γ from penguin modes

Jure Zupan

CERN & IJS & Univ. of Ljubljana

Main idea

- the $B \to K^{(*)}\pi$ amplitudes

$$A \sim P + Te^{i\gamma}$$

- $b \to s$ transition $\Rightarrow$ penguin dominated (NP?)
- cancel P (or extract from somewhere) $\Rightarrow$ obtain γ
- extracted value of γ sensitive to NP
- disclaimer: a lot of work done in the past, will show only recent ones

General comments

two ways we can use for NP searches

- construct theoretically clean observables/predictions
  - usually involves flavor symmetries, isospin, SU(3)
  - will show the example of $S_{K_S\pi^0}$
- in the light of "imminent" ATLAS, CMS discoveries
  - can constrain parameter space/flavor structure
  - need calculational tools: $1/m_b$ expansion

a lot of other relevant info beside γ

- relative phases in $B \to K^*\pi$ measurable
- useful test of $1/m_b$ expansion

see talk by M. Pierini

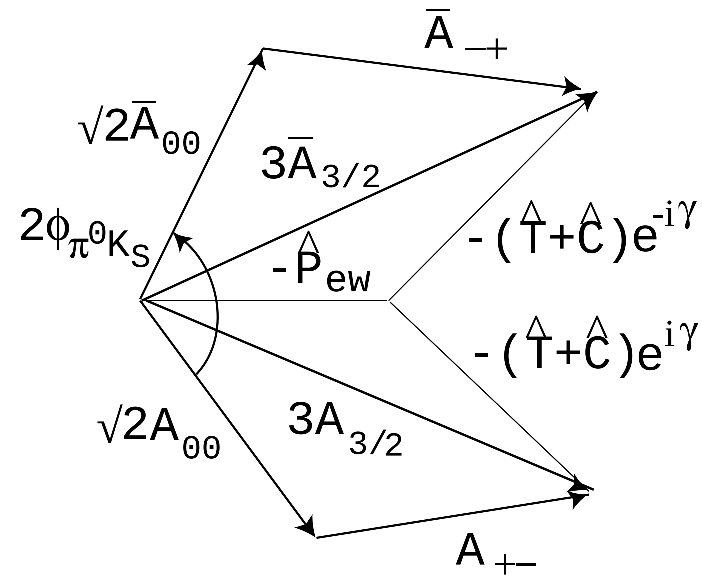
$$B \to K\pi$$

Precise prediction for $S_{K_S\pi^0}$

Fleischer, Jager, Pirjol, JZ, 2008
Gronau, Rosner, 2008

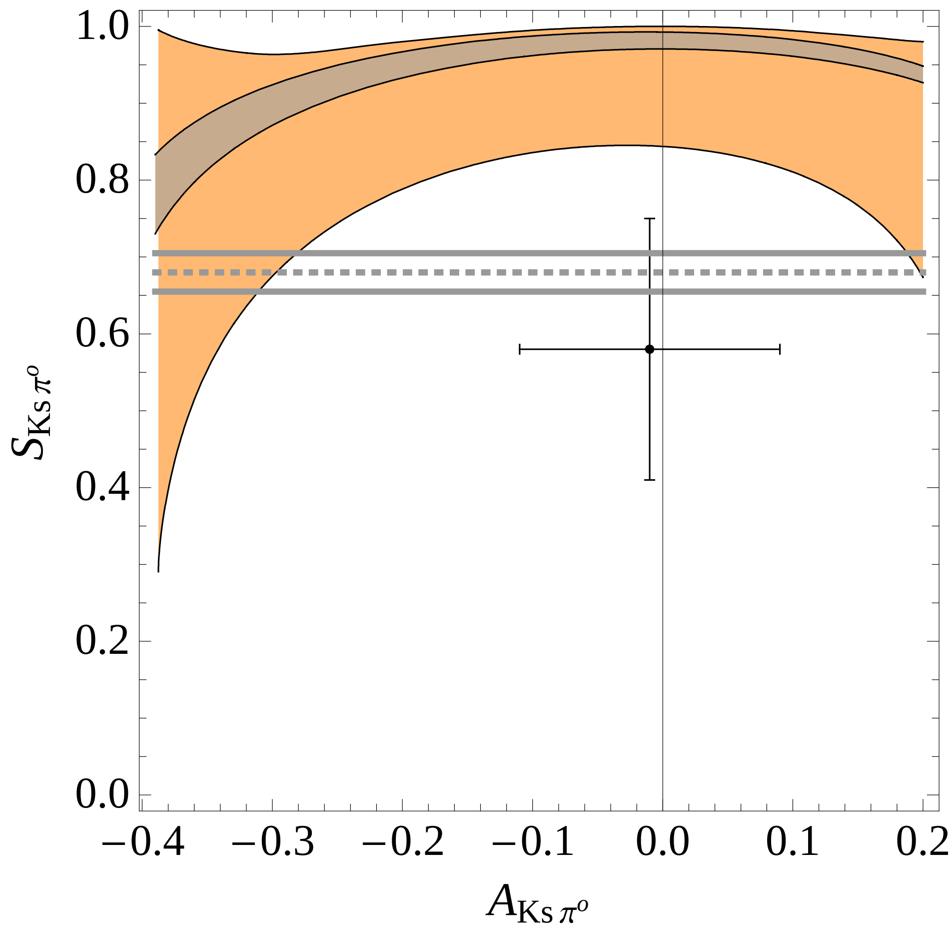
- use isospin relation

$$\sqrt{2}\,A(\pi^0 K^0) + A(\pi^- K^+) =$$
$$-\left[(\hat{T}+\hat{C})e^{i\gamma} + \hat{P}_{\rm ew}\right] \equiv 3A_{3/2}$$



- $P_{\rm ew}/(\hat{T}+\hat{C})$ from Neubert-Rosner relation
- $|\hat{T}+\hat{C}|$ from $B^+ \to \pi^+\pi^0$
- $S_{\pi^0 K_S} \propto \sin(2\beta - 2\phi_{\pi^0 K_S})$
- using $(K\pi)^0$ data + isospin $\Rightarrow S_{K_S\pi^0}$
  - theoretically clean
  - four-fold ambig. resolved using $\pi\pi$ or $1/m_b$

Precise prediction for $S_{K_S\pi^0}$



- ICHEP08 inputs $S_{K_S\pi^0} = 0.99^{+0.00}_{-0.15}$
- larger than $1/m_b$ predictions
- theor. very clean
- percent level theor. errors possible with progress on LQCD

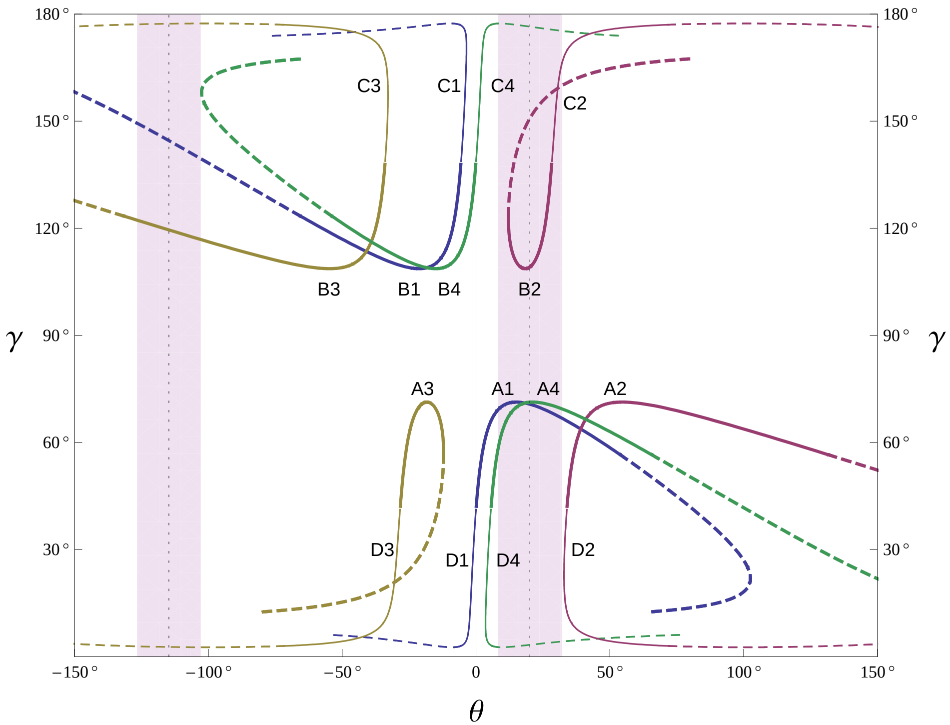
will need $F_+^{B\to K}/F_+^{B\to\pi}$ from Lattice QCD

γ extraction

Kim, Oh, Woong Yoon, 2007

- to extract γ need also charged $K\pi$
- 4×4 ambig. if $\pi^+\pi^0$ is not used to fix $|\hat{T}|$
- need to impose $P_{EW}^c = 0$, $P_{(KP)^+} = P_{(KP)^0}$

2007:

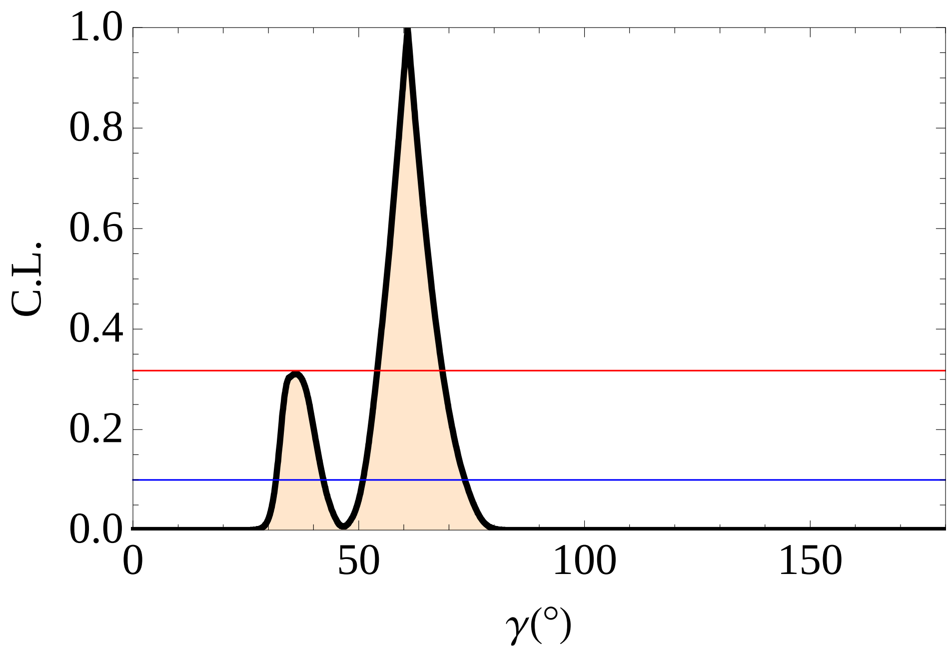


$\theta = 2\phi_{\pi^0 K_S}$

bands: measured θ

dashed lines: $|\hat{T}/\hat{P}| \geq 1$

γ extraction: $(+\pi\pi)$



$$\gamma = 60.8^{\circ}{}^{+7.7^{\circ}}_{-6.7^{\circ}}$$

90% C.L. ranges:

$[31.7^{\circ}, 42.2^{\circ}]$&$[51.0^{\circ}, 73.5^{\circ}]$

- use all $K\pi$ data (+ all $\pi\pi$ data)
- 30%, 30° flat SU(3) errors in $\pi\pi$ amplitudes
- neglect doubly Cabbibo supp. difference between charged and neutral P in $K\pi$, impose $\arg(P^{c}_{EW}) = 0$

$$B \to K^*\pi$$

Theory

Ciuchini, Pierini, Silvestrini, 2006; Gronau, Pirjol, Soni, JZ, 2006, 2007

- relative phases of $B \to K^*\pi$ amplitudes from $B \to K\pi\pi$
- no penguins in: $3A_{3/2} = A(K^{*+}\pi^-) + \sqrt{2}A(K^{*0}\pi^0)$
- in the limit of zero EWP

$$\gamma = \Phi_{3/2} \equiv -1/2 \times \text{arg}\big(\bar{A}_{3/2}/A_{3/2}\big)$$

- with EWP ($C = -0.27 = 3(C_9 + C_{10})/\big(2\lambda^2(C_1 + C_2)\big)$)

$$\boxed{\bar{\eta} = \tan\Phi_{3/2}\big[\bar{\rho} + C[1 - 2\text{Re}(r_{3/2})] + \mathcal{O}(r_{3/2}^2)\big]}$$

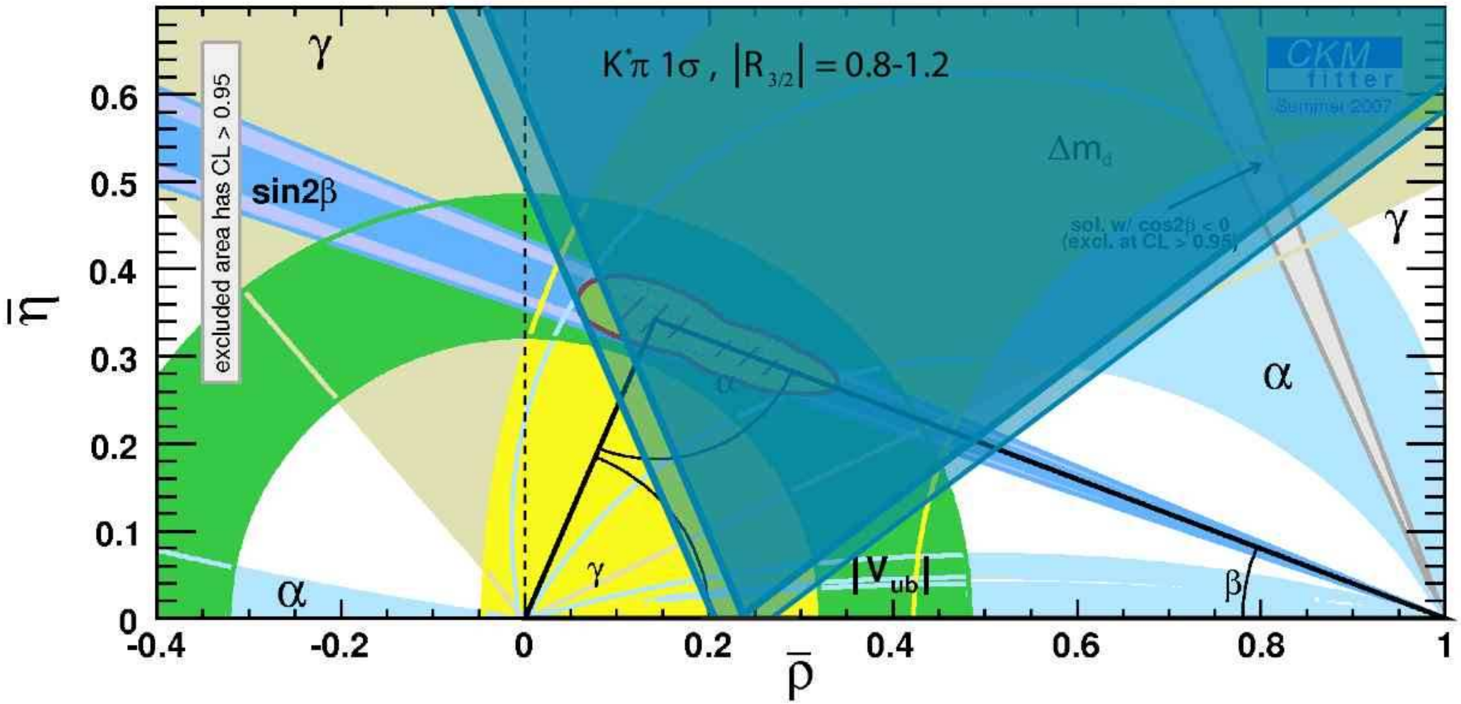
  - for $K\pi$: $r_{3/2} = 0$ in SU(3) limit
  - $r_{3/2}$ correction to this Neubert-Rosner shift
    - $r_{3/2} < 0.05$ using naive factorization
    - $r_{3/2} = 0.054 \pm 0.045 \pm 0.023$ using SU(3)

CKM constraint

Gronau, Pirjol, Soni, JZ, 2007

- the relevant phases measured in $B^0 \to K^+\pi^-\pi^0$ and $B^0(t) \to K_S\pi^+\pi^-$

BaBar: 0711.4417, 0708.2097



- does not include BaBar arXiv:0807.4567 ($2\times$ the data, but NLL for phases not published)

Conclusions

- showed experimentally improvable prediction on $S_{K_S\pi}$
- CKM constraints from $B \to K^*\pi$

Backup slides

$K\pi, \pi\pi$ amplitudes

$$A(B^+ \to \pi^+ K^0) = P + \lambda_u^{(s)} P_{tu},$$

$$\sqrt{2} A(B^+ \to \pi^0 K^+) = -(P + T + C + P_{\rm EW} + \lambda_u^{(s)} P_{tu}),$$

$$A(B^0 \to \pi^- K^+) = -(P + T + P_{\rm EW}^c),$$

$$\sqrt{2} A(B^0 \to \pi^0 K^0) = P - C + P_{\rm EW}^c - P_{\rm EW},$$

$$\sqrt{2} A(B^+ \to \pi^+ \pi^0) = \tilde{C} + \tilde{T} + \tilde{P}_{\rm EW}$$

$$\sqrt{2} A(B^0 \to \pi^0 \pi^0) = \tilde{P} - \tilde{C} + \tilde{P}_{\rm EW}^c - \tilde{P}_{\rm EW},$$

$$A(B^0 \to \pi^+ \pi^-) = \tilde{T} + \tilde{P} + \tilde{P}_{\rm EW}^c.$$

$r_{3/2}$ definition

$$\gamma = \Phi_{3/2} \equiv -\frac{1}{2}\text{arg}\left(R_{3/2}\right) \ ,$$

$$R_{3/2} \equiv \frac{\bar{A}_{3/2}}{A_{3/2}} \ ,$$

$$R_{3/2} = e^{-2i[\gamma + \arg(1+\kappa)]}\frac{1 + c_\kappa^* r_{3/2}}{1 + c_\kappa r_{3/2}} \ ,$$

$$\kappa \equiv -\frac{3}{2}\frac{C_9 + C_{10}}{C_1 + C_2}\frac{V_{tb}^* V_{ts}}{V_{ub}^* V_{us}} \ , \quad c_\kappa \equiv \frac{1-\kappa}{1+\kappa} \ ,$$

$$r_{3/2} \equiv \frac{(C_1 - C_2)\langle (K^*\pi)_{I=3/2}|\mathcal{O}_1 - \mathcal{O}_2|B^0\rangle}{(C_1 + C_2)\langle (K^*\pi)_{I=3/2}|\mathcal{O}_1 + \mathcal{O}_2|B^0\rangle} \ .$$