Observation of $D_{sJ}(2460)$ and Confirmation of $D_{sJ}^*(2317)$ at CLEO

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Introduction & Background

We need to interpret fundamental properties of quarks as revealed in CKM angle determinations, rare decay studies and CP violation measurements. Often we need to use QCD to extract the vital information from the data. Thus incisive studies of QCD are crucial to our fundamental understanding.

Prior to April 2003:
- The known $c\bar{s}$ mesons were $D_s(1969), D_s(2112), D_s(2366), D_s(2536)$.
- Theoretical expectations were that the remaining two $c\bar{s}$ states ($0^+$ and $1^+$) were above DK threshold and had large widths.

After April 2003:
- BaBar observed the narrow state $D_s(2317)$ decaying to $D_s\pi^0$, consistent with $J^P=0^+$ [PRL 90, 242001 (2003)].
- CLEO confirmed this new state and observed a second peak at 2460 MeV.

The $D_{sJ}(2317)$ and $D_{sJ}(2460)$ Signals at CLEO

Reconstructing the decay chains:
- $D_{sJ}(2317) \rightarrow D_s\pi^0$
- $D_{sJ}(2460) \rightarrow D_s\pi^0$

The observations of the $D_{sJ}(2317)$ [BaBar] and $D_{sJ}(2460)$ [CLEO] states were surprising because they are:
- narrow resonances (intrinsic width $< 7$ MeV);
- observed in the isospin-violating $D_s\pi^0$ channel;
- less massive than most theoretical predictions for a $0^+$ or $1^+$ $c\bar{s}$ state that could decay via these channels.

Cross Feed between $D_s\pi^0$ and $D_s^*\pi^0$

The state at 2460 MeV will generate a peak at 2317 if the photon from the $D_s$ decay is not observed! The probability of feeding down is $(84\pm9\%)$ and results in smearing of the width according to Monte Carlo simulations.

Spectroscopy of the $c\bar{s}$ Mesons

<table>
<thead>
<tr>
<th>$J^P$</th>
<th>Discovery</th>
<th>$M(D_s\pi^0)$ (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0^+$</td>
<td>1984 - ARGUS</td>
<td>2317 + 7</td>
</tr>
<tr>
<td>$1^+$</td>
<td>1983 - CLEO</td>
<td>2460 + 7</td>
</tr>
</tbody>
</table>

Theoretical Explanations

- DK molecule [Close & Lipkin, hep-ph/0305025]
- Ordinary excited $c\bar{s}$ states:
  - $D_s$'s are narrow because isospin is violated in the decay (only way for hadronic decay to occur since they are below DK threshold) [Cho & Wise, PRD 1994].
  - HQET + chiral symmetry explain the mass difference [Bardeen, Eichten & Hill, hep-ph/0305045].
- Contradictory lattice results [Bali, hep-ph/0305209 & UKQCD collaboration, hep-lat/0307001]
  - Unitarized meson model [Beveren & Rupp, hep-ph/0305035]
  - Mixture of 4-quark states $|c\bar{s}\pi^0\pi^0\rangle$ above $D^0\bar{D}^0$ threshold [Browder et al., hep-ph/0307054]

Searching in Other Final States

We have searched for $D_{sJ}(2317)$ and $D_{sJ}(2460)$ in other decay channels: $D_s\pi^0$, $D_{sJ}^*\pi^0$, however, there is no sign of any structure in the mass difference spectrum in the region where a signal from $D_{sJ}(2317)$ or $D_{sJ}(2460)$ decay would be expected.

Summary & Conclusions

- CLEO has observed a new state at mass of 2460 MeV decaying to $D_s\pi^0$, as expected for $J^P=1^+$; $M(D_s\pi^0) - M(D_s) = 351.2 \pm 1.7 \pm 1.0$ MeV.
- We have also confirmed the BaBar discovery of the state at 2317 MeV decaying to $D_s\pi^0$, as expected for $J^P=0^+$; $M(D_s\pi^0) - M(D_s) = 350.5 \pm 1.2 \pm 1.0$ MeV.
- Results are compatible with models based on HQET and chiral symmetry, that predict $1^+$ and $0^+$ are the chiral partners of the $1^+$ and $0^+$ states, with the same mass splitting [Bardeen et al.].
- Results are reported in hep-ex/0305100, [PRD 68, 023002 (2003)].
- Both states are also confirmed by Belle in continuum $e^+e^-$ collisions [hep-ex/0307052] and $B\rightarrow D_{sJ}\pi^0$ decays [hep-ex/0303819].