Light singlet scenario in R-symmetric SUSY

P. Dießner[†], J. Kalinowski[‡], **Wojciech Kotlarski**[†‡], D. Stöckinger[†]

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[†]Technische Universität Dresden, [‡]University of Warsaw

R-symmetry

[Fayet; Salam & Strathdee, ...]

- additional symmetry of the SUSY algebra allowed by the Haag - Łopuszański - Sohnius theorem
- for N=1 it is a global $U_R(1)$ symmetry under which the SUSY generators are charged
- implies that the spinorial coordinates are also charged $Q_R(\theta) = 1, \; \theta \to e^{\imath\alpha}\theta$
- Superpotential example

$$\mathcal{L} \ni \int d^2\theta \, W$$

- Superpotential is polynomial in fields. For W to transform homogeneously superfields must have definite R-charges

$$\begin{array}{ccccccc} e^{\imath\alpha Q_R} & & e^{\imath\alpha Q_R} & & e^{\imath\alpha(Q_R-1)} & & \\ \Phi & = & \phi(y) & + & \sqrt{2}\theta\psi(y) & + & \theta\theta F(y) \end{array}$$

- Similarly one can work out other parts of the Lagrangian

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Low-energy R-symmetry realization

- Different possible models that one can construct
- "Natural" choice

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	Φ	$\phi(y)$	$\sqrt{2}\theta\psi(y)$
leptons and quarks	$Q_R = 1$	$Q_R = 1$	$Q_R = 0$
Higgs	$Q_R = 0$	$Q_R = 0$	$Q_R = -1$

- Good: no barion and lepton number violating terms
- Bad: No Majorana masses for higgsinos and gauginos

One way to fix it: Dirac masses
Minimal R-Symmetric Supersymmetric Standardmodel (MRSSM)
Kribs et.al. arXiv:0712.2039

			$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_R$
Additional fields:	Singlet	$\hat{S}$	1	1	0	0
	Triplet	$\hat{T}$	1	3	0	0
	Octet	$\hat{O}$	8	1	0	0
	R-Higgses	$\hat{R}_u$	1	2	$-1/2$	2
		$\hat{R}_d$	1	2	$1/2$	2

$$\begin{aligned} W =& \mu_d \hat{R}_d \hat{H}_d + \mu_u \hat{R}_u \hat{H}_u \\ &+ \Lambda_d \hat{R}_d \hat{T} \hat{H}_d + \Lambda_u \hat{R}_u \hat{T} \hat{H}_u + \lambda_d \hat{S} \hat{R}_d \hat{H}_d + \lambda_u \hat{S} \hat{R}_u \hat{H}_u \\ &- Y_d \hat{d} \hat{q} \hat{H}_d - Y_e \hat{e} \hat{l} \hat{H}_d + Y_u \hat{u} \hat{q} \hat{H}_u \end{aligned}$$

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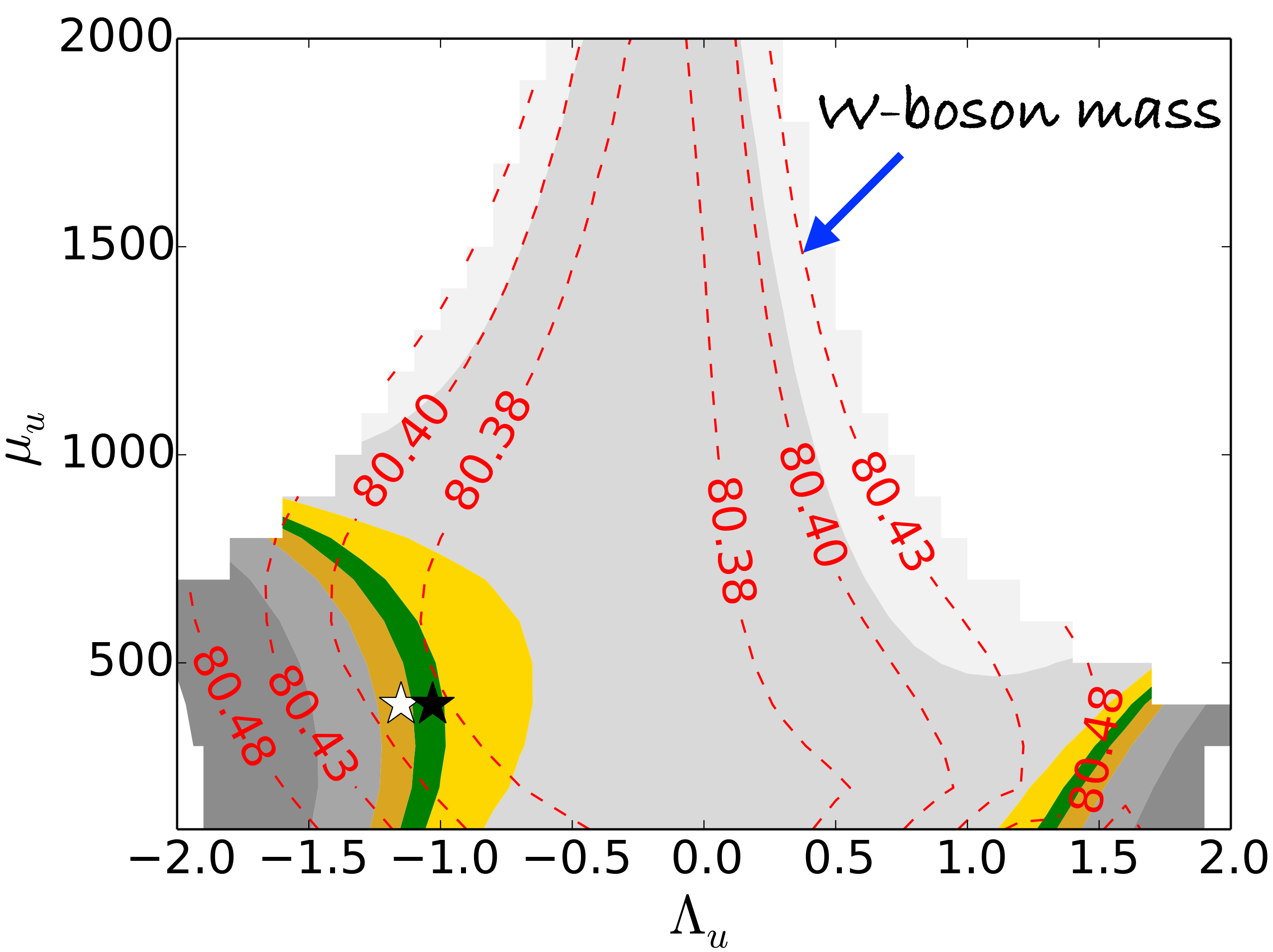
4 physical Higgses. Two options: 125 GeV Higgs is the lightest or second-to-lightest Higgs

Option 1: 125 GeV Higgs as the lightest Higgs

- Tree-level contribution from the mixing

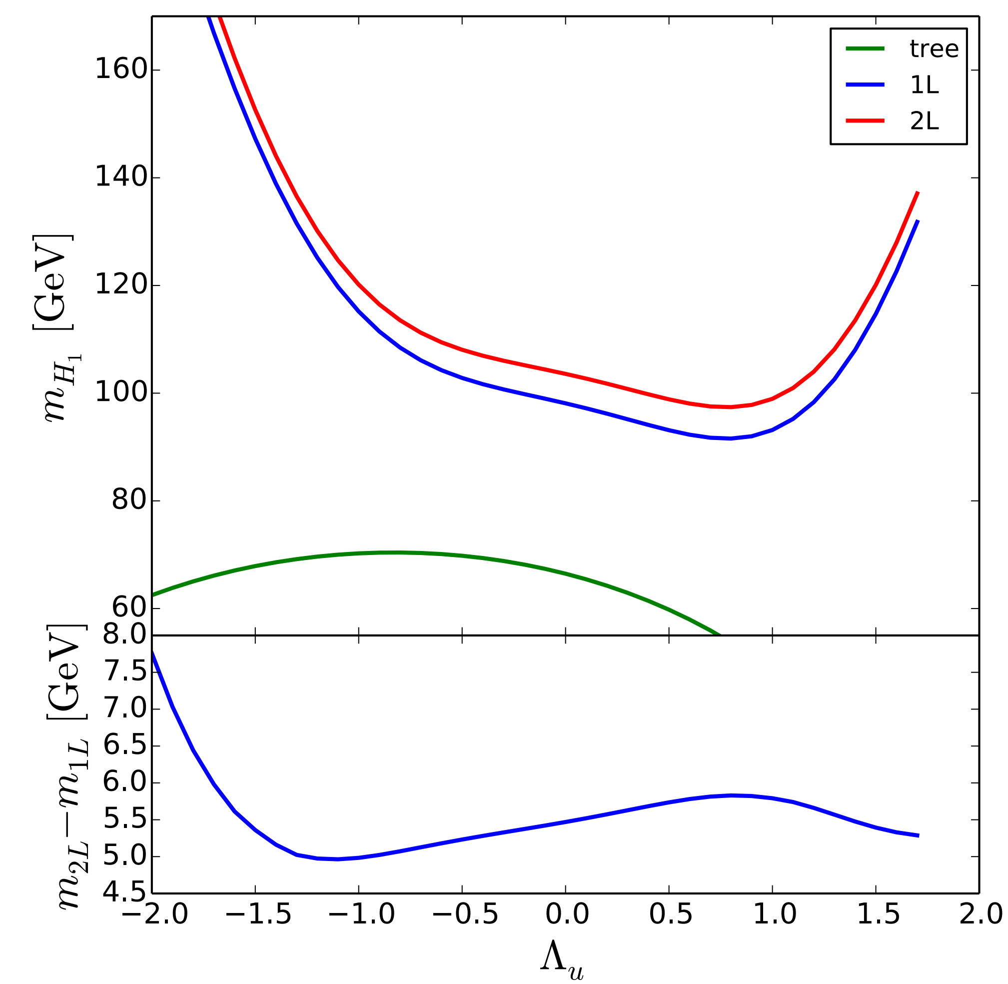
$$m_{h,\text{approx}}^2 = M_Z^2 \cos^2 2\beta - v^2 \left(\frac{\left(g_1 M_D^B + \sqrt{2}\lambda\mu\right)^2}{4(M_D^B)^2 + m_S^2} + \frac{\left(g_2 M_D^W + \Lambda\mu\right)^2}{4(M_D^W)^2 + m_T^2} \right) \cos^2 2\beta$$

- Higgs mass vs W mass



$m_h = 126 \pm 2$ GeV $m_h = 126 \pm 8$ GeV

- Full 1-loop + leading 2-loop corrections



JHEP 1412 (2014) 124, Adv. in High Energy Phys. 2015 (2015) 760729

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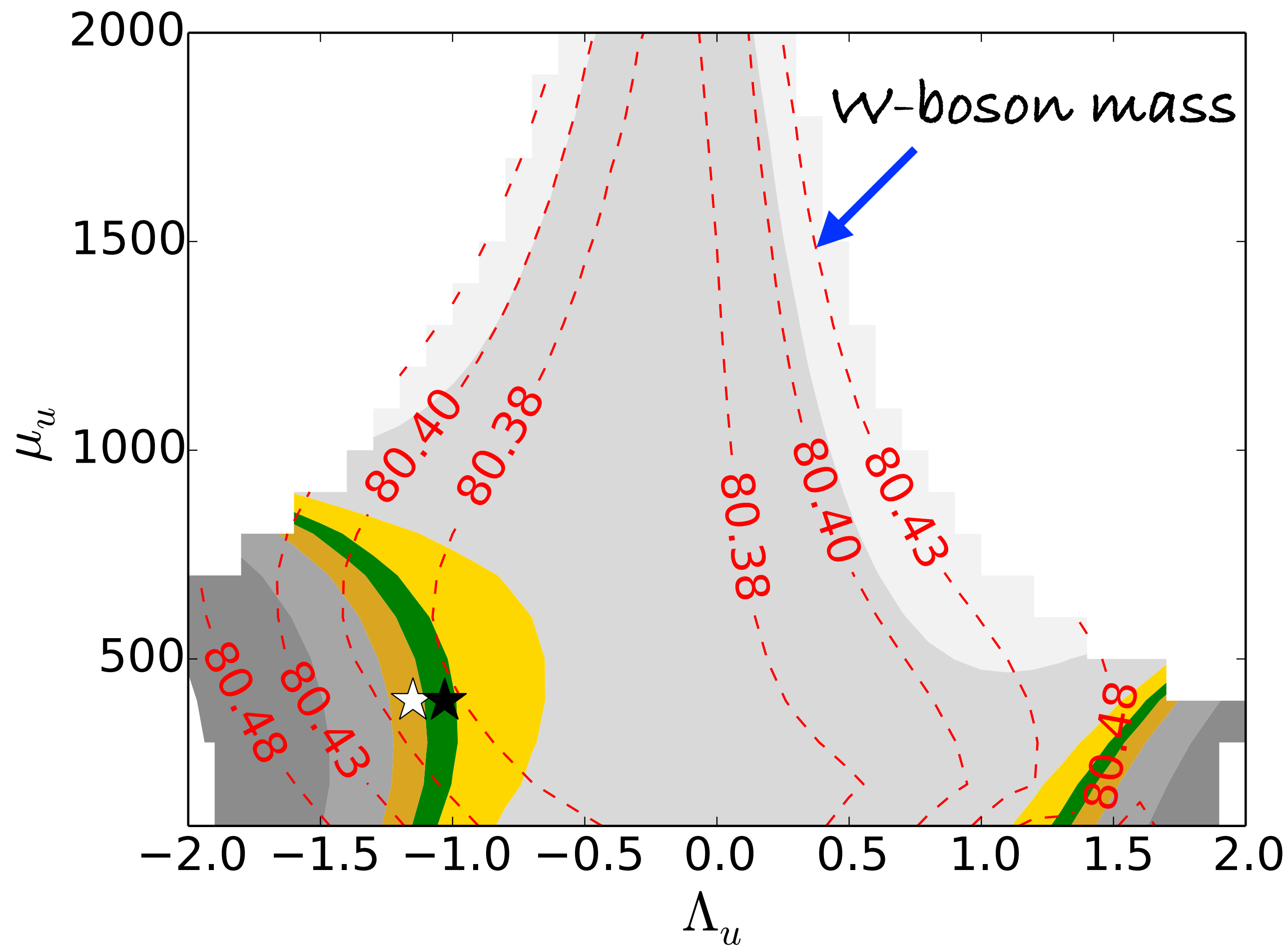

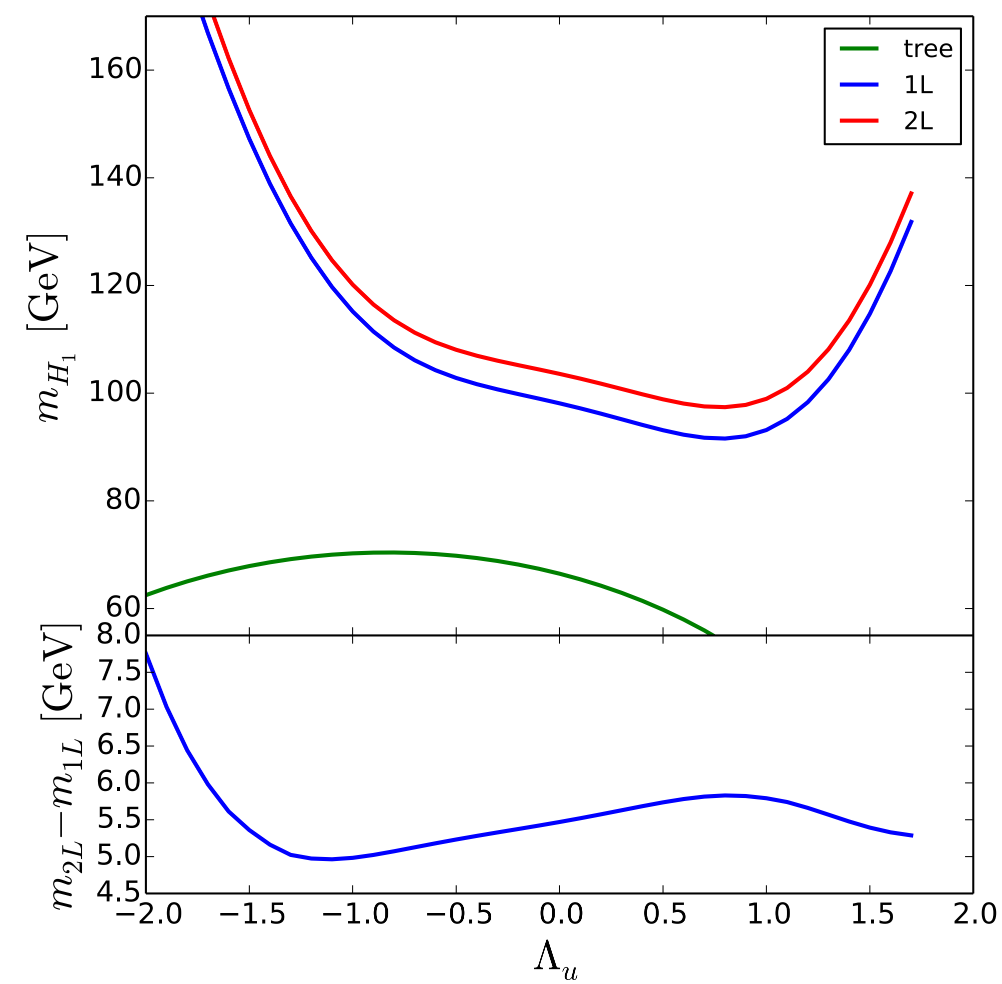

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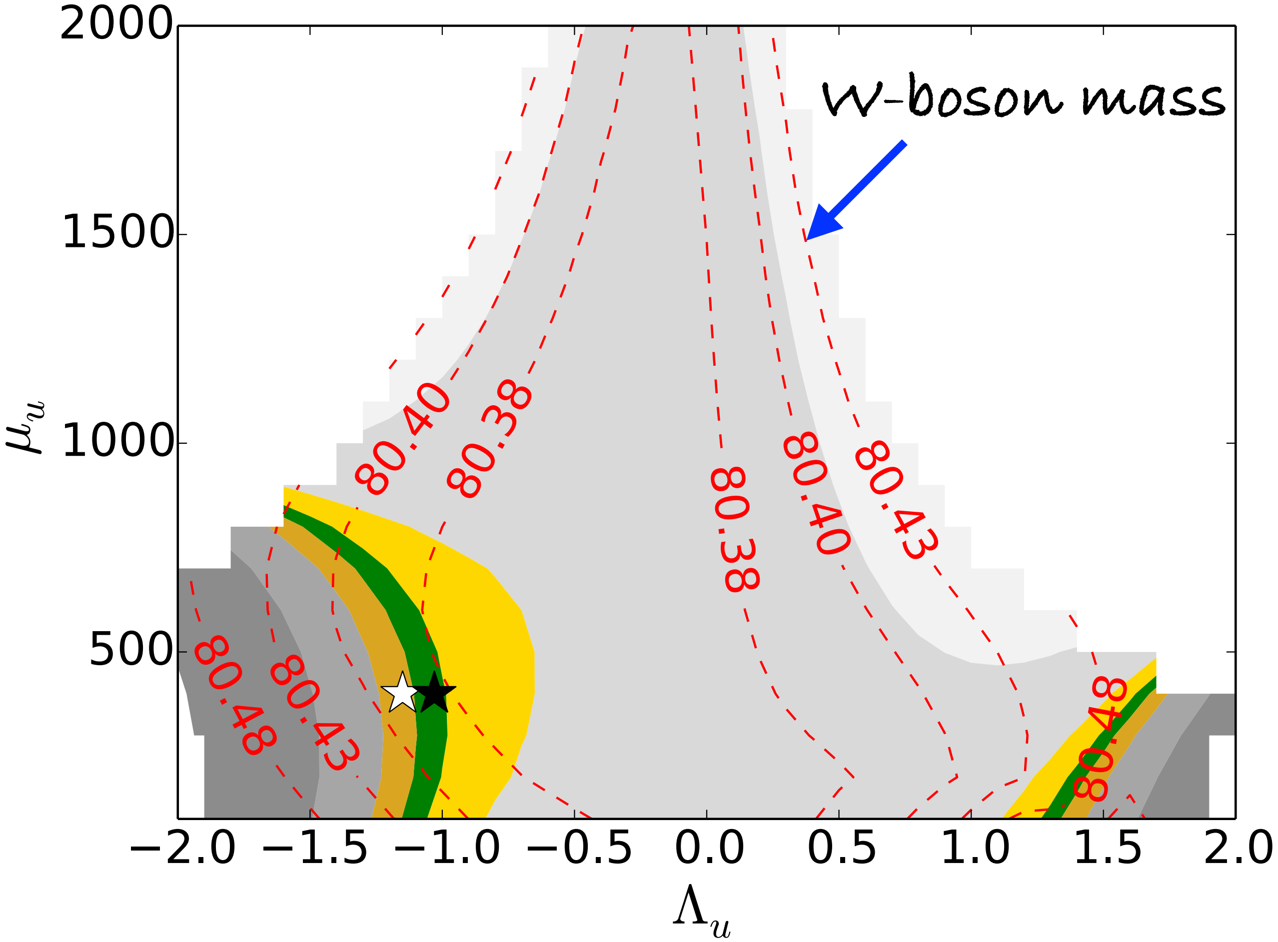

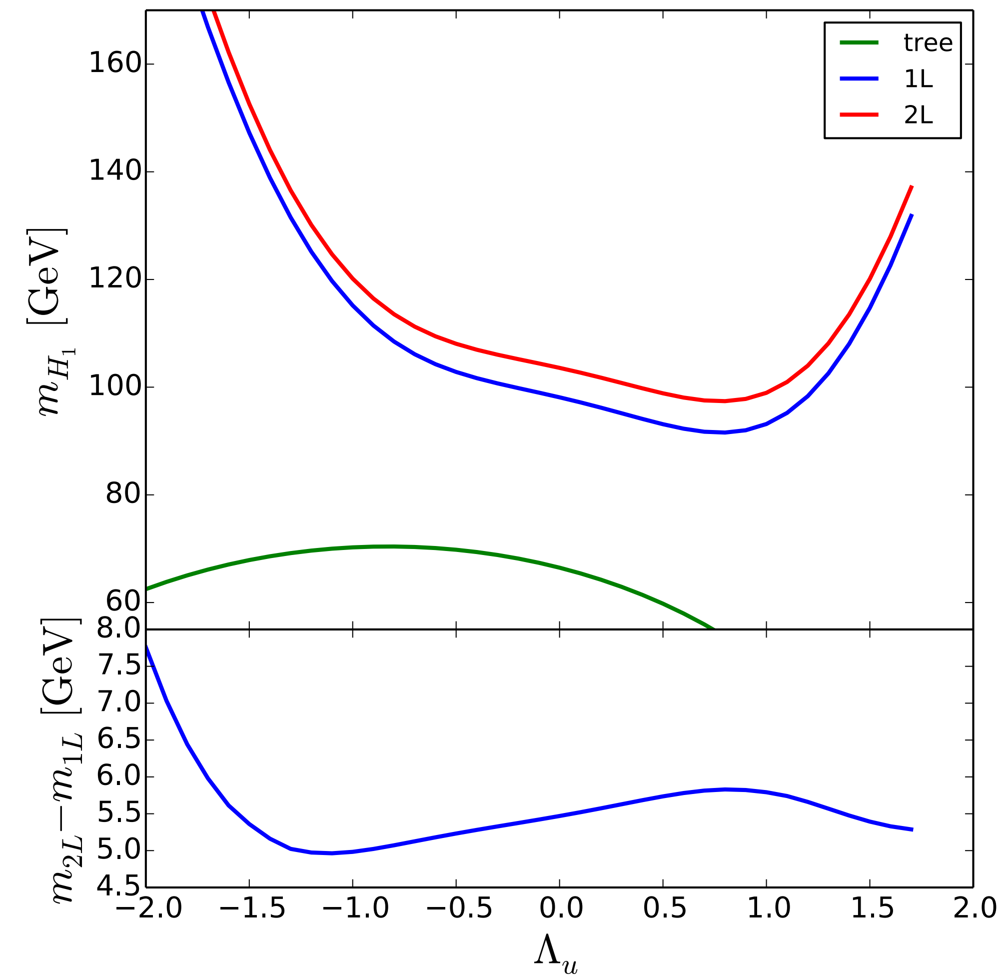

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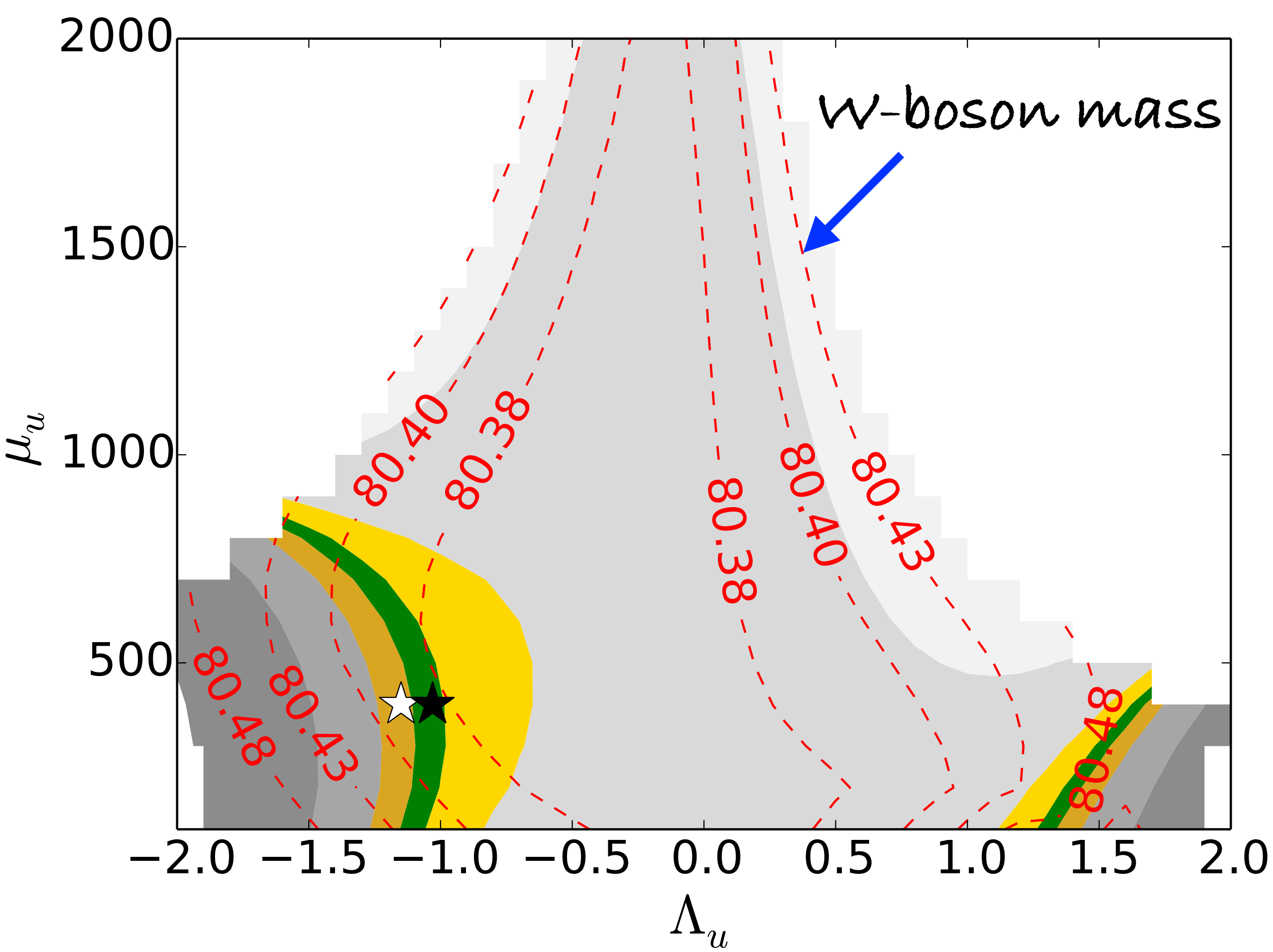

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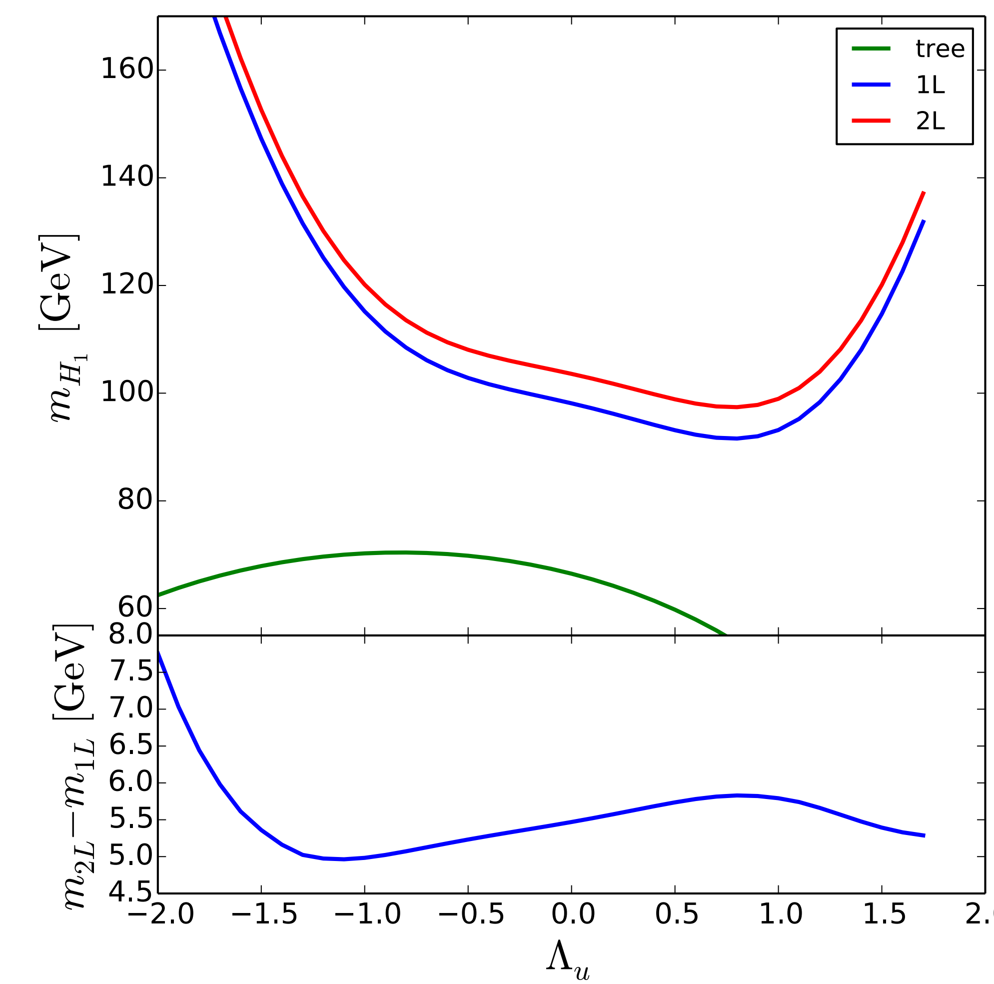

+5 GeV at 2-loop

Option 2: 125 GeV Higgs as the second-to-lightest Higgs

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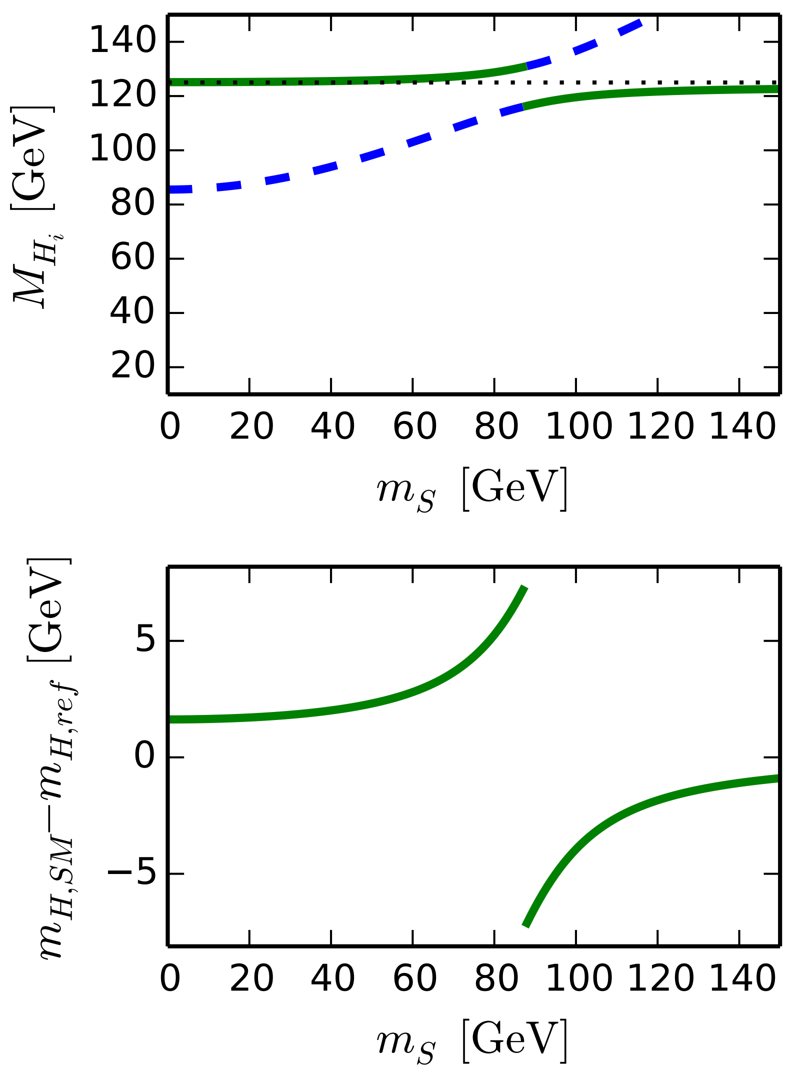
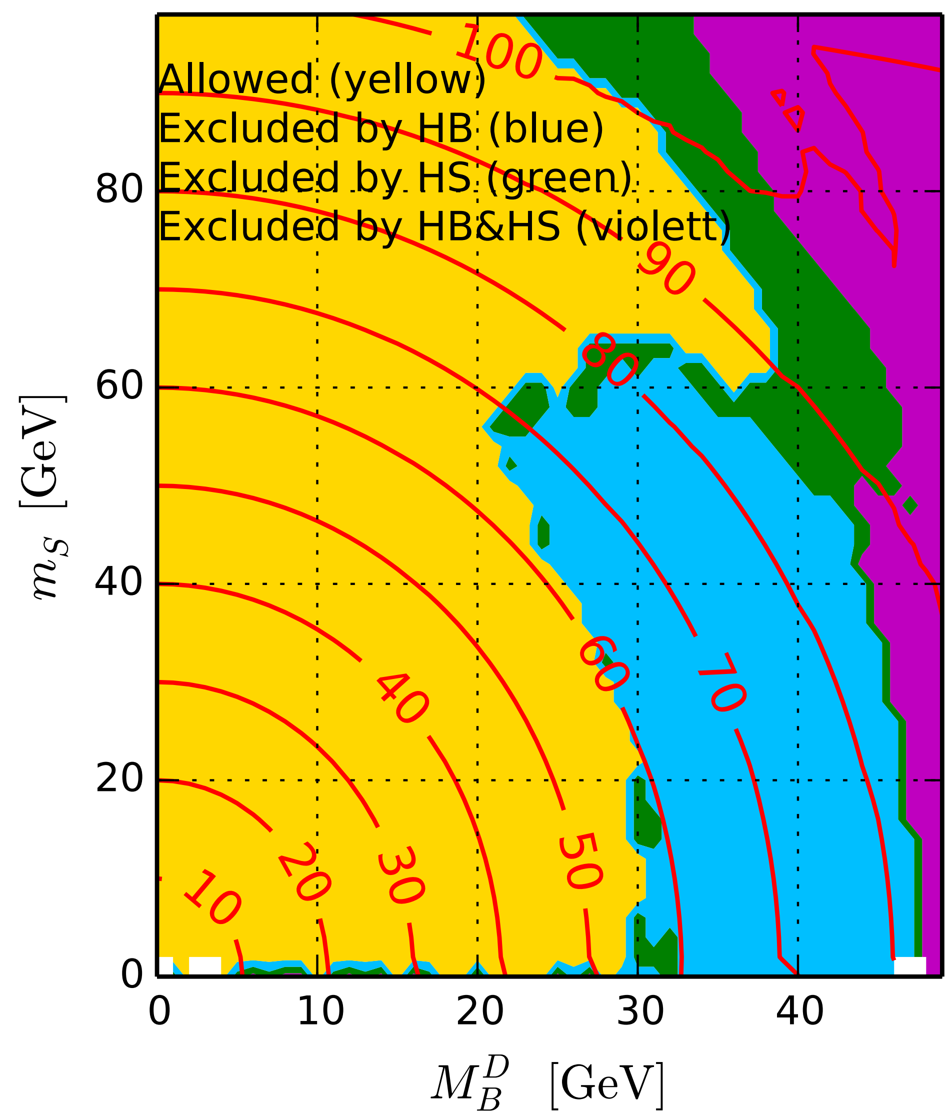
$$m_{h,\text{tree}}^2 \approx m_Z^2 \cos^2 2\beta + v^2 \cos^2 2\beta \left(\frac{(g_1 M_B^D + \sqrt{2}\lambda\mu)^2}{|m_S^2 + 4(M_B^D)^2 - m_Z^2 \cos^2 2\beta|} \right)$$

- "SM-like" Higgs composition



- Two main parameters: M_B^D and m_S



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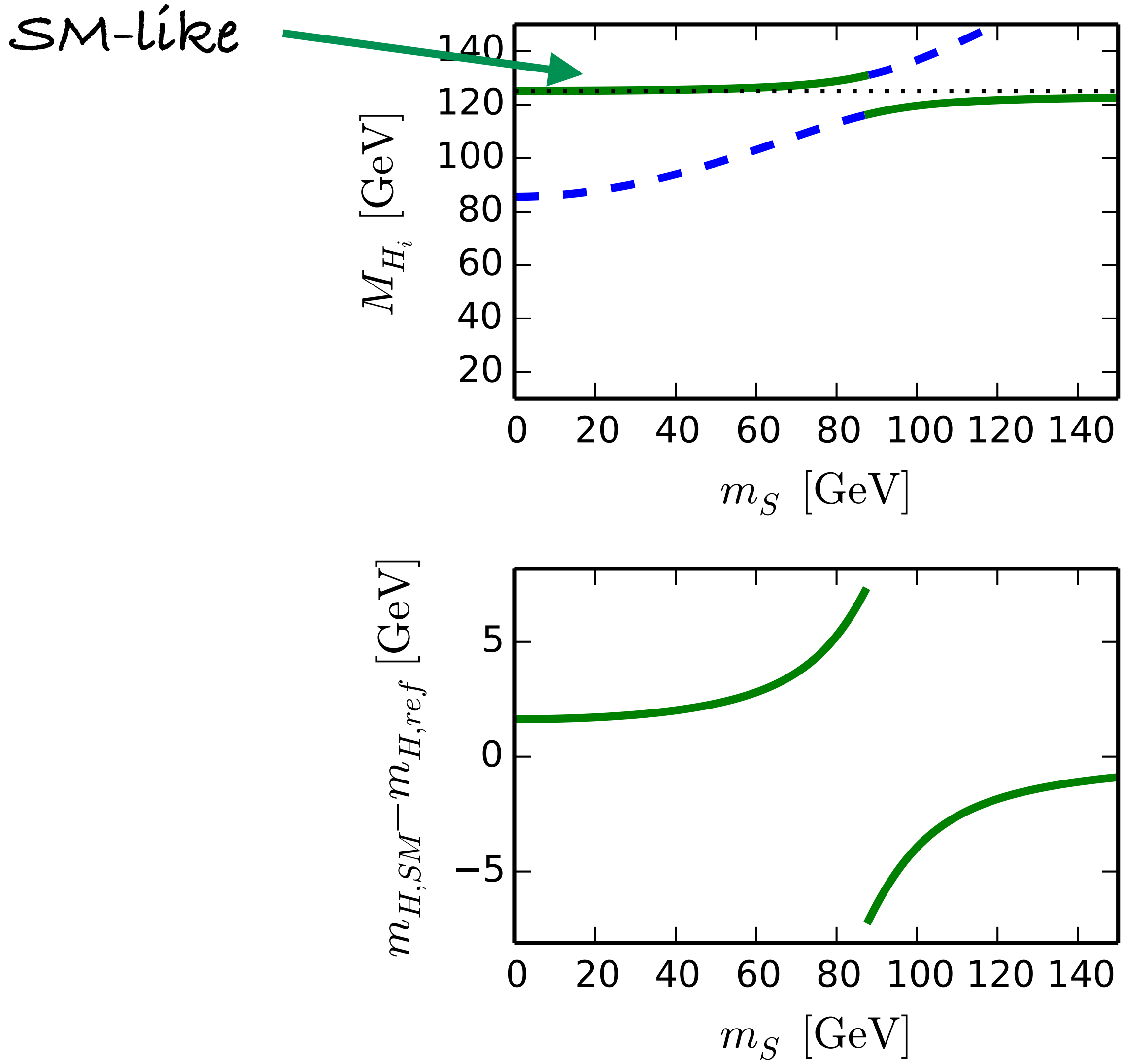

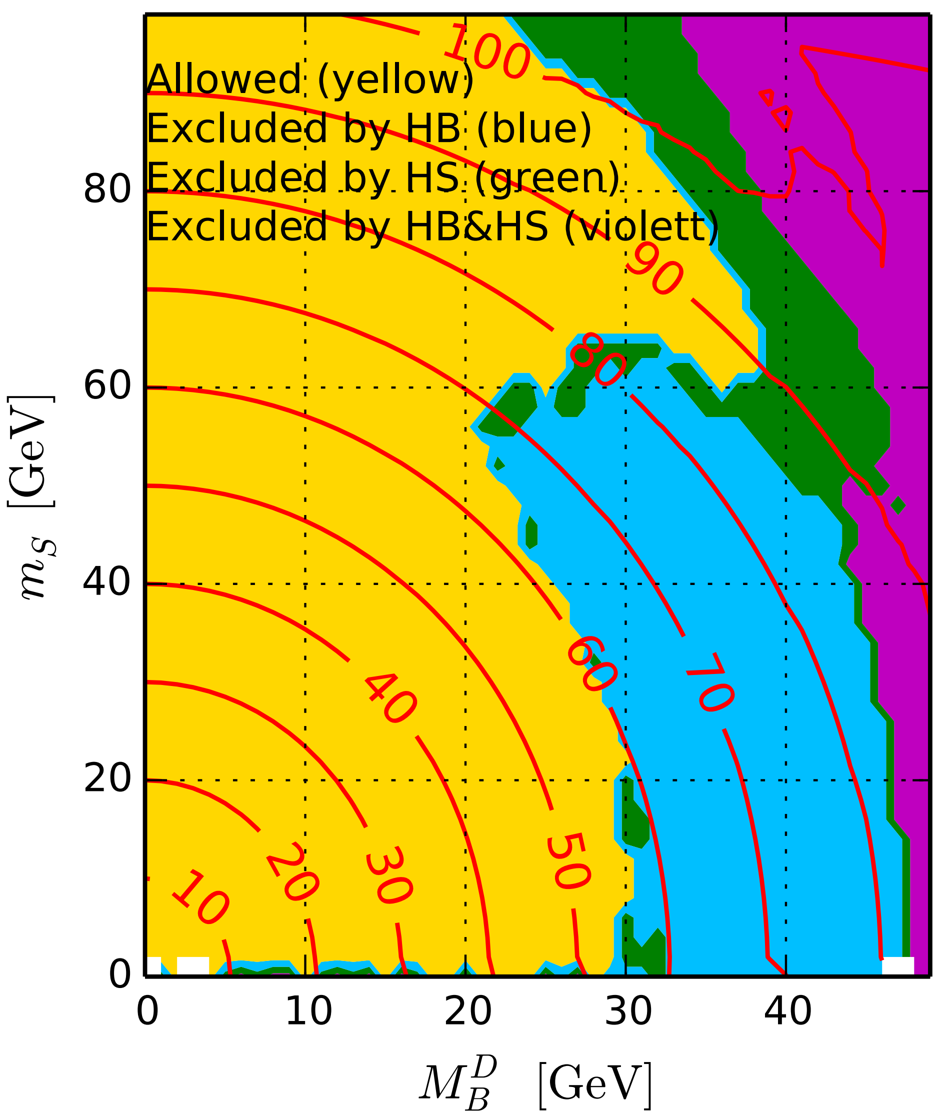

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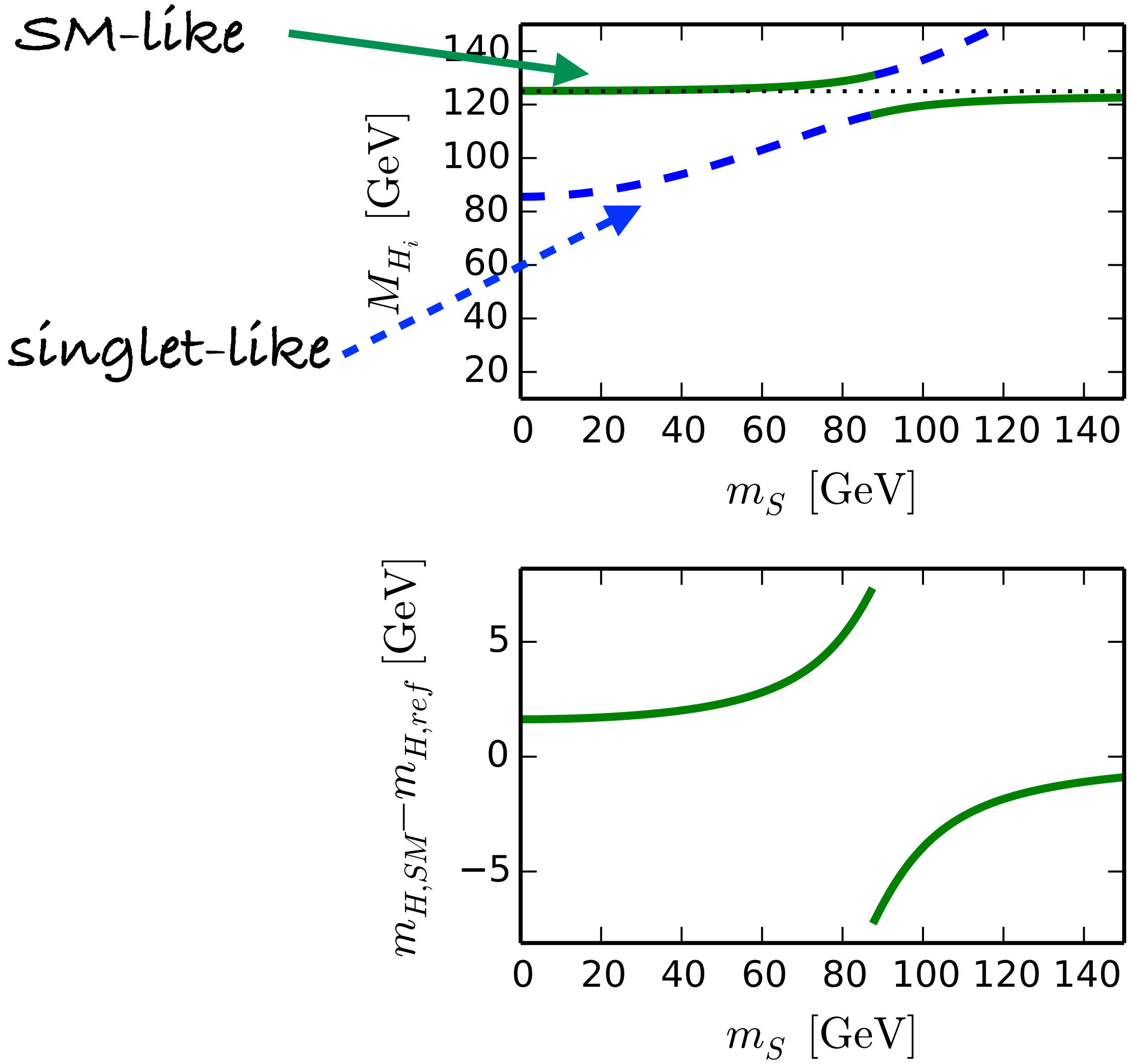

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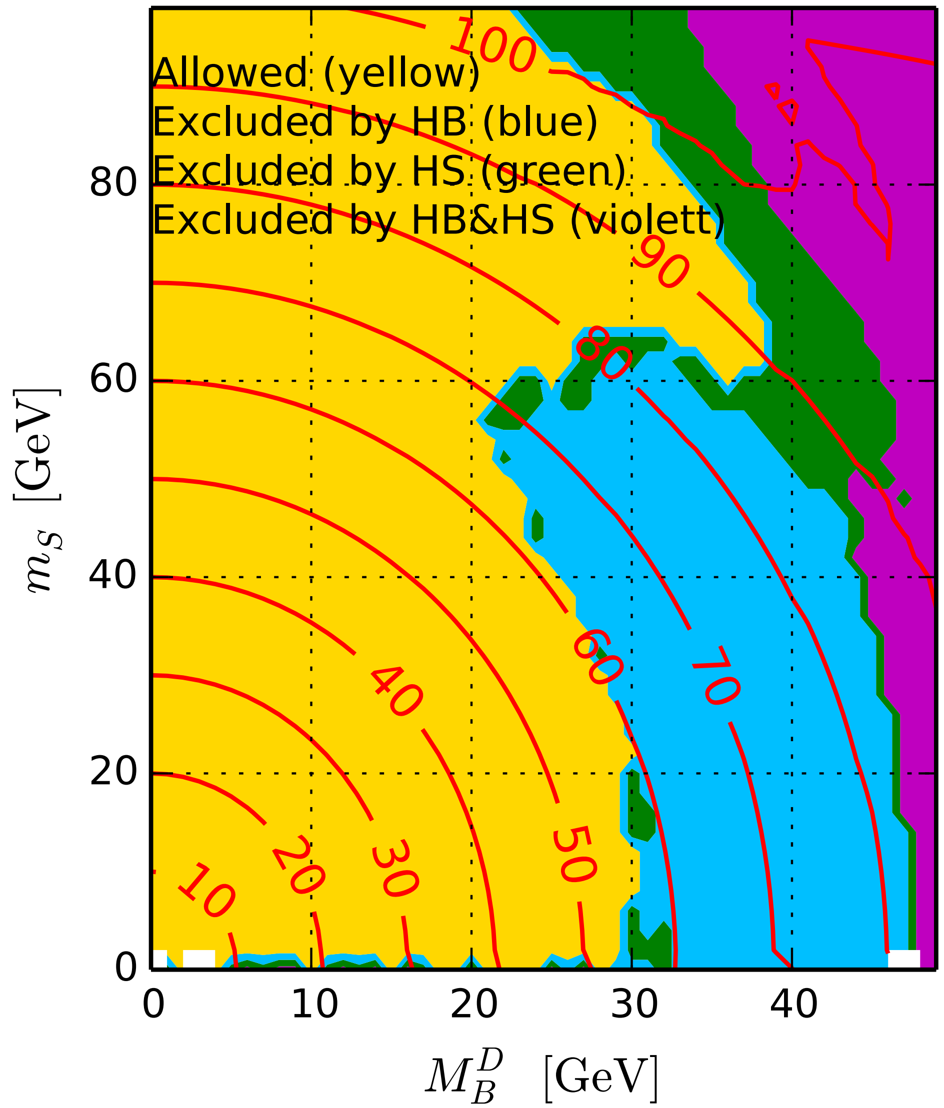

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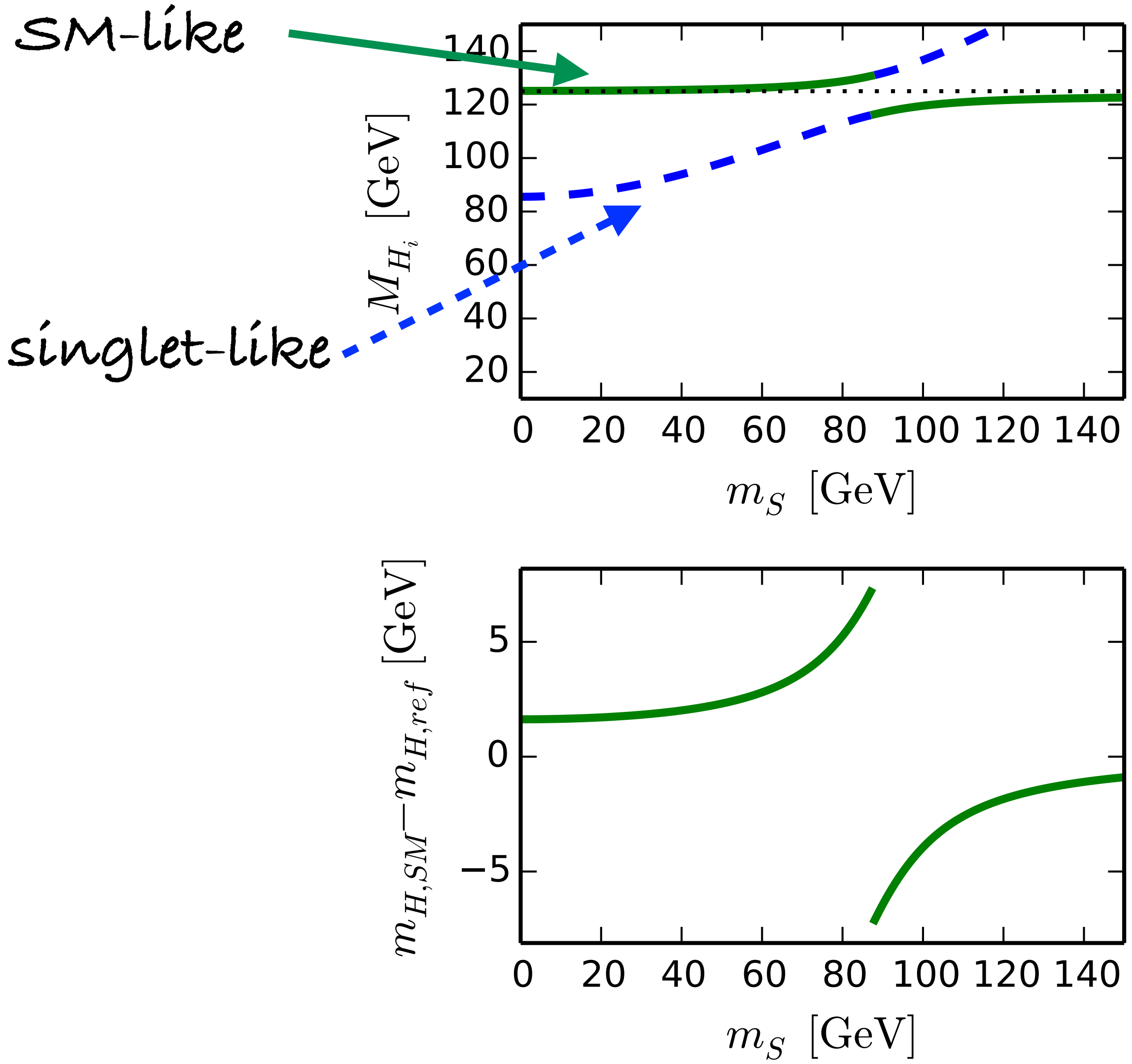

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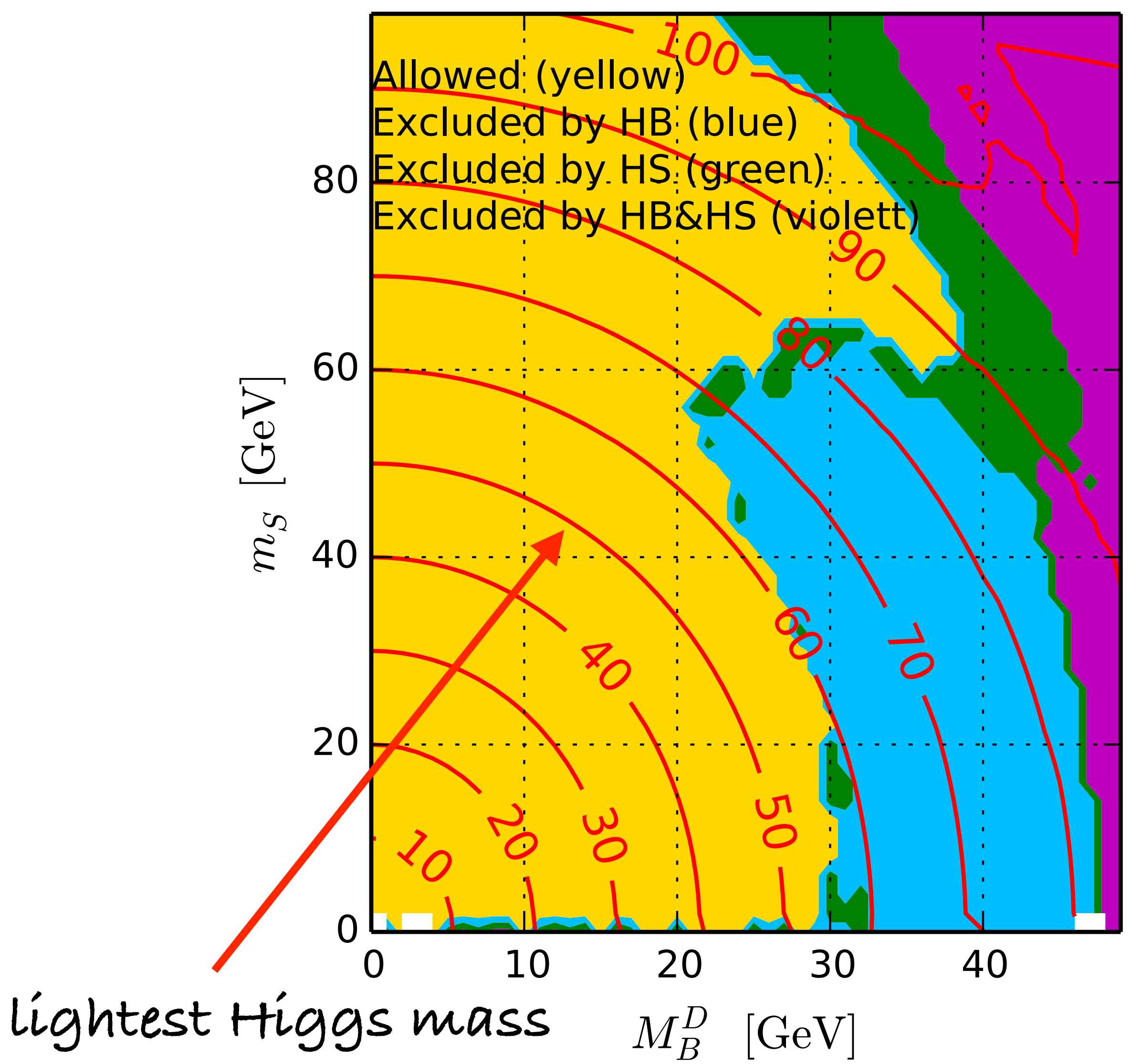
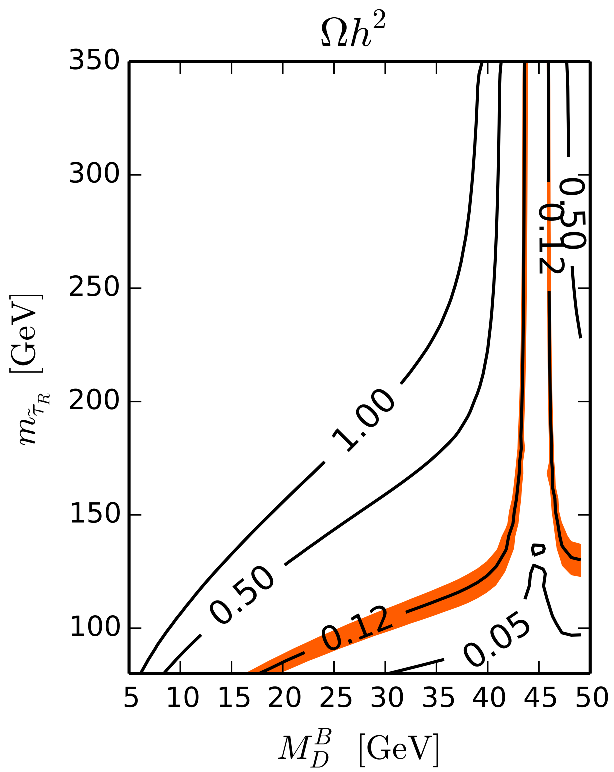
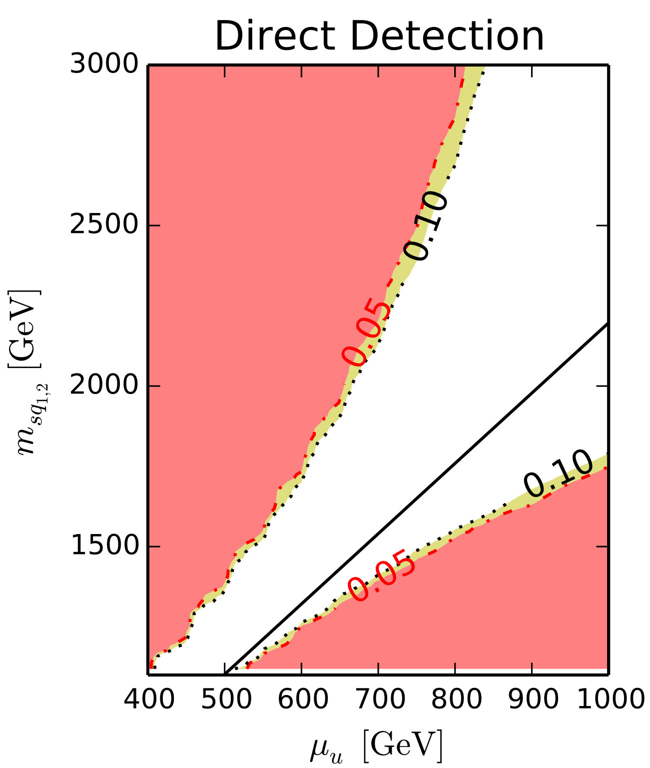


Dark matter and light “inos” in general

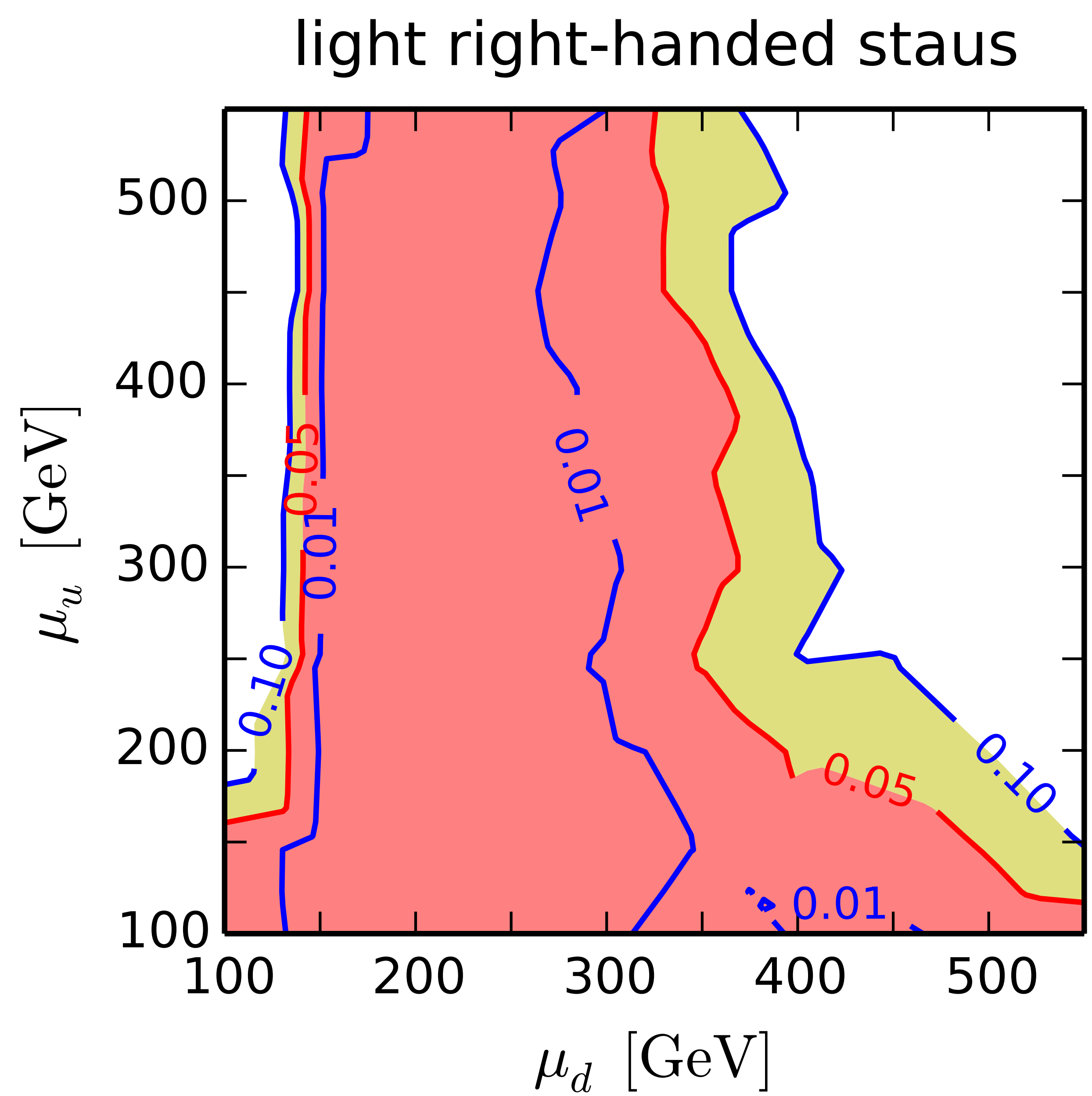
- Dark matter bino-singlino candidate





- 8 TeV exclusion limits

SARAH’s UFO + Herwig++ and CheckMate



Summary and outlook

- Viable realization of R-symmetric SUSY
  - ✅ ~125 GeV SM-like Higgs boson in 2 different ways
  - ✅ agreement with PEWO and flavor-physics
  - ✅ stable vacuum
  - ✅ LHC „friendly" particle spectra
  - ✅ viable candidate for dark matter
- Work in progress
  - ☐ R-symmetric SQCD at 13 TeV LHC

Particles content summary: MSSM vs. MRSSM

different number of physical states — Higgs, charginos

completely new states — R-Higgs, sgluon

	Higgs				R-Higgs		
	CP-even	CP-odd	charged	charginos	neutral	charged	sgluon
MSSM	2	1	1	2	0	0	0
MRSSM	4	3	3	2+2	2	2	1

	neutralino	gluino	
MSSM	4	1	Majorana fermions
MRSSM	4	1	Dirac fermions