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The anti-k_t jet clustering algorithm

A jet is a narrow cone of hadrons and other particles produced by the hadronization of a quark or gluon in a particle physics or heavy ion experiment. Particles carrying a color charge, such as quarks, cannot exist in free form because of QCD confinement which only allows for colorless states. When an object containing color charge fragments, each fragment carries away some of the color charge. In order to obey confinement, these fragments create other colored objects around them to form colorless objects. The ensemble of these objects is called a jet. Jets are measured in particle detectors and studied in order to determine the properties of the original quarks. The observed jets provide a view of the underlying hard quark and gluon interactions that occur at very small distance scales. So with a suitable definition of the jet cross section one hopes to minimize the effect of long distance physics and of the inherent jet ambiguities and obtain a fairly precise picture of the short distance dynamics. Here I describe a jet definition algorithm - anti-k_t algorithm which has been widely used at LHC.

We start by generalizing the existing sequential recombination algorithms, k_t and Cambridge/Aachen. As usual, one introduces distances d_{ij} between entities (particles, pseudojets) i and j and d_{iB} between entity i and the beam (B). The (inclusive) clustering proceeds by identifying the smallest of the distances and if it is a d_{ij} recombining entities i and j, while if it is d_{iB} calling i a jet and removing it from the list of entities. The distances are recalculated and the procedure repeated until no entities are left.

The extension relative to the k_t and Cambridge/Aachen algorithms lies in our definition of the distance measures:

$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p}) \frac{\Delta_{ij}^2}{R^2} \qquad (1.1a)$$

$$d_{iB} = k_{ti}^{2p} \qquad (1.1b)$$

where $\Delta^2_{ij} = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$ and k_{ti}, y_i and ϕ_i are respectively the transverse momentum, rapidity and azimuth of particle i. In addition to the usual radius parameter R, we have added a parameter p to govern the relative power of the energy versus geometrical (Δ_{ij}) scales. For $p = 1$ one recovers the inclusive k_t algorithm. It can be shown in general that for $p > 0$ the behavior of the jet algorithm with respect to soft radiation is rather similar to that observed for the k_t algorithm, because what matters is the ordering between particles and for finite Δ this is maintained for all positive values of p. The case of $p = 0$ is special and it corresponds to the inclusive Cambridge/Aachen algorithm.

Negative values of p might at first sight seem pathological. We shall see that they are not.2 The behavior with respect to soft radiation will be similar for all $p < 0$, so here we will concentrate on $p = -1$, and refer to it as the "anti-k_t" jet-clustering algorithm.

There starts to be a certain choice of infrared and collinear safe inclusive jet algorithms for hadron colliders. As we have seen, some of these (k_t and Cambridge/Aachen) belong to a more general class of sequential recombination algorithms, parametrized by a continuous parameter p, which sets the power of the transverse momentum scale relative to the geometrical distance ($p = 1$ gives k_t, $p = 0$ gives Cambridge/Aachen).

Rather surprisingly, taking p to be negative also yields an algorithm that is infrared and collinear safe and has sensible phenomenological behavior. We have specifically studied $p = -1$, the "anti-k_t" algorithm, and highlighted various simple theoretical properties, notably the resilience of its jet boundaries with respect to soft radiation. The other properties that we've discussed are essentially consequences of this feature. These properties are characteristic also of certain "iterative cone" algorithms, those with progressive removal (IC-PR) of the stable cones. However in the anti-k_t algorithm these properties are obtained without having to pay the price of collinear unsafety. Therefore the anti-k_t algorithm should be a good candidate as a replacement algorithm for IC-PR algorithms.