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Studying $D^0 \rightarrow K^- \pi^+ \eta^0$ Charm Decay

1.1 Introduction

The Belle detector at the KEKB collider observes decays and detects the particles produced. It is located in Tsubaka, Japan and it focuses on heavy flavor quarks. We will be using existing data from this server for the background. The work done was built on Yasiel Cabrera's work in 2014. He simulated $D^0 \rightarrow K^- \pi^+ \eta^0$ and reconstructed 826 signal decays. He then measured the efficiency, which he found to be 4.4% for the signal area. $D^0 \rightarrow K^- \pi^+ \eta^0$ is a CP- decay mode and could be used to study charm mixing and CP violation in a novel way. This mode has not yet been observed and establishing it was the first goal of the project. The distribution of D^0 peaking at its nominal mass in signal MC is shown and fitted in Figure 9.

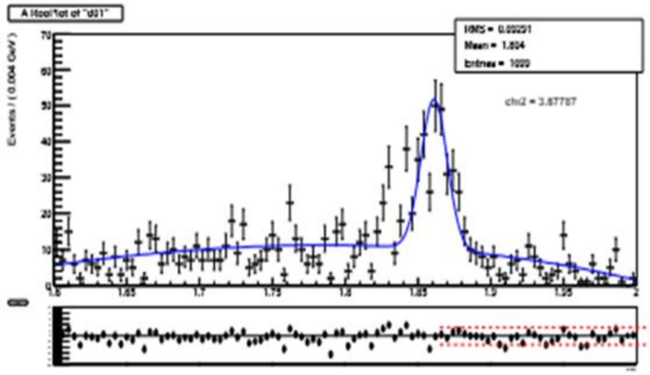


Figure 9: A fitted results from the distribution of D^0 peaking at the correct nominal mass in signal MC.

When Belle data was ran, Figure 10 was the result. It was overwhelmed by a lot background.

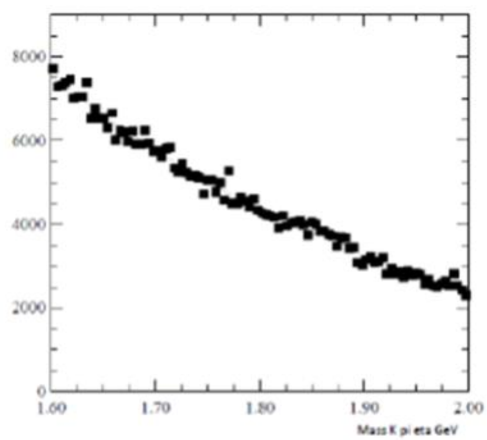


Figure 10: The invariant mass of D^0 with Belle I data, and fitted with a 2nd degree polynomial and gaussian function

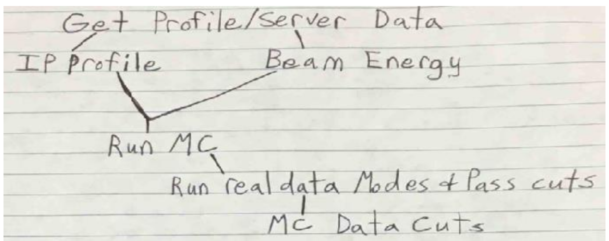
1.2 Original Goals

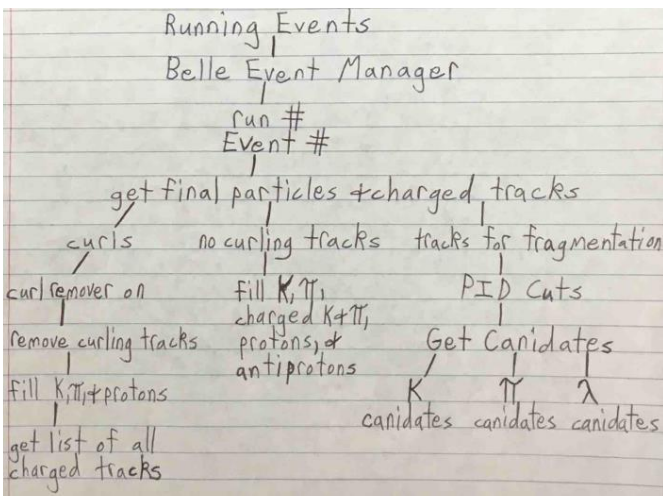
The first step will be to recreate the MC simulation of signal on the previous slide

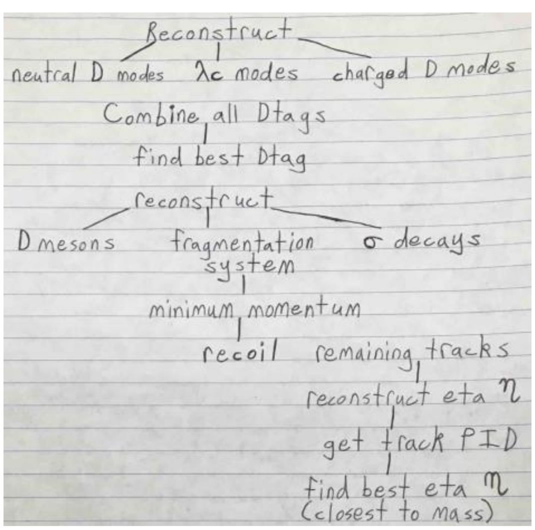
The original goal was to make selections for the Belle data that eliminates background while retaining maximal signal. After each selection, a new efficiency should have been calculated. One possible strategy will be to study the helicity angle which should be flat for $D^0 \rightarrow K^- \pi^+ \eta^0$ and sharply peaked for background. Although, other possible strategies were considered.

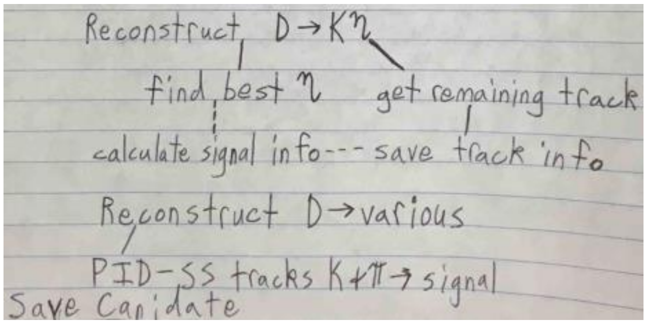
1.3 Preparation

Preparation for this project included reading The Physics of B Factories and various ROOT tutorials. Also, the existing recoilana code had to be deciphered before attempting to create signal with it.





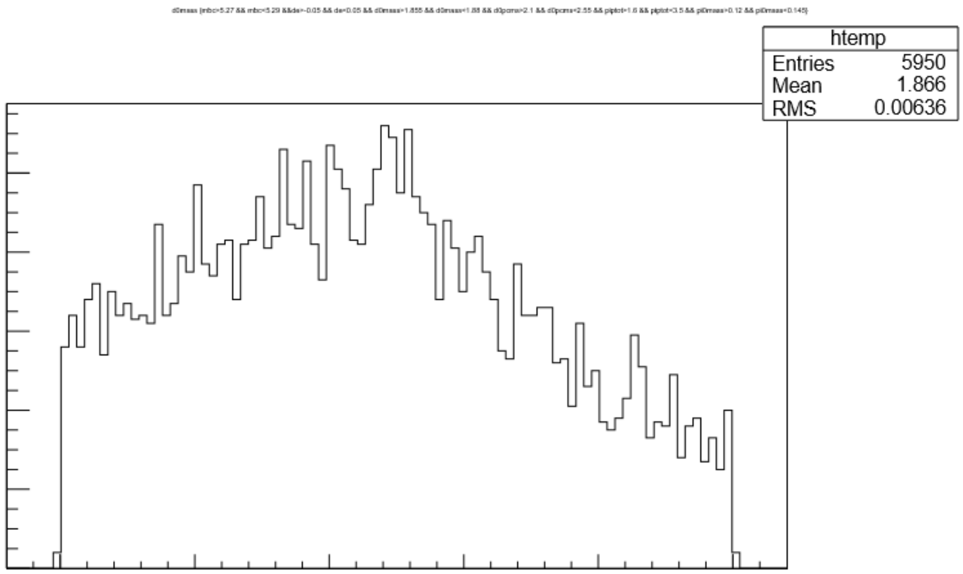




1.3 Event Generation and Variable Cuts

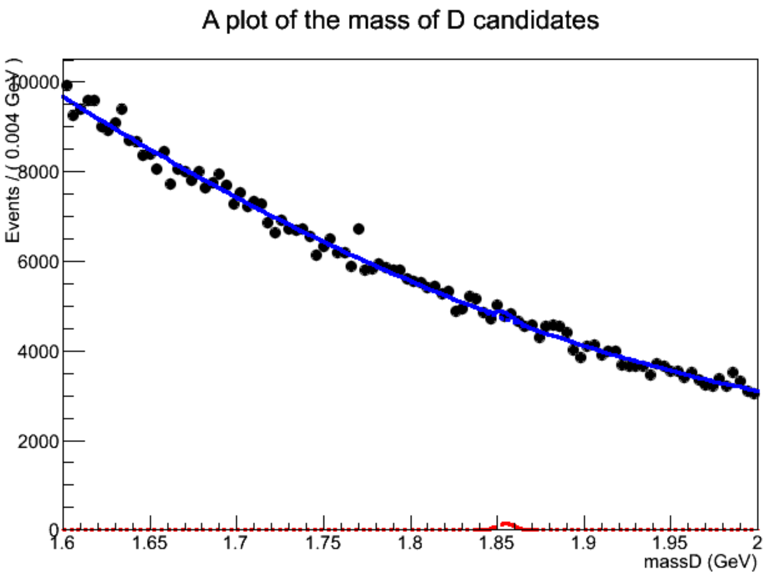
After understanding the code, the next step was to generate events. Originally, new signal was going to be generated. However, due to difficulties within the code and time restraints, both Yasiel's background and signal had to be used. The problem lay within the decay file being used for generation which had been updated since 2014 and therefore needed many changes that were impractical in the time frame. Once the decision was made on which files that were going to be used, cuts could start to be applied to strategic variables. Histogram (d) was the first attempt to cut the tails (background) from the mass of the D^0 meson variable of the root tree h2421.

d.



The most successful cuts were applied to the variables: pcmsds, kpid, and pipid. The variable pcmsds describes the momentum of the D meson in the center of mass in the system. The variable kpid is identification of kaons. The variable pipid is the identification of pions. The range on which the variable mass of D^0 was displayed was narrowed. The mass of the D^0 candidates which is found by building backwards from the kaons, pions, and eta mesons. In Figure (f) which plots the mass of D0 candidates, there is a small bump indicating signal at approximately 1.855 GeV.

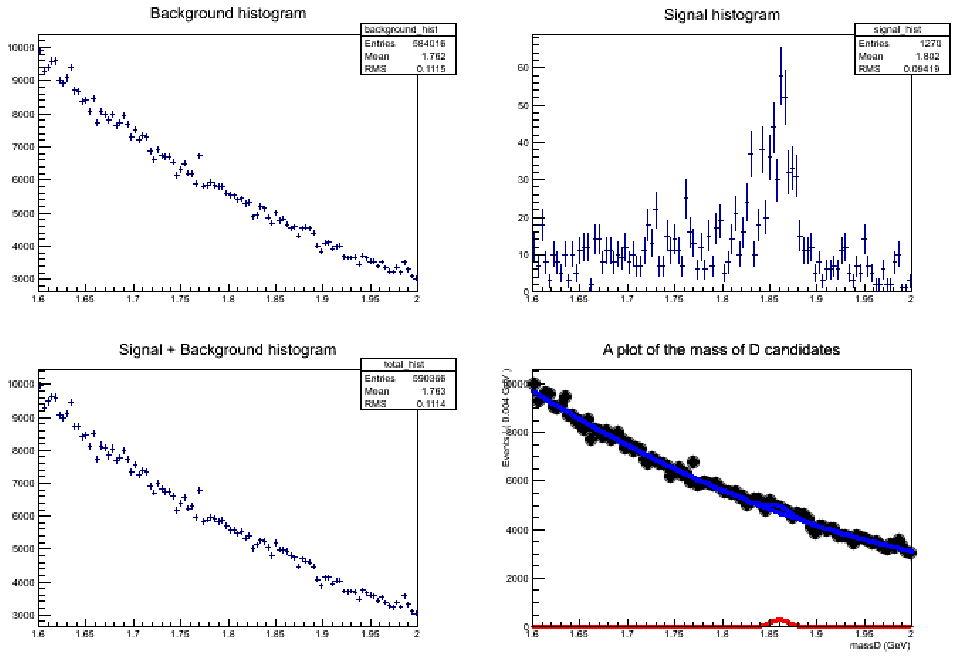
Figure (f)



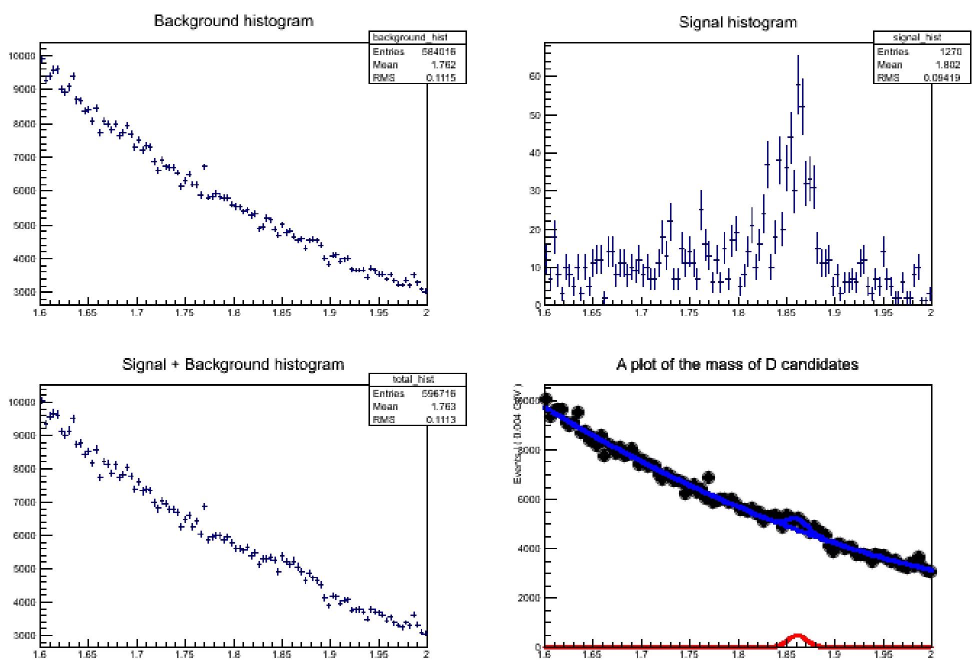
1.4 Fitting

After spending time practicing cuts, next was to revise and add cuts to the fit for the background, signal, and background+signal. The main change to the fit was to change the Argus function fitting the background to a polynomial function. Histogram (a) shows the data with 5 signal events for each original signal event which will be referred to as the weight. Histogram (b) shows each event being multiplied by 10 and histogram (c) shows each event being multiplied by 20. Histogram (d) shows the data with the signal being weighted 50 to more clearly demonstrate the signal.

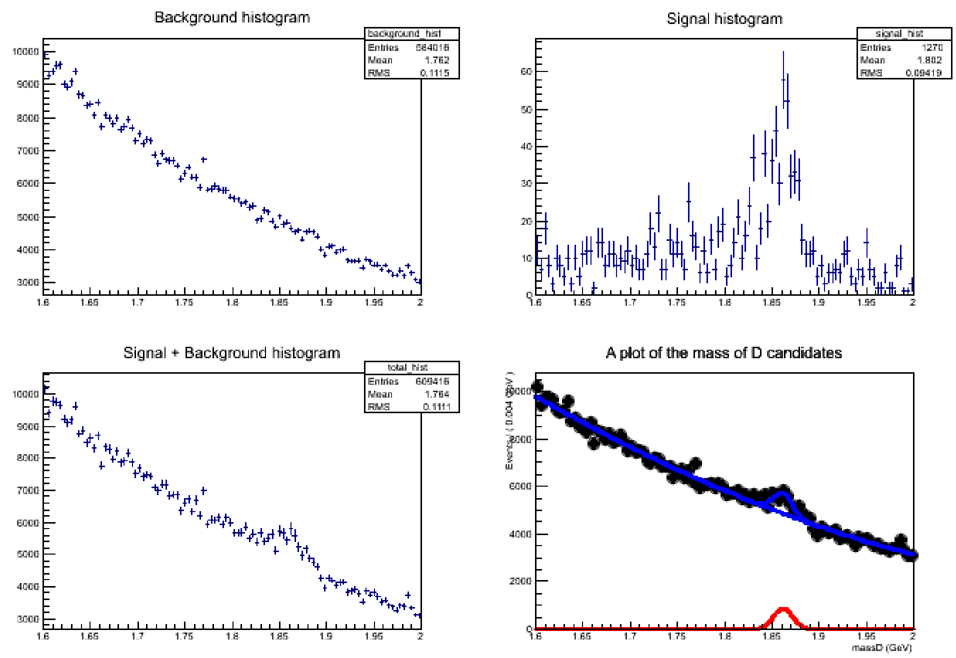
a.


Background histogram
background_hist
Entries 684016
Mean 1.762
RMS 0.1115
Signal histogram
signal_hist
Entries 1270
Mean 1.802
RMS 0.09419
Signal + Background histogram
total_hist
Entries 690366
Mean 1.763
RMS 0.1114
A plot of the mass of D candidates
Events / (0.004 GeV)
massD (GeV)

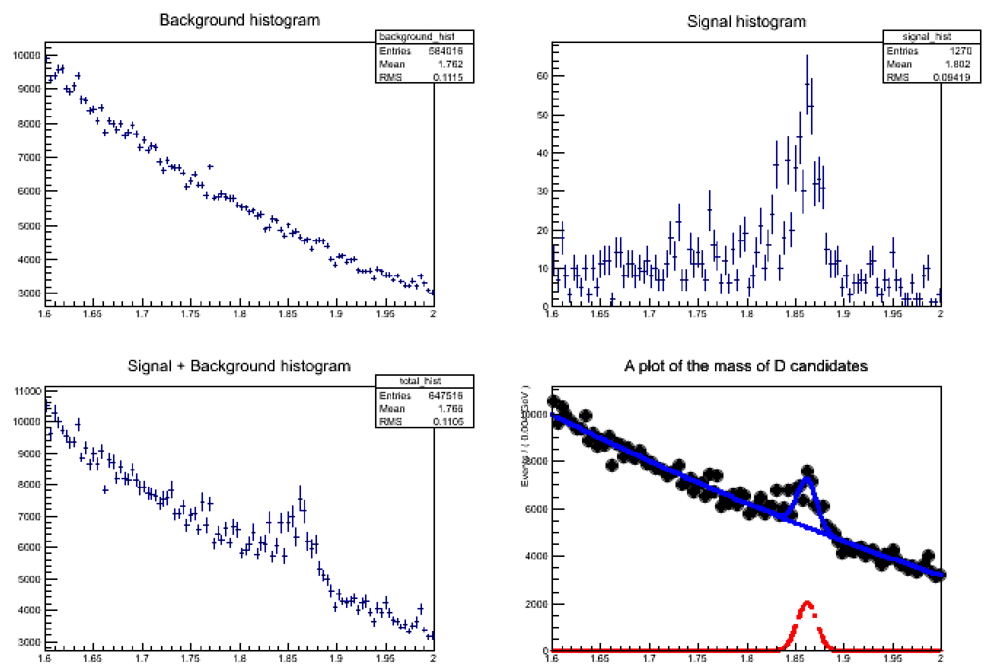
b.


Background histogram
background_hist
Entries 684016
Mean 1.762
RMS 0.1115
Signal histogram
signal_hist
Entries 1270
Mean 1.802
RMS 0.09419
Signal + Background histogram
total_hist
Entries 696716
Mean 1.763
RMS 0.1113
A plot of the mass of D candidates
Events / (0.004 GeV)
massD (GeV)

c.



d.



The table (e) contains the Ratio Peak Fraction which is between the Input Peak Fraction and the Fitted Signal Peak Fraction, and tests whether the fit is giving the right results. To do this, the signal fraction that was put into the fit was compared to the signal fraction that came out of the fit. If the ratio between the two included 1, then it is robust. If the Ratio Peak is not 1, then the error input parameters are not reproducible and the fit is losing sensitivity to the input parameters.

e.

Weight	Input Fraction	Input Peak Fraction	Fitted Signal Peak Fraction	Ratio	Ratio Peak
50	0.098±0.0028	0.020±0.0015	0.020±0.00042	0.20±0.0071	1.01±0.080
20	0.042±0.0012	0.0085±0.00065	0.0089±0.00039	0.21±0.011	0.96±0.084
10	0.021±0.00059	0.0042±0.00033	0.0050±0.00038	0.24±0.019	0.85±0.092
5	0.011±0.00030	0.0022±0.00017	0.0030±0.00038	0.28±0.036	0.72±0.12

1.5 Conclusion

Over the course of the project, various fits as well as the sensitivities in response to varying signal enhancements. It has been concluded that without any form of signal enhancement, there is no sensitivity to the fit. A next step in the analysis would be to add more event shape variables. In roughly two years, the Belle 2 project will start to collect larger data sample which will make harder signal cuts possible.