B^0

$I(J^P) = \frac{1}{2}(0^-)$

Quantum numbers not measured. Values shown are quark-model predictions.

See also the $B^{\pm}/B^0$ ADMIXTURE and $B^{\pm}/B^0/B^0_s/b$-baryon ADMIXTURE sections.

See the Note "Production and Decay of *b*-flavored Hadrons" at the beginning of the $B^{\pm}$ Particle Listings and the Note on "B^0-$\overline{B}^0$ Mixing and *CP* Violation in *B* Decay" near the end of the B^0 Particle Listings.

B^0 MASS

The fit uses m_{B^+}, $(m_{B^0} - m_{B^+})$, and m_{B^0} to determine m_{B^+}, m_{B^0}, and the mass difference.

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
5279.4±0.5 OUR FIT				
5279.3±0.7 OUR AVERAGE				
5279.1±0.7 ±0.3	135	[1] CSORNA 00	CLE2	$e^+e^- \to \Upsilon(4S)$
5281.3±2.2 ±1.4	51	ABE 96B	CDF	$p\overline{p}$ at 1.8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
5279.2±0.54±2.0	340	ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$
5278.0±0.4 ±2.0		BORTOLETTO 92	CLEO	$e^+e^- \to \Upsilon(4S)$
5279.6±0.7 ±2.0	40	[2] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$
5278.2±1.0 ±3.0	40	ALBRECHT 87C	ARG	$e^+e^- \to \Upsilon(4S)$
5279.5±1.6 ±3.0	7	[3] ALBRECHT 87D	ARG	$e^+e^- \to \Upsilon(4S)$
5280.6±0.8 ±2.0		BEBEK 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[1] CSORNA 00 uses fully reconstructed 135 $B^0 \to J/\psi^{(\prime)} K^0_S$ events and invariant masses without beam constraint.

[2] ALBRECHT 90J assumes 10580 for $\Upsilon(4S)$ mass. Supersedes ALBRECHT 87C and ALBRECHT 87D.

[3] Found using fully reconstructed decays with J/ψ. ALBRECHT 87D assume $m_{\Upsilon(4S)} =$ 10577 MeV.

$m_{B^0} - m_{B^+}$

VALUE (MeV)	*DOCUMENT ID*	*TECN*	*COMMENT*
0.33±0.28 OUR FIT Error includes scale factor of 1.1.			
0.34±0.32 OUR AVERAGE Error includes scale factor of 1.2.			
0.41±0.25±0.19	ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$
−0.4 ±0.6 ±0.5	BORTOLETTO 92	CLEO	$e^+e^- \to \Upsilon(4S)$
−0.9 ±1.2 ±0.5	ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$
2.0 ±1.1 ±0.3	[4] BEBEK 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[4] BEBEK 87 actually measure the difference between half of $E_{\rm cm}$ and the $B^{\pm}$ or B^0 mass, so the $m_{B^0} - m_{B^{\pm}}$ is more accurate. Assume $m_{\Upsilon(4S)} = 10580$ MeV.

$m_{B^0_H} - m_{B^0_L}$

See the B^0-$\overline{B}^0$ MIXING PARAMETERS section near the end of these B^0 Listings.

B^0 MEAN LIFE

See $B^{\pm}/B^0/B^0_s/b$-baryon ADMIXTURE section for data on B-hadron mean life averaged over species of bottom particles.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the $B^{\pm}$ Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10^{-12} s)	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
1.548±0.032 OUR EVALUATION					
Average is meaningless.	[(1.553 ± 0.032) × 10^{-12} s OUR 1998 AVERAGE]				
1.523±0.057±0.053		[5] ABBIENDI	99J	OPAL	$e^+e^- \rightarrow Z$
1.58 ±0.09 ±0.02		[6] ABE	98B	CDF	$p\overline{p}$ at 1.8 TeV
$1.474 \pm 0.039 ^{+0.052}_{-0.051}$		[7] ABE	98Q	CDF	$p\overline{p}$ at 1.8 TeV
1.52 ±0.06 ±0.04		[5] ACCIARRI	98S	L3	$e^+e^- \rightarrow Z$
1.64 ±0.08 ±0.08		[5] ABE	97J	SLD	$e^+e^- \rightarrow Z$
1.532±0.041±0.040		[8] ABREU	97F	DLPH	$e^+e^- \rightarrow Z$
1.61 ±0.07 ±0.04		[7] BUSKULIC	96J	ALEP	$e^+e^- \rightarrow Z$
$1.25 ^{+0.15}_{-0.13} \pm 0.05$	121	[6] BUSKULIC	96J	ALEP	$e^+e^- \rightarrow Z$
$1.49 ^{+0.17}_{-0.15} {}^{+0.08}_{-0.06}$		[9] BUSKULIC	96J	ALEP	$e^+e^- \rightarrow Z$
$1.61 ^{+0.14}_{-0.13} \pm 0.08$		[7,10] ABREU	95Q	DLPH	$e^+e^- \rightarrow Z$
1.63 ±0.14 ±0.13		[11] ADAM	95	DLPH	$e^+e^- \rightarrow Z$
1.53 ±0.12 ±0.08		[7,12] AKERS	95T	OPAL	$e^+e^- \rightarrow Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1.54 ±0.08 ±0.06		[7] ABE	96C	CDF	Repl. by ABE 98Q
1.55 ±0.06 ±0.03		[13] BUSKULIC	96J	ALEP	$e^+e^- \rightarrow Z$
1.62 ±0.12		[14] ADAM	95	DLPH	$e^+e^- \rightarrow Z$
1.57 ±0.18 ±0.08	121	[6] ABE	94D	CDF	Repl. by ABE 98B
$1.17 ^{+0.29}_{-0.23} \pm 0.16$	96	[7] ABREU	93D	DLPH	Sup. by ABREU 95Q
1.55 ±0.25 ±0.18	76	[11] ABREU	93G	DLPH	Sup. by ADAM 95
$1.51 ^{+0.24}_{-0.23} {}^{+0.12}_{-0.14}$	78	[7] ACTON	93C	OPAL	Sup. by AKERS 95T
$1.52 ^{+0.20}_{-0.18} {}^{+0.07}_{-0.13}$	77	[7] BUSKULIC	93D	ALEP	Sup. by BUSKULIC 96J
$1.20 ^{+0.52}_{-0.36} {}^{+0.16}_{-0.14}$	15	[15] WAGNER	90	MRK2	$E^{ee}_{\rm cm}$= 29 GeV
$0.82 ^{+0.57}_{-0.37} \pm 0.27$		[16] AVERILL	89	HRS	$E^{ee}_{\rm cm}$= 29 GeV

[5] Data analyzed using charge of secondary vertex.

[6] Measured mean life using fully reconstructed decays.

[7] Data analyzed using $D\,/\,D^*\,\ell X$ event vertices.

[8] Data analyzed using inclusive $D/D^{*}\ell X$.

[9] Measured mean life using partially reconstructed $D^{*-}\pi^{+}$X vertices.

[10] ABREU 95Q assumes $\mathrm{B}(B^0 \to D^{**-}\ell^{+}\nu_{\ell}) = 3.2 \pm 1.7\%$.

[11] Data analyzed using vertex-charge technique to tag B charge.

[12] AKERS 95T assumes $\mathrm{B}(B^0 \to D_s{}^{(*)}D^{0\,(*)}) = 5.0 \pm 0.9\%$ to find B^{+}/B^{0} yield.

[13] Combined result of $D/D^{*}\ell$x analysis, fully reconstructed B analysis, and partially reconstrued $D^{*-}\pi^{+}$X analysis.

[14] Combined ABREU 95Q and ADAM 95 result.

[15] WAGNER 90 tagged B^0 mesons by their decays into $D^{*-}e^{+}\nu$ and $D^{*-}\mu^{+}\nu$ where the D^{*-} is tagged by its decay into $\pi^{-}\overline{D}^{0}$.

[16] AVERILL 89 is an estimate of the B^0 mean lifetime assuming that $B^0 \to D^{*+} +$ X always.

MEAN LIFE RATIO τ_{B^+}/τ_{B^0}

τ_{B^+}/τ_{B^0} (average of direct and inferred)

VALUE	*DOCUMENT ID*
1.060±0.029 OUR AVERAGE	Includes data from the 2 datablocks that follow this one.

τ_{B^+}/τ_{B^0} (direct measurements)

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the $B^{\pm}$ Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
The data in this block is included in the average printed for a previous datablock.					
1.062±0.029 OUR EVALUATION					
Average is meaningless.		[1.03 ± 0.04 OUR 1998 AVERAGE]			
$1.079 \pm 0.064 \pm 0.041$		[17] ABBIENDI	99J	OPAL	$e^+e^- \to Z$
$1.06 \pm 0.07 \pm 0.02$		[18] ABE	98B	CDF	$p\overline{p}$ at 1.8 TeV
$1.110 \pm 0.056 {}^{+0.033}_{-0.030}$		[19] ABE	98Q	CDF	$p\overline{p}$ at 1.8 TeV
$1.09 \pm 0.07 \pm 0.03$		[17] ACCIARRI	98S	L3	$e^+e^- \to Z$
$1.01 \pm 0.07 \pm 0.06$		[17] ABE	97J	SLD	$e^+e^- \to Z$
$0.98 \pm 0.08 \pm 0.03$		[19] BUSKULIC	96J	ALEP	$e^+e^- \to Z$
$1.27 {}^{+0.23}_{-0.19} {}^{+0.03}_{-0.02}$		[18] BUSKULIC	96J	ALEP	$e^+e^- \to Z$
$1.00 {}^{+0.17}_{-0.15} \pm 0.10$		[19,20] ABREU	95Q	DLPH	$e^+e^- \to Z$
$1.06 {}^{+0.13}_{-0.10} \pm 0.10$		[21] ADAM	95	DLPH	$e^+e^- \to Z$
$0.99 \pm 0.14 {}^{+0.05}_{-0.04}$		[19,22] AKERS	95T	OPAL	$e^+e^- \to Z$

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

$1.01 \pm 0.11 \pm 0.02$		[19] ABE 96C	CDF	Repl. by ABE 98Q
$1.03 \pm 0.08 \pm 0.02$		[23] BUSKULIC 96J	ALEP	$e^+e^- \rightarrow Z$
$1.02 \pm 0.16 \pm 0.05$	269	[18] ABE 94D	CDF	Repl. by ABE 98B
$1.11^{+0.51}_{-0.39} \pm 0.11$	188	[19] ABREU 93D	DLPH	Sup. by ABREU 95Q
$1.01^{+0.29}_{-0.22} \pm 0.12$	253	[21] ABREU 93G	DLPH	Sup. by ADAM 95
$1.0^{+0.33}_{-0.25} \pm 0.08$	130	ACTON 93C	OPAL	Sup. by AKERS 95T
$0.96^{+0.19}_{-0.15}{}^{+0.18}_{-0.12}$	154	[19] BUSKULIC 93D	ALEP	Sup. by BUSKULIC 96J

[17] Data analyzed using charge of secondary vertex.

[18] Measured using fully reconstructed decays.

[19] Data analyzed using $D/D^*\ell X$ vertices.

[20] ABREU 95Q assumes B($B^0 \rightarrow D^{**-}\ell^+\nu_\ell$) = 3.2 ± 1.7%.

[21] Data analyzed using vertex-charge technique to tag B charge.

[22] AKERS 95T assumes B($B^0 \rightarrow D_s{}^{(*)}D^{0\,(*)}$) = 5.0 ± 0.9% to find B^+/B^0 yield.

[23] Combined result of $D/D^*\ell X$ analysis and fully reconstructed B analysis.

τ_{B^+}/τ_{B^0} (inferred from branching fractions)

These measurements are inferred from the branching fractions for semileptonic decay or other spectator-dominated decays by assuming that the rates for such decays are equal for B^0 and B^+. We do not use measurements which assume equal production of B^0 and B^+ because of the large uncertainty in the production ratio.

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
The data in this block is included in the average printed for a previous datablock.					
$\mathbf{0.95^{+0.117}_{-0.080} \pm 0.091}$			[24] ARTUSO 97	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$1.15 \pm 0.17 \pm 0.06$			[25] JESSOP 97	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
$0.93 \pm 0.18 \pm 0.12$			[26] ATHANAS 94	CLE2	Sup. by ARTUSO 97
$0.91 \pm 0.27 \pm 0.21$			[27] ALBRECHT 92C	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
1.0 ± 0.4		29	[27,28] ALBRECHT 92G	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
$0.89 \pm 0.19 \pm 0.13$			[27] FULTON 91	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
$1.00 \pm 0.23 \pm 0.14$			[27] ALBRECHT 89L	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
0.49 to 2.3	90		[29] BEAN 87B	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[24] ARTUSO 97 uses partial reconstruction of $B \rightarrow D^*\ell\nu_\ell$ and independent of B^0 and B^+ production fraction.

[25] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[26] ATHANAS 94 uses events tagged by fully reconstructed B^- decays and partially or fully reconstructed B^0 decays.

[27] Assumes equal production of B^0 and B^+.

[28] ALBRECHT 92G data analyzed using $B \rightarrow D_s\overline{D}$, $D_s\overline{D}^*$, $D_s^*\overline{D}$, $D_s^*\overline{D}^*$ events.

[29] BEAN 87B assume the fraction of $B^0\overline{B}^0$ events at the $\Upsilon(4S)$ is 0.41.

B^0 DECAY MODES

$\overline{B}^0$ modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing. Modes which do not identify the charge state of the B are listed in the $B^{\pm}/B^0$ ADMIXTURE section.

The branching fractions listed below assume 50% $B^0\overline{B}^0$ and 50% B^+B^- production at the $\Upsilon(4S)$. We have attempted to bring older measurements up to date by rescaling their assumed $\Upsilon(4S)$ production ratio to 50:50 and their assumed D, D_s, D^*, and ψ branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$\ell^+\nu_\ell$ anything	[a]	(10.5 ± 0.8) %	
Γ_2	$D^-\ell^+\nu_\ell$	[a]	(2.10 ± 0.19) %	
Γ_3	$D^*(2010)^-\ell^+\nu_\ell$	[a]	(4.60 ± 0.27) %	
Γ_4	$\rho^-\ell^+\nu_\ell$	[a]	$(2.6 ^{+0.6}_{-0.7}) \times 10^{-4}$	
Γ_5	$\pi^-\ell^+\nu_\ell$		$(1.8 \pm 0.6) \times 10^{-4}$	

Inclusive modes

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_6	$\pi^-\mu^+\nu_\mu$			
Γ_7	K^+ anything		(78 ± 8) %	

D, *D**, or *D_s* modes

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_8	$D^-\pi^+$		$(3.0 \pm 0.4) \times 10^{-3}$	
Γ_9	$D^-\rho^+$		$(7.9 \pm 1.4) \times 10^{-3}$	
Γ_{10}	$\overline{D}^0\pi^+\pi^-$		$< 1.6 \times 10^{-3}$	CL=90%
Γ_{11}	$D^*(2010)^-\pi^+$		$(2.76 \pm 0.21) \times 10^{-3}$	
Γ_{12}	$D^-\pi^+\pi^+\pi^-$		$(8.0 \pm 2.5) \times 10^{-3}$	
Γ_{13}	$(D^-\pi^+\pi^+\pi^-)$ nonresonant		$(3.9 \pm 1.9) \times 10^{-3}$	
Γ_{14}	$D^-\pi^+\rho^0$		$(1.1 \pm 1.0) \times 10^{-3}$	
Γ_{15}	$D^-a_1(1260)^+$		$(6.0 \pm 3.3) \times 10^{-3}$	
Γ_{16}	$D^*(2010)^-\pi^+\pi^0$		(1.5 ± 0.5) %	
Γ_{17}	$D^*(2010)^-\rho^+$		$(6.8 \pm 3.4) \times 10^{-3}$	
Γ_{18}	$D^*(2010)^-\pi^+\pi^+\pi^-$		$(7.6 \pm 1.8) \times 10^{-3}$	S=1.4
Γ_{19}	$(D^*(2010)^-\pi^+\pi^+\pi^-)$ nonresonant		$(0.0 \pm 2.5) \times 10^{-3}$	
Γ_{20}	$D^*(2010)^-\pi^+\rho^0$		$(5.7 \pm 3.2) \times 10^{-3}$	
Γ_{21}	$D^*(2010)^-a_1(1260)^+$		(1.30 ± 0.27) %	
Γ_{22}	$D^*(2010)^-\pi^+\pi^+\pi^-\pi^0$		(3.5 ± 1.8) %	
Γ_{23}	$\overline{D}{}^*_2(2460)^-\pi^+$		$< 2.2 \times 10^{-3}$	CL=90%

Γ_{24}	$\overline{D}{}_2^*(2460)^- \rho^+$	$< 4.9 \times 10^{-3}$	CL=90%
Γ_{25}	$D^- D^+$	$< 1.2 \times 10^{-3}$	CL=90%
Γ_{26}	$D^- D_s^+$	$(8.0 \pm 3.0) \times 10^{-3}$	
Γ_{27}	$D^*(2010)^- D_s^+$	$(9.6 \pm 3.4) \times 10^{-3}$	
Γ_{28}	$D^- D_s^{*+}$	(1.0 ± 0.5) %	
Γ_{29}	$D^*(2010)^- D_s^{*+}$	(2.0 ± 0.7) %	
Γ_{30}	$D_s^+ \pi^-$	$< 2.8 \times 10^{-4}$	CL=90%
Γ_{31}	$D_s^{*+} \pi^-$	$< 5 \times 10^{-4}$	CL=90%
Γ_{32}	$D_s^+ \rho^-$	$< 7 \times 10^{-4}$	CL=90%
Γ_{33}	$D_s^{*+} \rho^-$	$< 8 \times 10^{-4}$	CL=90%
Γ_{34}	$D_s^+ a_1(1260)^-$	$< 2.6 \times 10^{-3}$	CL=90%
Γ_{35}	$D_s^{*+} a_1(1260)^-$	$< 2.2 \times 10^{-3}$	CL=90%
Γ_{36}	$D_s^- K^+$	$< 2.4 \times 10^{-4}$	CL=90%
Γ_{37}	$D_s^{*-} K^+$	$< 1.7 \times 10^{-4}$	CL=90%
Γ_{38}	$D_s^- K^*(892)^+$	$< 9.9 \times 10^{-4}$	CL=90%
Γ_{39}	$D_s^{*-} K^*(892)^+$	$< 1.1 \times 10^{-3}$	CL=90%
Γ_{40}	$D_s^- \pi^+ K^0$	$< 5 \times 10^{-3}$	CL=90%
Γ_{41}	$D_s^{*-} \pi^+ K^0$	$< 3.1 \times 10^{-3}$	CL=90%
Γ_{42}	$D_s^- \pi^+ K^*(892)^0$	$< 4 \times 10^{-3}$	CL=90%
Γ_{43}	$D_s^{*-} \pi^+ K^*(892)^0$	$< 2.0 \times 10^{-3}$	CL=90%
Γ_{44}	$\overline{D}{}^0 \pi^0$	$< 1.2 \times 10^{-4}$	CL=90%
Γ_{45}	$\overline{D}{}^0 \rho^0$	$< 3.9 \times 10^{-4}$	CL=90%
Γ_{46}	$\overline{D}{}^0 \eta$	$< 1.3 \times 10^{-4}$	CL=90%
Γ_{47}	$\overline{D}{}^0 \eta'$	$< 9.4 \times 10^{-4}$	CL=90%
Γ_{48}	$\overline{D}{}^0 \omega$	$< 5.1 \times 10^{-4}$	CL=90%
Γ_{49}	$\overline{D}{}^*(2007)^0 \pi^0$	$< 4.4 \times 10^{-4}$	CL=90%
Γ_{50}	$\overline{D}{}^*(2007)^0 \rho^0$	$< 5.6 \times 10^{-4}$	CL=90%
Γ_{51}	$\overline{D}{}^*(2007)^0 \eta$	$< 2.6 \times 10^{-4}$	CL=90%
Γ_{52}	$\overline{D}{}^*(2007)^0 \eta'$	$< 1.4 \times 10^{-3}$	CL=90%
Γ_{53}	$\overline{D}{}^*(2007)^0 \omega$	$< 7.4 \times 10^{-4}$	CL=90%
Γ_{54}	$D^*(2010)^+ D^*(2010)^-$	$(6.2 {}^{+4.1}_{-3.1}) \times 10^{-4}$	
Γ_{55}	$D^*(2010)^+ D^-$	$< 1.8 \times 10^{-3}$	CL=90%
Γ_{56}	$D^{(*)0} \overline{D}{}^{(*)0}$	< 2.7 %	CL=90%

Charmonium modes

Γ_{57}	$J/\psi(1S) K^0$	$(8.9 \pm 1.2) \times 10^{-4}$	
Γ_{58}	$J/\psi(1S) K^+ \pi^-$	$(1.2 \pm 0.6) \times 10^{-3}$	
Γ_{59}	$J/\psi(1S) K^*(892)^0$	$(1.50 \pm 0.17) \times 10^{-3}$	
Γ_{60}	$J/\psi(1S) \pi^0$	$< 5.8 \times 10^{-5}$	CL=90%
Γ_{61}	$J/\psi(1S) \eta$	$< 1.2 \times 10^{-3}$	CL=90%
Γ_{62}	$J/\psi(1S) \rho^0$	$< 2.5 \times 10^{-4}$	CL=90%

Γ_{63}	$J/\psi(1S)\omega$	$< 2.7 \times 10^{-4}$	CL=90%
Γ_{64}	$\psi(2S)K^0$	$< 8 \times 10^{-4}$	CL=90%
Γ_{65}	$\psi(2S)K^+\pi^-$	$< 1 \times 10^{-3}$	CL=90%
Γ_{66}	$\psi(2S)K^*(892)^0$	$(9.3 \pm 2.3) \times 10^{-4}$	
Γ_{67}	$\chi_{c1}(1P)K^0$	$< 2.7 \times 10^{-3}$	CL=90%
Γ_{68}	$\chi_{c1}(1P)K^*(892)^0$	$< 2.1 \times 10^{-3}$	CL=90%

K or *K** modes

Γ_{69}	$K^+\pi^-$	$(1.5 {}^{+0.5}_{-0.4}) \times 10^{-5}$	
Γ_{70}	$K^0\pi^0$	$< 4.1 \times 10^{-5}$	CL=90%
Γ_{71}	$\eta' K^0$	$(4.7 {}^{+2.8}_{-2.2}) \times 10^{-5}$	
Γ_{72}	$\eta' K^*(892)^0$	$< 3.9 \times 10^{-5}$	CL=90%
Γ_{73}	$\eta K^*(892)^0$	$< 3.0 \times 10^{-5}$	CL=90%
Γ_{74}	ηK^0	$< 3.3 \times 10^{-5}$	CL=90%
Γ_{75}	ωK^0	$< 5.7 \times 10^{-5}$	CL=90%
Γ_{76}	$\omega K^*(892)^0$	$< 2.3 \times 10^{-5}$	CL=90%
Γ_{77}	K^+K^-	$< 4.3 \times 10^{-6}$	CL=90%
Γ_{78}	$K^0\overline{K}^0$	$< 1.7 \times 10^{-5}$	CL=90%
Γ_{79}	$K^+\rho^-$	$< 3.5 \times 10^{-5}$	CL=90%
Γ_{80}	$K^0\pi^+\pi^-$		
Γ_{81}	$K^0\rho^0$	$< 3.9 \times 10^{-5}$	CL=90%
Γ_{82}	$K^0 f_0(980)$	$< 3.6 \times 10^{-4}$	CL=90%
Γ_{83}	$K^*(892)^+\pi^-$	$< 7.2 \times 10^{-5}$	CL=90%
Γ_{84}	$K^*(892)^0\pi^0$	$< 2.8 \times 10^{-5}$	CL=90%
Γ_{85}	$K_2^*(1430)^+\pi^-$	$< 2.6 \times 10^{-3}$	CL=90%
Γ_{86}	$K^0K^+K^-$	$< 1.3 \times 10^{-3}$	CL=90%
Γ_{87}	$K^0\phi$	$< 3.1 \times 10^{-5}$	CL=90%
Γ_{88}	$K^-\pi^+\pi^+\pi^-$	[b] $< 2.3 \times 10^{-4}$	CL=90%
Γ_{89}	$K^*(892)^0\pi^+\pi^-$	$< 1.4 \times 10^{-3}$	CL=90%
Γ_{90}	$K^*(892)^0\rho^0$	$< 4.6 \times 10^{-4}$	CL=90%
Γ_{91}	$K^*(892)^0 f_0(980)$	$< 1.7 \times 10^{-4}$	CL=90%
Γ_{92}	$K_1(1400)^+\pi^-$	$< 1.1 \times 10^{-3}$	CL=90%
Γ_{93}	$K^- a_1(1260)^+$	[b] $< 2.3 \times 10^{-4}$	CL=90%
Γ_{94}	$K^*(892)^0K^+K^-$	$< 6.1 \times 10^{-4}$	CL=90%
Γ_{95}	$K^*(892)^0\phi$	$< 2.1 \times 10^{-5}$	CL=90%
Γ_{96}	$K_1(1400)^0\rho^0$	$< 3.0 \times 10^{-3}$	CL=90%
Γ_{97}	$K_1(1400)^0\phi$	$< 5.0 \times 10^{-3}$	CL=90%
Γ_{98}	$K_2^*(1430)^0\rho^0$	$< 1.1 \times 10^{-3}$	CL=90%
Γ_{99}	$K_2^*(1430)^0\phi$	$< 1.4 \times 10^{-3}$	CL=90%
Γ_{100}	$K^*(892)^0\gamma$	$(4.0 \pm 1.9) \times 10^{-5}$	

Γ_{101}	$K_1(1270)^0\gamma$		$<$	7.0	$\times 10^{-3}$	CL=90%
Γ_{102}	$K_1(1400)^0\gamma$		$<$	4.3	$\times 10^{-3}$	CL=90%
Γ_{103}	$K_2^*(1430)^0\gamma$		$<$	4.0	$\times 10^{-4}$	CL=90%
Γ_{104}	$K^*(1680)^0\gamma$		$<$	2.0	$\times 10^{-3}$	CL=90%
Γ_{105}	$K_3^*(1780)^0\gamma$		$<$	1.0	%	CL=90%
Γ_{106}	$K_4^*(2045)^0\gamma$		$<$	4.3	$\times 10^{-3}$	CL=90%

Light unflavored meson modes

Γ_{107}	$\pi^+\pi^-$		$<$	1.5	$\times 10^{-5}$	CL=90%
Γ_{108}	$\pi^0\pi^0$		$<$	9.3	$\times 10^{-6}$	CL=90%
Γ_{109}	$\eta\pi^0$		$<$	8	$\times 10^{-6}$	CL=90%
Γ_{110}	$\eta\eta$		$<$	1.8	$\times 10^{-5}$	CL=90%
Γ_{111}	$\eta'\pi^0$		$<$	1.1	$\times 10^{-5}$	CL=90%
Γ_{112}	$\eta'\eta'$		$<$	4.7	$\times 10^{-5}$	CL=90%
Γ_{113}	$\eta'\eta$		$<$	2.7	$\times 10^{-5}$	CL=90%
Γ_{114}	$\eta'\rho^0$		$<$	2.3	$\times 10^{-5}$	CL=90%
Γ_{115}	$\eta\rho^0$		$<$	1.3	$\times 10^{-5}$	CL=90%
Γ_{116}	$\omega\eta$		$<$	1.2	$\times 10^{-5}$	CL=90%
Γ_{117}	$\omega\eta'$		$<$	6.0	$\times 10^{-5}$	CL=90%
Γ_{118}	$\omega\rho^0$		$<$	1.1	$\times 10^{-5}$	CL=90%
Γ_{119}	$\omega\omega$		$<$	1.9	$\times 10^{-5}$	CL=90%
Γ_{120}	$\phi\pi^0$		$<$	5	$\times 10^{-6}$	CL=90%
Γ_{121}	$\phi\eta$		$<$	9	$\times 10^{-6}$	CL=90%
Γ_{122}	$\phi\eta'$		$<$	3.1	$\times 10^{-5}$	CL=90%
Γ_{123}	$\phi\rho^0$		$<$	1.3	$\times 10^{-5}$	CL=90%
Γ_{124}	$\phi\omega$		$<$	2.1	$\times 10^{-5}$	CL=90%
Γ_{125}	$\phi\phi$		$<$	1.2	$\times 10^{-5}$	CL=90%
Γ_{126}	$\pi^+\pi^-\pi^0$		$<$	7.2	$\times 10^{-4}$	CL=90%
Γ_{127}	$\rho^0\pi^0$		$<$	2.4	$\times 10^{-5}$	CL=90%
Γ_{128}	$\rho^\mp\pi^\pm$	[*c*]	$<$	8.8	$\times 10^{-5}$	CL=90%
Γ_{129}	$\pi^+\pi^-\pi^+\pi^-$		$<$	2.3	$\times 10^{-4}$	CL=90%
Γ_{130}	$\rho^0\rho^0$		$<$	2.8	$\times 10^{-4}$	CL=90%
Γ_{131}	$a_1(1260)^\mp\pi^\pm$	[*c*]	$<$	4.9	$\times 10^{-4}$	CL=90%
Γ_{132}	$a_2(1320)^\mp\pi^\pm$	[*c*]	$<$	3.0	$\times 10^{-4}$	CL=90%
Γ_{133}	$\pi^+\pi^-\pi^0\pi^0$		$<$	3.1	$\times 10^{-3}$	CL=90%
Γ_{134}	$\rho^+\rho^-$		$<$	2.2	$\times 10^{-3}$	CL=90%
Γ_{135}	$a_1(1260)^0\pi^0$		$<$	1.1	$\times 10^{-3}$	CL=90%
Γ_{136}	$\omega\pi^0$		$<$	1.4	$\times 10^{-5}$	CL=90%
Γ_{137}	$\pi^+\pi^+\pi^-\pi^-\pi^0$		$<$	9.0	$\times 10^{-3}$	CL=90%
Γ_{138}	$a_1(1260)^+\rho^-$		$<$	3.4	$\times 10^{-3}$	CL=90%
Γ_{139}	$a_1(1260)^0\rho^0$		$<$	2.4	$\times 10^{-3}$	CL=90%
Γ_{140}	$\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-$		$<$	3.0	$\times 10^{-3}$	CL=90%
Γ_{141}	$a_1(1260)^+a_1(1260)^-$		$<$	2.8	$\times 10^{-3}$	CL=90%
Γ_{142}	$\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-\pi^0$		$<$	1.1	%	CL=90%

Baryon modes

Γ_{143}	$p\overline{p}$		$<$	7.0	$\times 10^{-6}$	CL=90%
Γ_{144}	$p\overline{p}\pi^+\pi^-$		$<$	2.5	$\times 10^{-4}$	CL=90%
Γ_{145}	$p\overline{\Lambda}\pi^-$		$<$	1.3	$\times 10^{-5}$	CL=90%
Γ_{146}	$\overline{\Lambda}\Lambda$		$<$	3.9	$\times 10^{-6}$	CL=90%
Γ_{147}	$\Delta^0\overline{\Delta}^0$		$<$	1.5	$\times 10^{-3}$	CL=90%
Γ_{148}	$\Delta^{++}\Delta^{--}$		$<$	1.1	$\times 10^{-4}$	CL=90%
Γ_{149}	$\overline{\Sigma}_c^{--}\Delta^{++}$		$<$	1.0	$\times 10^{-3}$	CL=90%
Γ_{150}	$\overline{\Lambda}_c^- p\pi^+\pi^-$			(1.3 ± 0.6)	$\times 10^{-3}$	
Γ_{151}	$\overline{\Lambda}_c^- p$		$<$	2.1	$\times 10^{-4}$	CL=90%
Γ_{152}	$\overline{\Lambda}_c^- p\pi^0$		$<$	5.9	$\times 10^{-4}$	CL=90%
Γ_{153}	$\overline{\Lambda}_c^- p\pi^+\pi^-\pi^0$		$<$	5.07	$\times 10^{-3}$	CL=90%
Γ_{154}	$\overline{\Lambda}_c^- p\pi^+\pi^-\pi^+\pi^-$		$<$	2.74	$\times 10^{-3}$	CL=90%

Lepton Family number (*LF*) violating modes, or $\Delta B = 1$ weak neutral current (*B1*) modes

Γ_{155}	$\gamma\gamma$			$<$	3.9	$\times 10^{-5}$	CL=90%
Γ_{156}	e^+e^-	*B1*		$<$	5.9	$\times 10^{-6}$	CL=90%
Γ_{157}	$\mu^+\mu^-$	*B1*		$<$	6.8	$\times 10^{-7}$	CL=90%
Γ_{158}	$K^0 e^+e^-$	*B1*		$<$	3.0	$\times 10^{-4}$	CL=90%
Γ_{159}	$K^0\mu^+\mu^-$	*B1*		$<$	3.6	$\times 10^{-4}$	CL=90%
Γ_{160}	$K^*(892)^0 e^+e^-$	*B1*		$<$	2.9	$\times 10^{-4}$	CL=90%
Γ_{161}	$K^*(892)^0\mu^+\mu^-$	*B1*		$<$	4.0	$\times 10^{-6}$	CL=90%
Γ_{162}	$K^*(892)^0\nu\overline{\nu}$	*B1*		$<$	1.0	$\times 10^{-3}$	CL=90%
Γ_{163}	$e^\pm\mu^\mp$	*LF*	[c]	$<$	3.5	$\times 10^{-6}$	CL=90%
Γ_{164}	$e^\pm\tau^\mp$	*LF*	[c]	$<$	5.3	$\times 10^{-4}$	CL=90%
Γ_{165}	$\mu^\pm\tau^\mp$	*LF*	[c]	$<$	8.3	$\times 10^{-4}$	CL=90%

[a] An ℓ indicates an e or a μ mode, not a sum over these modes.

[b] B^0 and B_s^0 contributions not separated. Limit is on weighted average of the two decay rates.

[c] The value is for the sum of the charge states or particle/antiparticle states indicated.

B^0 BRANCHING RATIOS

For branching ratios in which the charge of the decaying B is not determined, see the $B^\pm$ section.

$\Gamma(\ell^+\nu_\ell\,\text{anything})/\Gamma_{\text{total}}$ Γ_1/Γ

VALUE		*DOCUMENT ID*		*TECN*	*COMMENT*
0.105 ±0.008 OUR AVERAGE					
0.1078±0.0060±0.0069	[30]	ARTUSO	97	CLE2	$e^+e^- \to \Upsilon(4S)$
0.093 ±0.011 ±0.015		ALBRECHT	94	ARG	$e^+e^- \to \Upsilon(4S)$
0.099 ±0.030 ±0.009		HENDERSON	92	CLEO	$e^+e^- \to \Upsilon(4S)$

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

0.109 ±0.007 ±0.011	ATHANAS	94	CLE2	Sup. by ARTUSO 97

[30] ARTUSO 97 uses partial reconstruction of $B \to D^* \ell \nu_\ell$ and inclusive semileptonic branching ratio from BARISH 96B (0.1049 ± 0.0017 ± 0.0043).

$\Gamma(D^- \ell^+ \nu_\ell)/\Gamma_{\text{total}}$ Γ_2/Γ

ℓ denotes e or μ, not the sum.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.0210±0.0019 OUR AVERAGE				
0.0209±0.0013±0.0018	[31] BARTELT	99	CLE2	$e^+ e^- \to \Upsilon(4S)$
0.0235±0.0020±0.0044	[32] BUSKULIC	97	ALEP	$e^+ e^- \to Z$
0.018 ±0.006 ±0.003	[33] FULTON	91	CLEO	$e^+ e^- \to \Upsilon(4S)$
0.020 ±0.007 ±0.006	[34] ALBRECHT	89J	ARG	$e^+ e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.0187±0.0015±0.0032	[35] ATHANAS	97	CLE2	Repl. by BARTELT 99

[31] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[32] BUSKULIC 97 assumes fraction (B^+) = fraction (B^0) = (37.8 ± 2.2)% and PDG 96 values for B lifetime and branching ratio of D^* and D decays.

[33] FULTON 91 assumes assuming equal production of B^0 and B^+ at the $\Upsilon(4S)$ and uses Mark III D and D^* branching ratios.

[34] ALBRECHT 89J reports 0.018 ± 0.006 ± 0.005. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \to K^- \pi^+$).

[35] ATHANAS 97 uses missing energy and missing momentum to reconstruct neutrino.

$\Gamma(D^*(2010)^- \ell^+ \nu_\ell)/\Gamma_{\text{total}}$ Γ_3/Γ

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.0460±0.0027 OUR AVERAGE					
0.0508±0.0021±0.0066		[36] ACKERSTAFF	97G	OPAL	$e^+ e^- \to Z$
0.0553±0.0026±0.0052		[37] BUSKULIC	97	ALEP	$e^+ e^- \to Z$
0.0552±0.0017±0.0068		[38] ABREU	96P	DLPH	$e^+ e^- \to Z$
0.0449±0.0032±0.0039	376	[39] BARISH	95	CLE2	$e^+ e^- \to \Upsilon(4S)$
0.045 ±0.003 ±0.004		[40] ALBRECHT	94	ARG	$e^+ e^- \to \Upsilon(4S)$
0.047 ±0.005 ±0.005	235	[41] ALBRECHT	93	ARG	$e^+ e^- \to \Upsilon(4S)$
0.040 ±0.004 ±0.006		[42] BORTOLETTO	89B	CLEO	$e^+ e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.0518±0.0030±0.0062	410	[43] BUSKULIC	95N	ALEP	Sup. by BUSKULIC 97
seen	398	[44] SANGHERA	93	CLE2	$e^+ e^- \to \Upsilon(4S)$
0.070 ±0.018 ±0.014		[45] ANTREASYAN	90B	CBAL	$e^+ e^- \to \Upsilon(4S)$
		[46] ALBRECHT	89C	ARG	$e^+ e^- \to \Upsilon(4S)$
0.060 ±0.010 ±0.014		[47] ALBRECHT	89J	ARG	$e^+ e^- \to \Upsilon(4S)$
0.070 ±0.012 ±0.019	47	[48] ALBRECHT	87J	ARG	$e^+ e^- \to \Upsilon(4S)$

[36] ACKERSTAFF 97G assumes fraction (B^+) = fraction (B^0) = (37.8±2.2)% and PDG 96 values for B lifetime and branching ratio of D^* and D decays.

[37] BUSKULIC 97 assumes fraction (B^+) = fraction (B^0) = (37.8 ± 2.2)% and PDG 96 values for B lifetime and D^* and D branching fractions.

[38] ABREU 96P result is the average of two methods using exclusive and partial D^* reconstruction.

[39] BARISH 95 use B($D^0 \to K^- \pi^+$) = (3.91 ± 0.08 ± 0.17)% and B($D^{*+} \to D^0 \pi^+$) = (68.1 ± 1.0 ± 1.3)%.

[40] ALBRECHT 94 assumes B($D^{*+} \rightarrow D^0\pi^+$) = 68.1 ± 1.0 ± 1.3%. Uses partial reconstruction of D^{*+} and is independent of D^0 branching ratios.

[41] ALBRECHT 93 reports 0.052 ± 0.005 ± 0.006. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \rightarrow K^-\pi^+$). We have taken their average e and μ value. They also obtain $\alpha = 2{*}\Gamma^0/(\Gamma^- + \Gamma^+) - 1 = 1.1 \pm 0.4 \pm 0.2$, $A_{AF} = 3/4{*}(\Gamma^- - \Gamma^+)/\Gamma = 0.2 \pm 0.08 \pm 0.06$ and a value of $|V_{cb}|$ = 0.036–0.045 depending on model assumptions.

[42] We have taken average of the the BORTOLETTO 89B values for electrons and muons, 0.046 ± 0.005 ± 0.007. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \rightarrow K^-\pi^+$). The measurement suggests a D^* polarization parameter value $\alpha = 0.65 \pm 0.66 \pm 0.25$.

[43] BUSKULIC 95N assumes fraction (B^+) = fraction (B^0) = 38.2 ± 1.3 ± 2.2% and τ_{B^0} = 1.58 ± 0.06 ps. $\Gamma(D^{*-}\ell^+\nu_\ell)$/total = [5.18 − 0.13(fraction(B^0)−38.2)−1.5(τ_{B^0} − 1.58)]%.

[44] Combining $\overline{D}^{*0}\ell^+\nu_\ell$ and $\overline{D}^{*-}\ell^+\nu_\ell$ SANGHERA 93 test $V{-}A$ structure and fit the decay angular distributions to obtain $A_{FB} = 3/4{*}(\Gamma^- - \Gamma^+)/\Gamma = 0.14 \pm 0.06 \pm 0.03$. Assuming a value of V_{cb}, they measure V, A_1, and A_2, the three form factors for the $D^*\ell\nu_\ell$ decay, where results are slightly dependent on model assumptions.

[45] ANTREASYAN 90B is average over B and $\overline{D}^*(2010)$ charge states.

[46] The measurement of ALBRECHT 89C suggests a D^* polarization γ_L/γ_T of 0.85 ± 0.45. or $\alpha = 0.7 \pm 0.9$.

[47] ALBRECHT 89J is ALBRECHT 87J value rescaled using B($D^*(2010)^- \rightarrow D^0\pi^-$) = 0.57 ± 0.04 ± 0.04. Superseded by ALBRECHT 93.

[48] ALBRECHT 87J assume μ-e universality, the B($\Upsilon(4S) \rightarrow B^0\overline{B}^0$) = 0.45, the B($D^0 \rightarrow K^-\pi^+$) = (0.042 ± 0.004 ± 0.004), and the B($D^*(2010)^- \rightarrow D^0\pi^-$) = 0.49 ± 0.08. Superseded by ALBRECHT 89J.

$\Gamma(\rho^-\ell^+\nu_\ell)/\Gamma_{\text{total}}$ Γ_4/Γ

$\ell = e$ or μ, not sum over e and μ modes.

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$2.6\ ^{+0.6}_{-0.7}$ OUR AVERAGE				
$2.57 \pm 0.29\,^{+0.53}_{-0.62}$		[49] BEHRENS 00	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$2.5 \pm 0.4\ ^{+0.7}_{-0.9}$		[50] ALEXANDER 96T	CLE2	Repl. by BEHRENS 00
<4.1	90	[51] BEAN 93B	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[49] BEHRENS 00 reports systematic errors $^{+0.33}_{-0.46} \pm 0.41$, where the second error is theoretical model dependence. We combine these in quadrature.

[50] ALEXANDER 96T gives systematic errors $^{+0.5}_{-0.7} \pm 0.5$ where the second error reflects the estimated model dependence. We combine these in quadrature. Assumes isospin symmetry: $\Gamma(B^0 \rightarrow \rho^-\ell^+\nu_\ell) = 2 \times \Gamma(B^+ \rightarrow \rho^0\ell^+\nu_\ell) \sim 2 \times \Gamma(B^+ \rightarrow \omega\ell^+\nu_\ell)$.

[51] BEAN 93B limit set using ISGW Model. Using isospin and the quark model to combine $\Gamma(\rho^0\ell^+\nu_\ell)$ and $\Gamma(\omega\ell^+\nu_\ell)$ with this result, they obtain a limit $<(1.6\text{–}2.7) \times 10^{-4}$ at 90% CL for $B^+ \rightarrow (\omega \text{or } \rho^0)\ell^+\nu_\ell$. The range corresponds to the ISGW, WSB, and KS models. An upper limit on $|V_{ub}/V_{cb}| < 0.08\text{–}0.13$ at 90% CL is derived as well.

$\Gamma(\pi^- \ell^+ \nu_\ell)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (units 10^{-4})	*DOCUMENT ID*	*TECN*	*COMMENT*
1.8±0.4±0.4	[52] ALEXANDER 96T	CLE2	$e+ \; e^- \to \Upsilon(4S)$

[52] ALEXANDER 96T gives systematic errors ±0.3 ± 0.2 where the second error reflects the estimated model dependence. We combine these in quadrature. Assumes isospin symmetry: $\Gamma(B^0 \to \pi^- \ell^+ \nu_\ell) = 2 \times \Gamma(B^+ \to \pi^0 \ell^+ \nu_\ell)$.

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

VALUE	*DOCUMENT ID*	*TECN*
• • • We do not use the following data for averages, fits, limits, etc. • • •		
seen	[53] ALBRECHT 91C	ARG

[53] In ALBRECHT 91C, one event is fully reconstructed providing evidence for the $b \to u$ transition.

$\Gamma(K^+ \text{anything})/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.78±0.08 OUR AVERAGE			
0.78±0.08	[54] ALBRECHT 96D	ARG	$e^+ e^- \to \Upsilon(4S)$

[54] Average multiplicity.

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

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0030±0.0004 OUR AVERAGE				
0.0029±0.0004±0.0002	81	[55] ALAM 94	CLE2	$e^+ e^- \to \Upsilon(4S)$
0.0027±0.0006±0.0005		[56] BORTOLETTO 92	CLEO	$e^+ e^- \to \Upsilon(4S)$
0.0048±0.0011±0.0011	22	[57] ALBRECHT 90J	ARG	$e^+ e^- \to \Upsilon(4S)$
$0.0051^{+0.0028}_{-0.0025}{}^{+0.0013}_{-0.0012}$	4	[58] BEBEK 87	CLEO	$e^+ e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.0031±0.0013±0.0010	7	[57] ALBRECHT 88K	ARG	$e^+ e^- \to \Upsilon(4S)$

[55] ALAM 94 reports [B($B^0 \to D^- \pi^+$) × B($D^+ \to K^- \pi^+ \pi^+$)] = 0.000265 ± 0.000032 ± 0.000023. We divide by our best value B($D^+ \to K^- \pi^+ \pi^+$) = (9.0 ± 0.6) × 10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[56] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[57] ALBRECHT 88K assumes $B^0 \overline{B}^0$:$B^+ B^-$ production ratio is 45:55. Superseded by ALBRECHT 90J which assumes 50:50.

[58] BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92.

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

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0079±0.0014 OUR AVERAGE				
0.0078±0.0013±0.0005	79	[59] ALAM 94	CLE2	$e^+ e^- \to \Upsilon(4S)$
0.009 ±0.005 ±0.003	9	[60] ALBRECHT 90J	ARG	$e^+ e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.022 ±0.012 ±0.009	6	[60] ALBRECHT 88K	ARG	$e^+ e^- \to \Upsilon(4S)$

[59] ALAM 94 reports $[B(B^0 \to D^- \rho^+) \times B(D^+ \to K^- \pi^+ \pi^+)] = 0.000704 \pm 0.000096 \pm 0.000070$. We divide by our best value $B(D^+ \to K^- \pi^+ \pi^+) = (9.0 \pm 0.6) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[60] ALBRECHT 88K assumes $B^0 \overline{B}^0 : B^+ B^-$ production ratio is 45:55. Superseded by ALBRECHT 90J which assumes 50:50.

$\Gamma(\overline{D}^0 \pi^+ \pi^-)/\Gamma_{\text{total}}$ Γ_{10}/Γ

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0016	90		[61] ALAM 94	CLE2	$e^+ e^- \to \Upsilon(4S)$

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

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.007	90		[62] BORTOLETTO 92	CLEO	$e^+ e^- \to \Upsilon(4S)$
<0.034	90		[63] BEBEK 87	CLEO	$e^+ e^- \to \Upsilon(4S)$
0.07 ± 0.05		5	[64] BEHRENDS 83	CLEO	$e^+ e^- \to \Upsilon(4S)$

[61] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[62] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D. The product branching fraction into $D_0^*(2340)\pi$ followed by $D_0^*(2340) \to D^0 \pi$ is < 0.0001 at 90% CL and into $D_2^*(2460)$ followed by $D_2^*(2460) \to D^0 \pi$ is < 0.0004 at 90% CL.

[63] BEBEK 87 assume the $\Upsilon(4S)$ decays 43% to $B^0 \overline{B}^0$. We rescale to 50%. $B(D^0 \to K^- \pi^+) = (4.2 \pm 0.4 \pm 0.4)\%$ and $B(D^0 \to K^- \pi^+ \pi^+ \pi^-) = (9.1 \pm 0.8 \pm 0.8)\%$ were used.

[64] Corrected by us using assumptions: $B(D^0 \to K^- \pi^+) = (0.042 \pm 0.006)$ and $B(\Upsilon(4S) \to B^0 \overline{B}^0) = 50\%$. The product branching ratio is $B(B^0 \to \overline{D}^0 \pi^+ \pi^-) B(\overline{D}^0 \to K^+ \pi^-) = (0.39 \pm 0.26) \times 10^{-2}$.

$\Gamma(D^*(2010)^- \pi^+)/\Gamma_{\text{total}}$ Γ_{11}/Γ

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.00276 ± 0.00021 OUR AVERAGE				
$0.00281 \pm 0.00024 \pm 0.00005$		[65] BRANDENB... 98	CLE2	$e^+ e^- \to \Upsilon(4S)$
$0.0026 \pm 0.0003 \pm 0.0004$	82	[66] ALAM 94	CLE2	$e^+ e^- \to \Upsilon(4S)$
$0.00337 \pm 0.00096 \pm 0.00002$		[67] BORTOLETTO 92	CLEO	$e^+ e^- \to \Upsilon(4S)$
$0.00236 \pm 0.00088 \pm 0.00002$	12	[68] ALBRECHT 90J	ARG	$e^+ e^- \to \Upsilon(4S)$
$0.00236^{+0.00150}_{-0.00110} \pm 0.00002$	5	[69] BEBEK 87	CLEO	$e^+ e^- \to \Upsilon(4S)$

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

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
$0.010 \pm 0.004 \pm 0.001$	8	[70] AKERS 94J	OPAL	$e^+ e^- \to Z$
$0.0027 \pm 0.0014 \pm 0.0010$	5	[71] ALBRECHT 87C	ARG	$e^+ e^- \to \Upsilon(4S)$
$0.0035 \pm 0.002 \pm 0.002$		[72] ALBRECHT 86F	ARG	$e^+ e^- \to \Upsilon(4S)$
$0.017 \pm 0.005 \pm 0.005$	41	[73] GILES 84	CLEO	$e^+ e^- \to \Upsilon(4S)$

[65] BRANDENBURG 98 assume equal production of B^+ and B^0 at $\Upsilon(4S)$ and use the D^* reconstruction technique. The first error is their experiment's error and the second error is the systematic error from the PDG 96 value of $B(D^* \to D\pi)$.

[66] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $B(D^*(2010)^+ \to D^0 \pi^+)$ and absolute $B(D^0 \to K^- \pi^+)$ and the PDG 1992 $B(D^0 \to K^- \pi^+ \pi^0)/B(D^0 \to K^- \pi^+)$ and $B(D^0 \to K^- \pi^+ \pi^+ \pi^-)/B(D^0 \to K^- \pi^+)$.

[67] BORTOLETTO 92 reports $0.0040 \pm 0.0010 \pm 0.0007$ for $B(D^*(2010)^+ \to D^0 \pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0 \pi^+) = (67.7 \pm 0.5) \times$

10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[68] ALBRECHT 90J reports $0.0028 \pm 0.0009 \pm 0.0006$ for $B(D^*(2010)^+ \rightarrow D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \rightarrow D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[69] BEBEK 87 reports $0.0028^{+0.0015}_{-0.0012}{}^{+0.0010}_{-0.0006}$ for $B(D^*(2010)^+ \rightarrow D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \rightarrow D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92 and ALBRECHT 90J.

[70] Assumes $B(Z \rightarrow b\overline{b}) = 0.217$ and 38% B_d production fraction.

[71] ALBRECHT 87C use PDG 86 branching ratios for D and $D^*(2010)$ and assume $B(\Upsilon(4S) \rightarrow B^+B^-) = 55\%$ and $B(\Upsilon(4S) \rightarrow B^0\overline{B}^0) = 45\%$. Superseded by ALBRECHT 90J.

[72] ALBRECHT 86F uses pseudomass that is independent of D^0 and D^+ branching ratios.

[73] Assumes $B(D^*(2010)^+ \rightarrow D^0\pi^+) = 0.60^{+0.08}_{-0.15}$. Assumes $B(\Upsilon(4S) \rightarrow B^0\overline{B}^0) = 0.40 \pm 0.02$ Does not depend on D branching ratios.

$\Gamma(D^-\pi^+\pi^+\pi^-)/\Gamma_{\rm total}$ Γ_{12}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0080±0.0021±0.0014	[74] BORTOLETTO92	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[74] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma((D^-\pi^+\pi^+\pi^-)\text{ nonresonant})/\Gamma_{\rm total}$ Γ_{13}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0039±0.0014±0.0013	[75] BORTOLETTO92	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[75] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma(D^-\pi^+\rho^0)/\Gamma_{\rm total}$ Γ_{14}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0011±0.0009±0.0004	[76] BORTOLETTO92	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[76] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma(D^-a_1(1260)^+)/\Gamma_{\rm total}$ Γ_{15}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0060±0.0022±0.0024	[77] BORTOLETTO92	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[77] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma(D^*(2010)^- \pi^+ \pi^0)/\Gamma_{\text{total}}$ Γ_{16}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0152±0.0052±0.0001	51	[78] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.015 ±0.008 ±0.008	8	[79] ALBRECHT 87C	ARG	$e^+e^- \to \Upsilon(4S)$

[78] ALBRECHT 90J reports $0.018 \pm 0.004 \pm 0.005$ for $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[79] ALBRECHT 87C use PDG 86 branching ratios for D and $D^*(2010)$ and assume $B(\Upsilon(4S) \to B^+B^-) = 55\%$ and $B(\Upsilon(4S) \to B^0\overline{B}^0) = 45\%$. Superseded by ALBRECHT 90J.

$\Gamma(D^*(2010)^- \rho^+)/\Gamma_{\text{total}}$ Γ_{17}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0068 ±0.0034 OUR AVERAGE				
0.0160 ±0.0113 ±0.0001		[80] BORTOLETTO 92	CLEO	$e^+e^- \to \Upsilon(4S)$
0.00589±0.00352±0.00004	19	[81] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$

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

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0074 ±0.0010 ±0.0014	76	[82,83] ALAM 94	CLE2	Sup. by JESSOP 97
0.081 ±0.029 $^{+0.059}_{-0.024}$	19	[84] CHEN 85	CLEO	$e^+e^- \to \Upsilon(4S)$

[80] BORTOLETTO 92 reports $0.019 \pm 0.008 \pm 0.011$ for $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[81] ALBRECHT 90J reports $0.007 \pm 0.003 \pm 0.003$ for $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[82] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $B(D^*(2010)^+ \to D^0\pi^+)$ and absolute $B(D^0 \to K^-\pi^+)$ and the PDG 1992 $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$ and $B(D^0 \to K^-\pi^+\pi^+\pi^-)/B(D^0 \to K^-\pi^+)$.

[83] This decay is nearly completely longitudinally polarized, $\Gamma_L/\Gamma = (93 \pm 5 \pm 5)\%$, as expected from the factorization hypothesis (ROSNER 90). The nonresonant $\pi^+\pi^0$ contribution under the ρ^+ is less than 9% at 90% CL.

[84] Uses $B(D^* \to D^0\pi^+) = 0.6 \pm 0.15$ and $B(\Upsilon(4S) \to B^0\overline{B}^0) = 0.4$. Does not depend on D branching ratios.

$\Gamma(D^*(2010)^- \pi^+ \pi^+ \pi^-)/\Gamma_{\text{total}}$ Γ_{18}/Γ

VALUE	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
0.0076±0.0018 OUR AVERAGE			Error includes scale factor of 1.4. See the ideogram below.		
0.0063±0.0010±0.0011		49	[85,86] ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$
0.0134±0.0036±0.0001			[87] BORTOLETTO 92	CLEO	$e^+e^- \to \Upsilon(4S)$
0.0101±0.0041±0.0001		26	[88] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$

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

0.033 ±0.009 ±0.016		27	[89] ALBRECHT	87C	ARG	$e^+e^- \to \Upsilon(4S)$
<0.042	90		[90] BEBEK	87	CLEO	$e^+e^- \to \Upsilon(4S)$

[85] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $\mathrm{B}(D^*(2010)^+ \to D^0\pi^+)$ and absolute $\mathrm{B}(D^0 \to K^-\pi^+)$ and the PDG 1992 $\mathrm{B}(D^0 \to K^-\pi^+\pi^0)/\mathrm{B}(D^0 \to K^-\pi^+)$ and $\mathrm{B}(D^0 \to K^-\pi^+\pi^+\pi^-)/\mathrm{B}(D^0 \to K^-\pi^+)$.

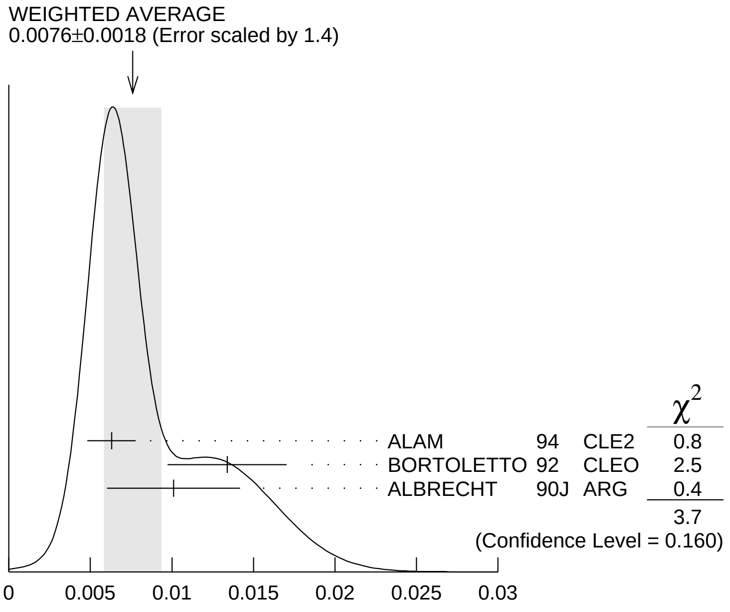
[86] The three pion mass is required to be between 1.0 and 1.6 GeV consistent with an a_1 meson. (If this channel is dominated by a_1^+, the branching ratio for $\overline{D}^{*-}a_1^+$ is twice that for $\overline{D}^{*-}\pi^+\pi^+\pi^-$.)

[87] BORTOLETTO 92 reports $0.0159 \pm 0.0028 \pm 0.0037$ for $\mathrm{B}(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $\mathrm{B}(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[88] ALBRECHT 90J reports $0.012 \pm 0.003 \pm 0.004$ for $\mathrm{B}(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $\mathrm{B}(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[89] ALBRECHT 87C use PDG 86 branching ratios for D and $D^*(2010)$ and assume $\mathrm{B}(\Upsilon(4S) \to B^+B^-) = 55\%$ and $\mathrm{B}(\Upsilon(4S) \to B^0\overline{B}^0) = 45\%$. Superseded by ALBRECHT 90J.

[90] BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92.



$\Gamma\left(D^*(2010)^-\pi^+\pi^+\pi^-\right)/\Gamma_{\mathrm{total}}$

$\Gamma((D^*(2010)^-\pi^+\pi^+\pi^-)\ \textbf{nonresonant})/\Gamma_{\text{total}}$ Γ_{19}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0000±0.0019±0.0016	[91] BORTOLETTO92	CLEO	$e^+e^- \to \Upsilon(4S)$

[91] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D and $D^*(2010)$.

$\Gamma(D^*(2010)^-\pi^+\rho^0)/\Gamma_{\text{total}}$ Γ_{20}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0057 ±0.0032 OUR AVERAGE			
0.00573±0.00317±0.00004	[92] BORTOLETTO92	CLEO	$e^+e^- \to \Upsilon(4S)$

[92] BORTOLETTO 92 reports 0.0068 ± 0.0032 ± 0.0021 for $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma(D^*(2010)^-a_1(1260)^+)/\Gamma_{\text{total}}$ Γ_{21}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0130±0.0027 OUR AVERAGE			
0.0126±0.0020±0.0022	[93,94] ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$
0.0152±0.0070±0.0001	[95] BORTOLETTO92	CLEO	$e^+e^- \to \Upsilon(4S)$

[93] ALAM 94 value is twice their $\Gamma(D^*(2010)^-\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$ value based on their observation that the three pions are dominantly in the $a_1(1260)$ mass range 1.0 to 1.6 GeV.

[94] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $B(D^*(2010)^+ \to D^0\pi^+)$ and absolute $B(D^0 \to K^-\pi^+)$ and the PDG 1992 $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$ and $B(D^0 \to K^-\pi^+\pi^+\pi^-)/B(D^0 \to K^-\pi^+)$.

[95] BORTOLETTO 92 reports 0.018 ± 0.006 ± 0.006 for $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma(D^*(2010)^-\pi^+\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_{22}/Γ

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.035 ±0.018 OUR AVERAGE				
0.0345±0.0181±0.0003	28	[96] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$

[96] ALBRECHT 90J reports 0.041 ± 0.015 ± 0.016 for $B(D^*(2010)^+ \to D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (67.7 \pm 0.5) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma(\overline{D}{}_2^*(2460)^-\pi^+)/\Gamma_{\text{total}}$ Γ_{23}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0022	90	[97] ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$

[97] ALAM 94 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute $B(D^0 \to K^-\pi^+)$ and $B(D_2^*(2460)^+ \to D^0\pi^+) = 30\%$.

$\Gamma\big(\overline{D}{}_2^*(2460)^-\rho^+\big)/\Gamma_{\rm total}$ Γ_{24}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.0049	90	[98] ALAM 94	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[98] ALAM 94 assumesequal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute B($D^0 \rightarrow K^-\pi^+$) and B($D_2^*(2460)^+ \rightarrow D^0\pi^+$) = 30%.

$\Gamma\big(D^-D^+\big)/\Gamma_{\rm total}$ Γ_{25}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<5.9 \times 10^{-3}$	90	BARATE 98Q	ALEP	$e^+e^- \rightarrow Z$
$\mathbf{<1.2 \times 10^{-3}}$	90	ASNER 97	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

$\Gamma\big(D^-D_s^+\big)/\Gamma_{\rm total}$ Γ_{26}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0080±0.0030 OUR AVERAGE				
$0.0084\pm0.0030^{+0.0020}_{-0.0021}$		[99] GIBAUT 96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
0.013 ±0.011 ±0.003		[100] ALBRECHT 92G	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
0.007 ±0.004 ±0.002		[101] BORTOLETTO 92	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.012 ±0.007	3	[102] BORTOLETTO 90	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[99] GIBAUT 96 reports $0.0087 \pm 0.0024 \pm 0.0020$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.035. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[100] ALBRECHT 92G reports $0.017 \pm 0.013 \pm 0.006$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes PDG 1990 D^+ branching ratios, e.g., B($D^+ \rightarrow K^-\pi^+\pi^+$) = 7.7 ± 1.0%.

[101] BORTOLETTO 92 reports $0.0080 \pm 0.0045 \pm 0.0030$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.030 ± 0.011. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[102] BORTOLETTO 90 assume B($D_s \rightarrow \phi\pi^+$) = 2%. Superseded by BORTOLETTO 92.

$\Gamma\big(D^*(2010)^-D_s^+\big)/\Gamma_{\rm total}$ Γ_{27}/Γ

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.0096±0.0034 OUR AVERAGE				
0.0090±0.0027±0.0022		[103] GIBAUT 96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
0.010 ±0.008 ±0.003		[104] ALBRECHT 92G	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
0.013 ±0.008 ±0.003		[105] BORTOLETTO 92	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.024 ±0.014	3	[106] BORTOLETTO 90	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[103] GIBAUT 96 reports $0.0093 \pm 0.0023 \pm 0.0016$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.035. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[104] ALBRECHT 92G reports $0.014 \pm 0.010 \pm 0.003$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their

experiment's error and our second error is the systematic error from using our best value. Assumes PDG 1990 D^+ and $D^*(2010)^+$ branching ratios, e.g., $B(D^0 \to K^- \pi^+) = 3.71 \pm 0.25\%$, $B(D^+ \to K^- \pi^+ \pi^+) = 7.1 \pm 1.0\%$, and $B(D^*(2010)^+ \to D^0 \pi^+) = 55 \pm 4\%$.

[105] BORTOLETTO 92 reports $0.016 \pm 0.009 \pm 0.006$ for $B(D_s^+ \to \phi\pi^+) = 0.030 \pm 0.011$. We rescale to our best value $B(D_s^+ \to \phi\pi^+) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D and $D^*(2010)$.

[106] BORTOLETTO 90 assume $B(D_s \to \phi\pi^+) = 2\%$. Superseded by BORTOLETTO 92.

$\Gamma(D^- D_s^{*+})/\Gamma_{\text{total}}$ Γ_{28}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.010±0.005 OUR AVERAGE			
0.010±0.004±0.002	[107] GIBAUT 96	CLE2	$e^+e^- \to \Upsilon(4S)$
0.020±0.014±0.005	[108] ALBRECHT 92G	ARG	$e^+e^- \to \Upsilon(4S)$

[107] GIBAUT 96 reports $0.0100 \pm 0.0035 \pm 0.0022$ for $B(D_s^+ \to \phi\pi^+) = 0.035$. We rescale to our best value $B(D_s^+ \to \phi\pi^+) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[108] ALBRECHT 92G reports $0.027 \pm 0.017 \pm 0.009$ for $B(D_s^+ \to \phi\pi^+) = 0.027$. We rescale to our best value $B(D_s^+ \to \phi\pi^+) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes PDG 1990 D^+ branching ratios, e.g., $B(D^+ \to K^- \pi^+ \pi^+) = 7.7 \pm 1.0\%$.

$[\Gamma(D^*(2010)^- D_s^+) + \Gamma(D^*(2010)^- D_s^{*+})]/\Gamma_{\text{total}}$ $(\Gamma_{27}+\Gamma_{29})/\Gamma$

VALUE (units 10^{-2})	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{4.15 \pm 1.11 ^{+0.99}_{-1.02}}$	22	[109] BORTOLETTO 90	CLEO	$e^+e^- \to \Upsilon(4S)$

[109] BORTOLETTO 90 reports 7.5 ± 2.0 for $B(D_s^+ \to \phi\pi^+) = 0.02$. We rescale to our best value $B(D_s^+ \to \phi\pi^+) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(D^*(2010)^- D_s^{*+})/\Gamma_{\text{total}}$ Γ_{29}/Γ

VALUE	*DOCUMENT ID*	*TECN*	*COMMENT*
0.020±0.007 OUR AVERAGE			
0.020±0.006±0.005	[110] GIBAUT 96	CLE2	$e^+e^- \to \Upsilon(4S)$
0.019±0.011±0.005	[111] ALBRECHT 92G	ARG	$e^+e^- \to \Upsilon(4S)$

[110] GIBAUT 96 reports $0.0203 \pm 0.0050 \pm 0.0036$ for $B(D_s^+ \to \phi\pi^+) = 0.035$. We rescale to our best value $B(D_s^+ \to \phi\pi^+) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[111] ALBRECHT 92G reports $0.026 \pm 0.014 \pm 0.006$ for $B(D_s^+ \to \phi\pi^+) = 0.027$. We rescale to our best value $B(D_s^+ \to \phi\pi^+) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes PDG 1990 D^+ and $D^*(2010)^+$ branching ratios, e.g., $B(D^0 \to K^- \pi^+) = 3.71 \pm 0.25\%$, $B(D^+ \to K^- \pi^+ \pi^+) = 7.1 \pm 1.0\%$, and $B(D^*(2010)^+ \to D^0 \pi^+) = 55 \pm 4\%$.

$\Gamma(D_s^+\pi^-)/\Gamma_{\text{total}}$ Γ_{30}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00028	90	[112] ALEXANDER 93B	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.0013	90	[113] BORTOLETTO90	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[112] ALEXANDER 93B reports $< 2.7 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = 0.036.

[113] BORTOLETTO 90 assume B($D_s \rightarrow \phi\pi^+$) = 2%.

$\Gamma(D_s^{*+}\pi^-)/\Gamma_{\text{total}}$ Γ_{31}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0005	90	[114] ALEXANDER 93B	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[114] ALEXANDER 93B reports $< 4.4 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = 0.036.

$\left[\Gamma(D_s^+\pi^-)+\Gamma(D_s^-K^+)\right]/\Gamma_{\text{total}}$ $(\Gamma_{30}+\Gamma_{36})/\Gamma$

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0013	90	[115] ALBRECHT 93E	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[115] ALBRECHT 93E reports $< 1.7 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = 0.036.

$\left[\Gamma(D_s^{*+}\pi^-)+\Gamma(D_s^{*-}K^+)\right]/\Gamma_{\text{total}}$ $(\Gamma_{31}+\Gamma_{37})/\Gamma$

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0009	90	[116] ALBRECHT 93E	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[116] ALBRECHT 93E reports $< 1.2 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = 0.036.

$\Gamma(D_s^+\rho^-)/\Gamma_{\text{total}}$ Γ_{32}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0007	90	[117] ALEXANDER 93B	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.0016	90	[118] ALBRECHT 93E	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[117] ALEXANDER 93B reports $< 6.6 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = 0.036.

[118] ALBRECHT 93E reports $< 2.2 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \rightarrow \phi\pi^+$) = 0.036.

$\Gamma(D_s^{*+}\rho^-)/\Gamma_{\text{total}}$ Γ_{33}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0008	90	[119] ALEXANDER 93B	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.0019	90	[120] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[119] ALEXANDER 93B reports $< 7.4 \times 10^{-4}$ for B($D_s^+ \to \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

[120] ALBRECHT 93E reports $< 2.5 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^+ a_1(1260)^-)/\Gamma_{\text{total}}$ Γ_{34}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0026	90	[121] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[121] ALBRECHT 93E reports $< 3.5 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^{*+} a_1(1260)^-)/\Gamma_{\text{total}}$ Γ_{35}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0022	90	[122] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[122] ALBRECHT 93E reports $< 2.9 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^- K^+)/\Gamma_{\text{total}}$ Γ_{36}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00024	90	[123] ALEXANDER 93B	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.0013	90	[124] BORTOLETTO90	CLEO	$e^+e^- \to \Upsilon(4S)$

[123] ALEXANDER 93B reports $< 2.3 \times 10^{-4}$ for B($D_s^+ \to \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

[124] BORTOLETTO 90 assume B($D_s \to \phi\pi^+$) = 2%.

$\Gamma(D_s^{*-} K^+)/\Gamma_{\text{total}}$ Γ_{37}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00017	90	[125] ALEXANDER 93B	CLE2	$e^+e^- \to \Upsilon(4S)$

[125] ALEXANDER 93B reports $< 1.7 \times 10^{-4}$ for B($D_s^+ \to \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^- K^*(892)^+)/\Gamma_{\text{total}}$ Γ_{38}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0010	90	[126] ALEXANDER 93B	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.0034	90	[127] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[126] ALEXANDER 93B reports $< 9.7 \times 10^{-4}$ for B($D_s^+ \to \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

[127] ALBRECHT 93E reports $< 4.6 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^{*-} K^*(892)^+)/\Gamma_{\text{total}}$ Γ_{39}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0011	90	[128] ALEXANDER 93B	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.004	90	[129] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[128] ALEXANDER 93B reports $< 11.0 \times 10^{-4}$ for B($D_s^+ \to \phi\pi^+$) = 0.037. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

[129] ALBRECHT 93E reports $< 5.8 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^- \pi^+ K^0)/\Gamma_{\text{total}}$ Γ_{40}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.005	90	[130] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[130] ALBRECHT 93E reports $< 7.3 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^{*-} \pi^+ K^0)/\Gamma_{\text{total}}$ Γ_{41}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0031	90	[131] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[131] ALBRECHT 93E reports $< 4.2 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^- \pi^+ K^*(892)^0)/\Gamma_{\text{total}}$ Γ_{42}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.004	90	[132] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[132] ALBRECHT 93E reports $< 5.0 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(D_s^{*-} \pi^+ K^*(892)^0)/\Gamma_{\text{total}}$ Γ_{43}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0020	90	[133] ALBRECHT 93E	ARG	$e^+e^- \to \Upsilon(4S)$

[133] ALBRECHT 93E reports $< 2.7 \times 10^{-3}$ for B($D_s^+ \to \phi\pi^+$) = 0.027. We rescale to our best value B($D_s^+ \to \phi\pi^+$) = 0.036.

$\Gamma(\overline{D}^0\pi^0)/\Gamma_{\text{total}}$ Γ_{44}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00012	90	[134] NEMATI 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.00048	90	[135] ALAM 94	CLE2	Repl. by NEMATI 98

[134] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[135] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+\pi^0$)/B($D^0 \rightarrow K^-\pi^+$) and B($D^0 \rightarrow K^-\pi^+\pi^+\pi^-$)/B($D^0 \rightarrow K^-\pi^+$).

$\Gamma(\overline{D}^0\rho^0)/\Gamma_{\text{total}}$ Γ_{45}/Γ

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00039	90		[136] NEMATI 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.00055	90		[137] ALAM 94	CLE2	Repl. by NEMATI 98
<0.0006	90		[138] BORTOLETTO 92	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
<0.0027	90	4	[139] ALBRECHT 88K	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[136] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[137] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+\pi^0$)/B($D^0 \rightarrow K^-\pi^+$) and B($D^0 \rightarrow K^-\pi^+\pi^+\pi^-$)/B($D^0 \rightarrow K^-\pi^+$).

[138] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

[139] ALBRECHT 88K reports < 0.003 assuming $B^0\overline{B}^0$:B^+B^- production ratio is 45:55. We rescale to 50%.

$\Gamma(\overline{D}^0\eta)/\Gamma_{\text{total}}$ Γ_{46}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00013	90	[140] NEMATI 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.00068	90	[141] ALAM 94	CLE2	Repl. by NEMATI 98

[140] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[141] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+\pi^0$)/B($D^0 \rightarrow K^-\pi^+$) and B($D^0 \rightarrow K^-\pi^+\pi^+\pi^-$)/B($D^0 \rightarrow K^-\pi^+$).

$\Gamma(\overline{D}^0\eta')/\Gamma_{\text{total}}$ Γ_{47}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00094	90	[142] NEMATI 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.00086	90	[143] ALAM 94	CLE2	Repl. by NEMATI 98

[142] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[143] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+\pi^0$)/B($D^0 \rightarrow K^-\pi^+$) and B($D^0 \rightarrow K^-\pi^+\pi^+\pi^-$)/B($D^0 \rightarrow K^-\pi^+$).

$\Gamma(\overline{D}^0\omega)/\Gamma_{\text{total}}$ Γ_{48}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00051	90	[144] NEMATI 98	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.00063	90	[145] ALAM 94	CLE2	Repl. by NEMATI 98

[144] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[145] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute B($D^0 \to K^-\pi^+$) and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+$) and B($D^0 \to K^-\pi^+\pi^+\pi^-$)/B($D^0 \to K^-\pi^+$).

$\Gamma(\overline{D}^*(2007)^0\pi^0)/\Gamma_{\text{total}}$ Γ_{49}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00044	90	[146] NEMATI 98	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.00097	90	[147] ALAM 94	CLE2	Repl. by NEMATI 98

[146] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[147] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II B($D^*(2007)^0 \to D^0\pi^0$) and absolute B($D^0 \to K^-\pi^+$) and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+$) and B($D^0 \to K^-\pi^+\pi^+\pi^-$)/B($D^0 \to K^-\pi^+$).

$\Gamma(\overline{D}^*(2007)^0\rho^0)/\Gamma_{\text{total}}$ Γ_{50}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00056	90	[148] NEMATI 98	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.00117	90	[149] ALAM 94	CLE2	Repl. by NEMATI 98

[148] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[149] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II B($D^*(2007)^0 \to D^0\pi^0$) and absolute B($D^0 \to K^-\pi^+$) and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+$) and B($D^0 \to K^-\pi^+\pi^+\pi^-$)/B($D^0 \to K^-\pi^+$).

$\Gamma(\overline{D}^*(2007)^0\eta)/\Gamma_{\text{total}}$ Γ_{51}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00026	90	[150] NEMATI 98	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.00069	90	[151] ALAM 94	CLE2	Repl. by NEMATI 98

[150] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[151] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II B($D^*(2007)^0 \to D^0\pi^0$) and absolute B($D^0 \to K^-\pi^+$) and the PDG 1992 B($D^0 \to K^-\pi^+\pi^0$)/B($D^0 \to K^-\pi^+$) and B($D^0 \to K^-\pi^+\pi^+\pi^-$)/B($D^0 \to K^-\pi^+$).

$\Gamma(\overline{D}^*(2007)^0 \eta')/\Gamma_{\rm total}$ Γ_{52}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0014	90	BRANDENB... 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.0019	90	[152] NEMATI 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
<0.0027	90	[153] ALAM 94	CLE2	Repl. by NEMATI 98

[152] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[153] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $B(D^*(2007)^0 \rightarrow D^0\pi^0)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and the PDG 1992 $B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+)$ and $B(D^0 \rightarrow K^-\pi^+\pi^+\pi^-)/B(D^0 \rightarrow K^-\pi^+)$.

$\Gamma(\overline{D}^*(2007)^0 \omega)/\Gamma_{\rm total}$ Γ_{53}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.00074	90	[154] NEMATI 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.0021	90	[155] ALAM 94	CLE2	Repl. by NEMATI 98

[154] NEMATI 98 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the PDG 96 values for D^0, D^{*0}, η, η', and ω branching fractions.

[155] ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $B(D^*(2007)^0 \rightarrow D^0\pi^0)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and the PDG 1992 $B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+)$ and $B(D^0 \rightarrow K^-\pi^+\pi^+\pi^-)/B(D^0 \rightarrow K^-\pi^+)$.

$\Gamma(D^*(2010)^+ D^*(2010)^-)/\Gamma_{\rm total}$ Γ_{54}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{(6.2^{+4.0}_{-2.9} \pm 1.0) \times 10^{-4}}$		[156] ARTUSO 99	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$< 6.1 \times 10^{-3}$	90	[157] BARATE 98Q	ALEP	$e^+e^- \rightarrow Z$
$< 2.2 \times 10^{-3}$	90	[158] ASNER 97	CLE2	Repl. by ARTUSO 99

[156] ARTUSO 99 uses $B(\Upsilon(4S) \rightarrow B^0\overline{B}^0)=(48 \pm 4)\%$.

[157] BARATE 98Q (ALEPH) observes 2 events with an expected background of 0.10 ± 0.03 which corresponds to a branching ratio of $(2.3^{+1.9}_{-1.2} \pm 0.4) \times 10^{-3}$.

[158] ASNER 97 at CLEO observes 1 event with an expected background of 0.022 ± 0.011. This correcsponds to a branching ratio of $(5.3^{+7.1}_{-3.7} \pm 1.0) \times 10^{-4}$.

$\Gamma(D^*(2010)^+ D^-)/\Gamma_{\rm total}$ Γ_{55}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{<1.8 \times 10^{-3}}$	90	ASNER 97	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<5.6 \times 10^{-3}$	90	BARATE 98Q	ALEP	$e^+e^- \rightarrow Z$

$\Gamma(D^{(*)0}\overline{D}^{(*)0})/\Gamma_{\rm total}$ Γ_{56}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.027	90	BARATE 98Q	ALEP	$e^+e^- \rightarrow Z$

$\Gamma(J/\psi(1S)K^0)/\Gamma_{\text{total}}$ Γ_{57}/Γ

VALUE (units 10^{-4})	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
8.9±1.2 OUR AVERAGE					
$8.5^{+1.4}_{-1.2}\pm0.6$			[159] JESSOP 97	CLE2	$e^+e^- \to \Upsilon(4S)$
$11.5\pm2.3\pm1.7$			[160] ABE 96H	CDF	$p\overline{p}$ at 1.8 TeV
$7.0\pm4.1\pm0.1$			[161] BORTOLETTO92	CLEO	$e^+e^- \to \Upsilon(4S)$
$9.3\pm7.3\pm0.2$		2	[162] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$7.5\pm2.4\pm0.8$		10	[161] ALAM 94	CLE2	Sup. by JESSOP 97
<50	90		ALAM 86	CLEO	$e^+e^- \to \Upsilon(4S)$

[159] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[160] ABE 96H assumes that $B(B^+ \to J/\psi K^+) = (1.02 \pm 0.14) \times 10^{-3}$.

[161] BORTOLETTO 92 reports $6 \pm 3 \pm 2$ for $B(J/\psi(1S) \to e^+e^-) = 0.069 \pm 0.009$. We rescale to our best value $B(J/\psi(1S) \to e^+e^-) = (5.93 \pm 0.10) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[162] ALBRECHT 90J reports $8 \pm 6 \pm 2$ for $B(J/\psi(1S) \to e^+e^-) = 0.069 \pm 0.009$. We rescale to our best value $B(J/\psi(1S) \to e^+e^-) = (5.93 \pm 0.10) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(J/\psi(1S)K^+\pi^-)/\Gamma_{\text{total}}$ Γ_{58}/Γ

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.0012 ±0.0006 OUR AVERAGE					
0.00116±0.00056±0.00002			[163] BORTOLETTO92	CLEO	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
<0.0013	90		[164] ALBRECHT 87D	ARG	$e^+e^- \to \Upsilon(4S)$
<0.0063	90	2	GILES 84	CLEO	$e^+e^- \to \Upsilon(4S)$

[163] BORTOLETTO 92 reports $0.0010 \pm 0.0004 \pm 0.0003$ for $B(J/\psi(1S) \to e^+e^-) = 0.069 \pm 0.009$. We rescale to our best value $B(J/\psi(1S) \to e^+e^-) = (5.93 \pm 0.10) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[164] ALBRECHT 87D assume $B^+B^-/B^0\overline{B}^0$ ratio is 55/45. $K\pi$ system is specifically selected as nonresonant.

$\Gamma(J/\psi(1S)K^*(892)^0)/\Gamma_{\text{total}}$ Γ_{59}/Γ

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.00150±0.00017 OUR AVERAGE				
$0.00174\pm0.00020\pm0.00018$		[165] ABE 98O	CDF	$p\overline{p}$ 1.8 TeV
$0.00132\pm0.00017\pm0.00017$		[166] JESSOP 97	CLE2	$e^+e^- \to \Upsilon(4S)$
$0.00128\pm0.00066\pm0.00002$		[167] BORTOLETTO92	CLEO	$e^+e^- \to \Upsilon(4S)$
$0.00128\pm0.00060\pm0.00002$	6	[168] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$
$0.0041\pm0.0018\pm0.0001$	5	[169] BEBEK 87	CLEO	$e^+e^- \to \Upsilon(4S)$

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

$0.00136 \pm 0.00027 \pm 0.00022$		[170] ABE	96H	CDF	Sup. by ABE 98O
$0.00169 \pm 0.00031 \pm 0.00018$	29	[171] ALAM	94	CLE2	Sup. by JESSOP 97
		[172] ALBRECHT	94G	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
0.0040 ± 0.0030		[173] ALBAJAR	91E	UA1	$E_{\rm cm}^{p\overline{p}} = 630$ GeV
0.0033 ± 0.0018	5	[174] ALBRECHT	87D	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
0.0041 ± 0.0018	5	[175] ALAM	86	CLEO	Repl. by BEBEK 87

[165] ABE 98O reports $[B(B^0 \rightarrow J/\psi(1S)K^*(892)^0)]/[B(B^+ \rightarrow J/\psi(1S)K^+)] = 1.76 \pm 0.14 \pm 0.15$. We multiply by our best value $B(B^+ \rightarrow J/\psi(1S)K^+) = (9.9 \pm 1.0) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[166] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[167] BORTOLETTO 92 reports $0.0011 \pm 0.0005 \pm 0.0003$ for $B(J/\psi(1S) \rightarrow e^+e^-) = 0.069 \pm 0.009$. We rescale to our best value $B(J/\psi(1S) \rightarrow e^+e^-) = (5.93 \pm 0.10) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[168] ALBRECHT 90J reports $0.0011 \pm 0.0005 \pm 0.0002$ for $B(J/\psi(1S) \rightarrow e^+e^-) = 0.069 \pm 0.009$. We rescale to our best value $B(J/\psi(1S) \rightarrow e^+e^-) = (5.93 \pm 0.10) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[169] BEBEK 87 reports $0.0035 \pm 0.0016 \pm 0.0003$ for $B(J/\psi(1S) \rightarrow e^+e^-) = 0.069 \pm 0.009$. We rescale to our best value $B(J/\psi(1S) \rightarrow e^+e^-) = (5.93 \pm 0.10) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Updated in BORTOLETTO 92 to use the same assumptions.

[170] ABE 96H assumes that $B(B^+ \rightarrow J/\psi K^+) = (1.02 \pm 0.14) \times 10^{-3}$.

[171] The neutral and charged B events together are predominantly longitudinally polarized, $\Gamma_L/\Gamma = 0.080 \pm 0.08 \pm 0.05$. This can be compared with a prediction using HQET, 0.73 (KRAMER 92). This polarization indicates that the $B \rightarrow \psi K^*$ decay is dominated by the $CP = -1$ CP eigenstate. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[172] ALBRECHT 94G measures the polarization in the vector-vector decay to be predominantly longitudinal, $\Gamma_T/\Gamma = 0.03 \pm 0.16 \pm 0.15$ making the neutral decay a CP eigenstate when the K^{*0} decays through $K_S^0\pi^0$.

[173] ALBAJAR 91E assumes B_d^0 production fraction of 36%.

[174] ALBRECHT 87D assume $B^+B^-/B^0\overline{B}^0$ ratio is 55/45. Superseded by ALBRECHT 90J.

[175] ALAM 86 assumes $B^\pm/B^0$ ratio is 60/40. The observation of the decay $B^+ \rightarrow J/\psi K^*(892)^+$ (HAAS 85) has been retracted in this paper.

$\Gamma(J/\psi(1S)K^*(892)^0)/\Gamma(J/\psi(1S)K^0)$ Γ_{59}/Γ_{57}

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{1.39 \pm 0.36 \pm 0.10}$	ABE	96Q	CDF	$p\overline{p}$

$\Gamma(J/\psi(1S)\pi^0)/\Gamma_{\rm total}$ Γ_{60}/Γ

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$\mathbf{<5.8 \times 10^{-5}}$	90		BISHAI	96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

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

$<3.2 \times 10^{-4}$	90		[176] ACCIARRI	97C	L3	
$<6.9 \times 10^{-3}$	90	1	[177] ALEXANDER	95	CLE2	Sup. by BISHAI 96

[176] ACCIARRI 97C assumes B^0 production fraction ($39.5 \pm 4.0\%$) and B_s ($12.0 \pm 3.0\%$).

[177] Assumes equal production of B^+B^- and $B^0\overline{B}^0$ on $\Upsilon(4S)$.

$\Gamma\big(J/\psi(1S)\eta\big)/\Gamma_{\text{total}}$ Γ_{61}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<1.2 \times 10^{-3}$	90	[178] ACCIARRI 97C	L3

[178] ACCIARRI 97C assumes B^0 production fraction (39.5 ± 4.0%) and B_s (12.0 ± 3.0%).

$\Gamma\big(J/\psi(1S)\rho^0\big)/\Gamma_{\text{total}}$ Γ_{62}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.5 \times 10^{-4}$	90	BISHAI 96	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma\big(J/\psi(1S)\omega\big)/\Gamma_{\text{total}}$ Γ_{63}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.7 \times 10^{-4}$	90	BISHAI 96	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma\big(\psi(2S)K^0\big)/\Gamma_{\text{total}}$ Γ_{64}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0008	90	[179] ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$

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

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0015	90	[179] BORTOLETTO 92	CLEO	$e^+e^- \to \Upsilon(4S)$
<0.0028	90	[179] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$

[179] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma\big(\psi(2S)K^+\pi^-\big)/\Gamma_{\text{total}}$ Γ_{65}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.001	90	[180] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$

[180] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma\big(\psi(2S)K^*(892)^0\big)/\Gamma_{\text{total}}$ Γ_{66}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$(9.3 \pm 2.3) \times 10^{-4}$ OUR AVERAGE				
$0.00090 \pm 0.00022 \pm 0.00009$		[181] ABE 98O	CDF	$p\overline{p}$ 1.8 TeV
$0.0014 \pm 0.0008 \pm 0.0004$		[182] BORTOLETTO 92	CLEO	$e^+e^- \to \Upsilon(4S)$

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

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
< 0.0019	90	[182] ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$
< 0.0023	90	[182] ALBRECHT 90J	ARG	$e^+e^- \to \Upsilon(4S)$

[181] ABE 98O reports $[B(B^0 \to \psi(2S)K^*(892)^0)]/[B(B^+ \to J/\psi(1S)K^+)] = 0.908 \pm 0.194 \pm 0.10$. We multiply by our best value $B(B^+ \to J/\psi(1S)K^+) = (9.9 \pm 1.0) \times 10^{-4}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[182] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma\big(\chi_{c1}(1P)K^0\big)/\Gamma_{\text{total}}$ Γ_{67}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<0.0027	90	[183] ALAM 94	CLE2	$e^+e^- \to \Upsilon(4S)$

[183] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\chi_{c1}(1P)K^*(892)^0)/\Gamma_{\text{total}}$ Γ_{68}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.0021	90	[184] ALAM	94	CLE2	$e^+e^- \to \Upsilon(4S)$

[184] BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(K^+\pi^-)/\Gamma_{\text{total}}$ Γ_{69}/Γ

VALUE (units 10^{-5})	CL%	DOCUMENT ID		TECN	COMMENT
$\mathbf{1.5^{+0.5}_{-0.4}\pm0.14}$		GODANG	98	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$2.4^{+1.7}_{-1.1}\pm0.2$		[185] ADAM	96D	DLPH	$e^+e^- \to Z$
$<$ 1.7	90	ASNER	96	CLE2	Sup. by ADAM 96D
$<$ 3.0	90	[186] BUSKULIC	96V	ALEP	$e^+e^- \to Z$
$<$ 9	90	[187] ABREU	95N	DLPH	Sup. by ADAM 96D
$<$ 8.1	90	[188] AKERS	94L	OPAL	$e^+e^- \to Z$
$<$ 2.6	90	[189] BATTLE	93	CLE2	$e^+e^- \to \Upsilon(4S)$
$<$18	90	ALBRECHT	91B	ARG	$e^+e^- \to \Upsilon(4S)$
$<$ 9	90	[190] AVERY	89B	CLEO	$e^+e^- \to \Upsilon(4S)$
$<$32	90	AVERY	87	CLEO	$e^+e^- \to \Upsilon(4S)$

[185] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$. Contributions from B^0 and B_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

[186] BUSKULIC 96V assumes PDG 96 production fractions for B^0, B^+, B_s, b baryons.

[187] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12. Contributions from B^0 and B^0_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

[188] Assumes B($Z \to b\overline{b}$) = 0.217 and B^0_d (B^0_s) fraction 39.5% (12%).

[189] BATTLE 93 assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

[190] Assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$.

$\Gamma(K^0\pi^0)/\Gamma_{\text{total}}$ Γ_{70}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$\mathbf{<4.1\times10^{-5}}$	90	GODANG	98	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<4.0\times10^{-5}$	90	ASNER	96	CLE2	Rep. by GODANG 98

$\Gamma(\eta' K^0)/\Gamma_{\text{total}}$ Γ_{71}/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
$\mathbf{(4.7^{+2.7}_{-2.0}\pm0.9)\times10^{-5}}$	BEHRENS	98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\eta' K^*(892)^0)/\Gamma_{\text{total}}$ Γ_{72}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$\mathbf{<3.9\times10^{-5}}$	90	BEHRENS	98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\eta K^*(892)^0)/\Gamma_{\text{total}}$ Γ_{73}/Γ

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$\mathbf{<3.0\times10^{-5}}$	90	BEHRENS	98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\eta K^0)/\Gamma_{\text{total}}$ Γ_{74}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.3 \times 10^{-5}$	90	BEHRENS 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

$\Gamma(\omega K^0)/\Gamma_{\text{total}}$ Γ_{75}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<5.7 \times 10^{-5}$	90	[191] BERGFELD 98	CLE2

[191] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\omega K^*(892)^0)/\Gamma_{\text{total}}$ Γ_{76}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<2.3 \times 10^{-5}$	90	[192] BERGFELD 98	CLE2

[192] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$[\Gamma(K^+\pi^-) + \Gamma(\pi^+\pi^-)]/\Gamma_{\text{total}}$ $(\Gamma_{69}+\Gamma_{107})/\Gamma$

VALUE	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
$(1.9\pm0.6\quad) \times 10^{-5}$ OUR AVERAGE				
$(2.8^{+1.5}_{-1.0}\pm2.0) \times 10^{-5}$		[193] ADAM 96D	DLPH	$e^+e^- \rightarrow Z$
$(1.8^{+0.6}_{-0.5}{}^{+0.3}_{-0.4}) \times 10^{-5}$	17.2	ASNER 96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$(2.4^{+0.8}_{-0.7}\pm0.2) \times 10^{-5}$		[194] BATTLE 93	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[193] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$. Contributions from B^0 and B_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

[194] BATTLE 93 assumes equal production of $B^0\overline{B}{}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(K^+K^-)/\Gamma_{\text{total}}$ Γ_{77}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<4.3 \times 10^{-6}$	90	GODANG 98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<4.6 \times 10^{-5}$		[195] ADAM 96D	DLPH	$e^+e^- \rightarrow Z$
$<0.4 \times 10^{-5}$	90	ASNER 96	CLE2	Repl. by GODANG 98
$<1.8 \times 10^{-5}$	90	[196] BUSKULIC 96V	ALEP	$e^+e^- \rightarrow Z$
$<1.2 \times 10^{-4}$	90	[197] ABREU 95N	DLPH	Sup. by ADAM 96D
$<0.7 \times 10^{-5}$	90	[198] BATTLE 93	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[195] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$. Contributions from B^0 and B_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

[196] BUSKULIC 96V assumes PDG 96 production fractions for B^0, B^+, B_s, b baryons.

[197] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12. Contributions from B^0 and B_s^0 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

[198] BATTLE 93 assumes equal production of $B^0\overline{B}{}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(K^0\overline{K}^0)/\Gamma_{\text{total}}$ Γ_{78}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.7 \times 10^{-5}$	90	GODANG	98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

$\Gamma(K^+\rho^-)/\Gamma_{\text{total}}$ Γ_{79}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<3.5 \times 10^{-5}$	90	ASNER	96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

$\Gamma(K^0\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{80}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<4.4 \times 10^{-4}$	90	ALBRECHT	91E	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

$\Gamma(K^0\rho^0)/\Gamma_{\text{total}}$ Γ_{81}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<3.9 \times 10^{-5}$	90	ASNER	96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<3.2 \times 10^{-4}$	90	ALBRECHT	91B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
$<5.0 \times 10^{-4}$	90	[199] AVERY	89B	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
<0.064	90	[200] AVERY	87	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[199] AVERY 89B reports $< 5.8 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[200] AVERY 87 reports < 0.08 assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^0 f_0(980))/\Gamma_{\text{total}}$ Γ_{82}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<3.6 \times 10^{-4}$	90	[201] AVERY	89B	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[201] AVERY 89B reports $< 4.2 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ Γ_{83}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<7.2 \times 10^{-5}$	90	ASNER	96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
$<3.8 \times 10^{-4}$	90	[202] AVERY	89B	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<6.2 \times 10^{-4}$	90	ALBRECHT	91B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
$<5.6 \times 10^{-4}$	90	[203] AVERY	87	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[202] AVERY 89B reports $< 4.4 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[203] AVERY 87 reports $< 7 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^*(892)^0\pi^0)/\Gamma_{\text{total}}$ Γ_{84}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<2.8 \times 10^{-5}$	90	ASNER	96	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

$\Gamma(K_2^*(1430)^+\pi^-)/\Gamma_{\rm total}$ Γ_{85}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.6 \times 10^{-3}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma(K^0K^+K^-)/\Gamma_{\rm total}$ Γ_{86}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.3 \times 10^{-3}$	90	ALBRECHT 91E	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma(K^0\phi)/\Gamma_{\rm total}$ Γ_{87}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.1 \times 10^{-5}$ (CL = 90%) [$<8.8 \times 10^{-5}$ (CL = 90%) OUR 1998 BEST LIMIT]				
$<3.1 \times 10^{-5}$	90	[204] BERGFELD 98	CLE2	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<8.8 \times 10^{-5}$	90	ASNER 96	CLE2	$e^+e^- \to \Upsilon(4S)$
$<7.2 \times 10^{-4}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$
$<4.2 \times 10^{-4}$	90	[205] AVERY 89B	CLEO	$e^+e^- \to \Upsilon(4S)$
$<1.0 \times 10^{-3}$	90	[206] AVERY 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[204] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[205] AVERY 89B reports $< 4.9 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[206] AVERY 87 reports $< 1.3 \times 10^{-3}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^-\pi^+\pi^+\pi^-)/\Gamma_{\rm total}$ Γ_{88}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.3 \times 10^{-4}$	90	[207] ADAM 96D	DLPH	$e^+e^- \to Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2.1 \times 10^{-4}$	90	[208] ABREU 95N	DLPH	Sup. by ADAM 96D

[207] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$. Contributions from B^0 and B_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

[208] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12. Contributions from B^0 and B_s^0 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

$\Gamma(K^*(892)^0\pi^+\pi^-)/\Gamma_{\rm total}$ Γ_{89}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.4 \times 10^{-3}$	90	ALBRECHT 91E	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma(K^*(892)^0\rho^0)/\Gamma_{\rm total}$ Γ_{90}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<4.6 \times 10^{-4}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<5.8 \times 10^{-4}$	90	[209] AVERY 89B	CLEO	$e^+e^- \to \Upsilon(4S)$
$<9.6 \times 10^{-4}$	90	[210] AVERY 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[209] AVERY 89B reports $< 6.7 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[210] AVERY 87 reports $< 1.2 \times 10^{-3}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^*(892)^0 f_0(980))/\Gamma_{\rm total}$ Γ_{91}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.7 \times 10^{-4}$	90	[211] AVERY 89B	CLEO	$e^+e^- \to \Upsilon(4S)$

[211] AVERY 89B reports $< 2.0 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K_1(1400)^+\pi^-)/\Gamma_{\rm total}$ Γ_{92}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.1 \times 10^{-3}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma(K^- a_1(1260)^+)/\Gamma_{\rm total}$ Γ_{93}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.3 \times 10^{-4}$	90	[212] ADAM 96D	DLPH	$e^+e^- \to Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<3.9 \times 10^{-4}$	90	[213] ABREU 95N	DLPH	Sup. by ADAM 96D

[212] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$. Contributions from B^0 and B_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

[213] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12. Contributions from B^0 and B_s^0 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.

$\Gamma(K^*(892)^0 K^+ K^-)/\Gamma_{\rm total}$ Γ_{94}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<6.1 \times 10^{-4}$	90	ALBRECHT 91E	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma(K^*(892)^0 \phi)/\Gamma_{\rm total}$ Γ_{95}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.1 \times 10^{-5}$ (CL = 90%) [$<4.3 \times 10^{-5}$ (CL = 90%) OUR 1998 BEST LIMIT]				
$<2.1 \times 10^{-5}$	90	[214] BERGFELD 98	CLE2	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<4.3 \times 10^{-5}$	90	ASNER 96	CLE2	$e^+e^- \to \Upsilon(4S)$
$<3.2 \times 10^{-4}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$
$<3.8 \times 10^{-4}$	90	[215] AVERY 89B	CLEO	$e^+e^- \to \Upsilon(4S)$
$<3.8 \times 10^{-4}$	90	[216] AVERY 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[214] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[215] AVERY 89B reports $< 4.4 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[216] AVERY 87 reports $< 4.7 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K_1(1400)^0 \rho^0)/\Gamma_{\rm total}$ Γ_{96}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.0 \times 10^{-3}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma(K_1(1400)^0 \phi)/\Gamma_{\rm total}$ Γ_{97}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<5.0 \times 10^{-3}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma\big(K_2^*(1430)^0\rho^0\big)/\Gamma_{\text{total}}$ Γ_{98}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<1.1 \times 10^{-3}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma\big(K_2^*(1430)^0\phi\big)/\Gamma_{\text{total}}$ Γ_{99}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<1.4 \times 10^{-3}$	90	ALBRECHT 91B	ARG	$e^+e^- \to \Upsilon(4S)$

$\Gamma\big(K^*(892)^0\gamma\big)/\Gamma_{\text{total}}$ Γ_{100}/Γ

VALUE (units 10^{-5})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
$4.0 \pm 1.7 \pm 0.8$		8	[217] AMMAR 93	CLE2	$e^+e^- \to \Upsilon(4S)$

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

VALUE (units 10^{-5})	CL%	EVTS	DOCUMENT ID	TECN	COMMENT
< 21	90		[218] ADAM 96D	DLPH	$e^+e^- \to Z$
< 42	90		ALBRECHT 89G	ARG	$e^+e^- \to \Upsilon(4S)$
< 24	90		[219] AVERY 89B	CLEO	$e^+e^- \to \Upsilon(4S)$
<210	90		AVERY 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[217] AMMAR 93 observed 6.6 ± 2.8 events above background.

[218] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$.

[219] AVERY 89B reports $< 2.8 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma\big(K_1(1270)^0\gamma\big)/\Gamma_{\text{total}}$ Γ_{101}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.0070	90	[220] ALBRECHT 89G	ARG	$e^+e^- \to \Upsilon(4S)$

[220] ALBRECHT 89G reports < 0.0078 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma\big(K_1(1400)^0\gamma\big)/\Gamma_{\text{total}}$ Γ_{102}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.0043	90	[221] ALBRECHT 89G	ARG	$e^+e^- \to \Upsilon(4S)$

[221] ALBRECHT 89G reports < 0.0048 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma\big(K_2^*(1430)^0\gamma\big)/\Gamma_{\text{total}}$ Γ_{103}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
$<4.0 \times 10^{-4}$	90	[222] ALBRECHT 89G	ARG	$e^+e^- \to \Upsilon(4S)$

[222] ALBRECHT 89G reports $< 4.4 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma\big(K^*(1680)^0\gamma\big)/\Gamma_{\text{total}}$ Γ_{104}/Γ

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.0020	90	[223] ALBRECHT 89G	ARG	$e^+e^- \to \Upsilon(4S)$

[223] ALBRECHT 89G reports < 0.0022 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K_3^*(1780)^0\gamma)/\Gamma_{\text{total}}$ Γ_{105}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.010	90	[224] ALBRECHT	89G	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[224] ALBRECHT 89G reports < 0.011 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K_4^*(2045)^0\gamma)/\Gamma_{\text{total}}$ Γ_{106}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.0043	90	[225] ALBRECHT	89G	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[225] ALBRECHT 89G reports < 0.0048 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{107}/Γ

VALUE	*CL%*	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.5 \times 10^{-5}$	90		GODANG	98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$<4.5 \times 10^{-5}$	90		[226] ADAM	96D	DLPH	$e^+e^- \rightarrow Z$
$<2.0 \times 10^{-5}$	90		ASNER	96	CLE2	Repl. by GODANG 98
$<4.1 \times 10^{-5}$	90		[227] BUSKULIC	96V	ALEP	$e^+e^- \rightarrow Z$
$<5.5 \times 10^{-5}$	90		[228] ABREU	95N	DLPH	Sup. by ADAM 96D
$<4.7 \times 10^{-5}$	90		[229] AKERS	94L	OPAL	$e^+e^- \rightarrow Z$
$<2.9 \times 10^{-5}$	90		[230] BATTLE	93	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
$<1.3 \times 10^{-4}$	90		[230] ALBRECHT	90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
$<7.7 \times 10^{-5}$	90		[231] BORTOLETTO	89	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
$<2.6 \times 10^{-4}$	90		[231] BEBEK	87	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
$<5 \times 10^{-4}$	90	4	GILES	84	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[226] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$.

[227] BUSKULIC 96V assumes PDG 96 production fractions for B^0, B^+, B_s, b baryons.

[228] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12.

[229] Assumes $B(Z \rightarrow b\overline{b}) = 0.217$ and B_d^0 (B_s^0) fraction 39.5% (12%).

[230] Assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

[231] Paper assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$ Γ_{108}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<9.3 \times 10^{-6}$	90	GODANG	98	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<0.91 \times 10^{-5}$	90	ASNER	96	CLE2	Repl. by GODANG 98
$<6.0 \times 10^{-5}$	90	[232] ACCIARRI	95H	L3	$e^+e^- \rightarrow Z$

[232] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0\%$.

$\Gamma(\eta\pi^0)/\Gamma_{\text{total}}$ Γ_{109}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<8 \times 10^{-6}$	90	BEHRENS 98	CLE2	$e^+e^- \to \Upsilon(4S)$

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

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.5 \times 10^{-4}$	90	[233] ACCIARRI 95H	L3	$e^+e^- \to Z$
$<1.8 \times 10^{-3}$	90	[234] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$

[233] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0\%$.

[234] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\eta\eta)/\Gamma_{\text{total}}$ Γ_{110}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.8 \times 10^{-5}$	90	BEHRENS 98	CLE2	$e^+e^- \to \Upsilon(4S)$

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

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<4.1 \times 10^{-4}$	90	[235] ACCIARRI 95H	L3	$e^+e^- \to Z$

[235] ACCIARRI 95H assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0\%$.

$\Gamma(\eta'\pi^0)/\Gamma_{\text{total}}$ Γ_{111}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.1 \times 10^{-5}$	90	BEHRENS 98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\eta'\eta')/\Gamma_{\text{total}}$ Γ_{112}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<4.7 \times 10^{-5}$	90	BEHRENS 98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\eta'\eta)/\Gamma_{\text{total}}$ Γ_{113}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.7 \times 10^{-5}$	90	BEHRENS 98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\eta'\rho^0)/\Gamma_{\text{total}}$ Γ_{114}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.3 \times 10^{-5}$	90	BEHRENS 98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\eta\rho^0)/\Gamma_{\text{total}}$ Γ_{115}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.3 \times 10^{-5}$	90	BEHRENS 98	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\omega\eta)/\Gamma_{\text{total}}$ Γ_{116}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<1.2 \times 10^{-5}$	90	[236] BERGFELD 98	CLE2

[236] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\omega\eta')/\Gamma_{\text{total}}$ Γ_{117}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<6.0 \times 10^{-5}$	90	[237] BERGFELD 98	CLE2

[237] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\omega\rho^0)/\Gamma_{total}$ Γ_{118}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<1.1\times10^{-5}$	90	[238] BERGFELD 98	CLE2

[238] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\omega\omega)/\Gamma_{total}$ Γ_{119}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<1.9\times10^{-5}$	90	[239] BERGFELD 98	CLE2

[239] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\phi\pi^0)/\Gamma_{total}$ Γ_{120}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<0.5\times10^{-5}$	90	[240] BERGFELD 98	CLE2

[240] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\phi\eta)/\Gamma_{total}$ Γ_{121}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<0.9\times10^{-5}$	90	[241] BERGFELD 98	CLE2

[241] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\phi\eta')/\Gamma_{total}$ Γ_{122}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<3.1\times10^{-5}$	90	[242] BERGFELD 98	CLE2

[242] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\phi\rho^0)/\Gamma_{total}$ Γ_{123}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<1.3\times10^{-5}$	90	[243] BERGFELD 98	CLE2

[243] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\phi\omega)/\Gamma_{total}$ Γ_{124}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*
$<2.1\times10^{-5}$	90	[244] BERGFELD 98	CLE2

[244] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\phi\phi)/\Gamma_{total}$ Γ_{125}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.2\times10^{-5}$ (CL = 90%) [$<3.9\times10^{-5}$ (CL = 90%) OUR 1998 BEST LIMIT]				
$<1.2\times10^{-5}$	90	[245] BERGFELD 98	CLE2	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<3.9\times10^{-5}$	90	ASNER 96	CLE2	$e^+e^-\to\Upsilon(4S)$

[245] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{total}$ Γ_{126}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<7.2\times10^{-4}$	90	[246] ALBRECHT 90B	ARG	$e^+e^-\to\Upsilon(4S)$

[246] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\rho^0\pi^0)/\Gamma_{\text{total}}$ Γ_{127}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.4 \times 10^{-5}$	90	ASNER 96	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<4.0 \times 10^{-4}$	90	[247] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$

[247] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\rho^\mp\pi^\pm)/\Gamma_{\text{total}}$ Γ_{128}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<8.8 \times 10^{-5}$	90	ASNER 96	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<5.2 \times 10^{-4}$	90	[248] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$
$<5.2 \times 10^{-3}$	90	[249] BEBEK 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[248] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

[249] BEBEK 87 reports $< 6.1 \times 10^{-3}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{129}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.3 \times 10^{-4}$	90	[250] ADAM 96D	DLPH	$e^+e^- \to Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2.8 \times 10^{-4}$	90	[251] ABREU 95N	DLPH	Sup. by ADAM 96D
$<6.7 \times 10^{-4}$	90	[252] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$

[250] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$.

[251] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12.

[252] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\rho^0\rho^0)/\Gamma_{\text{total}}$ Γ_{130}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.8 \times 10^{-4}$	90	[253] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2.9 \times 10^{-4}$	90	[254] BORTOLETTO 89	CLEO	$e^+e^- \to \Upsilon(4S)$
$<4.3 \times 10^{-4}$	90	[254] BEBEK 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[253] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

[254] Paper assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(a_1(1260)^\mp\pi^\pm)/\Gamma_{\text{total}}$ Γ_{131}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<4.9 \times 10^{-4}$	90	[255] BORTOLETTO 89	CLEO	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<6.3 \times 10^{-4}$	90	[256] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$
$<1.0 \times 10^{-3}$	90	[255] BEBEK 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[255] Paper assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[256] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(a_2(1320)^{\mp}\pi^{\pm})/\Gamma_{\rm total}$ Γ_{132}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.0 \times 10^{-4}$	90	[257] BORTOLETTO 89	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<1.4 \times 10^{-3}$	90	[257] BEBEK 87	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[257] Paper assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\pi^+\pi^-\pi^0\pi^0)/\Gamma_{\rm total}$ Γ_{133}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.1 \times 10^{-3}$	90	[258] ALBRECHT 90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[258] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\rho^+\rho^-)/\Gamma_{\rm total}$ Γ_{134}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.2 \times 10^{-3}$	90	[259] ALBRECHT 90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[259] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(a_1(1260)^0\pi^0)/\Gamma_{\rm total}$ Γ_{135}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.1 \times 10^{-3}$	90	[260] ALBRECHT 90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[260] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\omega\pi^0)/\Gamma_{\rm total}$ Γ_{136}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.4 \times 10^{-5}$ (CL = 90%) [$<4.6 \times 10^{-4}$ (CL = 90%) OUR 1998 BEST LIMIT]				
$<1.4 \times 10^{-5}$	90	[261] BERGFELD 98	CLE2	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<4.6 \times 10^{-4}$	90	[262] ALBRECHT 90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[261] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[262] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\pi^+\pi^+\pi^-\pi^-\pi^0)/\Gamma_{\rm total}$ Γ_{137}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<9.0 \times 10^{-3}$	90	[263] ALBRECHT 90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[263] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(a_1(1260)^+\rho^-)/\Gamma_{\rm total}$ Γ_{138}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.4 \times 10^{-3}$	90	[264] ALBRECHT 90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[264] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(a_1(1260)^0\rho^0)/\Gamma_{\rm total}$ Γ_{139}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.4 \times 10^{-3}$	90	[265] ALBRECHT 90B	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[265] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-)/\Gamma_{\text{total}}$ Γ_{140}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.0 \times 10^{-3}$	90	[266] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$

[266] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(a_1(1260)^+ a_1(1260)^-)/\Gamma_{\text{total}}$ Γ_{141}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.8 \times 10^{-3}$	90	[267] BORTOLETTO 89	CLEO	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<6.0 \times 10^{-3}$	90	[268] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$

[267] BORTOLETTO 89 reports $< 3.2 \times 10^{-3}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[268] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_{142}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.1 \times 10^{-2}$	90	[269] ALBRECHT 90B	ARG	$e^+e^- \to \Upsilon(4S)$

[269] ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(4S)$.

$\Gamma(p\overline{p})/\Gamma_{\text{total}}$ Γ_{143}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<7.0 \times 10^{-6}$ (CL = 90%) [$<1.8 \times 10^{-5}$ (CL = 90%) OUR 1998 BEST LIMIT]				
$<7.0 \times 10^{-6}$	90	[270] COAN 99	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<1.8 \times 10^{-5}$	90	[271] BUSKULIC 96V	ALEP	$e^+e^- \to Z$
$<3.5 \times 10^{-4}$	90	[272] ABREU 95N	DLPH	Sup. by ADAM 96D
$<3.4 \times 10^{-5}$	90	[273] BORTOLETTO 89	CLEO	$e^+e^- \to \Upsilon(4S)$
$<1.2 \times 10^{-4}$	90	[274] ALBRECHT 88F	ARG	$e^+e^- \to \Upsilon(4S)$
$<1.7 \times 10^{-4}$	90	[273] BEBEK 87	CLEO	$e^+e^- \to \Upsilon(4S)$

[270] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[271] BUSKULIC 96V assumes PDG 96 production fractions for B^0, B^+, B_s, b baryons.

[272] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12.

[273] Paper assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[274] ALBRECHT 88F reports $< 1.3 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(p\overline{p}\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{144}/Γ

VALUE (units 10^{-4})	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
<2.5	90	[275] BEBEK 89	CLEO	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<9.5	90	[276] ABREU 95N	DLPH	Sup. by ADAM 96D
$5.4 \pm 1.8 \pm 2.0$		[277] ALBRECHT 88F	ARG	$e^+e^- \to \Upsilon(4S)$

[275] BEBEK 89 reports $< 2.9 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[276] Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12.

[277] ALBRECHT 88F reports $6.0 \pm 2.0 \pm 2.2$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(p\overline{\Lambda}\pi^-)/\Gamma_{\text{total}}$ Γ_{145}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.3 \times 10^{-5}$ (CL = 90%)		[$<1.8 \times 10^{-4}$ (CL = 90%) OUR 1998 BEST LIMIT]			
$<1.3 \times 10^{-5}$	90	[278] COAN	99	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$<1.8 \times 10^{-4}$	90	[279] ALBRECHT	88F	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[278] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

[279] ALBRECHT 88F reports $< 2.0 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\overline{\Lambda}\Lambda)/\Gamma_{\text{total}}$ Γ_{146}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<3.9 \times 10^{-6}$	90	[280] COAN	99	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[280] Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$.

$\Gamma(\Delta^0\overline{\Delta}^0)/\Gamma_{\text{total}}$ Γ_{147}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.0015	90	[281] BORTOLETTO	89	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[281] BORTOLETTO 89 reports < 0.0018 assuming $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\Delta^{++}\Delta^{--})/\Gamma_{\text{total}}$ Γ_{148}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<1.1 \times 10^{-4}$	90	[282] BORTOLETTO	89	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[282] BORTOLETTO 89 reports $< 1.3 \times 10^{-4}$ assuming $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\overline{\Sigma}_c^{--}\Delta^{++})/\Gamma_{\text{total}}$ Γ_{149}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.0010	90	[283] PROCARIO	94	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[283] PROCARIO 94 reports < 0.0012 for $B(\Lambda_c^+ \rightarrow pK^-\pi^+) = 0.043$. We rescale to our best value $B(\Lambda_c^+ \rightarrow pK^-\pi^+) = 0.050$.

$\Gamma(\overline{\Lambda}_c^- p\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{150}/Γ

VALUE (units 10^{-3})	*DOCUMENT ID*		*TECN*	*COMMENT*
$1.33^{+0.46}_{-0.42} \pm 0.37$	[284] FU	97	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[284] FU 97 uses PDG 96 values of Λ_c branching fraction.

$\Gamma(\overline{\Lambda}_c^- p)/\Gamma_{\text{total}}$ Γ_{151}/Γ

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
$<2.1 \times 10^{-4}$	90	[285] FU	97	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$

[285] FU 97 uses PDG 96 values of Λ_c branching ratio.

$\Gamma(\overline{\Lambda}_c^- p \pi^0)/\Gamma_{\text{total}}$ Γ_{152}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{<5.9 \times 10^{-4}}$	90	[286] FU 97	CLE2	$e^+e^- \to \Upsilon(4S)$

[286] FU 97 uses PDG 96 values of Λ_c branching ratio.

$\Gamma(\overline{\Lambda}_c^- p \pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_{153}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{<5.07 \times 10^{-3}}$	90	[287] FU 97	CLE2	$e^+e^- \to \Upsilon(4S)$

[287] FU 97 uses PDG 96 values of Λ_c branching ratio.

$\Gamma(\overline{\Lambda}_c^- p \pi^+\pi^-\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{154}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{<2.74 \times 10^{-3}}$	90	[288] FU 97	CLE2	$e^+e^- \to \Upsilon(4S)$

[288] FU 97 uses PDG 96 values of Λ_c branching ratio.

$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{155}/Γ

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{<3.9 \times 10^{-5}}$	90	[289] ACCIARRI 95I	L3	$e^+e^- \to Z$

[289] ACCIARRI 95I assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_s} = 12.0 \pm 3.0\%$.

$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ Γ_{156}/Γ

Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak interactions.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{<5.9 \times 10^{-6}}$	90	AMMAR 94	CLE2	$e^+e^- \to \Upsilon(4S)$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<1.4 \times 10^{-5}$	90	[290] ACCIARRI 97B	L3	$e^+e^- \to Z$
$<2.6 \times 10^{-5}$	90	[291] AVERY 89B	CLEO	$e^+e^- \to \Upsilon(4S)$
$<7.6 \times 10^{-5}$	90	[292] ALBRECHT 87D	ARG	$e^+e^- \to \Upsilon(4S)$
$<6.4 \times 10^{-5}$	90	[293] AVERY 87	CLEO	$e^+e^- \to \Upsilon(4S)$
$<3 \times 10^{-4}$	90	GILES 84	CLEO	Repl. by AVERY 87

[290] ACCIARRI 97B assume PDG 96 production fractions for B^+, B^0, B_s, and Λ_b.

[291] AVERY 89B reports $< 3 \times 10^{-5}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[292] ALBRECHT 87D reports $< 8.5 \times 10^{-5}$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

[293] AVERY 87 reports $< 8 \times 10^{-5}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ Γ_{157}/Γ

Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak interactions.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$\mathbf{<6.8 \times 10^{-7}}$	90	[294] ABE 98	CDF	$p\overline{p}$ at 1.8 TeV

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

$<4.0 \times 10^{-5}$	90	ABBOTT 98B	D0	$p\overline{p}$ 1.8 TeV
$<1.0 \times 10^{-5}$	90	[295] ACCIARRI 97B	L3	$e^+e^- \rightarrow Z$
$<1.6 \times 10^{-6}$	90	[296] ABE 96L	CDF	Repl. by ABE 98
$<5.9 \times 10^{-6}$	90	AMMAR 94	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
$<8.3 \times 10^{-6}$	90	[297] ALBAJAR 91C	UA1	$E_{\text{cm}}^{p\overline{p}}$= 630 GeV
$<1.2 \times 10^{-5}$	90	[298] ALBAJAR 91C	UA1	$E_{\text{cm}}^{p\overline{p}}$= 630 GeV
$<4.3 \times 10^{-5}$	90	[299] AVERY 89B	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
$<4.5 \times 10^{-5}$	90	[300] ALBRECHT 87D	ARG	$e^+e^- \rightarrow \Upsilon(4S)$
$<7.7 \times 10^{-5}$	90	[301] AVERY 87	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
$<2 \times 10^{-4}$	90	GILES 84	CLEO	Repl. by AVERY 87

[294] ABE 98 assumes production of $\sigma(B^0) = \sigma(B^+)$ and $\sigma(B_s)/\sigma(B^0) = 1/3$. They normalize to their measured $\sigma(B^0, p_T(B) > 6, |y| < 1.0) = 2.39 \pm 0.32 \pm 0.44\ \mu$b.

[295] ACCIARRI 97B assume PDG 96 production fractions for B^+, B^0, B_s, and Λ_b.

[296] ABE 96L assumes equal B^0 and B^+ production. They normalize to their measured $\sigma(B^+,\ p_T(B) > 6\ \text{GeV}/c,\ |y| < 1) = 2.39 \pm 0.54\ \mu$b.

[297] B^0 and B_s^0 are not separated.

[298] Obtained from unseparated B^0 and B_s^0 measurement by assuming a B^0:B_s^0 ratio 2:1.

[299] AVERY 89B reports $< 5 \times 10^{-3}$ assuming the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[300] ALBRECHT 87D reports $< 5 \times 10^{-5}$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

[301] AVERY 87 reports $< 9 \times 10^{-5}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^0 e^+ e^-)/\Gamma_{\text{total}}$ Γ_{158}/Γ

Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak interactions.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.0 \times 10^{-4}$	90	ALBRECHT 91E	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

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

$<5.2 \times 10^{-4}$	90	[302] AVERY 87	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[302] AVERY 87 reports $< 6.5 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$ Γ_{159}/Γ

Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak interactions.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.6 \times 10^{-4}$	90	[303] AVERY 87	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

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

$<5.2 \times 10^{-4}$	90	ALBRECHT 91E	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

[303] AVERY 87 reports $< 4.5 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(K^*(892)^0 e^+ e^-)/\Gamma_{\text{total}}$ Γ_{160}/Γ

Test for $\Delta B = 1$ weak neutral current.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<2.9 \times 10^{-4}$	90	ALBRECHT 91E	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

$\Gamma(K^*(892)^0\mu^+\mu^-)/\Gamma_{\text{total}}$ Γ_{161}/Γ

Test for $\Delta B = 1$ weak neutral current.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<4.0\times10^{-6}$ (CL = 90%)	[$<2.3\times10^{-5}$ (CL = 90%) OUR 1998 BEST LIMIT]			
$<4.0\times10^{-6}$	90	[304] AFFOLDER 99B	CDF	$p\overline{p}$ at 1.8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<2.5\times10^{-5}$	90	[305] ABE 96L	CDF	Repl. by AFFOLDER 99B
$<2.3\times10^{-5}$	90	[306] ALBAJAR 91C	UA1	$E^{p\overline{p}}_{\text{cm}}$= 630 GeV
$<3.4\times10^{-4}$	90	ALBRECHT 91E	ARG	$e^+e^- \to \Upsilon(4S)$

[304] AFFOLDER 99B measured relative to $B^0 \to J/\psi(1S)K^*(892)^0$.

[305] ABE 96L measured relative to $B^0 \to J/\psi(1S)K^*(892)^0$ using PDG 94 branching ratios.

[306] ALBAJAR 91C assumes 36% of $\overline{b}$ quarks give B^0 mesons.

$\Gamma(K^*(892)^0\nu\overline{\nu})/\Gamma_{\text{total}}$ Γ_{162}/Γ

Test for $\Delta B = 1$ weak neutral current.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<1.0\times10^{-3}$	90	[307] ADAM 96D	DLPH	$e^+e^- \to Z$

[307] ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$.

$\Gamma(e^\pm\mu^\mp)/\Gamma_{\text{total}}$ Γ_{163}/Γ

Test of lepton family number conservation.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<3.5\times10^{-6}$ (CL = 90%)	[$<5.9\times10^{-6}$ (CL = 90%) OUR 1998 BEST LIMIT]			
$<3.5\times10^{-6}$	90	ABE 98V	CDF	$p\overline{p}$ at 1.8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$<1.6\times10^{-5}$	90	[308] ACCIARRI 97B	L3	$e^+e^- \to Z$
$<5.9\times10^{-6}$	90	AMMAR 94	CLE2	$e^+e^- \to \Upsilon(4S)$
$<3.4\times10^{-5}$	90	[309] AVERY 89B	CLEO	$e^+e^- \to \Upsilon(4S)$
$<4.5\times10^{-5}$	90	[310] ALBRECHT 87D	ARG	$e^+e^- \to \Upsilon(4S)$
$<7.7\times10^{-5}$	90	[311] AVERY 87	CLEO	$e^+e^- \to \Upsilon(4S)$
$<3\times10^{-4}$	90	GILES 84	CLEO	Repl. by AVERY 87

[308] ACCIARRI 97B assume PDG 96 production fractions for B^+, B^0, B_s, and Λ_b.

[309] Paper assumes the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%.

[310] ALBRECHT 87D reports $< 5\times10^{-5}$ assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%.

[311] AVERY 87 reports $< 9\times10^{-5}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.

$\Gamma(e^\pm\tau^\mp)/\Gamma_{\text{total}}$ Γ_{164}/Γ

Test of lepton family number conservation.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<5.3\times10^{-4}$	90	AMMAR 94	CLE2	$e^+e^- \to \Upsilon(4S)$

$\Gamma(\mu^\pm\tau^\mp)/\Gamma_{\text{total}}$ Γ_{165}/Γ

Test of lepton family number conservation.

VALUE	*CL%*	*DOCUMENT ID*	*TECN*	*COMMENT*
$<8.3\times10^{-4}$	90	AMMAR 94	CLE2	$e^+e^- \to \Upsilon(4S)$

POLARIZATION IN B^0 DECAY

Γ_L/Γ in $B^0 \to J/\psi(1S)K^*(892)^0$

$\Gamma_L/\Gamma = 1[0]$ would indicate that $B^0 \to J/\psi(1S)K^*(892)^0$ followed by $K^*(892)^0 \to K^0_S\pi^0$ is a pure *CP* eigenstate with $CP = -1[+1]$.

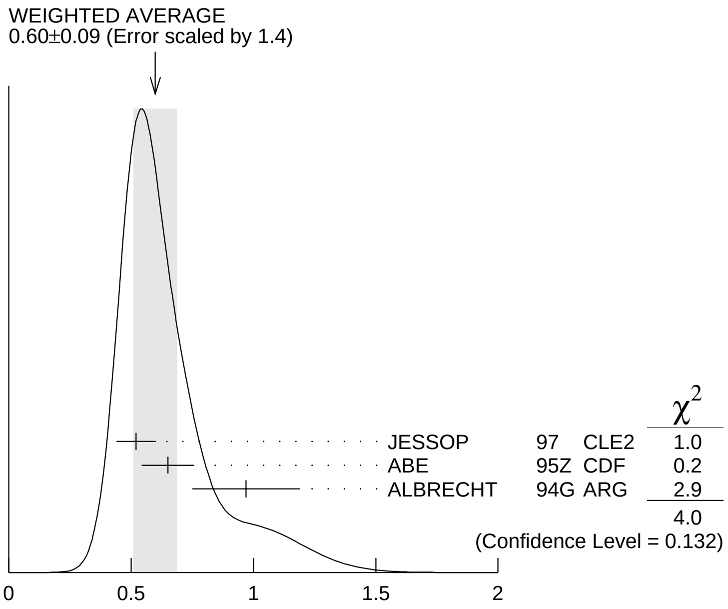
VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.60±0.09 OUR AVERAGE	Error includes scale factor of 1.4. See the ideogram below.				
0.52±0.07±0.04		[312] JESSOP	97	CLE2	$e^+e^- \to \Upsilon(4S)$
0.65±0.10±0.04	65	ABE	95Z	CDF	$p\overline{p}$ at 1.8 TeV
0.97±0.16±0.15	13	[313] ALBRECHT	94G	ARG	$e^+e^- \to \Upsilon(4S)$

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

0.80±0.08±0.05	42	[313] ALAM	94	CLE2	Sup. by JESSOP 97

[312] JESSOP 97 is the average over a mixture of B^0 and B^+ decays. The *P*-wave fraction is found to be 0.16 ± 0.08 ± 0.04.

[313] Averaged over an admixture of B^0 and B^+ decays.



Γ_L/Γ in $B^0 \to J/\psi(1S)K^*(892)^0$

Γ_L/Γ in $B^0 \to D^{*-}\rho^+$

VALUE	*EVTS*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.93±0.05±0.05	76	ALAM	94	CLE2	$e^+e^- \to \Upsilon(4S)$

B^0–$\overline{B}^0$ MIXING

Written March 2000 by O. Schneider (Univ. of Lausanne)

Formalism in quantum mechanics

There are two neutral B^0–$\overline{B}^0$ meson systems, B_d–$\overline{B}_d$ and B_s–$\overline{B}_s$ (generically denoted B_q–$\overline{B}_q$, $q = s, d$), which exhibit the phenomenon of particle-antiparticle mixing [1]. Such a system is produced in one of its two possible states of well-defined flavor: $|B^0\rangle$ ($\overline{b}q$) or $|\overline{B}^0\rangle$ ($b\overline{q}$). Due to flavor-changing interactions, this initial state evolves into a time-dependent quantum superposition of the two flavor states, $a(t)|B^0\rangle + b(t)|\overline{B}^0\rangle$, satisfying the equation

$$i\frac{\partial}{\partial t}\begin{pmatrix} a(t) \\ b(t) \end{pmatrix} = \left(\mathbf{M} - \tfrac{i}{2}\mathbf{\Gamma}\right)\begin{pmatrix} a(t) \\ b(t) \end{pmatrix}, \tag{1}$$

where $\mathbf{M}$ and $\mathbf{\Gamma}$, known as the mass and decay matrices, describe the dispersive and absorptive parts of B^0–$\overline{B}^0$ mixing. These matrices are hermitian, and CPT invariance requires $M_{11} = M_{22} \equiv M$ and $\Gamma_{11} = \Gamma_{22} \equiv \Gamma$, where M and Γ are the mass and decay width of the B^0 and $\overline{B}^0$ flavor states.

The two eigenstates of the effective hamiltonian matrix $(\mathbf{M} - \frac{i}{2}\mathbf{\Gamma})$ are given by

$$|B_\pm\rangle = p|B^0\rangle \pm q|\overline{B}^0\rangle\,, \tag{2}$$

and correspond to the eigenvalues

$$\lambda_\pm = \left(M - \tfrac{i}{2}\Gamma\right) \pm \frac{q}{p}\left(M_{12} - \tfrac{i}{2}\Gamma_{12}\right)\,, \tag{3}$$

where

$$\frac{q}{p} = \sqrt{\frac{M_{12}^* - \frac{i}{2}\Gamma_{12}^*}{M_{12} - \frac{i}{2}\Gamma_{12}}}\,. \tag{4}$$

We choose a convention where $\mathrm{Re}(q/p) > 0$ and $CP|B^0\rangle = |\overline{B}^0\rangle$.

An alternative notation is

$$|B_\pm\rangle = \frac{(1+\epsilon)|B^0\rangle \pm (1-\epsilon)|\overline{B}^0\rangle}{\sqrt{2(1+|\epsilon|^2)}} \qquad \text{with} \qquad \frac{1-\epsilon}{1+\epsilon} = \frac{q}{p}\,. \tag{5}$$

The time dependence of these eigenstates of well-defined masses $M_\pm = \mathrm{Re}(\lambda_\pm)$ and widths $\Gamma_\pm = -2\,\mathrm{Im}(\lambda_\pm)$ is given by the phases $e^{-i\lambda_\pm t} = e^{-iM_\pm t}e^{-\frac{1}{2}\Gamma_\pm t}$: the evolution of a pure $|B^0\rangle$ or $|\overline{B}^0\rangle$ state at $t = 0$ is thus given by

$$|B^0(t)\rangle = g_+(t)\,|B^0\rangle + \frac{q}{p}\,g_-(t)\,|\overline{B}^0\rangle\,, \tag{6}$$

$$|\overline{B}^0(t)\rangle = g_+(t)\,|\overline{B}^0\rangle + \frac{p}{q}g_-(t)\,|B^0\rangle\,, \tag{7}$$

where

$$g_\pm(t) = \frac{1}{2}\left(e^{-i\lambda_+ t} \pm e^{-i\lambda_- t}\right)\,. \tag{8}$$

This means that the flavor states oscillate into each other with time-dependent probabilities proportional to

$$|g_\pm(t)|^2 = \frac{e^{-\Gamma t}}{2}\left[\cosh\!\left(\frac{\Delta\Gamma}{2}\,t\right) \pm \cos(\Delta m\,t)\right]\,, \tag{9}$$

where

$$\Delta m = |M_+ - M_-|\,, \qquad \Delta\Gamma = |\Gamma_+ - \Gamma_-|\,. \tag{10}$$

Time-integrated mixing probabilities are only well defined when considering decays to flavor-specific final states, *i.e.* final states f such that the instantaneous decay amplitudes $A_{\overline{f}} = \langle\overline{f}|H|B^0\rangle$ and $\overline{A}_f = \langle f|H|\overline{B}^0\rangle$, where H is the weak interaction hamiltonian, are both zero. Due to mixing, a produced B^0 can decay to the final state $\overline{f}$ (mixed event) in addition to the final state f (unmixed event). Restricting the sample to these two decay channels, the time-integrated mixing probability is given by

$$\begin{aligned}\chi_f^{B^0\to\overline{B}^0} &= \frac{\int_0^\infty |\langle\overline{f}|H|B^0(t)\rangle|^2dt}{\int_0^\infty |\langle\overline{f}|H|B^0(t)\rangle|^2dt + \int_0^\infty |\langle f|H|B^0(t)\rangle|^2dt} \\ &= \frac{|\xi_f|^2(x^2+y^2)}{|\xi_f|^2(x^2+y^2)+2+x^2-y^2}\,,\end{aligned} \tag{11}$$

where we have defined $\xi_f = \dfrac{q}{p}\dfrac{\overline{A}_{\overline{f}}}{A_f}$ and

$$x = \frac{\Delta m}{\Gamma}\,, \qquad y = \frac{\Delta\Gamma}{2\Gamma}\,. \tag{12}$$

The mixing probability $\chi_f^{\overline{B}^0\to B^0}$ for the case of a produced $\overline{B}^0$ is obtained by replacing ξ_f with $1/\xi_f$ in Eq. (11). It is different from $\chi_f^{B^0\to\overline{B}^0}$ if $|\xi_f|^2 \neq 1$, a condition reflecting non-invariance under the CP transformation. CP violation in the decay amplitudes is discussed elsewhere [2] and we assume $|\overline{A}_{\overline{f}}| = |A_f|$ from now on. The deviation of $|q/p|^2$ from 1, namely the quantity

$$1 - \left|\frac{q}{p}\right|^2 = \frac{4\,\mathrm{Re}(\epsilon)}{1+|\epsilon|^2} + \mathcal{O}\left(\left(\frac{\mathrm{Re}(\epsilon)}{1+|\epsilon|^2}\right)^2\right)\,, \tag{13}$$

describes CP violation in B^0–$\overline{B}^0$ mixing. As can be seen from Eq. (4), this can occur only if $M_{12} \neq 0$, $\Gamma_{12} \neq 0$ and if the phase difference between M_{12} and Γ_{12} is different from 0 or π.

In the absence of CP violation, $|q/p|^2 = 1$, $\mathrm{Re}(\epsilon) = 0$, the mass eigenstates are also CP eigenstates,

$$CP\,|B_\pm\rangle = \pm|B_\pm\rangle\,, \tag{14}$$

the phases $\varphi_{M_{12}} = \arg(M_{12})$ and $\varphi_{\Gamma_{12}} = \arg(\Gamma_{12})$ satisfy

$$\sin(\varphi_{M_{12}} - \varphi_{\Gamma_{12}}) = 0\,, \tag{15}$$

the mass and decay width differences reduce to

$$\Delta m = 2\,|M_{12}|\,, \qquad \Delta\Gamma = 2\,|\Gamma_{12}|\,, \tag{16}$$

and the time-integrated mixing probabilities $\chi_f^{B^0\to\overline{B}^0}$ and $\chi_f^{\overline{B}^0\to B^0}$ become both equal to

$$\chi = \frac{x^2 + y^2}{2(x^2+1)}\,. \tag{17}$$

Standard Model predictions and phenomenology

In the Standard Model, the transitions $B^0_q \to \overline{B}^0_q$ and $\overline{B}^0_q \to B^0_q$ are due to the weak interaction. They are described, at the lowest order, by the box diagrams involving two W bosons and two up-type quarks, as is the case for K^0–$\overline{K}^0$ mixing. However, the long range interactions arising from intermediate virtual states are negligible for the neutral B meson systems, because the large B mass is away from the region of hadronic resonances. The calculation of the dispersive and absorptive parts of the box diagrams yields the following predictions for the off-diagonal element of the mass and decay matrices [3],

$$M_{12} = -\frac{G_F^2 m_W^2 \eta_B m_{B_q} B_{B_q} f_{B_q}^2}{12\pi^2} S_0(m_t^2/m_W^2)\,(V_{tq}^* V_{tb})^2 \qquad (18)$$

$$\begin{aligned}\Gamma_{12} = {} & \frac{G_F^2 m_b^2 \eta'_B m_{B_q} B_{B_q} f_{B_q}^2}{8\pi} \\ & \times \left[(V_{tq}^* V_{tb})^2 + V_{tq}^* V_{tb} V_{cq}^* V_{cb}\ \mathcal{O}\left(\frac{m_c^2}{m_b^2}\right)\right. \\ & \left. \quad + (V_{cq}^* V_{cb})^2\ \mathcal{O}\left(\frac{m_c^4}{m_b^4}\right)\right] \end{aligned} \qquad (19)$$

where G_F is the Fermi constant, m_W the W mass, m_i the mass of quark i, and where $m_{B_q} = M$, f_{B_q} and B_{B_q} are the B^0_q mass, decay constant and bag parameter. The known function $S_0(x_t)$ can be approximated very well with $0.784\,x_t^{0.76}$ [4] and V_{ij} are the elements of the CKM matrix [5]. The QCD corrections η_B and η'_B are of order unity. The only non negligible contributions to M_{12} are from top-top diagrams. The phases of M_{12} and Γ_{12} satisfy

$$\varphi_{M_{12}} - \varphi_{\Gamma_{12}} = \pi + \mathcal{O}\left(\frac{m_c^2}{m_b^2}\right) \qquad (20)$$

implying that the mass eigenstates have mass and width differences of opposite signs. This means that, like in the K^0–$\overline{K}^0$ system, the "heavy" state with mass $M_{\rm heavy} = \max(M_+, M_-)$ has a smaller decay width than that of the "light" state with mass $M_{\rm light} = \min(M_+, M_-)$. We thus redefine

$$\Delta m = M_{\rm heavy} - M_{\rm light}\,, \qquad \Delta\Gamma = \Gamma_{\rm light} - \Gamma_{\rm heavy}\,, \tag{21}$$

where Δm is positive by definition and $\Delta\Gamma$ is expected to be positive in the Standard Model.

Furthermore, since Γ_{12} is, like M_{12}, dominated by the top-top diagrams, the quantity

$$\left|\frac{\Gamma_{12}}{M_{12}}\right| \simeq \frac{3\pi}{2}\frac{m_b^2}{m_W^2}\frac{1}{S_0(m_t^2/m_W^2)} \sim \mathcal{O}\left(\frac{m_b^2}{m_t^2}\right) \tag{22}$$

is small, and a power expansion of $|q/p|^2$ yields

$$\left|\frac{q}{p}\right|^2 = 1 + \left|\frac{\Gamma_{12}}{M_{12}}\right| \sin(\varphi_{M_{12}} - \varphi_{\Gamma_{12}}) + \mathcal{O}\left(\left|\frac{\Gamma_{12}}{M_{12}}\right|^2\right)\,. \tag{23}$$

Therefore, considering both Eqs. (20) and (22), the CP-violating parameter

$$1 - \left|\frac{q}{p}\right|^2 \simeq {\rm Im}\left(\frac{\Gamma_{12}}{M_{12}}\right) \tag{24}$$

is expected to be tiny: $\sim \mathcal{O}(10^{-3})$ for the B_d–$\overline{B}_d$ system and $\lesssim \mathcal{O}(10^{-4})$ for the B_s–$\overline{B}_s$ system [6].

In the approximation of negligible CP violation in the mixing, the ratio $\Delta\Gamma/\Delta m$ is equal to the small quantity $|\Gamma_{12}/M_{12}|$ of Eq. (22); it is hence independent of CKM matrix elements, *i.e.* the same for the B_d–$\overline{B}_d$ and B_s–$\overline{B}_s$ systems. It can be calculated with lattice QCD techniques; typical results are $\sim 5 \times 10^{-3}$ with quoted uncertainties of 30% at least. Given the current experimental knowledge (discussed below) on the mixing parameter x,

$$\begin{cases} x_d = 0.73 \pm 0.03 & (B_d\text{–}\overline{B}_d \text{ system}) \\ x_s \gtrsim 20 \ \text{ at } 95\% \text{ CL} & (B_s\text{–}\overline{B}_s \text{ system}) \end{cases} , \tag{25}$$

the Standard Model thus predicts that $\Delta\Gamma/\Gamma$ is very small for the B_d–$\overline{B}_d$ system (below 1%), but may be quite large for the B_s–$\overline{B}_s$ system (up to $\sim$ 20%). This width difference is caused by the existence of final states to which both the B^0_q and $\overline{B}^0_q$ mesons can decay. Such decays involve $b \to c\overline{c}q$ quark-level transitions, which are Cabibbo-suppressed if $q = d$ and Cabibbo-allowed if $q = s$. If the final states common to B^0_s and $\overline{B}^0_s$ are predominantly CP-even as discussed in Ref. 7, then the B_s–$\overline{B}_s$ mass eigenstate with the largest decay width corresponds to the CP-even eigenstate. Taking Eq. (21) into account, one thus expects $\Gamma_{\text{light}} = \Gamma_+$ and

$$\Delta m_s = M_- - M_+ > 0\,, \qquad \Delta\Gamma_s = \Gamma_+ - \Gamma_- > 0\,. \tag{26}$$

Experimental issues and methods for oscillation analyses

Time-integrated measurements of B^0–$\overline{B}^0$ mixing were published for the first time in 1987 by UA1 [8] and ARGUS [9], and since then by many different experiments. These are typically based on counting same-sign and opposite-sign lepton pairs from the semileptonic decay of the produced $b\overline{b}$ pairs. At high energy colliders, such analyses cannot easily separate the B_d and B_s contributions, therefore experiments at $\Upsilon(4S)$ machines are best suited to measure χ_d.

However, better sensitivity is obtained from time-dependent analyses aimed at the direct measurement of the oscillation frequencies Δm_d and Δm_s, from the proper time distributions of B_d or B_s candidates identified through their decay in (mostly) flavor-specific modes and suitably tagged as mixed or unmixed. This is particularly true for the B_s–$\overline{B}_s$ system where the large value of x_s implies maximal mixing, *i.e.* $\chi_s \simeq 1/2$. In such analyses, performed at high-energy colliders, the neutral B mesons are either partially reconstructed from a charm meson, or selected from a lepton with high transverse momentum with respect to the b jet, or selected from a reconstructed displaced vertex. The proper time $t = \frac{m_B}{p} L$ is measured from the distance L between the production vertex and the B decay vertex, as measured with a silicon vertex detector, and from an estimate of the B momentum p.

The statistical significance $\mathcal{S}$ of an oscillation signal can be approximated as [10]

$$\mathcal{S} \approx \sqrt{N/2}\, f_{\rm sig}\, (1 - 2\eta)\, e^{-(\Delta m\, \sigma_t)^2/2}\,, \tag{27}$$

where N and $f_{\rm sig}$ are the number of candidates and the fraction of signal in the selected sample, η is the mistag probability, and σ_t is the proper time resolution. The quantity $\mathcal{S}$ decreases very quickly as Δm increases; this dependence is controlled by σ_t, which is therefore a critical parameter for Δm_s analyses. The proper time resolution $\sigma_t \sim \frac{m_B}{\langle p \rangle} \sigma_L \oplus t \frac{\sigma_p}{p}$ includes a constant contribution due to the decay length resolution σ_L (typically 0.1–0.3 ps), and a term due to the relative momentum resolution $\frac{\sigma_p}{p}$ (typically 10–20% for partially reconstructed decays), which increases with proper time.

In order to tag a B candidate as mixed or unmixed, it is necessary to determine its flavor state both at production (initial state) and at decay (final state). The initial and final state mistag probabilities, η_i and η_f, degrade $\mathcal{S}$ by a total factor $(1-2\eta) = (1-2\eta_i)(1-2\eta_f)$. In inclusive lepton analyses, the final state is tagged by the charge of the lepton from $b \to \ell^-$ decays; the biggest contribution to η_f is then due to $\overline{b} \to \overline{c} \to \ell^-$ decays. Alternatively, the charge of a reconstructed charm meson (D^{*-} from B_d^0 or D_s^- from B_s^0), or that of a kaon thought to come from a $b \to c \to s$ decay [11], can be used. For fully inclusive analyses based on topological vertexing, final state tagging techniques include jet charge [12] and charge dipole methods [11].

The initial state tags are somewhat less dependent on the procedure used to select B candidates. They can be divided in two groups: the ones that tag the initial charge of the $\overline{b}$ quark contained in the B candidate itself (same-side tag), and the ones that tag the initial charge of the other b quark produced in the event (opposite-side tag). On the same side, the charge of a track from the primary vertex is correlated with the production state of the B if that track is a decay product of a B^{**} state or the first particle in the fragmentation chain [13,14]. Jet charge techniques work on both sides. Finally, the charge of a lepton from $b \to \ell^-$ or of a kaon from $b \to c \to s$ can be used as opposite side tags, keeping in mind that their performance depends on integrated mixing. At SLC, the beam polarization produced a sizeable forward-backward asymmetry in the $Z \to b\overline{b}$ decays and provided another very interesting and effective initial state tag based on the polar angle of the B candidate [11]. Initial state tags have also been combined to reach $\eta_i \sim 26\%$ at LEP [14,15] or even 16% at SLD [11] with full efficiency. The equivalent figure at CDF is currently $\sim 40\%$ [16].

In the absence of experimental evidence for a width difference, and since $\Delta\Gamma/\Delta m$ is predicted to be very small, oscillation analyses typically neglect $\Delta\Gamma$ and describe the data with the physics functions $\Gamma e^{-\Gamma t}(1 \pm \cos \Delta m t)/2$. As can be seen from Eq. (9), a non zero value of $\Delta\Gamma$ would effectively reduce the oscillation amplitude with a small time-dependent factor that would be very difficult to distinguish from time resolution effects. Whereas measurements of Δm_d are usually extracted from the data using a maximum likelihood fit, no significant B_s–$\overline{B}_s$ oscillations have been seen so far, and all B_s analyses set lower limits on Δm_s. The original technique used to set such limits was to study the likelihood as a function of Δm_s. However, these limits turned out to be difficult to combine. A method was therefore developed [10], in which a B_s oscillation amplitude $\mathcal{A}$ is measured at each fixed value of Δm_s, using a maximum likelihood fit based on the functions $\Gamma_s e^{-\Gamma_s t}(1 \pm \mathcal{A} \cos \Delta m_s t)/2$. To a very good approximation, the statistical uncertainty on $\mathcal{A}$ is Gaussian and equal to $1/\mathcal{S}$ [10]. Measurements of $\mathcal{A}$ performed at a given value of Δm_s can be averaged easily. If $\Delta m_s = \Delta m_s^{\rm true}$, one expects $\mathcal{A} = 1$ within the total uncertainty $\sigma_{\mathcal{A}}$; however, if Δm_s is far from its true value, a measurement consistent with $\mathcal{A} = 0$ is expected. A value of Δm_s can be excluded at 95% CL if $\mathcal{A} + 1.645\,\sigma_{\mathcal{A}} \leq 1$. If $\Delta m_s^{\rm true}$ is very large, one expects $\mathcal{A} = 0$, and all values of Δm_s such that $1.645\,\sigma_{\mathcal{A}}(\Delta m_s) < 1$ are expected to be excluded at 95% CL. Because of the proper time resolution, the quantity $\sigma_{\mathcal{A}}(\Delta m_s)$ is an increasing function of Δm_s and one therefore expects to be able to exclude individual Δm_s values up to $\Delta m_s^{\rm sens}$, where $\Delta m_s^{\rm sens}$, called here the sensitivity of the analysis, is defined by $1.645\,\sigma_{\mathcal{A}}(\Delta m_s^{\rm sens}) = 1$.

B_d *mixing studies*

Many B_d–$\overline{B}_d$ oscillations analyses have been performed by the ALEPH [17,12], CDF [13,18], DELPHI [19], L3 [20], OPAL [21] and SLD [11] collaborations. Although a variety of different techniques have been used, the Δm_d results have remarkably similar precision. The systematic uncertainties are not negligible; they are often dominated by sample composition, mistag probability, or b-hadron lifetime contributions. Before being combined, the measurements are adjusted on the basis of a common set of input values, including the b-hadron lifetimes and fractions published in this *Review*. Some measurements are statistically correlated. Systematic correlations arise both from common physics sources (fragmentation fractions, lifetimes, branching ratios of b hadrons), and from purely experimental or algorithmic effects (efficiency, resolution, tagging, background description). Combining all published measurements [17,13,19,20,21] and accounting for all identified correlations as described in Ref. 22 yields $\Delta m_d = 0.478 \pm 0.012(\text{stat}) \pm 0.013(\text{syst})\ \text{ps}^{-1}$.

On the other hand, ARGUS and CLEO have published time-integrated measurements based on semileptonic decays [23,24], which average to $\chi_d^{\Upsilon(4S)} = 0.156 \pm 0.024$. The width difference $\Delta\Gamma_d$ could in principle be extracted from the measured value of Γ_d, and the above averages for Δm_d and χ_d (see Eqs. (12) and (17)). The results are however compatible with $\Delta\Gamma_d = 0$, and their precision is still insufficient to provide an interesting constraint. Neglecting $\Delta\Gamma_d$ and using the measured B_d lifetime, the Δm_d and χ_d results are combined to yield the world average

$$\Delta m_d = 0.472 \pm 0.017\ \text{ps}^{-1} \tag{28}$$

or, equivalently,

$$\chi_d = 0.174 \pm 0.009\,. \tag{29}$$

Evidence for CP violation in B_d mixing has been searched for, both with semileptonic and inclusive B_d decays, in samples where the initial flavor state is tagged. In the semileptonic case, where the final state tag is also available, the following asymmetry

$$\frac{N(\overline{B}{}^0_d(t) \to \ell^+\nu_\ell X) - N(B^0_d(t) \to \ell^-\overline{\nu}_\ell X)}{N(\overline{B}{}^0_d(t) \to \ell^+\nu_\ell X) + N(B^0_d(t) \to \ell^-\overline{\nu}_\ell X)}$$

$$= a_{CP} \simeq 1 - |q/p|^2_d \simeq \frac{4\mathrm{Re}(\epsilon_d)}{1+|\epsilon_d|^2} \tag{30}$$

has been measured, either in time-integrated analyses at CLEO [24] and CDF [25], or in more recent and sensitive time-dependent analyses at LEP [26,27,28]. In the inclusive case, also investigated at LEP [29,27,30], no final state tag is used, and the asymmetry [31]

$$\frac{N(B^0_d(t) \to \mathrm{all}) - N(\overline{B}{}^0_d(t) \to \mathrm{all})}{N(B^0_d(t) \to \mathrm{all}) + N(\overline{B}{}^0_d(t) \to \mathrm{all})}$$

$$\simeq a_{CP}\left[\frac{x_d}{2}\sin(\Delta m_d\, t) - \sin^2\left(\frac{\Delta m_d\, t}{2}\right)\right] \tag{31}$$

must be measured as a function of the proper time to extract information on CP violation. In all cases asymmetries compatible with zero have been found, with a precision limited by the available statistics. A simple average of all published and preliminary results [24–30] neglecting small possible statistical correlations and assuming half of the systematics to be correlated, is $a_{CP} = -0.017 \pm 0.016$, a result which does not yet constrain the Standard Model.

The Δm_d result of Eq. (28) provides an estimate of $|M_{12}|$ and can be used, together with Eqs. (16) and (18), to extract the modulus of the CKM matrix element V_{td} within the Standard Model [32]. The main experimental uncertainties on the resulting estimate of $|V_{td}|$ come from m_t and Δm_d; however, these are at present completely dominated by the

15–20% uncertainty usually quoted on the hadronic matrix element $f_{B_d}\sqrt{B_{B_d}} \sim 200$ MeV obtained from lattice QCD calculations [33].

B_s *mixing studies*

B_s–$\overline{B}_s$ oscillation has been the subject of many recent studies from ALEPH [14], CDF [34], DELPHI [35,15], OPAL [36] and SLD [37]. No oscillation signal has been found so far. The most sensitive analyses appear to be the ones based on inclusive lepton samples, and on samples where a lepton and a D_s meson have been reconstructed in the same jet. All results are limited by the available statistics. These are combined to yield the amplitudes $\mathcal{A}$ shown in Fig. 1 as a function of Δm_s [22].

As before, the individual results have been adjusted to common physics inputs, and all known correlations have been accounted for; furthermore, the sensitivities of the inclusive analyses, which depend directly through Eq. (27) on the assumed fraction f_s of B_s mesons in an unbiased sample of weakly-decaying b hadrons, have been rescaled to a common value of $f_s = 0.100 \pm 0.012$ [22]. The combined sensitivity for 95% CL exclusion of Δm_s values is found to be 14.5 ps^{-1}. All values of Δm_s below 14.3 ps^{-1} are excluded at 95% CL, and no deviation from $\mathcal{A} = 0$ is seen in Fig. 1 that would indicate the observation of a signal.

Some Δm_s analyses are still preliminary [15,37]. Using only published results, the combined Δm_s result is

$$\Delta m_s > 10.6 \ \text{ps}^{-1} \qquad \text{at 95\% CL}\,, \tag{32}$$

with a sensitivity of 12.1 ps^{-1}.

The information on $|V_{ts}|$ obtained, in the framework of the Standard Model, from the combined limit is hampered by

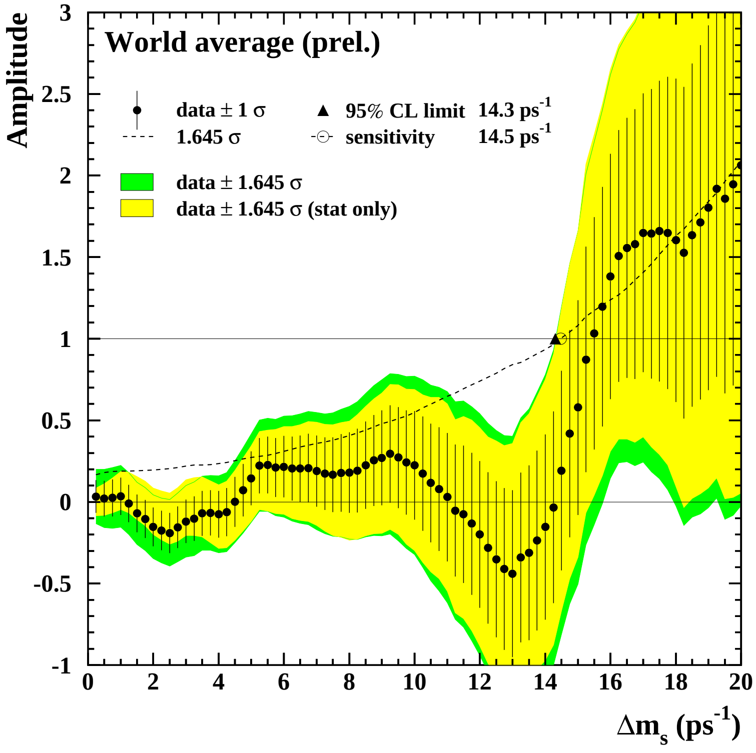


Figure 1: Combined measurements of the B_s oscillation amplitude as a function of Δm_s [22], including all preliminary results available at the end of 1999. The measurements are dominated by statistical uncertainties. Neighboring points are statistically correlated.

the hadronic uncertainty, as in the B_d case. However, many uncertainties cancel in the frequency ratio

$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s}}{m_{B_d}}\,\xi^2 \left|\frac{V_{ts}}{V_{td}}\right|^2 , \tag{33}$$

where $\xi = (f_{B_s}\sqrt{B_{B_s}})/(f_{B_d}\sqrt{B_{B_d}})$, of order unity, is currently estimated from lattice QCD with a 5–6% uncertainty [33]. The CKM matrix can be constrained using the experimental results on Δm_d, Δm_s, $|V_{ub}/V_{cb}|$ and ϵ_K, together with theoretical inputs and unitarity conditions [32]. Given the information available from $|V_{ub}/V_{cb}|$ and ϵ_K measurements, the constraint from our knowledge on the ratio $\Delta m_d/\Delta m_s$ is presently more effective in limiting the position of the apex of the CKM unitarity triangle than the one obtained from the Δm_d measurements alone, due to the reduced hadronic uncertainty in Eq. (33). We note also that the Standard Model would not easily accommodate values of Δm_s above $\sim 25\ \text{ps}^{-1}$.

Information on $\Delta\Gamma_s$ can be obtained by studying the proper time distribution of untagged data samples enriched in B_s mesons [38]. In the case of an inclusive B_s selection [39] or a semileptonic B_s decay selection [40,41], both the short- and long-lived components are present, and the proper time distribution is a superposition of two exponentials with decay constants $\Gamma_s \pm \Delta\Gamma_s/2$. In principle, this provides sensitivity to both Γ_s and $(\Delta\Gamma_s/\Gamma_s)^2$. Ignoring $\Delta\Gamma_s$ and fitting for a single exponential leads to an estimate of Γ_s with a relative bias proportional to $(\Delta\Gamma_s/\Gamma_s)^2$. An alternative approach, which is directly sensitive to first order in $\Delta\Gamma_s/\Gamma_s$, is to determine the lifetime of B_s candidates decaying to CP eigenstates; measurements already exist for $B_s^0 \to J/\psi\phi$ [42] and $B_s^0 \to D_s^{(*)+}D_s^{(*)-}$ [43], which are mostly CP-even states [7]. An estimate of $\Delta\Gamma_s/\Gamma_s$ has also been obtained directly from a measurement of the $B_s^0 \to D_s^{(*)+}D_s^{(*)-}$ branching ratio [43], under the assumption that these decays practically account for all the CP-even final states.

Present data is not precise enough to efficiently constrain both Γ_s and $\Delta\Gamma_s/\Gamma_s$; since the B_s and B_d lifetimes are predicted to be equal within less than a percent [44], an expectation compatible with the current experimental data [45], the constraint $\Gamma_s = \Gamma_d$ can also be used to extract $\Delta\Gamma_s/\Gamma_s$. Applying the combination procedure described in Ref. 22 on the published B_s lifetime results [40,42,46] yields

$$\Delta\Gamma_s/\Gamma_s < 0.65 \qquad \text{at } 95\% \text{ CL} \tag{34}$$

without external constraint, or

$$\Delta\Gamma_s/\Gamma_s < 0.33 \qquad \text{at } 95\% \text{ CL} \tag{35}$$

when constraining $1/\Gamma_s$ to the measured B_d lifetime. These results are not yet precise enough to test Standard Model predictions.

Average b-hadron mixing and b-hadron production fractions

Let f_u, f_d, f_s and f_{baryon} be the B_u, B_d, B_s and b-baryon fractions composing an unbiased sample of weakly-decaying b hadrons produced in high energy colliders. LEP experiments have measured $f_s \times \text{BR}(B^0_s \rightarrow D^-_s \ell^+ \nu_\ell X)$ [47], $\text{BR}(b \rightarrow \Lambda^0_b) \times \text{BR}(\Lambda^0_b \rightarrow \Lambda^+_c \ell^- \overline{\nu}_\ell X)$ [48] and $\text{BR}(b \rightarrow \Xi^-_b) \times \text{BR}(\Xi^-_b \rightarrow \Xi^- \ell^- \overline{\nu}_\ell X)$ [49] from partially reconstructed final states including a lepton, f_{baryon} from protons identified in b events [50], and the production rate of charged b hadrons [51]. The various b hadron fractions have also been measured at CDF from electron-charm final states [52]. All the published results have been combined following the procedure and assumptions described in Ref. 22, to yield $f_u = f_d = (38.4 \pm 1.8)\%$, $f_s = (11.7 \pm 3.0)\%$ and $f_{\text{baryon}} = (11.5 \pm 2.0)\%$ under the constraints

$$f_u = f_d \qquad \text{and} \qquad f_u + f_d + f_s + f_{\text{baryon}} = 1\,. \tag{36}$$

Time-integrated mixing analyses performed with lepton pairs from $b\overline{b}$ events produced at high energy colliders measure the quantity

$$\overline{\chi} = f'_d \chi_d + f'_s \chi_s \,, \tag{37}$$

where f'_d and f'_s are the fractions of B_d and B_s hadrons in a sample of semileptonic b-hadron decays. Assuming that all b hadrons have the same semileptonic decay width implies $f'_q = f_q/(\Gamma_q \tau_b)$ $(q = s, d)$, where τ_b is the average b-hadron lifetime. Hence $\overline{\chi}$ measurements can be used to improve our knowledge on the fractions f_u, f_d, f_s and $f_{\rm baryon}$.

Combining the above estimates of these fractions with the average $\overline{\chi} = 0.118 \pm 0.005$ (published in this *Review*), χ_d from Eq. (29) and $\chi_s = \frac{1}{2}$ yields, under the constraints of Eq. (36),

$$f_u = f_d = (38.9 \pm 1.3)\% \,, \tag{38}$$

$$f_s = (10.7 \pm 1.4)\% \,, \tag{39}$$

$$f_{\rm baryon} = (11.6 \pm 2.0)\% \,, \tag{40}$$

showing that mixing information substantially reduces the uncertainty on f_s. These results and the averages quoted in Eqs. (28) and (29) for χ_d and Δm_d have been obtained in a consistent way by the B oscillations working group [22], taking into account the fact that many individual measurements of Δm_d depend on the assumed values for the b-hadron fractions.

Summary and prospects

B^0–$\overline{B}^0$ mixing has been a field of intense study in the last few years. The mass difference in the B_d–$\overline{B}_d$ system is very well measured (with an accuracy of $\sim 3.5\%$) but, despite an impressive theoretical effort, the hadronic uncertainty still limits the precision of the extracted estimate of $|V_{td}|$. The mass difference in the B_s–$\overline{B}_s$ system is much larger and still unmeasured. However, the current experimental lower limit on Δm_s already provides, together with Δm_d, a significant constraint on the CKM matrix within the Standard Model. No strong experimental evidence exists yet for the rather large decay width difference expected in the B_s–$\overline{B}_s$ system. It is interesting to recall that the ratio $\Delta\Gamma_s/\Delta m_s$ does not depend on CKM matrix elements in the Standard Model (see Eq. (22)), and that a measurement of either Δm_s or $\Delta\Gamma_s$ could be turned into a Standard Model prediction of the other one.

The LEP and SLD experiments have still not finalized all their B_s oscillation analyses, but a measurement of Δm_s from data collected at the Z pole becomes unlikely. In the near future, the most promising prospects for B_s mixing are from Run II at the Tevatron, where both Δm_s and $\Delta\Gamma_s$ are expected to be measured; CDF will be able to observe B_s oscillations for values of Δm_s up to $\sim 40\ \text{ps}^{-1}$ [53], well above the current Standard Model prediction.

CP violation in B mixing, which has not been seen yet, as well as the phases involved in B mixing, will be further investigated with the large statistics that will become available both at the B factories and at the Tevatron.

B mixing may not have delivered all its secrets yet, because it is one of the phenomena where new physics might very well reveal itself (for example new particles involved in the box diagrams). Theoretical calculations in lattice QCD are becoming more reliable and further progress in reducing hadronic uncertainties is expected. In the long term, a stringent check of the consistency, within the Standard Model, of the B_d and B_s mixing measurements with all other measured observables in B physics (including CP asymmetries in B decays) will be possible, allowing to place limits on new physics or, better, discover new physics.

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B^0-$\overline{B}^0$ MIXING PARAMETERS

For a discussion of B^0-$\overline{B}^0$ mixing see the note on "B^0-$\overline{B}^0$ Mixing" in the B^0 Particle Listings above.

χ_d is a measure of the time-integrated B^0-$\overline{B}^0$ mixing probability that a produced $B^0(\overline{B}^0)$ decays as a $\overline{B}^0(B^0)$. Mixing violates $\Delta B \neq 2$ rule.

$$\chi_d = \frac{x_d^2}{2(1+x_d^2)}$$

$$x_d = \frac{\Delta m_{B^0}}{\Gamma_{B^0}} = (m_{B^0_H} - m_{B^0_L})\,\tau_{B^0} \,,$$

where H, L stand for heavy and light states of two B^0 CP eigenstates and $\tau_{B^0} = \frac{1}{0.5(\Gamma_{B^0_H}+\Gamma_{B^0_L})}$.

χ_d

This B^0-$\overline{B}^0$ mixing parameter is the probability (integrated over time) that a produced B^0 (or $\overline{B}^0$) decays as a $\overline{B}^0$ (or B^0), e.g. for inclusive lepton decays

$$\begin{aligned} \chi_d &= \Gamma(B^0 \to \ell^- \mathrm{X}\ (\text{via } \overline{B}^0))/\Gamma(B^0 \to \ell^\pm \mathrm{X}) \\ &= \Gamma(\overline{B}^0 \to \ell^+ \mathrm{X}\ (\text{via } B^0))/\Gamma(\overline{B}^0 \to \ell^\pm \mathrm{X}) \end{aligned}$$

Where experiments have measured the parameter $r = \chi/(1-\chi)$, we have converted to χ. Mixing violates the $\Delta B \neq 2$ rule.

Note that the measurement of χ at energies higher than the $\Upsilon(4S)$ have not separated χ_d from χ_s where the subscripts indicate $B^0(\overline{b}d)$ or $B^0_s(\overline{b}s)$. They are listed in the B^0_s-$\overline{B}^0_s$ MIXING section.

The experiments at $\Upsilon(4S)$ make an assumption about the $B^0\overline{B}^0$ fraction and about the ratio of the $B^\pm$ and B^0 semileptonic branching ratios (usually that it equals one).

OUR EVALUATION, provided by the LEP B Oscillation Working Group, includes χ_d calculated from Δm_{B^0} and τ_{B^0}.

VALUE	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
0.174±0.009 OUR EVALUATION					
0.156±0.024 OUR AVERAGE					
0.16 ±0.04 ±0.04		[314] ALBRECHT	94	ARG	$e^+e^- \to \Upsilon(4S)$
0.149±0.023±0.022		[315] BARTELT	93	CLE2	$e^+e^- \to \Upsilon(4S)$
0.171±0.048		[316] ALBRECHT	92L	ARG	$e^+e^- \to \Upsilon(4S)$

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

$0.20 \pm 0.13 \pm 0.12$		[317] ALBRECHT	96D ARG	$e^+e^- \rightarrow \Upsilon(4S)$
$0.19 \pm 0.07 \pm 0.09$		[318] ALBRECHT	96D ARG	$e^+e^- \rightarrow \Upsilon(4S)$
0.24 ± 0.12		[319] ELSEN	90 JADE	e^+e^- 35–44 GeV
$0.158^{+0.052}_{-0.059}$		ARTUSO	89 CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
0.17 ± 0.05		[320] ALBRECHT	87I ARG	$e^+e^- \rightarrow \Upsilon(4S)$
<0.19	90	[321] BEAN	87B CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
<0.27	90	[322] AVERY	84 CLEO	$e^+e^- \rightarrow \Upsilon(4S)$

[314] ALBRECHT 94 reports r=$0.194 \pm 0.062 \pm 0.054$. We convert to χ for comparison. Uses tagged events (lepton + pion from D^*).

[315] BARTELT 93 analysis performed using tagged events (lepton+pion from D^*). Using dilepton events they obtain $0.157 \pm 0.016^{+0.033}_{-0.028}$.

[316] ALBRECHT 92L is a combined measurement employing several lepton-based techniques. It uses all previous ARGUS data in addition to new data and therefore supersedes ALBRECHT 87I. A value of $r = 20.6 \pm 7.0\%$ is directly measured. The value can be used to measure $x = \Delta M/\Gamma = 0.72 \pm 0.15$ for the B_d meson. Assumes $f_{+-}/f_0 = 1.0 \pm 0.05$ and uses $\tau_{B^\pm}/\tau_{B^0} = (0.95 \pm 0.14)\ (f_{+-}/f_0)$.

[317] Uses $D^{*+} K^\pm$ correlations.

[318] Uses $(D^{*+}\ell^-)\ K^\pm$ correlations.

[319] These experiments see a combination of B_s and B_d mesons.

[320] ALBRECHT 87I is inclusive measurement with like-sign dileptons, with tagged B decays plus leptons, and one fully reconstructed event. Measures r=0.21 ± 0.08. We convert to χ for comparison. Superseded by ALBRECHT 92L.

[321] BEAN 87B measured $r <$ 0.24; we converted to χ.

[322] Same-sign dilepton events. Limit assumes semileptonic BR for B^+ and B^0 equal. If $B^0/B^\pm$ ratio <0.58, no limit exists. The limit was corrected in BEAN 87B from $r <$ 0.30 to $r <$ 0.37. We converted this limit to χ.

$\Delta m_{B^0} = m_{B^0_H} - m_{B^0_L}$

$\Delta m_{B^0_s}$ is a measure of 2π times the B^0-$\overline{B}^0$ oscillation frequency in time-dependent mixing experiments.

The second "OUR EVALUATION" (0.478 ± 0.018) is an average of the data listed below performed by the LEP B Oscillation Working Group as described in our "Review of B-$\overline{B}$ Mixing" in the B^0 Section of these Listings. The averaging procedure takes into account correlations between the measurements.

The first "OUR EVALUATION" (0.472 ± 0.017), also provided by the LEP B Oscillation Working Group, includes Δm_d calculated from χ_d measured at $\Upsilon(4S)$.

VALUE ($10^{12}\ \hbar\ \mathrm{s}^{-1}$)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
0.472±0.017 OUR EVALUATION				
0.478±0.018 OUR EVALUATION				
Average is meaningless.	[$(0.467 \pm 0.015) \times 10^{12}\ \hbar\ \mathrm{s}^{-1}$ OUR 1998 AVERAGE]			
$0.503 \pm 0.064 \pm 0.071$		[323] ABE	99K CDF	$p\overline{p}$ at 1.8 TeV
$0.500 \pm 0.052 \pm 0.043$		[324] ABE	99Q CDF	$p\overline{p}$ at 1.8 TeV

$0.516 \pm 0.099 ^{+0.029}_{-0.035}$		[325] AFFOLDER	99C	CDF	$p\overline{p}$ at 1.8 TeV
$0.471 ^{+0.078}_{-0.068} {}^{+0.033}_{-0.034}$		[326] ABE	98C	CDF	$p\overline{p}$ at 1.8 TeV
$0.458 \pm 0.046 \pm 0.032$		[327] ACCIARRI	98D	L3	$e^+e^- \rightarrow Z$
$0.437 \pm 0.043 \pm 0.044$		[328] ACCIARRI	98D	L3	$e^+e^- \rightarrow Z$
$0.472 \pm 0.049 \pm 0.053$		[329] ACCIARRI	98D	L3	$e^+e^- \rightarrow Z$
$0.523 \pm 0.072 \pm 0.043$		[330] ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.493 \pm 0.042 \pm 0.027$		[328] ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.499 \pm 0.053 \pm 0.015$		[331] ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.480 \pm 0.040 \pm 0.051$		[327] ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.444 \pm 0.029 ^{+0.020}_{-0.017}$		[328] ACKERSTAFF	97U	OPAL	$e^+e^- \rightarrow Z$
$0.430 \pm 0.043 ^{+0.028}_{-0.030}$		[327] ACKERSTAFF	97V	OPAL	$e^+e^- \rightarrow Z$
$0.482 \pm 0.044 \pm 0.024$		[332] BUSKULIC	97D	ALEP	$e^+e^- \rightarrow Z$
$0.404 \pm 0.045 \pm 0.027$		[328] BUSKULIC	97D	ALEP	$e^+e^- \rightarrow Z$
$0.452 \pm 0.039 \pm 0.044$		[327] BUSKULIC	97D	ALEP	$e^+e^- \rightarrow Z$
$0.539 \pm 0.060 \pm 0.024$		[333] ALEXANDER	96V	OPAL	$e^+e^- \rightarrow Z$
$0.567 \pm 0.089 ^{+0.029}_{-0.023}$		[334] ALEXANDER	96V	OPAL	$e^+e^- \rightarrow Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.444 \pm 0.028 \pm 0.028$		[335] ACCIARRI	98D	L3	$e^+e^- \rightarrow Z$
0.497 ± 0.035		[336] ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.467 \pm 0.022 ^{+0.017}_{-0.015}$		[337] ACKERSTAFF	97V	OPAL	$e^+e^- \rightarrow Z$
0.446 ± 0.032		[338] BUSKULIC	97D	ALEP	$e^+e^- \rightarrow Z$
$0.531 ^{+0.050}_{-0.046} \pm 0.078$		[339] ABREU	96Q	DLPH	Sup. by ABREU 97N
$0.496 ^{+0.055}_{-0.051} \pm 0.043$		[327] ACCIARRI	96E	L3	Repl. by ACCIARRI 98D
$0.548 \pm 0.050 ^{+0.023}_{-0.019}$		[340] ALEXANDER	96V	OPAL	$e^+e^- \rightarrow Z$
0.496 ± 0.046		[341] AKERS	95J	OPAL	Repl. by ACKERSTAFF 97V
$0.462 ^{+0.040}_{-0.053} {}^{+0.052}_{-0.035}$		[327] AKERS	95J	OPAL	Repl. by ACKERSTAFF 97V
$0.50 \pm 0.12 \pm 0.06$		[330] ABREU	94M	DLPH	Sup. by ABREU 97N
$0.508 \pm 0.075 \pm 0.025$		[333] AKERS	94C	OPAL	Repl. by ALEXANDER 96V
$0.57 \pm 0.11 \pm 0.02$	153	[334] AKERS	94H	OPAL	Repl. by ALEXANDER 96V
$0.50 ^{+0.07}_{-0.06} {}^{+0.11}_{-0.10}$		[327] BUSKULIC	94B	ALEP	Sup. by BUSKULIC 97D
$0.52 ^{+0.10}_{-0.11} {}^{+0.04}_{-0.03}$		[334] BUSKULIC	93K	ALEP	Sup. by BUSKULIC 97D

[323] Uses di-muon events.

[324] Uses jet-charge and lepton-flavor tagging.

[325] Uses $\ell^- D^{*+}-\ell$ events.

[326] Uses π-B in the same side.

[327] Uses ℓ-ℓ.

[328] Uses ℓ-Q_{hem}.

[329] Uses ℓ-ℓ with impact parameters.

[330] Uses $D^{*\pm}$-Q_{hem}.

[331] Uses $\pi_s^\pm$ ℓ-Q_{hem}.

[332] Uses $D^{*\pm}$-ℓ/Q_{hem}.

[333] Uses $D^{*\pm}$ ℓ-Q_{hem}.

[334] Uses $D^{*\pm}$-ℓ.

[335] ACCIARRI 98D combines results from ℓ-ℓ, ℓ-Q_{hem}, and ℓ-ℓ with impact parameters.

[336] ABREU 97N combines results from $D^{*\pm}$-Q_{hem}, ℓ-Q_{hem}, $\pi_s^\pm$ ℓ-Q_{hem}, and ℓ-ℓ.

[337] ACKERSTAFF 97V combines results from ℓ-ℓ, ℓ-Q_{hem}, D^*-ℓ, and $D^{*\pm}$-Q_{hem}.

[338] BUSKULIC 97D combines results from $D^{*\pm}$-ℓ/Q_{hem}, ℓ-Q_{hem}, and ℓ-ℓ.

[339] ABREU 96Q analysis performed using lepton, kaon, and jet-charge tags.

[340] ALEXANDER 96V combines results from $D^{*\pm}$-ℓ and $D^{*\pm}$ ℓ-Q_{hem}.

[341] AKERS 95J combines results fromt charge measurement, $D^{*\pm}$ ℓ-Q_{hem} and ℓ-ℓ.

$x_d = \Delta m_{B^0}/\Gamma_{B^0}$

The second "OUR EVALUATION" (0.740 ± 0.031) is an average of the data listed in Δm_{B^0} section performed by the LEP *B* Oscillation Working Group as described in our "Review of B-$\overline{B}$ Mixing" in the B^0 Section of these Listings. The averaging procedure takes into account correlations between the measurements.

The first "OUR EVALUATION" (0.730 ± 0.029), also provided by the LEP *B* Oscillation Working Group, includes χ_d measured at $\Upsilon(4S)$.

VALUE	*DOCUMENT ID*
0.730±0.029 OUR EVALUATION	
0.740±0.031 OUR EVALUATION	

CP VIOLATION IN *B* DECAY – STANDARD MODEL PREDICTIONS

Revised January 2000 by H. Quinn (SLAC) and A.I. Sanda (Nagoya University).

With the commissioning of the asymmetric B Factories at KEKB and PEP II, and of CESR III and with the completion of the main ring injector at Fermilab, we are headed into an exciting time for the study of CP violation in B meson decays. This review outlines the basic ideas of such studies. For the most part, we follow the discussions given in Refs. [1–3].

Time evolution of neutral B meson states

Neutral B mesons, like neutral K mesons, have mass eigenstates which are not flavor eigenstates. This subject is reviewed separately [4]. Here we give some formulae to establish the notation used in this review. The mass eigenstates are given by:

$$\begin{aligned} |B_1\rangle &= p|B^0\rangle + q|\overline{B}^0\rangle \ , \\ |B_2\rangle &= p|B^0\rangle - q|\overline{B}^0\rangle \ , \end{aligned} \tag{1}$$

where B^0 and $\overline{B}^0$ are flavor eigenstates containing the $\overline{b}$ and b quarks respectively. The ratio

$$\frac{q}{p} = +\sqrt{\frac{M_{12}^* - \frac{i}{2}\Gamma_{12}^*}{M_{12} - \frac{i}{2}\Gamma_{12}}} \ . \tag{2}$$

Here, the CP operator is defined so that $CP|B^0\rangle = |\overline{B}^0\rangle$, and CPT symmetry is assumed. We define $M_{12} = \overline{M}_{12}e^{i\xi}$, where the phase ξ is restricted to $-\frac{1}{2}\pi < \xi < \frac{1}{2}\pi$, and $\overline{M}_{12}$ is taken to be real but not necessarily positive; and similarly (with a different phase) for Γ_{12}. The convention used here is that the real part of q/p is positive.

The differences in the eigenvalues $\varDelta M = M_2 - M_1$ and $\varDelta\Gamma = \Gamma_1 - \Gamma_2$ are given by

$$\begin{aligned}\varDelta M &= -2\mathrm{Re}\left(\frac{q}{p}(M_{12} - \frac{i}{2}\Gamma_{12})\right)\\ &\simeq -2\overline{M}_{12}\\ \varDelta\Gamma &= -4\mathrm{Im}\left(\frac{q}{p}(M_{12} - \frac{i}{2}\Gamma_{12})\right)\\ &\simeq 2\overline{\Gamma}_{12}\cos\zeta\ .\end{aligned} \tag{3}$$

Here we denoted $\dfrac{\Gamma_{12}}{M_{12}} = re^{i\zeta}$. As we expect $r \sim 10^{-3}$ in the Standard Model for B_d, we kept only the leading order term in r. In the Standard Model, with these conventions and given that all models give a positive value for the parameter B_B, $\varDelta M$ is positive, so that B_2 is heavier than B_1; this is unlikely to be tested soon. (Note that a common alternative convention is to name the two states B_L and B_H for light and heavy respectively; then the sign of q/p becomes the quantity to be tested.)

This review focuses on the B_d system, but also mentions some possibly interesting studies for CP violation in B_s decays, which may be pursued at hadron colliders. Much of the discussion here can be applied directly for B_s decays with the appropriate replacement of the spectator quark type.

The time evolution of states starting out at time $t = 0$ as pure B^0 or $\overline{B}^0$ is given by:

$$\begin{aligned}|B^0(t)\rangle &= g_+(t)|B^0\rangle + \frac{q}{p}g_-(t)|\overline{B}^0\rangle\\ |\overline{B}^0(t)\rangle &= g_+(t)|\overline{B}^0\rangle + \frac{p}{q}g_-(t)|B^0\rangle,\end{aligned} \tag{4}$$

where

$$g_{\pm}(t) = \frac{1}{2} e^{-iM_1 t} e^{-\frac{1}{2}\Gamma_1 t} \left[1 \pm e^{-i\Delta M t} e^{\frac{1}{2}\Delta\Gamma t} \right] \ . \tag{5}$$

We define

$$\begin{aligned} A(f) &= \langle f|H|B^0\rangle \ , \\ \overline{A}(f) &= \langle f|H|\overline{B}^0\rangle \ , \\ \overline{\rho}(f) &= \frac{\overline{A}(f)}{A(f)} = \rho(f)^{-1} \ , \end{aligned} \tag{6}$$

where f is a final state that is possible for both B^0 and $\overline{B}^0$ decays. The time-dependent decay rates are thus given by

$$\begin{aligned} &\Gamma(B^0(t) \to f) \\ &\propto e^{-\Gamma_1 t} |A(f)|^2 \Bigg[K_+(t) + K_-(t) \left|\frac{q}{p}\right|^2 |\overline{\rho}(f)|^2 \\ &+ 2\mathrm{Re}\Big[L^*(t) \left(\frac{q}{p}\right) \overline{\rho}(f) \Big] \Bigg] \ , \end{aligned} \tag{7}$$

$$\begin{aligned} &\Gamma(\overline{B}^0(t) \to f) \\ &\propto e^{-\Gamma_1 t} |\overline{A}(f)|^2 \Bigg[K_+(t) + K_-(t) \left|\frac{p}{q}\right|^2 |\rho(f)|^2 \\ &+ 2\mathrm{Re}\left[L^*(t) \left(\frac{p}{q}\right) \rho(f) \right] \Bigg], \end{aligned} \tag{8}$$

where

$$\begin{aligned} |g_{\pm}(t)|^2 &= \frac{1}{4} e^{-\Gamma_1 t} K_{\pm}(t) \ , \\ g_-(t) g_+^*(t) &= \frac{1}{4} e^{-\Gamma_1 t} L^*(t) \ , \\ K_{\pm}(t) &= 1 + e^{\Delta\Gamma t} \pm 2 e^{\frac{1}{2}\Delta\Gamma t} \cos \Delta M t \ , \\ L^*(t) &= 1 - e^{\Delta\Gamma t} + 2i e^{\frac{1}{2}\Delta\Gamma t} \sin\ \Delta M t \ . \end{aligned} \tag{9}$$

For the case of B_d decays the quantity $\Delta\Gamma/\Gamma$ is small and is usually dropped, for B_s decays it may be significant [6] and hence is retained in Eqs. 4–8.

Three classes of CP violation in B decays

When two amplitudes with different phase-structure contribute to a B decay, they may interfere and produce CP-violating effects [5]. There are three distinct types of CP violation: (1) CP violation from nonvanishing relative phase between the mass and the width parts of the mixing matrix which gives $|q/p| \neq 1$, often called "indirect;" (2) Direct CP violation, which is any effect that indicates two decay amplitudes have different weak phases (those arising from Lagrangian couplings), in particular it occurs whenever $|\rho(f)| \neq 1$; (3) Interference between a decays with and without mixing which can occur for decays to CP eigenstates whenever $\mathrm{Arg}((q/p)\overline{\rho}(f)) \neq 0$. This can occur even for modes where both the other types do not, *i.e.* $|q/p|,\ |\rho(f)| = 1$.

(1) Indirect CP violation

In the next few years, experiments will accumulate a large number of semileptonic B decays. Any asymmetry in the wrong-sign semileptonic decays (or in any other wrong-flavor decays) is a clean sign of indirect CP violation.

The semileptonic asymmetry for the wrong sign B_q decay, where $q = d$ or s, is given by

$$a_{SL}(B_q) = \frac{\Gamma(\overline{B}_q(t) \to \ell^+ X) - \Gamma(B_q(t) \to \ell^- X)}{\Gamma(\overline{B}_q(t) \to \ell^+ X) + \Gamma(B_q(t) \to \ell^- X)}$$

$$= \frac{|p/q|^2 - |q/p|^2}{|p/q|^2 + |q/p|^2} = r_{B_q} \sin \zeta_{B_q} \ , \qquad (10)$$

where we kept only the leading order term in r_{B_q}. Within the context of the Standard Model, if hadronic rescattering effects are small then $\sin\zeta_{B_q}$ is small because M_{12} and Γ_{12} acquire their phases from the same combination of CKM matrix elements. Since this asymmetry is tiny in the Standard Model, this may be a fruitful area to search for physics beyond the Standard Model.

(2) Direct CP violation

Direct CP violation is the name given to CP violation that arises because there is a difference between the weak phases of any two decay amplitudes for a single decay. Weak phases are those that arise because of a complex coupling constant in the Lagrangian. Note that a single weak phase from a complex coupling constant is never physically meaningful because it can generally be removed by redefining some field by a phase. Only the differences between the phases of couplings which cannot be changed by such redefinitions are physically meaningful. The strong and electromagnetic couplings can always be defined to be real but, as Kobayashi and Maskawa first observed, in the three generation Standard Model one cannot remove all the phases from the CKM matrix by any choice of field redefinitions [7].

There are two distinct ways to observe direct CP-violation effects in B decays:

- $|\overline{A}_{\overline{f}}/A_f| \neq 1$ leading to rate asymmetries for CP-conjugate decays. Here, two amplitudes with different weak phases must contribute to the same decay; they must also have different strong phases, that is, the phases that arise because of absorptive parts (often called final-state interaction effects). When the final state f has different flavor content than its CP conjugate, this gives a rate asymmetry that is directly observable. The asymmetry is given by

$$a = \frac{2A_1A_2\sin(\xi_1-\xi_2)\sin(\delta_1-\delta_2)}{A_1^2+A_2^2+2A_1A_2\cos(\xi_1-\xi_2)\cos(\delta_1-\delta_2)} \ , \tag{11}$$

where the A_i are the magnitudes, the ξ_i are the weak phases, and the δ_i are the strong phases of the two amplitudes contributing to A_f. The impact of direct CP violation of this type in decays of neutral B's to flavor eigenstates is discussed below.

- Any difference (other than an overall sign) between the CP asymmetries for decays of B_d mesons to flavor eigenstates, or between those of neutral B_s mesons, is an evidence of direct CP violation. As is shown below, such asymmetries arise whenever the decay weak phase is not canceled by the mixing weak phase, hence any two different results imply that there is a difference between the weak phases of the amplitudes for the two decays. Only if the asymmetries are the same can one choose a phase convention which ascribes all CP-violating phases to the mixing amplitude. For example, the expected asymmetries for the $B \to J/\psi K_S$ and $B \to \pi\pi$ decays are different (whether or not penguin graphs add additional direct CP-violating effects of the type $|\overline{A}_{\overline{f}}/A_f| \neq 1$ in the latter channel) because the dominant decay amplitudes have different weak phases in the Standard Model.

(3) Decays of B^0 and $\overline{B}^0$ to CP eigenstates

In decays to CP eigenstates, the time-dependent asymmetry is given by

$$a_f(t) = \frac{\Gamma(\overline{B}^0(t) \to f) - \Gamma(B^0(t) \to f)}{\Gamma(\overline{B}^0(t) \to f) + \Gamma(B^0(t) \to f)} \ . \tag{12}$$

Asymmetry is generated if: (i) both $A(B \to f)$ and $A(\overline{B} \to f)$ are nonzero; and (ii) the mixing weak phase in $\frac{q}{p}$ is different from the weak decay phase in $\overline{\rho}(f)$. To the leading order in r, the Standard Model predicts

$$q/p = \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} = e^{-i2\phi_{\text{mixing}}} \ . \tag{13}$$

If there is only one amplitude (or two with the same weak phase) contributing to $A(B \to f)$ and $A(\overline{B} \to f)$ then $|\overline{\rho}(f)| = 1$ and the relationship between the measured asymmetry and the Kobayshi-Maskawa phases is cleanly predicted by

$$\begin{aligned} a_f(t) &= \mathrm{Im}\left(\frac{q}{p}\overline{\rho}(f)\right)\sin \mathit{\Delta} M t \\ &= -\eta_f \sin 2(\phi_{\mathrm{mixing}} + \phi_{\mathrm{decay}}) \sin \mathit{\Delta} M t \ . \end{aligned} \tag{14}$$

Here we have used the fact that in such cases we can write $\overline{\rho}(f) = \eta_f e^{-i2\phi_{\mathrm{decay}}}$ where $\eta_f = \pm$ is the CP eigenvalue of the state f. The weak phases ϕ_{mixing} and ϕ_{decay} are parameterization dependent quantities, but the combination $\phi_{\mathrm{mixing}} + \phi_{\mathrm{decay}}$ is parameterization independent. This is CP violation due to the interference between decays with and without mixing. Note that a single measurement of $\sin(2\phi)$ yields four ambiguous solutions for ϕ.

When more than one amplitude with different weak phases contribute to a decay to a CP eigenstate there can also be direct CP violation effects $|\lambda_f = (q/p)\,\rho(f)| \neq 1$ and the asymmetry takes the more complicated form

$$a_f(t) = \frac{(|\lambda_f|^2 - 1)\cos(\mathit{\Delta} M t) + 2\mathrm{Im}\lambda_f \sin(\mathit{\Delta} M t)}{(1 + |\lambda_f|^2)} \ . \tag{15}$$

The quantity λ_f involves the ratio of the two amplitudes that contribute to A_f as well as their relative strong phases and hence introduces the uncertainties of hadronic physics into the relationship between the measured asymmetry and the K–M phases. However in certain cases such channels can be useful in resolving the ambiguities mentioned above. If $\cos(2\phi)$ can be measured as well as $\sin(\phi)$ only a two-fold ambiguity remains. This can be resolved only by knowledge of the sign of certain strong phase shifts [8].

When a B meson decays to a CP self-conjugate set of quarks the final state is in general a mixture of CP even and CP odd states, which contribute opposite sign and hence partially canceling asymmetries. In two special cases, namely the decay to two spin zero particles, or one spin zero and one non-zero spin particle there is a unique CP eigenvalue because there is only one possible relative angular momentum between the two final state particles. Quasi-two-body modes involving two particles with non-zero spin can sometimes be resolved into contributions of definite CP by angular analysis of the decays of the “final-state” particles [9].

There can also be a direct CP violation in these channels from the interference of two contributions to the same decay amplitude, $|\rho(f)| \neq 1$. This introduces dependence on the relative strengths of the two amplitude contributions and on their relative strong phases. Since these cannot be reliably calculated at present, this complicates the attempt to relate the measured asymmetry to the phases of CKM matrix elements.

Standard Model predictions for CP-violating asymmetries

- ***Unitarity Triangles***

The requirement that the CKM matrix be unitary leads to a number of relationships among its entries. The constraints that the product of row i with the complex conjugate of row j is zero are generically referred to as “unitarity triangles” because they each take the form of a sum of three complex numbers equal to zero and hence can be represented by triangles in the complex plane. There are six such relationships, (see for example Ref. 10); the most commonly studied is that with all angles of the same order of magnitude, given by the relationship

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 \ . \qquad (16)$$

This relation can be represented as a triangle on the complex plane, as shown in Fig. 1, where the signs of all three angles are also defined. When the sides are scaled by $|V_{cd}V^*_{cb}|$, the apex of the triangle is the point ρ, η, where these parameters are defined by the Wolfenstein parameterization of the CKM matrix [11]. If $\eta = 0$, the CKM matrix is real and there is no CP violation in the Standard Model.

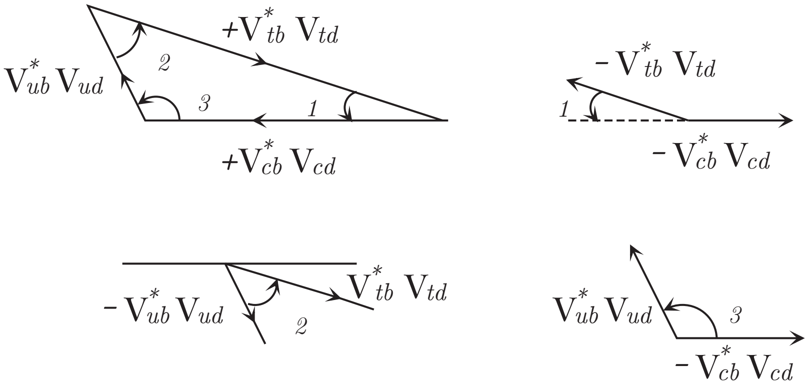

Figure 1: Angles of the unitarity triangle are related to the Kobayashi-Maskawa phases of the CKM matrix. The right-hand rule gives the positive direction of the angle between two vectors. This figure was reproduced from Ref. 1 with permission from Cambridge University Press.

The angles of the triangle are

$$\phi_1 = \pi - \arg\left(\frac{-\mathbf{V}^*_{tb}V_{td}}{-V^*_{cb}V_{cd}}\right) = \beta \ ,$$

$$\phi_2 = \arg\left(\frac{V^*_{tb}V_{td}}{-V^*_{ub}V_{ud}}\right) = \alpha \ ,$$

$$\phi_3 = \arg\left(\frac{V^*_{ub}V_{ud}}{-V^*_{cb}V_{cd}}\right) = \gamma \ . \tag{17}$$

Two naming conventions for these angles are commonly used in the literature [12,13]; we provide the translation dictionary in Eq. (17), but use the ϕ_i notation in the remainder of this review, where ϕ_i is the angle opposite the side $V_{ib}^* V_{id}$ of the unitarity triangle and i represents the i-th up-type quark. As defined here, for consistency with the measured value of ϵ_K, these angles are all positive in the Standard Model, thus a determination of the sign of these angles constitutes a test of the Standard Model [14].

There are two other independent angles of the Standard Model which appear in other triangles. These are denoted

$$\begin{aligned} \chi &= \arg\left(\frac{-V_{cs}^* V_{cb}}{V_{ts}^* V_{tb}}\right) = \beta_s \\ \chi' &= \arg\left(\frac{-V_{ud}^* V_{us}}{V_{cd}^* V_{cs}}\right) = -\beta_K \ . \end{aligned} \tag{18}$$

Again there are two naming conventions in common usage so we give both. These angles are of order λ^2 and λ^4 respectively [15], where $\lambda = V_{us}$. The first of them is the phase of the B_s mixing and thus is in principle measurable, though it will not be easy to achieve a result significantly different from zero for such a small angle. The angle χ' will be even more difficult to measure. Meaningful standard model tests can be defined which use the measured value of λ coupled with χ and any two of the three ϕ_i [16].

A major aim of CP-violation studies of B decays is to make enough independent measurements of the sides and angles that this unitarity triangle is overdetermined, and thereby check the validity of the Standard Model predictions that relate various measurements to aspects of this triangle. Constraints can be made on the basis of present data on the B-meson mixing and lifetime, and on the ratio of charmless decays to decays with charm (V_{ub}/V_{cb}), and on ϵ in K decays [17]. These constraints have been discussed in many places in the literature; for a recent summary of the measurements involved, see Ref. [18]. Note, however, that any given "Standard Model allowed range" cannot be interpreted as a statistically-based error range. The ranges of allowed values depend on matrix element estimates. Improved methods to calculate such quantities, and understand the uncertainties in them, are needed to further sharpen tests of the Standard Model. Recent progress in lattice simulation using dynamical fermions seems encouraging [19]. It can be hoped that reliable computations of f_B, B_B, and B_K will be completed in the next few years. This will reduce the theoretical uncertainties in the relationships between measured mixing effects and the magnitudes of CKM parameters.

In the Standard Model there are only two independent phases in this triangle since, by definition, the three angles add up to π. The literature often discusses tests of whether the angles add up to π; but this really means tests of whether relationships between different measurements, predicted in terms of the two independent parameters in the Standard Model, hold true. For example, many models that go beyond the Standard Model predict an additional contribution to the mixing matrix. Any change in phase of M_{12} will change the measured asymmetries so that $\phi_1(\text{measured}) \rightarrow \phi_1 - \phi_{\text{new}}$ and $\phi_2(\text{measured}) \rightarrow \phi_2 + \phi_{\text{new}}$. Thus the requirement that the sum of the three angles must add up to π is not sensitive to ϕ_{new} [20]. However, the angles as determined from the sides of the triangle would, in general, no longer coincide with those measured from asymmetries. It is equally important to check the asymmetries in channels for which the Standard model predicts very small or vanishing asymmetries. A new mixing contribution which changes the phase of M_{12} will generate significant asymmetries in such channels. In the Standard Model the CKM matrix must be unitary, this leads to relationships among its entries.

• *Standard Model decay amplitudes*

In the Standard Model, there are two classes of quark-level diagrams that contribute to hadronic B decays, as shown in Fig. 2. Tree diagrams are those where the W produces an additional quark-antiquark pair. Penguin diagrams are loop diagrams where the W reconnects to the same quark line. Penguin diagrams can further be classified by the nature of the particle emitted from the loop: gluonic or QCD penguins if it is a gluon, and electroweak penguins if it is a photon or a Z boson. In addition, one can label penguin diagrams by the flavor of the up-type quark in the loop; for any process all three flavor types contribute. For some processes, there are additional annihilation-type diagrams; these always contribute to the same CKM structure as the corresponding trees. For a detailed discussion of the status of calculations based on these diagrams, or rather on the more complete operator product approach which also includes higher order QCD corrections see, for example, Ref. 21. Note that the distinction between tree and penguin contributions is a heuristic one, the separation of contributions by the operator that enters is more precise.

To explore possible CP violations, it is useful to tabulate all possible decays by the CKM structure of the various amplitudes. Let us first consider decays $b \to q\overline{q}'s$. The CKM factors for the diagrams for such decays are given in Table 1. Here we have used the fact that, for all such decays, the contribution to the amplitude from penguin graphs has the structure

$$A_P(q\overline{q}s) = V_{tb}V_{ts}^*P_t + V_{cb}V_{cs}^*P_c + V_{ub}V_{us}^*P_u \ , \tag{19}$$

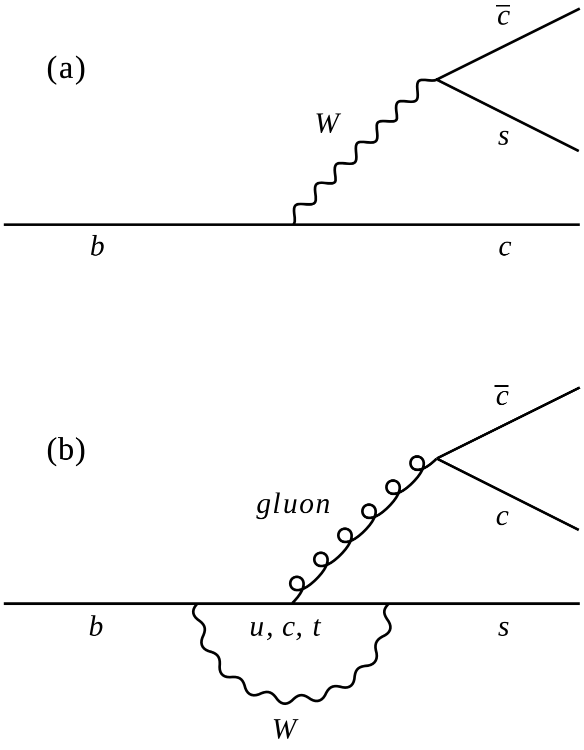

Figure 2: Quark level processes for the example of $b \to c\bar{c}s$. (a) Tree diagram; (b) Penguin diagram. In the case of electroweak penguin contributions, the gluon is replaced by a Z or a γ.

where the P_i quantities are the amplitudes described by the loop diagram with a flavor i quark apart from the explicitly shown CKM factor (*i.e.*, including strong phases). These are actually divergent quantities, so it is convenient to use a Standard Model unitarity relationship, $V_{tb}V_{ts}^* + V_{cb}V_{cs}^* + V_{ub}V_{us}^* = 0$, to regroup them in the following way

$$A_P(q\overline{q}s) = V_{cb}V_{cs}^*(P_c - P_t) + V_{ub}V_{us}^*(P_u - P_t) \ , \qquad (20)$$

or, equivalently,

$$A_P(q\overline{q}s) = V_{tb}V^*_{ts}(P_t - P_c) + V_{ub}V^*_{us}(P_u - P_c)\ . \qquad (21)$$

The first term is of order λ^2, whereas the second is of order λ^4, and can be ignored in most instances. For modes with $q' \neq q$, there are no penguin contributions. Note also that for the $q\overline{q} = u\overline{u}, d\overline{d}$ cases, the QCD penguin graphs contribute only to the isospin zero combinations, whereas tree graphs contribute only for $u\overline{u}$ and hence have both $\Delta I = 0$ and $\Delta I = 1$ parts, as do electroweak penguins.

The CKM coefficients for $b \to q\overline{q}'d$ are listed in Table 2. A similar exercise to that described above for the penguins yields

$$A_P(q\overline{q}d) = V_{tb}V^*_{td}(P_t - P_c) + V_{ub}V^*_{ud}(P_u - P_c)\ . \qquad (22)$$

Here the two CKM contributions are of the same order of magnitude λ^3, so both must be considered. This grouping is generally preferred over the alternative, because the second term here is somewhat smaller than the first term; it has no top-quark contribution and would vanish if the up and charm quarks were degenerate. In early literature it was often dropped, but, particularly for modes where there is no tree contribution, its effect in generating direct CP violation may be important [22]. Here the $q\overline{q} = u\overline{u}, d\overline{d}$ cases in the penguin graph contribute only to the isospin zero combinations, yielding $\Delta I = 1/2$ for the three-quark combination, whereas tree graphs and electroweak penguins have both $\Delta I = 1/2$ and $\Delta I = 3/2$ parts. For $q\overline{q} = c\overline{c}$, isospin does not distinguish between tree and penguin contributions.

Table 1: $B \to q\overline{q}s$ decay modes

Quark process	Leading term	Secondary term	Sample B_d modes	B_d angle	Sample B_s modes	B_s angle
$b \to c\overline{c}s$	$V_{cb}V_{cs}^* = A\lambda^2$ tree + penguin$(c-t)$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$ penguin only$(u-t)$	$J/\psi\ K_S$	β	$J/\psi\eta$ $D_s\overline{D}_s$	0
$b \to s\overline{s}s$	$V_{cb}V_{cs}^* = A\lambda^2$ penguin only$(c-t)$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$ penguin only$(u-t)$	$\phi\, K_S$	β	$\phi\eta'$	0
$b \to u\overline{u}s$ $b \to d\overline{d}s$	$V_{cb}V_{cs}^* = A\lambda^2$ penguin only$(c-t)$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$ tree + penguin$(u-t)$	$\pi^0\ K_S$ $\rho\, K_S$	competing terms	$\phi\pi^0$ $K_S\overline{K}_S$	competing terms

Table 2: $B \to q\overline{q}d$ decay modes

Quark process	Leading term	Secondary term	Sample B_d modes	B_d angle	Sample B_s modes
$b \to c\overline{c}d$	$V_{cb}V^*_{cd} = -A\lambda^3$ tree + penguin$(c-u)$	$V_{tb}V^*_{td} = A\lambda^3(1-\rho+i\eta)$ penguin only$(t-u)$	D^+D^-	$^*\beta$	$J/\psi\, K_S$
$b \to s\overline{s}d$	$V_{tb}V^*_{td} = A\lambda^3(1-\rho+i\eta)$ penguin only$(t-u)$	$V_{cb}V^*_{cd} = A\lambda^3$ penguin only$(c-u)$	$\phi\pi$ $K_S\overline{K}_S$	competing terms	$\phi\, K_S$
$b \to u\overline{u}d$ $b \to d\overline{d}d$	$V_{ub}V^*_{ud} = A\lambda^3(\rho-i\eta)$ tree + penguin$(u-c)$	$V_{tb}V^*_{td} = A\lambda^3(1-\rho+i\eta)$ penguin only$(t-c)$	$\pi\pi$; $\pi\rho$ $\pi\, a_1$	$^*\alpha$	π^0K_S ρ^0K_S
$b \to c\overline{u}d$	$V_{cb}V^*_{ud} = A\lambda^2$	0	$D^0\pi^0,\ D^0\rho^0$ $\hookrightarrow CP$ eigenstate	β	D^0K_S $\hookrightarrow CP$ eigenstate

*Leading terms only, large secondary terms shift asymmetry.

Modes with direct CP violation

The largest direct CP violation is expected when there are two comparable magnitude contributions with different weak phases. Modes where the tree graphs are Cabibbo suppressed, compared to the penguins or modes with two comparable penguin contributions, are thus the best candidates. As can be seen from the tables and expressions for penguin contributions above, there are many possible modes to study. Because strong phases cannot usually be predicted, there is no clean prediction as to which modes will show the largest direct CP-violation effects. One interesting suggestion is to study three-body modes with more than one resonance in the same kinematic region. Then the different amplitudes can have very different, possibly known, strong phase structure because of the resonance (Breit-Wigner) phases [23].

Over the past two years, new information has become available from the CLEO Collaboration which suggests that penguin contributions, at least for some modes, are larger than initial estimates suggested. This is seen by using SU(3) and comparing $B \to K\pi$ and $B \to \pi\pi$ decays. To get an order of magnitude picture, we ignore such details as Clebsch-Gordan coefficients and assume that top penguins dominate the penguin contributions. Thus, we identify the tree and penguin contributions, minus their CKM coefficients, as T and P, the same for both modes. Writing $A_{T,P}(K\pi)$ for the tree and penguin contributions to the $K\pi$ amplitude, and similarly for $\pi\pi$ from the Tables, we see that $|A^T(K\pi)/A^T(\pi\pi)| = \mathcal{O}(\lambda)$. Thus, if the tree graph matrix elements were to dominate both decays, we would expect $\mathrm{Br}(B \to K\pi)/\mathrm{Br}(B \to \pi\pi) \sim \mathcal{O}(\lambda^2)$. Naively, this was expected, since the ratio of tree to penguin contribution was estimated to be $\dfrac{P}{T} = \dfrac{\alpha_S}{12\pi}\log\dfrac{m_t^2}{m_b^2} \sim \mathcal{O}(0.02)$. Experimentally, this is not so [24]; in fact, the $K\pi$ branching ratio is larger. This indicates that $A^P(K\pi) \sim A^T(\pi\pi)$, which suggests that $\dfrac{P}{T} = \mathcal{O}(\lambda)$ or larger, considerably bigger than expected. Note that this is one way that new physics could be hidden in modes with $|\rho(f)| \neq 1$; any new physics contribution can always be written as a sum of two terms with the weak phases of the two Standard Model terms (for example in Eq. (22)), and thus, when added to the Standard Model contributions, appears only as a change in the sizes of P and T from that expected in the Standard Model. However, we cannot calculate these relative sizes well enough to identify such an effect with confidence.

From the point of view of looking for direct CP-violation effects, a large P/T is good news. The largest asymmetry is expected when the interfering amplitudes have comparable magnitudes. This may be so in $B \to K\pi$ decay (or the penguin contribution may even be larger than the tree). There is no reason for the strong phases to be equal (although they could both be small). Therefore, $B^\pm \to K^\pm\pi$ is a likely hunting ground for direct CP violation. (Note there is no gluonic penguin contribution to charged $B \to \pi\pi$, and hence, no significant CP violation expected in the Standard Model.) However, as we will see below, a large P/T complicates the relationship between the measured asymmetry in neutral B decays to $\pi^+\pi^-$ and KM phases.

Studies of CP eigenstates

• $f = J/\psi K_S$

The asymmetry in the Golden Mode $B \to J/\psi K_S$ [25] will be measured soon. Since, using Eq. (20), the dominant penguin contribution has the same weak phase as the tree graph, and the remaining term is tiny, there is effectively only one weak phase in the decay amplitude. Hence, in the asymmetry, all dependence on the amplitudes cancel. With about 1% uncertainty,

$$\frac{q}{p}\overline{\rho}(J/\psi K_S) \simeq -\frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \cdot \frac{V_{cb} V_{cs}^*}{V_{cb}^* V_{cs}} \cdot \frac{V_{cs} V_{cd}^*}{V_{cs}^* V_{cd}} \equiv -e^{-2i\phi_1} \ , \qquad (23)$$

where the last factor arises from the K^0–$\overline{K}^0$ mixing amplitude and appears because of the K_S in the final state. The asymmetry is thus given by

$$a_{J/\psi K_S} = \sin(2\phi_1) \sin \Delta M t \ , \qquad (24)$$

where the angle ϕ_1 is defined in Fig. 1. Given current constraints a large positive value for $\sin(2\phi_1)$ will be strongly suggestive that the KM ansatz for CP violation is at least one of the sources of this interesting phenomenon.

• $B^0 \to \pi^+\pi^-$

The tree and penguin terms appear at the same order in λ (see Eq. (22) and Table 2.) If penguin decays were negligible the asymmetry would directly measure $\sin(2\phi_2)$. Given the enhanced penguin contribution seen from comparing $\pi\pi$ and $K\pi$ decays, the penguins cannot be ignored, and a treatment that does not assume $|\rho(f)| = 1$ must be made.

If all six modes of $B^+ \to \pi^+\pi^0$, $B^0 \to \pi^+\pi^-$, $B^0 \to \pi^0\pi^0$ and their charge conjugates can be measured with sufficient accuracy, ϕ_2 can be extracted using an isospin analysis [26], up to small corrections from electroweak penguins. However, the branching ratio for the charged modes is less than 10^{-5} [24], and that for the more difficult to measure $B^0 \to \pi^0\pi^0$ is expected to be even smaller. Therefore, further ingenuity is needed to get at this angle cleanly. A future possibility is to study the Dalitz plot of $B \to 3\pi$ decays [27].

Further Measurements

As Tables 1 and 2 suggest there are many more CP-eigenstate modes that are interesting to study, both for B_d and similarly for B_s decays. The latter states are not accessible for the B factories operating at the $\Upsilon(4S)$ resonance, but may be studied at hadronic colliders. The CDF result on the asymmetry in the $J/\psi K_S$ mode is an indication of the capabilities of such facilities for B physics [29]. Upgrades of the Fermilab detectors are in progress and proposals for new detectors with the capability to achieve fast triggers for a larger variety of purely hadronic modes are under development, promising some future improvement in this capability.

In addition to CP-eigenstate modes there are many additional modes for which particular studies have been proposed, in particular those focussed on extracting ϕ_3 (γ). Modes such as DK, DK^* and D^*K where the D mesons decay to CP eigenstates provide theoretically clean extraction of this parameter but have small branching ratios [30]. Other approaches involve the more copious $K\pi$ modes but rely on the use of isospin and SU(3) (U-spin) symmetries, so have larger theoretical uncertainties [31]. This is an active area of current theoretical work.

For a recent review of how predictions for CP-violating effects are affected by Beyond Standard Model effects see Ref. 28. There are also many ways to search for new physics effects in B decays that do not involve just the CP-violation effects. For example searches for isospin breaking effects in $K\pi$ modes have recently been suggested as a likely method to isolate such effects [32].

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CP VIOLATION PARAMETERS

$\mathrm{Re}(\epsilon_{B^0})/(1+|\epsilon_{B^0}|^2)$

CP Impurity in B_d^0 system. It is obtained from either $a_{\ell\ell}$, the charge asymmetry in like-sign dilepton events or a_{cp}, the time-dependent asymmetry of inclusive B^0 and $\overline{B}^0$ decays.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.002±0.007 OUR AVERAGE				
0.001±0.014±0.003	[342] ABBIENDI	99J	OPAL	$e^+e^- \to Z$
0.002±0.007±0.003	[343] ACKERSTAFF	97U	OPAL	$e^+e^- \to Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.045	[344] BARTELT	93	CLE2	$e^+e^- \to \Upsilon(4S)$

[342] Data analyzed using the time-dependent asymmetry of inclusive B^0 decay. The production flavor of B^0 mesons is determined using both the jet charge and the charge of secondary vertex in the opposite hemisphere.

[343] ACKERSTAFF 97U assumes CPT and is based on measuring the charge asymmetry in a sample of B^0 decays defined by lepton and $Q_{\rm hem}$ tags. If CPT is not invoked, $\mathrm{Re}(\epsilon_B) = -0.006 \pm 0.010 \pm 0.006$ is found. The indirect CPT violation parameter is determined to $\mathrm{Im}(\delta B) = -0.020 \pm 0.016 \pm 0.006$.

[344] BARTELT 93 finds $a_{\ell\ell} = 0.031 \pm 0.096 \pm 0.032$ which corresponds to $|a_{\ell\ell}| < 0.18$, which yields the above $|\mathrm{Re}(\epsilon_{B^0})/(1+|\epsilon_{B^0}|^2|$.

sin(2β)

For a discussion of CP violation, see the note on "CP Violation in B Decay Standard Model Predictions" in the B^0 Particle Listings above. $\sin(2\beta)$ is a measure of the CP-violating amplitude in the $B^0_d \to J/\psi(1S)K^0_S$.

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.9 ±0.4 OUR AVERAGE				
$0.79^{+0.41}_{-0.44}$	[345] AFFOLDER	00C	CDF	$p\overline{p}$ at 1.8 TeV
$3.2\ ^{+1.8}_{-2.0}\ \pm0.5$	[346] ACKERSTAFF	98Z	OPAL	$e^+e^- \to Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.8 ±1.1 ±0.3	[347] ABE	98U	CDF	Repl. by AFFOLDER 00C

[345] AFFOLDER 00C uses about 400 $B^0 \to J/\psi(1S)K^0_S$ events. The production flavor of B^0 was determined using three tagging algorithms: a same-side tag, a jet-charge tag, and a soft-lepton tag.

[346] ACKERSTAFF 98Z uses 24 candidates for $B^0_d \to J/\psi(1S)K^0_S$ decay. A combination of jet-charge and vertex-charge techniques were used to tag the B^0_d production flavor.

[347] ABE 98U uses 198 ± 17 $B^0_d \to J/\psi(1S)K^0$ events. The production flavor of B^0 was determined using the same side tagging technique.

$B^0 \to D^{*-}\ell^+\nu_\ell$ FORM FACTORS

R_1 (form factor ratio $\sim V/A_1$)

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
1.18±0.30±0.12	DUBOSCQ	96	CLE2	$e^+e^- \to \Upsilon(4S)$

R_2 (form factor ratio $\sim A_2/A_1$)

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.71±0.22±0.07	DUBOSCQ	96	CLE2	$e^+e^- \to \Upsilon(4S)$

$\rho^2_{A_1}$ (form factor slope)

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.91±0.15±0.06	DUBOSCQ	96	CLE2	$e^+e^- \to \Upsilon(4S)$

B^0 REFERENCES

AFFOLDER	00C	PR D61 072005	T. Affolder *et al.*	(CDF Collab.)
BEHRENS	00	PR D61 052001	B.H. Behrens *et al.*	(CLEO Collab.)
CSORNA	00	PR D61 111101	S.E. Csorna *et al.*	(CLEO Collab.)
ABBIENDI	99J	EPJ C12 609	G. Abbiendi *et al.*	(OPAL Collab.)
ABE	99K	PR D60 051101	F. Abe *et al.*	(CDF Collab.)
ABE	99Q	PR D60 072003	F. Abe *et al.*	(CDF Collab.)
AFFOLDER	99B	PRL 83 3378	T. Affolder *et al.*	(CDF Collab.)
AFFOLDER	99C	PR D60 112004	T. Affolder *et al.*	(CDF Collab.)
ARTUSO	99	PRL 82 3020	M. Artuso *et al.*	(CLEO Collab.)
BARTELT	99	PRL 82 3746	J. Bartelt *et al.*	(CLEO Collab.)
COAN	99	PR D59 111101	T.E. Coan *et al.*	(CLEO Collab.)
ABBOTT	98B	PL B423 419	B. Abbott *et al.*	(D0 Collab.)
ABE	98	PR D57 R3811	F. Abe *et al.*	(CDF Collab.)
ABE	98B	PR D57 5382	F. Abe *et al.*	(CDF Collab.)
ABE	98C	PRL 80 2057	F. Abe *et al.*	(CDF Collab.)
Also	99C	PR D59 032001	F. Abe *et al.*	(CDF Collab.)
ABE	98O	PR D58 072001	F. Abe *et al.*	(CDF Collab.)
ABE	98Q	PR D58 092002	F. Abe *et al.*	(CDF Collab.)
ABE	98U	PRL 81 5513	F. Abe *et al.*	(CDF Collab.)
ABE	98V	PRL 81 5742	F. Abe *et al.*	(CDF Collab.)
ACCIARRI	98D	EPJ C5 195	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	98S	PL B438 417	M. Acciarri *et al.*	(L3 Collab.)
ACKERSTAFF	98Z	EPJ C5 379	K. Ackerstaff *et al.*	(OPAL Collab.)
BARATE	98Q	EPJ C4 387	R. Barate *et al.*	(ALEPH Collab.)
BEHRENS	98	PRL 80 3710	B.H. Behrens *et al.*	(CLEO Collab.)
BERGFELD	98	PRL 81 272	T. Bergfeld *et al.*	(CLEO Collab.)
BRANDENB...	98	PRL 80 2762	G. Brandenbrug *et al.*	(CLEO Collab.)
GODANG	98	PRL 80 3456	R. Godang *et al.*	(CLEO Collab.)
NEMATI	98	PR D57 5363	B. Nemati *et al.*	(CLEO Collab.)
ABE	97J	PRL 79 590	K. Abe *et al.*	(SLD Collab.)
ABREU	97F	ZPHY C74 19	P. Abreu *et al.*	(DELPHI Collab.)
Also	97K	ZPHY C75 579 erratum		
ABREU	97N	ZPHY C76 579	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	97B	PL B391 474	M. Acciarri *et al.*	(L3 Collab.)
ACCIARRI	97C	PL B391 481	M. Acciarri *et al.*	(L3 Collab.)
ACKERSTAFF	97G	PL B395 128	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	97U	ZPHY C76 401	K. Ackerstaff *et al.*	(OPAL Collab.)
ACKERSTAFF	97V	ZPHY C76 417	K. Ackerstaff *et al.*	(OPAL Collab.)
ARTUSO	97	PL B399 321	M. Artuso *et al.*	(CLEO Collab.)
ASNER	97	PRL 79 799	D. Asner *et al.*	(CLEO Collab.)
ATHANAS	97	PRL 79 2208	M. Athanas *et al.*	(CLEO Collab.)
BUSKULIC	97	PL B395 373	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	97D	ZPHY C75 397	D. Buskulic *et al.*	(ALEPH Collab.)
FU	97	PRL 79 3125	X. Fu *et al.*	(CLEO Collab.)
JESSOP	97	PRL 79 4533	C.P. Jessop *et al.*	(CLEO Collab.)
ABE	96B	PR D53 3496	F. Abe *et al.*	(CDF Collab.)
ABE	96C	PRL 76 4462	F. Abe *et al.*	(CDF Collab.)
ABE	96H	PRL 76 2015	F. Abe *et al.*	(CDF Collab.)
ABE	96L	PRL 76 4675	F. Abe *et al.*	(CDF Collab.)
ABE	96Q	PR D54 6596	F. Abe *et al.*	(CDF Collab.)
ABREU	96P	ZPHY C71 539	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	96Q	ZPHY C72 17	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	96E	PL B383 487	M. Acciarri *et al.*	(L3 Collab.)
ADAM	96D	ZPHY C72 207	W. Adam *et al.*	(DELPHI Collab.)
ALBRECHT	96D	PL B374 256	H. Albrecht *et al.*	(ARGUS Collab.)
ALEXANDER	96T	PRL 77 5000	J.P. Alexander *et al.*	(CLEO Collab.)
ALEXANDER	96V	ZPHY C72 377	G. Alexander *et al.*	(OPAL Collab.)
ASNER	96	PR D53 1039	D.M. Asner *et al.*	(CLEO Collab.)
BARISH	96B	PRL 76 1570	B.C. Barish *et al.*	(CLEO Collab.)
BISHAI	96	PL B369 186	M. Bishai *et al.*	(CLEO Collab.)
BUSKULIC	96J	ZPHY C71 31	D. Buskulic *et al.*	(ALEPH Collab.)
BUSKULIC	96V	PL B384 471	D. Buskulic *et al.*	(ALEPH Collab.)
DUBOSCQ	96	PRL 76 3898	J.E. Duboscq *et al.*	(CLEO Collab.)
GIBAUT	96	PR D53 4734	D. Gibaut *et al.*	(CLEO Collab.)
PDG	96	PR D54 1		
ABE	95Z	PRL 75 3068	F. Abe *et al.*	(CDF Collab.)
ABREU	95N	PL B357 255	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	95Q	ZPHY C68 13	P. Abreu *et al.*	(DELPHI Collab.)
ACCIARRI	95H	PL B363 127	M. Acciarri *et al.*	(L3 Collab.)

ACCIARRI	95I	PL B363 137	M. Acciarri *et al.*	(L3 Collab.)
ADAM	95	ZPHY C68 363	W. Adam *et al.*	(DELPHI Collab.)
AKERS	95J	ZPHY C66 555	R. Akers *et al.*	(OPAL Collab.)
AKERS	95T	ZPHY C67 379	R. Akers *et al.*	(OPAL Collab.)
ALEXANDER	95	PL B341 435	J. Alexander *et al.*	(CLEO Collab.)
Also	95C	PL B347 469 (erratum)	J. Alexander *et al.*	(CLEO Collab.)
BARISH	95	PR D51 1014	B.C. Barish *et al.*	(CLEO Collab.)
BUSKULIC	95N	PL B359 236	D. Buskulic *et al.*	(ALEPH Collab.)
ABE	94D	PRL 72 3456	F. Abe *et al.*	(CDF Collab.)
ABREU	94M	PL B338 409	P. Abreu *et al.*	(DELPHI Collab.)
AKERS	94C	PL B327 411	R. Akers *et al.*	(OPAL Collab.)
AKERS	94H	PL B336 585	R. Akers *et al.*	(OPAL Collab.)
AKERS	94J	PL B337 196	R. Akers *et al.*	(OPAL Collab.)
AKERS	94L	PL B337 393	R. Akers *et al.*	(OPAL Collab.)
ALAM	94	PR D50 43	M.S. Alam *et al.*	(CLEO Collab.)
ALBRECHT	94	PL B324 249	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	94G	PL B340 217	H. Albrecht *et al.*	(ARGUS Collab.)
AMMAR	94	PR D49 5701	R. Ammar *et al.*	(CLEO Collab.)
ATHANAS	94	PRL 73 3503	M. Athanas *et al.*	(CLEO Collab.)
Also	95	PRL 74 3090 (erratum)	M. Athanas *et al.*	(CLEO Collab.)
BUSKULIC	94B	PL B322 441	D. Buskulic *et al.*	(ALEPH Collab.)
PDG	94	PR D50 1173	L. Montanet *et al.*	(CERN, LBL, BOST+)
PROCARIO	94	PRL 73 1306	M. Procario *et al.*	(CLEO Collab.)
STONE	94	HEPSY 93-11		
ABREU	93D	ZPHY C57 181	P. Abreu *et al.*	(DELPHI Collab.)
ABREU	93G	PL B312 253	P. Abreu *et al.*	(DELPHI Collab.)
ACTON	93C	PL B307 247	P.D. Acton *et al.*	(OPAL Collab.)
ALBRECHT	93	ZPHY C57 533	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	93E	ZPHY C60 11	H. Albrecht *et al.*	(ARGUS Collab.)
ALEXANDER	93B	PL B319 365	J. Alexander *et al.*	(CLEO Collab.)
AMMAR	93	PRL 71 674	R. Ammar *et al.*	(CLEO Collab.)
BARTELT	93	PRL 71 1680	J.E. Bartelt *et al.*	(CLEO Collab.)
BATTLE	93	PRL 71 3922	M. Battle *et al.*	(CLEO Collab.)
BEAN	93B	PRL 70 2681	A. Bean *et al.*	(CLEO Collab.)
BUSKULIC	93D	PL B307 194	D. Buskulic *et al.*	(ALEPH Collab.)
Also	94H	PL B325 537 (errata)		
BUSKULIC	93K	PL B313 498	D. Buskulic *et al.*	(ALEPH Collab.)
SANGHERA	93	PR D47 791	S. Sanghera *et al.*	(CLEO Collab.)
ALBRECHT	92C	PL B275 195	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	92G	ZPHY C54 1	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	92L	ZPHY C55 357	H. Albrecht *et al.*	(ARGUS Collab.)
BORTOLETTO	92	PR D45 21	D. Bortoletto *et al.*	(CLEO Collab.)
HENDERSON	92	PR D45 2212	S. Henderson *et al.*	(CLEO Collab.)
KRAMER	92	PL B279 181	G. Kramer, W.F. Palmer	(HAMB, OSU)
ALBAJAR	91C	PL B262 163	C. Albajar *et al.*	(UA1 Collab.)
ALBAJAR	91E	PL B273 540	C. Albajar *et al.*	(UA1 Collab.)
ALBRECHT	91B	PL B254 288	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	91C	PL B255 297	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	91E	PL B262 148	H. Albrecht *et al.*	(ARGUS Collab.)
BERKELMAN	91	ARNPS 41 1	K. Berkelman, S. Stone	(CORN, SYRA)
"Decays of *B* Mesons"				
FULTON	91	PR D43 651	R. Fulton *et al.*	(CLEO Collab.)
ALBRECHT	90B	PL B241 278	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	90J	ZPHY C48 543	H. Albrecht *et al.*	(ARGUS Collab.)
ANTREASYAN	90B	ZPHY C48 553	D. Antreasyan *et al.*	(Crystal Ball Collab.)
BORTOLETTO	90	PRL 64 2117	D. Bortoletto *et al.*	(CLEO Collab.)
ELSEN	90	ZPHY C46 349	E. Elsen *et al.*	(JADE Collab.)
ROSNER	90	PR D42 3732		
WAGNER	90	PRL 64 1095	S.R. Wagner *et al.*	(Mark II Collab.)
ALBRECHT	89C	PL B219 121	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	89G	PL B229 304	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	89J	PL B229 175	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	89L	PL B232 554	H. Albrecht *et al.*	(ARGUS Collab.)
ARTUSO	89	PRL 62 2233	M. Artuso *et al.*	(CLEO Collab.)
AVERILL	89	PR D39 123	D.A. Averill *et al.*	(HRS Collab.)
AVERY	89B	PL B223 470	P. Avery *et al.*	(CLEO Collab.)
BEBEK	89	PRL 62 8	C. Bebek *et al.*	(CLEO Collab.)
BORTOLETTO	89	PRL 62 2436	D. Bortoletto *et al.*	(CLEO Collab.)

BORTOLETTO	89B	PRL 63 1667	D. Bortoletto *et al.*	(CLEO Collab.)
ALBRECHT	88F	PL B209 119	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	88K	PL B215 424	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	87C	PL B185 218	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	87D	PL B199 451	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	87I	PL B192 245	H. Albrecht *et al.*	(ARGUS Collab.)
ALBRECHT	87J	PL B197 452	H. Albrecht *et al.*	(ARGUS Collab.)
AVERY	87	PL B183 429	P. Avery *et al.*	(CLEO Collab.)
BEAN	87B	PRL 58 183	A. Bean *et al.*	(CLEO Collab.)
BEBEK	87	PR D36 1289	C. Bebek *et al.*	(CLEO Collab.)
ALAM	86	PR D34 3279	M.S. Alam *et al.*	(CLEO Collab.)
ALBRECHT	86F	PL B182 95	H. Albrecht *et al.*	(ARGUS Collab.)
PDG	86	PL 170B	M. Aguilar-Benitez *et al.*	(CERN, CIT+)
CHEN	85	PR D31 2386	A. Chen *et al.*	(CLEO Collab.)
HAAS	85	PRL 55 1248	J. Haas *et al.*	(CLEO Collab.)
AVERY	84	PRL 53 1309	P. Avery *et al.*	(CLEO Collab.)
GILES	84	PR D30 2279	R. Giles *et al.*	(CLEO Collab.)
BEHRENDS	83	PRL 50 881	S. Behrends *et al.*	(CLEO Collab.)