arXiv:hep-ph/0011265v2 30 Nov 2000

Hyperons, Charm and Beauty Hadrons: Conclusion and Outlook

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In this concluding talk, the advances in the Flavour Problem studies are discussed, following the structure of the presentations in the Conference. The subjects touched are organized as follows: Baryons, K-physics, Charm and Beauty production, Charm and Beauty decays, B-Mixing and CP-Violation, Heavy Quarkonium.

1. Introduction.

The subjects presented in the Conference [1] have in common their contribution to the understanding of the Flavour Problem "from below", i.e., from detailed studies of the structures, regularities and differences among the flavoured hadrons. In this edition, many new interesting results have been presented and my discussion will be necessarily limited in scope. I apologize for the omissions or simplifications in the conclusions given here.

The quarks carry (among other properties) the flavour quantum number conserved by strong and electroweak neutral current interactions to leading order. They are organized in three families which appear as replicas. Besides the anthropic statement that three families is the minimum number able to build a Universe with the prospect of being understood by humans through science, we do not have still an explanation for the mistery of this replication. Except for weak charged current interactions, the other fundamental forces are unable to connect the families each other. In the Standard Model, the CKM Mixing Matrix gives account of this problem according to the scheme in Fig. 1. The second mistery in the Flavour Problem is the hierarchy of mixings, with intensities of order λ, λ^2, λ^3 for the transitions shown in the Fig. 1. In the step from quarks to hadrons, however, the different quark masses provide an essential difference between the structure of light hadrons (u, d and s) and that of heavy systems (c, b and t). The plan of this contribution is as follows. In Section 2, we discuss Baryons, with some emphasis on Hyperons. Section 3 is devoted to K-physics, with the highlight of the last two years: KTeV and NA48 confirm the $3.5\,\sigma$ NA31 result of direct CP-violation. In Section 4, charm and beauty production, the study of the fragmentation function provides the link between quarks and hadrons. Section 5 discusses charm and beauty decays, including semileptonic, purely leptonic, hadronic and rare decays. The problem of B (and D) Mixing and CP Violation is presented in Section 6, with the novel results of BaBar at PEP-II and Belle at KEK B. Heavy Quarkonium is discussed in Section 7. Finally, Section 8 gives some Outlook.

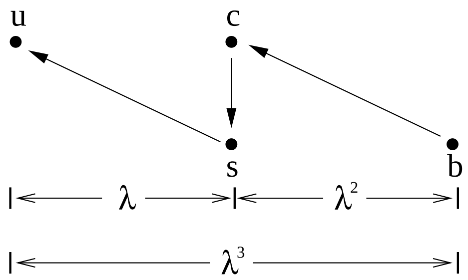

Figure 1. CKM Mixing Matrix scheme.

Table 1
Comparison between the predicted and experimental values of the inclusive semileptonic widths of Λ_c and Λ_b.

$\mathrm{BR}_{SL}(\%)$	Model	Experiment
Λ_c	5.5	4.5 ± 1.7
Λ_b	10.7	$9^{+\ 3.1}_{-\ 3.8}$

2. Baryons.

The study of semileptonic decays of heavy baryons has been addressed [2] in a consistent quark model describing baryons. A single set of parameters is used for the whole spectra and the resulting structure is tested with decays. The investigation of inclusive semileptonic Λ_b decays can provide information on the CKM matrix elements V_{cb} and V_{ub}, as well as on the structure of Λ_b. The approach is that of a potential model with physical values of the couplings. The sum over final hadronic states is treated by means of duality. The predicted value of the inclusive semileptonic widths of Λ_c and Λ_b are confronted to the experiment [3] in Table 1, where the branching ratios are given.

The exclusive/inclusive ratio R_E of semileptonic $\Lambda_b \to \Lambda_c$ decay has been compared with the corresponding ratio for the meson $B \to D + D^*$, with the conclusion [4] that it should be larger. One needs the slope parameter ρ_B^2 of the Isgur-Wise form factor $F_B(\omega)$ in $\Lambda_b \to \Lambda_c\, l\, \nu$

$$F_B(\omega) \,=\, 1 \,-\, \rho_B^2\,(\omega - 1) \,+\, c\,(\omega - 1)^2 \,+\, \cdots \quad (1)$$

and an upper bound is taken from the spectator quark model limit

$$\rho_B^2 \,\leq\, 2\,\rho_M^2 \,-\, \frac{1}{2} \qquad (2)$$

with the experimental value [3] $\rho_M^2 \,=\, 0.70 \pm 0.10$. From QCD sum rules, $0.65 \leq \rho_B^2 \leq 0.85$, and one finds a ratio

$$0.81 \,\leq\, R_E(\text{baryon}) \,\leq\, 0.92$$

to be compared with $R_E(\text{meson}) = 66\%$.

Table 2
Comparison between the predicted and experimental values of the b hadron lifetime ratios.

	Experiment	Theory
$\frac{\tau(B^+)}{\tau(B_d)}$	1.065 ± 0.023	$1 + 0.05 \left(\frac{f_B}{200\,\mathrm{MeV}}\right)^2$
$\frac{\tau(B_s)}{\tau(B_d)}$	0.937 ± 0.040	1 ± 0.01
$\frac{\tau(\text{b baryon})}{\tau(B_d)}$	0.773 ± 0.036	0.9

The exclusive process $\Lambda_b \,\to\, \Lambda_c\, l\, \nu_l$ has been experimentally searched by DELPHI Collaboration [5], with the analysis addressed to measure the slope parameter ρ_B^2 of the form factor (1). With appropiate cuts in p_l and $p_\perp$, the invariant masses $M(\Lambda_c\, e)$, $M(\Lambda_c\, \mu)$, a candidate is taken as the sign of l opposite to that of Λ_c. They find 57 ± 8 events and the measure of the slope parameter gives

$$\rho_B^2 \,=\, 1.6 \,\pm\, 0.6\,(\text{sta}) \,\pm\, 0.6\,(\text{syst}) \qquad (3)$$

when the absolute event rate is included in the fit.

A review on the b hadron lifetimes was presented [6] by Wasserbaech, ALEPH Coll. Recent measurements from LEP, SLD and CDF indicate that we have still a problem with the lifetime of Λ_b. From the theoretical side, the measurement of the individual lifetimes of B^+, B_d, B_s and Λ_b yields information about nonspectator mechanisms. The experimental results for the lifetime ratios are given in Table 2, together with the theoretical predictions from QCD-based Heavy Quark expansions.

A theoretical study [7] of the lifetime problem in the light-front quark model suggests that the Fermi motion of the b quark inside Λ_b can produce a reduction of about $12 \pm 2\%$, accounting for a significant fraction of the discrepancy.

The measurement of the ratio of meson lifetimes has also been considered recently [8] by SLD, with the result $\tau(B^+)/\tau(B_d) = 1.037 \pm 0.04$, to be compared with the value in Table 2.

The Hyperon Working Group of the KTeV Collaboration at Fermilab has studied [9] the Ξ^0 beta decay branching ratio

$$\begin{aligned} \Xi^0 \longrightarrow \quad & \Sigma^+ \quad + e^- + \bar{\nu}_e \\ & \hookrightarrow \quad p + \pi^0 \end{aligned} \tag{4}$$

with a signal of 626 ± 25 events and a background of 45 ± 18 events. The process is described by the hadronic vertex of Fig. 2 with 6 form factors, 3 vector and 3 axial. The pseudotensor (or weak electricity) form factor cannot be generated in the standard model with quark constituents. The scalar and pseudoscalar form factors give contributions proportional to the electron mass and thus negligible. This argument is not valid for muons. The Collaboration aims for the extraction of the three forms: vector, magnetic and axial, for Ξ^0 beta decay with 2000 events. The present result for the branching ratio is

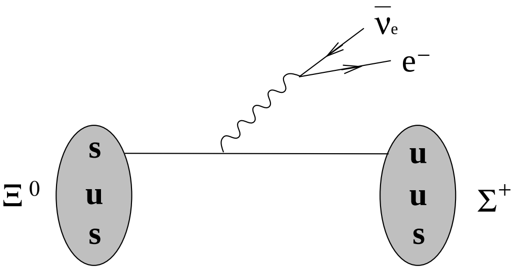

Figure 2. Hadronic vertex for $\Xi^0 \to \Sigma^+ \, e^- \, \bar{\nu}_e$.

$$BR(e) = (\, 2.60 \pm \, 0.11 \, \pm \, 0.16 \,) \, \times \, 10^{-4} \tag{5}$$

to be compared to the theoretical $SU(3)_f$ predicted value $(2.61 \pm 0.11) \times 10^{-4}$. In the CM of Σ^+, and using the 98% analyzing power of $\Sigma^+ \to p \, \pi^0$, the angular correlation between p and e^- is the decay asymmetry. For the muonic channel, with a few events, the measured branching ratio is

$$BR(\mu) = (\, 3.5 {}^{+}_{-} \;\; {}^{2}_{1} {}^{+}_{-} \;\; {}^{0.5}_{\;\;1}) \, \times \, 10^{-6} \tag{6}$$

The KTeV Hyperon Program also includes the measurement [10] of the Hyperon Radiative Decays. The 1997 run has emphasized the channel $\Xi^0 \to \Sigma^0 + \gamma$, with a preliminary result $B.R. = (3.34 \pm 0.12) \times 10^{-3}$. To obtain the asymmetry parameter, one must study a three stage process:

$$\Xi^0 \to \Sigma^0 + \gamma \, , \, \Sigma^0 \to \Lambda + \gamma \, , \, \Lambda \to p + \pi^- \tag{7}$$

The detected particles are p,π from the Λ decay, a γ from the Σ^0 decay and a γ from the Ξ^0 decay. The present value for the asymmetry is

$$\alpha = -0.65 \pm 0.13 \tag{8}$$

More data is expected from the 1999 run.

The theoretical studies of $\Xi^0 \to \Sigma^0 \gamma$ are based on the quark diagrams in Fig. 3 corresponding to the penguin diagrams ($s \to d$ FCNC transition) plus the exchange diagram. The last amplitude occurs for hyperons containing a u-quark.

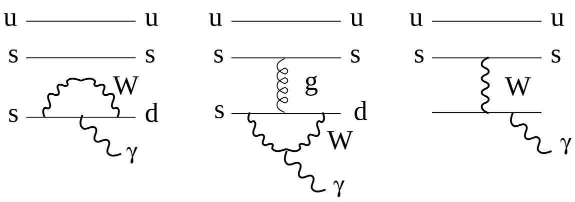

Figure 3. Quark diagrams for $\Xi^0 \to \Sigma^0 \, \gamma$.

The radiative Ξ^0 decays, in the modes $\Xi^0 \to \Lambda \, \gamma$ and $\Xi^0 \to \Sigma^0 \, \gamma$, have also been considered by the NA48 Collaboration [11]. NA48, designed to measure ϵ'/ϵ, has two beam lines to generate K_S and K_L simultaneously and obtains the neutral hyperons from the K_S-Target. The results from 1997 Data are, in units of 10^{-3},

$$\begin{aligned} BR(\Xi^0 \to \Lambda\gamma) &= (1.9 \pm 0.34 \pm 0.19) \\ BR(\Xi^0 \to \Sigma^0\gamma) &= (3.14 \pm 0.76 \pm 0.32) \end{aligned} \tag{9}$$

They can be measured with ∼ 5% accuracy. In 2002, the high intensity K_S run will produce a statistical gain by a factor of at least ∼ 100.

NA48 has also found about 60 events of the semileptonic Beta Decay of Ξ^0.

The future NA48 programs for K_S and Hyperon rare decays have been discussed by Fantechi [12], in competition with KLOE and KTeV, respectively. A novelty is the aim to look for direct CP violation by means of an asymmetry in the Dalitz plot density of the three-body decays $K^\pm \to \pi^\pm\pi^+\pi^-$ and $K^\pm \to \pi^\pm\pi^0\pi^0$. Sensitivities of the order 10^{-4} are envisaged for the later phase.

An exotic role of the hyperons in Astrophysics has been presented by Miralles [13]. The presence of hyperons allows a scenario in which a proto-neutron star is formed and emits neutrinos during tens of seconds. After deleptonization, it collapses to a black hole. This mechanism can be invoked to explain the lack of a neutron star remnant in the SN1987A and the detection of neutrinos from the supernova explosion.

3. K-physics.

The present world average for ϵ'/ϵ has been discussed [14] by Unal, from the NA48 Collaboration. With the results of the last two years, KTeV and NA48 have confirmed the original 3.5σ finding by NA31 of direct CP-violation in the $K^0-\bar{K}^0$ system. With indirect CP-violation, i.e., in the $\Delta S = 2$ mixing, established since 1964, the mass eigenstates $K_{S,L}$ are not pure CP eigenstates ($K_\pm$):

$$\begin{aligned} K_S &\approx K_+ + \epsilon\, K_- \\ K_L &\approx K_- + \epsilon\, K_+ \end{aligned} \qquad (10)$$

where $|\epsilon| = (2.28 \pm 0.02) \times 10^{-3}$.

To generate Direct CP-violation, i.e., in the decay amplitude $|A(K^0 \to f\bar{f})| \neq |A(\bar{K}^0 \to f\bar{f})|$, one needs the interference of two decay amplitudes. The final state of two pions has contributions from isospin $I = 0$ and $I = 2$, A_0 and A_2. The imaginary part of the interference generated by weak CP phases (besides the strong phases) leads to the ϵ' parameter

$$\epsilon' = \frac{i}{\sqrt{2}}\,\mathrm{Im}\left(\frac{A_2}{A_0}\right) e^{i(\delta_2-\delta_0)} \qquad (11)$$

The ratio of amplitudes from K_L and K_S has contributions from ϵ and ϵ'

$$\begin{aligned} \frac{A(K_L \to \pi^+\pi^-)}{A(K_S \to \pi^+\pi^-)} &\equiv \eta^{+-} = \epsilon + \epsilon' \\ \frac{A(K_L \to \pi^0\pi^0)}{A(K_S \to \pi^0\pi^0)} &\equiv \eta^{00} = \epsilon - 2\epsilon' \end{aligned} \qquad (12)$$

In order to separate ϵ' experimentally, one considers the ratio of ratios of decay rates

$$\begin{aligned} R &= \frac{\Gamma(K_L \to \pi^0\pi^0)\,\Gamma(K_S \to \pi^+\pi^-)}{\Gamma(K_S \to \pi^0\pi^0)\,\Gamma(K_L \to \pi^+\pi^-)} \\ &= 1 - 6\,\mathrm{Re}\left(\frac{\epsilon'}{\epsilon}\right) \end{aligned} \qquad (13)$$

To establish Direct CP Violation, one needs $R \neq 1$.

In the standard model, ϵ is generated from the box diagram whereas ϵ' gets its dominant value from gluonic and electroweak penguin diagrams.

The experimental situation is pictured in the Figure 4.

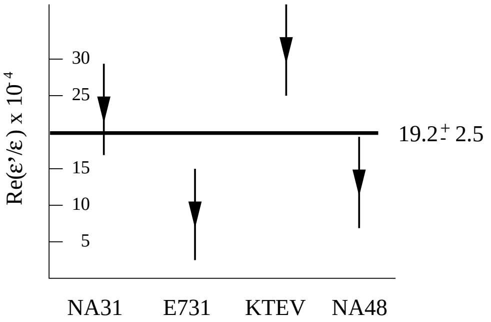

Figure 4. Experimental measurements of ϵ'/ϵ.

One realizes from the world average value that $\epsilon'/\epsilon \neq 0$ is well established, but the actual value is probably not. As illustrated in Figure 4, the χ^2 is poor. More results from NA48, KTeV and KLOE, which uses a different method, will clarify the experimental situation.

The establishment of Direct CP-violation tells us that a superweak [15] explanation is ruled out, and that the K-system needs a milliweak model to describe CP violation. In the standard model, this description is understood in terms of the relative magnitudes of the sides of the unitary triangle, shown in Fig 5. The CP-asymmetries are

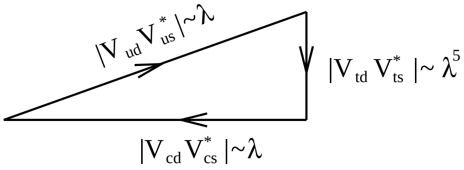

Figure 5. The (sd) unitarity triangle.

thus expected to be of order λ^4.

The calculation of the two isospin amplitudes $A_{0,2}$ makes use of the $\Delta S = 1$ effective hamiltonian, which leads to four-quark operators of the current-current form $(Q_{1,2})$, QCD penguin $(Q_{3\to 6})$ and electroweak penguin $(Q_{7\to 10})$ diagrams. In conventional notation, Q_6 and Q_8 are most important, but their matrix elements have opposite signs. Possible cancellations are thus a potential danger in the theoretical calculations. In fact, $\mathrm{Im}\, A_0$ is dominated by Q_6 whereas $\mathrm{Im}\, A_2$ is dominated by Q_8.

It is well known that, around 500 MeV, the $\pi\pi$ interaction is very strong in the scalar-isoscalar channel. The role of final state interactions is thus very important [16] for the A_0-amplitude. What is a subject of debate [17] is whether the dispersive computation has enough reliability. This is a difficult problem, but the Omnès resummation of chiral logarithms [16] gives a 50% enhancement. In this case, A_0 and thus Q_6, is the primary problem. This leads to an estimate $\epsilon'/\epsilon = (15\pm 5)\times 10^{-4}$, compatible with the present experimental value.

Models of low energy dynamics point towards a connection between the $\Delta I = 1/2$ rule and a "large" ϵ'/ϵ. Lattice QCD simulations will tell us whether this suggestion has a firm ground.

A review on the final CPLEAR results on CP, T and CPT in the neutral kaon system was presented by Zavrtanik [18]. For the 2π decay channel, this experiment has observed for the first time a difference in the time dependence of the K^0 and $\bar{K}^0$ decay rates. CP violation implies T violation or CPT violation or both. Is T-violated? CPLEAR has measured the Kabir asymmetry [19], by comparing $K^0 \to \bar{K}^0$ versus $\bar{K}^0 \to K^0$. The flavour tag at the production time is defined by the charged kaon $p\bar{p} \to K^-\pi^+K^0$, $K^+\pi^-\bar{K}^0$. The strangeness of the neutral kaon at the decay time is defined by the lepton charge in the semileptonic decay $(\Delta S = \Delta Q)$. The Kabir asymmetry is a genuine T-violating observable, which needs both T-violation and $\Delta\Gamma \neq 0$. This method works thus for neutral kaons, due to the difference in K_S and K_L lifetimes. CPLEAR results are compatible with equal CP and T violations and CPT invariance.

4. Charm and Beauty production

In the production of heavy hadrons, the fragmentation function [20] is the link between the heavy quark and the heavy hadron. It is parametrized by the probability $f(z)$ that a hadron shares a fraction z of the quark momentum

$$z = \frac{(E + p_{\|})_H}{(E + p)_Q} \qquad (14)$$

The problem with the variable z is the denominator, which refers to the quark before fragmentation, so that z is not accessible on a event-by-event basis. New variables which are experimentally accessible are defined as the hadron energy with respect to the beam energy

$$x_E \equiv \frac{E_H}{E_{beam}} \qquad (15)$$

There are recent results on $\langle x_B \rangle$ for the B meson from ALEPH, DELPHI, OPAL and from SLD, with values for the leading B energy ranging from 0.72 → 0.74. The methodology follows different strategies, and still one has to understand the consistency of the different analyses. At SLD, the polarization of the electron beam is used to tag b-quarks with 100% efficiency [8]. The reconstruction of the secondary vertex by exploiting the kinematics leads to a measurement of the mean energy of weakly-decaying B hadrons, with a value $\langle x_B \rangle = 0.714 \pm 0.009$.

The SELEX experiment [21] emphasizes the understanding of charm production in the forward hemisphere. QCD factorization predicts that heavy quarks hadronize through jet fragmentation functions independently of the initial state. The experimental data show that the produced charm (anticharm) quark combines with a projectile valence quark. Λ_c^+ is a leading particle when produced by the 3 beams π^-, p, Σ^-. The Λ_c hadroproduction has a hard x_F distribution. There is a strong production asymmetry in favour of Λ_c^+ over Λ_c^- for baryon beams. It is less strong for a π^- beam.

5. Charm and Beauty decays

The semileptonic b-decay studies have the double objective of the understanding of the dynamics of heavy quark decays plus the extraction of the CKM coupling constants V_{cb}, V_{ub}. The inclusive $BR(b)_{SL}$ has been discussed by Margoni [22], with different strategies of b-lifetime and lepton tags exploited at LEP. For the first time, DELPHI has explicitly separated by direct measurement $BR(b \to \bar{c} \to l^-)$. At present the analyses to extract V_{cb} are mainly limited by theory ($b \to l$, $b \to c \to l$ decay models). The most precise determination in the OPE approach to analyze the LEP data gives

$$\begin{aligned} |V_{cb}|^{\text{incl}}_{\text{LEP}} &= (\,40.76 \pm 0.41\,(\text{exp.}) \\ &\pm \; 2.04\,(\text{theo})\,) \times 10^{-3} \end{aligned} \tag{16}$$

The alternative to the inclusive decay is the study of the exclusive $B^0 \to D^*\,l\,\nu$ decay as a function of the D^* recoil

$$\frac{d\Gamma}{d\omega} \,=\, K(\omega)\,F^2(\omega)\,|V_{cb}|^2 \tag{17}$$

where $K(\omega)$ is a phase space factor and $F(\omega)$ is the Isgur-Wise form factor, for which the heavy-quark-effective-theory value for no recoil $\omega = 1$ is estimated. The problem is that, due to $K(\omega)$, the decay rate vanishes at $\omega = 1$. The procedure is thus the measurement of $\frac{d\Gamma}{d\omega}$ to fit it and extrapolate to $\omega = 1$ to obtain $F(1)\,|V_{cb}|$. These measurements at LEP have been presented by Terem [23]. There is a problem with $b \to D^{**}\,l\,\nu$, followed by $D^{**} \to D^{*+}\,X$, which is an important systematic effect. ALEPH and DELPHI fit to D^* and D^{**} contributions gives

$$\begin{aligned} &\text{Br}(B^- \to D^{**0}\left(\to D^{*+}\pi^-\right)\,l\,\nu) \\ &\;=\; (\,1.24 \pm 0.19 \pm 0.04\,)\,\% \end{aligned} \tag{18}$$

The LEP average for the exclusive analysis gives $|F(1)V_{cb}| = (34.9 \pm 1.7) \times 10^{-3}$, with higher experimental error than (16) due to small samples, but much cleaner theoretical approach.

The determinations of V_{ub} can come from either the exclusive $B \to \pi, \rho\,l\,\nu$ decays, where the main limitation is statistics or the inclusive lepton endpoint analysis, above the process $b \to c\,l\,\nu$. This method, limited by theoretical uncertainties, extracts [24] a measurement of the branching ratio for inclusive charmless semi-leptonic b decays

$$\text{Br}(b \to X_u\,l\,\nu) \,=\, (\,1.67 \pm 0.60\,) \times 10^{-3} \tag{19}$$

from ALEPH, DELPHI and L3 at LEP. The LEP average for the V_{ub} value derived using HQET is

$$|V_{ub}| \,=\, \left(4.04\,^{+0.62}_{-0.74}\right) \times 10^{-3} \tag{20}$$

ALEPH takes 4 million $e^+\,e^- \to Z \to q\,\bar{q}$ events to measure [25] the branching fractions for $D_s \to \tau\,\nu$ ($\tau \to e\,\nu\bar{\nu}$ or $\tau \to \mu\,\nu\,\bar{\nu}$) and $D_s \to \mu\,\nu$. Due to chirality suppression in the pseudoscalar decay of Fig. 6 the $D_s \to e\,\nu$ decay is not accessible. The two leptonic τ decay channels, which give consistent signals, measure

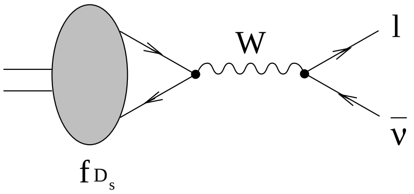

Figure 6. Pseudoscalar decay $D_s \to l\,\bar{\nu}$.

$$\text{Br}(D_s \to \tau\,\nu) \,=\, (\,5.79 \pm 0.76 \pm 1.78\,)\% \tag{21}$$

whereas the $D_s \to \mu\,\nu$ analysis gives

$$\mathrm{Br}(D_s \to \mu\,\nu) \;=\; (\,0.68 \pm 0.11 \pm 0.18\,)\% \qquad (22)$$

The two results (21) and (22) are consistent with the chirality suppression and phase space factors $m_l^2\,\left(1 - \frac{m_l^2}{M_{D_s}^2}\right)^2$ and provide a proof of leptonic universality in charged current decays. Combinig them, one gets for the decay constant

$$f_{D_s} \;=\; (\,285 \pm 20 \pm 40\,)\,\mathrm{MeV} \qquad (23)$$

which can be used to check the validity of its prediction by different theoretical models. Lattice QCD predicts a value $240^{+\;30}_{-\;25}$ MeV.

Hadronic decays $B^* \to B\,\pi$, $D^* \to D\,\pi$ allow [26] the extraction of the physical coupling

$$\begin{aligned} \langle B^0(p)\,\pi^+(q)|B^{*+}(p')\rangle \;&=\; g_{B^*B\pi}(q^2)\,\epsilon^\mu\,q_\mu \quad (24)\\ g_B \;&=\; \lim_{q^2 \to m_\pi^2} g_{B^*B\pi}(q^2) \end{aligned}$$

and analogously for the $D^*\,D$ transition. These form factors have been obtained theoretically from QCD sum rules [27]. They cannot be described by a monopole function. Two different methods give consistent results and one gets for the coupling constants

$$g_D \;=\; 5.7 \pm 0.4 \qquad , \qquad g_B \;=\; 14.5 \pm 3.9 \qquad (25)$$

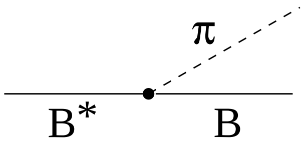

Figure 7. Vertex B^*-B-π.

The excited states of D, D_s, B and B_s mesons have been studied [28] in the framework of the relativistic heavy chiral quark model, with the determination of spectrum and wavefunctions. The $1/m_h$-effects are relevant for the calculation of the decay amplitudes of $B^{**} \to B + \eta$, π and K. Decay channels of B^{**} are useful for flavour tagging in particle detectors.

The decays D^+, $D_s^+ \to \pi^-\pi^+\pi^+$ were studied experimentally by the E791 Collaboration [29], at Fermilab fixed target programme. The experiment runs for 500 GeV π^--nucleon interactions and the signals yield (1240 ± 51) D^+ events and (858 ± 49) D_s^+ events. Besides the branching ratios, a detailed analysis of the Dalitz plots has been perfomed. The invariant mass $M^2_{\pi^+\pi^-}$ distribution for $D_s^+ \to \pi^-\pi^+\pi^+$ is completely dominated by $f_0(980)$ and $f_0(1370)$, as shown in the Fig. 8, with a negligible non-resonant contribution. The behaviour of the $M^2_{\pi^+\pi^-}$ distribution for $D^+ \to \pi^-\pi^+\pi^+$ is however completely different, with a dominant non-resonant contribution shown in Fig. 9. What is the origin of the low mass peak? One is led naturally to the σ-meson, the scalar-isoscalar predicted by Nambu and Jona-Lasinio in a linear realization of the chiral Lagrangian. Experimentally, it has suffered all kinds of up's and down's in the Review of particle properties along the years. The inclusion of the σ in the fit leads to an spectacular improvement and to the determination of its mass (483 ± 30) MeV and width $(338{\pm}50)$ MeV. The light $\sigma(500)$, in spite of its broadness, is up again !

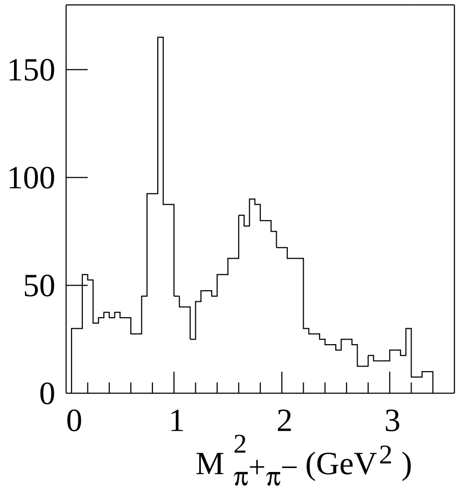

Figure 8. $M^2_{\pi^+\pi^-}$ distribution for $D_s^+ \to \pi^-\pi^+\pi^+$.

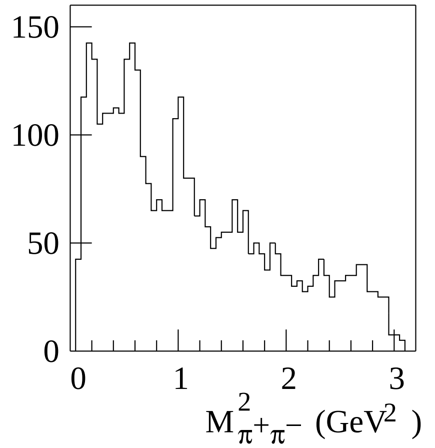

Figure 9. $M^2_{\pi^+\pi^-}$ distribution for $D^+ \to \pi^- \pi^+ \pi^+$.

Rare decays are a good probe for searching new physics. The branching ratios for the inclusive $B \to X_s\, l^+\, l^-$ and exclusive $B \to K^{(*)}\, l^+\, l^-$ decays are smaller in the standard model than the experimental bounds, so that there is room for contributions from models beyond the standard theory. In particular, there is a very interesting property [30] in $B \to K^*\, l^+\, l^-$: the zero of the forward-backward asymmetry provides a discrimination between the standard model and supersymmetry.

The very rare $\Delta S = 2$ process $b \to s\, s\, \bar{d}$ is described in the standard model by the box diagram of Fig. 10. with a branching ratio of the order 10^{-11}. Whereas the MSSM squark-gaugino box diagram in Fig. 11 can increase [31] the theoretical branching ratio to levels of 10^{-8}, the MSSM with R parity violating couplings induced by the sneutrino, see Fig. 12, is not restricted. On the contrary, data from LEP1, around the Z resonance, allow the search for $B^- \to K^-\, K^-\, \pi^+$ [32]. The upper limit of $\sim 10^{-4}$ for the branching ratio leads to new limits on the contribution of R parity violating couplings in this process.

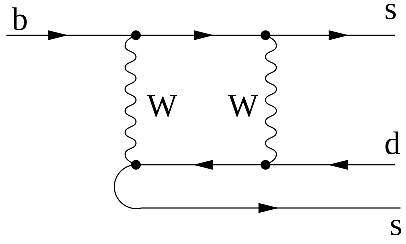

Figure 10. Standard Model box diagram for $b \to s s \bar{d}$.

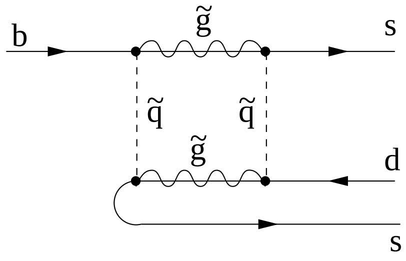

Figure 11. MSSM squark-gaugino box diagram for $b \to s s \bar{d}$.

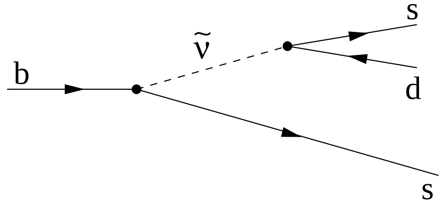

Figure 12. MSSM sneutrino-mediated diagram for $b \to s s \bar{d}$.

6. B(D) mixing and CP-violation

For charm mesons, the two parameters of mixing

$$x = \frac{\Delta M}{\Gamma} \quad , \quad y = \frac{\Delta\Gamma}{2\,\Gamma} \tag{26}$$

are small. The experimental methods to see x or y are either by mixing, with wrong sign final lepton, or comparing the lifetime of CP eigenstates. The last method takes into account the expectation that CP-violation for the charm sector is small. FOCUS(E831) selects [33] the two channels

$$\begin{aligned} D^0 &\rightarrow K^+ K^- \,(\mathrm{CP}+) \\ D^0 &\rightarrow K^- \pi^+ \,(\mathrm{CP}+ : \mathrm{CP}- = 1 : 1) \end{aligned} \tag{27}$$

and the direct comparison of CP final state lifetimes finds y_{CP} as

$$y_{\mathrm{CP}} = \frac{\tau(D \rightarrow K\,\pi)}{\tau(D \rightarrow K\,K)} - 1 \tag{28}$$

The experimental result is $(3.42 \pm 1.39 \pm 0.74)\%$.

The standard model predicts that direct CP violation in D decay rates is the largest in singly Cabbibo-suppressed decays $D^+ \rightarrow K^- K^+ \pi^+$, $D^0 \rightarrow K^- K^+$, $\pi^- \pi^+$. The CP asymmetry results [33] show no evidence for CP violation at the level of few percent.

In the b sector, the problems of B_d and B_s mixing allow the extraction of V_{td} and V_{td}/V_{ts} matrix elements of the CKM matrix. In the time integrated approach, the B_d-mixing leads to a world average $\Delta m_d = 0.484 \pm 0.015$ ps^{-1}, but the B_s-mixing has no sensitivity to Δm_s. The method used [34,38] needs a time dependent experimental approach. The time dependent mixing generates a periodic signal. The amplitude fit method measures the oscillation amplitude A at fixed frequency Δm_s. One expects $A = 1$ on a frequency equal to the true Δm_s, whereas $A = 0$ for a wrong frequency. The world combination leads to the conclusion that B_s oscillations have not yet been resolved, with a lower limit $\Delta m_s > 14.6$ ps^{-1}. The standard model preferred value is close to the present reach. In the ALEPH data, there is a hint of a signal around 17 ps^{-1}. With expected sensitivities like ~ 19 ps^{-1}, one can envisage very interesting results in the near future.

The measurement of $\Delta\Gamma_s$ has been addressed with many methods [6]. An appreciable value would allow to see CP violation in untagged B_s, contrary to B_d in which $\Delta\Gamma_d \approx 0$. With the constraint $\Gamma_s = \Gamma_d = \Gamma$, the present combined experimental value by the LEP Working Group is $\frac{\Delta\Gamma_s}{\Gamma} = 0.16^{+0.08}_{-0.09}$. This is still an insufficient sensitivity to claim an observed width difference. The standard model preferred value is 0.05 ± 0.03 [35], using Lattice HQET and extrapolated Lattice QCD.

One of the highlights of the Conference is the presentation that the two B-factories and the corresponding detectors, BABAR at PEP-II [36,37] and BELLE at KEK B [38,39], are working very well. The PEP-II 9 GeV e^- against 3.1 GeV e^+ collider expects a luminosity of about 6×10^{33} cm^{-2} s^{-1} around summer 2000, whereas the KEK B 8 GeV e^- against 3.5 GeV e^+ collider had a luminosity about 2×10^{33} cm^{-2} s^{-1} just before the Conference in June 2000. Some of the many physics results which are being analyzed by the two Collaborations have been presented, in particular, the lifetimes $\tau(b)$, $\tau(c)$ and $\tau(\tau)$, the mixing Δm_d, the inclusive $B \rightarrow J/\psi\, X$ decay, the charmless $B \rightarrow \rho\,\pi$ decay, the dominant "Cabibbo allowed" Br$(B \rightarrow D^*\,\pi)$ and Br$(B \rightarrow D_s^{*+}\,D^{*-})$, or the rare $B \rightarrow K^*\,\gamma$, $B \rightarrow K^*\,l^+\,l^-$ decays.

The main objective of the B-factories is to establish CP-violation outside the K-system and see whether its description obeys to the CKM mixing matrix in the standard model. For the (bd) unitarity triangle, the three sides mediated by u, c, t quarks are of similar size of order λ^3. When the CP conserving direction is taken as a reference and the associated side is normalized to one, the (bd) unitarity triangle is shown in Fig. 13. B-Physics has the power to find observables able to overconstrain the parameters of this triangle.

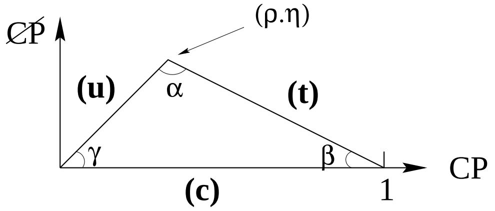

Figure 13. (bd) unitarity triangle.

The separate measurement of the weak CP phases α, β, γ is possible. The value of $\sin(2\beta)$ is accessible from the CP asymmetry in $B \to J/\psi\, K_s$ generated from the interplay of mixing and decay. This method needs a flavour tag, as given by the lepton channel or others. Suppose the decay of $\Upsilon(4S)$ into an entangled state of two B's:

$$\Upsilon(4S) \to B_1\, B_2 \begin{cases} \bullet\!\!\longrightarrow B \to D^-\, e^+\, \nu\, (\mathrm{Tag}) \\ \\ \bullet\!\!\xrightarrow[\Delta z]{} \bar{B} \to J/\psi\, K_s \end{cases} \tag{29}$$

After a time Δt (or length Δz) from the tag, the CP eigenstate B_- is observed: the comparison of $B^0 \to B_-$ versus $\bar{B}^0 \to B_-$ measures CP violation.

Bañuls [40] has discussed the way to use these decays to look for T and CPT violation. Starting from the transition $B^0 \to B_-$, one has

$$\begin{tikzcd} & B_- \to B^0 \\ B^0 \to B_- \arrow[ur, Rightarrow, "T"] \arrow[dr, Rightarrow, "CPT"'] & \\ & B_- \to \bar{B}^0 \end{tikzcd} \tag{30}$$

These transformed transitions need a CP tag. In order to project first on B_-, the B of the other side has to be identified as B_+, a difficult problem. There is, however, an equivalent transition for hermitian hamiltonians. In the limit $\Delta\Gamma_d = 0$ (an excellent approximation for B_d), the transition $B_- \to B^0$ is equivalent to $B_+ \to \bar{B}^0$, which is obtained from the original $B^0 \to B_-$ by a temporal exchange $\Delta z \to -\Delta z$ of the two decay channels: leptonic and $J/\psi\, K_s$. Although the temporal and T-odd asymmetries are conceptually different, they become equivalent in the limit $\Delta\Gamma_d = 0$ and the temporal asymmetry is a T-odd observable.

The problem of B-physics and CP-violation is a source of inspiration and dedication in the hadronic machines too. At the Conference, the prospects of CDF-II [41], BTeV [42], CKM [43], and Run II [44] at FermiLab, as well as HERA b [45] at DESY and ATLAS [46], CMS [47] and LHCb [48] at LHC [49] were given. A brilliant scenario appears at the near future. Contrary to the B-factory preparation, the B-production mechanism is thought to be here incoherent from the individual b quark, with no entanglement. One can proceed then to flavour tags, but there is no possibility of CP tags as discussed above.

It is worth to emphasize that, inside the Standard Model, the CP phases can be also extracted from CP conserving observables in exclusive B-decays. For example, $\cos\alpha$ is measured in the rare $B \to \rho\gamma$ decay [50,51]. The evidence for $\alpha \neq 0$ in the (bd) unitary triangle is here $\cos\alpha \neq 1$ in these observables, contrary to $\sin\alpha \neq 0$ (yes-no experiment) in the CP-odd asymmetries.

The chapter of SM Physics was also addressed by Narain [52], with an excellent review of Top Quark Physics at the Tevatron (Run I and Run II) and the LHC as a top factory.

7. Heavy Quarkonium

Quarkonia are special hadrons, for which a description in terms of factorization between the hard and soft scales is believed to be valid. For the case of Υ, confinement effects are small and basic perturbative QCD calculations on some observables [53] can be envisaged. These observables refer to structure and decays. The only flavour dependent parameter is the b quark mass m at the scale of the bound state. The running of the b quark mass has been established [54]. With the velocity $v \sim \alpha$ for Coulomb systems, one has a multiscale problem with m, $p \sim mv$, $E \sim mv^2$. The separation of scales is made by means of an effective field theory [55].

There is a J/ψ and ψ' surplus in direct production at the Tevatron. An interesting production mechanism which has been suggested is the Colour-Octet component in NRQCD. Chao [56] has discussed a test of this mechanism, which incorporates the colour-octet gluon fragmentation shown in Fig. 14 based on the polarization of charmonium at the Tevatron. In the NRQCD factorization approach, an explicit calculation of the production cross section [57] shows that the colour-octet contributions can describe Tevatron data. The experimental J/ψ polarization at high p_T is, however, in disagreement with the calculation for direct J/ψ production plus the feed-down from intermediate χ_c and ψ'. More tests are needed to understand this problem.

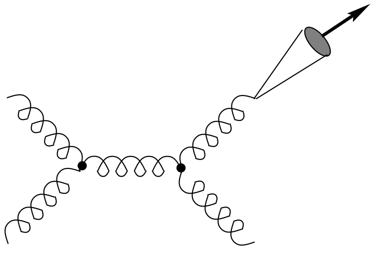

Figure 14. Color-octet gluon fragmentation.

The inelastic J/ψ production in DIS ($2 < Q^2 < 80$ GeV^2) at HERA shows [58] that the colour-singlet contribution is below data, but the shape is in reasonable agreement. When the colour-octet contribution, as suggested by the Tevatron data, is included, the theoretical magnitude is above data and the shapes disagree. Clearly one has to conclude that the problem of the production mechanism is not understood yet.

8. Outlook

The Conference was a great event. Many experimental results and theoretical ideas were presented and discussed. The understanding of the Flavour Problem is one of the main pending questions in fundamental physics. In the quark sector, this study involves strange, charm and beauty hadrons, and so the control of the interplay between electroweak and strong interactions. It is gratifying for this field that all major facilities in particle physics around the world have a strong programme in it. As a consequence, we can expect important breakthroughs in the next two years and to have a fruitful rendez-vous at Vancouver 2002.

9. Acknowledgements

I would like to thank the Organizers of the Conference for the appropriate environment and to Vicent Giménez for a critical reading of the manuscript. This work was supported by CICYT, under Grant AEN99-0692.

REFERENCES

1. Transparencies of most Conference talks are available at http://ific.uv.es/conf2000/contributions.html.
2. C.S. Kalman, these Proceedings.
3. Review of Particle Physics, C. Caso et al. Eur. Phys. J. 3 (1998)1 [hep-ph/9808385].
4. J.G. Körner and B. Melic, these Proceedings and hep-ph/0010188.
5. T. Moa, these Proceedings.
6. S.R. Wasserbaech, these Proceedings.
7. I.M. Narodetskii, these Proceedings and hep-ph/0010169.
8. K. Baird, these Proceedings.
9. N. Solomey, these Proceedings and hep-ex/0010073.
10. D.A. Jensen, these Proceedings.
11. U. Koch, these Proceedings.
12. R. Fantechi, these Proceedings.
13. J.A. Miralles, these Proceedings.
14. G. Unal, these Proceedings.
15. L. Wolfenstein, Phys. Rev. Lett. 13 (1964) 562.
16. A. Pich, these Proceedings and hep-ph/0010181.
17. L. Silvestrini, these Proceedings and hep-ph/0009284.
18. D. Zavrtanik, these Proceedings.
19. P.K. Kabir, The CP Puzzle, Academic Press (1968)
20. T. Bocali, these Proceedings.
21. M. Iori, these Proceedings and hep-ex/0009049.
22. M. Margoni, these Proceedings.
23. S. Terem, these Proceedings.
24. M. Battaglia, these Proceedings and hep-ex/0008066.
25. H. He, these Proceedings.
26. P. Singer and D. Guetta, these Proceedings and hep-ph/0009057.
27. M. Nielsen, these Proceedings.
28. M. Di Pierro and E. Eichten, these Proceedings and hep-ph/0009177.
29. I. Bediaga, these Proceedings and hep-ex/0011042.
30. C.-S. Huang, these Proceedings and hep-ph/0009149.

31. S. Fajfar, these Proceedings.
32. Y. Rozen, these Proceedings.
33. D. Y. Kim, these Proceedings.
34. G. Boix, these Proceedings.
35. J. Reyes and V. Giménez, these Proceedings; hep-lat/0009007 and hep-lat/0010048.
    D. Becirevic *et al.*, hep-ph/0006135.
36. P.C. Bloom, these Proceedings.
37. B. Meadows, these Proceedings.
38. B.A. Shwartz, these Proceedings.
39. B.G. Cheon, these Proceedings.
40. M.C. Bañuls, these Proceedings and hep-ph/0009317.
41. A. Ruiz, these Proceedings.
42. Y. Kubota, these Proceedings.
43. C. Milstene, these Proceedings and hep-ex/0009046 (with the CKM Collaboration).
44. R. Jesik, these Proceedings.
45. K. Ehret, these Proceedings.
46. M. Smizanska, these Proceedings.
47. P. Arce, these Proceedings.
48. J. Libby, these Proceedings.
49. N. Ellis, these Proceedings.
50. B. Grinstein, these Proceedings.
51. L.T. Handoko, these Proceedings and hep-ph/0009023.
52. M. Narain, these Proceedings.
53. F.J. Yndurain, these Proceedings.
54. M. J. Costa, J. Fuster, these Proceedings.
55. A. Manohar, these Proceedings.
    A. Pineda, these Proceedings and hep-ph/0008327.
56. K.T. Chao, these Proceedings.
57. M. Krämer, these Proceedings and hep-ph/0010137.
58. A. Polini, these Proceedings.