B PHYSICS

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A review over recent experimental progress in the physics of the fifth quark is given.
7: B Physics

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1 Introduction

The value of the mass of the fifth, the beauty-quark, around 5 GeV leads to a special role of the b-hadrons. The most heavy quark, the top quark, is too heavy to build hadrons. This is because it can decay by “weak” interaction into a real W-boson and a b-quark. This decay occurs much faster than the typical time needed to bind with an antiquark into a meson by the strong interaction. Thus, hadrons containing a b-quark are the heaviest hadrons. On the other hand, the b-quark mass is much larger than the typical scale of the strong interaction, \( \Lambda_{QCD} \), responsible for the binding of quarks into hadrons. This is the reason for the success of Heavy Quark Effective Theory. A B-meson consisting of a heavy b-quark and a light antiquark thus resembles lots of properties of the hydrogen atom.

This review gives a short (due to space limitations) summary of the state of the field. More extensive recent summaries of LEP results are found in [1] and [2], on B-decays in [3]. Note also the companion theoretical talk at this conference [4]. The transparencies of this talk can be found in [5].

At this conference the first experimental verification of the running of the b-quark mass has been presented [6, 7]. The relative 3-jet rate in \( b\bar{b} \) events is compared to the relative 3-jet rate in light quark events. A three jet topology originates from gluon radiation off a quark line. This radiation is suppressed for heavy quarks. Comparing the measured ratio to new next-to-leading-order (NLO) QCD calculations [8] the running \( \overline{MS} \) mass has been determined to

\[
m_b(M_Z) = 2.67 \pm 0.25(stat.) \pm 0.34(frag.) \pm 0.27(theo.) GeV/c^2,
\]

to be compared to \( m(b(M_B/2)) = 4.16 \pm 0.18 GeV/c^2 \) from Upsilon spectroscopy. There is clear evidence for a running, see Fig.1a.

2 \( b \) quark production

2.1 \( b \) production at the Tevatron

Both CDF and D0 find \( b \) production cross sections about 2 times as large as NLO QCD predictions [9]. The shape of the transverse momentum
spectrum as well as the dependence on the c.m.s. energy is roughly described, not however the rapidity distribution: the discrepancy gets larger in the forward region.

2.2 $b$ production in $Z$ decays

The ratio $R_b$ of $Z$ decays into $b\bar{b}$-quark relative to all hadronic (i.e. $q\bar{q}$) decays is interesting due to the large mass of the $b$-quark, since an enhanced $R_b$ could indicate a Higgs-like Yukawa coupling to masses.

There was lots of excitement because with increasing precision the world average actually showed a discrepancy, with more than 3$\sigma$ in 1995. At last year’s Warsaw Conference ALEPH \cite{10} presented an analysis with very small errors ( $R_b = 0.2161 \pm 0.0009 \pm 0.0011$), in perfect agreement with the SM prediction of 0.2158. This was less dependent on charm background and had strongly reduced hemisphere correlations.

This year also other collaborations presented new analyses. Especially DELPHI [eps419] has undertaken a major effort to reprocess all their data with a strongly improved pattern recognition and track fitting procedure, leading to a much cleaner reconstruction especially in dense jets. Also the $b$-tagging algorithm was optimised by including the z-measurements of the silicon vertex detector, vertexing, and additional variables like invariant mass and track rapidities. The $b$-tagging performances of the different detectors are summarized in fig 1b. Note the SLD 96 point which is due to a new vertex detector with twice as good resolution. Unfortunately, SLD is lacking statistics compared to the LEP Collaborations.
The average determined by the LEP electroweak working group \[11\] is 0.2171 ± 0.0009, well compatible with the SM prediction with an accuracy of 0.4%. For more details see \[\text{[12].}\]

2.3 Gluon splitting

The gluon splitting probability \( f \to \bar{b}b \) is an important ingredient in the \( R_b \) measurement, constituting the largest single systematic uncertainty. DELPHI (0.21 ± 0.11 ± 0.09\%)\[13\] and ALEPH (0.257 ± 0.040 ± 0.087\%)\[\text{[eps606]}\] have determined this parameter employing an analysis of b-tagged jets in four jet events, the (simple) average being (0.24 ± 0.09)\%.

2.4 \( B_s \) and \( B^+ \) rates in b-jets at LEP

The classical method of determining the primary \( B_s \) rate \( f_s \) consists of a comparison of the integrated \( \bar{B}B \) mixing \( \chi \) in \( Z \) decays with the expectation \( \chi = f_d \chi_d + f_s \chi_s \), taking the measured \( \chi_d \) (see below) and assuming a fast \( B_s \) mixing frequency leading to \( \chi_s = 0.5 \). The baryon contribution is estimated from lepton-\( A_c \) and lepton-\( \Xi \) correlations. The results of the LEP mixing working group \[14\] are \( f_{\text{baryon}} = 0.1062^{+0.0373}_{-0.0273} \), \( f_d = f_u = 0.3954^{+0.0156}_{-0.0203} \) and \( f_s = 0.1031^{+0.0158}_{-0.0153} \). DELPHI \[\text{[eps451]}\] has performed a search for a charged fragmentation kaon accompanying a primary \( B_s \) (including the excited states \( B_s^*, \bar{B}_s^* \)) at high rapidity, separating out background contributions from \( B^+ \) accompanied by a \( K^- \).

The primary \( B_s \) rate \( f_S^s \) has been determined to (12.0 ± 1.4 ± 2.5)\%. This value \[13\] is smaller than that of the contributed paper, due to a different, probably more solid assumption about the validity of the model. With an estimated \( B_s^* \) rate of (27 ± 6)\% this corresponds to a rate \( f_{B_s} = (8.8 ± 1.0 ± 1.8 ± 1.0)\% \) of weakly decaying \( B_s \) mesons, where the last error is due to the \( B_s^* \) rate.

In the same paper \[\text{[eps451]}\] an analysis of the rate of charged versus neutral weak B-hadrons is presented:

\[
B(\bar{b} \to X^0_b) = (57.8 ± 0.5 ± 1.0)\%, \quad B(\bar{b} \to X^+_{b}) = (42.2 ± 0.5 ± 1.0)\%.
\]

Making an assumption about the small contribution of charged \( \Xi_b \) and \( \Omega_b \) production \((1.0 ± 0.6)\%\) leads to \( B(\bar{b} \to B^+) = (41.2 ± 1.3)\% \).

ALEPH has also presented a new measurement of the b-baryon rate of (12.1 ± 0.9 ± 3.1)\% \[\text{[eps597]}\].

3 Spectroscopy

The mesons \( B^0, B^+ \) and \( B_s \) are clearly established and their masses measured. The vector meson \( B^* \) is seen in its decays into \( B\gamma \) and \( Be^+e^- \) \[\text{[eps450]}\]. The existence of the \( L = 1 \) orbitally excited \( B^{**} \) mesons is established, but there is not yet a clear decomposition into the expected 2
narrow and 2 broad states. DELPHI has preliminary evidence for two narrow \( B^{*\ast}_{s} \) states decaying into \( BK \) and some evidence for a radial excitation in \( B\pi^{+}\pi^{-} \), which need confirmation. The latter analysis triggered a similar analysis in the charm sector, where a narrow resonance in \( D^{*}\pi^{+}\pi^{-} \) has been found \[eps452\]. No \( L > 1 \) B-mesons are known. Also searches for the beautiful charmed \( B_{c} \)-meson have been hitherto unsuccessful.

In the baryon sector, the \( \Lambda_{b} \) is clearly established now by CDF \[16\], the mass being measured to \( 5621 \pm 4 \pm 3 \) MeV. There are \( \Sigma_{b} \) and \( \Sigma_{b}^{*} \) candidates seen by DELPHI, which need confirmation. The existence of the \( \Xi_{b} \) is proven, but there is no mass measurement available. No other b-baryon states are known: no \( \Xi_{b}', \Xi_{b}^{*}, \Omega_{b} \) or \( \Omega_{b}^{*} \), also no orbital or radial excitation. For more extensive summaries on B-spectroscopy see e.g.\[17, 18\].

4 Lifetimes

Again there have been many new lifetime measurement contributions, which are averaged by a b-lifetime working group \[19\] taking into account correlated systematics etc. The results are:

\[
\begin{align*}
\tau_{\text{average}} &= 1.554 \pm 0.013 \text{ps} \\
\tau(B^{0}) &= 1.57 \pm 0.04 \text{ps} \\
\tau(B^{+}) &= 1.67 \pm 0.04 \text{ps} \\
\tau(B^{+})/\tau(B^{0}) &= 1.07 \pm 0.04 \\
\tau(B_{s}) &= 1.54 \pm 0.06 \text{ps} \\
\tau(b - \text{baryon}) &= 1.22 \pm 0.05 \text{ps}
\end{align*}
\]

Thus the qualitative picture remains intact: Charged B mesons live slightly longer, the \( B^{0} \) and \( B_{s} \) lifetimes are roughly the same, and the \( \Lambda_{b} \) has a much shorter lifetime than the mesonic states. The \( \Lambda_{b} \) lifetime is correlated with a small semileptonic branching ratio, see below. The origin of the low b-baryon lifetime is not yet clarified.

5 Mixing

Second order weak interactions lead to particle-antiparticle oscillations between \( B_{0} \) and \( \bar{B}_{0} \) and \( B_{s} \) and \( \bar{B}_{s} \). They are described by a mass difference of the CP-eigenstates constructed by the sum and difference of the original wave functions. In the Standard Model, the mass differences are related to the Kobayashi Maskawa matrix elements \( V_{td} \) and \( V_{ts} \), respectively. To measure the time dependence of the mixing, one needs to know the b-flavour at production and decay time to define whether a mixing occurred or not, as well as the decay length and energy to reconstruct the proper
Fig. 2. Mass excitation curves of the $K_0 - \bar{K}_0$ ($\Gamma_s > \Delta m \approx \Gamma_l$, $\Delta \Gamma$ large), $B_s - \bar{B}_s$ ($\Delta m > \Gamma$, $\Delta \Gamma$ small), and $B^0 - \bar{B}^0$ ($\Delta m \approx \Gamma$, $\Delta \Gamma$ small) systems. Curves are due to E. Golowich, Moriond 1995

Fig. 3. Expected oscillation patterns for $B_d$ with $\Delta m = 0.474 \text{ps}^{-1}$ and $B_s$ with $\Delta m = 10 \text{ps}^{-1}$.

decay time. Many different methods have been developed for this purpose. Fig. 4 gives an overview of the available results for the $B^0$ mass difference $\Delta m_4$, which is proportional to the oscillation frequency: The preliminary average derived by the LEP oscillation working group is $0.472 \pm 0.018 \text{ps}^{-1}$. $B_s$ mixing proceeds much faster than $B^0$ mixing, and the time evolution has not yet been resolved. Only a lower limit could be derived: $\Delta m_s > 10.2 \text{ps}^{-1}$ at 95% c.l. Especially noteworthy at this conference is the new ALEPH measurement using an inclusive lepton ansatz [eps612]. The large sensitivity came somewhat surprising, since it was common belief that more exclusive methods with better resolution (but less statistics) are superior.
Fig. 4. Measurements of $\Delta m_d$

Fig. 5. Sensitivity on $\Delta m_s$
6 Decays

6.1 Inclusive properties

A new analysis of the mean charged multiplicity in b-hadron decays produced at the Z by DELPHI [eps850] of \( \bar{n}(B) = 4.96 \pm 0.03 \pm 0.05 \) has much smaller systematic uncertainties than previous measurements.

6.2 Semileptonic decays

The semileptonic branching ratio \( B_{sl} \) is measured to be smaller than expected. Possible explanations are large QCD corrections to \( b \rightarrow c \bar{c}s \) (which implies a large \( N_c \)), or a large hadronic Penguin contribution \( b \rightarrow s g \). \( N_c \) however seems to be low also (see talk of Neubert). One should however not overlook that there are experimental mysteries: there seem to be differences both in \( N_c \) and \( B_{sl} \) between the experiments using \( \Upsilon(4S) \) and \( Z \) decays to produce the b-quarks, but these differences are not as expected from the different b-hadron composition.

Both ARGUS and CLEO have performed almost model-independent analyses. They could separate the direct \( b \rightarrow l \) and the cascade \( b \rightarrow c \rightarrow l \) decays using a high energy lepton charge from the other B meson in the event, their mean value being 10.19 ± 0.37%. In particular, the CLEO Collaboration is sure that their result is not altered by the discovery of "upper vertex" D production, as described below.

There is a contradiction with the LEP experiments, whose latest value is \( B_{sl} = 11.12 \pm 0.20 \) as averaged by the electroweak working group. It is
interesting to have a closer look at this average. For the LEP HF-EW working group $B_{sl}$ is an auxiliary quantity in the complete electroweak heavy flavour fit. The early measurements essentially measured $R_b \times B_{sl}$, i.e. there are large correlation coefficients between $R_b$ and $B_{sl}$. With the current very precise values of $R_b$, the old 1991 measurements get huge weights (and are on the high side) for the average $B_{sl}$ determination. This result however crucially depends on the correlation matrix elements, including the estimates of the systematics correlation. Furthermore, it might be allowed to doubt that the systematics was as well under control in 1991 as now. It should also be remarked that the upper vertex D production is not yet included in the Monte Carlo models used for acceptance and background calculations, and there is no serious study yet about the possible influence. The value at LEP is not necessarily the same as at CLEO, due to the different B-hadron contribution. The $A_b$ has been measured to have a lower semileptonic branching ratio (see below), but this should lead to a smaller value at LEP than in $\Upsilon(4S)$ decays.

6.3 $A_b$ semileptonic branching ratio

OPAL [eps153] measured the ratio $R_{sl} = B(A_b \rightarrow \Lambda l^- X)/B(A_b \rightarrow \Lambda X) = (7.0 \pm 1.2 \pm 0.7)\%$, and ALEPH [eps597] the corresponding ratio $R_{pl} = (7.8 \pm 1.2 \pm 1.4)\%$ (i.e. $\Lambda$ replaced by proton), both of which can be assumed to be very similar to $B(A_b \rightarrow \Lambda X)$. Both are significantly smaller than the average semileptonic branching ratio. Given the apparent smaller lifetime of the $A_b$, this is consistent with the hypothesis of a constant semileptonic width for all B-hadrons.

6.4 Wrong sign charm

The determination of the average number of charm and anticharm quarks per b-hadron decay is called charm counting. In most of the cases exactly one charm quark is produced from the b-quark by W-emission. Only a small number of cases without c-quark is expected, either from $b \rightarrow u$ transitions or due to loop (Penguin) processes. A second (anti-) charm quark is produced when the W decays into $s\bar{c}$. Up to recently it was thought that these two quarks always end up in a single $D_s$ meson. Through the measurements $B(B \rightarrow D\bar{X})/B(B \rightarrow \bar{D}X) = 0.100 \pm 0.026 \pm 0.016$ (CLEO [eps383], $B(B^{0,-} \rightarrow D^0 D^0 X, D^0 D^- X, D^0 D^+ X) = 12.8 \pm 2.7 \pm 2.6$ (ALEPH) [20] and $B(B^{0,-} \rightarrow D^{*+} D^{*-} X) = 1.0 \pm 0.2 \pm 0.3$ (DELPHI) [21] we know that this is not true. CLEO has performed this measurement by analysing angular correlations of D-mesons with high momentum leptons. CLEO also has observed four exclusive double charm decay modes and has placed limits on three others [eps337]. The observed large rates including $D^*$ mesons suggest that the wrong sign D mesons have a very soft spectrum in the B cms. CLEO also has searched for resonances (especially the
$J^P = 1^+D^*_K(2536)$ in the upper vertex $D^*K$ spectra, but didn’t find any enhancement. From their upper limit $B(B \to D^*_sX) < 0.95\%$ at 95\% c.l., one can deduce that the axial vector coupling constant $f_{D^*_s}$ is at least a factor 2.5 lower than that of the pseudoscalar $D^+_s$.

6.5 Charm Counting

Classical charm counting experiments consist in measuring the rates of the weakly decaying D-hadrons in selected b-events. The published values differ quite a bit: CLEO: $N_c = 111.9 \pm 1.8 \pm 2.3 \pm 3.3\%$ [22], ALEPH: $N_c = 123.0 \pm 3.6 \pm 3.8 \pm 5.3\%$ [23], OPAL: $N_c = 106.1 \pm 4.5 \pm 6.0 \pm 3.7\%$ [24], where the last error is due to D branching ratios, largely correlated between the experiments. OPAL measures comparatively small $D^0$ and $D^+$ rates. A main difference between the experiments however are assumptions made about the unmeasured $\Xi_c$ contribution, which is set to 0 in the case of OPAL, whereas ALEPH estimates it to be $6.3 \pm 2.1\%$. Accepting this last estimate and including also DELPHI’s measurement of $D^0$ and $D^+$ rates the averaged result is $N_c = (120.2 \pm 4.0(stat + syst) \pm 5.3(BR))\%$.

Two alternative methods to determine the fraction of b-decays into 0,1 and 2 charmed hadrons have been suggested by the DELPHI Collaboration [25, 26]: An analysis of the hemisphere b-tagging probability distribution in terms of Monte Carlo expectations of the three components delivers the result $B(b \to 0c) = 4.4 \pm 2.5\%$, $B(b \to 2c) = 16.3 \pm 4.6\%$, and $N_c = 116.3 \pm 4.5\%$. In another ansatz correlations of identified charged kaons with inclusively reconstructed D mesons are analysed. A fit of the transverse momentum spectra of same sign and opposite sign K pairs results in $B(b \to 2c) = 17.0 \pm 3.5 \pm 3.2\%$ and $B(b \to DD_sX)/B(b \to 2c) = 0.84 \pm 0.16 \pm 0.09$. Large rates of $b \to sg$, as proposed by Kagan [22], would show up as extra source of charged kaons, especially visible at high momentum in the B c.m.s. This is not seen in DELPHI, and an upper limit $B(b \to sg) < 5\%$ at 95\% c.l. is derived. The SLD Collaboration [29] however finds a small excess in the kaon $p_T$ spectrum, when they demand that the tracks form a good single vertex (to enhance b-decays without secondary charm decay), but they did not present a numerical analysis yet.

In their wrong sign charm paper CLEO [eps383] also derives the numbers $B(b \to sg) = 0.2 \pm 4.0\%(< 6.8\%$ at 90\% c.l.), $B(b \to c\bar{c}s) = 21.9 \pm 3.6\%$ and $n_c = 120.4 \pm 3.7\%$.

Although there still are some discrepancies at the 2 sigma level, and there were controversial discussions on many of the analyses involved, it seems that there is not a serious $N_c$ problem any more. Combining all the numbers leads to $N_c = 117.6 \pm 2.3\%$. 
6.6 $B^+$ branching fractions

Although many inclusive branching ratios have been measured at ARGUS and CLEO, most of them are B-inclusive and do not distinguish between $B^+$, $B^0$, $\bar{B}^0$, and $B^-$. DELPHI [eps473] has presented a feasibility study of a method to enrich inclusively $B^+$ mesons and to measure $\pi^+$, $\pi^-$, $K^+$, $K^-$, $e^+$, $e^-$, and $\mu^+$ and $\mu^-$ rates as function of the momentum in the B-meson c.m.s.. Also the rates of different D-hadron species in $B^+$ decays are largely unknown and can be addressed with this method. Furthermore the method can be modified to a flavour-specific ($b$-$\bar{b}$) study.

![Figure 7. ALEPH signal of $B \rightarrow s\gamma$](image)

6.7 $V_{cb}$

There is not much news on $V_{cb}$. Mean values from different reactions are $B \rightarrow D^*\nu$: $(38.7 \pm 3.1) \cdot 10^{-3}$, $B \rightarrow D l\nu$: $(39.4 \pm 5) \cdot 10^{-3}$, $\Upsilon(4S)$ inclusive: $(38.7 \pm 2.1) \cdot 10^{-3}$, $Z^0$ inclusive: $(40.6 \pm 2.1) \cdot 10^{-3}$. The last two correlated values can be combined into $(39.9 \pm 2.2) \cdot 10^{-3}$, leading to an overall average value of $(39.5 \pm 1.7) \cdot 10^{-3}$. A limiting factor in exclusive and semiexclusive analyses is the bad knowledge of $D^{**}$ and nonresonant $D\pi$ production.

6.8 $V_{ub}$

Three measurements of $V_{ub}$ are available: CLEO’s lepton endpoint spectrum $(3.1 \pm 0.8) \cdot 10^{-3}$, CLEO’s exclusive $B \rightarrow \pi/\rho l\nu$ value $3.3 \pm 0.3^{+0.3}_{-0.3} \pm 0.7) \cdot 10^{-3}$ and ALEPH’s neural network analysis [30] with
(4.3 ± 0.6 ± 0.6) · 10^{-3}. All of them are strongly model dependent, however in different ways. The good agreement between the numbers is thus comforting.

6.9  $b \to s\gamma$

The electromagnetic penguin $b \to s\gamma$ has now also been observed by the ALEPH Collaboration at a rate of $B(b \to s\gamma) = (3.29 ± 0.71 ± 0.68) · 10^{-4}$. Averaged with the 1994 CLEO result this corresponds to a new mean value of $B(b \to s\gamma) = (2.578 ± 0.57) · 10^{-4}$. New next to leading order calculations [31] are $(3.28 ± 0.31) · 10^{-4}$ and $(3.48 ± 0.33) · 10^{-4}$, slightly larger than the measured value. One has to wait for an updated CLEO number with smaller errors.

6.10 Hadronic penguins

CLEO, ALEPH and DELPHI have observed a number of still very small signals on exclusive charmless final states with branching ratios in the order of $10^{-5}$. A new CLEO analysis [eps334] show that the penguin contributions (e.g. $B \to K\pi$) might be larger than expected compared to $b \to u$ transitions (like $B \to \pi\pi$). Especially this latter result is worrisome for the prospects of measuring the CKM-phase $\gamma$ at future b-factories from the decay $B \to \pi^+\pi^-$. Particle identification becomes more and more important!

6.11 $B$ decays involving $\eta'$

CLEO finds relatively large rates of charmless decays involving $\eta'$ mesons [eps335]: $B(B^\pm \to \eta' K^\pm) = (7.1^{+2.5}_{-2.1} ± 0.9) · 10^{-5}$, $B(B^0 \to \eta' K^0) = (5.3^{+2.9}_{-2.2} ± 1.2) · 10^{-5}$ [eps333], and inclusively $B(B \to \eta' X) = (6.2^{±1.6 ± 1.1} · 10^{-4}$ (with $2.0 < p(\eta') < 2.7 GeV$) [eps332]. One might speculate whether there is a larger than expected $c\bar{c}$ or glueball component in the $\eta'$ wave function. In this respect also another CLEO analysis is of interest: The measurement of the electromagnetic form factors of the $\pi^0, \eta$ and $\eta'$, as pioneered by TPC/2\gamma [43] and CELLO [24], now is measured up to such high $Q^2$ that a very remarkable qualitative statement can be made [eps703]: The $Q^2$ dependence of the $\eta'$ form factor cannot be described simultaneously at low and high $Q^2$ with the same formalism as the $\pi^0$ and $\eta$ mesons. This might be another clue that there is something more than just light quarks inside the $\eta'$.

CLEO finds much smaller branching ratios for decays involving $\eta$ mesons, as predicted by Lipkin as interference effect between creating the $\eta$ and $\eta'$ by their $u\bar{u}, d\bar{d}$ component and their $s\bar{s}$ component.
7 Other puzzles and open questions, further studies

7.1 Interference
CLEO [eps339] has measured the interference sign between colour suppressed and colour allowed amplitudes (which are closely connected to internal and external spectator diagrams) to be positive and consistent with equal in the six final states $D\pi, D\rho, Da_1$ and $D^*\pi, D^*\rho$ and $D^*a_1$. From this they would expect an up to 15% larger $B^0$- than $B^+$-lifetime, in contradiction to experiment. This must mean that this interference pattern is not typical for the whole set of hadronic B-decays.

7.2 $B^+, B^0$ production rates in $\Upsilon(4S)$ decays
It is worrying to observe that the $B^+$ to $B^0$ production ratio in $\Upsilon(4S)$ decays still is known only very badly: $f_{+-}/f_{00} = 1.21 \pm 0.12 \pm 0.17$ (CLEO alone), or $f_{+-}/f_{00} = 1.074 \pm 0.129$ (CLEO, with world average lifetimes). Most analyses assume that the ratio is 1, but due to phase space effects a non-zero value is not excluded. If the charged and neutral lifetime are really different, and the production ratio is not 1, there could be quite some surprises in CLEO-LEP comparisons. However, a larger semileptonic branching ratio at LEP than at the $\Upsilon(4S)$ is not achievable with current input data.

7.3 Search for CP-violation
Both OPAL[eps162] and DELPHI[eps449] have searched for CP-violating effects and established limits on $Re(\epsilon_b)$. 

Fig. 8. CLEO signal of $B \to \eta' K$
7.4 CKM matrix fits

A combination of B-mixing results, $V_{ub}/V_{cb}$ and CP-violation parameters from $K^0$ decay shows clear evidence of a non-trivial unitarity triangle. With some input from theory two angles of the triangle can already be determined with quite good precision \cite{1}: $\sin^2 \alpha = -0.10 \pm 0.40$ and $\sin^2 \beta = 0.68 \pm 0.10$.

8 Summary and Outlook

There is a bright future for b-physics in front of us - it will dominate the experimental high energy physics scene between 2000 and the LHC startup in 2007 or so. At LEP the final analyses with optimised algorithms are being prepared. SLC will hopefully get higher statistics before it will be shut down. CLEO has upgraded the detector, and CESR’s luminosity will continue to improve. In 1999 the b-factory detectors BABAR and BELLE will start to take data. CDF and D0 get upgraded and will take data at much higher luminosity at the Tevatron, HERA-B at DESY will enter the scene, and finally LHCb and perhaps BTEV will be able to do many analyses with huge precision. In a few years from now many rare tree and penguin decays will be known, the $B_c$ will be discovered, time-dependence of $B_s$ mixing detected, and CP-violation observed in many channels. Then we will probably laugh about the few 2 sigma discrepancies that we have to deal with now.

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