

# $\Upsilon(2S)$

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

## $\Upsilon(2S)$ 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 Superseded by ARTAMONOV 00.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>44 ± 7 OUR EVALUATION</b>	See the Note on Width Determinations of the $\Upsilon$ states

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

Mode	Fraction ( $\Gamma_i/\Gamma$ )	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) %	
$\Gamma_4 \quad \mu^+\mu^-$	(1.31 ± 0.21) %	
$\Gamma_5 \quad e^+e^-$	(1.18 ± 0.20) %	
$\Gamma_6 \quad \Upsilon(1S)\pi^0$	< 1.1 × 10 <sup>-3</sup>	90%
$\Gamma_7 \quad \Upsilon(1S)\eta$	< 2 × 10 <sup>-3</sup>	90%
$\Gamma_8 \quad J/\psi(1S)$ anything	< 6 × 10 <sup>-3</sup>	90%

### Radiative decays

$\Gamma_9 \quad \gamma\chi_{b1}(1P)$	(6.8 ± 0.7) %	
$\Gamma_{10} \quad \gamma\chi_{b2}(1P)$	(7.0 ± 0.6) %	
$\Gamma_{11} \quad \gamma\chi_{b0}(1P)$	(3.8 ± 0.6) %	
$\Gamma_{12} \quad \gamma f_0(1710)$	< 5.9 × 10 <sup>-4</sup>	90%
$\Gamma_{13} \quad \gamma f_2'(1525)$	< 5.3 × 10 <sup>-4</sup>	90%
$\Gamma_{14} \quad \gamma f_2(1270)$	< 2.41 × 10 <sup>-4</sup>	90%
$\Gamma_{15} \quad \gamma f_J(2220)$		

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

$\Gamma(e^+e^-) \times \Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>	$\Gamma_5\Gamma_4/\Gamma$
<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	4 BARU 96 MD1		$e^+e^- \rightarrow \text{hadrons}$
0.54 ±0.04 ±0.02	4 JAKUBOWSKI 88 CBAL		$e^+e^- \rightarrow \text{hadrons}$
0.58 ±0.03 ±0.04	5 GILES 84B CLEO		$e^+e^- \rightarrow \text{hadrons}$
0.60 ±0.12 ±0.07	5 ALBRECHT 82 DASP		$e^+e^- \rightarrow \text{hadrons}$
0.54 ±0.07 <sup>+0.09</sup> / <sub>-0.05</sub>	5 NICZYPORUK 81c LENA		$e^+e^- \rightarrow \text{hadrons}$
0.41 ±0.18	5 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>	<u>TECN</u>	<u>COMMENT</u>
<b>0.52 ±0.03 ±0.01</b>	<sup>6</sup> ALBRECHT 95E ARG		$e^+e^- \rightarrow \text{hadrons}$

<sup>6</sup> Applying the formula of Kuraev and Fadin.

**$\Upsilon(2S)$  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>7</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		BESSION 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>7</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.52 \pm 0.17)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.07)\%$ .

**$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\text{total}}$   $\Gamma_2/\Gamma$**

<u>VALUE</u>	<u>EVTS</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.090±0.008 OUR AVERAGE</b>				
0.092±0.006±0.008	275	<sup>8</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>8</sup> Using  $B(\Upsilon(1S) \rightarrow e^+e^-) = (2.52 \pm 0.17)\%$  and  $B(\Upsilon(1S) \rightarrow \mu^+\mu^-) = (2.48 \pm 0.07)\%$ .

$\Gamma(\tau^+ \tau^-)/\Gamma_{\text{total}}$   $\Gamma_3/\Gamma$

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

$\Gamma(\mu^+ \mu^-)/\Gamma_{\text{total}}$   $\Gamma_4/\Gamma$

<u>VALUE</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.0131±0.0021 OUR AVERAGE</b>				
0.0122±0.0028±0.0019		<sup>9</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>10</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>9</sup> Taking into account interference between the resonance and continuum.

<sup>10</sup> Re-evaluated using  $B(\Upsilon(1S) \rightarrow \mu^+ \mu^-) = 0.026$ .

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

<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	$e^+ e^- \rightarrow l^+ l^- \gamma \gamma$

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

<0.008	90	LURZ	87 CBAL	$e^+ e^- \rightarrow l^+ l^- \gamma \gamma$
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$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$   $\Gamma_7/\Gamma$

<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	$e^+ e^- \rightarrow l^+ l^- \eta$
<0.005	90	ALBRECHT	87 ARG	$e^+ e^- \rightarrow \pi^+ \pi^- l^+ l^- \text{MM}$
<0.007	90	LURZ	87 CBAL	$e^+ e^- \rightarrow l^+ l^- (\gamma \gamma, 3\pi^0)$
<0.010	90	BESSION	84 CLEO	

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

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.068±0.007 OUR AVERAGE</b>			
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>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>0.070±0.006 OUR AVERAGE</b>			
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>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>	
<b>0.038±0.006 OUR AVERAGE</b>				
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	$e^+e^- \rightarrow \gamma X$	

$\Gamma(\gamma f_0(1710))/\Gamma_{\text{total}}$				$\Gamma_{12}/\Gamma$
<u>VALUE (units 10<sup>-5</sup>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;59</b>	90	<sup>11</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma K^+ K^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
< 5.9	90	<sup>12</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^-$
<sup>11</sup> Re-evaluated assuming $B(f_0(1710) \rightarrow K^+ K^-) = 0.19$ .				
<sup>12</sup> Includes unknown branching ratio of $f_0(1710) \rightarrow \pi^+ \pi^-$ .				

$\Gamma(\gamma f'_2(1525))/\Gamma_{\text{total}}$				$\Gamma_{13}/\Gamma$
<u>VALUE (units 10<sup>-5</sup>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;53</b>	90	<sup>13</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma K^+ K^-$
<sup>13</sup> Re-evaluated assuming $B(f'_2(1525) \rightarrow K\bar{K}) = 0.71$ .				

$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$				$\Gamma_{14}/\Gamma$
<u>VALUE (units 10<sup>-5</sup>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;24.1</b>	90	<sup>14</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^-$
<sup>14</sup> Using $B(f_2(1270) \rightarrow \pi\pi) = 0.84$ .				

$\Gamma(\gamma f_J(2220))/\Gamma_{\text{total}}$				$\Gamma_{15}/\Gamma$
<u>VALUE (units 10<sup>-5</sup>)</u>	<u>CL%</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<6.8	90	<sup>15</sup> ALBRECHT	89 ARG	$\Upsilon(2S) \rightarrow \gamma K^+ K^-$
<sup>15</sup> Includes unknown branching ratio of $f_J(2220) \rightarrow K^+ K^-$ .				

## $\Upsilon(2S)$ REFERENCES

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