Hot Results from CLEO-c

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I briefly review some of the latest results obtained using the CLEO-c detector.

I. INTRODUCTION

The CLEO detector has been taking data at the Cornell Electron Storage Ring since 1980. Its latest (and last) configuration is CLEO-c, which is optimized for running in the charm threshold region. The main differences between it and the CLEO III configuration, is the replacement of the silicon vertex detector with a lightweight inner drift chamber. The magnetic field is now 1T. These two changes both help with the measurement of low momentum tracks.

The main datasets taken by CLEO-c are a) around 54 pb$^{-1}$ taken at the $\psi(2S)$ resonance (corresponding to around 27,000,000 $\psi(2S)$ decays), b) a large block of running at the $\psi(3770)$, of which 281 pb$^{-1}$ is processed, more is already taken, and the target is 720 pb$^{-1}$, c) running at just above 4170 MeV, which is just above the $D_s D_s^*$, of which most analyses use $\approx 195$ pb$^{-1}$, some use $\approx 300$ pb$^{-1}$, and more data will be taken (with a target of 720 pb$^{-1}$), and d) an energy scan in the region 3970-4260 MeV. Note, that there is no environment can compete with an $\psi(3770)$ energy scan in the region 3970-4260 MeV. Note, that there is no CLEO-c results using 56 pb$^{-1}$ of data. This second analysis has been presented in detail elsewhere [2]. We already have doubled this dataset, but that new data has not yet been analyzed, and yet more is on the way.

The basic technique depends on the fact that if there is one $D$ meson in the event, there must be one $\bar D$ meson, and nothing else. By first cutting on $\Delta(E) = E_{D-\overline{TAG}} - E_{\overline{BEAM}}$, we can plot $M_{BC} = \sqrt{E_{\overline{BEAM}}^2 - p_{D-\overline{TAG}}^2}$ and the signals are spectacularly clean. We then calculate the ratio of doubly-tagged events (those where both the $D$ and $\bar D$ were constructed), to singly-tagged events (those where only one of the two is reconstructed), we can extract the absolute branching fractions for $3\ D^+$ decays and 6 $D^0$ decays.

Table I: $D^0$ Hadronic Branching Fractions

| Particle | Decay | Branching Fraction (%) | 1σ |
|---------|-------|------------------------|----|
| $D^0$  | $K^-\pi^+$ | $3.88 \pm 0.04 \pm 0.09$ |    |
| $D^0$  | $K^-\pi^+\pi^0$ | $14.6 \pm 0.1 \pm 0.4$ |    |
| $D^0$  | $K^-\pi^+\pi^-\pi^+$ | $8.3 \pm 0.1 \pm 0.3$ |    |
| $D^+$  | $K^-\pi^+\pi^+$ | $9.2 \pm 0.1 \pm 0.3$ |    |
| $D^+$  | $K^-\pi^+\pi^0\pi^+$ | $6.0 \pm 0.1 \pm 0.2$ |    |
| $D^+$  | $K^-\pi^+\pi^0\pi^-\pi^+$ | $1.55 \pm 0.02 \pm 0.05$ |    |
| $D^+$  | $K^-\pi^+\pi^0\pi^-\pi^+$ | $7.2 \pm 0.1 \pm 0.3$ |    |
| $D^+$  | $K^-\pi^+\pi^0\pi^-\pi^+$ | $3.13 \pm 0.05 \pm 0.14$ |    |
| $D^+$  | $K^-\pi^+\pi^-\pi^+$ | $0.93 \pm 0.02 \pm 0.03$ |    |

I would just like to mention that CLEO-c has also recently made the most precise measurement of the $D^0$ mass [3]. This was made using the decay mode $D^0 \rightarrow K^0\phi$. The result is $M(D^0) = 1864.847 \pm 0.150 \pm 0.095$ MeV. The result is particularly important because it leads to the conclusion that the binding energy of the $X(3872)$ when interpreted as a $DD$ molecule is 0.6±0.6 MeV.

III. $D_s$ BRANCHING FRACTIONS

It is fitting that CLEO is still interested in the $D_s$, as it was responsible for the discovery of the particle in 1984 [4]. That, and many other measurements in this sector, were performed using $e^+e^-$ collision energies in the $\Upsilon$ region. Now, we have the chance to work at a little above $D_s$ threshold. First, a scan was taken in the energy range 3.97-4.26 GeV. It was found that the optimal place to operate is 4.17 GeV, and so 314 pb$^{-1}$ of data has been taken there. At each energy of the scan, the cross section for $D_s D_S, D_s^0 D_s^0, D_s D_s^*$ was calculated along with the cross section of $DD$. These cross-sections are interesting in themselves, and details can be seen elsewhere [5].

At the energy of 4.17 GeV, the majority of the $D_s$ mesons are produced via $D_s D_s^*$. This produces a complication not present in the non-strange case, as there is a low-energy photon in the event as well as the two mesons we are interested in. However, there is good
kinematic separation between the modes. This analysis (based on 195 \( pb^{-1} \) of data), is presented in more detail elsewhere. Here I just present the \( D_s \) absolute branching fractions in Table II.

| Particle  | Decay            | Branching Fraction (%) |
|-----------|------------------|------------------------|
| \( D_s^+ \) | \( K^0 K^+ \)    | 1.50 ± 0.09 ± 0.05     |
| \( D_s^+ \) | \( K^- K^{+} \pi^+ \) | 5.57 ± 0.30 ± 0.19     |
| \( D_s^+ \) | \( K^- K^{+} \pi^+ \pi^0 \) | 5.62 ± 0.33 ± 0.51     |
| \( D_s^+ \) | \( \pi^- \pi^0 \pi^+ \) | 1.12 ± 0.08 ± 0.05     |
| \( D_s^+ \) | \( \pi^+ \eta' \) | 1.47 ± 0.12 ± 0.14     |
| \( D_s^0 \) | \( \pi^+ \eta' \) | 4.02 ± 0.27 ± 0.30     |

Note that we do not include the traditional normalizing mode for \( D_s \) decays, namely \( \phi \pi^+ \). This is because there is a non-trivial background to the \( \phi \to K^+ K^- \) signal, and different experiments have chosen different \( \phi \) mass cuts, leading to different amounts of this background being included. The complicated substructure of this decay mode make it a candidate for an amplitude analysis rather than using it as a normalizing mode.

IV. DECAY MODES OF \( D_s \) INTO TWO PSEUDO-SCALARS

The analysis technique here is straightforward as we look for single \( D_s \) decays here in the 4170 MeV data (note that in this preliminary analysis, \( \approx 300 pb^{-1} \) are used). We search for four Cabibbo suppressed modes \( \{ \pi^0 K^+, K^{+} \eta, K^{+} \eta', K^{+} K^0 \} \), one decay that is expected to be forbidden \( \{ \pi^+ \pi^0 \} \), and compare these with three Cabibbo-allowed decays measured in the same dataset \( \{ \pi^+ \eta, \pi^+ \eta', K^+ K^0 \} \). The preliminary results for the branching ratios, seen in public for the first time are:

\[
\begin{align*}
(D_s \to K^+ \eta)/(D_s \to \pi^+ \eta) & = 0.080 \pm 0.015 \\
(D_s \to K^+ \eta')/(D_s \to \pi^+ \eta') & = 0.039 \pm 0.013 \\
(D_s \to K^0 \pi^+)/ (D_s \to K^+ K^0) & = 0.083 \pm 0.009 \\
(D_s \to K^+ \eta)/(D_s \to K^+ K^0) & = 0.042 \pm 0.012 \\
(D_s \to \pi^+ \pi^0)/ (D_s \to K^+ K^0) & < 0.04 \\
\end{align*}
\]

These results are preliminary statistics dominated, and more statistics will be available.

V. CHARMED MESON DECAY CONSTANTS

Measurement of the decay constants \( f_{D^+} \) and \( f_{D_s} \) are of great interest, but are very difficult experimentally because they require investigation of modes with neutrinos in their final state. CLEO-c has published analyses of \( D^+ \to \mu^+ \nu \) and \( D^+ \to e^+ \nu \), and also \( D_s \to \tau^+ \nu \), each with the 281 \( pb^{-1} \) dataset. The analysis of \( D_s^0 \to \mu^+ \) and \( D_s^0 \to \tau^+ \nu \) has now been sent for publication using 314 \( pb^{-1} \), and details can be found there. The second \( D_s \) analysis, using the decays of the \( \tau \) into electrons, is complementary to the first and largely independent of it. The value for \( f_{D_s} \) is found to be \( (223 \pm 17 \pm 3) \) MeV, the combined value for \( f_{D_s} \), is \( (273 \pm 10 \pm 5) \) MeV, and the ratio, \( (f_{D_s} / f_{D_i}) \), is \( 1.22 \pm 0.09 \pm 0.03 \) (these results are all preliminary). This ratio is very consistent with most models, including recent lattice QCD models.

VI. \( \psi(2S) \) DATA

There are already some results shown using \( \psi(2S) \) data, demonstrating its use as a factory for \( \chi_c \) production. We now have an order of magnitude more data taken. This will enable us to study the decays of all three \( \chi_c \) states, the \( \eta_c \) and the \( h_c \), in unprecedented detail. It is also possible to do some detailed analysis of \( J/\psi \) decays found from the di-pion decays of the \( \psi(2S) \). Just one example of \( \chi_c \) physics is the decays into \( KK \pi \pi \), which can be seen in six different charge combinations, each with good signal to noise ratios. It will take a lot of work to understand the rich resonant substructure of these decay modes. These are just a few of the 50 or so \( \chi_c \) decay modes that we can measure, and we are limited only by the manpower to do the necessary analyses.

VII. CONCLUSIONS

I have presented a series of results, most preliminary and some final, from the data taken by the CLEO-c detector configuration. With much more data becoming available, please expect many more results in the next months and years.

Acknowledgments

I thank my collaborators in CLEO for their help in preparing this talk, in particular Hanna Mahlke, Istvan Danko and Mikhail Dubrovin.

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