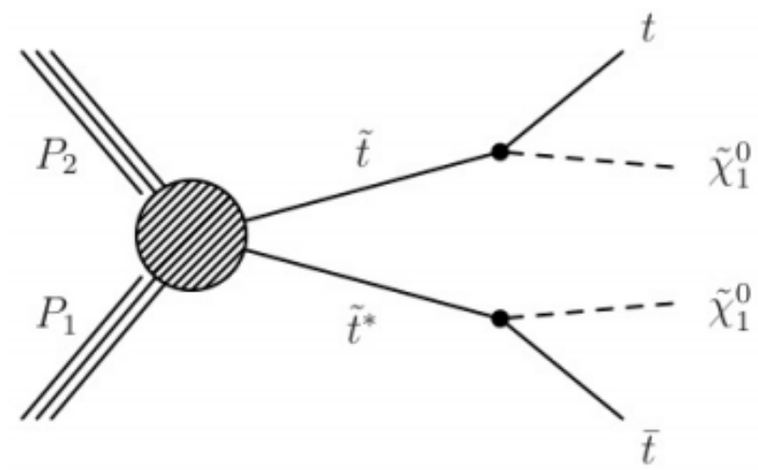
New Approaches to Stop Searches

Daniele Alves
FNAL

Implications of LHC results for
TeV-scale physics - July/12

(Very) Recent work by theorists



kinematic variables with endpoints for background

arXiv:1203.4813 Bai, Cheng, Gallicchio, Gu

Spin correlations and rapidity gaps

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Top-tagging boosted tops from stop decays

arXiv:1205.5816 Kaplan, Rehermann, Stolarski

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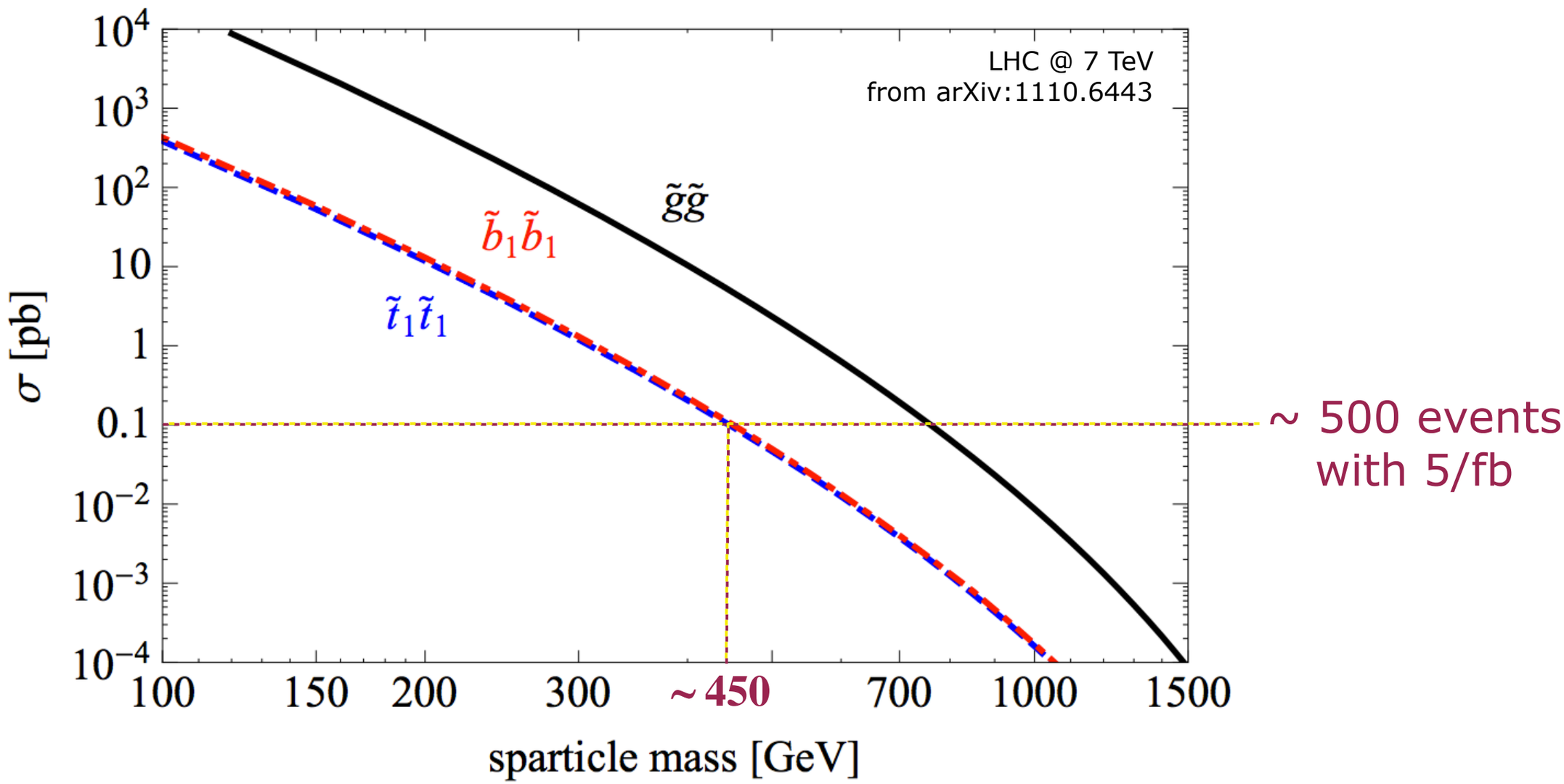
MET and M_T shapes

arXiv:1205.5805 Alves, Buckley, Fox, Lykken, Yu

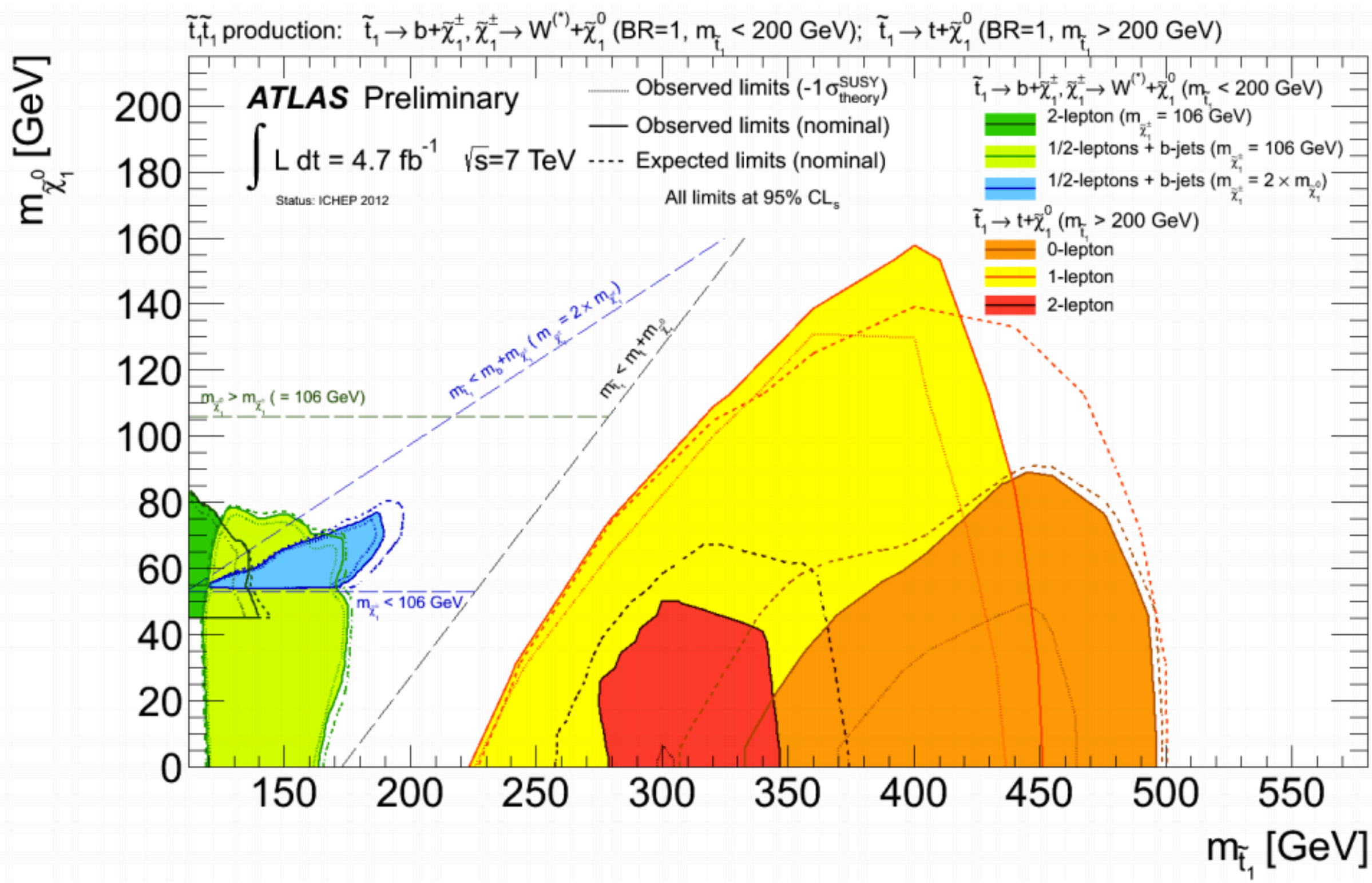
LHC @ 8 TeV: interesting times for stop searches



LHC is starting to probe
direct production of 3rd generation squarks

First analyses just released at ICHEP'12 !

First Results for Direct Stop Production



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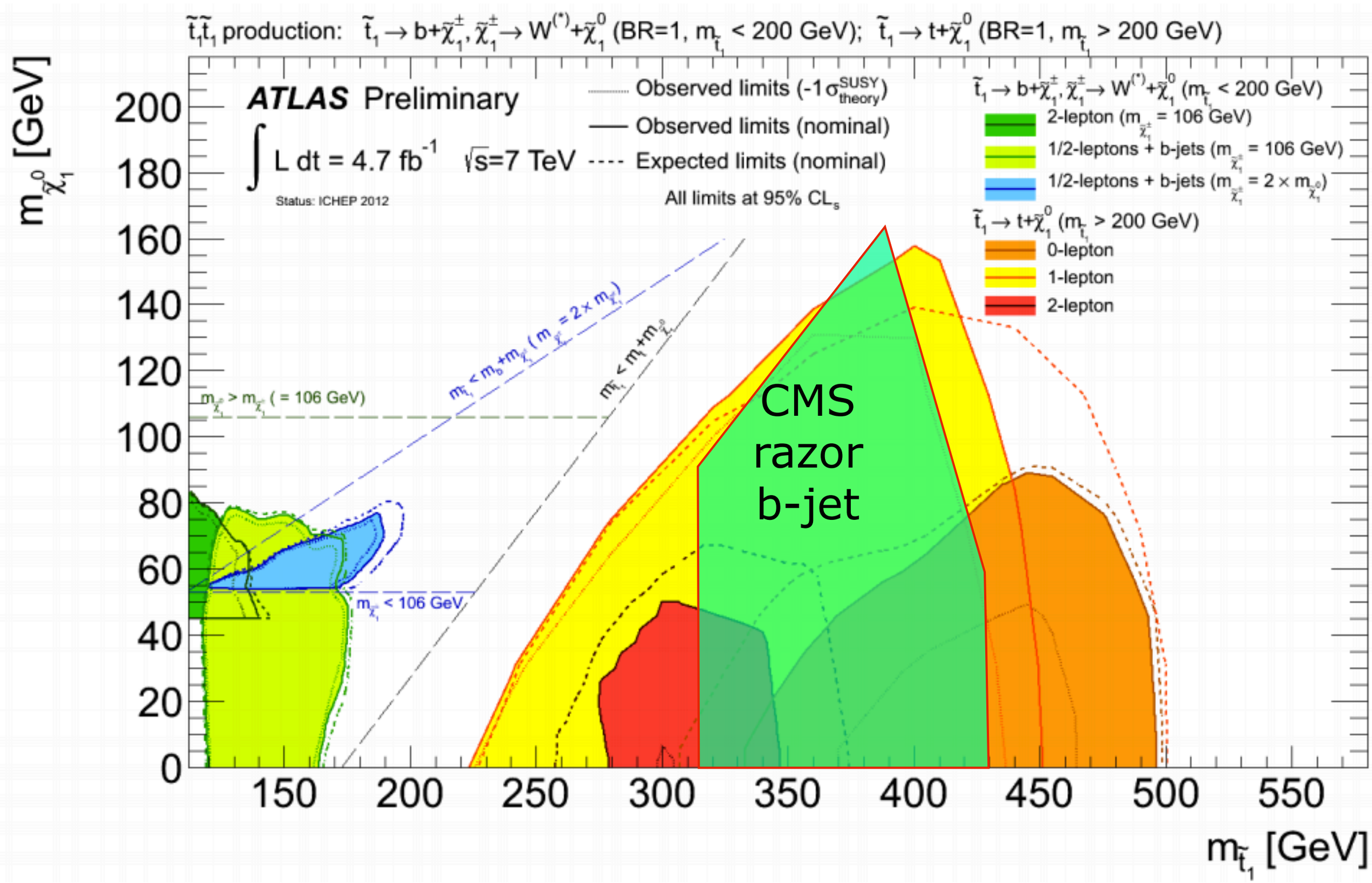

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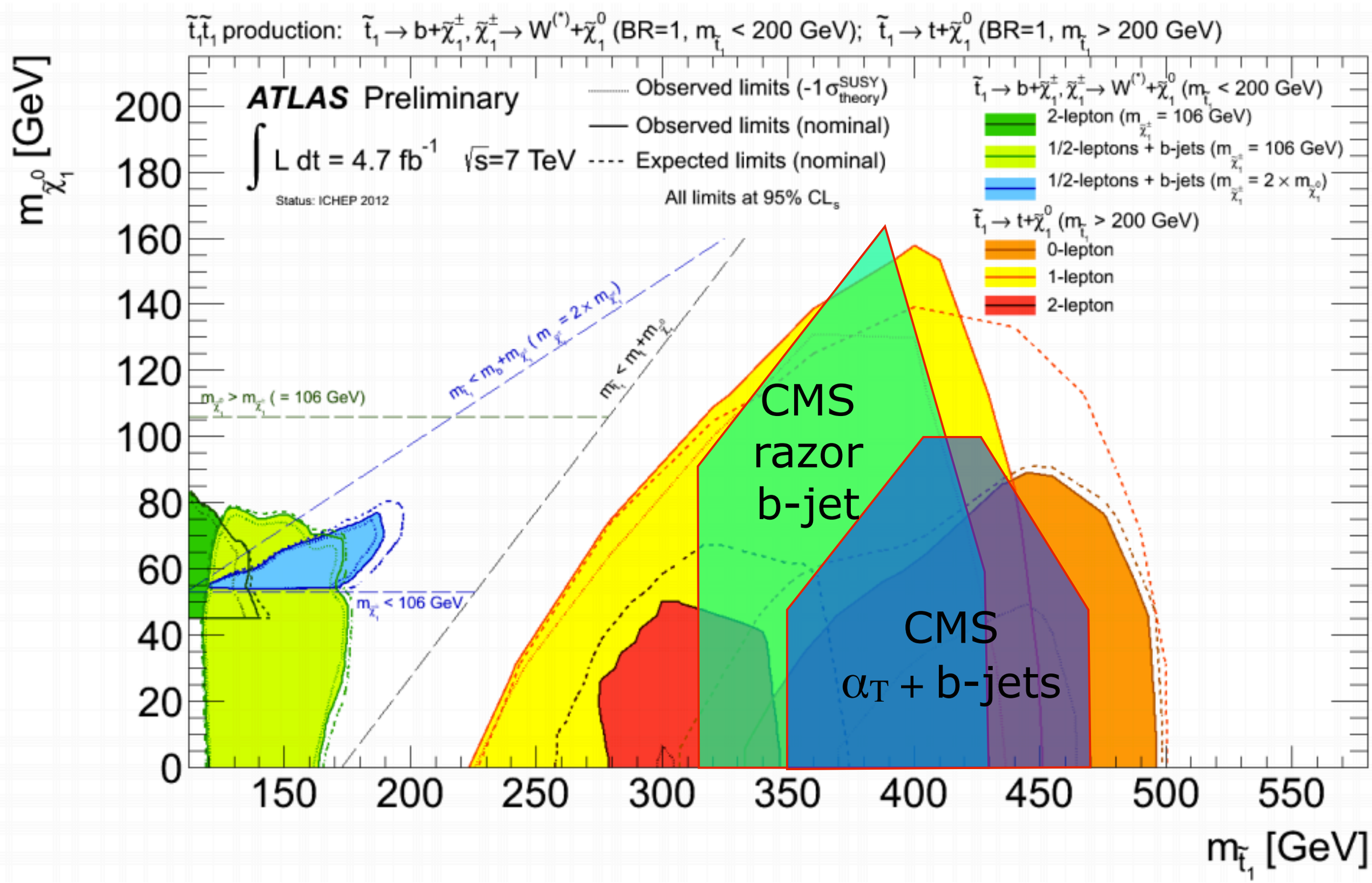
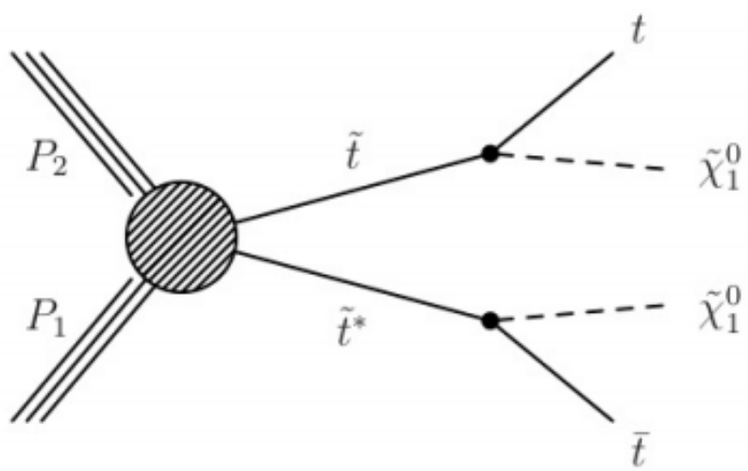
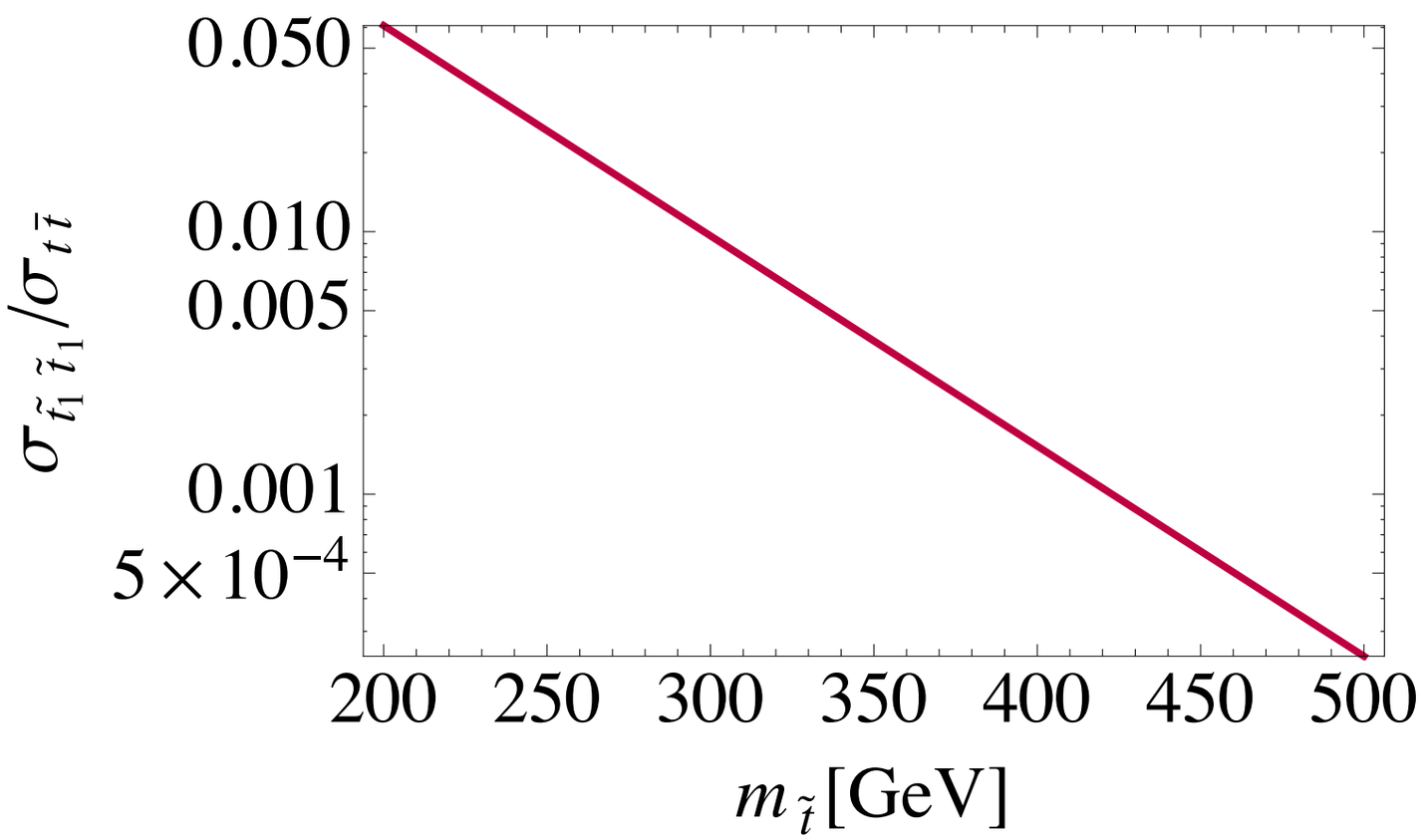


- progress made is encouraging
- but there are still difficult regions to reach



- ttbar challenging very for stop searches
- small signal cross-section

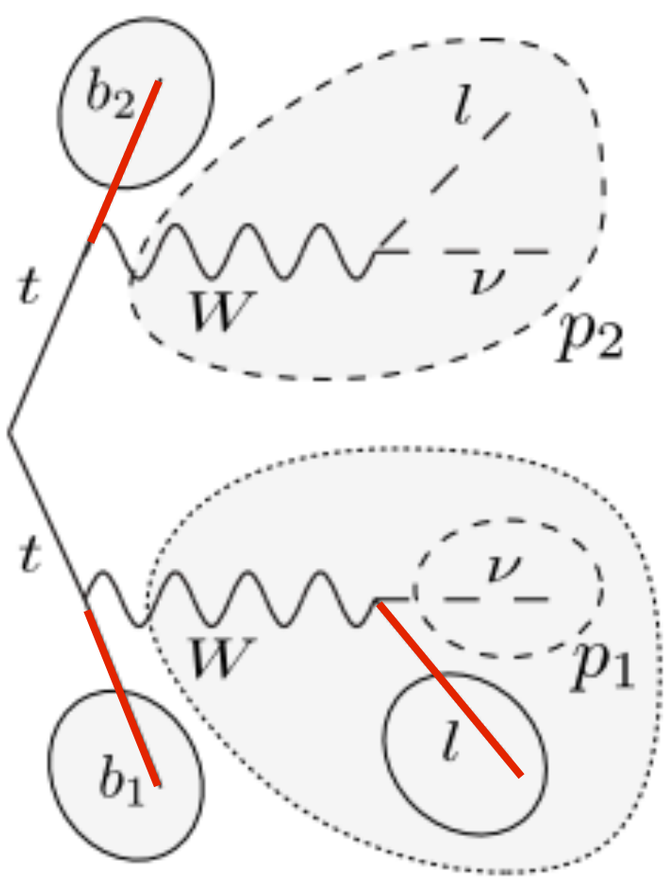


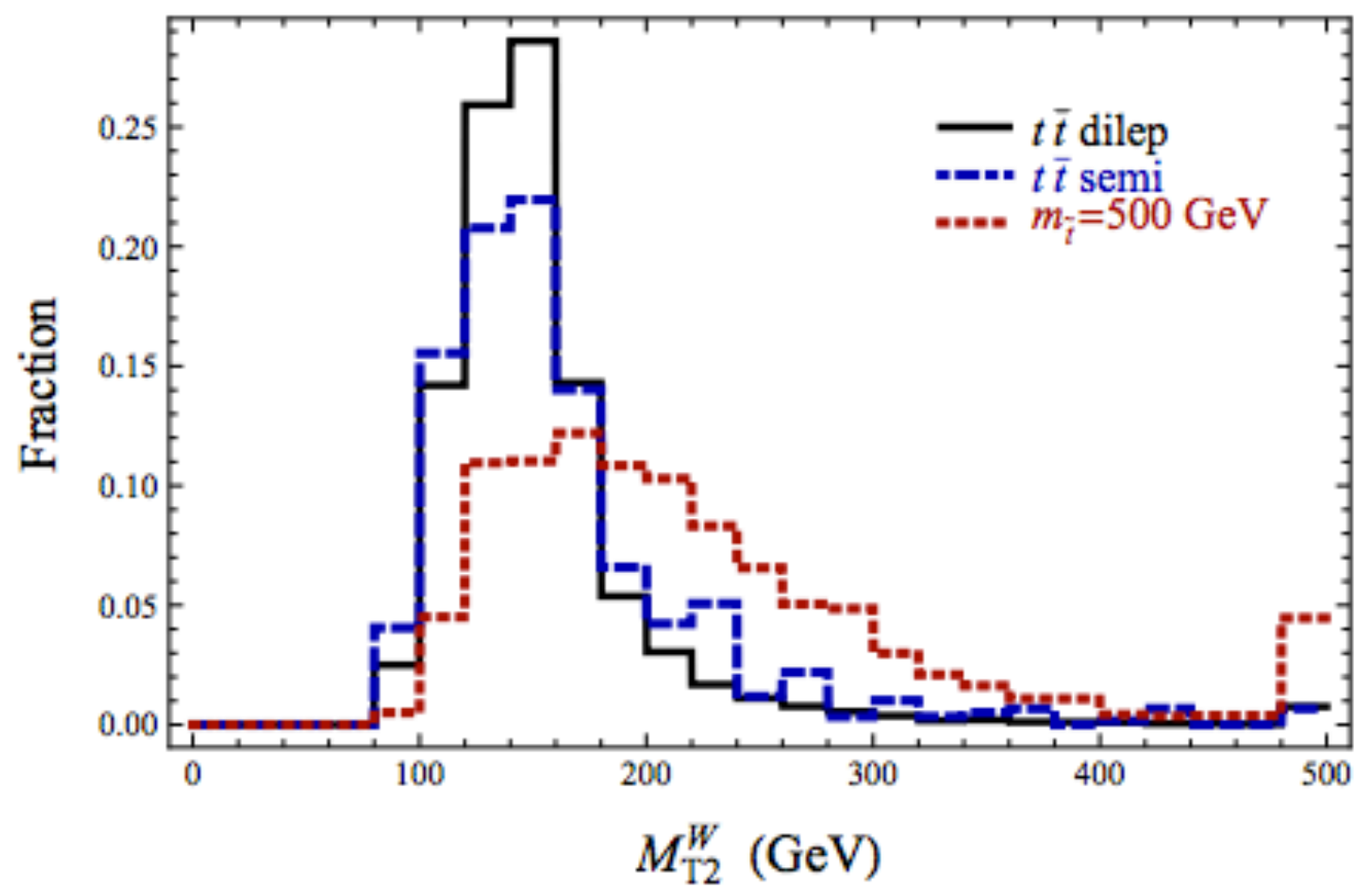
Kinematic variables with endpoints for background

arXiv:1203.4813 Bai, Cheng, Gallicchio, Gu

semileptonic channel, MET>150 GeV, M_T>100 GeV

$$M_{T2}^{W} = \min\left\{ m_y \text{ consistent with: } \left[\begin{array}{r} \vec{p}_1^{\,T} + \vec{p}_2^{\,T} = \vec{E}_T^{\text{miss}}\,,\ p_1^2 = 0\,,\ (p_1 + p_\ell)^2 = p_2^2 = M_W^2\,, \\ (p_1 + p_\ell + p_{b_1})^2 = (p_2 + p_{b_2})^2 = m_y^2 \end{array} \right] \right\}$$





Kinematic variables with endpoints for background

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(assuming $m_{\tilde{\chi}^0} = 100$ GeV)

$E_T^{\rm miss}$	$m_{\rm eff}$	M_{T2}^W	M_{T2}^b	M_{T2}^{bl}	$S_{20fb^{-1}}$	$B_{20fb^{-1}}$	S/B	σ	
200	562	177	-	-	50.7	48.5	1.05	6.33	$m_{\tilde{t}} = 400$ GeV
299	709	172	-	-	9.8	6.2	1.59	3.19	$m_{\tilde{t}} = 500$ GeV
337	727	168	-	-	5.9	3.0	2.01	2.66	$m_{\tilde{t}} = 600$ GeV

Kinematic variables with endpoints for background

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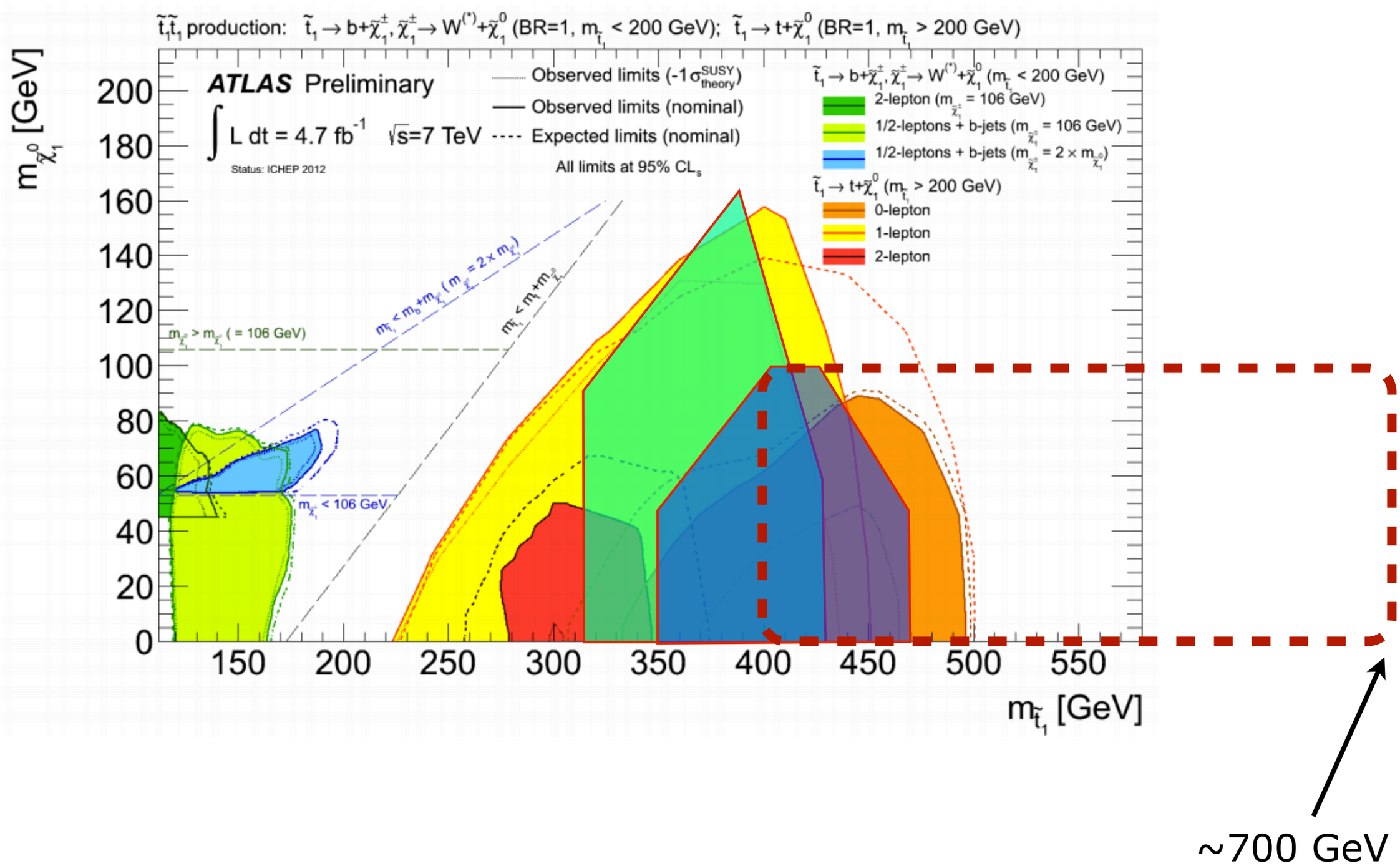
estimated reach with 20/fb @ 7 TeV

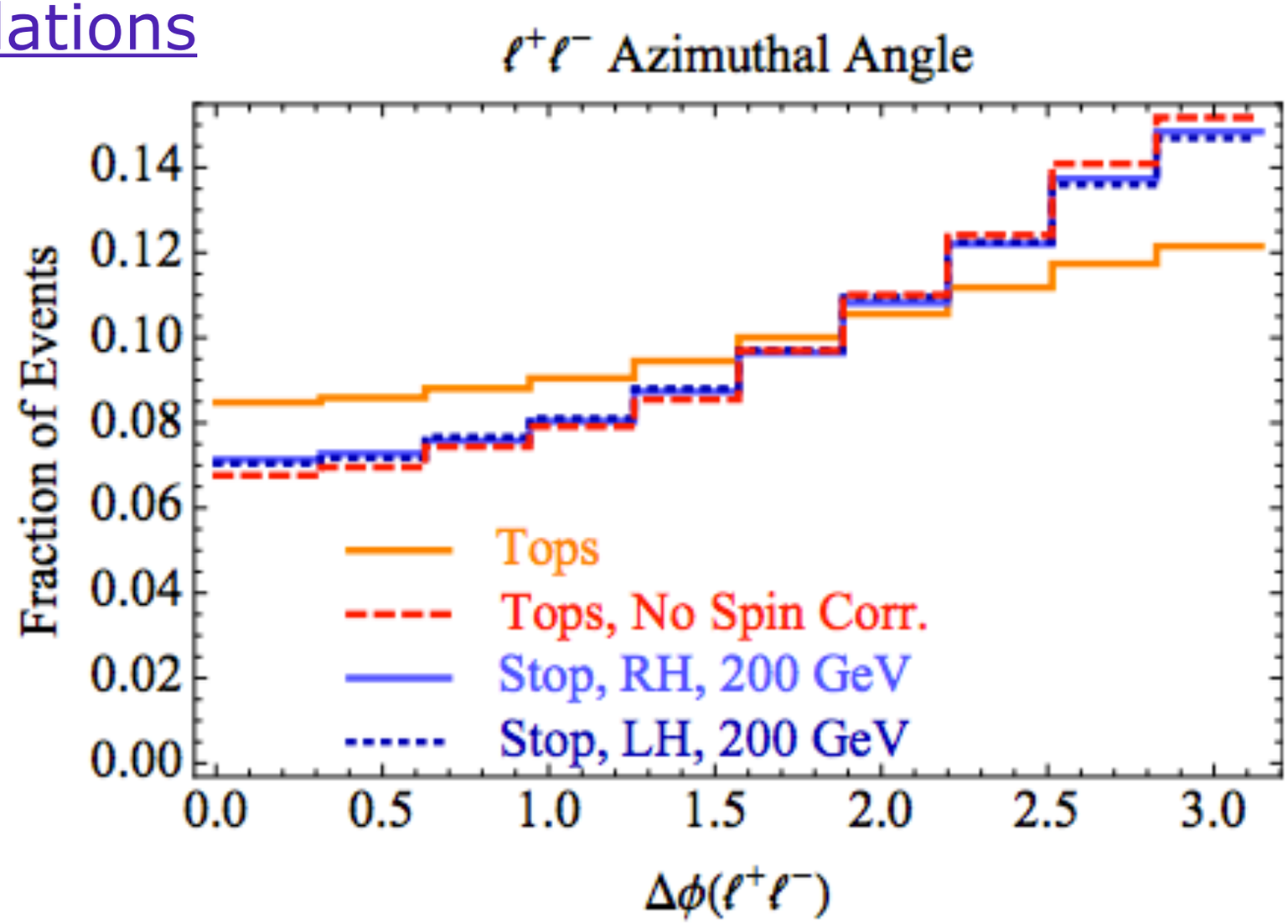


Spin correlations and rapidity gaps

arXiv:1205.5808 Han, Katz, Krohn, Reece

- focused on window around top mass and massless LSP/gravitino
- dileptonic mode with one b-tag

spin correlations



- insensitive to higher order corrections

Spin correlations and rapidity gaps

arXiv:1205.5808 Han, Katz, Krohn, Reece

- reconstructed the 2 neutrinos from MET + W and top mass constraints

- for each event, compute probability of (un)correlation using matrix element with(out) correlations

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

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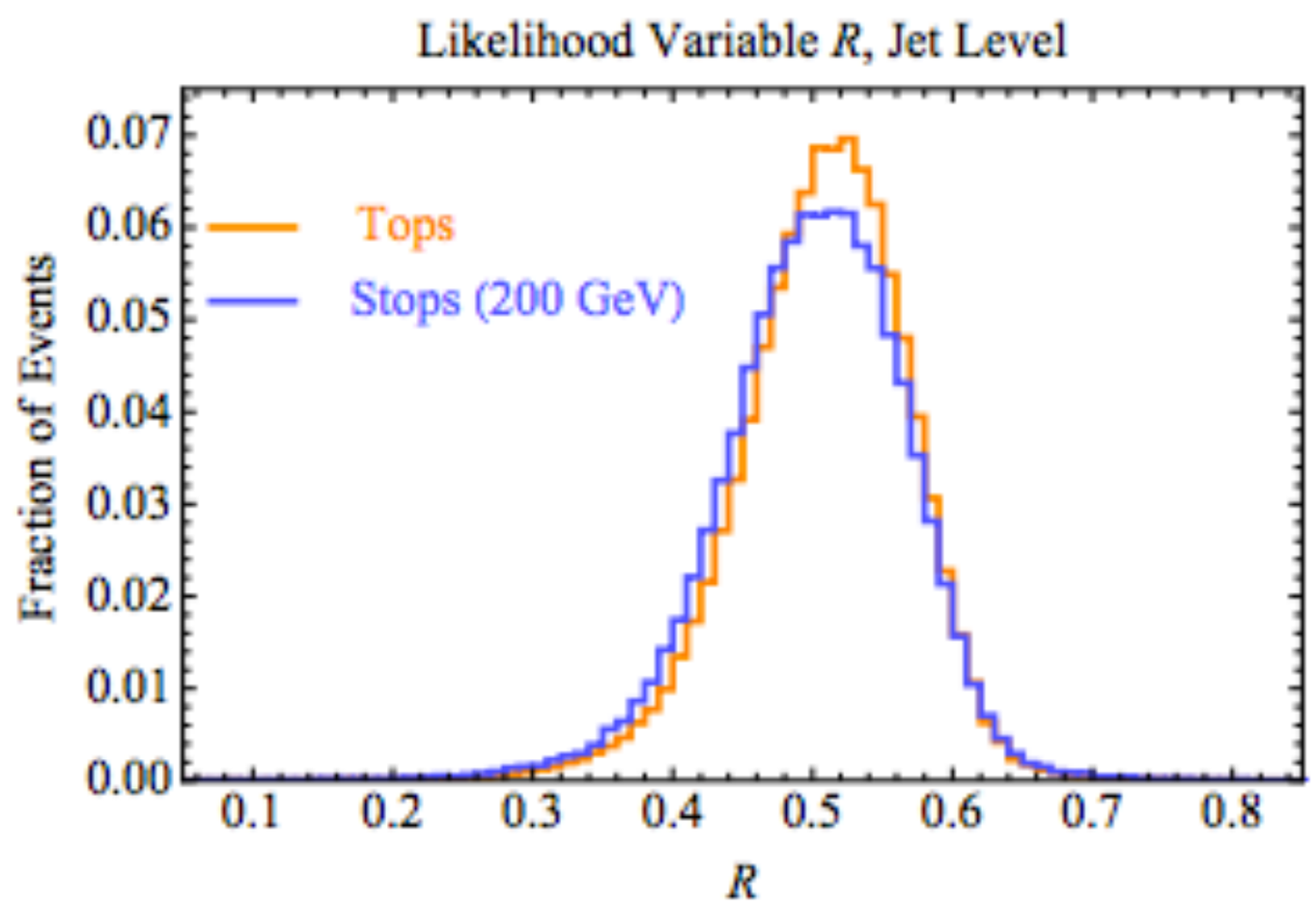
- define likelihood for an event to be a correlated top-pair

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



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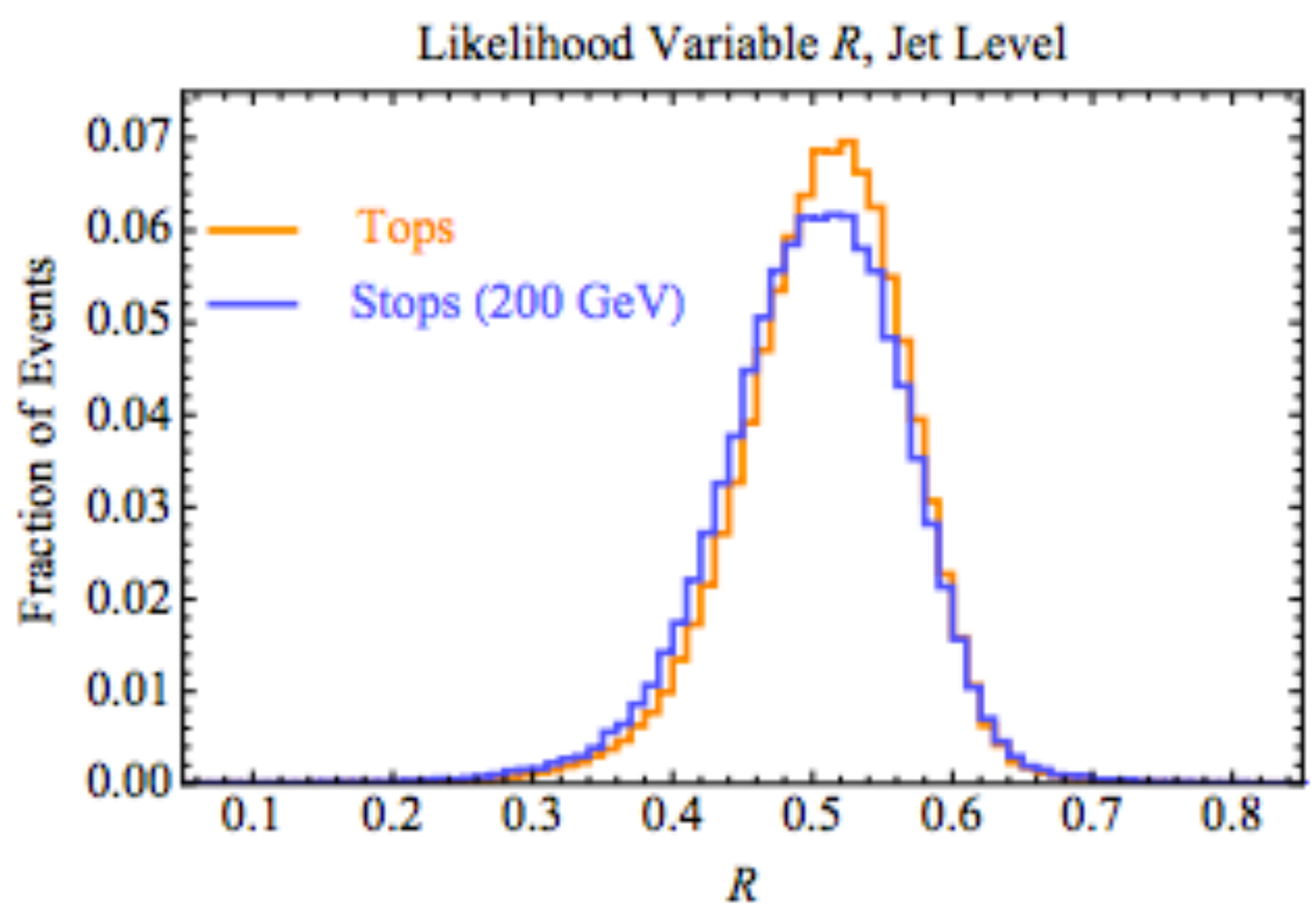
- define likelihood for an event to be a correlated top-pair

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

- with likelihood fit of "R" distribution, exclude m_{stop}=200 GeV @ 95%C.L.



Spin correlations and rapidity gaps

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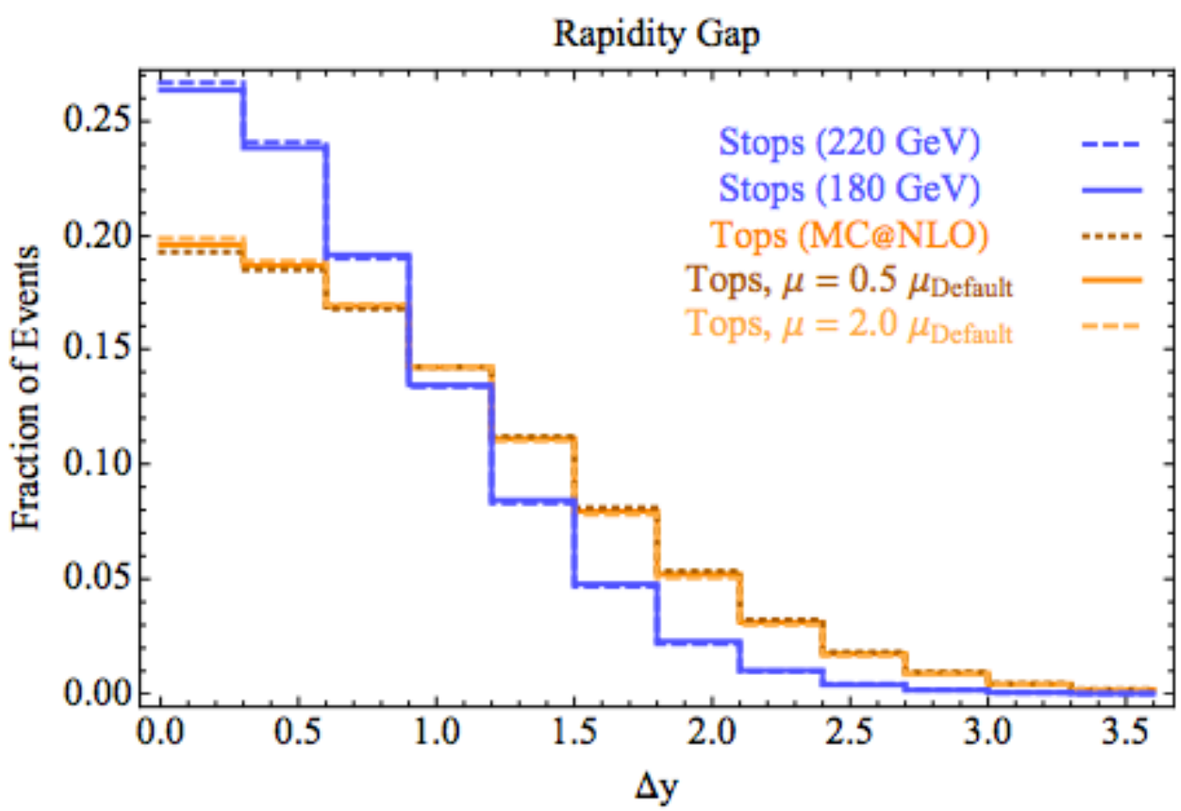
ttbar rapidity gap

- for ttbar, u- and t-channel singularities (regulated by top mass) lead to more forward tops produced than stops



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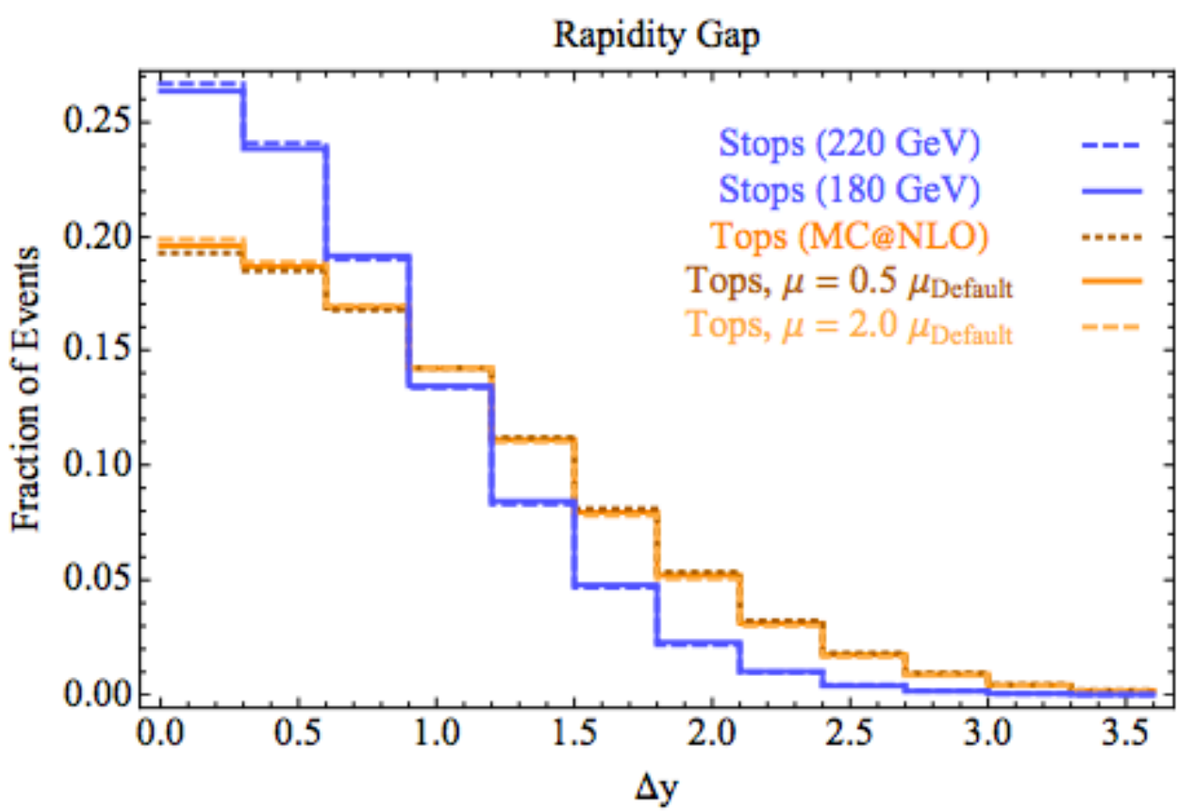
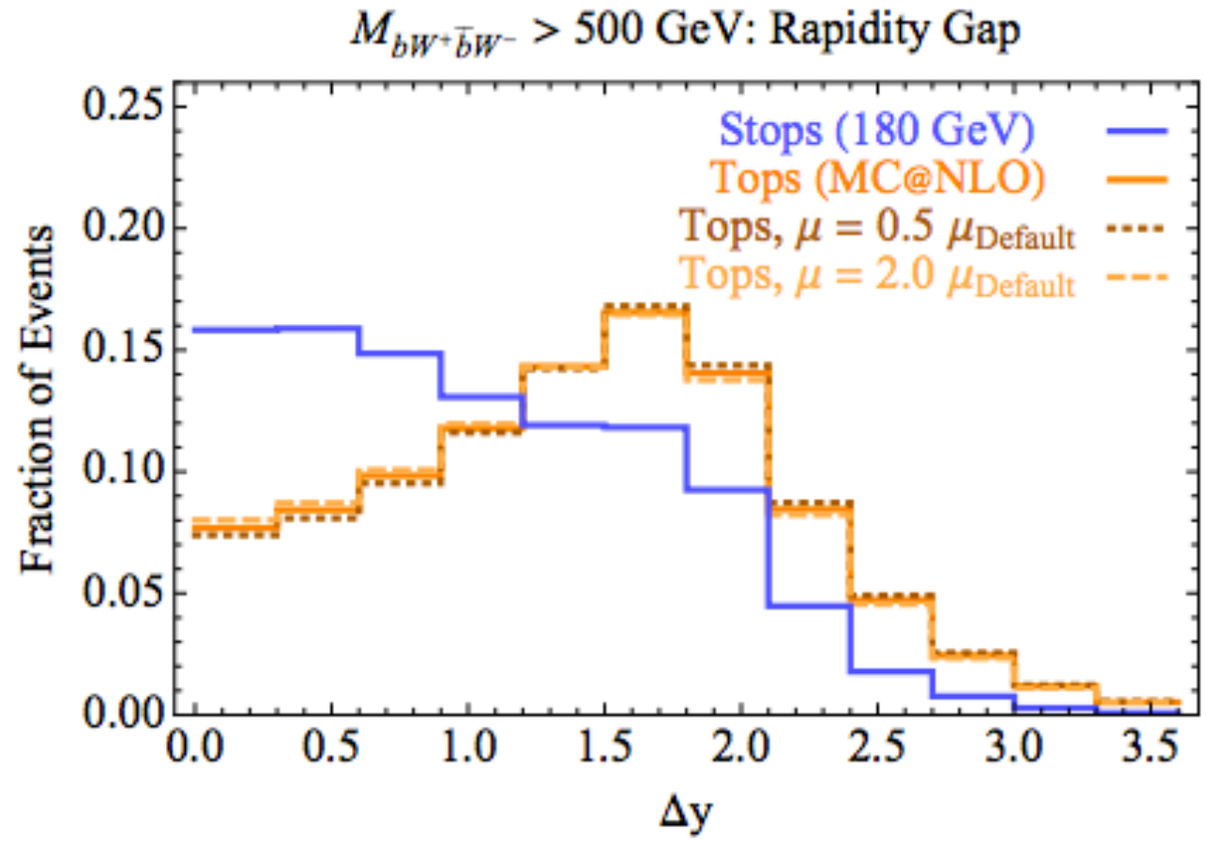
ttbar rapidity gap

- for ttbar, u- and t-channel singularities (regulated by top mass) lead to more forward tops produced than stops
- difference increases at high ttbar invariant mass

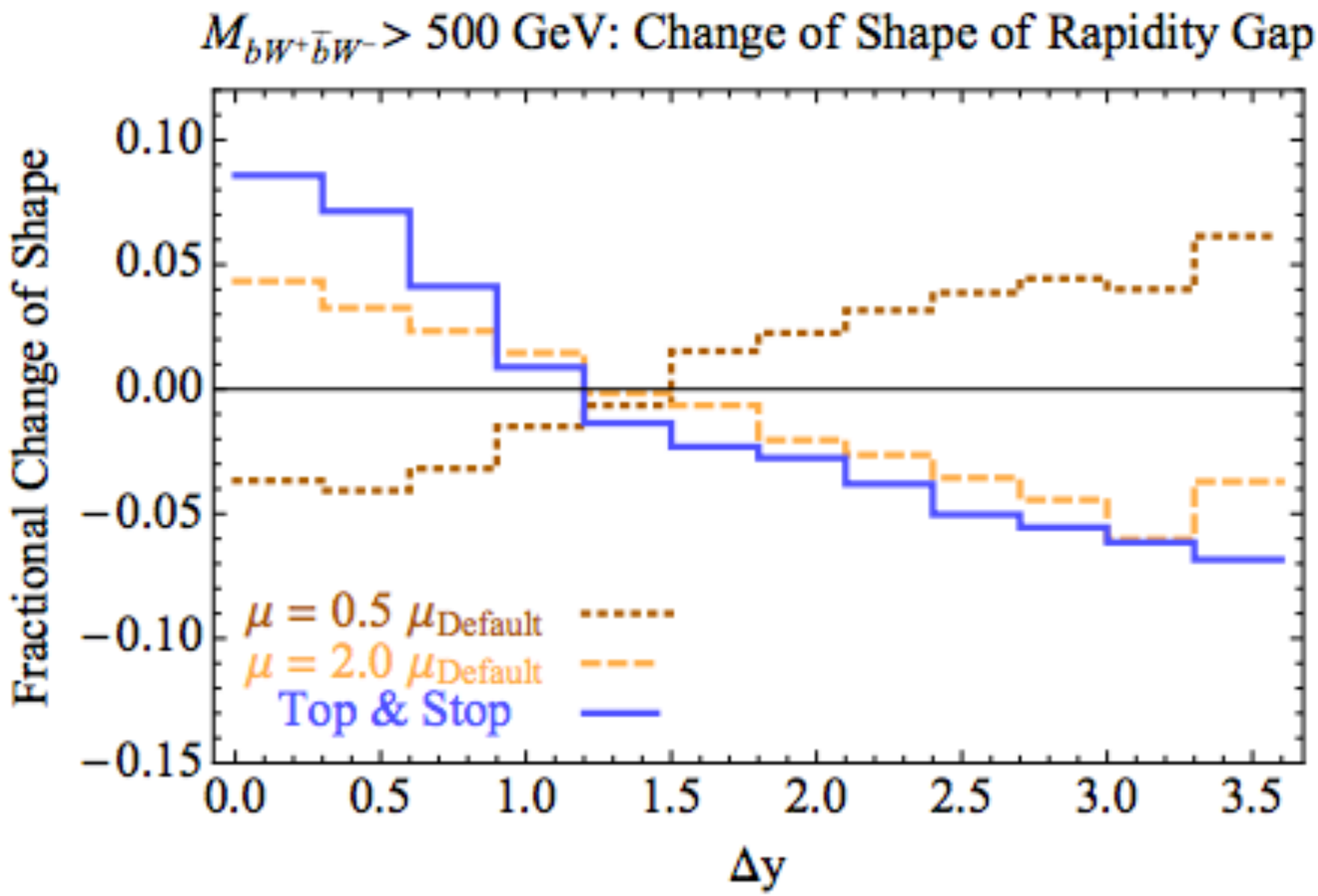




Spin correlations and rapidity gaps

arXiv:1205.5808 Han, Katz, Krohn, Reece

- effect can be mimicked by change in renormalization and factorization scales



Spin correlations and rapidity gaps

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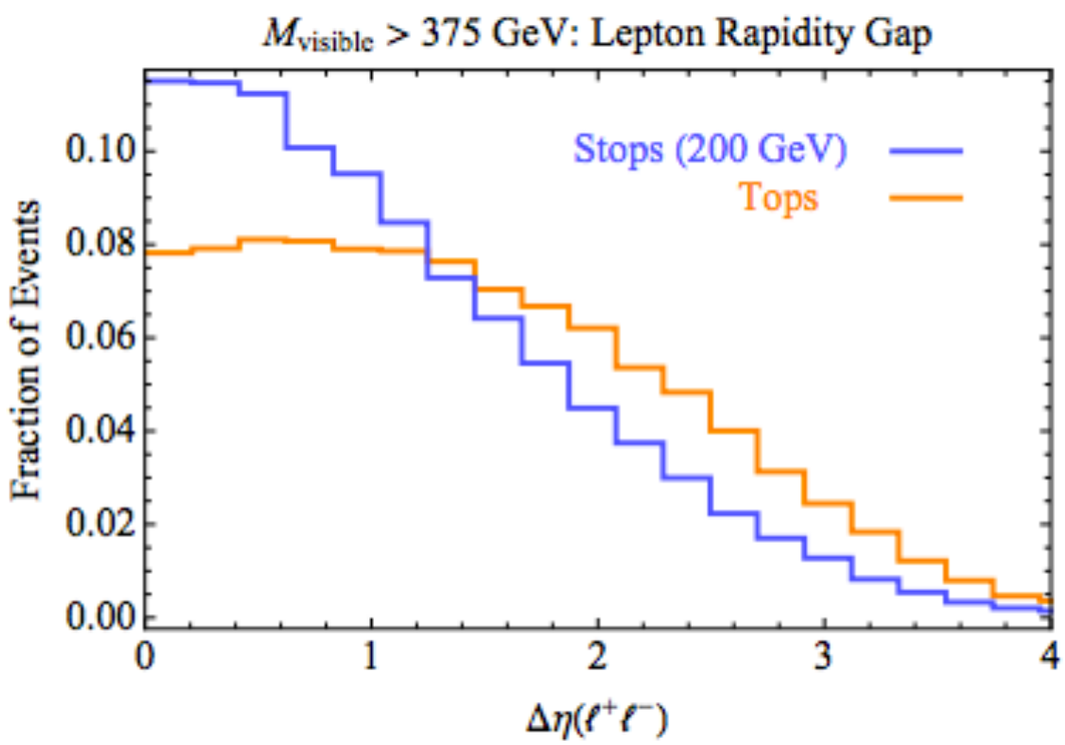
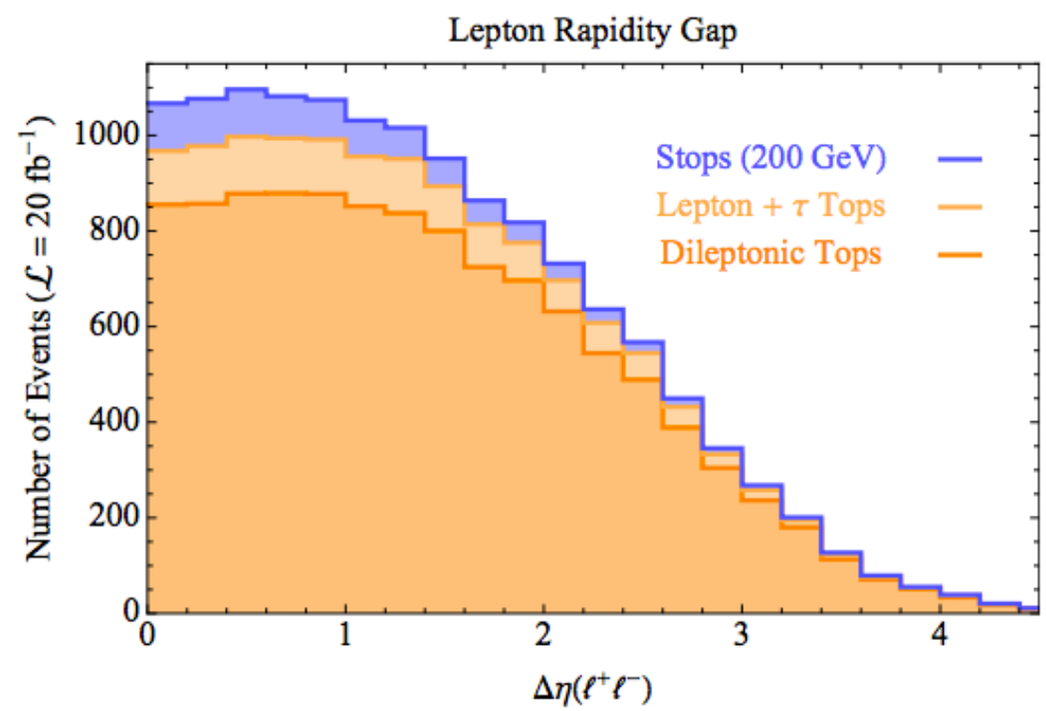
- effect also present in lepton rapidity gap





- using difference in rapidity gap distribution between ttbar and stops, exclude m_{stop}=200 GeV at 2σ.

- combining rapidity gap + spin correlation, exclusion reaches 3σ with 20/fb @ 8 TeV.

Spin correlations and rapidity gaps

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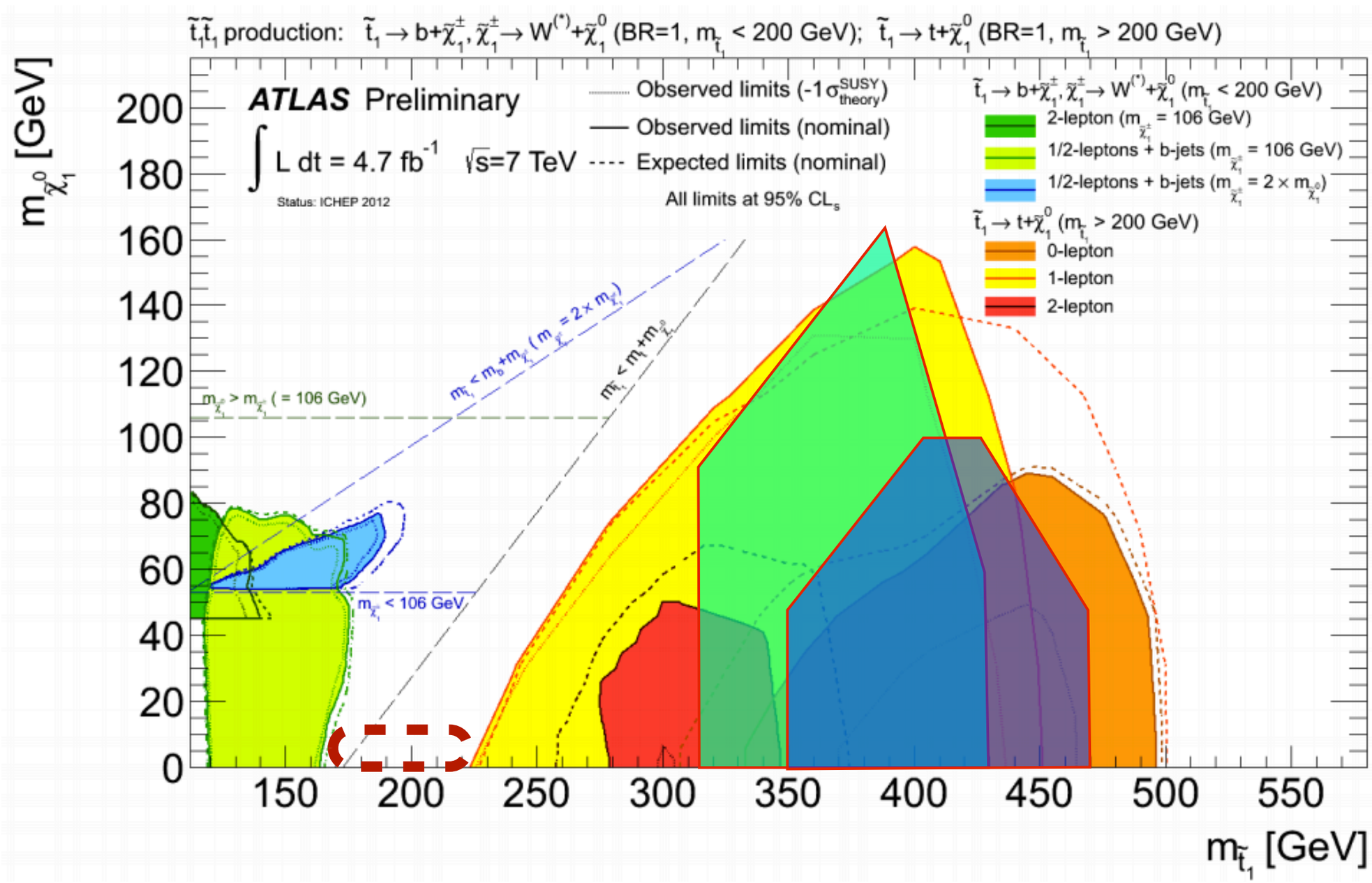
estimated reach with 20/fb @ 8 TeV



Top-tagging boosted tops from stop decays

arXiv:1205.5816 Kaplan, Rehermann, Stolarski

(see also arXiv:1205.2696 Plehn, Spannowsky, Takeuchi)

- fully hadronic stop decays

event selection:

- veto on isolated leptons
- MET > 175 GeV
- cluster all hadronic activity into “fat jets” (Cambrigde-Aachen algorithm with R=1.2)
- require one of the 2 leading fat jets to pass a HEPTopTagger
- require other fat jet to be b-tagged

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kills QCD and hadronic tops

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kills V+bbar+jets

- require other fat jet to be b-tagged

kills V+jets

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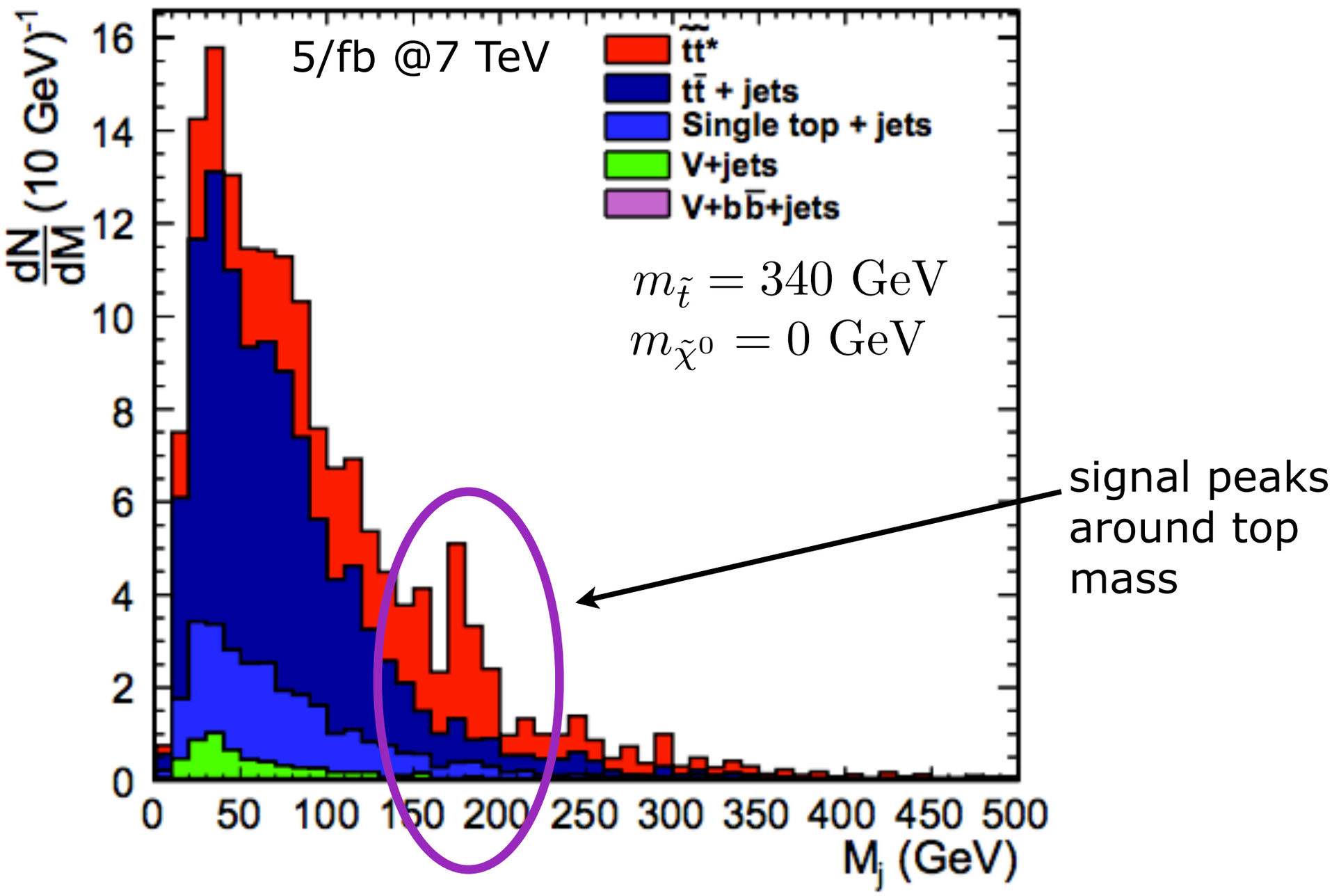
- look at filtered invariant mass of non-HEPTop-tagged jet



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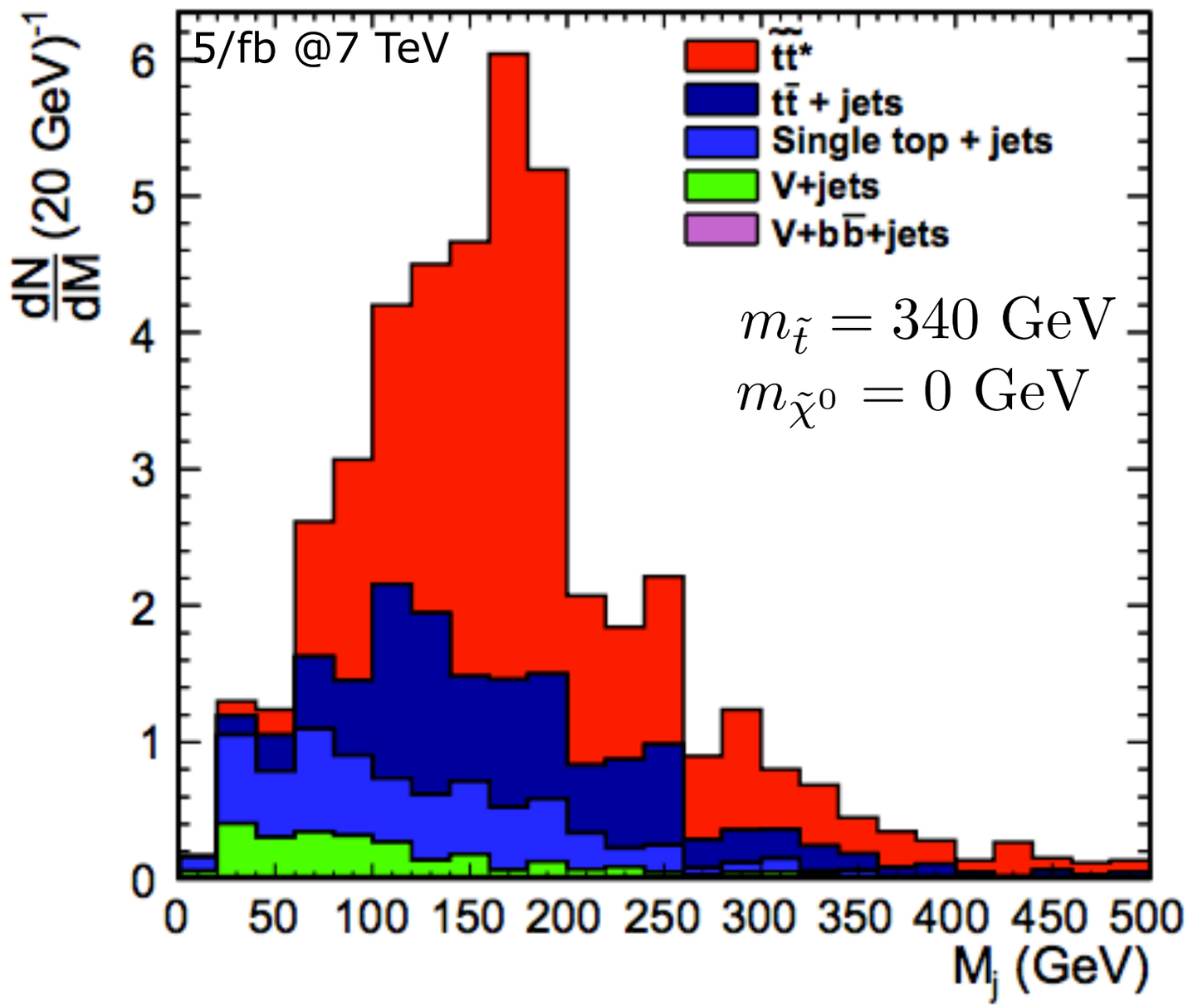
exacerbate peak by requiring:

- M_{T2}(MET+2 fat jets) > 200 GeV
- min[m_T(fat jet, MET)] > 200 GeV



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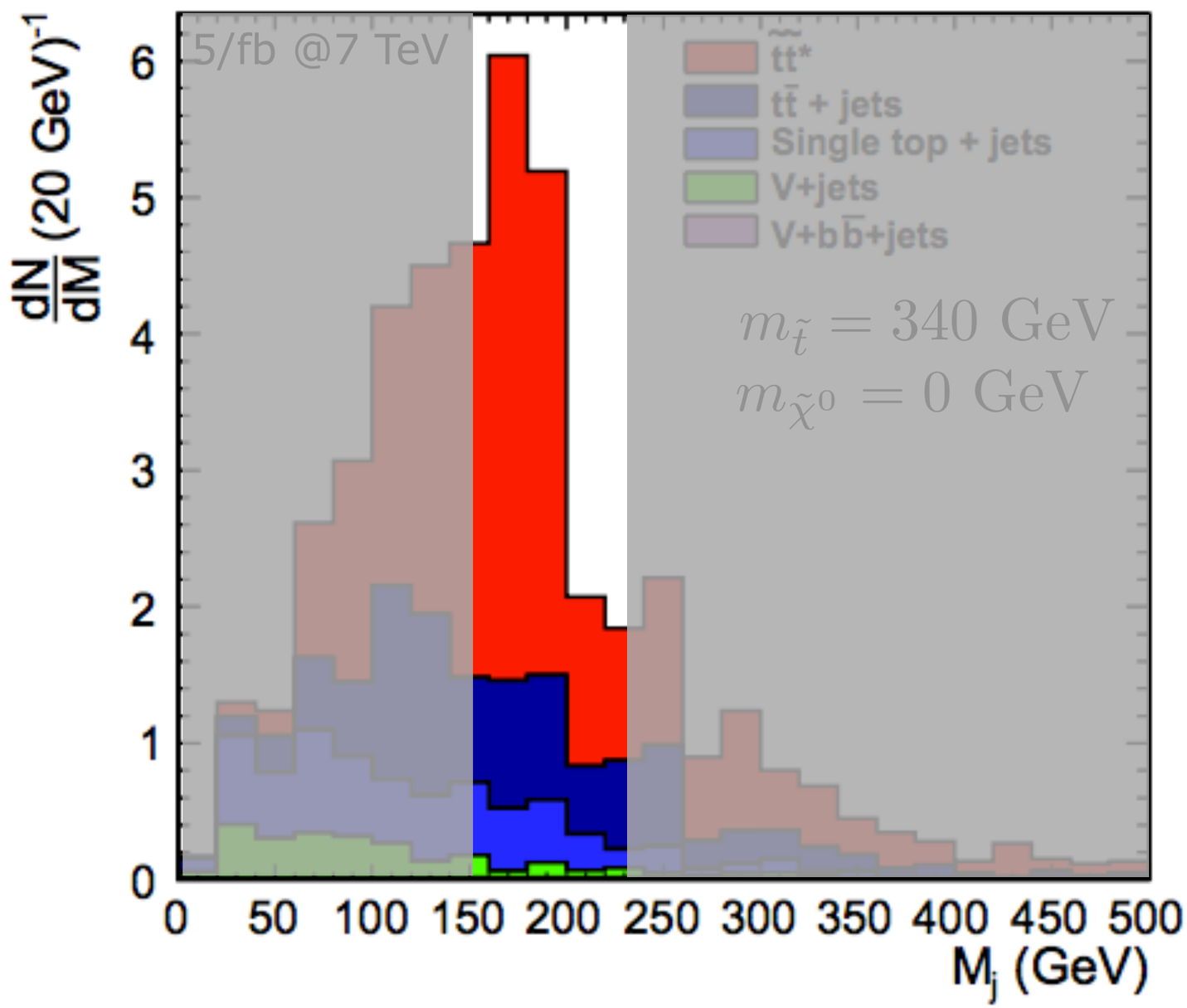
- cut and counts in window 150 < M_j < 230 GeV



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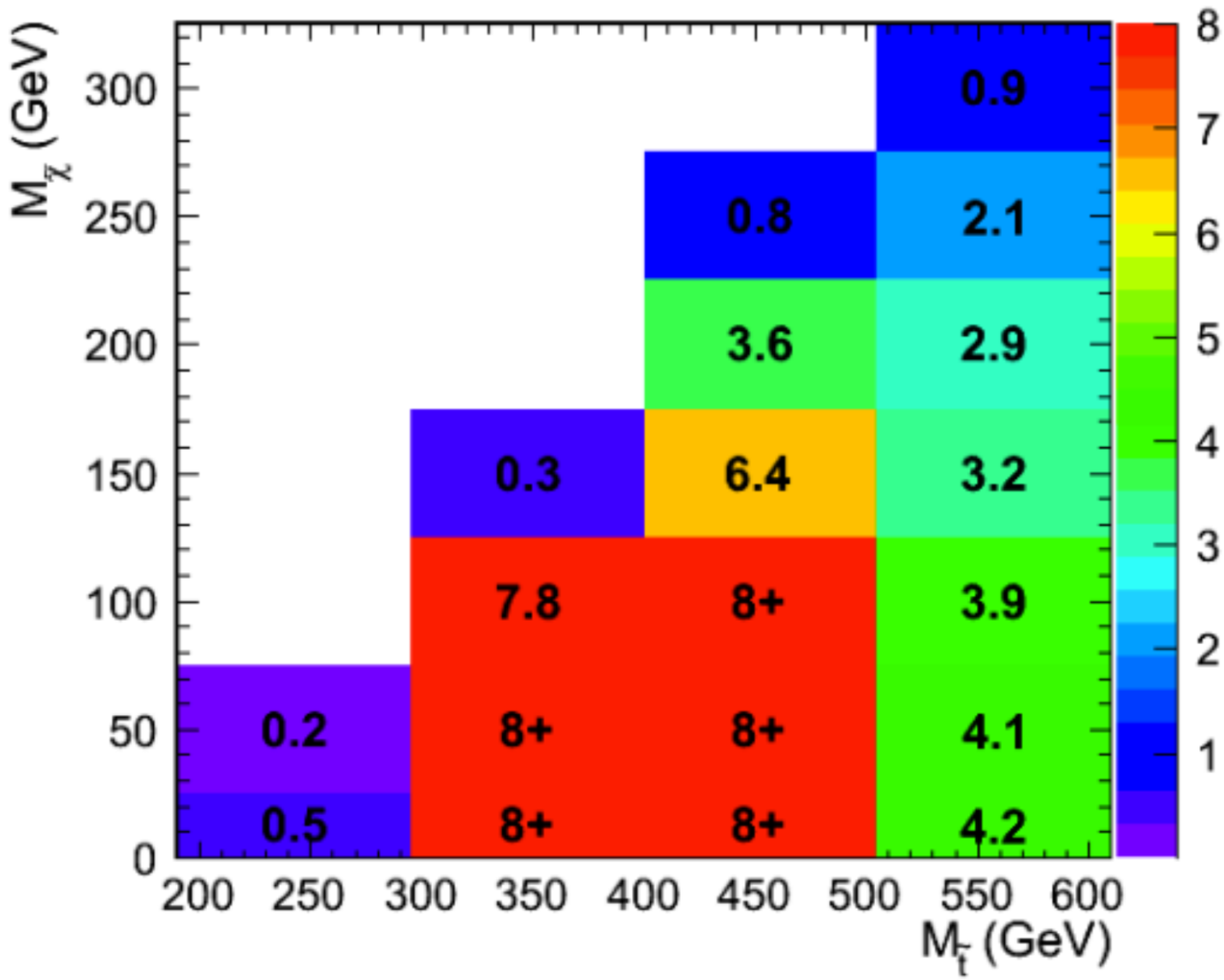

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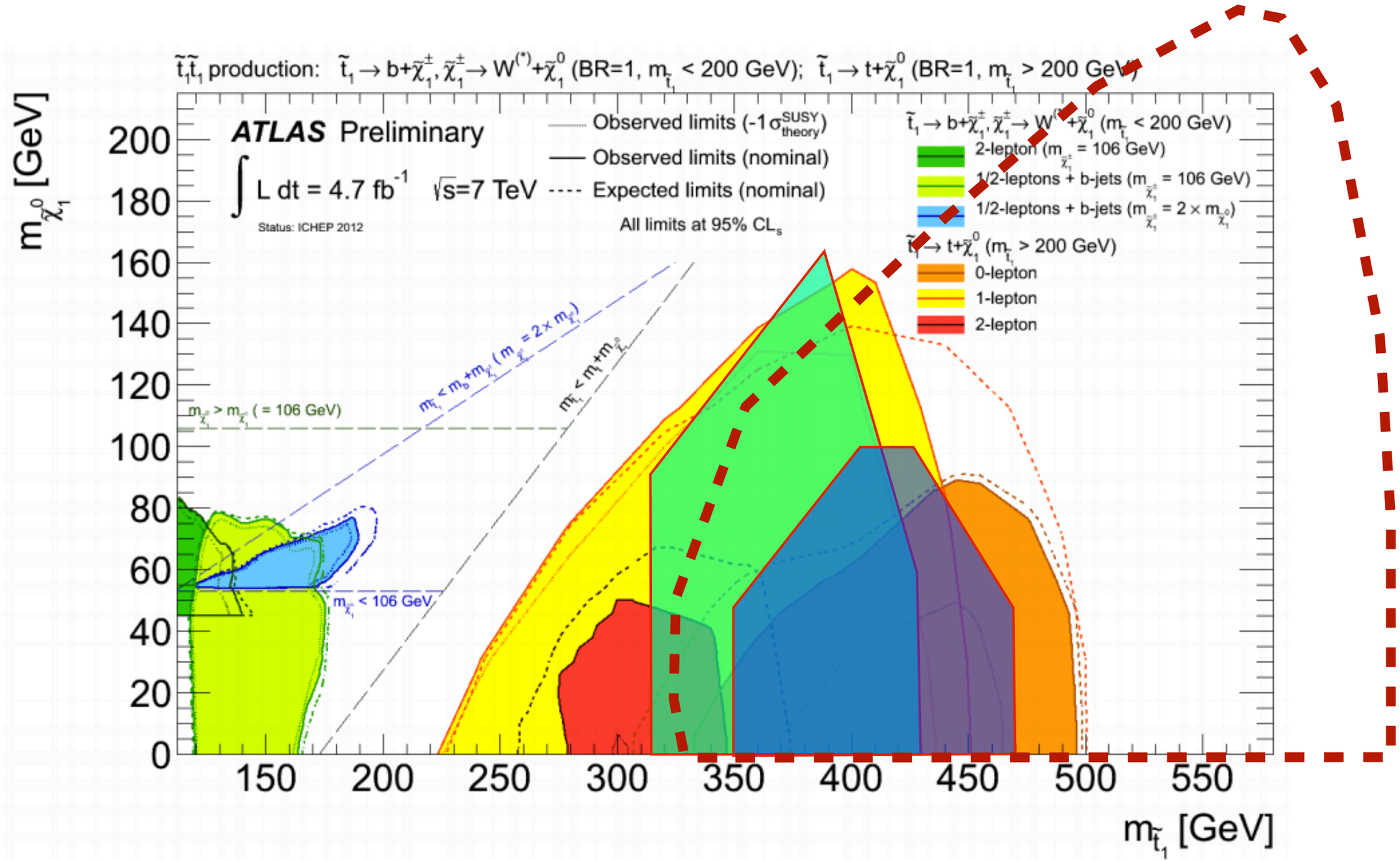
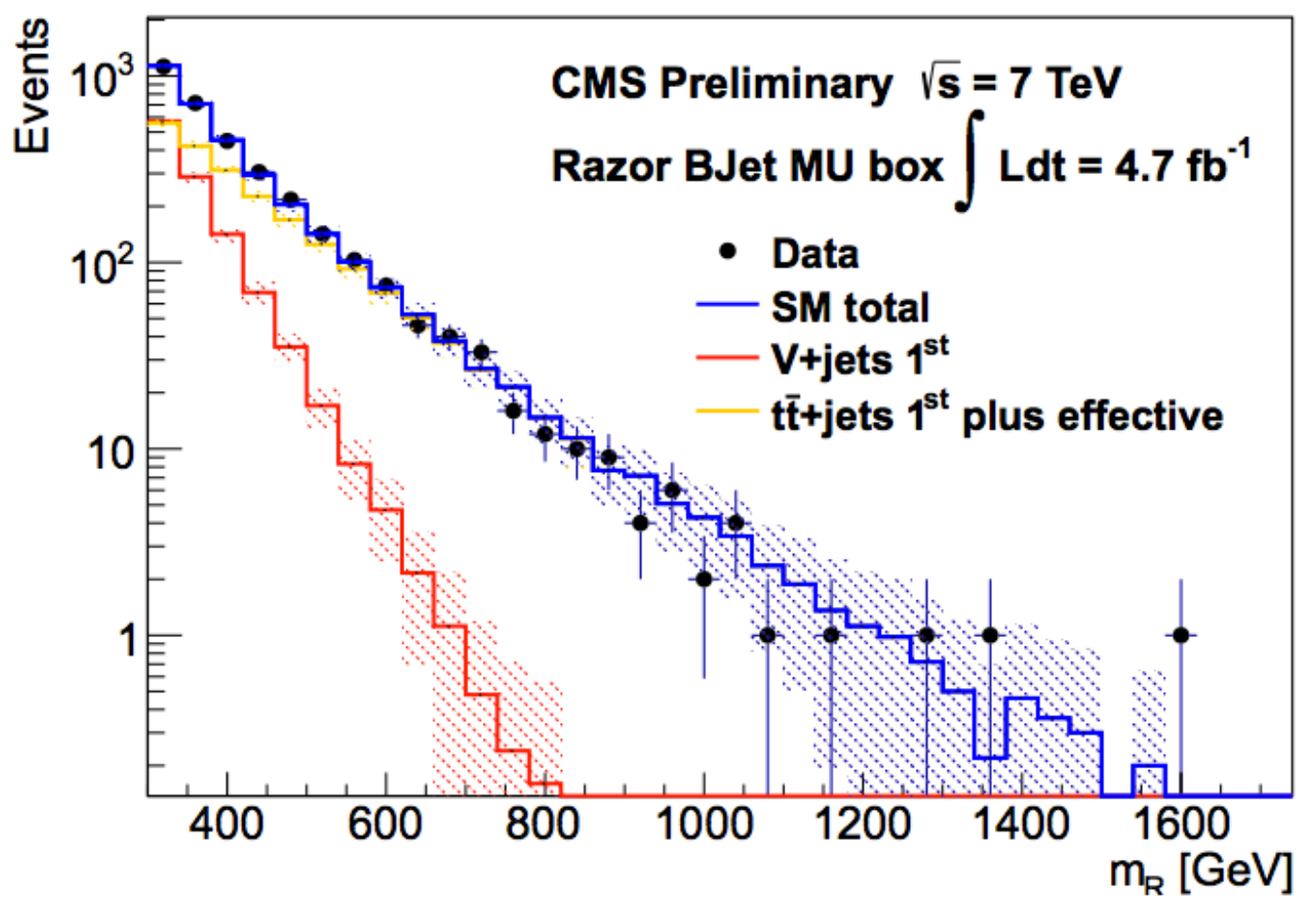


MET and M_T shapes

arXiv:1205.5805 Alves, Buckley, Fox, Lykken, Yu

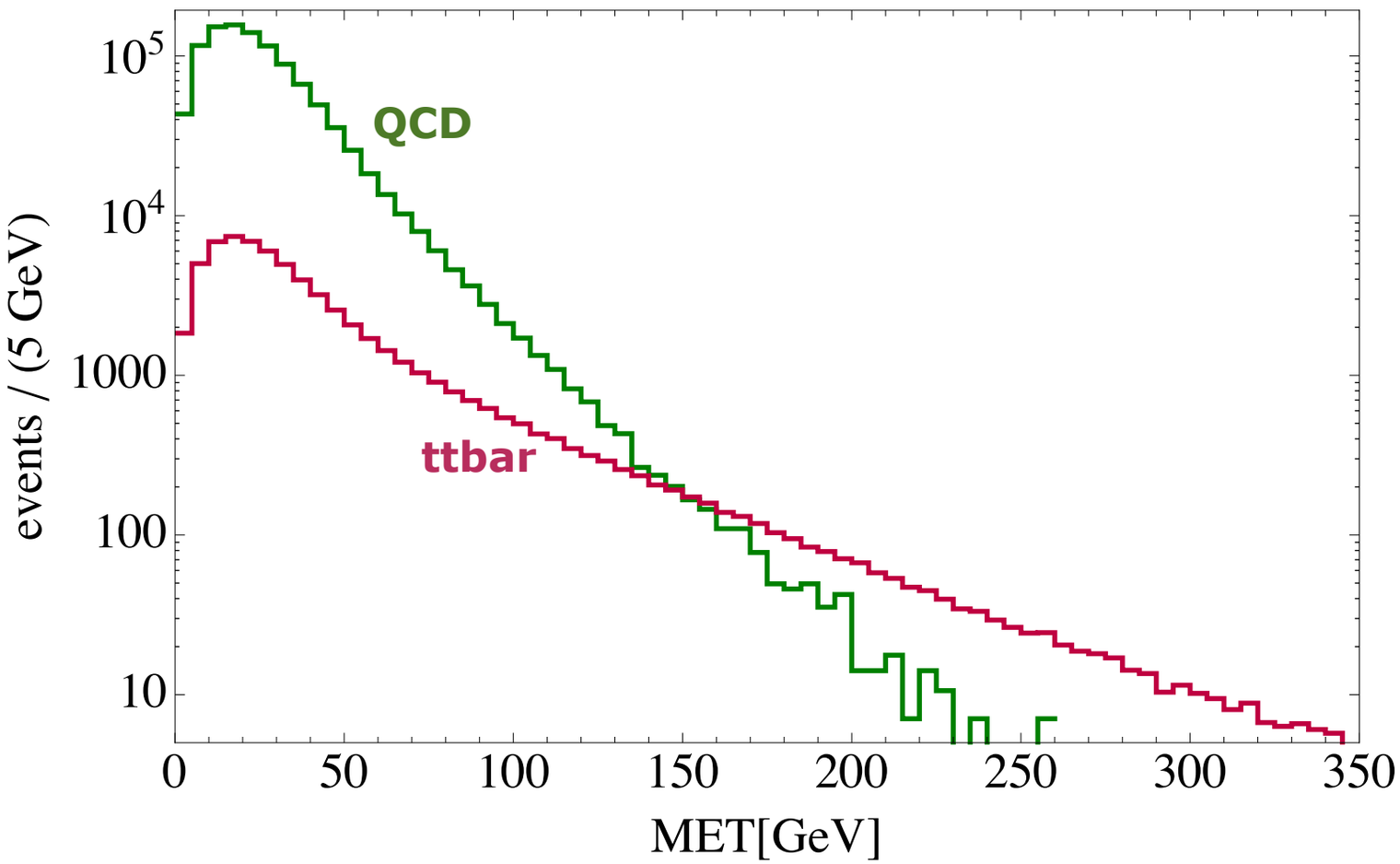
- MET shape in fully hadronic channel
- M_T shape in semi-leptonic channel

- inspired by razor analysis
  - modeling of background by simple analytical functions in certain regions of parameter space



Hadronic Stops: MET shape

- main backgrounds: QCD and ttbar



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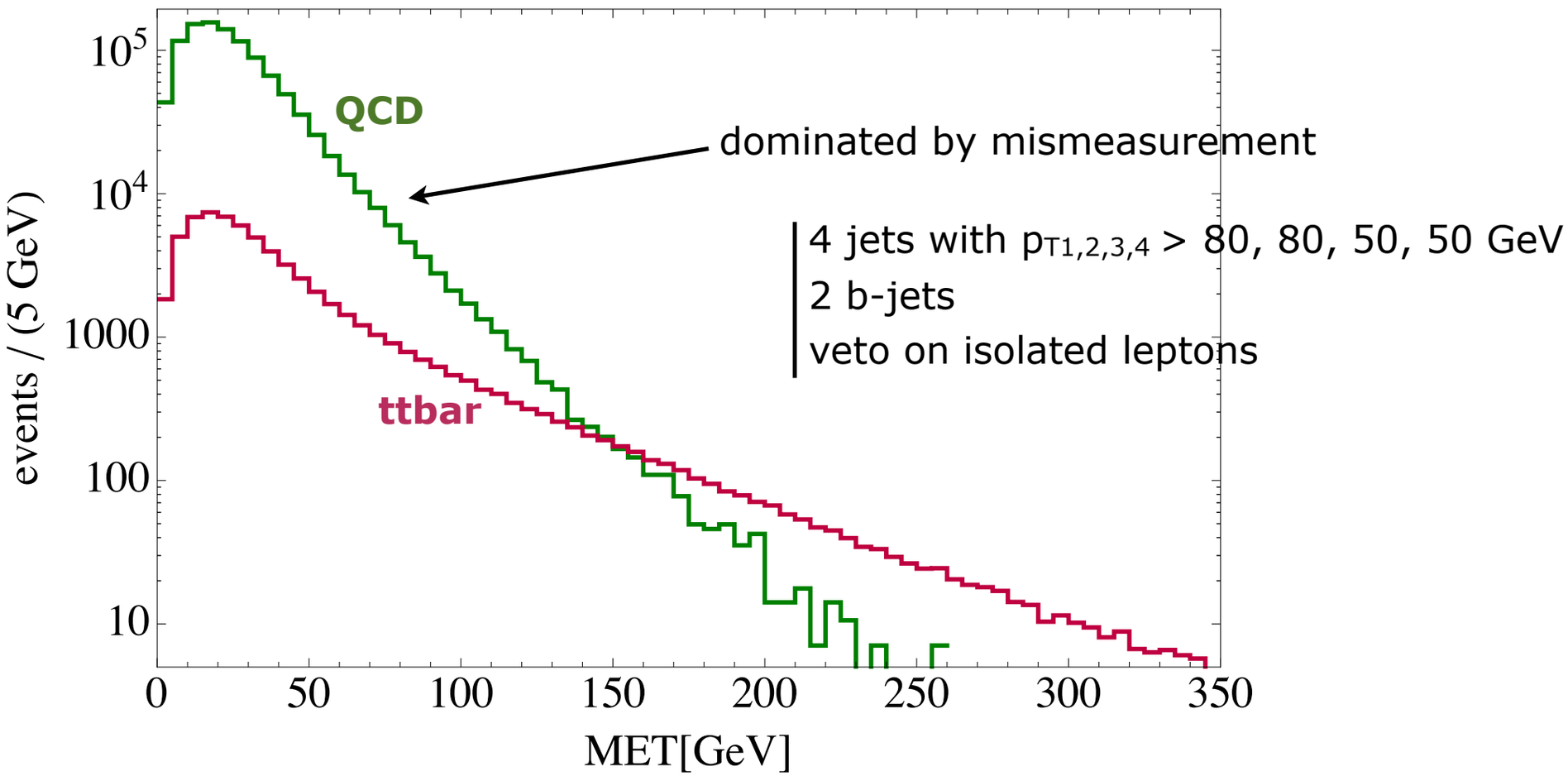

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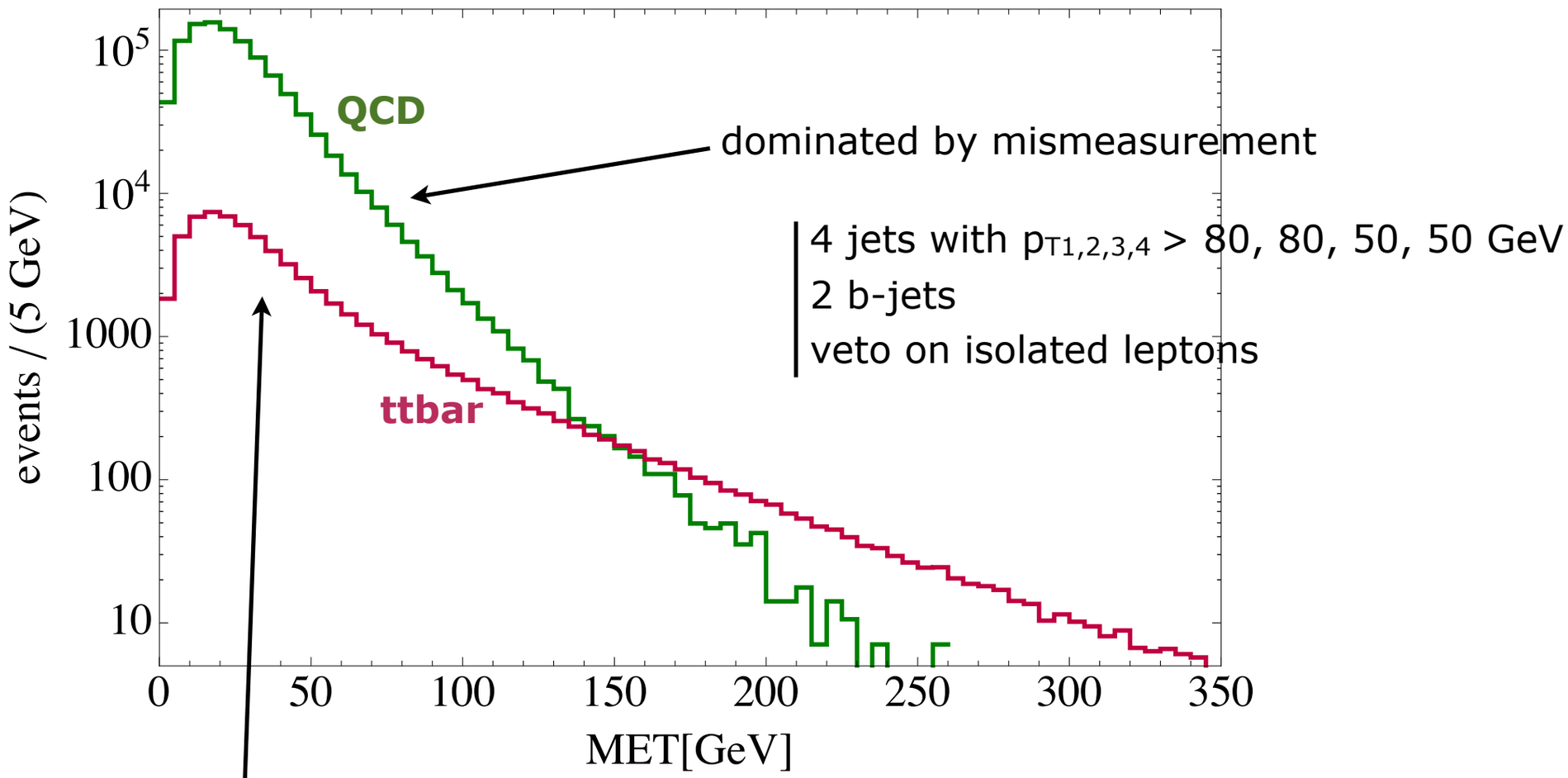

mismeasurement +
ν's from heavy flavor decays

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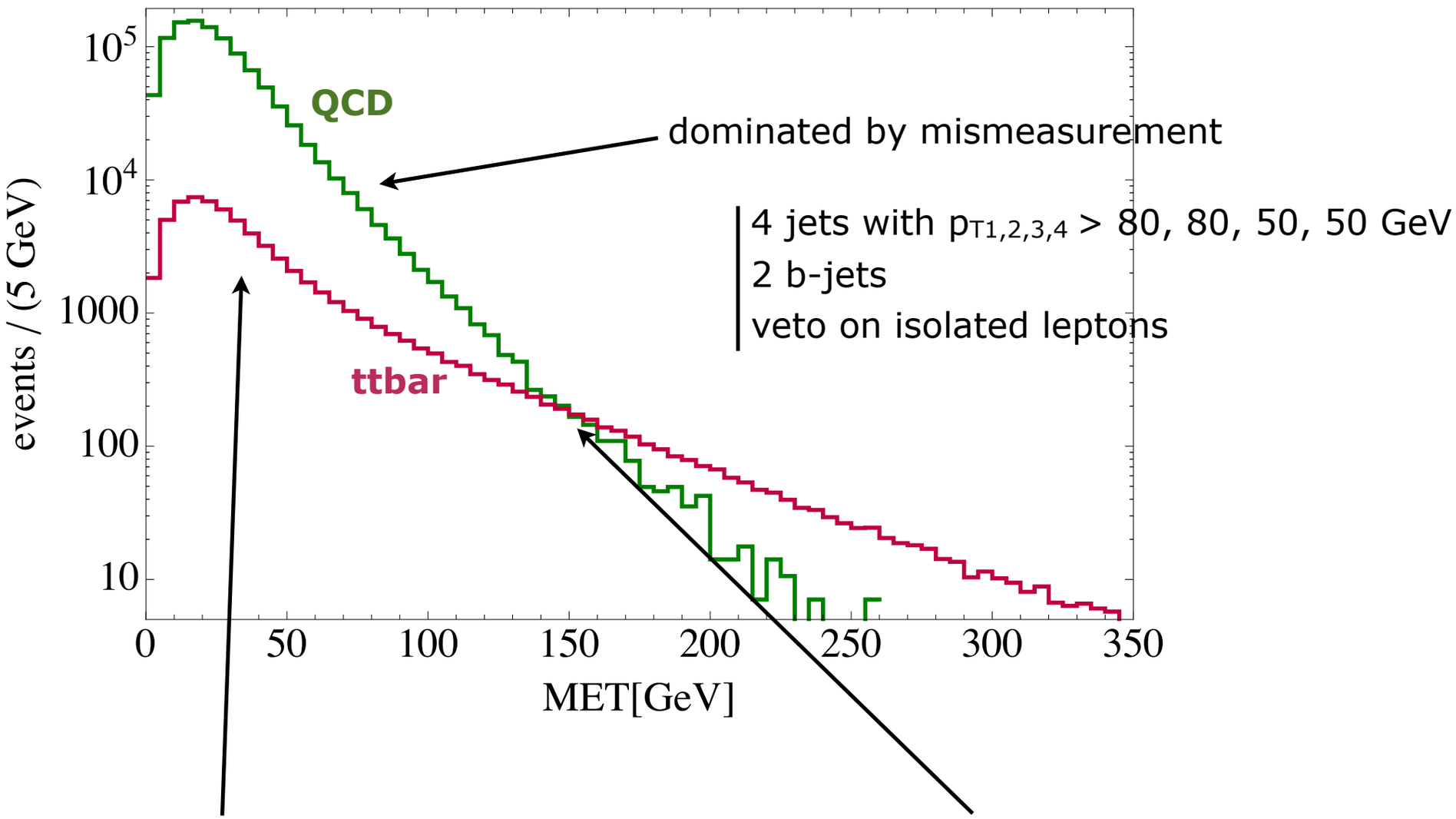

mismeasurement +
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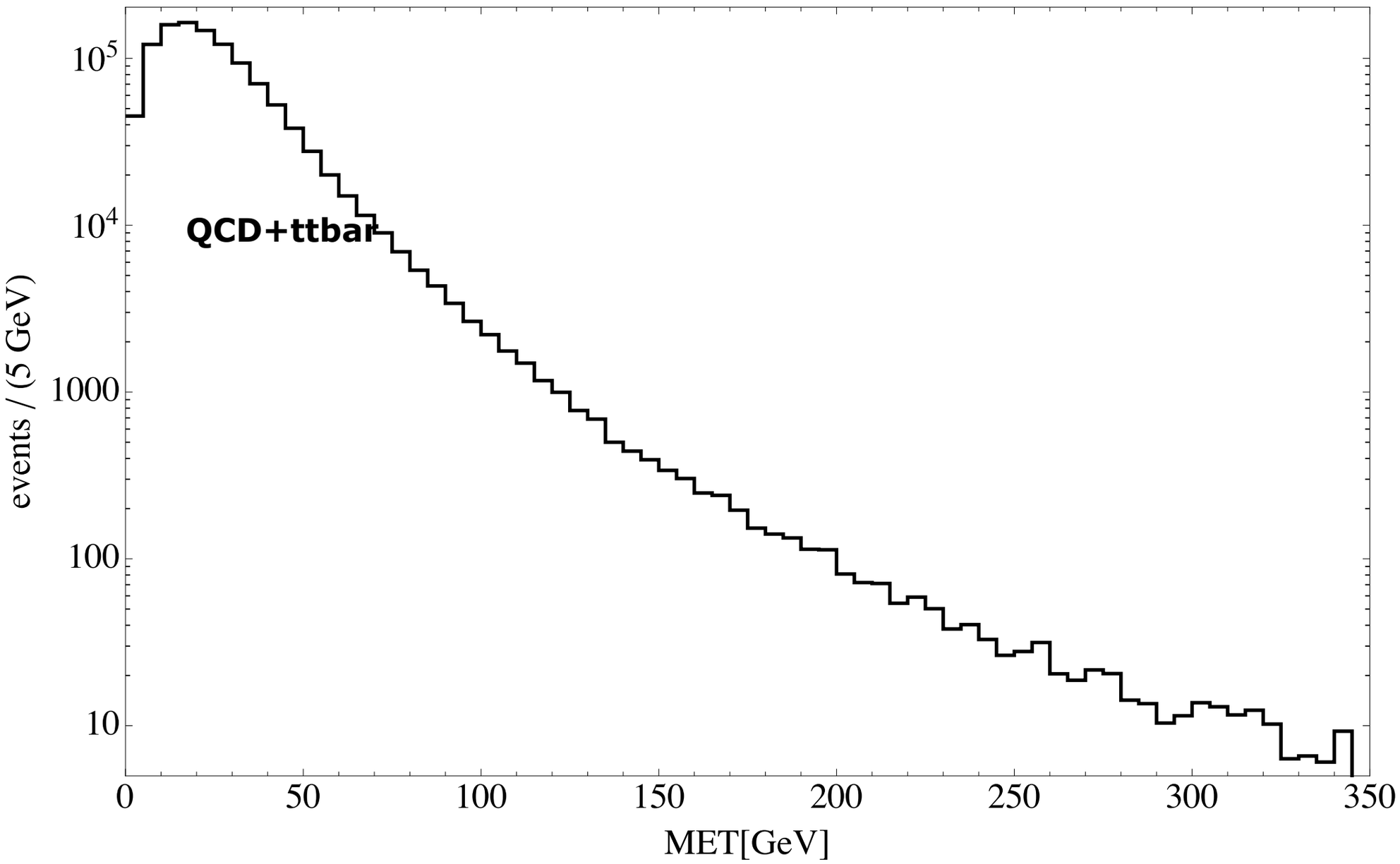
top decays to hadronic τ's

MET for background and signal



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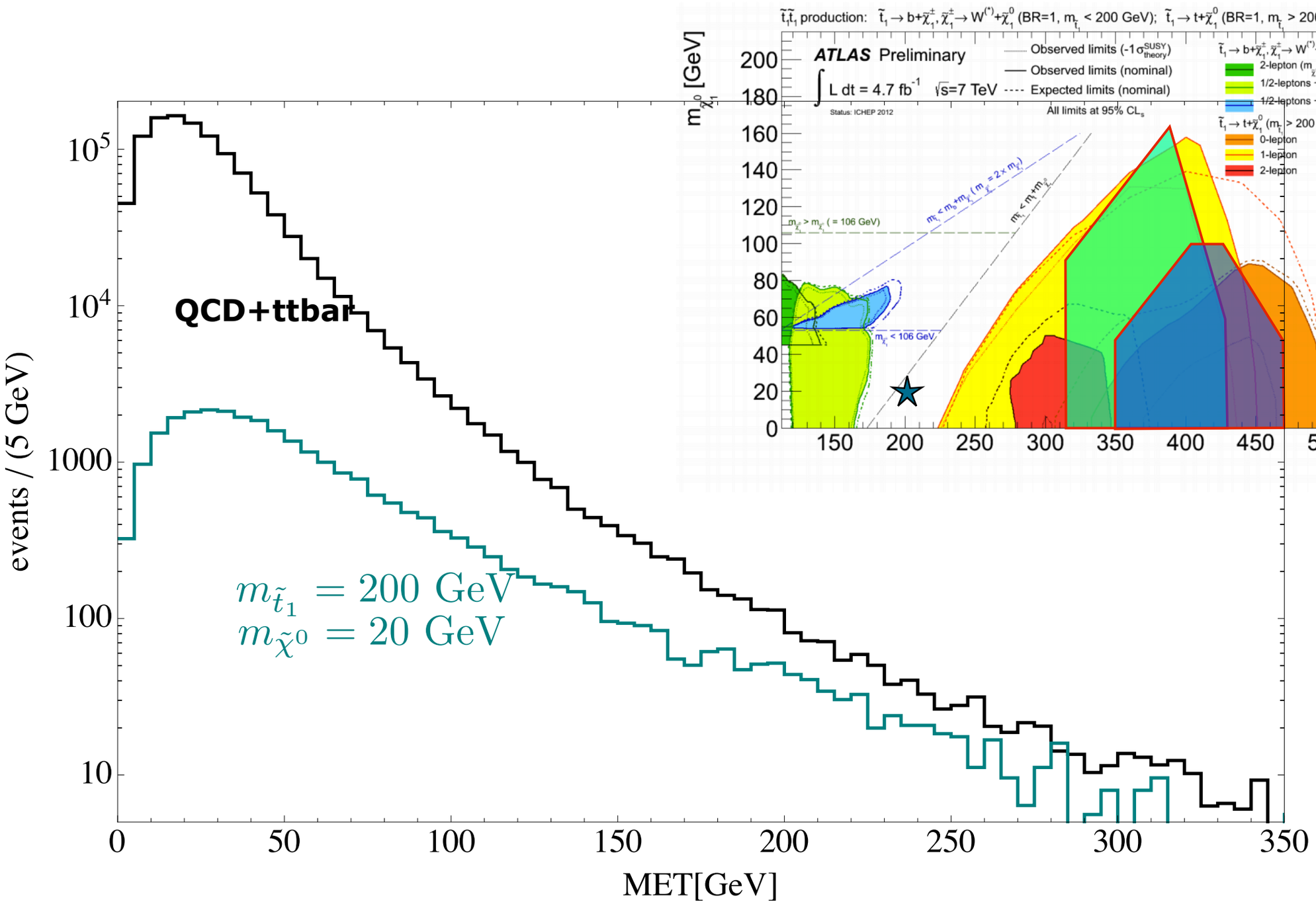

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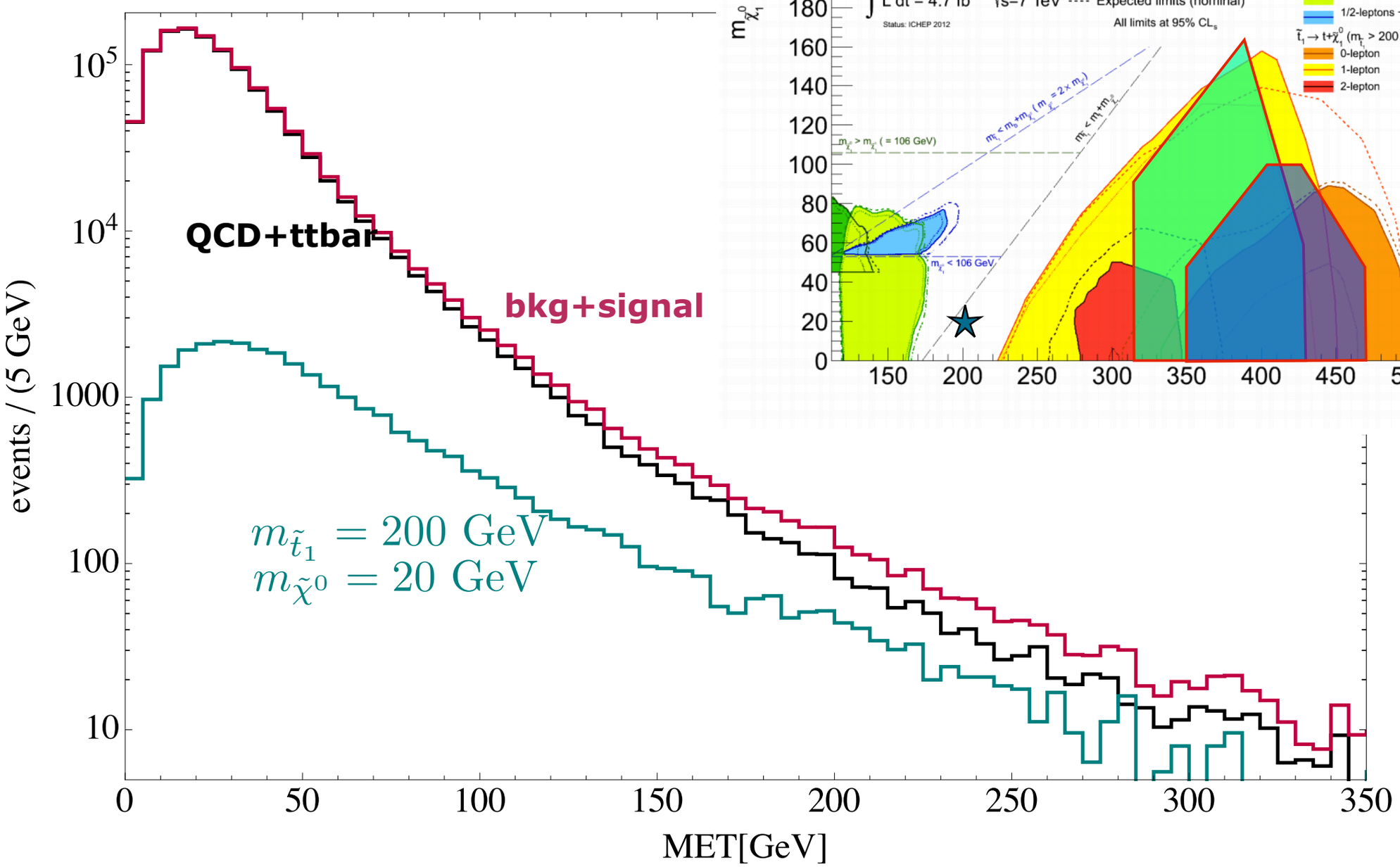
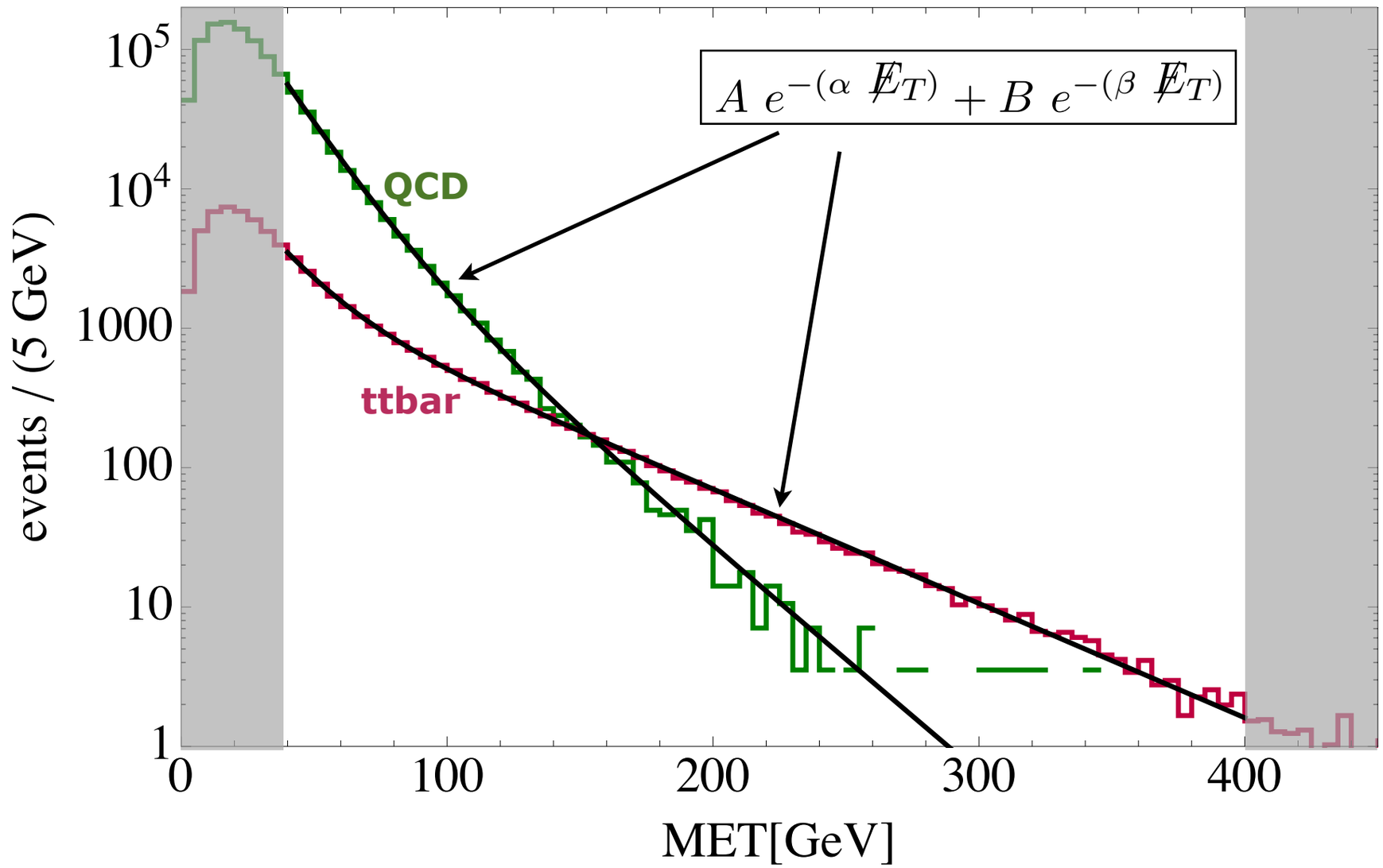


- analytic fit to both backgrounds, 20 fb^{-1} of MC @ 8TeV



- generated 200 toys experiments with background hypothesis
- for each toy, extracted signal exclusion using binned likelihood
- included fit errors in likelihood
- to be conservative, ignored correlations between parameters

MET and M_T shapes

arXiv:1205.5805 Alves, Buckley, Fox, Lykken, Yu

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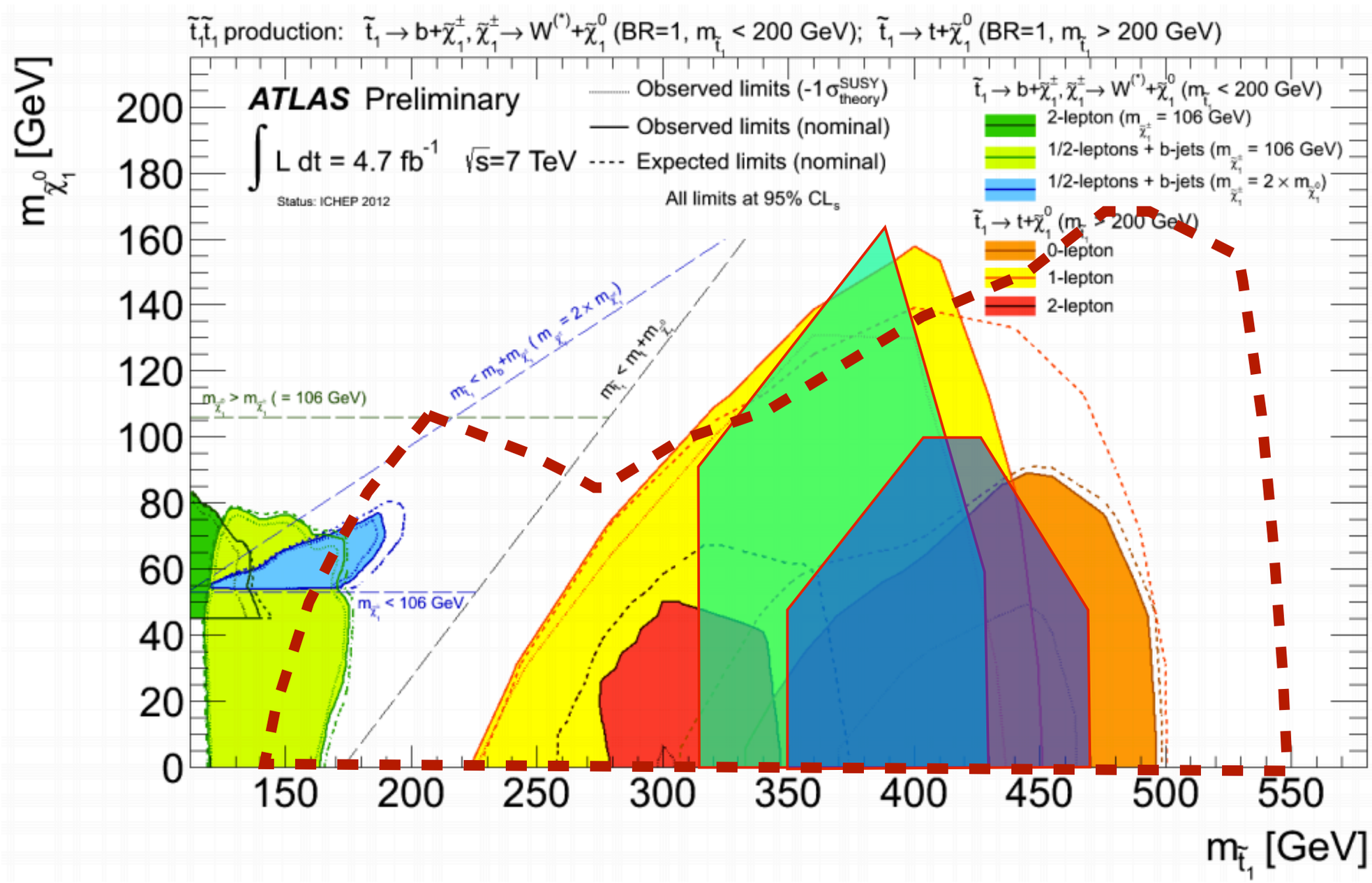
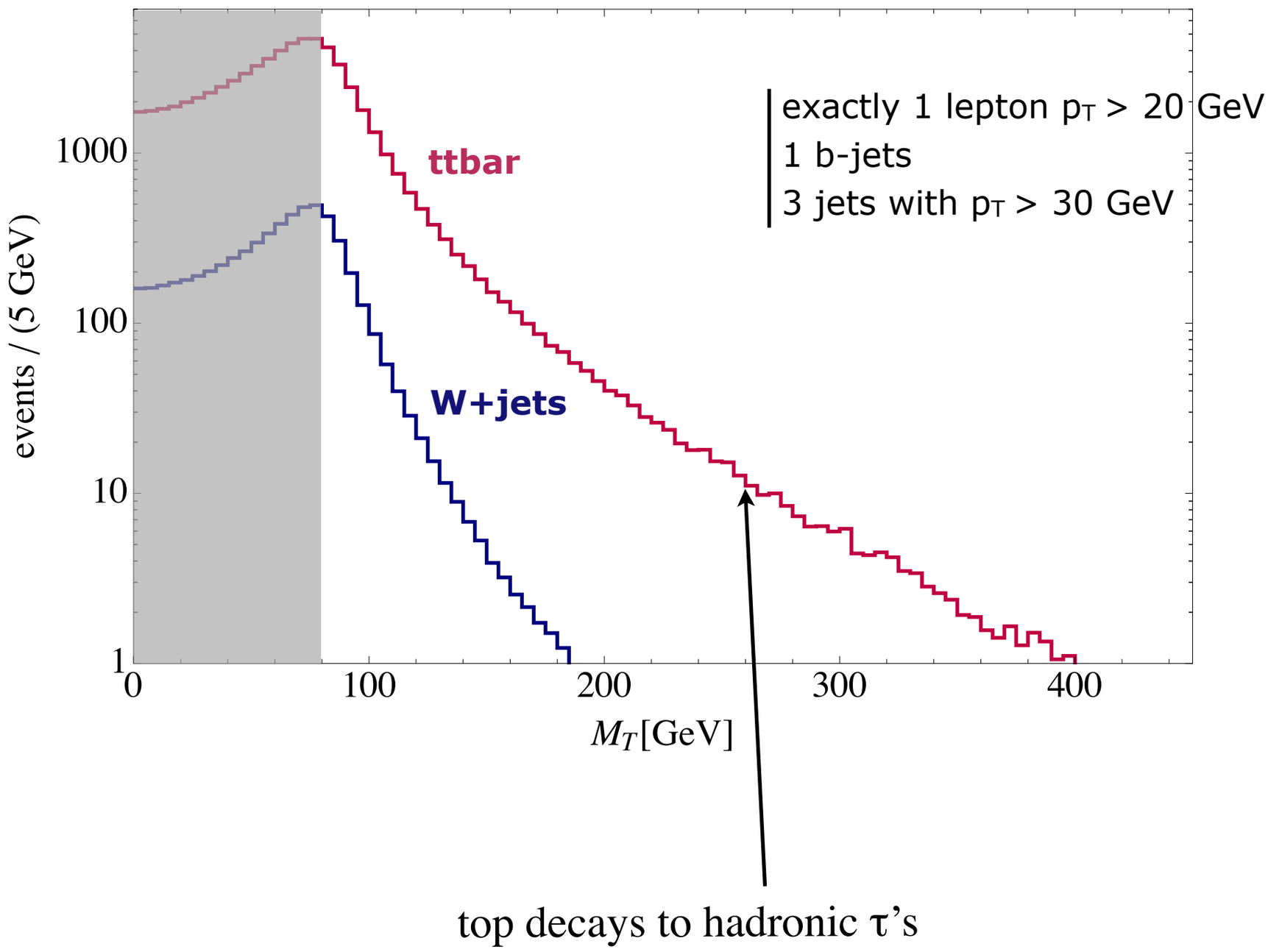


Semi-Leptonic Stops: M_T shape

- main backgrounds: ttbar and W+jets



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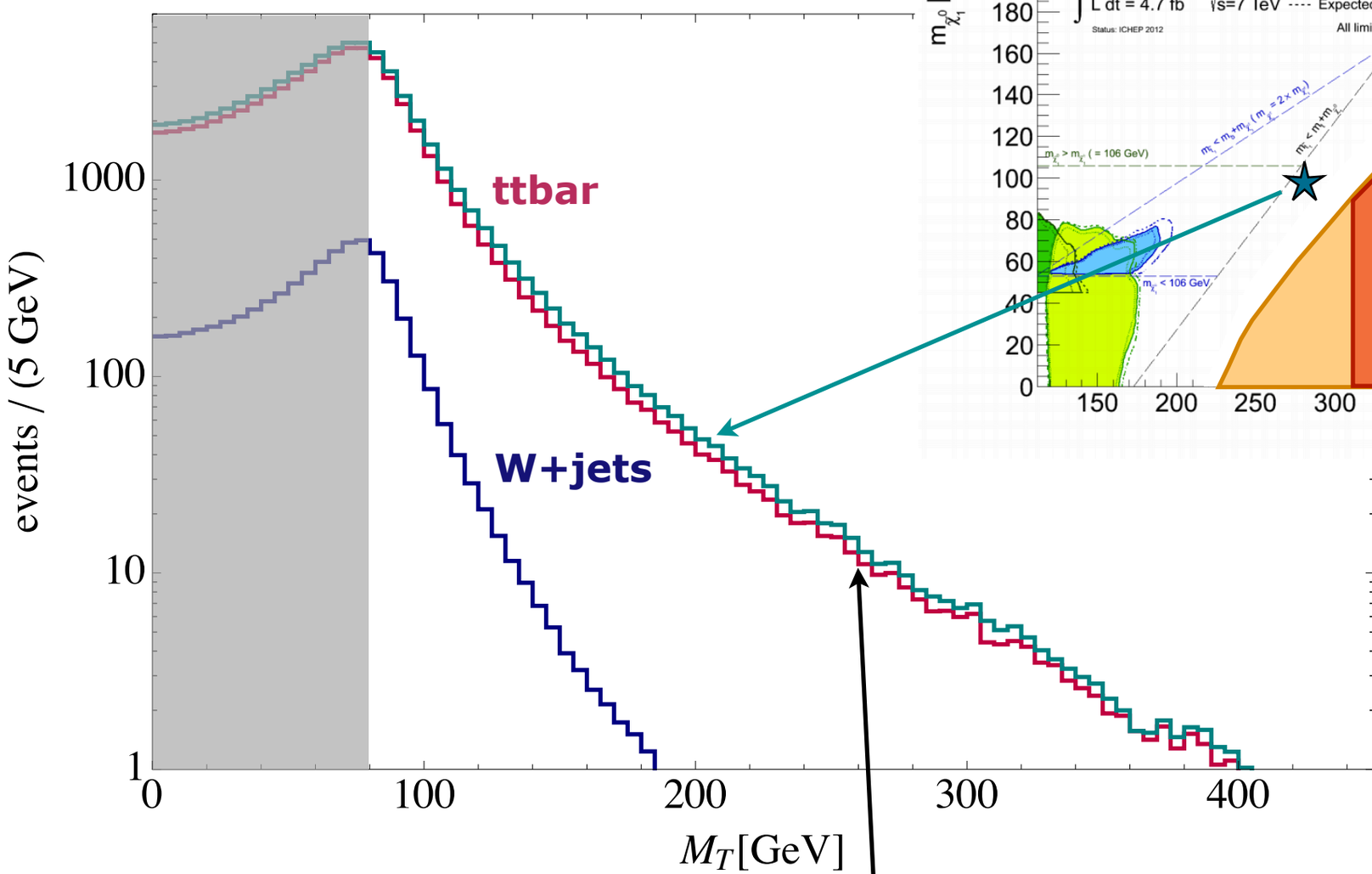
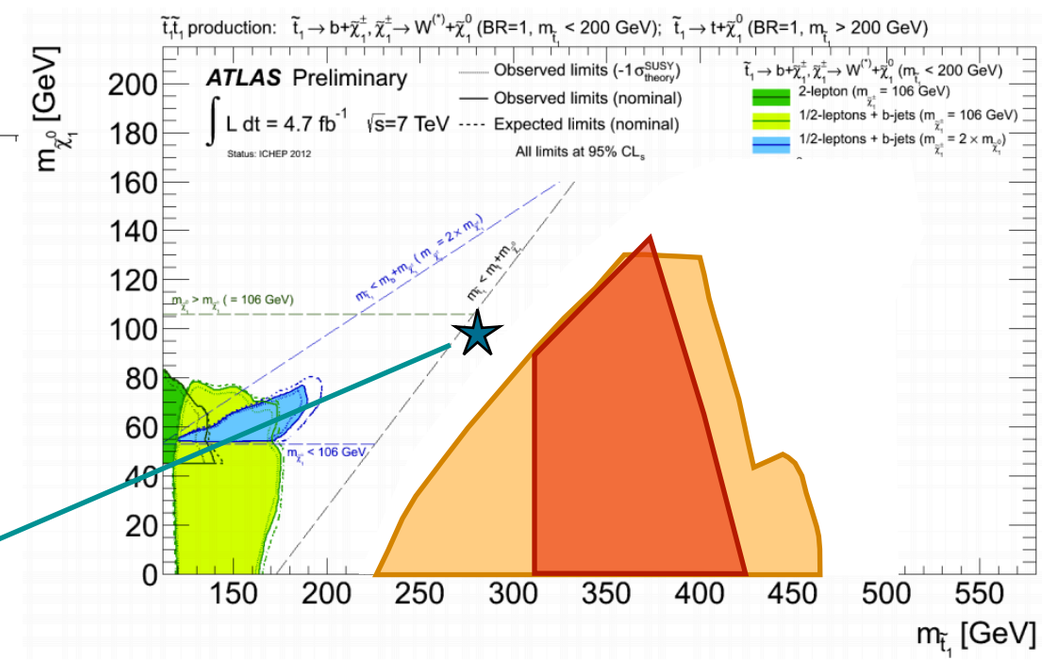
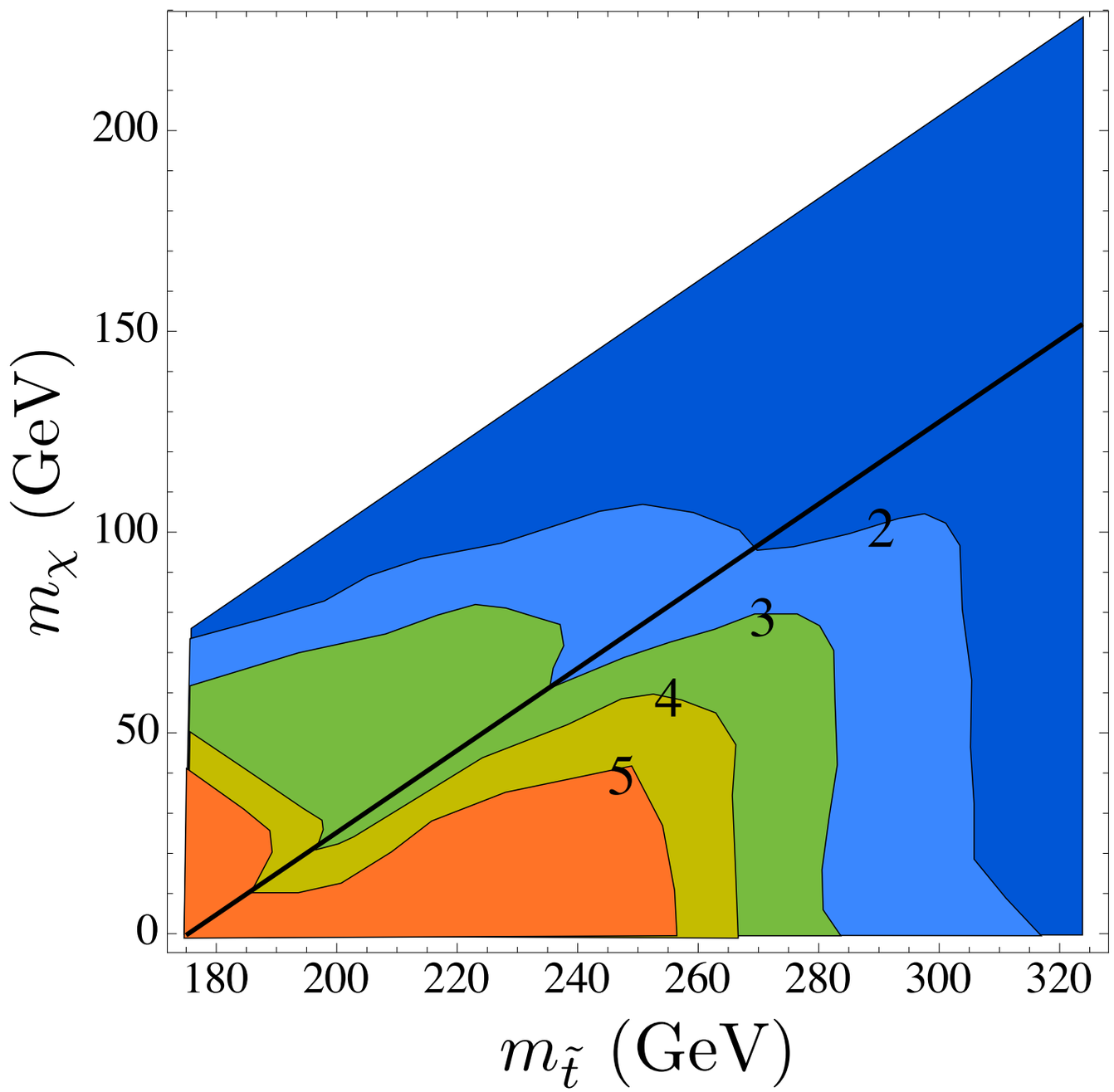




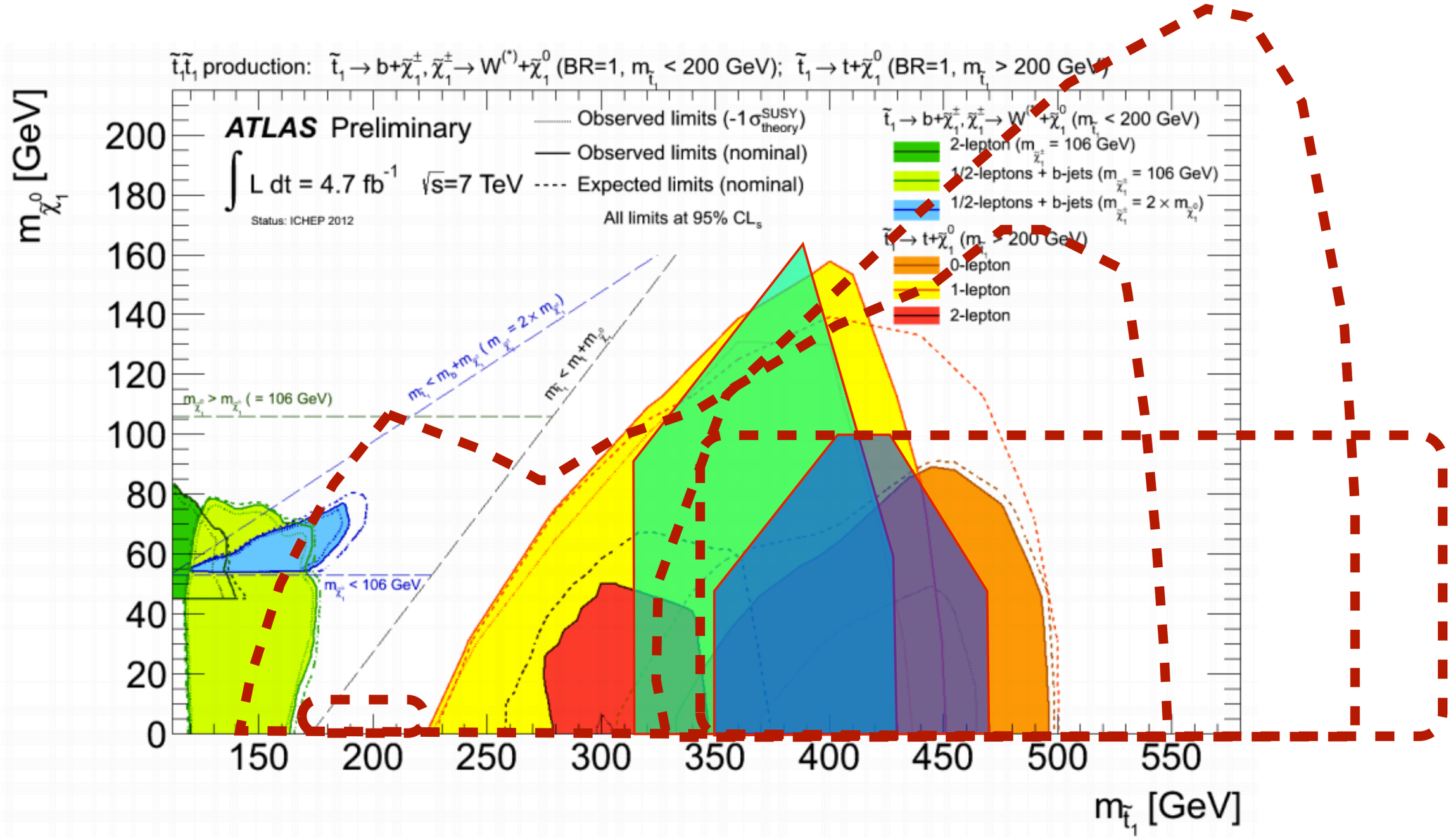
top decays to hadronic τ's

Expected exclusion reach for semi-leptonic M_T shape analysis



Putting it all together

estimated reach with 20/fb @ 8 TeV



Summary

- First LHC results for direct stop pair production
  - covered interesting regions of parameter space
- Challenging regions still allowed
- Lots of new ideas on how to explore challenging regions
- May be useful in other searches as well