The light stop window

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Summary

- Higgs Mass
- RG Evolution
- Flavor constraints
- Dark Matter
- Bounds from existing LHC analyses
- Dedicated Analyses

Constraints from Higgs mass

$$m_h^2 = m_Z^2 cos^2\beta + \frac{3y_t^2 m_t^2}{(4\pi)^2}\left[log\left(\frac{m_S^2}{m_t^2}\right) + X_t^2\left(1 - \frac{X_t^2}{12}\right)\right] + \cdots$$

average mass (m_S^2)

stop mixing parameter (X_t^2)

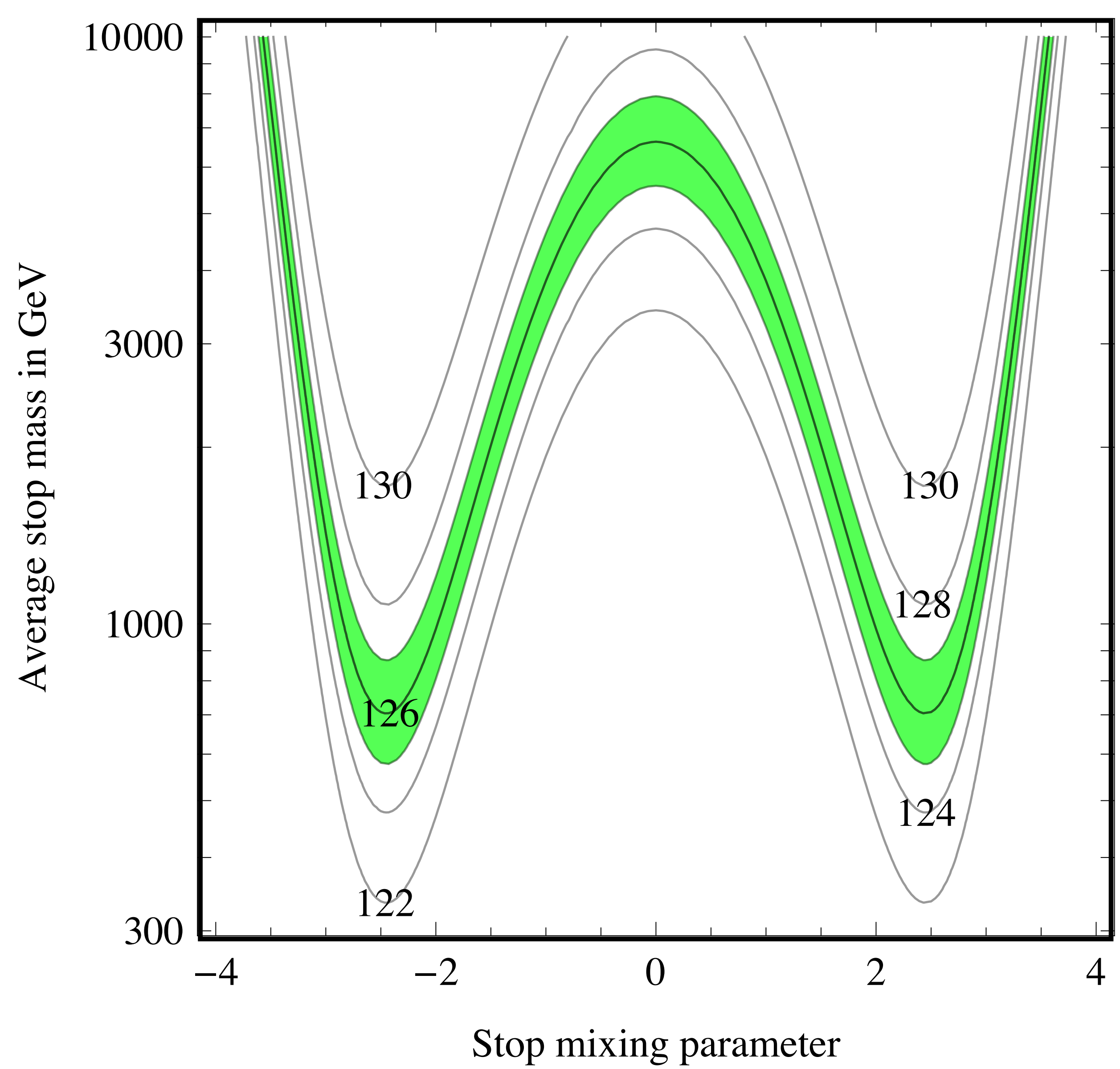
$$m_h^2 \sim 126\ GeV$$

Region compatible in plane (X_t, m_S)

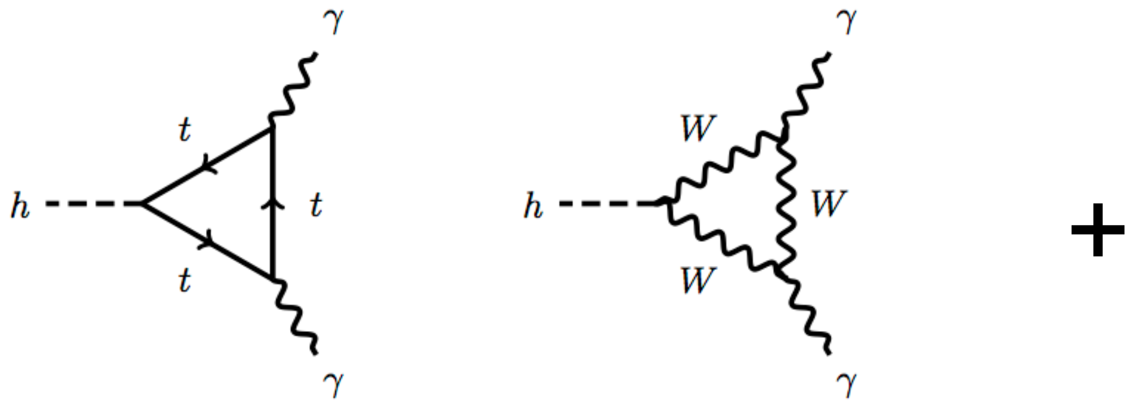
Minimal fine-tuning electroweak symmetry breaking:

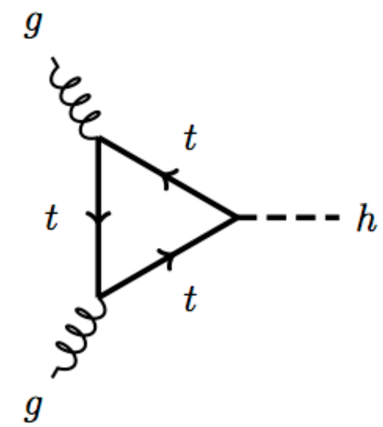
$$m_S = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}} \sim 500\ Gev$$

$$X_t^2 \sim 6$$



Constraints from decay rates



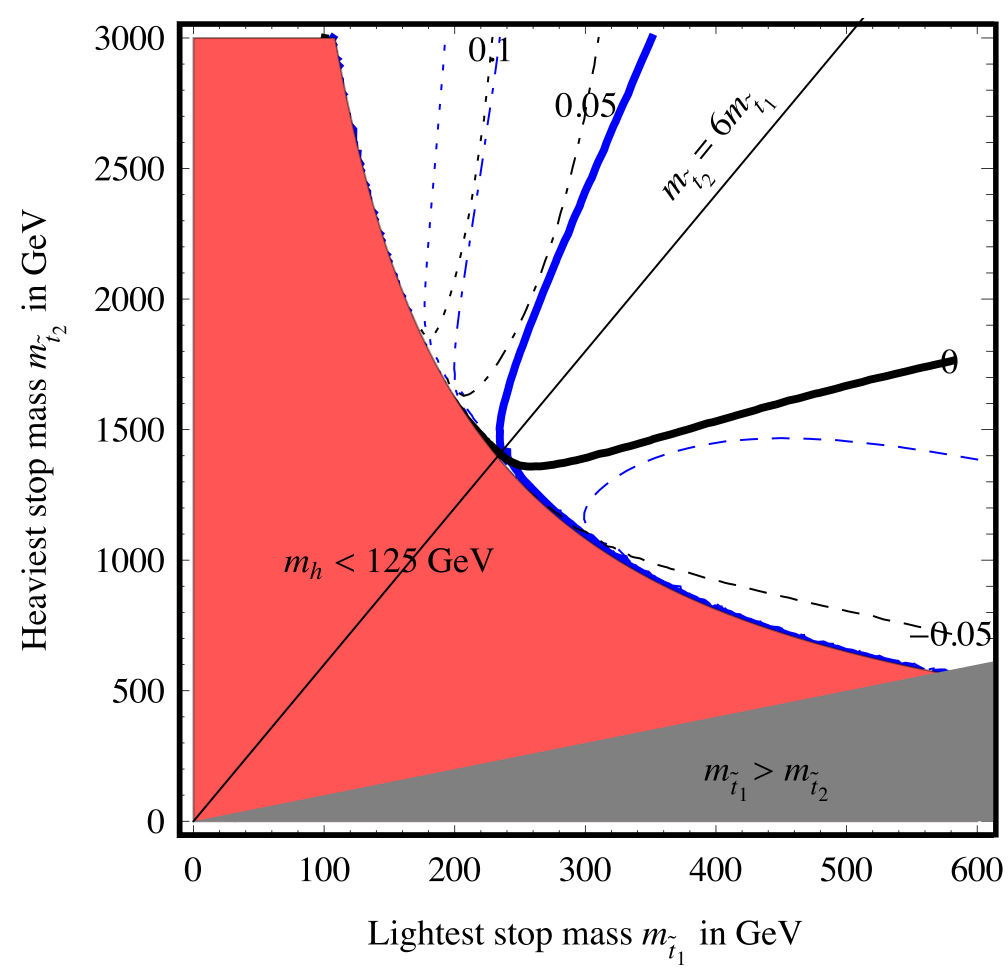


$$\frac{\Gamma(h\to\gamma\gamma)}{\Gamma(h\to\gamma\gamma)_{SM}} = (1-0.28\Delta_t)^2$$

$$\frac{\Gamma(h\leftrightarrow gg)}{\Gamma(h\leftrightarrow gg)_{SM}} = (1+\Delta_t)^2$$

$$\Delta_t \sim \frac{m_t^2}{4}\left(\frac{1}{m_{\tilde{t}_1}^2}\right) + \frac{1}{m_{\tilde{t}_2}^2} - \frac{X_t^2}{m_S^2}$$

Present data: $\Delta_t = -0.04 \pm 0.11$



- **No significant constraint**
- **No deviations from SM if:**

$$m_{\tilde{t}_2} \approx 6m_{\tilde{t}_1}$$

Constraints from RG evolution

$$8\pi^2 \frac{dm^2_{\tilde{t}_L}}{dlog\mu} = y_t^2 Y_y - \frac{16}{3} g_3^2 M_3^2 - 3 g_2 M_2^2 - \frac{1}{15} g_1^2 M_1^2$$

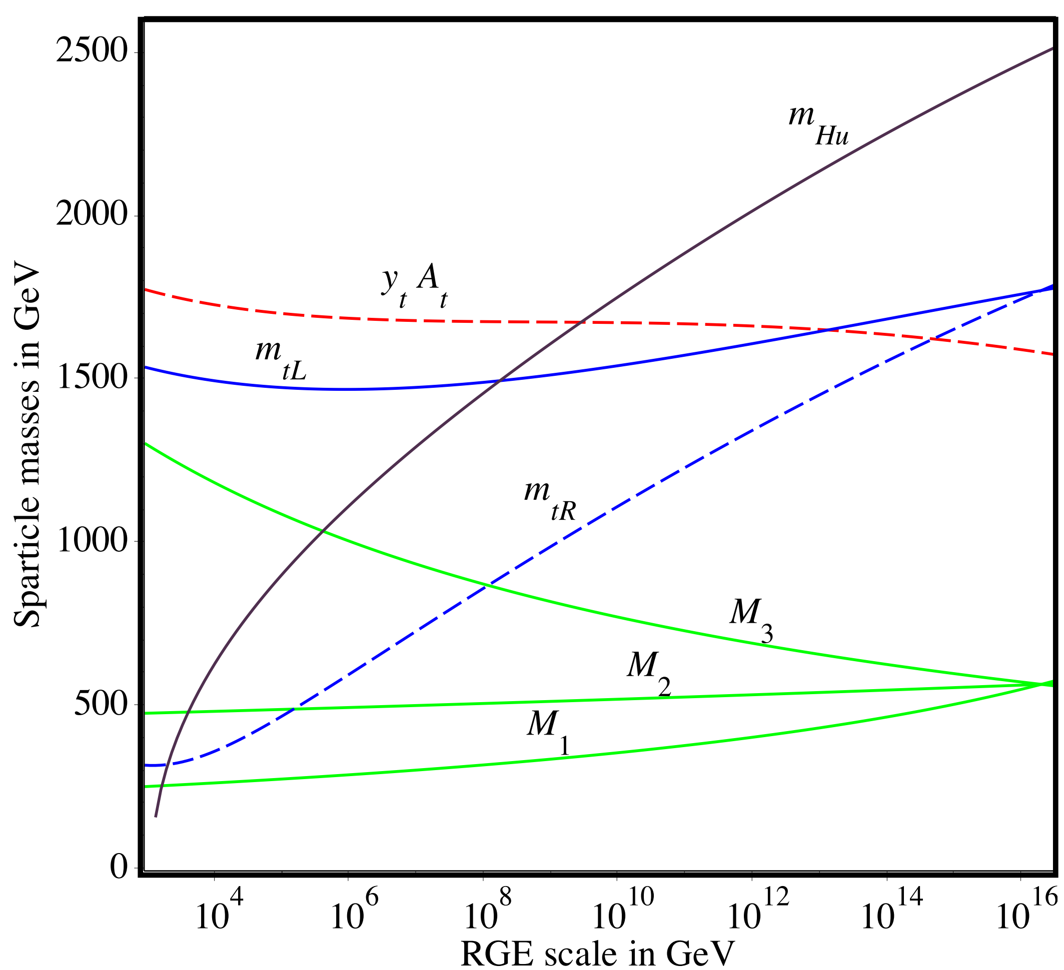
$$8\pi^2 \frac{dm^2_{\tilde{t}_R}}{dlog\mu} = 2 y_t^2 Y_y - \frac{16}{3} g_3^2 M_3^2 - \frac{16}{15} g_1^2 M_1^2$$

Yukawa term

QCD term

Experimental bounds + Higgs

- QCD and Yukawa term compensate in running of $m_{\tilde{t}_L}$
- Yukawa term leads to $m_{\tilde{t}_R} \ll m_{\tilde{t}_L}$
- $m_{\tilde{t}_R} < 300 \text{ GeV}$ consistent with weak scale configuration



Large mass splitting

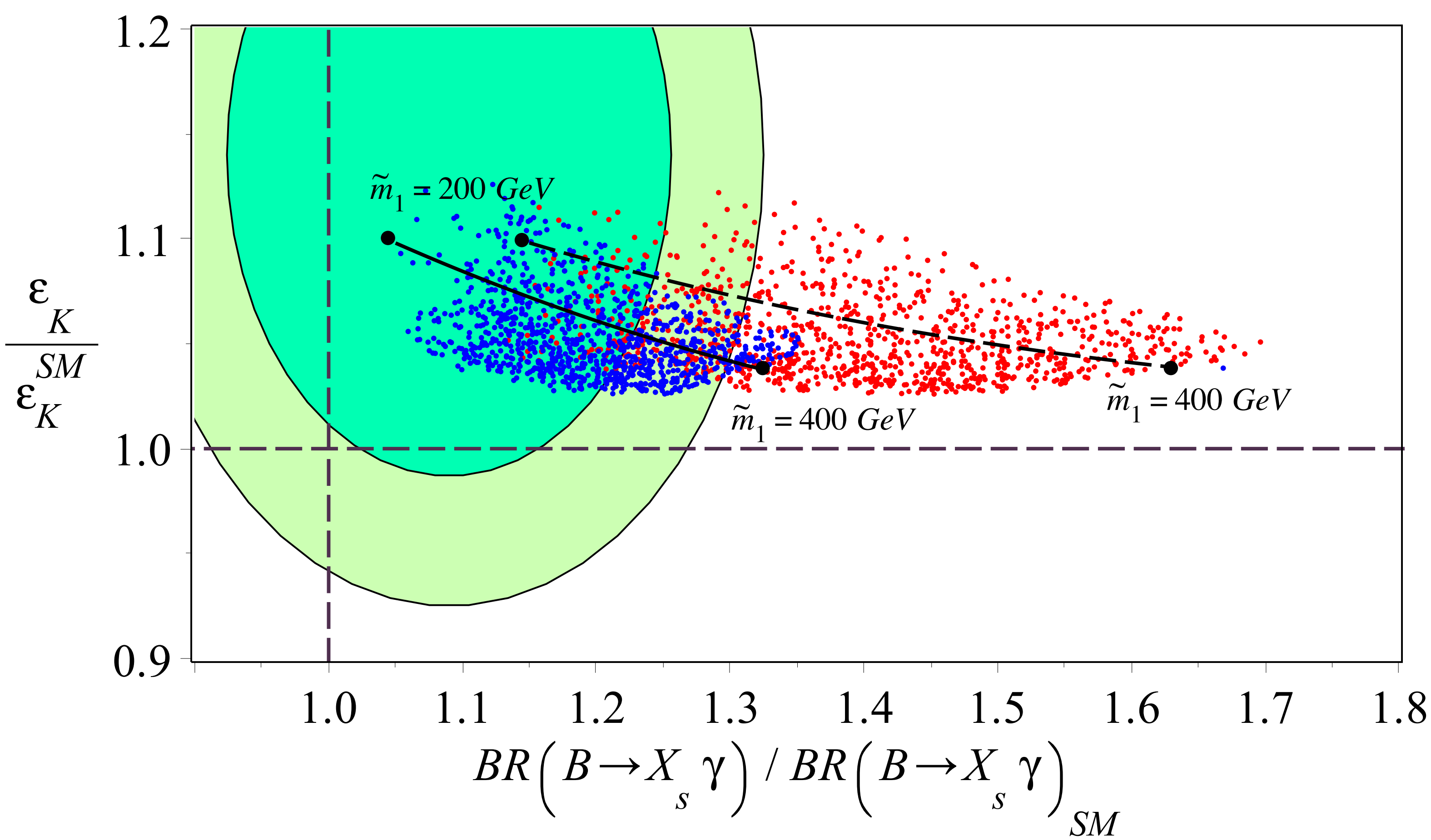
- $m_{\tilde{t}_1} \sim m_{\tilde{t}_R} \quad m_{\tilde{t}_2} \sim m_{\tilde{t}_L}$
- $m_{\tilde{t}_1} < 400\ GeV$
- Gluino mass $M_3 < 1.6\ TeV$

Constraints from flavor physics

Small mixing: remaining flavor violation described by CKM angles

$$\frac{BR(B \to X_S\gamma)}{BR(B \to X_S\gamma)_{SM}} = 1 - 2.5\Delta C_7 - 0.7\Delta C_8$$

Correlation with ϵ_K



Experimental Data:

$$\frac{BR(B \to X_S\gamma)_{exp}}{BR(B \to X_S\gamma)_{SM}} = 1.09 \pm 0.11$$

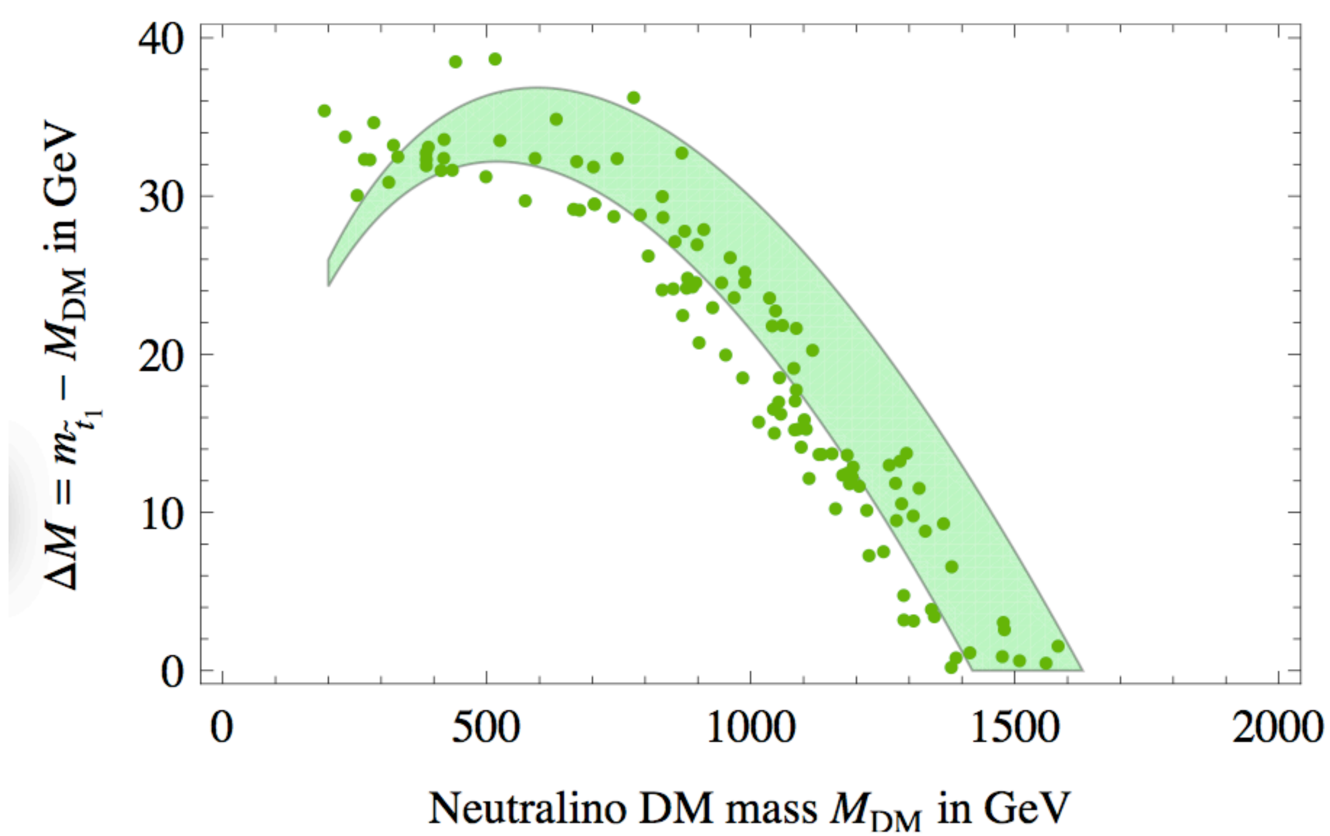
- Large mass splitting
- Small mixing

Constraints from dark matter

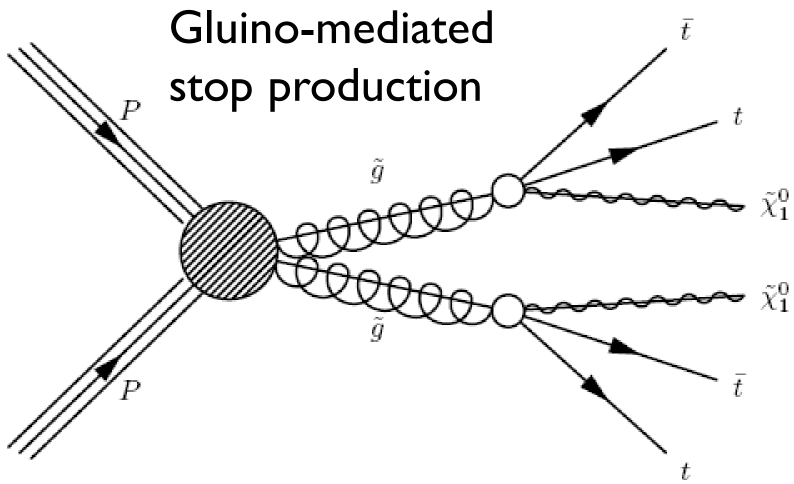
A light stop cures the excessive relic abundance of B-ino LSP

$$\sigma v_{\rm cosmo} = e^{-2\Delta M/T}\frac{3}{8}\sigma(\tilde{t}_1\tilde{t}_1^* \to gg)v \quad \Longleftrightarrow \quad \sigma v_{\rm cosmo} \equiv (2.3 \pm 0.1) \times 10^{-26}\,{\rm cm}^3{\rm s}^{-1}$$

Lightest neutralino mass slightly smaller than lightest stop



Stop decay rates



Dark matter

$$\Delta M \equiv m_{\tilde{t}_1} - M_{DM} \sim 30\ GeV$$

Two decay channels (comparable for $\theta_{tc} \sim 10^{-5}$)

Mixing $\tilde{t}_R - \tilde{c}_L$

ΔM **small** $\quad \Gamma(\tilde{t}_1 \to cN) = \dfrac{2g^2 tan^2\theta_W \theta_{tc}^2 \Delta M^2}{9\pi m_{\tilde{t}_1}} = 100\ cm^{-1} \left(\dfrac{\theta_{tc}}{10^{-5}}\right)^2 \left(\dfrac{\Delta M}{30\ GeV}\right)^2 \left(\dfrac{400\ GeV}{m_{\tilde{t}_1}}\right)$

Presence of one soft jet in final state

ΔM **large** $\quad \Gamma(\tilde{t}_1 \to Nbl^+\nu_l) = \dfrac{3g^6 tan^2\theta_W \Delta M^8}{70(6\pi)^5 M_W^4 m_t^2 m_{\tilde{t}_1}} = 28\ cm^{-1} \left(\dfrac{\Delta M}{30\ GeV}\right)^8 \left(\dfrac{400\ GeV}{m_{\tilde{t}_1}}\right)$

Presence of charged leptons in final state

Bounds from existing LHC searches

How can we detect stop decays?

Reconstruction + identification of soft decay products

Problem

Trigger $\longrightarrow$ Jets and leptons too soft

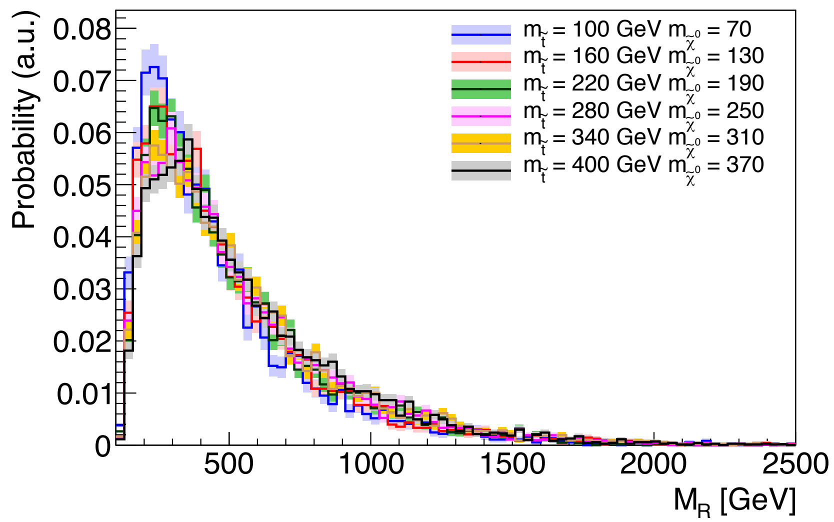
Solution

Detect through associate jet production $\widetilde{t}\widetilde{t}^* + Jets$

- $p_T^{jet} > 60\ GeV$ for the first two jets
- $p_T^{jet} > 40\ GeV$ for the other jets

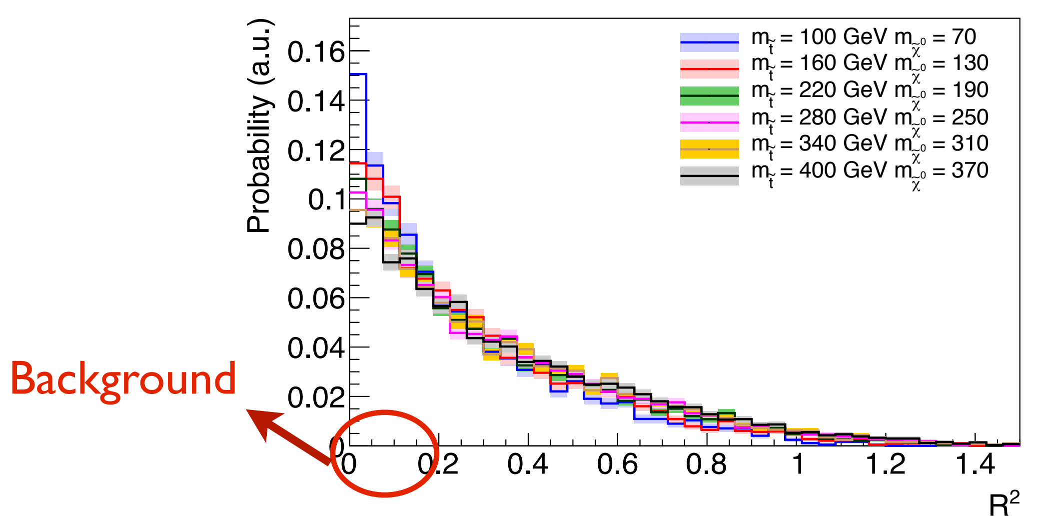
Bounds from existing LHC searches

Emulation of razor analysis ($\tilde{t}\tilde{t}^{*}$ $\sqrt{s} = 7\ TeV\ pp\ PYTHIA8$)



$M_R \sim 150$ GeV

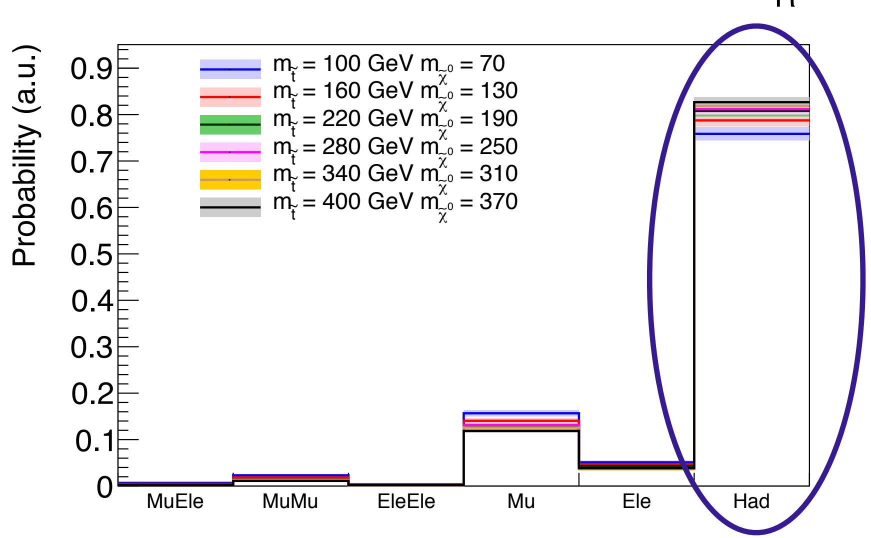
The analysis is only sensitive to the events with $n_{jets} \geq 2$



$$R = \frac{M_R^T}{M_R} \qquad M_R^T < M_\Delta$$

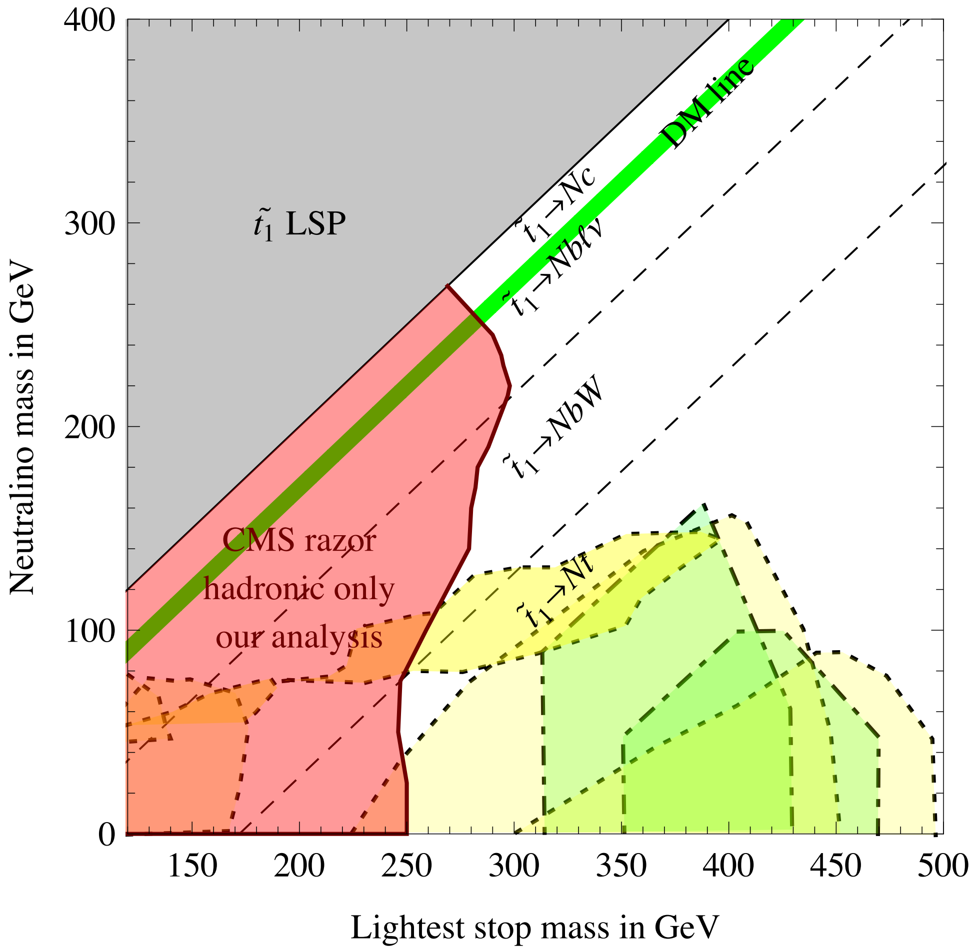
Transverse invariant mass

The result is largely indipendent on the final state



The majority of the events falls in the hadronic box; however there is some sensivity in the Mu and Ele boxes

Dedicated analyses



Monojet and **Razor Analyses**

Missing Transverse Energy + $P_T > 30\ GeV$

More efficient
More performant

At large splits the limit from the Razor Analyses is consistent with the official limit on stop pair production

How the sensivity could be improved?

- Extending the razor analysis at the tail of R^2 for law M_R
- Changing in the lepton selection
- Requiring a displaced vertex from the primary one of the p-p collision

Dedicated analyses

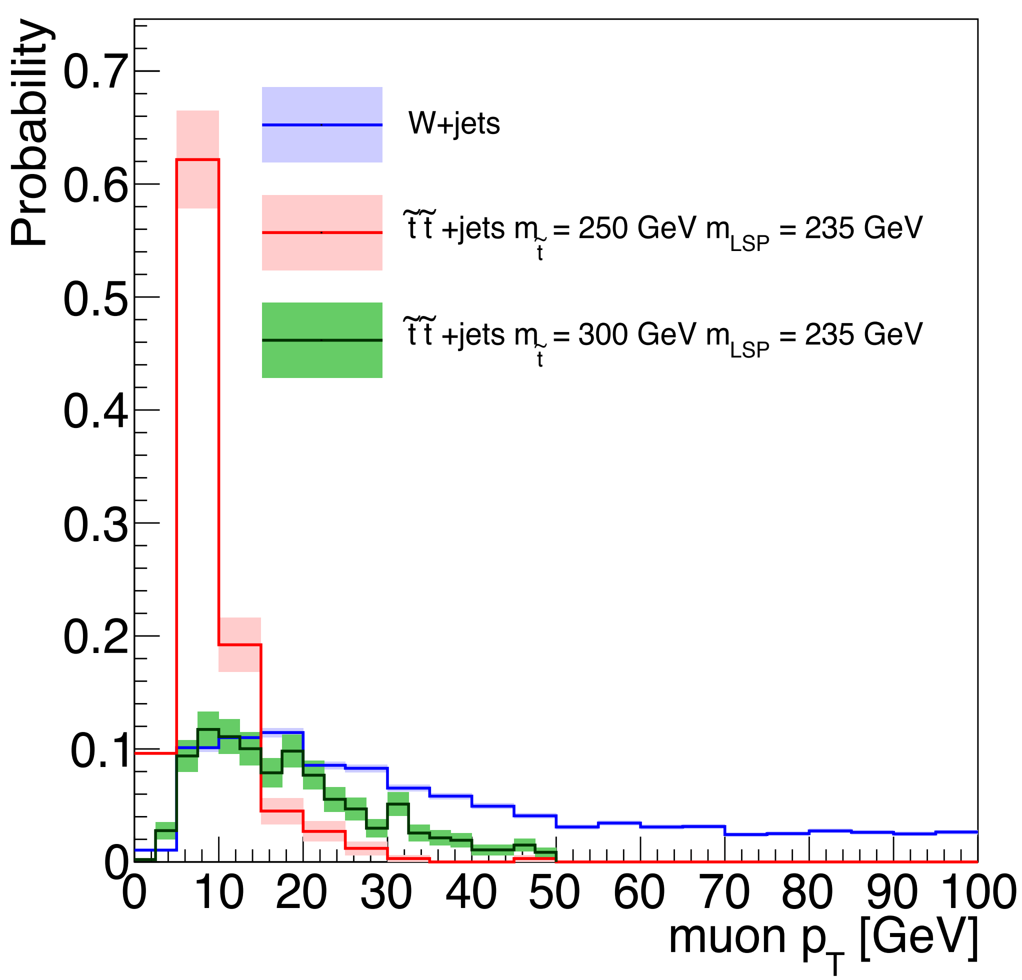
Monojet analysis

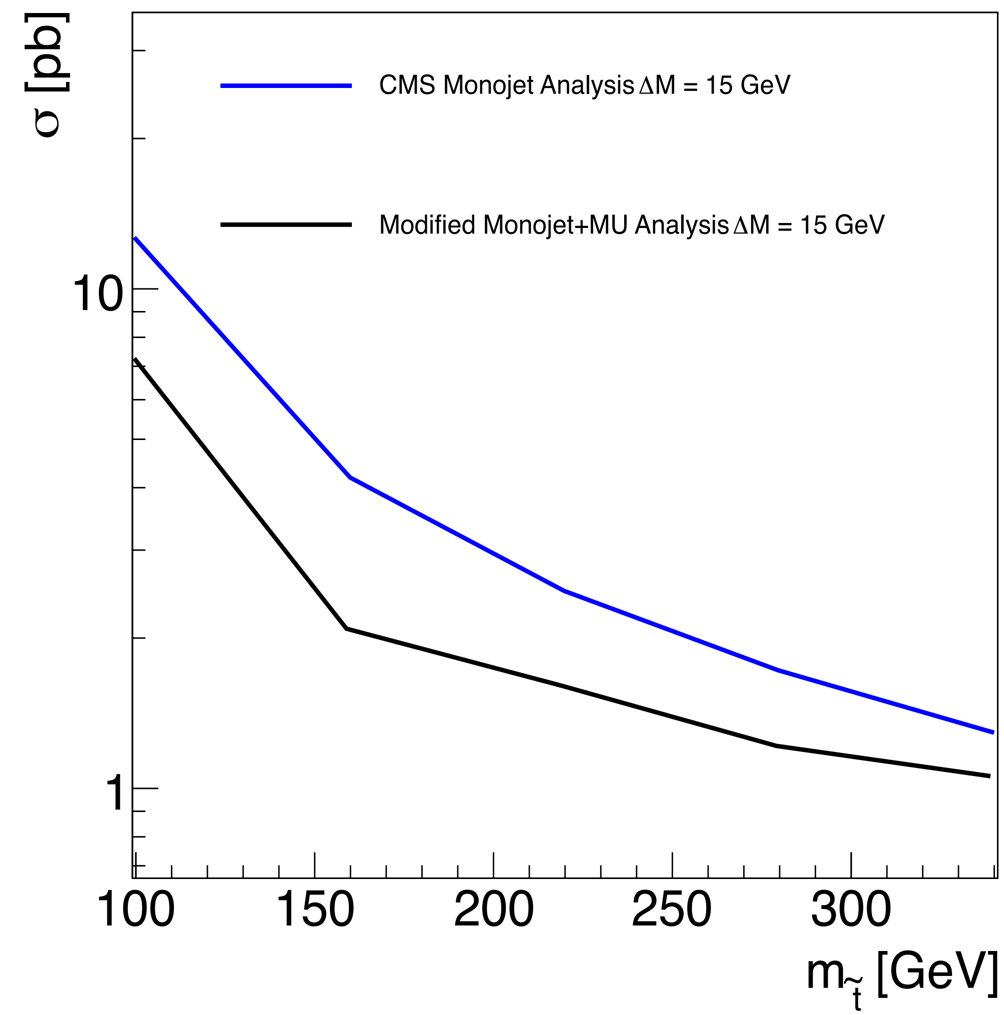
Two values of the stop mass (150 GeV - 270 GeV) ⟶ $\Delta M = 15$ GeV

$$p_T < 15 \text{ GeV}$$

↓

$Z(\nu\nu)$+jets Background





Expected excluded cross section

Better analyses and improved sensitivity for the future 14 TeV

Conclusions

- $m_{\tilde{t}_1} \sim m_{\tilde{t}_R}$ with $m_{\tilde{t}_1}$ = 200-400 GeV
- $m_{\tilde{t}_2} \sim m_{\tilde{t}_L}$ with $m_{\tilde{t}_2}$ = 1-2 TeV
- Gluino mass below 1.5 TeV
- $\tilde{t}_1 \to N b \ell^+ \nu_\ell$ compete with $\tilde{t}_1 \to cN$
- Limits on stop masses of about 250 GeV