VANILLA STOP SEARCHES

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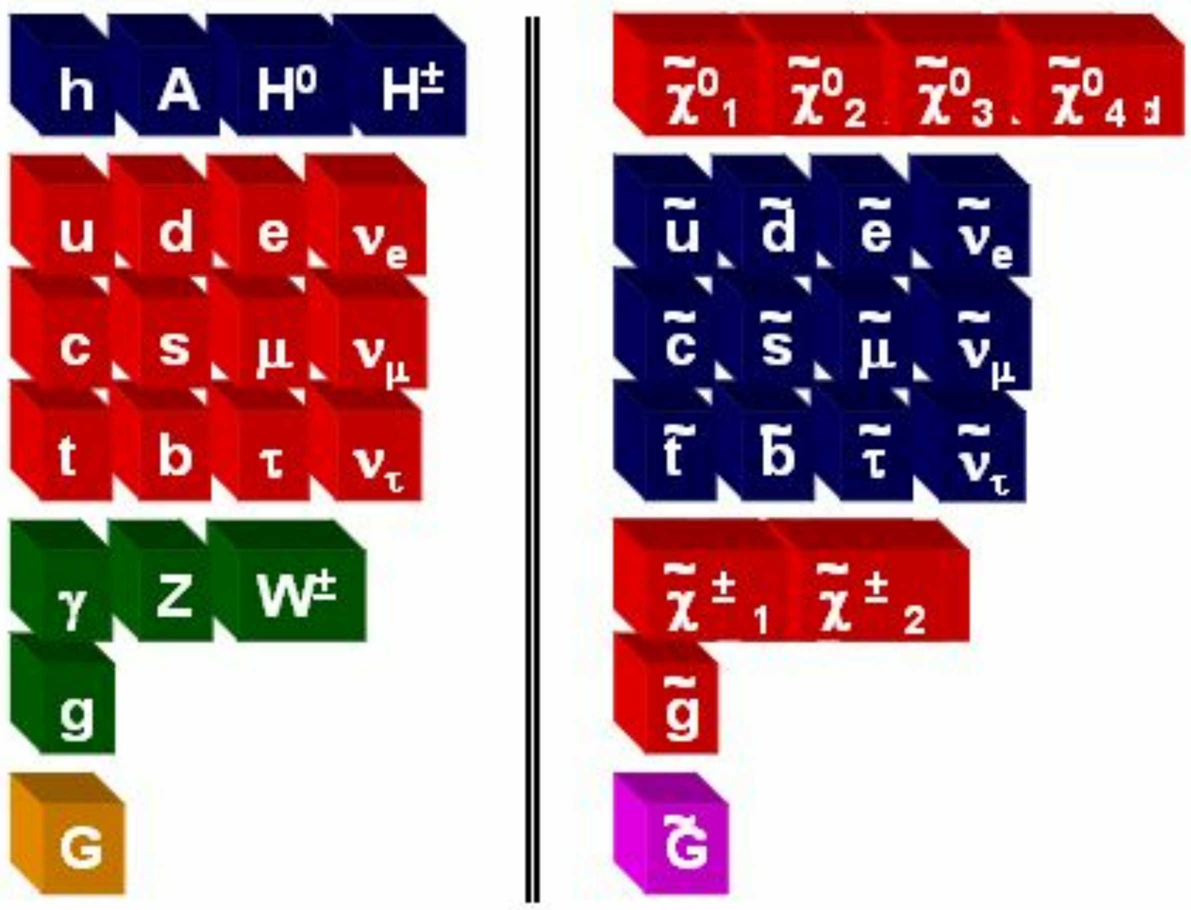
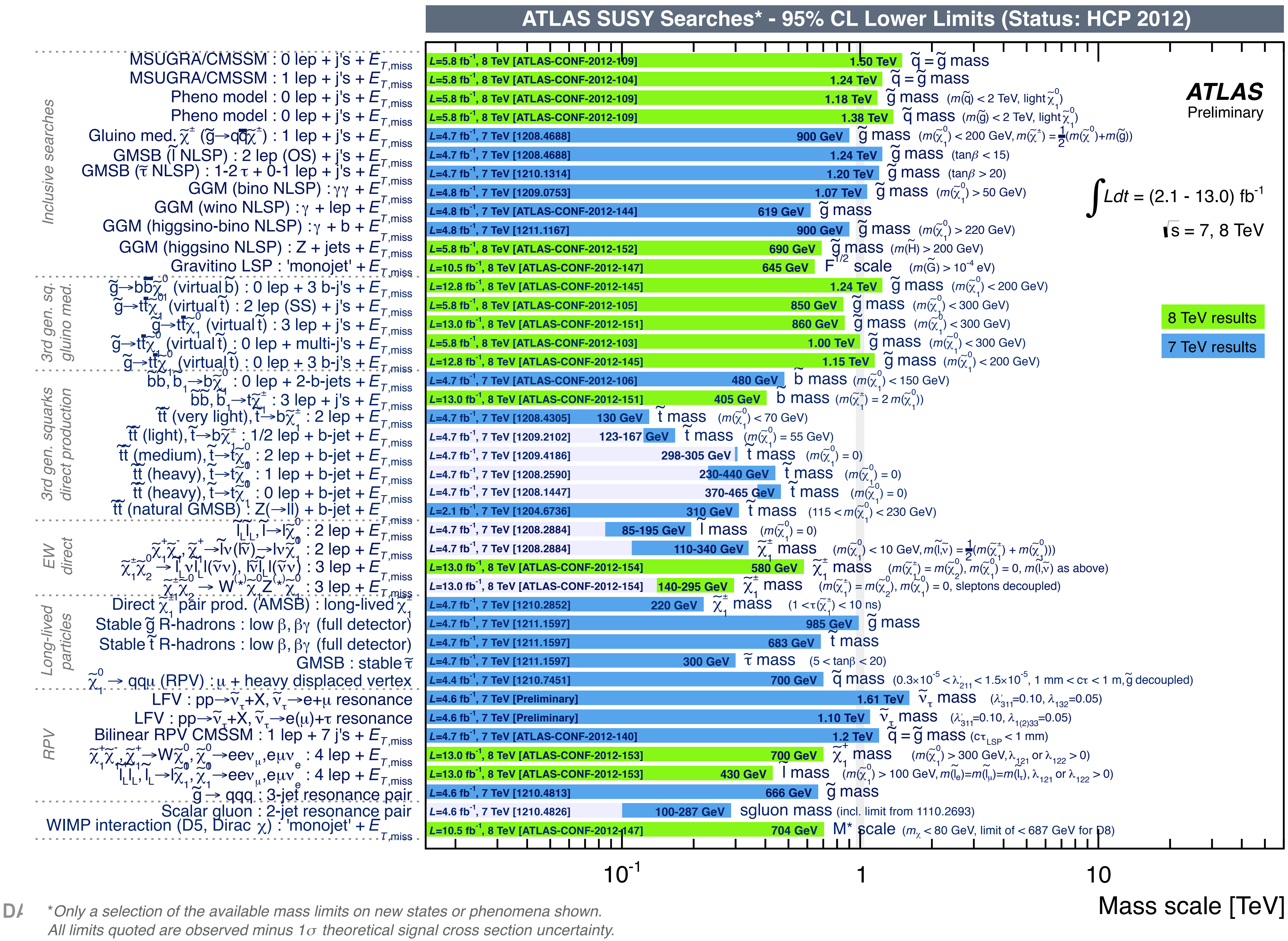
A SNOWMASS MINI-REPORT WITH YANG BAI AND TOBIAS GOLLING

SUPERSYMMETRY IS GREAT!

- Elegant extension of spacetime symmetries
- Grand unification works better than SM
- Well motivated *R*-parity automatically gives dark matter candidate
- Solves hierarchy problem?



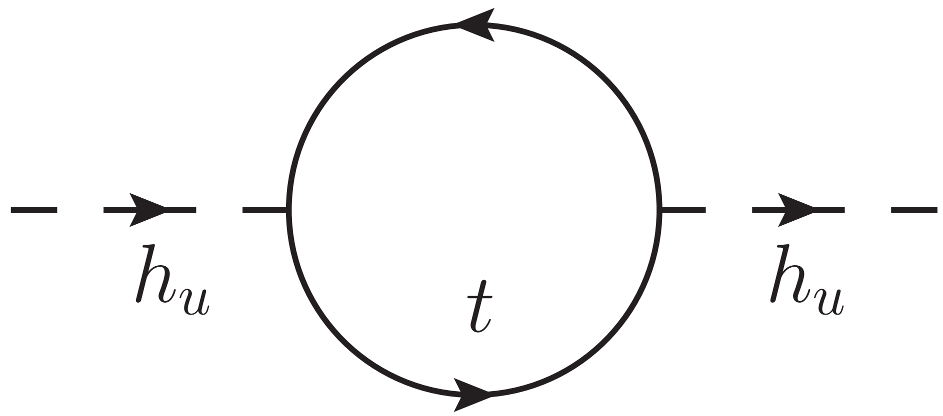
LHC ASSAULT



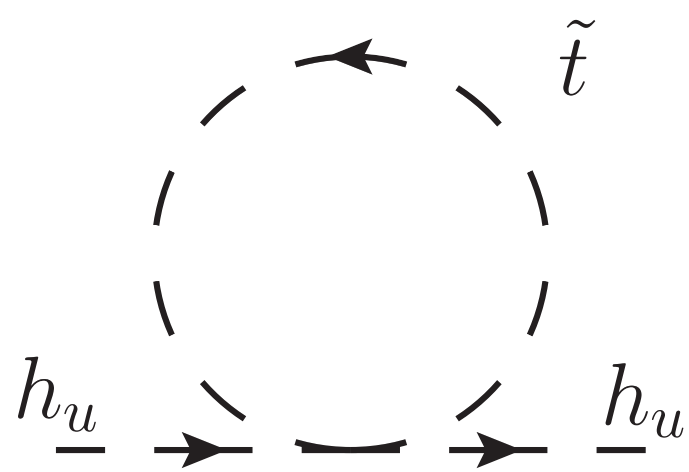
ATLAS SUSY Searches* - 95% CL Lower Limits (Status: HCP 2012)
Inclusive searches
MSUGRA/CMSSM : 0 lep + j's + $E_{T,miss}$ — L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-109] — 1.50 TeV $\tilde{q} = \tilde{g}$ mass
MSUGRA/CMSSM : 1 lep + j's + $E_{T,miss}$ — L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-104] — 1.24 TeV $\tilde{q} = \tilde{g}$ mass
Pheno model : 0 lep + j's + $E_{T,miss}$ — L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-109] — 1.18 TeV $\tilde{g}$ mass ($m(\tilde{q}) < 2$ TeV, light $\tilde{\chi}^0_1$)
Pheno model : 0 lep + j's + $E_{T,miss}$ — L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-109] — 1.38 TeV $\tilde{q}$ mass ($m(\tilde{g}) < 2$ TeV, light $\tilde{\chi}^0_1$)
Gluino med. $\tilde{\chi}^\pm$ ($\tilde{g} \to q\bar{q}\tilde{\chi}^\pm$) : 1 lep + j's + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1208.4688] — 900 GeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) < 200$ GeV, $m(\tilde{\chi}^\pm) = \frac{1}{2}(m(\tilde{\chi}^0)+m(\tilde{g}))$)
GMSB ($\tilde{l}$ NLSP) : 2 lep (OS) + j's + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1208.4688] — 1.24 TeV $\tilde{g}$ mass ($\tan\beta < 15$)
GMSB ($\tilde{\tau}$ NLSP) : 1-2 τ + 0-1 lep + j's + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1210.1314] — 1.20 TeV $\tilde{g}$ mass ($\tan\beta > 20$)
GGM (bino NLSP) : $\gamma\gamma + E_{T,miss}$ — L=4.8 fb^{-1}, 7 TeV [1209.0753] — 1.07 TeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) > 50$ GeV)
GGM (wino NLSP) : γ + lep + $E_{T,miss}$ — L=4.8 fb^{-1}, 7 TeV [ATLAS-CONF-2012-144] — 619 GeV $\tilde{g}$ mass
GGM (higgsino-bino NLSP) : γ + b + $E_{T,miss}$ — L=4.8 fb^{-1}, 7 TeV [1211.1167] — 900 GeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) > 220$ GeV)
GGM (higgsino NLSP) : Z + jets + $E_{T,miss}$ — L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-152] — 690 GeV $\tilde{g}$ mass ($m(\tilde{H}) > 200$ GeV)
Gravitino LSP : 'monojet' + $E_{T,miss}$ — L=10.5 fb^{-1}, 8 TeV [ATLAS-CONF-2012-147] — 645 GeV $F^{1/2}$ scale ($m(\tilde{G}) > 10^{-4}$ eV)
3rd gen. sq. gluino med.
$\tilde{g} \to b\bar{b}\tilde{\chi}^0_1$ (virtual $\tilde{b}$) : 0 lep + 3 b-j's + $E_{T,miss}$ — L=12.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-145] — 1.24 TeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) < 200$ GeV)
$\tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ (virtual $\tilde{t}$) : 2 lep (SS) + j's + $E_{T,miss}$ — L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-105] — 850 GeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) < 300$ GeV)
$\tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ (virtual $\tilde{t}$) : 3 lep + j's + $E_{T,miss}$ — L=13.0 fb^{-1}, 8 TeV [ATLAS-CONF-2012-151] — 860 GeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) < 300$ GeV)
$\tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ (virtual $\tilde{t}$) : 0 lep + multi-j's + $E_{T,miss}$ — L=5.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-103] — 1.00 TeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) < 300$ GeV)
$\tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ (virtual $\tilde{t}$) : 0 lep + 3 b-j's + $E_{T,miss}$ — L=12.8 fb^{-1}, 8 TeV [ATLAS-CONF-2012-145] — 1.15 TeV $\tilde{g}$ mass ($m(\tilde{\chi}^0_1) < 200$ GeV)
3rd gen. squarks direct production
$\tilde{b}\tilde{b}$, $\tilde{b}_1 \to b\tilde{\chi}^0_1$: 0 lep + 2-b-jets + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [ATLAS-CONF-2012-106] — 480 GeV $\tilde{b}$ mass ($m(\tilde{\chi}^0_1) < 150$ GeV)
$\tilde{b}\tilde{b}$, $\tilde{b}_1 \to t\tilde{\chi}^\pm_1$: 3 lep + j's + $E_{T,miss}$ — L=13.0 fb^{-1}, 8 TeV [ATLAS-CONF-2012-151] — 405 GeV $\tilde{b}$ mass ($m(\tilde{\chi}^\pm_1) = 2\,m(\tilde{\chi}^0_1)$)
$\tilde{t}\tilde{t}$ (very light), $\tilde{t} \to b\tilde{\chi}^\pm_1$: 2 lep + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1208.4305] — 130 GeV $\tilde{t}$ mass ($m(\tilde{\chi}^0_1) < 70$ GeV)
$\tilde{t}\tilde{t}$ (light), $\tilde{t} \to b\tilde{\chi}^\pm_1$: 1/2 lep + b-jet + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1209.2102] — 123-167 GeV $\tilde{t}$ mass ($m(\tilde{\chi}^0_1) = 55$ GeV)
$\tilde{t}\tilde{t}$ (medium), $\tilde{t} \to t\tilde{\chi}^0_1$: 2 lep + b-jet + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1209.4186] — 298-305 GeV $\tilde{t}$ mass ($m(\tilde{\chi}^0_1) = 0$)
$\tilde{t}\tilde{t}$ (heavy), $\tilde{t} \to t\tilde{\chi}^0_1$: 1 lep + b-jet + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1208.2590] — 230-440 GeV $\tilde{t}$ mass ($m(\tilde{\chi}^0_1) = 0$)
$\tilde{t}\tilde{t}$ (heavy), $\tilde{t} \to t\tilde{\chi}^0_1$: 0 lep + b-jet + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1208.1447] — 370-465 GeV $\tilde{t}$ mass ($m(\tilde{\chi}^0_1) = 0$)
$\tilde{t}\tilde{t}$ (natural GMSB) : Z($\to ll$) + b-jet + $E_{T,miss}$ — L=2.1 fb^{-1}, 7 TeV [1204.6736] — 310 GeV $\tilde{t}$ mass ($115 < m(\tilde{\chi}^0_1) < 230$ GeV)
EW direct
$\tilde{l}_L\tilde{l}_L$, $\tilde{l} \to l\tilde{\chi}^0_1$: 2 lep + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1208.2884] — 85-195 GeV $\tilde{l}$ mass ($m(\tilde{\chi}^0_1) = 0$)
$\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^+_1 \to \tilde{l}\nu(l\tilde{\nu}) \to l\nu\tilde{\chi}^0_1$: 2 lep + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [1208.2884] — 110-340 GeV $\tilde{\chi}^\pm_1$ mass ($m(\tilde{\chi}^0_1) < 10$ GeV, $m(\tilde{l},\tilde{\nu}) = \frac{1}{2}(m(\tilde{\chi}^\pm_1) + m(\tilde{\chi}^0_1))$)
$\tilde{\chi}^\pm_1\tilde{\chi}^0_2 \to \tilde{l}_L\nu\tilde{l}_L l(\tilde{\nu}\nu)$, $l\tilde{\nu}\tilde{l}_L l(\tilde{\nu}\nu)$: 3 lep + $E_{T,miss}$ — L=13.0 fb^{-1}, 8 TeV [ATLAS-CONF-2012-154] — 580 GeV $\tilde{\chi}^\pm_1$ mass ($m(\tilde{\chi}^\pm_1) = m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1) = 0$, $m(\tilde{l},\tilde{\nu})$ as above)
$\tilde{\chi}^\pm_1\tilde{\chi}^0_2 \to W^{(*)}\tilde{\chi}^0_1 Z^{(*)}\tilde{\chi}^0_1$: 3 lep + $E_{T,miss}$ — L=13.0 fb^{-1}, 8 TeV [ATLAS-CONF-2012-154] — 140-295 GeV $\tilde{\chi}^\pm_1$ mass ($m(\tilde{\chi}^\pm_1) = m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1) = 0$, sleptons decoupled)
Long-lived particles
Direct $\tilde{\chi}^\pm_1$ pair prod. (AMSB) : long-lived $\tilde{\chi}^\pm_1$ — L=4.7 fb^{-1}, 7 TeV [1210.2852] — 220 GeV $\tilde{\chi}^\pm_1$ mass ($1 < \tau(\tilde{\chi}^\pm_1) < 10$ ns)
Stable $\tilde{g}$ R-hadrons : low β, $\beta\gamma$ (full detector) — L=4.7 fb^{-1}, 7 TeV [1211.1597] — 985 GeV $\tilde{g}$ mass
Stable $\tilde{t}$ R-hadrons : low β, $\beta\gamma$ (full detector) — L=4.7 fb^{-1}, 7 TeV [1211.1597] — 683 GeV $\tilde{t}$ mass
GMSB : stable $\tilde{\tau}$ — L=4.7 fb^{-1}, 7 TeV [1211.1597] — 300 GeV $\tilde{\tau}$ mass ($5 < \tan\beta < 20$)
$\tilde{\chi}^0_1 \to qq\mu$ (RPV) : μ + heavy displaced vertex — L=4.4 fb^{-1}, 7 TeV [1210.7451] — 700 GeV $\tilde{q}$ mass ($0.3\times10^{-5} < \lambda'_{211} < 1.5\times10^{-5}$, 1 mm < c$\tau$ < 1 m, $\tilde{g}$ decoupled)
RPV
LFV : pp$\to\tilde{\nu}_\tau$+X, $\tilde{\nu}_\tau \to e+\mu$ resonance — L=4.6 fb^{-1}, 7 TeV [Preliminary] — 1.61 TeV $\tilde{\nu}_\tau$ mass (λ'_{311}=0.10, λ_{132}=0.05)
LFV : pp$\to\tilde{\nu}_\tau$+X, $\tilde{\nu}_\tau \to e(\mu)+\tau$ resonance — L=4.6 fb^{-1}, 7 TeV [Preliminary] — 1.10 TeV $\tilde{\nu}_\tau$ mass (λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05)
Bilinear RPV CMSSM : 1 lep + 7 j's + $E_{T,miss}$ — L=4.7 fb^{-1}, 7 TeV [ATLAS-CONF-2012-140] — 1.2 TeV $\tilde{q} = \tilde{g}$ mass (cτ_{LSP} < 1 mm)
$\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^+_1 \to W\tilde{\chi}^0_1$, $\tilde{\chi}^0_1 \to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$: 4 lep + $E_{T,miss}$ — L=13.0 fb^{-1}, 8 TeV [ATLAS-CONF-2012-153] — 700 GeV $\tilde{\chi}^\pm_1$ mass ($m(\tilde{\chi}^0_1) > 300$ GeV, λ_{121} or $\lambda_{122} > 0$)
$\tilde{l}_L\tilde{l}_L$, $\tilde{l}_L \to l\tilde{\chi}^0_1$, $\tilde{\chi}^0_1 \to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$: 4 lep + $E_{T,miss}$ — L=13.0 fb^{-1}, 8 TeV [ATLAS-CONF-2012-153] — 430 GeV $\tilde{l}$ mass ($m(\tilde{\chi}^0_1) > 100$ GeV, $m(\tilde{l}_e)=m(\tilde{l}_\mu)=m(\tilde{l}_\tau)$, λ_{121} or $\lambda_{122} > 0$)
$\tilde{g} \to qqq$: 3-jet resonance pair — L=4.6 fb^{-1}, 7 TeV [1210.4813] — 666 GeV $\tilde{g}$ mass
Scalar gluon : 2-jet resonance pair — L=4.6 fb^{-1}, 7 TeV [1210.4826] — 100-287 GeV sgluon mass (incl. limit from 1110.2693)
WIMP interaction (D5, Dirac χ) : 'monojet' + $E_{T,miss}$ — L=10.5 fb^{-1}, 8 TeV [ATLAS-CONF-2012-147] — 704 GeV M* scale ($m_\chi < 80$ GeV, limit of < 687 GeV for D8)
ATLAS
Preliminary
$\int L dt = (2.1 - 13.0)$ fb^{-1}
$\sqrt{s}$ = 7, 8 TeV
8 TeV results
7 TeV results
10^{-1}
1
10
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

TOP SQUARK (STOP)

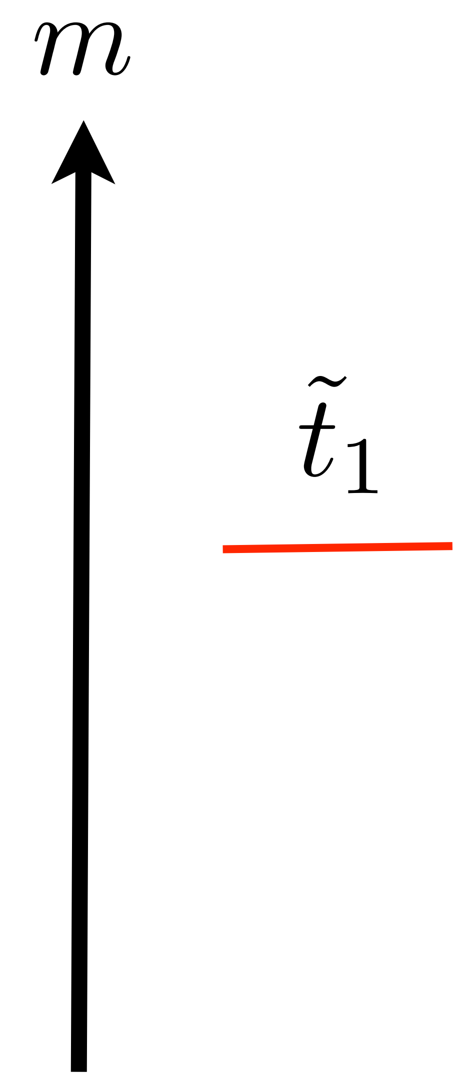
Largest contribution to Higgs radiative correction comes from top



Stop cuts of quadratic divergence, giving log divergence

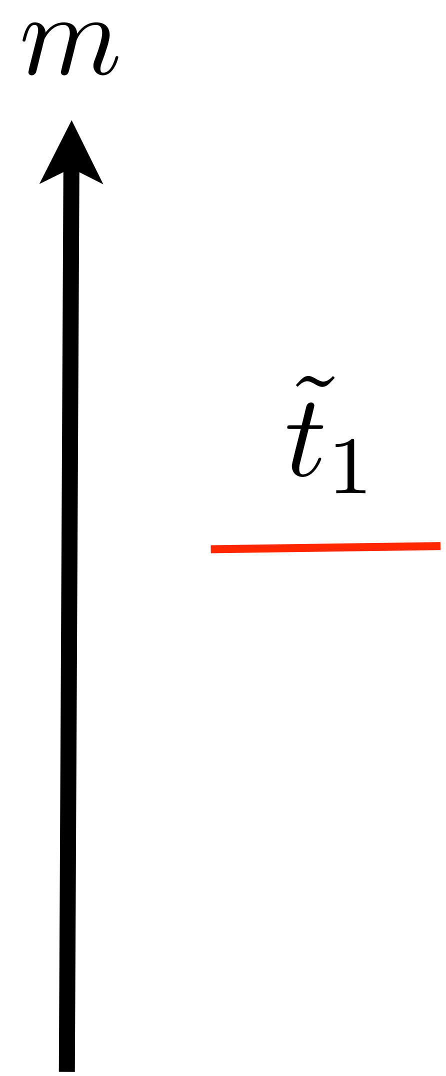


STOP SCENARIO



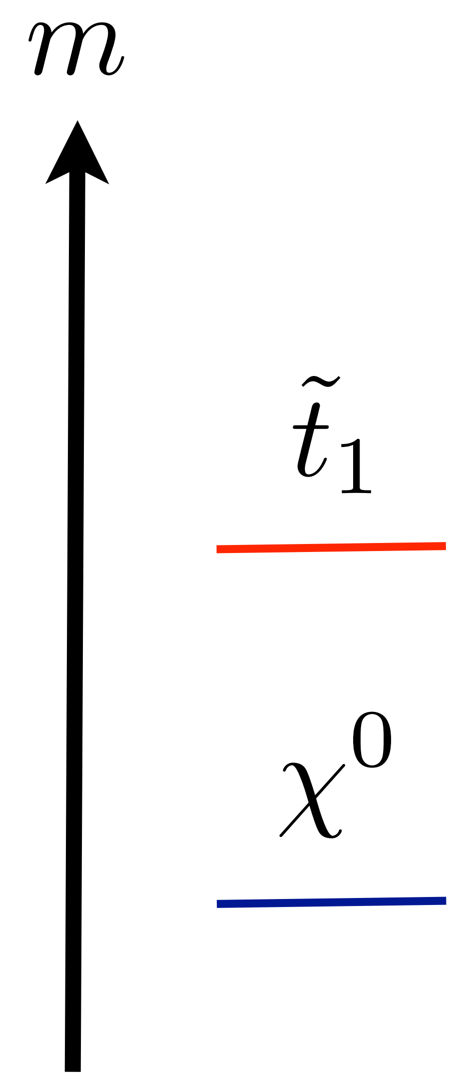
STOP SCENARIO

- Stop is lightest colored particle, consider only one species



STOP SCENARIO

- Stop is lightest colored particle, consider only one species
- R-parity and neutralino LSP is well motivated, possible chargino as well



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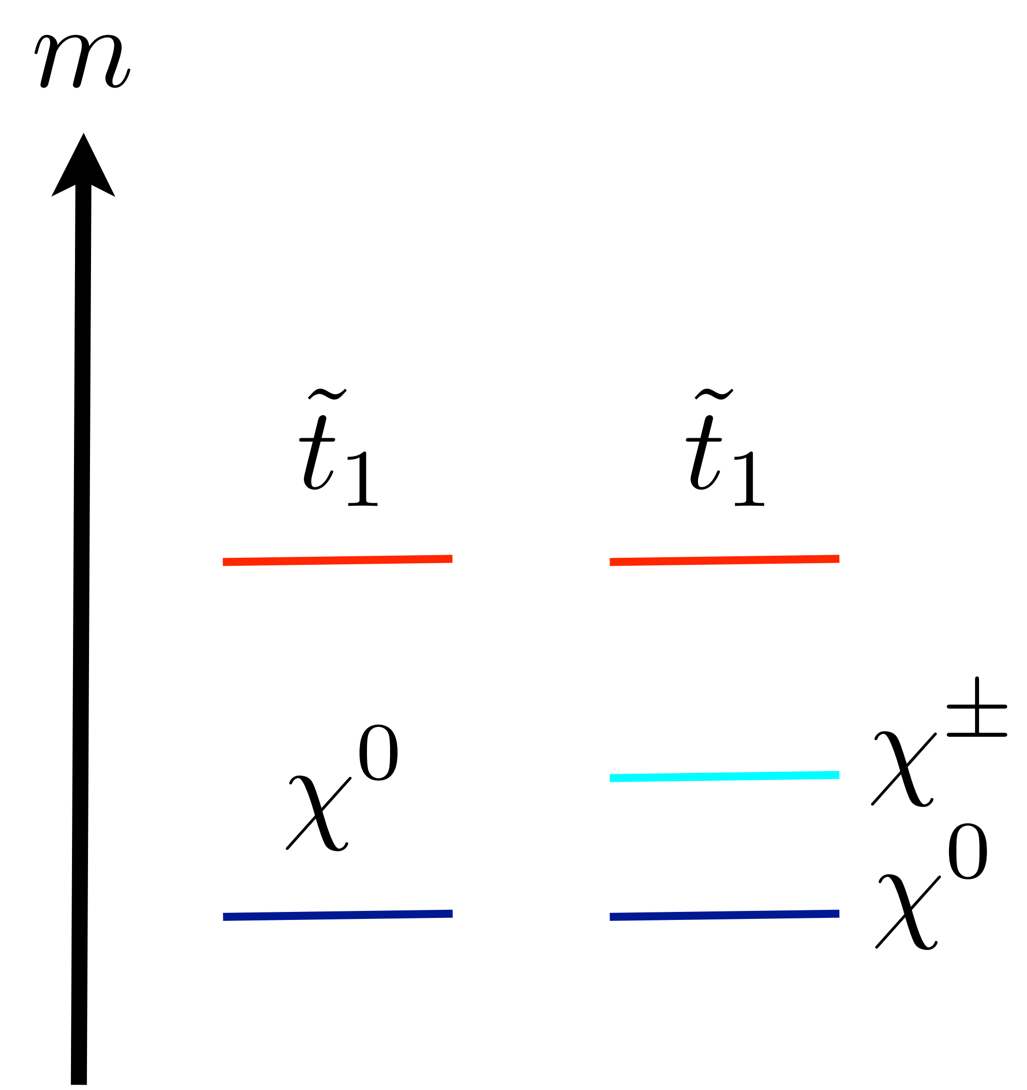

STOP SCENARIO

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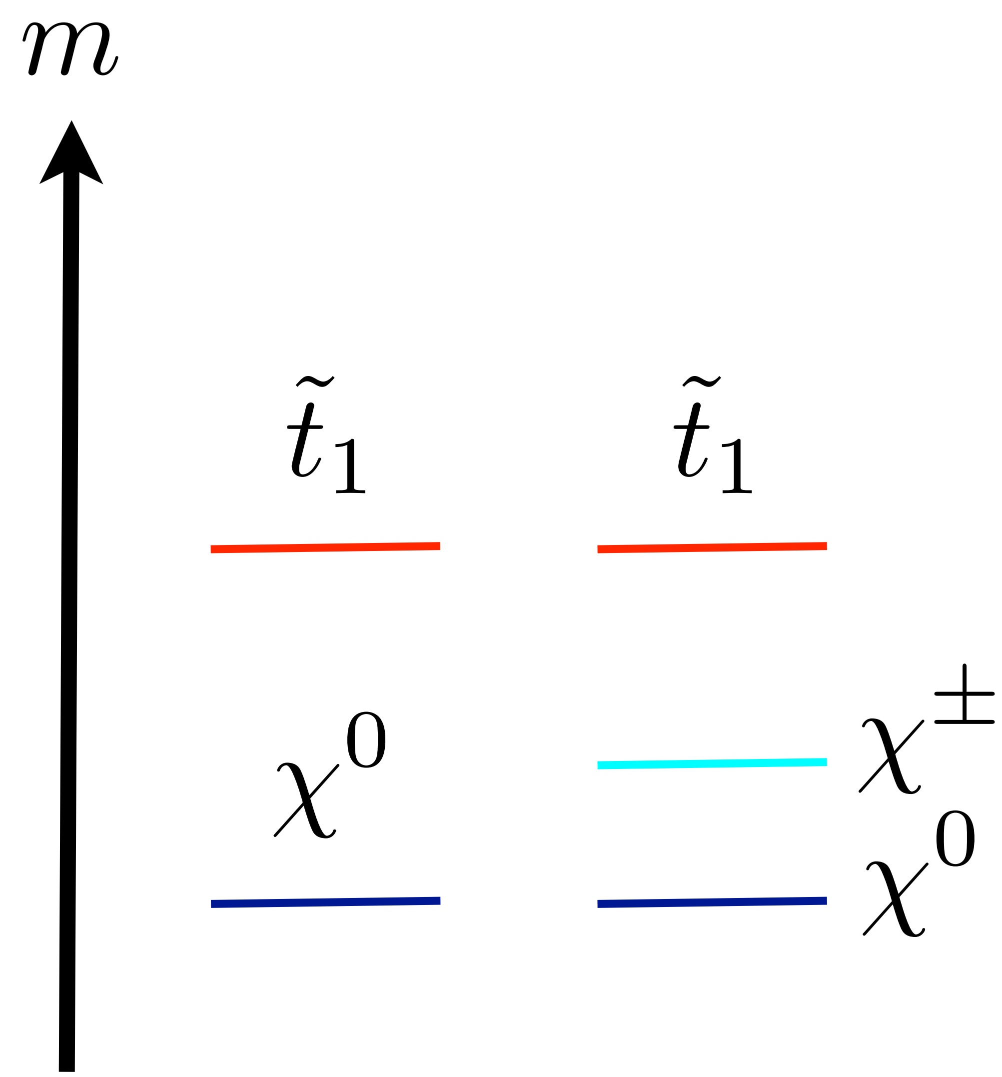
- Require $m_{\tilde{t}} > m_t + m_{\chi^0}$



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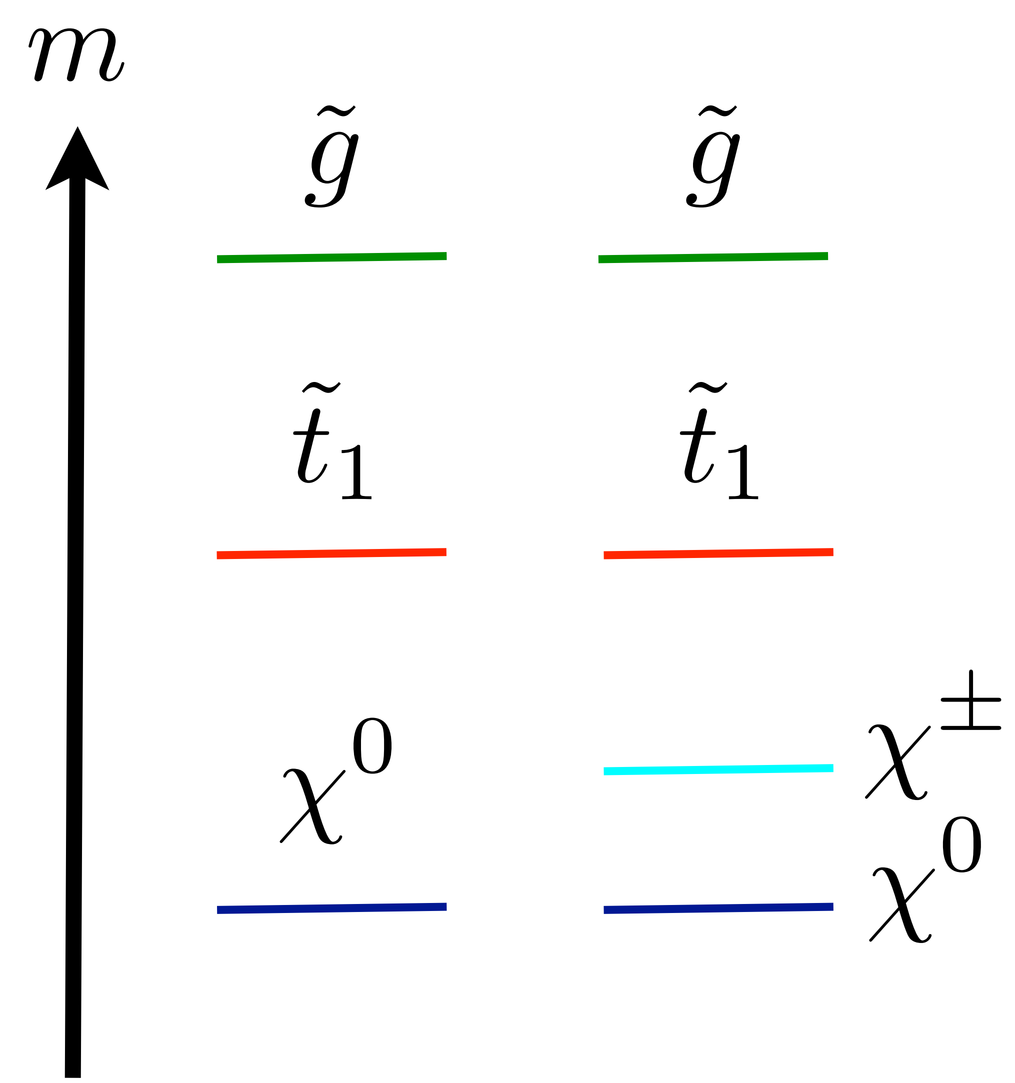
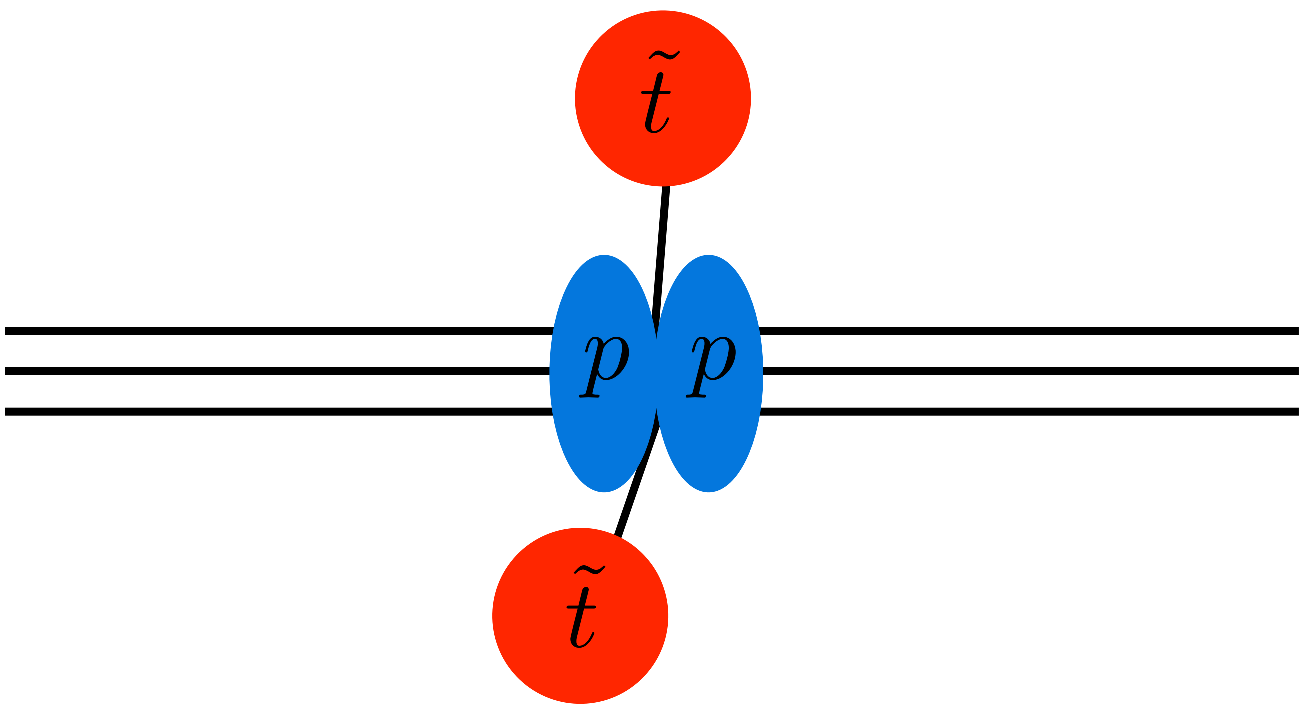


STOP EVENTS



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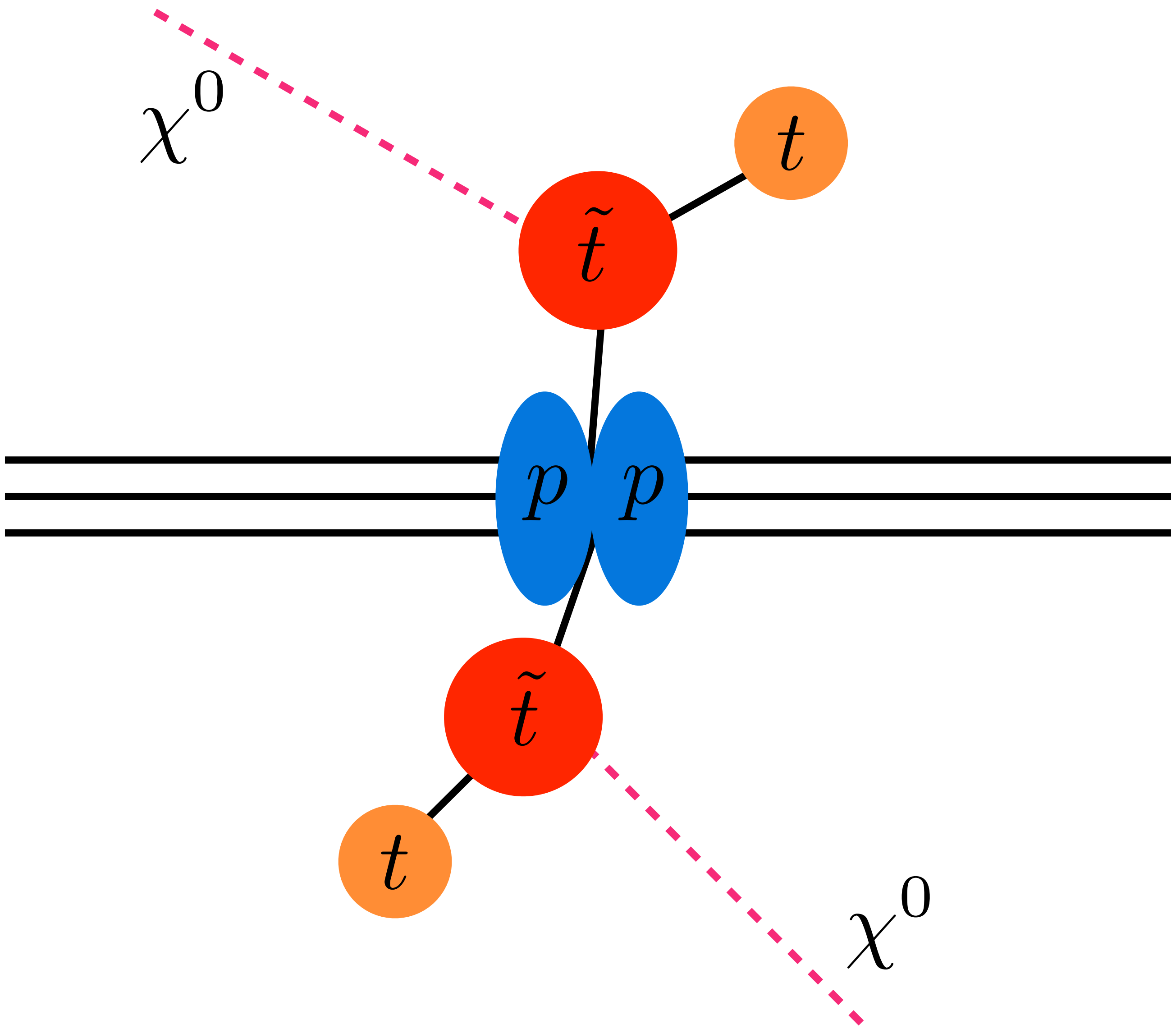

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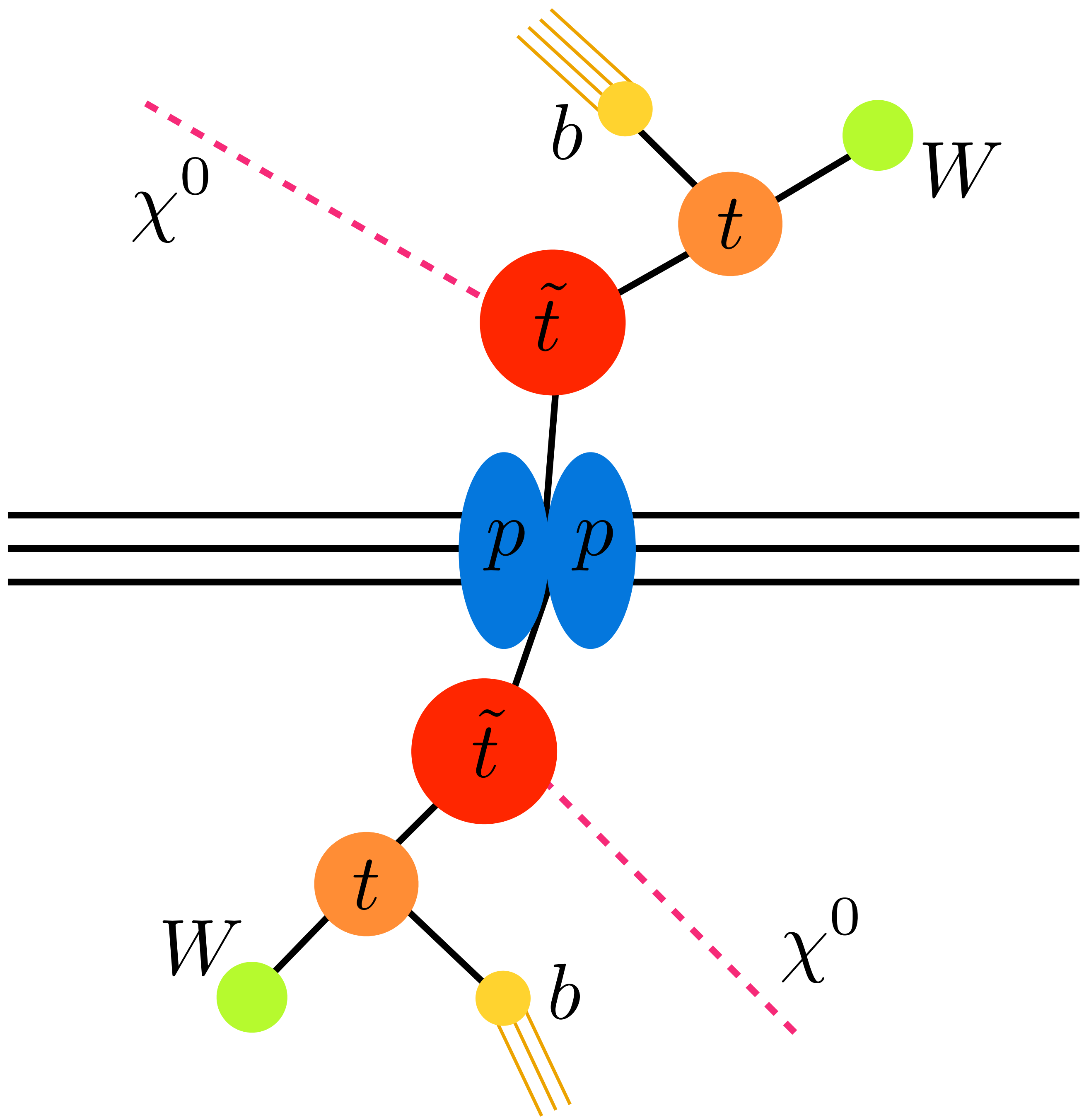

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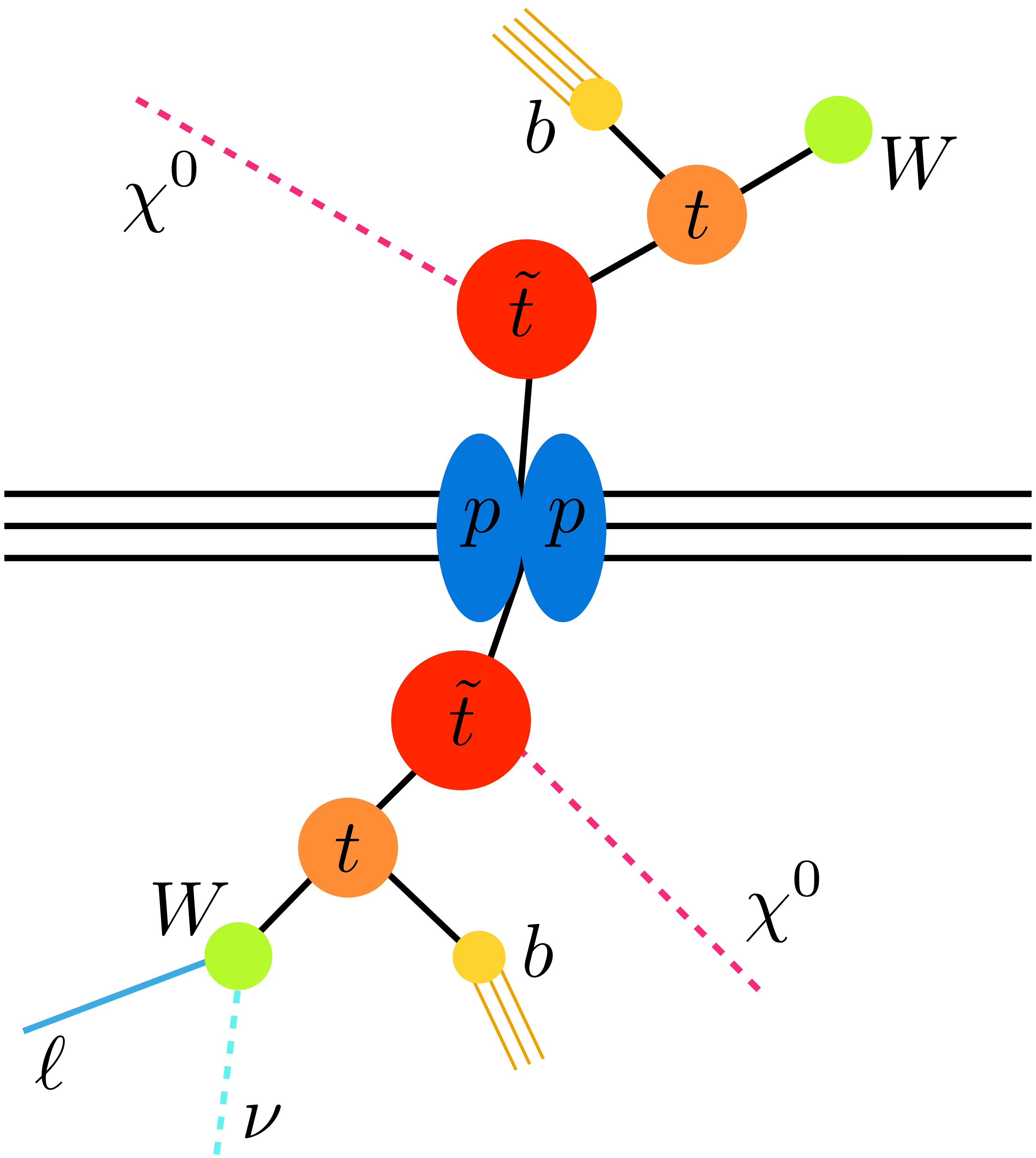

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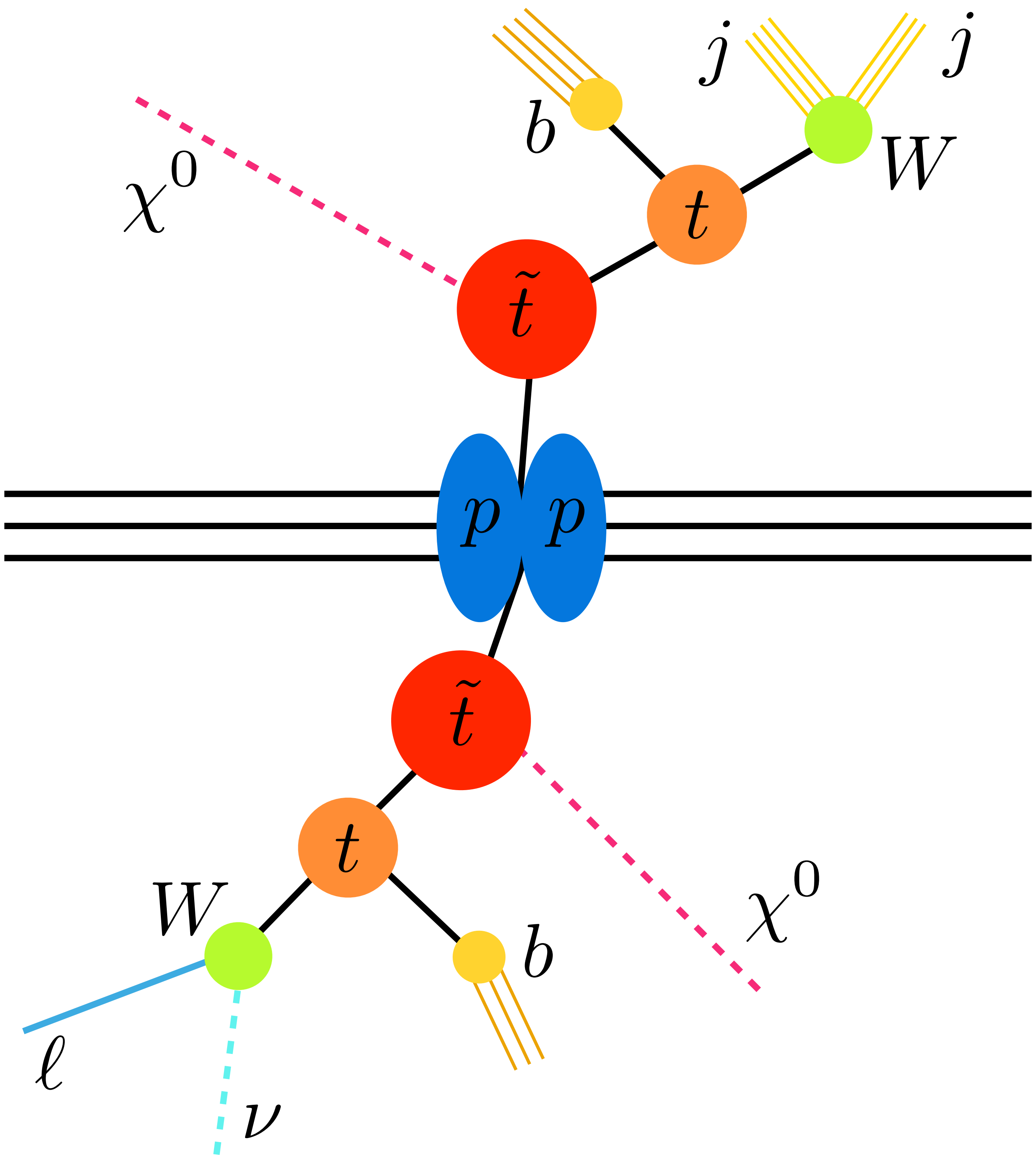

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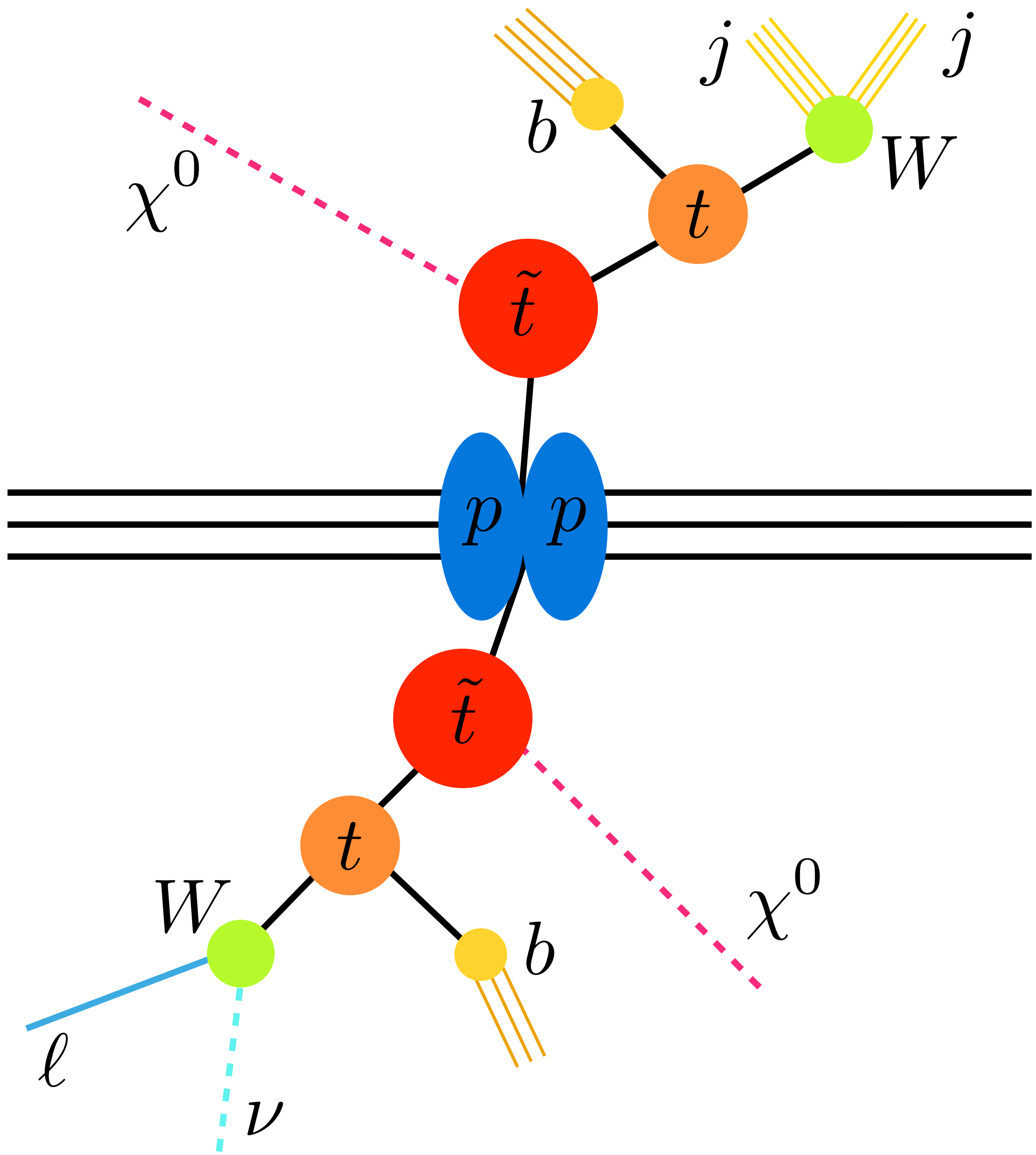
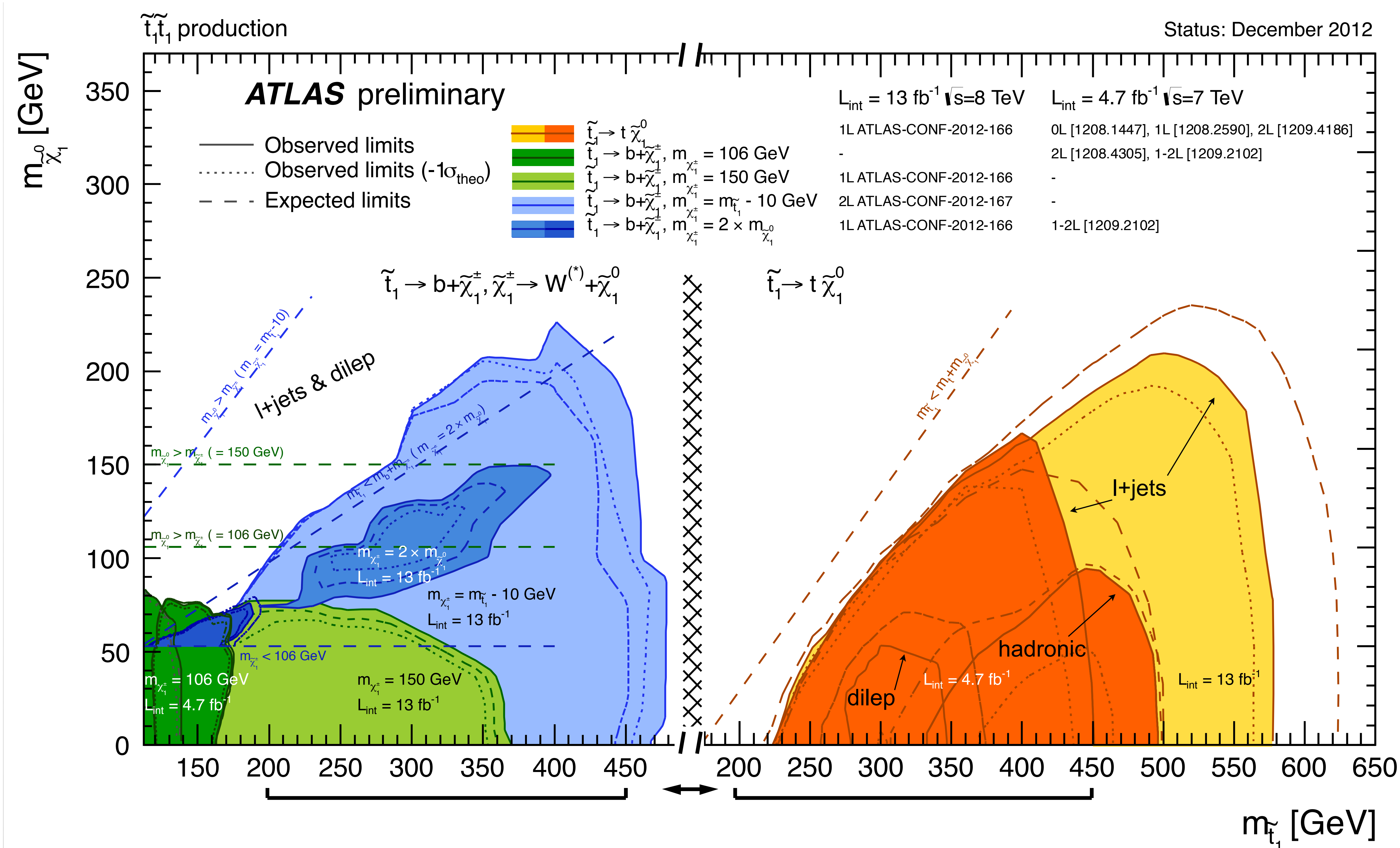


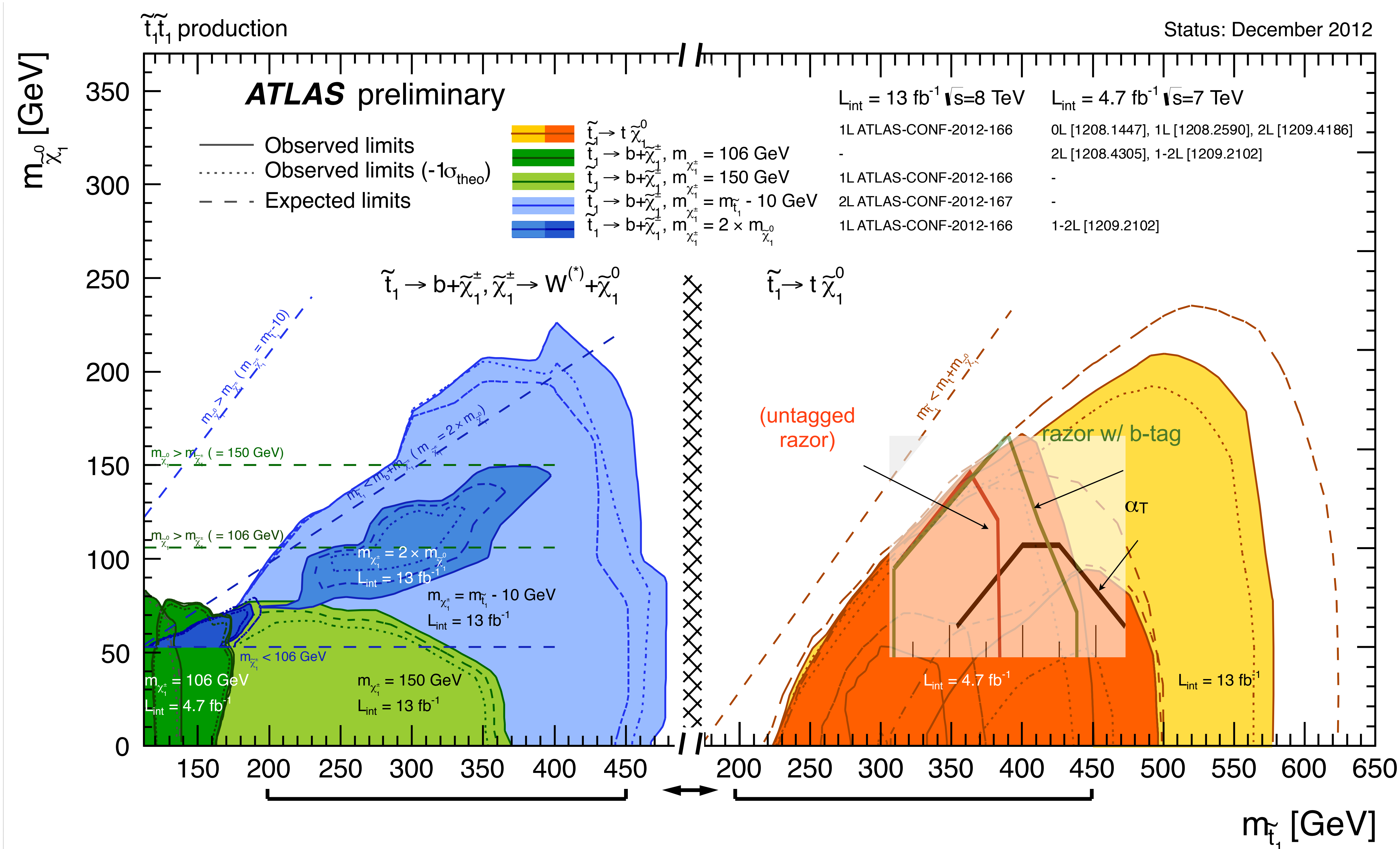
Searches performed with 0, 1, and 2 leptons in final state

CURRENT BOUNDS



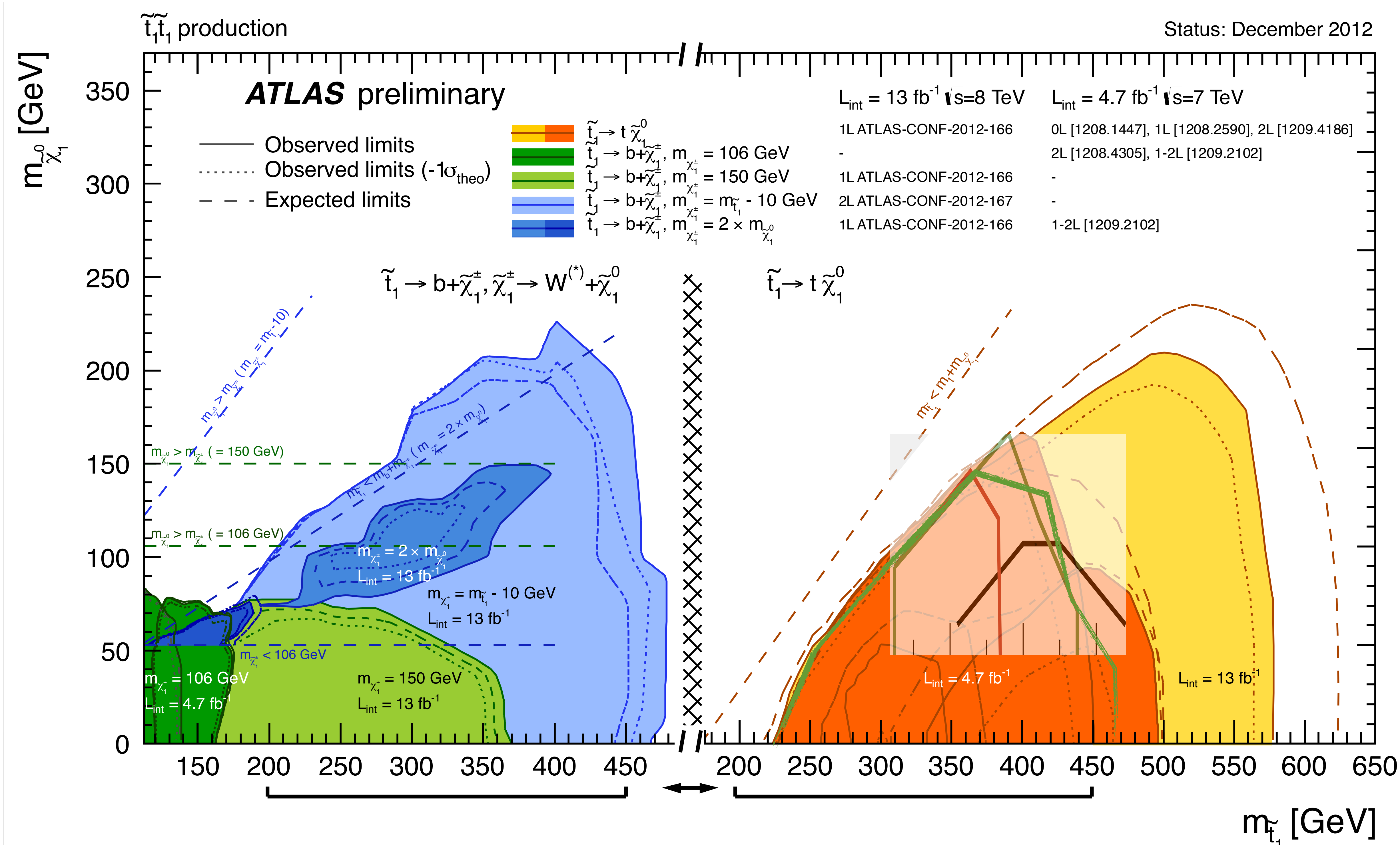
ATLAS Results

CURRENT BOUNDS



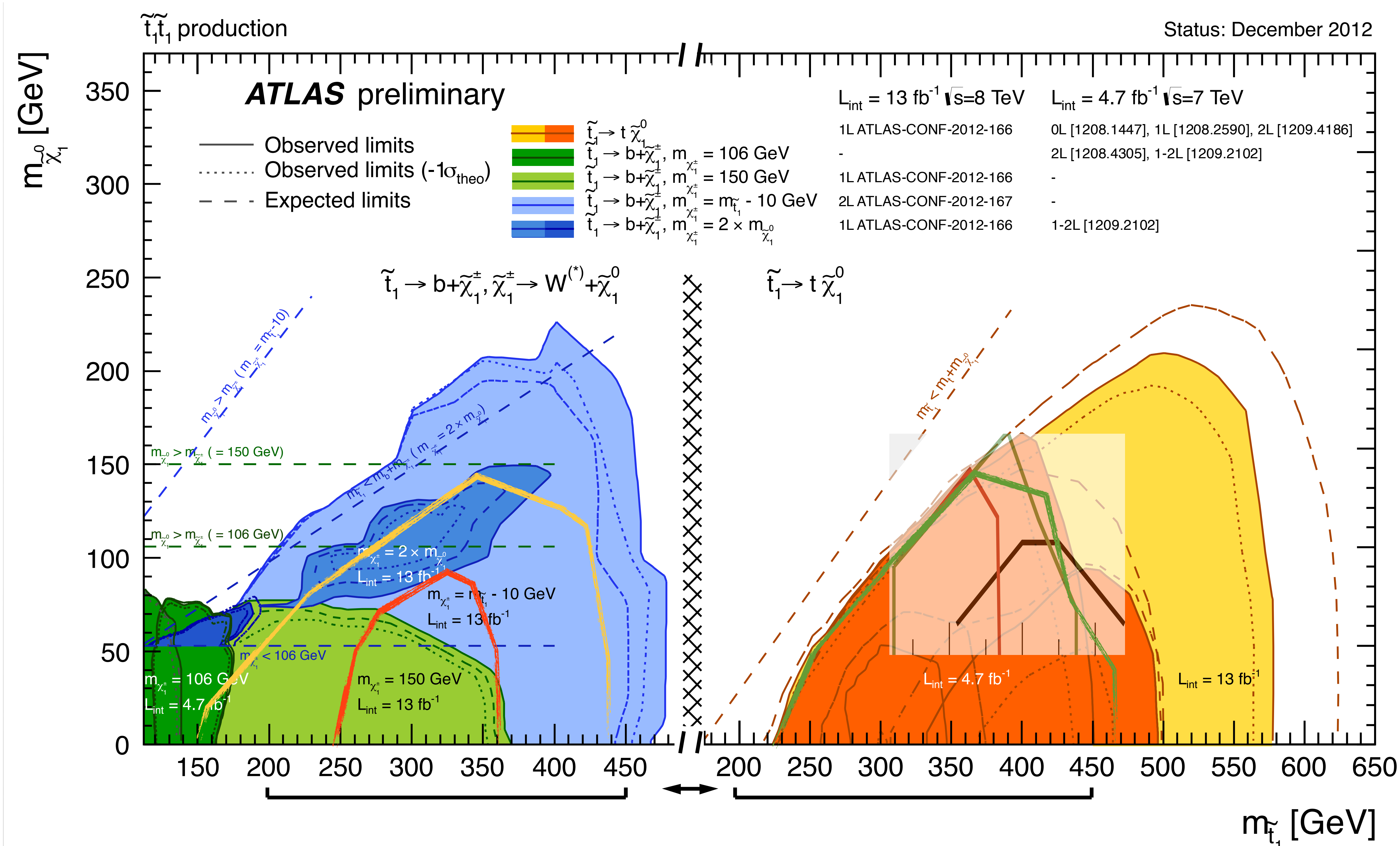
ATLAS + CMS multijet (courtesy of Brock Tweedie)

CURRENT BOUNDS



+ CMS 1 lepton (8 TeV, 10 fb^{-1})

CURRENT BOUNDS

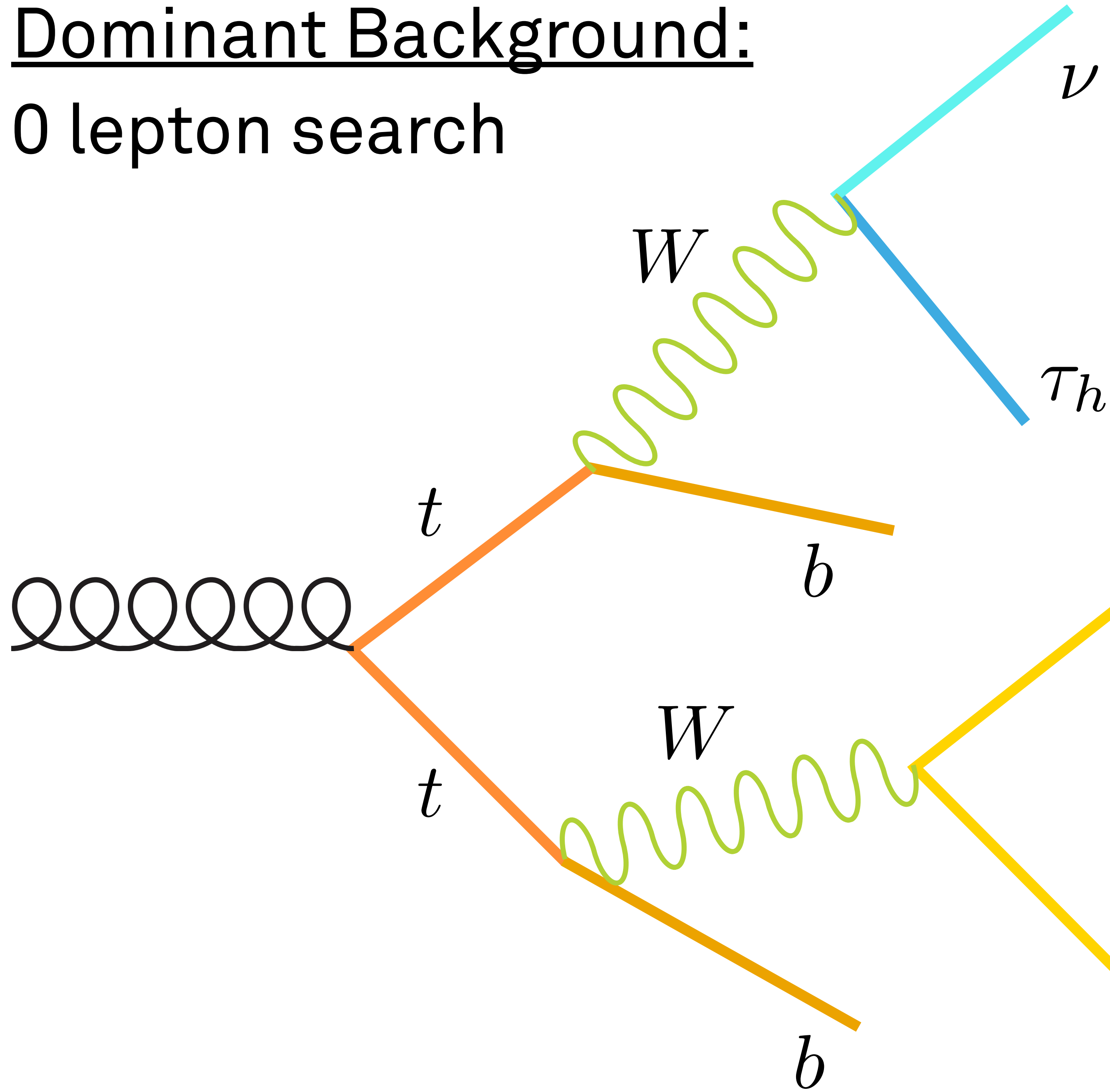


+ CMS 1 lepton (8 TeV, 10 fb^{-1})

POTENTIAL IMPROVEMENTS

Dominant Background:

0 lepton search



- Use modern top-taggers
- More sophisticated tau-veto

POTENTIAL IMPROVEMENTS

<u>Dominant Background:</u>

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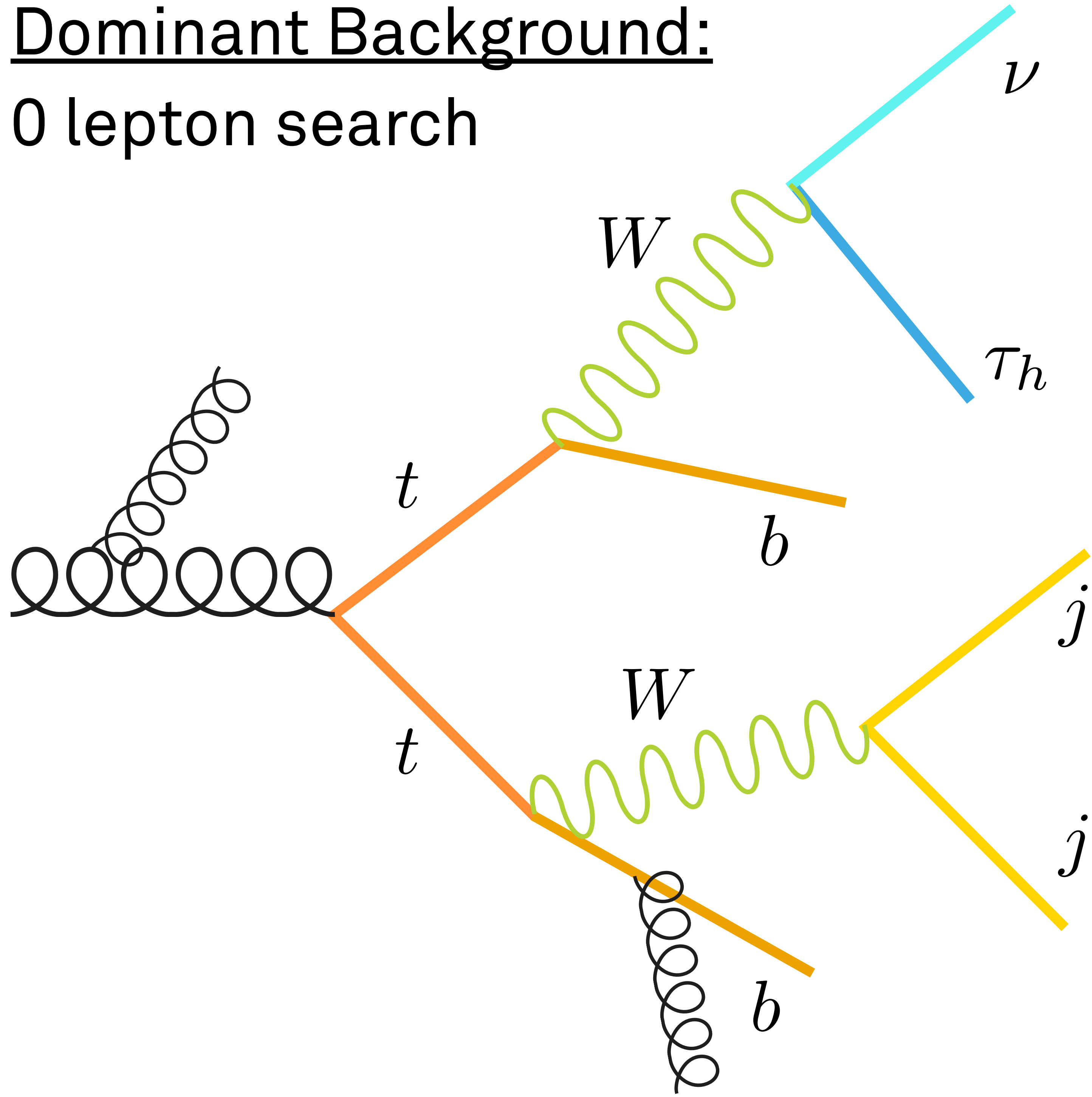

POTENTIAL IMPROVEMENTS

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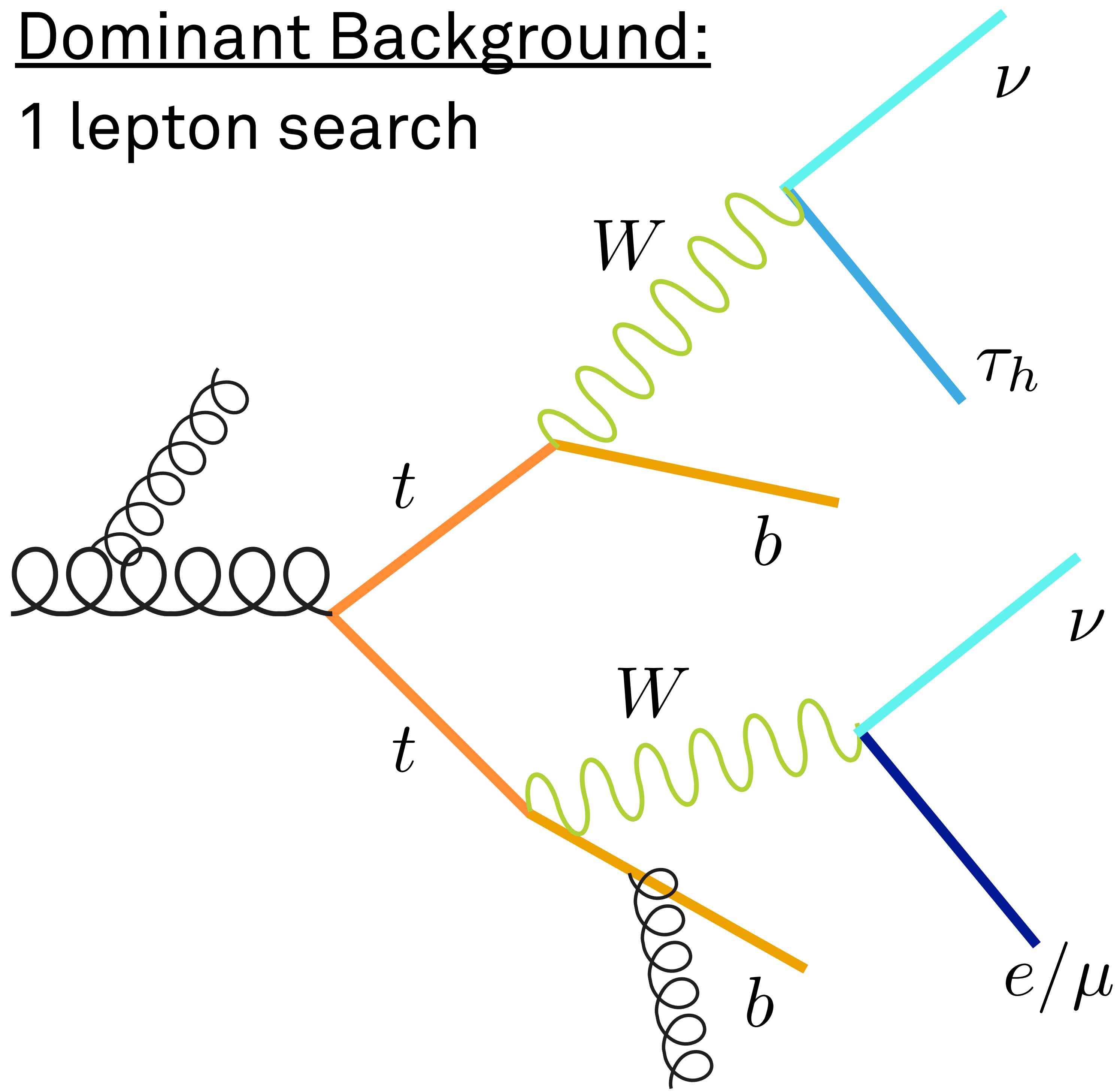
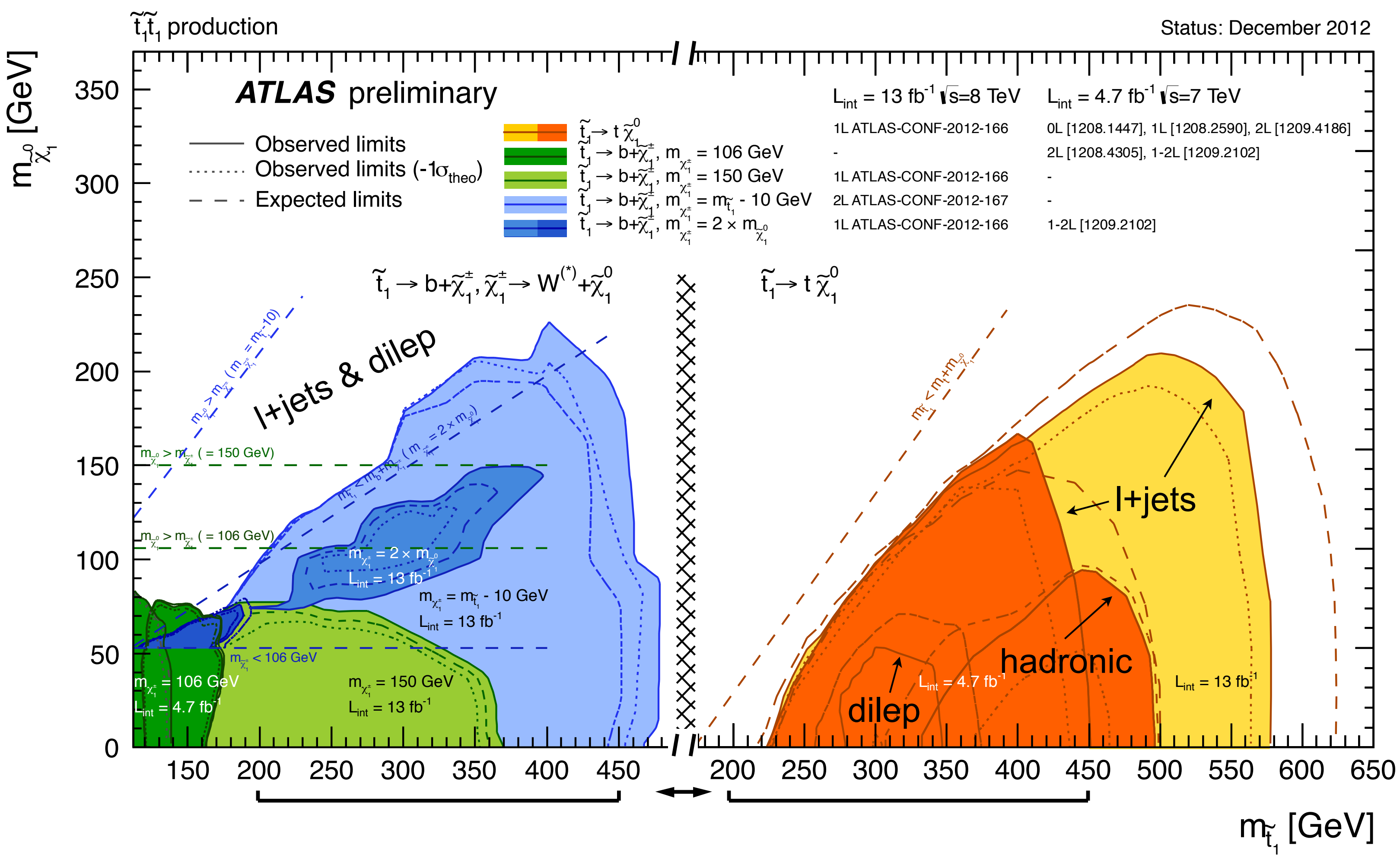


- Use modern top-taggers

- More sophisticated tau-veto

ADDITIONAL WORK

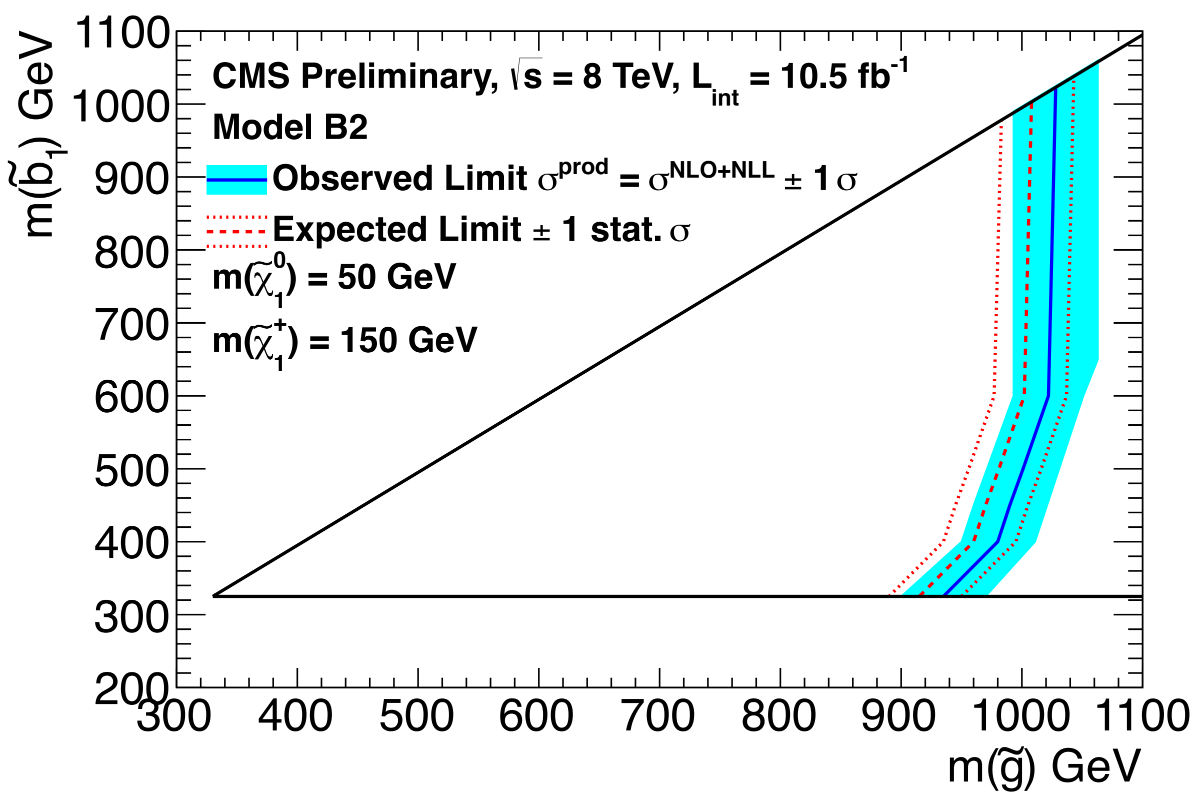
- Projection for 14 TeV, 300 fb^{-1}, 3,000 fb^{-1}?
- Reach at VLHC? Linear collider? Muon collider?
- Audience suggestions?



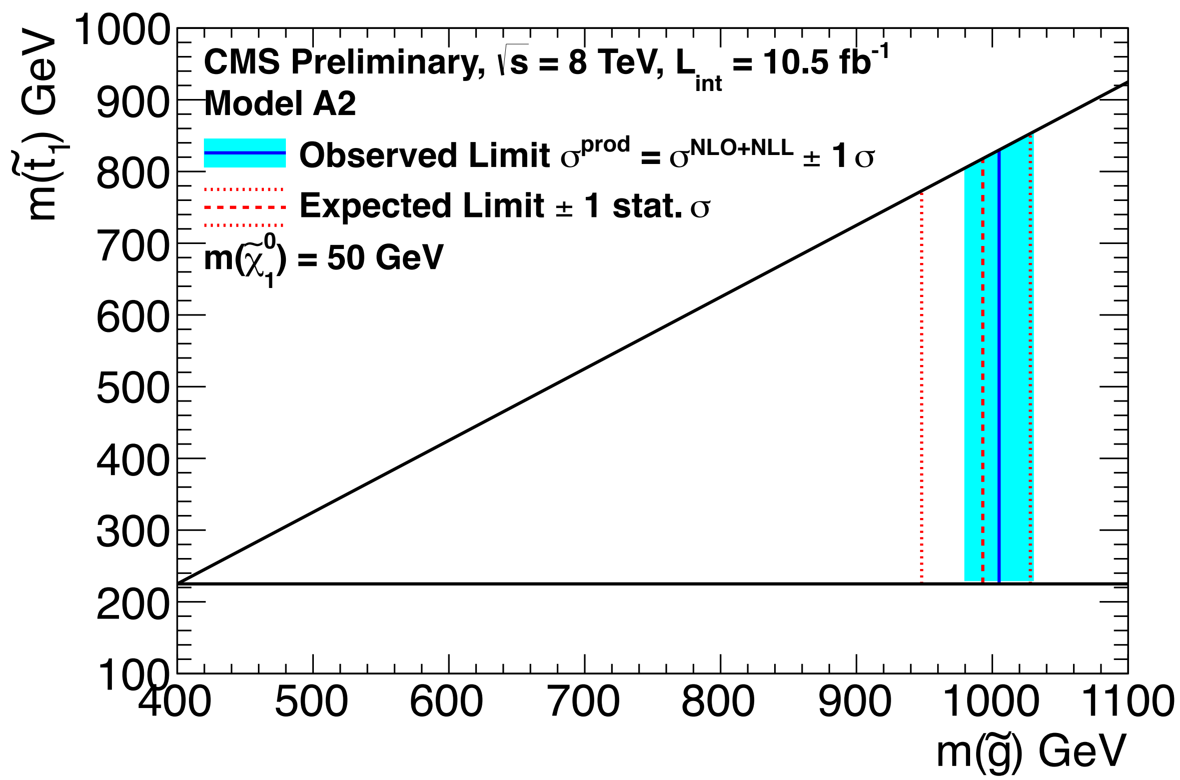
THANK YOU

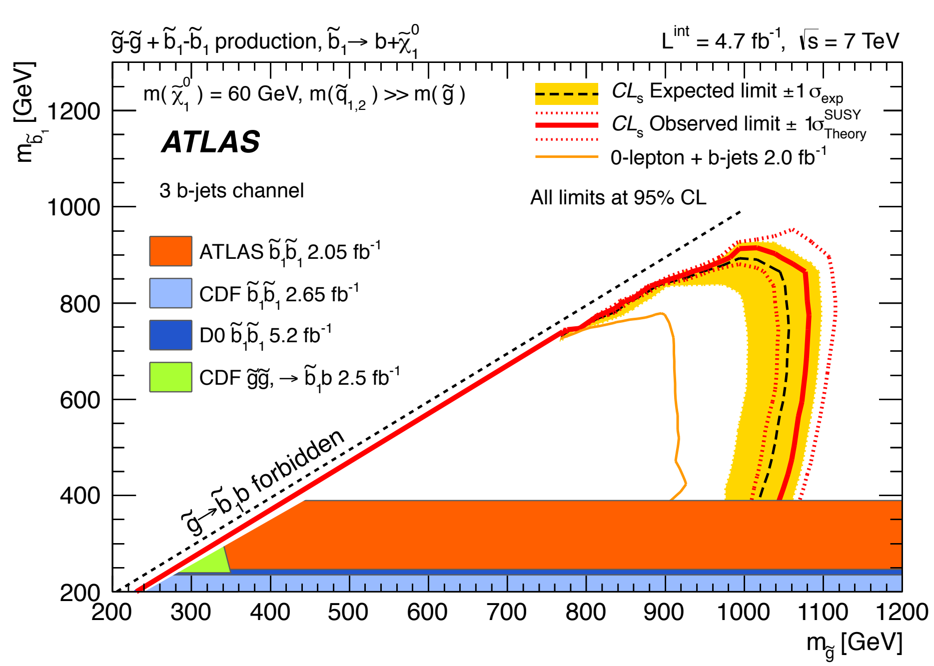
GLUINO BOUNDS

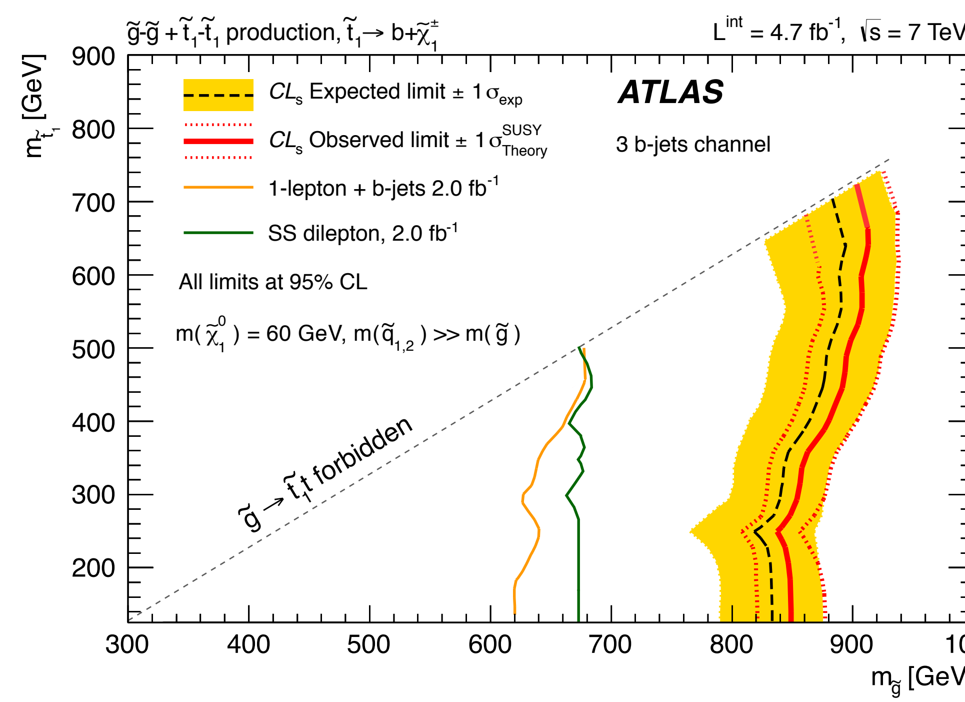
$\tilde{g} + \tilde{b}$



$\tilde{g} + \tilde{t}$







TOP TAGGING

Use HEPTopTagger to distinguish hadronic top Plehn, Spannowsky, Takeuchi, Zerwas, 1006.2833. See also Thaler et. al. 0806.0023, Kaplan et. al. 0806.0848, Almeida et. al. 0807.0234.