Recasting LLP searches with GAMBIT

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on behalf of the GAMBIT Collaboration

CERN, 16 May 2018

UiO : University of Oslo

1. Introduction:
GAMBIT & ColliderBit

GAMBIT: The Global And Modular BSM Inference Tool

gambit.hepforge.org EPJC **77** (2017) 784 arXiv:1705.07908

- Fast definition of new datasets and theoretical models
- Plug and play scanning, physics and likelihood packages
- 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

ATLAS	F. Bernlochner, A. Buckley, P. Jackson, M. White
LHCb	M. Chrząszcz, N. Serra
Belle-II	F. Bernlochner, P. Jackson
Fermi-LAT	J. Conrad, J. Edsjö, G. Martinez, P. Scott
CTA	C. Balázs, T. Bringmann, M. White
CMS	C. Rogan
IceCube	J. Edsjö, P. Scott
XENON/DARWIN	B. Farmer, R. Trotta
Theory	P. Athron, C. Balázs, S. Bloor, T. Bringmann, J. Cornell, J. Edsjö, B. Farmer, A. Fowlie, T. Gonzalo, J. Harz, S. Hoof, F. Kahlhoefer, S. Krishnamurthy, A. Kvellestad, F.N. Mahmoudi, J. McKay, A. Raklev, R. Ruiz, P. Scott, R. Trotta, A. Vincent, C. Weniger, M. White, S. Wild

31 Members in 9 Experiments, 12 major theory codes, 11 countries

GAMBIT

What's in the box?

Core

- Models — EPJC, arXiv:1705.07908

Physics modules

- ColliderBit: *fast* LHC sim, Higgs searches, LEP SUSY limits — EPJC, arXiv:1705.07919
- DarkBit: relic density, gamma ray signal yields, ID/DD likelihoods — EPJC, arXiv:1705.07920
- FlavBit: wide range of flavour observables & likelihoods — EPJC, arXiv:1705.07933
- SpecBit: spectrum objects, RGE running
- DecayBit: decay widths
- PrecisionBit: precision BSM tests

  } EPJC, arXiv:1705.07936

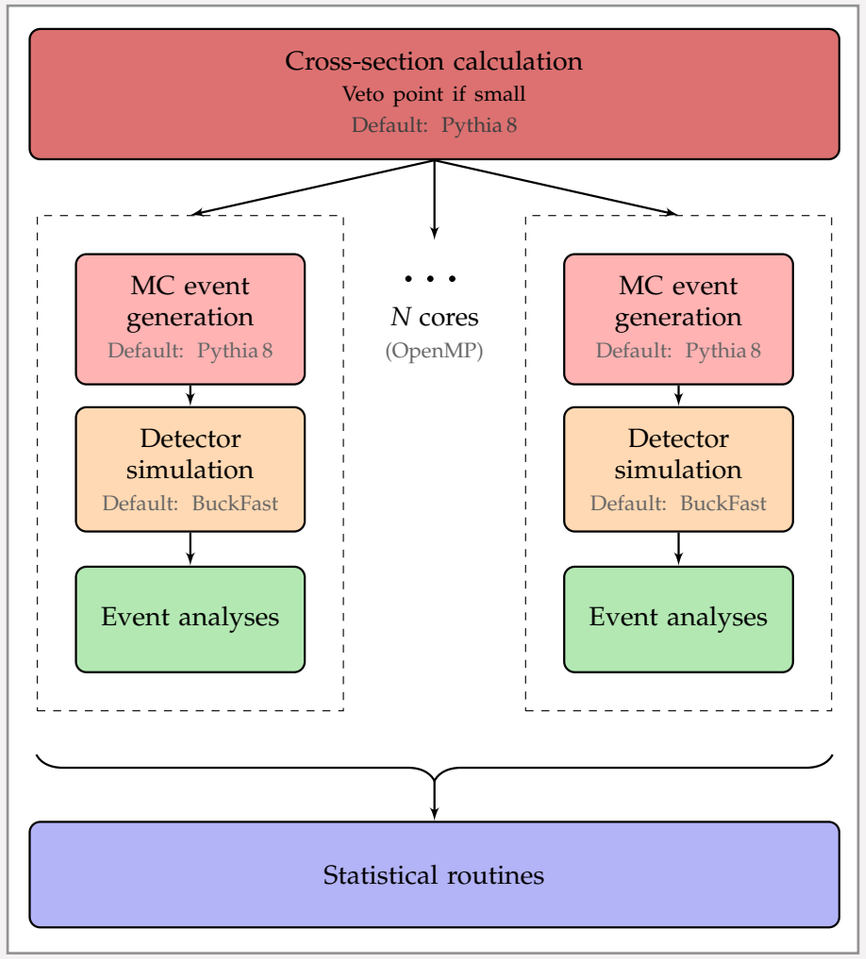
Statistics and sampling

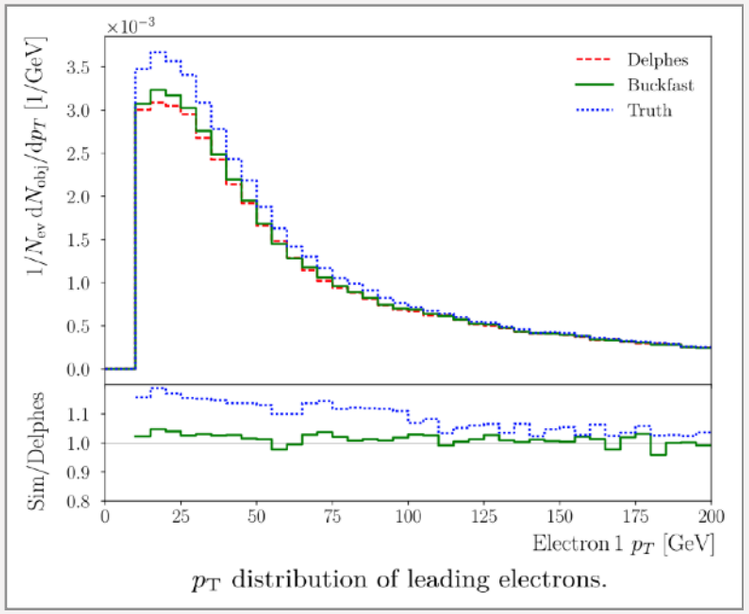
- ScannerBit: stats & sampling (Diver, MultiNest, T-Walk, ++) — EPJC, arXiv:1705.07959

Backends (external tools)

ColliderBit

- **Higgs:** Connect HiggsBounds and HiggsSignals as backends (more to come)
- **LEP limits (SUSY):** Calculate $\sigma \times BR$ and check against published limits
- **LHC particle searches:** Full Poisson likelihood from fast MC simulation of LHC searches
  - Parallellized MC event generation and analysis loop inside ColliderBit
  - Event generation with Pythia 8
  - Fast detector simulator: BuckFast (4-vector smearing)
- **Focus on speed,** as required for use in global fits





[arXiv:1705.07919]

ColliderBit

- **Higgs:** C
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- **LEP limi**
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- **LHC par**
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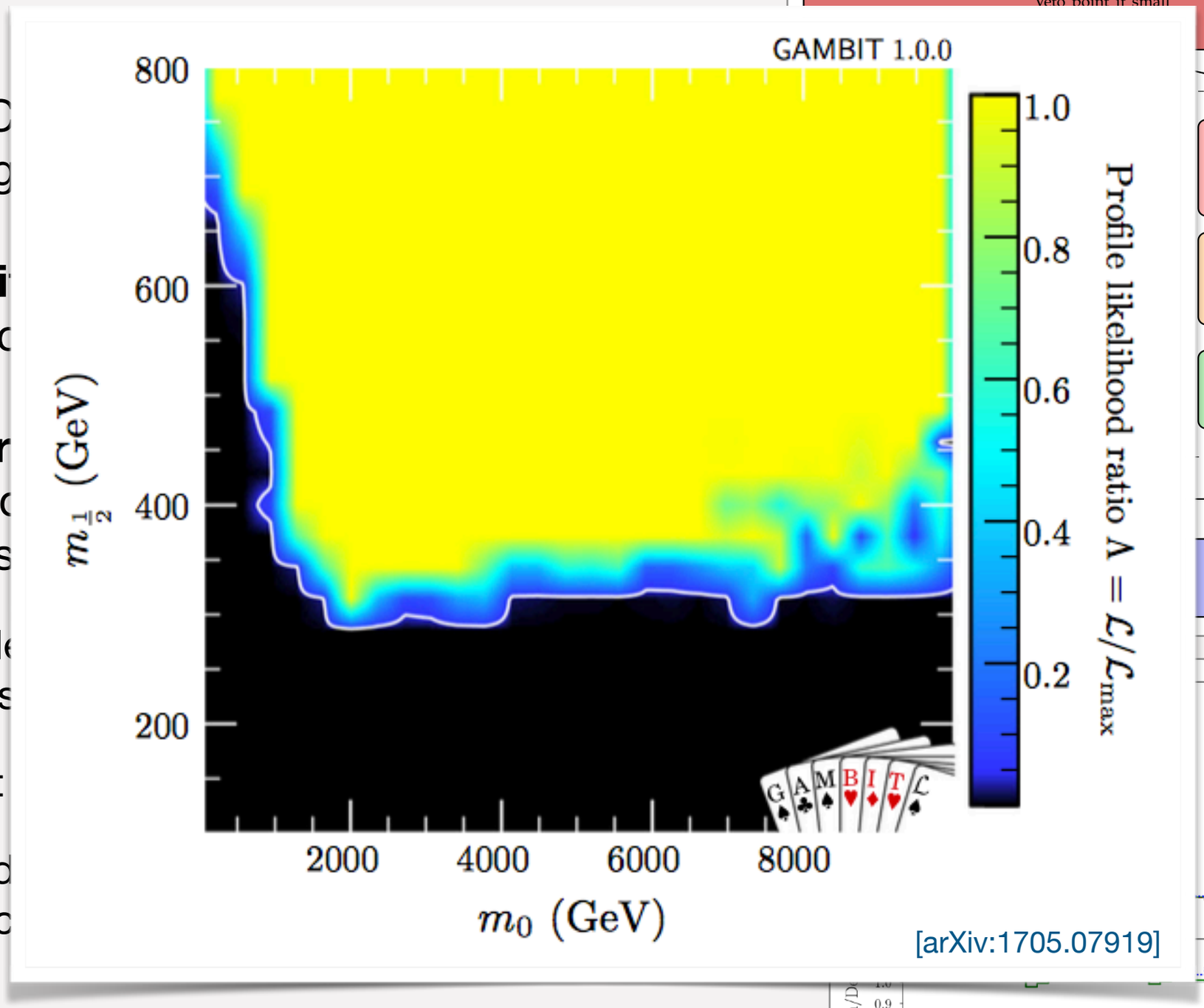
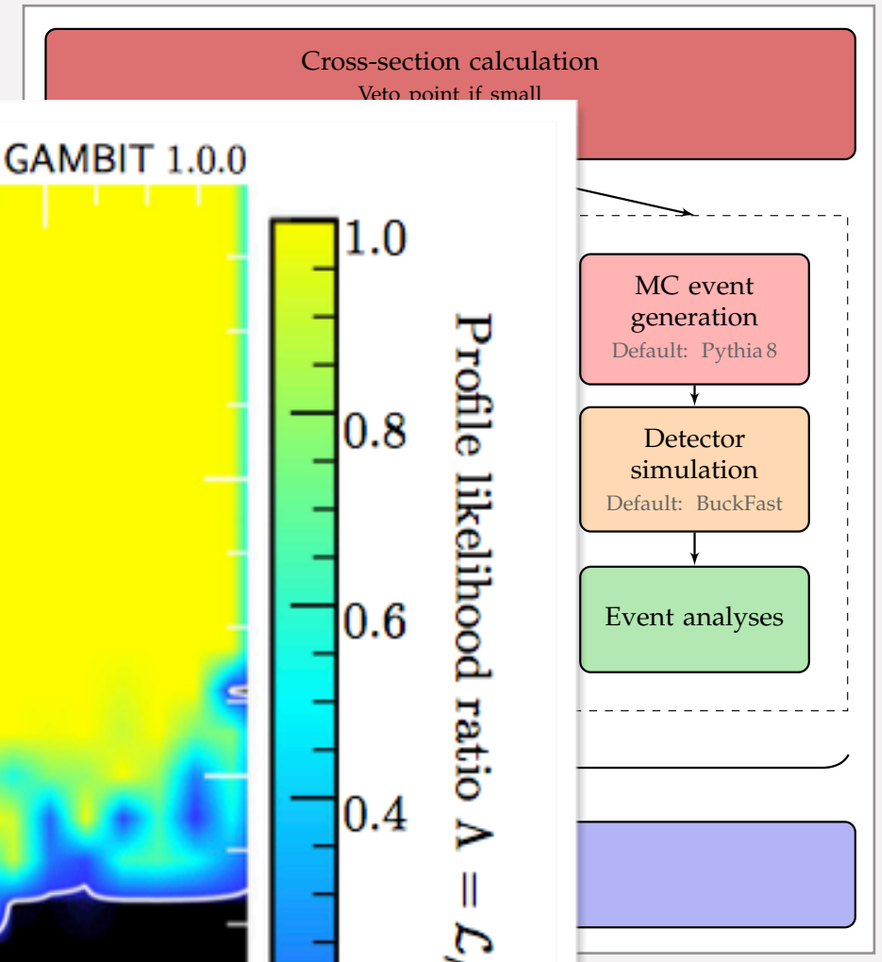
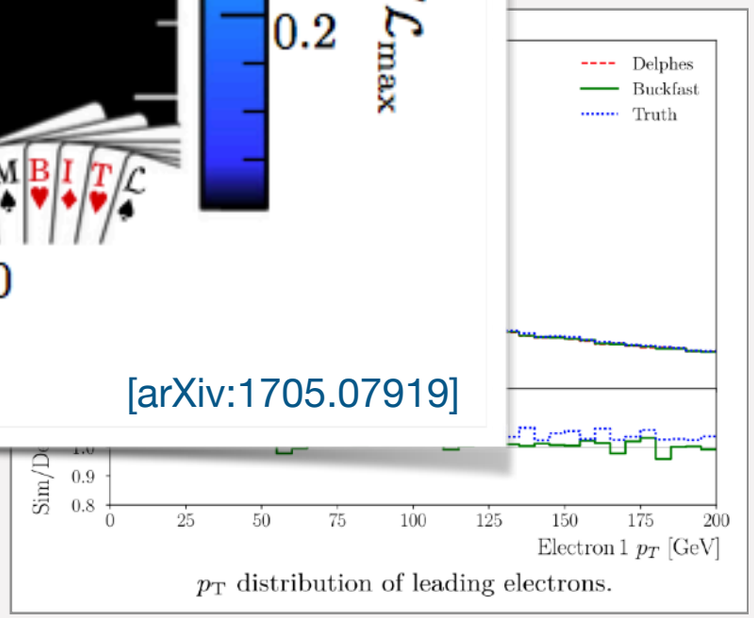


[arXiv:1705.07919]



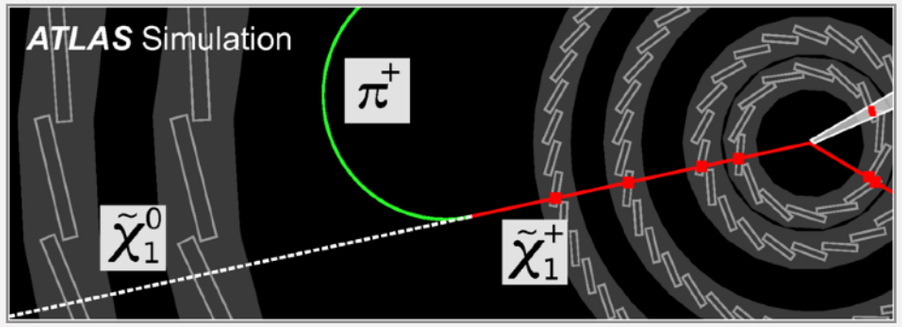


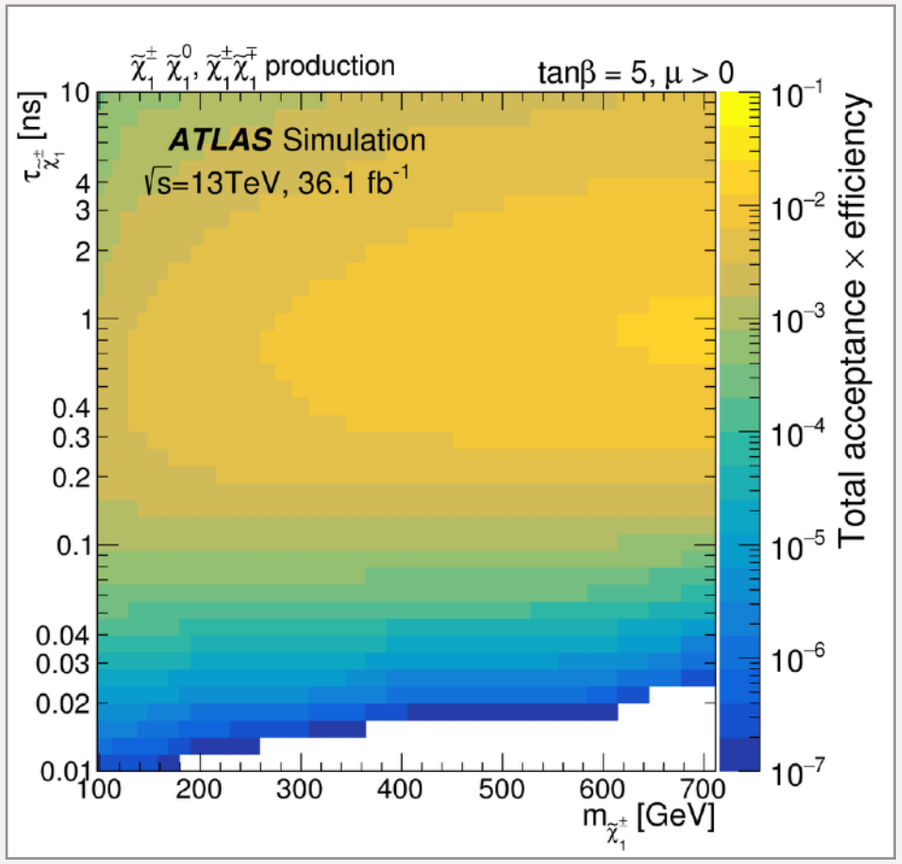
[arXiv:1705.07919]

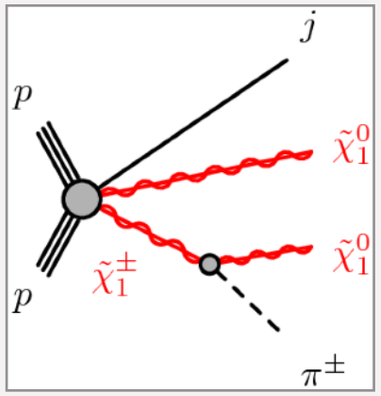
2. Current work:
Simulation-less LLP recasting

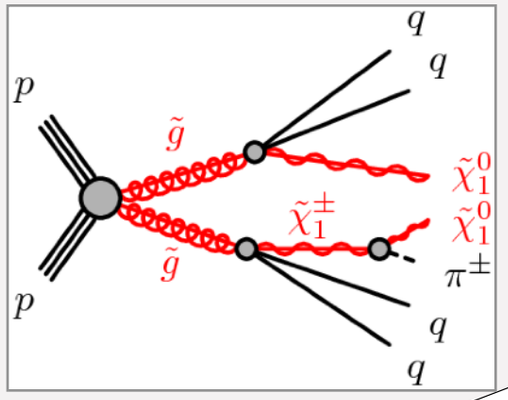
Simulation-less recasts

[arXiv:1712.02118]









- Get mass and lifetime predictions from SpecBit and DecayBit
- Production cross-section in ColliderBit
- Signal-specific maps of acceptance x efficiency from experimental analysis, in the plane of the LLP mass and lifetime
  A lot of very useful material provided on HepData!
- No event generation or detector simulation needed — perfect for large global fits
- Full Poisson likelihood, not only comparison to 95% CL limit
- First target: ATLAS disappearing track search for long-lived charginos (arXiv:1712.02118)

Mass and lifetime

- Masses from SpecBit
  (via FlexibleSUSY or SPheno)
- Lifetime from DecayBit calculations of decay widths at small mass splittings (not included in SDECAY)
- Chargino and stau decays implemented so far
  C.-H. Chen et al [PRD, arXiv:hep-ph/9607421]
  T. Jittoh et al [PRD, arXiv:hep-ph/0512197]
- *Future:* Also connect SOFTSUSY-4 to SpecBit & DecayBit

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$$\tilde{\chi}_1^+ \to \tilde{\chi}_1^0 \pi^+$$
$$\tilde{\chi}_1^+ \to \tilde{\chi}_1^0 \mu^+ \nu$$
$$\tilde{\chi}_1^+ \to \tilde{\chi}_1^0 e^+ \nu$$

$$\tilde{\tau}_1^+ \to \tilde{\chi}_1^0 \tau^+$$
$$\tilde{\tau}_1^+ \to \tilde{\chi}_1^0 \pi^+ \bar{\nu}$$
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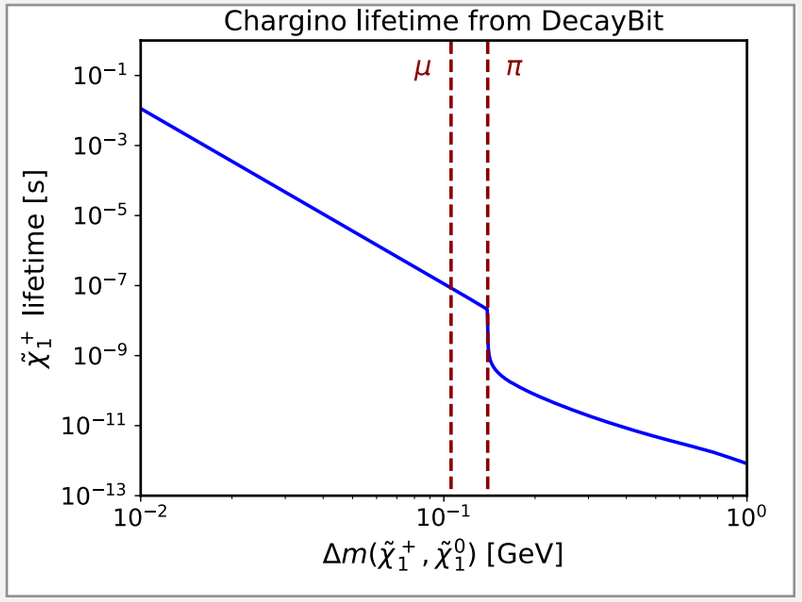
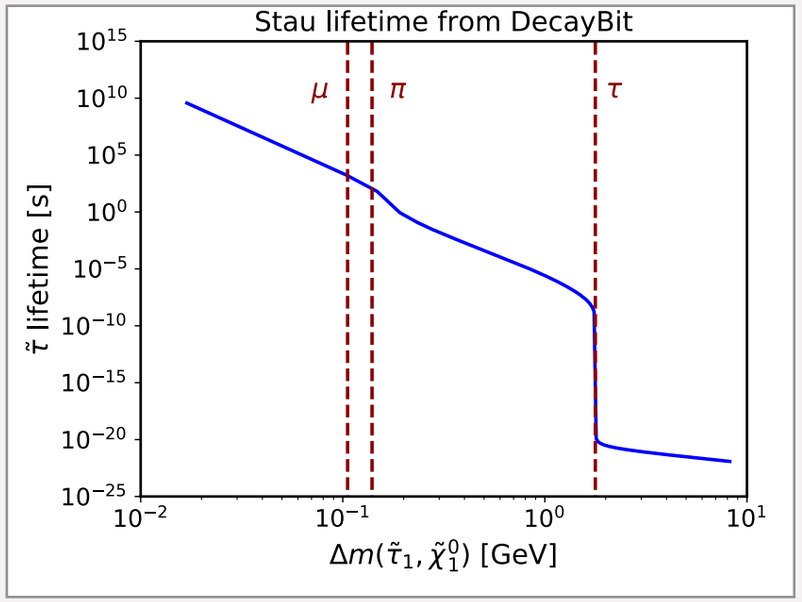
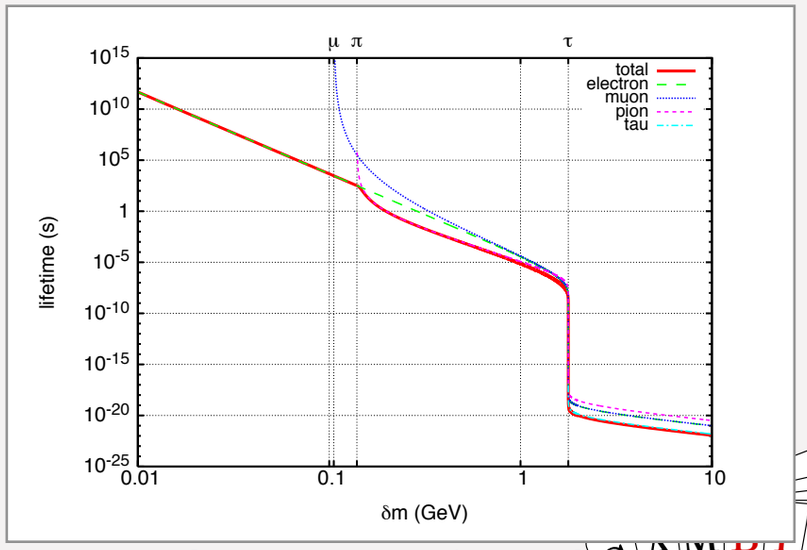
$$\tilde{\tau}_1^+ \to \tilde{\chi}_1^0 e^+ \nu \bar{\nu}$$



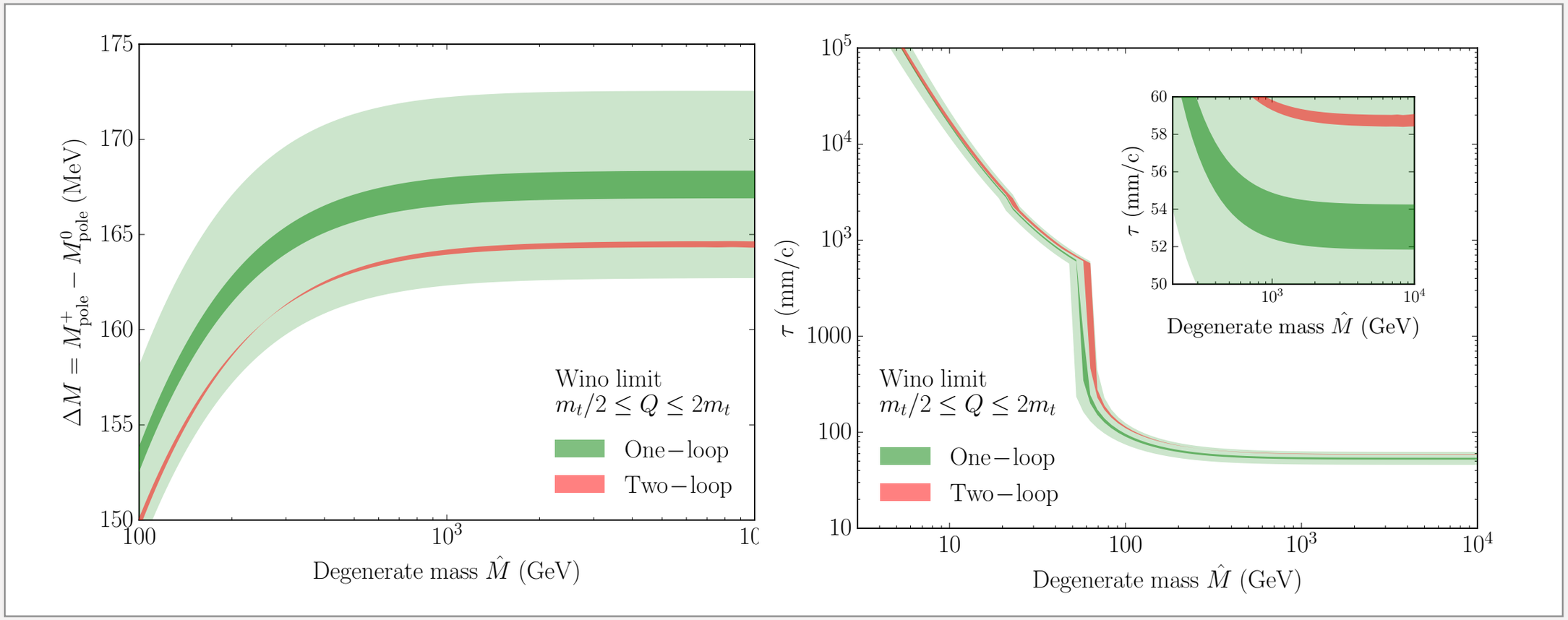




T. Jittoh et al [PRD, arXiv:hep-ph/0512197]

Mass and lifetime

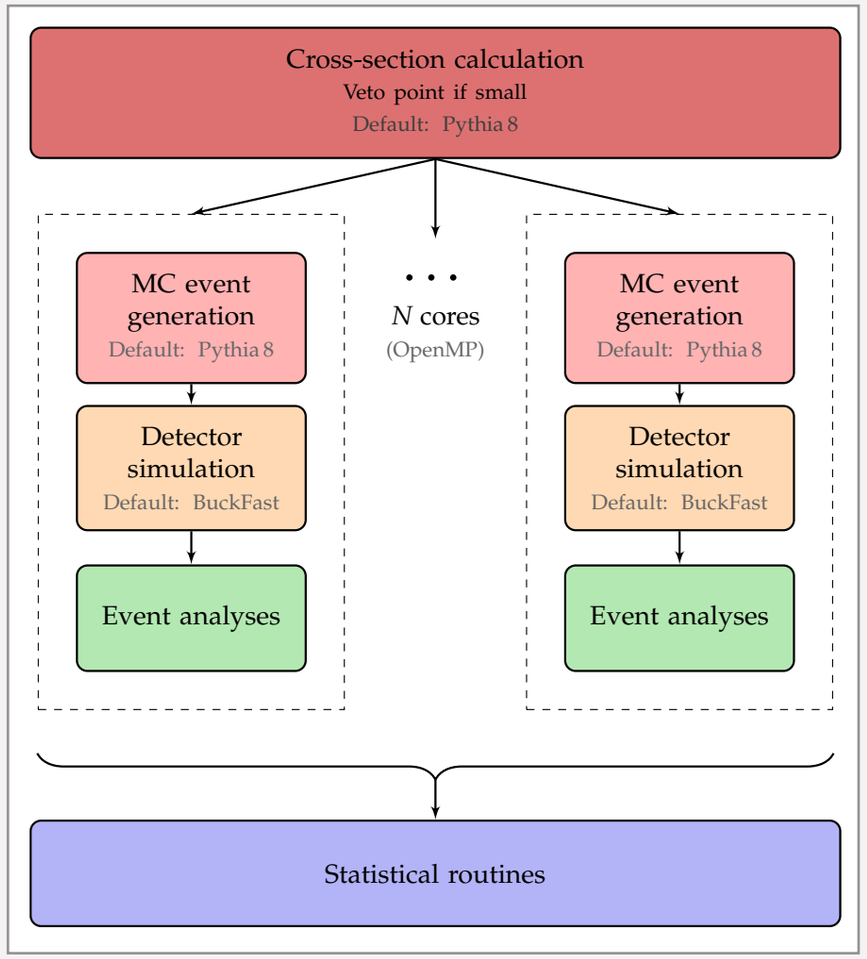
- *Todo:* Refine chargino lifetime with two-loop calculation of chargino—neutralino mass splitting (wino limit)



J. MacKay, P. Scott [PRD, arXiv:1712.00968]

Cross-sections and ColliderBit structure

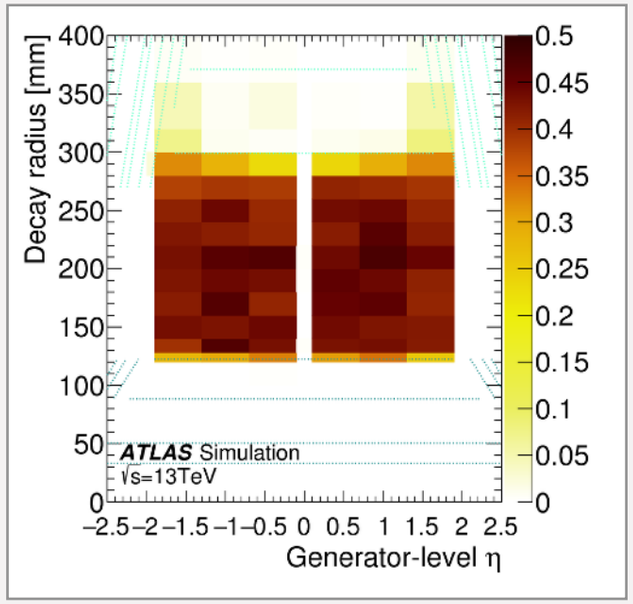
- *Currently:*
  - Tree-level cross-sections from Pythia8
- *Ongoing work:*
  - Detach cross-section calculation from the parallelized event generation in ColliderBit
  - Allow cross-section input from backend
  - Fast evaluation of NLO SUSY cross-sections
  - Add simulation-less analyses as a new category of analyses in ColliderBit

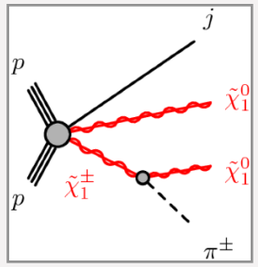


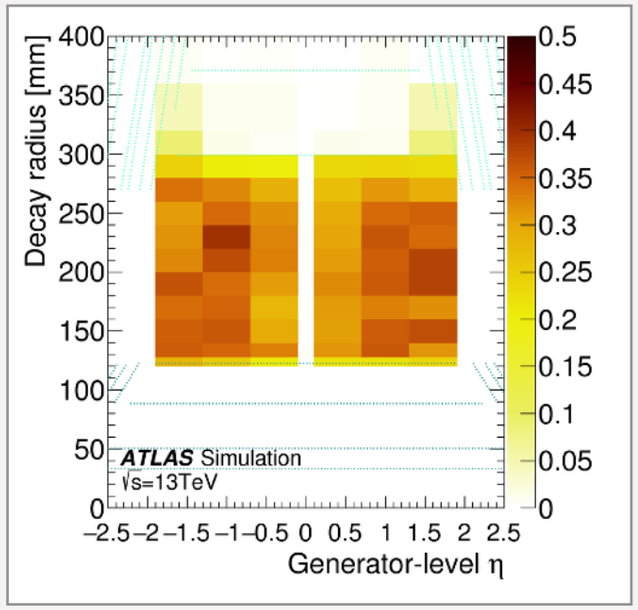
3. Next step:
Event-level LLP recasting

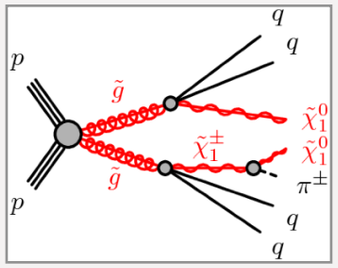
Next step: Event-level LLP recasting

- Use generator-level efficiency maps in decay radius and eta — code in place for doing this
- Slight tweaking of Pythia for decays at very small mass splittings
- Extend the ColliderBit analysis framework to include decay radius information









Conclusion and outlook

- Ongoing effort to implement LLP searches in ColliderBit
- Focus on speed — intended for use in large-scale global fits
- Starting with the simplest case: simulation-less recasting of SUSY LLP searches
- Some decay width calculations implemented, to be extended and refined
- Work ongoing on cross-section evaluations and extending the ColliderBit structure
- Next step: move on to event-level LLP recasting

gambit.hepforge.org

Backup slides

Getting started with GAMBIT

Clone git repository from GitHub

- github.com/patscott/gambit_1.1

Download tarballs

- hepforge.org/downloads/gambit

Pre-compilied version with Docker

- `docker run -it jmcornell/gambit`

See quick start guide in arXiv:1705.07908

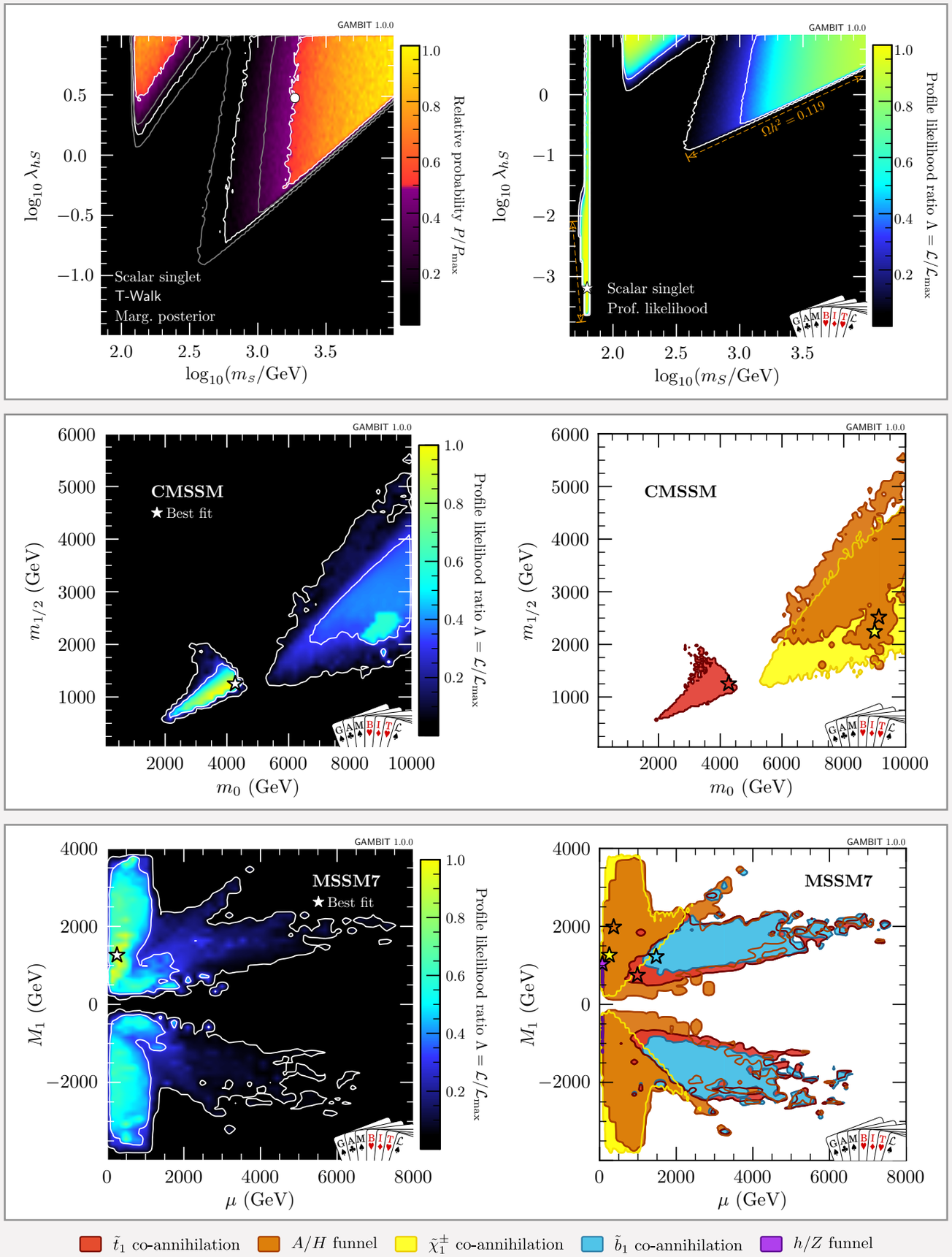
GAMBIT

First physics results

- **Scalar singlet dark matter**
  arXiv:1705.07931

- **GUT-scale MSSM**
  CMSSM, NUHM1, NUHM2
  arXiv:1705.07935

- **Weak-scale MSSM7**
  arXiv:1705.07917



All results publicly available

Results available on zenodo.cern.ch

- Parameter point samples (hdf5 files)
- GAMBIT input files for all scans
- Example plotting routines

Links at gambit.hepforge.org/pubs