Recent Highlights from BaBar

S. Emery-Schrenk([1]),
On Behalf of the BaBar collaboration.

([1]) DSM/IRFU/SPP, CEA centre de Saclay, France.

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 $B \to D^{(*)}\tau\nu$.

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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. Equation 1

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

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

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

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 σ 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 σ 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.

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):

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

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]:

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

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]:

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

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 $B^0_d - \bar{B}^0_d$ mixing with partially reconstructed $B^0 \rightarrow D^* l \nu$ decays.

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

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

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 uses the partial reconstruction of one of the neutral mesons into $B^0 \rightarrow D^* l \nu$, 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.

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_ν^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 preliminary result for A_{CP}:

$$A_{CP} = [0.06 \pm 0.17(stat) \begin{array}{c} +0.36 \\ -0.32 \end{array} (syst)]\% \tag{8}$$

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 [4] 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: BF($B \to K\nu\bar{\nu}$)=(0.36 to 0.52)$\times 10^{-5}$ and BF($B \to K^*\nu\bar{\nu}$)=(0.68 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 [5] 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

TABLE II. – *Preliminary results on searches for $B \to K^{(*)}\nu\bar{\nu}$ decays [5].*

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

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 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.

TABLE III. – *Preliminary results on searches for invisible charmonium [5].*

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

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 [6], and the smallest upper limits from the B factories lie within an order of magnitude from the standard model predictions.

Searches are presented here [7] 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 [7]. 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: $BF(B^+ \to \pi^+\mu^+\mu^-) = (-0.6 \begin{array}{c}+4.4\\-3.2\end{array} \pm 0.9) \times 10^{-8}$ is much larger than the one from the LHCb measurement [6] $BF(B^+ \to \pi^+\mu^+\mu^-) =$

$(2.4 \pm 0.6 \pm 0.2) \times 10^{-8}$, 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[7].*

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

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

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:

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

The *BABAR* measurements show a 3.4 σ deviation from the standard model [8] 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 [8], 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 [9] 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 [8] 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_d^0 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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