Possibility of Large FSI Phases in light of

$B \to K\pi$ & $\pi\pi$ Data

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I. Pathway to $\gamma\ (\phi_3) \gtrsim 90^\circ$ AND Factorization

II. (Central Value) Problems (?)

$K^0\pi^0$ Too Large! $\pi\pi$ too small? A_{CP} central values?

III. Large γ AND $\underbrace{\delta}_{\text{FSI Rescattering Phase Difference}}$?

IV. Remarks & Comments

V. Conclusion

Contributed Paper # 533

I. Pathway to $\gamma \gtrsim 90^\circ$ AND Factorization

Data Driven!

Thank you, CLEO!

Data ↴

1997 $K\pi$, $K^0\pi$ ⟹ <u>Fleischer - Mannel Bound</u> (γ)

⇛ Model-Indep. Methods

1998 $\left.\begin{array}{l} K\pi^0 \sim K\pi \\ \sim K^0\pi \end{array}\right\}$ ⟹ Large γ? EWP?

Deshpande, He, Hou, Pakvasa PRL 1999

1999 $\rho^0\pi$, $\rho\pi$ ⟹ He, Hou & Yang PRL 1999

$\pi\pi \sim \neq K\pi$

$\omega\pi$ (ωK disappear)

$K^0\pi^0$

$\boxed{\text{“}\cos\gamma \lesssim 0 \Rightarrow \text{Factorization Works!”}}$

⇓

<u>Global Fit</u> of

Smith, Hou & Würthwein
hep-ex/9910014

$\gamma \simeq 105^\circ$ w/ Ali, Kramer, Lü Wilson Coeff's

⟹ Conflict with CKM Fit: $58.5^\circ \pm 7.1^\circ$?
A. Stocchi

Well, by end 1999, all B Practitioners [redacted] switch to $\gamma \gtrsim 80^\circ \sim 90^\circ$

2000? ϕK from Belle ↔ CLEO

$\pi\pi/K\pi$ from Belle ↔ BaBar

⋮

II. Problems ?

[$\eta' K$ not understood ....]

- $K^0\pi^0$ Too Large !
- $\pi\pi$ too small ?
- A_{CP} central values ?

Illustrate with Fig. & Table

- EWP ?

Suppresses $K^0\pi^0$

$$\frac{K\pi^0}{K\pi} \sim 0.65 \ \checkmark \quad \because \ \text{EWP} \oplus \text{P}$$

but

$$\frac{K^0\pi^0}{K^0\pi} \simeq \underbrace{\left(\frac{1}{\sqrt{2}}\right)^2}_{\pi^0 \text{ w.f.}} \left| 1 \ominus \underbrace{r_0}_{\frac{f_\pi}{f_K}\frac{F_0^{BK}}{F_0^{B\pi}} \simeq 0.9} \frac{1.5\, a_9}{a_4 + a_6 R} \right|^2 \simeq 1/3 \quad \because \ \boxed{\text{EWP} \ominus \text{P}}$$

$\uparrow \because d\bar{d} \to \pi^0$

$$R = 2\frac{m_K^2}{(m_b - m_d)(m_s + m_d)}$$ chiral enhancement factor

[discuss more latter talks]

- Final State Interactions ?

Alone (with $\gamma = 60^\circ$) Can't Do.

$\pi\pi$ accountable, but $K\pi$ a mess.

Fig.

$K\pi/\pi\pi$ Data $(\times 10^{-6})$

	CLEO	$\overbrace{\text{Belle} \quad \text{BaBar}}^{\text{New}}$	
	CLEO	Belle	BaBar
$K\pi$	17 ± 3	17 ± 6	$12.5^{+3.3}_{-3.1}$
$K^0\pi$	18 ± 5	$[17^{+10}_{-8}]$	
$K\pi^0$	12 ± 3	19 ± 6	
$K^0\pi^0$	15 ± 6	21^{+10}_{-8}	
$\pi\pi$	$4.3^{+1.7}_{-1.5}$	$[6.3 \pm 4.2]$	$9.3^{+2.9}_{-2.7}$
$\pi\pi^0$	$[5.4^{+2.6}_{-2.5}]$	$[3.3^{+3.6}_{-2.8}]$	
KK	<2	<6	<6.6
KK^0	<5	<8	

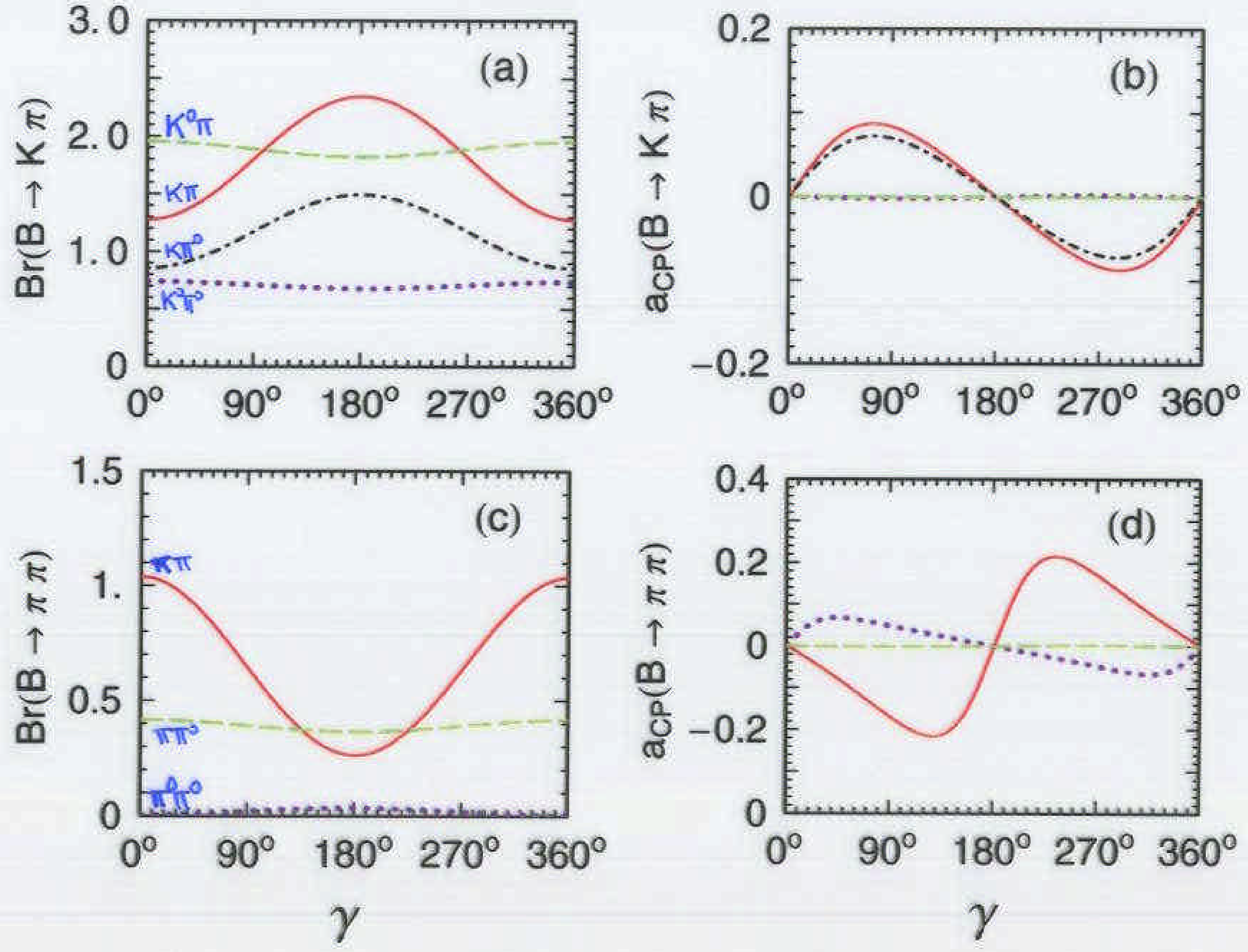
A_{CP} from CLEO

	CLEO	TH (fac.)
$K^-\pi^+$	-0.04 ± 0.16	$+$ few %
$K^-\pi^0$	-0.29 ± 0.23	$+$ few %
$\bar{K}^0\pi^-$	$+0.18 \pm 0.24$	$\sim 0\%$

Curves first drawn in Deshpande, He, Hou & Pakvasa, PRL 1999
to illustrate Large γ Needed $\ni$ $K\pi \sim K^0\pi$

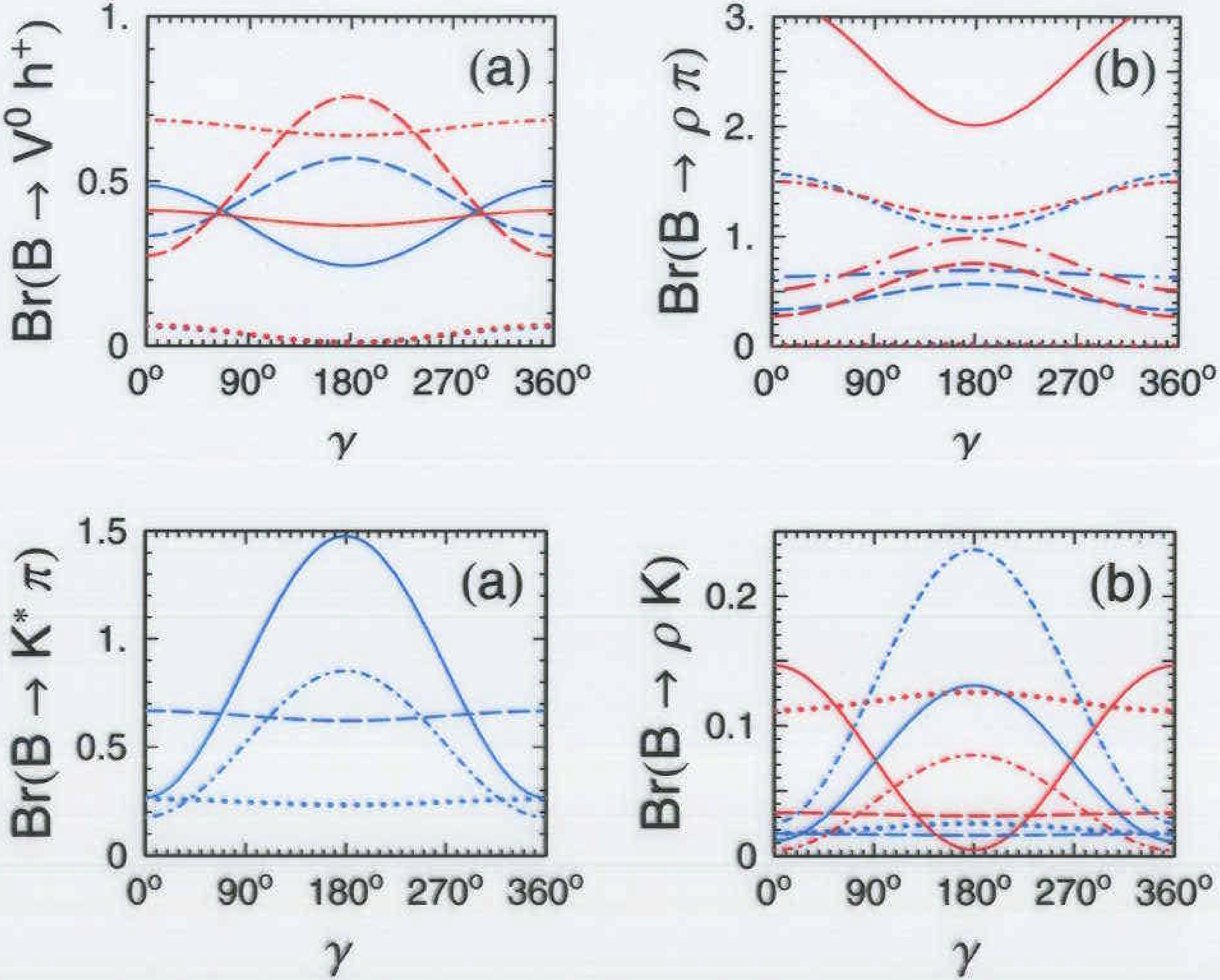
$K^0\pi^0$
Not
Well
Accounted

Large γ leads to $\pi\pi$ suppression
first discussed by He, Hou & Yang, PRL 1999

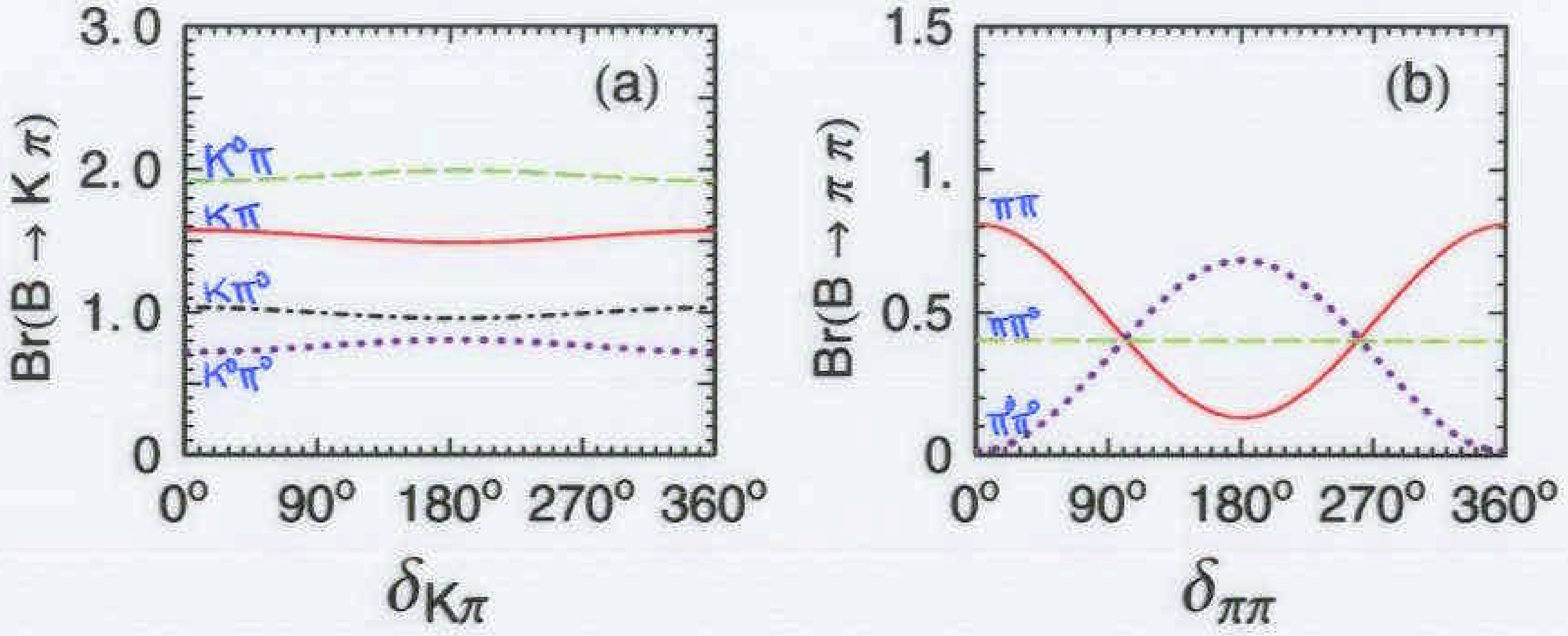


Br(B → K π)
3.0
2.0
1.0
0
(a)
K⁰π
Kπ
Kπ⁰
K⁰π⁰
aCP(B → K π)
0.2
0
−0.2
(b)
Br(B → π π)
1.5
1.
0.5
0
(c)
ππ
ππ⁰
π⁰π⁰
aCP(B → π π)
0.4
0.2
0
−0.2
0
(d)
0° 90° 180° 270° 360°
γ

From He, Hou, Yang 1999



$\gamma = 64^\circ$ taken



$K\pi \longleftrightarrow K^0\pi^0$

$K^0\pi \longleftrightarrow K\pi^0$

$\pi\pi \longleftrightarrow \pi^0\pi^0$

III. Large γ & δ?

Hou & Yang, PRL 2000

Simple Formalism for $\delta \neq 0$ (beyond factorization)

$$\begin{cases} \mathcal{A}(B \to \pi\pi) = A_0 e^{i\delta_0} + A_2 e^{i\delta_2} \\ \mathcal{A}(B \to \pi^0\pi^0) = \frac{1}{\sqrt{2}} A_0 e^{i\delta_0} - \sqrt{2} A_2 e^{i\delta_2} \\ \mathcal{A}(B \to \pi\pi^0) = \frac{3}{\sqrt{2}} A_2 e^{i\delta_2} \end{cases}$$

$I_{\pi\pi} = 0, 2$

$$\begin{cases} \mathcal{A}(B \to K\pi) = A_{3/2} e^{i\delta_{3/2}} - (A_{1/2} - B_{1/2}) e^{i\delta_{1/2}} \\ \mathcal{A}(B \to K^0\pi^0) = \sqrt{2} A_{\frac{3}{2}} e^{i\delta_{3/2}} + \frac{1}{\sqrt{2}} (A_{\frac{1}{2}} - B_{1/2}) e^{i\delta_{1/2}} \\ \mathcal{A}(B \to K^0\pi) = -A_{3/2} e^{i\delta_{3/2}} + (A_{1/2} + B_{1/2}) e^{i\delta_{1/2}} \\ \mathcal{A}(B \to K\pi^0) = \sqrt{2} A_{3/2} e^{i\delta_{3/2}} + \frac{1}{\sqrt{2}} (A_{1/2} + B_{1/2}) e^{i\delta_{1/2}} \end{cases}$$

$I_{K\pi} = \frac{1}{2}, \frac{3}{2}$

Ansatz: $\begin{cases} A_{0,2} \ \& \ A_{\frac{1}{2},\frac{3}{2}} \text{ from factorization} \\ \delta_{0,2} \ \& \ \delta_{\frac{1}{2},\frac{3}{2}} \text{ "model" FSI hadronic phase} \end{cases}$

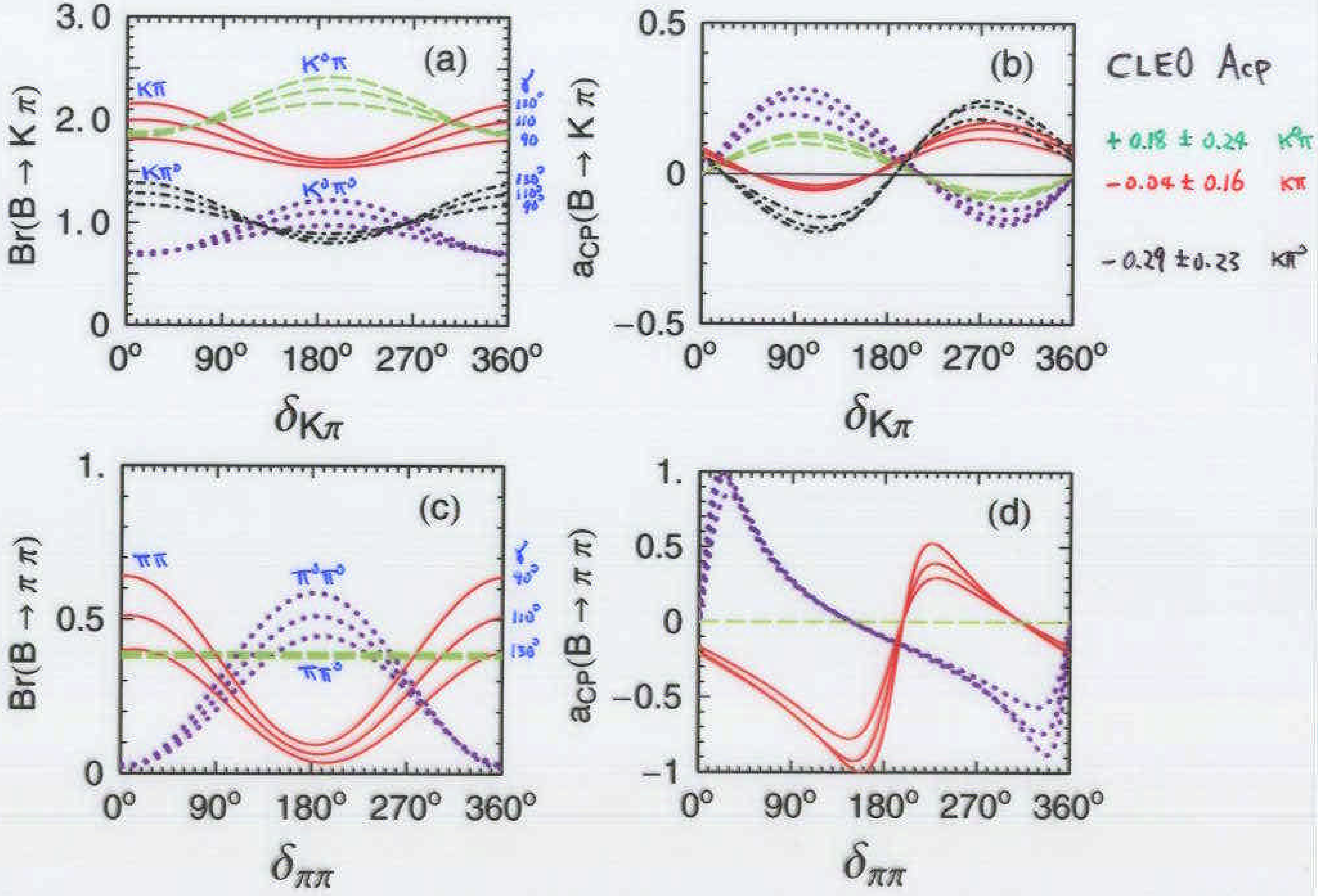
Tempting to use SU(3), but although $\delta_2 \cong \delta_{3/2}$, $\delta_0 \neq \delta_{1/2}$

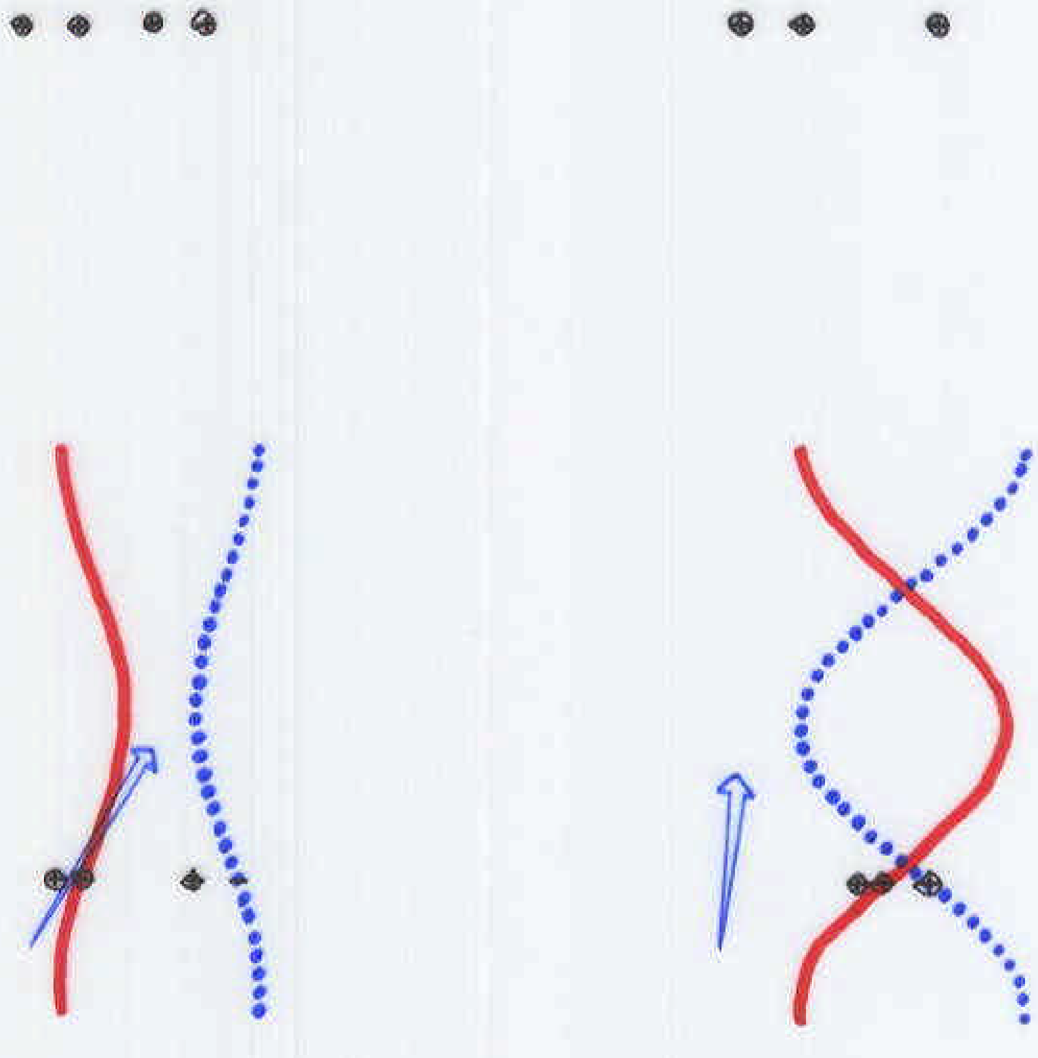
$\because (\pi\pi)_{I=0}$ has $\underset{\sim}{1}$, 8, 27

Furthermore $B \to K^+K^-$ Not observed.

$\therefore$ New params.: $\delta_{\pi\pi} = \delta_2 - \delta_0$ & $\delta_{K\pi} = \delta_{3/2} - \delta_{1/2}$

Fig.


(a)
Br(B → K π)
3.0
2.0
1.0
0
0°
90°
180°
270°
360°
δKπ
Kπ
K°π
Kπ°
K°π°
γ
130°
110
90
130°
110°
90°
(b)
aCP(B → K π)
0.5
0
−0.5
(c)
Br(B → π π)
1.
0.5
ππ
π°π°
ππ°
90°
110°
130°
δππ
(d)
aCP(B → π π)
−1
CLEO ACP
+0.18 ± 0.24 K°π
−0.04 ± 0.16 Kπ
−0.29 ± 0.23 Kπ°



Trend Good !

	$K\pi$	:	$K^0\pi$	:	$K\pi^0$	:	$K^0\pi^0$	
Data	1	:	1.06	:	0.67	:	0.85	(CLEO only)
$\gamma \simeq 110^\circ$	1	:	0.94	:	0.65	:	0.35	
" ⊕ $\delta \sim 90^\circ$	1	:	1.12	:	0.61	:	0.47	Δ 35% increase

$\pi\pi < \pi\pi^0$ achieved

Central Value for $K\pi, K^0\pi, K\pi^0$ Acp's Just Right.

Predictions [γ Large, $\delta \sim 90^\circ$]

- $A_{CP}^{\bar{K}^0\pi^0} \sim - A_{CP}^{K^0\pi^0}$
- $\pi^0\pi^0 \sim \pi\pi \sim \underbrace{3-5 \times 10^{-6}}_{\text{still satisfy CLEO bound}} \lesssim \pi\pi^0$
- $A_{CP}^{\pi\pi} \sim -60\%$! (Possible)

$A_{CP}^{\pi^0\pi^0} \sim -30\%$

But, BaBar $\pi\pi$ ....

Measurable in couple of years.

[Detailed numbers may shift, but trend as above]

IV. Remarks & Comments

- Inelasticity?

$$|B\rangle \longrightarrow \underbrace{|i\rangle \longrightarrow K\pi}_{\text{Highly Inelastic}}$$

Our Simple Approach ~ Elastic $2 \longrightarrow 2$ only

But, $\begin{cases} \text{"Pomeron"}: & \sim e^{i\frac{\pi}{2}}\ \forall_{\text{channel}} \Longrightarrow \delta \equiv \delta_1 - \delta_2 \simeq 0 \\ \text{"Regge"}: & \text{subleading} \Longrightarrow \delta \simeq 10^\circ - 20^\circ \end{cases}$

[supported by averaging over random inelasticities, too]

Furthermore, $K^-\pi^+ \longrightarrow \bar{K}^0\pi^0$ ~ charge exchange @ $p_K \sim p_\pi \sim 2.5$ GeV?

Counter-Intuitive!

★ Our Approach is **Phenomenological**

Large γ ⊕ Simple Factorization

⇝ Minimal Extension of FSI phase.

- pQCD: Beneke, Buchalla, Neubert & Sachrajda

Long-distance effects $1/m_B$ suppressed

but, Keum, Li & Sanda et al.

$\delta \sim 90^\circ$ ∵ Annihilation Contribution?

Interesting to see how to account for Large δ in QCD! (if true)

Comments

- Some people define $\delta = \delta_P - \delta_T$
  This is a mixture of inelastic and elastic.
- Followup work by Wu & Zhou, PRD 2000
  Force $K^0\pi$ to be pure P. Assumption too strong.
- Zhou, Wu, Ng & Geng, hep-ph/0006225
  - "SU(3)": $\delta_{3/2} \simeq \delta_2$ OK, but $\delta_{1/2} \simeq \underbrace{\delta_0}_{(\pi\pi)_0 \text{ has } 1}$ X
  - $b^u_{1/2} \simeq b^c_{1/2}$? Probably too strong.
  - To explain $K^0\pi^0$ large, find
    "$a^c_{3/2}$" $\sim$ 8 − 10 × $\underbrace{\text{factorization result}}_{\text{EWP}}$
    Argue that, EWP cannot be large
    $\Rightarrow$ FSI such as $D\bar{D} \to \pi\pi$, $D\bar{D}_s \to \pi K$
    This cannot be right!
    $B \to D\bar{D}_s + X \sim b \to c\bar{c}s$ is $\Delta I = 0$
    CANNOT ENTER $a^c_{3/2}$!
- Xing, hep-ph/0007136
  $\underbrace{\text{illustrate}}$ $B \to D\bar{D} \to \pi\pi$ Inelastic rescattering
  OK. But single channel is meaningless.

Inelastic Phases Impossible to understand,
$\because$ Too many channels.

$\boxed{2 \to 2 \text{ Elastic is Unique}}$

And models hadronic interactions beyond factorization.

Conclusion

- Data Well accounted for by Factorization, for $\gamma \gtrsim 90^\circ$

  Except: $K^0\pi^0$ Large / $\pi^+\pi^-$ small / $A_{CP}^{K\pi}$ pattern

- Find Coherent Picture:

  γ is Large ⊕ FSI δ Large

  if Current Central Values(*) taken at face value.

Consequence $\Rightarrow$
$$\begin{cases} \text{Large } a_{CP} \text{ in } \bar{K}^0\pi^- \text{ \& } \bar{K}^0\pi^0 \\ \text{Large } \pi^0\pi^0 \; (\sim \pi^+\pi^- \lesssim \pi^+\pi^0) \\ \text{Large } a_{CP}^{\pi^+\pi^-} \sim -60\% \end{cases}$$

Testable in couple of years.

(*) Yes, I'm aware of "Central Value Problem"