EXPERIMENTAL HIGHLIGHTS OF B MESON PRODUCTION AND DECAY

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This edition reflects the impact that CLEO–II has had on beauty, charm, and τ physics in the last two years. Starting in 1991, the CESR storage ring with the new CLEO–II detector ran in the $\Upsilon(4S)$ resonance region collecting record luminosities for a symmetric e^+e^- collider in its first year of $\sim$ 8–9 pb^{-1}/day. Over the past year, the luminosity has risen to $\sim$ 15 pb^{-1}/day and CLEO–II has logged a total of more than 2 fb^{-1}. This edition also contains many new measurements of B mesons and baryons from Z decay, made possible by the addition of high-precision silicon vertex detectors in many of the LEP detectors coupled with their large average accumulations of $\sim$ 750K Z/year since 1992. The implementation of silicon vertexing in CDF at FNAL has made possible the measurement of precise B lifetimes from exclusive decays. The high-energy e^+e^- colliders and detectors (LEP and SLD/SLC) with their silicon-tracking systems are now starting to produce and tag heavy-flavor decays (charm and beauty) of the Z with very high efficiency and purity. This has already resulted in improvements in inclusive and exclusive lifetime measurements, the direct observation of B^0–$\overline{B}^0$ mixing by time evolution, and precision electroweak tests (measurements of the $Zb\overline{b}$ and $Zc\overline{c}$ vertex), both with and without polarized beams.

Perhaps the most exciting result to appear this year is the first observation of radiative "penguin" decays ($b \to s\gamma$ transitions). Extensive sets of branching fraction limits on many exclusive channels in the few parts per 10^4 range were reported previously by CLEO and ARGUS for both hadronic ($b \to sg$) and radiative ($b \to s\gamma$) penguins. In 1993, CLEO–II (AMMAR 93), using about 1.6 fb^{-1} of data, reconstructed eight candidate events in the channel $B^0 \to K^*(892)^0\gamma$ and five in the $B^+ \to K^*(892)^+\gamma$ channel. The $B^0 \to K^*(892)^0\gamma$ branching fraction is about 4×10^{-5} while the $B^+ \to K^*(892)^+\gamma$ branching fraction is 6×10^{-5}. These decays are important because they establish the existence of the penguin diagram, a necessary (but not sufficient) requirement for describing direct

CP violation in the Standard Model. The observed branching fractions also set stringent limits on the mass of a charged Higgs scalar in a large class of models, giving $m_{H^+} > 250$ GeV, whereas direct limits from LEP are only about 43 GeV. In the continuing search for hadronic penguins, it appears that CLEO–II is now close to having the sensitivity to observe the simplest two-body channels.

The mixing of B^0 and $\overline{B}^0$ mesons, first suggested by UA1 and subsequently measured by ARGUS, provided the first indirect evidence of a heavy t quark. Mixing of the B^0 has similarly been measured by CLEO with dilepton events at the $\Upsilon(4S)$, and by the LEP experiments at the Z resonance. This year, ALEPH (BUSKULIC 93K) made the first direct measurement of the B^0 mixing by observation of the mixing-oscillation itself over time. This is the forerunner of the measurement of B_s^0 mixing, where present constraints on the CKM matrix suggest that B_s^0 mixing will be found to be nearly maximal ($\chi_s \approx 0.5$). If χ_s is greater than about 0.3–0.4, then greater sensitivity to the CKM parameters ($|V_{tb}V_{ts}^*|$) through B_s mixing will likely come from direct measurement of the mixing-oscillation frequency (the time evolution) rather than from a time-averaged quantity such as χ_s. These studies are only likely to occur in hadron and electron machines where the B mesons are adequately boosted and where pure tagging can be accomplished.

The measured average lifetime of B hadrons has changed dramatically since first measurements at PEP and PETRA. The average value of about 1.29 ± 0.05 ps in our 1992 edition was dominated by LEP measurements using high-statistics impact-parameter techniques with hadrons and leptons. Later LEP measurements average closer to 1.5 ± 0.03 ps. This significant upward drift perhaps reflects improvements in understanding of vertex detectors. The longer average lifetime is confirmed by CDF (ABE 93J). Theory suggests that the inequality of B^+ and B^0 lifetimes may be as small as 5 or 10%, providing an interesting experimental challenge. The separate lifetimes of B^+ and B^0 mesons have been measured indirectly at LEP, looking at the correlation with D^{*+} as an indicator of the B charge. Other techniques have also been applied. The equality of B^+ and B^0 lifetimes is established within about 10% by averaging LEP measurements. Separate B^+ and B^0 lifetimes at this precision will come either from tagging of B mesons at the $\Upsilon(4S)$ with subsequent measurement of the semileptonic decay of the recoil, or from improved statistics for exclusive $B_{\ell 3}$ decays, or from the direct measurement of a decay lifetime of a B^+ or B^0 at LEP/SLC or CDF using vertexing techniques.

Experiments at LEP and CDF at FNAL have isolated B_s^0 and B-baryon decays using ϕ-lepton and Λ-lepton correlations. Explicit examples of decays of the B_s^0 have been reconstructed, and the mass and lifetime have been measured using these events. While the B_s^0 lifetime is similar to those of the B^+ and B^0, the B-baryon lifetime appears to be shorter, perhaps owing to a contribution of exchange diagrams in its decays.

The semileptonic branching fractions are important for establishing the values of the CKM parameters V_{cb} and V_{ub}. The branching fractions to exclusive states $B \to \overline{D}\ell^+\nu_\ell$ and $B \to \overline{D}^*\ell^+\nu_\ell$ have been measured and both CLEO and ARGUS have done form factor decompositions (ALBRECHT 92C, ALBRECHT 93, and SANGHER 93). The inclusive rate for semileptonic decay appears to remain at about $10.0 \pm 0.5\%$. It appears that the sum of $\overline{D}\ell^+\nu_\ell$ and $\overline{D}^*\ell^+\nu_\ell$ contributions accounts for about two-thirds of the inclusive branching fraction. The balance must be a mixture of other channels such as $\overline{D}^{**}\ell^+\nu_\ell$, $\overline{D}\pi\ell^+\nu_\ell$, $\overline{D}^*\pi\ell^+\nu_\ell$ *etc.* Improvements can be anticipated from a comparison of single- and double-tagged semileptonic decays combined with higher-statistics measurements of the exclusive charged and neutral $B_{\ell 3}$ channels. For more details on semileptonic decays, see the following note.

In the next few years, CLEO–II and the detectors at high-energy machines at LEP, SLC, HERA, and FNAL should provide new insights into all aspects of B^+, B^0, B_s^0 meson decays. The experimental reach of the present program should be adequate to address all the interesting areas of B physics except CP violation, the study of which requires B factories. follows for a review of the many new results in that area.