Resolving Combinatorical Ambiguities at Hadron Colliders with MT2

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Motivation

- With the Tevatron still running and 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
  - KK gluon producion
- 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

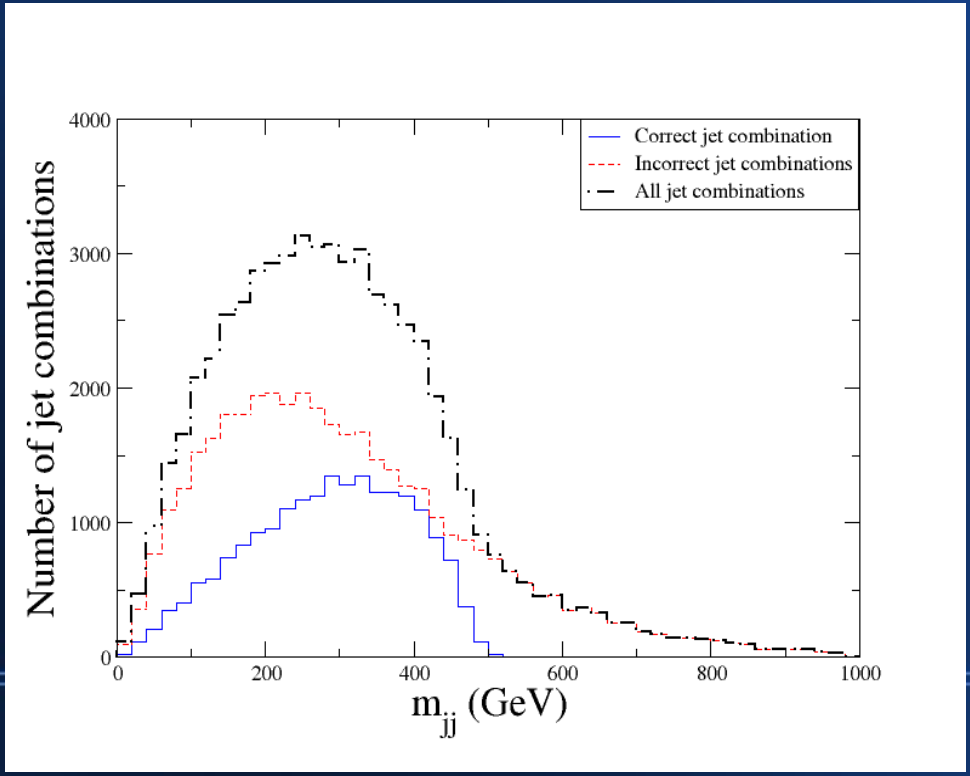
- Bi-Event subtraction (arXiv:1104.2508) takes care of this problem but not on an event by event basis.

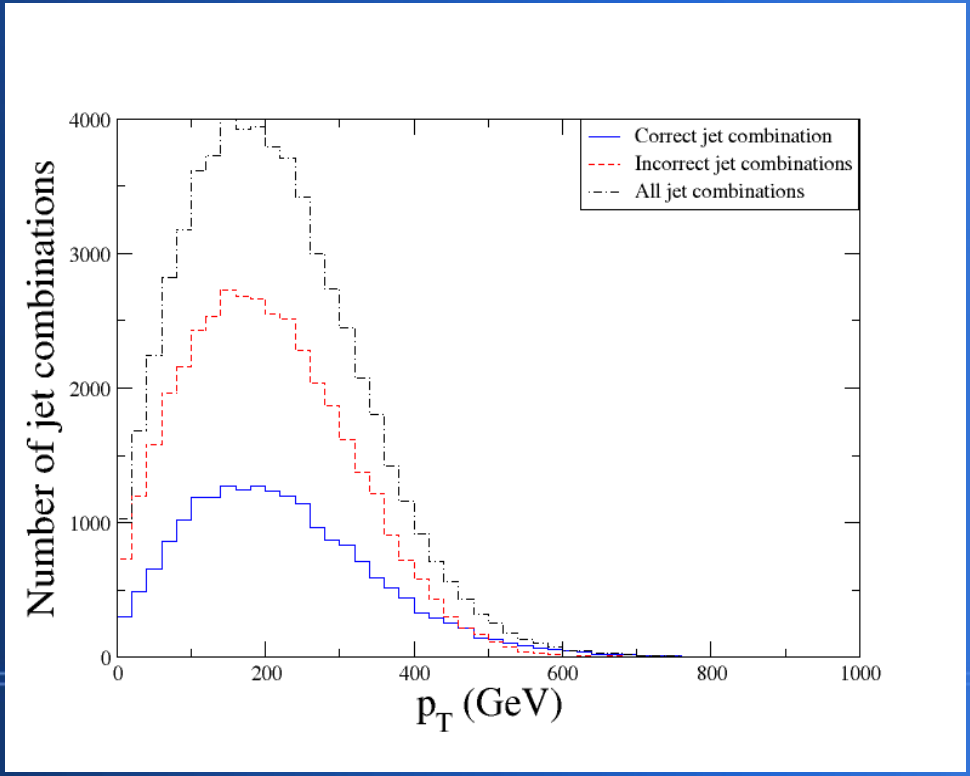
Previous Study

- Rajaraman and Yu studied a method to resolve this combinatorical issue using invariant mass and transverse momentum. (Phys.Lett.B700:126-132,2011)
  - Assumptions
    - No backrounds.
    - Large squark masses
    - ISR jets have been isolated
    - Gluino mass = 600 GeV and Neutralino mass = 100 GeV
- Events generated using MadGraph (10K)
- Assumed 7 TeV LHC w/Energy Smearing

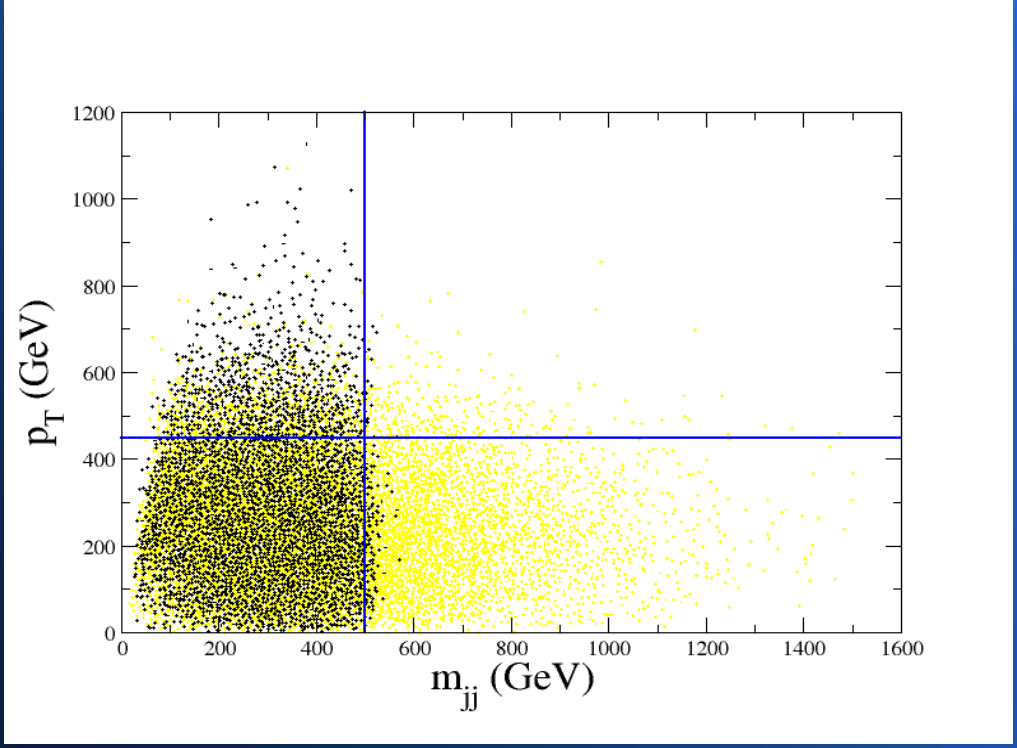
Previous Study

- A cut is made so that 1 of the 3 combinations
  - Invariant mass < 500 GeV
  - Transverse momentum > 450 GeV



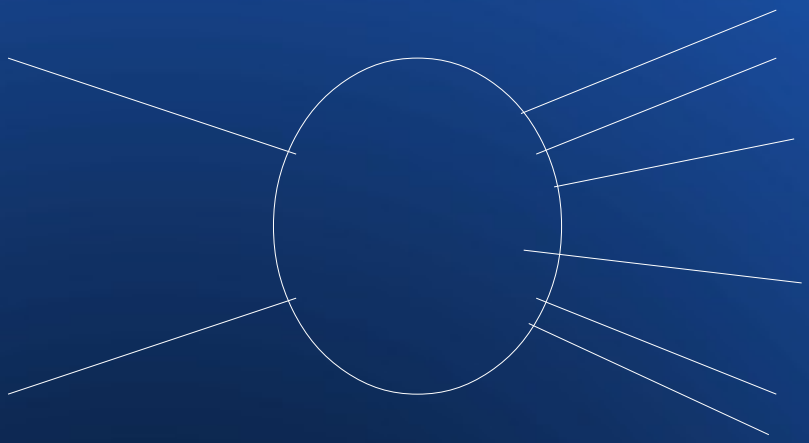


Previous Study



- 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

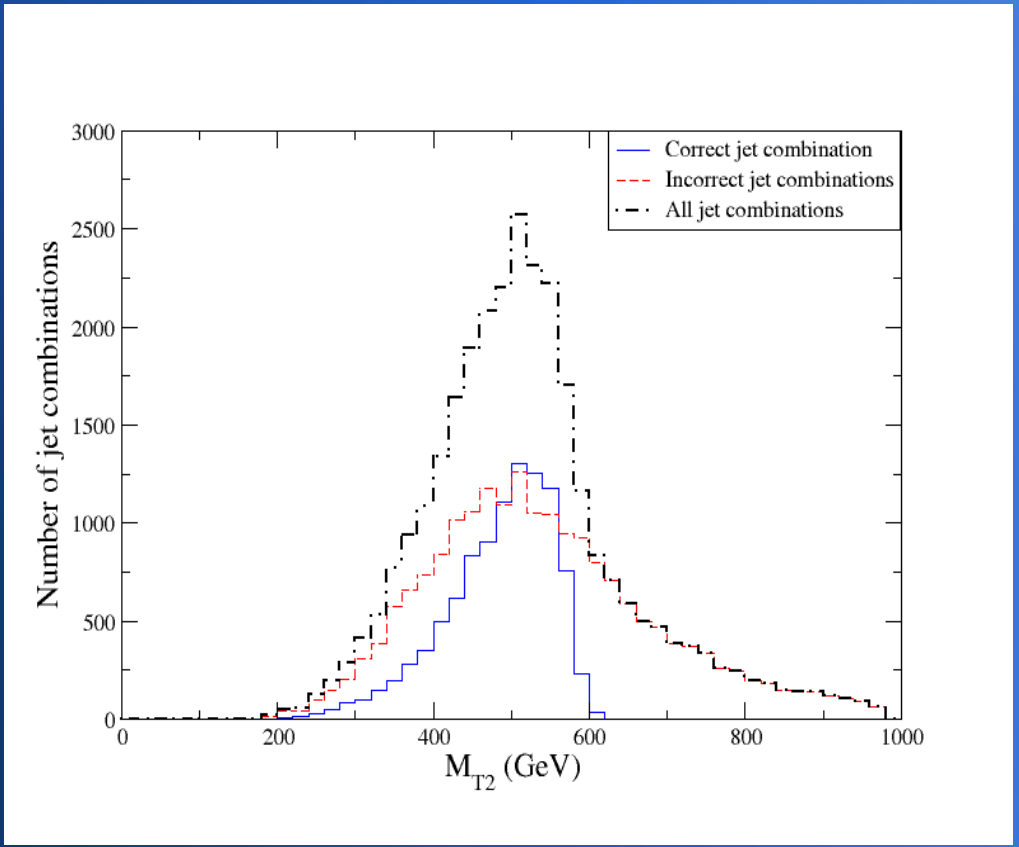
$$M_{T2} = \min_{\{\not{p}_{1T}+\not{p}_{2T}=\not{p}_T\}} \{\max[M_{T1}, M_{T2}]\}$$

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

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

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 cut from previous study.



Results

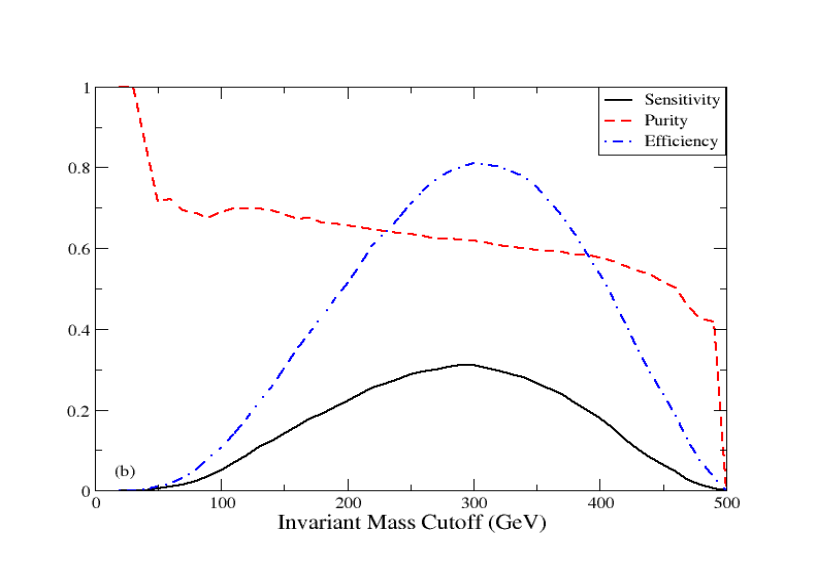
Number of jet combinations	Percent of Events	Percent of Events with the correct combination
0	70	n/a
1	2003	1896
2	3135	3076
3	4792	4792

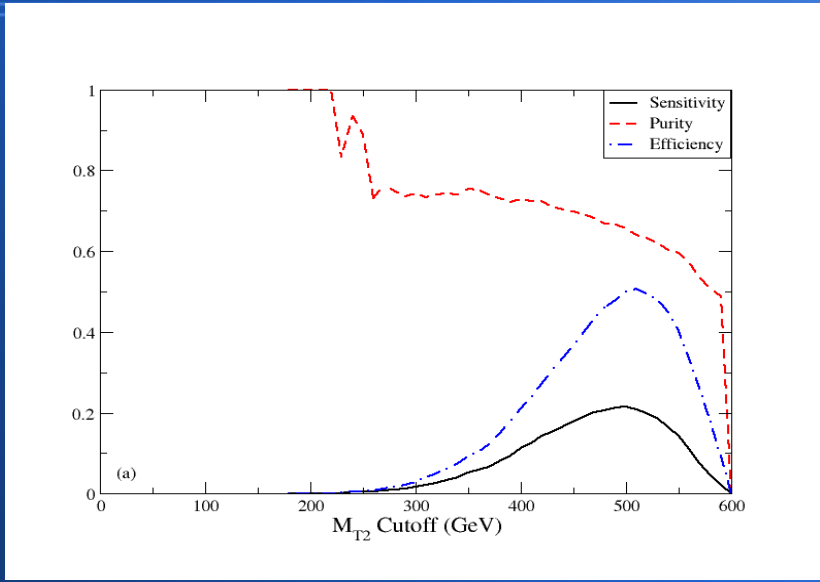
- Just looking at events with 1 passed combination we have an event efficiency of 20% and a purity of 95%!

Improvements

- Most of the correct combinations of jets have not been excluded using our cuts
- It may be possible to use further cuts on just the events where two combinations pass to try and extract the correct combination
  - e.g. taking the MT2 or invariant mass closest to the cutoff as the correct combination
  - To find the best cutoff we maximize sensitivity $\varepsilon(2P-1)^2$

Improvements





- To maximize sensitivity we find the invariant mass cut and MT2 cut to be at 300 GeV and 500 GeV, respectively.
  - inv. mass: 35% efficiency and 76% purity
  - MT2: 30% efficiency and 82% purity.

Different Mass Spectra

- We want to see how this method performs over different values of the gluino and neutralino mass.
  - Assume that particle masses are known
  - Cuts change with different spectra
    - MT2 < gluino mass
    - inv. mass < gluino mass – neutralino mass
- In general, we find that this method is very robust over different mass spectra.

Different Mass Spectra

Neutralino Mass /Gluino Mass	50 GeV	100 GeV	150 GeV	200 GeV	250 GeV
700 GeV	0.15 / 0.94	0.17 / 0.94	0.20 / 0.93	0.22 / 0.93	0.28 / 0.93
600 GeV	0.17 / 0.95	0.20 / 0.94	0.24 / 0.93	0.26 / 0.93	0.28 / 0.92
500 GeV	0.21 / 0.94	0.24 / 0.93	0.28 / 0.93	0.31 / 0.93	0.36 / 0.91
400 GeV	0.25 / 0.94	0.30 / 0.93	0.34 / 0.91	0.37 / 0.91	0.43 / 0.87
300 GeV	0.30 / 0.93	0.36 / 0.92	0.42 / 0.90	0.48 / 0.85	0.54 / 0.80

ISR

- Important to be able to identify ISR from jets from the gluino decay
  - Phys.Rev.Lett.103:151802,2009

    (Alwall, Hiramastsu, Nojiri, and Shimizu)
- Method uses MT2 (5 jet case)
  - First two hardest jets are put in separate decays
  - Take out one of the remaining 3 jets and calculate MT2
  - For the smallest MT2 the jet taken out is the ISR

ISR

- With this method the ISR can be identified about 24% of the time
  - Improvements can be made by requiring that the MT2 exceeds a minimum value
  - Increases ISR identification to 36%.
- Of the events where the ISR is correctly identified, applying our method yields a 16% efficiency and 92% purity.
- Shows how important it is to correctly identify the ISR jets

Conclusions

- We introduced a method for resolving combinatorical ambiguities on an event by event basis.
- Improved results compared to previous studies
- With few correct combianations failing our cuts there is room for improvement with more refined cuts
- Robust over different mass spectra
- Applicable to many different processes (e.g. ttbar in the dilepton channel, KK gluon production)

The End

Thank You!