Disturbing the Universe - Summary of BEACH 2008

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Results and perspectives in heavy flavour physics research, presented at the 2008 edition of the International Conference on Beauty, Charm and Hyperons held in Columbia (SC, USA), are briefly reviewed.

1. Introduction

It is a hard job to summarize the many valuable contributions presented at BEACH2008, the 8th edition of the International Conference on Beauty, Charm and Hyperons in Hadronic Interactions. I apologize in advance for omitting some of them for reason of space.

A lot of interesting results have been shown, clearly demonstrating that heavy flavour physics is a very active and appealing field of study and research.

Great progresses in different areas of flavour physics have been attained over the past years. The success of the Cabibbo-Kobayashi-Maskawa (CKM) model of quark mixing and CP violation is an impressive confirmation of the Standard Model (SM) and one of the most important achievement in particle physics. However, despite the robustness of the SM, well describing a huge amount of phenomena, many fundamental questions are still unanswered.

The observation of neutrinos oscillations clearly established the existence of new flavour mixing structures, beyond the SM, needed to accommodate neutrinos masses, which could cause sizeable non-standard effects in quarks and charged- lepton rare decays. On the other hand, the search for deviations from the SM in the quark flavour sector and in the

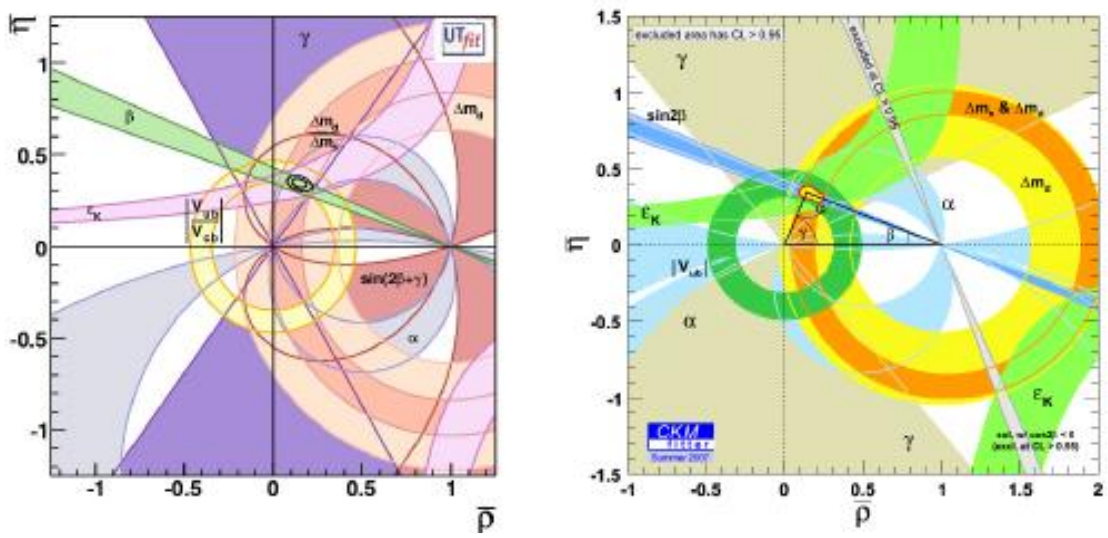

Figure 1. Global CKM fit from, respectively, the UTfit [1] and CKMfitter [2]collaborations

electroweak precision tests has been, up to now, quite frustrating. In fact, the huge amount of experimental data available from the B-Factories, Tevatron, HERA and from the fixed target experiments are in good agreement with the SM.
Two groups, the UTfit [1] and the CKMfitter collaborations [2], currently perform global CKM and Unitarity Triangle (UT) fits, using different methods. The global fits to the CKM quark mixing parameters are in good agreement, as shown in Fig. 1. Those measurements have achieved an accuracy of few percent, without revealing any significant deviation from the SM. This is an impressive proof of the validity of the CKM description of flavour and CP violation within the SM.
Now, after many confirmations, the issue turns into improving the level of precision in probing flavour, both experimentally and theoretically, and looking for small deviations from the SM predictions, in order to see the nature of new physics beyond it.

A crucial role in the interpretation of experiments is played by Quantum Chromodynamics (QCD), the well established theory of strong interactions and building block of the SM. The main issue, here, is hadronic uncertainty in the theoretical predictions, i.e. the improvement of calculations in order to overcome QCD and get to fundamental physics.
Inputs from measurements are essential to reduce hadronic uncertainty. QCD provides the framework for the computation of hard processes through non-perturbative methods and perturbative calculations. The perturbative approach, based on asymptotic freedom, successfully describes hard processes, still giving the main quantitative connection with the experiments. Great achievements in the interpretation of experimental data have been obtained over the last years by theorists calculating effects at the next-to-next-to-leading-order (NNLO) Predictions from non-perturbative QCD are based on a combination of lattice simulations and effective models in specific domains, e.g. Non Relativistic QCD, Chiral Perturbation Theory, Soft Collinear Effective Theories, etc.
Additional flavoured particles or new interactions are added to the known ones in most models of new physics. Two accidental features of the SM are crucial in this respect: the absence, at tree level, of CP violation and the suppression of tree-level Flavour-Changing Neutral Currents (FCNC). This allows for additional contributions to low-energy flavour transitions and make flavour physics very sensitive to the presence of new effects beyond SM.

According to the CKM mechanisms, the measured strength of FCNC transition scale, in term of the Cabibbo angle λ, as $\sim\lambda^2$ ($|V^\dagger_{tb}V_{ts}|$) for the transition $b\to s$, as $\sim\lambda^3$ ($|V^\dagger_{tb}V_{td}|$) for $b\to d$ and as $\sim\lambda^5$ ($|V^\dagger_{ts}V_{td}|$) for $s\to d$. It is, therefore, important to collect as much information as possible on the above processes to check if the useful FCNC observables, listed in Table 1 [3], are consistent with each other, within errors. Many data are already available on FCNC and on CP violating contributions to K and B meson decays, without clear signatures of deviations from SM (see Fig. 1), thus giving strong constraints on the proposed models of new physics [4]. A deep insight in heavy flavour physics data offers, therefore, a unique opportunity to investigate the SM and to provide significant constraints on new physics beyond it.

FLAVOUR COUPLINGS
(→ decreasing SM contribution →)

ELECTROWEAK STRUCTURE (← decreasing SM contribution ←)

FCNC	$b\to s\ (\sim\lambda^2)$	$b\to d\ (\sim\lambda^3)$	$s\to d\ (\sim\lambda^5)$
$\Delta F=2$	ΔM_{Bs} $A_{CP}(B_s\to\psi\phi)$	ΔM_{Bs} $A_{CP}(B_d\to\psi K)$	$\Delta M_K, \varepsilon_K$
$\Delta F=1$ 4-quark	$B_d\to\phi K,\ \pi K,\ldots$	$B_d\to\pi\pi,\ \rho\pi,\ldots$	$\varepsilon'/\varepsilon,\ K\to\pi\pi\pi,\ldots$
gluon penguin	$B_d\to X_s\gamma$, $B_d\to\phi K,\ \pi K,\ldots$	$B_d\to X_d\gamma,\ \pi\pi,\ \ldots$	ε'/ε, $K_L\to\pi^0\ell^+\ell^-,\ldots$
γ penguin	$B_d\to X_s\gamma,\ X_s\ell^+\ell^-$, $B_d\to\phi K,\ \pi K,\ldots$	$B_d\to X_d\ell^+\ell^-$, $B_d\to X_d\gamma,\ \pi\pi,\ \ldots$	ε'/ε, $K_L\to\pi^0\ell^+\ell^-,\ldots$
Z^0 penguin	$B_d\to X_s\ell^+\ell^-$, $B_s\to\mu^+\mu^-$, $B_d\to\phi K,\ \pi K,\ldots$	$B_d\to X_d\ell^+\ell^-$, $B_d\to\mu^+\mu^-$, $B_d\to\pi\pi,\ \ldots$	ε'/ε, $K\to\pi\nu\bar{\nu},\ \ldots$ $K_L\to\pi^0\ell^+\ell^-,\mu^+\mu^-$
H^0 penguin	$B_s\to\mu^+\mu^-$	$B_d\to\mu^+\mu^-$	$K_L\to\pi^0\ell^+\ell^-$, $K_L\to\mu^+\mu^-$

Table 1: FCNC observables [3]

Discrepancies between the SM expectations and the measurement of some flavour observables, which could possibly indicate the presence of new physics, have been reported in several talks at this conference. The puzzling patterns include $B^0-\bar{B}^0$ mixing and the B^0_S mixing phase [5], the CKM angle $\sin(2\beta)$ [6], the decay constant f_{Ds} [5], the CP violating asymmetries in $B\to K\pi$ decays [7][8]. However, further work is needed to improve the calculations given as inputs to the analyses, in order to settle the origin of the disagreements and fully exploit the potential of the CKM observables in constraining new physics.

2. Theory: an overview of results

The status of lattice QCD calculations of D and B mesons decay constants and semileptonic decay form factors, needed to extract the CKM matrix elements, as well as the simulation of $B^0 - \bar{B}^0$ mixing parameters were reviewed [5].
The decays of heavy mesons into leptons involve both weak and strong interactions. The weak interaction is described by the annihilation of the quark antiquark pair via the intermediate vector $W^{\pm}$ bosons and are related to the relevant CKM matrix element. The strong interactions are given by gluon exchanges between quark and anti-quark in the meson, parameterized in terms of the decay constant. The interplay between theory and experiment is different for each particle. The QCD determination of pseudoscalar decay constants, together with the experimental measurements of pseudoscalar leptonic decay widths, can be used to extract CKM matrix elements involved in the process. However, theoretical predictions that are necessary in the B sector can be successfully tested, for example, in the charm sector, being, in this case, the decay constants well determined experimentally [9] and the related CKM matrix elements known with good precision.
While the lattice calculation of the decay constant f_{D+} agrees very well with experiments, the same technique gives smaller values than the measured ones in the case of f_{Ds} [5]. More work is needed to fully understand this disagreement, known as "f_{Ds} puzzle", which could point out to new physics effects. Lattice results for the decay constants in the B sector are also useful, since the CKM matrix elements used to extract information from the experiments are less known than in the D case.
Effects due to physics beyond SM could appear in the $\bar{B}^0_q$–B^0_q system. In the SM, $\bar{B}^0_q$–B^0_q mixing is due to box diagrams with the exchange of W bosons. New physics effects could enter through new contributions at tree level or through the exchange of new particles in box diagrams. A disagreement between the direct experimental measurement of the phase of the B^0_s mixing amplitude and the SM prediction has been recently claimed [10]. Work is in progress on the lattice simulation of the $\bar{B}^0_q$–B^0_q mixing [5], which includes the determination of B^0_s and B^0_d mixing parameters and of the ratio ξ of the corresponding lattice matrix elements and decay constants, an important ingredient in the UT analyses. The error on the lattice parameter ξ is significantly smaller than that on the individual matrix elements, due to cancellations in the ratio. A final uncertainty of 2–3% is expected on ξ, hopefully useful to disentangle the presence of possible effects due to new physics.

CP violation in $b \to s$ penguin modes is an interesting probe of physics beyond SM. To first approximation in the SM, the time dependent CP asymmetries of $B \to \phi K_S$ ($b \to \bar{s}ss$) and $B \to J/\psi K_S$ ($b \to \bar{c}cs$) verify:

$$a_{CP}(B \to J/\psi K_S) = a_{CP}(B \to \phi K_S) = \sin 2\beta \, .$$

A difference in the experimental values of these observables could account for the presence of effects due to new physics. The status of the measurements can be seen in Fig. 2, showing the comparison among the average experimental values of the indirect measurements of $\sin(2\beta) \equiv \sin(2\phi_1)$ in B decays dominated by $b \to \bar{q}qs$ penguin modes [11].

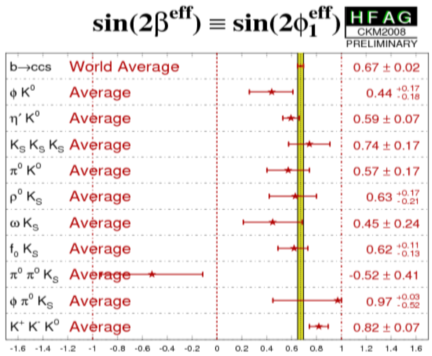

Figure 2: Indirect measurements of $\sin 2\beta \equiv (\sin 2\phi_1)$ [11]

During the recent years, Belle results for $(\sin 2\beta)_{\phi Ks}$ have moved towards the SM reference value of $(\sin 2\beta)_{J/\psi Ks}$, and now they are, within the errors, in agreement with the BaBar findings. In addition, the mixing-induced CP asymmetries of other $b \to s$ penguin modes show central values that are smaller than the SM prediction. This feature may be due to the presence of new physics contributions to the corresponding decay amplitudes. An additional CP violating phase in the $b \to \bar{s}ss$ amplitude, extending the CKM mechanisms beyond the SM, could account for the disagreement [6]. However, the large uncertainties do not yet allow to draw definite conclusions.

Improvements have been achieved on QCD lattice calculations of hyperon spectroscopy, axial coupling constants, electric charge radii, magnetic moments and semileptonic decay form factors [12]. The results presented at this conference demonstrate a clear progress toward the determination of the hyperon spectrum, structure and decays from first principles. Hyperons are an ideal system to study SU(3) flavour symmetry breaking by replacing up or down quarks in nucleons by strange ones. In addition, their semileptonic decays allow a further independent measurement of the CKM matrix element V_{us} and a unique opportunity to understand baryon structure and decay mechanisms. The successful development of lattice QCD in the simulation of the nucleon accounts for its reliability in predicting the properties of hyperons, which, however, are not well determined as the nucleon ones, due to their weak decays.

A method to calculate form factors in the framework of the Anti De Sitter–Conformal Field Theory correspondence has been presented, mainly focusing on vector, axial, and pseudoscalar mesons [13]. That correspondence establishes an unexpected link between gauge theories, like QCD, and gravitational theories that may be used to carry out precision calculations in gauge theories. Recently, methods inspired by the AdS/CFT correspondence have had surprising success in addressing both qualitative and quantitative aspects of non-perturbative QCD physics. Results on meson form factors, both electromagnetic and gravitational, have also been discussed.

Recent developments in the interpretation of heavy-quarkonium phenomenology within the Non Relativistic QCD (NRQCD) factorization approach have been described [14], focused on three topics:

a. the disagreement between data and predictions of the polarization of prompt J/Ψ produced at high p_T at the Fermilab Tevatron, not yet understood, which requires more accurate determinations of NRQCD matrix elements for the quarkonium production;
b. the discrepancy between the leading order predictions and the measurements of the cross sections for the exclusive production of double-charmonium $e^+e^- \rightarrow J/\Psi + \eta_C$ at the B-Factories, very recently resolved thanks to the use of a new resummation method for the relativistic corrections, in combination with large QCD corrections;
c. the analysis of new inclusive charm production data in bottomonium decays recorded by CLEO, still in progress, which will improve the knowledge of NRQCD matrix elements for heavy-quarkonium decays into hadrons.

A new class of SM interactions, emerging at low energy in connection with the SM anomalous baryon currents, has been presented [15]. The axial vector anomaly plays a fundamental role in the structure of the SM and describes many physical processes involving electromagnetic, weak and baryon currents, among which neutrino-photon interactions, parity violation, etc. Anomaly mediated interactions between photons and neutrinos may play an important role in neutrino experiments and astrophysical processes, and should be observed at present and/or at near-future experiments.

Theoretical predictions for the masses of baryons containing the b quark, as well as an effective supersymmetry between heavy quark baryons and mesons have been developed in the framework of the Constituent Quark Model. This is a low energy phenomenological model, still awaiting a rigorous derivation from QCD. However, its predictions for mass splittings and magnetic moments of barions containing the b quark are accurate, suggesting also the possibility of observing exotic hadrons containing heavy quarks. The model successfully predicts the value of the mass cascade Ξ_b [16][17].

The main activities of the European research and training network Flavianet have been summarized [3]. Flavianet activity is focused on low energy phenomenology, with emphasis on quark flavour physics, bringing together experimentalists and theoreticians in a common effort for a better understanding of low energy hadronic physics and the identification of new promising directions in the quest for physics beyond the SM. Some recent analyses done within the Kaon Physics Working Group of Flavianet have been presented [18] addressing three issues:

a. high precision tests of the SM in charged currents and the extraction of V_{us} using leptonic and semileptonic K_{l2} and K_{l3} decays: the analysis includes all recent results by BNL experiment E865, KLOE, KTeV, ISTRA+, and NA48, critically reviewed and combined taking into account the theoretical constraints on the semileptonic kaon form factors, in order to get rid of the disagreement currently present among the measurements; an accurate determination of V_{us} is obtained, useful for stringent tests of the SM predictions (see also [19] and [20]).
b. high precision measurements of fundamental QCD parameters: the quality of the most recent

measurements of the $\pi\pi$ scattering lengths done by NA48/2, thanks to the analyses of the Cusp effect and of K_{e4} processes, allows remarkable tests of strong interactions in the non-perturbative regime and addresses the issue of the spontaneous chiral symmetry breaking, achieving the needed sensitivity to the quark condensate (see also [21] and [22]);

c. stringent tests of the SM and the scenario beyond it, through the study of very rare kaon decays, highly suppressed in the SM (see also [20] and [23]).

3. Flavour Physics at e^+e^- colliders

3.1 The B-Factories

B-physics plays a privileged role in flavour physics study, thanks to the large b quark mass and the wealth of b-observables sensitive to new physics.

The BaBar and Belle experiments, installed at the high-luminosity electron-positron colliders PEPII at SLAC (USA) and at KEKB (Japan), were built in order to investigate the CKM model of quark flavour mixing and CP violation and detect possible departures from it.

The B-Factories have been highly successful since their starting of operation in 1999. The challenge for the highest luminosities was carried on together with the improvements of the measurements of the UT parameters. Fig. 3 shows the peak luminosity trends in the last 30 years, compared with the ultimate values expected for the next generation B-Factories, recently proposed [24][25].

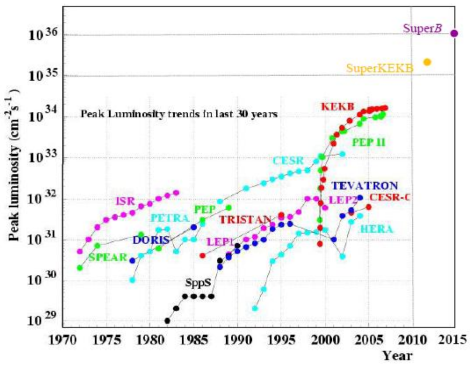

Fig. 3: Peak Luminosity trends in last 30 years

The last collision in BaBar took place in april 2008, six months in advance with respect to the schedule. The experiment recorded a total integrated luminosity of 531.4 fb^{-1}. Belle has accumulated more than 800 fb^{1} integrated luminosity, with the world highest peak luminosity of 1.7×10^{34} cm^{-2}s^{-1} . It is expected to collect close to one billion $\Upsilon(4S)$ events by the time it will come to an end, in 2009. The two experiments clearly demonstrate that B mixing and CP violation agree with the SM prediction; both continue to produce a huge amount of outstanding results.

A selection of many recent and new experimental observations from BaBar and Belle presented at this conference are here briefly described.

Charmless hadronic B decays

Charmless hadronic B decays are dominated by penguin one-loop transitions of comparable sizes. Large direct CP violation effects could arise from the interference between the two main amplitudes, given the absence of the dominant $b\to c$ decay contribution. However, direct CP violation could also be due to unknown contributions from new physics in the penguin loop. Therefore, different non-zero values of the decay-rate asymmetry parameter A_{CP} between the decay widths of charge-conjugate processes, due to direct CP violation, may reveal the presence of new physics.

The decays $B\to K\pi$, given by $b\to s$ transitions, are good probes of effects due to new physics. There are many SM relations between the rates and the CP asymmetries of the four modes $B^0 \to K^+\pi^-$, $K^-\pi^+$ and $B^+ \to K^0\pi^+$, $K^+\pi^0$. For those modes, the observables are divided into CP-conserving and CP-violating ones. In the former case, the key quantities are given by the ratios of CP-averaged $B\to\pi K$ branching ratios for neutral and charged decays. To first approximation, decay rates are equal and the SM prediction is stable, with significantly reduced errors. The B-Factory data have moved towards the SM value, thereby reducing the so-called "$B\to\pi K$ puzzle" for the CP-averaged branching ratios.

Direct CP violation is well established in $B^0 \to K^+\pi^-$ processes both by BaBar and Belle [7][8]. However, the observed asymmetry A_{CP} parameter for neutral and charged modes of $B\to K\pi$ appears to have opposite sign. In the case of the most recent result from Belle [26], the difference is established at the 4.4σ level:

$$A_{CP}(B\to K^{\pm}\pi^{0}) - A_{CP}(B\to K^{\pm}\pi^{\pm}) = 0.164 \pm 0.037\ .$$

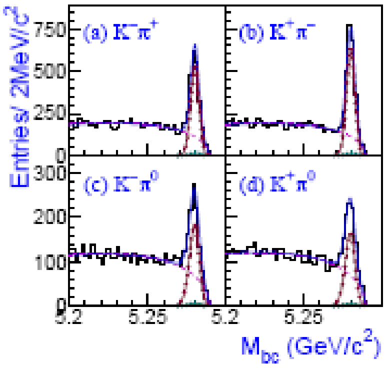

Figure 4: Beam energy constrained mass spectra for the four $B\rightarrow K\pi$ decay modes; the solid line is the overall fit to data (histograms). Contribution are from signal (point-dashed line), continuum background (dashed line) and fake $\pi^{\pm}\pi$ components (small bumps in signal region) [7].

The difference is also clear in the reconstructed mass spectra of $B\rightarrow K\pi$ candidates, shown in Fig. 4.

In charged B decays, a large direct CP violation in the channel $B^+ \rightarrow K^+ \rho^0$ was observed by both BaBar and Belle, with consistent results. The decay topology of this process is similar to $B^+\rightarrow K^+\pi^0$. Recently, BaBar [27] reported a 3.7σ evidence of direct CP violation in $B^+\rightarrow K^+ \pi^+\pi^-$ processes:

$$A_{CP}\,(K^+\rho^0) = 0.44 \pm 0.17\ .$$

This value is consistent with the SM, unlike the case of $A_{CP}(K^+\pi^0)$. The non-vanishing difference of CP violating asymmetries, however, is likely to be generated through hadronic effects and not through the existence of new physics beyond the SM.

Input from measurements is neede to reduce hadronic uncertainties. Systematic measurements of branching ratios and A_{CP} asymmetries in various decays are important to improve the theoretical understanding. A global description of experimental measurements of CP Asymmetries in charmless B decays is show in Fig. 5 [11].

The latest BaBar results on amplitude analyses of several known and new charmless rare B decays, focused on the study of $B^{\pm}\rightarrow\varphi K_J^{(*\pm)}$ processes, have been discussed [28] in order to understand the disagreement between the SM predictions and the measurements of the polarization of the Vector–Vector decay $B\rightarrow\varphi K^*$, where a large transverse polarization, unexpected from the SM, was measured. The first measurement of the polarization of the VectorAxial–Vector B decay $B^{\pm}\rightarrow\varphi K_1^{\pm}$ is also in disagreement with the SM expectation of longitudinal polarization dominance. The observed polarization pattern requires the presence of new contributions to the decay amplitude, still unknown. The analyses of both $b\rightarrow s$ and $b\rightarrow d$ transitions are compared in order to resolve the polarization puzzle.

Results from the analysis of the FCNC processes $B\rightarrow K^*l^+l^-$, with lepton pair in the final state, have been presented [7][29]. In this case the SM predicts an angular dependence of the decay rates. Accordingly, a better understanding of the underlying decay mechanism is achievable through the measurement of the lepton angular distribution, since those decays are forbidden at tree level in the SM, and are theoretically clean due to reduced hadronic contributions. The measurements of branching fractions, forward-backward lepton asymmetries and CP violation are in agreement when compared among several decay modes.

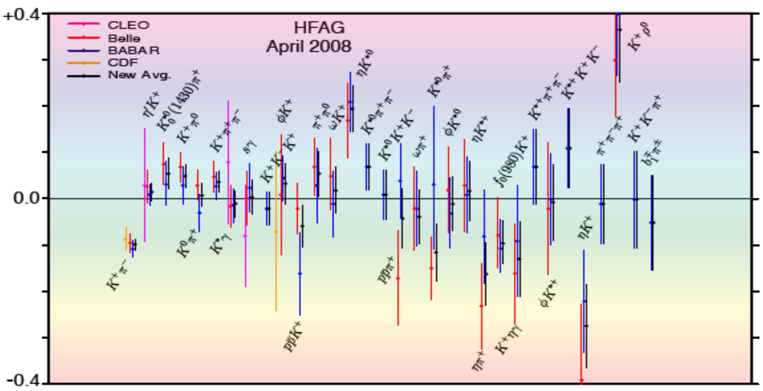

Figure 5: CP Asymmetries in charmless B decays [11]

However more data are needed to increase the sensitivity to physics beyond the SM: a precise study can only be realized by the new generation B-Factories or at LHC.

The most recent results on rare 3-body charmless baryonic B decays and the observation of new modes in BaBar and Belle have been reported [7].
After the first observation of the process $B^+ \rightarrow p\bar{p}K^+$, many 3-body charmless baryonic B decays into K and π mesons have been found, all showing an unexpected peak near threshold in the baryon–antibaryon mass distribution. This indicates that the baryon-antibaryon pair is likely to move in parallel in the B rest frame, in the opposite direction with respect to the meson. Further studies of the angular distributions of the proton-antiproton pair system near threshold and of the observed enhancement are needed to fully understand the decay mechanism.

Radiative B meson decays

An improved measurement of radiative B meson decays, based on an enlarged data sample collected by Belle, has been presented [30][31].
Inclusive radiative B-meson decays are higly sensitive probes of physics beyond SM, being FCNC decays, forbidden at tree level in the SM, and also theoretically very clean. New physics could produce a sizeable deviation from the SM branching fraction prediction. The average experimental branching ratio [11] is compatible with the QCD predictions at NNLO [32]. However, small effects due to physics beyond the SM are still allowed with significant constraints on new physics models. Therefore, it is important to improve experimental measurements of radiative B meson decays. The e^+e^- machines are particularly well suited for inclusive measurements.
A new measurement of the branching ratio and the photon energy spectrum of $B \rightarrow X_s\gamma$ decays have been done by Belle in a fully inclusive way over the 97% of the photon energy spectrum, allowing the theoretical uncertainties to be reduced to a very low level. The preliminary result, obtained in the range 1.7 GeV $\leq E_\gamma^{cms} \leq$ 2.8 GeV of the photon energy in the centre-of-mass system, is the most accurate value to date:

$$BR(B \rightarrow X_s\gamma) = (3.31 \pm 0.19 \pm 0.37 \pm 0.01) \times 10^{-4}.$$

The errors are, respectively, statistical, systematic and given by the boost correction in the transformation from the rest frame of the Υ(4S) to the one of the B-meson. This result is in agreement with the latest theoretical calculations and can be used to give constraints on new physics. In addition, it is also useful to determine SM parameters such as the b-quark mass from the photon energy spectrum, being the photon monochromatic at parton level with energy E $\approx m_b/2$ in the b-quark rest frame. Fig. 6 shows the photon energy spectrum for the signal candidates events $B \rightarrow X_{s,d}\,\gamma$.

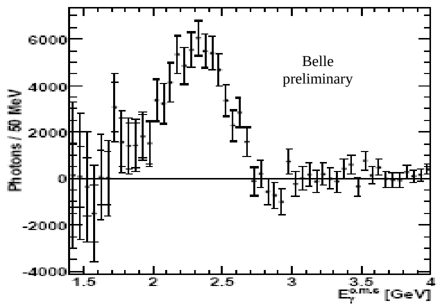

Figure 6: photon energy spectrum of $B \rightarrow X_{s,d}\,\gamma$; error bars show statistical and total errors [31].

Measurements of UT angles

Experimental techniques and analyses of the UT angles in BaBar have been reviewed [33]. The values of β and α are obtained by studying time-dependent CP violating asymmetries; the newest result on the γ angle is also given, based on the determination of direct CP violating asymmetries.
The precision of the measurement of sin(2β) in $b \rightarrow \bar{c}cs$ transitions (e.g. $B^0 \rightarrow J/\Psi K^0$) is approaching the accuracy of SM calculations. The measurements of β, done in channels involving $b \rightarrow \bar{c}cd$, $b \rightarrow \bar{d}ds$ and $b \rightarrow \bar{s}ss$ transitions, are consistent with the reference value from charmonium decays, as also shown in Fig. 2. A difference between the central experimental values of the HFAG [11] and the UTfit collaborations [1], which are, anyway, compatible within the uncertainties, appears to be due to the different values of the V_{ub} matrix element used in the calculations. A V_{ub}–independent determination of sin(2β), based on the most recent measurements of V_{cb}, $\Delta M_s/\Delta M_d$ and the neutral kaon CP violation parameter ε_K, finds a value about 1.5σ away from the experimental average [6]. Further work is needed before interpreting this deviation as a new physics signal.
Complementary and consistent results are obtained on the measurement of α [33] based on the analysis of $b \rightarrow uud$ transitions in $B \rightarrow \pi\pi$, $\rho\rho$ and $\pi\rho$ decays,

thus allowing the reduction of uncertainties due to the presence of penguin diagrams.
A new measurement of the angle γ, the most difficult to be determined, is done by BaBar with an uncertainty of about 20°, using the Dalitz analysis of $B^{\pm}\to D^{(*)}K^{(*)\pm}$ decays [33]. Fig. 7 shows (1-CL) as a function of the UT angle γ, separately for each decay and for their combination. The BaBar new result, including all errors, is:

$$\gamma = (76^{+23}_{-24})° \quad 68.3\%\ \mathrm{CL}\ .$$

This implies direct CP violation with a 3.0σ significance. The uncertainty is dominated by the analysis method. Further improvements are expected using all the available data sample.

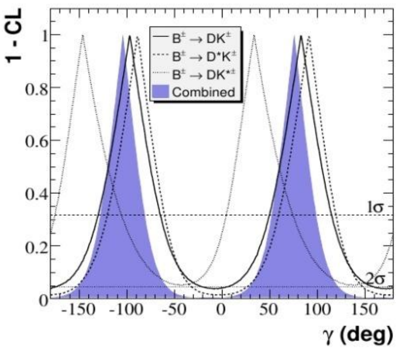

Figure 7: (1-CL) as a function of the UT angle γ from the Dalitz analysis of $B^{\pm}\to D^{(*)}K^{(*)\pm}$ decays separately, and for their combination [33].

Bottomonium spectroscopy
The data collected by BaBar at the Υ(3S) and Υ(2S) energies are the world's largest samples and provide a wide platform for testing QCD in the Upsilon system. The $b\bar{b}$ bound state system contains many states and transitions and is well modelled in QCD. However, many aspects are still missing to broaden the knowledge of this subject. In this respect, the first observation of the bottomonium ground state η_b in the radiative decay of the Υ(3S), claimed by BaBar [34] few weeks after the end of this conference, is a remarkable achievement and a milestone in understanding the way quarks interact and behave.

B Meson Masses
A statistically significant difference, at the 5 σ level, between the masses of charged and neutral B mesons is measured by BaBar [35][36] for the first time, with more than 200 millions B pairs:

$$M(B^0)-M(B^+)=0.33\pm0.05(\mathrm{stat})\pm0.03(\mathrm{syst})\ \mathrm{MeV}/c^2.$$

The $B^0\to J/\psi K^+\pi$ and $B^+\to J/\psi K^+$ decays, with large signals and low background, are selected for this measurement. The achieved precision is important for the knowledge of the production ratio of neutral and charged B mesons.

Initial State Radiation
B-Factories are excellent places to study hadronic final states in e^+e^- annihilation. The analysis of Initial State Radiation (ISR) at the Υ(4S) can provide measurements of the same observables as the low energy e^+e^- experiments, i.e. measurements of precise cross sections, of the ratio R between the cross sections of hadron to di-muon production, of form factors from hadron pair production and of $J^{PC}=1^{--}$ hadron spectroscopy, leading to the discovery of new states.
Thanks to well suited analysis techiques, it is possible to study the events produced not only at the collider nominal centre-of-mass energy but also at lower energy, from the production threshold up to the 4–5 GeV region. The advantage in the case of the B-Factories is that no energy scan is needed: a continuous range of energies is produced measuring at one beam energy, thus reducing systematic uncertainties. In addition, the high luminosity and the detector performance make this analysis method competitive with respect to targeted, lower-energy experiments.

ISR studies led to the first observation of the process $e^+e^-\to p\bar{p}p\bar{p}$ by BaBar [35], with a cross section of 2.8±0.4 fb. The track invariant mass distribution is shown in Fig. 8. This mode, previously unobserved at any energy, poses interesting questions about production mechanisms.

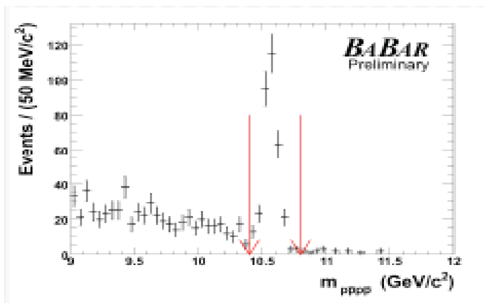

Figure 8: invariant mass distribution for the process $e^+e^-\to p\bar{p}p\bar{p}$ [35]

Charm physics at B-Factories

Recent developments in D mixing physics and charm spectroscopy both in BaBar and Belle have been discussed in this conference [37][38].

As for other neutral mesons like K or B, $\overline{D}^0$–D^0 mixing is also expected, although the mixing strength is considered to be very small, being strongly suppressed in SM, because of the relatively low mass of b, s or d quarks involved in the loop diagram of the mixing process. The $\overline{D}^0$–D^0 mixing is the only place where the contribution to the CP violation of down-type quarks in the mixing diagram can be explored. Moreover, understanding the D mixing is important in the search of CP violation in the charm sector.

There are several ways to measure $\overline{D}^0$–D^0 mixing, according to D^0 decays and analysis methods. The most precise constraints are obtained using the time dependence of D decays. A summary of results of different experimental approaches to measure the $\overline{D}^0$–D^0 mixing parameters, involving the decays $D^0\to K^+\pi^-$, $D^0\to K^+K^-$ or $\pi^+\pi^-$ and $D^0\to K^-\pi^+\pi^0$ have been presented [37][38].

Mixing in the $\overline{D}^0$–D^0 system has been searched for years. BaBar presented in 2007 the first evidence of this phenomena in the proper time distribution of the rare hadronic $D^0\to K^+\pi^-$ decays, doubly Cabibbo-suppressed, compared with that of the Cabibbo-favoured mode $D^0\to K^-\pi^+$. The D^0 flavour was determined by the sign of the pion in the $D^{*+}\to D^0\pi^+$ decay from which they originate [39]. Belle [40] and CDF [41] have also observed evidence for $\overline{D}^0$–D^0 mixing. All the measurements can be combined to yield world average values for the mixing parameters $x = (m_1-m_2)/\Gamma$ and $y = (\Gamma_1-\Gamma_2)/(2\Gamma)$, where m_1, m_2 and Γ_1, Γ_2 are the masses and decay widths of the mass eigenstates D_1 and D_2.

The combined world average constraints on the mixing parameters (x, y) from the HFAG collaboration [11] are shown in Fig. 9. From the fit results, the experimental data are consistent with $\overline{D}^0$–D^0 mixing: the no mixing point $x = y = 0$ is excluded at 9.2σ. New physics effects cannot be easily disentangled, due to the probable presence of long-distance processes. The CP-even state is shorter-lived, as in the $\overline{K}^0$–K^0 system; however, it is also heavier, unlike in the $\overline{K}^0$–K^0 system. There is no evidence yet for CP violation: observing CP violation at the current level of sensitivity would indicate new physics.

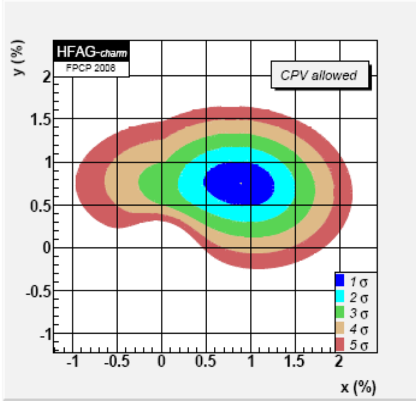

Figure 9: combined results for the charm mixing parameters (x, y) [11].

The issue of ISR production of charmonium is also addressed at the B-Factories. Recent results from BaBar [35] and Belle [38] on this subject have been presented. The search for states containing the charm quark has been performed by analysing the data of exclusive ISR production of $\overline{D}D$ pairs in $e^+e^-\to\overline{D}D$. However, it is not obvious how to fix resonance parameters in order to take into account the interference among decay channels, the non-resonant contributions and many open charm thresholds. Some known states are not found in the $\overline{D}D$ invariant mass distribution. This is, in particular, the case of the ϒ(4260) state, which, unexpectedly, does not decay to DD, for reasons not yet understood.

3.2 The Cornell e^+e^- storage ring (CESR)

The Cornell storage ring exploits e^+e^- collisions at a center of mass energy $\sqrt{s}$ of 9 to 12 GeV and a peak luminosity of 1.2×10^{33} $cm^{-2}s^{-1}$. D mesons at CESR are produced in pairs at threshold, providing a huge amount of clean low multiplicity data.

The most recent results from CLEO on hadronic and leptonic branching fractions of D mesons have been presented in this conference [9].

Very precise measurements of the absolute branching ratios of both charged and neutral D meson hadronic decays into several modes with K, π, and η mesons in the final state, have been achieved by CLEO. These measurements are essential in the normalization of D and B meson branching fractions, in order to reduce systematic uncertainties, with a significant impact on the precision of tests of the SM. The analyses are based on subsamples of the available D pair statistics, selected from the processes $e^+e^- \rightarrow \Psi(3770) \rightarrow \bar{D}D$ (281 pb^{-1}) and $e^+e^- \rightarrow \Psi(4170) \rightarrow \bar{D}_sD_s^*$ (298 pb^{-1}), with a double-tag technique. The results for the $\bar{D}D$ modes [42], compared to the 2004 value of the Particle Data Group [43], are shown in Fig. 10.

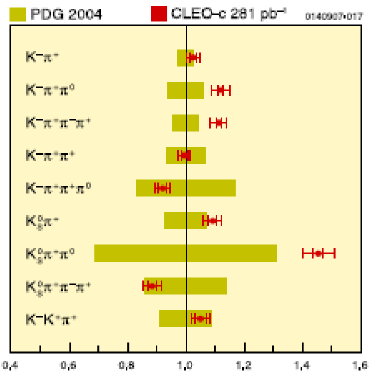

Figure 10: CLEO hadronic branching fractions, compared with PDG2004 [43].

The latest high statistics determination of several absolute branching ratios of D_s^+ hadronic decays, simultaneously measured for the first time, has also been described [9][44]. The results are significantly more precise than any previous absolute measurements of D_s branching fractions. The production cross section of $D_sD_s^*$ pairs at the energy of 4.17 GeV has been measured with the same data sample. The result, consistent with earlier CLEO measurements, is:

$$\sigma(e^+e^- \rightarrow D_sD_s^*) = (0.98 \pm 0.05 \pm 0.02 \pm 0.01) \text{ nb} .$$

The errors are, respectively, statistical, systematic due to the measurement and systematic due to luminosity.

Both weak and strong interactions are involved in purely leptonic decays of heavy mesons. Decay rates are connected to the product of the weak interaction CKM matrix element of the constituent quarks and a strong interaction parameter related to the overlap of the quark and anti-quark in the meson, called the decay constant. The rate of the process is measured in order to extract the decay constants. If the decay constant measurement is accurate and the related CKM matrix element is known with good precision, the comparison with the QCD prediction is an effective probe of the theory. That is the case of the decay constants in the charm sector, which provide a successful test of lattice QCD techniques [5].

The recent CLEO measurements of the branching ratio of D^+ purely leptonic decay, based on 818 pb^{-1} of data taken on the $\psi(3770)$ resonance, are the most accurate to date [9][45]. By combining the branching ratio of $D^+ \rightarrow \mu^+\nu$ with the well measured D^+ lifetime and assuming $V_{cd}=V_{us}$ they report:

$$f_{D+} = 205.8 \pm 8.5 \pm 2.5 \text{ MeV}.$$

The combination of two measurements of f_{Ds}, given by the D_s decays into $\mu\nu$ and $\tau\nu$, is [46]:

$$f_{Ds} = (274 \pm 10 \pm 5) \text{ MeV}$$

While the lattice calculation of the decay constant f_{D+} agrees very well with the experiments, the measurement of f_{Ds} differs from the most precise unquenched lattice calculation and may indicate the presence of new physics effects [47][5].

3.2 The Dafne e^+e^- collider

The study of kaon physics is addressed at the DAΦNE Φ-Factory, which exploits e^+e^- collisions at a center-of-mass energy of $\sqrt{s} \approx 1019$ GeV, around the Φ meson mass M(Φ). All types of K mesons, produced almost at rest, are available at DAΦNE, being neutral and charged kaon pairs are the most probable Φ decays.

The KLOE experiment at the Φ-Factory exploits the correlated decays of $K_S - K_L$ and $K^+ - K^-$ from the Φ resonance produced in e^+e^- collisions. A total integrated luminosity of 2.5 fb^{-1} of data at the M(Φ) have been recorded with KLOE between 2001 and 2005, yielding about 2.5×10^9 $K_S - K_L$ pairs, with a peak luminosity of 2.5×10^{32} $cm^{-2}s^{-1}$. Pure kaon beams are reconstructed in KLOE by tagging the companion K decays. A review of recent precision SM test in KLOE, related to semileptonic and leptonic K_{l3} and K_{l2} decays into both electrons and muons, has been presented [19]. An accurate determination of the CKM matrix element V_{us} and tests of physics beyond SM have been described (see also [18],[20]). KLOE has measured most decay branching ratios of K_S, K_L and K^+, K^- mesons. K_L and $K^{\pm}$ lifetime have been also measured and the shape of the form factors involved in kaon semileptonic decays have been determined [48].
Results on K physics are also discussed in Section 5.

4. Flavour physics at hadron facilities

Hadron colliders, once called “discovery machines”, became recently high precision machines and competitors to B-Factories in the field of heavy flavour physics research.
A selection of results presented from the Tevatron at Fermilab, Hera at Desy and expectations from the LHC experiments at CERN will be described.

4.1 The Tevatron

In $\sqrt{s}$ = 1.96 TeV $p\bar{p}$ collisions at the Tevatron, B hadrons are mostly produced in pairs. Gluon fusion is the the main $b\bar{b}$ production mechanism. The $b\bar{b}$ production cross section is about 30 μb, large with respect to B-Factories, allowing a very rich B physics program. The total inelastic cross section being 1000 times larger than the $b\bar{b}$ cross section, well-suited triggers that target specific decays are used in order to suppress the large background contribution.
A statistics of about 4.2 fb^{-1} of data, corresponding to about 3.5 fb^{-1} of recorded events, has been delivered by the Tevatron since the beginning of Run II, in march 2001, enabling unprecedented studies of heavy flavour hadron properties. The peak luminosity was 2.85×10^{32} $cm^{-2}s^{-1}$. A data sample of about 8 fb^{-1} is expected by the end of 2010. Many results were provided by both CDF and D0 experiments at this conference.

B_c and B_s mesons properties

Recent Tevatron measurements of mass and lifetime of the B_c meson, as well as lifetime, mixing and CP violation properties of B_s mesons have been presented [17][49].

The $B^{\pm}_c$ meson is composed of a b and a c quark and is too massive to be produced at the B-Factories. With a large b quark production cross section and the powerful multipurpose detectors CDF and D0, the Tevatron is well suited to study all species of B hadrons, including the $B^{\pm}_c$ meson. The most precise measurement of the B_c mass was recently done by the CDF experiment, based on a sample of 2.4 fb^{-1} of data [50]. The value of the B_c mass is determined with an unbinned log likelihood method, using candidates with a fully reconstructed $B_c\to J/\psi\pi$ signal and has a significance exceeding 8σ:

$$M(B_c)= 6275.6 \pm 2.9(stat) \pm 2.5(syst)\ MeV/c^2\ .$$

The result agrees with the D0 measurement [51][17]:

$$M(B_c)= 6300 \pm 14(stat) \pm 5(syst)\ MeV/c^2\ .$$

The lifetime of the B_c meson is measured by CDF using the semileptonic mode $B_c\to J/\psi(\mu\mu)\ l\nu X$ [52] with a data sample of about 1 fb^{-1}. The lepton can either be a muon or an electron. The same data sample selected for the B_c mass measurement, given by about 5.5 million $J/\psi\to\mu\mu$ candidates, is used for the B_c lifetime. The B_c lifetime is obtained separately in the $J/\psi(ee)$ and $J/\psi(\mu\mu)$ channels, using an un-binned likelihood fit. The combined value of the B_c lifetime is:

$$c\tau = 142.5_{-14.8}^{+15.8}\ (stat) \pm 5.5(syst)\ \ \mu m.$$

This value agrees with the present most precise measurement, done by the D0 experiment [53][17] in the $B_c\to J/\psi\ \mu\nu\ X$ channel, with 1.3 $fb^{-1}$of data:

$$c\tau = 134.4_{-10.8}^{+11.4}\ (stat) \pm 9.6(syst)\ \ \mu m.$$

Fig. 11 shows the comparison of present B_c lifetime experimental results. The measurements of CDF and D0 are in agreement with each other and with the theoretical predictions.

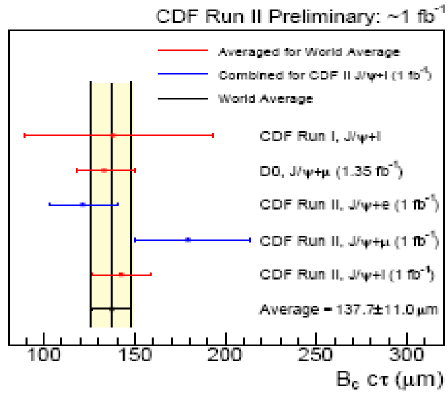

Figure 11: B_c lifetime experimental results [49]

B^0_s–B^0_s Mixing

The measurement of $\bar{B}^0_s$–B^0_s oscillation frequency ΔM_s and the decay width difference $\Delta\Gamma_s$ are crucial for the determination of some elements of the CKM matrix. The Tevatron is the only place, at present, where it is possible to make this measurement. Both CDF and D0 are pursuing the exploration of the B_s mixing sector in various different ways.

The frequency of the $\bar{B}^0_s$–B^0_s oscillation was measured for the first time in 2006 by the CDF collaboration, that found $\Delta M_s = 17.77 \pm 0.10(\text{stat}) \pm 0.07(\text{syst})\ ps^{-1}$ [54], in agreement with the SM. The high accuracy of this measurement allowed to obtain precise values of the CKM matrix elements V_{td} and V_{ts}. The D0 measurement is consistent with the CDF one [55].

The study of $\bar{B}^0_s$–B^0_s mixing is also interesting for its sensitivity to new physics, through the phase ϕ_s of the B^0_s mixing amplitude: a disagreement between direct experimental measurements of this parameter and the SM prediction has been recently claimed by M. Bona et al. [10] in an analysis which combines all the experimental information on B_s mixing. Updated Tevatron analyses with higher statistics and future high-precision measurements at the LHC, are, in this respect, of the utmost importance.

CDF used a sample of $B_s \rightarrow J/\psi\phi$ events collected in 1.7 fb^{-1} of data to measure the B_s lifetime and decay width difference, extracted from the distributions of mass, decay time and angles of the final state particles with an unbinned likelihood method [49].

The CDF results are:

$$\tau_s = 1.52 \pm 0.04\ (\text{stat}) \pm 0.02\ (\text{syst})\ \ ps$$
$$\Delta\Gamma_s = 0.076_{-0.063}^{+0.059}\ (\text{stat}) \pm 0.006\ (\text{syst})\ \ ps^{-1}$$

D0 analysis of flavour-tagged $B_s \rightarrow J/\psi\phi$ decays on 2.8 fb^{-1} of data, gives [56]:

$$\Delta\Gamma_s = 0.19 \pm 0.07\ (\text{stat})\ _{-0.01}^{+0.02}\ (\text{syst})\ \ ps^{-1}$$

The recent measurements of the B_s lifetime in both $B_s \rightarrow J/\psi\phi$ and flavour specific $B_s \rightarrow D_s\pi$ channels confirm the theoretical predictions that $\tau_s \approx \tau_d$ [49].

$B_s \rightarrow J/\psi\phi$ decays have been analysed by both CDF and D0 in order to study CP violation and measure the CP violating mixing phase ϕ_s. To enhance the sensitivity to the measurement of the CP violation phase in both experiments the flavour of the B_s or the $\bar{B}_s$ is identified at production by means of flavour tagging.

The CP violating mixing phase β_s in $B_s \rightarrow J/\psi\phi$ decays was measured for the first time by the CDF collaboration using 1.35 fb^{-1} of data [57]. They report confidence regions in the two-dimensional space given by the phase $2\beta_s$ and the decay-width difference $\Delta\Gamma_s$. Assuming the SM predictions of $2\beta_s$ and $\Delta\Gamma$, the probability of the deviation observed in the data is 15%, corresponding to a significance of 1.5σ. The latest results of D0 on CP violation in the decay $B_s \rightarrow J/\psi\phi$ are based on about 2.8 fb^{-1} of data [55]. Using an unbinned maximum likelihood to fit the proper decay time distribution and fixing the ΔM_s value, they obtain confidence level contours in the ϕ_s–$\Delta\Gamma_s$ plane assuming the CP violating weak phase $\phi_s \approx -2\beta_s$. Their results are consistent with the CDF ones. The HFAG collaboration has combined the both CDF and D0 measurements of the time-dependent decay $B_s \rightarrow J/\psi\phi$ and reports confidence regions in the two-dimensional space of $\phi_s = -2\beta_s$ and decay-width difference $\Delta\Gamma_s$. Results are given with and without external assumptions on the world average B^0_s lifetime and semileptonic charge asymmetry. After the combination, the consistency of the best fit values of $\Delta\Gamma_s$ and $\phi_s = -2\beta_s$ with the SM predictions with and without constraints has, respectively, a significance of 2.4σ and 2.2σ. Fig. 12 shows the HFAG results in the ϕ_s–$\Delta\Gamma_s$ plane with no external constraints [11].

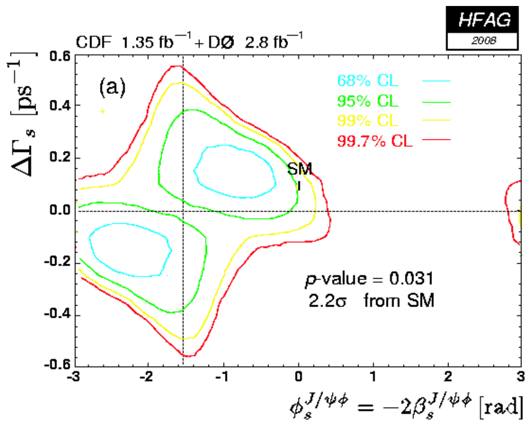

Figure 12: confidence regions in the ϕ_s–$\Delta\Gamma_s$ plane for the CDF and D0 combined results with no external constrains [11].

Direct CP violation in $B^{\pm} \rightarrow J/\psi K^{\pm}$

The SM predicts a small direct CP violation, of about 1%, in the decay $B^{\pm} \rightarrow J/\psi K^{\pm}$. The observable in this case is the CP violating charge asymmetry A_{CP}. Constraints on new physics could be posed with a precise measurement of this variable. The most accurate measurement up to date of the charge asymmetry in the decay $B^{\pm} \rightarrow J/\psi K^{\pm}$ has been presented by D0, using 2.8 fb^{-1} of data [55]:

$$A_{CP} = 0.0075 \pm 0.0061(\text{stat}) \pm 0.0027(\text{syst})$$

The achieved precision is of the order of the SM prediction.

4.2 The LHC

After the machine commissioning, the Large Hadron Collider (LHC) at CERN will exploit proton-proton collisions at a center-of-mass energy of 14 TeV, and a design luminosity of 10^{34} cm^2s^{-1} , becoming the world's highest energy particle collider. This is now expected to happen in late summer 2009, according to the latest news after the recent machine accident.

The main goals of the LHC are the search for the Higgs boson, the last undiscovered particle of the SM, and the search for physics beyond the SM. The physics potential of the LHC is unprecedented: the TeV scale region will be directly accessible for the first time. The core of the program consists of two general-purpose detectors (ATLAS and CMS) and two special-purpose experiments ALICE (heavy-ion physics) and LHCb (b physics). Other specialized experiments at LHC are TOTEM, to measure the total pp cross section [58] , and LHCf, to measure photons and neutrons zero angle production [59] .

A luminosity of about 10^{30} cm^2s^{-1} will be delivered at the beginning of the LHC operation, according to the current schedule. At this point there will be no problem with pile-up, due to the lower bunch currents, and the trigger will have a large acceptance also for high transverse momentum processes. Even at the relatively low integrated luminosity of 10 pb^{-1} a remarkable physics program is accessible at the LHC, particularly in the heavy flavour sector. Many di-jet, W, Z, and top quark events will be recorded. At any energy and luminosity, soft hadronic interactions, the so-called “minimum bias” processes, will be the most common types of event, useful to set the scale for background and reconstruction.

The understanding of SM processes will be crucial in the early search for new physics at the LHC, therefore a considerable effort will be invested to precisely measure those processes at the beginning of machine operation. Only a good understanding of the SM background, in fact, will allow to achieve results in the search for new physics at the LHC.

Both ATLAS and CMS experiments are well suited for a wide range study of heavy flavour physics, since their startup [60-63] . A clear physics program on heavy hadrons studies, with benchmark analyses, is established since the beginning of data taking, with early data samples. It includes measurements of lifetimes at the world average precision, done with samples of few fb^{-1} of data; measurement of B hadron properties (CPV, B_s oscillations), accessible within 20 fb^{-1}. At about 100 fb^{-1}, rare decays and possible discovery of not yet observed heavy hadrons will already be possible. B physics will have a crucial role in searching for new physics, due to the SM Higgs decays into $b\bar{b}$ pairs and SUSY particle decay chains having $b\bar{b}$ pairs as final states.

In this conference we listened to the ATLAS plans on heavy flavour physics measurements, with emphasis on studies needed for the preparation of analyses based on early data taking [60-61]. Simulated data samples for the measurements of quarkonium production and polarization [60], heavy hadron masses, lifetimes, production rates, and the possible discovery of new heavy hadrons [61], are used.

The issue of b production and identification at CMS was described. The CMS capability to measure inclusive b-hadron production cross section [62], rare B decays and other heavy flavour physics [63] was presented, based on realistic detector simulations. The method used to identify b-jets, with a discussion of the expected performance in terms of efficiencies and misidentification probabilities under realistic conditions [62], and the method to select and reconstruct heavy flavour decays in the presence of high backgrounds and relatively low particle momenta [63] are addressed.

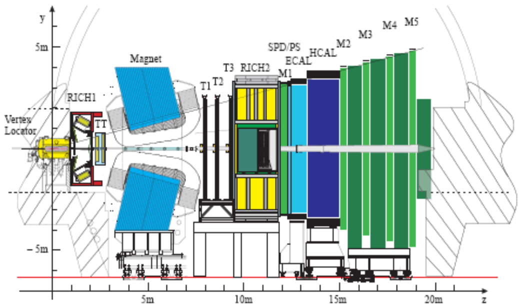

Figure 13: schematic view of the LHCb detector

LHCb [64] is the LHC experiment for precision measurement of CP violation and rare decays of beauty and charm hadrons. The LHCb detector and its expected performance have been presented together with selected topics of the physics program. In proton-proton collisions at $\sqrt{s}$ = 14 TeV, the $b\bar{b}$ cross section is about 500 μb., corresponding to a yield of 10^{12} $b\bar{b}$ pairs per year (10^7 s), i.e. to about 2 fb^{-1} of data at the LHCb operational luminosity of 2×10^{32} $cm^{-2}s^{-1}$. This luminosity is obtained by defocusing the beams with respect to the nominal configuration. A cleaner environment is achieved in this case, with maximal probability of a single interaction per bunch crossing, simplified event reconstruction and reduced radiation level. Gluon fusion is the dominant $b\bar{b}$ production mechanism in proton-proton collisions at the LHC, resulting in a strongly asymmetric momenta of the incoming partons: the $b\bar{b}$ production is correlated and sharply peaked forward and backward. Therefore, the LHCb detector is designed as a single-arm forward spectrometer, as shown in Fig. 13. All B mesons will be produced: $B_u^{\pm}$, B_d^0, B_s^0, $B_c^{\pm}$. However, the $b\bar{b}$ cross section is less than 1% of the total inelastic cross section at the LHC center-of-mass energy, hence the trigger selection is a major issue [65].

4.3 Heavy Flavour at Hera

The study of heavy flavour production at HERA provides an important test of perturbative QCD and also valuable information for the measurements to be made at the LHC. HERA, the only electron-proton collider, stopped data taking at the end of june 2007, after 15 years of operation. By the end of the running the two experiments H1 and ZEUS had collected about 0.5 fb^{-1} of data. While many data are still to be analyzed, a lot of remarkable results are already available, aiming at the ultimate goal of a detailed knowledge of the structure of the proton.

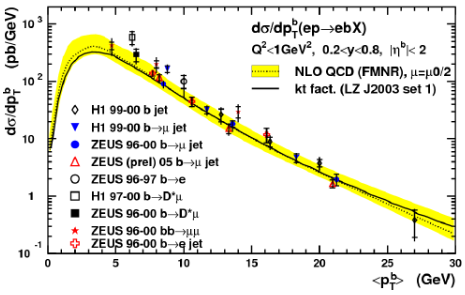

Figure 13. Differential cross section for b-quark production as a function of the transverse momentum compared to the results of previous ZEUS measurements (points) [66]. The error bars show the statistical uncertainty and the statistical and systematic uncertainties added in quadrature. The solid line shows the NLO QCD prediction with the theoretical uncertainty shown as the shaded band .

Heavy flavour production is one of the key component of the HERA II physics program, providing important tests of perturbative QCD and useful information for the future measurements at the LHC. A selection of the recent results obtained by the H1 and ZEUS collaborations have been presented at this conference [66-67] .

Many measurements of beauty photoproduction are compared in Fig 13: they are in agreement each other and with the NLO QCD calculations [66].

Recent measurements of heavy quark fragmentation and spectroscopy have been described [67]. Understanding the way quarks and gluons convert to colour-less hadrons is a remarkable problem in particle physics. In the case of the charm quark, the measurements of the fragmentation properties in H1 and ZEUS, obtained with different experimental procedures, are compatible with each other and with results from e^+e^- experiments, supporting the universality of charm fragmentation.

Structure functions are known over a wide range of the squared 4-momentum Q^2 and the Bjorken scaling variable *x*. New measurements on the heavy c and b quark contents of the proton are available. Fig. 14 shows the measurements of $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ [66].

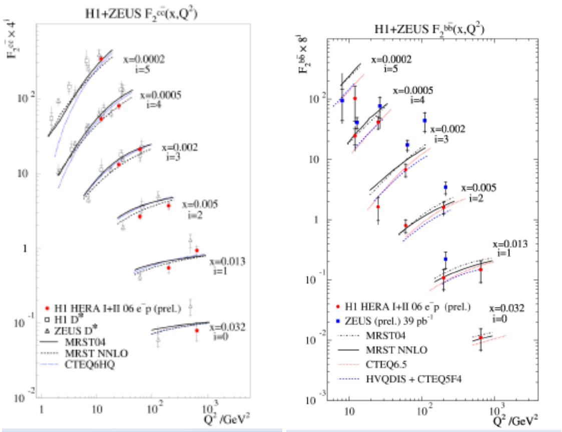

Figure 14: $F_2^{c\bar{c}}$ (left) and $F_2^{b\bar{b}}$ (right) as a function of Q^2 for different *x* ranges [66]. The error bars show the statistical uncertainty and the statistical and systematic uncertainties added in quadrature.

5. Flavour Physics at Fixed Target

5.1 Kaon Physics

The study of the properties of K mesons has always been a powerful tool to achieve fundamental results in the development of particle physics. The concept of strangeness led to the quark model and to the basic issues of QCD; the first evidence of parity violation showed the chiral nature of weak gauge forces; the suppression of FCNC suggested the charm quark and the GIM mechanism; the discovery of CP violation established matter-antimatter asymmetry and the three generation structure of matter; basic investigation of lepton-flavour and CPT symmetries have been possible; tests of theoretical techniques such as Chiral Perturbation Theory (ChPT), which account for the low energy behavior of QCD, became feasible in kaon decays, dominated by long distance contributions.

The study of rare kaon decays has several motivations. Physics beyond SM can be addressed through the search for explicit lepton-flavour violation, predicted at some level in many theoretical models. Lepton-flavour violation can be pursued to remarkable sensitivity in kaon leptonic and semileptonic processes which violate the lepton number conservation, with excellent signature. Rare kaon decays proceeding through FCNC are very sensitive to new physics effects. Kaon processes dominated by long-distance contributions are useful tools to sharpen theoretical techniques aimed at describing QCD in non-perturbative regime, such as ChPT. The relevant UT can be completely determined with measurements of rare K decays

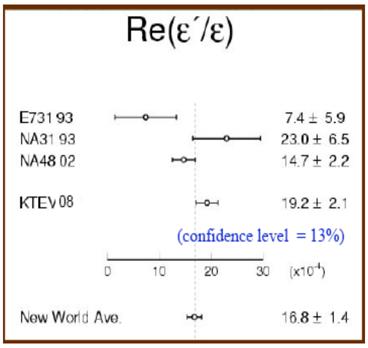

Figure 15: summary of experimental results on the direct CP violation parameter Re(ε'/ε)

CP violation was discovered in $K^0 \to \pi\pi$ decays in 1964 [68]. The same mode provided also the evidence for direct CP violation [69-71] .

The KTeV experiment at Fermilab presented its final measurement of direct CP violation in neutral kaons [70]. Displaced K_L and K_S regenerated beams were used in KTeV for this measurement. With an improved modelling of energy non linearity, which reduces the systematic uncertainty of the electromagnetic cluster reconstruction, they obtain:

$$\mathrm{Re}(\varepsilon'/\varepsilon) = (19.2 \pm 1.1\,(\mathrm{stat}) \pm 1.8\,(\mathrm{syst})) \times 10^{-4}$$
$$= (19.2 \pm 2.1) \times 10^{-4}$$

Fig. 15 summarizes the current measurements of the direct CP violation parameter Re(ε'/ε) in neutral kaons. The world average quoted there has a significance of more that 10σ. This result is compatible with the SM predictions. Despite the impressive progresses in recent years, theoretical uncertainty still prevent Re(ε'/ε) to be a quantitative test of the SM, due to non-perturbative calculations of hadronic physics. Progresses in the lattice QCD should possibly overcome such problem.

The NA48 experiment at the CERN SPS measured the direct CP violation parameter Re(ε'/ε) exploiting simultaneous K_L and K_S beams[71]. In 2002 NA48 was redesigned as NA48/2 to search for direct CP violation in $K^\pm \to 3\pi$ decays. This configuration has also allowed studying several rare decay processes of charged kaons in order to test ChPT. With a data sample of about 10^6 $K^\pm \to \pi^+\pi^- e^\pm \nu$ decays precise values of a_0 and a_2, the isospin I=0 and I=2 s-wave $\pi\pi$ scattering lengths are extracted with an unprecedented experimental precision. The same scattering lengths are also measured using about 60×10^6 $K^\pm \to \pi^\pm\pi^0\pi^0$ decays where a cusp structure in the Dalitz plot has been observed for the first time. Fig. 16 shows the cusp effect observed by NA48/2 in more than 2/3 of the available data statistics. The precision of the measurements allows remarkable tests of strong interactions in the non-perturbative regime and addresses the issue of spontaneous chiral symmetry breaking, achieving the needed sensitivity to the quark condensate [21].

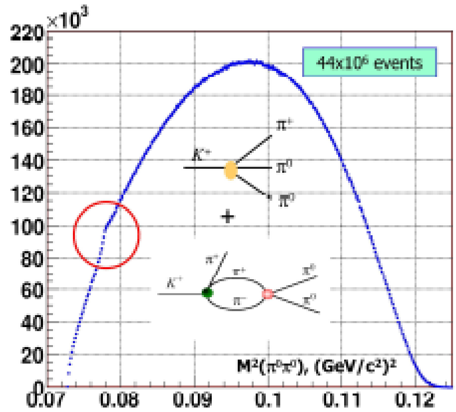

Figure 16: the cusp structure of the $\pi^0\pi^0$ invariant in $K^\pm \to \pi^\pm\pi^0\pi^0$ decay (2004 data).

The cusp effect is also visible in $K_L \to 3\ \pi^0$ data, as shown by KTeV for the first time. This evidence is in agreement with the NA48/2 results on $\pi\pi$ scattering lengths [72].Radiative kaon decays give informations on the structure of the weak interactions at low energies, being the γ in the final state well suited probes of the intrinsic dynamic of the process. A review of many recent and new results on non-leptonic radiative decays from the NA48/2 experiment at CERN was presented, providing crucial tests of ChPT at leading and next-to-leading orders [73].

KTeV searches for lepton-flavour violation in neutral kaon, through the experimental signature of the presence of a lepton pair μe in any kaon decay have been presented [74].

Precise measurements of fundamental quantities, among which the $\bar{K}^0 - K^0$ oscillation frequency, the K_S lifetime, the CP violating phase in $K^0 \to \pi\pi$ etc., have been done by KTeV with the regenerated K_S beam [70]. The precision test of the pseudoscalar structure of the π^0 meson is also addressed by KTeV thanks to the huge amount of π^0 available in their data statistics. A new evidence of the parity of π^0 is achieved with the analysis of the angular distribution of the 2 photons in double-Dalitz decays $\pi^0 \to \gamma\gamma \to e^+e^-\ e^+e^-$ with a much higher significance than the previous measurement, which was 46 years old [74]

The ratio $R_K = \Gamma(K^{\pm}_{e2})/\Gamma(K^{\pm}_{\mu 2})$ between the two leptonic decay rates of charged kaons is precisely predicted within the SM [75]. A recent theoretical work [76] noticed that SUSY extensions of the SM could induce muon-electron universality violation, thus shifting the R_K value to few percent with respect to the SM prediction. The present uncertainty on R_K is 1.3%, including recent measurements from NA48 and KLOE, as shown in the fit of the Flavianet Kaon Working Group, in Fig. 16 [18]. They found:

$$R_K = (2.457 \pm 0.032) \times 10^{-5}\ \mathrm{MeV}/c^2 \quad (\chi^2/\mathrm{d.o.f.}=2.44/3)$$

This measurement greatly improved the PDG value and is in good agreement with the SM [75].
A new precise measurement of R_K is expected from NA62, which in 2007-08 took dedicated data to achieve a 0.5% precision on the ratio. A sample of about 110000 K^+_{e2} decays has been collected and special runs have been dedicated to the study of the main sources of systematic effects [20]. The comparison of the experimental results with the Flavianet Kaon Working Group determination of R_K is given in Fig. 16 [18], showing the sensitivity to possible breaking of lepton-flavour symmetry. The final measurements by KLOE and NA62, based on the whole sample of data, will soon be available, hopefully allowing stringent tests of specific models beyond SM.

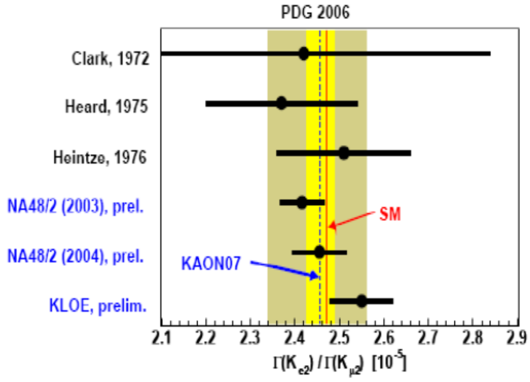

Figure 16: Flavianet measurement of R_K compared to the experimental results and the SM

5.2 Hyperons

The decays of hyperons are of particular interest as they are sensitive to sources of CP violation beyond SM to which kaons are not sensitive. This is especially important due to the fact that the amount of CP violation in weak interactions predicted by the SM is too small to account for the observed matter dominance. The latest measurements of CP violation search in the HyperCP experiment at Fermilab have been presented [77]

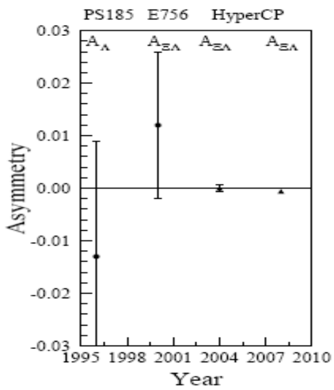

Figure 16: CP asymmetry measurements in Ξ and Λ hyperon decays [Mc]

The HyperCP Collaboration is searching for CP violation in charged hyperon decays by comparing the angular decay distributions of protons and antiprotons from $\Xi^- \to \Lambda\pi^-$, $\Lambda \to p\pi^-$ and $\bar{\Xi}^+ \to \bar{\Lambda}\pi^+$, $\bar{\Lambda} \to \bar{p}\pi^+$ decays. In HyperCP Ξ^- and $\bar{\Xi}^+$ are produced unpolarized. Any difference in the angular distribution of the final protons of the two decay chains would be evidence of CP violation in either the Ξ or the Λ decay, or both of them. The CP violating observable is the difference A_{CP} between the proton angular distributions. From the analysis of more than 10^9 Ξ^- and $\bar{\Xi}^+$ decays, a preliminary measurement of the CP observable gives:

$$A_{CP} = (-6.0 \pm 2.1(\text{stat}) \pm 2.0(\text{syst})) \times 10^{-4}$$

This result is consistent with the previous results and 40 times more precise of the best result from other experiments. Fig. 16 shows the improvement in hyperon CP asymmetry measurements over time.

5.3 Charm Physics

Although charm was discovered in e^+e^- collisions at SLAC and BNL and even open charm, i.e. D mesons, was first observed in e^+e^- experiments, many charm results come from fixed target experiments with hadron beams. The history of charm hadro-production experiments and the summary of their major physics achievements has been presented, based mainly on Fermilab projects, among which E791, FOCUS, SELEX [78]. Highlights include charm mixing, searches for CP violation and for rare decays, studies of semileptonic decays and charm baryons, as well as studies of charm production based on pioneering Dalitz-plot distribution analyses, used at that time by fixed target collaborations.

5.4 Muons

The MEG experiment at the Paul Sherrer Institute (PSI) has been designed to search for lepton-flavour violation in $\mu \to e\gamma$ decay [79]. It exploits the world most intense proton beam, available at the ring cyclotron of the PSI accelerator complex, used to produce a pure μ beam, well suited for the MEG purpose. The high performance detector and the experimental technique would improve by 2 order of magnitudes the current limit on $\mu \to e\gamma$ decay, thus allowing to measure possible branching fractions at the level of 10^{-13}. This precision would probe some new physics models predictions of branching fractions within the experimental reach of MEG. The experiment started running for physics in summer 2008, aiming at a limit comparable to the present best measurements with the analysis of the data taken on 2008. Results are expected soon.

6. Future Experiments

6.1 SuperB-Factories

Ambitious SuperB-Factories are being designed to possibly increase current luminosities by two orders of magnitude into the 10^{36} $cm^{-2}s^{-1}$ luminosity range and make possible the measurement of new physics flavour couplings in the LHC era. Their design is based on the excellent performance of PEPII and KEKB and on innovative schemes developed in order to avoid limitations due to high beam currents. Correspondingly, studies of the detector requirements and of the experimental techniques suited for the next generation B-Factories are also pursued [24] [25].

Given the large power consumption of upgrades based on a conventional approach, a new concept of bunch collision scheme, the so-called “crab waist” is being developed [25]. It combines extensions of the design of the current B-Factories, based on circular colliders, with new concepts of low emittance damping rings and strong focusing of final focus as developed for linear colliders and tested in the corresponding test facilities. This new scheme should allow the SuperB-Factory to reach a luminosity of 10^{36} $cm^{-2}s^{-1}$ without increasing beam currents, background rates and power consumption. This new scheme is presently being tested in DAΦNE and has already brought an improvement: a peak luminosity of 3.32×10^{32} has recently been measured with very stable beams; this might allow the extension of the physics program at the Frascati Φ-Factory, with an upgraded KLOE detector.

A doubling of the luminosity in Super KEKB is provided by the “crab crossing” in which the bunches encouter head-on even with beam trajectories crossing at an angle [24] . This scheme is presently being commissioned and tested on KEKB during the Belle data taking: the bunches are tilted with respect to their orbit by the special structure of the RF cavity (Crab cavity). Also in this case the crab crossing of the beams already improved the machine performances; luminosities higher than $2\times10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ are expected at KEKB, thanks to this technique.

Review of the physics reach of SuperB-Factories have been presented [24][25]. The major challenge for particle physics in the next decade is to go beyond the SM. The new generation of B-Factories rely on a prejudice: if there is new physics at the TeV scale it must have a flavour-CP structure. It then follows that the SuperB-Factories are particularly well suited to detect new effects in SM forbidden or suppressed processes. A statistics of $50\mathrm{ab}^{-1}$ of data, equivalent to about 10^9 $\bar{B}B$ pairs, is needed in order to reduce experimental errors below the theoretical uncertainty for the most sensitive analyses. SuperB-Factories also produce a huge number of charmed hadrons and τ leptons. This would allow sensitive searches for CP violation in D meson mixing, an effective probe of new physics, and studies of τ decays, in particular searches for lepton number violation, with an unprecedented sensitivity. Flavour observables accessible at SuperB-Factories are complementary to those available at LHC, i.e. the energy frontier. There is an unquestionable interplay between LHC and new generation B-Factories: the latter will measure new flavour parameters that cannot be studied at LHC if new physics will be discovered; however, if new physics will not appear, they would provide a powerful alternate to searches for new physics beyond the LHC scale. Physics reach is complementary to the LHC one: the next generation B-Factories would measure many rare decays not accessible at the LHC; they could address test of lepton-flavour violation in τ decays and would have the power to discriminate among different new physics models.

6.1 Future Kaon Experiments

A renewed interest in rare kaon decays appeared in the last years, focusing the attention to the rare decays $K\rightarrow\pi\,\bar{\nu}\nu$. These FCNC processes, the "golden decays" in the kaon sector, are theoretically very clean, since they are dominated by short-distance contributions. In particular, direct CP violating short-distance contributions dominate the $K_L^0\rightarrow\pi^0\,\bar{\nu}\nu$ mode. The accurate measurement of the branching fractions of the $K\rightarrow\pi\,\bar{\nu}\nu$ modes leads to the precise determination of the height and the side of the relevant UT in an independent way from the B meson measurements. The uncertainty on the theoretical calculation of the branching fractions is at the level of a few percent; improvements are expected thanks to NNLO calculations. The measurement also gives important information on physics beyond the SM, since any deviation would give rise to remarkable effects.

The status of future kaon experiments was presented at this conference [80]. Measuring $K\rightarrow\pi\,\bar{\nu}\nu$ events at the 10^{-10}-10^{-11} branching ratio level, set by the SM predictions, represents a significant experimental challenge. The poorly defined signal consists of a kaon followed by a pion, with no other observed particles. Potential backgrounds, primarily from other kaon decays at branching ratios 10 orders of magnitude higher, have similar signatures. Current experimental results on kaon golden modes are:

a. $BR(K^+\rightarrow\pi^+\,\bar{\nu}\nu) = 1.47_{-0.89}^{+1.30}\times10^{-10}$, based on 3 events measured by the E949 experiment at BNL, to be compared with the SM prediction of $(8.22\pm0.84)\times10^{-11}$.
b. $BR(K_L^0\rightarrow\pi^0\,\bar{\nu}\nu)<6.7\times10^{-8}$ at 90%CL, measured by the E391a experiment at KEK, to be compared with the SM prediction of $(2.76\pm0.40)\times10^{-11}$.

The E391a project is the first step toward a more ambitious experiment proposed at the J-PARC Facility in Japan, which aims to collect about 300 SM events in 3 years. The evolution of this concept depends on the results of the E391a pilot project and the availability of a neutral kaon beam line at J-PARC. Actual operation of E949 was prematurely stopped by DOE after one short run.

Many experiments aiming at the measurement of kaon golden decays have been proposed in the last years, with alternating fortunes.

The KAMI project at Fermilab was not approved, CKM proposal at Fermilab and Kopio proposal at BNL were canceled.

A new experiment NA62 at the CERN SPS [81] was proposed in 2005, aiming at the measurement of the rare decay $K^+\rightarrow\pi^+\,\bar{\nu}\nu$ [20].

A new intense charged K^+ beam, with an energy of 75 GeV and 1% spread in momentum, will produce 4×10^{12} K^+ decays per year (10^7 s). With new detectors and the existing NA48 LKr calorimeter, suitably upgraded, it will be possible to reduce the main background given by $K^+\rightarrow\pi^+\pi^0$ and $K^+\rightarrow\mu^+\nu$ events by a factor of at least 10^{12}, aiming at a signal to background ratio of 10/1. With the proposed detector, which takes advantage of the potential for incremental improvements in a well established technique, the acceptance for the decay $K^+\to\pi^+ \bar{\nu}\nu$ is about 10%. NA62 will collect about 80 events in two years of data taking, bringing to a precision on the measurement of the UT vertex comparable with that of the B sector, in a complementary way. The first phase of this experiment, approved in 2007, already took place, with the successful measurement of the ratio $R_K=\Gamma(K^{\pm}_{e2})/\Gamma(K^{\pm}_{\mu2})$ described above, which required improvements both of detector and beam line, increasing therefore confidence in the soundness of the experimental technique and in the feasibility of the second phase of the project. The R&D program for the final NA62 detector is completed. The approval of the experiment has been recently proposed by the referees of the relevant scientific committee at CERN. The scrutiny will follow in the next few months, hopefully giving soon a positive answer and therefore green light to the construction of the final detector in order to fulfil the expected physics program.

Using the International Linear Collider technology being developed at Fermilab, an intensity-frontier accelerator at about one percent of the ILC's length will be built and combined with existing Fermilab accelerators to create Project X [80]. The complex makes use of the Fermilab proton beam available at the booster, upgraded with an 8 GeV linac operating with ILC-like parameters, in order to increase the beam power by a factor of 10. Correspondingly, the high intensity proton source is expected to deliver 2.25×10^{14} protons per 1.4 s cycle, about 10 times higher than for the existing Booster. The main purpose of the Project X's intense proton beams is the improvement of neutrino physics experiments at the Main Injector. Precision measurements of the kaon golden decays, together with the measurements of the μ-e conversion process and of the anomalous muon magnetic moment g–2, were proposed to make use of the excess of 8 GeV protons. Due to budget restrictions, the kaon physics program is not currently on the high priority list for Project-X at Fermilab. However, in a growing budget scenario, a kaon program could start soon.

6.3 Future Charm Experiments

A new generation experiment addressing the issue of charm hadroproduction at fixed target hadron beams, to be possibly installed at the Tevatron, is under study [82]. A broad charm physics program would be available at a future fixed target Tevatron experiment, using already the existing beam lines. Very large samples of D* mesons, decaying through $D^{*+}\to D^0\pi^+$, $D^0\to K^+\pi^-$ and charge-conjugate modes, would be available, at statistics order of magnitudes larger than those of the previous Fermilab FOCUS and E791 experiments. This would allow the determination of tiny effects in the decay time distribution of double Cabibbo-suppressed $D^0\to K^+\pi^-$ decay, sensitive to the $\bar{D}^0$–D^0 mixing parameters x and y and to CP violation. The newly designed experimental apparatus will profit from the now well established technological improvements in vertex detectors, which are based on the use of silicon strips and pixels, and of trigger concepts, based on the reconstruction of separated vertices, as developed by HERA-B, CDF, BTeV and LHCb for b triggering.

A study of the performance of the new experiment, focused on the analysis of $\bar{D}^0$–D^0 mixing and CP violation in $D^0\to K^+\pi^-$, $K^-\pi^+$ decays, is described in [84]. The expected signal for the analysis of CP violation effects in $D^0\to K^+\pi^-$, $K^-\pi^+$ decays is obtained by scaling the yields of fixed target experiments (E791 at Fermilab and HERA-B at DESY) whose center-of-mass energy and detector geometry are compatible with those of the future Tevatron experiment. The new experiment appears to have better sensitivity to mixing and CP violation than the whole Belle and Babar actual statistics. The Tevatron data should have less background than LHCb data. Systematic uncertainties may also be reduced with respect to those of the B-Factory experiments and LHCb.

A working group has been recently formed to investigate the physics potential of a future fixed target charm experiment at the Tevatron in more detail [83].

7. Conclusions and outlook

"The Standard Model of fundamental interactions is remarkably successful, but leaves an unfinished agenda. Several major questions seem ripe for exploration in the near future. I anticipate that the coming decade will be a Golden Age of discovery in fundamental physics" (F. Wilczek)[84].

There are two independent ways of exploiting frontier research in particle physics: one is the high energy challenge, to access observables directly, the other is the indirect way of the high precision measurements of rare processes. Both the precision and the high energy experimental programs have to

be considered within a coherent common effort in addressing the study of flavour physics. The two methods, in fact, are essential for a comprehensive investigation of fundamental interactions from different perspectives in complementary way.
LHC will soon start taking data; new experiments at high intensity beams, addressing the issue of precision measurement of rare processes in the heavy flavour sector, are either taking data or have been proposed in several laboratories all around the world. In many respects, the time is ripe to finally disturb the Universe with the established evidence of new physics beyond SM. The hope is that it will happen soon.

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References

1. UTfit Collaboration, http://www.utfit.org/
2. CKMfitter Collab., http://ckmfitter.in2p3.fr/
3. C. Smith, paper presented at this conference; see also FlaviaNET Coll., http://ific.uv.es/flavianet/
4. G. Isidori, arXiv:0801.3039 [hep-ph]
5. E. Gamiz, paper presented at this conference
6. E. Lunghi, paper presented at this conference; E. Lunghi, A. Soni, arXiv:0803.4340 [hep-ph]
7. W. Min-Zu, paper presented at this conference
8. K. Suzuki, paper presented at this conference
9. Q. He, paper presented at this conference
10. M. Bona et al., arXiv:0803.0659 [hep-ph]
11. Heavy Flavour Averaging Group, E. Barberio et al, arXiv:0808.1297v1 [hep-ex], http://www.slac.stanford.edu/xorg/hfag/
12. H.W. Lin, paper presented at this conference
13. C. Carlson, paper presented at this conference
14. J. Lee et al., paper presented at this conference
15. R. Hill, paper presented at this conference
16. M. Karliner, paper presented at this conference
17. H. E.Fisk, paper presented at this conference
18. E. Passemar, paper presented at this conference
19. T. Spadaro, paper presented at this conference
20. G. Saracino, paper presented at this conference
21. B. Peyaud, paper presented at this conference
22. D. Kessler, paper presented at this conference
23. D. A. Jensen, paper presented at this conference
24. K. Kinoshita, paper presented at this conference: Prospects for upgrade of KEKB
25. D. Hitlin, paper presented at this conference
26. S.-W. Lin et al. (Belle Collaboration), Nature 452, 332 (2008)
27. B. Aubert et al. (BaBar Collaboration), Phys. Rev. D78, 012004 (2008)
28. Y. Y. Gao, paper presented at this conference
29. D. N. Brown, paper presented at this conference
30. K. Kinoshita, paper presented at this conference: Improved measurement of inclusive radiative B decays
31. A. Limosani et al. (Belle Collaboration) arXiv:0804.1580v1 [hep-ex]
32. M. Misiak et al., Phys. Rev. Lett. 98, 022002 (2007), hep-ph/0609232
33. F. Martinez-Vidal: paper presented at this conference.
34. P. Grenier (BaBar Collaboration) arXiv:0809.1672v1 [hep-ex]
35. D.N. Brown, paper presented at this conference
36. B. Aubert et al. (BaBar Collaboration) arXiv:0805.0497v2 [hep-ex]
37. V. Santoro, paper presented at this conference
38. B.D. Yabsley, paper presented at this conference
39. B. Aubert et al. (BaBar Collaboration) Phys. Rev. Lett. 98, 211802 (2007)
40. M. Staric et al. (Belle Collaboration), Phys. Rev. Lett. 98, 211803 (2007).
41. T. Aaltonen et al. (CDF Collaboration), Phys. Rev. Lett. 100, 121802 (2008).
42. S. Dobbs et al. (CLEO Collaboration) arXiv:0709.3783v2 [hep-ex]
43. The Particle Data Group: http://pdg.lbl.gov/
44. J. Alexander et al. (CLEO Collaboration) arXiv:0801.0680v2 [hep-ex]
45. B. I. Eisenstein et al. (CLEO Collaboration) arXiv:0806.2112v3 [hep-ex]
46. K. M. Ecklund et al. (CLEO Collaboration) arXiv:0712.1175v2 [hep-ex]
47. Jonathan L. Rosner, Sheldon Stone, arXiv:0802.1043v3 [hep-ex]
48. F. Ambrosino et al. (KLOE Collaboration) arXiv:0802.3009v1 [hep-ex]
49. G. Giurgiu, paper presented at this conference
50. T. Aaltonen et al. (CDF Collaboration), Phys. Rev. Lett. 100 (2008) 182002 arXiv:0712.1506v1 [hep-ex]
51. V. M. Abazov et al. (D0 Collaboration), Phys. Rev. Lett. 101, 012001 (2008) arXiv:0802.4258v1 [hep-ex]

52.http://wwwcdf.fnal.gov/physics/new/bottom/080327.blessed-BC LT SemiLeptonic/ arXiv:0805.2614v1 [hep-ex]
53. V. M. Abazov et al. (D0 Collaboration), arXiv:0805.2614v1 [hep-ex]
54. A. Abulencia et al. (CDF Collaboration), Phys. Rev. Lett. 97 (2006) 242003[hep-ex/0609040].
55. G.A. Garcia-Guerra, paper presented at this conference
56. V. M. Abazov et al. (D0 Collaboration), arXiv:0802.2255v1 [hep-ex]
57. T. Aaltonen et al. (CDF Collaboration), Phys. Rev. Lett. 100, 121802 (2008) arXiv:0712.2397v1 [hep-ex]
58. The TOTEM Collaboration, G Anelli *et al*, "*The TOTEM Experiment at the CERN Large Hadron Collider"* , 2008 JINST **3** S08007
59. The LHCf Collaboration, O Adriani *et al*, The LHCf detector at the CERN Large Hadron Collider 2008 JINST **3** S08006
60. Erez Etzion, paper presented at this conference
61. E. De La Cruz Burelo, paper presented at this conference
62. A. Smith, paper presented at this conference
63. K.A.Ulmer, paper presented at this conference
64. S. T'Jampens, paper presented at this conference
65. J. Albrecht, paper presented at this conference
66. C. Brock, paper presented at this conference
67. D. Ozerov, paper presented at this conference
68. J. H. Christenson et al., Phys. Rev. Lett. 13, 138 (1964).
69. H. Burkhardt et al. (NA31 Collaboration), Phys. Lett. B 206 , 169 (1988).
70. A. Alavi-Harati et al. (KTeV Collabor.), Phys. Rev. Lett. 83 , 22 (1999).
71. V. Fanti et al. (NA48 Collaboration), Phys. Lett. B 465 , 335 (1999).
72. D. Kessler, paper presented at this conference
73. C. Lazzeroni, paper presented at this conference
74. M. Akashi-Ronquest, paper presented at this conference
75. V. Cirigliano, I Rosell JHEP 0710:005 (2007) arXiv:0707:4464
76. A. Masiero, P. Paradisi, R. Petronzio PRD74 (2006) 011701
77. C. Materniak, this proceedings
78. M. V. Purhoit, paper presented at this conference
79. S. Dussoni, paper presented at this conference
80. Jensen D. A., paper presented at this conference
81 G. Anelli *et al.* [P326 Collaboration], CERN Report *CERN/SPSC 2005-013* (2005).
82. A. J. Schwartz, paper presented at this conference
83. http://www.nevis.columbia.edu/twiki/bin/view/FutureTev/WebHome.
84. F. Wilczek: *"Anticipating a New Golden Age",* arXiv:0708.4236v3 [hep-ph]