Recent Charm from CLEO

Yongsheng Gao

Physics Department, Southern Methodist University, Dallas, TX 75275, USA

Received: October 15, 2003/ Revised version: October 15, 2003

Abstract. We present some recent results in rare charm decays from CLEO Collaboration. The data were collected by the CLEO II and III detectors at the Cornell Electron Storage Ring (CESR). A brief future outlook for the CESR-c/CLEO-c program is also presented.

PACS. 1 13.20.Fc

1 Introduction

Charm sector is a good hunting ground for possible new physics beyond the Standard Model (SM). Because the SM processes are highly suppressed, the opportunity for evidence of new physics to emerge becomes enhanced in charm relative to the other flavors \[1\].

2 Cabibbo-Suppressed \(D^+\) Decays

\(D^+ \rightarrow \pi^+\pi^0\) and \(K^+K^0\) are single Cabibbo-Suppressed decays and \(D^+ \rightarrow K^+\pi^0\) is a doubly Cabibbo-Suppressed decay. One of the main interest in charm physics has been the \(D^0\rightarrow \bar{D}^0\) mixing. To unravel any non SM contributions to \(D^0\rightarrow \bar{D}^0\) mixing, we need to understand the SU(3) symmetry breaking effects. These Cabibbo-Suppressed decays will provide useful estimation of the SU(3) violating effects in the \(D\) system.

The details of the analysis can be found in \[4\]. We also measured the ratio \(R1\) which is expected to be 1 in the limit of SU(3) symmetry. Our measurement of 1.84±0.38 is higher than the theoretical prediciton that the SU(3) symmetry breaking effects are at about 30% level.

It is believed that in the \(D\) system the interference between external and internal decay amplitudes is destructive. Our measurement of \(R2\) of 2.03±0.32 indicates this is indeed the case.

We perform maximum likelihood fit to the selected data sample and extract the signal from unbinned maximum likelihood fits. The signal yields are summarized in Table 1. They translate into the following ratios of branching fractions: \(Br(\frac{D^+\rightarrow K^+\pi^0}{D^+\rightarrow K^-\pi^+\pi^-})\) = 0.0144 ± 0.0019 ± 0.0001, \(Br(\frac{D^+\rightarrow K^+\bar{K}^0}{D^+\rightarrow K^-\pi^+\pi^-})\) = 0.1892 ± 0.0155 ± 0.0073, \(Br(\frac{D^+\rightarrow K^+\bar{K}^0}{D^+\rightarrow K^-\pi^+\pi^-})\) = 0.0029 ± 0.0018 ± 0.0009.

Using PDG \[2\] values of \(Br(\frac{D^+\rightarrow K^+\pi^0}{D^+\rightarrow K^-\pi^+\pi^-})\) = (9.1 ± 0.6)\% and \(Br(\frac{D^+\rightarrow K^+\bar{K}^0}{D^+\rightarrow K^-\pi^+\pi^-})\) = (2.77 ± 0.18)\%, we obtain the following branching fraction measurements: \(Br(D^+ \rightarrow \pi^+\pi^0)\) = (1.31 ± 0.17 ± 0.09 ± 0.09) \times 10^{-3}, \(Br(D^+ \rightarrow K^+\bar{K}^0)\) = (5.24 ± 0.43 ± 0.20 ± 0.34) \times 10^{-3}, \(Br(D^+ \rightarrow K^+\bar{K}^0)\) = (2.64 ± 1.64 ± 0.82 ± 0.17) \times 10^{-4} and \(Br(D^+ \rightarrow K^+\bar{K}^0) < 4.2 \times 10^{-4}\) at 90% C.L. The first error is statistical and the second error is systematic. The third error in the measurements is due to the uncertainty in the normalization branching fractions. For \(\pi^+\pi^0\) and \(K^+K_s\) decays, these numbers are the best single measurements. For \(K^+\pi^0\). These numbers give the first limit on this decay mode.

We performed Dalitz analysis of \(D^0\rightarrow \pi^+\pi^-\pi^0\)

Three-body decays provide excellent opportunities to study the interference among the intermediate state resonances, allowing the measurements of both the amplitudes and phases of the intermediate states. For example, in the Dalitz analysis of \(D^+ \rightarrow \pi^+\pi^-\pi^+\), E791 reported significant evidence for a borad neutral scalar resonance, the \(\sigma(500)\) \[5\].

We performed Dalitz analysis of \(D^0\rightarrow \pi^+\pi^-\pi^0\) at CLEO. About 80% of the events entering the Dalitz plot in Figure 1 are signal events. We then extract the amplitude

Table 1. Yields from the maximum likelihood fit with statistical errors and reconstruction efficiencies.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Yield</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\pi^+\pi^0)</td>
<td>171.3±22.1</td>
<td>(6.20±0.11)%</td>
</tr>
<tr>
<td>(K^+K_s)</td>
<td>277.7±20.8</td>
<td>(4.94±0.23)%</td>
</tr>
<tr>
<td>(K^+\pi^0)</td>
<td>34.3±20.9</td>
<td>(6.08±0.22)%</td>
</tr>
<tr>
<td>(K^-\pi^+\pi^+)</td>
<td>12898.0±156.6</td>
<td>(6.74±0.12)%</td>
</tr>
<tr>
<td>(\pi^+K_s)</td>
<td>1434.7±48.0</td>
<td>(4.83±0.23)%</td>
</tr>
</tbody>
</table>
Table 2. Dalitz analysis fit results.

<table>
<thead>
<tr>
<th>Resonance</th>
<th>Amplitude (Γ)</th>
<th>Phase (°)</th>
<th>Fraction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho^+$</td>
<td>1.0 (fixed)</td>
<td>0.0 (fixed)</td>
<td>76.5±1.8±4.8</td>
</tr>
<tr>
<td>$\rho^0$</td>
<td>0.56±0.02±0.07</td>
<td>10±3±3</td>
<td>23.9±1.8±4.6</td>
</tr>
<tr>
<td>$\rho^-$</td>
<td>0.65±0.03±0.04</td>
<td>-4±3±4</td>
<td>32.3±2.1±2.2</td>
</tr>
<tr>
<td>non res.</td>
<td>1.03±0.17±0.31</td>
<td>77±8±11</td>
<td>2.7±0.9±1.7</td>
</tr>
</tbody>
</table>

Fig. 2. The Q distribution for the decay $D^{+}\rightarrow D^0(K_S^0\pi^0)^+\pi^-$. Standard Model (SM) predicts the rate for the $D^0 \rightarrow \gamma\gamma$ decay of $\sim 10^{-8}$ or less. Non SM extension, i.e. gluino exchange in SUSY, might enhance this rate by two orders of magnitude. A measurement of this decay mode is a good test of new physics beyond the SM.

For this analysis $D^{+}\rightarrow D^0\pi^+$ candidates where $D^0 \rightarrow \pi^0\pi^0$ and $D^0 \rightarrow \gamma\gamma$. The circles with error bars are CLEO data which are fit using a binned likelihood fit to a Gaussian function with expected mean and width determined from signal Monte Carlo simulation, on top of a threshold background function. For $D^{+} \rightarrow D^0\pi^+$ where $D^0 \rightarrow \pi^0\pi^0$, $628.0\pm31.8$ signal events of $D^0 \rightarrow \pi^0\pi^0$ are observed. The signal and background levels found in the data are in good agreement with those obtained from Monte Carlo simulations. For $D^{+} \rightarrow D^0\pi^+$ where $D^0 \rightarrow \gamma\gamma$, no significant enhancement is observed in the signal region. The signal yield of $D^0 \rightarrow \gamma\gamma$ from the fit is $19.2\pm9.3$ events. From Monte Carlo simulations, the relative efficiency for $D^0 \rightarrow \gamma\gamma$ and $D^0 \rightarrow \pi^0\pi^0$ is determined to be: $\epsilon(\gamma\gamma)/\epsilon(\pi^0\pi^0) = 1.58\pm0.05$. We set upper limits:

$$B(D^0 \rightarrow \gamma\gamma)/B(D^0 \rightarrow \pi^0\pi^0) < 0.033$$

and

$$B(D^0 \rightarrow \gamma\gamma) < 2.9 \times 10^{-5} \text{ @ 90\%C.L.}$$

This is the first search for the decay mode of $D^0 \rightarrow \gamma\gamma$. The details of the analysis can be found in [8].

4 First Observation of $D^0 \rightarrow K_S^0\eta\pi^0$

This work was motivated by BaBar and CLEO’s recent Dalitz analyses results of $D^0 \rightarrow K_S^0K^+K^-$ and $K_S^0\pi^+\pi^-$. As $a_0(980)$ to $\eta\pi^0$ is the dominating decay mode, we expect to observe $D^0 \rightarrow K_S^0\eta\pi^0$ as well.

To study this decay we use decay channels: $K_S^0 \rightarrow \pi^+\pi^-$, $\eta \rightarrow \gamma\gamma$, $\pi^0 \rightarrow \gamma\gamma$. The decay $D^0 \rightarrow K_S^0\eta\pi^0$ is used for systematic cross-checks and normalization. Using the energy release variable $Q = M(D^{+}) - M(D^0) - m_{\pi^+}$, we observe a clean signal in the $Q$ distribution as shown in Figure 2. This is the first observation of the decay mode of $D^0 \rightarrow K_S^0\eta\pi^0$. The preliminary measured the ratio of branching fractions is:

$$R = \frac{BR(D^0 \rightarrow K_S^0\eta\pi^0)}{BR(D^0 \rightarrow K_S^0\pi^0)} = 0.38\pm0.07_{\text{stat.}}\pm0.05_{\text{syst.}}$$

We are performing Dalitz plot analysis for the decay $D^0 \rightarrow K_S^0\eta\pi^0$. Final results will be ready in the near future.
6 CLEO-c and CESR-c project news

In early 2003, the NSF approved a five year program of charm physics called CESR-c and CLEO-c. From 2003 to 2006, the Cornell Electron Storage Ring (CESR) accelerator will operate at center of mass energies at 4140, 3770 and 3100 MeV with the expected luminosity of a few 10^{32} cm^{-2}s^{-1}.

One may wonder what physics can CLEO-c offer in the next few years when we expect lots of data from Tevatron and B factories. Especially BaBar and Belle will have a few hundred fb^{-1} of data which contains lots of charm decays.

Running at Charm threshold with D tagging provides an extremely powerful and “background free” environment that allow some very precise measurements which are not possible at other environments.

For example, recently there have been exciting progress in Lattice QCD which will be able to calculate with accuracies of 1 to 2 percent. The CLEO-c decay constant and form factor measurements with similar precision will provide a golden and timely test of Lattice QCD.

Large uncertainties in the current and future measurements of CKM matrix elements come from our poor measurements of the absolute charm branching fractions. Again, CLEO-c will be the ideal place to provide these crucial information in a timely fashion.

There are also potential to observe new forms of matter: Glueballs and hybrids. As we all know, glueballs have been sighted too many times without confirmation. With 1 billion J/ψ data, CLEO-c can either find it or debunk it.

The CESR-c/CLEO-c program can be briefly listed as follow:

- 2004 – 2005 Act II: √s ~ 4100 MeV — 3 fb^{-1}; 1.5M D_s D_s, 0.3M tagged D_s (480 x MARK III).

This statistics is required for precise measurement of branching ratios, decay constants and other SM parameters in the charm sector.

References

4. CLEO Collaboration, K. Arns et al., CLNS 03/1832, CLEO 03-10.
6. CLEO Collaboration, V. V. Frolov et al., CLEO CONF 03-03.
9. CLEO-c and CESR-c: A New Frontier of Weak and Strong Interactions, CLNS-01/1742.