Conference Summary
Jonathan L. Rosner a *

aEnrico Fermi Institute and Department of Physics, University of Chicago
5640 S. Ellis Avenue, Chicago, IL 60637

A summary is given of the 5th International Conference on Hyperons, Charm and Beauty Hadrons held in Vancouver, Canada, June 25th to 29th, 2002. This series of conferences began in 1995 in Strasbourg, France, in large part through the efforts of A. Fridman, to whose memory this talk is dedicated. Topics reviewed include kaon and hyperon physics, charm and beauty production and decays, heavy baryons, the physics of the Cabibbo-Kobayashi-Maskawa matrix and CP violation, and precision electroweak analyses. An attempt is made to combine a review of the high points of the conference with a more general overview of the field and its prospects.

1. INTRODUCTION AND DEDICATION

This series of conferences was begun in Strasbourg in 1995, largely through the efforts of A. Fridman, or “Fredy,” as he was known, a remarkable individual whom I came to know during one of his visits to Tel Aviv University in 1968 and later when we were both at CERN. My family and I have fond memories of his generous hospitality in Strasbourg in 1973, when he treated us at a restaurant in the nearby French countryside to one of the best meals I have ever had. Fredy cared deeply about physics and had particular tastes (such as heavy baryons) which ensured that topics which were not always fashionable received the attention they deserved. We miss him greatly.

The start of my visit to Canada speaks well for the visibility of particle physics here. At the border the guard asked my wife and me for photo identification and for the purpose of our visit. When I named the conference, he asked: “What’s your favorite subatomic particle? Do you think dark matter will be found? Will the Universe keep expanding or collapse back to a point? Personally, I like the cyclic idea.” I asked him if he wanted to see our proof of citizenship; he answered: “Nope. Have a nice day!” We later learned that the press coverage of particle physics in Vancouver (and the rest of Canada) has been extensive, and that the guards are quite well-informed.

This Conference has been an enjoyable mixture of topics which, while not all answering the border guard’s deep questions, shed light on many fundamental issues, such as the pattern of quark masses and mixings, the origin of the CP violation in the kaon and B meson systems, and possibilities for physics beyond the Standard Model. I first discuss the unitarity of the Cabibbo-Kobayashi-Maskawa (CKM) matrix as probed via the first two quark families (Sec. 2), and then kaons (Sec. 3) and hyperons (Sec. 4). A trio of sections is devoted to spectroscopy: quarkonium (Sec. 5), particles with charm (Sec. 6) and particles with beauty (Sec. 7). In the last two of these I also discuss weak decays and what they teach us about the strong and weak interactions and the CKM matrix. A separate section (8) is devoted to heavy quark production. I then treat the electroweak sector in Sec. 9, including the neutral-current couplings of heavy quarks and the search for the Higgs boson. Physics beyond the Standard Model (mainly supersymmetry) is discussed in Sec. 10, while Sec. 11 concludes.
2. CKM AND THE FIRST TWO FAMILIES

Is the CKM matrix unitary \(1\)? Superallowed transitions in nuclei \(2\) yield \(|V_{ud}| \approx 0.9740(5)\), while the lifetime and \(g_A/g_V\) of the neutron yield a slightly smaller value \(\approx 0.973\). The value of \(|V_{us}|\) quoted for many years \(3\), based on \(K_{e3}\) decays, has been \(0.220 \pm 0.002\), yielding \(\sum |V_{ui}|^2 \approx 0.996 \pm 0.002\), a \(2\sigma\) discrepancy. At this conference we heard of a new analysis of hyperon decays \(4\) which gives \(|V_{us}| = 0.2250 \pm 0.0027\), while a new \(K_{e3}\) experiment is likely to give about a \(3\%\) increase in the old value of \(|V_{us}|\) modulo radiative corrections \(5\).

The value of \(|V_{cd}|\) is roughly 0.22, in accord with unitarity expectations \(6\). At this conference we heard of a new value of \(|V_{cs}|\) extracted from \(W\) decays \(7\). Using precision measurements and theoretical estimates of the \(W\) production cross section, the LEP II collaborations have measured \(B(W \to\text{hadrons}) = (67.92 \pm 0.27)\%\) (67.5\% in the Standard Model \(\text{SM}\)) and \(B(W \to l\nu) = (10.69 \pm 0.09)\%\) (10.8\% in the \(\text{SM}\)), where the \(\text{SM}\) predictions are based on \(\alpha_s(M_W) = 0.121 \pm 0.002\). This constrains \(\sum |V_{ij}|^2\), where \(i = u, c; j = d, s, b\). Subtracting known values, one finds \(|V_{cs}| = 0.996 \pm 0.013\), whereas unitarity would predict \(\approx 0.975\). The agreement is better than \(2\sigma\).

3. KAONS

The KLOE detector at the DAFNE electron-positron collider at Frascati has been studying \(e^+e^- \to \phi \to \pi^+\pi^-\) \(\ldots\), where in addition to \(KK\) the final states include \(f_0\gamma\) and \(\eta'\gamma\). The newly measured branching ratio \(B(\phi \to \eta'\gamma) = (6.8 \pm 0.6 \pm 0.5) \times 10^{-5}\) probes the strange quark content of the \(\eta'\). Writing \(|\eta'| = X|\bar{u}u + \bar{d}d|/\sqrt{2} + Y|\bar{s}s| + Z|\text{glue}|\), one finds that \(X^2 + Y^2 = 0.95^{+0.11}_{-0.07}\), limiting the amount of glue in the \(\eta'\) wave function \(8\).

Two events of the rare decay \(K^+ \to \pi^+\nu\bar{\nu}\) have now been seen \(9\), corresponding to \(B = (1.57^{+1.75}_{-0.82}) \times 10^{-10}\). This is to be compared with the SM prediction of \(B = (0.82 \pm 0.32) \times 10^{-10}\); the amplitude probes a combination proportional to \(|1.4 - \rho - i\eta|\) of the Wolfenstein \(12\) parameters \(\rho\) and \(\eta\). The goals of BNL experiment E949 \(10\) and the Fermilab CKM experiment \(13\) are to record 10 and 100 events of this process, respectively, if the SM prediction is correct.

Events have been seen in \(K_L^0 \to \pi^0 e^+e^-\) and \(K_L^0 \to \pi^0\mu^+\mu^-\) at a level consistent with background \(14\). Further study of radiative \(K_L^0\) decays (e.g., to \(\gamma\gamma e^+e^-\)) and a search for \(K_S \to \pi^0 e^+e^-\) will provide useful information. The present limit is \(B(K_S \to \pi^0 e^+e^-) < 1.4 \times 10^{-7}\) \(15\). The CP-conserving amplitude for this process is fed by rescattering from \(K_L \to \pi^0\gamma\gamma\), for which NA48 has presented new results \(13\). The amplitude for \(K_L^0 \to \pi^0\nu\bar{\nu}\) is proportional to the CP-violating parameter \(\eta\). The SM prediction \(B = (3.1 \pm 1.3) \times 10^{-11}\) will be approached stepwise, with experiments at KEK (E391), the Japan Hadron Facility (JHF) and BNL (KOPIO) \(14\).

The parameter \(\epsilon'/\epsilon\) in \(K_{S,L} \to \pi\pi\) is still evolving. Fermilab E832 presented its value based on the full 1996-7 data set, \(\epsilon'/\epsilon = (20.7 \pm 2.8) \times 10^{-4}\) \(14\). A new value from CERN NA48, \(\epsilon'/\epsilon = (14.8 \pm 2.2) \times 10^{-4}\) \(15\), when combined with the Fermilab result, yields a world average \(\epsilon'/\epsilon = (17.0 \pm 2.9) \times 10^{-4}\), where I have increased the error from \(\pm 1.7\) by \(S \equiv (\chi^2)^{1/2}\) \(14\). The Fermilab experiment’s results of its 1999 run should reduce the error further.

The amplitudes contributing to \(K_{S,L} \to \pi\pi\) consist of a penguin (with a weak phase, leading only to an \(I = 0\) final state) and a tree (with no weak phase, leading to both \(I = 0\) and \(I = 2\) final states). The relative phase of the \(I = 2\) and \(I = 0\) amplitudes leads to \(\epsilon' \neq 0\). Despite the difficulty of estimating the relative strength of penguin and tree contributions, the Fermilab and CERN measurements definitely establish the presence of direct CP violation.

Other rare \(K\) decay process include \(K_L \to e^+e^-\gamma\) and \(K_L \to \mu^+\mu^-\), whose dependence on \(m(l^+l^-)\) probes the form factor in \(K_L \to \gamma\gamma\), useful for estimating the contribution of the long-distance dispersive contribution (and hence also the short-distance contribution) to \(K_L \to \mu^+\mu^-\) \(14\). It now appears that the \(e^+e^-\gamma\) and \(\mu^+\mu^-\gamma\) results give the same form-factor parameters, which was not always the case.
4. HYPERONS

The neutral hyperons produced in neutral kaon beams have been studied at Fermilab [1,14] and CERN [20]. The decay $\Xi^0 \rightarrow \Sigma^+ e^- \bar{\nu}_e$ is related to $n \rightarrow p e^- \bar{\nu}_e$ by the U-spin transformation $d \leftrightarrow s$; differences between the two probe SU(3) breaking. The Fermilab group [14] has recently studied a large sample of events for this process. The CERN group [20] has measured the $\Xi^0$ mass much more precisely than previously, allowing a test of the Coleman-Glashow relation $m(n) - m(p) + m(\Xi^0) - m(\Sigma^-) = m(\Sigma^-) - m(\Sigma^+)$. This relation should be good to 0.1 MeV [12], as it seems to be.

Radiative hyperon decays [22] have posed a long-standing puzzle. Up to now we have not had a consistent description of all rates and polarization asymmetries for the processes $\Sigma^+ \rightarrow \gamma \gamma$, $\Lambda \rightarrow n \gamma$, $\Xi^0 \rightarrow (\Lambda, \Sigma^0) \gamma$, $\Xi^- \rightarrow \Sigma^- \gamma$, and $\Omega^- \rightarrow \Xi^- \gamma$. Early work [22] showed that an elementary $s \rightarrow d \gamma$ transition was not enough, while a quark-model treatment [24] appeared to disagree with data. Recent CERN NA48 data on the asymmetry parameter in $\Xi^0 \rightarrow \Lambda \gamma$ seems to have resolved the question in favor of the general scheme of predictions of the quark model [24] and in favor of Hara’s Theorem [25], which says that polarization asymmetries in these radiative decays should vanish in the limit of exact SU(3).

The HyperCP Experiment at Fermilab has provided new information on charged hyperons. The decay $\Omega^- \rightarrow \Xi^- \pi^+ \pi^-$ has been observed with $B = (3.6 \pm 0.3) \times 10^{-4}$ [24]. The mechanism is still unclear; should one see a $\Xi^0(1530) (3/2^+)$ intermediate state? The T-violating asymmetry in $\Xi^- \rightarrow \Lambda \pi^- \rightarrow p \pi^- \pi^-$ has been bounded [24]: $A_{\Xi \Lambda} = (-7 \pm 6 \pm 2.6) \times 10^{-4}$, with an error of $2 \times 10^{-4}$ (still above SM expectations) expected for the full sample.

5. QUARKONIUM

The Belle Collaboration has discovered the radial excitation of the $^1S_0$ quarkonium ground state, the $\eta_c(2S)$ with a mass of 3654 MeV [28], through the decay $B \rightarrow \eta_c(2S) K \rightarrow K_S K^* \pi^+ K$. The $2S$ hyperfine splitting $\psi' - \eta_c = 32$ MeV is considerably less than the $1S$ splitting $J/\psi - \eta_c = 118$ MeV and less than one would estimate on the basis of the $J/\psi$ and $\psi'$ leptonic widths, suggesting the possibility that coupled-channel effects and/or mixing with the $\psi''(3770)$ are pushing down the $\psi'$ mass [23,30,31].

The search for singlet $P$-wave $c\bar{c}$ and $b\bar{b}$ states has not yet produced a firm candidate. The Fermilab E835 Collaboration [22] still is mute regarding their previous (E760) claim for a $h_c \equiv c\bar{c}(1P_1)$ state at 3526 MeV. Suzuki [24] has suggested looking for $B \rightarrow h_c K$, with $h_c \rightarrow \eta_c \gamma$. As for the $h_b = b\bar{b}(1P_1)$, which should decay largely to $\gamma \eta_b$, it should be produced via $\Upsilon(3S) \rightarrow \pi^0 h_b$ [24] or $\Upsilon(3S) \rightarrow \pi^+ \pi^- h_b$ [23]. For other suggestions for $P$-wave singlet observation, and a summary of mass predictions, see [30].

The D-wave quarkonium levels [5,18,28] include the observed $c\bar{c}(3D_1)$ state $\psi''(3770)$ and a candidate for a $b\bar{b}(3D_2)$ state $\Upsilon(10162)$ reported since this conference by the CLEO Collaboration at ICHEP2002 in Amsterdam [13]. Chao [38] has suggested that the $c\bar{c}(1D_2)$ state may be narrow and easily observed.

In light of new data on quarkonium decays (e.g., [32,41]), new approaches based on non-relativistic QCD (NRQCD) [42,43,44,45], and realization of the importance of color octet contributions to quarkonium wave functions, previous $\alpha_s$ determinations based on heavy quarkonium decays to light hadrons (e.g., [14]) should be updated. The BES group [11] has presented impressive evidence that $f_2(1710)$ produced in $J/\psi \rightarrow f_2 \gamma$ has $J = 0$; it is a leading candidate for the lightest glueball.

6. PARTICLES WITH CHARM

Candidates for doubly-charmed baryons presented by the Fermilab SELEX Collaboration [17,48] are summarized in Table 1. These entail several mysteries.

- The FOCUS Collaboration [10] does not see a signal, though they detect many more $\Lambda_c$'s.
- The isospin splitting between the first two states is enormous. One usually expects
isospin splittings to be at most a few MeV.

- The production rate of the doubly-charmed baryons is so large that fully half of all observed $\Lambda_c$'s must come from their decays.
- The hyperfine splitting between the last two states (presumably $J = 1/2$ and $J = 3/2$ candidates) is larger than one might estimate by elementary means (see, e.g., [50]).

Impressive results on charmed particle photoproduction have been presented by the FOCUS (ES31) Collaboration at the Fermilab Tevatron.

Charmed particle semileptonic decays [51] have yielded evidence for an $S$-wave $K\pi$ contribution under the dominant $\bar{K}^*(890)$ vector meson resonance in $D^+ \to K^-\pi^+\mu^+\nu_\mu$. The branching ratio $B(D^+ \to \bar{K}^{*0}\mu^+\nu_\mu) = (5.5 \pm 0.4)\%$ is larger than the Particle Data Group [14] value of $(4.8 \pm 0.4)\%$ but 1.6$\sigma$ below the CLEO [52] value of $(6.7 \pm 0.8)\%$. It was always puzzling why this branching ratio was not larger [53]. The new FOCUS measurement $B(D_s \to \phi\mu^+\nu_\mu)/B(D_s \to \phi\pi^+) = 0.54 \pm 0.06$ can be helpful in calibrating absolute $D_s$ branching ratios if supplemented by theoretical estimates of the $D_s \to \phi$ form factors.

Charmed baryon decays [49] have been observed by FOCUS in several Cabibbo-suppressed $\Lambda_c^+$ modes, including $\Sigma^+\bar{K}^{*0}$ (strangeness $S = -2$), $\Sigma^+K^{*0}$ ($S = 0$), and $\Sigma^-K^+\pi^+$ ($S = 0$). Cabibbo-favored $S = -1$ modes such as $\Sigma^+\pi^+\pi^-$ and $\Sigma^+K^+K^-$ also have been observed; in the latter case the Dalitz plot shows a $\phi$ band in $K^+K^-$ and a $\Xi^*$ band in $\Sigma^+K^-$. As mentioned, there are no signs of SELEX’s $ccq$ baryons.

Charmed particle lifetimes [53] exhibit a hierarchy which is qualitatively understood from the standpoint of heavy quark symmetry. In Table 2 we compare the FOCUS results with Particle Data Group (2002) averages. The FOCUS $D_s$ and $\Omega_c$ values are preliminary.

The CLEO Collaboration [53] has presented results on $D^0 \to K^-\pi^+\pi^-$ in which the doubly-Cabibbo-suppressed decay $D^0 \to K^{*+}\pi^-$ is seen via interference on the Dalitz plot. Through a study of related decay modes one can learn about final-state phase differences [50] in the same way as for the Cabibbo-favored modes [57].

Several presentations at this Conference dealt with charmed meson spectroscopy and rare decays. Predictions of the lowest $ccq$ state differed greatly: 3241 MeV [53] or 3640–3690 MeV [65], where both values refer to the spin-weighted $J = 1/2$ and $J = 3/2$ average. The latter is consistent with the SELEX [17] claim. It would be helpful to have predictions of hyperfine splittings to compare with SELEX’s large value.

S. Fajfer [49] pointed out that in $D \to V\gamma$ and $D \to \gamma\gamma$, long-distance effects are likely to dominate, with $B(D^0 \to \gamma\gamma) \simeq 2.1 \times 10^{-8}$ and $B(D_s^+ \to \rho^+\gamma) \simeq 2.1 \times (4 \times 10^{-4})$. Short-distance effects could lead to a difference between $B(D^0 \to \rho\gamma)$ and $B(D^0 \to \omega\gamma)$.

### 7. Particles with Beauty

#### 7.1. Semileptonic Decays

##### 7.1.1. Inclusive $b \to c$ Transitions

The leading-order expression for the semileptonic $b \to c$ decay width is

$$\Gamma_0 = \frac{G_F^2m_b^5}{192\pi^3}|V_{cb}|^2f(m_c/m_b),$$

where $f(x)$ is a known function equal to 1 for $x = 0$ and about 1/2 for $x = m_c/m_b$. This expression is clearly very sensitive to $m_b$, though less so when $m_b - m_c$ is confined within its known limits (about 3.34 to 3.4 GeV). As a result of work reported at this conference [14, 15, 16, 17, 18], the $m_b$ dependence is being tamed; information on $b \to s\gamma$ is helpful. Calculations of the semileptonic spectra agree with experiment and can be used for baryons as well [19]. One finds $|V_{cb}| \simeq 0.041$ with about a 5% error. There seems to be no missing charm problem in $B$ decays [20].
7.1.2. Exclusive $b \to c$ transitions

The measurement of the spectrum in $B \to D^*\ell
\nu$ and extrapolation to the zero-recoil (maximum $m_{\ell\nu}$, mass) point now has been performed by a number of groups, leading to a world average $F(1)|V_{cb}| = (37.8 \pm 1.1) \times 10^{-3}$. CLEO and ALEPH find values somewhat larger and smaller, respectively, than this average, which also contains values from Belle, DELPHI, and OPAL. The most recent estimate from lattice gauge theory calculations is $F(1)|V_{cb}| = 0.919^{+0.030}_{-0.035}$, so that this exclusive method again gives $|V_{cb}| \approx 0.041$ with about a 5% error.

7.1.3. Inclusive $b \to u$ transitions

The decay $B \to X_u\ell\nu$, which occurs with about 50 times the rate. There are several ways to isolate the desired signal $\pi\rho\omega$. The best is to make cuts in both $q^2$, $M_X$, and the lepton energy $E_\ell$, but this is exactly opposite to experimental feasibility!

At present CLEO $^{17.59}$ has used an inclusive method to determine $|V_{ub}| \approx 0.10|V_{cb}|$ with about a 15% error; reduction to 10% seems feasible.

7.1.4. Exclusive $b \to u$ transitions

The decays $B \to (\pi, \rho, \omega)\ell\nu$ can provide information on $|V_{ub}|$ when form factors are specified (e.g., through lattice gauge theory calculations). A value based on Belle data was presented by Piilonen $^{15.5}$ at the DESY meeting in 1999. The study of $B \to \pi\ell\nu$, in particular, is helpful in estimating the contribution of the tree amplitude in $B \to \pi\pi$ if factorization is assumed $^{15.4}$.

7.2. $B \to D\pi$ isospin triangle

A year ago Belle and CLEO reported observation of some color-suppressed $D$ decays, including $B^0 \to \bar{D}^0\pi^0$. The rate for this process was found to be sufficiently large that the triangle of complex amplitudes for $B^0 \to \bar{D}^0\pi^0$, $B^0 \to D^-\pi^+$, and $B^+ \to \bar{D}^0\pi^+$ appeared to have non-zero area. The branching ratios for the last two processes were based on a sub-sample of the CLEO data. Now CLEO has reported a new analysis of the last two modes $^{15.5,16}$, which strengthens the argument for a non-zero final state phase difference between the $I = 1/2$ and $I = 3/2$ amplitudes. Defining $\delta_I = \text{Arg}(A_{3/2}/A_{1/2})$ (using the convention of $^{14.5}$), and the new branching ratios $B(B^0 \to D^-\pi^+) = (26.8 \pm 2.9) \times 10^{-4}$, $B(B^+ \to \bar{D}^0\pi^+) = (49.7 \pm 3.8) \times 10^{-4}$ as well as the Belle-CLEO average $B(B^0 \to \bar{D}^0\pi^0) = (2.92 \pm 0.45) \times 10^{-4}$, one finds $\delta_I \simeq 30^\circ$, $16^\circ \leq \delta_I \leq 33^\circ$ with 90% confidence, or $\cos \delta_I < 1$ at 2.4$\sigma$.

Non-zero final-state phases in $B$ decays would be useful in observing direct CP violation. No such effects have been seen yet; the closest is in $B \to \pi\pi$, where Belle sees a direct CP asymmetry but BaBar does not (see below).

7.3. Decays involving $\eta$ and $\eta'$

A review of $B$ decays involving $\eta$ and $\eta'$ was presented by B. Brau $^{17}$. Several speakers $^{17.71.72.73}$ were concerned with whether the large branching ratio $B(B \to K\eta') \simeq 63 \times 10^{-6}$ represents a serious challenge to theory. The standard penguin amplitude may be represented by $P$, and an additional “singlet penguin” contribution, in which the $\eta$ or $\eta'$ couples to the process in a manner violating the Okubo-Zweig-Iizuka (OZI) rule. We represent

\[ \eta \simeq (u\bar{u} + d\bar{d} - s\bar{s})/\sqrt{3}, \]

(2)

\[ \eta' \simeq (u\bar{u} + d\bar{d} + 2s\bar{s})/\sqrt{6}. \]

(3)
Then (neglecting a small tree contribution to the charged $B$ decay)

$$A(B \rightarrow \eta K) = 0 \cdot P + \frac{1}{\sqrt{3}} S , \quad (4)$$

$$A(B \rightarrow \eta' K) = \frac{3}{\sqrt{6}} P + \frac{4}{\sqrt{3}} S . \quad (5)$$

The penguin contributions of nonstrange and strange quarks interfere destructively in $\eta K$ and constructively in $\eta' K$. They cancel completely for the particular mixing chosen in [77], which corresponds to octet-singlet mixing with an angle of 19°.

Calibrating the strength of the penguin amplitude with the process $B^+ \rightarrow \pi^+ K^0$, whose branching ratio is $B \simeq 17 \times 10^{-6}$, one predicts the branching ratios shown in Table 3. A small singlet $(S)$ contribution is needed to obtain the observed $\eta' K$ branching ratio. This contribution is larger than most perturbative QCD estimates, but is obtained satisfactorily by Beneke et al. in their generalized factorization approach [78].

The pattern of interference of contributions to the penguin amplitude of the nonstrange and strange quarks is reversed for $B \rightarrow K^*(\eta, \eta')$ in comparison with that for $B \rightarrow K(\eta, \eta')$ [77]. Thus, one gets constructive interference in $B \rightarrow K^* \eta$ and destructive interference in $B \rightarrow K^* \eta'$. With the mixing pattern adopted above, one has (again neglecting small tree contributions to $B^+$ decays)

$$A(B \rightarrow \eta K^*) = \frac{2}{\sqrt{3}} P_{PV} + \frac{1}{\sqrt{3}} S_{PV} ,$$

$$A(B \rightarrow \eta' K^*) = -\frac{1}{\sqrt{3}} P_{PV} + \frac{4}{\sqrt{3}} S_{PV} .$$

Here it is the $\eta K^*$ decay which is seen, with a branching ratio of about $2 \times 10^{-5}$ [80]. If the singlet penguin contribution $S_{PV}$ were neglected, one would have $\Gamma(\eta' K^*) = (1/8) \Gamma(\eta K^*)$, in the absence of phase space suppression, whose inclusion leads to the prediction $B(B \rightarrow \eta' K^*) = 2 \times 10^{-6}$. Deviation from this prediction would indicate evidence for the singlet penguin [79].

The sign flip just mentioned arises from the behavior under charge conjugation when one compares penguin amplitudes in which the spectator quark ends up in the $\eta$ or $\eta'$ with those in which the $K^*$ contains the spectator. Other evidence for a similar sign flip arises in the differing relative phases of $I = 1/2$ and $I = 3/2$ amplitudes in $D \rightarrow K^* \pi$ and $D \rightarrow K \rho$ [77], and in the observation [77] that $B(D^+ \rightarrow K^{*+} K^0) = (3.1 \pm 1.4)\%$ shows an enhancement while $B(D^+ \rightarrow K^{+} K^0) = (0.42 \pm 0.05)\%$ does not, presumably because of constructive vs. destructive interference of “annihilation” and “tree” amplitudes.

### 7.4. $B_s-\bar{B}_s$ mixing and CKM elements

Experimental [30] and theoretical [31] aspects of $B_s-\bar{B}_s$ mixing may be summarized by noting that the present lower limit $\Delta m_s \geq 14.9$ ps$^{-1}$ was not expected until recently to be much below the actual value. This was based on the estimate

$$\frac{\Delta m_s}{m_{B_d}} = \xi^2 \frac{m_{B_d}}{m_{B_s}} , \quad \xi \equiv \frac{f_{B_s} \sqrt{m_{B_s}}}{f_{B_d} \sqrt{m_{B_d}}} ,$$

with lattice gauge theory estimates in the vicinity of $\xi \simeq 1.14 \pm 0.06$. However [82], the error on $\xi$ may have been underestimated in applying chiral perturbation theory when extrapolating to light masses of the $u, d, s$ quarks; the new value is $\xi = 1.30 \pm 0.10$, which for fixed Wolfenstein parameters $(\rho, \eta)$ changes $\Delta m_s$ by $+30$%, allowing values up to 30 ps$^{-1}$. For fixed $\Delta m_s$ it allows larger values of $|V_{td}|, |1 - \rho - i \gamma|$, and $\gamma$.

A quark model estimate [33] used the near-equality of hyperfine splittings in the $D^*_s-D_s$ and $D^*-D$ systems to estimate $f_{D_s}/f_{D} \simeq 1.25$, with the relation [34] $f_{B_s}/f_{B} \simeq f_{D_s}/f_{D}$ then yielding a similar ratio for $f_{B_s}/f_{B}$. There are good prospects for measuring $f_{D_s}/f_{D}$ at CLEO-c [35].

### 7.5. Angles of the unitarity triangle

The angles of the unitarity triangle were called $\phi_1, \phi_2$, and $\phi_3$ (opposite the sides corresponding to the products $V_{td}^* V_{ud}$ for the first, second,
and third families) in 1987 [83]. These “hiragana” names, used by the Belle Collaboration, are expressed in “katakana” by the BaBar Collaboration as \( \alpha \equiv \phi_2, \beta \equiv \phi_1, \) and \( \gamma \equiv \phi_3. \)

D. Marlow [87] reported a world average \( \sin(2\phi_1) = 0.78 \pm 0.08 \) based on the CP asymmetries in \( B \to J/\psi K_S \) and closely related decays, driven mainly by the BaBar and Belle data. These have subsequently been updated, with BaBar [88] now reporting \( \sin(2\phi_1) = 0.741 \pm 0.067 \pm 0.033 \) and Belle [89] reporting \( \sin(2\phi_1) = 0.719 \pm 0.074 \pm 0.035. \) My average of these two values is \( 0.731 \pm 0.055. \)

The best information on \( \phi_2 = \alpha \) comes from \( B^0 \to \pi^+\pi^- \), whose penguin amplitude (about 0.3 of the dominant tree) complicates the analysis. One can obtain the penguin from \( B^+ \to K^0\pi^+ \) (where it dominates) with the help of flavor SU(3) and an estimate of symmetry-breaking. Time-dependent asymmetries in this process are proportional to \( S_{\pi\pi} \sin(\Delta mt) - C_{\pi\pi} \cos(\Delta mt) \).

The “indirect” \( S_{\pi\pi} \) term is proportional to \( \sin(2\phi_{2\text{eff}}) \), where \( \phi_{2\text{eff}} \to \phi_2 \) in the limit of a vanishing penguin amplitude. The “direct” \( C_{\pi\pi} \) term is proportional to the sine of a strong phase difference between penguin and tree amplitudes, expected to be small in the generalized factorization approach [88]. As pointed out by Morii [90], present data are beginning to constrain \( \phi_2. \)

Datta [91] (reporting on work in collaboration with D. London) has noted that analysis of several \( B^0 \to K^{(*)0}K^{(*)0} \) modes may allow a clean determination of \( \phi_2. \)

The angle \( \phi_3 = \gamma \) is harder to pin down in a model-independent way, though there are ways to measure it to about \( \pm 10^\circ \) using various manifestations of tree-penguin interference [84,92,93]. These occur in such processes as \( B \to \pi\pi, B_{(s)} \to K\pi, B_{s} \to KK, \) and modes involving one light pseudoscalar and one light vector meson. For these (as well as for the modes \( B^+ \to \pi^+\eta \) and \( B^+ \to \pi^+\eta' \) which exhibit direct CP asymmetries) it will be necessary to measure branching ratios with an accuracy of \( \pm (1-2) \times 10^{-6}. \)

### 7.6. SCET and factorization

The “generalized factorization” approach we have mentioned has been simplified considerably thanks to work by Stewart and collaborators [94], who developed a technique known as the soft collinear effective theory (SCET). They are able to prove factorization to all orders in \( B^0 \to D^-\pi^+ \). Corrections of order \( 1/m_c \) are responsible for the fact that \( B(D^0\pi^+) \simeq 1.85B(D^-\pi^+). \) They are comfortable with the range of \( \delta_I = \arg(A_{3/2}/A_{1/2}) \) reported by CLEO [95-97]. An investigation of \( B^0 \to \pi^+\pi^- \) is in progress. At stake is whether the strong relative phase between tree and penguin amplitudes is small (e.g., [98]) or large (e.g., [99]). At the moment experiment is no help in deciding this question, since BaBar and Belle report very different values of the direct asymmetry parameter \( C_{\pi\pi} \), as shown in Table 4.

| Expt. | \( S_{\pi\pi} \) | \( C_{\pi\pi} \) |
|-------|-----------------|-----------------|
| BaBar | 0.02            | -0.30           |
| Belle | +0.34 \pm 0.05  | +0.25 \pm 0.04  |
|       | -1.21           | -0.94           |
|       | +0.31 \pm 0.16  | +0.31 \pm 0.09  |

One point in favor of small \( C_{\pi\pi} \) is the flavor-SU(3) relation \( \Delta(B^0 \to \pi^+\pi^-) = -\Delta(B^0 \to K^+\pi^-), \) where \( \Delta(B \to PP) = \Gamma(B \to PP) - \Gamma(B \to K^+\pi^-). \) Since the direct CP asymmetry in \( B^0 \to K^+\pi^- \) is small, one may also expect it to be small in \( B^0 \to \pi^+\pi^- \).

Applying the SCET, Leibovich [98] reported on a study of \( \Upsilon \) radiative decays near the end point, where one can justify the use of a nonperturbative “shape function” near \( z \equiv 2E_\gamma/M_\Upsilon = 1. \) The effect of the color-octet admixture in the \( \Upsilon \) wave function is found to be surprisingly small. Calculations are now in progress for the color-singlet component of the wave function.

Colangelo [99] reported on a study of three-body \( B^0 \to D^+D_s^{(*)0}K^+ \) decays in which one can select the effects of contributing \( D_s^{(*)0} \) poles; factorization (like Niels Bohr’s horseshoe) works even when it isn’t supposed to, as has been found elsewhere [83,100].
7.7. $B \to (s\gamma, sl^+l^-, l^+l^-)$ decays

The experimental situation on radiative $b$ decays continues to improve. Braun [73] reported on a branching ratio $B(B \to X_s \gamma) = (3.22 \pm 0.40) \times 10^{-4}$, to be compared with the standard model prediction [101] of $(3.54 \pm 0.49) \times 10^{-4}$. A lot of the theoretical uncertainty arises from uncertainty in $m_c/m_b$. With $500 \, \text{fb}^{-1}$ the experimental error is anticipated to be $\pm 1.8\%$, making $\pm 3\%$ a useful theoretical goal. BaBar has an upper limit on $B \to \rho\gamma$ entailing $|V_{td}/V_{ts}| < 0.36$, approaching the SM level of 0.2.

Both BaBar [73] and Belle [103] now see a $B^+ \to K^+\ell^+\ell^-$ signal, with BaBar newly reporting $B = (0.84^{+0.24}_{-0.18}) \times 10^{-6}$. Belle’s inclusive branching ratios $B(B \to X_s l^+l^-) = (8.9^{+2.3}_{-2.1} \pm 1.7) \times 10^{-6}$ and $B(B \to X_s l^+l^-) = (7.1^{+1.6}_{-1.2}) \times 10^{-6}$ are a bit above the SM predictions [101] of $B(B \to X_s e^+e^-) = (6.9 \pm 1.0) \times 10^{-6}$ and $B(B \to X_s \mu^+\mu^-) = (4.2 \pm 0.7) \times 10^{-6}$.

In a discussion of radiative $b$ decays and related gateways to new physics, Hiller [101] listed the “Top 10 observables beyond $b \to s\gamma$.” Briefly, these are: (1) CP violation and (2) photon helicity in $b \to s\gamma$, (3) $\sin(2\phi_1)$ in $B \to \phi K$, (4) the dilepton mass spectrum and (5) the forward-backward asymmetry in $b \to sl^+l^-$, (6) the question of where and whether this asymmetry vanishes as a function of dilepton mass, (7) CP violation in this forward-backward asymmetry, (8) $B_c-B_s$ mixing and the effects of $Z$ penguins, (9) Higgs boson exchange in $B \to l^+l^-$, and (10) the neutron electric dipole moment. Geng [104] has suggested looking for new physics in $T$-violating observables in $\Lambda_b \to \Lambda e^+e^-$; P. Cooper pointed out in the discussion that one should first look for the much more abundant process $\Sigma^+ \to pe^+e^-$.

Huang [106] notes that an interesting level for $B(B^0 \to l^+l^-)$ to display non-standard physics is in excess of $2 \times 10^{-5}$, which sets an initial goal for high-statistics studies of this low-background process.

8. HEAVY QUARK PRODUCTION

The fragmentation of $c$ and $b$ quarks produced in $Z$ decays turns out to be an important source of charmed and $b$ flavored baryons. The DELPHI Collaboration [106] has presented evidence for $c \to \Xi^0 \to \Xi^-\pi^+$ and $b \to \Xi_c \to \Xi^-lX$ with branching ratios $B \sim 5-6 \times 10^{-4}$.

The color-octet part of the quarkonium wave function seems to be needed to explain $J/\psi$ production at the Tevatron, but it is not so clearly required in some other cases [107]. It is also claimed to be needed in the description of decays to light hadrons (see, e.g., [108]), raising the question of how the value of $\alpha_s(m_b)$ extracted in older analyses (e.g., [46]) would be affected. In production models, one of the hardest things to get right is the $J/\psi$ polarization, reminiscent of the difficulties that Regge pole fits in the 1960s had in coping with polarization data.

The production cross section for $b$ quarks at the Tevatron [109] (and also in $ep$ [110] and $\gamma\gamma$ reactions) exceeds the predictions of non-leading-order (NLO) QCD, by as much as a factor of 2.5 in the case of $\bar{p}p$ collisions at 1.8 TeV. Is this due to a subtlety in the choice of QCD scale or an indication of new physics? One proposed scenario [111] involves a light gluino and $b$ squark, whereby $b$ quark pair production boosts the $b$ quark production cross section. It seems difficult to rule out this scenario based on the $Q^2$ dependence of $\alpha_s$ [112]. Hadronic and $ep$ charm production, paradoxically, seems less out-of-line [110].

Leading-quark effects in hadronic charm production have been studied by the SELEX Collaboration [111]. The presence of a specific quark or antiquark in the beam governs the nature of the leading $D$ or $\bar{D}$, which will contain that quark. An interesting difference between $x_F$ distributions occurs between $D^+$ and $D^{**}$ produced by $\Sigma^-$ beams.

The HERA-b Collaboration has measured the $b$ production cross section for 920 GeV protons on a fixed nuclear target: $\sigma(b\bar{b}) = 32^{+14+9}_{-12-9}$ nb/nucleon [119]. At this energy, roughly 1/3 of prompt $J/\psi$ particles come from $\chi_c \to J/\psi\gamma$.

In a tour de force of track finding and scanning, the CHORUS Collaboration has measured $D^0$ and $\Lambda_c$ yields in charged-current neutrino interactions at average beam energy 27 GeV [113]:

$$\frac{\sigma(D^0)}{\sigma_{cc}} = (1.99 \pm 0.13 \pm 0.17)\%$$
9. ELECTROWEAK SECTOR

A cut $p_t < 30$ GeV was imposed in order to ensure sufficient hadronic boost in the hybrid emulsion detector.

Heavy-ion hyperon and charm production has been studied at CERN [116]. There appears to be an enhancement of hyperon production in nucleus-nucleus collisions, while an abrupt suppression of $J/\psi$ production occurs as the atomic number of the colliding particles is increased, suggesting the onset of production of a quark-gluon plasma in which quarkonium is dissociated.

In the SM one has $g_{LL} = -\frac{1}{2} + \sin^2 \theta$, $g_{RR} = \sin^2 \theta$, $g_{Lb} = -(1/2) + (1/3) \sin^2 \theta$, $g_{Rb} = (1/3) \sin^2 \theta$. The observed value of $A_{FB}^{b}$ entails $\sin^2 \theta = 0.23218 \pm 0.00031$, to be compared with $0.23149 \pm 0.00017$ in the overall fit. This could be interpreted as a discrepancy in $g_{Rb}$, with the data implying 0.095 ± 0.008 to be compared with $\pm 0.077$ in the SM. However, $g_{Lb}$ seems to agree roughly with its SM value of $\simeq -0.42$. Other data, such as the polarization asymmetry $A_{LR}$ measured at SLD [113], suggest a lower value of $\sin^2 \theta$, entailing a value of the Higgs boson mass $M_H$ lower than the experimental lower bound! (See [116] for a discussion.) Above the $Z$ [20], there seem to be no anomalies in electroweak couplings. The $\tau$ lepton appears to behave as a standard-model sequential fermion [121].

If one also includes recent data from the NuTeV Collaboration [122] on the neutral current cross section $\sigma_{NC}(\nu N)$ for deep-inelastic scattering of neutrinos on nucleons, which entail a higher value of $\sin^2 \theta$, the overall quality of the fit to electroweak data is degraded, but the bound on $M_H$ is relaxed [123][124]. Higgs boson searches will tell us whether this is the correct alternative. At LEP [124], only ALEPH claims a signal ($3\sigma$, 115.6 GeV), diluted to 2.1$\sigma$ when data from DELPHI, L3, and OPAL are included. The measurement of four-fermion production at LEP II [125] is instrumental in understanding backgrounds. Inclusion of NuTeV data in electroweak fits relaxes the upper bound on $M_H$ to 212 GeV, assuming only Higgs doublets acquire vacuum expectation values (VEVs). With less than a 3% admixture of weak-SU(2) triplet VEVs, this bound is removed for all practical purposes [23].

10. BEYOND THE STANDARD MODEL

The reigning candidate for physics beyond the Standard Model is supersymmetry, a beautiful concept which implies that there may be quantities more fundamental than space and time. Its implementation at the electroweak scale is problematic for model-builders, perhaps because of a lack of experimental clues. I am tempted to ask, as A. Pais used to do on other occasions, “Where’s the joke?” Are we simply going to be confronted with a whole new set of superpartner masses and mixings as inexplicable as those of the quarks and leptons? Or will supersymmetry help us understand something about the pattern of quark and lepton families?

A very nice review of LEP searches for supersymmetry was presented by B. Clerbaux [26]. I am partial to one scheme based on the grand unified group $E_6$ that is at least partly supersymmetric. Start with the grand unified group SO(10), in which each quark and lepton family – including a right-handed neutrino – is represented by a 16-dimensional spinor. The simplest scalars in this scheme correspond to the 10-dimensional vector representation. Superpartners of these states would be 16-dimensional scalars (squarks and sleptons) and 10-dimensional fermions (higgsinos). By adding one more SO(10) singlet per family, one can form families which belong to the 27-dimensional (fundamental) representation of $E_6$. The three SO(10) singlet fermions correspond to sterile neutrinos. The $E_6$ group fits nicely into superstring schemes, and has been discussed recently by Bjorken, Pakvasa, and Tuan [127].
Present $e^+e^-$ searches for supersymmetry (or for any particles coupling with at least electroweak strength to the $\gamma$ and $Z$) typically exclude most superpartners with masses less than the beam energy minus a small model-dependent amount. Unsurprisingly, lower limits at the Tevatron tend to be higher but require a larger mass difference between the next-to-lightest and lightest superpartner.

11. PROSPECTS

Future experiments on beauty, charm, and hyperons hold great promise. BaBar and Belle each are approaching integrated luminosities of 100 fb$^{-1}$ and expect to have 500 fb$^{-1}$ by 2006. The CDF and D0 detectors have new capabilities for studying $b$ physics with high statistics and may have a shot at the Higgs boson [10,12,19,30]. The CLEO-c project [85] is on track to make a major impact on charm studies in the next few years. In the longer run, the forward special-purpose detectors BTeV [131,132] and LHCb [133] will be designed to take advantage of the relatively large hadronic $b$ production cross section while suppressing backgrounds. The general-purpose ATLAS and CMS detectors at the LHC also will have many capabilities related to topics discussed at this Conference [134,135,136,137,138,139].

Examples of questions I would like to see answered are the following.

(1) What value of $\phi_2 = \alpha$ is implied by the indirect CP asymmetry in $B^0 \to \pi^+\pi^-$? The BaBar-Belle discrepancy should be resolved. The branching ratio $B(B^0 \to \pi^+\pi^-)$ is itself of interest. It can be combined with information on $B \to \pi l\nu$, using factorization, to estimate the effects of tree-penguin interference [7].

(2) What is $\Delta m_s$? This will be an early Tevatron result if all goes well.

(3) Can we obtain a value of $\phi_3 = \gamma$ by studying such decays as $B^0 \to \pi^+\pi^-$, $B_s \to K^+K^-$, and ($B^0$ or $B_s$) $\to K^\pm\pi^\mp$, or will symmetry-breaking and rescattering effects prove uncontrollable? Measurements of branching ratios at the level of $10^{-7}$ will help settle these questions.

(4) Can we exploit $B_s \to J/\psi\phi$ by employing transversity analyses to separate out CP-even and CP-odd final states? The CP eigenstates $J/\psi\eta$ or $J/\psi\eta'$ may also be useful. The Standard Model predicts the CP asymmetries in these modes to be small but there could always be surprises.

(5) If we see non-standard physics (e.g., in $B \to \phi K_S$), will we able to identify it? Hiller’s “top 10” list [10] is an interesting starting point; what then?

(6) If we see a Higgs boson, will we be able to tell whether it is the Standard Model or supersymmetric variety?

(7) Are we sufficiently attuned to the wide variety of new things we could see (supersymmetry, extra dimensions, exotic quarks and leptons, ... ) at Tevatron Run II?

(8) What will the LHC reveal (and when)?

ACKNOWLEDGMENTS

The smooth arrangements made by our hosts have made us all feel exceptionally welcome at UBC. I would like to thank the Conference Assistants: Travis Beale, Patrick Brukiewich, Janet Johnson, Mark Laidlaw, and Douglas Thiessen, for their efforts, and the Organizing Committee: Janis McKenna, Tom Mattison, John Ng, Marco Bozzo, Calvin Kalman, Zoltan Ligeti, Miguel-Antonio Sanchis-Lozano, and Paul A. Singer, for putting together a varied and informative program. We in Chicago look forward to welcoming you to our city for the Sixth Conference on Beauty, Charm, and Hyperons in 2004.

I am grateful to the Theory Groups of Fermilab and Argonne National Laboratory for hospitality during the preparation of the written version of this talk, and to Matthias Neubert for useful discussions. This work was supported in part by the United States Department of Energy through Grant No. DE FG02 90ER40560.

REFERENCES

1. A. Manohar, this conference.
2. F. Gilman, K. Kleinknecht, and Z. Renk, subsection on CKM elements in Review of Particle Properties.
3. See [3]. The Perkeo II experiment reports
$|V_{ud}| = 0.9713(13)$. See H. Abele et al., Phys. Rev. Lett. 88 (2002) 211801.
4. E. Swallow, this conference.
5. Brookhaven National Laboratory Experiment E865, presented by A. Sher at DPF 2002 Meeting, Williamsburg, VA, May 26, 2002.
6. V. Bytev, E. Kuraev, A. Baratt, and J. Thompson, [hep-ph/0210049].
7. A. Ealet, this conference.
8. J. L. Rosner, Phys. Rev. D 27 (1983) 1101.
9. KLOE Collaboration, presented by P. Branchini, this conference.
10. BNL E87 Collaboration, presented by T. Numao, this conference.
11. Brookhaven National Laboratory Experiment E87, S. Adler et al., Phys. Rev. Lett. 88 (2002) 041803.
12. L. Wolfenstein, Phys. Rev. Lett. 51 (1983) 1945.
13. CKM Collaboration, presented by H. Nguyen, this conference.
14. KTeV Collaboration, presented by E. Monnier, this conference.
15. NA48 Collaboration, presented by M. Sozzi, this conference.
16. NA48 Collaboration, A. Lai et al., Phys. Lett. B 536 (2002) 229.
17. Fermilab E832 Collaboration, A. Alavi-Harati et al., preprint [hep-ex/0208001], submitted to Phys. Rev. D.
18. NA48 Collaboration, J. R. Batley et al., Phys. Lett. B 544 (2002) 97.
19. Particle Data Group, K. Hagiwara et al., Phys. Rev. D 66 (2002) 010001.
20. CERN NA48 Collaboration, presented by D. Munday, this conference.
21. E. Jenkins, Ann. Rev. Nucl. Part. Sci. 48 (1998) 81.
22. P. Żenczykowski, this conference; [hep-ph/0207193].
23. F. J. Gilman and M. Wise, Phys. Rev. D 19 (1979) 976.
24. M. B. Gavela et al., Phys. Lett. B101 (1981) 41.
25. Y. Hara, Phys. Rev. Lett. 12 (1964) 378.
26. Fermilab HyperCP Collaboration, presented by N. Solomey, this conference; [hep-ex/0208026].
27. Fermilab HyperCP Collaboration, presented by P. Żyla, this conference.
28. Belle Collaboration, S. K. Choi et al., Phys. Rev. Lett. 89 (2002) 129901(E).
29. A. Martin and J. M. Richard, Phys. Lett. 115B (1982) 323.
30. J. L. Rosner, Phys. Rev. D 64 (2001) 094002.
31. E. J. Eichten, K. D. Lane, and C. Quigg, Fermilab report no. FERMILAB-PUB-02-104-T, [hep-ph/0206018] submitted to Phys. Rev. D.
32. Fermilab E835 Collaboration, presented by P. Rumerio, this conference; S. Bagnasco et al., Phys. Lett. B 533 (2002) 237.
33. M. Suzuki, Phys. Rev. D 66 (2002) 037503.
34. M. B. Voloshin, Yad. Fiz. 43 (1986) 1571 [Sov. J. Nucl. Phys., 43 (1986) 1011].
35. Y.-P. Kuang and T.-M. Yan, Phys. Rev. D 24 (1981) 2874.
36. S. Godfrey and J. L. Rosner, Phys. Rev. D 66 (2002) 014012.
37. W. Kwong and J. L. Rosner, Phys. Rev. D 38 (1988) 279.
38. K.-T. Chao, this conference; L.-K. Hao, K.-Y. Liu, and K.-T. Chao, [hep-ph/0206228]; K.-T. Chao and L.-K. Hao, [hep-ph/0209189].
39. S. Godfrey and J. L. Rosner, Phys. Rev. D 64 (2001) 097501.
40. CLEO Collaboration, S. E. Csorna et al., CLEO-CONF 02-06, reported by T. Skwarnicki at International Conference on High Energy Physics, Amsterdam, July 2002.
41. BES Collaboration, presented by Y. Zhu, this conference.
42. N. Brambilla, this conference, [hep-ph/0209096]; N. Brambilla et al., [hep-ph/0208019].
43. A. Pineda, this conference, [hep-ph/0209128].
44. M. A. Sanchis-Lozano, this conference, [hep-ph/0206150].
45. A. Vairo, this conference.
46. W. Kwong, P. Mackenzie, R. Rosenfeld, and J. L. Rosner, Phys. Rev. D 37 (1988) 3210.
47. SELEX Collaboration, presented by P. Cooper, this conference.
48. SELEX Collaboration, M. Mattson et al., Phys. Rev. Lett. 89 (2002) 112001.
49. FOCUS Collaboration, presented by S. Ratti, this conference.
50. A. De Rújula, H. Georgi, and S. L. Glashow, Phys. Rev. D 12 (1975) 147.
51. FOCUS Collaboration, presented by A. Lopez, this conference.
52. CLEO Collaboration, G. Brandenburg et al., Cornell University Report CLNS-02-1776, hep-ex/0203030, submitted to Phys. Rev. Lett.
53. J. Amundson and J. L. Rosner, Phys. Rev. D 47 (1993) 1951.
54. FOCUS Collaboration, presented by E. Vanander, this conference.
55. CLEO Collaboration results on charm production, presented by T. Pedlar, this conference.
56. C.-W. Chiang and J. L. Rosner, Phys. Rev. D 65 (2002) 054007.
57. J. L. Rosner, Phys. Rev. D 60 (1999) 114026.
58. D. Matrasulov, this conference; D. Matrasulov et al., Eur. Phys. J. A 14 (2002) 81.
59. I. Narodetskii and M. A. Trusov, this conference, hep-ph/0209044.
60. S. Fajfer, this conference; S. Fajfer et al., hep-ph/0208201.
61. C. Bauer, this conference.
62. F. Chishtie, this conference; M. R. Ahmady et al., hep-ph/0207075; Phys. Rev. D 66 (2002) 014010.
63. C. Jin, this conference; hep-ph/0210005.
64. CLEO Collaboration, presented by J. Urheim, this conference.
65. D. Waller, this conference.
66. C. S. Kalman, this conference; I. D’Souza et al., hep-ph/0209045.
67. V. Elias, this conference; M. R. Ahmady et al., hep-ph/0209001; J. Phys. G 28 (2002) L15.
68. M. Luke, this conference; C. W. Bauer, M. Luke, and T. Mannel, Phys. Lett. B 543 (2002) 261.
69. R. V. Kowalewski, this conference; R. V. Kowalewski and S. Menke, Phys. Lett. B 541 (2002) 29.
70. L. Piilonen, this conference.
71. Z. Luo and J. L. Rosner, Phys. Rev. D 65 (2002) 054027.
72. CLEO Collaboration, S. Ahmed et al., Phys. Rev. D 66 (2002) 031101.
73. B. Brau, this conference.
74. S. Gardner, this conference, hep-ph/0209080.
75. H. J. Lipkin, this conference; A. Datta, H. J. Lipkin, and P. J. O’Donnell, Phys. Lett. B 544 (2002) 145.
76. P. J. O’Donnell, this conference.
77. H. Lipkin, Phys. Rev. Lett. 46 (1981) 1307; Phys. Lett. B 254 (1991) 247.
78. M. Beneke, preprint hep-ph/0207228, talk at Conference on Flavor Physics and CP Violation (FPCP), Philadelphia, Pennsylvania, 16–18 May 2002; M. Neubert, Cornell University report CLNS-02-1794, hep-ph/0207327, invited plenary talk given at International Workshop on Heavy Quarks and Leptons, Vietri sul Mare, Salerno, Italy, 27 May – 1 Jun 2002, and at QCD 02: High-Energy Physics International Conference on Quantum Chromodynamics, Montpellier, France, 2–9 Jul 2002.
79. C.-W. Chiang and J. L. Rosner, Phys. Rev. D 65 (2002) 074035.
80. T. Moore, this conference.
81. F. Parodi, this conference.
82. A. S. Kronfeld and S. Ryan, Phys. Lett. B 543 (2002) 59.
83. J. L. Rosner, Phys. Rev. D 42 (1990) 3732.
84. B. Grinstein, Phys. Rev. Lett. 71 (1993) 3067.
85. T. Pedlar, talk on CLEO-c, this conference.
86. C. Hamzaoui, J. L. Rosner, and A. I. Snda, in Proc. of Fermilab Workshop on High Sensitivity Beauty Physics, Batavia, IL, Nov 11–14, 1987, edited by J. Slaughter et al., eConf code cnum c87/11/11.
87. D. Marlow, for the Belle and BaBar Collaborations, this conference.
88. BaBar Collaboration, B. Aubert et al., SLAC report SLAC-PUB-9297, hep-ex/0207070, contributed to 31st International Conference on High Energy Physics (ICHEP 2002), Amsterdam, The Netherlands, 24–31 July 2002.
89. Belle Collaboration, K. Abe et al., BELLECONF-0201, hep-ex/0207099, contributed to 31st International Conference on High Energy Physics (ICHEP 2002), Amsterdam, The Netherlands, 24–31 July 2002.
90. M. Morii, for the Belle and BaBar Collaborations, this conference.
91. A. Datta, this conference; A. Datta and D. London, hep-ph/0208144.
92. X.-G. He, this conference.
93. M. Gronau and J. L. Rosner, Phys. Rev. D 61 (2000) 073008; Phys. Lett. B 482 (2000) 71; Phys. Rev. D 65 (2002) 013004, 079901(E), 093012, 113008; Technion report TECHNION-PH-2002-21, hep-ph/0205323, to be published in Phys. Rev. D.
94. I. Stewart, this conference, hep-ph/0209159.
95. Y.-Y. Keum, H.-N. Li, and A. I. Sanda, Phys. Lett. B 504 (2001) 6.
96. BaBar Collaboration, B. Aubert et al., SLAC-PUB-9317, hep-ex/0207055.
97. Belle Collaboration, K. Abe et al., BELLE-PREPRINT-2002-8, hep-ex/0204002.
98. A. Leibovich, this conference, hep-ph/0207245.
99. P. Colangelo, this conference, hep-ph/0210035; P. Colangelo and F. De Fazio, Phys. Lett. B 532 (2002) 193.
100. Z. Luo and J. L. Rosner, Phys. Rev. D 64 (2001) 094001.
101. G. Hiller, this conference, hep-ph/0207121.
102. See also P. Gambino and M. Misiak, Nucl. Phys. B611 (2001) 338, who quote $B(\bar{B} \to X_s \gamma)|_{E_\gamma > 1.6 \text{ GeV}, \phi, \phi' = (3.60 \pm 0.30) \times 10^{-4}}$. We thank L. Roszkowski for this reference.
103. Belle Collaboration, K. Abe et al., Phys. Rev. Lett. 88 (2002) 021801.
104. C.-Q. Geng, this conference; C.-H. Chen, C. Q. Geng, and J. N. Ng, Phys. Rev. D 65 (2002) 091502.
105. C.-S. Huang, this conference.
106. DELPHI Collaboration, presented by L. Berntson, this conference.
107. R. Brugnera, this conference.
108. A. Petrelli et al., Nucl. Phys. B514 (1998) 245; F. Maltoni, M. L. Mangano, and A. Petrelli, Nucl. Phys. B519 (1998) 361.
109. J. Cranshaw, this conference, Fermilab report FERMILAB-CONF-02-220-E.
110. R. Gerhards, this conference.
111. E. L. Berger et al., Phys. Rev. Lett. 86 (2001) 4231.
112. C.-W. Chiang, Z. Luo, and J. L. Rosner, Argonne National Laboratory report ANL-HEP-PR-02-055, hep-ph/0207235, submitted to Phys. Rev. D.
113. SELEX Collaboration, presented by M. Iori, this conference.
114. HERA-b Collaboration, presented by M. Mevius, this conference; I. Abt et al., hep-ex/0205106.
115. CHORUS Collaboration, presented by K. Narita, this conference; A. Kayis-Topaksu et al., Phys. Lett. B 527 (2002) 173.
116. K. Šafarík, this conference; NA57 Collaboration, K. Fanebust et al., J. Phys. G 28 (2002) 1607.
117. W. Liebig, this conference.
118. SLD Collaboration, presented by N. de Groot, this conference.
119. M. Chanowitz, Lawrence Berkeley National Laboratory report LBNL-50718, hep-ph/0207123 (unpublished).
120. I. Vorobiev, this conference.
121. R. Sobie, this conference.
122. NuTeV Collaboration, G. P. Zeller et al., Phys. Rev. Lett. 88 (2002) 091802.
123. J. L. Rosner, Phys. Rev. D 65 (2002) 073026.
124. LEP Collaborations, presented by A. Holzner, this conference, hep-ex/0208047.
125. O. Boeriu, this conference.
126. B. Clerbaux, this conference.
127. J. D. Bjorken, S. Pakvasa, and S. F. Tuan, Phys. Rev. D 66 (2002) 053088.
128. CDF Collaboration, presented by S. Miller, this conference.
129. D0 Collaboration, presented by R. Jesik, this conference.
130. R. Moore, this conference.
131. P. Kasper, this conference.
132. S. Kwan, this conference.
133. Z. Ajaltouni, this conference.
134. A. Nairz, this conference; B. Epp, V. M. Ghete, and A. Nairz, hep-ph/0202192.
135. F. Malek-Ohlsson, this conference.
136. R. Ranieri, this conference.
137. G. Segneri, this conference.
138. M. Smizanska, this conference.
139. T. Speer, this conference.