Clean Signals of New Physics in B decays

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KEK Physics Seminar, Tuesday 27th June 2006

4:00 pm

Talk at:

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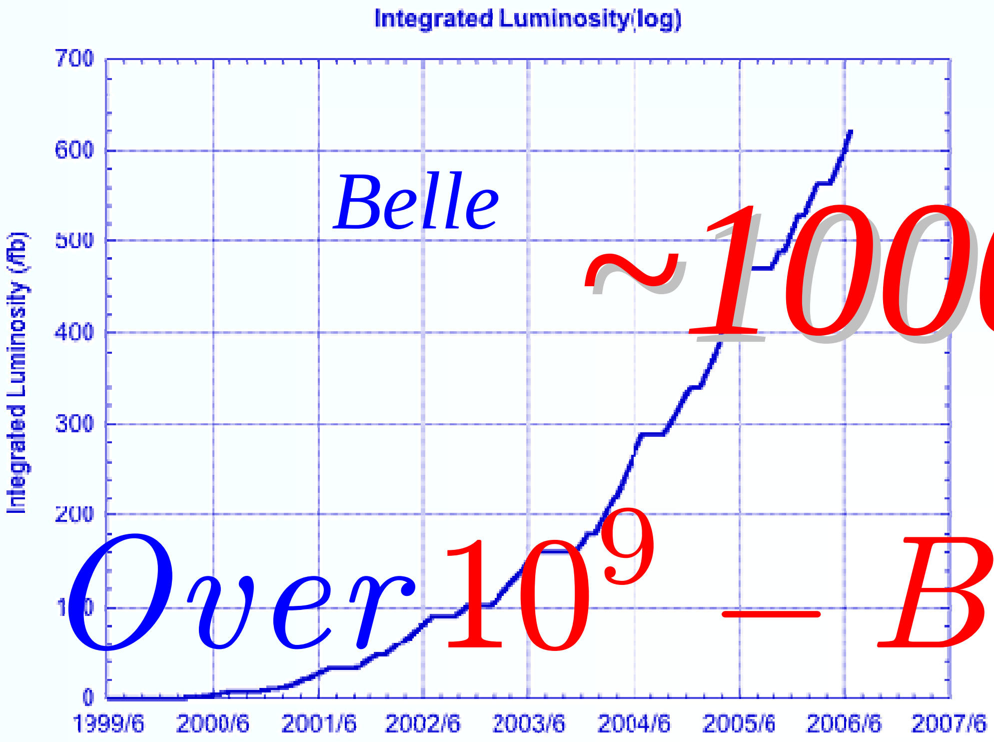
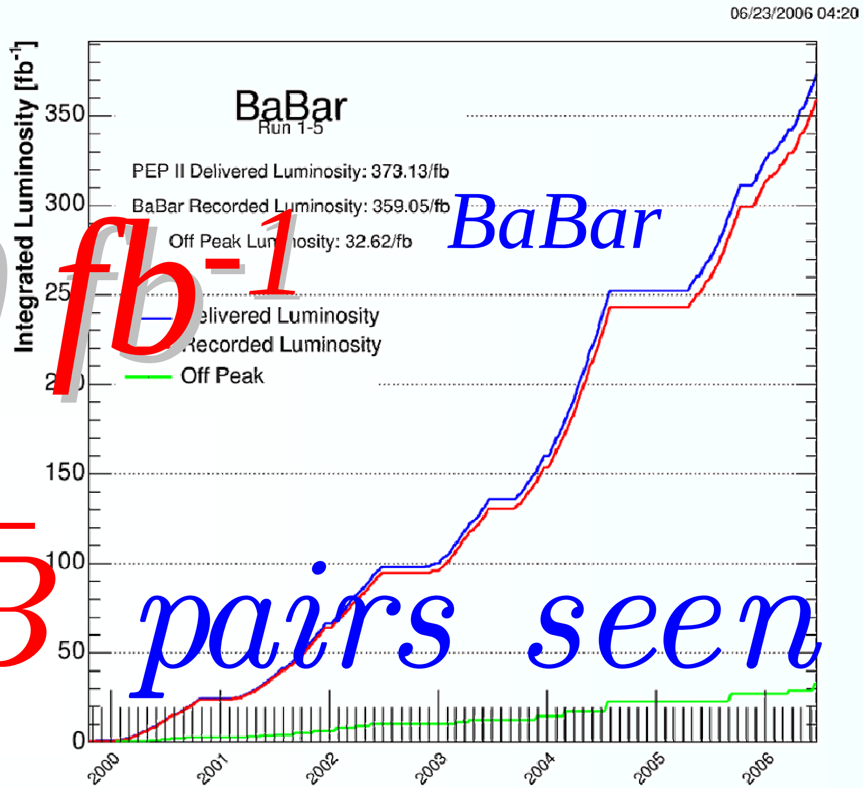
…the effect is telling us that at some tiny level there is a fundamental asymmetry between matter and antimatter, …. We know that improvements in detector technology and quality of accelerators will permit even more sensitive experiments in coming decades. We are hopeful, then at some epoch, perhaps distant, this cryptic message from nature will be deciphered

Cronin (Nobel lectures 1980)

KEK

Spectacular performance at B factories





$\sim 1000\ fb^{-1}$

$Over\ 10^9 - B\bar{B}\ pairs\ seen$

Confirmation of KM theory. Look for deviations not alternatives.
Any deviation from KM not breakdown of KM but New Physics.
Fortunate, since NP must be small.

Large data sets herald start of a new era
$\rightarrow$ B physics becomes precision physics.

CKM matrix has hierarchical structure

Wolfenstein Parameterization

$$\mathbf{V} = \begin{pmatrix} V_{ud} & V_{us} & Vub \\ V_{cd} & V_{cs} & Vcb \\ V_{td} & V_{ts} & Vtb \end{pmatrix} = \begin{pmatrix} 1-\frac{\lambda^2}{2}-\frac{\lambda^4}{8} & \lambda & A\lambda^3(\rho+i\eta) \\ -\lambda+A^2\lambda^5(\frac{1}{2}-\rho-i\eta) & 1-\frac{\lambda^2}{2}-\frac{\lambda^4}{8}(1+4A^2) & A\lambda^2 \\ A\lambda^3(1-\bar{\rho}-i\bar{\eta}) & -A\lambda^2+A\lambda^4(\frac{1}{2}-\rho-i\eta) & 1-\frac{1}{2}A^2\lambda^4 \end{pmatrix} + \mathcal{O}(\lambda^6)$$

How sensitive are we to λ^4 order terms? Don't give up. New Physics (NP) can be at this order or smaller.

Fortunately we already see hints of NP, probably at this order.

- *The value of sin2ϕ_1 measured using various modes differs.*
- *Ratios of branching fractions of $B \rightarrow K\pi$ modes inconsistent with SM expectation: $K\pi$ puzzle.*
- *An unexpectedly large transverse polarization amplitude in $B^0 \rightarrow \phi K^*$ has also been observed.*

Unfortunately, curse of QCD. Weak decays are masked by non-perturbative QCD effects. Difficult to estimate. These effects do not allow simple signal of NP.

One wonders whether these hints are mere hadronic/QCD effects or signals of NP. ***Dilemma in B-physics today because convincing arguments lacking.***

Correct questions:

- *Under what conditions can these discrepancies be regarded as an unambiguous signal of NP?*
- *Are there any clean signals of NP, i.e. signals free of QCD/hadronic effects.*

We examine these questions within a model independent approach.

Discrepancy in measured $\sin 2\phi_1$

Rahul Sinha, Basudha Misra and Wei-Shu Hou, hep-ph/0605194

World Averages $b \to s$ *Penguins*

$\sin 2\phi_1 (b \to c\bar{c}s) = 0.69 \pm 0.03$

$\sin 2\phi_1 (b \to sq\bar{q}) = 0.50 \pm 0.06$

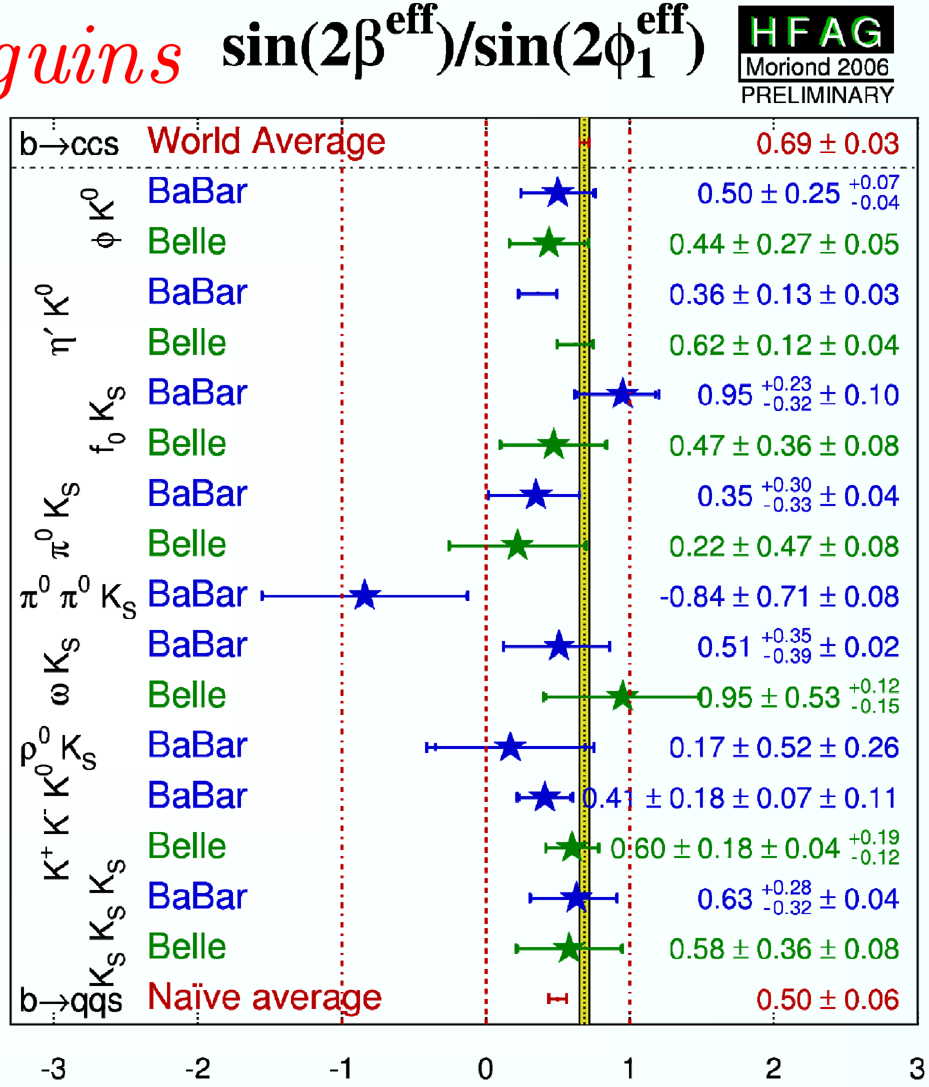
Naive average $q = u,d,s$

C.L. ~0.0092 (2.6 σ)

Discussion does not really depend on naïve average

Deviation from SM

New Physics ???...



Compare with CKM fitter value $\sin 2\phi_1 = 0.742^{+0.072}_{-0.026}$

The most general amplitude for $b \to s$ transition modes within SM may be written as

$$A^{b\to s} = \mathcal{A}_u e^{i\delta_u} v_u + \mathcal{A}_c e^{i\delta_c} v_c + \mathcal{A}_t e^{i\delta_t} v_t$$

Amplitudes for quark level contributions

Strong phases

$v_j = V^*_{jb} V_{js}$

Unitarity of CKM $\Rightarrow$ $v_u + v_c + v_t = 0$

v_c is real upto $\mathcal{O}(\lambda^6)$

$v_u = A\lambda^4(\rho + i\eta)$ $\quad v_t = -A\lambda^2 + A(\frac{1}{2} - \rho - i\eta)\lambda^4 + \mathcal{O}(\lambda^6)$

$\gamma \equiv \phi_3 \approx 60^o$ $\quad \beta_s \equiv \phi_4 = 1.045^{o}{}^{+0.061^o}_{-0.057^o}$ CKM Fitter

The same amplitudes may be written as

$$A^{b\to s} = (\mathcal{A}_c e^{i\delta_c} - \mathcal{A}_t e^{i\delta_t}) v_c + (\mathcal{A}_u e^{i\delta_u} - \mathcal{A}_t e^{i\delta_t}) v_u \qquad v_t = -v_u - v_c$$

$$A^{b\to s} = e^{i\Theta'}\left[a' + b' e^{i\delta'} e^{i\phi_3}\right] \qquad a' = |v_c|\,\hat{a}' = |v_c|\left|\mathcal{A}_c e^{i\delta_c} - \mathcal{A}_t e^{i\delta_t}\right|,$$

Θ' overall strong phase $\to 0$ $\qquad b' = |v_u|\,\hat{b}' = |v_u|\left|\mathcal{A}_u e^{i\delta_u} - \mathcal{A}_t e^{i\delta_t}\right|,$

δ' is the strong phase difference between a' and b'

Or using $v_u = -v_t - v_c$

$$A^{b\to s} = (\mathcal{A}_c e^{i\delta_c} - \mathcal{A}_u e^{i\delta_u})v_c + (\mathcal{A}_t e^{i\delta_t} - \mathcal{A}_u e^{i\delta_u})v_t$$

$$A^{b\to s} = e^{i\Theta''}\left[a'' + b''\, e^{i\delta''}\, e^{i\phi_4}\right] \qquad a'' = |v_c|\,\hat{a}'' = |v_c|\left|\mathcal{A}_c\, e^{i\delta_c} - \mathcal{A}_u e^{i\delta_u}\right|$$

$$\Theta'' \to 0 \qquad b'' = |v_t|\,\hat{b}'' = |v_t|\left|\mathcal{A}_u\, e^{i\delta_u} - \mathcal{A}_t\, e^{i\delta_t}\right|$$

δ'' *is the strong phase difference between* a'' *and* b''

Amplitude for decay of $B_d^0 \to f_i$ $\qquad A_i = a_i + b_i e^{i\delta_i}\, e^{i\phi}$

ϕ *can be* ... $\bar{B}_d^0 \to f_i$ $\qquad \bar{A}_i = a_i + b_i e^{i\delta_i}\, e^{-i\phi}$

Measured value

Time depen...

$$\Gamma(B^0(t) \to f_i) \propto B_i\,(1 + C_i \cos(\Delta M t) - S_i \sin(\Delta M t))$$

polluting phase in SM

$$B_i = \frac{|A_i|^2 + |\bar{A}_i|^2}{2} = a_i^2 + b_i^2 + 2\,a_i\,b_i\,\cos\phi\cos\delta_i,$$

$$C_i = \frac{|A_i|^2 - |\bar{A}_i|^2}{|A_i|^2 + |\bar{A}_i|^2} = \frac{-2\,a_i\,b_i\,\sin\phi\sin\delta_i}{B_i}$$

$$S_i = \sqrt{1 - C_i^2}\,\sin 2\phi_1^i = -\sqrt{1 - C_i^2}\,\frac{\mathrm{Im}(e^{-2i\phi_1} A_i^* \bar{A}_i)}{|A_i||\bar{A}_i|}$$

Since the measured $\sin 2\phi_1$ *differs between two modes, we must relate this difference with the weak phase* ϕ.

$$\sin(2\phi_1^i) \Rightarrow 2\phi_1^i, \pi - 2\phi_1^i \qquad \text{2-fold ambiguity}$$

4 fold ambiguity in the difference between the values measured using two different modes. $\pm(2\phi_1^i - 2\phi_1^j), \pm\pi \mp (2\phi_1^i + 2\phi_1^j)$

- *Worry only about the principal values.*
- *Derive a relation or bound between the deviation in the principal values and* ϕ.
- *We can then conclude that* $\sin 2\phi_1{}^i$ *for the two modes must be such that their principal values obey the relation or bound.*

Define

$$\eta_i = \arg A_i - \arg \bar{A}_i \qquad A_i^* \bar{A}_i = |A_i||\bar{A}_i| e^{-i\eta_i} \Rightarrow \eta_i = 2\phi_1^i - 2\phi_1$$

$$\omega = (2\phi_1^i - 2\phi_1^j) = \eta_1 - \eta_2 \qquad Define\, \omega > 0 \Rightarrow 2\phi_1^{(1)} > 2\phi_1^{(2)}$$

4 observables B_i, C_i, S_i, ϕ 4 variables $a_i, b_i, \delta_i, \phi_1$

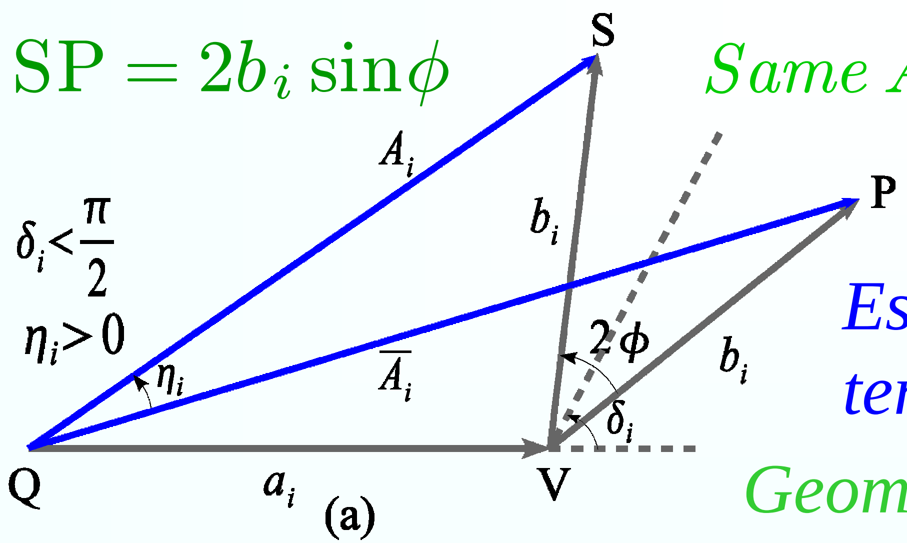
$$A_i = a_i + b_i e^{i\delta_i} e^{i\phi}$$
$$\bar{A}_i = a_i + b_i e^{i\delta_i} e^{-i\phi}$$
$$\Rightarrow$$
$$A_i - \bar{A}_i = 2b_i \sin\phi$$
$$A_i e^{-i\phi} - \bar{A}_i e^{i\phi} = -2a_i \sin\phi$$

Easy to derive

Relation between η_i and ϕ

$$a_i^2 = \frac{B_i}{2\sin^2\phi}\left(1 - \sqrt{1 - C_i^2}\cos(\eta_i - 2\phi)\right)$$
$$b_i^2 = \frac{B_i}{2\sin^2\phi}\left(1 - \sqrt{1 - C_i^2}\cos(\eta_i)\right)$$
$$\tan\delta_i = \frac{C_i \sin\phi}{\cos\phi - \sqrt{1 - C_i^2}\cos(\eta_i - \phi)}$$

$$\mathrm{SP} = 2b_i \sin\phi$$

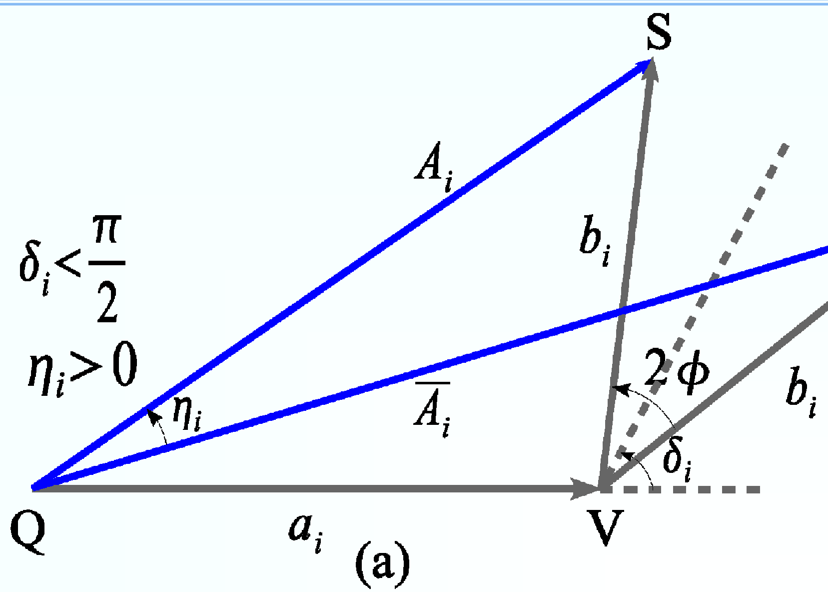


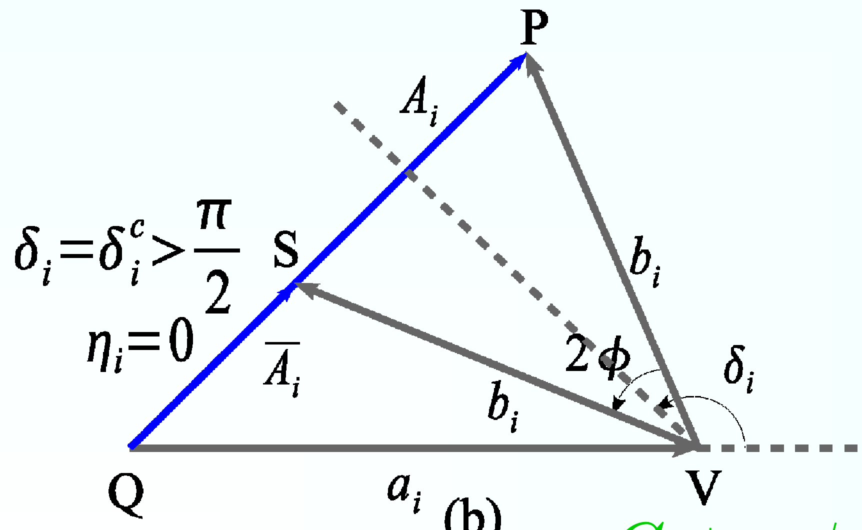
Same A_i and $\bar{A}_i$ using different $a_i, b_i, \eta_i, \delta_i$

V can lie along bisector of SP

Essential to express all quantities in terms of irreducible variables

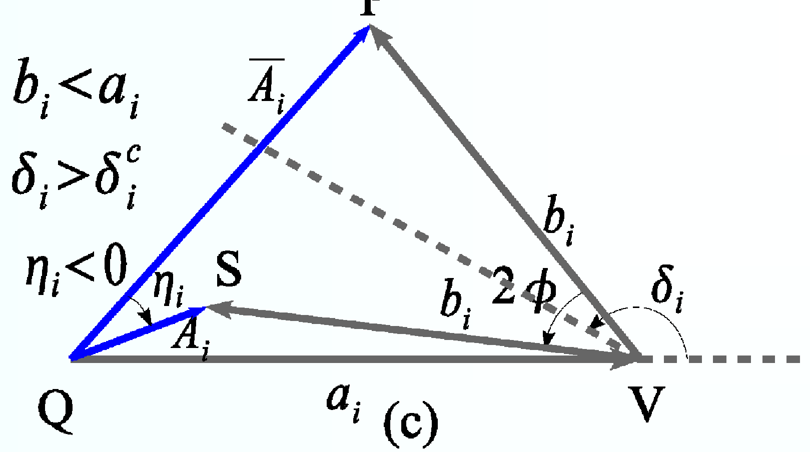
Geometric approach superior over algebraic

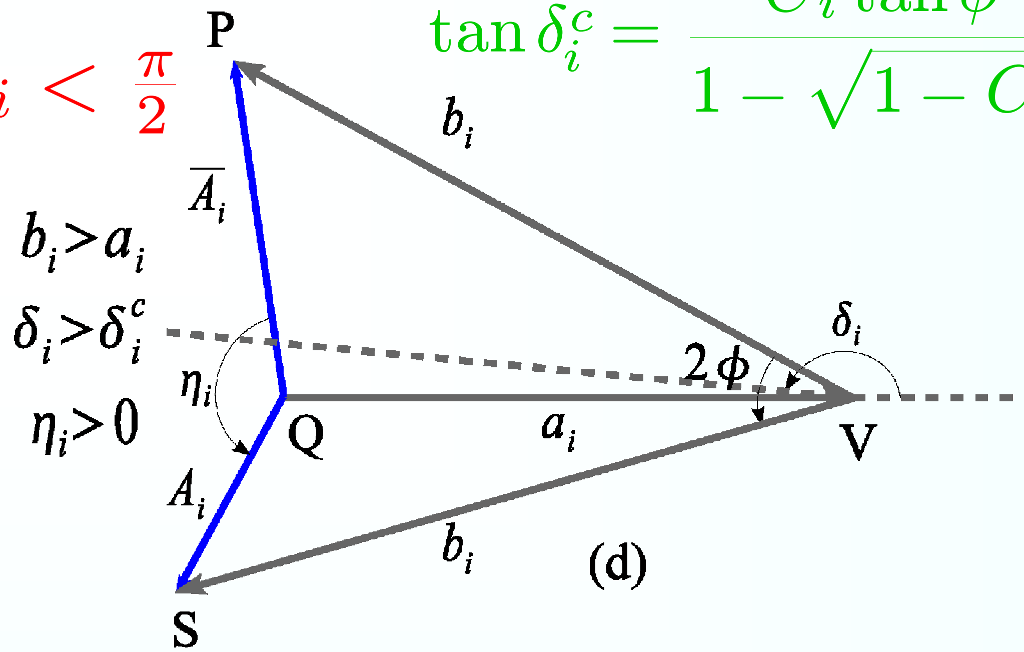




$$\tan\delta_i^c = \frac{C_i\tan\phi}{1-\sqrt{1-C_i^2}}$$

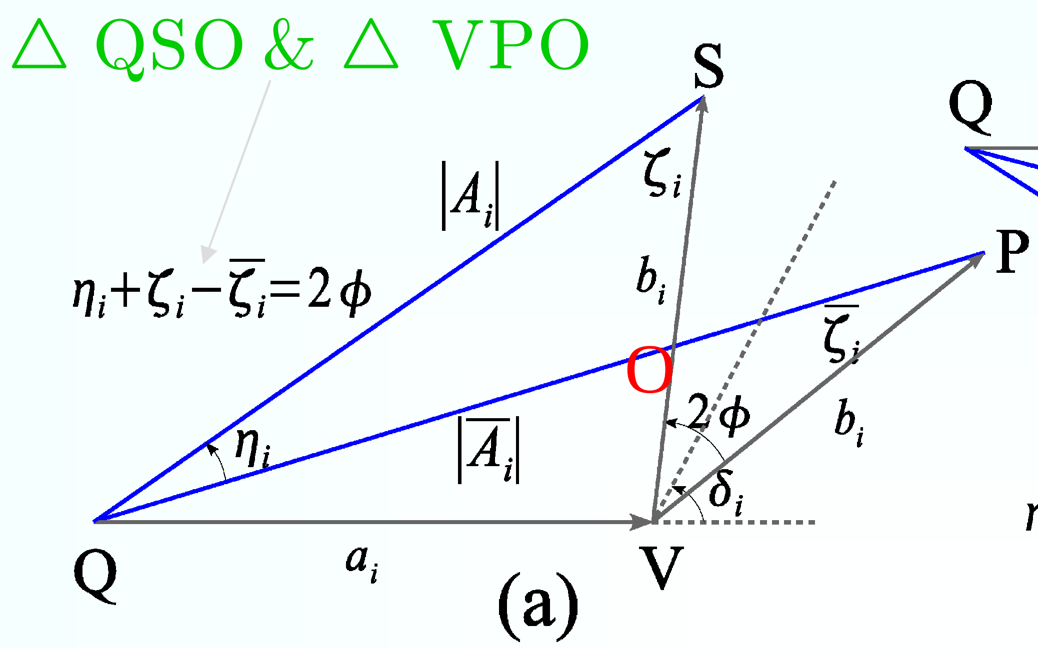
$$\phi > 0, 0 < \delta_i < \frac{\pi}{2}$$

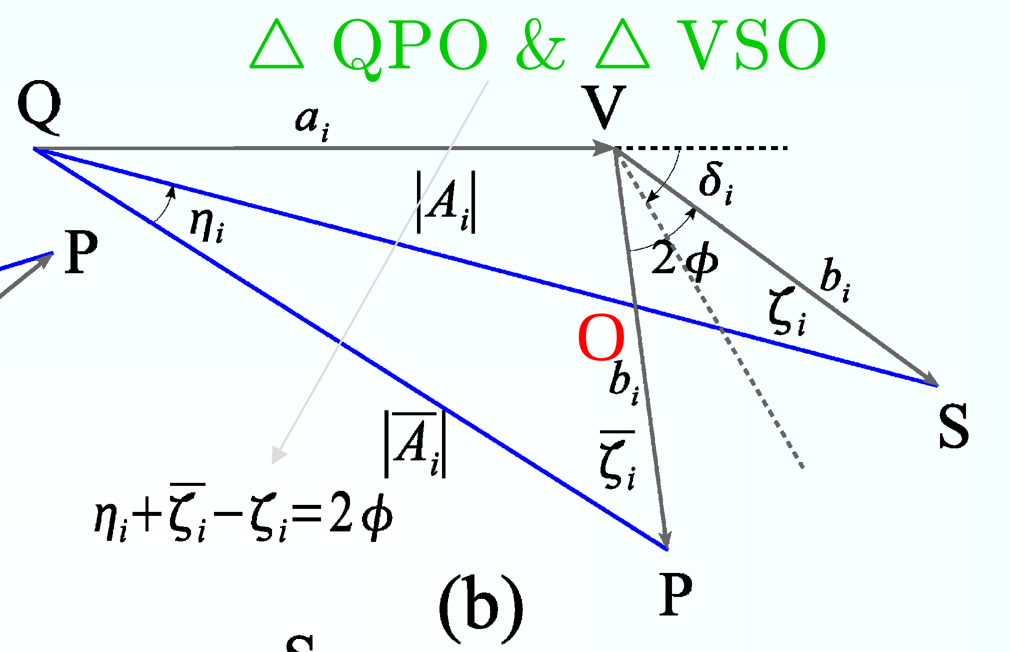


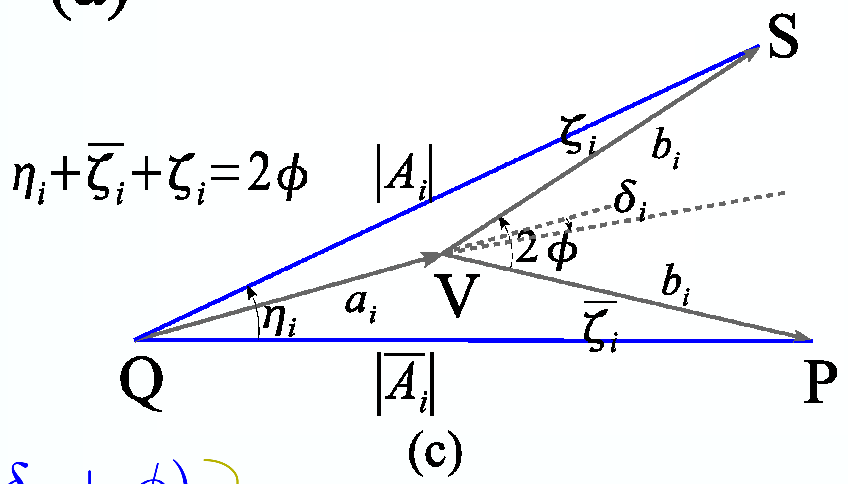


Easily generalize to $\phi < 0$ *and/or* $-\frac{\pi}{2} < \delta_i < 0$

ϕ *and* η_i *have same sign as long as* $|\delta_i| < |\delta_i^c|$







$$\phi > 0, 0 < \delta_i < \frac{\pi}{2}$$

$$\left.\begin{array}{l} \dfrac{\sin\zeta_i}{a_i} = \dfrac{\sin(\delta_i+\phi)}{|A_i|} \\[2ex] \dfrac{\sin\bar{\zeta}_i}{a_i} = \dfrac{\sin(\delta_i-\phi)}{|\bar{A}_i|} \end{array}\right\}$$

$$|A_i|\sin\zeta_i - |\bar{A}_i|\sin\bar{\zeta}_i = 2a_i\sin\phi\cos\delta_i$$

$$\delta < \frac{\pi}{2} \quad \Rightarrow \frac{\sin\bar{\zeta}_i}{\sin\zeta_i} < \frac{|A_i|}{|\bar{A}_i|} < 1 \quad \Rightarrow \bar{\zeta}_i < \zeta_i$$

$$0 \le \eta_i \le 2\phi$$

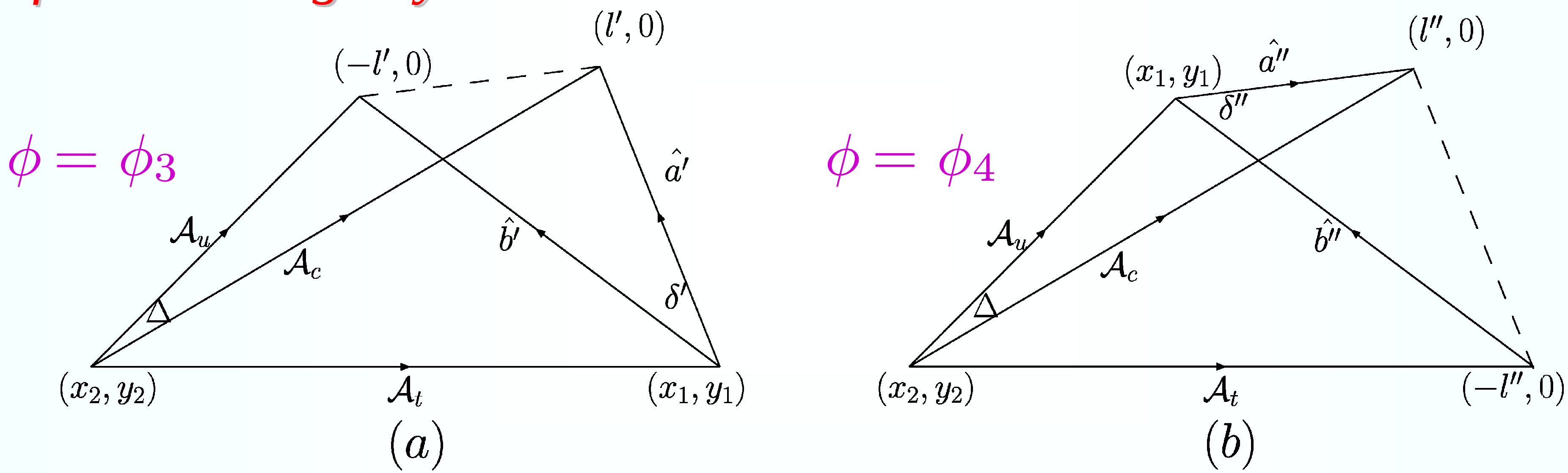
Reasonable to assume that $\mathcal{A}_c$ dominates in $b \to c\bar{c}s \quad \Rightarrow \eta_1 \approx 0$

$2\omega = \eta_1 - \eta_2 \approx -\eta_2 < 0$ *since* $0<\eta_i<2\phi$ **Contradiction**

Only way to resolve the contradiction is to assume that $|\delta_i| > |\delta_i^c|$

We need to determine when $|\delta_i| > |\delta_i^c|$ *and when* $|\delta_i| < |\delta_i^c|$

before drawing any conclusions.

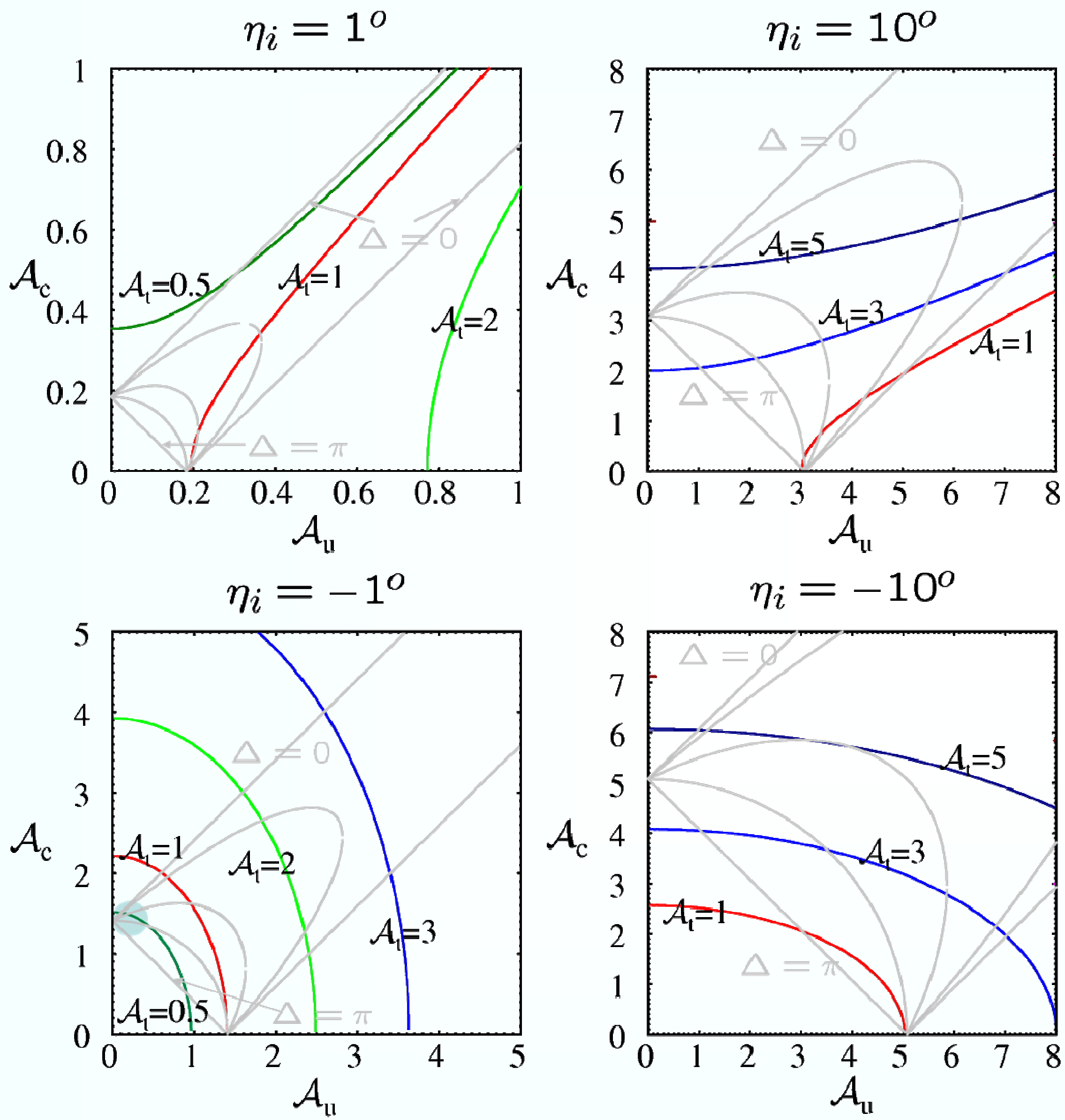


(x_1, y_1), (x_2, y_2), l'/l'' *can be solved in terms of* $\mathcal{A}_u, \mathcal{A}_c, a_i, b_i, \delta_i$

$a_i^2, b_i^2, \tan\delta_i$ *evaluated in terms of* η_i, ϕ *and observables*

$\mathcal{A}_t, \Delta \equiv |\delta_c - \delta_u|$ *expressed in terms of* $\mathcal{A}_u, \mathcal{A}_c, \eta_i$

$\mathcal{A}_u, \mathcal{A}_c, \mathcal{A}_t$ *CKM parameterization independent.*



$$\Delta = 0, \frac{\pi}{6}, \frac{\pi}{3}, \frac{\pi}{2}, \pi$$

Set C_i=0 consistent with data

Finite C_i implies large a_i,b_i

and $|\tan\delta_i| \Rightarrow$ *larger* $\mathcal{A}_q$

Normalization:

$$\mathcal{A}_u = \mathcal{A}_t = 0 \Rightarrow \mathcal{A}_c = 1$$

Clear hierarchy in values of

$\mathcal{A}_q$ *which depends only on* η_i

$|\mathcal{A}_u|^2(|\mathcal{A}_u|^2), |\mathcal{A}_t|^2 \approx 10-25$

times observed branching ratio

If 2ω =5^o in future, 10 times observed branching ratios.

$Parametrization\ \ \phi = \phi_4$

$$\left.\begin{array}{r}\sin 2\phi_1(b \to c\bar{c}s) = 0.69 \pm 0.03 \\ \sin 2\phi_1(b \to s\bar{q}q) = 0.50 \pm 0.06\end{array}\right\} 2\omega = (13.63 \pm 5.41)^o$$

		$0 < 2\phi$	η_2 bound	η_1 bound	ϕ_1 bound	Constraints
$\phi_1^{(2)} \leq \phi_1^{(1)} \leq \phi_1$	I	$\eta_2 \leq \eta_1 \leq 0 \leq 2\phi$	$\eta_2 \leq -2\omega$	$\eta_1 \leq 0$	$2\phi_1^{(1)} \leq 2\phi_1$	$\eta_2 \leq -13.63^o$
$\phi_1^{(2)} \leq \phi_1 \leq \phi_1^{(1)}$	II(a)	$\eta_2 \leq 0 \leq \eta_1 \leq 2\phi$	$\eta_2 \leq 2\phi - 2\omega$	$0 \leq \eta_1 \leq 2\phi$	$2\phi_1^{(1)} - 2\phi \leq 2\phi_1$	$\eta_2 \leq -11.54^o$
	II(b)	$\eta_2 \leq 0 \leq 2\phi \leq \eta_1$	$2\phi - 2\omega \leq \eta_2$	$2\phi \leq \eta_1 \leq 2\omega$	$2\phi_1^{(2)} \leq 2\phi_1 \leq 2\phi_1^{(1)} - 2\phi$	$-11.54^o \leq \eta_2; 2.09^o \leq \eta_1 \leq 13.63^o$ $30^o \leq 2\phi_1 \leq 41.54^o$
$\phi_1 \leq \phi_1^{(2)} \leq \phi_1^{(1)}$	III(a)	$0 \leq \eta_2 \leq 2\phi \leq \eta_1$	$0 \leq \eta_2 \leq 2\phi$	$2\omega \leq \eta_1$	$2\phi_1^{(2)} - 2\phi \leq 2\phi_1 \leq 2\phi_1^{(2)}$	$13.63^o \leq \eta_1$ $27.91^o \leq 2\phi_1 \leq 30^o$
	III(b)	$0 \leq 2\phi \leq \eta_2 \leq \eta_1$	$2\phi \leq \eta_2$	$2\omega + 2\phi \leq \eta_1$	$2\phi_1 \leq 2\phi_1^{(2)} - 2\phi$	$15.72^o \leq \eta_1; 2\phi_1 \leq 27.91^o$

Note that when $\eta_i<0$ or $\eta_i>2\phi$ one must have $|\delta_i| > |\delta_i^c|$

In none of the cases it is possible to have $|\delta_i| < |\delta_i^c|$ for both modes

Unless $0<2\omega<2\phi$ one cannot have $0<\eta_2<\eta_1<2\phi$, hence we do not consider this specific case.

The values close to 10 are possible only by lowering $2\phi_1$ away from $2\phi_1^i$ beyond acceptable values, close to $2\phi_2^i$

$$\hat{b}' = \hat{b''} = \hat{b} \Rightarrow \frac{\sin^2\phi_4}{\sin^2\phi_3} = \frac{|v_u|^2}{|v_t|^2} = \frac{\sin^2\beta_s}{\sin^2\beta}$$

NP indeed tested

To conclude, without making any hadronic model based assumptions we have shown that within the SM, it is impossible to explain the observed discrepancy in $B^0 - \bar{B}^0$ mixing phase measured using the $b \to c\bar{c}s$ and $b \to s\bar{q}q$ modes. The only possibility to forgo this conclusion is to accept that the observed branching ratios result from considerable fine tuned cancellations of significantly larger quark level amplitudes. This scenario of ``observed decay rates resulting from fine-tuned cancellations of large quark level amplitudes'' would be very difficult to accommodate, given the successful understanding of B_d decay rates.

Can B→VV help discover NP?

David London, Nita Sinha and Rahul Sinha, hep-ph/0304230, Euro. Phys. Lett. 67, 579 (2004) .

David London, Nita Sinha and Rahul Sinha, hep-ph/0402214, Phys. Rev. D 69, 114013 2004.

While number of parameters still exceeds number of observables,

- Additional signals of NP.
- Possible to bound the size of NP.
- Constrain its effect on measurement of the mixing phase.

In the presence of NP, decay amplitude for each of the helicity states:

$$\begin{aligned} A_\lambda \equiv Amp(B \to V_1 V_2)_\lambda &= a_\lambda e^{i\delta_\lambda^a} + b_\lambda e^{i\phi} e^{i\delta_\lambda^b} \;, \\ \bar{A}_\lambda \equiv Amp(\bar{B} \to \bar{V}_1 \bar{V}_2)_\lambda &= a_\lambda e^{i\delta_\lambda^a} + b_\lambda e^{-i\phi} e^{i\delta_\lambda^b} \end{aligned}$$

The time dependent decay of B→ VV must have a more complicated form and may be written as

$$\Gamma(B^0(t) \to f) = e^{-\Gamma t} \sum_{\lambda <= \sigma} \Big(\Lambda_{\lambda\sigma} + \Sigma_{\lambda\sigma} \cos(\Delta M t) - \rho_{\lambda\sigma} \sin(\Delta M t) \Big) f_{\lambda\sigma}$$

B→ VV decays provide large number of observables **Total 18**

$$\Lambda_{\lambda\lambda} = \frac{|A_\lambda|^2 + |\bar{A}_\lambda|^2}{2}$$

$$\Sigma_{\lambda\lambda} = \frac{|A_\lambda|^2 - |\bar{A}_\lambda|^2}{2}$$

$$\rho_{ii} = \mathrm{Im}\left(\frac{q}{p} A_i^* \bar{A}_i\right)$$

$$\rho_{\perp\perp} = -\mathrm{Im}\left(\frac{q}{p} A_\perp^* \bar{A}_\perp\right)$$

$3 \times 3 = 9$

$$\Lambda_{\perp i} = -\mathrm{Im}(A_\perp A_i^* - \bar{A}_\perp \bar{A}_i^*) \qquad \Lambda_{\|0} = \mathrm{Re}(A_\| A_0^* + \bar{A}_\| \bar{A}_0^*)$$

$$\Sigma_{\perp i} = -\mathrm{Im}(A_\perp A_i^* + \bar{A}_\perp \bar{A}_i^*) \qquad \Sigma_{\|0} = \mathrm{Re}(A_\| A_0^* - \bar{A}_\| \bar{A}_0^*)$$

$$\rho_{\perp i} = \mathrm{Re}\left(\frac{q}{p}[A_\perp^* \bar{A}_i + A_i^* \bar{A}_\perp]\right) \qquad \rho_{\|0} = -\mathrm{Im}\left(\frac{q}{p}[A_\|^* \bar{A}_0 + A_0^* \bar{A}_\|]\right)$$

$3 \times 2 = 6$ $\qquad$ $3 \times 1 = 3$ $\quad i = \{0, \|\}$

$\Lambda_{\lambda\sigma}$ terms and $\Sigma_{\lambda\sigma}$ terms can be obtained without time dependent study. Infact, $\Lambda_{\lambda\sigma}$ terms can be obtained without even flavor tagging.

We have 13 theoretical parameters

$$3a_\lambda\,'s + 3b_\lambda\,'s + \phi_1 + \phi + 3\delta_\lambda\,'s(\delta_\lambda \equiv \delta_\lambda^b - \delta_\lambda^a) + 2\Delta_i\,'s(\Delta_i \equiv \delta_\perp^a - \delta_i^a)$$

No. of independent observables: 11, 6 $\quad A_\lambda, \bar{A}_\lambda \quad$ magnitudes and relative phases Cannot obtain parameters purely in terms of observables, impossible to extract ϕ_1 or ϕ cleanly.

Observables in terms of parameters

$$
\begin{aligned}
\Lambda_{\lambda\lambda} &= a_\lambda^2 + b_\lambda^2 + 2a_\lambda b_\lambda \cos\delta_\lambda \cos\phi \ , \\
\Sigma_{\lambda\lambda} &= -2a_\lambda b_\lambda \sin\delta_\lambda \, {\color{red}\sin\phi} \ , \\
\rho_{ii} &= a_i^2 \sin 2\phi_1 + 2a_i b_i \cos\delta_i \sin(2\phi_1+\phi) + b_i^2 \sin(2\phi_1 + 2\phi) \ , \\
\rho_{\perp\perp} &= -a_\perp^2 \sin 2\phi_1 - 2a_\perp b_\perp \cos\delta_\perp \sin(2\phi_1+\phi) - b_\perp^2 \sin(2\phi_1+2\phi) \ ,
\end{aligned}
$$

Vanishing signals of NP

$$
\begin{aligned}
\Lambda_{\perp i} &= 2\left[a_\perp b_i \cos(\Delta_i - \delta_i) - a_i b_\perp \cos(\Delta_i + \delta_\perp)\right] \ {\color{red}\sin\phi} \ , \\
\Lambda_{\|0} &= 2\Big[a_\| a_0 \cos(\Delta_0 - \Delta_\|) + a_\| b_0 \cos(\Delta_0 - \Delta_\| - \delta_0)\cos\phi + a_0 b_\| \cos(\Delta_0 - \Delta_\| + \delta_\|)\cos\phi \\
&\qquad + b_\| b_0 \cos(\Delta_0 - \Delta_\| + \delta_\| - \delta_0)\Big] \ , \\
\Sigma_{\perp i} &= 2 - 2\left[a_\perp a_i \sin\Delta_i + a_\perp b_i \sin(\Delta_i - \delta_i)\cos\phi + a_i b_\perp \sin(\Delta_i + \delta_\perp)\cos\phi \right. \\
&\qquad \left. + b_\perp b_i \sin(\Delta_i + \delta_\perp - \delta_i)\right] \ , \\
\Sigma_{\|0} &= 2\left[a_\| b_0 \sin(\Delta_0 - \Delta_\| - \delta_0) - a_0 b_\| \sin(\Delta_0 - \Delta_\| + \delta_\|)\right] \ {\color{red}\sin\phi} \ , \\
\rho_{\perp i} &= 2\left[a_i a_\perp \cos\Delta_i \cos 2\phi_1 + a_\perp b_i \cos(\Delta_i - \delta_i)\cos(2\phi_1+\phi) + a_i b_\perp \cos(\Delta_i + \delta_\perp)\cos(2\phi_1+\phi) \right. \\
&\qquad \left. + b_i b_\perp \cos(\Delta_i + \delta_\perp - \delta_i)\cos(2\phi_1 + 2\phi)\right] \ , \\
\rho_{\|0} &= 2\Big[a_0 a_\| \cos(\Delta_0 - \Delta_\|)\sin 2\phi_1 + a_\| b_0 \cos(\Delta_0 - \Delta_\| - \delta_0)\sin(2\phi_1+\phi) \\
&\qquad + a_0 b_\| \cos(\Delta_0 - \Delta_\| + \delta_\|)\sin(2\phi_1+\phi) + b_0 b_\| \cos(\Delta_0 - \Delta_\| + \delta_\| - \delta_0)\sin(2\phi_1+2\phi)\Big] \ .
\end{aligned}
$$

In the absence of NP, $b_\lambda = 0$, $\phi=0$.

No. of parameters: reduced, 13→ 6 3 a_λ's, 2 strong Δ_i, and β.

No. of independent observables: 6, $(\Lambda'_{\lambda\lambda}s, 1\rho_{\lambda\lambda}, 2\Sigma_{\perp i})$

All parameters can be determined cleanly in terms of observables.

18 observables- 6 vanish & 6 independent) 6 additional relations

$$\Sigma_{\lambda\lambda} = \Sigma_{\|0} = \Lambda_{\perp i} = 0 \qquad \frac{\rho_{\perp i}^2}{4\Lambda_{\perp\perp}\Lambda_{ii} - \Sigma_{\perp i}^2} = \frac{\Lambda_{\perp\perp}^2 - \rho_{\perp\perp}^2}{\Lambda_{\perp\perp}^2}$$

$$\frac{\rho_{ii}}{\Lambda_{ii}} = -\frac{\rho_{\perp\perp}}{\Lambda_{\perp\perp}} = \frac{\rho_{\|0}}{\Lambda_{\|0}} \qquad \Lambda_{\|0} = \frac{1}{2\Lambda_{\perp\perp}}\left[\frac{\Lambda_{\lambda\lambda}^2\rho_{\perp 0}\rho_{\perp\|} + \Sigma_{\perp 0}\Sigma_{\perp\|}(\Lambda_{\lambda\lambda}^2 - \rho_{\lambda\lambda}^2)}{\Lambda_{\lambda\lambda}^2 - \rho_{\lambda\lambda}^2}\right]$$

any of

Violation of these 12 relations, smoking gun signals of New Physics!

•*Observable* $\Lambda_{\perp\,\mathrm{i}}$ *deserves special attention.*

•*Even if* $\delta_\lambda^{a,b} \to 0, \Lambda_{\perp i} \neq 0$ *in contrast to direct asymmetry.*

•$\Lambda_{\perp\mathrm{i}}$ *does not require flavor tagging, nor time dependence.*

•$\perp$ i *terms are CP-odd* $\Rightarrow \Lambda_{\perp\,\mathrm{i}}$ *survives in an untagged sample.*

• $\Lambda_{\perp\,\mathrm{i}}$ *has been measured.*

Is it possible that all NP signals vanish, even if NP is present?

Yes! If the singular situation:

1. *All the strong phase differences* δ_λ*'s vanish,*
2. *ratio* $r_\lambda = b_\lambda / a_\lambda$ *is same for all helicities,*

Then all 12 relations are satisfied.

For this very special conditions, angular analysis of $B \to V_1 V_2$ *leads to no signal for NP even if present, measured value of* $\phi_1 \neq B^0 - \bar{B}^0$ *mixing phase.*

Conclusions

- *The discrepancy in the measured values of* $\sin 2\phi_1$ *can be a clean signal of NP. How the signals stay and we discover NP.*
- *The* $K\pi$ *puzzle can be resolved using* $K^*\pi$ *modes. An anomaly in the size of the observed topological amplitudes (or derived asymmetries) is the only sign of NP.*
- *NP if it exists will provide clean signals in* $B\to VV$ *modes. There are 12 smoking gun signals which are unlikely to fail us.*