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MEASUREMENT OF THE AVERAGE LIFETIME OF B HADRONS AT SLD*

GREG PUNKAR †
Stanford Linear Accelerator Center, Stanford University,
Stanford, California 94309, USA

ABSTRACT

We present preliminary measurements of the average B hadron lifetime using a sample of 50,000 Z^0 events collected by SLD at the SLC in 1993. Our first technique uses the impact parameter of tracks in jets opposite tagged b jets. We obtain $\tau_B(\delta) = 1.617 \pm 0.048 \pm 0.086$ ps, and $\tau_B(\sum\delta) = 1.627 \pm 0.054 \pm 0.132$ ps from single and summed impact parameter distributions. The second technique uses inclusive vertices reconstructed in three dimensions. From the decay length distribution, we extract $\tau_B = 1.577 \pm 0.032 \pm 0.046$ ps.

1. General Description and Experimental Procedure

The precise measurement of the average lifetime of B hadrons, τ_B, is important for the study of the b quark and its weak couplings to u and c quarks. Furthermore, recent measurements have shown a marked departure from the 1992 world average.[1]

The preliminary results presented here use the pixel-based Vertex Detector (VXD) and the Central Drift Chamber (CDC) for tracking, and the Liquid Argon Calorimeter (LAC)[2] for triggering and determining event shape properties. Within the VXD solid angle, 96% of all CDC tracks correctly link to one or more pixel-clusters. Angular errors in the extrapolated tracks combined with local errors $\sigma_{r\phi}$ and σ_{rz} of ~ 6 μm for the VXD clusters, lead to xy (orthogonal to the e^- beam) and rz (plane containing the e^- axis) impact parameter resolutions of $(\alpha,\beta)_{xy}$ = (11 μm, 70 μm) and $(\alpha,\beta)_{rz}$ = (38 μm, 70 μm).[3] During the 1993 SLD run the $\langle rms\rangle_{xyz}$ profile of SLC beams was $2.4 \times 0.8 \times 700$ μm^3 at the interaction point (IP). The IP x and y positions are tracked by SLD using reconstructed tracks from hadronic Z^0 events. Muon pairs (not used in the average IP determination) are used to check the IP xy position, giving $\sigma_{xy}^{IP} = 7 \pm 2$ μm. The z position of the IP is measured event by event with $\sigma_z \simeq 35$ μm as determined by simulation.

The Monte Carlo (MC) physics simulation models Z^0 and heavy flavor decays with the LUND JETSET (version 6.3) Monte Carlo generator, which has been adjusted to reflect current knowledge of the B and D decay spectra. The lifetime for B mesons (baryons) is set to 1.55 ps (1.10 ps). The MC detector simulation is based on GEANT

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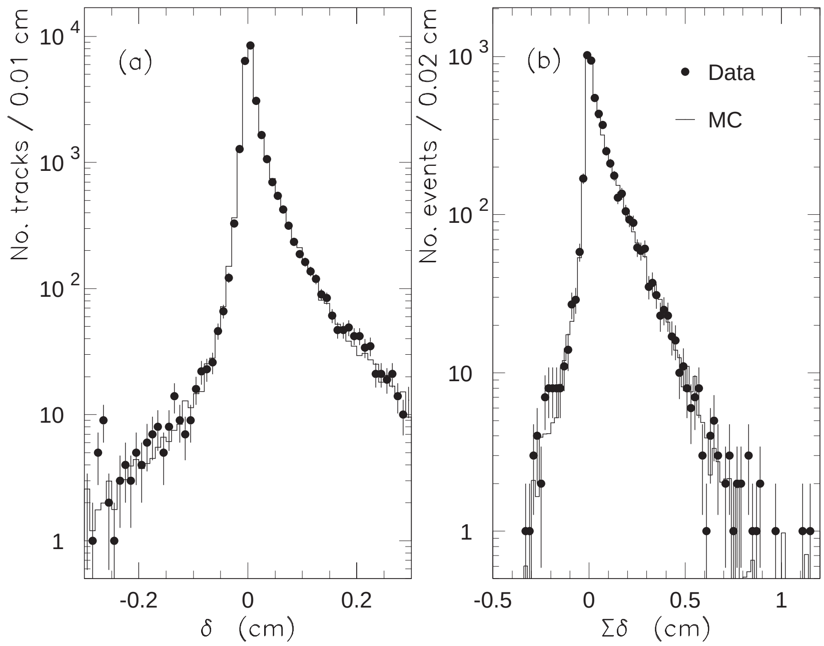

Fig. 1. Distributions of the impact parameter (a) and summed impact parameter (b).

and produces raw hits that are superimposed on randomly triggered events from the data, to simulate the unique SLC backgrounds. A difference in track finding efficiency between data and MC is observed and corrected for as a function of momentum, θ and ϕ (polar and azimuthal angles), and ξ (angle to jet direction), by randomly removing MC tracks. Approximately 7% of the MC tracks passing all track selection cuts are removed.

Standard hadronic event selection cuts[4] are applied, resulting in a sample of 29,400 Z^0 events. Jet axes are determined from energy clusters in the LAC using the JADE algorithm with $y_{cut} = 0.02$. For each track passing selection criteria,[4] we form the xy impact parameter (δ) relative to the IP and $\delta_{norm} \equiv \delta/\sigma$, where σ is obtained from σ_δ and σ_{xy}^{IP} added in quadrature. The impact parameter is signed with respect to the nearest jet axis following the standard convention.[4] An event is b-tagged by requiring a minimum number of 3 tracks with $\delta_{norm} > 3$. A jet is b-tagged by applying the same criteria to tracks in a given jet. The corresponding efficiencies and purities are $\epsilon_{event} = 69\%$, $\epsilon_{jet} = 30\%$, $\Pi_{event} = 82\%$, and $\Pi_{jet} = 93\%$ for event- and jet-tagging, respectively.

2. Lifetime Analyses

The **impact parameter** lifetime measurements use 2- and 3-jet events and take advantage of the fact that tracks resulting from heavy quark decays have large positive δ while those resulting from fragmentation and light quark decays have small positive or negative δ. In the first method, the lifetime is determined from the impact parameter distribution for *all* quality tracks in the jet(s) opposite the tagged jet (in the case of double tagged events, for both analyses, all jets are used). Since all tracks are used directly in the lifetime measurement, the method provides a high analyzing

Detector Modeling	δ (%)	$\sum\delta$ (%)	Physics Modeling	δ (%)	$\sum\delta$ (%)
Track Resolution	1.4	3.6	R_b (0.218 ± 0.015)	1.9	2.3
Track./Link. Eff.	0.9	3.8	R_c (0.181 ± 0.030)	2.0	2.8
IP Position Tails	0.2	0.2	b fragmentation	2.9	2.9
Subtotal	1.7	5.2	$(\langle x_E \rangle = 0.700 \pm 0.011)$		
			c fragmentation	0.4	1.4
			$(\langle x_E \rangle = 0.49 \pm 0.03)$		
			B multiplicity (5.5 ± 0.2)	1.9	3.1
			B baryon fraction	2.0	2.0
			(0.088 ± 0.050)		
			Charm content of B decay	1.3	1.3
			Subtotal	5.0	6.2
TOTAL				5.3	8.1

Table 1. Systematic errors in the average B hadron lifetime for impact parameter methods.

power. In the summed impact parameter ($\sum\delta$) method,[5] a scalar sum of the signed impact parameters from quality tracks in the jet opposite the tagged jet is formed. The advantage of this method is in its enhancement of the lifetime signal since jets from light quarks will have $\sum\delta \simeq 0$.

To extract τ_B, the δ and $\sum\delta$ distributions are fit to their corresponding MC distributions. Since the b MC sample is generated at fixed lifetime, the τ_B dependence is introduced to the fitting function through a weighting procedure. Jets containing a B hadron are given a weight which represents the probability of its being generated with a new lifetime, relative to the probability for its generated lifetime. Each entry in the δ and $\sum\delta$ MC distributions is weighted by the product of the weight for the un-tagged jet to which it belongs and the weight for the jet tagging the event. This accounts for the b-jet tagging purity and efficiency as a function of B hadron lifetime. MC δ and $\sum\delta$ distributions are formed ranging from $\tau_B = 0.5$ to 2.5 ps in 0.02 ps steps. The data distributions are fit to each of the MC distributions using a Maximum Likelihood procedure utilizing a multinomial probability function. The resulting δ and $\sum\delta$ distributions for data and best fit MC are shown in Fig. 1.

Table 1 summarizes the fractional systematic errors for the δ and $\sum\delta$ lifetime measurements. The detector errors contribute 1.7% (5.2%) for the δ ($\sum\delta$) method; these are expected to improve in the near future as our understanding of the tracking systems continues to improve. The systematic errors are dominated by the uncertainties in b-quark fragmentation and modeling. The physics modeling errors contribute 5.0% (6.2%) for the δ ($\sum\delta$) method. Added in quadrature, the net systematic error is 5.3% (8.1%) for the δ ($\sum\delta$) method. The resulting values for the lifetime are $\tau_B(\delta) = 1.617 \pm 0.048(stat.) \pm 0.086(syst.)$ ps, and $\tau_B(\sum\delta) = 1.627 \pm 0.054(stat.) \pm 0.132(syst.)$ ps.

The fit results are stable with respect to the following: different tag requirement, maximum number of jets allowed in the event (2 or 3), average lifetime of generated MC (1.55 ps or 2.00 ps for B mesons), fit method, range and binning.

The lifetime is also extracted using **3-D reconstructed vertices**. In this technique we use quality tracks from b-tagged events to reconstruct all possible geometrical vertices in three dimensions. The number of vertices is then reduced by looking at the global event topology and by choosing the set of independent (i.e. not sharing any track) vertices that maximizes the product of the vertex fit probablities. Further cuts are applied to remove vertices containing tracks originating from the IP. In particular, the decay length is required to be greater than 1 mm. Only the vertex closest to the IP is kept in each event hemisphere. The final sample consists of 4294 b-tagged events with 5427 selected vertices. Monte Carlo studies indicate that 88% of selected vertices carry B hadron lifetime information.

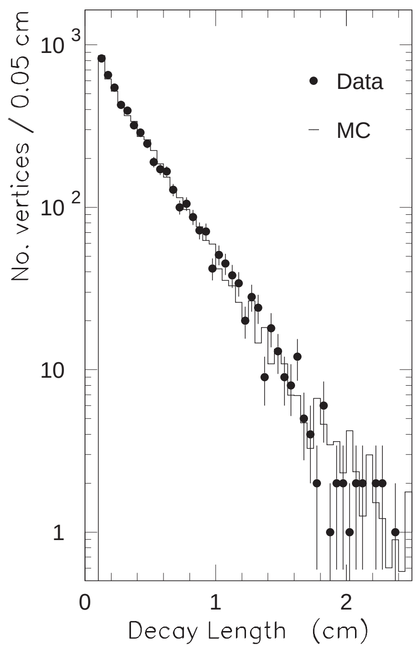

Figure 2. Decay length distribution for selected vertices.

The lifetime is extracted from the decay length distribution (Fig. 2) by following a similar weighting and fit procedure as described above. The lifetime is measured to be $\tau_B = 1.577 \pm 0.032(stat.) \pm 0.046(syst.)$ ps, where the systematic error is dominated by the uncertainty in the b-quark fragmentation. A complete account of this analysis technique and results is given elsewhere.[6]

3. Conclusions

We have made preliminary measurements of the average B hadron lifetime using 2-D impact parameters and 3-D vertices. Each of these measurements is currently limited by systematic errors which should decrease as we continue to improve our understanding of the detector and the physics modeling. In addition, we hope to be able to extend the 3-D vertexing technique to study exclusive B decay lifetimes in the near future.

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* K. Abe,[28] I. Abt,[14] T. Akagi,[26] W.W. Ash,[26] D. Aston,[26]
N. Bacchetta,[21] K.G. Baird,[24] C. Baltay,[32] H.R. Band,[31]
M.B. Barakat,[32] G. Baranko,[10] O. Bardon,[16] T. Barklow,[26]
A.O. Bazarko,[11] R. Ben-David,[32] A.C. Benvenuti,[2] T. Bienz,[26]
G.M. Bilei,[22] D. Bisello,[21] G. Blaylock,[7] J.R. Bogart,[26]
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B. Camanzi,[12] M. Carpinelli,[23] R. Cassell,[26] R. Castaldi,[23]
A. Castro,[21] M. Cavalli-Sforza,[7] E. Church,[30] H.O. Cohn,[27]
J.A. Coller,[3] V. Cook,[30] R. Cotton,[4] R.F. Cowan,[16] D.G. Coyne,[7]
A. D'Oliveira,[8] C.J.S. Damerell,[25] S. Dasu,[26] R. De Sangro,[13]
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B.I. Eisenstein,[14] R. Elia,[26] D. Falciai,[22] C. Fan,[10] M.J. Fero,[16]
R. Frey,[20] K. Furuno,[20] T. Gillman,[25] G. Gladding,[14] S. Gonzalez,[16]
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S.L. Shapiro,[26] D.J. Sherden,[26] N.B. Sinev,[20] C. Simopoulos,[26]
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S.L. White,[27] F.J. Wickens,[25] D.A. Williams,[7] D.C. Williams,[16]

S.H. Williams,[26] S. Willocq,[32] R.J. Wilson,[9] W.J. Wisniewski,[5]
M. Woods,[26] G.B. Word,[24] J. Wyss,[21] R.K. Yamamoto,[16]
J.M. Yamartino,[16] S.J. Yellin,[6] C.C. Young,[26] H. Yuta,[28]
G. Zapalac,[31] R.W. Zdarko,[26] C. Zeitlin,[20] and J. Zhou[20]

[1] Adelphi University, Garden City, New York 11530
[2] INFN Sezione di Bologna, I-40126 Bologna, Italy
[3] Boston University, Boston, Massachusetts 02215
[4] Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom
[5] California Institute of Technology, Pasadena, California 91125
[6] University of California at Santa Barbara, Santa Barbara, California 93106
[7] University of California at Santa Cruz, Santa Cruz, California 95064
[8] University of Cincinnati, Cincinnati, Ohio 45221
[9] Colorado State University, Fort Collins, Colorado 80523
[10] University of Colorado, Boulder, Colorado 80309
[11] Columbia University, New York, New York 10027
[12] INFN Sezione di Ferrara and Università di Ferrara, I-44100 Ferrara, Italy
[13] INFN Lab. Nazionali di Frascati, I-00044 Frascati, Italy
[14] University of Illinois, Urbana, Illinois 61801
[15] Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720
[16] Massachusetts Institute of Technology, Cambridge, Massachusetts 02139
[17] University of Massachusetts, Amherst, Massachusetts 01003
[18] University of Mississippi, University, Mississippi 38677
[19] Nagoya University, Chikusa-ku, Nagoya 464 Japan
[20] University of Oregon, Eugene, Oregon 97403
[21] INFN Sezione di Padova and Università di Padova, I-35100 Padova, Italy
[22] INFN Sezione di Perugia and Università di Perugia, I-06100 Perugia, Italy
[23] INFN Sezione di Pisa and Università di Pisa, I-56100 Pisa, Italy
[24] Rutgers University, Piscataway, New Jersey 08855
[25] Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX United Kingdom
[26] Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309
[27] University of Tennessee, Knoxville, Tennessee 37996
[28] Tohoku University, Sendai 980 Japan
[29] Vanderbilt University, Nashville, Tennessee 37235
[30] University of Washington, Seattle, Washington 98195
[31] University of Wisconsin, Madison, Wisconsin 53706
[32] Yale University, New Haven, Connecticut 06511

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