NSUSY Fits.

Papers discussed:

Lee, Sanz, Trott arXiv:1204.0802

Espinosa, Grojean, Sanz, Trott arXiv:1207.7355

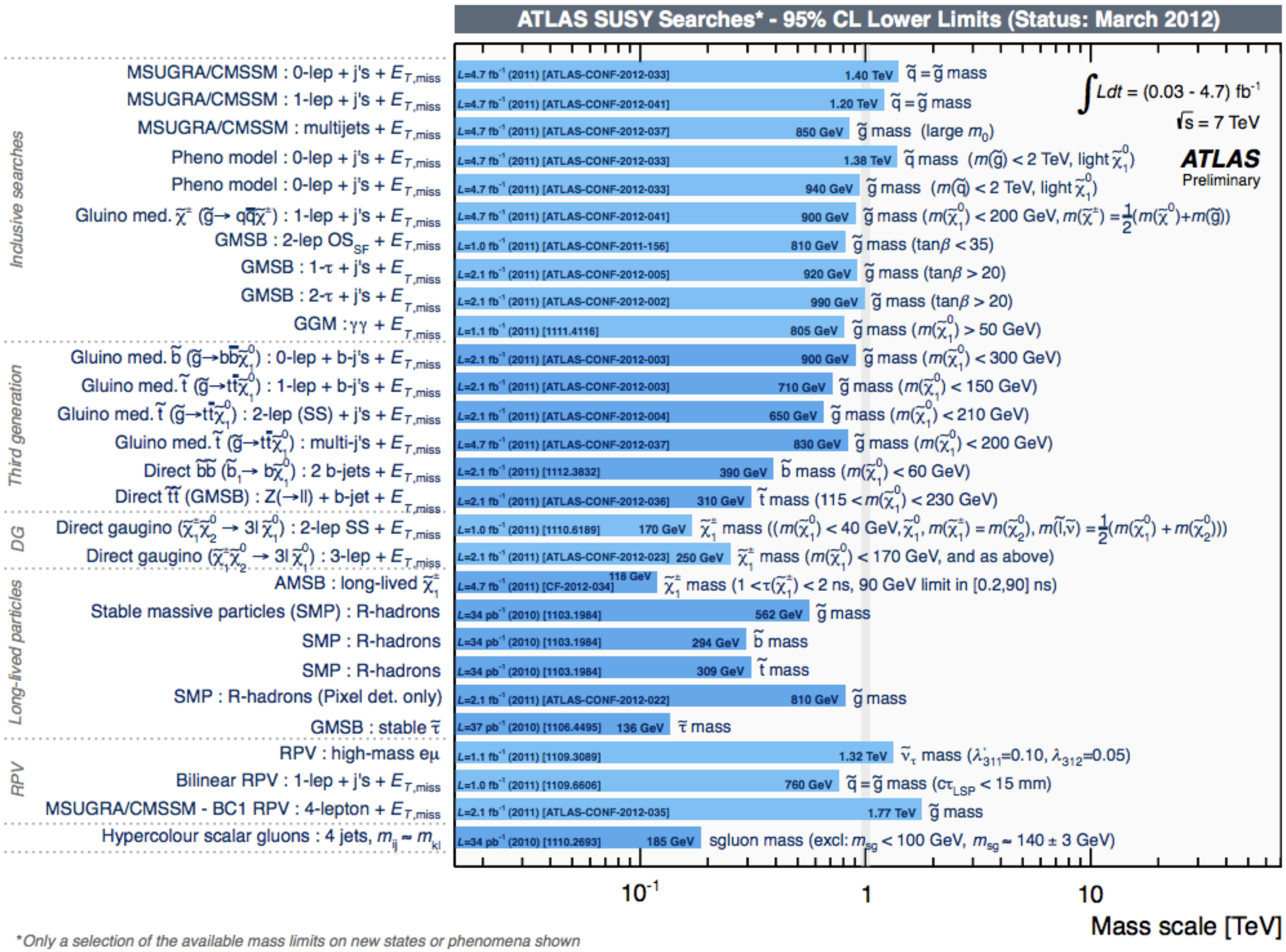
Content (for ref):

hitting sbottom

Higgs data, fits, other constraints

Natural SUSY

In light of recent LHC searches for the lowest lying SUSY fruit being fruitless to date:



Summary of bounds on New physics from ATLAS.

Natural SUSY

Theorists are re-examining what is minimally desired out of a SUSY spectrum.

From an effective field theory point of view what do you want?

One wants SUSY to solve the hierarchy problem by ensuring that the threshold matching corrections of the Higgs mass operator

$$\mu^2 \, \phi^\dagger \, \phi$$

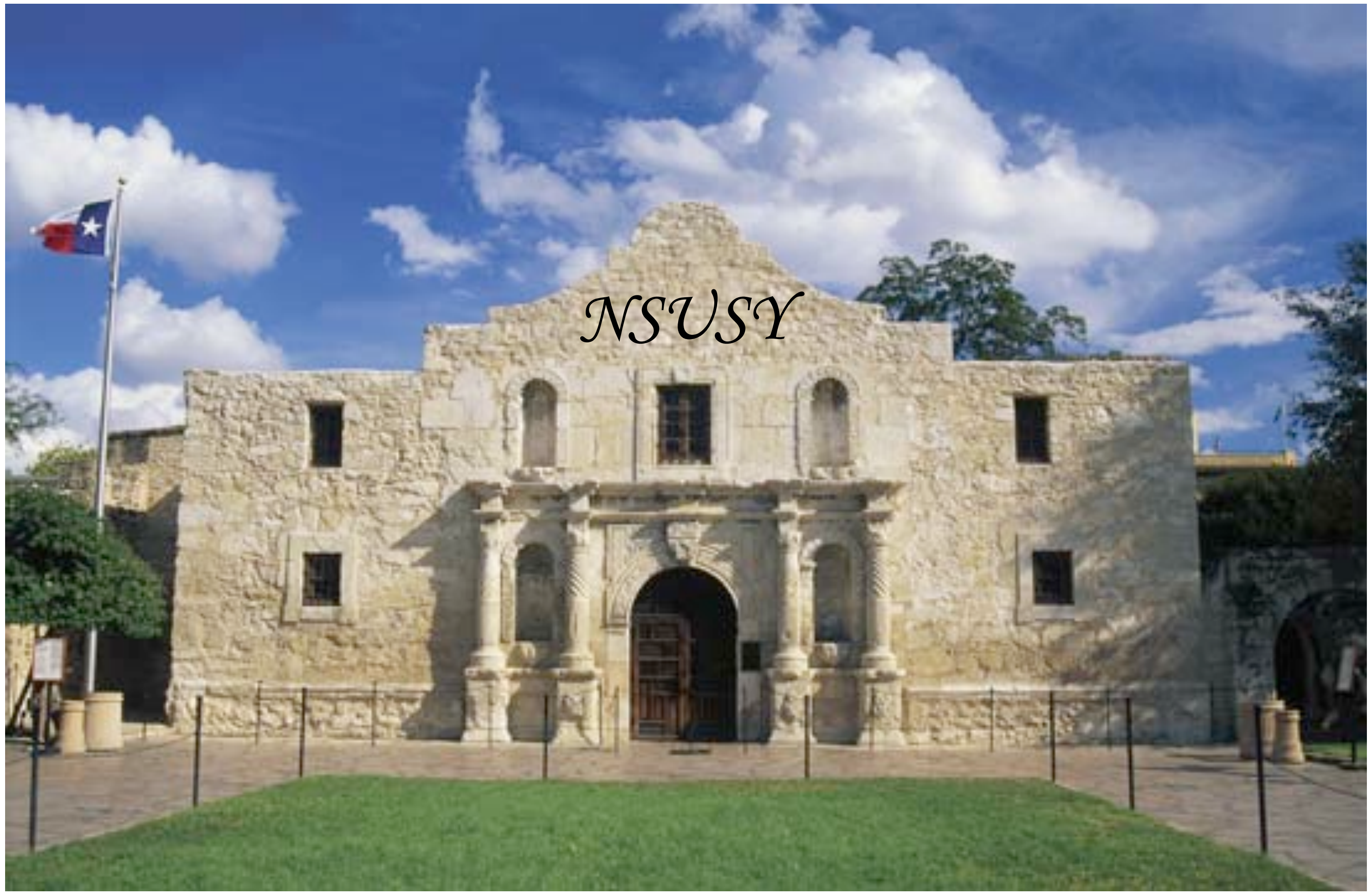
effectively cancel up to weak scale matching differences: $(\delta m_B^2 - \delta m_F^2)\phi^\dagger \, \phi$

So that large NP mass scales can exist and not intrinsically lead to fine tuning in the Higgs mass operator. (See Meade's talk yesterday for exposition)

In solving the Hierarchy problem this way you do not want to re-introduce (significant) fine tuning in the solution.

Natural SUSY

What is the minimal required spectrum for SUSY motivated out of naturalness?



In honour of texas, the SUSY Alamo.

Natural SUSY

Particle theory community by and large

LHC data
to date

Light gluino with R parity conservation

Natural SUSY

What is the minimal required spectrum for SUSY motivated out of naturalness?

What do we need to hold out? Lots of options actually.

Natural SUSY

What is the minimal required spectrum for SUSY motivated out of naturalness?

What do we need to hold out?

.... we need a spectrum like this perhaps:

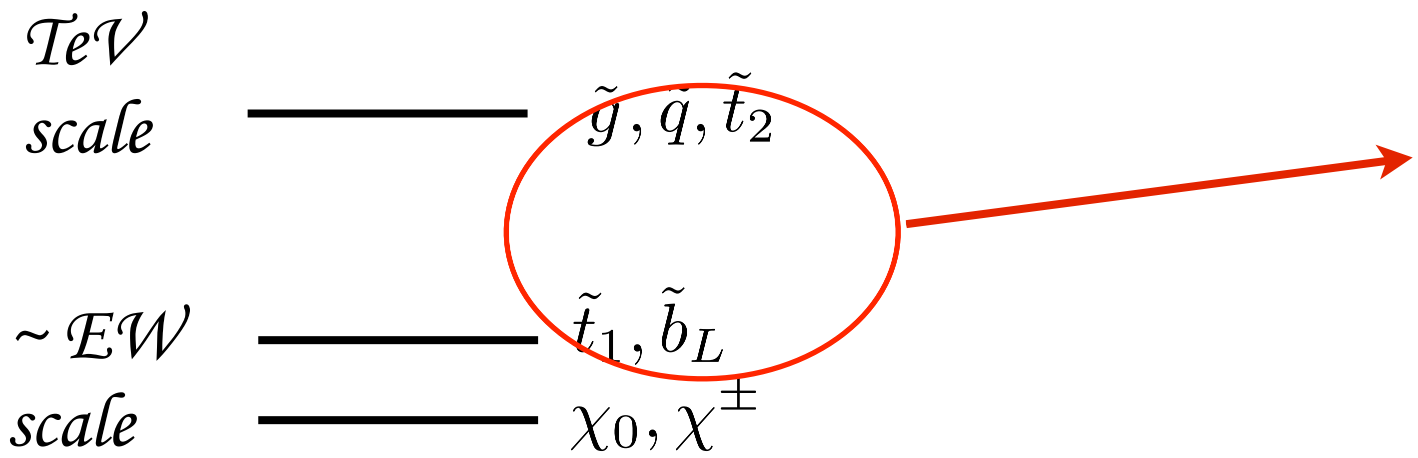
TeV scale	———	$\tilde{g}, \tilde{q}, \tilde{t}_2$
~ EW scale	———	$\tilde{t}_1, \tilde{b}_L?$
	———	$\chi_0, \chi^{\pm}$

Want this spectrum to not re-introduce fine tuning: higgsinos linked to μ *and*

$$\delta_{\tilde{t}}\, m_Z^2 \simeq \frac{3}{8\,\pi^2\, v^2}\left[2m_t^2(m_{\tilde{t}_1}^2 + m_{\tilde{t}_2}^2 - 2m_t^2) + \frac{1}{4}(\delta m)^4 \sin^2(2\theta_{\tilde{t}})\right] \log\left(\frac{2\,\Lambda^2}{m_{\tilde{t}_1}^2 + m_{\tilde{t}_2}^2}\right)$$

Natural SUSY

Lets see what the data says for lowish : $\tan\beta \sim 10$



Custodial sym violation: precision mW

What "hitting sbottom" is about.

Natural SUSY

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TeV scale ——— $\tilde{g}\,, \tilde{q}, \tilde{t}_2$

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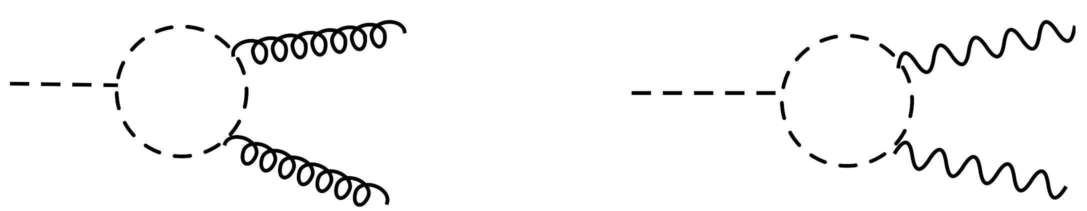
What "hitting sbottom" is about.

Higgs properties



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TeV scale $\tilde{g}, \tilde{q}, \tilde{t}_2$

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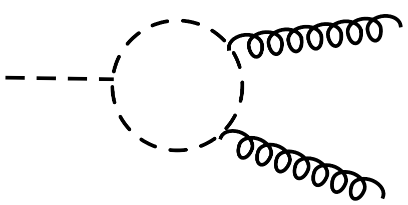
Precision flavour physics constraints sensitive to the stop splitting

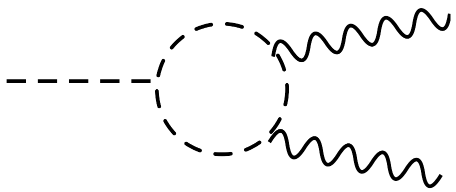
$\mathrm{Br}(\bar{B} \to X_s\, \gamma)$

Custodial sym violation: precision mW

What "hitting sbottom" is about.

Higgs properties





Natural Susy

Do a real EFT matching taking into account the QCD latching correction (in the no mixing limit) :

Stop contributions to Higgs production:

$$\frac{\sigma(gg \to h)}{\sigma^{SM}(gg \to h)} \simeq \frac{\Gamma(h \to gg)}{\Gamma^{SM}(h \to gg)} \simeq |1 + r_g|^2 \qquad r_g = \frac{C_g(\alpha_s) F_g(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \theta_{\tilde{t}})}{F_g^{SM}(m_t, m_b \cdots)}$$

QCD squark matching correction

Stop contributions to interesting decays:

$$\frac{\Gamma(h \to \gamma\gamma)}{\Gamma^{SM}(h \to \gamma\gamma)} \simeq |1 + r_\gamma|^2, \qquad r_\gamma = \frac{N_c Q_{\tilde{t}}^2 C_\gamma(\alpha_s) F_g(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \theta_{\tilde{t}})}{F_\gamma^{SM}(m_t, W, m_b \cdots)}$$

Same loop functions, non abelian nature of QCD irrelevant at leading order in matching.

Natural Susy

Do a real EFT matching taking into account the QCD latching correction (in the no mixing limit):

The Effective Lagrangian:

$$\mathcal{L}_{HD} = -\frac{c_g\, g_3^2}{2\,\Lambda^2} H^\dagger H\, G^A_{\mu\nu} G^{A\mu\nu} - \frac{c_W\, g_2^2}{2\,\Lambda^2} H^\dagger H\, W^a_{\mu\nu} W^{a\mu\nu} - \frac{c_B\, g_1^2}{2\,\Lambda^2} H^\dagger H\, B_{\mu\nu} B^{\mu\nu}$$
$$-\frac{c_{WB}\, g_1\, g_2}{2\,\Lambda^2} H^\dagger \tau^a H\, B_{\mu\nu} W^{a\mu\nu}\,,$$

In terms of operators:

$$\sigma_{gg\to h} \approx \sigma^{SM}_{gg\to h} \left|1 + \frac{2}{F_g^{SM}} \frac{v^2\,\tilde{c}_g}{\Lambda^2}\right|^2, \quad \Gamma_{h\to\gamma\gamma} \approx \Gamma^{SM}_{h\to\gamma\gamma} \left|1 + \frac{1}{F_\gamma^{SM}} \frac{v^2\,\tilde{c}_\gamma}{\Lambda^2}\right|^2$$

Matching with no running: $\frac{v^2\,\tilde{c}_g}{\Lambda^2} \simeq C_g(\alpha_s)\,\frac{F_g}{2}, \qquad \frac{v^2\,\tilde{c}_\gamma}{\Lambda^2} \simeq N_c\, Q_{\tilde{t}}^2\, C_\gamma(\alpha_s)\, F_g$

$$C_g(\alpha_s) = 1 + \frac{25\,\alpha_s}{6\,\pi}, \qquad C_\gamma(\alpha_s) = 1 + \frac{8\,\alpha_s}{3\,\pi}.$$

Natural Susy

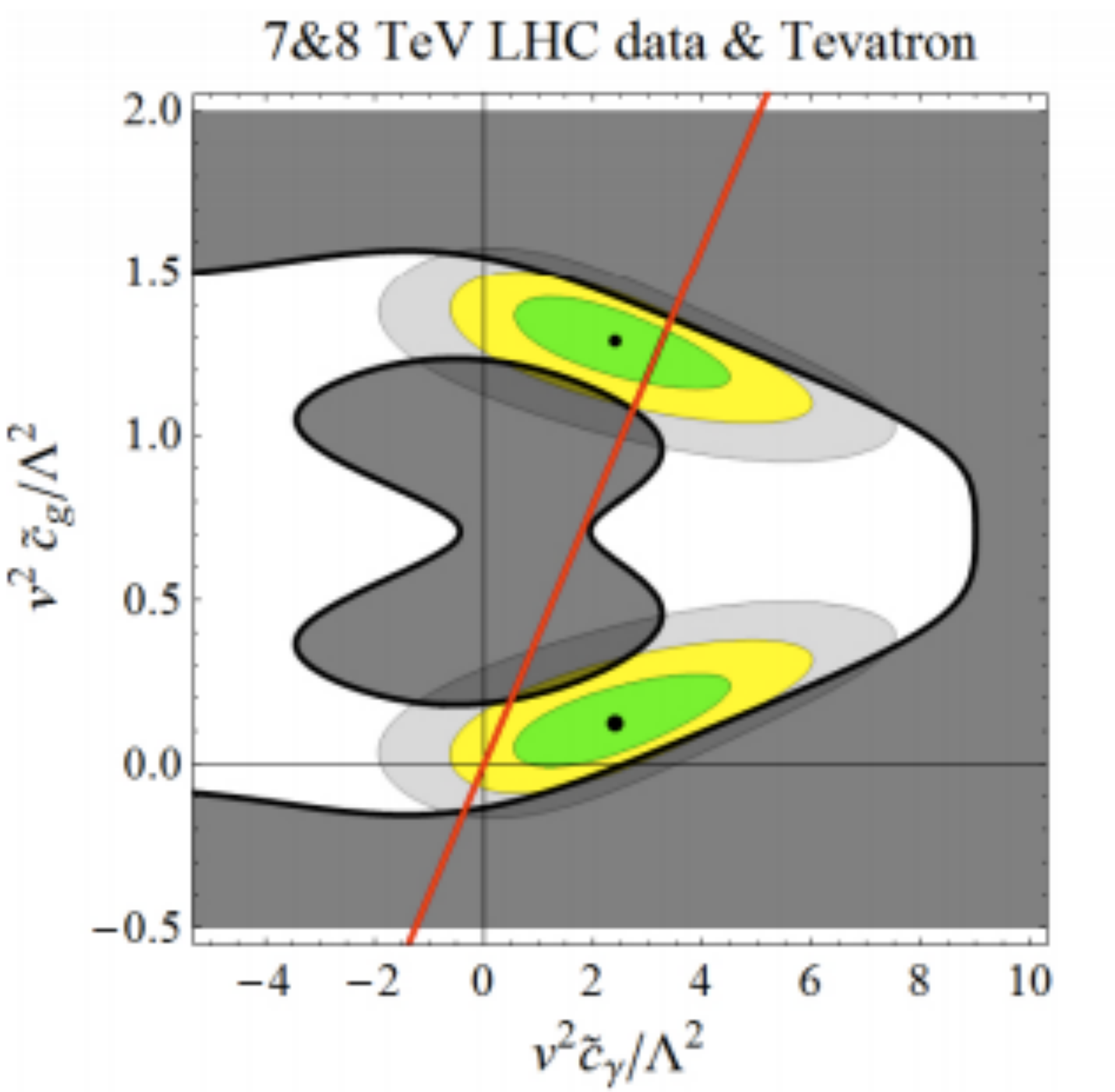
Espinosa, Grojean, Sanz, Trott arXiv:1207.7355

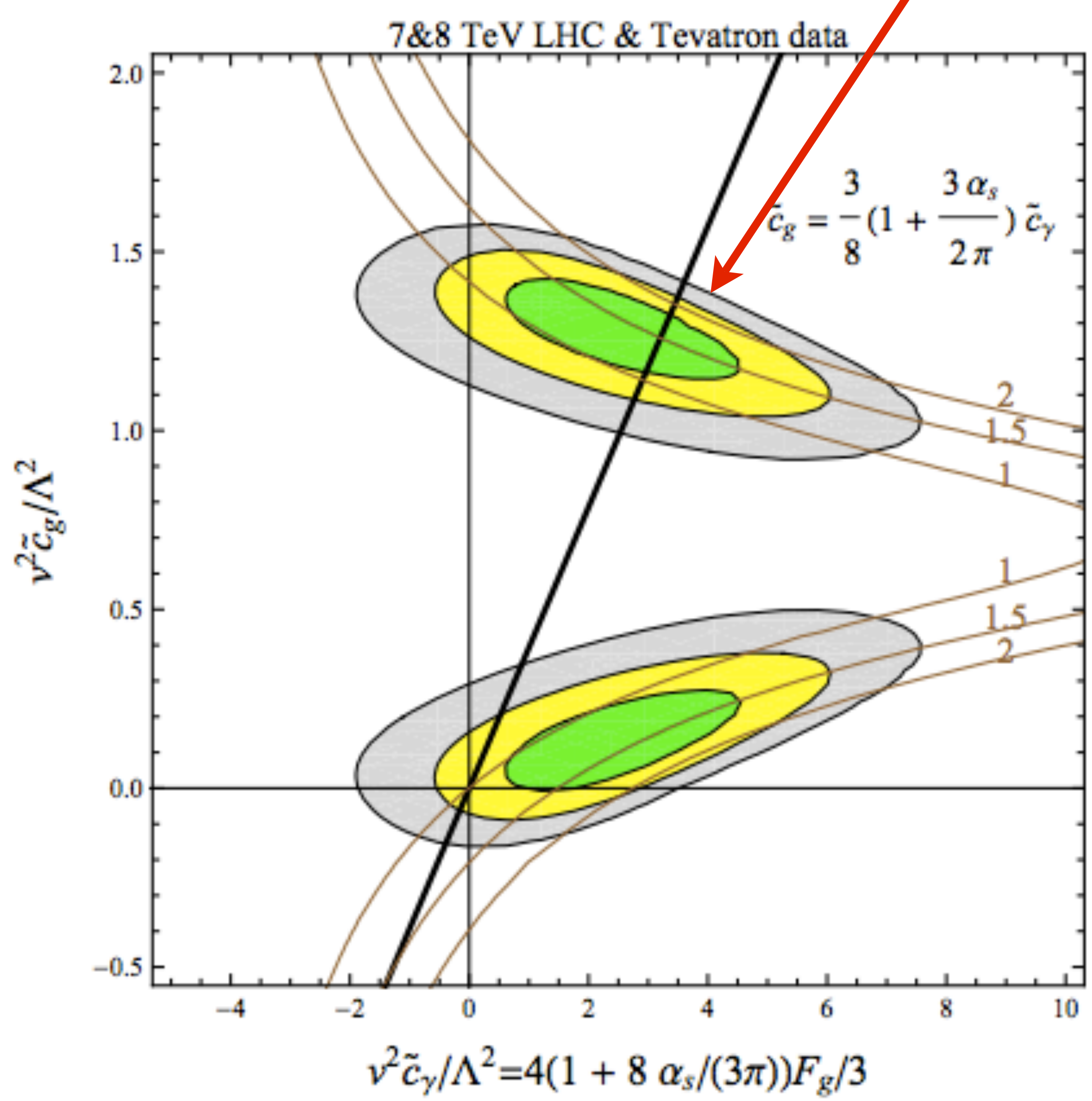
This is a predictive scenario for the wilson coefficients of the higher d ops:

$$\frac{\tilde{c}_g}{\tilde{c}_\gamma} = \frac{1}{2N_c Q_{\tilde{t}}^2} \frac{C_g(\alpha_s)}{C_\gamma(\alpha_s)} = \frac{3}{8}\left(1 + \frac{3\,\alpha_s}{2\,\pi}\right)$$

monophoton exclusions limit parameter space

sanz et al. arXiv:1205.1463



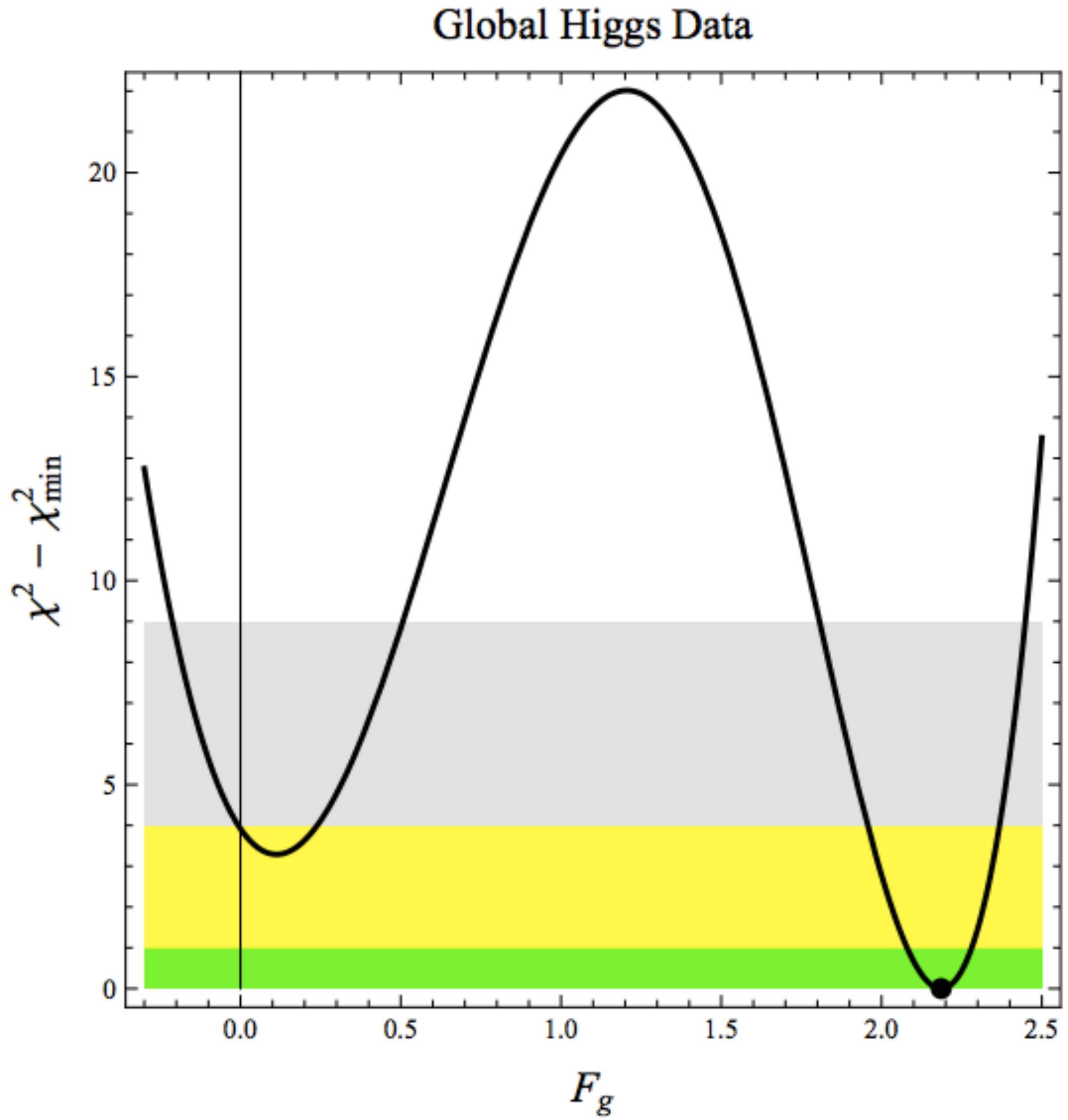


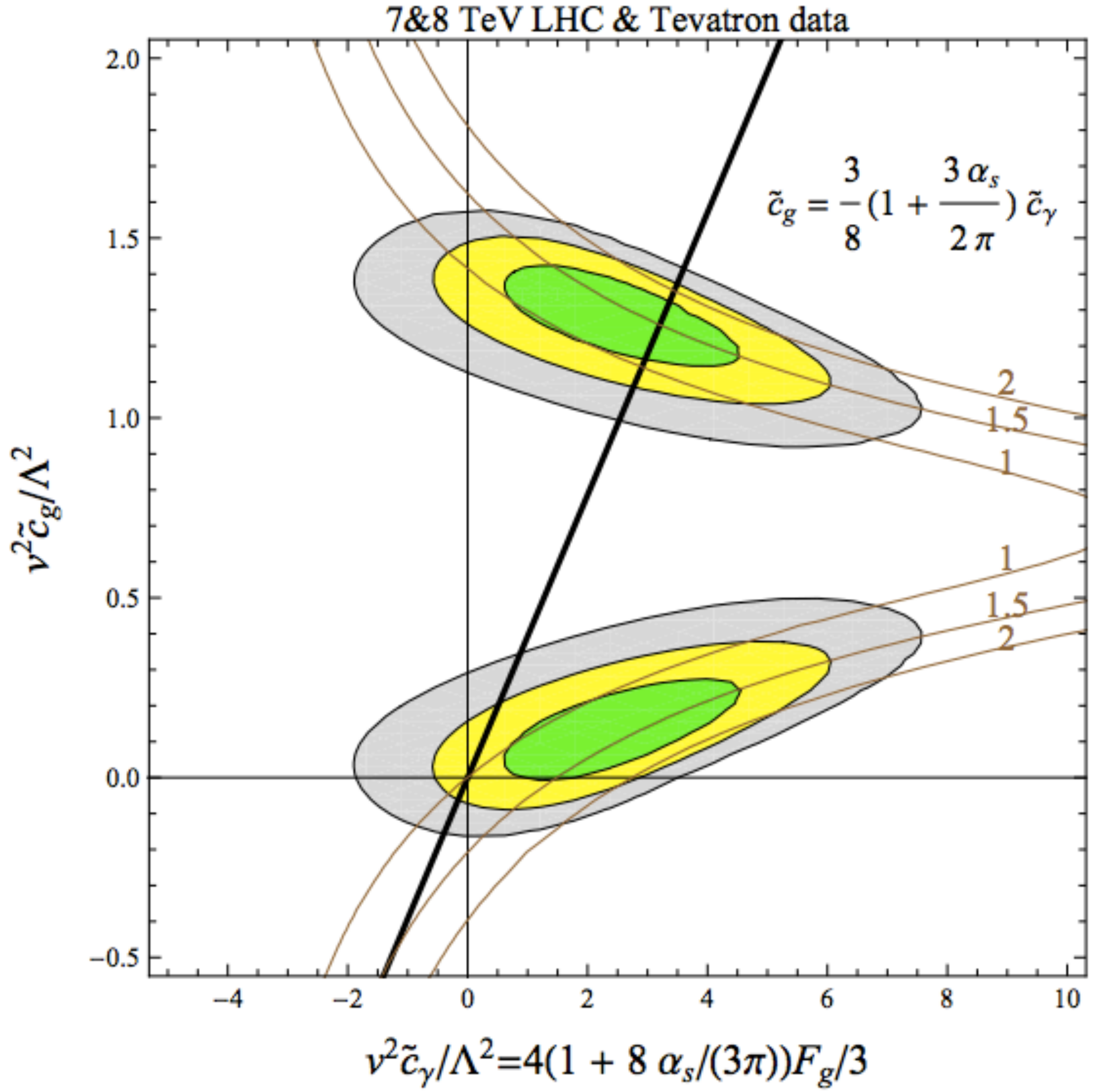
Natural Susy

Espinosa, Grojean, Sanz, Trott arXiv:1207.7355

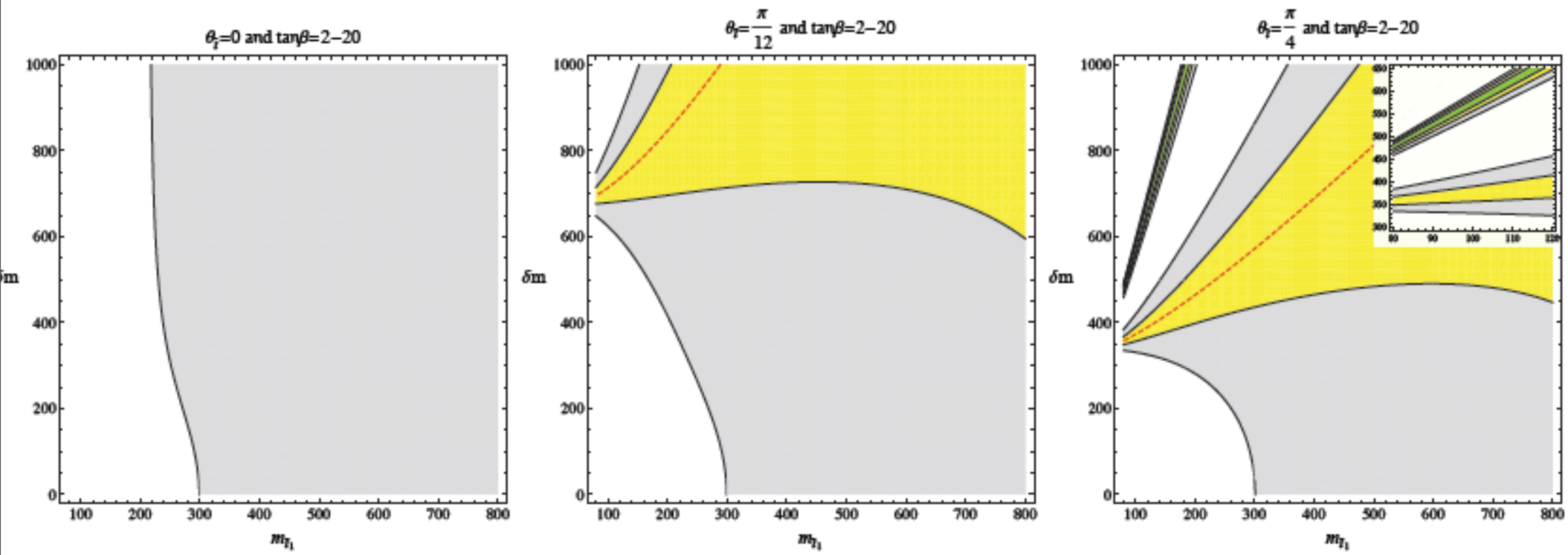
Consider minimal spectrum of stops, left handed sbottom, charginos and neutralinos with large guagino mass.

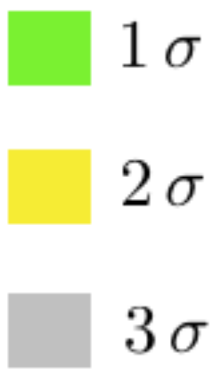
This is a predictive scenario for the wilson coefficients of the higher d ops:





Translate to stop space



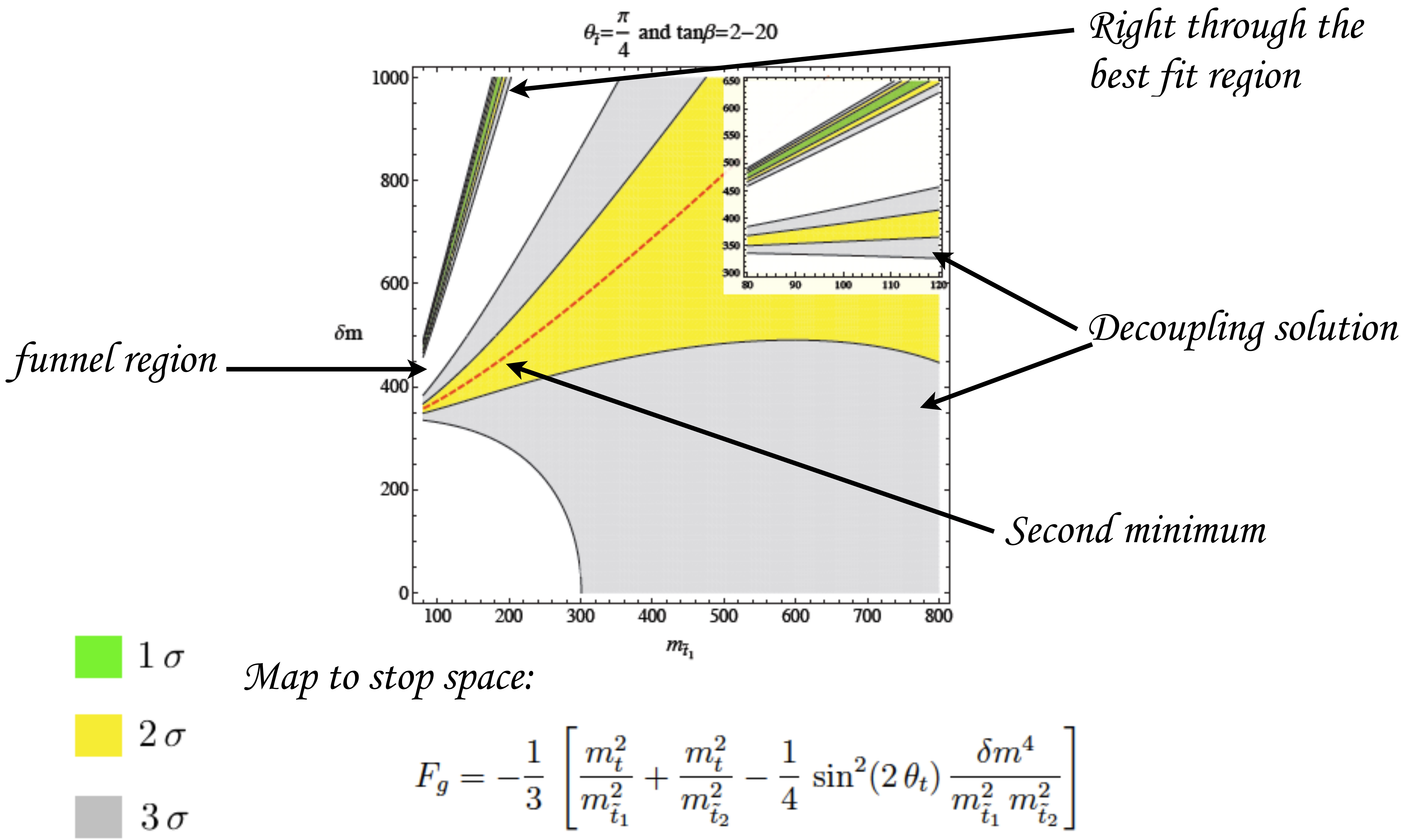


Map to stop space:

$$F_g = -\frac{1}{3}\left[\frac{m_t^2}{m_{\tilde{t}_1}^2} + \frac{m_t^2}{m_{\tilde{t}_2}^2} - \frac{1}{4}\sin^2(2\,\theta_t)\,\frac{\delta m^4}{m_{\tilde{t}_1}^2\, m_{\tilde{t}_2}^2}\right]$$

Light unmixed stops in bad shape, large mixing preferred in the data.

Translate to stop space



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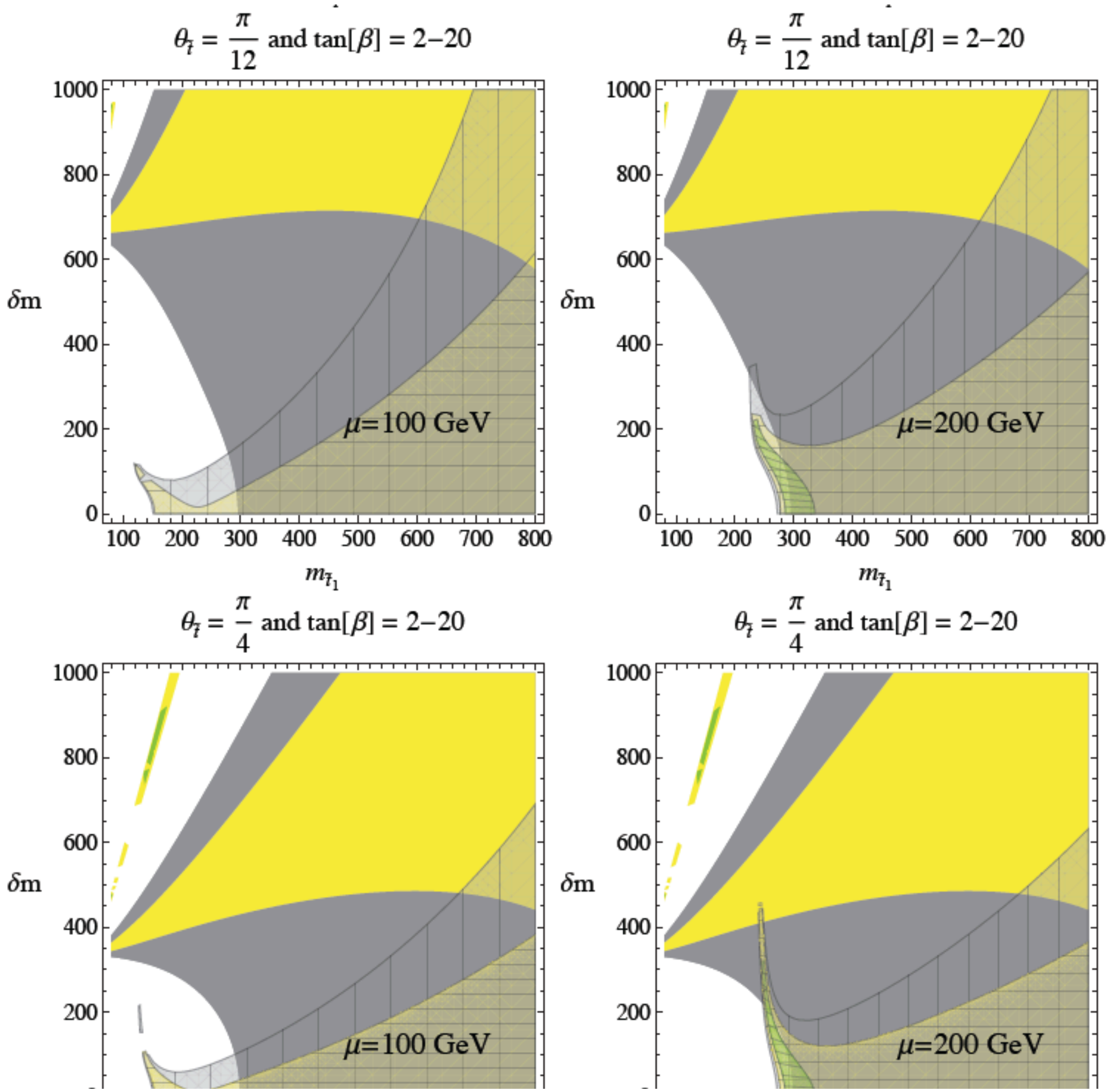
Consistency of B to s gamma



Not so good news...

μ dependance as the light chargino contributes here in NSUSY

$\mathrm{Br}(\bar{B} \to X_s \gamma)$ *basically wants degenerate stops, this will become stronger once the latest BABAR result is averaged in.*

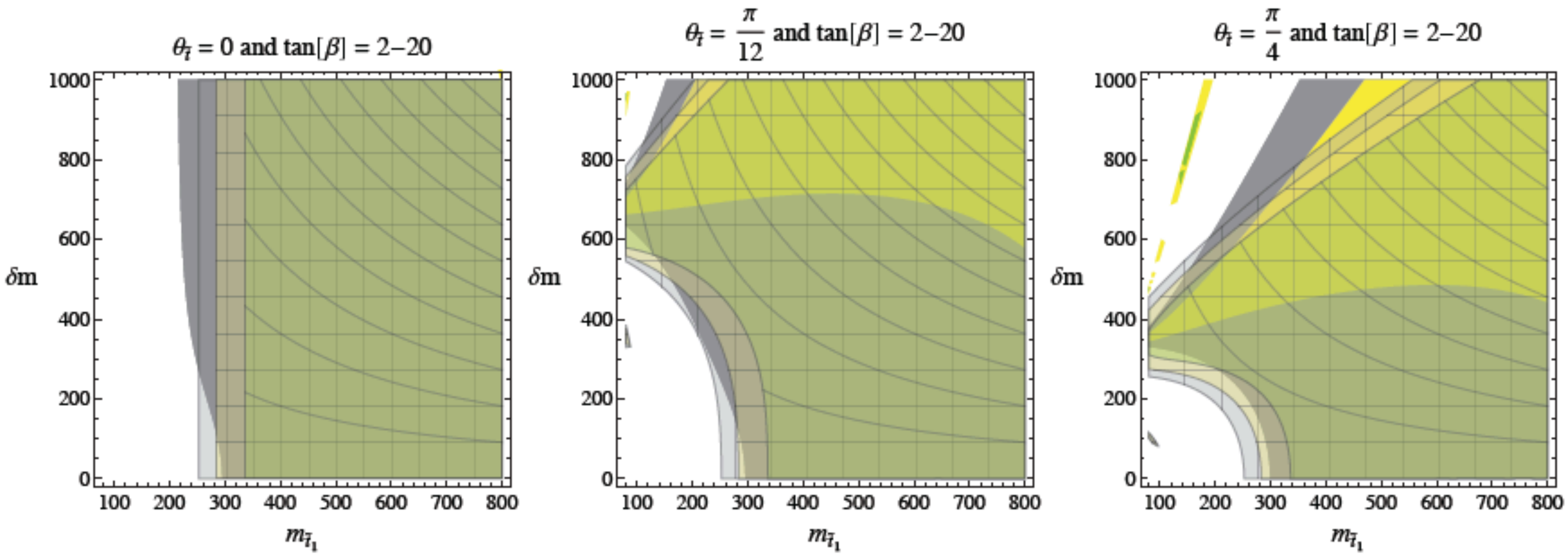
$$\mathrm{BR}(\bar{B} \to X_s \gamma)_{E_\gamma > 1.6\,\mathrm{GeV}} = [(3.15 \pm 0.23) - 8.0\,\Delta C_7(\mu_0) - 1.9\,\Delta C_8(\mu_0)] \times 10^{-4}$$

Theory prediction: B. Grzadkowski and M. Misiak, Phys. Rev. D **78**, 077501 (2008) [hep-ph/0802.1413].

$$\mathrm{BR}(\bar{B} \to X_s \gamma)_{E_\gamma > 1.6\,\mathrm{GeV}} = [3.55 \pm 0.24 \pm 0.09] \times 10^{-4}$$

Precision EW

To be fair there might also be good news... what an astonishing coincidence!



Recent precise measurements of Mw from the Tevatron:

$$(m_W)_{exp} = 80.385 \pm 0.015\,\text{GeV},$$
$$(m_W)_{SM} = 80.368 \pm 0.006\,\text{GeV}$$

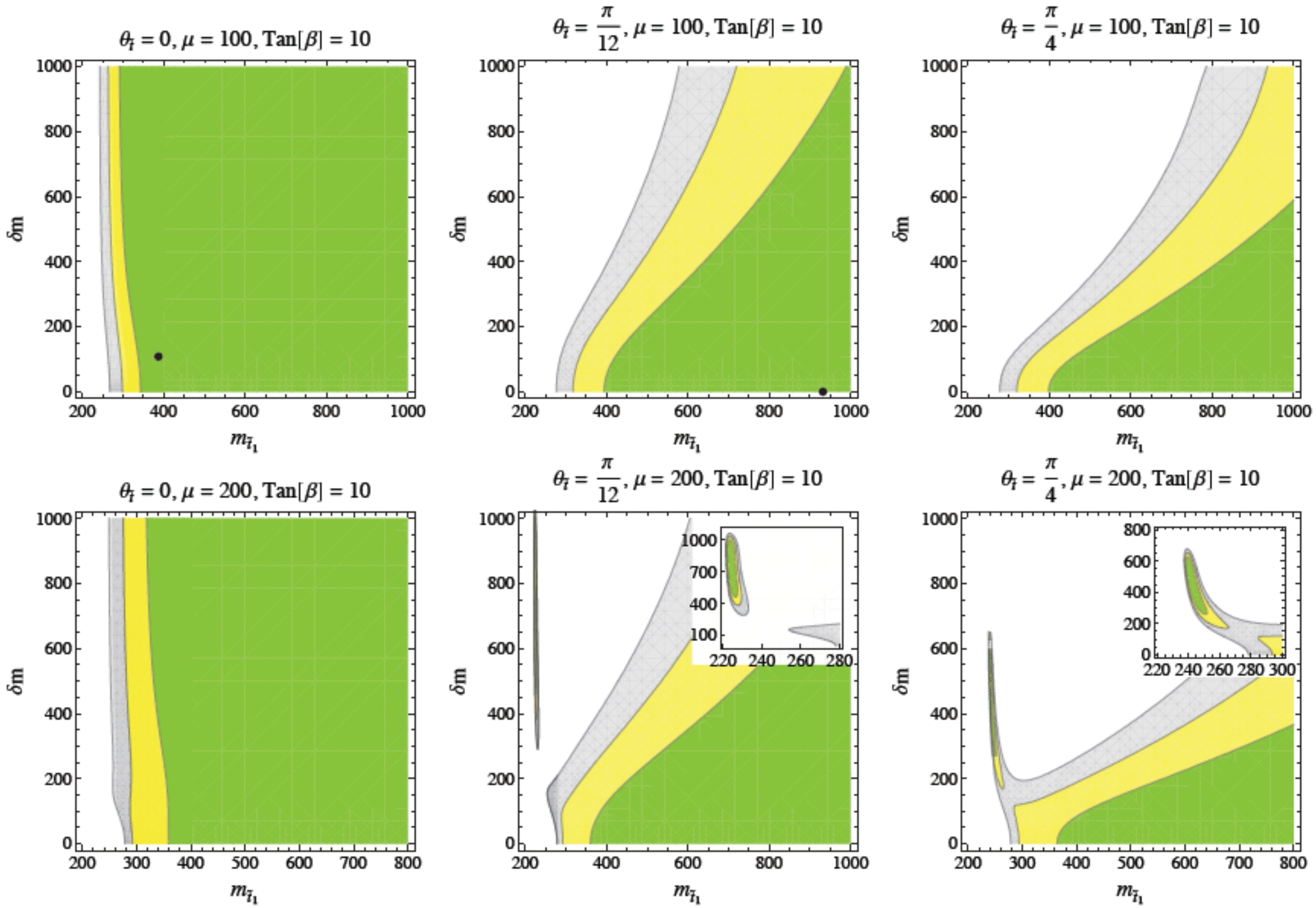
SUSY contribution:

$$(\Delta m_W)^{SUSY} \simeq \frac{m_W\, c_W^2}{2\,(c_W^2 - s_W^2)}\,\Delta\rho^{SUSY}$$

$$\Delta\rho_0^{SUSY} \simeq \frac{3\,G_F}{8\,\sqrt{2}\,\pi^2}\left\{\sum_{i=1,2} |\langle\tilde t_L|\tilde t_i\rangle|^2\, F_0[m^2_{\tilde t_i}, m^2_{\tilde b_L}] - |\langle\tilde t_L|\tilde t_1\rangle|^2 |\langle\tilde t_L|\tilde t_2\rangle|^2\, F_0[m^2_{\tilde t_1}, m^2_{\tilde t_2}]\right\}$$

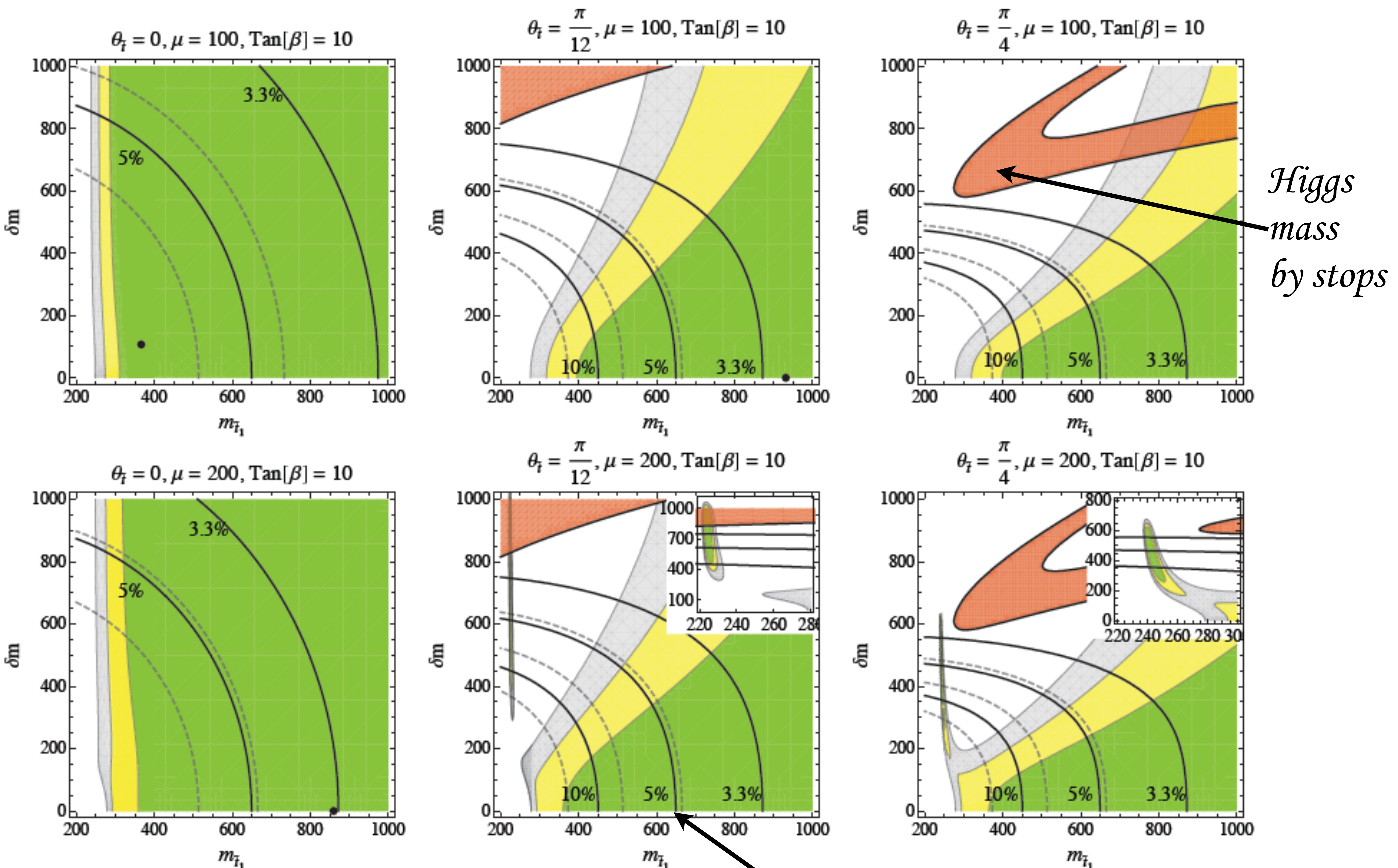
$$\Delta\rho^{SUSY} \lesssim (3.0 \pm 2.8) \times 10^{-4}.$$

Put it all together: Indirect stop fit



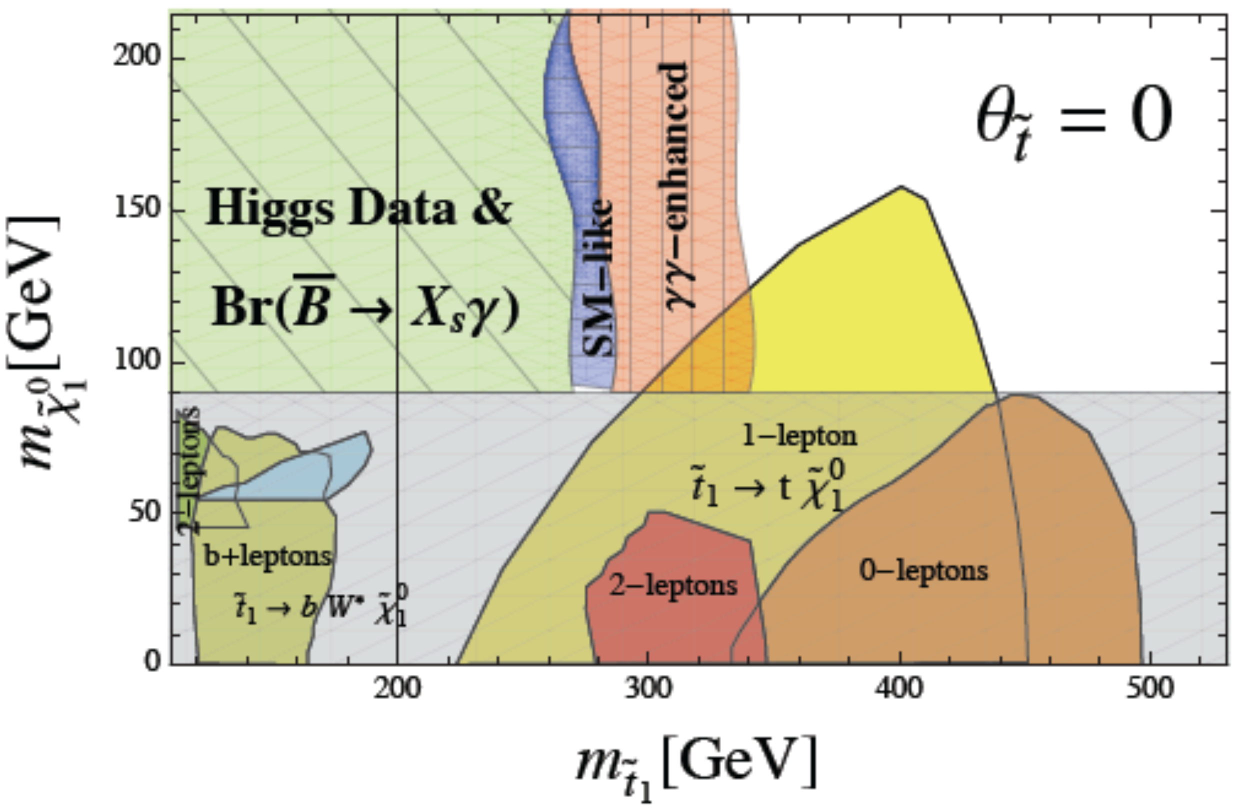
Putting everything together a good fit to the data for ~ 400 gev stop state comparable in quality of fit to the SM, no dramatic improvement. Higgs mass hard to accommodate

Put it all together: Indirect stop fit

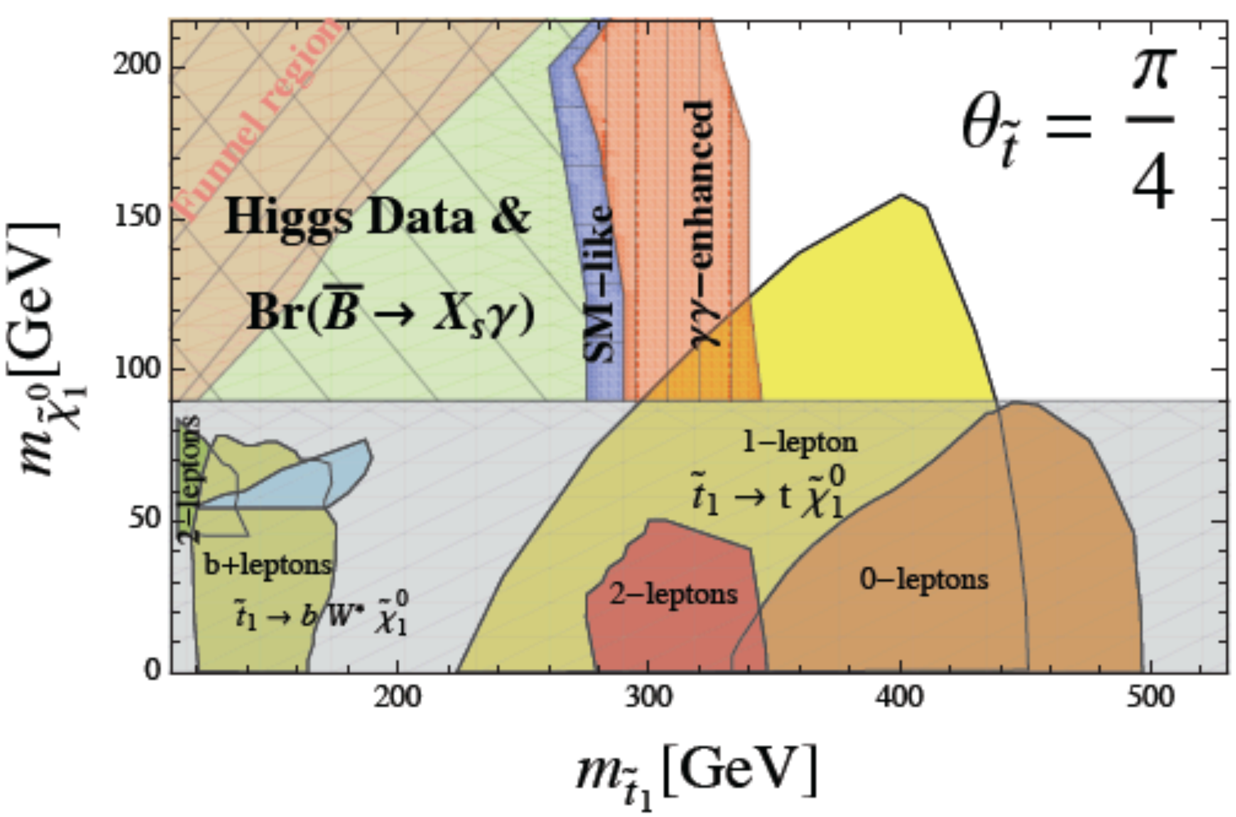


Indirect Exclusion currently and prospects for stops

Espinosa, Grojean, Sanz, Trott arXiv:1207.7355

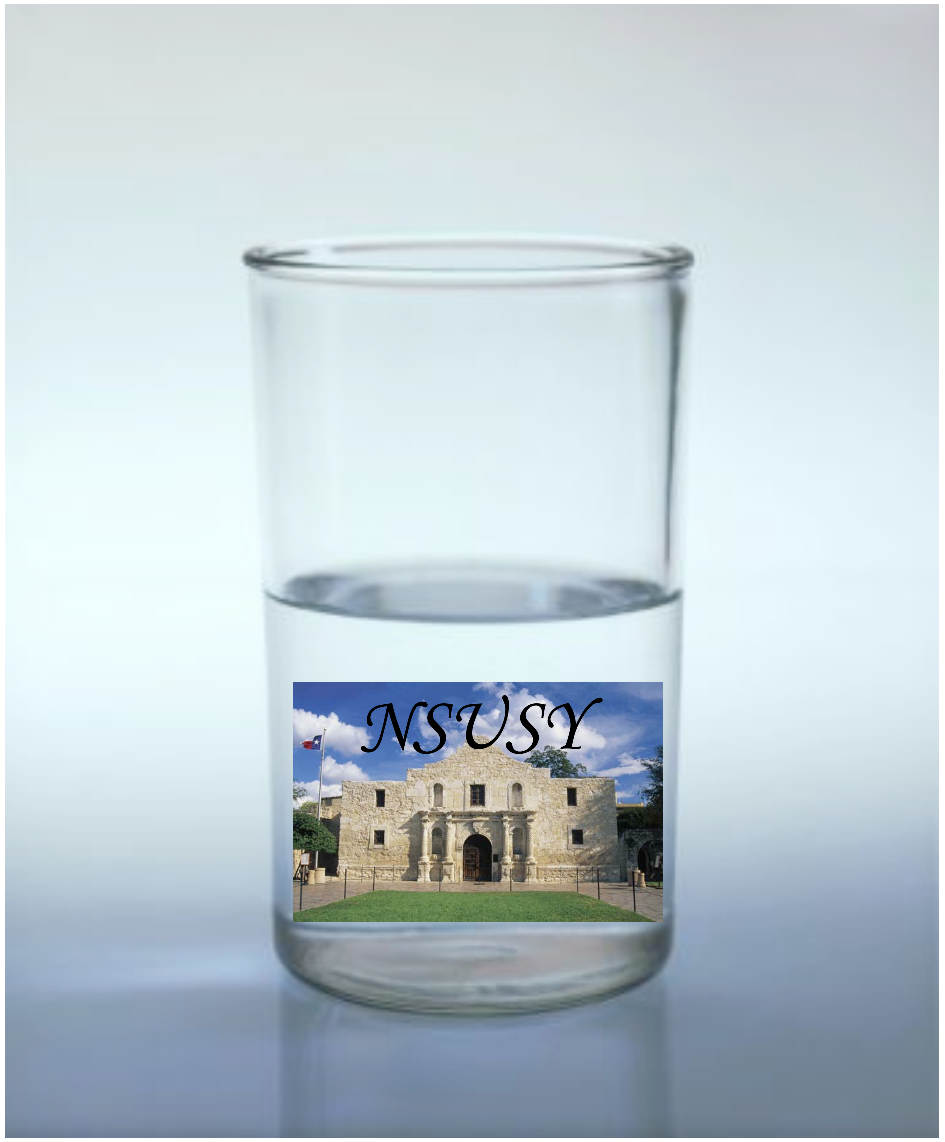


Combined exclusion with demand that the higgs properties 95 % CL exclude and $\mathrm{Br}(\bar{B} \to X_s\,\gamma)$ *be within 2 sigma of its experimental value*



Indirect probes for stops are powerful tools. Dedicated experimental study warranted and underway now in ATLAS

Conclusions



Need more data.