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Recent highlights from BaBar

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Summary. — We report on recent results from the BaBar experiment using the complete dataset collected at the $\Upsilon(4S)$. Three of the analyses presented here are time-dependent: the first observation of time-reversal violation, a new measurement of CP violation in $B^0 \to D^{*+}D^{*-}$ decays, and the search for CP violation in B^0-$\bar{B}^0$ mixing by partially reconstructing $B^0 \to D^* l\nu$ decays. Three time-independent analyses search for new physics in the decays: $B \to K^{(*)}\nu\bar{\nu}$, $B \to \pi/\eta l^+l^-$, and $B \to D^{(*)}\tau\nu$.

PACS 11.30.Er – Charge conjugation, parity, time reversal, and other discrete symmetries.
PACS 25.75.Dw – Particle and resonance production.
PACS 98.80.Cq – Particle-theory and field-theory models of the early Universe (including cosmic pancakes, cosmic strings, chaotic phenomena, inflationary universe, etc.).

1. – Experimental introduction

About 470 million B-meson pairs (from $e^+e^- \to \Upsilon(4S) \to B\bar{B}$), either $B^0\bar{B}^0$ in a coherent state or B^+B^-, were recorded at the asymmetric beauty factory *BaBar* at PEPII in USA. The *BaBar* analyses presented here use all the recorded data. The boost $\beta\gamma = 0.56$ of the $\Upsilon(4S)$ allows time dependent CP, CPT, and T asymmetry measurements. One B meson B^0_{rec} or $\bar{B}^0_{rec}$ decaying at time t_{rec} is reconstructed into a CP state resulting either from a $c\bar{c}s$ transition such as $J/\Psi K^0_{S,L}$, or from a $c\bar{c}d$ transition like $D^{*+}D^{*-}$. The meson B^0_{rec} can also be reconstructed into a flavor state $B^0 \to D^* l\nu_l$ or a rare decay. The other neutral B meson, B_{tag}, decaying at time t_{tag}, tags the flavor B^0_{rec} or $\bar{B}^0_{rec}$ at t_{tag}, for example by using the charge of the lepton from a semileptonic decay, or the charge of a kaon from the B_{tag} decay. The decay time difference $\Delta t = t_{rec} - t_{tag}$ is measured by the distance between the two B decay vertices (of the order of 250 μm).

Event shape variables combined in a neural network or a Fisher discriminant suppress jet-like continuum events and favor 'spherical' $B\bar{B}$ events. The signal is discriminated from the background using the beam energy substituted mass $m_{ES} = \sqrt{E^{*2}_{beam} - p^{*2}_B}$ and the energy difference $\Delta E = E^*_B - E^*_{beam}$ functions of the beam and B meson energy in the $\Upsilon(4S)$ rest frame, and peaking at the B meson mass and at zero, respectively, for the signal.

2. – First direct observation of time reversal violation at BABAR

Time reversal violation is observed directly for the first time [1] by analysing $B^0\bar{B}^0$ pairs in which one B meson is reconstructed as a $c\bar{c}s$ CP state ($\{K^0_S, K^0_L\}$ with $c\bar{c} = J/\Psi$, $\Psi(2s)$ or χ_{c1}), and the other B meson is selected as a flavor state like a semileptonic decay. For example the $J/\Psi K^0_L(K^0_S)$ final state projects the CP even (odd) eigenstate, and a semileptonic decay projects the flavor state B^0 ($\bar{B}^0$) for a lepton l^+ (l^-).

The measurement is made possible using the EPR entanglement between the two B mesons from the $\Upsilon(4S)$ decay, as applied to flavor and CP states. If the first B meson to decay (at time t_1) is reconstructed as a flavor (CP) state, the second B meson decays later (at time t_2) and is reconstructed as a CP (flavor) state. Due to EPR entanglement, at the moment the first B meson decays, the second B meson has the opposite flavor (CP eigenvalue) to the first B meson. This allows one to compare four independent processes for which the first decaying B meson is measured as a flavor state B^0 or $\bar{B}^0$ and the second meson is then reconstructed as a CP even or odd eigenstate, to the time-reversed processes in which the first decaying B meson is reconstructed as a CP state. In terms of reconstructed states, those comparisons between time-reversed processes imply opposite Δt signs, opposite CP eigenvalues for the CP states ($J/\Psi K^0_S$ *versus* $J/\Psi K^0_L$), and opposite flavor states (B^0 *versus* $\bar{B}^0$). The analysis allows in a similar way four independent CP and CPT comparisons.

The time difference distribution $g^{\pm}_{\alpha,\beta}(\Delta t)$ (eq. (1)) obtained by reconstructing one B meson into the CP state β and the other B meson into the flavor state α allows the extraction of eight sets of $\{S, C\}$ parameters(1). Comparing appropriate pairs of parameters measures T, CP, and CPT violation, as shown in table I.

The following equation (1) assumes no lifetime difference between the neutral B meson physics states, as well as perfect signal and time recontruction, but the experimental effects are taken into account in the analysis:

$$
\begin{aligned}
&g^{\pm}_{\alpha,\beta}(\Delta t) \propto e^{-\Gamma|\Delta t|} \times (1 + S^{\pm}_{\alpha,\beta} \sin(\Delta m_d|\Delta t|) + C^{\pm}_{\alpha,\beta} \cos(\Delta m_d|\Delta t|)) \\
&\alpha \in \{B^0, \bar{B}^0\}; \beta \in \{K^0_S, K^0_L\}; +(-) \equiv \Delta t > 0 (< 0).
\end{aligned} \tag{1}
$$

Time reversal violation is observed directly for the first time with a $14\,\sigma$ significance. This is expected due to CPT conservation and the well known CP violation in the interference between the neutral B meson decay to a CP eigenstate with and without B^0 mixing. CP violation is also measured in this analysis with a $16.6\ \sigma$ signifance, and compensates T violation to result in no CPT violation. Note that T and CP ΔS parameters are different from zero and ΔC parameters connected to direct CP violation in the B meson decay are consistent with zero. These results represent the first direct observation of T violation through the exchange of initial and final states in transitions that can only be connected by a T-symmetry transformation.

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(1) Note that in the classical CP violation analysis assuming the conservation of CPT, just one single set of $\{S, C\}$ parameters is measured.

TABLE I. – *Results on T, CP, and CPT asymmetries* [1].

Parameter	Result
$\Delta S_T^+ = S^-_{l^- X, J/\Psi K^0_L} - S^+_{l^+ X, c\bar{c}K^0_S}$	$-1.37 \pm 0.14 \pm 0.06$
$\Delta S_T^- = S^+_{l^- X, J/\Psi K^0_L} - S^-_{l^+ X, c\bar{c}K^0_S}$	$+1.17 \pm 0.18 \pm 0.11$
$\Delta C_T^+ = C^-_{l^- X, J/\Psi K^0_L} - C^+_{l^+ X, c\bar{c}K^0_S}$	$+0.10 \pm 0.16 \pm 0.08$
$\Delta C_T^- = C^+_{l^- X, J/\Psi K^0_L} - C^-_{l^+ X, c\bar{c}K^0_S}$	$+0.04 \pm 0.16 \pm 0.08$
$\Delta S_{CP}^+ = S^+_{l^- X, c\bar{c}K^0_S} - S^+_{l^+ X, c\bar{c}K^0_S}$	$-1.30 \pm 0.10 \pm 0.07$
$\Delta S_{CP}^- = S^-_{l^- X, c\bar{c}K^0_S} - S^-_{l^+ X, c\bar{c}K^0_S}$	$+1.33 \pm 0.12 \pm 0.06$
$\Delta C_{CP}^+ = C^+_{l^- X, c\bar{c}K^0_S} - C^+_{l^+ X, c\bar{c}K^0_S}$	$+0.07 \pm 0.09 \pm 0.03$
$\Delta C_{CP}^- = C^-_{l^- X, c\bar{c}K^0_S} - C^-_{l^+ X, c\bar{c}K^0_S}$	$+0.08 \pm 0.10 \pm 0.04$
$\Delta S_{CPT}^+ = S^-_{l^+ X, J/\Psi K^0_L} - S^+_{l^+ X, c\bar{c}K^0_S}$	$+0.16 \pm 0.20 \pm 0.09$
$\Delta S_{CPT}^- = S^+_{l^+ X, J/\Psi K^0_L} - S^-_{l^+ X, c\bar{c}K^0_S}$	$-0.03 \pm 0.13 \pm 0.06$
$\Delta C_{CPT}^+ = C^-_{l^+ X, J/\Psi K^0_L} - C^+_{l^+ X, c\bar{c}K^0_S}$	$+0.15 \pm 0.17 \pm 0.07$
$\Delta C_{CPT}^- = C^+_{l^+ X, J/\Psi K^0_L} - C^-_{l^+ X, c\bar{c}K^0_S}$	$+0.03 \pm 0.14 \pm 0.08$

3. – Time dependent CP asymmetry of partially reconstructed $B^0 \to D^{*+}D^{*-}$ decays

This $b \to c\bar{c}d$ transition to a CP final state allows a measurement of $\sin 2\beta$ that can be compared to the measurements using the CP states $J/\Psi K^0_{S,L}$ resulting from $c\bar{c}s$ transitions. Both $b \to c\bar{c}s$ and $b \to c\bar{c}d$ transitions are dominated by tree contributions; but in the $b \to c\bar{c}d$ transition the penguin contribution, expected to be of the order of a few percents in the standard model, could be enhanced by a contribution from new physics virtual particles.

As the $D^{*+}D^{*-}$ final state is a two vectors state, an angular analysis is needed to separate the CP eigenstates, and thus requires the full reconstruction of the $D^{*+}D^{*-}$ state, as it was done in [2]. In analyses using full reconstruction, the CP even component CP parameters S_+ and C_+, as well as the fraction $R_\perp$ of CP odd amplitude are measured.

The new analysis presented here [3] is based on a partial reconstruction of the $D^{*+}D^{*-}$ final state, to gain statistics. So only the average S and C CP parameters are measured, and the fraction $R_\perp$ measured in [2] is used to calculate the related S_+ and C_+ parameters (if the penguin contribution is neglected):

$$C_+ = C; \qquad S = S_+ \times (1 - 2 \times R_\perp). \tag{2}$$

One of the B meson is partially reconstructed as a $D^{*+}D^{*-}$ state, as the othe B meson is used to tag its flavor using a lepton or a kaon from its decay. The partial reconstruction of the $D^{*+}D^{*-}$ requires only one charged D^* to be fully reconstructed into a D^0 and a slow charged pion, the D^0 itself is reconstructed through $K\pi$, $K\pi\pi^0$, $K3\pi$, or $K_S\pi^+\pi^-$ decays. The second charged D^* meson is not reconstructed, only the charged slow pion resulting from its decay is required.

The average CP parameters S and C are extracted [3] from a maximum likelihood fit over the decay time difference between the two B mesons, the reconstructed recoiling

D^0 mass, and a Fisher discriminant of the event shape [3]:

$$S = -0.34 \pm 0.12 \pm 0.05; \qquad C = +0.15 \pm 0.09 \pm 0.04. \tag{3}$$

Using eq. (2) and the value of $R_\perp = 0.158 \pm 0.029$ measured in [2] allows one to extract the CP even parameters [3]:

$$S_+ = -0.49 \pm 0.18 \pm 0.07 \pm 0.04(R_\perp); \qquad C_+ = +0.15 \pm 0.09 \pm 0.04. \tag{4}$$

These results are consistent with the latest BaBar and $BELLE$ results based of the full $D^{*+}D^{*-}$ reconstruction, as well as with the measurements with charmonium in the final state. This new measurement using partial $D^{*+}D^{*-}$ reconstruction results in a decrease of the global BaBar uncertainty by about 20% on the CP even parameters when combined with the full reconstruction analysis.

4. – Search for CP violation in the B_d^0–$\bar{B}_d^0$ mixing with partially reconstructed $B^0 \to D^* l\nu$ decays

The physics eigenstates $|B^{L,H}\rangle$ are related to the flavor eigenstates B^0 and $\bar{B}^0$ by this equation defining the mixing parameters q and p:

$$|B^{L,H}\rangle = \frac{1}{\sqrt{1+|q/p|^2}} \times \left(|B^0\rangle \pm (q/p)|\bar{B}^0\rangle\right). \tag{5}$$

There is CP violation in the mixing if the probability for a B^0 to mix into a $\bar{B}^0$ is different from the probability for a $\bar{B}^0$ to mix into a B^0, which is equivalent to a non-zero CP asymmetry:

$$A_{CP} = \frac{N(B^0B^0) - N(\bar{B}^0\bar{B}^0)}{N(B^0B^0) + N(\bar{B}^0\bar{B}^0)} = \frac{1-|q/p|^4}{1+|q/p|^4}, \tag{6}$$

where the two B mesons result from a $\Upsilon(4S)$ decay, and one of them has mixed before their flavor is tagged at their decay time. The standard model prediction for this time independent asymmetry is small ($O(10^{-4})$), and measuring a larger value would indicate new physics.

A_{CP} was previously measured using dilepton events. The new approach presented here [4] uses the partial reconstruction of one of the neutral mesons into $B^0 \to D^* l\nu$, where the lepton charge allows one to tag its flavor, while a kaon is used to tag the flavor of the other neutral B meson. Without backgrounds, A_{CP} would be

$$A_{CP} = \frac{N(B^0B^0) - N(\bar{B}^0\bar{B}^0)}{N(B^0B^0) + N(\bar{B}^0\bar{B}^0)} = \frac{N(l^+K^+) - N(l^-K^-)}{N(l^+K^+) + N(l^-K^-)}. \tag{7}$$

Note that if the CP asymmetry in the mixing is independent of the difference between the decay times of the two B mesons, a time-dependent analysis is performed to better constrain nuisance parameters related to detector charge asymmetries and backgrounds. The main background is due to the selection of a kaon from the decay of the partially reconstructed B meson into $D^* l\nu$, instead of a kaon from the decay of the other "tag" B meson.

TABLE II. – *Preliminary results on searches for $B \to K^{(*)}\nu\bar{\nu}$ decays* [6].

Mode	BF $\times 10^{-5}$	90% CL limit $\times 10^{-5}$	90% CL limit $\times 10^{-5}$ combined with semileptonic
$B^+ \to K^+\nu\bar{\nu}$	$1.5 \begin{matrix} +1.7 & +0.4 \\ -0.8 & -0.2 \end{matrix}$	> 0.4 and < 3.7	< 1.6
$B^0 \to K^0\nu\bar{\nu}$	$0.14 \begin{matrix} +6.0 & +1.7 \\ -1.9 & -0.9 \end{matrix}$	< 8.1	< 4.9
$B^+ \to K^{*+}\nu\bar{\nu}$	$3.3 \begin{matrix} +6.2 & +1.7 \\ -3.6 & -1.3 \end{matrix}$	< 11.6	< 6.4
$B^0 \to K^{*0}\nu\bar{\nu}$	$2.0 \begin{matrix} +5.2 & +2.0 \\ -4.3 & -1.7 \end{matrix}$	< 9.3	< 12
$B \to K\nu\bar{\nu}$	$1.4 \begin{matrix} +1.4 & +0.3 \\ -0.9 & -0.2 \end{matrix}$	> 0.2 and < 3.2	< 1.7
$B \to K^*\nu\bar{\nu}$	$2.7 \begin{matrix} +3.8 & +1.2 \\ -2.9 & -1.0 \end{matrix}$	< 7.9	< 7.6

The A_{CP} asymmetry is extracted from a maximum-likelihood fit over time and three discriminating variables: the angle $\cos\theta_{lK}$ between the lepton and the kaon tracks, the kaon momentum p_K, and the reconstructed neutrino invariant mass M_v^2 for the $D^*l\nu$ decay (peaking at zero for the signal). Opposite signs lK pairs are also used in the fit to better constrain nuisance parameters. The result for A_{CP} [4],

$$A_{CP} = \left[0.06 \pm 0.17(\text{stat.}) \begin{matrix} +0.38 \\ -0.32 \end{matrix} (\text{syst.})\right]\%, \tag{8}$$

is consistent with but more accurate than the previous $\Upsilon(4S)$ HFAG average. It is also consistent with the standard model and other results on $B^0_{d,s}$ mixing. It is even more important to get the most precise measurement as a discrepancy is observed between the $D0$ experiment dimuon result [5] and the standard model prediction.

5. – Search for $B \to K^{(*)}\nu\bar{\nu}$ and invisible charmonium decays

In the standard model, the $B \to K^{(*)}\nu\bar{\nu}$ decay is governed by electroweak penguin and box diagrams. The branching fraction predictions: $\text{BF}(B \to K\nu\bar{\nu}) = (0.36 \text{ to } 0.52) \times 10^{-5}$ and $\text{BF}(B \to K^*\nu\bar{\nu}) = (0.68 \text{ to } 1.30) \times 10^{-5}$ are small but more accurate than for the $B \to K^{(*)}l^+l^-$ decays as there is no electromagnetic contribution. New physics contributions in the loops could enhance these branching fractions. The new preliminary searches presented here [6] also cover invisible charmonium decays sharing the same final state $K^{(*)}\nu\bar{\nu}$, but for which the neutrinos $\nu\bar{\nu}$ result from the decay of a charmonium state $c\bar{c}$. Such charmonium decays could also be enhanced by new physics contributions. In order to constrain the non-detected neutrinos, while one of the B meson of the event is reconstructed as the signal $B \to K^{(*)}\nu\bar{\nu}$, the other B meson is reconstructed in one of many exclusive hadronic decays. The $B \to K^{(*)}\nu\bar{\nu}$ decay is reconstructed as one of the six modes: $B^+ \to K^+\nu\bar{\nu}$, $B^0 \to K^0_S\nu\bar{\nu}$, $B^+ \to [K^{*+} \to K^+\pi^0]\nu\bar{\nu}$, $B^+ \to [K^{*+} \to K^0_S\pi^+]\nu\bar{\nu}$, $B^0 \to [K^{*0} \to K^+\pi^-]\nu\bar{\nu}$, $B^0 \to [K^{*0} \to K^0_S\pi^0]\nu\bar{\nu}$. The normalized $\nu\bar{\nu}$ invariant mass $s_B = q^2/m_B^2 = (pB_{sig} - pK^{(*)})/m_B^2$ is then reconstructed and a "cut and count" method is used to derive the branching fractions in tables II and III. Typical variables presented in

TABLE III. – *Preliminary results on searches for invisible charmonium* [6].

Mode	BF $\times 10^{-3}$	90% CL limit $\times 10^{-3}$	BF$(c\bar{c} \to \nu\bar{\nu})$ / BF$(c\bar{c} \to e^+e^-)$
$J/\Psi \to \nu\bar{\nu}$	$0.2\ {}^{+2.7}_{-0.9}$ (stat.) ${}^{+0.5}_{-0.4}$ (syst.)	< 3.9	$< 6.6 \times 10^{-2}$
$\Psi(2s) \to \nu\bar{\nu}$	$5.6\ {}^{+7.4}_{-4.6}$ (stat.) ${}^{+1.6}_{-1.4}$ (syst.)	< 15.5	< 2.0

the experimental introduction are used to suppress the background. To derive branching fractions for $B \to K^{(*)}\nu\bar{\nu}$ decays, s_B is required to be lower than 0.3, as the search for invisible charmonium concentrates in $m_{\nu\bar{\nu}}$ areas around the J/Ψ and $\Psi(2s)$ resonances. No significant signal is observed, in agreement with the standard model predictions. The first limit on the $B^+ \to K^+\nu\bar{\nu}$ decay, and the most stringent upper limits using the hadronic tag reconstruction are given for $B^0 \to K^0\nu\bar{\nu}$, $B^+ \to K^{*+}\nu\bar{\nu}$, and $B^0 \to K^{*0}\nu\bar{\nu}$ decays. The first upper limit on the invisible charmonium decay $\Psi(2s) \to \nu\bar{\nu}$ is also provided.

New physics can change not only global branching fractions, but also their dependence on s_B: for example the contribution from invisible scalars could enhance the branching fraction at values of s_B between 0.2 and 0.8. A measurement of the branching fractions as a function of s_B shows no sign of such enhancement.

6. – Search for $B \to \pi/\eta l^+l^-$ decay

Like the $B \to K^{(*)}\nu\bar{\nu}$ decays, the $B \to \pi/\eta l^+l^-$ decays are governed by electroweak and box diagrams, and new physics could enhance the small expectations from the standard model for the branching fractions. The $b \to dl^+l^-$ transition is similar to $b \to sl^+l^-$ but its rate is suppressed by $|V_{td}|^2/|V_{ts}|^2 \approx 0.04$ and the standard model prediction for the branching fraction is of the order of 10^{-8}. Only the $B^+ \to \pi^+\mu^+\mu^-$ decay has been observed so far at LHCb [7], and the smallest upper limits from the B factories lie within an order of magnitude from the standard model predictions.

Searches are presented here [8] on the $B^+ \to \pi^+l^+l^-$, $B^0 \to \pi^0l^+l^-$, and $B^0 \to \eta l^+l^-$ decays, for which the lepton pair l^+l^- can be either e^+e^- or $\mu^+\mu^-$. The η is reconstructed into three pions or two photons. Lepton-flavor averages assume equal branching fractions for e^+e^- and $\mu^+\mu^-$, as isospin average assumes BF$(B^+ \to \pi^+l^+l^-) = 2 \times$ BF$(B^0 \to \pi^0l^+l^-)$.

The branching fractions given in table IV are extracted from an unbinned maximum-likelihood fit to the kinematical variables m_{ES} and ΔE [8]. No significant signal has been found as expected from the standard model. As a cross check, the branching fraction for the $B^+ \to K^+l^+l^-$ decay is measured and found consistent with current world averages. The lowest upper limits to date are obtained on the $B^0 \to \pi^0e^+e^-$, $B^0 \to \pi^0\mu^+\mu^-$ and $B^0 \to \pi^0l^+l^-$ branching fractions. Note that the uncertainty on the branching fraction for the $B^+ \to \pi^+\mu^+\mu^-$ decay: BF$(B^+ \to \pi^+\mu^+\mu^-) = \left(-0.6\ {}^{+4.4}_{-3.2} \pm 0.9\right) \times 10^{-8}$ is much larger than the one from the LHCb measurement [7] BF$(B^+ \to \pi^+\mu^+\mu^-) = (2.4 \pm 0.6 \pm 0.2) \times 10^{-8}$, but most of the other modes with neutral particules in the final state are much more difficult to study at LHCb.

TABLE IV. – *Preliminary isospin and lepton-flavor averaged results on $B \to \pi/\eta l^+ l^-$ decays* [8].

Mode	BF $\times 10^{-8}$	90% CL limit $\times 10^{-8}$
$B \to \pi e^+ e^-$	$4.0 \begin{array}{c} +5.1 \\ -4.2 \end{array} \pm 1.6$	11.0
$B \to \pi \mu^+ \mu^-$	$-0.9 \begin{array}{c} +3.9 \\ -3.0 \end{array} \pm 1.2$	5.0
$B^+ \to \pi^+ l^+ l^-$	$2.5 \begin{array}{c} +3.9 \\ -3.3 \end{array} \pm 1.2$	6.6
$B^0 \to \pi^0 l^+ l^-$	$1.2 \begin{array}{c} +3.9 \\ -3.3 \end{array} \pm 0.2$	5.3
$B^0 \to \eta l^+ l^-$	$-2.8 \begin{array}{c} +6.6 \\ -5.2 \end{array} \pm 0.3$	6.4
$B \to \pi l^+ l^-$	$2.5 \begin{array}{c} +3.3 \\ -3.0 \end{array} \pm 1.0$	5.9

7. – Study of the $B \to D^{(*)} \tau \nu$ decay

This decay is sensitive to a possible contribution from a charged Higgs boson $H^\pm$ in the tree diagram, instead of the $W^\pm$. The decay rate for the semileptonic decay $B \to D^{(*)} l \nu$ is governed by:

$$\text{(9)} \qquad \frac{\mathrm{d}\Gamma_l}{\mathrm{d}q^2} = \frac{G_F^2 |V_{cb}|^2 |p_{D^{(*)}}| q^2}{96\pi^3 m_B^2} \left(1 - \frac{m_l^2}{q^2}\right)^2 \times \left[(|H_+|^2 + |H_-|^2 + |H_0|^2) \left(1 + \frac{m_l^2}{2q^2}\right) + \frac{3m_l^2}{2q^2} |H_S|^2 \right],$$

where the lepton l can be an electron, a muon, or a tau. H_+, H_-, and H_0 are the hadronic amplitudes, where H_+ and H_- are only relevant for $B \to D^* l \nu$ decays, and a charged Higgs scalar contribution would enter into the amplitude H_S. It is suppressed for electron and muon compared to tau lepton, due to the m_l^2 term in factor of $|H_S|^2$ in eq. (9).

The standard model is tested by measuring the following ratios in which several theoretical and experimental uncertainties cancel out:

$$\text{(10)} \qquad R(D) = \frac{\bar{B} \to D\tau\nu}{\bar{B} \to Dl\nu}; \qquad R(D^*) = \frac{\bar{B} \to D^*\tau\nu}{\bar{B} \to D^* l\nu}.$$

The BABAR measurements show a 3.4 σ deviation from the standard model [9] by combining the correlated results on $R(D) = 0.440 \pm 0.058 \pm 0.042$ and $R(D^*) = 0.332 \pm 0.024 \pm 0.018$.

The analysis is based on the selection of the $B \to D^{(*)} \tau \nu$ candidate where the other B meson is fully reconstructed into a hadronic channel. An unbinned maximum-likelihood fit is performed over the lepton momentum p_l^* in the $\Upsilon(4S)$ rest frame and the missing invariant mass corresponding to the neutrinos $m_{miss}^2 = (P_{e^+e^-} - P_{Btag} - P_{D^{(*)}} - P_l)^2$.

The simplest two Higgs Doublet Model 2HDM of type II has also been tested in [9], by comparing the allowed ranges for $R(D)$ and $R(D^*)$ *versus* $\tan\beta/m_{H^+}$ from the measurements and the theoretical predictions. In the 2HDM model of type II, the theoretical predictions and the experimental expectations are consistent for very different values of $\tan\beta/m_{H^+}$ for $R(D)$ and $R(D^*)$. This allows one to exclude the 2HDM of type II with a confidence level of 99.8%. The preliminary comparison [10] of the measured $q^2 = (p_B - p_{D^{(*)}})^2$ distributions to the predictions for the $B \to D\tau\nu$ and $B \to D^*\tau\nu$ decays show an agreement with the standard model and with 2HDM models for lower values of $\tan\beta/m_{H^+}$. The combination of those results with the previous ones in [9] allows a strong constraint of the 2HDM of type III. But other more general charged Higgs models of new physics contributions with non-zero spin are also compatible with the *BABAR* measurements.

8. – Conclusion

Five years after the end of the data taking, the *BABAR* experiment is still releasing many new results. Three time-dependent studies are shown here: the direct observation of time reversal violation, which is expected from the standard model but is measured for the first time, a new measurement of CP violation in $B^0 \to D^{*+}D^{*-}$ decays, improving the previous *BABAR* accuracy in this channel by 20%, a new preliminary search for CP violation in the B^0_d mixing which is the most precise single measurement so far.

Also two new searches for new physics in the $B \to K^{(*)}\nu\bar{\nu}$ and $B \to \pi/\eta l^+l^-$ rare decays were presented. No significant signal is found and new upper limits and improvements of existing limits on the branching fractions are given.

Studies of $B \to D^{(*)}\tau\nu$ decays yield a 3.4 σ deviation from the standard model. Within the simplest models involving a charged Higgs boson, the 2HDM type-II model is excluded as the 2HDM type-III model is strongly contrained.

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