

Combined collider constraints on SUSY with a light gravitino

Anders Kvellestad, University of Oslo
on behalf of the GAMBIT Collaboration

Spåtind 2023, 7 January, 2023



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Outline

- 1. How to get the most physics out of our data**
- 2. LHC impact on SUSY with a light gravitino**



1. How to get the most physics out of our data



Understanding the full implications of [experimental] searches requires the interpretation of the experimental results in the context of many more theoretical models than are currently explored at the time of publication.

HEP Software Foundation [arxiv:1712.06982]

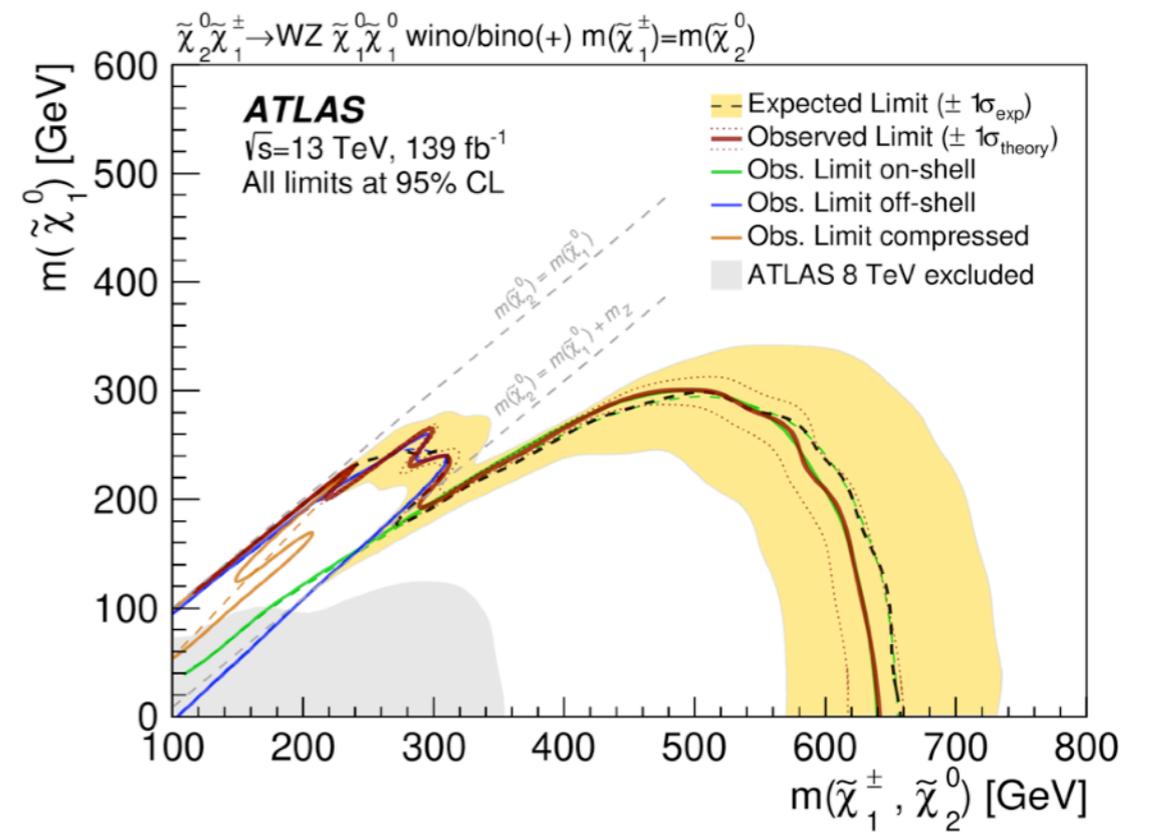
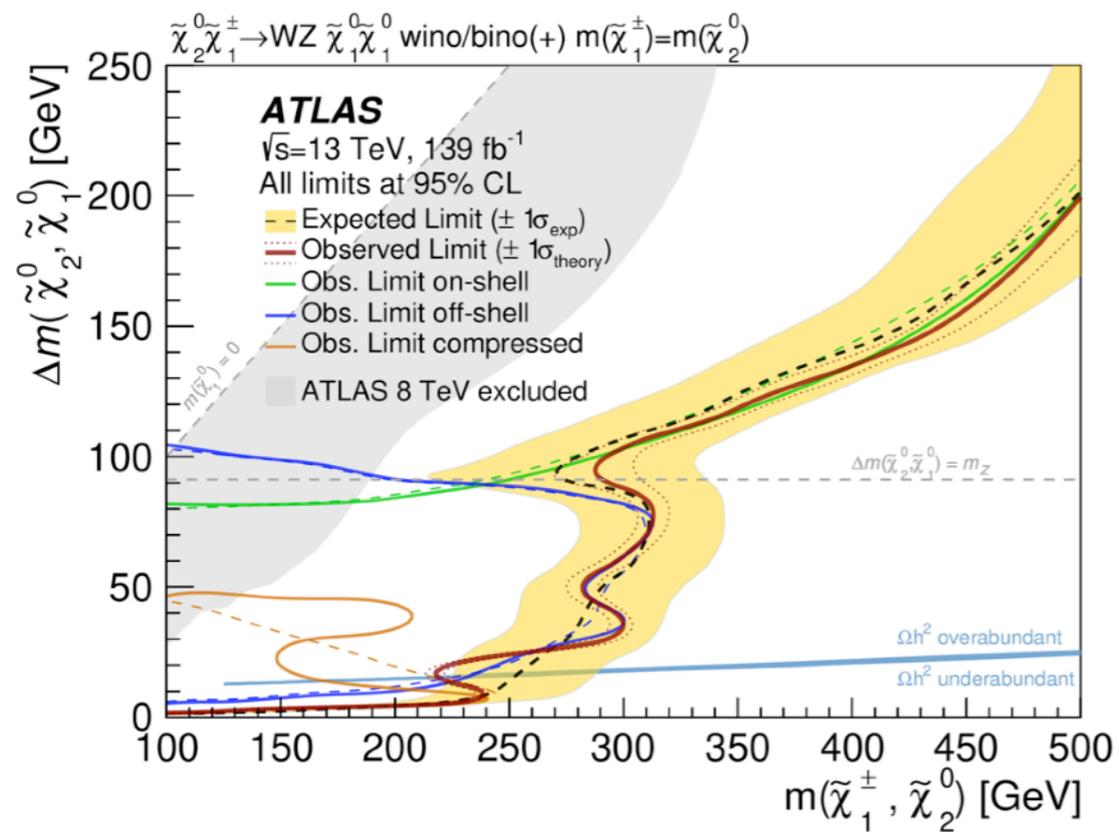
See also:

- *Publishing statistical models: Getting the most out of particle physics experiments*
[arxiv:2109.04981]
- *Reinterpretation of LHC Results for New Physics: Status and Recommendations after Run 2*
[arxiv:2003.07868]
- *Simple and statistically sound strategies for analysing physical theories*
[arxiv:2012.09874]



We need your help!

These are very nice...



[ATLAS, 2106.01676]

We need your help!

...but **this** is the real gold!

Regions	SR ^{wh} _{SFOS} -1	SR ^{wh} _{SFOS} -2	SR ^{wh} _{SFOS} -3	SR ^{wh} _{SFOS} -4	SR ^{wh} _{SFOS} -5	SR ^{wh} _{SFOS} -6	SR ^{wh} _{SFOS} -7
Observed	152	14	8	47	6	15	19
Fitted SM	136 ± 13	13.5 ± 1.7	4.3 ± 0.9	50 ± 5	4.3 ± 0.7	20.2 ± 2.1	16.0 ± 2.1
WZ	107 ± 12	10.2 ± 1.7	3.8 ± 0.8	32 ± 4	2.7 ± 0.6	12.3 ± 1.6	10.8 ± 1.7
t \bar{t}	10.3 ± 2.5	1.6 ± 0.6	0.13 ± 0.12	7.7 ± 1.9	0.74 ± 0.34	3.5 ± 1.0	2.5 ± 0.7
Z+jets	2.5 ± 2.9	0.00 ^{+0.02} _{-0.00}	0.00 ^{+0.02} _{-0.00}	2.0 ± 1.6	0.00 ^{+0.04} _{-0.00}	0.00 ^{+0.04} _{-0.00}	0.00 ^{+0.02} _{-0.00}
Higgs	5.7 ± 0.6	0.69 ± 0.07	0.20 ± 0.03	3.12 ± 0.31	0.26 ± 0.05	0.00 ± 0.00	0.00 ± 0.00
Triboson	1.9 ± 0.5	0.22 ± 0.07	0.07 ± 0.02	1.4 ± 0.4	0.28 ± 0.09	0.00 ± 0.00	0.00 ± 0.00
Others	8.6 ± 1.9	0.84 ± 0.11	0.08 ± 0.05	4.0 ± 0.5	0.23 ± 0.24	0.00 ± 0.00	0.00 ± 0.00

Regions	SR ^{wh} _{SFOS} -8	SR ^{wh} _{SFOS} -9	SR ^{wh} _{SFOS} -10	SR ^{wh} _{SFOS} -11	SR ^{wh} _{SFOS} -12
Observed	113	184	28	5	82
Fitted SM	108 ± 13	180 ± 17	31 ± 4	6.6 ± 0.9	90 ± 11
WZ	54 ± 6	127 ± 13	19.3 ± 2.3	5.3 ± 0.8	47 ± 6
t \bar{t}	21 ± 6	33 ± 10	8.2 ± 2.3	0.7 ± 0.5	28 ± 8
Z+jets	19 ± 10	2.3 ± 1.9	1.0 ± 1.3	0.10 ± 0.21	2.1 ± 3.1
Higgs	1.91 ± 0.19	3.63 ± 0.35	0.67 ± 0.06	0.15 ± 0.02	2.98 ± 0.25
Triboson	0.79 ± 0.24	1.4 ± 0.4	0.41 ± 0.13	0.12 ± 0.05	1.6 ± 0.5
Others	11.1 ± 2.2	12.2 ± 2.2	1.8 ± 0.4	0.22 ± 0.05	9.0 ± 1.1

Regions	SR ^{wh} _{SFOS} -15	SR ^{wh} _{SFOS} -16	SR ^{wh} _{SFOS} -17	SR ^{wh} _{SFOS} -18	SR ^{wh} _{SFOS} -19
Observed	51	5	37	7	4
Fitted SM	46 ± 7	9.8 ± 1.6	43 ± 7	12.6 ± 1.7	1.8 ± 0.4
WZ	18.9 ± 2.2	3.9 ± 0.8	35 ± 6	9.8 ± 1.6	1.44 ± 0.32
t \bar{t}	18 ± 6	3.2 ± 1.3	1.00 ± 0.34	0.33 ± 0.17	0.00 ^{+0.01} _{-0.00}
Z+jets	0.00 ^{+0.12} _{-0.00}				

Rivet analyses reference

ATLAS_2020_I1803608

Electroweak Zj at 13 TeV
 Experiment: ATLAS (LHC)
 Inspire ID: 1803608
 Status: VALIDATED
 Authors:

- Stephen Weber
- Dag Gillberg

References:

- arXiv:2006.15458
- Eur. Phys. J. C 81 (2021) 163

Beams: p+ p+
 Beam energies: (6500.0, 6500.0) GeV
 Run details:

- pp → Z (→ ee and muμ) + jets production at 13 TeV

Differential cross-section measurements are presented for the electroweak production of two jets in association with a ZZ boson. These measurements are sensitive to the vector-boson fusion production mechanism and provide a fundamental test of the gauge structure of the Standard Model. The analysis is based on proton-proton collision data collected by ATLAS at $\sqrt{s} = 13$ TeV and with an integrated luminosity of 36.1 fb⁻¹. The differential cross-sections are measured in the Z → ℓℓ decay channel (ℓ = e, μ) as a function of the dijet invariant mass, the rapidity interval spanned by the two jets, the signed azimuthal angle between the two jets, and the transverse momentum of the dilepton pair. The data are corrected for detector inefficiency and resolution and are sufficiently precise to distinguish between different theoretical predictions calculated using Powheg+Pythia8, Herwig+Vbfno and Sherpa 2.2. The measurements are used to search for anomalous weak-boson self-interactions using a dimension-6 effective theory. The measurement of the signed azimuthal angle between the two jets is found to be sensitive to the interference between the Standard Model and dimension-six scattering amplitudes and is used as a test of charge-conjugation and parity invariance in the weak-boson self-interactions. Note that this analysis is for the inclusive Z+2jet selections. For the EW-only measurement use the option TY=EW in the Rivet analysis. Both cases, electron and muon channels are to be summed.

Source code: ATLAS_2020_I1803608.cc

```

1 // --> C++ -->
2 #include "Rivet/Analysis.hh"
3 #include "Rivet/Projections/FinalState.hh"
4 #include "Rivet/Projections/PromptFinalState.hh"
5 #include "Rivet/Projections/DressedLeptons.hh"
6 #include "Rivet/Projections/FastJets.hh"
7
8 namespace Rivet {
9
10
11 // VBFZ in pp at 13 TeV
12 class ATLAS_2020_I1803608 : public Analysis {
13 public:
14 // Constructor
15 ATLAS_2020_I1803608(Rivet::Analysis* a): Analysis(a) {}
16
17 // @name Analysis methods
18 // @
19
20 // Book histograms and initialise projections before the run
21 void Init() {
22   FinalState fs(Cuts::abseta < 5.0);
23   PromptFinalState photons(Cuts::abspid == PID::PHOTON);
24   PromptFinalState electrons(Cuts::abspid == PID::ELECTRON);
25   PromptFinalState muons(Cuts::abspid == PID::MUON);
26
27   Cut cuts_el = {Cuts::pT > 25GeV} && { Cuts::abseta < 1.37 } | {Cuts::abseta < 2.4};
28   Cut cuts_mu = {Cuts::pT > 25GeV} && {Cuts::abseta < 2.4};
29
30   DressedLeptons dressed_electrons(photons, electrons, 0.1, cuts_el);
31   declare(dressed_electrons, "DressedElectrons");
32
33   DressedLeptons dressed_muons(photons, muons, 0.1, cuts_mu);
34   declare(dressed_muons, "DressedMuons");
35
36
37

```

	a	b	c	d	e	f1	f2	g1	g2	a through g2
Common cuts										
Z × σ					1394866					1394866
Z × σ × BF					45634					45634
Z × σ × BF × fit. eff.					16811					16811
3 isolated lepton selection					2.66e+03					2.66e+03
bveto					2.55e+03					2.55e+03
Trigger selection					1.81e+03					1.81e+03
m _{ℓℓ} > m _{ℓℓ} ^{min} (GeV)					< 75					1.79e+03
Common cuts SR ^{EW} _{SFOS}										
m _{ℓℓ} ^{min} [GeV]				[12, 40]	1.70e+03			[40, 75]	14.6	1.71e+03
lepton p _T ^{min} [GeV]				> 10]	1.44e+03			> 15]	7.74	1.45e+03
PNP lepton cleaning (conversions)					1.12e+03					1.12e+03
m _{ℓℓ} ^{min} [GeV]				< 60]	1.02e+03					1.03e+03
m _{ℓℓ} ^{min} [GeV]		[12, 15]	47.0	[15, 20]	119	[30, 30]	406	[30, 40]	452	1.03e+03
m _{ℓℓ} ^{min} [GeV]		< 115]	19.4	< 120]	74.7	< 130]	374	< 140]	452	926
minΔR		< 1.6]	19.4	< 1.6]	73.2	< 1.6]	295	< 1.6]	452	846
Cuts SR ^{EW} _{SFOS}										
m _{ℓℓ} ^{min} [GeV]		[0]	12.2	[0]	49.5	[0]	186	[0]	291	542
m _{ℓℓ} ^{min} [GeV]		< 50]	11.2	< 50]	42.9	< 50]	147	< 50]	242	446
m _{ℓℓ} ^{min} [GeV]		> 1.5]	123	> 1.5]	34.7	> 1.5]	123	> 1.5]	182	350
m _{ℓℓ} ^{min} [GeV]		> 100]	182	> 100]	0.656	> 100]	0.656	> 100]	0.656	349
m _{ℓℓ} ^{min} [GeV]		[0]	97.8	[0]	158	[0]	158	[0]	158	297
m _{ℓℓ} ^{min} [GeV]		[1, 1]	64.3	[1, 1]	138	[1, 1]	138	[1, 1]	138	231
m _{ℓℓ} ^{min} [GeV]			59.3		126		126		126	211
m _{ℓℓ} ^{min} [GeV]		[0]	110	[0]	161	[0]	2.64	[0]	0	304
m _{ℓℓ} ^{min} [GeV]		< 200]	102	< 200]	150	< 200]	2.64	< 200]	0	282
m _{ℓℓ} ^{min} [GeV]		> 3]	76.3	> 3]	106	> 3]	1.70	> 3]	0	205
m _{ℓℓ} ^{min} [GeV]		< 50]	42.9	< 60]	65.7	< 60]	1.41	> 90]	0	124
m _{ℓℓ} ^{min} [GeV]		< 1.0]	36.5	< 1.0]	59.9	< 1.2]	1.34	< 1.2]	0	111
m _{ℓℓ} ^{min} [GeV]			33.7		53.0		1.25		0	100
m _{ℓℓ} ^{min} [GeV]		[0]	422	[0]	541	[0]	11.1	[0]	0.148	1.17e+03
m _{ℓℓ} ^{min} [GeV]		< 130]	388	< 140]	540	< 160]	11.1	< 175]	0.148	1.14e+03
m _{ℓℓ} ^{min} [GeV]		[0]	239	[0]	341	[0]	7.28	[0]	0.148	649
m _{ℓℓ} ^{min} [GeV]		> 50]	50.8	> 50]	67.0	> 50]	1.08	> 50]	0	131
m _{ℓℓ} ^{min} [GeV]		> 3.0]	46.1	> 3.0]	60.5	> 3.0]	0.805	> 3.0]	0	119
m _{ℓℓ} ^{min} [GeV]		< 60]	43.3	< 60]	52.4	< 70]	0.805	> 90]	0	107
m _{ℓℓ} ^{min} [GeV]			40.2		48.6		0.700		0	99.5
m _{ℓℓ} ^{min} [GeV]		[0]	661	[0]	746	[0]	14.5	[0]	0.148	1.78e+03
m _{ℓℓ} ^{min} [GeV]		< 130]	607	< 140]	744	< 160]	14.5	< 175]	0.148	1.56e+03
m _{ℓℓ} ^{min} [GeV]		[0]	282	[0]	287	[0]	5.24	[0]	0	622

GitLab repository view showing files for ATLAS_2020_I1803608. The sidebar includes navigation options like Simple Analysis, Project information, Repository, Files, Commits, Branches, Tags, Contributors, Graph, Compare, Locked Files, Issues, Merge requests, CI/CD, Deployments, Monitor, Packages & Registries, and Analytics.

HEPData Repository for publication-related High-Energy Physics data. Search on 9506 publications and 100479 data tables. Search for a paper, author, experiment, reaction. Search Advanced. e.g. reaction P P → LQ LQ X, title has "photon collisions", collaboration is LHCf or D0.

We need your help!

As a community we can learn far more physics from an experimental result that is reinterpretable compared to one that is not.

2. LHC impact on SUSY with a light gravitino



Collider constraints on electroweakinos in the presence of a light gravitino

The GAMBIT Collaboration: Viktor Ananyev¹, Csaba Balázs², Ankit Beniwal³, Lasse Lorentz Braseth¹, Andy Buckley⁴, Jonathan Butterworth⁵, Christopher Chang⁶, Matthias Danninger⁷, Andrew Fowlie⁸, Tomás E. Gonzalo⁹, Anders Kvellestad¹, Farvah Mahmoudi^{10,11}, Gregory D. Martinez¹², Markus T. Prim¹³, Tomasz Procter⁴, Are Raklev¹, Pat Scott¹⁴, Patrick Stöcker¹⁵, Jeriek Van den Abeele¹, Martin White¹⁶, Yang Zhang^{17,18}



GAMBIT: The Global And Modular BSM Inference Tool

gambit.hepforge.org

github.com/GambitBSM

EPJC 77 (2017) 784

arXiv:1705.07908

- Extensive model database, beyond SUSY
- Fast definition of new datasets, theories
- Extensive observable/data libraries
- Plug&play scanning/physics/likelihood packages
- Various statistical options (frequentist /Bayesian)
- Fast LHC likelihood calculator
- Massively parallel
- Fully open-source

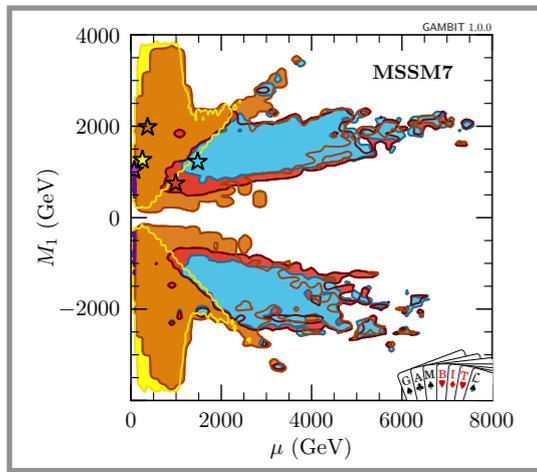


Members of: ATLAS, Belle-II, CLiC, CMS, CTA, Fermi-LAT, DARWIN, IceCube, LHCb, SHiP, XENON

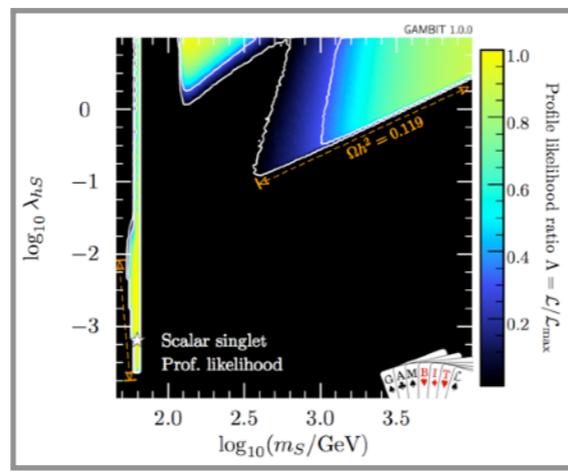
Authors of: BubbleProfiler, Capt'n General, Contur, DarkAges, DarkSUSY, DDCalc, DirectDM, Diver, EasyScanHEP, ExoCLASS, FlexibleSUSY, gamLike, GM2Calc, HEPLike, IsaTools, MARTY, nuLike, PhaseTracer, PolyChord, Rivet, SOFTSUSY, SuperIso, SUSY-AI, xsec, Vevacious, WIMPSim

Recent collaborators: P Athron, C Balázs, A Beniwal, S Bloor, T Bringmann, A Buckley, J-E Camargo-Molina, C Chang, M Chrzaszcz, J Conrad, J Cornell, M Danninger, J Edsjö, T Emken, A Fowlie, T Gonzalo, W Handley, J Harz, S Hoof, F Kahlhoefer, A Kvellestad, P Jackson, D Jacob, C Lin, N Mahmoudi, G Martinez, MT Prim, A Raklev, C Rogan, R Ruiz, P Scott, N Serra, P Stöcker, W. Su, A Vincent, C Weniger, M White, Y Zhang, ++

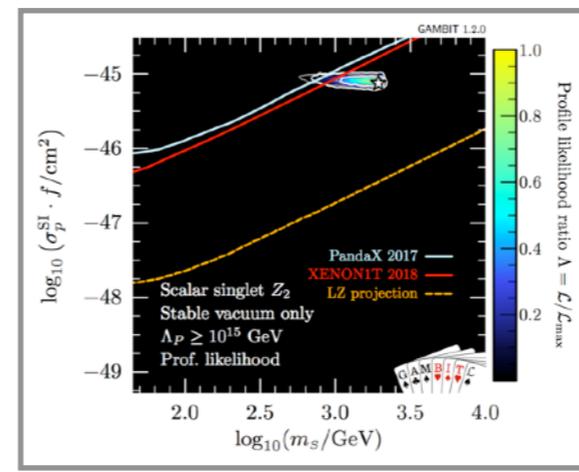
70+ participants in many experiments and numerous major theory codes



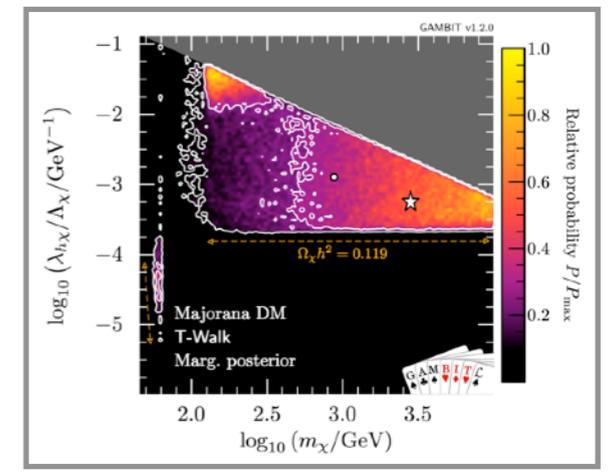
MSSM7: 1705.07917
GUT-scale SUSY: 1705.07935



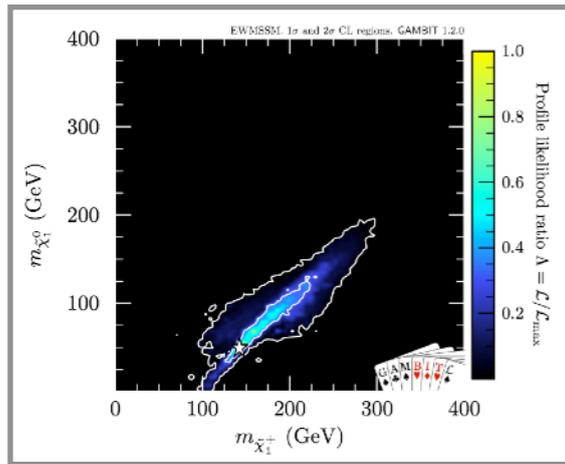
Scalar Higgs portal DM: 1705.07931



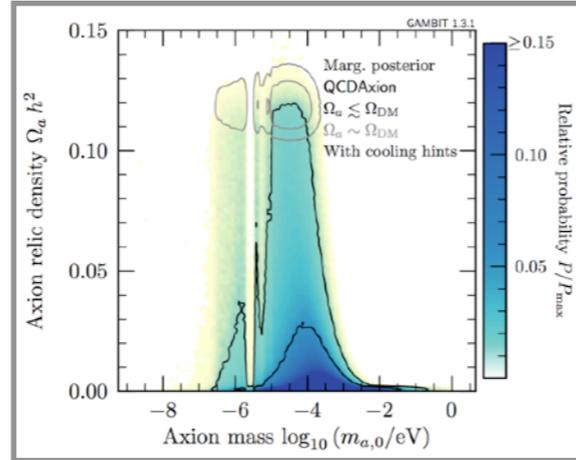
Scalar Higgs portal DM w/ vac. stability: 1806.11281



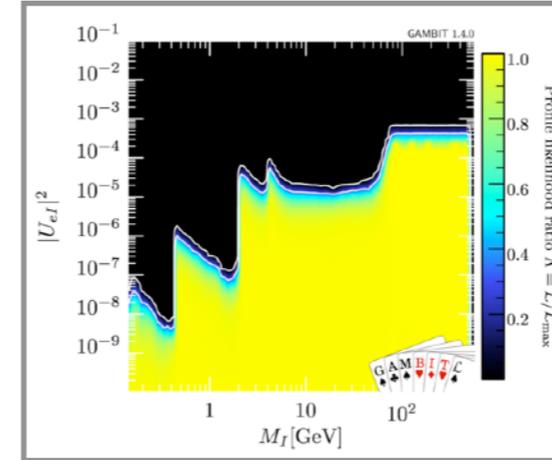
Vector and fermion Higgs portal DM: 1808.10465



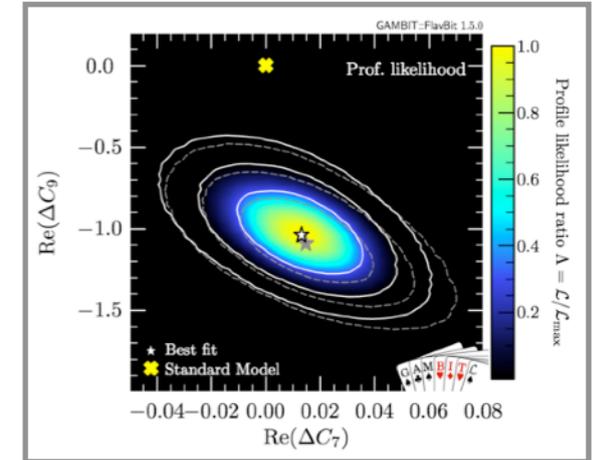
EWMSSM: 1809.02097



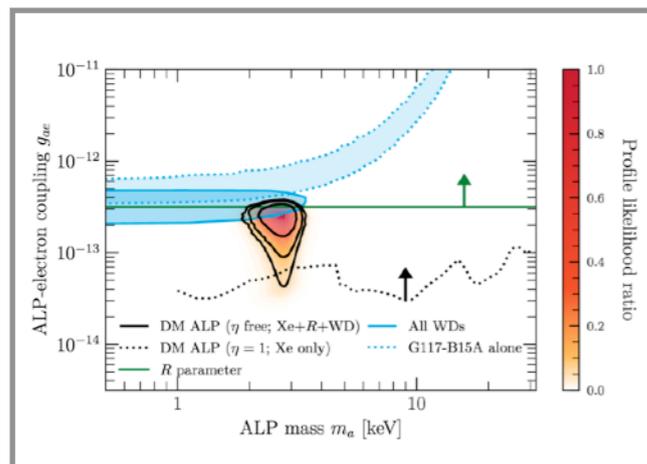
Axion-like particles: 1810.07192



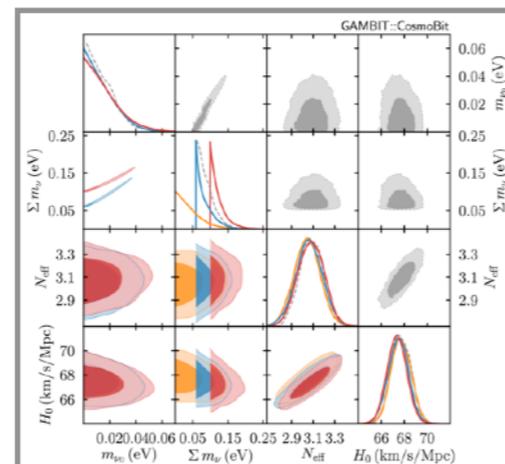
Right-handed neutrinos: 1908.02302



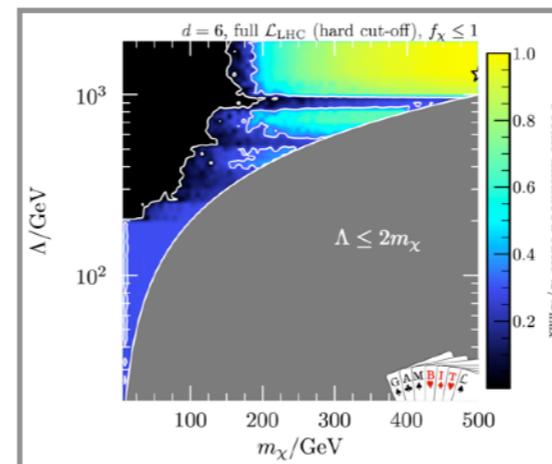
Flavour EFT: 2006.03489



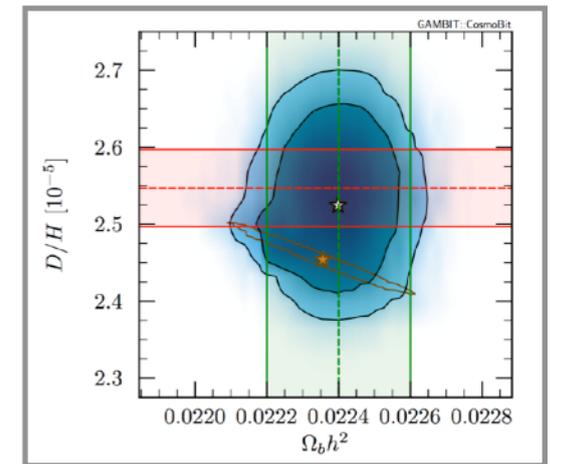
More axion-like particles: 2006.03489



Neutrinos and cosmo: 2009.03287



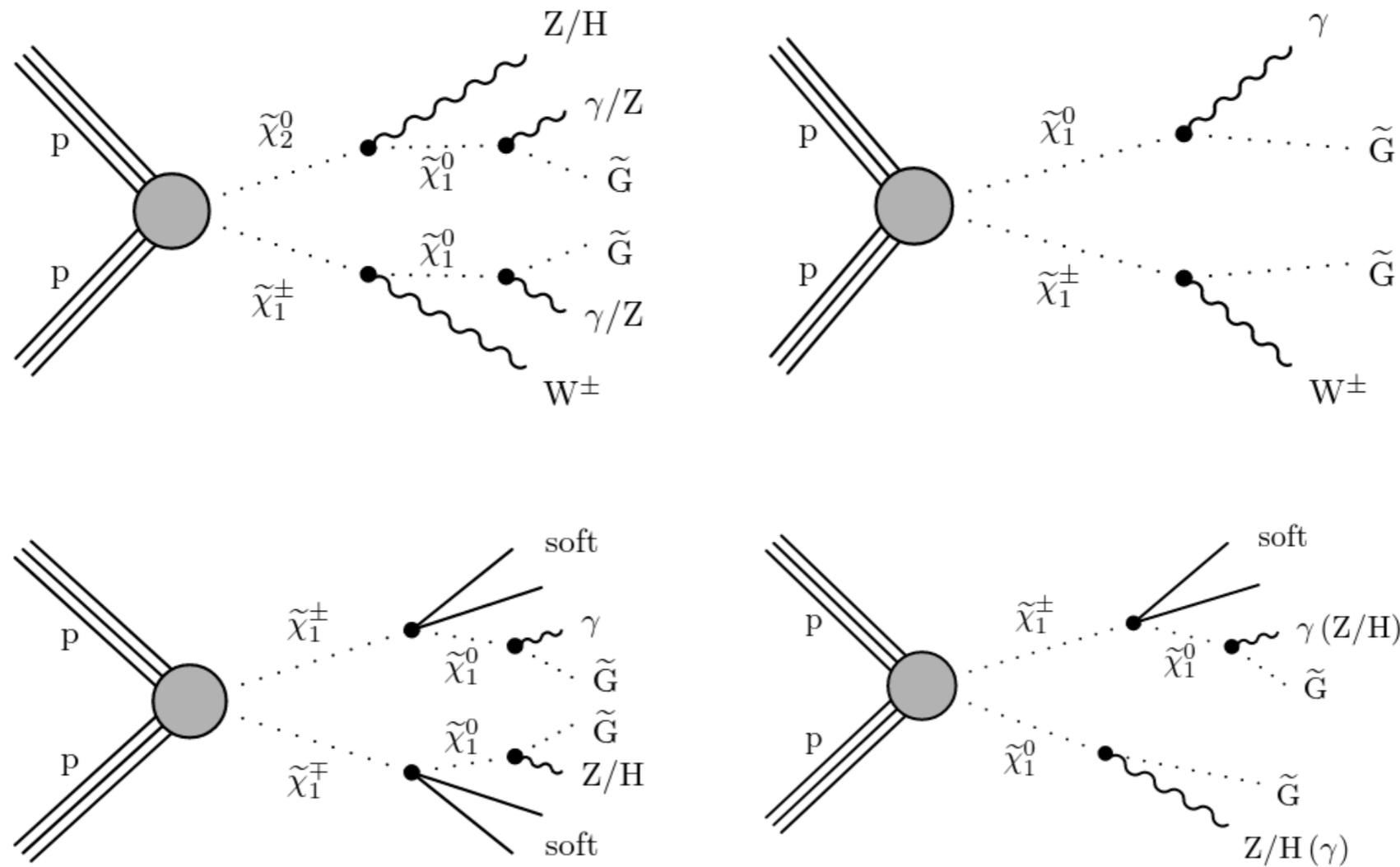
Dark matter EFTs: 2106.02056



Cosmo ALPs: 2205.13549



SUSY w/ light gravitino at the LHC



Typical ATLAS/CMS simplified model:

- Production of lightest neutralinos/charginos
- 1-2 fixed branching ratios
- Near massless gravitino as LSP



Our model: all MSSM EWinos + gravitino

- **Model:** MSSM w/ neutralinos, charginos and gravitino within LHC reach
- **7 SUSY particles below 1 TeV:** 4 neutralinos, 2 charginos, light gravitino
- **4D theory parameter space:** M_1 , M_2 , μ , $\tan\beta$
- **Why a gravitino?**
 - necessary consequence of supergravity
 - gauge-mediated symmetry breaking (GMSB): gravitino likely the LSP
- Distinct collider pheno: **the lightest neutralino/chargino will decay**
- Gravitino mass fixed to 1 eV \rightarrow **prompt decay** of lightest neutralino/chargino



Parameter space

$$M_1 \quad M_2 \quad \mu \quad \tan \beta$$

Neutralinos

$$\psi^0 = (\tilde{B}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0)$$

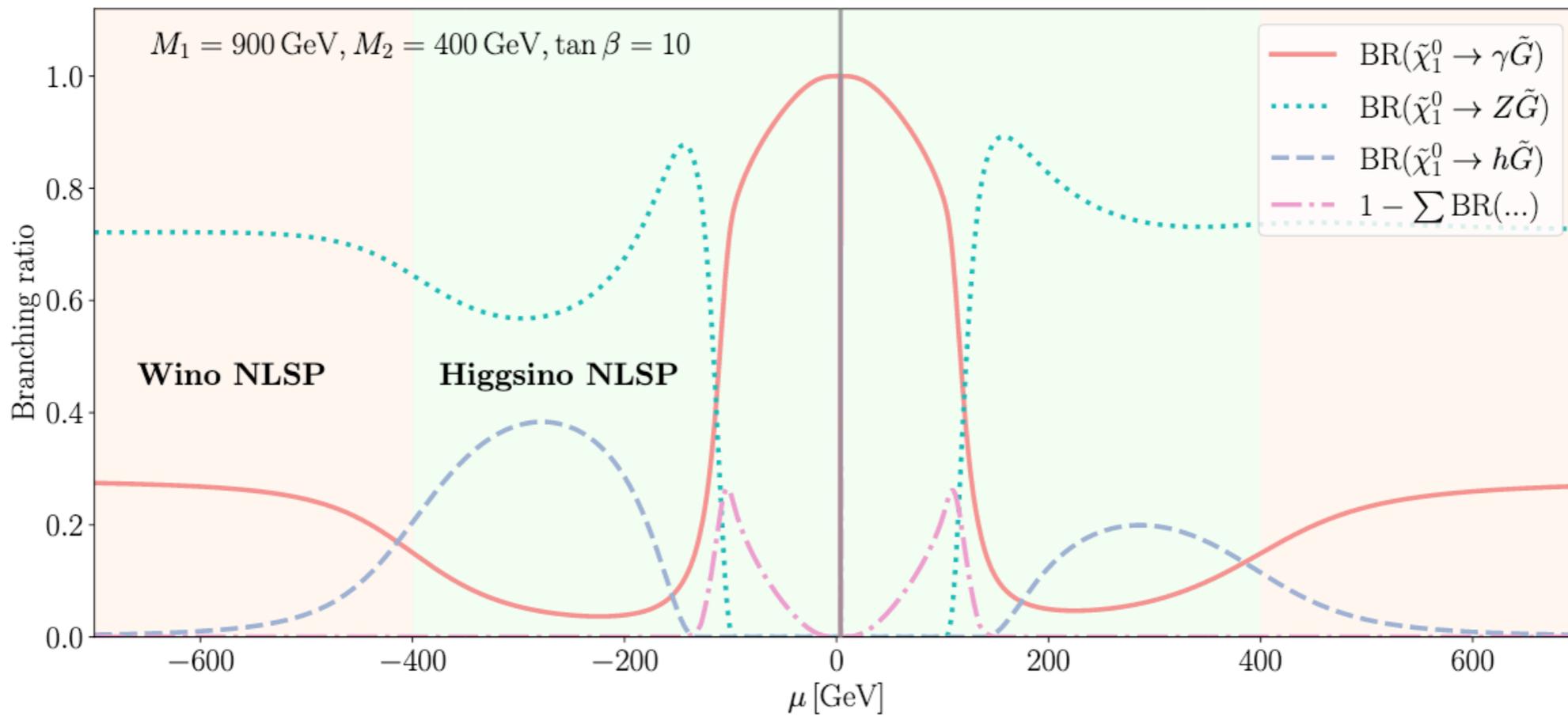
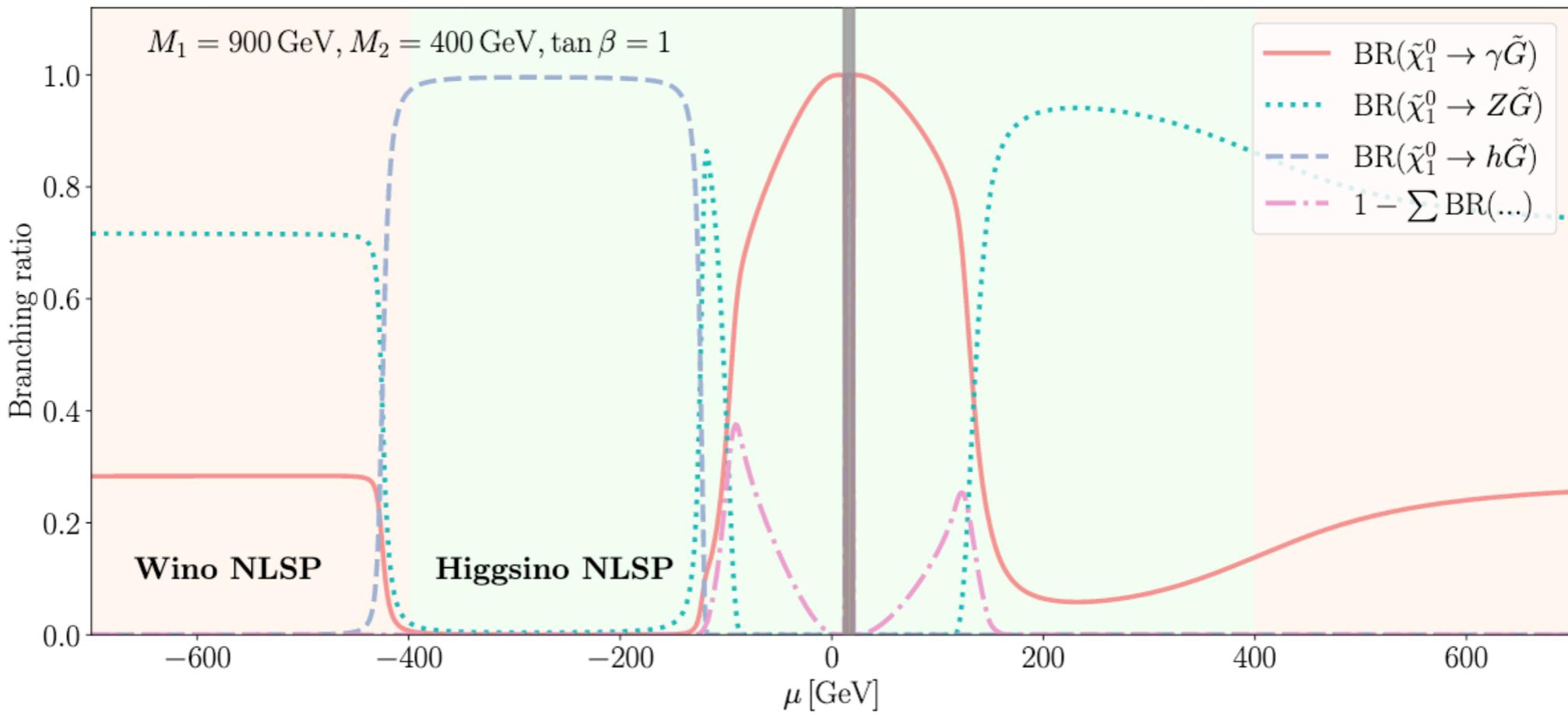
$$M_N = \begin{pmatrix} M_1 & 0 & -\frac{1}{2}g'vc_\beta & \frac{1}{2}g'vs_\beta \\ 0 & M_2 & \frac{1}{2}gvc_\beta & -\frac{1}{2}gvs_\beta \\ -\frac{1}{2}g'vc_\beta & \frac{1}{2}gvc_\beta & 0 & -\mu \\ \frac{1}{2}g'vs_\beta & -\frac{1}{2}gvs_\beta & -\mu & 0 \end{pmatrix}$$

Charginos

$$\psi^\pm = (\tilde{W}^+, \tilde{H}_u^+, \tilde{W}^-, \tilde{H}_d^-)$$

$$M_C = \begin{pmatrix} 0 & X^T \\ X & 0 \end{pmatrix}, \quad \text{where } X = \begin{pmatrix} M_2 & \frac{gvs_\beta}{\sqrt{2}} \\ \frac{gvc_\beta}{\sqrt{2}} & \mu \end{pmatrix}.$$





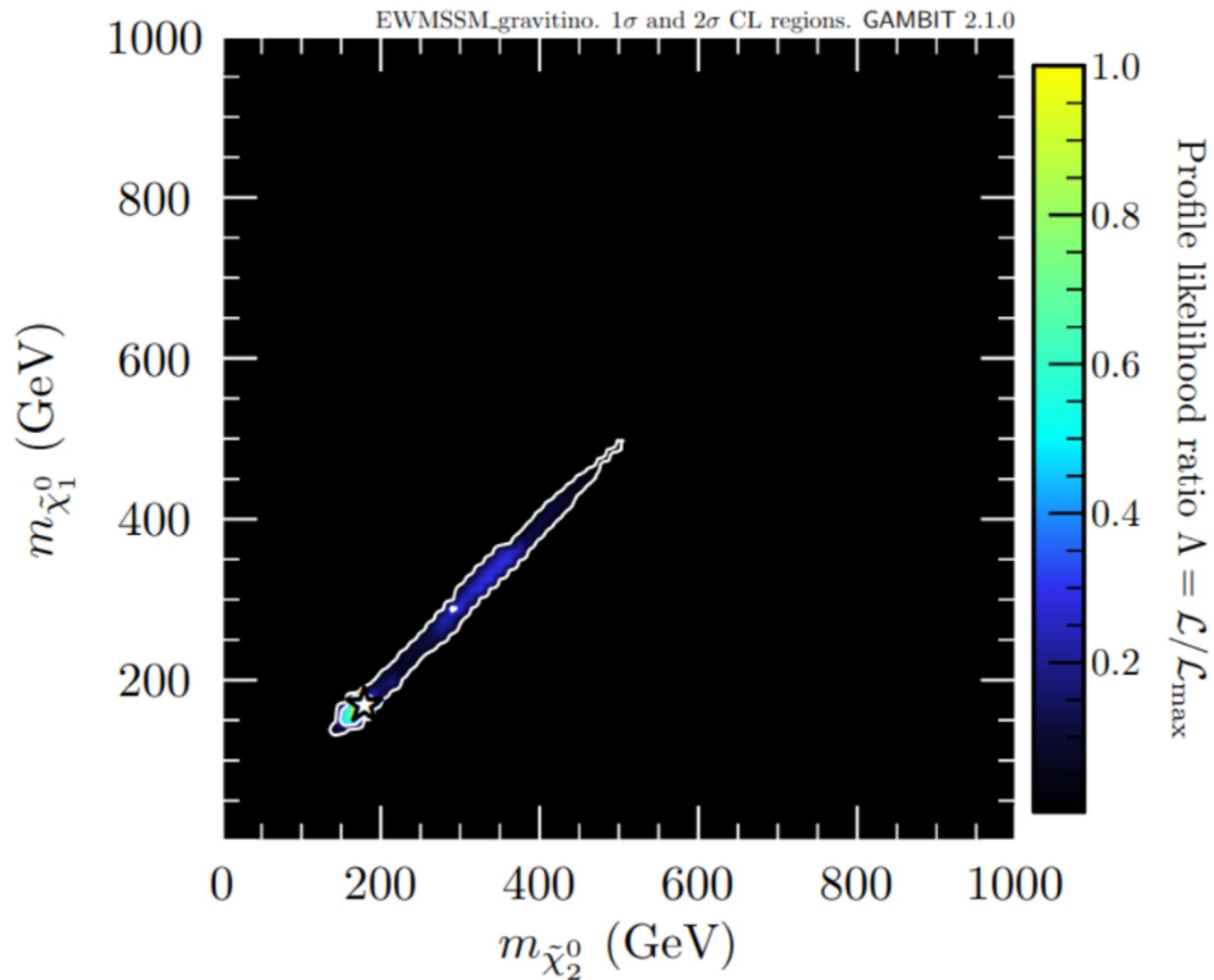
Analysis

- Series of parameter scans w/ GAMBIT
- Scanner: **Diver** (differential evolution)
- Per point: **simulate 16M SUSY events** (Pythia, via ColliderBit)
- CPU cost: tens of millions of CPU hours...
- **Likelihoods:**
 - **ATLAS & CMS searches** (in ColliderBit)
 - **ATLAS & CMS «SM measurements»** (Contur+Rivet, via ColliderBit)
 - apply relevant LEP cross-section limits (in ColliderBit)



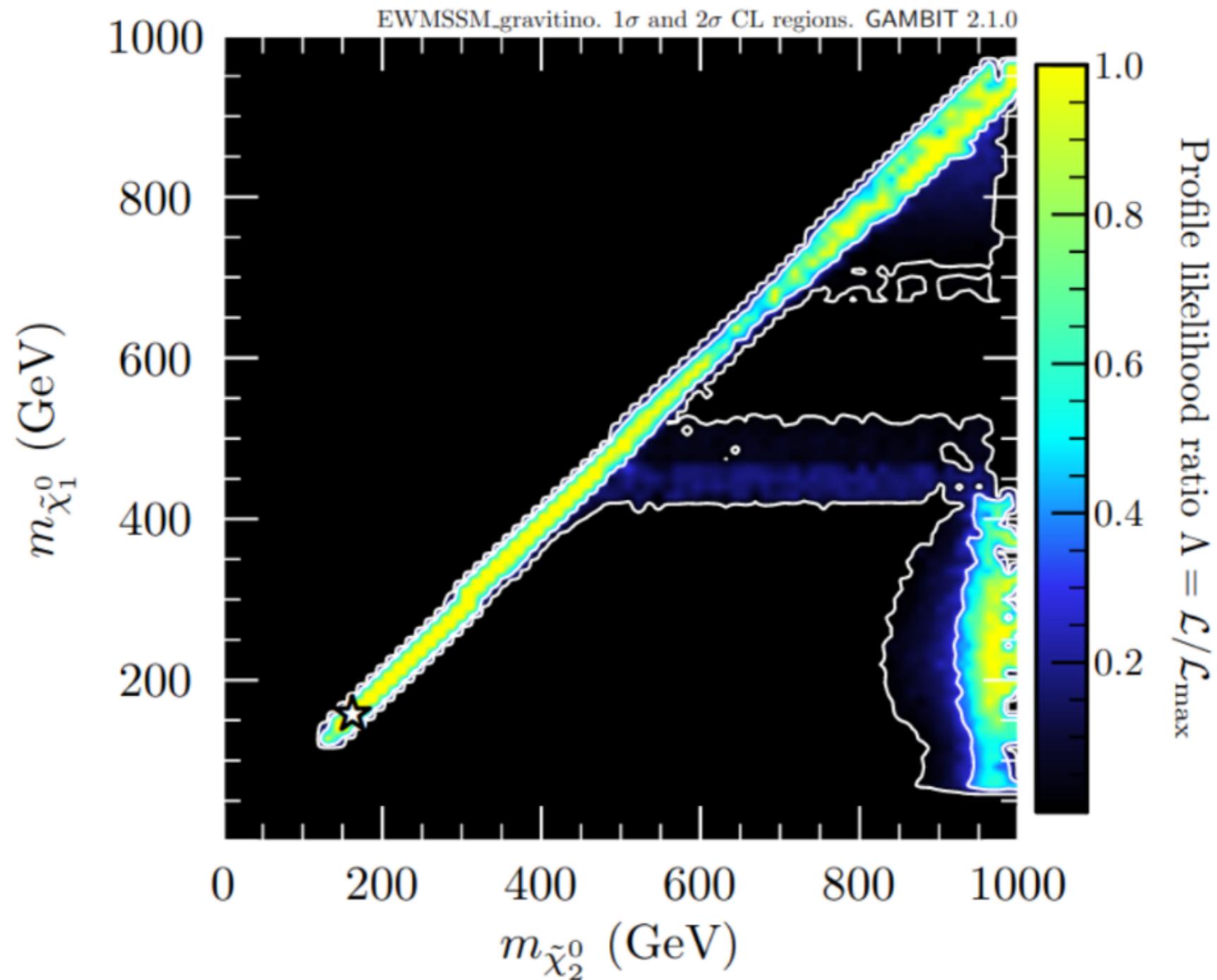
Preliminary results

Profile likelihood ratio



Preliminary results

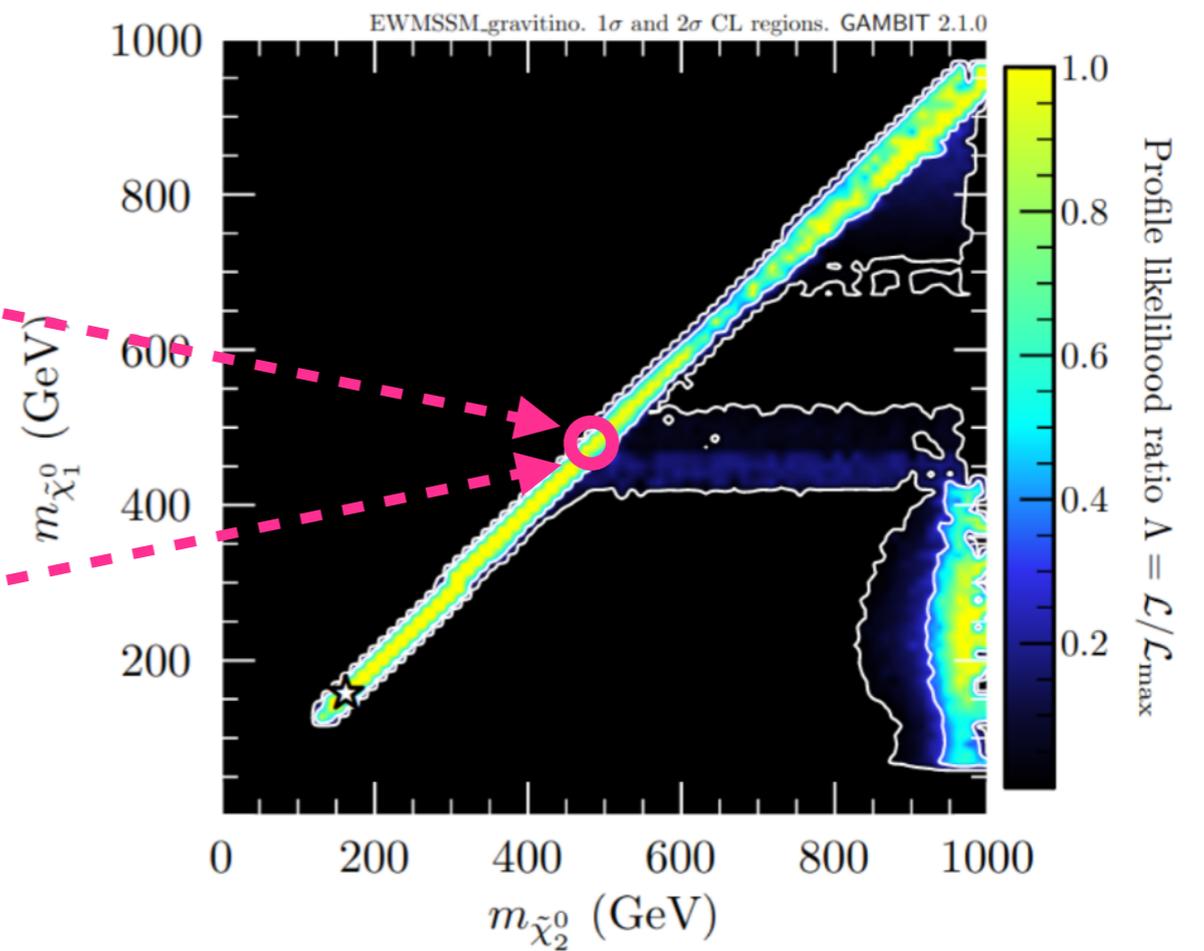
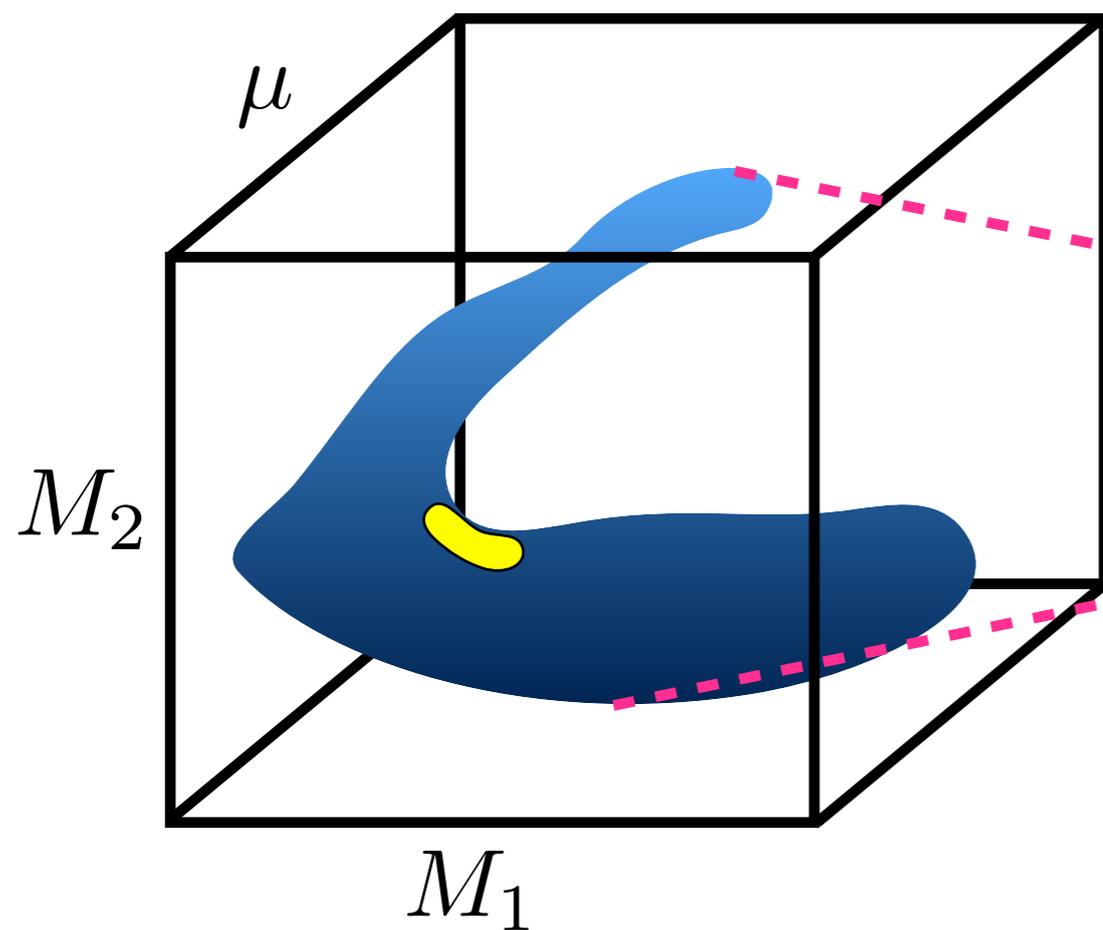
Profile likelihood ratio, likelihood capped at SM expectation ($s=0$)



Preliminary results

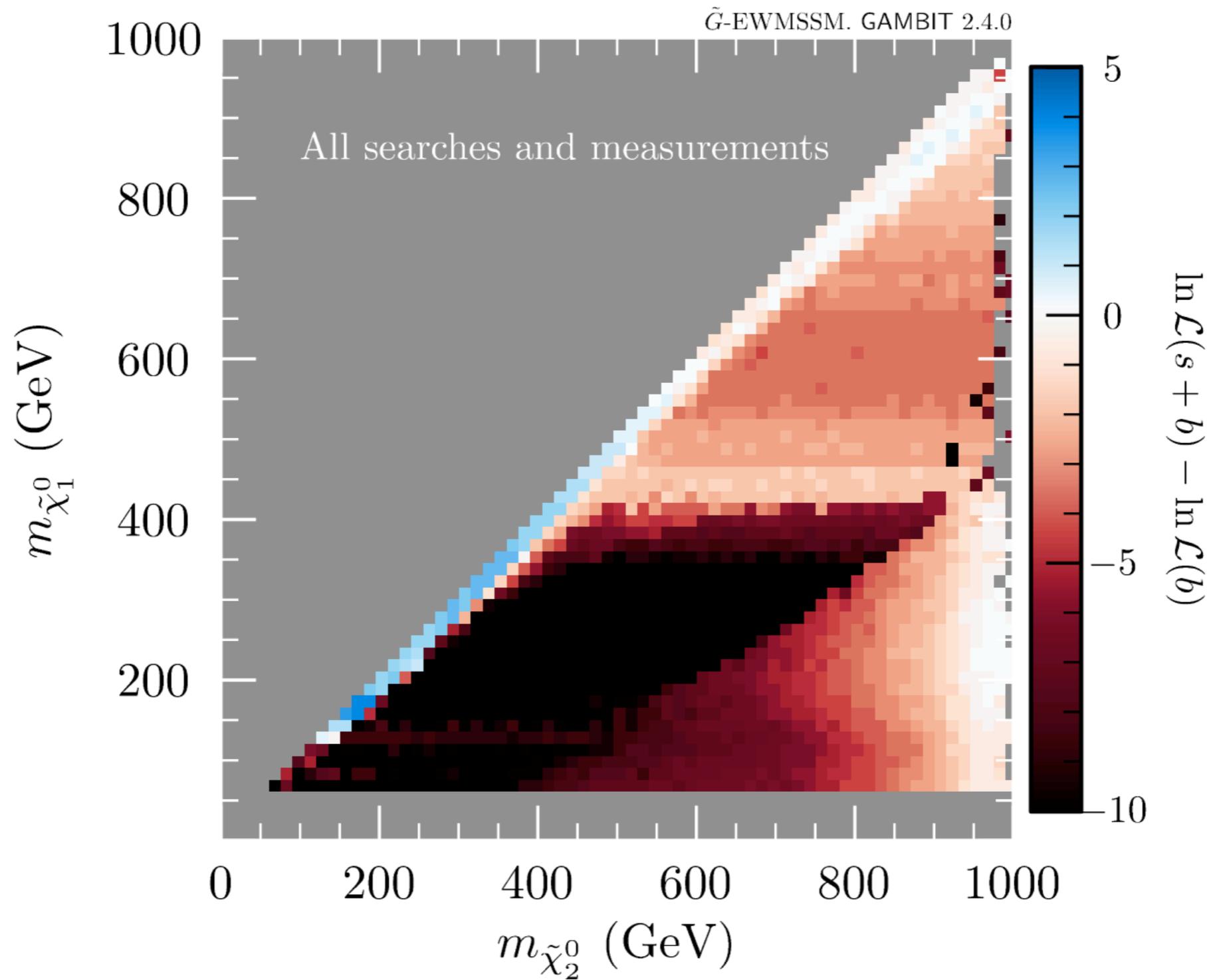
Interpretation: A yellow point means that there is *at least one point* in the G-EWSSM parameter space that fits the data as well as (or better than) the SM expectation.

This does not tell us anything about *the size* of the viable parameter space...



Preliminary results

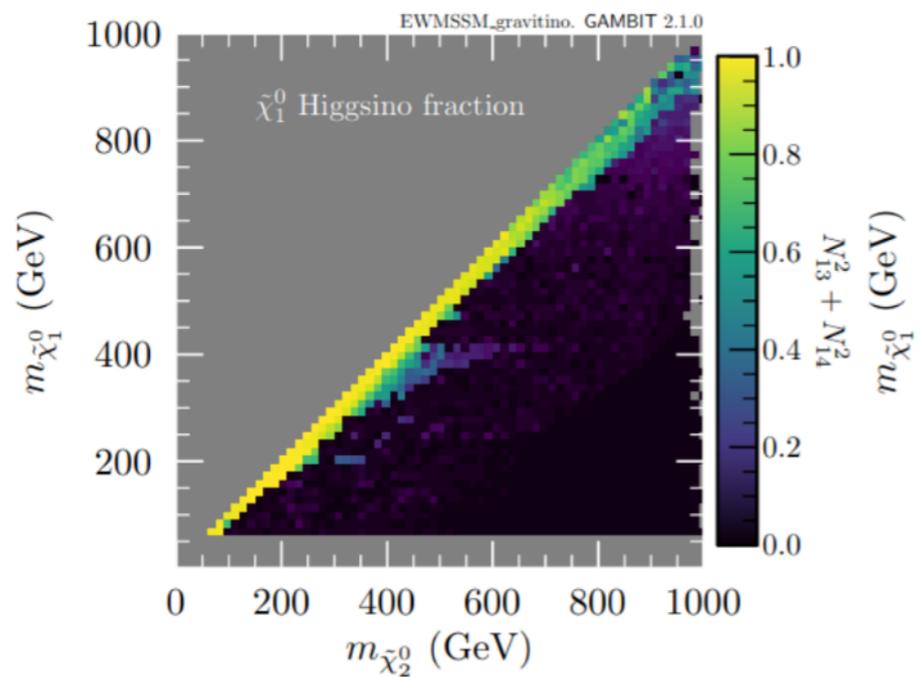
$\ln L(s+b) - \ln L(b)$



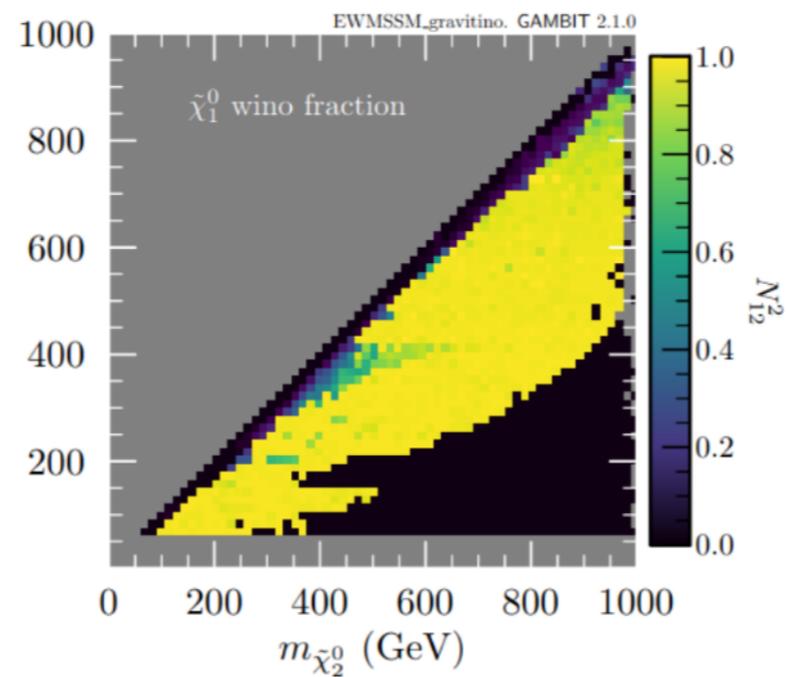
Preliminary results

Profiling picks out **different theory scenarios** in **different regions** of **the mass plane**

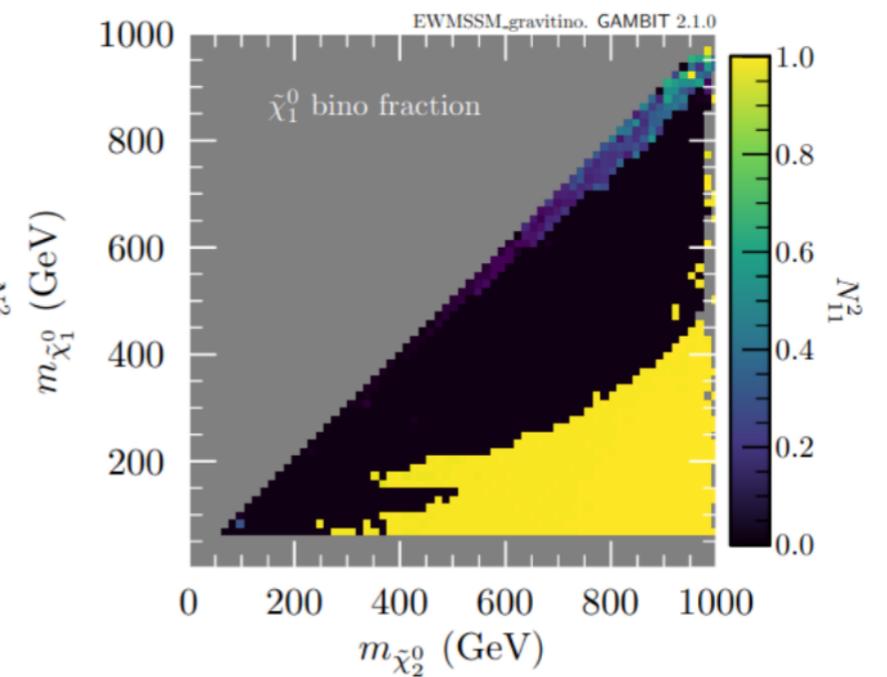
$\tilde{\chi}_0^1$ Higgsino fraction



$\tilde{\chi}_0^1$ wino fraction

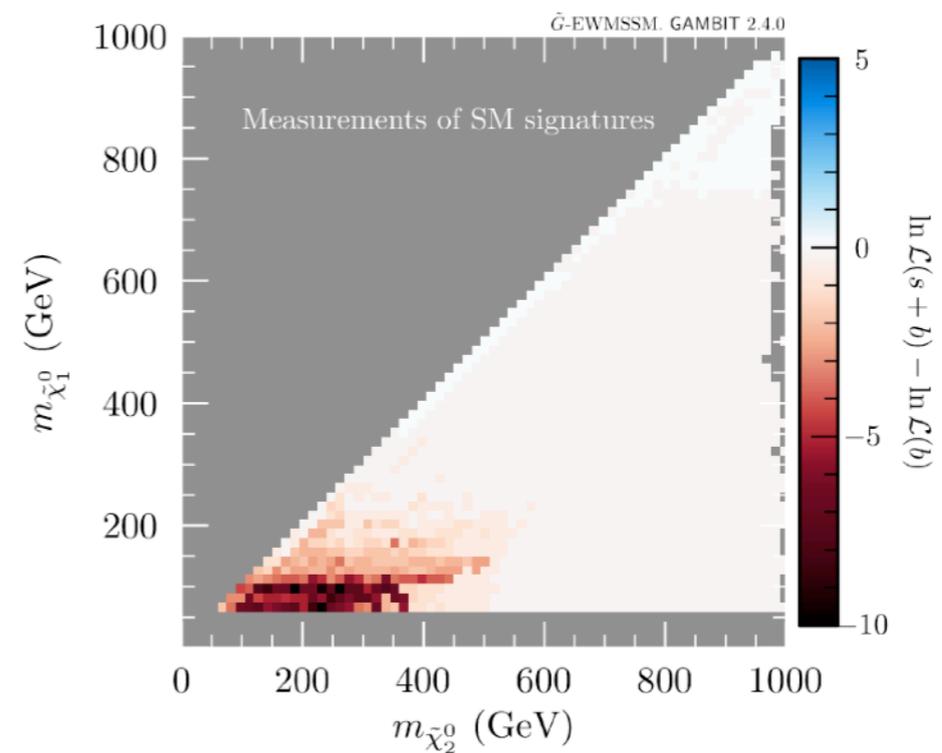
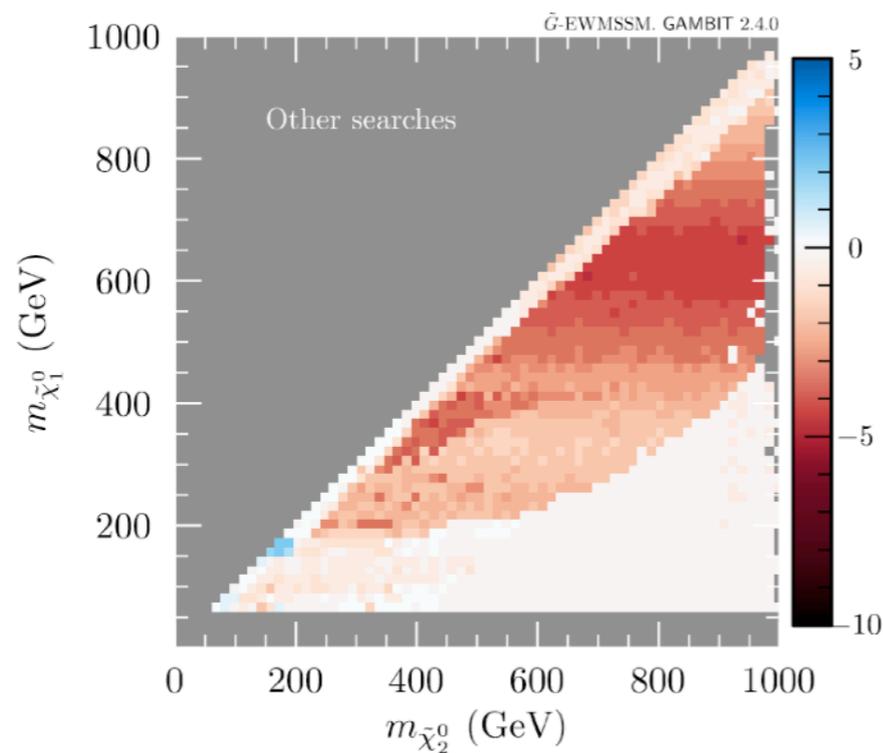
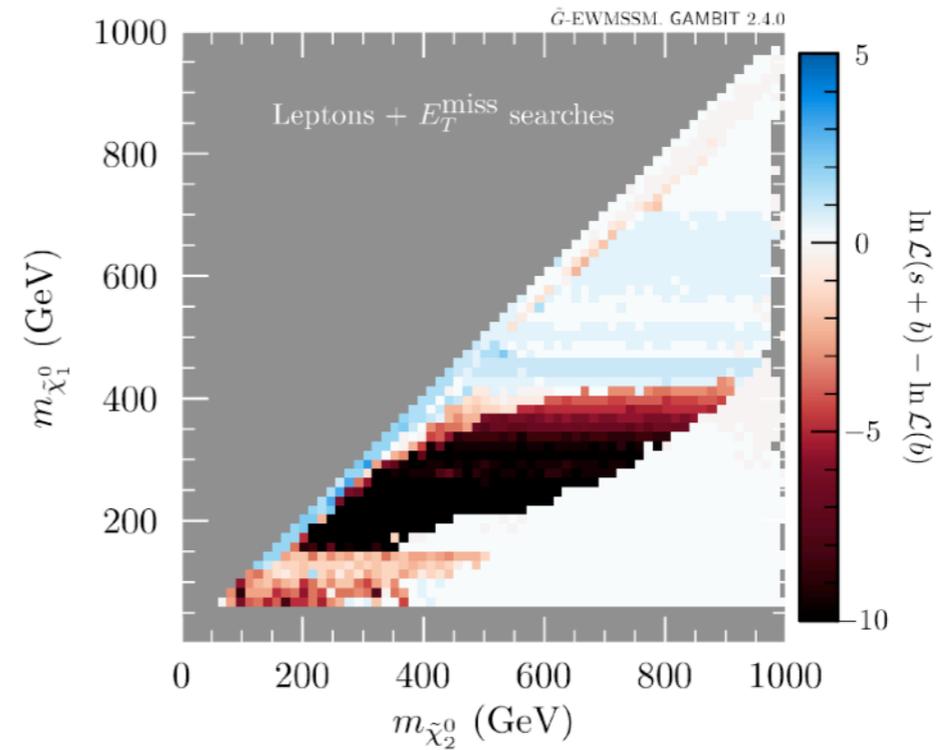
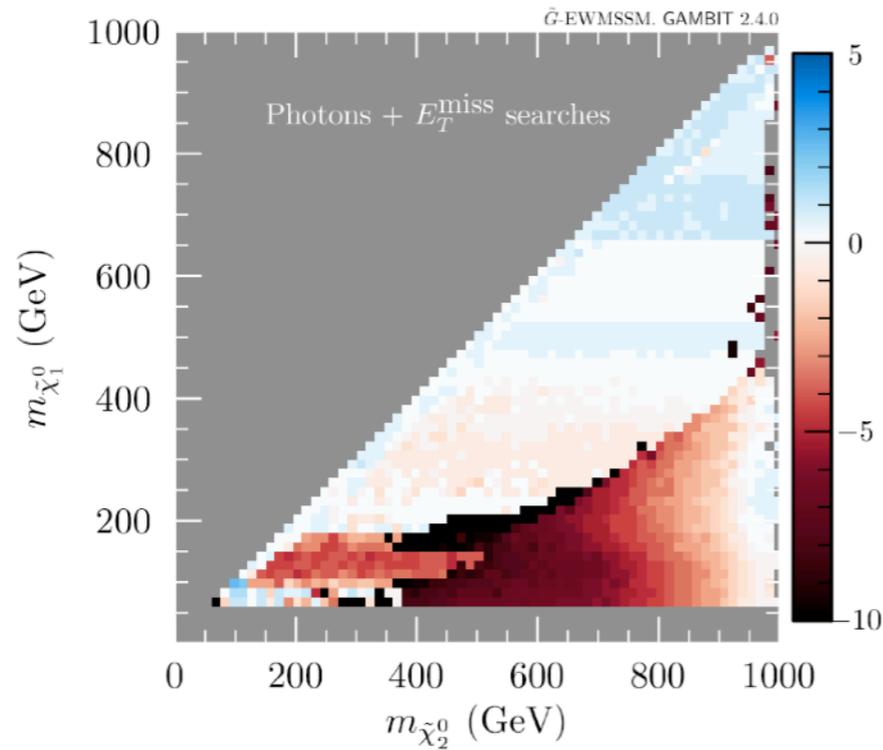


$\tilde{\chi}_0^1$ bino fraction



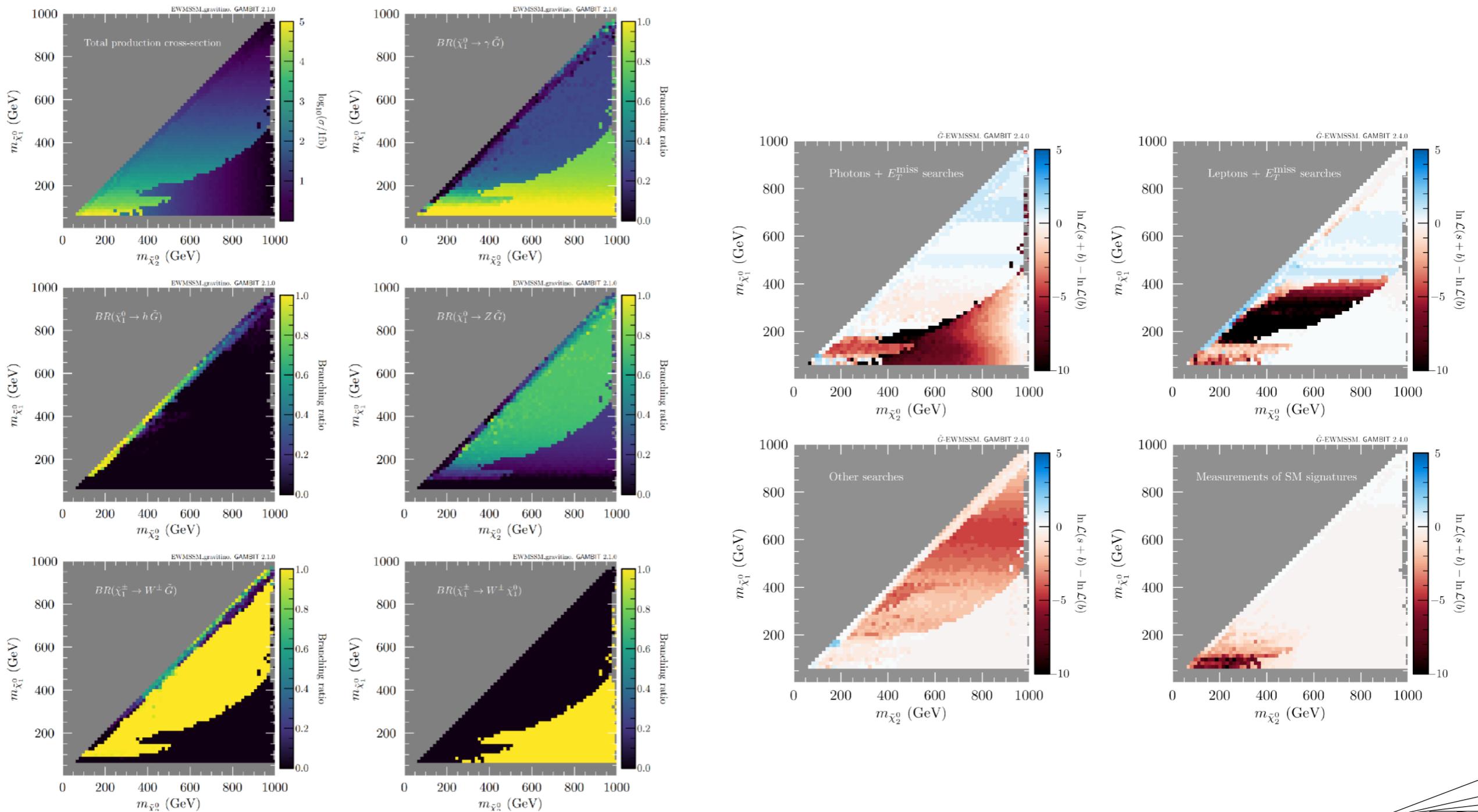
Preliminary results

Impact of different classes of searches/measurements



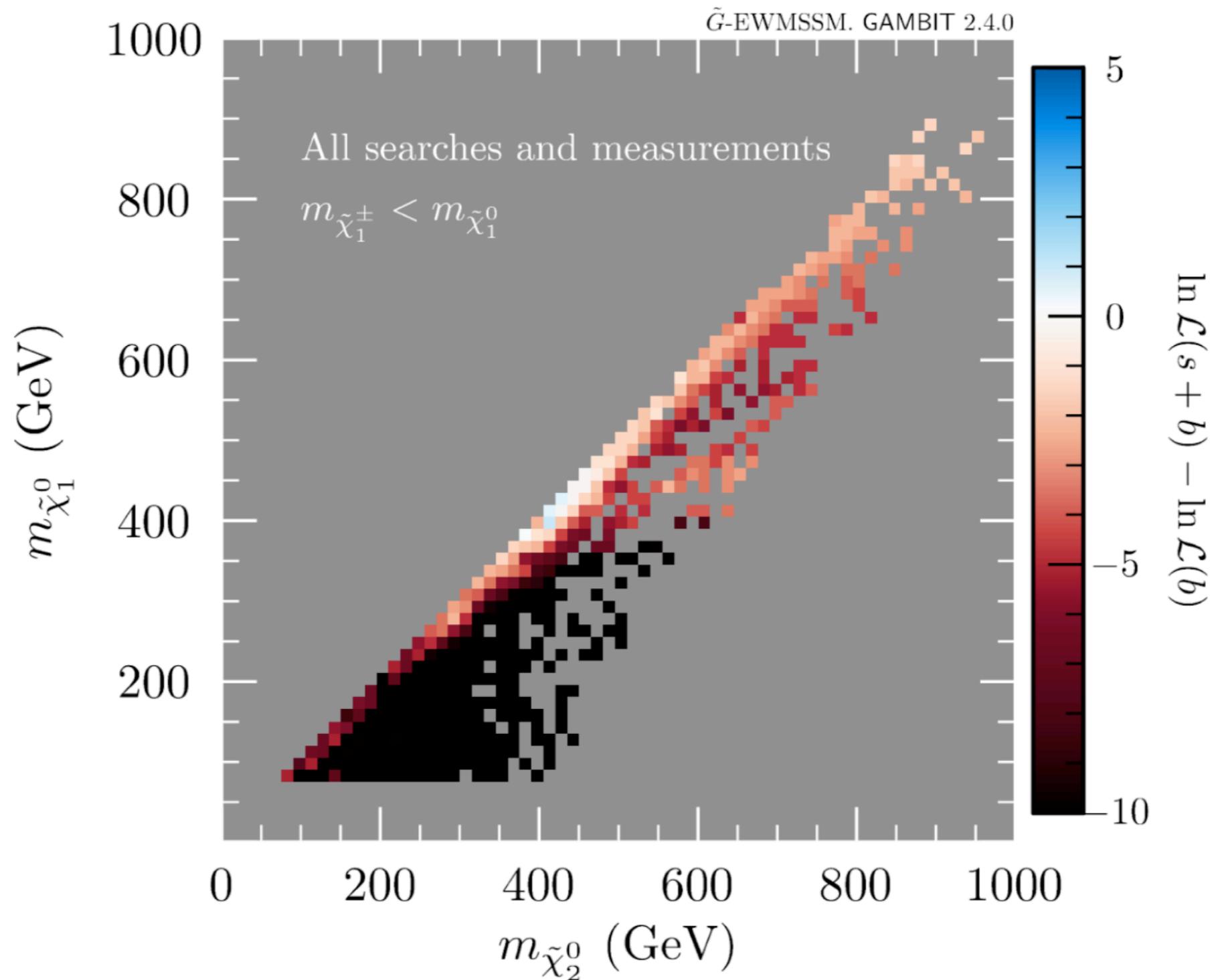
Preliminary results

Structure of results explained by **collection of experimental results + profiling + pattern of BRs + total production cross-section**



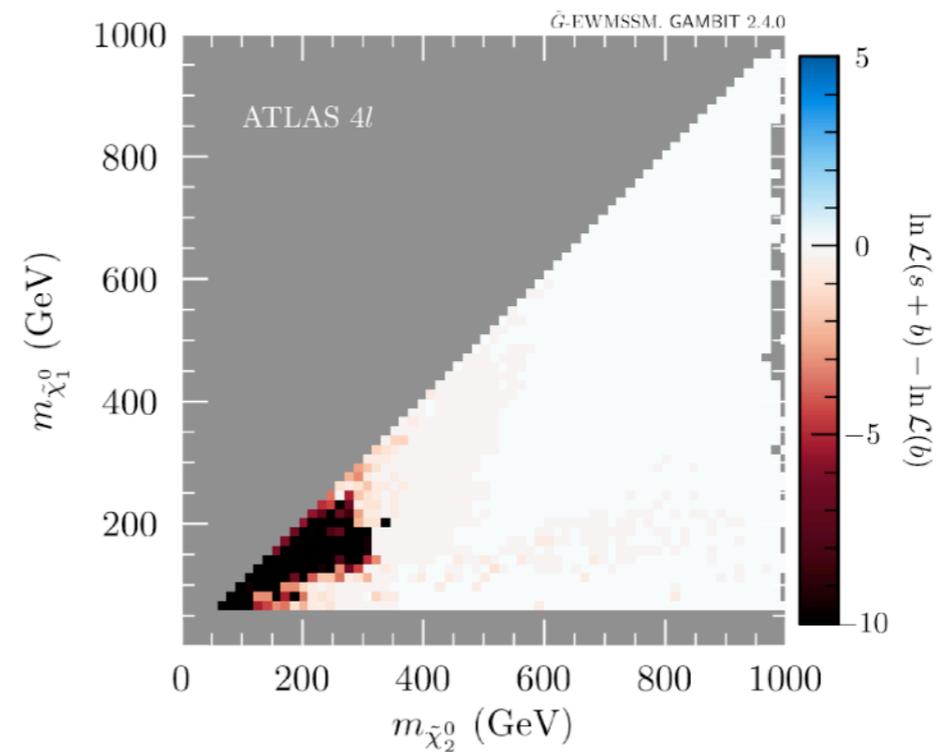
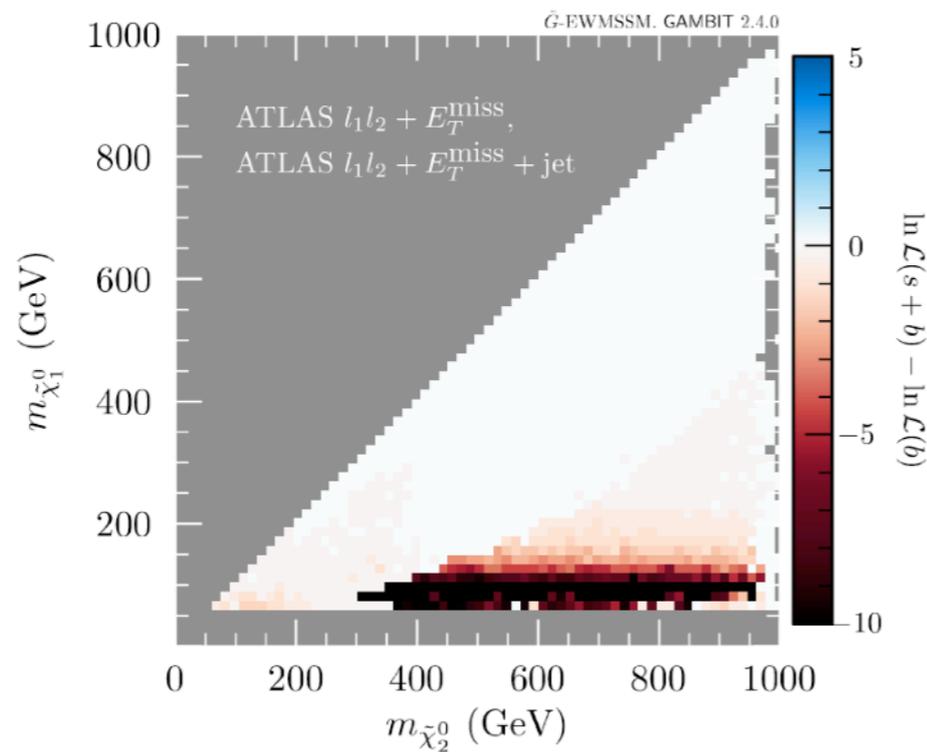
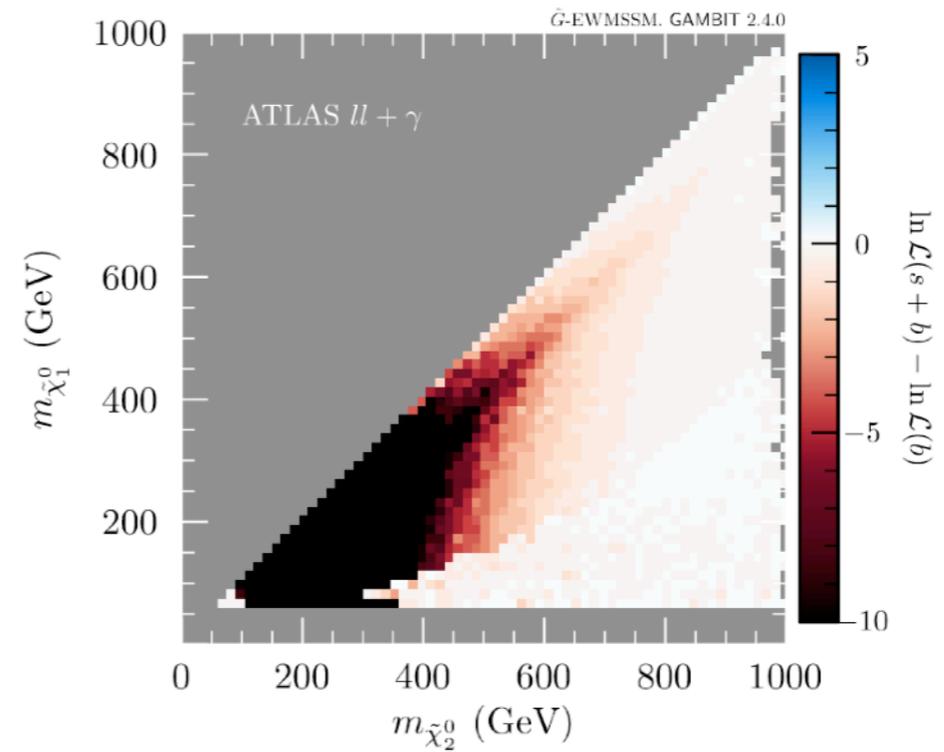
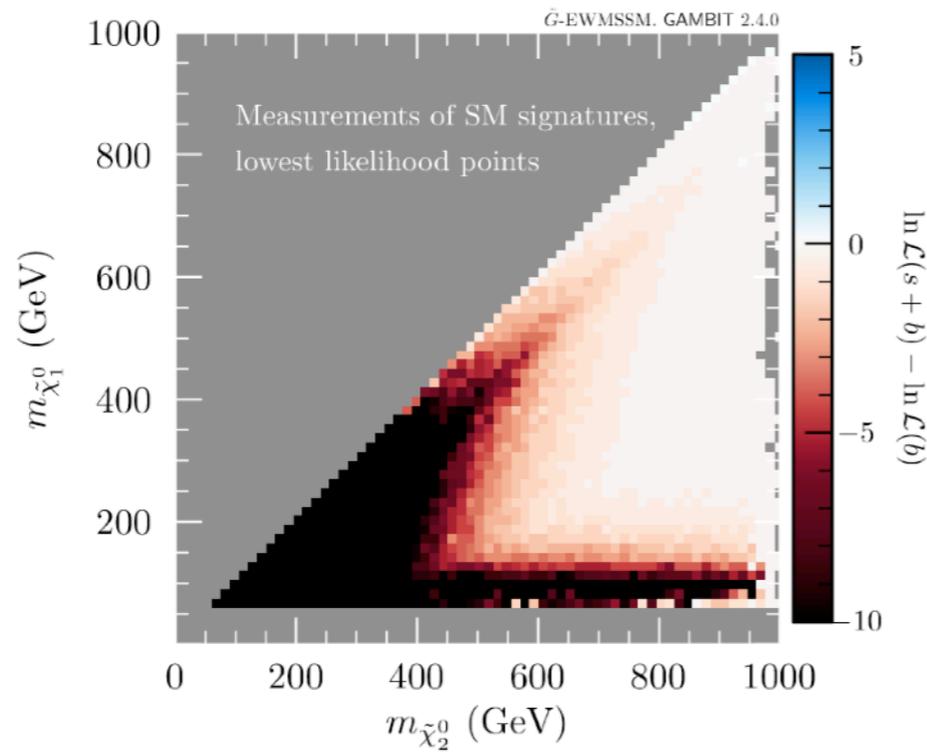
Preliminary results

Can have a chargino lighter than the lightest neutralino



Preliminary results

Points most constrained by the «SM measurements» alone



Summary

- How can we **maximise the scientific impact of experimental results?**
 - Reinterpret experimental results in terms of many (realistic) theories
 - Combine constraints from many experiments in a statistically sound way
- **New GAMBIT study:** LHC impact on SUSY w/ light gravitino
 - Largest proper global fit with full collider event simulations
 - First time we include LHC «SM measurements» w/ full event simulations
 - Weak preference for Higgsinos ~ 200 GeV (small excesses in MET+leptons/jets searches)
 - Difficult to exclude: lightest EWinos as mostly, but not pure, Higgsinos
 - Demonstrates importance of recasting LHC results in non-simplified models
 - Results will be publicly available: zenodo.org/communities/gambit-official



Bonus tracks



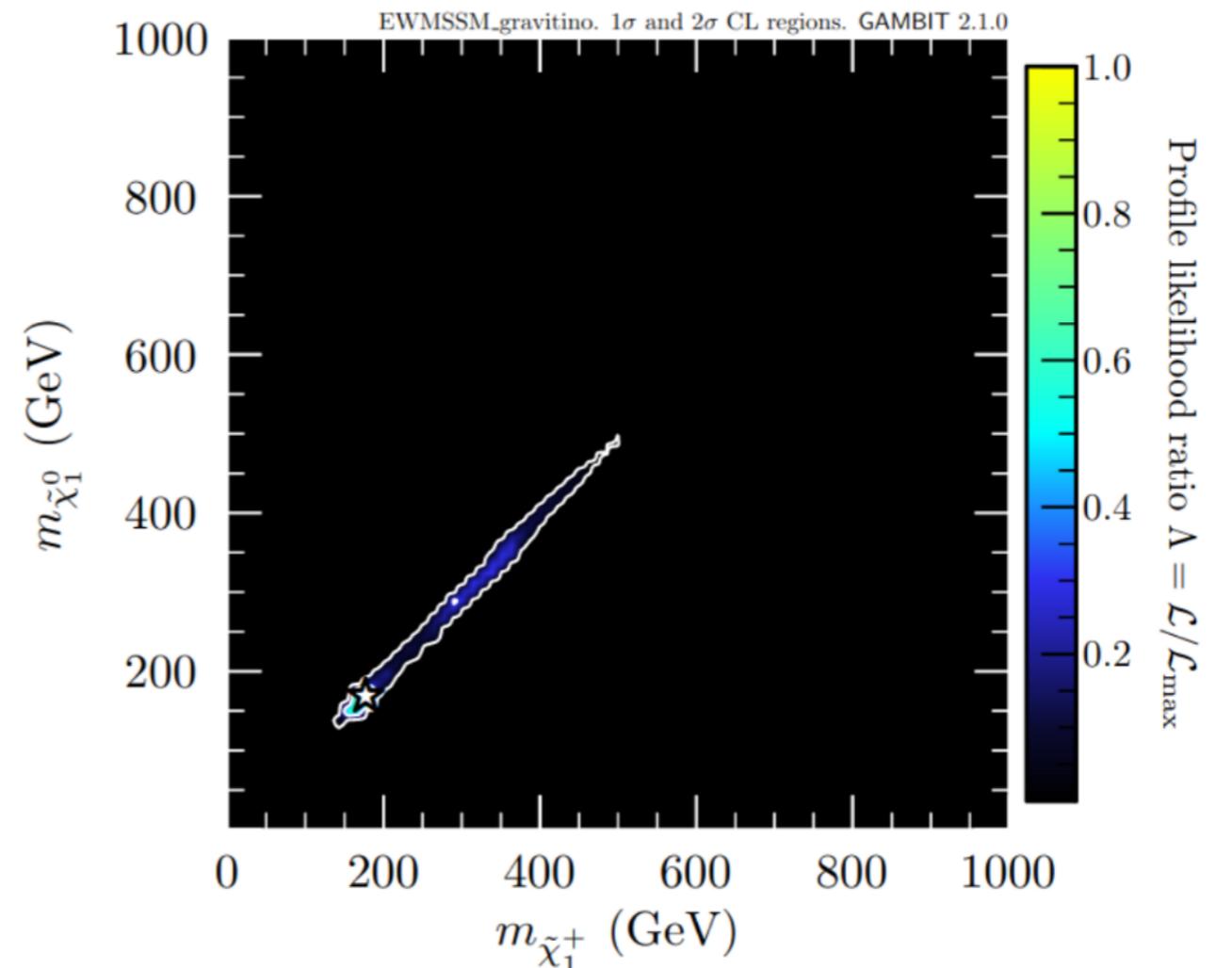
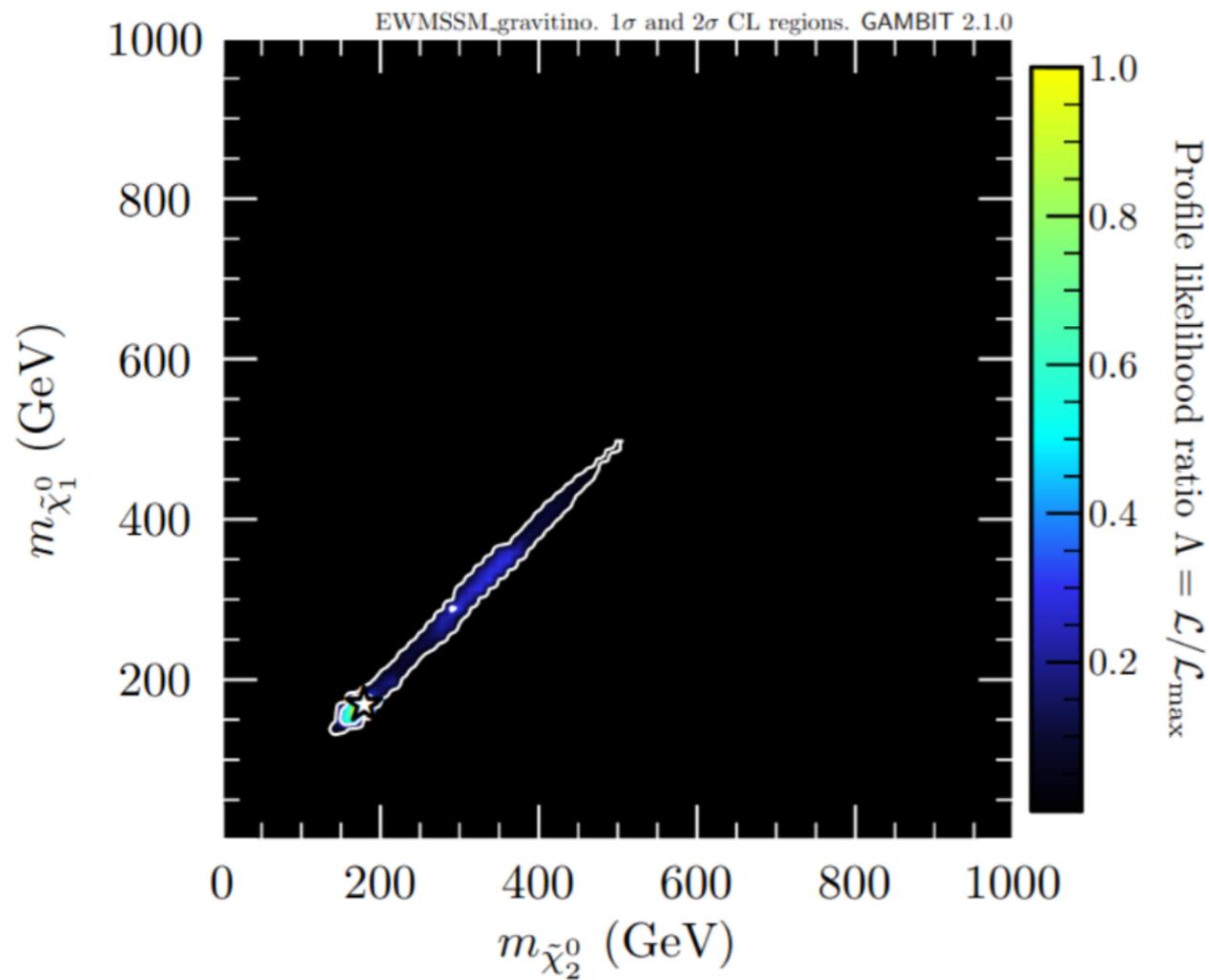
LHC searches:

Search label	Luminosity	Source
ATLAS_2BoostedBosons	139 fb ⁻¹	ATLAS hadronic chargino/neutralino search [102]
ATLAS_0lep	139 fb ⁻¹	ATLAS 0-lepton search [94]
ATLAS_0lep_stop	36 fb ⁻¹	ATLAS 0-lepton stop search [103]
ATLAS_1lep_stop	36 fb ⁻¹	ATLAS 1-lepton stop search [104]
ATLAS_2lep_stop	139 fb ⁻¹	ATLAS 2-lepton stop search [105]
ATLAS_2OSlep_Z	139 fb ⁻¹	ATLAS stop search with Z/H final states [107]
ATLAS_2OSlep_chargino	139 fb ⁻¹	ATLAS 2-lepton chargino search [95]
ATLAS_2b	36 fb ⁻¹	ATLAS 2- <i>b</i> -jet stop/sbottom search [108]
ATLAS_3b	24 fb ⁻¹	ATLAS 3- <i>b</i> -jet Higgsino search [109]
ATLAS_3lep	139 fb ⁻¹	ATLAS 3-lepton chargino/neutralino search [96]
ATLAS_4lep	139 fb ⁻¹	ATLAS 4-lepton search [97]
ATLAS_MultiLep_strong	139 fb ⁻¹	ATLAS leptons + jets search [98]
ATLAS_PhotonGGM_1photon	139 fb ⁻¹	ATLAS 1-photon GGM search [110]
ATLAS_PhotonGGM_2photon	36 fb ⁻¹	ATLAS 2-photon GGM search [111]
ATLAS_Z_photon	80 fb ⁻¹	ATLAS Z + photon search [112]
CMS_0lep	137 fb ⁻¹	CMS 0-lepton search [113]
CMS_1lep_bb	36 fb ⁻¹	CMS 1-lepton + <i>b</i> -jets chargino/neutralino search [115]
CMS_1lep_stop	36 fb ⁻¹	CMS 1-lepton stop search [116]
CMS_2lep_stop	36 fb ⁻¹	CMS 2-lepton stop search [117]
CMS_2lep_soft	36 fb ⁻¹	CMS 2 soft lepton search [118]
CMS_2OSlep	137 fb ⁻¹	CMS 2-lepton search [119]
CMS_2OSlep_chargino_stop	36 fb ⁻¹	CMS 2-lepton chargino/stop search [120]
CMS_2SSlep_stop	137 fb ⁻¹	CMS 2 same-sign lepton stop search [121]
CMS_MultiLep	137 fb ⁻¹	CMS multilepton chargino/neutralino search [100]
CMS_photon	36 fb ⁻¹	CMS 1-photon GMSB search [122]
CMS_2photon	36 fb ⁻¹	CMS 2-photon GMSB search [123]
CMS_1photon_1lepton	36 fb ⁻¹	CMS 1-photon + 1-lepton GMSB search [124]



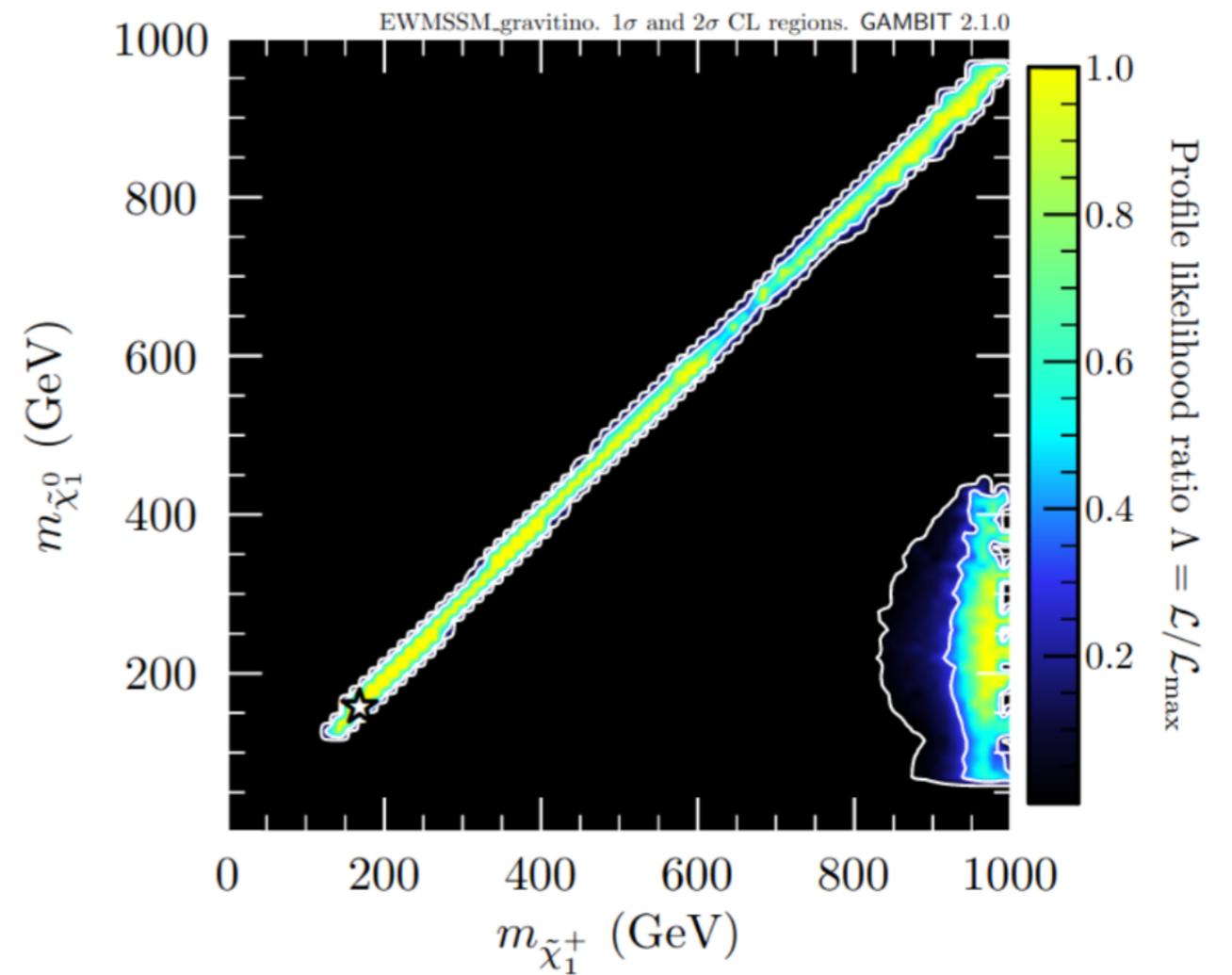
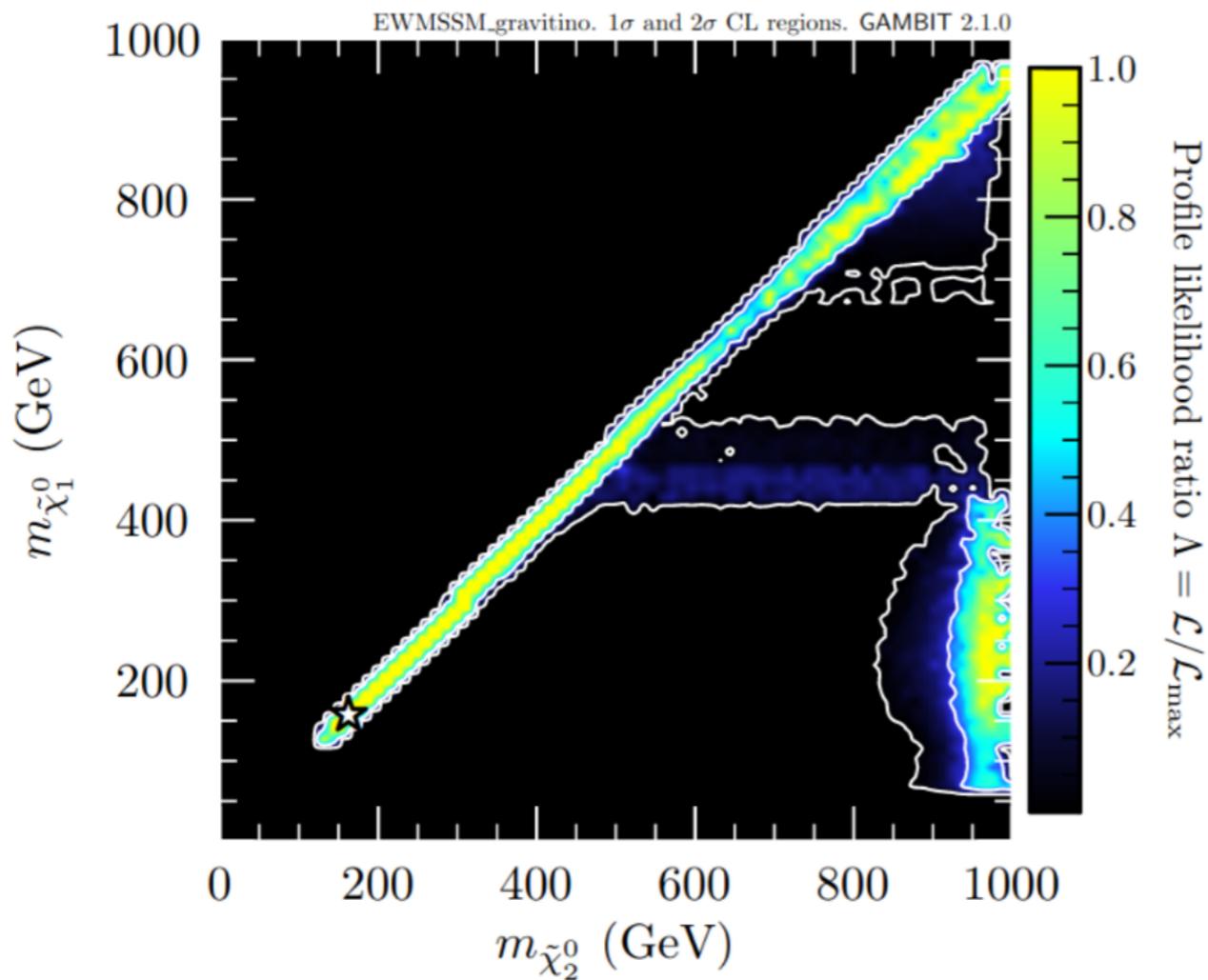
Preliminary results

Profile likelihood ratio



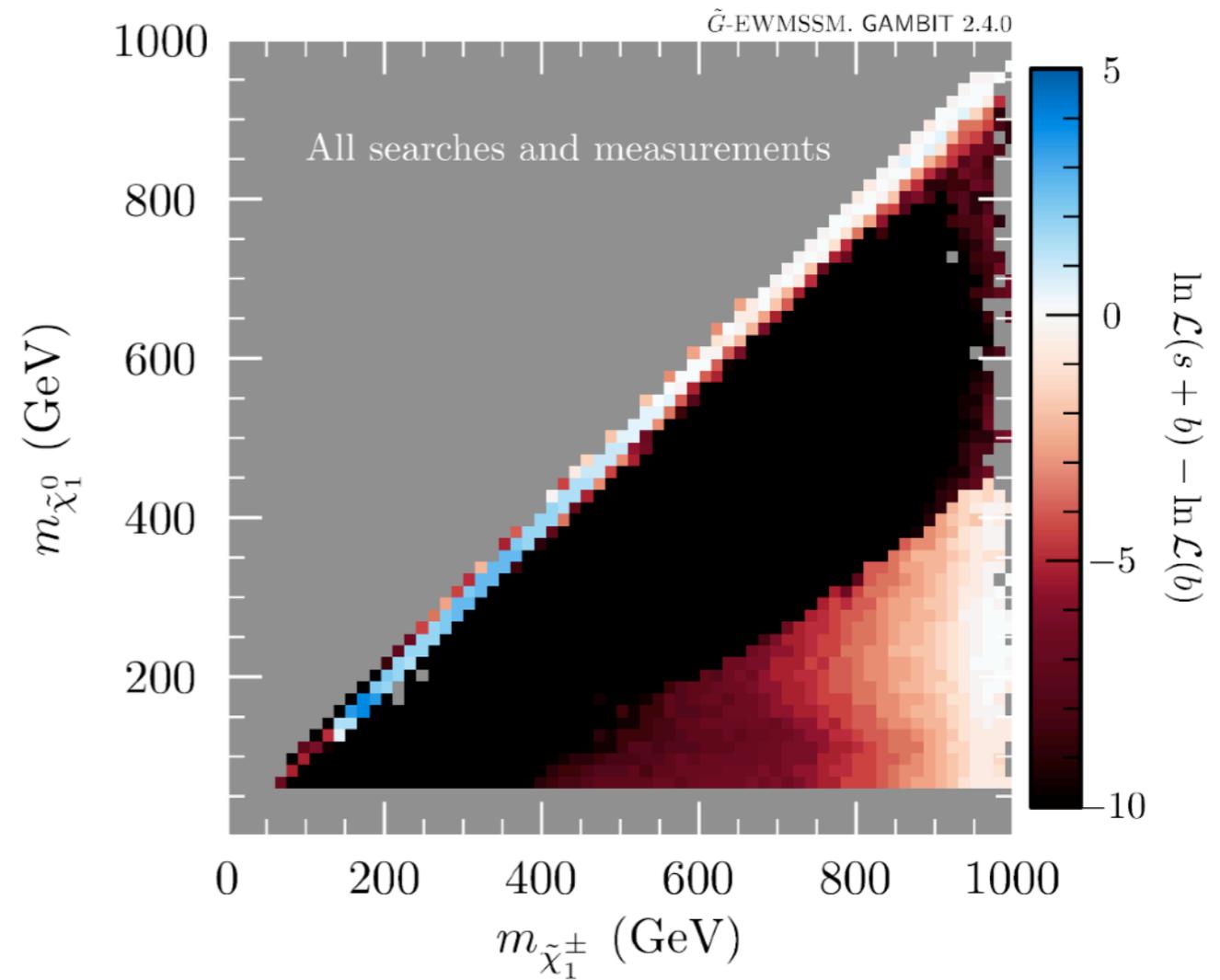
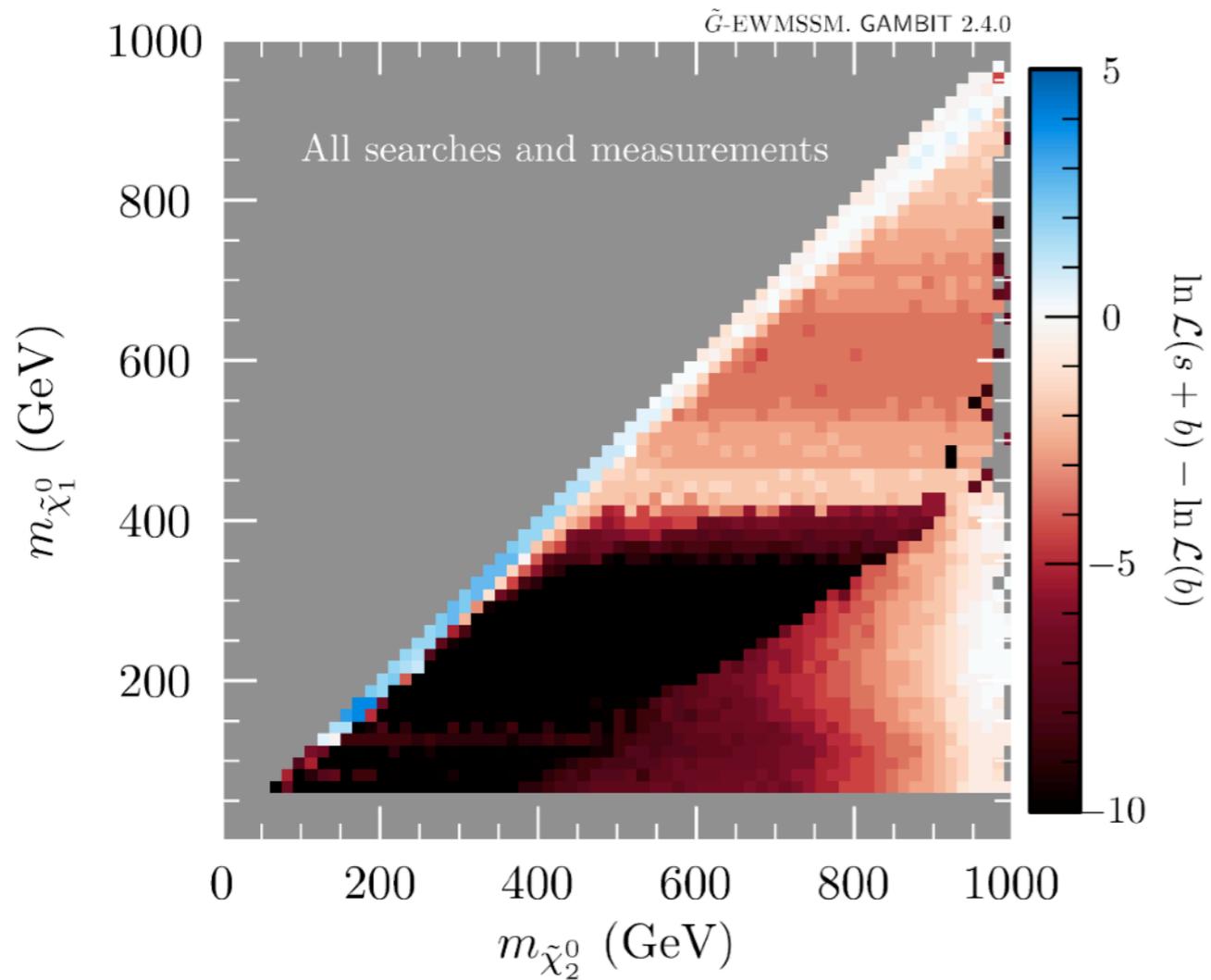
Preliminary results

Profile likelihood ratio, likelihood capped at SM expectation (s=0)



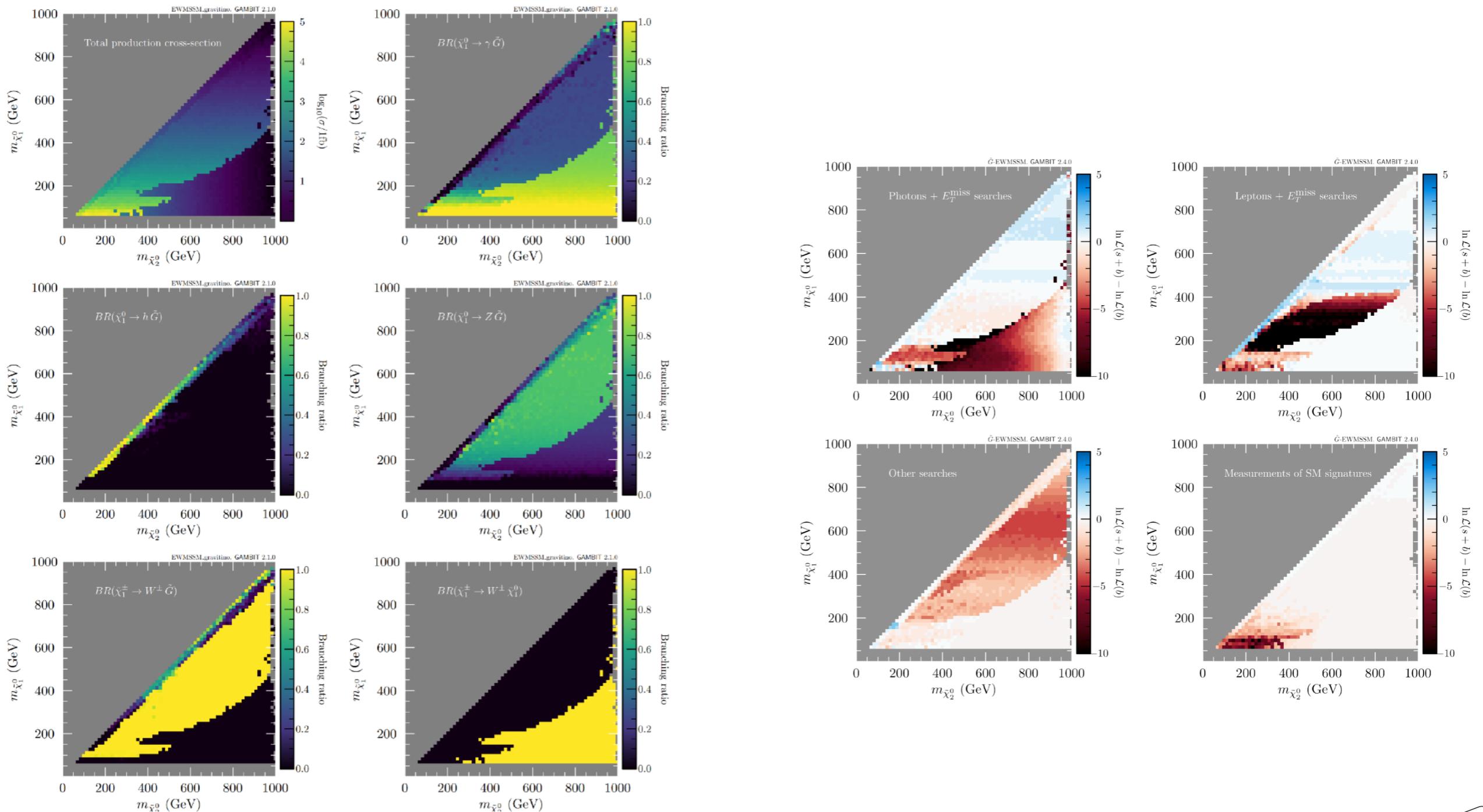
Preliminary results

$\ln L(s+b) - \ln L(b)$



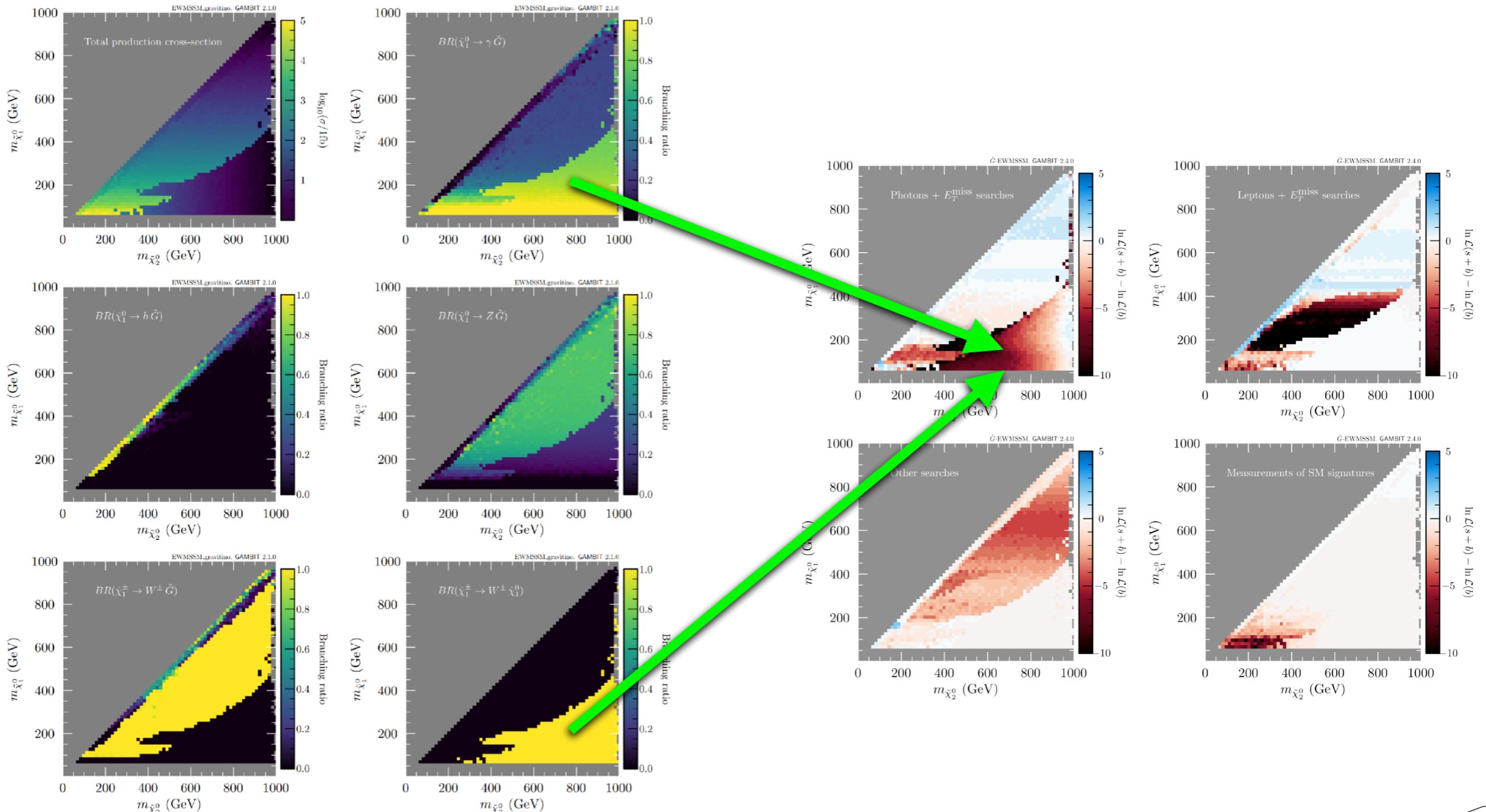
Preliminary results

Structure of results explained by **collection of experimental results + profiling + pattern of BRs + total production cross-section**



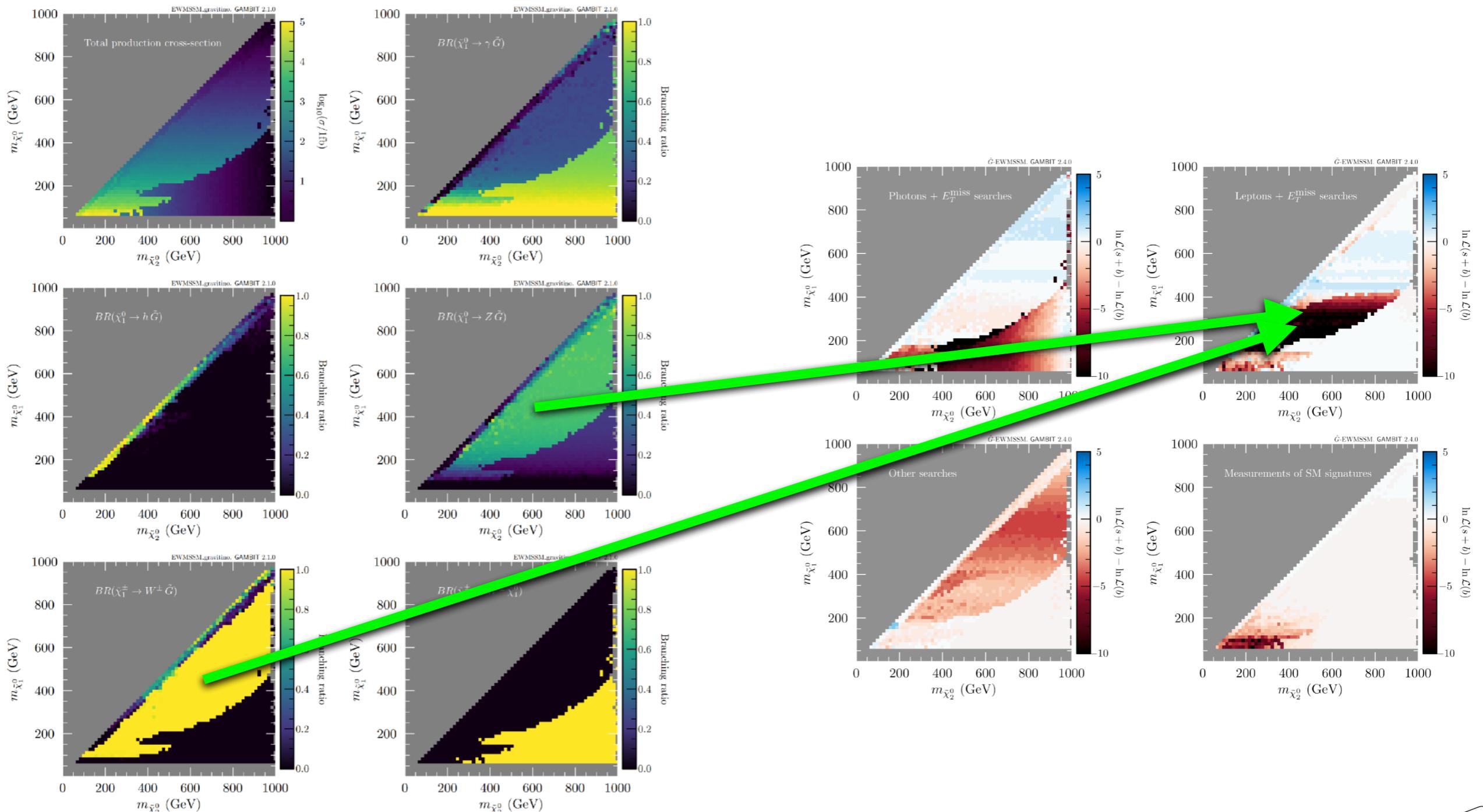
Preliminary results

Structure of results explained by **collection of experimental results + profiling + pattern of BRs + total production cross-section**



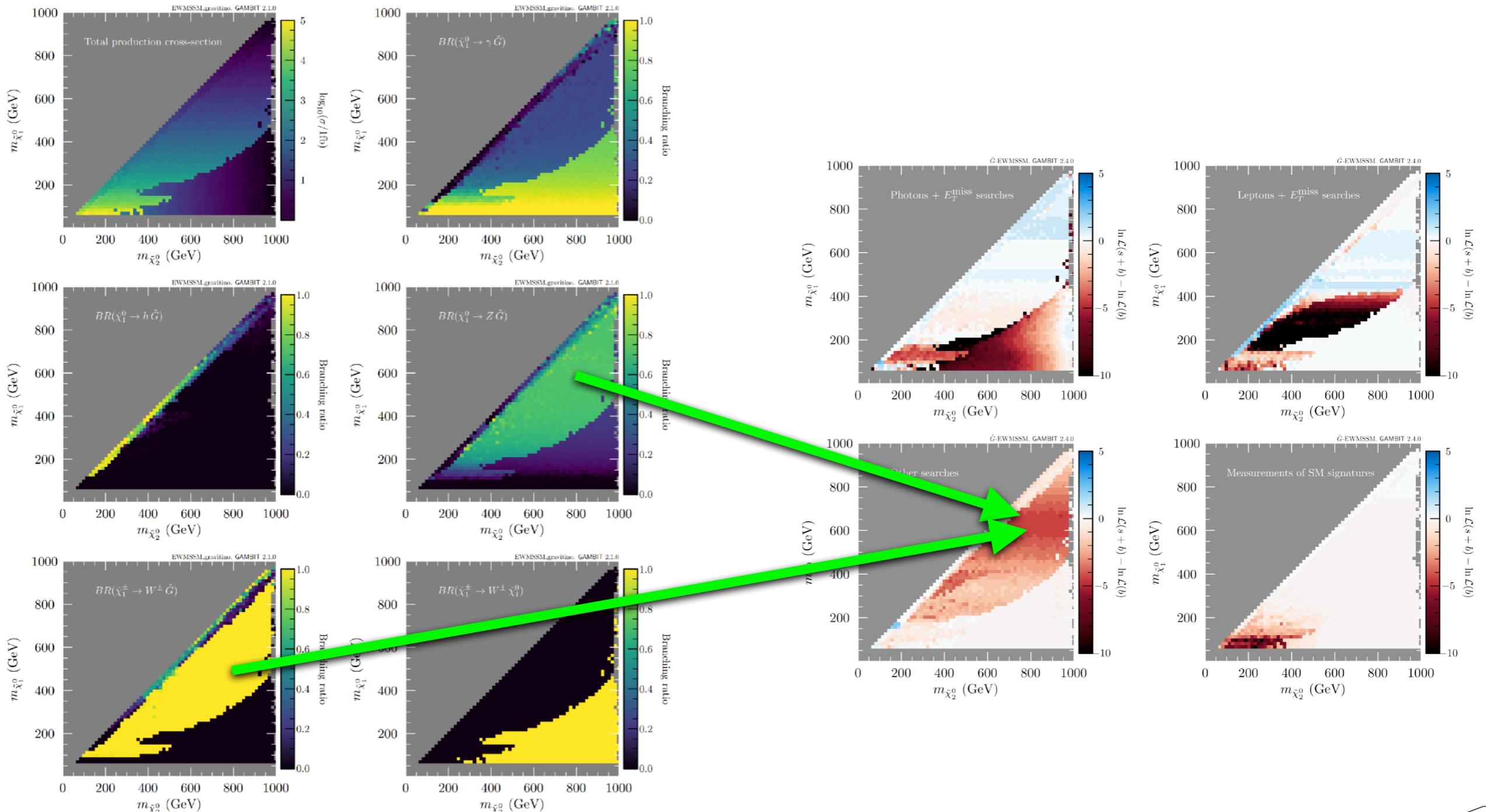
Preliminary results

Structure of results explained by **collection of experimental results + profiling + pattern of BRs + total production cross-section**

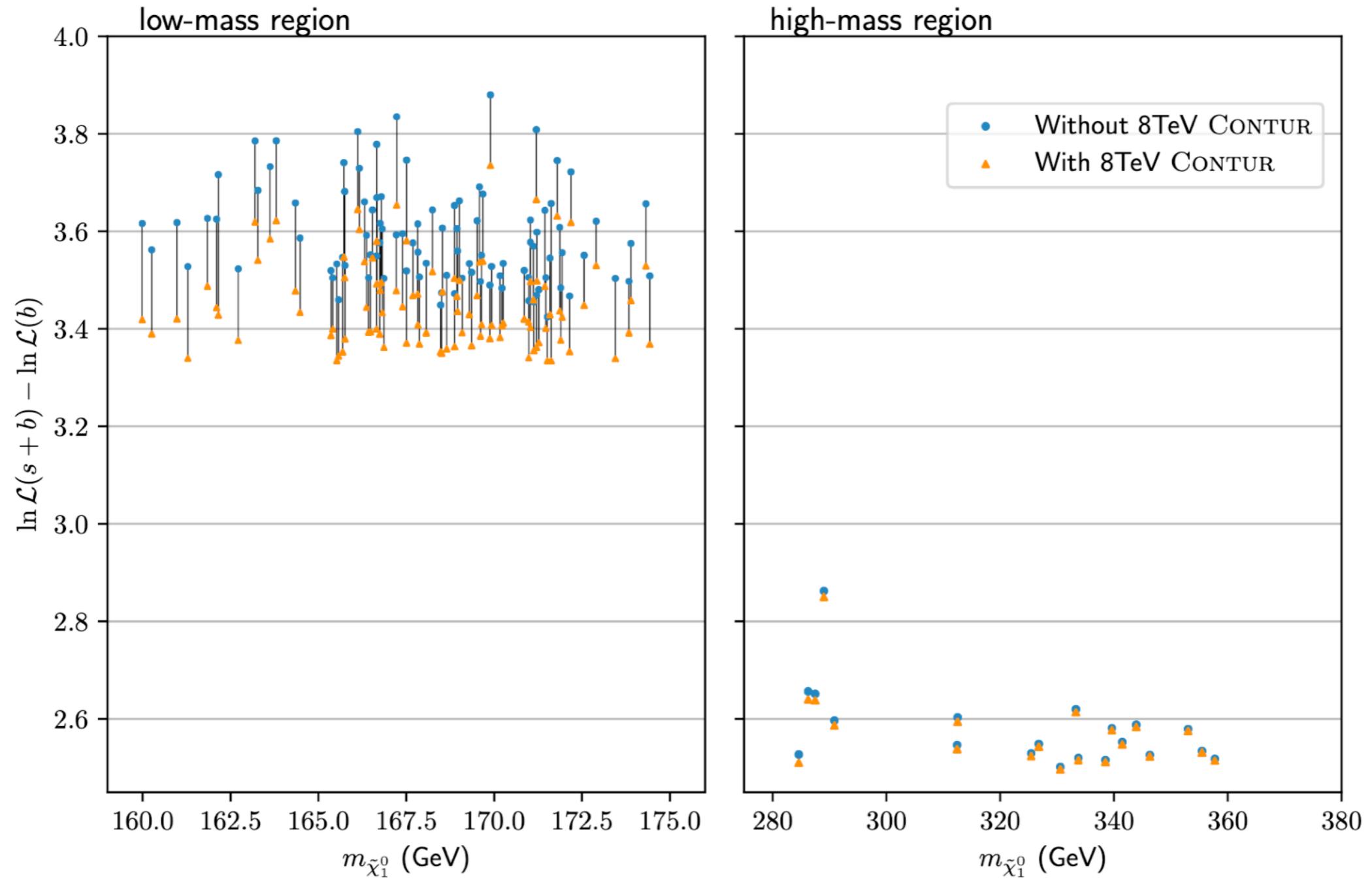


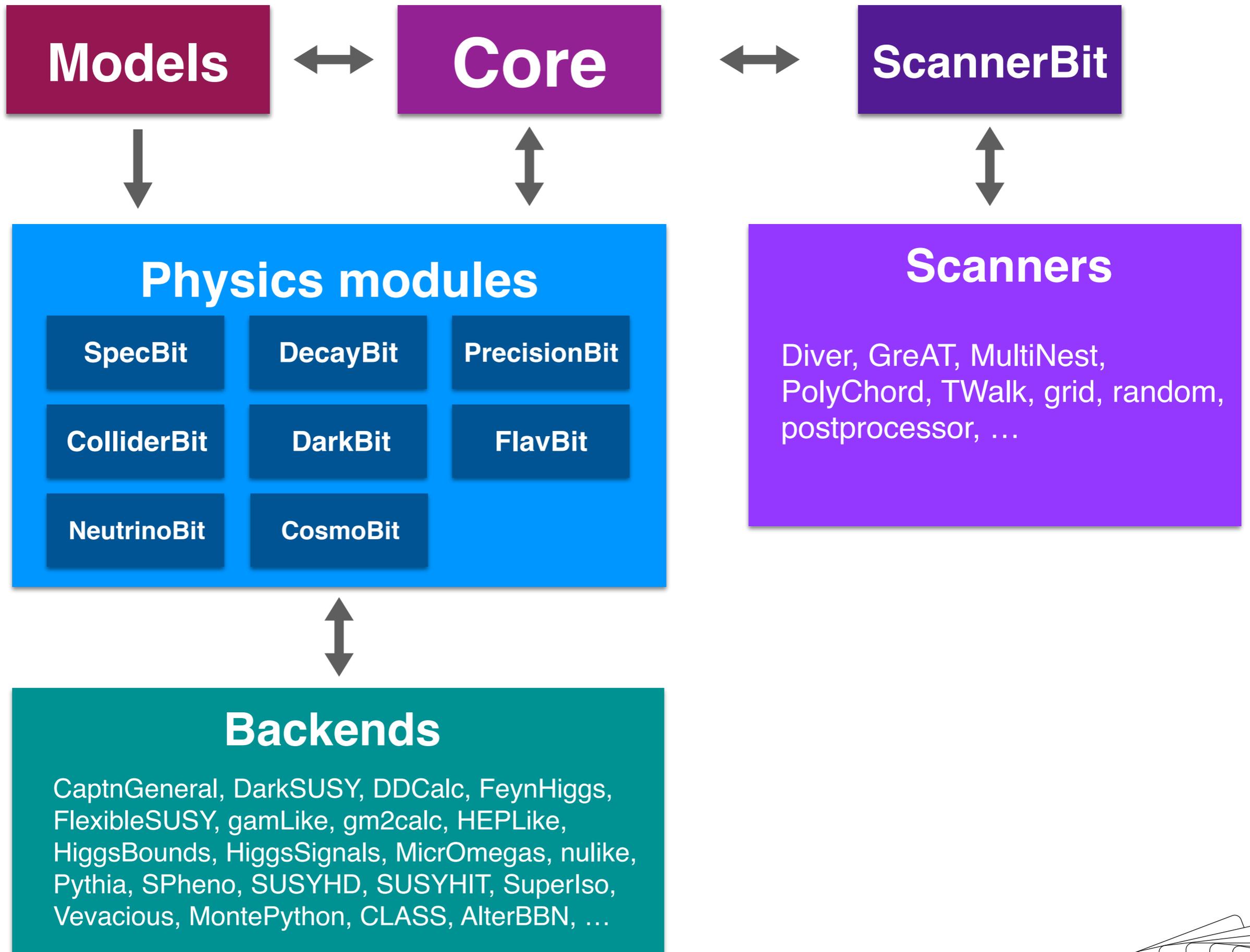
Preliminary results

Structure of results explained by **collection of experimental results + profiling + pattern of BRs + total production cross-section**



Preliminary results



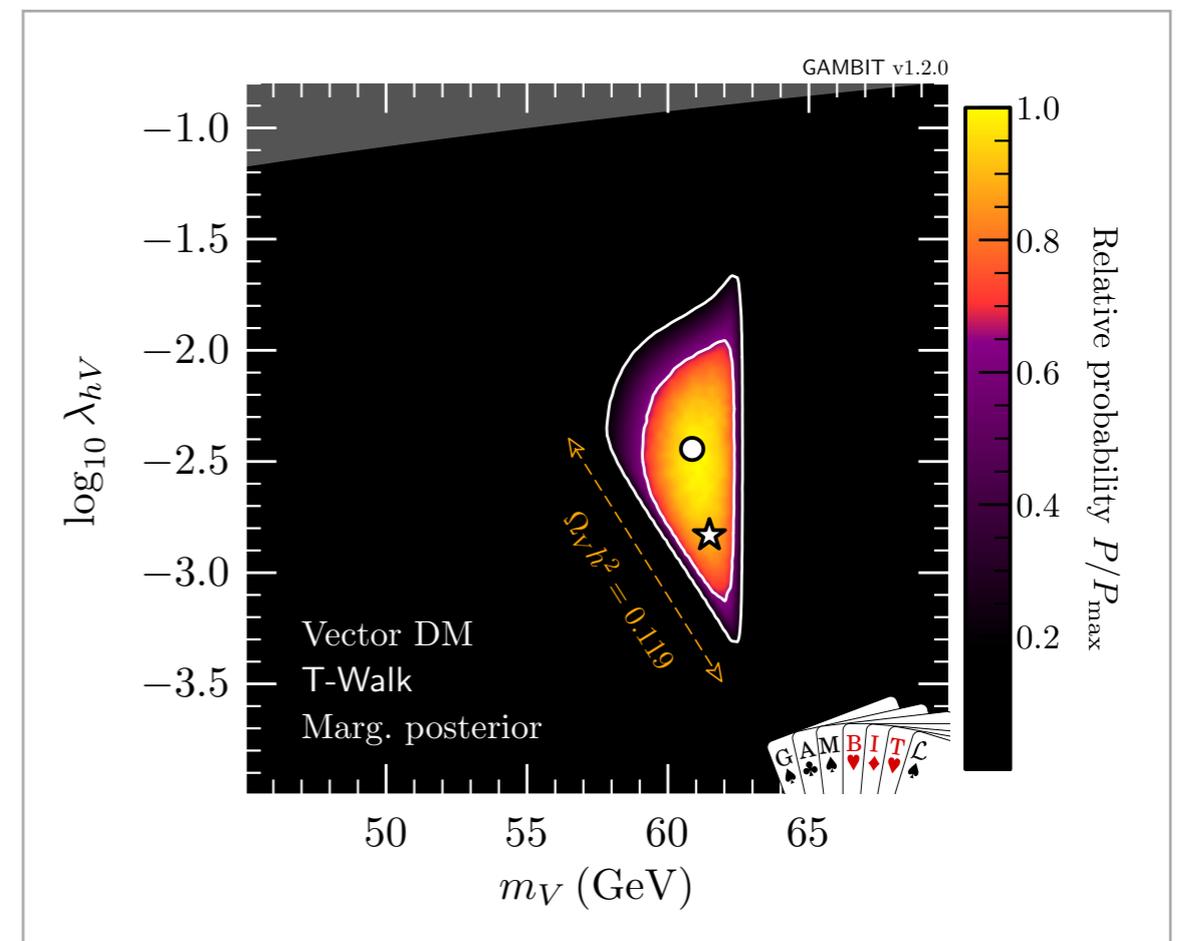
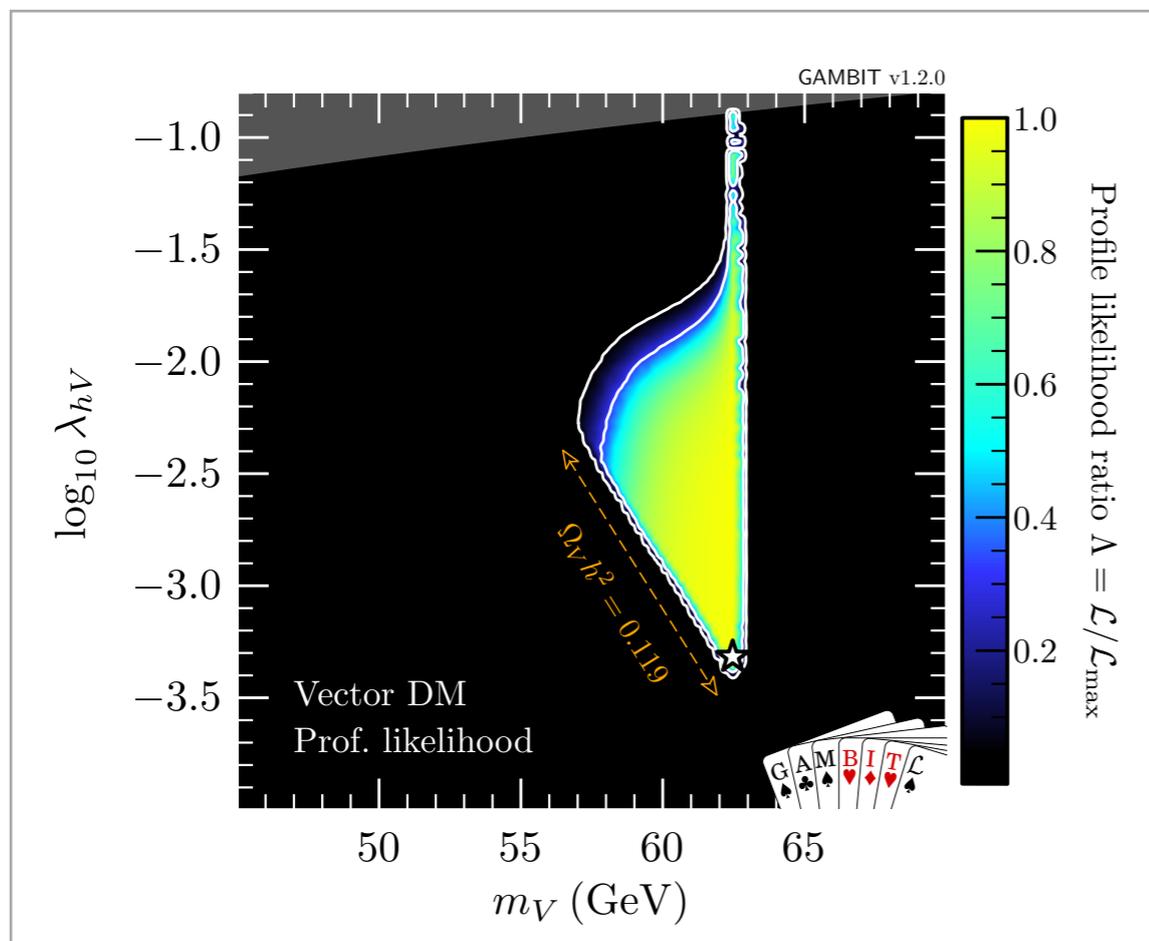


Some technical features

- **Two-level parallelisation:**
 - **MPI** for parameter sampling algorithm
 - **OpenMP** for per-point physics computations
- Collection of **state-of-the-art sampling algorithms** as plug-ins
- Backend system for using **C, C++, Fortran, Python** and **Mathematica** codes as **runtime plug-ins** for physics computations
- Run configuration through **YAML** input file
- **Dynamic dependency resolution:** order of computations not hard-coded
- GAMBIT Universal Model machine (GUM): **code auto-generation** for new physics models

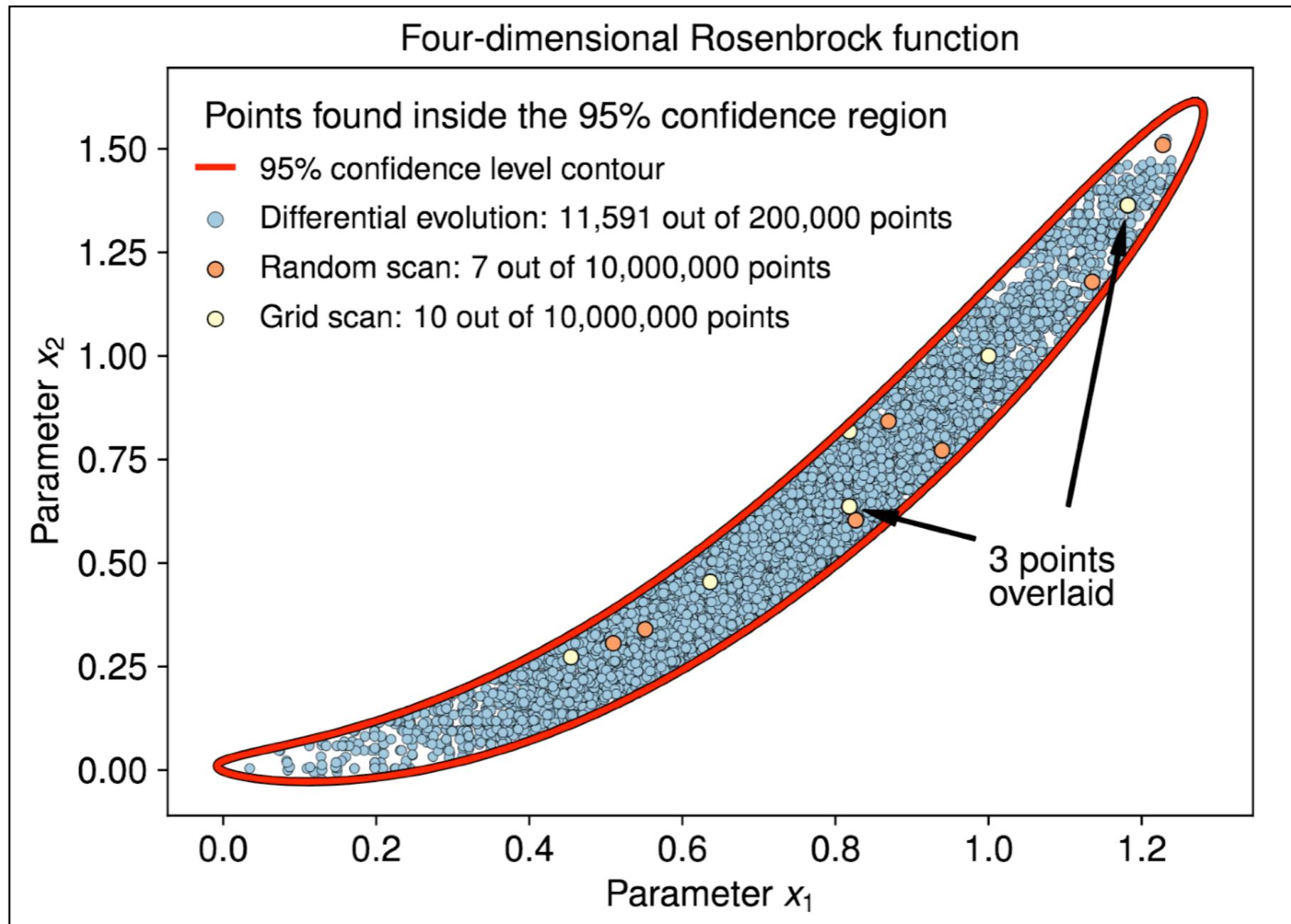


Results usually presented as **profile likelihood** or **posterior density** plots



[arxiv:1808.10465]

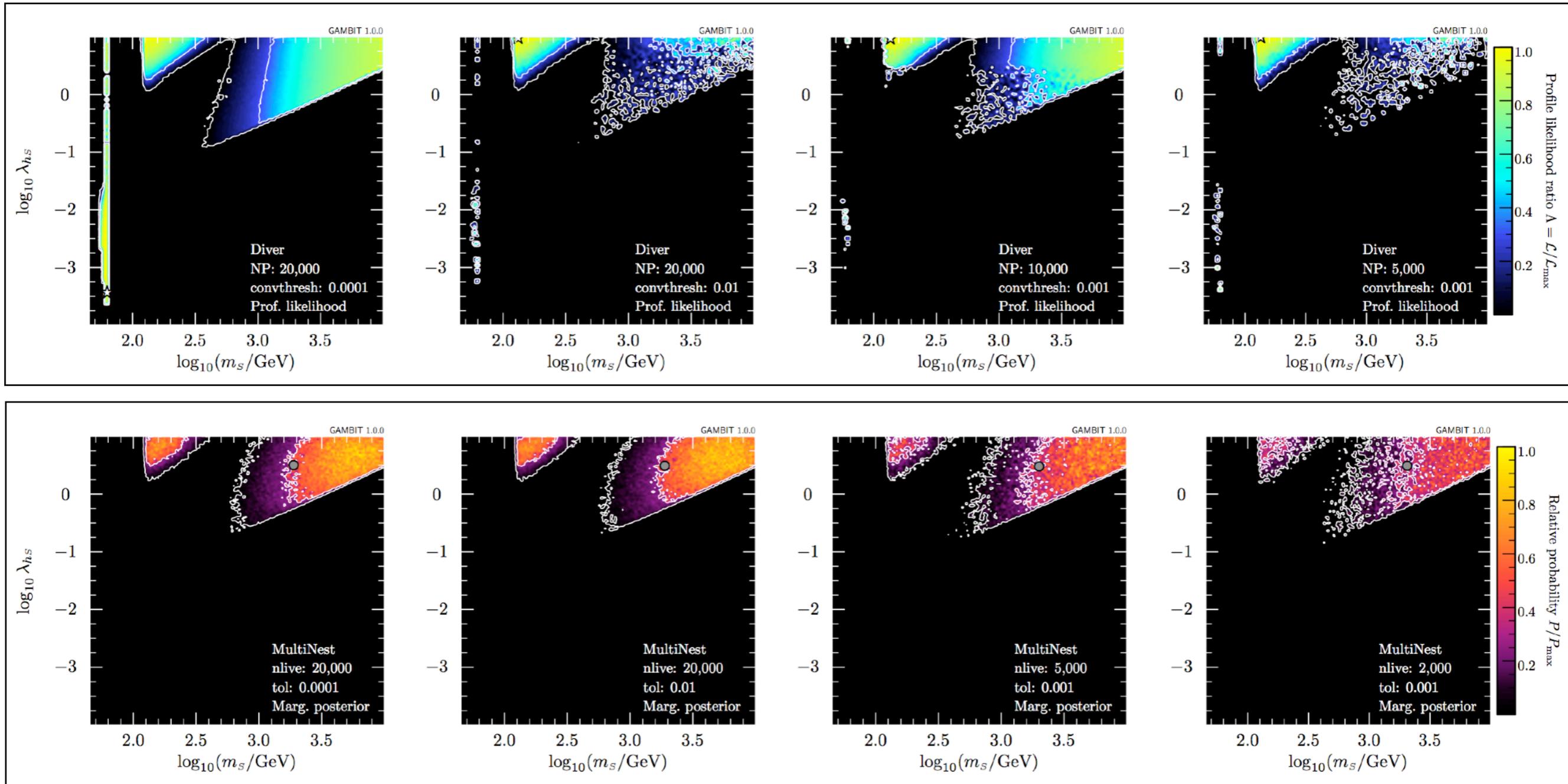
Parameter space exploration



[arxiv:2012.09874]



Parameter space exploration



[arxiv:1705.07959]



Dependency resolution

- Basic building blocks: **module functions**
- A physics module: **a collection of module functions** related to the same physics topic
- Each module function has a single **capability** (what it calculates)
- A module function can have **dependencies** on the results of other module functions
- A module function can declare which **models** it can work with
- GAMBIT determines which module functions should be run in which order for a given scan (**dependency resolution**)

```
void function_name(double &result)
{
    ...
    result = ... // something useful
}
```

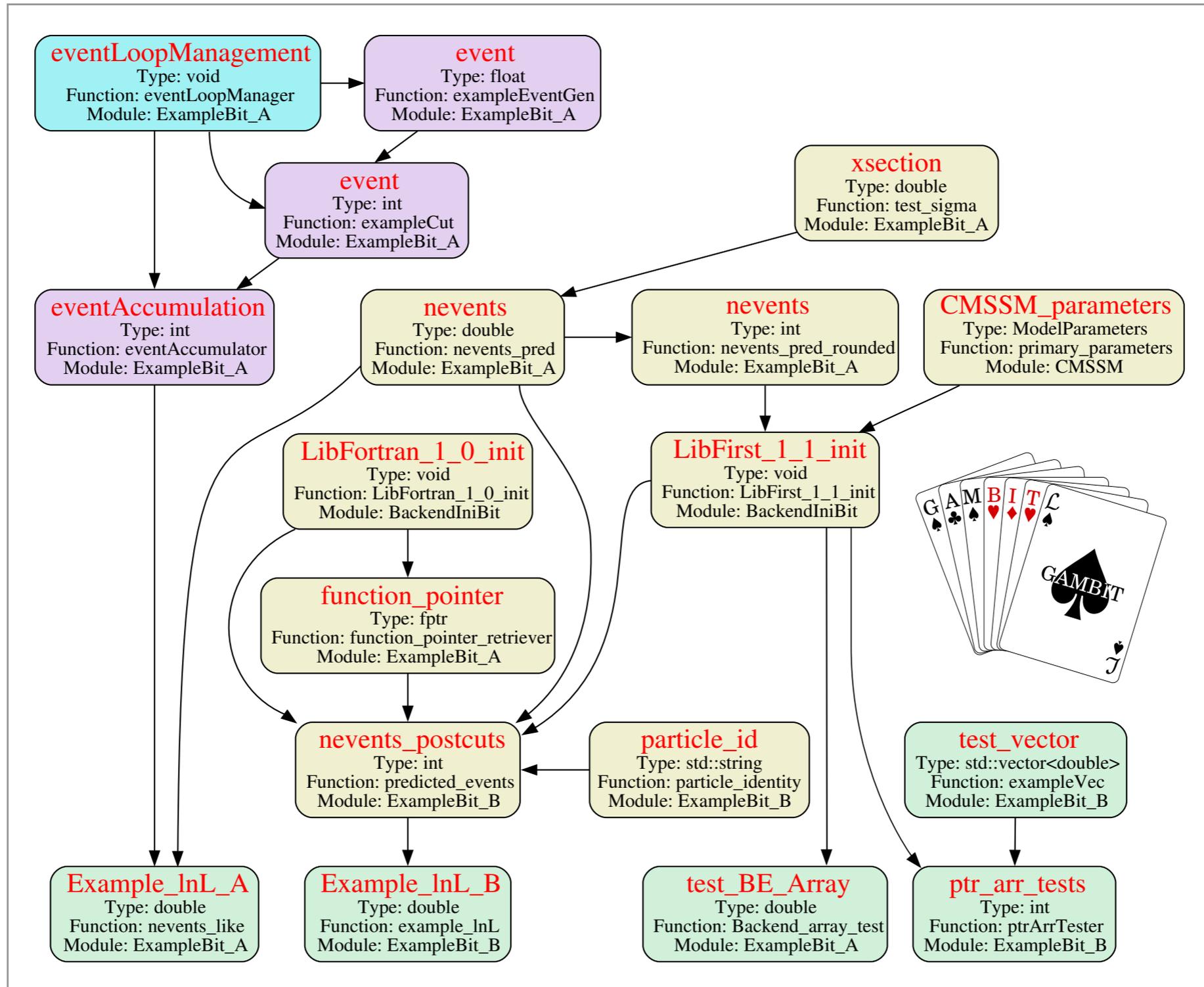
```
// Observable: BR(B -> tau nu)
#define CAPABILITY Btaunu
START_CAPABILITY
#define FUNCTION SI_Btaunu
START_FUNCTION(double)
DEPENDENCY(SuperIso_modelinfo, parameters)
BACKEND_REQ(Btaunu, (libsUPERISO), double, (const parameters*))
BACKEND_OPTION( (SuperIso, 3.6), (libsUPERISO) )
#undef FUNCTION
#undef CAPABILITY
```

```
/// Br B->tau nu_tau decays
void SI_Btaunu(double &result)
{
    using namespace Pipes::SI_Btaunu;

    parameters const& param = *Dep::SuperIso_modelinfo;
    result = BEreq::Btaunu(&param);
}
```

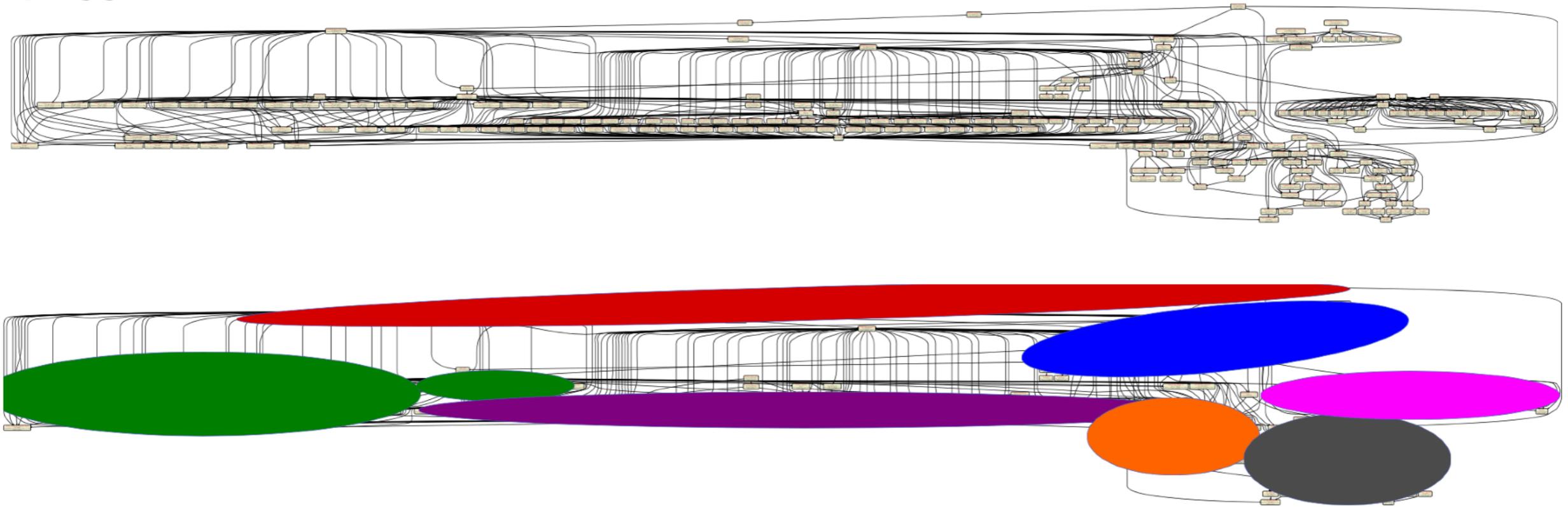


Dependency resolution



Dependency resolution

CMSSM:



- 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

