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MEASURING THE BRANCHING FRACTION FOR $Z^0 \to b\bar{b}$ USING PRECISION VERTEX DETECTORS*

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Abstract

We have measured the fraction of $b\bar{b}$ events in hadronic Z^0 decays, $R_{b\bar{b}}$, using the vertex detector system of the Mark II detector at the SLC. We tag $b\bar{b}$ events by requiring at least three tracks with significant impact parameters. This tag is 50% efficient and results in a sample of 85% purity. We find $R_{b\bar{b}} = 0.251 \pm 0.049 \pm 0.030$, in good agreement with other measurements and the Standard Model prediction.

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1. Introduction

In this paper we report on a measurement of the fraction of $b\bar{b}$ events from Z^0 decay, $R_{b\bar{b}} \equiv \Gamma(Z^0 \to b\bar{b}) \,/\, \Gamma(Z^0 \to \text{hadrons})$. Our measurement differs from previous ones[1–5] in that the $b\bar{b}$ events are identified by requiring that several tracks have significant impact parameters with respect to the interaction point.

2. Tagging $b\bar{b}$ Events

The Mark II detector[6] was upgraded for the 1990 SLAC Linear Collider (SLC) runs by the addition of high precision vertex detectors. Charged particle tracking was performed by three detector systems: the Central Drift Chamber (CDC), the Drift Chamber Vertex Detector (DCVD), and the Silicon Strip Vertex Detector (SSVD). The 72-layer CDC was used to find charged tracks and measure their momenta. Inside the CDC was the 38-layer DCVD[7] which had a spatial resolution of $\sigma^2 = (28\ \mu\text{m})^2 + (43\ \mu\text{m})^2 \cdot D(\text{cm})$. The innermost detector, the SSVD,[8] consisted of three cylindrical layers of silicon detector modules located from 29 to 38 mm. The average spatial resolution of all SSVD modules was measured to be 7 μm. Since neither the DCVD nor the SSVD gave information about the position of the track along the beam axis, all impact parameters used in this analysis are projections onto the plane perpendicular to the beam axis.

Hadronic events were selected by requiring that there be at least 7 charged tracks in the fiducial tracking volume and that the sum of the charged and neutral tracks exceed half of the center of mass energy. The efficiency for hadronic events passing these cuts is 0.80, although it is about 3% higher for $b\bar{b}$ events. A total of 220 events were selected.

In order to eliminate poorly measured tracks from the analysis, each track was required to pass a series of cuts. The polar angle from the beam axis, θ, must satisfy $|\cos\theta| < 0.8$. There must be at least 150 MeV/c of momentum perpendicular to the beam axis. The distance of closest approach to the e^-e^+ interaction point (IP) must be less than 15 mm along the beam direction and less than 2 mm in the plane perpendicular to the beam direction. Each track must have at least 25 position measurements in the CDC, 15 in the DCVD and 1 in the SSVD. The calculated error on the track position, extrapolated back to its distance of closest approach to the IP, must be less than 200 μm.

The impact parameters were calculated with respect to an interaction point which was fit for each event. The fitting procedure started with a seed of three tracks. Each of the remaining tracks were added to that seed in turn and the track with the highest vertex probability kept. This process was repeated as long as the vertex probability with the new candidate track was greater than 1%.

An event was tagged as a $Z^0 \rightarrow b\bar{b}$ if there were three or more tracks passing the above cuts with an impact parameter significance, b/σ_b, of at least 3.0 (Reference 9). The impact parameter is signed such that it is positive if the extrapolated track crosses the thrust axis in the thrust hemisphere of that track. The impact parameter error was calculated as $\sigma_b^2 = \sigma_{TR}^2 + \sigma_{IP}^2 + (15\ \mu m)^2$ where σ_{TR} is the extrapolated track error, σ_{IP} is the projected impact parameter error and the 15 μm is included primarily to account for residual detector misalignment.[10] The average impact parameter resolution was measured to be $\sigma_b^2 = (29\ \mu m)^2 + (70\ \mu m)^2 / p_{xy}^2 \sin\theta$.

In order for the Monte Carlo to reliably estimate the tag efficiencies, the detector simulation was tuned by considering the effects from detector efficiencies, multiple Coulomb scattering, elastic and inelastic nuclear scattering, residual alignment errors and beam associated backgrounds. Figure 1(a) shows the distribution of b/σ_b for high resolution tracks ($\sigma_{TR} < 25\ \mu m$) which were used to study the intrinsic detector performance. As tracks from bottom and charm decays pref-

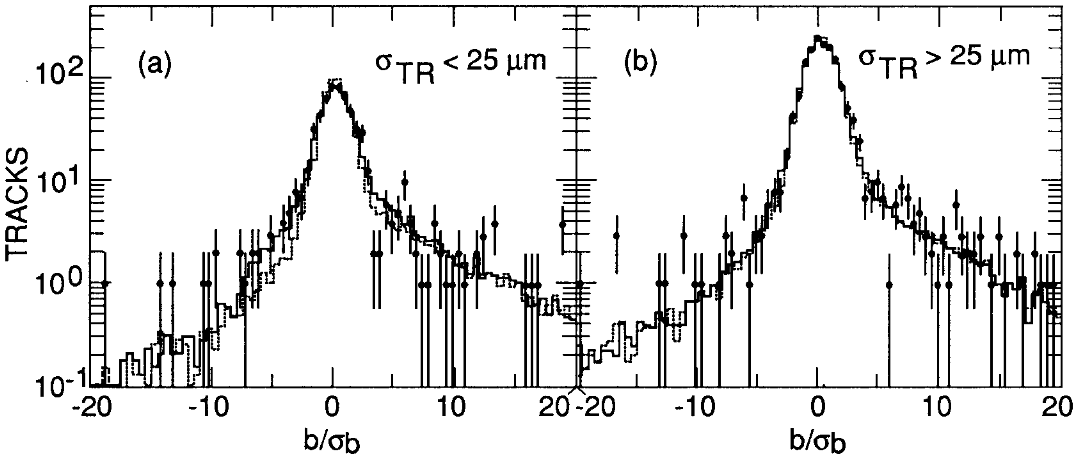

Figure 1. Distribution of b/σ_b shown for data (points), (a) MC before additional track smearing (dotted histogram) and (b) MC after additional track smearing (solid histogram).

Source of Systematic Error	Contribution
Resolution Function	±9%
Tracking Efficiency	±2%
Material & Multiple Scattering	±4%
Fragmentation Model	±4%
B Hadron Lifetime	±4%
B Decay Properties	±3%
Charm Fraction	±2%

Table 1: Contributions to systematic error.

erentially populate the positive tail, the negative half of the distribution is much less sensitive to the value of $R_{b\bar{b}}$ and therefore only this side was used to study resolution. The original MC distribution underestimates negative tail. To compensate, we adjusted the resolution used in the detector simulation by adding 75 μm of Gaussian smearing to the impact parameters of 15% of the tracks chosen at random. The effect of this adjustment on the low momentum tracks, shown in Figure 1(b), was small.

Applying the above cuts to the data, we tagged 32 of the 220 events. Using efficiencies determined from the MC, we calculated that $R_{b\bar{b}} = 0.251 \pm 0.049$ (stat.). This result has been checked by varying the impact parameter significance cuts and the number of tracks required. These results all yield values of $R_{b\bar{b}}$ consistent with the above value.

3. Systematic Errors

The significant contributions to the systematic error in $R_{b\bar{b}}$ are listed in Table 1. To study the effects of detector resolution, we varied the additional track smearing applied in the MC simulation within allowable limits from the resolution studies. We also investigated the effects of other correlated tracking errors, for instance, an error localized to one section of the detector in azimuth. The tracking efficiency error is due to uncertainty in CDC track finding efficiency of ±2%. The scattering material was uncertain to a level of ±2% from studies on the data.

The systematic errors associated with the event properties were found by varying $\langle x_E \rangle_b$ by ±0.03, the average B lifetime by ±0.12 psec, the B decay momenta and multiplicity spectra within limits from CLEO and ARGUS, and the charm fraction by ±0.04. The combined systematic error, translates to a 12% systematic error in $R_{b\bar{b}}$.

4. Conclusion

We have presented a method for tagging $Z^0 \to b\bar{b}$ events based on precise measurement of impact parameters. This method is quite efficient (50%) and yields a sample of high purity (85%) and as such holds great promise for the future. We have measured $R_{b\bar{b}}$ to be 0.251 ± 0.049 (stat.) ± 0.030 (syst.), in good agreement with the Standard Model.

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