Asymmetries in the D Meson Decays

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We made an extensive surveys of decays of charmed mesons into a final state with one isospin zero particle. Using the CLEO II and CLEO 2.5 data, we measured the CP asymmetry for D meson decay for final states $D \to k^0\omega$ and $D \to k^-\eta\pi^+$.

I. INTRODUCTION

In the hadronic decay of a charmed D meson into an isospin zero particle(I) and another particle(X), the amount of decay may be different depending on if the decaying D is a matter or an anti-matter. Since this asymmetry has never been studied before, even if we find some asymmetry we will still have to examine if it is actually due to the asymmetry in the decay or due to the error which arises because the detector is made of just matter and not of antimatter. We use CLEO II data to search for any asymmetry in the charmed D decay.

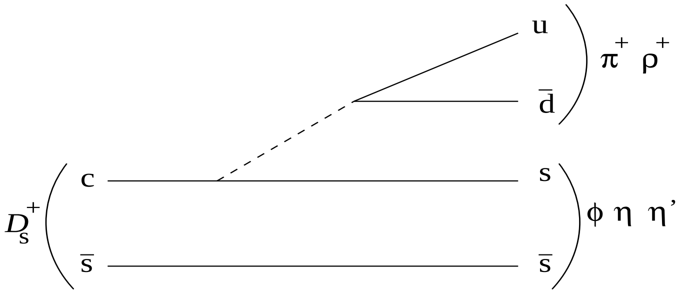

FIG. 1: [1] Feynman diagram for hadronic D_s^+ decay

II. EVENT SELECTION

In the detector after the e^- and e^+ collides and turns into other different particles, the new particles are tracked by keeping track of the signal they leave when they go through the detector. The code written by Dr G. Bonvicini goes through the CLEO II data and tries to find the D→ IX decays we are interested in. It selects particles that could be the daughter of a certain particle we are looking for. The code plots a histogram of the mass of the decaying particle or any of the daughter particle versus the abundance. We expect the histogram to have a peak(signal) and very little background. We expect the mass value at the peak to be consistent with the already known values of the mass of those particles. But a lot of times these selected particles arent the daughters of the mother particle but just some other ramdom particle which happen to be the same particle as the daughter would have been. To select samples as clean as possible, we try to maximize the figure of merit of a histogram.

$$Figure\ of\ Merit\ =\ \frac{S}{\sqrt{B}}$$

To cut on background and improve the signal, and to thus improve the figure of merit, we use different techniques like:

Momentum Cut
This cut is based on the fact that energy is conserved. For the decays we are concerned with, the available momentum is usually 2/3 of the maximum momentum they can have. As these particles are pretty hard, we specify the minimum momentum for these particles. This cuts out on combinatorics background and also improve the mass resolution.

$$E = \sqrt{p^2 + M^2}$$

Vertexing
The trails left by different particles are reconstructed to see the decay. Sometimes when the computer program connects the dots for the tracks, it doesnt quiet do it right, so we have to force the tracks to go through the vertex improving the momentum resolution.

Start Production
Instead of starting the decay from the D^0's and D^+'s, we start production from D^*'s. Since daughter particles are used to reconstruct the decay and to find the mother particles, we have to be able to differentiate in between the daughter particles to be able to find different mother particles.

$$D^0 \rightarrow k^0\omega$$
$$\bar{D}^0 \rightarrow \bar{k}^0\omega$$

Here, D^0, is reconstructed by matching the paths of k^0 and ω. Similarly, $\bar{D}^0$, is reconstructed by matching the paths of $\bar{k}^0$ and ω. But, k^0 and $\bar{k}^0$ are the same and we cannot tell the difference between the two, therefore, we will not be able to tell the difference between D^0 and $\bar{D}^0$ because they have the same daughter particles. Thus we have to start from D^{*+} or D^{*-} to make the D's. In this case,

$$D^{*+} \rightarrow D^0\pi^+$$
$$D^{*-} \rightarrow \bar{D}^0\pi^-$$

Thus by keeping track of the π produced and looking at its charge, we can tell if it is D^0 or a $\bar{D}^0$.

III. MEASUREMENT OF ASYMMETRY

In a D → IX decays, the amount of decay may be different depending on if the decaying D is a matter or an anti-matter. We can measure the asymmetry by using:

$$A = \frac{N^- - N^+}{N^- + N^+}$$

where
N^- is the number of anti D^0 decay.
N^+ is the number of D^0 decay .
Assymmetry is a number between +1 and -1 and we expect it to be a negative number.

Background Substraction Method
This method is used to find the values of N^+ and N^- which will be used to calculate the assymmetry. We check if the event has a matter daughter or an anti-matter daughter. (D is the first daughter of D^*). If it is a matter and if the mass of first daughter is in between a and b, count of v1 increases by 1, if in between c and d, count of v2 increases by 1 and if in between e and f count of v3 increases by 1. For matters, $N^+ = v2 - \frac{v1+v3}{2}$. Similarly we use v4, v5 and v6 to find the N^-

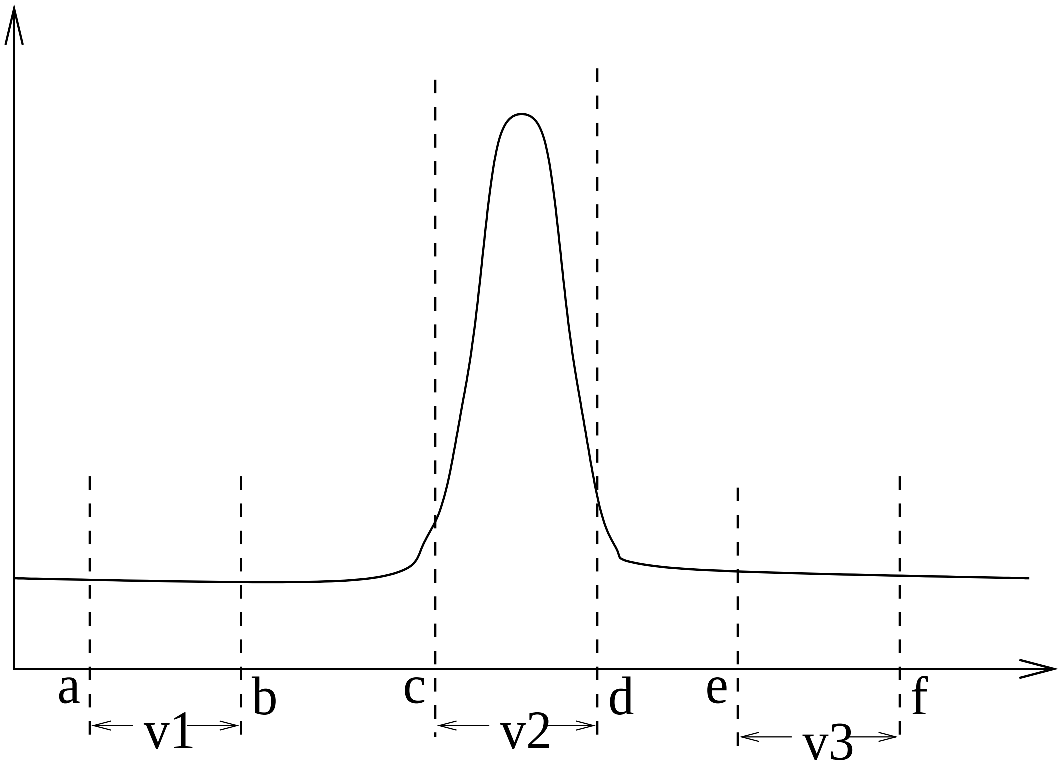

FIG. 2: Background substraction method

Calculating the errors in the asymmetries.

$$e(A)^2 \;=\; \left(\frac{\partial A}{\partial v1}\right)^2 e(v1)^2 + \left(\frac{\partial A}{\partial v2}\right)^2 e(v2)^2 + \left(\frac{\partial A}{\partial v3}\right)^2 e(v3)^2$$

$$+\left(\frac{\partial A}{\partial v4}\right)^2 e(v4)^2+\left(\frac{\partial A}{\partial v5}\right)^2 e(v5)^2+\left(\frac{\partial A}{\partial v6}\right)^2 e(v6)^2$$

IV. RESULTS

We measured the asymmetries for different final states we were interested in:

$$\mathbf{Control\ Mode:\ D^0 \rightarrow k^-}\pi^+$$

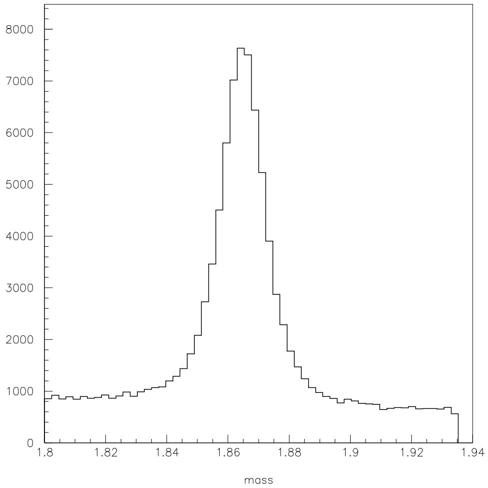

FIG. 3: $\bar{D}^0 \rightarrow k^+\pi^-$ decay

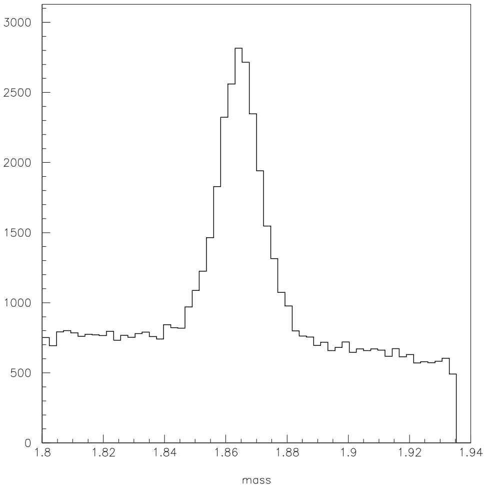

FIG. 4: $\bar{D}^0$ decay

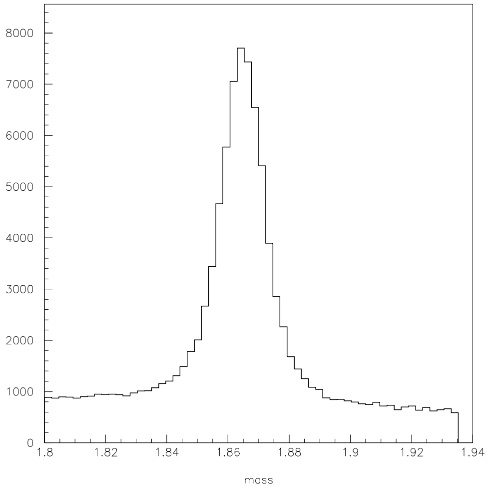

FIG. 5: $D^0 \rightarrow k^-\pi^+$ decay

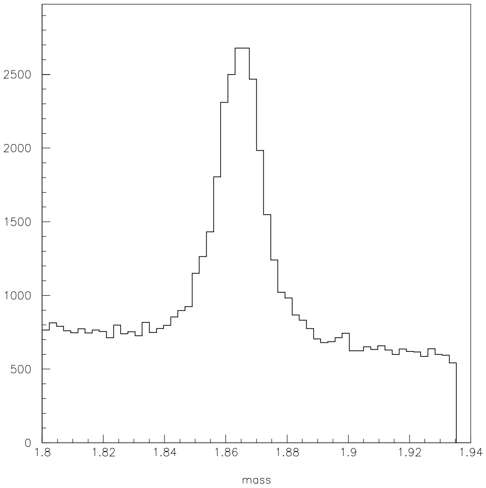

FIG. 6: D^0 decay

Asymmetry = -8.4558828 $\times 10^{-3}$

Error = 0.0150

Control Mode $\mathbf{D^0 \to k^- \pi^+ \pi^0}$

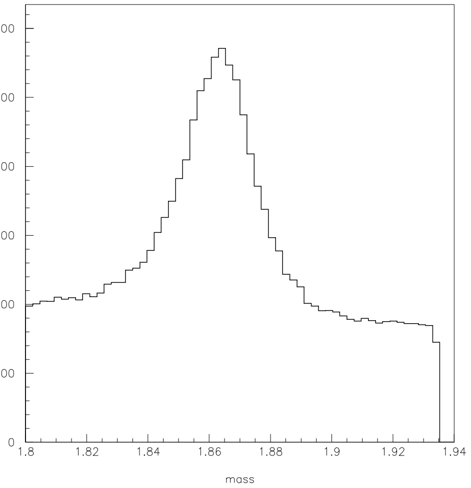

FIG. 7: $\bar{D^0} \to k^+ \pi^- \pi$ decay

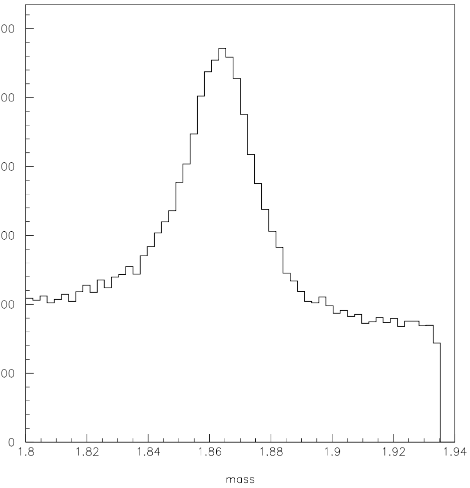

FIG. 8: $D^0 \to k^- \pi^+ \pi$ decay

Asymmetry = 2.3634622 $\times 10^{-2}$
Error = 0.0142

Mode $\mathbf{D^0 \to k^- \eta \pi^+}$

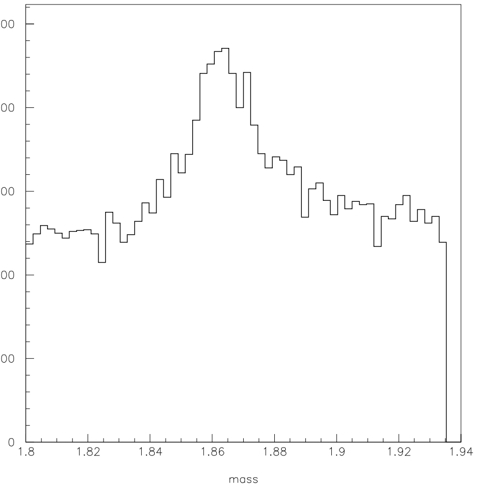

FIG. 9: $\bar{D^0} \to k^+ \eta \pi^-$ decay

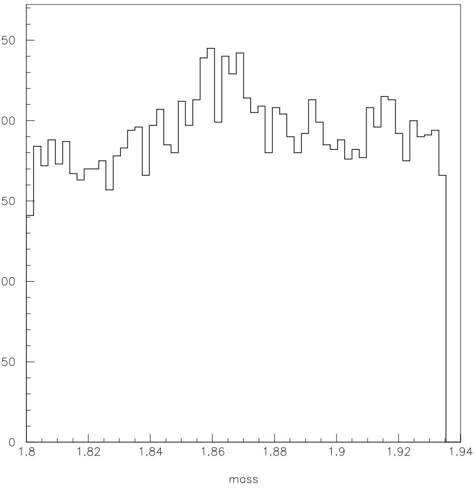

FIG. 10: $\bar{D^0}$ decay

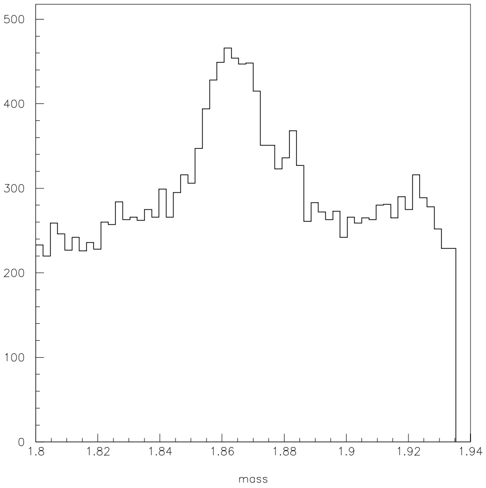

FIG. 11: $D^0 \to k^- \eta \pi^+$ decay

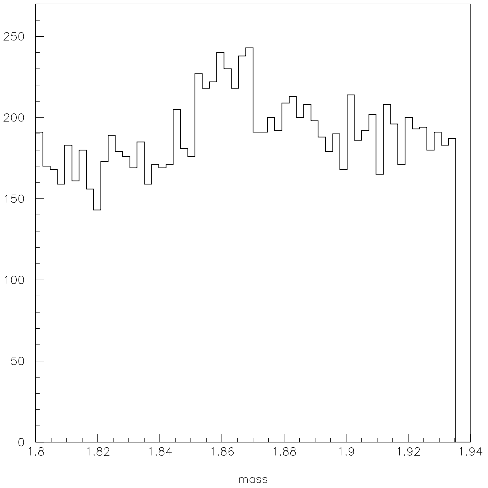

FIG. 12: D^0 decay

Asymmetry = -6.3435067 $\times 10^{-3}$
Error = 0.0127

Mode $\mathbf{D^0 \to k^0}\omega$

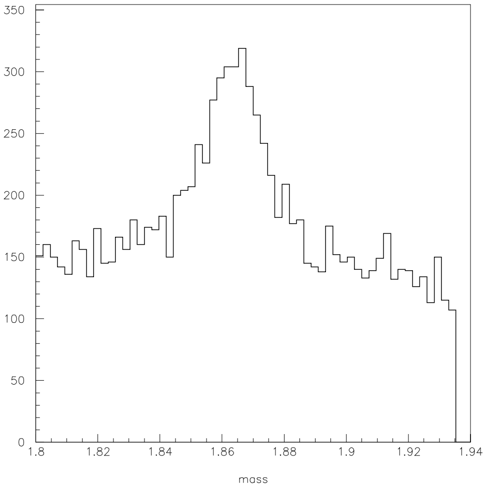

FIG. 13: $\bar{D}^0 \to k^0 \omega$ decay

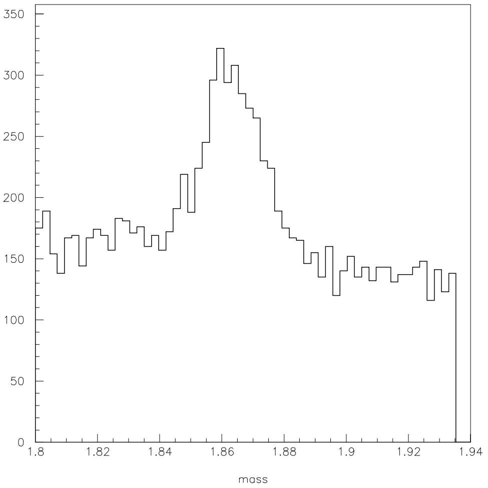

FIG. 14: $D^0 \to k^0 \omega$ decay

Asymmetry =1.5873017 $\times 10^{-2}$
Error = 0.0174

V. CONCLUSIONS

We use control samples on our code to check if the code is working right since the control samples are abundantly available and have been known to have zero CP assymmety. So, if we see any asymmetry in the control samples (we will use this for error correction), we will find the error which arises due to the fact that the detector is made of just matter and not of antimatter.

Fig. 3. through Fig. 8. are the figures of the asymmetries in the control samples and we can see that we get very small values for asymmetry for them. We also get very small values of asymmetries for our sample modes. Since the control sample and our sample have comparable values and since control samples are known to have zero asymmetry, we can say that our samples also do not show any asymmetry.

VI. ACKNOWLEDGMENTS

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[1] CLEO Collaboration, Clns 97/1515, Cleo 97-22
[2] T. Bergfeld and M. Selen,CBX 95-59