

$\Upsilon(3S)$

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

 $\Upsilon(3S)$ MASS

<u>VALUE (GeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
10.3552 ± 0.0005	¹ ARTAMONOV 00	MD1	$e^+ e^- \rightarrow$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •			
10.3553 ± 0.0005	^{2,3} BARU	86B REDE	$e^+ e^- \rightarrow$ hadrons
¹ Reanalysis of BARU 86B using new electron mass (COHEN 87).			
² Reanalysis of ARTAMONOV 84.			
³ Superseded by ARTAMONOV 00.			

 $\Upsilon(3S)$ WIDTH

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>
20.32 ± 1.85 OUR EVALUATION	See the Note on "Width Determinations of the Υ States"

 $\Upsilon(3S)$ DECAY MODES

Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1 $\Upsilon(2S)$ anything	(10.6 ± 0.8) %	
Γ_2 $\Upsilon(2S) \pi^+ \pi^-$	(2.8 ± 0.6) %	S=2.2
Γ_3 $\Upsilon(2S) \pi^0 \pi^0$	(2.00 ± 0.32) %	
Γ_4 $\Upsilon(2S) \gamma \gamma$	(5.0 ± 0.7) %	
Γ_5 $\Upsilon(1S) \pi^+ \pi^-$	(4.48 ± 0.21) %	
Γ_6 $\Upsilon(1S) \pi^0 \pi^0$	(2.06 ± 0.28) %	
Γ_7 $\Upsilon(1S) \eta$	< 2.2 × 10 ⁻³	CL=90%
Γ_8 $\tau^+ \tau^-$	(2.29 ± 0.30) %	
Γ_9 $\mu^+ \mu^-$	(2.18 ± 0.21) %	S=2.1
Γ_{10} $e^+ e^-$	seen	

Radiative decays

Γ_{11} $\gamma \chi_{b2}(2P)$	(13.1 ± 1.6) %	S=3.4
Γ_{12} $\gamma \chi_{b1}(2P)$	(12.6 ± 1.2) %	S=2.4
Γ_{13} $\gamma \chi_{b0}(2P)$	(5.9 ± 0.6) %	S=1.4
Γ_{14} $\gamma \chi_{b0}(1P)$	(3.0 ± 1.1) × 10 ⁻³	
Γ_{15} $\gamma \eta_b(2S)$	< 6.2 × 10 ⁻⁴	CL=90%
Γ_{16} $\gamma \eta_b(1S)$	< 4.3 × 10 ⁻⁴	CL=90%
Γ_{17} $\gamma X \rightarrow \gamma + \geq 4$ prongs	[a] < 2.2 × 10 ⁻⁴	CL=95%

[a] 1.5 GeV < m_X < 5.0 GeV

$\Upsilon(3S) \Gamma(i) \Gamma(e^+ e^-) / \Gamma(\text{total})$

$\Gamma(\text{hadrons}) \times \Gamma(e^+ e^-) / \Gamma_{\text{total}}$ $\Gamma_0 \Gamma_{10} / \Gamma$

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.414 ± 0.007 OUR AVERAGE			
0.413 ± 0.004 ± 0.006	ROSNER	06	CLEO 10.4 $e^+ e^- \rightarrow$ hadrons
0.45 ± 0.03 ± 0.03	⁴ GILES	84B	CLEO $e^+ e^- \rightarrow$ hadrons
⁴ Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.			

$\Upsilon(3S)$ PARTIAL WIDTHS

$\Gamma(e^+ e^-)$ Γ_{10}

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>
0.443 ± 0.008 OUR EVALUATION	

$\Upsilon(3S)$ BRANCHING RATIOS

$\Gamma(\Upsilon(2S) \text{anything}) / \Gamma_{\text{total}}$ Γ_1 / Γ

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.106 ± 0.008 OUR AVERAGE				
0.1023 ± 0.0105	4625	^{5,6,7} BUTLER	94B	CLE2 $e^+ e^- \rightarrow \ell^+ \ell^- X$
0.111 ± 0.012	4891	^{6,7,8} BROCK	91	CLEO $e^+ e^- \rightarrow \pi^+ \pi^- X,$ $\pi^+ \pi^- \ell^+ \ell^-$

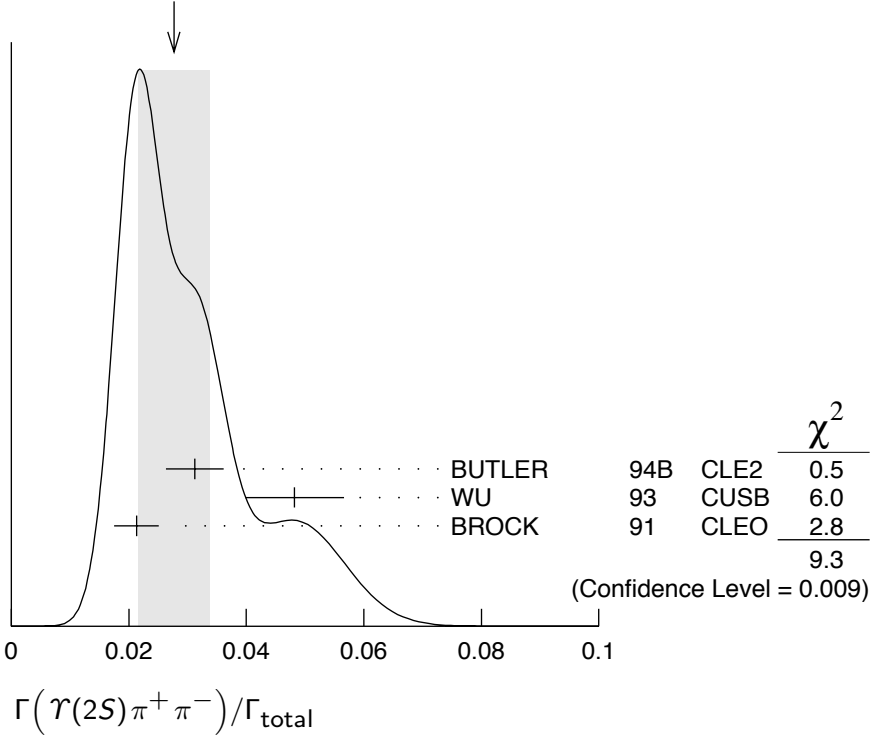
$\Gamma(\Upsilon(2S) \pi^+ \pi^-) / \Gamma_{\text{total}}$ Γ_2 / Γ

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.028 ± 0.006 OUR AVERAGE Error includes scale factor of 2.2. See the ideogram below.				
0.0312 ± 0.0049	980	^{5,9} BUTLER	94B	CLE2 $e^+ e^- \rightarrow$ $\pi^+ \pi^- \ell^+ \ell^-$
0.0482 ± 0.0065 ± 0.0053	138	⁸ WU	93	CUSB $\Upsilon(3S) \rightarrow$ $\pi^+ \pi^- \ell^+ \ell^-$
0.0213 ± 0.0038	974	⁸ BROCK	91	CLEO $e^+ e^- \rightarrow$ $\pi^+ \pi^- X,$ $\pi^+ \pi^- \ell^+ \ell^-$

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0.031 ± 0.020	5	MAGERAS	82	CUSB $\Upsilon(3S) \rightarrow$ $\pi^+ \pi^- \ell^+ \ell^-$
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WEIGHTED AVERAGE
 0.028 ± 0.006 (Error scaled by 2.2)



$\Gamma(\tau(2S)\pi^0\pi^0)/\Gamma_{total}$

Γ_3/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0200 ± 0.0032	OUR AVERAGE			
0.0216 ± 0.0039	9,10	BUTLER 94B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$
$0.017 \pm 0.005 \pm 0.002$	10	11 HEINTZ 92	CSB2	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$

$\Gamma(\tau(2S)\gamma\gamma)/\Gamma_{total}$

Γ_4/Γ

VALUE	DOCUMENT ID	TECN	COMMENT
0.0502 ± 0.0069	9 BUTLER 94B	CLE2	$e^+e^- \rightarrow \ell^+\ell^-2\gamma$

$\Gamma(\tau(1S)\pi^+\pi^-)/\Gamma_{total}$

Γ_5/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0448 ± 0.0021	OUR AVERAGE			
0.0452 ± 0.0035	11830	6 BUTLER 94B	CLE2	$e^+e^- \rightarrow \pi^+\pi^-X,$ $\pi^+\pi^-\ell^+\ell^-$
$0.0446 \pm 0.0034 \pm 0.0050$	451	6 WU 93	CUSB	$\gamma(3S) \rightarrow$ $\pi^+\pi^-\ell^+\ell^-$
0.0446 ± 0.0030	11221	6 BROCK 91	CLEO	$e^+e^- \rightarrow \pi^+\pi^-X,$ $\pi^+\pi^-\ell^+\ell^-$

• • • We do not use the following data for averages, fits, limits, etc. • • •

0.049 ± 0.010	22	GREEN 82	CLEO	$\gamma(3S) \rightarrow$ $\pi^+\pi^-\ell^+\ell^-$
0.039 ± 0.013	26	MAGERAS 82	CUSB	$\gamma(3S) \rightarrow$ $\pi^+\pi^-\ell^+\ell^-$

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0206 ± 0.0028 OUR AVERAGE				
0.0199 ± 0.0034	56	⁶ BUTLER	94B	CLE2 $e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$
0.022 ± 0.004 ± 0.003	33	¹² HEINTZ	92	CSB2 $e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$

$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.0022	90	BROCK	91	CLEO $e^+e^- \rightarrow \pi^+\pi^-\pi^0\ell^+\ell^-$

$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
2.29 ± 0.21 ± 0.22	15k	¹³ BESSON	07	CLEO $e^+e^- \rightarrow \Upsilon(3S) \rightarrow \tau^+\tau^-$

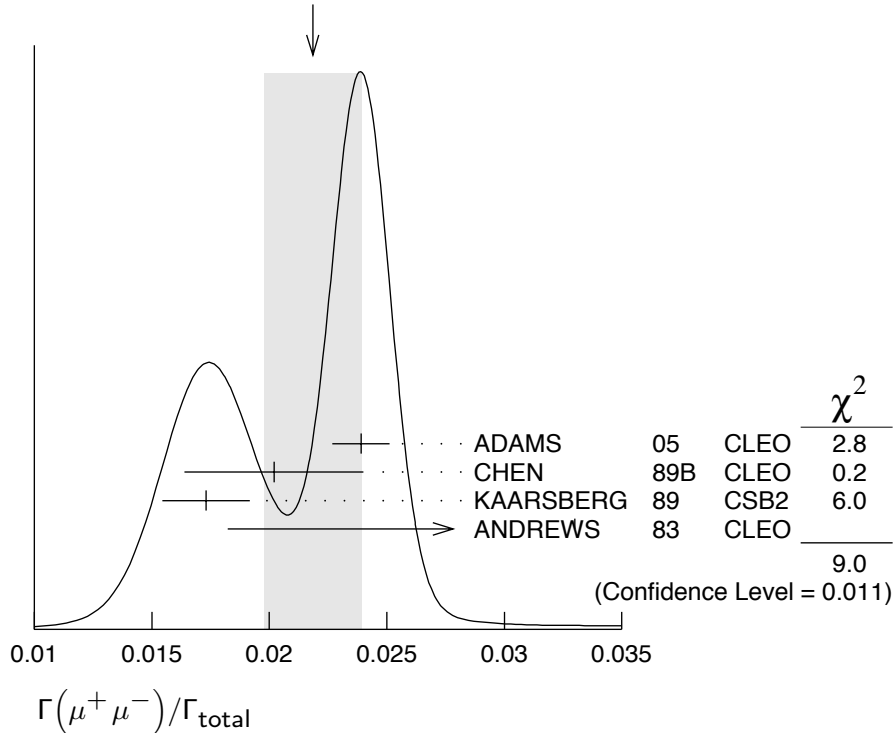
$\Gamma(\tau^+\tau^-)/\Gamma(\mu^+\mu^-)$ Γ_8/Γ_9

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
1.05 ± 0.08 ± 0.05	15k	BESSON	07	CLEO $e^+e^- \rightarrow \Upsilon(3S)$

$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ Γ_9/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0218 ± 0.0021 OUR AVERAGE Error includes scale factor of 2.1. See the ideogram below.				
0.0239 ± 0.0007 ± 0.0010	81k	ADAMS	05	CLEO $e^+e^- \rightarrow \mu^+\mu^-$
0.0202 ± 0.0019 ± 0.0033		CHEN	89B	CLEO $e^+e^- \rightarrow \mu^+\mu^-$
0.0173 ± 0.0015 ± 0.0011		KAARSBERG	89	CSB2 $e^+e^- \rightarrow \mu^+\mu^-$
0.033 ± 0.013 ± 0.007	1096	ANDREWS	83	CLEO $e^+e^- \rightarrow \mu^+\mu^-$

WEIGHTED AVERAGE
0.0218 ± 0.0021 (Error scaled by 2.1)

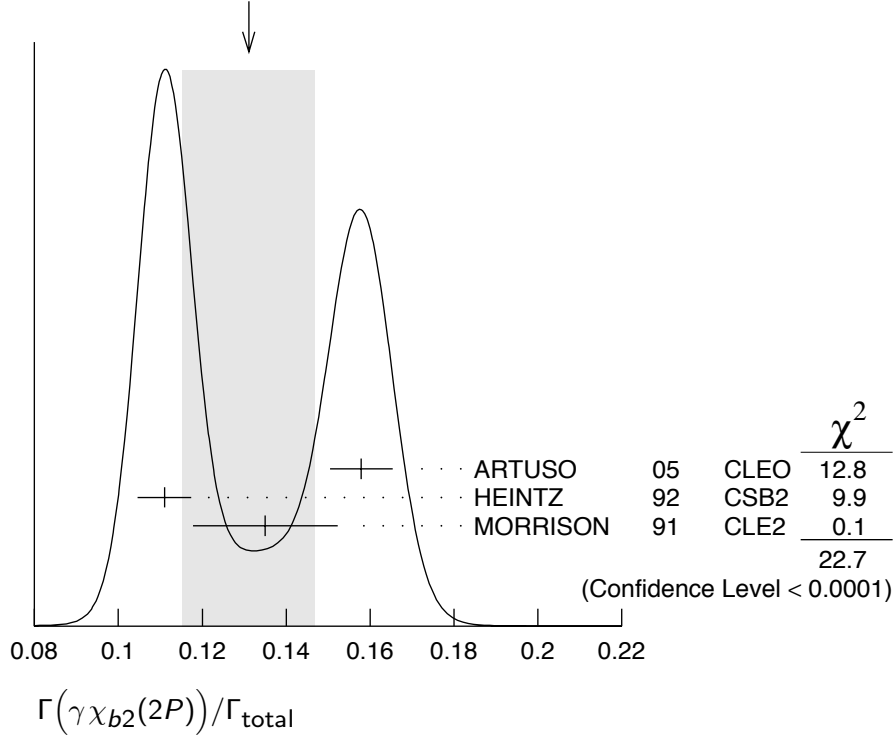


$\Gamma(\gamma\chi_{b2}(2P))/\Gamma_{\text{total}}$

Γ_{11}/Γ

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.131 ± 0.016 OUR AVERAGE				Error includes scale factor of 3.4. See the ideogram below.
0.1579 ± 0.0017 ± 0.0073	568k	ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$
0.111 ± 0.005 ± 0.004	10319	¹⁴ HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X$
0.135 ± 0.003 ± 0.017	30741	MORRISON	91	CLE2 $e^+e^- \rightarrow \gamma X$

WEIGHTED AVERAGE
0.131 ± 0.016 (Error scaled by 3.4)

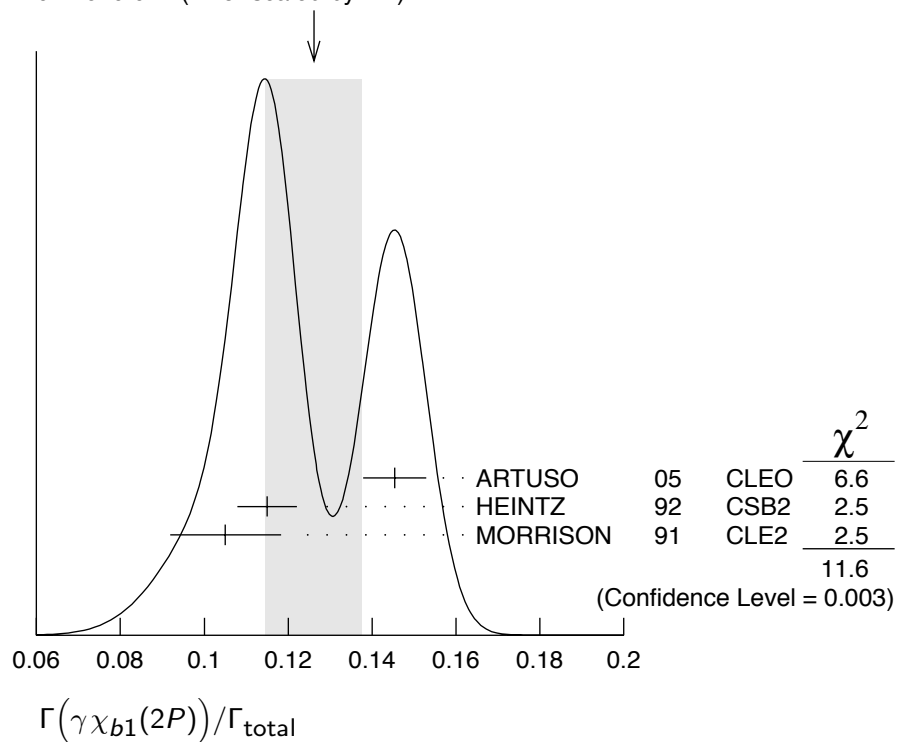


$\Gamma(\gamma\chi_{b1}(2P))/\Gamma_{\text{total}}$

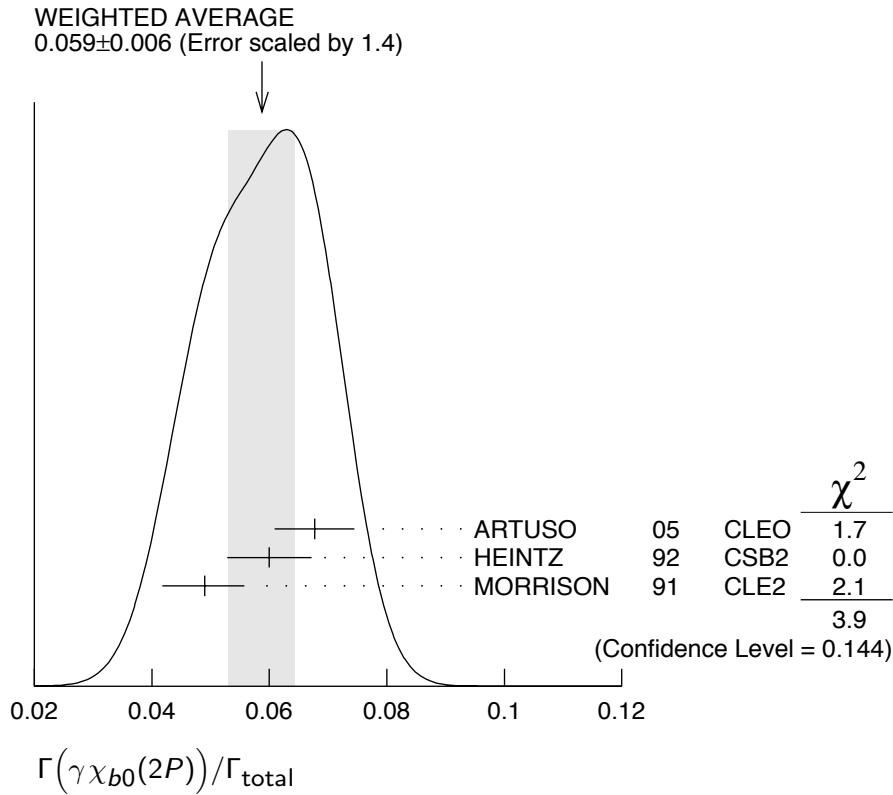
Γ_{12}/Γ

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.126 ± 0.012 OUR AVERAGE				Error includes scale factor of 2.4. See the ideogram below.
0.1454 ± 0.0018 ± 0.0073	537k	ARTUSO	05	CLEO $e^+e^- \rightarrow \gamma X$
0.115 ± 0.005 ± 0.005	11147	¹⁴ HEINTZ	92	CSB2 $e^+e^- \rightarrow \gamma X$
0.105 $\begin{smallmatrix} +0.003 \\ -0.002 \end{smallmatrix}$ ± 0.013	25759	MORRISON	91	CLE2 $e^+e^- \rightarrow \gamma X$

WEIGHTED AVERAGE
 0.126 ± 0.012 (Error scaled by 2.4)



$\Gamma(\gamma\chi_{b0}(2P))/\Gamma_{\text{total}}$						Γ_{13}/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT		
0.059 ± 0.006 OUR AVERAGE				Error includes scale factor of 1.4. See the ideogram below.		
$0.0677 \pm 0.0020 \pm 0.0065$	225k	ARTUSO	05	CLEO	$e^+e^- \rightarrow \gamma X$	
$0.060 \pm 0.004 \pm 0.006$	4959	¹⁴ HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X$	
$0.049 \begin{smallmatrix} +0.003 \\ -0.004 \end{smallmatrix} \pm 0.006$	9903	MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$	



$\Gamma(\gamma\chi_{b0}(1P))/\Gamma_{\text{total}}$ **Γ_{14}/Γ**

VALUE (units 10^{-2})	EVTS	DOCUMENT ID	TECN	COMMENT
$0.30 \pm 0.04 \pm 0.10$	8.7k	ARTUSO 05	CLEO	$e^+e^- \rightarrow \gamma X$

$\Gamma(\gamma\eta_b(2S))/\Gamma_{\text{total}}$ **Γ_{15}/Γ**

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<6.2	90	ARTUSO 05	CLEO	$e^+e^- \rightarrow \gamma X$

$\Gamma(\gamma\eta_b(1S))/\Gamma_{\text{total}}$ **Γ_{16}/Γ**

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<4.3	90	ARTUSO 05	CLEO	$e^+e^- \rightarrow \gamma X$

$\Gamma(\gamma X \rightarrow \gamma + \geq 4 \text{ prongs})/\Gamma_{\text{total}}$ **Γ_{17}/Γ**
 ($1.5 \text{ GeV} < m_X < 5.0 \text{ GeV}$)

VALUE (units 10^{-4})	CL%	DOCUMENT ID	TECN	COMMENT
<2.2	95	ROSNER 07A	CLEO	$e^+e^- \rightarrow \gamma X$

⁵ Using $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) = (0.038 \pm 0.007)\%$, and $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) = (1/2)B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-)$.

⁶ Using $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.06)\%$. With the assumption of $e\mu$ universality.

⁷ Using $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-) = (18.5 \pm 0.8)\%$.

⁸ Using $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$, $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\gamma\gamma) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.188 \pm 0.035)\%$, and $B(\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^0\pi^0) \times 2B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (0.436 \pm 0.056)\%$. With the assumption of $e\mu$ universality.

⁹ From the exclusive mode.

¹⁰ $B(\Upsilon(2S) \rightarrow \mu^+\mu^-) = (1.31 \pm 0.21)\%$ and assuming $e\mu$ universality.

- ¹¹ $B(\Upsilon(2S) \rightarrow \mu^+ \mu^-) = (1.44 \pm 0.10)\%$ and assuming $e\mu$ universality. Supersedes HEINTZ 91.
- ¹² Using $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.57 \pm 0.07)\%$ and assuming $e\mu$ universality. Supersedes HEINTZ 91.
- ¹³ BESSON 07 reports $[B(\Upsilon(3S) \rightarrow \tau^+ \tau^-)] / [B(\Upsilon(3S) \rightarrow \mu^+ \mu^-)] = 1.05 \pm 0.08 \pm 0.05$. We multiply by our best value $B(\Upsilon(3S) \rightarrow \mu^+ \mu^-) = (2.18 \pm 0.21) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.
- ¹⁴ Supersedes NARAIN 91.

$\Upsilon(3S)$ REFERENCES

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