Claudia Frugiuele

Fermilab

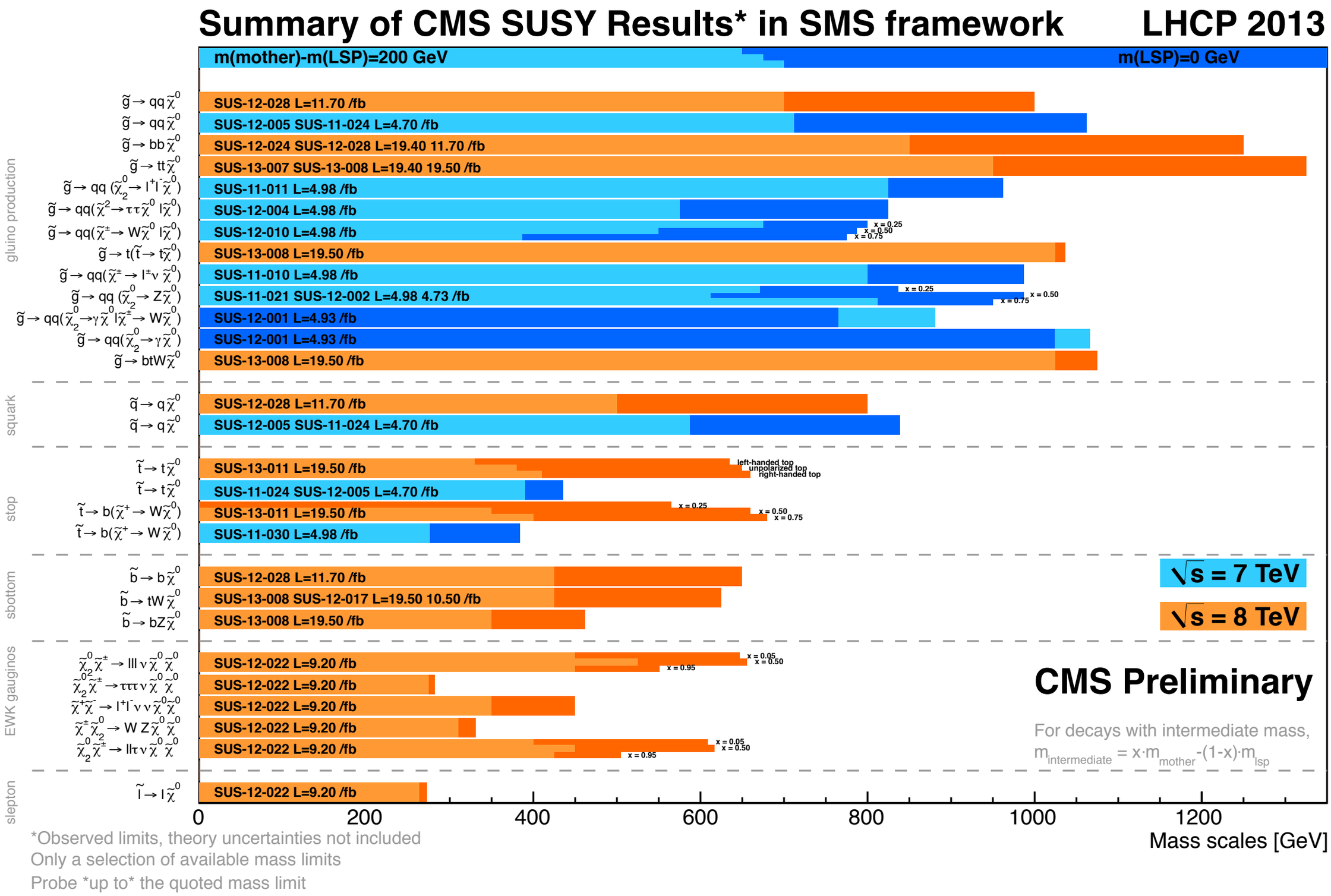
Mixing stops at the LHC

in collaboration with P. Agrawal

hep ph 1304.3068

GGI
07/06/2013

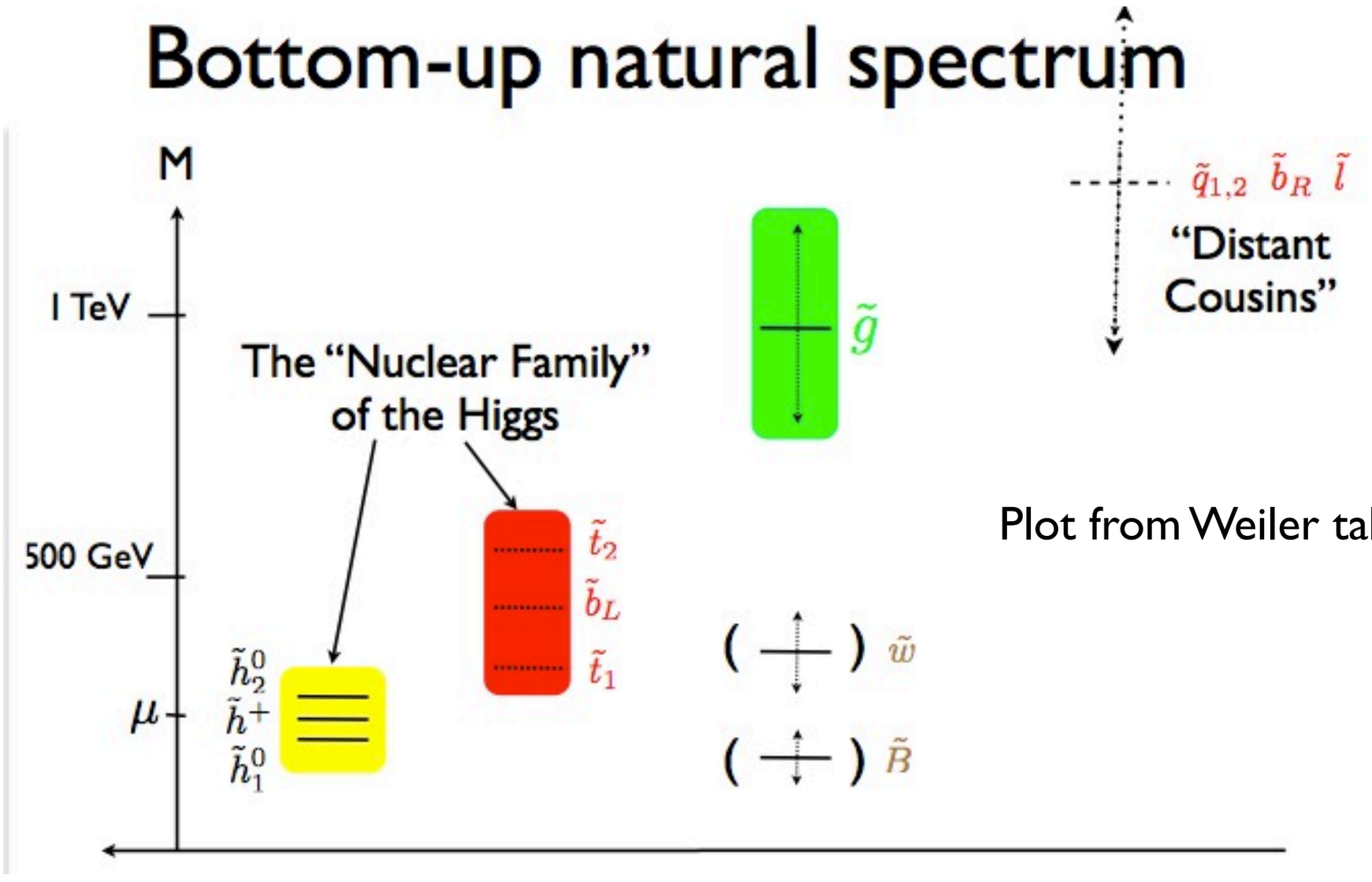
SUSY after the LHC first run



*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

Natural SUSY after the first run

Bounds on gluinos and degenerate 1&2 generation squarks reached the TeV threshold...

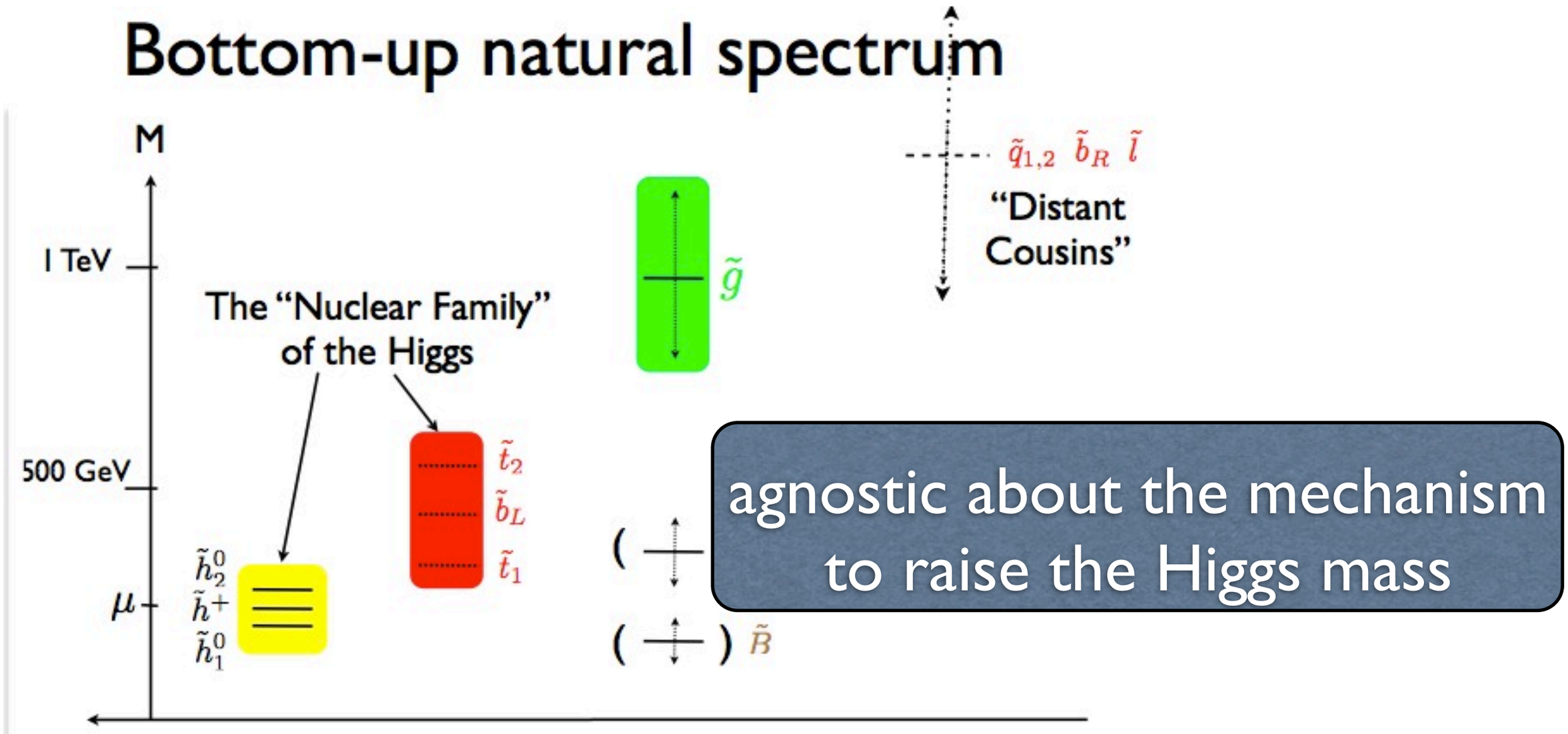


Plot from Weiler talk on natural susy

limits on gluino are already in tension with naturalness Dirac gluinos?

Natural SUSY after the first run

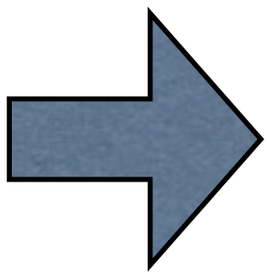
Bounds on Gluinos and degenerate 1&2 generation squarks reached the TeV threshold...



limits on gluino are already in tension with naturalness Dirac gluinos?

Naturalness+LHC bounds on squarks

suggest SUSY breaking mediation knows about flavor



exploring other structure beyond MFV

what does this imply for the LHC pheno?

No much freedom in the MSSM due to the severe flavor problem

somewhat large mixing allowed between right handed stop and charm (Blanke,Giudice,Paradisi,Perez,Zupan,'13)

Beyond the MSSM?

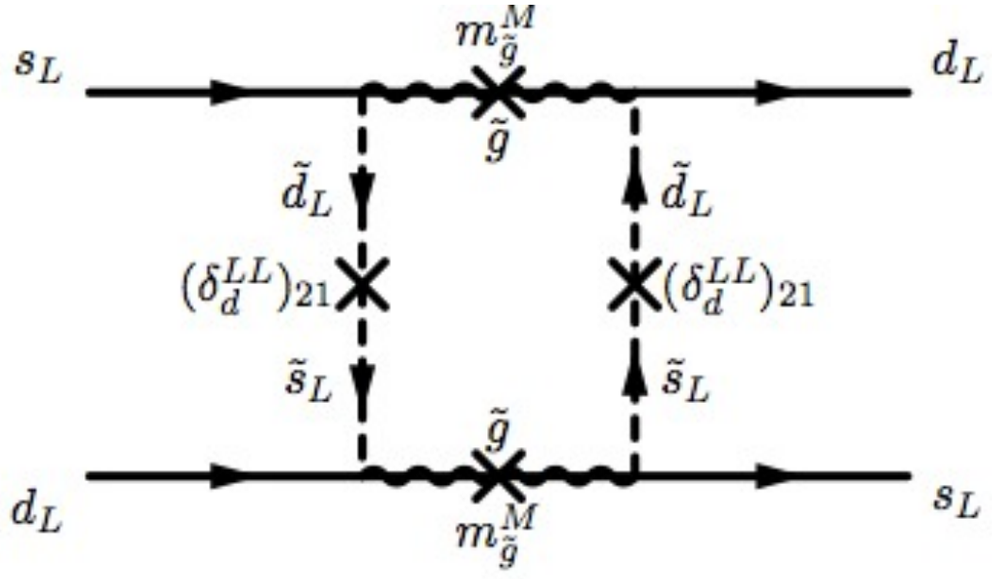
Having R symmetry ameliorates the flavor problem

kribs,weiner,poppitz '07

most of the dangerous contributions to flavor observable arise from R violating terms:

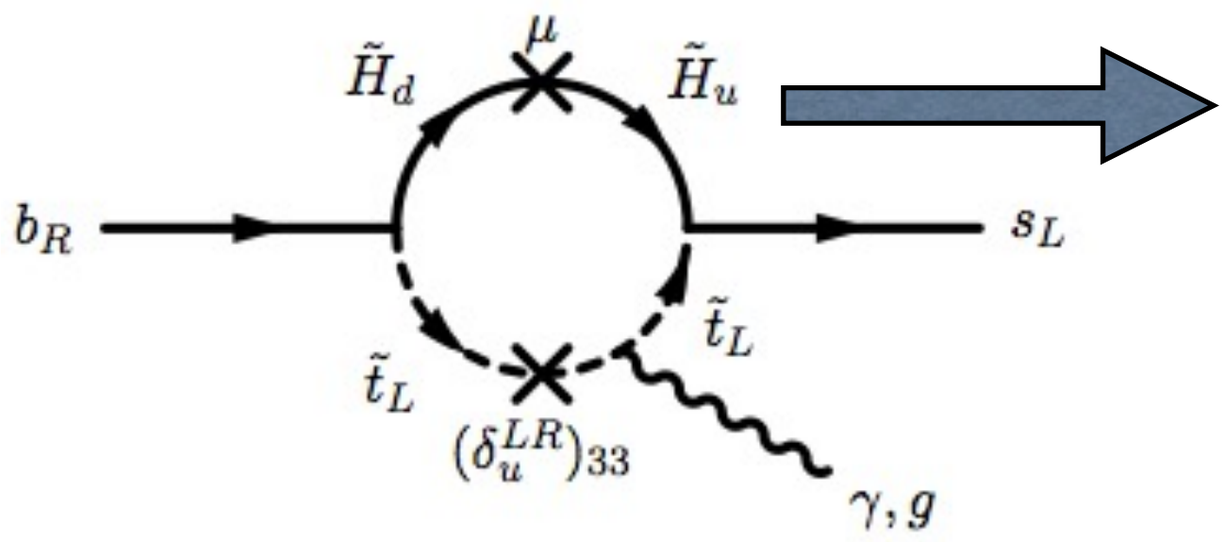
- Majorana masses for the gauginos
- A term
- Mu term

$\Delta F = 2$



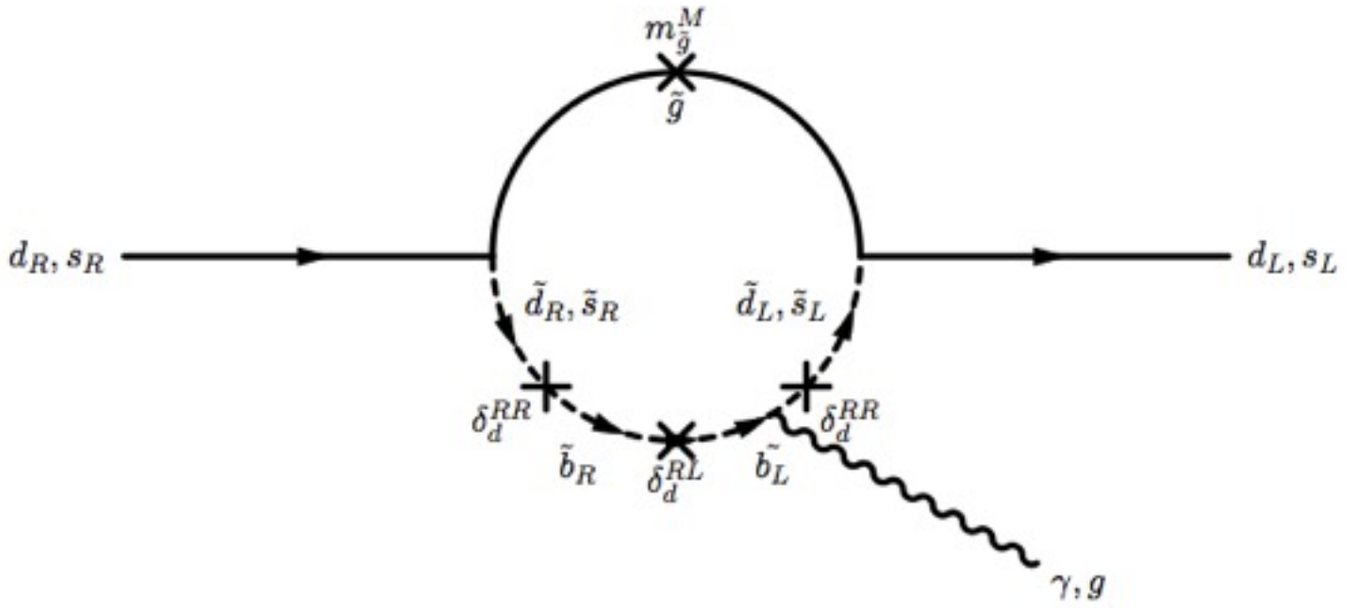
gluino Majorana mass insertion

$\Delta F = 1$



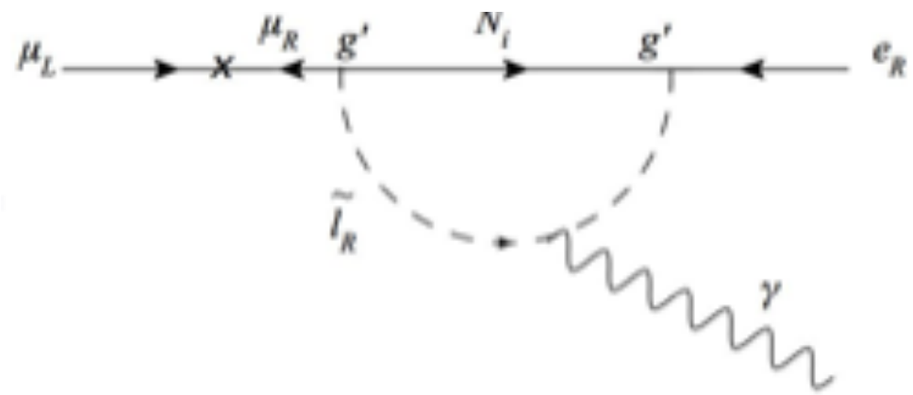
mu term

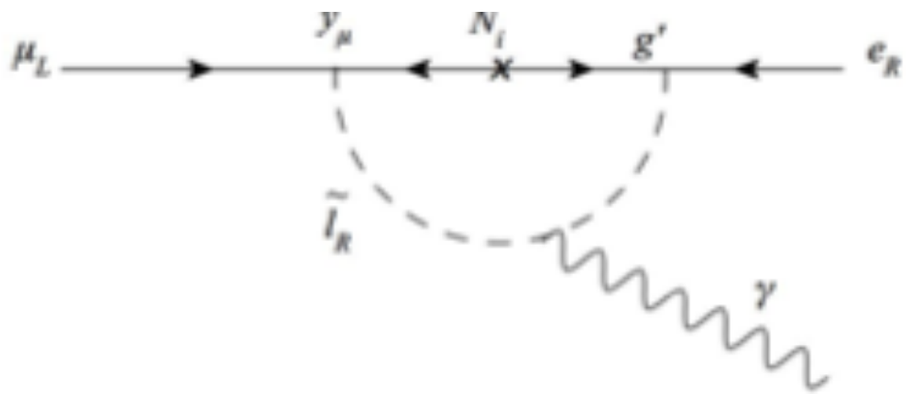
EDM bounds



$\mu \longrightarrow e\gamma$

no chirality flip from Majorana mass insertion or mu term



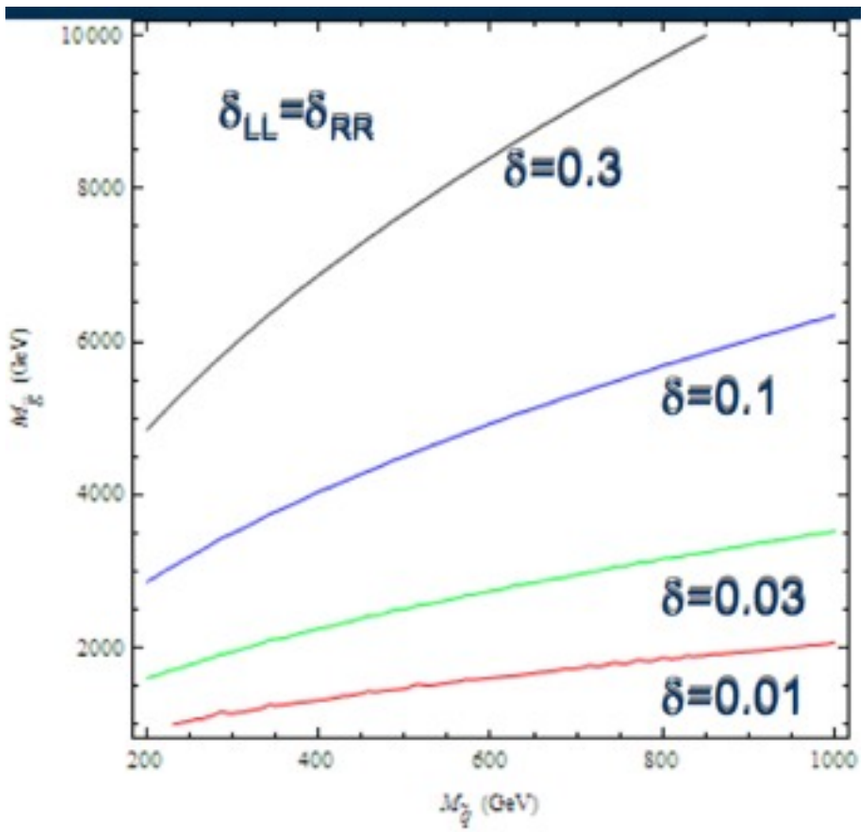


suppressed by the Yukawa coupling

Flavor problem relaxed but not solved

some flavor structure still required

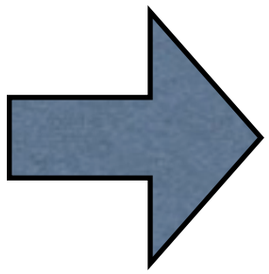
Mixing between first&second generation
still suppressed by K0K0 mixing



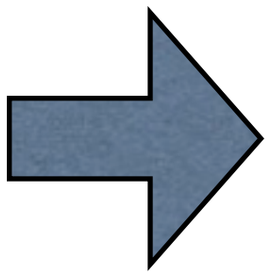
$$\delta = \frac{M_{12}^2}{\sqrt{M_{11}^2 M_{22}^2}}$$

even stronger bounds considering ϵ_K

R symmetry relax several of the flavor bounds



interesting ingredient to build a flavorful SUSY breaking mediation mechanism



allows larger flavor violation in the squark sector

what is the impact of this on the LHC phenomenology?

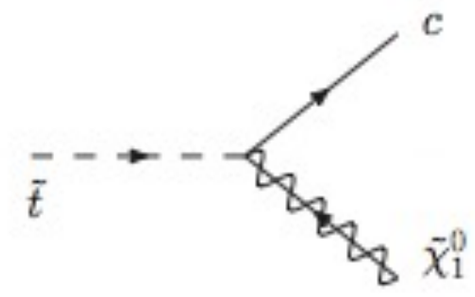
Mixed third generation at the LHC

$$\delta_{13}^{LL/RR} = \frac{M_{13}^2}{\sqrt{M_{11}^2 M_{33}^2}} \sim 1 \quad \text{or} \quad \delta_{23}^{LL/RR} = \frac{M_{23}^2}{\sqrt{M_{22}^2 M_{33}^2}} \sim 1$$

single top production

kribs,martin,roy'09

Flavor violating (FV) decay mode of the stop is dominant in a large region of the parameter space

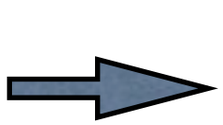


(Light) stop NLSP

$\tilde{t} \longrightarrow b\chi^{\pm}$ kinematically forbidden

LSP gravitino, singlino or bino

better if it is pseudo-dirac



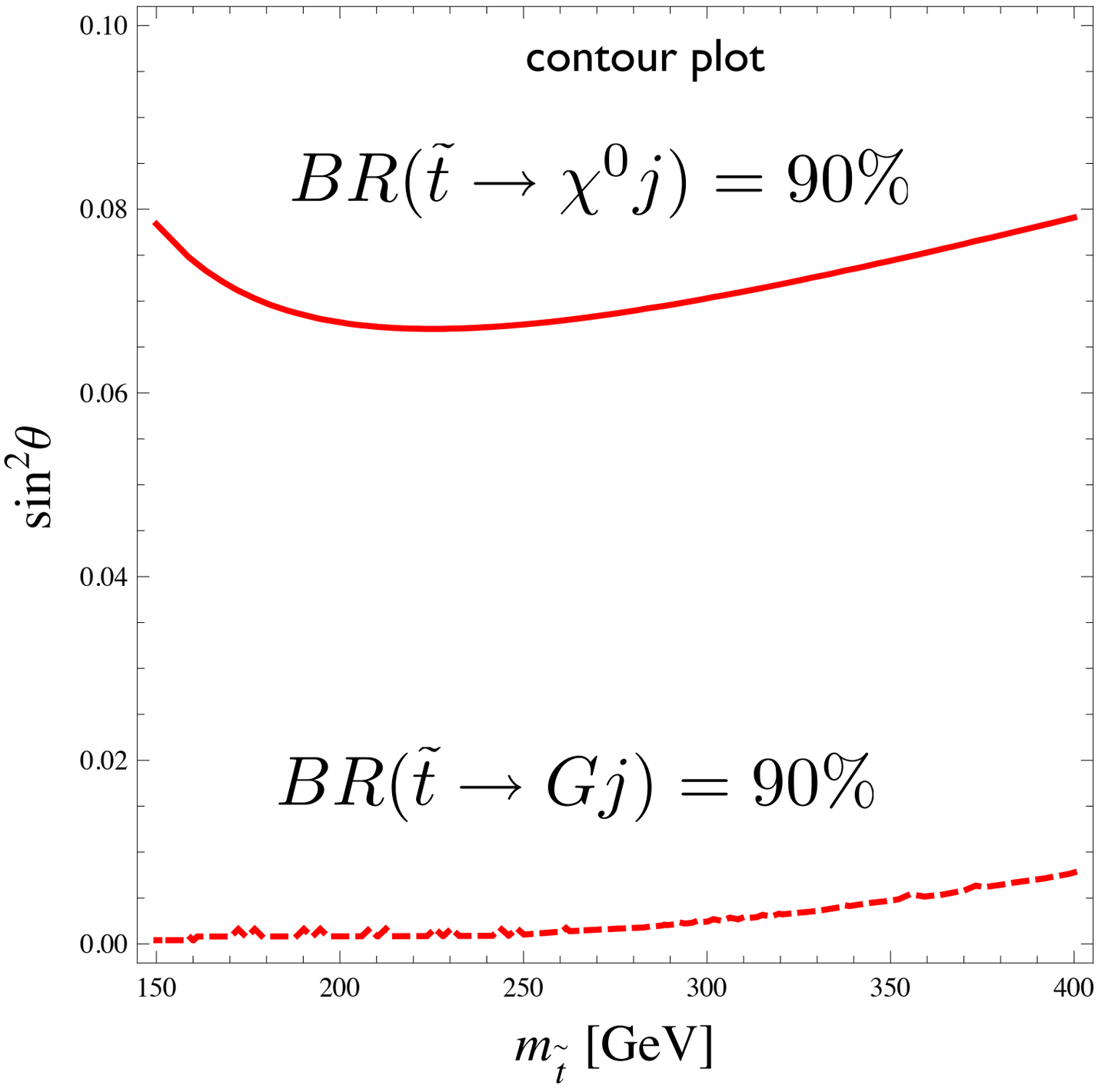
natural region if the stop is light

$$m_{\tilde{t}} < \mu < 300\mathrm{GeV}$$

$m_{\tilde{t}} < m_t + m_{LSP}$ $\tilde{t} \longrightarrow t$ LSP

also kinematically forbidden

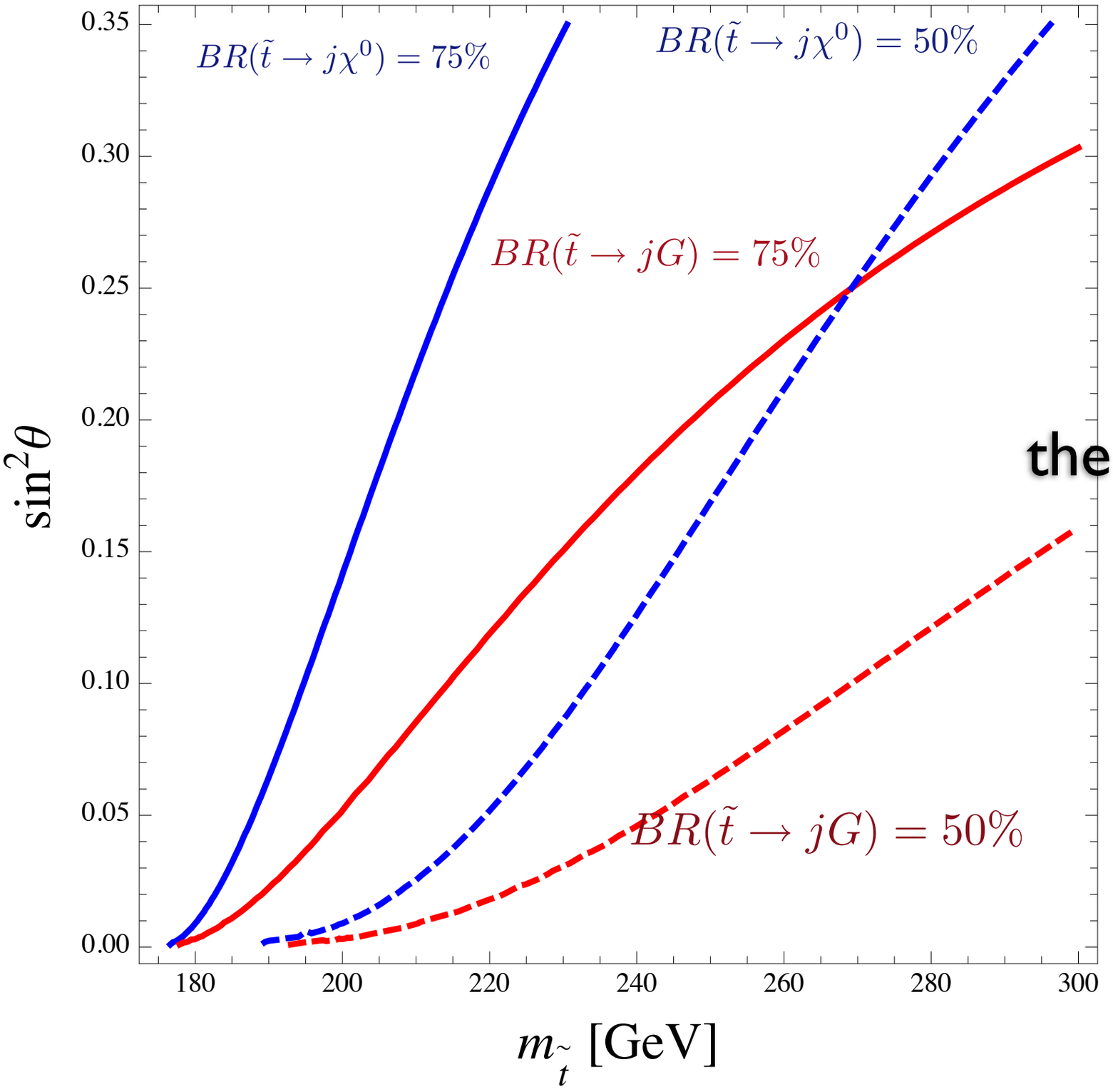
FV decay mode dominates over the 3 body decay



$m_{\tilde{t}} - m_{LSP} = 150$ GeV

more compressed spectrum FV dominates for even smaller mixing angle

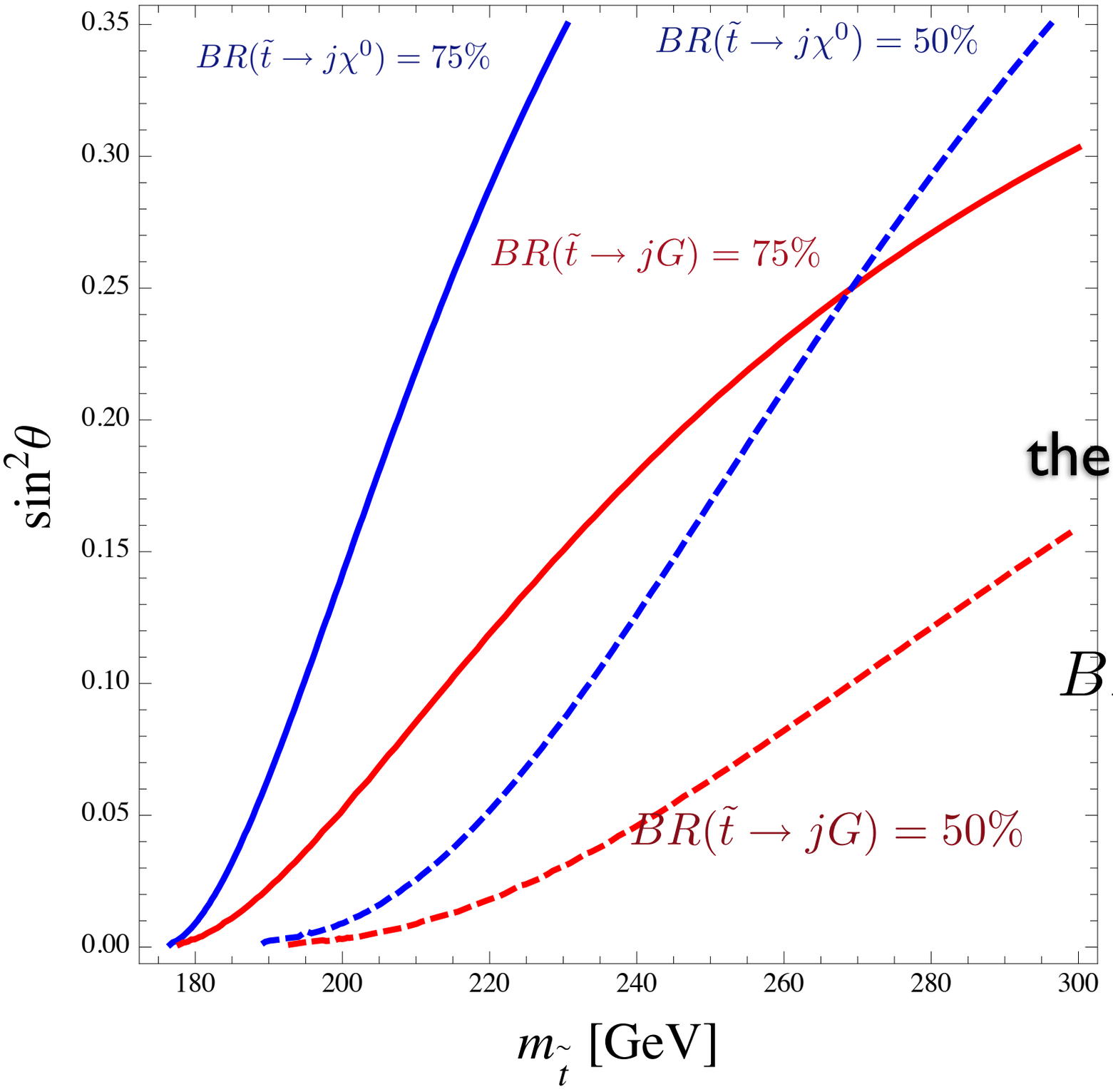
Significant BR also when the decay into top+LSP is open!



massless LSP

light stop FV is still the dominant decay mode

Significant BR also when the decay into top+LSP is open!



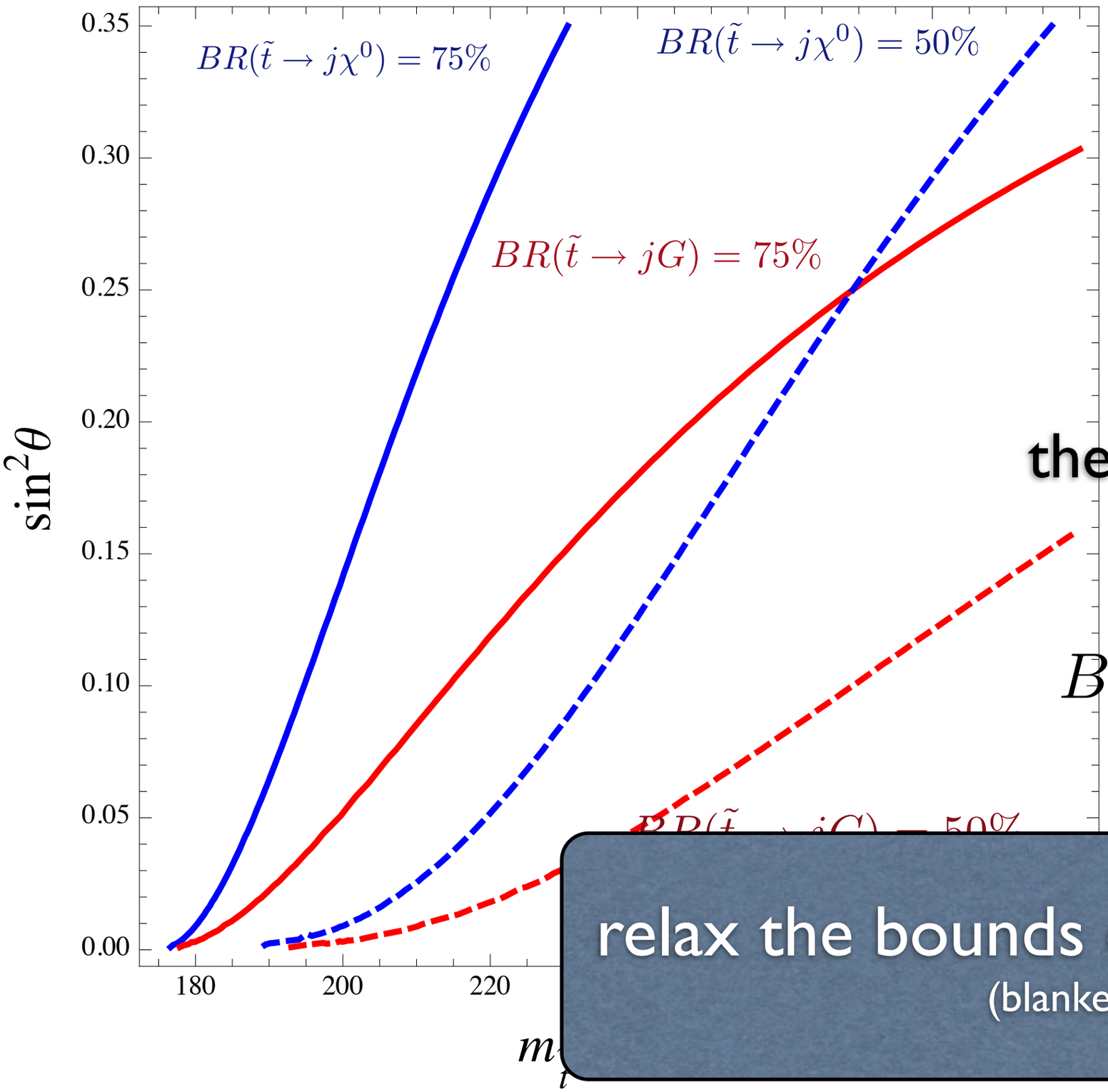
massless LSP

light stop FV is still the dominant decay mode

heavier stops FV

$$BR(\tilde{t} \to j\mathrm{LSP}) \sim \sin^2\theta$$

Significant BR also when the decay into top+LSP is open!



massless LSP

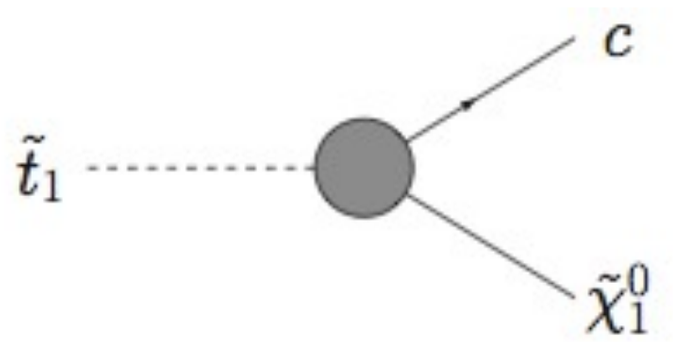
light stop FV is still the dominant decay mode

heavier stops FV

$$BR(\tilde{t} \to j\mathrm{LSP}) \sim \sin^2\theta$$

relax the bounds on the stop mass
(blanke et al)

MSSM with MFV



$$\theta_{tc} \sim \frac{v A y_t y_b V_{cb} V_{tb}^*}{16\pi^2 \tilde{m}^2} \log \frac{\Lambda_{UV}}{\tilde{m}} \sim 10^{-5}$$

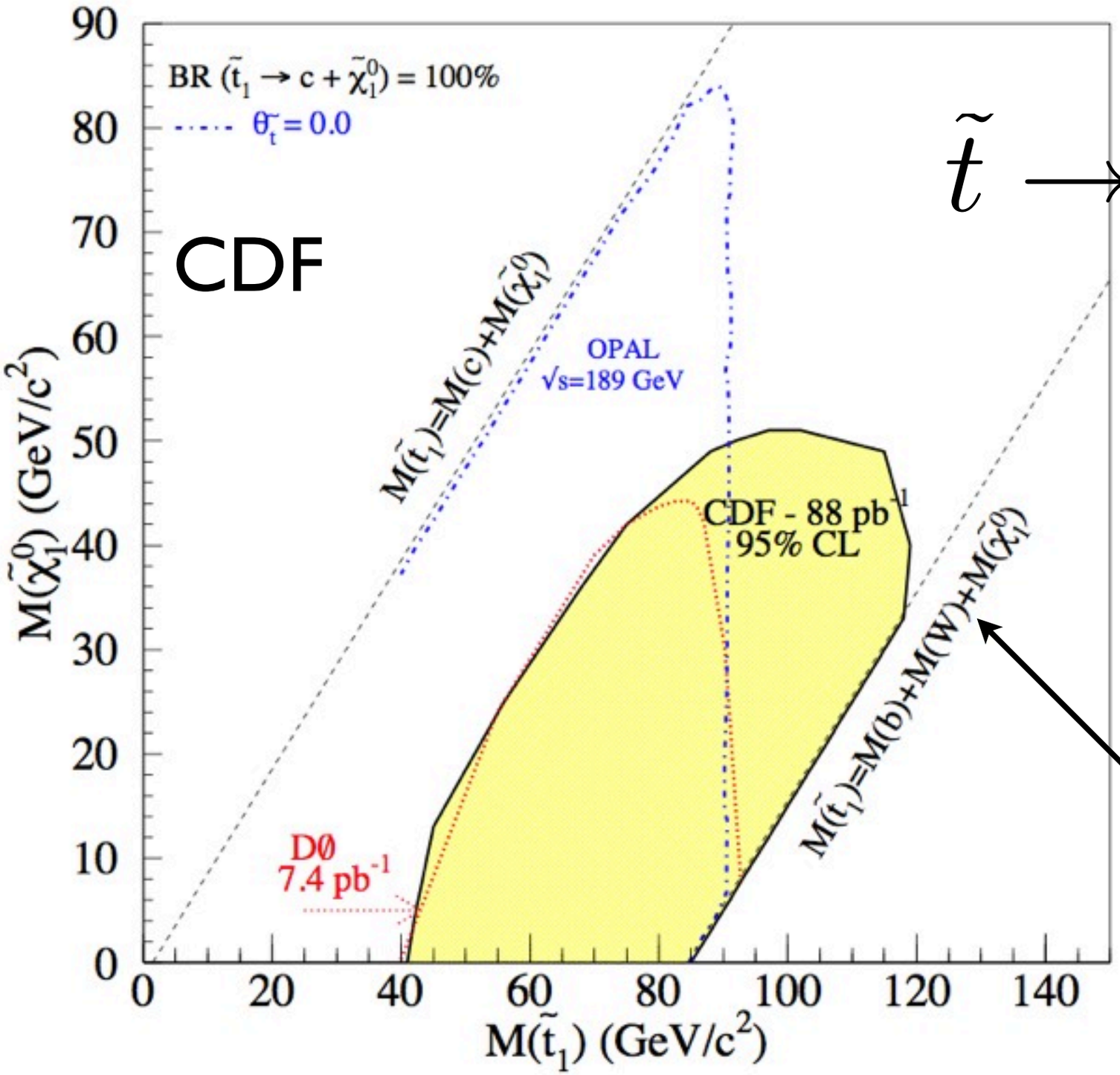
CKM suppressed

FV significant only for

$$m_{\tilde{t}} < m_b + m_W + m_{LSP}$$

compete with the 4 body decay

Tevatron dedicated searches covered just the parameter space relevant for the MSSM



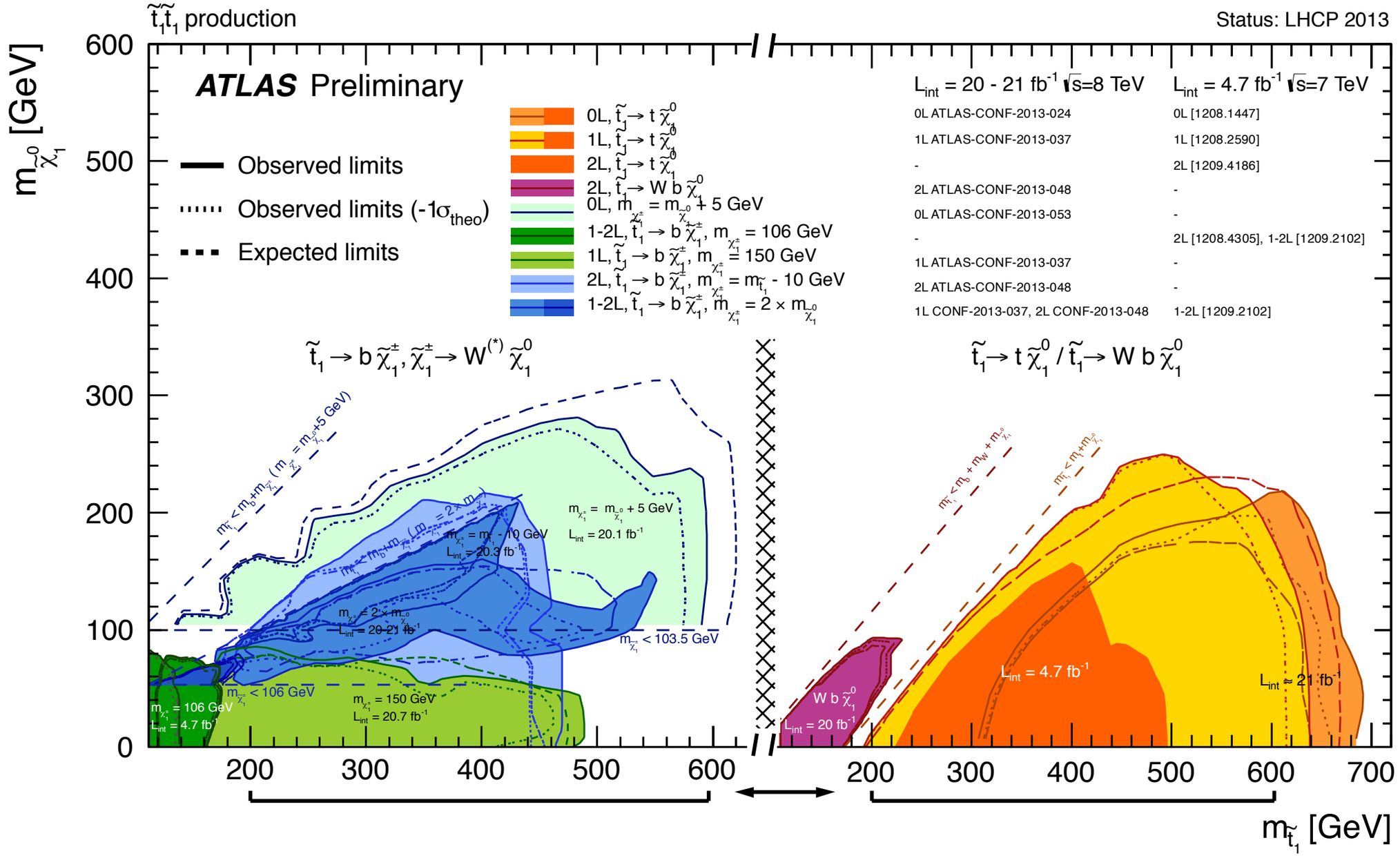
$$\tilde{t} \to c\ LSP$$

what about this region?

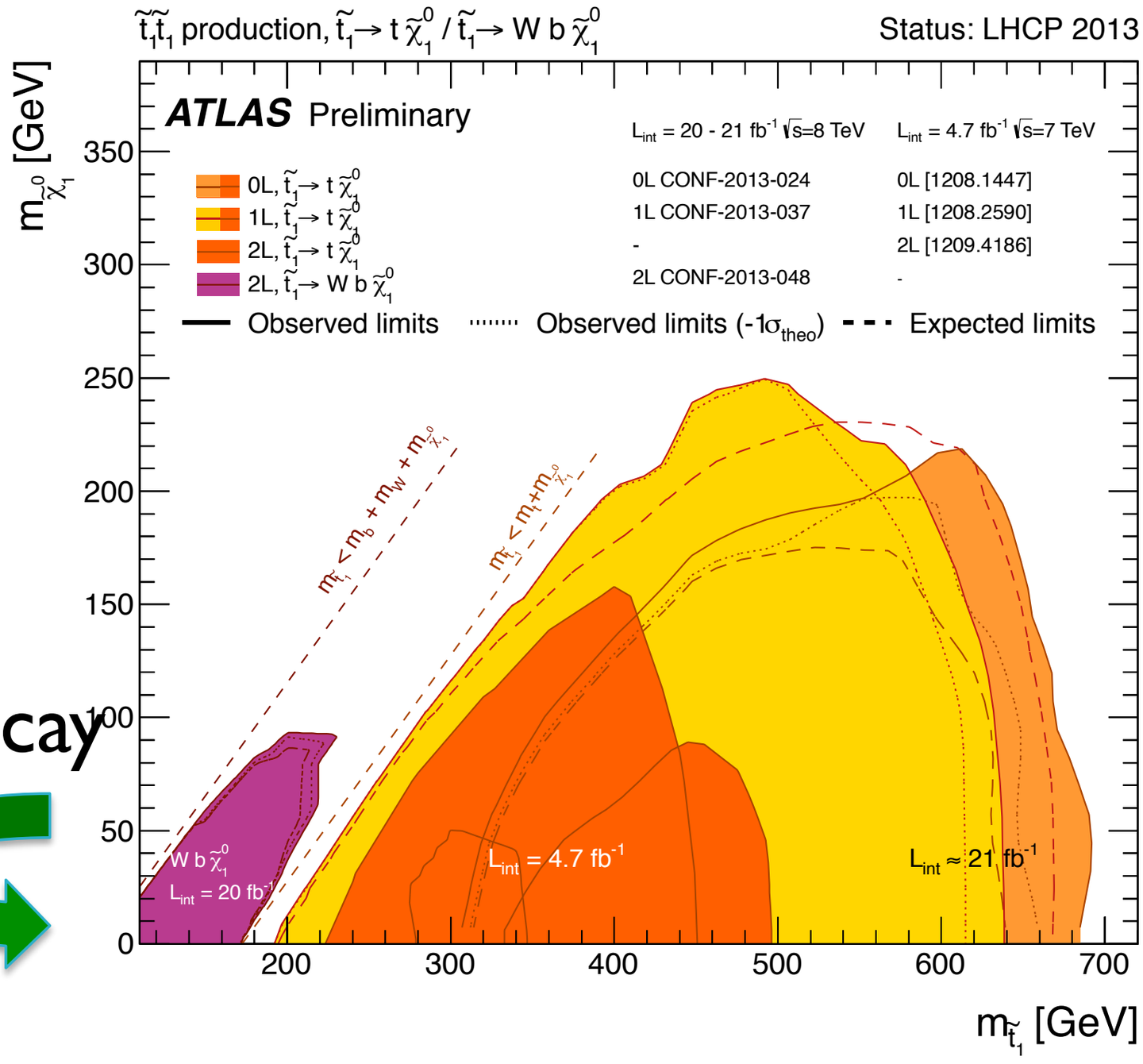
Stops searches at the LHC

both ATLAS and CMS are looking for stops in

$$\tilde{t} \longrightarrow b\chi^{+} \qquad \tilde{t} \longrightarrow t\chi^{0}$$



Stop NLSP

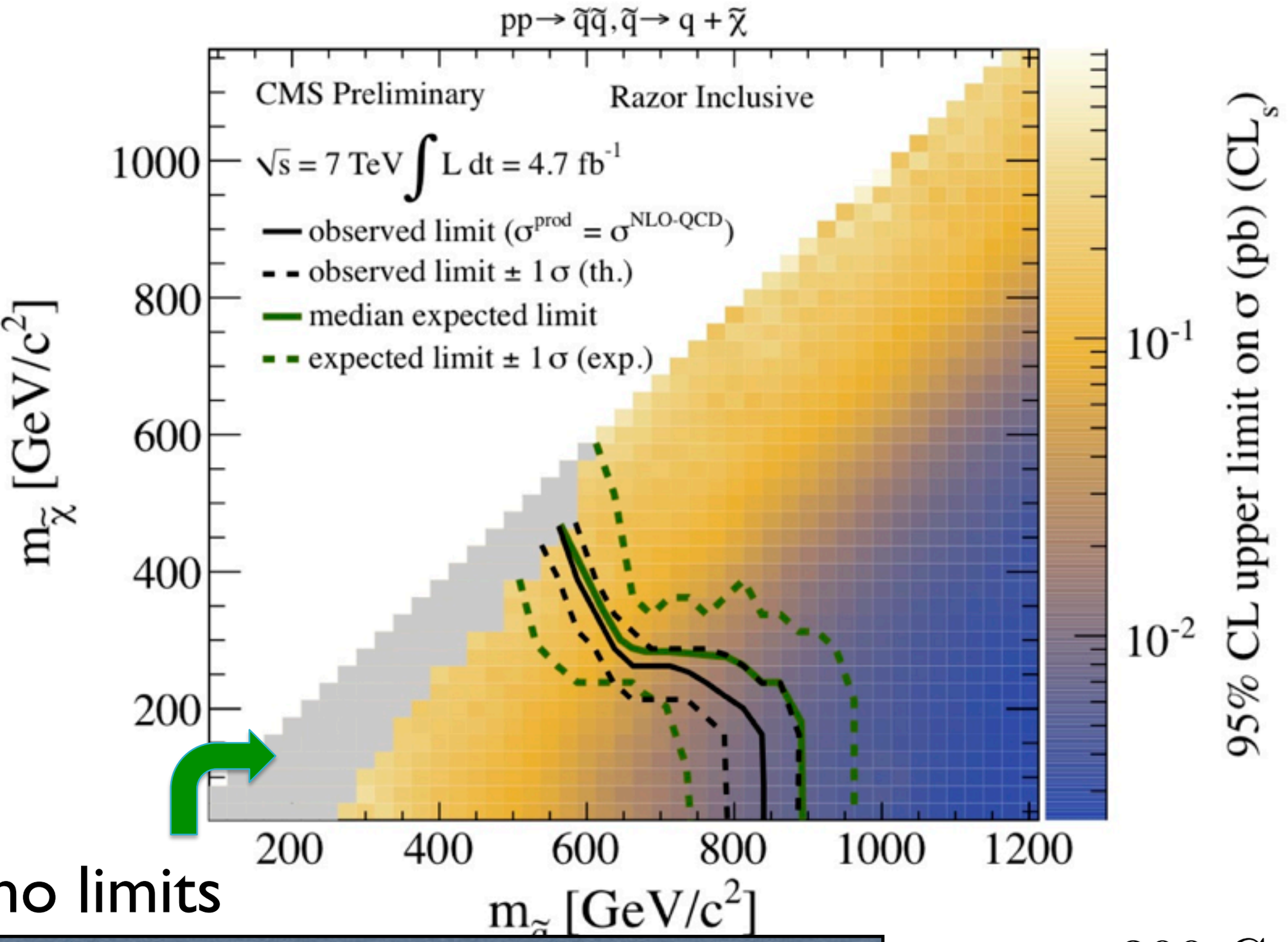


3 body decay

what about our topology?

no dedicated searches

Standard jets+MET searches ?



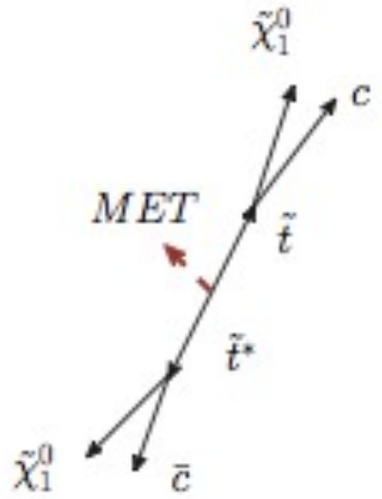
no limits

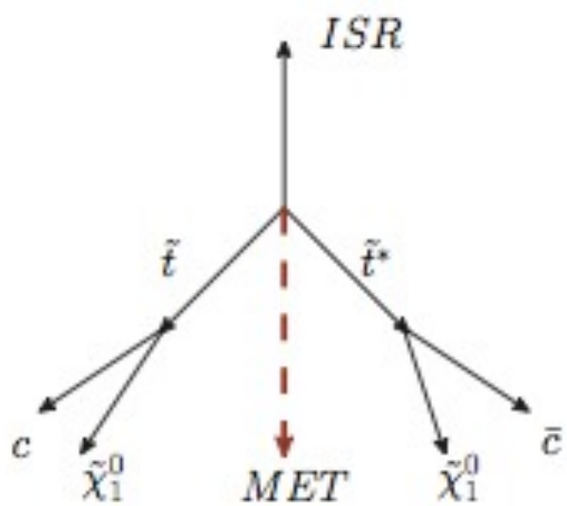
region interesting for us left uncostrained

$$m_{\tilde{t}} < 300 \text{ GeV}$$

$$m_{\tilde{t}} - m_{LSP} < 150 \text{ GeV}$$

ISR dependence of the efficiency





in compressed spectrum the two LSPs are produced back to back as the mother particles

important to include initial state radiation

large MET from ISR recoil

Our study

We generated with MadGraph5

$$\tilde{t}\tilde{t}^*$$
$$\tilde{t}\tilde{t}^* + j$$
$$\tilde{t}\tilde{t}^* + 2j$$

decay, parton shower and hadronization with Phytia

Matched sample

Detector simulation with PGS

$$BR(\tilde{t} \to j\mathrm{LSP}) = 100\%$$

Limits from CMS razor and alphaT analysis

CMS razor analysis

- inclusive search (jets+MET+(0,1,2)leptons)

At least two jets required- all the hard jets combined into megajets

- data driven background (no heavy use of MC simulations). Background has an exponential shape in the razor variables.

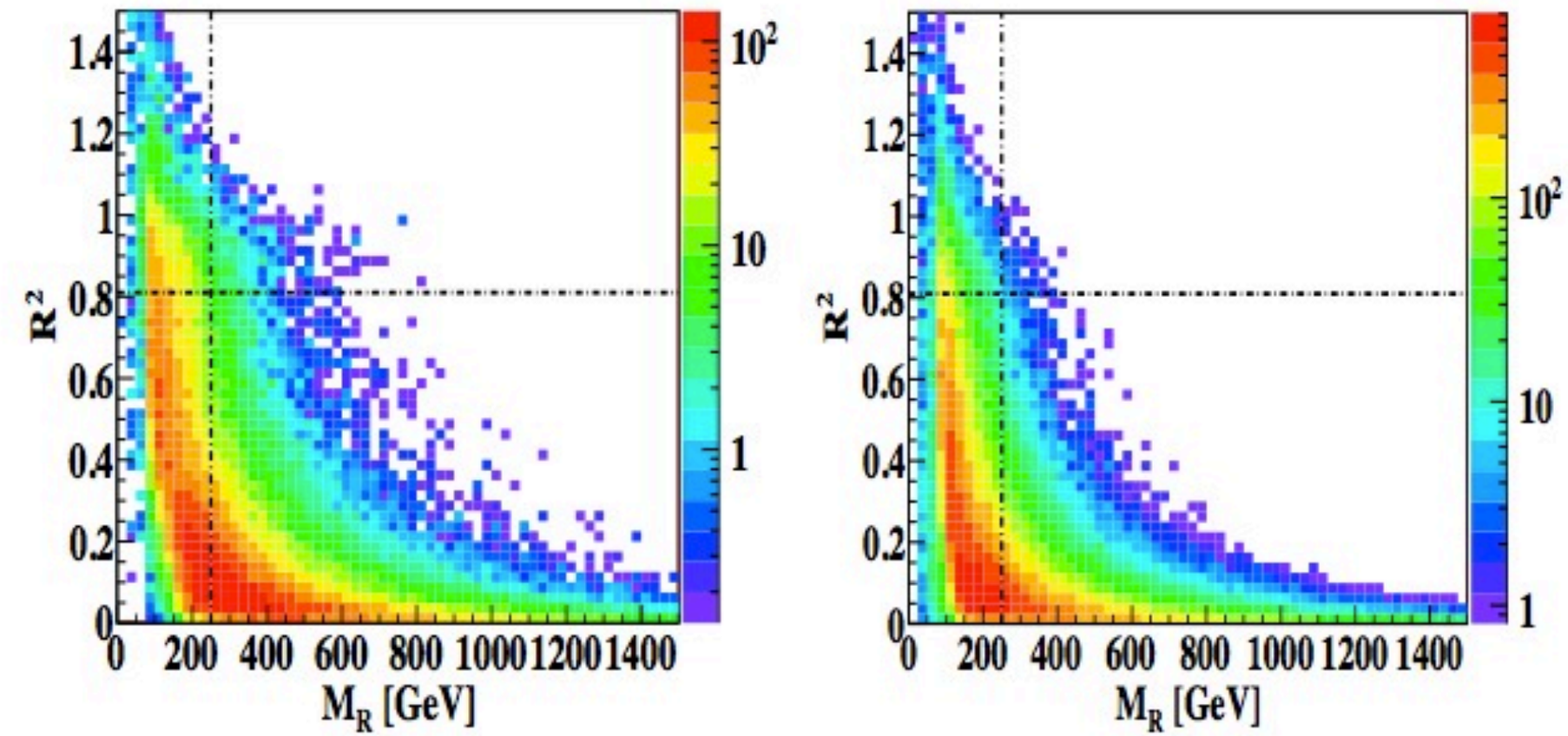
Razor variables

R^2 relate of the missing energy in the event and to the angle between the megajets

M_R estimate of the energy scale of event

Cuts on razor variables

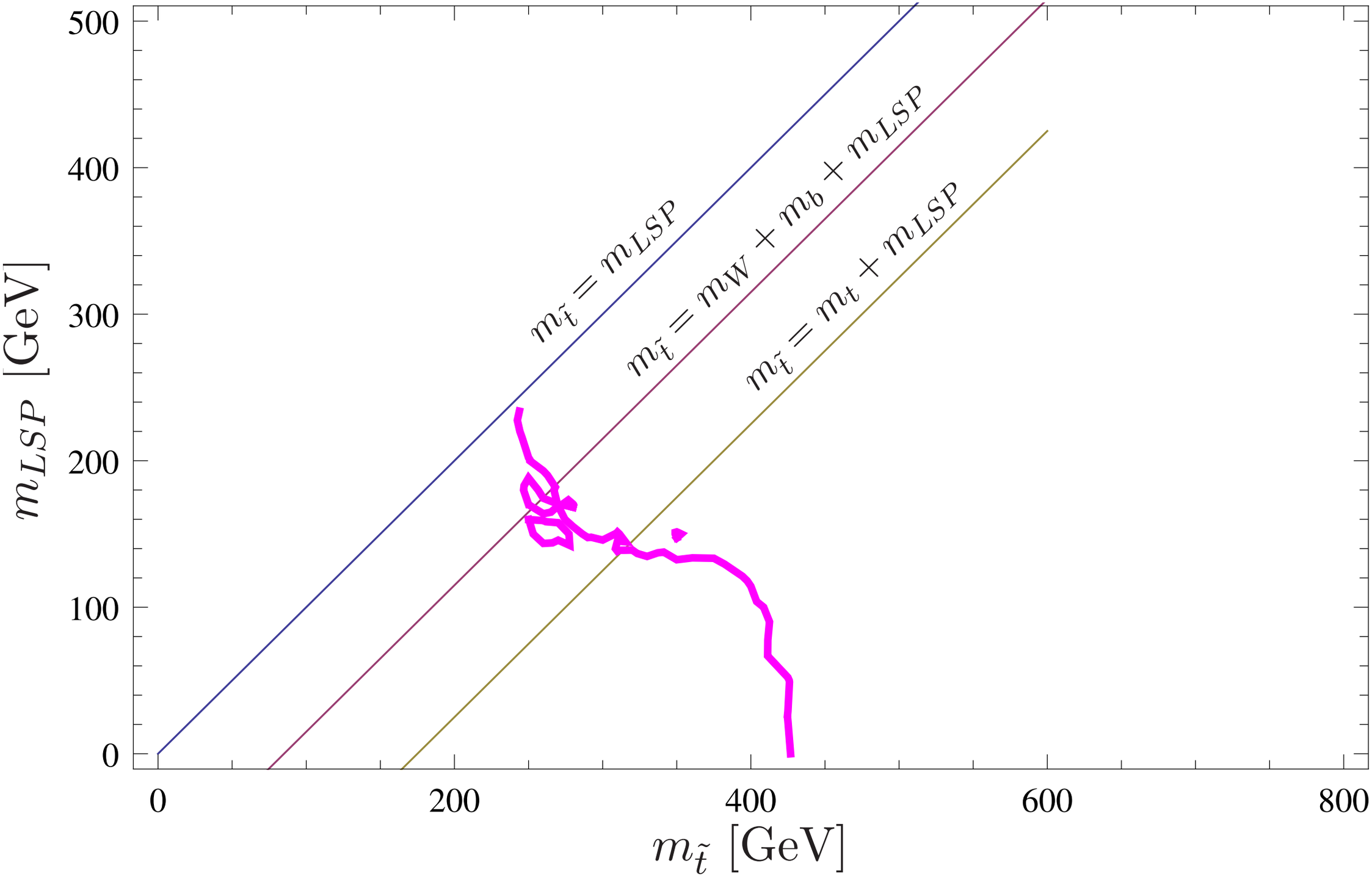
QCD multijet background killed by a cut on R^2



(a) $(Z \to \bar{\nu}\nu)$+jets. (b) W+jets.

2D cuts more efficient to reduce the backgrounds without killing also signals

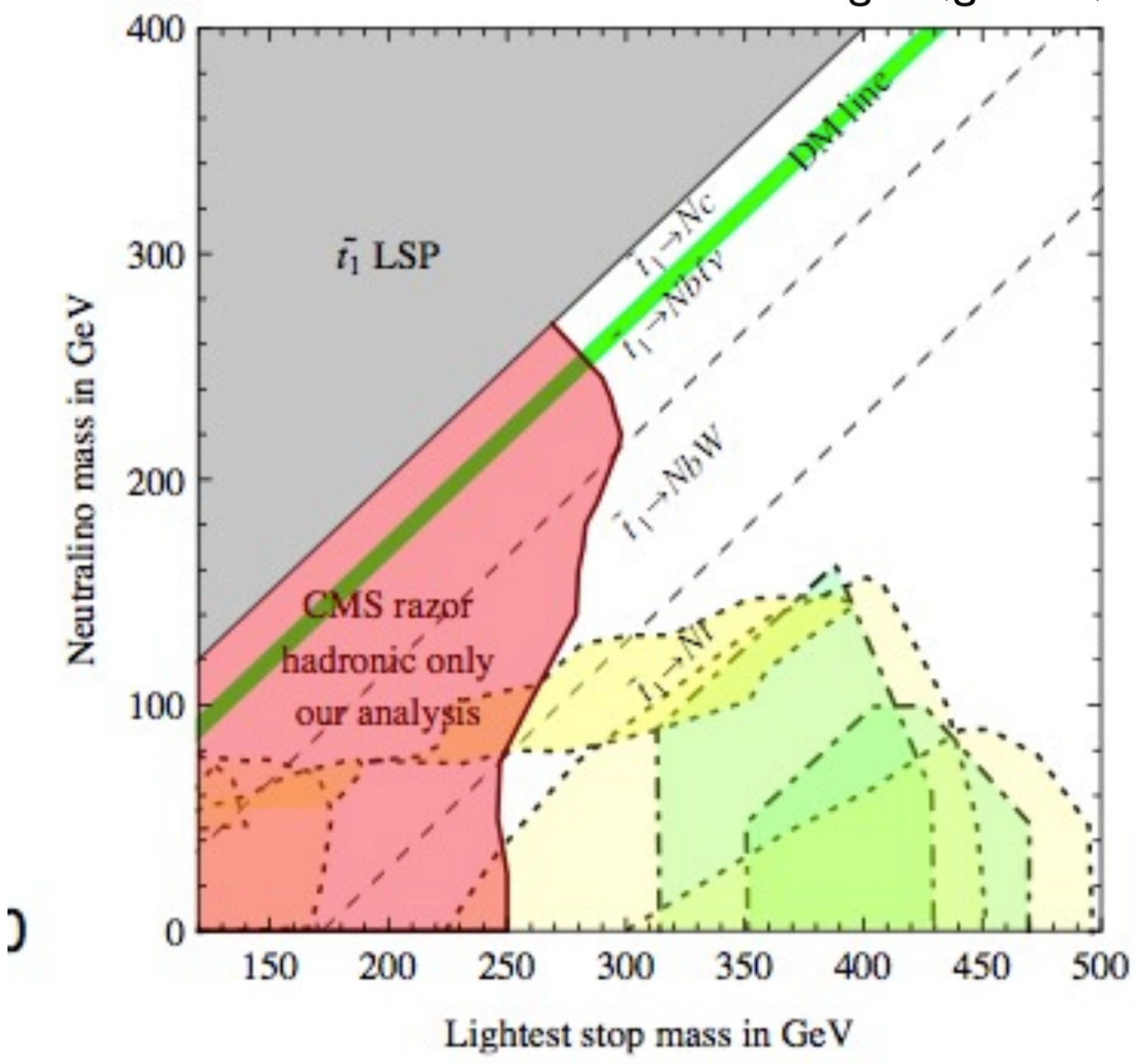
Our limits



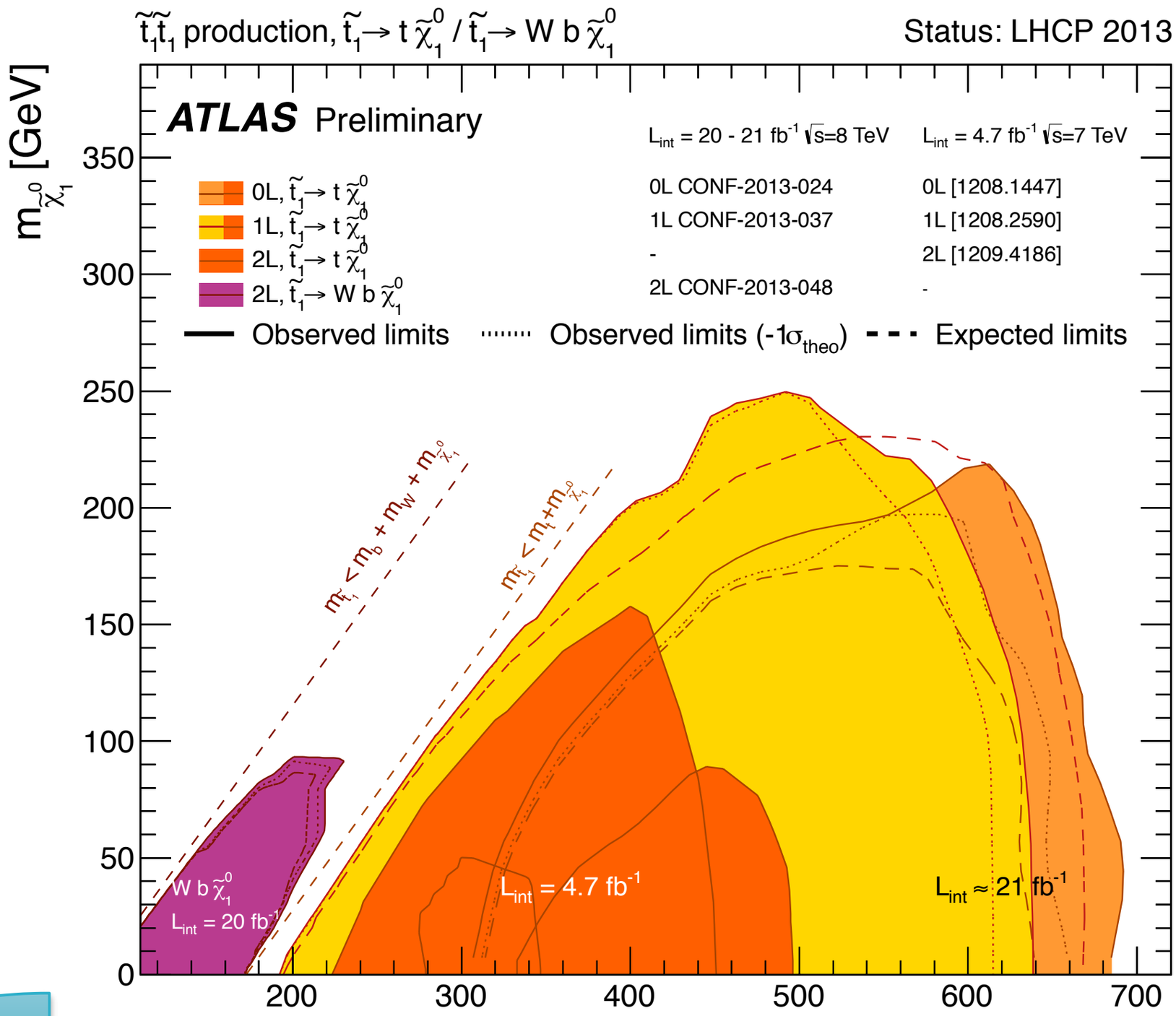
natural region $m_{\tilde{t}} < \mu < 300$ GeV almost excluded

Razor almost close the light stop window?

delgado,giudice,isidori,pierini,strumia '12

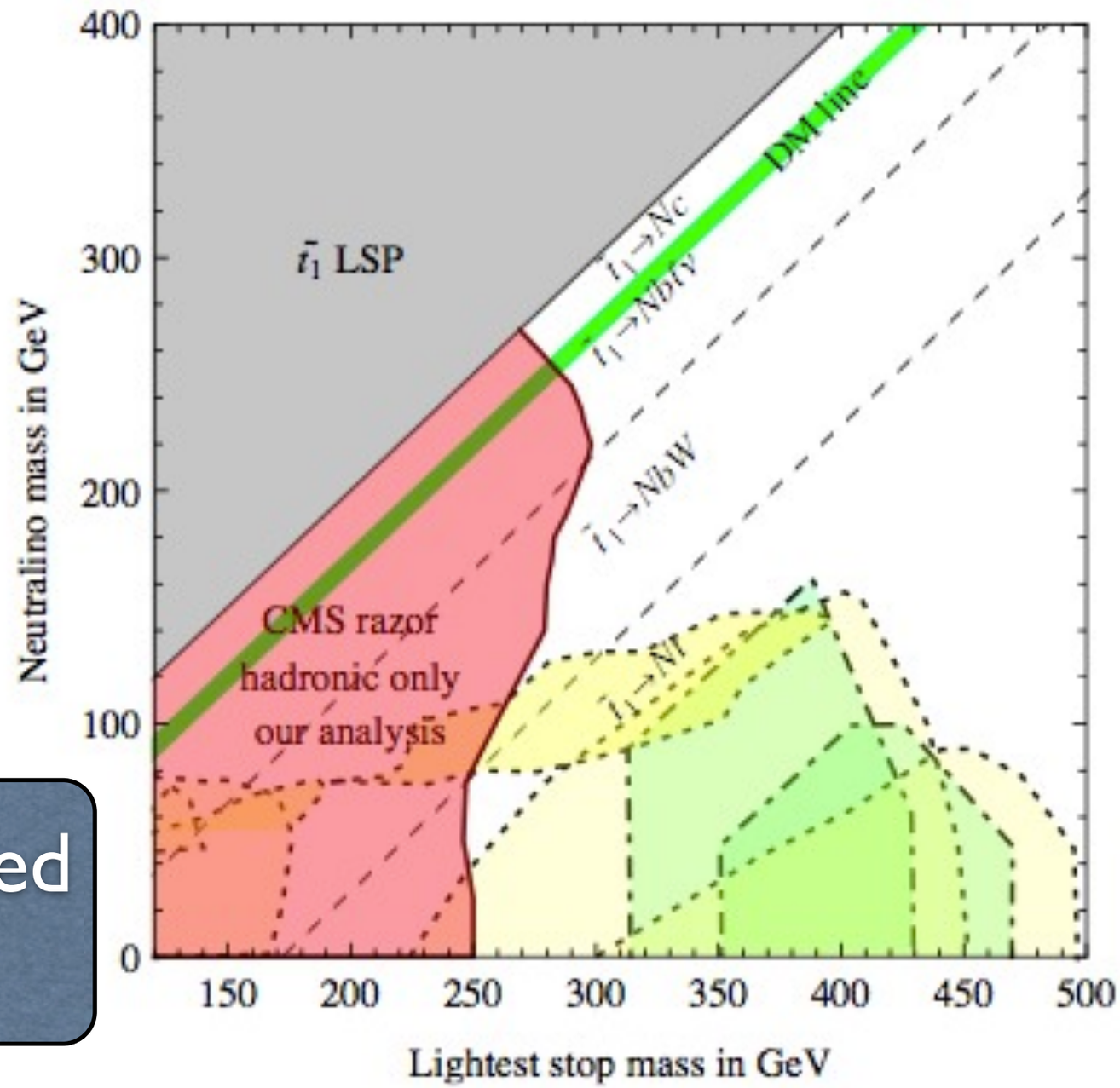


Left unconstrained by the dedicated searches



$$175\ \text{GeV} < m_{\tilde{t}} < 200\ \text{GeV}$$

Razor almost close the light stop window?



stealth stop ruled out?

work in progress with P.Agrawal and J.Lykken

Summarizing..

- Exploring scenarios beyond the MSSM can improve existing searches and eventually suggest new ones, but LHC is already doing a pretty good job already.
- CMS is updating its analysis to the compressed region having also our scenario in mind.
- it seems we really need to kill the missing energy of the event to escape LHC searches and hide SUSY

backup

Dirac gauginos

New Adjoints superfields for each SM gauge group

$$\psi_{\tilde{B}} \;\; \psi_{\tilde{W}} \;\; \psi_{\tilde{g}}$$

N=2 SUSY gauge sector

Supersoft SUSY Breaking

$$\int \frac{d^2\theta}{M} W'_\alpha W_i^\alpha \psi_i \qquad W'_\alpha \sim D\theta_\alpha$$

D term spurion

Fox, Nelson, Weiner, 2002