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Measurements of partial branching fractions for $B \to X_u l\nu$ and determination of $|V_{ub}|$ at BaBar

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Summary. — We present partial branching fractions for inclusive charmless semileptonic B decays $B \to X_u l\nu$, and the determination of the CKM matrix element $|V_{ub}|$. The analysis is based on a sample of 467 million $\Upsilon(4S)$ decays into $B\overline{B}$ pairs collected with the BaBar detector at the $PEPII$ e^+e^- storage rings. The invariant mass of the hadronic system, M_X, the squared invariant mass of the lepton pair, q^2, and the variable $P_+ = E_X - |P_X|$ and their combinations, in the process $B \to X_u l\nu$ are used as discriminant variables to suppress semileptonic decays with charm. Partial branching fractions are measured as a function of the cuts on the above variables. Theoretical calculations are used to compute acceptances and related uncertainties, thereby allowing to extract $|V_{ub}|$.

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1. – Introduction

In the Standard Model, the elements of the Cabibbo-Kobayashi-Maskawa matrix [1,2] describe the coupling between the quarks and the weak charged currents. By construction, this matrix is unitary and one of the unitarity conditions can be represented graphically by the so-called Unitarity Triangle (UT). The angles and sides of the UT can be measured by studying B-meson decays. The determination of $|V_{ub}|$ matrix element is particularly interesting since it is one of the smallest and least known matrix elements. In addition divided by $|V_{cb}|$ it measures the side of the UT opposite the well-known angle β (uncertainty 4% [3, 4]). While the determination of $|V_{cb}|$ is at the 2% level [5], the uncertainty on $|V_{ub}|$ is still at the 9% level [6, 7]. The need for an improvement in the precision on $|V_{ub}|$ is therefore evident.

2. – Analysis technique

In this paper, we present a measurement of partial branching fractions for inclusive charmless semileptonic decays, $B \to X_u l\nu$. $\Upsilon(4S) \to B\overline{B}$ events are tagged by the full reconstruction of a hadronic decay of one of the B-mesons (B_{reco}). The semileptonic decay of the second B-meson (B_{recoil}) is identified by the presence of an electron or a

TABLE I. – *Summary of the fitted number of signal events and extracted $|V_{ub}|$ for the four kinematic regions. The first uncertainty is statistical, the second systematic, and the third is due to BLNP theoretical model* [8]*. The total uncertainty in percent is shown in the last column. The number of semileptonic decays is N_{SL}.*

Phase space region	$N_{b\to u}$	$\lvert V_{ub}\rvert \times 10^{-3}$ from BLNP [8]	Error
$m_X < 1.55\,\mathrm{GeV}/c^2$	1073 ± 73	$3.92 \pm 0.14_{stat} \pm 0.10_{syst} \pm 0.30_{theo}$	8.8%
$P_+ < 0.66\,\mathrm{GeV}/c^2$	894 ± 61	$3.74 \pm 0.13_{stat} \pm 0.12_{syst} \pm 0.29_{theo}$	9.1%
$m_X < 1.7\,\mathrm{GeV}/c^2$, $q^2 > 8\,\mathrm{GeV}^2/c^2$	713 ± 53	$4.24 \pm 0.16_{stat} \pm 0.13_{syst} \pm 0.33_{theo}$	9.2%
m_X, q^2 full phase space	1568 ± 101	$4.34 \pm 0.16_{stat} \pm 0.16_{syst} \pm 0.23_{theo}$	7.4%

muon (extracted about 222000 $B \to Xl\nu$ decays). This technique results in a low event selection efficiency but allows the determination of the momentum, charge and flavour of the B-mesons. Experimentally, the principal challenge is to separate the rare $B \to X_u l\nu$ decays from the approximately 50 times larger $B \to X_c l\nu$ background. Given that the u-quark is much lighter than the c-quark, regions of phase space can be defined where the background is suppressed. We use three kinematic variables to separate $B \to X_u l\nu$ decays from the dominant $B \to X_c l\nu$ background: m_X, the invariant mass of the hadronic system $X_{u,c}$; q^2, the invariant mass squared of the lepton-neutrino system; and $P_+ = E_X - |P_X|$, where E_X and P_X are the energy and three-momentum of the hadronic system $X_{u,c}$ calculated in the B rest frame. We measure the fraction of partial rates of charmless semileptonic decays $\Delta R_{u/sl} = \Delta\mathcal{B}(B \to X_u l\nu)/\mathcal{B}(B \to Xl\nu)$ in restricted phase-space regions corrected for resolution effects in order to reduce systematic uncertainties. To relate the decays rate of the B-meson to V_{ub}, parton level calculations have to be corrected for perturbative and non-perturbative QCD effects. QCD calculation is available to determinate these corrections [8].

3. – Results and conclusions

In table I the number of signal events and the extracted $|V_{ub}|$ values with their uncertainties are reported for the four kinematic regions analyzed. The results presented here are slightly better in precision (about 10%), with respect to inclusive measurements published by BaBar [6] and Belle [7] with similar technique. At present the inclusive determination is only marginally compatible with the exlcusive determination. The two approaches differ by about 2σ. These discrepancies have to be understood in the next future.

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