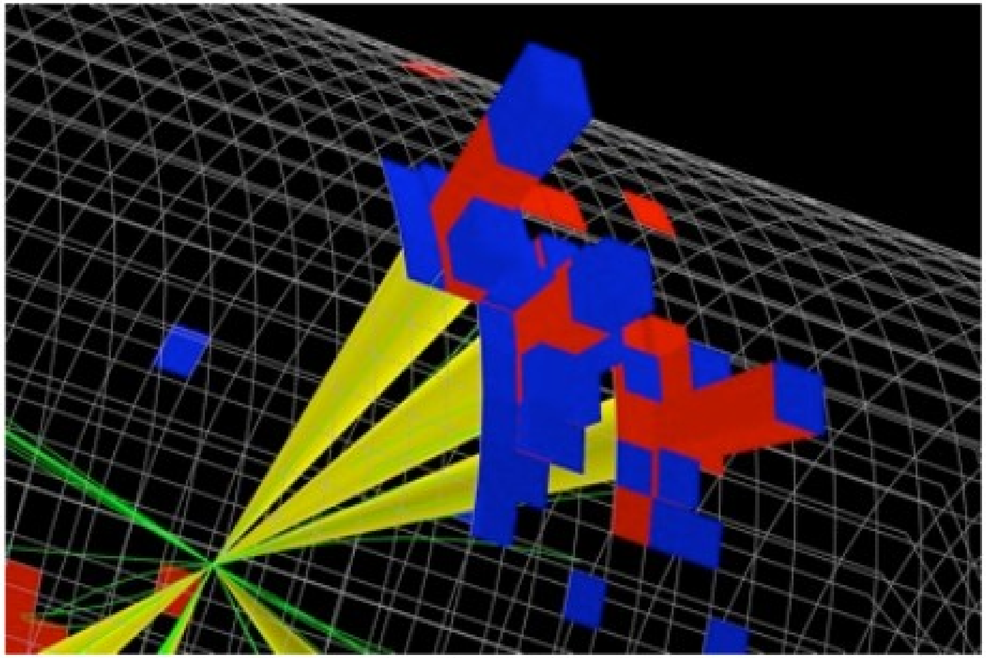
Jet Substructure in pp Collisions at 7 TeV in CMS

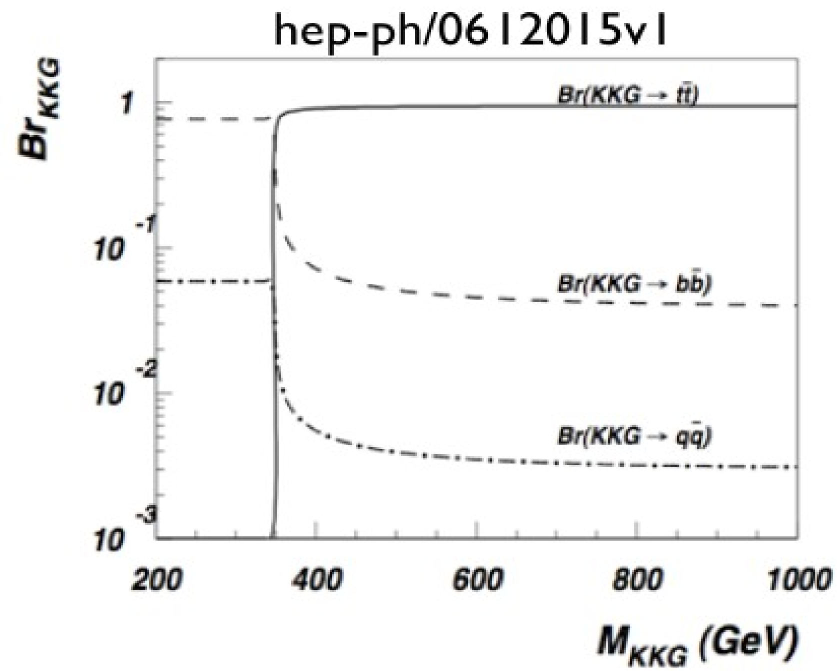


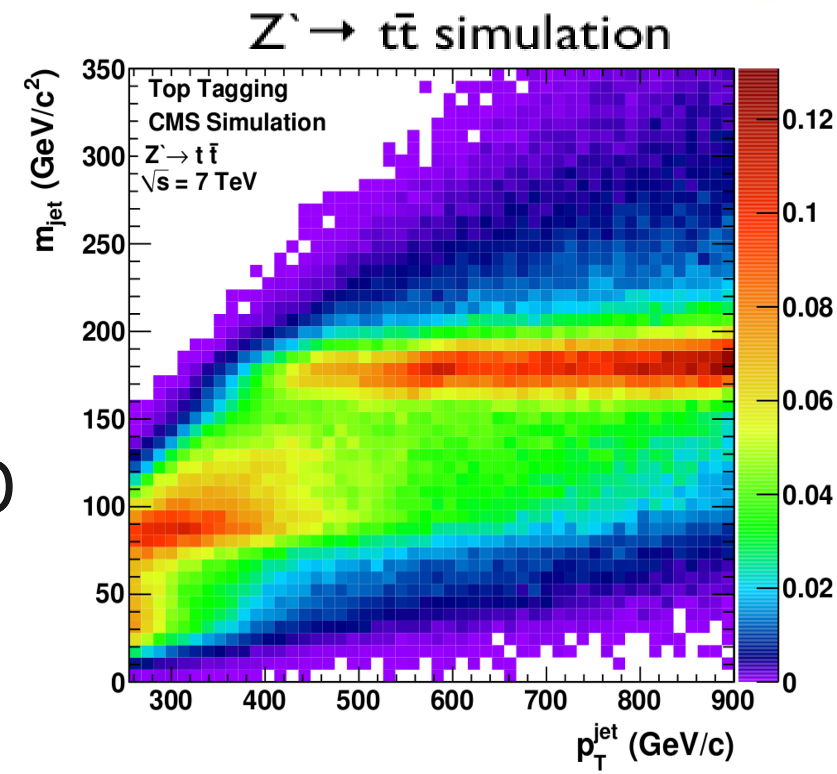
Guofan Hu (Johns Hopkins University),
on behalf of the CMS TTBSM and JetMET Groups

Boston Jet Workshop, Jan 14, 2010

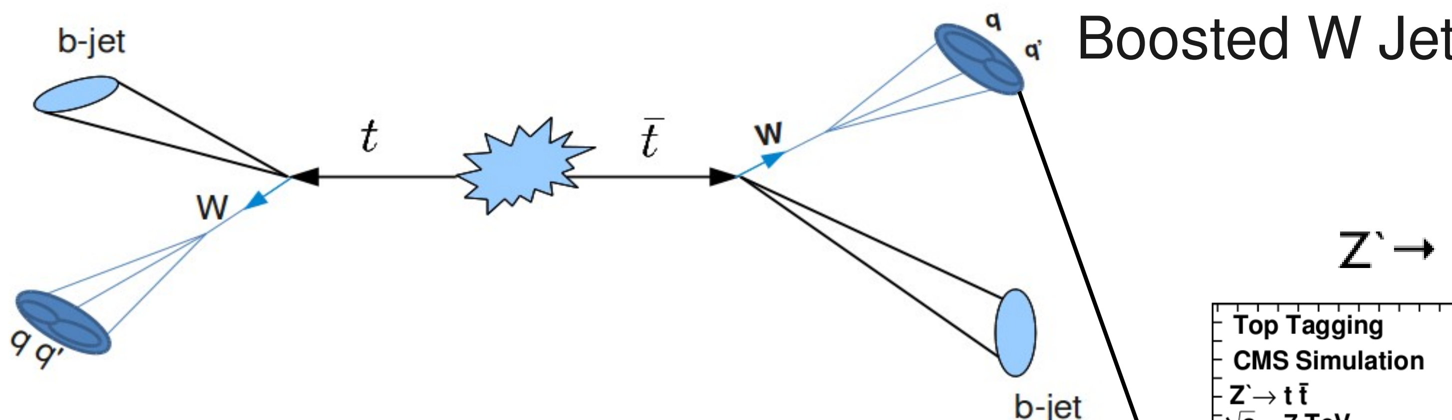
Motivation

- New physics scenarios often involve boosted hadronic resonances
  - Top
  - W/Z
- The decay products are highly boosted, and thus may merge within one jet
- Jet substructure is exploited to distinguish merged jets with QCD jets

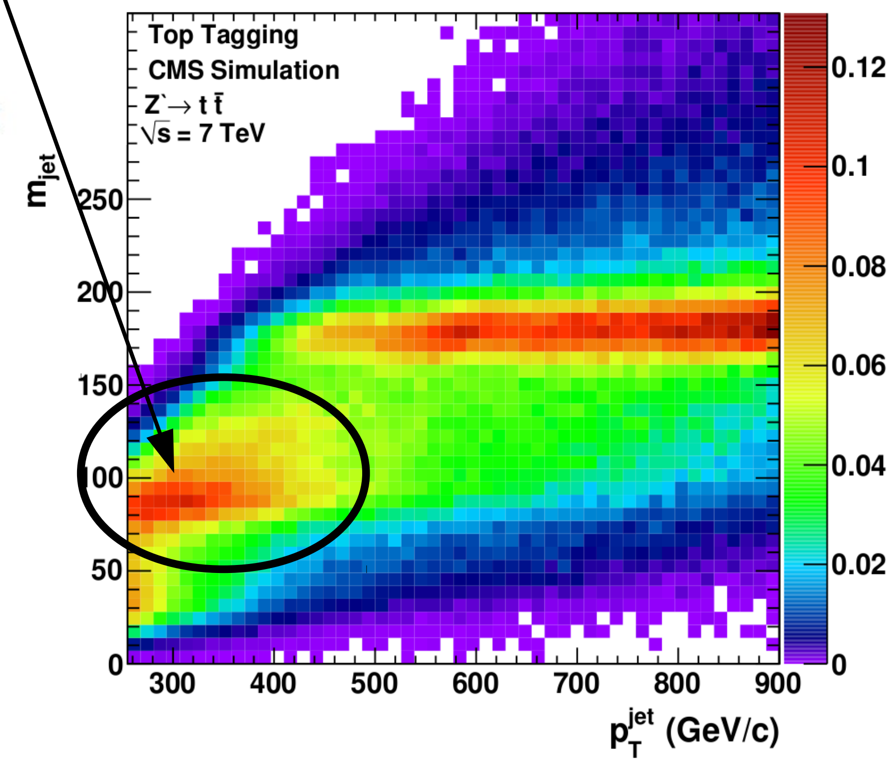




W Jet



Z` → t$\bar{t}$ simulation



Use jet pruning algorithm to prune jets and find jet substructure to identify W jets

Jet Pruning Details

- Based on Univ of Washington jet pruning algorithm (Stephen D. Ellis, Christopher K. Vermilion, and Jonathan R. Walsh) (arXiv:0903.5081)
- Cluster particle flow candidates using Cambridge Aachen R=0.8
- Recluster each jet, requiring that each recombination satisfy the following:

$$\frac{\min(p_{\mathrm{T}1}, p_{\mathrm{T}2})}{p_{\mathrm{T}p}} > 0.1$$

$$\Delta R_{12} < 0.5 \times \frac{m_{\mathrm{jet}}}{p_{\mathrm{T}}}$$

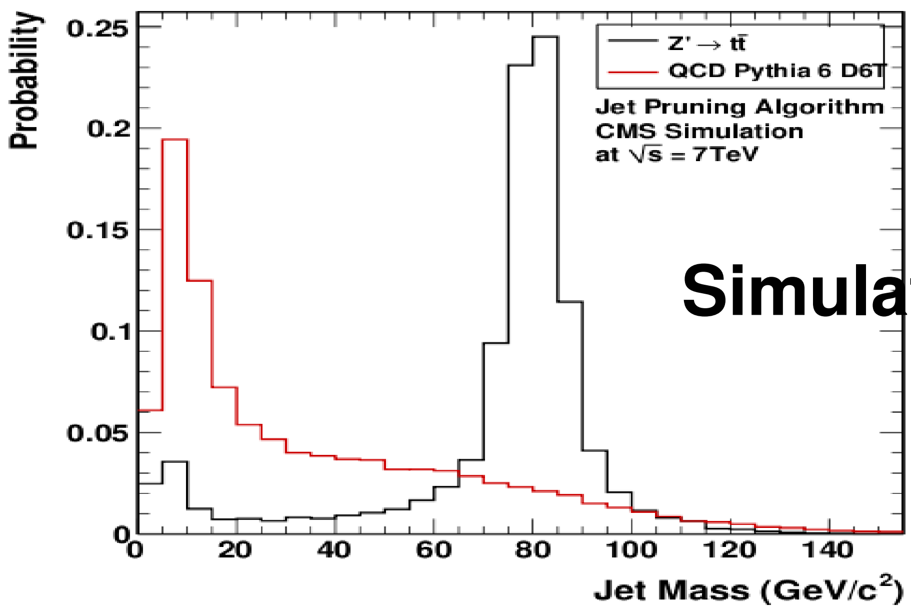
- 2 body decay in boosted W's. 2 subjets are defined as the two legs in the last step of recombination

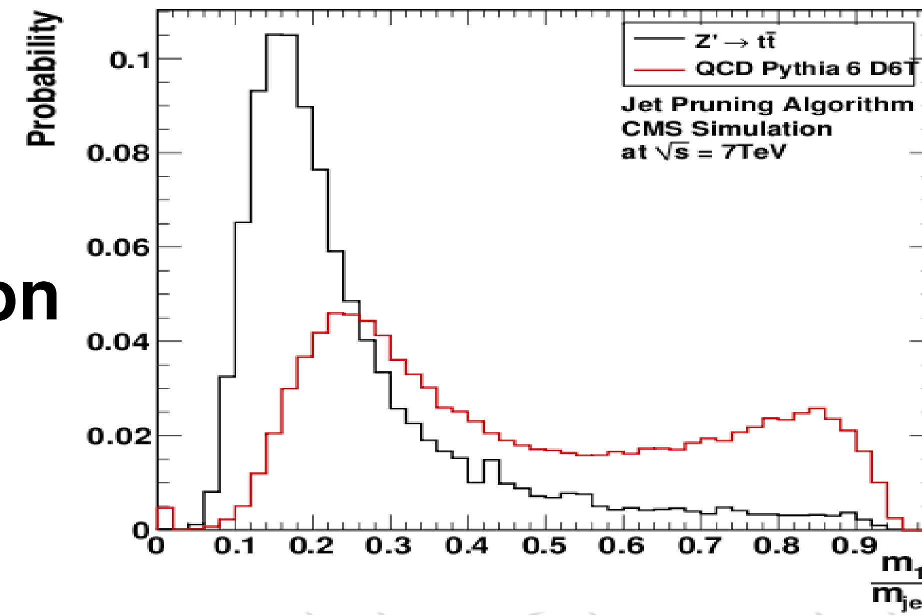
W Jet Tagging Variables

- Four variables are investigated:
  1. Jet mass, – W jets have mass within a W mass window
  2. Mass Drop (mu) $\mu = \frac{m_{j1}}{m_j}$
  3. Subjets ΔR
  4. Subjets pT asymmetry $y = \frac{\min(p_{T1}^2, p_{T2}^2) \cdot (\Delta R_{12})^2}{m_{\mathrm{jet}}^2}$

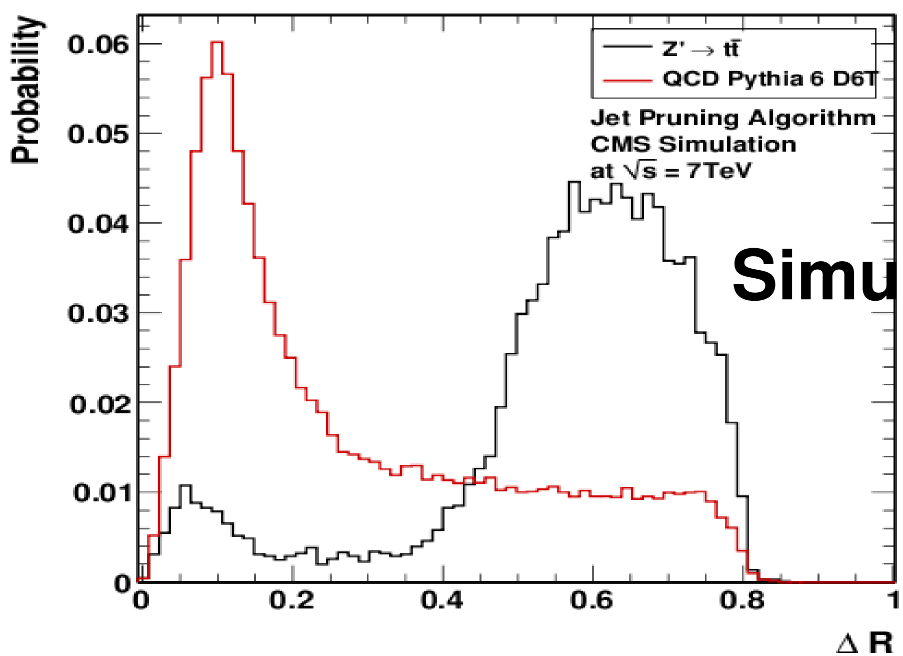
arXiv:0810.0409 (Jonathan M. Butterworth, Adam R. Davison, Mathieu Rubin, Gavin P. Salam)

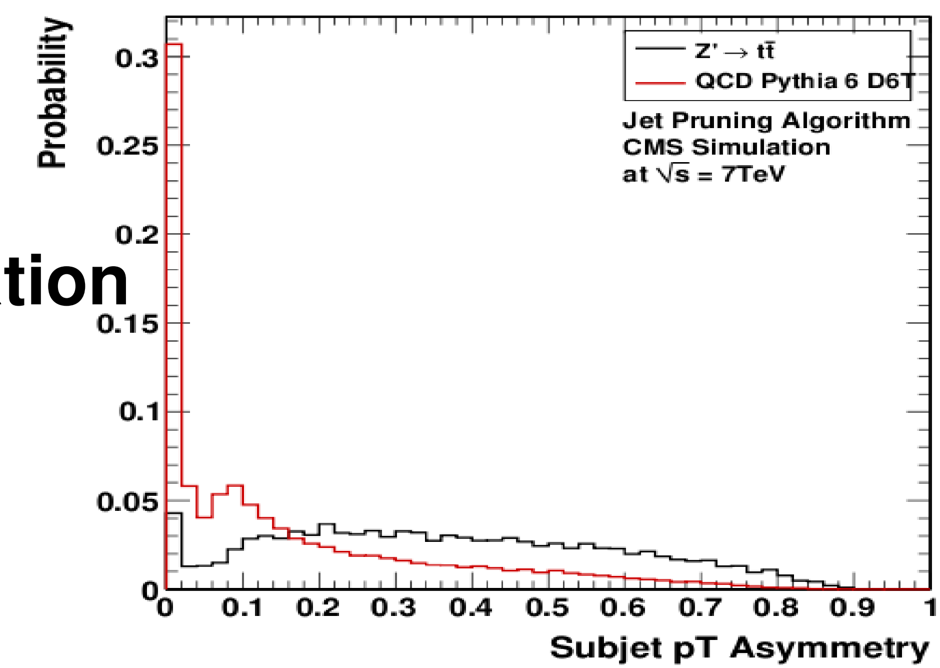
W Jet Tagging Variables





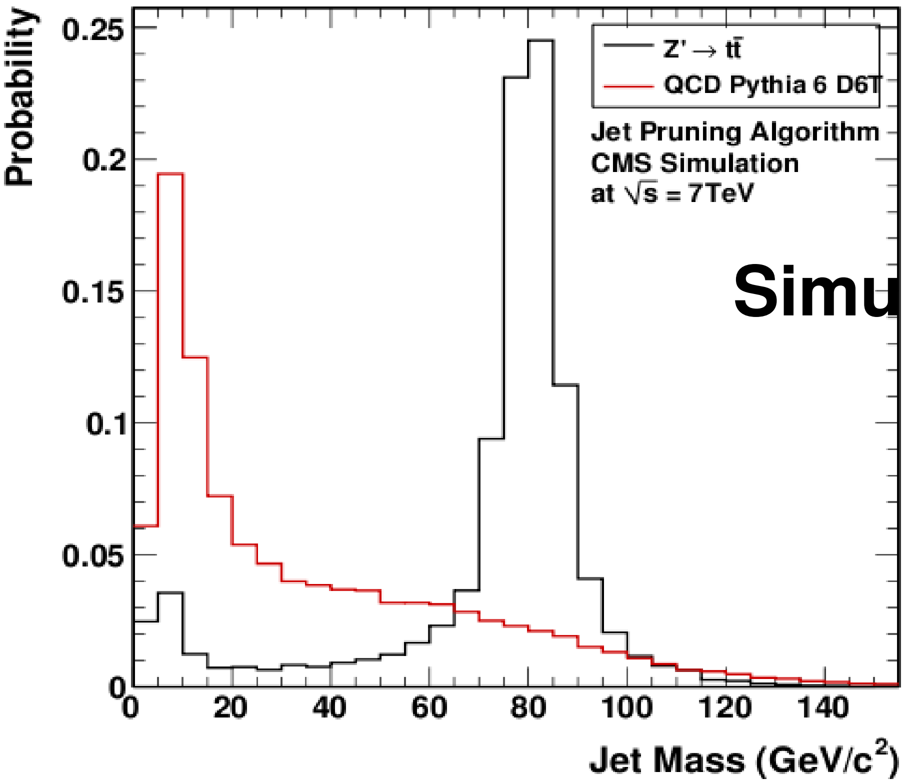
Simulation



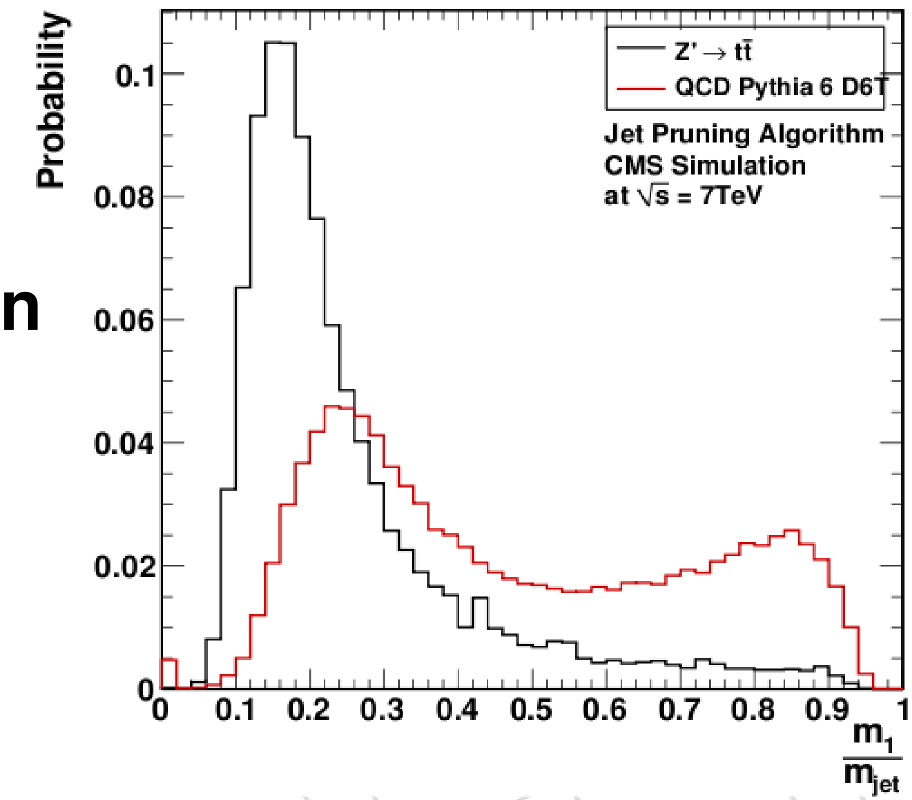


Simulation

W Jet Tagging Variables



Simulation



Define W Tag Cuts

$$60GeV/c^2 < m_{jet} < 100GeV/c^2$$
$$\mu < 0.4$$

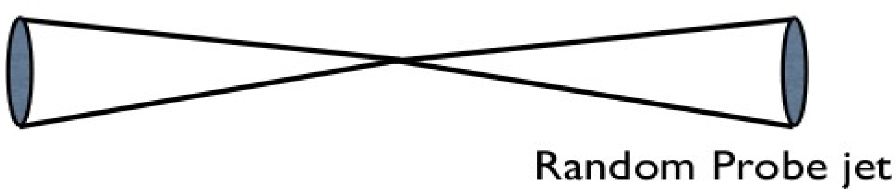
Other two variables have weak discrimination after cuts

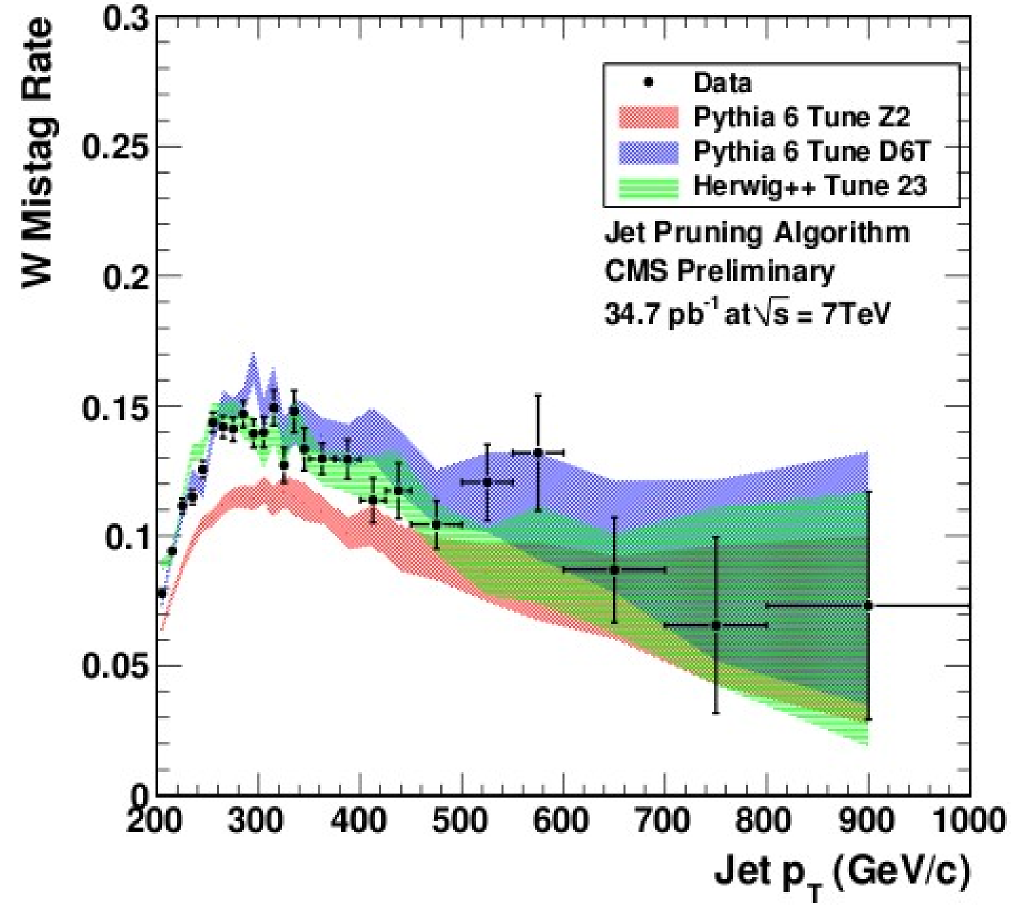
New Results from CMS

- CMS has approved our first measurements using the W tagging algorithm with data
- Public document, “Study of jet substructure in pp collisions at 7 TeV in CMS”
  - Measured W mistag rate from data
    - The mistag rate can be used to do background estimation in new physics search analysis.
  - Commissioned the algorithm
    - Compared multiple Monte Carlo generators and tunes with data
  - Studied the pileup effect

W Mistag Rate from Data

- Select dijet samples with jet pT > 200 GeV/c
- Random method
  - Randomly select one jet
  - That is the probe



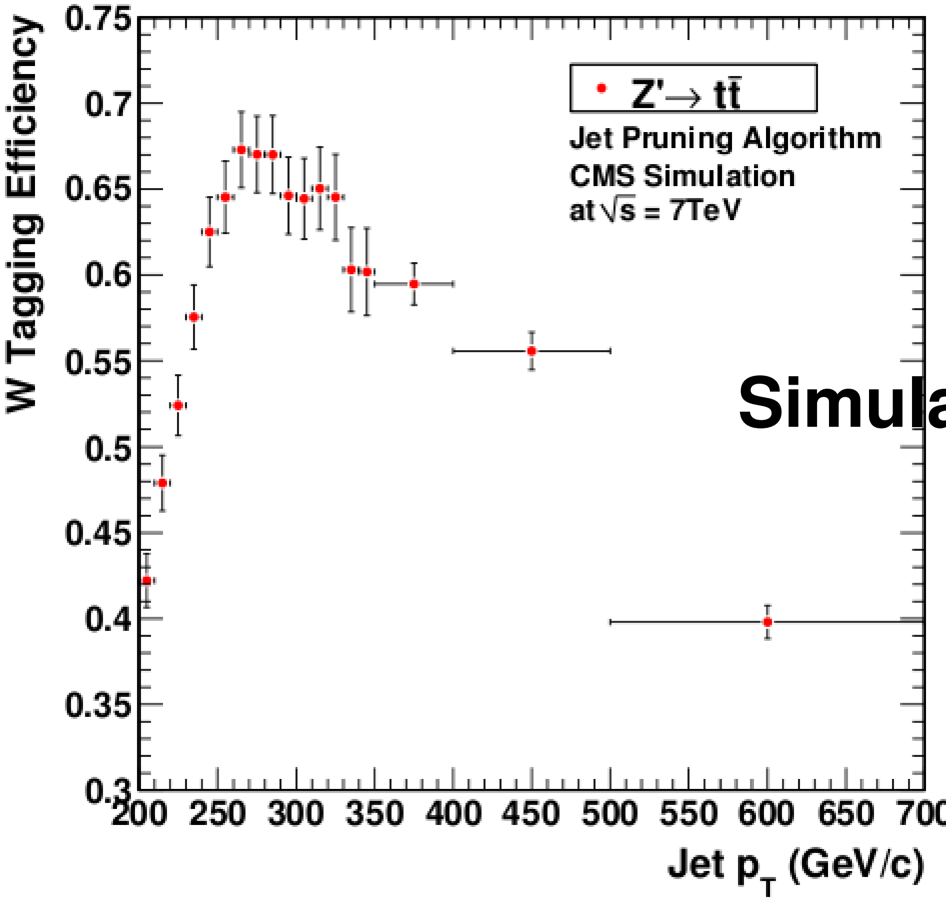


$$\text{Mistag Rate} = \frac{\text{Number of probe jets that are tagged}}{\text{Number of probe jets}}$$

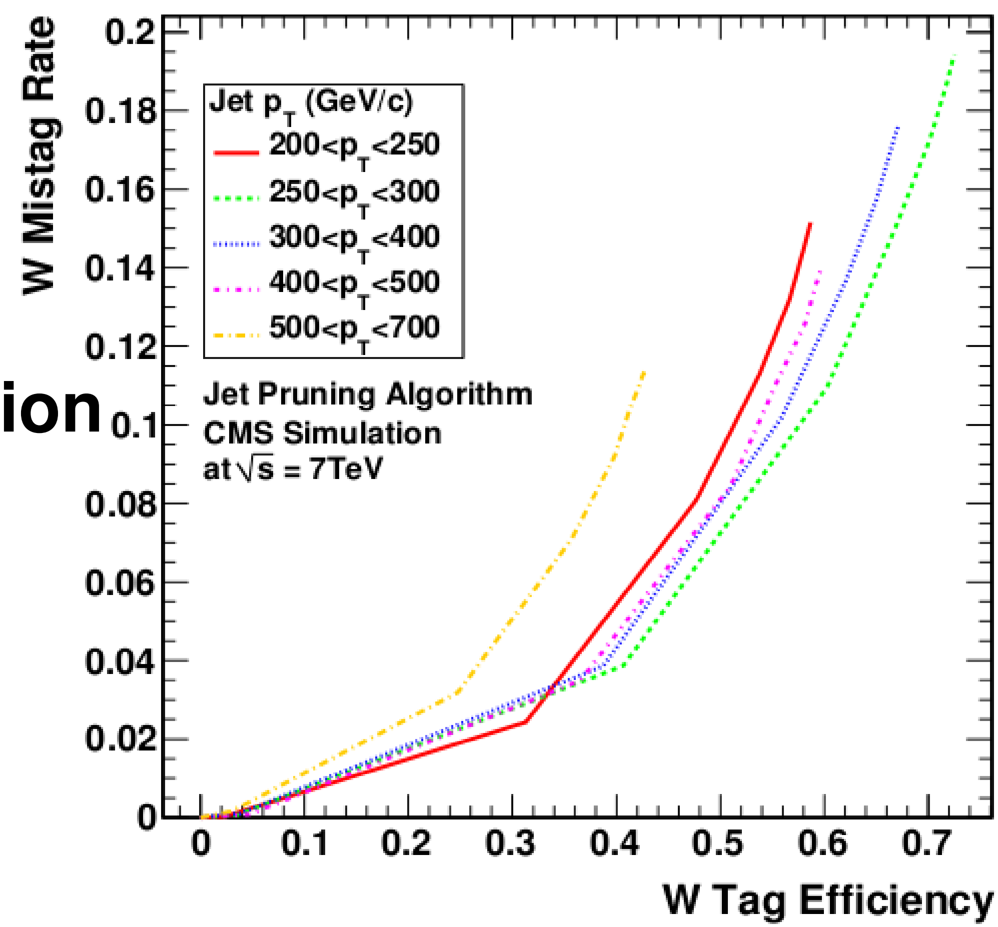
Dependence on shower model and tune, overall good agreement

W Tagging MC Efficiency

Monte Carlo signal efficiency for W tagging

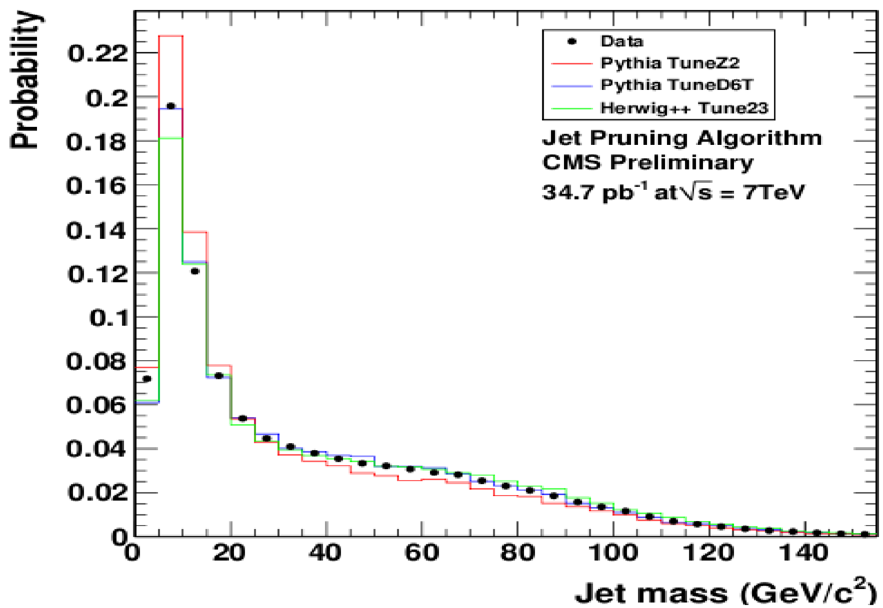


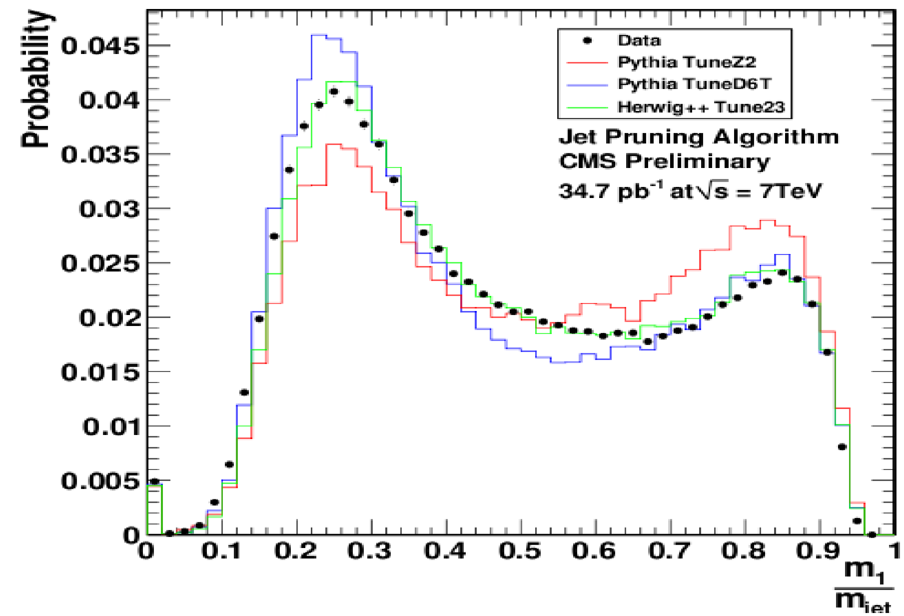
Monte Carlo mistag rate vs tag efficiency

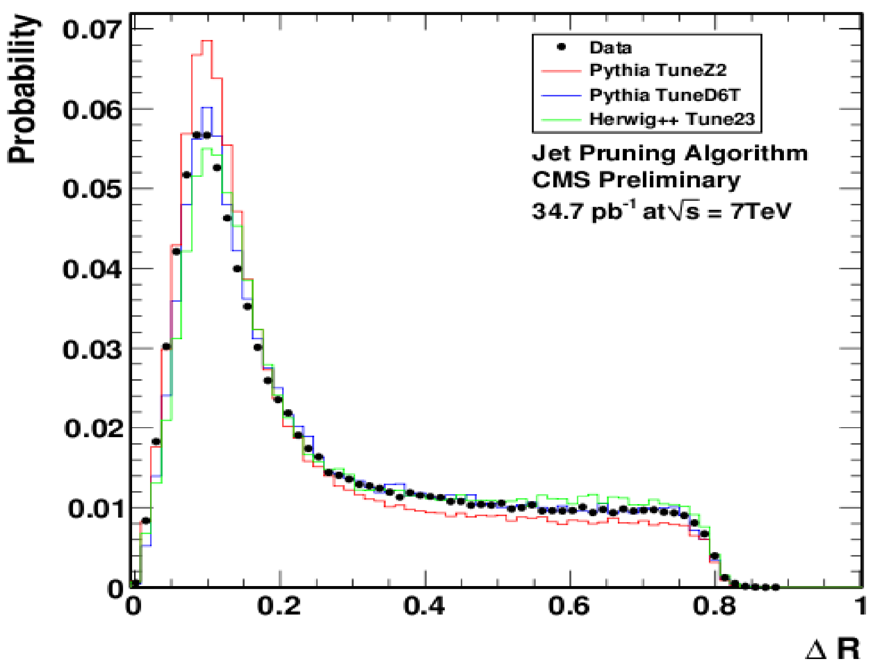


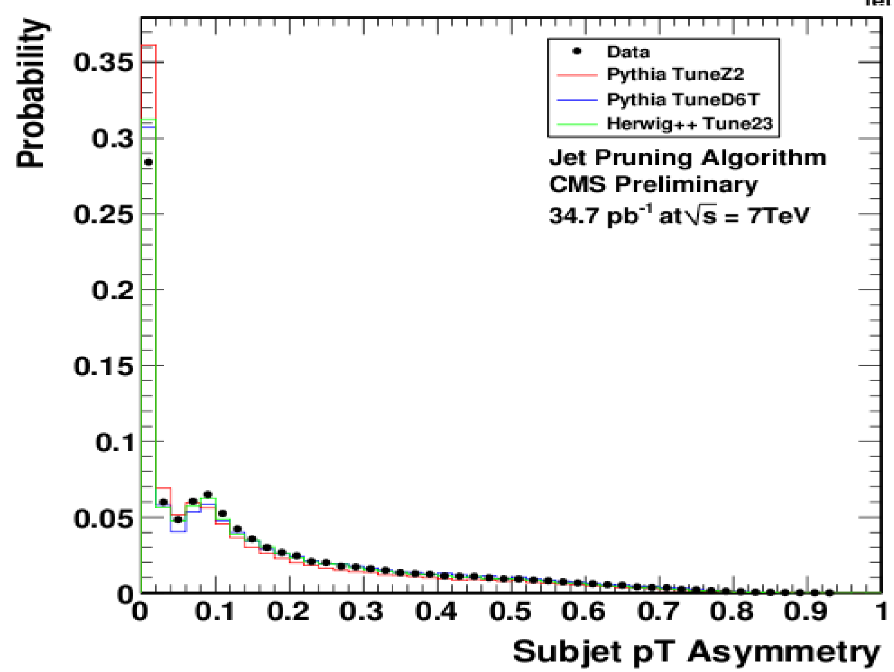
Simulation

Commissioning

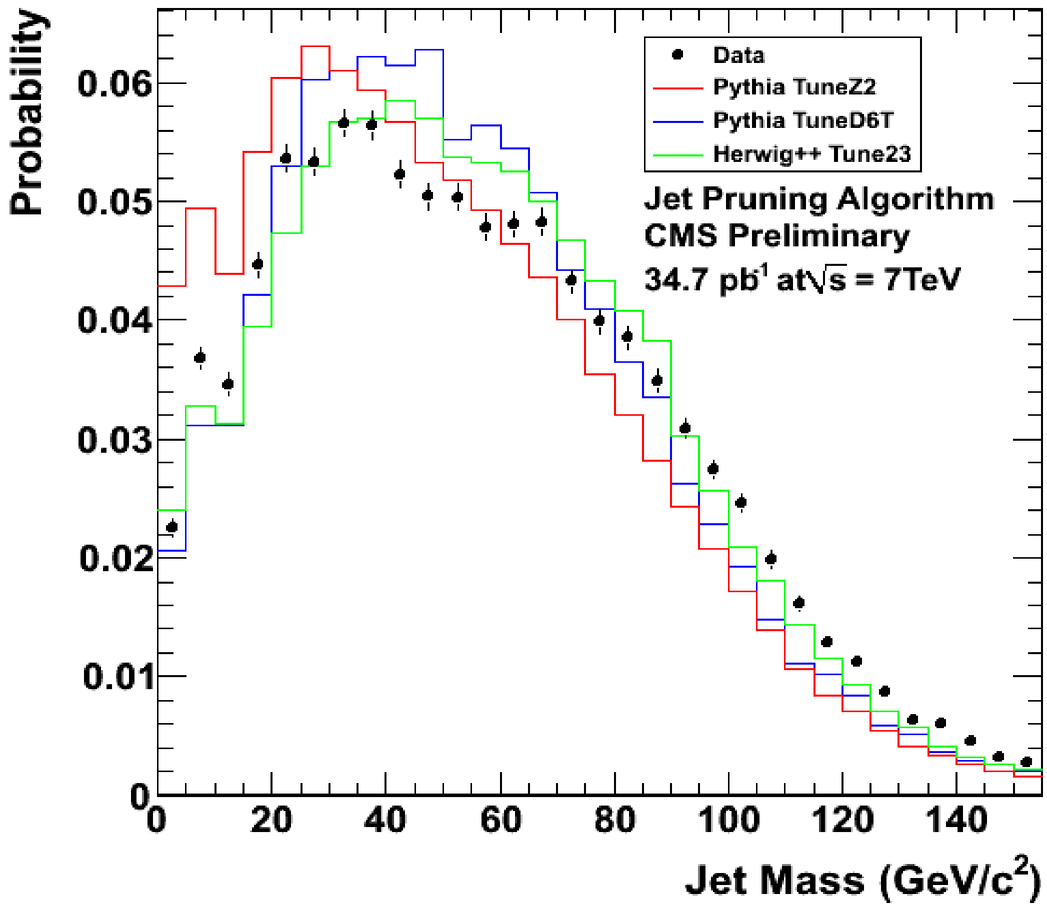




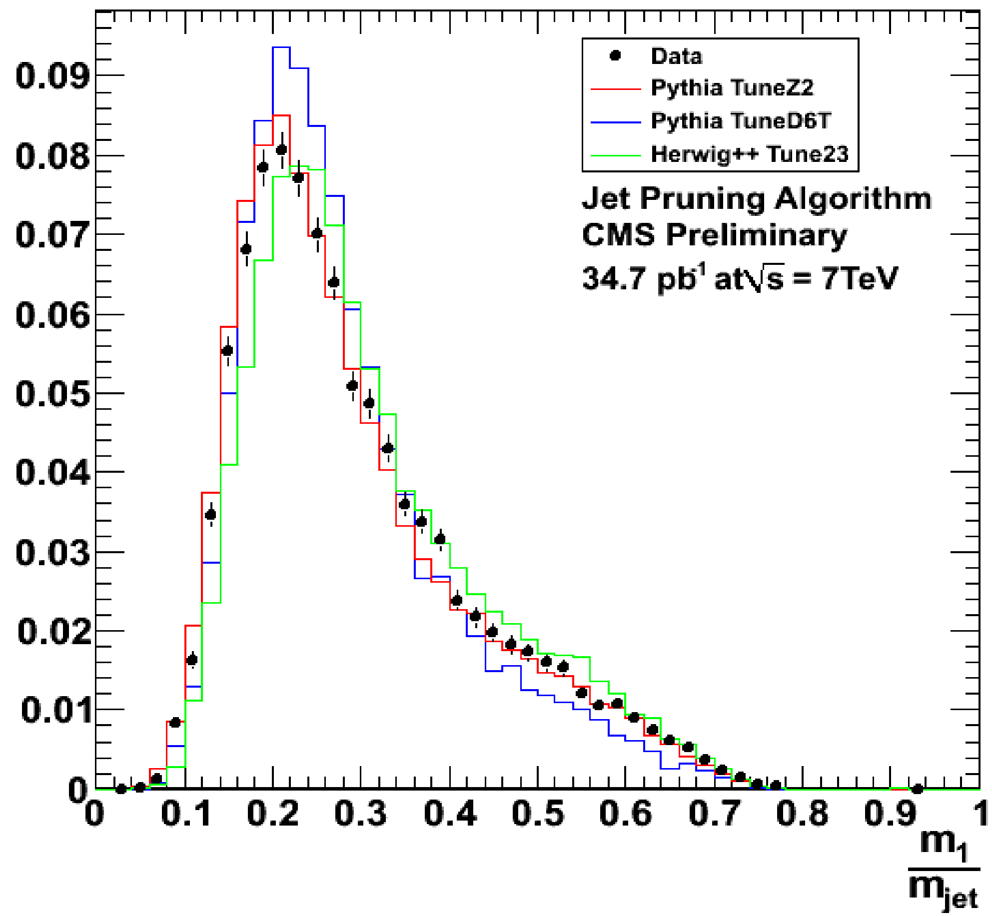




Apply "N-1" Cuts



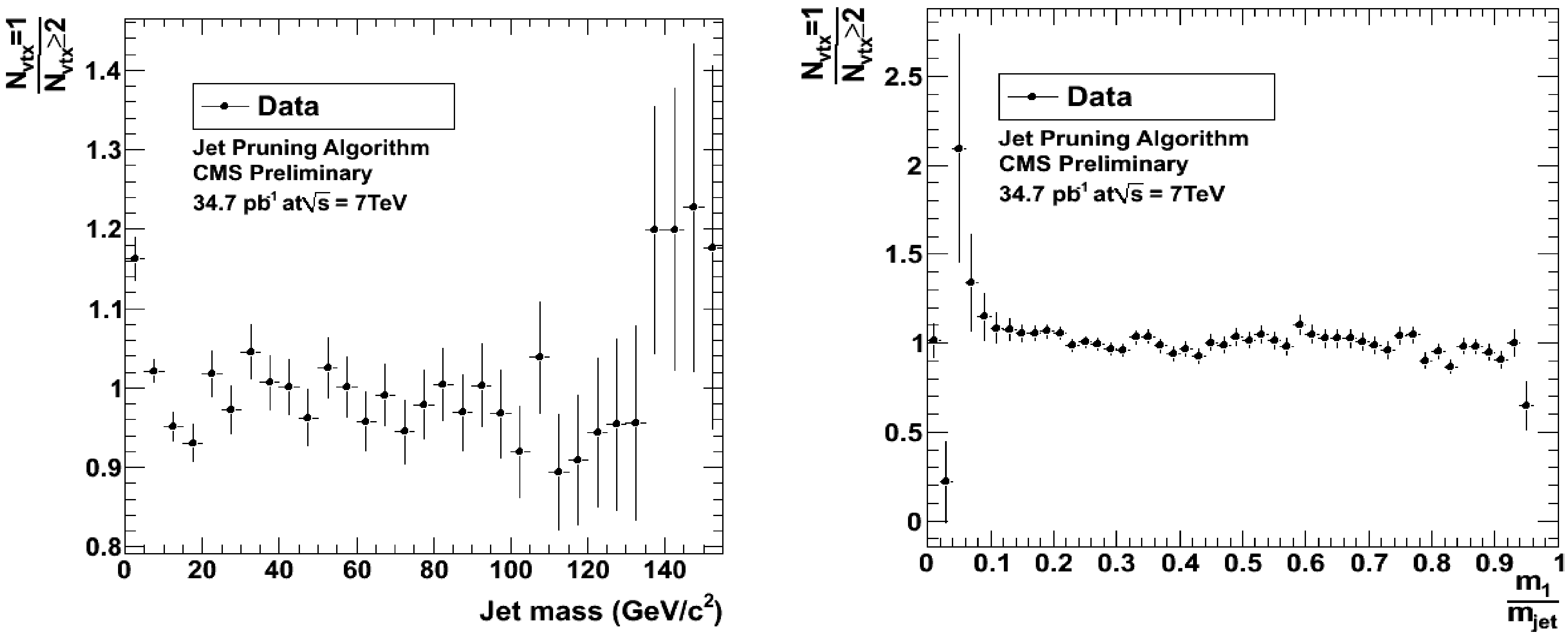
Apply mu cut only



Apply jet mass cut only

Pileup Dependence

- Look at events with 1Pimary Vertex (PV) and >=2 PV



- Very small pileup effect under current luminosity

Conclusion

- W mistag rate has been measured from data
  - QCD background estimations for new physics searches using W jet tagging algorithm can now be completed using data-driven methods.
- The tagging variables has been examined with collision data.
  - Good agreement with Monte Carlo simulation
  - Some dependency on the tune and shower model
  - Mild dependence on pileup