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Study of Ds Decays*

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Abstract

A limit for the absolute branching ratio of BR($D_s \rightarrow \phi\pi$)<4.1% at 90% C.L. and evidence for the decay $D_s \rightarrow f_o(975)\pi$ is presented from the Mark III.

In the spectator model, the lowest lying bound state of the charm–strange quarks, the D_s meson, is predicted to decay via W emission from the charm quark and form states with $s\bar{s}$ hidden strangeness. The conventional hadronic modes will contain $K\bar{K}$, ϕ and the $f_o(975)$, which is considered to be the $J^{PC}=0^{++}$ isoscalar $s\bar{s}$ meson. Hadronic decays of the D_s meson have been measured in relatively few modes[1] and all modes are measured relative to the $\phi\pi$ mode. In this paper, an upper limit for the absolute branching ratio of the D_s decay into the $\phi\pi$ mode and evidence for the the decay, $D_s \rightarrow f_o(975)\pi$ is presented from the Mark III.

Data Set and Mark III detector

The data for the D_s analysis was taken at a center mass energy of 4.14 GeV with a total integrated luminosity of the 6.3±0.46 inverse picobarns. The main features of the Mark III detector[2] have been discussed elsewhere. This analysis used tracking information from the drift chamber[3], timing measurements from the time–of–flight (TOF) counters[4] and shower tracks detected in the barrel[5] and endcap[6] shower counters.

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Analysis of the Absolute Branching Ratio upper limit

The production of the Ds decays into final states i and j occurs in the reaction $e^+e^- \rightarrow DsDs^*$, Ds→*final state i*, $D^*s \rightarrow \gamma Ds$, Ds→*final state j*. The produced rate of this exclusive reaction will be, B(Ds→*final state i*)·B(Ds→*final state j*)·$\sigma(e^+e^- \rightarrow DsDs^*)\cdot\int \mathcal{L} dt$. By measuring several exclusive reactions (called double tags) and forming the various ratios, we may divide out the cross section and obtain a measurement of the absolute branching ratios. In this analysis the final states i and j were investigated in the modes; $\phi\pi^+$, $K^\circ K^+$, $f_o(975)\pi^+$, $K^*(892)^\circ K^+$, $K^{*\circ}K^{*+}$, $\phi\pi^+\pi^+\pi^-$, and $\phi\pi^+\pi^\circ$ and this results in a limit on the branching ratio $B(Ds \rightarrow \phi\pi^+)$. A total of twenty–eight possible double tag final states were considered.[7,8]

For the individual final states, combinations of shower and drift chamber tracks are selected and the charged tracks assigned masses. The charged tracks were used as a π or a K unless the measured TOF was more than 5σ away from the predicted time of its mass hypothesis. Kinematic fits are applied to the hypothesis $e^+e^- \rightarrow DsDs^* \rightarrow \gamma Ds^+Ds^-$ and the Ds^+ and Ds^- candidates are constrained to have equal but unspecified mass M(X). The $DsDs^*$ events will produce a peak in the M(X) distribution at the Ds mass. In the region of the M(X) distribution which would contain 95% of the Ds signal as estimated by Monte Carlo, no events were observed and this results in an upper limit for the absolute branching ratio. In Fig. 1 is shown the M(X) distribution where in the Ds region no events are detected. A Monte Carlo estimate of 2.8 produced Ds events is drawn in.

An upper limit for $B(Ds \rightarrow \phi\pi^+)$ is obtained by computing the likelihood of observing zero events as a function of $B(Ds \rightarrow \phi\pi^+)$. The expected number of double–tag events is $[\sigma(e^+e^- \rightarrow DsDs^*)\cdot\int \mathcal{L} dt\cdot B(Ds\rightarrow\phi\pi^+)]\cdot B(Ds\rightarrow\phi\pi^+)\cdot\Sigma b(i)b(j)\varepsilon_{ij}$, where b(i) is the ratio of B(Ds→*final state i*) divided by $B(Ds\rightarrow\phi\pi^+)$ and ε_{ij} is the Monte Carlo determined efficiency of reconstructing the event of double i and j. The measured values used in the likelihood calculation are: $[\sigma(e^+e^- \rightarrow DsDs^*)\cdot\int \mathcal{L} dt\cdot B(Ds\rightarrow\phi\pi^+)] = 156\pm38$[9], $b(K^\circ K^+)=.92\pm.38$,[10] $b(f_o\pi^+)=.28\pm.10$,[11] $b(K^{*\circ}K^+)=.93\pm.12$,[12-15] $b(K^{*\circ}K^{*+})=2.3\pm1.4$,[16] $b(\phi\pi\pi\pi)=.41\pm.10$,[16,15,17] and $b(\phi\pi\pi^\circ)= 2.4\pm 1.1$.[18] In the likelihood function, Poisson statistical errors is used for the observed number of events and Gaussian statistical errors is used for the measured quantities. The correlations between the measurements of Mark III results are included. The marginal likelihood is determined by integrating the likelihood over the $\sigma(e^+e^- \to DsDs^*)\cdot\int\mathcal{L}dt\cdot B(Ds\to\phi\pi^+)$ and the b(i)'s. This results in an upper limit of $B(Ds \to\phi\pi^+)<3.8\%$ at 90% C.L. and this is shown in Fig. 2. This limit corresponds to 2.8 observed events which is drawn in Fig. 1. The uncertainties on the number of signal events includes the errors on the track reconstruction (7%), Monte Carlo generation (2%), and the efficiency of the signal cuts (2%). This totals in quadrature to 8% and enlarges our final value on the upper limit to;

$$B(Ds \to\phi\pi^+) < 4.1\% \text{ at } 90\% \text{ C.L.}$$

Evidence for the decay $Ds\to f_o(975)\pi$

In this analysis the initial track selection requires three charged tracks with total charge sum of ±1. If any track has a TOF measurement then it's time of arrival must be more consistent to a kaon mass hypothesis than a pion mass hypothesis. All three tracks are then assumed to be pions and then required to have a recoil mass near the Ds* mass (2.075–2.125 GeV/c^2). These tracks are then subjected to a kinematic 1–C fit to the hypothesis, $e^+e^- \to\pi^+\pi^-\pi^\pm Ds^*$ where the Ds* is not measured. If the event has a probability greater than 2% it is retained. There is an excess of events with a $\pi^+\pi^-$ invariant mass near that of the $f_o(975)$ and a $\pi^+\pi^-\pi^\pm$ mass near that of the Ds*. The $\pi^+\pi^-$ invariant mass is shown in Fig. 3 (a) where the $\pi^+\pi^-\pi^\pm$ mass is required to lie between 1.94 and 1.98 GeV/c^2. In Fig. 3(b) is a Monte Carlo predicted mass distribution using the mass and width as determined from the $f_o(975)$ observed in the Mark III J/ψ data. The $\pi^+\pi^-\pi^\pm$ mass is shown in Fig. 4 where the $\pi^+\pi^-$ invariant mass is require to lie between 0.94 and 0.98 GeV/c^2 . The background shape is obtained by requiring the $\pi^+\pi^-$ invariant mass to lie within the sideband region (0.86 to 0.90 GeV/c^2). If all the events with the $\pi^+\pi^-$ combinations with masses between 0.94 and 0.98 are assumed to be from the $f_o(975)$ decay, we obtain a preliminary measurement;

$$\sigma(e^+e^- \to DsDs^*)B(Ds\to f_o(975)\pi^+)=(14.9\pm4.2\pm6.5)\text{ pb}$$

Using our measured rate for $\sigma(e^+e^-\to DsDs^*)B(Ds\to\phi\pi^+)$, we obtain the preliminary ratio;

$$B(Ds\to f_o(975)\pi^+)/B(Ds\to\phi\pi^+)=0.58\pm0.21\pm0.03$$

If in the above measurement, the entire Ds signal is contained in the mass interval, .94–.98 GeV/c^2, the result will increase by a factor of two if we use the 50 MeV/c^2 width of the $f_o(975)$ as measured in the reaction $J/\Psi \rightarrow \phi\, f_o(975)$ by the Mark III. Our measurement for this ratio is in agreement with the value of 0.28±0.10±0.03 obtained by the E691 group.[11]

Table 1.

Experiment	CME	B($Ds \rightarrow \phi\pi$)
CLEO	10 GeV	4.4%[19]
	10	2.0±0.5±0.3[20]
TASSO	30-42	13±3±4[21]
	35-44	3.3±1.6±1.0[22]
ARGUS	10	3.0±0.8[23]
	10	1.7±0.2±0.3[17]
HRS	29	3.3±1.1[24]
	29	2.8±1.0[25]
PDG	--	8±5[1]

Discussion of the Results

The absolute branching ratio appears to be somewhat smaller than expected and this indicates that the Ds production rates are higher than previously estimated. Using early measurements of the $\phi\pi$ rate, the absolute rate was estimated to be 4% by estimating the charm content in the continuum and assuming a Ds momentum distribution and a contribution from the strange sea. In table 1 are the estimated branching ratios[8] of various experiments as a function of center mass energy. The last value is the particle data group value.[1] The more recent values have decreased due to lower remeasured values of the inclusive $\phi\pi$ rates.

The evidence for the decay of the Ds into $f_o(975)\pi^+$ is consistent with the spectator model where the $f_o(975)$ is the conventional $s\bar{s}$ scalar. Our result agrees with the E691 results which also observed nonresonant three pion decays. We are not sensitive enough to determine the nonresonant three pion contribution. One feature of this result is that the $f_o(975)$ observed in this decay mode of the Ds must contain hidden strangeness. In certain studies[26] evidence has been presented where the S* resonance was in fact composed of a narrow $s\bar{s}$ scalar and a glueball scalar. Unfortunately the statistics in our measurement is not sufficient to determine if in fact what is observed here differs from the S* candidates seen in other experiments. If a difference is found it could provide compelling evidence for bound states of gluonium.

Figure Captions

1. Equal mass distribution, m(X), from e+e-→γDs^+Ds^- where the $Ds^\pm$ candidates are constrained to have equal but unspecified masses. No events are observed in the Ds region. A Monte Carlo estimate of 2.8 produced events is shaded in the figure.

2. Maximum likelihood distribution as a function of the variable $B(Ds^\pm \to \phi\pi^\pm)$, The arrow points to the 90% C.L. value of the branching ratio obtained from the integration of this likelihood distribution.

3. a) $\pi^+\pi^-$ mass distribution from the data. b) $\pi^+\pi^-$ mass distribution of the $f_o(975)$ from a Monte Carlo using values of the mass and width obtained from the signal observed in the Mark III J/ψ data.

4. $\pi^+\pi^-$ mass distribution from the data that is fit with a sideband background and the $Ds^\pm \to f_o(975)\pi^\pm$ signal.

References

[1] G. P. Yost *et al.*, Phys. Lett. **204B**, 212 (1989).

[2] D. Bernstein *et al.*, Nucl. Instrum. Methods, **226**, 301 (1984).

[3] J. Roehrig *et al.*, Nucl. Instrum. Methods, **226**, 319 (1984).

[4] J. Brown, *et al.*, Nucl. Instrum. Methods, **221**, 503 (1984).

[5] W. Toki, *et al.*, Nucl. Instrum. Methods, **219**, 476 (1984)

[6] R. Fabrizio, *et al.*, Nucl. Instrum. Methods, **227**, 220 (1984).

[7] J. Adler *et al.*, SLAC preprint SLAC-PUB-5044, July 1989, submitted for publication to Physical Review Letters.

[8] S. Wasserbaech, Phd thesis, Stanford University, SLAC report no. 345, June 1989.

[9] Using the Mark III measurements of $Ds \to K^{*o}K^+$ and $\phi\pi^+$ and the world average value for the ratio of $K^{*o}K^+/\phi\pi^+$ and including common systematic errors yields 156±38 events. The integrated luminosity errors cancel entirely.

[10] J. Adler *et al.*, SLAC preprint SLAC-PUB-4952, May 1989, submitted for publication to Physical Review Letters.

[11] J.C. Anjos *et al..*, Phys. Rev. Lett. **62**, 125 (1989).

[12] H. Albrecht *et al.*, Phys. Lett. **179B**, 398 (1986)

[13] S. Barlag *et al.*, CERN preprint CERN-EP/88-103, 1988 (unpublished)

[14] M. Alvarez *et al.*, CERN preprint CERN-EP/88-148, 1988 (unpublished)

[15] J. Anjos *et al.*, Phys. Rev. Lett. **60**, 897 (1988)

[16] S. Barlag *et al.*, CERN preprint CERN-EP/88-103, 1988 (unpublished)
[17] J. McKenna, Phd. thesis, University of Toronto, unpublished.
[18] J. Anjos *et al.*, Phys. Rev. Lett. **223**, 267 (1989)
[19] A. Chen *et al.*, Phys. Rev. Lett. **51**, 634 (1983).
[20] D. Hartill, invited talk to this conference.
[21] M. Althoff *et al.*, Phys. Lett. **B136**, 130 (1984).
[22] W. Braunschweig *et al.*, Z. Phys. **C35**, 317 (1987).
[23] H. Albrecht *et al.*, Phys. Lett. **B187**, 425 (1987).
[24] M. Derrick *et al.*, Phys. Rev. Lett. **54**, 2568 (1985).
[25] S. Abachi et al., preprint ANL-HEP-CP-86-71 (1986).
[26] K. L. Au, D. Morgan and M. Pennington, Phys. Rev. **D35**, 1633 (1987).

Figure 1

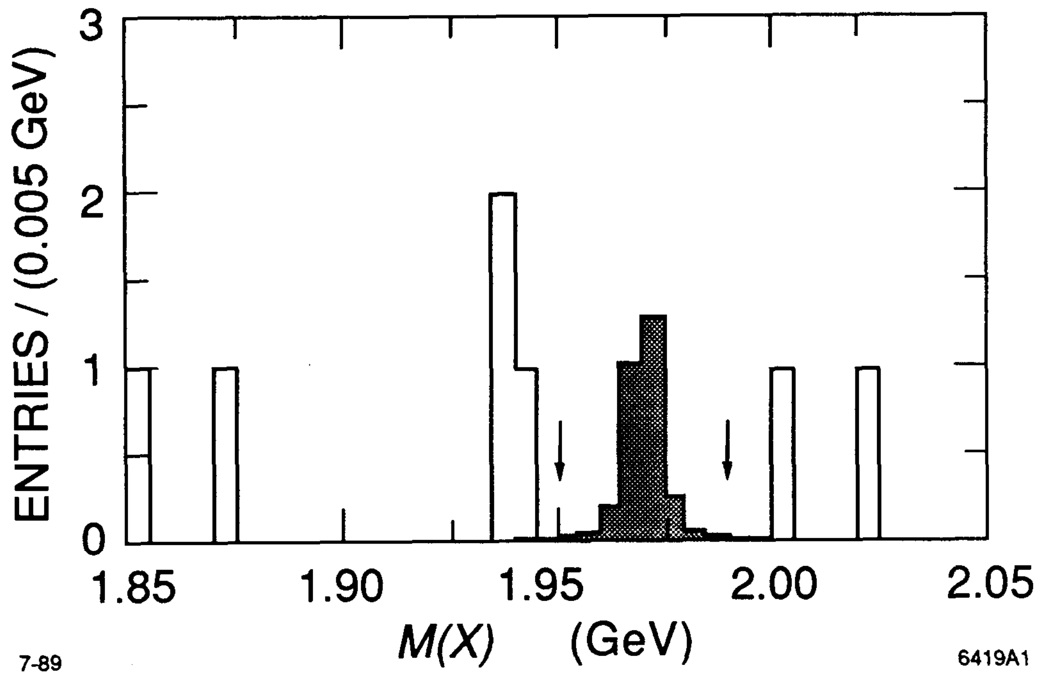

Figure 2

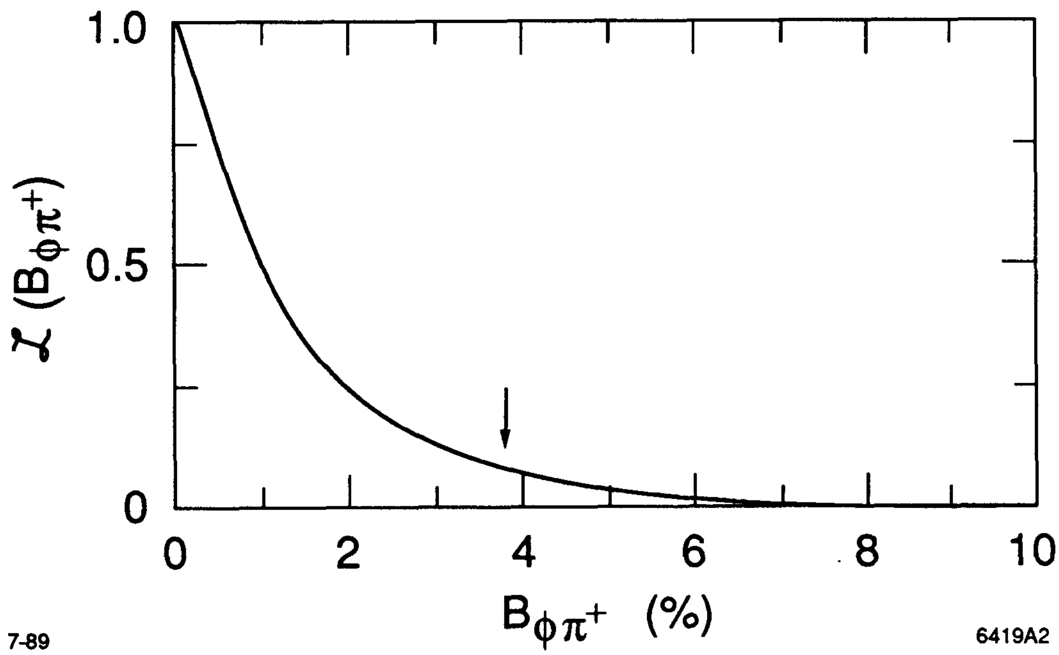

Figure 3

$\pi^+\pi^-$ mass distribution about the Ds mass

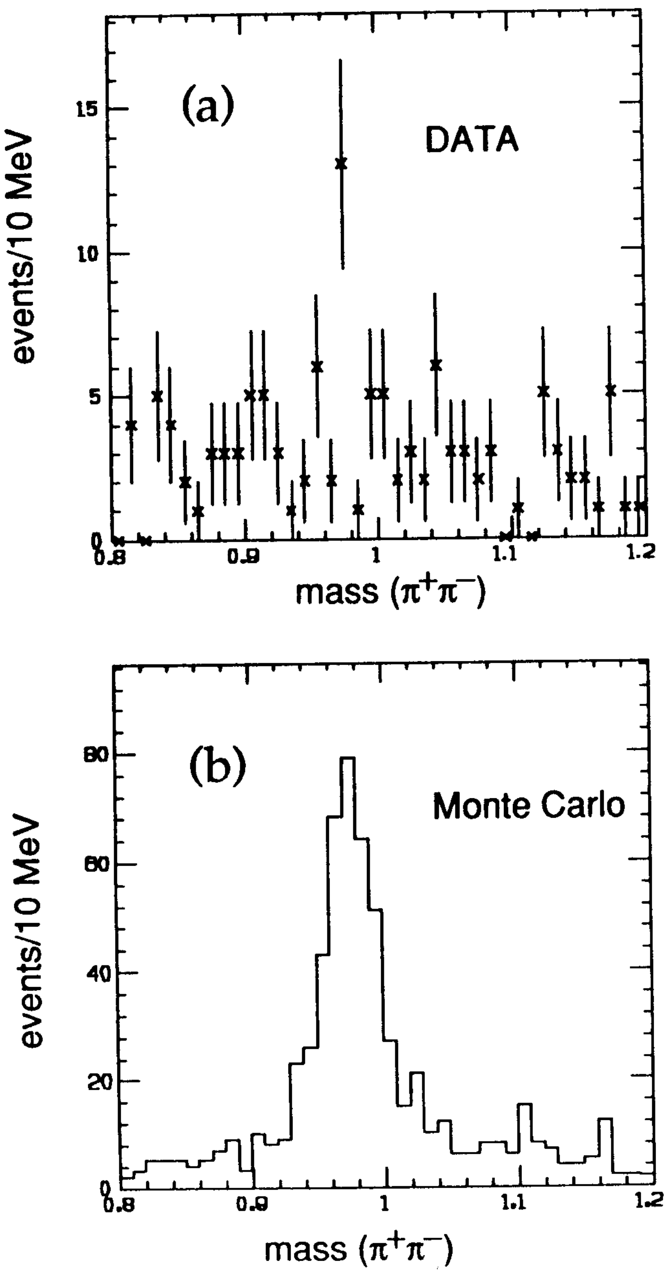

Figure 4

Fit to $\pi^+\pi^-\pi^\pm$ Mass Distribution with $D_s \to f_0\pi^+$