Workshop Summary

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BCP4

Ise - Shima, Japan

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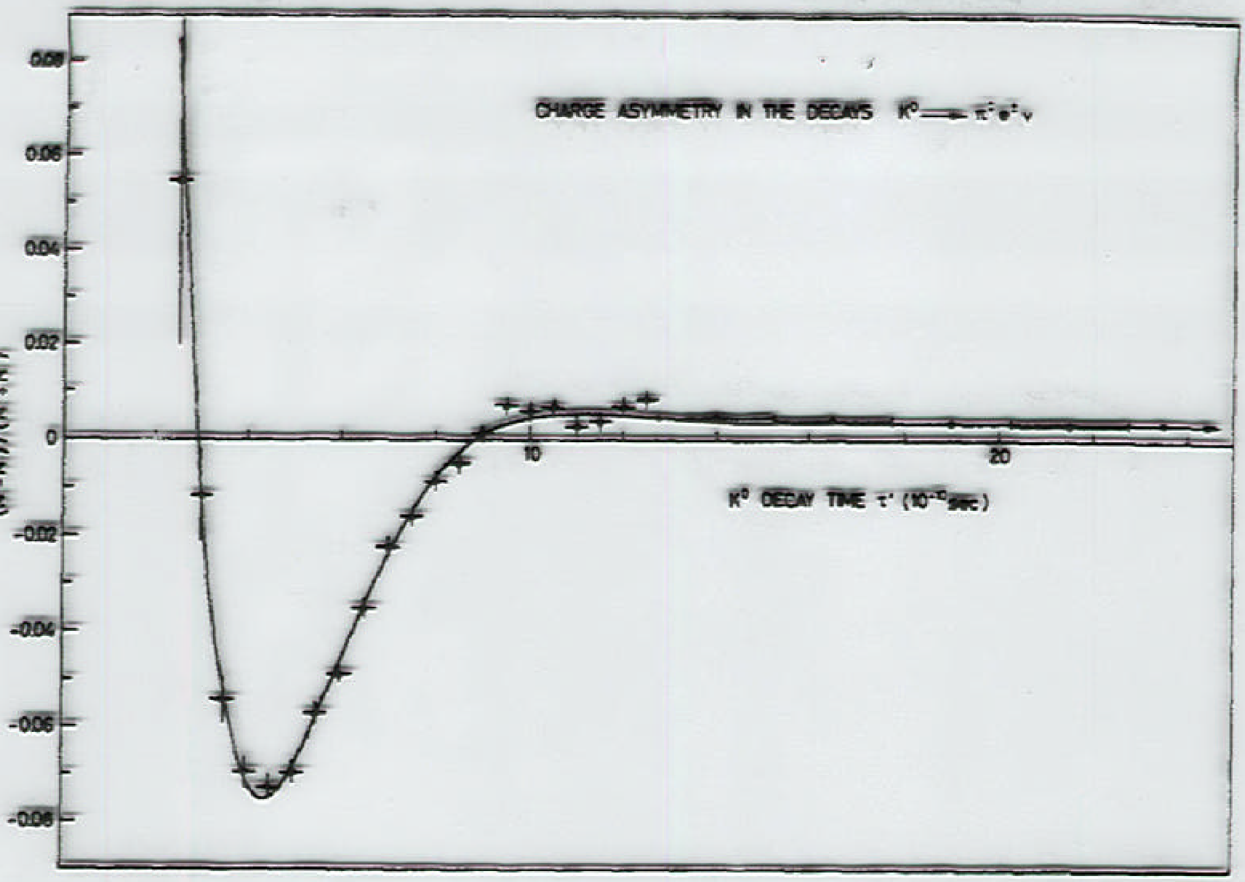
Introduction

- In the middle of the last century, it was understood that neutral, flavored mesons would "mix" with their antiparticles.

  Therefore, mass eigenstates are superpositions of particle and antiparticle.
- Experiments verified this mixing and then that the mass eigenstates were not CP eigenstates.
- For neutral K mesons, $\Delta M \sim -\Delta\Gamma/2$ and the two eigenstates have very different lifetimes,

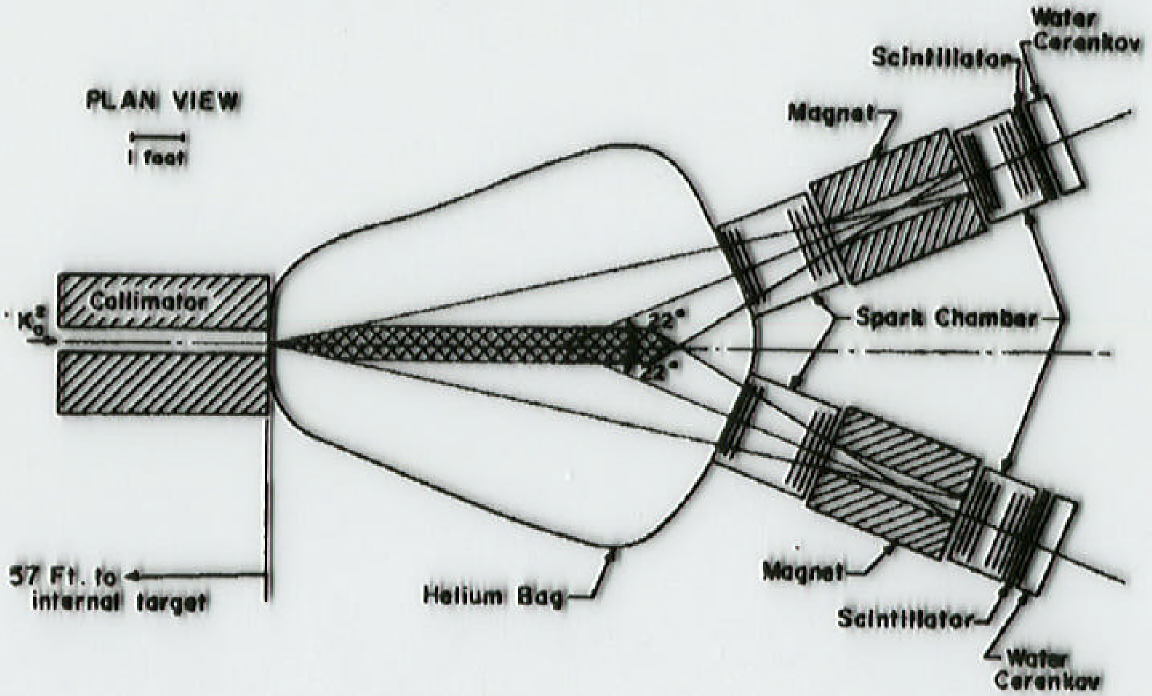
  $\Gamma_S \gg \Gamma_L$

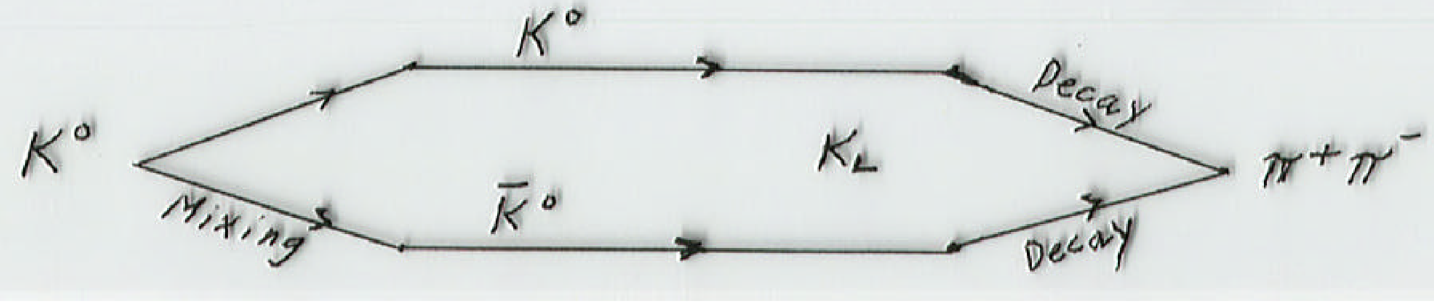


STEINBERGER et al. 1974
VERA LUTH THESIS

FITCH
CRONIN
1964

Experimental Layout
Two Paths to a CP Eigenstate





$B^o - \bar{B}^o$ Mixing

- For the neutral B_d system, $\Delta\Gamma << \Delta M$, and $\Delta M \sim 0.8\ \Gamma$. BOZZ HASTIN
- For the neutral B_s system we have only lower limits on $\Delta M \sim 25\ \Gamma$, while $\Delta\Gamma \sim 0.1\ \Gamma$. BO
- New data were presented to the Workshop on $B^o - \bar{B}^o$ oscillations and lifetimes.
- The analogue of the parameter ε in the neutral K system (due to CP violation in the mass matrix) is small in the neutral B system as well. ECKLU

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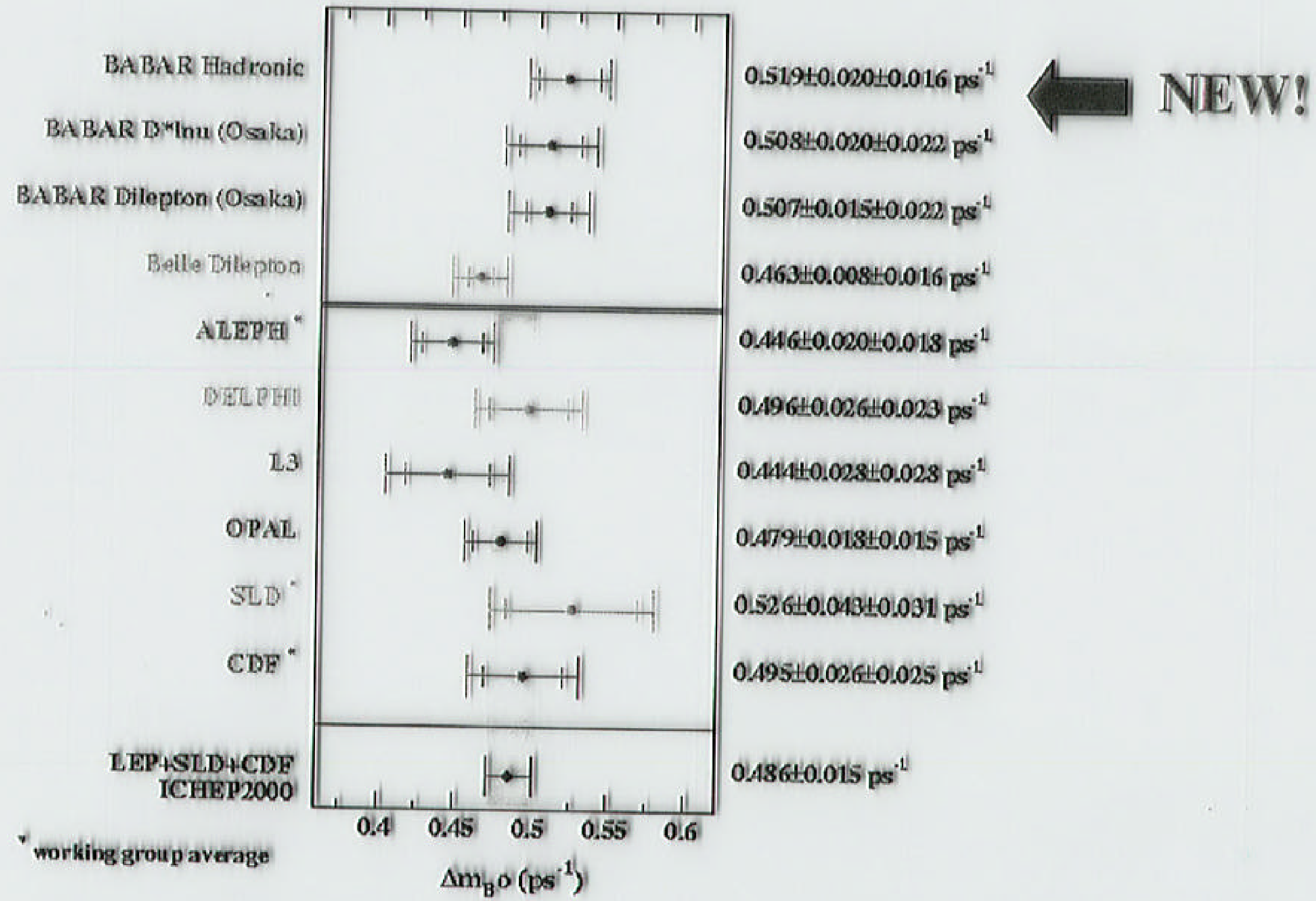
Mixing measurements



Summary Of Results (BELLE)

Mixing:

Method	Δm (ps^{-1})
Dilepton	$0.463 \pm 0.008 \pm 0.016$
Semileptonic	0.522 ± 0.026 (stat)
Hadronic	0.527 ± 0.032 (stat)
PDG	0.472 ± 0.17

Lifetime:

Method	τ_{B^0} (ps)	τ_{B^+} (ps)
Semileptonic	1.518 ± 0.045	1.628 ± 0.060
Hadronic	$1.585^{+0.053}_{-0.051}$	$1.679^{+0.049}_{-0.048}$
PDG	1.548 ± 0.032	1.653 ± 0.028

All lifetime errors are statistical

CPT limits from dileptons:

$$|m_{B^0} - m_{\bar{B}^0}|/m_{B^0} < 1.6 \times 10^{-14} \quad (90\%\text{C.L.})$$
$$|\Gamma_{B^0} - \Gamma_{\bar{B}^0}|/\Gamma_{B^0} < 0.161 \quad (90\%\text{C.L.})$$

All results other than dilepton are preliminary.

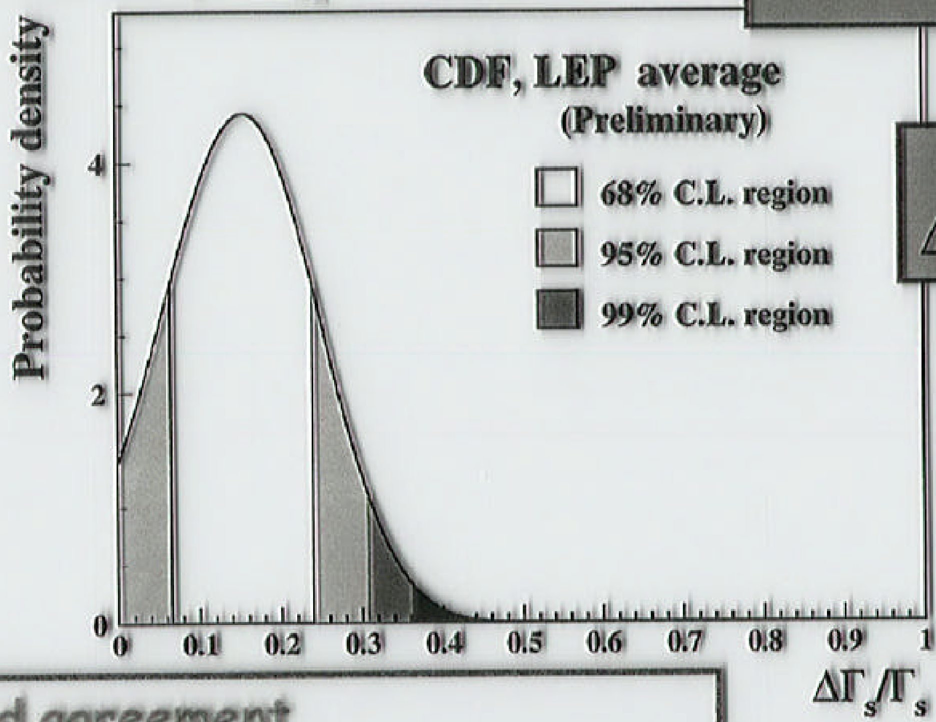
- Most precise measerment of Δm to date.
- New CPT bound.
- Precsion lifetime measurements.

G. BOIX

$\Delta\Gamma_s$ World Average

With the $1/\Gamma_s = \tau_{B_d}$ constraint

$\Delta\Gamma_s/\Gamma_s = 0.16^{+0.08}_{-0.09}$



NLO+Lattice**:
$\Delta\Gamma_s/\Delta m_s = (6.5 \pm 2) \times 10^{-3}$

$\Delta m_s = 16 \pm 10\ ps^{-1}$
or
$\Delta m_s < 36\ ps^{-1}$ @ 95 CL

In good agreement
with theory*: $\Delta\Gamma_s^{theo}/\Gamma_s = 0.09 \pm 0.04$

Dominated by: scale dependence
and $1/m_b$ corrections

* Beneke *et al.* hep-ph/0012222
** Beneke, update of Phys Lett B 459 (1999)

RESULTS

Our dilepton analysis gives:

$$a^0_{\ell\ell} = (+0.013 \pm 0.050 \pm 0.005)(1.00 \pm 0.10)$$

Combining with our hadronic tag analysis which found (PLB **490**, 36 (2000)):

$$a^0_{\ell\ell} = +0.017 \pm 0.070 \pm 0.014$$

We measure:

$$\frac{\Re e(\epsilon_B)}{1 + |\epsilon_B|^2} = +0.0035 \pm 0.0103 \pm 0.0015$$

CLNS 01-1717, CLEO 01-01 (hep-ex/0101006), submitted to PRL

Particle – Antiparticle Mixing

- The time evolution of the mixing is governed by a 2 x 2 matrix with elements $M_{ij} - i\ \Gamma_{ij}/2$
- The diagonalized matrix gives the mass and width of the physical states.
- CP is conserved if and only if $Im(M_{12}\ \Gamma_{12}^{*}) = 0$.
- We can calculate M_{12} in the Standard Model from electroweak box diagrams involving W's and heavy quarks. QCD corrections are important and have been done in leading order and next-to-leading order.
- The couplings at the vertices of the box diagram are the elements of the Cabibbo-Kobayashi-Maskawa matrix.

The CKM Matrix

- In the Standard Model, the Cabibbo-Kobayashi-Maskawa (CKM) matrix, V, relates quark mass-eigenstates to weak-eigenstates

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

- V is a 3 by 3 unitary matrix, which is specified physically by three angles and one phase.
- CP violation occurs if the phase is not 0 or 180° and the other angles are not 0 or 90° (they are neither).
- The CKM matrix gives a pattern of FCNC and CP violation in the K, D, and B systems.

The Unitarity Triangle

- Unitarity applied to the first and third colums of the CKM matrix, together with values (which are all close to unity) of the diagonal elements, gives: $V_{ub}^{*} + V_{td} = s_{12} V_{cb}^{*}$
- Represented in the complex plane, this gives `the' unitarity triangle, which visually summarizes the less well-known CKM parameters.
- If one normalizes the base to unity, the other vertex is at (ρ , η) , the Wolfenstein parameters
- A non-trivial unitarity triangle <=> CP violation

Status of the Unitarity Triangle

- We know the base ($|s_{12} V_{cb}|$) well, and one side ($|V_{ub}|$) moderately well, so we need another side or an angle to fix the position of the top vertex. Want other measurements to test consistency.
- Measurements of $|V_{cb}|$ and $|V_{ub}|$ were presented to the Workshop. A new $|V_{cb}|$ analysis from CLEO uses moments in semileptonic and b -> s γ inclusive decays to fix parameters. A more precise $|V_{ub}|$ is coming.
- Have as extra input (if these originate in the SM)
  - ε from CP violation in neutral K mixing
  - B_d mixing
  - B_s mixing limits

FORTY
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THORNDIKE.

THORNDIKE (CLEO)

$|V_{cb}|$ Status

CLEO Inclusive $|V_{cb}|$: (New syst. from α_s added)

$$
\begin{aligned}
|V_{cb}| &= (41.3 \pm 0.9 \pm 0.6 \pm 0.4 \pm 1.0) \times 10^{-3} \\
&= (41.3 \pm 0.9 \pm 1.2) \times 10^{-3}
\end{aligned}
$$

The above does not include theory uncertainty for quark-hadron duality assumption.

Estimate at 5% giving

$$|V_{cb}| = (41.3 \pm 1.5 \text{ expt.} \pm 2.0 \text{ theory}) \times 10^{-3}$$

CLEO + LEP $D^*\ell\nu$	$\|V_{cb}\| = (40.9 \pm 1.4 \pm 1.9) \times 10^{-3}$
CLEO Inclusive	$\|V_{cb}\| = (41.3 \pm 1.5 \pm 2.0) \times 10^{-3}$
LEP Inclusive	$\|V_{cb}\| = (40.7 \pm 2.1 \pm 2.0) \times 10^{-3}$

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Status of the Unitarity Triangle (con't)

- There is a big improvement over the last decade.
- Most of the uncertainties are now theoretical, especially in hadronic matrix elements of operators containing quarks. Discussion continues over how to treat these theoretical errors and how big they are. This has physics consequences: Is the unitarity triangle non-trivial just from the present information on its sides?
- Ultimately lattice QCD calculations will lower these uncertainties; progress continues to be made.
- The next major advance? - measurement of B_s mixing at the Tevatron collider to "fix" $|V_{td}|$ in the Standard Model.

LACKE
FALK
HÖCKER
SONI
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AOKI
HASHIMOTO
KRONFELD
TAYLOR

DIB
DUNIETZ
F.G.
NIR
(1989)

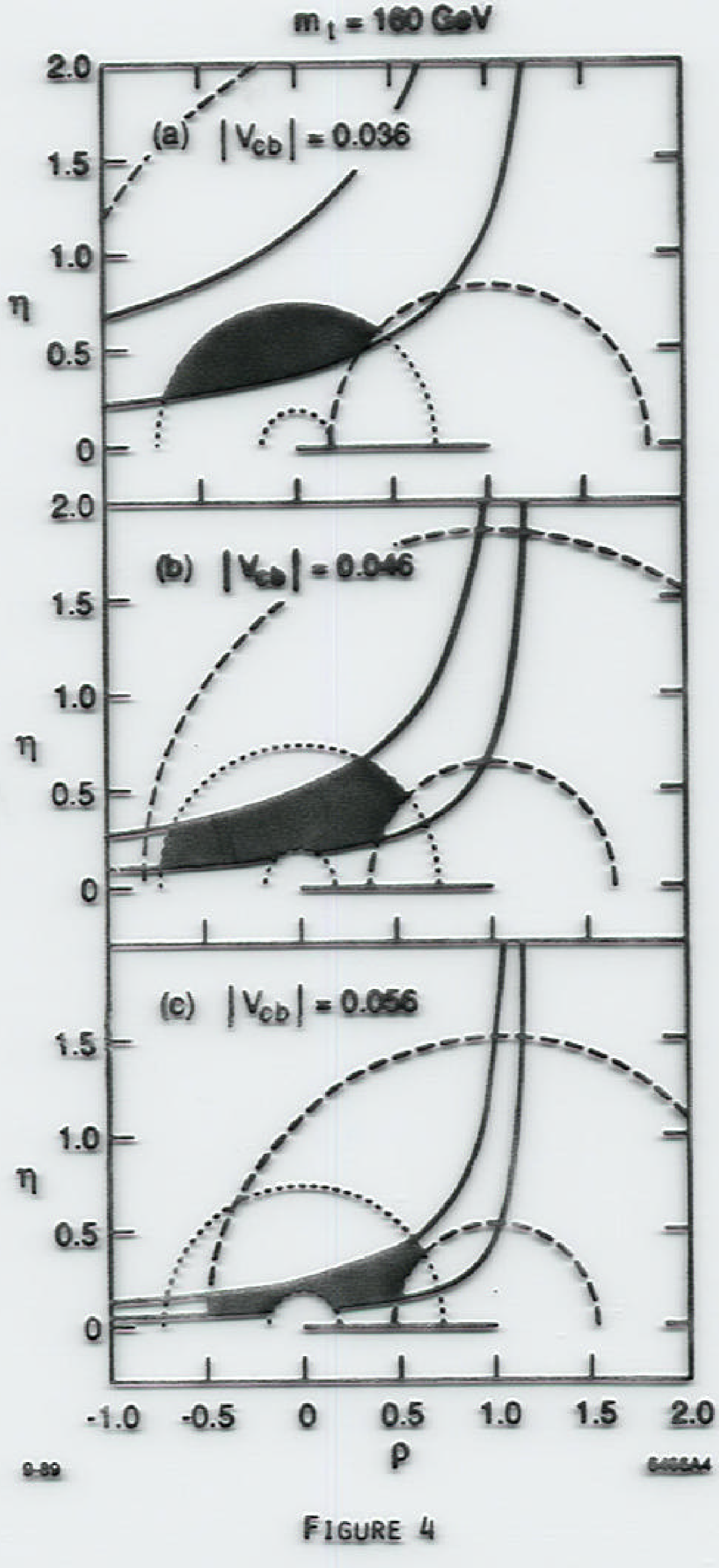
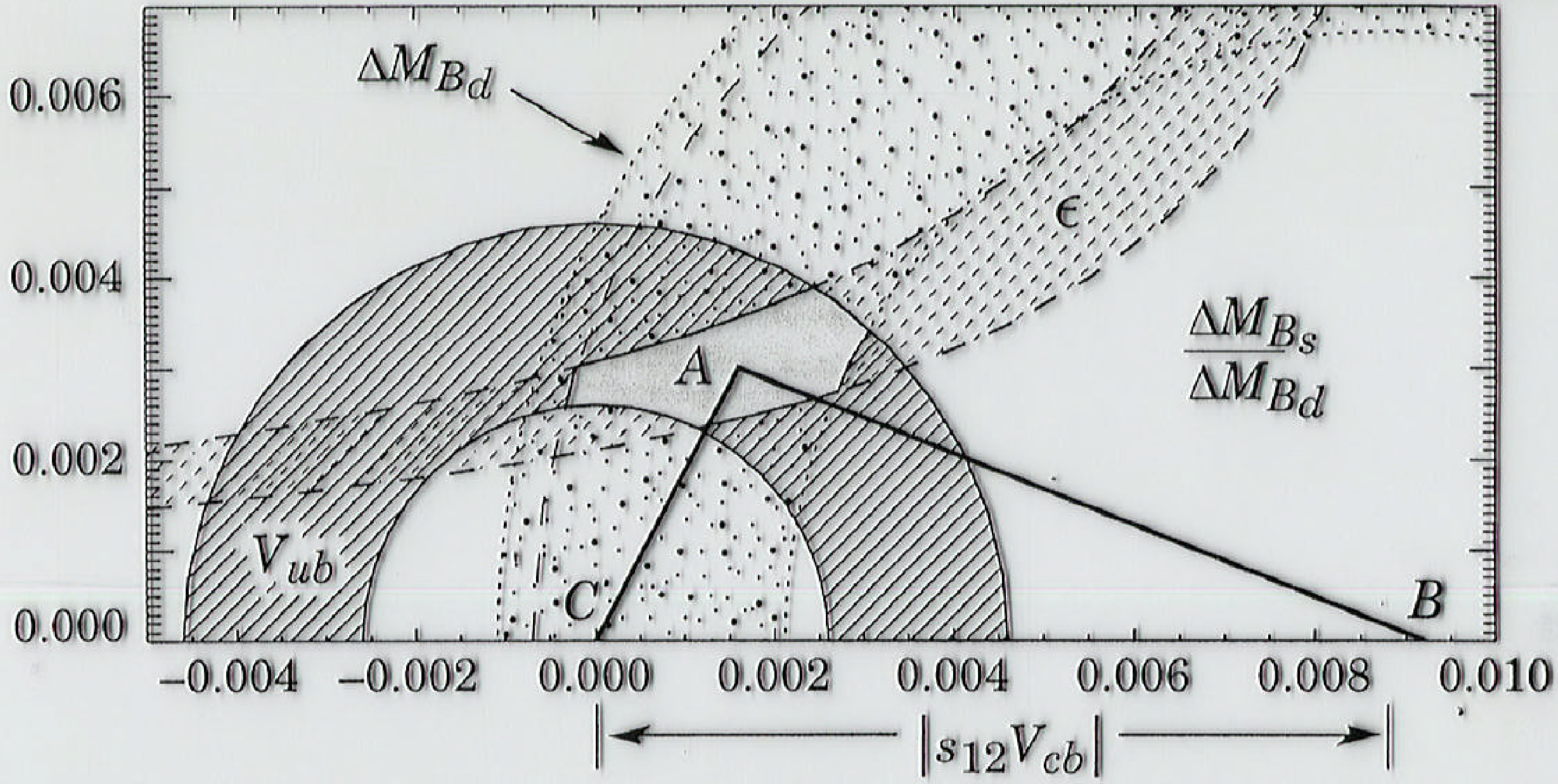


FIGURE 4

F.G., KLEINKNECHT, RENK
RPP (2000)



CIUCHINI et al. (2000)

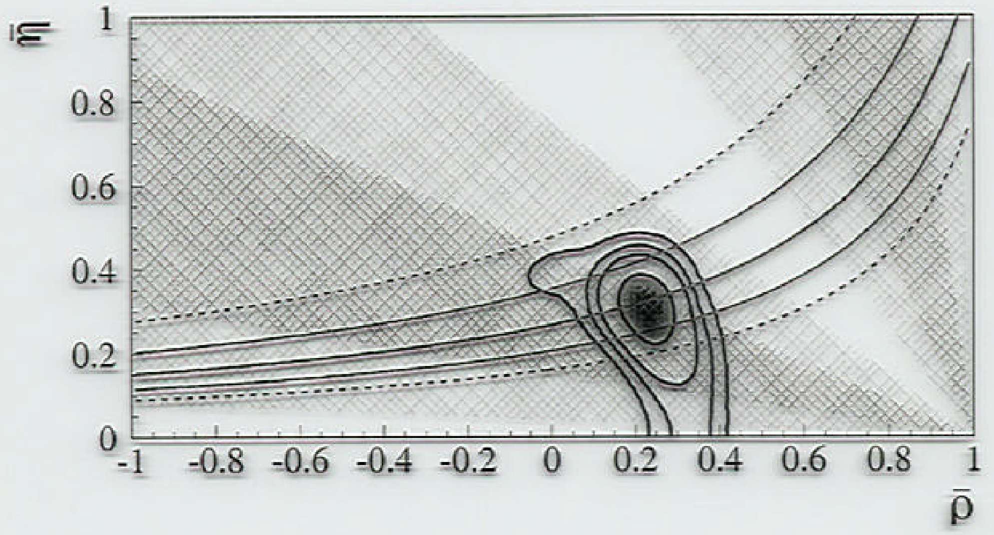


Figure 10: The allowed regions (at 68%, 95%, 99% and 99.9% probability) for $\bar{\rho}$ and $\bar{\eta}$ using the constraints given by the measurements of $|V_{ub}|\,/\,|V_{cb}|$, Δm_d and Δm_s. The constraint due to $|\varepsilon_K|$ is not included. The regions (at 68% and 95% probability) selected by the measurements of $|\varepsilon_K|$ (continuous (1σ) and dotted (2σ) curves) and $\sin(2\beta)$ (darker (1σ) and clearer (2σ) zones) are shown. For $\sin(2\beta)$ the two solutions are displayed.

to examine under which conditions these decays can be described by the same value of γ as found in the present study. An exploratory work in this direction can be found in [81].

7.2 The CKM triangle from b-physics alone

As four constraints are used to determine the values of two parameters, it is possible to relax, in turn, one (or more) of these constraints, still obtaining significant confidence intervals. An interesting exercise consists in removing the theoretical constraint for $\hat{B}_K$ in the measurement of $|\varepsilon_K|$ [82]. The corresponding selected region in the ($\bar{\rho}$, $\bar{\eta}$) plane is shown in Figure 10, where the region selected by the measurement of $|\varepsilon_K|$ alone is also drawn. This comparison shows that the Standard Model picture of CP violation in the K system and of B decays and oscillations are consistent. In the same figure, we also compare the allowed regions in the ($\bar{\rho}$, $\bar{\eta}$) plane with those selected by the measurement of $\sin(2\beta)$ using $J/\psi K_S$ events.

Using constraints from b-physics alone the following results are obtained

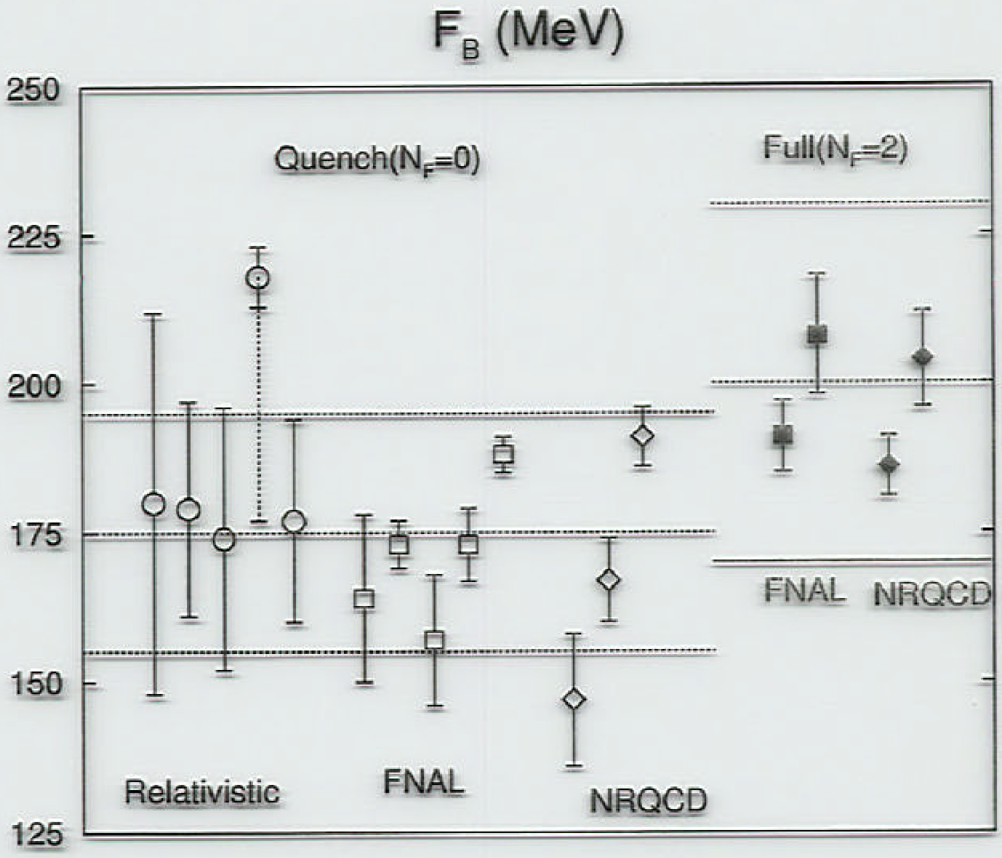
$$\begin{aligned} \bar{\eta} &= 0.302^{+0.052}_{-0.061} \quad ; \quad [0.145-0.400] \ \text{at } 95\% \quad ; \ > 0.08 \text{ at } 99\% \\ \sin(2\beta) &= 0.678^{+0.078}_{-0.101} \quad ; \quad [0.392-0.818] \ \text{at } 95\% \end{aligned} \tag{57}$$

(in terms of average and standard deviation the results are $\bar{\eta} = 0.296 \pm 0.063$ and $\sin(2\beta) = 0.663 \pm 0.109$).

Another way for illustrating the agreement between K and B measurements consists in

Leptonic decay constant F_B

- important for CKM matrix, most extensively investigated
- results from different methods are consistent in quenched QCD
- $\sim 10\%$ increase of F_B in full QCD



APE97/99/00,UKQCD00,Lellouch-Lin00, FNAL97,JLQCD98,MILC98/00,CPPACS00, AliKhan98,JLQCD99,CPPACS00, MILC00,CPPACS00,Collins99,CPPACS00

CP Violation Involving Mixing

- Decay of an initial B^o to a final state f can occur by $B^o \to f$ with amplitude A and by $B^o \to \bar{B}^o$ through mixing followed by $\bar{B}^o \to f$ with amplitude $\bar{A}$. Under charge conjugation the weak phases in A change sign, the strong phases do not.
- If f is a CP eigenstate, then the time dependent decay rate $d\Gamma[(B^o(t)/\bar{B}^o(t) \to f_{CP})]/dt$ is proportional to $[1 \pm \eta_{CP} \sin 2\phi \sin(2\Delta M t)]$, where the phase ϕ arises from a combination of CKM matrix elements. In simple cases, it is an angle of the unitarity triangle.

CP Violation in Decay Amplitudes

- One can also have interference of two amplitudes that contribute to a given decay. To get a non-zero rate difference one must have at least two amplitudes with different weak and strong phases.
- An example is provided by the neutral K system, where interference of tree and penguin amplitudes into the I = 0 and I = 2 final states in $K \to \pi\ \pi$ gives a non-zero rate difference characterized in the amplitude by $\varepsilon'/\varepsilon \sim 2 \times 10^{-3}$

The B- Factories

- Their performance is absolutely remarkable.
- For the future: PEPII luminosities should reach 5 x 10^{33} this year and an upgrade plan is in place to reach 10^{34} in 2003. Feasibility studies are being conducted of several avenues to 3 x 10^{34}. KEKB plans call for reaching 7 x 10^{33} in 2002-2003 and more that 10^{34} in 2005-2006. Discussion of super KEKB with 10^{35} has just started.

SEEMAN

KUROKAWA

ALEXANDER

& e^+e^- AND BEYOND TALKS

J. SEEMAN

PEP-II Records

–	Achieved	Design
Peak luminosity (x 10^33/cm^2/s)	3.10	3.00
Peak luminosity with BaBar	3.02	3.00
Integrated lumi. per shift (pb-1)	62	45
Integrated lumi. per day (pb-1)	174	135
Integrated lumi. per week (pb-1)	975	785
Integrated lumi. per month (fb-1)	3.6	3.3
Peak HER e- current (mA)	920	750
Peak LER e+ current (mA)	2140	2140

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S. KUROKAWA

Performances of KEKB

	As of 00/07/25	As of 00/12/28
Energy e^+/e^- (GeV)	3.5/8.0	3.5/8.0
Peak luminosity ($10^{33}cm^{-2}s^{-1}$)	2.04	2.37
Current e^+/e^- (A) at peak L Maximum current e^+/e^- (A)	0. 47/0.42 0.75/0.50	0.60/0.49 0.86/0.65
Number of bunches	1146	1153
Bunch spacing(ns)	8	8
Beta function at IP β_y^* (cm)	0.7	0.7
Beam sizes at IP σ_x^* / σ_y^* (μm)	112(e^+)145 (e^-)/1.7	
Beam-beam tuneshift e^+ ξ_x/ξ_y e^- ξ_x/ξ_y	0.036/0.037 0.029/0.023	0. 045/0.038 0.042/0.020
Max int. luminosity/day (1/pb)	90.6	135.3
Max int. luminosity/week (1/pb)	505	880
Logged luminosity by BELLE (1/fb)	6.83	11.09

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DDGN
(1989)
3σ A_{CP} IN ψK_S

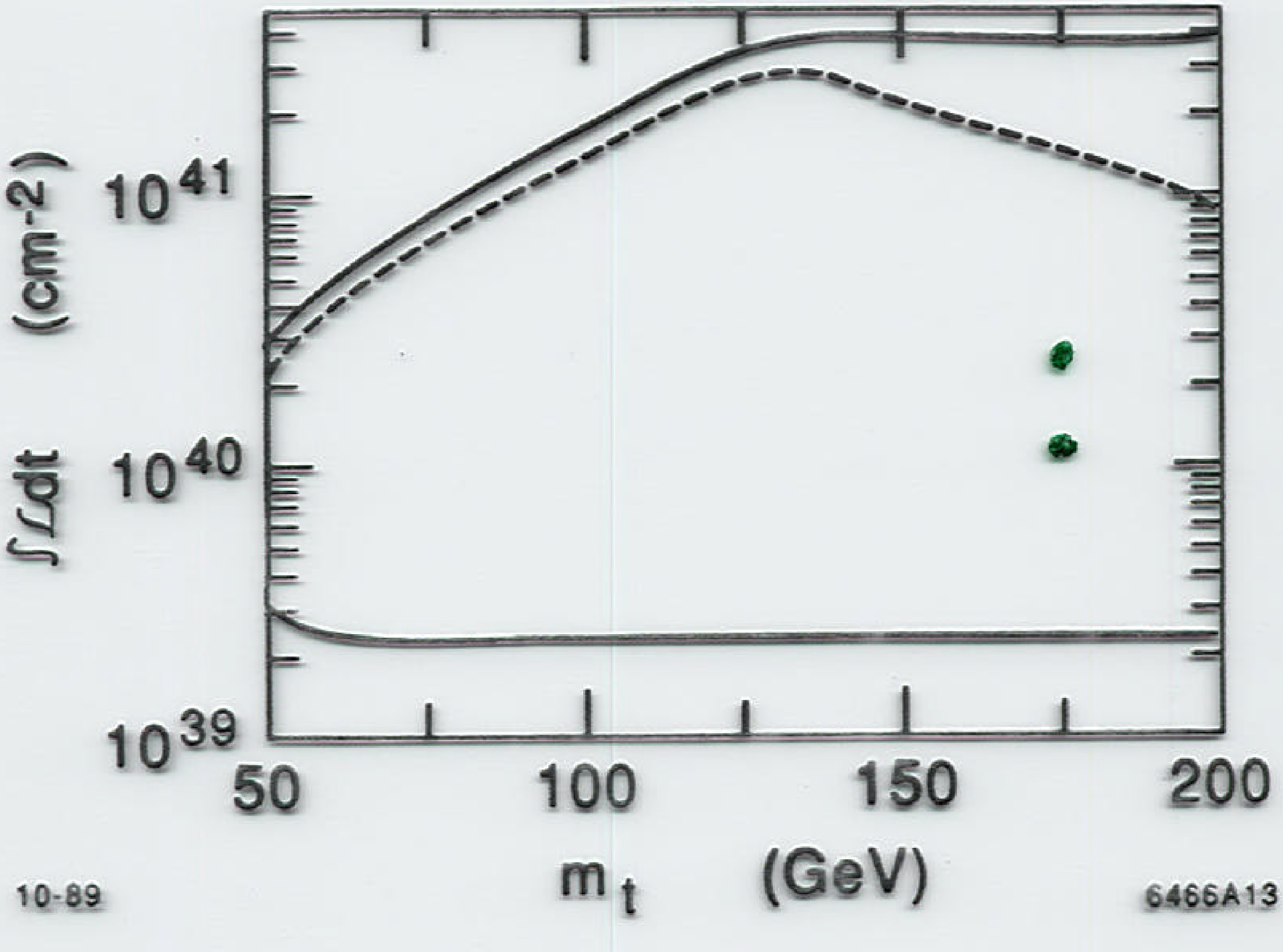

FIGURE 9

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