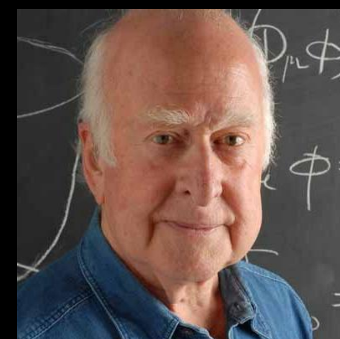
Jet Grooming

?



Brock Tweedie

Johns Hopkins University

23 June 2010

Outline

- Growing jets
- Grooming jets

Growing Jets

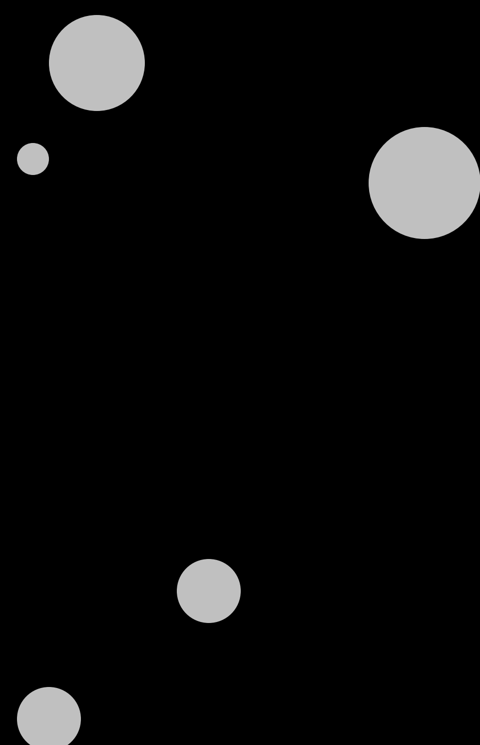
Sequential Algorithms

- Cambridge/Aachen
- kT
- Anti-kT

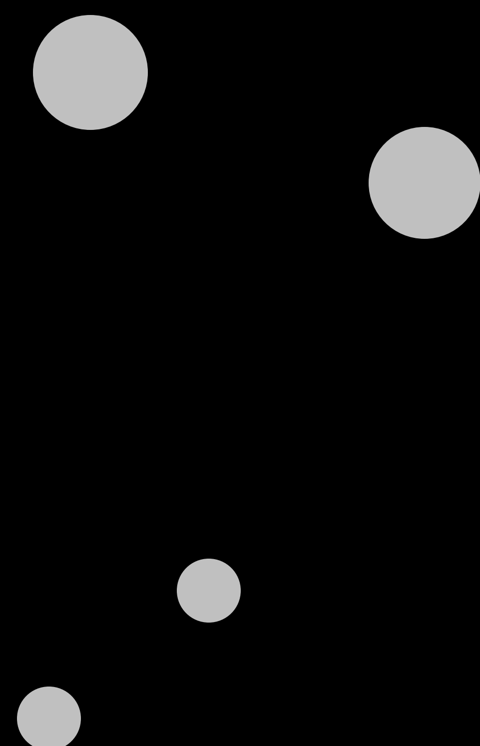
Cambridge/Aachen

- Sequentially sum up nearest-neighbor 4-vectors in the $\eta-\phi$ plane until all 4-vectors are distanced by more than a prespecified R

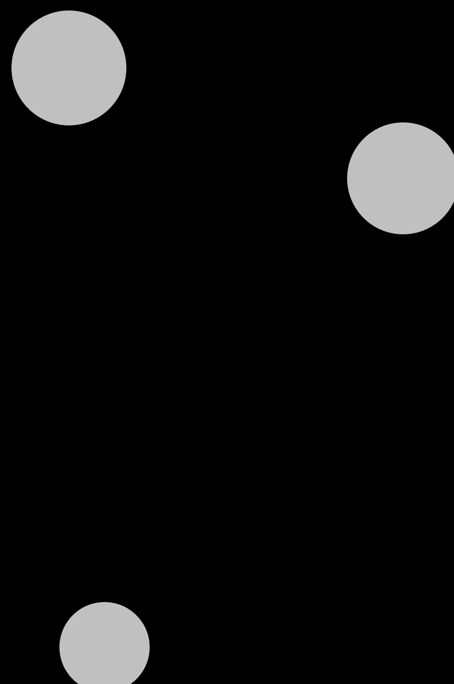
Cambridge/Aachen



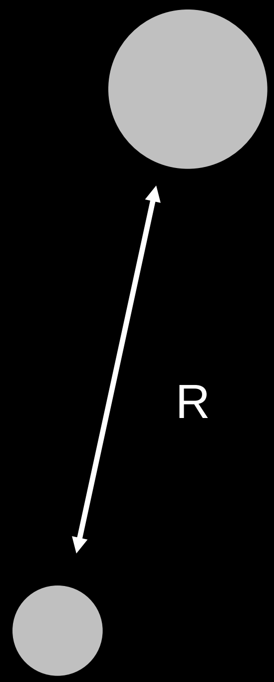
Cambridge/Aachen



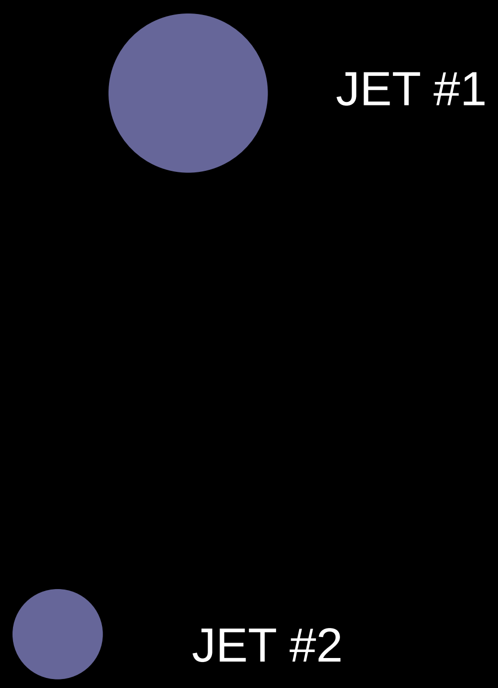
Cambridge/Aachen



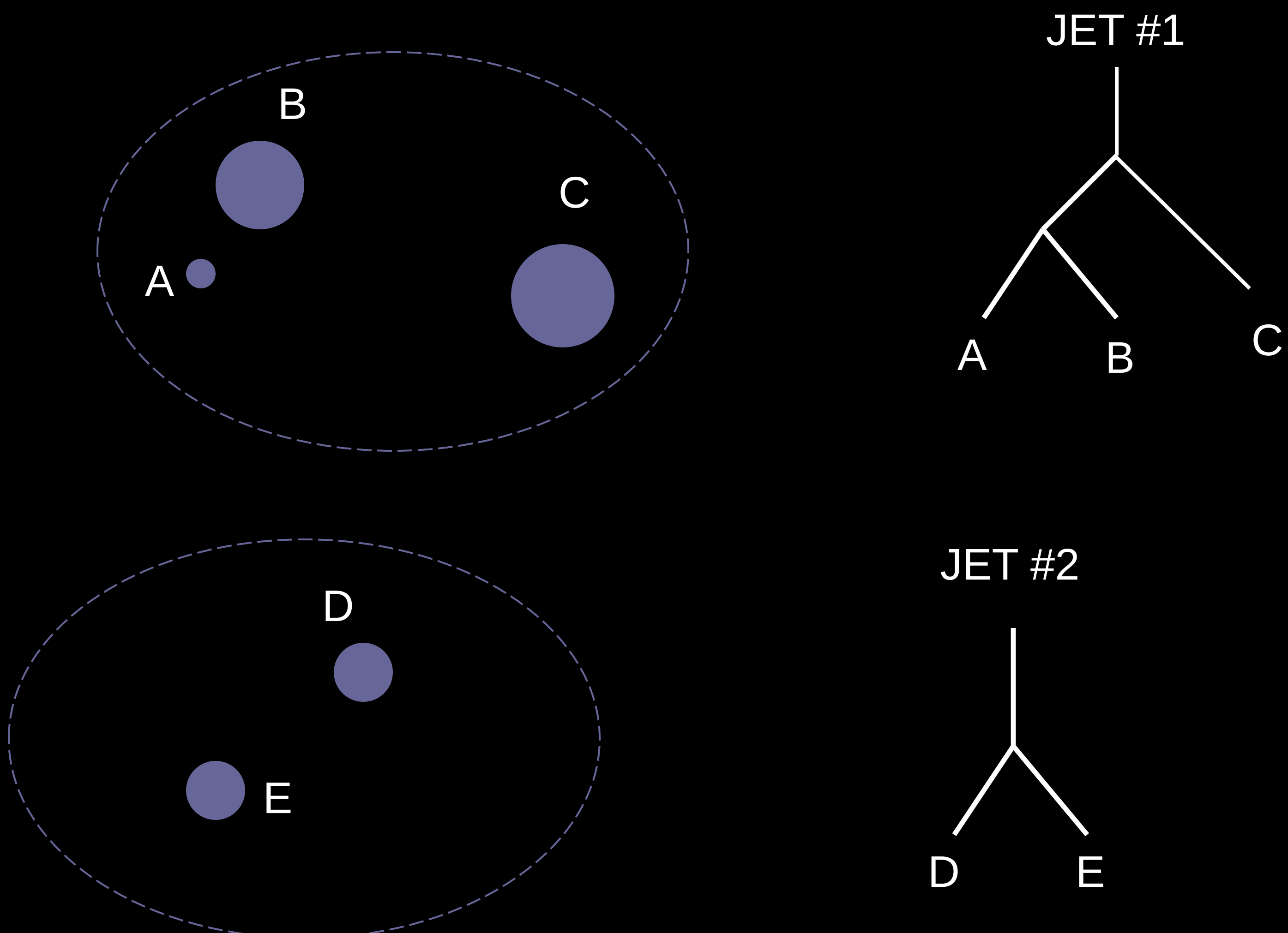
Cambridge/Aachen



Cambridge/Aachen



Cambridge/Aachen



kT

- C/A-like, with R-parameter
- Nontrivial distance measure between 4-vectors…sensitive to energy
- “Beam distance” criterion for jet formation

kT

$$D_{ij} = \min(p_{Ti},p_{Tj}) * \Delta R_{ij}$$

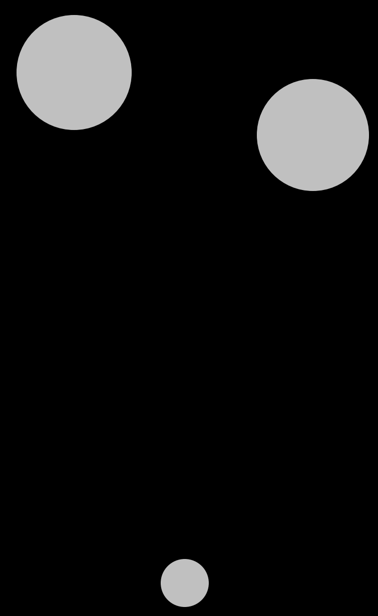
$$D_{iB} = p_{Ti} * R$$

← Defined for pairs of 4-vectors

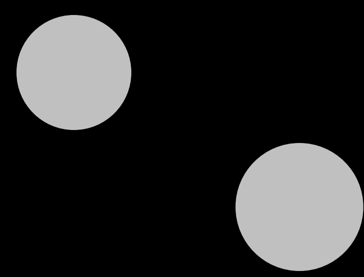
← Defined for individual 4-vectors

- Add D-closest pairs of 4-vectors unless a D_{iB} is smallest
- If D_{iB} is smallest, promote i to a jet, pluck it from the list, and continue clustering what remains

kT



kT



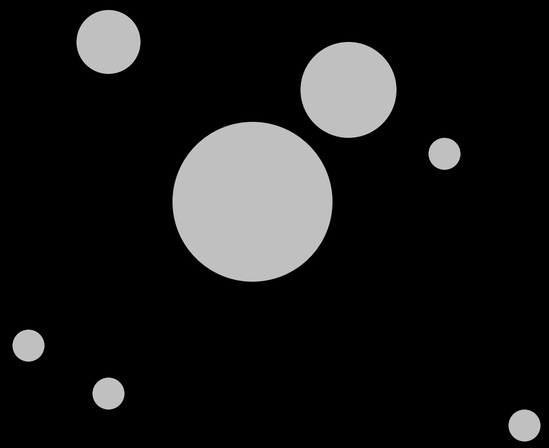
Anti-kT

$$D_{ij} = \min(1/p_{Ti}, 1/p_{Tj}) * \Delta R_{ij}$$

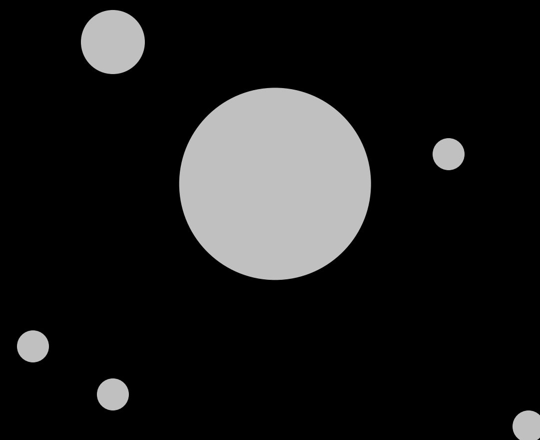
$$D_{iB} = (1/p_{Ti}) * R$$

- Same as kT, but measure now prioritizes clustering with *hard* 4-vectors

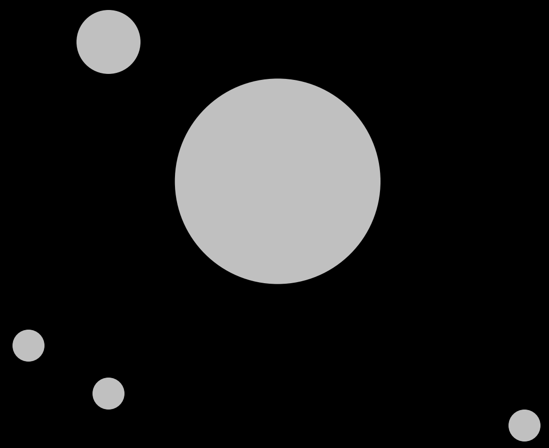
Anti-kT



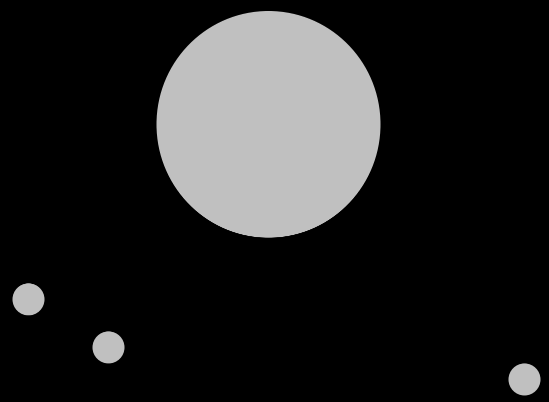
Anti-kT



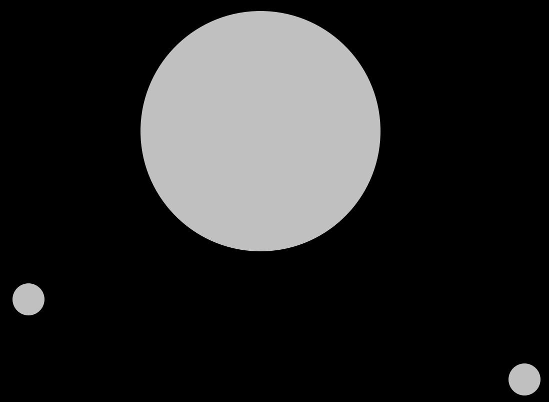
Anti-kT



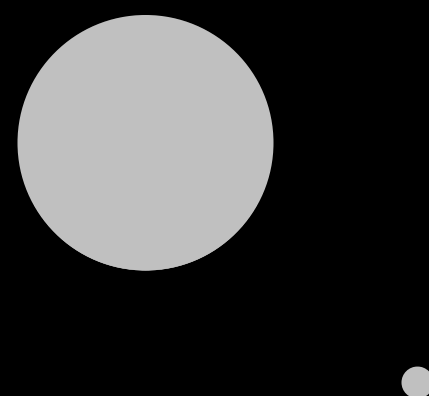
Anti-kT



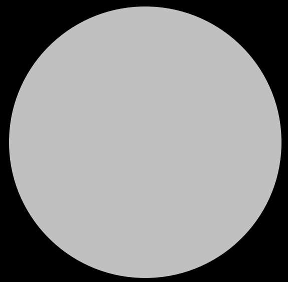
Anti-kT



Anti-kT

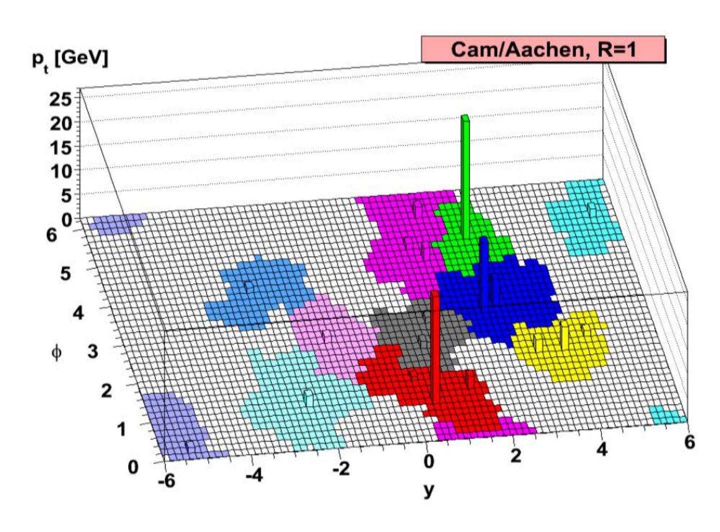


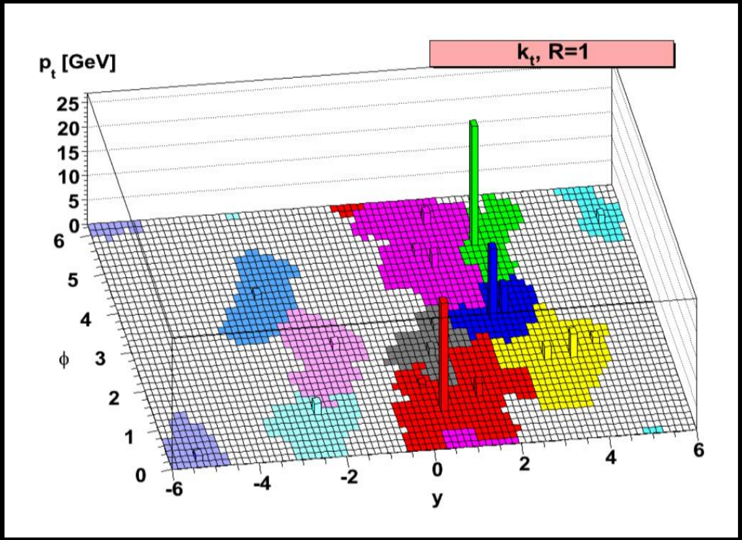
Anti-kT



Catchment Area Comparison

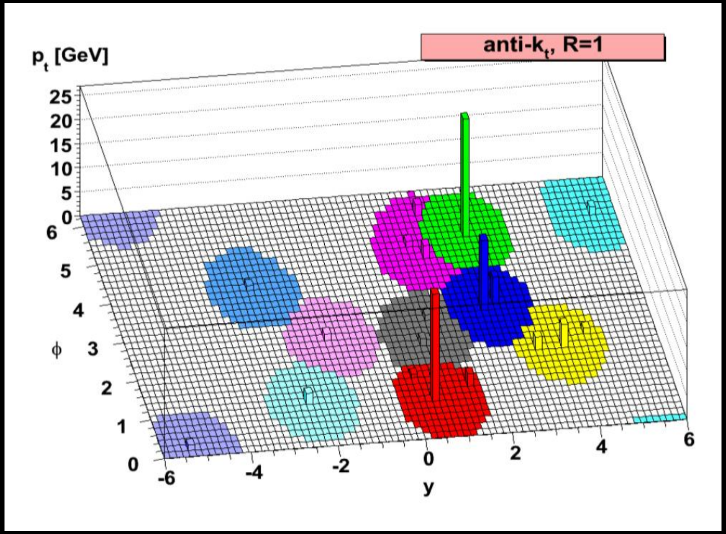
C/A





kT

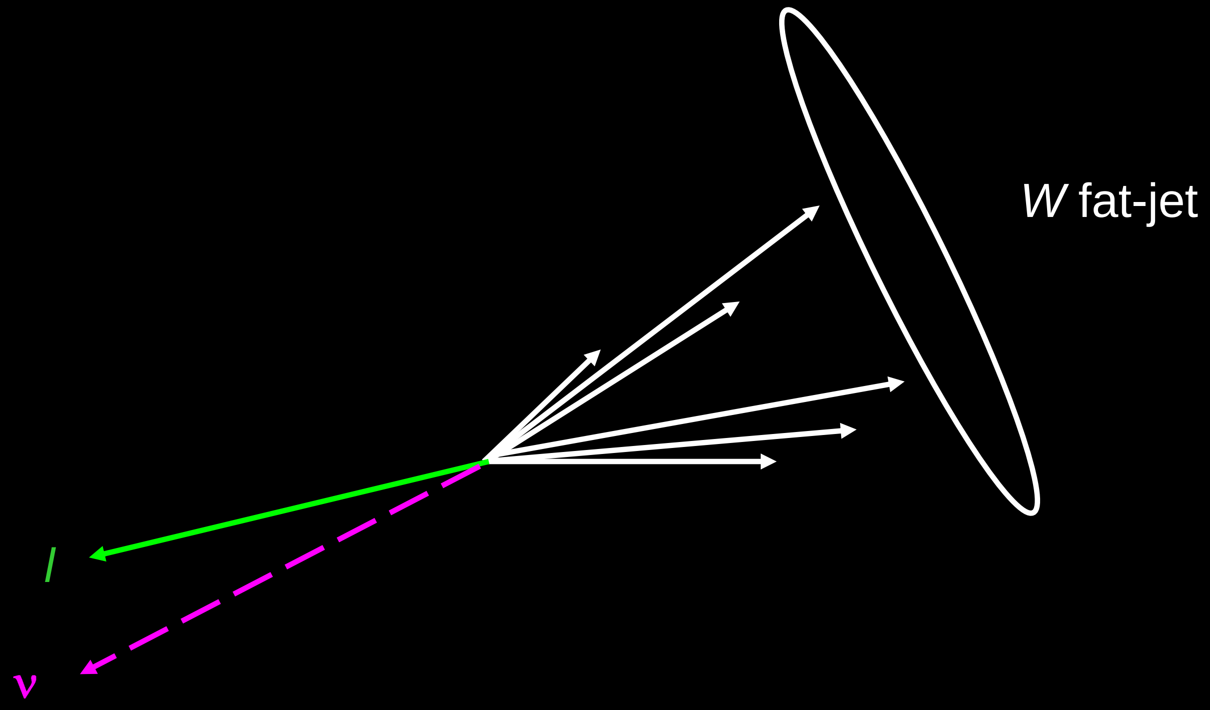
Anti-kT



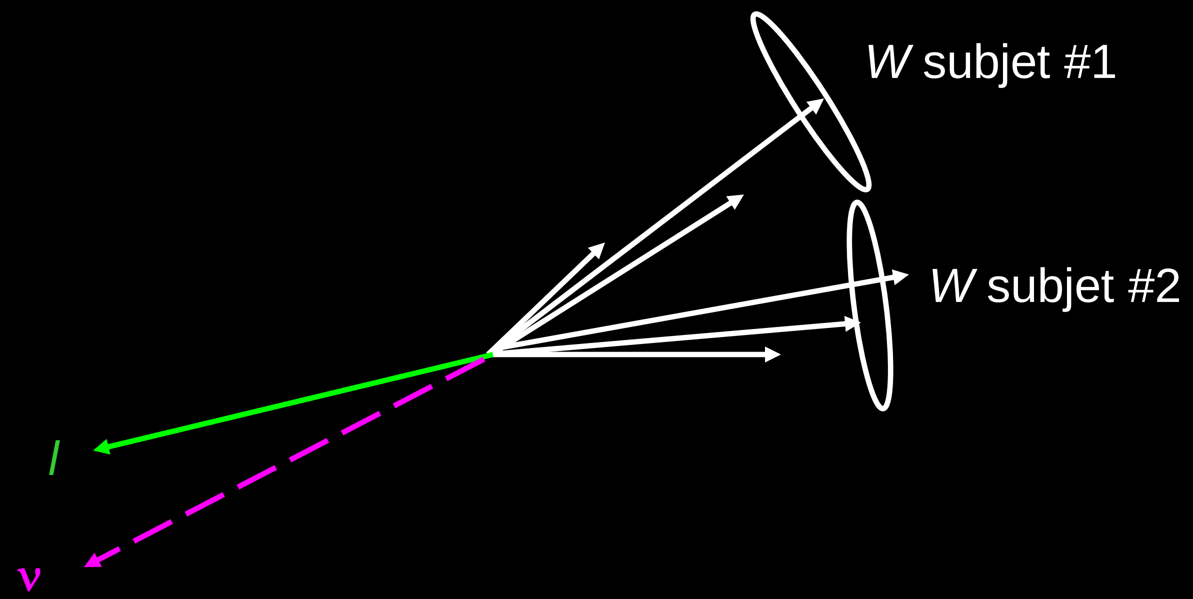
Cacciari & Salam

Grooming Jets

WW in Idealization



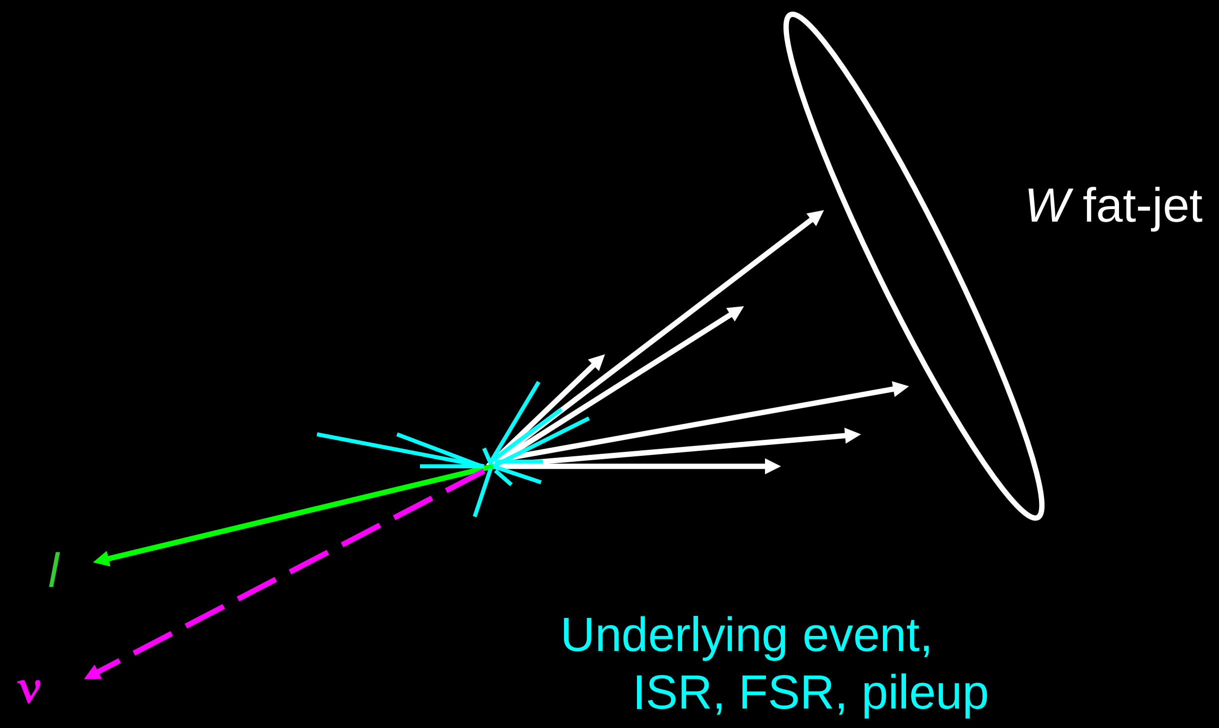
WW in Idealization



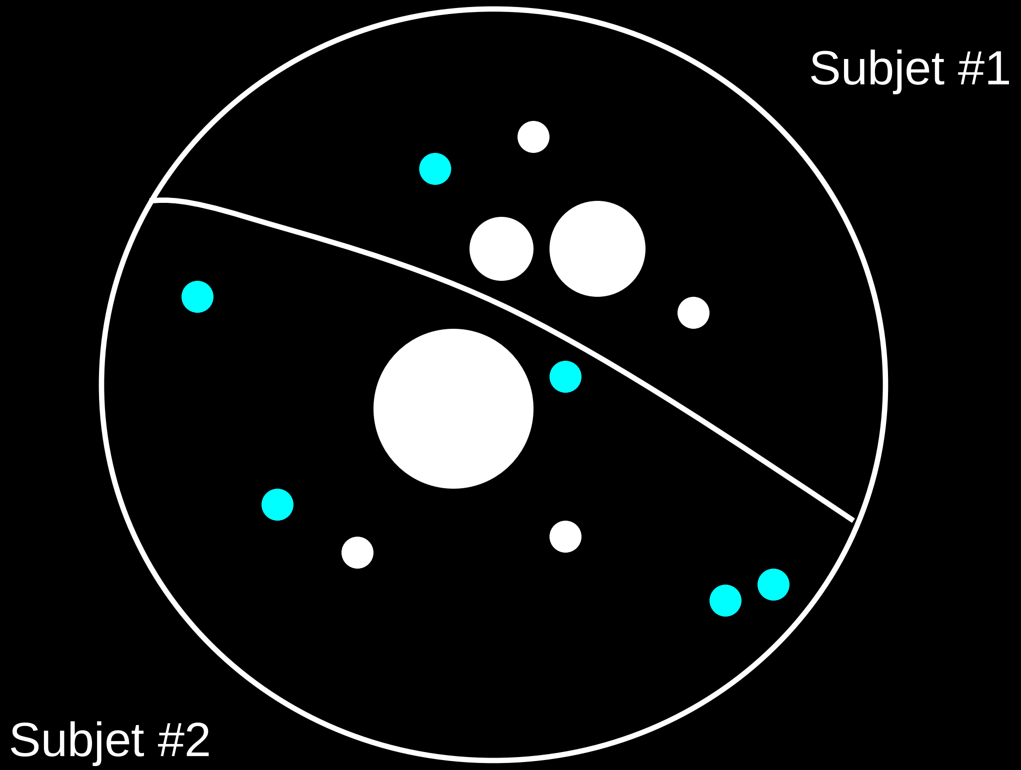
Discriminators against QCD:

1. Jet mass ~ m_W
2. k_T / z / cosθ* / ΔR / …

WW in Reality

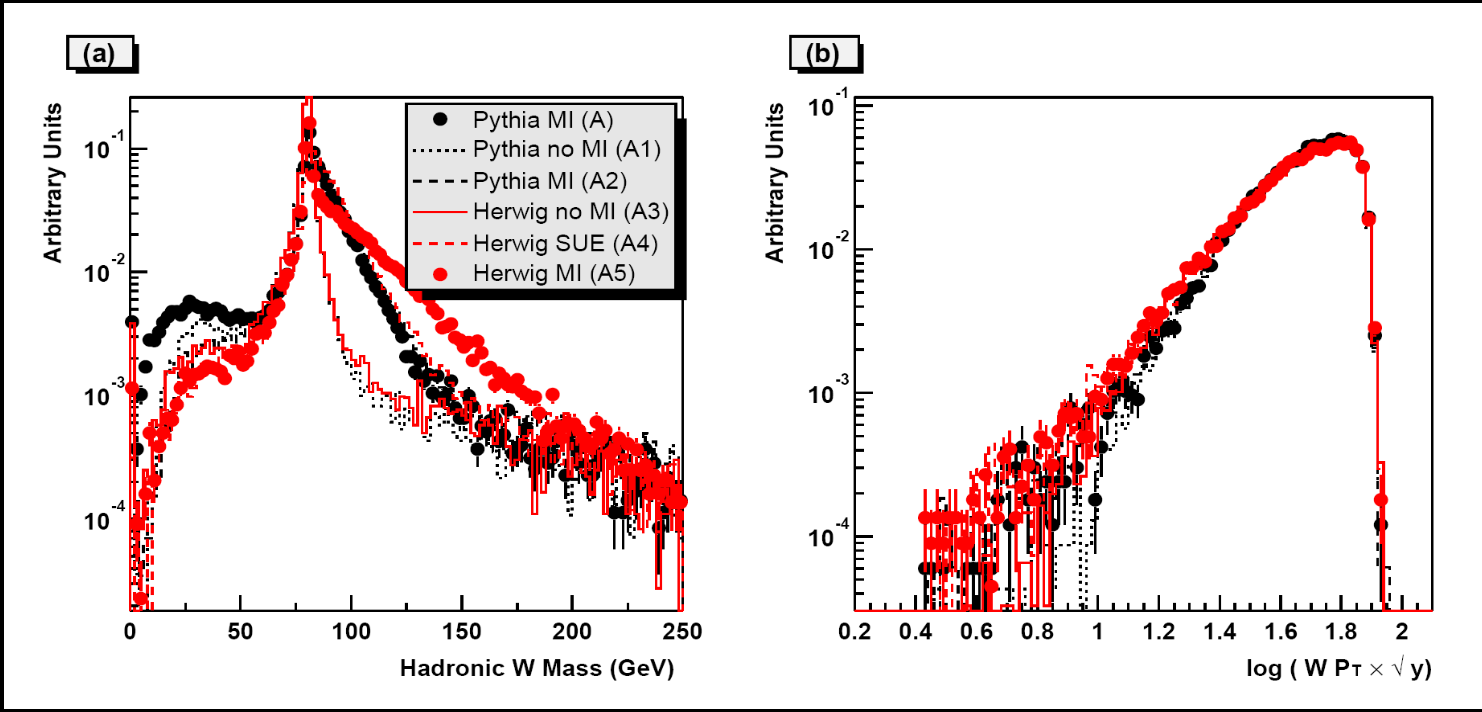


WW in Reality



W-Jets with YSplitter

p_{TW} = 300 ~ 500 GeV

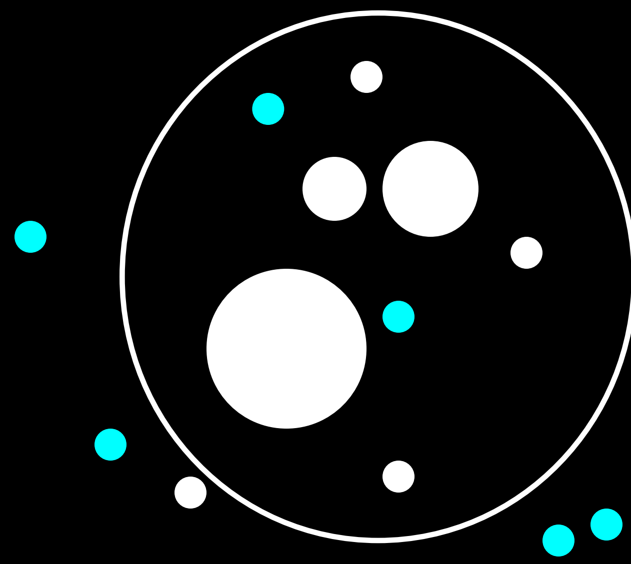


W fat-jet mass

W fat-jet kT scale

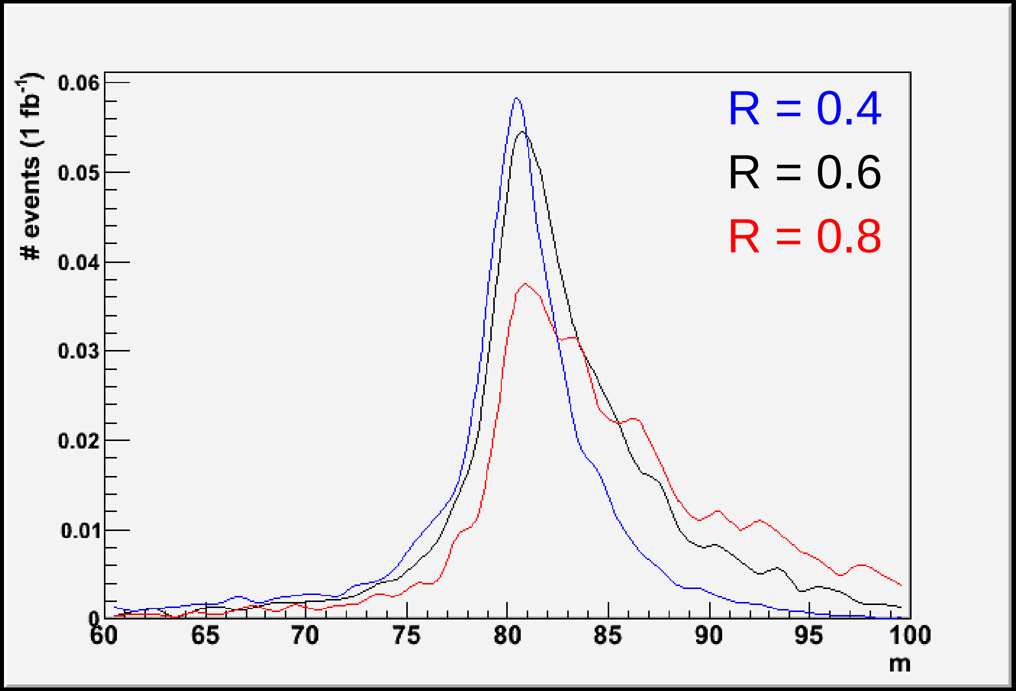
Butterworth, Cox, Forshaw

Simple Fix #1: Shrinking Fat-Jets



$R_{fat} \sim \# / p_{TW}$

Seems to Work Okay…



p_{TW} = [400,500]

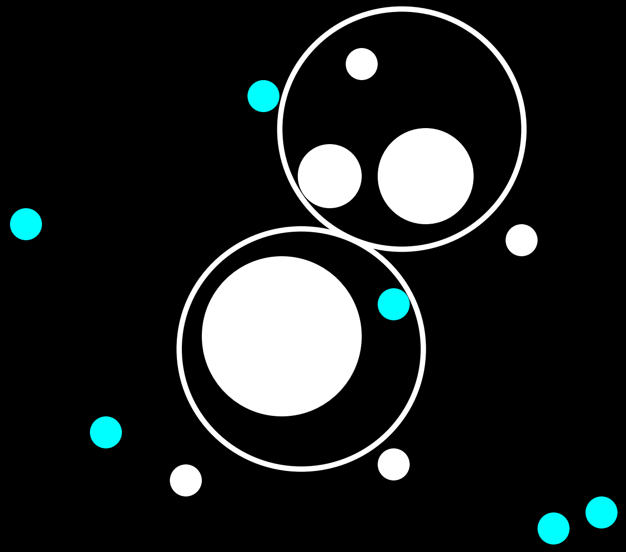
C/A jets

* PYTHIA 6.4 default UE tune

Why Don't We Just Do This?

- Introduction of user-defined mass scale…have to know what you're looking for!
- Not obvious that this gets always gets rid of all of the junk
  - Intermediate-boost regime (Higgsstrahlung)
  - 3+ body decays spread out more irregularly
- Fails to constrain substructure beyond 2-body, but we could continue investigating the distribution of jet constituents afterwards

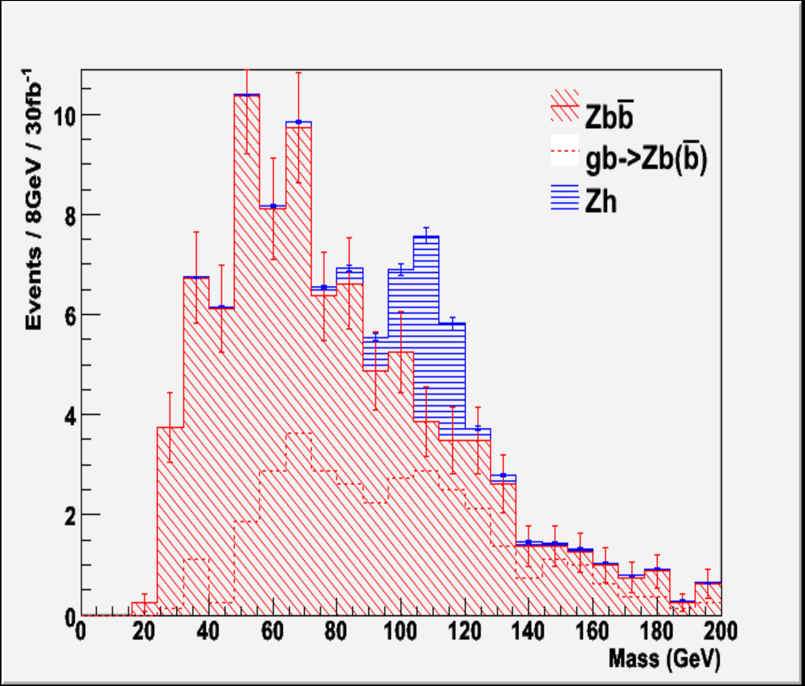
Simple Fix #2: Shrinking Thin-Jets



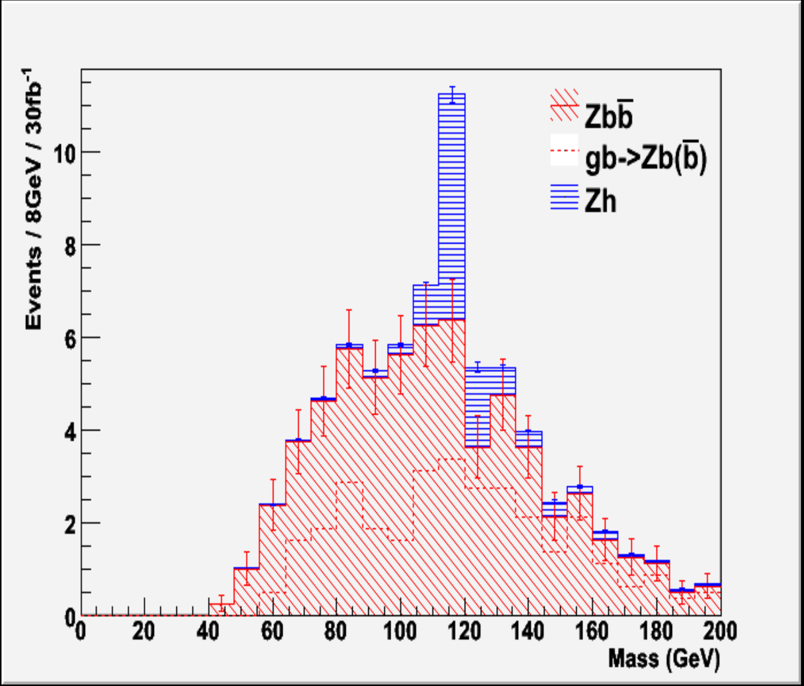
$R_{thin} \sim \# / p_{TW}$

Degraded Signal Peak vs Bump-on-a-Bump

Intermediately-boosted Higgs from Higgsstrahlung



R = 0.2 C/A

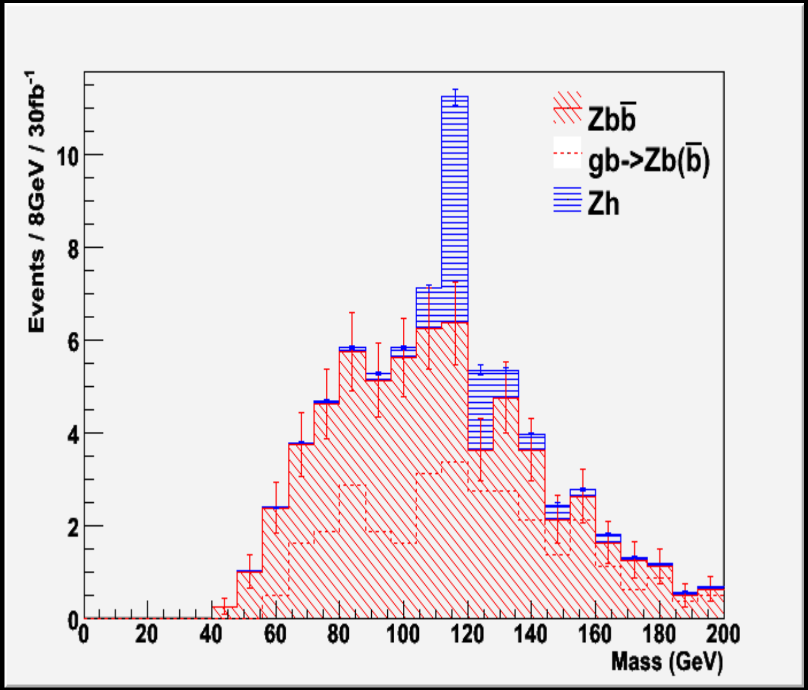


R = 0.5 C/A

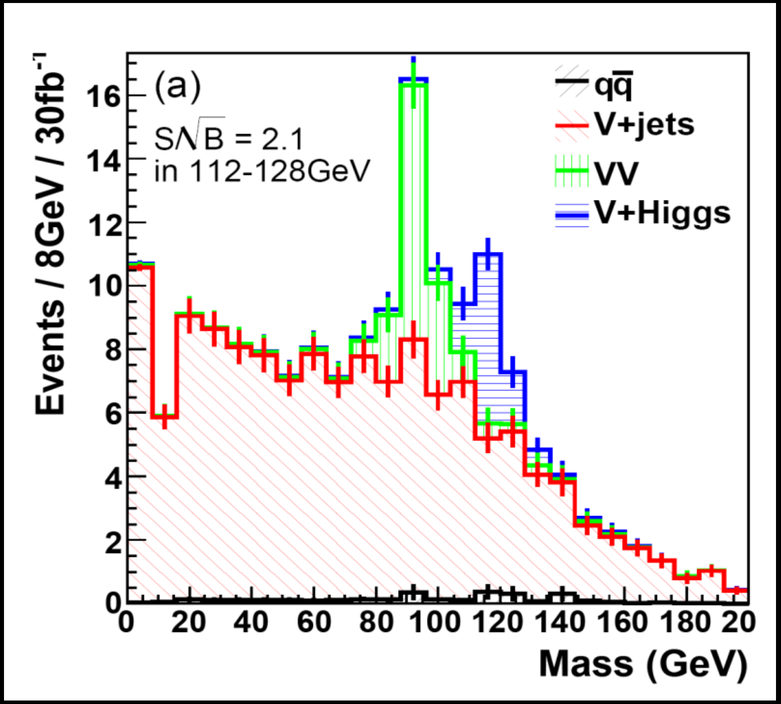
More Refined Strategies

- Filtering
- Pruning
- Trimming

Filtering Advertisement



R = 0.5 C/A

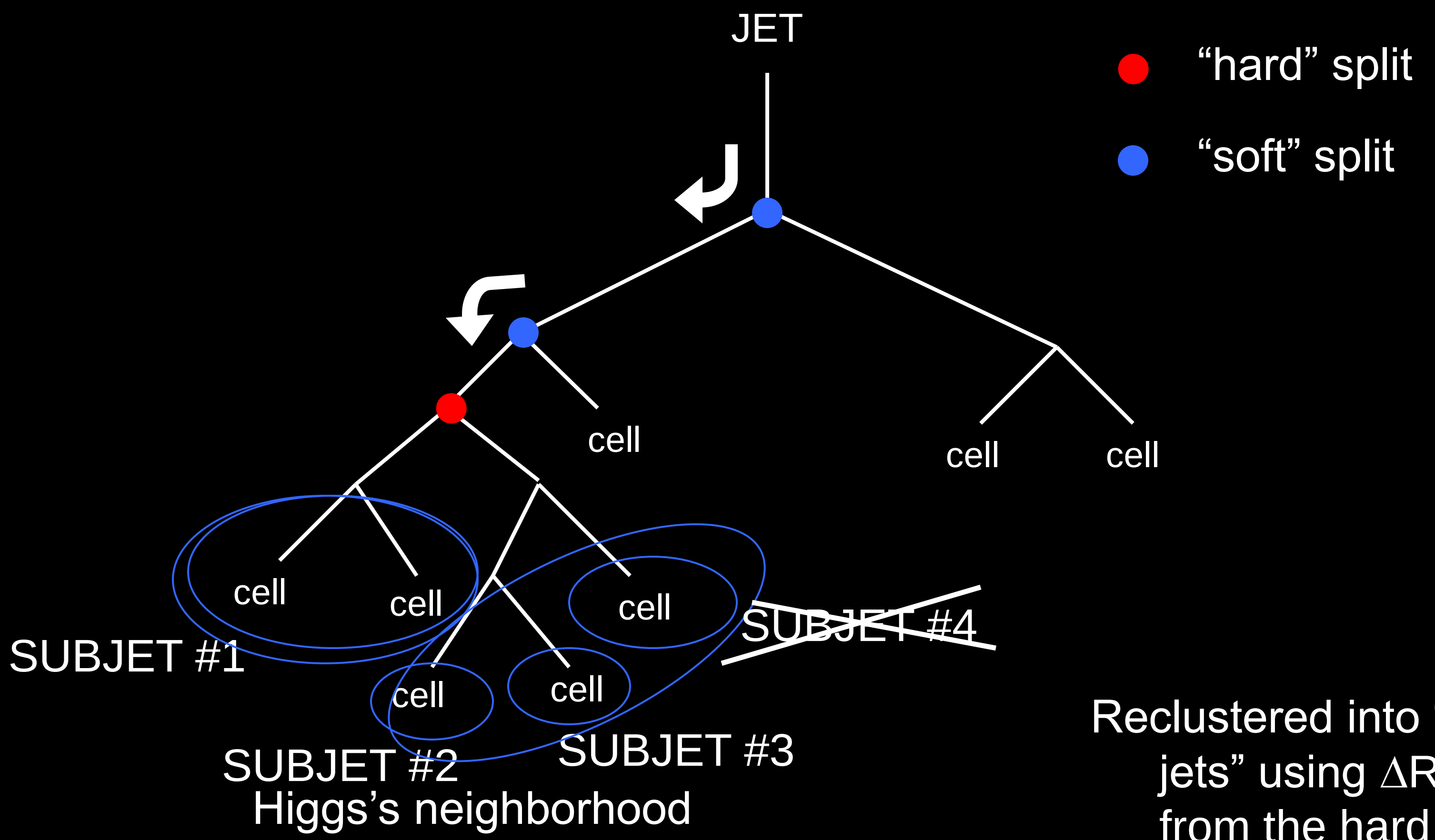


BDRS filtering

Butterworth, Davison, Rubin, Salam

Filtering: A Top-Down View

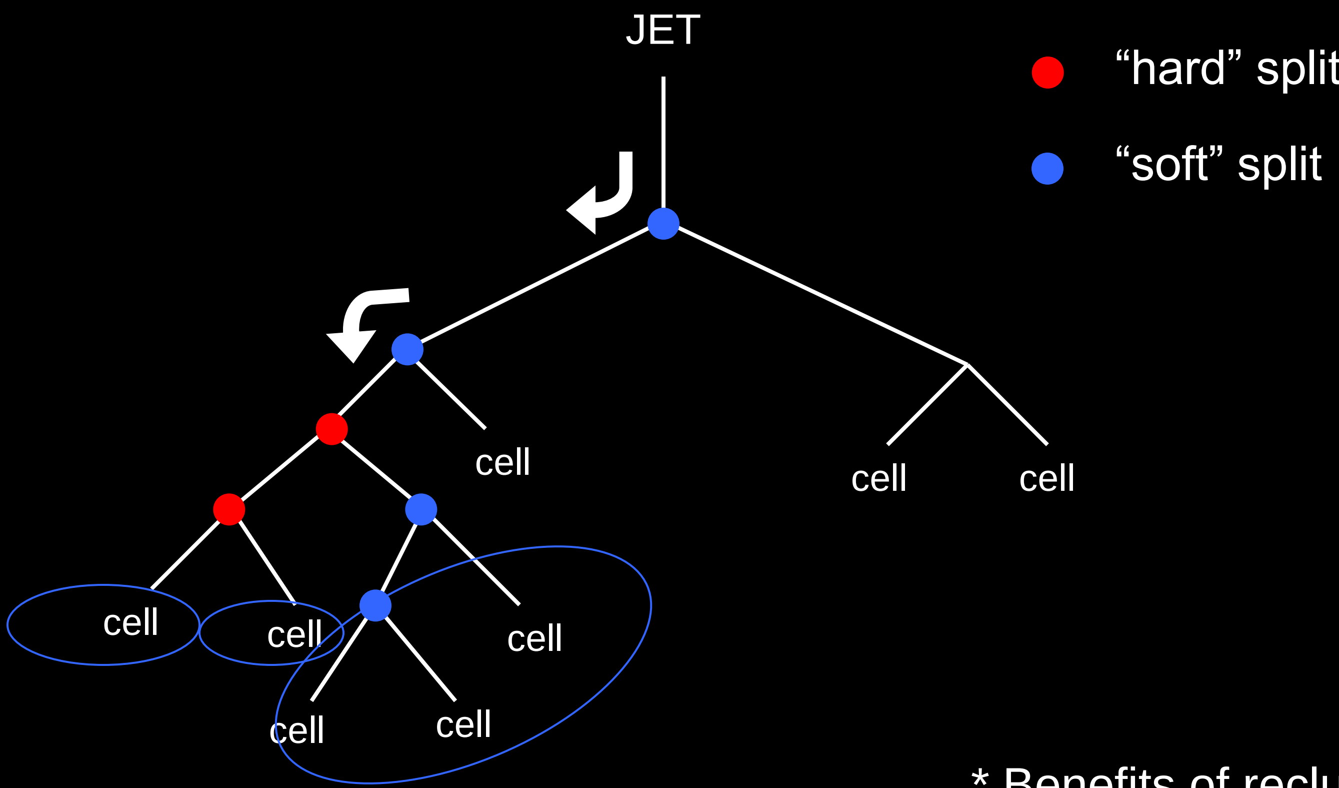
Fat-jet clustered with C/A



Reclustered into “thin-jets” using ΔR-scale from the hard split

Filtering: A Top-Down View

Fat-jet clustered with C/A



top neighborhood

* Benefits of reclustering depend on process and p_T range of interest

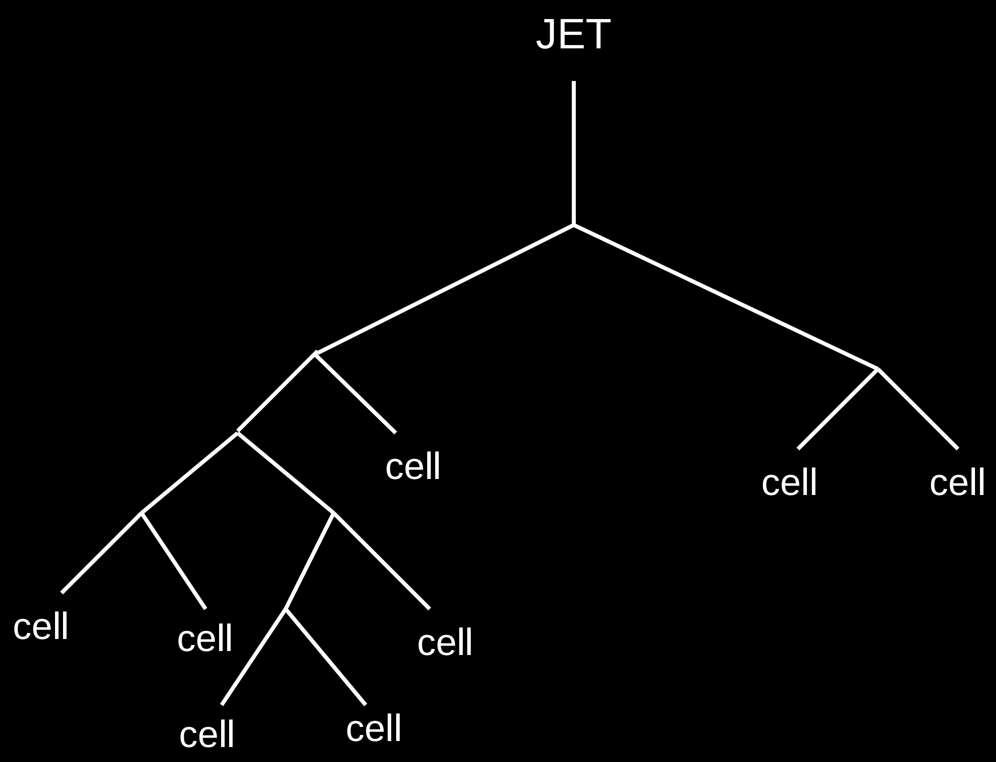
Hard Measures

- Original BDRS: fractional drop in mass, and energy asymmetry between split clusters
  - Scale-invariant -> no mass features sculpted into backgrounds
- JHU Top-tag: energy relative to original fat-jet, and ΔR between clusters

Filtering Advantages

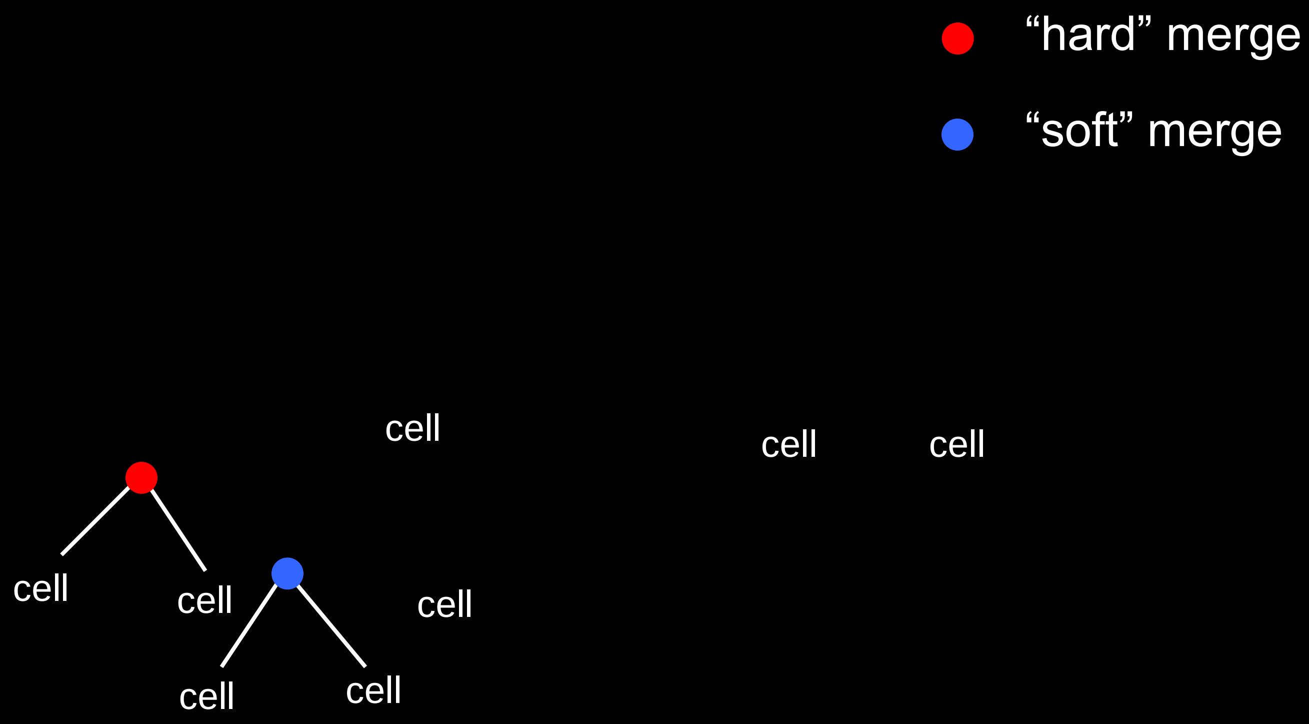
- Ditches large-angle soft junk automatically
- Adaptively determines appropriate ΔR scales for clustering substructures
- Easy to define scale-invariant hardness measures
- Can be easily extended to flexible searches for arbitrary multiplicities of substructures
  - Top-jets
  - Neutralino-jets
  - Boosted Higgs in busy environment (SUSY, *tth*)

Pruning: A Bottom-Up View

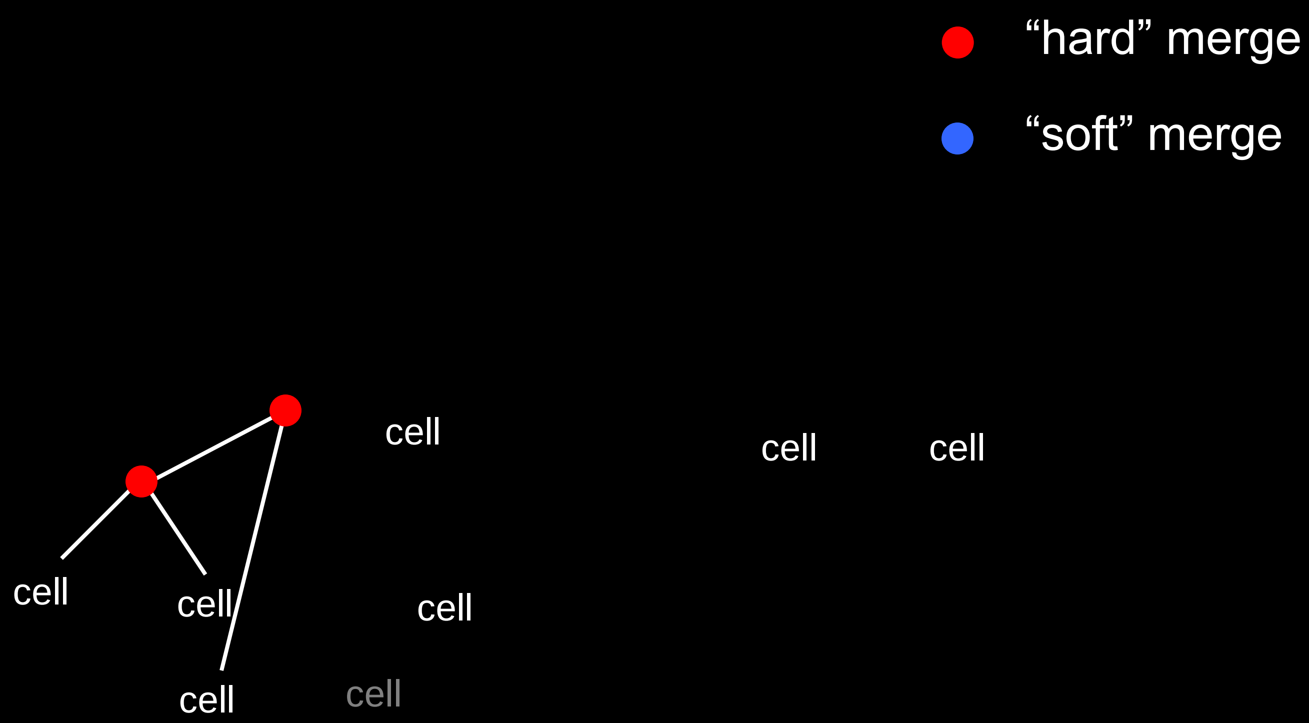


Ellis, Vermillion, Walsh

Pruning: A Bottom-Up View



Pruning: A Bottom-Up View



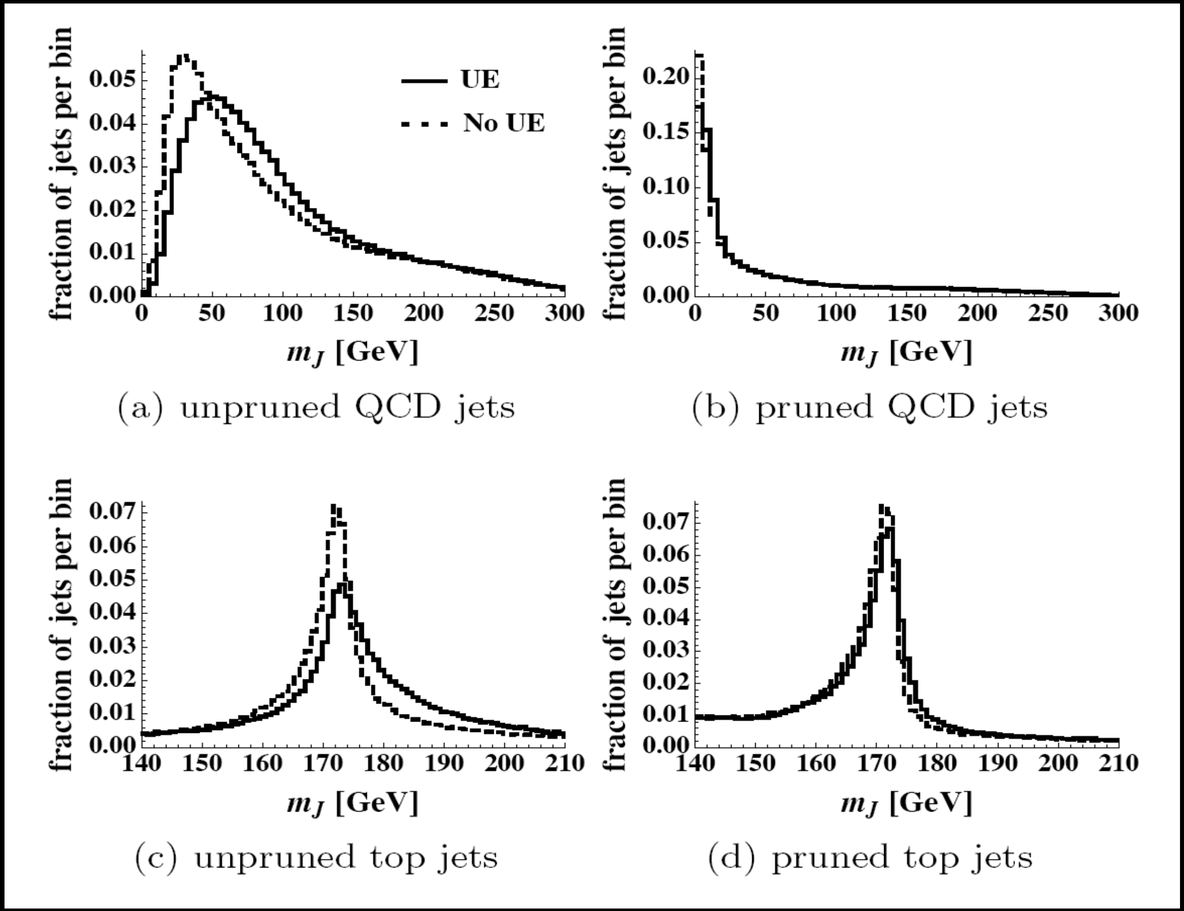
Nominal Pruning Parameters

- Merging 4-vectors cannot simultaneously be too asymmetric and too far apart…"hard" merging means:
  - $\mathrm{Min}(p_{T1},p_{T2})/(p_{T1}+p_{T2}) > z_{cut}$

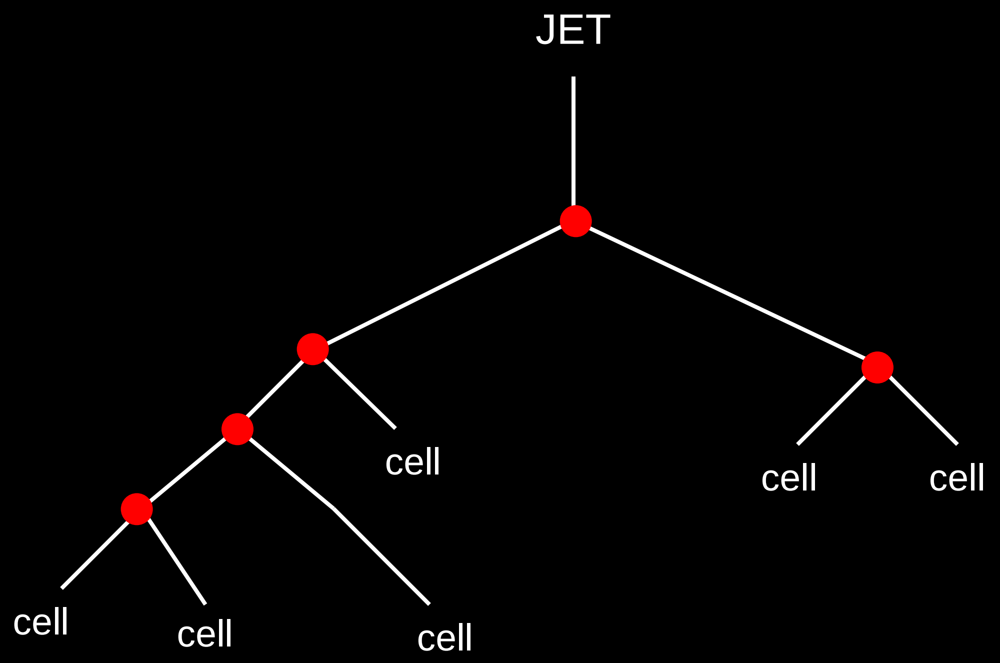
    OR

  - $\Delta R_{12} < D_{cut} \sim m_{fat}/p_{Tfat}$

Case Study: Boosted Top Mass



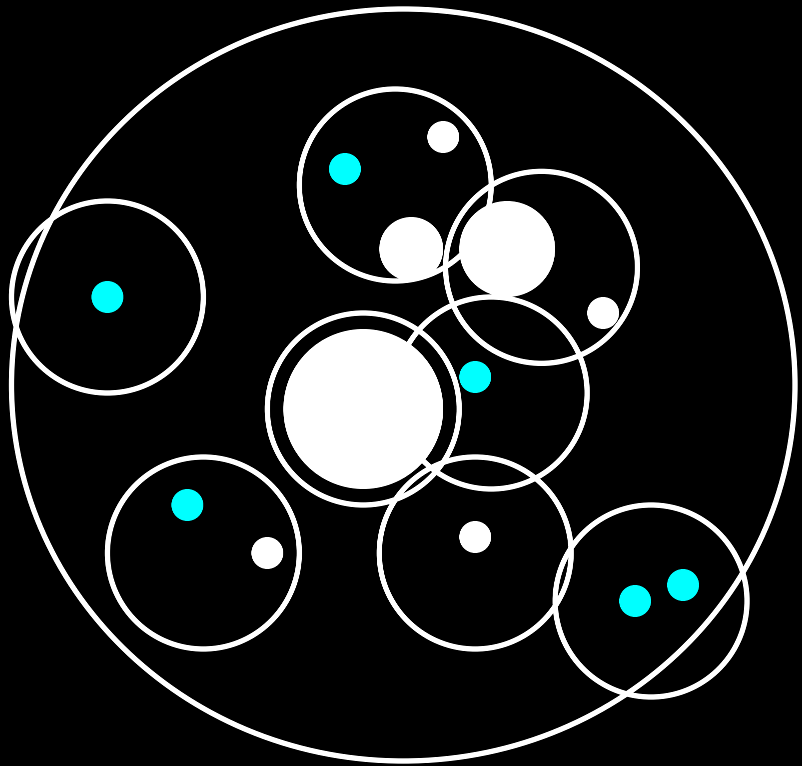
Detailed Substructure is "Trivial"



* However, tied to this specific (local) definition of "hard"

Trimming

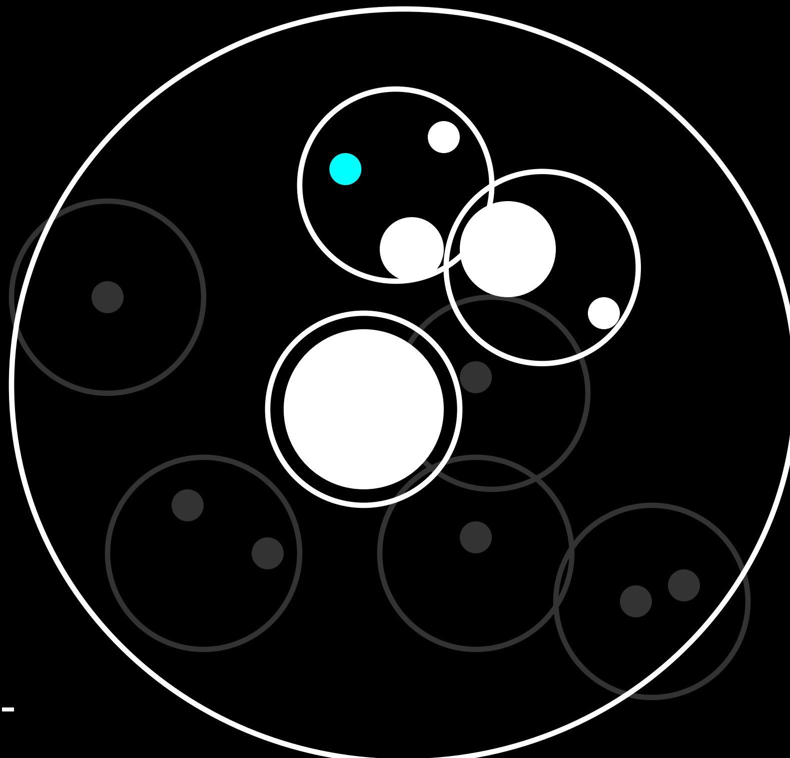
1. Recluster fat-jet constituents into *very* thin jets



Krohn, Thaler, Wang

Trimming

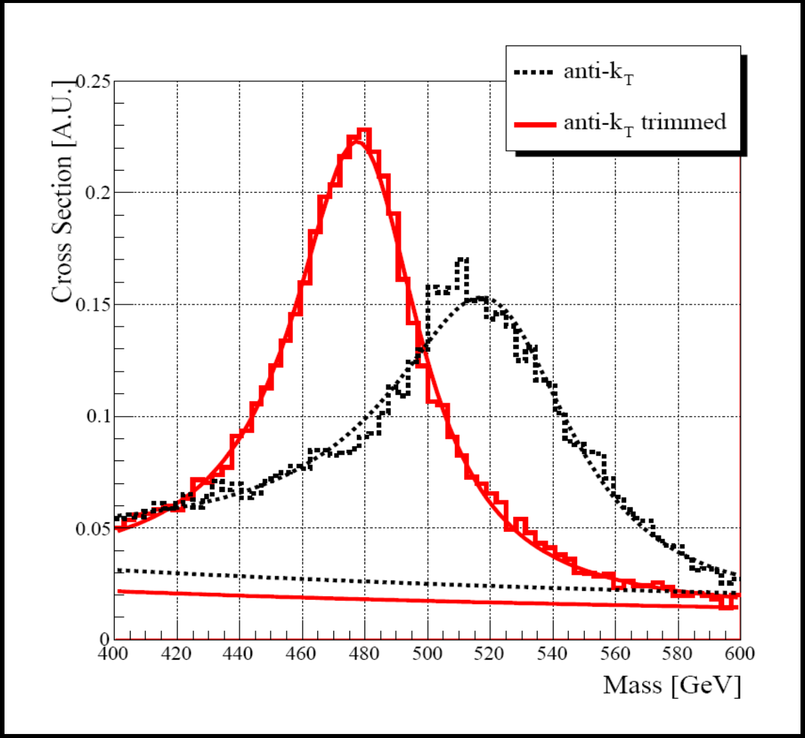
1. Recluster fat-jet constituents into *very* thin jets



2. Throw away thin-jets that are too soft

Krohn, Thaler, Wang

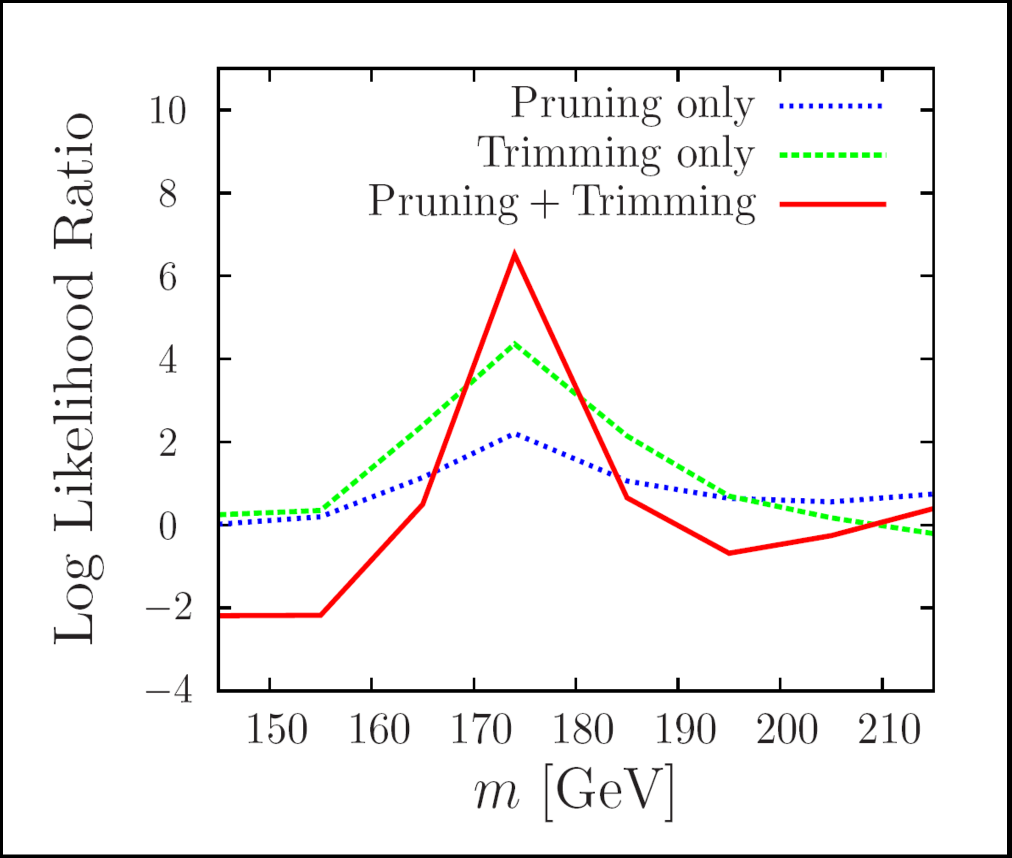
Case Study: Dijet Resonance



R = 1.5 anti-kT, reclustered with R = 0.2

Throw away if p_T ~< (1%)*p_{Tfat}

Boosting Discovery from Combining Algorithms?



Soper & Spannowsky

Summary: Growing

- We know how to make jets in ways that either organize substructure or form nice circles in a trustable way

Summary: Grooming

- Interesting jets are full of junk as well as substructure
  - Mass resolution degrades
- Simple-minded workarounds tend to get us into trouble or are non-optimal
- Variety of more sophisticated procedures are now on the market…all with similar names!

Summary: Grooming

- Filtering
  - Trace back through a fat-jet's clustering history, find "hard" splits (discarding "soft" splits), maybe recluster with refined R using this info
- Pruning
  - Redo clustering of a fat-jet's constituents, vetoing mergings that are too far AND too asymmetric
- Trimming
  - Recluster fat-jet with tiny R and throw away thin-jets that are too soft

Summary: Grooming

- Not much systematic comparison (still)
  - But see Soper & Spannowsky