SLAC-PUB-5208
February 7, 1990
(E)

Note on Ds Decays*

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New data on Ds decays, since the last Review of Particle Properties[1], comes from the CLEO, ACCMOR, NA14', Mark III and ARGUS groups. This brief note discusses new results in hadronic decays, the absolute branching ratios and the P-wave Ds candidates, obtained from recent publications , preprints and summaries[2].

The new Ds hadronic modes and recent measurements which differ substantially from previous measurements are listed in Table 1. The decay mode $\overline{K}^{\circ}K^{*+}$ is analogous to the $\overline{K}^{\circ}K^{+}$ and $\overline{K}^{*\circ}K^{+}$ modes previously observed and is seen at a comparable rate to that of $\phi\pi$. The existence of these $K\overline{K}$ decays indicates that the strength of the internal W emission diagrams is sizable. The $\phi\pi^{+}\pi^{\circ}$ mode is seen only in one experiment and due to the limited statistics, it is not possible to determine if the decay is through the quasi-two body mode $\phi\rho^{\circ}$. The $f^{\circ}\pi$ mode has been observed in the three pion Daltiz plot by E691 and confirmed by Mark III. The $f^{\circ}\pi$ mode is predicted to occur by the weak spectator decay as the f° is believed to be the scalar particle of hidden strangeness with a mass below $K\overline{K}$ threshold. The evidence for the $\eta\pi$ and $\eta'\pi$ modes is still controversial. A previous Mark II measurement reported a rate relative to $\phi\pi$ of 3.0 ± 1.1 and 4.8 ± 2.1[11] for these modes respectively. Recently E691 and Mark III have set upper limits whereas NA14' has now seen a very large Ds signal decaying to $\eta'\pi$. The true value may lie somewhere in between and awaits more experimental data.

Submitted to *Review of Particle Properties.*

*Work supported in part by the National Science Foundation and by the Department of Energy contracts DE-AC03-76SF00515,DE-AC02-76ER01195,DE-AC03-81ER40050, DE-AC02-87ER40318 and DE-AM03-76SF000324

Table 1. Ds Hadronic Decay modes

Decay Mode	$\Gamma(\text{mode})/\Gamma(Ds^{\pm}\to\phi\pi^{\pm})$	Experiment
$\overline{K}^{\circ}K^{*+}$	0.89±.32	ACCMOR[3]
$\overline{K}^{\circ}K^{*+}$	1.20±.21	CLEO[4]
$\phi\pi^{+}\pi^{\circ}$	~3.5 at 90%CL	NA14'[5]
$\phi\pi^{+}\pi^{\circ}$	2.4±1.0±0.5	TPS[6]
$\pi^{+}\pi^{-}\pi^{+}\pi^{\circ}$	~3.3 at 90% CL	TPS[6]
$\omega\pi^{+}$	<0.5 at 90% CL	TPS[6]
$f^{\circ}\pi$	0.28±0.21±0.28	TPS[7]
$f^{\circ}\pi$	0.58f0.21f.028	MarkIII[8]
$\eta\pi^{+}$	<1.5 at 90% CL	TPS[6]
$\eta\pi^{+}$	<2.5 at 90% CL	MarkIII[9]
$\eta'\pi^{+}$	<1.9 at 90% CL	MarkIII[9]
$\eta'\pi^{+}$	6.9±2.4±1.4	NA14'[10]

Knowledge of the absolute branching ratios of the Ds is required to normalize all the reactions which contain the Ds and observe it via the $\phi\pi$ mode. There are three different approaches to estimate this rate, all from e^+e^- production. The first method measures the inclusive rate of $\sigma_{exp}(e^+e^-\to Ds^{\pm}+X, Ds^{\pm}\to\phi\pi^{\pm})$ and theoretically determines the total Ds cross section, $\sigma_{th}(e^+e^-\to Ds^{\pm}+X)$, from estimates of the total charm content in R and the strange sea. The absolute branching ratio is then $BR(Ds^{\pm}\to\phi\pi^{\pm}) = \sigma_{exp}(e^+e^-\to Ds^{\pm}+X, Ds^{\pm}\to\phi\pi^{\pm}) / \sigma_{th}(e^+e^-\to Ds^{\pm}+X)$. The second method used by the CLEO group attempts a more precise estimate of $\sigma_{th}(e^+e^-\to Ds^{\pm}+X)$ by again estimating the total charm content in R by measuring all the charm baryons and mesons (except the Ds) and attributing the remaining missing charm from e^+e^- reactions to Ds production. The third method uses a search for associated production of exclusive Ds pairs in e^+e^- production into various decay modes near threshold and compares the rate to the inclusive Ds production in the Ds decay modes. Thus the branching ratio for the $\phi\pi$ mode is equal to $BR(Ds\to\phi\pi) = \sigma_{exp}(e^+e^-$

Table 2. Absolute $Ds \to \phi\pi$ Branching Ratio Estimates

Method	Absolute BR($Ds \to \phi\pi$)	Group
Charm Continuum estimate	1.7-l 3%	Many groups[12]
All Inclusive measurement	2±1%	CLEO[13]
Associated Production	~4.1 at 90% CL	Mark III[14]

$\to Ds^+ Ds^-$, $Ds^+ \to \phi\pi^+$, $Ds^- \to \phi\pi^-$) $/\sigma_{exp}(e^+e^- \to Ds^{\pm}+X,\ Ds^{\pm} \to \phi\pi^{\pm})$. This technique, often called the double tag method, was attempted by the Mark III for the Ds, but because of limited size of the data sample, no events were found and an upper limit was set. The first two approaches are model dependent and require several theoretical estimates. The last approach while model independent requires much more data to obtain a measurement. The estimates are listed in Table 2. As the $\phi\pi$ branching ratio drops we expect the existance of many more decays that have not been measured. These missing decay modes should contain hidden strangeness and probably have high charged multiplicities and/or many neutral secondaries.

Table 3. Excited P-Wave Ds Candidate

Decay Mode	Mass	Width	Group
$D^{*+}K^{\circ}$	2535.9f.6f2.0 MeV/c^2	~4.6 MeV/c^2	ARGUS[15]
$D^{*+}K^{\circ}$	2535.6±.7±.4 MeV/c^2	~5.44 MeV/c^2	CLEO[16]

Both ARGUS and CLEO observe a narrow resonance in the mode $Ds^* \to D^{*+}K^{\circ}$ as shown in Table 3. This can be identified as the P-wave $c\bar{s}$ state that strongly decays into charmed and strange mesons. The lack of evidence of the state in the mode D^+K° suggests that the state is not the lowest lying P-wave scalar but possibly the $^1P_1$ or $^3P_1$ states. The mass is roughly 100 MeV/c^2 above the P-wave $c\bar{u}$ candidate at 2428 MeV/c^2. This is where the P-wave $c\bar{s}$ candidate is expected since the P-wave mass splittings between charm-strange and charm-non-strange mesons should follow the S-wave splittings, $M(c\bar{s},{}^1S_0)$ - $M(c\bar{u},{}^1S_0) \approx M(c\bar{s},{}^3S_1) - M(c\bar{u},{}^3S_1) \approx 100$ MeV/c^2. The width is surprisingly narrow but may be a consequence of mixing between the two 1^+ states.

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