$b\overline{b}$ MESONS

$\Upsilon(1S)$

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

Mass $m = 9460.30 \pm 0.26$ MeV   (S = 3.3)
Full width $\Gamma = 53.0 \pm 1.5$ keV
$\Gamma_{ee} = 1.314 \pm 0.029$ 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 ± 0.11) %			4730
$\mu^+\mu^-$	(2.48 ± 0.06) %			4729
Hadronic decays				
$\eta'(958)$ anything	(2.8 ± 0.4) %			−
$J/\psi(1S)$ anything	$(1.1\pm0.4)\times10^{-3}$			4223
$\rho\pi$	< 2	$\times10^{-4}$	90%	4697
$\pi^+\pi^-$	< 5	$\times10^{-4}$	90%	4728
K^+K^-	< 5	$\times10^{-4}$	90%	4704
$p\overline{p}$	< 5	$\times10^{-4}$	90%	4636
$\pi^0\pi^+\pi^-$	< 1.84	$\times10^{-5}$	90%	4725
Radiative decays				
$\gamma\pi^+\pi^-$	$(6.3\pm1.8)\times10^{-5}$			4728
$\gamma\pi^0\pi^0$	$(1.7\pm0.7)\times10^{-5}$			4728
$\gamma 2h^+2h^-$	$(7.0\pm1.5)\times10^{-4}$			4720
$\gamma 3h^+3h^-$	$(5.4\pm2.0)\times10^{-4}$			4703
$\gamma 4h^+4h^-$	$(7.4\pm3.5)\times10^{-4}$			4679
$\gamma\pi^+\pi^-K^+K^-$	$(2.9\pm0.9)\times10^{-4}$			4686
$\gamma 2\pi^+2\pi^-$	$(2.5\pm0.9)\times10^{-4}$			4720
$\gamma 3\pi^+3\pi^-$	$(2.5\pm1.2)\times10^{-4}$			4703
$\gamma 2\pi^+2\pi^-K^+K^-$	$(2.4\pm1.2)\times10^{-4}$			4658
$\gamma\pi^+\pi^-p\overline{p}$	$(1.5\pm0.6)\times10^{-4}$			4604
$\gamma 2\pi^+2\pi^-p\overline{p}$	$(4\pm6)\times10^{-5}$			4563
$\gamma 2K^+2K^-$	$(2.0\pm2.0)\times10^{-5}$			4601
$\gamma\eta'(958)$	< 1.6	$\times10^{-5}$	90%	4682
$\gamma\eta$	< 2.1	$\times10^{-5}$	90%	4714
$\gamma f_2'(1525)$	< 1.4	$\times10^{-4}$	90%	4607
$\gamma f_2(1270)$	$(8\pm4)\times10^{-5}$			4644
$\gamma\eta(1405)$	< 8.2	$\times10^{-5}$	90%	4625
$\gamma f_0(1710) \to \gamma K\overline{K}$	< 2.6	$\times10^{-4}$	90%	4576

$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	< 2	$\times 10^{-4}$	90%	4475
$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	< 1.5	$\times 10^{-5}$	90%	4469
$\gamma f_J(2220) \rightarrow \gamma \pi^+ \pi^-$	< 1.2	$\times 10^{-5}$	90%	–
$\gamma f_J(2220) \rightarrow \gamma p \overline{p}$	< 1.6	$\times 10^{-5}$	90%	–
$\gamma \eta(2225) \rightarrow \gamma \phi \phi$	< 3	$\times 10^{-3}$	90%	4469
γX	< 3	$\times 10^{-5}$	90%	–
(X = pseudoscalar with m< 7.2 GeV)				
$\gamma X \overline{X}$	< 1	$\times 10^{-3}$	90%	–
($X \overline{X}$ = vectors with m< 3.1 GeV)				

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

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

Mass $m = 9859.9 \pm 1.0$ MeV

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

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

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

Mass $m = 9892.7 \pm 0.6$ MeV   (S = 1.1)

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

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

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

Mass $m = 9912.6 \pm 0.5$ MeV   (S = 1.1)

$\chi_{b2}(1P)$ 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 $\Gamma = 43 \pm 6$ keV
$\Gamma_{ee} = 0.576 \pm 0.024$ keV

$\Upsilon(2S)$ DECAY MODES	Fraction (Γ_i/Γ)		Confidence level	p (MeV/c)
$\Upsilon(1S)\pi^+\pi^-$	$(18.8 \pm 0.6\ )$ %			475
$\Upsilon(1S)\pi^0\pi^0$	$(9.0 \pm 0.8\ )$ %			480
$\tau^+\tau^-$	$(1.7 \pm 1.6\ )$ %			4686
$\mu^+\mu^-$	(1.31 ± 0.21) %			5011
e^+e^-	(1.34 ± 0.20) %			5012
$\Upsilon(1S)\pi^0$	$<\ 1.1$	$\times 10^{-3}$	90%	531
$\Upsilon(1S)\eta$	$<\ 2$	$\times 10^{-3}$	90%	126
$J/\psi(1S)$ anything	$<\ 6$	$\times 10^{-3}$	90%	4533
Radiative decays				
$\gamma\chi_{b1}(1P)$	$(6.8 \pm 0.7\ )$ %			130
$\gamma\chi_{b2}(1P)$	$(7.0 \pm 0.6\ )$ %			110
$\gamma\chi_{b0}(1P)$	$(3.8 \pm 0.6\ )$ %			162
$\gamma f_0(1710)$	$<\ 5.9$	$\times 10^{-4}$	90%	4865
$\gamma f_2'(1525)$	$<\ 5.3$	$\times 10^{-4}$	90%	4896
$\gamma f_2(1270)$	$<\ 2.41$	$\times 10^{-4}$	90%	4930

$\chi_{b0}(2P)$ [a] $I^G(J^{PC}) = 0^+(0^{++})$
J needs confirmation.

Mass $m = 10.2321 \pm 0.0006$ 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

$\chi_{b1}(2P)$ [a] $I^G(J^{PC}) = 0^+(1^{++})$
J needs confirmation.

Mass $m = 10.2552 \pm 0.0005$ 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)
$\gamma\Upsilon(2S)$	$(21\ \pm 4\ )$ %	1.5	229
$\gamma\Upsilon(1S)$	(8.5 ± 1.3) %	1.3	764

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

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

J needs confirmation.

Mass $m = 10.2685 \pm 0.0004$ 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)
$\gamma \, \Upsilon(2S)$	(16.2 ± 2.4) %	242
$\gamma \, \Upsilon(1S)$	$(\ 7.1 \pm 1.0)$ %	776

$\Upsilon(3S)$

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

Mass $m = 10.3552 \pm 0.0005$ GeV

Full width $\Gamma = 26.3 \pm 3.4$ 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
$\Upsilon(1S)\eta$	$<\ 2.2 \qquad \times 10^{-3}$	CL=90%	677
$\mu^+\mu^-$	$(\ 1.81 \pm 0.17)$ %		5177
e^+e^-	seen		5178
Radiative decays			
$\gamma\chi_{b2}(2P)$	$(11.4 \pm 0.8\ )$ %	S=1.3	86
$\gamma\chi_{b1}(2P)$	$(11.3 \pm 0.6\ )$ %		100
$\gamma\chi_{b0}(2P)$	$(\ 5.4 \pm 0.6\ )$ %	S=1.1	122

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

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

Mass $m = 10.5800 \pm 0.0035$ GeV

Full width $\Gamma = 20 \pm 4$ MeV

$\Gamma_{ee} = 0.248 \pm 0.031$ keV   (S = 1.3)

$\Upsilon(4S)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$B\overline{B}$	> 96 %	95%	335
non-$B\overline{B}$	$<\ 4$ %	95%	—
e^+e^-	$(\ 2.8 \pm 0.7) \times 10^{-5}$		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%	1027
$\Upsilon(2S)\pi^+\pi^-$	< 3.9	$\times 10^{-4}$	90%	469

$\boxed{\Upsilon(10860)}$ $\qquad\qquad I^G(J^{PC}) = 0^-(1^{--})$

Mass $m = 10.865 \pm 0.008$ GeV $\quad$ (S = 1.1)
Full width $\Gamma = 110 \pm 13$ MeV
$\Gamma_{ee} = 0.31 \pm 0.07$ keV $\quad$ (S = 1.3)

$\Upsilon(10860)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
e^+e^-	$(2.8\pm0.7) \times 10^{-6}$	5432

$\boxed{\Upsilon(11020)}$ $\qquad\qquad I^G(J^{PC}) = 0^-(1^{--})$

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