Unfortunately, both CLEO and ARGUS have difficulty in measuring the rate in this region because the decay of the slow-moving D^* produces a very slow pion, which is difficult to detect with high efficiency. The rate at zero recoil is therefore obtained by measuring the rate as a function of w and then extrapolating to $w = 1$. This procedure introduces some model dependence because HQET does not predict the w dependence of the form factors, which involves nonperturbative QCD physics. (Several groups are using lattice QCD to predict the w dependence and are beginning to obtain interesting results [35].) Because the w range is small, however, the form factors are expected to have only modest variation, which is approximately linear. CLEO and ARGUS use a variety of functional forms to parametrize the w dependence. The different extrapolations to $w = 1$ lead to a range of values for $|V_{cb}|$, some of which are listed in Table 6. The systematic errors on the CLEO measurements are due to uncertainties in the soft-pion detection efficiency, smearing effects, background ($B \to \overline{D}^{**}\ell^+\nu_\ell$), and sensitivity to the values of the form factors. As discussed for the exclusive branching ratios, these measurements assume $\mathrm{B}\big(\Upsilon(4S) \to B^0\overline{B}^0\big) = 0.5$. It should be noted that $|V_{cb}|$ can also be obtained from the total rates for $B \to \overline{D}\ell^+\nu_\ell$ and $B \to \overline{D}^*\ell^+\nu_\ell$. The theoretical predictions, however, are less reliable than those for the zero-recoil configuration of $B \to \overline{D}^*\ell^+\nu_\ell$.

Table 6: Measurements of $|V_{cb}|$ and $\widehat{\rho}^2$ using the decay $B \to \overline{D}^*\ell^+\nu_\ell$ and HQET predictions. The ARGUS measurements of $|V_{cb}|$ have been corrected to a B lifetime of 1.49 ps.

Expt.	Ref.	$\xi(w) = \xi(v_B \cdot v_{D^*})$	$\widehat{\rho}^2$	$\lvert V_{cb}\rvert$
ARGUS	[29]	$1 - \widehat{\rho}^2(w-1)$	$1.17 \pm 0.22 \pm 0.06$	$0.042 \pm 0.005 \pm 0.003$
ARGUS	[29]	$\exp[-\widehat{\rho}^2(w-1)]$	$1.88 \pm 0.38 \pm 0.16$	$0.047 \pm 0.008 \pm 0.002$
ARGUS	[29]	$[2/(w+1)]^{2\widehat{\rho}^2}$	$2.10 \pm 0.38 \pm 0.18$	$0.048 \pm 0.008 \pm 0.003$
CLEO-II	[17] (prelim.)	$1 - \widehat{\rho}^2(w-1)$	$1.2 \pm 0.5 \pm 0.3$	$0.038 \pm 0.006 \pm 0.004$
CLEO-II	[17] (prelim.)	$\exp[-\widehat{\rho}^2(w-1)]$	$1.0 \pm 0.4 \pm 0.2$	$0.037 \pm 0.005 \pm 0.004$
CLEO-II	[17] (prelim.)	$[2/(w+1)]^{2\widehat{\rho}^2}$	$1.1 \pm 0.5 \pm 0.2$	$0.038 \pm 0.005 \pm 0.004$

Form factor measurements

Both ARGUS and CLEO have used measurements of kinematic distributions to obtain information on the form factors for $B \to \overline{D}^*\ell^+\nu_\ell$. In contrast to D-meson semileptonic decays, however, one expects the predictions of heavy quark effective theory to be applicable to $B \to X_{\overline{c}}\ell^+\nu_\ell$. Here, both the initial- and final-state quarks are heavy compared with the typical hadronic scale set by Λ_{QCD}. With sufficiently large data samples, the $B \to \overline{D}^*\ell^+\nu_\ell$ decay should provide useful tests of HQET predictions. Ideally, one would determine the q^2 dependence of each of these form factors with minimal assumptions. In practice, due to the limited data samples so far available, experiments have taken the shapes of the q^2 dependence from models. The ratios of the form factors at a particular q^2, usually q^2_{max}, are then obtained from fits to observed kinematic distributions.

Both ARGUS and CLEO have extracted the values of two key observables that can be related to the values of the form factors. The first of these is A_{FB}, the forward-backward asymmetry of leptons in the virtual-W rest frame (see Section II). The nonzero value of A_{FB} is a consequence of the parity-violating $V-A$ coupling, which results in more leptons being produced in the hemisphere opposite the D^* momentum vector than in the hemisphere containing it. The second observable is the polarization parameter α (see Section II). It is important to recognize that although both A_{FB} and α are defined as integrals over all of phase space, the lepton asymmetry and the D^* polarization are actually functions of q^2. Thus, measurements for which the acceptance over phase space is not uniform must be either corrected or compared with theoretical predictions incorporating the same acceptance.

Table 7 compares theoretical predictions of A_{FB} and α from Neubert [2] with measurements from ARGUS and CLEO. The measurements, however, are slightly different. In the CLEO-II measurement, A_{FB} is an average over all decays for which $p_\ell > 1.0$ GeV/c. In ARGUS, the same cut is used (for both A_{FB} and α), but the effect of this cut is removed using theoretical models. CLEO-I has also measured [36] $\alpha = 0.65 \pm 0.66 \pm 0.25$ for $p_\ell > 1.4$ GeV/c.

The dependence of the CLEO results on the momentum cuts disappears only when the form factor ratios are calculated (for each model) using a least-squares fit that incorporates the acceptance. In the ARGUS analysis, on the other hand, the kinematic distributions are fitted directly to models in which the only free parameters are form factor ratios. The values of A_{FB} and α are then derived from each model using the fitted values for the form factors. Thus, the dependence of A_{FB} and α on the lepton-momentum cut is removed model by model. ARGUS finds that their values of A_{FB} and α are insensitive to the model used. (They do not quote the form factor ratios obtained from the fits.)

The observation of a positive value for A_{FB} is consistent with predictions of form factor models that assume $V-A$ couplings at both W-boson vertices. CLEO has shown that models in which the hadronic current has a $V+A$ structure do not describe the data well, assuming that $V-A$ is still used for the leptonic current [37]. (However, the measurement of A_{FB} cannot rule out the case in which both the hadronic and leptonic currents are $V+A$.) The predicted value of A_{FB} is a function of ρ^2, the slope of the Isgur-Wise function, as can be seen from Table 7.