

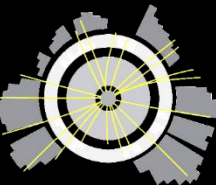


GAMBIT

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MONASH
University



COEPP
ARC Centre of Excellence for
Particle Physics at the Terascale

MoCA
Monash Centre for Astrophysics



GAMBIT at a glance

next gen **global** fitting
framework

modular and flexible
architecture

models **beyond** the Standard

sophisticated statistical
inference

plug&play **tools** to calc
observables



GAMBIT

a universal phenomenology tool

- **pseudo-observable calculations** auto-generation of masses and couplings (soon from \mathcal{L})
- **observable calculations** cosmology, astrophysics (dark matter), collider, precision, flavor...
- **many different models** effective, simplified, Higgs extensions, neutrinos, SUSY, axions...
- **parameter scans** grid, random, (ensemble) MCMC, nested sampling, differential evolution...
- **statistical inference** parameter estimation, Frequentists goodness of fit calculation, Bayesian model comparison



GAMBIT ad

- open-source code to calculate observables and likelihoods for generic Beyond the Standard Model(s) theories
- designed to allow easy definition of new models, observables, likelihoods, samplers and backend physics codes

<https://gambit.hepforge.org>

EPJC 77 (2017) 784 arXiv:1705.07908

11 experiments

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

70+ community members

P Athron, C Balázs, A Beniwal, S Bloor, T Bringmann, A Buckley, J Camargo-Molina, M Chrzęszcz, J Cornell, M Danninger, J Edsjö, B Farmer, A Fowlie, T Gonzalo, W Handley, S Hoof, S Hotinli, F Kahlhoefer, A Kvellestad, J Harz, P Jackson, F Mahmoudi, G Martinez, A Raklev, J Renk, C Rogan, R de Austri, P Scott, P Stöcker, A Vincent, C Weniger, M White, Y Zhang, ...

14 major theory codes

DarkSUSY, DDCalc, Diver, FlexibleSUSY, gamlike, GM2Calc, IsaJet, nulike, PolyChord, Rivet, SOFTSUSY, SuperIso, SUSY-AI, WIMPSim



GAMBIT modules

provide GAMBIT with a range of capabilities
to calculate a certain quantity

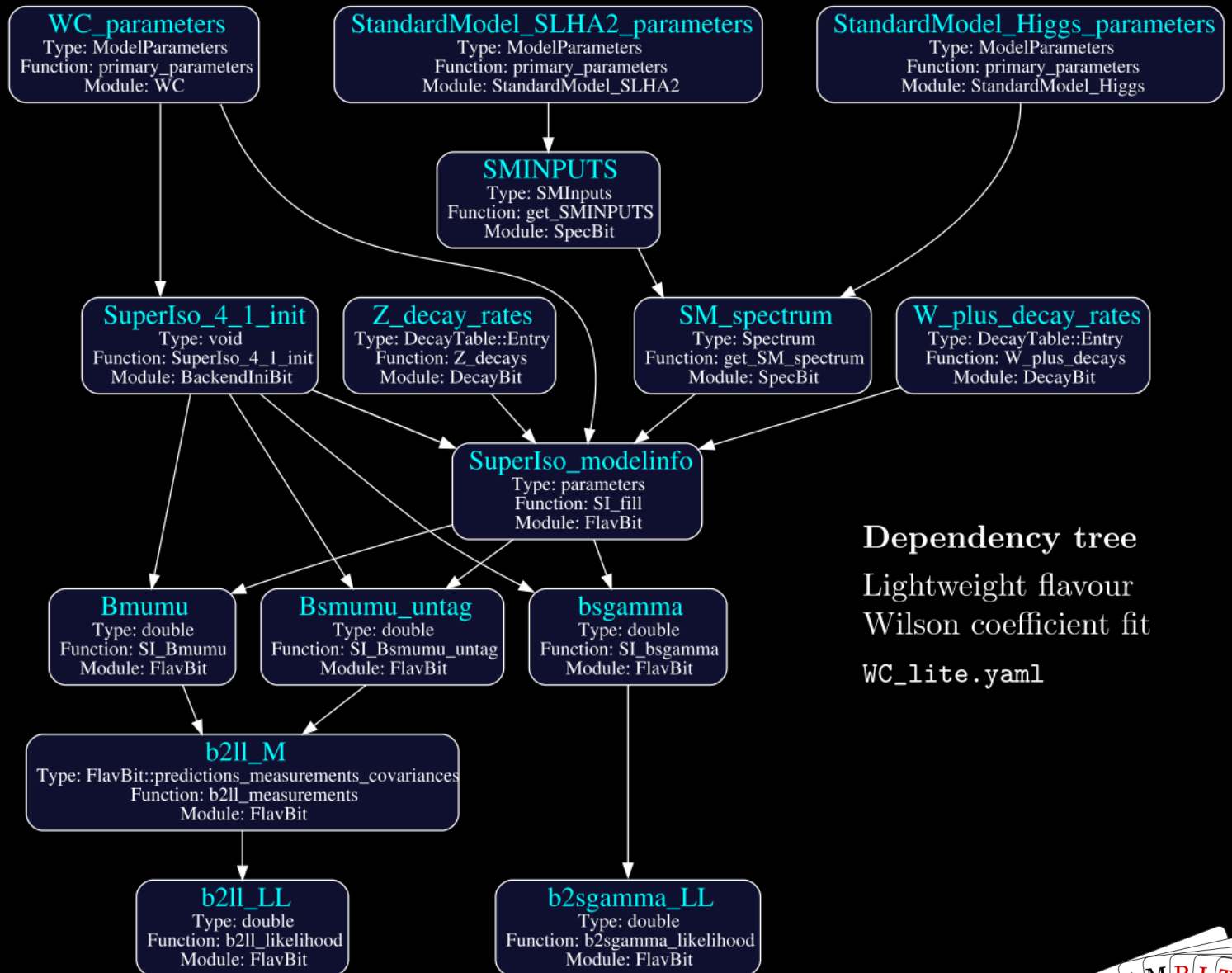
- ColliderBit: event gen., fast sim., Z, H obs.s, search limits... [arXiv:1705.07919](https://arxiv.org/abs/1705.07919)
- DarkBit: DM abundance, direct-, indirect detection... [arXiv:1705.07920](https://arxiv.org/abs/1705.07920)
- DecayBit: SM & NP (SUSY...) decay widths, BRs... [arXiv:1705.07936](https://arxiv.org/abs/1705.07936)
- FlavBit: NP (SUSY...) 100s of flavor obs.s, rare decays... [arXiv:1705.07933](https://arxiv.org/abs/1705.07933)
- PrecisionBit: EW precision observables, $g-2$... [arXiv:1705.07936](https://arxiv.org/abs/1705.07936)
- SpecBit: SM & NP masses, mixings, couplings, RGEs... [arXiv:1705.07936](https://arxiv.org/abs/1705.07936)
- ScannerBit: sampling, parameter est., model comparison... [arXiv:1705.07959](https://arxiv.org/abs/1705.07959)
- NeutrinoBit: neutrino observables, likelihoods, RHNs, ... [arXiv:1908.02302](https://arxiv.org/abs/1908.02302)
- CosmoBit: Λ CDM+, inflation, ... [arXiv:2009.03286](https://arxiv.org/abs/2009.03286)

Coming soon: GUM, GAMBIT 2.0, GPU support, ...



GAMBIT run overview

- user chooses model, observables, stat. method
- using graph-theory GAMBIT constructs a dependency tree to optimize the calculation
- GAMBIT samples para. space by calling the necessary module and backend functions for each parameter point



Dependency tree
Lightweight flavour
Wilson coefficient fit
WC_lite.yaml



GAMBIT technical

- scanners: nested sampling, diff. evolution, MCMC, T-walk, particle swarm...
- parallelization: mixed-mode MPI+openMP, mostly automated, 10k+ cores scaling
- automatic getters for downloading, configuring + compiling backends
- currently interfaced backends: CalcHEP, Capt'n General, DDCalc, DarkSUSY, FeynHiggs, Flavio, gamLike, HepLike, HiggsBounds, HiggsSignals, Micromegas, nulyke, Pythia8, SPheno, SUSYHD, SUSY-HIT, SuperIso
- BOSS: dynamic loading of C++ classes from backend shared libraries (!) All-in or module standalone modes – easily implemented from single cmake script
- diskless generalisation of various Les Houches Accords
- flexible output streams (ASCII, databases, HDF5, . . .)
- available as docker plugin or vagrant virtual machine
- GAMBIT2: Lagrangian to likelihood automation, more models, observables, stats...



public results available on
zenodo.cern.ch

- parameter point samples
- GAMBIT input files for all scans
- example plotting routines

links at
gambit.hepforge.org/pubs



The screenshot shows the Zenodo website interface. At the top, the Zenodo logo is on the left, a search bar containing 'GAMBIT' is in the center, and 'Upload' and 'Communities' links are on the right. Below the search bar, there are three search results, each with a 'View' button on the right. Each result includes a date and version in a blue box, a 'Dataset' label in a grey box, and an 'Open Access' label in a green box. The first result is dated 'June 29, 2018 (v1)' and is titled 'Supplementary Data: Impact of vacuum stability, perturbativity and XENON1T on global fits of Z2 and Z3 scalar singlet dark matter (arXiv:1806.11281)'. The second result is dated 'August 22, 2017 (v2)' and is titled 'Supplementary Data: Status of the scalar singlet dark matter model (arXiv:1705.07931)'. The third result is dated 'August 15, 2017 (v2)' and is titled 'Supplementary Data: A global fit of the MSSM with GAMBIT (arXiv:1705.07917)'. The fourth result is dated 'August 15, 2017 (v2)' and is titled 'Supplementary Data: Global fits of GUT-scale SUSY models with GAMBIT (arXiv:1705.07935)'. Each result also includes a description of the data and the GAMBIT Collaboration name. In the bottom right corner, there is a small graphic of playing cards with the letters G, A, M, B, I, T on them.

zenodo

GAMBIT

Upload Communities

June 29, 2018 (v1) Dataset Open Access View

Supplementary Data: Impact of vacuum stability, perturbativity and XENON1T on global fits of Z2 and Z3 scalar singlet dark matter (arXiv:1806.11281)

The GAMBIT Collaboration;

Supplementary Data Impact of vacuum stability, perturbativity and XENON1T on global fits of Z2 and Z3 scalar singlet dark matter arXiv:1806.11281 The files in this record contain data for the scalar singlet dark matter models considered in the GAMBIT "Scalar singlet Mark II&qu

Uploaded on July 2, 2018

August 22, 2017 (v2) Dataset Open Access View

Supplementary Data: Status of the scalar singlet dark matter model (arXiv:1705.07931)

The GAMBIT Collaboration;

Supplementary Data Status of the scalar singlet dark matter model arXiv:1705.07931 The files in this record contain data for the scalar singlet dark matter model considered in the GAMBIT "Round 1" scalar singlet paper. The files consist of Three YAML files, each corresponding to a different pa

Uploaded on August 23, 2017

1 more version(s) exist for this record

August 15, 2017 (v2) Dataset Open Access View

Supplementary Data: A global fit of the MSSM with GAMBIT (arXiv:1705.07917)

The GAMBIT Collaboration;

Supplementary Data A global fit of the MSSM with GAMBIT arXiv:1705.07917 The files in this record contain data for the MSSM7 model considered in the GAMBIT "Round 1" weak-scale SUSY paper. The files consist of A number of YAML files corresponding to different sets of sampling parameters and/

Uploaded on August 16, 2017

1 more version(s) exist for this record

August 15, 2017 (v2) Dataset Open Access View

Supplementary Data: Global fits of GUT-scale SUSY models with GAMBIT (arXiv:1705.07935)

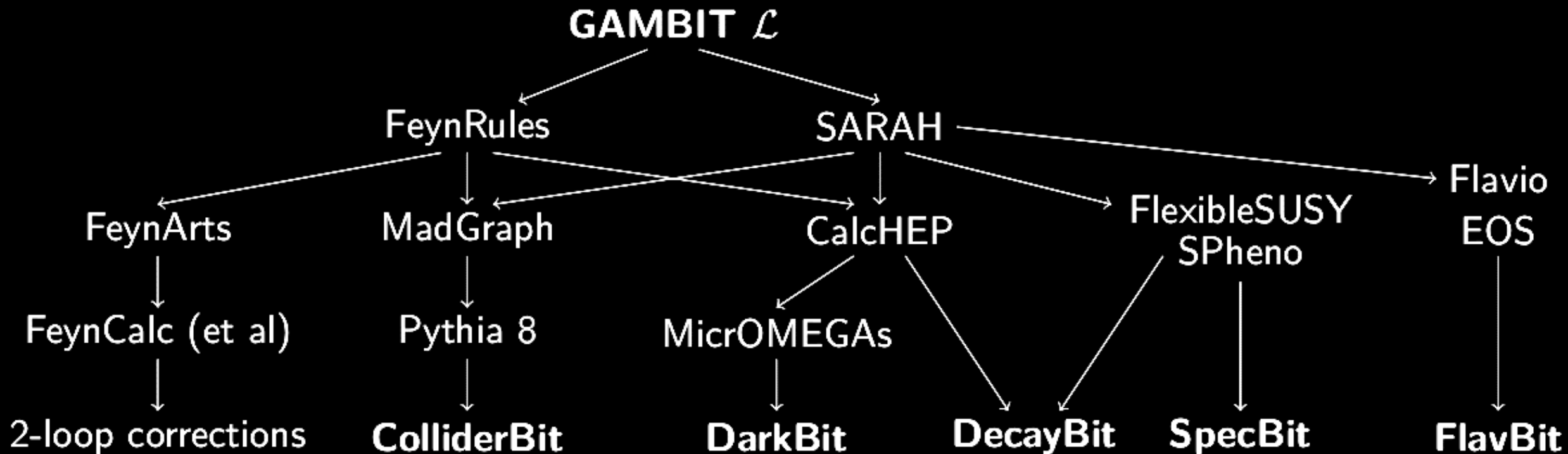
The GAMBIT Collaboration;

Supplementary Data Global fits of GUT-scale SUSY models with GAMBIT arXiv:1705.07935 The files in this data for the CMSSM, NUHM1 and NUHM2 models considered in the GAMBIT "Round 1" GUT-scale SUSY pa model, there are A number of YAML files, each corresponding to a di

GAMBIT 2

Extension to model building

- GAMBIT Universal Model (GUM), interface to Lagrangian-level
- Auto code generation for spectra, cross sections, observables ...



collaboration opportunities

- implementing and/or improving experimental likelihoods
- targeted flavor/neutrino physics studies (not just global fits!)
- new flavor/neutrino global fits
- GAMBIT and/or backend code improvements
 - machine learning likelihoods, cross sections
 - new scanning methods (exploring dozens already)
 - GPU translations (grant application in)
 - ...





backup slides

GAMBIT features

global and modular

- **diverse BSM model database** (SM+SS, EFTs, 2HDMs, MSSM63, axions, RHNs...)
- changeable model assumptions for astrophysics, nuclear, ...
- **built-in experimental likelihoods** (LEP, ATLAS, CMS, LHCb, DM searches, ...)
- **composite likelihood** (consistent treatment of uncertainties, nuisances, ...)
- several scanning algorithms (ensemble MCMC, differential evolution, nested...)
- auto dependency resolution (ID functions, optimize execution order!)
- dual-level parallel execution: MPI and OpenMP
- ...



GAMBIT features

flexible and extendable

- fast definition of new models, data sets, sampling methods
- plug&play theory tools auto-download, compile, dynamically link
- easily switch between backends calculating the same quantities
- C/C++, Fortran, Python, Mathematica interfaces for backends
- input: model, para.s, observables, sampler, stat. inference
- customizable output streams: ASCII, HDF5...
- GAMBIT 2: input Lagrangian, auto-generate code for observables...
- ...



the future

statistically reliable determination of model plausibility: p values,
Bayesian odds (for nested models), ...

fast and systematic model comparison and selection based on
robust statistical tools

papers focusing on various models and future facilities:
future dark matter detection, future colliders, ...

more models, more data, more projections, more automation, ...

getting started

- clone git repo github.com/patscott/gambit_1.1 or
- download tarballs hepforge.org/downloads/gambit or
- get pre-compiled version `docker run -it jmcornell/gambit` and
- see quick start guide in [arXiv:1705.07908](https://arxiv.org/abs/1705.07908)



adding a new model to GAMBIT

1. Add the model to the **model hierarchy**:

- Choose a model name, and declare any **parent model**
- Declare the model's parameters
- Declare any **translation function** to the parent model

```
#define MODEL NUHM1
#define PARENT NUHM2
START_MODEL
DEFINEPARS(M0,M12,mH,A0,TanBeta,SignMu)
INTERPRET_AS_PARENT_FUNCTION(NUHM1_to_NUHM2)
#undef PARENT
#undef MODEL
```

2. Write the translation function as a standard C++ function:

```
void MODEL_NAMESPACE::NUHM1_to_NUHM2 (const ModelParameters &myP, ModelParameters &targetP)
{
    // Set M0, M12, A0, TanBeta and SignMu in the NUHM2 to the same values as in the NUHM1
    targetP.setValues(myP,false);
    // Set the values of mHu and mHd in the NUHM2 to the value of mH in the NUHM1
    targetP.setValue("mHu", myP["mH"]);
    targetP.setValue("mHd", myP["mH"]);
}
```

3. If needed, declare that existing module functions work with the new model, or add new functions that do.



adding a new observable/likelihood to GAMBIT

Adding a new module function is easy:

1. Declare the function to GAMBIT in a module's **rollcall header**
 - Choose a capability
 - Declare any **backend requirements**
 - Declare any **dependencies**
 - Declare any specific **allowed models**
 - other more advanced declarations also available

```
#define MODULE FlavBit // A tasty GAMBIT module.
START_MODULE

#define CAPABILITY Rmu // Observable: BR(K->mu nu)/BR(pi->mu nu)
START_CAPABILITY
#define FUNCTION SI_Rmu // Name of a function that can compute Rmu
START_FUNCTION(double) // Function computes a double precision result
BACKEND_REQ(Kmunu_pimunu, (my_tag), double, (const parameters*)) // Needs function from a backend
BACKEND_OPTION( (SuperIso, 3.6), (my_tag) ) // Backend must be SuperIso 3.6
DEPENDENCY(SuperIso_modelinfo, parameters) // Needs another function to calculate SuperIso info
ALLOW_MODELS(MSSM63atQ, MSSM63atMGUT) // Works with weak/GUT-scale MSSM and descendents
#undef FUNCTION
#undef CAPABILITY
```

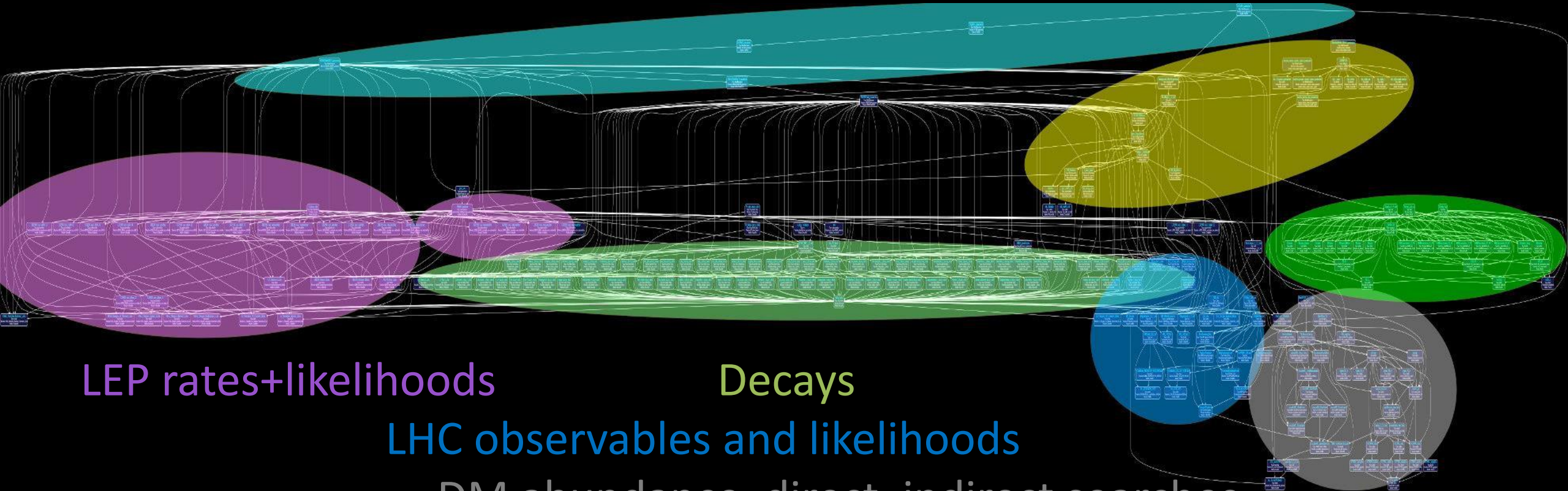
2. Write the function as a standard C++ function
(one argument: the result)



GAMBIT dependency resolution for CMSSM

Model parameter translations

Precision calculations



LEP rates+likelihoods

Decays

LHC observables and likelihoods

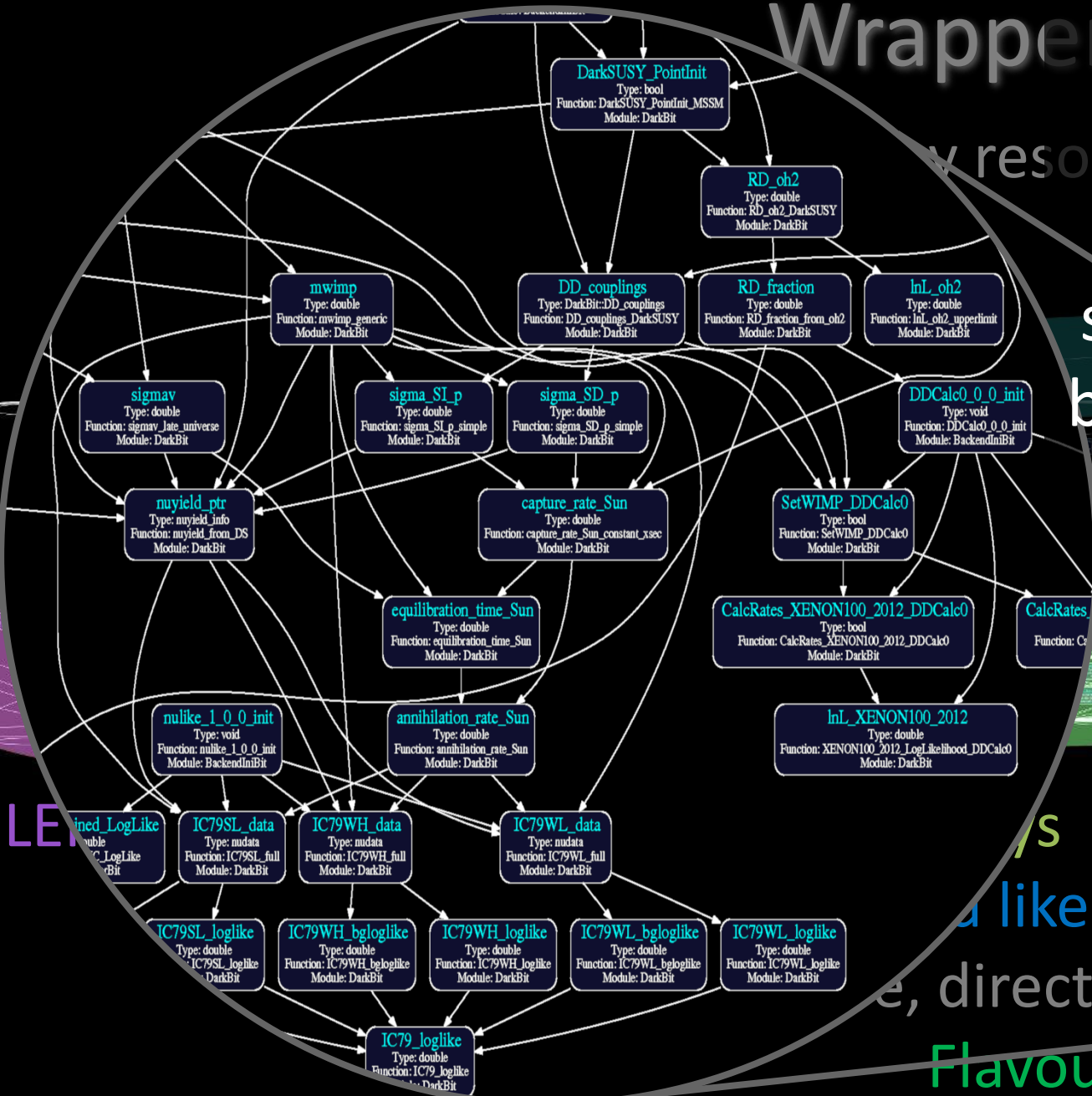
DM abundance, direct, indirect searches

Flavour physics observables



Wrapper?

dependencies constructed dynamically at run-time using graph-theoretic methods to solve for required observables, backends, evaluation order, etc.



LEP

likelihoods

direct, indirect searches

Flavour physics observables



GAMBIT results related to dark matter

EFTs: SM + scalar, fermion, vector singlet (simplest DM model)

EPJ C77 (2017) 8 568 arXiv:1705.07931

EPJ C78 (2018) 10 830 arXiv:1806.11281

EPJ C79 (2019) 1 38 arXiv:1808.10465

axions, axion-like particles (QCD axion, DFSZ, KSVZ, generic ALP)

JHEP 1903 (2019) 191 arXiv:1810.07192

constrained SUSY: CMSSM, NUHM1, NUHM2 (GUT scale BCs)

EPJ C77 (2017) 12 824 arXiv:1705.07935

low-dim SUSY: MSSM-7, MSSM-EW (weak scale BCs)

EPJ C77 (2017) 12 879 arXiv:1705.07917

EPJ C79 (2019) 5 395 arXiv:1809.02097

more EFTs, more ALPs, more SUSY and other models in prep

