SLAC-PUB-3187
August 1983
(T/E)

TAU AND B LIFETIME MEASUREMENTS FROM THE MARK II*

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INTRODUCTION

Measurement of the τ lifetime checks whether the τ couples to the charged weak current with the same universal coupling strength as the e and μ. The lifetime of bottom hadrons measures the weak coupling between the bottom quark and the charm and up quarks. Measurements of these lifetimes have been made with the MARK II detector at the e^+e^- storage ring PEP at 29.0 GeV center-of-mass energy at the Stanford Linear Accelerator Center.

VERTEX DETECTOR AND DETERMINATION OF e^+e^- INTERACTION POINT

The MARK II vertex detector,[1] a high-precision cylindrical drift chamber, has been used in conjunction with the main drift chamber to enable us to extrapolate tracks to the origin with a resolution of about 100 μ. The beam position is measured by finding the position which minimizes the distance of closest approach for good tracks. In a typical two hour run, the average beam position is measured to within 20 μ vertically and 50 μ horizontally. We measure the rms beam size to be 65 $\pm$ 15 μ vertically and 480 $\pm$ 10 μ horizontally.

TAU LIFETIME MEASUREMENT

A new, more precise measurement of the τ lifetime has been made using data corresponding to an integrated luminosity of 41 pb^{-1}. Events consisting of a $\tau^+\tau^-$ pair are selected as two-jet events with at least one of the τ's decaying to three charged prongs.

Tracks are required to be well-measured in both the vertex detector and the main drift chamber. The decay length is calculated from the decay vertex position relative to the beam position , the beam and vertex error matrices, the τ direction (assumed to be the three-pion direction), and the angle between the τ direction and the beam direction. The decay length resolution depends on the opening angles, track momenta, and orientation of each decay. Requiring the resolution to be less than 1700 μ leaves 156 decays. Figure 1 shows the decay length distribution.

A maximum likelihood fit is used to determine the average decay length. The fitting function is a convolution of an exponential decay distribution with a Gaussian resolution function whose width is calculated event by event. The decay length is corrected for backgrounds and initial state radiation. The total systematic error is estimated to be 80 μ.

The τ lifetime is thus measured to be $\tau_\tau = (3.20 \pm 0.41 \pm 0.35) \times 10^{-13}$ sec, where the first error is statistical and the second systematic. The measurement is in agreement with previous measurements,[2] which had larger statistical and systematic errors. It is also in agreement with the prediction of $(2.8 \pm 0.2) \times 10^{-13}$ sec from e-μ-τ universality.

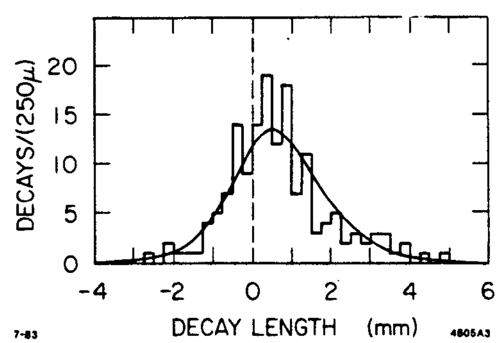

Fig. 1. Measured τ decay lengths. The solid curve is the best fit to the data described in the text.

*Work supported by the Department of Energy, contracts DE-AC03-76SF00515, W-7405-ENG-48, and DE-AC03-76SF00098.

Presented at the International Europhysics Conference on High Energy Physics, Brighton, United Kingdom, July 20-27, 1983

B LIFETIME MEASUREMENT

The average lifetime of bottom hadrons is determined from the measurement of projected impact parameters of leptons produced in their decay. The data for this measurement consist of multihadronic events corresponding to 80 pb^{-1} integrated luminosity. Electrons are identified over 64% of the solid angle with a lead–liquid–argon calorimeter.[3] Muons are identified over 45% of the solid angle using a four-layered system of hadron absorber and proportional tubes.

Leptons originating from charm and bottom decays are separated on the basis of their transverse momentum (p_T) relative to the thrust direction, which is determined using all charged tracks in the event. Leptons with $p_T < 1\,\mathrm{GeV/c}$ and momentum (p) $> 3\,\mathrm{GeV/c}$ comprise the charm–enriched sample, those with $p_T > 1\,\mathrm{GeV/c}$ and $p > 2\,\mathrm{GeV/c}$ the bottom–enriched sample. In the b-region $20 \pm 7\%$ of the lepton candidates are misidentified hadrons or pion and kaon decay products; $34 \pm 9\%$ of the lepton candidates in the c–region come from these backgrounds. From our analysis of the inclusive lepton p and p_T distributions,[3] we find $80 \pm 8\%$ of the prompt leptons in the b–region are from bottom decays, and $20 \pm 8\%$ are from charm decays. In the c–region $32 \pm 8\%$ of the prompt leptons are from bottom decays, and $68 \pm 8\%$ are from charm decays.

The impact parameter is taken to be the distance of closest approach between the lepton trajectory, projected in the plane perpendicular to the beams, and the beam position. The error in the impact parameter is dominated by the beam size and ranges from $120\,\mu$ to $490\,\mu$ depending on the lepton azimuthal angle. The impact parameter error is required to be less than $350\,\mu$, leaving 307 leptons for further analysis. The impact parameter distributions for the b–region and the c–region are shown in Figs. 2a and 2b, respectively.

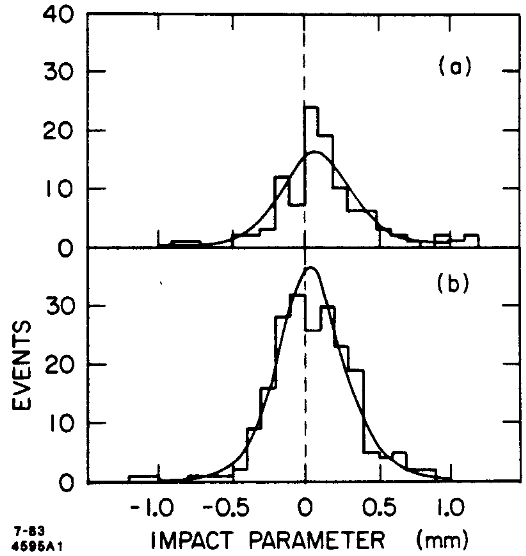

Fig. 2. Impact parameter distributions for (a) leptons in the b–region and (b) leptons in the c–region. The solid curves are the result of the fit described in the text.

The measured impact parameter distributions are fit by a maximum likelihood technique to the sums of distributions from three sources—background, leptons from b decays, and leptons from c decays—weighted by their fractions in the sample. The impact parameter distribution for the background is measured from nonleptons. The shapes of the impact parameter distributions for charm and bottom decays are calculated by Monte Carlo techniques; the distributions scale with the lifetimes of the parents. These distributions are convoluted with a Gaussian resolution function whose width is calculated event by event. To obtain the value of τ_b, we use $\tau_c = (6.0 \pm 1.5) \times 10^{-13}$ sec. We have estimated an over all systematic error of 25% due to uncertainties in the background and bottom–hadron fractions, fragmentation functions and fitting procedures. We find $\tau_b = (12.0^{+4.5}_{-3.6} \pm 3.0) \times 10^{-13}$ sec, where the first error is statistical and the second systematic, consistent with the value reported by the MAC collaboration.[4]

From the bottom lifetime measurement we find the Kobayashi-Maskawa matrix element[5] $|U_{bc}| = 0.053^{+.010}_{-.009}$. The value of the bottom hadron lifetime also imposes limits on the top quark mass.[6]

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