Gambit in a nutshell

Marcin Chrząszcz
mchrzasz@cern.ch

Universität Zürich,
Institute of Nuclear Physics, Polish Academy of Science

June 17, 2016

How to find New Physics?

⇛ There is no shortage of Beyond Standard Models! ⇛ Any BSM can show up in lots of places:

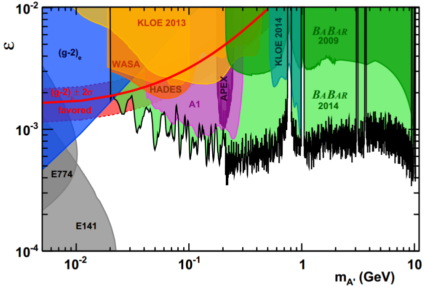
- Flavour Physics.
- Higgs and supersymmetry searches at the LHC and its predecessors.
- Measurements of the magnetic moment of the muon.
- Beam dump/fixed target (NA62, SHIP,...).
- Electroweak precision tests.
- Dark matter.
- Neutrino mixing.
- Gamma ray searches (e.g. FERMI-LAT, HESS, CTA, etc)
- Radio data.
- etc.

This begs the question...

⇛ How to combine results from all relevant experimental searches?

⇛ This is straightforward for models with few parameters:

- Overlay exclusion curves from different experiments/measurements.
- Look for ”excluded” and ”non-excluded regions”



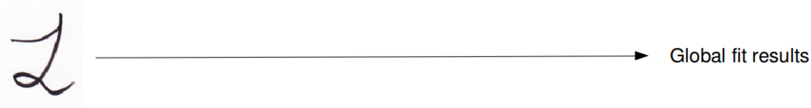
⇛ But the problem is not trivial if one has many parameters: ⇛ Scan the space (need very smart methods for a large number of parameters).

⇛ Interpret the results (Bayesian/frequentist).

⇛ Project down to parameters of interest (marginalise/profile)

⇛ Need a global fitting code: GAMBIT.

I had a dream...


Global fit results

⇛ Recent years have seen an explosion of tools that make study of user-defined Lagrangians easier.

⇛ e.g. Feynrules → Madgraph interface, CalcHEP interface to Micromegas, MadDM, automated NLO calculations through Madgraph/NLOCT + much, much more.

⇛ The global fit world has not kept up with this.

⇛ Most people hard-code their own solution for each particular study

⇛ Several innovations are need to rectify this:

⇛ How do we store model parameters in a sufficiently abstract way?

⇛ How do we tie disparate codes together?

⇛ How do we make LHC and other constraints model independent?

GAMBIT: a *second-generation* global fit code

GAMBIT: The Global And Modular BSM Inference Tool

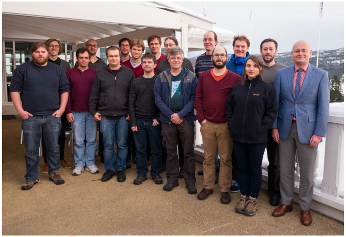
Overriding principles of GAMBIT: flexibility and modularity

- General enough to allow fast definition of new datasets and theoretical models
- Plug and play scanning, physics and likelihood packages
- Extensive model database – not just small modifications to constrained MSSM (NUHM, etc), and not just SUSY!
- Extensive observable/data libraries (likelihood modules)
- Many statistical options – Bayesian/frequentist, likelihood definitions, scanning algorithms
- A smart and *fast* LHC likelihood calculator
- Massively parallel
- Full open-source code release

The GAMBIT Collaboration

30 Members, 17 institutions, 10 countries, 11 Experiments, 4 major theory codes

ATLAS	A. Buckley, P. Jackson, C. Rogan, M. White,
LHCb	M. Chrzaszcz, N. Serra
Fermi-LAT	J. Conrad, J. Edsjö, G. Martinez P. Scott
CTA	C. Balázs, T. Bringmann, J. Conrad, M. White
HESS	J. Conrad
IceCube	J. Edsjö, P. Scott
AMS-02	A. Putze
CDMS, DM-ICE	L. Hsu
XENON/DARWIN	J. Conrad
Theory	P. Athron, C. Balázs, T. Bringmann, J. Cornell, J. Edsjö, B. Farmer, A. Krislock, A. Kvellestad, M. Pato, F. Mahmoudi, A. Raklev, P. Scott, C. Weniger, M. White



+recently joined: T. Gonzales, F. Kahlhoefer, J. McKay, R. Ruiz, R. Trotta
-recently retired: L. Dal, A. Saavedra, C. Savage

Modules

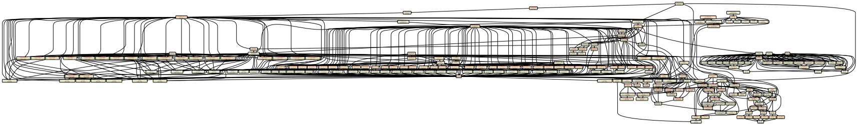
Physics modules

- DarkBit – dark matter observables (relic density, direct + indirect detection)
- ColliderBit – collider observables inc. Higgs + SUSY searches from ATLAS, CMS + LEP
- FlavBit – flavour physics inc. $g-2$, $b \to s\gamma$, B decays (new channels, angular obs., theory uncerts, LHCb likelihoods)
- SpecBit – generic BSM spectrum object, providing RGE running, masses, mixings, etc via interchangeable interfaces to different RGE codes
- DecayBit – decay widths for all relevant SM & BSM particles
- PrecisionBit – SM likelihoods, precision BSM tests (W mass, $\Delta\rho$ etc)

Each consists of a number of **module functions** that can have **dependencies** on each other

+ScannerBit: manages stats, sampling and optimisation

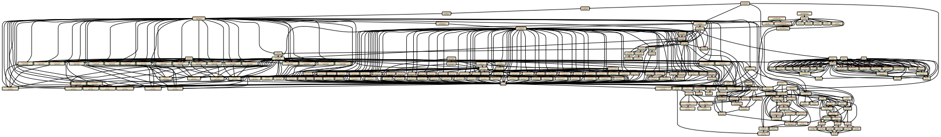
Dependency Resolution



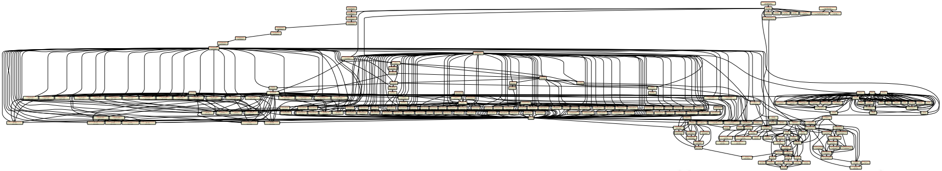
- Module functions and backend functions get arranged into a **dependency tree**
- Starting with requested observables and likelihoods, GAMBIT fills each dependency and backend requirement
- Obeys **rules** at each step: allowed models, allowed backends, constraints from input file, etc
- → tree constitutes a directed acyclic graph
- → GAMBIT uses graph-theoretic methods to ‘solve’ the graph to determine function evaluation order

Dependency Resolution

CMSSM:

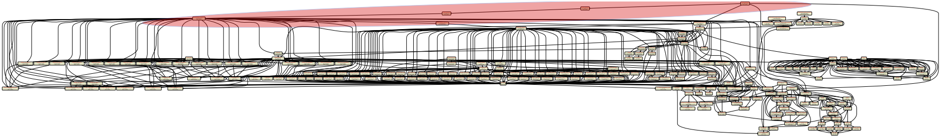


MSSM7:

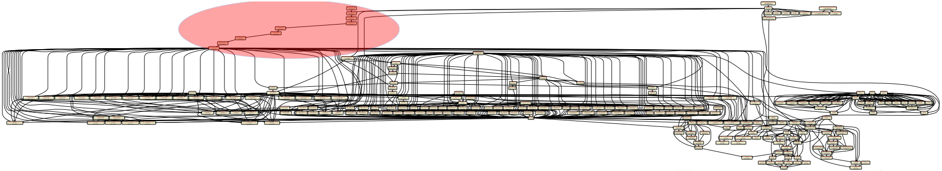


Dependency Resolution

CMSSM:



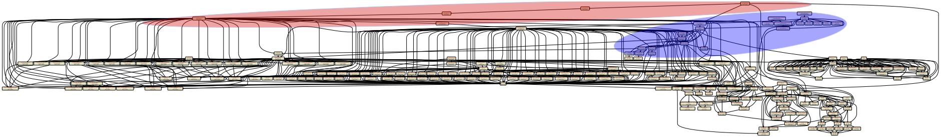
MSSM7:



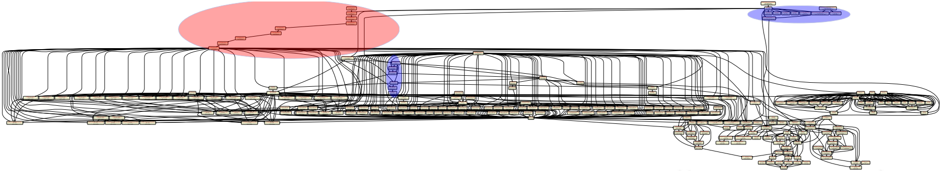
Red: Model parameter translations

Dependency Resolution

CMSSM:



MSSM7:

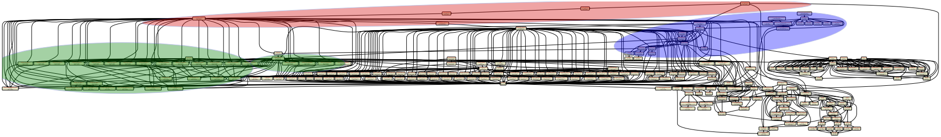


Red: Model parameter translations

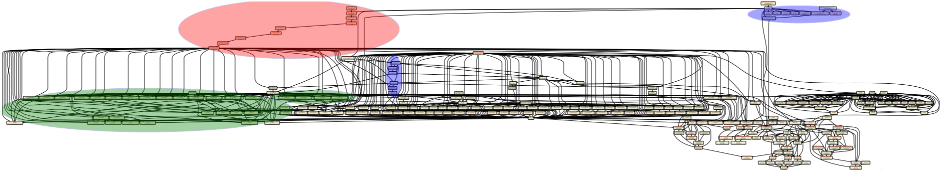
Blue: Precision calculations

Dependency Resolution

CMSSM:



MSSM7:



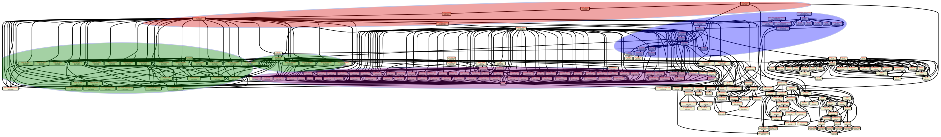
Red: Model parameter translations

Blue: Precision calculations

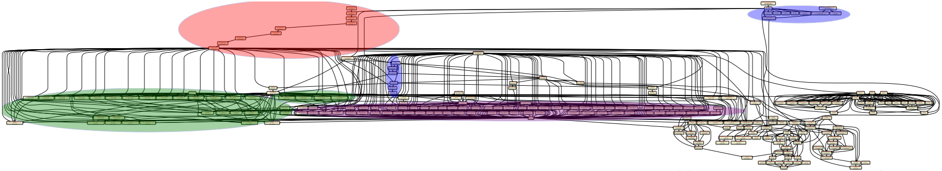
Green: LEP rates+likelihoods

Dependency Resolution

CMSSM:



MSSM7:



Red: Model parameter translations

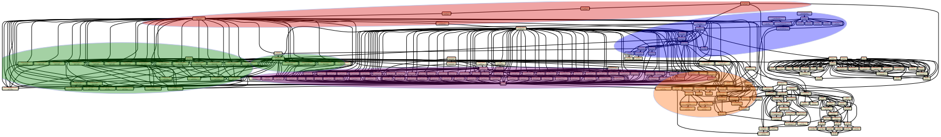
Blue: Precision calculations

Green: LEP rates+likelihoods

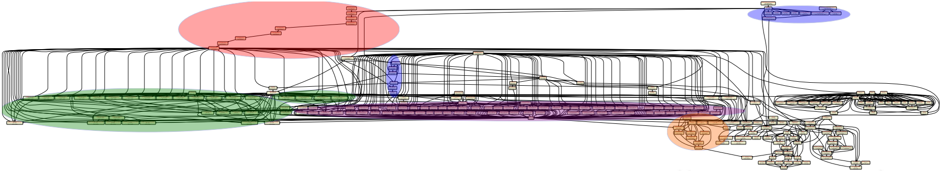
Purple: Decays

Dependency Resolution

CMSSM:



MSSM7:



Red: Model parameter translations

Blue: Precision calculations

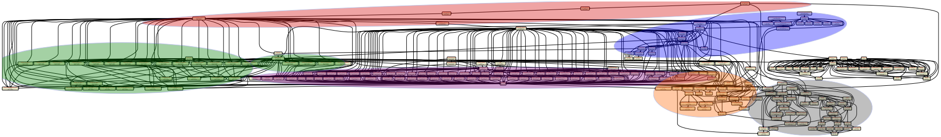
Green: LEP rates+likelihoods

Purple: Decays

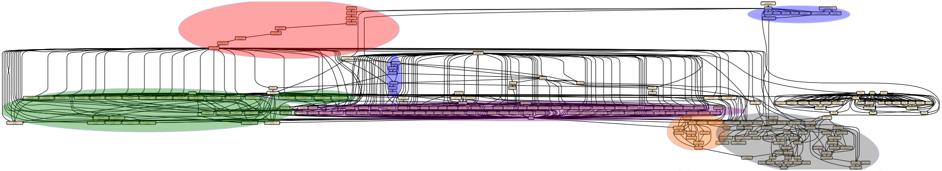
Orange: LHC observables and likelihoods

Dependency Resolution

CMSSM:



MSSM7:



Red: Model parameter translations

Blue: Precision calculations

Green: LEP rates+likelihoods

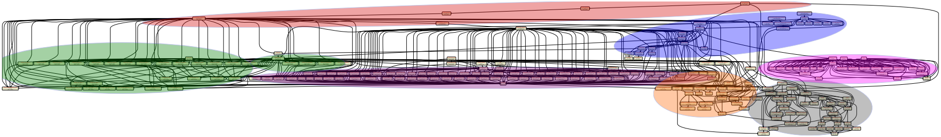
Purple: Decays

Orange: LHC observables and likelihoods

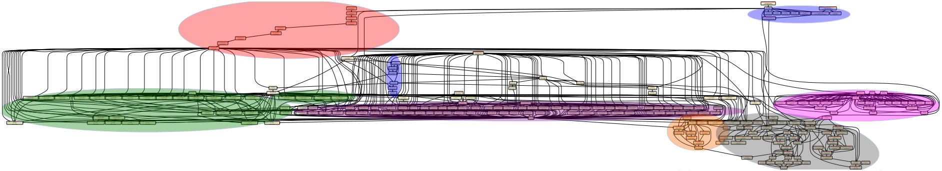
Grey: DM direct, indirect and relic density

Dependency Resolution

CMSSM:



MSSM7:



Red: Model parameter translations

Blue: Precision calculations

Green: LEP rates+likelihoods

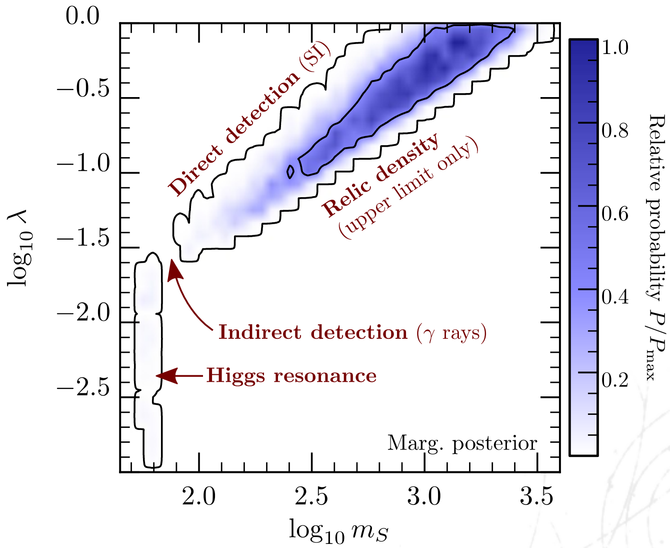
Purple: Decays

Orange: LHC observables and likelihoods

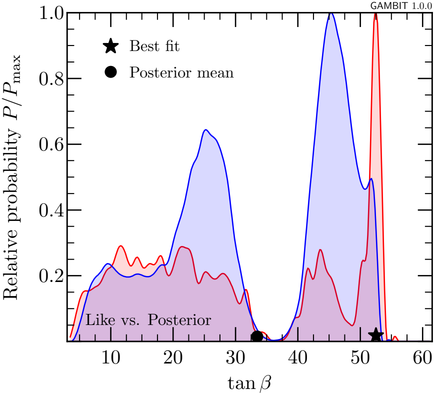
Grey: DM direct, indirect and relic density

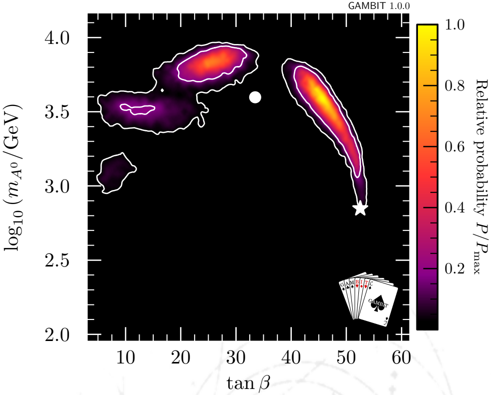
Pink: Flavour physics

Preliminary results: scalar singlet model



Preliminary results: SUSY (CMSSM – *example only*)





Backup