

# LIGHT UNFLAVORED MESONS ( $S = C = B = 0$ )

For  $I = 1$  ( $\pi, \rho, \omega$ ):  $u\bar{d}, (u\bar{u}-d\bar{d})/\sqrt{2}, d\bar{u}$ ;  
for  $I = 0$  ( $\eta, \eta', h, h', \omega, \phi, f, f'$ ):  $c_1(u\bar{u} + d\bar{d}) + c_2(s\bar{s})$

$\pi^\pm$

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

Mass  $m = 139.57039 \pm 0.00018$  MeV ( $S = 1.8$ )

Mean life  $\tau = (2.6033 \pm 0.0005) \times 10^{-8}$  s ( $S = 1.2$ )

$$c\tau = 7.8045$$
 m

$\pi^\pm \rightarrow \ell^\pm \nu \gamma$  form factors [a]

$$F_V = 0.0254 \pm 0.0017$$

$$F_A = 0.0119 \pm 0.0001$$

$$F_V \text{ slope parameter } a = 0.10 \pm 0.06$$

$$R = 0.059^{+0.009}_{-0.008}$$

$\pi^-$  modes are charge conjugates of the modes below.

For decay limits to particles which are not established, see the section on Searches for Axions and Other Very Light Bosons.

$\pi^+$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$\mu^+ \nu_\mu$	[b] (99.98770 ± 0.00004) %		30
$\mu^+ \nu_\mu \gamma$	[c] ( 2.00 ± 0.25 ) × 10 <sup>-4</sup>		30
$e^+ \nu_e$	[b] ( 1.230 ± 0.004 ) × 10 <sup>-4</sup>		70
$e^+ \nu_e \gamma$	[c] ( 7.39 ± 0.05 ) × 10 <sup>-7</sup>		70
$e^+ \nu_e \pi^0$	( 1.036 ± 0.006 ) × 10 <sup>-8</sup>		4
$e^+ \nu_e e^+ e^-$	( 3.2 ± 0.5 ) × 10 <sup>-9</sup>		70
$\mu^+ \nu_\mu \nu \bar{\nu}$	< 9	× 10 <sup>-6</sup> 90%	30
$e^+ \nu_e \nu \bar{\nu}$	< 1.6	× 10 <sup>-7</sup> 90%	70
<b>Lepton Family number (LF) or Lepton number (L) violating modes</b>			
$\mu^+ \bar{\nu}_e$	L [d] < 1.5	× 10 <sup>-3</sup> 90%	30
$\mu^+ \nu_e$	LF [d] < 8.0	× 10 <sup>-3</sup> 90%	30
$\mu^- e^+ e^+ \nu$	LF < 1.6	× 10 <sup>-6</sup> 90%	30

$\pi^0$

$$I^G(J^{PC}) = 1^-(0^-+)$$

 Mass  $m = 134.9768 \pm 0.0005$  MeV (S = 1.1)

 $m_{\pi^\pm} - m_{\pi^0} = 4.5936 \pm 0.0005$  MeV

 Mean life  $\tau = (8.43 \pm 0.13) \times 10^{-17}$  s (S = 1.2)

 $c\tau = 25.3$  nm

 For decay limits to particles which are not established, see the appropriate Search sections ( $A^0$  (axion) and Other Light Boson ( $X^0$ ) Searches, etc.).

$\pi^0$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)	
$2\gamma$	$(98.823 \pm 0.034)$ %	S=1.5	67	
$e^+ e^- \gamma$	$(1.174 \pm 0.035)$ %	S=1.5	67	
$\gamma$ positronium	$(1.82 \pm 0.29) \times 10^{-9}$		67	
$e^+ e^+ e^- e^-$	$(3.34 \pm 0.16) \times 10^{-5}$		67	
$e^+ e^-$	$(6.46 \pm 0.33) \times 10^{-8}$		67	
$4\gamma$	$< 2$	$\times 10^{-8}$ CL=90%	67	
invisible	$< 4.4$	$\times 10^{-9}$ CL=90%	–	
$\nu_e \bar{\nu}_e$	$< 1.7$	$\times 10^{-6}$ CL=90%	67	
$\nu_\mu \bar{\nu}_\mu$	$< 1.6$	$\times 10^{-6}$ CL=90%	67	
$\nu_\tau \bar{\nu}_\tau$	$< 2.1$	$\times 10^{-6}$ CL=90%	67	
$\gamma \nu \bar{\nu}$	$< 1.9$	$\times 10^{-7}$ CL=90%	67	
<b>Charge conjugation (C) or Lepton Family number (LF) violating modes</b>				
$3\gamma$	C	$< 3.1$	$\times 10^{-8}$ CL=90%	67
$\mu^+ e^-$	LF	$< 3.8$	$\times 10^{-10}$ CL=90%	26
$\mu^- e^+$	LF	$< 3.2$	$\times 10^{-10}$ CL=90%	26
$\mu^+ e^- + \mu^- e^+$	LF	$< 3.6$	$\times 10^{-10}$ CL=90%	26

$\eta$

$$I^G(J^{PC}) = 0^+(0^-+)$$

 Mass  $m = 547.862 \pm 0.017$  MeV

 Full width  $\Gamma = 1.31 \pm 0.05$  keV

**C-nonconserving decay parameters**
 $\pi^+ \pi^- \pi^0$  left-right asymmetry =  $(0.09^{+0.11}_{-0.12}) \times 10^{-2}$ 
 $\pi^+ \pi^- \pi^0$  sextant asymmetry =  $(0.12^{+0.10}_{-0.11}) \times 10^{-2}$ 
 $\pi^+ \pi^- \pi^0$  quadrant asymmetry =  $(-0.09 \pm 0.09) \times 10^{-2}$ 
 $\pi^+ \pi^- \gamma$  left-right asymmetry =  $(0.9 \pm 0.4) \times 10^{-2}$ 
 $\pi^+ \pi^- \gamma$   $\beta$  (D-wave) =  $-0.02 \pm 0.07$  (S = 1.3)

**CP-nonconserving decay parameters**
 $\pi^+ \pi^- e^+ e^-$  decay-plane asymmetry  $A_\phi = (-1.6 \pm 2.6) \times 10^{-2}$

**Other decay parameters**

$\pi^0\pi^0\pi^0$  Dalitz plot  $\alpha = -0.0296 \pm 0.0016$  ( $S = 1.7$ )

Parameter  $\Lambda$  in  $\eta \rightarrow \ell^+\ell^-\gamma$  decay =  $0.731 \pm 0.013 \text{ GeV}/c^2$  ( $S = 1.3$ )

$\eta$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
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**Neutral modes**

neutral modes	$(71.95 \pm 0.29) \%$	S=1.3	–
$2\gamma$	$(39.36 \pm 0.18) \%$	S=1.1	274
$3\pi^0$	$(32.56 \pm 0.21) \%$	S=1.2	179
$\pi^0 2\gamma$	$(2.55 \pm 0.22) \times 10^{-4}$		257
$2\pi^0 2\gamma$	$< 1.2 \times 10^{-3}$	CL=90%	238
$4\gamma$	$< 2.8 \times 10^{-4}$	CL=90%	274
invisible	$< 2.4 \times 10^{-5}$	CL=90%	–

**Charged modes**

charged modes	$(28.05 \pm 0.29) \%$	S=1.3	–
$\pi^+\pi^-\pi^0$	$(23.02 \pm 0.25) \%$	S=1.2	174
$\pi^+\pi^-\gamma$	$(4.28 \pm 0.07) \%$	S=1.1	236
$e^+e^-\gamma$	$(6.96 \pm 0.18) \times 10^{-3}$		274
$\mu^+\mu^-\gamma$	$(2.98 \pm 0.13) \times 10^{-4}$		253
$e^+e^-$	$< 7 \times 10^{-7}$	CL=90%	274
$\mu^+\mu^-$	$(5.8 \pm 0.8) \times 10^{-6}$		253
$2e^+2e^-$	$(2.40 \pm 0.22) \times 10^{-5}$		274
$\pi^+\pi^-e^+e^-(\gamma)$	$(2.76 \pm 0.16) \times 10^{-4}$	S=1.5	235
$e^+e^-\mu^+\mu^-$	$< 6.88 \times 10^{-6}$	CL=90%	253
$2\mu^+2\mu^-$	$(5.0 \pm 1.3) \times 10^{-9}$		161
$\mu^+\mu^-\pi^+\pi^-$	$< 4.0 \times 10^{-7}$	CL=90%	113
$\pi^+e^-\bar{\nu}_e + \text{c.c.}$	$< 1.7 \times 10^{-4}$	CL=90%	256
$\pi^+\pi^-2\gamma$	$< 2.1 \times 10^{-3}$		236
$\pi^+\pi^-\pi^0\gamma$	$< 6 \times 10^{-4}$	CL=90%	174
$\pi^0\mu^+\mu^-\gamma$	$< 3 \times 10^{-6}$	CL=90%	210

**Charge conjugation (C), Parity (P),  
Charge conjugation  $\times$  Parity (CP), or  
Lepton Family number (LF) violating modes**

$\pi^0\gamma$	C	$[e] < 9$	$\times 10^{-5}$	CL=90%	257
$\pi^+\pi^-$	P,CP	$< 4.4$	$\times 10^{-6}$	CL=90%	236
$2\pi^0$	P,CP	$< 3.5$	$\times 10^{-4}$	CL=90%	238
$2\pi^0\gamma$	C	$< 5$	$\times 10^{-4}$	CL=90%	238
$3\pi^0\gamma$	C	$< 6$	$\times 10^{-5}$	CL=90%	179
$3\gamma$	C	$< 1.6$	$\times 10^{-5}$	CL=90%	274
$4\pi^0$	P,CP	$< 6.9$	$\times 10^{-7}$	CL=90%	40

$\pi^0 e^+ e^-$	C	$[f] < 8$	$\times 10^{-6}$	CL=90%	257
$\pi^0 \mu^+ \mu^-$	C	$[f] < 5$	$\times 10^{-6}$	CL=90%	210
$\mu^+ e^- + \mu^- e^+$	LF	$< 6$	$\times 10^{-6}$	CL=90%	264
$\pi^+ \pi^+ e^- e^- + c.c.$	LF	$< 4.6$	$\times 10^{-6}$	CL=90%	235

**$f_0(500)$**

$$I^G(J^{PC}) = 0^+(0^{++})$$

also known as  $\sigma$ ; was  $f_0(600)$ ,  $f_0(400-1200)$

See the review on "Scalar Mesons below 1 GeV."

Mass (T-Matrix Pole  $\sqrt{s}$ ) = (400–550)– $i$ (200–350) MeV

Mass (Breit-Wigner) = 400 to 800 MeV

Full width (Breit-Wigner) = 100 to 800 MeV

<b><math>f_0(500)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi \pi$	seen	–
$\gamma \gamma$	seen	–

**$\rho(770)$**

$$I^G(J^{PC}) = 1^+(1^{--})$$

See the review on "Spectroscopy of Light Meson Resonances."

T-Matrix Pole  $\sqrt{s} = (761-765) - i(71-74)$  MeV

$\rho^0$  mass (Breit-Wigner) =  $775.26 \pm 0.23$  MeV [ $g$ ]

$\rho^\pm$  mass (Breit-Wigner) =  $775.11 \pm 0.34$  MeV [ $h$ ]

$\rho^0$  full width (Breit-Wigner) =  $147.4 \pm 0.8$  MeV [ $g$ ] (S = 2.0)

$\rho^\pm$  full width (Breit-Wigner) =  $149.1 \pm 0.8$  MeV [ $h$ ]

<b><math>\rho(770)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\pi \pi$	$\sim 100$ %		363

**$\rho(770)^\pm$  decays**

$\pi^\pm \gamma$	$(4.5 \pm 0.5) \times 10^{-4}$	S=2.2	375
$\pi^\pm \eta$	$< 6 \times 10^{-3}$	CL=84%	152
$\pi^\pm \pi^+ \pi^- \pi^0$	$< 2.0 \times 10^{-3}$	CL=84%	254

**$\rho(770)^0$  decays**

$\pi^+ \pi^- \gamma$	$(9.9 \pm 1.6) \times 10^{-3}$		362
$\pi^0 \gamma$	$(4.7 \pm 0.8) \times 10^{-4}$	S=1.7	376
$\eta \gamma$	$(3.00 \pm 0.21) \times 10^{-4}$		194
$\pi^0 \pi^0 \gamma$	$(4.5 \pm 0.8) \times 10^{-5}$		363
$\mu^+ \mu^-$	[ $i$ ] $(4.55 \pm 0.28) \times 10^{-5}$		373
$e^+ e^-$	[ $i$ ] $(4.72 \pm 0.05) \times 10^{-5}$		388

$\pi^+ \pi^- \pi^0$	$( 9 \pm 4 ) \times 10^{-5}$	323
$\pi^+ \pi^- \pi^+ \pi^-$	$( 1.8 \pm 0.9 ) \times 10^{-5}$	251
$\pi^+ \pi^- \pi^0 \pi^0$	$( 1.6 \pm 0.8 ) \times 10^{-5}$	256
$\pi^0 e^+ e^-$	$< 1.2 \times 10^{-5}$	CL=90% 376

**$\omega(782)$**

$$I^G(J^{PC}) = 0^-(1^- -)$$

Mass  $m = 782.66 \pm 0.13$  MeV ( $S = 2.0$ )

Full width  $\Gamma = 8.68 \pm 0.13$  MeV

<b><math>\omega(782)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\pi^+ \pi^- \pi^0$	$(89.2 \pm 0.7) \%$		327
$\pi^0 \gamma$	$( 8.33 \pm 0.25 ) \%$	S=2.1	380
$\pi^+ \pi^-$	$( 1.53 \pm 0.12 ) \%$	S=1.2	366
neutrals (excluding $\pi^0 \gamma$ )	$( 7 \begin{smallmatrix} +7 \\ -5 \end{smallmatrix} ) \times 10^{-3}$	S=1.1	—
$\eta \gamma$	$( 4.5 \pm 0.4 ) \times 10^{-4}$	S=1.1	200
$\pi^0 e^+ e^-$	$( 7.7 \pm 0.6 ) \times 10^{-4}$		380
$\pi^0 \mu^+ \mu^-$	$( 1.34 \pm 0.18 ) \times 10^{-4}$	S=1.5	349
$e^+ e^-$	$( 7.41 \pm 0.19 ) \times 10^{-5}$	S=1.8	391
$\pi^+ \pi^- \pi^0 \pi^0$	$< 2 \times 10^{-4}$	CL=90%	262
$\pi^+ \pi^- e^+ e^-$	$< 2.8 \times 10^{-6}$	CL=90%	365
$\pi^+ \pi^- \gamma$	$< 3.6 \times 10^{-3}$	CL=95%	366
$\pi^+ \pi^- \pi^+ \pi^-$	$< 1 \times 10^{-3}$	CL=90%	256
$\pi^0 \pi^0 \gamma$	$( 6.7 \pm 1.1 ) \times 10^{-5}$		367
$\eta \pi^0 \gamma$	$< 3.3 \times 10^{-5}$	CL=90%	162
$\mu^+ \mu^-$	$( 7.4 \pm 1.8 ) \times 10^{-5}$		377
$3\gamma$	$< 1.9 \times 10^{-4}$	CL=95%	391

**Charge conjugation (C) violating modes**

$\eta \pi^0$	C	$< 2.1 \times 10^{-4}$	CL=90%	162
$2\pi^0$	C	$< 2.2 \times 10^{-4}$	CL=90%	367
$3\pi^0$	C	$< 2.3 \times 10^{-4}$	CL=90%	330
invisible		$< 7 \times 10^{-5}$	CL=90%	—

**$\eta'(958)$**

$$I^G(J^{PC}) = 0^+(0^- +)$$

Mass  $m = 957.78 \pm 0.06$  MeV

Full width  $\Gamma = 0.188 \pm 0.006$  MeV

<b><math>\eta'(958)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\pi^+ \pi^- \eta$	$(42.5 \pm 0.5) \%$		232
$\rho^0 \gamma$ (including non-resonant $\pi^+ \pi^- \gamma$ )	$(29.48 \pm 0.35) \%$		165

$\pi^0\pi^0\eta$	(22.4 ±0.5 ) %		239
$\omega\gamma$	( 2.52 ±0.07 ) %		159
$\omega e^+ e^-$	( 2.0 ±0.4 ) × 10 <sup>-4</sup>		159
$\gamma\gamma$	( 2.307±0.033) %		479
$3\pi^0$	( 2.50 ±0.17 ) × 10 <sup>-3</sup>		430
$\mu^+ \mu^- \gamma$	( 1.13 ±0.28 ) × 10 <sup>-4</sup>		467
$\pi^+ \pi^- \mu^+ \mu^-$	( 2.13 ±0.13 ) × 10 <sup>-5</sup>		401
$\pi^+ \pi^- \pi^0$	( 3.61 ±0.17 ) × 10 <sup>-3</sup>		428
$(\pi^+ \pi^- \pi^0)$ S-wave	( 3.8 ±0.5 ) × 10 <sup>-3</sup>		428
$\pi^\mp \rho^\pm$	( 7.4 ±2.3 ) × 10 <sup>-4</sup>		106
$2(\pi^+ \pi^-)$	( 8.51 ±0.33 ) × 10 <sup>-5</sup>		372
$\pi^+ \pi^- 2\pi^0$	( 2.11 ±0.15 ) × 10 <sup>-4</sup>		376
$2(\pi^+ \pi^-)$ neutrals	< 1	%	95% -
$2(\pi^+ \pi^-)\pi^0$	< 1.8	× 10 <sup>-3</sup>	90% 298
$2(\pi^+ \pi^-)2\pi^0$	< 1	%	95% 197
$3(\pi^+ \pi^-)$	< 3.1	× 10 <sup>-5</sup>	90% 189
$K^\pm \pi^\mp$	< 4	× 10 <sup>-5</sup>	90% 334
$\pi^+ \pi^- e^+ e^-$	( 2.43 ±0.06 ) × 10 <sup>-3</sup>		458
$\pi^+ e^- \nu_e + c.c.$	< 2.1	× 10 <sup>-4</sup>	90% 469
$\gamma e^+ e^-$	( 4.80 ±0.15 ) × 10 <sup>-4</sup>		479
$\pi^0 \gamma\gamma$	( 3.20 ±0.24 ) × 10 <sup>-3</sup>		469
$\pi^0 \gamma\gamma$ (non resonant)	( 6.2 ±0.9 ) × 10 <sup>-4</sup>		-
$\eta\gamma\gamma$	< 1.33	× 10 <sup>-4</sup>	90% 322
$4\pi^0$	< 1.2	× 10 <sup>-5</sup>	90% 380
$e^+ e^-$	< 5.6	× 10 <sup>-9</sup>	90% 479
$e^+ e^- e^+ e^-$	( 4.5 ±1.1 ) × 10 <sup>-6</sup>		479
$e^+ e^- \mu^+ \mu^-$	< 1.8	× 10 <sup>-6</sup>	90% 467
$\mu^+ \mu^- \mu^+ \mu^-$	< 5	× 10 <sup>-7</sup>	90% 419
invisible	< 2.1	× 10 <sup>-4</sup>	90% -
$\gamma$ Dark Photon	5 × 10 <sup>-7</sup> to 3.5 × 10 <sup>-6</sup>		90% -

**Charge conjugation (C), Parity (P),  
Lepton family number (LF) violating modes**

$\pi^+ \pi^-$	<i>P, CP</i>	< 1.8	× 10 <sup>-5</sup>	90%	458
$\pi^0 \pi^0$	<i>P, CP</i>	< 4	× 10 <sup>-4</sup>	90%	459
$\pi^0 e^+ e^-$	<i>C</i>	[ <i>f</i> ] < 1.4	× 10 <sup>-3</sup>	90%	469
$\pi^0 \rho^0$	<i>C</i>	< 4	%	90%	111
$\eta e^+ e^-$	<i>C</i>	[ <i>f</i> ] < 2.4	× 10 <sup>-3</sup>	90%	322
$3\gamma$	<i>C</i>	< 1.0	× 10 <sup>-4</sup>	90%	479
$\mu^+ \mu^- \pi^0$	<i>C</i>	[ <i>f</i> ] < 6.0	× 10 <sup>-5</sup>	90%	445
$\mu^+ \mu^- \eta$	<i>C</i>	[ <i>f</i> ] < 1.5	× 10 <sup>-5</sup>	90%	273
$e\mu$	<i>LF</i>	< 4.7	× 10 <sup>-4</sup>	90%	473
$\pi^+ \pi^-$ ALP → $\pi^+ \pi^- e^+ e^-$		< 1.9	× 10 <sup>-5</sup>	90%	-

**$f_0(980)$**

$$I^G(J^{PC}) = 0^+(0^{++})$$

See the review on "Scalar Mesons below 1 GeV."

T-matrix pole  $\sqrt{s} = (980-1010) - i(20-35)$  MeV [1]

Mass (Breit-Wigner) =  $990 \pm 20$  MeV [1]

Full width (Breit-Wigner) = 10 to 100 MeV [1]

<b><math>f_0(980)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi$	seen	476
$K\bar{K}$	seen	36
$\gamma\gamma$	seen	495

**$a_0(980)$**

$$I^G(J^{PC}) = 1^-(0^{++})$$

See the review on "Scalar Mesons below 1 GeV."

T-matrix pole  $\sqrt{s} = (970-1020) - i(30-70)$  MeV [1]

Mass  $m = 980 \pm 20$  MeV [1]

Full width  $\Gamma = 50$  to 100 MeV [1]

<b><math>a_0(980)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\pi$	seen	319
$K\bar{K}$	seen	†
$\eta'\pi$	seen	†
$\rho\pi$	not seen	138
$\gamma\gamma$	seen	490

**$\phi(1020)$**

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 1019.460 \pm 0.016$  MeV

Full width  $\Gamma = 4.249 \pm 0.013$  MeV ( $S = 1.1$ )

<b><math>\phi(1020)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$K^+K^-$	(50.1 $\pm$ 0.6 ) %	S=1.6	127
$K_L^0 K_S^0$	(33.6 $\pm$ 0.4 ) %	S=1.3	110
$\rho\pi^+ \pi^+ \pi^- \pi^0$	(14.7 $\pm$ 0.4 ) %	S=1.5	—
$\eta\gamma$	( 1.306 $\pm$ 0.024 ) %	S=1.2	363
$\pi^0\gamma$	( 1.33 $\pm$ 0.05 ) $\times 10^{-3}$		501
$\ell^+ \ell^-$	—		510
$e^+ e^-$	( 2.963 $\pm$ 0.034 ) $\times 10^{-4}$	S=1.4	510
$\mu^+ \mu^-$	( 2.86 $\pm$ 0.22 ) $\times 10^{-4}$	S=1.2	499

$\eta e^+ e^-$	$( 1.08 \pm 0.04 ) \times 10^{-4}$		363
$\pi^+ \pi^-$	$( 9.5 \pm 1.9 ) \times 10^{-5}$	S=2.0	490
$\omega \pi^0$	$( 4.7 \pm 0.5 ) \times 10^{-5}$		171
$\omega \gamma$	< 5	% CL=84%	209
$\rho \gamma$	< 1.2	$\times 10^{-5}$ CL=90%	215
$\pi^+ \pi^- \gamma$	$( 4.1 \pm 1.3 ) \times 10^{-5}$		490
$f_0(980) \gamma$	$( 3.22 \pm 0.19 ) \times 10^{-4}$	S=1.1	29
$\pi^0 \pi^0 \gamma$	$( 1.13 \pm 0.06 ) \times 10^{-4}$		492
$\pi^+ \pi^- \pi^+ \pi^-$	$( 3.9 \begin{smallmatrix} +2.8 \\ -2.2 \end{smallmatrix} ) \times 10^{-6}$		410
$\pi^+ \pi^+ \pi^- \pi^- \pi^0$	< 4.6	$\times 10^{-6}$ CL=90%	342
$\pi^0 e^+ e^-$	$( 1.33 \begin{smallmatrix} +0.07 \\ -0.10 \end{smallmatrix} ) \times 10^{-5}$		501
$\pi^0 \eta \gamma$	$( 7.27 \pm 0.30 ) \times 10^{-5}$	S=1.5	346
$a_0(980) \gamma$	$( 7.6 \pm 0.6 ) \times 10^{-5}$		39
$K^0 \bar{K}^0 \gamma$	< 1.9	$\times 10^{-8}$ CL=90%	110
$\eta'(958) \gamma$	$( 6.23 \pm 0.21 ) \times 10^{-5}$		60
$\eta \pi^0 \pi^0 \gamma$	< 2	$\times 10^{-5}$ CL=90%	293
$\mu^+ \mu^- \gamma$	$( 1.4 \pm 0.5 ) \times 10^{-5}$		499
$\rho \gamma \gamma$	< 1.2	$\times 10^{-4}$ CL=90%	215
$\eta \pi^+ \pi^-$	< 1.8	$\times 10^{-5}$ CL=90%	288
$\eta \mu^+ \mu^-$	< 9.4	$\times 10^{-6}$ CL=90%	321
$\eta U \rightarrow \eta e^+ e^-$	< 1	$\times 10^{-6}$ CL=90%	–
invisible	< 1.7	$\times 10^{-4}$ CL=90%	–

**Lepton Family number (LF) violating modes**

$e^\pm \mu^\mp$	LF	< 2	$\times 10^{-6}$ CL=90%	504
$\pi^+ \pi^+ e^- e^-$	L	< 1.3	$\times 10^{-5}$ CL=90%	490

**$h_1(1170)$**

$$I^G(J^{PC}) = 0^-(1^{+-})$$

Mass  $m = 1166 \pm 6$  MeV

Full width  $\Gamma = 375 \pm 35$  MeV

<b><math>h_1(1170)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho \pi$	seen	305

**$b_1(1235)$**

$$I^G(J^{PC}) = 1^+(1^{+-})$$

Mass  $m = 1229.5 \pm 3.2$  MeV (S = 1.6)

Full width  $\Gamma = 142 \pm 9$  MeV (S = 1.2)

<b><math>a_1(1235)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\omega\pi$	seen		348
[ $D/S$ amplitude ratio = $0.277 \pm 0.027$ ]			
$\pi^\pm\gamma$	$(1.6 \pm 0.4) \times 10^{-3}$		607
$\eta\rho$	seen		†
$\pi^+\pi^+\pi^-\pi^0$	< 50 %	84%	535
$K^*(892)^\pm K^\mp$	seen		†
$(K\bar{K})^\pm\pi^0$	< 8 %	90%	248
$K_S^0 K_L^0 \pi^\pm$	< 6 %	90%	235
$K_S^0 K_S^0 \pi^\pm$	< 2 %	90%	235
$\phi\pi$	< 1.5 %	84%	147

**$a_1(1260)$  [ $k$ ]**

$$I^G(J^{PC}) = 1^-(1^{++})$$

T-Matrix Pole  $\sqrt{s} = (1209_{-10}^{+13}) - i(288_{-12}^{+45})$  MeV

Mass (Breit-Wigner) =  $1230 \pm 40$  MeV [ $l$ ]

Full width (Breit-Wigner) = 250 to 600 MeV [ $l$ ]

<b><math>a_1(1260)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$3\pi$	seen	577
$(\rho\pi)_{S\text{-wave}}, \rho \rightarrow \pi\pi$	seen	353
$(\rho\pi)_{D\text{-wave}}, \rho \rightarrow \pi\pi$	seen	353
$(\rho(1450)\pi)_{S\text{-wave}}, \rho \rightarrow \pi\pi$	seen	†
$(\rho(1450)\pi)_{D\text{-wave}}, \rho \rightarrow \pi\pi$	seen	†
$f_0(500)\pi, f_0 \rightarrow \pi\pi$	seen	—
$f_0(980)\pi, f_0 \rightarrow \pi\pi$	seen	179
$f_0(1370)\pi, f_0 \rightarrow \pi\pi$	seen	†
$f_2(1270)\pi, f_2 \rightarrow \pi\pi$	seen	†
$\pi^+\pi^-\pi^0$	seen	576
$\pi^0\pi^0\pi^0$	not seen	577
$KK\pi$	seen	250
$K^*(892)K$	seen	†
$\pi\gamma$	seen	608

**$f_2(1270)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

T-Matrix Pole  $\sqrt{s} = (1260-1283) - i(90-110)$  MeV

Mass (Breit-Wigner) =  $1275.4 \pm 0.8$  MeV ( $S = 1.1$ )

Full width (Breit-Wigner) =  $186.6_{-2.2}^{+2.8}$  MeV ( $S = 1.5$ )

<b><math>f_2(1270)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$\rho$ (MeV/c)
$\pi\pi$	(84.3 $^{+2.8}_{-1.0}$ ) %	S=1.2	623
$\pi^+\pi^-2\pi^0$	( 7.7 $^{+1.2}_{-3.1}$ ) %	S=1.2	563
$K\bar{K}$	( 4.6 $\pm 0.4$ ) %	S=2.7	404
$2\pi^+2\pi^-$	( 2.8 $\pm 0.4$ ) %	S=1.2	559
$\eta\eta$	( 4.0 $\pm 0.8$ ) $\times 10^{-3}$	S=2.1	326
$4\pi^0$	( 3.0 $\pm 1.0$ ) $\times 10^{-3}$		565
$\gamma\gamma$	( 1.42 $\pm 0.24$ ) $\times 10^{-5}$	S=1.4	638
$\eta\pi\pi$	< 8 $\times 10^{-3}$	CL=95%	478
$K^0K^-\pi^+ + \text{c.c.}$	< 3.4 $\times 10^{-3}$	CL=95%	293
$e^+e^-$	< 6 $\times 10^{-10}$	CL=90%	638

 **$f_1(1285)$** 

$$I^G(J^{PC}) = 0^+(1^{++})$$

 Mass  $m = 1281.8 \pm 0.5$  MeV (S = 1.7)

 Full width  $\Gamma = 23.0 \pm 1.0$  MeV (S = 1.5)

<b><math>f_1(1285)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$\rho$ (MeV/c)
$4\pi$	(32.7 $\pm 1.8$ ) %	S=1.2	568
$\pi^0\pi^0\pi^+\pi^-$	(21.8 $\pm 1.2$ ) %	S=1.2	566
$2\pi^+2\pi^-$	(10.9 $\pm 0.6$ ) %	S=1.2	563
$\rho^0\pi^+\pi^-$	(10.9 $\pm 0.6$ ) %	S=1.2	336
$\rho^0\rho^0$	seen		†
$4\pi^0$	< 7 $\times 10^{-4}$	CL=90%	568
$\eta\pi^+\pi^-$	(35 $\pm 15$ ) %		479
$\eta\pi\pi$	(52.2 $\pm 1.9$ ) %	S=1.2	482
$a_0(980)\pi$ [ignoring $a_0(980) \rightarrow K\bar{K}$ ]	(38 $\pm 4$ ) %		238
$\eta\pi\pi$ [excluding $a_0(980)\pi$ ]	(14 $\pm 4$ ) %		482
$K\bar{K}\pi$	( 9.0 $\pm 0.4$ ) %	S=1.1	308
$K\bar{K}^*(892)$	not seen		†
$\pi^+\pi^-\pi^0$	( 3.0 $\pm 0.9$ ) $\times 10^{-3}$		603
$\rho^\pm\pi^\mp$	< 3.1 $\times 10^{-3}$	CL=95%	390
$\gamma\rho^0$	( 6.1 $\pm 1.0$ ) %	S=1.7	407
$\phi\gamma$	seen		236
$e^+e^-$	< 9.4 $\times 10^{-9}$	CL=90%	641

**$\eta(1295)$** 

$$I^G(J^{PC}) = 0^+(0^-+)$$

See the review on "Spectroscopy of Light Meson Resonances."

Mass  $m = 1294 \pm 4$  MeV ( $S = 1.6$ )Full width  $\Gamma = 55 \pm 5$  MeV

<b><math>\eta(1295)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\pi^+\pi^-$	seen	487
$a_0(980)\pi$	seen	248
$\eta\pi^0\pi^0$	seen	490
$\eta(\pi\pi)_{S\text{-wave}}$	seen	—
$\sigma\eta$	seen	—
$K\bar{K}\pi$	seen	320

 **$\pi(1300)$** 

$$I^G(J^{PC}) = 1^-(0^-+)$$

Mass  $m = 1300 \pm 100$  MeV [i]Full width  $\Gamma = 200$  to  $600$  MeV [i]

<b><math>\pi(1300)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	seen	404
$\pi(\pi\pi)_{S\text{-wave}}$	seen	—

 **$a_2(1320)$** 

$$I^G(J^{PC}) = 1^-(2^{++})$$

T-Matrix Pole  $\sqrt{s} = (1305-1321)-i(52-58)$  MeVMass (Breit-Wigner) =  $1318.2 \pm 0.6$  MeV ( $S = 1.2$ )Full width  $\Gamma = 107 \pm 5$  MeV

<b><math>a_2(1320)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$3\pi$	(70.1 $\pm$ 2.7 ) %	S=1.2	624
$\eta\pi$	(14.5 $\pm$ 1.2 ) %		535
$\omega\pi\pi$	(10.6 $\pm$ 3.2 ) %	S=1.3	366
$K\bar{K}$	( 4.9 $\pm$ 0.8 ) %		437
$\eta'(958)\pi$	( 5.5 $\pm$ 0.9 ) $\times 10^{-3}$		288
$\pi^\pm\gamma$	( 2.91 $\pm$ 0.27 ) $\times 10^{-3}$		652
$\gamma\gamma$	( 9.4 $\pm$ 0.7 ) $\times 10^{-6}$		659
$e^+e^-$	< 5 $\times 10^{-9}$	CL=90%	659

**$f_0(1370)$**

$$I^G(J^{PC}) = 0^+(0^{++})$$

See the review on "Spectroscopy of Light Meson Resonances."

T-Matrix Pole  $\sqrt{s} = (1250-1440) - i (60-300)$  MeV

Mass (Breit-Wigner) = 1200 to 1500 MeV

Full width (Breit-Wigner) = 200 to 500 MeV

<b><math>f_0(1370)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi$	seen	672
$4\pi$	seen	617
$4\pi^0$	seen	617
$2\pi^+ 2\pi^-$	seen	612
$\pi^+ \pi^- 2\pi^0$	seen	615
$\rho\rho$	seen	†
$2(\pi\pi)_S$ -wave	seen	—
$\pi(1300)\pi$	seen	†
$a_1(1260)\pi$	seen	35
$\eta\eta$	seen	411
$K\bar{K}$	seen	475
$K\bar{K}n\pi$	not seen	†
$6\pi$	not seen	508
$\omega\omega$	not seen	†
$\gamma\gamma$	seen	685
$e^+ e^-$	not seen	685

**$\eta(1405)$**

$$I^G(J^{PC}) = 0^+(0^{-+})$$

See the review on "Spectroscopy of Light Meson Resonances." See also  $\eta(1475)$ .

Mass  $m = 1408.0^{+1.8}_{-1.2}$  MeV (S = 2.1)

Full width  $\Gamma = 49.8^{+2.3}_{-2.0}$  MeV (S = 1.6)

<b><math>\eta(1405)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$K\bar{K}\pi$	seen		423
$\eta\pi\pi$	seen		562
$a_0(980)\pi$	seen		344
$\eta(\pi\pi)_S$ -wave	seen		—
$f_0(980)\eta$	seen		†
$4\pi$	seen		638
$\rho\rho$	<58 %	99.85%	†

$\rho^0 \gamma$	seen	491
$\phi \gamma$	seen	335
$K^*(892) K$	seen	120

### $h_1(1415)$

$$I^G(J^{PC}) = 0^-(1^{+-})$$

Mass  $m = 1409^{+9}_{-8}$  MeV (S = 1.9)

Full width  $\Gamma = 78 \pm 11$  MeV

### $f_1(1420)$

$$I^G(J^{PC}) = 0^+(1^{++})$$

See the review on "Spectroscopy of Light Meson Resonances."

Mass  $m = 1427.7^{+1.7}_{-1.4}$  MeV (S = 2.1)

Full width  $\Gamma = 55.4 \pm 3.2$  MeV (S = 1.3)

$f_1(1420)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K \bar{K} \pi$	seen	439
$K \bar{K}^*(892) + \text{c.c.}$	seen	165
$\eta \pi \pi$	possibly seen	574
$\phi \gamma$	seen	350

### $\omega(1420)$ [j]

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 1410 \pm 60$  MeV [j]

Full width  $\Gamma = 290 \pm 190$  MeV [j]

$\omega(1420)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho \pi$	seen	480
$\rho(1450) \pi$	possibly seen	†
$\omega \pi \pi$	seen	437
$\omega \eta$	possibly seen	230
$b_1(1235) \pi$	seen	112
$e^+ e^-$	seen	705

### $a_0(1450)$

$$I^G(J^{PC}) = 1^-(0^{++})$$

See the review on "Spectroscopy of Light Meson Resonances."

T-Matrix Pole  $\sqrt{s} = (1290-1500) - i(30-140)$  MeV

Mass (Breit-Wigner) =  $1439 \pm 34$  MeV (S = 1.8)

Full width (Breit-Wigner) =  $258 \pm 14$  MeV

Branching fractions are given relative to the one **DEFINED AS 1**.

<b><math>a_0(1450)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\eta$	$0.093 \pm 0.020$	607
$\pi\eta'(958)$	$0.033 \pm 0.017$	384
$K\bar{K}$	$0.082 \pm 0.028$	523
$\omega\pi\pi$	<b>DEFINED AS 1</b>	458
$a_0(980)\pi\pi$	seen	310
$\gamma\gamma$	seen	719

 **$\rho(1450)$** 

$$I^G(J^{PC}) = 1^+(1^- -)$$

See the review on "Spectroscopy of Light Meson Resonances."

$$\text{Mass } m = 1465 \pm 25 \text{ MeV [j]}$$

$$\text{Full width } \Gamma = 400 \pm 60 \text{ MeV [j]}$$

<b><math>\rho(1450)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi$	seen	720
$\pi^+\pi^-$	seen	719
$4\pi$	seen	669
$e^+e^-$	seen	732
$\eta\rho$	seen	311
$a_2(1320)\pi$	not seen	55
$K\bar{K}$	seen	541
$K^+K^-$	seen	541
$K\bar{K}^*(892) + \text{c.c.}$	possibly seen	229
$\pi^0\gamma$	seen	726
$\eta\gamma$	seen	630
$f_0(500)\gamma$	not seen	—
$f_0(980)\gamma$	not seen	398
$f_0(1370)\gamma$	not seen	92
$f_2(1270)\gamma$	not seen	177

 **$\eta(1475)$** 

$$I^G(J^{PC}) = 0^+(0^- +)$$

See the review on "Spectroscopy of Light Meson Resonances." See also  $\eta(1405)$ .

$$\text{Mass } m = 1476 \pm 4 \text{ MeV } (S = 1.4)$$

$$\text{Full width } \Gamma = 96 \pm 9 \text{ MeV } (S = 1.7)$$

$\eta(1475)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}\pi$	seen	477
$K\bar{K}^*(892)+\text{c.c.}$	seen	244
$a_0(980)\pi$	seen	396
$\gamma\gamma$	seen	738
$K_S^0 K_S^0 \eta$	possibly seen	†
$\gamma\phi(1020)$	possibly seen	386

**$f_0(1500)$**

$$I^G(J^{PC}) = 0^+(0^{++})$$

See the review on "Spectroscopy of Light Meson Resonances."

T-Matrix Pole  $\sqrt{s} = (1430-1530) - i(40-90)$  MeV

Mass (Breit-Wigner) =  $1522 \pm 25$  MeV

Full width (Breit-Wigner) =  $108 \pm 33$  MeV

$f_0(1500)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$p$ (MeV/c)
$\pi\pi$	$(34.5 \pm 2.2) \%$	1.2	749
$\pi^+\pi^-$	seen		748
$2\pi^0$	seen		749
$4\pi$	$(48.9 \pm 3.3) \%$	1.2	700
$4\pi^0$	seen		700
$2\pi^+2\pi^-$	seen		696
$2(\pi\pi)_{S\text{-wave}}$	seen		—
$\rho\rho$	seen		†
$\pi(1300)\pi$	seen		163
$a_1(1260)\pi$	seen		234
$\eta\eta$	$(6.0 \pm 0.9) \%$	1.1	528
$\eta\eta'(958)$	$(2.2 \pm 0.8) \%$	1.4	107
$K\bar{K}$	$(8.5 \pm 1.0) \%$	1.1	579
$\gamma\gamma$	not seen		761

**$f'_2(1525)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 1517.3 \pm 2.4$  MeV ( $S = 2.8$ )

Full width  $\Gamma = 72^{+7}_{-6}$  MeV

$f'_2(1525)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}$	$(88.8 \pm 2.2) \%$	576
$\eta\eta$	$(10.3 \pm 2.2) \%$	525

$\pi\pi$	$(8.2 \pm 1.5) \times 10^{-3}$	747
$\gamma\phi$	seen	416
$\gamma\gamma$	$(1.12 \pm 0.15) \times 10^{-6}$	759

## $f_2(1565)$

$$J^{PC} = 0^+(2^{++})$$

See the review on "Spectroscopy of Light Meson Resonances."

T-Matrix Pole  $\sqrt{s} = (1495-1560) - i(40-110)$  MeV

Mass (Breit-Wigner) =  $1571 \pm 13$  MeV

Full width (Breit-Wigner) =  $132 \pm 23$  MeV (S = 1.1)

$f_2(1565)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi$	seen	774
$\pi^+\pi^-$	seen	773
$\pi^0\pi^0$	seen	774
$\rho^0\rho^0$	seen	126
$2\pi^+2\pi^-$	seen	722
$\eta\eta$	seen	563
$\omega\omega$	seen	64
$K\bar{K}$	seen	611
$\gamma\gamma$	seen	785

## $\pi_1(1600)$

$$J^{PC} = 1^-(1^{-+})$$

See the review on "Spectroscopy of Light Meson Resonances."

Mass (T-Matrix Pole  $\sqrt{s}$ ) =  $(1480-1680) - i(150-300)$  MeV

Mass (Breit-Wigner,  $\eta\pi$  mode) =  $1354 \pm 25$  MeV (S = 1.8)

Mass (Breit-Wigner, non- $\eta\pi$  mode) =  $1645^{+40}_{-17}$  MeV (S = 1.3)

Full width (Breit-Wigner,  $\eta\pi$  mode) =  $330 \pm 35$  MeV

Full width (Breit-Wigner, non- $\eta\pi$  mode) =  $370^{+50}_{-60}$  MeV

$\pi_1(1600)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi\pi$	seen	795
$\rho^0\pi^-$	seen	631
$f_2(1270)\pi^-$	not seen	304
$b_1(1235)\pi$	seen	343
$\eta'(958)\pi^-$	seen	532
$\eta\pi$	seen	725
$f_1(1285)\pi$	seen	300

**$a_1(1640)$**

$$I^G(J^{PC}) = 1^-(1^{++})$$

Mass  $m = 1655 \pm 16$  MeV (S = 1.2)

Full width  $\Gamma = 250 \pm 40$  MeV (S = 1.8)

<b><math>a_1(1640)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi\pi\pi$	seen	800
$f_2(1270)\pi$	seen	314
$\sigma\pi$	seen	—
$\rho\pi$ S-wave	seen	638
$\rho\pi$ D-wave	seen	638
$\omega\pi\pi$	seen	607
$f_1(1285)\pi$	seen	309
$a_1(1260)\eta$	not seen	†

**$\eta_2(1645)$**

$$I^G(J^{PC}) = 0^+(2^{-+})$$

Mass  $m = 1617 \pm 5$  MeV

Full width  $\Gamma = 181 \pm 11$  MeV

<b><math>\eta_2(1645)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$a_2(1320)\pi$	seen	242
$K\bar{K}\pi$	seen	580
$K^*\bar{K}$	seen	404
$\eta\pi^+\pi^-$	seen	685
$a_0(980)\pi$	seen	499
$f_2(1270)\eta$	not seen	†

**$\omega(1650)$  [n]**

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 1670 \pm 30$  MeV [j]

Full width  $\Gamma = 150 \pm 50$  MeV [j]

<b><math>\omega(1650)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	seen	647
$\rho(1450)\pi$	seen	145
$\omega\pi\pi$	seen	617
$\omega\eta$	seen	500
$e^+e^-$	seen	835
$\pi^0\gamma$	not seen	830

**$\omega_3(1670)$**

$$I^G(J^{PC}) = 0^-(3^{--})$$

Mass  $m = 1667 \pm 4$  MeV

Full width  $\Gamma = 168 \pm 10$  MeV

<b><math>\omega_3(1670)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi$	seen	645
$\omega\pi\pi$	seen	615
$b_1(1235)\pi$	possibly seen	361

**$\pi_2(1670)$**

$$I^G(J^{PC}) = 1^-(2^{-+})$$

Mass  $m = 1670.6^{+2.9}_{-1.2}$  MeV ( $S = 1.3$ )

Full width  $\Gamma = 258^{+8}_{-9}$  MeV ( $S = 1.2$ )

<b><math>\pi_2(1670)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$3\pi$	$(95.8 \pm 1.4) \%$		808
$f_2(1270)\pi$	$(56.3 \pm 3.2) \%$		327
$\rho\pi$	$(31 \pm 4) \%$		647
$\sigma\pi$	$(10 \pm 4) \%$		—
$\pi(\pi\pi)_{S\text{-wave}}$	$(8.7 \pm 3.4) \%$		—
$\pi^\pm\pi^+\pi^-$	$(53 \pm 4) \%$		806
$K\bar{K}^*(892) + \text{c.c.}$	$(4.2 \pm 1.4) \%$		453
$\omega\rho$	$(2.7 \pm 1.1) \%$		302
$\pi^\pm\gamma$	$(7.0 \pm 1.2) \times 10^{-4}$		829
$\gamma\gamma$	$< 2.8 \times 10^{-7}$	90%	835
$\eta\pi$	$< 5 \%$		739
$\pi^\pm 2\pi^+ 2\pi^-$	$< 5 \%$		735
$\rho(1450)\pi$	$< 3.6 \times 10^{-3}$	97.7%	145
$b_1(1235)\pi$	$< 1.9 \times 10^{-3}$	97.7%	364
$f_1(1285)\pi$	possibly seen		322
$a_2(1320)\pi$	not seen		291

**$\phi(1680)$**

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 1680 \pm 20$  MeV [ $j$ ]

Full width  $\Gamma = 150 \pm 50$  MeV [ $j$ ]

<b><math>\phi(1680)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}^*(892) + \text{c.c.}$	seen	461
$K_S^0 K\pi$	seen	621

$K\bar{K}$	seen	680
$e^+e^-$	seen	840
$\omega\pi\pi$	not seen	623
$K^+K^-\pi^+\pi^-$	seen	544
$\eta\phi$	seen	290
$\eta\gamma$	seen	751
$\rho(770)\pi$	not seen	653
$f'_2(1525)\gamma$	not seen	155

**$\rho_3(1690)$**

$$I^G(J^{PC}) = 1^+(3^{--})$$

Mass  $m = 1688.8 \pm 2.1$  MeV

Full width  $\Gamma = 161 \pm 10$  MeV ( $S = 1.5$ )

<b><math>\rho_3(1690)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor	$p$ (MeV/c)
$4\pi$	(71.1 $\pm$ 1.9 ) %		790
$\pi^\pm\pi^+\pi^-\pi^0$	(67 $\pm$ 22 ) %		787
$\omega\pi$	(16 $\pm$ 6 ) %		655
$\pi\pi$	(23.6 $\pm$ 1.3 ) %		834
$K\bar{K}\pi$	( 3.8 $\pm$ 1.2 ) %		629
$K\bar{K}$	( 1.58 $\pm$ 0.26 ) %	1.2	685
$\eta\pi^+\pi^-$	seen		727
$\rho(770)\eta$	seen		520
$\pi\pi\rho$	seen		633
$a_2(1320)\pi$	seen		307
$\rho\rho$	seen		335

**$\rho(1700)$**

$$I^G(J^{PC}) = 1^+(1^{--})$$

See the review on "Spectroscopy of Light Meson Resonances."

Mass  $m = 1720 \pm 20$  MeV [ $J$ ] ( $\eta\rho^0$  and  $\pi^+\pi^-$  modes)

Full width  $\Gamma = 250 \pm 100$  MeV [ $J$ ] ( $\eta\rho^0$  and  $\pi^+\pi^-$  modes)

<b><math>\rho(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$2(\pi^+\pi^-)$	seen	803
$\rho\pi\pi$	seen	653
$\rho^0\pi^+\pi^-$	seen	651
$\rho^\pm\pi^\mp\pi^0$	seen	652
$a_1(1260)\pi$	seen	404
$h_1(1170)\pi$	seen	450
$\pi(1300)\pi$	seen	349

$\rho\rho$	seen	373
$\pi^+\pi^-$	seen	849
$\pi\pi$	seen	849
$K\bar{K}^*(892)+\text{c.c.}$	seen	496
$\eta\rho$	seen	545
$a_2(1320)\pi$	not seen	334
$K\bar{K}$	seen	704
$e^+e^-$	seen	860
$\pi^0\omega$	seen	674
$\pi^0\gamma$	not seen	855
$f_0(1500)\gamma$	not seen	187

**$a_2(1700)$**

$$I^G(J^{PC}) = 1^-(2^{++})$$

T-Matrix Pole  $\sqrt{s} = (1630-1780) - i(60-250)$  MeV  
 Mass  $m = 1706 \pm 14$  MeV (S = 1.2)  
 Full width  $\Gamma = 380^{+60}_{-50}$  MeV (S = 3.9)

<b><math>a_2(1700)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\pi$	(2.5±0.6) %	758
$\eta'\pi$	seen	574
$\gamma\gamma$	(7.9±1.7) × 10 <sup>-7</sup>	853
$\rho\pi$	seen	669
$f_2(1270)\pi$	seen	357
$K\bar{K}$	(1.3±0.8) %	695
$\omega\pi^-\pi^0$	seen	639
$\omega\rho$	seen	347

**$f_0(1710)$**

$$I^G(J^{PC}) = 0^+(0^{++})$$

See the review on "Spectroscopy of Light Meson Resonances."  
 T-matrix pole  $\sqrt{s} = (1680-1820) - i(50-180)$  MeV  
 Mass (Breit-Wigner) = 1723<sup>+7</sup><sub>-6</sub> MeV (S = 1.3)  
 Full width (Breit-Wigner) = 149 ± 10 MeV (S = 1.4)

<b><math>f_0(1710)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}$	seen	706
$\eta\eta$	seen	665
$\eta\eta'$	not seen	407
$\pi\pi$	seen	851
$\gamma\gamma$	seen	862
$\omega\omega$	seen	360

**$\pi(1800)$**

$$I^G(J^{PC}) = 1^-(0^-+)$$

See the review on "Spectroscopy of Light Meson Resonances."

$$\text{Mass } m = 1810_{-11}^{+9} \text{ MeV} \quad (S = 2.2)$$

$$\text{Full width } \Gamma = 215_{-8}^{+7} \text{ MeV}$$

<b><math>\pi(1800)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\pi^+ \pi^- \pi^-$	seen	878
$f_0(500) \pi^-$	seen	—
$f_0(980) \pi^-$	seen	624
$f_0(1370) \pi^-$	seen	366
$f_0(1500) \pi^-$	not seen	232
$\rho \pi^-$	not seen	731
$\eta \eta \pi^-$	seen	660
$a_0(980) \eta$	seen	471
$a_2(1320) \eta$	not seen	†
$f_2(1270) \pi$	not seen	441
$f_0(1370) \pi^-$	not seen	366
$f_0(1500) \pi^-$	seen	232
$\eta \eta'(958) \pi^-$	seen	373
$K_0^*(1430) K^-$	seen	†
$K^*(892) K^-$	not seen	568

**$\phi_3(1850)$**

$$I^G(J^{PC}) = 0^-(3^{--})$$

$$\text{Mass } m = 1854 \pm 7 \text{ MeV}$$

$$\text{Full width } \Gamma = 87_{-23}^{+28} \text{ MeV} \quad (S = 1.2)$$

<b><math>\phi_3(1850)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K \bar{K}$	seen	785
$K \bar{K}^*(892) + \text{c.c.}$	seen	602

**$\eta_2(1870)$**

$$I^G(J^{PC}) = 0^+(2^-+)$$

$$\text{Mass } m = 1842 \pm 8 \text{ MeV}$$

$$\text{Full width } \Gamma = 225 \pm 14 \text{ MeV}$$

<b><math>\eta_2(1870)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta \pi \pi$	seen	816
$a_2(1320) \pi$	seen	434

$f_2(1270)\eta$	seen	119
$a_0(980)\pi$	seen	651
$\gamma\gamma$	seen	921

**$\pi_2(1880)$**

$$I^G(J^{PC}) = 1^-(2^-+)$$

Mass  $m = 1874_{-5}^{+26}$  MeV (S = 1.6)

Full width  $\Gamma = 237_{-30}^{+33}$  MeV (S = 1.2)

<b><math>\pi_2(1880)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\eta\pi^-$	seen	702
$a_0(980)\eta$	seen	528
$a_2(1320)\eta$	seen	76
$f_0(1500)\pi$	seen	294
$f_1(1285)\pi$	seen	485
$\omega\pi^-\pi^0$	seen	744

**$f_2(1950)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

T-Matrix Pole  $\sqrt{s} = (1830-2020) - i(110-220)$  MeV

Mass (Breit-Wigner) =  $1936 \pm 12$  MeV (S = 1.3)

Full width (Breit-Wigner) =  $464 \pm 24$  MeV

<b><math>f_2(1950)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K^*(892)\bar{K}^*(892)$	seen	377
$\pi^+\pi^-$	seen	958
$\pi^0\pi^0$	seen	959
$4\pi$	seen	921
$\eta\eta$	seen	798
$K\bar{K}$	seen	833
$\gamma\gamma$	seen	968
$\gamma\phi$	seen	700
$p\bar{p}$	seen	238

**$a_4(1970)$**

$$I^G(J^{PC}) = 1^-(4^{++})$$

Mass  $m = 1967 \pm 16$  MeV (S = 2.1)

Full width  $\Gamma = 324_{-18}^{+15}$  MeV

<b><math>a_4(1970)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$K\bar{K}$	seen	851
$\pi^+\pi^-\pi^0$	seen	959
$\rho\pi$	seen	825
$f_2(1270)\pi$	seen	559
$\omega\pi^-\pi^0$	seen	801
$\omega\rho$	seen	601
$\eta\pi$	seen	902
$\eta'(958)\pi$	seen	743

**$f_2(2010)$**

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 2010^{+60}_{-80}$  MeV

Full width  $\Gamma = 200 \pm 60$  MeV

<b><math>f_2(2010)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\phi\phi$	seen	†
$K\bar{K}$	seen	876
$\gamma\phi$	seen	747

**$f_0(2020)$**

$$I^G(J^{PC}) = 0^+(0^{++})$$

T-Matrix Pole  $\sqrt{s} = (1870-2080) - i(120-240)$  MeV

Mass (Breit-Wigner) =  $1982^{+54.1}_{-3.0}$  MeV

Full width (Breit-Wigner) =  $440 \pm 50$  MeV

<b><math>f_0(2020)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\rho\pi\pi$	seen	814
$\pi^0\pi^0$	seen	982
$\rho\rho$	seen	617
$\omega\omega$	seen	608
$\eta\eta$	seen	826
$\eta'\eta'$	seen	254

**$f_4(2050)$**

$$I^G(J^{PC}) = 0^+(4^{++})$$

Mass  $m = 2018 \pm 11$  MeV ( $S = 2.1$ )

Full width  $\Gamma = 237 \pm 18$  MeV ( $S = 1.9$ )

<b><math>f_4(2050)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\omega\omega$	seen	637
$\pi\pi$	$(17.0 \pm 1.5) \%$	1000
$K\bar{K}$	$(6.8^{+3.4}_{-1.8}) \times 10^{-3}$	880
$\eta\eta$	$(2.1 \pm 0.8) \times 10^{-3}$	848
$4\pi^0$	$< 1.2 \%$	964
$\gamma\gamma$	seen	1009
$a_2(1320)\pi$	seen	567

### $f_2(2150)$

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 2157 \pm 12$  MeV

Full width  $\Gamma = 152 \pm 30$  MeV ( $S = 1.4$ )

<b><math>f_2(2150)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta\eta$	seen	929
$K\bar{K}$	seen	959
$f_2(1270)\eta$	seen	542
$a_2(1320)\pi$	seen	666
$p\bar{p}$	seen	532

### $\phi(2170)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass  $m = 2164 \pm 5$  MeV

Full width  $\Gamma = 88^{+26}_{-21}$  MeV ( $S = 2.5$ )

<b><math>\phi(2170)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$e^+e^-$	seen	1082
$\phi\eta$	seen	728
$\phi\eta'$	seen	439
$\phi\pi\pi$	seen	815
$\phi f_0(980)$	seen	401
$K^+K^- f_0(980) \rightarrow$	seen	—
$K^+K^-\pi^+\pi^-$		
$K^+K^- f_0(980) \rightarrow K^+K^-\pi^0\pi^0$	seen	—
$K^{*0}K^\pm\pi^\mp$	not seen	762
$K^*(892)^0\bar{K}^*(892)^0$	not seen	612

**$f_2(2300)$** 

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 2297 \pm 28$  MeVFull width  $\Gamma = 150 \pm 40$  MeV

<b><math>f_2(2300)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\phi\phi$	seen	529
$K\bar{K}$	seen	1037
$\gamma\gamma$	seen	1149
$\Lambda\bar{\Lambda}$	seen	273

 **$f_2(2340)$** 

$$I^G(J^{PC}) = 0^+(2^{++})$$

Mass  $m = 2346^{+21}_{-10}$  MeVFull width  $\Gamma = 331^{+27}_{-18}$  MeV

<b><math>f_2(2340)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\phi\phi$	seen	580
$\eta\eta$	seen	1037
$\eta'\eta'$	seen	677

## NOTES

- [a] See the review on “Form Factors for Radiative Pion and Kaon Decays” for definitions and details.
- [b] Measurements of  $\Gamma(e^+ \nu_e)/\Gamma(\mu^+ \nu_\mu)$  always include decays with  $\gamma$ 's, and measurements of  $\Gamma(e^+ \nu_e \gamma)$  and  $\Gamma(\mu^+ \nu_\mu \gamma)$  never include low-energy  $\gamma$ 's. Therefore, since no clean separation is possible, we consider the modes with  $\gamma$ 's to be subreactions of the modes without them, and let  $[\Gamma(e^+ \nu_e) + \Gamma(\mu^+ \nu_\mu)]/\Gamma_{\text{total}} = 100\%$ .
- [c] See the  $\pi^\pm$  Particle Listings for the energy limits used in this measurement; low-energy  $\gamma$ 's are not included.
- [d] Derived from an analysis of neutrino-oscillation experiments.
- [e] Forbidden by angular momentum conservation.
- [f] C parity forbids this to occur as a single-photon process.
- [g] As measured in  $e^+ e^- \rightarrow \rho^0$ .
- [h] As measured in  $e^+ e^- \rightarrow \pi^+ \pi^- \pi^0$  and  $\tau$  decays.
- [i] The  $\omega\rho$  interference is then due to  $\omega\rho$  mixing only, and is expected to be small. If  $e\mu$  universality holds,  $\Gamma(\rho^0 \rightarrow \mu^+ \mu^-) = \Gamma(\rho^0 \rightarrow e^+ e^-) \times 0.99785$ .
- [j] Our estimate. See the Particle Listings for details.
- [k] See the “Note on  $a_1(1260)$ ” in the  $a_1(1260)$  Particle Listings in PDG 06, *Journal of Physics* **G33** 1 (2006).
- [l] See also the  $\omega(1650)$ .
- [n] See also the  $\omega(1420)$ .