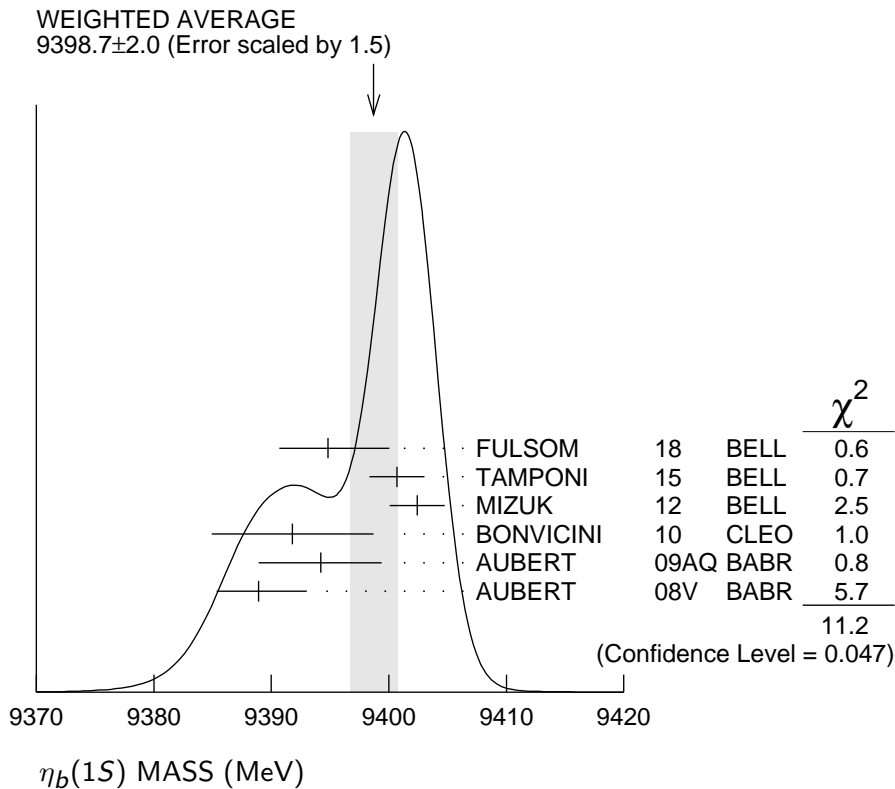# $\eta_b(1S)$

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

Quantum numbers shown are quark-model predictions. Observed in radiative decay of the $\Upsilon(3S)$, therefore $C = +$.

$\eta_b(1S)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
9398.7± 2.0 OUR AVERAGE		Error includes scale factor of 1.5. See the ideogram below.			
$9394.8^{+\ 2.7}_{-\ 3.1}{}^{+\ 4.5}_{-\ 2.7}$	29K	FULSOM	18	BELL	$\Upsilon(2S) \to \gamma X$
$9400.7\pm 1.7\pm 1.6$	33.1k	TAMPONI	15	BELL	$e^+e^- \to \gamma\eta+$ hadrons
$9402.4\pm 1.5\pm 1.8$	34k	[1] MIZUK	12	BELL	$e^+e^- \to \gamma\pi^+\pi^- +$ hadrons
$9391.8\pm 6.6\pm 2.0$	2.3k	[2] BONVICINI	10	CLEO	$\Upsilon(3S) \to \gamma X$
$9394.2^{+\ 4.8}_{-\ 4.9}\pm 2.0$	13k	[2] AUBERT	09AQ	BABR	$\Upsilon(2S) \to \gamma X$
$9388.9^{+\ 3.1}_{-\ 2.3}\pm 2.7$	19k	[2] AUBERT	08V	BABR	$\Upsilon(3S) \to \gamma X$

$\bullet \bullet \bullet$ We do not use the following data for averages, fits, limits, etc. $\bullet \bullet \bullet$

$9393.2\pm 3.4\pm 2.3$	10	[2,3] DOBBS	12		$\Upsilon(2S) \to \gamma$ hadrons
$9300 \ \pm 20 \ \pm 20$		HEISTER	02D	ALEP	181–209 e^+e^-

WEIGHTED AVERAGE
9398.7±2.0 (Error scaled by 1.5)

			χ^2
FULSOM	18	BELL	0.6
TAMPONI	15	BELL	0.7
MIZUK	12	BELL	2.5
BONVICINI	10	CLEO	1.0
AUBERT	09AQ	BABR	0.8
AUBERT	08V	BABR	5.7
			11.2

(Confidence Level = 0.047)

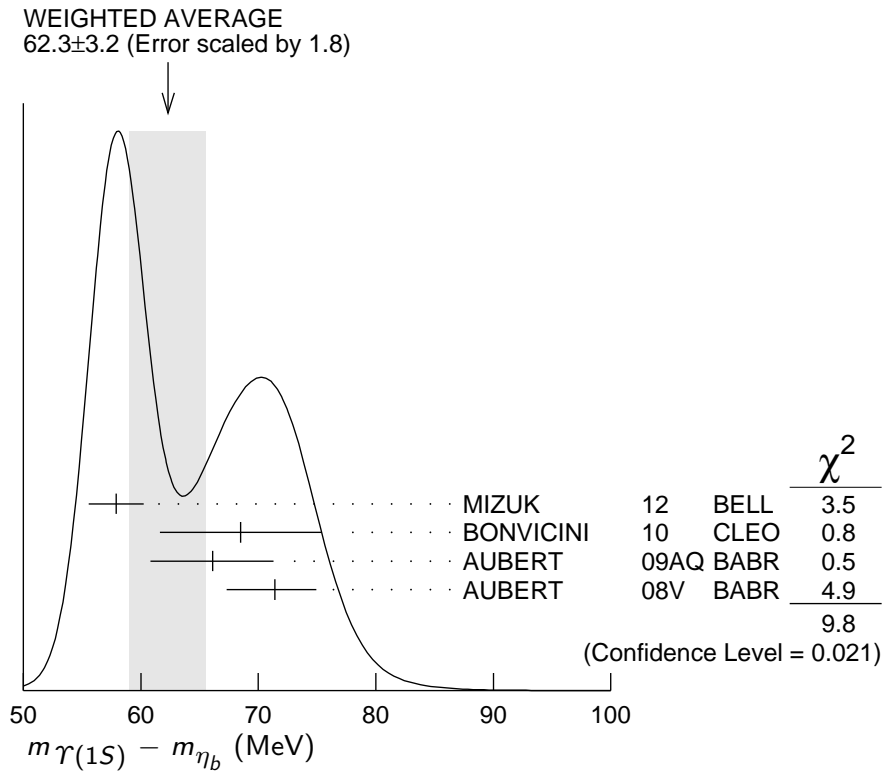9370 9380 9390 9400 9410 9420

$\eta_b(1S)$ MASS (MeV)

[1] With floating width. Not independent of the corresponding mass difference measurement.
[2] Assuming $\Gamma_{\eta_b(1S)} = 10$ MeV. Not independent of the corresponding γ energy or mass difference measurements.
[3] Obtained by analyzing CLEO III data but not authored by the CLEO Collaboration.

$m_{\Upsilon(1S)} - m_{\eta_b}$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
62.3±3.2 OUR AVERAGE	Error includes scale factor of 1.8. See the ideogram below.				
57.9±1.5±1.8	34k	[1] MIZUK	12	BELL	$e^+e^- \to \gamma\pi^+\pi^-$ + hadrons
68.5±6.6±2.0	2.3±0.5k	[2] BONVICINI	10	CLEO	$\Upsilon(3S) \to \gamma X$
66.1$^{+4.8}_{-4.9}$±2.0	13±5k	[2] AUBERT	09AQ	BABR	$\Upsilon(2S) \to \gamma X$
71.4$^{+2.3}_{-3.1}$±2.7	19±3k	[2] AUBERT	08V	BABR	$\Upsilon(3S) \to \gamma X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
67.1±3.4±2.3	10$^{+5}_{-4}$	[2,3] DOBBS	12		$\Upsilon(2S) \to \gamma$ hadrons

[1] With floating width. Not independent of the corresponding mass measurement.

[2] Assuming $\Gamma_{\eta_b(1S)} = 10$ MeV. Not independent of the corresponding γ energy or mass measurements.

[3] Obtained by analyzing CLEO III data but not authored by the CLEO Collaboration.

WEIGHTED AVERAGE
62.3±3.2 (Error scaled by 1.8)

			χ^2
MIZUK	12	BELL	3.5
BONVICINI	10	CLEO	0.8
AUBERT	09AQ	BABR	0.5
AUBERT	08V	BABR	4.9
			9.8

(Confidence Level = 0.021)

$m_{\Upsilon(1S)} - m_{\eta_b}$ (MeV)

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
920.6$^{+2.8}_{-3.2}$ OUR AVERAGE					
918.6±6.0±1.9	2.3±0.5k	[1] BONVICINI	10	CLEO	$\Upsilon(3S) \to \gamma X$
921.2$^{+2.1}_{-2.8}$±2.4	19±3k	[1] AUBERT	08V	BABR	$\Upsilon(3S) \to \gamma X$

[1] Assuming $\Gamma_{\eta_b(1S)} = 10$ MeV. Not independent of the corresponding mass or mass difference measurements.

γ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
$609.3^{+4.6}_{-4.5}\pm1.9$	13 ± 5k	[1] AUBERT	09AQ BABR	$\Upsilon(2S)\to\gamma X$

[1] Assuming $\Gamma_{\eta_b(1S)}=10$ MeV. Not independent of the corresponding mass or mass difference measurements.

$\eta_b(1S)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
10^{+5}_{-4} **OUR AVERAGE**				
$8^{+6}_{-5}\pm5$	33.1k	[1] TAMPONI	15 BELL	$e^+e^-\to\gamma\eta+$ hadrons
$10.8^{+4.0+4.5}_{-3.7-2.0}$	34k	[1] MIZUK	12 BELL	$e^+e^-\to\gamma\pi^+\pi^-+$ hadrons

[1] With floating mass.

$\eta_b(1S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	hadrons	seen	
Γ_2	$3h^+3h^-$	not seen	
Γ_3	$2h^+2h^-$	not seen	
Γ_4	$4h^+4h^-$	not seen	
Γ_5	$\gamma\gamma$	not seen	
Γ_6	$\mu^+\mu^-$	$<9\times10^{-3}$	90%
Γ_7	$\tau^+\tau^-$	$<8\%$	90%

$\eta_b(1S)$ $\Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$

$\Gamma(3h^+3h^-)\times\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_2\Gamma_5/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<470	95	ABDALLAH	06 DLPH	161–209 e^+e^-
<132	95	HEISTER	02D ALEP	181–209 e^+e^-

$\Gamma(2h^+2h^-)\times\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_3\Gamma_5/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<190	95	ABDALLAH	06 DLPH	161–209 e^+e^-
<48	95	HEISTER	02D ALEP	181–209 e^+e^-

$\Gamma(4h^+4h^-) \times \Gamma(\gamma\gamma)/\Gamma_{total}$ $\Gamma_4\Gamma_5/\Gamma$

VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT
\bullet\bullet\bullet We do not use the following data for averages, fits, limits, etc. \bullet\bullet\bullet			
<660	95	ABDALLAH 06	DLPH	161–209 e^+e^-

$\eta_b(1S)$ BRANCHING RATIOS

$\Gamma(hadrons)/\Gamma_{total}$ Γ_1/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
seen	34k	MIZUK 12	BELL	$e^+e^- \to \gamma\pi^+\pi^- +$ hadrons

$\Gamma(\mu^+\mu^-)/\Gamma_{total}$ Γ_6/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<9 × 10^{-3}	90	[1] AUBERT 09Z	BABR	$e^+e^- \to \Upsilon(2S,3S) \to \gamma\eta_b$

[1] Obtained using B($\Upsilon(2S) \to \gamma\eta_b) = (4.2^{+1.1}_{-1.0} \pm 0.9) \times 10^{-4}$ and B($\Upsilon(3S) \to \gamma\eta_b) = (4.8 \pm 0.5 \pm 0.6) \times 10^{-4}$. This limit is equivalent to B($\eta_b \to \mu^+\mu^-) = (-0.25 \pm 0.51 \pm 0.33)\%$ measurement.

$\Gamma(\tau^+\tau^-)/\Gamma_{total}$ Γ_7/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<8 × 10^{-2}	90	AUBERT 09P	BABR	$e^+e^- \to \gamma\tau^+\tau^-$

$\eta_b(1S)$ REFERENCES

FULSOM	18	PRL 121 232001	B.G. Fulsom *et al.*	(BELLE Collab.)
TAMPONI	15	PRL 115 142001	U. Tamponi *et al.*	(BELLE Collab.)
DOBBS	12	PRL 109 082001	S. Dobbs *et al.*	
MIZUK	12	PRL 109 232002	R. Mizuk *et al.*	(BELLE Collab.)
BONVICINI	10	PR D81 031104	G. Bonvicini *et al.*	(CLEO Collab.)
AUBERT	09AQ	PRL 103 161801	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	09P	PRL 103 181801	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	09Z	PRL 103 081803	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	08V	PRL 101 071801	B. Aubert *et al.*	(BABAR Collab.)
ABDALLAH	06	PL B634 340	J.M. Abdallah *et al.*	(DELPHI Collab.)
HEISTER	02D	PL B530 56	A. Heister *et al.*	(ALEPH Collab.)