

Reconstructing Massive Particles with the k_T Algorithm

Toward Search Strategies for the LHC

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work with

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Searching for New Physics in Jets at the LHC

- Rich, complex jet environment expected, but few tools exist to deal with the QCD background
- Jet substructure with k_T and other recombination algorithms show promise:
 - Specific searches: finding W , h (Butterworth, Ellis, Raklev; Butterworth, Davison, Rubin, Salam)
 - Studies on k_T , variants: (SM Handles & Candles Working Group; Cacciari, Salam, Soyez)
- We take a model independent approach to searching for new physics in jets:
 - Find variables that characterize a large class of new physics models distinctly from their QCD background
 - Useful in generic searches, or may be tuned for a model-dependent search
 - The QCD background is reduced by weighting/cutting on these variables and by using correlations within an event

The k_T Algorithm and Jet Substructure

The k_T algorithm uses a p_T and ΔR weighted metric to define a sequence of recombinations from calorimeter cells to jets:

0. Begin with a list P of 4-vectors.
1. For each $a \in P$, compute the value of the metric for a and its nearest neighbor a_{NN} in P ,

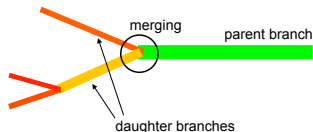
$$k_T(a, a_{NN}) \equiv \min(p_{T,a}, p_{T,a_{NN}}) \frac{\Delta R_{a,a_{NN}}}{D}$$

2. Find

$$\min_{a \in P} \{k_T(a, b), p_{T,a}\}$$

3. If some $k_T(a, a_{NN})$ is smallest, then merge objects a and a_{NN} together to form a new $x \in P$ by adding their 4-vectors. Remove a, a_{NN} from P . Otherwise, if some $p_{T,a}$ is smallest, promote a to a jet and remove it from P .
4. Return to step 1 until P is empty.

the k_T algorithm tree



Large D Jets

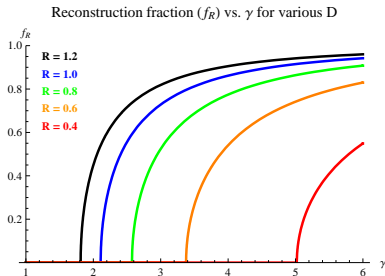
Need a systematic way to reconstruct massive particles in hadronic channels – use a large angular parameter D in the jet algorithm.

Advantages:

- Can reconstruct particles in single jets closer to threshold
- Allows for single jet analysis – can apply kinematic variables to the substructure of jets to identify massive particles

Disadvantages:

- QCD can be difficult to understand in large jets
- Large D jets more susceptible to the underlying event, systematic effects of k_T
- Using large D is not applicable in some scenarios



Kinematic Variables and Jet Substructure

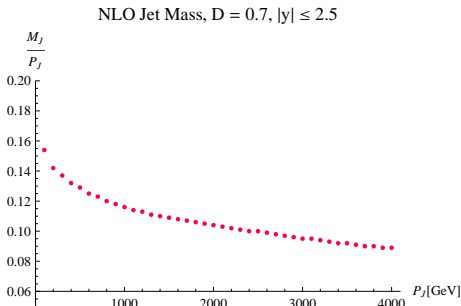
Our goal is to understand how to identify reconstructed objects in jets. So we must:

- Derive kinematic distributions in a decay
- Understand the requirement for reconstruction in a single jet
- Understand systematic effects from the k_T algorithm
- Test these distributions against sample processes in a Monte Carlo (e.g. $t\bar{t}$, Hidden Valley)
- Find whether these variables predict different distributions from QCD

This enables us to develop a search strategy – weight jets or events by how likely they are to contain a reconstructed massive particle.

m/p_T Can Classify Jets

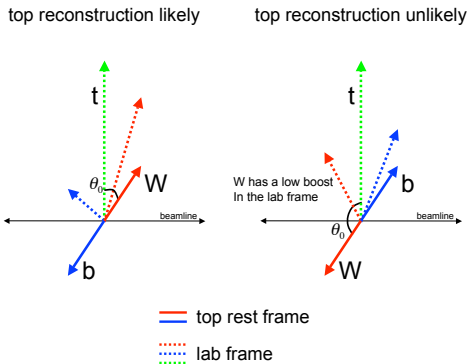
An interesting and useful variable is m/p_T – can be very different for reconstructed massive particles and QCD jets with large D .



This variable is useful when applied to jet substructure – we have found cutting on m/p_T can improve the S/B factor in generic searches, but has difficulty significantly improving S/\sqrt{B} .

Kinematic Effects on Reconstruction

The kinematics of a decay have an effect on the ability to reconstruct the particle with k_T :



The daughters must be sufficiently boosted so that we reconstruct and merge them together directly.

Building a Computational Framework for the k_T Algorithm

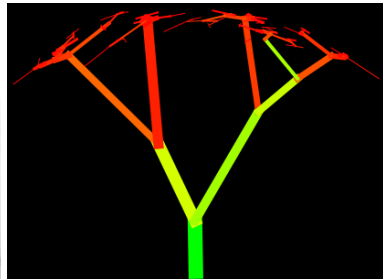
We have developed a program, Baobab, with 3 main, independent functions:

- Run the k_T algorithm on MC events
- Streamline data analysis with a client-style program
- Produce visualizations of events – gives a visually striking difference between typical QCD events and events with new physics.

A baobab tree is characteristic of the visualizations in events:

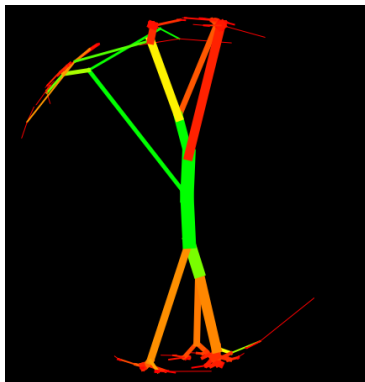


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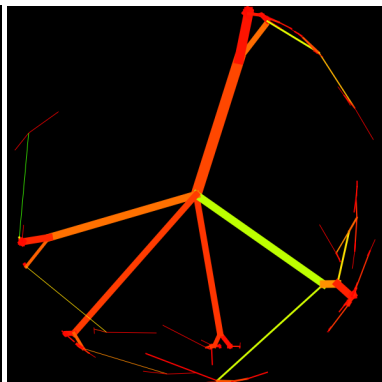


Visualizations in Baobab

Visualizations: written in HepRep, interpreted by HepRApp – automatically produced when k_T is run, lets us encode variables visually



$t\bar{t}$ event



4j event

Variables we use (easy to change): p_T – thickness; m/p_T – color; k_T – radius; $(\Delta R, \phi)$ – angles

Future Work and Acknowledgments

There are several topics for further work in this vein:

- Continue work on reconstructing and identifying decays with jet algorithm substructure
- Make Baobab public, possibly synthesize with other tools
- Develop techniques for characterizing QCD (more to come soon)
- Study background subtraction methods (need more sophisticated QCD MC samples)
- Extend to other classes of signals (i.e. SUSY, semi-leptonic channels)

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