

Global fits with



<http://gambit.hepforge.org>

Jonathan Cornell, on
behalf of the collaboration

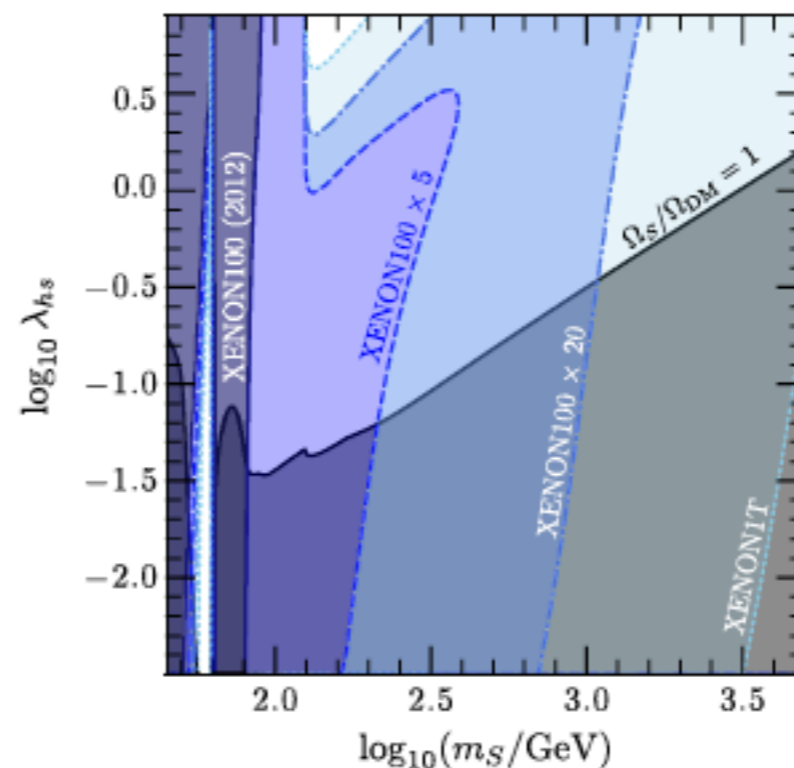
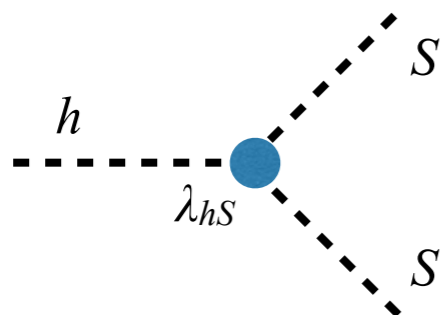


McGill

TeV Particle Astrophysics 2017

- There is a menagerie of new physics models.
- One approach to determining their validity — overlay limits in parameter space:

Scalar Singlet DM Model



Cline, et. al. (2013)

- But what if you have more complicated parameter spaces, or have many constraints, or what if we discover something...

Another approach: Global Fits

- Calculate a combined *consistent* likelihood from all relevant experimental results:

$$\mathcal{L} = \mathcal{L}_{\text{Collider}} \mathcal{L}_{\text{DM}} \mathcal{L}_{\text{Flavor}} \dots$$

- Scan over the parameter space of theories to determine:
 1. The best fit regions of parameter space of a particular theory.
 2. Which theories give the best fit to the data.
- Existing codes to do this for BSM (*i.e.* MSSM-like) models: MasterCode, Fittino, SuperBayes, SFitter...

GAMBIT: The **G**lobal **A**nd **M**odular **B**eyond-the-standard-model **I**nference **T**ool

arXiv:1705.07908

*The design philosophy is based on the concepts of **modularity and flexibility**.*

- Large (and growing) database of models, SUSY and others
- Extensive library of observables/likelihoods that can easily be enabled or disabled for a particular scan
- Tools for simple interfacing with external codes
- Many statistical options – Bayesian/frequentist, likelihood definitions, scanning algorithms
- Massively parallel, both OpenMP and MPI
- Easy to add new models, observables, likelihoods, and scanners!

The Collaboration

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31 members 11 countries 9 experiments

ATLAS, Belle-II, CMS, CTA, DARWIN, Fermi-LAT, IceCube, LHCb, Xenon

The Bits

- *DarkBit* — dark matter relic density, event rates and likelihoods for indirect and direct searches ([arXiv:1705.07920](#))
- *ColliderBit* — LHC and LEP searches for new particle production, Higgs constraints ([arXiv:1705.07919](#))
- *FlavBit* – flavor physics, particularly B decays. Likelihoods from LHCb measurements. ([arXiv:1705.07933](#))
- *SpecBit* – generic BSM spectrum object, providing RGE running, masses, mixings, etc. via interchangeable interfaces to different RGE codes ([arXiv:1705.07936](#))
- *DecayBit* – decay widths for all relevant SM & BSM particles ([arXiv:1705.07936](#))
- *PrecisionBit* – SM likelihoods, muon $g - 2$, precision BSM tests (W mass, etc.) ([arXiv:1705.07936](#))
- + *ScannerBit* – manages stats, sampling and optimization ([arXiv:1705.07959](#))

Bits can also be used as standalone codes.

The Bits

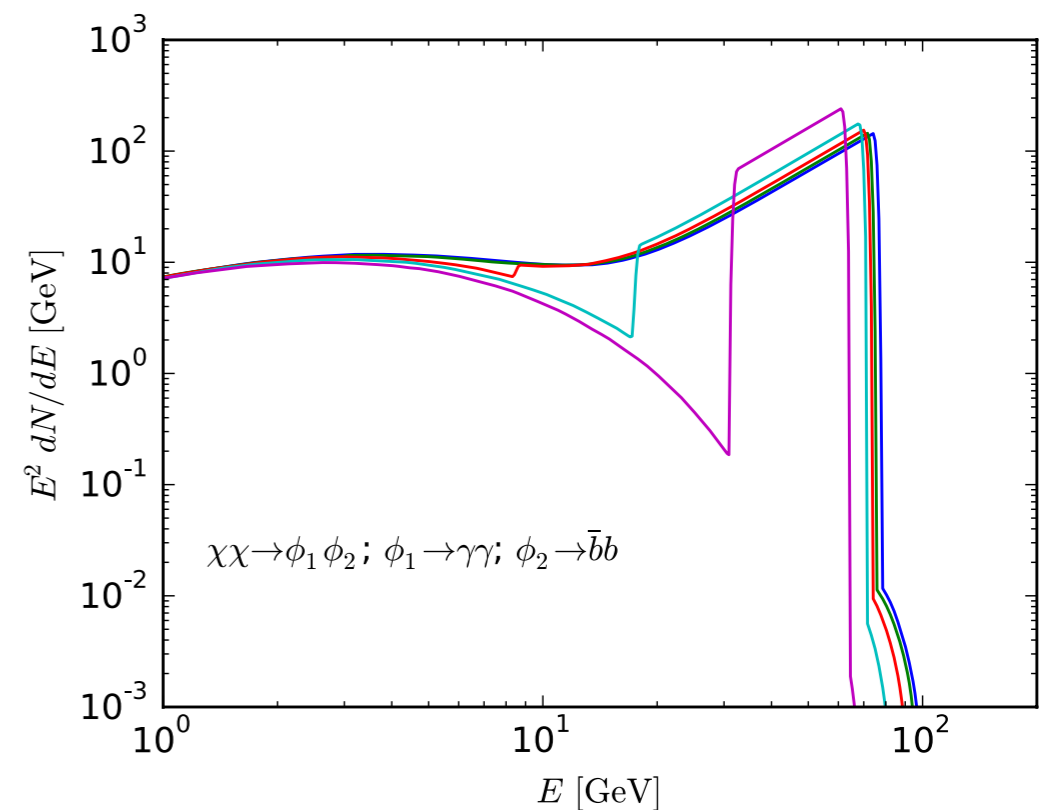
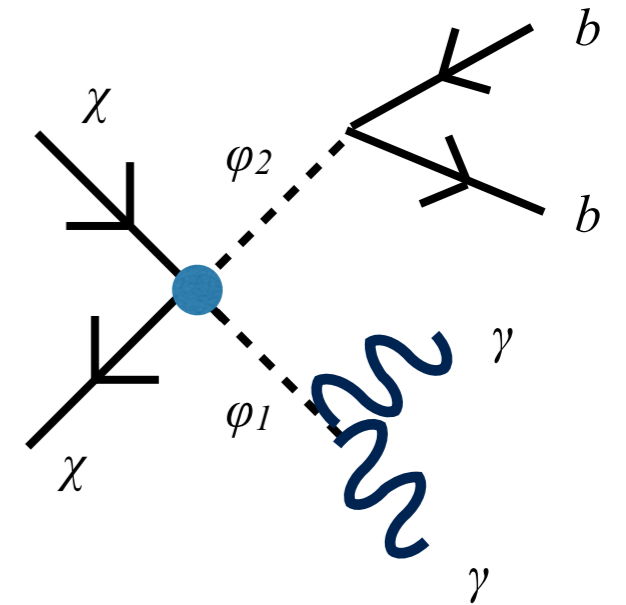
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Bits can also be used as standalone codes.

DarkBit: Indirect Detection

Gamma rays:

- Theoretical spectra calculated using branching fractions and tabulated gamma-ray yields
- Non-SM final state particles and Higgs are decayed on the fly with cascade Monte Carlo
- *gamLike* (gamlike.hepforge.org): New standalone code with likelihoods for DM searches from Fermi-LAT (dwarf spheroidals, galactic center excess) and H.E.S.S. (galactic halo)

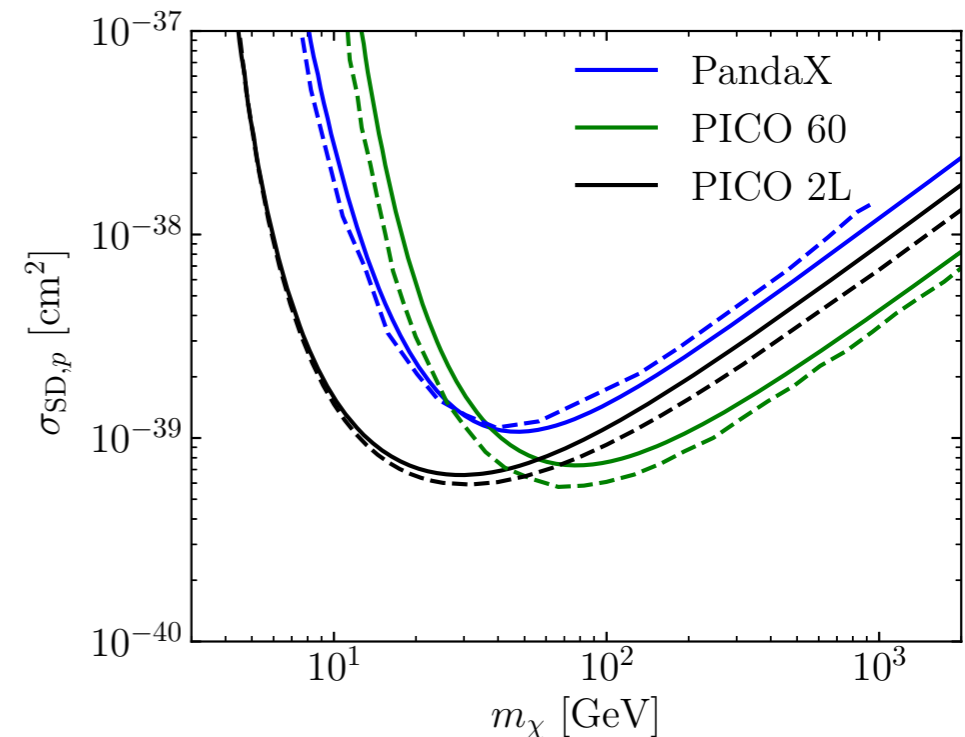
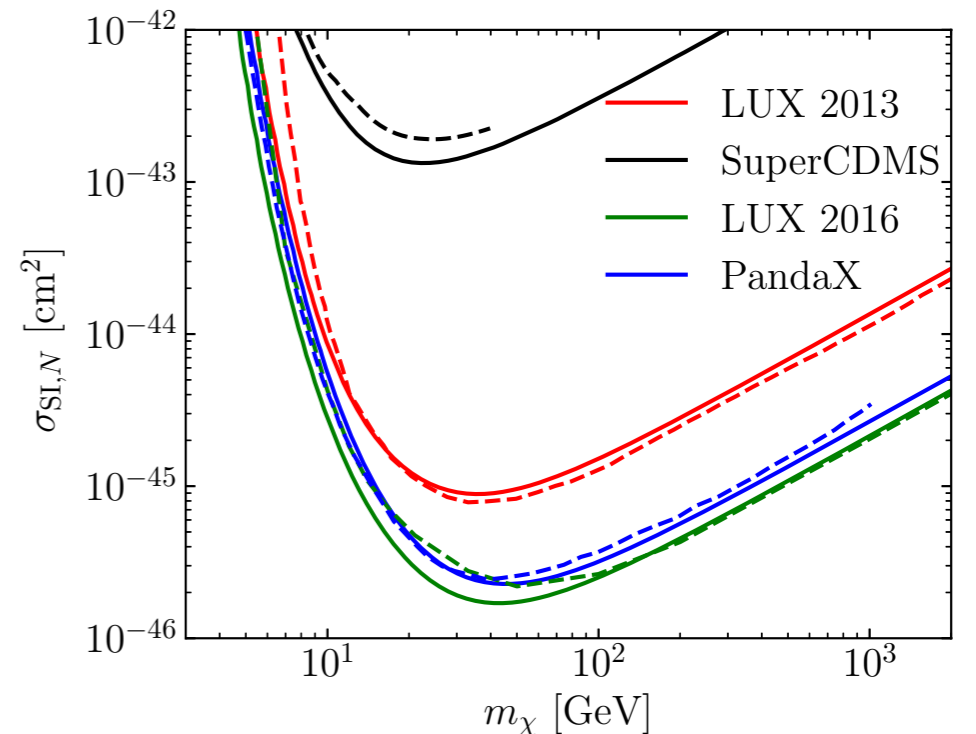


Solar neutrinos:

- Yields from DM annihilation in sun calculated by DarkSUSY. IceCube likelihoods contained in *nulike* (nulike.hepforge.org) standalone code.

DarkBit: Direct Detection

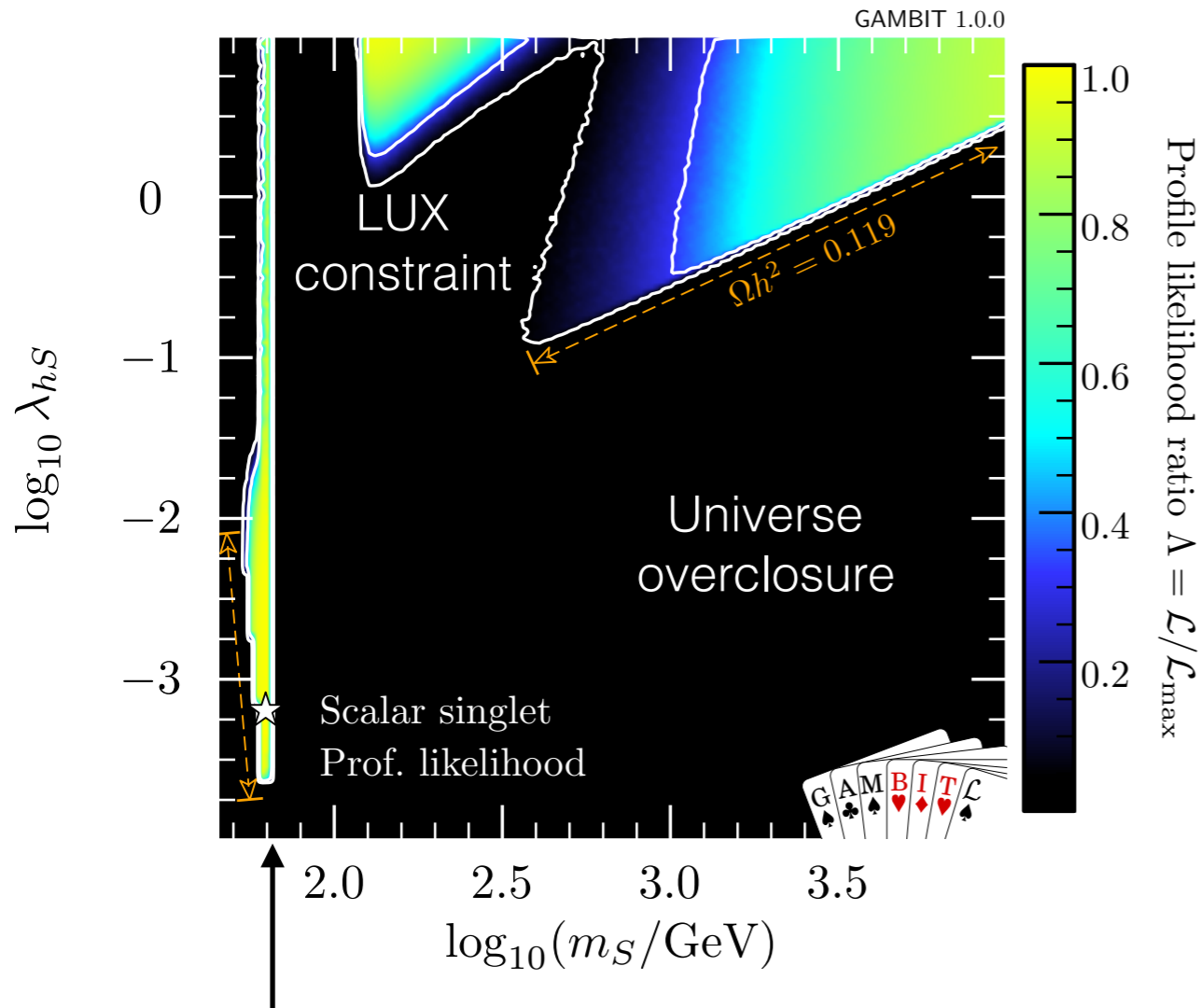
- In parallel with GAMBIT, we introduce *DDCalc* (ddcalc.hepforge.org), a tool to calculate event rates and complete likelihood functions for direct detection experiments taking into account:
 - A mix of both spin-independent and dependent contributions to the scattering rate.
 - Halo parameters (local density, DM velocity dispersion, etc.) chosen by the user.
- We currently have implemented likelihoods for Xenon(1T, 100), LUX, PandaX, SuperCDMS, PICO(60, 2L), and SIMPLE



----- Official 90% CL limit
—— DDCalc

Scalar Singlet DM

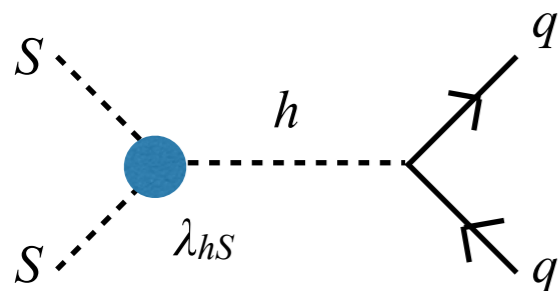
arXiv:1705.07931



Likelihoods include:

- Relic density (upper limit)
- Fermi-LAT DM searches in dwarf spheroidals
- Direct Detection (LUX, PandaX, etc..)
- IceCube limits on DM scattering from solar neutrinos
- Higgs invisible width

Higgs resonance



2 *model* parameters: 13 *nuisance* parameters:

λ_{hS}, M_S

- 10 SM ($m_h, m_q, G_F, \alpha_S, \alpha_{EM}$)
- 2 nuclear (σ_s, σ_l),
- Local DM density (ρ_0)

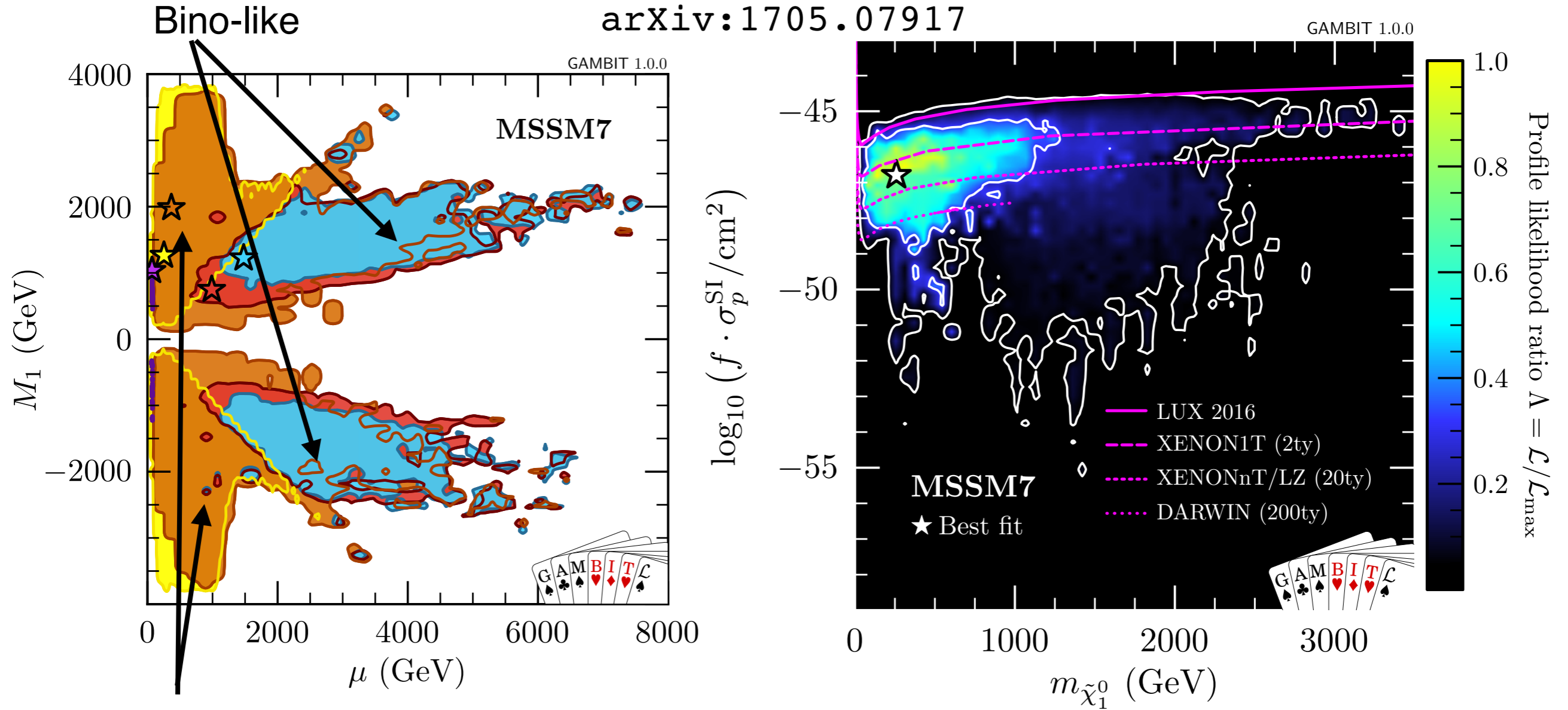
MSSM-7

arXiv:1705.07917

- 7 *model* parameters, defined at a lower energy scale (1 TeV):
 - M_2 Wino mass parameter (related to M_1 and M_3 via GUT scale relation).
 - M_{H_u}, M_{H_d} Higgs doublet mass parameters
 - A_{u_3}, A_{d_3} Trilinear couplings
 - $m_{\tilde{f}}^2$ Unified sfermion mass parameter
 - $\tan \beta$ Ratio of Higgs vevs
- 5 *nuisance* parameters:
 - α_s, m_t SM parameters: strong coupling and top mass
 - ρ_0 Local DM density
 - σ_s, σ_l Hadronic matrix elements
- The same *likelihoods* as for Scalar Singlet DM +:
 - LHC run 1 SUSY searches (and 0 lepton run 2 search)
 - LHC Higgs constraints
 - flavour physics from LHCb
 - precision SM likelihoods (particularly muon $g - 2$)

MSSM-7

arXiv:1705.07917



■ \tilde{t}_1 co-annihilation
 ■ A/H funnel
 ■ $\tilde{\chi}_1^\pm$ co-annihilation
 ■ \tilde{b}_1 co-annihilation
 ■ h/Z funnel

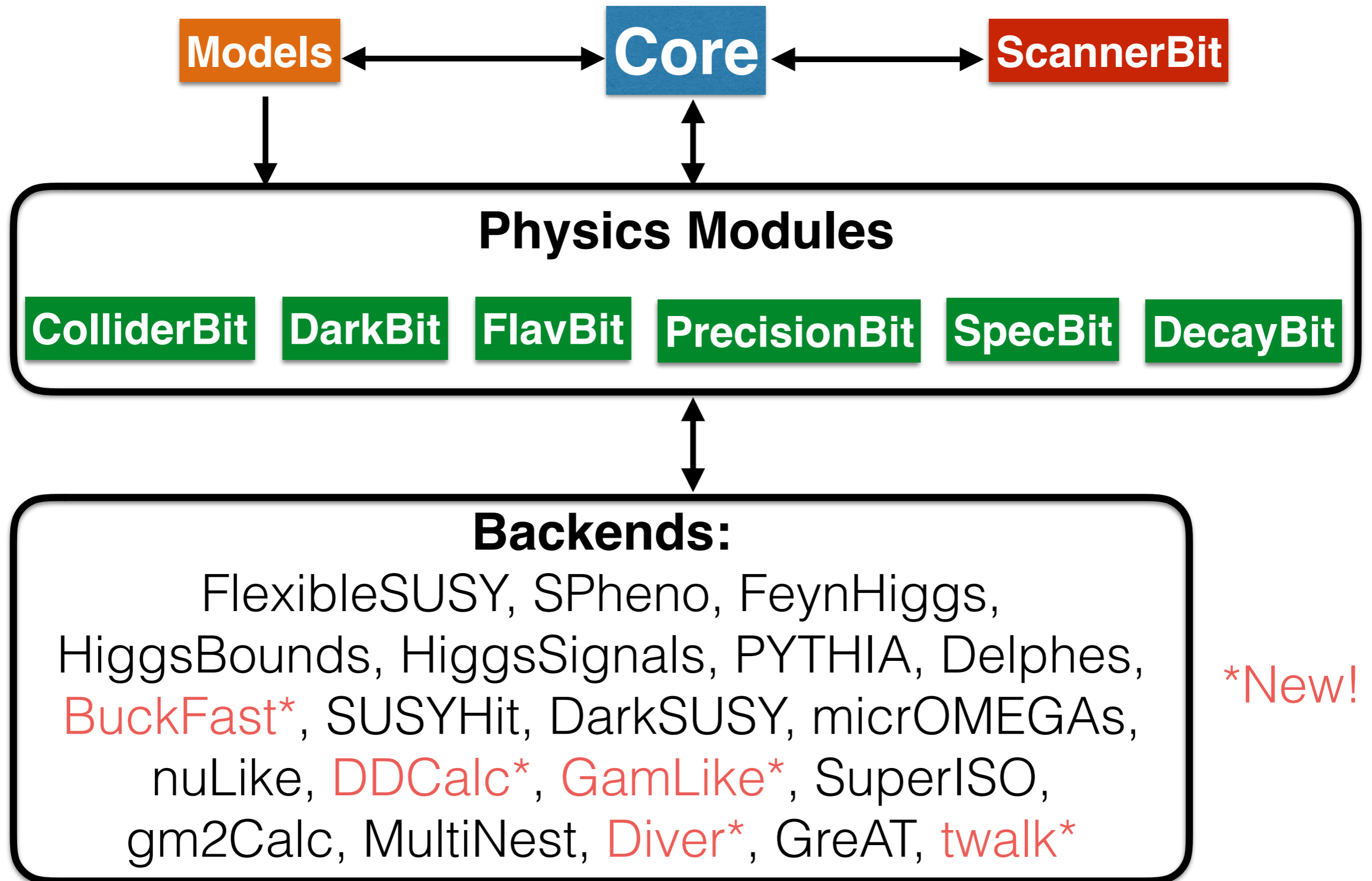
- Preference for light ($m_\chi < 1$ TeV at 68% CL)
Higgsino-like neutralino

Summary and Future Plans

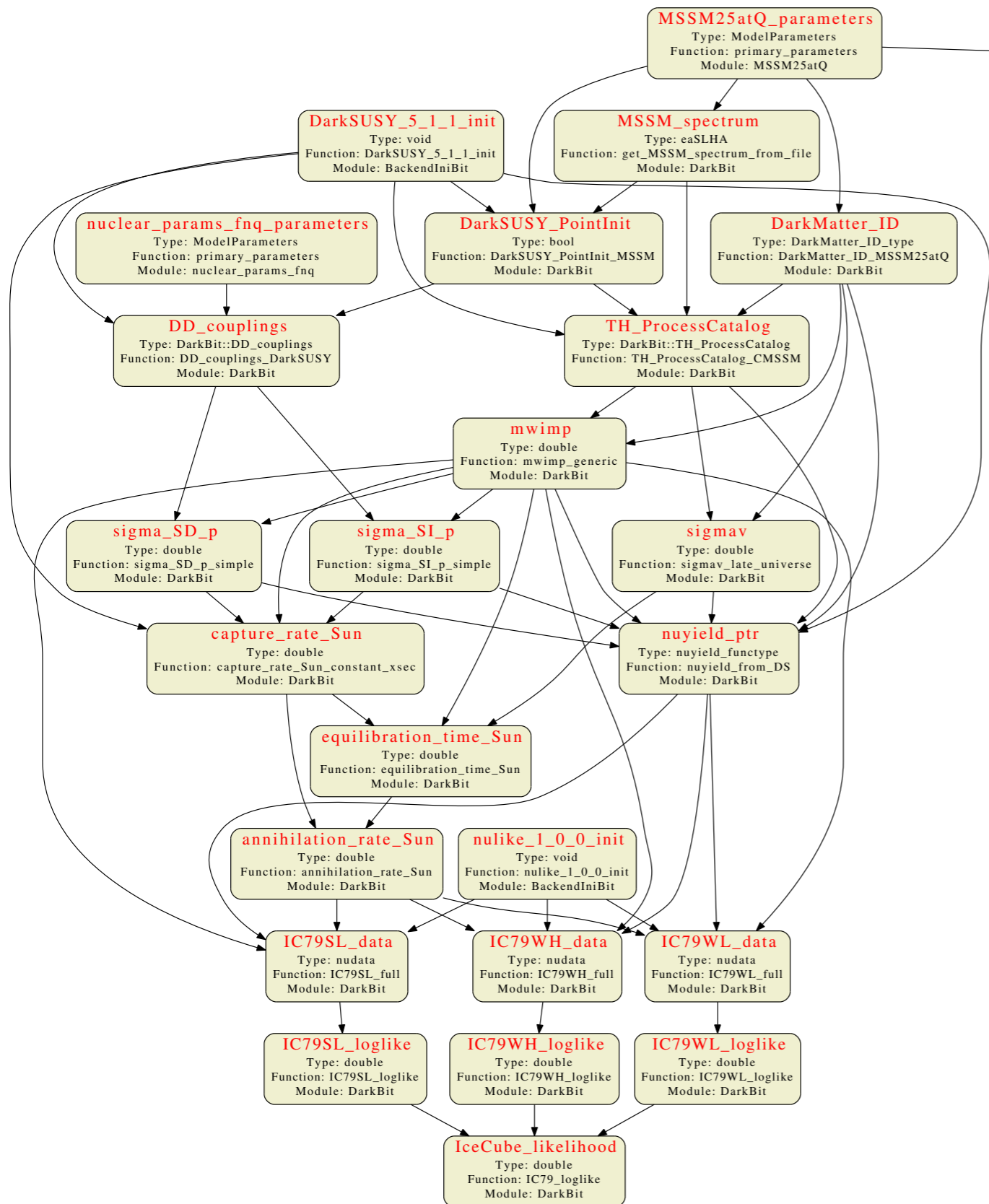
- GAMBIT, a new fitting framework for BSM theories that includes a wide range of experimental results, is now publicly released! (Download here: gambit.hepforge.org)
- We have used the code to do scans the scalar singlet DM model, and both GUT scale (not presented here) and weak scale SUSY models
- **Future Plans**
 - More models (axions, Higgs portal DM, more general MSSM's, right handed neutrinos ...) and observables
 - New modules (neutrinos and cosmology)
 - Integration with matrix element generators (CalcHEP and Madgraph) for easy implementation of new models

Backups

Code Structure



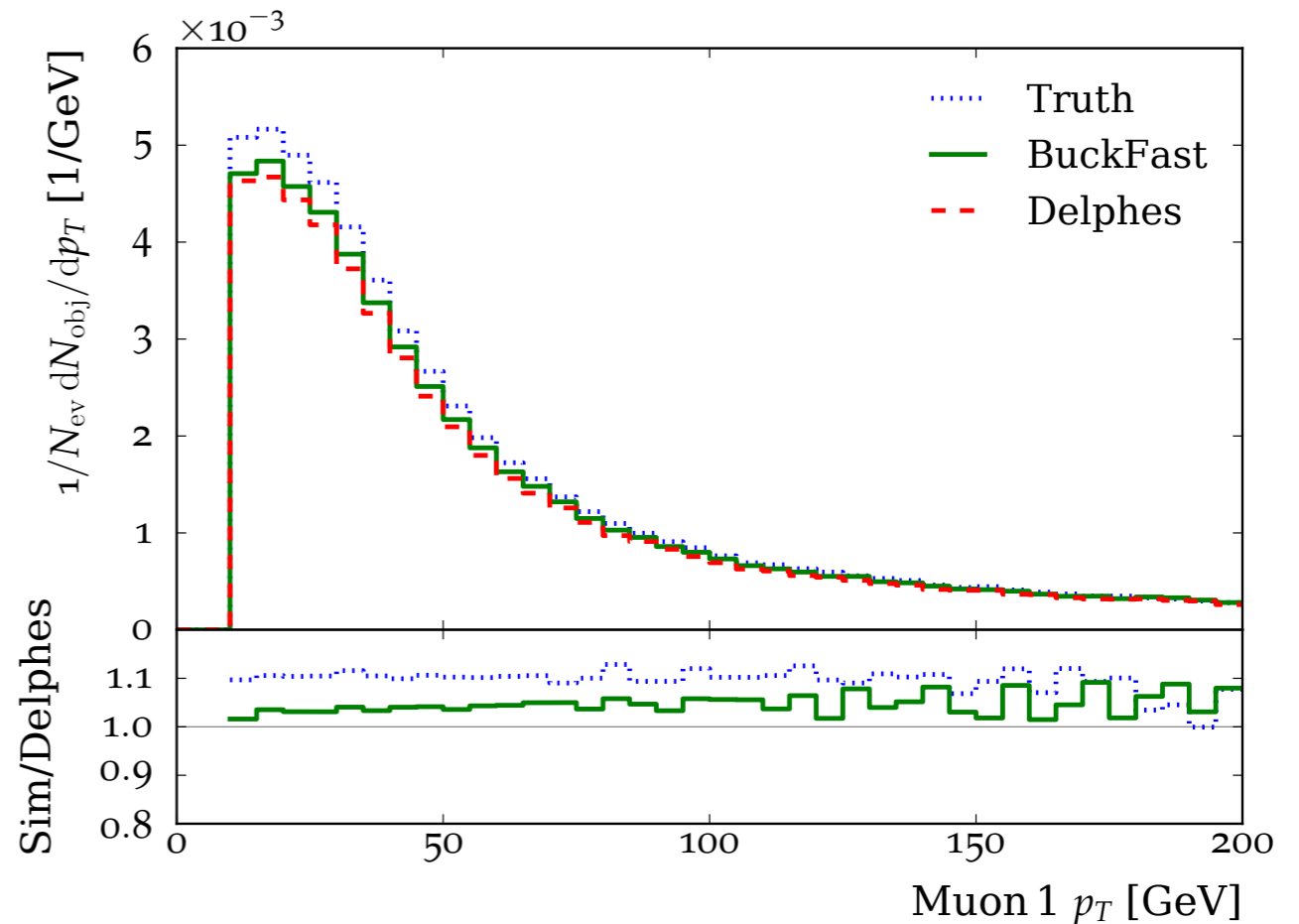
Dependency Resolution



- Automatic generation of dependency tree for calculation of likelihoods and all necessary intermediate values.
- No redundancy — each needed quantity calculated once per point in the scan.
- Can change how calculations are done by specifying rules in input file.

Collider Bit

- Full analysis chain for doing LHC recasts (focus on speed):
 - Cross section calculation and event generation using parallelized version of Pythia
 - Fast detector simulation using 4-vector smearing (BuckFast)

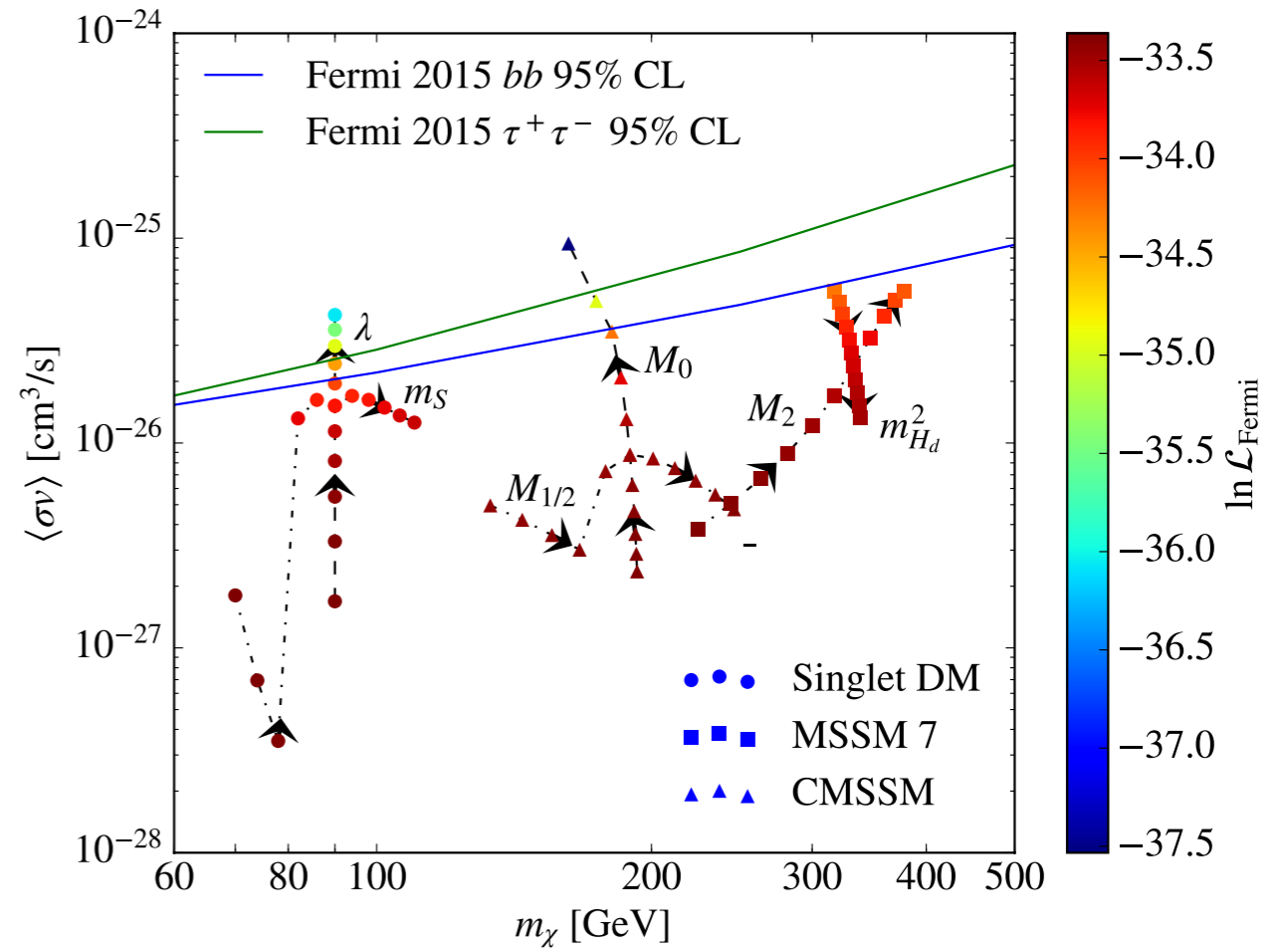
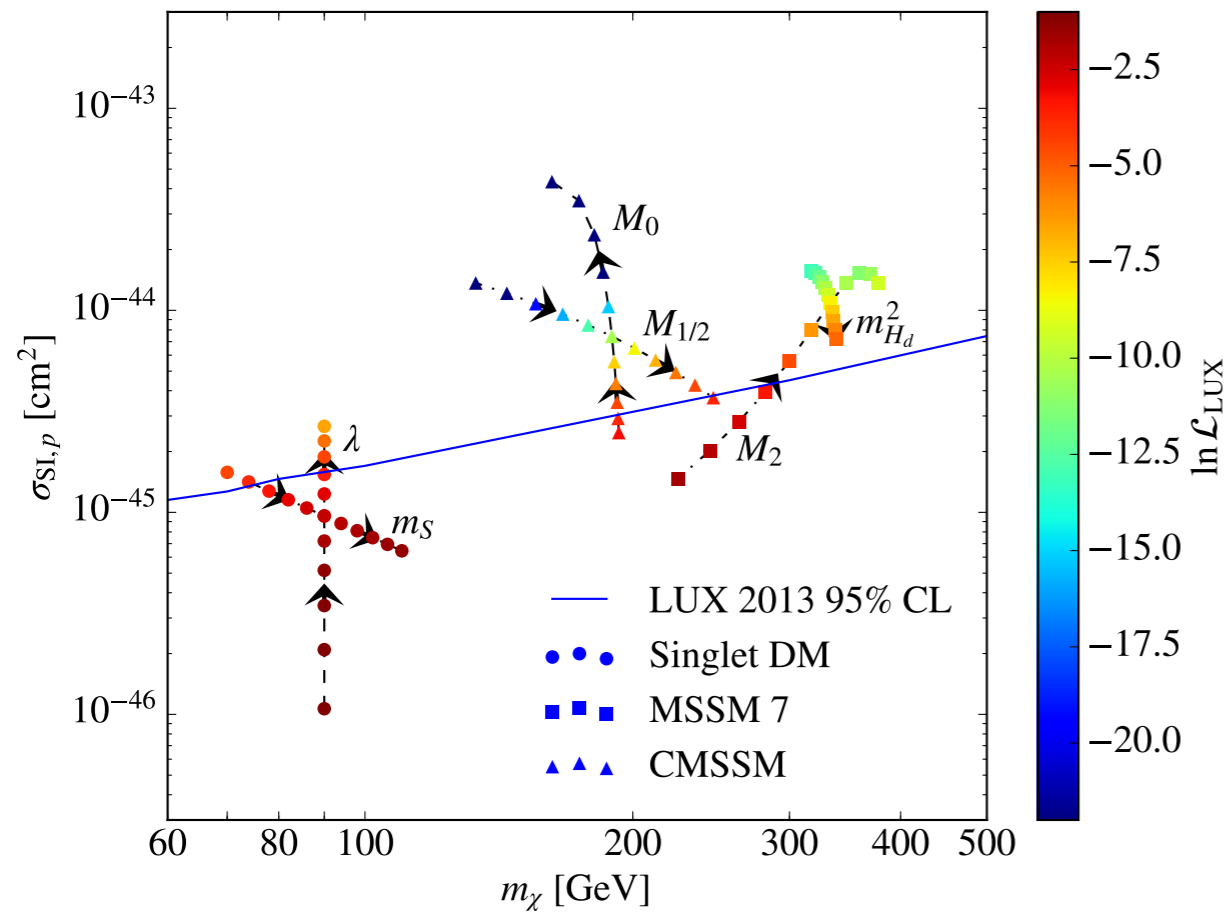


Currently includes (LHC 8 TeV):

- ATLAS SUSY searches (0 l , 0/1/2 l \tilde{t} , b jets + MET, 2/3 l EW)
- CMS multi- l SUSY
- CMS DM (monojet)
- Higgs physics from HiggsSignals and HiggsBounds

+ (LHC 13 TeV)
ATLAS 0 l SUSY
search

Dark Bit



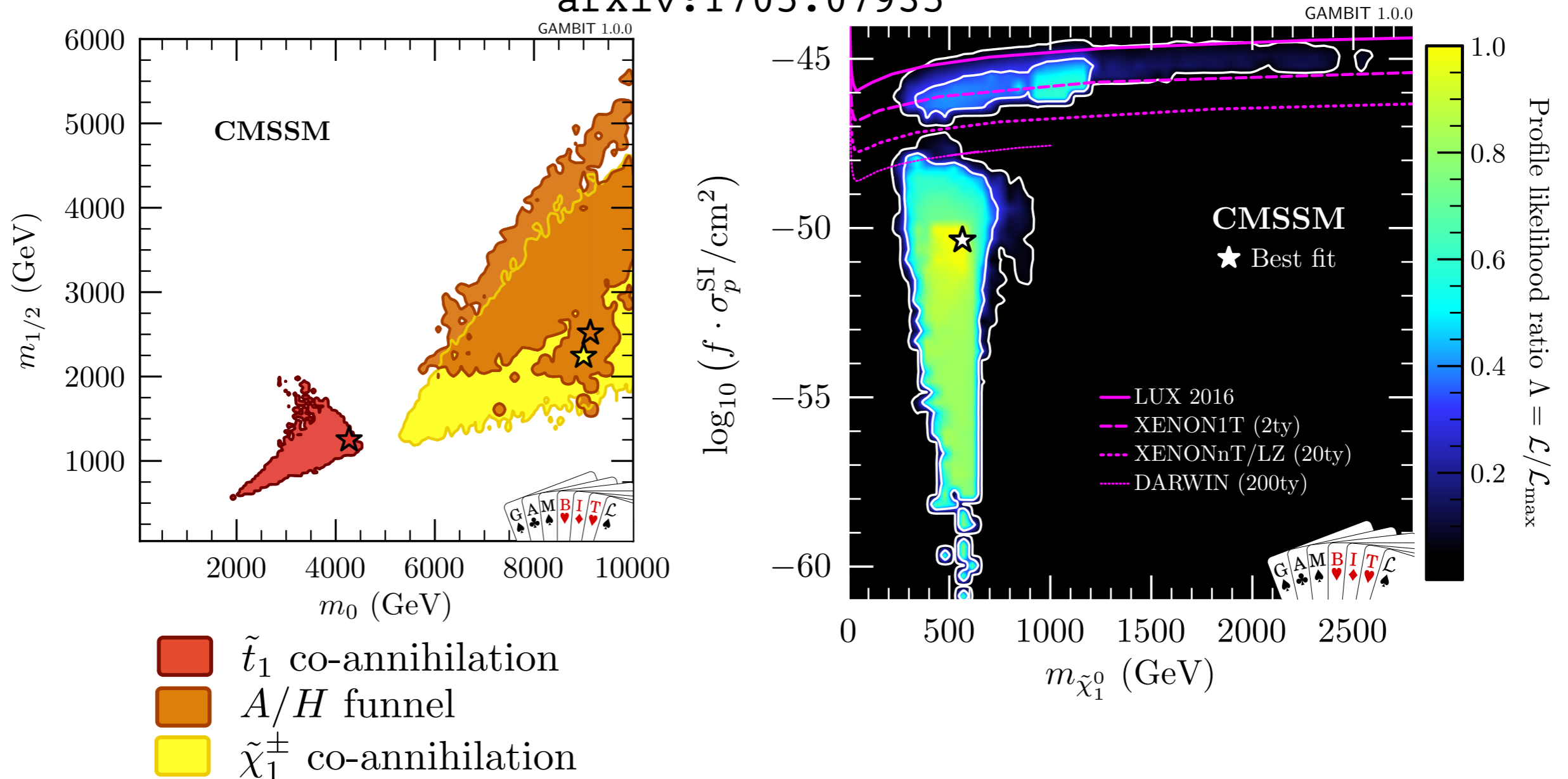
Constrained MSSM

arXiv:1705.07935

- 5 *model* parameters, defined at GUT scale:
 - $m_0, m_{1/2}$ Unified scalar, gaugino mass parameters
 - A_0 Universal trilinear coupling
 - $\tan \beta$ Higgs sector parameters
 - $\text{sign}(\mu)$
- 5 *nuisance* parameters:
 - α_s, m_t SM parameters: strong coupling and top mass
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- The same *likelihoods* as for Scalar Singlet DM +
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Constrained MSSM

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- We find stau coannihilation disfavoured at 95% CL
- Future DD searches will fully probe A/H funnel and chargino co-annihilation regions