Jet Radiation Radius

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arXiv:1402.1494

5/6/2014, Pheno 2014 @ Pittsburgh

Motivation

- Jet radiation important in jet substructure studies
- Often contaminated
    - High multiplicity events (e.x., SUSY cascades)
    - W's in top decays (contaminated by b jets)
    - Initial state radiation
    - Underlying event
    - Pileups

There are ways to alleviate the problems, but how is the "intrinsic" radiation distributed?

Outline

- QCD radiation in jet substructure studies
  - W jet tagging
  - Difficulties with pileup
- Jet radiation radius
  - Definition and properties
  - Application in W jet tagging
- Outlook and conclusion

W jet tagging

- Differences between w jets and quark/gluon jets
  - W mass peak vs QCD continuum
  - 2 balanced hard subjets vs hierarchical momenta
  - Color singlet vs triplet/octet: different radiation patterns
    - W: radiation concentrated in a small cone
    - QCD: radiation diffused.

The three differences are (almost) uncorrelated.
Employ all of them!

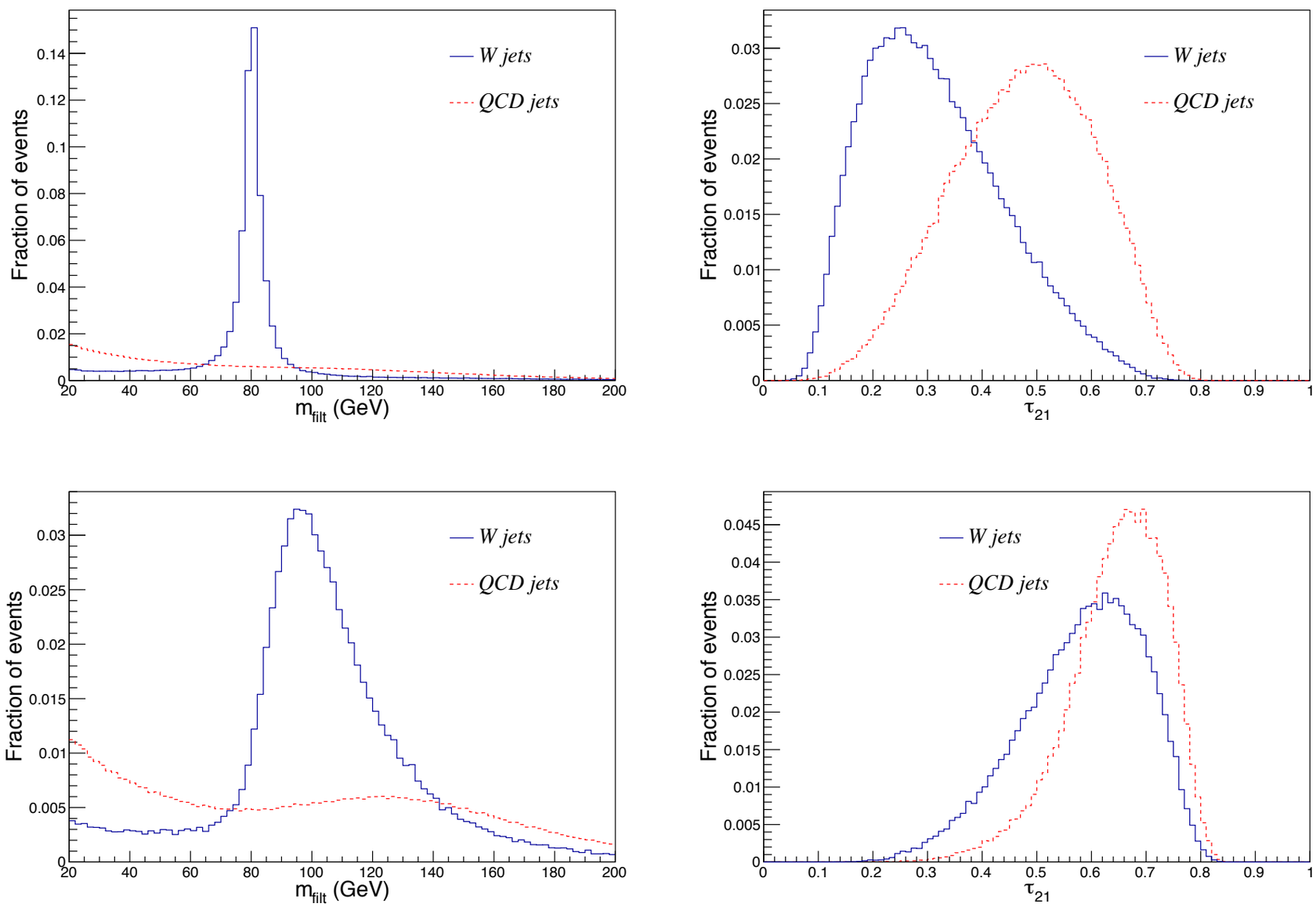
Variables

- Kinematic variables
  - Jet grooming (jet mass after filtering, mfilt)
  - Radiation information lost
- Radiation variables
  - N-subjettiness (tau2/tau1)
  - Charged particle multiplicity
  - ….

Pileup

filtered mass

tau2/tau1 after filtered mass window cut



without pileup

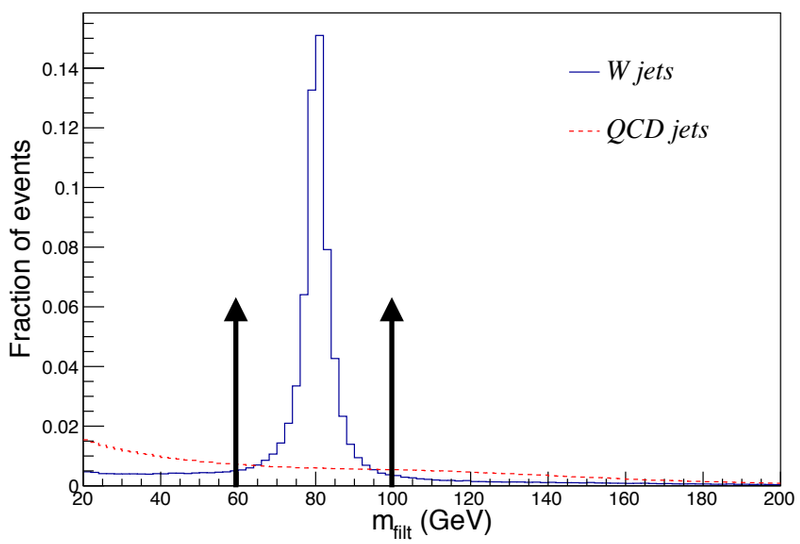
with pileup, <NPU>=60

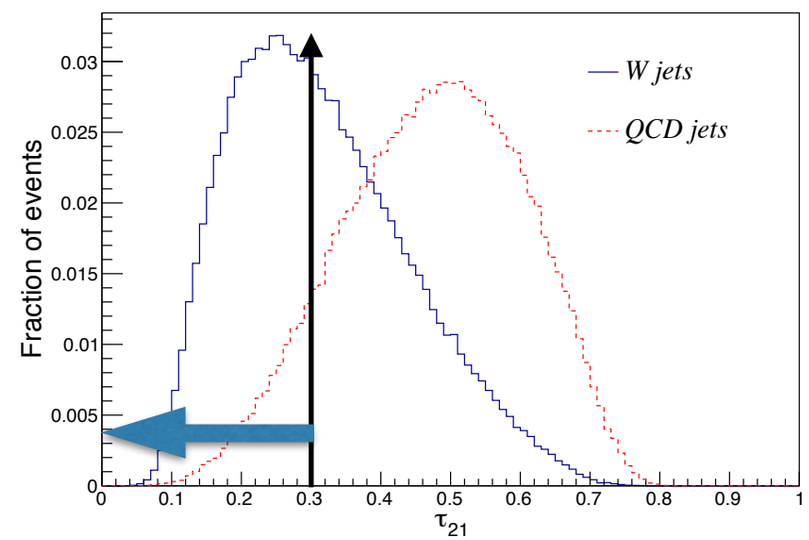
*particle level simulation
R=1.2

Pileup

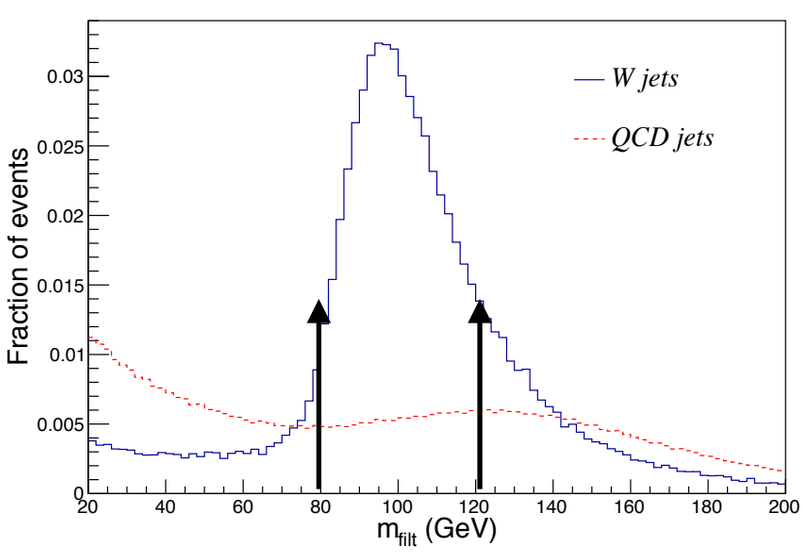
mfilt ~(60,100), significance x1.8

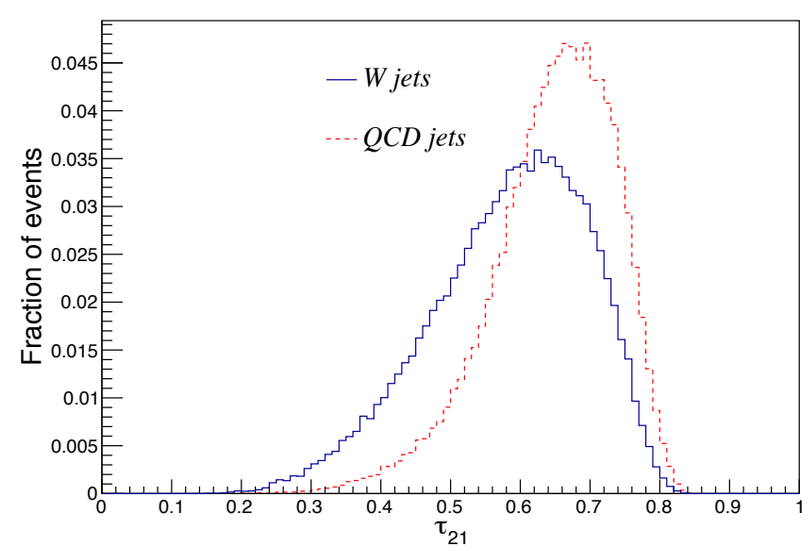
cut on tau2/tau1, significance x1.6





without pileup





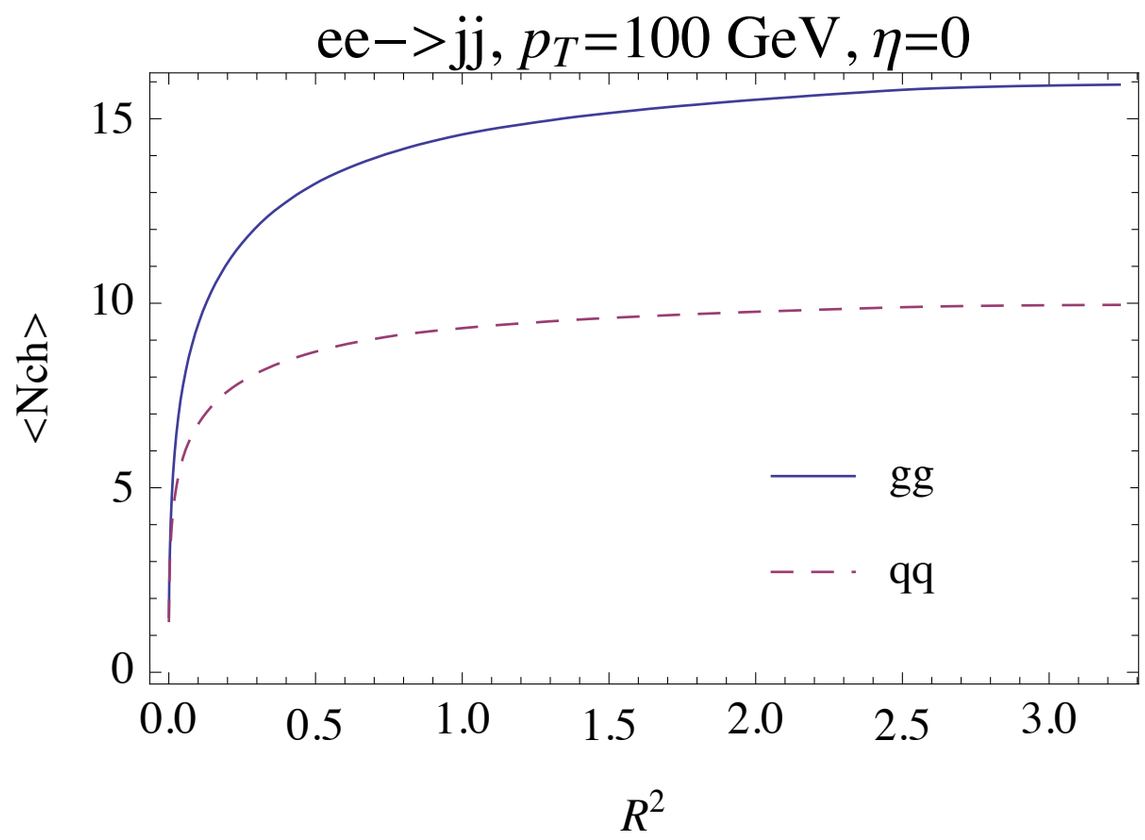
with pileup,
<NPU>=60

mfilt ~(80,120), significance x1.5

no increase in significance

*particle level simulation
R=1.2

Jet radiation radius - motivation

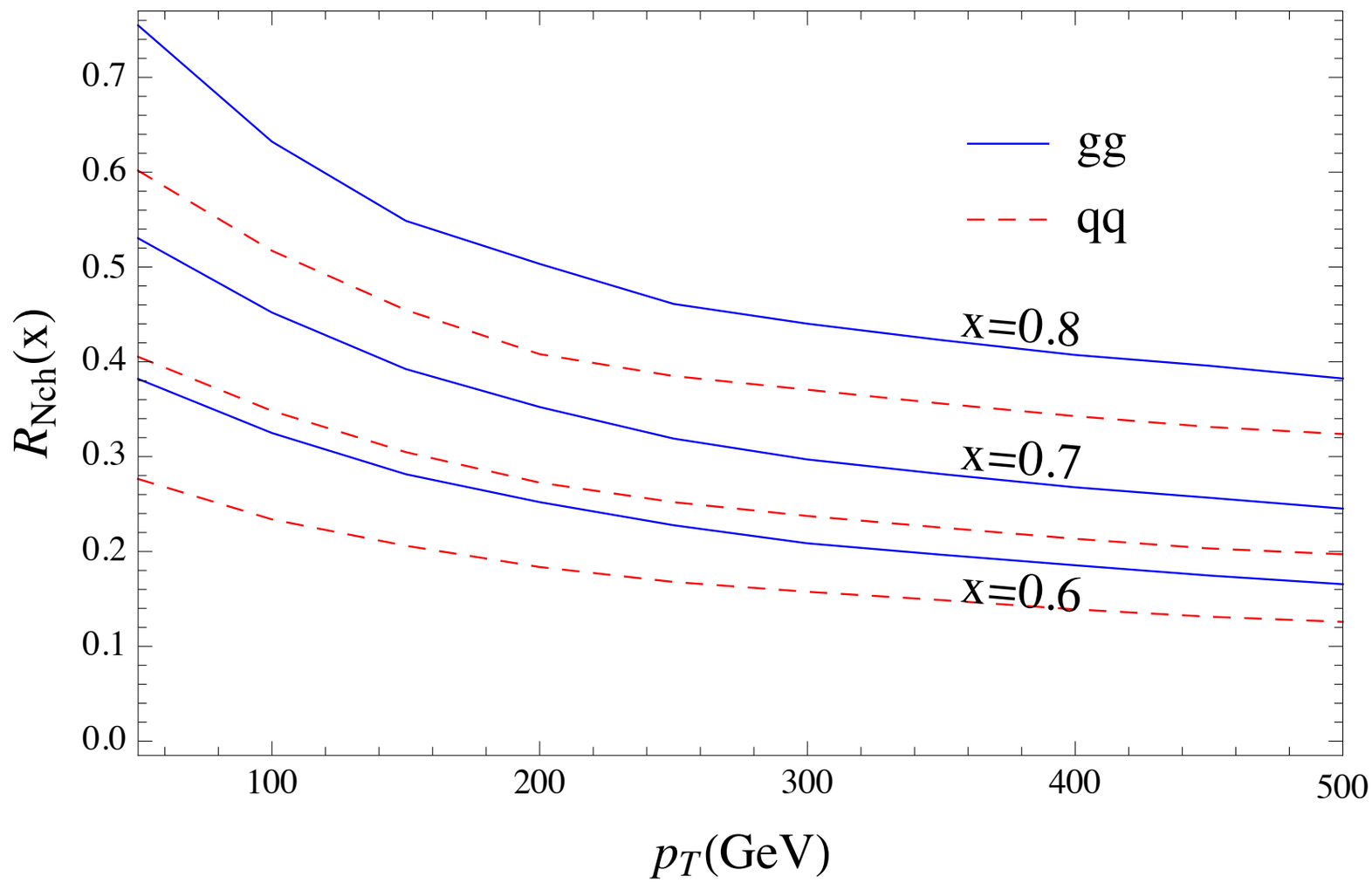


Number of charged particles as a function of jet radius squared
e+e- machine, (almost) no contamination, "intrinsic radiation"

Jet radiation radius - definition

- What's the best radius to evaluate jet radiation variables?
- What's the 'intrinsic size' of a jet?
- Jet radiation radius:
  - *In a 2(or N)-jet color singlet system in its center of mass frame, a jet radiation radius, R(x) is defined as jet radius that the average amount of radiation within the 2 (or N) jets is a fraction of x of the average total amount of radiation.*
    - Defined as the average over an ensemble (diquark, digluon…), not event by event
    - The "amount of radiation" depends on the variable used.

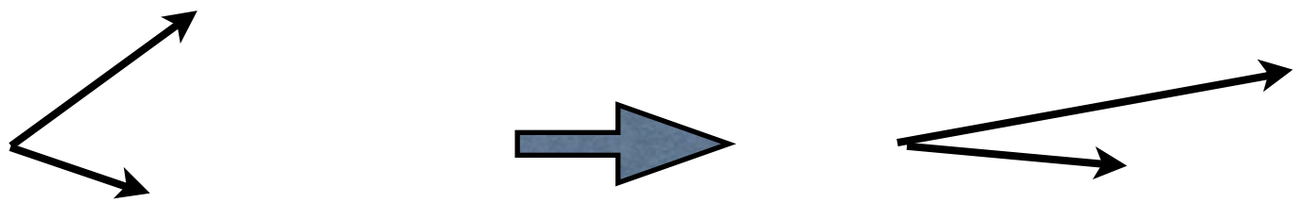
PT dependence
ee->qq, gg



Smaller radiation radius for larger PT: running of QCD coupling

Boosted color singlet system (W,Z,H)

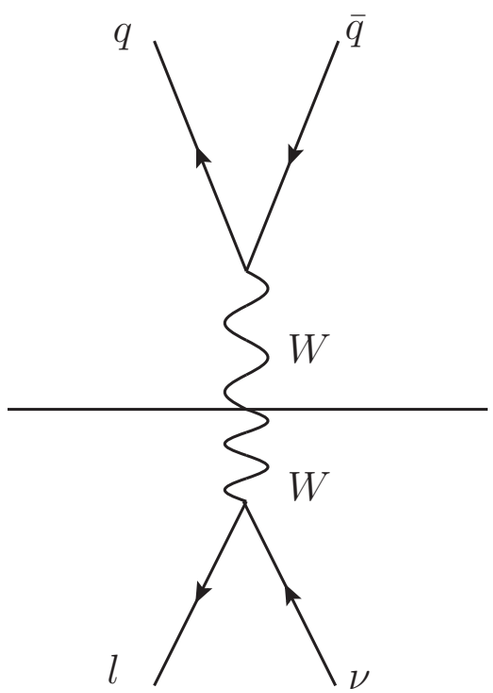
- Shrinking cone size R ~ 1/PT :

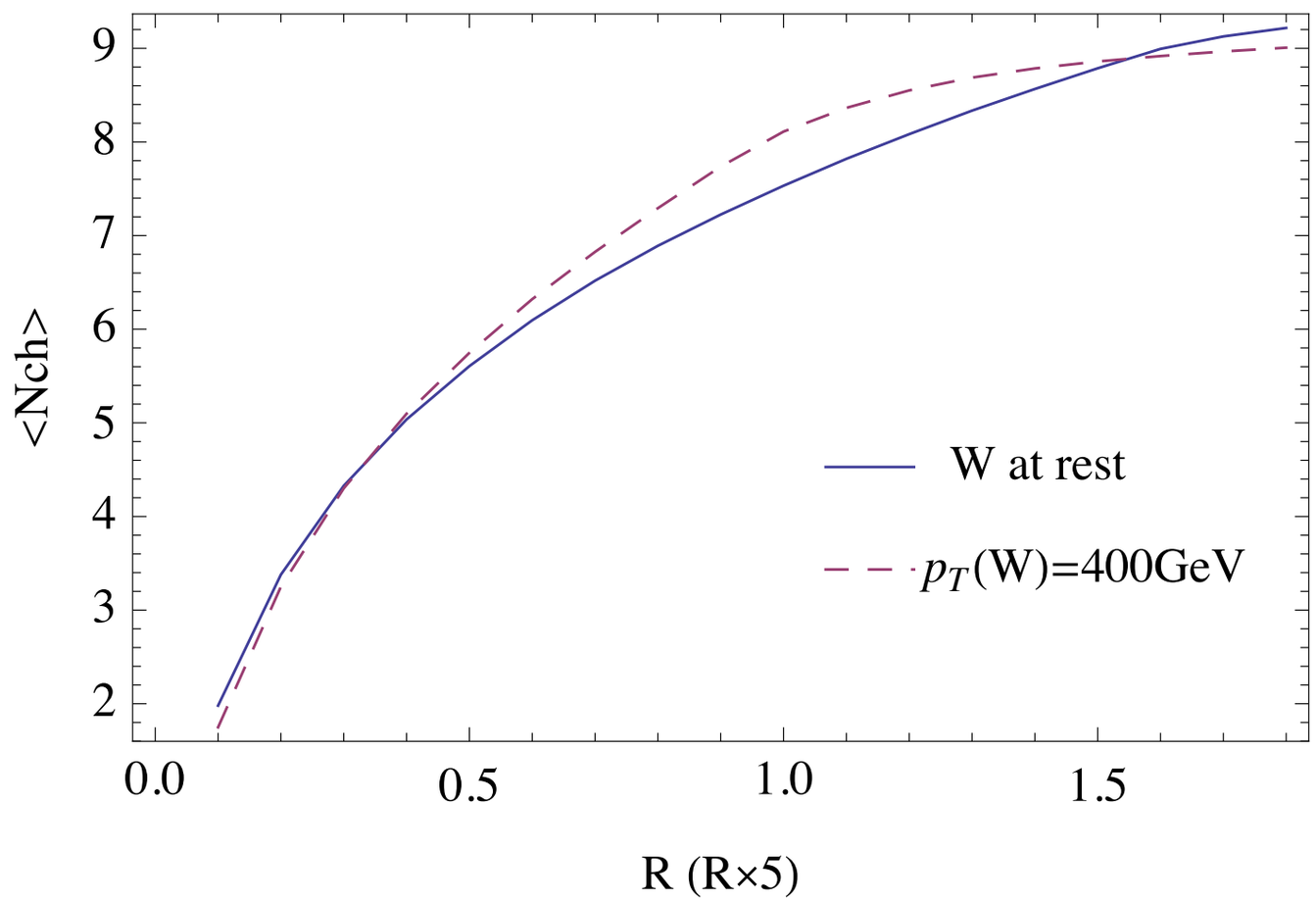


- Radiation radius inversely proportional to PT
- Different radius for the two subjets in a W decay

*When jets merged, jet radius becomes subjet radius

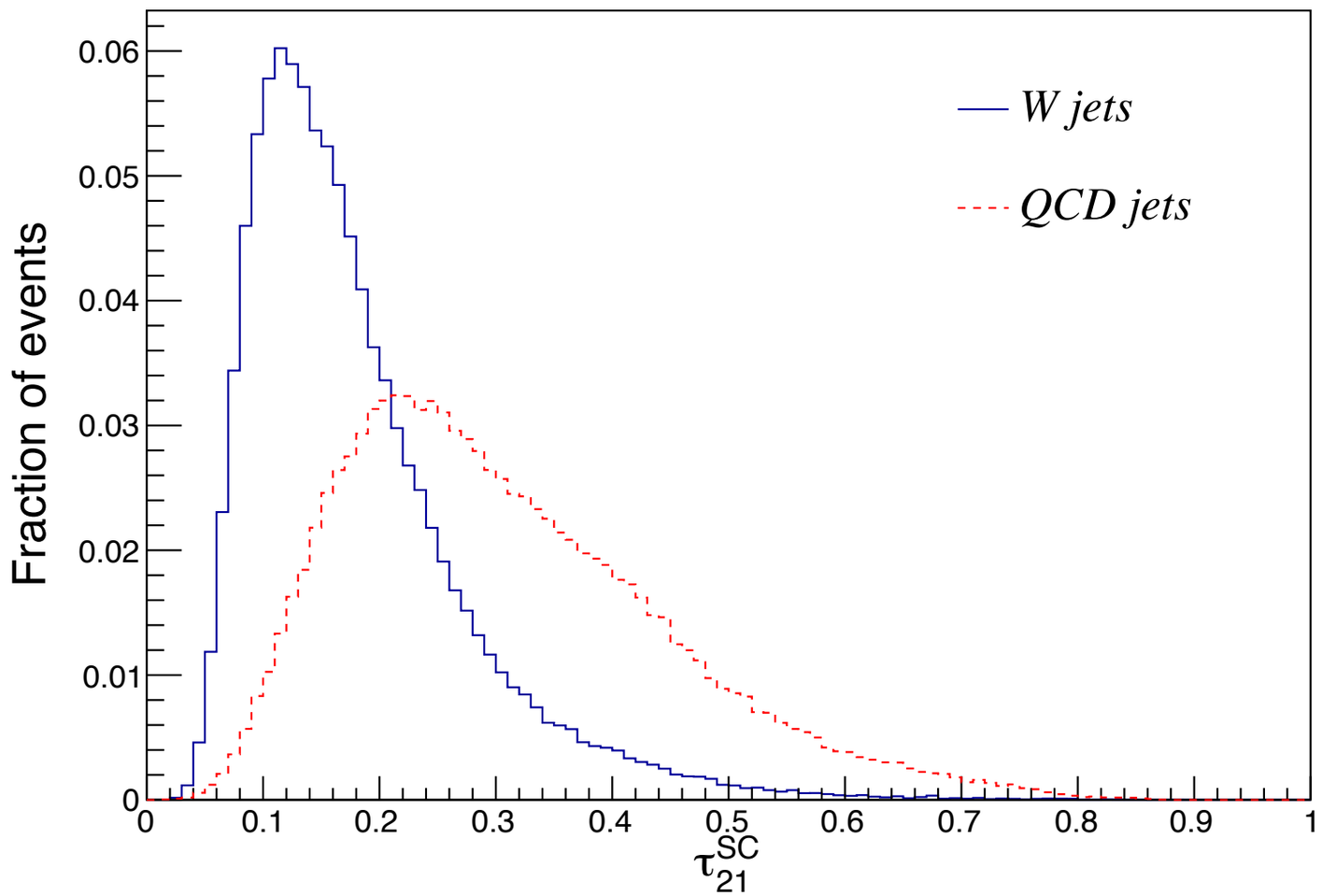
Boosted W





40 GeV *vs* 200 GeV quarks from W decay (ee->WW)

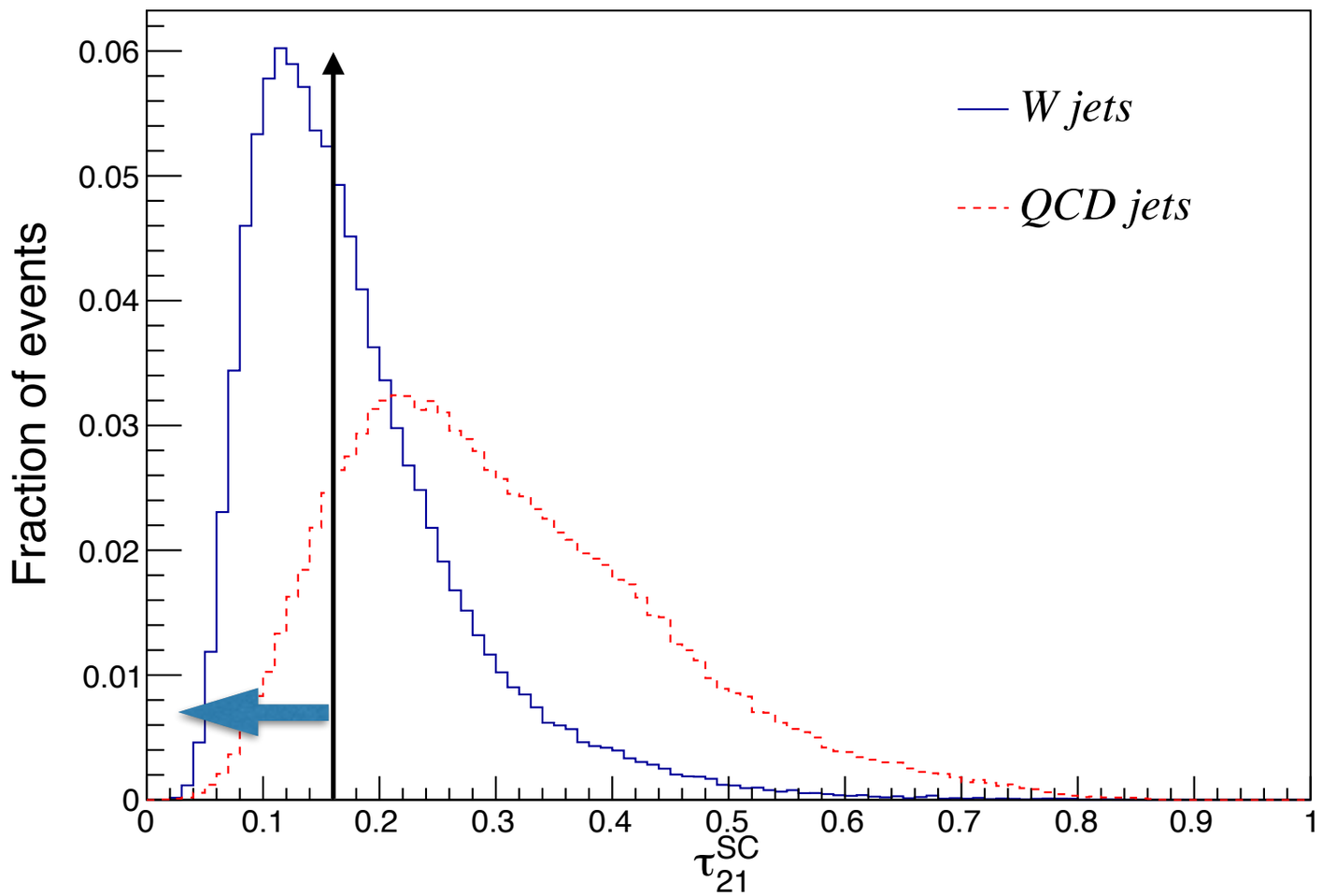
Shrinking cone algorithm for W tagging



Identify subjets with filtering first, evaluate jet radiation variables around two subjet axes with Rsub determined by:

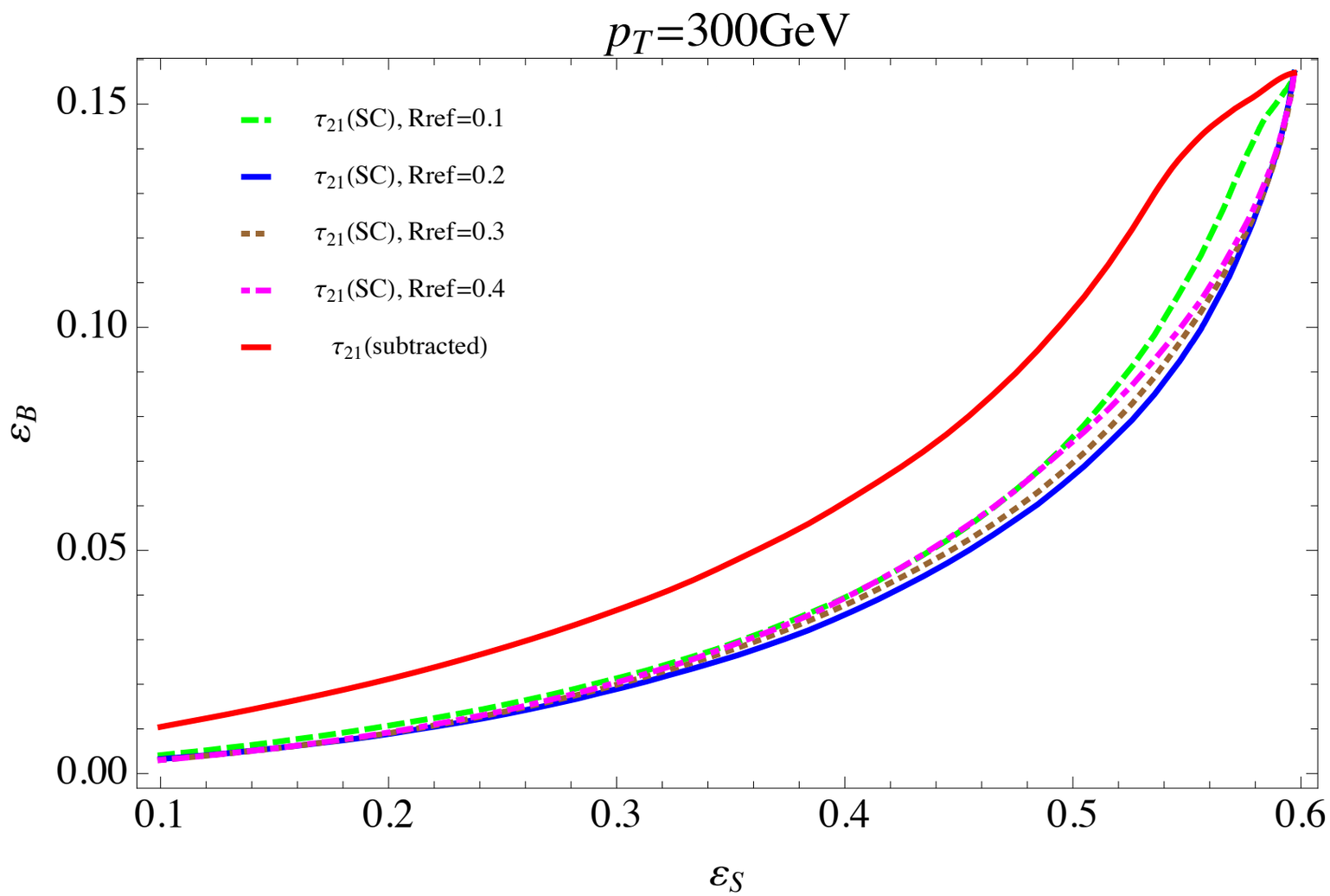
$$R_{\rm sub} = R_{\rm ref}(100\ {\rm GeV})\frac{100\ {\rm GeV}}{p_{T,{\rm sub}}}$$

Shrinking cone algorithm for W tagging



significance x1.5

Choices of Rref



Best Rref(100GeV)=0.2

*subtracted = after a subtraction method by Soyez, Salam, Kim, Dutta, Cacciari
(good for filtering, not for radiation variables)

Future directions

- Theoretical calculations. Monte Carlo validation.
- More sophisticated R_{sub} choices? Other variables? Combine with charged hadron subtraction?
- Other applications
  - Quark-gluon discrimination
  - Higgs search, top tagging…
  - Processes with many final state partons

Conclusion

- Radiation of a hard parton is concentrated, which can be quantified by jet radiation radius.
- The jet radiation radius is smaller for larger momentum/boost
- By selecting a small cone size dependent on the (sub)jet momentum to calculate radiation variables, we can reduce the impact from pileups and improve the tagging efficiencies for boosted objects.