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# HollowConeSieveForTops

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The LHC is a top factory: in the SM about 8,000 top pairs should have been produced with more than 47 pb−1 integrated luminosity already taken per detector at 7 TeV. Since the LHC center-of-mass energy is high compared to the top mass, the tops will typically be highly boosted, so that the decay products are close to each other. Thus, in the detector, at first sight, the top decay products may look like a fat jet instead of the several separate ones of which it is composed. In the top reconstruction, to catch all the three main decay products of a top a a single fat jet, it is natural to use a large jet size. If a large R = 1.5 is used, it is likely that two jets will be constructed in the event (one from the top and the other from the t), while more will be constructed using a small R.
The light jets behave differently from the top jets, in that the number of reconstructed light jets does not vary with
R. So, after subtracting light jets from dijet events, the top contribution can be seen in the variation of the number
of jets with cone size R. We develop the "hollow cone " idea to tag top pairs. Consider the anti-kt algorithm as a " perfect cone " algorithm. When a larger cone size is used, both a ttbar event and a QCD dijet event will give two jets, when a smaller cone size is used, a ttbar event will have more jets while a QCD dijet event still have two. This means, for a fat jet with a large cone size, after subtracting a jet of small cone size in the interior, if some jets remain in the hollow cone, the jet is likely to be
a top jet, and if there is no jet in the hollow cone, it is likely to be a light quark jet or a gluon jet.
Our top tagging algorithm proceeds in the following steps, trying to separate top pairs from the QCD dijet events:
1) Reconstruct jets using the anti-kt jet algorithm with R = 1.5 to obtain a set of jets. The number of jets is njets.
2) Redo the jet reconstruction,with R = 0.6 (or R = 0.7), following recent works of ATLAS and CMS , to obtain another set of jets.
3) Keep the event as a tt candidate if n_{jets,R=1.5} = 2 and n_{R=0.6 }>2 .
4) Go into the 2 jets reconstructed in step 1, find all the subjets for each fat jet, for a fat jet of invariant mass of mj , undo the last step of jet clustering to obtain two jets j1 and j2, with
invariant masses mj1 and mj2 ( mj1 > mj2 ). If mj1 <0.9 mj , keep both j1 and j2, otherwise, keep only j1 to add to
the subjet list and decompose further. Add ji to the jet substructure list if mji < 30 GeV, otherwise decompose ji
iteratively. If the total number of subjets is less than 4, reject the event, because a hadronic top and one semileptonic
top should give 4 subjets in total, and two hadronic tops will result in 6 subjets.
5) See whether there is a W inside either of the 2 fat jets, if not, reject the event. To do this, look into a fat jet and
iterate over all of the 2 subjets configurations. After the jet filtering, if the invariant mass of the 2 subjes falls in the window of 65 GeV to 95 GeV, tag that configuration as a W.
6⊠ See whether either of the two jets has a subjet can be tagged as a b jet. The jet candidates of a W must not be
tagged as a b-jet. Keep other b-tagged events.
7)Any event that survives the above sequence is tagged as a tt event.
Backgrounds:
The main backgrounds are Wbbbar and Z bbbar. Since there will be b jets in both cases, and the Z mass is close to

W mass, these two backgrounds are indistinguishable in their hadronic decay channels. Other backgrounds are the
QCD dijets from light quarks and gluons and QCD multi-jet events. QCD dijets events will be gotten rid of by the "
hollow cone " cut, since the anti-kt jet algorithm is collinear and infrared safe. QCD trijet events will be eliminated
by requiring 4 or more subjets. With fake b-jets, Wjj and Zjj events contribute to the background also.we apply the following cuts in
sequence :
cut 1 : The "hollow cone" sieve. Require njets = 2 and nveto > 2.
cut 2 : Total number of subjets >=4.
cut 3 : A hadronic W can be tagged.
cut 4 : A b jet can be tagged.
After the cut, ttbar is 4.05 pb, Wbbbar is down to 0.18, Zbbbar is down to 0.43, Wjj is down to 0.08, Zjj is down to 0.26.
The resulting ratio of hadronic tops to semileptonic tops is 2.81, which is consistent with the ratio of decay branching
fractions of 3.13. The transverse momentum distribution of tagged top shows that the method is picking top jets instead of light jets,
and also demonstrates that top jets with relatively low pt can be tagged. Former top tagging techniques require the
pT of the top to be harder than 200 GeV.

## Summary

1 We introduce a new top tagging method, using the anti-kt algorithm to define jets, events with nj = 2 fat jets of cone size R = 1.5 are decomposed into R = 0.6 sub-jets and retained if nj (R=0.6) >=4 . One pair of sub-jets reconstructs the W-mass and another jet is tagged as a b-jet, as necessary for hadronic or semileptonic events of ttbar origin.
2 This 'hollow cone' method distinguishes the tt events from the light parton QCD dijet events.

**Primary authors:** Ms HUANG, Peisi (Department of Physics-University of Wisconsin-Madison); Prof. BARGER, Vernon (Department of Physics-University of Wisconsin-Madison)

**Presenter:** Ms HUANG, Peisi (Department of Physics-University of Wisconsin-Madison)

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