv: 2010.07940)
 - graph network methods for LHC searches (arXiv: 1912.10625)

GAMBIT: DM physics won't just show up in DM experiments

- low-energy accelerators
- measurements of the magnetic moment of the muon
- beam dump/fixed target
- electroweak precision tests
- dark matter direct detection experiments
- searches for antimatter in cosmic rays
- nuclear cosmic ray ratios
- radio astronomy data
- effects of dark matter on reionisation, recombination and helioseismology
- the observed dark matter cosmological abundance
- neutrino masses and mixings
- gamma ray searches (e.g. FERMI-LAT, HESS, CTA, etc)

Solving the DM problem *necessarily* involves combining experimental probes

- It isn't just useful to combine data from different experiments
- It is **essential**
- Direct and indirect detection measurements can only be interpreted via poorly constrained astrophysical nuisance parameters (e.g. density plus velocity distributions, nuclear uncertainties, etc)
 - knowing the particle physics from the LHC would substantially improve our knowledge
- The LHC alone cannot discover dark matter at all...

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,
IsaTools, nulike, PolyChord, Rivet, SoftSUSY, SuperISO, SUSY-
AI, WIMPsim

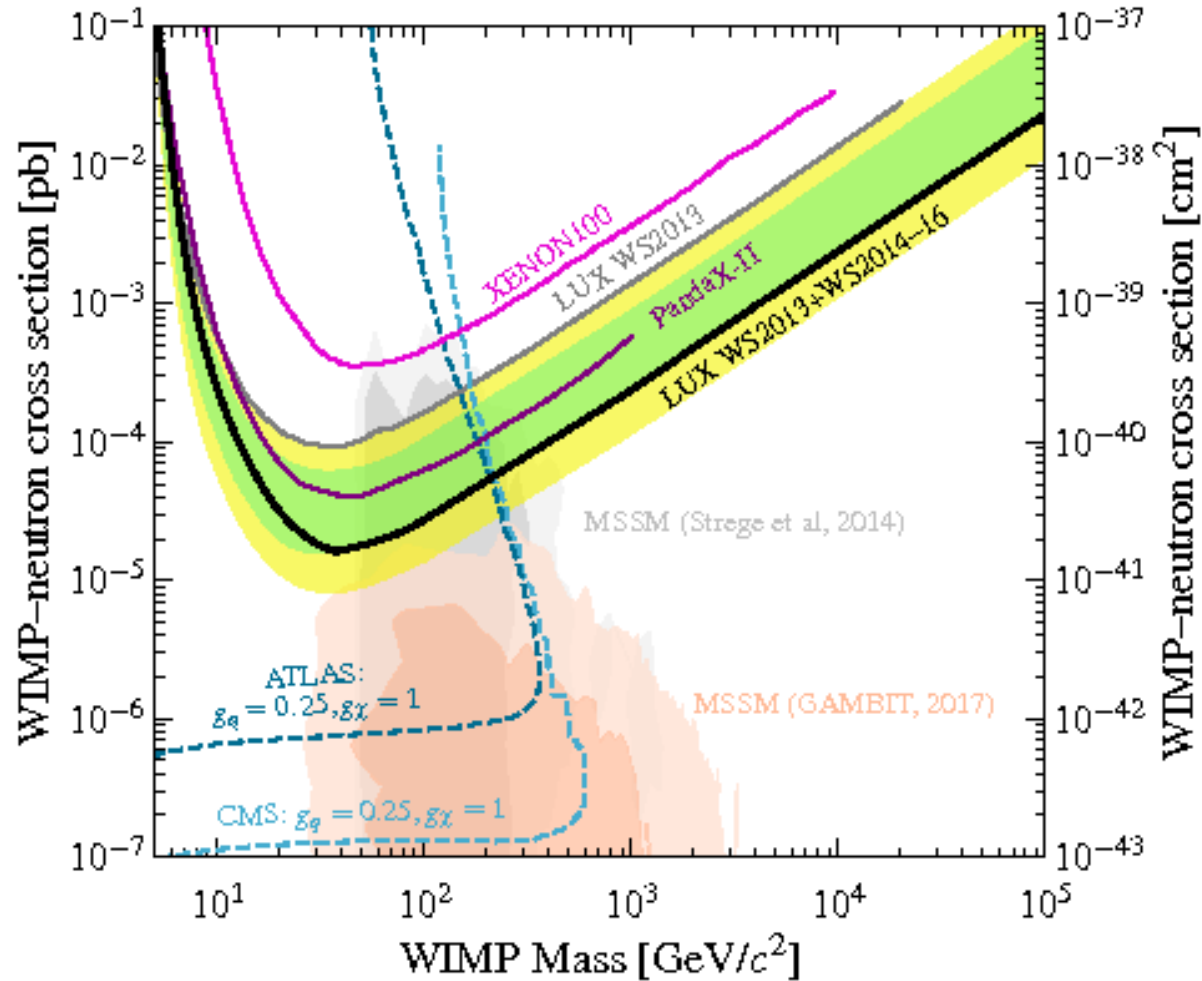


Recent collaborators:

V Ananyev, P Athron, C Balázs, A Beniwal, S Bloor, T
Bringmann, A Buckley, J Eliel Camargo-Molina, C Chang, M
Chrzaszcz, J Conrad, J Cornell, M Danninger, J Edsjö, B
Farmer, A Fowlie, T Gonzalo, P Grace, W Handley, J Harz, S
Hoof, F Kahlhoefer, N Avis Kozar, A Kvellestad, P Jackson, R
Jardine, A Ladhu, N Mahmoudi, G Martinez, M Prim, F Rajec,
A Raklev, J Renk, C Rogan, R Ruiz, I Sáez Casares, N Serra, A
Scaffidi, P Scott, P Stöcker, W Su, J Van den Abeele, A Vincent,
C Weniger, M White, Y Zhang

40+ participants in 11 experiments and 14 major theory codes

MSSM7: GAMBIT → DM experiments



Phys.Rev.Lett. **118** (2017) no.25, 251302

GAMBIT modules

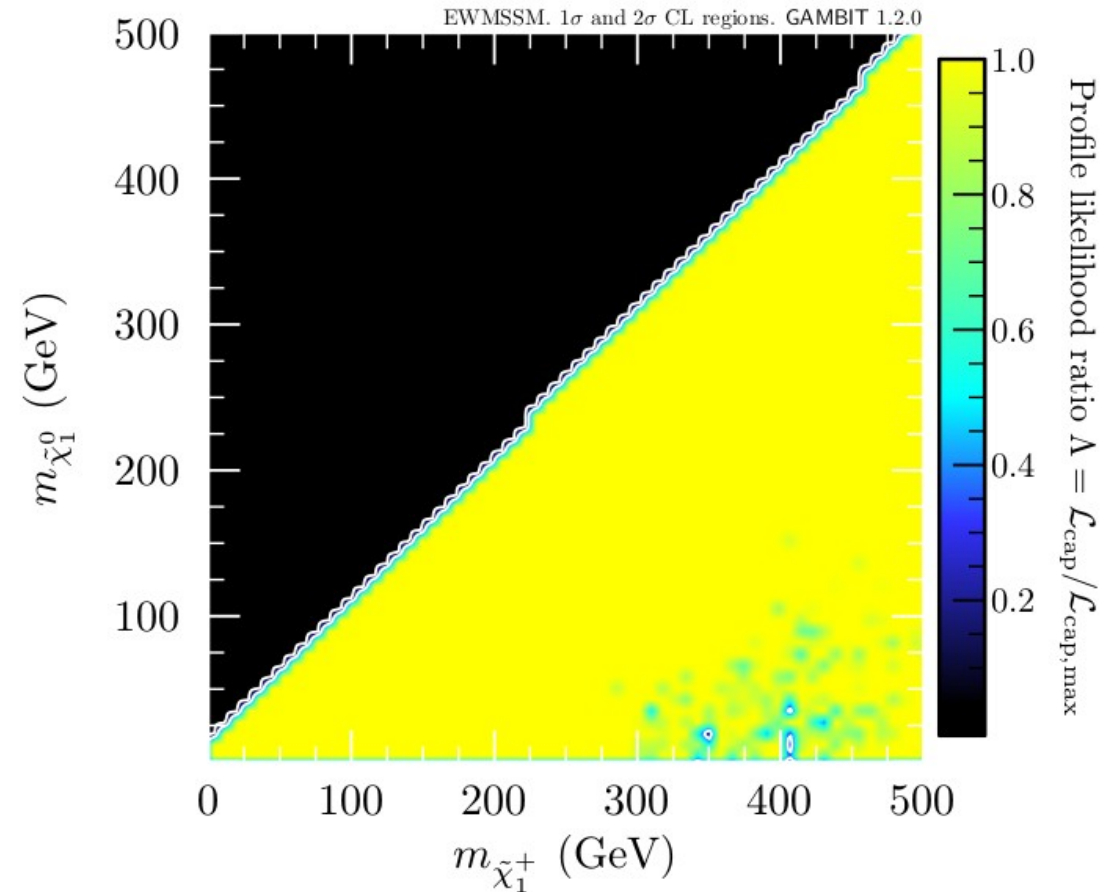
- **ColliderBit:** collider observables including Higgs + SUSY Searches from ATLAS, CMS, LEP
- **DarkBit:** WIMP dark matter observables (relic density, direct & indirect detection), plus axions
- **FlavBit:** including $g - 2$, $b \rightarrow s\gamma$, B decays (new channels), angular obs., theory unc., LHCb likelihoods
- **SpecBit:** generic BSM spectrum object, providing RGE running, masses, mixings
- **DecayBit:** decay widths for all relevant SM and BSM particles
- **PrecisionBit:** precision EW tests (mostly via interface to FeynHiggs or SUSY-POPE)
- **ScannerBit:** manages stats, sampling and optimisation
- **NeutrinoBit:** likelihoods to right-handed neutrino studies
- **CosmoBit:** constraints from large-scale structure, Type Ia supernovae, Big Bang Nucleosynthesis and the cosmic microwave background



LHC searches for SUSY dark matter

- In a test of exclusion power, we find *no general constraint* on the MSSM EW sector from the LHC!

arXiv: 1809.02097



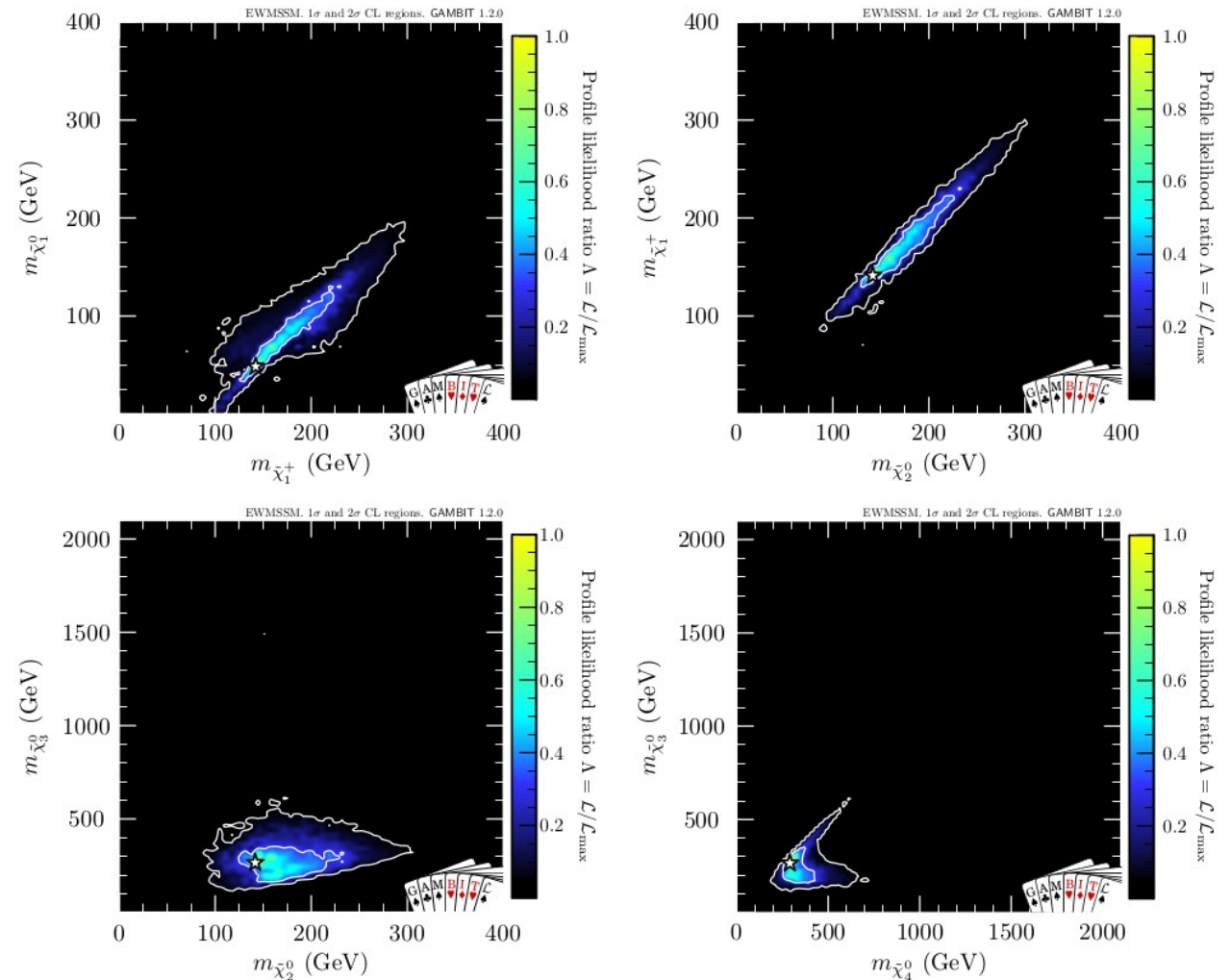
Allowing searches to give positive evidence

- If we allow for the presence of a signal, our results get more interesting
- A particular mass scale is picked out by a series of anomalies in ATLAS and CMS searches
- All electroweakinos are light, and we either have:

Bino $<$ winos $<$ higgsinos

Or

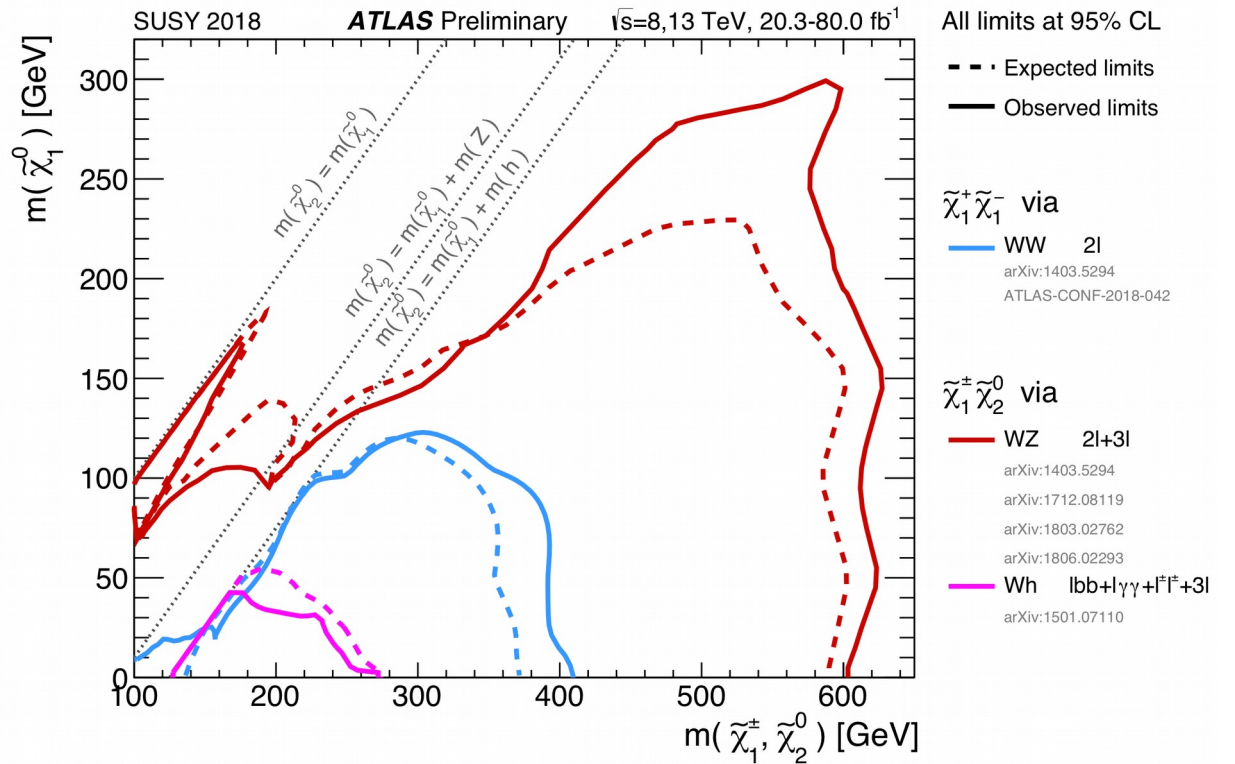
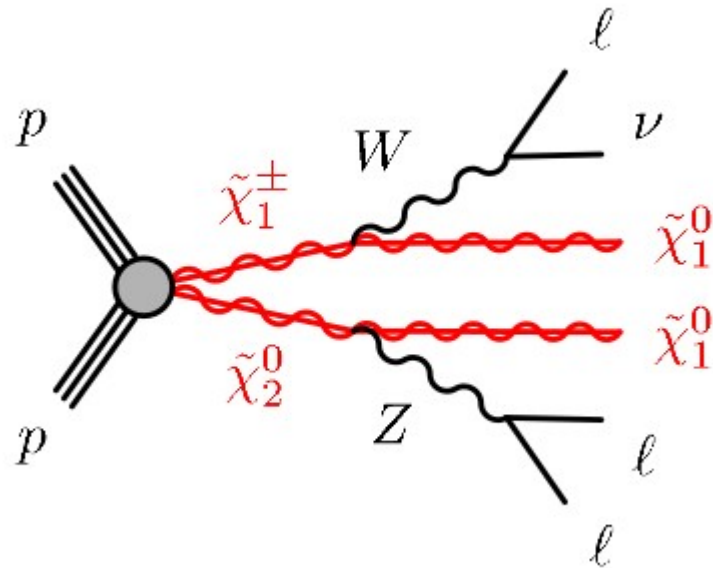
Bino $<$ higgsinos $<$ winos



Other GAMBIT DM highlights

- Axion study: [arXiv:1810.07192](https://arxiv.org/abs/1810.07192)
- Axion Xenon 1T interpretation: [arXiv:2007.05517](https://arxiv.org/abs/2007.05517)
- Higgs portal DM: [arXiv:1808.10465](https://arxiv.org/abs/1808.10465), [1806.11281](https://arxiv.org/abs/1806.11281), [1705.07931](https://arxiv.org/abs/1705.07931)
- GUT-scale SUSY models: [arXiv:1705.07935](https://arxiv.org/abs/1705.07935)
- Weak-scale SUSY: [arXiv: 1705.07917](https://arxiv.org/abs/1705.07917)

New techniques for LHC searches



Ideas for improvement



1) Simple but not simplified

2) Unsupervised learning for LHC searches (with Adam Leinweber, Melissa van Beekveld, Sascha Caron, Luc Hendriks, Paul Jackson)

3) Mapping the topology of LHC events using network analysis (with Anna Mullin, Stuart Nicholls, Holly Pacey, Andy Parker, Sarah Williams)

A quick advert: <https://darkmachines.org/>



Projects, datasets and challenges

We are currently investigating the following projects.
Click the project name for information on how to join.

[Collider searches and unsupervised: or supervised or not-yet-thought-off learning](#)

[Exploring high dimensional parameter spaces](#)

[Generative models as event simulator](#)

[Inclusive analysis of Fermi-LAT point sources](#)

[Learning dark matter distributions in galaxies](#)

[Library of classification and regression models](#)

[Particle track reconstruction with ML](#)

[Strong lensing and unsupervised learning](#)

