Naturalness at the LHC

Chris Brust – 5/7/13

Work done with Andrey Katz and Raman Sundrum

Based on 1206.2353

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University of Maryland, College Park

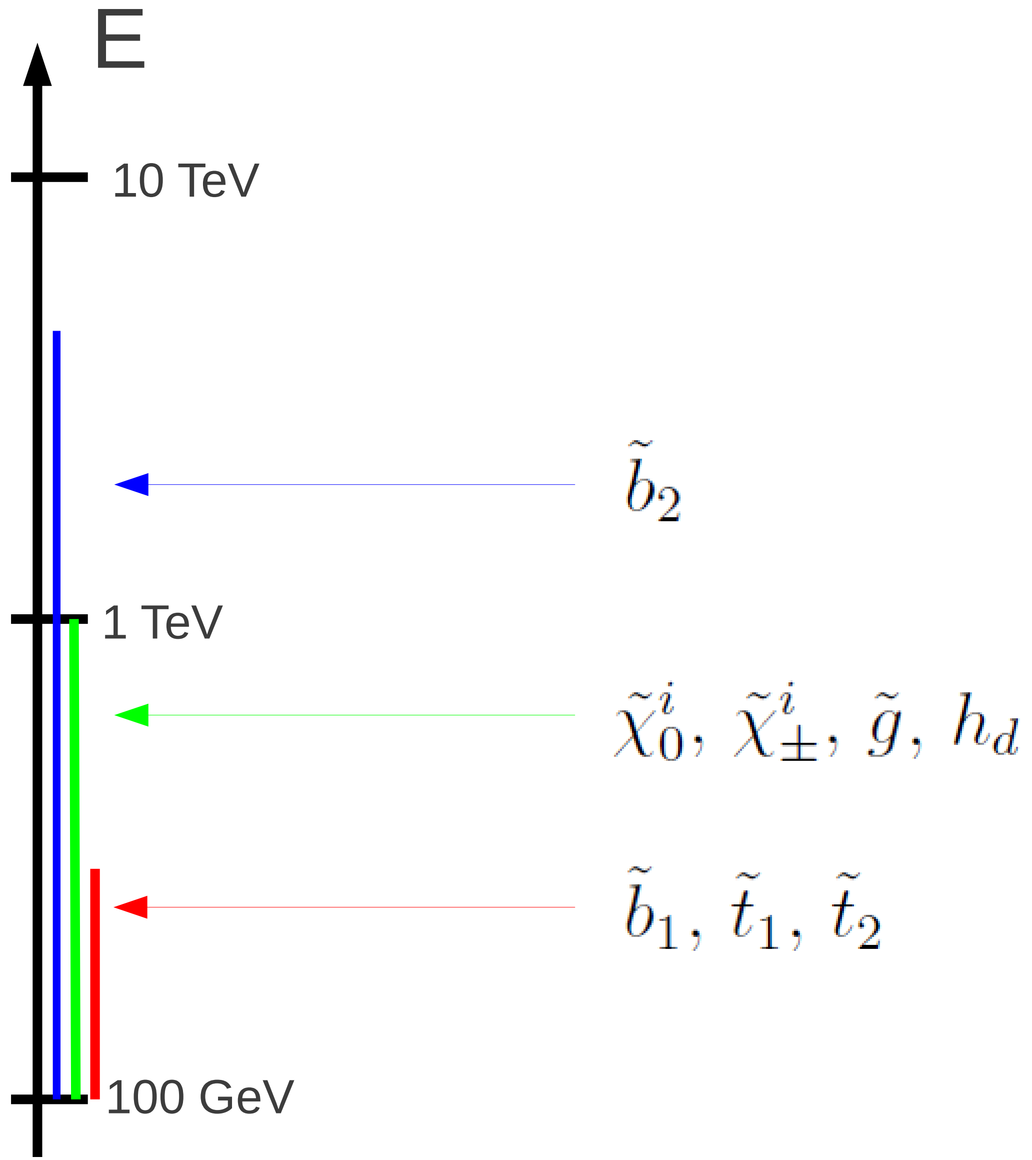
Punchlines

- We must test naturalness thoroughly
- Parts of baryon number-violating natural SUSY parameter space are not and can be explored
- Cut-and-count sometimes doesn't cut it

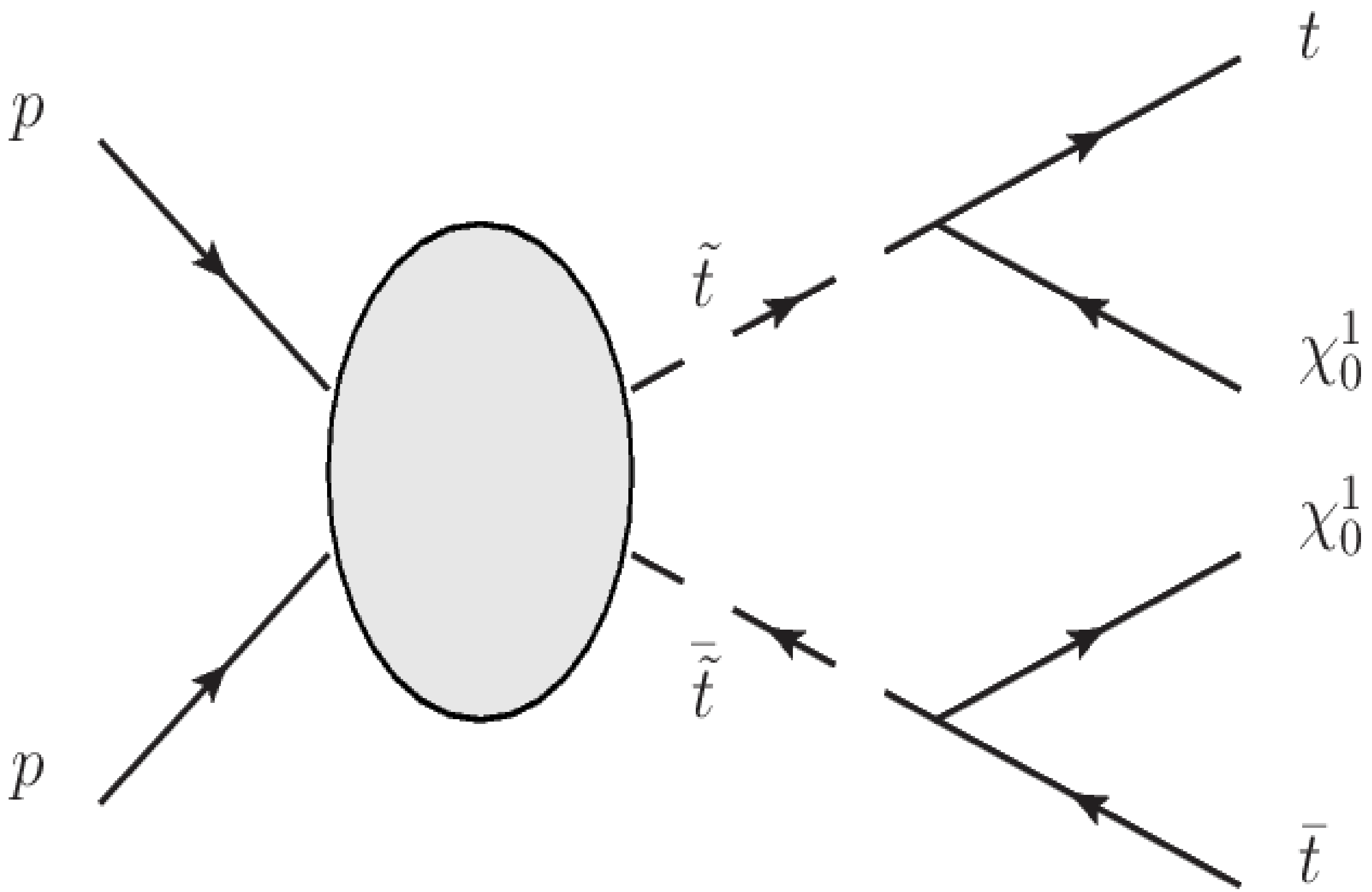
Postulate of Naturalness

- Postulate of naturalness: Fine-tuning is not at play in our universe!
- Or, $\left|\frac{\delta m^2}{m^2_{phys}}\right| \leq 1$
- Predicts new colored states below 1 TeV

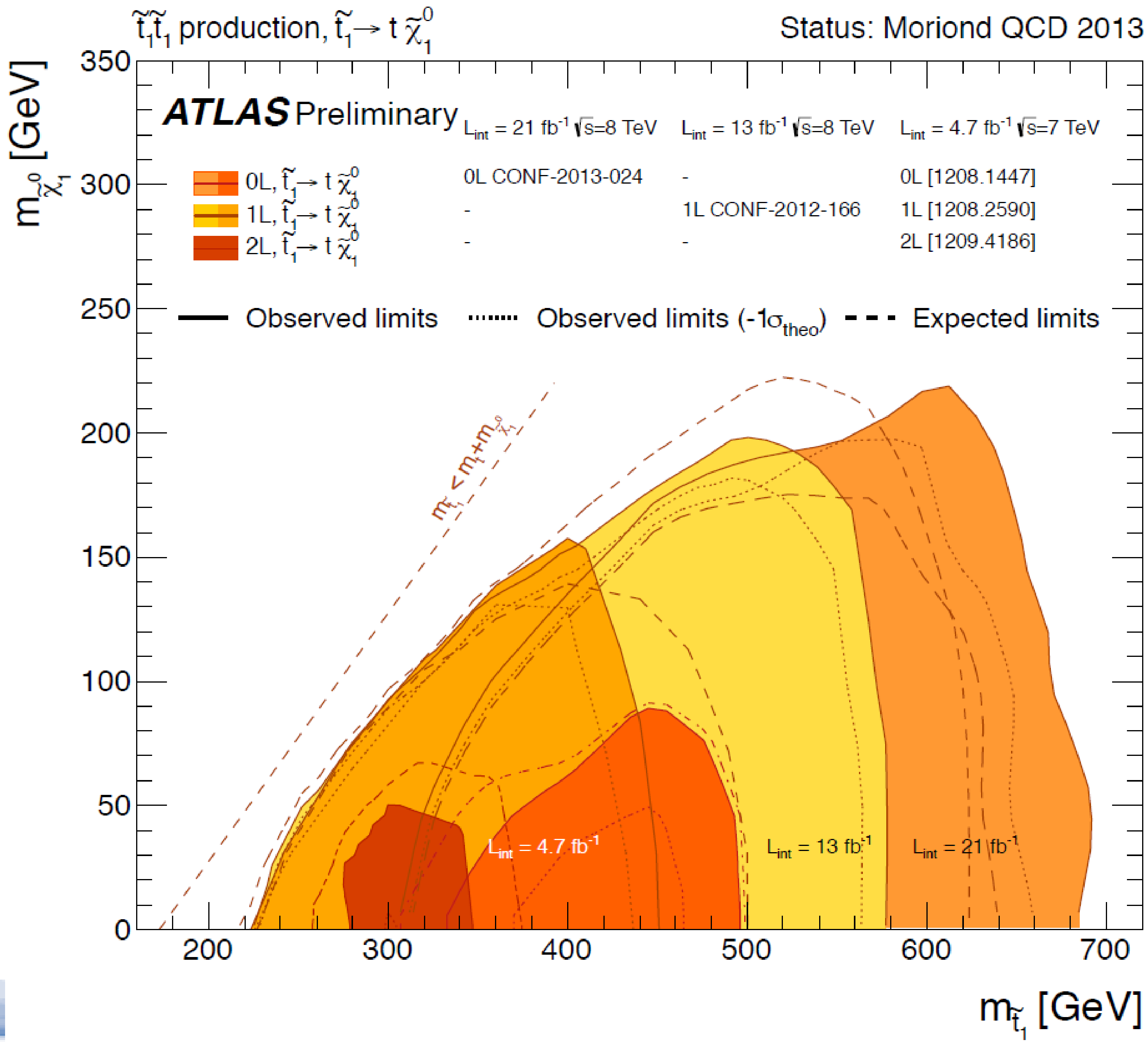
Natural SUSY Spectrum Summary



Natural SUSY at the LHC



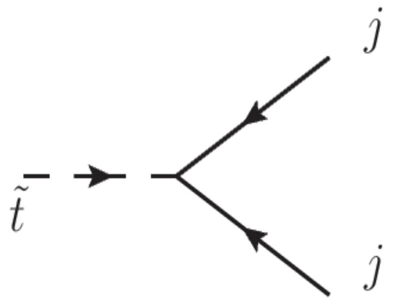
Latest from Moriond



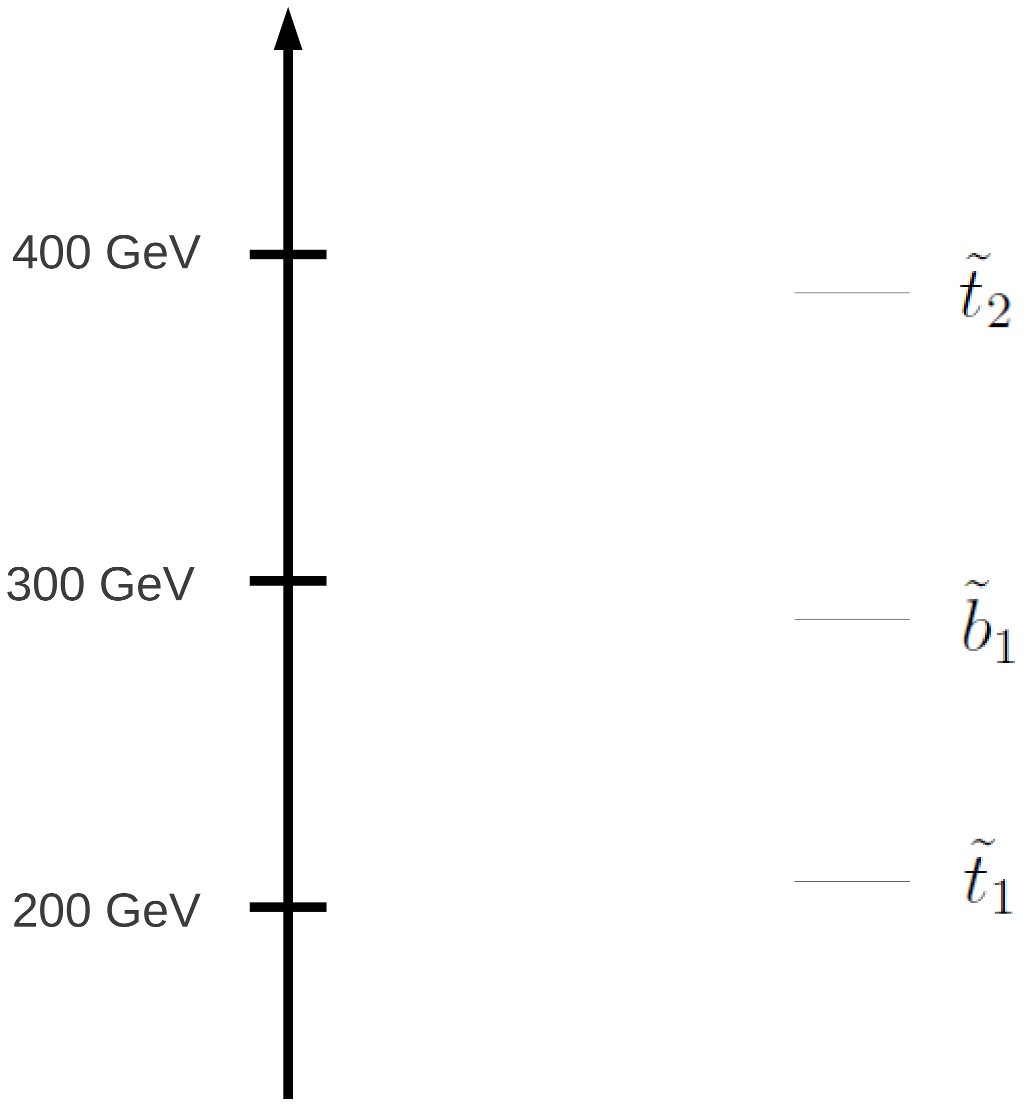
Throwing in the Towel?

- Baryon number violation far from excluded

$$\lambda''_{ijk} U^c_i D^c_j D^c_k \longrightarrow$$



Example Sub-TeV Spectrum



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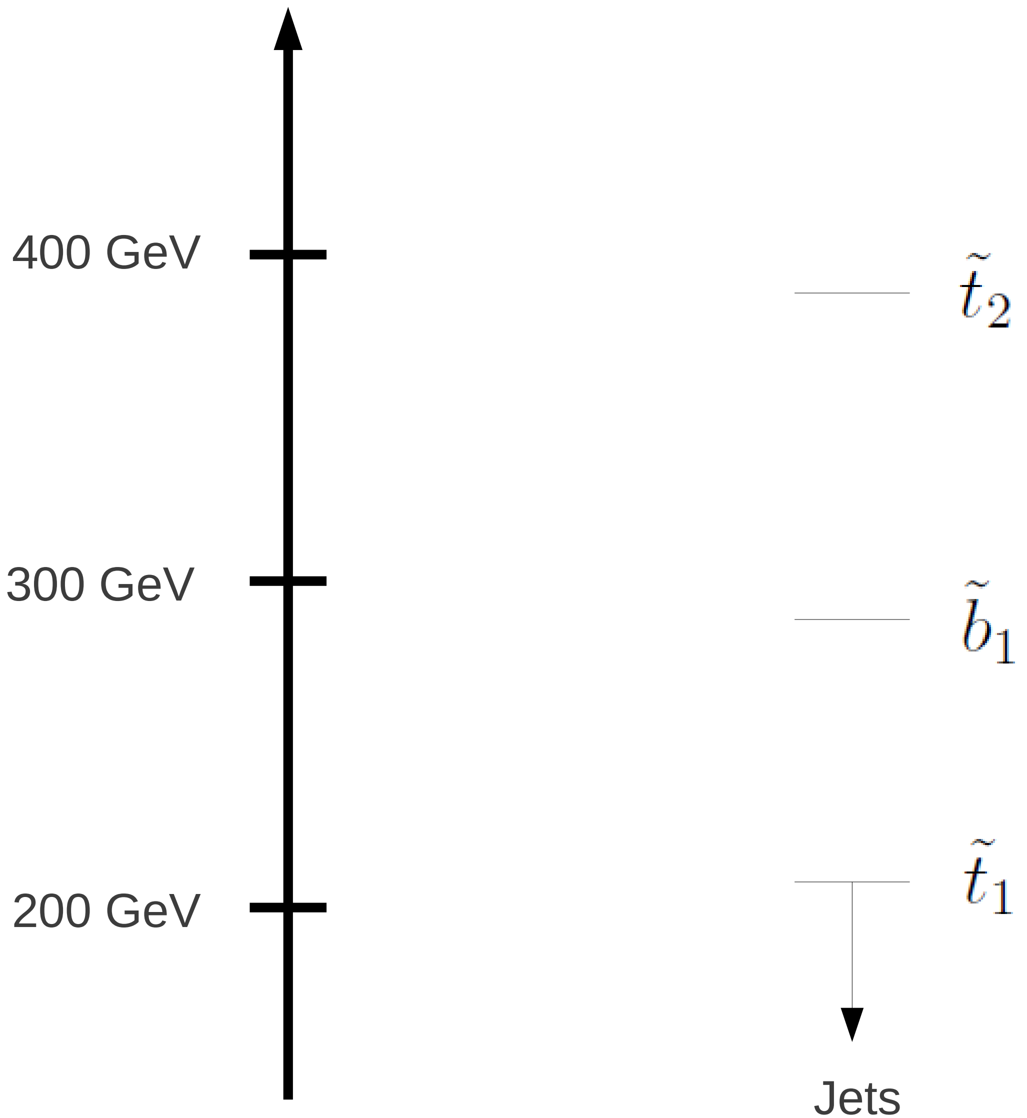

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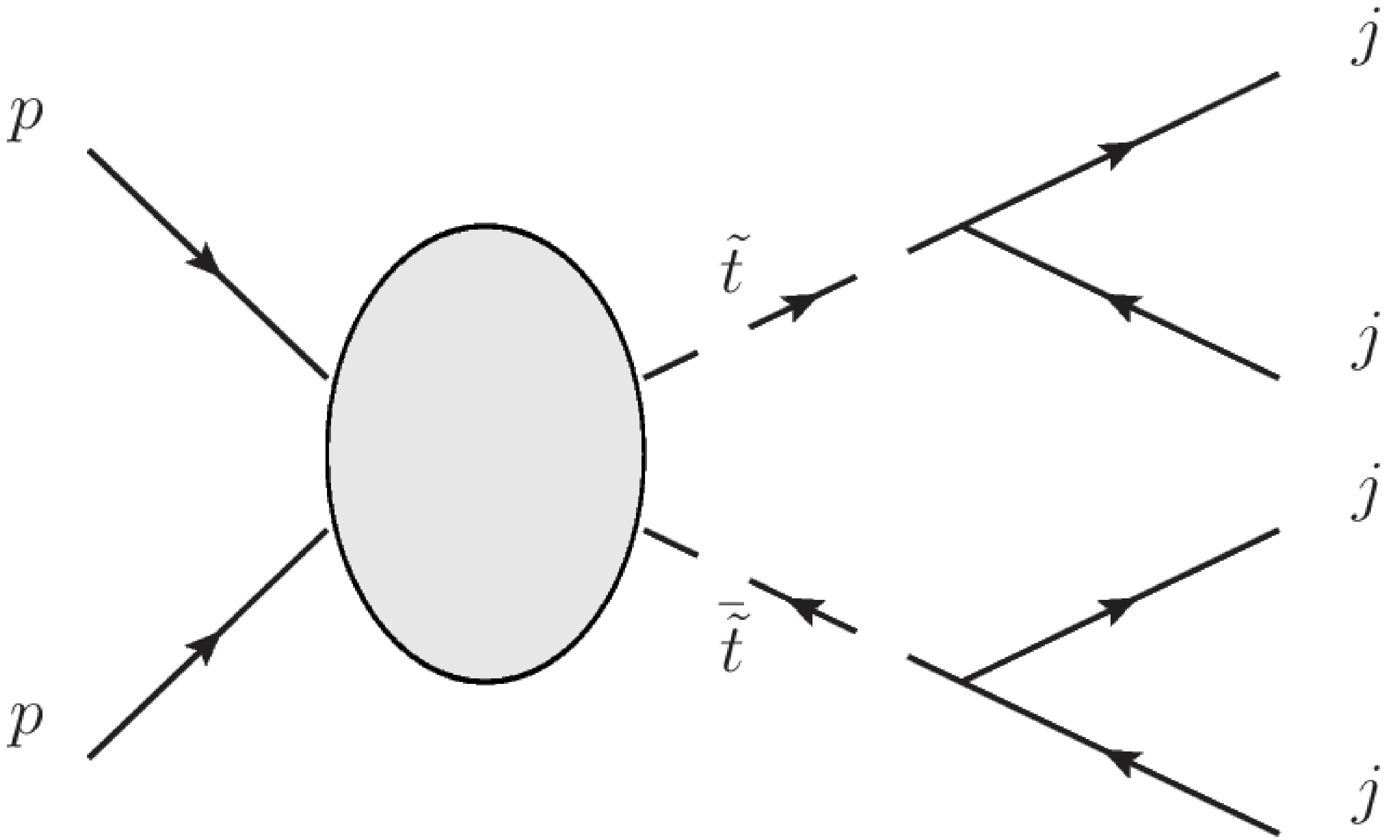

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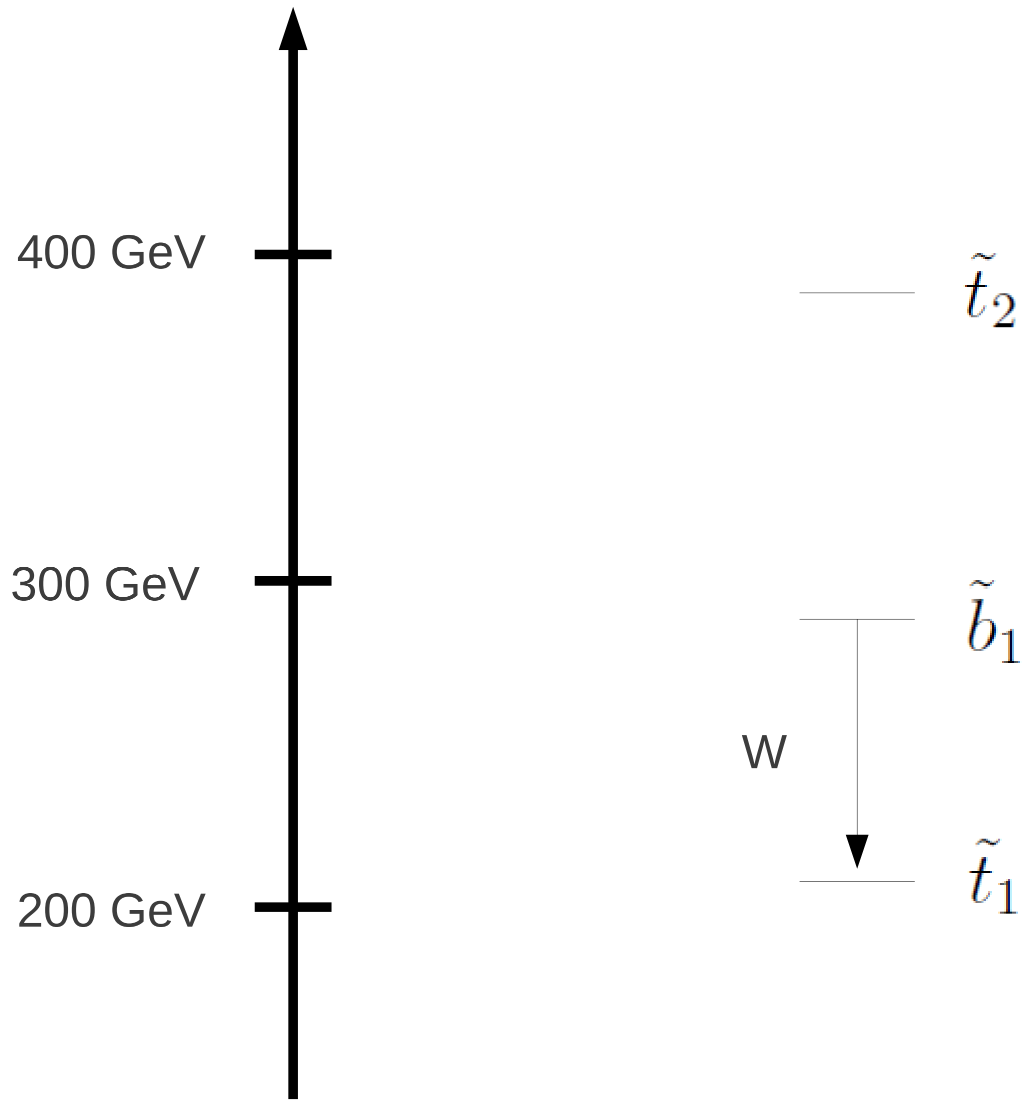
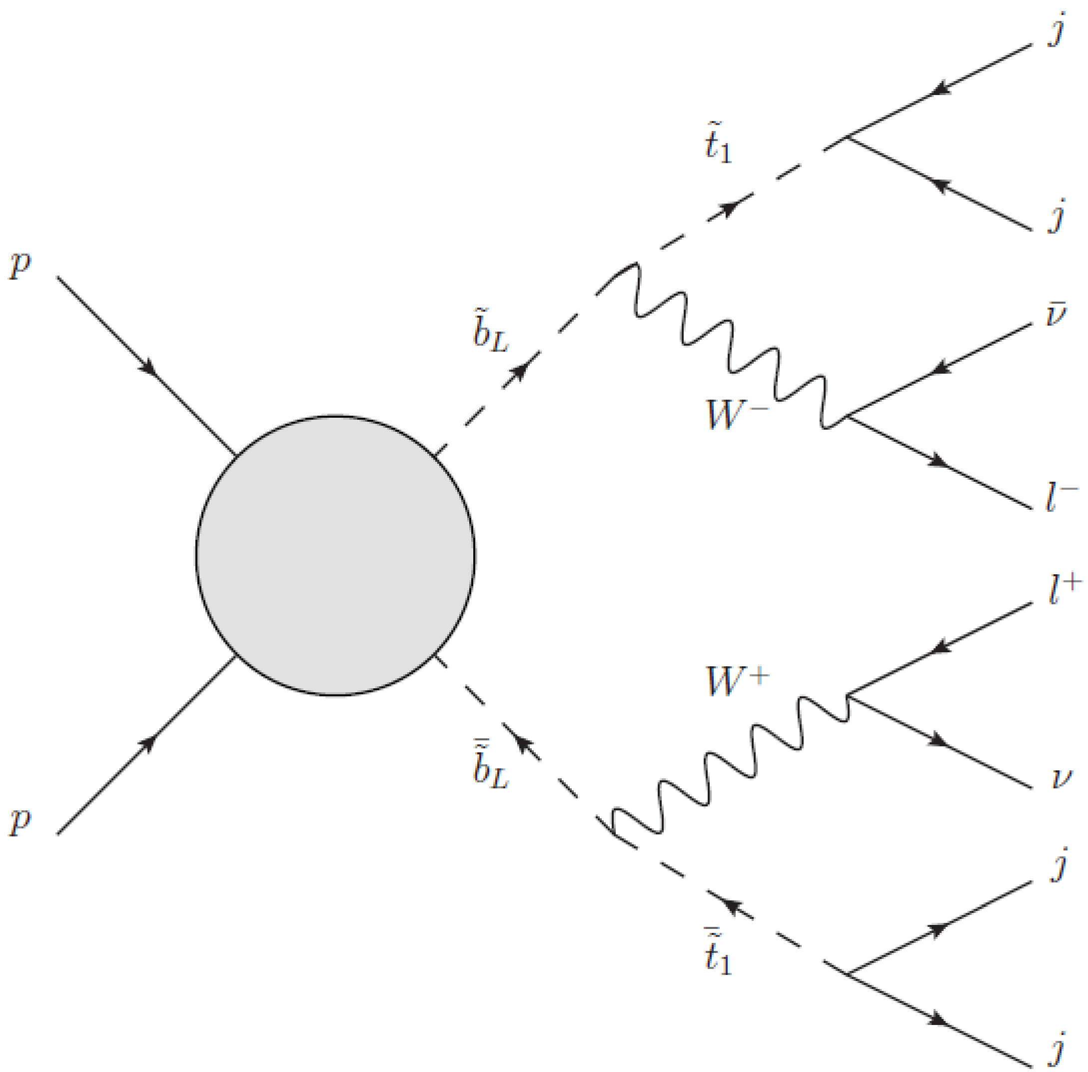


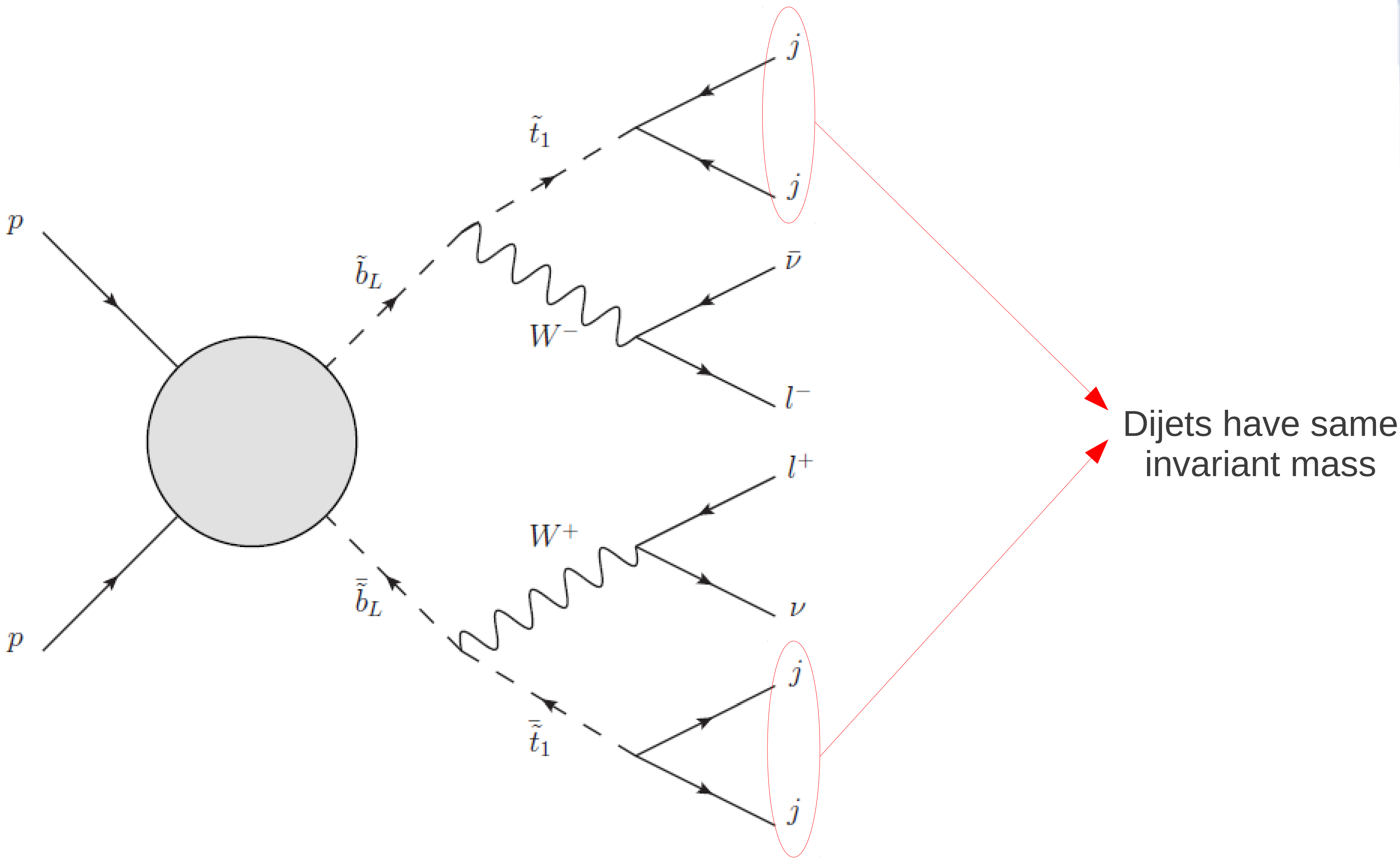
Strategies for Searching



Dominant background:

Leptonic $t\bar{t}$
w/ and w/o τs

Strategies for Searching



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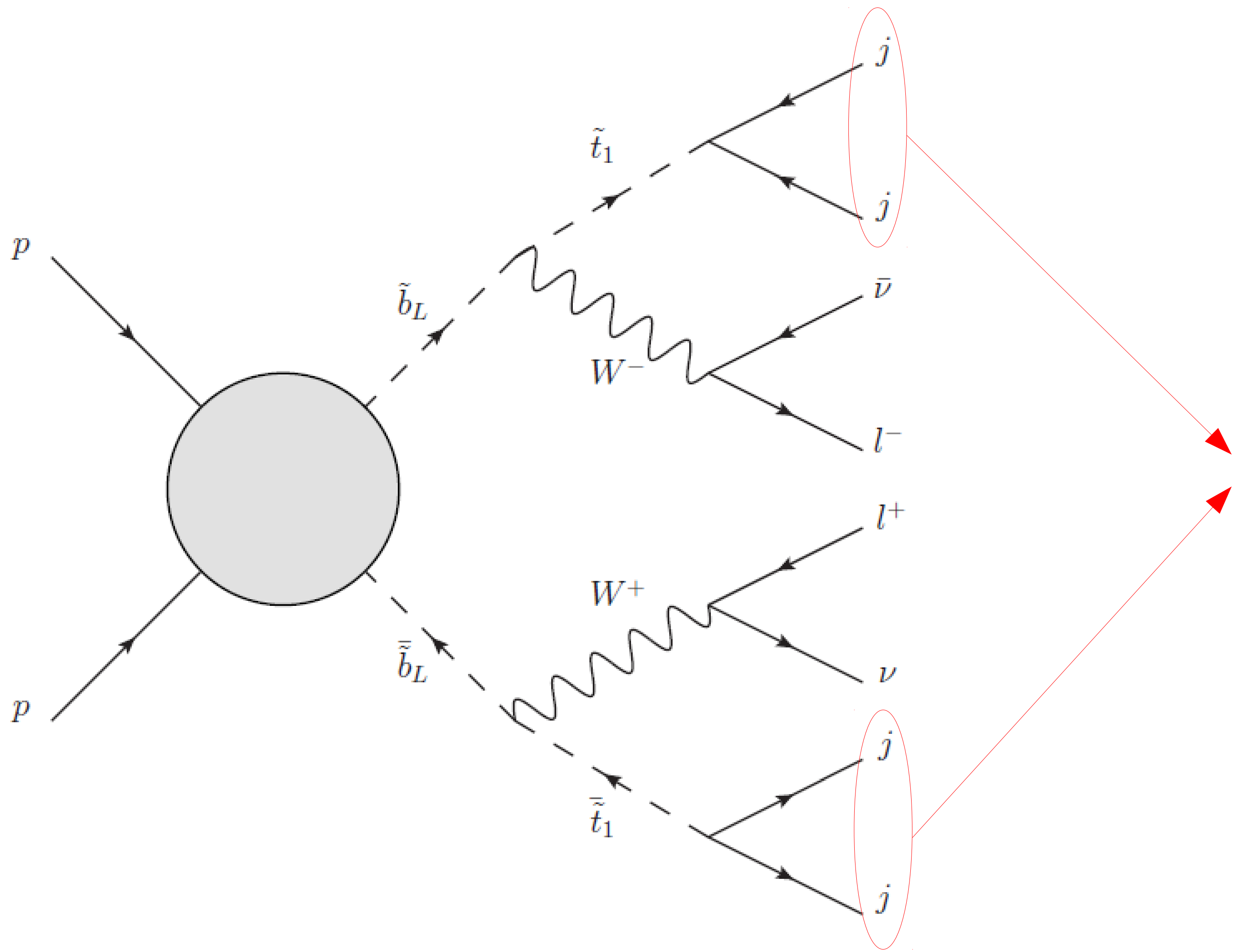
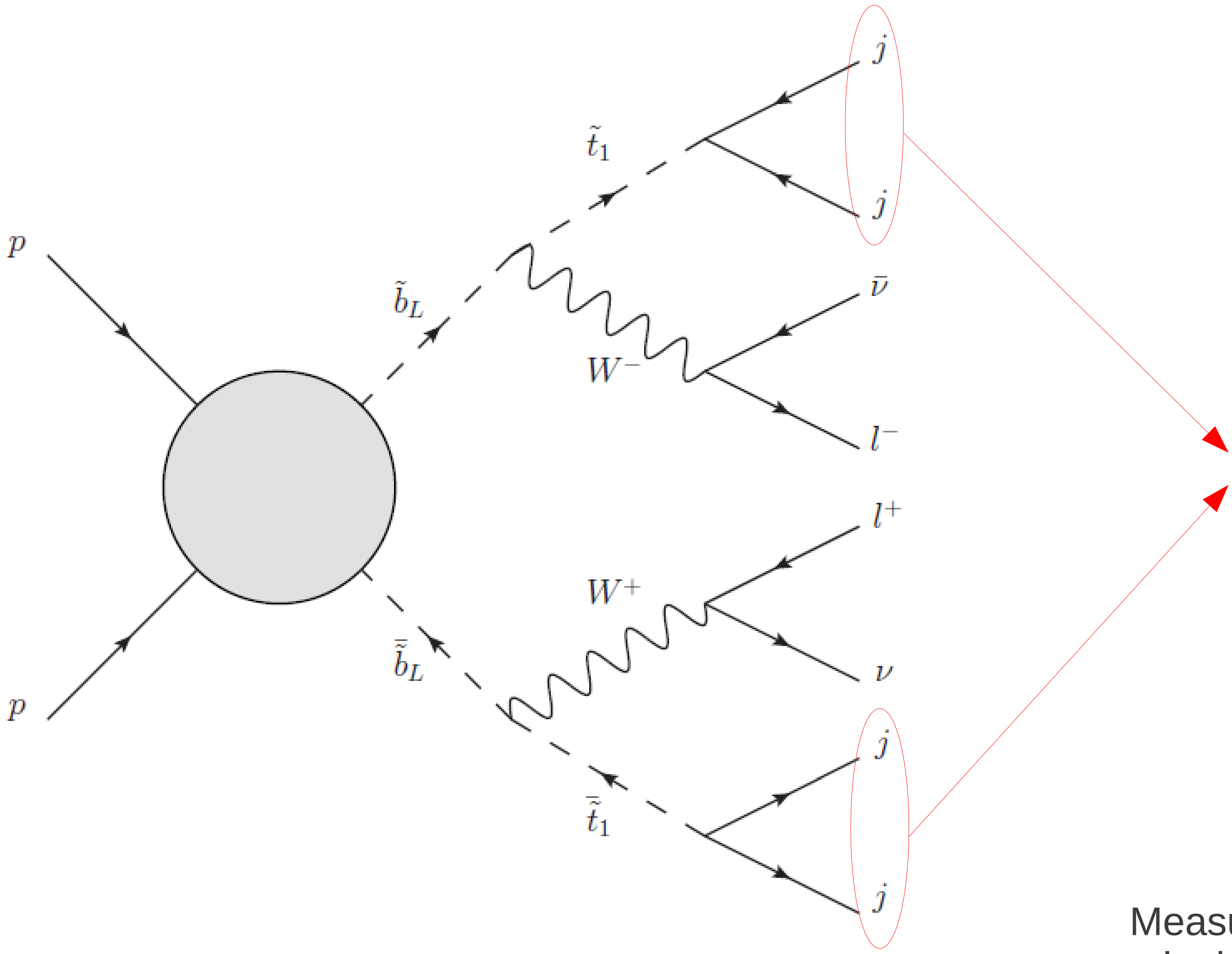


Dijets have same invariant mass

↓

Cut on difference in invariant mass

Strategies for Searching



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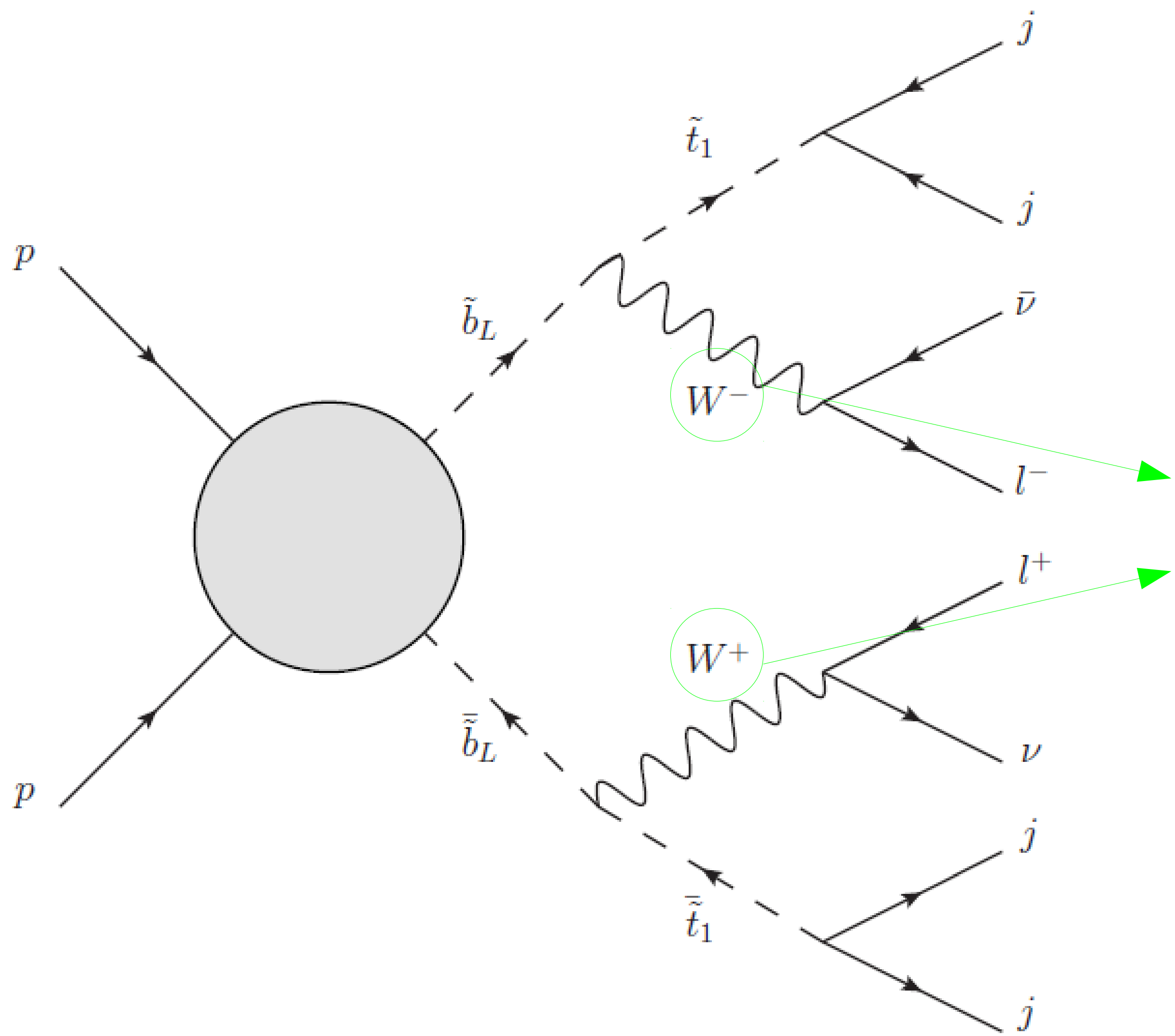
Measure stop mass by plotting invariant mass!

Strategies for Searching



Depending on sbottom-stop mass splitting, Ws may be soft or offshell

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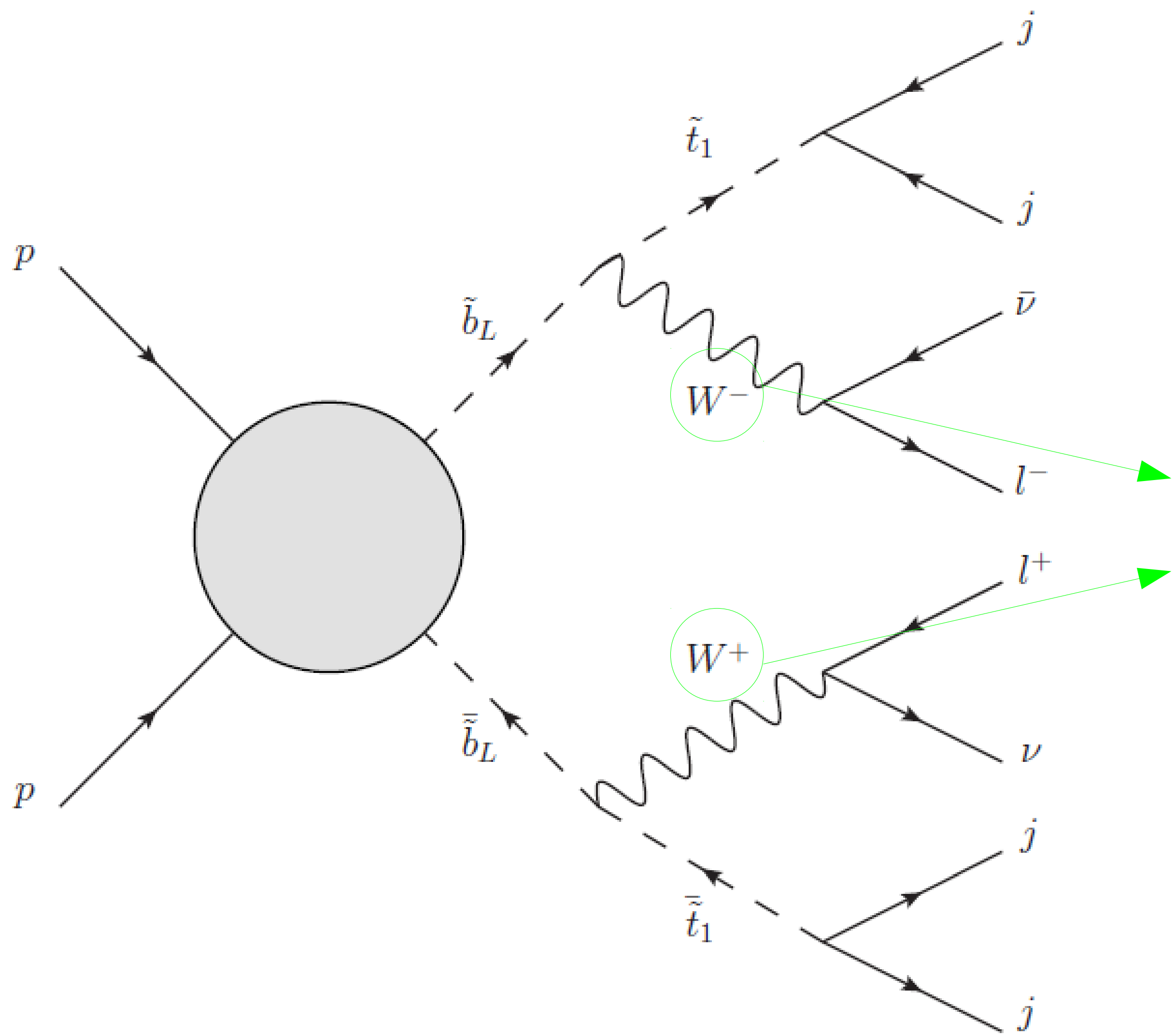

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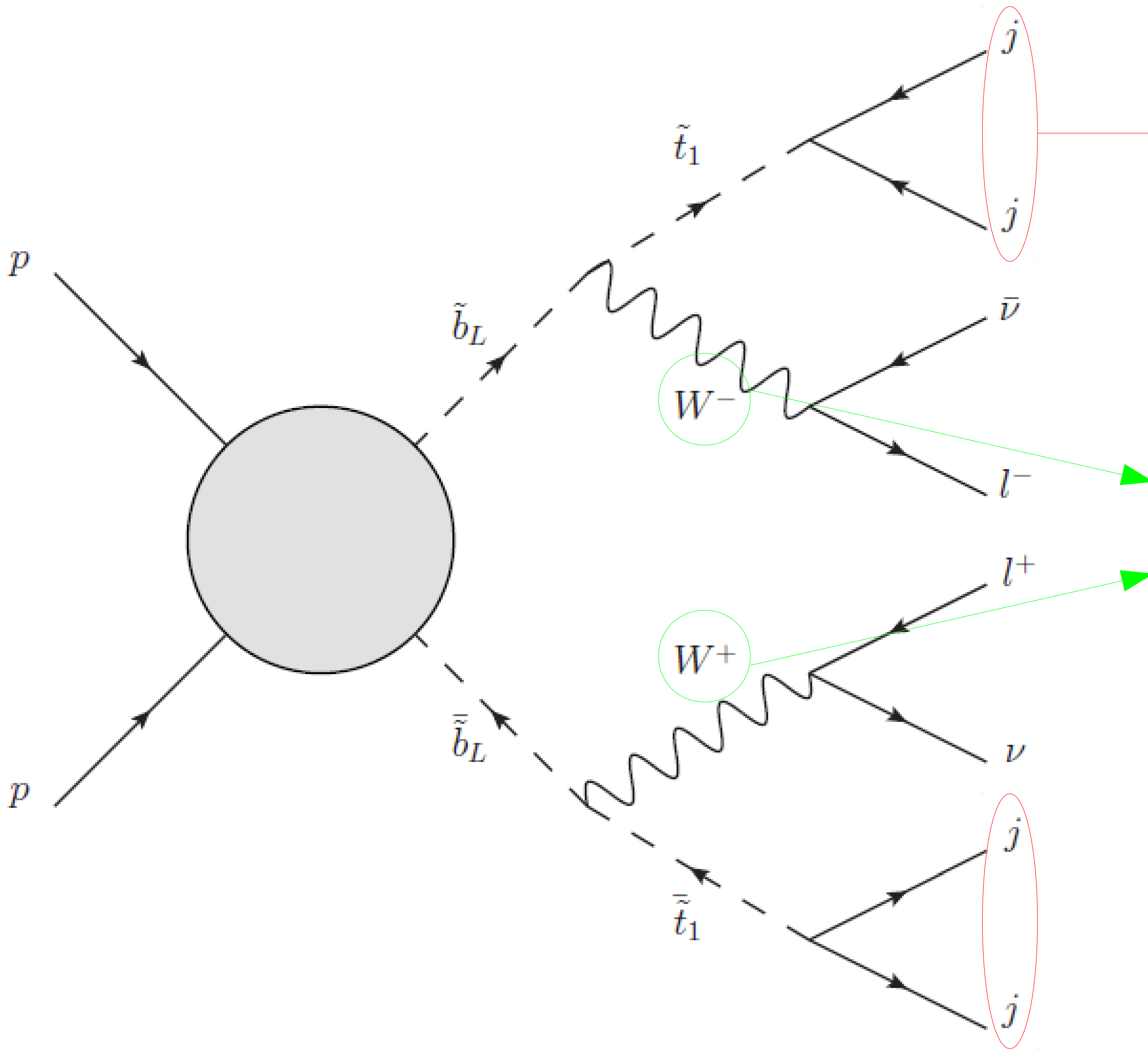
Softer leptons and less MET than tops

Strategies for Searching



On average, harder than $t\bar{t}$

Depending on sbottom-stop mass splitting, Ws may be soft or offshell

Softer leptons and less MET than tops

Strategies for Searching

- Cut on

$$r_l \equiv \frac{p_T(l_1)}{S_T} \quad \text{and/or} \quad r_{\not{E}_T} \equiv \frac{\not{E}_T}{S_T}$$

where

$$S_T \equiv \sum_i p_T(j_i) + \sum_k p_T(l_k) + \not{E}_T$$

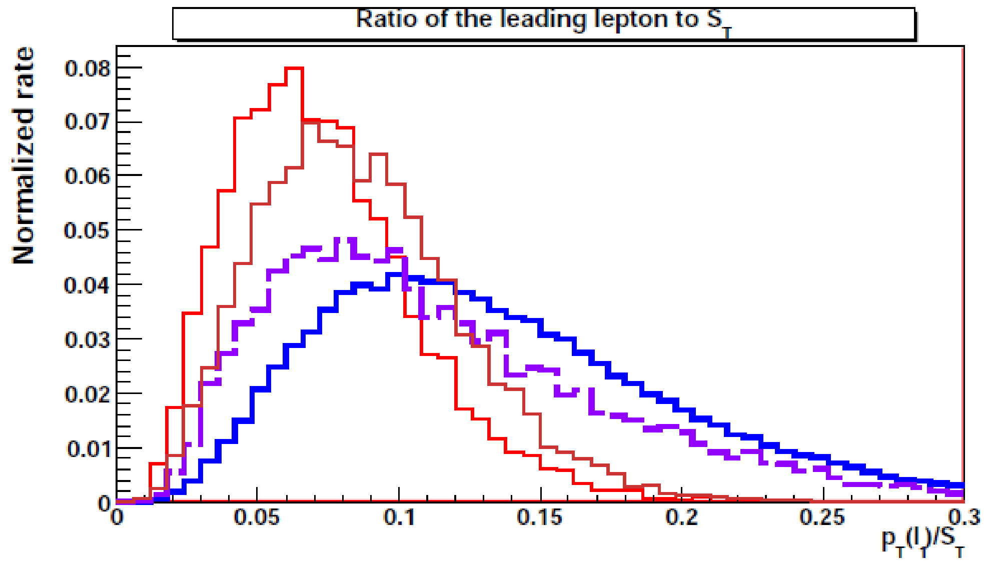
Strategies for searching

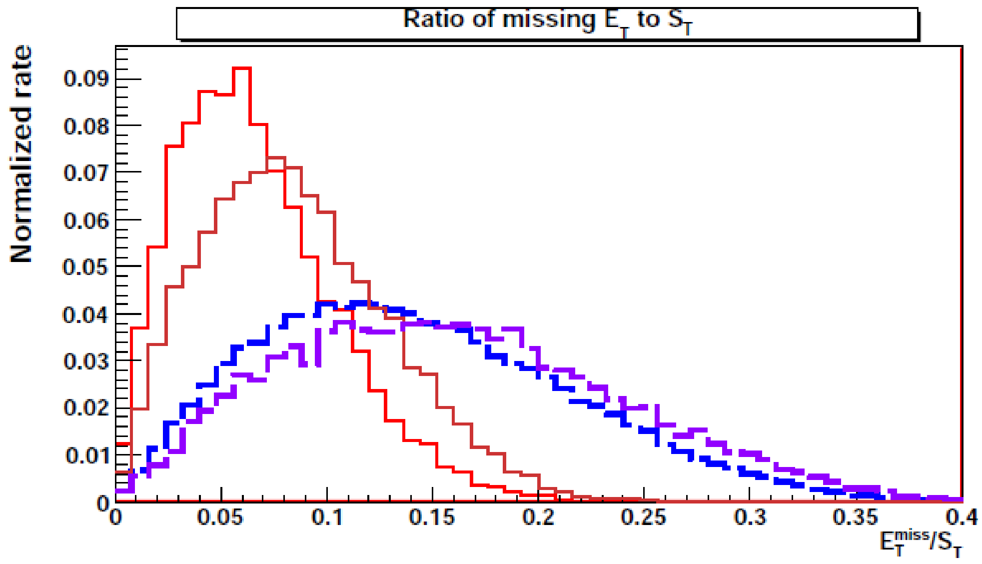
Light red: $m_{\tilde{b}} = 250\ \mathrm{GeV},\ m_{\tilde{t}_1} = 186\ \mathrm{GeV}$

Blue: Leptonic $t\bar{t}$

Dark red: $m_{\tilde{b}} = 270\ \mathrm{GeV},\ m_{\tilde{t}_1} = 189\ \mathrm{GeV}$

Violet: l/τ $t\bar{t}$





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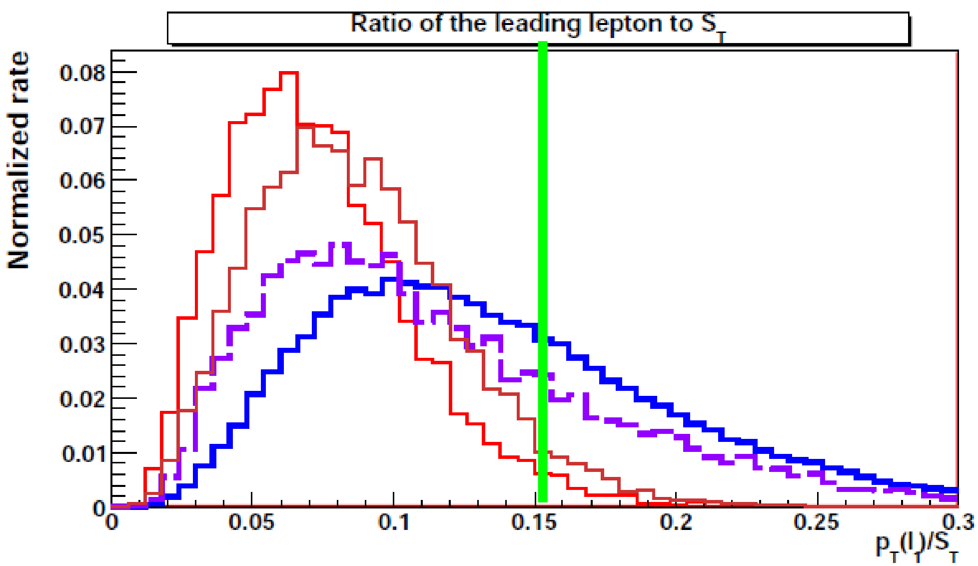
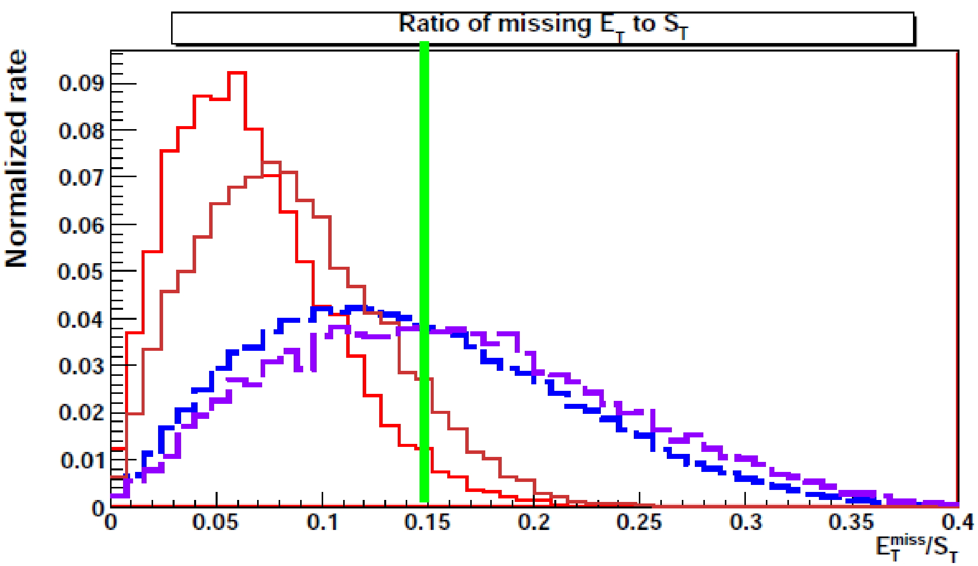
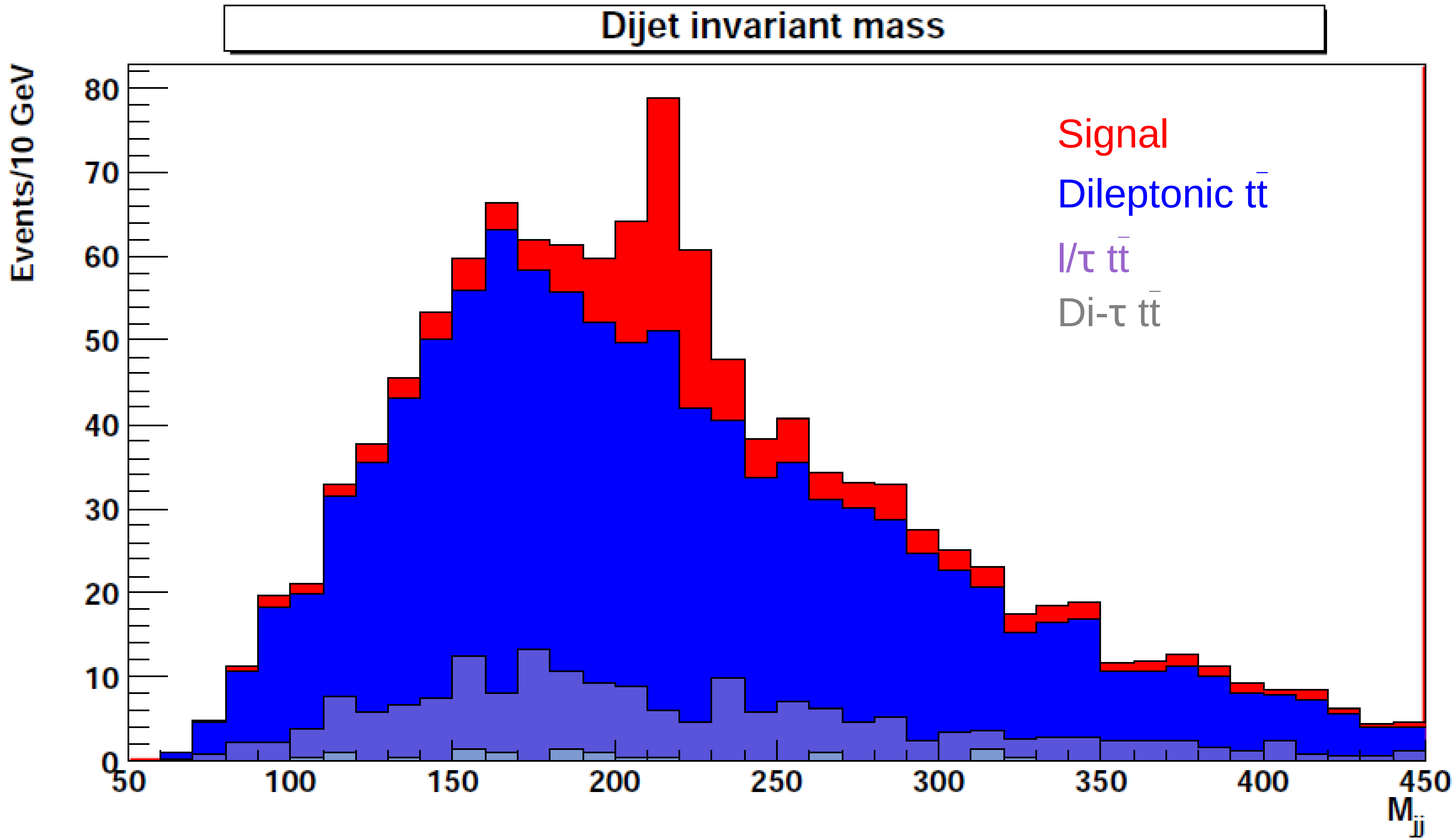




Results

$$m_{\tilde{b}} = 300 \text{ GeV}, \; m_{\tilde{t}_1} = 217 \text{ GeV}$$

$$\sqrt{s} = 8 \text{ TeV}$$
$$\mathcal{L} = 20 \text{ fb}^{-1}$$



Conclusions

- Imperative to address naturalness of the electroweak scale
- Baryon number-violating natural SUSY parameter space must be and can be fully explored
- Cut and count experiments oftentimes insufficient here

Details of Search Strategy

1. Cluster all the hadronic activity with anti-k_T algorithm, clustering radius $R = 0.7$. Relatively large clustering radius is dictated by the fact that we are looking for the resonances, and smaller radius usually leads to losing relevant hadronic activity. The clustering radius is not optimized, but radii of order $R \sim 1.0$ are likely to be the most adequate.

2. Demand precisely two isolated leptons (carrying more than 85% of the p_T in the cone around the lepton with radius $R = 0.3$) in each event. We demand $p_T(l_1) > 20$ GeV and $p_T(l_2) > 10$ GeV.[4] The leptons should have $|\eta| < 2.5$. We discard the event if the leptons have same flavor *and* 81 GeV $< m_{ll} <$ 101 GeV to remove the background from Z + jets events.

3. Demand that the event is sufficiently hard, $S_T > 400$ GeV as defined in Eq. (3.2) and $\not{E}_T > 35$ GeV.

Details of Search Strategy

4. Require four or more hard jets in the event with $p_T(j_4) > 30$ GeV. This requirement is natural since we are trying to reconstruct two resonances of $\tilde{t}_1$, which both decay into two quarks.

5. Using the variables in Eq. (3.3), demand $r_{\not{E}_T} < 0.15$ and $r_l < 0.15$.

6. Try all possible pairings between four leading jets, and pick up the combination which minimizes the difference between the reconstructed invariant masses. Discard the event if the minimal possible mass difference is bigger than 10 GeV.[5] If the event has five or more jets with $p_T > 25$ GeV, try all possible pairings of two and three jets. If we get better results when taking the fifth jet into account, use the best combination which minimizes the mass difference between the reconstructed objects.

7. Look for resonances in the reconstructed dijet invariant mass.