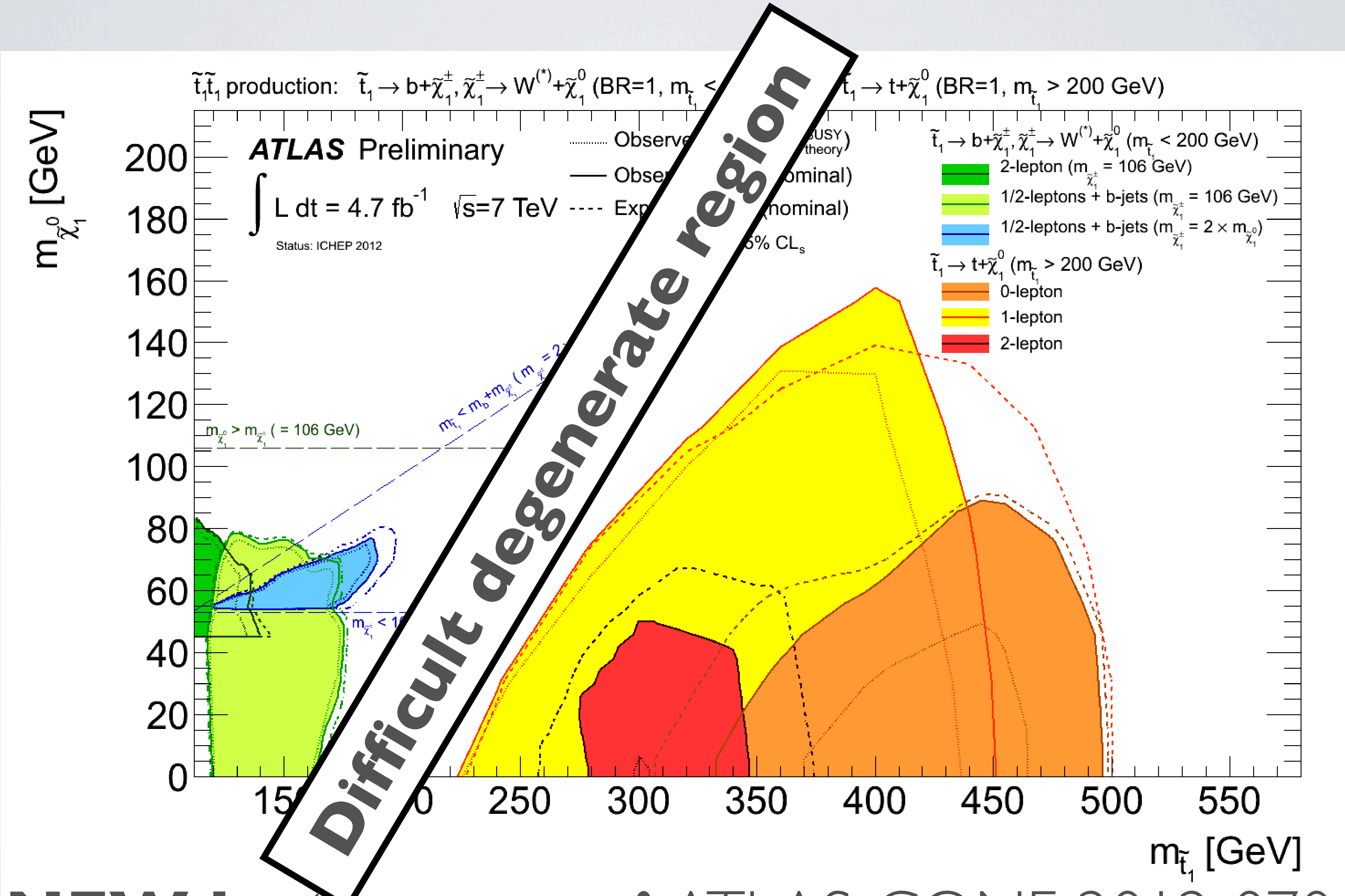
STEALTH STOP SEARCHES

Matt Reece

January 30, 2013

Based mostly on: Z. Han, A. Katz, D. Krohn, MR 1205.5808

DIRECT STOP LIMITS

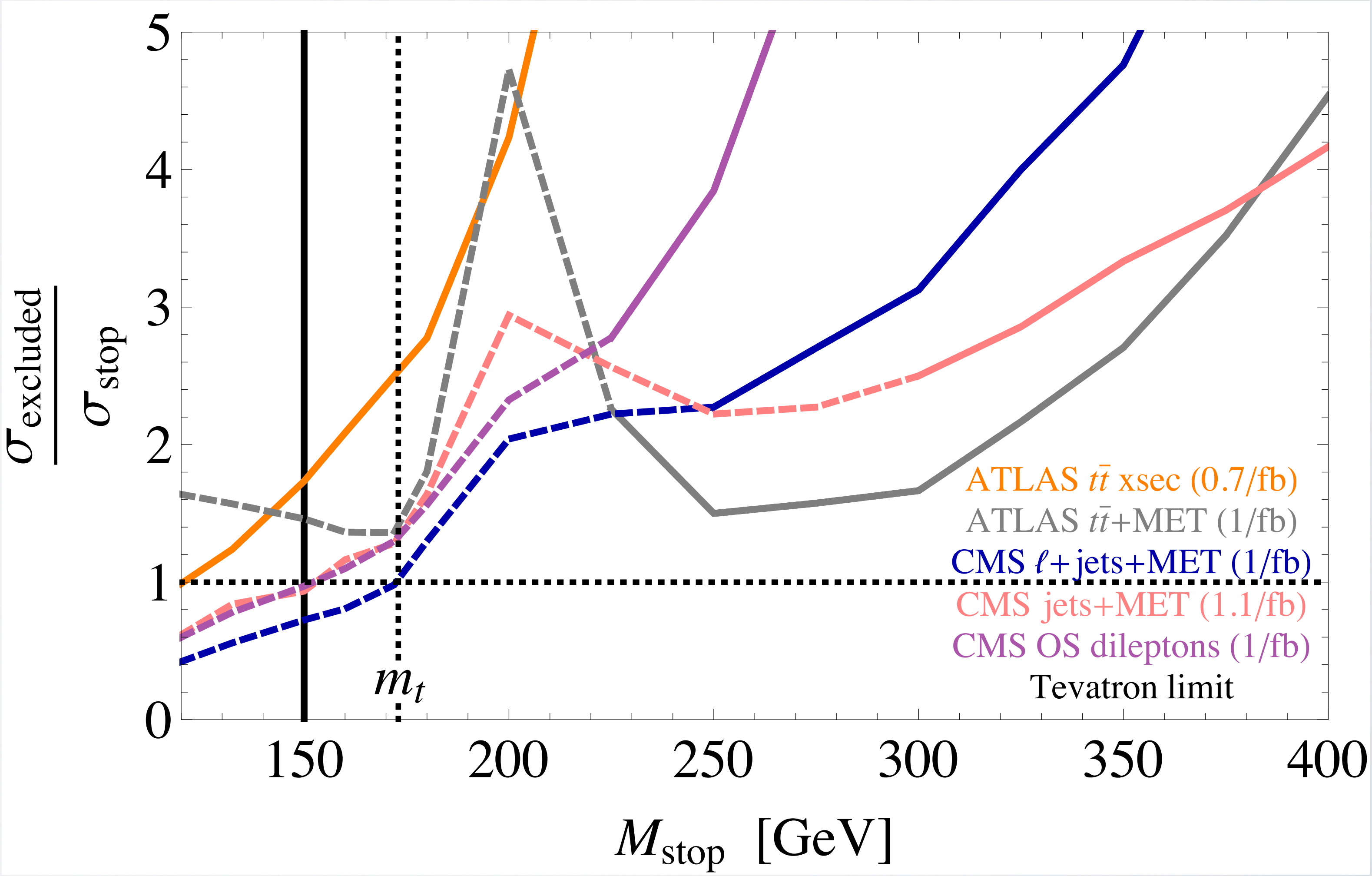


NEW last summer! ATLAS-CONF-2012-070/071/073/074; CMS-PAS-SUS-12-009, SUS-11-022, ...

A STEALTHY STOP?

The stop could be lurking very near the top quark mass, canceling the Higgs mass corrections.

Very hard to see in this mass range; an instance of **"stealth supersymmetry"** (J. Fan, MR, J. Ruderman, '11)



Y. Kats, P. Meade, MR, D. Shih '11

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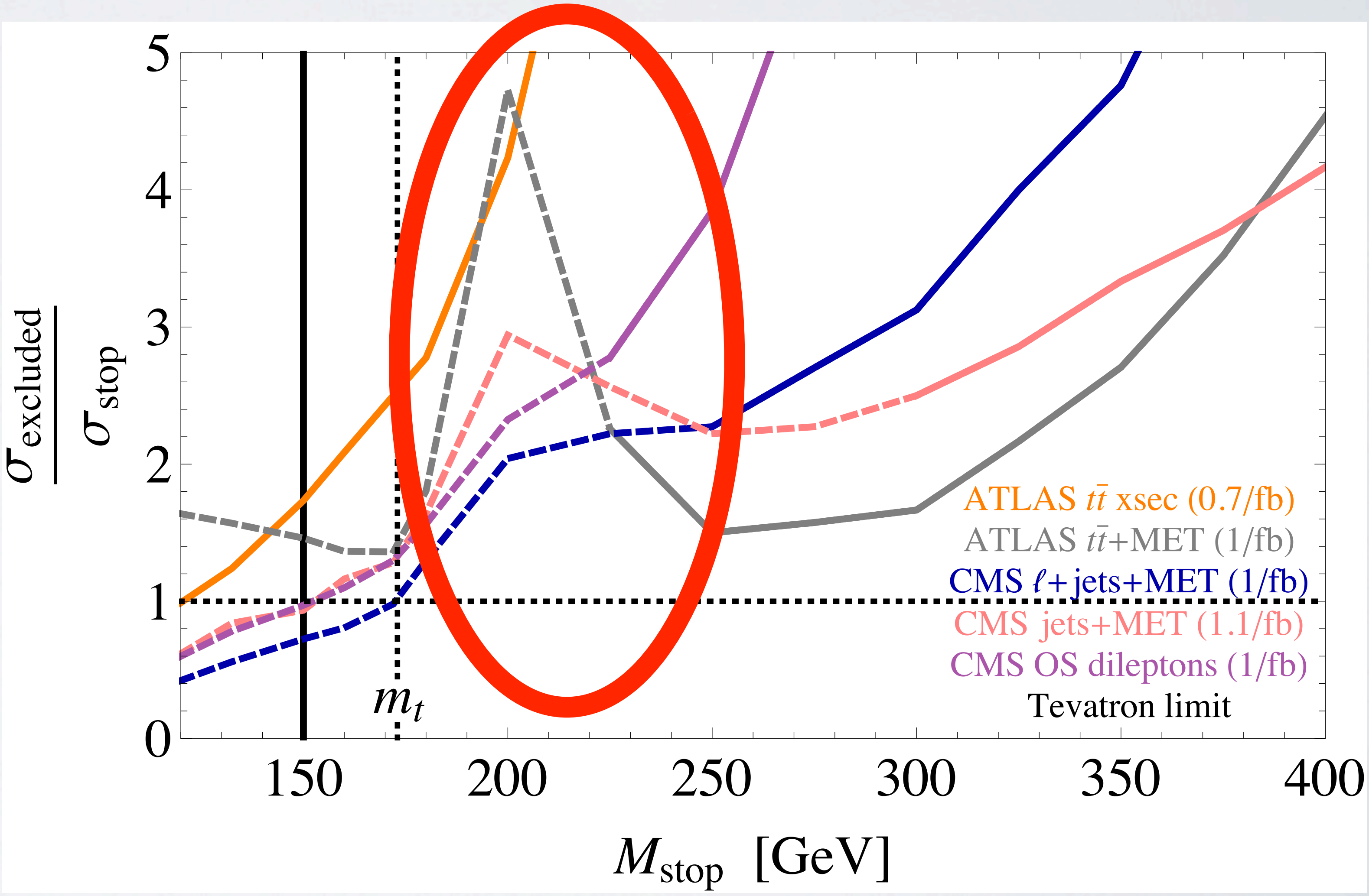

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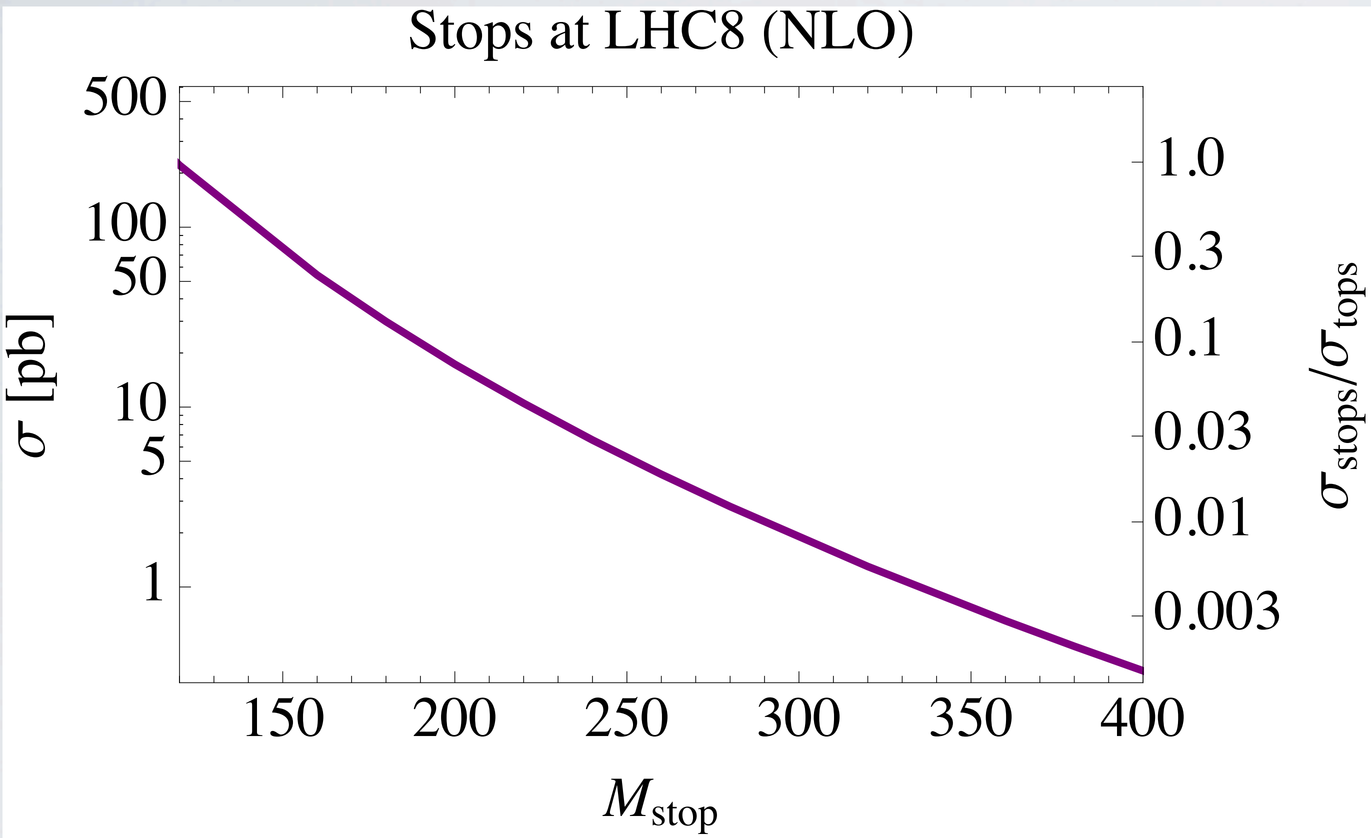
STOP & TOP CROSS SECTION



At stop mass = top mass, rate is about 1/6 of top rate.

Why so small? Very naive: both color triplets, 1/2 the degrees of freedom, why not 1/2 the rate?

Madgraph LO:

$$\sigma(gg \to t\bar{t}) \approx 68 \text{ pb} \qquad \sigma(gg \to \tilde{t}_1\tilde{t}_1^\dagger) \approx 11 \text{ pb}$$

$$\sigma(q\bar{q} \to t\bar{t}) \approx 23 \text{ pb} \qquad \sigma(q\bar{q} \to \tilde{t}_1\tilde{t}_1^\dagger) \approx 1.6 \text{ pb}$$

THRESHOLD DEPENDENCE

Madgraph LO:

$$\sigma(gg \to t\bar{t}) \approx 68 \text{ pb} \qquad \sigma(gg \to \tilde{t}_1\tilde{t}_1^\dagger) \approx 11 \text{ pb}$$

$$\sigma(q\bar{q} \to t\bar{t}) \approx 23 \text{ pb} \qquad \sigma(q\bar{q} \to \tilde{t}_1\tilde{t}_1^\dagger) \approx 1.6 \text{ pb}$$

The smallness of stop production from q-qbar is related to the threshold behavior. Must produce the stops in a *p*-wave, so rate goes ~ β^3.

Top production and stops from gluons are ~ β, so need a better explanation of the small ratio of stops.

MASSLESS LIMIT

Production rate of stops from gluons:

$$\sigma(gg \to \tilde{t}_1 \tilde{t}_1^\dagger) \to_{s \gg m} \frac{5\alpha_s^2 \pi}{48 s}$$

Production rate of fermionic quarks from gluons:

$$\frac{d\sigma}{d\Omega}(gg \to q\bar{q}) = \frac{\alpha_s^2}{24 s}\left(t^2 + u^2\right)\left(\frac{1}{tu} - \frac{9}{4s^2}\right).$$

Have a forward singularity: cut off by the stop mass, but **enhances the top rate**.

Real kinematic difference we should try to exploit.

AMPLITUDES

Consider the even simpler example of $\gamma\gamma \to \tilde{e}^+\tilde{e}^-$

$$A(1^+, 2^-, 3_\phi, 4_\phi) = ie^2 \frac{[1\ 3]\,\langle 2\ 3\rangle}{\langle 1\ 3\rangle\,[2\ 3]}$$

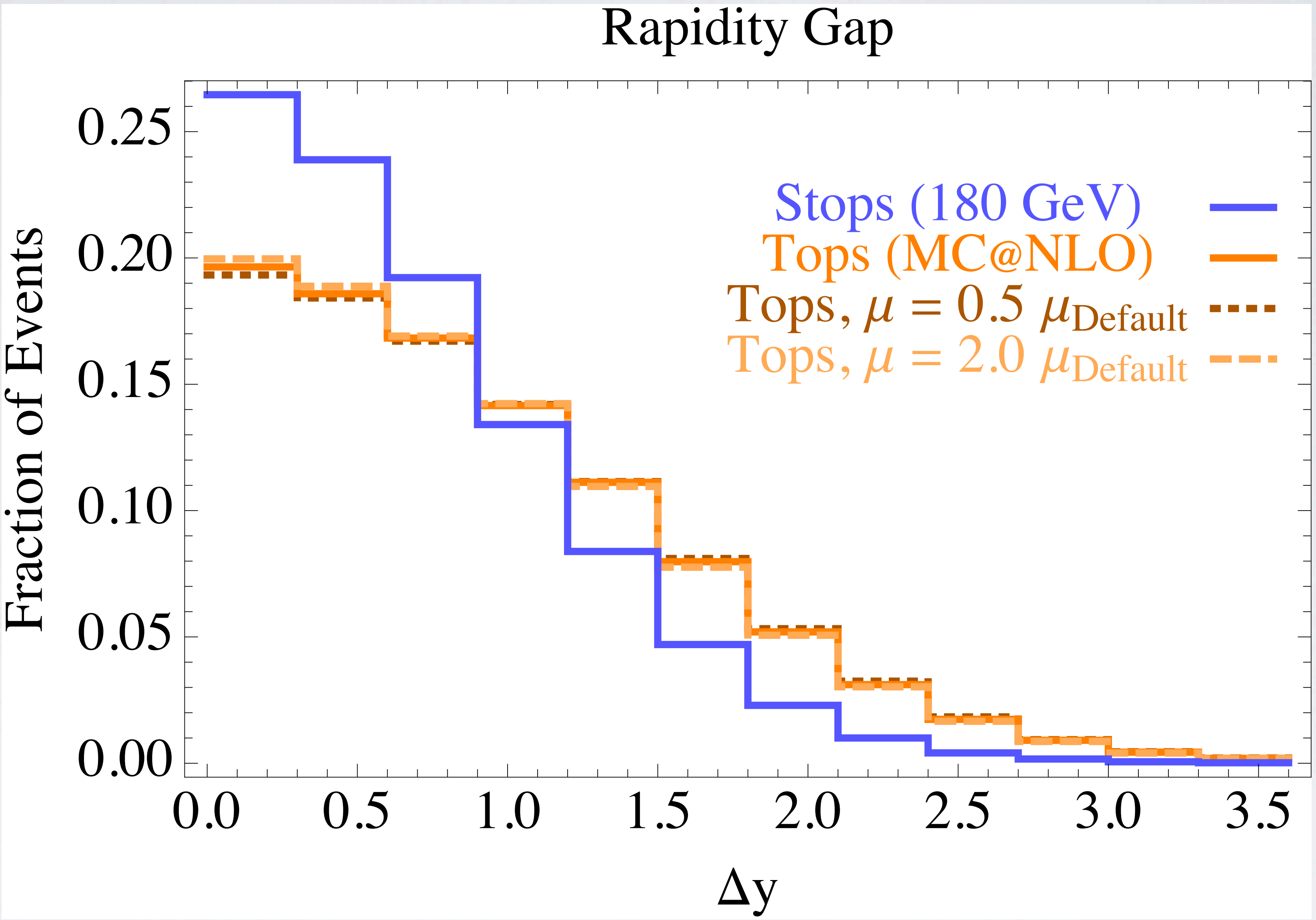
The amplitude is a pure phase.

The *t*-channel pole is absent; a photon can't split into collinear scalars while conserving angular momentum.

For fermions, the usual splitting amplitude story ameliorates the $1/t$ pole to a $1/\sqrt{t}$:

$$A^{\text{tree}}(1^+, 2^-, 3^+_{\bar{\psi}}, 4^-_{\psi}) = ie^2 \frac{[1\ 4]\,\langle 2\ 3\rangle}{\langle 1\ 3\rangle\,[2\ 3]} \sim ie^2 \sqrt{\frac{u}{t}} \times \text{ phase}$$

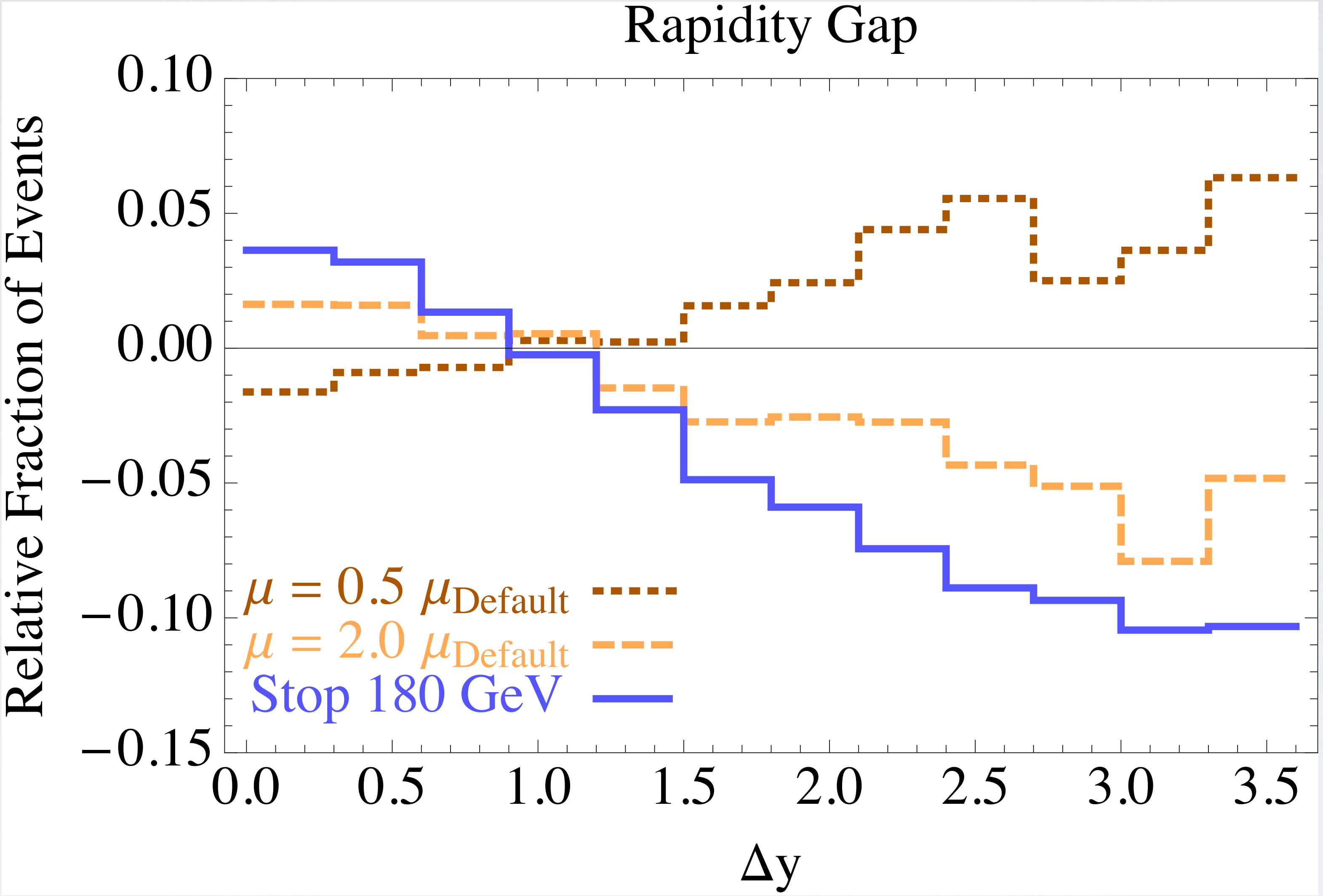
RAPIDITY DIFFERENCES



Result of the *t*-channel singularity for top production. Interesting stop/top difference, coming from **angular momentum conservation.**

HOWEVER...

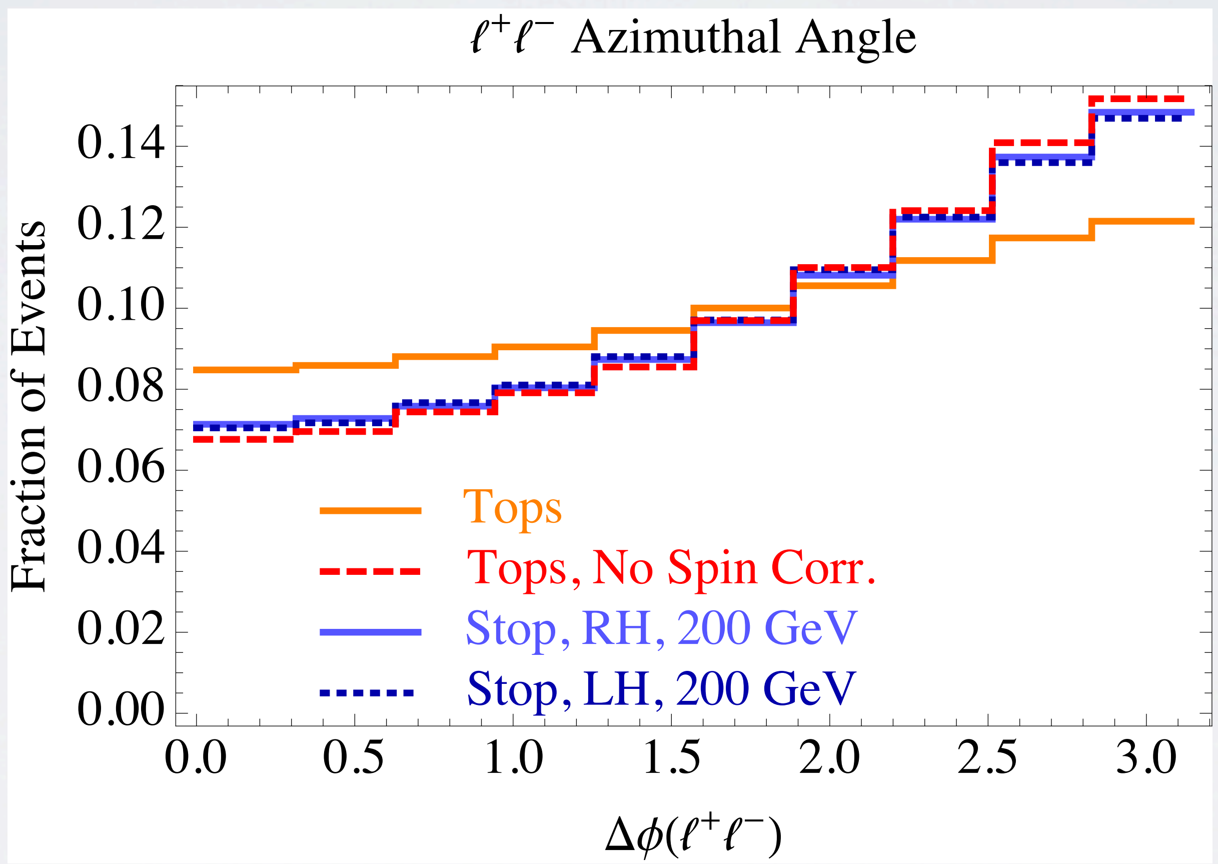
Stop/top rate is small, so it's a small change in shape.



To some extent, mimicked by a larger RG scale choice in the NLO calculation. **Need better Standard Model theory! Understanding tops is key.**

SPIN CORRELATIONS

Stops have no spin correlation; sensitive observables, like azimuthal angle between leptons, look similar for stealthy stops and tops with spin correlations "turned off":



Adapt work of Melnikov & Schulze on top spin correlations (1103.2122) to this context.

LIKELIHOOD

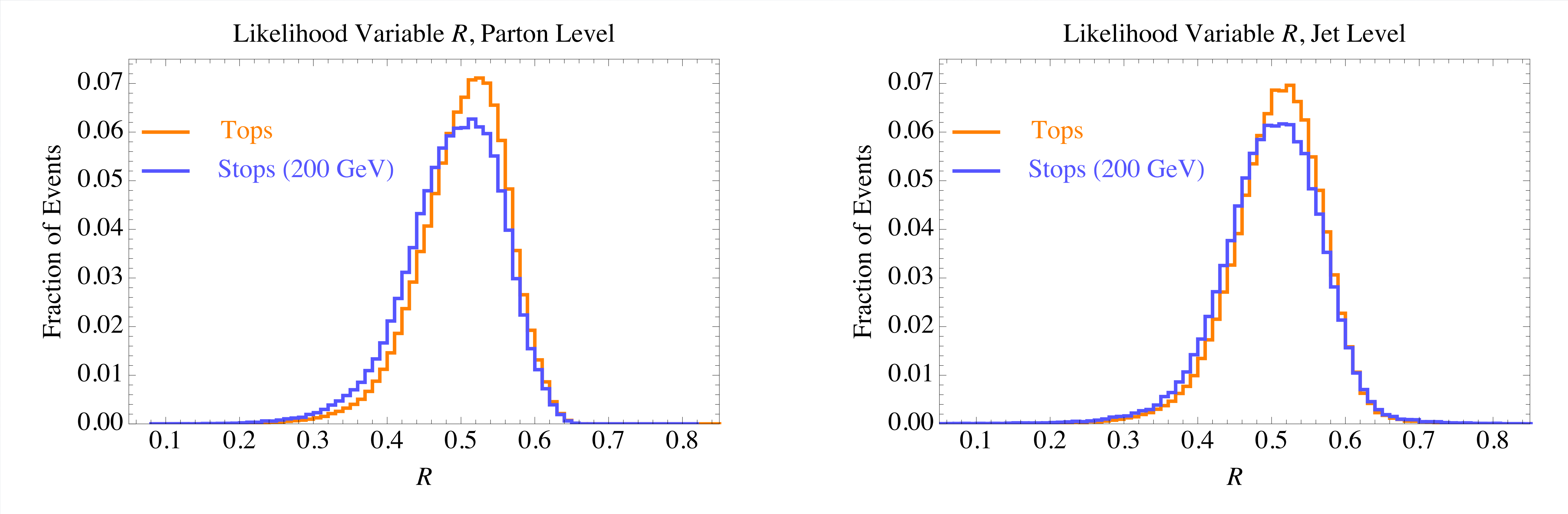
Matrix-element based probability for the two hypotheses, $H = \{corr, uncorr\}$

$$P_H = \mathcal{N}_H^{-1} \sum_{ij} \sum_a J_a f_i^{(a)} f_j^{(a)} \left| \mathcal{M}_H^{ij} \left(p_{\rm obs}, p_\nu^{(a)}, p_{\bar{\nu}}^{(a)} \right) \right|^2$$

Likelihood ratio for an event to be a correlated top pair:

$$\mathcal{R} = \frac{P_{\rm corr}}{P_{\rm corr} + P_{\rm uncorr}}.$$

LIKELIHOOD

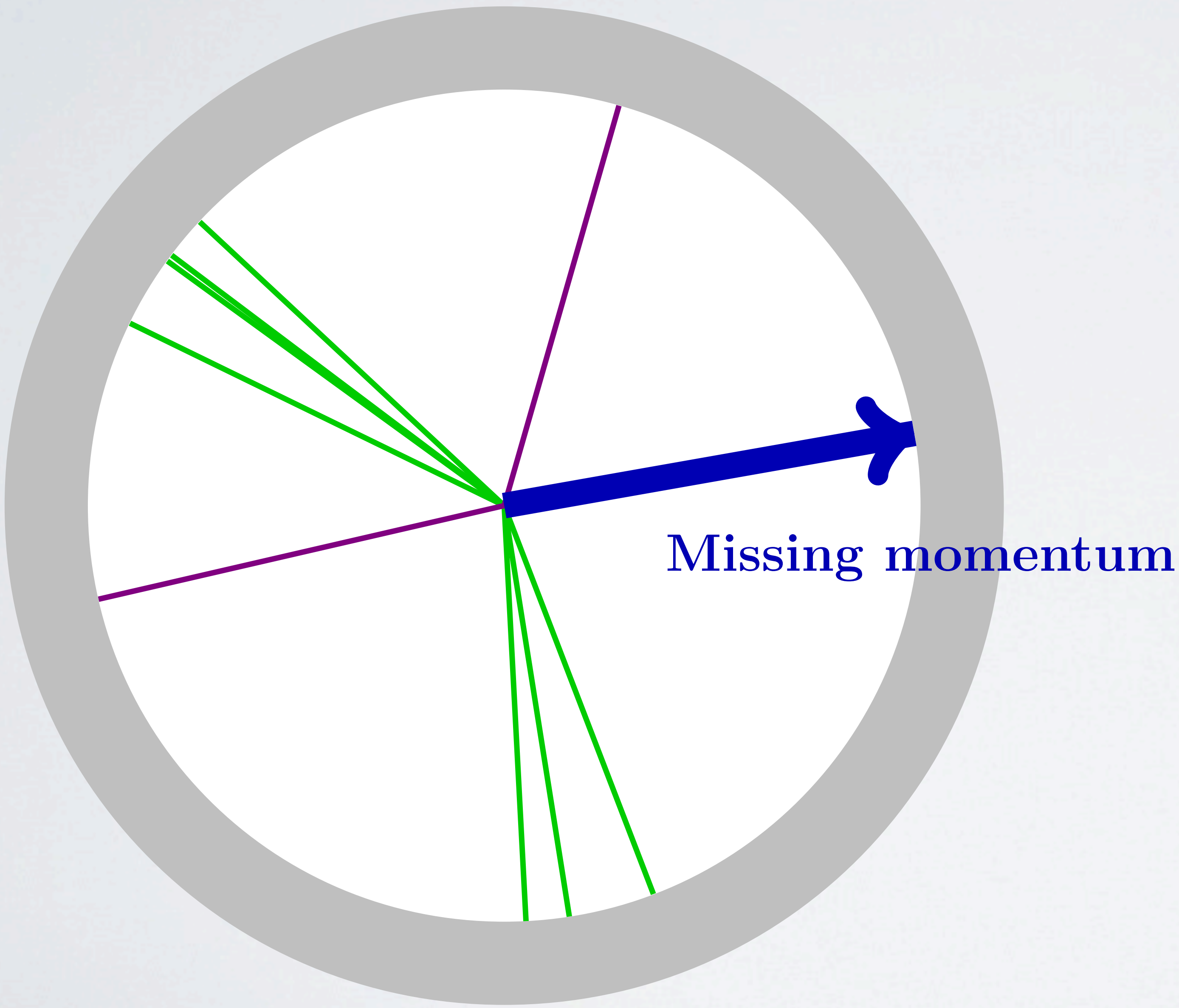


This has some discriminating power. Monte Carlo pseudo-experiments: exclude 200 GeV stop at 95% CL with 20/fb data.

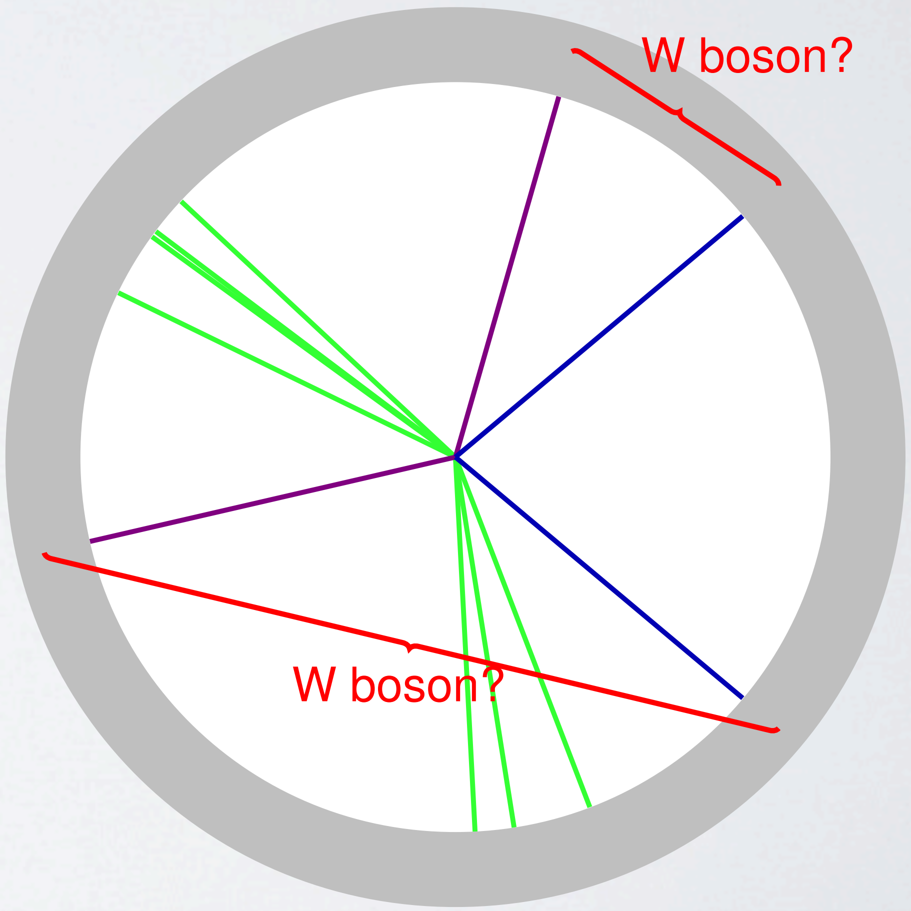
Seems more robust to NLO scale variation.

LIGHT STOPS

One idea: leptonic M_{T2}.



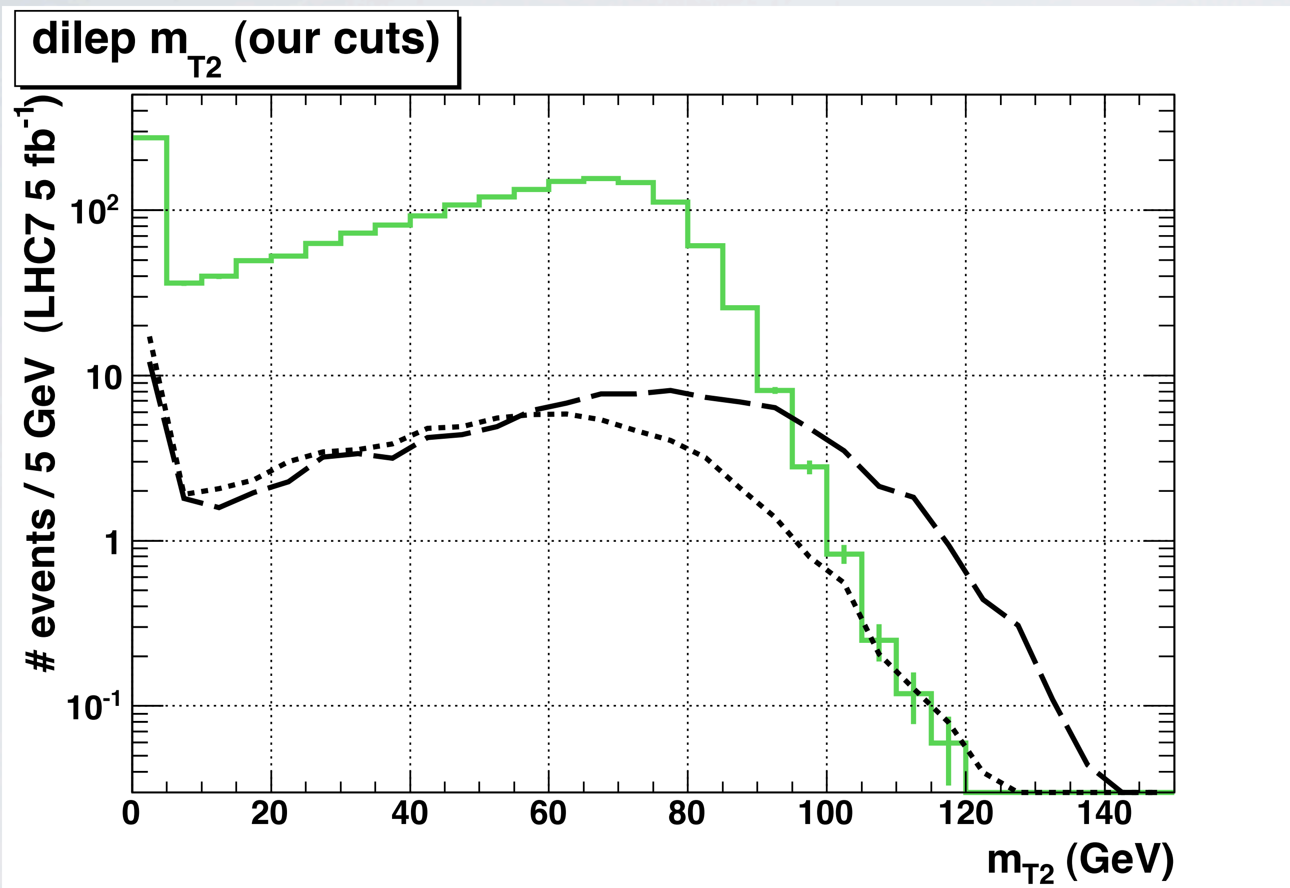
M_{T2} or "stransverse mass" variable from Lester, Summers hep-ph/9906349

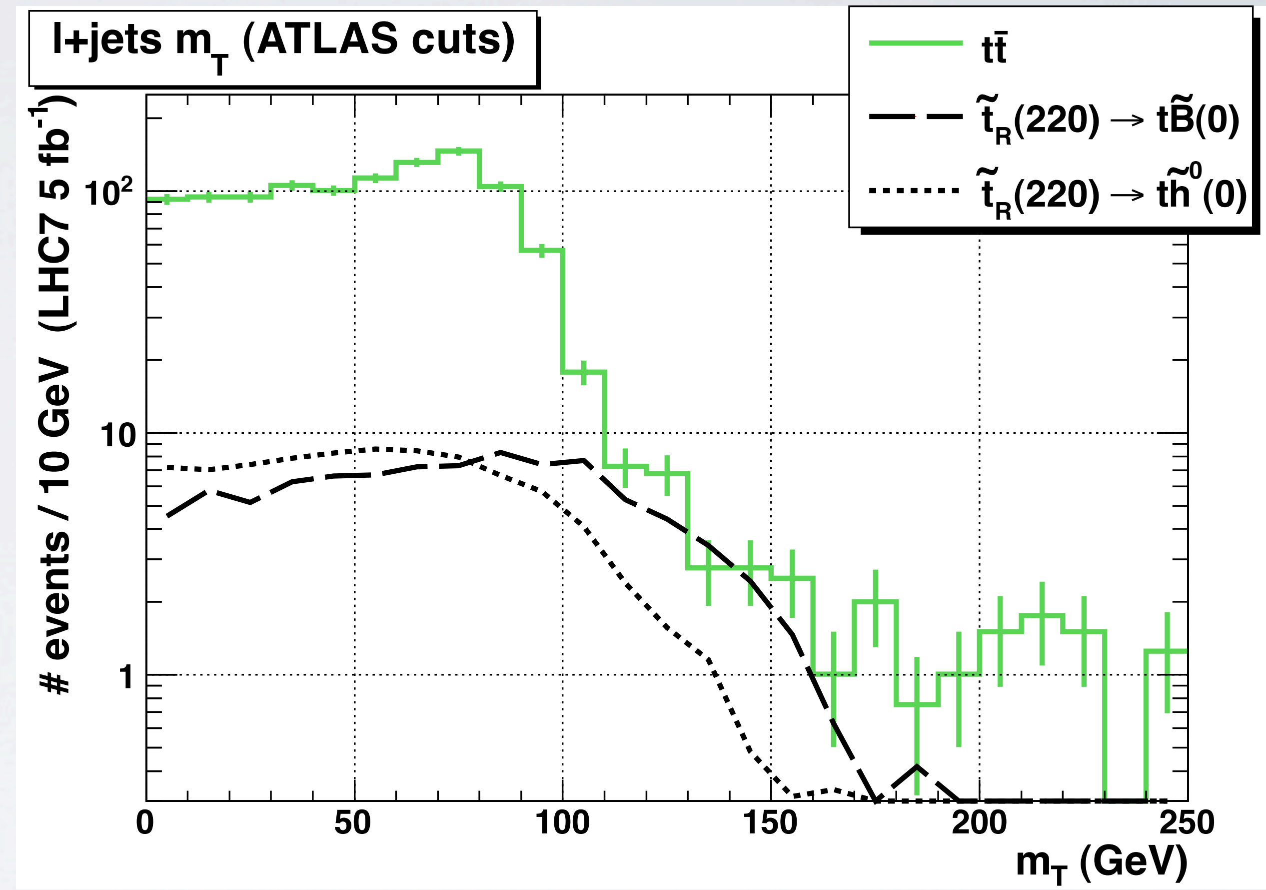


Edge at the W mass (see: Cohen, Kuflik, Zurek 1003.2204)

DILEPTONIC MT2

Kilic, Tweedie 1211.6106

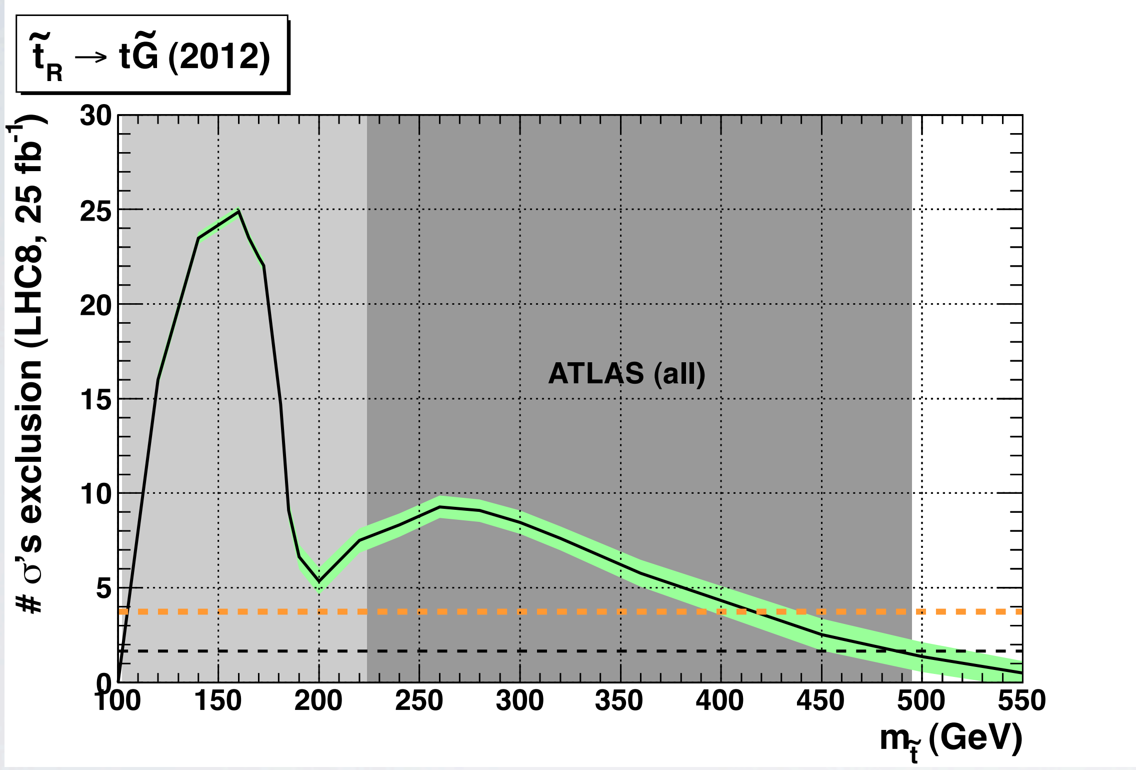


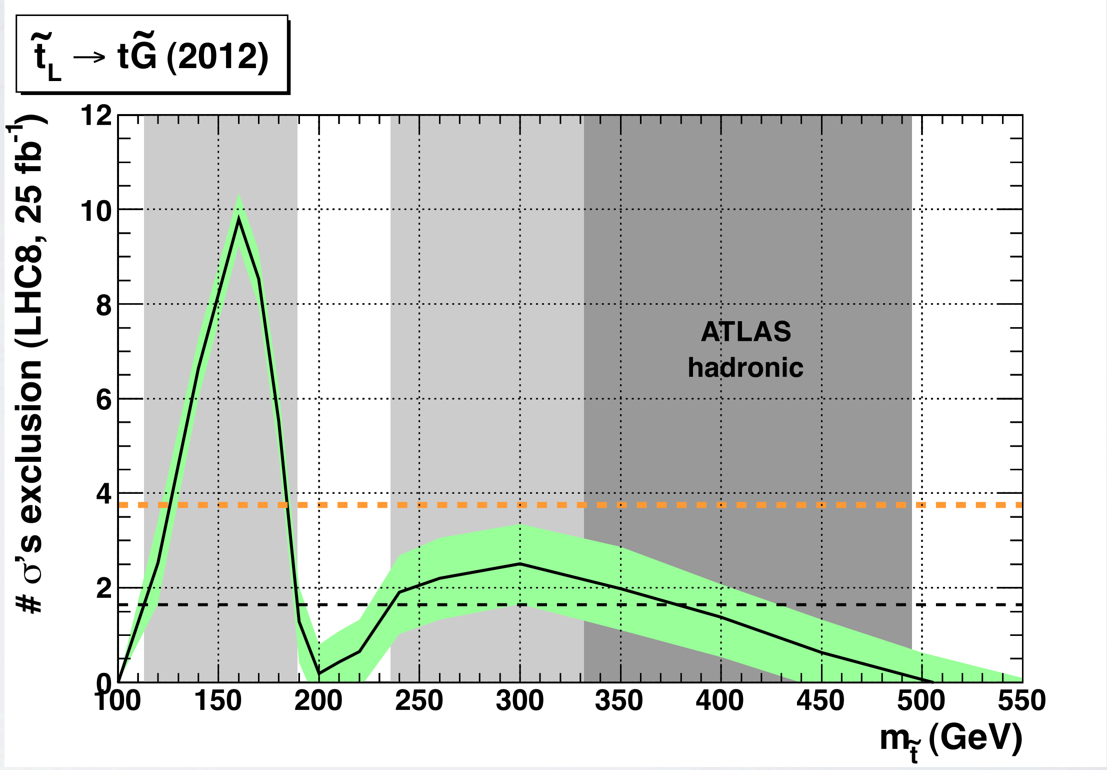


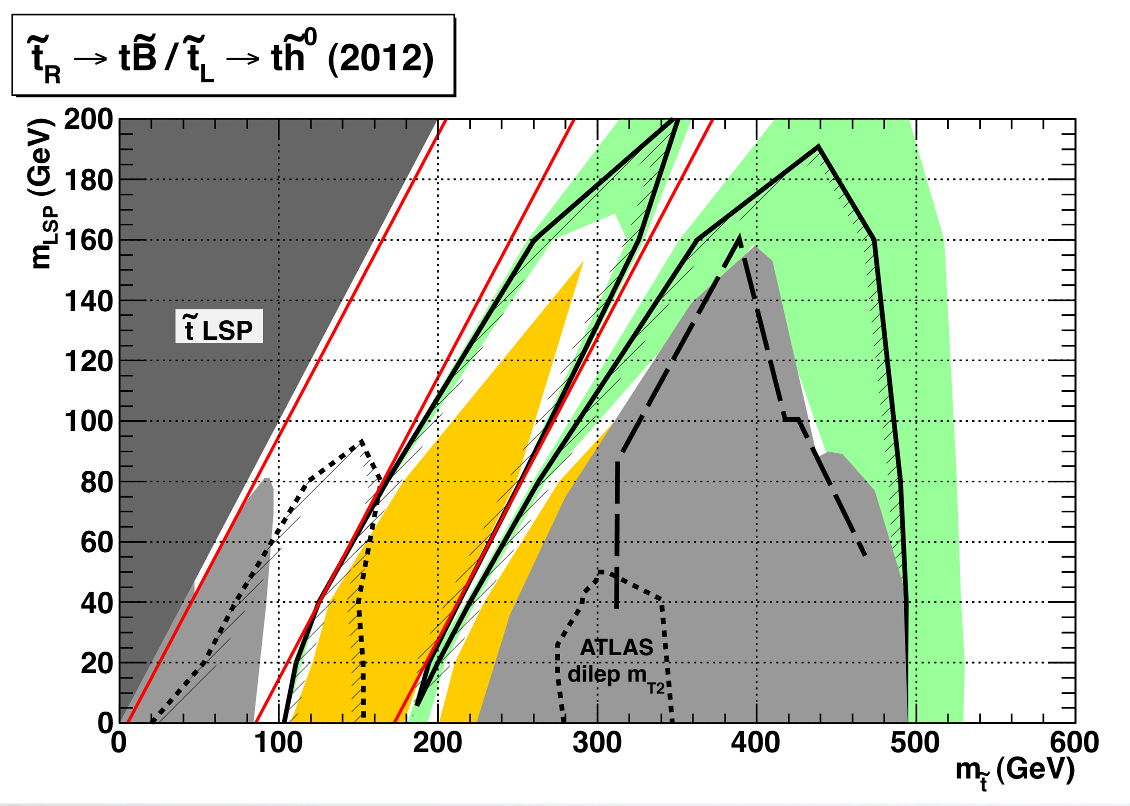
Good discriminator, seems robust to systematics. Note interesting distinction between bino/higgsino LSP: chirality determines neutrino aligned or anti-aligned with neutralino.

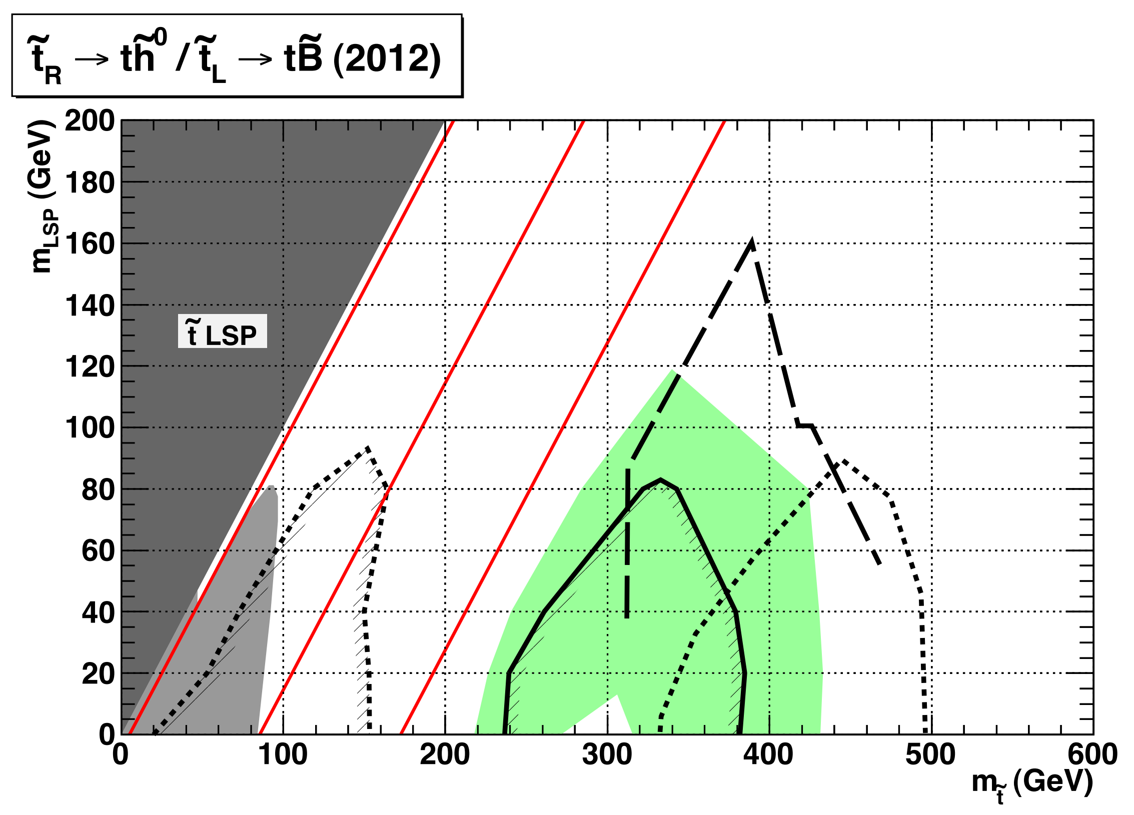
ESTIMATED EXCLUSIONS

Kilic, Tweedie









FUTURE WORK?

On the experimental end, it's clear what we need: **try to exclude this region** with spin correlations, dileptonic M_{T2}, anything else that seems promising.

But keep in mind **large theory systematics**: if stops look a lot like tops at only 10% of the rate, **we'd better understand tops well!**

More studies of effects of **uncertainties** at NLO, maybe incorporating new progress at NNLO, but also e.g. parton distribution uncertainties (which we didn't examine)...