

# $b\bar{b}$ MESONS (including possibly non- $q\bar{q}$ states)

 **$\eta_b(1S)$** 

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

 Mass  $m = 9398.7 \pm 2.0$  MeV (S = 1.5)

 Full width  $\Gamma = 10^{+5}_{-4}$  MeV

<b><math>\eta_b(1S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
hadrons	seen		—
$3h^+3h^-$	not seen		4672
$2h^+2h^-$	not seen		4689
$4h^+4h^-$	not seen		4648
$\gamma\gamma$	not seen		4699
$\mu^+\mu^-$	$<9 \times 10^{-3}$	90%	4698
$\tau^+\tau^-$	$<8\%$	90%	4350

 **$\Upsilon(1S)$** 

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

 Mass  $m = 9460.30 \pm 0.26$  MeV (S = 3.3)

 Full width  $\Gamma = 54.02 \pm 1.25$  keV

<b><math>\Upsilon(1S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\tau^+\tau^-$	( 2.60 $\pm$ 0.10 ) %		4384
$e^+e^-$	( 2.38 $\pm$ 0.11 ) %		4730
$\mu^+\mu^-$	( 2.48 $\pm$ 0.05 ) %		4729

### Hadronic decays

$ggg$	(81.7 $\pm$ 0.7 ) %		—
$\gamma gg$	( 2.2 $\pm$ 0.6 ) %		—
$\eta'(958)$ anything	( 2.94 $\pm$ 0.24 ) %		—
$J/\psi(1S)$ anything	( 5.4 $\pm$ 0.4 ) $\times 10^{-4}$	S=1.4	4223
$J/\psi(1S)\eta_c$	$< 2.2$	$\times 10^{-6}$ CL=90%	3623
$J/\psi(1S)\chi_{c0}$	$< 3.4$	$\times 10^{-6}$ CL=90%	3429
$J/\psi(1S)\chi_{c1}$	( 3.9 $\pm$ 1.2 ) $\times 10^{-6}$		3382
$J/\psi(1S)\chi_{c2}$	$< 1.4$	$\times 10^{-6}$ CL=90%	3359
$J/\psi(1S)\eta_c(2S)$	$< 2.2$	$\times 10^{-6}$ CL=90%	3317
$J/\psi(1S)X(3940)$	$< 5.4$	$\times 10^{-6}$ CL=90%	3148
$J/\psi(1S)X(4160)$	$< 5.4$	$\times 10^{-6}$ CL=90%	3020

$X(4350)$ anything, $X \rightarrow J/\psi(1S)\phi$	$< 8.1$	$\times 10^{-6}$	CL=90%	—
$Z_c(3900)^\pm$ anything, $Z_c \rightarrow J/\psi(1S)\pi^\pm$	$< 1.3$	$\times 10^{-5}$	CL=90%	—
$Z_c(4200)^\pm$ anything, $Z_c \rightarrow J/\psi(1S)\pi^\pm$	$< 6.0$	$\times 10^{-5}$	CL=90%	—
$Z_c(4430)^\pm$ anything, $Z_c \rightarrow J/\psi(1S)\pi^\pm$	$< 4.9$	$\times 10^{-5}$	CL=90%	—
$X_{cs}^\pm$ anything, $X \rightarrow J/\psi K^\pm$	$< 5.7$	$\times 10^{-6}$	CL=90%	—
$\psi(4230)$ anything, $\psi \rightarrow J/\psi(1S)\pi^+\pi^-$	$< 3.8$	$\times 10^{-5}$	CL=90%	—
$\psi(4230)$ anything, $\psi \rightarrow J/\psi(1S)K^+K^-$	$< 7.5$	$\times 10^{-6}$	CL=90%	—
$\chi_{c1}(4140)$ anything, $\chi_{c1} \rightarrow J/\psi(1S)\phi$	$< 5.2$	$\times 10^{-6}$	CL=90%	—
$\chi_{c0}$ anything	$< 4$	$\times 10^{-3}$	CL=90%	—
$\chi_{c1}$ anything	$(1.90 \pm 0.35) \times 10^{-4}$			—
$\chi_{c1}(1P)X_{tetra}$	$< 3.78$	$\times 10^{-5}$	CL=90%	—
$\chi_{c2}$ anything	$(2.8 \pm 0.8) \times 10^{-4}$			—
$\psi(2S)$ anything	$(1.23 \pm 0.20) \times 10^{-4}$			—
$\psi(2S)\eta_c$	$< 3.6$	$\times 10^{-6}$	CL=90%	3345
$\psi(2S)\chi_{c0}$	$< 6.5$	$\times 10^{-6}$	CL=90%	3124
$\psi(2S)\chi_{c1}$	$< 4.5$	$\times 10^{-6}$	CL=90%	3070
$\psi(2S)\chi_{c2}$	$< 2.1$	$\times 10^{-6}$	CL=90%	3043
$\psi(2S)\eta_c(2S)$	$< 3.2$	$\times 10^{-6}$	CL=90%	2994
$\psi(2S)X(3940)$	$< 2.9$	$\times 10^{-6}$	CL=90%	2797
$\psi(2S)X(4160)$	$< 2.9$	$\times 10^{-6}$	CL=90%	2645
$\psi(4230)$ anything, $\psi \rightarrow \psi(2S)\pi^+\pi^-$	$< 7.9$	$\times 10^{-5}$	CL=90%	—
$\psi(4360)$ anything, $\psi \rightarrow \psi(2S)\pi^+\pi^-$	$< 5.2$	$\times 10^{-5}$	CL=90%	—
$\psi(4660)$ anything, $\psi \rightarrow \psi(2S)\pi^+\pi^-$	$< 2.2$	$\times 10^{-5}$	CL=90%	—
$X(4050)^\pm$ anything, $X \rightarrow \psi(2S)\pi^\pm$	$< 8.8$	$\times 10^{-5}$	CL=90%	—
$Z_c(4430)^\pm$ anything, $Z_c \rightarrow \psi(2S)\pi^\pm$	$< 6.7$	$\times 10^{-5}$	CL=90%	—
$\chi_{c1}(3872)$ anything	$< 2.5$	$\times 10^{-4}$	CL=90%	—
$Z_c(4200)^+ Z_c(4200)^-$	$< 2.23$	$\times 10^{-5}$	CL=90%	—
$Z_c(3900)^\pm Z_c(4200)^\mp$	$< 8.1$	$\times 10^{-6}$	CL=90%	—
$Z_c(3900)^+ Z_c(3900)^-$	$< 1.8$	$\times 10^{-6}$	CL=90%	—
$X(4050)^+ X(4050)^-$	$< 1.58$	$\times 10^{-5}$	CL=90%	—
$X(4250)^+ X(4250)^-$	$< 2.66$	$\times 10^{-5}$	CL=90%	—

$X(4050)^\pm X(4250)^\mp$	< 4.42	$\times 10^{-5}$	CL=90%	—
$Z_c(4430)^+ Z_c(4430)^-$	< 2.03	$\times 10^{-5}$	CL=90%	—
$X(4055)^\pm X(4055)^\mp$	< 2.33	$\times 10^{-5}$	CL=90%	—
$X(4055)^\pm Z_c(4430)^\mp$	< 4.55	$\times 10^{-5}$	CL=90%	—
$\rho\pi$	< 3.68	$\times 10^{-6}$	CL=90%	4697
$\omega\pi^0$	< 3.90	$\times 10^{-6}$	CL=90%	4697
$\pi^+\pi^-$	< 5	$\times 10^{-4}$	CL=90%	4728
$K^+K^-$	< 5	$\times 10^{-4}$	CL=90%	4704
$p\bar{p}$	< 5	$\times 10^{-4}$	CL=90%	4636
$\pi^+\pi^-\pi^0$	( 2.1 $\pm$ 0.8 )	$\times 10^{-6}$		4725
$\phi K^+K^-$	( 2.4 $\pm$ 0.5 )	$\times 10^{-6}$		4622
$\omega\pi^+\pi^-$	( 4.5 $\pm$ 1.0 )	$\times 10^{-6}$		4694
$K^*(892)^0 K^-\pi^+ + \text{c.c.}$	( 4.4 $\pm$ 0.8 )	$\times 10^{-6}$		4667
$\phi f'_2(1525)$	< 1.63	$\times 10^{-6}$	CL=90%	4551
$\omega f_2(1270)$	< 1.79	$\times 10^{-6}$	CL=90%	4611
$\rho(770)a_2(1320)$	< 2.24	$\times 10^{-6}$	CL=90%	4605
$K^*(892)^0 \bar{K}_2^*(1430)^0 + \text{c.c.}$	( 3.0 $\pm$ 0.8 )	$\times 10^{-6}$		4578
$K_1(1270)^\pm K^\mp$	< 2.41	$\times 10^{-6}$	CL=90%	4634
$K_1(1400)^\pm K^\mp$	( 1.0 $\pm$ 0.4 )	$\times 10^{-6}$		4613
$b_1(1235)^\pm \pi^\mp$	< 1.25	$\times 10^{-6}$	CL=90%	4649
$\pi^+\pi^-\pi^0\pi^0$	( 1.28 $\pm$ 0.30 )	$\times 10^{-5}$		4720
$K_S^0 K^+\pi^- + \text{c.c.}$	( 1.6 $\pm$ 0.4 )	$\times 10^{-6}$		4696
$K^*(892)^0 \bar{K}^0 + \text{c.c.}$	( 2.9 $\pm$ 0.9 )	$\times 10^{-6}$		4675
$K^*(892)^- K^+ + \text{c.c.}$	< 1.11	$\times 10^{-6}$	CL=90%	4675
$f_1(1285)$ anything	( 4.6 $\pm$ 3.1 )	$\times 10^{-3}$		—
$D^*(2010)^\pm$ anything	( 2.52 $\pm$ 0.20 )	%		—
$f_1(1285) X_{tetra}$	< 6.24	$\times 10^{-5}$	CL=90%	—
${}^2H$ anything	( 2.85 $\pm$ 0.25 )	$\times 10^{-5}$		—
Sum of 100 exclusive modes	( 1.200 $\pm$ 0.017 )	%		—

### Radiative decays

$\gamma\pi^+\pi^-$	( 6.3 $\pm$ 1.8 )	$\times 10^{-5}$		4728
$\gamma\pi^0\pi^0$	( 1.7 $\pm$ 0.7 )	$\times 10^{-5}$		4728
$\gamma\pi\pi$ (S-wave)	( 4.6 $\pm$ 0.7 )	$\times 10^{-5}$		4728
$\gamma\pi^0\eta$	< 2.4	$\times 10^{-6}$	CL=90%	4713
$\gamma K^+K^-$	[a] ( 1.14 $\pm$ 0.13 )	$\times 10^{-5}$		4704
$\gamma p\bar{p}$	[b] < 6	$\times 10^{-6}$	CL=90%	4636
$\gamma 2h^+ 2h^-$	( 7.0 $\pm$ 1.5 )	$\times 10^{-4}$		4720
$\gamma 3h^+ 3h^-$	( 5.4 $\pm$ 2.0 )	$\times 10^{-4}$		4703
$\gamma 4h^+ 4h^-$	( 7.4 $\pm$ 3.5 )	$\times 10^{-4}$		4679
$\gamma\pi^+\pi^- K^+ K^-$	( 2.9 $\pm$ 0.9 )	$\times 10^{-4}$		4686
$\gamma 2\pi^+ 2\pi^-$	( 2.5 $\pm$ 0.9 )	$\times 10^{-4}$		4720
$\gamma 3\pi^+ 3\pi^-$	( 2.5 $\pm$ 1.2 )	$\times 10^{-4}$		4703
$\gamma 2\pi^+ 2\pi^- K^+ K^-$	( 2.4 $\pm$ 1.2 )	$\times 10^{-4}$		4658

$\gamma\pi^+\pi^-p\bar{p}$	( 1.5 ±0.6 ) × 10 <sup>-4</sup>	4604
$\gamma 2\pi^+2\pi^-p\bar{p}$	( 4 ±6 ) × 10 <sup>-5</sup>	4563
$\gamma 2K^+2K^-$	( 2.0 ±2.0 ) × 10 <sup>-5</sup>	4601
$\gamma\eta'(958)$	< 1.9 × 10 <sup>-6</sup> CL=90%	4682
$\gamma\eta$	< 1.0 × 10 <sup>-6</sup> CL=90%	4714
$\gamma f_0(980)$	< 3 × 10 <sup>-5</sup> CL=90%	4678
$\gamma f'_2(1525)$	( 2.9 ±0.6 ) × 10 <sup>-5</sup>	4608
$\gamma f_2(1270)$	( 1.01 ±0.06 ) × 10 <sup>-4</sup>	4644
$\gamma\eta(1405)$	< 8.2 × 10 <sup>-5</sup> CL=90%	4625
$\gamma f_0(1500)$	< 1.5 × 10 <sup>-5</sup> CL=90%	4610
$\gamma f_0(1500) \rightarrow \gamma K^+K^-$	( 1.0 ±0.4 ) × 10 <sup>-5</sup>	—
$\gamma f_0(1710)$	< 2.6 × 10 <sup>-4</sup> CL=90%	4577
$\gamma f_0(1710) \rightarrow \gamma K^+K^-$	( 1.01 ±0.32 ) × 10 <sup>-5</sup>	—
$\gamma f_0(1710) \rightarrow \gamma\pi^+\pi^-$	( 5.3 ±2.0 ) × 10 <sup>-6</sup>	—
$\gamma f_0(1710) \rightarrow \gamma\pi^0\pi^0$	< 1.4 × 10 <sup>-6</sup> CL=90%	—
$\gamma f_0(1710) \rightarrow \gamma\eta\eta$	< 1.8 × 10 <sup>-6</sup> CL=90%	—
$\gamma f_4(2050)$	< 5.3 × 10 <sup>-5</sup> CL=90%	4515
$\gamma f_0(2200) \rightarrow \gamma K^+K^-$	< 2 × 10 <sup>-4</sup> CL=90%	4475
$\gamma f_J(2220) \rightarrow \gamma K^+K^-$	< 8 × 10 <sup>-7</sup> CL=90%	4469
$\gamma f_J(2220) \rightarrow \gamma\pi^+\pi^-$	< 6 × 10 <sup>-7</sup> CL=90%	—
$\gamma f_J(2220) \rightarrow \gamma p\bar{p}$	< 1.1 × 10 <sup>-6</sup> CL=90%	—
$\gamma\eta(2225) \rightarrow \gamma\phi\phi$	< 3 × 10 <sup>-3</sup> CL=90%	4469
$\gamma\eta_c(1S)$	< 2.9 × 10 <sup>-5</sup> CL=90%	4260
$\gamma\eta_c(2S)$	< 4 × 10 <sup>-4</sup> CL=90%	4031
$\gamma\chi_{c0}$	< 6.6 × 10 <sup>-5</sup> CL=90%	4114
$\gamma\chi_{c1}$	( 4.7 <sup>+2.4</sup> <sub>-1.9</sub> ) × 10 <sup>-5</sup>	4079
$\gamma\chi_{c2}$	< 7.6 × 10 <sup>-6</sup> CL=90%	4062
$\gamma\chi_{c1}(3872)$	< 4 × 10 <sup>-5</sup> CL=90%	3938
$\gamma\chi_{c1}(3872), \chi_{c1} \rightarrow \pi^+\pi^-\pi^0 J/\psi$	< 2.8 × 10 <sup>-6</sup> CL=90%	—
$\gamma\chi_{c0}(3915) \rightarrow \omega J/\psi$	< 3.0 × 10 <sup>-6</sup> CL=90%	—
$\gamma\chi_{c1}(4140) \rightarrow \phi J/\psi$	< 2.2 × 10 <sup>-6</sup> CL=90%	—
$\gamma X$	[c] < 4.5 × 10 <sup>-6</sup> CL=90%	—
$\gamma X\bar{X} (m_X < 3.1 \text{ GeV})$	[d] < 1 × 10 <sup>-3</sup> CL=90%	—
$\gamma X\bar{X} (m_X < 4.5 \text{ GeV})$	[e] < 2.4 × 10 <sup>-4</sup> CL=90%	—
$\gamma X \rightarrow \gamma + \geq 4 \text{ prongs}$	[f] < 1.78 × 10 <sup>-4</sup> CL=95%	—
$\gamma a_1^0 \rightarrow \gamma\mu^+\mu^-$	[g] < 9 × 10 <sup>-6</sup> CL=90%	—
$\gamma a_1^0 \rightarrow \gamma\tau^+\tau^-$	[a] < 1.30 × 10 <sup>-4</sup> CL=90%	—
$\gamma a_1^0 \rightarrow \gamma g g$	[h] < 1 % CL=90%	—
$\gamma a_1^0 \rightarrow \gamma s\bar{s}$	[h] < 1 × 10 <sup>-3</sup> CL=90%	—

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

$\mu^\pm\tau^\mp$	LF < 6.0 × 10 <sup>-6</sup> CL=95%	4563
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**Other decays**

invisible	< 3.0	$\times 10^{-4}$	CL=90%	–
hadrons	(97 $\pm$ 5	) %		–

 **$\chi_{b0}(1P)$  [i]**

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

 $J$  needs confirmation.

Mass  $m = 9859.44 \pm 0.42 \pm 0.31$  MeV

<b><math>\chi_{b0}(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$\gamma \Upsilon(1S)$	( 1.94 $\pm$ 0.27 ) %		391
$D^0 X$	< 10.4	%	90%
$\pi^+ \pi^- K^+ K^- \pi^0$	< 1.6	$\times 10^{-4}$	90%
$2\pi^+ \pi^- K^- K_S^0$	< 5	$\times 10^{-5}$	90%
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	< 5	$\times 10^{-4}$	90%
$2\pi^+ 2\pi^- 2\pi^0$	< 2.1	$\times 10^{-4}$	90%
$2\pi^+ 2\pi^- K^+ K^-$	( 1.1 $\pm$ 0.6 ) $\times 10^{-4}$		4861
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	< 2.7	$\times 10^{-4}$	90%
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	< 5	$\times 10^{-4}$	90%
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	< 1.6	$\times 10^{-4}$	90%
$3\pi^+ 3\pi^-$	< 8	$\times 10^{-5}$	90%
$3\pi^+ 3\pi^- 2\pi^0$	< 6	$\times 10^{-4}$	90%
$3\pi^+ 3\pi^- K^+ K^-$	( 2.4 $\pm$ 1.2 ) $\times 10^{-4}$		4827
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	< 1.0	$\times 10^{-3}$	90%
$4\pi^+ 4\pi^-$	< 8	$\times 10^{-5}$	90%
$4\pi^+ 4\pi^- 2\pi^0$	< 2.1	$\times 10^{-3}$	90%
$J/\psi J/\psi$	< 7	$\times 10^{-5}$	90%
$J/\psi \psi(2S)$	< 1.2	$\times 10^{-4}$	90%
$\psi(2S) \psi(2S)$	< 3.1	$\times 10^{-5}$	90%
$J/\psi(1S)$ anything	< 2.3	$\times 10^{-3}$	90%

 **$\chi_{b1}(1P)$  [i]**

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

 $J$  needs confirmation.

Mass  $m = 9892.78 \pm 0.26 \pm 0.31$  MeV

<b><math>\chi_{b1}(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$P$ (MeV/c)
$\gamma \Upsilon(1S)$	(35.2 $\pm$ 2.0) %		423
$D^0 X$	(12.6 $\pm$ 2.2) %		–
$\pi^+ \pi^- K^+ K^- \pi^0$	( 2.0 $\pm$ 0.6 ) $\times 10^{-4}$		4892
$2\pi^+ \pi^- K^- K_S^0$	( 1.3 $\pm$ 0.5 ) $\times 10^{-4}$		4892
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	< 6	$\times 10^{-4}$	90%
$2\pi^+ 2\pi^- 2\pi^0$	( 8.0 $\pm$ 2.5 ) $\times 10^{-4}$		4921

$2\pi^+ 2\pi^- K^+ K^-$	$(1.5 \pm 0.5) \times 10^{-4}$		4878
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(3.5 \pm 1.2) \times 10^{-4}$		4863
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(8.6 \pm 3.2) \times 10^{-4}$		4845
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$(9.3 \pm 3.3) \times 10^{-4}$		4844
$3\pi^+ 3\pi^-$	$(1.9 \pm 0.6) \times 10^{-4}$		4921
$3\pi^+ 3\pi^- 2\pi^0$	$(1.7 \pm 0.5) \times 10^{-3}$		4898
$3\pi^+ 3\pi^- K^+ K^-$	$(2.6 \pm 0.8) \times 10^{-4}$		4844
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$(7.5 \pm 2.6) \times 10^{-4}$		4825
$4\pi^+ 4\pi^-$	$(2.6 \pm 0.9) \times 10^{-4}$		4897
$4\pi^+ 4\pi^- 2\pi^0$	$(1.4 \pm 0.6) \times 10^{-3}$		4867
$\omega$ anything	$(4.9 \pm 1.4) \%$		—
$\omega X_{tetra}$	$< 4.44 \times 10^{-4}$	90%	—
$J/\psi J/\psi$	$< 2.7 \times 10^{-5}$	90%	3857
$J/\psi \psi(2S)$	$< 1.7 \times 10^{-5}$	90%	3594
$\psi(2S) \psi(2S)$	$< 6 \times 10^{-5}$	90%	3298
$J/\psi(1S)$ anything	$< 1.1 \times 10^{-3}$	90%	—
$J/\psi(1S) X_{tetra}$	$< 2.27 \times 10^{-4}$	90%	—

 **$h_b(1P)$** 

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

 Mass  $m = 9899.3 \pm 0.8$  MeV

<b><math>h_b(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\eta_b(1S)\gamma$	$(52_{-5}^{+6}) \%$	488

 **$\chi_{b2}(1P)$  [i]**

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

 $J$  needs confirmation.

 Mass  $m = 9912.21 \pm 0.26 \pm 0.31$  MeV

<b><math>\chi_{b2}(1P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\gamma \Upsilon(1S)$	$(18.0 \pm 1.0) \%$		442
$D^0 X$	$< 7.9 \%$	90%	—
$\pi^+ \pi^- K^+ K^- \pi^0$	$(8 \pm 5) \times 10^{-5}$		4902
$2\pi^+ \pi^- K^- K_S^0$	$< 1.0 \times 10^{-4}$	90%	4901
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	$(5.3 \pm 2.4) \times 10^{-4}$		4873
$2\pi^+ 2\pi^- 2\pi^0$	$(3.5 \pm 1.4) \times 10^{-4}$		4931
$2\pi^+ 2\pi^- K^+ K^-$	$(1.1 \pm 0.4) \times 10^{-4}$		4888
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(2.1 \pm 0.9) \times 10^{-4}$		4872
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(3.9 \pm 1.8) \times 10^{-4}$		4855
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$< 5 \times 10^{-4}$	90%	4854

$3\pi^+ 3\pi^-$	$( 7.0 \pm 3.1 ) \times 10^{-5}$		4931
$3\pi^+ 3\pi^- 2\pi^0$	$( 1.0 \pm 0.4 ) \times 10^{-3}$		4908
$3\pi^+ 3\pi^- K^+ K^-$	$< 8 \times 10^{-5}$	90%	4854
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$( 3.6 \pm 1.5 ) \times 10^{-4}$		4835
$4\pi^+ 4\pi^-$	$( 8 \pm 4 ) \times 10^{-5}$		4907
$4\pi^+ 4\pi^- 2\pi^0$	$( 1.8 \pm 0.7 ) \times 10^{-3}$		4877
$J/\psi J/\psi$	$< 4 \times 10^{-5}$	90%	3869
$J/\psi \psi(2S)$	$< 5 \times 10^{-5}$	90%	3608
$\psi(2S) \psi(2S)$	$< 1.6 \times 10^{-5}$	90%	3313
$J/\psi(1S)$ anything	$( 1.5 \pm 0.4 ) \times 10^{-3}$		—

$\Upsilon(2S)$

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

Mass  $m = 10023.26 \pm 0.31$  MeV  
 $m_{\Upsilon(3S)} - m_{\Upsilon(2S)} = 331.50 \pm 0.13$  MeV  
 Full width  $\Gamma = 31.98 \pm 2.63$  keV

<b><math>\Upsilon(2S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\Upsilon(1S) \pi^+ \pi^-$	$(17.85 \pm 0.26) \%$		475
$\Upsilon(1S) \pi^0 \pi^0$	$( 8.6 \pm 0.4 ) \%$		480
$\tau^+ \tau^-$	$( 2.00 \pm 0.21 ) \%$		4686
$\mu^+ \mu^-$	$( 1.93 \pm 0.17 ) \%$	S=2.2	5011
$e^+ e^-$	$( 1.91 \pm 0.16 ) \%$		5012
$\Upsilon(1S) \pi^0$	$< 4 \times 10^{-5}$	CL=90%	531
$\Upsilon(1S) \eta$	$( 2.9 \pm 0.4 ) \times 10^{-4}$	S=2.0	126
$J/\psi(1S)$ anything	$< 6 \times 10^{-3}$	CL=90%	4533
$J/\psi(1S) \eta_c$	$< 5.4 \times 10^{-6}$	CL=90%	3984
$J/\psi(1S) \chi_{c0}$	$< 3.4 \times 10^{-6}$	CL=90%	3808
$J/\psi(1S) \chi_{c1}$	$< 1.2 \times 10^{-6}$	CL=90%	3765
$J/\psi(1S) \chi_{c2}$	$< 2.0 \times 10^{-6}$	CL=90%	3744
$J/\psi(1S) \eta_c(2S)$	$< 2.5 \times 10^{-6}$	CL=90%	3707
$J/\psi(1S) X(3940)$	$< 2.0 \times 10^{-6}$	CL=90%	3555
$J/\psi(1S) X(4160)$	$< 2.0 \times 10^{-6}$	CL=90%	3442
$\chi_{c1}$ anything	$( 2.2 \pm 0.5 ) \times 10^{-4}$		—
$\chi_{c1}(1P)^0 X_{tetra}$	$< 3.67 \times 10^{-5}$	CL=90%	—
$\chi_{c2}$ anything	$( 2.3 \pm 0.8 ) \times 10^{-4}$		—
$\psi(2S) \eta_c$	$< 5.1 \times 10^{-6}$	CL=90%	3732
$\psi(2S) \chi_{c0}$	$< 4.7 \times 10^{-6}$	CL=90%	3536
$\psi(2S) \chi_{c1}$	$< 2.5 \times 10^{-6}$	CL=90%	3488
$\psi(2S) \chi_{c2}$	$< 1.9 \times 10^{-6}$	CL=90%	3464
$\psi(2S) \eta_c(2S)$	$< 3.3 \times 10^{-6}$	CL=90%	3422
$\psi(2S) X(3940)$	$< 3.9 \times 10^{-6}$	CL=90%	3250
$\psi(2S) X(4160)$	$< 3.9 \times 10^{-6}$	CL=90%	3120

$Z_c(3900)^+ Z_c(3900)^-$	< 1.0	$\times 10^{-6}$	CL=90%	—
$Z_c(4200)^+ Z_c(4200)^-$	< 1.67	$\times 10^{-5}$	CL=90%	—
$Z_c(3900)^\pm Z_c(4200)^\mp$	< 7.3	$\times 10^{-6}$	CL=90%	—
$X(4050)^+ X(4050)^-$	< 1.35	$\times 10^{-5}$	CL=90%	—
$X(4250)^+ X(4250)^-$	< 2.67	$\times 10^{-5}$	CL=90%	—
$X(4050)^\pm X(4250)^\mp$	< 2.72	$\times 10^{-5}$	CL=90%	—
$Z_c(4430)^+ Z_c(4430)^-$	< 2.03	$\times 10^{-5}$	CL=90%	—
$X(4055)^\pm X(4055)^\mp$	< 1.11	$\times 10^{-5}$	CL=90%	—
$X(4055)^\pm Z_c(4430)^\mp$	< 2.11	$\times 10^{-5}$	CL=90%	—
$\overline{^2H}$ anything	$( 2.78 \pm 0.30 )$	$\times 10^{-5}$	S=1.2	—
hadrons	$( 94 \pm 11 )$	%		—
$ggg$	$( 58.8 \pm 1.2 )$	%		—
$\gamma g g$	$( 1.87 \pm 0.28 )$	%		—
$\phi K^+ K^-$	$( 1.6 \pm 0.4 )$	$\times 10^{-6}$		4910
$\omega \pi^+ \pi^-$	< 2.58	$\times 10^{-6}$	CL=90%	4977
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	$( 2.3 \pm 0.7 )$	$\times 10^{-6}$		4952
$\phi f'_2(1525)$	< 1.33	$\times 10^{-6}$	CL=90%	4842
$\omega f_2(1270)$	< 5.7	$\times 10^{-7}$	CL=90%	4899
$\rho(770) a_2(1320)$	< 8.8	$\times 10^{-7}$	CL=90%	4894
$K^*(892)^0 \overline{K}_2^*(1430)^0 + \text{c.c.}$	$( 1.5 \pm 0.6 )$	$\times 10^{-6}$		4869
$K_1(1270)^\pm K^\mp$	< 3.22	$\times 10^{-6}$	CL=90%	4921
$K_1(1400)^\pm K^\mp$	< 8.3	$\times 10^{-7}$	CL=90%	4901
$b_1(1235)^\pm \pi^\mp$	< 4.0	$\times 10^{-7}$	CL=90%	4935
$\rho \pi$	< 1.16	$\times 10^{-6}$	CL=90%	4981
$\pi^+ \pi^- \pi^0$	< 8.0	$\times 10^{-7}$	CL=90%	5007
$\omega \pi^0$	< 1.63	$\times 10^{-6}$	CL=90%	4980
$\pi^+ \pi^- \pi^0 \pi^0$	$( 1.30 \pm 0.28 )$	$\times 10^{-5}$		5002
$K_S^0 K^+ \pi^- + \text{c.c.}$	$( 1.14 \pm 0.33 )$	$\times 10^{-6}$		4979
$K^*(892)^0 \overline{K}^0 + \text{c.c.}$	< 4.22	$\times 10^{-6}$	CL=90%	4959
$K^*(892)^- K^+ + \text{c.c.}$	< 1.45	$\times 10^{-6}$	CL=90%	4960
$f_1(1285)$ anything	$( 2.2 \pm 1.6 )$	$\times 10^{-3}$		—
$f_1(1285) X_{tetra}$	< 6.47	$\times 10^{-5}$	CL=90%	—
Sum of 100 exclusive modes	$( 2.90 \pm 0.30 )$	$\times 10^{-3}$		—

### Radiative decays

$\gamma X_{b1}(1P)$	$( 6.9 \pm 0.4 )$	%		130
$\gamma X_{b2}(1P)$	$( 7.15 \pm 0.35 )$	%		110
$\gamma X_{b0}(1P)$	$( 3.8 \pm 0.4 )$	%		162
$\gamma f_0(1710)$	< 5.9	$\times 10^{-4}$	CL=90%	4867
$\gamma f'_2(1525)$	< 5.3	$\times 10^{-4}$	CL=90%	4897
$\gamma f_2(1270)$	< 2.41	$\times 10^{-4}$	CL=90%	4930
$\gamma \eta_c(1S)$	< 2.7	$\times 10^{-5}$	CL=90%	4567
$\gamma X_{c0}$	< 1.0	$\times 10^{-4}$	CL=90%	4430
$\gamma X_{c1}$	< 3.6	$\times 10^{-6}$	CL=90%	4397

$\gamma\chi_{c2}$	$< 1.5$	$\times 10^{-5}$	CL=90%	4381
$\gamma\chi_{c1}(3872)$	$< 2.1$	$\times 10^{-5}$	CL=90%	4264
$\gamma\chi_{c1}(3872), \chi_{c1} \rightarrow \pi^+\pi^-\pi^0 J/\psi$	$< 2.4$	$\times 10^{-6}$	CL=90%	—
$\gamma\chi_{c0}(3915) \rightarrow \omega J/\psi$	$< 2.8$	$\times 10^{-6}$	CL=90%	—
$\gamma\chi_{c1}(4140) \rightarrow \phi J/\psi$	$< 1.2$	$\times 10^{-6}$	CL=90%	—
$\gamma X(4350) \rightarrow \phi J/\psi$	$< 1.3$	$\times 10^{-6}$	CL=90%	—
$\gamma\eta_b(1S)$	$(5.5 \pm_{-0.9}^{+1.1}) \times 10^{-4}$		S=1.2	605
$\gamma\eta_b(1S) \rightarrow \gamma$ Sum of 26 exclusive modes	$< 3.7$	$\times 10^{-6}$	CL=90%	—
$\gamma X_{b\bar{b}} \rightarrow \gamma$ Sum of 26 exclusive modes	$< 4.9$	$\times 10^{-6}$	CL=90%	—
$\gamma X \rightarrow \gamma + \geq 4$ prongs	[j] $< 1.95$	$\times 10^{-4}$	CL=95%	—
$\gamma A^0 \rightarrow \gamma$ hadrons	$< 8$	$\times 10^{-5}$	CL=90%	—
$\gamma a_1^0 \rightarrow \gamma\mu^+\mu^-$	$< 8.3$	$\times 10^{-6}$	CL=90%	—

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

$e^\pm \tau^\mp$	LF	$< 3.2$	$\times 10^{-6}$	CL=90%	4854
$\mu^\pm \tau^\mp$	LF	$< 3.3$	$\times 10^{-6}$	CL=90%	4854

**$\Upsilon_2(1D)$**

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

was  $\Upsilon(1D)$

$$\text{Mass } m = 10163.7 \pm 1.4 \text{ MeV} \quad (S = 1.7)$$

<b><math>\Upsilon_2(1D)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\gamma\gamma \Upsilon(1S)$	seen	679
$\gamma\chi_{bJ}(1P)$	seen	300
$\eta \Upsilon(1S)$	not seen	426
$\pi^+\pi^- \Upsilon(1S)$	$(6.6 \pm 1.6) \times 10^{-3}$	623

**$\chi_{b0}(2P)$  [i]**

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

$J$  needs confirmation.

$$\text{Mass } m = 10232.5 \pm 0.4 \pm 0.5 \text{ MeV}$$

<b><math>\chi_{b0}(2P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\gamma \Upsilon(2S)$	$(1.38 \pm 0.30) \%$		207
$\gamma \Upsilon(1S)$	$(3.8 \pm 1.7) \times 10^{-3}$		743
$D^0 X$	$< 8.2$	%	90%
$\pi^+\pi^- K^+ K^- \pi^0$	$< 3.4$	$\times 10^{-5}$	90%
$2\pi^+\pi^- K^- K_S^0$	$< 5$	$\times 10^{-5}$	90%

$2\pi^+\pi^-K^-K_S^02\pi^0$	$< 2.2$	$\times 10^{-4}$	90%	5036
$2\pi^+2\pi^-2\pi^0$	$< 2.4$	$\times 10^{-4}$	90%	5092
$2\pi^+2\pi^-K^+K^-$	$< 1.5$	$\times 10^{-4}$	90%	5050
$2\pi^+2\pi^-K^+K^-\pi^0$	$< 2.2$	$\times 10^{-4}$	90%	5035
$2\pi^+2\pi^-K^+K^-2\pi^0$	$< 1.1$	$\times 10^{-3}$	90%	5019
$3\pi^+2\pi^-K^-K_S^0\pi^0$	$< 7$	$\times 10^{-4}$	90%	5018
$3\pi^+3\pi^-$	$< 7$	$\times 10^{-5}$	90%	5091
$3\pi^+3\pi^-2\pi^0$	$< 1.2$	$\times 10^{-3}$	90%	5070
$3\pi^+3\pi^-K^+K^-$	$< 1.5$	$\times 10^{-4}$	90%	5017
$3\pi^+3\pi^-K^+K^-\pi^0$	$< 7$	$\times 10^{-4}$	90%	4999
$4\pi^+4\pi^-$	$< 1.7$	$\times 10^{-4}$	90%	5069
$4\pi^+4\pi^-2\pi^0$	$< 6$	$\times 10^{-4}$	90%	5039

 **$\chi_{b1}(2P)$  [i]**

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

 $J$  needs confirmation.

$$\text{Mass } m = 10255.46 \pm 0.22 \pm 0.50 \text{ MeV}$$

$$m_{\chi_{b1}(2P)} - m_{\chi_{b0}(2P)} = 23.5 \pm 1.0 \text{ MeV}$$

<b><math>\chi_{b1}(2P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\omega \Upsilon(1S)$	$(1.63^{+0.40}_{-0.34})\%$	135
$\gamma \Upsilon(2S)$	$(18.1 \pm 1.9)\%$	230
$\gamma \Upsilon(1S)$	$(9.9 \pm 1.0)\%$	764
$\pi\pi\chi_{b1}(1P)$	$(9.1 \pm 1.3) \times 10^{-3}$	238
$D^0 X$	$(8.8 \pm 1.7)\%$	—
$\pi^+\pi^-K^+K^-\pi^0$	$(3.1 \pm 1.0) \times 10^{-4}$	5075
$2\pi^+\pi^-K^-K_S^0$	$(1.1 \pm 0.5) \times 10^{-4}$	5075
$2\pi^+\pi^-K^-K_S^02\pi^0$	$(7.7 \pm 3.2) \times 10^{-4}$	5047
$2\pi^+2\pi^-2\pi^0$	$(5.9 \pm 2.0) \times 10^{-4}$	5104
$2\pi^+2\pi^-K^+K^-$	$(10 \pm 4) \times 10^{-5}$	5062
$2\pi^+2\pi^-K^+K^-\pi^0$	$(5.5 \pm 1.8) \times 10^{-4}$	5047
$2\pi^+2\pi^-K^+K^-2\pi^0$	$(10 \pm 4) \times 10^{-4}$	5030
$3\pi^+2\pi^-K^-K_S^0\pi^0$	$(6.7 \pm 2.6) \times 10^{-4}$	5029
$3\pi^+3\pi^-$	$(1.2 \pm 0.4) \times 10^{-4}$	5103
$3\pi^+3\pi^-2\pi^0$	$(1.2 \pm 0.4) \times 10^{-3}$	5081
$3\pi^+3\pi^-K^+K^-$	$(2.0 \pm 0.8) \times 10^{-4}$	5029
$3\pi^+3\pi^-K^+K^-\pi^0$	$(6.1 \pm 2.2) \times 10^{-4}$	5011
$4\pi^+4\pi^-$	$(1.7 \pm 0.6) \times 10^{-4}$	5080
$4\pi^+4\pi^-2\pi^0$	$(1.9 \pm 0.7) \times 10^{-3}$	5051

**$h_b(2P)$** 

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

Mass  $m = 10259.8 \pm 1.2$  MeV

<b><math>h_b(2P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
hadrons	not seen	—
$\eta_b(1S)\gamma$	$(22 \pm 5)$ %	825
$\eta_b(2S)\gamma$	$(48 \pm 13)$ %	257

 **$\chi_{b2}(2P)$  [i]**

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

 $J$  needs confirmation.Mass  $m = 10268.65 \pm 0.22 \pm 0.50$  MeV

$$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)} = 13.10 \pm 0.24$$
 MeV

<b><math>\chi_{b2}(2P)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$\omega \Upsilon(1S)$	$(1.10^{+0.34}_{-0.30})$ %		194
$\gamma \Upsilon(2S)$	$(8.9 \pm 1.2)$ %		242
$\gamma \Upsilon(1S)$	$(6.6 \pm 0.8)$ %		777
$\pi\pi\chi_{b2}(1P)$	$(5.1 \pm 0.9) \times 10^{-3}$		229
$D^0 X$	$< 2.4$ %	90%	—
$\pi^+\pi^-K^+K^-\pi^0$	$< 1.1 \times 10^{-4}$	90%	5082
$2\pi^+\pi^-K^-K_S^0$	$< 9 \times 10^{-5}$	90%	5082
$2\pi^+\pi^-K^-K_S^0 2\pi^0$	$< 7 \times 10^{-4}$	90%	5054
$2\pi^+2\pi^-2\pi^0$	$(3.9 \pm 1.6) \times 10^{-4}$		5110
$2\pi^+2\pi^-K^+K^-$	$(9 \pm 4) \times 10^{-5}$		5068
$2\pi^+2\pi^-K^+K^-\pi^0$	$(2.4 \pm 1.1) \times 10^{-4}$		5054
$2\pi^+2\pi^-K^+K^-2\pi^0$	$(4.7 \pm 2.3) \times 10^{-4}$		5037
$3\pi^+2\pi^-K^-K_S^0\pi^0$	$< 4 \times 10^{-4}$	90%	5036
$3\pi^+3\pi^-$	$(9 \pm 4) \times 10^{-5}$		5110
$3\pi^+3\pi^-2\pi^0$	$(1.2 \pm 0.4) \times 10^{-3}$		5088
$3\pi^+3\pi^-K^+K^-$	$(1.4 \pm 0.7) \times 10^{-4}$		5036
$3\pi^+3\pi^-K^+K^-\pi^0$	$(4.2 \pm 1.7) \times 10^{-4}$		5017
$4\pi^+4\pi^-$	$(9 \pm 5) \times 10^{-5}$		5087
$4\pi^+4\pi^-2\pi^0$	$(1.3 \pm 0.5) \times 10^{-3}$		5058

 **$\Upsilon(3S)$** 

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

Mass  $m = 10355.2 \pm 0.5$  MeV

$$m_{\Upsilon(3S)} - m_{\Upsilon(2S)} = 331.50 \pm 0.13$$
 MeV

Full width  $\Gamma = 20.32 \pm 1.85$  keV

<b><math>\Upsilon(3S)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level	$p$ (MeV/c)
$\Upsilon(2S)$ anything	(10.6 $\pm$ 0.8 ) %		296
$\Upsilon(2S)\pi^+\pi^-$	( 2.82 $\pm$ 0.18) %	S=1.6	177
$\Upsilon(2S)\pi^0\pi^0$	( 1.85 $\pm$ 0.14) %		190
$\Upsilon(2S)\gamma\gamma$	( 5.0 $\pm$ 0.7 ) %		327
$\Upsilon(2S)\pi^0$	< 5.1	$\times 10^{-4}$ CL=90%	298
$\Upsilon(1S)\pi^+\pi^-$	( 4.37 $\pm$ 0.08) %		813
$\Upsilon(1S)\pi^0\pi^0$	( 2.20 $\pm$ 0.13) %		816
$\Upsilon(1S)\eta$	< 1	$\times 10^{-4}$ CL=90%	677
$\Upsilon(1S)\pi^0$	< 7	$\times 10^{-5}$ CL=90%	846
$h_b(1P)\pi^0$	< 1.2	$\times 10^{-3}$ CL=90%	426
$h_b(1P)\pi^0 \rightarrow \gamma\eta_b(1S)\pi^0$	( 4.3 $\pm$ 1.4 ) $\times 10^{-4}$		—
$h_b(1P)\pi^+\pi^-$	< 1.2	$\times 10^{-4}$ CL=90%	353
$\tau^+\tau^-$	( 2.29 $\pm$ 0.30) %		4863
$\mu^+\mu^-$	( 2.18 $\pm$ 0.21) %	S=2.1	5177
$e^+e^-$	( 2.18 $\pm$ 0.20) %		5178
hadrons	(93 $\pm$ 12 ) %		—
$ggg$	(35.7 $\pm$ 2.6 ) %		—
$\gamma gg$	( 9.7 $\pm$ 1.8 ) $\times 10^{-3}$		—
${}^2H$ anything	( 2.33 $\pm$ 0.33) $\times 10^{-5}$		—

### Radiative decays

$\gamma\chi_{b2}(2P)$	(13.1 $\pm$ 1.6 ) %	S=3.4	86
$\gamma\chi_{b1}(2P)$	(12.6 $\pm$ 1.2 ) %	S=2.4	99
$\gamma\chi_{b0}(2P)$	( 5.9 $\pm$ 0.6 ) %	S=1.4	122
$\gamma\chi_{b2}(1P)$	(10.0 $\pm$ 1.0 ) $\times 10^{-3}$	S=1.7	434
$\gamma\chi_{b1}(1P)$	( 9 $\pm$ 5 ) $\times 10^{-4}$	S=1.8	452
$\gamma\chi_{b0}(1P)$	( 2.7 $\pm$ 0.4 ) $\times 10^{-3}$		484
$\gamma\eta_b(2S)$	< 6.2	$\times 10^{-4}$ CL=90%	350
$\gamma\eta_b(1S)$	( 5.1 $\pm$ 0.7 ) $\times 10^{-4}$		912
$\gamma A^0 \rightarrow \gamma$ hadrons	< 8	$\times 10^{-5}$ CL=90%	—
$\gamma X \rightarrow \gamma + \geq 4$ prongs	[k] < 2.2	$\times 10^{-4}$ CL=95%	—
$\gamma a_1^0 \rightarrow \gamma\mu^+\mu^-$	< 5.5	$\times 10^{-6}$ CL=90%	—
$\gamma a_1^0 \rightarrow \gamma\tau^+\tau^-$	[l] < 1.6	$\times 10^{-4}$ CL=90%	—

### Lepton Family number (LF) violating modes

$e^\pm\tau^\mp$	LF	< 4.2	$\times 10^{-6}$ CL=90%	5025
$\mu^\pm\tau^\mp$	LF	< 3.1	$\times 10^{-6}$ CL=90%	5025

**$\chi_{b1}(3P)$  [i]**

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

$J$  needs confirmation.

$$\text{Mass } m = 10513.4 \pm 0.7 \text{ MeV}$$

$\chi_{b1}(3P)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Upsilon(1S)\gamma$	seen	1000
$\Upsilon(2S)\gamma$	seen	479
$\Upsilon(3S)\gamma$	seen	157

**$\chi_{b2}(3P)$  <sup>[i]</sup>**

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

$J$  needs confirmation.

Mass  $m = 10524.0 \pm 0.8$  MeV

$\chi_{b2}(3P)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Upsilon(3S)\gamma$	seen	167

**$\Upsilon(4S)$**

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

also known as  $\Upsilon(10580)$

Mass  $m = 10579.4 \pm 1.2$  MeV

Full width  $\Gamma = 20.5 \pm 2.5$  MeV

$\Upsilon(4S)$ DECAY MODES	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$B\bar{B}$	> 96 %	95%	326
$B^+B^-$	(51.4 ± 0.6) %		331
$D_S^+$ anything + c.c.	(17.8 ± 2.6) %		—
$B^0\bar{B}^0$	(48.6 ± 0.6) %		326
$J/\psi K_S^0 + (J/\psi, \eta_c) K_S^0$	< 4 × 10 <sup>-7</sup>	90%	—
non- $B\bar{B}$	< 4 %	95%	—
$e^+e^-$	(1.57 ± 0.08) × 10 <sup>-5</sup>		5290
$\rho^+\rho^-$	< 5.7 × 10 <sup>-6</sup>	90%	5233
$K^*(892)^0\bar{K}^0$	< 2.0 × 10 <sup>-6</sup>	90%	5240
$J/\psi(1S)$ anything	< 1.9 × 10 <sup>-4</sup>	95%	—
$D^{*+}$ anything + c.c.	< 7.4 %	90%	5099
$\phi$ anything	(7.1 ± 0.6) %		5240
$\phi\eta$	< 1.8 × 10 <sup>-6</sup>	90%	5226
$\phi\eta'$	< 4.3 × 10 <sup>-6</sup>	90%	5196
$\rho\eta$	< 1.3 × 10 <sup>-6</sup>	90%	5247
$\rho\eta'$	< 2.5 × 10 <sup>-6</sup>	90%	5217
$\Upsilon(1S)$ anything	< 4 × 10 <sup>-3</sup>	90%	1053
$\Upsilon(1S)\pi^+\pi^-$	(8.2 ± 0.4) × 10 <sup>-5</sup>		1026

$\Upsilon(1S)\eta$	$(1.81 \pm 0.18) \times 10^{-4}$		924
$\Upsilon(1S)\eta'$	$(3.4 \pm 0.9) \times 10^{-5}$		—
$\Upsilon(2S)\pi^+\pi^-$	$(8.2 \pm 0.8) \times 10^{-5}$		468
$h_b(1P)\pi^+\pi^-$	not seen		600
$h_b(1P)\eta$	$(2.18 \pm 0.21) \times 10^{-3}$		390
$\eta_b(1S)\omega$	$< 1.8 \times 10^{-4}$	90%	—
${}^2H$ anything	$< 1.3 \times 10^{-5}$	90%	—

**Double Radiative Decays**

$\gamma\gamma \Upsilon(D) \rightarrow \gamma\gamma\eta \Upsilon(1S)$	$< 2.3 \times 10^{-5}$	90%	—
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**Z<sub>b</sub>(10610)**

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

was X(10610)

Mass  $m = 10607.2 \pm 2.0$  MeVFull width  $\Gamma = 18.4 \pm 2.4$  MeV

<b>Z<sub>b</sub>(10610) DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Upsilon(1S)\pi^+$	$(5.4^{+1.9}_{-1.5}) \times 10^{-3}$	1077
$\Upsilon(1S)\pi^0$	not seen	1077
$\Upsilon(2S)\pi^+$	$(3.6^{+1.1}_{-0.8}) \%$	551
$\Upsilon(2S)\pi^0$	seen	552
$\Upsilon(3S)\pi^+$	$(2.1^{+0.8}_{-0.6}) \%$	207
$\Upsilon(3S)\pi^0$	seen	210
$h_b(1P)\pi^+$	$(3.5^{+1.2}_{-0.9}) \%$	671
$h_b(2P)\pi^+$	$(4.7^{+1.7}_{-1.3}) \%$	313
$B^+\bar{B}^0$	not seen	505
$B^+\bar{B}^{*0} + B^{*+}\bar{B}^0$	$(85.6^{+2.1}_{-2.9}) \%$	—

**Z<sub>b</sub>(10650)**

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

 $I, G, C$  need confirmation.was X(10650)<sup>±</sup>Mass  $m = 10652.2 \pm 1.5$  MeVFull width  $\Gamma = 11.5 \pm 2.2$  MeV

$Z_b(10650)^-$  decay modes are charge conjugates of the modes below.

<b><math>Z_b(10650)^+</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$\Upsilon(1S)\pi^+$	$(1.7^{+0.8}_{-0.6}) \times 10^{-3}$	1117
$\Upsilon(2S)\pi^+$	$(1.4^{+0.6}_{-0.4}) \%$	595
$\Upsilon(3S)\pi^+$	$(1.6^{+0.7}_{-0.5}) \%$	259
$h_b(1P)\pi^+$	$(8.4^{+2.9}_{-2.4}) \%$	714
$h_b(2P)\pi^+$	$(15 \pm 4) \%$	360
$B^+\bar{B}^0$	not seen	703
$B^+\bar{B}^{*0} + B^{*+}\bar{B}^0$	not seen	—
$B^{*+}\bar{B}^{*0}$	$(74^{+4}_{-6}) \%$	122

**$\Upsilon(10860)$**

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

Mass  $m = 10885.2^{+2.6}_{-1.6}$  MeV

Full width  $\Gamma = 37 \pm 4$  MeV

<b><math>\Upsilon(10860)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	Confidence level	$p$ (MeV/c)
$B\bar{B}X$	$(76.2^{+2.7}_{-4.0}) \%$	—	—
$B\bar{B}$	$(5.5 \pm 1.0) \%$	—	1322
$B\bar{B}^* + \text{c.c.}$	$(13.7 \pm 1.6) \%$	—	—
$B^*\bar{B}^*$	$(38.1 \pm 3.4) \%$	—	1127
$B\bar{B}^{(*)}\pi$	$< 19.7 \%$	90%	1015
$B\bar{B}\pi$	$(0.0 \pm 1.2) \%$	—	1015
$B^*\bar{B}\pi + B\bar{B}^*\pi$	$(7.3 \pm 2.3) \%$	—	—
$B^*\bar{B}^*\pi$	$(1.0 \pm 1.4) \%$	—	739
$B\bar{B}\pi\pi$	$< 8.9 \%$	90%	551
$B_s^{(*)}\bar{B}_s^{(*)}$	$(20.1 \pm 3.1) \%$	—	905
$B_s\bar{B}_s$	$(5 \pm 5) \times 10^{-3}$	—	905
$B_s\bar{B}_s^* + \text{c.c.}$	$(1.35 \pm 0.32) \%$	—	—
$B_s^*\bar{B}_s^*$	$(17.6 \pm 2.7) \%$	—	543
no open-bottom	$(3.8^{+5.0}_{-0.5}) \%$	—	—
$e^+e^-$	$(8.3 \pm 2.1) \times 10^{-6}$	—	5443
$K^*(892)^0\bar{K}^0$	$< 1.0 \times 10^{-5}$	90%	5395
$\Upsilon(1S)\pi^+\pi^-$	$(5.3 \pm 0.6) \times 10^{-3}$	—	1306
$\Upsilon(1S)\eta$	$(8.5 \pm 1.7) \times 10^{-4}$	—	1229
$\Upsilon(1S)\eta'$	$< 6.9 \times 10^{-5}$	90%	985

$\Upsilon(2S)\pi^+\pi^-$	$( 7.8 \pm 1.3 ) \times 10^{-3}$		783
$\Upsilon(2S)\eta$	$( 4.1 \pm 0.6 ) \times 10^{-3}$		639
$\Upsilon(3S)\pi^+\pi^-$	$( 4.8 \begin{smallmatrix} +1.9 \\ -1.7 \end{smallmatrix} ) \times 10^{-3}$		440
$\Upsilon(1S)K^+K^-$	$( 6.1 \pm 1.8 ) \times 10^{-4}$		959
$\eta \Upsilon_J(1D)$	$( 4.8 \pm 1.1 ) \times 10^{-3}$		—
$h_b(1P)\pi^+\pi^-$	$( 3.5 \begin{smallmatrix} +1.0 \\ -1.3 \end{smallmatrix} ) \times 10^{-3}$		903
$h_b(2P)\pi^+\pi^-$	$( 5.7 \begin{smallmatrix} +1.7 \\ -2.1 \end{smallmatrix} ) \times 10^{-3}$		544
$\chi_{bJ}(1P)\pi^+\pi^-\pi^0$	$( 2.5 \pm 2.3 ) \times 10^{-3}$		894
$\chi_{b0}(1P)\pi^+\pi^-\pi^0$	$< 6.3 \times 10^{-3}$	90%	894
$\chi_{b0}(1P)\omega$	$< 3.9 \times 10^{-3}$	90%	631
$\chi_{b0}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$	$< 4.8 \times 10^{-3}$	90%	—
$\chi_{b1}(1P)\pi^+\pi^-\pi^0$	$( 1.85 \pm 0.33 ) \times 10^{-3}$		861
$\chi_{b1}(1P)\omega$	$( 1.57 \pm 0.30 ) \times 10^{-3}$		582
$\chi_{b1}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$	$( 5.2 \pm 1.9 ) \times 10^{-4}$		—
$\chi_{b2}(1P)\pi^+\pi^-\pi^0$	$( 1.17 \pm 0.30 ) \times 10^{-3}$		841
$\chi_{b2}(1P)\omega$	$( 6.0 \pm 2.7 ) \times 10^{-4}$		552
$\chi_{b2}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$	$( 6 \pm 4 ) \times 10^{-4}$		—
$\gamma X_b \rightarrow \gamma \Upsilon(1S)\omega$	$< 3.8 \times 10^{-5}$	90%	—
$\eta_b(1S)\omega$	$< 1.3 \times 10^{-3}$	90%	1177
$\eta_b(2S)\omega$	$< 5.6 \times 10^{-3}$	90%	399

### Inclusive Decays.

These decay modes are submodes of one or more of the decay modes above.

$\phi$ anything	$( 13.8 \begin{smallmatrix} +2.4 \\ -1.7 \end{smallmatrix} ) \%$	—
$D^0$ anything + c.c.	$(108 \pm 8) \%$	—
$D_s$ anything + c.c.	$( 46 \pm 6 ) \%$	—
$J/\psi$ anything	$( 2.06 \pm 0.21 ) \%$	—
$B^0$ anything + c.c.	$( 77 \pm 8 ) \%$	—
$B^+$ anything + c.c.	$( 72 \pm 6 ) \%$	—

**$\Upsilon(11020)$**

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

Mass  $m = 11000 \pm 4$  MeV

Full width  $\Gamma = 24 \begin{smallmatrix} +8 \\ -6 \end{smallmatrix}$  MeV

<b><math>\Upsilon(11020)</math> DECAY MODES</b>	Fraction ( $\Gamma_i/\Gamma$ )	$p$ (MeV/c)
$e^+e^-$	$(5.4 \begin{smallmatrix} +1.9 \\ -2.1 \end{smallmatrix}) \times 10^{-6}$	5500
$\chi_{bJ}(1P)\pi^+\pi^-\pi^0$	$(9 \begin{smallmatrix} +9 \\ -8 \end{smallmatrix}) \times 10^{-3}$	1007

$\chi_{b1}(1P)\pi^+\pi^-\pi^0$	seen	975
$\chi_{b2}(1P)\pi^+\pi^-\pi^0$	seen	956

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## NOTES

- [a]  $2m_\tau < M(\tau^+\tau^-) < 9.2$  GeV
- [b]  $2$  GeV  $< m_{K^+K^-} < 3$  GeV
- [c]  $X$  = scalar with  $m < 8.0$  GeV
- [d]  $X\bar{X}$  = vectors with  $m < 3.1$  GeV
- [e]  $X$  and  $\bar{X}$  = zero spin with  $m < 4.5$  GeV
- [f]  $1.5$  GeV  $< m_X < 5.0$  GeV
- [g]  $201$  MeV  $< M(\mu^+\mu^-) < 3565$  MeV
- [h]  $0.5$  GeV  $< m_X < 9.0$  GeV, where  $m_X$  is the invariant mass of the hadronic final state.
- [i] Spectroscopic labeling for these states is theoretical, pending experimental information.
- [j]  $1.5$  GeV  $< m_X < 5.0$  GeV
- [k]  $1.5$  GeV  $< m_X < 5.0$  GeV
- [l] For  $m_{\tau^+\tau^-}$  in the ranges 4.03–9.52 and 9.61–10.10 GeV.