Introduction

The main purpose of my work is to study the performance of the combination of Particle flow algorithm (PFlow) and SoftKiller (SK), “PF+SK”. ATLAS experiment currently employs Topological clusters (Topo) for jet reconstruction, but we want to replace it with more effective one, PFlow. PFlow provides us with another method to reconstruct jets[1]. With this algorithm, we combine the energy deposits in calorimeters with the measurement in ID tracker. This strategy enables us to claim these consistent measurements in a detector come from same particles and avoid double counting. SK is a simple and effective way of suppressing pile-up[2]. This way, we divide rapidity-azimuthal plane into square patches and eliminate particles lower than the threshold $p_T^{cut}$, which is derived from each $p_T^{max}$ so that the median of $p_T$ density becomes zero. Practically, this is equal to gradually increasing $p_T^{cut}$ till exactly half of patches becomes empty. Because there is no official calibration on PF+SK so far, we have tried to derive our own calibration that performs well with PF+SK and to compare it with the performance of the official one. Especially as for MET, this is the first study of PF+SK (reference [3] is the prior research in PF+SK for jet performance).

Because our calibration target is always jets, we derive new calibration with dijet samples where all we have is jets by Monte-Carlo simulation (MC), no reconstructed data included in this process. We calculate jet response of the events (non-closure response) and derive a calibration which corrects this response (closure response) and ideally leads this response to unit value. Then by applying the calibration to reconstructed events (in this report, I focus on ttbar events), we can look into its ultimate performance, “performance study”. In this study, in addition to PFlow and SoftKiller, we calculate various combinations of jet reconstruction, Topo, and pile-up suppression, like Voronoi subtraction (Vor) and Constituent subtraction (CS) [4].

Jet response (our calibration)

First, fig.2 and fig.3 are the results of jet performance from both of calibration on dijet and performance study on ttbar. At the level of calibration, the closure response looks pretty good, which is close to unit value. As for ttbar in fig.3, jet response looks, to some extent, close to unit value, but it is a bit overestimated.

Comparison of calibrations (Jet efficiency and fake rate)

Next, I compare our calibration I mentioned above with official calibration. As I described previously, because we don’t have the official calibration on PF+SK, we have to use the jet collections without SK, like AntiKt4EMTopo and AntiKt4EMPFlow in the above figures, for drawing this comparison. In fig.4, I show the comparison of each calibration, official, official without residual calibration and our calibration. This comparison makes us good insight to the quality of our calibration.
Unfortunately, for either of Topo and PFlow, our calibration performs worse than the official calibration.

Despite of the worse performance in jet response, our calibration show good quality of jet efficiency, a fraction of true jet matched to reconstructed jet, as well as the official calibration (see fig.5). But in principle, high jet response increase jet efficiency, so this effect might be just apparent. What is interesting is, as fig.5(b) shows, it affects jet response much if the official calibration is with or without residual calibration. Because it is not included in our calibration, which has only EtaJES in it, it can be good possibility to improve our calibration.

Fig.6 shows fake rate of each calibration, which is defined by a fraction of reconstructed jets not matched to true MET. This value shows, by definition, the rate of contribution from pile-up. This is very interesting to see with fig.5, jet efficiency. As I mentioned, for jet
efficiency, it is the official calibration without residual calibration which has relatively big deviation from others. But when it comes to fake rate, it is our calibration and ours perform awful especially in the forward region. In addition to it, in the central region, we can see a kind of bump around $40<p_T^{reco}$ [GeV]$<60$ for every calibration. Next step must be to understand these strange shapes.

Regarding the bump, there is the probability that we confuse jets with muons. In order to check this, in fig.7, I calculated the distance between them on the rapidity-azimuthal plane.

For some reason, only PFlow, w/o SK, shows so small distance to muons. It suggests that the bump in fig.6(a) is attributable to this confusion of fake jets with muons; however, the reason remains to be solved why this happens to PFlow and PFlow is the only one showing this shape (for Topo(+whatever)), it is less likely to happen because it doesn’t consider track, while muons hardly leave high energy in calorimeters.

Up to this point, I’ve used tttbar event for performance study, in order to do study according to eta region with enough precision, we need the large amount of stats for keep the quality of fits good. Unfortunately, because we didn’t have such tttbar samples, we move on to next stage with dijet samples. But in principle, this can be a fair comparison because without regard to the kind of events, pile-up(contribution to fake rate) normalized by events should be same. Fig.8 and fig.9 shows the result after applying scale factor to jet response in the eta bins, $|\eta| < 2.4$, $2.4 < |\eta| < 3.2$ and $3.2 < |\eta|$. Comparing fig.9 to fig.6, we can see well-improved fake rate in PFlow. Next, fig.8 and fig.9 give us good comparison of PF and PFSK in our calibration.
(a): central region, PFSK is worse than PF in either of jet efficiency and fake rate, which suggests that SoftKiller possibly wrongly eliminates the soft particles from interesting vertex.

(b): forward region, while PFSK perform better than PF in jet efficiency, PFSK is awful in fake rate, which looks as if the number of jets were much larger in PFSK. Because this is impossible in principle, we should be back to jet response. For PFSK, response showed strange, not stable, shape and this makes it difficult to understand this distribution for now.

**MET performance (our calibration)**

Here, we discuss the result of MET performance, MET resolution and MET scale. MET resolution show how far reconstructed MET is from true MET. MET scale shows how well-balanced each component is. Hopefully, we expect PF+SK to perform better than other collection. Fig.10, MET resolution on tbar, suggests that this combination have worse quality, but this is a kind of hasty conclusion. The MET scale on Z->ee in fig.11 shows another crucial defect of our calibration, i.e. PF+SK looks as if there was no contribution from jets. Now we use TST with which we only consider the measurement in ID tracker for soft term. Because charged particle accounts only for 60% of soft term, we miss one third of the term, which leads to underestimation of MET. On the other hand, hard term is dominant beyond the threshold and it is relatively much close to 0. Therefore, for MET Scale of Z->ee, we always expect that it linearly goes down till the cutoff and then gradually goes up and converges on 0. But fig.11 shows PF+SK continuously linearly goes down. Because of this
fault, fig.10 makes no sense. In addition to jet performance itself like I mentioned in above sections, future study should solve this problem in the contribution from jets to MET

**Conclusions**

In this study, we could get a variety of insight to PF+SK. It can be even one fruit that we could see, to some extent, a good jet response of PF+SK as well as other well-known jet collections with our calibration. But there are still many problems that remain to be solved.

First, as I mentioned with fig.5, residual calibration might affect jet performance much. More specifically in this study, we found the big difference made by the calibration in the forward region. Therefore, it can reach interesting result to combine our current calibration with residual calibration.

Second, regarding fig.6 and fig.7, we have to cope with the confusion of fake jets with muons. This is also so strange that this is true only of PF, w/o SK.

Third, we should check the jet performance with eta-dependency factor for ttbar. Because fig.8 and fig.9 are the result for dijet, in fact it might spoil the fairness of comparison. But, as we mention soon in the final conclusion, it is relatively a bit trivial.

Forth, in addition to jet performance, we should get MET performance largely improved. As a first study of MET of PF+SK, this study reveals that our calibration can’t deal with the contribution from jets to MET at present. This is helpful to map out a course of next action.

Finally, what is the most important is to get the better jet response on the phase of the calibration derivation. The usage of scaling-up(or down) factor in the performance study is just a kind of approximation. Ideally, we need to make everything included in the calibration.

**References**


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