

$b\bar{b}$ MESONS

$\Upsilon(1S)$

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

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

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

$\Gamma_{ee} = 1.340 \pm 0.018$ keV

$\Upsilon(1S)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	P (MeV/c)
$\tau^+ \tau^-$	$(2.67^{+0.14}_{-0.16})\%$		4384
$e^+ e^-$	$(2.38 \pm 0.11)\%$		4730
$\mu^+ \mu^-$	$(2.48 \pm 0.05)\%$		4729

Hadronic decays

$\eta'(958)$ anything	$(2.8 \pm 0.4)\%$		—
$J/\psi(1S)$ anything	$(6.5 \pm 0.7) \times 10^{-4}$		4223
χ_{c0} anything	$< 5 \times 10^{-3}$	90%	—
χ_{c1} anything	$(2.3 \pm 0.7) \times 10^{-4}$		—
χ_{c2} anything	$(3.4 \pm 1.0) \times 10^{-4}$		—
$\psi(2S)$ anything	$(2.7 \pm 0.9) \times 10^{-4}$		—
$\rho\pi$	$< 2 \times 10^{-4}$	90%	4697
$\pi^+ \pi^-$	$< 5 \times 10^{-4}$	90%	4728
$K^+ K^-$	$< 5 \times 10^{-4}$	90%	4704
$p\bar{p}$	$< 5 \times 10^{-4}$	90%	4636
$\pi^0 \pi^+ \pi^-$	$< 1.84 \times 10^{-5}$	90%	4725

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
$K^+ K^-$ with $2 < m_{K^+ K^-} < 3$ GeV	$(1.14 \pm 0.13) \times 10^{-5}$		—
$\gamma p\bar{p}$ with $2 < m_{p\bar{p}} < 3$ GeV	$< 6 \times 10^{-6}$	90%	—
$\gamma 2h^+ 2h^-$	$(7.0 \pm 1.5) \times 10^{-4}$		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
$\gamma \pi^+ \pi^- p\bar{p}$	$(1.5 \pm 0.6) \times 10^{-4}$		4604
$\gamma 2\pi^+ 2\pi^- p\bar{p}$	$(4 \pm 6) \times 10^{-5}$		4563
$\gamma 2K^+ 2K^-$	$(2.0 \pm 2.0) \times 10^{-5}$		4601

$\gamma\eta'(958)$	< 1.6	$\times 10^{-5}$	90%	4682
$\gamma\eta$	< 2.1	$\times 10^{-5}$	90%	4714
$\gamma f_0(980)$	< 3	$\times 10^{-5}$	90%	4679
$\gamma f_2'(1525)$	$(3.7^{+1.2}_{-1.1})$	$\times 10^{-5}$		4607
$\gamma f_2(1270)$	(1.00 ± 0.10)	$\times 10^{-4}$		4644
$\gamma\eta(1405)$	< 8.2	$\times 10^{-5}$	90%	4625
$\gamma f_0(1710)$	< 1.8	$\times 10^{-4}$	90%	4574
$\gamma f_4(2050)$	< 5.3	$\times 10^{-5}$	90%	4513
$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	< 2	$\times 10^{-4}$	90%	4475
$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	< 8	$\times 10^{-7}$	90%	4469
$\gamma f_J(2220) \rightarrow \gamma \pi^+ \pi^-$	< 6	$\times 10^{-7}$	90%	—
$\gamma f_J(2220) \rightarrow \gamma p \bar{p}$	< 1.1	$\times 10^{-6}$	90%	—
$\gamma\eta(2225) \rightarrow \gamma \phi \phi$	< 3	$\times 10^{-3}$	90%	4469
γX	< 3	$\times 10^{-5}$	90%	—
$(X = \text{pseudoscalar with } m < 7.2 \text{ GeV})$				
$\gamma X \bar{X}$	< 1	$\times 10^{-3}$	90%	—
$(X \bar{X} = \text{vectors with } m < 3.1 \text{ GeV})$				

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

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

J needs confirmation.

$$\text{Mass } m = 9859.44 \pm 0.42 \pm 0.31 \text{ MeV}$$

$\chi_{b0}(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	<i>p</i> (MeV/c)
$\gamma \Upsilon(1S)$	$< 6\%$	90%	391

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

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

J needs confirmation.

$$\text{Mass } m = 9892.78 \pm 0.26 \pm 0.31 \text{ MeV}$$

$\chi_{b1}(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	<i>p</i> (MeV/c)
$\gamma \Upsilon(1S)$	$(35 \pm 8)\%$	423

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

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

J needs confirmation.

$$\text{Mass } m = 9912.21 \pm 0.26 \pm 0.31 \text{ MeV}$$

$\chi_{b2}(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\gamma \Upsilon(1S)$	(22±4) %	442

$\Upsilon(2S)$

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

Mass $m = 10.02326 \pm 0.00031$ GeV
 Full width $\Gamma = 31.98 \pm 2.63$ keV
 $\Gamma_{ee} = 0.612 \pm 0.011$ keV

$\Upsilon(2S)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\Upsilon(1S)\pi^+\pi^-$	(18.8 ± 0.6) %		475
$\Upsilon(1S)\pi^0\pi^0$	(9.0 ± 0.8) %		480
$\tau^+\tau^-$	(1.7 ± 1.6) %		4686
$\mu^+\mu^-$	(1.93±0.17) %	S=2.2	5011
e^+e^-	(1.91±0.16) %		5012
$\Upsilon(1S)\pi^0$	< 1.1	$\times 10^{-3}$ CL=90%	531
$\Upsilon(1S)\eta$	< 2	$\times 10^{-3}$ CL=90%	127
$J/\psi(1S)$ anything	< 6	$\times 10^{-3}$ CL=90%	4533

Radiative decays

$\gamma\chi_{b1}(1P)$	(6.9 ± 0.4) %		130
$\gamma\chi_{b2}(1P)$	(7.15±0.35) %		110
$\gamma\chi_{b0}(1P)$	(3.8 ± 0.4) %		162
$\gamma f_0(1710)$	< 5.9	$\times 10^{-4}$ CL=90%	4864
$\gamma f'_2(1525)$	< 5.3	$\times 10^{-4}$ CL=90%	4896
$\gamma f_2(1270)$	< 2.41	$\times 10^{-4}$ CL=90%	4930
$\gamma\eta_b(1S)$	< 5.1	$\times 10^{-4}$ CL=90%	697

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

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

J needs confirmation.

Mass $m = 10.2325 \pm 0.0004 \pm 0.0005$ GeV

$\chi_{b0}(2P)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\gamma \Upsilon(2S)$	(4.6±2.1) %	207
$\gamma \Upsilon(1S)$	(9 ± 6) $\times 10^{-3}$	743

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

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

J needs confirmation.

Mass $m = 10.25546 \pm 0.00022 \pm 0.00050$ GeV
 $m_{\chi_{b1}(2P)} - m_{\chi_{b0}(2P)} = 23.5 \pm 1.0$ MeV

$\chi_{b1}(2P)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	p (MeV/c)
$\omega \Upsilon(1S)$	$(1.63^{+0.38}_{-0.34})\%$		135
$\gamma \Upsilon(2S)$	$(21 \pm 4)\%$	1.5	230
$\gamma \Upsilon(1S)$	$(8.5 \pm 1.3)\%$	1.3	764
$\pi\pi \chi_{b1}(1P)$	$(8.6 \pm 3.1) \times 10^{-3}$		238

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

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

J needs confirmation.

$$\text{Mass } m = 10.26865 \pm 0.00022 \pm 0.00050 \text{ GeV}$$

$$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)} = 13.5 \pm 0.6 \text{ MeV}$$

$\chi_{b2}(2P)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\omega \Upsilon(1S)$	$(1.10^{+0.34}_{-0.30})\%$	194
$\gamma \Upsilon(2S)$	$(16.2 \pm 2.4)\%$	242
$\gamma \Upsilon(1S)$	$(7.1 \pm 1.0)\%$	777
$\pi\pi \chi_{b2}(1P)$	$(6.0 \pm 2.1) \times 10^{-3}$	229

$\Upsilon(3S)$

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

$$\text{Mass } m = 10.3552 \pm 0.0005 \text{ GeV}$$

$$\text{Full width } \Gamma = 20.32 \pm 1.85 \text{ keV}$$

$$\Gamma_{ee} = 0.443 \pm 0.008 \text{ keV}$$

$\Upsilon(3S)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\Upsilon(2S)$ anything	$(10.6 \pm 0.8)\%$		296
$\Upsilon(2S) \pi^+ \pi^-$	$(2.8 \pm 0.6)\%$	S=2.2	177
$\Upsilon(2S) \pi^0 \pi^0$	$(2.00 \pm 0.32)\%$		190
$\Upsilon(2S) \gamma \gamma$	$(5.0 \pm 0.7)\%$		327
$\Upsilon(1S) \pi^+ \pi^-$	$(4.48 \pm 0.21)\%$		813
$\Upsilon(1S) \pi^0 \pi^0$	$(2.06 \pm 0.28)\%$		816
$\Upsilon(1S) \eta$	$< 2.2 \times 10^{-3}$	CL=90%	677
$\mu^+ \mu^-$	$(2.18 \pm 0.21)\%$	S=2.1	5177
$e^+ e^-$	seen		5178

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
$\gamma\chi_{b0}(1P)$	(3.0 \pm 1.1) $\times 10^{-3}$		484
$\gamma\eta_b(2S)$	< 6.2 $\times 10^{-4}$	CL=90%	–
$\gamma\eta_b(1S)$	< 4.3 $\times 10^{-4}$	CL=90%	1001

$\Upsilon(4S)$ or $\Upsilon(10580)$

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

Mass $m = 10.5794 \pm 0.0012$ GeV

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

$\Gamma_{ee} = 0.272 \pm 0.029$ keV (S = 1.5)

$\Upsilon(4S)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$B\bar{B}$	> 96 %	95%	330
B^+B^-	(50.9 \pm 0.7) %		335
D_s^+ anything + c.c.	(18.2 \pm 3.2) %		–
$B^0\bar{B}^0$	(49.1 \pm 0.7) %		330
non- $B\bar{B}$	< 4 %	95%	–
e^+e^-	(1.57 \pm 0.08) $\times 10^{-5}$		5290
$J/\psi(1S)$ anything	< 1.9 $\times 10^{-4}$	95%	–
D^{*+} anything + c.c.	< 7.4 %	90%	5099
ϕ anything	< 2.3 $\times 10^{-3}$	90%	5240
$\Upsilon(1S)$ anything	< 4 $\times 10^{-3}$	90%	1053
$\Upsilon(1S)\pi^+\pi^-$	< 1.2 $\times 10^{-4}$	90%	1026
$\Upsilon(2S)\pi^+\pi^-$	< 3.9 $\times 10^{-4}$	90%	468

$\Upsilon(10860)$

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

Mass $m = 10.865 \pm 0.008$ GeV (S = 1.1)

Full width $\Gamma = 110 \pm 13$ MeV

$\Gamma_{ee} = 0.31 \pm 0.07$ keV (S = 1.3)

$\Upsilon(10860)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
e^+e^-	(2.8 \pm 0.7) $\times 10^{-6}$	5432
D_s anything + c.c.	(45 \pm 11) %	–

$\Upsilon(11020)$

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

Mass $m = 11.019 \pm 0.008$ GeV

Full width $\Gamma = 79 \pm 16$ MeV

$\Gamma_{ee} = 0.130 \pm 0.030$ keV

$\Upsilon(11020)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$e^+ e^-$	$(1.6 \pm 0.5) \times 10^{-6}$	5510

NOTES

[a] Spectroscopic labeling for these states is theoretical, pending experimental information.