2022 international workshop on the high energy CEPC, 27 Oct

GAMBIT: GLOBAL INTERPRETATIONS FOR BSM THEORIES

WEI SU

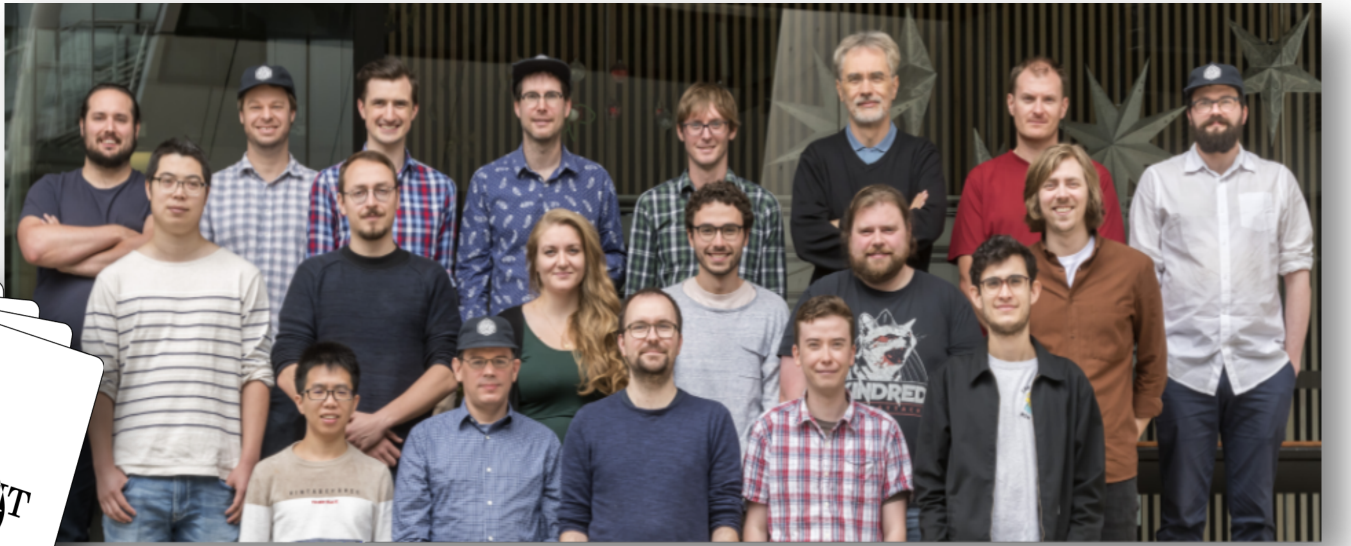
ON BEHALF OF THE GAMBIT COMMUNITY

ARXIV: 2203.04828, 2203.07883

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, Superlso, SUSY-AI, xsec, Vevacious, WIMPSim

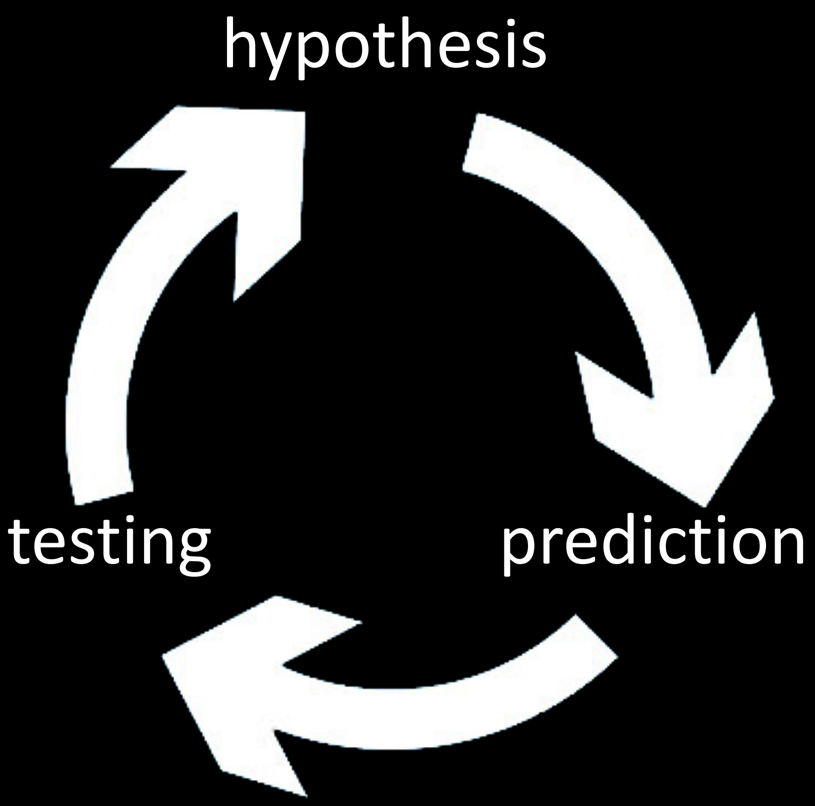
Recent collaborators: P Athron, C Balázs, A Beniwal, S Bloor, T Bringmann, A Buckley, J-E Camargo-Molina, C Chang, M Chrzaszcz, J Conrad, J Cornell, M Danninger, J Edsjö, T Emken, A Fowlie, T Gonzalo, W Handley, J Harz, S Hoof, F Kahlhoefer, A Kvellestad, P Jackson, D Jacob, C Lin, N Mahmoudi, G Martinez, 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

global fits

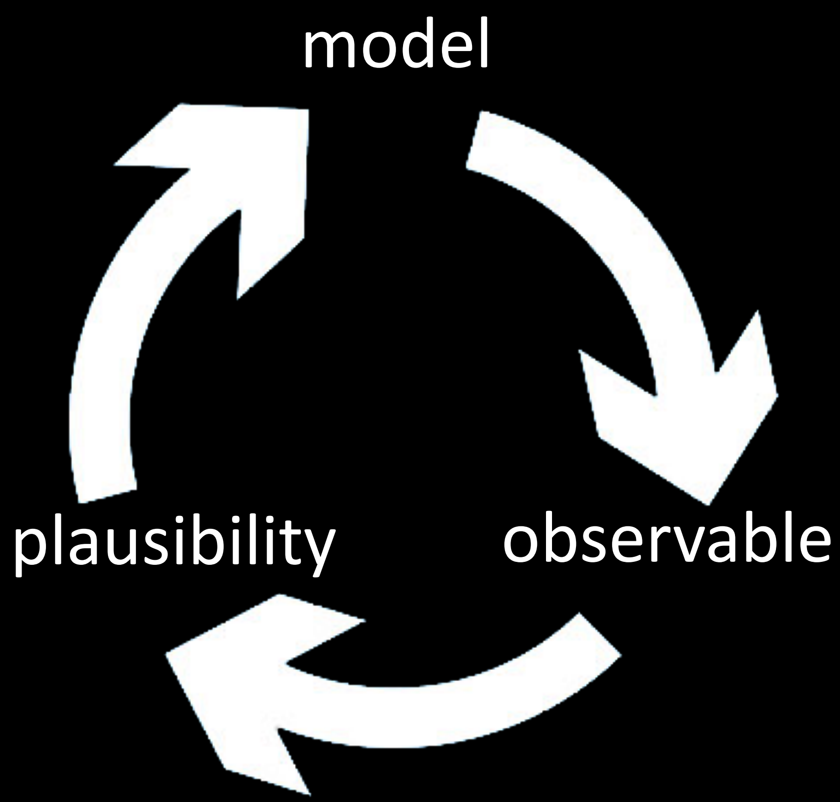
scientific method

(simplified)



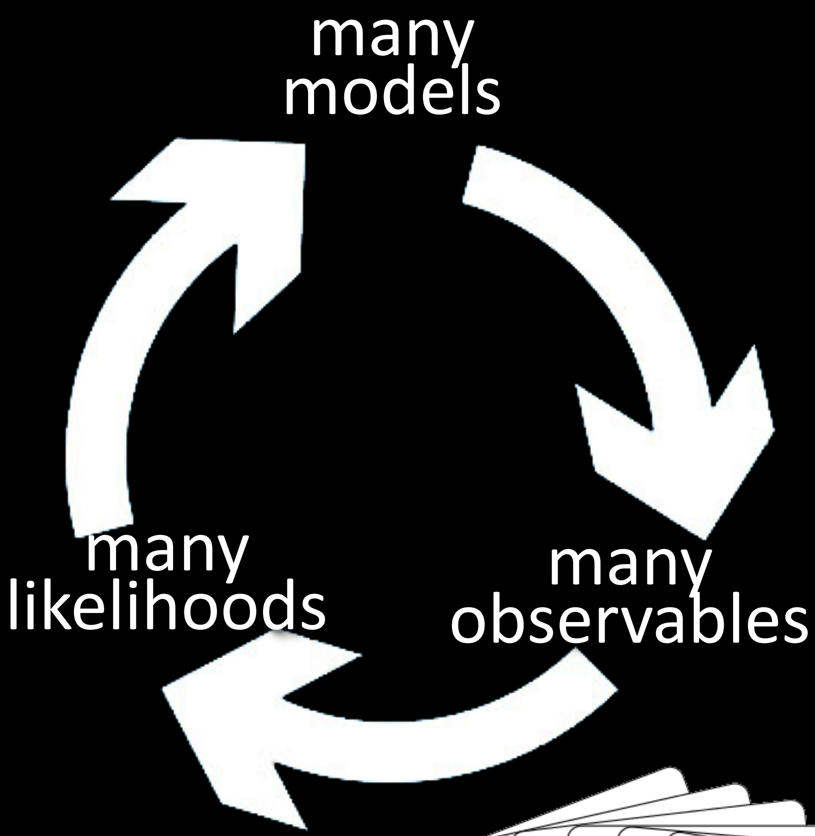
phenomenology

(simplified)



GAMBIT

(simplified)



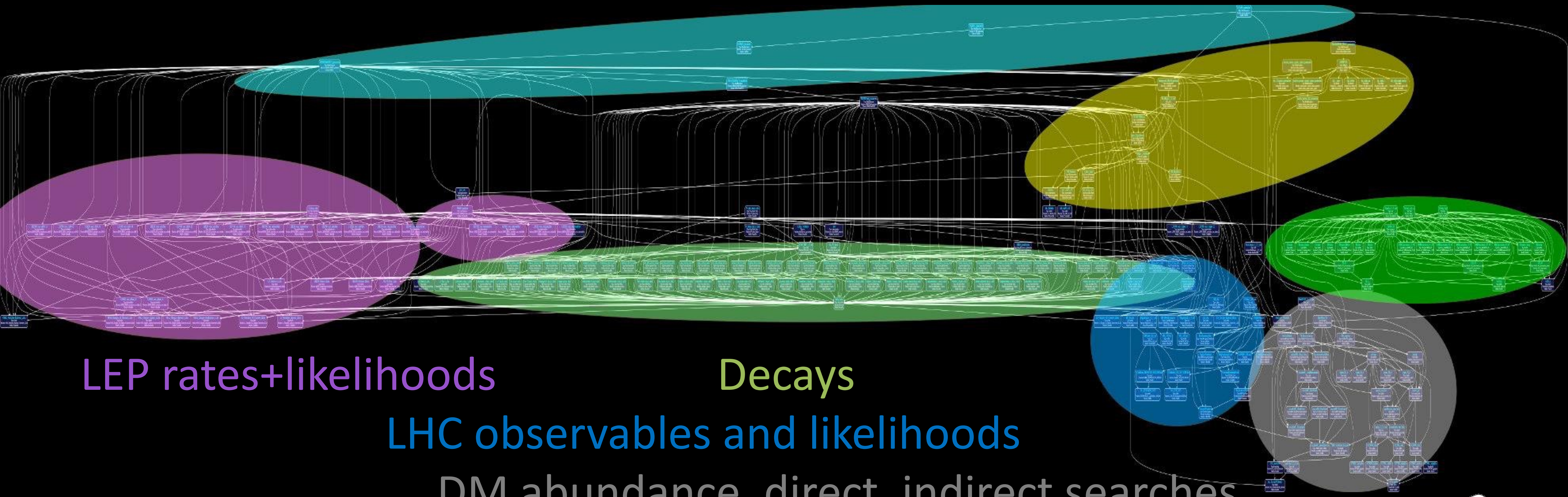
From C Balázs

Wrapper? It's a "CEO"

GAMBIT dependency resolution for CMSSM

Model parameter translations

Precision calculations



LEP rates+likelihoods

Decays

LHC observables and likelihoods

DM abundance, direct, indirect searches

Flavour physics observables

Gambit modules

Physics modules

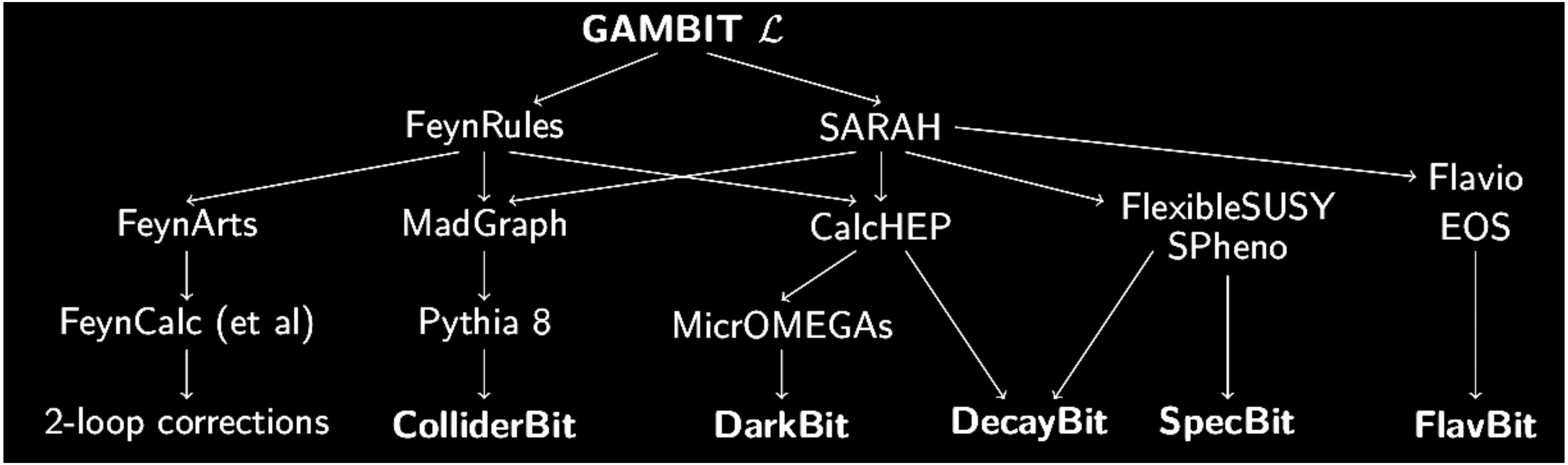
- DarkBit – dark matter observables (EPJC / arXiv:1705.07920)
- ColliderBit – collider observables (EPJC / arXiv:1705.07919)
- FlavBit – flavour physics (EPJC / arXiv:1705.07933)
- SpecBit – generic BSM spectrum object (EPJC / arXiv:1705.07936)
- DecayBit – decay widths (EPJC / arXiv:1705.07936)
- PrecisionBit – precision SM/BSM tests (EPJC / arXiv:1705.07936)

Each consists of a number of **module functions** that can have **dependencies** on each other

Statistics module

- ScannerBit: stats & sampling (EPJC / arXiv:1705.07959)

Gambit modules



Public results

links at

- https://gambit.hepforge.org/pubs
- https://inspirehep.net/literature?q=gambit

INSPIRE HEP | literature | gambit

Global fits beyond the standard Beyond-the-Standard-Model models
#1

GAMBIT Collaboration • Anders Kvellestad (Oslo U.) for the collaboration. (Jul 14, 2022)

Published in: *PoS* CompTools2021 (2022) 033 • Contribution to: CompTools2021, 033

pdf DOI cite 0 citations

Cosmological constraints on decaying axion-like particles: a global analysis
#2

Csaba Balázs (Monash U.), Sanjay Bloor (Imperial Coll., London), Tomás E. Gonzalo (RWTH Aachen U. and KIT, Karlsruhe, IKP and KIT, Karlsruhe, TTP), Will Handley (Cambridge U. and Cambridge U., KICC), Sebastian Hoof (Inst. Astrophys. Gottingen) et al. (May 26, 2022)

e-Print: 2205.13549 [astro-ph.CO]

pdf cite 2 citations

Recent dark matter results from the GAMBIT collaboration
#3

GAMBIT Collaboration • Martin John White (Adelaide U.) for the collaboration. (May 12, 2022)

Contribution to: Moriond 2022 QCD • e-Print: 2205.06431 [hep-ph]

pdf cite 0 citations

Global fit of 2HDM with future collider results
#4

Ankit Beniwal (King's Coll. London), Filip Rajec (Adelaide U.), Markus Tobias Prim (Bonn U.), Pat Scott (Queensland U. and Imperial Coll., London), Wei Su (Korea Inst. Advanced Study, Seoul) et al. (Mar 15, 2022)

Contribution to: 2022 Snowmass Summer Study • e-Print: 2203.07883 [hep-ph]

Public results

- results available on zenodo.cern.ch

- parameter point samples
- GAMBIT input files for all scans
- example plotting routines

zenodo | GAMBIT | Upload | Communities

May 28, 2021 (v1) | Dataset | Open Access | View

Supplementary Data: Thermal WIMPs and the Scale of New Physics: Global Fits of Dirac Dark Matter Effective Field Theories

Athron, Peter; Avis Kozar, Neil; Balázs, Csaba; Beniwal, Ankit; Bloor, Sanjay; Bringmann, Torsten; Brod, Joachim; Chang, Christopher; Cornell, Jonathan M.; Farmer, Ben; Fowlie, Andrew; Gonzalo, Tomás E.; Handley, Will; Kahlhoefer, Felix; Kvellestad, Anders; Mahmoudi, Farvah; Prim, Markus T.; Raklev, Are; Renk, Janina J.; Scaffidi, Andre; Scott, Pat; Stöcker, Patrick; Vincent, Aaron C.; White, Martin; Wild, Sebastian; Zupan, Jure;

Supplementary Data Thermal WIMPs and the Scale of New Physics: Global Fits of Dirac Dark Matter Effective Field Theories. The files in this record contain supplementary data including the samples and plotting scripts used for the results in Athron. P et al. "Thermal WIMPs and the Scale of New

Uploaded on June 4, 2021

January 10, 2021 (v1) | Other | Open Access | View

Supplementary Material for Global fits of axion-like particles to XENON1T and astrophysical data

Athron, Peter; Balázs, Csaba; Beniwal, Ankit; Camargo-Molina, J. Eliel; Fowlie, Andrew; Gonzalo, Tomás E.; Hoof, Sebastian; Kahlhoefer, Felix; Marsh, David J. E.; Prim, Markus Tobias; Scaffidi, Andre; Scott, Pat; Su, Wei; White, Martin; Wu, Lei; Zhang, Yang;

This record contains the YAML files used in Athron et al., "Global fits of axion-like particles to XENON1T and astrophysical data." The semantic file names refer to the scenario considered: the solar ALP hypothesis (alp), the DM ALP hypothesis (dm), the tritium hypothesis (3h), the R&nbs

Uploaded on February 19, 2021

November 5, 2019 (v1) | Presentation | Open Access | View

GUM: GAMBIT Universal Models

Sanjay Bloor; Pat Scott;

GUM is a new feature of the GAMBIT global fitting software framework, which provides a direct interface between Lagrangian level tools and GAMBIT. GUM automatically writes GAMBIT routines to compute observables and likelihoods for physics beyond the Standard Model. I will describe the structure of G

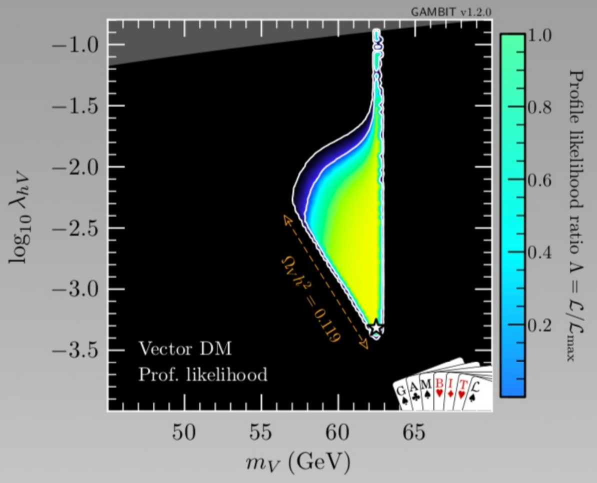
Uploaded on January 7, 2020

May 26, 2020 (v2) | Dataset | Open Access | View

Supplementary Data: A Frequentist Analysis of Three Right-Handed Neutrinos with GAMBIT

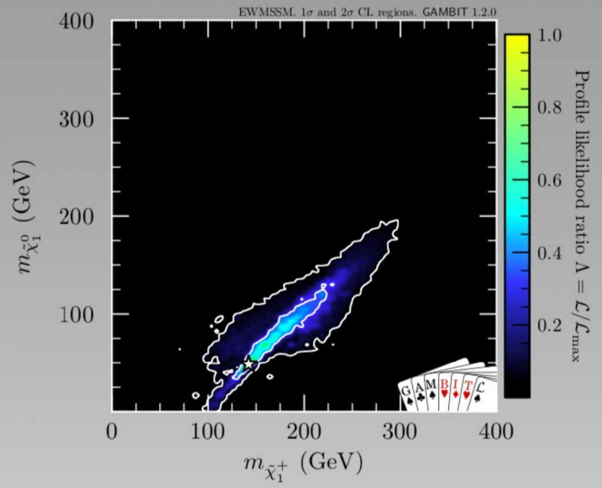
Higgs-portal DM

[Eur.Phys.J.C 79 (2019) 1, 38]



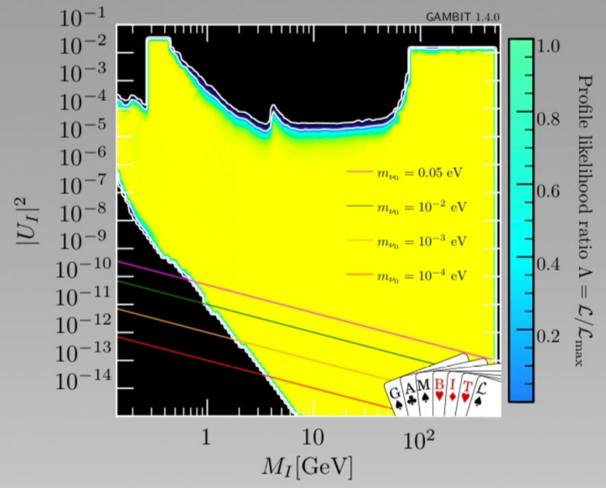
MSSM-EW

[Eur.Phys.J.C 79 (2019) 5, 395]



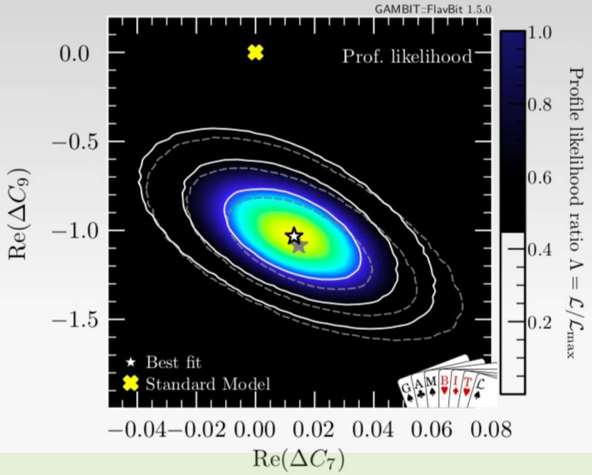
Right-Handed Neutrinos

[Eur.Phys.J.C 80 (2020) 6, 569]



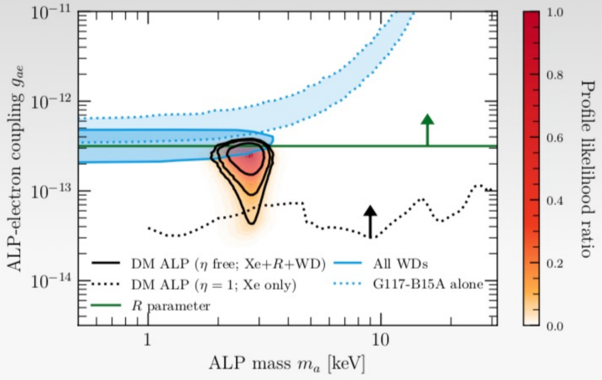
Flavour EFT

[arXiv:2006.03489 hep-ph]



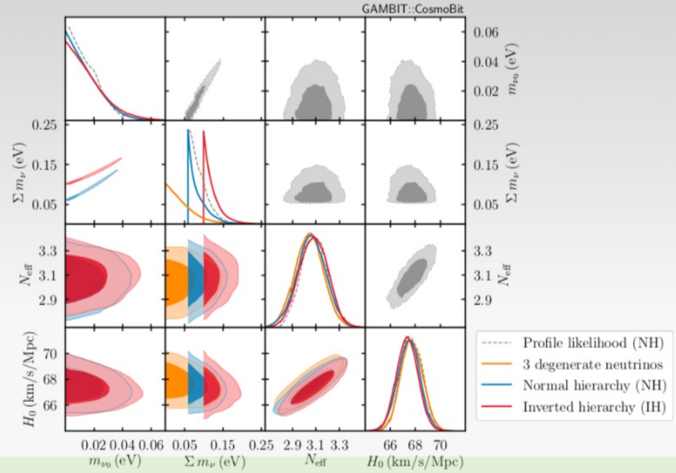
DM ALPs

[arXiv:2007.05517 astro-ph.CO]



Cosmo

[arXiv:2009.03287 astro-ph.CO]



Gambit Under Future Lepton Colliders

SUSY

- We post-process the publicly available data for global fits of SUSY models with additional likelihoods for the proposed Higgs factories.
- 7.1×10^7 viable samples for CMSSM, 9.4×10^7 samples for NUHM1 , 1.2×10^8 samples for NUHM2, 1.8×10^8 samples for MSSM7.
- a few days to run on 1280 supercomputer cores.

Study Strategy

$$\mathscr{L}_{\text{Present+CEPC}} = \mathscr{L}_{\text{CEPC}}\mathscr{L}_{\text{Present}}$$
$$= \mathscr{L}_{\text{CEPC}}\mathscr{L}_{\text{collider}}\,\mathscr{L}_{\text{DM}}\mathscr{L}_{\text{flavor}}\,\mathscr{L}_{\text{EWPO}}\cdots$$

collider	CEPC	FCC-ee		ILC					
$\sqrt{s}$	240 GeV	240 GeV	365 GeV		250 GeV	350 GeV		500 GeV	
$\int \mathcal{L}dt$	5.6 ab^{-1}	5 ab^{-1}	1.5 ab^{-1}		2 ab^{-1}	200 fb^{-1}		4 ab^{-1}	
production	Zh	Zh	Zh	$\nu\bar{\nu}h$	Zh	Zh	$\nu\bar{\nu}h$	Zh	$\nu\bar{\nu}h$
$\Delta\sigma/\sigma$	0.5%	0.5%	0.9%	–	0.71%	2.0%	–	1.05	–
decay	$\Delta(\sigma\cdot BR)/(\sigma\cdot BR)$								
$h\to b\bar{b}$	0.27%	0.3%	0.5%	0.9%	0.46%	1.7%	2.0%	0.63%	0.23%
$h\to c\bar{c}$	3.3%	2.2%	6.5%	10%	2.9%	12.3%	21.2%	4.5%	2.2%
$h\to gg$	1.3%	1.9%	3.5%	4.5%	2.5%	9.4%	8.6%	3.8%	1.5%
$h\to WW^*$	1.0%	1.2%	2.6%	3.0%	1.6%	6.3%	6.4%	1.9%	0.85%
$h\to\tau^+\tau^-$	0.8%	0.9%	1.8%	8.0%	1.1%	4.5%	17.9%	1.5%	2.5%
$h\to ZZ^*$	5.1%	4.4%	12%	10%	6.4%	28.0%	22.4%	8.8%	3.0%
$h\to\gamma\gamma$	6.8%	9.0%	18%	22%	12.0%	43.6%	50.3%	12.0%	6.8%
$h\to\mu^+\mu^-$	17%	19%	40%	–	25.5%	97.3%	178.9%	30.0%	25.0%
$(\nu\bar{\nu})h\to b\bar{b}$	2.8%	3.1%	–	–	3.7%	–	–	–	–

Table 1: Estimated statistical precisions for Higgs measurements obtained at the proposed CEPC program with 5.6 ab^{-1} integrated luminosity [5, 6], FCC-ee program with 5 ab^{-1} integrated luminosity [7, 8], and ILC with various center-of-mass energies [9].

SUSY

$$\mu_i = \frac{\sigma_i \times \text{Br}_i}{\sigma_i^{\text{SM}} \times \text{Br}_i^{\text{SM}}}$$

	CMSSM BF point	Present central value	ILC	Precision FCC-*ee*	CEPC
m_Z	91.1876 GeV	91.1876 GeV	2.1 MeV	0.1 MeV	0.5 MeV
m_t	173.267 GeV	173.34 GeV	0.03 GeV	0.6 GeV	0.6 GeV
$\alpha_s^{\overline{\text{MS}}}(m_Z)$	0.11862	0.1185	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-4}
m_W	80.3786 GeV	80.385 GeV	5 MeV	8 MeV	3 MeV
$\sin^2\theta_W$	0.231424	0.23155	1.3×10^{-5}	0.3×10^{-5}	4.6×10^{-5}

Higgs

$$-2\ln\mathcal{L}_{\text{Higgs factories}} = \frac{(m_h - m_h^{\text{obs}})^2}{\sigma_{\mu_h}^2} + \frac{(\sigma_{Zh} - \sigma_{Zh}^{\text{obs}})^2}{\sigma_{\sigma_{Zh}}^2} + \sum \frac{(\mu_i - \mu_i^{\text{obs}})^2}{\sigma_{\mu_i}^2}$$

Z pole

$$-2\ln\mathcal{L}_{Z\text{ factories}} = \frac{(m_t - m_t^{\text{obs}})^2}{\sigma_{m_t}^2} + \frac{(\alpha_s^{\overline{\text{MS}}}(m_Z) - \alpha_s^{\overline{\text{MS}}}(m_Z)^{\text{obs}})^2}{\sigma^2_{\alpha_s^{\overline{\text{MS}}}(m_Z)}} + \frac{(m_W - m_W^{\text{obs}})^2}{\sigma_{m_W}^2} + \frac{(\sin^2\theta_W - \sin^2\theta_W^{\text{obs}})^2}{\sigma^2_{\sin^2\theta_W}}.$$

SUSY

$$\mu_i = \frac{\sigma_i \times \mathrm{Br}_i}{\sigma_i^{\mathrm{SM}} \times \mathrm{Br}_i^{\mathrm{SM}}}$$

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Higgs

$$-2\ln\mathcal{L}_{\mathrm{Higgs\ factories}} = \frac{(m_h - m_h^{\mathrm{obs}})^2}{\ldots} + \frac{(\sigma_{Zh} - \sigma_{Zh}^{\mathrm{obs}})^2}{\ldots} + \sum \frac{(\mu_i - \mu_i^{\mathrm{obs}})^2}{\ldots}$$

SUSY Assumption: μ_i^{obs} , current Best Fit are central values

of signal strength at future facilities

$$\ldots m_t \ldots \alpha_s^{\mathrm{MS}}(m_Z)$$

$$+ \frac{(m_W - m_W^{\mathrm{obs}})^2}{\sigma_{m_W}^2} + \frac{(\sin^2\theta_W - \sin^2\theta_W^{\mathrm{obs}})^2}{\sigma_{\sin^2\theta_W}^2}.$$

SUSY

Here we only show two scenarios

GUT scale

$$\mathcal{L}_{\text{soft}} \sim M^2_{H_{u,d}}|H_{u,d}|^2 + m_0^2 \tilde{F}_i^\dagger \tilde{F}_i + \frac{1}{2} m_{1/2} \tilde{G}_j \tilde{G}_j + A_0 \tilde{F}_i^c H_{u,d} \tilde{F}_i + \cdots$$

$$\text{CMSSM: } m_0^2 = M^2_{H_{u,d}}$$

Weak scale

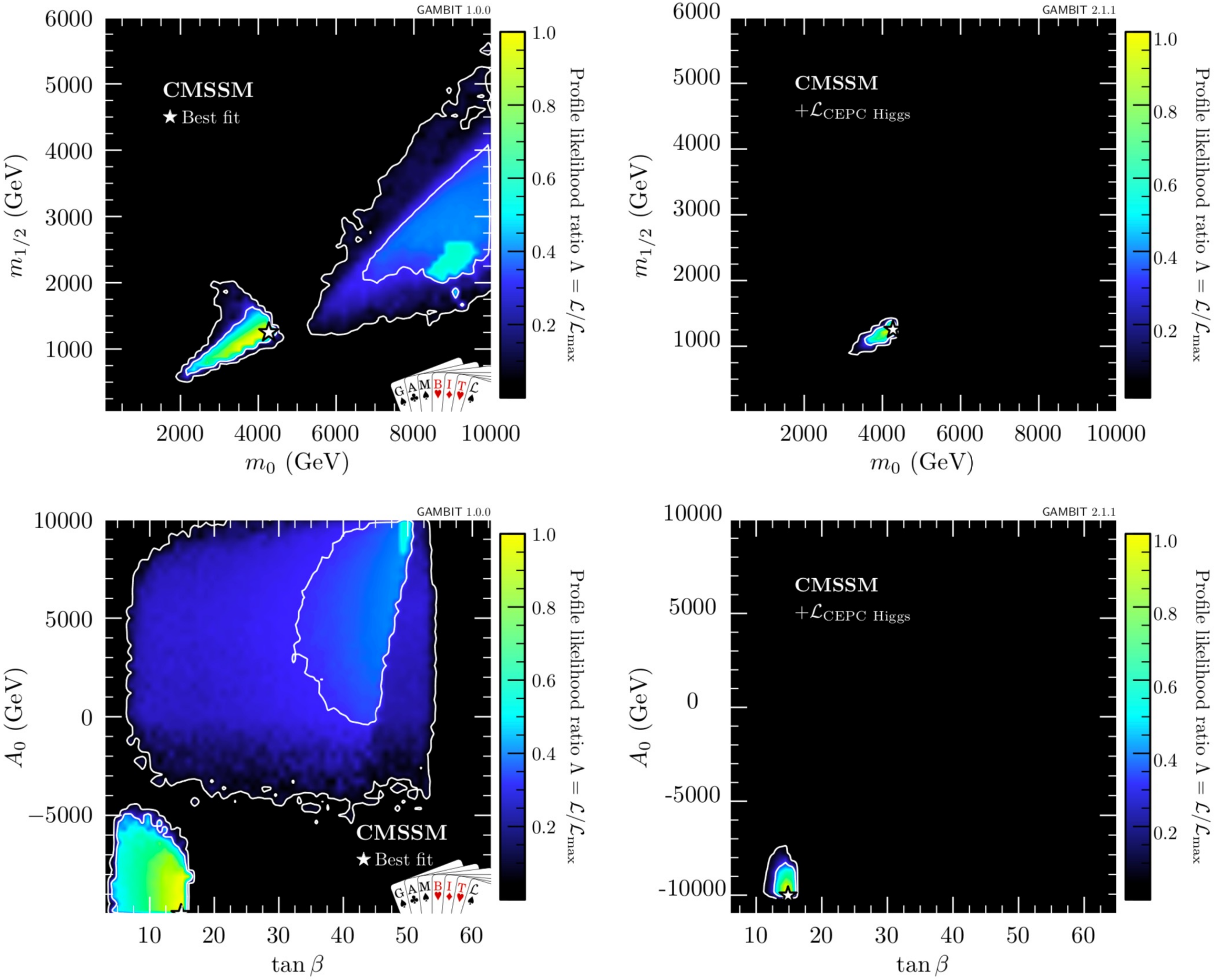
$$\mathcal{L}_{\text{soft}} \sim M^2_{H_{u,d}}|H_{u,d}|^2 + m^2_{\tilde{f}_i} \tilde{F}_i^\dagger \tilde{F}_i + \frac{1}{2} M_j \tilde{G}_j \tilde{G}_j + A_{f_i} \tilde{F}_i^c H_{u,d} \tilde{F}_i + \cdots$$

$$\text{MSSM7: } \tan\beta, A_u = A_d = A_e = 0, \text{ except for } (A_u)_{33} = A_{u3'} (A_d)_{33} = A_{d3}.$$

Results

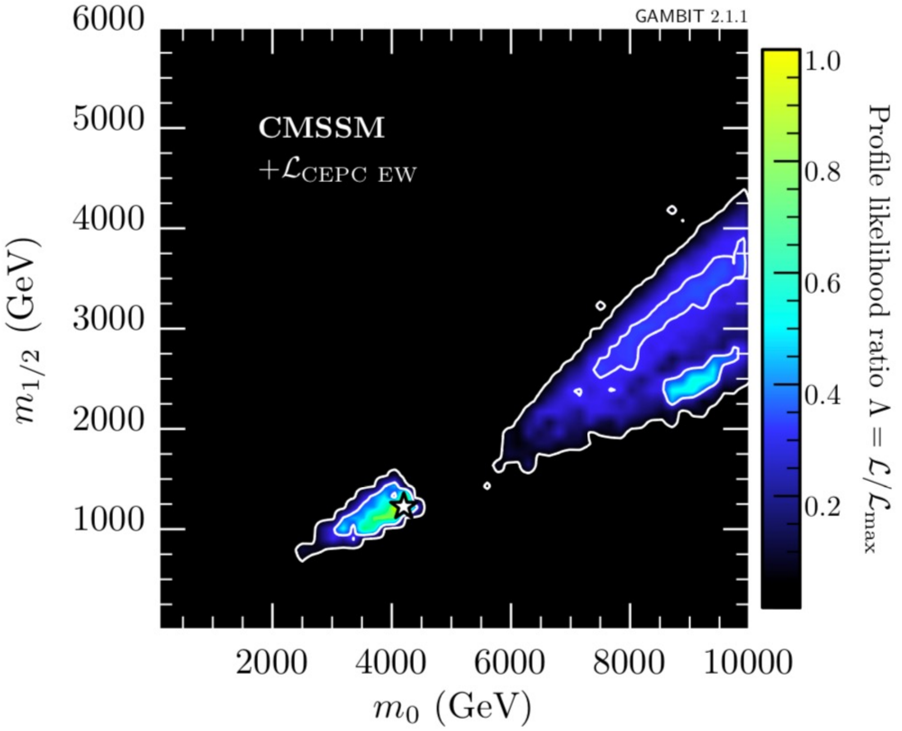
CMSSM

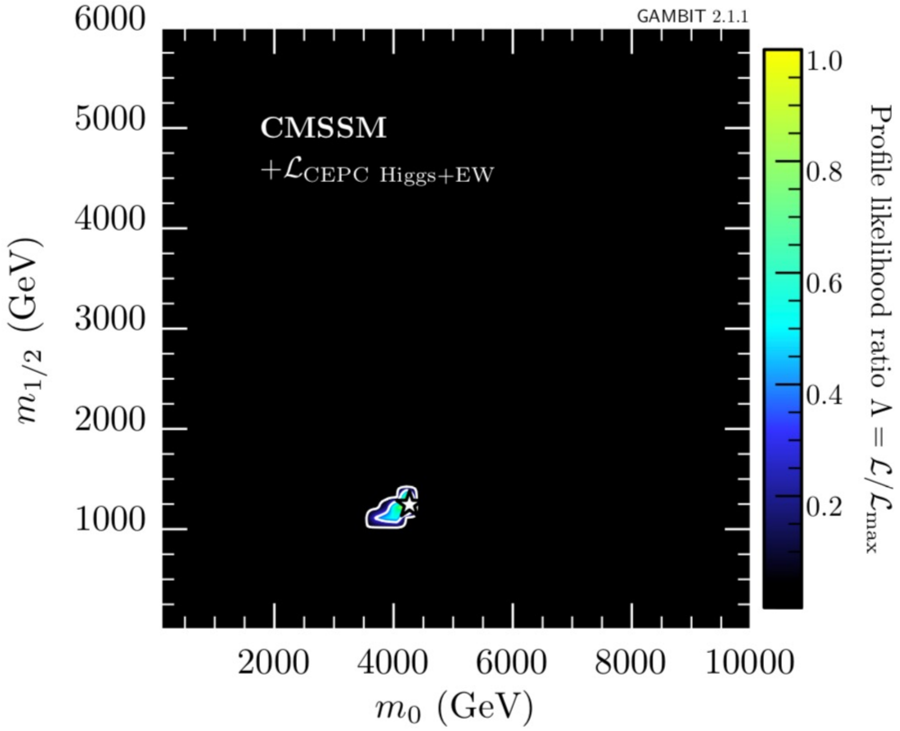
- theoretical uncertainties are k=0.2 times smaller than the current SM value.
- The position of the best-fit point holds
- The preferred regions shrink significantly



Results

Electroweak Contribution



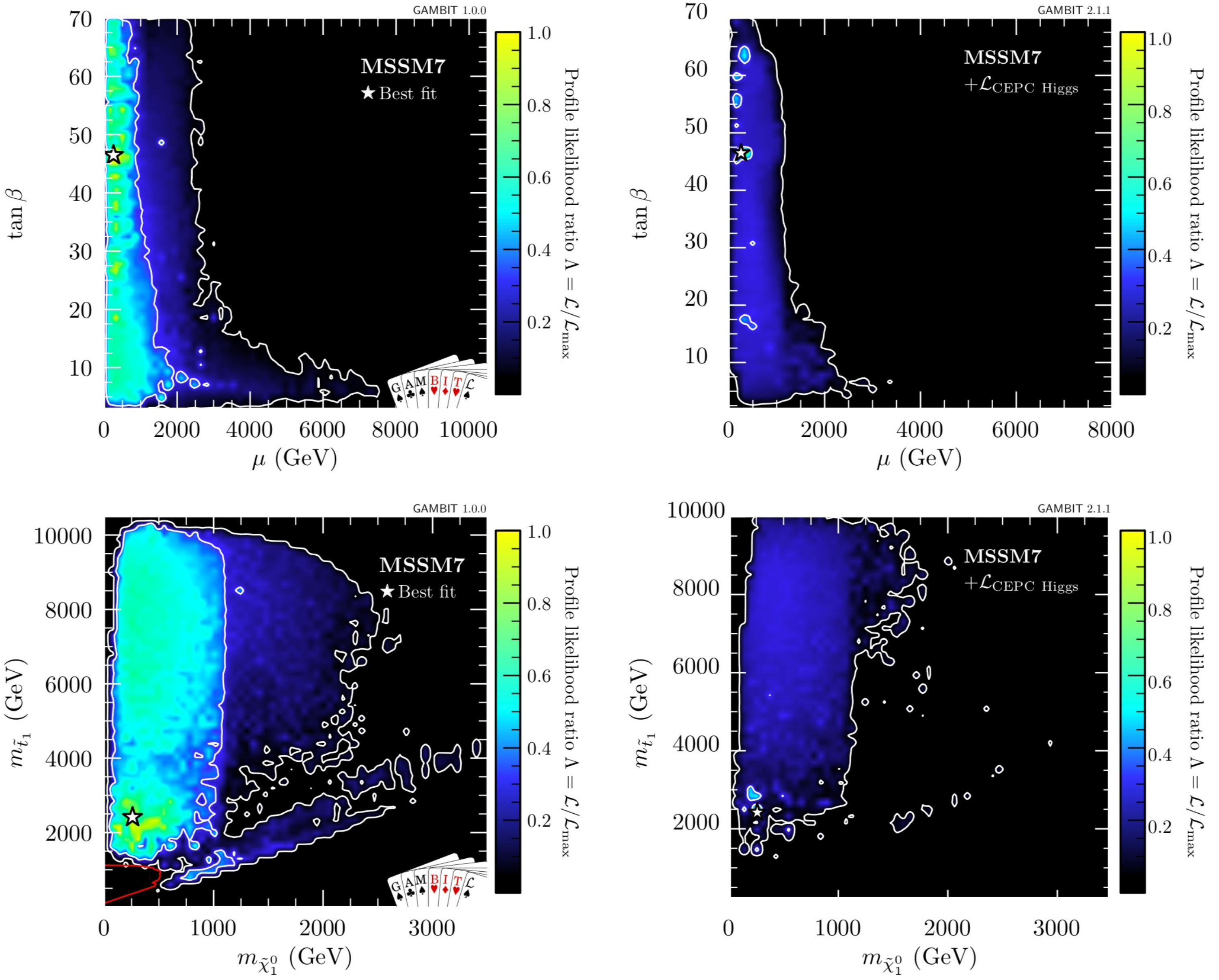


Results

MSSM7

- 1 sigma region does changes significantly

- 2 sigma region does not change a lot



SUSY

SUSY Assumption: μ_i^{obs} , current Best Fit are central values of signal strength at future facilities

2HDM: Brief Introduction

- Two Higgs Doublet Model

$$\Phi_i = \begin{pmatrix} \phi_i^+ \\ (v_i + \phi_i^0 + iG_i)/\sqrt{2} \end{pmatrix}$$

$$v_u^2 + v_d^2 = v^2 = (246\text{GeV})^2$$
$$\tan\beta = v_u/v_d$$

$$\begin{pmatrix} H^0 \\ h^0 \end{pmatrix} = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} \phi_1^0 \\ \phi_2^0 \end{pmatrix}, \quad \begin{aligned} A &= -G_1 \sin\beta + G_2 \cos\beta \\ H^\pm &= -\phi_1^\pm \sin\beta + \phi_2^\pm \cos\beta \end{aligned}$$

	Φ_1	Φ_2
Type I	u,d,l	
Type II	u	d,l
lepton-specific	u,d	l
flipped	u,l	d

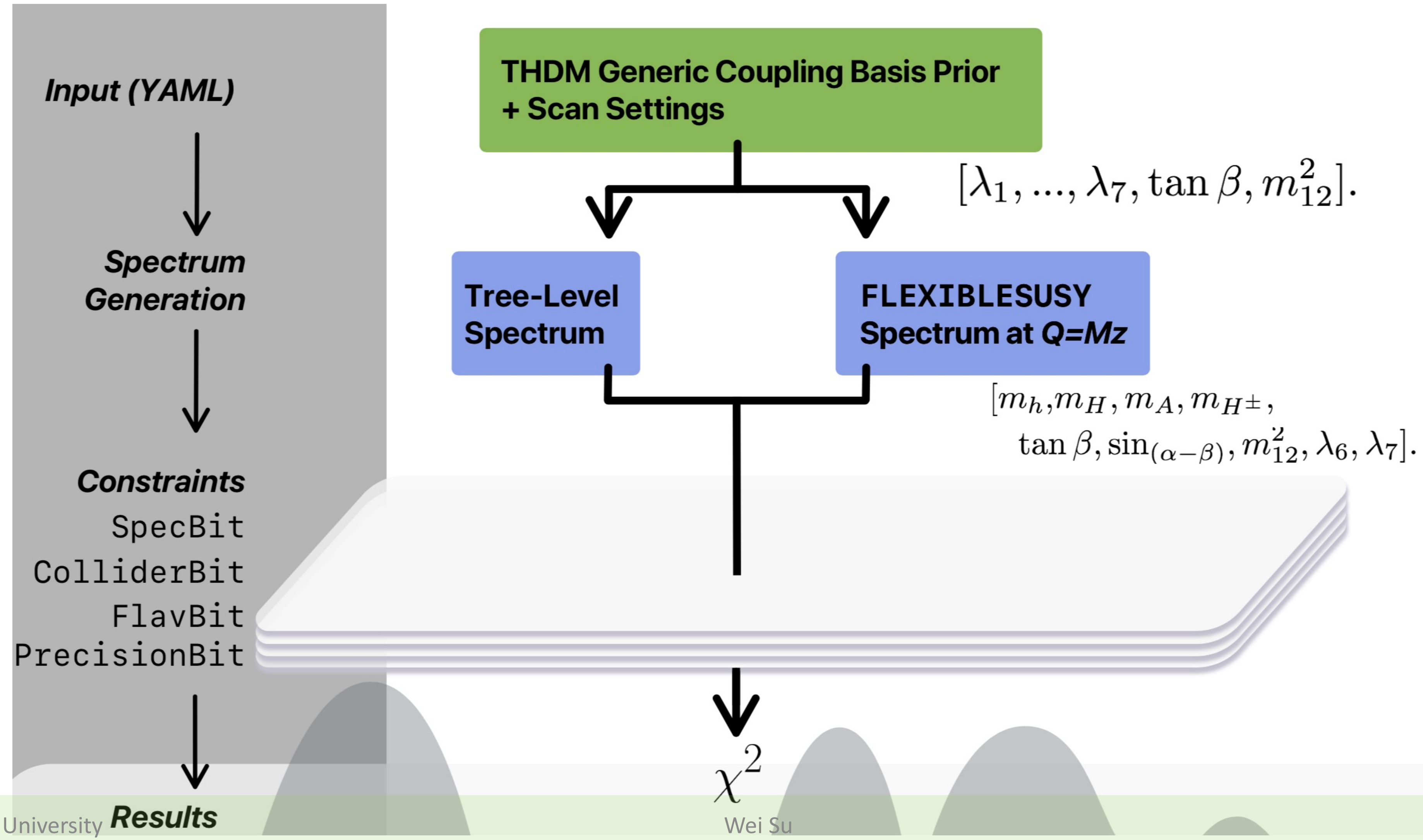
- Parameters (CP-conserving, Z_2 Symmetry)

$m_{11}^2, m_{22}^2, \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5$ → $v, \tan\beta, \alpha, m_h, m_H, m_A, m_{H^\pm}$

v → 246 GeV; m_h → 125. GeV

Soft Z_2 symmetry breaking: m_{12}^2

2HDM branch @Gambit



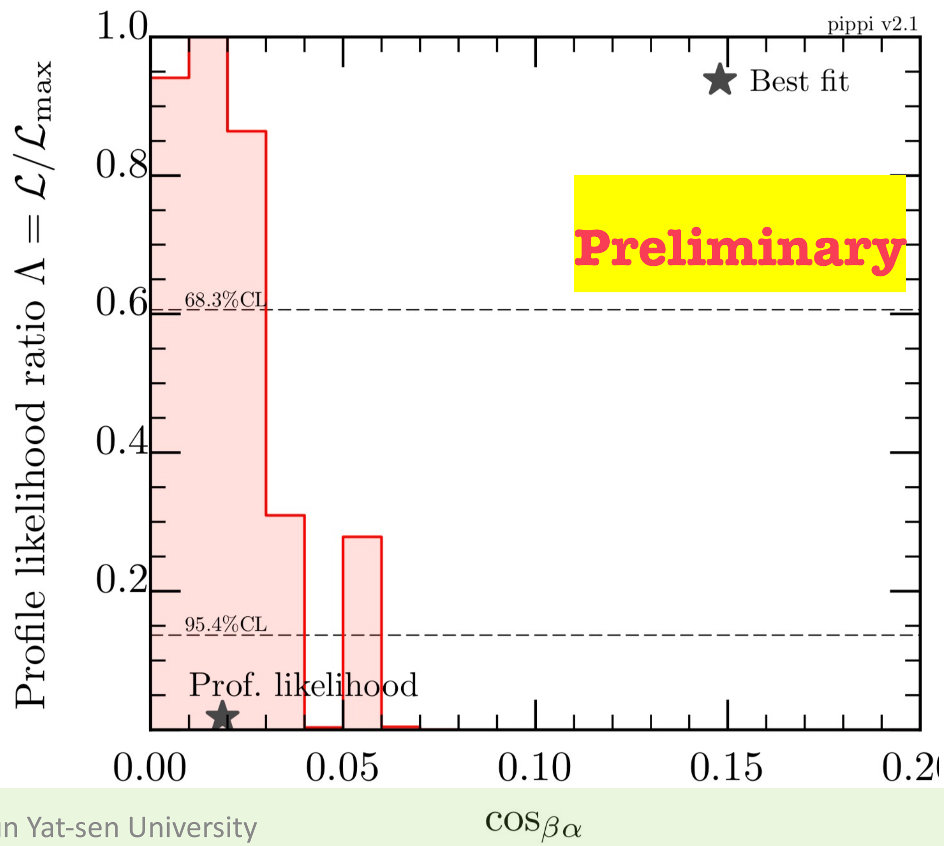
Future Z

Different to SUSY strategy

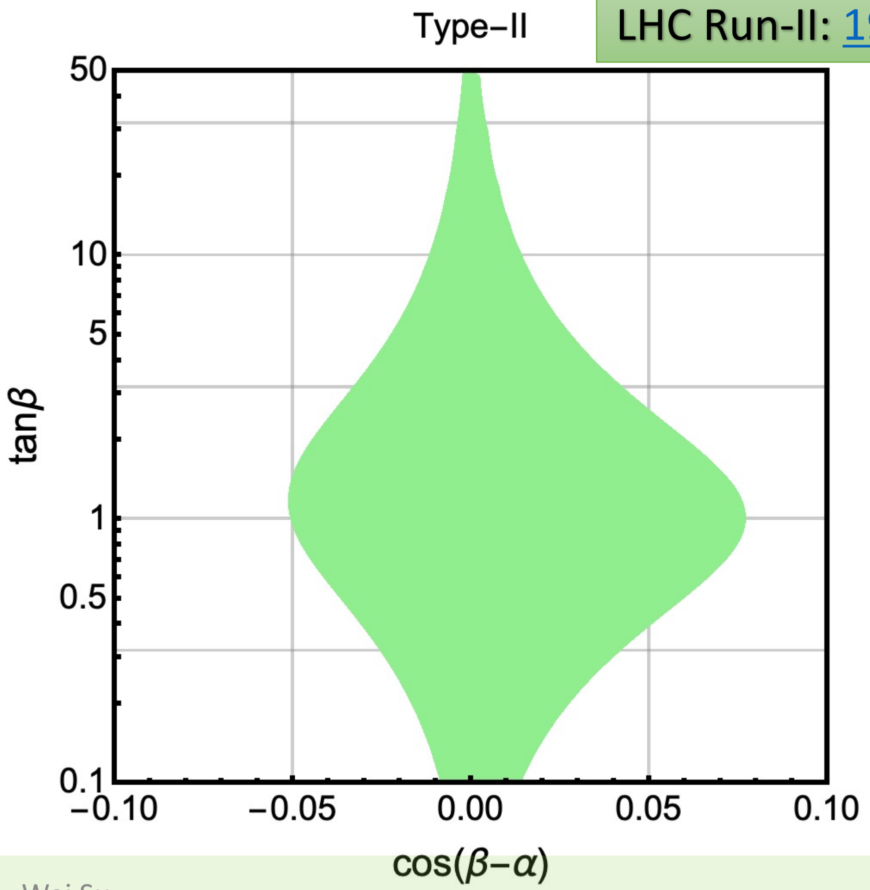
	Current (1.7×10^7 Z's)				CEPC ($10^{10} Z$'s)				FCC-ee ($7 \times 10^{11} Z$'s)				ILC ($10^9 Z$'s)			
	σ	correlation			σ	correlation			σ	correlation			σ	correlation		
		S	T	U	(10^{-2})	S	T	U	(10^{-2})	S	T	U	(10^{-2})	S	T	U
S	0.04 ± 0.11	1	0.92	-0.68	2.46	1	0.862	-0.373	0.67	1	0.812	0.001	3.53	1	0.988	-0.879
T	0.09 ± 0.14	–	1	-0.87	2.55	–	1	-0.735	0.53	–	1	-0.097	4.89	–	1	-0.909
U	-0.02 ± 0.11	–	–	1	2.08	–	–	1	2.40	–	–	1	3.76	–	–	1

Constraints: ColliderBit

- HiggsBounds (LEP)   HiggsSignals (LHC)

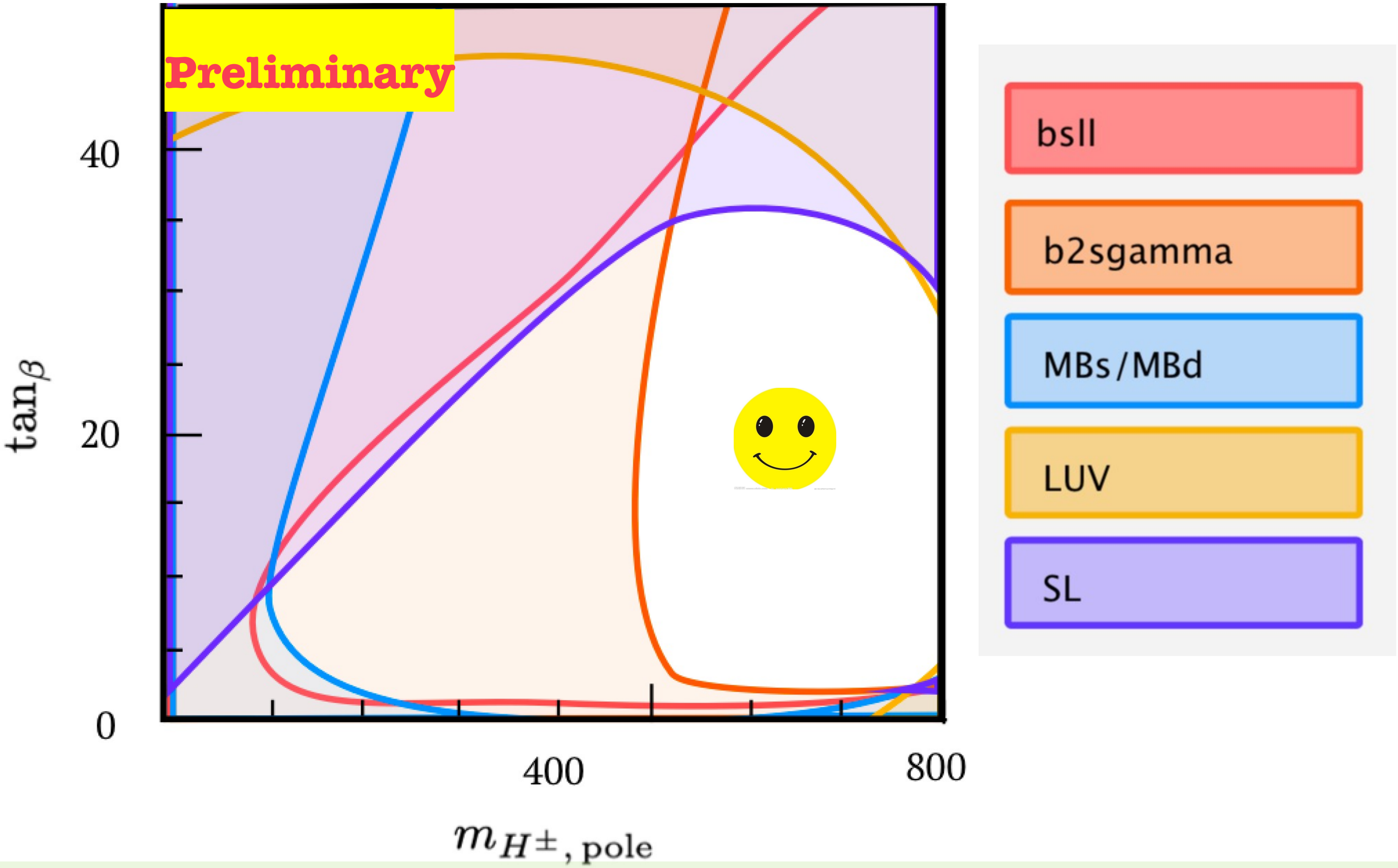


LHC Run-II: 1910.06269 , WS

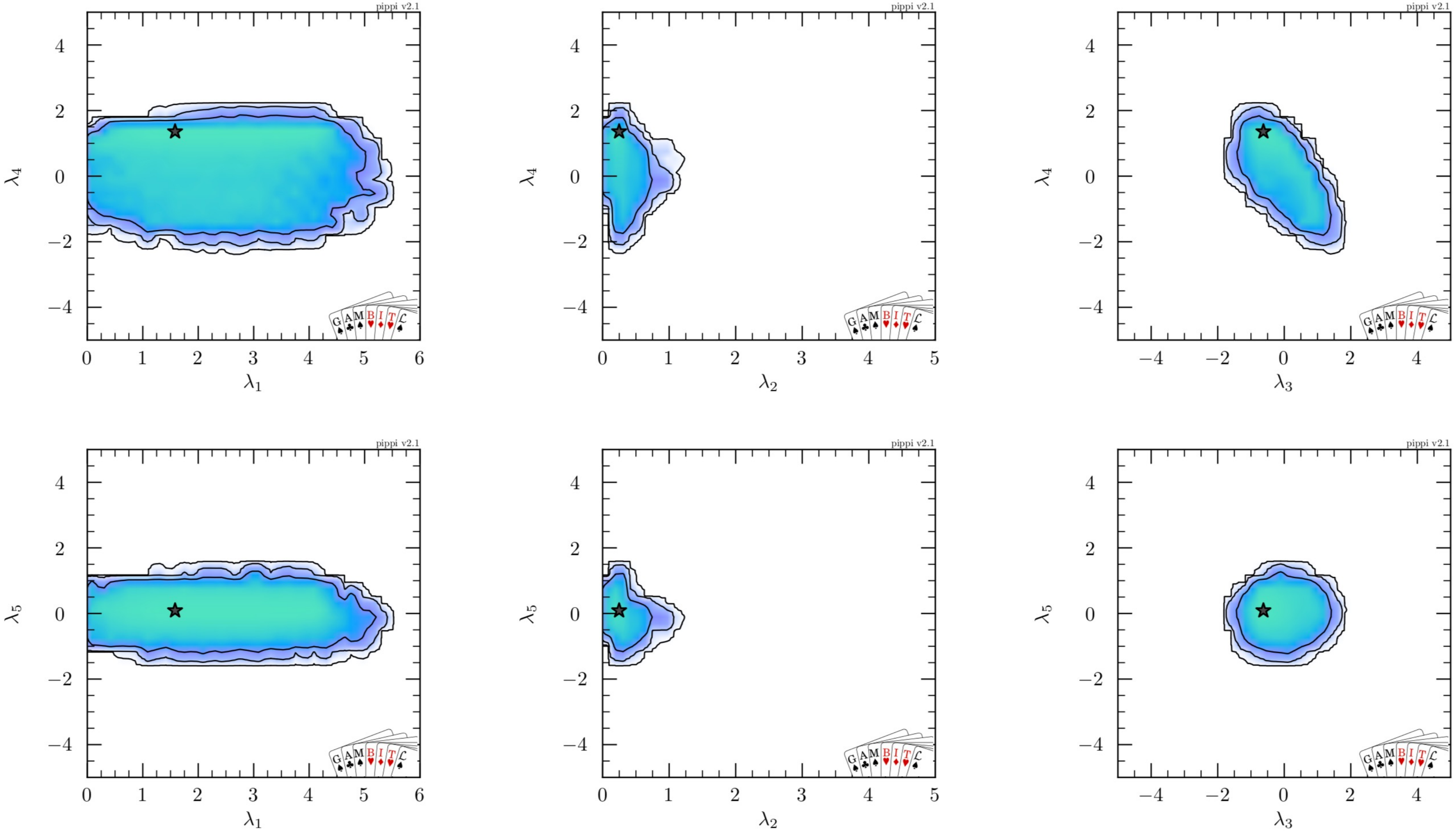


Constraints: FlavBit

- Radiative B Decay ($B \to$
- Electroweak penguins (B
- Rare fully leptonic B dec
- Tree-level leptonic and s processes) *(LUV)*
- Tree-level leptonic and s processes) *(SL)*
- B_s Mass Splitting (ΔM
- B_d Mass Splitting (ΔM

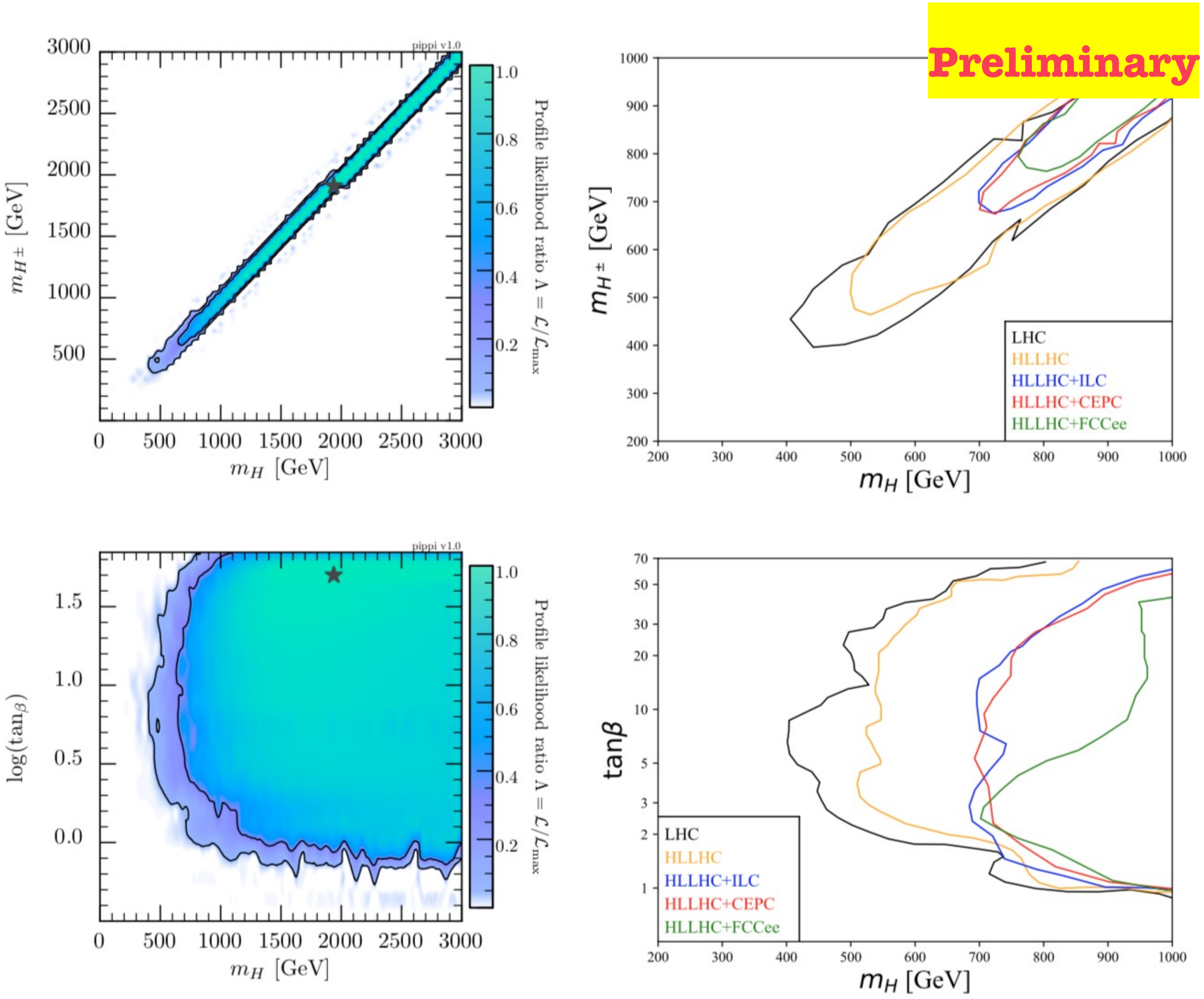


Results: present



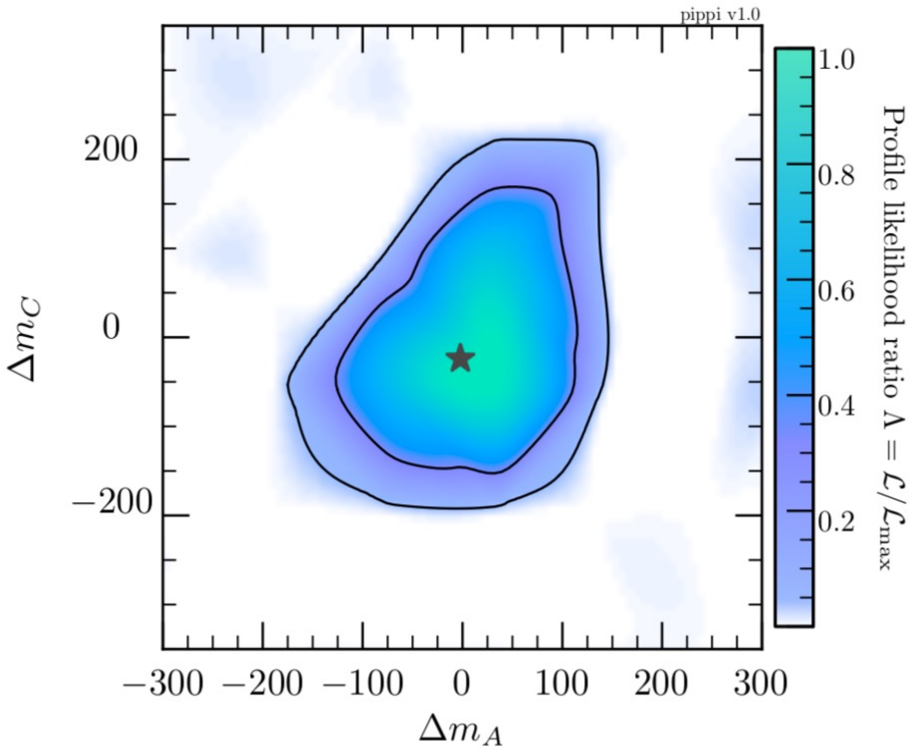
Results

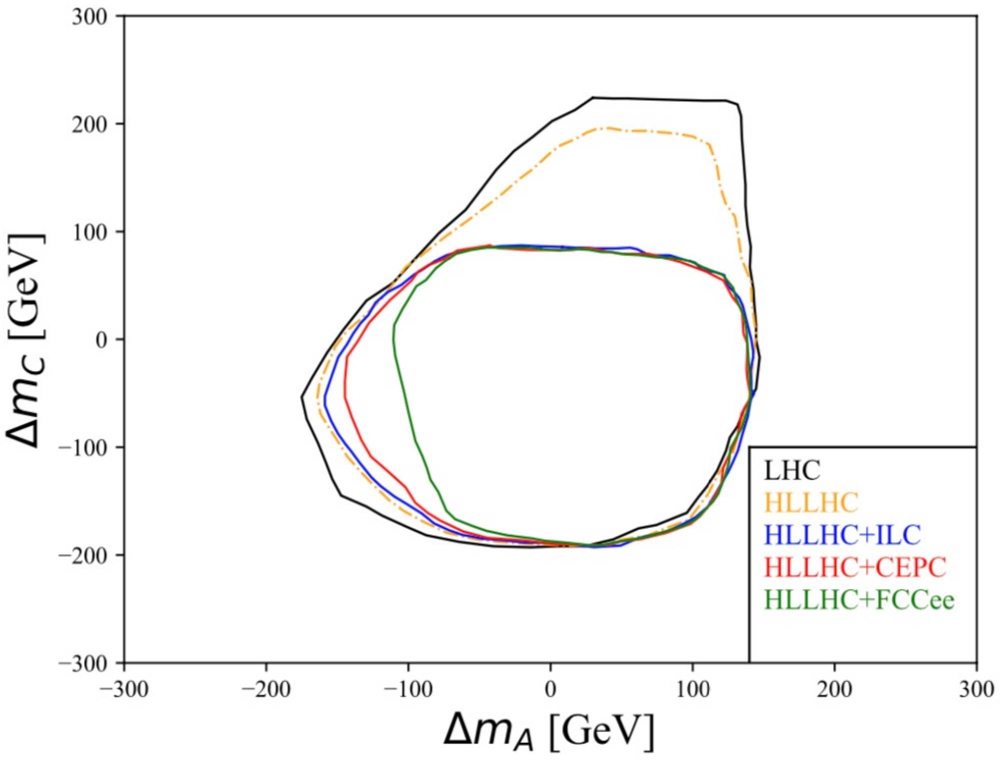
- m_H>400 GeV
- + HL-LHC m_H>500 GeV
- + CEPC m_H>700 GeV
- + FCCee m_H>800 GeV



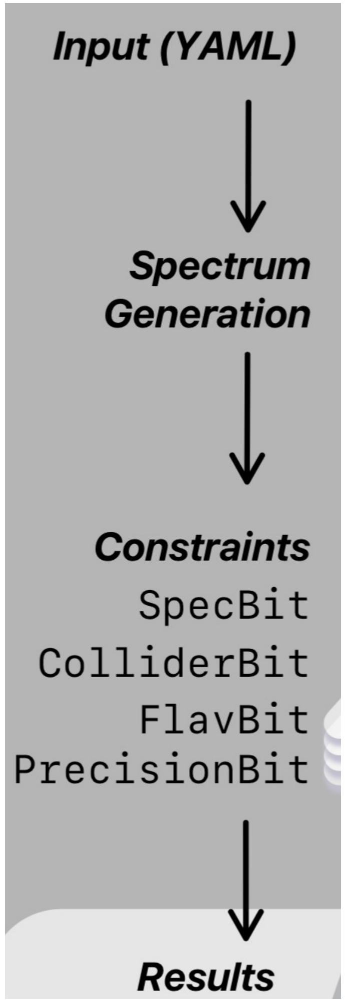
Results

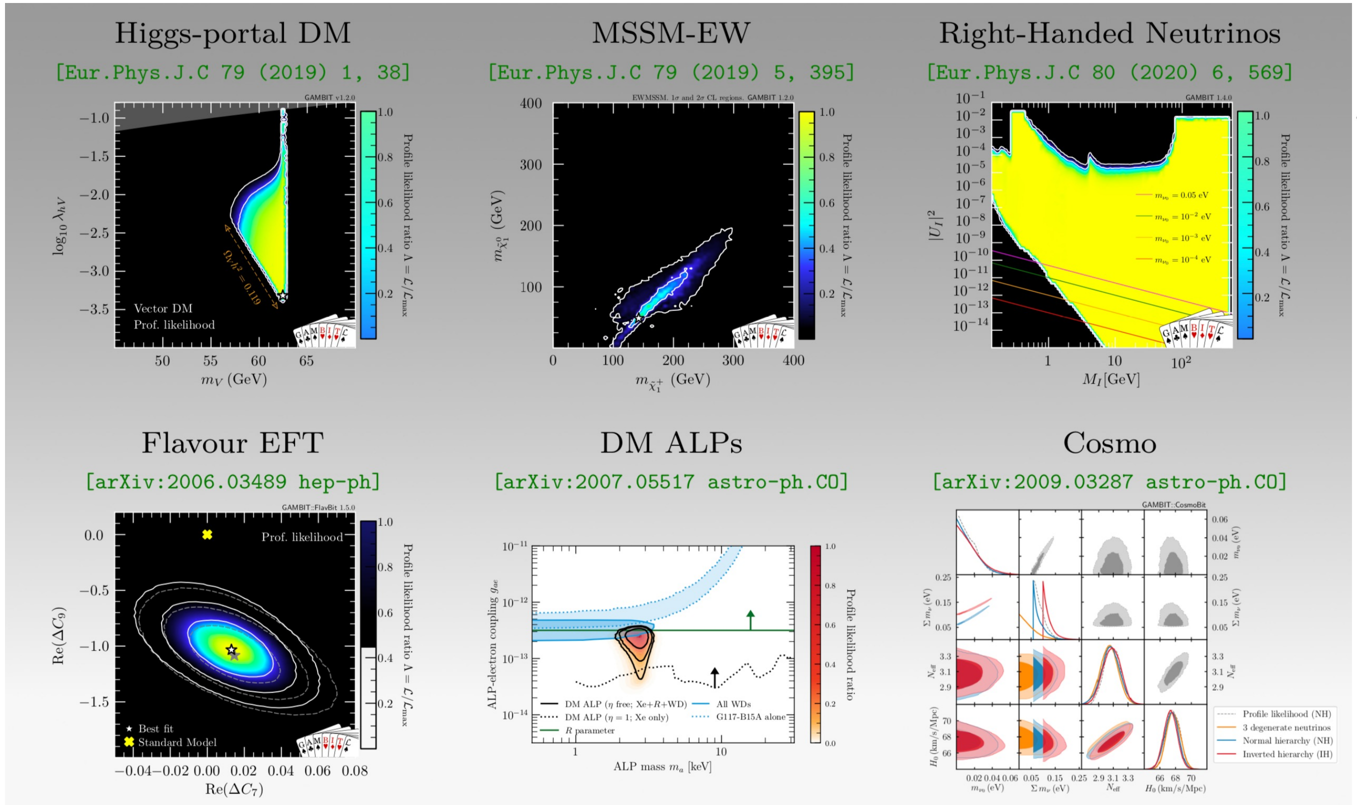
$$\Delta m_A = m_A - m_H \qquad \Delta m_C = m_{H^\pm} - m_H$$

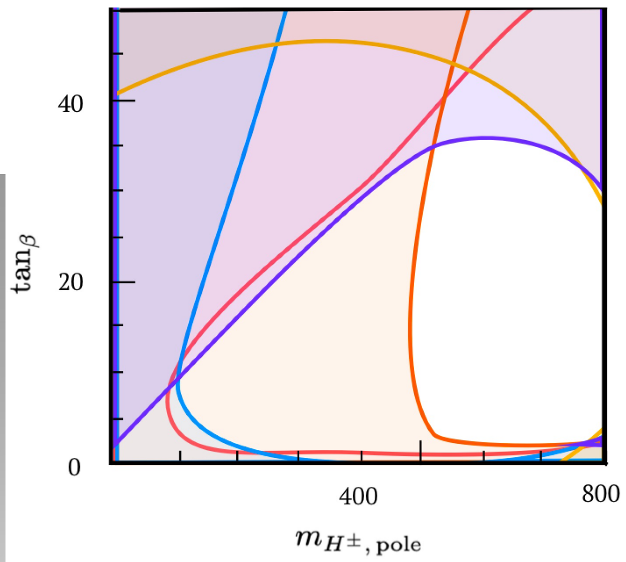


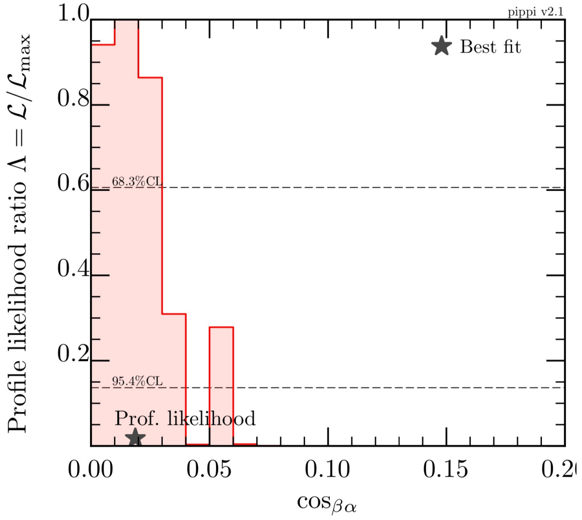


Summary


Input (YAML)
Spectrum Generation
Constraints
SpecBit
ColliderBit
FlavBit
PrecisionBit
Results


Higgs-portal DM
[Eur.Phys.J.C 79 (2019) 1, 38]
MSSM-EW
[Eur.Phys.J.C 79 (2019) 5, 395]
Right-Handed Neutrinos
[Eur.Phys.J.C 80 (2020) 6, 569]
Flavour EFT
[arXiv:2006.03489 hep-ph]
DM ALPs
[arXiv:2007.05517 astro-ph.CO]
Cosmo
[arXiv:2009.03287 astro-ph.CO]


$\tan_\beta$
$m_{H^\pm,\,\text{pole}}$

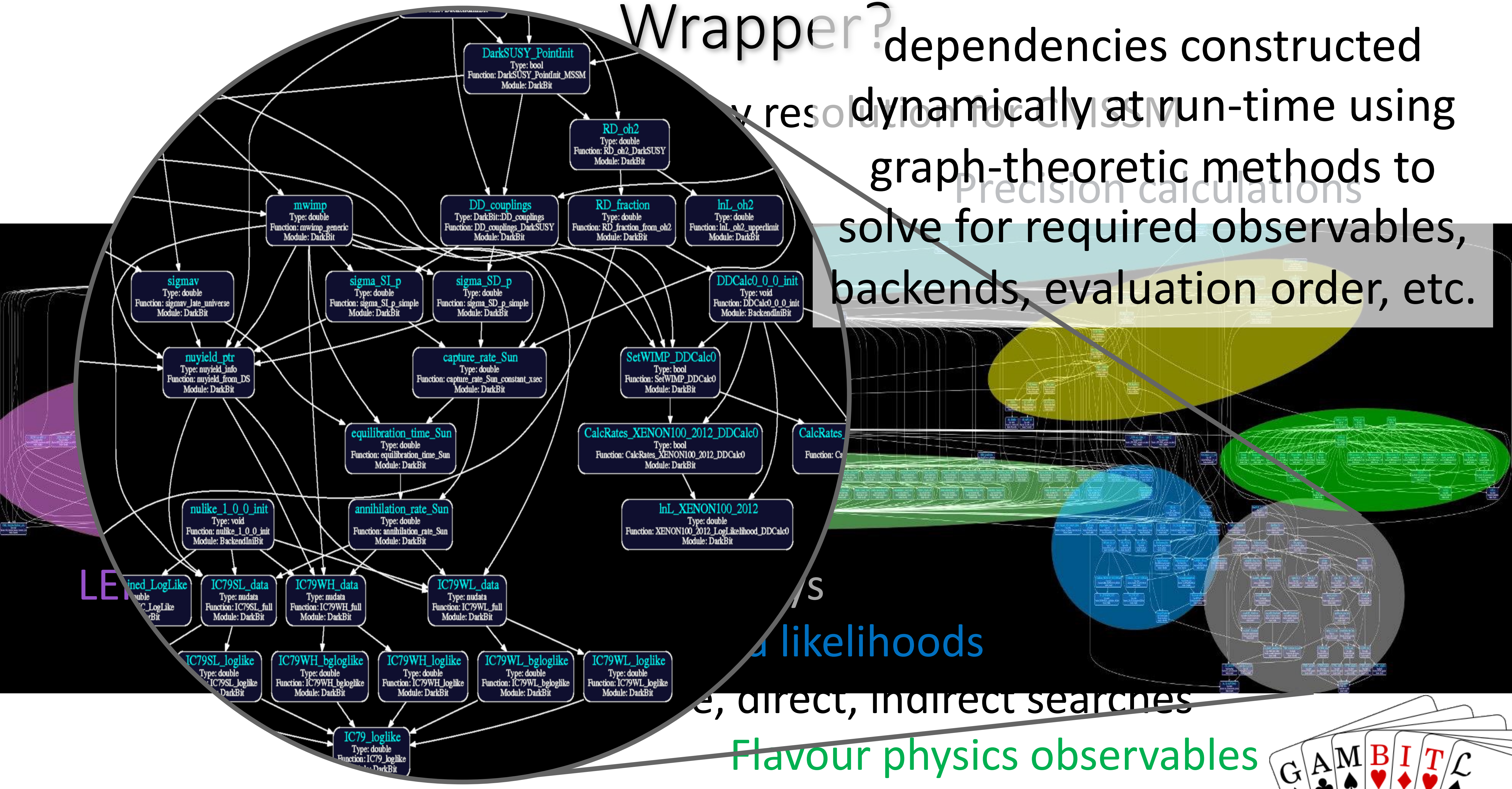

Profile likelihood ratio $\Lambda = \mathcal{L}/\mathcal{L}_{\max}$
Best fit
68.3%CL
95.4%CL
Prof. likelihood
$\cos_{\beta\alpha}$

Thanks !

Backup

Wrapper?

dependencies constructed dynamically at run-time using graph-theoretic methods to solve for required observables, backends, evaluation order, etc.



…y resolution for CMSSM

Precision calculations

LE… …s

…d likelihoods

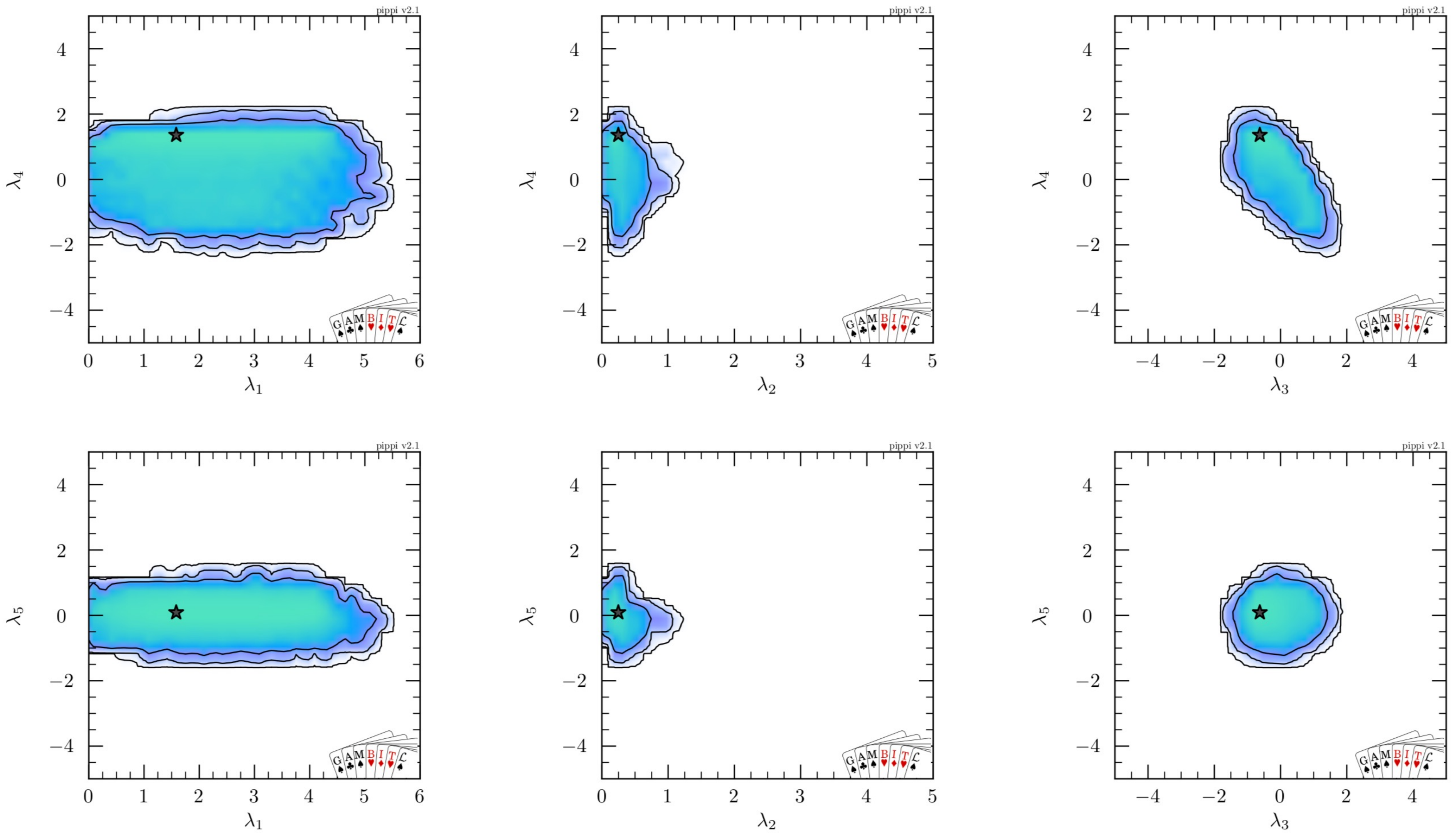
…e, direct, indirect searches

Flavour physics observables

GAMBIT

λ_4

λ_5



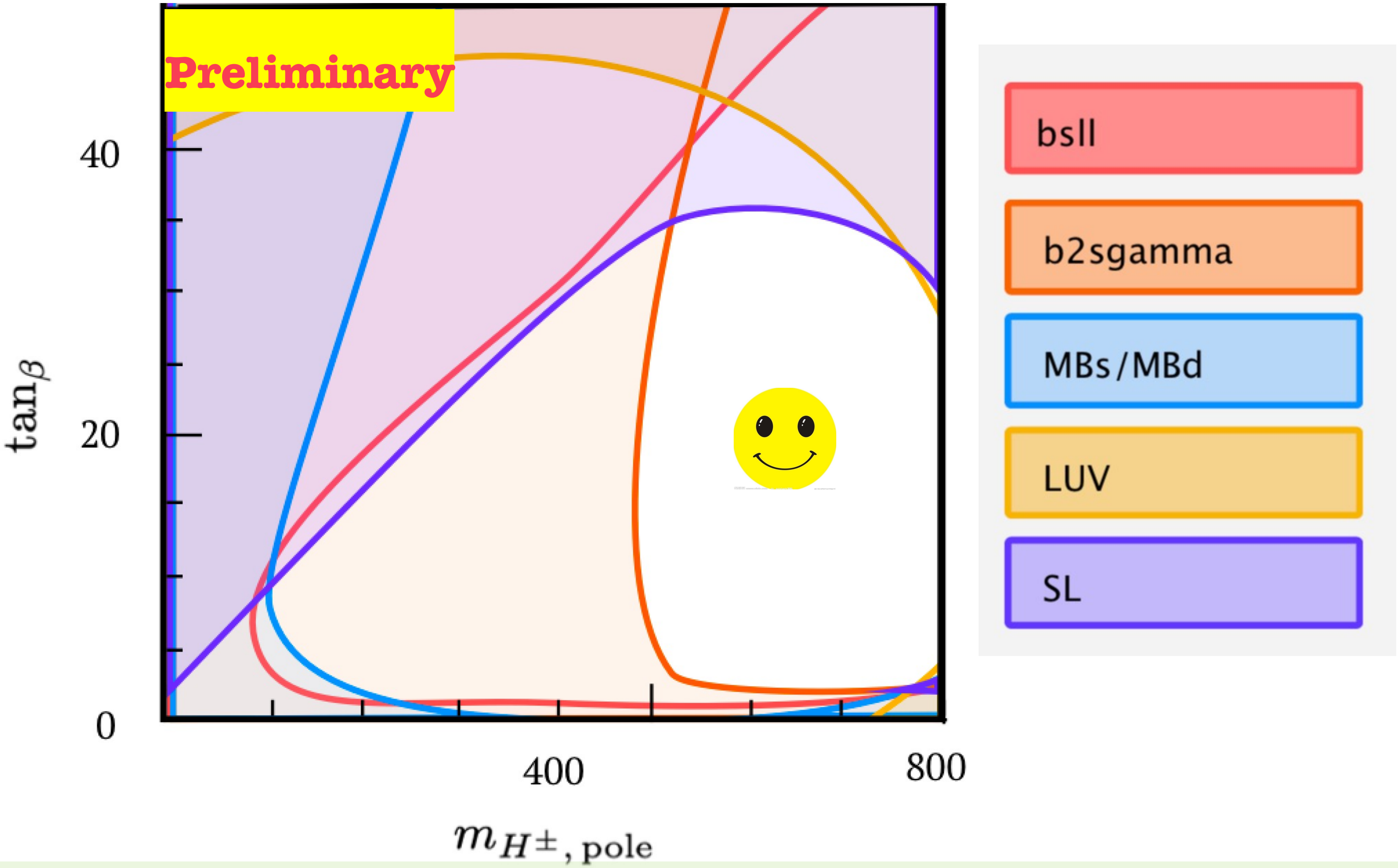
λ_1 λ_2 λ_3

Constraints: FlavBit

- Radiative B Decay ($B \to X_s \gamma$)
- Electroweak penguins ($B \to K^* \mu^+ \mu^-$) *(b2sll)*
- Rare fully leptonic B decays ($B_s \to \mu^+ \mu^-$) *(b2ll)*
- Tree-level leptonic and semi-leptonic B & D decays (see description for processes) *(LUV)*
- Tree-level leptonic and semi-leptonic B & D decays (see description for processes) *(SL)*
- B_s Mass Splitting (ΔM_{B_s})
- B_d Mass Splitting (ΔM_{B_d})

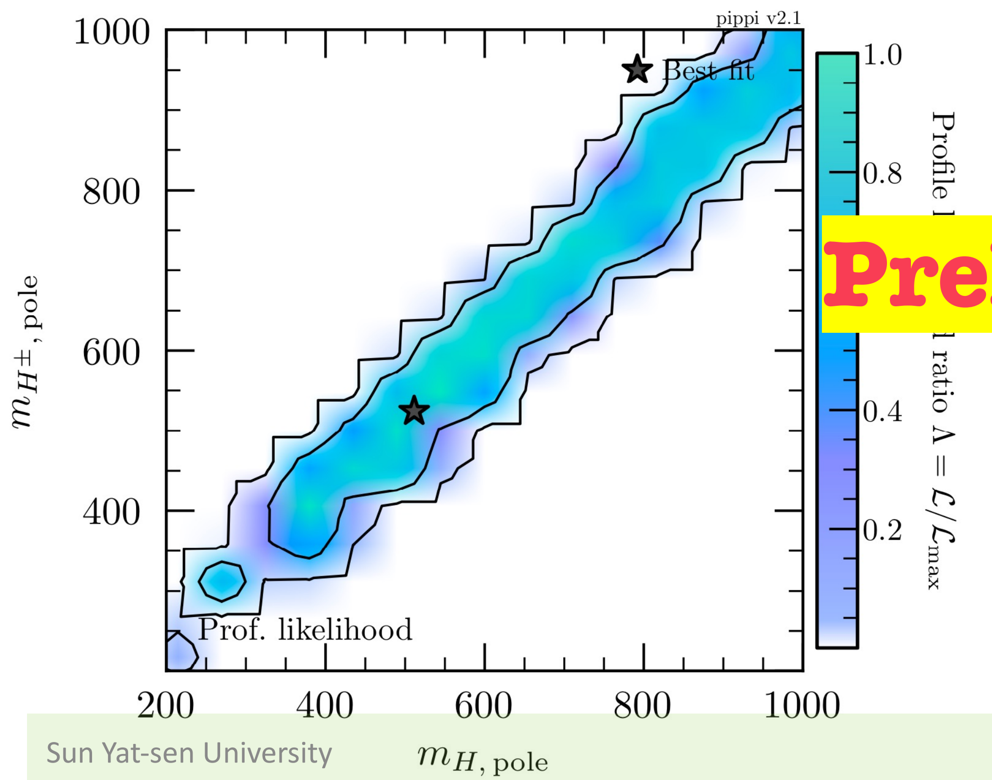
Constraints: FlavBit

- Radiative B Decay ($B \rightarrow$
- Electroweak penguins (B
- Rare fully leptonic B dec
- Tree-level leptonic and s processes) *(LUV)*
- Tree-level leptonic and s processes) *(SL)*
- B_s Mass Splitting (ΔM
- B_d Mass Splitting (ΔM

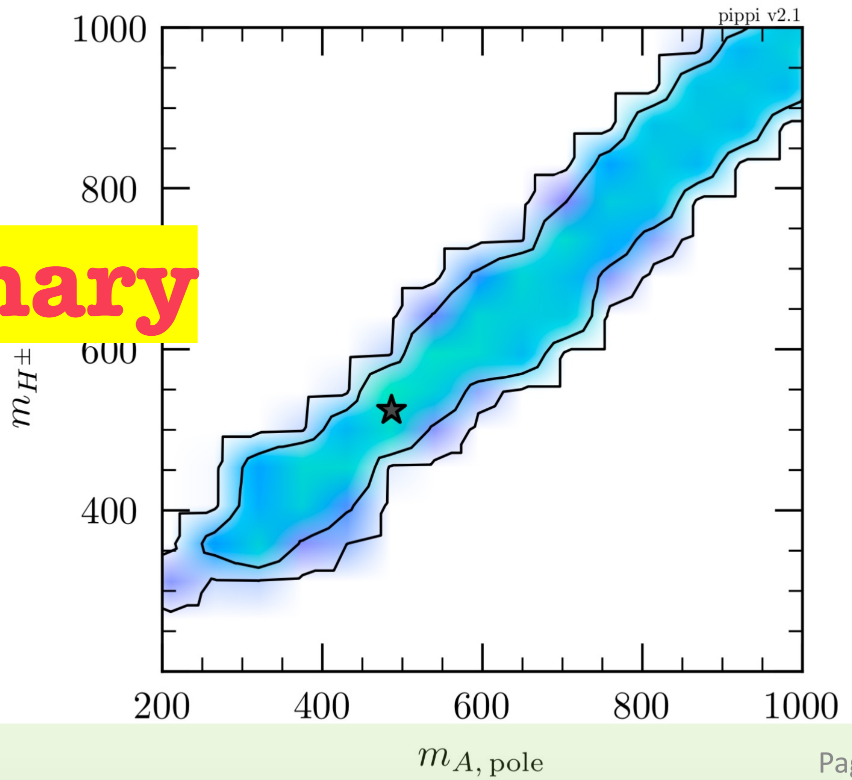


Constraints: EW physics

- Muon g-2 anomaly
- Electroweak precision parameters (oblique parameters)

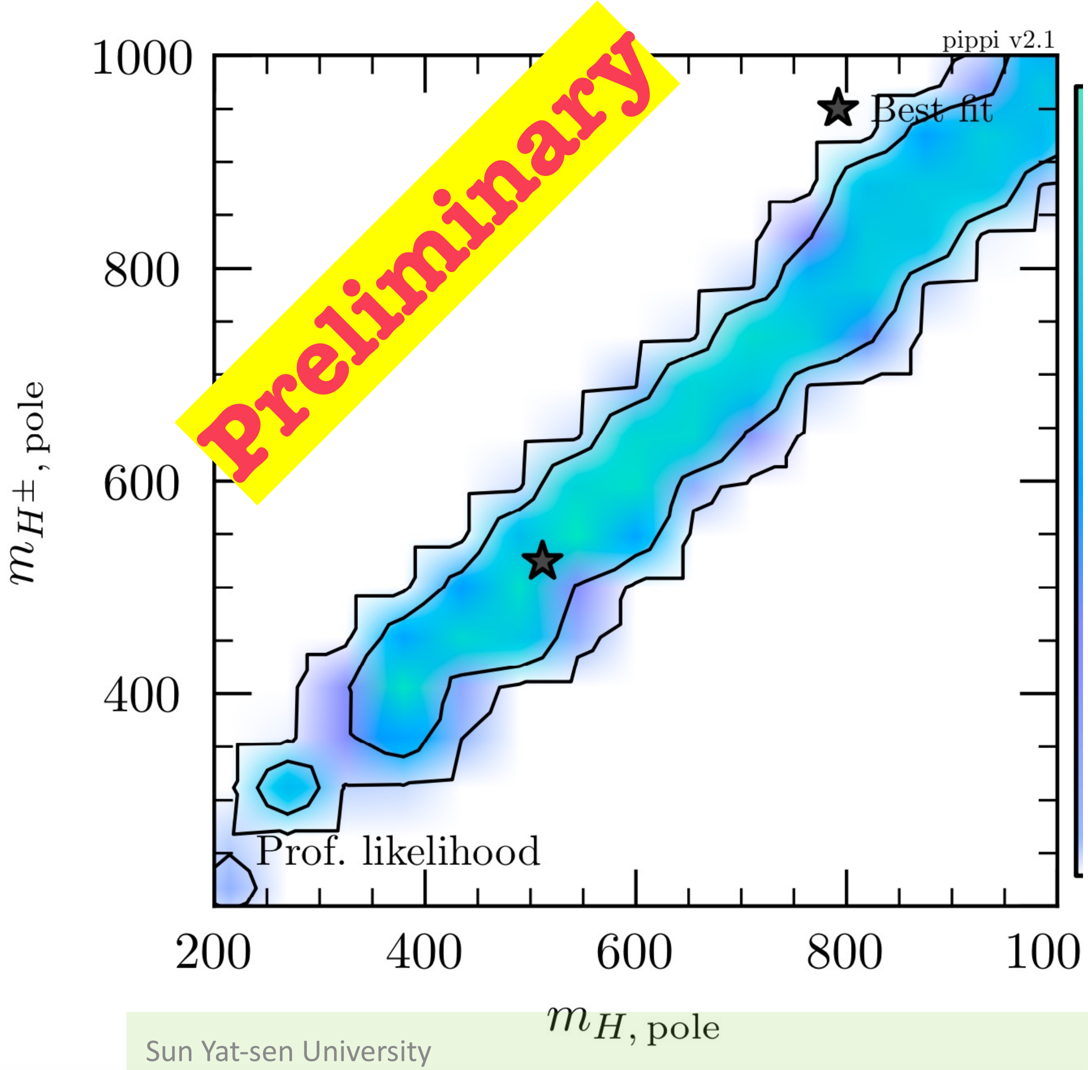


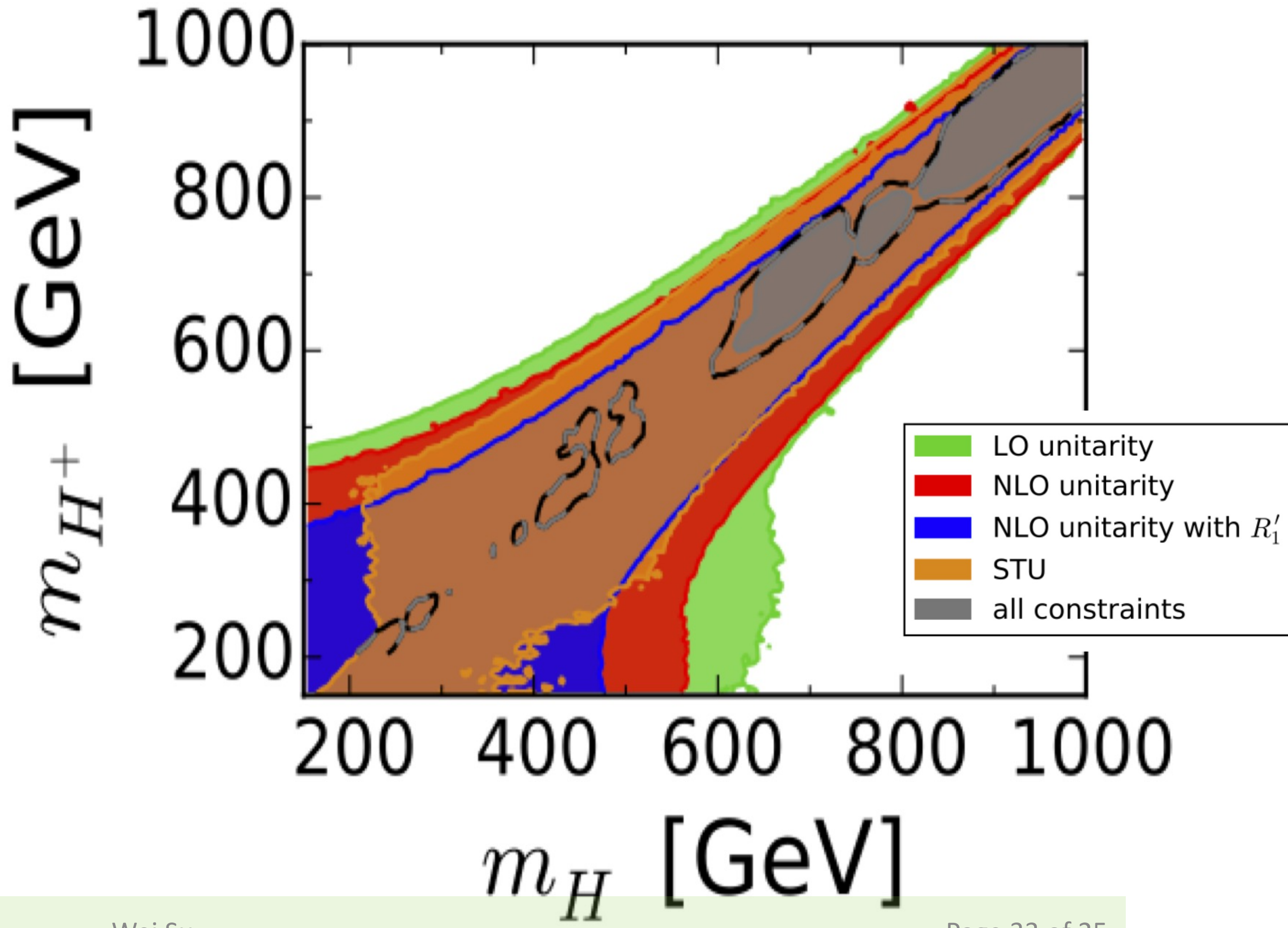
Preliminary



Constraints: EW physics

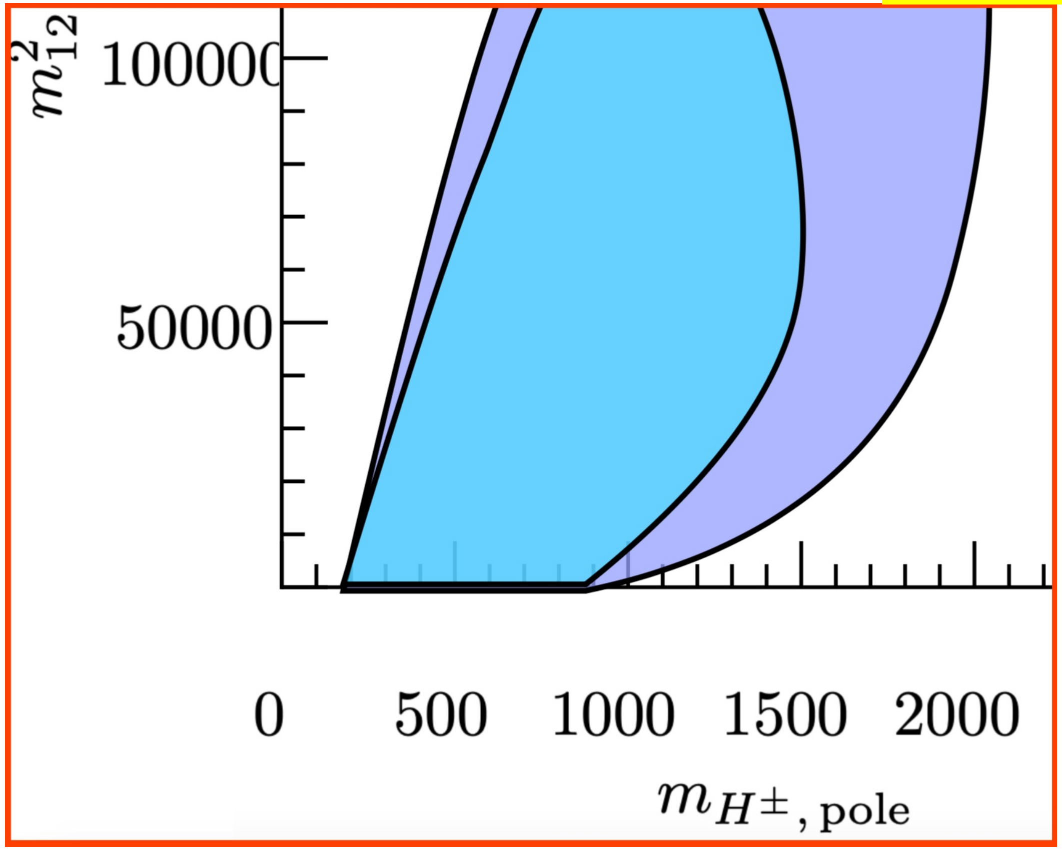
1609.01290: HEP-fit

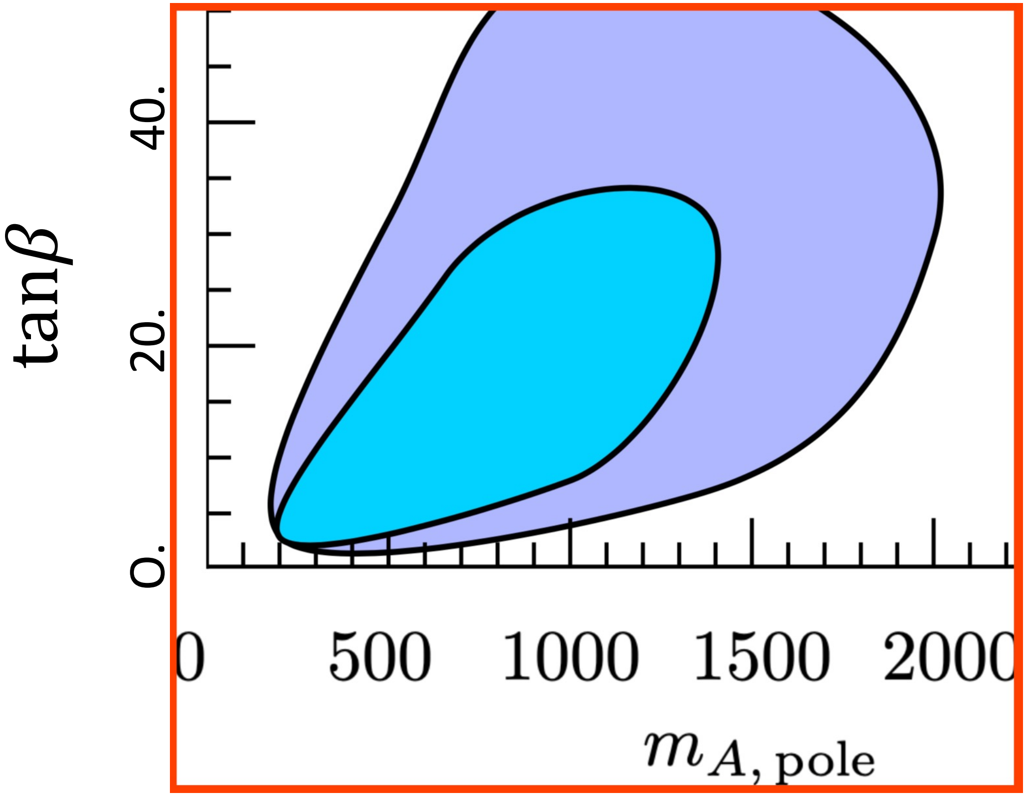




Global fitting results

Preliminary

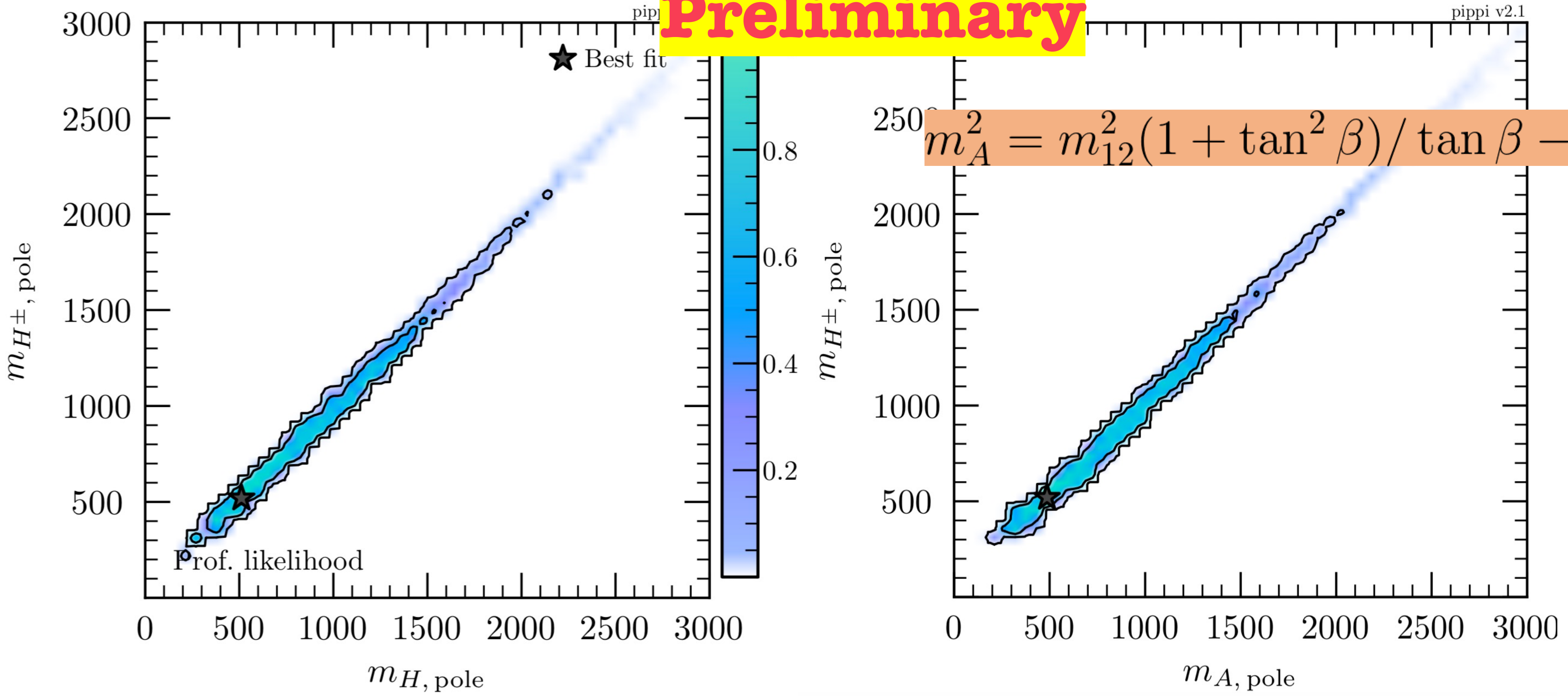




Global fitting results

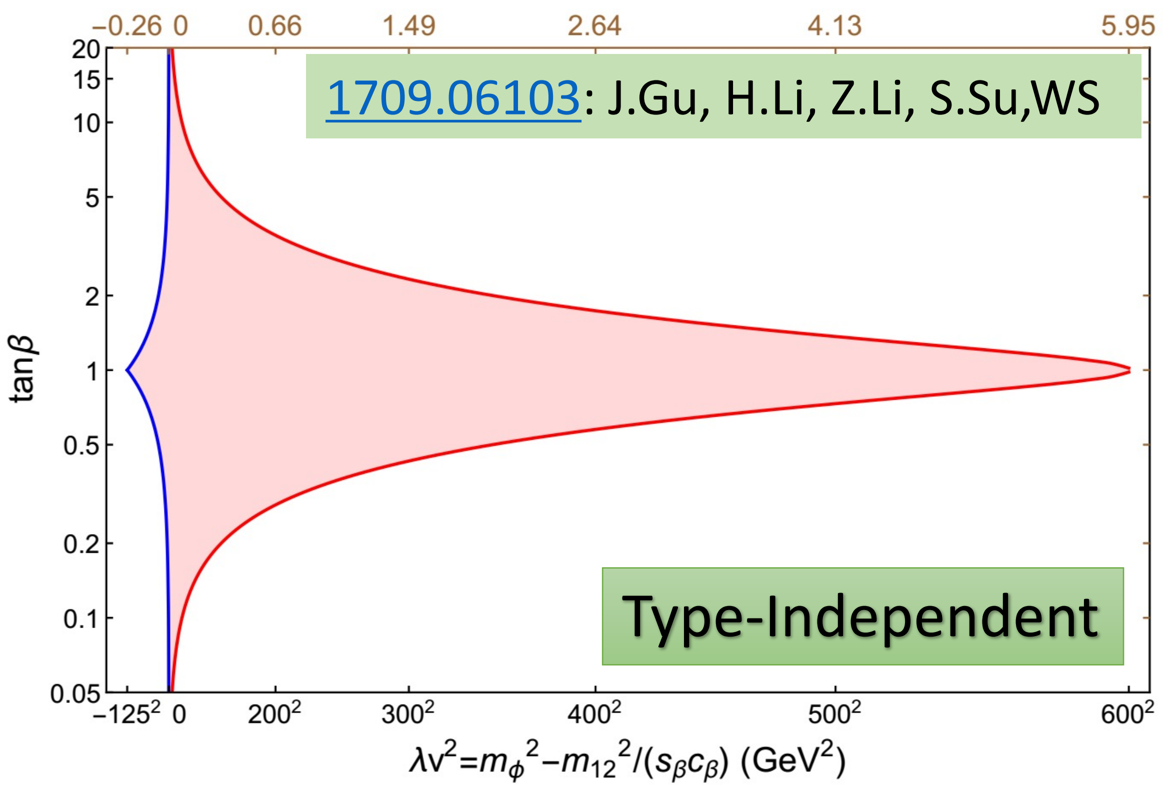
Preliminary

$$m_A^2 = m_{12}^2(1 + \tan^2\beta)/\tan\beta - \lambda_5^2 v^2$$



Global fitting results

$$m_A^2 = m_{12}^2(1+\tan^2\beta)/\tan\beta - \lambda_5^2 v^2$$



1709.06103: J.Gu, H.Li, Z.Li, S.Su,WS

Type-Independent

$$\lambda \in (-0.26, 5.95)$$
$$\lambda_4 = \lambda_5 = \lambda_3 - 0.258 = -\lambda$$

1808.02037 : N.Chen, T.Han, S.Su, WS,Y.Chen

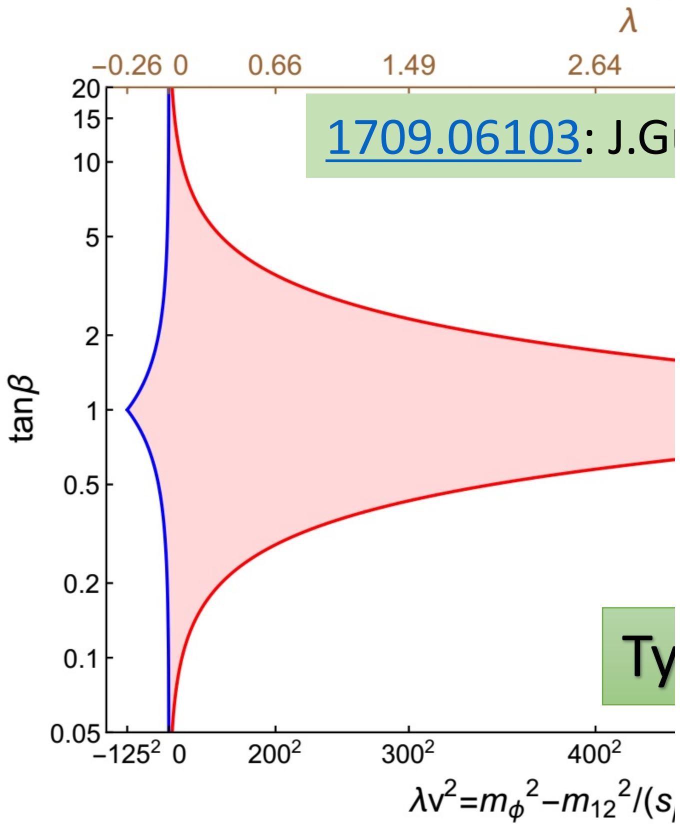
$$-125^2\mathrm{GeV}^2 < \lambda v^2 < 600^2\mathrm{GeV}^2$$

$$\lambda v^2 \equiv m_\Phi^2 - m_{12}^2/s_\beta c_\beta$$

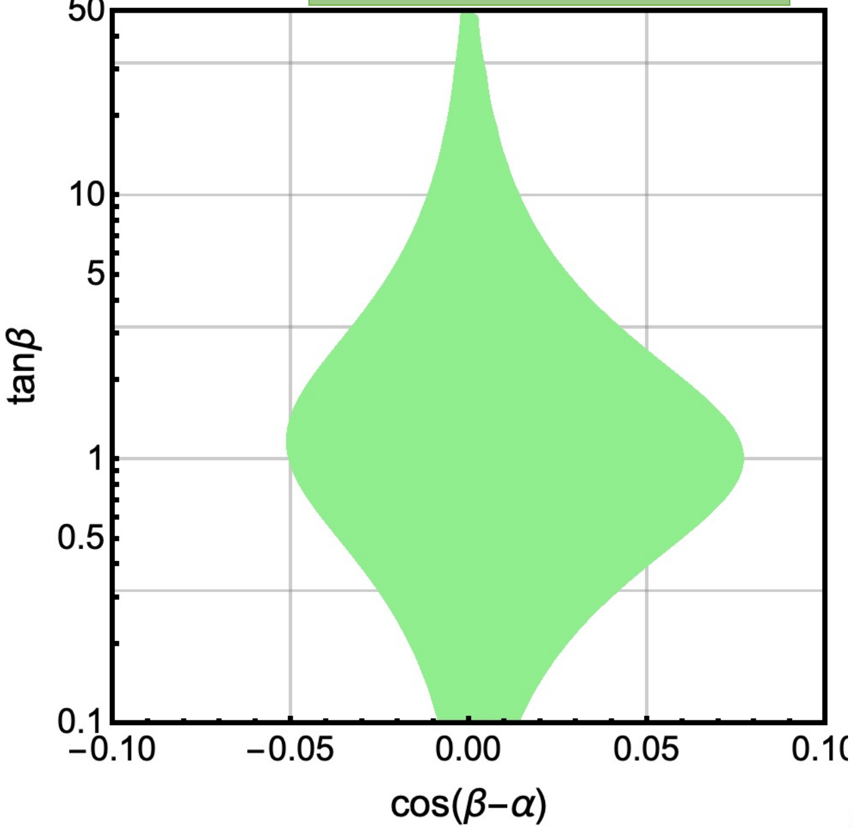
Global fitting results

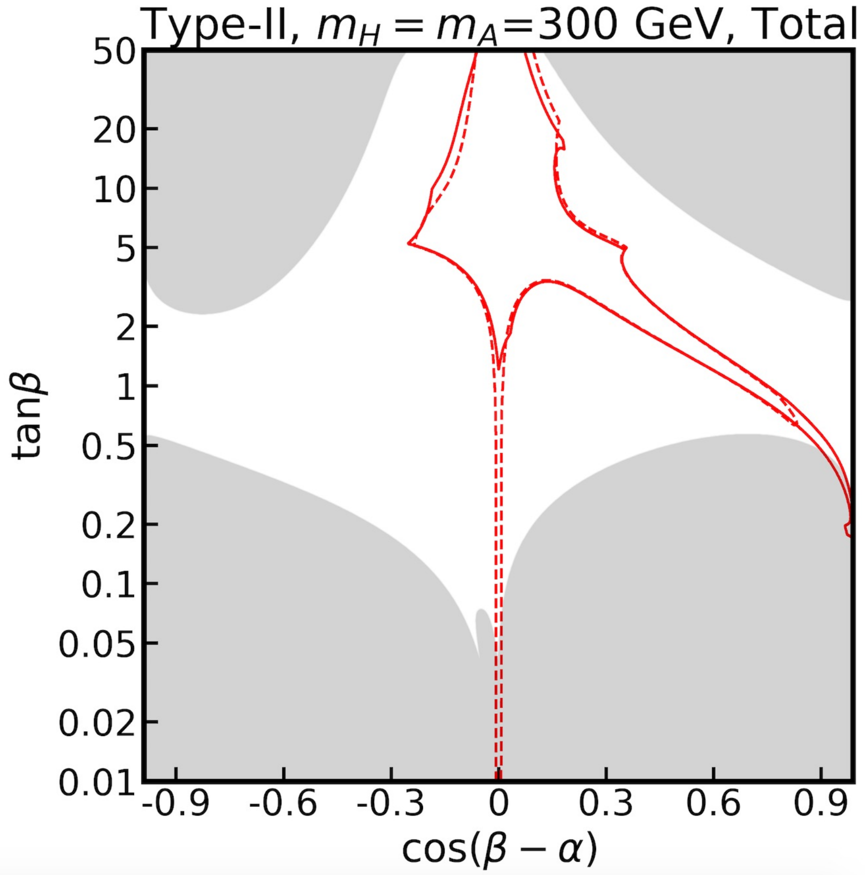
$m_A^2 = m_{12}^2(1+\tan^2\beta)/\tan\beta - \lambda_5^2 v^2$

Constraints from Vacuum stabiltiy, Unitarity and Perturbativity



1910.06269 , WS



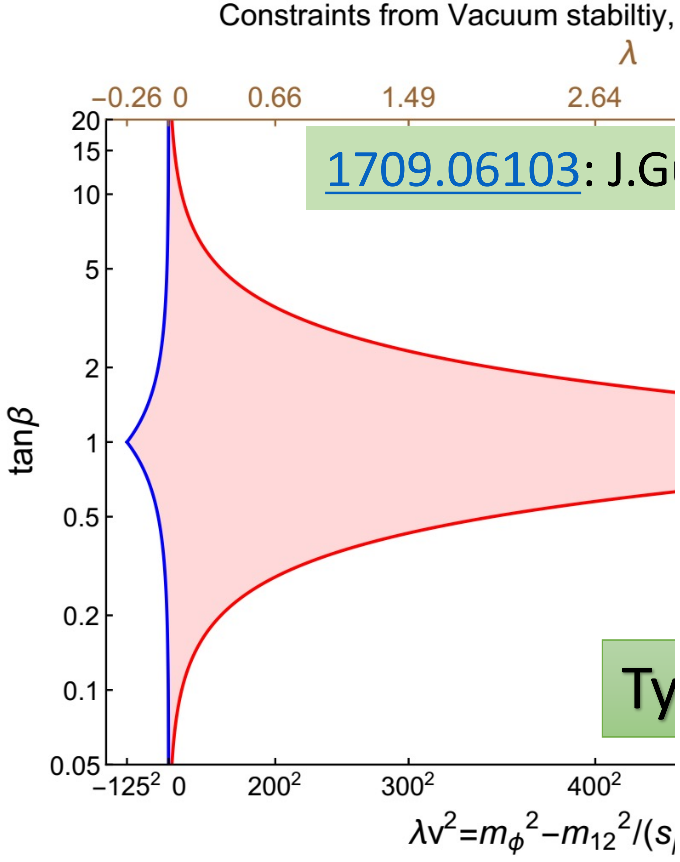


$-125^2\mathrm{GeV}^2 < \lambda v^2 <$

1909.09035 WS, M.White, AG.Williams,Y.Wu

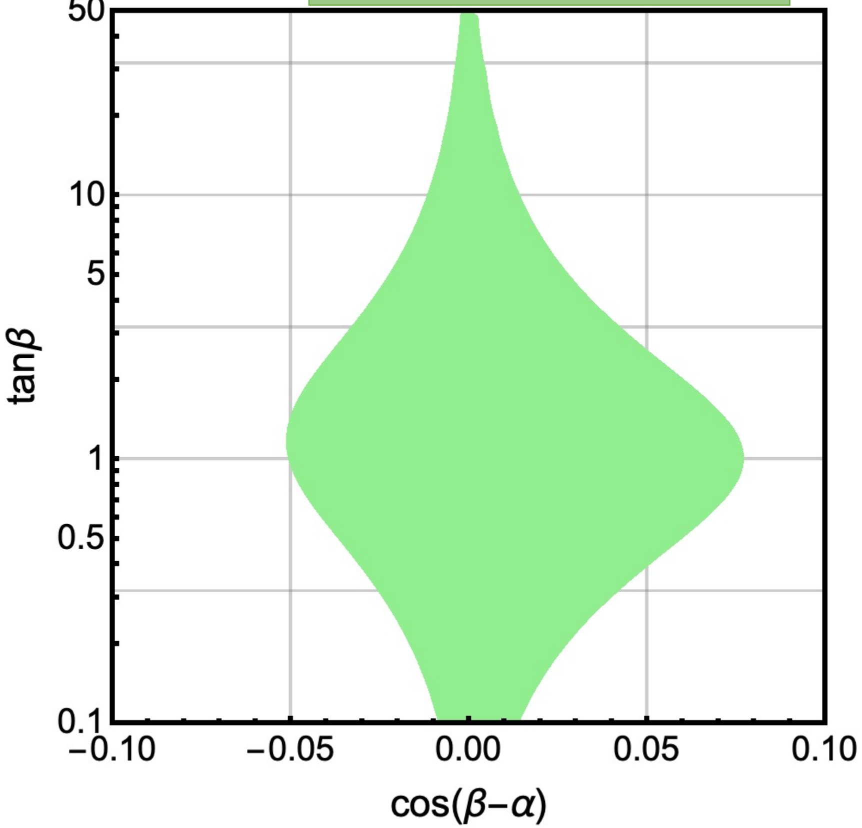
$\lambda v^2 = m_\Phi^2 - m_{12}^2/s_\beta c_\beta$

Global fitting results

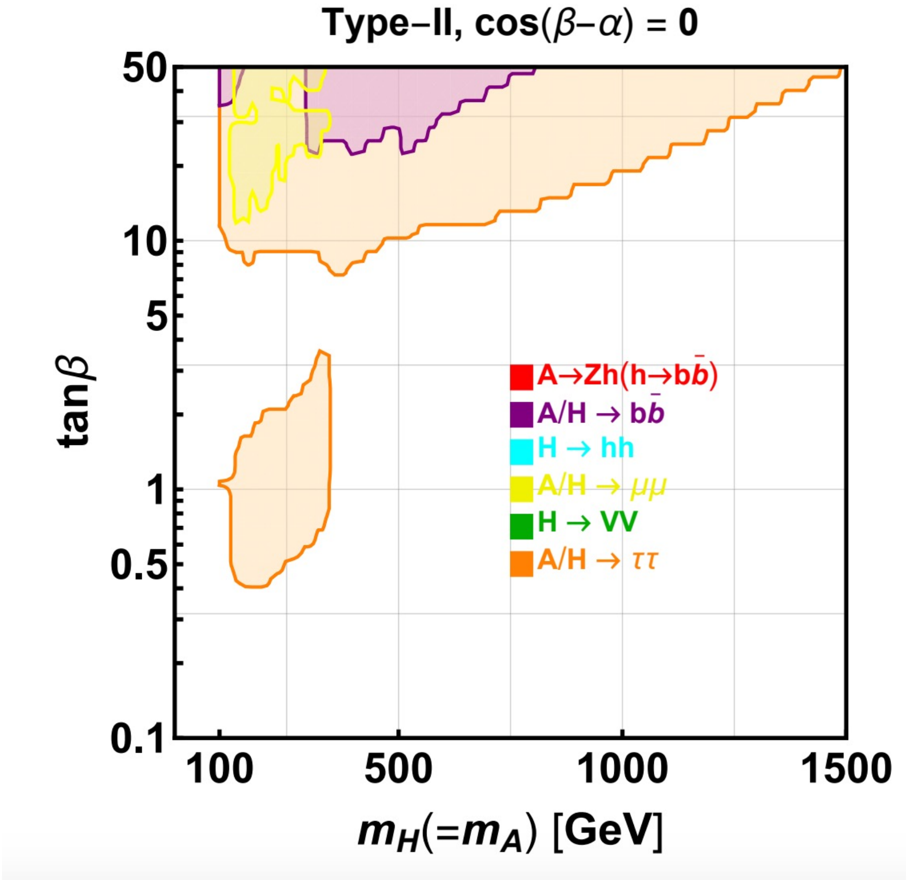


$-125^2\mathrm{GeV}^2 < \lambda v^2 <$

1910.06269 , WS



$m_A^2 = m_{12}^2(1+\tan^2\beta)/\tan\beta - \lambda_5^2 v^2$



$\lambda v^2 \equiv m_\Phi^2 - m_{12}^2/s_\beta c_\beta$

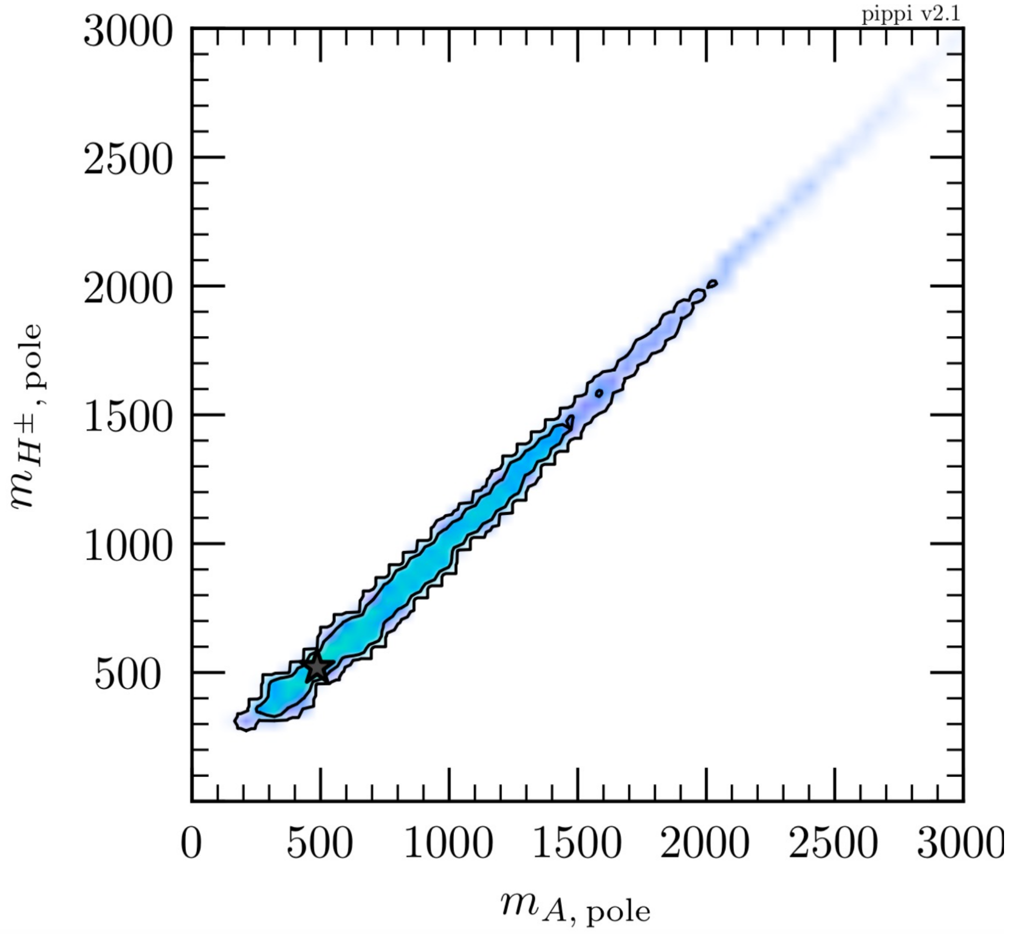
Global fitting results

$$\lambda \in (-0.26, 5.95)$$
$$\lambda_4 = \lambda_5 = \lambda_3 - 0.258 = -\lambda$$

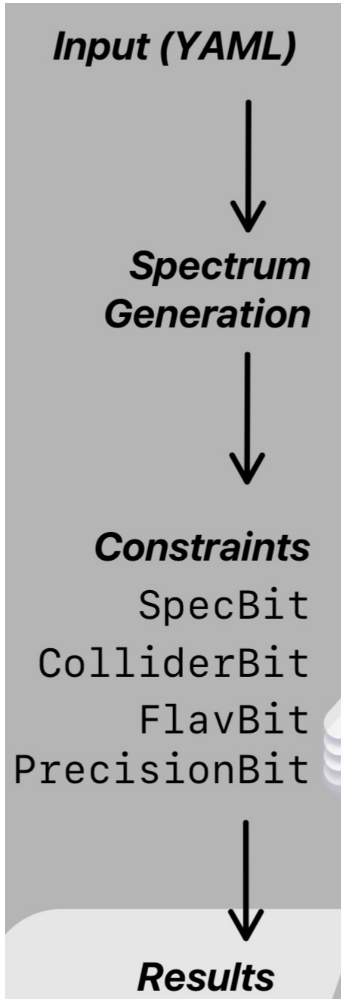
$$m_{12}^2 < 10^6, \tan\beta < 50$$

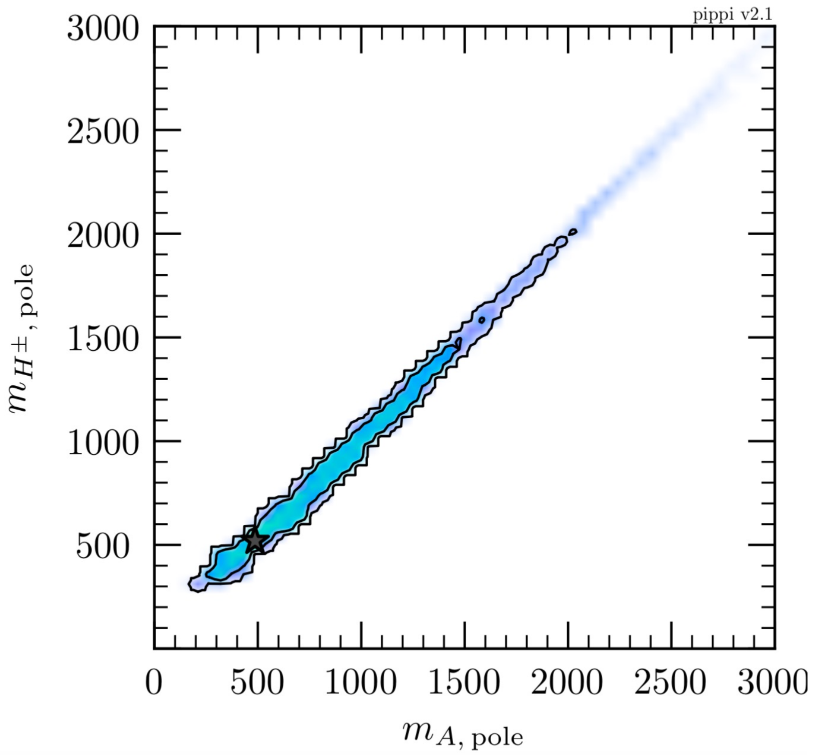
$$m_A^2 = m_{12}^2(1+\tan^2\beta)/\tan\beta - \lambda_5^2 v^2$$

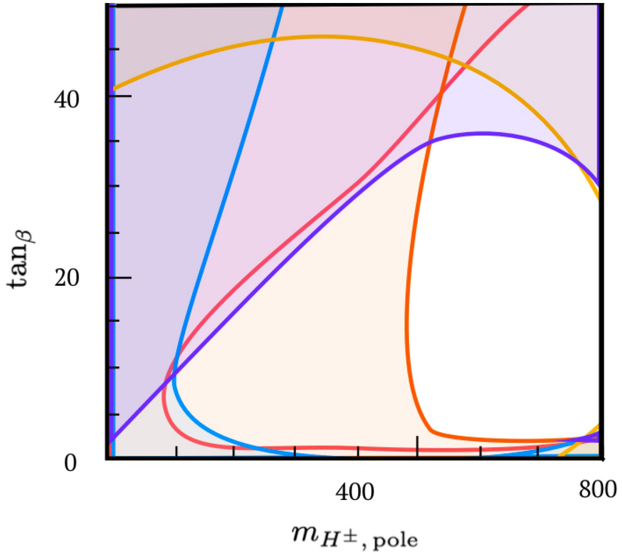
$$m_{H^\pm}^2 = m_A^2 + v^2(\lambda_5 - \lambda_4)/2$$

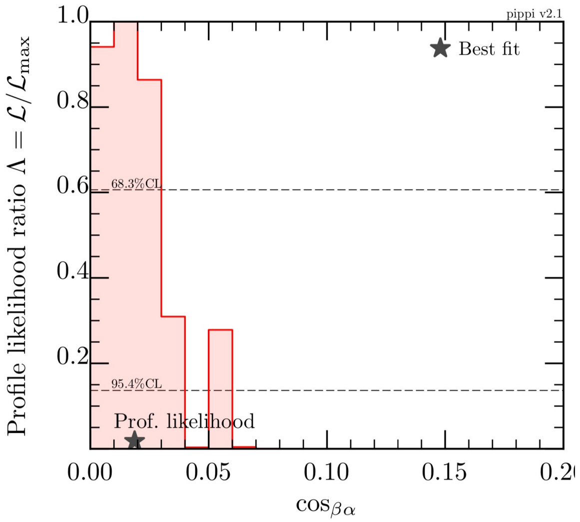


Conclusion


Input (YAML)
Spectrum Generation
Constraints
SpecBit
ColliderBit
FlavBit
PrecisionBit
Results


pippi v2.1
$m_{H^\pm,\,\mathrm{pole}}$
$m_{A,\,\mathrm{pole}}$
0
500
1000
1500
2000
2500
3000


$\tan_\beta$
0
20
40
400
800
$m_{H^\pm,\,\mathrm{pole}}$


pippi v2.1
Best fit
Profile likelihood ratio $\Lambda = \mathcal{L}/\mathcal{L}_{\max}$
68.3%CL
95.4%CL
Prof. likelihood
1.0
0.8
0.6
0.4
0.2
0.00
0.05
0.10
0.15
$\cos_{\beta\alpha}$

backup

ECFA-Higgs-GLOBAL workshop III, 23 Sep

GAMBIT: Global Interpretations for BSM theories

Wei Su

On behalf of the GAMBIT community

arXiv: 2203.04828, 2203.07883

- The vast majoriy of UV complete models of new physics contain multitude of pa- rameters and can be constrained by a large variety of experimental searches. Hence, global studies of these models are fundamental in order to understand their full po- tential. This is particularly crucial for future e-e+ colliders, since their extremely precise measurements will have strong consequences on the survability of these mod- els that can better be appreciated in a global scope. At the forefront in the field of global interpretations is GAMBIT, a computational framework capable of performing highly-dimensional, efficient and rigorous inference studies of particle, astroparticle and cosmological models. In this talk I will introduce GAMBIT and argue its position as the best candidate to perfom global studies of new physics models, and present some examples of how the results from future colliders will affect global studies of UV com- plete models such as supersymmetry, two-Higgs doublet models, and heavy neutrino models.

- What is GAMBIT?
- The amazing breadth of physics we've studied already
- Plans for comprehensive future facilities study using these results (plus we're happy to work with interested collaborators)
- Any preliminary results we have already (e.g. 2HDM, something else we can generate quickly?)

public results

results available on zenodo.cern.ch

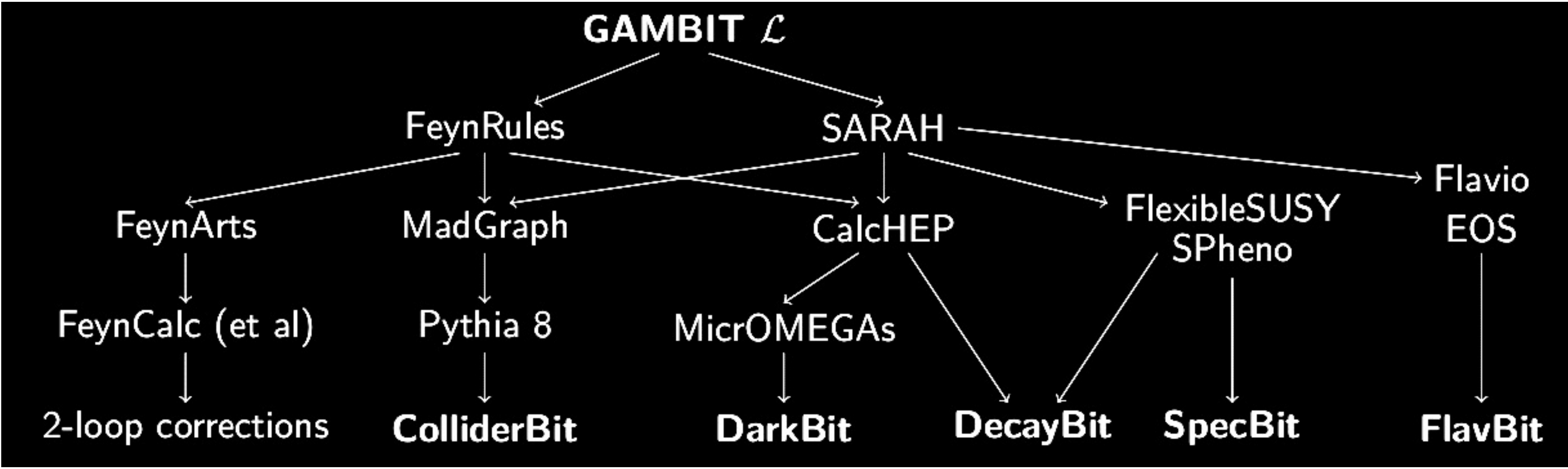
- parameter point samples
- GAMBIT input files for all scans
- example plotting routines

links at gambit.hepforge.org/pubs

GAMBIT 2

Extension to model building

- GAMBIT Universal Model (GUM), interface to Lagrangian-level
- Auto code generation for spectra, cross sections, observables …



getting started

- clone git repo github.com/patscott/gambit_1.1   or
- download tarballs hepforge.org/downloads/gambit   or
- get pre-compilied version docker run -it jmcornell/gambit   and
- see quick start guide in arXiv:1705.07908

add

1. Add the model to the **model hierarchy**:
   - Choose a model name, and declare any **parent model**
   - Declare the model's parameters
   - Declare any **translation function** to the parent model

```
#define MODEL NUHM1
#define PARENT NUHM2
  START_MODEL
  DEFINEPARS(M0,M12,mH,A0,TanBeta,SignMu)
  INTERPRET_AS_PARENT_FUNCTION(NUHM1_to_NUHM2)
#undef PARENT
#undef MODEL
```

2. Write the translation function as a standard C++ function:

```
void MODEL_NAMESPACE::NUHM1_to_NUHM2 (const ModelParameters &myP, ModelParameters &targetP)
{
   // Set M0, M12, A0, TanBeta and SignMu in the NUHM2 to the same values as in the NUHM1
   targetP.setValues(myP,false);
   // Set the values of mHu and mHd in the NUHM2 to the value of mH in the NUHM1
   targetP.setValue("mHu", myP["mH"]);
   targetP.setValue("mHd", myP["mH"]);
}
```

3. If needed, declare that existing module functions work with the new model, or add new functions that do.

from Pat Scott

add

Adding a new module function is easy:

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

```
#define MODULE FlavBit                                   // A tasty GAMBIT module.
START_MODULE

  #define CAPABILITY Rmu                                 // Observable: BR(K->mu nu)/BR(pi->mu nu)
  START_CAPABILITY
    #define FUNCTION SI_Rmu                              // Name of a function that can compute Rmu
    START_FUNCTION(double)                               // Function computes a double precision result
    BACKEND_REQ(Kmunu_pimunu, (my_tag), double, (const parameters*)) // Needs function from a backend
    BACKEND_OPTION( (SuperIso, 3.6), (my_tag) )                     // Backend must be SuperIso 3.6
    DEPENDENCY(SuperIso_modelinfo, parameters)           // Needs another function to calculate SuperIso info
    ALLOW_MODELS(MSSM63atQ, MSSM63atMGUT)                // Works with weak/GUT-scale MSSM and descendents
    #undef FUNCTION
  #undef CAPABILITY
```

2. Write the function as a standard C++ function (one argument: the result)

from Pat Scott

Type-II: key1

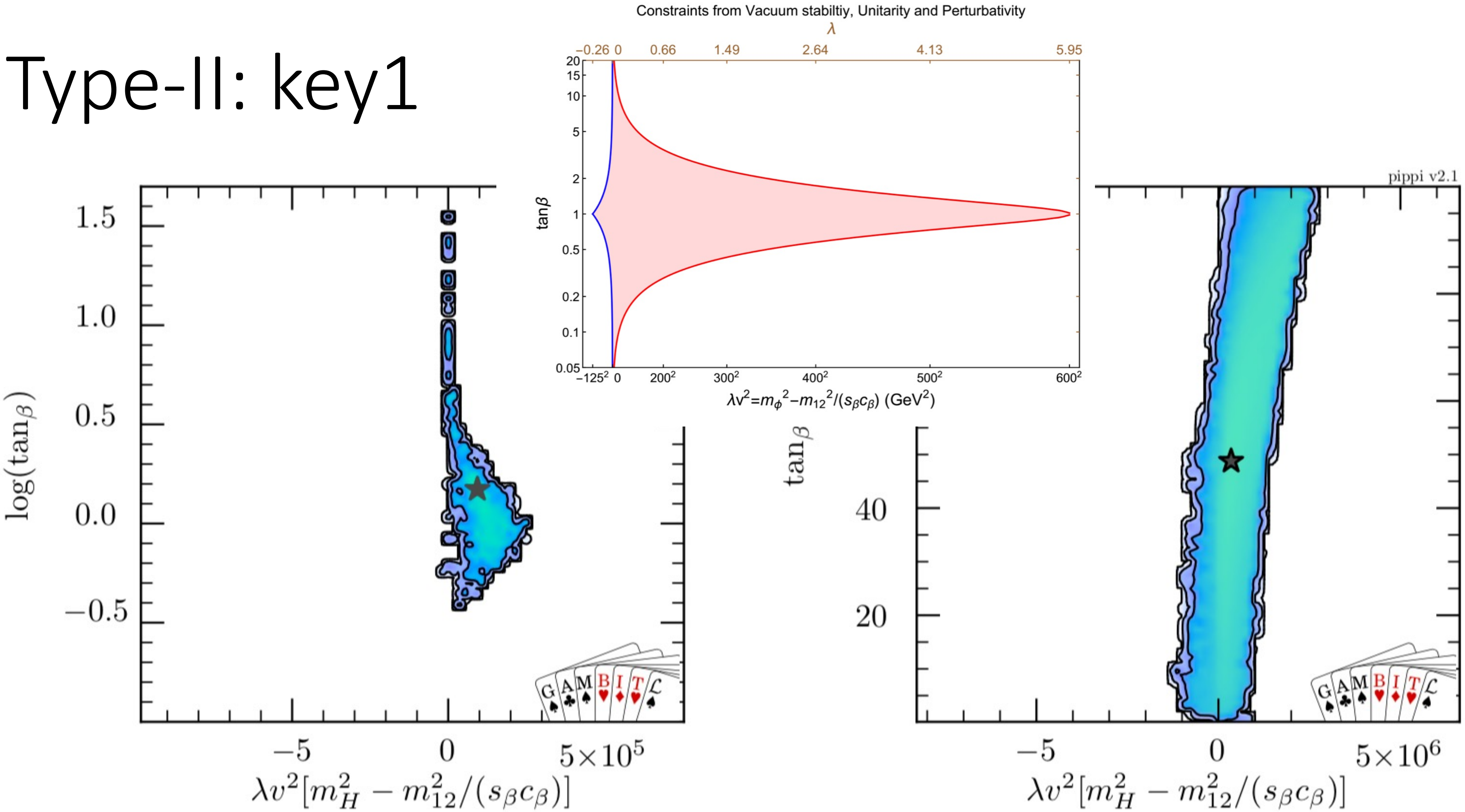


Fig. 12: The theoretical allowed region at LO(left) and NLO (right) level. **Wei: reshape the plots**

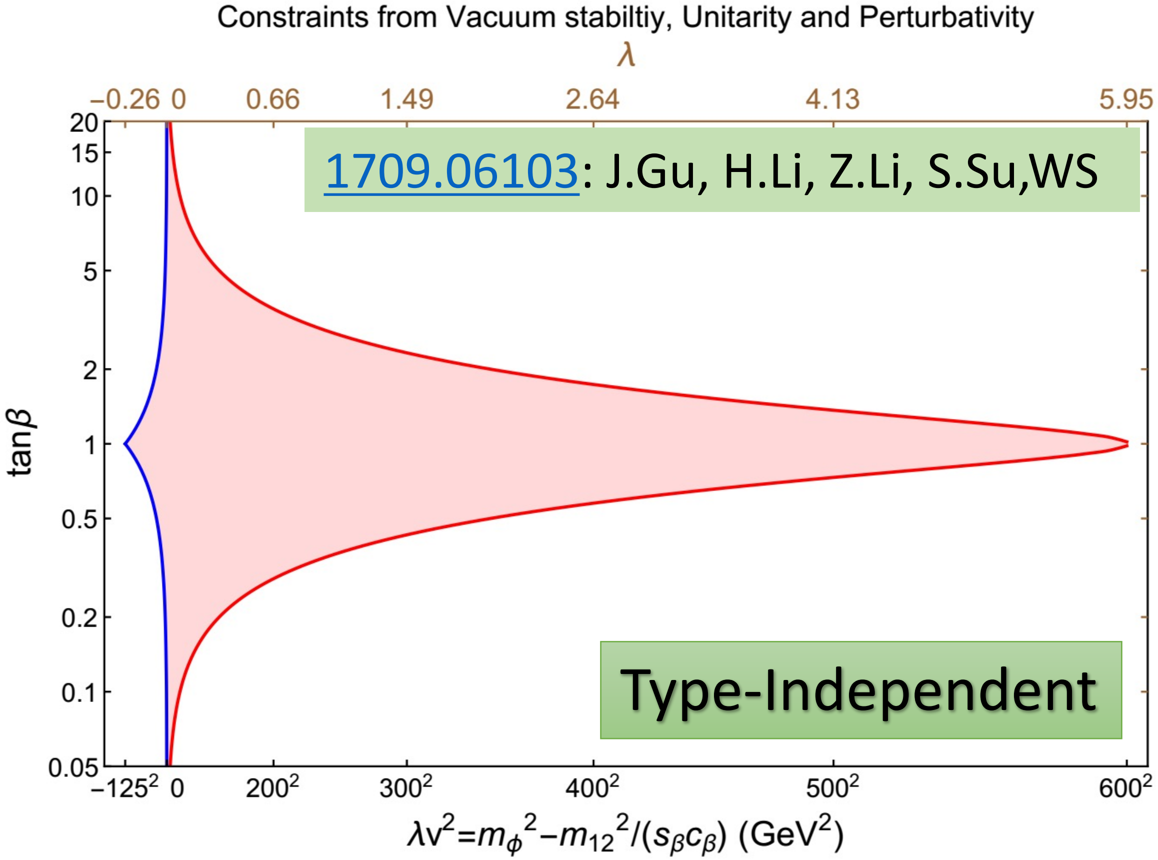
Constraints: theory

- Perturbativity
- Stability of the potential
- Unitarity of the scattering matrix

$$\cos(\beta - \alpha) = 0,$$
$$m_\Phi \equiv m_H = m_A = m_{H^\pm}$$

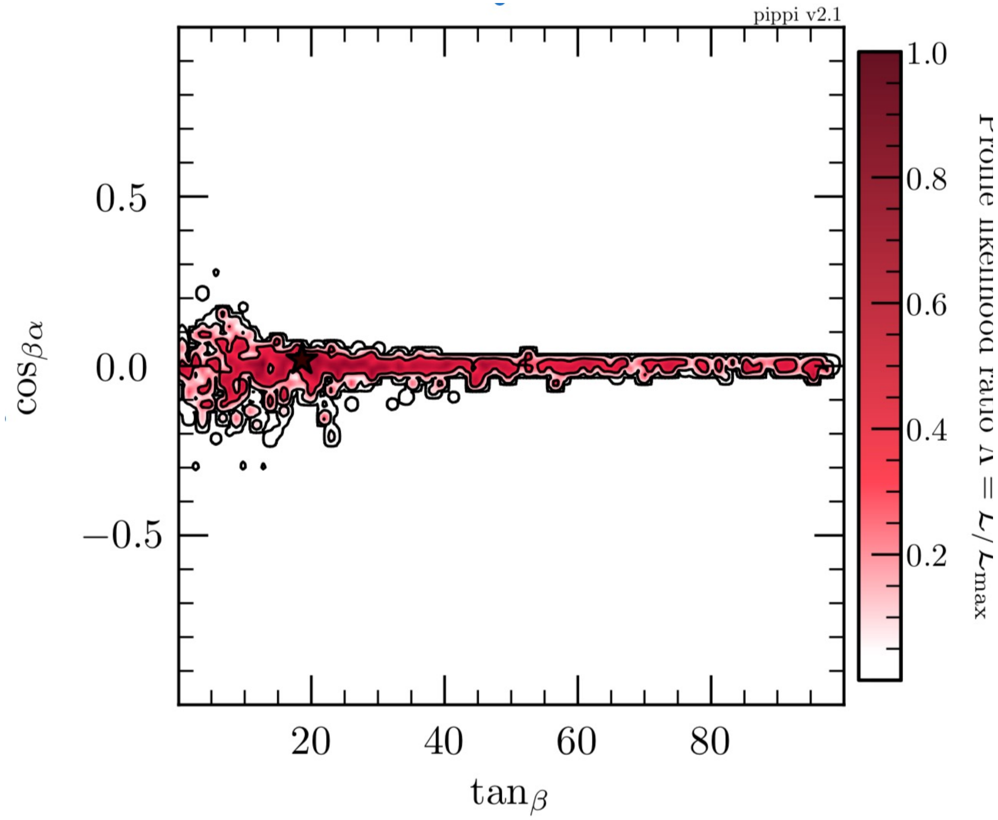
$$\lambda v^2 \equiv m_\Phi^2 - m_{12}^2 / s_\beta c_\beta$$

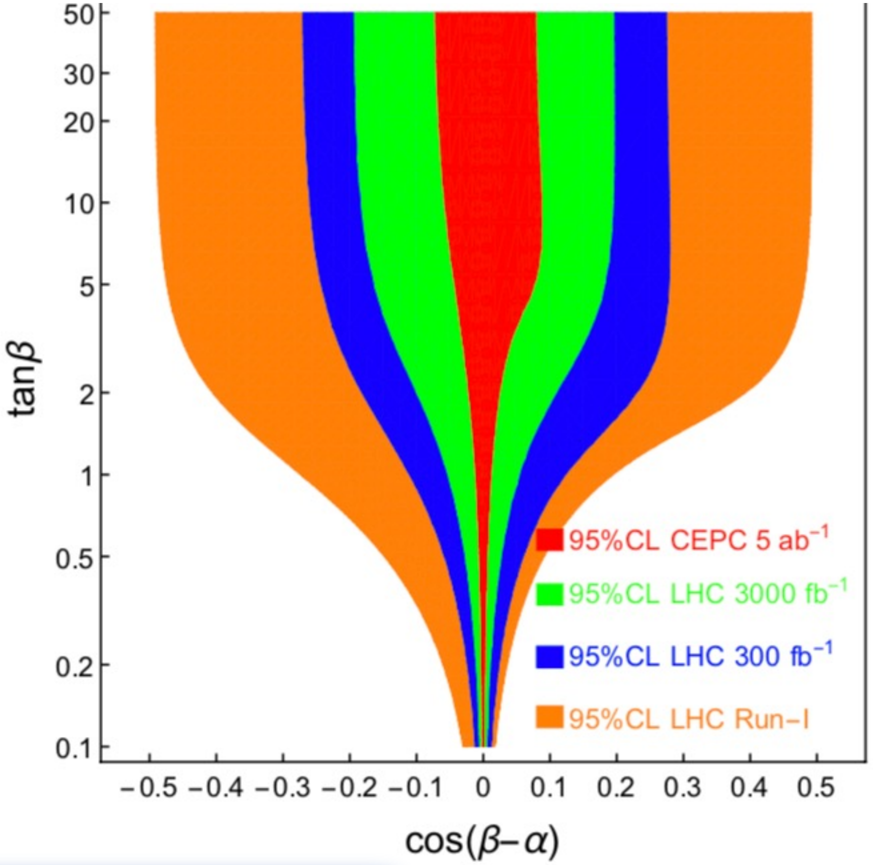
$$-125^2\mathrm{GeV}^2 < \lambda v^2 < 600^2\mathrm{GeV}^2$$



Type-I

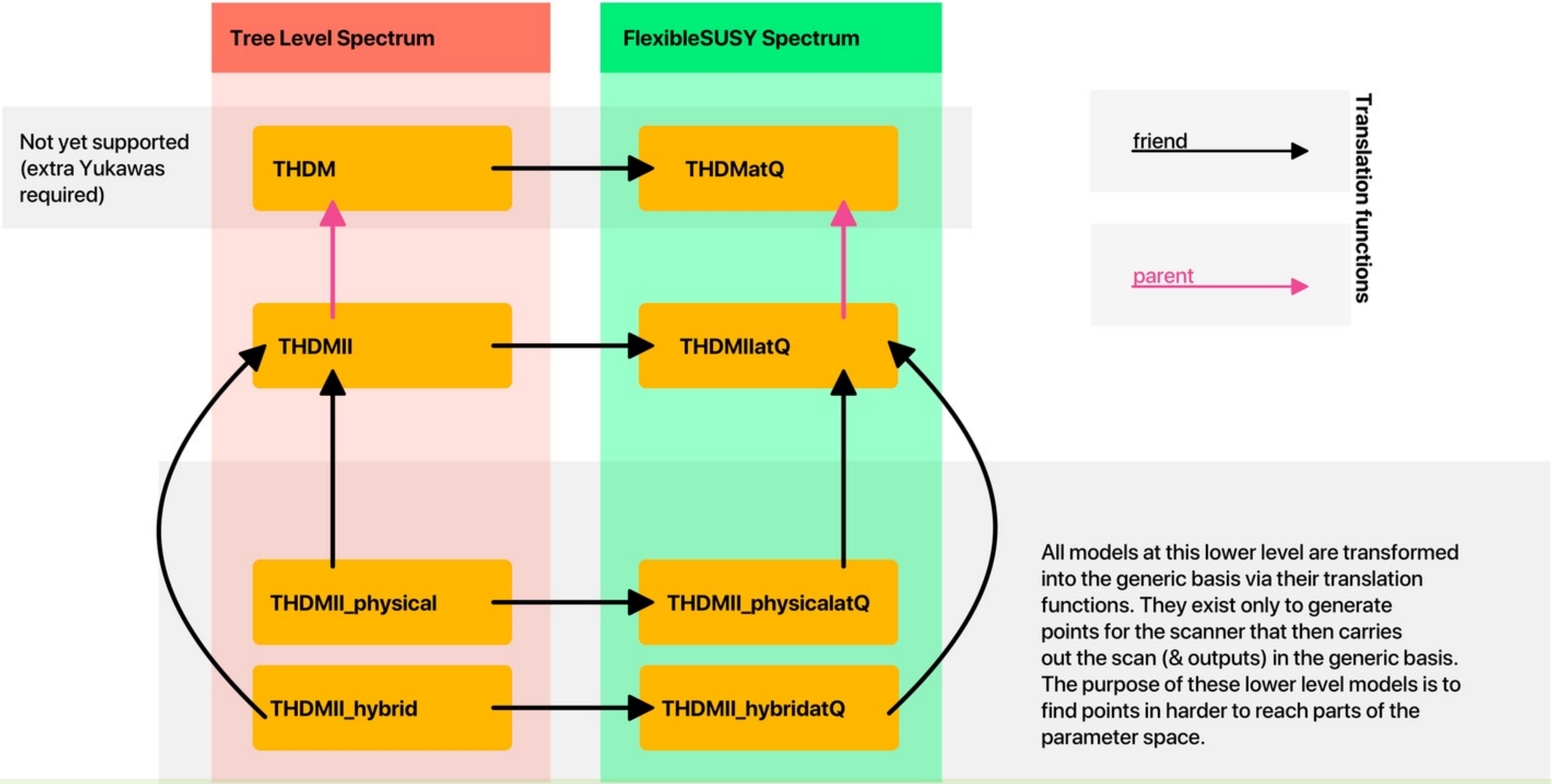
Model	κ_V	κ_u	κ_d	κ_ℓ
2HDM-I	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$
2HDM-II	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$-\sin\alpha/\cos\beta$
2HDM-L	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$
2HDM-F	$\sin(\beta-\alpha)$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$





$$\Delta\kappa_{u,d,e} = \frac{\cos\alpha}{\sin\beta} - 1 = -\frac{1}{2}\cos^2(\beta-\alpha) + \frac{\cos(\beta-\alpha)}{\tan\beta}$$

2HDM branch @Gambit



GAMBIT features

flexible and extendable

- fast definition of new models, data sets, sampling methods
- plug&play theory tools (auto-download, compile, dynamically link!)
- easily switch between backends calculating the same quantities
- C/C++, Fortran, Python, Mathematica interfaces for backends
- input: model, para.s, observables, sampler, stat. inference
- customizable output streams: ASCII, HDF5…
- GAMBIT 2: input Lagrangian, auto-generate code for obs.s, …
- …

GAMBIT: The Global And Modular BSM Inference Tool

gambit.hepforge.org github.com/GambitBSM EPJC 77 (2017) 784 arXiv:1705.07908

database, beyond SUSY

Blah…

Who cares about global fits?

Is this a glorified wrapper?

What can it do for *me*?

tDM, Diver,
EasyScanHEP, ExoCLASS, FlexibleSUSY, gamLike, GM2Calc, HEPLike, IsaTools, MARTY, nuLike, PhaseTracer, PolyChord, Rivet, SOFTSUSY, Superlso, SUSY-AI, xsec, Vevacious, WIMPSim

ators: P Athron, C Balázs, A Beniwal, S
ngmann, A Buckley, J-E Camargo-Molina, C
ang, 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