PROCEEDINGS OF SCIENCE

Flavour Physics at the Intensity Frontier

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The paper discusses selected recent results from B factories, precision measurements of the unitarity triangle (final Belle measurement of $\sin 2\phi_1$, a new method to determine ϕ_3, exclusive and inclusive measurements of $|V_{ub}|$), reviews the studies of rare B decays, direct CP violation and searches for CPT violation, investigation of CP violation in D decays, studies of $\Upsilon(5S)$ decays, new resonances h_b and Z_b, and properties of the $X(3872)$ state. Finally, the paper reviews plans for the future related to super B factories, and gives a summary and an outlook.

The 2011 Europhysics Conference on High Energy Physics-HEP 2011,
July 21-27, 2011
Grenoble, Rhône-Alpes France

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PoS(EPS-HEP2011)027

1. Introduction

The two B factories, PEP-II with BaBar and KEKB with Belle, have been a real success story. They were built with the primary goal of measuring CP violation in the B system. From the discovery of large CP violation in 2001, the B factory results evolved into a precision measurement of the CP violation parameter $\sin 2\phi_1$ in $B \to (c\bar{c})K^0$ decays [1, 2, 3]. The constraints from measurements of angles and sides of the unitarity triangle show a remarkable agreement [4, 5], which contributed significantly to the 2008 Nobel prize awarded to Kobayashi and Maskawa. The two B factories also observed direct CP violation in B decays, measured many rare decay modes of B mesons, and observed mixing of D^0 mesons. They measured CP violation in $b \to s$ transitions, thus probing new sources of CP violation. The study of forward-backward asymmetry in $B \to K^* l^+ l^-$ has become a powerful tool in the search for physics beyond the Standard Model (SM). Both collaborations also searched for lepton flavor violating τ decays, and, last but not least, they observed a long list of new hadrons, some of which do not seem to fit into the standard meson and baryon schemes. All this was only possible because of the fantastic performance of the accelerators, much beyond their design values. In the KEKB case, the peak luminosity reached a world record value of $2.1 \cdot 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, exceeding the design value by a factor of more than two. The two collaborations have accumulated data samples corresponding to integrated luminosities of 557 fb^{-1} (BaBar) and 1041 fb^{-1} (Belle). While most of the data have been collected at the $\Upsilon(4S)$ resonance, just above the $B\bar{B}$ production threshold, the recorded data include sizable samples of $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ and $\Upsilon(5S)$ decays (in total 34 fb^{-1}, mostly at $\Upsilon(3S)$, at BaBar, and 150 fb^{-1}, mostly at $\Upsilon(5S)$ and $\Upsilon(2S)$, at Belle). Although the different constraints from measurements of angles and sides of the unitarity

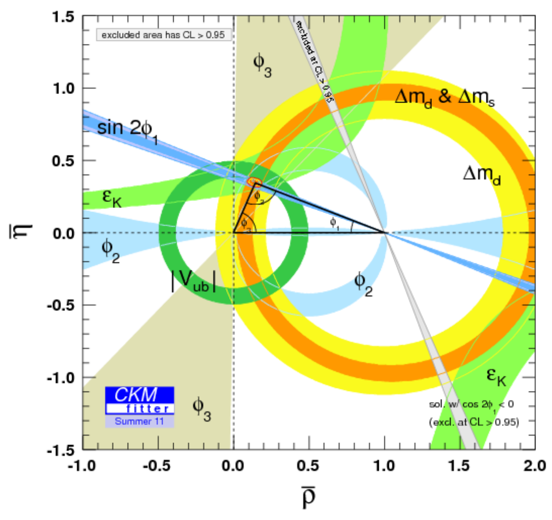

Figure 1: Present status of the unitarity triangle determinations from B decays (angles and $|V_{ub}|$), B_d and B_s mixing, and CP violation in K decays (ε_K) [4]. The constraints on the unitarity triangle include the final Belle measurement of $\sin 2\phi_1 (= \sin 2\beta)$ [6] as discussed in this paper.

triangle (Fig. 1) show a remarkable agreement, there is still room for effects of physics beyond SM at the level of 10-20%. This fact makes the field very interesting, and it is no wonder that at this conference there were 29 talks related to the topic of this review. In what follows we shall discuss some selected results on unitarity triangle precision measurements. We shall also review studies of rare B decays, direct CP violation and searches for CPT violation, search for CP violation in D decays, studies of $\Upsilon(5S)$ decays, new resonances h_b and Z_b, and properties of the $X(3872)$ state. Finally, we will conclude with plans for the future, related to super B factories, and give a summary and an outlook.

2. Precision measurements of the unitarity triangle

2.1 Final Belle measurement of $\sin 2\phi_1$

The most accurate determination of the angle $\phi_1(=\beta)$ of the unitarity triangle comes from measurements of the time dependent CP violation in the $B^0 \to (c\bar{c})K^0$ transition. The final measurement of this quantity by the Belle collaboration uses the full $\Upsilon(4S)$ data set corresponding to 710 fb^{-1}, with $(c\bar{c}) = J/\psi, \psi(2S), \chi_{c1}$, in total $\approx$ 25k events. The considerable increase in the number of reconstructed events is partly due to a larger data sample size, and partly due to an improved tracking algorithm. The preliminary Belle values of CP violation parameters are $S = 0.668 \pm 0.023 \pm 0.013$, $A = 0.007 \pm 0.016 \pm 0.013$ [6]; in SM, $\sin 2\phi_1$ is expected to be equal to S, and $A = 0$. We note that the determination of $\sin 2\phi_1$ is still statistically limited. We also note that the tension between $BR(B \to \tau\nu_\tau)$ and $\sin 2\phi_1$ at a $\approx 2.5\sigma$ level still remains [7].

The value of $\sin 2\phi_1$ can also be determined in $b \to c\bar{c}d$ transitions, e.g. in $B \to D^+D^-$ in decays, where again SM predicts $S \sim \sin 2\phi_1$ and $A \sim 0$. Belle presented a new measurement, based on 320 signal events [6]. The new values of $S = -1.06 \pm 0.18 \pm 0.07$, $A = +0.43 \pm 0.16 \pm 0.04$, are in agreement with the previous measurement by Belle on a smaller statistics sample, $S = -1.13 \pm 0.37 \pm 0.09$, $A = +0.91 \pm 0.23 \pm 0.06$ [8]; with more statistics the unexpectedly large A is now closer to the expected zero value. The same parameters can also be determined from CP violation in $B \to D^{*+}D^{*-}$ decays. The analysis is more complex in this case because of the two vector mesons in the final state, such that an additional angular analysis is required to resolve the CP odd and even components. On a sample of 1225 signal events, corresponding to a twofold increase in the yield with respect to the previous measurement, the following values were derived, $S = -0.79 \pm 0.13 \pm 0.03$, $A = +0.15 \pm 0.08 \pm 0.02$ [6]. These measurements are a clear evidence that in the decays of B mesons, CP violation is not a rare phenomenon, there are large effects in many transitions.

Belle reported an improved precision measurement of the CPT-violating parameter z and normalized total decay width difference $\Delta\Gamma_d/\Gamma_d$ in $B^0 \to J/\psi K^0$, $B \to D^{(*)}h\,(h = \pi, \rho)$ and $B^0 \to D^*\ell\nu$ decays using $535 \cdot 10^6$ $B\bar{B}$ pairs [6]. The study showed that $Re(z) = (+1.9 \pm 3.7 \pm 3.2) \cdot 10^{-2}$, $Im(z) = (-5.7 \pm 3.3 \pm 6.0) \cdot 10^{-3}$, i.e. they could not observe any CPT violation in B meson decays. Their new estimate for the normalized total decay width difference is $\Delta\Gamma_d/\Gamma_d = (-1.7 \pm 1.8 \pm 1.1) \cdot 10^{-2}$.

2.2 Measurements of $\phi_3(=\gamma)$

The best way to measure ϕ_3 is by using the so called Dalitz method [9], i.e. by a Dalitz analysis of $B \to DK$, $D \to K^0_S\pi^+\pi^-$ decays. The values of ϕ_3 as determined by Belle and BaBar (including $D \to K_S^0 K^+ K^-$ decays) are $\phi_3 = (78 \pm 12 \pm 4 \pm 9)^\circ$ [10] and $\phi_3 = (68 \pm 14 \pm 4 \pm 3)^\circ$ [11], respectively. In this method, a sizable part of the systematic uncertainty comes from the model dependent description of the decay amplitude for D decays (last error term); the parameters of the model are derived directly from $D^* \to D\pi$ decays in continuum data.

In a new approach, ϕ_3 is determined in a model-independent way by using a binned Dalitz method [12]. In this approach, the Dalitz space of the D meson decays is suitably subdivided into bins. The analysis of the Dalitz plot employs the strong phase differences between the bins as extracted from $D^0 \to K_S \pi^+ \pi^-$ decays at the charm threshold by the CLEO-c Collaboration [13]. The proof of principle for such an approach comes from a Belle study on the full data sample corresponding to 710 fb^{-1} [14]. By using only the DK final state and a signal sample of 1176 ± 43 events, the measured value of ϕ_3 is $\phi_3 = (77 \pm 15 \pm 4 \pm 4)^\circ$. The model error is now replaced with an error on the measured strong phases, which can be reduced in future by a larger BESIII data sample and by a possible charm threshold running at super B factories [14].

Another model independent method for measuring ϕ_3 relies on the ADS method [15]. In this case, ϕ_3 is determined by comparing the rates for $B^- \to [K^+\pi^-]_D K^-$ and $B^- \to [K^-\pi^+]_D K^-$ decays. The breakthrough for this method comes from Belle, where the rare decay channel $B^- \to [K^+\pi^-]_D K^-$, in total $N_{sig} = 56 \pm 15$ events on 710 fb^{-1} of data, was observed with a significance of 4.1σ [16]. Note that the same method can be used in other decay channels, e.g. $B \to D^0 K$, $D^0 \to K\pi\pi^0$ [17].

Combining all ϕ_3 measurements, we get $\phi_3 = (68^{+13}_{-14})^\circ$. While at the start of the B factories expectations for measuring this angle were not optimistic, the above results have proven the opposite. Clearly, this is not the last word from B factories, several analyses still have to be finalized.

2.3 Exclusive and inclusive measurements of $|V_{ub}|$

For the exclusive determination of $|V_{ub}|$, the decay $B^0 \to \pi^- \ell^+ \nu$ is being analyzed. There are three recent measurements of the branching fraction for this decay, two from BaBar, $BR = (1.41 \pm 0.05 \pm 0.07) \cdot 10^{-4}$ and $(1.42 \pm 0.05 \pm 0.07) \cdot 10^{-4}$, and one from Belle with $BR = (1.49 \pm 0.04 \pm 0.07) \cdot 10^{-4}$ [18]. The value of $|V_{ub}|$ is extracted from the data by fitting simultaneously the measured branching fraction and the data provided from lattice calculations [19] as a function of the invariant mass squared of the lepton pair (q^2). BaBar data yield a value of $|V_{ub}| = (3.13 \pm 0.12 \pm 0.28) \cdot 10^{-3}$, Belle data result in $|V_{ub}| = (3.43 \pm 0.33) \cdot 10^{-3}$, and a simultaneous fit of both gives $|V_{ub}| = (3.26 \pm 0.30) \cdot 10^{-3}$ [20, 21].

Recent inclusive measurements of $|V_{ub}|$ all rely on using samples with fully reconstructed B mesons as tags. A new study presented by BaBar yielded $|V_{ub}| = (4.31 \pm 0.25 \pm 0.16) \cdot 10^{-3}$. The tension between values of $|V_{ub}|$ as determined in inclusive and exclusive decays therefore remains.

In a search for missing exclusive modes in semileptonic B decays, the branching fractions for $B \to D_s^{(*)} K \ell \nu$ decays were measured by Belle [20]. By fitting separately for $B \to D_s^* K \ell \nu$ and $B \to D_s K \ell \nu$ decays, the two contributions could be disentangled for the first time, and have been established with a combined 6σ significance. The two branching fractions are $BR(B \to D_s K \ell \nu) = (3.0 \pm 1.2^{+1.1}_{-0.8}) \cdot 10^{-4}$ and $BR(B \to D_s^* K \ell \nu) = (2.9 \pm 1.6^{+1.1}_{-1.0}) \cdot 10^{-4}$.

3. Rare B decays

3.1 Direct CP violation in $B \to hh$ decays

Belle updated their result on the so called $K\pi$ puzzle, an unexpected difference in the extent of direct CP violation between $B^0 \to K^+\pi^-$ and $B^+ \to K^+\pi^0$ decays as originally observed in 2007 [22]. With the full data set and an improved reconstruction, corresponding to a twofold increase in the signal yield, they measure $A_{CP}(K^\pm\pi^0) = +0.043 \pm 0.024 \pm 0.002$ and $A_{CP}(K^\pm\pi^\mp) = -0.069 \pm 0.014 \pm 0.007$. This gives $\Delta A_{K\pi} = A_{CP}(K^\pm\pi^0) - A_{CP}(K^\pm\pi^\mp) = +0.112 \pm 0.028$ with a 4σ significance [23].

Belle has also measured direct CP violation in $B \to \eta K^+$ and $\eta\pi^+$ decays. The value of A_{CP} for the decay channel $B \to \eta K^+$ as obtained on the full sample is $A_{CP} = -0.38 \pm 0.10 \pm 0.01$, which differs from 0 with a 3.8σ significance [23]. This result is in good agreement with previous Belle and BaBar measurements. The CP asymmetry for the $\eta\pi^+$ decay channel is $A_{CP} = -0.19 \pm 0.06 \pm 0.01$ (3.0σ significance). We note that there still remains a tension between Belle and BaBar measurements ($A_{CP} = -0.03 \pm 0.09 \pm 0.03$ [24]).

In all the measurements discussed in this section, Belle and BaBar made use of an essential feature of detectors at B factories, i.e., their capability to detect neutral particles.

3.2 $B \to D^{(*)}\tau\nu_\tau$ decays

Examples of particularly challenging measurements which are only possible at a B factory are the studies of B meson decays with more than one neutrino in the final state. Such processes are the decays $B \to \tau\nu_\tau$ and $B \to D\tau\nu_\tau$, which are followed by the decay of the τ lepton with one or two additional neutrinos in the final state. In the SM, this transition proceeds via W bosons, but in some new physics (NP) extensions they could also be mediated by a charged Higgs boson [25, 26, 27]. The measured branching fraction can therefore be used to set limits on two parameters, the charged Higgs mass $M_{H^\pm}$ and the ratio of vacuum expectation values, $\tan\beta$.

Such rare processes are searched for in the following way [28]. First, one of the B mesons is fully reconstructed in a number of exclusive hadronic decay channels like $B \to D^{(*)}\pi$. Because of the exclusive associated production of B meson pairs in a B factory, the remaining particles in the event must be the decay products of the associated B. In this measurement we greatly profit from the excellent hermeticity of the detectors at B factories. It is worth noting that while LHC experiments are sensitive to the $H-b-t$ coupling, in $B \to \tau\nu_\tau$ and $B \to D\tau\nu_\tau$ we probe the $H-b-u$ and $H-b-c$ couplings.

Compared to the measurement of $B \to \tau\nu_\tau$ decays, the decay channels $B \to D^{(*)}\tau\nu_\tau$ have several advantages; in addition to a larger branching fraction [29, 30], the differential distributions can be used to discriminate the contributions of W^+ and $H^\pm$. Another advantage of this decay channel is that the ratio $R(D) = BR(B \to D\tau\nu)/BR(B \to D\ell\nu)$ has a smaller theoretical uncertainty than $BR(B \to \tau\nu)$. The decay $B \to D^*\tau\nu$ was first observed by Belle in 2007 [29]. At this conference, BaBar presented a 5σ observation of $B \to D\tau\nu$ decays [21]. The measured branching fractions $(1.73 \pm 0.17 \pm 0.18)\%$ ($D^{*0}\tau^+\nu$), $(1.82 \pm 0.19 \pm 0.17)\%$ ($D^{*-}\tau^+\nu$), $(0.96 \pm 0.17 \pm 0.14)\%$ ($D^0\tau^+\nu$), $(1.08 \pm 0.19 \pm 0.15)\%$ ($D^-\tau^+\nu$), are all exceeding the SM predictions, as illustrated in Fig. 2. From a comparison of their combined value of $R(D)$ to the theoretical prediction as a func-

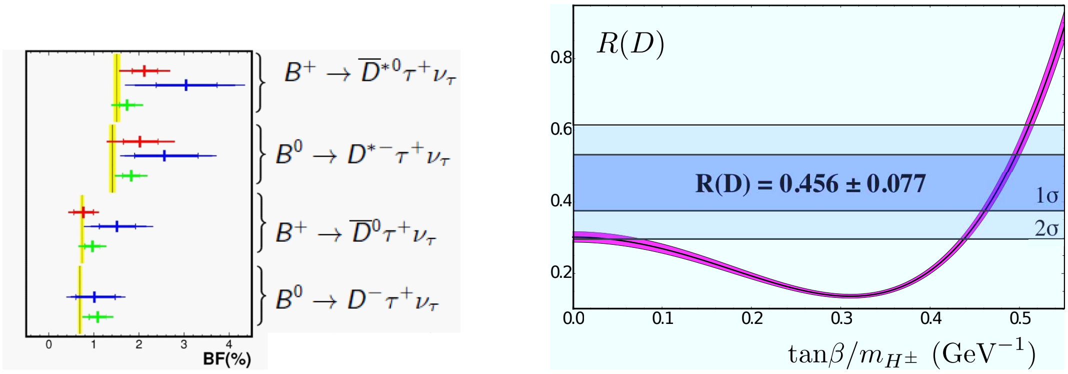

Figure 2: $B \to D\tau\nu_\tau$ decays, left: comparison of Belle inclusive (red) and exclusive (blue) and BaBar exclusive (green) branching fraction measurements with the SM predictions (yellow); right: BaBar combined $R(D)$ [21] compared to the theoretical prediction as a function of the ratio $\tan\beta/M_{H^\pm}$ [27].

tion of the ratio $\tan\beta/M_{H^\pm}$ [27], an interesting limit on the charged Higgs mass and $\tan\beta$ can be derived (Fig. 2).

A similar experimental technique has been applied by Belle in a search for $B \to \nu\bar{\nu}$ decays. This decay is, similarly to $B \to \mu^+\mu^-$, a very sensitive channel in searches for new physics. Because of a strong helicity suppression, any signal would be a sign of new physics. By using the measured remaining energy in the calorimeter and angular distribution as the fit variables, an upper limit of $BR < 2.2 \cdot 10^{-4}$ at 90% C.L. could be derived [20].

4. Charm and τ physics

B factories are also charm and τ factories, even more so because charm and τ decays from $e^+e^- \to c\bar{c}$ and $e^+e^- \to \tau^+\tau^-$ transitions represent a substantial part of the samples recorded in the energy region of any of the $\Upsilon(nS)$ resonances. As a result, the integrated luminosity of the samples used for charm and τ studies is larger than for the B physics studies (1041 fb^{-1} for Belle, 550 fb^{-1} for Babar). The charm and τ results presented at this conference were mainly related to CP violation searches and rare decays. Note that searches for lepton flavour violation in τ decays are the subject of a separate review talk [31].

CP violation is expected to be very small in D decays, with decay rate asymmetries A_{CP} of O(0.1%) in SM. This makes it a good place to look for New Physics which could enhance it up to O(1%).

Belle recently searched for CP violation in $D^+_{(s)} \to \phi\pi^+$ decays [32]. To eliminate any contribution of the apparatus to the observed asymmetry, they measured the difference of asymmetries A_{rec} for $D^+ \to \phi\pi^+$ and $D^+_s \to \phi\pi^+$ decays. The asymmetry was determined in bins of $\cos\vartheta^*$, p_π and $\cos\vartheta_\pi$, $\Delta A_{rec}(\cos\vartheta^*, p_\pi, \cos\vartheta_\pi) = \Delta A_{CP} + \Delta A_{FB}(cos\vartheta^*)$. Since the forward-backward asymmetry $A_{FB}(cos\vartheta^*)$ is odd in $\cos\vartheta^*$, this term can also be eliminated by summing up opposite bins in $\cos\vartheta^*$. Finally, since no CP violation is expected in the Cabbibo favoured decay $D^+_s \to \phi\pi^+$, the study yields $A_{CP}(D^+ \to \phi\pi^+) = (+0.51 \pm 0.28 \pm 0.05)\%$. Including measurements in other

D meson decays [33], B factories are constraining possible CP asymmetries in charm sector with sensitivities approaching O(10^{-3}) level.

BaBar searched for CP violation in D decays by studying T-odd correlations in $D^+ \to K_S h^+ h^- h^+$ decays. In this study, effects of final state interactions were eliminated by measuring the difference $A_T(D^+) - A_T(D^-)$. The result is consistent with no CP asymmetry [34]. They also searched for rare D decays, and derived a 90%C.L. upper limit of $BR(D \to \gamma\gamma) < 2.4 \cdot 10^{-6}$, corresponding to a ten times improvement with respect to the PDG value [35], considerably constraining new physics estimates [36].

5. Physics at $\Upsilon(5S)$

For studies of B_s decays, Belle uses their 121 fb^{-1} of data, recorded at the $\Upsilon(5S)$ resonance. The first 21 fb^{-1} of data were used to measure branching fractions of $B_s \to D_s^{(*)}\pi, D_s^{(*)}\rho, D_s^{(*)}D_s^{(*)}$ decays, and to determine the B_s and B_s^* masses in the world's best measurement. The final sample of 121 fb^{-1} of $\Upsilon(5S)$ data contains a clean sample of 15 million B_s decays.

This sample was used for several interesting studies. For the first time a baryonic B_s transition could be observed in the decay to the $\Lambda_c\Lambda\pi$ final state. This sample is also very useful for studies of CP eigenstates. In addition to observing the $B_s \to J/\psi f_0$ decay, Belle saw the first evidence for the $B_s \to J/\psi f_0(1370)$ decay [37]. We note that these studies are complementary to B_s studies at hadron machines [38] because of neutral and neutrino detection capabilities. Several channels of this type are currently under study, including B_s decays to $J/\psi\eta$ and $J/\psi\eta'$. It is interesting that Belle could also measure $\sin 2\phi_1$ in $\Upsilon(5S) \to BB\pi$ decays [37].

One of the puzzles of $\Upsilon(5S)$ decays is due to the fact that the transitions $\Upsilon(5S) \to \Upsilon(nS)\pi^+\pi^-$, where $n = 1,2,3$, are by two orders of magnitude more probable than $\Upsilon(2S)$, $\Upsilon(3S)$ and $\Upsilon(4S)$ decays to $\Upsilon(1S)\pi^+\pi^-$ [39]. Belle also carried out a dedicated energy scan, and observed that the shape of R_b, the B hadron production cross section ratio, differs (at a 2σ level) from the energy dependence of the cross section for $\Upsilon(1S)\pi^+\pi^-$ production [40]. Clearly, $\Upsilon(5S)$ is very interesting and not yet understood.

6. Spectroscopy of charmonium and bottomonium like states

6.1 Observation of $h_b(nP)$ and resonant substructures in $\Upsilon(5S) \to h_b(nP)\pi^+\pi^-$ decays

The state $h_b(nP)$ is a bottomonium with $S = 0, L = 1, J^{PC} = 1^{+-}$. The first evidence for this state comes from an analysis of $\Upsilon(3S) \to \pi^0 h_b(1P) \to \pi^0\gamma\eta_b(1S)$ decays [41] by the BaBar Collaboration. Belle performed an inclusive search for the signal in the $\Upsilon(5S) \to h_b(nP)\pi^+\pi^-$ transition, by studying the recoil mass of the two charged pions. The significance of the signal of the $h_b(1P)$ and $h_b(2P)$ states - including the systematic uncertainties - amounts to 5.5σ and 11.2σ, respectively [42, 43]. The measurements of relative branching ratios of $\Upsilon(5S) \to h_b(nP)\pi^+\pi^-$ and $\Upsilon(5S) \to \Upsilon(2S)\pi^+\pi^-$ decays show that h_b production is not suppressed if compared to $\Upsilon(2S)$ production in spite of the spin flip in the former, indicating an exotic mechanism of production.

By measuring the $\Upsilon(5S) \to h_b(nP)\pi^+\pi^-$ yield in bins of the mass recoiling against π^- (corresponding to the invariant mass of $h_b(nP)\pi^+$), two more states, $Z_b^+(10610)$ and $Z_b^+(10650)$, decaying into $h_b(nP)\pi^+$, were observed with $M = 10608.1 \pm 1.7$ MeV, $\Gamma = 15.5 \pm 2.4$ MeV, and $M = 10653.3 \pm 1.5$ MeV, $\Gamma = 14.0 \pm 2.8$ MeV, respectively. These resonances were observed in five different final states, including $\Upsilon(5S) \to \Upsilon(1S)\pi^+\pi^-$, $\Upsilon(5S) \to \Upsilon(2S)\pi^+\pi^-$, and $\Upsilon(5S) \to \Upsilon(3S)\pi^+\pi^-$ transitions [43]. Masses and widths are consistent in all decay channels.

A $J^P = 1^+$ spin-parity assignment is in agreement with the data; other values of J^P are disfavored. The nature of Z_b^+ remains a mystery, it is not clear whether this is a molecule, tetraquark or cusp, to name just a few of them.

6.2 Properties of $X(3872)$

The $X(3872)$ state was first observed by Belle in 2003 in $B \to KX$, $X \to J/\psi\pi^+\pi^-$ transitions [44]. Its mass is close to the $D^0 + D^{*0}$ production threshold, and its width is less than the experimental resolution. While the existence of the state was confirmed by BaBar, CDF, D0, LHCb and CMS, its nature is still not understood.

From the new results obtained from the full Belle data sample, the following conclusions could be made [45, 46]. By using the decay channel $X \to J/\psi\pi^+\pi^-$, Belle determined the mass difference of X produced in $B^0 \to K^0X$ and $B^+ \to K^+X$ decays, $\Delta M = (-0.71 \pm 0.96 \pm 0.19)$ MeV; from this they conclude that X is the same particle in both reactions. From the angular distributions of particles in the final state they conclude that J^{PC} of X is consistent with both the 1^{++} and 2^{-+} hypotheses.

From the study of radiative decays of $X(3872)$, the following limit could be derived $BR(X \to \gamma\psi(2S)/BR(X \to \gamma J/\psi) < 2.1$ at 90% CL [47]. Note that in the molecular model of X, the radiative $X \to \gamma\psi(2S)$ transition is highly suppressed compared to $X \to \gamma J/\psi$.

7. Outlook: Super B factories

While B factories were built to check whether the Standard Model with the CKM matrix is correct, the next generation of B factories (super B factories) will search for new physics effects. For studies of deviations from the SM predictions, a ≈ 50 times larger data sample of decays of B and D mesons and τ leptons is needed, corresponding to an integrated luminosity of 50-75 ab^{-1}. A substantial upgrade is therefore required, both of the accelerator complex as well as of the detector [48]. Note, however, that it will be a different world in four years, when the first super B factory starts to operate; there will be many new results also in the field of flavor physics from the LHCb and BESIII experiments. Still, e^+e^- colliders operating at (or near) the $\Upsilon(4S)$ resonance will have considerable advantages in several classes of measurements, e.g., with final states involving neutral particles (γ, π^0) and neutrinos, and will be complementary in many more.

Two recent publications summarize the physics potential of a super B factory [49, 50]. To summarize, there is a good chance to see new phenomena, such as CP violation in B decays from new physics sources, or lepton flavor violation in τ decays [51]. The Super B factory results will help to diagnose or constrain new physics models. The $B \to \tau\bar{\nu}_\tau$ and $B \to D^{(*)}\tau\nu_\tau$ decays can probe the charged Higgs contribution in the large $\tan\beta$ region. The physics motivation for a super B factory is independent of LHC. If LHC experiments find new physics phenomena, precision flavour physics is compulsory to understand their nature; if no new physics is found at LHC, high statistics B and τ decays would be a unique way to search for new physics above the TeV scale (or at the TeV scale in case of the minimal flavour violation scenario). Needless to say that there are many more topics to explore, including CP violation searches for charmed hadrons, searches for new hadrons etc.

There are two super B factory projects under way. The first one, SuperKEKB, foresees a substantial redesign of elements of the existing KEKB accelerator complex while retaining the same tunnel and related infrastructure. After 11 years of successful operation, the last KEKB beam was ceremonially aborted on June 30, 2010. This opened the way for the construction of SuperKEKB. To increase the luminosity by a factor of 40, the plan is to modestly increase the current (by a factor of 2) with respect to the KEKB values, and dramatically shrink the beam size at the collision point, while the beam-beam parameter is kept at the KEKB value. In this 'nano-beam' scheme which was invented by P. Raimondi for the Italian super B factory [52], the beams collide at a rather large angle of 83 mrad (compared to 22 mrad in KEKB). In addition, a lower beam asymmetry of 7 GeV and 4 GeV instead of 8 GeV and 3.5 GeV is needed to reduce the beam losses due to Touschek scattering in the lower energy beam. The modifications of the KEKB complex include: improvements in electron injection, a new positron target and damping ring, redesign of the lattices of the low energy and high energy rings, replacing short dipoles with longer ones (in the low energy ring), installing TiN-coated beam pipe with ante-chambers, modifications of the RF system, and a completely redesigned interaction region [53].

Another approach to the design of a super B factory will be exploited in the Italian SuperB project [54]. There it is foreseen that a new tunnel will be built at the Tor Vergata University campus close to Frascati. Parts of the beam elements of PEP-II will be reused in the accelerator construction. In addition to the nano-beam scheme, an essential feature of the SuperB accelerator is the crab waist collision of two beams in which special sextupoles will be used close to the interaction region to maximize the overlap of the two beams. This scheme was successfully tested at the DAΦNE ring [55]. The SuperB accelerator is designed in such a way that it can be modified to run at the $\psi(3770)$ resonance close to the charm threshold, where pairs of D^0 mesons are produced in a coherent $L = 1$ state. Data accumulated at charm threshold would allow precision charm mixing, CP violation and CPT violation studies. Another feature of the SuperB accelerator will be the polarization of the low energy (electron) beam. This could improve the sensitivity to lepton flavour violating τ decays and CP violation in τ decays [50]; it would also enable a precise $\sin^2\Theta_W$ measurement.

The substantial increase in luminosity requires a careful design of the detectors. To maintain the excellent performance of the B factory spectrometers, the critical issues will be to mitigate the effects of higher backgrounds (by a factor of 10 to 20), leading to an increase in occupancy and radiation damage, as well as fake hits and pile-up noise in the electromagnetic calorimeter. Higher event rates will require substantial modifications in the trigger scheme, DAQ and computing relative to the current experiments. In addition, improved hadron identification is needed, and similarly good (or better) hermeticity is required [53].

The SuperKEKB/Belle-II project has received initial construction funding in 2010 for the positron damping ring, and with the Japanese 'Very Advanced Research Support Program' a sizable fraction of funds for the main ring upgrade (exceeding 100 MUSD) for the period 2010-2012. KEK and collaborating institutions also managed to secure additional funds to complete the construction as scheduled, i.e., start the SuperKEKB commissioning in the autumn of 2014, and start data taking in 2015. It is expected that by 2017 the first 5 ab^{-1} of data will be collected, and the full data sample of 50 ab^{-1} will be reached in 2020/2021.

The SuperB project is the first in the list of 'flagship projects' of the new Italian national research plan over the next few years. The Italian government has delivered an initial funding for 2010 and as a part of a multi-annual funding program. The aim of the project is to accumulate 75 ab^{-1} on a time scale similar to SuperKEKB/Belle-II.

8. Summary

B factories have proven to be an excellent tool for flavour physics, with reliable long term operation, constant improvement of operation, achieving and surpassing design performance. At this conference several important new results were presented. With the full Belle data sample $\sin 2\phi_1$ was measured with a 4% error. A model-independent determination of ϕ_3 (important for future studies at LHCb) was developed and successfully tested. New BaBar results on $B \to D^{(*)}\tau\nu$ decays are all above Standard Model predictions. Analyses using hadronic tag at Belle have been considerably improved due to a twofold increase in the reconstruction efficiency, with important consequences for the near-future studies of $B \to D^{(*)}\tau\nu_\tau$, $B \to \tau\nu_\tau$, $B \to K\nu\bar{\nu}$, and exclusive $b \to u$ transitions. Several interesting phenomena could be observed in $\Upsilon(5S)$ decays.

Note that many measurements are currently being updated with the final data sets, such that we can soon expect results on $b \to s\gamma, d\gamma$ by BaBar, and from Belle the final measurement of ϕ_2 in $B \to \pi^+\pi^-$, $B \to a_1\pi$, $B \to \pi^0\pi^0$, and $B \to \rho^0\rho^0$ decays. The two experiments will concentrate on measurements that use the unique capabilities of B factories.

A major upgrade has started at KEK to construct the SuperKEKB accelerator and the Belle-II detector, and be ready for data taking by 2015. The SuperB project in Italy foresees building a new tunnel, reusing and upgrading the PEP-II accelerator and the BaBar detector. Its special features are a polarized electron beam and the ability to operate at the charm threshold. Analysis of the physics reach suggests that we can expect a new and exciting era of discoveries, complementary to the LHC.

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