Measurements of γ/ϕ_3

Results from Belle and BaBar

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Outline

- Current indirect constraints on γ
- Brief overview of proposed approaches to measure γ
  - Time dependent analysis
  - Relation between branching fractions
- Time dependent analysis in B → $D^{(*)}\pi$
- B → $D^{(*)}K^{(*)}$ branching ratio
- Charmless B decays
- Summary and Outlook

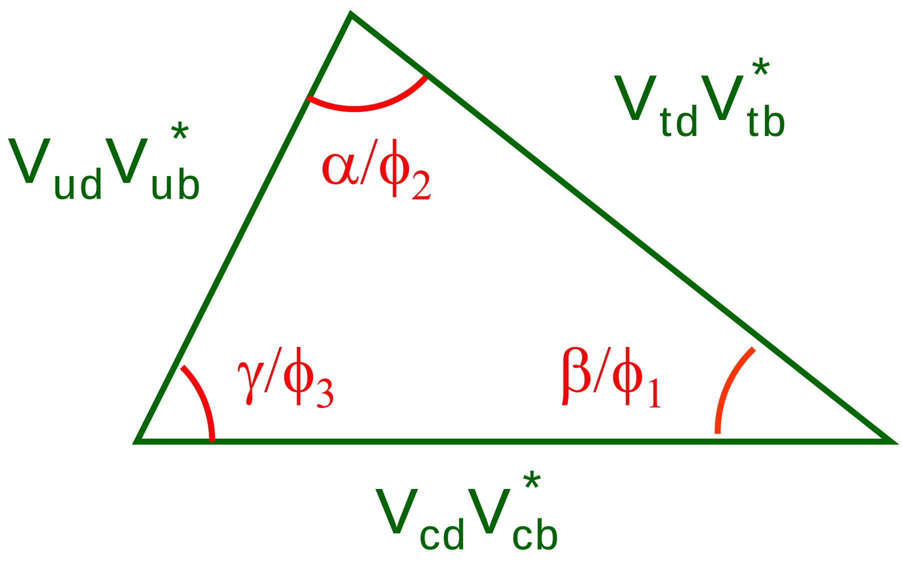
CP Violation in Standard Model

Standard Model with 3 generations accommodates CP violation through a phase in CKM matrix

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

Unitarity of the CKM Matrix

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

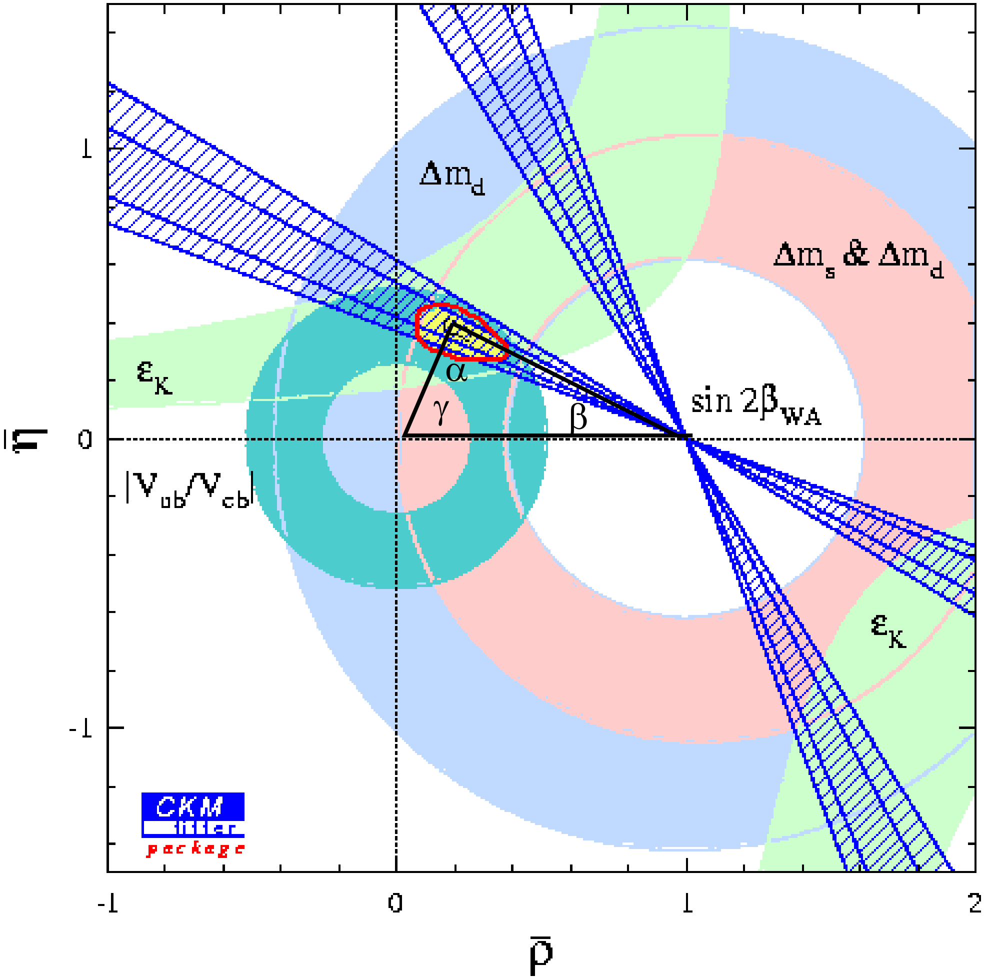


Area ≠ 0 → CP violation

Sides: measured in decay rates
Angles: CP violating effects

Current Constraints on the CKM Angles

World Average
$\sin 2\beta = 0.736 \pm 0.049$



95% CL intervals with CKM Fitter:

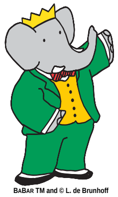
$$19.4^\circ < \beta < 26.5^\circ$$
$$77^\circ < \alpha < 122^\circ$$
$$37^\circ < \gamma < 80^\circ$$

More aggressive constraints on γ possible with strong theoretical assumptions

A. Hoecker et al, Eur. Phys. Jour. C21 (2001) 225, [hep-ph/0104062]

Direct measurement of γ is needed!

Data Samples Collected with Belle and BaBar

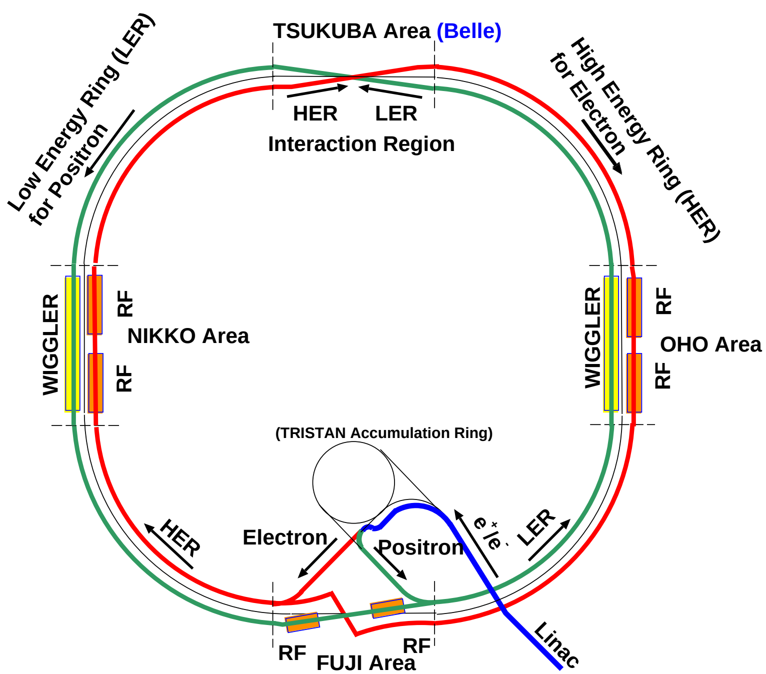


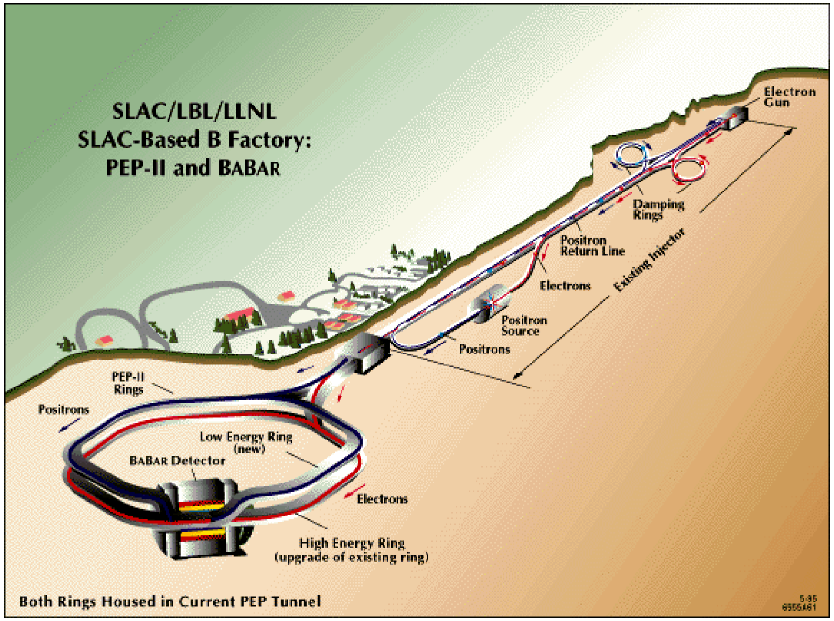
BELLE @ KEK-B Accelerator

140 fb^{-1} on $\Upsilon(4s)$ (158 fb^{-1} total)
152 million B B events

BaBar @ PEP-II Accelerator

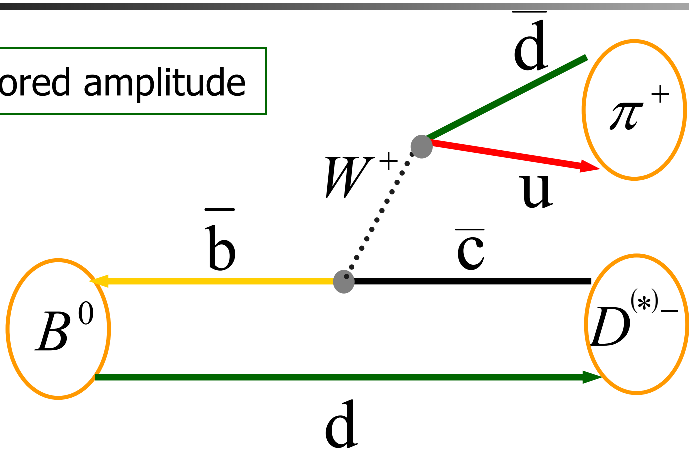
113 fb^{-1} on $\Upsilon(4s)$ (126 fb^{-1} total)
124 million B B events





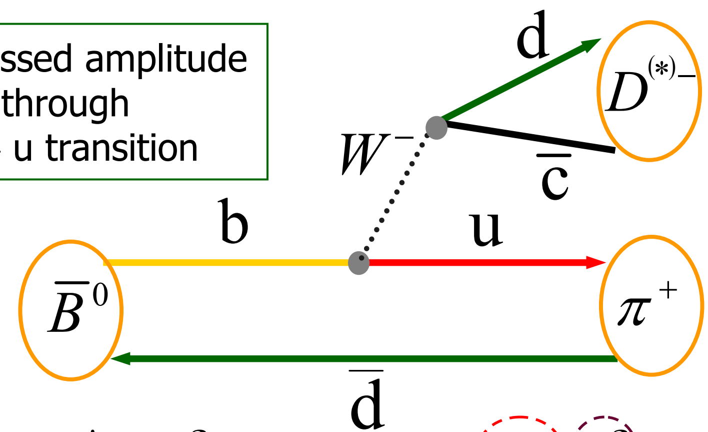
Measurement of sin(2β+γ) in $B^0 \to D^{(*)}\pi$

Favored amplitude



$$V_{cb} V_{ud}^* = A$$

Suppressed amplitude through $b \to u$ transition



$$V_{ub} V_{cd}^* e^{i\delta} = r_{(*)} A e^{-i\gamma} e^{i\delta}$$

CKM angle

Strong phase difference

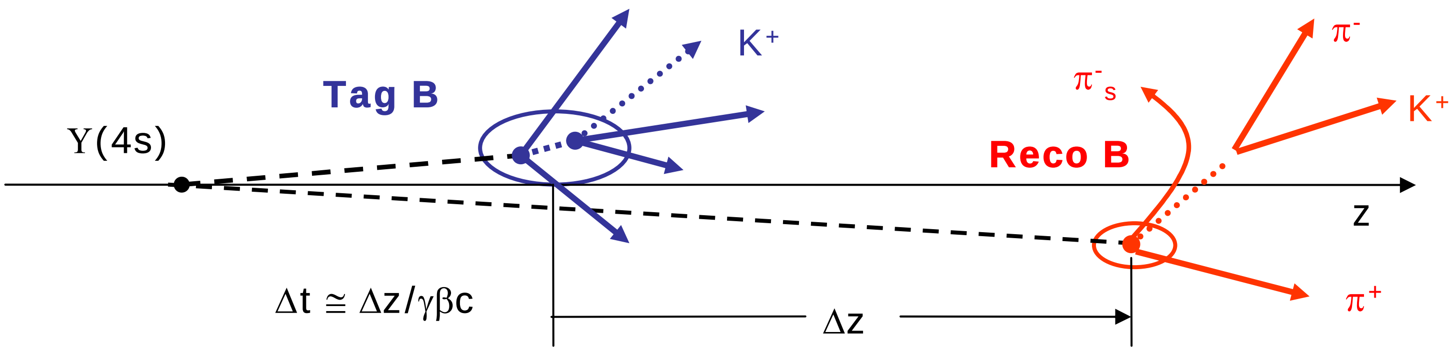
- CP violation from interference of decay and mixing

- Advantage:
  - Large branching fraction for favored decay (~3 x 10^{-3})
  - Most other techniques rely on modes with small BR

- Disadvantage:
  - Much smaller BR for suppressed decay (~10^{-6})
  - Small CP violating amplitude:

$$r(D^{(*)}\pi) \equiv r_{(*)} = \left| \frac{A(\overline{B}^0 \to D^{(*)-}\pi^+)}{A(B^0 \to D^{(*)-}\pi^+)} \right| \approx 0.02$$

Time-dependent decay rate distributions



$$f\left(B^0 \to D^{(*)-}\pi^+, \Delta t\right) = N e^{-\Gamma|\Delta t|}\left\{1 + C^{(*)}\cos\left(\Delta m_d \Delta t\right) + S^{(*)}\sin\left(\Delta m_d \Delta t\right)\right\}$$

$$f\left(\overline{B}^0 \to D^{(*)-}\pi^+, \Delta t\right) = N e^{-\Gamma|\Delta t|}\left\{1 - C^{(*)}\cos\left(\Delta m_d \Delta t\right) - S^{(*)}\sin\left(\Delta m_d \Delta t\right)\right\}$$

$$f\left(\overline{B}^0 \to D^{(*)+}\pi^-, \Delta t\right) = N e^{-\Gamma|\Delta t|}\left\{1 + C^{(*)}\cos\left(\Delta m_d \Delta t\right) - \overline{S}^{(*)}\sin\left(\Delta m_d \Delta t\right)\right\}$$

$$f\left(B^0 \to D^{(*)+}\pi^-, \Delta t\right) = N e^{-\Gamma|\Delta t|}\left\{1 - C^{(*)}\cos\left(\Delta m_d \Delta t\right) + \overline{S}^{(*)}\sin\left(\Delta m_d \Delta t\right)\right\}$$

$$C^{(*)} = \frac{1 - r_{(*)}^2}{1 + r_{(*)}^2} \approx 1$$

$$S^{(*)} = \frac{2r_{(*)}}{1 + r_{(*)}^2}\sin(2\beta + \gamma - \delta^{(*)})$$

$$\overline{S}^{(*)} = \frac{2r_{(*)}}{1 + r_{(*)}^2}\sin(2\beta + \gamma + \delta^{(*)})$$

$$\approx [-0.04 : 0.04]$$

- Measurement of S and $\overline{S}$ determine $2\beta+\gamma$ and δ
- Using Dπ and D$^*\pi$ removes some ambiguities

4 ambiguities on $2\beta+\gamma$

Impact of CP Violation on tag side

- Similar interference occurs in B decay used for flavor tagging
  - Potential competing CP-violating effect
  - Modified time distributions

(Long, Baak, Cahn, Kirkby: PRD68, 034010)

- For example:

$$f\left(D^{(*)-}\pi^{+},\Delta t\right)\propto\ 1+C^{(*)}\cos\left(\Delta m_d \Delta t\right)$$
$$+\sin\left(\Delta m_d \Delta t\right)\left[\pm 2r\sin(2\beta+\gamma+\delta)+2r'\sin(2\beta+\gamma\pm\delta')\right]$$

signal side — tag side

- Re-parameterize the sine coefficients as a sum of 3 terms
  - 1 term unchanged, 2 terms absorb the tag-side effect

Lepton flavor tags

$$\begin{cases} a\equiv 2r\sin(2\beta+\gamma)\cos\delta \\ b\equiv 0 \\ c_{lep}\equiv 2r\cos(2\beta+\gamma)\sin\delta \end{cases}$$

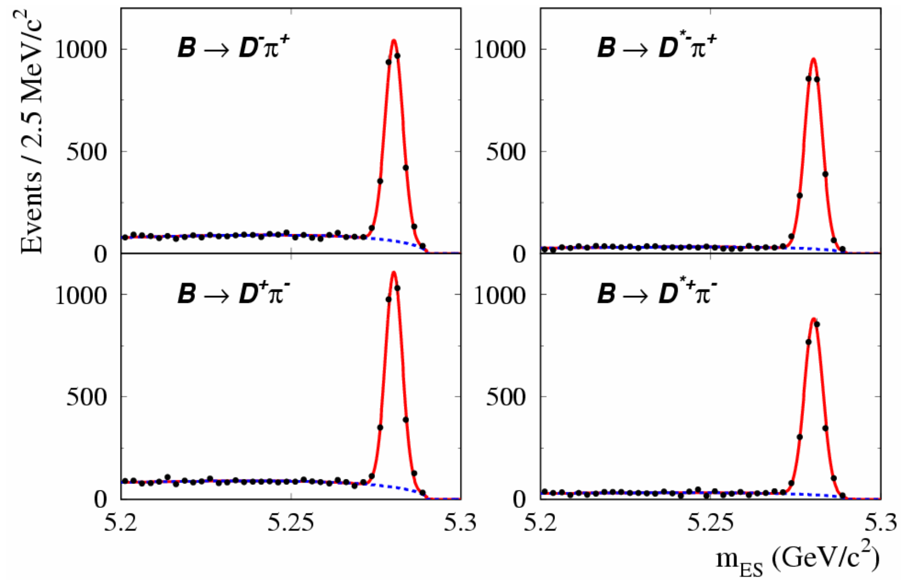
No corresponding Vub amplitude in semileptonic decays

Kaon and other flavor tags

$$\begin{cases} a\equiv 2r\sin(2\beta+\gamma)\cos\delta \\ b\equiv 2r'\sin(2\beta+\gamma)\cos\delta' \\ c\equiv 2\cos(2\beta+\gamma)(r\sin\delta-r'\sin\delta') \end{cases}$$

81 fb^{-1} Exclusive and Partially Reconstructed samples

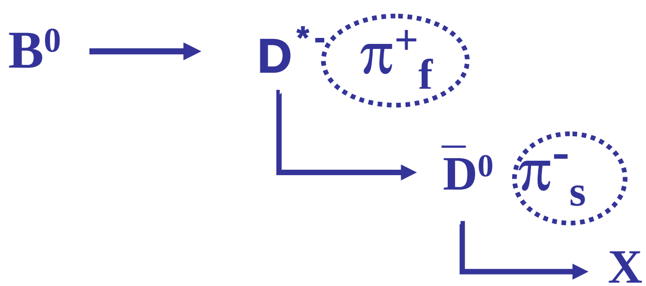
- Exclusive reconstruction
  - High purity
  - 'Smaller' than partially reconstructed sample



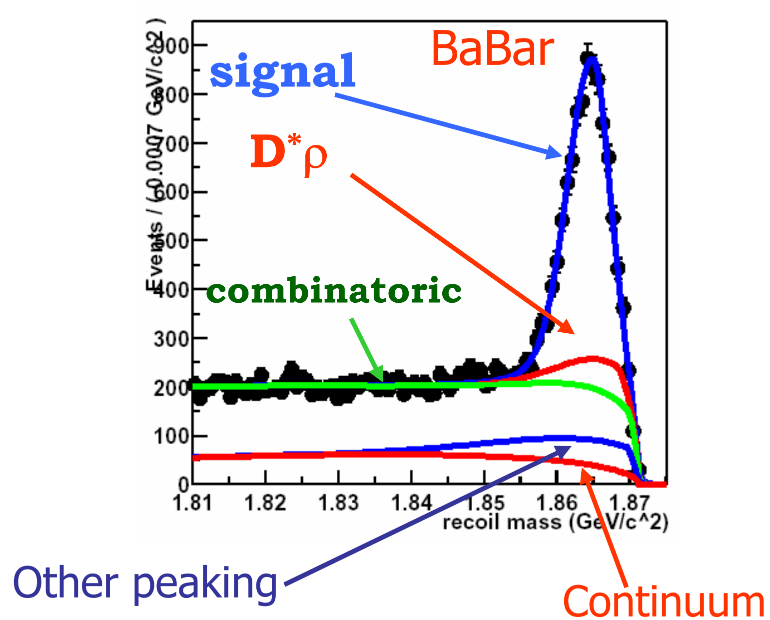
N($D\pi$) = 5207 ± 87
Purity = 85 %

N($D^*\pi$) = 4746 ± 78
Purity= 94 %

- Partial Reconstruction



  - More background that needs to be understood



Results from fully reconstructed sample with BaBar

All tags

$$2r\ \sin(2\beta+\gamma)\ \cos\delta[D\pi] = -0.022 \pm 0.038\,(\text{stat.}) \pm 0.021\,(\text{syst.})$$

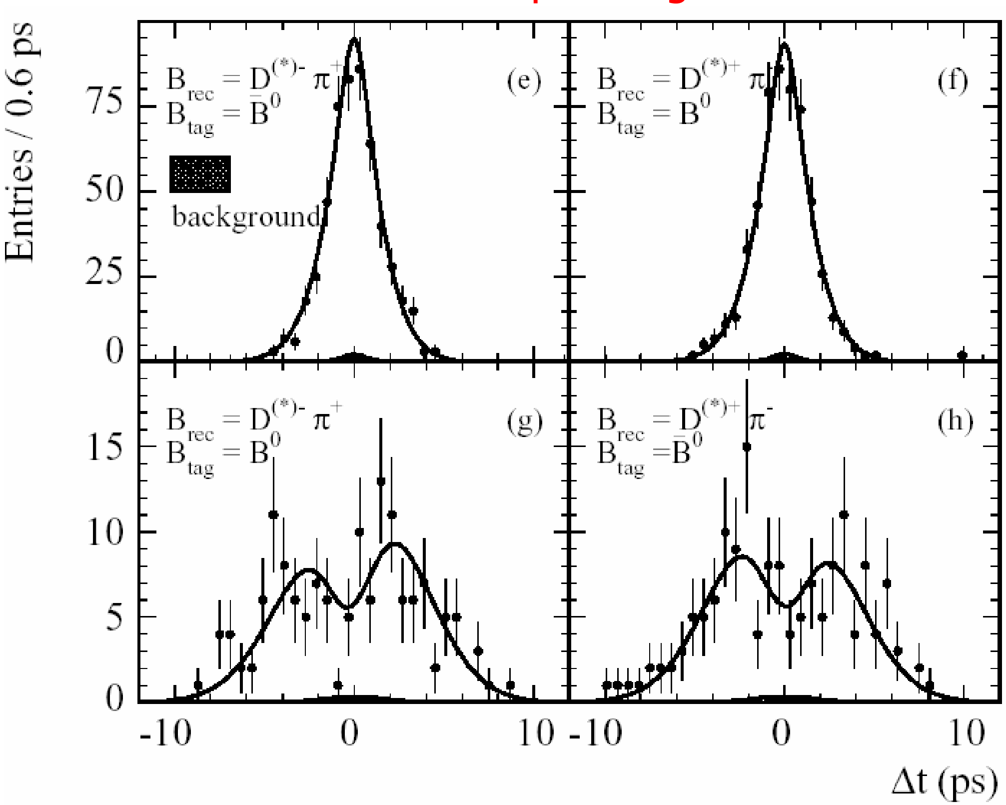
$$2r_*\ \sin(2\beta+\gamma)\ \cos\delta[D^*\pi] = -0.068 \pm 0.038\,(\text{stat.}) \pm 0.021\,(\text{syst.})$$

Leptons

$$2r\ \cos(2\beta+\gamma)\ \sin\delta[D\pi] = +0.025 \pm 0.068\,(\text{stat.}) \pm 0.035\,(\text{syst.})$$

$$2r_*\ \cos(2\beta+\gamma)\ \sin\delta[D^*\pi] = +0.031 \pm 0.070\,(\text{stat.}) \pm 0.035\,(\text{syst.})$$

Lepton tags



- How to interpret the result?
  - Estimate r from $B^0 \to D_s^{(*)+}\pi^-$ decays using SU(3) symmetry

$$r_{(*)} \approx \sqrt{\frac{\mathcal{B}(B^0 \to D_s^{(*)+}\pi^-)}{\mathcal{B}(B^0 \to D^{(*)-}\pi^+)}}\left|\frac{V_{cd}}{V_{cs}}\right|\frac{f_{D^{(*)}}}{f_{D_s^{(*)}}}$$

$$r_{(D^*\pi)} = 0.017^{+0.005}_{-0.007}$$

$$r_{(D\pi)} = 0.021^{+0.004}_{-0.005}$$

30% Theoretical Uncertainty

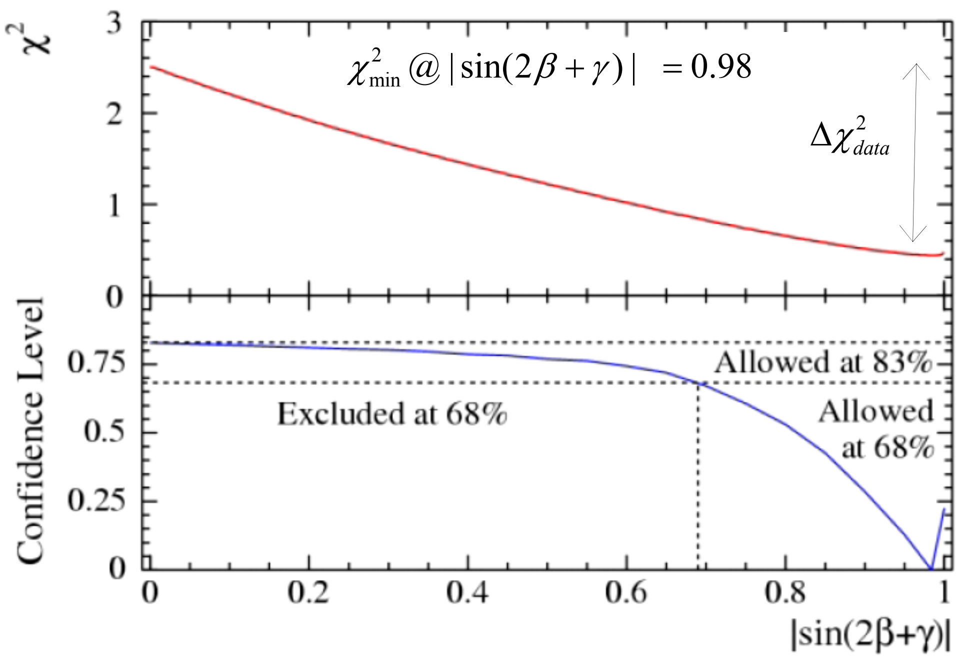
Limits on |sin(2β+γ)|

- Limits on |sin(2β+γ)| with a frequentist approach
  - Minimize $\chi^2(\sin(2\beta+\gamma),\delta,\delta^*,r,r_*)$ computed from measured parameters in data with respect to sin(2β+γ),δ,δ*,r,r
  - Generate toy experiments for all values of sin(2β+γ)
  - Confidence Level defined as $\mathrm{CL}\left(|\sin(2\beta+\gamma)|\right) = \mathit{fraction}\left(\Delta\chi^2_{toy} < \Delta\chi^2_{data}\right)$

|sin(2β+γ)| > 0.69 @ 68.3% CL

|sin(2β+γ)| = 0 excluded @ 83% CL

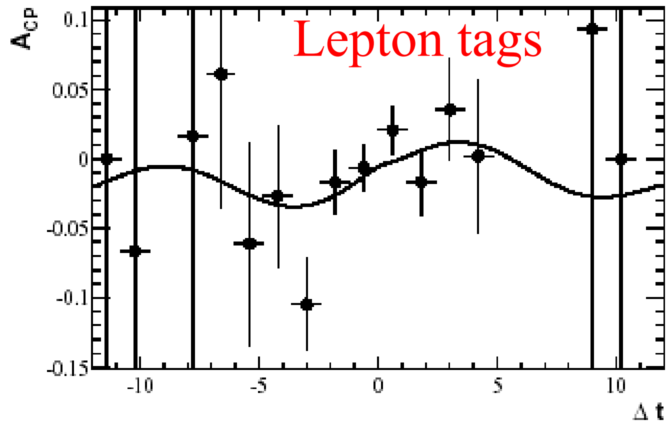
hep-ex/0308018

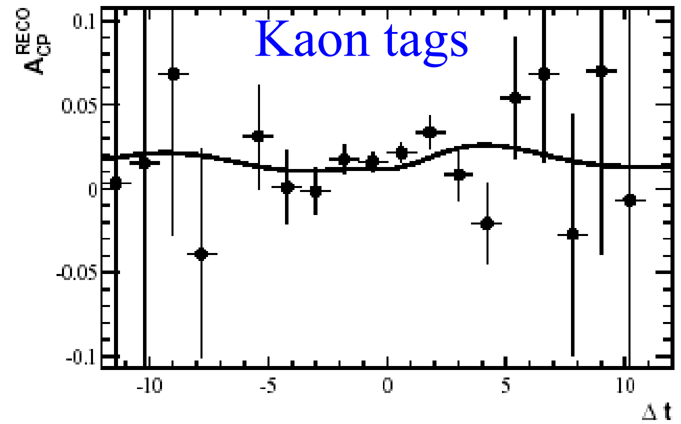


Results from Partial Reconstruction with BaBar

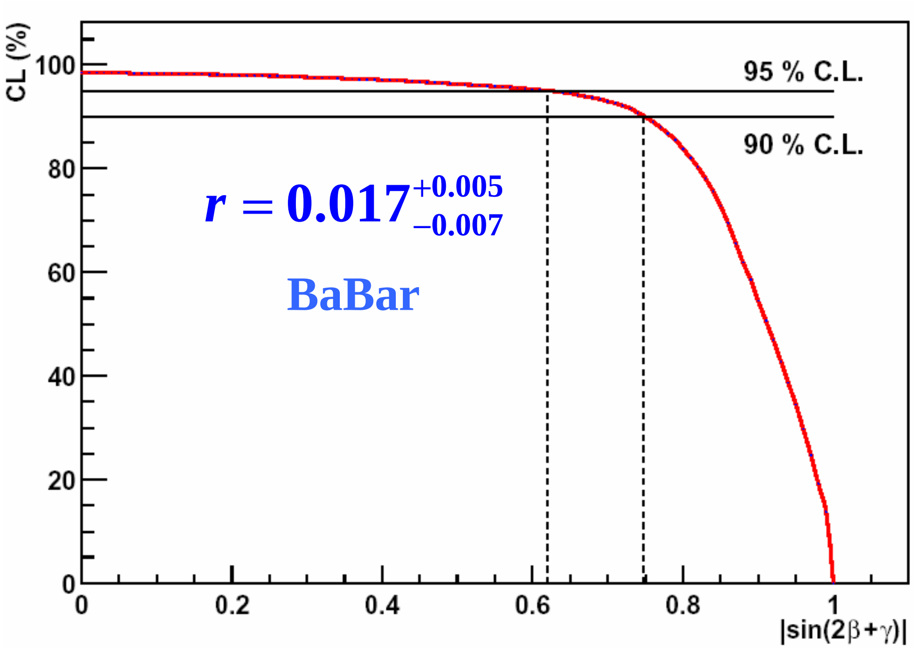
hep-ex/0307036

$$A_{CP} = \frac{\left(N_{B^0_{tag}} - N_{\bar{B}^0_{tag}}\right)}{\left(N_{B^0_{tag}} + N_{\bar{B}^0_{tag}}\right)}$$





Combined result : $2\,r\,\sin(2\beta+\gamma)\cos\delta = -0.063 \pm 0.024_{stat} \pm 0.017_{syst}$



Confidence level on $|\sin(2\beta+\gamma)|$ by minimizing $\chi^2(\sin(2\beta+\gamma),\delta)$

$|\sin(2\beta+\gamma)| > 0.88$ **at 68.3% C.L.**

$|\sin(2\beta+\gamma)| > 0.75$ **at 90% C.L.**

$|\sin(2\beta+\gamma)| > 0.62$ **at 95% C.L.**

$|\sin(2\beta+\gamma)| = 0$ **excluded at 98.3% C.L.**

D$^{(*)}\pi$ Results from Belle

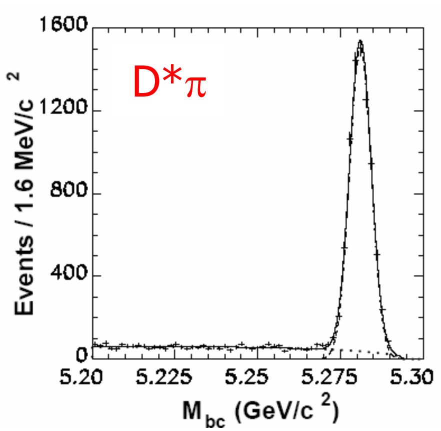
hep-ex/0308048

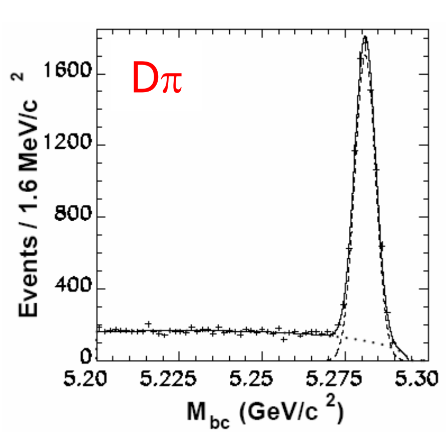
- Same technique used in BaBar

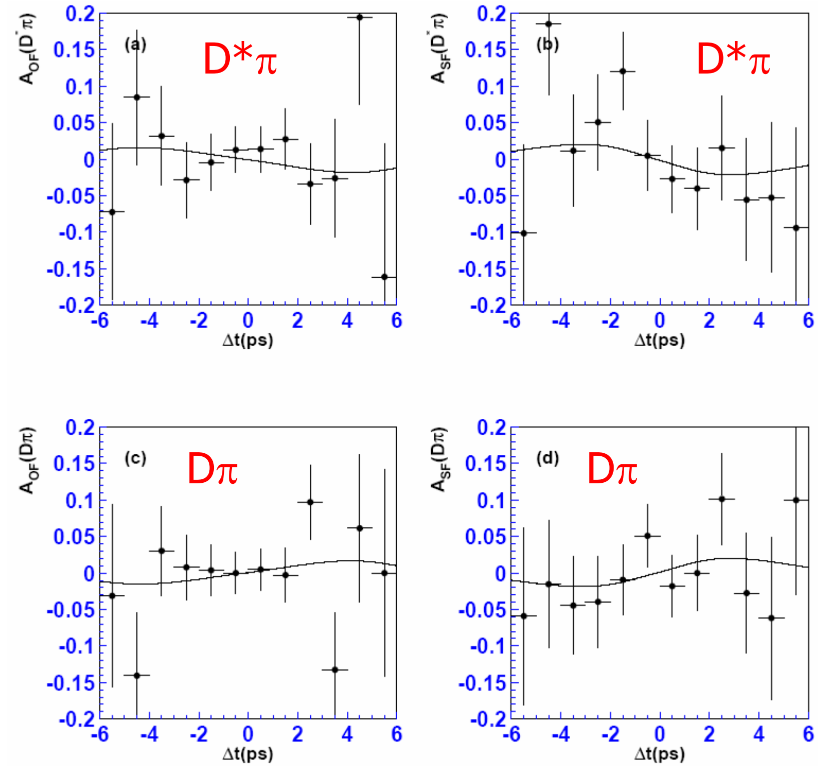
Decay mode	Candidates	Purity
$B^0(\bar{B}^0) \to D^*\pi$	7556	95%
$B^0(\bar{B}^0) \to D\pi$	8375	88%

$$A_{\rm OF} \equiv \frac{\Gamma(\bar{B}^0 \to D^{(*)+}\pi^-) - \Gamma(B^0 \to D^{(*)-}\pi^+)}{\Gamma(\bar{B}^0 \to D^{(*)+}\pi^-) + \Gamma(B^0 \to D^{(*)-}\pi^+)}$$

$$A_{\rm SF} \equiv \frac{\Gamma(\bar{B}^0 \to D^{(*)-}\pi^+) - \Gamma(B^0 \to D^{(*)+}\pi^-)}{\Gamma(\bar{B}^0 \to D^{(*)-}\pi^+) + \Gamma(B^0 \to D^{(*)+}\pi^-)}.$$







$$2r_{D^*\pi}\sin(2\beta+\gamma+\delta_{D^*\pi}) = 0.092 \pm 0.059 \pm 0.016 \pm 0.036(D^* l\nu)$$

$$2r_{D^*\pi}\sin(2\beta+\gamma-\delta_{D^*\pi}) = 0.033 \pm 0.056 \pm 0.016 \pm 0.036(D^* l\nu)$$

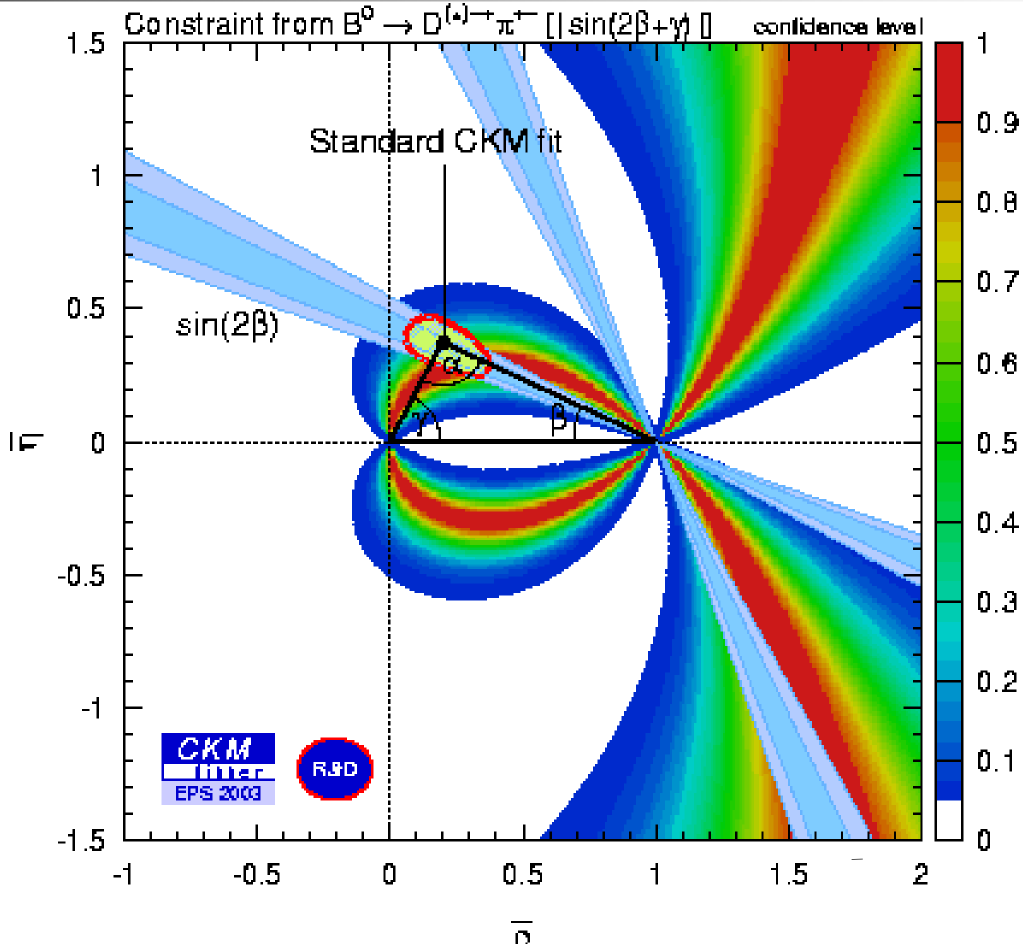
$$2r_{D\pi}\sin(2\beta+\gamma+\delta_{D\pi}) = 0.094 \pm 0.059 \pm 0.013 \pm 0.036(D^* l\nu)$$

$$2r_{D^*\pi}\sin(2\beta+\gamma-\delta_{D^*\pi}) = 0.022 \pm 0.056 \pm 0.013 \pm 0.036(D^* l\nu)$$

BaBar and Belle results compatible within the current large errors

- Systematic on possible bias from D*lν sample (no tagside effect)

Constraints on Unitarity Triangle from BaBar Results



$$|\sin(2\beta+\gamma)| > 0.89 \text{ @ } 68.3\% \text{ C.L.}$$

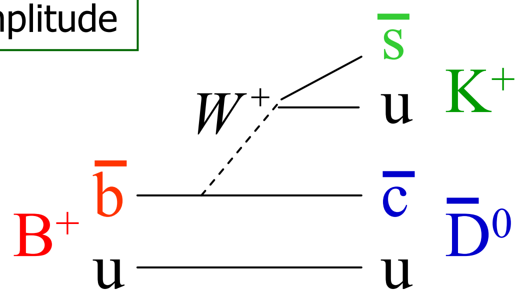
$$|\sin(2\beta+\gamma)| > 0.76 \text{ @ } 90\% \text{ C.L.}$$

Preference for one solution of β in the η > 0 plane

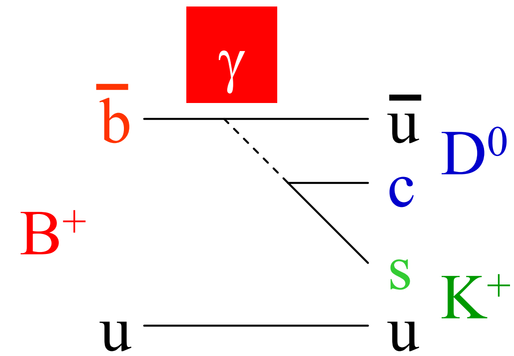
Measurement and Constraints on γ with $B \rightarrow D^{(*)} K^{(*)}$ Decays

γ with $B^- \to D^0 K^-$ decays

Favored amplitude



Suppressed amplitude:
b → u transition
Color suppression



$$r \equiv \frac{|A(B^+ \to D^0 K^+)|}{|A(B^+ \to \bar{D}^0 K^+)|} \sim 0.2$$

From color-suppressed $B^0 \to D^0 \pi^0$ decays

- Many proposed methods with a variety of decay modes
  - Gronau-Wyler-London (GWL) method: use flavor and CP final states of D^0

Gronau, Wyler, Phys Rev Lett **B265**, 172 (1991)
Gronau, London
Gronau, Phys Rev **D58**, 037301 (1998)

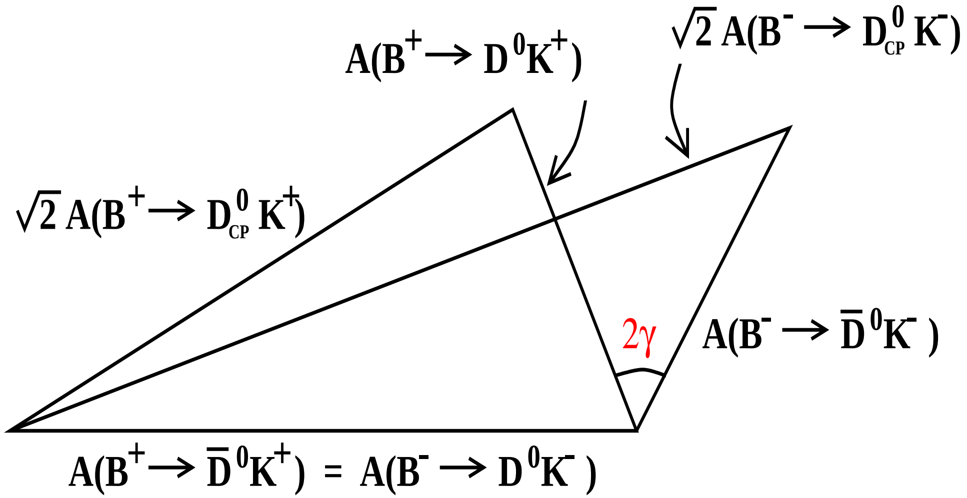
  - Atwood-Dunietz-Soni (ADS):
    - Interference of $A(B^+ \to [\, f\,]\, K^+)$ and $A(B^+ \to [\, \bar{f}\,]\, K^+)$ with $BF(\bar{D}^0 \to [\, f\,]) << BF(D^0 \to [\, f\,])$

D. Atwood, I. Dunietz, A. Soni, Phys Rev Lett **D58**, 3257 (1997)

Gronau-Wyler method in $B^- \to D^0 K^-$ decays

Jang, Ko, PRD 58, 111
Gronau, Rosner, PLB 439, 171

- $\sin^2\gamma$ without theoretical error by measuring 6 decay amplitudes
  (Discrete ambiguities remain!)



$$D^0_{CP\pm} = \left(D^0 \pm \overline{D^0}\right)/\sqrt{2}$$

- Method sensitivity depends on ratio

$$r \equiv \frac{|A(B^+ \to D^0 K^+)|}{|A(B^+ \to \bar{D}^0 K^+)|} \sim 0.2$$

- $A(B^+ \to D^0 K^+)$ can not be measured in hadronic decays
  - Comparable amplitude from $B^+ \to \bar{D}^0 K^+$ followed by Cabibbo-suppressed decay of $\bar{D}^0$

$$B^+ \to D^0 K^-, \quad D^0 \to K^- \pi^+$$

$$B^+ \to \bar{D}^0 K^-, \quad \bar{D}^0 \to K^- \pi^+$$

Constraints on γ from $B^- \rightarrow D^0_{CP}K^-$ decays

- Constraints on r and γ from measurement of

Gronau, hep-ph/0211282

$$R_{CP} = \frac{BR(B^- \rightarrow D^0_{CP}\ K^-) + BR(B^+ \rightarrow D^0_{CP}\ K^+)}{BR(B^- \rightarrow D^0\ K^-) + BR(B^+ \rightarrow D^0\ K^+)}$$

$$\sin^2\gamma \leq R_{CP\pm}$$

$$r \geq |R_{CP+} - R_{CP-}|$$

- Can be further refined by measuring direct CP violating asymmetry A_{CP}

$$A_{CP\pm} = \frac{Br(B^- \rightarrow D^0_{CP\pm}K^-) - Br(B^+ \rightarrow D^0_{CP\pm}K^+)}{Br(B^- \rightarrow D^0_{CP\pm}K^-) + Br(B^+ \rightarrow D^0_{CP\pm}K^+)} = \frac{\pm 2r\sin\delta\sin\gamma}{1 \pm 2r\cos\delta\cos\gamma + r^2}$$

$$A_{CP\pm}R_{CP\pm} = \pm 2r\sin\delta\sin\gamma$$

$$A(B^+ \rightarrow \overline{D}^0 K^+) = |A|$$

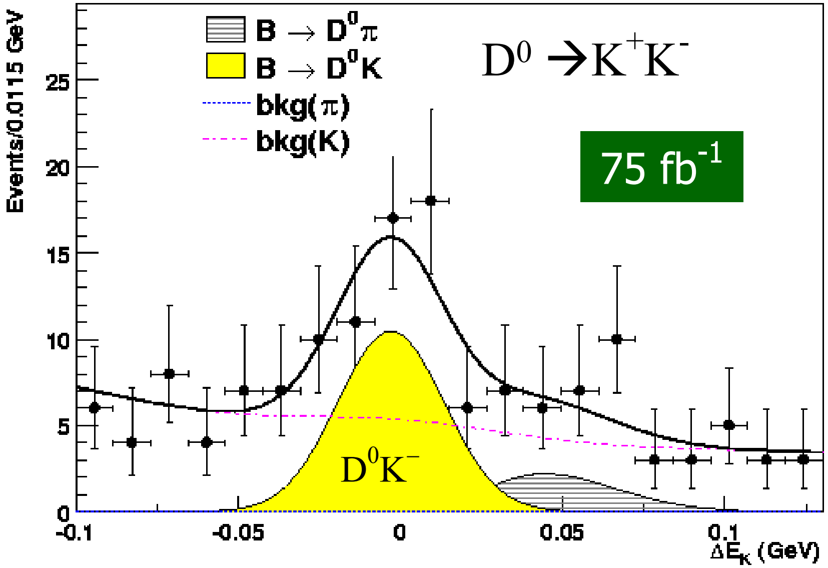
$$A(B^+ \rightarrow D^0 K^+) = |\overline{A}|e^{i\delta}e^{i\gamma}$$

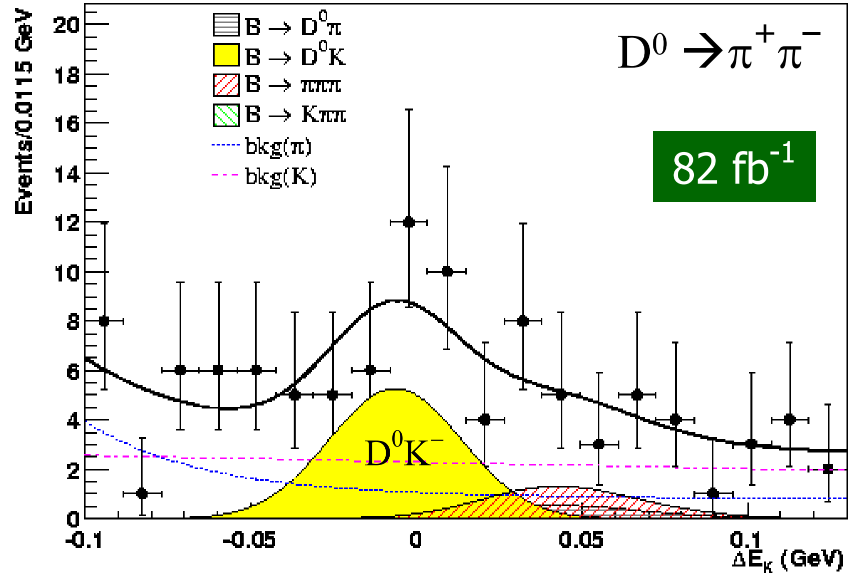
δ is the strong phase

Measure A_{CP} and BR with $D^0 \rightarrow K^+K^-, \pi^+\pi^-$ (CP=+1) Belle BaBar

$D^0 \rightarrow Ks\ \pi^0\rho^0, \phi, \omega, \eta, \eta'$ (CP=-1) Belle

$B^- \to D^0_{CP} K^-$ decays with Belle and BaBar





$$N_{D^0K} = 44.3 \pm 9.0$$

$$N_{D^0K} = 24.2 \pm 7.2(stat)$$

$$\frac{BR(B^- \to D^0_{CP}\, K^-) + BR(B^+ \to D^0_{CP}\, K^+)}{BR(B^- \to D^0_{CP}\, \pi^-) + BR(B^+ \to D^0_{CP}\, \pi^+)} = 7.4 \pm 1.7 \pm 0.6\%$$

$$\frac{BR(B^- \to D^0_{CP}\, K^-) + BR(B^+ \to D^0_{CP}\, K^+)}{BR(B^- \to D^0_{CP}\, \pi^-) + BR(B^+ \to D^0_{CP}\, \pi^+)} = 12.9 \pm 4.0^{+1.1}_{-1.5}\%$$

See Sanjay Swain's talk
in Session 8, Wednesday @ 16:15

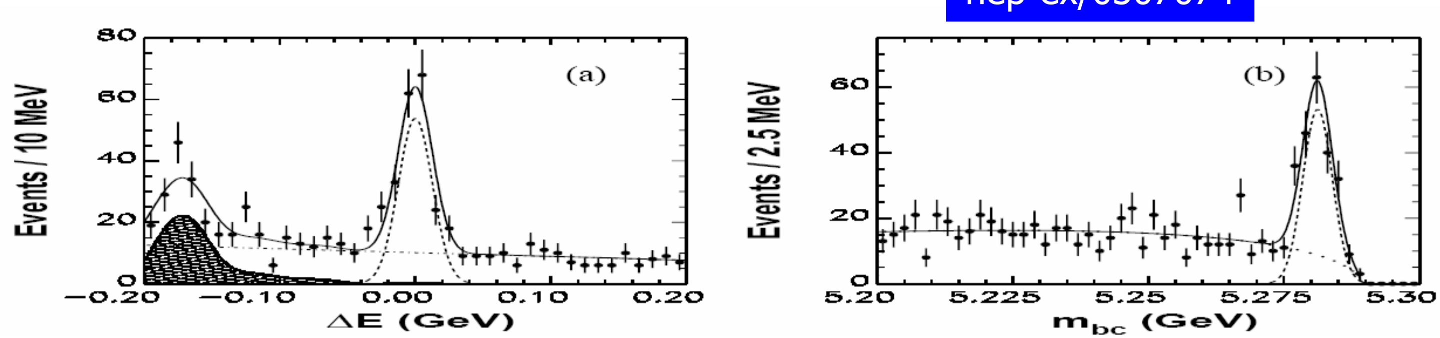
hep-ex/0304032

$B^- \rightarrow D^0_{CP} K^{*-}$ Branching Fractions with Belle

hep-ex/0307074

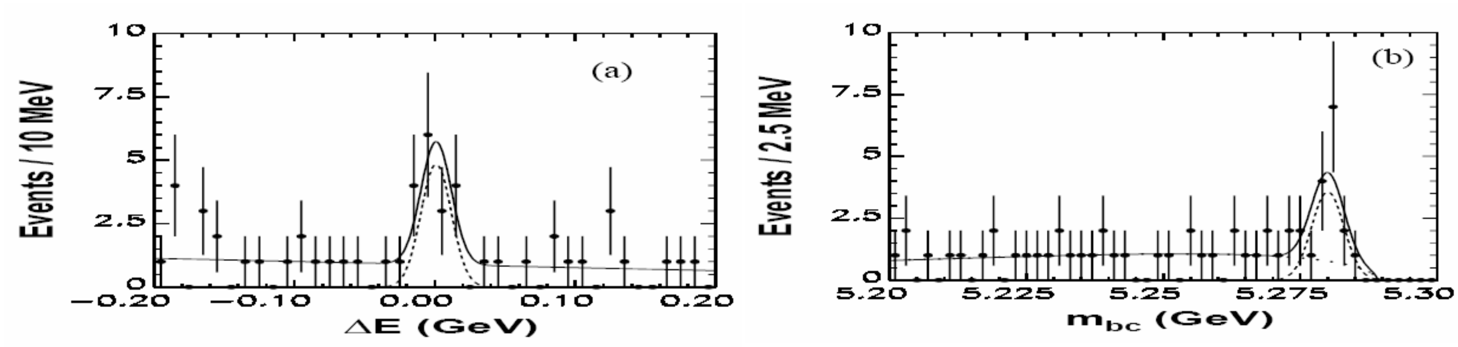
91 fb^{-1}

Flavor modes
for calibration
$D^0 \rightarrow K\pi, K\pi\pi\pi, K\pi\pi^0$



D_{+1}=K^+K^-, $\pi^+\pi^-$

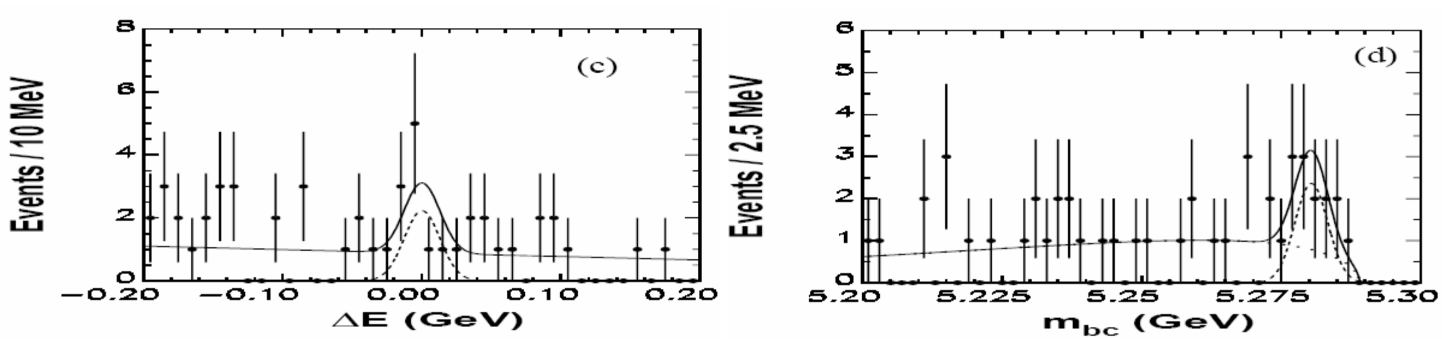
Events:13.1±4.3
Significance: 4.3σ



D_{-1}=$K_s\pi^0$, $K_s\phi$, $K_s\omega$

Events:7.2±3.6

Significance: 2.4σ



First measurement of these modes!

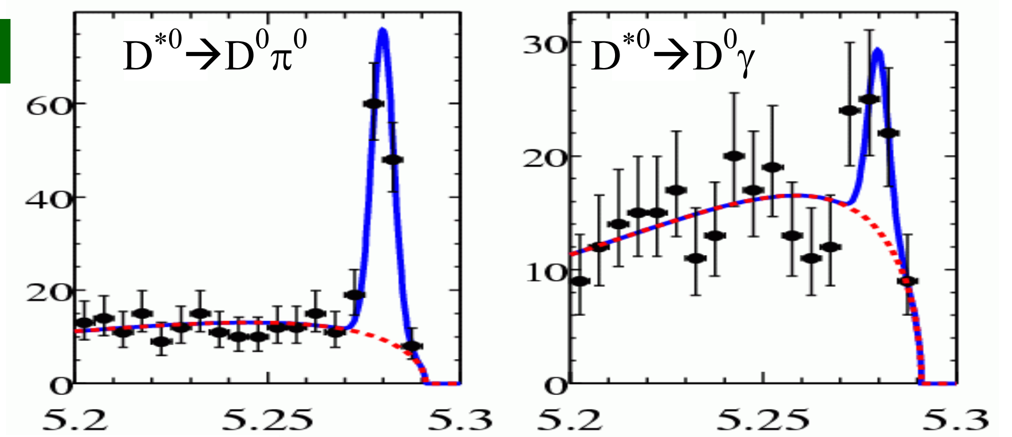
80 fb^{-1}

$B^- \rightarrow D^{*0}K^{*-}$ Branching Fractions from BaBar

$B^- \rightarrow D^{*0}K^{*-}$

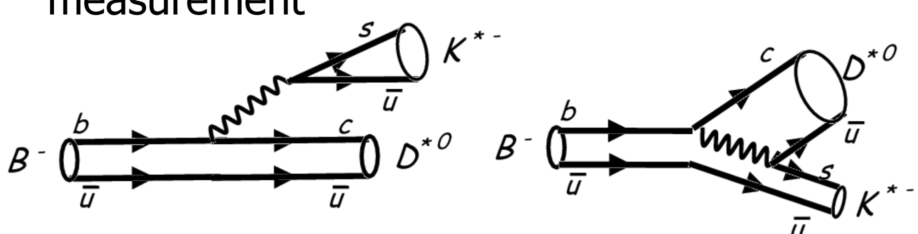
hep-ex/0308057

- Start with the more abundant flavor modes: $K\pi$, $K3\pi$, $K\pi\pi^0$



$$\mathcal{B}(B^- \rightarrow D^{*0}K^{*-}) = (7.6 \pm 1.0(\text{stat}) \pm 0.9(\text{sys})) \times 10^{-4}$$

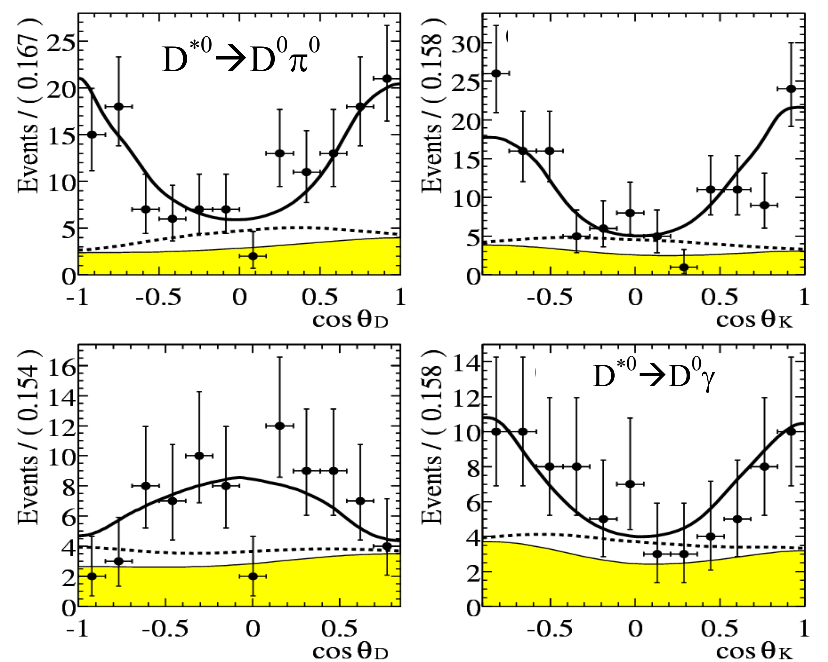
- Test of Factorization from polarization measurement



$$\frac{\Gamma_L}{\Gamma} = \frac{|H_0|^2}{|H_0|^2 + |H_+|^2 + |H_-|^2}$$

Factorization prediction: $\Gamma_L/\Gamma \approx 90\%$ for 1st diagram

$\Gamma_L/\Gamma = 0.86 \pm 0.06$ (stat) ± 0.03 (syst)



Summary of Measured Asymmetries

$$\sin^2\gamma \le R_{CP\pm} \qquad A_{CP\pm}R_{CP\pm} = \pm 2r\sin\delta\sin\gamma$$

$B^- \to D^0_{CP}K^-$

	$R_{CP=+1}$	$A_{CP=+1}$	$R_{CP=-1}$	$A_{CP=-1}$
Belle	1.21 ±0.25 ±0.14	0.06 ±0.19 ±0.04	1.41 ±0.27 ±0.15	-0.19 ±0.17 ±0.05
BaBar	1.06 ±0.26 ±0.17	0.17 ±0.23 ±0.08		

$B^- \to D^0_{CP}K^{*-}$

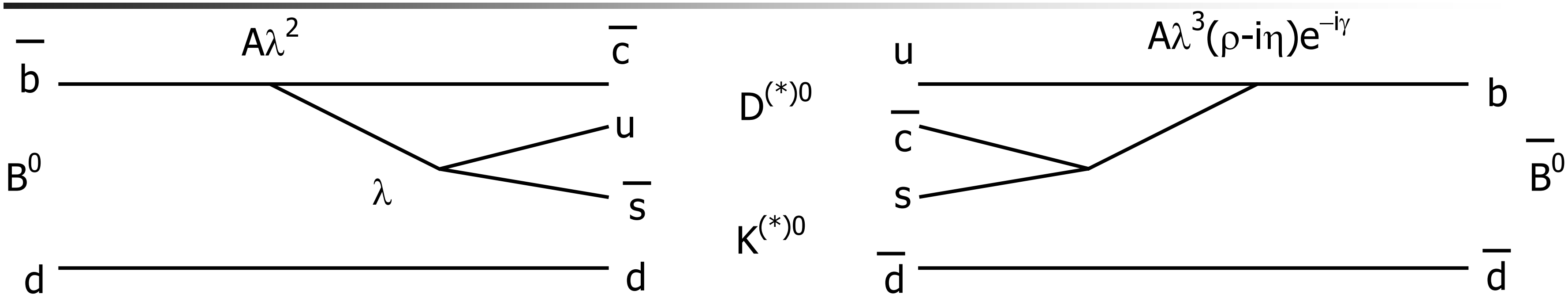
	BF(10^{-4})	$R_{CP=+1}$	$A_{CP=+1}$	$R_{CP=-1}$	$A_{CP=-1}$
Belle	5.2 ±0.5 ±0.6		-0.02 ±0.33 ±0.07		0.19 ±0.50 ±0.04

- Errors still large to put significant limits on γ
  - Add as many more as possible: many drops in the bucket
  - Measure all sides of the 2 triangles
- A good measurement of r required
- Assuming r~0.2 and using 1σ uncertainties: $\gamma > 72^\circ$

Gronau
hep-ph/0306308

In agreement with existing constraints

$\sin(2\beta+\gamma)$ in $B^0 \to D^{(*)0} K^{(*)0}$



$$V_{cb} V_{us}^{*} = A \qquad\qquad V_{ub} V_{cs}^{*} e^{i\delta} = r\, A\, e^{-i\gamma} e^{i\delta}$$

Strong phase difference

- Similar to $D(*)\pi$: interference between decay and mixing, but…
  - Advantages:
    - Much larger asymmetries:
    - CP violation from tag-side not significant

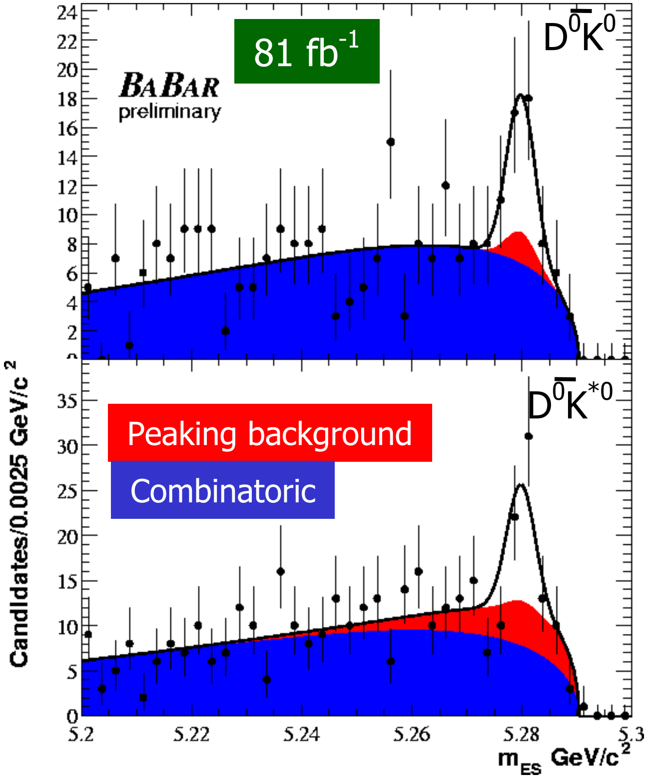
$$r = \left| \frac{A\left(B^0 \to D^0 K^{(*)0}\right)}{A\left(B^0 \to \bar{D}^0 K^{(*)0}\right)} \right| = \left| \frac{V_{ub} V_{cs}^{*}}{V_{cb} V_{us}^{*}} \right| \sim 0.4$$

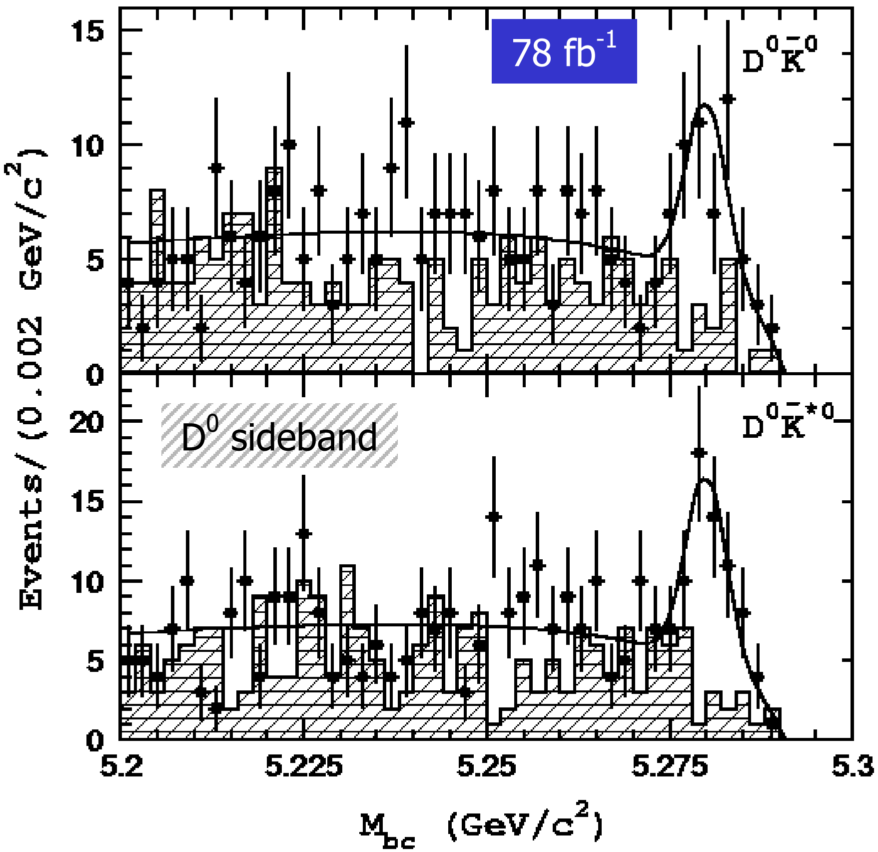
Measure r with $K^{*0} \to K^- \pi^+$

  - Disadvantages:
    - Color suppressed decays: Smaller branching fractions
    - Possible competing effects from Doubly-Cabibbo-suppressed D^0 decays
    - Requires tagging for time-dependent studies: 70% tagging efficiency

Kayser, London, PRD 61, 116013
Atwood, Soni, hep-ph/0206045

Current measurements and limits in $B^0 \to \bar{D}^{(*)0} K^{(*)0}$





Mode	Br(x10-5) Belle	Br(x10-5) BaBar
$B^0 \to \bar{D}^0 K^{*0}$	4.8 ±1.1 ±0.5	3.0 ±1.3 ±0.6
$B^0 \to \bar{D}^0 K^0$	5.0 ±1.3 ±0.6	3.4 ±1.3 ±0.6

V_{ub}

$B^0 \to \bar{D}^{*0} K^0$	<6.6 (90% c.l.)
$B^0 \to \bar{D}^{*0} K^{*0}$	<6.9 (90% c.l.)
$B^0 \to D^0 K^{*0}$	<1.8 (90% c.l.)
$B^0 \to D^{*0} K^{*0}$	<4.0 (90% c.l.)

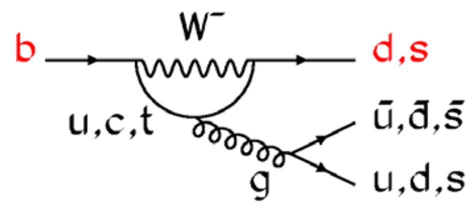
V_{ub} contribution necessary for measurement of γ not observed yet!

Measurement and Constraints on γ with Charmless B Decays

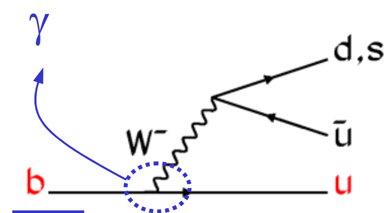
γ in Charmless B $\rightarrow$ PP,PV decays

$$A(B\rightarrow f)=\left(|P|e^{i\delta}+|T|e^{+i\gamma}\right)$$

$$\bar{A}(\bar{B}\rightarrow \bar{f})=\left(|P|e^{i\delta}+|T|e^{-i\gamma}\right)$$



P $\quad V_{cb}^{*}V_{cs} \sim \lambda^{2}$



T $\quad V_{ub}^{*}V_{us} \sim \lambda^{4}$

- Tree amplitude suppressed in Standard Model

Possible window on New Physics

  - Penguin contributions large: $\dfrac{B\rightarrow K\pi}{B\rightarrow \pi\pi}\approx 4$ ← 5% if neglecting penguins
  - Interference between Tree and Penguin

⇒ Branching fractions and CP asymmetries sensitive to γ

$$BF \propto 1+2\left|\frac{P}{T}\right|\cos\delta\cos\gamma+\left|\frac{P}{T}\right|^{2}$$

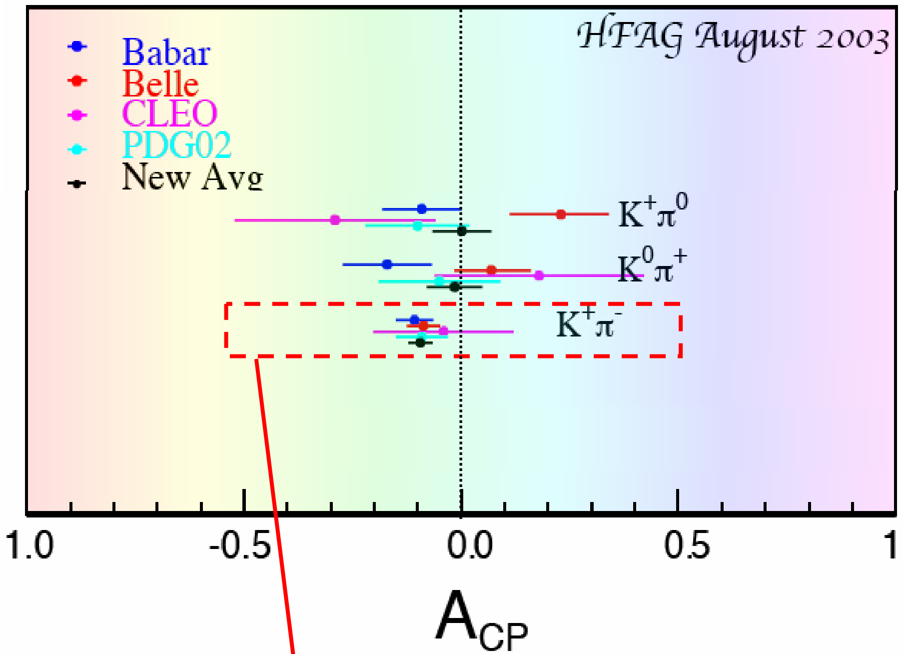
$$A_{CP}=-2\left|\frac{P}{T}\right|\sin\delta\sin\gamma$$

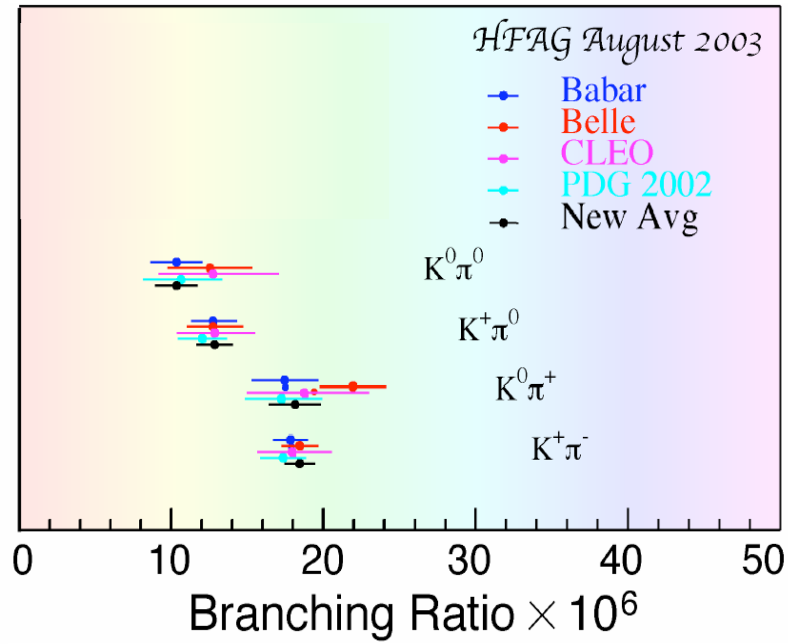
- Main Challenges
  - Background suppression
  - Contribution of EW penguins
  - Effects of Final State Interaction
  - **Requires estimate of |P/T|**

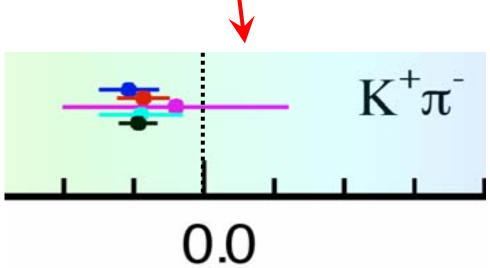
A_{CP} alone not sufficient

Need also BF to have a handle on δ

Status of B → Kπ BF and A_{CP} measurements







$$A_{K\pi} = -0.086 \pm 0.035 \pm 0.014 (Belle)$$
$$= -0.107 \pm 0.041 \pm 0.012 (BaBar)$$
$$= -0.04 \pm 0.16 \pm 0.02 (CLEO)$$
$$Average = -0.09 \pm 0.03$$

3.4σ significant!
Expected to be small in Standard Model

Constraints on γ with current measurements

- Gronau-Rosner Method:
  - Measure A_{CP} and BF

$$R_{c,n} = 1 - 2r_{c,n}(\cos\gamma - \delta_{EW})\cos\delta_{c,n} + (1 - 2\delta_{EW}\cos\gamma + \delta_{EW}^2)r_{c,n}^2$$

$$A_0^{c,n} = 2r_{c,n}\sin\delta_{c,n}\sin\gamma$$

$$\begin{Bmatrix} R_c \\ A_0^c \end{Bmatrix} = 2\left[\frac{Br(B^+ \to K^+\pi^0) \pm Br(B^- \to K^-\pi^0)}{Br(B^+ \to K^0\pi^+) + Br(B^- \to \overline{K}^0\pi^-)}\right]$$

$$\begin{Bmatrix} R \\ A_0 \end{Bmatrix} = \left[\frac{Br(B^0 \to K^+\pi^-) \pm Br(\overline{B}^0 \to K^-\pi^+)}{Br(B^+ \to K^+\pi^0) + Br(B^- \to \overline{K}^0\pi^-)}\right]\frac{t_{B+}}{t_{B0}}$$

$$\begin{Bmatrix} R_n \\ A_0^n \end{Bmatrix} = \frac{1}{2}\left[\frac{Br(B^0 \to K^+\pi^-) \pm Br(\overline{B}^0 \to K^-\pi^+)}{Br(B^0 \to K^0\pi^0) + Br(\overline{B}^0 \to \overline{K}^0\pi^0)}\right]$$

  - Eliminate strong phase $\delta_{c,n} \to R_{c,n} = R_{c,n}(A_{c,n},\gamma)$
    - Constraint on γ from experimental error on $R_{c,n}$ and $A_{c,n}$

Heavy Flavor Average Group:

R_0=0.99±0.09	**A_0= -0.09 ±0.03**
R_c=1.30±0.15	A_c= 0.0 ± 0.06
R_n=0.8 ±0.11	A_n= -0.07 ± 0.03

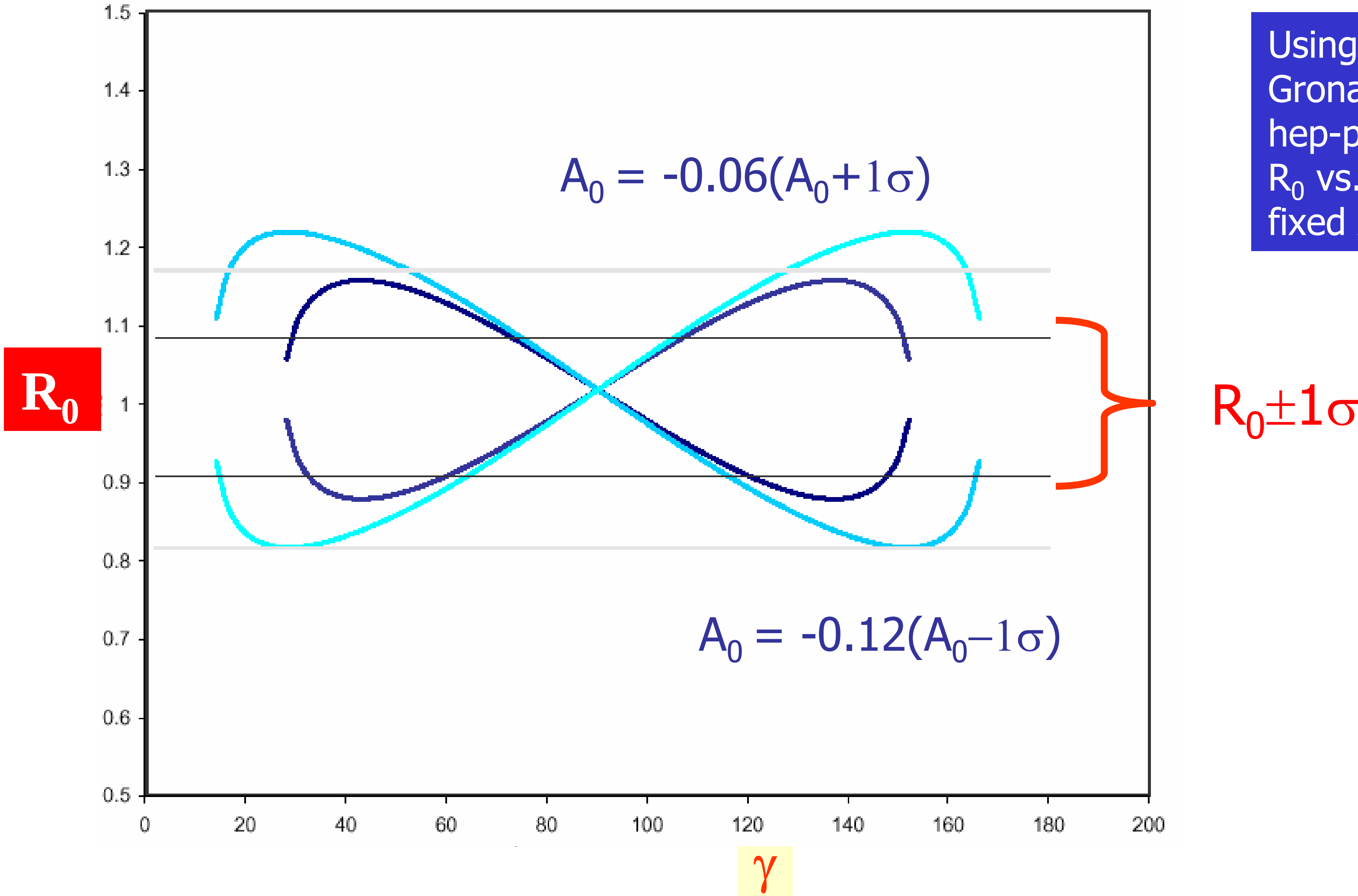
3.4σ significant! Expected to be small in Standard Model

    - No strong constraint yet: in agreement with CKM fitter constraints

Gronau,Rosner hep-ph/0307095

- QCD Factorization: See M. Neubert's talk later in this session
- Constraints also from Fleischer and Mannel

Example of Constraint on γ



Using method in Gronau,Rosner hep-ph/0307095: R_0 vs. γ for fixed $A_0 \pm$ 1s

60 < γ <120 at 1σ level

No useful limit at 2 s level

Consistent with CKM range:

$$37^o < \gamma < 80^o$$

Summary and Outlook

- Different families of B decays offer observables sensitive to γ
  - No single "Golden" mode for a precise and clean measurement
  - Typical pattern: abundant modes with small CP-violating amplitudes and viceversa

- First limits on $|\sin(2\beta+\gamma)|$ with time-dependent analysis of $D^*\pi$
  - Use SU(3) symmetry to estimate $|A(V_{ub})/A(V_{cb})|$

- Many $B \rightarrow D^{(*)}K^{(*)}$ modes under study at B factories
  - Larger data samples needed for precise measurements of branching fractions
  - γ can be measured with GWL, ADS and time-dependent analyses

- Progress in charmless $B \rightarrow PP,PV$ decay modes
  - More branching fractions and CP asymmetries now measured
  - SU(3) symmetry and QCD Factorization approaches combining all measurements
    - Limits compatible with γ values from CKM fitter

Chiang, Gronau, Luo, Rosner, Suprun hep-ph/0307395
Neubert, Beneke hep-ph/0308039