一生に一度は
伊勢参り！

STATUS of the CKM Paradigm

Amarjit Soni

Brookhaven National Lab HET Group

Work done with DAVID ATWOOD, IOWA STATE UNIV

RELATED WORKS

J. ROSNER ...

A. ALI + D. LONDON

STOCCHI ...
MARTINELLI ...
MELE
} "ROMANS"

S. PLASZCZYNSKI + M-H SCHUNE

G. EIGEN

S. STONE

M. ARTUSO

R. FORTY --

Here { A. HOECKER
H. LACKER }

! ! !

ATWOOD + I since TECHNION WKSHP '94?

OUTLINE

(3)

1. Theoretical Underpinnings
   - We Hold These Truths
   - More Mundane
2. Inputs and Concerns
   - Experiment
   - Hadronic Parameters
3. Constraints and their Stability
4. Implications for the SM
5. Desperately Seeking Godot
6. Future Directions
7. Conclusions/Outlook

(4)

Progress of Theoretical Physics, Vol. 49, No. 2, February 1973

CP-Violation in the Renormalizable Theory of Weak Interaction

Makoto KOBAYASHI and Toshihide MASKAWA

Department of Physics, Kyoto University, Kyoto

(Received September 1, 1972)

In a framework of the renormalizable theory of weak interaction, problems of *CP*-violation are studied. It is concluded that no realistic models of *CP*-violation exist in the quartet scheme without introducing any other new fields. Some possible models of *CP*-violation are also discussed.

When we apply the renormalizable theory of weak interaction[1] to the hadron system, we have some limitations on the hadron model. It is well known that there exists, in the case of the triplet model, a difficulty of the strangeness changing neutral current and that the quartet model is free from this difficulty. Furthermore, Maki and one of the present authors (T.M.) have shown[2] that, in the latter case, the strong interaction must be chiral $SU(4)\times SU(4)$ invariant as precisely as the conservation of the third component of the iso-spin I_3. In addition to these arguments, for the theory to be realistic, *CP*-violating interactions should be incorporated in a gauge invariant way. This requirement will impose further limitations on the hadron model and the *CP*-violating interaction itself. The purpose of the present paper is to investigate this problem. In the following, it will be shown that in the case of the above-mentioned quartet model, we cannot make a *CP*-violating interaction without introducing any other new fields when we require the following conditions: a) The mass of the fourth member of the quartet, which we will call ζ, is sufficiently large, b) the model should be consistent with our well-established knowledge of the semi-leptonic processes. After that some possible ways of bringing *CP*-violation into the theory will be discussed.

We consider the quartet model with a charge assignment of Q, $Q-1$, $Q-1$

(5)

Next we consider a 6-plet model, another interesting model of *CP*-violation. Suppose that 6-plet with charges $(Q, Q, Q, Q-1, Q-1, Q-1)$ is decomposed into $SU_{\text{weak}}(2)$ multiplets as $2+2+2$ and $1+1+1+1+1+1$ for left and right components, respectively. Just as the case of (A, C), we have a similar expression for the charged weak current with a 3×3 instead of 2×2 unitary matrix in Eq. (5). As was pointed out, in this case we cannot absorb all phases of matrix elements into the phase convention and can take, for example, the following expression:

$$\begin{pmatrix} \cos\theta_1 & -\sin\theta_1\cos\theta_3 & -\sin\theta_1\sin\theta_3 \\ \sin\theta_1\cos\theta_2 & \cos\theta_1\cos\theta_2\cos\theta_3-\sin\theta_2\sin\theta_3 e^{i\delta} & \cos\theta_1\cos\theta_2\sin\theta_3+\sin\theta_2\cos\theta_3 e^{i\delta} \\ \sin\theta_1\sin\theta_2 & \cos\theta_1\sin\theta_2\cos\theta_3+\cos\theta_2\sin\theta_3 e^{i\delta} & \cos\theta_1\sin\theta_2\sin\theta_3-\cos\theta_2\sin\theta_3 e^{i\delta} \end{pmatrix}. \tag{13}$$

Then, we have *CP*-violating effects through the interference among these different current components. An interesting feature of this model is that the *CP*-violating effects of lowest order appear only in $\Delta S\neq0$ non-leptonic processes and in the semi-leptonic decay of neutral strange mesons (we are not concerned with higher states with the new quantum number) and not in the other semi-leptonic, $\Delta S=0$ non-leptonic and pure-leptonic processes.

So far we have considered only the straightforward extensions of the original Weinberg's model. However, other schemes of underlying gauge groups and/or scalar fields are possible. Georgi and Glashow's model[4] is one of them. We can easily see that *CP*-violation is incorporated into their model without introducing any other fields than (many) new fields which they have introduced already.

References

1) S. Weinberg, Phys. Rev. Letters **19** (1967), 1264; **27** (1971), 1688.
2) Z. Maki and T. Maskawa, RIFP-146 (preprint), April 1972.
3) P. W. Higgs, Phys. Letters **12** (1964), 132; **13** (1964), 508.
G. S. Guralnik, C. R. Hagen and T. W. Kibble, Phys. Rev. Letters **13** (1964), 585.
4) H. Georgi and S. L. Glashow, Phys. Rev. Letters **28** (1972), 1494.

ELEMENTARY INTERACTION

$$g_2 (\bar u\ \bar c\ \bar t)\, \gamma_\mu V_{CKM} \begin{pmatrix} d \\ s \\ b \end{pmatrix} W^\mu$$

V_{CKM} ENCAPASULATES ROTATION Bet. Change current e.s. & Mass e.s.

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

Foll. PDB adopt parameterization of CHAU+KEUNG

$$V_{CKM} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -s_{23}c_{12} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix}$$

$s_{12} = |V_{us}| \sim .22$; $s_{23} = |V_{cb}| \sim .04$ $s_{13} = |V_{ub}| \sim .004$

CABIBBO ANGLE

δ is the KOBAYASHI-MASKAWA PHASE

CRUCIAL for CP

Hierarchy of b.s MORE Readily depicted in the WOLFENSTEIN Reps.

$$V_{WOLF} = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

λ, A, ρ, η

FOLLOWING BURAS et al and SCHMIDTLER + SCHUBERT, to avoid truncation (in λ^4..) and to restore unitarity exactly:

$$S_{12}=\lambda \;,\; S_{23}=A\lambda^2 \qquad S_{13}e^{-i\delta} = A\lambda^3(\rho - i\eta)$$

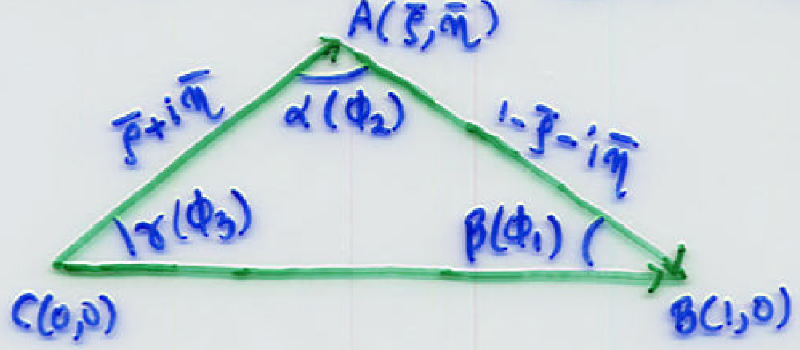
ALLOWS NOW FOR A Generalization of UΔ to Higher order in λ.

Thus $V_{us}=\lambda+O(\lambda^7)$; $V_{ub}=A\lambda^3(\rho-i\eta)$, $V_{cb}=A\lambda^2+O(\lambda^8)$

$$V_{td}=A\lambda^3[1-\bar{\rho}-i\bar{\eta}] \;;\; \bar{\rho}=\rho(1-\lambda^2);\; \bar{\eta}=\eta(1-\lambda^2)$$

$\not{CP}$ $\quad \tan\delta = \eta/\rho = \bar{\eta}/\bar{\rho}$

$b\to d$ UNITARITY: $V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$



$$\sin 2\phi_1 \equiv \sin 2\beta = 2\bar{\eta}(1-\bar{\rho})/[(1-\bar{\rho})^2+\bar{\eta}^2]$$

$$\sin 2\phi_2 \equiv \sin 2\alpha = 2\bar{\eta}(\bar{\eta}^2+\bar{\rho}^2-\bar{\rho})/\{(\bar{\rho}^2+\bar{\eta}^2)[(1-\bar{\rho})^2+\bar{\eta}^2]\}$$

$$\sin 2\phi_3 \equiv \sin 2\gamma = 2\bar{\rho}\bar{\eta}/(\bar{\rho}^2+\bar{\eta}^2) = 2\rho\eta/(\rho^2+\eta^2)$$

NOTE $\alpha, \beta, \gamma\, (\phi_1, \phi_2, \phi_3) \propto \eta \neq 0 \Rightarrow \not{CP}$

Recall: $V_{td} = |V_{td}|\, e^{-i\phi_1} = |V_{td}|\, e^{-i\beta}$

$V_{ub} = |V_{ub}|\, e^{-i\phi_3} = |V_{ub}|\, e^{-i\gamma}$

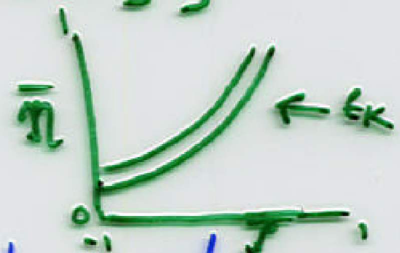
EXPTAL + Theo. Input.

I $K^0 - \overline{K^0}$ ~~Cf~~: $|\epsilon_K| = \hat{B}_K C_K \lambda^6 A^2 \bar{\eta} \{ \eta_1 S(x_c) + \eta_2 S(x_t) [A^2 \lambda^4 (1-\bar{\rho})] + \eta_3 S(x_c, x_t)] \}$

$C_K = G_F^2 f_K^2 m_K m_W^2 / 6\sqrt{2}\pi^2 \Delta m_K$

$x_q = m_q^2 / m_W^2$

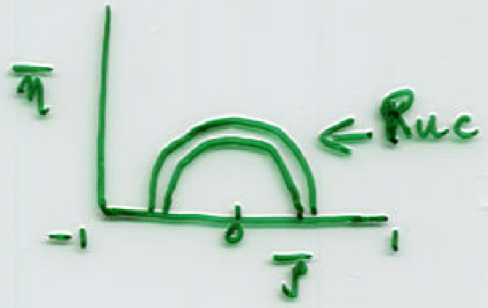
$\bar{\eta} \neq 0$ Due ϵ_K



II SEMI-LEPTONIC CHARMLESS B-Decays i.e. $b \to u e \nu / b \to c e \nu$

$$R_{uc} \equiv \frac{|V_{ub}|}{|V_{cb}|} = \lambda (\bar{\rho}^2 + \bar{\eta}^2)^{1/2} / (1 - \lambda^2/2)$$

CLEO+LEP $\Rightarrow$ $.085 \pm .0033 \pm .0125$
"NOMINAL"



III $B - \bar{B}$ Osc $\quad \Delta m_d = f_{B_d}^2 \hat{B}_{B_d} \frac{G_F^2}{6\pi^2} m_{B_d} m_W^2 \eta_c S(x_t) A^2 * \lambda^6 [(1-\bar{\rho})^2 + \bar{\eta}^2]$

IV $\bar{B}_s - B_s$ Osc (Lim from Lep)

$$\frac{\Delta m_d}{\Delta m_s} = \xi^{-2} \frac{m_{Bd}}{m_{Bs}} \lambda^2 [(1-\bar{\rho})^2 + \bar{\eta}^2]$$

$\xi \equiv f_{B_s} \sqrt{\hat{B}_{B_s}} / f_{B_d} \sqrt{\hat{B}_{Bd}}$ ← SU(3) Breaking Ratio

(G. Boix)

LEP + SLD, CDF : $\Delta m_s > 15.0\ ps^{-1}$ @ 95% CL

HADRONIC PARAMETERS from LATTICE

QTY	NOMINAL	COMMENTS
$\hat{B}_K$	$.86 \pm .06 \pm .14$	COINCIDENTALLY SAME AS LELLOUCH @ LAT2000 ↓ DWQ; SU(3)↑; UNQ ? all 3 small effects. FIG JLQCD; CP-PACS; B+S; RBCC
$f_{B_d}\sqrt{\hat{B}_{B_d}}$	230 ± 40 MeV	Bernard @ LAT00 S. AOKI here central value ↑ ~10-15% due Quench.
$\xi = \frac{\sqrt{B_{B_s}}\, f_{B_s}}{\sqrt{B_{B_d}}\, f_{B_d}}$	$1.16 \pm .08$	BERNARD, AOKI } $1.16 \pm .05$

CONCERN ALTERNATE METHOD B.B.S. PRD98
c ALSO L+L

$$\frac{\langle B_s | [\bar{b}\gamma_\mu(1-\gamma_5)s]^2 | \bar{B}_s \rangle}{\langle B_d | [\bar{b}\gamma_\mu(1-\gamma_5)d]^2 | \bar{B}_d \rangle} = \frac{m^2_{B_s}}{m^2_{B_d}} \xi^2$$

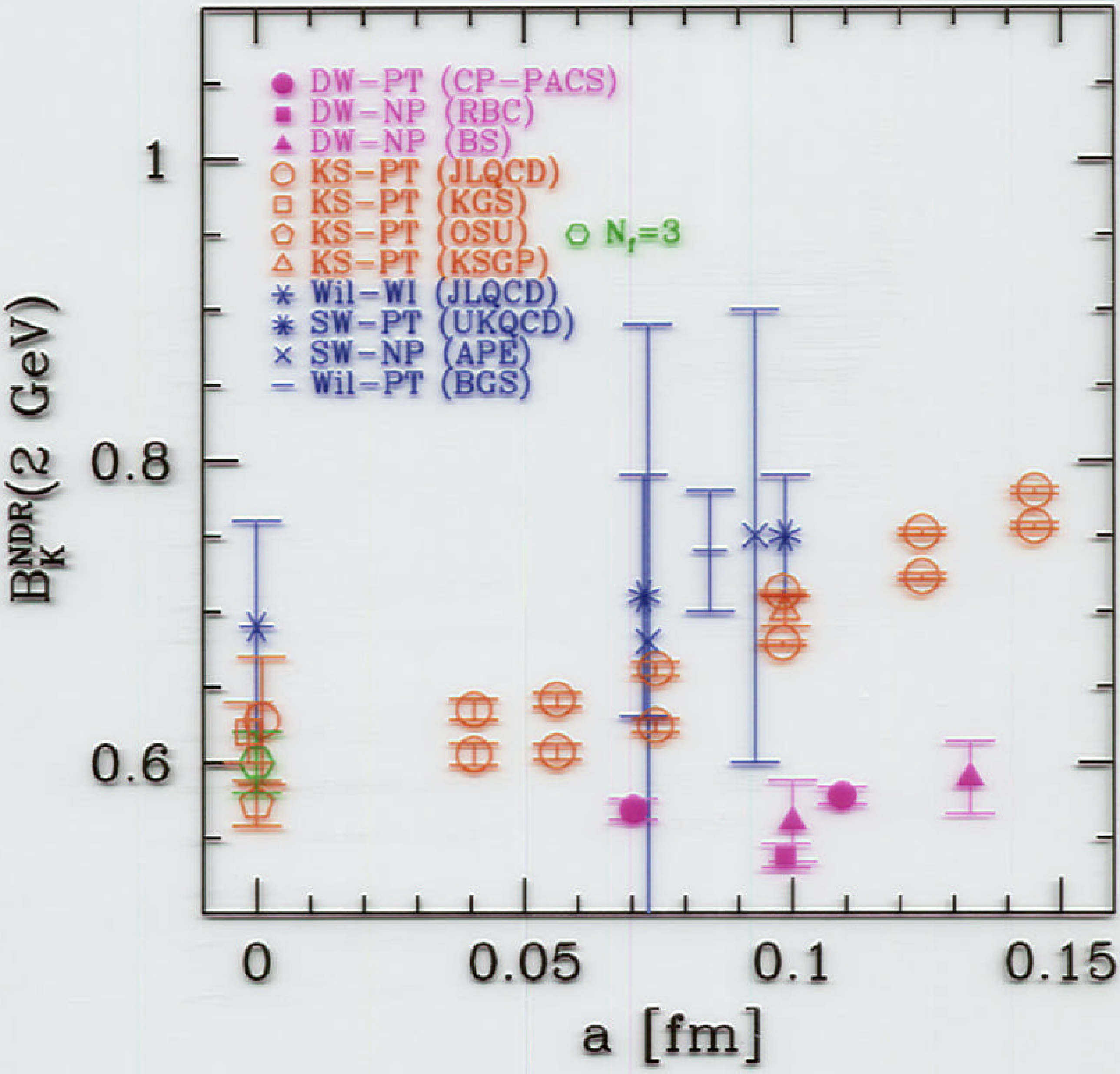
[USE of B param is a historical accident]

tend to lower $\sin 2\beta$

WILL ALSO STUDY MORE "CONSERVATIVE" CHOICES

$\hat{B}_K$	$.90 \pm .06 \pm .14$	UNQ↑ Kilcup et al → INDICATION
$f_{B_d}\sqrt{B_{B_d}}$	~~[illegible]~~ 217 ± 40 MeV	B_{B_d} ↓ UNQ GIMENES + REYES

Lellouch Review @ LAT2000 (10)



(11)

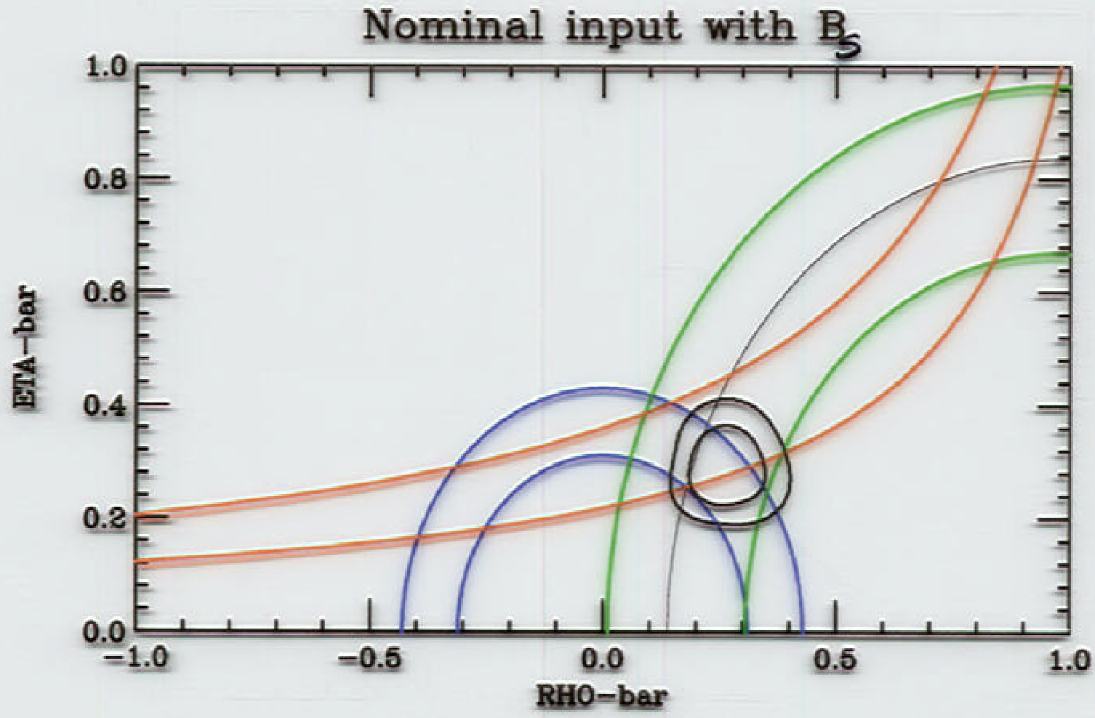
nominal-Bs

Input Values
Thu Feb 15 17:43:55 CST 2001

thing	variable	value	err_1	err_2
$\|V_{cb}\|$	vvcb	0.04	0.002	-1.
$\|V_{ub}/V_{cb}\|$	vruc	0.085	0.01362	-1.
$B_{Bb}\sqrt{f_{Bb}}$	vbrf	0.23 GeV	0.04	-1.
ξ	vxi	1.16	0.08	-1.
B_K	vbk	0.86	0.1523	-1.
$m_t(\overline{ms})$	vamt	167. GeV	5.	-1.
$\lambda(\approx \sin\theta_C)$	val	0.2237	0.0018	-1.
x_d	vxd	0.723	0.032	-1.
τ_B	vtaub	1.548	0.032	-1.
$\epsilon_K(10^{-3})$	vepsk	2.28	0.019	-1.
η_1	vet_1	1.38	0.53	-1.
η_2	vet_2	0.574	0.004	-1.
η_3	vet_3	0.47	0.04	-1.
η_b	vet_b	0.55	0.01	-1.
Δm_{Bd}	vd_mbd	0.467054264 $\hbar\ ps^{-1}$	0.0206718346	-1.
Δm_{Bs}-bound	vd_mbd	15. $\hbar\ ps^{-1}$	...	...

Notes:

- -1 indicates that this error is not used
- err_1 is a gausian pdf; err_2 is a square shaped pdf.
- If both are on they are multiplied if iconv=0 and convoluted if iconv=1
- $m_t(\overline{ms}) \approx m_{phys} - 9$
- Δm_{Bd} is derived from x_d
- Δm_{Bs} is a bound



$\bar{\eta} \Rightarrow$ .242 — .336 (68%)
~~.164~~ — ~~.373~~ (95%)
.203 — .385

$\bar{\rho} \Rightarrow$ .207 — .316 68%
.164 — .373 95%

(13)

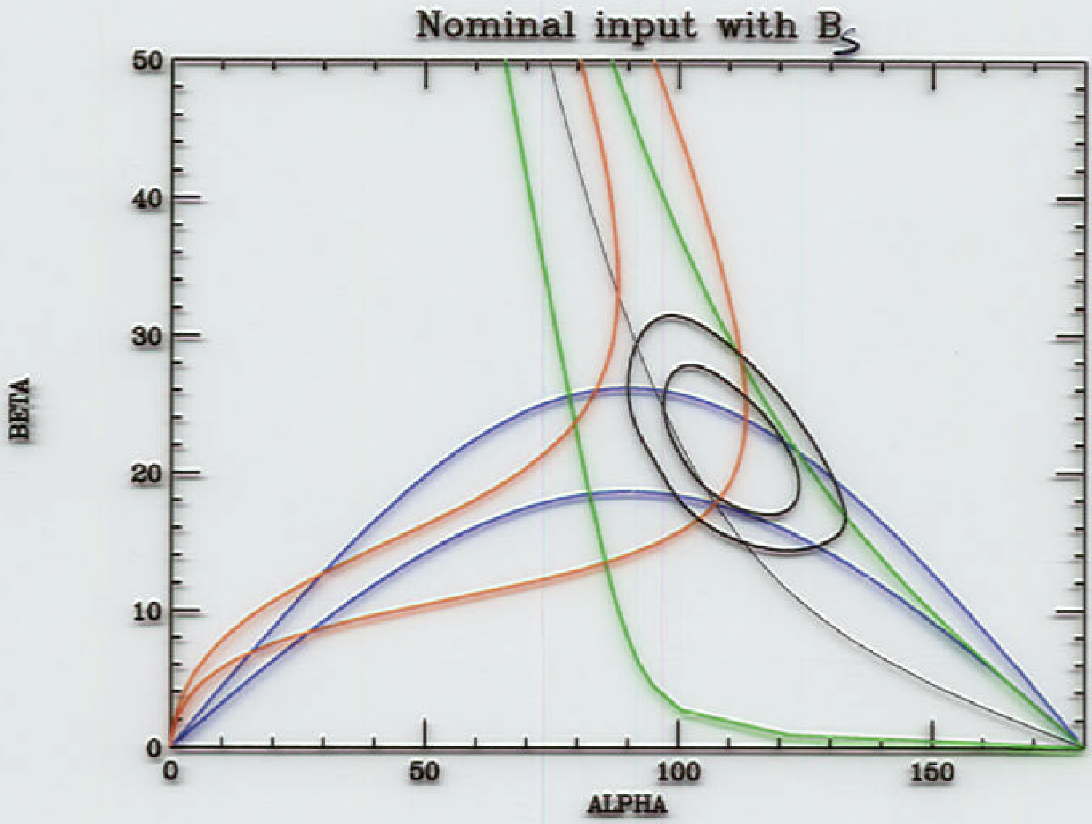
Other Inputs:

- iconv = 1
- blob contour(rat_b) = 0.68 and also: 0.95
- histogram intervals = 0.68; 0.95
- plot elements(dots,curves,blob) =(0, 1, 1)
- iseed= 334567
- iter= 15000
- iswbs=1, B_s data used
- tag =nominal-Bs
- color = 1
- graph title =Nominal input with B

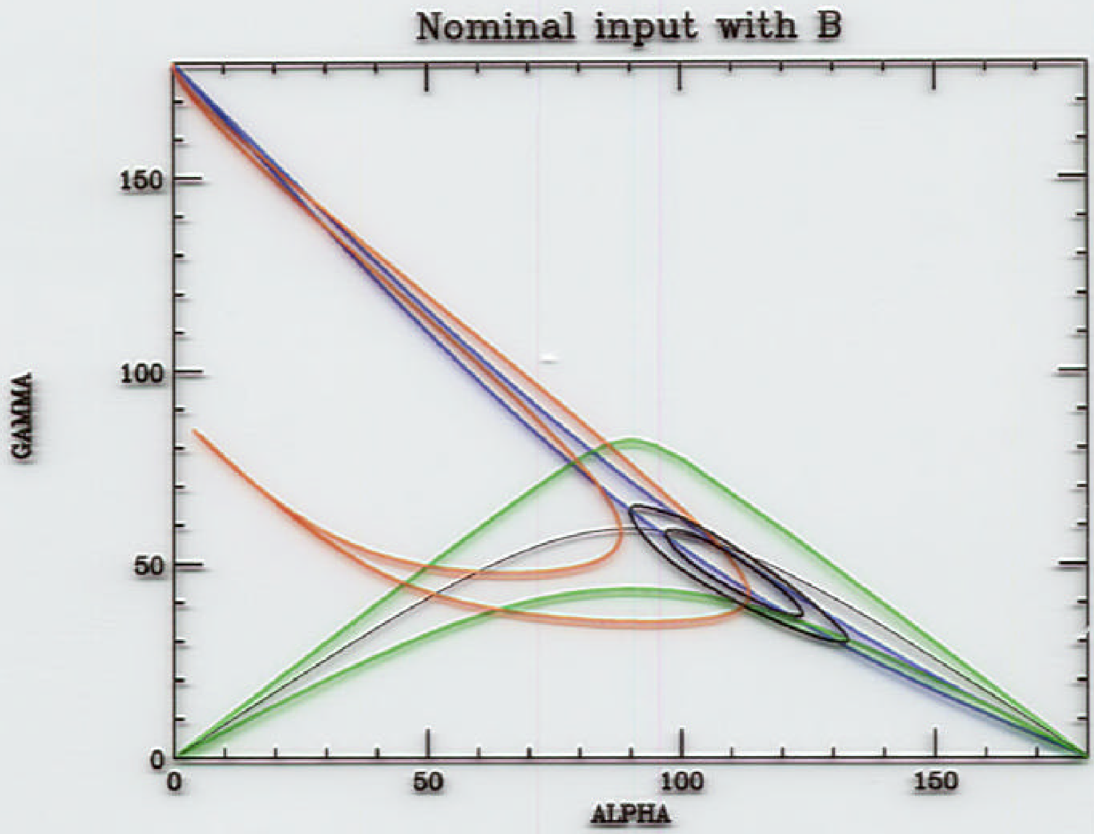
Statistic

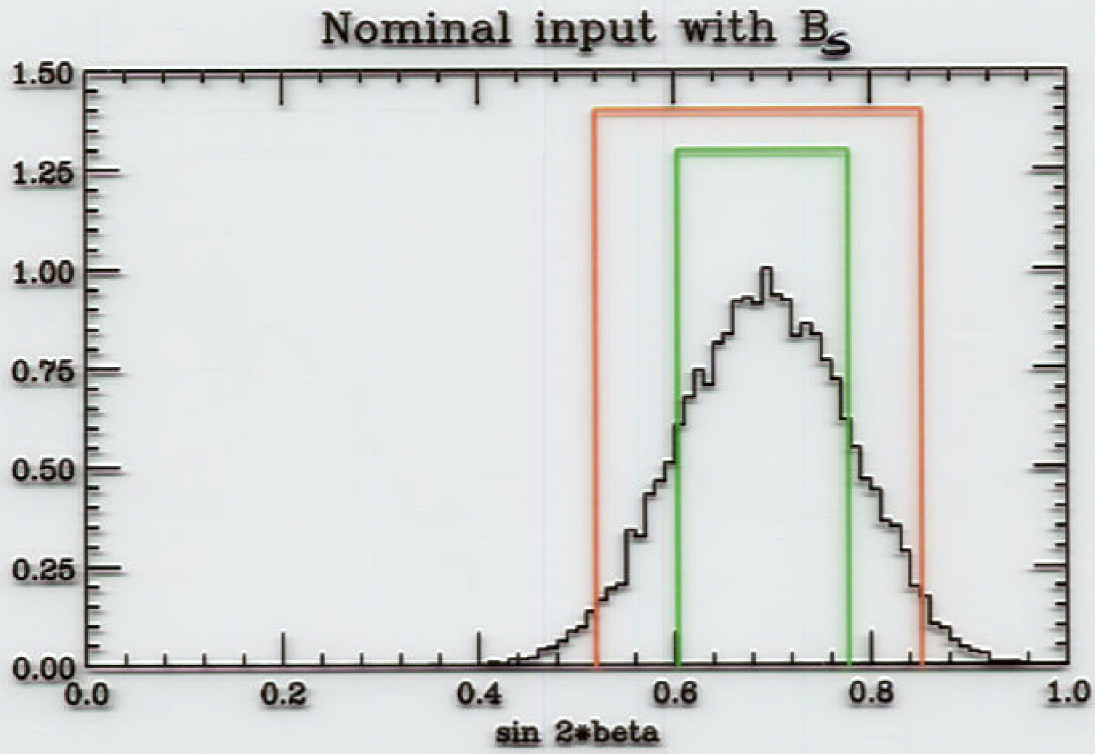
- $\sin(2\beta)$ = 0.692 $[0.6032, 0.7776]$ $[0.5195, 0.8521]$
- $Br(K_L \to \pi^0 \nu\bar{\nu}) = 0.2033$ $[0.155, 0.2673]$ $[0.118, 0.3463]$ $(\times 10^{-10})$
- $Br(K^+ \to \pi^+ \nu\bar{\nu}) = 0.6589$ $[0.5725, 0.762]$ $[0.5024, 0.8754]$ $(\times 10^{-10})$
- $\sin(2\alpha)$ = -0.633 $[-0.8506, -0.3666]$ $[-0.9704, -0.118]$
- $\gamma(^\circ) = 43.3483$ $[36.2922, 50.0473]$ $[30., 55.9224]$
- $J_{CP} = 1.23$ $[1.0753, 1.4135]$ $[0.9395, 1.6074]$ $(\times 10^{-5})$
- $\bar{\rho} = 0.2584$ $[0.2069, 0.316]$ $[0.1638, 0.3733]$
- $\bar{\eta} = 0.2867$ $[0.2422, 0.3358]$ $[0.2033, 0.3853]$
- $|V_{td}/V_{ts}| = 0.1784$ $[0.1655, 0.1896]$ $[0.1524, 0.1993]$
- $Im(\lambda_t) = 1.1005$ $[0.961, 1.2643]$ $[0.8387, 1.4391]$ $(\times 10^{-4})$

(14)



(15)



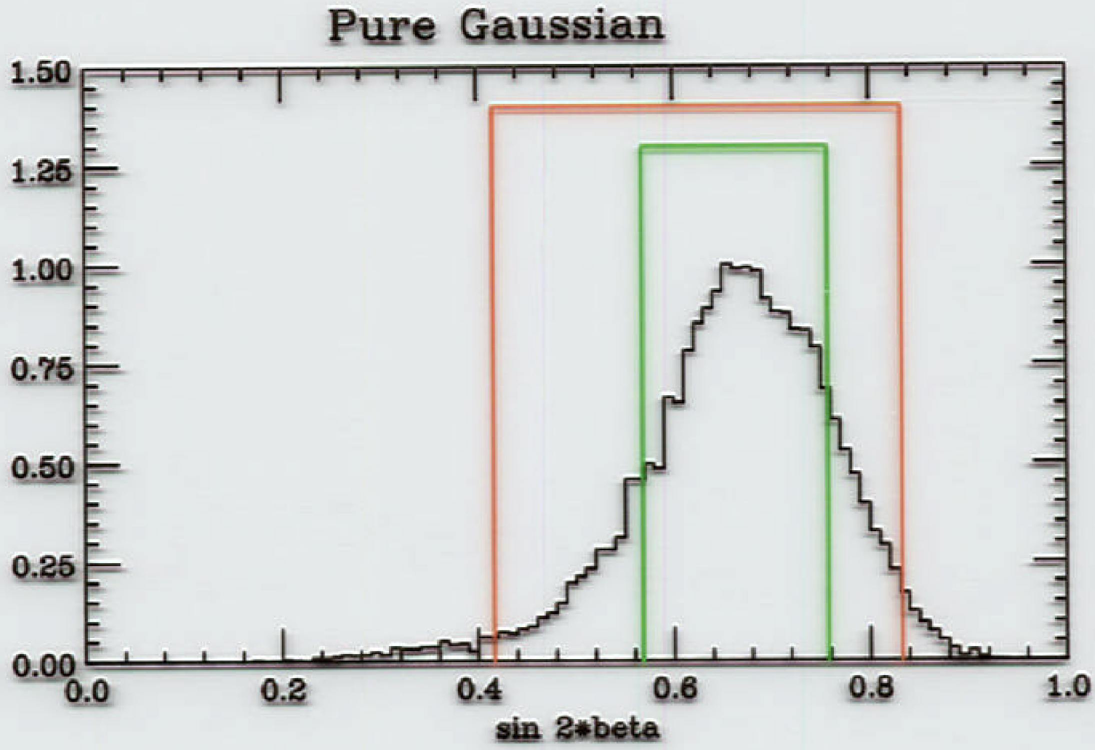


$\sin 2\beta$ $.52$ —— $.85$ (95%); $.60$ —— $.78$ 68%

($\sin 2\alpha$ $-.97$ —— $-.12$ $-.85$ —— $-.37$

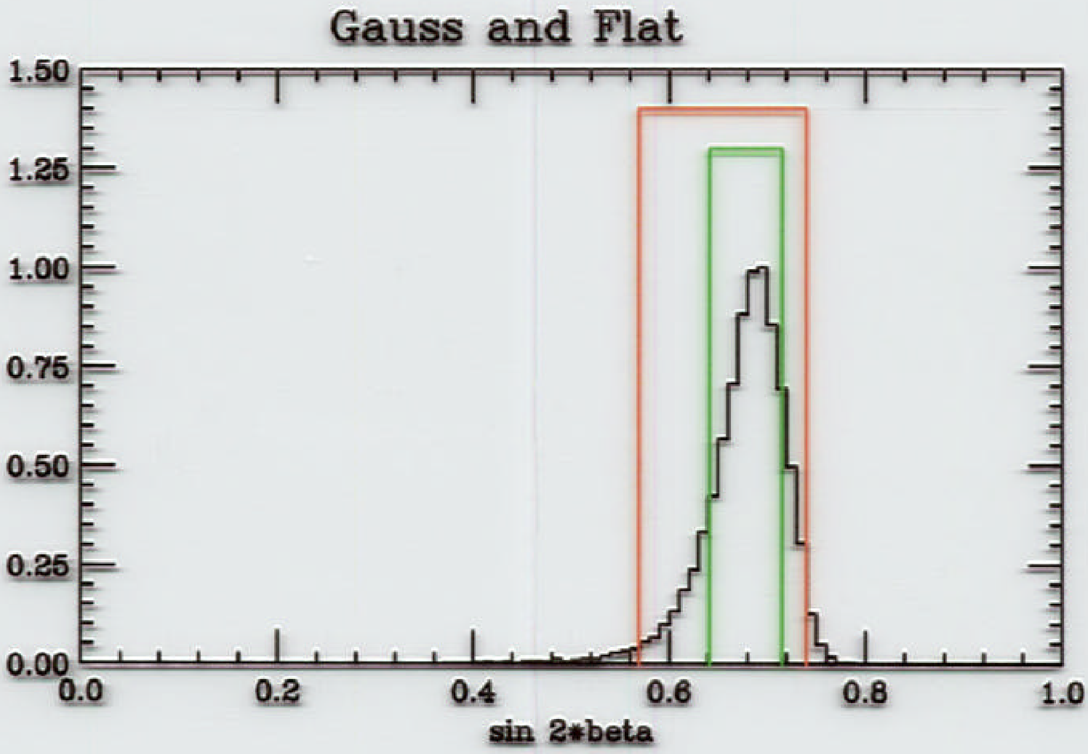
γ 30° —— 56°_6 36° —— 50°)

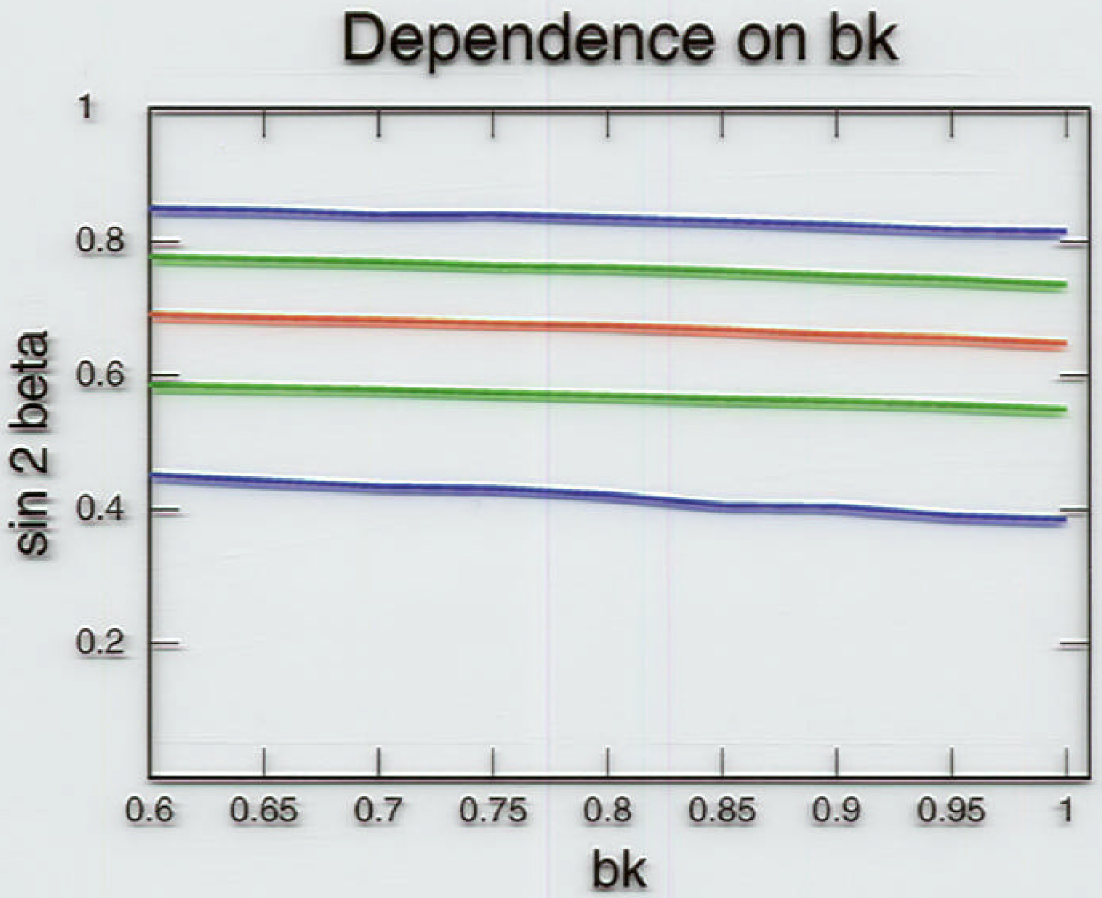
No B_s



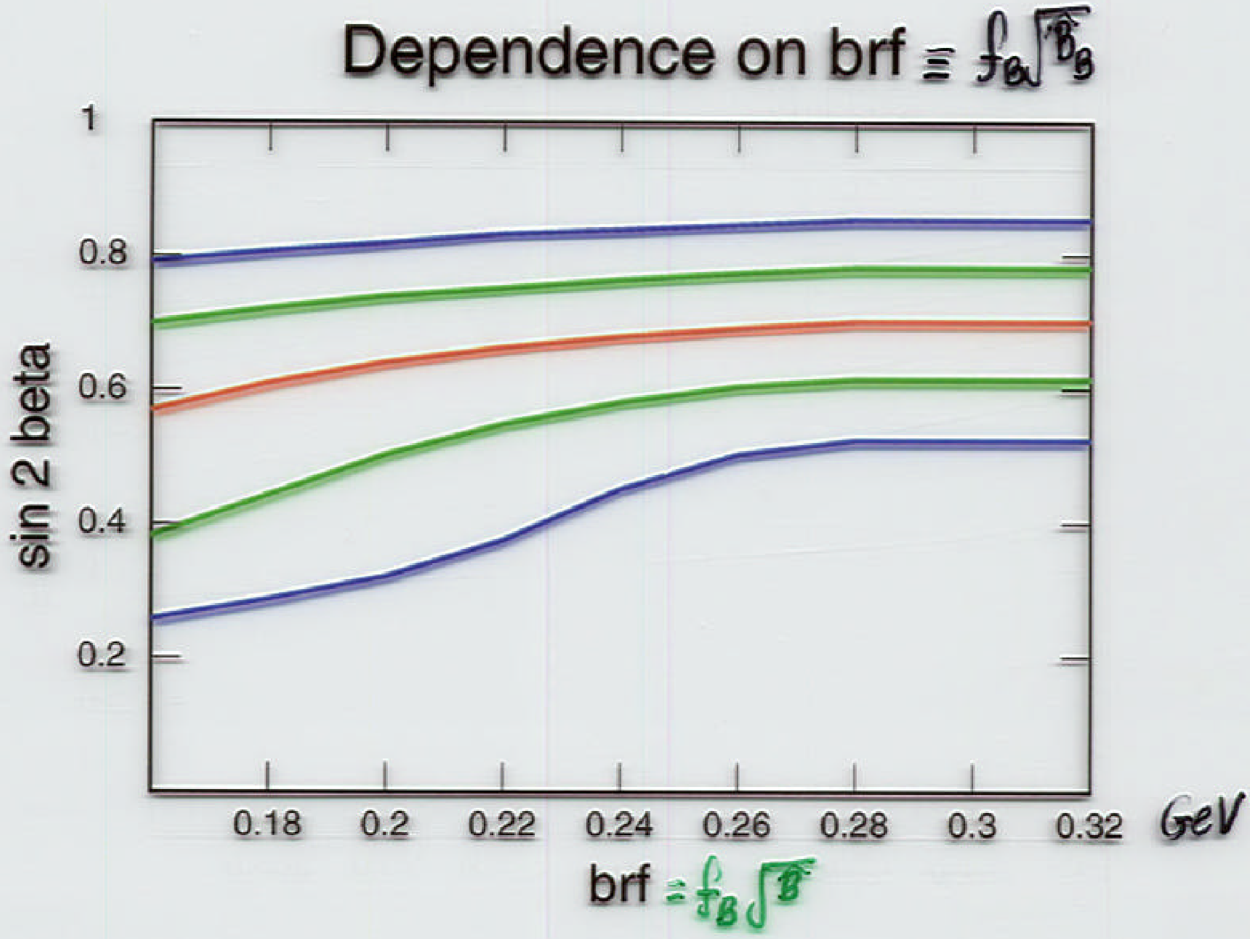
Pure Gaussian
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.2
0.4
0.6
0.8
1.0
sin 2*beta

No B_s

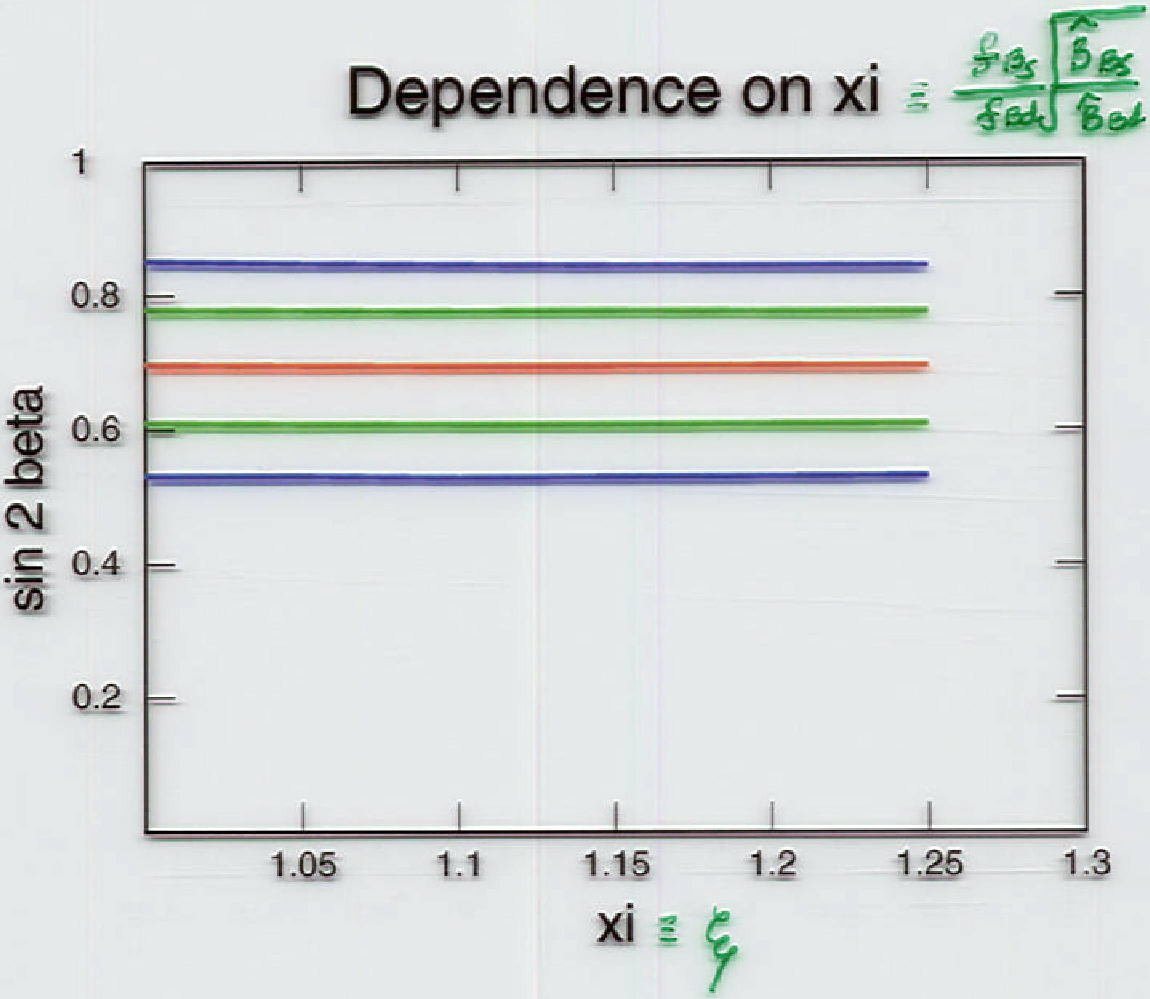

Gauss and Flat
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.2
0.4
0.6
0.8
1.0
sin 2*beta



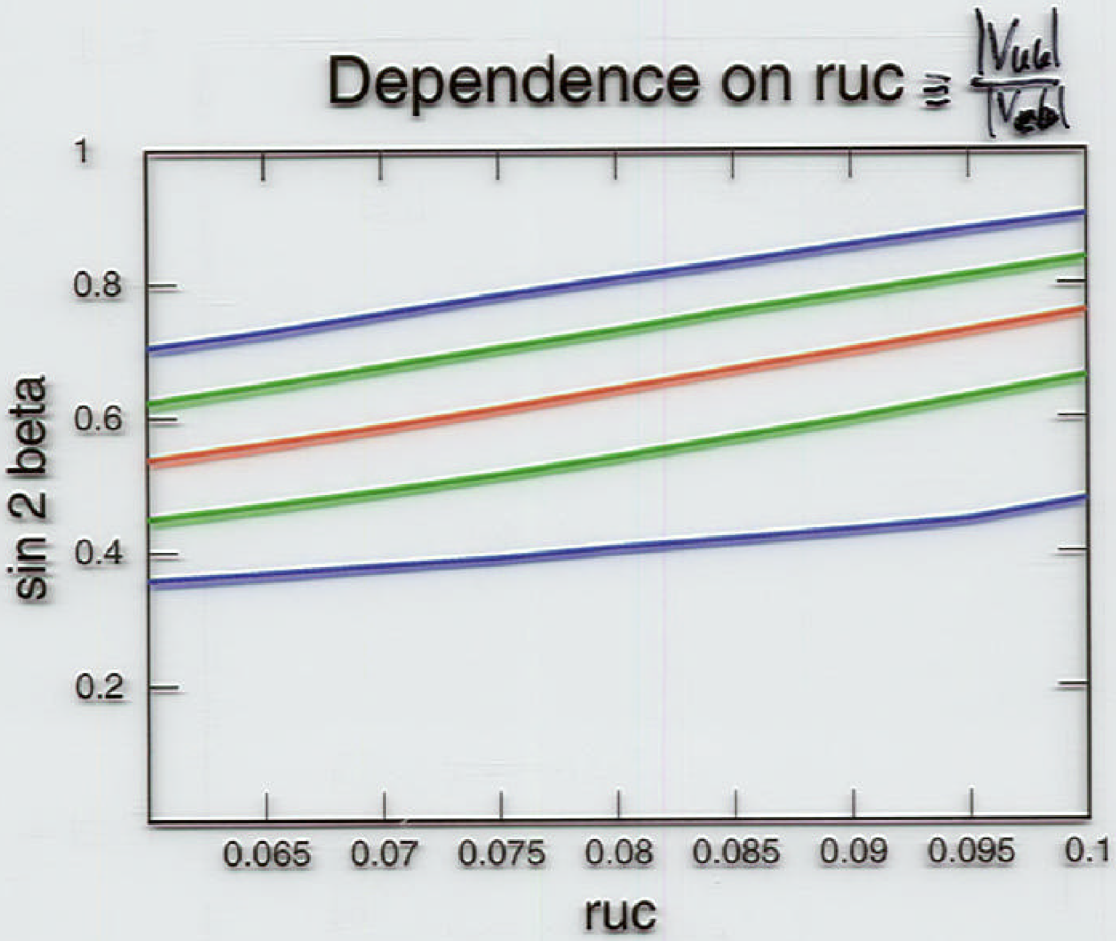
NOMINAL $B_K = 0{\cdot}86 \pm 0{\cdot}15$



NOMINAL $f_B\sqrt{\hat{B}} = .23 \pm .04$

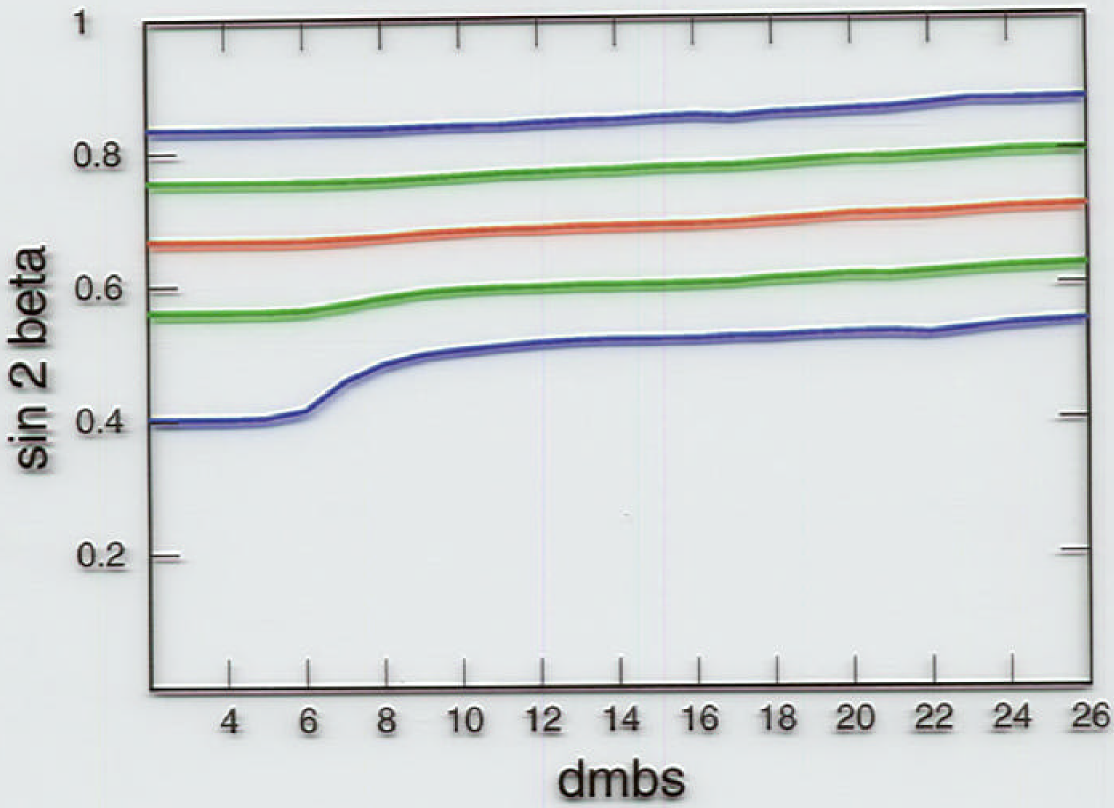


NOMINAL VALUE: $\xi = 1.16 \pm .08$

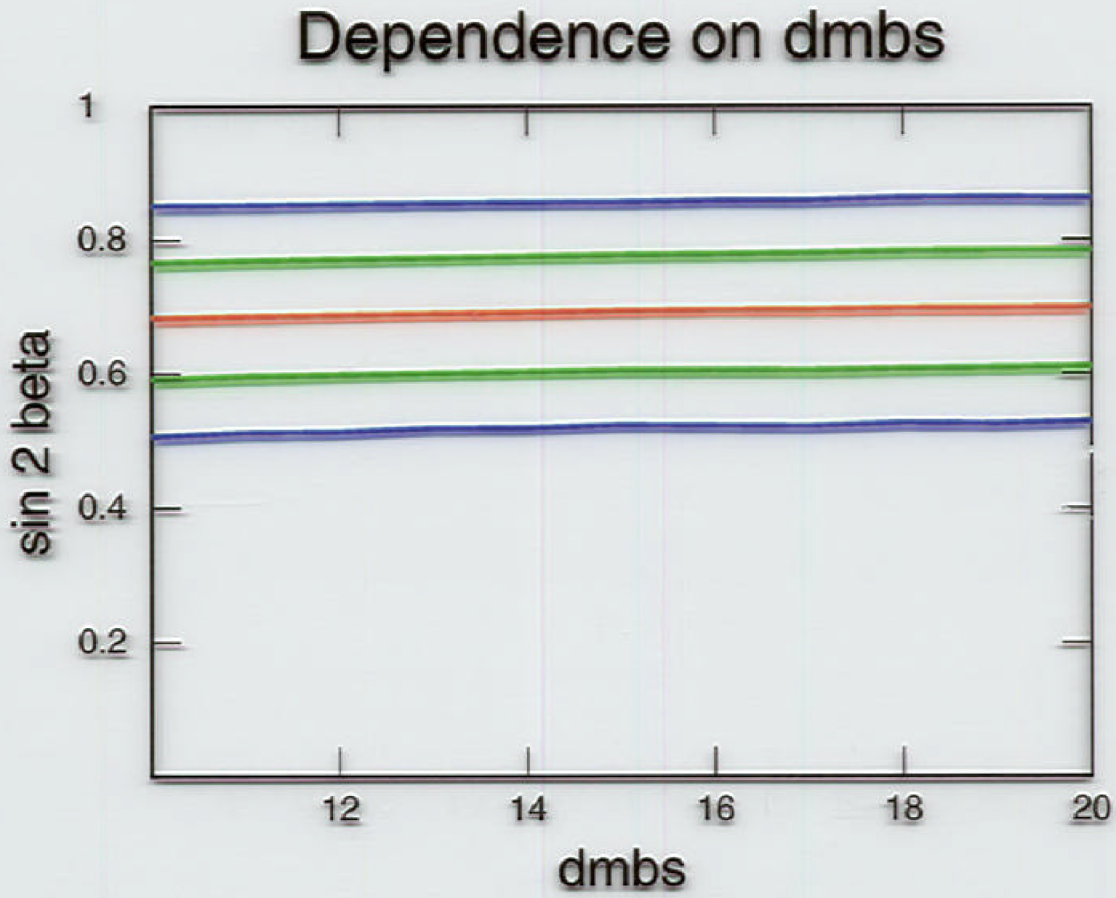


NOMINAL $R_{uc} \equiv \frac{|V_{ub}|}{|V_{cb}|} = 0.085 \pm 0.0136$

Dependence on dmbs $\equiv \Delta m_{B_s}^{BOUND}$



NOMINAL $\Delta m_{B_s} > 15\ \hbar/ps$


Dependence on dmbs
1
0.8
0.6
0.4
0.2
sin 2 beta
12
14
16
18
20
dmbs

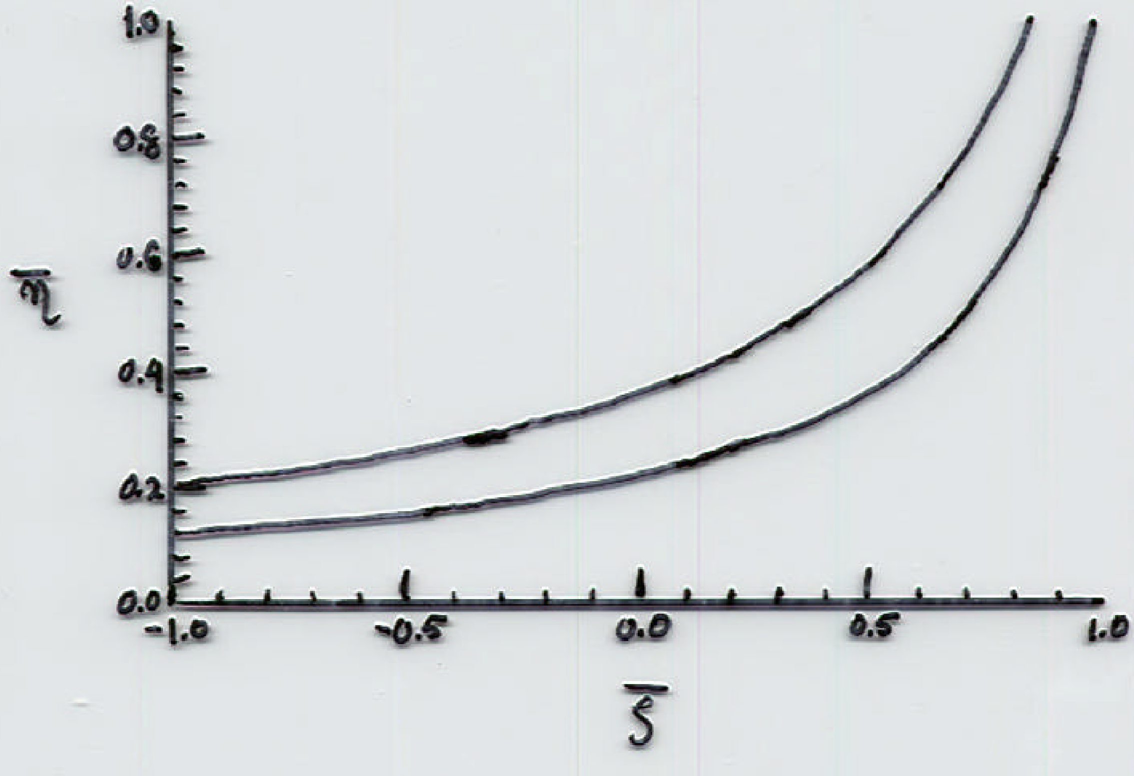
$\sin 2\beta(\phi_1)$ Vs. INPUTS

	68%	95%
1. NOMINAL (with B_s)	.60 — .78	.52 — .85
2. NOMINAL B_s – No $f_B\sqrt{B}$	.61 — .79	.53 — .86
3. " WIDE V_{ub}	.62 — .87	.51 — .97
4. Weaken B_K & $f_B\sqrt{B}$	.59 — .77	.51 — .85
5. NOMINAL – No B_s	.56 — .76	.41 — .84
6. "MAGIC" NOMINAL B_s (NO ϵ_K)	.44 — .71	.32 — .82

(CP Conserving Phenomena require $\beta \neq 0$ [$\eta \neq 0$]!)

($\bar{\eta}$: 0.16 — 0.29 (68%) .11 — .36 (95%)

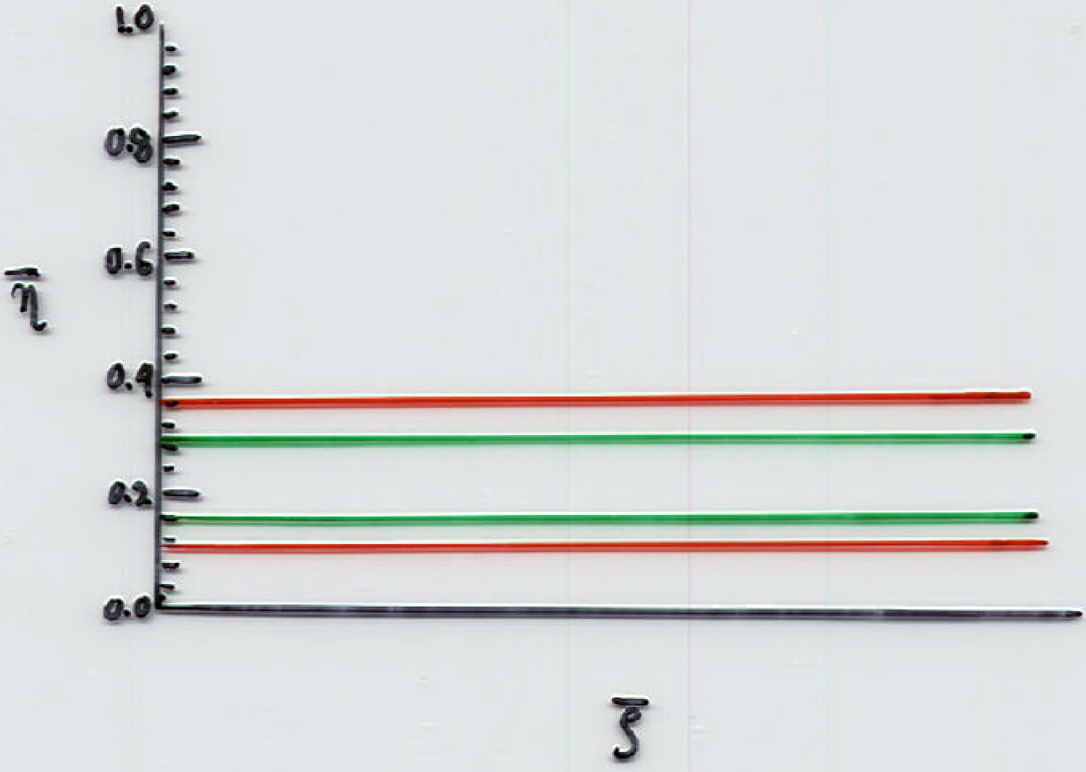
$\bar{\rho}, \bar{\eta}$ Constraint Due ϵ_K ALONE



68% + 95% BOUNDS on $\bar{\eta}$ from B PHYSICS

CP Conserving

$\Rightarrow \bar{\eta} \neq 0$



TIME-Dependent CP Asymmetry in $B^0 \to \psi K^0$

CARTER + SANDA PRL '81
BIGI + SANDA NPB '81

$f = \bar{f}$

$$a(t) = \frac{\Gamma(B_d^0 \to f) - \Gamma(\bar{B}_d^0 \to f)}{+}$$

$$= - f_{CP} \sin 2\phi_1(\beta) \; \sin(\Delta m_{B_d} t)$$

$f_{CP} = \pm 1$

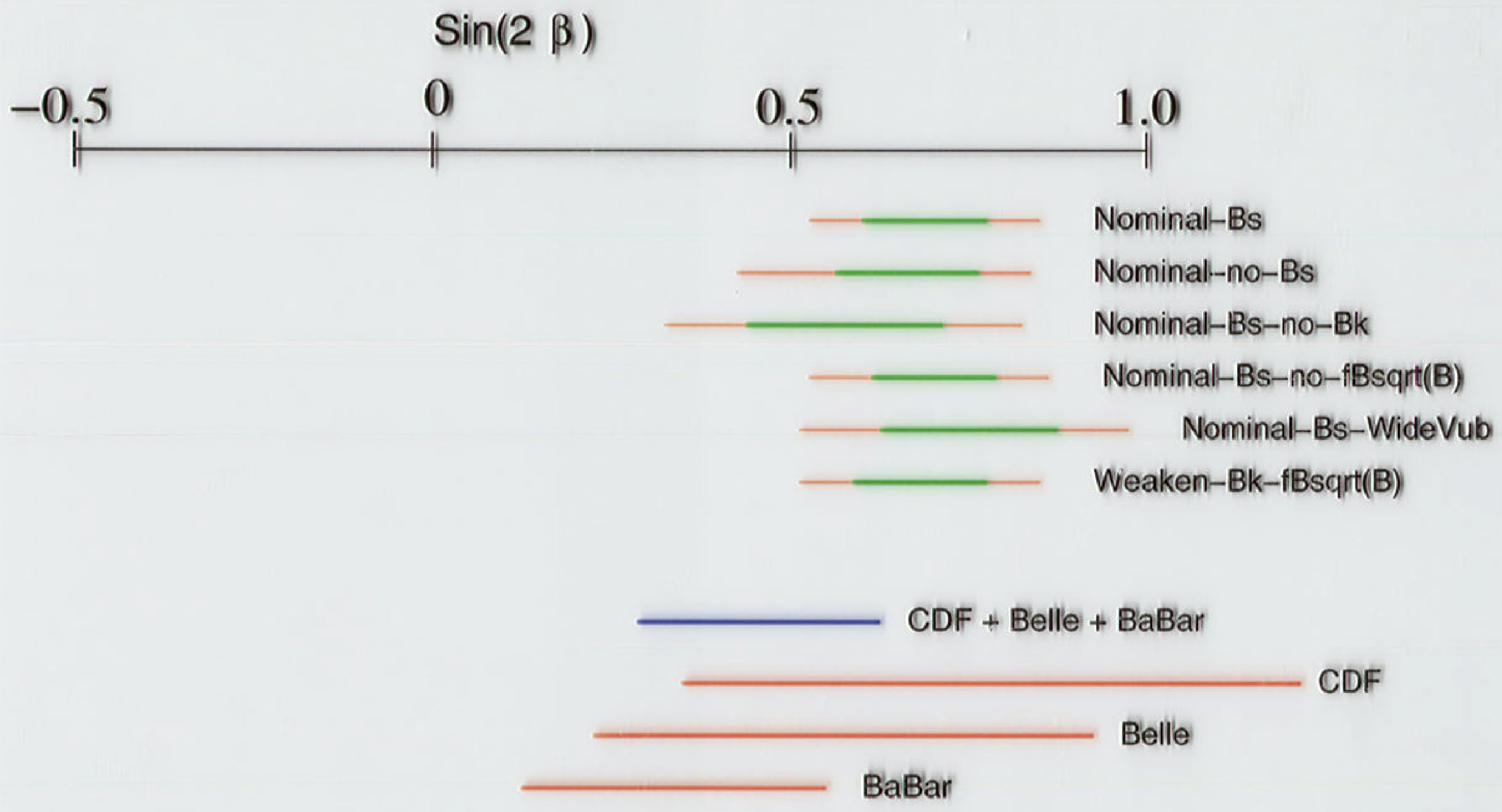
b Amp $\delta_1 \alpha \leftarrow 1$

CLEAN WAY TO Determine $\sin 2\beta(\phi_1)$

due absence of Peng Poll in ψK^0

EXPT	$\sin 2\phi_1(\beta)$
BELLE	$0.58 {}^{+.32}_{-.34} \pm {}^{.09}_{.10}$
BABAR	$0.34 \pm .20 \pm .05$
CDF	$0.79 \pm .44$
COMBINED	0.46 ± 0.17

$\cancel{CP}$ Measurements in $B^0 \to \phi K^0$ Confront the CKM Paradigm



DESPERATELY SEEKING ---.

"WHERE HAVE ALL the BSM ~~CP~~ Phases Gone?

⇒ CKM gives a qualitative and quantitative good account for $\epsilon_K + a_{CP}(B^0 \to \psi K_S)$

⇒ IT IS RATHER DIFFICULT to MAKE AN EXTENSION of SM with CKM phase = 0 AND give a "Natural" (qualitative & quantitative) account of $\epsilon_K + a_{CP}(B^0 \to \psi K_S) + \cdots$

ILLUSTRATION

"TWO HIGGS Doublet Model for the Top Quark"

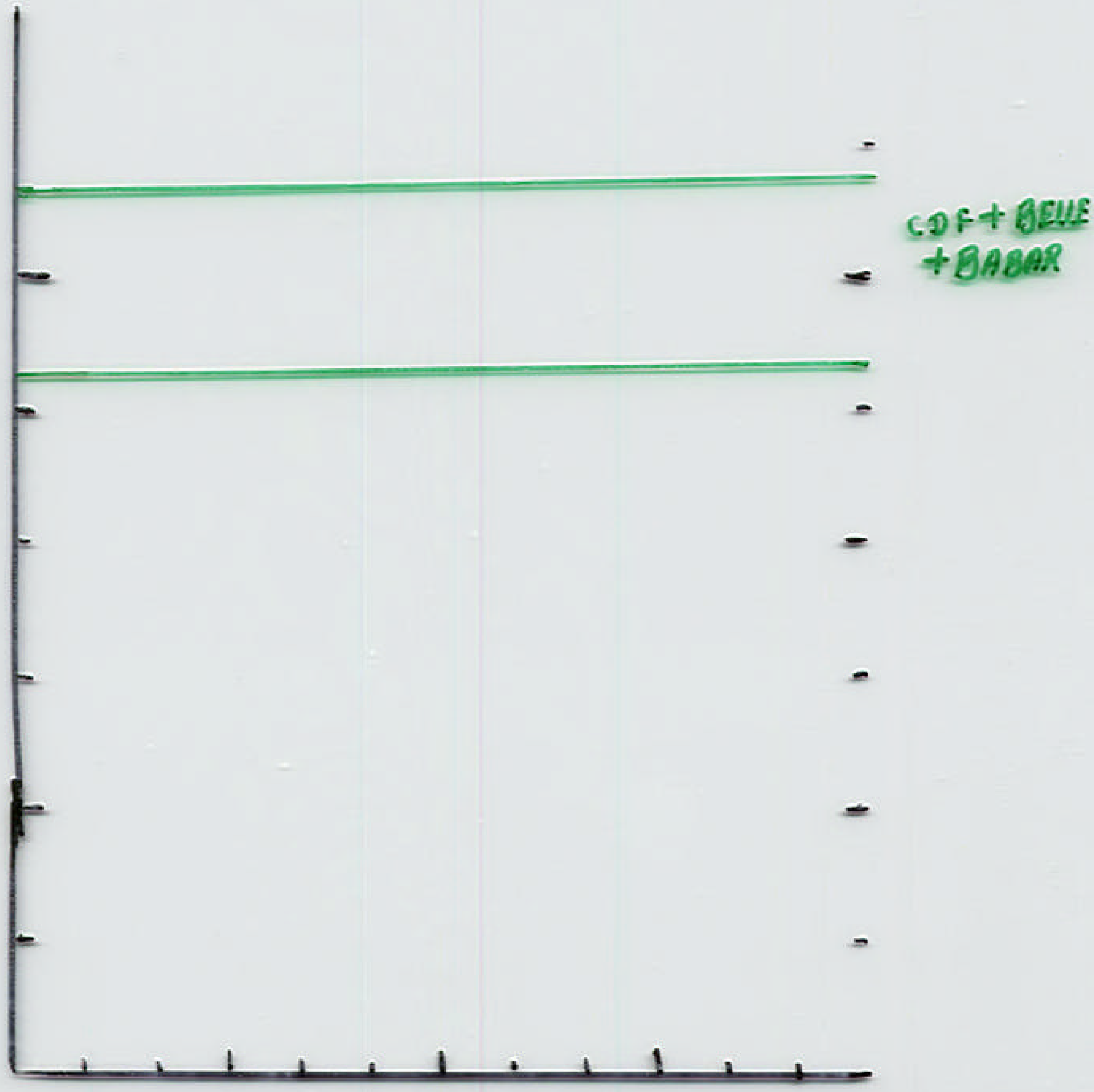
DAS + KAO

K KIERS, AS + G HWu

TOP quark is very heavy
∴ TOP is The only quark that couples to the 2nd doublet with a very large VeV.

You can view it LEET incorporating dynamical model such as TOP-COLOR

⇒ $H^\pm$ CP new phases FCNC in $t \to c \to u$

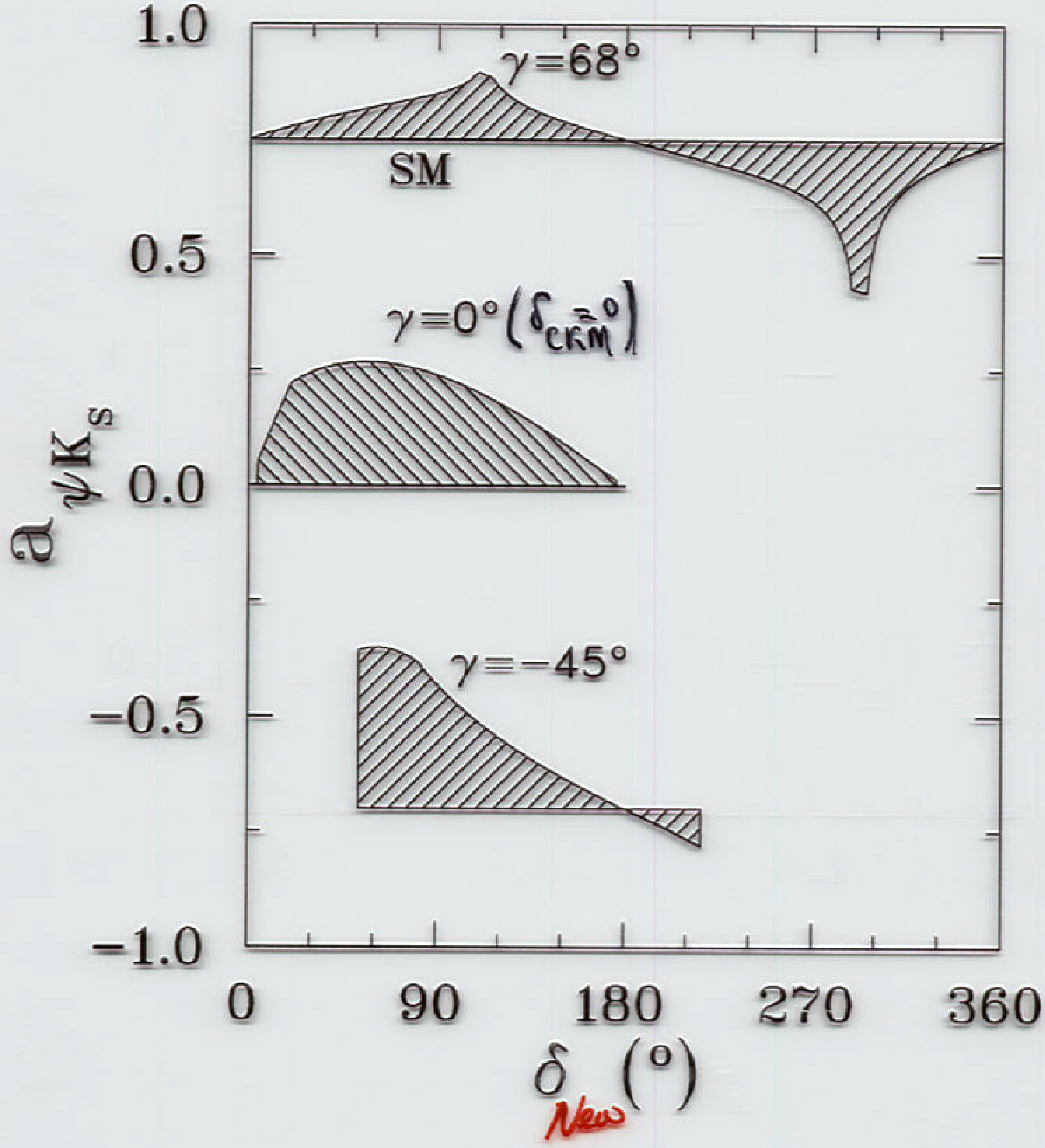


⇒ SEARCHING FOR BSMCP phases in these „channels
will require PRECISION STUDIES"

KIERS, S, WU PRD 99

$a_{\psi K_S} = \sin(2\beta_{CKM} + \theta_{New})$

(Model can accomodate ϵ_K with $\delta_{CKM} = 0$)

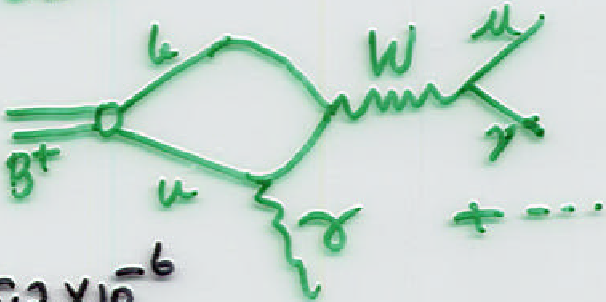


EXPTAL DETERMINATION Of f_B via $B^\pm \to \ell^\pm \nu \gamma$

Use $f_B = 200$ MeV; $\frac{V_{ub}}{V_{cb}} = 0.085$

$BR(B \to \tau\nu) \sim 7.5\times10^{-5}$

$BR(B \to \mu\nu) \sim 3.2\times10^{-7}$



Method

CQM: ATWOOD+EILAM+AS 96 $\sim 5.2\times10^{-6}$

LIGHT CONE + HQET: KORCHEMSKY, PIRJOL, YAN, 99 $\sim (5.2\pm2.2)\times10^{-6}$

Light Front: Geng, Lih, Zhang, 98 $\sim 3.7\times10^{-6}$

Rel. Potl. {COLANGELO, de Fazio + NARDULLI} 96 $\sim 1\times10^{-6}$

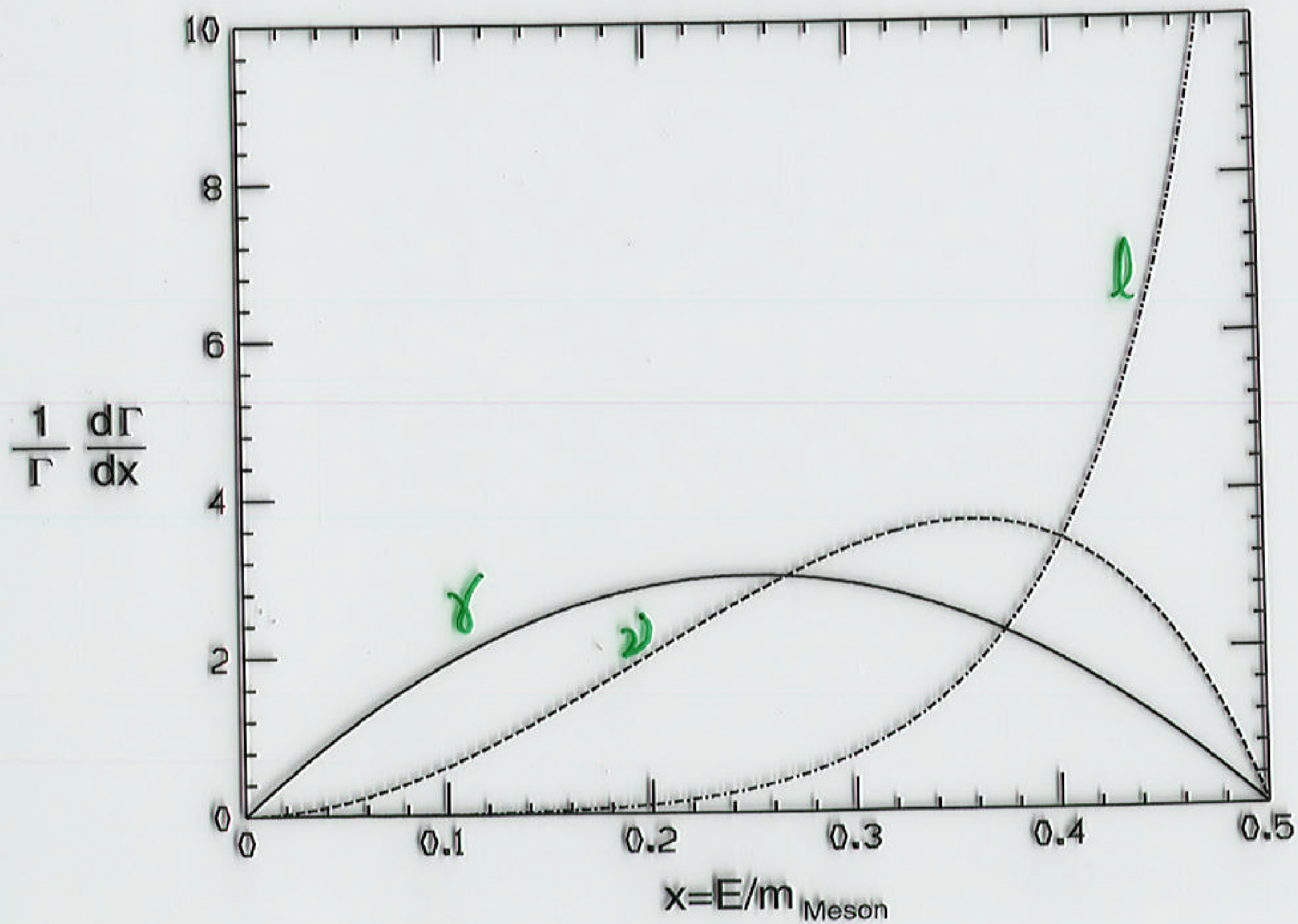
⋮ ⋮ ⋮

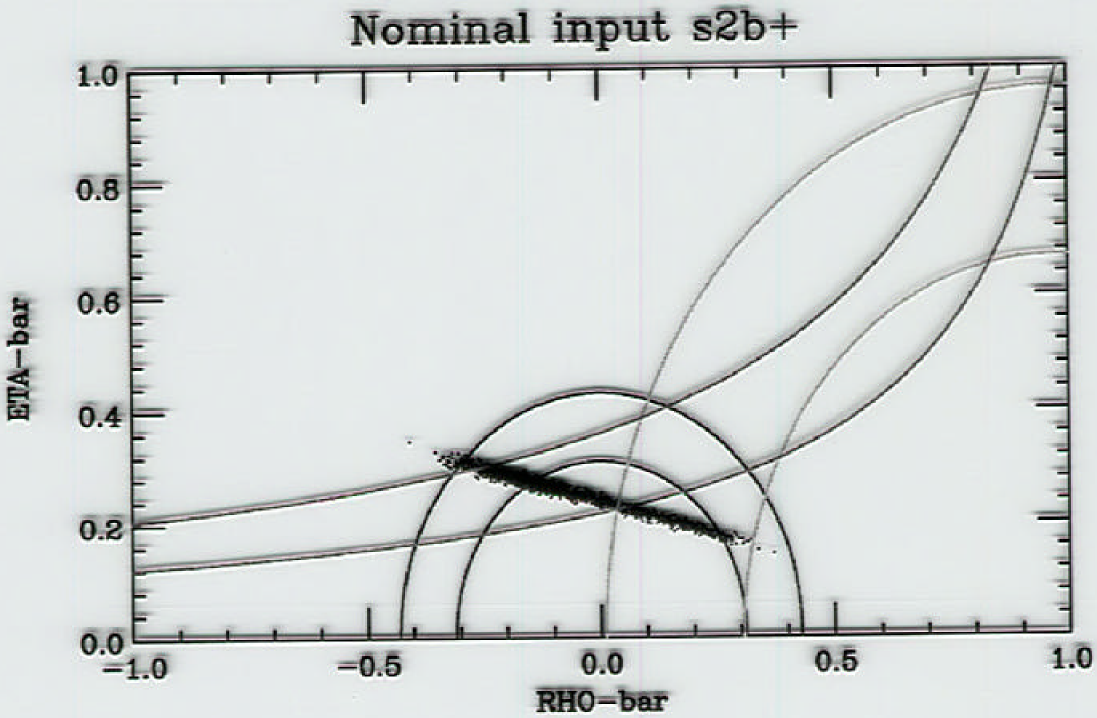
NOT VERY CLEAN But ~ 30% or so gives f_B

$(\mu\nu\gamma + e\nu\gamma) \sim 10^{-5}$

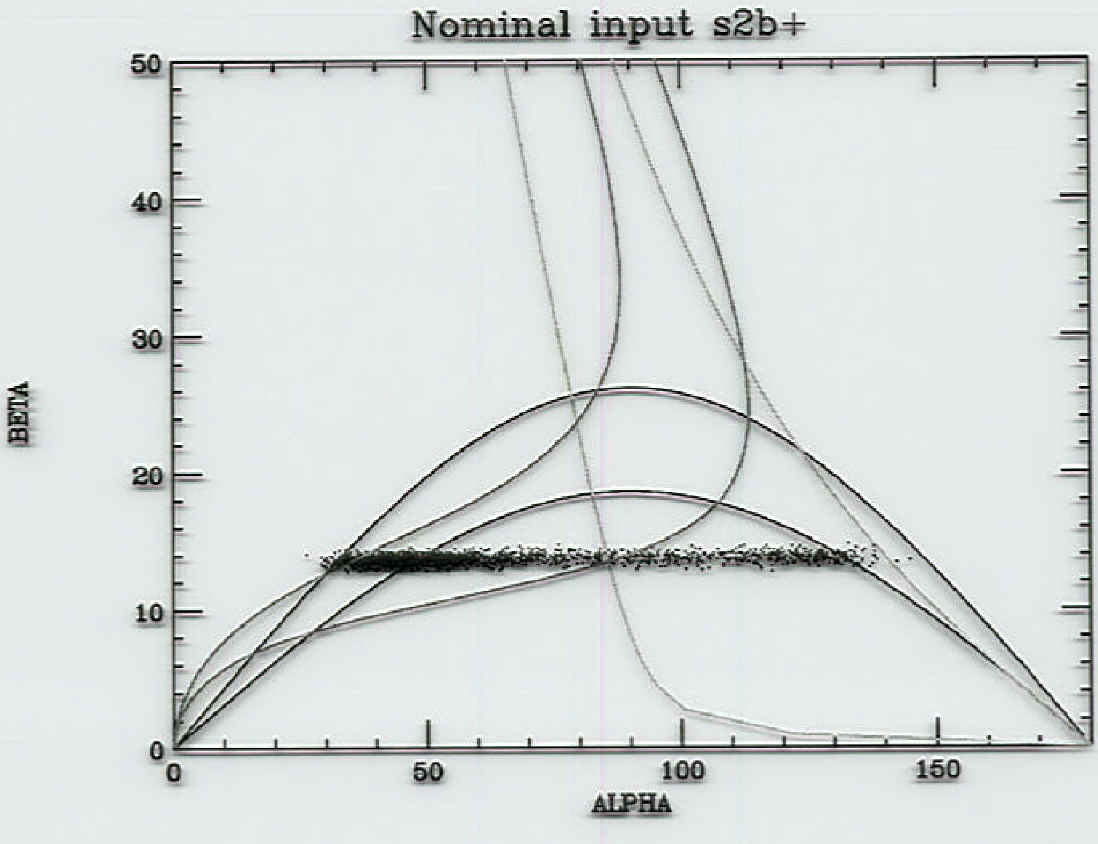
characteristic photon spectrum "SPIN Flip"

Figure 2


10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
γ
ν
ℓ
$\frac{1}{\Gamma}\frac{d\Gamma}{dx}$
$x = E/m_{Meson}$


Nominal input s2b+
ETA-bar
RHO-bar
1.0
0.8
0.6
0.4
0.2
0.0
−1.0
−0.5
0.0
0.5
1.0

35



NEED $|V_{td}|$ better

1) $B_s - \overline{B_s}$ Osc --- ...TEV, BTEV, LHCB ---
BEYOND LEP Bound

2) a) EXPTALLY Measure $B^0 \to \rho^0 + \gamma$ (NOT $B^\pm$)

Atwood, BLOK, AS

$$\frac{|V_{td}|}{|V_{ts}|} = C_{PS}\left[\frac{BR(B^0 \to \rho^0 \gamma)}{BR(B^0 \to K^* \gamma)}\right]^{1/2} \xi^{\gamma}$$

phase space correction

$\leftarrow$ SU(3) Breaking FROM THE LATTICE

$M_\mu = \langle V(k) | J_\mu | B(p) \rangle \qquad J_\mu = \bar{q}\, \sigma^{\mu\nu} Q_\nu b_R$

$$M_\mu = 2\epsilon_{\mu\nu\rho\sigma}\eta^\nu(k)\, p^\lambda k^\sigma T_1(Q^2) + [\quad] T_2(Q^2) + \eta \cdot Q [\quad] T_3(Q^2) \qquad Q = p - k$$

$$R_V \equiv \frac{\Gamma(B \to V\gamma)}{\Gamma(b \to q\gamma)} = 4\left(\frac{m_B}{m_b}\right)^3\left[1 - \frac{m_V^2}{m_B^2}\right]^3 T_1(0)$$

BERNARD, HSIEH + AS PRL 94
UK QCD, APE - -

SU(3) Breaking "small"

NEEDS PRECISION

(Propagators Can be shared with other heavy light physics such V_{ub} form factors)

ξ^γ IS Much EASIER THAN $T_1(0)$

3) $|V_{td}|$ via $K^+ \to \pi^+ \nu\bar{\nu}$

Extremely clean

E787 BR $\left(1.5^{+3.4}_{-1.2}\right) \times 10^{-10}$

EXPECTATIONS from our fit : $(.50 — .88) \times 10^{-10}$

New Efforts AGS E949 10^{-11} sensitivity

FNAL CKM 10^{-12} "

IMPORTANT for cross-checks.

CONCLUSIONS / OUTLOOK

- Using ϵ_K, R_{uc}, Δm_d, $\frac{\Delta m_s}{\Delta m_d}$, in approp. linear. comb. + theory $\Rightarrow$ valuable const on the CKM matrix. In particular,
- Using B-physics (CP-conserving) input $\Rightarrow$ KM phase $\neq 0$
  $.11 < \bar{\eta} < .36$ (95%) ; $.32 < \sin 2\beta < .82$ (95%)
  Recall $\epsilon_K \neq 0$ $\Rightarrow$ Requires $\bar{\eta} > .12$
- ϵ_K, R_{uc}, $\Delta m_s / \Delta m_d$ INPUTS + THEORY ≠ ROBUST [No $f_B \sqrt{B}$ used]
  $\Rightarrow$ $.51 < \sin 2\beta < .85$ (95%)
- Using ALL 4 with conservative theory input $\Rightarrow$
  $.51 < \sin 2\beta < .86$ (95%)
- CDF + BELLE + BABAR $\Rightarrow$ $\sin 2\beta = 0.46 \pm .17$
  $\Rightarrow$ Completely compatible with Theo. EXPECTATIONS
  $\Rightarrow$ No GLARING SIGNS of NEW CP-odd Phase
  $\Rightarrow$ SEARCH FOR BSM CP phase (s) IN THESE CHANNELS WILL REQUIRE PRECISION STUDIES
  MORE DATA, EXPT Effort at f_B, $\frac{V_{td}}{V_{ts}}$, B_s Osc, $B^0 \to \rho^0 \gamma$

$\Rightarrow$ B-FACTORY EXPERIMENTS (INFO SO FAR) SPELLS RESOUNDING SUCCESS OF THE CKM PARADIGM