$b\overline{b}$ MESONS

$\Upsilon(1S)$

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

Mass $m = 9460.30 \pm 0.26$ MeV (S = 3.3)
Full width $\Gamma = 54.02 \pm 1.25$ keV
$\Gamma_{ee} = 1.340 \pm 0.018$ keV

$\Upsilon(1S)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$\tau^+\tau^-$	(2.60±0.10) %		4384
e^+e^-	(2.38±0.11) %		4730
$\mu^+\mu^-$	(2.48±0.05) %		4729
Hadronic decays			
$\eta'(958)$ anything	(2.94±0.24) %		–
$J/\psi(1S)$ 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
$p\overline{p}$	$< 5 \times 10^{-4}$	90%	4636
$\pi^0\pi^+\pi^-$	$< 1.84 \times 10^{-5}$	90%	4725
$\overline{d}$ anything	$(2.86 \pm 0.28) \times 10^{-5}$		–
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
$\gamma\pi^0\eta$	$< 2.4 \times 10^{-6}$	90%	4713
K^+K^- with $2<m_{K^+K^-}<3$ GeV	$(1.14 \pm 0.13) \times 10^{-5}$		–
$\gamma p\overline{p}$ with $2<m_{p\overline{p}}<3$ 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
$\gamma\pi^+\pi^-p\overline{p}$	$(1.5 \pm 0.6) \times 10^{-4}$		4604
$\gamma 2\pi^+2\pi^-p\overline{p}$	$(4 \pm 6) \times 10^{-5}$		4563

$\gamma 2K^+2K^-$		$(2.0 \pm 2.0) \times 10^{-5}$			4601
$\gamma\eta'(958)$		< 1.9	$\times 10^{-6}$	90%	4682
$\gamma\eta$		< 1.0	$\times 10^{-6}$	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
$\gamma f_2(1270)$		$(1.01 \pm 0.09) \times 10^{-4}$			4644
$\gamma\eta(1405)$		< 8.2	$\times 10^{-5}$	90%	4625
$\gamma f_0(1500)$		< 1.5	$\times 10^{-5}$	90%	4610
$\gamma f_0(1710)$		< 2.6	$\times 10^{-4}$	90%	4573
$\gamma f_0(1710) \to \gamma K^+K^-$		< 7	$\times 10^{-6}$	90%	–
$\gamma f_0(1710) \to \gamma\pi^0\pi^0$		< 1.4	$\times 10^{-6}$	90%	–
$\gamma f_0(1710) \to \gamma\eta\eta$		< 1.8	$\times 10^{-6}$	90%	–
$\gamma f_4(2050)$		< 5.3	$\times 10^{-5}$	90%	4515
$\gamma f_0(2200) \to \gamma K^+K^-$		< 2	$\times 10^{-4}$	90%	4475
$\gamma f_J(2220) \to \gamma K^+K^-$		< 8	$\times 10^{-7}$	90%	4469
$\gamma f_J(2220) \to \gamma\pi^+\pi^-$		< 6	$\times 10^{-7}$	90%	–
$\gamma f_J(2220) \to \gamma p\overline{p}$		< 1.1	$\times 10^{-6}$	90%	–
$\gamma\eta(2225) \to \gamma\phi\phi$		< 3	$\times 10^{-3}$	90%	4469
γX	[a]	< 3	$\times 10^{-5}$	90%	–
$\gamma X\overline{X}$	[b]	< 1	$\times 10^{-3}$	90%	–
$\gamma X \to \gamma +$ ≥ 4 prongs	[c]	< 1.78	$\times 10^{-4}$	95%	–
Other decays					
invisible		< 2.5	$\times 10^{-3}$	90%	–

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

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

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

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

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

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

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

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

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

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

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

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

$\Upsilon(2S)$

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

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
$\tau^+\tau^-$	(2.00± 0.21) %		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%	126
$J/\psi(1S)$ anything	< 6 $\times 10^{-3}$	CL=90%	4533
$\overline{d}$ anything	(3.4 ± 0.6) $\times 10^{-5}$		–
hadrons	(94 ±11) %		–
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%	4863
$\gamma f_2'(1525)$	< 5.3 $\times 10^{-4}$	CL=90%	4896
$\gamma f_2(1270)$	< 2.41 $\times 10^{-4}$	CL=90%	4931
$\gamma\eta_b(1S)$	< 5.1 $\times 10^{-4}$	CL=90%	697
$\gamma X \to \gamma + \geq 4$ prongs	[e] < 1.95 $\times 10^{-4}$	CL=95%	–

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

$I^G(J^{PC}) = 0^+(0^{++})$
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
$\gamma\,\Upsilon(1S)$	$(9 \pm 6) \times 10^{-3}$	743

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

$I^G(J^{PC}) = 0^+(1^{++})$
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 ±4) %	1.5	230
$\gamma\,\Upsilon(1S)$	(8.5 ±1.3) %	1.3	764
$\pi\pi\,\chi_{b1}(1P)$	(8.6 ±3.1) $\times 10^{-3}$		238

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

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

Mass $m = 10.26865 \pm 0.00022 \pm 0.00050$ GeV
$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)} = 13.5 \pm 0.6$ 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 ±2.4) %	242
$\gamma\,\Upsilon(1S)$	(7.1 ±1.0) %	777
$\pi\pi\,\chi_{b2}(1P)$	(6.0 ±2.1) $\times 10^{-3}$	229

$\Upsilon(3S)$

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

Mass $m = 10.3552 \pm 0.0005$ GeV
Full width $\Gamma = 20.32 \pm 1.85$ keV
$\Gamma_{ee} = 0.443 \pm 0.008$ keV

$\Upsilon(3S)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\Upsilon(2S)$ anything	(10.6 ±0.8) %		296
$\Upsilon(2S)\pi^+\pi^-$	(2.8 ±0.6) %	S=2.2	177
$\Upsilon(2S)\pi^0\pi^0$	(2.00±0.32) %		190
$\Upsilon(2S)\gamma\gamma$	(5.0 ±0.7) %		327
$\Upsilon(1S)\pi^+\pi^-$	(4.48±0.21) %		813
$\Upsilon(1S)\pi^0\pi^0$	(2.06±0.28) %		816
$\Upsilon(1S)\eta$	$<$ 2.2 $\times 10^{-3}$	CL=90%	677
$\tau^+\tau^-$	(2.29±0.30) %		4863
$\mu^+\mu^-$	(2.18±0.21) %	S=2.1	5177
e^+e^-	seen		5178
Radiative decays			
$\gamma\chi_{b2}(2P)$	(13.1 ±1.6) %	S=3.4	86
$\gamma\chi_{b1}(2P)$	(12.6 ±1.2) %	S=2.4	99
$\gamma\chi_{b0}(2P)$	(5.9 ±0.6) %	S=1.4	122
$\gamma\chi_{b0}(1P)$	(3.0 ±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
$\gamma X \rightarrow \gamma + \geq 4$ prongs	[f] $<$ 2.2 $\times 10^{-4}$	CL=95%	–

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

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

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)
$B\overline{B}$	> 96 %	95%	328
B^+B^-	(51.6 $\pm$0.6) %		334
D_s^+ anything + c.c.	(18.3 $\pm$2.6) %		–
$B^0\overline{B}^0$	(48.4 $\pm$0.6) %		328
$J/\psi K_S^0(J/\psi,\ \eta_c)K_S^0$	$< 4 \times 10^{-7}$	90%	–
non-$B\overline{B}$	< 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	(7.1 $\pm$0.6) %		5240
$\phi\eta$	$< 2.5 \times 10^{-6}$	90%	5226
$\Upsilon(1S)$ anything	$< 4 \times 10^{-3}$	90%	1053
$\Upsilon(1S)\pi^+\pi^-$	(9.0 $\pm$1.5) $\times 10^{-5}$		1026
$\Upsilon(2S)\pi^+\pi^-$	(8.8 $\pm$1.9) $\times 10^{-5}$		468
$\overline{d}$ anything	$< 1.3 \times 10^{-5}$	90%	–

$\Upsilon(10860)$

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

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)	Confidence level	p (MeV/c)
e^+e^-	(2.8 $\pm$ 0.7) $\times 10^{-6}$		5432
$B\overline{B}X$	(59 $\pm$14) %		–
$B\overline{B}$	< 13.8 %	90%	1280
$B\overline{B}^*$ + c.c.	(14 $\pm$ 6) %		–
$B^*\overline{B}^*$	(44 $\pm$11) %		–
$B\overline{B}^{(*)}\pi$	< 19.7 %	90%	–
$B\overline{B}\pi\pi$	< 8.9 %	90%	441
$B_s^{(*)}\overline{B}_s^{(*)}(X)$	(19.3 $\pm$ 2.9) %		–
$\Upsilon(1S)\pi^+\pi^-$	(5.3 $\pm$ 0.6) $\times 10^{-3}$		1288
$\Upsilon(2S)\pi^+\pi^-$	(7.8 $\pm$ 1.3) $\times 10^{-3}$		763
$\Upsilon(3S)\pi^+\pi^-$	(4.8 $^{+\ 1.9}_{-\ 1.7}$) $\times 10^{-3}$		416
$\Upsilon(1S)K^+K^-$	(6.1 $\pm$ 1.8) $\times 10^{-4}$		933

Inclusive Decays.

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

ϕ anything	(13.8 $^{+\ 2.4}_{-\ 1.7}$) %	–
D^0 anything + c.c.	(108 ± 8) %	–
D_s anything + c.c.	(47 ± 6) %	–
J/ψ anything	(2.06± 0.21) %	–

$\Upsilon(11020)$

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

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)
$e^+ e^-$	$(1.6\pm0.5) \times 10^{-6}$	5510

NOTES

[*a*] X = pseudoscalar with $m < 7.2$ GeV

[*b*] $X\overline{X}$ = vectors with $m < 3.1$ GeV

[*c*] 1.5 GeV $< m_X <$ 5.0 GeV

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

[*e*] 1.5 GeV $< m_X <$ 5.0 GeV

[*f*] 1.5 GeV $< m_X <$ 5.0 GeV