Clean Unitarity Δ and a lot more at a SuperB Factory

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Outline

Introduction

B2SUPERB, MAIN PURPOSE : Relentless pursuit of the BEYOND

↳ will allow 3 stabs @ the SM

1. with some theory input
2. with no theory input
3. direct search for X_{BSM}

Given the importance of our goal multipronged attack is essential.

Introduction

SUPERB performance of B-Factories

LEARNED very valuable lesson: Not only CKM phase exists, it is also large.

Compelling arguments for BSM-physics esp. $\mathcal{K}_{BSM}$

$\Rightarrow$ RATIONALE for our OBSESSION

Requirements for a successful search

Remember the 2)

LHC on our mind

Back to the future: Just like the 80s

Desperately Seeking BSM ~~CP~~ Phase(s) (χ) (3)

$\Rightarrow$ NOTHING SACRED ABOUT CP in Field Theory

$\Rightarrow$ Addition of gauge bosons, fermions, Higgs...
in general entails new CP phases

$\Rightarrow$ Baryogenesis is difficult to account for
in the SM

(4) (2+4)(3+)

THEORY ERRORS (SHOULD BE) ARE A SERIOUS CONCERN

∵ They can THWART EXPERIMENTAL EFFORT TO UNCOVER χ_{BSM}

χ_{BSM} MAY WELL CAUSE ONLY SMALL DEVITIONS FROM THE SM IN B-PHYSICS

IMPORTANT LESSON FROM THE SM

KM phase δ_{13} ($= \gamma \approx 50^\circ \pm 10^\circ$) NOT SMALL

$K_L \to \pi\pi$ $B \to \psi K_S$

$\epsilon_K \sim 10^{-3}$ $a_{CP} \sim 80\%$

e.g. $\chi_{BSM} \Leftrightarrow H$

⇒ EVEN IF $\chi_{BSM} \sim O(1)$ IN B-PHYSICS IT MAY WELL CAUSE ONLY VERY SMALL DEVIATIONS ($\sim 10^{-3}$?)

# of B's to see asy $\sim 10^{-3}$ SAY IN $B \to \eta' K_S$ (LARGEST MODE)

$\sim \frac{10}{10^{-6} * 10^{-3}} \sim 10^{10}$

⇒ THE Drive for more B's via SUPER (BELLE/BABAR) CDF/DØ/BTEV/LHCB

⇒ DEVELOP TESTS of SM THAT HAVE "ZERO" THEORY ERR

NOTE AT the Level of 10^{-3} even ISOSPIN

~~APPO~~ APPROX. CAN MASK χ_{BSM}

Fig. 22. Exclusive Oscillation Limits.

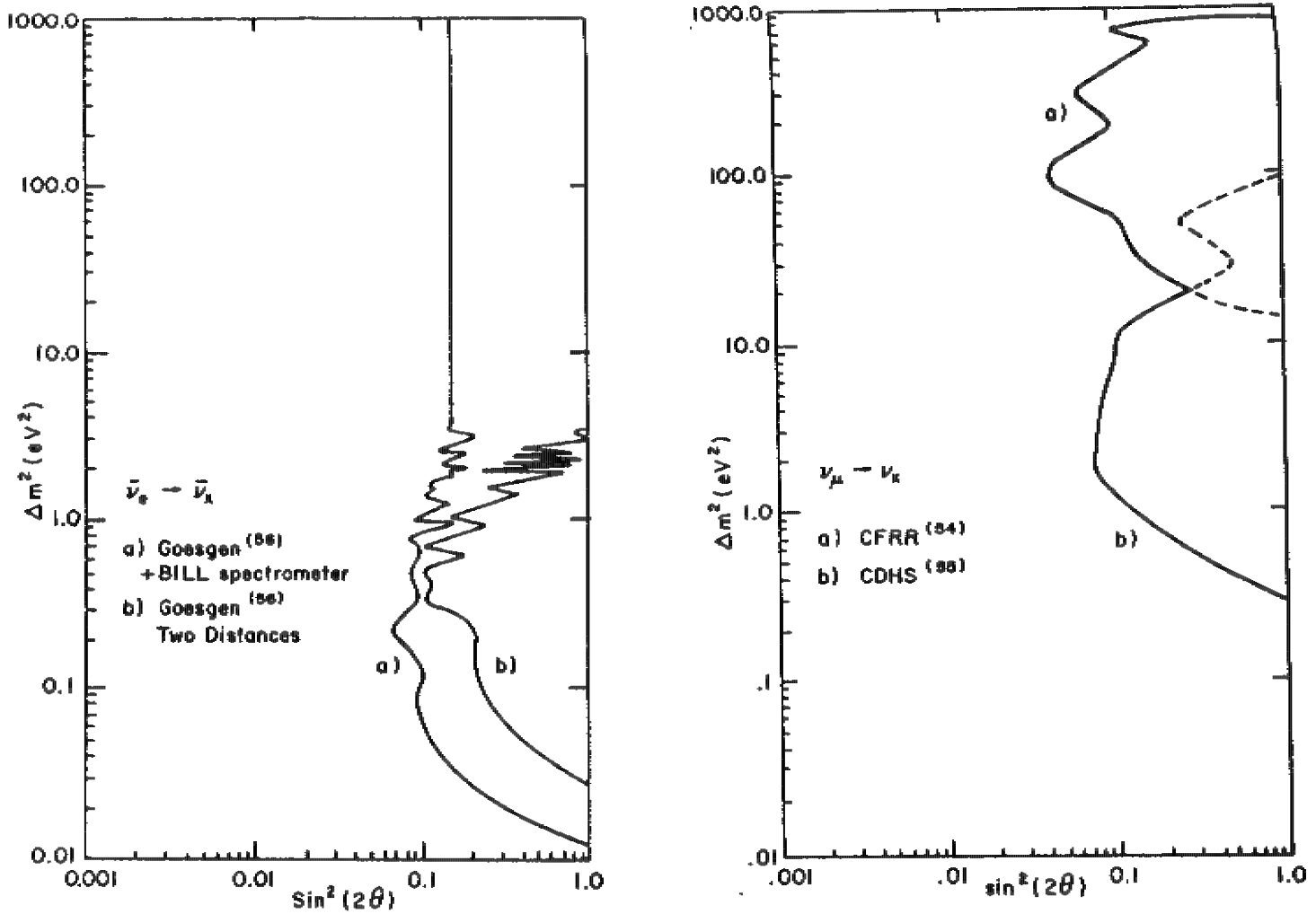

Fig. 23. Inclusive Oscillation Limits.

M. Shaevitz
Lepton-Photon
'83

03- 7-11;19:04 ;BELLE GROUP scan for file ;+81-298-64-5340 # 5/ 87
M. SHAEVITZ
167

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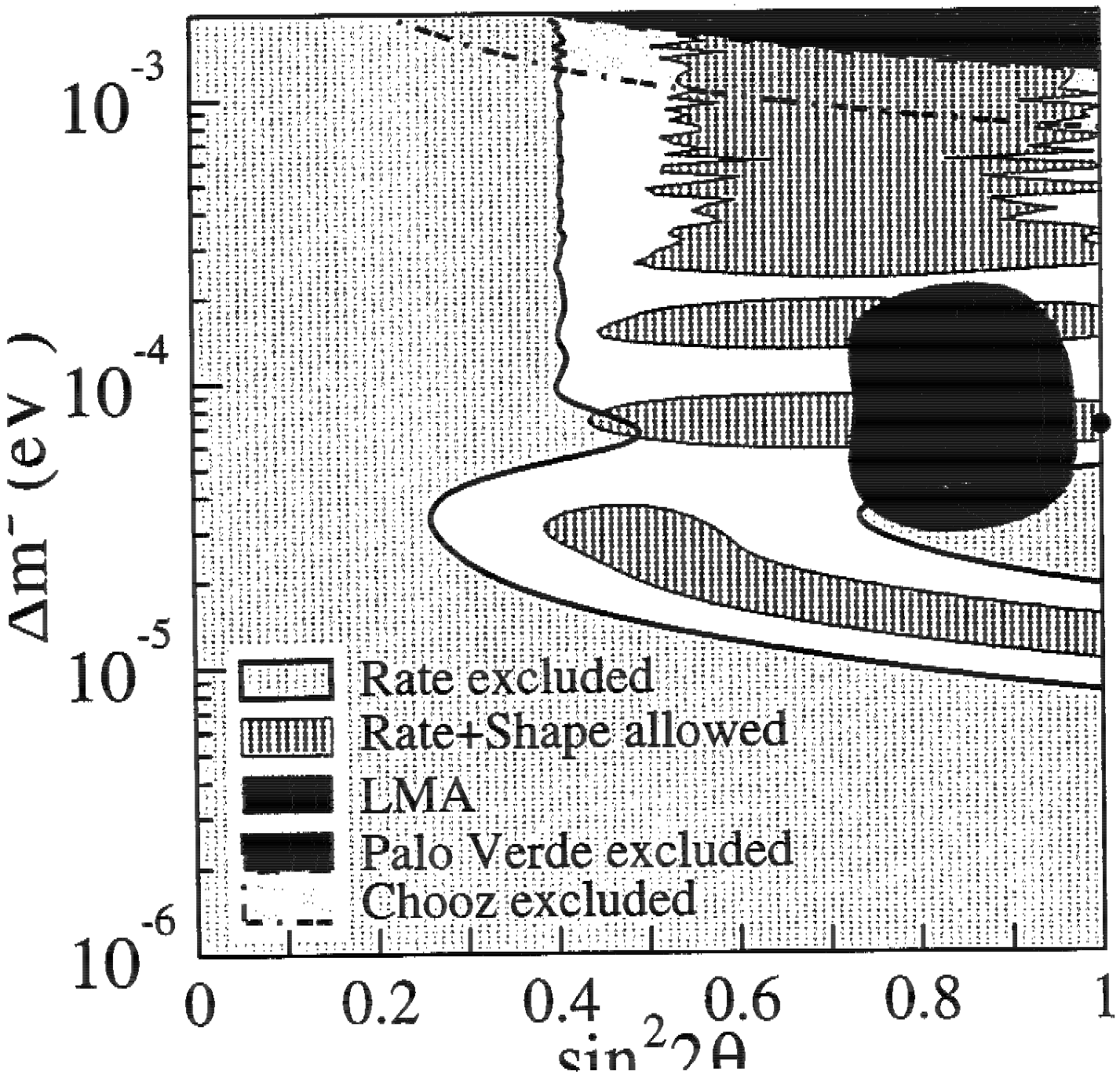
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Δm^2 (eV^2)
Rate excluded
Rate+Shape allowed
LMA
Palo Verde excluded
Chooz excluded
0
0.2
0.4
0.6
0.8
1
$\sin^2 2\theta$

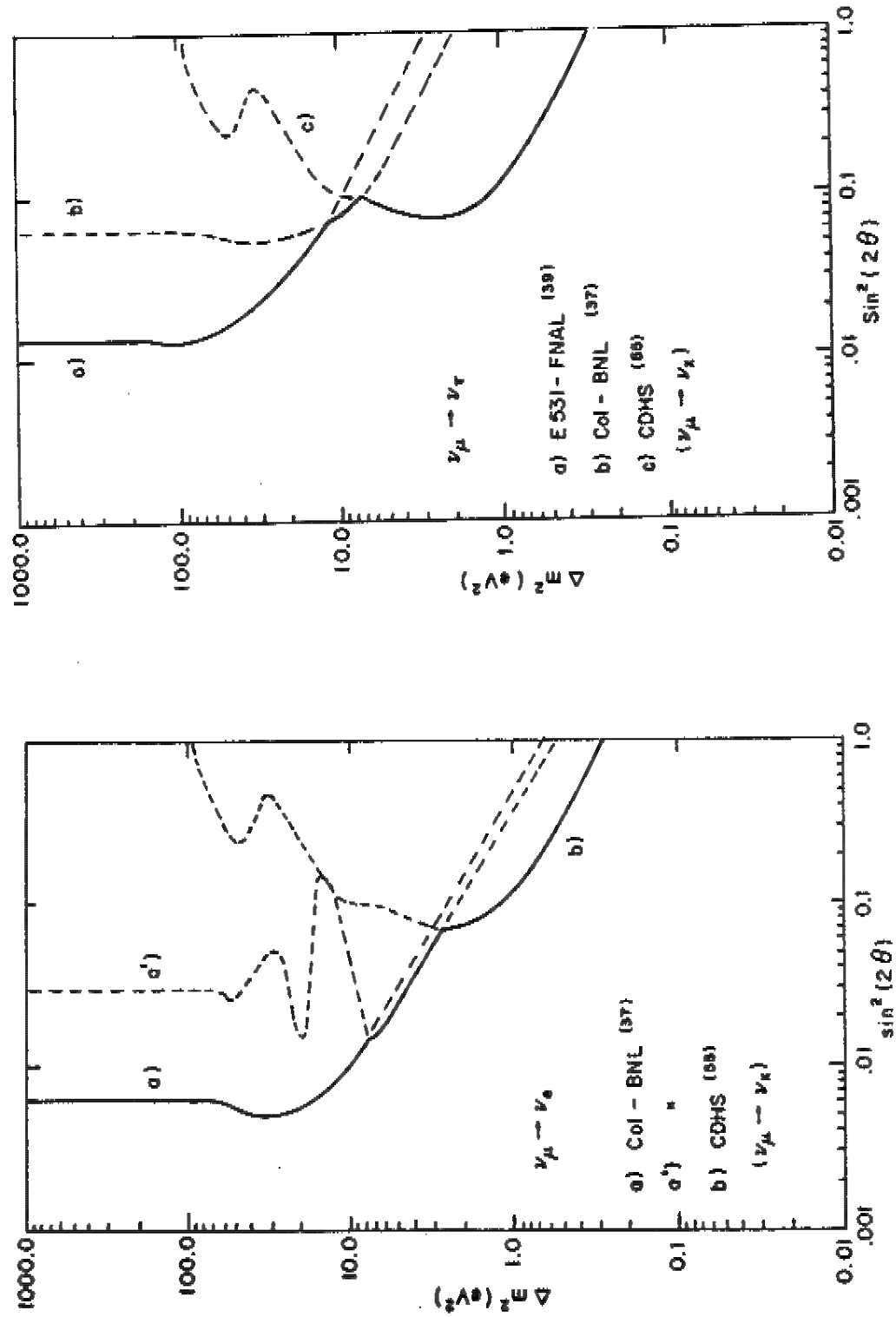

Fig. 22. Exclusive Oscillation Limits.

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LHC

Some Thinks that LHC will come on line and we will reach NIRVANA

1. Dangers of fake SUSY(S)
   Precise understanding of SM from studies at B and Super B along with other constraints can play a valuable role in discarding fake from genuine NP.

2. Machine Systematics; pp not self conjugate

3. detector systematics in a hadronic environment.

   If $A_K^{CP} \lesssim$ a few% as may well be the case, then these potential shortcomings can become a serious concern.

PHYSICS PROSPECTS FOR A LINEAR COLLIDER B-$\bar{B}$ FACTORY

David B. Cline and A. Soni
Department of Physics
University of California, Los Angeles, CA 90024

MORIOND '87

BSTRACT. Physics motivation for a dedicated, high luminosity B-$\bar{B}$ factory s emphasised. B decays can give very useful information on some mportant parameters of the Standard Model (such as mixing angles) and larify the role of QCD in weak decays. B decays are far cleaner than K ecays so far as QCD corrections are concerned. The strength of some of he flavor-changing loop decays of B are also vastly enhanced over the orresponding decays of kaons making such loop decays invaluable for esting the full machinery of the Standard Model (SM) to one loop. ossibilty of observation of CP violation in a new arena remains the most antalizing promise of a B factory. However, that would require > 10^8 's. As such an e^+e^- linear collider B-B factory with a luminosity of $0^{34}/cm^2$ is highly desirable.

B Factories have fulfilled this Promise !

ıent of much improved
:hallenge is clearly the
e are improvements to
he program more pow-
ıx detectors with three
echniques.

ND RATES FOR

ır three energy regimes:
ıtinuum (for the sake of
ctory at the Z^0. In each
nachines. Furthermore,
es with collisions in the
that are "boosted" or
y as to produce moving
able 1. There is clearly
a factor of five over the
construction, SLC and
, which is at least fifty
be competitive with a
ies should be improved
in the continuum, such

as PEP, the luminosity should be an order of magnitude greater than a B-factory at the $\Upsilon(4S)$ in order to obtain roughly the same number of $b\bar{b}$ events.

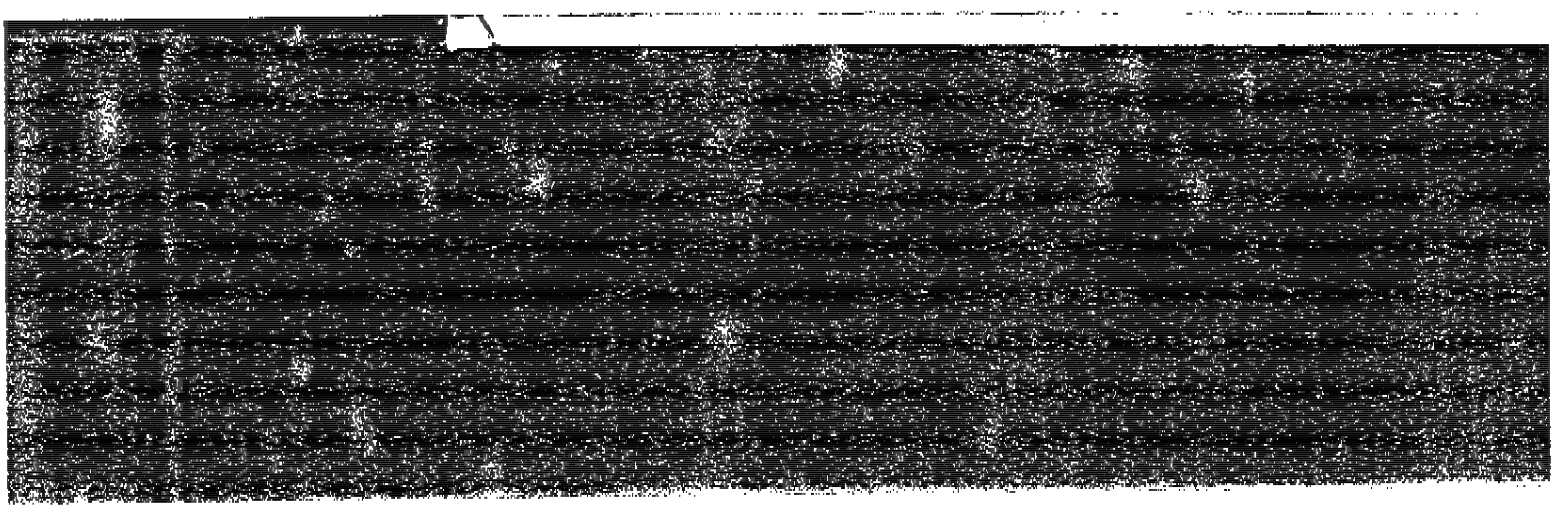
Since we are mostly interested in detector requirements and performance, we concentrate here only on those aspects of machines that might have a significant effect on the detectors.

TABLE 1.

Future $b\bar{b}$ factories and sweat shops. None of the luminosities shown in the Table have been achieved. Factors of two difference in luminosity are not significant.

E_{CM} GeV	Class	$E_1 \times E_2$ GeV × GeV	$\sigma_{b\bar{b}}$	Peak L proposed $cm^{-2}sec^{-1}$	$b\bar{b}$ events/yr $10^7 sec$ @ peak L	References
$\Upsilon(4S)$	CM RING	5 × 5	1 nb	5×10^{32}	$5 \cdot 10^6$	*SIN Proposal*[1]
	CM LINEAR	5 × 5		10^{33}	10^7	*Amaldi & Coignet*[2]
	BOOSTED LINEAR	2 × 12.5		5×10^{32}	$5 \cdot 10^6$	*Sessler & Wurtele*[3]
	BOOSTED RING	2 × 12.5		5×10^{32}	$5 \cdot 10^6$	*Oddone*[4]
Continuum 20 GeV	RING		0.1 nb	5×10^{32}	$5 \cdot 10^6$	*Bloom*[5]
	LINEAR			10^{34}	10^7	*Amaldi & Coignet*[2]
Z^0	LINEAR SLC	45 × 45	5 nb	5×10^{30}	$2.5 \cdot 10^5$	*SLC Study*[6]
	LEP	45 × 45		2×10^{31}	$8 \cdot 10^5$	*LEP Study*[7]
	RING IMAGINARY	45 × 45		5×10^{33}	$2.5 \cdot 10^6$	

PIERRE ODDONE : Proceedings of the Linear-Collider $B\bar{B}$ FACTORY CONCEPTUAL DESIGN JAN 1987 (UCLA)



Physics GOALS[240] of a B-Factory (A. Soni)
UCLA WORKSHOP Jan '87

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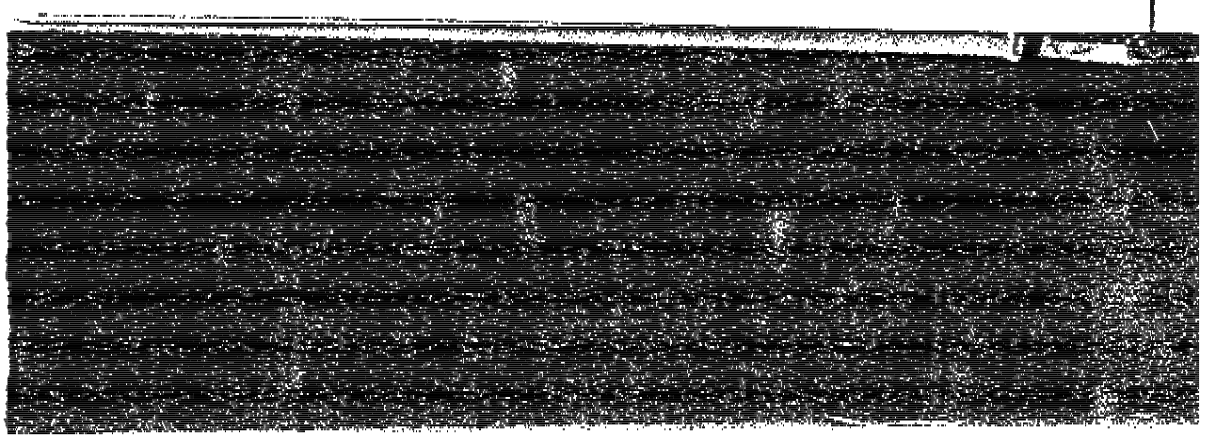
Table: Illustrative Sample of Some Important Decay Modes of B.

MODE	PHYSICS MOTIVATION	EXPECTED BR and CP asymmetry	EXPECTED # events and sensitivity to CP with 10^7 B's and Remarks.
$K\pi$	CP, QCD	$\sim 10^{-5}$, $\sim \cdot 2S$	15-60); (Δ_S>40Z)...10^8 more promising
$D^0 + X$, $\bar{K}_S + Y$	CP	$\cdot 1$ (1-5Z)	1000±200; (Δ_S>40Z)... Needs 10^9
$K + X_d$ (NO CHARM)	QCD, 4th Family	1 to 10Z	Experimentally appears too difficult
$K + 3\pi$ (NO CHARM)	" " " "	$\sim \cdot 1$Z	3000±100; (Δ_S>15Z)
$K\ell\ell$	SMTest, 4th Family	10^{-6}–10^{-5}	3 - 30 with little background.
$K\nu\bar{\nu}$	" "	5×10^{-6}–5×10^{-5}	Difficult
$K^*\gamma$	SMTest, 4th Family, Supersymmetry	$\sim 5\times10^{-5}$	250±80
$\tau\nu_\tau$	CKM	$\sim 10^{-4}$	~1...Feasible at 10^8
$K\mu e$, $K\mu\tau$	Horizontal Gauge Interactions[14]	10^{-5}–10^{-9} i.e. $m_H \geq 10$TeV	upperbound 10^{-6}–10^{-7}



Refine tests of SM that require some Theory Input.

$$(\phi_1, \phi_2, \phi_3) \equiv (\beta, \alpha, \gamma)$$

WONDERS of the KOBAYASHI – MASKAWA MECHANISM of CP VIOLATION

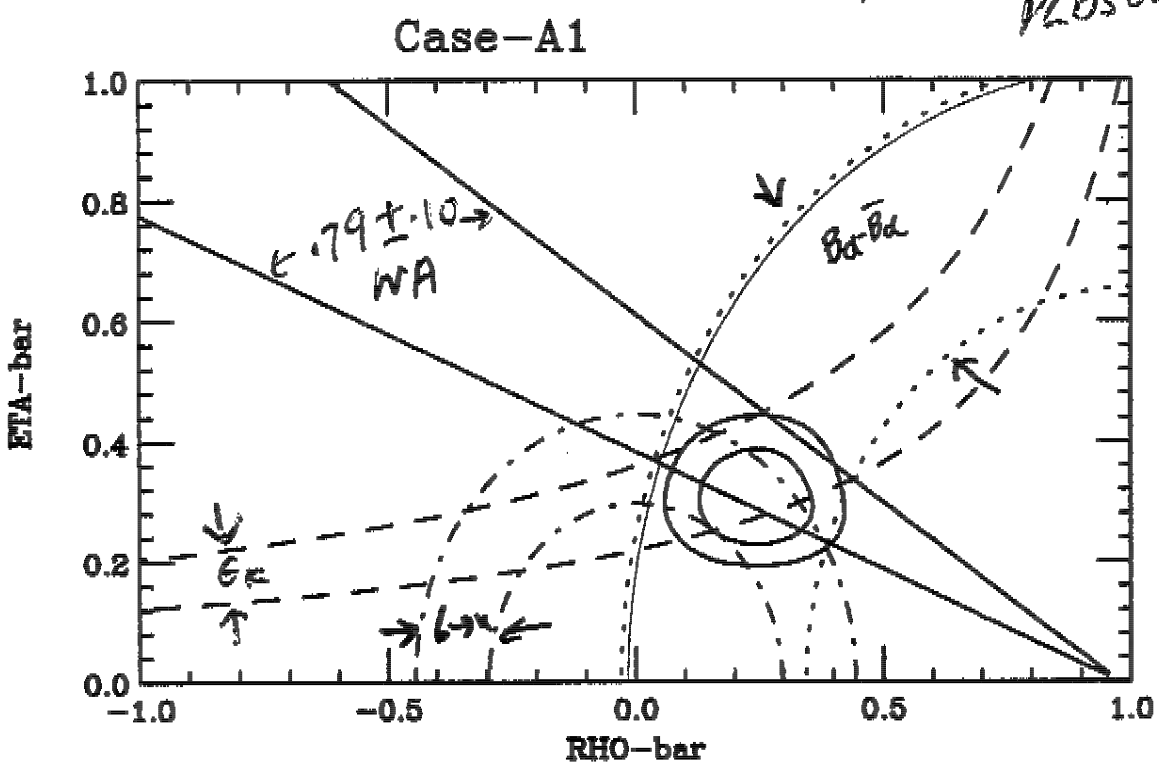
$O(10^3)$ ⟶

⟵ CP Asym in $B \to \psi K_S$

SIN DIRECT CP in $K_L \to \pi\pi$ $\epsilon_K \sim 2.3 \times 10^{-3}$

5

ATWOOD+ AS PLB508, 17(01)



$\sin 2\beta^{SM} = .70 \pm .10$

8 12
14

Table 1: Comparison of some fits.

Input Quantity	Atwood & Soni (PL '01)	Ciuchini *et al* (PL '01)	Hocker (PL '0
$R_{uc} \equiv \lvert V_{ub}/V_{cb}\rvert$	$.085 \pm .017$	$.089 \pm .009$	$.087 \pm .006$ $.014$
$F_{B_d}\sqrt{\hat{B}_{B_d}}$ MeV	230 ± 50	$230 \pm 25 \pm 20$	230 ± 28 28
ξ	$1.16 \pm .08$	$1.14 \pm .04 \pm .05$	$1.16 \pm .03$ $.05$
$\hat{B}_K$	$.86 \pm 0.15$	$.87 \pm 0.06 \pm 0.13$	$.87 \pm .06$ $\pm .13$
Output Quantity			
$\sin 2\beta$	$.70 \pm .10$	$.695 \pm .065$	$.68 \pm$
$\sin 2\alpha$	$-.50 \pm .32$	$-.425 \pm .220$	
γ	$46.2^\circ \pm 9.1^\circ$	54.85 ± 6.0	$56 \pm$
$\bar{\eta}$	$.30 \pm .05$	$.316 \pm .040$	$.34 \pm$
$\bar{\rho}$	$.25 \pm .07$	$.22 \pm .038$	$.22 \pm$
$\lvert V_{td}/V_{ts}\rvert$	$.185 \pm .015$		$.19 \pm$
$\Delta m_{B_s}(ps^{-1})$	19.8 ± 3.5	$17.3^{+1.5}_{-0.7}$	$24.6 \pm$
J_{CP}	$(2.55 \pm .35) \times 10^{-5}$		$(2.8 \pm .8)$
$BR(K^+ \to \pi^+ \nu\bar{\nu})$	$(0.67 \pm 0.10) \times 10^{-10}$		$(.74 \pm .23)$
$BR(K_L \to \pi^0 \nu\bar{\nu})$	$(0.225 \pm 0.065) \times 10^{-10}$		$(.27 \pm .14)$

$(\sin 2\beta)^{WA} = .734 \pm .054$

Expectation from our fit:

$\beta \sim 25^\circ$

$\gamma \sim 45^\circ$

$\alpha \sim 110^\circ$ VERY POORLY KNOWN

LATTICE INPUT FOR CKM FITS

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	ATWOOD + A.S '01	CIUCHINI et al '01	HOCKER et al '01
$R_{uc} \equiv V_{ub}/V_{cb}$	$0.085 \pm .017$	$0.089 \pm .009$	$0.087 \pm .006 \pm .0$
$f_{B_d}\sqrt{\hat{B}_{B_d}}$ (MeV)	230 ± 50	$\Leftrightarrow$ $230 \pm 25 \pm 20$	$230 \pm 28 \pm 25$
ξ	$\begin{cases} 1.16 \pm .08 \\ 1.25 \pm .10 \end{cases}$	$\Leftrightarrow$ $1.14 \pm .04 \pm .05$	$1.16 \pm .03 \pm .0$
$\frac{\xi}{\sqrt{\hat{B}_K}}$	$.86 \pm .15$	$.87 \pm .06 \pm .13$	$.87 \pm .06 \pm .1$

⇒ COMMENTS HOCKER et al & CIUCHINI et al SERIOUSLY underestimate errors on ξ (also $\frac{V_{ub}}{V_{cb}}$)

⇒ LATTICE '02 REASSESMENT of ERRORS in ξ due CHIRAL EXTRAPOLATION

RYAN & KRONFELD & N. YAMADA

± 0.05 IS NOT JUSTIFIED *

⇒ LELLOUCH SUMMARY ICHEP '02

$f_{B_d}\sqrt{\hat{B}_{B_d}}$ /MeV $= 235 \pm 33^{+0}_{-24}$

$\xi = 1.18 \pm .04^{+.12}_{-0}$

$\frac{\xi}{\sqrt{\hat{B}_K}} = .86 \pm .06 \pm .14$

* BUT THEIR NUMERICAL ESTIMATES OF ERRORS NOT JUSTIFIED.)

CKM Constraints — THEORY

For past several years fall 4 items are the key.

$$\epsilon_K \; ; \quad x_{B_d} = \frac{\Delta m_{B_d}}{\Gamma_{B_d}} \; ; \quad \frac{x_{B_s}}{x_{B_d}} \; ; \quad \frac{b\to u l \nu}{b\to c l \nu} = 0.085 \pm .017$$

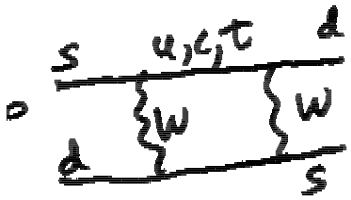
$\epsilon_K = (2.274 \pm .017) \times 10^{-3}$; $x_{B_d} = 0.755 \pm .015$

$x_{B_s} > 19.0$ 95% CL

e.g. for $K-\bar{K}$: $\mathcal{M}_K = \langle \bar{K}^0 | [\bar{s}\gamma_\mu(1-\gamma_5)d]^2 | K^0 \rangle$

$\equiv \frac{8}{3} m_K^2 f_K^2 B_K$

INTRODUCE $\tilde{\mathcal{M}}_K \equiv \frac{3}{8} m_K^2 \mathcal{M}_K \equiv f_K^2 B_K$



$$\text{I} \quad |\epsilon_K| = \tilde{\mathcal{M}}_K C_K \lambda^6 A^2 \bar{\eta} \left\{ \eta_1 S(x_c) + \eta_2 S(x_t) A^2 \lambda^4 (1-\bar{\rho}) + \eta_3 S(x_c, x_t) \right\}$$

$x_j = m_{q_j}^2 / M_W^2$

η_1, η_2, η_3 QCD CORRECTIONS to NLO

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

S's are INAMI-LIN FUNCTIONS

$\lambda, A, \bar{\rho}, \bar{\eta}$ CKM PARAMETERS IN WOLFENSTEIN REPRESENTN

9-15 (13)

Table 2: Stability of our Fit

Input Quantity	Atwood & Soni (PL '01)		
$R_{ub} \equiv \lvert V_{ub}/V_{cb}\rvert$	$.085 \pm .017$		
$f_B\sqrt{\hat{B}_B}$, MeV	230 ± 50 MeV		
ξ	$1.16 \pm .08$		$1.25 \pm .10$
$\hat{B}_K$	$.86 \pm 0.15$	$.75 \pm .13$	$.75 \pm .13$
Output Quantity			
$\sin 2\beta$	$.70 \pm .10$	$.73 \pm .10$	$.72 \pm .10$
$\sin 2\alpha$	$-.50 \pm .32$		$-.28 \pm .40$
γ	$46.2^\circ \pm 9.1^\circ$	48.7 ± 8.5	52.3 ± 12.1
$\bar{\eta}$	$.30 \pm .05$	$.32 \pm .03$	$.33 \pm .05$
$\bar{\rho}$	$.25 \pm .07$		$.21 \pm .08$
$\lvert V_{td}/V_{ts}\rvert$	$.185 \pm .015$		$.193 \pm .020$
$\Delta m_{B_s}(ps^{-1})$	19.8 ± 3.5		
J_{CP}	$(2.55 \pm .35) \times 10^{-5}$		$(2.76 \pm .40) \times 10^{-5}$
$BR(K^+ \to \pi^+ \nu\bar{\nu})$	$(0.67 \pm 0.10) \times 10^{-10}$		$(0.71 \pm .13) \times 10^{-10}$
$BR(K_L \to \pi^0 \nu\bar{\nu})$	$(0.225 \pm 0.065) \times 10^{-10}$		$(.25 \pm .08) \times 10^{-10}$

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EXPECTED Improvements in CKM determinations From EXPT and from Lattice

EXPT: $B^{\pm} \to \tau \nu_\tau$

$\to \mu \nu_\mu \gamma$, $e \nu_e \gamma$

$B^0 \to \rho^0(\omega)\gamma$

$B \to X_d \gamma$

$B \to \pi(\rho) l \nu_l$ precise q^2 distribution

LATTICE

TECHNICAL ~~[illegible]~~ Chiral Sym on Lattice

Dynamical Simulations

HARDWARE SCIDAC [Scientific Discovery through Adv. Computing Initiative]

EXPECT ~ 20 increment in computer power by FALL 2004.

SHOULD ALLOW considerable reduction in systematic errors.

IMPORTANT INPUT from EXPT ON THE HORIZON

↳ to CKM Determinations

I $B^{\pm} \to \tau^{\pm} \nu_\tau (\bar{\nu}_\tau)$

← BY ADDING MILCE MCIS in quad.

$f_B = 203 \pm 34$ MeV ; $\frac{V_{ub}}{V_{cb}} = .085 \pm .017$
($\simeq 40$ MeV)

$\Rightarrow B(B \to \tau \nu_\tau) = (7.8 \pm 2.0) \times 10^{-5}$ *2

$\Sigma \tau \to \mu, e, \pi, \rho \Rightarrow 45\%$

With 10% efficiency $\Rightarrow$ 800 events in $10^8 B\bar{B}$'s.

~~BELLE/BABAR SHOULD BE ABLE TO DO THIS~~ *2

BTW a) Note $\mathcal{B}(B \to \mu \nu) \sim 3.3 \times 10^{-7}$ ↳ $B^{\pm} \to \tau^{\pm} \nu_\tau$

May Need SuperB

→ b) $f_{D_s}^{Expt} = 268 \pm 38$ MeV from ~~$D_s \to \mu\nu$ 6.1±1.9~~

PDG $\begin{cases} B(D_s \to \tau \nu) = (6.4 \pm 1.5)\% \\ (D_s \to \mu \nu) = (5.1 \pm 1.9) \times 10^{-3} \end{cases}$

$f_{D_s}^{lattice} = 241(5)\left(^{+27}_{-26}\right)\left(^{+9}_{-5}\right)\left(^{+5}_{-0}\right)$ MeV.

$\sim 241 \pm 30$ MeV

→

NOTE: IF $f_B^{lattice}$ ERROR COULD BE Reduced to $\lesssim 5\%$ then
$B \to \tau \nu_\tau$ gives a clean $\frac{|V_{ub}|}{|V_{cb}|} \Rightarrow \lambda [\rho^2 + \eta^2]^{1/2}$

B-Pseudoscalar Decay Const vs the Lattice (23-5)

$\langle B|\bar{b}\gamma_0\gamma_5 u|0\rangle = f_B m_B$

ANNUAL LATTICE SYMPOSIA---
EACH year a PLENARY SPEAKER SUMMARIZES PROGRESS (in f_B) using diff methods, various groups--

	f_B QUENCHED
SONI '95	173 ± 25 MeV
FLYNN '96	175 ± 25 "
ONOGI '97	163 ± 23 "
DRAPER '98	165 ± 20 "
HASHIMOTO '99	170 ± 20 "
BERNARD '00	175 ± 20 "
RYAN '01	173 ± 23 "
YAMADA '02	173 ± 23 "

MILC '02

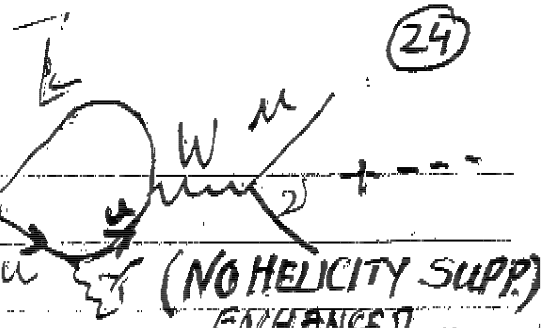
$$\frac{f_B^{m_f=3}}{f_B^{m_f=0}} = 1.23 \pm .04 \pm .06$$

$\Rightarrow$ UNQUENCHING HAS A RATHER LARGE CORRECTION.

(20)

(24)

II $B(B \to \mu\nu\gamma)$



(NO HELICITY SUPP.)
ENHANCED
BUT NOT VERY "CLEAN"

Method	Ref.	Br
CQM	ATWOOD+EILAM+A-S (96)	$\sim 5.2\times10^{-6}$
LC+HQET	KORCHEMSKY, PIROL+YAN (100)	$\sim (5.2\pm2.2)\times10^{-6}$
Light-Front	Geu, Lih+Zhang ('98)	$\sim 3.7\times10^{-6}$
Rel Pot'l	COLANGELO, de FAZIO+NARDULLI '96	$\sim 1\times10^{-6}$
SCET	Lunghi, Pirjol+Wyler '02	
QCDF	DESCOTES—Genon+ SACHRAJDA } 102	$\sim 3\times10^{-6}$

EXPECTED BR $\sim (4\pm1.5)\times10^{-6} \propto \frac{Q^2}{\lambda_B}$

HARD PHOTON SPECTRUM

e.g. $\frac{dN}{d\lambda_\gamma} = \frac{m_B}{\Gamma}\frac{d\Gamma_{l\nu\gamma}}{dE_\gamma} = 24\,\lambda_\gamma(1-2\lambda_\gamma)$

in the NAIVE QM

$\lambda_\gamma = E_\gamma/m_B$

ANOTHER IMPORTANT INPUT ON THE HORIZON IS

Measurement of $B^0 \to \rho^0 + \gamma$

$$\frac{BR(B^0 \to \rho^0 \gamma)}{BR(B \to K^* \gamma)} = \left[\frac{1 - m_\rho^2/m_B^2}{1 - m_{K^*}^2/m_B^2}\right]\left[\frac{T_1^{B\to\rho}(0)}{T_1^{B\to K^*}(0)}\right]^2 \frac{|V_{td}|^2}{|V_{ts}|^2}$$

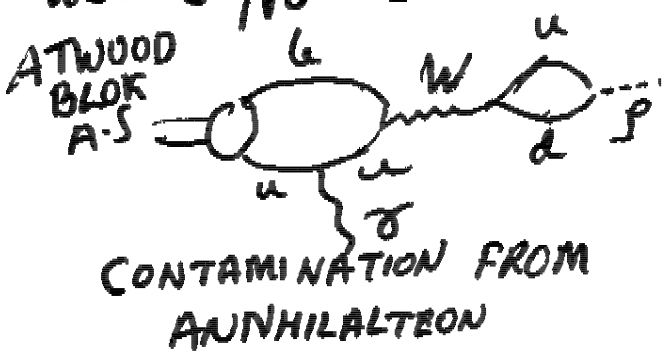
BECIREVIC et al (SPQCDR) BLUM + A.S $\Rightarrow$ SU(3) breaking from Lattice

$\Rightarrow$ EXPECTED $BR(B^0 \to \rho^0 \gamma) \sim 1.5 \times 10^{-6}$

$\Rightarrow$ FOR $B \to \rho\gamma$ SHOULD ONLY USE B^0 NOT $B^\pm$

$(B^0, B^\pm \to K^* \gamma$ is OK)

ANNIHILATION IS Cabibbo Suppressed.



$\Rightarrow$ The SU(3) breaking here $\left[\frac{T_1^{B\to\rho}(0)}{T_1^{B\to K^*}(0)}\right]$ has some advantages [esp. renorm. & op.] & some not [Needs large Recoil] Compared to

{ That controls X_s/X_d

Picture

Following BHS PRL 94

$$H_{eff} = G_{g_1 g_2 g_3}(m_t, \mu)\, V_{tb}^* V_{ts}\, \bar{s}\, \sigma_{\mu\nu} b_R(x)\, F^{\mu\nu}(x)$$

$$M_\mu = \langle V(k) | J_\mu | B(p) \rangle, \quad J_\mu \equiv \bar{s}\, \sigma_{\mu\nu} q_\nu b_R = (v + a)_\mu$$

$$= 2\epsilon_{\mu\nu\lambda\sigma}\, \eta^\nu(k)\, p^\lambda k^\sigma\, T_1(q^2) + \Big[\eta_\mu(k)(m_H^2 - m_V^2)$$

$$- \eta\cdot q\,(p+k)_\mu\Big] T_2(q^2) + \eta\cdot q\left[q_\mu - \frac{q^2}{m_H^2 - m_V^2}(p+k)_\mu\right] T_3(q^2)$$

$$\sigma_{\mu\nu}\gamma_5 \equiv -\frac{1}{2}\epsilon_{\mu\nu\lambda\rho}\,\sigma^{\lambda\rho} \Rightarrow T_2(0) = T_1(0)$$

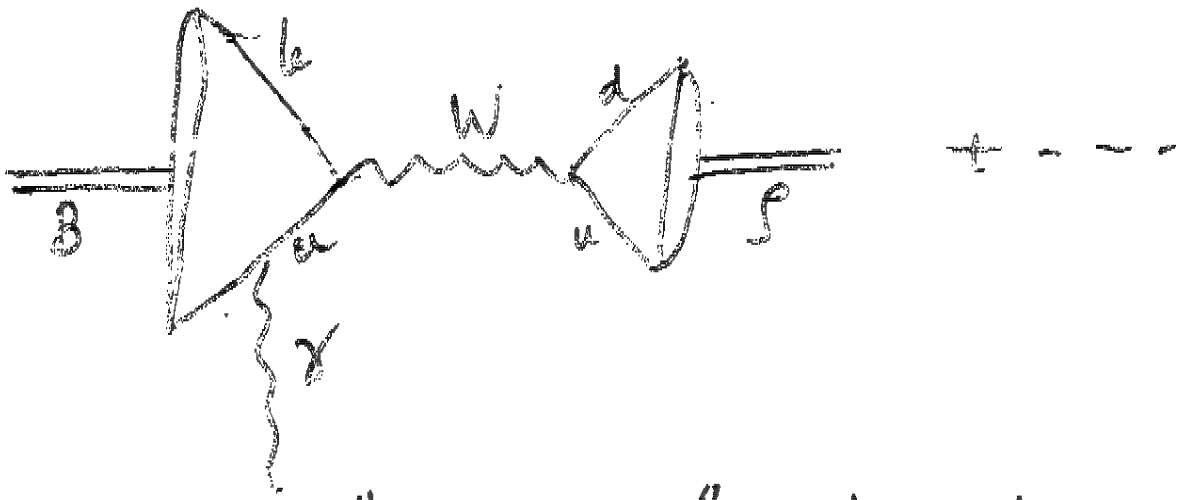
HADRONIZATION RATIO

$$R_{K^*} \equiv \frac{\Gamma(B \to K^* \rho)}{\Gamma(b \to s\gamma)}$$

$$= 4\left(\frac{m_B}{m_b}\right)^3 \left[1 - \frac{m_{K^*}^2}{m_B^2}\right] |T_1(0)|^2$$

$$C_{K^*\rho} \equiv \frac{1 - m_\rho^2/m_B^2}{1 - m_{K^*}^2/m_B^2}$$

Enhanced Annihilation to $B^{\pm} \to \rho^{\pm}\gamma$



Source for "Long-distance" enhanced contribution ... Amp $\propto \frac{1}{m_u}$ × constituent

Atwood + Blok + AS

Can be a 10–20% contribution to

$B^{\pm} \to \rho^{\pm}\gamma$ i.e. exists even if $V_{td} = 0$

It is useful to separate charged and neutral B decays to $\rho^{\pm}\gamma$, $\rho^{0}\gamma$, $\omega\gamma$

(THIS IS NOT needed for $K^{*}\gamma$)

$B^0 \to X_d \gamma$

Experimentally more difficult than excl. $\rho\gamma$, $\omega\gamma$ ...
Theory is a lot better [Dont NEED non-perturbative hadronic matrix elements]

In principle gives $\frac{|V_{td}|}{|V_{ts}|}$ very cleanly:

$$\frac{|V_{td}|}{|V_{ts}|} = \left[\frac{Br(B^0 \to X_d \gamma)}{Br(B \to X_s \gamma)}\right]^{1/2}$$

A possible handle on $B \to X_d \gamma$

Use a multiplicity cut on X_d (say $\lesssim 5$)

Should be able to correct for this cut by using $B \to X_s \gamma$

Precise determination of $B \to X_d \gamma$ MAY BE feasible at a Super-B → $(\rho,\omega)\gamma$

$B \to \pi(\rho)\, l\, \nu_l$

Experimental knowledge of the precise form of the q^2 ($p_l + p_\nu \equiv q$) distribution would be very helpful (to lattice studies of formfactor)

$\Rightarrow$ further reduce errors on V_{ub}.

For $B \to \pi$ (setting $m_l = 0$)

$$\frac{d\Gamma}{dq^2} = G_F^2 \frac{|V_{ub}|^2}{192\pi^3} \lambda^{3/2} |f_+(q^2)|^2$$

$$\lambda \equiv [m_B^2 - m_\pi^2 - q^2]^2 - 4 m_\pi^2 q^2$$

Then Need from the lattice precise value of $f_+(q^2)$ at a fixed q^2 $\Rightarrow$ V_{ub}

//ly $B \to \rho\, l\, \nu_l$

End point region is especially interesting ($q^2 \simeq q^2_{max}$)

$$\frac{d\Gamma}{dq^2} \xrightarrow[q^2 \to q^2_{max}]{} \frac{G_F^2 |V_{ub}|^2 \lambda^{1/2}}{64\pi^3} q^2 (m_B + m_\rho)^2 |A_1(q^2)|^2$$

$\Uparrow$ Need only 1 form factor

Bernard + Elkhadrat AS LAT '91

Refined Lattice Calc + High Statistics q^2 spectrum

$\Rightarrow$ Nail V_{ub} more precisely.

PACE of PROGRESS of INPUT

16
17
30

	OLD FIT LATTICE '95	NEW FIT BCP4 Feb'01
$\frac{V_{ub}}{V_{cb}}$	$\cdot 08 \pm \cdot 02$	$\cdot 085 \pm \cdot 017$
V_{cb}	$\cdot 04 \pm \cdot 005$	$\cdot 04 \pm \cdot 002$
$f_{B_d}\sqrt{\hat{B}_{B_d}}$ MeV (LATTICE INPUTS)	237 ± 65	230 ± 50
ξ (LATTICE INPUTS)	$1 \cdot 16 \pm \cdot 10$	$1 \cdot 20 \pm \cdot 10$
$\hat{B}_K$ (LATTICE INPUTS)	$\cdot 85 \pm \cdot 21$	$\cdot 86 \pm \cdot 15$
$\sin 2\beta$ (OUTPUTS)	$\cdot 59 \pm \cdot 20$	$\cdot 70 \pm \cdot 10$
η (OUTPUTS)	$\cdot 32 \pm \cdot 10$	$\cdot 30 \pm \cdot 05$
$\frac{V_{td}}{V_{ts}}$ (OUTPUTS)	$\cdot 22 \pm \cdot 05$	$\cdot 185 \pm \cdot 015$

PACE of PROGRESS IN LATTICE INPUT HAS BEEN VERY SLOW (IN COMPARISON TO EXPT... See Later)
EXPECTED TO PICK UP.

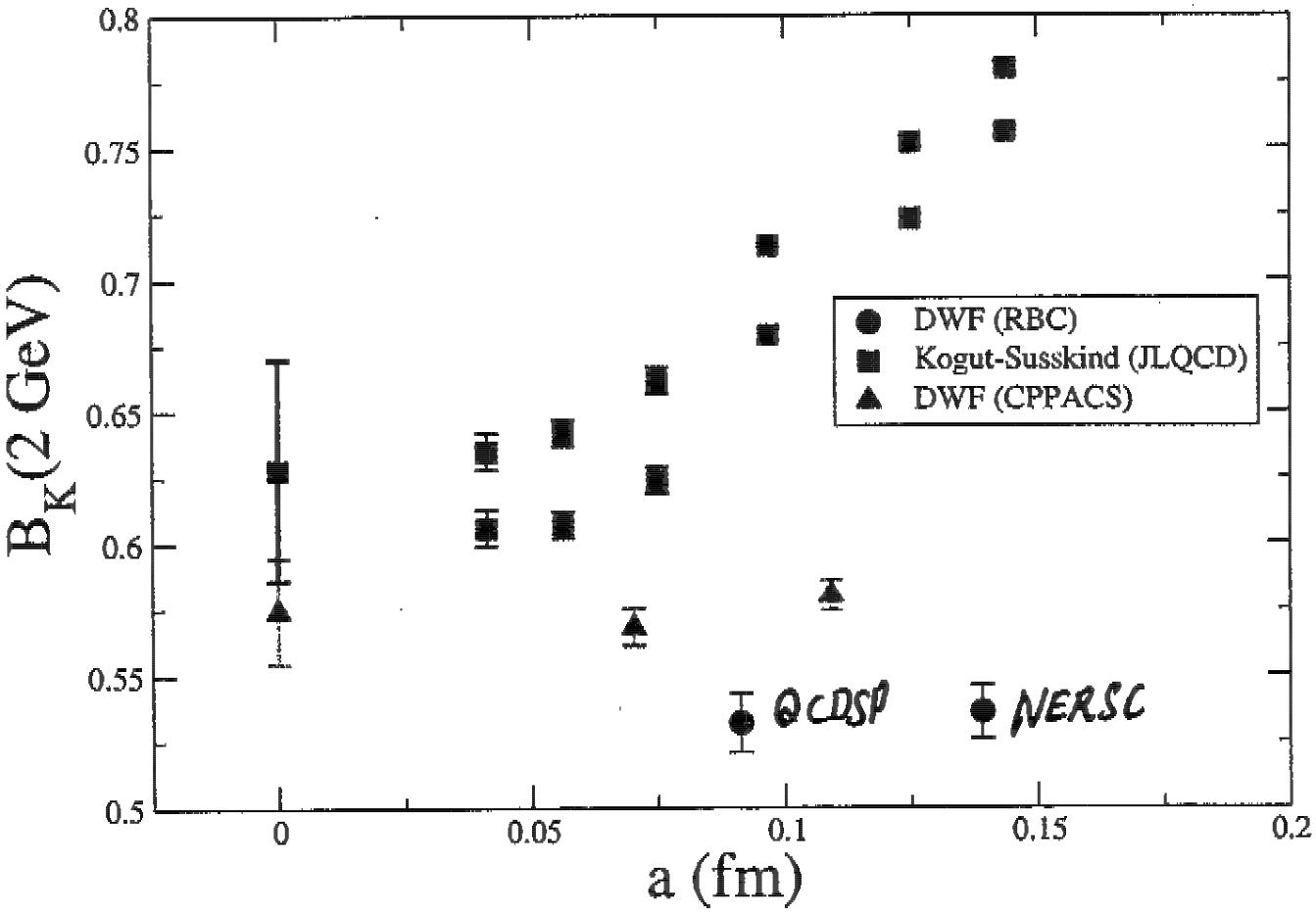
Expected Improvements from Lattice & phenomenology.

	Now	Futuristic (a few years)	
$f_B\sqrt{B_B}$	± 50 MeV	± 20 ?	Inputs
ξ	± .10	± .03	
B_K	± .15	± .05	
V_{cb}	± .02	± .01	
$\frac{V_{ub}}{V_{cb}}$	± .017	± .006	
$\sin 2\phi_1$	± .10	± .03	outputs.
ϕ_3	± 10°	± 4°	

The kaon B parameter B_K

$\overline{MS}$ scheme, $\mu \approx 2$ GeV

Leading error is a^2 in each case



(JLQCD: S. Aoki, *et al.*, PRL 80 (1998); CP-PACS: Ali-Khan, *et al.*, PRD 64, 114506; RBC Collaboration: T. Blum *et al.*, hep-lat/0110075 (2001).)

EXPERIMENTAL Progress on $\sin 2\beta$

SUMMER '02

		$\sin 2\beta$
BELLE	($\sim 85 \times 10^6$ $B\bar{B}$)	$.719 \pm .074 \pm .035$
BABAR	($\sim 88 \times 10^6$ $B\bar{B}$)	$.741 \pm .067 \pm .035$

WORLD AVERAGE (INC. CDF & LEP)

$\sim$ MAR '01	$.48 \pm .16$
$\sim$ MAR '02	$.79 \pm .10$
$\sim$ July '02	$.734 \pm .054$ $\Leftarrow$

Super B EXPECTATIONS

$\sin 2\beta$ $\pm .01$

(INTRINSIC Theory error $\lesssim 1\%$)

Just improving $\sin 2\beta$ is unlikely to be enough, MUST TARGET Precise Extraction of α & γ as well.

ϕ_2 ϕ_3

PRISTINE EXTRACTION of $\mathcal{U}\Delta \Rightarrow$ GOLD PLATED

↓

Meaning No input from Theory

↑

TESTS OF the SM

(a la $\sin 2\phi_1$ from $B \to \psi K_S$ or better)

Determination of ϕ_3 via $B \to K D^0$ (35)

ATWOOD+AS hep-ph/0208091
02/2071

BUILD ON EARLIER WORKS OF
GRONAU, LONDON, WYLER, SONDA, BRANCO, LAVOURA,
ALEKSAN, SILVA, KAISER, ATWOOD, DUNIETZ, SONI
ALSO Related WORKS SILVA, SOFFER
LONDON, SINHA, SINHA
GRASSMAN, LIGETTI, SOFFER
ALEKSAN, PETERSEN, SOFFER

IN CHARGED AND NEUTRAL B DECAYS FINAL STATES CONTAINING $D^0(\bar{D}^0)$ HOLD THE KEY.

γ VIA $B^\pm \to K^\pm$ [$D^0, \bar{D}^0$] ← D/R CP
COMMON FS of $D^0, \bar{D}^0$
β-α, β VIA $B^0, \bar{B}^0 \to K^0$ [$D^0, \bar{D}^0$] ← TD CP

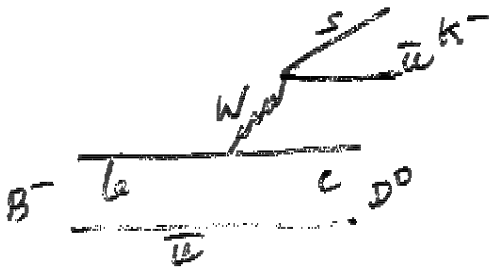
($K^\pm$, K^0 above are examples) TREE GRAPHS

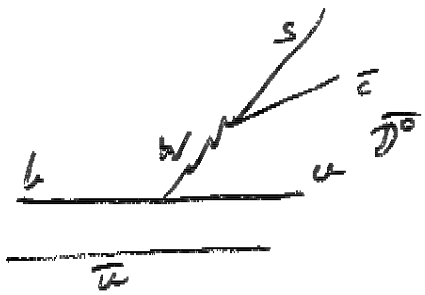
1. BASIC FORMALISM
2. PLETHORA OF FS
3. CHALLENGE & PROMISE OF K_L
4. POSSIBLE ROLE of CLEO-C

BEST WAY to Search May be Via Monochromatic $K^\pm, K^0, \bar{K}^0(\pi)$
with $E_K \sim \frac{m_B^2 + m_{K(\pi)}^2 - m_D^2}{2m_B}$ ≈ 2.1 ± ... GeV

SIMPLE EXAMPLES

$B^\pm \to K^\pm \mathcal{D}, \overline{D^0}$

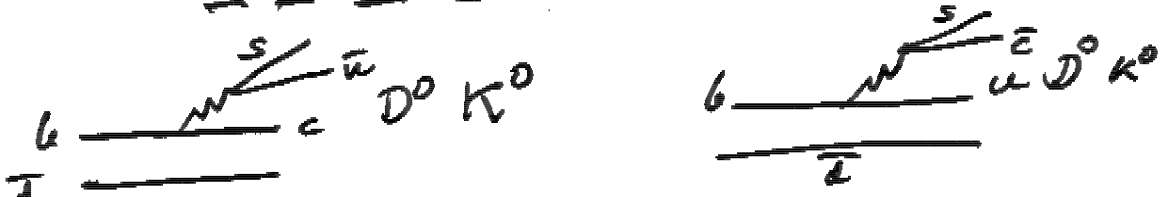




DIRECT CP

INTERFERENCE $\sim \frac{V_{ub}}{V_{cb} V_{us}} \frac{1}{N_c} \sim O(10\%)$ ASYMMETRY

CAN GIVE σ (ϕ_3)



Time Dep. CP

Interference $\sim \frac{V_{ub}}{V_{cb} V_{us}} \sim O(30\%)$

CAN GIVE $\delta \equiv \beta - \alpha + \pi = 2\beta + \sigma$ AND β

GRONAU - LONDON - WYLER CONSTRUCTION

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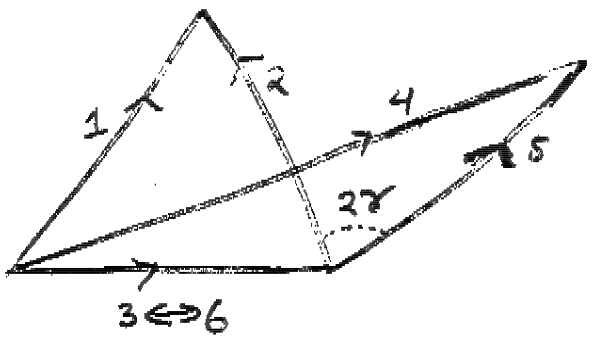
γ Can be extracted from the following 6 measurements (2 are equal)

1. $A(B^+ \to D^0_{CP} K^+)$
2. $A(B^+ \to D^0 K^+)$
3. $A(B^+ \to \bar{D}^0 K^+)$
4. $A(B^- \to D^0_{CP} K^-)$
5. $A(B^- \to \bar{D}^0 K^-)$
6. $A(B^- \to D^0 K^-)$

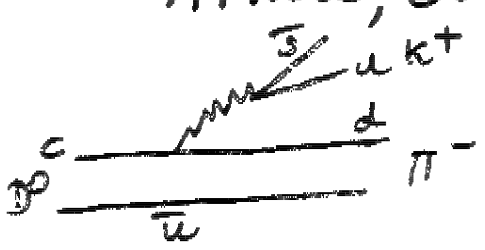


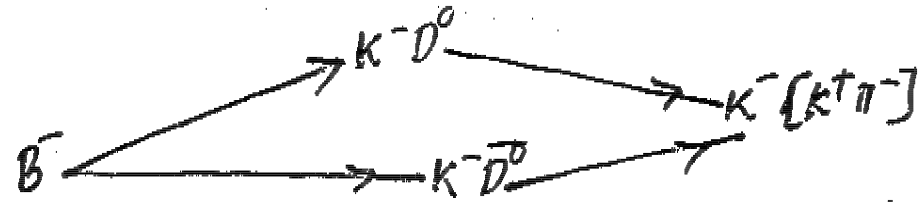
$\bar{D}^0$ in

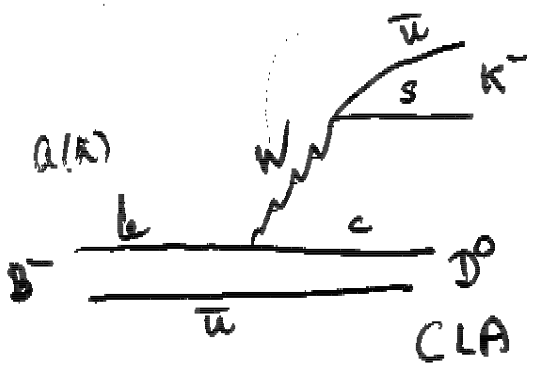
FLAVOR TAGGING of $B^- \to K^- \bar{D}^0$ difficult.

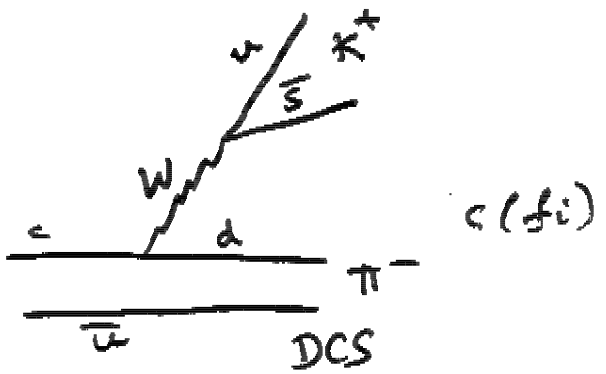
1. S.l. tag has serious BG from prompt sl B^- decay
2. Had tag receives contamination from doubly Cabibbo suppressed D decays.

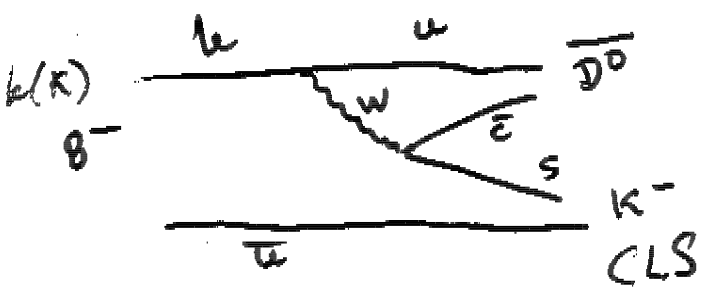
THIS IS TURNED INTO A VIRTUE BY ATWOOD, DUNIETZ, A.S.

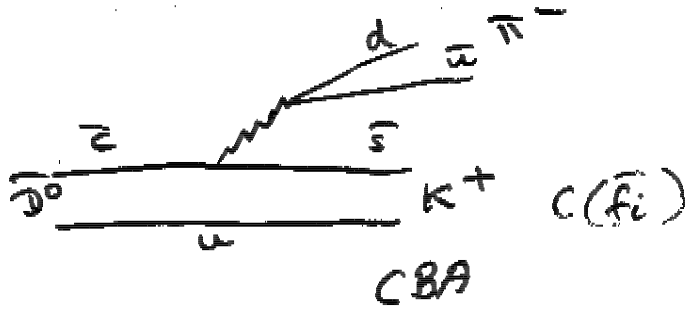












BASIC Eqns $i = 1, 2$ 4 Eqns

$$d(K, f_i) = a(K)\,C(f_i) + b(K)\,C(\bar{f}_i) + 2\sqrt{ab\,c\bar{c}}\,\cos(\xi^K_{f_i} + \gamma)$$

$$\bar{d}(K, f_i) = a(K)\,C(f_i) + b(K)\,C(\bar{f}_i) + 2\sqrt{ab\,c\bar{c}}\,\cos(\xi^K_{f_i} - \gamma)$$

$\xi^K_{f_1}, \xi^K_{f_2}$, $b(K)$, γ ← gem 4 unknowns

strong phases ↳ "unmeasurable" BR

[NOTE In SM $a(K) \equiv B(\bar{B}^0 \to K^- D^0) = \bar{a}(K) \equiv B(B^+ \to K^+ \bar{D}^0)$

$\Rightarrow\Rightarrow$ $\bar{b}(K) = b(K)$

ALSO $\bar{c}(f_i) = c(f_i)$ and $\bar{c}(\bar{f}_i) = c(\bar{f}_i)$]

Interference

$CLA * DCS \Leftrightarrow CLS * CBA$

$$\frac{V_{ub}}{N_C}\frac{1}{V_{cb}V_{cd}V_{us}} \sim \frac{.085}{3*.2*.2} \sim 70\%$$

LARGISH ASYM

but "needs" DCSD

MINIMUM NEED

BR $B^- \to K^- \bar{D}^0$ ↑

4 Unknowns 2 Strong phases, $k(\kappa)$, γ

2 Common decay modes of D^0, $\overline{D^0}$

EXAMPLES 1. $K^+\pi^-$
$K^{+*}\pi^-$

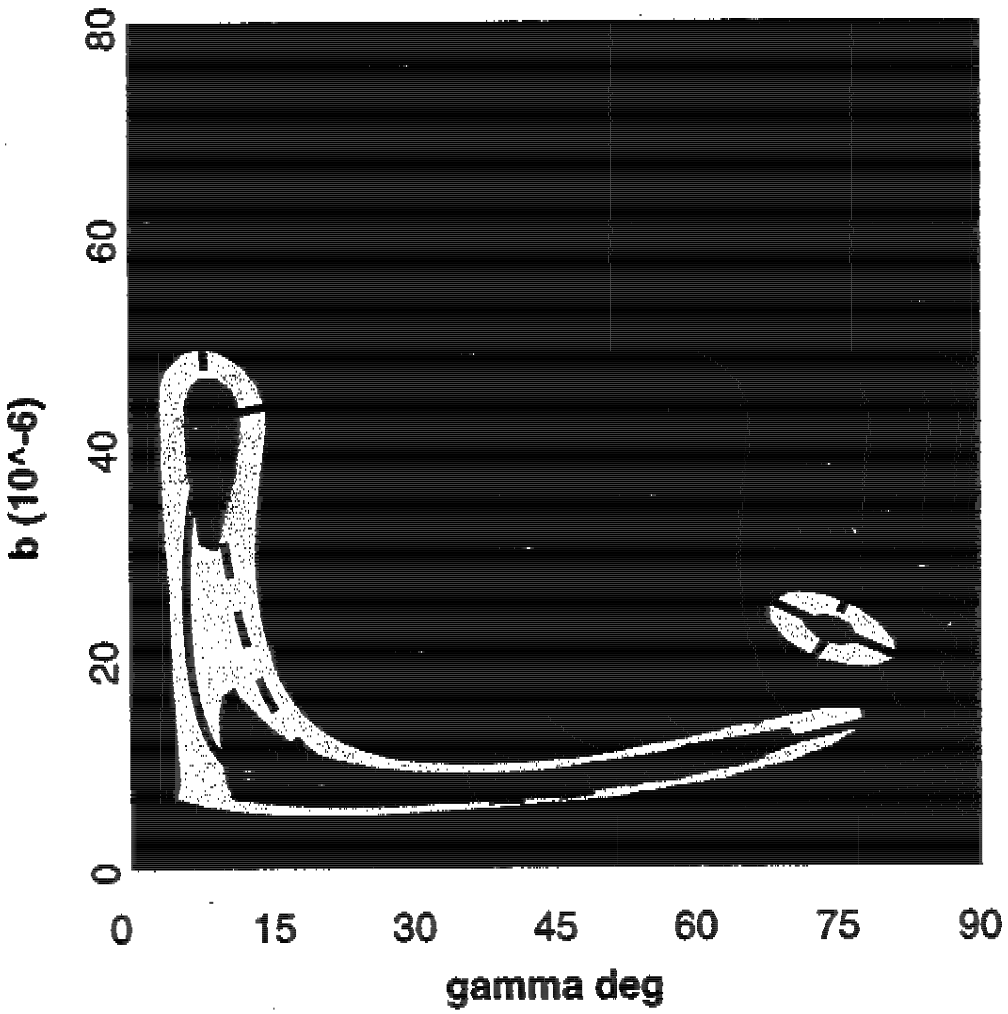
2. $K^+\pi^-$ & $K_S\pi^0$

OR

IMPT. PT. ONLY 1 CPNES suffices, others can be CPES

- Just two modes used:
  - $K^+\pi^-$ (solid)
  - $K_s\pi^0$ (short dashes)
- Confidence regions assuming that $N_B(acceptance) = 10^8$:
  90%; 68%

↳ detection eff left out



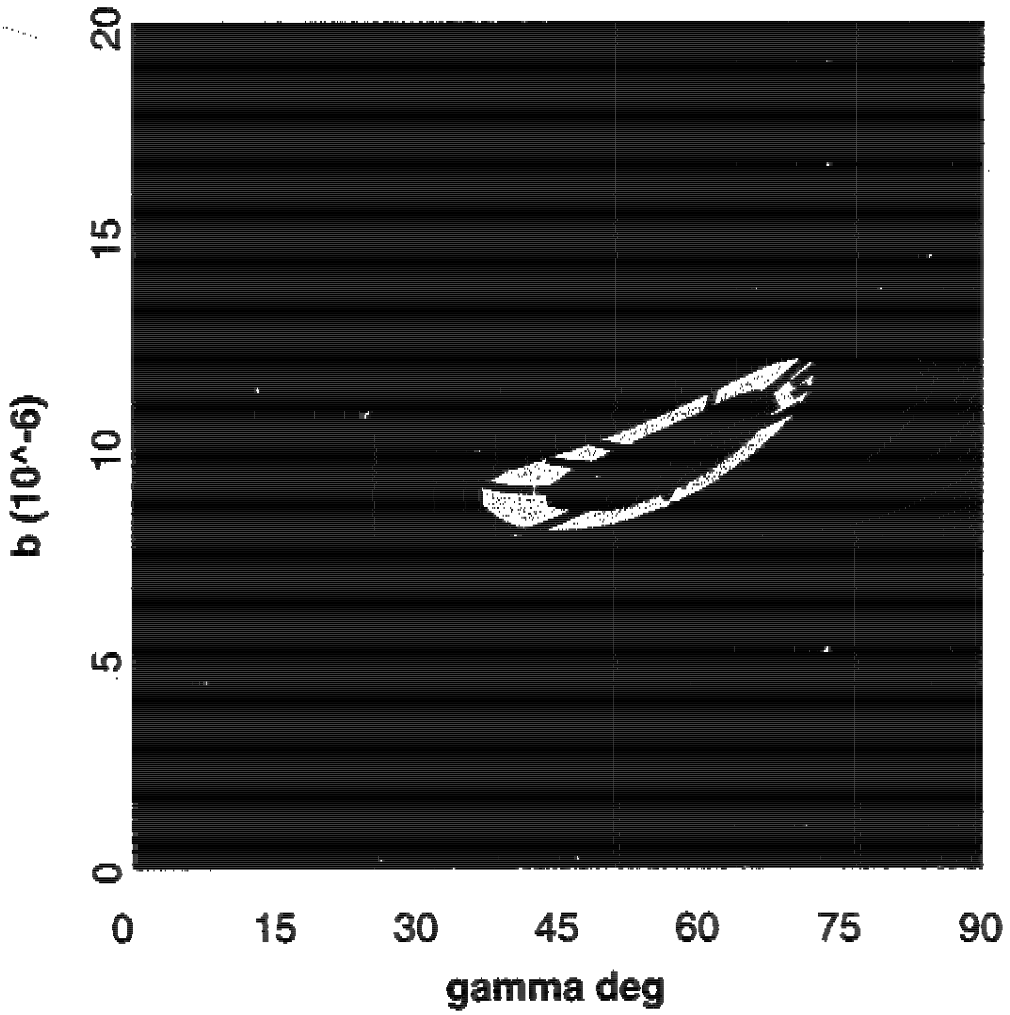
- ~~All the~~ MANY modes used:

ADS 41 PRD00

- $K^+\pi^-$ (solid) $K_s\pi^0$ (short dashes)
  $K^+\rho^-$ (long dashes) $K^+a_1^-$ (dash-dot)
  $K_s\rho^0$ (dash-dot-dot) $K^{*+}\pi^-$ (dash-dash-dot)

- Confidence regions assuming that $N_B(acceptance) = 10^8$:
  90%;

ONLY 2 CPES MODES included
If All then ÷3



$\sim (1-5)\times 10^8\, B\bar{B} \Rightarrow \phi_3 \equiv \gamma \sim 60^\circ \pm 12^\circ$

$\sim (1-5)\times 10^{10}\, B\bar{B} \Rightarrow \simeq \pm 1\text{-}2^\circ$

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BR CP

CPNES of D^0

- DCS (e.g. $K^+\pi^-$) — small LARGE
- Singly Cabibbo Supp K^+K^- — large SMALL
  SCS
  GROSSMAN, LIGETI, Soffer

SCCS Interference

$\frac{V_{cb}V_{us}}{V_{us}V_{cb}} \sim \frac{\cdot 085}{}$ ⇒ small CP

In practice its probably best to combine info from CPNES (DCSD, SCS) + CPES

Some of the Relevant Modes of $D^0, \bar{D}^0$

(93)

~~CP~~

1. CPES [CBA/SCBS] {e.g. $K_S\pi^0$, $K_S\eta$, $K_S\eta'$, $K_S\omega$, $K_S\rho^0$, $\pi^+\pi^-$, K^+K^- ...] $\lesssim 10\%$
   $Z \sim 5\%$

2. CPNES [SCBS] e.g. $\underbrace{K^+K^{*-}, \pi^+\rho^-, \pi^+a_1^-}_{\sim 1\%}$ ... $\lesssim 10\%$

3. CPNES [DCBS] $\lesssim 70\%$
   e.g $\underbrace{K^+(K^{+*})\{\pi^-, \rho^-, a_1^-\}}_{\sim 30\%}$

THIS LARGE ~~CP~~ in these modes should be observable $\sim 10^8$ B's and makes these modes very attractive even if in the absence of accurate knowledge of DCSD Br, precise extraction of γ will be difficult to start.

Many DCSD BR are predictable to accuracy $\lesssim 20$-30%.
[THIS IS ONLY A TEMPRORY STRATEGY]

POSSIBLE STRATEGY FOR EARLY (i.e. somewhat crude) determination of $\phi_3 \equiv \gamma$ (4)

TEMPRORARILY USE some input from theory

From theory take DCS Br. For the relevant modes the theory error $\lesssim 30\%$
(THEORY is much better here than in Col Supp Modes)

For Modes with Large CP asym $\gtrsim 20\%$,
eff. Br $\sim (2-5)\times 10^{-7}$

will need $\sim \frac{3^2}{(2-5)\times 10^{-7} \times (.5)^2 \times \eta_{eff}} \sim \frac{(.7-1.8)\times 10^8}{\frac{B\bar{B}}{\eta_{eff}}}$

(Br, CP Asy, eff)

$\Rightarrow (1-5)\times 10^8\ B\bar{B}$

Likely to work best to combine info from CPES, CPNES [SCS and DCS] of $D^0, \bar{D}^0$

And also include $B^- \to K^-(K^{*-})\, D^0/\bar{D}^0$

RECALL e.g. 1 CPNES MODE of D^0 + 1 CPES CAN DO.
LARGE Asy

$B^0 \to K^0 D^0, \bar{D}^0 \ldots$

Time Dependent CP to extract $\delta \equiv \beta - \alpha + \pi$
$= 2\beta + \gamma$

Gronau + London '91; Branco, Lavoura, Silva '99; Sanda '02
[Rely on Fl tag of $D^0, \bar{D}^0$]

KAYSER + London [use common CPNES of $D^0, \bar{D}^0$ a la ADS] '01

Atwood + Soni hep-ph/0206045
[CPNES, CPES ....]

	CP Asym	
CPNES	$\sim 35\%$	DISCRETE AMBIGUITIES SUFFERS (esp. if only 1 mode)
CPES	$\sim 75\%$	VERY effective in getting rid of them.

TDCP in B^0 need Larger # of B's compared to $B^\pm$

$\sim O(10^9)$ $\longleftrightarrow$ $\sim O(10^8)$

$\Uparrow$

But should be compared to $B^0 \to \rho\pi, \pi\pi$

Charm Factory can help both.

NOTE : CLEO-C CAN PLAY 46 27
A CRUCIAL ROLE IN
DETERMINING r_D & η_D ↑ strong phase

Formalism

[Use Wolfenstein representation for the CKM matrix]

For each f_i the four relevant amplitudes are:

$$\begin{aligned}
\mathcal{A}_1(f_i) &\equiv \mathcal{A}(\bar{B}^0 \to K_S[D^0 \to f_i]) = A \\
\mathcal{A}_2(f_i) &\equiv \mathcal{A}(B^0 \to K_S[\bar{D}^0 \to f_i]) = A r_D e^{+i\eta_D} \\
\mathcal{A}_3(f_i) &\equiv \mathcal{A}(\bar{B}^0 \to K_S[\bar{D}^0 \to f_i]) = A r_D r_B e^{+i(\eta_D+\eta_B-\gamma)} \\
\mathcal{A}_4(f_i) &\equiv \mathcal{A}(B^0 \to K_S[D^0 \to f_i]) = A r_B e^{+i(\eta_B+\gamma)} \qquad (1)
\end{aligned}$$

where, without loss of generality, we can choose the strong phase convention so that $\mathcal{A}_1 = A$ is real. The quantity r_D is the ratio $\left|\mathcal{A}(\bar{D}^0 \to f_i)/\mathcal{A}(D^0 \to f_i)\right|$ which we will assume is known from the study of D^0 decay. The strong phase $\eta_D(f_i) = arg\left(\mathcal{A}(\bar{D}^0 \to f_i)/\mathcal{A}(D^0 \to f_i)\right)$ we will assume to be not known apriori. Likewise the parameter r_B and the strong phase η_B given by

$r_B e^{i\eta_B} = e^{-i\gamma}\mathcal{A}(B^0 \to K_S D^0)/\mathcal{A}(\bar{B}^0 \to K_S D^0)$ are also assumed to be not known apriori. Note that $\{r_D,\, \eta_D,\, A\}$ depend on the state f_i while $\{r_B,\, \eta_B\}$ are independent.

The time dependent decay rates for this decay is:

$$2\Gamma(B^0/\bar{B}^0(t) \to K_S F) = e^{-|\tau|}\left[X(F) + bY(F)\cos(x_B\tau) - bZ(F)\sin(x_B\tau)\right]$$

where $F \equiv \{f_i\}$ and in general $F \neq \bar{F}$, $\tau = \Gamma_B t$ and $x_B = \Delta m_B/\Gamma_B$ while $b = +1$ for $B(t)$ and $b = -1$ for $\bar{B}(t)$. Defining $\mathcal{A}(f_i) = \mathcal{A}_2(f_i) + \mathcal{A}_4(f_i)$ and $\bar{\mathcal{A}}(f_i) = \mathcal{A}_1(f_i) + \mathcal{A}_3(f_i)$, the coefficients X, Y and Z in Eqn. (2) are given by:

F/T to the above eqn to extract observables X, Y, Z

$$2X(F) = \sum_i (|\mathcal{A}(f_i)|^2 + |\bar{\mathcal{A}}(f_i)|^2) \qquad (2)$$

$$2Y(F) = \sum_i (|\mathcal{A}(f_i)|^2 - |\bar{\mathcal{A}}(f_i)|^2) \qquad (3)$$

$$Z(F) = \sum_i Im(e^{-2i\beta}\mathcal{A}(f_i)^*\bar{\mathcal{A}}(f_i)) \qquad (4)$$

We can expand these quantities in terms of eqn. (1) and obtain

$$\begin{aligned} X(F) &= \big((1+\hat{r}_D^2)(1+r_B^2)/2 \\ &+ 2R_F r_B \hat{r}_D \cos(\hat{\eta}_D - \gamma)\cos\eta_B\big)\hat{A}^2 \\ Y(F) &= -\big((1-\hat{r}_D^2)(1-r_B^2)/2 \end{aligned} \qquad (5)$$

$$
\begin{aligned}
& - \quad 2R_F r_B \hat{r}_D \sin(\hat{\eta}_D - \gamma) \sin\eta_B \big) \hat{A}^2 \\
Z(F) \quad &= \quad \big(R_F r_B^2 \hat{r}_D \sin(2\alpha + \hat{\eta}_D) - R_F \hat{r}_D \sin(2\beta + \hat{\eta}_D) \\
& + \quad \hat{r}_D^2 r_B \sin(\eta_B - \delta) - r_B \sin(\eta_B + \delta) \big) \hat{A}^2 \qquad (6)
\end{aligned}
$$

where $\hat{A}^2 = \sum_i A^2(f_i)$,
$\hat{r}_D^2 = (\sum_i A^2(f_i) r_D^2(f_i))/\hat{A}^2$ and
$R_F e^{i\hat{\eta}_D} = (\sum_i A(f_i) r_D(f_i) e^{i\eta_D(f_i)})/(\hat{A}\hat{r}_D)$.

The corresponding quantities for $\bar{F}$ are given by $X(\bar{F})\ (\eta_B, \eta_D, \gamma) = X(F)(-\eta_B, -\eta_D, \gamma)$; $Y(\bar{F})(\eta_B, \eta_D, \gamma) = -Y(F)(-\eta_B, -\eta_D, \gamma)$ and $Z(\bar{F})(\eta_B, \eta_D, \gamma) = Z(F)(-\eta_B, -\eta_D, \gamma)$ assuming that there is no additional CP violation in D^0 (as well as in K^0) decay.

50 46

Time Dep. CP # of OBSERVABLES ⟷ # of Parameters.

	# OBS	# PARAM w.r.t ph.
e.g. $B^0 \to K_S D^0$ ↳$K^+\pi^-$ CPNES	6	5 $\{A, r_B, \eta_B, \boxed{\delta}, \eta_D\}$
I CPES $B^0 \to K_S D^0$ ↳$K_S\pi^0$	3	4 [SAME AS ABOVE]
I + II	9	5

[Addition of CPES helps significantly to reduce disc. ambig.]

III Add 1 More CPNES e.g. $K^{*+}\pi^-$	6	+1 (r_D')
I + II + III	15	6

Redundacy is extremely helpful.

K_L Detection Can Help

SIMPLE ILLUSTRATIVE EXAMPLE

	# of obs.	# of Param.	
$B^0 \to K_S D^0 \hookrightarrow K_S \eta'$	3	4	BY itself Not enough
EITHER $B^0 \to K_L D^0 \hookrightarrow K_S \eta'$ OR $B^0 \to K_S D^0 \hookrightarrow K_L \eta'$	2 New	0 (ie same 4)	
	5	4	Sufficient info

$\Rightarrow K_L$ Not essential (ie can do also with say CP NES $K^+\pi^-$ or $\pi^+\pi^-$) But Desirable

$\Rightarrow$ More Powerful than in $B^0 \to \psi K_L$

PROMISING IDEAS

(a) $B^0 \to K_L D^0 \hookrightarrow K^+\pi^-$ (e.g.) $\hookrightarrow K_S\omega, K_S\eta'$? } Analogous to $B^0 \to K_L \psi \hookrightarrow e^+e^-$

(b) $B^0 \to K_S D^0 \hookrightarrow K_L + \eta'$ $K_L + \omega$??

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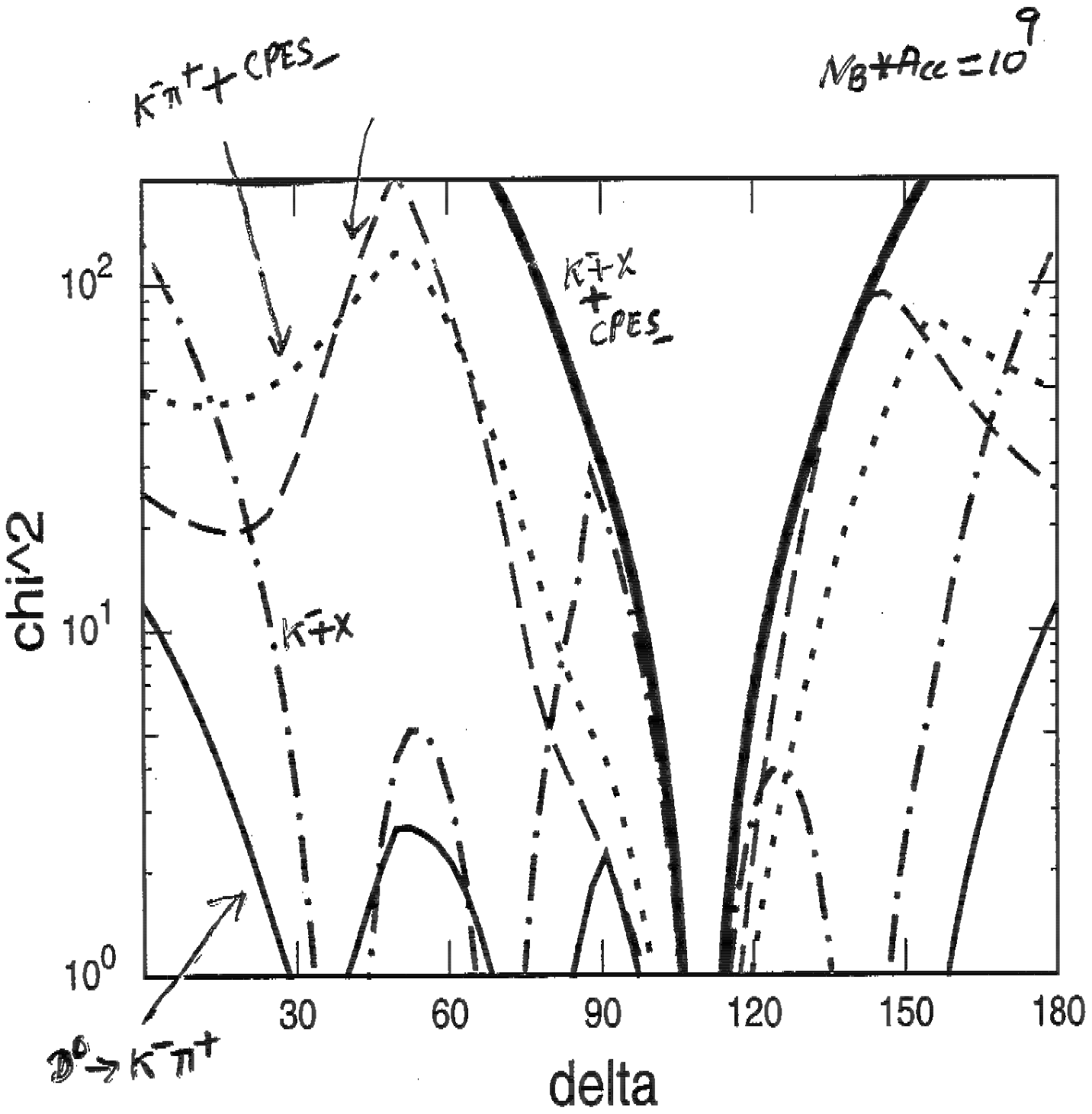


INCLUSIVE D^0 decays ($D^0 \to K^- + X$) require Charm factory input.

(53)

ILLUSTRATIVE RESULTS from Toy model

Atwood+ A.S.
hep-ph/0206045

N_B (€ Acceptance) $= 10^9$; 1σ Accuracy on δ

$\delta \equiv (\phi_1 - \phi_2 + \pi) \equiv (\beta - \alpha + \pi)$

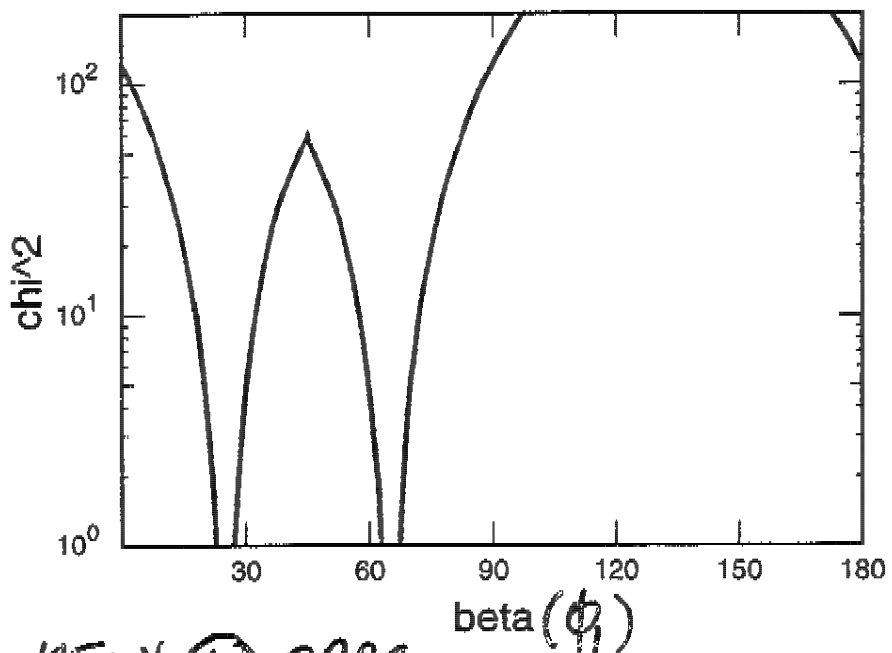
	INPUT	Accuracy
1.	CP−FS with K_S and CP+ with $\pi^+\pi^-$, $K_S f_0$, K^+K^+	$\pm 18.2^\circ$
2.	CPNES with $K^-\pi^+$ + CPES (with K_S)	$\pm 9.0^\circ$
3.	K^-+X + CPES (with K_S)	± 2.5

(True value of $\delta = 110^\circ$)

⇒ SUPER B should be able to get this error to $\sim 1-2^\circ$

(24) +17

(4) β DETERMINATION with $B^0 \to D^0 K^0$ $\hat{N}_B = 10^9$



INPUT: $K^- + X$ ⊕ CPES

(15) ERROR ON $(\phi)\beta \sim 2^0$ ***

PROVIDES AN EXTREMELY IMP. CHECK of β from $B \to \psi K_S$

⇒ CRUCIAL TEST OF CKM PARADIGM

In this method THEORY ERROR on β is ALSO VERY small (as in the $B \to \psi K_S^0$ method)

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Methods for Extracting the UT with Zero Theory Error

gle	Mode(s)	Original Ref.	Type of CP	Pollution QCDP	Pollution EWP	Limiting Theory Error	# of B's Needed $/10^8$
)	$B \to \psi K^0$	Bigi + Sanda	time dep.	$\sim$ 1–2%	$\sim$ 1%	~~$\sim$ 1%~~	0.5–5
)	$K^{\pm} D^0_{\downarrow}(\bar{D}^0_{\downarrow})$ $K^+\pi^-$	Atwood Dunietz, Soni	Direct	0	0	~ 0 *	5–50
ϕ_2)	$K^0 D^0(\bar{D}^0)$ ↓ CPES,CPNES, Inclusive	Atwood +AS	Direct	0	0	~ 0 *	~~[illegible]~~ $\sim 10-100$

Range in # of B's corresponds to # initial measurement to refined ones (where theory error may set in)

* 2nd order weak contribution cause error $\sim O(.1\%)$

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Sample of Methods for Extracting the UT

gle	Mode(s)	Original Ref.	Type of CP	Pollution QCDP	Pollution EWP	Limiting Theory Error	# of B's Needed $/10^8$
)	$B \to \psi K^0$	Bigi + Sanda	time dep.	~ 1–2%	~ 1%	~ 1–2%	0.5–5
)	$K^\pm D^0_\downarrow(\bar{D}^0_\downarrow)$ $K^+\pi^-$	Atwood Dunietz, Soni	Direct	0	0	~ 0	5–50
ϕ_2)	$K^0 D^0(\bar{D}^0)$ ↓ CPES, CPNES, Inclusive	Atwood +AS	time dep.	0	0	~ 0	~~6–50~~ 10–100
)	$\pi\pi$	Gronau + London	time dep.	≈ 30%	few% (5–10%)	~ 5–10%	~~10–50~~ 10 – 100
	$\rho\pi$	Quinn *et al*	"	≈ 30%	"	~ 5–10%	5–50
	$\rho(\omega)P$ ($P = \pi$, $\eta, a_0 \ldots$)	Atwood + Soni	"	≈ 30%	"	~ 1–2%	5–50
	$\rho\pi + \rho(\omega)P$	Comb. of above 2	"	"	"	~ 1%	5–50
ϕ_2)	$B^\pm$, $B^0_\downarrow(\bar{B}^0_\downarrow)$ $\rho\omega$, $K^{*0}\rho^+$	Atwood +AS	Direct	≈ 20%	≈ 5%	$\lesssim$ 5%	5–50
ϕ_3)	$B \to K^*\rho(\omega)$	"	"	"	"	"	5–50

Estimate of Attainable Accuracy

ANGLE	# of BBs $\sim(1-5)\times 10^8$	$\sim 10^{10}$
$\sin 2\phi_1$ (ψK_S)	$\sim .04$	$\sim .01$
ϕ_3 (DK D)	$\sim$ ~~10°~~	$\sim$ ~~1°~~
$\sin 2\phi_2$ ($\rho\pi$)	$\sim .20$	$.05 \rightarrow .01$ *
$\sin 2\phi_2$ ($\pi\pi$)	?	$\sim .03 \rightarrow .01$ *

[* will require additional inputs to get to around $\sim .01$]

Testing the SM through Precise UTs at a SuperB

ϕ_1 { ϕK_S V_S ψK_S
$\eta' K_S$ V_S ψK_S
$B^0 \to K^0 D^0$ V_S ψK_S

ϕ_2 from $B^0 \to K^0 D^0$ V_S $\rho\pi, \pi\pi$

use all 3 very clean ones:

$\phi_1(\psi K_S) + \phi_2(\pi\pi, \rho\pi) + \phi_3(B^\pm \to K^\pm D) - \pi = ?$

ϕ_3 from $B^\pm \to K^\pm D^0$ with ϕ_3 from
$B_S \to K^\pm D_S^\mp$ ← TEVATRON/LHC

SUPER B WILL OPEN UP MANY PATHS

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Search for the Beyond

Two Complementary Approaches

1. Precision Extraction of $U\Delta$
2. Search for CP where CKM predicts ~ 0

MODEL INDEPENDENT SEARCHES FOR χ_{BSM}

$B^0 \to \psi K_S$ TDCP $a_{CP}(\psi K_S) = \sin[2\beta_{CKM} + \chi_{BSM}]$	NIR...; WOLFENSTEIN; BALL, Frere + Matias Wu + Soni	DOMINANT from CKM; Restrict param. space fr BSM
I. $\sin 2\beta$ from Pure Penguins TDCP $B^0 \to \phi(\eta, \eta', \pi^0, \omega, \eta) + K_S$	GROSSMAN + WORAH; LONDON + SONI HURTH + MANNEL	INDICATIONS?
II $B^\pm \to \psi K^\pm (K^{*\pm})$ DIRCP	WU + SONI	Extremely small CP from SM.
IV. $B \to \gamma[K^*, \rho]$ TDCP $B \to \gamma X_s(K^*)$ DIRCP	Atwood + Gronau + AS Gottoctal; Chua + Hou SOARES; WOLFENSTEIN + Wu; KAGAN + NEUBERT;	$b \to s$ SM gives very small CP
$B \to \gamma X_d(\rho, \omega)$ DIRCP	KIERS, WU + A.S.	$b \to d$ $\lesssim 20\%$
V $B \to \eta' X_s$ DIRCP	ATWOOD + SONI HOU + TSENG	SM gives very small CP
VI $B \to D(X_c)\tau\nu_\tau$ DIRCP (Transverse pol. Asym)	ATWOOD, EILAM + SONI; GROSSMAN + LIGETI	SM PREDICTS STRICKLY 0 ASYM.

ALL THESE AVENUES SHOULD BE PURSUED TO VERY HIGH SENSITIVITY

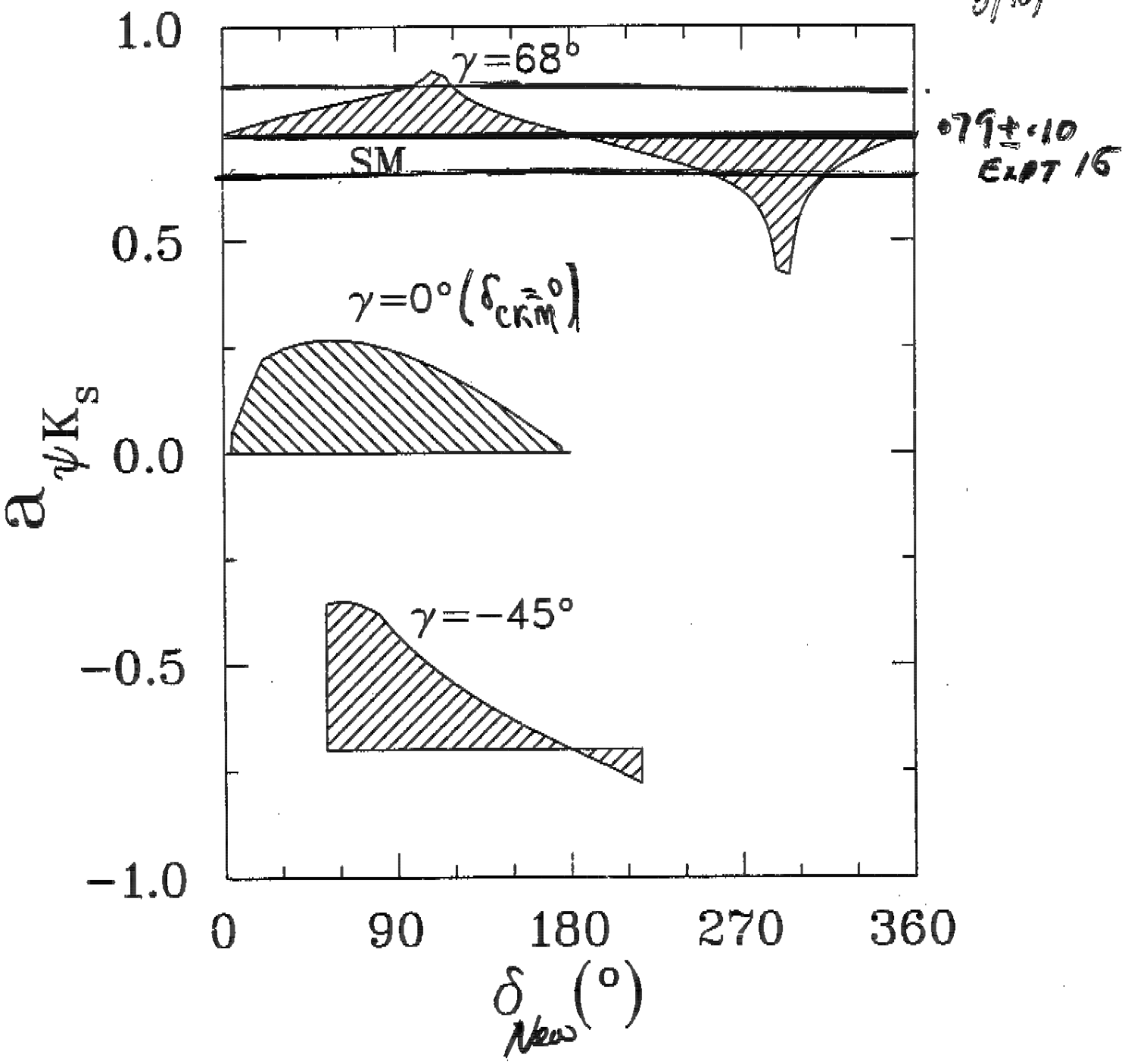
[REMEMBER $\epsilon_K \sim 10^{-3}$]

30 61 30 48

KIERS, S, Wu PRD 49

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

(Model can accomodate ϵ_K with $\delta_{CKM} = 0$) NOT TRUE ANYMORE 3/10/02



⇒ ILLUSTRATES that BELLE/BABAR/CDF..

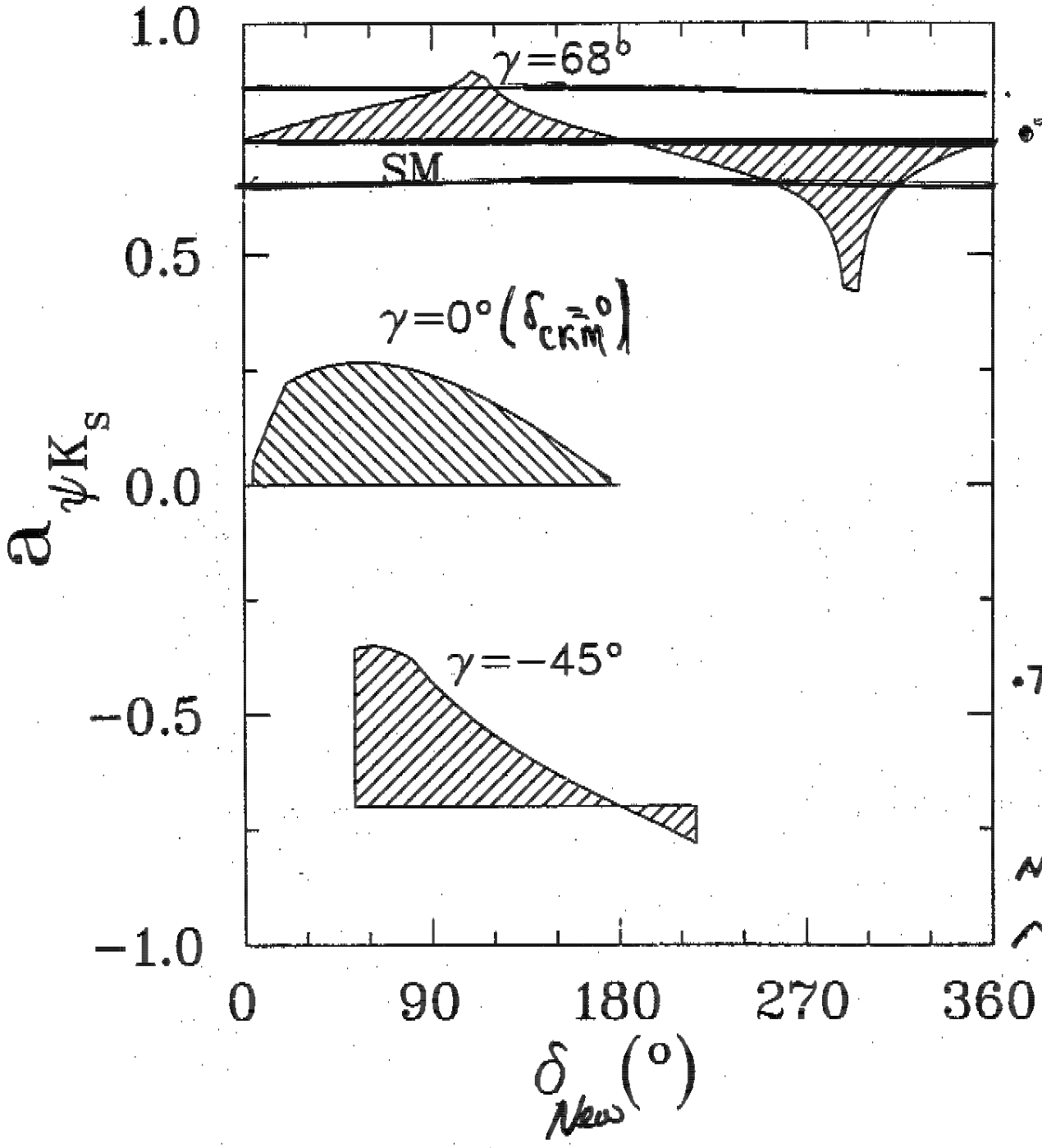
⇒ CKM phase dominant in ψK_S^0

30 61 30 48

KIERS, S, Wu PRD 49

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

(Model can accomodate ϵ_K with $\delta_{CKM} = 0$) NOT TRUE ANYMORE 3/10/02



$\cdot 79 \pm \cdot 10$ EXPT 16

$\eta' K_S$

$\cdot 76 \pm \cdot 36 \pm \cdot 05$

$N - \cdot 15 \pm \cdot 50$

$\sim 1 \cdot 76$

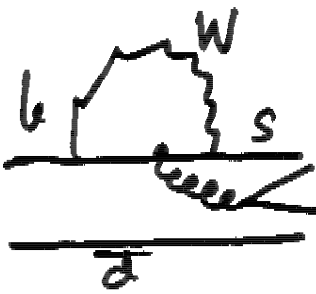
⇒ ILLUSTRATES that BELLE/BABAR/CDF--
[1. Given (in 2β) SM agrees with WA so well
2. NP is unlikely to treat ϕ & η' so differently]
CKM phase dominant in ψK_S

SIN 2β From "Pure" Penguins

GROSSMAN + WORAH; LONDON + A.S.

TDCP Asy from $B^0 - \bar{B}^0 \to \phi K_S, \eta' K_S$ ..... is another way to get the mixing phase, $\Phi_M = \beta$ as the decay phase is 0 in SM.

SIN 2β = SIN $(\Phi_{MIX} + \Phi_{DECAY})$



$\Phi, \eta' \ldots$

$\Phi_{Decay} \cong 0$

BSM Penguins Contribution $\Phi_{Decay} \neq 0$

SIN 2β Measurements From

	ψK_S	ϕK_S
BELLE	$.719 \pm .074 \pm .035$	$-.73 \pm .64 \pm .18$
BABAR	$.741 \pm .067 \pm .035$	$-.19 \pm .51 \pm .09$
WA	$.734 \pm .054$	$-.39 \pm .41$

$\sim 2.7\sigma$ deviation

$\Rightarrow$ MANY THEORY PAPERS

VERY UNLIKELY TO BE A REAL EFFECT

MIXING Induced $\not{CP}$ in Radiative B Decays.

ATWOOD + GRONAU + AS
PRL '97

Key pt. γ in b decays in the SM is predominantly L.H
$\bar{b}$ RH

esp. sensitive to presence of RH currents due BSM

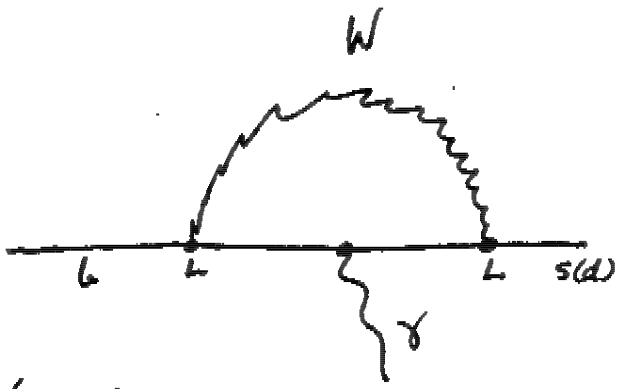
In the SM TDCP in $B \to \gamma\,[\rho, \omega, K^*\ldots]$
$\propto \frac{m_d}{m_b}$ or $\frac{m_s}{m_b}$ EXCEEDINGLY SMALL

BSM eg. LRSM, SUSY --- can cause measurable asymmetries

LRSM AGS '97

SUSY { GOTTO et al hep-ph/0306093
Chua & Hou /0110106

SM



In General $(q = s, d)$

$$H_{eff} = -\sqrt{8}\, G_F \frac{e m_b}{16\pi^2} F_{\mu\nu} \left[\frac{1}{2} F_L^q \bar{q} \sigma^{\mu\nu} (1+\gamma_5) b + \frac{1}{2} F_R^q \bar{q} \sigma^{\mu\nu} (1-\gamma_5) b \right]$$

In the SM $F_R^q / F_L^q \simeq m_q / m_b$

Mixing induced CP asymmetry in $B - \bar{B}$ decay requires both B & $\bar{B}$ be able to decay to the same FS ie a state with the same photon helicity $\propto F_R^q / F_L^q \longrightarrow 0$ as $m_q/m_b \to 0$

In Contrast LR Model as an example

Now F_R^q / F_L^q can be appreciably bigger

Presence of RH currents $\Rightarrow \frac{m_t}{m_b}$ enhancement for F_R^q / F_L^q

TD CP in $B \to M^0 \gamma$

$CP|M^0\rangle = \xi|M^0\rangle \; ; \xi = \pm 1$

$A(\bar{B} \to M^0 \gamma_L) = A \cos\psi \, e^{i\phi_L}$

$A(\bar{B} \to M^0 \gamma_R) = A \sin\psi \, e^{i\phi_R}$

$A(B \to M^0 \gamma_R) = \xi A \cos\psi \, e^{-i\phi_L}$

$A(B \to M^0 \gamma_L) = \xi A \sin\psi \, e^{-i\phi_R}$

$\tan\psi = \frac{F_R^V}{F_L^V}$

$$\Gamma(t) = \Gamma(B_q(t) \to M^0\gamma) = e^{-\Gamma t}|A|^2\left\{1 + \xi \sin(2\psi)\sin(\phi_M - \phi_L - \phi_R)\sin\Delta m\right\}$$

ϕ_M is the CP-odd phase in mixing

ϕ_L, ϕ_R . . . . decays.

TD CP Asy

$$\mathcal{A}(t) = \frac{\Gamma(t) - \bar{\Gamma}(t)}{+} = \xi \sin(2\psi)\sin(\phi_M - \phi_L - \phi_R)\sin(\Delta m t)$$

SM

$b \to s\gamma$: $\sin(2\psi) \approx 2\frac{m_s}{m_b}$; $\phi_L = \phi_R \approx 0$, $\phi_M = 2\phi_1(2\beta)$

$b \to d\gamma$: $\sin(2\psi) \approx 2\frac{m_d}{m_b}$; $\phi_L = \phi_R \approx \phi_1(\beta)$; $\phi_M = 2\phi_1(2\beta$

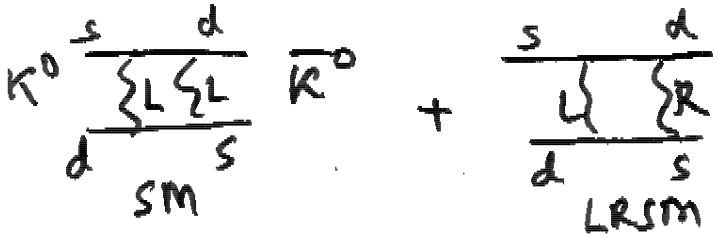
TD CP $\to 0$ for $b \to d\gamma \Rightarrow \mathcal{A}(t)(B^0 \to \rho^0\gamma) \approx 0$

$\propto \sin 2\phi_1$ $b \to s\gamma \Rightarrow \mathcal{A}(t)(B^0 \to K^{*}\gamma) \approx 2\frac{m_s}{m_b}\sin 2\phi_1 *$ $\sin(\Delta m t)$

LRSM $G = SU(2)_L \times SU(2)_R \times U(1)$

$$\begin{pmatrix} u \\ d \end{pmatrix}_{L,R} \quad \begin{pmatrix} \nu_e \\ e \end{pmatrix}_{L,R}$$

ν mass arises naturally.



Beall + Bander + AS '82

$m_R \gtrsim 1.5$ TeV

Given that $m_\nu \neq 0$ (and TeV is no longer as imposing) model ought to be reconsidered as a nice low energy effective Theory.

Done recently Kiers + AS + Wu PRD 2002

Higgs Bidoublet $\Phi = \begin{pmatrix} \phi_1^0 & \phi_2^+ \\ \phi_1^- & \phi_2^0 \end{pmatrix}$ $\quad \langle \Phi \rangle = \begin{pmatrix} K & 0 \\ 0 & K' \end{pmatrix}$

$$|K'/K| = m_b/m_t$$

$\Rightarrow$ CKM angle hierarchy arises

$\Rightarrow$ $(CKM)_R = (CKM)_L$!

$\delta_R = \delta_L$! !

Considerable predictive power

For $SU(2)_L \times SU(2)_R \times U(1)$

$$\begin{pmatrix} W_1^+ \\ W_2^+ \end{pmatrix} = \begin{pmatrix} \cos\varphi & e^{-i\omega}\sin\varphi \\ -\sin\varphi & e^{-i\omega}\cos\varphi \end{pmatrix} \begin{pmatrix} W_L^+ \\ W_R^+ \end{pmatrix}$$

$\varphi \lesssim 3\times10^{-3}$ Beall+Soni; Wolfenstein '84

$m_R \gtrsim 1.5$ TeV Beall, Bander+AS '82

Fujikawa & Yamada '94

Basu + " + " '94

Cho + Misiak '94

Radiative B decays in LRSM

$$F_L \propto F(x) + \eta_{QCD} + \varphi \frac{m_t}{m_b} e^{i\omega} \tilde{F}(x)$$

$$F_R \propto \varphi \frac{m_t}{m_b} e^{-i\omega} \tilde{F}(x) \qquad x \equiv \left(\frac{m_t}{m_{W_1}}\right)^2, \quad \eta_{QCD} = -.18$$

	SM	LRSM
$A(B^0 \to K^{*0}\gamma)$	$2\frac{m_s}{m_b}\sin 2\beta \sin(\Delta m t)$	$\sin 2\omega \cos 2\beta \sin(\Delta m t)$
$A(B^0 \to \rho^0\gamma)$	$\simeq 0$	$\sin 2\omega \sin(\Delta m t)$ $\lvert\sin 2\omega\rvert \leq 0.67$

In Both cases TDCPA can be tens of percents even if the rate agrees with the SM.

DIRECT CP IN RADIATIVE B DECAYS

Kiers, Liu + A.S. PRD'00
HURTH + MANNEL
MISIAK etc.

TABLES

Model	$A_{CP}^{b\to s\gamma}$ (%)	$A_{CP}^{b\to d\gamma}$ (%)
SM	0.6	-16
2HDM (Model II)	~ 0.6	~ -16
3HDM	-3 to $+3$	-20 to $+20$
T2HDM	~ 0 to $+0.6$	~ -16 to $+4$
Supergravity [40,41,47]	~ -10 to $+10$	$-(5-45)$ and $+(2-21)$
SUSY with squark mixing [42,43,9]	~ -15 to $+15$	
SUSY with R-parity violation [46]	~ -17 to $+17$	

TABLE I. CP asymmetries in various models. Quoted ranges are approximate; see the text for details. The blank entries represent quantities that have not, to our knowledge, been considered in the literature. The rate asymmetry for $b \to s\gamma$ from SUSY with squark mixing could be larger than the quoted $\pm 15\%$ if the gluino mass is significantly lighter than the squark masses [9]. Note that the range quoted for the R-parity violating case assumes $m_{\nu_\tau} \sim 10$ keV. The asymmetry is negligible if $m_{\nu_\tau} \ll 10$ keV, as is indicated by the SuperKamiokande atmospheric neutrino oscillation data [52].

NOTE $B^0 \to \rho^0 + \gamma$ ALSO Very imp. for $\frac{V_{td}}{V_{ts}}$
(NOT B^-)

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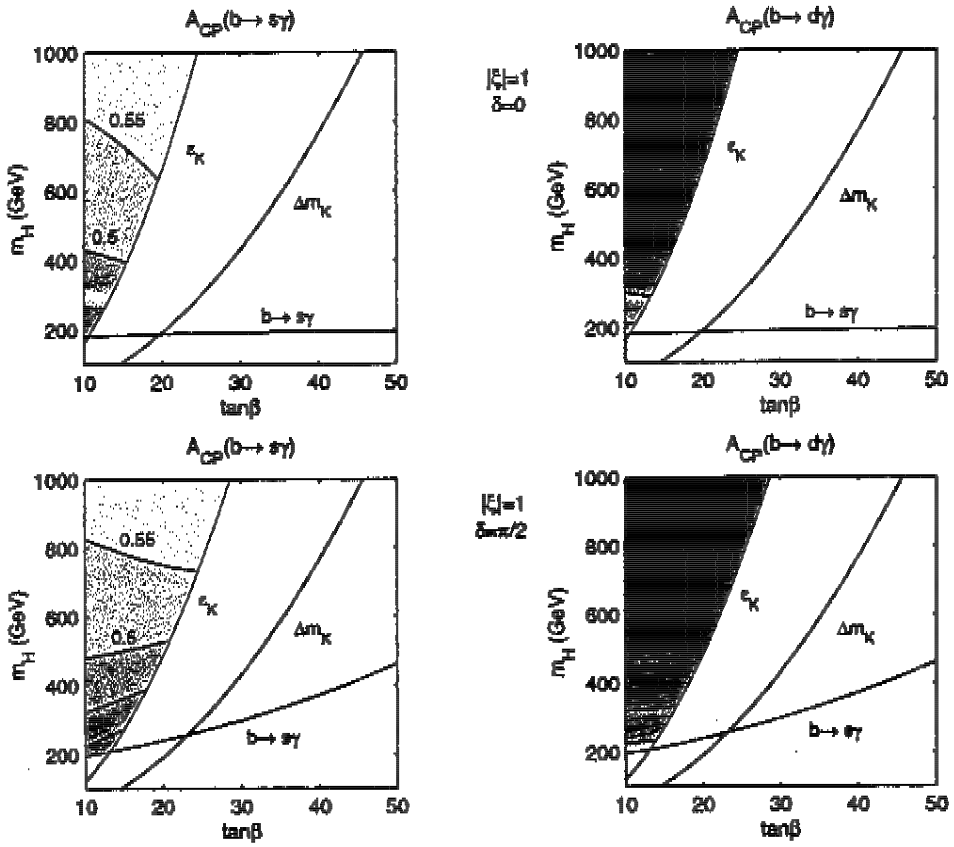

FIG. 5. Contour plots of PRA's in $b \to s\gamma$ and $b \to d\gamma$ in the T2HDM – SM-like scenario: ρ and η take their SM best fit values ($\rho = 0.20$ and $\eta = 0.37$). The experimentally allowed regions are shaded, and the contours show the asymmetries as percentages.

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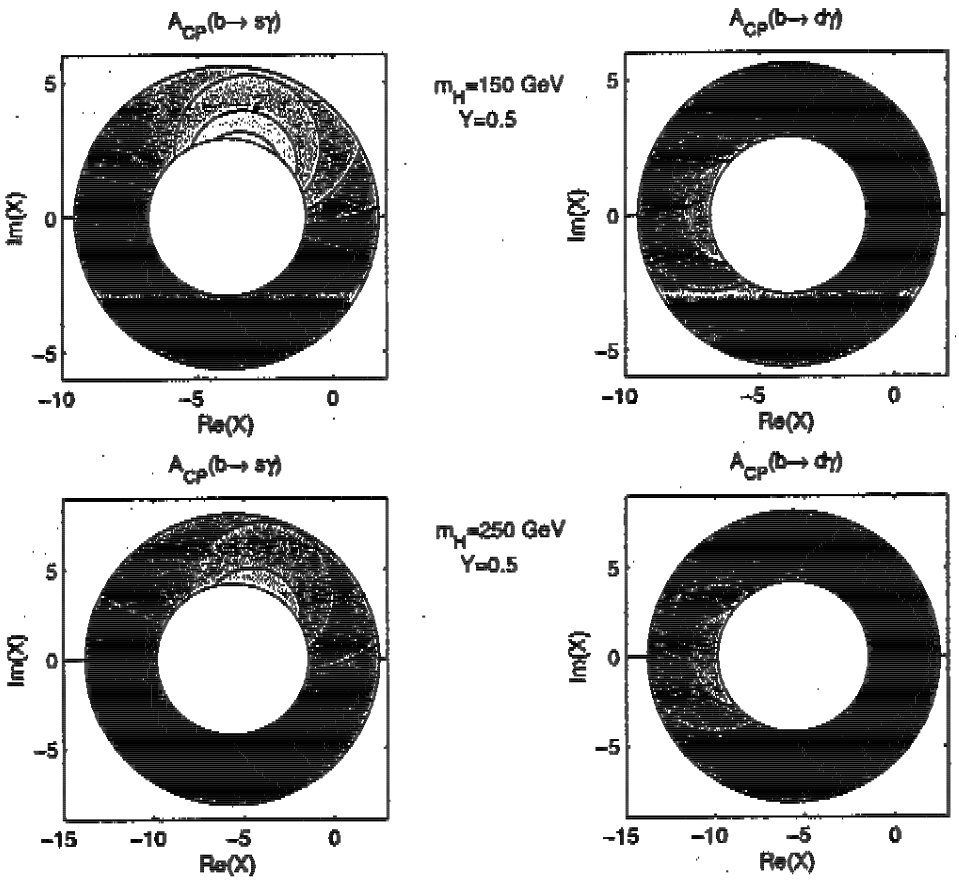

FIG. 2. Contour plots of partial rate asymmetries in the decays $b \to s\gamma$ and $b \to d\gamma$ in the 3HDM with $\rho = 0.20$ and $\eta = 0.37$. The shaded ring-like regions are experimentally allowed. The contour lines show the CP asymmetries as percentages.

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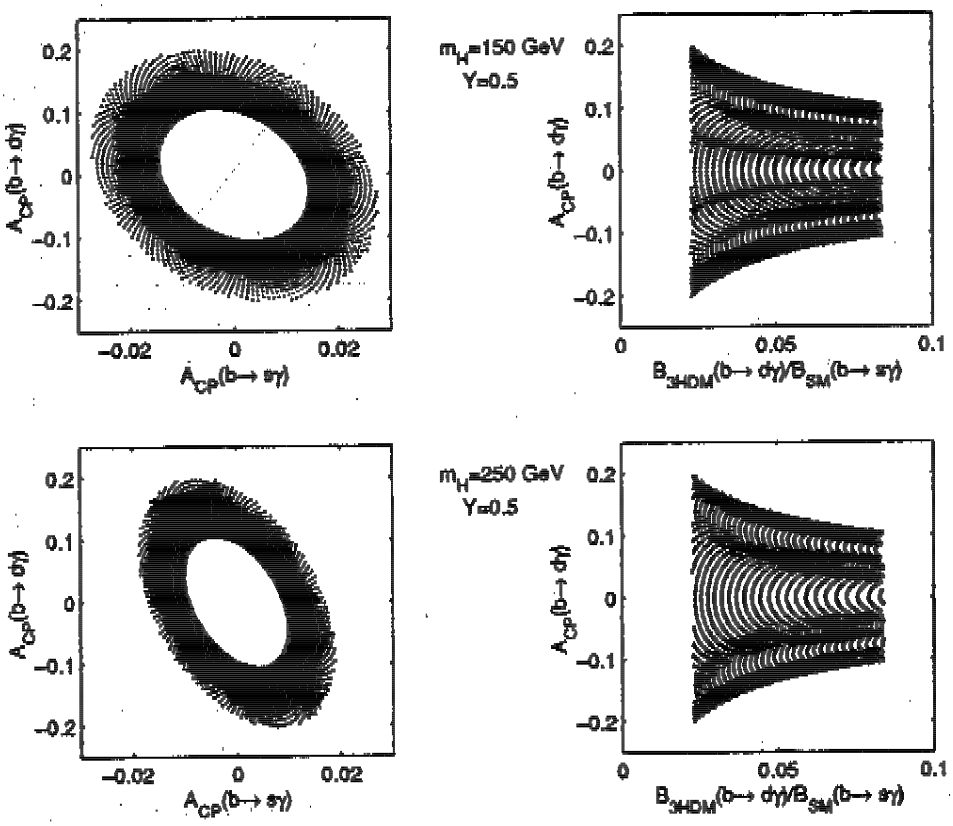

FIG. 4. Correlation between the rate asymmetries of $b \to s\gamma$ and $b \to d\gamma$ in the 3HDM. Also shown are the ranges of the ratio of branching ratios for the radiative decays.

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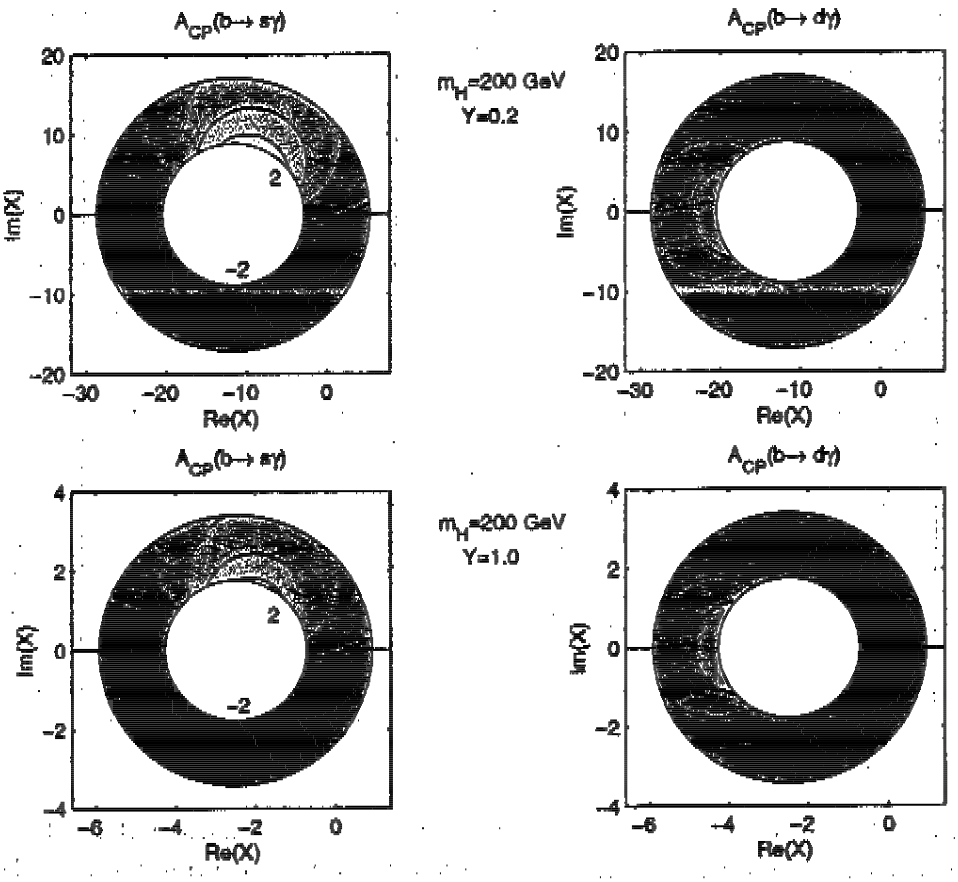


FIG. 3. Same as Fig. 2, but with different values for m_H and Y.

CONSTRAINING HIGGS SECTOR with $B \to D^{(*)} \tau \nu_\tau$ 73

①

MAIN Points

* q^2 ($q \equiv p_B - q_D$) distribution rather sensitive to $\frac{\tan\beta}{m_H}$

* B-Fact ($\sim 10^8 B\bar{B}$) $\Rightarrow \frac{\tan\beta}{m_H} \lesssim .04$ $\to m_H > 500$ GeV

For $\tan\beta = 20$

* SUPER-B ($\sim 10^{10} B\bar{B}$) $\Rightarrow$ $\lesssim .01$ $m_H > 2$ TeV

UNLIKE $B \to X_s \gamma$ SUSY CANNOT INVOKE CANCELLATION

* Transverse pol of ($P_\perp$) of τ extremely sensitive and UNIQUELY CLEAN PROBE of CP-odd $H^\pm$ phase

10^8 B's $\Rightarrow \langle P_\perp \rangle \sim 1\%$. Accessible ?)*

10^{10} " $\Rightarrow$ $\sim 0.1\%$

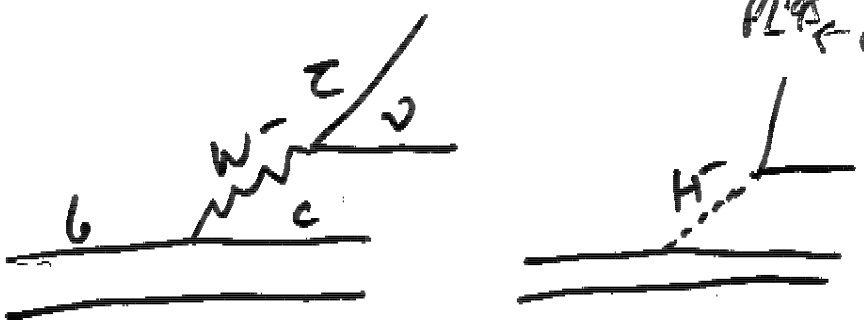
$\langle P_\perp \rangle_{SM} = 0$ ← EXACT

$\boxed{m_\nu \neq 0!}$

* Assume $\eta^\perp_{eff} \sim 1\%$

Constraints ON HIGGS Sector with $B \to D \tau \nu_\tau$

HOU + GRZADKOWSKI PL91
TANAKA ZP'95
PL'95 ← Grossman, Haber & NIR
KIERS + A.S PRD97



The Needed SL Form Factors Can be NAILED DOWN accurately via $B \to D \ell \nu$, $D \mu \nu$

Need 3 Form Factor

$$\langle D(p') | \bar{c} \gamma_\mu b | B(p) \rangle = F_1(t) \left\{ (p+p')_\mu - \frac{m_B^2 - m_D^2}{q^2} q_\mu \right\} + F_0(t) \frac{m_B^2 - m_D^2}{q^2} q_\mu$$

$$t \equiv q^2 / m_B^2$$

$$\langle D | \bar{c} b | B \rangle = (m_B + m_D) F_S(t)$$

For this study D is better than D^*

(3/15)

$$\frac{d\Gamma_\tau}{dt} = f(r_\tau, r_D, t, \xi(t), \delta_H(t))$$

$r_D = \frac{m_D^2}{m_B^2}$, $r_\tau = \frac{m_\tau^2}{m_B^2}$ $\xi(t) = F_0(t)/F_1(t)$

$\delta_H(t) = -\left(\frac{t-m_B^2}{m_H}\right)^2 \frac{m_b}{m_B - m_D} \left[1 + \frac{m_c}{m_b}(t/m_B^2)\right] \frac{F_3(t)}{F_0(t)}$ $\delta_H(t) \Rightarrow F_3(t)/F_0(t)$

HQS $F_0(t) \Rightarrow -\frac{1}{2r_D^{1/4}}\left[\frac{t-(1+\sqrt{r_D})^2}{1+\sqrt{r_D}}\right] \xi(\omega)$

$F_1(t) \Rightarrow \frac{1+\sqrt{r_D}}{2r_D^{1/4}} \xi(\omega)$ ← ISGUR-WISE fn

$F_3(t) \Rightarrow F_0(t)$

$\omega = v \cdot v' = (1 + r_B - t)/2\sqrt{r_D}$

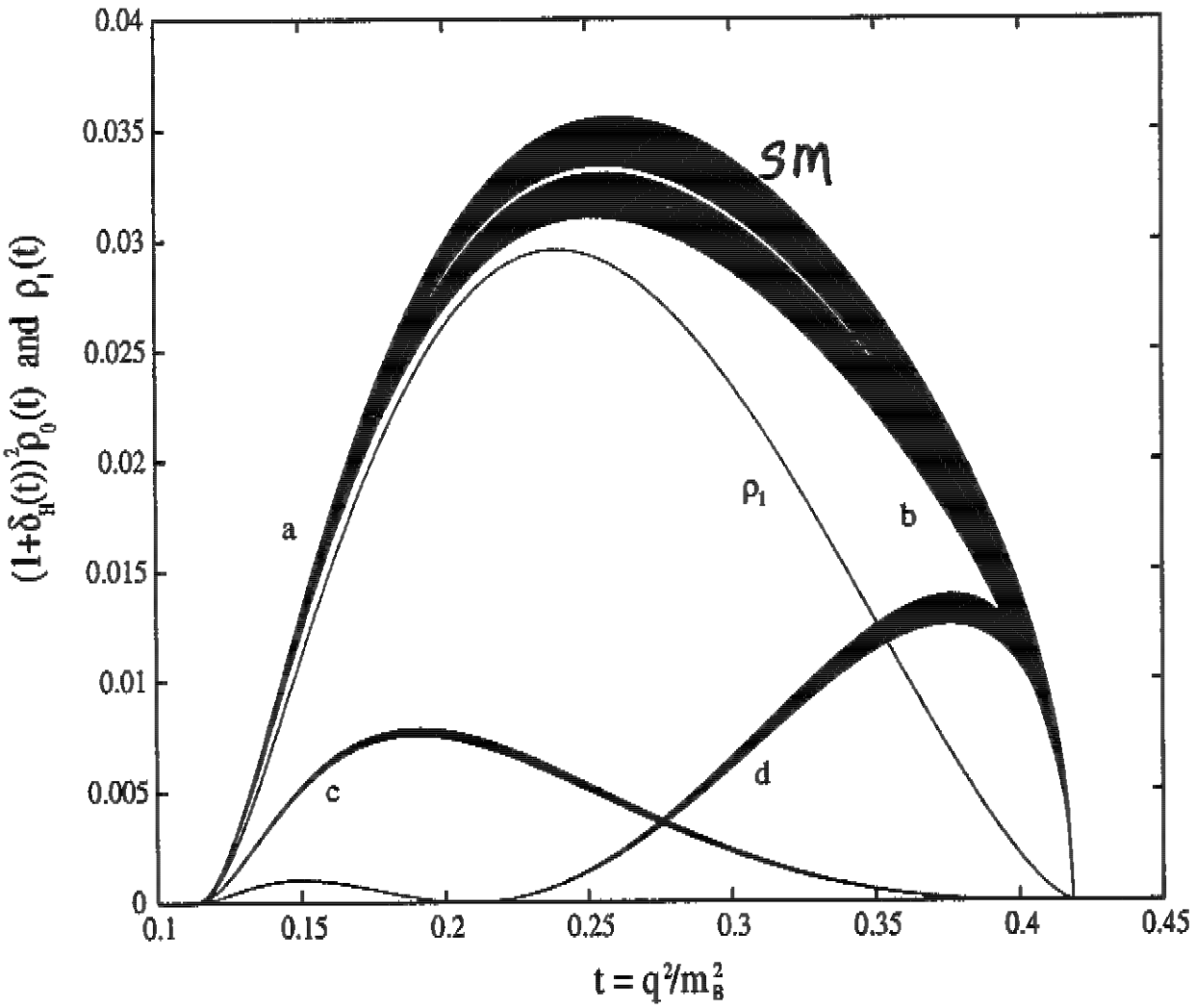
ALTHOUGH $\frac{1}{m_Q}$ Corrections on individual form factors are appreciable their ratios receive very small residual corrections. We use NEUBERT and parameterize ~~[illegible]~~ remaining errors P.R.

ALSO USE $\xi(\omega) = 1 - .075(\omega - 1)$

SPIN 0 & 1 Contributions to the Differential Distribution

	tamp m_H GeV	
a	0	→ SM
b	0.06	
c	0.25	
d	0.35	

DIFFICULT to go below 0.06 due to Theory



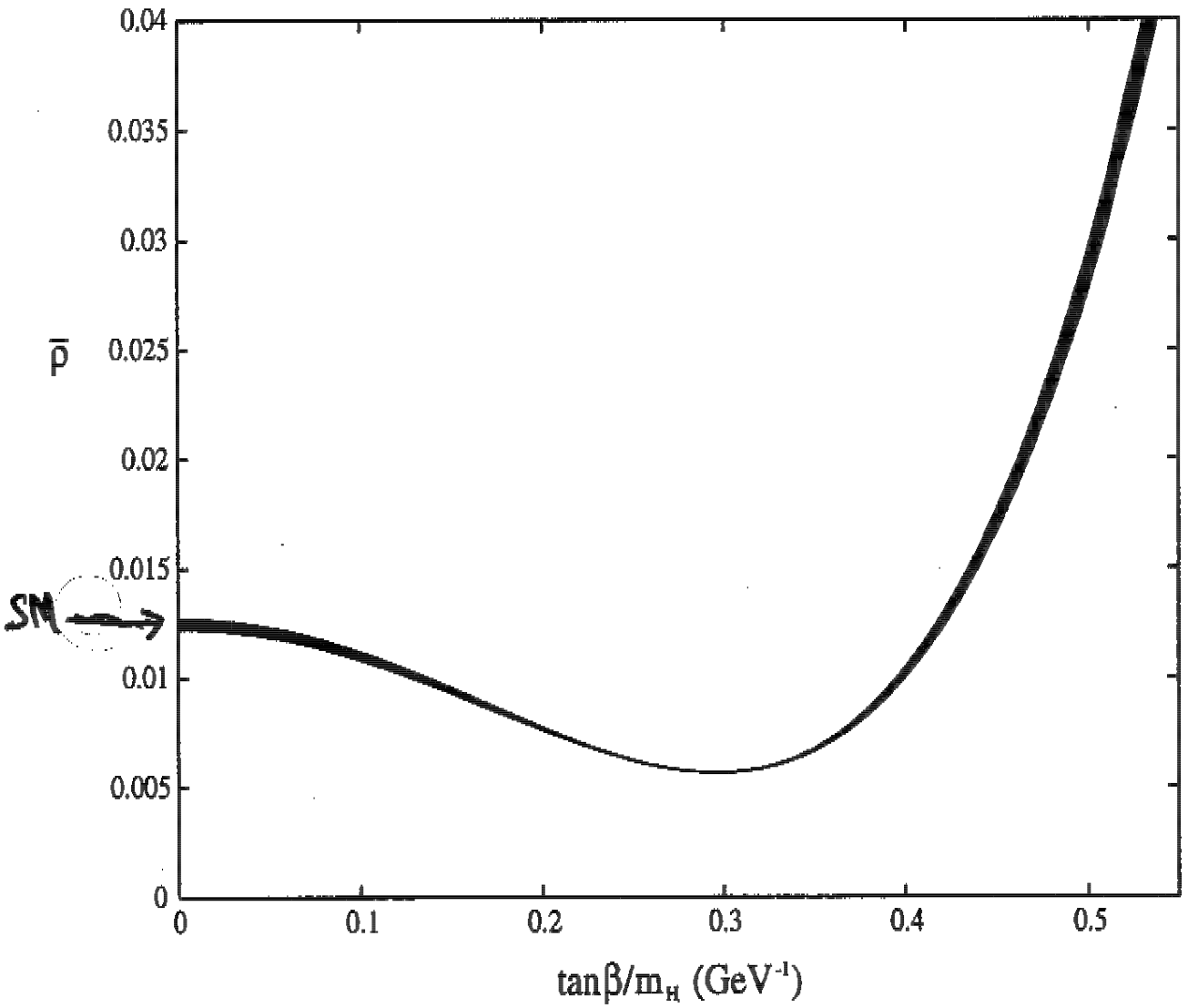
SM BR($B \to \tau \nu_\tau D$) ~ 1/2 % ⇒ efficiency 10%

B-Fact ~ 4×10^4

SuperB 4×10^6

NORMALIZE Integrated Width as a fn of $\frac{\tan\beta}{m_H}$ 77

$\tan\beta/m_H$	$\bar{\rho}/\bar{\rho}_{SM}$
0.3	50%
→ 0.1	80%
0	1



Normalization $\frac{G_F^2 m_B^5 |V_{cb}|^2}{128\pi^3}$

GROSSMAN + HABER + NIR

FIGURES

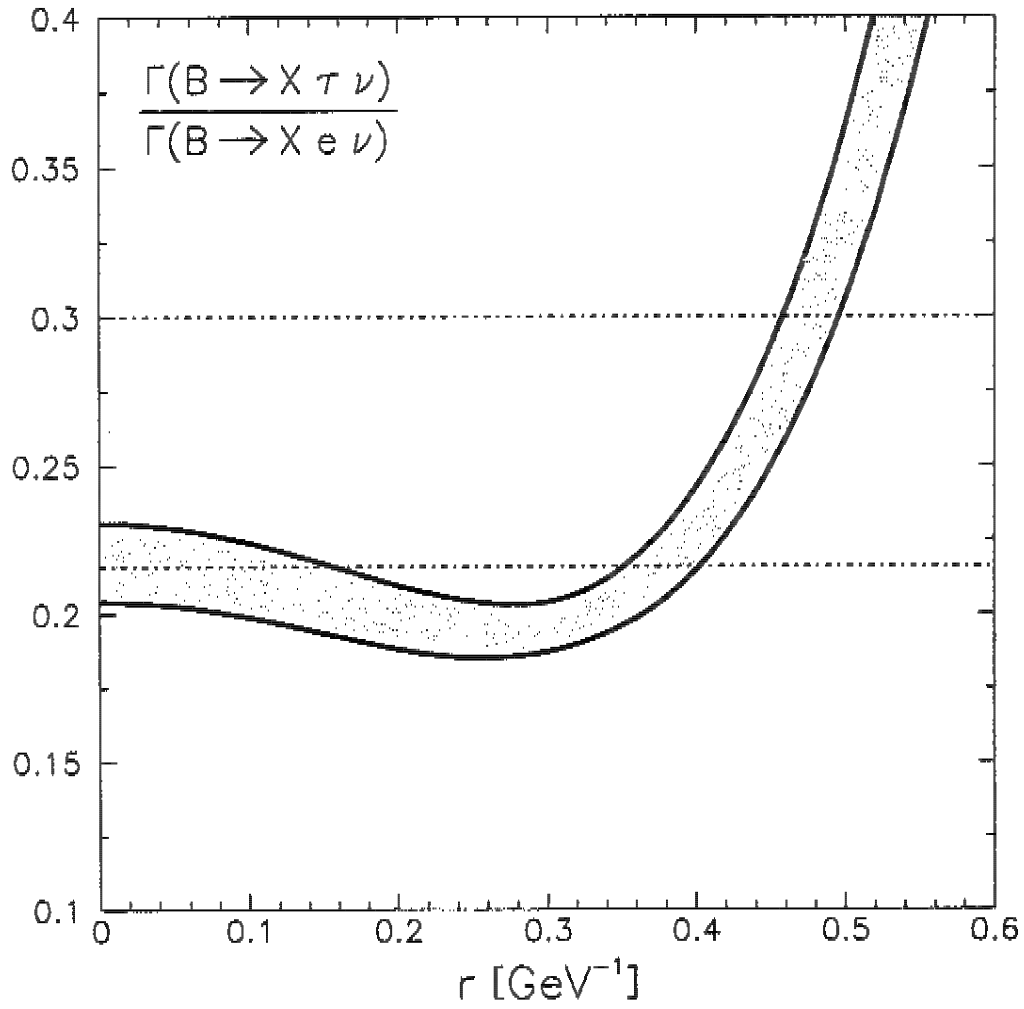
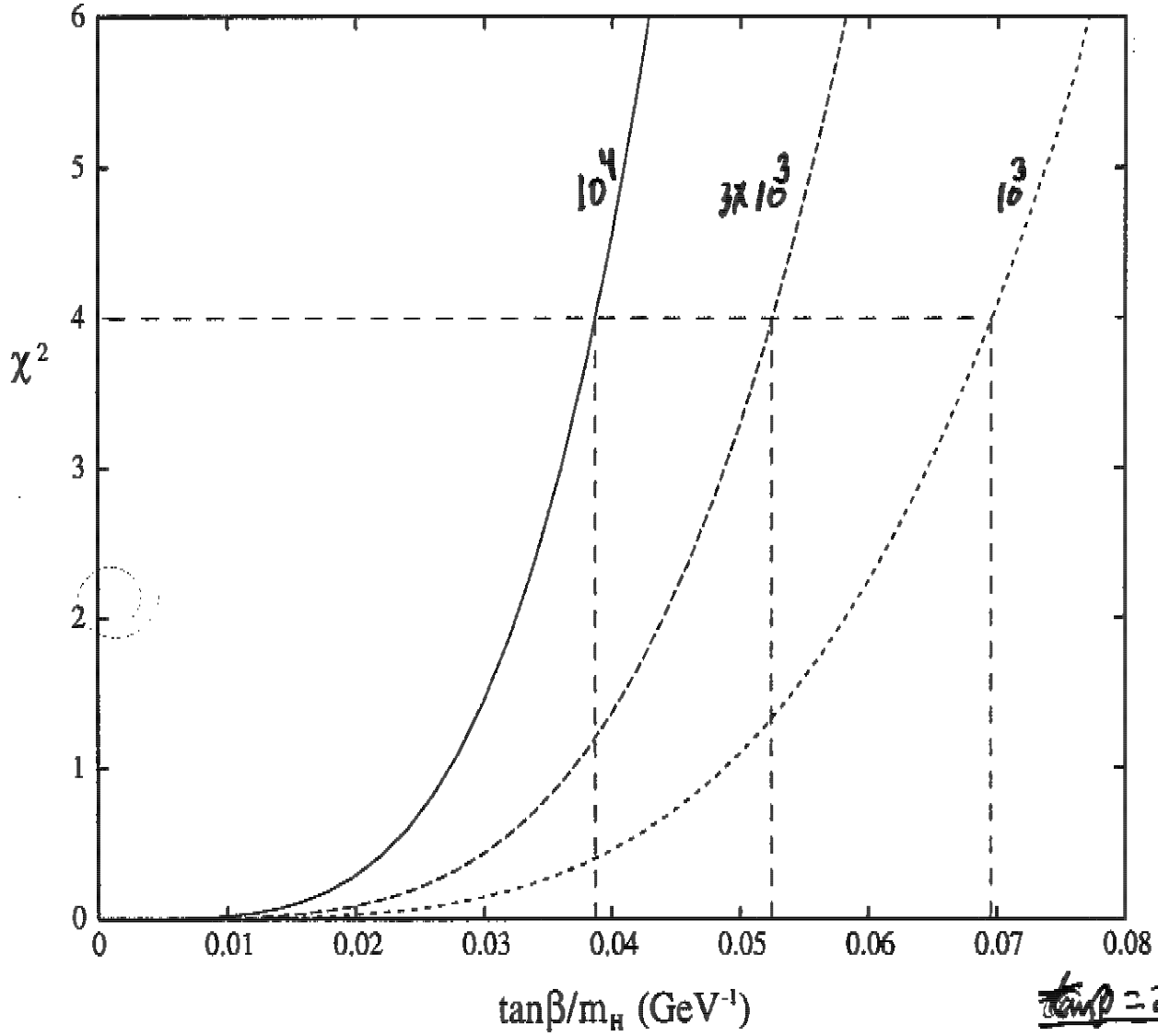


FIG. 1. $\Gamma(B \to X\tau\nu)/\Gamma(B \to Xe\nu)$ as a function of $r = \tan\beta/m_H$. The shaded area between the solid lines is our result. The dash-dotted lines give the experimental 1σ bounds.

At $\frac{\tan\beta}{m_H} \sim .3/\text{GeV}$ inclusive width becomes 80–90% of SM

(79)

USE "OPTIMIZED OBSERVABLE" (ATWOOD+AS PRD92; GUNION+GRZADKOWSKI+He, PRL 96)



$\tan\beta = 20$

m_H ~ 500 GeV

~ 2 TeV

$10^8\ B\bar{B} \Rightarrow 5\times10^4\ B\to D\tau\nu_\tau \Rightarrow \tan\beta/m_H \lesssim .04$

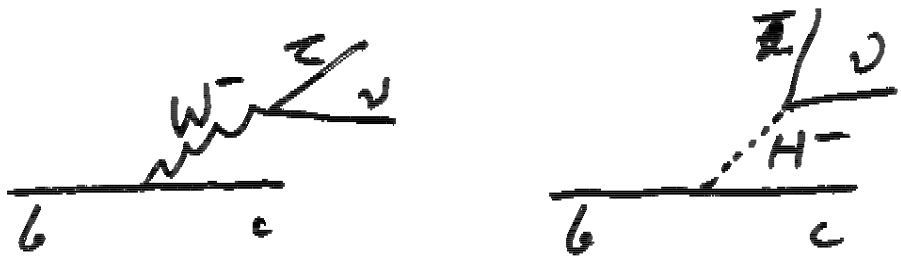
10^{10} " $\Rightarrow 5\times10^6$ $\lesssim .01$

(8)

TRANSVERSE τ Polarization in $B \to \tau \nu X$

Extremely Sensitive Probe of $\mathcal{H}^{H^\pm}_{BSM}$

NO SM BACKGROUND



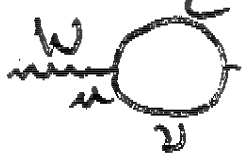
CP observable $\to$ T_N-even e.g. $\langle E_\tau \rangle$ or a_{PRA} $\propto$ Im Feyn Amp

CPT $\propto$ Re " "

T_N-odd $\langle P_\perp \rangle$

$$P_\perp = \frac{\vec{S}_\tau \cdot (\vec{P}_\tau \times \vec{P}_X)}{|\vec{P}_\tau \times \vec{P}_X|}$$

$* \langle E_\tau \rangle$, a_{PRA} Im Feyn Amp $\Rightarrow \frac{\alpha_s}{\pi} \sim 0.1$

$* \langle E_\tau \rangle$, "  $\Rightarrow \frac{m_\tau}{m_B} \sim \frac{1}{3}$

$\Rightarrow \langle P_\tau \rangle / \langle E_\tau \rangle (a_{PRA}) \sim 30$ MAY BE

ATWOOD + EILAM + A.S. PRL 93

GROSSMAN + LIGETI $\to$ hep-ph/9409418

HOWEVER EXPTAL Detection of transverse pol (Decay correlation in $\tau \to \pi\nu$, $\mu\nu\nu$, $\rho\nu$ etc)

Much harder than Energy asy or Rate Asym.

$$\mathcal{L}_{eff} = -V_{cb}\frac{4G_F}{\sqrt{2}}\left\{(\bar{c}\gamma_\mu P_L b)(\bar{\tau}\gamma_\mu P_L \nu_\tau) - R_H(\bar{c}P_R b)(\bar{\tau}P_L\nu_\tau)\right]$$

$\leftarrow$ SM $\rightarrow$

EXT. HIGGS sector

$$R_H = r_H^2\, m_\tau m_b \qquad r_H = X Z^*/m_H^2$$

$$\Gamma(B\to\tau\nu X) \Rightarrow W_{SM} - \text{Int} + |r_H^2|$$

$\uparrow$ Dest Int.

$BR(B\to\tau\nu X) = 2.98 \pm .47\%$ Don't have newer #

~~∴ of dest interference Br maybe difficult to go beyond~~

~~$r_H \lesssim .35/\text{GeV}$~~

$r_H < .47\,\text{GeV}^{-1}$ GROSSMAN + LIGETI

FIGURES GROSSMAN + LIGETI

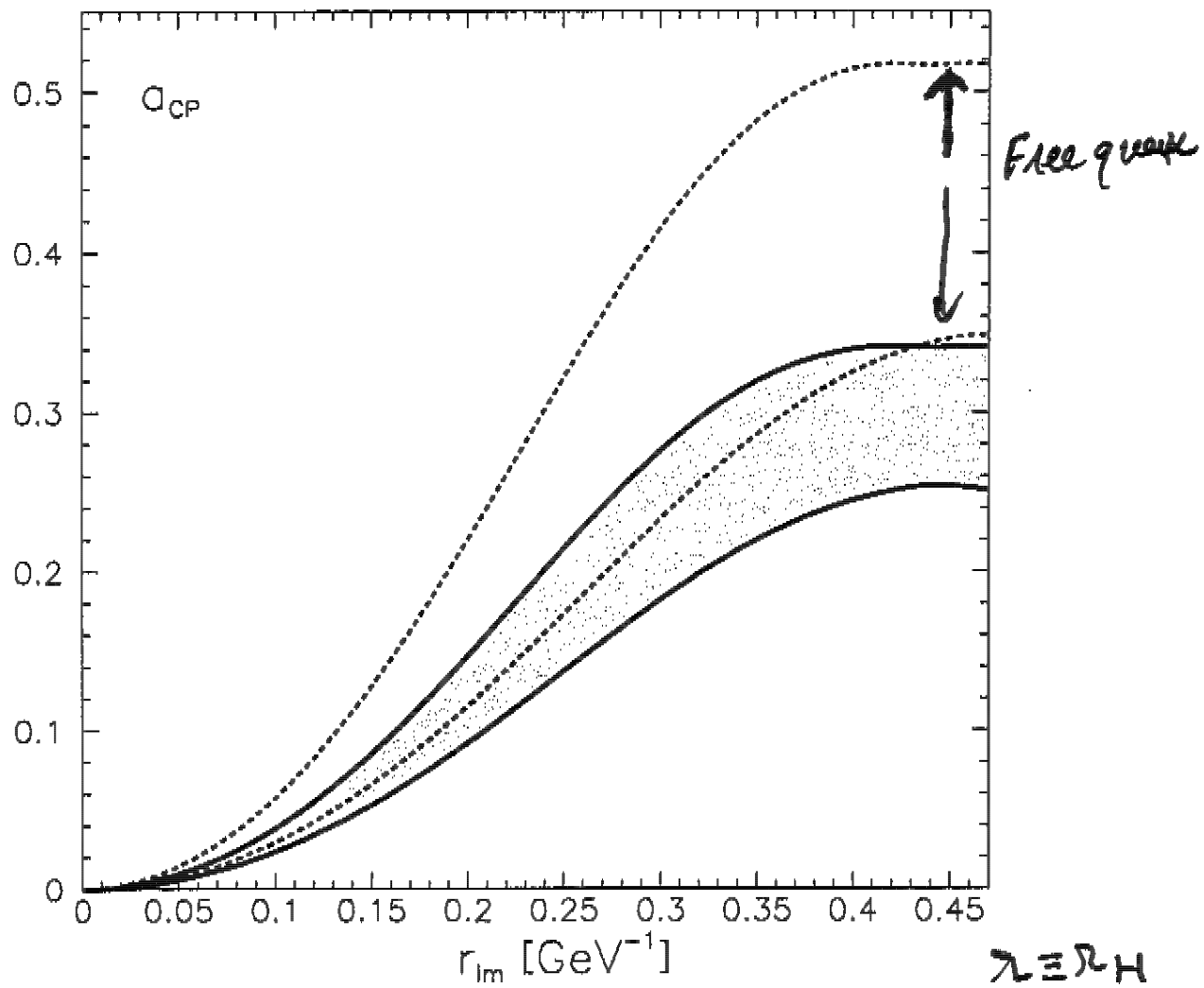


FIG. 1. a_{CP} as a function of $r_{\rm Im} = \sqrt{|{\rm Im}\,(r^2)|} = \sqrt{|{\rm Im}\,(X Z^*)|}/m_H$. The shaded area between the solid lines is our result. The area between the dashed lines gives the free quark decay model result.

POWER Corrections ($\sim 1/m_c^2$) can suppress the asymmetry as much as 30% from the free quark expectation

(83)

Assume $\eta_{eff}^{\perp pol} \sim 1\%$

Assume $\langle P_T \rangle \sim 1\%$

Need # of B's for 3σ observation $\sim \frac{9}{3\times10^{-2}\times10^{-4}\times10^{-2}} \sim 3\times10^{8}$

FAKE Asym (FSI) can arise if only τ^- or τ^+ is studied. GENUINE P_T will switch SIGN from τ^- to τ^+

Clearly Rate (Energy Asym) should also be studied esp'ly detection efficiency for those is much higher

If $\langle P_T \rangle < 1\% \Rightarrow \mathcal{R}_H \lesssim 0.05$ X10 improvement

* With $\eta_{eff}^{\perp pol} \sim 1\%$ SUPERB could push to $\langle P_T \rangle \leq .1\%$

#84

DIR CP

Model Independent Description of $B \to \eta' X_s$

ATWOOD+AS PRL97

Assume some contribution to the large rate comes from BSM physics

$$\Lambda_\mu^{bsg} = V_t \frac{G_F}{\sqrt{2}} \bar{s}_i T^a_{ij} \{ -iF(q^2)(q^2\gamma_\mu - q_\mu X)L$$

$$+ \frac{g_s}{2\pi^2} m_b q_\mu \epsilon_\nu \sigma^{\mu\nu} G(q^2) R \} b_j$$

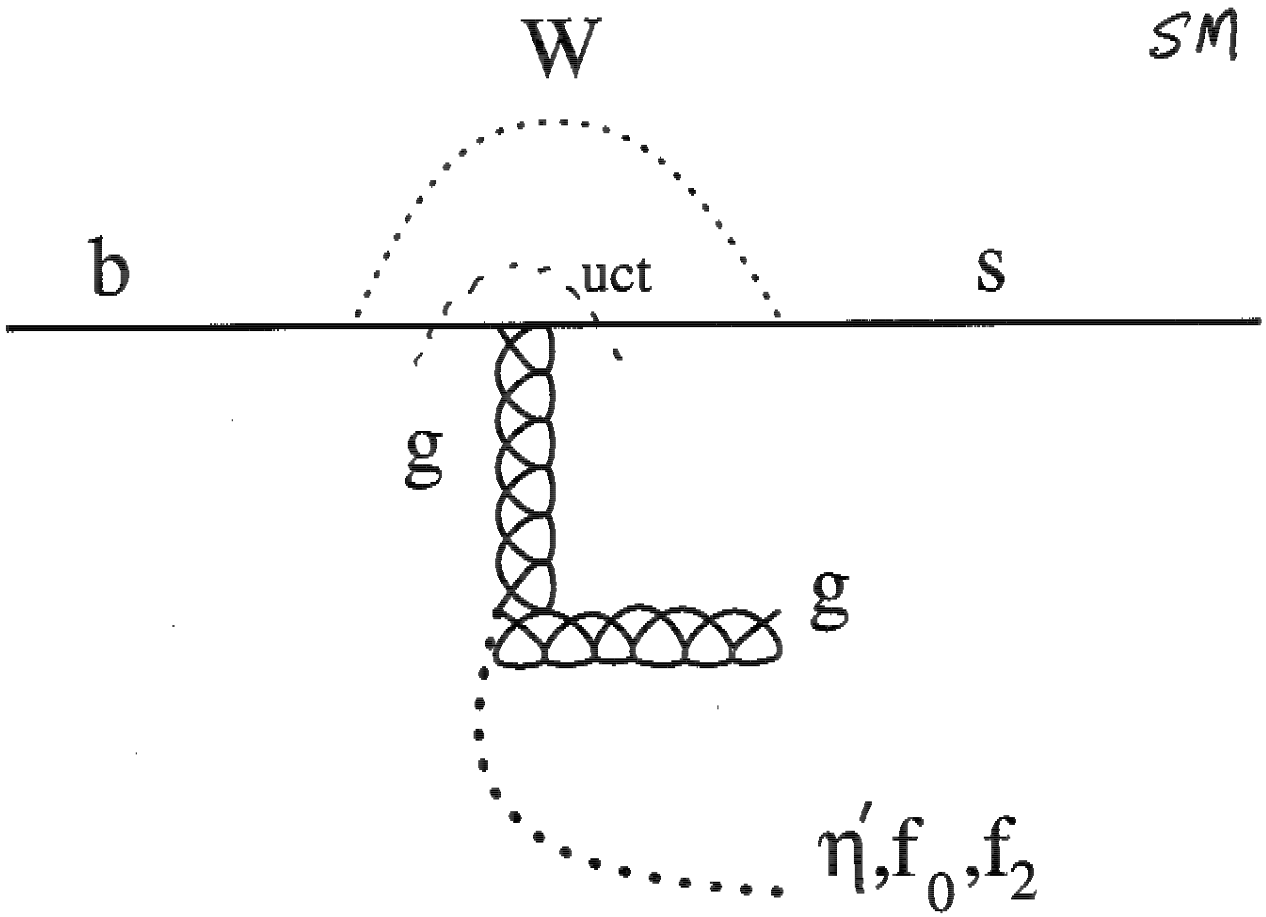
$$F(q^2) = e^{i\delta_{st}} F_{SM} + e^{i\chi_F} F_\chi$$

$$G(q^2) = G_{SM} + e^{i\chi_G} G_\chi$$

$\chi \equiv$ BSM CP-odd Phase: $\delta_{st} =$ CP-even, FSI phase

$$\Gamma_A = \frac{1}{2} \frac{d(\Gamma - \bar{\Gamma})}{ds dt} =$$
$$2 \sin\delta_{ST} F_{SM} [F_X \Gamma_1 \sin\chi_F + G_X \Gamma_3 \sin\chi_G]$$

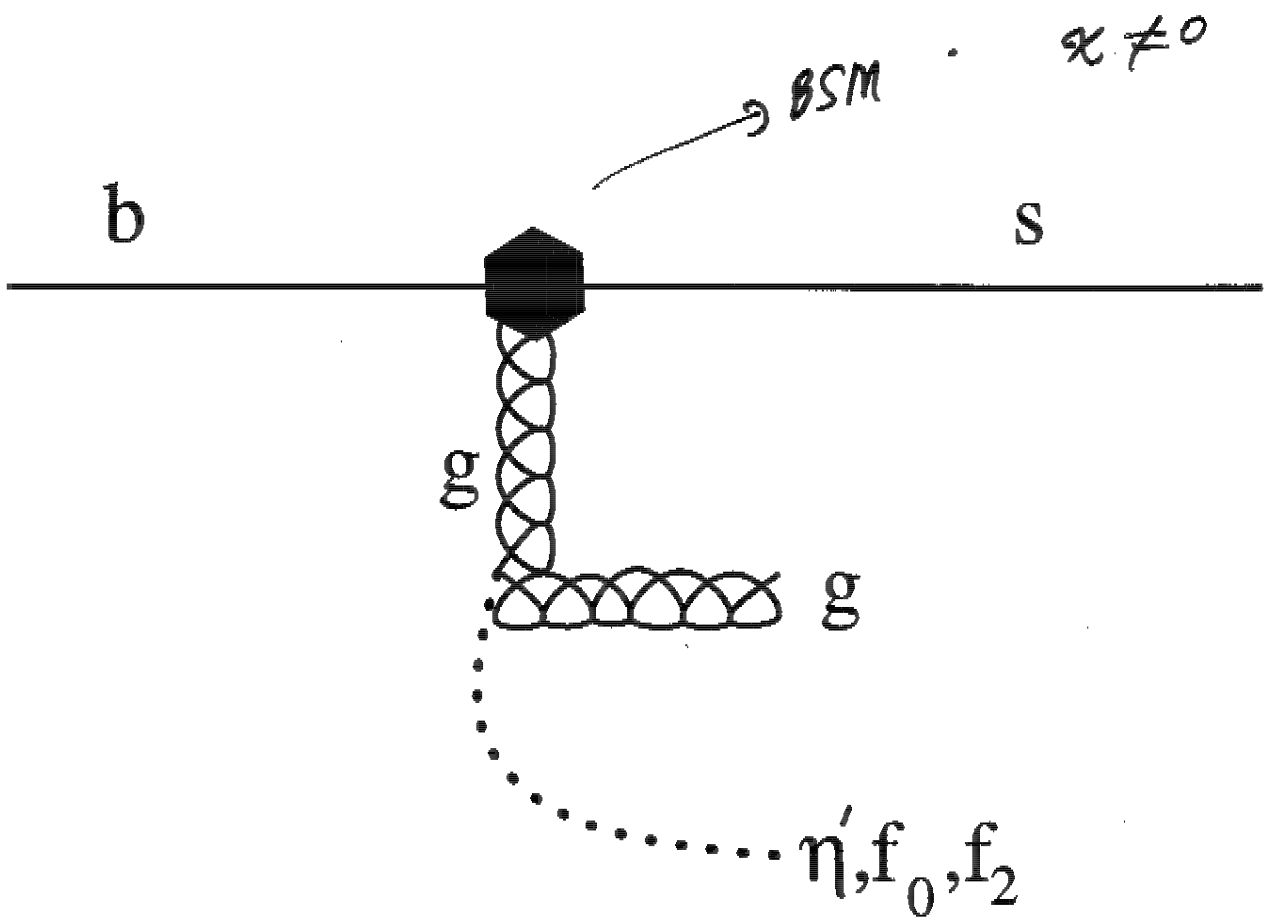
$s \equiv (p_b - p_s)^2, t = (p_s - p_g)^2$
Γ_1 and Γ_3 are functions of s, t and masses..



$u\bar{u} \to u\bar{u}$, $c\bar{c} \to c\bar{c}$ provide FSI phase

CKM phase CP-odd ≈ 0

86 40 27



$x \neq 0$

CKM phase $\simeq 0$

03- 7-11;19:04 ;BELLE GROUP ;+81-298-64-5340 # 86/ 87
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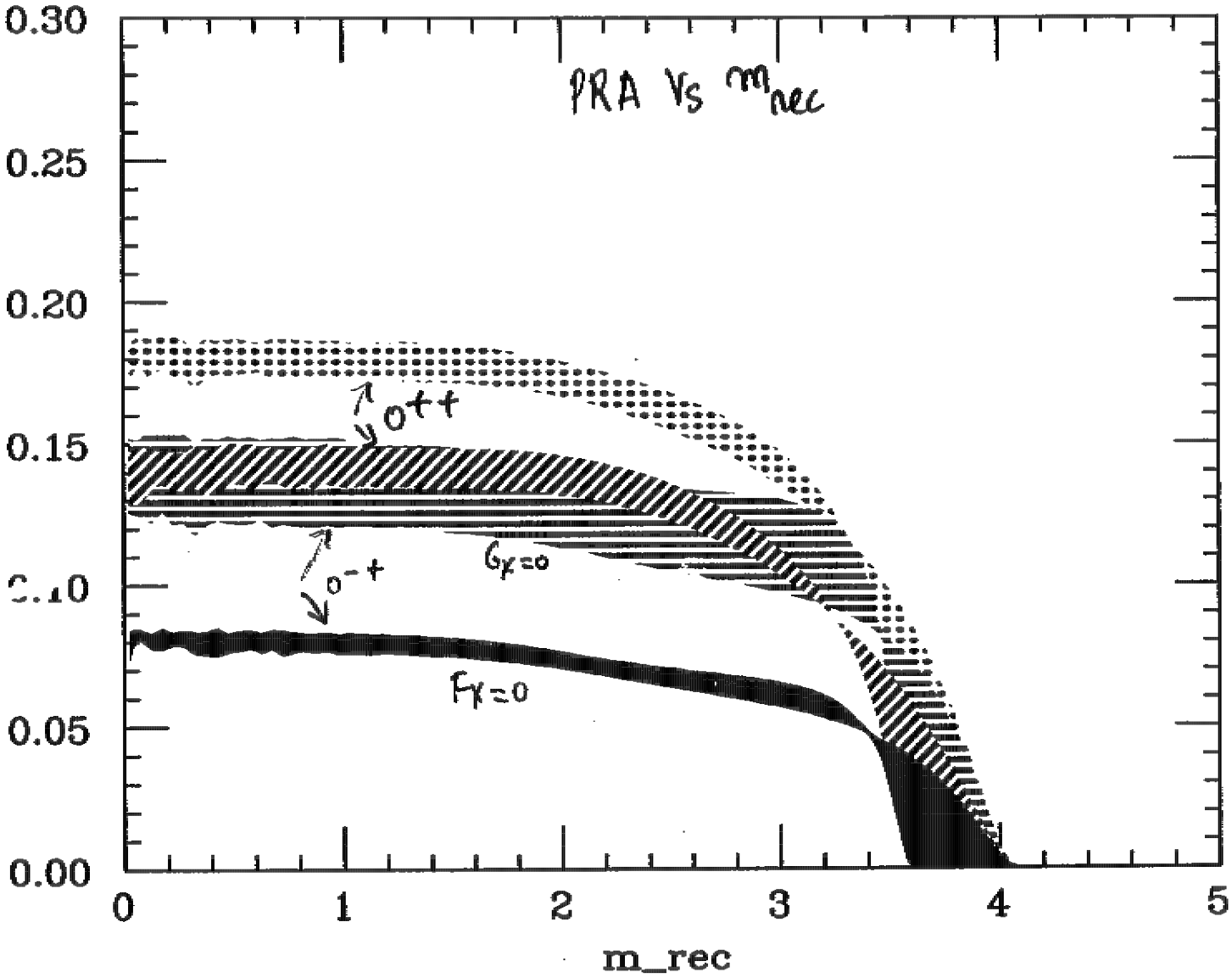
87 (4) ATWOOD TAS PRL 97

Figure 2a

Assume BSM contributes 10% to rate in $\eta' K_S$

$\sin\chi = 1$



24%

28%

24%

12%

For 50% contribution to rate

87 (7)

SUMMARY

GREAT START BY B-FACTORIES ON ANIMP. HUNT
IMPORTANT MILESTON ---- CKM PHASE !
NOT Continuation onto SUPER B will mean Unfinished Job.
SUPER-B with $\sim 10^{10}$ B's will allow :

⇒ Very CLEAN Determination of ALL 3 angles (perhaps can attain the Irreducible Theory error $\lesssim 1\%$)

⇒ NUMEROUS IMPORTANT MEASUREMENTS $B \to \rho\gamma \ldots X_d\gamma$, $X_{s,d} \ell^+\ell^-$ ($\hookrightarrow (K^*, K, \rho, \pi \ldots)$); q^2 dist. for $\rho(\pi)\ell\nu$; $D\tau\nu_\tau$
$\eta' X_d(\pi,\rho)$, $\eta X_d(\pi,\rho)$ + tens more --
THESE WOULD SHARPEN THE THEORETICAL UNDERPINNINGS esp for EWP, pQCD, QCDF ---

⇒ NUMEROUS SEARCHES for X_{BSM} via $A^{CP}(t)$ in
ϕK_S, $\eta' K_S$, $K^*(\rho)\gamma$, $\ell^\pm X$ ----
ALSO via DIR CP in ψK^+, $D\tau\nu_\tau$, τ^1_{pol}; $\gamma X_s(K^*)$, $\gamma X_d(\rho,\omega)$; $K\pi\ell^+\ell^- \ldots$; $\pi^+\pi^0$; $\rho^+\rho^0$
$\eta, \eta' X_s(K_S)$, $\phi\pi$, $\eta' X_d(\pi,\rho)$ ---
SM predicts negligible asy in many cases---

SUPER-B WILL REFINE OUR UNDERSTADING OF FLAVOR PHYSICS TO AN UNPRECEDENTED level --
MOST TANTALIZING PRIZE --- WE should be able to make a serious search for X_{BSM} and thereby significantly illuminate our understandip of Baryogenesis.