Measurements of Bottom Hadron Lifetimes and the Λ^0 Production Rate in $Z^0 \rightarrow b\bar{b}$ Events using Data from the OPAL Experiment

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Synopsis

The OPAL detector has been used to collect data from decays of the Z^0 boson, produced with e^+e^- collisions at the LEP collider. Approximately 3.5 million events, recorded between 1991 and 1994 with the silicon microvertex detector operational, were considered for measurements of the average bottom hadron lifetime, τ_b, and the bottom baryon lifetime, $\tau_{\Lambda_b^0}$. The Λ^0 baryon production rate in $Z^0 \to b\bar{b}$ events was studied using approximately one million multihadronic events, recorded between 1991 and 1992. A neural network algorithm was used to enhance $Z^0 \to b\bar{b}$ events relative to other hadronic decay modes of the Z^0 boson.

The average bottom hadron lifetime was evaluated using a binned maximum likelihood fit to the reconstructed decay time distribution formed using estimates of the bottom hadron decay length and momentum. The lifetime measurement :

$$\tau_b = (1.637 \pm 0.008\,(\mathrm{stat}) \pm 0.034\,(\mathrm{syst}))\,\mathrm{ps},$$

has a systematic error dominated by uncertainties on the bottom quark fragmentation modelling in the Monte Carlo and the resolution function that describes the distribution of reconstructed decay times for a given true decay time.

A study of Λ^0 baryon production in $Z^0 \to b\bar{b}$ events was used to measure :

$$\mathrm{Br}(\mathrm{b\ hadron} \to \Lambda^0 X) = (5.9 \pm 0.6\,(\mathrm{stat})^{+0.5}_{-0.4}\,(\mathrm{syst}))\,\%.$$

The systematic error is dominated by uncertainties on the momentum spectrum of Λ^0's from bottom quark fragmentation. The bottom baryon production rate was subsequently estimated as :

$$f(b \to \Lambda_b^0)\,\mathrm{Br}(\Lambda_b^0 \to \Lambda^0 X) = (2.3^{+0.9}_{-0.8})\,\%.$$

The bottom baryon lifetime was measured with the same overall technique as used for the measurement of τ_b. The additional requirement of a high momentum Λ^0, associated with the jet in which the decay length measurement is made, enhanced the bottom baryon component in the reconstructed decay time distribution. This bottom baryon enhanced lifetime was measured as :

$$\tau_{b\Lambda^0} = (1.38 \pm 0.09\,(\mathrm{stat}) \pm 0.06\,(\mathrm{syst}))\,\mathrm{ps},$$

where, the dominant contribution to the systematic error comes from uncertainties in the signal resolution function. An estimate of the proportion of the $\tau_{b\Lambda^0}$ sample due to a bottom baryon component was used to derive :

$$\tau_{\Lambda_b^0} = (1.10 \pm 0.19\,(\mathrm{stat}) \pm 0.13\,(\mathrm{syst}) \pm 0.05\,(\mathrm{syst}))\,\mathrm{ps}.$$

The first error is due to the statistical uncertainty on $\tau_{b\Lambda^0}$ and the second error is due to the systematic error on $\tau_{b\Lambda^0}$ and τ_b. The final error is due to the uncertainty on the contribution of bottom baryons to the $\tau_{b\Lambda^0}$ sample.

This method of measuring the bottom baryon lifetime is systematically different to other techniques that use baryon-lepton correlations ($\Lambda_c^+\ell$, $\Lambda^0\ell$ or $p\mu$).