Tracking Hyper Boosted Top Quarks

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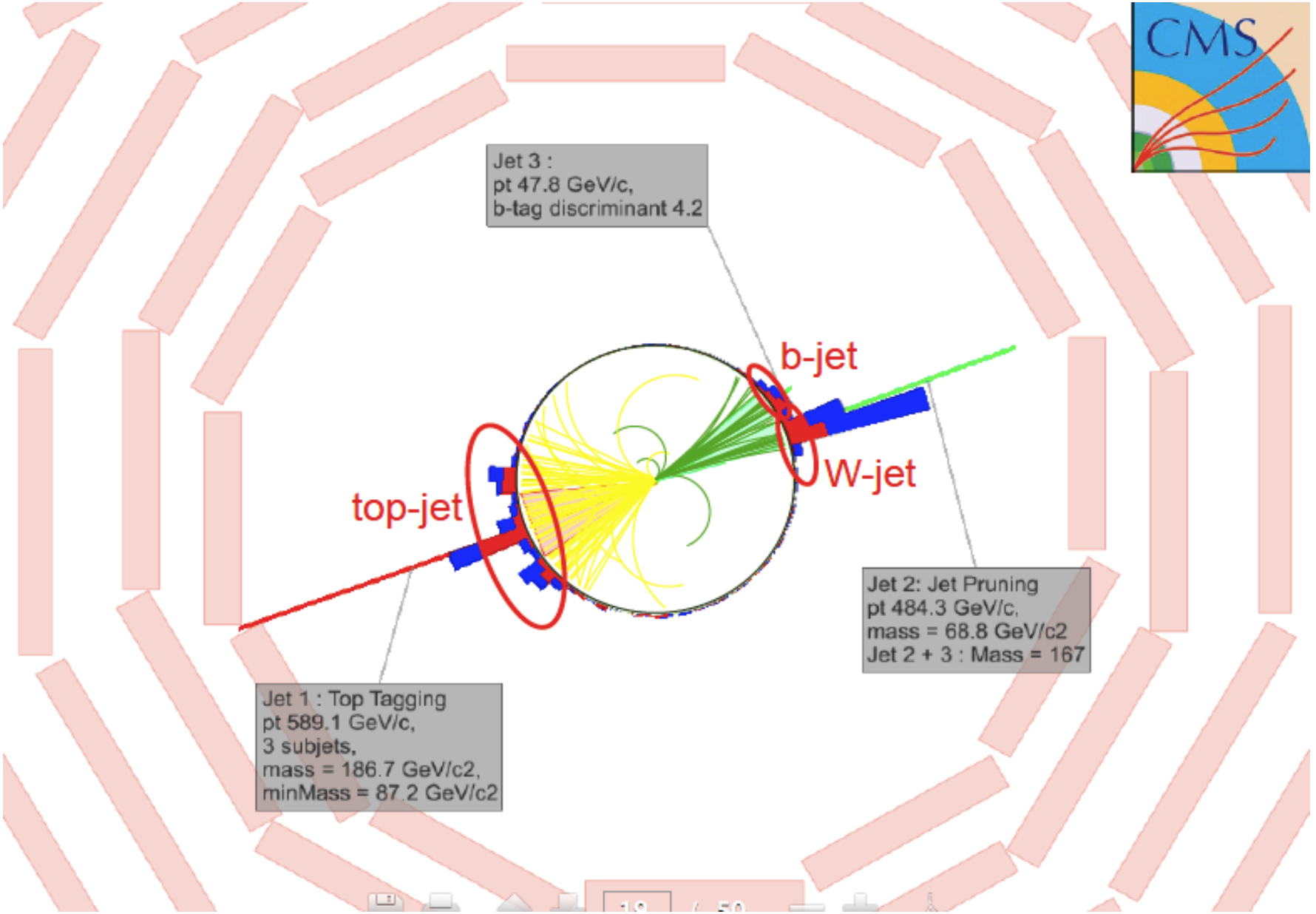
Why boosted tops ?

- 100 TeV p-p collider has potential to probe undiscovered particles with masses to 10-30 TeV
- These heavy resonances will decay (in part) to highly boosted top quarks (> 2-10 TeV)
- Several techniques for identifying jet sub-structure exist, and are widely used in ATLAS and CMS

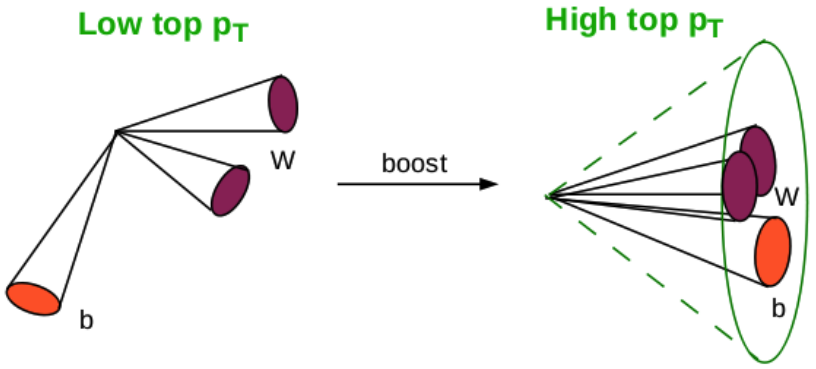
Do currently used techniques work at the Terascale?

Can we think of some observables that can help?

Event display



Boosted jets



- cone size R ~ 1 / boost
- min. distance to resolve two partons:

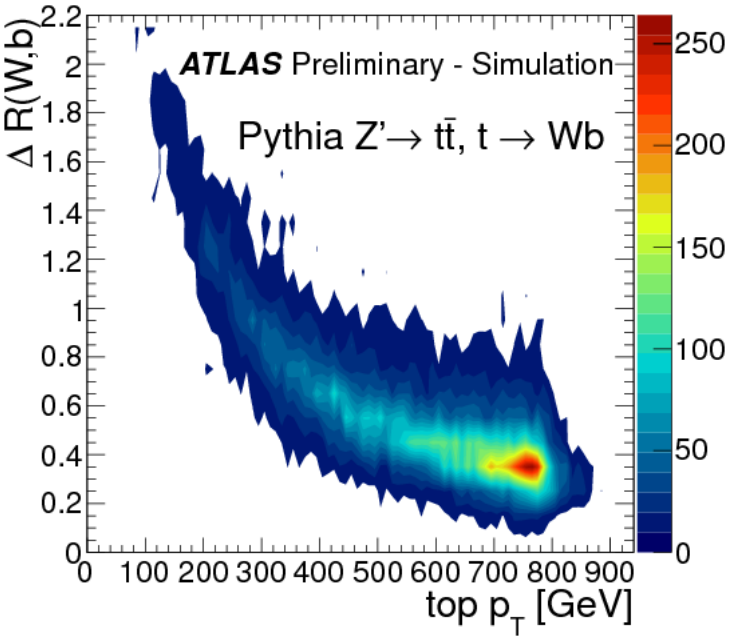
$$\Delta R \approx 2\ m / p_T$$

ex for top:

p_T = 200 GeV → R ~ 2

p_T = 1 TeV → R ~ 0.4

p_T = 10 TeV → R ~ 0.05



Techniques on the market

- Jet Mass

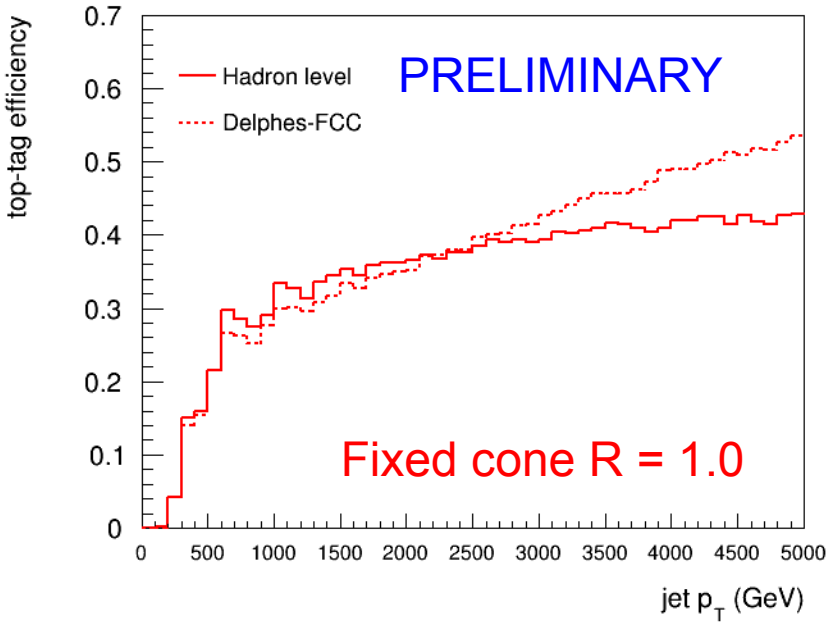
- N-subjettiness
- Grooming (pruning, trimming)

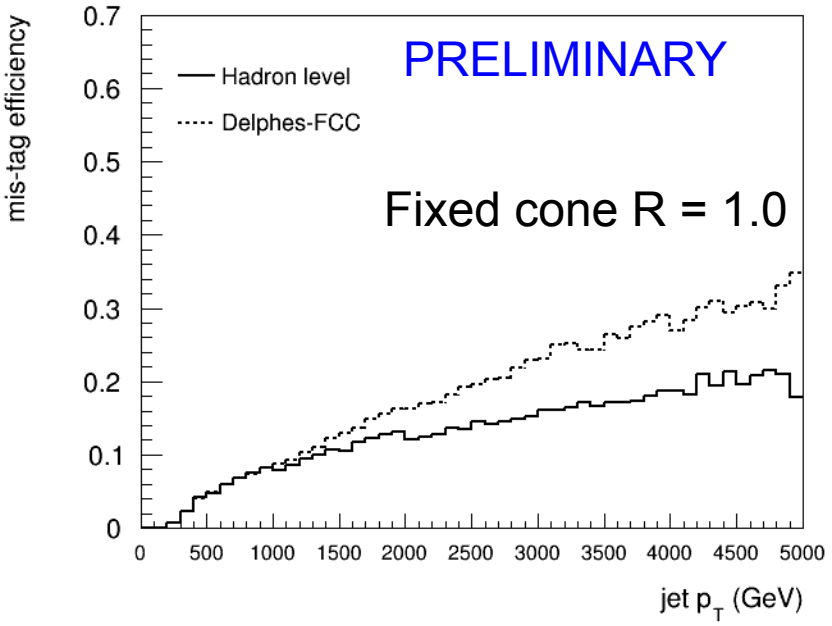
- CMS/JHU Top Tagger
- HepTopTagger

- Event deconstruction

  ...

HepTopTagger at high p_T





- at high p_T , signal eff is flat, while mistag rate increases due to QCD emissions
- In reco, emissions at large angles can form masses comparable to m_t, while HTT fails to identify hard prongs due to calo cell merging

NEXT: use shrinking cone as f(p_T)

Approach

- Most methods will suffer a decrease in performance at high p_T

  → increased QCD radiation can spoil their effectiveness
  → angular separation provided by calorimeters is limited

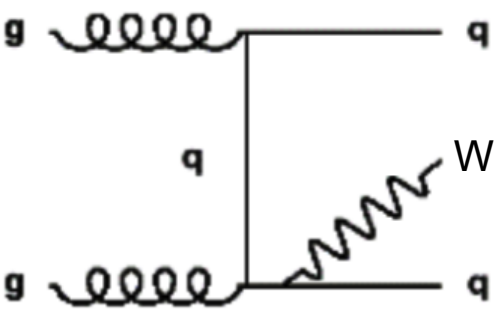
- Neutral hadrons will be measured poorly in such a dense environment

- Make maximal use of measured information on charged particles (for better angular resolution, more robust against pile-up)

- Look at observables built on tracking (or Particle-Flow) information that can help discriminating between top and background jets

Setup

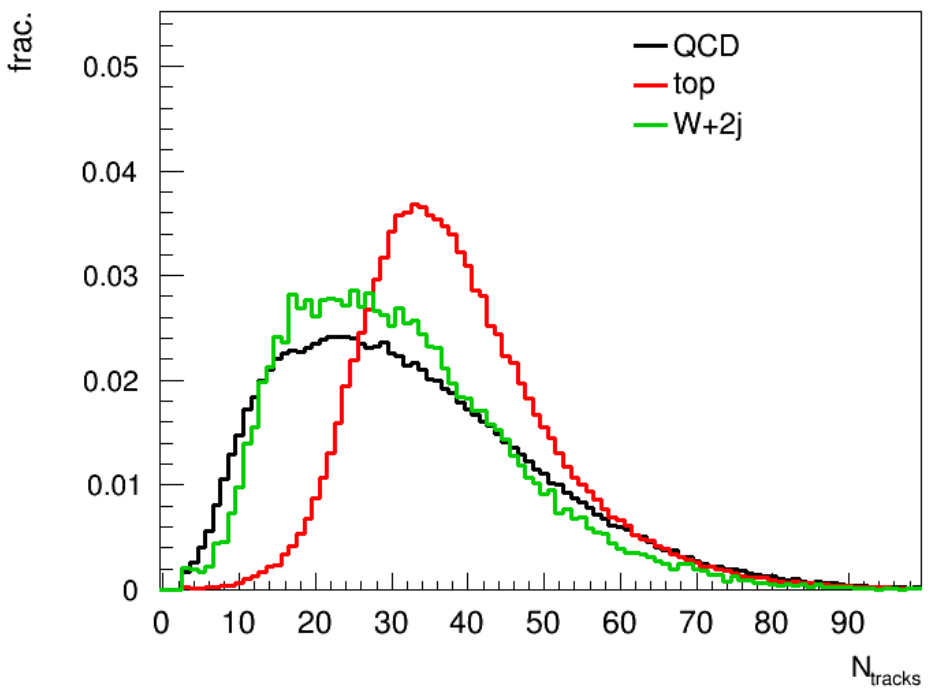
- Samples @100TeV (MadGraph5+Pythia6)
  - p p $\rightarrow$ t t (signal)
  - p p $\rightarrow$ j j (bkg)
  - p p $\rightarrow$ w j j (bkg)

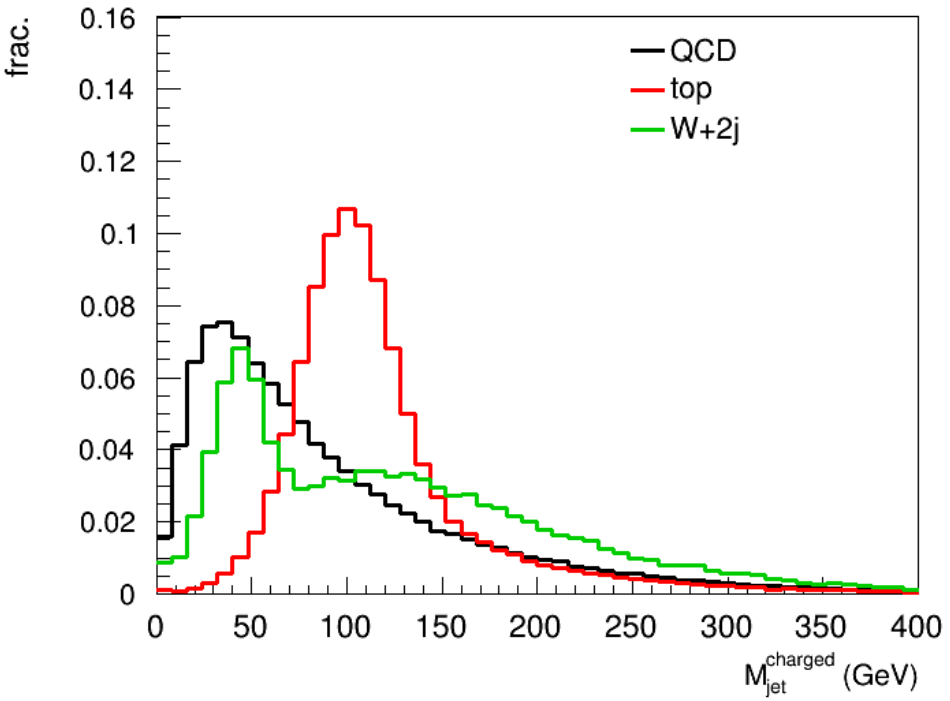


- looking at hadronic W decays only
- hadron level
- jets clustered with anti-k_T algorithm with R = 0.5
- highly boosted jets : $p_T > 2$ TeV , $|\eta| < 2.5$
- p_T spectrum of bkgs re-weighted to match top p_T distr.

low-level observables

Charged Multiplicity / Mass





N-subjettiness

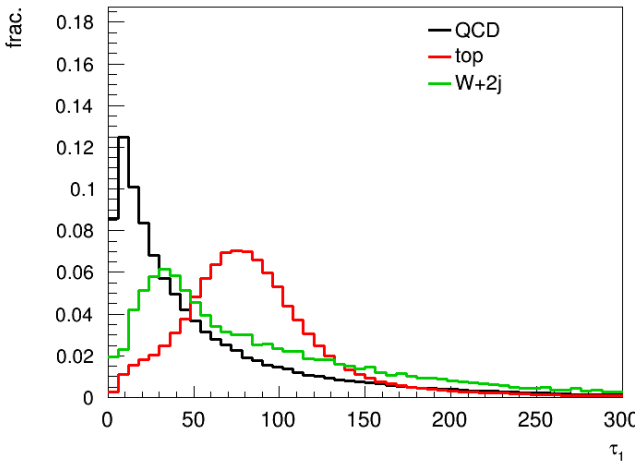
arXiv:1011.2268
arXiv:1108.2701
arXiv:1401.2158

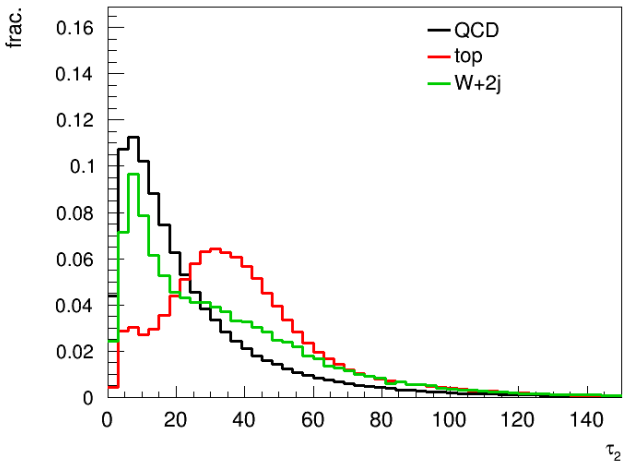
N-subjettiness

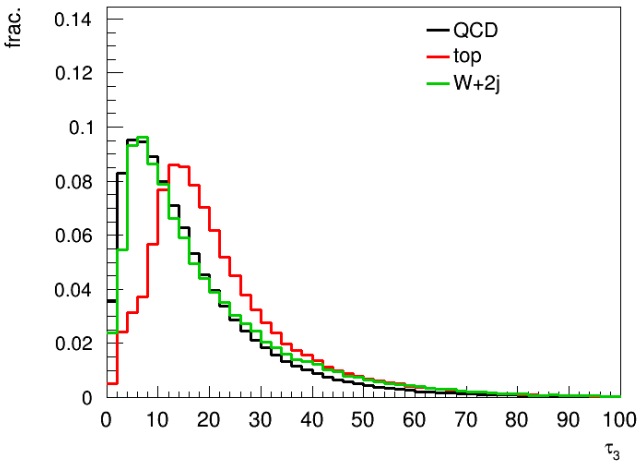
- T_N measures the distribution of energy in a jet about N axis

$$\tau_N^{(\beta)} = \sum_{i \in \text{jet}} p_{Ti} \min\left\{R_{i,1}^{\beta}, \ldots, R_{i,N}^{\beta}\right\}$$

- jets are clustered using neutral+charged particles
- only charged constituents are using to calculate T_N







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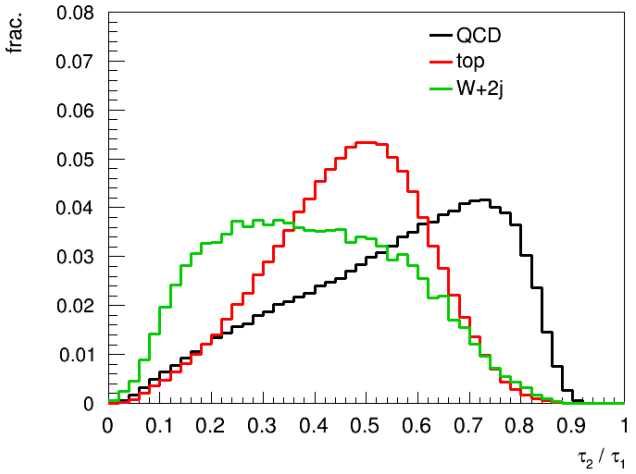
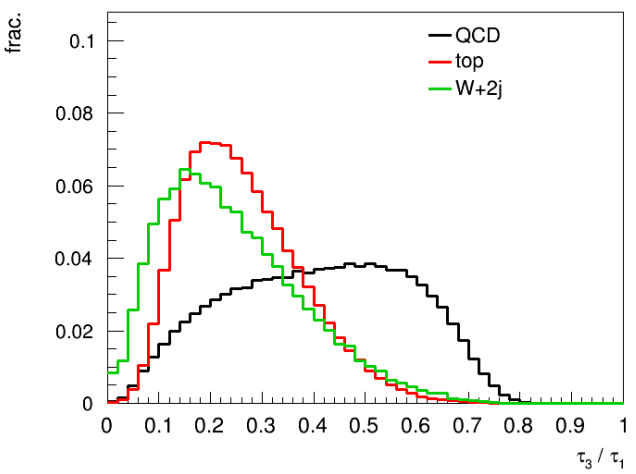
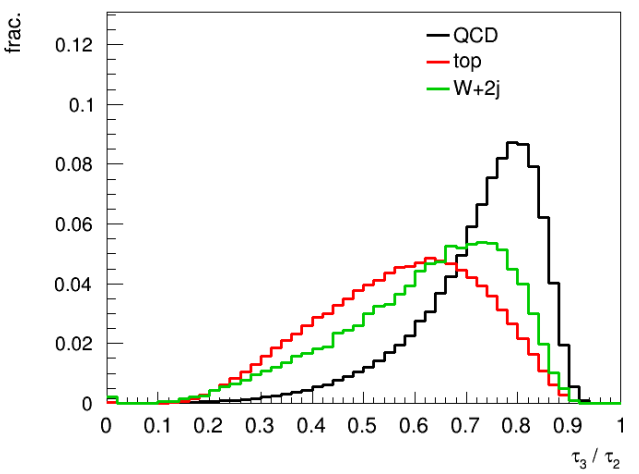






N-subjettiness ratios are powerful discriminants

Jet Charge Moments

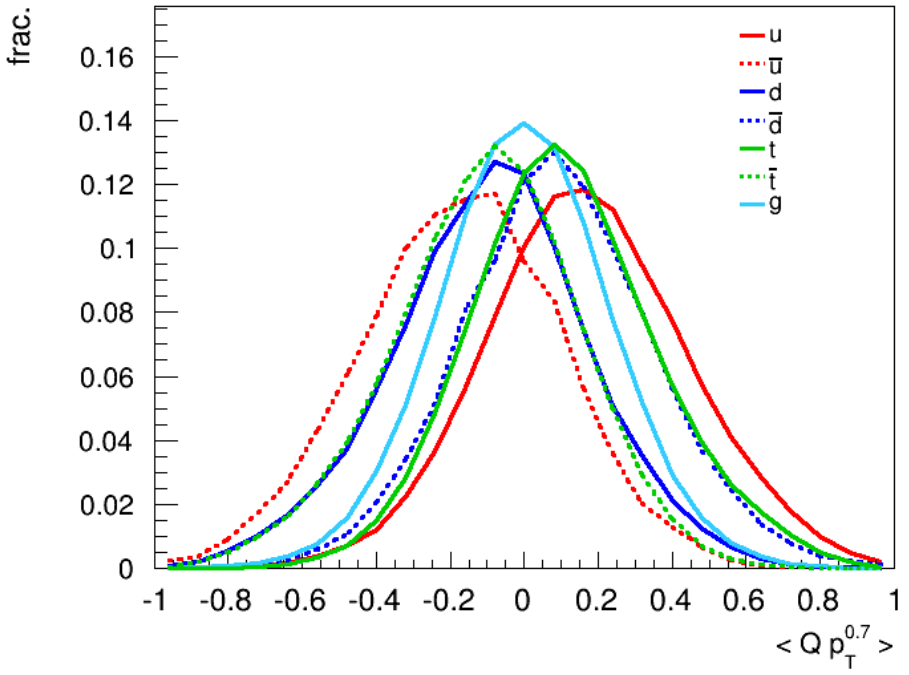
arXiv:1209.2421

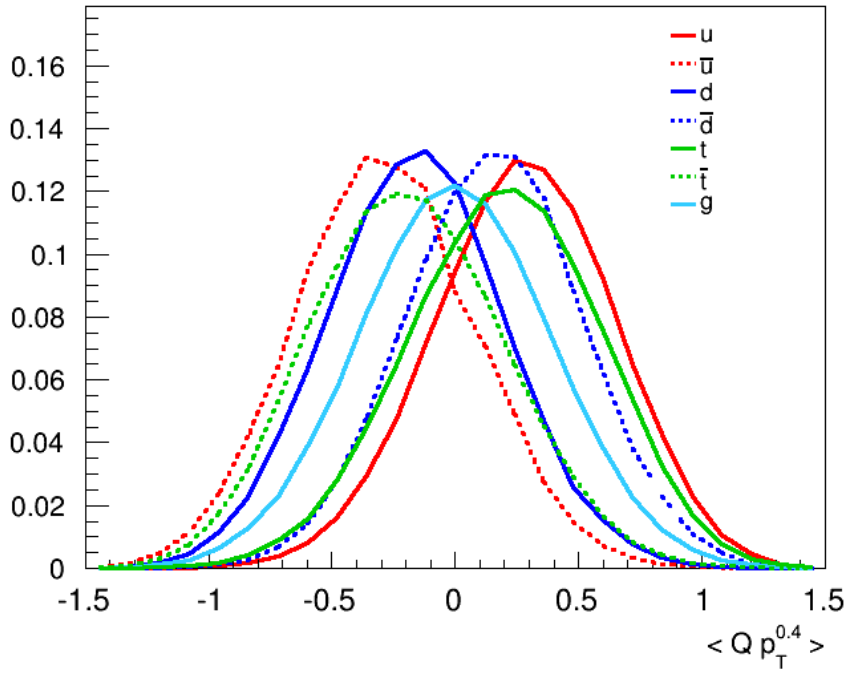
Jet Charge

- Jet charge moments are defined as:

$$Q_\kappa = \frac{1}{(p_{T\text{jet}})^\kappa} \sum_{i \in \text{jet}} p_{Ti}^\kappa Q_i$$

- shown to be able to discriminate between u, d and g





Summary and outlook

- We have shown some simple tracking based observables that can help in discriminating highly boosted top jets from QCD

- Other ideas can be explored such as:
  → sub-jet energy ratios
  → mass drop

- Hyper boosted objects will make our lives complicated

- New ideas are needed

- Need strong interplay between detector design and method building.