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

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

$\Upsilon(4S)$ MASS

VALUE (MeV)		DOCUMENT ID		TECN	COMMENT
10579.4±1.2 OUR AVERAGE					
10579.3±0.4±1.2		AUBERT	05Q	BABR	$e^+e^- \to$ hadrons
10580.0±3.5	[1]	BEBEK	87	CLEO	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •					
10577.4±1.0	[2]	LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

[1] Reanalysis of BESSON 85.
[2] No systematic error given.

$\Upsilon(4S)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
20.5±2.5 OUR AVERAGE				
20.7±1.6±2.5	AUBERT	05Q	BABR	$e^+e^- \to$ hadrons
20 ±2 ±4	BESSON	85	CLEO	$e^+e^- \to$ hadrons
• • • We do not use the following data for averages, fits, limits, etc. • • •				
25 ±2.5	LOVELOCK	85	CUSB	$e^+e^- \to$ hadrons

$\Upsilon(4S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$B\overline{B}$	> 96 %	95%
Γ_2	B^+B^-	(51.3 ±0.6) %	
Γ_3	D_s^+ anything + c.c.	(17.8 ±2.6) %	
Γ_4	$B^0\overline{B}^0$	(48.7 ±0.6) %	
Γ_5	$J/\psi K_S^0 (J/\psi, \eta_c) K_S^0$	$< 4 \times 10^{-7}$	90%
Γ_6	non-$B\overline{B}$	< 4 %	95%
Γ_7	e^+e^-	$(1.57\pm0.08) \times 10^{-5}$	
Γ_8	$\rho^+\rho^-$	$< 5.7 \times 10^{-6}$	90%
Γ_9	$J/\psi(1S)$ anything	$< 1.9 \times 10^{-4}$	95%
Γ_{10}	D^{*+} anything + c.c.	< 7.4 %	90%
Γ_{11}	ϕ anything	(7.1 ±0.6) %	
Γ_{12}	$\phi\eta$	$< 1.8 \times 10^{-6}$	90%
Γ_{13}	$\phi\eta'$	$< 4.3 \times 10^{-6}$	90%
Γ_{14}	$\rho\eta$	$< 1.3 \times 10^{-6}$	90%
Γ_{15}	$\rho\eta'$	$< 2.5 \times 10^{-6}$	90%

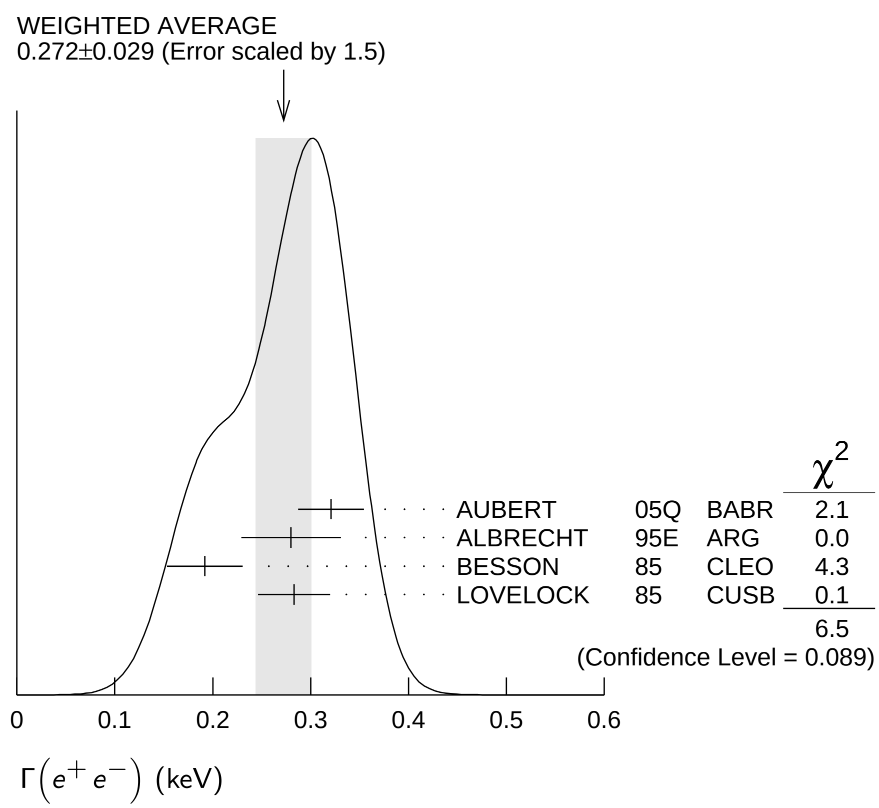
Γ_{16}	$\Upsilon(1S)$ anything	$< 4 \times 10^{-3}$	90%
Γ_{17}	$\Upsilon(1S)\pi^+\pi^-$	$(8.1 \pm 0.6) \times 10^{-5}$	
Γ_{18}	$\Upsilon(1S)\eta$	$(1.96 \pm 0.28) \times 10^{-4}$	
Γ_{19}	$\Upsilon(2S)\pi^+\pi^-$	$(8.6 \pm 1.3) \times 10^{-5}$	
Γ_{20}	$h_b(1P)\pi^+\pi^-$	not seen	
Γ_{21}	$\overline{d}$ anything	$< 1.3 \times 10^{-5}$	90%

$\Upsilon(4S)$ PARTIAL WIDTHS

$\Gamma(e^+e^-)$ Γ_7

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
0.272±0.029 OUR AVERAGE	Error includes scale factor of 1.5. See the ideogram below.			
0.321±0.017±0.029	AUBERT	05Q	BABR	$e^+e^- \rightarrow$ hadrons
0.28 ±0.05 ±0.01	[3] ALBRECHT	95E	ARG	$e^+e^- \rightarrow$ hadrons
0.192±0.007±0.038	BESSON	85	CLEO	$e^+e^- \rightarrow$ hadrons
0.283±0.037	LOVELOCK	85	CUSB	$e^+e^- \rightarrow$ hadrons

[3] Using LEYAOUANC 77 parametrization of $\Gamma(s)$.



$\Upsilon(4S)$ BRANCHING RATIOS

—— $B\overline{B}$ DECAYS ——

The ratio of branching fraction to charged and neutral B mesons is often derived assuming isospin invariance in the decays, and relies on the knowledge of the B^+/B^0 lifetime ratio. "OUR EVALUATION" is obtained based on averages of rescaled data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at http://www.slac.stanford.edu/xorg/hfag/. The averaging/rescaling procedure takes into account the common dependence of the measurement on the value of the lifetime ratio.

$\Gamma(B^+B^-)/\Gamma_{total}$ — Γ_2/Γ

VALUE	DOCUMENT ID
0.513±0.006 OUR EVALUATION	Assuming B($\Upsilon(4S) \to B\overline{B}$) = 1

$\Gamma(D_s^+$ anything + c.c.$)/\Gamma_{total}$ — Γ_3/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.178±0.021±0.016	[4] ARTUSO	05B	CLE3	$e^+e^- \to D_X X$

[4] ARTUSO 05B reports $[\Gamma(\Upsilon(4S) \to D_s^+$ anything + c.c.$)/\Gamma_{total}] \times [B(D_s^+ \to \phi\pi^+)] = (8.0 \pm 0.2 \pm 0.9) \times 10^{-3}$ which we divide by our best value $B(D_s^+ \to \phi\pi^+) = (4.5 \pm 0.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(B^0\overline{B}^0)/\Gamma_{total}$ — Γ_4/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.487±0.006 OUR EVALUATION	Assuming B($\Upsilon(4S) \to B\overline{B}$) = 1			
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.487±0.010±0.008	[5] AUBERT,B	05H	BABR	$\Upsilon(4S) \to \overline{B}B \to D^*\ell\nu_\ell$

[5] Direct measurement. This value is averaged with the value extracted from the $\Gamma(B^+B^-)$ / $\Gamma(B^0\overline{B}^0)$ measurements.

$\Gamma(B^+B^-)/\Gamma(B^0\overline{B}^0)$ — Γ_2/Γ_4

VALUE	DOCUMENT ID		TECN	COMMENT
1.055±0.025 OUR EVALUATION				
1.006±0.036±0.031	[6] AUBERT	04F	BABR	$\Upsilon(4S) \to B\overline{B} \to J/\psi K$
1.01 ±0.03 ±0.09	[6] HASTINGS	03	BELL	$\Upsilon(4S) \to B\overline{B} \to$ dileptons
1.058±0.084±0.136	[7] ATHAR	02	CLEO	$\Upsilon(4S) \to B\overline{B} \to D^*\ell\nu$
1.10 ±0.06 ±0.05	[8] AUBERT	02	BABR	$\Upsilon(4S) \to B\overline{B} \to (c\overline{c})K^*$
1.04 ±0.07 ±0.04	[9] ALEXANDER	01	CLEO	$\Upsilon(4S) \to B\overline{B} \to J/\psi K^*$

[6] HASTINGS 03 and AUBERT 04F assume $\tau(B^+) / \tau(B^0) = 1.083 \pm 0.017$.
[7] ATHAR 02 assumes $\tau(B^+) / \tau(B^0) = 1.074 \pm 0.028$. Supersedes BARISH 95.
[8] AUBERT 02 assumes $\tau(B^+) / \tau(B^0) = 1.062 \pm 0.029$.
[9] ALEXANDER 01 assumes $\tau(B^+) / \tau(B^0) = 1.066 \pm 0.024$.

$\Gamma(J/\psi K^0_S (J/\psi, \eta_c) K^0_S)/\Gamma_{total}$ — Γ_5/Γ

Forbidden by CP invariance.

VALUE (units 10^{-7})	CL%	DOCUMENT ID		TECN	COMMENT
<4	90	[10] TAJIMA	07A	BELL	$\Upsilon(4S) \rightarrow B^0 \overline{B}^0$

[10] $\Upsilon(4S)$ with $CP = +1$ decays to the final state with $CP = -1$.

non-$B\overline{B}$ DECAYS

$\Gamma(\text{non-}B\overline{B})/\Gamma_{total}$ — Γ_6/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.04	95	BARISH	96B	CLEO	$e^+ e^-$

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

VALUE (units 10^{-5})	DOCUMENT ID		TECN	COMMENT
1.57±0.08 OUR AVERAGE				
1.55±0.04±0.07	AUBERT	05Q	BABR	$e^+ e^- \rightarrow$ hadrons
2.77±0.50±0.49	[11] ALBRECHT	95E	ARG	$e^+ e^- \rightarrow$ hadrons

[11] Using LEYAOUANC 77 parametrization of $\Gamma(s)$.

$\Gamma(\rho^+ \rho^-)/\Gamma_{total}$ — Γ_8/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$<5.7 \times 10^{-6}$	90	AUBERT	08BO	BABR	$e^+ e^- \rightarrow \pi^+ \pi^- 2\pi^0$

$\Gamma(J/\psi(1S) \text{ anything})/\Gamma_{total}$ — Γ_9/Γ

VALUE (units 10^{-4})	CL%	DOCUMENT ID		TECN	COMMENT
<1.9	95	[12] ABE	02D	BELL	$e^+ e^- \rightarrow J/\psi X \rightarrow \ell^+ \ell^- X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<4.7	90	[12] AUBERT	01C	BABR	$e^+ e^- \rightarrow J/\psi X \rightarrow \ell^+ \ell^- X$

[12] Uses $B(J/\psi \rightarrow e^+ e^-) = 0.0593 \pm 0.0010$ and $B(J/\psi \rightarrow \mu^+ \mu^-) = 0.0588 \pm 0.0010$.

$\Gamma(D^{*+} \text{ anything} + \text{c.c.})/\Gamma_{total}$ — Γ_{10}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.074	90	[13] ALEXANDER	90C	CLEO	$e^+ e^-$

[13] For $x >$ 0.473.

$\Gamma(\phi \text{ anything})/\Gamma_{total}$ — Γ_{11}/Γ

VALUE (units 10^{-2})	CL%	DOCUMENT ID		TECN	COMMENT
7.1 ±0.1±0.6		HUANG	07	CLEO	$\Upsilon(4S) \rightarrow \phi X$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.23	90	[14] ALEXANDER	90C	CLEO	$e^+ e^-$

[14] For $x >$ 0.52.

$\Gamma(\phi\eta)/\Gamma_{total}$ — Γ_{12}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<1.8	90	[15] BELOUS	09	BELL	$e^+ e^- \rightarrow \phi\eta$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<2.5	90	AUBERT,BE	06F	BABR	$e^+ e^- \rightarrow \phi\eta$

[15] Using all intermedite branching fraction values from PDG 08.

$\Gamma(\phi\eta')/\Gamma_{total}$ — Γ_{13}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<4.3	90	[16] BELOUS	09	BELL	$e^+e^- \to \phi\eta'$

[16] Using all intermedite branching fraction values from PDG 08.

$\Gamma(\rho\eta)/\Gamma_{total}$ — Γ_{14}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<1.3	90	[17] BELOUS	09	BELL	$e^+e^- \to \rho\eta$

[17] Using all intermedite branching fraction values from PDG 08.

$\Gamma(\rho\eta')/\Gamma_{total}$ — Γ_{15}/Γ

VALUE (units 10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
<2.5	90	[18] BELOUS	09	BELL	$e^+e^- \to \rho\eta'$

[18] Using all intermedite branching fraction values from PDG 08.

$\Gamma(\Upsilon(1S)\text{ anything})/\Gamma_{total}$ — Γ_{16}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.004	90	ALEXANDER	90C	CLEO	e^+e^-

$\Gamma(\Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}$ — Γ_{17}/Γ

VALUE (units 10^{-5})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
8.1 ±0.6 OUR AVERAGE						
8.5 ±1.3 ±0.2		113 ± 16	[19] SOKOLOV	09	BELL	$e^+e^- \to \pi^+\pi^-\mu^+\mu^-$
8.00±0.64±0.27		430	[20] AUBERT	08BP	BABR	$\Upsilon(4S) \to \pi^+\pi^-\ell^+\ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
17.8 ±4.0 ±0.3			[21,22] SOKOLOV	07	BELL	$e^+e^- \to \pi^+\pi^-\mu^+\mu^-$
9.0 ±1.5 ±0.2		167 ± 19	[23] AUBERT	06R	BABR	$e^+e^- \to \pi^+\pi^-\mu^+\mu^-$
<12	90		GLENN	99	CLE2	e^+e^-

[19] SOKOLOV 09 reports $[\Gamma(\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}] \times [B(\Upsilon(1S) \to \mu^+\mu^-)] = (0.211 \pm 0.030 \pm 0.014) \times 10^{-5}$ which we divide by our best value $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.05) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[20] Using $B(\Upsilon(1S) \to e^+e^-) = (2.38 \pm 0.11)\%$ and $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.05)\%$.

[21] SOKOLOV 07 reports $[\Gamma(\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}] \times [B(\Upsilon(1S) \to \mu^+\mu^-)] = (4.42 \pm 0.81 \pm 0.56) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.05) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[22] According to the authors, systematic errors were underestimated.

[23] Superseded by AUBERT 08BP. AUBERT 06R reports $[\Gamma(\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-)/\Gamma_{total}] \times [B(\Upsilon(1S) \to \mu^+\mu^-)] = (2.23 \pm 0.25 \pm 0.27) \times 10^{-6}$ which we divide by our best value $B(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.05) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(\Upsilon(1S)\eta)/\Gamma_{total}$ Γ_{18}/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
1.96±0.26±0.09	56	[24] AUBERT	08BP	BABR	$\Upsilon(4S) \to \pi^+\pi^-\pi^0\ell^+\ell^-$

[24] Using B($\Upsilon(1S) \to e^+e^-$) = (2.38 ± 0.11)% and B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.05)%.

$\Gamma(\Upsilon(1S)\eta)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$ Γ_{18}/Γ_{17}

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
2.41±0.40±0.12	56	[25] AUBERT	08BP	BABR	$\Upsilon(4S) \to \pi^+\pi^-(\pi^0)\ell^+\ell^-$

[25] Not independent of other values reported by AUBERT 08BP.

$\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma_{total}$ Γ_{19}/Γ

VALUE (units 10^{-4})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
0.86±0.11±0.07		220	[26] AUBERT	08BP	BABR	$\Upsilon(4S) \to \pi^+\pi^-\ell^+\ell^-$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
0.88±0.17±0.08		97 ± 15	[27] AUBERT	06R	BABR	$e^+e^- \to \pi^+\pi^-\mu^+\mu^-$
<3.9	90		GLENN	99	CLE2	e^+e^-

[26] Using B($\Upsilon(2S) \to e^+e^-$) = (1.91 ± 0.16)% and B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.93 ± 0.17)%.

[27] Superseded by AUBERT 08BP. AUBERT 06R reports [$\Gamma(\Upsilon(4S) \to \Upsilon(2S)\pi^+\pi^-)/\Gamma_{total}$] × [B($\Upsilon(2S) \to \mu^+\mu^-$)] = (1.69 ± 0.26 ± 0.20) × 10^{-6} which we divide by our best value B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.93 ± 0.17) × 10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(\Upsilon(2S)\pi^+\pi^-)/\Gamma(\Upsilon(1S)\pi^+\pi^-)$ Γ_{19}/Γ_{17}

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.16±0.16±0.14	220	[28] AUBERT	08BP	BABR	$\Upsilon(4S) \to \pi^+\pi^-\ell^+\ell^-$

[28] Using B($\Upsilon(1S) \to e^+e^-$) = (2.38 ± 0.11)%, B($\Upsilon(1S) \to \mu^+\mu^-$) = (2.48 ± 0.05)%, B($\Upsilon(2S) \to e^+e^-$) = (1.91 ± 0.16)%, and B($\Upsilon(2S) \to \mu^+\mu^-$) = (1.93 ± 0.17)%. Not independent of other values reported by AUBERT 08BP.

$\Gamma(h_b(1P)\pi^+\pi^-)/\Gamma_{total}$ Γ_{20}/Γ

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
not seen	35 ± 21k	[29] ADACHI	12	BELL	10.58 $e^+e^- \to h_b(1P)\pi^+\pi^-$

[29] From the upper limit on the ratio of $\sigma(e^+e^- \to h_b(1P)\pi^+\pi^-)$ at the $\Upsilon(4S)$ to that at the $\Upsilon(5S)$ of 0.27.

$\Gamma(\overline{d}\text{ anything})/\Gamma_{total}$ Γ_{21}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
<1.3	90	ASNER	07	CLEO	$e^+e^- \to \overline{d}X$

$\Upsilon(4S)$ REFERENCES

ADACHI	12	PRL 108 032001	I. Adachi *et al.*	(BELLE Collab.)
BELOUS	09	PL B681 400	K. Belous *et al.*	(BELLE Collab.)
SOKOLOV	09	PR D79 051103	A. Sokolov *et al.*	(BELLE Collab.)
AUBERT	08BO	PR D78 071103	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	08BP	PR D78 112002	B. Aubert *et al.*	(BABAR Collab.)
PDG	08	PL B667 1	C. Amsler *et al.*	(PDG Collab.)
ASNER	07	PR D75 012009	D.M. Asner *et al.*	(CLEO Collab.)
HUANG	07	PR D75 012002	G.S. Huang *et al.*	(CLEO Collab.)
SOKOLOV	07	PR D75 071103	A. Sokolov *et al.*	(BELLE Collab.)
TAJIMA	07A	PRL 99 211601	O. Tajima *et al.*	(BELLE Collab.)
AUBERT	06R	PRL 96 232001	B. Aubert *et al.*	(BABAR Collab.)
AUBERT,BE	06F	PR D74 111103	B. Aubert *et al.*	(BABAR Collab.)
ARTUSO	05B	PRL 95 261801	M. Artuso *et al.*	(CLEO Collab.)
AUBERT	05Q	PR D72 032005	B. Aubert *et al.*	(BABAR Collab.)
AUBERT,B	05H	PRL 95 042001	B. Aubert *et al.*	(BABAR Collab.)
AUBERT	04F	PR D69 071101	B.Aubert *et al.*	
HASTINGS	03	PR D67 052004	N.C. Hastings *et al.*	(BELLE Collab.)
ABE	02D	PRL 88 052001	K. Abe *et al.*	(BELLE Collab.)
ATHAR	02	PR D66 052003	S.B. Athar *et al.*	(CLEO Collab.)
AUBERT	02	PR D65 032001	B. Aubert *et al.*	(BaBar Collab.)
ALEXANDER	01	PRL 86 2737	J.P. Alexander *et al.*	(CLEO Collab.)
AUBERT	01C	PRL 87 162002	B. Aubert *et al.*	(BaBar Collab.)
GLENN	99	PR D59 052003	S. Glenn *et al.*	
BARISH	96B	PRL 76 1570	B.C. Barish *et al.*	(CLEO Collab.)
ALBRECHT	95E	ZPHY C65 619	H. Albrecht *et al.*	(ARGUS Collab.)
BARISH	95	PR D51 1014	B.C. Barish *et al.*	(CLEO Collab.)
ALEXANDER	90C	PRL 64 2226	J. Alexander *et al.*	(CLEO Collab.)
BEBEK	87	PR D36 1289	C. Bebek *et al.*	(CLEO Collab.)
BESSON	85	PRL 54 381	D. Besson *et al.*	(CLEO Collab.)
LOVELOCK	85	PRL 54 377	D.M.J. Lovelock *et al.*	(CUSB Collab.)
LEYAOUANC	77	PL B71 397	A. Le Yaouanc *et al.*	(ORSAY)