Particle Identification between Kaon and Pion

Kazuhiro Nakamura
Main supervisor Sajan Easo
2nd supervisor Andrea Contu

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1 Introduction

Particle identification (PID) is important in LHCb as it enables to distinguish among several particles. Hadronic particle identification is achieved using the information coming from the two Ring Imaging Cherenkov Detectors (RICH) and the tracking system.

In this project, to tune the Monte Carlo (MC) to the real data, comparing between the real data and MC was conducted. And also as the first step for the tuning, three part of cut was applied for the number of tracks and then other quantities were compared between real data and MC.

2 Principle and Methods

To identify a particle, in LHCb, the RICH creates Cherenkov photons. Using the Cherenkov angle and momentum from the LHCb tracking system, the invariant mass can be calculated and the mass identifies the particle types[1].

$$\cos\theta = \frac{1}{n\beta} \tag{1}$$

$$\beta = \frac{v}{\mathrm{c}} = \frac{p}{E} = \frac{p}{\sqrt{p^2+m^2}} \tag{2}$$

(θ is Cherenkov angle and n is Refractive index.)

RICH detector give the information of the Cherenkov angle and the information enables to reconstruct the invariant mass. But usually there are many overlapping Cherenkov rings and also there are other effects to smear the reconstructed angle are different(For example resolution of the detection), so the Cherenkov angle cannot be calculated exactly and only a likelihood of particles is given.

To reproduce the result of the real data, MC is used. But usually there are still some difference between the real data and MC. The purpose of our project is to compare the difference between them and to modify some parameters of MC to tune for the real data.

In this project, the same channel of a decay was used for the PID calibration(Eq.3).

$$\begin{aligned} D^* \rightarrow \quad & D^0 \quad \pi \\ \hookrightarrow \quad & K \ \pi \end{aligned} \tag{3}$$

But the period that we used initially was different, so the comparison was not perfect. The real data is after September 2015 but MC data (Ntuples) is before August 2015. So it is necessary to consider that the comparison is not perfect. (Eventually the correct data period can be accuired.)

The quantities compared are shown below.

- $D^* - D^0$ Mass
- Number of Tracks
- Number of SPD Hits
- Number of Hits in RICH1, RICH2
- Transverse momentum (P_{T}) of Kaons, Pions
- Momentum of Kaons, Pions
- Difference in the log likelihood between Kaons and Pions (DLL K)
- Particle Identification (PID) performance

3 Results and discussions

In this section some results of the comparison between real data and MC will be shown. These histograms are normalised. Note that black histogram means real data and red one means MC in each graph.

The result of $D^* - D^0$ is shown in Fig.1. To get a clean sample of Kaons and Pions, a cut was applied on this quantity(Table 1).

3.1 Histograms of each quantity and PID performance

Histograms of transverse momentum of Kaons and Pions and momentum of them are shown in figure 2. These MC are similar to the real data.

Histograms of number of tracks and number of SPD hits and number of hits in RICH1 and RICH2 are shown in figure 3. In these graphs, there are some differences between MC and real data.

Histograms of DLLK of Kaons and Pions are shown in figure 4a, 4b. And PID performance is shown in figure 4c.

The cut in table 1 are applied to the data input to each histogram (from Figure 2 to Figure 4).

Each MC is similar to real data in transverse momentum and momentum of distributions of Kaons and Pions in figure 2. But there are some differences between MC and real data in number of tracks and number of SPD hits and number of hits in RICH1, RICH2.

Histograms of DLL K of Kaons and Pions and PID performance are shown in figure 4. MC of DLL K are similar to real data, but there are still some differences between MC and real data. And the behaviour of PID performance of MC is different from real data.

3.2 The applied cut data for number of tracks

Three part of cut was applied for number of tracks. These cut are (1)from 0 to 99, (2)from 100 to 199, (3)from 200 to 299. Using these cut, number of SPD hits and number of hits in RICH1, RICH2 was compared. And MC in the second cut (from 100 to 199) is the most similar to real data. The comparison of number of SPD hits and number of hits in RICH1, RICH2 are shown in figure 5, and also the comparison of DLL K of Kaons and Pions and PID performance are shown in figure 6. MC of number of SPD hits and number of RICH1, RICH2 hits (figure 5) became much similar to real

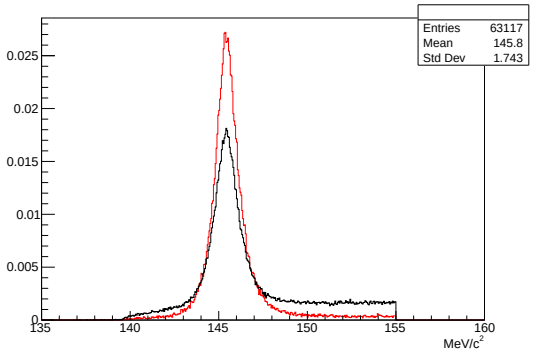
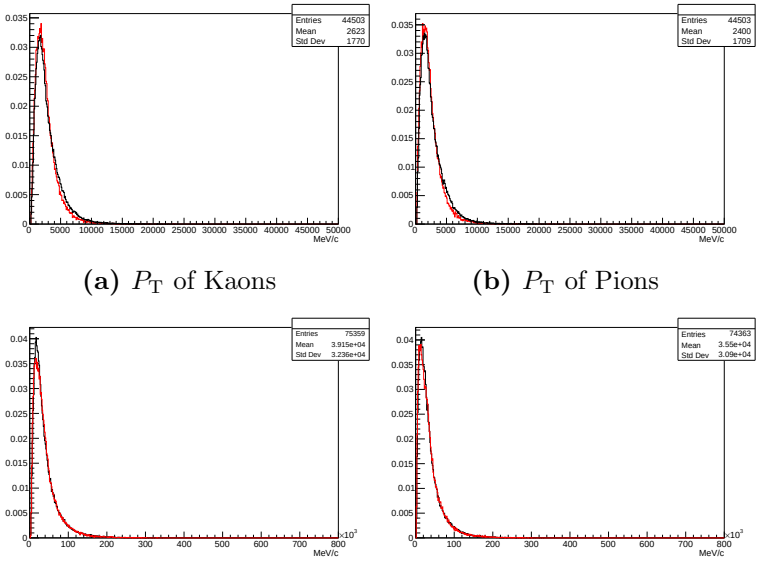


Figure 1: The difference between D^* and D^0 mass

Table 1: Cuts applied to the events

Particle	Applied cut
D^*	$1990 < \text{Mass} < 2030$
	$1600 < P_{\text{T}} < 30000$
	$1600 < P < 400000$
D^0	$1850 < P < 400000$
$D^* - D^0$	$144 < \text{Mass difference} < 147$
K	$160 < P_{\text{T}},\ 1600 < P$
	$-100 < DLL\ K < 100$
π	$160 < P_{\text{T}},\ 1600 < P$
	$-100 < DLL\ K < 100$



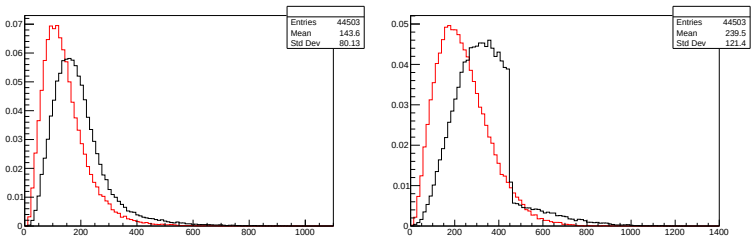
(a) P_{T} of Kaons **(b)** P_{T} of Pions

(c) P of Kaons **(d)** P of Pions

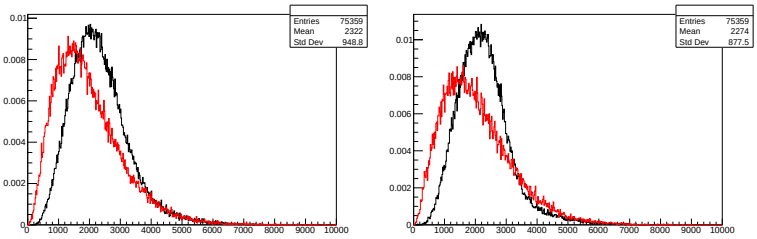
Figure 2: Transverse momentum and momentum of Kaons and Pions

data than non-cut histograms (figure 3). And DLL K of Kaons and Pions also became closer to real data than non-cut one (figure 6a, 6b). But there are still some differences in the PID performance between MC and real data.

One of the reason why there are still some differences came from the difference of the period between MC data (Ntuples) and real data. So before to tune MC for real data, it is necessary to use them in same period. Eventually this can be used to tune MC.

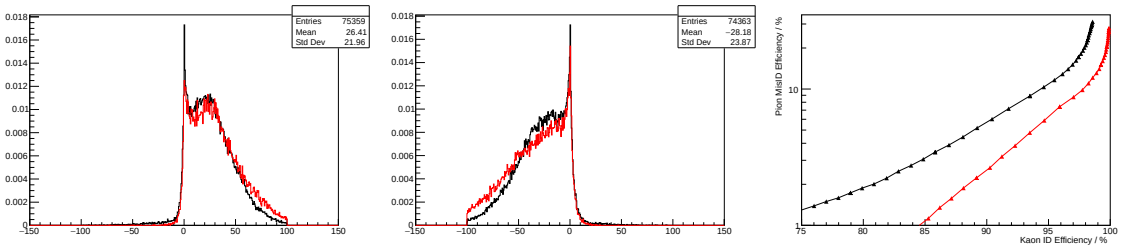


(a) nTracks **(b)** nSPD Hits



(c) nRICH1 Hits **(d)** nRICH2 Hits

Figure 3: Number of tracks, number of SPD hits, and number of hits in RICH1, RICH2



(a) DLL K of Kaons **(b)** DLL K of Pions **(c)** PID performance

Figure 4: DLL K of Kaons, DLL K of Pions and PID performance

4 Conclusions

Some quantities of data were plotted and compared between MC and real data. And some differences were seen between MC and real one in some quantities.

The number of tracks divided into three bins and then MC (number of SPD hits, number of hits in RICH1, RICH2) became similar to real data. But there are still some differences in DLL K of Kaons and Pions, and also in PID performance between MC and real data. The first reason of the difference is to be considered of the difference of the period between MC (Ntuples) and real data. So at first, the same period of datas should be used for the comparison. And after that, to tune MC can be conducted.

5 Acknowledgements

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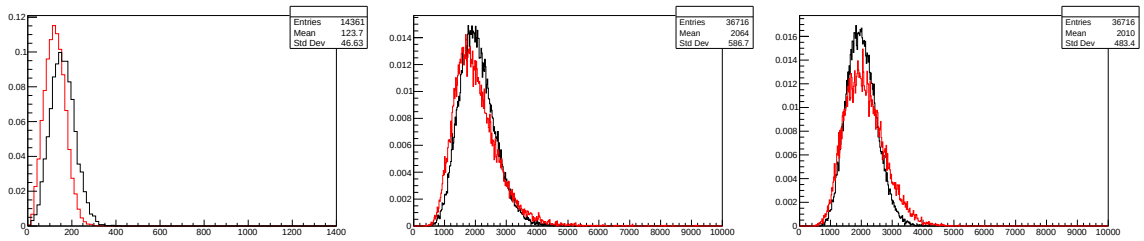
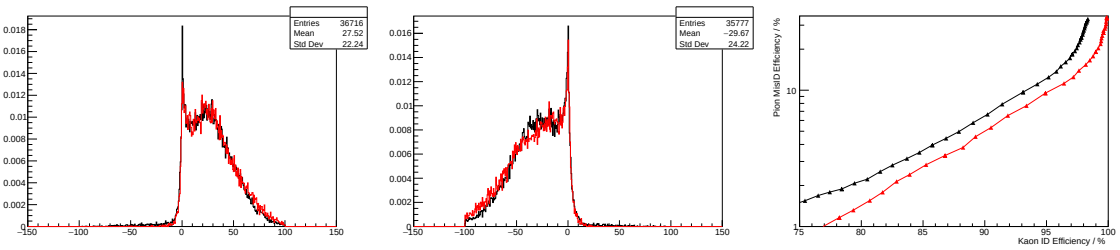


(a) nSPD Hits **(b)** nRICH1 Hits **(c)** nRICH2 Hits

Figure 5: number of SPD hits, number of hits in RICH1, nRICH2 after applying cut in the number of tracks



(a) DLL K of Kaons **(b)** DLL K of Pions **(c)** PID performance

Figure 6: DLL K of Kaons, DLL K of Pions, PID performance after applying cut in the number of tracks

lot.

And I'd also like to thank summer students. Thanks to them, I could have nice experience in CERN not only in project but also every activity. I really appreciate them as well.

References

[1] Warawick Week, Particle Identification in Graduate Student Lecture, (2016)