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DETERMINATION OF $|V_{ub}|$ FROM TAGGED AND UNTAGGED $B\overline{B}$ EVENTS WITH THE *BABAR* DETECTOR

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Measurements of charmless semileptonic B-meson decays and the CKM matrix element $|V_{ub}|$ are reported based on a sample of 88 million $B\overline{B}$ events recorded with the *BABAR* detector. Decays $B \to X_u \ell\nu$ are selected from both tagged and untagged $B\overline{B}$ events and separated from the dominant charm background, $B \to X_c \ell\nu$, using different kinematic variables: the lepton momentum E_ℓ, the squared four-momentum transfer q^2, and the hadronic mass m_X. The extrapolation to the total decay rate to determine $|V_{ub}|$ is performed for different theoretical models. We have also measured branching ratios for the exclusive semileptonic decays $B \to \pi(\rho, \omega, \eta, \eta', a_0)\ell\nu$, where a high signal purity is reached by fully or partially reconstructing the second B meson.

Keywords: V_{ub}; B meson; *BABAR*.

1. Introduction

The precise measurement of the magnitude of the CKM matrix element V_{ub} is one of the main issues in heavy flavor physics. An improved determination of $|V_{ub}|$ would contribute critically to tests of the consistency between angles and sides measurements of the Unitarity Triangle. Current progress for measuring $|V_{ub}|$ comes from charmless semileptonic B decays, $B \to X_u \ell\nu$.

The extraction of $|V_{ub}|$ is very challenging, both experimentally and theoretically. Since the dominant background from $B \to X_c \ell\nu$ decays is $\sim$50 times more abundant than the signal and has similar kinematic properties, harsh cuts are needed to select regions of phase space where the background is highly suppressed. This in turn introduces large theoretical uncertainties in the extrapolation to the full phase space.

In the following, we will report the results on studies of $B \to X_u \ell\nu$ decays using 88 million $B\overline{B}$ events recorded with the *BABAR* detector at the PEP-II e^+e^- storage ring, corresponding to an integrated luminosity of 81 fb^{-1} on the $\Upsilon(4S)$ resonance.

2. Inclusive $B \to X_u \ell\nu$ Decays

For inclusive decays, theoretical uncertainties arise due to uncertainties in the mass of the b quark and its Fermi motion inside the B meson, which determine the

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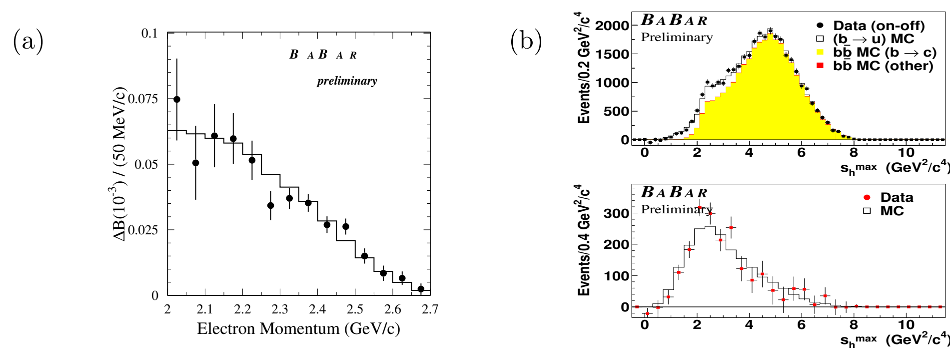

Fig. 1. (a) Differential branching ratio for $B \to X_u e\nu$ decays as function of electron momentum after background subtraction, (b) s_h^{max} distribution before and after subtraction of $B\overline{B}$ background. The data are shown as solid points with statistical errors, the histograms represent simulated signal (white) and $B\overline{B}$ background (yellow and red).

dynamics of the B meson decay. Calculations of the decay rate are based on operator product expansions (OPE) and include non-perturbative contributions, which are resummed into the so-called *shape function*. To reduce the theoretical uncertainties when extrapolating to the full phase space, kinematic cuts are chosen which are loose enough to retain a large fraction of the phase space and at the same time minimize the dependence of the selection on the shape function parameters ($\bar{\Lambda}^{SF}$ and λ_1^{SF}). Three different techniques have been studied with *BABAR*. For all three analyses, the shape function parameters are taken from the measurement of the photon energy spectrum in $b \to s\gamma$ transitions published by the CLEO Collaboration[1]. The results for $|V_{ub}|$ are summarized in Tab. 1.

2.1. *Electron momentum spectrum near the kinematic endpoint*

Due to the large c-quark mass, the kinematic endpoint of the electron momentum spectrum in $B \to X_c e\nu$ decays is ~2.3 GeV/c (in the $\Upsilon(4S)$ frame), about 300 MeV/c lower than for $B \to X_u e\nu$ decays. This analysis[2] updates a previous analysis by extending the interval chosen for signal extraction down to 2.0 GeV/c, retaining about 30% of signal decays. Non-$B\overline{B}$ background is estimated using off-resonance data as well as on-resonance data with electron momenta above 2.8 GeV/c, i.e. beyond the kinematic endpoint for electrons from B decays. The $B\overline{B}$ background is taken from simulation and the normalization of its individual contributions is fitted to the observed electron spectrum. Fig. 1(a) shows the resulting electron momentum distribution after subtraction of all backgrounds.

2.2. *Neutrino reconstruction*

In addition to selecting events with an electron momentum above 2.0 GeV/c, the second analysis[3] makes use of the neutrino momentum, which is inferred from the

e^+e^- beam energies and a measurement of the missing energy and momentum in the event. The neutrino kinematics are used to compute the maximum kinematically allowed mass squared of the hadron, s_h^{max}, which helps in suppressing $B \to X_c e\nu$ background. For $\pm E_e > \pm\frac{\sqrt{q^2}}{2}\sqrt{\frac{1\pm\beta}{1\mp\beta}}$, $s_h^{max} = m_B^2 + q^2 - 2m_B E_e\left(\frac{1\mp\beta}{1\pm\beta}\right) - 2m_B\left(\frac{q^2}{4E_e}\right)\sqrt{\frac{1\pm\beta}{1\mp\beta}}$, or else $s_h^{max} = m_B^2 + q^2 - 2m_B\sqrt{q^2}$, where $\beta = 0.06$ is the boost of the B meson in the $\Upsilon(4S)$ frame. Fig. 1(b) shows the distribution of s_h^{max} for data and simulation before and after subtraction of $B\overline{B}$ background.

2.3. *Mass of hadron recoiling against fully reconstructed B meson*

The third inclusive analysis[4] studies the hadronic mass spectrum of semileptonic B decays in events tagged by the fully reconstructed hadronic decay of the second B. The semileptonic decay of the recoiling B is identified by the presence of an electron or muon with momentum above 1.0 GeV/c. The hadronic mass is reconstructed from the energy depositions and tracks not associated with the tagged B. The extraction of $|V_{ub}|$ is performed following two approaches[4]. The first uses a cut on the hadronic mass, $m_X < 1.55$ GeV/c^2, to separate the signal from the charm background. The extrapolation to the full phase space is done using the De Fazio-Neubert[5] (DFN) parameterization. The second is based on a method proposed by Bauer et al.[6] (BLL), which suggests the extraction of $|V_{ub}|$ in a restricted region of the $q^2 - m_X$ plane, where OPE calculations are reliable and the uncertainties due to the shape function are reduced. Fig. 2(a) shows the measured values of $|V_{ub}|$ as a function of the cut on q^2, comparing the DFN and BLL models. In addition, the true m_X distribution for $B \to X_u \ell\nu$ decays and its spectral moments are extracted.

Table 1. Summary of inclusive $|V_{ub}|$ measurements.

Method	$\lvert V_{ub}\rvert$ / 10^{-3}
Electron endpoint	$3.94 \pm 0.25_{\rm exp} \pm 0.42_{\rm theo}$
Neutrino reconstruction	$4.63 \pm 0.47_{\rm exp} \pm 0.49_{\rm theo}$
m_X	$4.77 \pm 0.40_{\rm exp}\ {}^{+0.65}_{-0.39}{}_{\rm theo}$
q^2 vs. m_X	$4.92 \pm 0.53_{\rm exp} \pm 0.46_{\rm theo}$

3. Exclusive $B \to X_u \ell\nu$ Decays

Exclusive decays are studied using full or partial tags of the second B in the event. With these novel techniques, higher signal-to-background ratios are achieved than in previous analyses. No harsh kinematic cuts are needed to suppress the charm background and thus nearly the full phase space is analyzed. This reduces the theoretical uncertainties due to the B decay form factors and their variation with q^2.

Using fully reconstructed B mesons as tags[4], we measure branching ratios for the decays $\overline{B}^0 \to \pi^+(\rho^+, a_0^+)\ell^-\bar{\nu}$ and $B^- \to \pi^0(\rho^0, \omega, \eta, \eta', a_0^0)\ell^-\bar{\nu}$. As an example, Fig 2(b) shows the $m_{\gamma\gamma}$ distribution for $B^- \to \pi^0\ell^-\bar{\nu}$ and illustrates the high

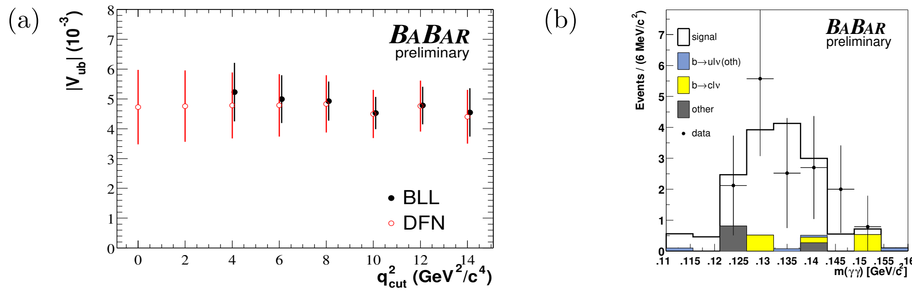

Fig. 2. (a) Measured value of $|V_{ub}|$ for $m_X < 1.7$ GeV/c^2 as function of cut on q^2 using acceptance estimates based on DFN (open points) and BLL (solid points). The error bars represent the total uncertainties, (b) m($\gamma\gamma$) distribution for exclusive $B^- \to \pi^0 \ell^- \bar{\nu}$.

signal purity achieved in this analysis. The second technique is based on a partial reconstruction of the tag-B in its semileptonic final state $B^0 \to D^{*-}\ell^+\nu$, using only the charged lepton and the soft pion from $D^{*-} \to \overline{D}^0\pi^-$. We extract the branching ratio for $\overline{B}^0 \to \pi^+\ell^-\bar{\nu}$ in three bins of q^2.

Combining the results of the two analyses inferring isospin and quark model relations, we obtain:

$$\mathcal{B}(\overline{B}^0 \to \pi^+\ell^-\bar{\nu}) = (1.22 \pm 0.19_{\rm stat} \pm 0.18_{\rm syst}) \cdot 10^{-4}$$
$$\mathcal{B}(\overline{B}^0 \to \rho^+\ell^-\bar{\nu}) = (2.57 \pm 0.52_{\rm stat} \pm 0.59_{\rm syst}) \cdot 10^{-4}.$$

4. Conclusions

We have presented the latest results on charmless semileptonic decays and $|V_{ub}|$ from *BABAR*. The inclusive analyses are still dominated by theoretical uncertainties due to the limited knowledge of non-perturbative contributions. More precise measurements of $b \to s\gamma$ transitions and advances in the theoretical understanding of the shape function will decrease these uncertainties. With higher statistics, the measurement of the m_X moments as well as lepton energy moments may also be used to constrain the shape function parameters. The novel recoil techniques are still statistically limited. However, with their high signal purity and the increasingly large luminosities of the B-factories, they will allow for a precise measurement of $|V_{ub}|$ in the near future.

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