Averages of B Hadron Lifetimes

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B Lifetime Group

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Version 1

Experiment	Method	Data set	τ_B (ps)	Reference
ALEPH	Lepton i.p. (3D)	91-93	$1.533 \pm 0.013 \pm 0.022$	[1]
L3	Lepton i.p. (2D)	91-94	$1.544 \pm 0.016 \pm 0.021$	[2][b]
OPAL	Lepton i.p. (2D)	90-91	$1.523 \pm 0.034 \pm 0.038$	[3]
Average set 1			1.537 ± 0.020	
ALEPH	Dipole	91	$1.511 \pm 0.022 \pm 0.078$	[4]
DELPHI	All track i.p.(2D)	91-92	$1.542 \pm 0.021 \pm 0.045$	[5][a]
DELPHI	Sec. vert.	91-93	$1.582 \pm 0.011 \pm 0.027$	[6][a]
L3	Sec. vert. + i.p.	91-94	$1.556 \pm 0.010 \pm 0.017$	[2][b]
OPAL	Sec. vert.	91-94	$1.611 \pm 0.010 \pm 0.027$	[7]
SLD	Sec. vert.	93	$1.564 \pm 0.030 \pm 0.036$	[8]
Average set 2			1.576 ± 0.016	
CDF	J/ψ vert.	92-95	$1.533 \pm 0.015 \, ^{+0.035}_{-0.031}$	[9]
Average			1.564 ± 0.014	

Table 1: Measurements of the average B hadron lifetime.
a) The combined DELPHI result quoted in [6] is $1.575 \pm 0.010 \pm 0.026$ ps.
b) The combined L3 result quoted in [2] is $1.549 \pm 0.009 \pm 0.015$ ps.

Comments

The available results have been divided into three sets:

1. measurements at LEP based on the identification of a lepton from b decay
2. measurements at LEP which will accept any b hadron decay
3. CDF J/ψ measurement

The reason for this division is that if the lifetimes of the individual b hadron species are different (and it would appear the the b baryons are lower than b mesons), then the average b hadron lifetime makes sense only for samples in which the composition of b hadron types is the same.

The measurements in set 2 will measure the average b hadron lifetime for a sample of b hadrons of the same composition as the production fractions at the Z0. Set 1 will measure a sample of hadrons depleted in b baryons with respect to the production fractions, and thus bias the lifetime higher by about 0.01 ps.

Finally the CDF J/ψ measurement will almost certainly be based on a different composition of b hadron species than either of the previous sets of measurements.

Correlated systematic considered :

- b fragmentation
- c fragmentation
- b models
- c models
- Br(B $\rightarrow \ell$)
- Br(B $\rightarrow$ c $\rightarrow \ell$)

- τ_{c}
- $\mathrm{Br}(\mathrm{c} \rightarrow \ell\ )$
- B charged track multiplicity

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Experiment	Method	Data set	τ_{B^0} (ps)	Reference
ALEPH	$\mathrm{D}^{(*)}\ell$	91-95	$1.518 \pm 0.053 \pm 0.034$	[1]
ALEPH	Exclusive rec.	91-94	$1.25^{+0.15}_{-0.13} \pm 0.05$	[2]
ALEPH	Partial rec. $\pi^+\pi^-$	91-94	$1.49^{+0.17+0.08}_{-0.15-0.06}$	[2]
CDF	$\mathrm{D}^{(*)}\ell$	92-95	$1.474 \pm 0.039^{+0.052}_{-0.051}$	[3]
CDF	Excl. $(J/\psi K)$	92-95	$1.497 \pm 0.073 \pm 0.032$	[4]
DELPHI	$\mathrm{D}^{(*)}\ell$	91-93	$1.61^{+0.14}_{-0.13} \pm 0.08$	[5]
DELPHI	Charge sec. vtx.	91-93	$1.63 \pm 0.14 \pm 0.13$	[6]
DELPHI	Inclusive $\mathrm{D}^*\ell$	91-93	$1.532 \pm 0.041 \pm 0.040$	[7]
L3	Charge sec. vtx.	94-95	$1.52 \pm 0.06 \pm 0.04$	[8]
OPAL	$\mathrm{D}^{(*)}\ell$	91-93	$1.53 \pm 0.12 \pm 0.08$	[9]
OPAL	Charge sec. vtx.	93-95	$1.523 \pm 0.057 \pm 0.053$	[10]
OPAL	Inclusive $\mathrm{D}^*\ell$	91-00	$1.541 \pm 0.028 \pm 0.023$	[11]
SLD	Charge sec. vtx.ℓ	93-95	$1.56^{+0.14}_{-0.13} \pm 0.10$	[12][a]
SLD	Charge sec. vtx.	93-95	$1.66 \pm 0.08 \pm 0.08$	[12][a]
BABAR	Exclusive rec.	99-00	$1.546 \pm 0.032 \pm 0.022$	[13]
BABAR	Inclusive $\mathrm{D}^*\ell$	99-01	$1.529 \pm 0.012 \pm 0.029$	[14]
BABAR	Exclusive $\mathrm{D}^*\ell$	99-02	$1.523^{+0.024}_{-0.023} \pm 0.022$	[15]
BABAR	Incl. $\mathrm{D}^*\pi$ & $\mathrm{D}^*\rho$	99-01	$1.533 \pm 0.034 \pm 0.038$	[16]
BELLE	Exclusive rec.	99-01	$1.554 \pm 0.030 \pm 0.019$	[17]
Average			1.536 ± 0.014	

Table 2: Measurements of the B^0 lifetime.
p) preliminary
a) The combined SLD result quoted in [12] is $1.64 \pm 0.08 \pm 0.08$ ps.

Experiment	Method	Data set	τ_{B^+}(ps)	Reference
ALEPH	$D^{(*)}\ell$	91-95	1.648±0.049 ± 0.035	[1]
ALEPH	Exclusive rec.	91-94	$1.58^{+0.21+0.04}_{-0.18-0.03}$	[2]
CDF	$D^{(*)}\ell$	92-95	$1.637\pm0.058^{+0.045}_{-0.043}$	[3]
CDF	Excl. $(J/\psi K)$	92-95	1.636 ± 0.058 ± 0.025	[4]
DELPHI	$D^{(*)}\ell$	91-93	1.61 ± 0.16 ± 0.12	[5][a]
DELPHI	Charge sec. vtx.	91-93	1.72 ± 0.08 ± 0.06	[6][a]
L3	Charge sec. vtx.	94-95	1.66± 0.06 ± 0.03	[8]
OPAL	$D^{(*)}\ell$	91-93	1.52 ± 0.14 ±0.09	[9]
OPAL	Charge sec. vtx.	93-95	1.643± 0.037 ± 0.025	[10]
SLD	Charge sec. vtx. ℓ	93-95	$1.61^{+0.13}_{-0.12}\pm 0.07$	[12][b]
SLD	Charge sec. vtx.	93-95	1.67± 0.07 ± 0.06	[12][b]
BABAR	Exclusive rec.	99-00	1.673± 0.032 ± 0.023	[13]
BELLE	Exclusive rec.	99-01	1.695± 0.026 ± 0.015	[17]
Average			1.671 ± 0.018	

Table 3: Measurements of the B^+ lifetime.
p) preliminary
a) The combined DELPHI result quoted in [6] is 1.70 ± 0.09.
b) The combined SLD result quoted in [12] is 1.66 ± 0.06 ± 0.05.

Experiment	Method	Data set	Ratio τ_+/τ_0	Reference
ALEPH	$D^{(*)}\ell$	91-95	1.085±0.059 ± 0.018	[1]
ALEPH	Exclusive rec.	91-94	$1.27^{+0.23+0.03}_{-0.19-0.02}$	[2]
CDF	$D^{(*)}\ell$	92-95	$1.110\pm0.056^{+0.033}_{-0.030}$	[3]
CDF	Excl. $(J/\psi K)$	92-95	1.093 ± 0.066 ± 0.028	[4]
DELPHI	$D^{(*)}\ell$	91-93	$1.00^{+0.17}_{-0.15}\pm 0.10$	[5]
DELPHI	Charge sec. vtx.	91-93	$1.06^{+0.13}_{-0.11}\pm 0.10$	[6]
L3	Charge sec. vtx.	94-95	1.09± 0.07 ± 0.03	[8]
OPAL	$D^{(*)}\ell$	91-93	$0.99\pm0.14^{+0.05}_{-0.04}$	[9]
OPAL	Charge sec. vtx.	93-95	1.079± 0.064 ± 0.041	[10]
SLD	Charge sec. vtx. ℓ	93-95	$1.03^{+0.16}_{-0.14}\pm 0.09$	[12][a]
SLD	Charge sec. vtx.	93-95	$1.01^{+0.09}_{-0.08}\pm 0.05$	[12][a]
BABAR	Exclusive rec.	99-00	1.082 ± 0.026± 0.012	[13]
BELLE	Exclusive rec.	99-01	1.091 ± 0.023± 0.014	[17]
Average			1.086 ± 0.017	

Table 4: Measurements of the ratio τ_+/τ_0.
a) The combined SLD result quoted in [12] is 1.01 ± 0.07 ± 0.06 ps

Correlated systematic considered (central values and errors scaled accordingly):

- D^{**} branching ratio uncertainties

- Momentum estimation ($X_E = 0.702 \pm 0.008$)
- Lifetime of B_u, B_s and B baryons as in this note
- Fraction of B_u ($f_{bu} = f_{bd} = 39.7 \pm 1.0\%$), of B_s ($f_s = 10.7 \pm 1.1\%$) and of B baryons ($f_{bbaryon} = 9.9 \pm 1.7\%$) produced in Z decays.

References

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Experiment	Method	Data set	τ_{B_s} (ps)	Reference
ALEPH	$D_s\ell$	91-95	$1.54^{+0.14}_{-0.13}\pm 0.04$	[1]
ALEPH	$D_s h$	91-95	$1.47\pm 0.14 \pm 0.08$	[2]
CDF	$D_s\ell$	92-96	$1.36\pm0.09^{+0.06}_{-0.05}$	[3]
CDF	Excl. $J/\psi\phi$	92-95	$1.34^{+0.23}_{-0.19}\pm 0.05$	[4]
DELPHI	$D_s\ell$	91-95	$1.42^{+0.14}_{-0.13}\pm 0.03$	[5]
DELPHI	$D_s h$	91-95	$1.53^{+0.16}_{-0.15}\pm 0.07$	[6]
DELPHI	D_s inclus.	91-94	$1.60\pm0.26^{+0.13}_{-0.15}$	[7]
OPAL	$D_s\ell$	90-95	$1.50^{+0.16}_{-0.15}\pm 0.04$	[8]
OPAL	D_s inclus.	90-95	$1.72^{+0.20+0.18}_{-0.19-0.17}$	[9]
Average			1.461 ± 0.057	

Table 5: Measurements of the B_s lifetime. Excluding the CDF $J/\psi\phi$ measurement the average is : $\tau_{B_s} = 1.471 \pm 0.059$.

Correlated systematic considered:

- Average B lifetime used in backgrounds
- B_s multiplicity
- Branching ratios used to determine backgrounds (e.g. $Br(B \to D_s D)$)

A knowledge of the multiplicity of B_s decays is important for measurements that partially reconstruct the final state such as $B_s \to D_s X$ (where X is not a lepton). The the boost deduced from Monte Carlo simulation depends on the multiplicity used. Since this is not well known the mutliplicity in the simulation is varied and this range of values observed is taken to be a systematic.

Similarly not all the branching ratios for the potential background processes are measured. Where they are available the PDG values are used for the error estimate. Where no measurements are available estimates can usually be made by using measured branching ratios of related processes and using some reasonable extrapolation.

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Experiment	Method	Data set	τ_{Λ_b} (ps)	Reference
ALEPH	$\Lambda\ell$	91-95	$1.20^{+0.08}_{-0.08}\pm 0.06$	[1]
ALEPH	$\Lambda_c\ell$	91-95	$1.18^{+0.13}_{-0.12}\pm 0.03$	[1]
ALEPH	$\Lambda\ell^-\ell^+$	91-95	$1.30^{+0.26}_{-0.21}\pm 0.04$	[1]
ALEPH	$\Xi\ell$	90-95	$1.35^{+0.37+0.15}_{-0.28-0.17}$	[2]
CDF	$\Lambda_c\ell$	91-95	$1.32\pm0.15\pm 0.06$	[3]
DELPHI	$\Lambda\ell\pi$ vtx	91-94	$1.16\pm0.20 \pm 0.08$	[4][a]
DELPHI	$\Lambda\mu$ i.p.	91-94	$1.10^{+0.19}_{-0.17} \pm 0.09$	[5][a]
DELPHI	$\Lambda_c\ell$	91-94	$1.11^{+0.19}_{-0.18} \pm 0.05$	[4][a]
DELPHI	pℓ	91-94	$1.19\pm0.14\pm 0.07$	[4][a]
DELPHI	$\Xi\ell$	91-93	$1.5\ ^{+0.7}_{-0.4}\pm 0.3$	[6]
OPAL	$\Lambda\ell$ i.p.	90-94	$1.21^{+0.15}_{-0.13}\pm 0.10$	[7][b]
OPAL	$\Lambda\ell$ vtx.	90-94	$1.15\pm0.12\pm 0.06$	[7][b]
OPAL	$\Lambda_c\ell\&\Lambda\ell^-\ell^+$	90-95	$1.29^{+0.24}_{-0.22}\pm 0.06$	[8]
Average			1.208 ± 0.051	

Table 6: Measurements of the b-baryon lifetime.
a) The combined DELPHI result quoted in [4] is $1.14\pm0.08 \pm 0.04$ ps.
b) The combined OPAL result quoted in [7] is $1.16 \pm 0.11 \pm 0.06$ ps.
The DELPHI and ALEPH $\Xi\ell$ results are not included in the quoted average since the selected data samples contain mostly Ξ_b while the data samples in the other measurements contain mostly Λ_b. The combined value between these two measurements gives :
$\tau_{\Xi_b} = 1.39^{+0.34}_{-0.28}$ ps.
Considering only the measurements obtained with $\Lambda_c\ell$ and $\Lambda\ell^-\ell^+$ correlations the average is : $\tau_{\Lambda_b} = 1.229^{+0.081}_{-0.079}$ ps.

Correlated systematic considered

- resolution (for ALEPH and OPAL inside the same experiment)
- fragmentation
- polarization
- baryon mass
- decay model
- B baryon purity
- Isgur Wise

Comments

In computing the averages the central values of the masses are scaled to m(Λ_b) = 5624 ± 9 MeV and m(b-baryon) = 5670 ± 100 MeV.

The meaning of decay model and the correlations are not always clear. Mostly it includes assumptions on n-body decays. To be conservative it is assumed that it is correlated whenever given as an error. DELPHI varies 4-body decays from 0.0 to 0.3. In computing the average the DELPHI result is corrected for 0.2+-0.2.

Furthermore, in computing the average the results are corrected for a polarisation of -0.45$^{+0.19}_{-0.17}$ and a Λ_b fragmentation parameter $X_E = 0.70 \pm 0.03$.

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