Previously on GAMBIT...

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(Re)interpreting the results of new physics searches at the LHC, CERN, 15 May 2018
Outline

1 Intro to GAMBIT

2 Core improvements

3 Collider improvements

4 Summary
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4 Summary
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
LHCb
Belle-II
Fermi-LAT
CTA
CMS
IceCube
XENON/DARWIN

Theory

F. Bernlochner, A. Buckley, P. Jackson, M. White
M. Chrząszcz, N. Serra
F. Bernlochner, P. Jackson
J. Conrad, J. Edsjö, G. Martinez, P. Scott
C. Balázs, T. Bringmann, M. White
C. Rogan
J. Edsjö, P. Scott
B. Farmer, R. Trolta
P. Athron, C. Balázs, S. Bloor, T. Bringmann,
J. Cornell, J. Edsjö, B. Farmer, A. Fowlie, T. Gonzalez,
J. Harz, S. Hoof, F. Kahlhoefer, S. Krishnamurthy,
A. Kvellestad, F.N. Mahmoudi, J. McKay, A. Raklev,
R. Ruiz, P. Scott, R. Trolta, A. Vincent, C. Weniger,
M. White, S. Wild

GAMBIT community: M. Danninger, P. Stöcker, S. Hotinli, ...

31 Members in 9 Experiments, 12 major theory codes, 11 countries
### Core & module papers

<table>
<thead>
<tr>
<th>Module</th>
<th>Paper Details</th>
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### Physics papers

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<th>Physics</th>
<th>Paper Details</th>
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<tr>
<td>Others in the pipeline</td>
<td>MSSMx, axions, Higgs-portal, sterile neutrinos,…</td>
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</table>
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Core improvements

**v 1.1**

- Latest release - published as an *addendum* to core paper
- Enabled use of *Mathematica* backends
  → Wolfram Symbolic Transfer Protocol (WSTP) ↔ Kernel

- Interface same as with C/C++/Fortran backends
- Alternative Higgs mass calculation → *SUSYHD*
Core improvements

v 1.2

- Will appear in the next release
- Enabled use of Python backends
  - Operability between C++ and Python: Pybind 11
- Same structure of Mathematica backends
  - Wrapper functions to Pybind calls
  - Wrapper to variables: import Pybind dictionary

- Alternative Higgs likelihood calculation → Lilith
- Energy injection + CMB → DarkAges
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Collider improvements

New searches

- Improved LEP limits $\rightarrow$ OPAL degenerate $\chi^0 - \chi^\pm$

\[
\begin{align*}
\text{OPAL $\sqrt{s} = 208$ GeV} \\
M_{\chi^\pm} [\text{GeV}] & \quad \text{5} & \quad \text{4} & \quad \text{3} & \quad \text{2} & \quad \text{1} & \quad \text{0} \\
M_{\chi^0} [\text{GeV}] & \quad \text{45} & \quad \text{50} & \quad \text{55} & \quad \text{60} & \quad \text{65} & \quad \text{70} & \quad \text{75} & \quad \text{80} & \quad \text{85} & \quad \text{90} & \quad \text{95}
\end{align*}
\]

- New 13 TeV analyses
  - $0l$ (ATLAS + CMS)
  - Multi-$l$ (ATLAS + CMS)
  - $\tilde{t} : 0l$ (ATLAS)
  - $\tilde{t} : 1l$ (ATLAS + CMS)
  - $\tilde{t} : 2l$ (ATLAS + CMS)
  - $bb + \text{MET}$ (ATLAS)
  - $l + bb$ (CMS)
  - $l^+ l^-$ (CMS)
  - $ll$-soft (CMS)
  - Mono-$j$ (CMS)
Collider improvements

Simplified Likelihoods

- Introduction of simplified likelihoods in GAMBIT
- Previously GAMBIT chose one signal region (expected to be most constraining)
  → e.g. CMS $l^+l^-$ analysis

\[
\begin{align*}
n(SR_2) &= 57, & n(SR_3) &= 29, \\
b(SR_2) &= 54.9 \pm 7, & b(SR_3) &= 21.6 \pm 5.6
\end{align*}
\]

- Now enabled use of covariance matrices (when provided)
  → e.g. Now with covariance matrix (+ other 5 SRs)

\[
cov = \begin{pmatrix} 52.8 & 12.7 \\ 12.7 & 41.4 \end{pmatrix}
\]
Collider improvements

Simplified Likelihoods

- Sampled marginalization
  \[ N_{\text{samples}} \sim 10^5 - 10^6 \]
- Dynamic convergence criterion
- Soon, likelihood profiling
- Provided by CMS for two analyses
  \[ l^+l^- \text{ with 7 SRs} \]
  \[ 0l \text{ with 174 SRs!!} \]
- Still some way to go . . .
  - Aggregate SRs
  - Difficult to scale with numer of analyses
  - Consistency between publication and data
  - Standardization
  - More of this from experiments
Collider improvements

Other new features

- More **detailed** output from scans
  → $lnL$ from individual analyses

- **Dynamic convergence** criterion for Pythia event generation
  → Check for convergence every certain number of events
  → Keeps a flat (target) percentage MC uncertainty

- Include output from analysis without adding them to the scan likelihood

```python
# Choose statistical settings for Monte Carlo event generator
- capability: MC_ConvergenceSettings
  options:
  min_nEvents: [20000]
  max_nEvents: [50000]
  events_between_convergence_checks: [20000]
  target_fractional_uncert: [0.3]
  halt_when_systematic-dominated: true
  all_SR_must_converge: false
```
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Summary

• Many **improvements** since GAMBIT 1.0 release

• Core improvements
  → **Mathematica**
  → **Python**

• Collider improvements
  → New analyses → 13 TeV
  → **Simplified likelihoods**
    ~> More data from experiments
  → MC convergence….

• Release will come soon: GAMBIT 1.2

• Many studies using these improvements:
  → MSSM9
  → MSSMEW ~> **Matthias Danninger’s talk**
  → …
Thanks!