New Physics in Top Couplings

SUSY, June ‘06
Puneet Batra & Tim Tait (hep-ph/0606068)

Intro

- The top mass is large

EWSB is communicated strongly to the top; models that modify the symmetry breaking sector can uniquely alter the top's couplings to the W & Z.

Strongly-coupled models, Little Higgs models, and yes, even SUSY models can shift the top quark couplings.

- Direct production of the new physics may be kinematically inaccessible. Maybe 1/100 is natural!

- Model independent, direct measurements, of the top quark couplings are crucial (for verification, discovery, and exclusion).

Shifts in top couplings

4th generation mixing: GIM mechanism, only the W-t-b coupling is affected

Little Higgs theories (Topcolor, too)

- Mixing with a electroweak singlet

$$\lambda_{t'_A} HQt^c + \lambda_{t'_B} HQT^c + m_{T'_A} Tt^c + \lambda_{T'_B} TT^c$$

$$(EWSB) \to m_t tt^c + m_T TT^c$$

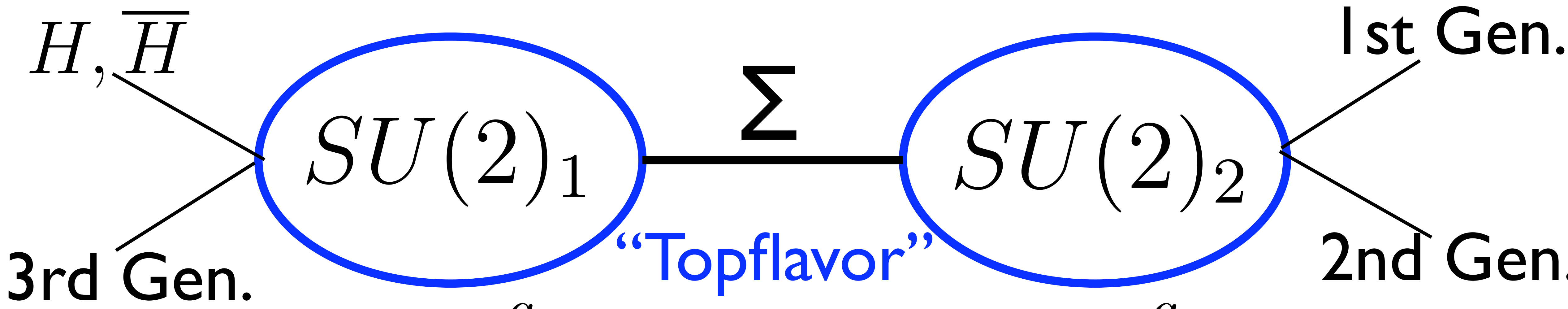
- Littlest Higgs, Simplest Higgs, Minimal Moose, ... T-Parity.
  Could be combined with gauge boson mixing or not.

- T-Parity: No mixing with heavy gauge bosons, but mixing with a singlet Top. Corrections depend on

$$\lambda_T h^0 T t^c \qquad\qquad m_T$$

and are of order $\mathcal{O}\left(\frac{\lambda_T^2 v^2 g}{m_T^2}\right)$

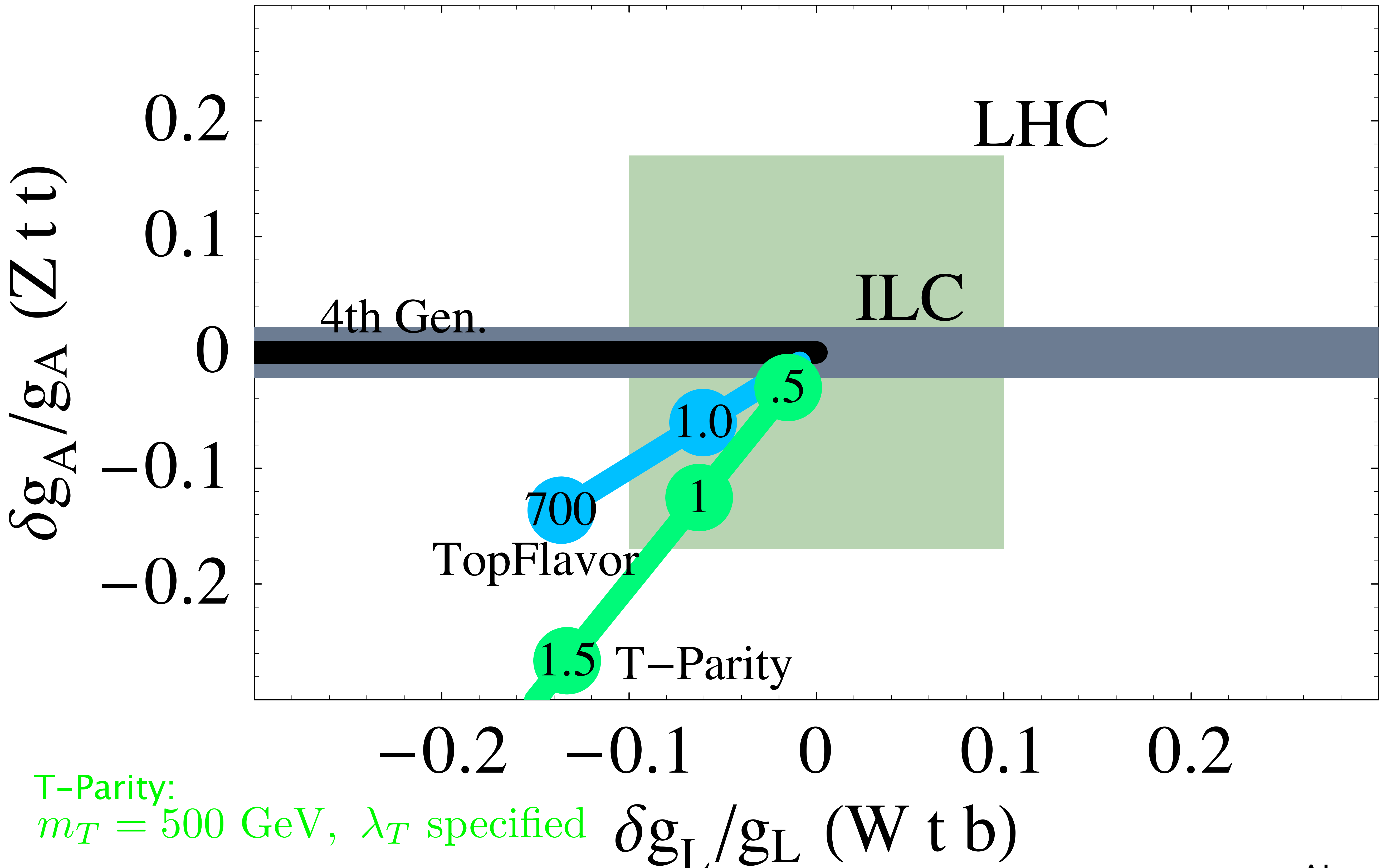
Shifts in top couplings



$$g_1 = \frac{g}{\cos\phi} \qquad g_2 = \frac{g}{\sin\phi}$$

- A possibility for flavor: explains why the third generation is 'off' (mass, mixing)
- Useful for addressing the SUSY little hierarchy problem.
- The observed W, Z are linear combinations of SU(2)_1 and SU(2)_2 gauge bosons--ρ corrections only at order $\left(\frac{v^2}{f^2}\right)^2$.
- For small cos(φ), significantly modified couplings for the third generation *only*. Shifts in couplings are from light-heavy mixing due to the Higgs vev: $\mathcal{O}\left((\sin\phi)^4 \frac{v^2}{f^2}\right)$

Expected Limits on SM-like top couplings

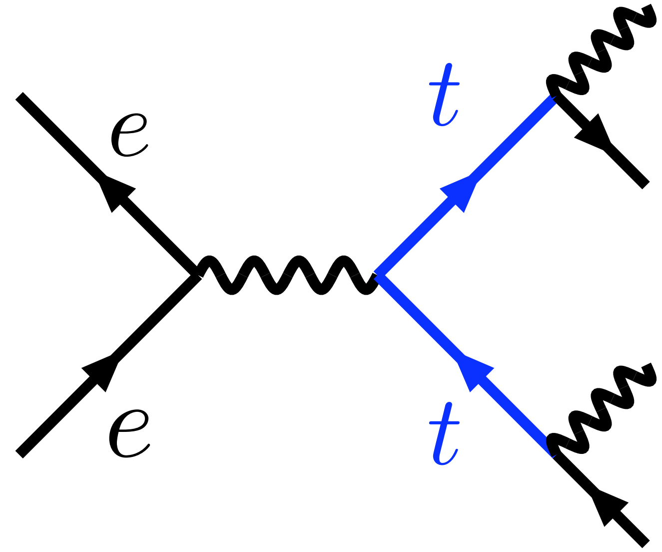


T−Parity:
$m_T = 500$ GeV, λ_T specified

TopFlavor:
$\sin\phi = .9$, $m_{Z'}$ indicated

Abe et al.
Baur, Juste, Orr, Rainwater
Beneke et al.

Single-top is hard at the ILC!



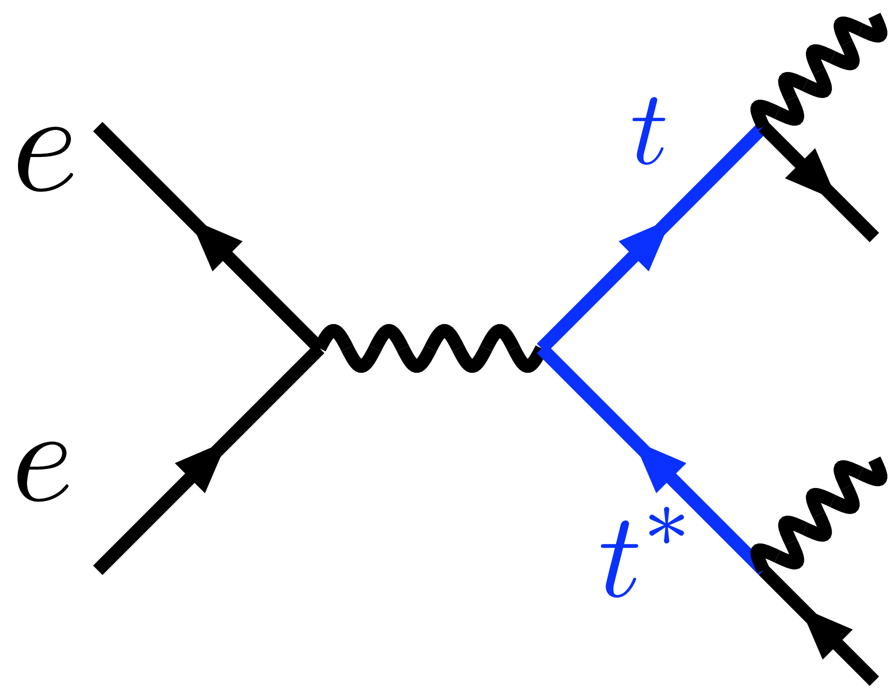
$t\bar{t}$ production dominates (~50 x greater) above threshold and is insensitive to the W-t-b coupling.

The 3 dominant single-top diagrams always have an additional real W and b!

Production x Decay : $\sigma \propto g^2_{Vt\bar{t}} \times \left\{ \frac{g^2_{Wtb}}{m_t^2 g^2_{Wtb}} \right\}^2$

Difficult to use single-top to measure $g\ \bar{t}_L \not{W} b_L$ without getting killed by the $t\bar{t}$ background.

Below Threshold Sensitivity



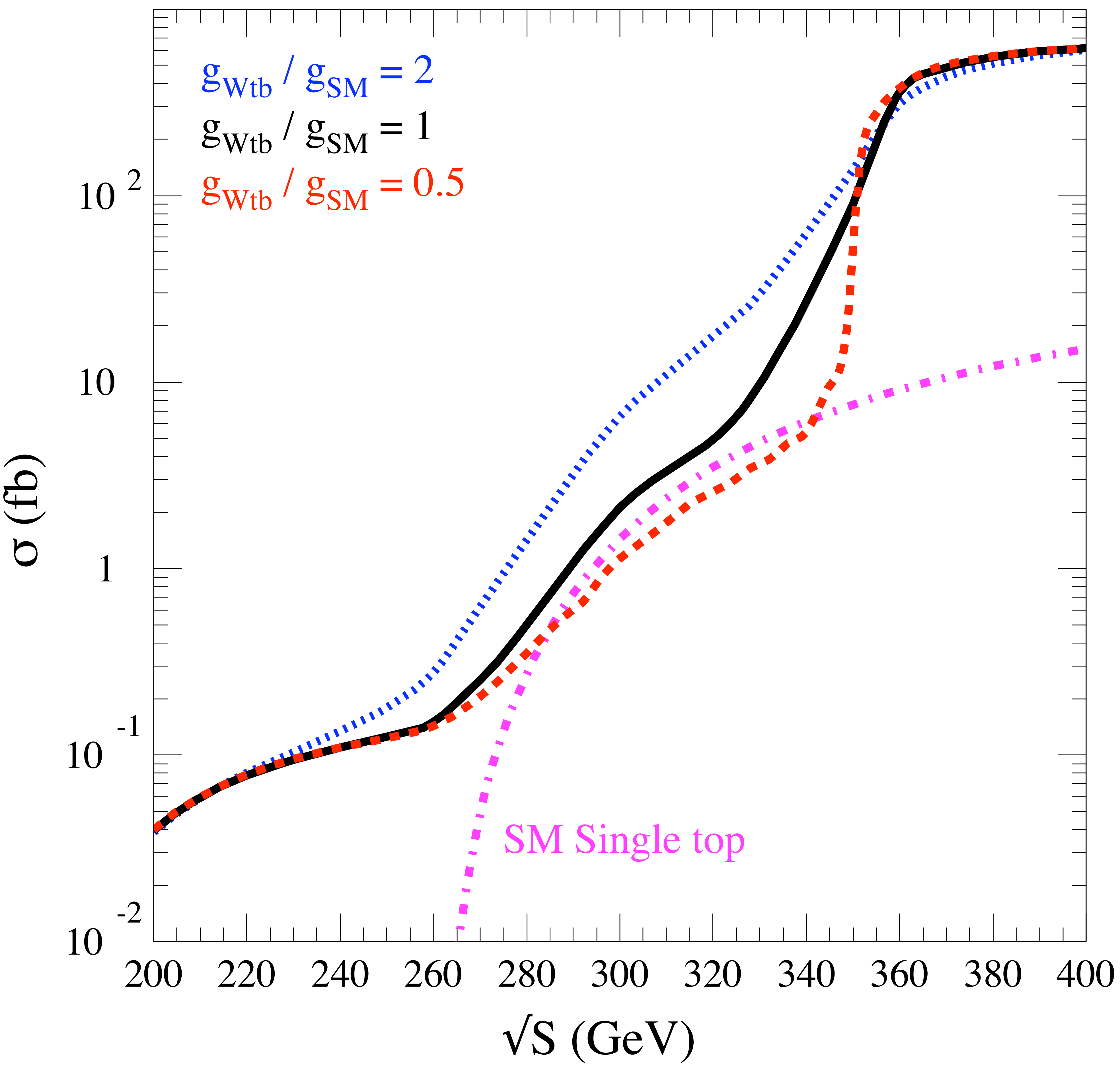
Simple observation: Below the $t\bar{t}$ threshold, sensitivity is regained:

$$\sigma \;\propto\; \frac{g_{Wtb}^2}{\left(q_{t^\star}^2 - m_t^2\right)^2 + m_t^2\Gamma_t^2}$$

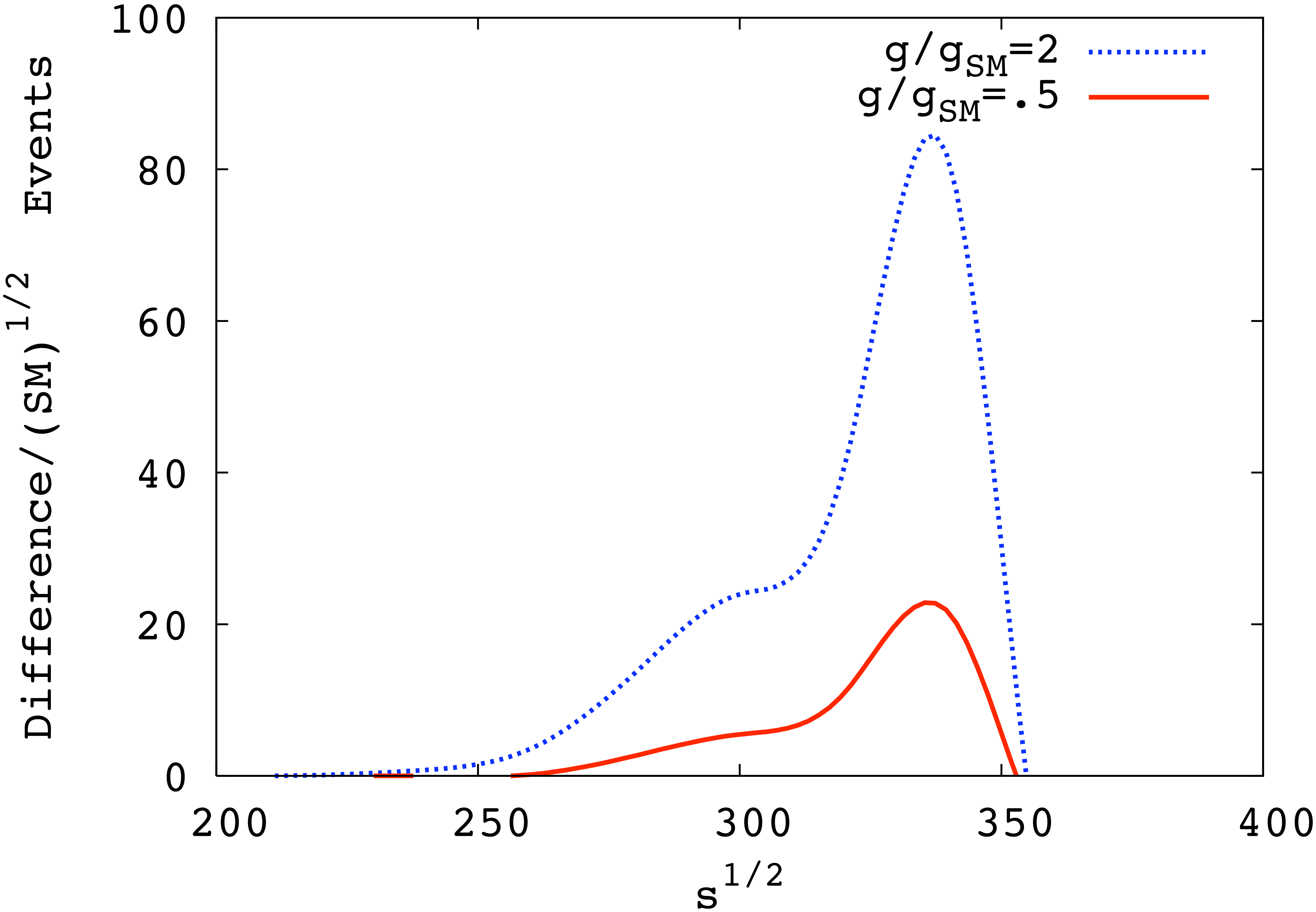
the virtual t* produces a dependence on the W-t-b coupling.

How much does this add to the single-top rate when trying to determine the left-handed W-t-b coupling?

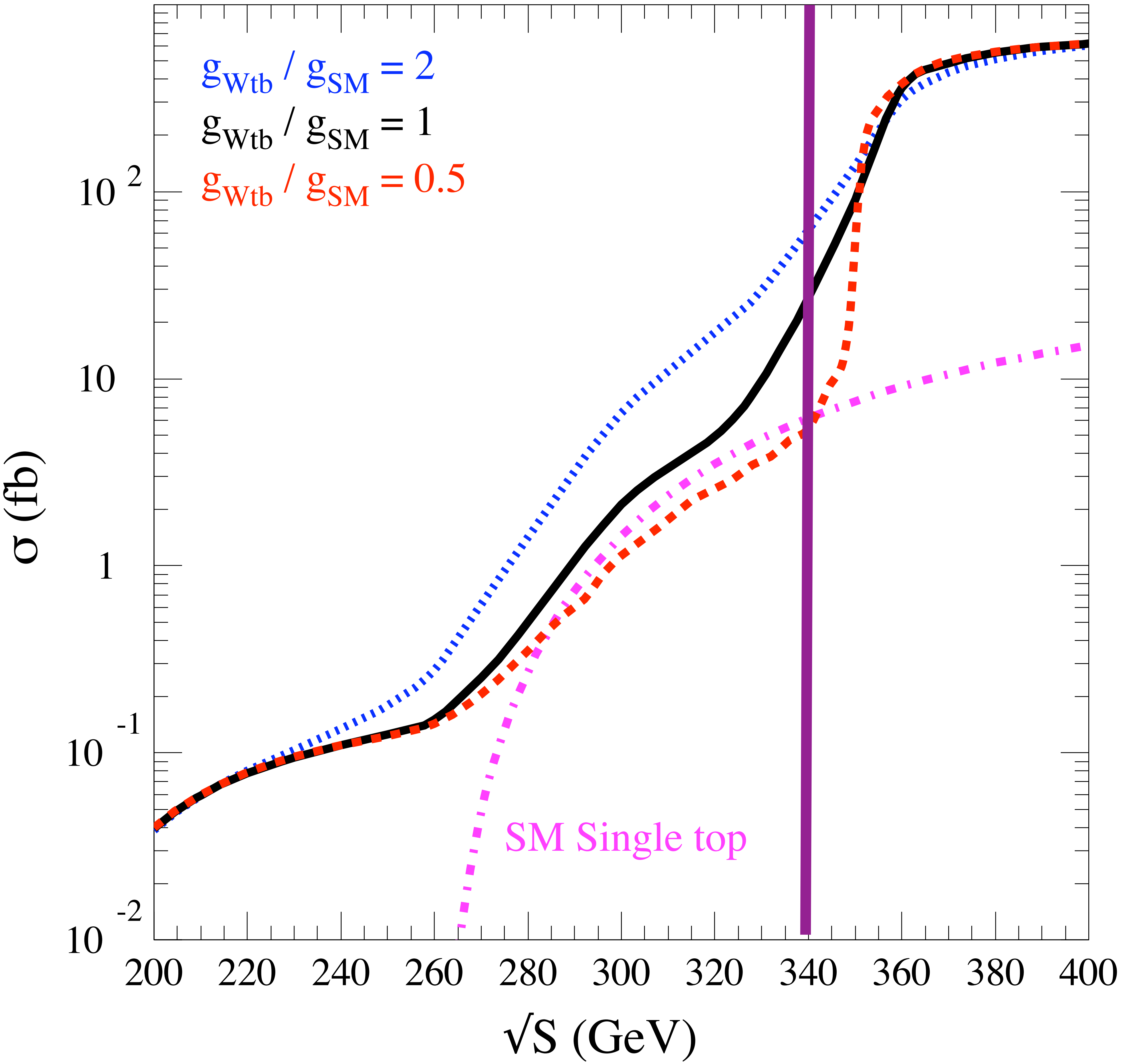
Sensitivity vs Energy



Sensitivity vs Energy



Sensitivity vs Energy



Signal estimation

• "Golden Channel" Semileptonic final state, triggering on the lepton and missing E_T

• Assume 100 fb^{-1}. For some scale, the standard top threshold scan is 30 fb^{-1} across 10 pts (one "well" below threshold). Could spread the needed luminosity across a few below-threshold points.

• Require 2 b-tags (each ~ 70 %)

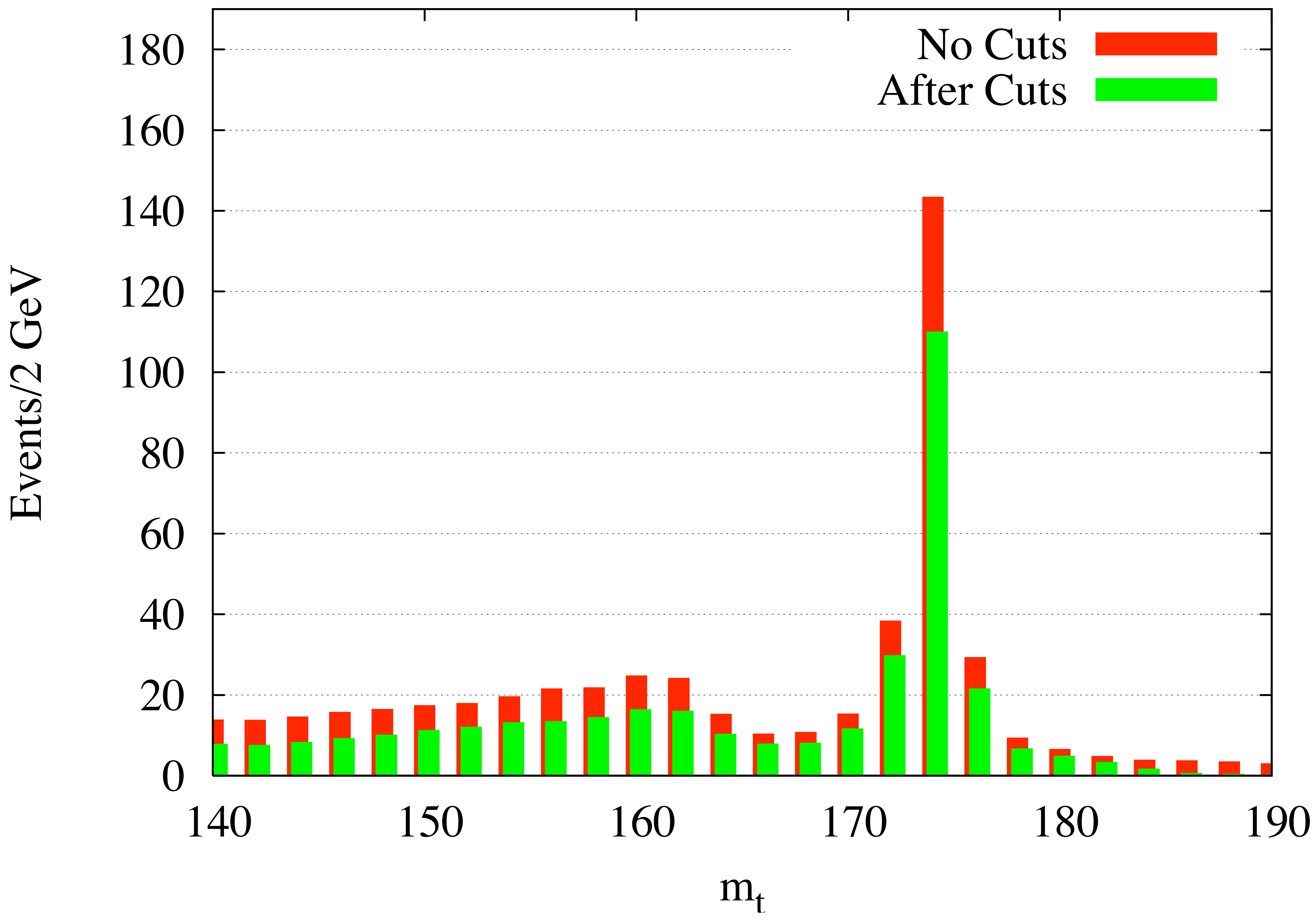
• Require a top mass and W mass reconstruction (without assuming b-charge) from both the leptonic and hadronic decay.

• LO, fully interfering, estimates (MadEvent), statistical errors

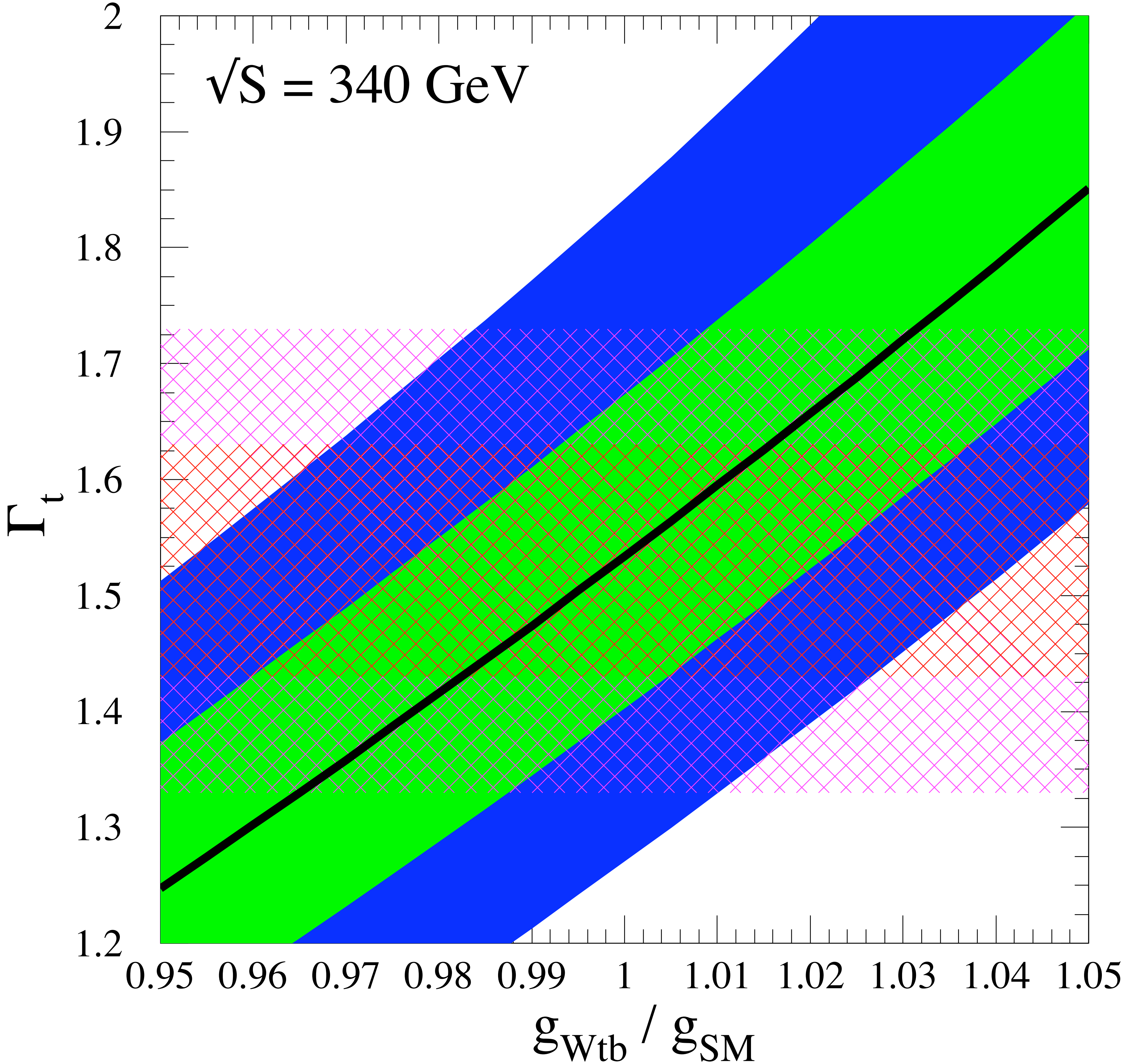
• mistag background small; the dominant background is from real WbWb production through intermediate Higgs and/or Z. Could beat down further with invariant mass rejections. Purity of final sample is very high.

• We estimate the event rate by multiplying each WbWb(g, Γ) with the monte-carloed SM efficiency that pass our cuts (~15%). (branching fractions + kinematic cuts)

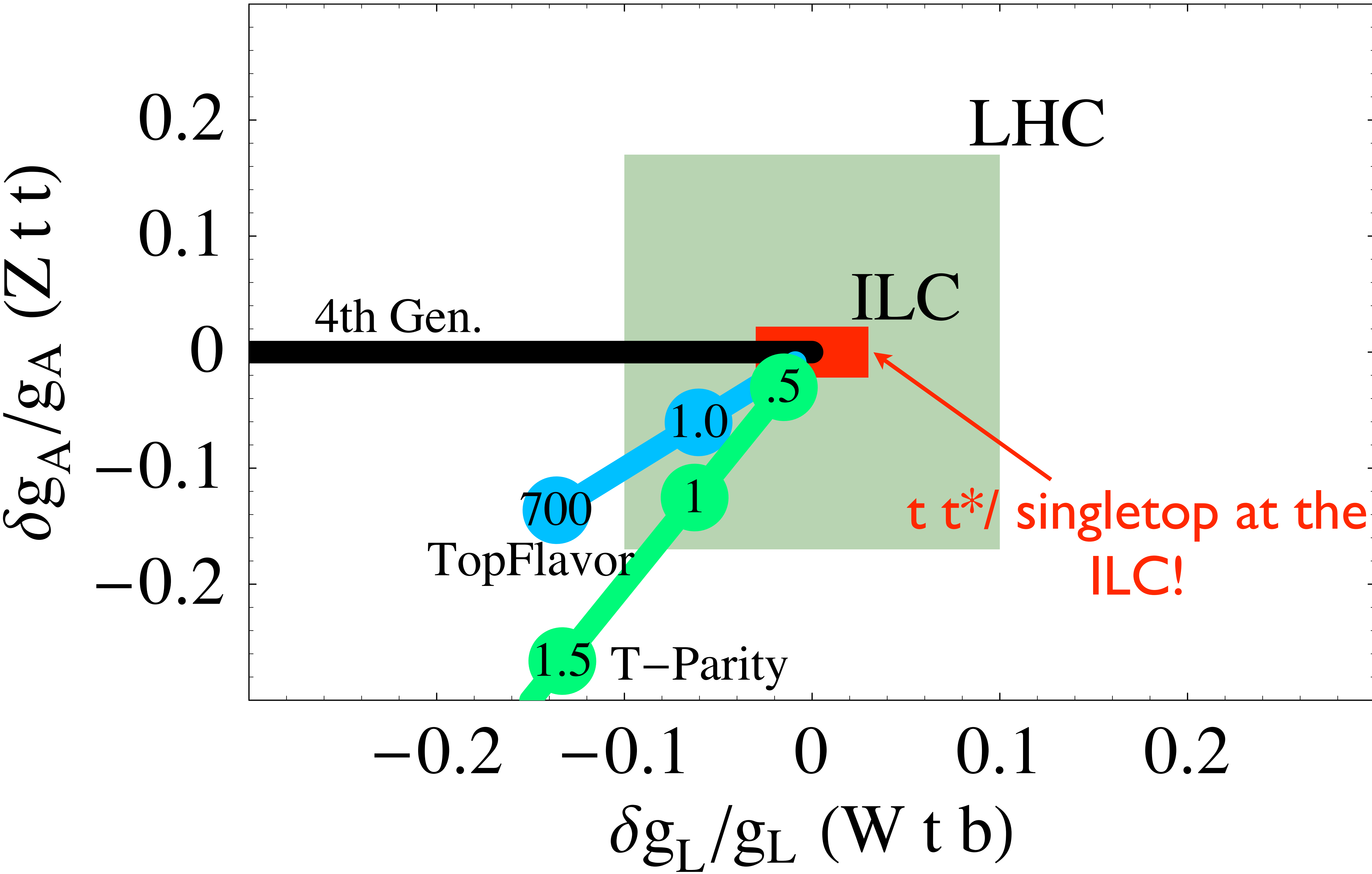
@ 340 GeV (Semileptonic final state)



Expected bounds



Conclusions



Conclusions

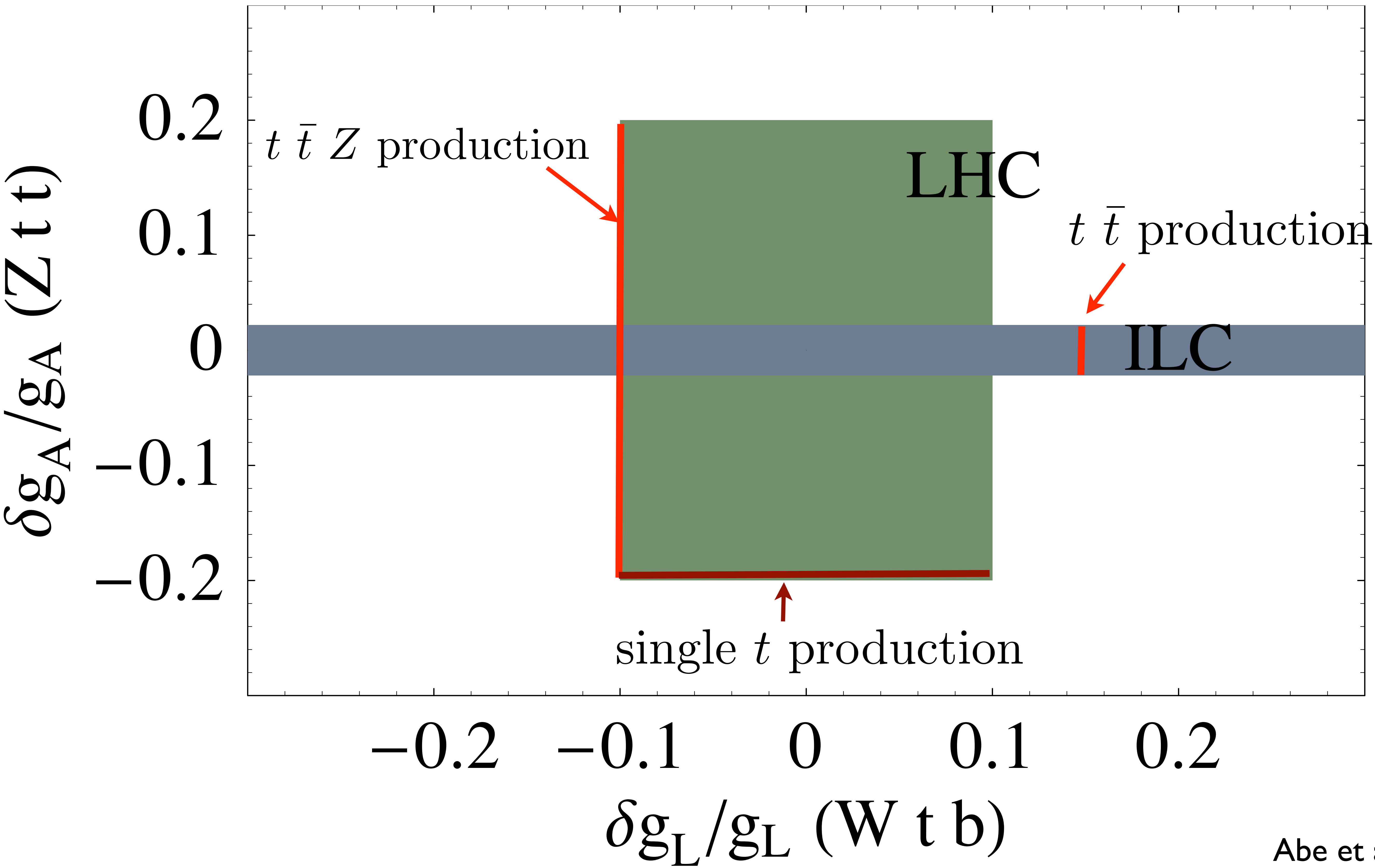
• Physics models that address the hierarchy problem often predict shifts in the gauge-boson-top couplings. Model-independent, direct measurements of these couplings are needed.

• Precise measurements of $g\ \bar{t}_L \not{W} b_L$ at an e+ e- collider are challenging at the ILC due to low statistics and a large $t\bar{t}$ background.

• t t* contributions do depend (unlike t t) on $g\ \bar{t}_L \not{W} b_L$ and enhance the 'single-top' like signal.

• a 3% measurement is possible in the semi-leptonic channel, can help rule out many models of BSM physics!

Expected Limits on SM-like top couplings



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