

# $\Upsilon(2S)$

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

## $\Upsilon(2S)$ MASS

<u>VALUE (GeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>10.02326 ± 0.00031 OUR AVERAGE</b>			
10.0235 ± 0.0005	<sup>1</sup> ARTAMONOV 00	MD1	$e^+e^- \rightarrow$ hadrons
10.0231 ± 0.0004	BARBER	84 REDE	$e^+e^- \rightarrow$ hadrons
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
10.0236 ± 0.0005	<sup>2,3</sup> BARU	86B REDE	$e^+e^- \rightarrow$ hadrons
<sup>1</sup> Reanalysis of BARU 86B using new electron mass (COHEN 87).			
<sup>2</sup> Reanalysis of ARTAMONOV 84.			
<sup>3</sup> Superseded by ARTAMONOV 00.			

## $\Upsilon(2S)$ WIDTH

<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>
<b>30.6 ± 2.3 OUR EVALUATION</b>	See the Note on Width Determinations of the $\Upsilon$ states

## $\Upsilon(2S)$ DECAY MODES

Mode	Fraction ( $\Gamma_i/\Gamma$ )	Scale factor/ Confidence level
$\Gamma_1 \quad \Upsilon(1S)\pi^+\pi^-$	(18.8 ± 0.6) %	
$\Gamma_2 \quad \Upsilon(1S)\pi^0\pi^0$	(9.0 ± 0.8) %	
$\Gamma_3 \quad \tau^+\tau^-$	(1.7 ± 1.6) %	
$\Gamma_4 \quad \mu^+\mu^-$	(1.93 ± 0.17) %	S=2.2
$\Gamma_5 \quad e^+e^-$	(1.92 ± 0.17) %	
$\Gamma_6 \quad \Upsilon(1S)\pi^0$	< 1.1 × 10 <sup>-3</sup>	CL=90%
$\Gamma_7 \quad \Upsilon(1S)\eta$	< 2 × 10 <sup>-3</sup>	CL=90%
$\Gamma_8 \quad J/\psi(1S)$ anything	< 6 × 10 <sup>-3</sup>	CL=90%

### Radiative decays

$\Gamma_9 \quad \gamma\chi_{b1}(1P)$	(6.9 ± 0.4) %	
$\Gamma_{10} \quad \gamma\chi_{b2}(1P)$	(7.15 ± 0.35) %	
$\Gamma_{11} \quad \gamma\chi_{b0}(1P)$	(3.8 ± 0.4) %	
$\Gamma_{12} \quad \gamma f_0(1710)$	< 5.9 × 10 <sup>-4</sup>	CL=90%
$\Gamma_{13} \quad \gamma f_2'(1525)$	< 5.3 × 10 <sup>-4</sup>	CL=90%
$\Gamma_{14} \quad \gamma f_2(1270)$	< 2.41 × 10 <sup>-4</sup>	CL=90%
$\Gamma_{15} \quad \gamma f_J(2220)$		
$\Gamma_{16} \quad \gamma\eta_b(1S)$	< 5.1 × 10 <sup>-4</sup>	CL=90%

### $\Upsilon(2S) \Gamma(i)\Gamma(e^+ e^-)/\Gamma(\text{total})$

$\Gamma(e^+ e^-) \times \Gamma(\mu^+ \mu^-)/\Gamma_{\text{total}}$				$\Gamma_5\Gamma_4/\Gamma$
<u>VALUE (eV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>	
<b>6.5±1.5±1.0</b>	KOBEL	92	CBAL	$e^+ e^- \rightarrow \mu^+ \mu^-$

$\Gamma(\text{hadrons}) \times \Gamma(e^+ e^-)/\Gamma_{\text{total}}$				$\Gamma_0\Gamma_5/\Gamma$
<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>	
<b>0.553±0.023 OUR AVERAGE</b>				
0.552±0.031±0.017	<sup>4</sup> BARU	96	MD1	$e^+ e^- \rightarrow \text{hadrons}$
0.54 ±0.04 ±0.02	<sup>4</sup> JAKUBOWSKI	88	CBAL	$e^+ e^- \rightarrow \text{hadrons}$
0.58 ±0.03 ±0.04	<sup>5</sup> GILES	84B	CLEO	$e^+ e^- \rightarrow \text{hadrons}$
0.60 ±0.12 ±0.07	<sup>5</sup> ALBRECHT	82	DASP	$e^+ e^- \rightarrow \text{hadrons}$
0.54 ±0.07 <sup>+0.09</sup> <sub>-0.05</sub>	<sup>5</sup> NICZYPORUK	81C	LENA	$e^+ e^- \rightarrow \text{hadrons}$
0.41 ±0.18	<sup>5</sup> BOCK	80	CNTR	$e^+ e^- \rightarrow \text{hadrons}$

<sup>4</sup> Radiative corrections evaluated following KURAEV 85.

<sup>5</sup> Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85.

### $\Upsilon(2S)$ PARTIAL WIDTHS

$\Gamma(e^+ e^-)$				$\Gamma_5$
<u>VALUE (keV)</u>	<u>DOCUMENT ID</u>			
<b>0.587±0.025 OUR EVALUATION</b>				

### $\Upsilon(2S)$ BRANCHING RATIOS

$\Gamma(J/\psi(1S) \text{ anything})/\Gamma_{\text{total}}$				$\Gamma_8/\Gamma$
<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;0.006</b>	90	MASCHMANN 90	CBAL	$e^+ e^- \rightarrow \text{hadrons}$

$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{\text{total}}$				$\Gamma_1/\Gamma$
<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.188±0.006 OUR AVERAGE</b>				
0.192±0.002±0.010	52.6k	<sup>6</sup> ALEXANDER	98	CLE2 $\pi^+\pi^-\ell^+\ell^-$ , $\pi^+\pi^-\text{MM}$
0.181±0.005±0.010	11.6k	ALBRECHT	87	ARG $e^+e^- \rightarrow \pi^+\pi^-\text{MM}$
0.169±0.040		GELPHMAN	85	CBAL $e^+e^- \rightarrow e^+e^-\pi^+\pi^-$
0.191±0.012±0.006		BESSON	84	CLEO $\pi^+\pi^-\text{MM}$
0.189±0.026		FONSECA	84	CUSB $e^+e^- \rightarrow \ell^+\ell^-\pi^+\pi^-$
0.21 ±0.07	7	NICZYPORUK	81B	LENA $e^+e^- \rightarrow \ell^+\ell^-\pi^+\pi^-$

<sup>6</sup> Using  $B(\Upsilon(1S) \rightarrow e^+ e^-) = (2.52 \pm 0.17)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = (2.48 \pm 0.07)\%$ .

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

$\Gamma_2/\Gamma$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.090±0.008 OUR AVERAGE</b>				
0.092±0.006±0.008	275	<sup>7</sup> ALEXANDER 98	CLE2	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$
0.095±0.019±0.019	25	ALBRECHT 87	ARG	$e^+e^- \rightarrow \pi^0\pi^0\ell^+\ell^-$
0.080±0.015		GELPHMAN 85	CBAL	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$
0.103±0.023		FONSECA 84	CUSB	$e^+e^- \rightarrow \ell^+\ell^-\pi^0\pi^0$

<sup>7</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.52 \pm 0.17)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.07)\%$ .

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

$\Gamma_3/\Gamma$

VALUE	DOCUMENT ID	TECN	COMMENT
<b>0.017±0.015±0.006</b>	HAAS	84B	CLEO $e^+e^- \rightarrow \tau^+\tau^-$

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

$\Gamma_4/\Gamma$

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
<b>0.0193±0.0017 OUR AVERAGE</b>					Error includes scale factor of 2.2. See the ideogram below.

0.0203±0.0003±0.0008	120k	ADAMS	05	CLEO	$e^+e^- \rightarrow \mu^+\mu^-$
0.0122±0.0028±0.0019		<sup>8</sup> KOBEL	92	CBAL	$e^+e^- \rightarrow \mu^+\mu^-$
0.0138±0.0025±0.0015		KAARSBERG	89	CSB2	$e^+e^- \rightarrow \mu^+\mu^-$
0.009 ±0.006 ±0.006		<sup>9</sup> ALBRECHT	85	ARG	$e^+e^- \rightarrow \mu^+\mu^-$
0.018 ±0.008 ±0.005		HAAS	84B	CLEO	$e^+e^- \rightarrow \mu^+\mu^-$

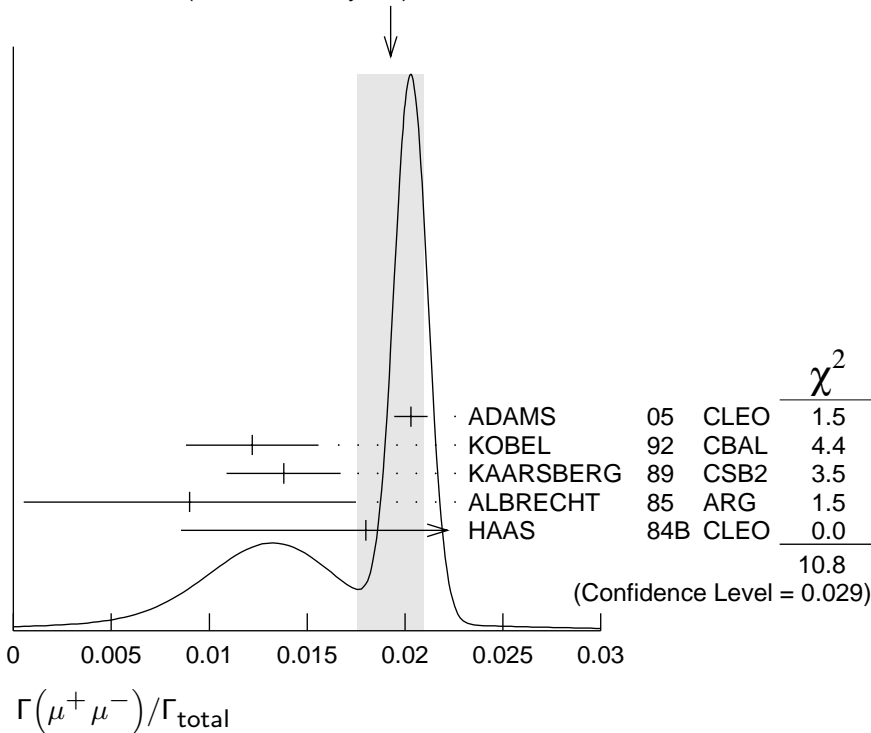
••• We do not use the following data for averages, fits, limits, etc. •••

<0.038	90	NICZYPORUK	81C	LENA	$e^+e^- \rightarrow \mu^+\mu^-$
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<sup>8</sup> Taking into account interference between the resonance and continuum.

<sup>9</sup> Re-evaluated using  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = 0.026$ .

WEIGHTED AVERAGE  
0.0193±0.0017 (Error scaled by 2.2)



$\Gamma(\Upsilon(1S)\pi^0)/\Gamma_{\text{total}}$   $\Gamma_6/\Gamma$

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;0.0011</b>	90	ALEXANDER	98 CLE2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
<0.008	90	LURZ	87 CBAL	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$

$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$   $\Gamma_7/\Gamma$

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;0.002</b>	90	FONSECA	84 CUSB	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
<0.0028	90	ALEXANDER	98 CLE2	$e^+e^- \rightarrow \ell^+\ell^-\eta$
<0.005	90	ALBRECHT	87 ARG	$e^+e^- \rightarrow \pi^+\pi^-\ell^+\ell^-MM$
<0.007	90	LURZ	87 CBAL	$e^+e^- \rightarrow \ell^+\ell^-(\gamma\gamma, 3\pi^0)$
<0.010	90	BESSON	84 CLEO	

$\Gamma(\gamma\chi_{b1}(1P))/\Gamma_{\text{total}}$   $\Gamma_9/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.069 ± 0.004 OUR AVERAGE</b>				
0.0693 ± 0.0012 ± 0.0041	407k	ARTUSO	05 CLEO	$e^+e^- \rightarrow \gamma X$
0.069 ± 0.005 ± 0.009		EDWARDS	99 CLE2	$\Upsilon(2S) \rightarrow \gamma\chi(1P)$
0.091 ± 0.018 ± 0.022		ALBRECHT	85E ARG	$e^+e^- \rightarrow \gamma\text{conv. } X$
0.065 ± 0.007 ± 0.012		NERNST	85 CBAL	$e^+e^- \rightarrow \gamma X$
0.080 ± 0.017 ± 0.016		HAAS	84 CLEO	$e^+e^- \rightarrow \gamma\text{conv. } X$
0.059 ± 0.014		KLOPFEN...	83 CUSB	$e^+e^- \rightarrow \gamma X$

$\Gamma(\gamma\chi_{b2}(1P))/\Gamma_{\text{total}}$   $\Gamma_{10}/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.0715 ± 0.0035 OUR AVERAGE</b>				
0.0724 ± 0.0011 ± 0.0040	410k	ARTUSO	05 CLEO	$e^+e^- \rightarrow \gamma X$
0.074 ± 0.005 ± 0.008		EDWARDS	99 CLE2	$\Upsilon(2S) \rightarrow \gamma\chi(1P)$
0.098 ± 0.021 ± 0.024		ALBRECHT	85E ARG	$e^+e^- \rightarrow \gamma\text{conv. } X$
0.058 ± 0.007 ± 0.010		NERNST	85 CBAL	$e^+e^- \rightarrow \gamma X$
0.102 ± 0.018 ± 0.021		HAAS	84 CLEO	$e^+e^- \rightarrow \gamma\text{conv. } X$
0.061 ± 0.014		KLOPFEN...	83 CUSB	$e^+e^- \rightarrow \gamma X$

$\Gamma(\gamma\chi_{b0}(1P))/\Gamma_{\text{total}}$   $\Gamma_{11}/\Gamma$

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.038 ± 0.004 OUR AVERAGE</b>				
0.0375 ± 0.0012 ± 0.0047	198k	ARTUSO	05 CLEO	$e^+e^- \rightarrow \gamma X$
0.034 ± 0.005 ± 0.006		EDWARDS	99 CLE2	$\Upsilon(2S) \rightarrow \gamma\chi(1P)$
0.064 ± 0.014 ± 0.016		ALBRECHT	85E ARG	$e^+e^- \rightarrow \gamma\text{conv. } X$
0.036 ± 0.008 ± 0.009		NERNST	85 CBAL	$e^+e^- \rightarrow \gamma X$
0.044 ± 0.023 ± 0.009		HAAS	84 CLEO	$e^+e^- \rightarrow \gamma\text{conv. } X$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
0.035 ± 0.014		KLOPFEN...	83 CUSB	$e^+e^- \rightarrow \gamma X$

$\Gamma(\gamma f_0(1710))/\Gamma_{\text{total}}$   $\Gamma_{12}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;59</b>	90	<sup>10</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma K^+ K^-$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

< 5.9	90	<sup>11</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^-$
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<sup>10</sup> Re-evaluated assuming  $B(f_0(1710) \rightarrow K^+ K^-) = 0.19$ .

<sup>11</sup> Includes unknown branching ratio of  $f_0(1710) \rightarrow \pi^+ \pi^-$ .

$\Gamma(\gamma f'_2(1525))/\Gamma_{\text{total}}$   $\Gamma_{13}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;53</b>	90	<sup>12</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma K^+ K^-$
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<sup>12</sup> Re-evaluated assuming  $B(f'_2(1525) \rightarrow K \bar{K}) = 0.71$ .

$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$   $\Gamma_{14}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;24.1</b>	90	<sup>13</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^-$
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<sup>13</sup> Using  $B(f_2(1270) \rightarrow \pi \pi) = 0.84$ .

$\Gamma(\gamma f_J(2220))/\Gamma_{\text{total}}$   $\Gamma_{15}/\Gamma$

VALUE (units $10^{-5}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • • •

<6.8	90	<sup>14</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma K^+ K^-$
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<sup>14</sup> Includes unknown branching ratio of  $f_J(2220) \rightarrow K^+ K^-$ .

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

VALUE (units $10^{-4}$ )	CL%	DOCUMENT ID	TECN	COMMENT
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<b>&lt;5.1</b>	90	ARTUSO	05 CLEO	$e^+ e^- \rightarrow \gamma X$
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### $\Upsilon(2S)$ REFERENCES

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