SUSY Global Fits With Future Colliders Using GAMBIT

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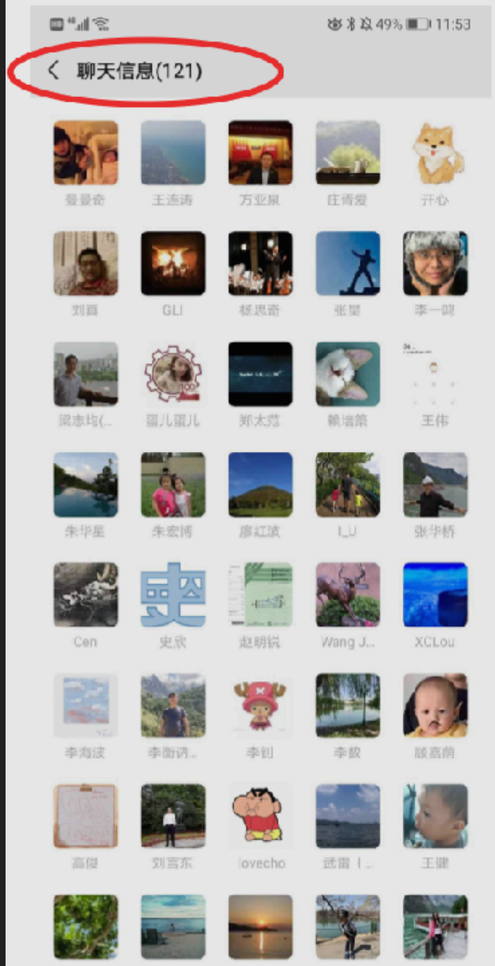
In collaboration with P. Athron, C. Balazs, A. Fowlie, H. Lv, F. Mahmoudi, M. T. Prim, P. Scott, , W. Su and L. Wu

Outline

- Motivation
- Preliminary results
- Plans of following works

Slide from Manqi Ruan's talk at CEPC working group: Toward the CEPC physics white papers

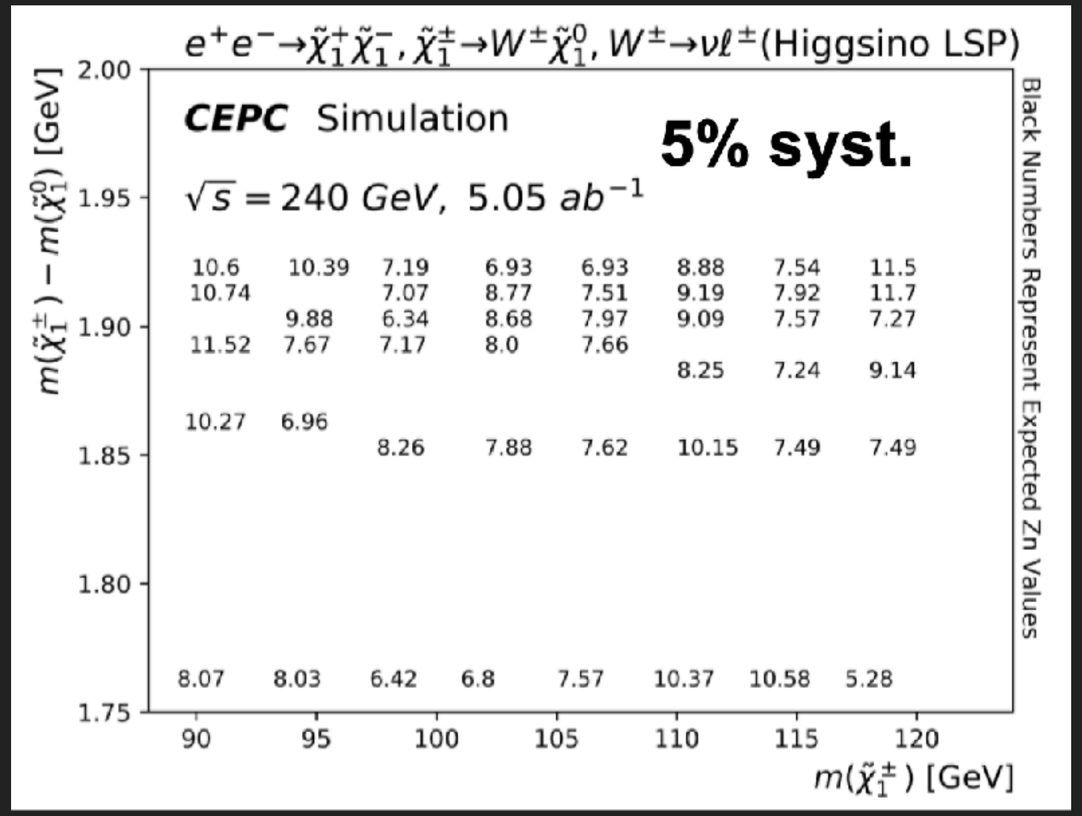
CEPC @ Snowmass



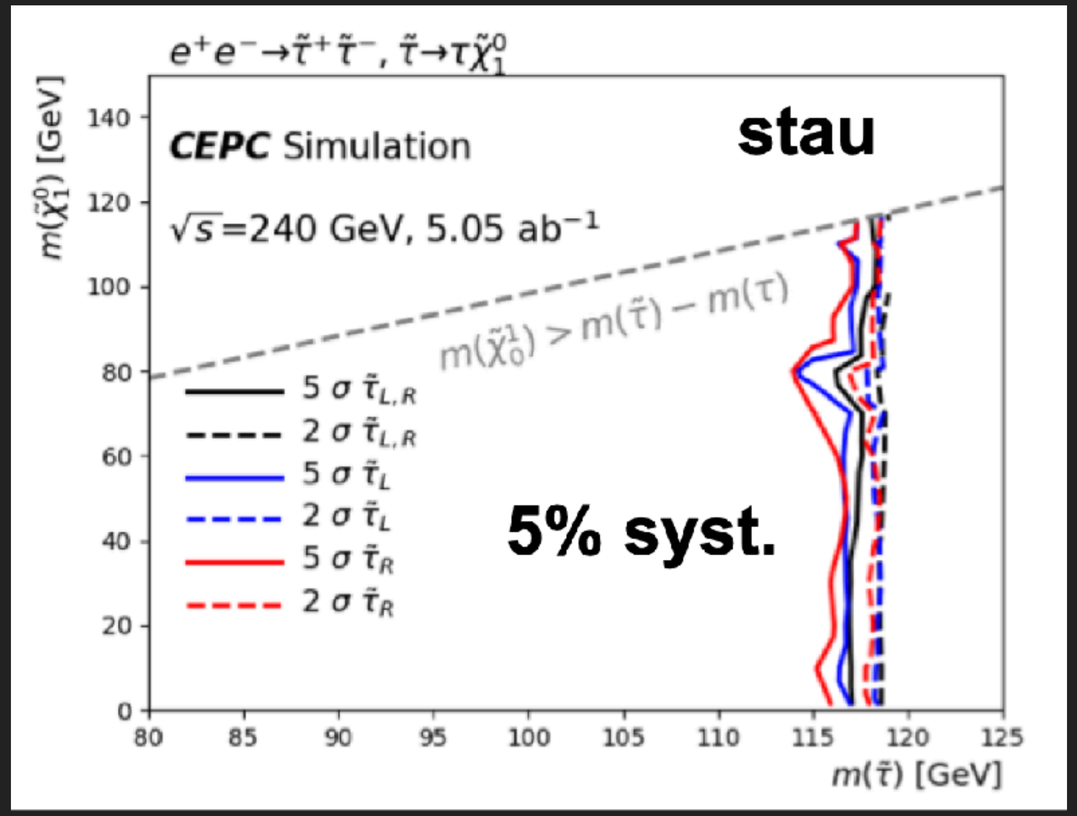
title	ID	author	link
Study of electroweak phase transition in exotic Higgs decays with CEPC Detector simulation	229-v1	Michael Ramsey-Musolf	URL
Exclusive Z decays	226-v1	Qin Qin	URL
Measurement of the leptonic effective weak mixing angle at CEPC	233-v1	Siqi Yang	URL
Heavy Neutrino search in Lepton-Rich Higgs Boson Rare Decays	244-v1	Yu Gao	URL
Higgs boson CP properties at CEPC	227-v1	Xin Shi	URL
Measurement of branching fractions of Higgs hadronic decays	228-v1	Yanping Huang	URL
Feasibility study of CP-violating Phase phi_s measurement via Bs->J/PsiPhi channel at CEPC	230-v1	Mingrui Zhao	URL
Probing top quark FCNC couplings tqr, tqZ at future e+e- collider	231-v1	Peiwen Wu	URL
Searching for $B_s \to \phi\nu\nu$ and other b->dvv processes at CEPC	232-v1	Yanyun Duan	URL
Probing new physics with the measurements of e+e- -> W+W- at CEPC with optimal observables	234-v1	Jiayin Gu	URL
NNLO electroweak correction to Higgs and Z associated production at future Higgs factory	235-v1	Zhao Li	URL
SUSY global fits with future colliders using GAMBIT	237-v1	Peter Athron	URL
Probing Supersymmetry and Dark Matter at the CEPC, FCCee, and ILC	238-v1	Waqas Ahmed	URL
Search for t + j + MET signals from dark matter models at future e+e- collider	239-v1	Peiwen Wu	URL
Search for Asymmetric Dark Matter model at CEPC by displaced lepton jets	240-v1	Mengchao Zhang	URL
Dark Matter via Higgs portal at CEPC	241-v1	Tianjun Li	URL
Lepton portal dark matter, gravitational waves and collider phenomenology	242-v1	Jia Liu	URL
CEPC Detectors Letter of Intent	245-v1	Jianchun Wang	URL

Exploring SUSY at CEPC

- Direct searches



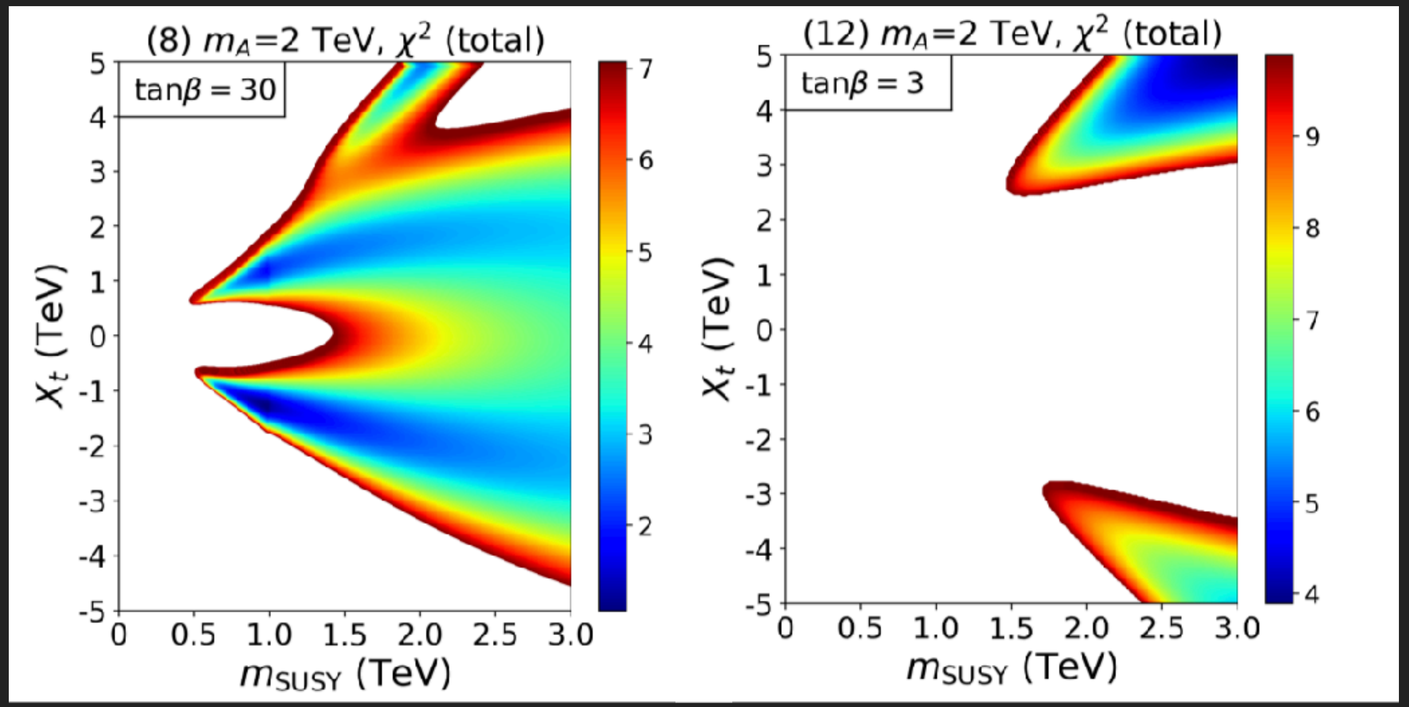
arXiv:2105.0613, J.R. Yuan, H.J. Cheng and X. Zhuang



From Xuai Zhuang's slides at CEPC workshop

Exploring SUSY at CEPC

- Indirect searches



arXiv:2010.09782, H. Li, H. Song, S. Su, W. Su, J. M. Yang

CEPC Higgs fit only

- MSSM contribution to κ_b, the Higgs coupling normalized to the SM value, is

$$\kappa_b = -\frac{\sin\alpha_{eff}}{\cos\beta}\tilde{\kappa}_h^b,$$

$$\tilde{\kappa}_h^b = \frac{1}{1+\Delta m_b}\left(1 - \Delta m_b \frac{1}{\tan\alpha_{eff}\tan\beta}\right)$$

- The loop contribution of the stop sector is

$$\Delta m_b^{stop} = \frac{h_t^2}{16\pi^2}\mu A_t \tan\beta I(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu)$$

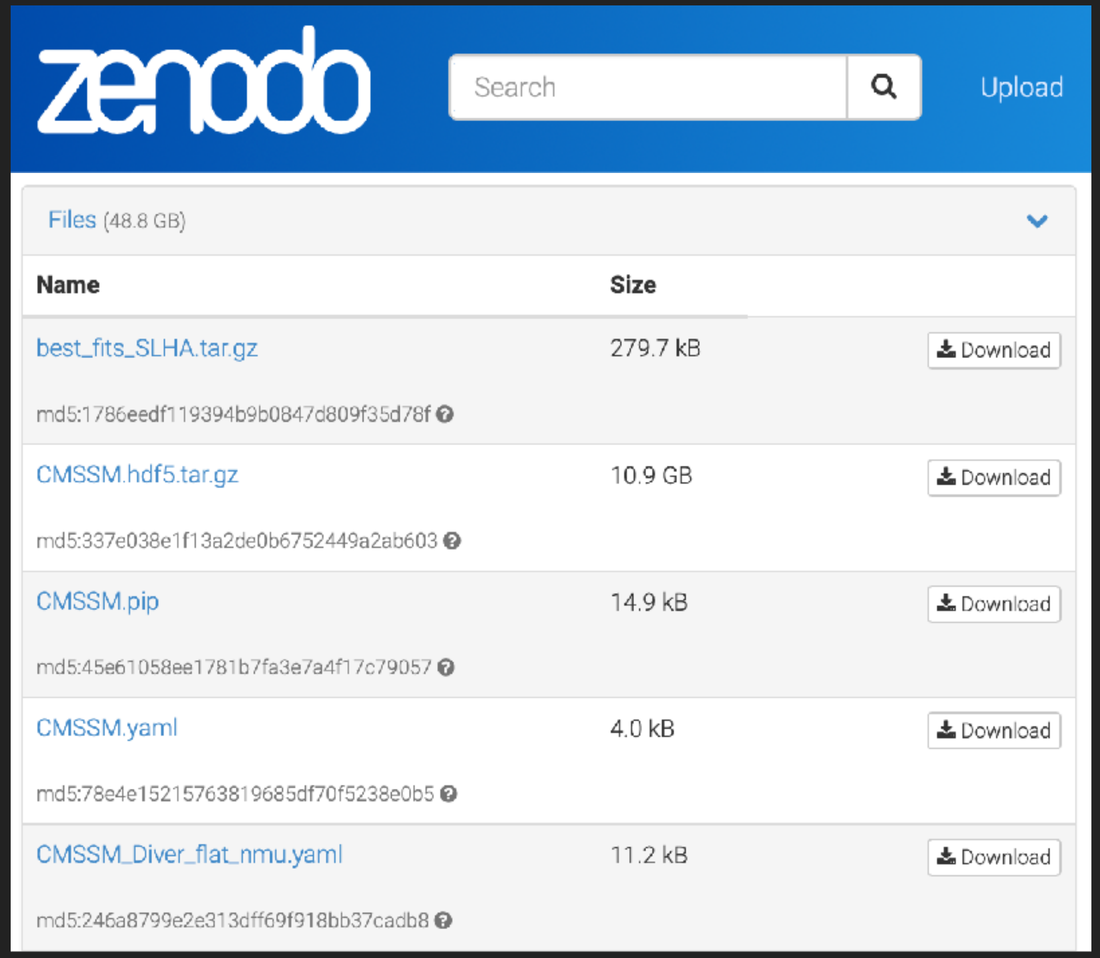
Exploring SUSY at CEPC

- Indirect searches
- Global fits with present likelihood:

$$\mathcal{L}_{\text{Present+CEPC}} = \mathcal{L}_{\text{CEPC}}\mathcal{L}_{\text{Present}}$$

$$= \mathcal{L}_{\text{CEPC}}\mathcal{L}_{\text{collider}}\mathcal{L}_{\text{DM}}\mathcal{L}_{\text{flavor}}\mathcal{L}_{\text{EWPO}} \cdots$$

- This is extremely time consuming.
- A short cut is to utilise data sampled using $\mathcal{L}_{\text{Present}}$.

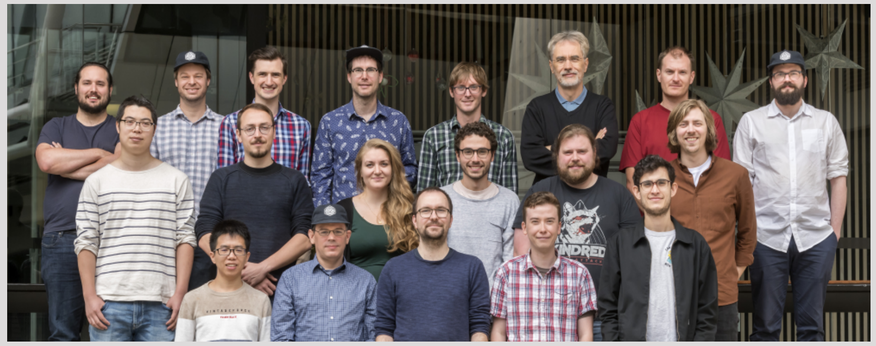


GAMBIT: The Global And Modular BSM Inference Tool

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



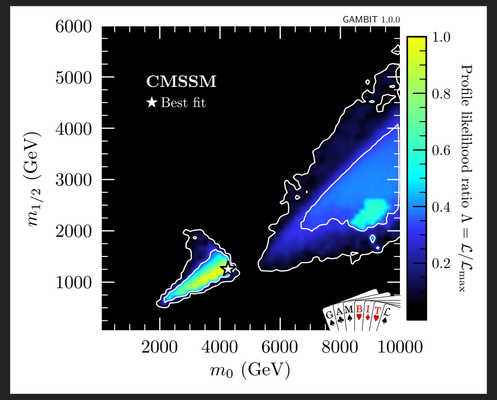
Members of:
ATLAS, Belle-II, CLiC, CMS, CTA, *Fermi*-LAT, DARWIN, IceCube, LHCb, SHiP, XENON

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

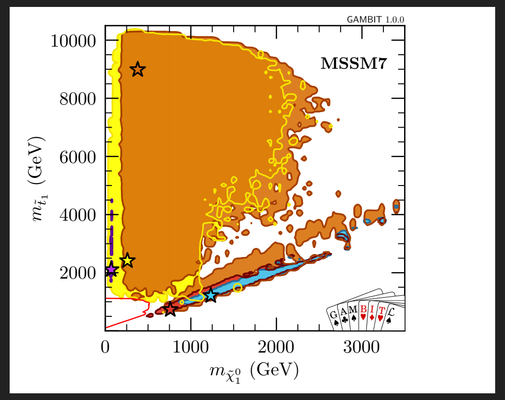
Recent collaborators:
F Agocs, V Ananyev, P Athron, C Balázs, A Beniwal, J Bhom, S Bloor, T Bringmann, A Buckley, J-E Camargo-Molina, C Chang, M Chrzaszcz, J Conrad, J Cornell, M Danninger, J Edsjö, B Farmer, A Fowlie, T Gonzalo, P Grace, W Handley, J Harz, S Hoof, S Hotinli, F Kahlhoefer, N Avis Kozar, A Kvellestad, P Jackson, A Ladhu, N Mahmoudi, G Martinez, MT 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

70+ participants in 11 experiments and 14 major theory codes

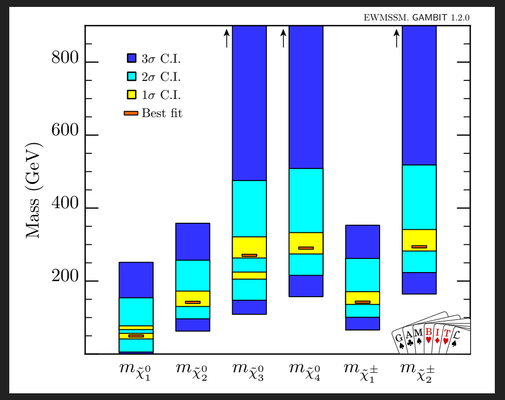
GAMBIT physics publications



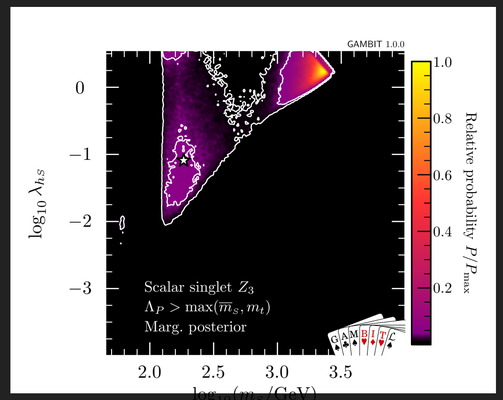
CMSSM/NUHM1/NUMH2
(EPJC, arXiv:1705.07935)



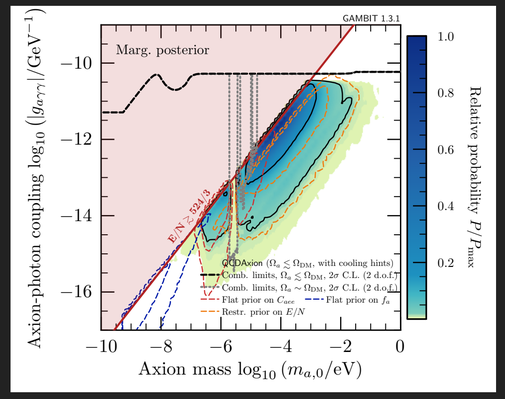
MSSM7
(EPJC, arXiv:1705.07917)



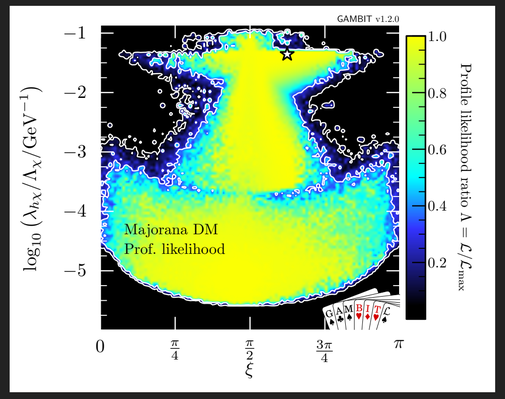
MSSM7
(EPJC, arXiv:1809.02097)



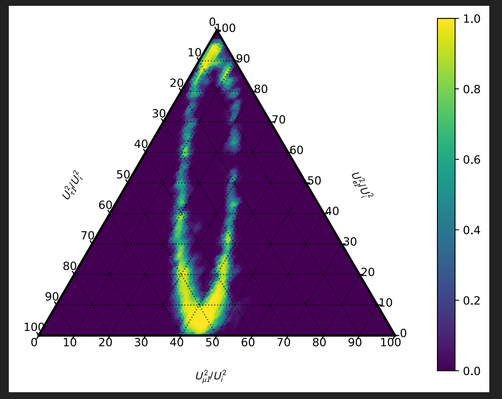
Scalar singlet dark matter
(EPJC, arXiv:1705.07931)



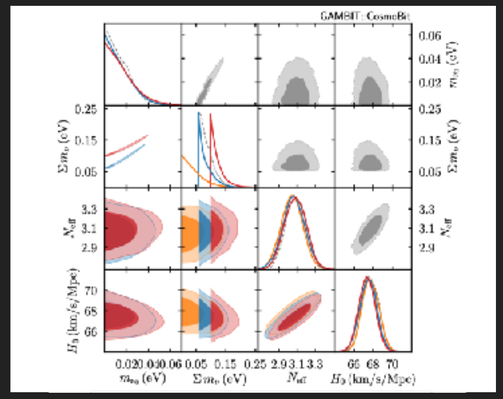
Axions & ALPs
(EPJC, arXiv:1810.07192)



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



Right-handed neutrinos
(EPJC / arXiv:1908.02302)



Neutrino masses
(PRD, arXiv:2009.03287)

CEPC Higgs likelihood

$$-2\ln\mathscr{L}_{\mathrm{CEPC}} = \frac{(m_h^{\mathrm{SUSY}} - m_h^{\mathrm{obs}})^2}{(\Delta m_h)^2} + \sum_{i=f,V,\ldots} \frac{(\mu_i^{\mathrm{SUSY}} - \mu_i^{\mathrm{obs}})^2}{(\Delta\mu_i)^2}, \quad \mu_i = \frac{(\sigma_i \times \mathrm{Br}_i)}{(\sigma_i \times \mathrm{Br}_i)^{\mathrm{SM}}}.$$

- $m_h^{\mathrm{obs}} = 125.25$ GeV, $\Delta m_h = \sqrt{0.17^2 + 2^2} = 2.007$ GeV

Decay mode	Branching ratio	Relative uncertainty
$H \to b\bar{b}$	57.7%	$+3.2\%, -3.3\%$
$H \to c\bar{c}$	2.91%	$+12\%, -12\%$
$H \to gg$	8.57%	$+10\%, -10\%$
$H \to \tau^+\tau^-$	6.32%	$+5.7\%, -5.7\%$
$H \to \mu^+\mu^-$	2.19×10^{-4}	$+6.0\%, -5.9\%$
$H \to WW^*$	21.5%	$+4.3\%, -4.2\%$
$H \to ZZ^*$	2.64%	$+4.3\%, -4.2\%$
$H \to \gamma\gamma$	2.28×10^{-3}	$+5.0\%, -4.9\%$
$H \to Z\gamma$	1.53×10^{-3}	$+9.0\%, -8.8\%$
Γ_H	4.07 MeV	$+4.0\%, -4.0\%$

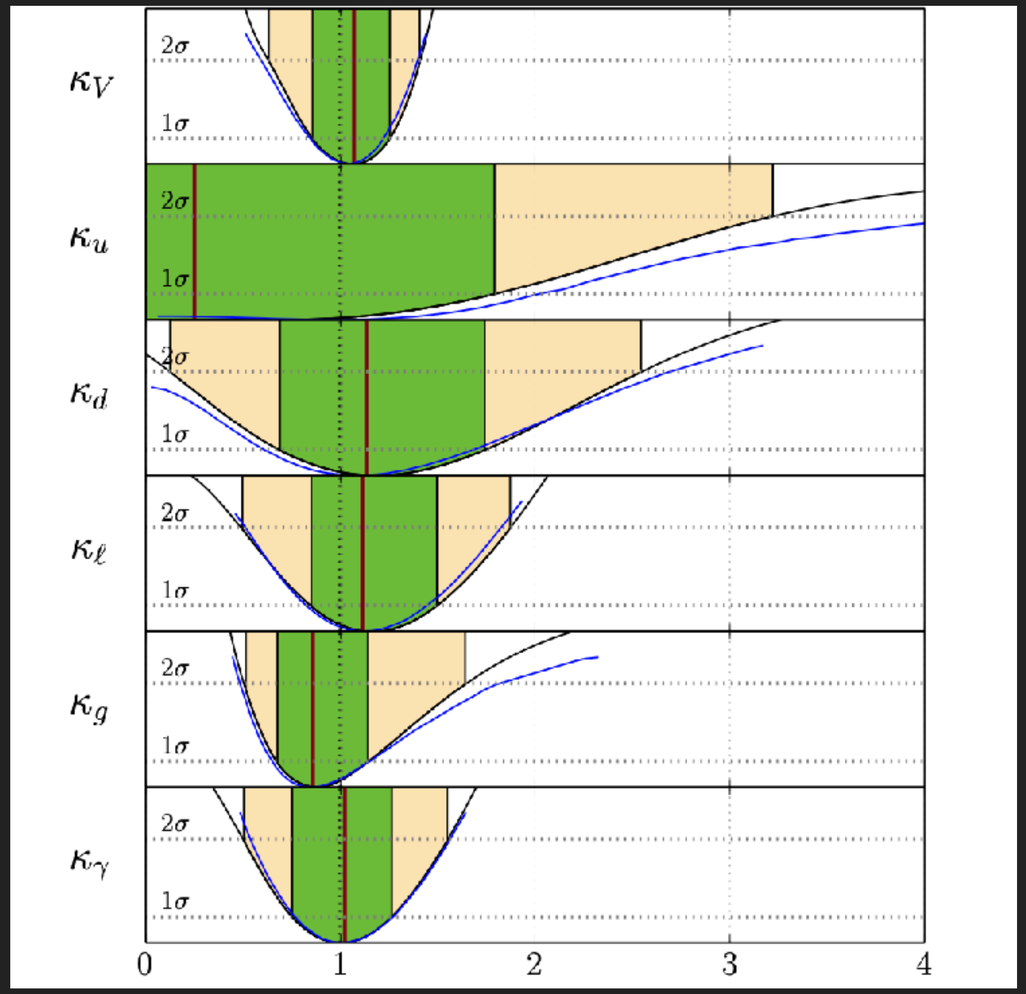
SM predictions for a 125 GeV Higgs boson

Property	Estimated Precision	
Decay mode	$\sigma(ZH) \times$ BR	BR
$H \to b\bar{b}$	0.27%	0.56%
$H \to c\bar{c}$	3.3%	3.3%
$H \to gg$	1.3%	1.4%
$H \to WW^*$	1.0%	1.1%
$H \to ZZ^*$	5.1%	5.1%
$H \to \gamma\gamma$	6.8%	6.9%
$H \to Z\gamma$	15%	15%
$H \to \tau^+\tau^-$	0.8%	1.0%
$H \to \mu^+\mu^-$	17%	17%
$H \to$ inv	–	$< 0.30\%$

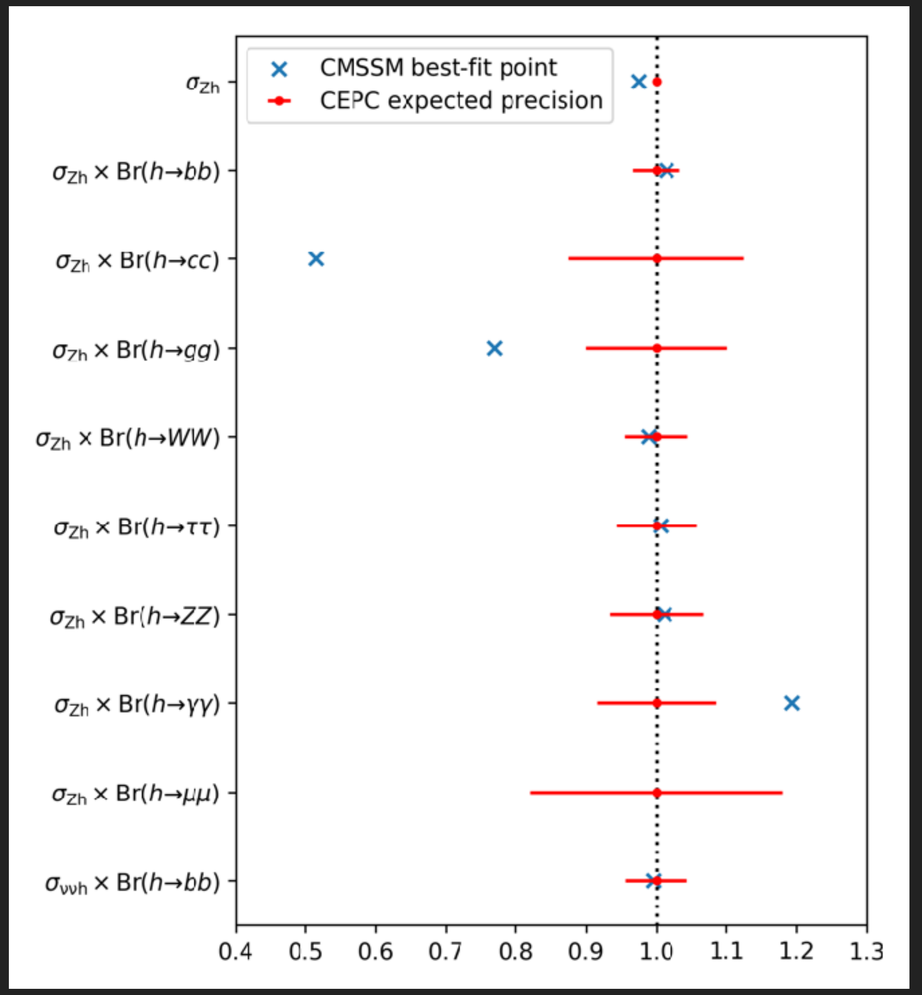
Estimated precision of CEPC

CEPC Higgs likelihood

$-2\ln \mathscr{L}^{\mathrm{SM}}_{\mathrm{CEPC}} = 81.6$



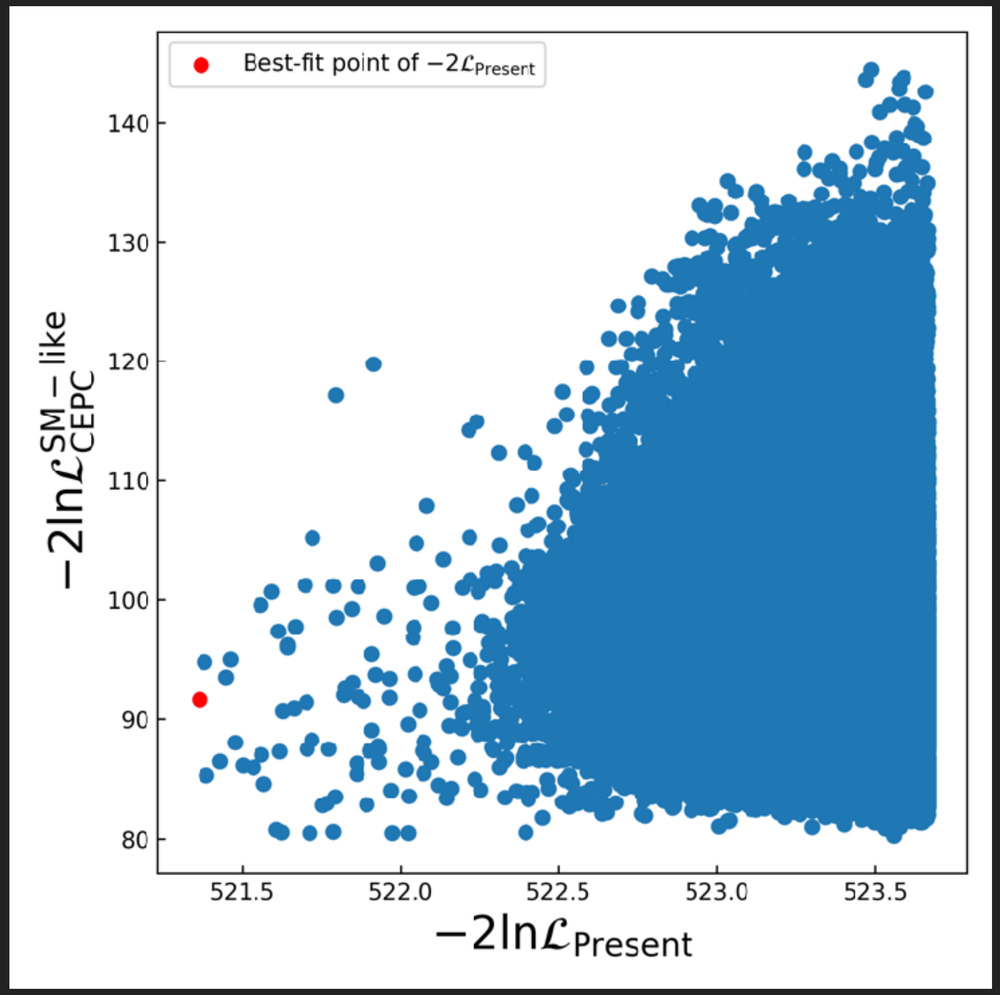
From HiggsSignals, arXiv:1403.1582

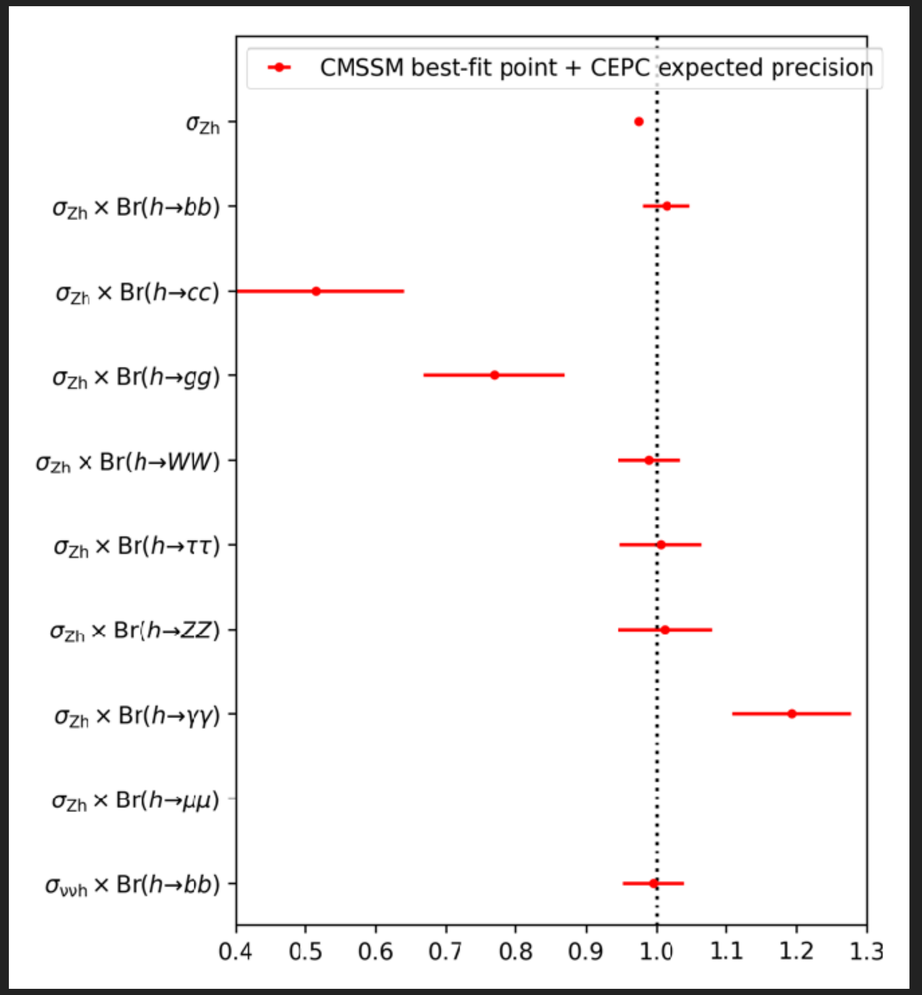


Normalised to SM

CEPC Higgs likelihood

$-2\ln \mathscr{L}^{\mathrm{BF}}_{\mathrm{CEPC}} = 0$

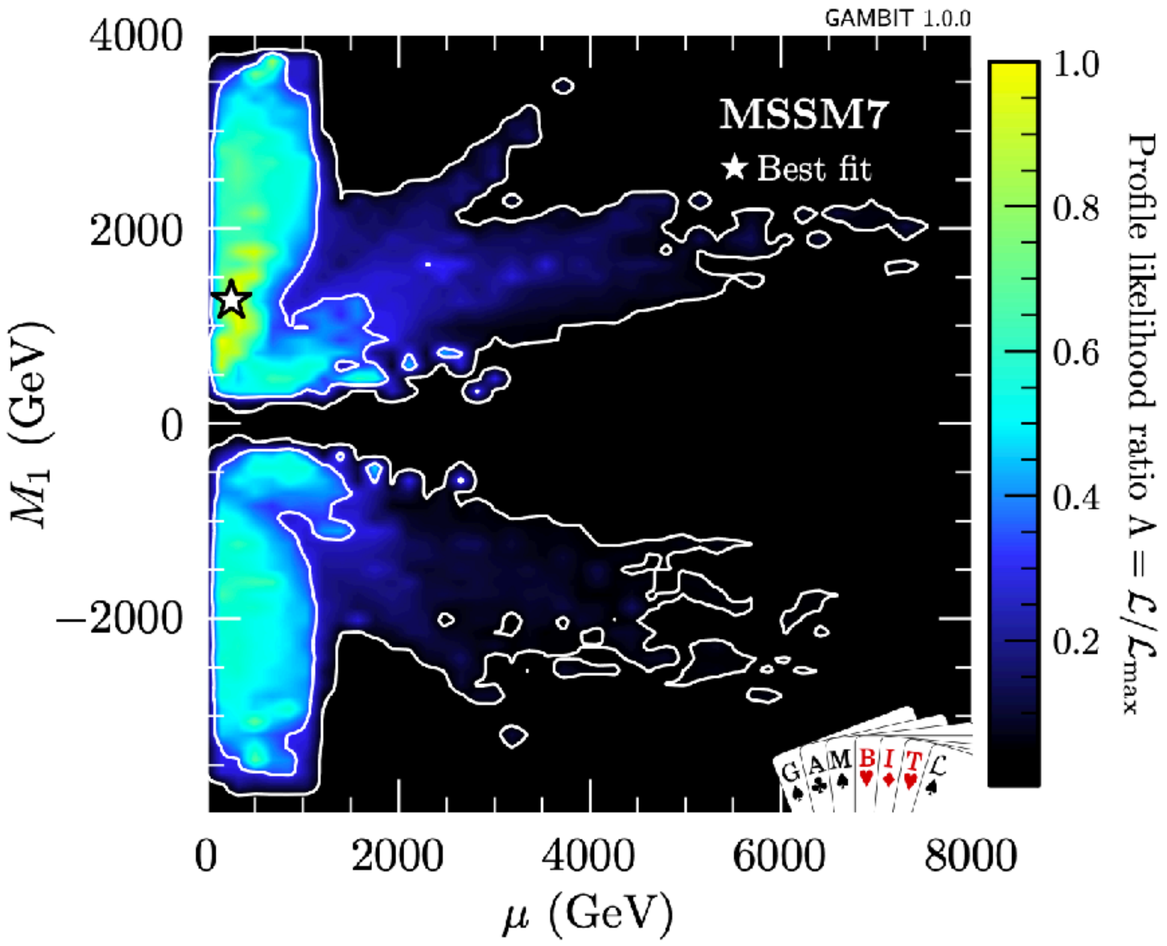


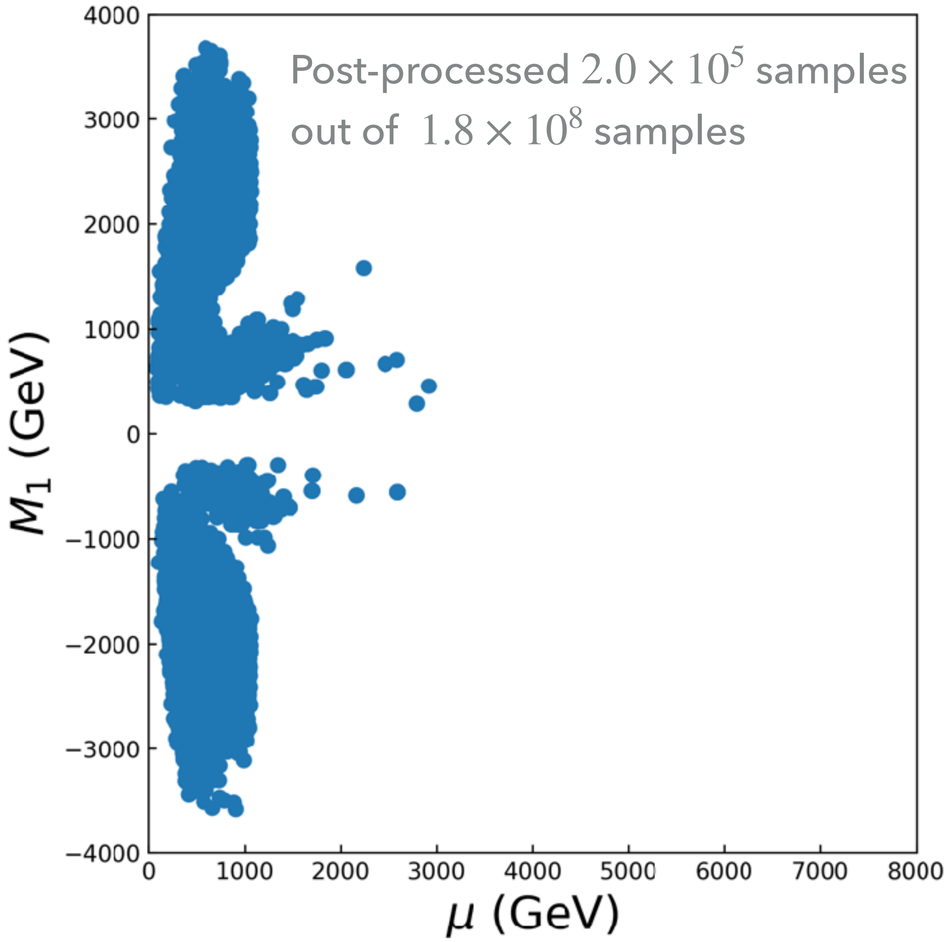


Normalised to SM

CEPC Higgs likelihood

As a test run, we post-processed some of the samples in 1σ region.





CEPC Higgs likelihood

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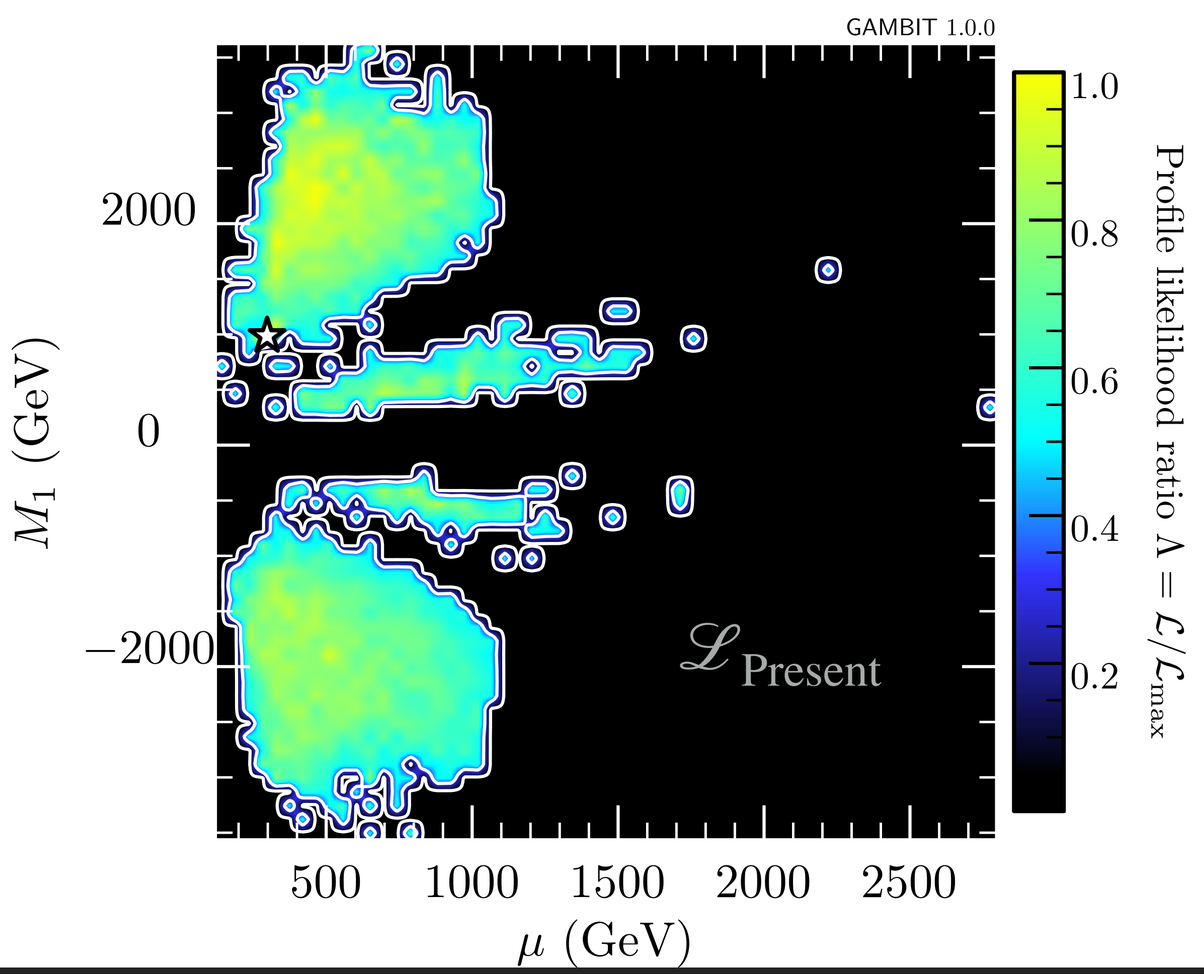
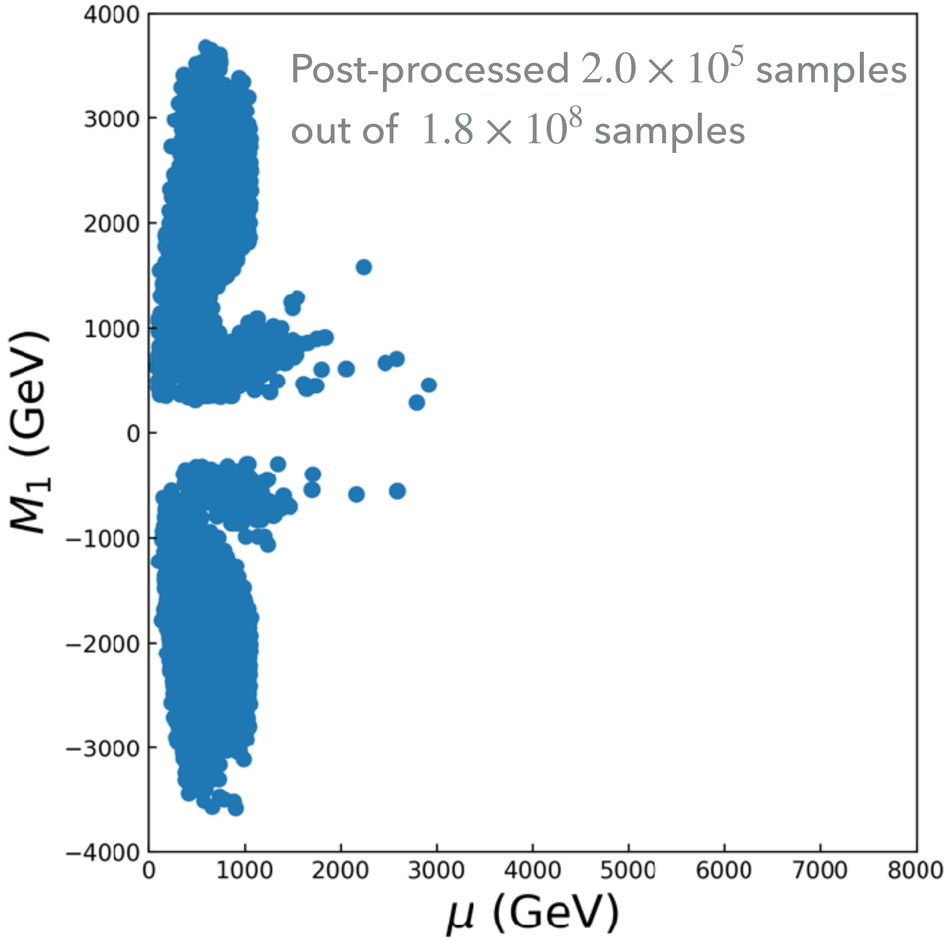
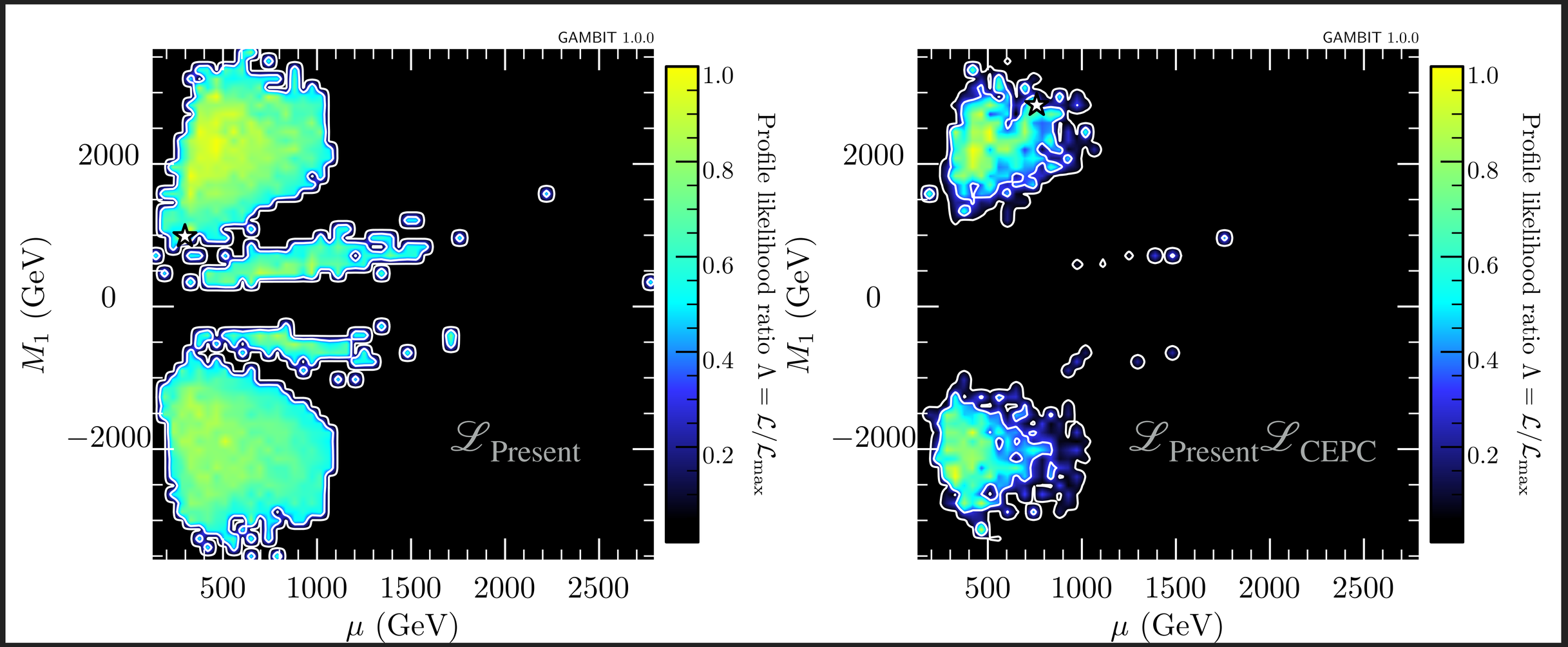
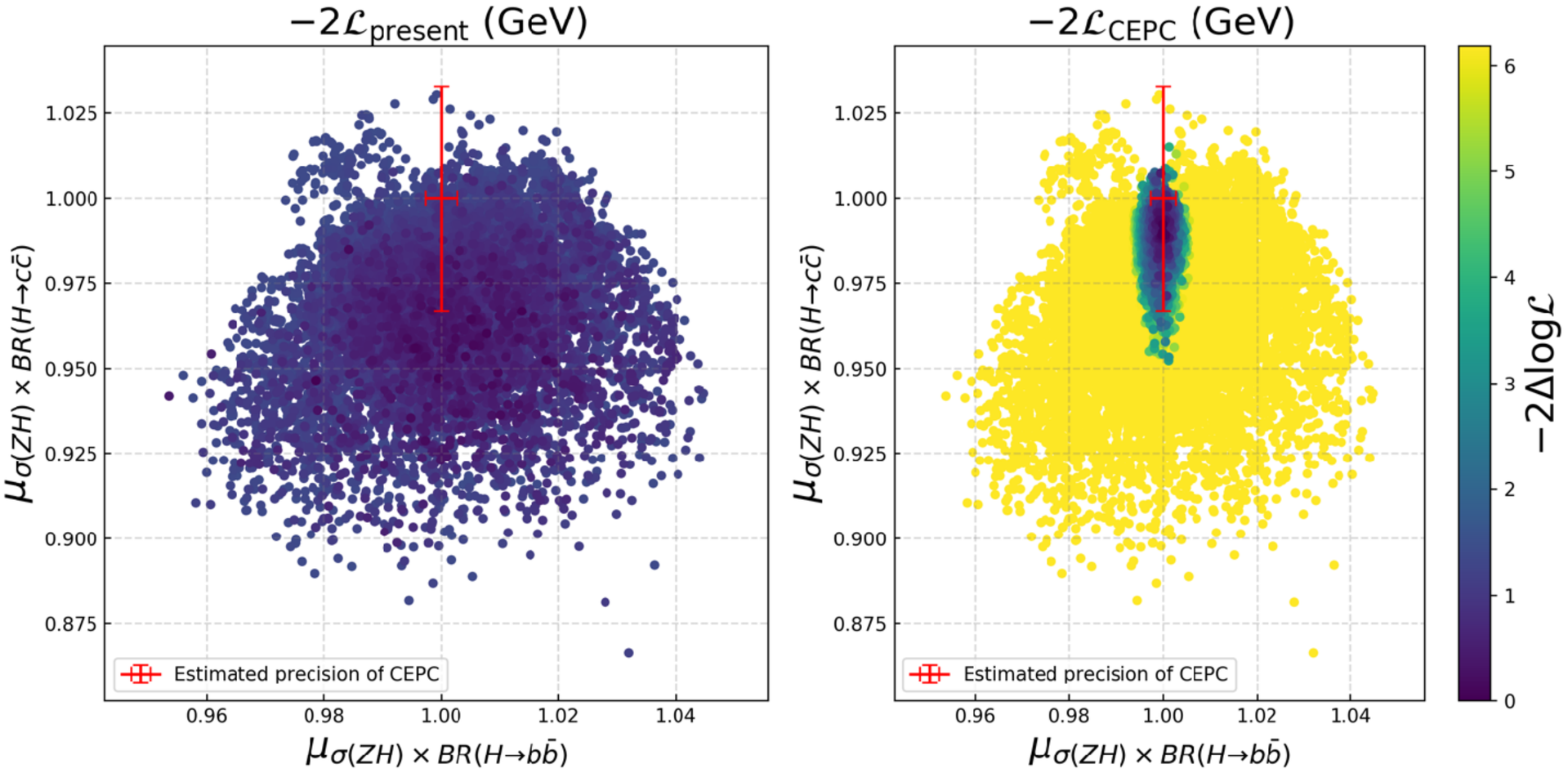




Impact of CEPC Higgs likelihood



Impact of CEPC Higgs likelihood



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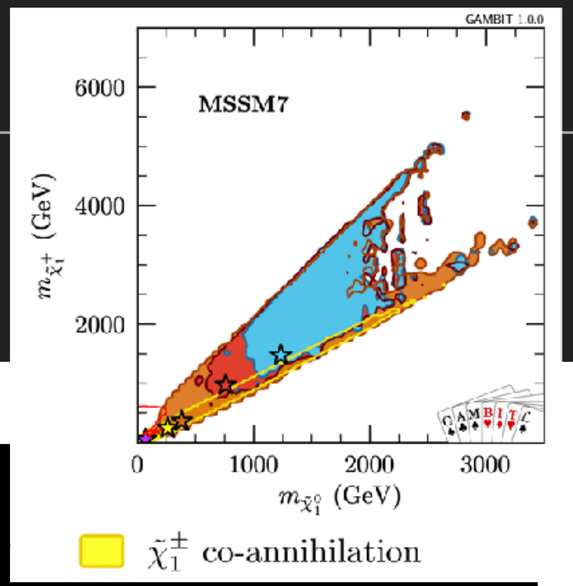
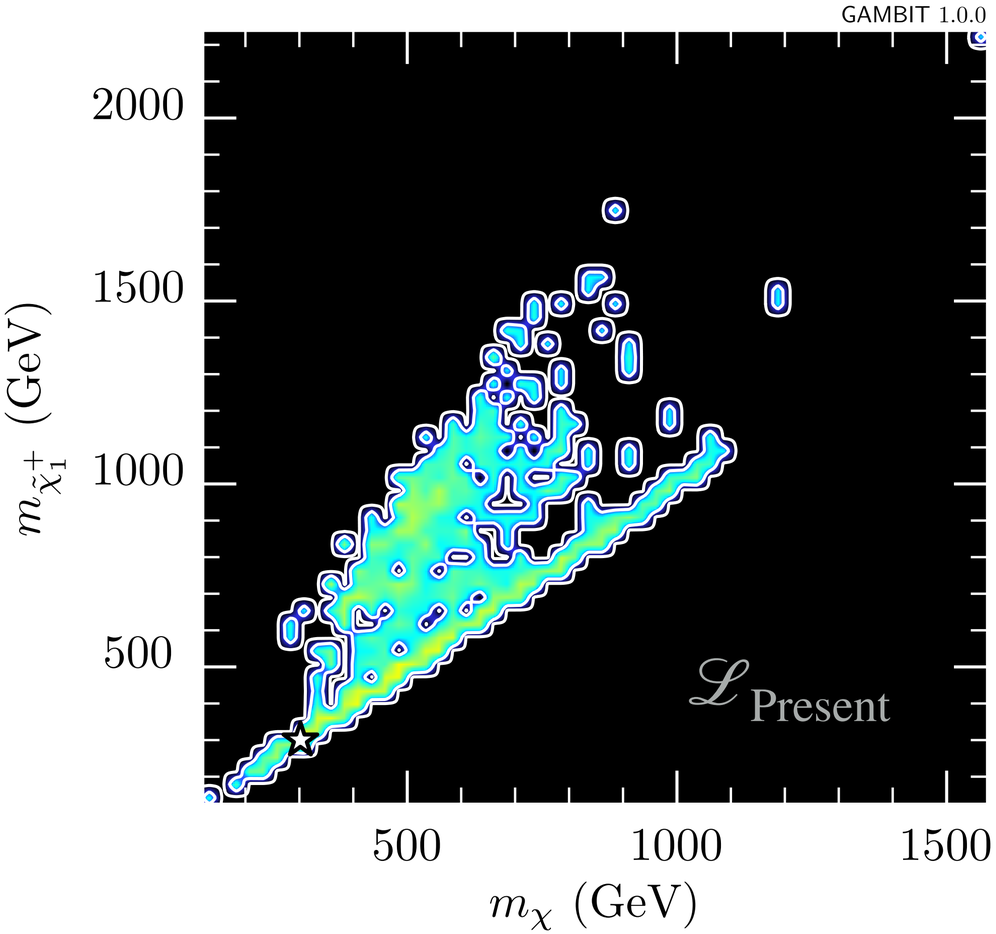
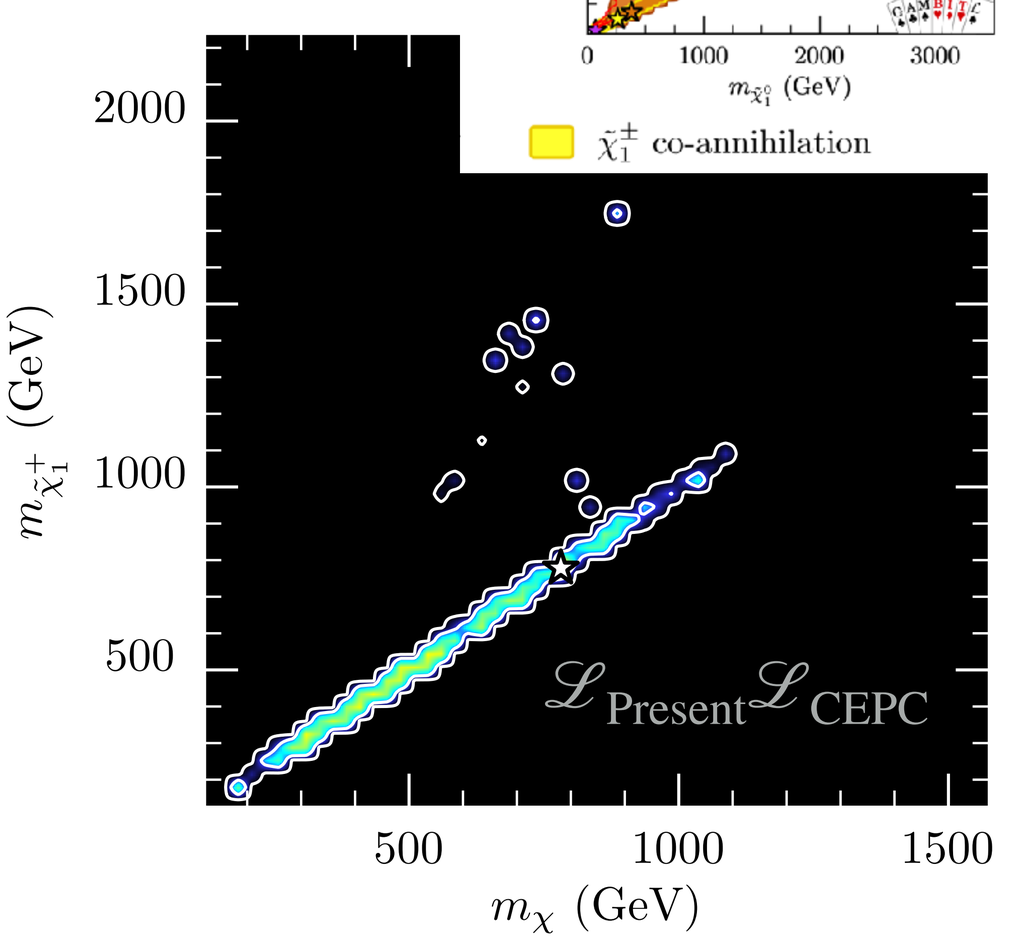
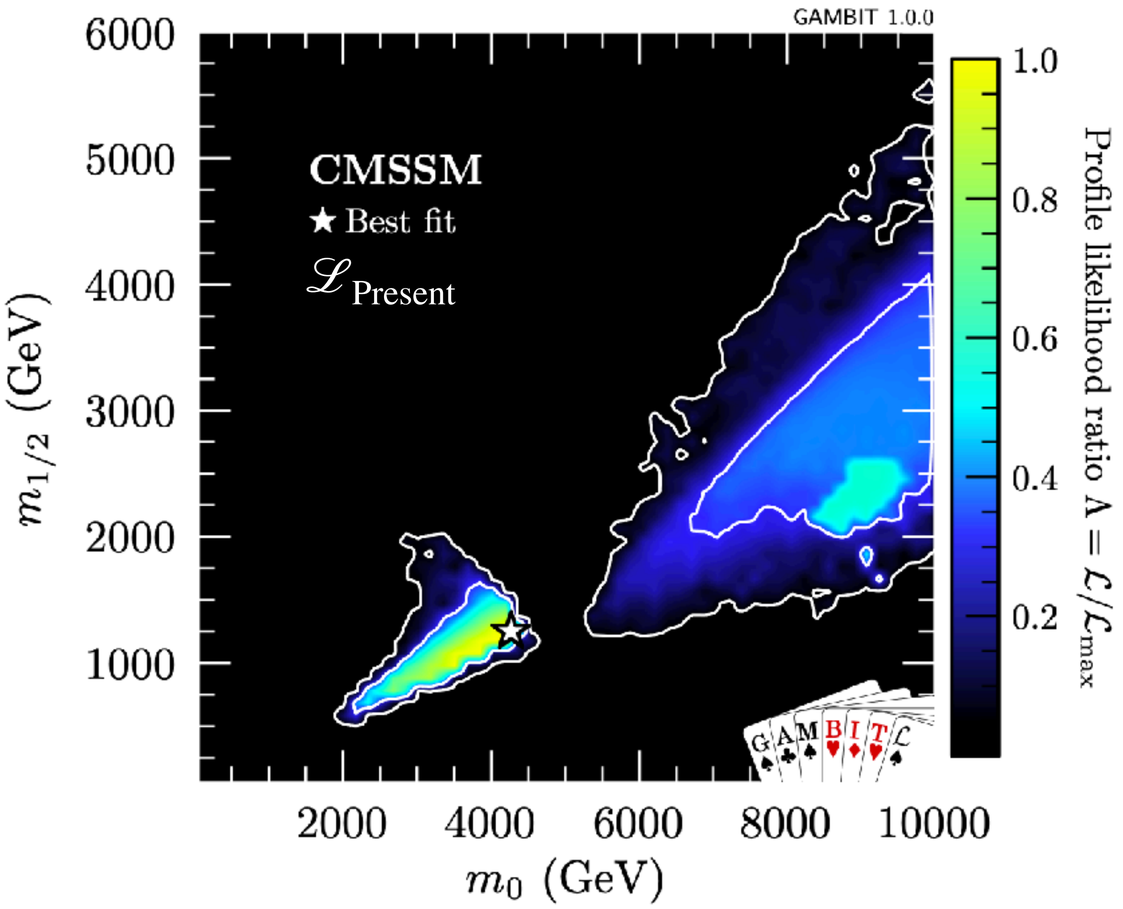
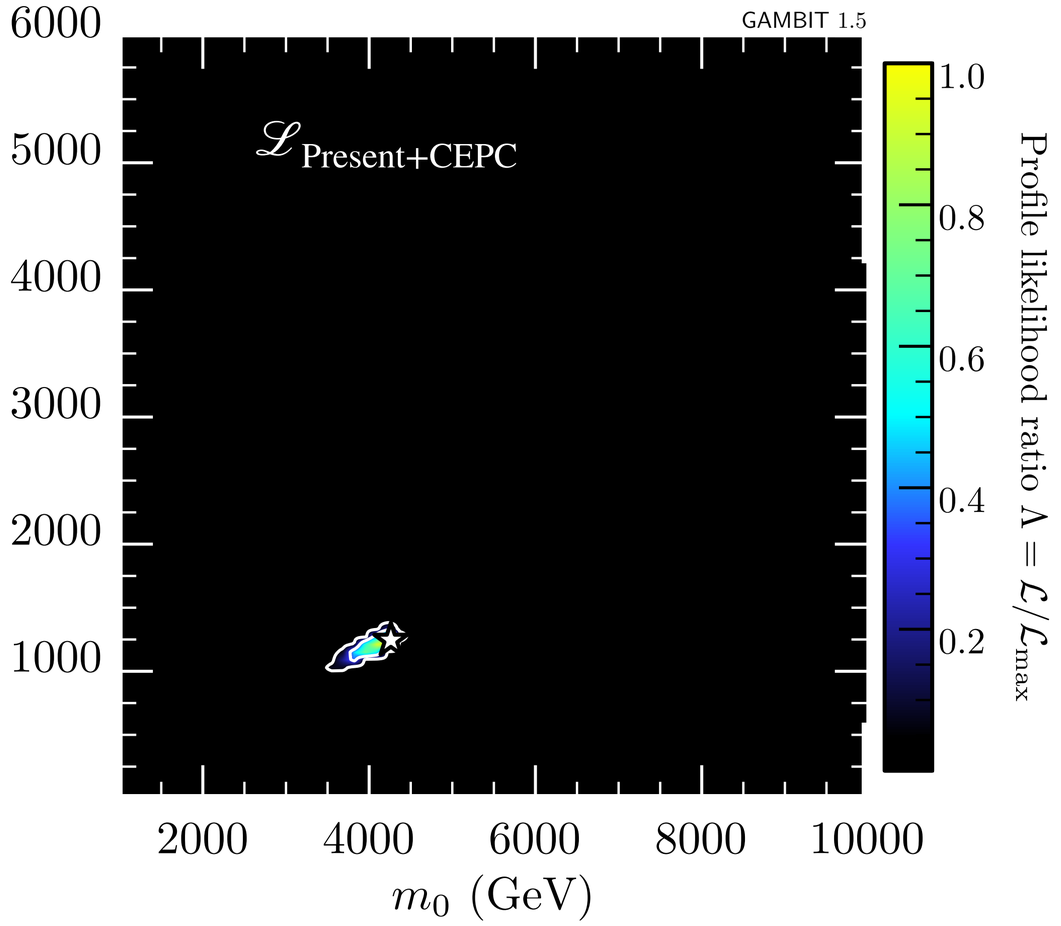




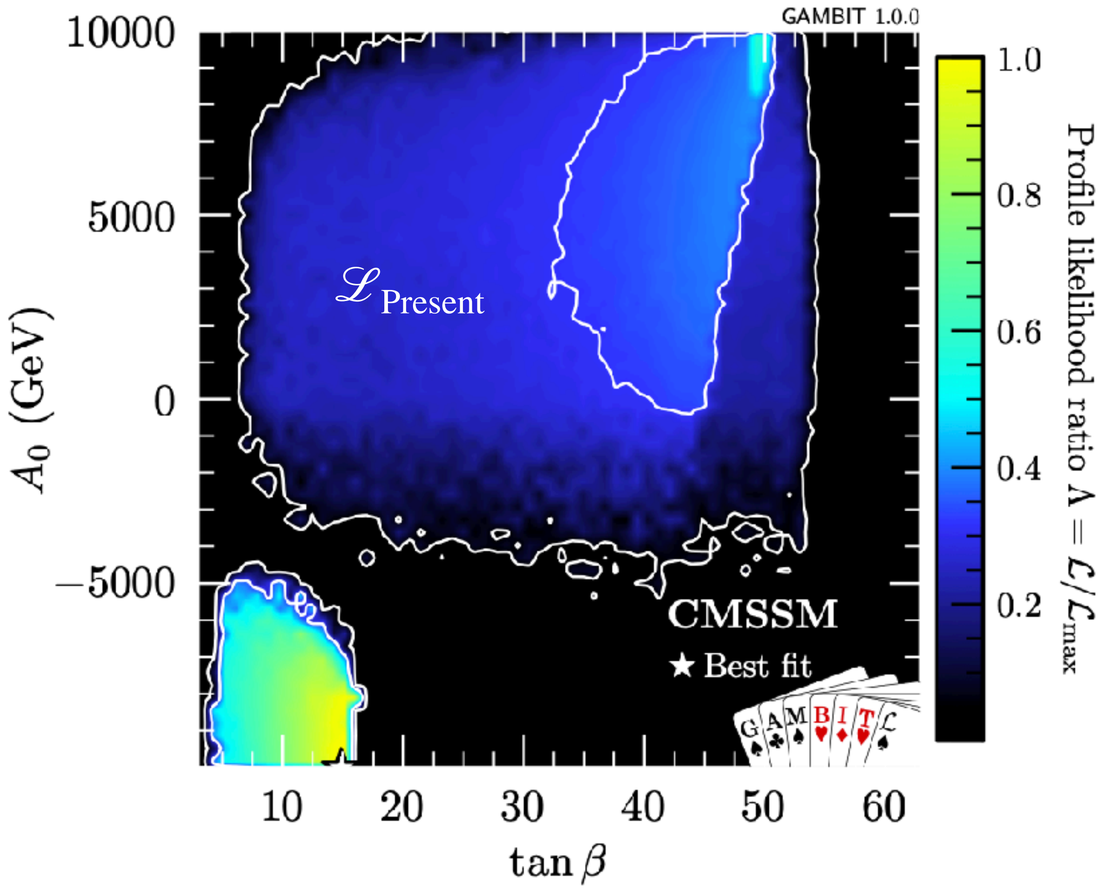


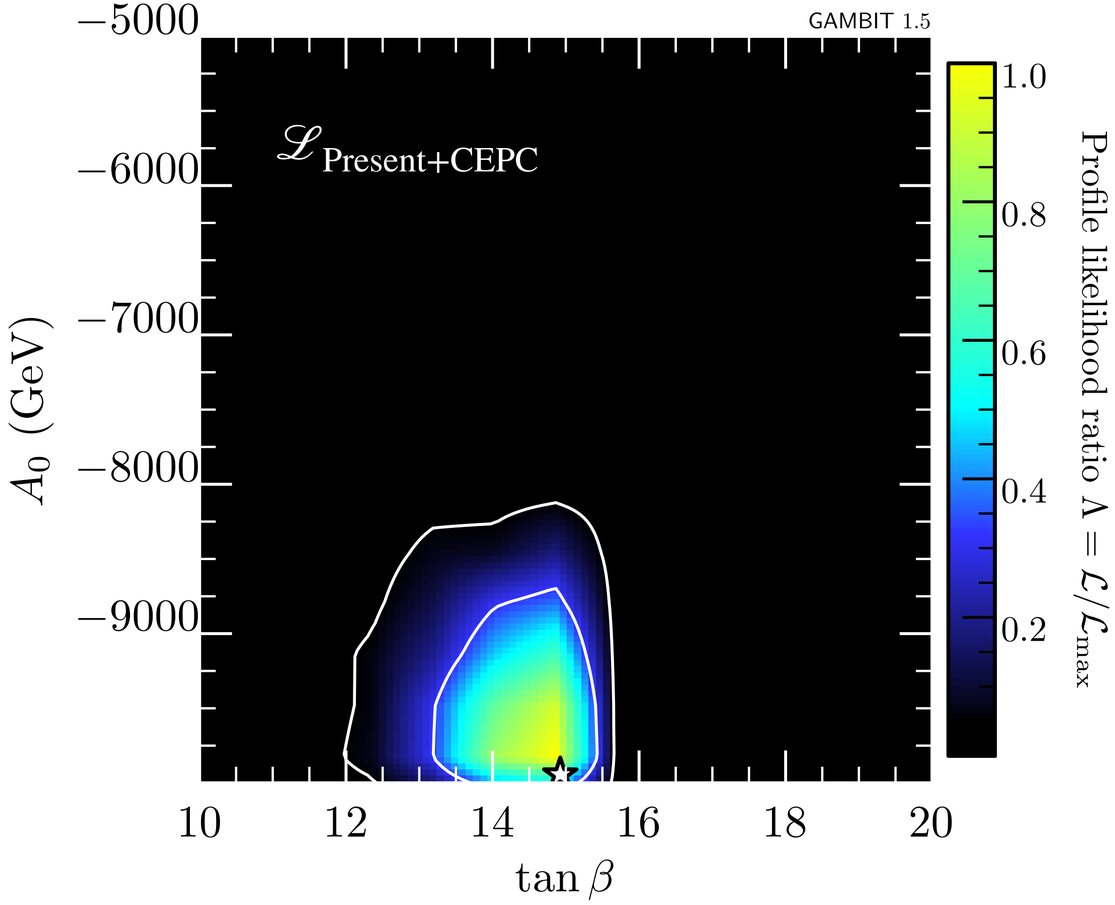
Impact of CEPC Higgs likelihood on CMSSM





Impact of CEPC Higgs likelihood on CMSSM





Plans

- Post-processed all the samples.
- Investigate the results.
- Do similar studies for NUHM1 and NUHM2.
- Add Z-pole measurements of future colliders to the likelihood?
- Write draft.

THANK YOU.