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Recent *CKM* and and *CP* Results from *BaBar*

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Abstract

We present recent results of B and charm decays from the *BABAR* experiment. These results include searches for rare or forbidden charm decays, measurements of $|V_{ub}|$ from inclusive $\overline{B} \to X_u l \bar{\nu}$ decays , observation of the semileptonic $\overline{B} \to D^{(*)} \tau^- \bar{\nu}_\tau$ decays, direct CP violation asymmetry in $B \to X_{s+d}\gamma$ and in $D^+ \to K^0_S \pi^+$, and T-violation in $D^+_{(s)} \to K^+ K^0_S \pi^+ \pi^-$. These studies are based on the final dataset collected by *BABAR* at the PEP-II B factory at SLAC in the period 1999-2008.

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1 Introduction

We present some recent results concerning B and charm decays from the *BABAR* experiment. These results include searches for rare or forbidden charm decays, measurements of $|V_{ub}|$ from inclusive $\overline{B} \to X_u l \bar{\nu}$ decays, observation of the semileptonic $\overline{B} \to D^{(*)}\tau^-\bar{\nu}_\tau$ decays, direct *CP* violation asymmetry in $B \to X_{s+d}\gamma$ and in $D^+ \to K^0_S\pi^+$, and T-violation in $D^+_{(s)} \to K^+K^0_S\pi^+\pi^-$. The aim of these measurements is to test the Standard Model (*SM*) mechanism of *CP* violation and to search for possible contributions from New Physics (*NP*) beyond the *SM*.

Important areas of search for *NP* are processes which are expected at low level in *SM* and which could be enhanced by *NP*. This is the case for example of the measurement of branching fraction of many rare decays , in particular Flavor Changing Neutral Currents (*FCNC*), and the measurement of *CP* violating asymmetries. Such measurements are sensitive to *NP* scenarios and have been already very powerful in constraining the parameter space of *NP* models.

The studies presented in this talk are based on the final (or almost final) dataset collected by *BABAR* in the period 1999-2008 at the PEP-II B factory at SLAC.

2 $D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$

FCNC decays, forbidden at tree level in *SM* [1] but allowed at higher order, have been already observed in K and B meson systems [2]. In the charm sector a *FCNC* process has an additional suppression due to the GIM mechanism [1]. Thus far no charm *FCNC* decay process has been observed. Interest in *FCNC* processes in the charm sector increased with the recent measurements of D^0 - $\overline{D}^0$ mixing [3]. Source of this mixing in fact can come from *NP*, enhancing the branching fraction of *FCNC* with respect to SM calculation [4, 5].

Calculations in the framework of vector meson dominance [4] and of heavy quark effective theory combined with chiral perturbation theory [6] predict for the $D^0 \to \gamma\gamma$ decay the dominance of long-range effects and a branching fraction of $(3.5^{+4.0}_{-2.6}) \times 10^{-8}$ and $(1.0 \pm 0.5) \times 10^{-8}$, respectively. These branching fraction estimates are orders of magnitude below the sensitivity of current experiments. But gluino exchange in Minimal Supersymmetric Standard Model (*MSSM*) can enhance the *SM* branching fraction up to a factor 200 [5] (so within *BABAR* sensitivity).

CLEO has measured an Upper Limit (*UL*) of 2.9×10^{-5} at 90% Confidence Level (*CL*) for the branching fraction of the decay $D^0 \to \gamma\gamma$ [7] and a branching fraction of $(8.1 \pm 0.5) \times 10^{-4}$ for the decay mode $D^0 \to \pi^0\pi^0$ [8].

Recently *BABAR* has studied the decays $D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$ with a dataset corresponding to an integrated luminosity of 470.5 fb^{-1}. D^0 is reconstructed with a D^{*+} tag in the decay $D^{*+} \to D^0\pi^+$ [9], with the charge of the soft pion from D^{*+} indicating the initial flavor of the D^0. This tag suppresses the dominant combinatoric background. To avoid uncertainties in the number of D^{*+}, the branching fractions of the decay modes $D^0 \to \gamma\gamma$ and $D^0 \to \pi^0\pi^0$ are measured relative to the reference decay mode $D^0 \to K^0_S\pi^0$. This mode has a large and precisely measured branching fraction $(1.22 \pm 0.05) \times 10^{-2}$ [10].

D^0 candidates are reconstructed in the decays $D^0 \to \gamma\gamma$, $D^0 \to \pi^0\pi^0$, and $D^0 \to K^0_S\pi^0$. In the decay $D^0 \to \gamma\gamma$ the photon candidates have a center-of-mass (*CM*) energy between 0.74 and 4 GeV and the main background $D^0 \to \pi^0\pi^0$ is suppressed with a π^0 veto. B background in $D^0 \to \gamma\gamma$ ($D^0 \to \pi^0\pi^0$) is rejected selecting D^* candidate with a *CM* momentum above 2.85 (2.4) GeV/c. Signal (reference mode) selection efficiency for the $D^0 \to \gamma\gamma$ mode is 6.1 (7.6) %. For the $D^0 \to \pi^0\pi^0$ mode the signal (reference mode) selection efficiency is 15.2 (12.0) %. Signal yields are extracted with unbinned Maximum Likelihood (ML) fit to the D^0 invariant mass distribution (Fig. 1).

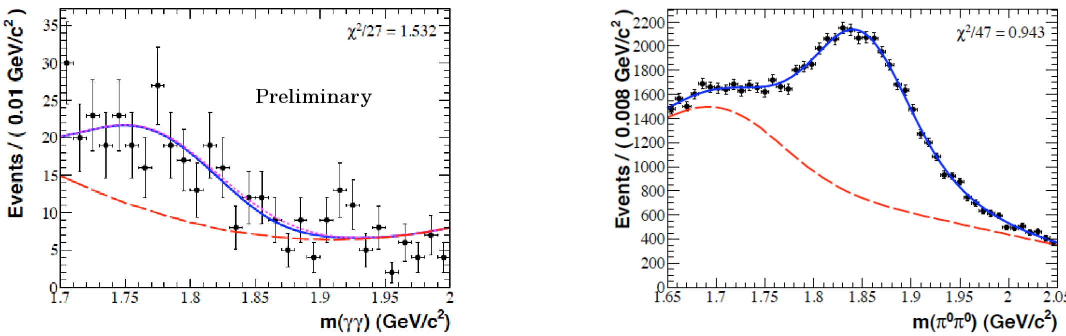

Figure 1: Fit results to $D^0 \to \gamma\gamma$ (on the left) showing data (points), the combinatoric background (long-dashed red), the combinatoric background plus the $D^0 \to \gamma\gamma$ background (short-dashed magenta) and and the total fit function including signal and the two backgrounds (solid blue); fit results to $D^0 \to \pi^0\pi^0$ (on the right) showing data (points), the combinatoric background (dashed red) and the full fit function (solid blue) including signal and combinatoric background.

For $D^0 \to \gamma\gamma$ the fit signal yield is -6 ± 15. Including statistical and systematic uncertainties the UL at 90% CL for this decay mode is 2.4×10^{-6}. This preliminary result is in agreement with SM expectation. Based on this result enhancement due to gluino exchange cannot exceed a factor 70.

The preliminary result for the branching fraction of the $D^0 \to \pi^0\pi^0$ decay is $(8.4 \pm 0.1 \pm 0.4 \pm 0.3) \times 10^{-4}$, where the uncertainties refer to statistical, systematic, and reference mode branching fractions uncertainties, respectively.

2.1 Search for $X_c \to hl^+l^-$

In a recent paper [11] *BABAR* searched for charm hadron decays of the type $X_c^+ \to h^\pm l^\mp l^{(\prime)+}$ [9], where X_c^+ is a charm hadron (D^+, D_s^+ or Λ_c^+), $l^{(\prime)+}$ is an electron or a muon, and $h^\pm$ can be a pion or a kaon (a proton in Λ_c^+ decay modes). The analysis is based on a data sample of 384 fb^{-1} of e^+e^- annihilation data collected at or close to the $\Upsilon(4S)$ resonance.

In total 35 decay modes have been studied. Among them there are decay modes with oppositely charged leptons of the same flavor which proceed through $FCNC$. These decays are very rare. There are decays with oppositely charged leptons of different flavor. These correspond to lepton-flavor violation decay modes which in SM are essentially forbidden because they can proceed only through lepton mixing. There are decays with two leptons of the same charge. These are lepton-number violating processes which are forbidden in the SM. The most stringent existing ULs for the branching fractions of the decays $X_c^+ \to h^\pm l^\mp l^{(\prime)+}$ are in the range $[1 - 700] \times 10^{-6}$ [12–16].

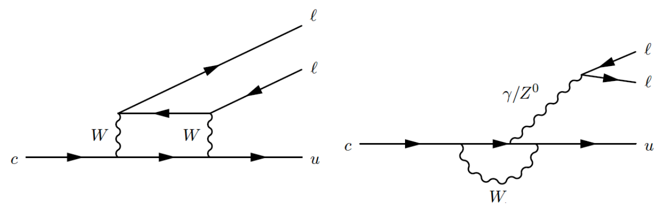

Figure 2: Standard Model short-distance contributions to the $c \to ul^+l^- transition$.

Transitions $c \to ul^+l^-$ proceed in *SM* through diagrams shown in Fig. 2 and are expected with branching fractions of $\mathcal{O}(10^{-8})$ [4,17]. Several extensions of the *SM* predict an enhancement of these branching fractions [4, 17, 18]. The target decay modes may have also long-distance contributions from leptonic decays of intermediate resonances like $D_{(s)} \to X_u V$ with $V \to l^-l^+$ which are expected with a branching fraction of $\mathcal{O}(10^{-6})$ [4, 17]. At current experimental sensitivity these long-distance contributions can come only from $D^+_{(s)} \to \pi^+\phi$ decays with $\phi \to l^-l^+$. The effect of these long-distance contributions is suppressed with a cut on the l^-l^+ invariant mass around the ϕ meson.

In the signal reconstruction three tracks, one identified as π, K, or proton and two identified as electron or muon ($ll^{(\prime)}$), are merged. Charm hadron is selected with a momentum p^* in e^+e^- *CM* > 2.5 GeV/c to suppress charm hadron production from B decays. The final selection is done with a likelihood ratio (*LR*) using three discriminating variables (p^*, total reconstructed energy in the event, and flight length significance of the charm hadron candidate). The minimum *LR* value is chosen independently for each decay mode.

Signal yields are extracted with extended unbinned *ML* fit to the invariant mass distributions of hll. There are three components in the fit: signal, combinatoric background, and background from nonleptonic charm decays in which two hadrons are misidentified as leptons. The fitted signal yields are translated into branching fractions by normalizing them to the yields of known charm decays with similar kinematics ($D^+_{(s)} \to \pi^+\phi$ ($\phi \to KK$) and $\Lambda_c^+ \to pK^-\pi^+$). No signals are found and Bayesian *UL*s at 90% *CL* are calculated. Limits in 32 of the 35 studied decay modes are improved upon the previous ones, in most cases by more than order of magnitude.

3 Measurement of $|V_{ub}|$ from Inclusive $\overline{B} \to X_u l\bar{\nu}$ Decays

The magnitude of the Cabibbo-Kobayashi-Maskawa quark-mixing matrix element V_{ub} [19] can be determined from inclusive semileptonic $\overline{B}$ decays to charmless final states $X_u l\bar{\nu}$, where $l = e$ or μ, and X_u is a hadronic system (without charm). The real difficulty in this inclusive measurement comes from the overwhelming charm background from $\overline{B} \to X_c l\bar{\nu}$ which has a rate fifty times larger and an event topology very similar to signal.

In a recent analysis [20] *BABAR*, using the full dataset of 467×10^6 $B\overline{B}$ pairs, has measured the partial branching fractions of the $\overline{B} \to X_u l\bar{\nu}$ decays [9], restricting the analysis in selected regions of the phase space where most effective is the suppression of the charm background. The event selection uses a hadronic tag: in the sample of $\Upsilon(4S) \to B\bar{B}$ events, one B decaying into hadrons is fully reconstructed (B_{reco}) and the other B (B_{recoil}) is identified by the presence of an electron or a muon. The B_{reco} is reconstructed in many exclusive hadronic decays $B_{reco} \to D^{(*)}Y^{\pm}$, where $D^{(*)}$ is a charmed meson (D^0, D^+, D^{*0}, or $D^{*\pm}$) while the charged hadronic system $Y^{\pm}$ consists of up to five charged hadrons, pions or kaons plus up to two neutral mesons (K^0_S, π^0).

In the B_{recoil} rest-frame we require only one charged lepton with momentum $p_l^* > 1$ GeV/c and the hadronic system X_u is reconstructed from charged particles and neutral clusters not associated to the B_{reco} or to the charged lepton. Neutrino is reconstructed from the missing four-momentum in the whole event. Requirements on several kinematic observables were applied in different phase space regions to select the final signal events.

Partial branching fractions are measured in several regions of phase space and are normalized to the total semileptonic branching fractions, thus reducing several systematic uncertainties. Considering the most inclusive measurement (based only on the requirement $p^* > 1.0$ GeV/c), from a two-dimensional $M_X - q^2$ ML fit to the hadronic invariant mass M_X and the leptonic mass squared q^2, we measure:

$$\Delta\mathcal{B}(\overline{B} \to X_u l\bar{\nu}; p_l^* > 1.0\,\mathrm{GeV}/c) = (1.80 \pm 0.13 \pm 0.15 \pm 0.02) \times 10^{-3}\,, \tag{1}$$

where the first uncertainty is statistical, the second systematic, and the third theoretical.

The measured partial branching fractions are related to $|V_{ub}|$ via the following relation:

$$|V_{ub}| = \sqrt{\frac{\Delta\mathcal{B}(\overline{B} \to X_u l\bar{\nu})}{\tau_B \Delta\Gamma_{theory}}}\,,$$

where τ_B is the B meson lifetime and $\Delta\Gamma_{theory}$ is the theoretically predicted $\Delta\mathcal{B}(\overline{B} \to X_u l\bar{\nu})$ partial branching fraction for the selected phase space region. This prediction is calculated on the basis of four different QCD models: Bosch, Lange, Neubert, and Paz (BLNP) [22], Gambino, Giordano, Ossola, and Uraltsev (GGOU) [23], Andersen and Gardi (DGE) [24], and Aglietti, Di Lodovico, Ferrera, and Ricciardi (ADFR) [25]. Results for $|V_{ub}|$ for these four different QCD calculations using the partial branching fraction obtained in the most inclusive measurement (Eq. 1) are presented in Table 1. In the last row of Table 1 we give the arithmetic average of the values and uncertainties obtained with the four QCD calculations (the first uncertainty is experimental and the second theoretical). The total uncertainty is about 6.9 %, comparable in precision with the Belle result [26].

Table 1: Results for $|V_{ub}|$ for the four different QCD calculations for the most inclusive partial branching fraction measurement.

QCD Calculation	$\lvert V_{ub}\rvert(10^{-3})$
BLNP	$4.27 \pm 0.15 \pm 0.18^{+0.23}_{-0.20}$
DGE	$4.34 \pm 0.16 \pm 0.18^{+0.22}_{-0.15}$
GGOU	$4.29 \pm 0.15 \pm 0.18^{+0.11}_{-0.14}$
ADFR	$4.35 \pm 0.19 \pm 0.20^{+0.15}_{-0.15}$
Arithmetic Average	$4.31 \pm 0.25 \pm 0.16$

The value of $|V_{ub}|$ obtained in this inclusive analysis is higher than the value obtained by *BABAR* in an exclusive analysis [21]. The discrepancy is at a level of about $2.7\,\sigma$ and is increased in the latest measurements obtained with significantly decreased uncertainties thanks to the improved experimental techniques and theoretical inputs. A similar discrepancy is also present in BELLE results [26, 27].

4 Measurement of the decays $\overline{B} \to D\tau^-\bar{\nu}_\tau$ and $\overline{B} \to D^*\tau^-\bar{\nu}_\tau$

Semileptonic B decays to τ lepton $\overline{B} \to D^{(*)}\tau^-\bar{\nu}_\tau$ [9] can provide constraints on the *SM* [28–30] and are sensitive to physics beyond the *SM*. In extensions of the *SM* (such as in the multi-Higgs doublet models and the *MSSM*), intermediate charged Higgs boson can contribute to the amplitude, modifying significantly the branching fraction [31–36]. Branching fractions of these decay modes are smaller compared to those of decay modes to final states containing a light lepton, l = e or μ. SM expectations for the relative rates between signal and reference modes are: $\mathcal{R}$(D) $= \mathcal{B}(\overline{B} \to D\tau\nu_\tau)/\mathcal{B}(\overline{B} \to Dl\nu_l) = 0.31 \pm 0.02$ [37] and $\mathcal{R}(D^*) = \mathcal{B}(\overline{B} \to D^*\tau\nu_\tau)/\mathcal{B}(\overline{B} \to D^*l\nu_l) = 0.25 \pm 0.02$ [35]. Multi-Higgs doublet models predict an effect on the ratio $\mathcal{R}$(D) much stronger than on $\mathcal{R}(D^*)$ [31–36]. This effect may enhance or decrease $\mathcal{R}(D^{(*)})$, depending on the value of the ratio $\tan\beta/m_{H^\pm}$ of the Higgs parameter $\tan\beta$ and the charged Higgs mass $m_{H^\pm}$.

Recently [38] *BABAR* updated with the full data sample of 471×10^6 $B\overline{B}$ pairs previous analyses [39] of the decays $\overline{B} \to D^{(*)}\tau\bar{\nu}_\tau$. $\Upsilon(4S) \to B\overline{B}$ events are tagged by the hadronic decay of one of the B mesons (B_{tag}). The tag decay modes are of the type $B_{tag} \to SX^\pm$, where S can be D, D^*, D_s, D_s^*, or J/ψ reconstructed in many s. $X^\pm$ is a charged state with a maximum of 5 particles (π or K) including up to two neutral particles (π^0 or K_S^0).

For each B_{tag} candidate in a selected event, the other $B(B_{sig})$ is searched for combining a single charged lepton and a $D^{(*)}$ meson. The τ lepton is reconstructed only in the purely leptonic decays $\tau^- \to e^-\bar{\nu}_e\nu_\tau$ and $\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$ while the $D^{(*)}$ meson is reconstructed in the four modes D^0, D^{*0}, D^+, and D^{*+}. D^0 (D^+) is reconstructed in 5 (6) decay modes for a combined branching fraction of 35.8% (27.3%). D^* meson is identified in the decays $D^{*+} \to D^0\pi^+$, $D^+\pi^0$ and $D^{*0} \to D^0\pi^0$, $D^0\gamma$. The signal modes have in the final state one secondary lepton and three neutrinos while the reference modes have a primary lepton and one neutrino.

For the separation of signal and reference modes the most discriminating variable is the missing mass squared , defined as $m^2_{miss} = (p_{e^+e^-} - p_{tag} - p_{D^{(*)}} - p_l)^2$, where p are four-momenta. This quantity peaks at zero in the reference decay modes where only one neutrino is missed while in the signal modes the m^2_{miss} distribution is broad and extends up to 8 $(\mathrm{GeV}/c^2)^2$. Further separation of signal and reference modes is obtained with a requirement on the minimum momentum transfer . For decays with a τ, $q^2 = (p_\tau + p_{\nu_\tau})^2 > m^2_\tau \cong 3.16$ $(\mathrm{GeV}/c^2)^2$. The applied requirement $q^2 > 4$ $(\mathrm{GeV}/c^2)^2$ retains 98% of the signal decays and rejects more than 30% of the reference modes.

Table 2: Results for the ratios $\mathcal{R}(D^{(*)})$, the individual signal branching fraction, and the signal significance S_{tot} including systematic uncertainties, and the significance S_{stat} (only statistical uncertainties)

Decay Mode	$\mathcal{R}(D^{(*)})$	$\mathcal{B}(B \to D^{(*)}\tau\nu)$ (%)	S_{tot} (S_{stat})
$D^0\tau^-\bar{\nu}_\tau$	$0.422 \pm 0.074 \pm 0.059$	$0.96 \pm 0.17 \pm 0.14$	5.0 (6.2)
$D^{*0}\tau^-\bar{\nu}_\tau$	$0.314 \pm 0.030 \pm 0.028$	$1.73 \pm 0.17 \pm 0.18$	8.9 (11.9)
$D^+\tau^-\bar{\nu}_\tau$	$0.513 \pm 0.081 \pm 0.067$	$1.08 \pm 0.19 \pm 0.15$	6.0 (7.5)
$D^{*+}\tau^-\bar{\nu}_\tau$	$0.356 \pm 0.038 \pm 0.032$	$1.82 \pm 0.19 \pm 0.17$	9.5 (12.1)
$D\tau^-\bar{\nu}_\tau$	$0.456 \pm 0.053 \pm 0.056$	$1.04 \pm 0.12 \pm 0.14$	6.9 (9.6)
$D^*\tau^-\bar{\nu}_\tau$	$0.325 \pm 0.023 \pm 0.027$	$1.79 \pm 0.13 \pm 0.17$	11.3 (17.1)

Combinatorial background is reduced constraining to the same vertex the charged daughters of the $D^{(*)}$ and B mesons. Improved discrimination of signal and reference modes from several backgrounds is obtained using a multivariate discrimination with a Boosted Decision Tree (*BDT*): 12 discriminating classifiers using 8 discriminating variables each.

Source of difficult background is the decay $\overline{B} \to D^{**} l^- \bar{\nu}_l$. D^{**} mainly decays to $D^{(*)}\pi$ which enter in the selection when the pion is neutral and not reconstructed or is charged and associated to B_{tag}. This background has been studied with four control samples ($D^{(*)}\pi^0$) identical to the signal, except for an additional π^0 selected in the mass range $[120\,,150]$ MeV.

To extract yields for signal and reference modes we perform an extended, unbinned *ML* 2D fits to the distribution of m^2_{miss} vs $|p^*_l|$ (lepton momentum calculated in the B meson rest frame). Simultaneous fit to the four signal channels (D^0, D^{*0}, D^+, D^{*+}) and the four $D^{(*)}\pi^0$ channels. Another fit is performed imposing the isospin constraint: $\mathcal{R}(D^0) = \mathcal{R}(D^+) \equiv \mathcal{R}(D)$ and $\mathcal{R}(D^{*0}) = \mathcal{R}(D^{*+}) \equiv \mathcal{R}(D^*)$.

The fit describes reasonable well the four $D^{(*)}\pi^0$ channels inside the sizable statistical uncertainties. The fit describes very well the large contributions of the reference decay modes. Fit results for D^{*0} and D^{*+} channels are very good. Both channels are observed with a significance higher than $11\,\sigma$ (only statistical uncertainties). For the D channels the fit projection onto m^2_{miss} shows an excess of data in the range $1.5 < m^2_{miss} < 3.5$ $(\,\mathrm{GeV}/c^2)^2$ and an overestimate of events for $m^2_{miss} > 5$ $(\,\mathrm{GeV}/c^2)^2$. These regions are dominated by continuum and B combinatorial backgrounds which are fixed in the fit to what is expected by simulation. It is not clear if the fit-data differences are statistical or systematic. Both D^0 and D^+ channels are observed with a significance (statistical uncertainties only) higher than $6\,\sigma$.

Main sources of systematic uncertainties are the MC simulation of the background, the statistical uncertainties of the simulated samples, and the $D^{**}l\nu$ decay modes. In order to understand the origin of the difference in the fit-data comparison, the *BDT* requirements have been changed in such a way to have a sample passing the selection 50%. 80%, 120%, and 200% compared to the nominal sample. The agreement between fit and data improved using both more and less restrictive *BDT* requirements. We assign a systematic uncertainty equal to half of the variation on $\mathcal{R}(D^{(*)}$ in the fit when applying tight BDT requirements (50% nominal sample) and loose *BDT* requirements (200% nominal sample). This systematic uncertainty (9.5% on $\mathcal{R}(D)$ and 6.5% on $\mathcal{R}(D^*)$) is comparable in size with statistical uncertainties. It should be eliminate or reduced once the source of the difference in fit-data is understood.

Table 2 summarizes the results obtained from the two fits: the first in which all four signal yields can vary independently, and the second (last two rows in the table) in which isospin relations are imposed.

These preliminary results are in agreement with previous BaBar results [39] and with Belle measurements [40] and have significantly reduced uncertainties. The decays $\overline{B}^0 \to D^+\tau^-\bar{\nu}_\tau$ and $B^- \to D^0\tau^-\bar{\nu}_\tau$ are observed for the first time.

Figure 3 shows $\mathcal{R}(D)$ as a function of the ratio $\tan\beta/m_{H^\pm}$. The violet band is the theoretical prediction [41] while the horizontal blue band is the present measurement. Present result favors large values of $\tan\beta/m_{H^\pm}$. Furthermore $\mathcal{R}(D)$ is about $1.8\,\sigma$ in excess over *SM* prediction. A similar excess is also measured for $\mathcal{R}(D^*)$.

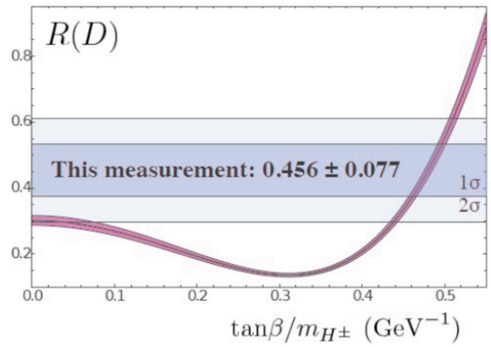

Figure 3: $\mathcal{R}(D)$ as a function of the ratio $\tan\beta/m_{H^\pm}$.

5 Direct CP Asymmetry in Inclusive $B \to X_{s+d}\gamma$

In the *SM* the inclusive electromagnetic radiative decays $b \to s\gamma$ or $b \to d\gamma$ proceed at the leading order Feynman diagram shown in Fig. 4.

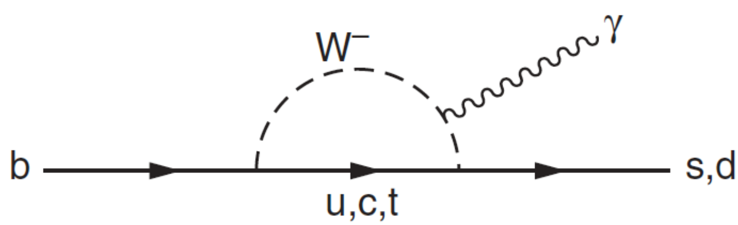

Figure 4: Leading order diagram for $b \to (s,d)\gamma$.

The branching fraction of the process $\mathcal{B}(B \to X_s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$ with $E_\gamma > 1.6$ GeV (in the B meson rest frame) has been calculate in *SM* at next-to-next-leading order with a precision of 7% [**?**]. Because new heavy particles may enter in the loop at leading order, the value of this branching fraction is highly sensitive to *NP* [43]. Another quantity highly sensitive to contributions of *NP* is the direct *CP* asymmetry [44] defined as:

$$\mathcal{A}_{CP} = \frac{\Gamma(b \to s\gamma + b \to d\gamma) - \Gamma(\bar{b} \to \bar{s}\gamma + \bar{b} \to \bar{d}\gamma)}{\Gamma(b \to s\gamma + b \to d\gamma) + \Gamma(\bar{b} \to \bar{s}\gamma + \bar{b} \to \bar{d}\gamma)}$$

This asymmetry in *SM* is expected $\approx 10^{-6}$ [44] with the asymmetries for $b \to s\gamma$ and $b \to d\gamma$ opposite with nearly exact cancellation. In *NP* scenarios $\mathcal{A}_{CP}$ can be at about 10% [45].

In a recent analysis *BABAR* has measured direct *CP* asymmetry in inclusive $B \to X_{s+d}\gamma$ using a data sample of 383×10^6 $B\overline{B}$ pairs. The reconstruction of the event uses a fully inclusive method with a semileptonic tag (Fig. 5).

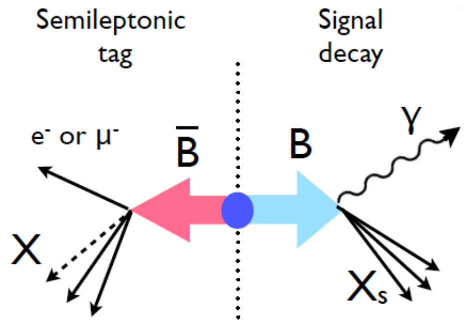

Figure 5: Semileptonic tag.

Signal events are identified by high energy photon and the X_s is not reconstructed. Therefore is not possible to distinguish X_s and X_d states and what is measured is $B \to X_{(s+d)}\gamma$. The B_{tag} is searched for in a semileptonic decay mode, checking that the remaining particles in the event are consistent with a B decay. Photon selection requires at least one photon with energy $1.53 < E^*_\gamma < 3.5$ GeV and the tag lepton can be an electron or a muon with momentum $p^* > 1.05$ GeV (E^*_γ and p^* are calculated in the $\Upsilon(4S)$ rest frame). Continuum background is suppressed using a neural network discriminant based on eight topological variables. Remaining continuum background in the final sample is estimated using off-resonance data collected 40 MeV below the $\Upsilon(4S)$ resonance. The $B\overline{B}$ background is mostly due to photons from low-mass mesons (mainly π^0 and η). This background is removed using explicit vetoes. Remaining $B\overline{B}$ background is estimated from MC simulation and is cross-checked against data with control samples. Continuum and $B\overline{B}$ background estimation have been validated with control samples provided by the photon spectrum.

In Fig. 6 we show the signal and backgrounds distributions with only the high energy photon requirement (on the left in logarithmic scale) and after all selection requirements (on the right in linear scale).

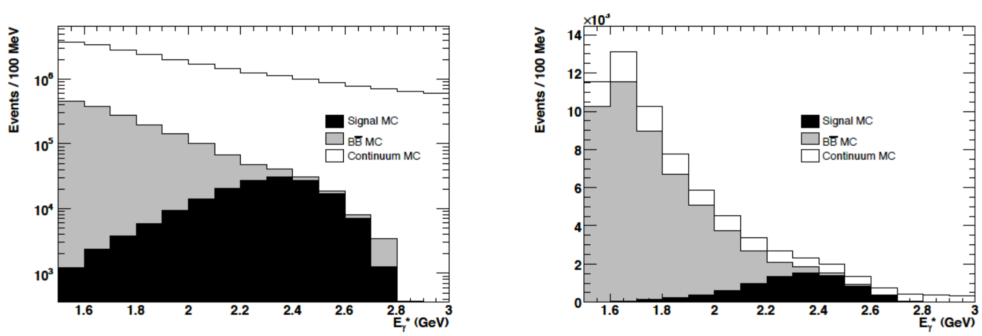

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Figure 6: Photon spectrum after requiring a high energy photon on the left and after all selection requirements on the right.

Direct CP asymmetry is insensitive to the photon energy cut. So to reduce the sensitivity to background the asymmetry is calculated in the optimized range $(2.1 - 2.8)$ GeV. Lepton charge gives B flavor and separation of B and $\overline{B}$ is done according to the charge of the lepton tag. The tagged signal yields are $N^{+} = 2623 \pm 158$ and $N^{-} = 2397 \pm 151$ and the measured CP asymmetry is:

$$\mathcal{A}_{CP}^{meas} = \frac{N^{+} - N^{-}}{N^{+} + N^{-}} = 0.045 \pm 0.044$$

This result must be corrected for the dilution due to mistag fraction ω, $\mathcal{A}_{CP} = \frac{\mathcal{A}_{CP}^{meas}}{1-2\omega}$, for the uncertainty in the $B\overline{B}$ background estimation, and for the bias induced by CP asymmetry in the $B\overline{B}$ background and by detection asymmetry. Correcting $\mathcal{A}_{CP}^{meas}$ for these effects we obtain the preliminary result:

$$\mathcal{A}_{CP} = 0.056 \pm 0.060_{stat} \pm 0.018_{syst}$$

No significant asymmetry is observed in agreement with SM expectations. This result is the most precise to date [46].

6 Search for CP Violation in $D^{+} \to K_S^0 \pi^{+}$

CP violating asymmetries have been measure both in K and B systems with results in agreement with SM expectations. CP violation has yet not been observed in charm decays, where the SM expectations for CV violating asymmetries are at the level of 10^{-3} or less [47].

In a recent analysis [48] *BABAR* searched for CP violation in the decay $D^{\pm} \to K_S^0 \pi^{\pm}$, measuring the direct CP violating parameter:

$$\mathcal{A}_{CP} = \frac{\Gamma(D^{+} \to K_S^0 \pi^{+}) - \Gamma(D^{-} \to K_S^0 \pi^{-})}{\Gamma(D^{+} \to K_S^0 \pi^{+}) + \Gamma(D^{-} \to K_S^0 \pi^{-})}$$

with Γ partial decay width of the decay.

Although the SM prediction for direct CP violation due to the interference between Cabibbo-allowed and doubly Cabibbo-suppressed amplitudes is negligible [49], K^0- $\overline{K}^0$ mixing induces a time-integrated CP violating asymmetry of $(-0.332 \pm 0.006)\%$ [10]. Contributions of physics beyond the SM may enhance the value of $\mathcal{A}_{CP}$ up to 1% [49,50]. Previous measurements of $\mathcal{A}_{CP}$ have been reported by CLEO-c $[-0.6 \pm 1.0 \pm 0.3\ \%]$ [51] and Belle Collaboration $[-0.71 \pm 0.19 \pm 0.20\%]$ [52]

We reconstruct $D_s^{\pm} \to K_S^0 \pi^{\pm}$ decays combining a K_S^0 candidate with a charged pion candidate. The K_S^0 decays to $\pi^{+}\pi^{-}$ and is selected with an invariant mass within ± 10 MeV/c^2 of the nominal K_S^0 mass [10]. The reconstructed pion candidate is selected with a momentum p_T in the plane perpendicular to the z axis greater than 400 GeV/c. The selected $D^{\pm}$ candidate has an invariant mass within ± 65 MeV/c^2 of the nominal D^{+} mass [10], and a momentum p^{*} in the $e^{+}e^{-}$ CM in the range $(2 - 5)$ GeV/c. Further suppression of background has been achieved using a BDT with seven event topological discriminating variables.

Signal yield is extracted with a binned ML fit to the invariant mass distribution of the selected $D^{\pm}$ candidates. There are three fit components: signal, a background from $D_s^{\pm} \to K_S^0 K^{\pm}$ and a combinatoric background.

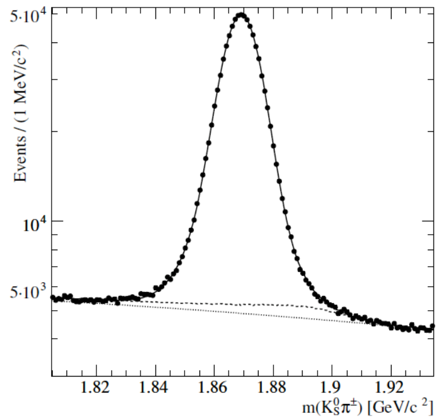

Figure 7: Invariant mass distribution for $K^0_S\pi^\pm$: solid curve is the fit to the data (points), the dashed line is the sum of backgrounds, and the dotted line is the combinatorial background only. The vertical scale on the plot is logarithmic.

Data and fit are shown in Fig. 7. The signal yield asymmetry is:

$$\mathcal{A} = \frac{N_{D^+} - N_{D^-}}{N_{D^+} + N_{D^-}} ,$$

where N_{D^+} and N_{D^-} are the fitted yields for $D^+ \to K^0_S\pi^+$ and $D^- \to K^0_S\pi^-$, respectively.

The quantity $\mathcal{A}$ includes contribution not only from $\mathcal{A}_{CP}$ but also from the forward-backward asymmetry $\mathcal{A}_{FB}$ in $e^+e^- \to c\bar{c}$ due to $\gamma^* - Z^0$ interference and other QED processes. Another source of asymmetry ($\mathcal{A}_\epsilon$) contribution to $\mathcal{A}$ is induced by the detector as a consequence of the difference in reconstruction efficiency of $D^+ \to K^0_S\pi^+$ and $D^- \to K^0_S\pi^-$ due to differences in reconstruction and identification efficiencies for π^+ and π^-. So we can write:

$$\mathcal{A} = \mathcal{A}_{CP} + \mathcal{A}_{FB} + \mathcal{A}_\epsilon \tag{2}$$

$\mathcal{A}_\epsilon$ has been measured using a control sample of $B\overline{B}$ decays. The bias of +0.05% to $\mathcal{A}_{CP}$ has been included in the systematics.

We separate $\mathcal{A}_{CP}$ and $\mathcal{A}_{FB}$ in Eq. 2 considering that $\mathcal{A}_{FB}$ is an odd function of $\cos\theta^*_D$, where θ^*_D is the polar angle of the $D^\pm$ candidate momentum in the e^+e^- CM, while $\mathcal{A}_{CP}$ is an even function of $\cos\theta^*_D$. Therefore the two asymmetries $\mathcal{A}_{CP}$ and $\mathcal{A}_{FB}$ can be written as a function of $|\cos\theta^*_D|$ as:

$$\mathcal{A}_{FB}(|\cos\theta^*_D|) = \frac{A(+|\cos\theta^*_D|) - A(-|\cos\theta^*_D|)}{2}$$

$$\mathcal{A}_{CP}(|\cos\theta^*_D|) = \frac{A(+|\cos\theta^*_D|) + A(-|\cos\theta^*_D|)}{2}$$

The selected sample is divided in subsamples corresponding to 5 bins of $|\cos\theta^*_D|$ and a simultaneous binned *ML* fit is performed to extract signal yield asymmetries.

The five measured values of the parameters $\mathcal{A}_{CP}$ and $\mathcal{A}_{FB}$ are shown in Fig. 8. We measure:

$$\mathcal{A}_{CP} = (-0.39 \pm 0.13 \pm 0.10)\% ,$$

where the first uncertainty is statistical and the second systematic. This value is in agreement with the prediction of the *SM*.

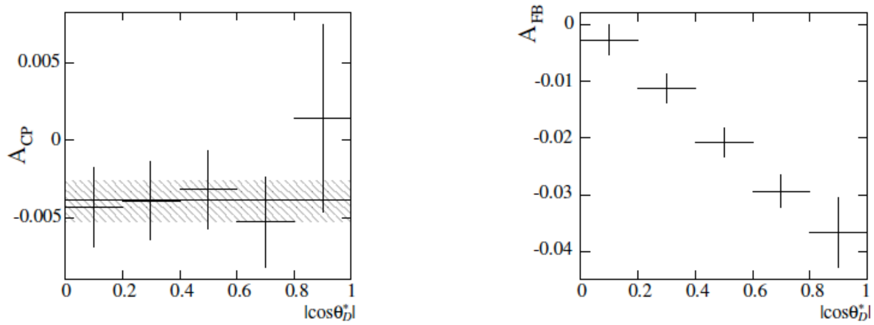

Figure 8: On the left $\mathcal{A}_{CP}$ with the central value (solid line) and the $\pm 1\sigma$ interval (hatched region), and $\mathcal{A}_{FB}$ (on the right) in bins of $|\cos\theta^*_D|$.

7 Search for T Violation using T-odd Correlations in $D^+_{(s)} \to K^+ K^0_S \pi^+ \pi^-$

T violation in the channels $D^+ \to K^+ K^0_S \pi^+ \pi^-$ and $D^+_s \to K^+ K^0_S \pi^+ \pi^-$ [9] can be measured using T-odd correlations. Using the momenta of the final particles in the $D^+_{(s)}$ rest frame, the T-odd correlation observable can be written as:

$$C_T \equiv \vec{p}_{K^+} \cdot (\vec{p}_{\pi^+} \times \vec{p}_{\pi^-})$$

This triple product is odd under time reversal. Assuming CPT invariance, T violation is equivalent to *CP* violation. We measure the asymmetry:

$$A_T \equiv \frac{\Gamma(C_T > 0) - \Gamma(C_T < 0)}{\Gamma(C_T > 0) + \Gamma(C_T < 0)} ,$$

where Γ is the decay rate of the process.

Because Final State Interactions (FSI) can produce an asymmetry A_T different from zero [53], we measure also the T-odd asymmetry for the *CP*-conjugate decay process:

$$\overline{A}_T \equiv \frac{\Gamma(-\overline{C}_T > 0) - \Gamma(-\overline{C}_T < 0)}{\Gamma(-\overline{C}_T > 0) + \Gamma(\overline{C}_T < 0)} ,$$

where $\overline{C}_T \equiv \vec{p}_{K^-} \cdot (\vec{p}_{\pi^-} \times \vec{p}_{\pi^+})$ with momenta calculated in the $D^-_{(s)}$ rest frame. To remove FSI effects we measure the quantity $\mathcal{A}_T$:

$$\mathcal{A}_T \equiv \frac{1}{2}(A_T - \overline{A}_T) \tag{3}$$

which is an asymmetry characterizing T violation in the weak process [54].

In a previous *BABAR* analysis [55] done on the neutral decay $D^0 \to K^+K^-\pi^+\pi^-$ no evidence of *CP* violation has been found.

We describe here the search for *CP* violation using T-odd correlations in the decays $D^+ \to K^+K^0_S\pi^+\pi^-$ and $D^+_s \to K^+K^0_S\pi^+\pi^+$ [56]. In the reconstruction we have considered inclusive D decays ($e^+e^- \to XD^+_{(s)}$), selected using kinematic constraints and particle identification. In the vertex fit, requiring that all three tracks with net charge +1 originate from a common vertex, a χ^2 fit probability $P1 > 0.1$ % has been imposed. A second fit constraining the three tracks to originate from the e^+e^- interaction region was also done. In this case the χ^2 fit probability $P2$ is large for most background events with tracks originating in the interaction region.

$D^+_{(s)}$ candidate must have a momentum p^* in the CM greater than 2.5 GeV/c. To improve signal and background separation we consider the signed transverse decay length:

$$L_T = \frac{\vec{d} \cdot \vec{p}_T}{|\vec{p}_T|} ,$$

where $\vec{d}$ is the distance vector between IR and the $D^+_{(s)}$ decay vertex in the transverse plane and $\vec{p}_T$ is the transverse momentum of $D^+_{(s)}$. With the variables p^*, P1-P2, and L_T we construct a *LR* to optimize the signal yields separately for D^+ and D^+_s. Separation requirements where optimized maximizing the statistical significance $S/\sqrt{S+B}$, where S is the number of signal and B the number of background events in the signal region.

Then the dataset is divided in four samples depending of the $D^+_{(s)}$ charge and sign of C_T ($\overline{C}_T$) and on these four datasets a simultaneous fit to mass spectra has been done to extract the asymmetry parameters A_T and $\overline{A}_T$. The measured values are:

$$\begin{aligned} A_T(D^+) &= (+11.2 \pm 14.1 \pm 5.7) \times 10^{-3} \\ \overline{A}_T(D^-) &= (+35.1 \pm 14.3 \pm 7.2) \times 10^{-3} \\ A_T(D^+_s) &= (+99.2 \pm 10.7 \pm 8.3) \times 10^{-3} \\ \overline{A}_T(D^-_s) &= (+72.1 \pm 10.9 \pm 10.7) \times 10^{-3} , \end{aligned}$$

where the first uncertainty is statistical and the second systematic. FSI Effects are larger in D^+_s than in D^+ decays. A study of such effects can be found in ref. [57]. The T violation asymmetries obtained using Eq. 3 are:

$$\begin{aligned} \mathcal{A}_T(D^+) &= (-12.0 \pm 10.0 \pm 4.6) \times 10^{-3} \\ \mathcal{A}_T(D^+_s) &= (-13.6 \pm 7.7 \pm 3.4) \times 10^{-3} \end{aligned}$$

T violation parameter is consistent with 0 for both the two decay modes.

8 Summary and Conclusions

We have presented *BABAR* results of recent searches for rare or forbidden charm decays , measurement of the magnitude of the CKM matrix element V_{ub}, the observation of the semileptonic $B \to D^{(*)}\tau\nu_\tau$ decays, searches for direct *CP* violation asymmetry in $B \to X_{(s+d)}\gamma$ and in $D^+ \to K^0_S \pi^+$, and T-violation in $D^+_{(s)} \to K^+ K^0_S \pi^+ \pi^-$. All these analyses use the final *BABAR* dataset. Results have been improved over previous analyses and are all consistent with *SM* expectations. No *CP* violation has been observed in $c \to s$ transitions , neither from *SM* nor from *NP*. More stringent limits are set on space parameters of *NP* models.

B-factories reached their sensitivity limit. We expect soon a significant impact in flavor physics from LHCb experiment [58] and (in a few years) from the next generation super B factories (SuperB [59] at the Cabibbo Laboratory (Tor Vergata, Rome) and SuperKEKB [60] at Tsukuba.

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