Global fit of BSM with CEPC using GAMBIT

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GAMBIT

The Global And Modular BSM Inference Tool

- 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 parallellization** with MPI and OpenMP
- **Hierarchical** model database
- **Flexible output streams** (ASCII, HDF5, …)
- Many **scanners** and **backends** already included

gambit.hepforge.org

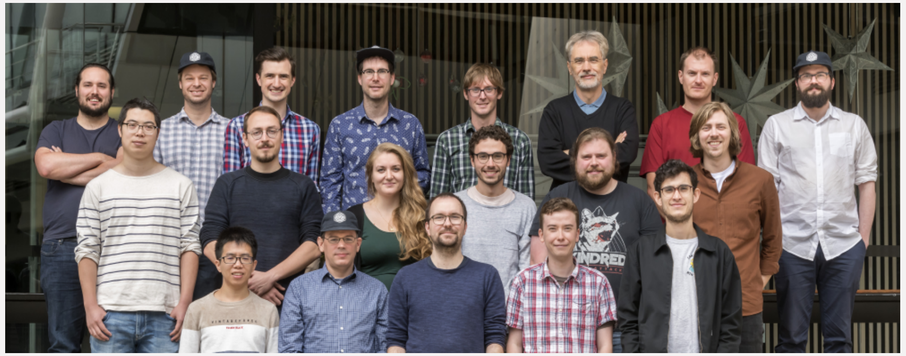
Slide from Anders Kvellestad

GAMBIT: The Global And Modular BSM Inference Tool

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



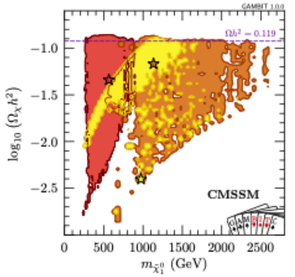
Members of:
ATLAS, Belle-II, CLiC, CMS, CTA, *Fermi*-LAT, DARWIN, IceCube, LHCb, SHiP, XENON

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

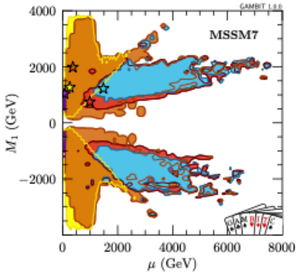
Recent collaborators:
P Athron, C Balázs, A Beniwal, S Bloor, T Bringmann, A Buckley, J Eliel Camargo-Molina, C Chang, M Chrzaszcz, J Conrad, J Cornell, M Danninger, J Edsjö, B Farmer, A Fowlie, T Gonzalo, P Grace, W Handley, J Harz, S Hoof, F Kahlhoefer, N Avis Kozar, A Kvellestad, P Jackson, R Jardine, 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

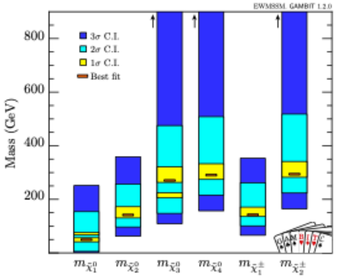
GAMBIT results



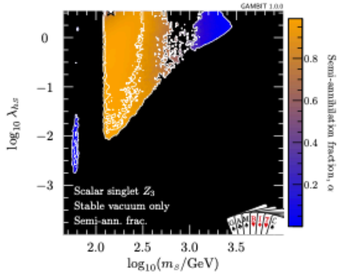
CMSSM/NUHM1/NUHM2
(EPJC / arXiv:1705.07935)



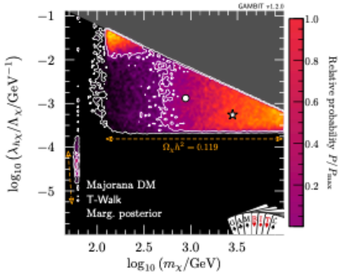
MSSM7
(EPJC / arXiv:1705.07917)



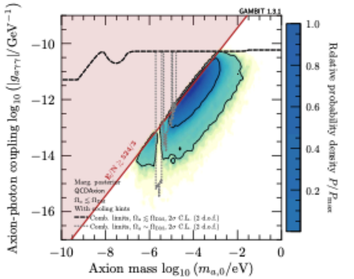
EWMSSM
(EPJC / arXiv:1809.02097)



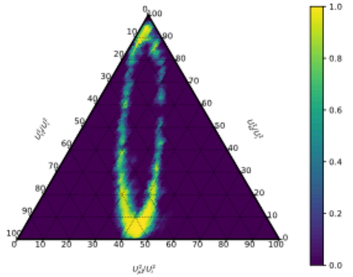
Scalar singlet dark matter
(EPJC / arXiv:1806.11281)



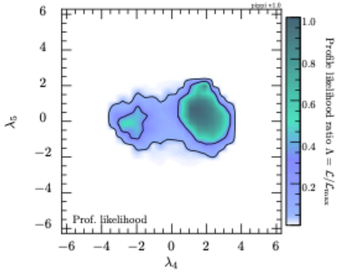
Fermion/vector Higgs portal
(EPJC / arXiv:1808.10465)



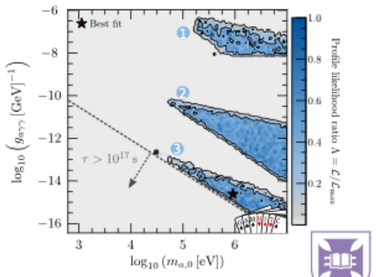
Axions & ALPs
(JHEP / arXiv:1810.07192)



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
CMSSM			
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
$\mathrm{sgn}(\mu)$	$-$	$+$	binary
NUHM1 – as per CMSSM plus			
m_H	50 GeV	10 TeV	flat, log
NUHM2 – as per CMSSM plus			
m_{H_u}	50 GeV	10 TeV	flat, log
m_{H_d}	50 GeV	10 TeV	flat, log

Parameter		Value(±Range)
Varied		
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	ρ_0	0.2–0.8 GeV cm^{-3}
Nuclear matrix el. (strange)	σ_s	43(24) MeV
Nuclear matrix el. (up + down)	σ_l	58(27) MeV

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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 spheriodal 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)

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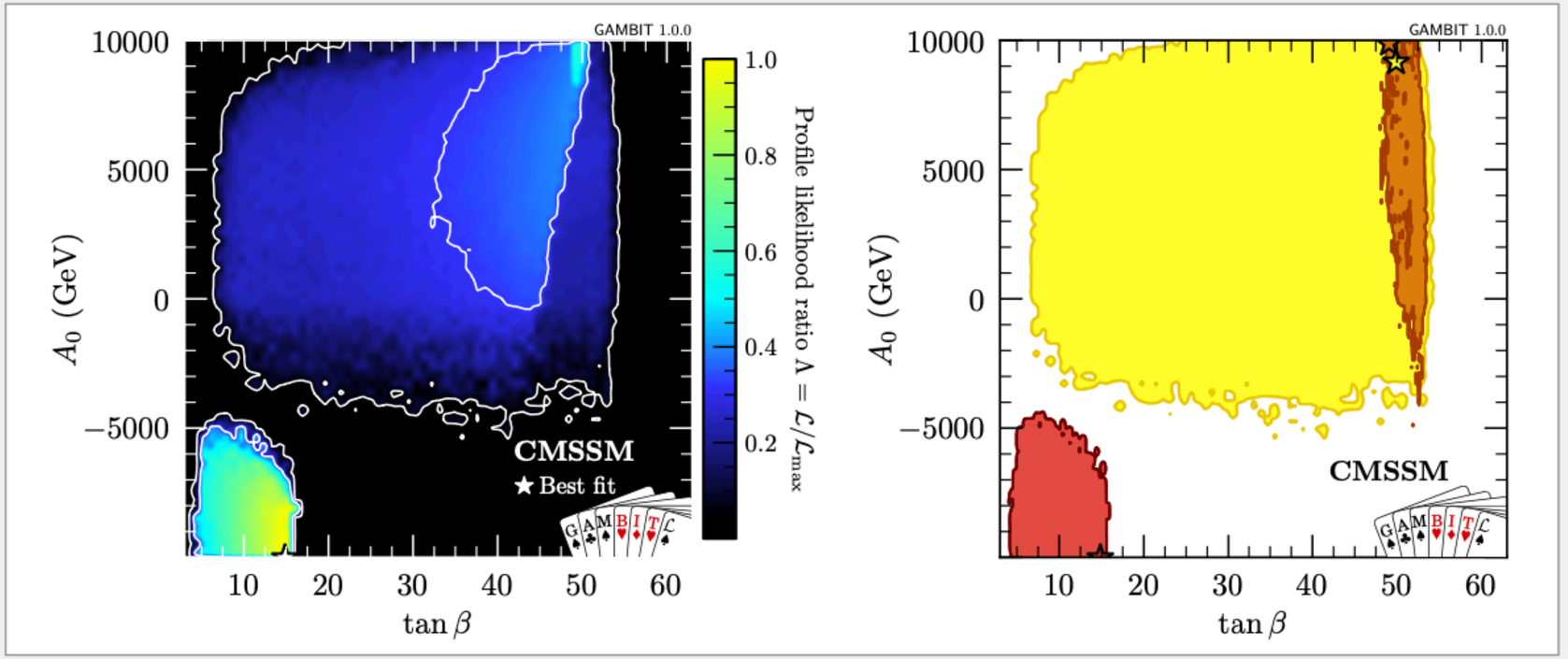
CMSSM



- 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 ~600 GeV)

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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

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Files (48.8 GB)

Name	Size	
best_fits_SLHA.tar.gz md5:1786eedf119394b9b0847d809f35d78f	279.7 kB	Download
CMSSM.hdf5.tar.gz md5:337e038e1f13a2de0b6752449a2ab603	10.9 GB	Download
CMSSM.pip md5:45e61058ee1781b7fa3e7a4f17c79057	14.9 kB	Download
CMSSM.yaml md5:78e4e15215763819685df70f5238e0b5	4.0 kB	Download
CMSSM_Diver_flat_nmu.yaml md5:246a8799e2e313dff69f918bb37cadb8	11.2 kB	Download
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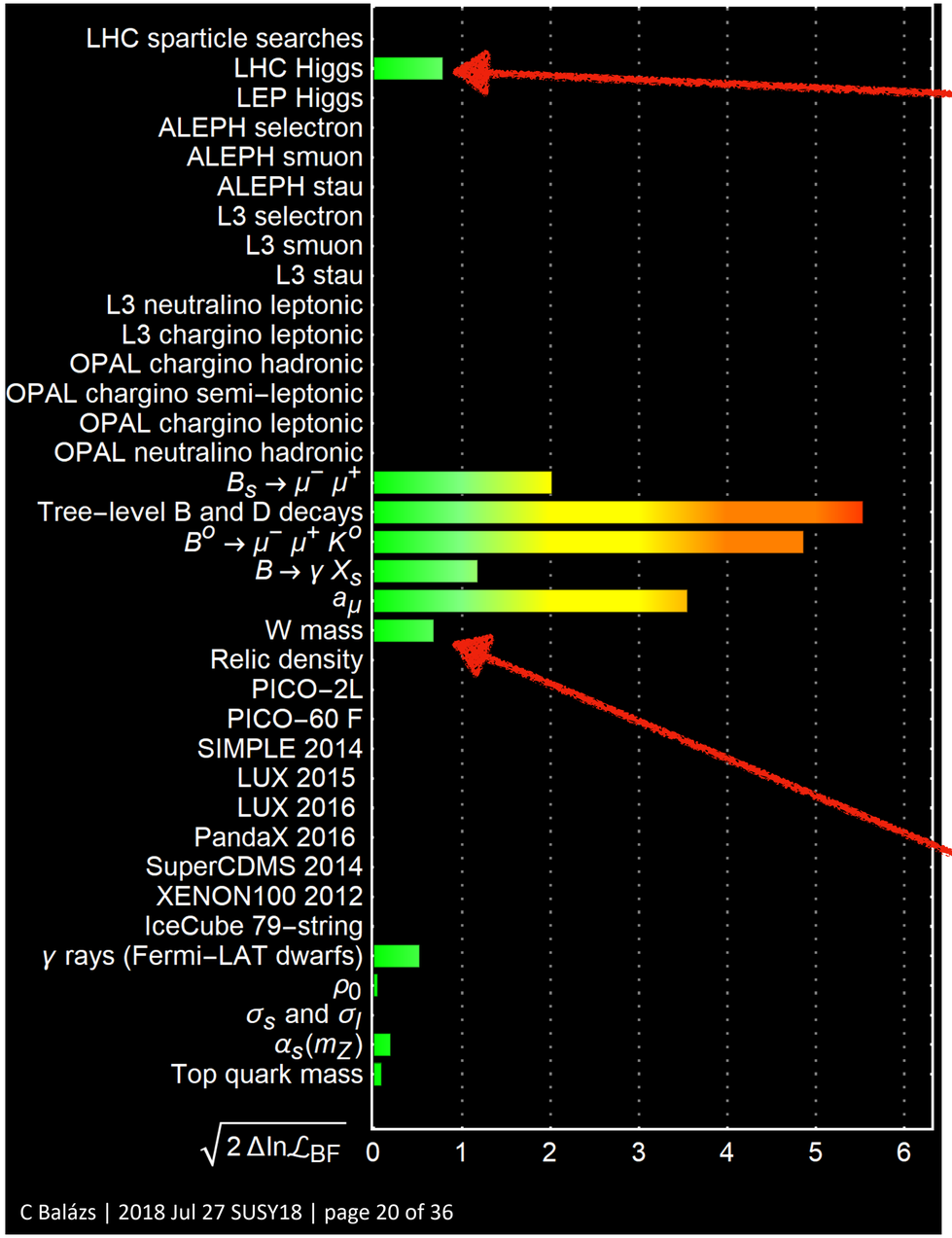
GAMBIT CMSSM Best-Fit Point



CEPC CDR

Physics Performance with Benchmark Processes

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