

Determining the efficiency of the ALICE TOF detector

William Bergan

August 14, 2014

Abstract

The ALICE TOF detector is vital for particle identification at intermediate momenta. We therefore wish to understand its efficiency, so we computed the fraction of tracks in the TPC which have an associated hit in the TOF. Since there are many reasons for a track to not have a hit in the TOF unrelated to the detector efficiency, we improved cleanliness cuts on the TOF tracks and required that they have a hit on the EMCAL to ensure that they were real particles and had passed through the TOF. In addition, we wanted to correct for the fact that some of the tracks would pass through dead areas of the TOF. Having applied all of our selections and this acceptance correction, we obtained a TOF efficiency of 0.978 ± 0.004 .

I. Introduction

ALICE (A Large Ion Collider Experiment) is one of the four large experiments in the LHC and is designed to study the quark-gluon plasma. This is a state of matter formed under extreme temperatures or particle densities when quarks and gluons are no longer confined inside hadrons but are able to move about freely. Although such a state of matter may be created by lead-lead collisions at LHC energies, it rapidly cools and hadrons reform, so it cannot be directly studied. However, we are able to gain insight into the nature of the quark-gluon plasma by observing the properties of the particles produced as it cools. The ALICE detector is designed to study these particles, so it is composed mainly of a series of subdetectors placed around the interaction point, with special care taken to deal with the high-multiplicity environment. A diagram of the detector is shown as Fig. 1.

Charged particle identification at intermediate momenta (a few GeV/c) relies primarily on the TPC (time projection chamber) and TOF (time of flight) detectors. The TPC tracks the particles as they move through the magnetic field in the detector, and, based on the curvature of their trajectories, we can assign a momentum to them. In addition, it is able to determine the energy of the particles from their rate of energy loss. The TOF measures the time it takes for the particles to travel from the interaction point to the detector, and, with the knowledge of the path length and momentum from the TPC, we may determine their masses.

We wish to determine the efficiency of the TOF detector elements. In order to do this, we count the number of tracks in the TPC with an associated hit in the TOF and divide by the number of tracks in the TPC. However, we wish to ensure that our tracks correspond to real particles

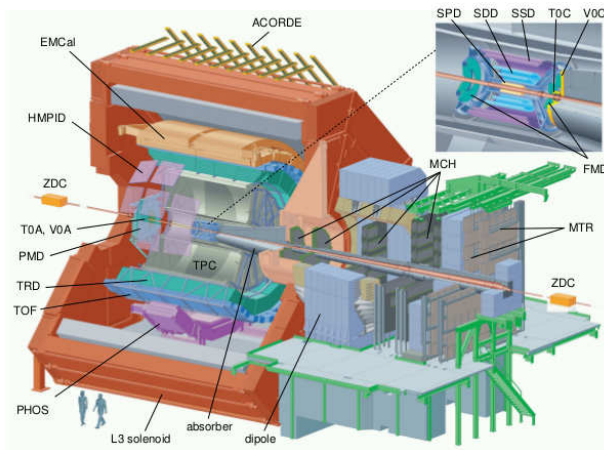


FIG. 1. The ALICE detector. Source: “Performance of the ALICE Experiment at the CERN LHC.”¹

produced in the primary interaction. We tried varying the various cut parameters in order to maximize the resulting efficiency. In addition, some of the particles may interact or be bent away before hitting the TOF. In order to remove these tracks, we selected only tracks which had a hit in the EMCAL (electromagnetic calorimeter). Since that detector is just outside the TOF, any particle which hits it must have passed through the TOF. Finally, some of the readout channels for the TOF have been disabled because either the corresponding detector components were not installed or were not operating properly. To correct for this, we scaled up our efficiency measurements by the appropriate factor.

II. Methods

We started by varying the existing track cut parameters to select clean tracks. There were three numerical* cut parameters: the minimum number of clusters in the TPC which were associated to the track, the maximum χ^2 per cluster, and the maximum distance of closest approach (DCA) to the interaction vertex in the z direction. After varying these parameters, we created histograms of efficiency as a function of transverse momentum and fit them with a constant function between 1 and 3 GeV/c, since tracks at low momenta often curve away and do not hit the TOF, while at high momenta, we had very low statistics.[†] An example of such a fit may be seen as Fig. 2.

We then added in a requirement that our tracks have an associated cluster in the EMCAL. Since this is just outside the TOF, as may be seen in Fig. 1, any track which deposits energy in it must have passed through the TOF as well. We then proceeded with an analysis similar to that done before. We also added in a new track cleanliness cut, the maximum number of TPC clusters per track, since tracks with a large number of TPC clusters appeared to have a lower efficiency than those with a lower number of clusters. We again varied the different cut parameters, this time with all of our new cuts applied and running on the grid with higher statistics than we had been using up to now.

*There were other cut parameters, but most were simple Boolean variables, and we assumed that they were already optimized.

[†]We also attempted fitting them with more accurate custom functions. However, we were unable to find any function which worked for all of our output histograms, so we quote these numbers for consistency.

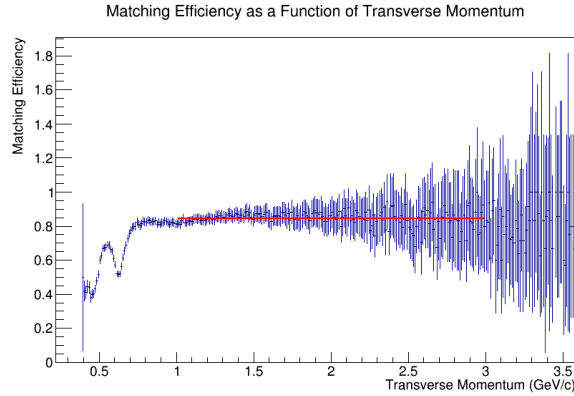


FIG. 2. TOF efficiency as a function of the transverse momentum using our strictest set of cuts. Note the drop at low momenta. The reason for the oscillatory behavior is unknown.

In addition, the ALICE TOF detector has a number of inactive regions. In order to get rid of this contribution to our efficiency, we calculated the fraction of good TOF channels in front of the EMCAL and scaled our efficiency up by the inverse of this fraction.

III. Results

After varying the values for the existing cleanliness cuts, we were unable to obtain a significant increase in efficiency over using the default values.[‡] The best efficiency we could get at this stage was 0.620 ± 0.003 . We also noted that reasonable variations in these cuts change the efficiency at only the sub-percent level.

Using the high-statistics run on the grid, with the EMCAL cut applied, but not yet having applied the cut on maximum number of TPC clusters, we systematically varied the minimum cutoff on the number of track clusters in the TPC. Our results are shown in Fig. 3. Of particular note is that there is a maximum at 60 or 70 clusters.[§] While the drop at low values of the cut is expected, the drop at high values is somewhat surprising and we not sure what may its cause might be. The addition of the EMCAL cut gives us an efficiency of 0.771 ± 0.001 , a significant increase over our previous value of 0.620 ± 0.003 .

When we added in a maximum TPC clusters cut, we varied both it and the minimum and eventually settled on using a minimum value of 80 and a maximum of 100. In addition, we decided to use a maximum χ^2 per cluster cut of 3 after variations of that parameter showed a slight increase in efficiency. (See Fig. 4). This configuration gives us an efficiency of 0.845 ± 0.004 , a significant improvement over our previous efficiency of 0.771 ± 0.001 .

We finally computed the fraction of channels in the TOF which were operating normally to be 89.6%. Restricting ourselves to only the portion of the TOF in front of the EMCAL, we obtain a value of 86.4%. We therefore scaled our final results up by this fraction to obtain a TOF efficiency of 0.978 ± 0.004 . A map of the good and bad channels may be seen as Fig. 5.

[‡]We required tracks to have at least 70 TPC clusters, a χ^2 per cluster of at most 4, and come within 2 cm of the primary interaction vertex in the z direction.

[§]It should be noted that these changes in efficiency are very small, at the sub-percent level.

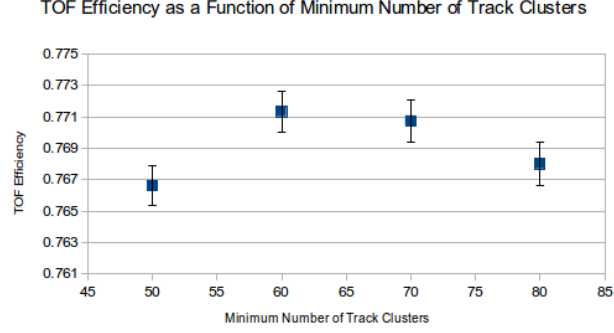


FIG. 3. TOF efficiency as a function of the cut on the minimum number of TPC clusters. Note the maximum in the neighborhood of 60 or 70 and the drops at high and low values.

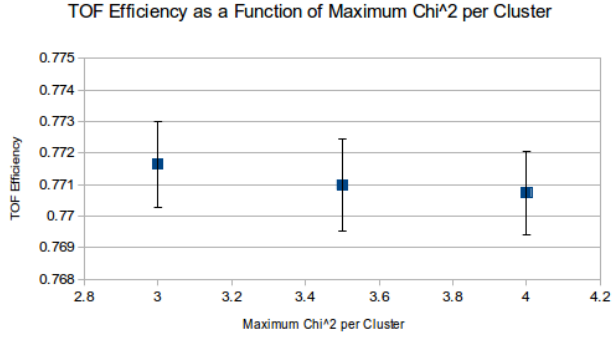


FIG. 4. A plot of the TOF efficiency as a function of the maximum χ^2 per cluster. This plot was made with the EMCAL cut applied, but without any cut on the maximum number of TPC clusters.

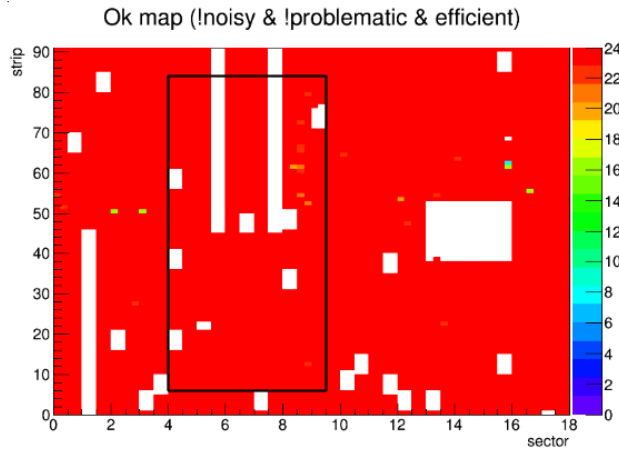


FIG. 5. A map of the good regions of the TOF. The color represents the number of working channels, with 24 being the maximum. The white areas have no working channels. The black box shows the region in front of the EMCAL.

IV. Conclusion

When we constrained our tracks to hit the EMCAL, have between 80 and 100 TPC clusters, have a χ^2 per TPC cluster under 3, and come within 2 cm of the primary interaction vertex in the z direction, we obtained a TOF efficiency of 0.978 ± 0.004 . This is close to the 0.985 efficiency of the individual TOF components as measured in the lab.¹ However, since we do not fully understand the cut on the maximum number of TPCs, this value should be taken with some reservations. If we use looser cuts where we require that the tracks have a hit in the EMCAL, at least 70 TPC clusters, a χ^2 per cluster of at most 4, and a distance of closest approach to the interaction vertex in z of at most 2 cm, we get an efficiency of 0.892 ± 0.002 . In addition, we have shown that the existing track cleanliness cuts do a good job at eliminating bad tracks and are not very sensitive to reasonable variations. Finally, we have shown that requiring that our tracks hit in the EMCAL does a good job at selecting tracks which passed through the TOF itself, so similar techniques may be applied elsewhere in this detector or in others.

V. Acknowledgements

I would like to thank Gilda Scioli and Francesca Bellini for their invaluable help throughout this project. I would like to thank the NSF and the University of Michigan, especially Steve Goldfarb, Junjie Zhu, and Emanuel Gull, for funding and organizing the University of Michigan CERN REU. In addition, I would like to thank the summer student team for running the CERN summer student program.

References

- [1] The ALICE Collaboration. “Performance of the ALICE Experiment at the CERN LHC .” arXiv:1402.4476v2 [nucl-ex].
- [2] The ALICE Collaboration. “The ALICE Experiment at the CERN LHC .” *IOPscience*. Retrieved from IOPscience, <http://iopscience.iop.org/1748-0221/3/08/S08002>, on June 3, 2014.
- [3] Akindinov, A; Alici, A; Agostiinelli, A; et al. “Performance of the ALICE Time-Of-Flight detector at the LHC.” *The European Journal of Physics Plus*. (2013) 128: 44.
- [4] Bellini, Francesca. “Measurement of $K(892)^0$ resonance production in PbPb collisions with the ALICE experiment at the LHC.” PhD Thesis for the University of Bologna. 2013.