

# Global fit of BSM with CEPC using GAMBIT

---

Yang Zhang (张阳), Monash University

2020.07.17



# GAMBIT

## The **G**lobal **A**nd **M**odular **B**SM **I**nference **T**ool

- A **general** framework for BSM global fits
- Fully **open source**
- **Modular design**: can be extended with
  - new models
  - new likelihoods
  - new theory calculators
  - new scanning algorithms
- Use external codes (**backends**) as **runtime plugins**
  - C, C++, Fortran, Python, Mathematica
- **Two-level parallelization** with MPI and OpenMP
- **Hierarchical** model database
- **Flexible output streams** (ASCII, HDF5, ...)
- Many **scanners** and **backends** already included



The screenshot shows the GAMBIT homepage layout. On the left is a navigation menu with a light green background, listing: Home, Results & Publications, Talks, Collaboration, Download, Source Code, Support (with sub-items: FAQ, Compiler matrix, Known issues, Documentation, Configuration examples, Report issue), Mailing list, Contact, and Internal pages (with sub-items: Wiki, Git repos: gambit (dev fork), gambit\_internal, gambit\_results). To the right is a large graphic of a hand of playing cards. The top card is the Jack of Spades, with 'GAMBIT' written on it. The cards behind it are labeled G, A, M, B, I, T, C. Below the cards, the text reads: 'GAMBIT The Global And Modular BSM Inference Tool'. A welcome message follows: 'Welcome to the GAMBIT homepage. GAMBIT is a global fitting code for generic Beyond the Standard Model theories, designed to allow fast and easy definition of new models, observables, likelihoods, scanners and backend physics codes.' Below that, it says: 'We have released GAMBIT to the public! Please check out the Source Code section and have fun with it!' and 'You can read more about GAMBIT in this Physics World article.'

[gambit.hepforge.org](http://gambit.hepforge.org)





# GAMBIT: The Global And Modular BSM Inference Tool

[gambit.hepforge.org](http://gambit.hepforge.org)

EPJC **77** (2017) 784

arXiv:1705.07908

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

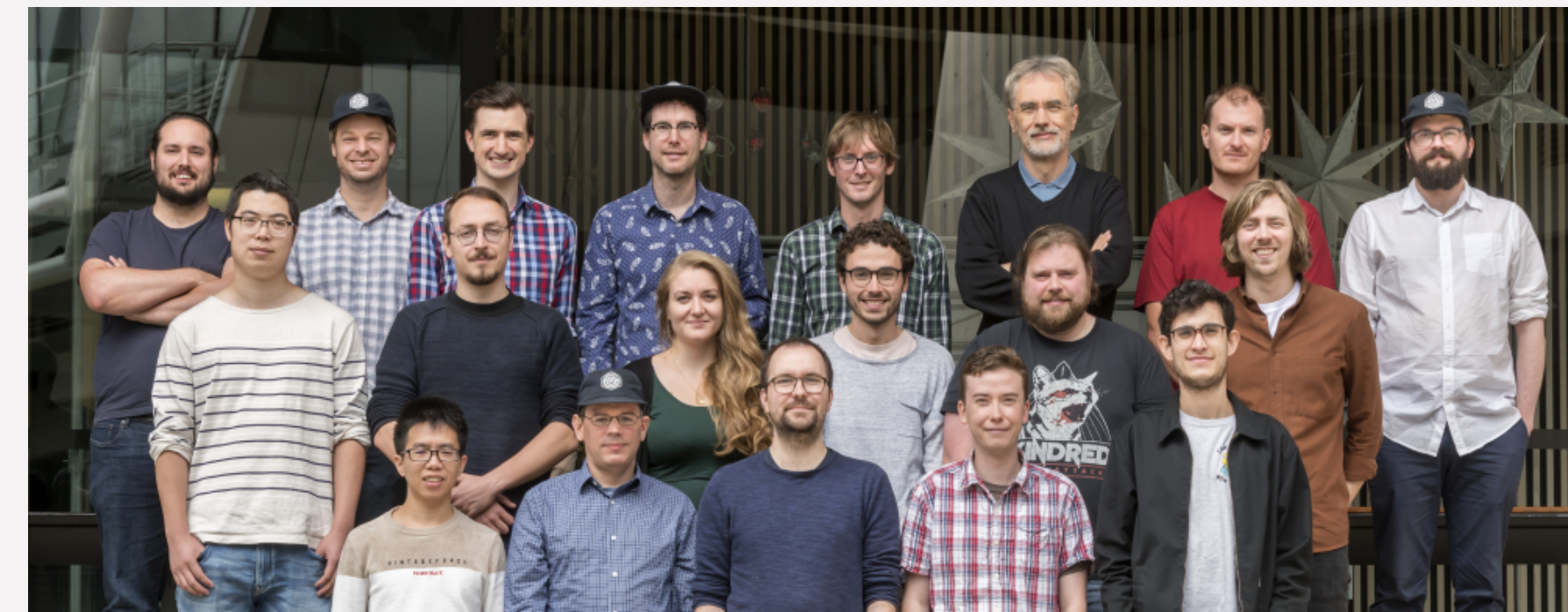


## Members of:

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

## Authors of:

DarkSUSY, DDCalc, Diver, FlexibleSUSY, gamlike, GM2Calc,  
IsaTools, nulike, PolyChord, Rivet, SoftSUSY, SuperISO, SUSY-  
AI, WIMPSim



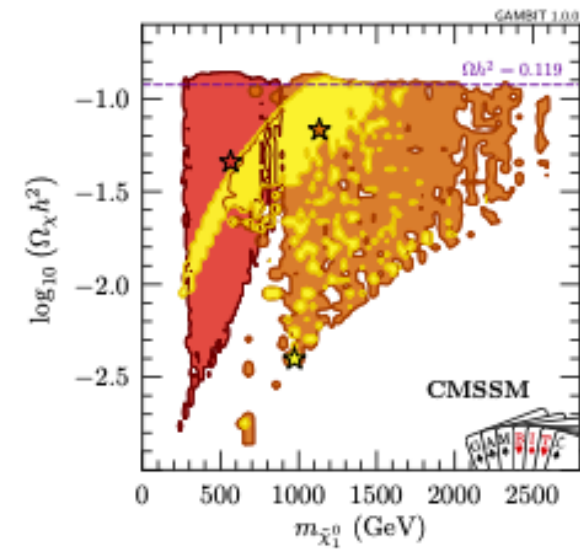
## Recent collaborators:

P Athron, C Balázs, A Beniwal, S Bloor, T Bringmann, A  
Buckley, J Eliel Camargo-Molina, C Chang, M Chrzaszcz, J  
Conrad, J Cornell, M Danninger, J Edsjö, B Farmer, A Fowlie,  
T Gonzalo, P Grace, W Handley, J Harz, S Hoof, F Kahlhoefer,  
N Avis Kozar, A Kvellestad, P Jackson, R Jardine, A Ladhu, N  
Mahmoudi, G Martinez, M Prim, F Rajec, A Raklev, J Renk, C  
Rogan, R Ruiz, I Sáez Casares, N Serra, A Scaffidi, P Scott, P  
Stöcker, W Su, J Van den Abeele, A Vincent, C Weniger, M  
White, Y Zhang

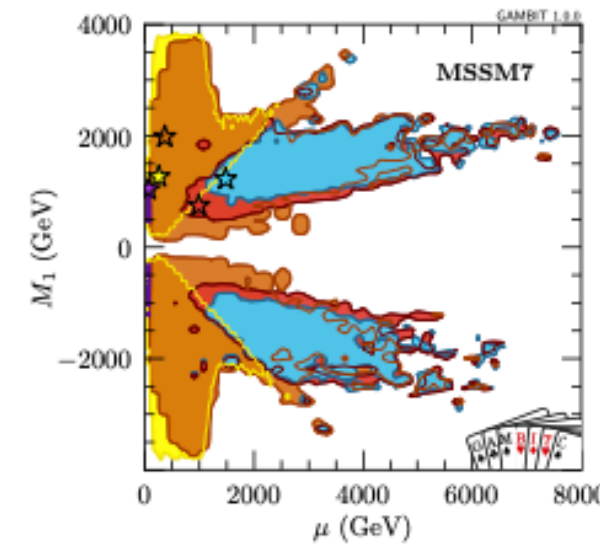
**40+ participants in 11 experiments and 14 major theory codes**



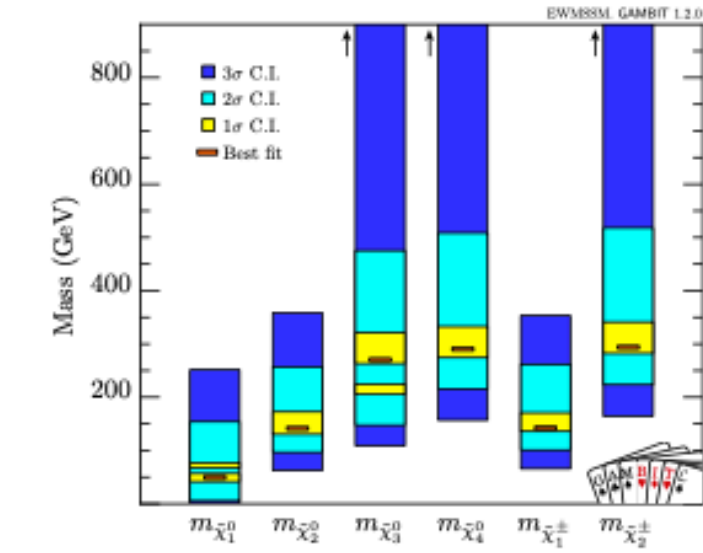
# GAMBIT results



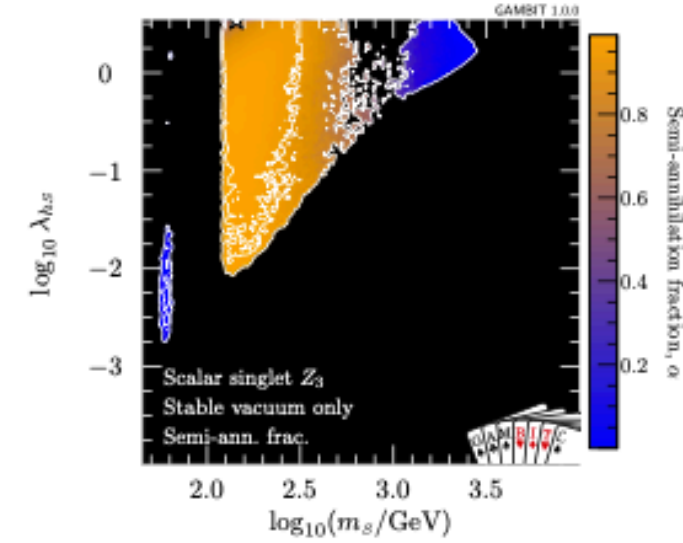
CMSSM/NUHM1/NUHM2  
(EPJC / arXiv:1705.07935)



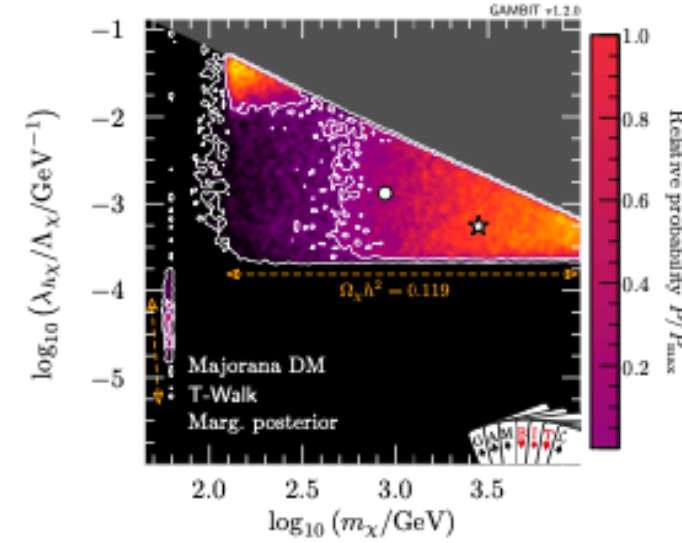
MSSM7  
(EPJC / arXiv:1705.07917)



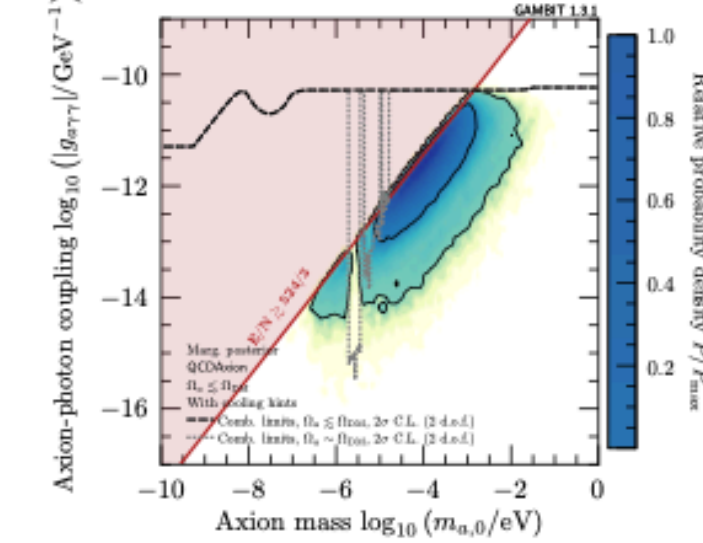
EWMSSM  
(EPJC / arXiv:1809.02097)



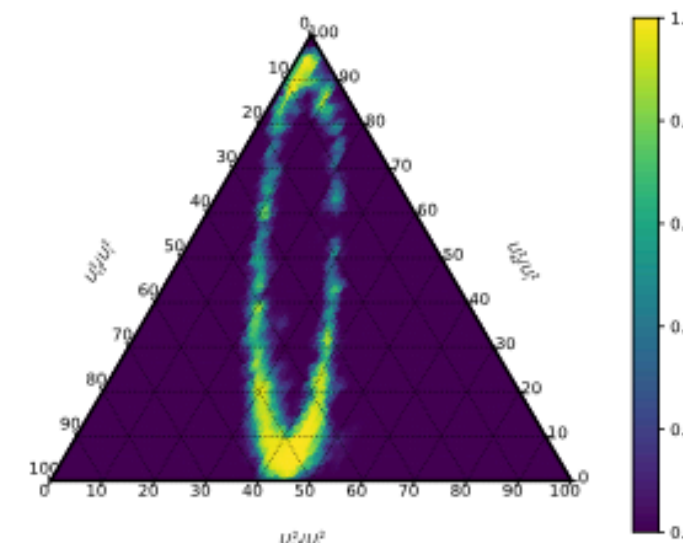
Scalar singlet dark matter  
(EPJC / arXiv:1806.11281)



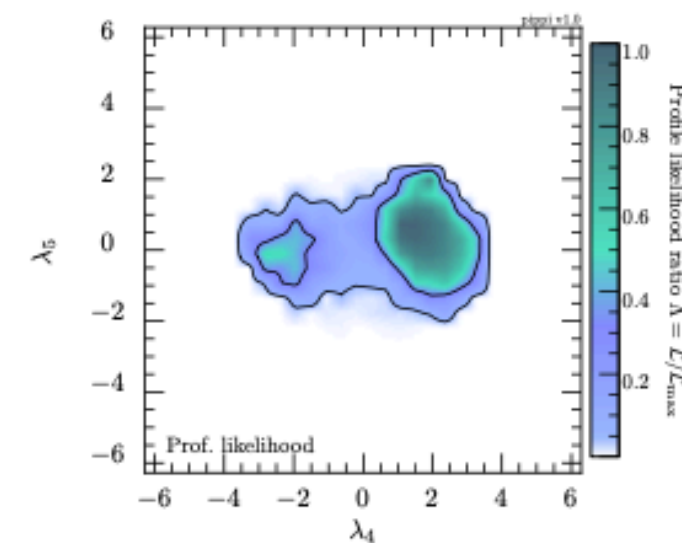
Fermion/vector Higgs portal  
(EPJC / arXiv:1808.10465)



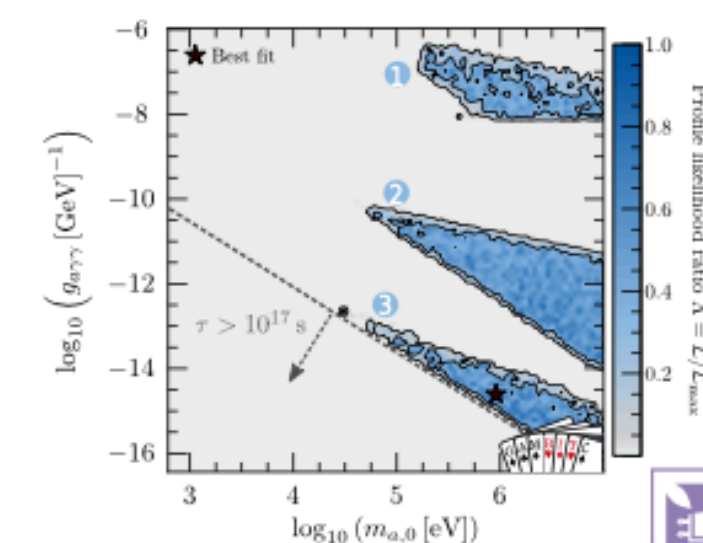
Axions & ALPs  
(JHEP / arXiv:1810.07192)



Right-handed neutrinos  
(arXiv:1908.02302)



Two Higgs Doublet Models  
(coming soon)



Cosmological models  
(coming soon as CosmoBit)

# Parameters and scanning

- Profile likelihood analysis
- Combine samples from scans with different priors and scanners (Diver & MultiNest)
- Additional scans to improve sampling of co-annihilation regions
- In total for all three models: 36 scans, ~280 million viable samples
- Vary 5 nuisance parameters (constrained by gaussian likelihoods)

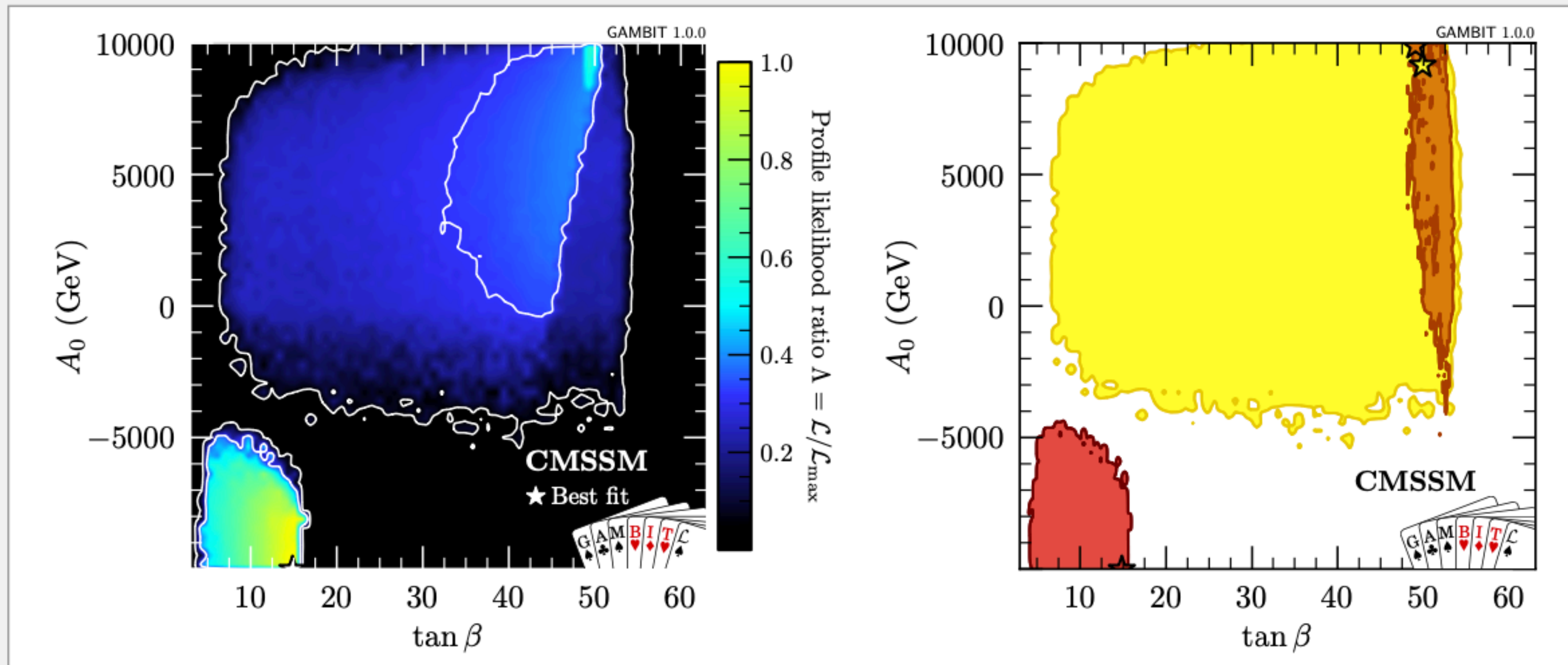
Parameter	Minimum	Maximum	Priors
<b>CMSSM</b>			
$m_0$	50 GeV	10 TeV	flat, log
$m_{1/2}$	50 GeV	10 TeV	flat, log
$A_0$	-10 TeV	10 TeV	flat, hybrid
$\tan \beta$	3	70	flat
$\text{sgn}(\mu)$	-	+	binary
<b>NUHM1</b> – as per CMSSM plus			
$m_H$	50 GeV	10 TeV	flat, log
<b>NUHM2</b> – as per CMSSM plus			
$m_{H_u}$	50 GeV	10 TeV	flat, log
$m_{H_d}$	50 GeV	10 TeV	flat, log
<hr/>			
Parameter	Value( $\pm$ Range)		
<b>Varied</b>			
Strong coupling	$\alpha_s^{\overline{MS}}(m_Z)$	0.1185(18)	
Top quark pole mass	$m_t$	173.34(2.28) GeV	
Local DM density	$\rho_0$	0.2–0.8 GeV cm <sup>-3</sup>	
Nuclear matrix el. (strange)	$\sigma_s$	43(24) MeV	
Nuclear matrix el. (up + down)	$\sigma_l$	58(27) MeV	



# Likelihoods

- Nuisance parameter likelihoods  
(SM, local halo model, nuclear matrix elements)
- DM relic density *as upper bound*
- DM Indirect detection
  - Gamma rays: Fermi-LAT  
(dwarf spheroidal galaxies)
  - Neutrinos from DM annihilation in the Sun:  
IceCube79
- DM Direct detection:
  - XENON100 (2012)
  - LUX (2016)
  - Panda-X (2016)
  - PICO (2015)
  - SuperCDMS (2014)
  - SIMPLE (2014)
- Electroweak precision observables
  - W mass
  - muon g-2
- 59 flavour observables
- Higgs mass and signal strengths
- SUSY cross section limits from LEP
- SUSY searches at LHC (simulated)
  - 0 lepton searches (Run I & II, ATLAS & CMS)
  - Stop searches (Run I, ATLAS & CMS)
  - 2 & 3 lepton searches (Run I, ATLAS & CMS)
  - Monojet search (Run I, CMS)

# CMSSM



■  $\tilde{t}_1$  co-annihilation

■  $A/H$  funnel

■  $\tilde{\chi}_1^\pm$  co-annihilation

- Three mechanisms to avoid DM overabundance: stop co-ann., chargino co-ann., heavy Higgs funnel
- **Stau co-ann. is ruled out at 95% CL** (present at higher CL)
- Overall best fit point in stop co-ann. region (stop/neutralino mass  $\sim 600$  GeV)



# All results publicly available

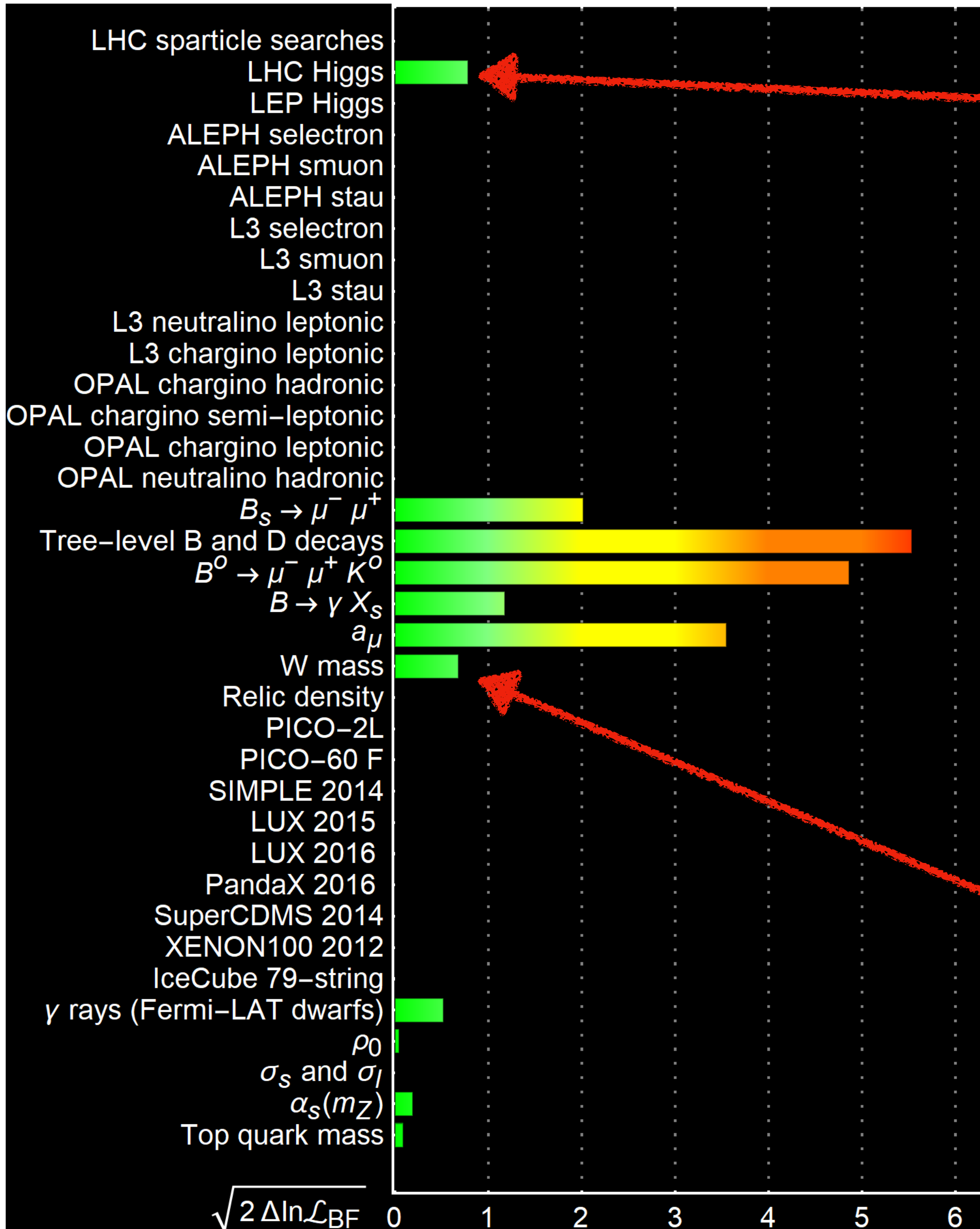
## Results and Publications

### Physics papers

- A frequentist analysis of three right-handed neutrinos with GAMBIT, [arxiv:1908.02302](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.3334971](#)
- Axion global fits with Peccei-Quinn symmetry breaking before inflation using GAMBIT, JHEP 03 (2019) 191, [arXiv:1810.07192](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.1423692](#)
- Combined collider constraints on neutralinos and charginos, Eur. Phys. J. C 79 (2019) 395, [arXiv:1809.02097](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.1410335](#)
- Global analyses of Higgs portal singlet dark matter models using GAMBIT, Eur. Phys. J. C 79 (2019) 38, [arXiv:1808.10465](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.1400654](#)
- Impact of vacuum stability, perturbativity and XENON1T on global fits of  $Z_2$  and  $Z_3$  scalar singlet dark matter, Eur. Phys. J. C 78 (2018) 830, [arXiv:1806.11281](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.1298566](#)
- A global fit of the MSSM with GAMBIT, Eur. Phys. J. C 77 (2017) 879, [arXiv:1705.07917](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.801639](#)
- Global fits of GUT-scale SUSY models with GAMBIT, Eur. Phys. J. C 77 (2017) 824, [arXiv:1705.07935](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.801641](#)
- Status of the scalar singlet dark matter model, Eur. Phys. J. C 77 (2017) 568, [arXiv:1705.07931](#).  
Supplementary data, including samples: DOI [10.5281/zenodo.801510](#)

Name	Size	Download
<a href="#">best_fits_SLHA.tar.gz</a>	279.7 kB	<a href="#">Download</a>
md5:1786eedf119394b9b0847d809f35d78f ?		
<a href="#">CMSSM.hdf5.tar.gz</a>	10.9 GB	<a href="#">Download</a>
md5:337e038e1f13a2de0b6752449a2ab603 ?		
<a href="#">CMSSM.pip</a>	14.9 kB	<a href="#">Download</a>
md5:45e61058ee1781b7fa3e7a4f17c79057 ?		
<a href="#">CMSSM.yaml</a>	4.0 kB	<a href="#">Download</a>
md5:78e4e15215763819685df70f5238e0b5 ?		
<a href="#">CMSSM_Diver_flat_nmu.yaml</a>	11.2 kB	<a href="#">Download</a>
md5:246a8799e2e313dff69f918bb37cadb8 ?		
<a href="#">CMSSM_Diver_flat_pmu.yaml</a>	11.2 kB	<a href="#">Download</a>
md5:5a65153cb2ad0f1549241a42b41b79e9 ?		
<a href="#">CMSSM_Diver_log_nmu.yaml</a>	11.4 kB	<a href="#">Download</a>
md5:3a5243f10e60db9228ea329f0860617a ?		





## Physics Performance with Benchmark Processes

- 11.1 Higgs boson physics
  - 11.1.1 Higgs boson production and decay
  - 11.1.2 Higgs boson tagging
  - 11.1.3 Measurements of  $\sigma(ZH)$  and the Higgs boson mass
  - 11.1.4 Analyses of the individual Higgs boson decay modes
  - 11.1.5 Combination of the individual analyses
  - 11.1.6 Higgs boson width
  - 11.1.7 Higgs boson coupling measurements
  - 11.1.8 The Higgs boson self-coupling
  - 11.1.9 Higgs boson and top-quark couplings
  - 11.1.10 Tests of Higgs boson spin/ $CP$
  - 11.1.11 Summary
- 11.2  $W$  and  $Z$  boson physics
  - 11.2.1  $Z$  pole measurements
  - 11.2.2 Measurement of the  $W$  boson mass
  - 11.2.3 Oblique parameters

# Our Plan

- ✓ Build the CEPC likelihood in GAMBIT
  - Using present experimental central values
- ✓ Postprocess the published CMSSM / NUMH1 / NUHM2 / MSSM global results
  - Experimental constraints in latest GAMBIT
  - CEPC proposed results
- ✓ Analysis the results
- People: Peter Athron, Csaba Balazs, Andrew Fowlie, Wei Su, Yang Zhang **from GAMBIT**  
Liangliang Su, Lei Wu **from Nanjing Normal University**



