New Approach to Identify Boosted Hadronically Decaying Particle using Jet Substructure in its Centre of Mass Frame

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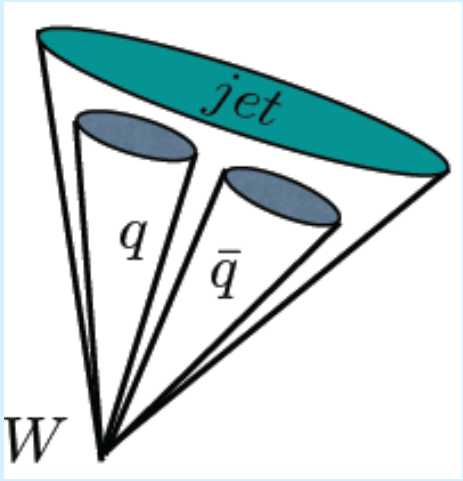
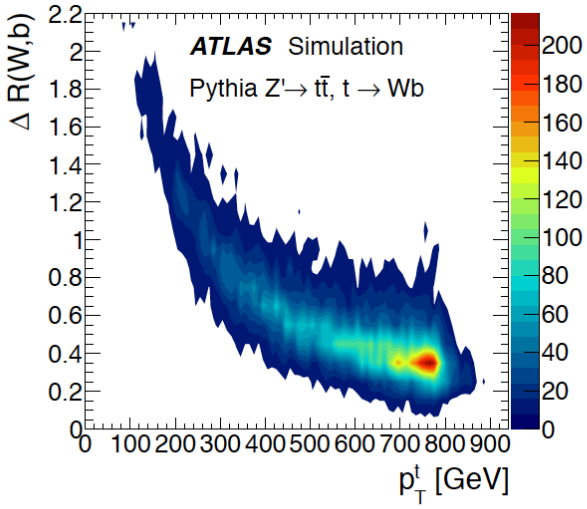
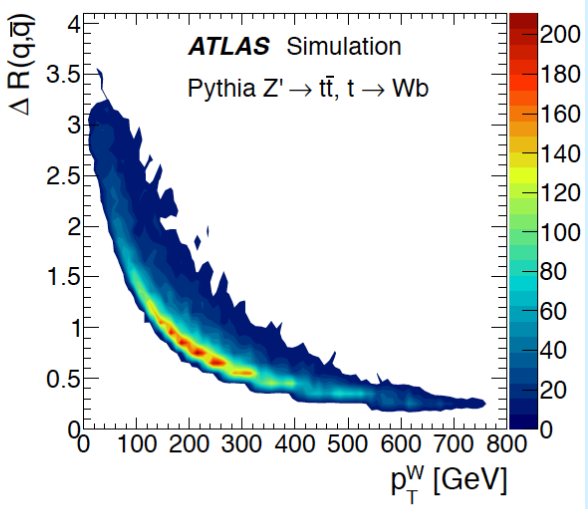
Why boosted hadronic W/Z/top

- Many NP models predict heavy resonance decay into W/Z/Top:
  - ✓ Boosted (high p_T) jets in the final decay states
  - ✓ Problem with traditional jet reconstruction
    - Jet merging, overlapping





(a) $t \to Wb$



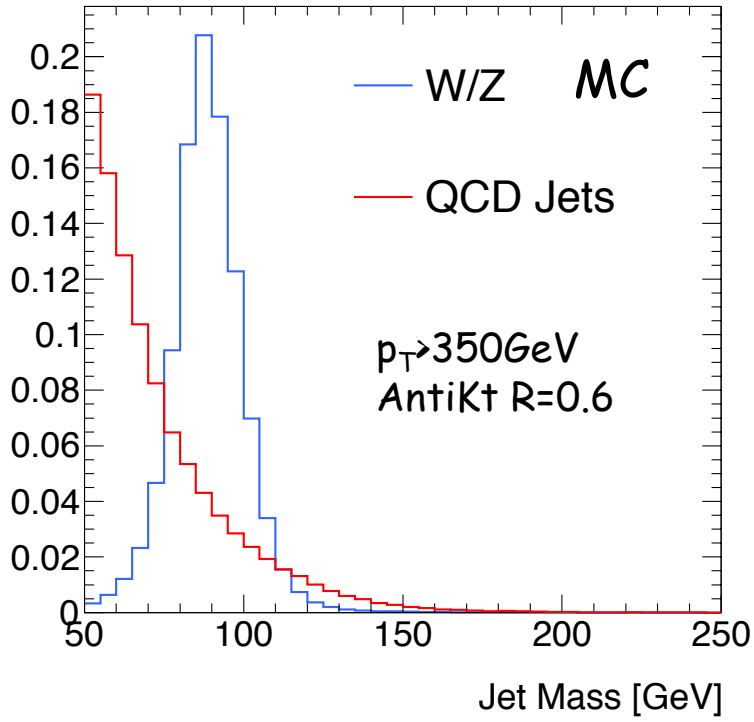
(b) $W \to q\bar{q}$

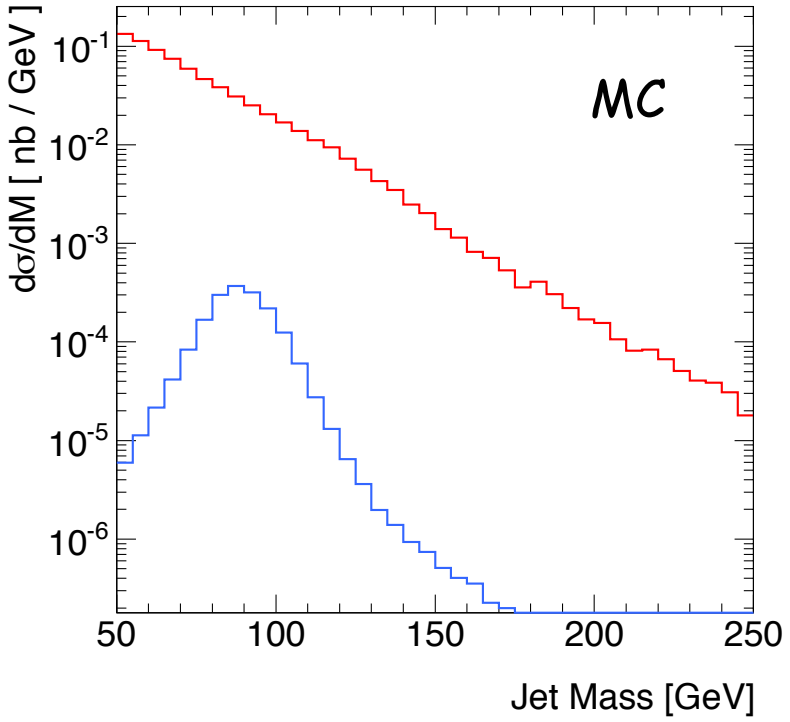
- Solution:
  - ✓ Jet algorithm with large cone-size
  - ✓ Reconstruct boosted particle in a single jet

$$\Delta R \approx \frac{2m}{p_{\mathrm{T}}}$$

How to identify boosted W/Z/top

- Jet mass tells the origin of the jet
  - ✓ QCD jet: originated from non-top quark or gluons

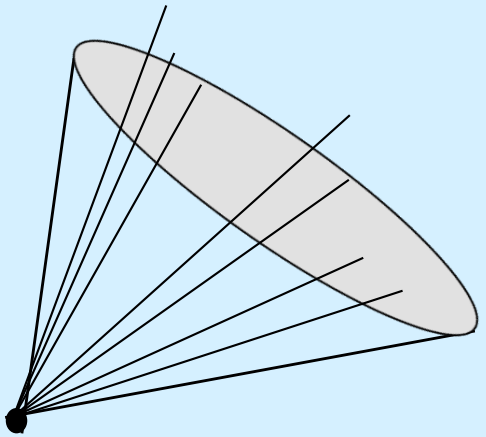




- Problem: QCD jet production a few orders magnitude higher
- Jet mass alone not enough discriminating power

Identification of boosted W/Z/t

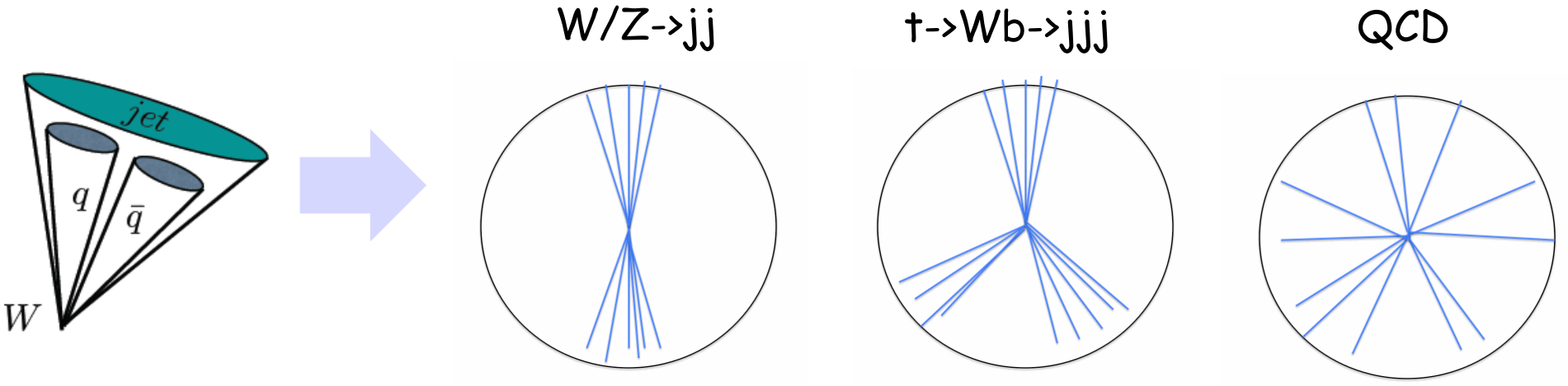
- Jet substructure for additional discriminating power
- Traditional method to identify boosted hadronic W/Z/top
  - ✓ Jet grooming, trimming etc
  - ✓ Shape variables:
    - Jet width, eccentricity, aplanarity etc
    - Using energy clusters in the (η, ϕ) plane



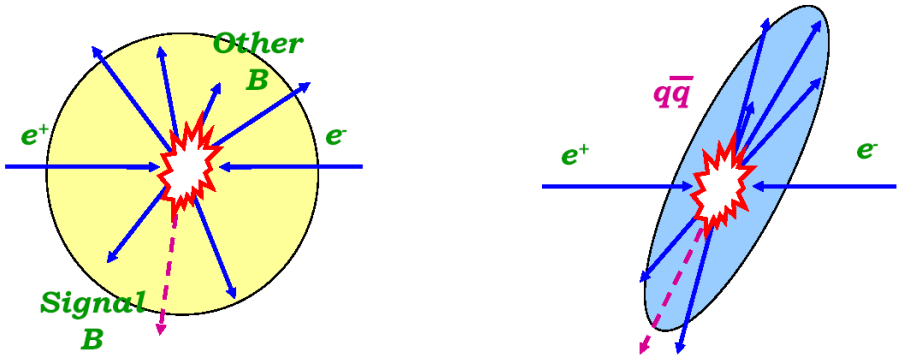
- Our proposal: shape variable/reclustering in jet rest frame:
  - ✓ Jet CM frame: jet 4 momentum = (0,0,0,m_{jet})
  - ✓ Similar technique used at LEP and B-factory
  - ✓ Better discriminating power against QCD background
  - ✓ Using full momentum information of the energy clusters

Jet substructure in the jet CM Frame

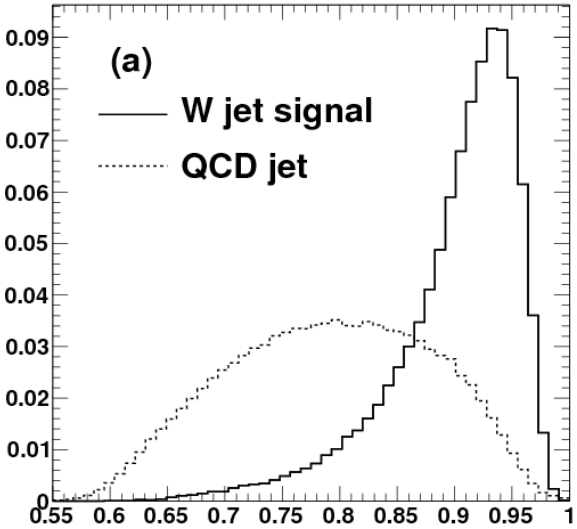
- Distribution of jet clusters in hadron collider:

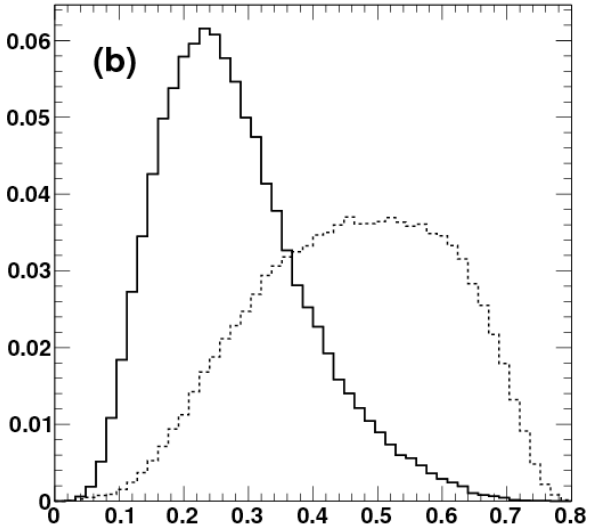


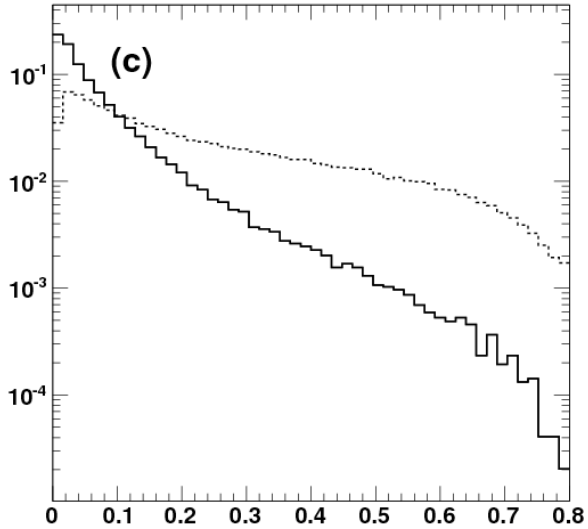
- Lesson learned from e^+e^- collider: event topology -> jet topology

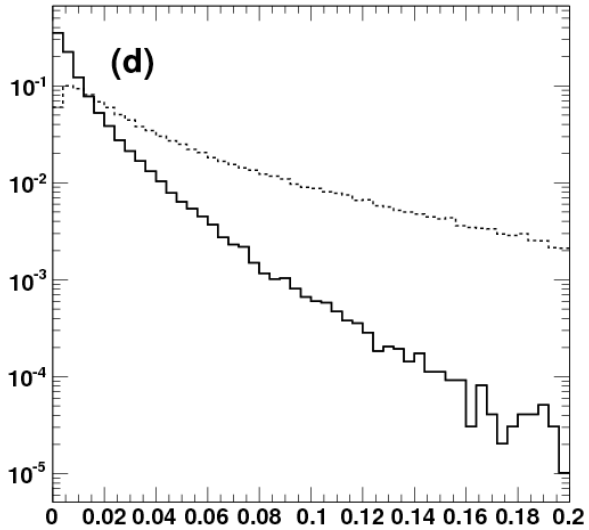


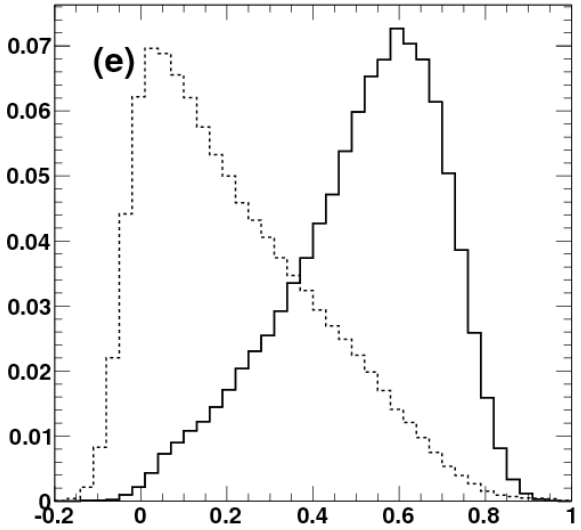
Shape Variables in Rest Frame





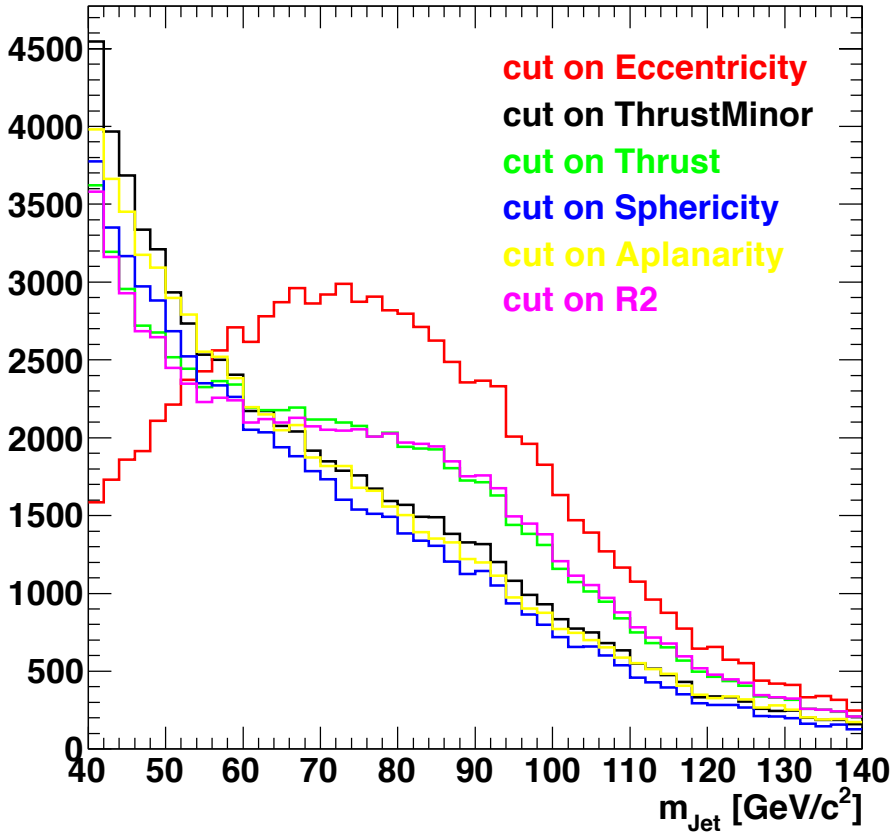






MC: pythia generator level study,
Particles in 0.1x0.1 cell group as a single cluster,
jet p_T>300GeV $|\eta|$<2.5
AntiKt algorithm, R=0.6

Correlation of shape variable & jet mass

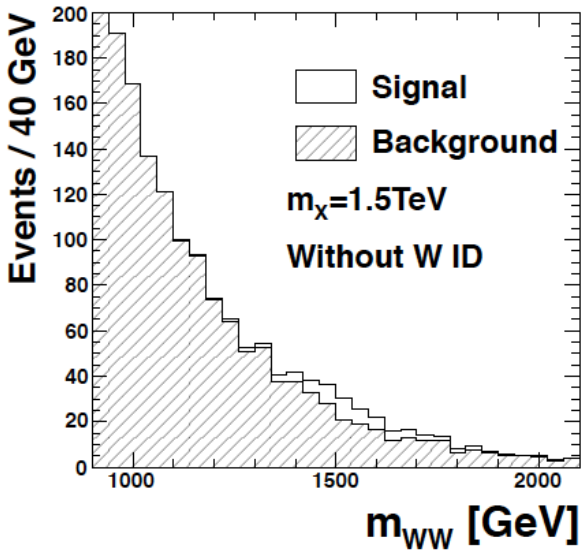


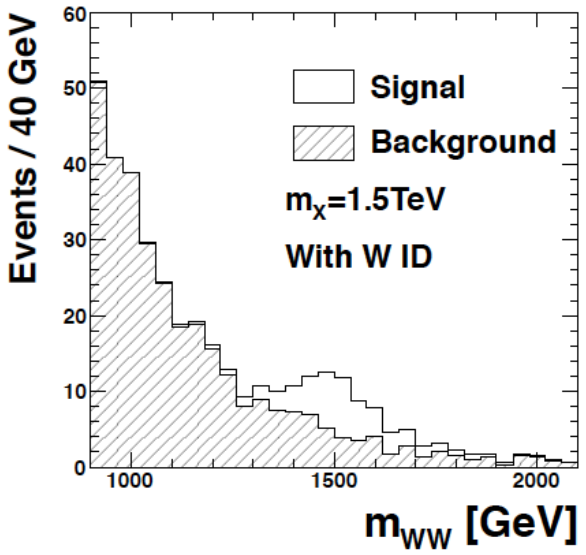
Distribution of the jet mass of QCD jets after cutting on each individual variable to reject 90% QCD jets

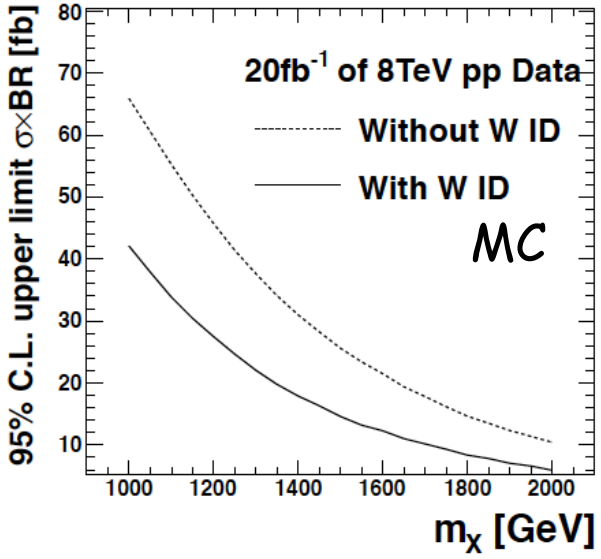
- Large correlation between eccentricity and jet mass
  - ✓ Eccentricity: a jet shape in lab frame used
- Small correlation for variables in CM frame
  - ✓ Sphericity, Aplanarity and Thrust_minor slightly better
- Better background rejection power for shape variables in CM

Using W ID to search for X->WW

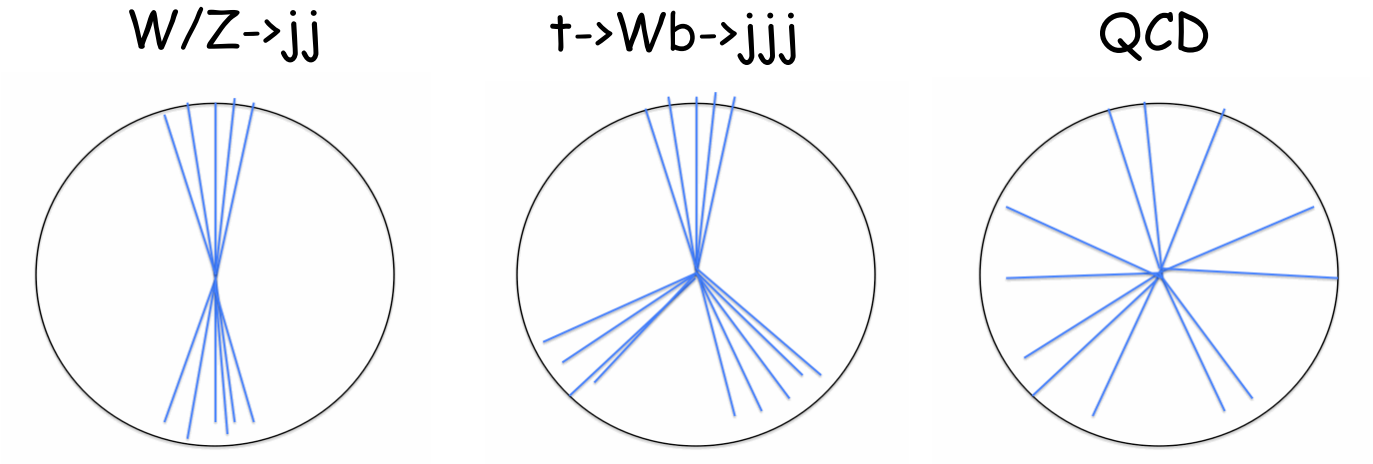
- Heavy resonance decaying into diboson:
- Using X->WW as example
  - ✓ One W decay leptonically,
  - ✓ The other decay hadronically
  - ✓ Full reconstruction of m_X
    - One neutrino in the event
    - Reconstruction using miss E_T & W mass constraint
  - ✓ Assuming production effective cross section : 20fb







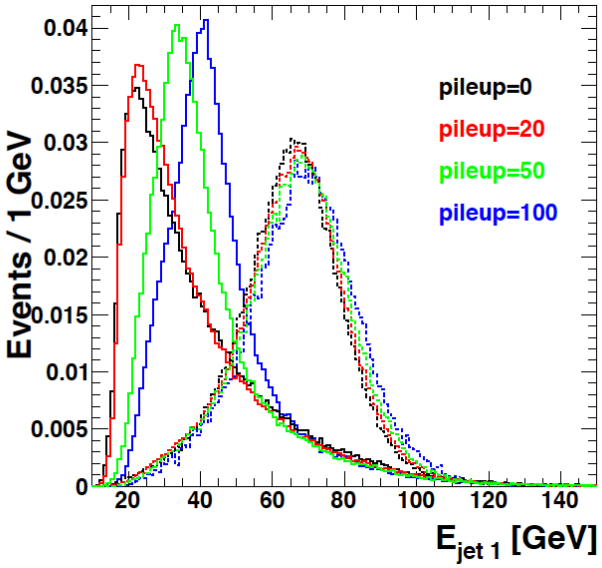
Reclustering in the rest frame

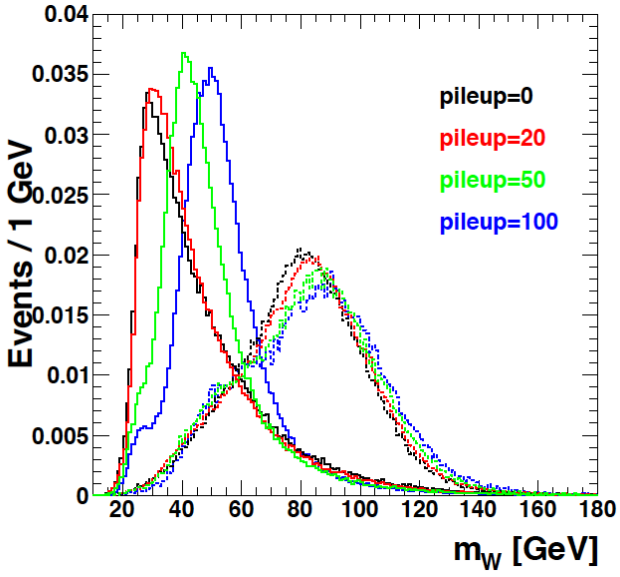


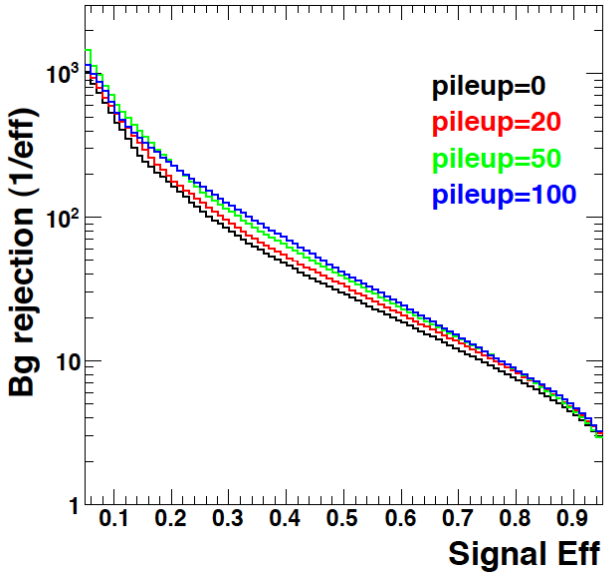
- Rerun the jet finding algorithm on the clusters in the CM frame
  - ✓ Fastjet
  - ✓ Jet algorithm similar (not identical) to e^+e^- experiments
    - Tradition jet algorithm based on η and Θ not appropriate
    - Combine 2 clusters in $\Delta\Theta<0.6$
    - Angle Θ: angle between 2 clusters

Subjets of boosted top in its CM frame

- p_T(top)>600GeV, W decay hadronically
- At least 3 subjets with E>10GeV



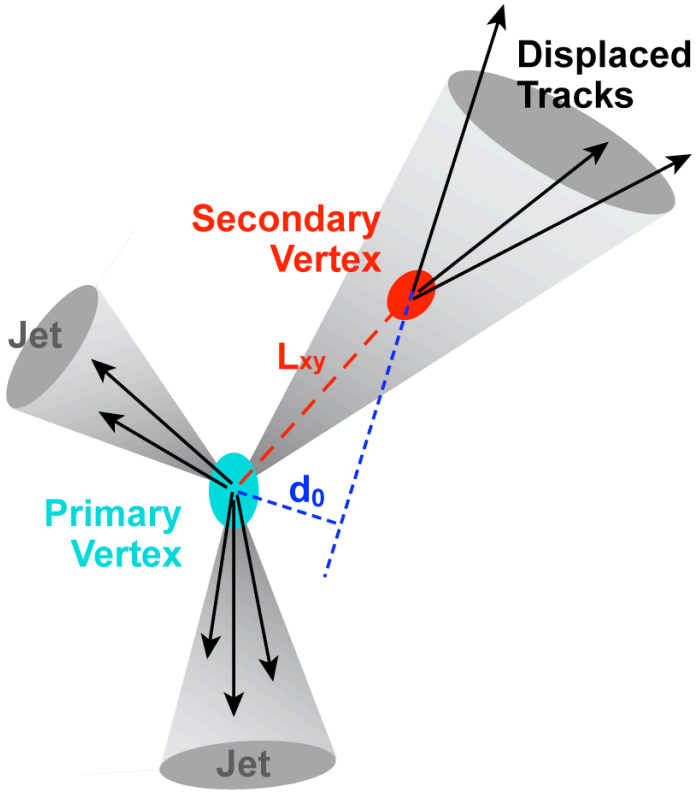


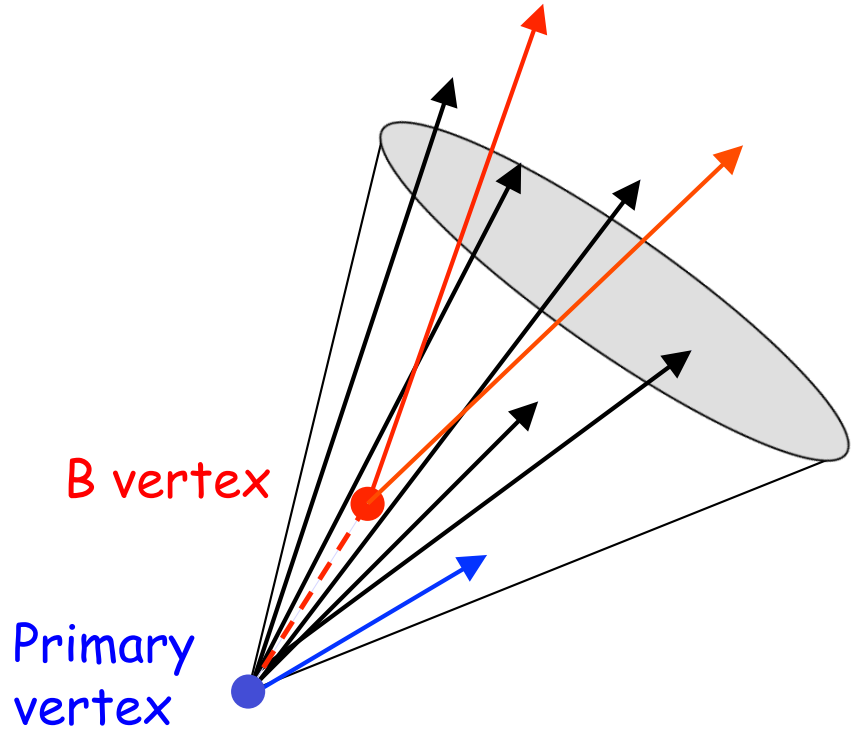


- Many jet substructure variables are correlated
- Multi variable approach to combine different variables
  - ✓ Energies of 3 leading jets, mass combinations ……

Identify b quark inside boosted top

- Top quark decays to Wb almost 100%
- Identify b quark (b-tagging) based on its long lifetime



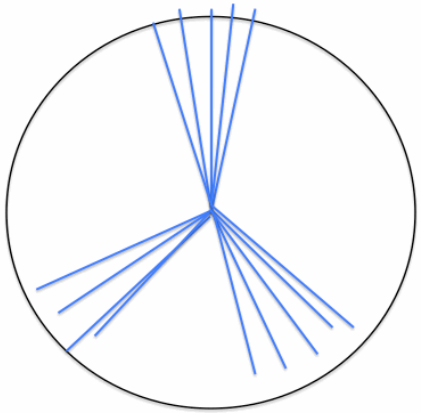


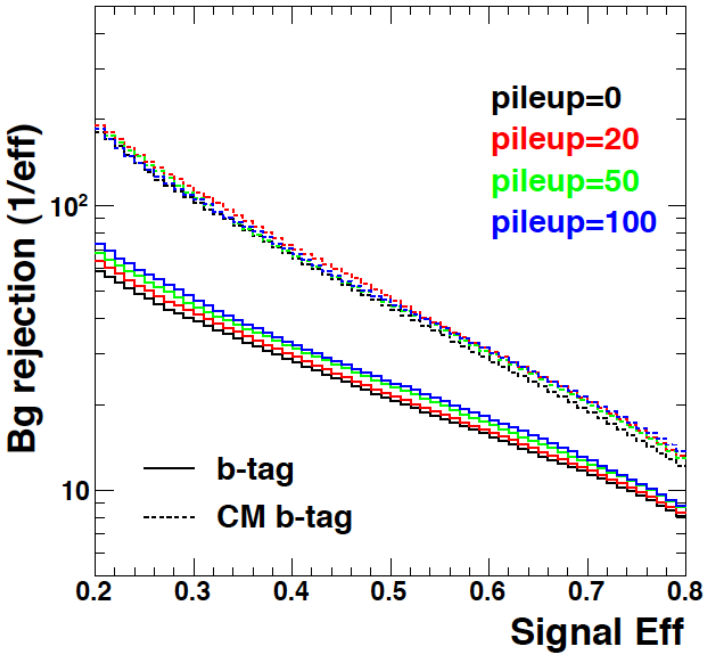
Problem of direct application of b-tagging for boosted top jet:
Difficult to disentangle tracks originated by b decays from tracks originated from W decay

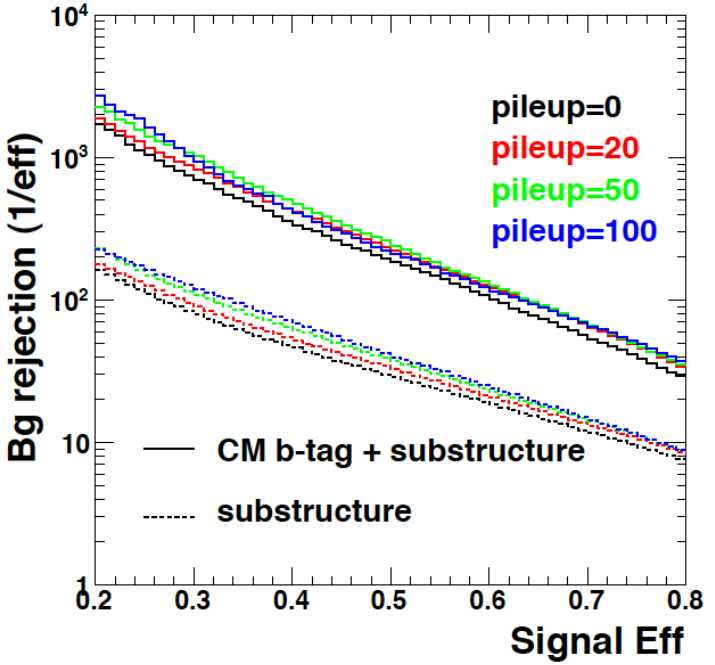
Identify b quark inside boosted top

- Boost charged tracks back into jet rest frame
- Associate tracks with subjets
- Separate tracks originated from different partons: b or W->qq'
- Comparing to direct application of b-tagging
  - ✓ Studies done using impact parameter algorithm b-tagging
  - ✓ Better performance using CM b-tagging
- Combine b-tagging with jet substructure

t->Wb->jjj

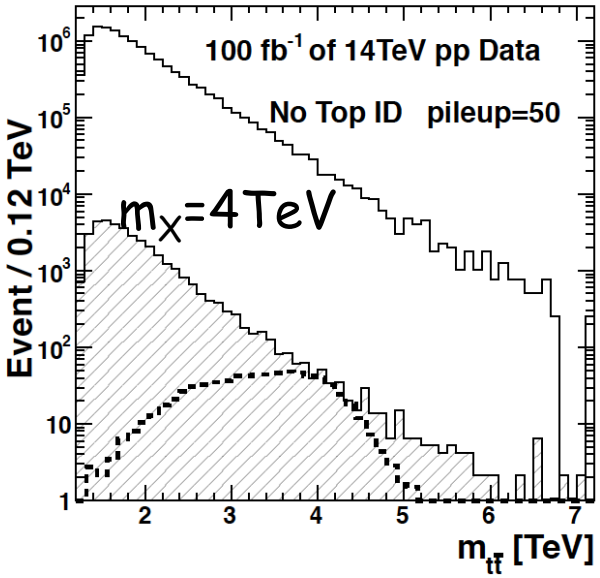


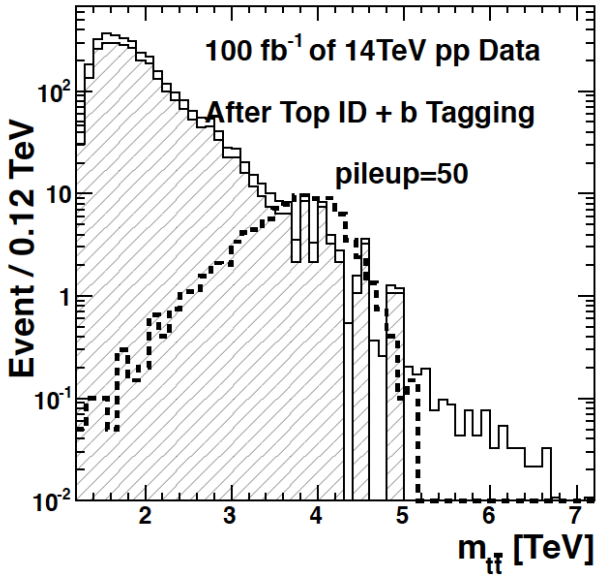


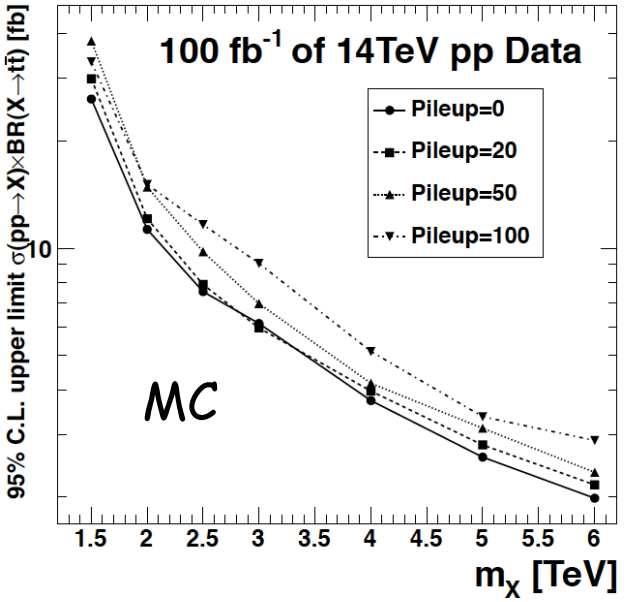


Using Top ID to search for X->ttbar

- Heavy resonance decaying into a top pair
- Both top decay hadronically: hadronic W
  - ✓ Dominant bg: SM mutijet production, top pair production
- Choose 2 leading jets as top candidate to form a X candidate
- Assuming effective production cross section of X: 10fb







Summary and Conclusion

- Propose a new approach to identify boosted particle
  - ✓ Based on shape variables/reclustering in jet CMS frame
- Show its application to identify boosted hadronic W/Z/top
- Improved b-tagging performance in boosted top quark
- Improve search sensitivities for heavy resonance decaying to final states containing W/Z bosons or top quarks
- Details in Reference:
  - ✓ C. Chen: Physical Review D 85, 034007 (2012)
  - ✓ C. Chen: Physical Review D 87, 074007 (2013)
  - ✓ C. Chen: arXiv:1307.4825 [hep-ph]