Dirac Gauginos and the Di-Photon Excess

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based on 1605.05313 [hep-ph]

in collaboration with K. Benakli, L. Darmé, M. Goodsell

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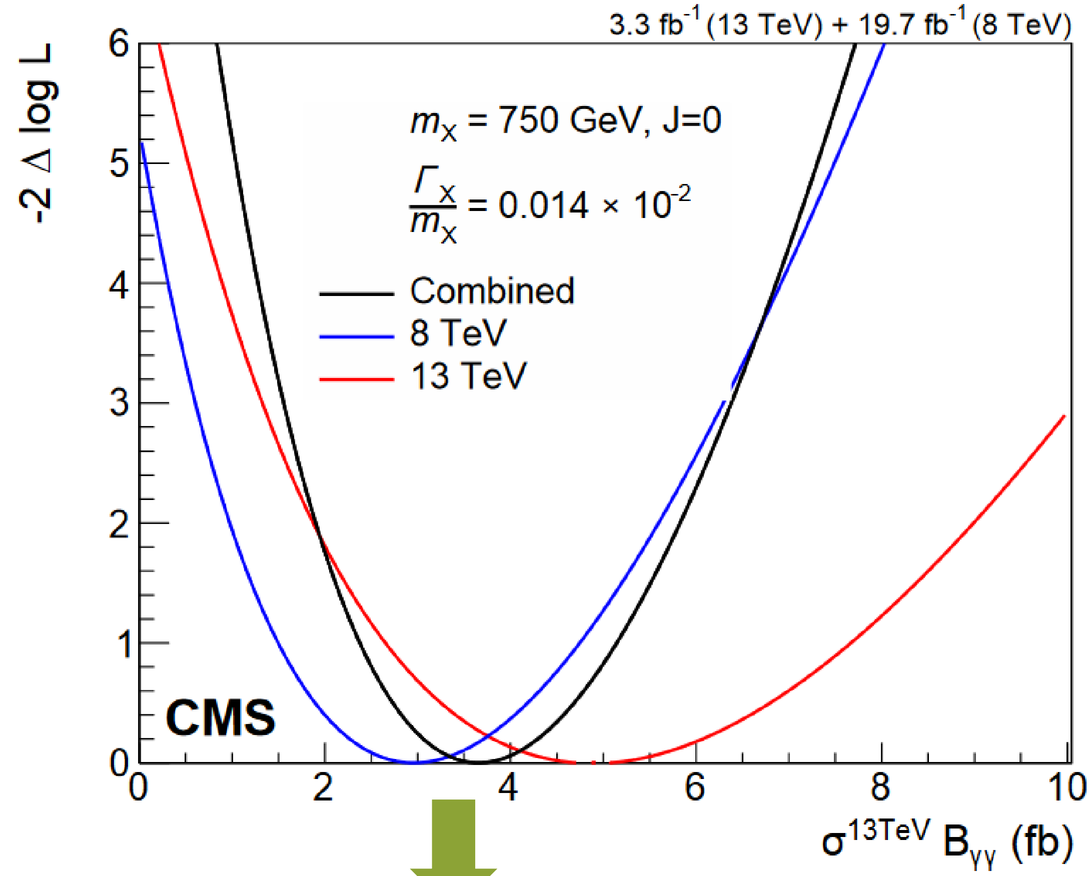
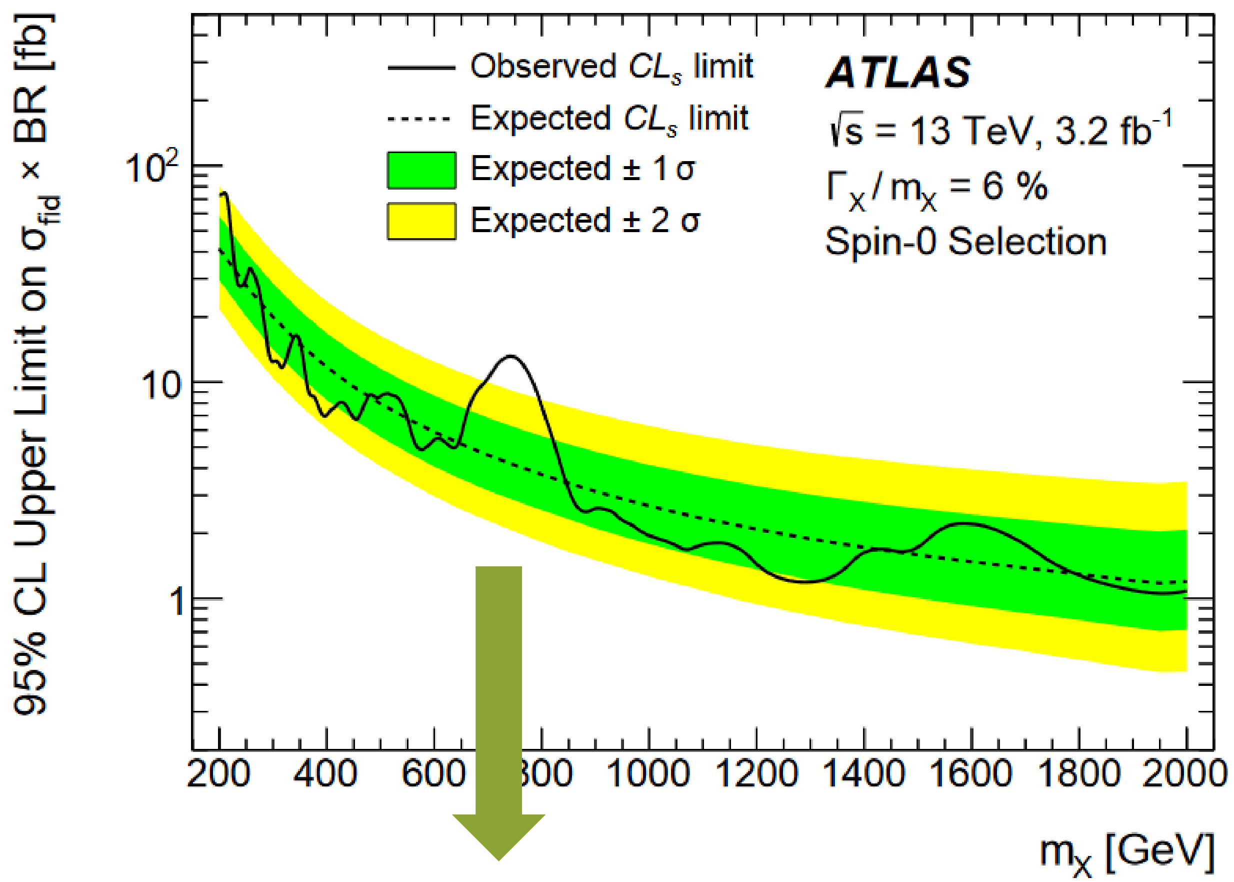
cnrs dépasser les frontières

New Physics just around the Corner...





CMS reports an excess at 750 GeV with a 3.4σ (local) and 1.6σ (global) significance

CMS points towards

$$\sigma^{13\text{TeV}} \times \text{BR} \approx (3.7 \pm 2)\text{fb}$$

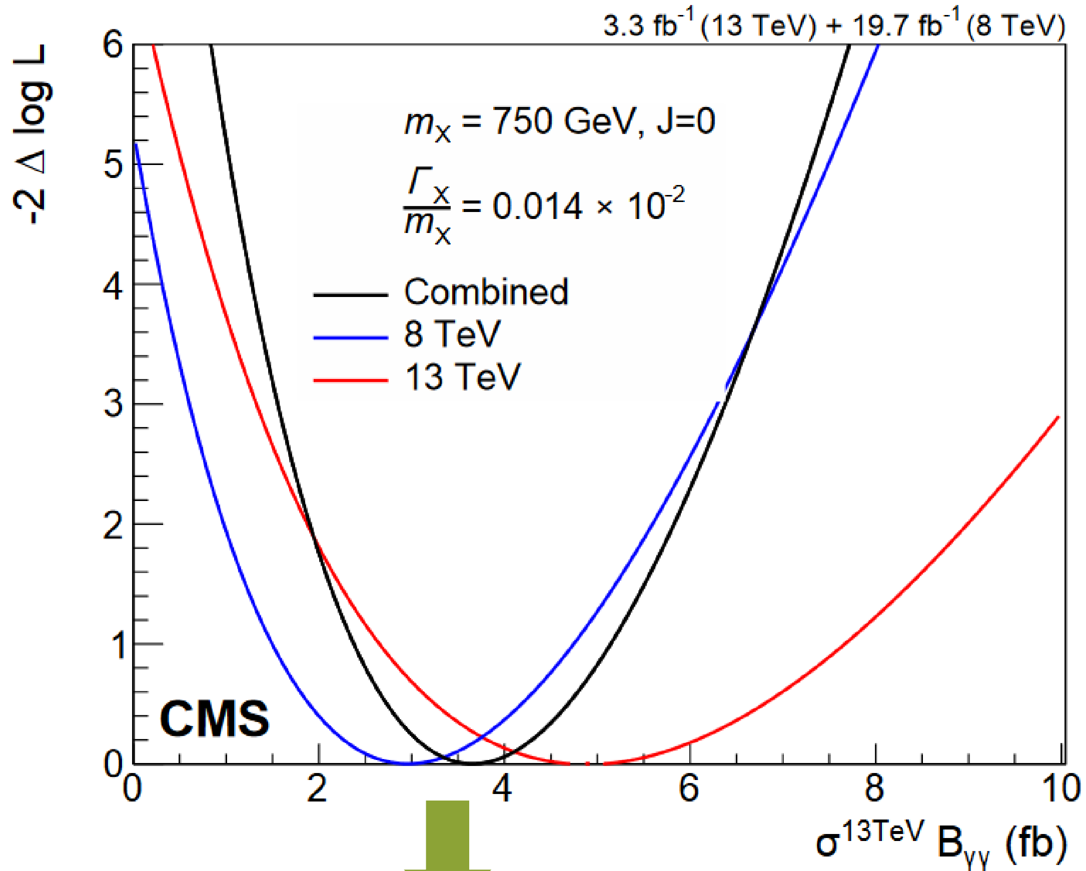
CMS-EXO-16-018

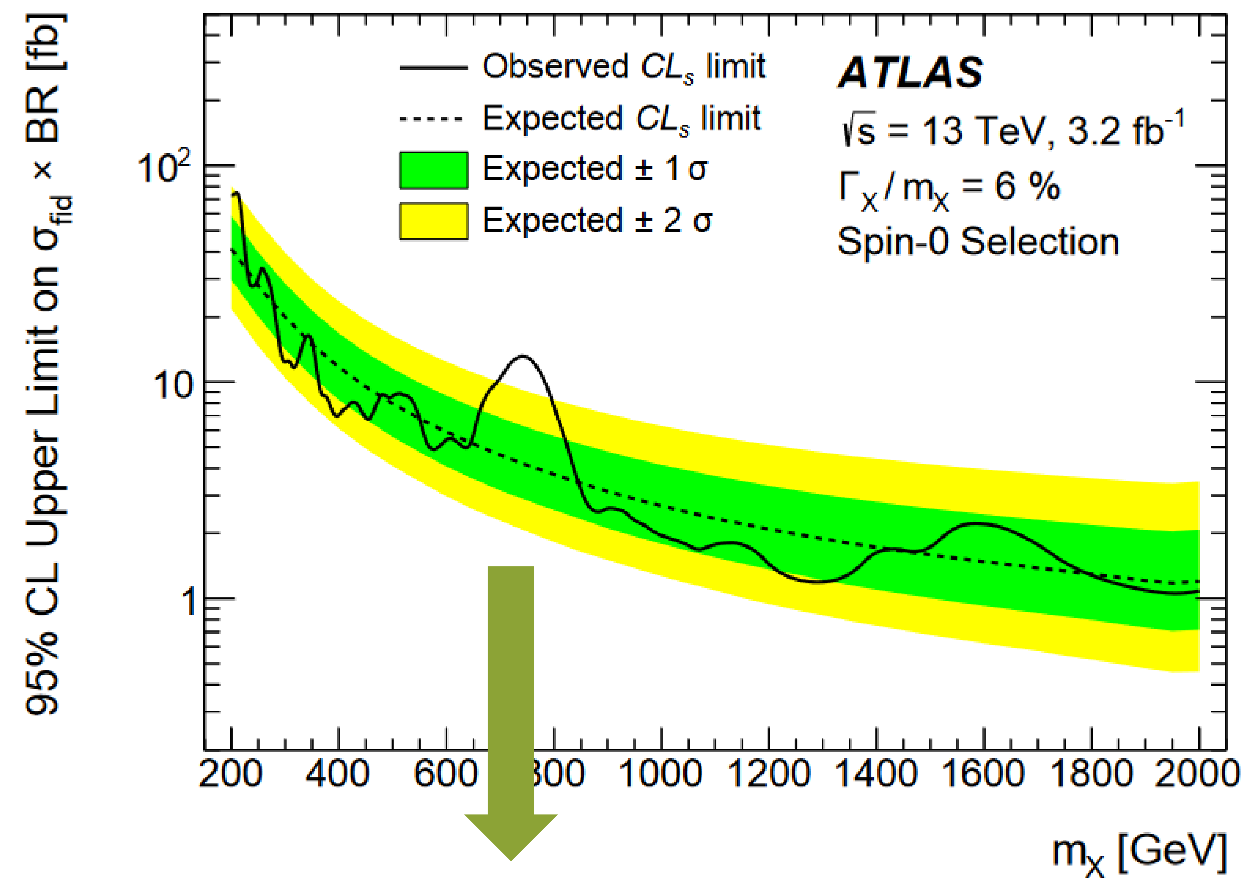
ATLAS reports an excess at 750 GeV with a 3.9σ (local) and 2.1σ (global) significance

ATLAS points towards a larger width of 50 GeV

CERN-EP-2016-120

New Physics just around the Corner... or not?





CMS reports an excess at 750 GeV
with a 3.4σ
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CMS points
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ATLAS reports an excess at 750 GeV
1σ (global)
arger width of
EP-2016-120

Jester @Resonaances · 21 juin

Rumor: 750 GeV diphoton bump is going away as more data is collected by LHC. Most likely, excess seen in 2015 was just statistical fluke.

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Our Goal

- explore the possibility of a diphoton excess within a supersymmetric model
- no addition of “ad-hoc” fields
- maintain perturbativity up to the GUT scale
- compatible with current exclusion limits
- study taking into account sophisticated tools

  → SARAH/SPheno (one-loop masses, two-loop RGEs etc. ..)

Minimal Dirac Gaugino Model (MDGSSM)

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- Majorana vs. Dirac mass term for gauginos

$$M_M \lambda\lambda + h.c. \qquad\qquad M_D \lambda\chi + h.c.$$

- Why should we consider Dirac Gauginos?

  - Majorana mass term violates R-Symmetry; Dirac gaugino masses do not
  - R-symmetry excludes B/L violating term in superpotential ← → R-parity in MSSM
  - motivated by N=2 gauge sector with D-Term SUSY breaking

- What are the phenomenological consequences?
  - "supersoft" (does not lead to new log divergent radiative contributions to other soft parameters as a Majorana mass would do)
  - "supersafe" (cross sections are suppressed at the LHC)
  - reduced fine tuning to soft Higgs mass
  - ameliorates the flavour problem

Minimal Dirac Gaugino Model (MDGSSM)

N=1 gauge vector supermultiplet

$$\underbrace{\begin{pmatrix} A_a \\ \lambda_a \end{pmatrix} \begin{pmatrix} \chi_a \\ a_a \end{pmatrix}}$$

new N=1 gauge chiral supermultiplet

forms N=2 vector hypermultiplet

- Extending MSSM particle content by Dirac gauginos **requires** three additional chiral superfields in the adjoint representation of the gauge groups:
  a singlet **S** under U(1), a triplet **T** under SU(2) and an color octet $\mathbf{O_g}$ under SU(3)

$$W_{\mathrm{DG}} = \int d^2\theta\sqrt{2}\theta^\alpha \left[m_{D1}\mathbf{S}W_{Y\,\alpha} + 2m_{D2}tr(\mathbf{T}W_{2\,\alpha}) + 2m_{D3}tr(\mathbf{O}W_{3\,\alpha}) \right]$$

BUT: natural unification of gauge couplings with respect to the MSSM spoiled

- GUT unification by $SU(3)^3$ gauge group

Requires extending particle content by
- two Higgs-like doublets R_u and R_d
- two pairs of vector-like right-handed electron superfields $E_{1,2}$ and $E'_{1,2}$

MSSM + Dirac gaugino masses + unification fields

MDGSSM- Particle Content

Names		Spin 0	Spin 1/2	Spin 1	$(SU(3), SU(2), U(1)_Y)$
Quarks	$\mathbf{Q}$	$\tilde{Q} = (\tilde{u}_L, \tilde{d}_L)$	(u_L, d_L)		$(\mathbf{3},\ \mathbf{2},\ 1/6)$
	$\mathbf{U^c}$	$\tilde{U}^c_L$	U^c_L		$(\overline{\mathbf{3}},\ \mathbf{1},\ -2/3)$
($\times$3 families)	$\mathbf{D^c}$	$\tilde{D}^c_L$	D^c_L		$(\overline{\mathbf{3}},\ \mathbf{1},\ 1/3)$
Leptons	$\mathbf{L}$	$(\tilde{\nu}_{eL}, \tilde{e}_L)$	(ν_{eL}, e_L)		$(\mathbf{1},\ \mathbf{2},\ -1/2)$
($\times$3 families)	$\mathbf{E^c}$	$\tilde{E}^c$	E^c		$(\mathbf{1},\ \mathbf{1},\ 1)$
Higgs	$\mathbf{H_u}$	(H_u^+, H_u^0)	$(\tilde{H}_u^+, \tilde{H}_u^0)$		$(\mathbf{1},\ \mathbf{2},\ 1/2)$
	$\mathbf{H_d}$	(H_d^0, H_d^-)	$(\tilde{H}_d^0, \tilde{H}_d^-)$		$(\mathbf{1},\ \mathbf{2},\ -1/2)$
Gluons	$\mathbf{W_{3\alpha}}$		$\lambda_{3\alpha}$ $[\equiv \tilde{g}_\alpha]$	g	$(\mathbf{8},\ \mathbf{1},\ 0)$
W	$\mathbf{W_{2\alpha}}$		$\lambda_{2\alpha}$ $[\equiv \tilde{W}^\pm, \tilde{W}^0]$	$W^\pm, W^0$	$(\mathbf{1},\ \mathbf{3},\ 0)$
B	$\mathbf{W_{1\alpha}}$		$\lambda_{1\alpha}$ $[\equiv \tilde{B}]$	B	$(\mathbf{1},\ \mathbf{1},\ 0\ )$
DG-octet	$\mathbf{O}$	O	χ_g $[\equiv \tilde{g}']$		$(\mathbf{8},\ \mathbf{1},\ 0)$
DG-triplet	$\mathbf{T}$	$\{T^0, T^\pm\}$	$\{\chi_T^0, \chi_T^\pm\}$ $[\equiv \{\tilde{W}'^\pm, \tilde{W}'^0\}]$		$(\mathbf{1},\mathbf{3},\ 0\ )$
DG-singlet	$\mathbf{S}$	S	χ_S $[\equiv \tilde{B}']$		$(\mathbf{1},\ \mathbf{1},\ 0\ )$
Higgs-like Leptons	$\mathbf{R_u}$	R_u	$\tilde{R}_u$		$(\mathbf{1},\ \mathbf{2},\ -1/2)$
	$\mathbf{R_d}$	R_d	$\tilde{R}_d$		$(\mathbf{1},\ \mathbf{2},\ 1/2)$
Fake electrons	$\hat{\mathbf{E}}(\times 2)$	$\hat{E}$	$\hat{\tilde{E}}$		$(\mathbf{1},\ \mathbf{1},1)$
	$\hat{\mathbf{E}}'(\times 2)$	$\hat{E}'$	$\hat{\tilde{E}}'$		$(\mathbf{1},\ \mathbf{1},-1)$

MDGSSM - Lagrangian

$$W = W_{Yukawa} + W_{DG} + W_{RV}$$

$$W_{Yukawa} = Y_u^{ij}\mathbf{U^c}_i\mathbf{Q}_j\mathbf{H}_u - Y_d^{ij}\mathbf{D^c}_i\mathbf{Q}_j\mathbf{H}_d - Y_e^{ij}\mathbf{E^c}_i\mathbf{L}_j\mathbf{H_d}$$

$$W_{RV\,\mathrm{Higgssector}} = \mu\mathbf{H}_u\mathbf{H}_d$$

R-symmetry breaking limited to Higgs sector

$$W_{DG(\mathrm{adjoints})} = (\mu + \lambda_S\mathbf{S})\mathbf{H_d}\mathbf{H_u} + \sqrt{2}\lambda_T\mathbf{H_d}\mathbf{T}\mathbf{H_u}$$

strong constraints on λ_S due to Higgs mixing

$$W_{DG(\mathrm{unifcation})} = (\mu_R + \lambda_{SR}\mathbf{S})\mathbf{R_u}\mathbf{R_d} + 2\lambda_{TR}\mathbf{R_u}\mathbf{T}\mathbf{R_d} + (\mu_{\hat{E}\,ij} + \lambda_{S\hat{E}^c\,ij}\mathbf{S})\hat{\mathbf{E}}_i\hat{\mathbf{E}}'_j + \lambda_{SEij}\mathbf{S}\mathbf{E^c}_i\hat{\mathbf{E}}'_j$$

new singlet couples to unification fields

$$W_{RV} = L\mathbf{S} + \frac{\hat{M}_1}{2}\mathbf{S}^2 + \frac{\kappa}{3}\mathbf{S}^3 + \hat{M}_2\mathrm{tr}(\mathbf{TT}) + \hat{M}_3\mathrm{tr}(\mathbf{OO}) + \lambda_{ST}\mathbf{S}\mathrm{tr}(\mathbf{TT}) + \lambda_{SO}\mathbf{S}\mathrm{tr}(\mathbf{OO}) + \frac{\kappa_O}{3}\mathrm{tr}(\mathbf{OOO})$$

we assume mostly conserved R-symmetry in SUSY sector

$$-\mathcal{L}^{\mathrm{D-term}}_{\mathrm{trilinear}} \supset g' m_{1D} S_R \sum_j Y_j \varphi_j^* \varphi_j$$

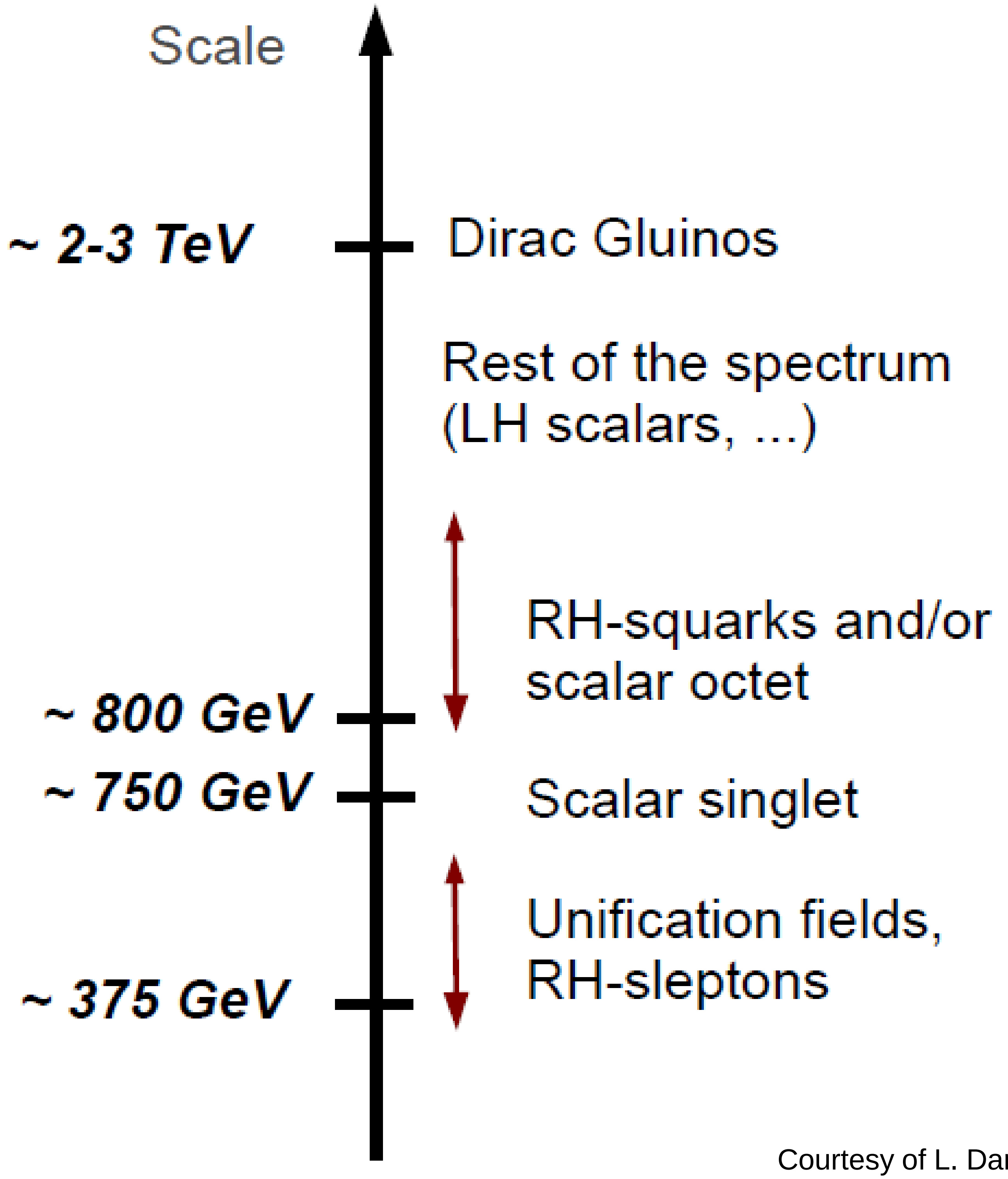
D-term contribution induces new trilinears

$$-\Delta\mathcal{L}^{\mathrm{scalar\ soft}}_{\mathrm{trilinear}} \supset T_{SE}^{ij} S\hat{E}_i\hat{E}'_j + T_{SR} S R_d R_u + T_{SO} S\mathrm{tr}(O^2) + h.c.$$

beyond other soft terms, trilinears of special interest

When preserving R-symmetry, (λ_{SE}, T_{SE}) and (λ_{SO}, T_{SO}) are not allowed simultaneously

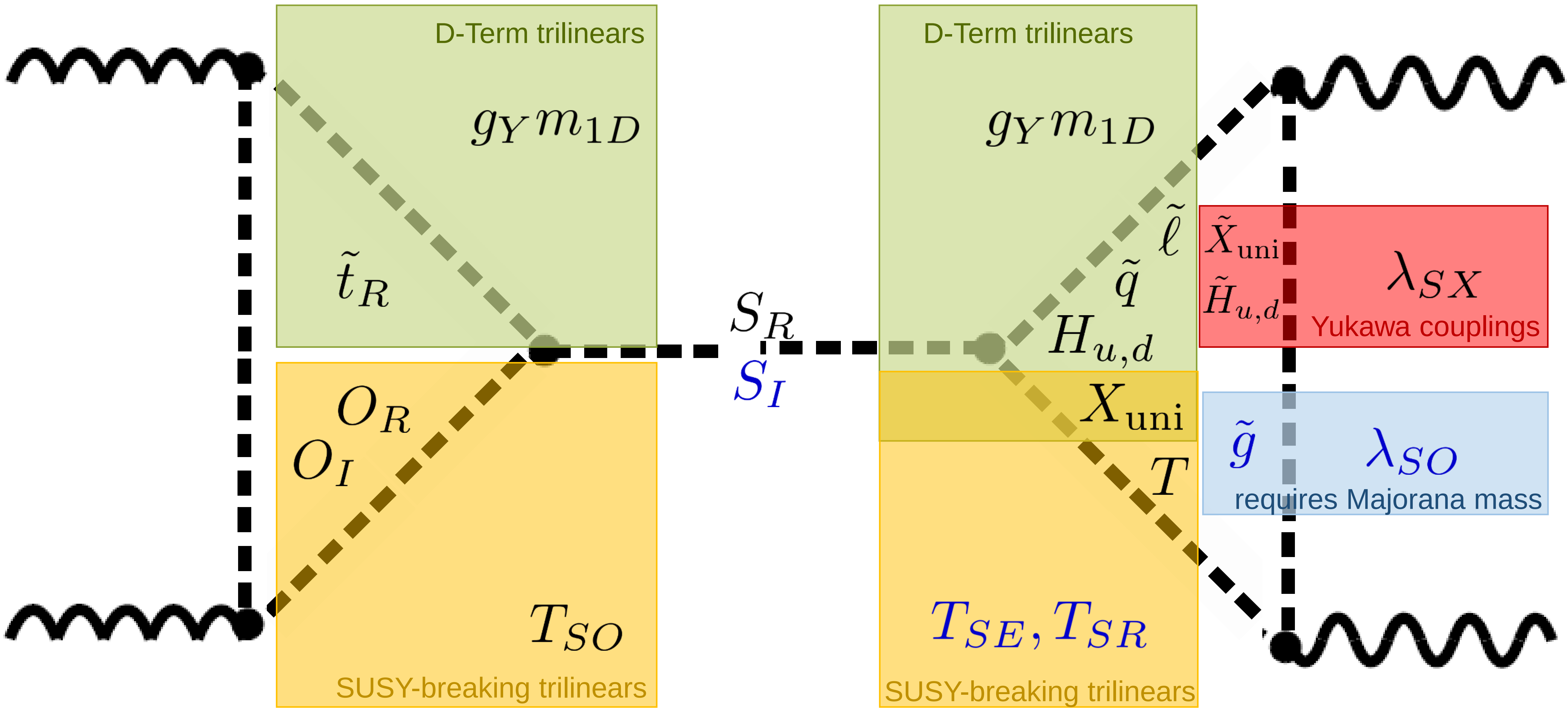
MDGSSM - possible mass spectrum



Courtesy of L. Darmé

Accomodating a diphoton signal in the MDGSSM

$$X_{\rm uni} = \hat{E}, \hat{E}', R_u, R_d$$



R-symmetric
R-violating

MDGSSM & current constraints

- Higgs, Higgs mixing and LHC8
  - constraint λ_S
  - larger λ_T
- Rho-parameter and naturalness
  - largish soft masses and m_{2D}
  - moderate m_T
- Collider limits on colour octets
  - Pseudo-scalar octet above 880 GeV
  - Scalar octet unlimited with gluino mass above 3TeV
- Perturbativity and Landau poles
  - $\lambda_{SE} < 0.7$
  - Similar constraints in R-violating scenarios
- Charge and colour breaking minima
  - stringent bound on T_{SE} due to upper limit on λ_{SE}
  - $T_{SO} < 310\mathrm{GeV}$, opens up for R-violating scenarios

Constraints from Higgs mixing and LHC8

Scalar singlet mix with SM Higgs:

$$\{h, H, S_R, T_R^0\}$$

$$\begin{pmatrix} M_Z^2 + \Delta_h s_{2\beta}^2 & \Delta_h s_{2\beta} c_{2\beta} & \Delta_{hS} & \Delta_{hT} \\ \Delta_h s_{2\beta} c_{2\beta} & M_A^2 - \Delta_h s_{2\beta}^2 & \Delta_{HS} & \Delta_{HT} \\ \Delta_{hS} & \Delta_{HS} & \tilde{m}_S^2 & \lambda_S \lambda_T \frac{v^2}{2} \\ \Delta_{hT} & \Delta_{HT} & \lambda_S \lambda_T \frac{v^2}{2} & \tilde{m}_T^2 \end{pmatrix}$$

Singlet admixture of SM Higgs given by

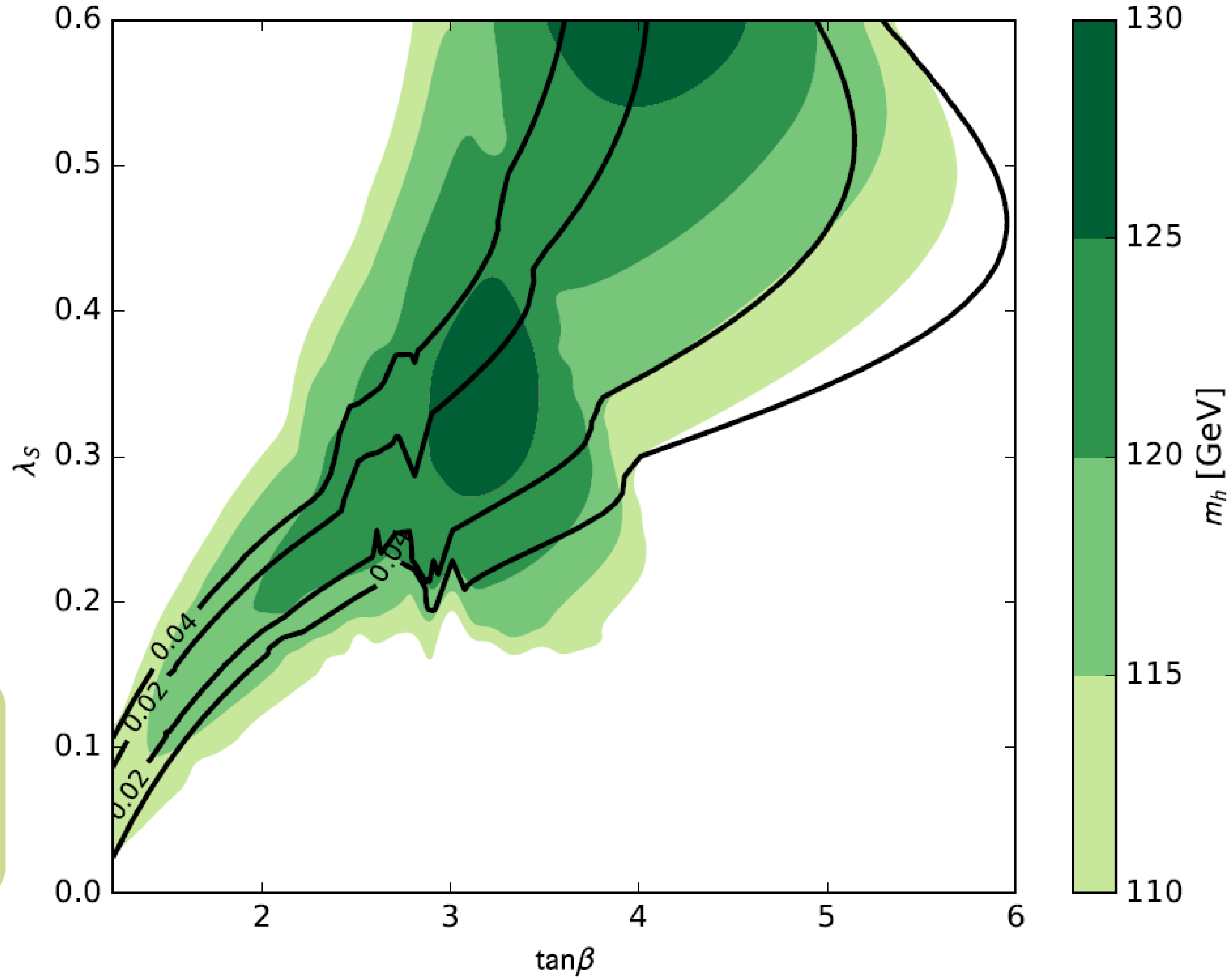
$$\begin{aligned} \Delta_{hS} &= v[v_S \lambda_S^2 - g' m_{1D} c_{2\beta} + \sqrt{2}\lambda_S \mu + \lambda_S \lambda_T v_T] \\ &= v[\sqrt{2}\lambda_S \tilde{\mu} - g' m_{1D} c_{2\beta}] \end{aligned}$$

Bounds on decays into hh, ZZ, WW from LHC8 searches constrain allowed mixing of the SM Higgs boson with the scalar singlet

$$\frac{\Gamma(S \to hh)}{\Gamma(S \to \gamma\gamma)} \simeq \frac{0.1 \times |S_{13}|^2 m_{SR}}{\Gamma(S \to \gamma\gamma)} < 50$$

$$\frac{\Gamma(S \to ZZ)}{\Gamma(S \to \gamma\gamma)} \simeq \frac{0.09 \times |S_{13}|^2 m_{SR}}{\Gamma(S \to \gamma\gamma)} < 15$$

$$\frac{\Gamma(S \to WW)}{\Gamma(S \to \gamma\gamma)} \simeq \frac{0.17 \times |S_{13}|^2 m_{SR}}{\Gamma(S \to \gamma\gamma)} < 50$$



SM Higgs mass bounded by

$$m_h^2 < M_Z^2 c_{2\beta}^2 + \frac{v^2}{2}(\lambda_S^2 + \lambda_T^2) s_{2\beta}^2$$

ideally lower m_{1D} and μ
moderate λ_S and larger λ_T

Rho-parameter & Naturalness

The Triplet with vev v_t contributes to the W-boson mass and is, thus, constrained by the ρ - parameter

$$\rho \equiv \frac{M_W^2}{c_{\theta_W}^2 M_Z^2} = 1 + \Delta\rho \sim 1 + \frac{4v_T^2}{v^2}$$

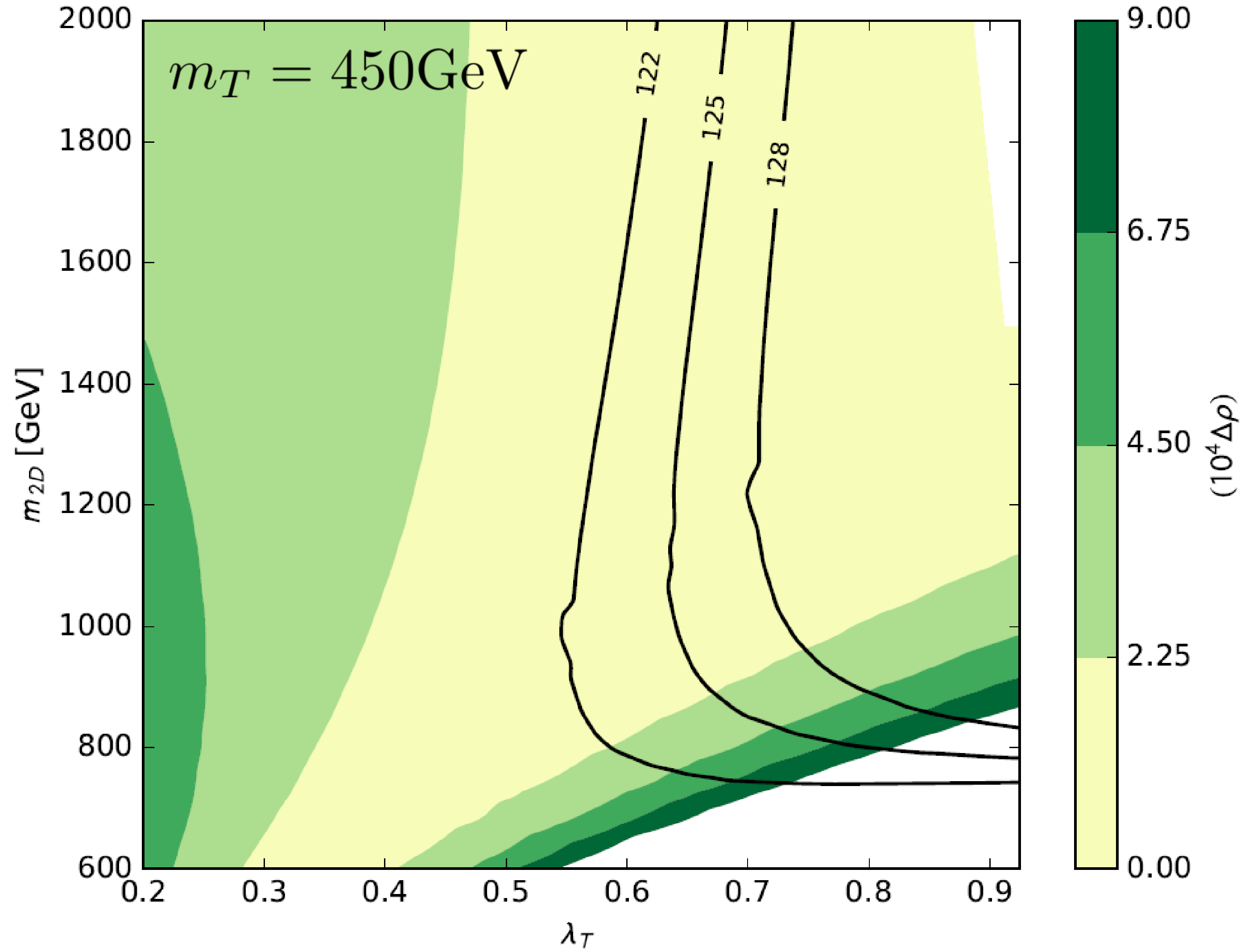
$$v_T \simeq \frac{v^2(-g m_{2D} c_{2\beta} - \sqrt{2}\tilde{\mu}\lambda_T)}{2(m_T^2 + 4m_{2D}^2 + B_T)}$$

Triplet scalars induce radiative corrections to $m^2_{H_{u,d}}$

$$\delta m^2_{H_{u,d}} \supset -\frac{1}{16\pi^2}(2\lambda_T^2 m_T^2)\log\left\{\frac{\Lambda}{\text{TeV}}\right\}$$

For fine-tuning of less than 10% we arrive at the condition for the soft triplet mass:

$$m_T \lesssim \frac{1}{\lambda_T} 450 \text{ GeV}$$



$$\Delta\rho < (4.2 \pm 2.7) \times 10^{-4}$$

ideally larger soft masses and larger m_{2D} while not having a too large triplet mass m_T

Constraints on Colour Octets

$$O^{(a)} = \frac{O_R^{(a)} + iO_I^{(a)}}{\sqrt{2}}$$

- Pair produced octets decay only to gluons and quarks
- leading to possible signatures of four jets, dijet/ditop and four tops

13 TeV four top search [ATLAS-CONF-2016-013] sets with 140 fb the most stringent constraint

$$\Gamma(O_2 \to gg) = \frac{5\alpha_s^3}{192\pi^2}\frac{m_{D3}^2}{M_{O_2}}\sin^2\left(\frac{\phi_{\tilde{B}}}{2}\right)|\lambda_{g_2}|^2$$

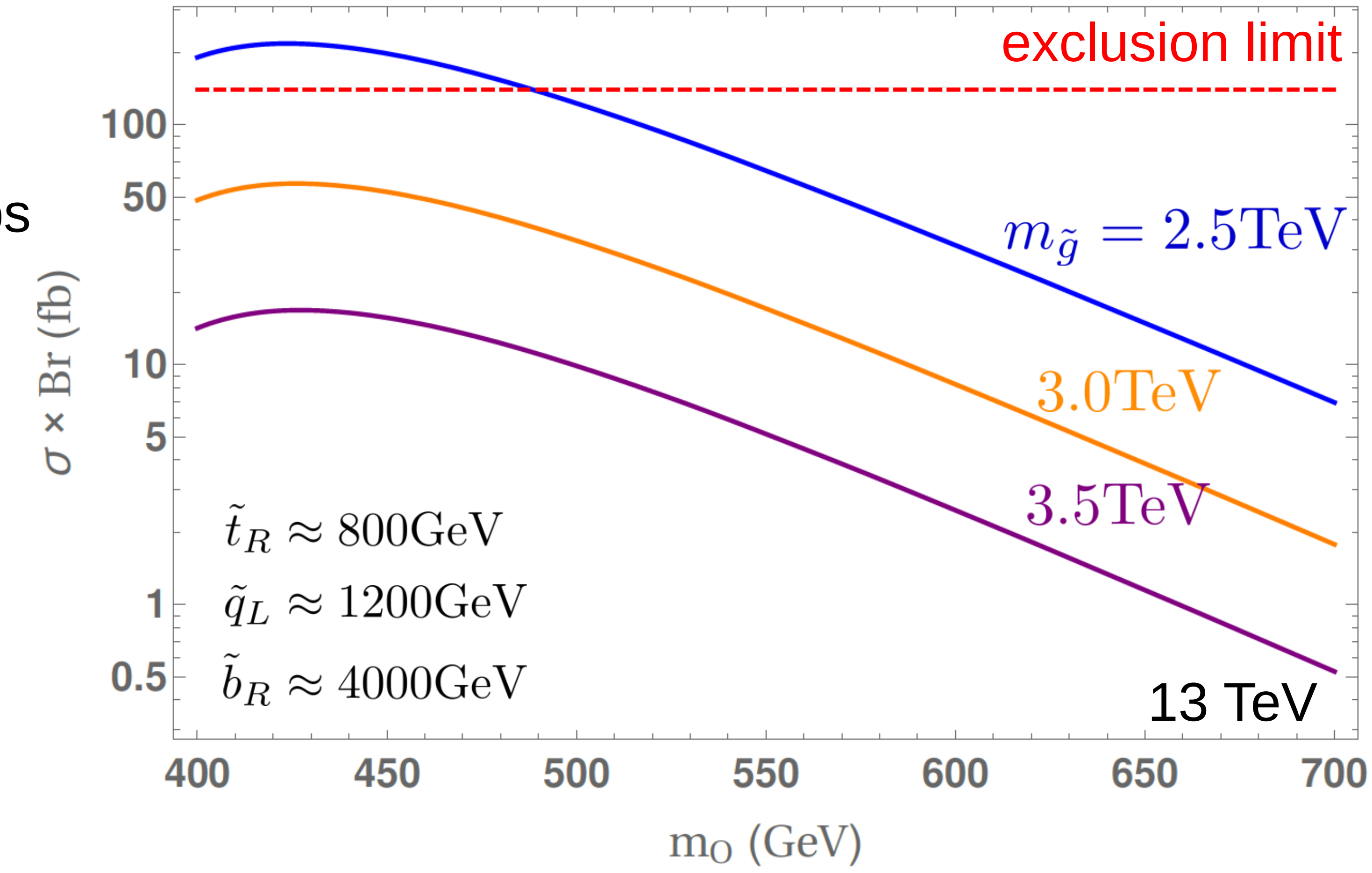
pseudo-scalar octet decays entirely into tops

restricts pseudo-scalar octet mass to be heavier than 880 GeV

$$\Gamma(O_1 \to gg) = \frac{5\alpha_s^3}{192\pi^2}\frac{m_{D3}^2}{M_{O_1}}\cos^2\left(\frac{\phi_{\tilde{B}}}{2}\right)|\lambda_{g_1}|^2$$

scalar octet decays into gluons and quarks

no constraints on scalar octet mass for gluinos heavier than 3 TeV



Perturbativity and Landau Poles

Numerical check if gauge couplings remain perturbative at two-loops up to the GUT scale

$$\beta_{\lambda_S} = \frac{1}{16\pi^2}\lambda_S[4\lambda_S^2 + 3\lambda_T^2 + 2\lambda_{SR}^2 + 2\lambda_{SE}^2 + 4\lambda_{SO}^2 - \frac{3}{5}g_1^2 - 3g_2^2 + 3y_t^2 + \ldots]$$

fixed by Higgs mixing

$$\beta_{\lambda_T} = \frac{1}{16\pi^2}\lambda_T[2\lambda_S^2 + 4\lambda_T^2 - \frac{3}{5}g_1^2 - 7g_2^2 + 3y_t^2 \ldots]$$

large value aimed for Higgs mass

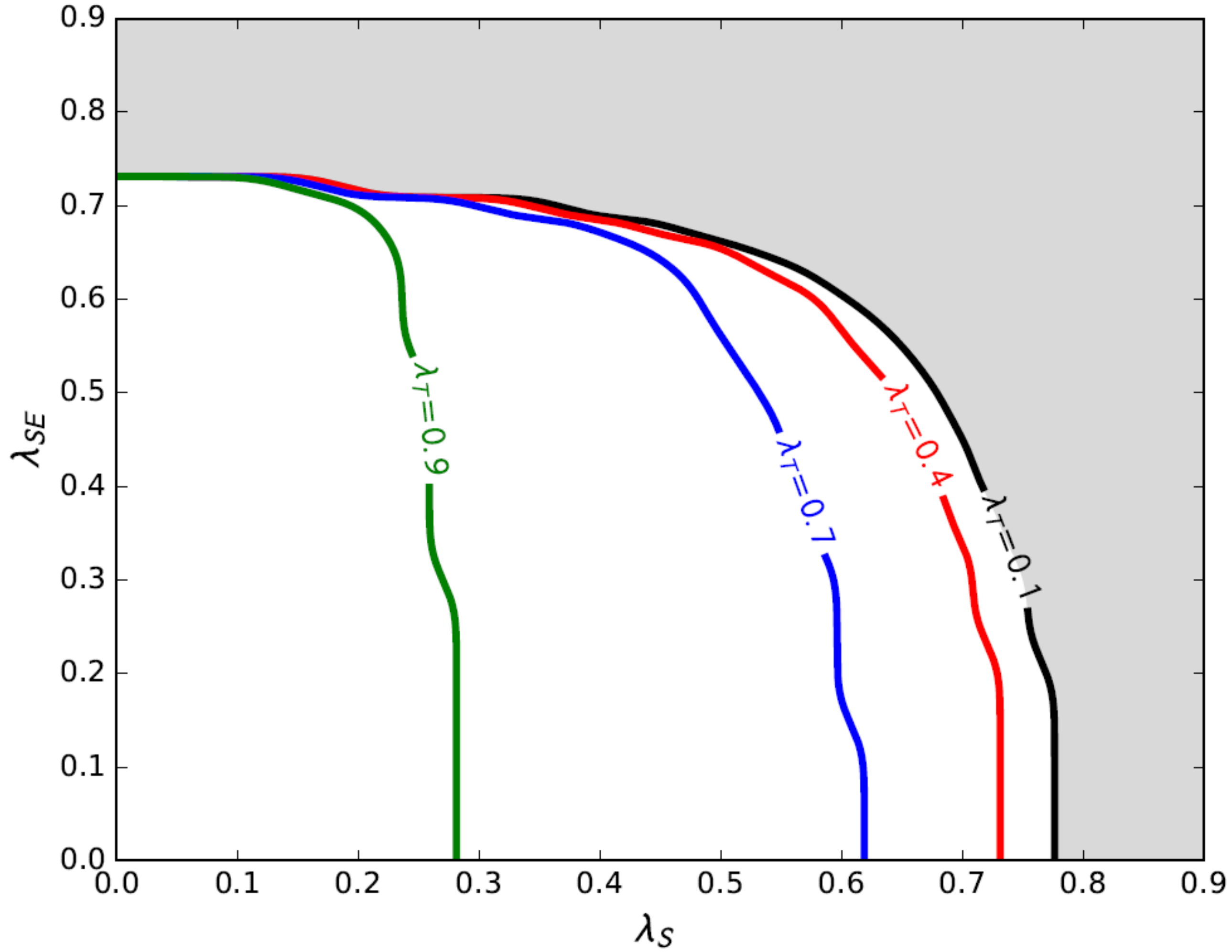
$$\beta_{\lambda_{SE}} = \frac{1}{16\pi^2}\lambda_{SE}[2\lambda_S^2 + 4\lambda_{SE}^2 + 2\lambda_{SR}^2 + 4\lambda_{SO}^2 - \frac{12}{5}g_1^2 + \ldots]$$

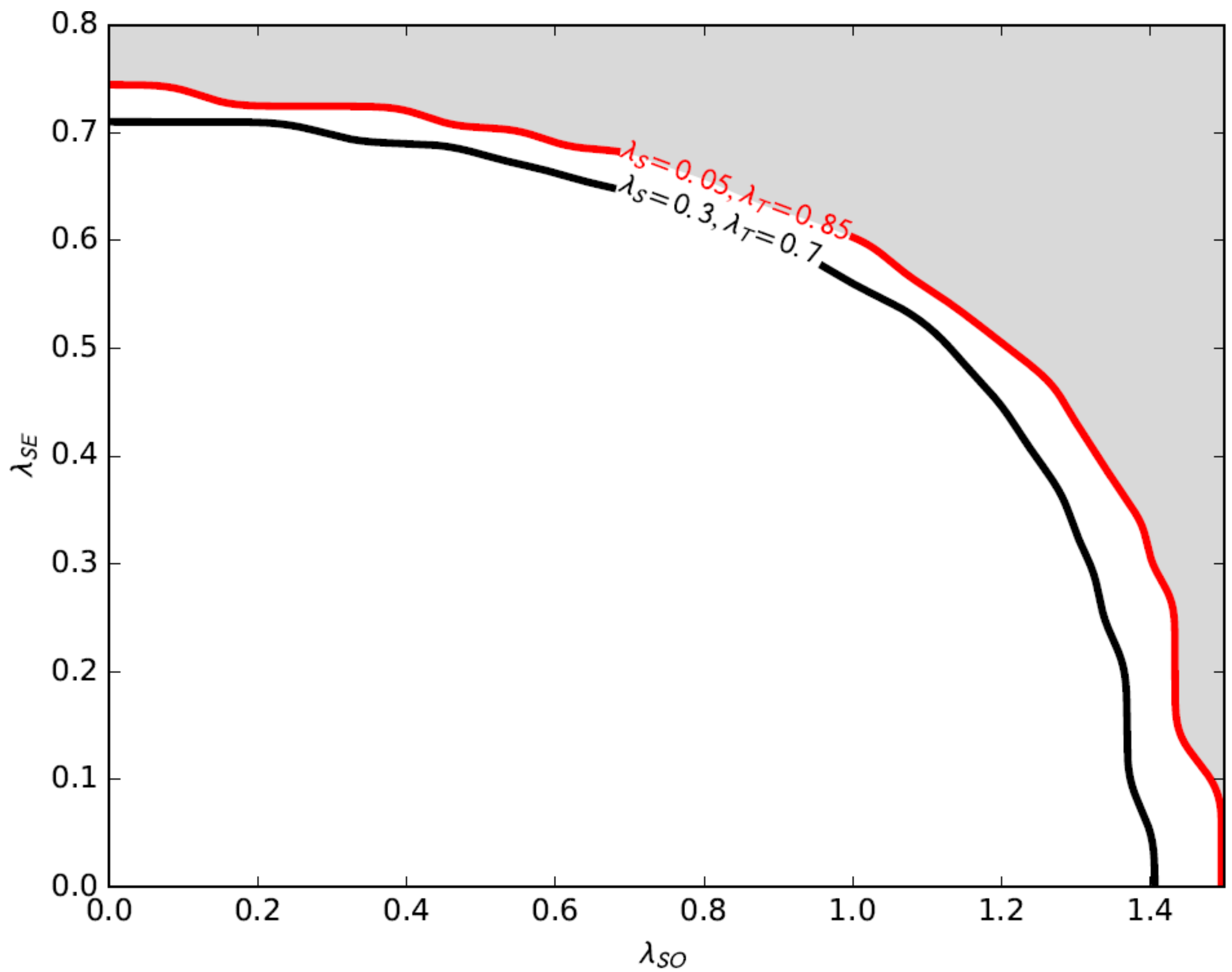
$$\beta_{\lambda_{SR}} = \frac{1}{16\pi^2}\lambda_{SR}[2\lambda_S^2 + 2\lambda_{SE}^2 + 4\lambda_{SR}^2 + 4\lambda_{SO}^2 - \frac{3}{5}g_1^2 - 3g_2^2 + \ldots]$$

large values favoured for increasing decay to photons

$$\beta_{\lambda_{SO}} = \frac{1}{16\pi^2}\lambda_{SO}[2\lambda_S^2 + 4\lambda_{SE}^2 + 2\lambda_{SR}^2 + 6\lambda_{SO}^2 - 12g_3^2 + \ldots]$$

only present in RV scenarios, stabilises potential for having larger T_{SO}





Charge and Colour breaking Minima

Including large trilinears makes a check for vacuum stability essential:

Charge breaking vacua

$$T_{SE}(S\hat{E}\hat{E}' + h.c.)$$

$$\lambda_{SE}^2|\hat{E}'\hat{E}|^2$$

$$\frac{T_{SE}^2}{\lambda_{SE}^2} > 2m_{ER}^2 + m_{SR}^2 + 2\sqrt{2}m_{ER}m_{SR}$$

$$m_{SR}^2 \equiv m_S^2 + B_S + 4m_{DY}^2$$
$$m_{ER}^2 \equiv m_{\hat{E}}^2 + m_{\hat{E}'}^2 + 2B_E + 2\mu_E^2$$

Stringent bound on T_{SE}

Color breaking vacua

$$T_{SO}(S\,\mathrm{tr}(OO) + h.c.)$$ Destabilising trilinears

$$\lambda_{SO}^2|\mathrm{tr}(OO)|^2$$ Stabilising quartics

In R-symmetric case, T_{SO} crucial for coupling of S with scalar octet; no quartic terms, assume additional quartics are loop induced

$$\frac{\lambda_O}{4}|O^a|^4 + \lambda_{SO}^H|S|^2|O^a|^2$$

$$T_{SO}^2 > \left(2\sqrt{\lambda_{SO}^H + \lambda_{SO}^2}\,m_{OR} + \sqrt{\lambda_O + \lambda_{SO}^2}\,m_{SR}\right)^2$$

$$m_{OR}^2 \equiv m_O^2 + B_O + 4|m_{D3}|^2$$

$\lambda_O, \lambda_{SO}^H \approx \mathcal{O}(0.04)$ → $T_{SO} \lesssim 310\,\mathrm{GeV}$

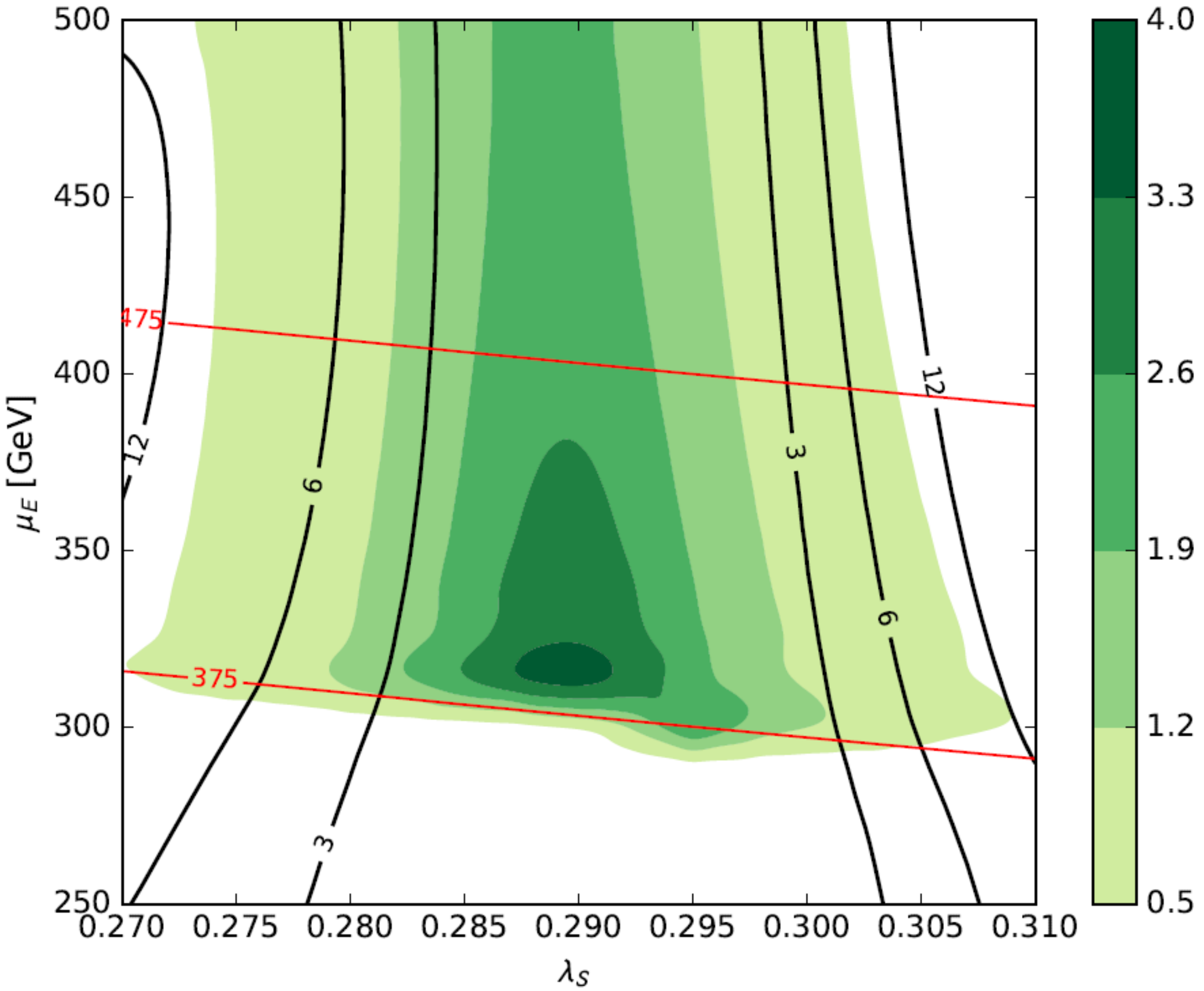
In R-violating case, allows for larger T_{SO}

Still, let us dream of an

750 GeV resonance…

We studied different scenarios…

Gluon fusion induced by light squarks

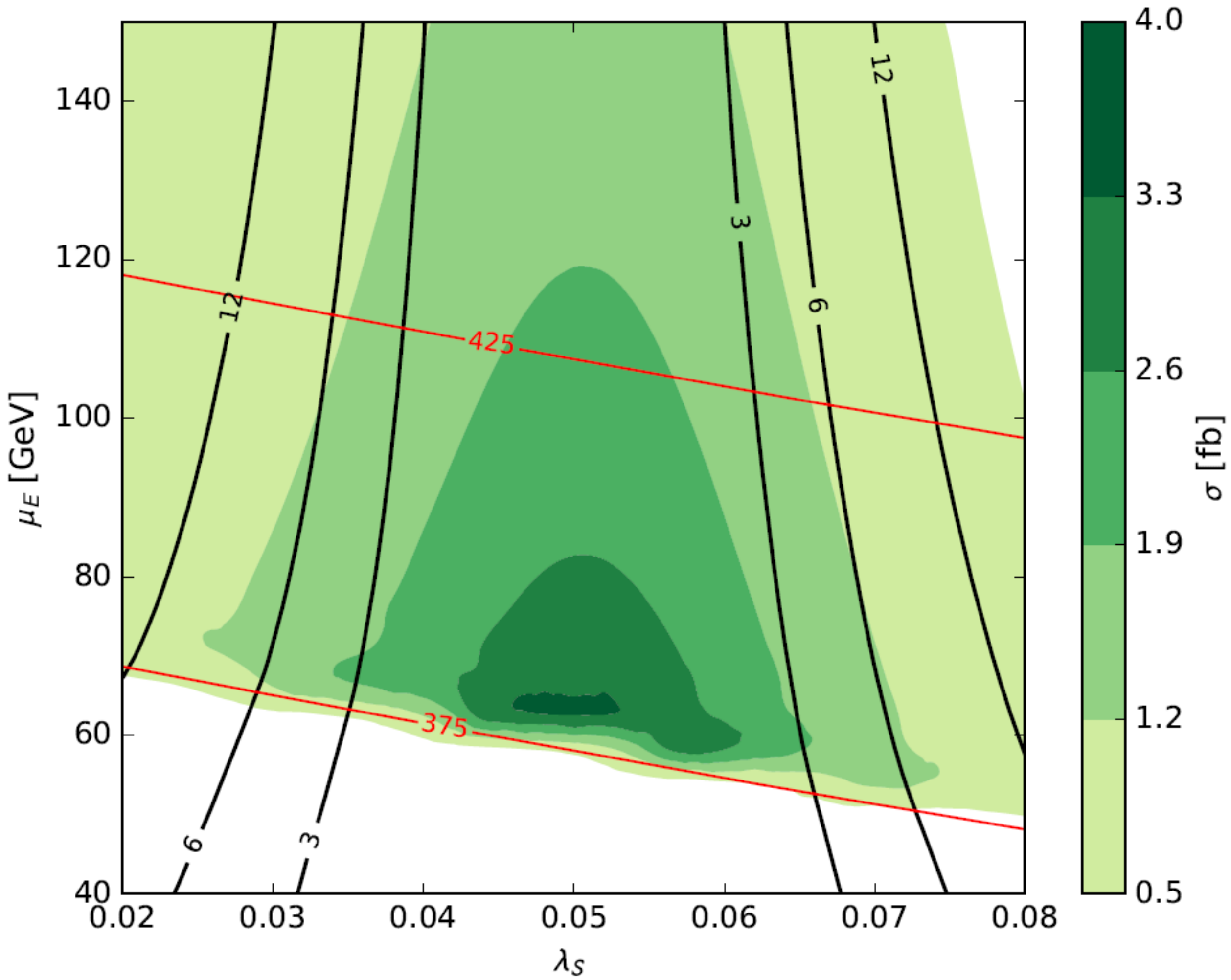


	Parameter	$\mathbf{R_a}$	$\mathbf{R_b}$
Higgs mass	μ	925 GeV	450 GeV
	$\tan\beta$	3	5
	λ_T	0.7	0.85
	m_T	500 GeV	1000 GeV
Singlet masses and mixing	m_{1D}	1250 GeV	100 GeV
	m_S	500 GeV	775 GeV
	B_S	-2.44^2 TeV^2	-200^2 GeV^2
	λ_S	0.29	0.05
Singlet decay /production amplitude to gg	T_{SO}	200 GeV	300 GeV
	m_O	1300 GeV	1025 GeV
	$m_{\tilde{t}_R}$	500 GeV	1200 GeV
Singlet decay amplitude to $\gamma\gamma$	$\lambda_{SR} = \lambda_{SE}$	0.7	0.7
	$m_E^2 = m_{R_{u,d}}^2$	10^2 GeV^2	150^2 GeV^2
	$\mu_E = \mu_{R_{u,d}}/1.4$	325 GeV	65 GeV
	$m_{\tilde{l}R}$	250 GeV	500 GeV
Outputs	m_h	125.5 GeV	124.9 GeV
	m_{S_R}	750.1 GeV	755.7 GeV
	m_{O_I}/m_{O_R} ($\mathbf{R_a}$ /$\mathbf{R_b}$)	945.5 GeV	390.0 GeV
	$m_{\tilde{t}_R}$	820.3 GeV	1165.0 GeV
	$m_{\tilde{l}_R}$	418 GeV	513 GeV
	$m_{\tilde{E}}$	397 GeV	382 GeV
	$\sigma(S \to \gamma\gamma)$	**3.20 fb**	**3.18 fb**
	$\Delta\rho$	0.97×10^{-4}	3.17×10^{-4}

- R-symmetric case: no trilinears T_{SE}, T_{SR}
- Gluon fusion induced by light squark loops enhanced due to large m_{1D}
- Photon decay via loops of (fake) sleptons and fake leptons $m_{1D}, \lambda_{SE}, \lambda_{SR}$
- large negative B_S for a scalar singlet mass of 750 GeV
- not (strongly) constrained by LHC8 data

We studied different scenarios…

Gluon fusion induced by scalar octets



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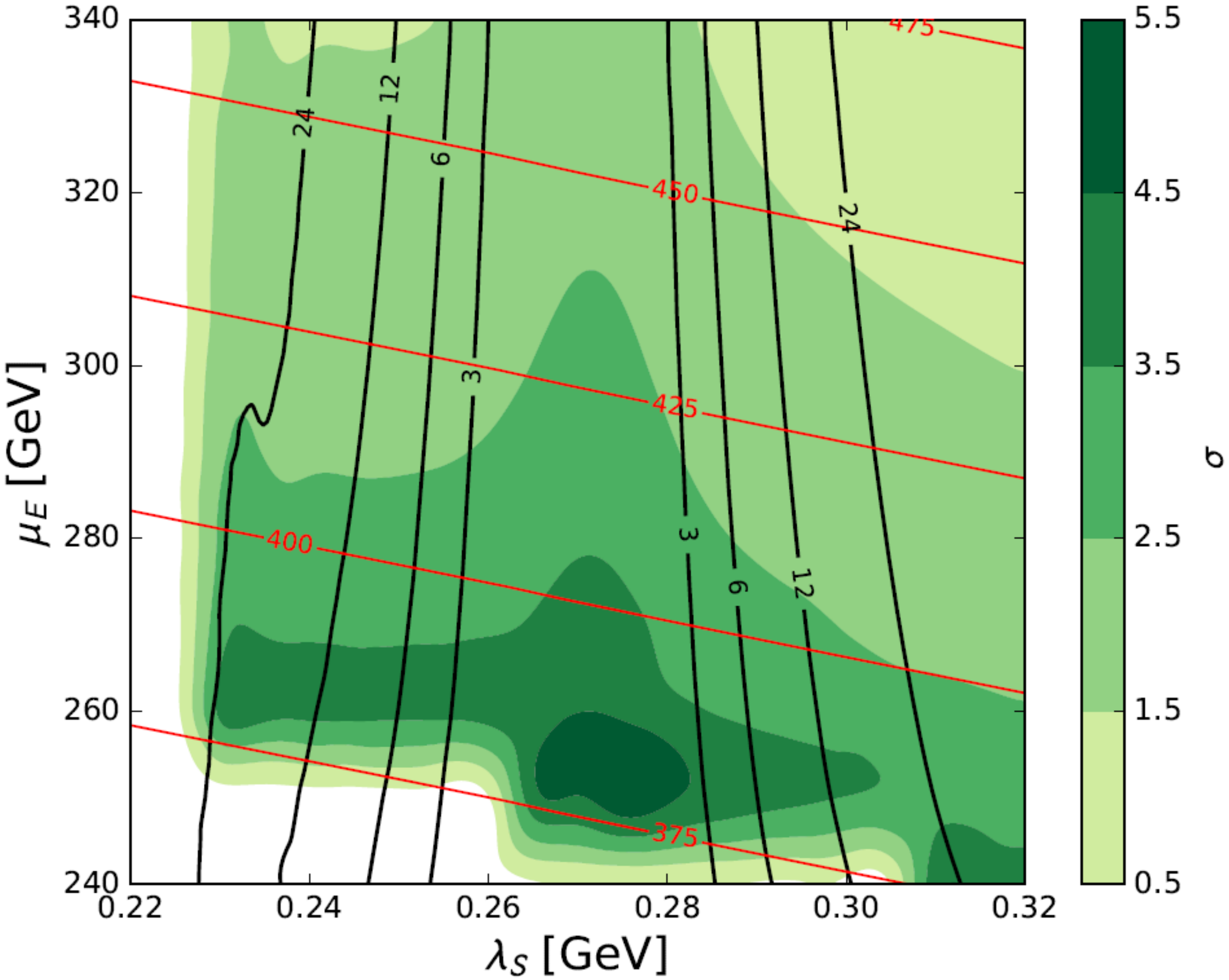
	$\Delta\rho$	0.97×10^{-4}	3.17×10^{-4}

- R-symmetric case: no trilinears T_{SE}, T_{SR}
- Gluon fusion induced by light scalar octets having large m_{3D}, and thus larger negative B_O
- Photon decay via loops of fake fermions $\lambda_{SE}, \lambda_{SR}$
- No photon decay induced via sleptons anymore (small m_{1D}) → less tuning in λ_S, B_S
- not (strongly) constrained by LHC8 data

... including also one "double peak" scenario...

allow for additional Majorana gaugino mass
→ breaks R-symmetry

Scalar and Pseudo-scalar Singlet @ 750 GeV



$\tan\beta$	4
μ	450 GeV
m_S	310 GeV
m_T	1200 GeV
m_O	890 GeV
M_3	1400 GeV
m_{1D}	490 GeV
m_{2D}	1000 GeV
m_{3D}	2300 GeV
λ_S	0.27
λ_T	0.70
λ_{SO}	0.65
$\lambda_{SR} = \lambda_{SE}$	0.65
B_S	-0.7^2 TeV^2
$T_{SE} = T_{SR}$	0 GeV
T_{SO}	600 GeV
m_h	125.9 GeV
m_{S_R}	756.5 GeV
m_{S_I}	751.0 GeV
m_{O_I}	886.3 GeV
m_E	386.7 GeV
$m_{\tilde{E}}$	377.2 GeV
$m_{\tilde{t}_1}$	1597.2 GeV
$m_{\tilde{g}}$	1916.0 GeV
ZZ	0.0
hh	1.2
WW	0.0
gg	4.4
$\Delta\rho$	2.4×10^{-4}
$\sigma(S \to \gamma\gamma)$	**4.4 fb**

- allows even much more flexibility by enhancing TSE, increasing mass hierarchy in unification fields etc…
- reason for ATLAS claiming wide width??

Conclusions

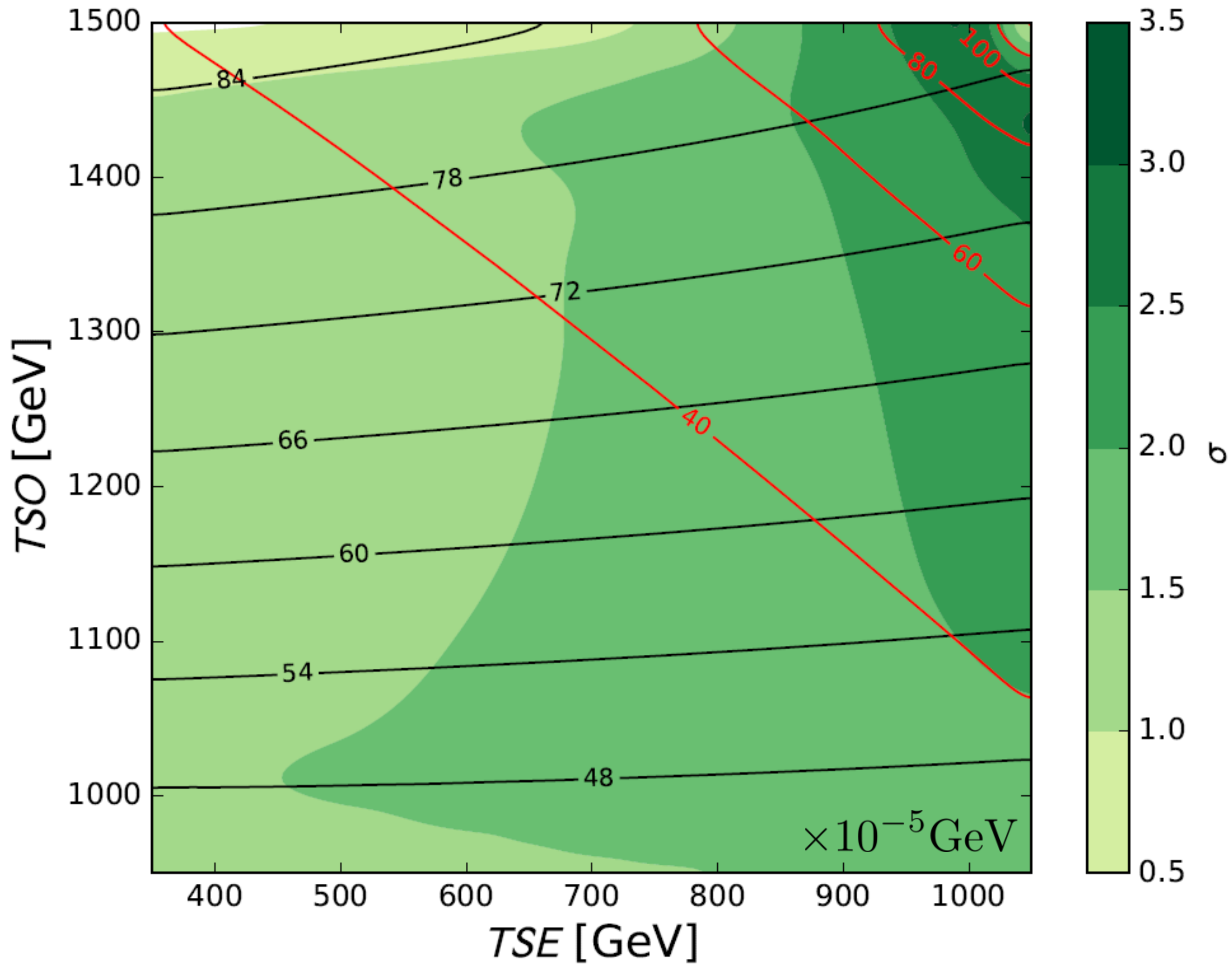
- The MDGSSM is an interesting and promising model
- Could generate a diphoton excess at 750 GeV
- we studied thoroughly experimental constraints
  - Higgs mass and mixing
  - LHC8 data
  - Naturalness
  - Rho parameter
  - exclusion bounds on scalar octets
- As well as constraints from
  - Perturbativity
  - Vacuum stability
- Demonstrated in different scenarios (pure R-symmetric as well as double peak scenario, etc…) that the MDGSSM can accommodate such an intriguing signal

Whatever the new data will show us – the MDGSSM was and is motivated from different perspectives!

Thank you!

R-symmetry violating Scenarios

Gluon fusion induced by pseudo-scalar octets



- allow $T_{SE} = T_{SR}$ while having $\lambda_{SE} = \lambda_{SR}$
- allow λ_{SO} and thus larger values for T_{SO}

increase of production via gluons as well as decay into photons

$\tan\beta$	2	4
μ	660 GeV	450 GeV
m_S	490 GeV	310 GeV
m_T	1250 GeV	1200 GeV
m_O	530 GeV	890 GeV
M_3	0	1400 GeV
m_{1D}	1250 GeV	490 GeV
m_{2D}	1000 GeV	1000 GeV
m_{3D}	1600 GeV	2300 GeV
λ_S	0.29	0.27
λ_T	0.65	0.70
λ_{SO}	0.65	0.65
$\lambda_{SR} = \lambda_{SE}$	0.65	0.65
B_S	-2.4^2 TeV^2	-0.7^2 TeV^2
$T_{SE} = T_{SR}$	-1000 GeV	0 GeV
T_{SO}	1500 GeV	600 GeV
m_h	124.8 GeV	125.9 GeV
m_{S_R}	755.7 GeV	756.5 GeV
m_{S_I}	1125.1 GeV	751.0 GeV
m_{O_I}	886.3 GeV	886.3 GeV
m_E	382.2 GeV	386.7 GeV
$m_{\tilde{E}}$	378.6 GeV	377.2 GeV
$m_{\tilde{t}_1}$	1776.5 GeV	1597.2 GeV
$m_{\tilde{g}}$	1825.8 GeV	1916.0 GeV
ZZ	0.1	0.0
hh	0.5	1.2
WW	0.3	0.0
gg	0.7	4.4
$\Delta\rho$	9.9×10^{-5}	2.4×10^{-4}
$\sigma(S \to \gamma\gamma)$	**3.1 fb**	**4.4 fb**

R-symmetry violating Scenarios

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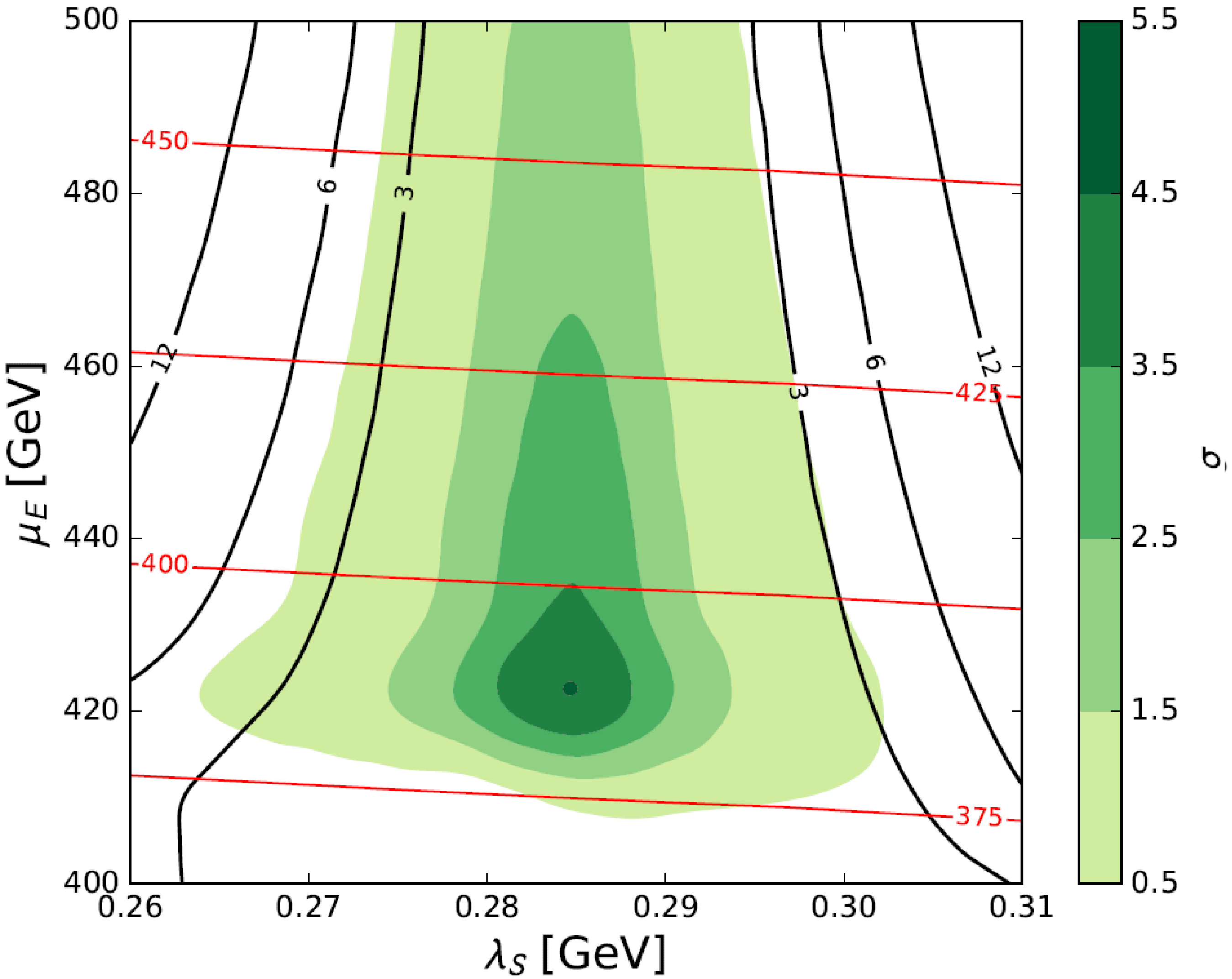

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R-symmetry violating Scenarios

"Double Peak" Scenario

Scalar and Pseudo-scalar Singlet @ 750 GeV

- without R-violation no production of pseudo-scalar Singlet

⇒ Majorana Gaugino Mass M_3 necessary

$$\Gamma(S_I \to gg) \approx \frac{9\alpha_s^2 \lambda_{SO}^2 m_{S_I}^3}{16\pi^3} \left(\frac{\cos^2\theta_{\tilde{g}}}{|M_{\tilde{g}_1}|} - \frac{\sin^2\theta_{\tilde{g}}}{|M_{\tilde{g}_2}|} \right)^2$$

$$\mathcal{L}_{m_{\tilde{g}}} = (\lambda_3 \quad \chi_g) \begin{pmatrix} M_3 & M_D \\ M_D & 0 \end{pmatrix} \begin{pmatrix} \lambda_3 \\ \chi_g \end{pmatrix} + \text{h.c.}$$

$$\begin{pmatrix} \tilde{g}_1 \\ \tilde{g}_2 \end{pmatrix} = \begin{pmatrix} \cos\theta_{\tilde{g}} & -\sin\theta_{\tilde{g}} \\ \sin\theta_{\tilde{g}} & \cos\theta_{\tilde{g}} \end{pmatrix} \begin{pmatrix} \chi_g \\ \lambda_3 \end{pmatrix}$$

in Dirac limit: $|M_{\tilde{g}_1}| = |M_{\tilde{g}_1}|$ and $\cos\theta_{\tilde{g}} = \sin\theta_{\tilde{g}} = 1/\sqrt{2}$

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