

# CHARMED, STRANGE MESONS ( $C = S = \pm 1$ )

$$D_s^+ = c\bar{s}, D_s^- = \bar{c}s, \quad \text{similarly for } D_s^{*'}s$$

$D_s^\pm$

$$I(J^P) = 0(0^-)$$

$$\text{Mass } m = 1968.27 \pm 0.10 \text{ MeV}$$

$$m_{D_s^\pm} - m_{D^\pm} = 98.69 \pm 0.05 \text{ MeV}$$

$$\text{Mean life } \tau = (500 \pm 7) \times 10^{-15} \text{ s} \quad (S = 1.3)$$

$$c\tau = 149.9 \text{ } \mu\text{m}$$

### CP-violating decay-rate asymmetries

$$A_{CP}(\mu^\pm \nu) = (5 \pm 6)\%$$

$$A_{CP}(K^\pm K_S^0) = (0.08 \pm 0.26)\%$$

$$A_{CP}(K^+ K^- \pi^\pm) = (-0.5 \pm 0.9)\%$$

$$A_{CP}(\phi \pi^\pm) = (-0.38 \pm 0.27)\%$$

$$A_{CP}(K^\pm K_S^0 \pi^0) = (-2 \pm 6)\%$$

$$A_{CP}(2K_S^0 \pi^\pm) = (3 \pm 5)\%$$

$$A_{CP}(K^+ K^- \pi^\pm \pi^0) = (0.0 \pm 3.0)\%$$

$$A_{CP}(K^\pm K_S^0 \pi^+ \pi^-) = (-6 \pm 5)\%$$

$$A_{CP}(K_S^0 K^\mp 2\pi^\pm) = (4.1 \pm 2.8)\%$$

$$A_{CP}(\pi^+ \pi^- \pi^\pm) = (-0.7 \pm 3.1)\%$$

$$A_{CP}(\pi^\pm \eta) = (1.1 \pm 3.1)\%$$

$$A_{CP}(\pi^\pm \eta') = (-2.2 \pm 2.3)\%$$

$$A_{CP}(\eta \pi^\pm \pi^0) = (-1 \pm 4)\%$$

$$A_{CP}(\eta' \pi^\pm \pi^0) = (0 \pm 8)\%$$

$$A_{CP}(K^\pm \pi^0) = (-27 \pm 24)\%$$

$$A_{CP}(\bar{K}^0 / K^0 \pi^\pm) = (0.4 \pm 0.5)\%$$

$$A_{CP}(K_S^0 \pi^\pm) = (3.1 \pm 2.6)\% \quad (S = 1.7)$$

$$A_{CP}(K^\pm \pi^+ \pi^-) = (4 \pm 5)\%$$

$$A_{CP}(K^\pm \eta) = (9 \pm 15)\%$$

$$A_{CP}(K^\pm \eta'(958)) = (6 \pm 19)\%$$

### CP violating asymmetries of P-odd (T-odd) moments

$$A_T(K_S^0 K^\pm \pi^+ \pi^-) = (-14 \pm 8) \times 10^{-3} \text{ [a]}$$

### $D_s^+ \rightarrow \phi \ell^+ \nu_\ell$ form factors

$$r_2 = 0.84 \pm 0.11 \quad (S = 2.4)$$

$$r_V = 1.80 \pm 0.08$$

$$\Gamma_L / \Gamma_T = 0.72 \pm 0.18$$

Unless otherwise noted, the branching fractions for modes with a resonance in the final state include all the decay modes of the resonance.  $D_S^-$  modes are charge conjugates of the modes below.

$D_S^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$\rho$ (MeV/c)
<b>Inclusive modes</b>			
$e^+$ semileptonic	[b] ( 6.5 $\pm$ 0.4 ) %		—
$\pi^+$ anything	(119.3 $\pm$ 1.4 ) %		—
$\pi^-$ anything	( 43.2 $\pm$ 0.9 ) %		—
$\pi^0$ anything	(123 $\pm$ 7 ) %		—
$K^-$ anything	( 18.7 $\pm$ 0.5 ) %		—
$K^+$ anything	( 28.9 $\pm$ 0.7 ) %		—
$K_S^0$ anything	( 19.0 $\pm$ 1.1 ) %		—
$\eta$ anything	[c] ( 29.9 $\pm$ 2.8 ) %		—
$\omega$ anything	( 6.1 $\pm$ 1.4 ) %		—
$\eta'$ anything	[d] ( 10.3 $\pm$ 1.4 ) %	S=1.1	—
$f_0(980)$ anything, $f_0 \rightarrow \pi^+ \pi^-$	< 1.3 %	CL=90%	—
$\phi$ anything	( 15.7 $\pm$ 1.0 ) %		—
$K^+ K^-$ anything	( 15.8 $\pm$ 0.7 ) %		—
$K_S^0 K^+$ anything	( 5.8 $\pm$ 0.5 ) %		—
$K_S^0 K^-$ anything	( 1.9 $\pm$ 0.4 ) %		—
$2K_S^0$ anything	( 1.70 $\pm$ 0.32 ) %		—
$2K^+$ anything	< 2.6 $\times 10^{-3}$	CL=90%	—
$2K^-$ anything	< 6 $\times 10^{-4}$	CL=90%	—
<b>Leptonic and semileptonic modes</b>			
$e^+ \nu_e$	< 8.3 $\times 10^{-5}$	CL=90%	984
$\mu^+ \nu_\mu$	( 5.56 $\pm$ 0.25 ) $\times 10^{-3}$		981
$\tau^+ \nu_\tau$	( 5.55 $\pm$ 0.24 ) %		182
$K^+ K^- e^+ \nu_e$	—		851
$\phi e^+ \nu_e$	[e] ( 2.39 $\pm$ 0.23 ) %	S=1.8	720
$\eta e^+ \nu_e + \eta'(958) e^+ \nu_e$	[e] ( 2.96 $\pm$ 0.29 ) %		—
$\eta e^+ \nu_e$	[e] ( 2.28 $\pm$ 0.24 ) %		908
$\eta'(958) e^+ \nu_e$	[e] ( 6.8 $\pm$ 1.6 ) $\times 10^{-3}$		751
$\omega e^+ \nu_e$	[f] < 2.0 $\times 10^{-3}$	CL=90%	829
$K^0 e^+ \nu_e$	( 3.9 $\pm$ 0.9 ) $\times 10^{-3}$		921
$K^*(892)^0 e^+ \nu_e$	[e] ( 1.8 $\pm$ 0.4 ) $\times 10^{-3}$		782
<b>Hadronic modes with a <math>K\bar{K}</math> pair</b>			
$K^+ K_S^0$	( 1.50 $\pm$ 0.05 ) %		850
$K^+ \bar{K}^0$	( 2.95 $\pm$ 0.14 ) %		850
$K^+ K^- \pi^+$	[g] ( 5.45 $\pm$ 0.17 ) %	S=1.2	805
$\phi \pi^+$	[e,h] ( 4.5 $\pm$ 0.4 ) %		712
$\phi \pi^+, \phi \rightarrow K^+ K^-$	[h] ( 2.27 $\pm$ 0.08 ) %		712

$K^+ \bar{K}^*(892)^0, \bar{K}^{*0} \rightarrow$ $K^- \pi^+$	( 2.61 ± 0.09 ) %	416
$f_0(980) \pi^+, f_0 \rightarrow K^+ K^-$	( 1.15 ± 0.32 ) %	732
$f_0(1370) \pi^+, f_0 \rightarrow K^+ K^-$	( 7 ± 5 ) × 10 <sup>-4</sup>	—
$f_0(1710) \pi^+, f_0 \rightarrow K^+ K^-$	( 6.7 ± 2.9 ) × 10 <sup>-4</sup>	198
$K^+ \bar{K}_0^*(1430)^0, \bar{K}_0^* \rightarrow$ $K^- \pi^+$	( 1.9 ± 0.4 ) × 10 <sup>-3</sup>	218
$K^+ K_S^0 \pi^0$	( 1.52 ± 0.22 ) %	805
$2K_S^0 \pi^+$	( 7.7 ± 0.6 ) × 10 <sup>-3</sup>	802
$K^0 \bar{K}^0 \pi^+$	—	802
$K^*(892)^+ \bar{K}^0$	[e] ( 5.4 ± 1.2 ) %	683
$K^+ K^- \pi^+ \pi^0$	( 6.3 ± 0.6 ) %	748
$\phi \rho^+$	[e] ( 8.4 <sup>+1.9</sup> <sub>-2.3</sub> ) %	401
$K_S^0 K^- 2\pi^+$	( 1.67 ± 0.10 ) %	744
$K^*(892)^+ \bar{K}^*(892)^0$	[e] ( 7.2 ± 2.6 ) %	416
$K^+ K_S^0 \pi^+ \pi^-$	( 1.03 ± 0.10 ) %	744
$K^+ K^- 2\pi^+ \pi^-$	( 8.7 ± 1.5 ) × 10 <sup>-3</sup>	673
$\phi 2\pi^+ \pi^-$	[e] ( 1.21 ± 0.16 ) %	640
$K^+ K^- \rho^0 \pi^+$ non- $\phi$	< 2.6 × 10 <sup>-4</sup> CL=90%	249
$\phi \rho^0 \pi^+, \phi \rightarrow K^+ K^-$	( 6.5 ± 1.3 ) × 10 <sup>-3</sup>	181
$\phi a_1(1260)^+, \phi \rightarrow$ $K^+ K^-, a_1^+ \rightarrow \rho^0 \pi^+$	( 7.5 ± 1.2 ) × 10 <sup>-3</sup>	†
$K^+ K^- 2\pi^+ \pi^-$ nonresonant	( 9 ± 7 ) × 10 <sup>-4</sup>	673
$2K_S^0 2\pi^+ \pi^-$	( 9 ± 4 ) × 10 <sup>-4</sup>	669

**Hadronic modes without K's**

$\pi^+ \pi^0$	< 3.5 × 10 <sup>-4</sup> CL=90%	975
$2\pi^+ \pi^-$	( 1.09 ± 0.05 ) % S=1.1	959
$\rho^0 \pi^+$	( 2.0 ± 1.2 ) × 10 <sup>-4</sup>	825
$\pi^+ (\pi^+ \pi^-)_{S\text{-wave}}$	[i] ( 9.1 ± 0.4 ) × 10 <sup>-3</sup>	959
$f_2(1270) \pi^+, f_2 \rightarrow \pi^+ \pi^-$	( 1.10 ± 0.20 ) × 10 <sup>-3</sup>	559
$\rho(1450)^0 \pi^+, \rho^0 \rightarrow \pi^+ \pi^-$	( 3.0 ± 2.0 ) × 10 <sup>-4</sup>	421
$\pi^+ 2\pi^0$	( 6.5 ± 1.3 ) × 10 <sup>-3</sup>	960
$2\pi^+ \pi^- \pi^0$	—	935
$\eta \pi^+$	[e] ( 1.70 ± 0.09 ) % S=1.1	902
$\omega \pi^+$	[e] ( 2.4 ± 0.6 ) × 10 <sup>-3</sup>	822
$3\pi^+ 2\pi^-$	( 8.0 ± 0.8 ) × 10 <sup>-3</sup>	899
$2\pi^+ \pi^- 2\pi^0$	—	902
$\eta \rho^+$	[e] ( 8.9 ± 0.8 ) %	724
$\eta \pi^+ \pi^0$	( 9.2 ± 1.2 ) %	885
$\omega \pi^+ \pi^0$	[e] ( 2.8 ± 0.7 ) %	802
$3\pi^+ 2\pi^- \pi^0$	( 4.9 ± 3.2 ) %	856
$\omega 2\pi^+ \pi^-$	[e] ( 1.6 ± 0.5 ) %	766

$\eta'(958)\pi^+$	[d,e] ( 3.94±0.25 ) %		743
$3\pi^+ 2\pi^- 2\pi^0$	—		803
$\omega\eta\pi^+$	[e] < 2.13 %	CL=90%	654
$\eta'(958)\rho^+$	[d,e] ( 5.8 ±1.5 ) %		465
$\eta'(958)\pi^+\pi^0$	( 5.6 ±0.8 ) %		720
$\eta'(958)\pi^+\pi^0$ nonresonant	< 5.1 %	CL=90%	720

**Modes with one or three K's**

$K^+\pi^0$	( 6.3 ±2.1 ) × 10 <sup>-4</sup>		917
$K_S^0\pi^+$	( 1.22±0.06 ) × 10 <sup>-3</sup>		916
$K^+\eta$	[e] ( 1.77±0.35 ) × 10 <sup>-3</sup>		835
$K^+\omega$	[e] < 2.4 × 10 <sup>-3</sup>	CL=90%	741
$K^+\eta'(958)$	[e] ( 1.8 ±0.6 ) × 10 <sup>-3</sup>		646
$K^+\pi^+\pi^-$	( 6.6 ±0.4 ) × 10 <sup>-3</sup>		900
$K^+\rho^0$	( 2.5 ±0.4 ) × 10 <sup>-3</sup>		745
$K^+\rho(1450)^0, \rho^0 \rightarrow \pi^+\pi^-$	( 7.0 ±2.4 ) × 10 <sup>-4</sup>		—
$K^*(892)^0\pi^+, K^{*0} \rightarrow$	( 1.42±0.24 ) × 10 <sup>-3</sup>		775
$K^+\pi^-$			
$K^*(1410)^0\pi^+, K^{*0} \rightarrow$	( 1.24±0.29 ) × 10 <sup>-3</sup>		—
$K^+\pi^-$			
$K^*(1430)^0\pi^+, K^{*0} \rightarrow$	( 5.0 ±3.5 ) × 10 <sup>-4</sup>		—
$K^+\pi^-$			
$K^+\pi^+\pi^-$ nonresonant	( 1.04±0.34 ) × 10 <sup>-3</sup>		900
$K^0\pi^+\pi^0$	( 1.00±0.18 ) %		899
$K_S^0 2\pi^+\pi^-$	( 3.0 ±1.1 ) × 10 <sup>-3</sup>		870
$K^+\omega\pi^0$	[e] < 8.2 × 10 <sup>-3</sup>	CL=90%	684
$K^+\omega\pi^+\pi^-$	[e] < 5.4 × 10 <sup>-3</sup>	CL=90%	603
$K^+\omega\eta$	[e] < 7.9 × 10 <sup>-3</sup>	CL=90%	366
$2K^+K^-$	( 2.18±0.21 ) × 10 <sup>-4</sup>		627
$\phi K^+, \phi \rightarrow K^+K^-$	( 8.9 ±2.0 ) × 10 <sup>-5</sup>		—

**Doubly Cabibbo-suppressed modes**

$2K^+\pi^-$	( 1.27±0.13 ) × 10 <sup>-4</sup>		805
$K^+K^*(892)^0, K^{*0} \rightarrow$	( 6.0 ±3.4 ) × 10 <sup>-5</sup>		—
$K^+\pi^-$			

**Baryon-antibaryon mode**

$p\bar{n}$	( 1.3 ±0.4 ) × 10 <sup>-3</sup>		295
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**$\Delta C = 1$  weak neutral current (C1) modes,  
Lepton family number (LF), or  
Lepton number (L) violating modes**

$\pi^+ e^+ e^-$	[j] < 1.3 × 10 <sup>-5</sup>	CL=90%	979
$\pi^+ \phi, \phi \rightarrow e^+ e^-$	[k] ( 6 <sup>+8</sup> / <sub>-4</sub> ) × 10 <sup>-6</sup>		—
$\pi^+ \mu^+ \mu^-$	[j] < 4.1 × 10 <sup>-7</sup>	CL=90%	968
$K^+ e^+ e^-$	C1 < 3.7 × 10 <sup>-6</sup>	CL=90%	922

$K^+ \mu^+ \mu^-$	CI	< 2.1	$\times 10^{-5}$	CL=90%	909
$K^*(892)^+ \mu^+ \mu^-$	CI	< 1.4	$\times 10^{-3}$	CL=90%	765
$\pi^+ e^+ \mu^-$	LF	< 1.2	$\times 10^{-5}$	CL=90%	976
$\pi^+ e^- \mu^+$	LF	< 2.0	$\times 10^{-5}$	CL=90%	976
$K^+ e^+ \mu^-$	LF	< 1.4	$\times 10^{-5}$	CL=90%	919
$K^+ e^- \mu^+$	LF	< 9.7	$\times 10^{-6}$	CL=90%	919
$\pi^- 2e^+$	L	< 4.1	$\times 10^{-6}$	CL=90%	979
$\pi^- 2\mu^+$	L	< 1.2	$\times 10^{-7}$	CL=90%	968
$\pi^- e^+ \mu^+$	L	< 8.4	$\times 10^{-6}$	CL=90%	976
$K^- 2e^+$	L	< 5.2	$\times 10^{-6}$	CL=90%	922
$K^- 2\mu^+$	L	< 1.3	$\times 10^{-5}$	CL=90%	909
$K^- e^+ \mu^+$	L	< 6.1	$\times 10^{-6}$	CL=90%	919
$K^*(892)^- 2\mu^+$	L	< 1.4	$\times 10^{-3}$	CL=90%	765

### $D_s^{*\pm}$

$$I(J^P) = 0(??)$$

$J^P$  is natural, width and decay modes consistent with  $1^-$ .

Mass  $m = 2112.1 \pm 0.4$  MeV

$m_{D_s^{*\pm}} - m_{D_s^\pm} = 143.8 \pm 0.4$  MeV

Full width  $\Gamma < 1.9$  MeV, CL = 90%

$D_s^{*-}$  modes are charge conjugates of the modes below.

$D_s^{*+}$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D_s^+ \gamma$	(93.5±0.7) %	139
$D_s^+ \pi^0$	( 5.8±0.7) %	48
$D_s^+ e^+ e^-$	( 6.7±1.6) $\times 10^{-3}$	139

### $D_{s0}^*(2317)^\pm$

$$I(J^P) = 0(0^+)$$

$J, P$  need confirmation.

$J^P$  is natural, low mass consistent with  $0^+$ .

Mass  $m = 2317.7 \pm 0.6$  MeV ( $S = 1.1$ )

$m_{D_{s0}^*(2317)^\pm} - m_{D_s^\pm} = 349.4 \pm 0.6$  MeV ( $S = 1.1$ )

Full width  $\Gamma < 3.8$  MeV, CL = 95%

$D_{s0}^*(2317)^-$  modes are charge conjugates of modes below.

$D_{s0}^*(2317)^\pm$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D_s^+ \pi^0$	seen	298
$D_s^+ \pi^0 \pi^0$	not seen	205

**$D_{s1}(2460)^\pm$**

$I(J^P) = 0(1^+)$

Mass  $m = 2459.5 \pm 0.6$  MeV (S = 1.1)

$m_{D_{s1}(2460)^\pm} - m_{D_s^{*\pm}} = 347.3 \pm 0.7$  MeV (S = 1.2)

$m_{D_{s1}(2460)^\pm} - m_{D_s^\pm} = 491.2 \pm 0.6$  MeV (S = 1.1)

Full width  $\Gamma < 3.5$  MeV, CL = 95%

$D_{s1}(2460)^-$  modes are charge conjugates of the modes below.

<b><math>D_{s1}(2460)^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$D_s^{*+} \pi^0$	(48 ± 11) %		297
$D_s^+ \gamma$	(18 ± 4) %		442
$D_s^+ \pi^+ \pi^-$	(4.3 ± 1.3) %	S=1.1	363
$D_s^{*+} \gamma$	< 8 %	CL=90%	323
$D_{s0}^*(2317)^+ \gamma$	(3.7 <sup>+5.0</sup> <sub>-2.4</sub> ) %		138

**$D_{s1}(2536)^\pm$**

$I(J^P) = 0(1^+)$

$J, P$  need confirmation.

Mass  $m = 2535.10 \pm 0.06$  MeV

Full width  $\Gamma = 0.92 \pm 0.05$  MeV

$D_{s1}(2536)^-$  modes are charge conjugates of the modes below.

<b><math>D_{s1}(2536)^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$D^*(2010)^+ K^0$	0.85 ± 0.12		149
$(D^*(2010)^+ K^0)_{S-wave}$	0.61 ± 0.09		149
$D^+ \pi^- K^+$	0.028 ± 0.005		176
$D^*(2007)^0 K^+$	<b>DEFINED AS 1</b>		167
$D^+ K^0$	< 0.34	90%	381
$D^0 K^+$	< 0.12	90%	391
$D_s^{*+} \gamma$	possibly seen		388
$D_s^+ \pi^+ \pi^-$	seen		437

**$D_{s2}^*(2573)$**

$I(J^P) = 0(2^+)$

$J^P$  is natural, width and decay modes consistent with  $2^+$ .

Mass  $m = 2569.1 \pm 0.8$  MeV (S = 2.4)

Full width  $\Gamma = 16.9 \pm 0.8$  MeV

$D_{s2}^*(2573)^-$  modes are charge conjugates of the modes below.

<b><math>D_{s2}^*(2573)^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$D^0 K^+$	seen	431
$D^*(2007)^0 K^+$	not seen	238

**$D_{s1}^*(2700)^\pm$** 

$$I(J^P) = 0(1^-)$$

$$\text{Mass } m = 2708.3_{-3.4}^{+4.0} \text{ MeV}$$

$$\text{Full width } \Gamma = 120 \pm 11 \text{ MeV}$$

## NOTES

- [a] See the Particle Listings for the (complicated) definition of this quantity.
- [b] This is the purely  $e^+$  semileptonic branching fraction: the  $e^+$  fraction from  $\tau^+$  decays has been subtracted off. The sum of our (non- $\tau$ )  $e^+$  exclusive fractions — an  $e^+ \nu_e$  with an  $\eta$ ,  $\eta'$ ,  $\phi$ ,  $K^0$ ,  $K^{*0}$ , or  $f_0(980)$  — is  $7.0 \pm 0.4$  %
- [c] This fraction includes  $\eta$  from  $\eta'$  decays.
- [d] Two times (to include  $\mu$  decays) the  $\eta' e^+ \nu_e$  branching fraction, plus the  $\eta' \pi^+$ ,  $\eta' \rho^+$ , and  $\eta' K^+$  fractions, is  $(18.6 \pm 2.3)\%$ , which considerably exceeds the inclusive  $\eta'$  fraction of  $(11.7 \pm 1.8)\%$ . Our best guess is that the  $\eta' \rho^+$  fraction,  $(12.5 \pm 2.2)\%$ , is too large.
- [e] This branching fraction includes all the decay modes of the final-state resonance.
- [f] A test for  $u\bar{u}$  or  $d\bar{d}$  content in the  $D_s^+$ . Neither Cabibbo-favored nor Cabibbo-suppressed decays can contribute, and  $\omega$ - $\phi$  mixing is an unlikely explanation for any fraction above about  $2 \times 10^{-4}$ .
- [g] The branching fraction for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers in the Particle Listings.
- [h] We decouple the  $D_s^+ \rightarrow \phi \pi^+$  branching fraction obtained from mass projections (and used to get some of the other branching fractions) from the  $D_s^+ \rightarrow \phi \pi^+$ ,  $\phi \rightarrow K^+ K^-$  branching fraction obtained from the Dalitz-plot analysis of  $D_s^+ \rightarrow K^+ K^- \pi^+$ . That is, the ratio of these two branching fractions is not exactly the  $\phi \rightarrow K^+ K^-$  branching fraction 0.491.
- [i] This is the average of a model-independent and a  $K$ -matrix parametrization of the  $\pi^+ \pi^-$   $S$ -wave and is a sum over several  $f_0$  mesons.
- [j] This mode is not a useful test for a  $\Delta C=1$  weak neutral current because both quarks must change flavor in this decay.
- [k] This is *not* a test for the  $\Delta C=1$  weak neutral current, but leads to the  $\pi^+ \ell^+ \ell^-$  final state.