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Recent Charm from CLEO

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Abstract. We present some recent results in rare charm decays from CLEO Collaboration. The data used 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.

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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

$D^+ \to \pi^+\pi^0$ and $K^+K_s^0$ are single Cabibbo-Suppressed decays and $D^+ \to K^+\pi^0$ is a doubly Cabibbo-Suppressed decay. One of the main interest in charm physics has been the $D^0-\bar{D}^0$ mixing. To unravel any non SM contributions to $D^0-\bar{D}^0$ 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.

Given the large uncertainties in absolute D^+ branching fractions, we use $D^+ \to K^-\pi^+\pi^+$ and $K_s^0\pi^+$ as normalization modes and measure the ratios of these Cabibbo-Suppressed decays relative to these normalization modes.

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 fraction measurements: $\frac{Br(D^+\to\pi^+\pi^0)}{Br(D^+\to K^-\pi^+\pi^+)} = 0.0144 \pm 0.0019 \pm 0.0010$, $\frac{Br(D^+\to K^+K_s)}{Br(D^+\to\pi^+K_s)} = 0.1892 \pm 0.0155 \pm 0.0073$, $\frac{Br(D^+\to K^+\pi^0)}{Br(D^+\to K^-\pi^+\pi^+)} = 0.0029 \pm 0.0018 \pm 0.0009$.

Using PDG [2] values of $Br(D^+ \to K^-\pi^+\pi^+) = (9.1 \pm 0.6)\%$ and $Br(D^+ \to \pi^+\bar{K^0}) = (2.77 \pm 0.18)\%$, we obtain the following branching fraction measurements: $Br(D^+ \to \pi^+\pi^0) = (1.31 \pm 0.17 \pm 0.09 \pm 0.09) \times 10^{-3}$, $Br(D^+ \to K^+\bar{K^0}) = (5.24 \pm 0.43 \pm 0.20 \pm 0.34) \times 10^{-3}$, $Br(D^+ \to K^+\pi^0) = (2.64 \pm 1.64 \pm 0.82 \pm 0.17) \times 10^{-4}$ and $Br(D^+ \to K^+\pi^0) < 4.2 \times 10^{-4}$ 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 braching 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.

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

Mode	Yield	Efficiency
$\pi^+\pi^0$	171.3±22.1	(6.20±0.11)%
K^+K_s	277.7±20.8	(4.94±0.23)%
$K^+\pi^0$	34.3±20.9	(6.08±0.22)%
$K^-\pi^+\pi^+$	12898.0±156.6	(6.74±0.12)%
π^+K_s	1434.7±48.0	(4.83±0.23)%

We also measured the ratio R1 [3] 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 predition 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 [3] of 2.03±0.32 indicates this is indeed the case.

The details of the analysis can be found in [4]

3 Dalitz Analysis of $D^0 \to \pi^+\pi^-\pi^0$

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 $D^+ \to \pi^+\pi^-\pi^+$, E791 reported significant evidence for a borad neutral scalar resonance, the $\sigma(500)$ [5].

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

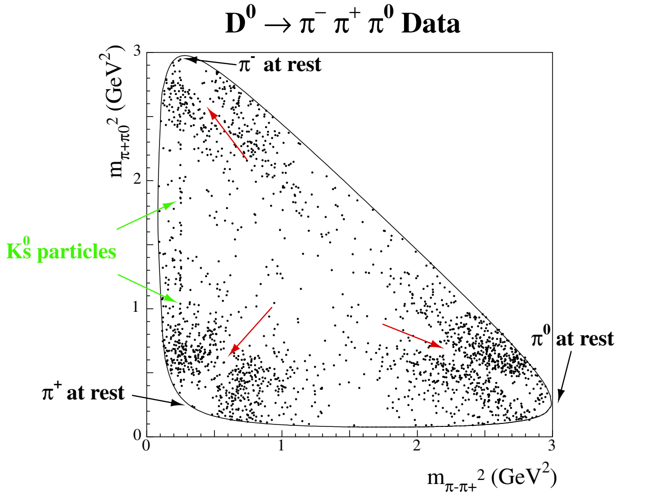

Fig. 1. Dalitz plot for $D^0 \to \pi^+\pi^-\pi^0$ from CLEO data.

Table 2. Dalitz analysis fit results.

Resonance	Amplitude	Phase (^{0})	Fraction (%)
ρ^+	1.0 (fixed)	0.0 (fixed)	76.5±1.8±4.8
ρ^0	0.56±0.02±0.07	10±3±3	23.9±1.8±4.6
ρ^-	0.65±0.03±0.04	−4±3±4	32.3±2.1±2.2
non res.	1.03±0.17±0.31	77±8±11	2.7±0.9±1.7

and phase of each component. The results are summaried in Table 2.

Including a scalar $\sigma(500)$ does not result in a significantly improved likelihood and yielded fit fraction is consistent with zero.

It is also interesting to mention that we do not see more massive ρ mesons like $\rho^+(1700)$ either.

The details of the analysis can be found in [6]

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

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

To study this decay we use decay channels: $K_S^0 \to \pi^+\pi^-$, $\eta \to \gamma\gamma$, $\pi^0 \to \gamma\gamma$. The decay $D^0 \to K_S^0\pi^0$ 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 $D^0 \to K_S^0\eta\pi^0$. The preliminary measured the ratio of branchings fractions is:

$$R = \frac{BR(D^0 \to K_S^0\eta\pi^0)}{BR(D^0 \to K_S^0\pi^0)} = 0.38 \pm 0.07_{stat.} \pm 0.05_{syst.}.$$

We are performing Dalitz plot analysis for the decay $D^0 \to K_S^0\eta\pi^0$. Final results will be ready in the near future.

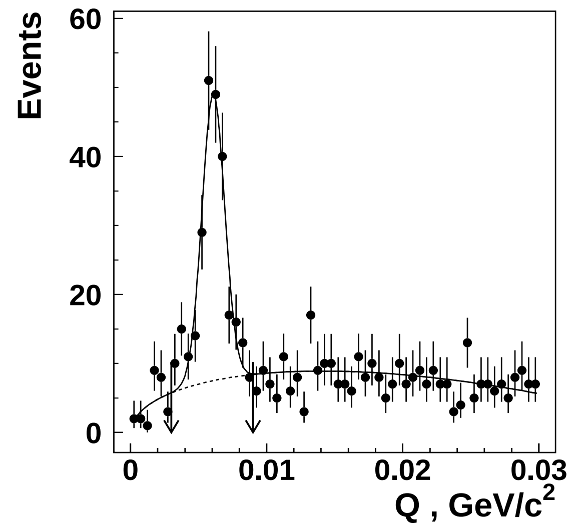

Fig. 2. The Q distribution for the decay $D^{*+} \to D^0(K_S^0\eta\pi^0)\pi^+$.

5 First Search for Flavor Changing Neutral Current Decay $D^0 \to \gamma\gamma$

Standard Model (SM) predicts the rate for the $D^0 \to \gamma\gamma$ decay of $\sim 10^{-8}$ or less [7,1]. 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 [8] we use CLEO II & II.V data sample. Combinatoric background is suppressed by the tagging process $D^{*+} \to D^0\pi^+$ using the energy release variable $Q = M(D^{*+}) - M(D^0) - m_{\pi^+}$.

Figure 3 shows the Q distributions for $D^{*+} \to D^0\pi^+$ candidates where $D^0 \to \pi^0\pi^0$ and $D^0 \to \gamma\gamma$. 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 $D^{*+} \to D^0\pi^+$ where $D^0 \to \pi^0\pi^0$, 628.0 ± 31.8 signal events of $D^0 \to \pi^0\pi^0$ are observed. The signal and background levels found in the data are in good agreement with those obtained from Monte Carlo simulations. For $D^{*+} \to D^0\pi^+$ where $D^0 \to \gamma\gamma$, no significant enhancement is observed in the signal region. The signal yield of $D^0 \to \gamma\gamma$ from the fit is 19.2 ± 9.3 events. From Monte Carlo simulations, the relative efficiency for $D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$ is determined to be: $\epsilon(\gamma\gamma)/\epsilon(\pi^0\pi^0) = 1.58 \pm 0.05$. We set upper limits:

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

and

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

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

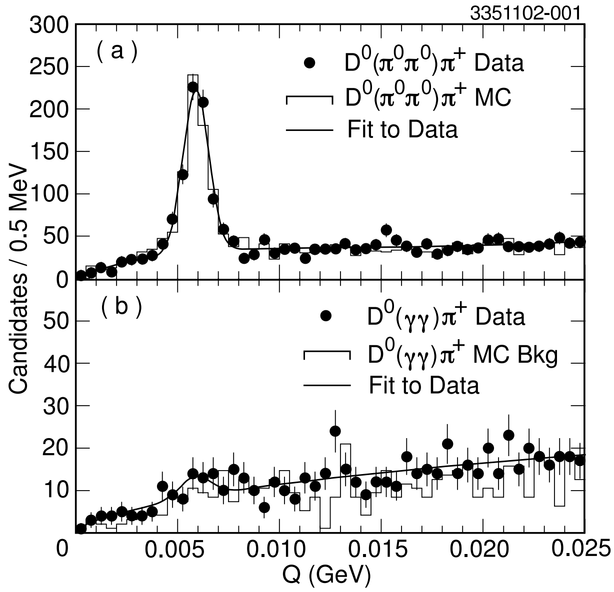

Fig. 3. Energy release in the decay $D^{*+} \rightarrow D^0\pi+$ for (a) $D^0 \rightarrow \pi^0\pi^0$; (b) $D^0 \rightarrow \gamma\gamma$.

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[9]. From 2003 to 2006, the Cornell Electron Storage Ring (CESR) accelerator will operate at center of mass energies at 4140, 3770 and 3100MeV 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 extremly 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 matix 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:

- **2003 – 2004 Act I:** $\psi(3770)$ — **3 fb^{-1}; 30M events, 6M *tagged* D (310 times MARK III).**
- **2004 – 2005 Act II:** $\sqrt{s} \sim 4100$ MeV — **3 fb^{-1}; 1.5M** $D_s\bar{D}_s$**, 0.3M *tagged*** D_s **(480 × MARK III).**
- **2005 – 2006 Act III:** $\psi(3100)$ — **1 fb^{-1}; 1 Billion** J/ψ **(170 times MARK III, 20 times BES II).**

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

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