Resolving Combinatorical Ambiguities in Gluino and Top Quark Pair Production

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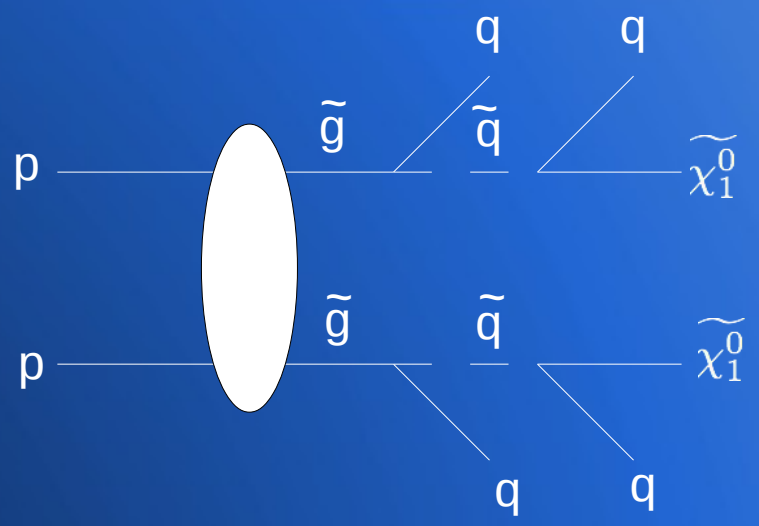
Motivation

- With the LHC now taking data it is very important to develop tools to help distinguish interesting signals from background.
- Some signals can have a combinatorical problem with the final state particles.
  - Gluino pair production
  - ttbar production in the dilepton chanel
- It would be useful to develop a method to reduce these combinatorical backgrounds.

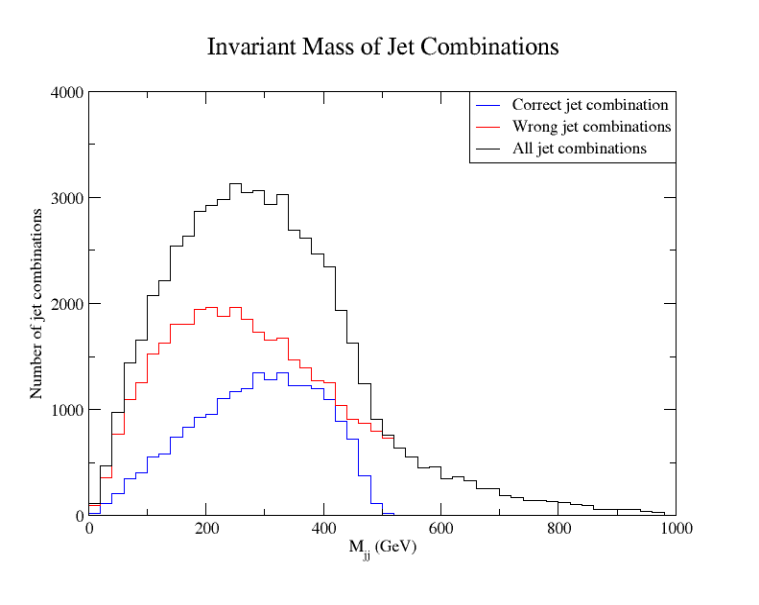
Gluino Pair Production

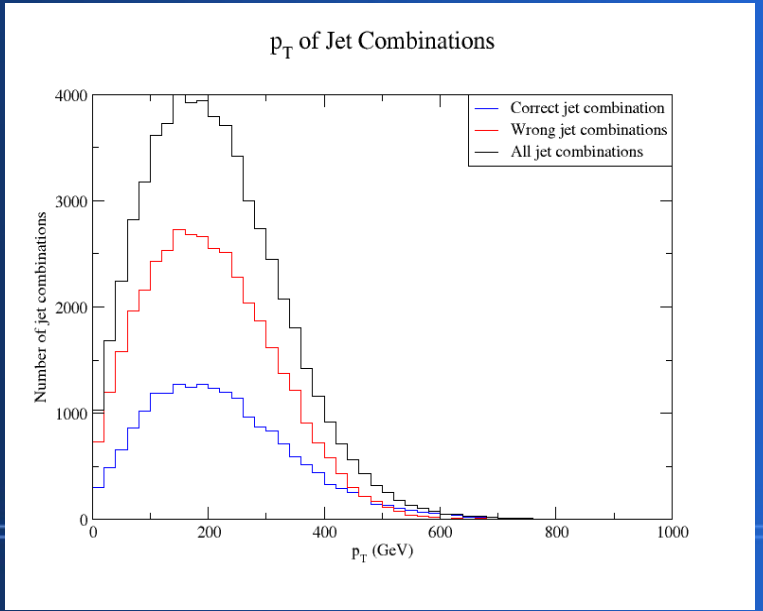
- Gluinos have a large number of possible decay chains.
- We consider a final state of four quarks and two neutralinos.
- We do not know a priori which pair of jets came from which gluino
  - 3 fold ambiguity



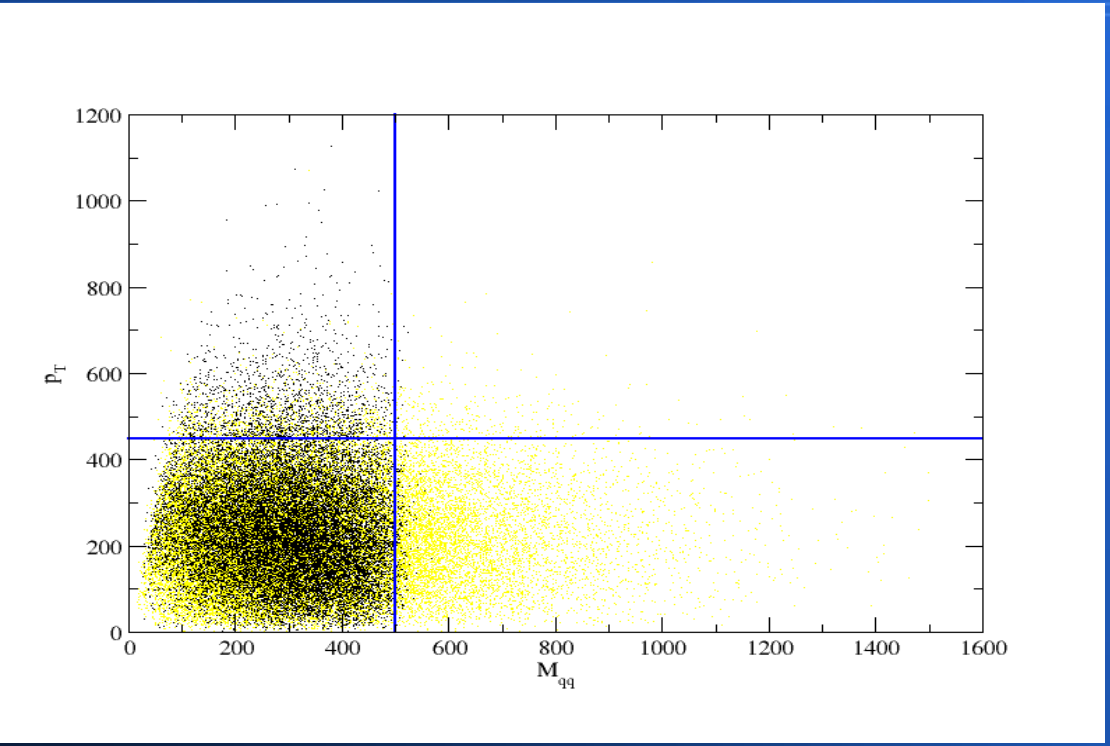
Previous Study

- Rajaraman and Yu did a study to try and resolve this combinatorical issue using invariant mass and transverse momentum.
  - Gluino mass = 600 GeV
  - Neutralino mass = 100 GeV



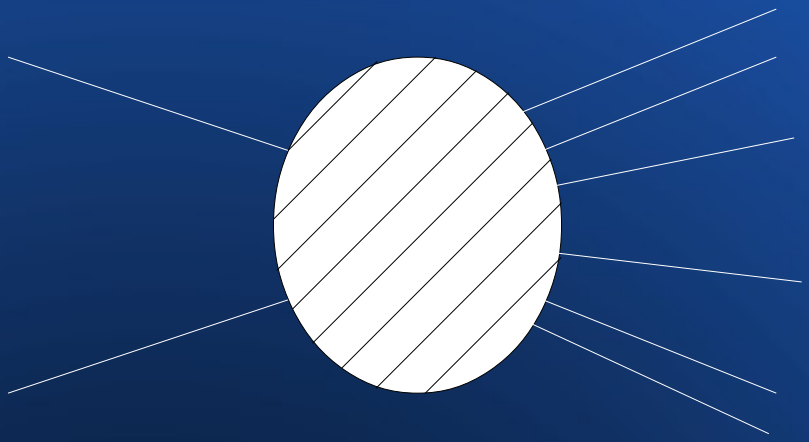


Previous Study



- Results in a 3% efficiency and 95% purity.
- We try to improve this analysis using MT2.

MT2



} Visible sector 1

Invisible particles

} Visible sector 2

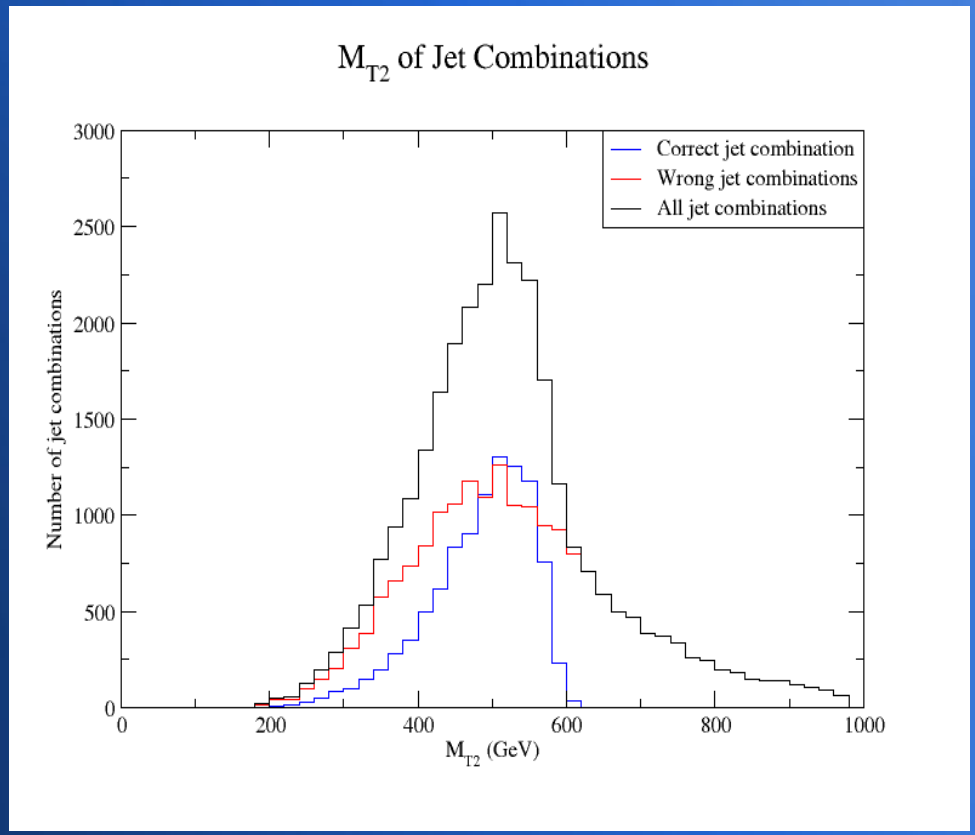
$$M_{T2} = \min_{\{\not{p}_{1T}+\not{p}_{2T}=\not{p}_T\}} \{\max [M_{T1}, M_{T2}]\}$$

$$M_{T_i} = \sqrt{\left(\sum_{\text{vis}} E_T + \not{E}_T\right)^2 - \left(\sum_{\text{vis}} \vec{p_T} + \not{\vec{p}}_T\right)^2}$$

$$\not{E}_T = \sqrt{m_\chi^2 + \not{p}_T{}^2}$$

MT2 cuts

- MT2 distribution for the correct combination has a cutoff at the gluino mass.
- We can make a cut of MT2 < 600 GeV for each jet combination.
- Use this along with invariant mass < 500 GeV cut from previous study



Results

Number of jet combinations	Percent of Events	Percent of Events with the correct combination
0	0.9%	2.7%
1	20.6%	19.3%
2	31.8%	31.2%
3	46.8%	46.8%

- Just looking at events with 1 passed combination we have an event efficiency of 20.6% and a purity of 94%!

Top Quark Pair Production

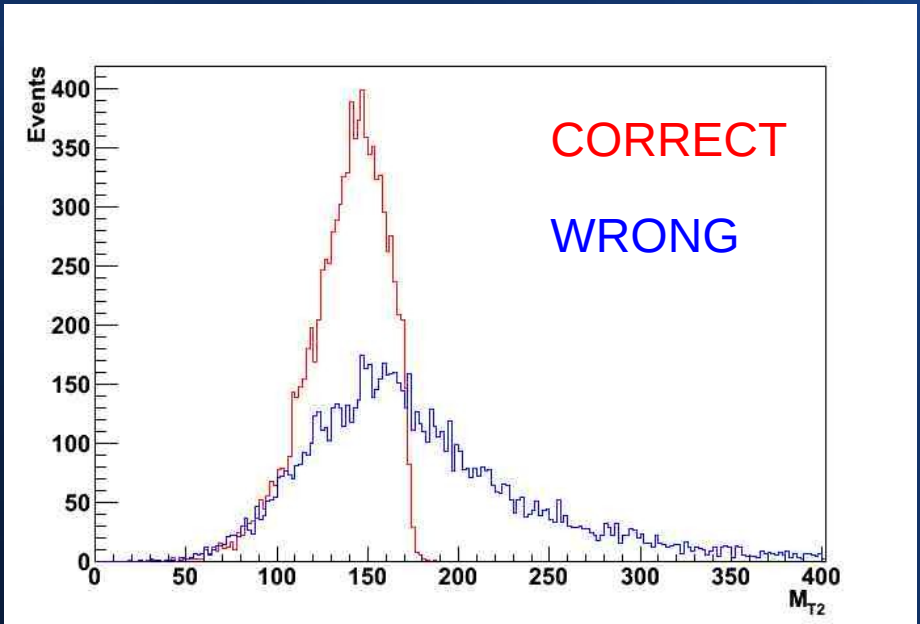
- Looking at dilepton decay of ttbar
- Final state includes: 2 b-jets, 2 leptons, MET
- Each event has at least two possible jet-lepton pairing possibilities, we want to find a way to figure out which pairing is correct
- Better understanding of event can help many different top quark studies:
  - Charge Asymmetry
  - W helicity

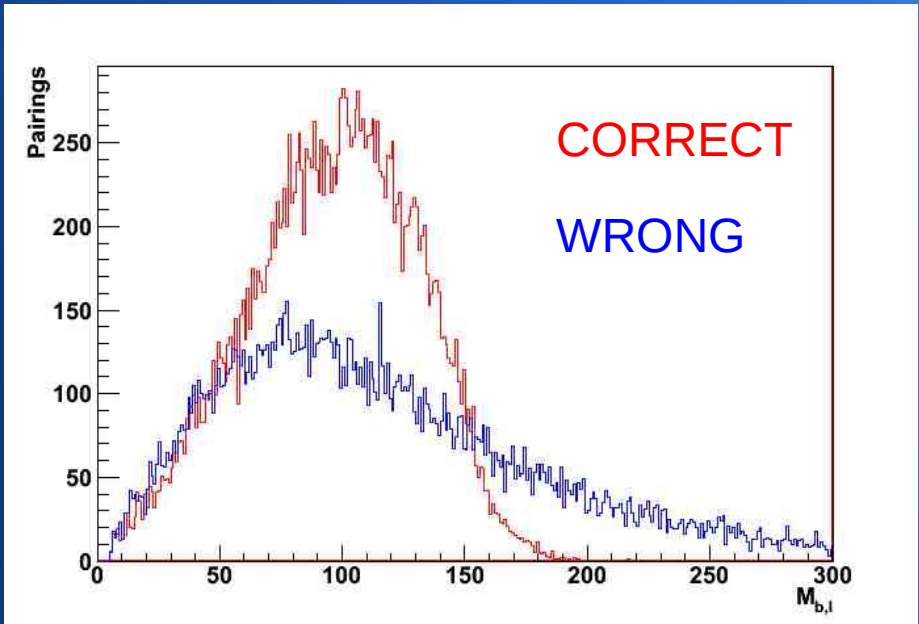
Our Method

- Using variables that should have a cutoff at specific values, we want to distinguish between the correct and wrong combinations
- Same two variables are used on top quarks as were used for gluino case
  - MT2
    - Visible sector consists of leptons and b jets
  - Invariant mass
    - Invariant mass of the two b-l pairings per combination

Our Method

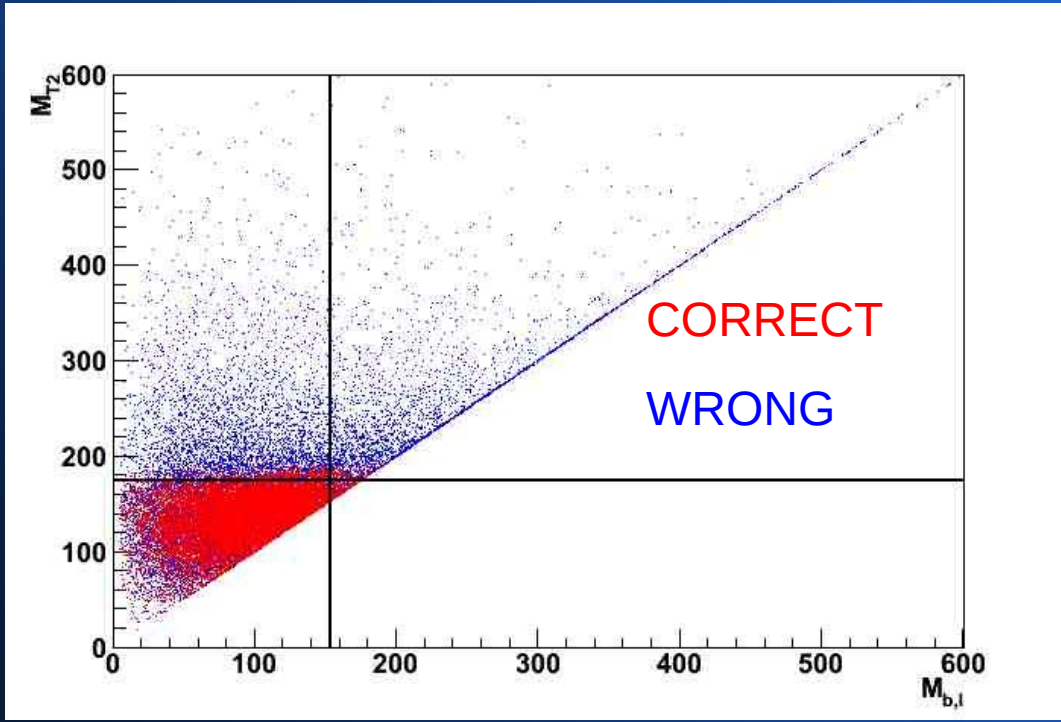
- M_{T2} and $M_{b,l}$ distributions have cutoffs on correct distributions





Our Method

- MT2 vs Invariant Mass Distribution



Our Method

- Apply upper limit cuts on M_{T2} and Invariant mass
  - $M_{T2} < 176$ GeV
  - Both $M_{b,l} < 156$ GeV
- Require events to have exactly one combination that falls within this region

Results

7 TeV

# of Passed Combinations	Events (out of 10000)	Events w/ Correct Combination Passing
0	248	0
1	5173	4908
2	4575	4416

- Efficiency = 51.8%, Purity = 94.9%

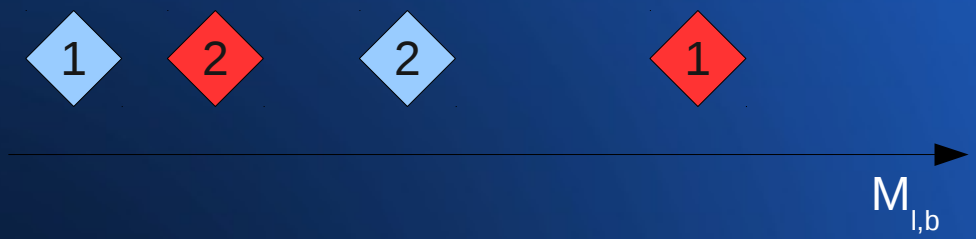
1.96 TeV

# of Passed Combinations	Events (out of 10000)	Events w/ Correct Combination Passing
0	180	0
1	4032	3740
2	5786	5585

- Efficiency = 40.3%, Purity = 92.8%

Comparison to other methods

- CDF: Mlbmax Cut Method
  - Take combination that doesn't have maximum $M_{l,b}$ pair, when maximum pair is above cut



- Raising Cut, Raise Purity, Lower Efficiency
- Eff: 39.5%
- Purity: 94.8%

How it can be improved

- We are throwing away a good number of events because both combinations pass
- These events can still be used
- Can another method be used on these events?
  - Mlbmax
  - Kinematic Fit

# of Passed Combinations	Events	Events w/ Correct Combination Passing
0	248	0
1	5173	4908
2	4575	4416

Summary

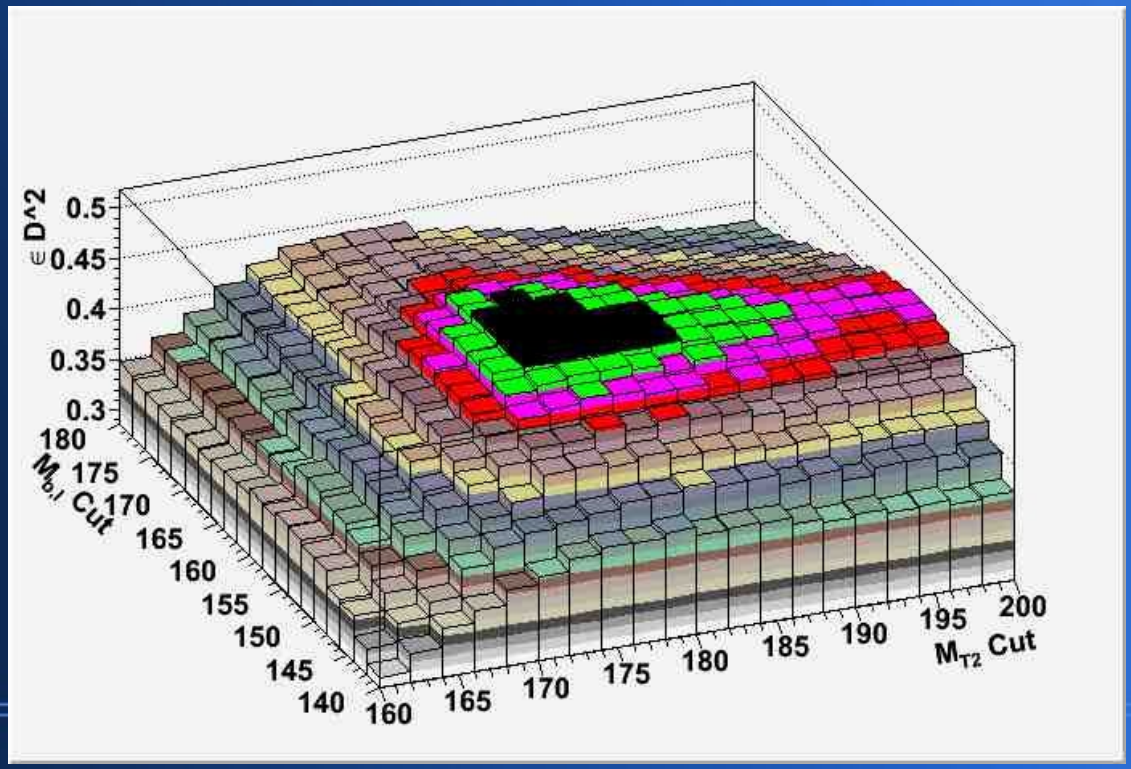
- Improving the combinatoric problems in particle decays allow for better detection and more accurate measurement of particles
- By combining the discriminating power of the invariant mass distributions and M_{T2} we can improve the ability to distinguish correct and incorrect combinations
- Top quark dilepton decay mode provides a good SM application of the method
- Method can be used to study gluino pair production or possibly other BSM processes

Thank you for listening.
Questions?

BACKUP SLIDES

ttbar Cut Selection

- Cuts were selected to maximize the sensitivity
  - $\epsilon\left(2\mathrm{P}^2-1\right)$
- Cuts set at
  - M_{T2}<176
  - $M_{b,l}$<156



ttbar Results with ISR

7 TeV

# of Passed Combinations	Events (out of 10000)	Events w/ Correct Combination Passing
0	447	0
1	1994	1156
2	2196	1264

- Efficiency = 19.9%, Purity = 58%

1.96 TeV

# of Passed Combinations	Events (out of 10000)	Events w/ Correct Combination Passing
0	655	0
1	2714	1767
2	3937	2749

- Efficiency = 27%, Purity = 65%

ttbar Backgrounds

Process	generator	order	final state	cross section (pb)
$t\bar{t}$	THEORY [?]	NNLL resummation	$t\bar{t}$	165
W^+	FEWZ [?]	NNLO	$\ell^+\nu$ + jets	16670
W^-	FEWZ	NNLO	$\ell^-\bar{\nu}$ + jets	11379
Z/γ^*	MCFM	NLO	$\ell^+\ell^-$ + jets	3000
W^+W^-	MCFM [?]	NLO	inclusive	43
$W^+ + Z/\gamma^*$	MCFM	NLO	inclusive	11.8
$W^- + Z/\gamma^*$	MCFM	NLO	inclusive	6.4
$Z/\gamma^* + Z/\gamma^*$	MCFM	NLO	inclusive	5.9