Update on GAMBIT

Pat Scott

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Slides at: tinyurl.com/patscott
GAMBIT: gambit.hepforge.org
Current global fit codes are hardcoded to deal with only a few
- theories (MSSM and/or mSUGRA+friends)
- theory calculators (often interfaced in a very ad hoc way)
- datasets and observables (often missing detailed likelihoods)
- scanning algorithms and statistical methods (generally just one)

⇒ hitting the wall on theories, data & computational methods
Global fits for dark matter and new physics

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How to quickly recast data, likelihood functions, scanning code ‘housekeeping’ and even theory predictions to new theories?
⇒ a new, very general global fitting framework
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How to quickly recast data, likelihood functions, scanning code ‘housekeeping’ and even theory predictions to new theories?
\[ \implies \text{a new, very general global fitting framework} \]

\[ \implies \text{GAMBIT} \]
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, 16 institutions, 10 countries, 11 Experiments, 4 major theory codes

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

Also recently joined or left: T. Gonzales, J. McKay, R. Ruiz,
A. Saavedra, C. Savage, R. Trotta

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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. $g - 2$, $b \rightarrow s\gamma$, $B$ 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
Hierarchical Model Database

- Models are defined by their parameters and relations to each other.
- Models can inherit from parent models.
- Points in child models can be automatically translated to ancestor models.
- Friend models also allowed (cross-family translation).
- Model dependence of every function/observable is tracked ⇒ maximum safety, maximum reuse.
Backends: mix and match

- Module functions can require specific functions from **backends**
- Backends are external code libraries (DarkSUSY, FeynHiggs, etc) that include different functions
- GAMBIT automates and abstracts the interfaces to backends → backend functions are tagged according to what they calculate
- → with appropriate module design, **different backends and their functions can be used interchangeably**
- GAMBIT dynamically adapts to use whichever backends are actually present on a user’s system (+ provides details of what it decided to do of course)
## Backends: mix and match

All relative paths are given with reference to `/home/pat/gambit`.

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Gambit diagnostic backend line 1 (press h for help or q to quit)

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## Backends: mix and match

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Gambit diagnostic backend line 1 (press h for help or q to quit)
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
CMSSM:

MSSM7:
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Red: Model parameter translations
CMSSM:

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Red: Model parameter translations
Blue: Precision calculations
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Purple: Decays

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Purple: Decays
Orange: LHC observables and likelihoods
Grey: DM direct, indirect and relic density
Pink: Flavour physics
Dependency Resolution: a closer look
Other nice technical features

- **Interface**: Simple, clean, intuitive and powerful YAML text file
- **Scanners**: Nested sampling, differential evolution, MCMC, genetic algorithm, t-walk...
- Mixed-mode **MPI + openMP** parallelisation, mostly automated → scales to 10k+ cores
- diskless generalisation of various Les Houches Accords
- **BOSS**: dynamic loading of C++ classes from backends (!)
- **all-in or module standalone** modes – easily implemented from single cmake script
- **automatic getters** for obtaining, configuring + compiling backends
- **flexible output streams** (ASCII, databases, HDF5, ...)
- more more more more...

1 if a backend won’t compile/crashes/steals your credit card info, blame the authors (not us... except where we are the authors...)
GAMBIT is almost here:
→ Global fits to many models for the first time
→ Better global fits to familiar ones
→ Highly modular, usable and extendable public code
→ Faster, more complete and more consistent theory explorations + experimental analysis prototyping

Series of 9 papers in preparation:
- EW-scale MSSMs, CMSSM±ε (NUHM, etc), Scalar Singlet
- DarkBit, ColliderBit, FlavBit, Spec+Decay+PrecisionBits
- GAMBIT framework, ScannerBit

After that:
more models, more observables, more data!
→→→ LHC Run 2!
Backup Slides
Expansion: adding new functions

Adding a new module function is easy:

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

   ```
   #define MODULE FlavBit
   START_MODULE
   
   #define CAPABILITY Kmumu_pimunu // Observable: BR(K->mu nu)/BR(pi->mu nu)
   START_CAPABILITY
   #define FUNCTION SI Kmumu_pimunu // Name of specific function providing the observable
   START_FUNCTION(double) // Function calculates a double precision variable
   DEPENDENCY(FlavBit fill, parameters) // Needs some other function to calculate FlavBit fill data
   BACKEND_REQ(Kmumu_pimunu, (libsuperiso), double, (struct parameters*)) // Needs a function from a backend
   BACKEND_OPTION((SuperIso, 3.4), (libsuperiso)) // Backend must be SuperIso v3.4
   ALLOW MODELS(MSSM78atQ, MSSM78atMGUT) // Can be used with GUT-scale or other-scale MSSM-78, and all their children
   #undef FUNCTION
   #undef CAPABILITY
   ```

2. Write the function as a simple C++ function
   (one argument: the result)
Basic interface for a scan is a YAML initialisation file

- specify parameters, ranges, priors
- select likelihood components
- select other observables to calculate
- define generic rules for how to fill dependencies
- define generic rules for options to be passed to module functions
- set global options (scanner, errors/warnings, logging behaviour, etc)
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