Measurements of CP violation in B decays and CKM parameters

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On behalf of the BABAR Collaboration

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Outline

- Introduction
- CP violation and the CKM model
- Experimental setups and methods
- The angles
  - $\beta = \varphi_1$
  - $\alpha = \varphi_2$
  - $\gamma = \varphi_3$
- Direct CP asymmetries
- Putting all together: a flavor of the CKM fits
- Summary and outlook

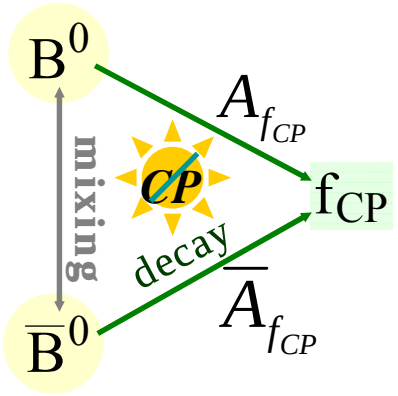
Both B factories
Focus on recent results
TeVatron not repeated

Introduction

At least 2 amplitudes for CP violation to occur.

3 types of CP violation:

- **Direct** **charged and neutral B** **strong phases**
- **In mixing** **neutral** **suppressed**
- **In the interference between mixing and decay** **neutral** **golden modes** **+ others.**
- One or several types.

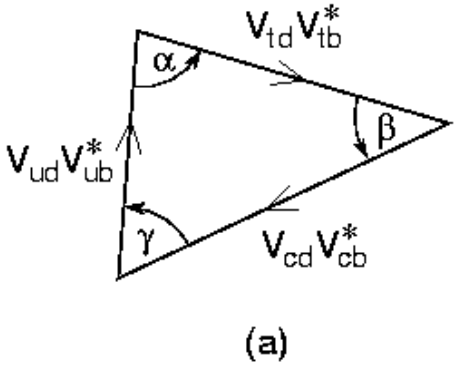


Standard ~~or not ?~~

- **The standard model (SM) accommodates CP violation through the CKM quark mixing.**

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$\approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

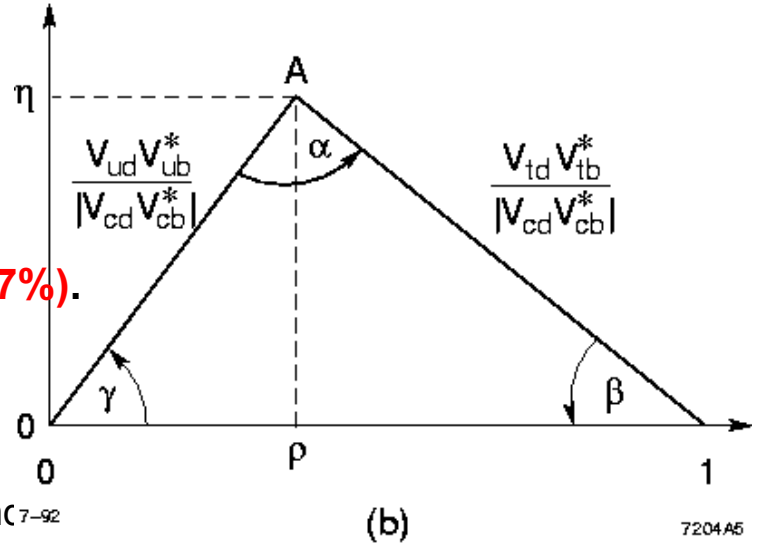


(a)

Experimental protocol

Overconstrain the 4 CKM parameters (angles)

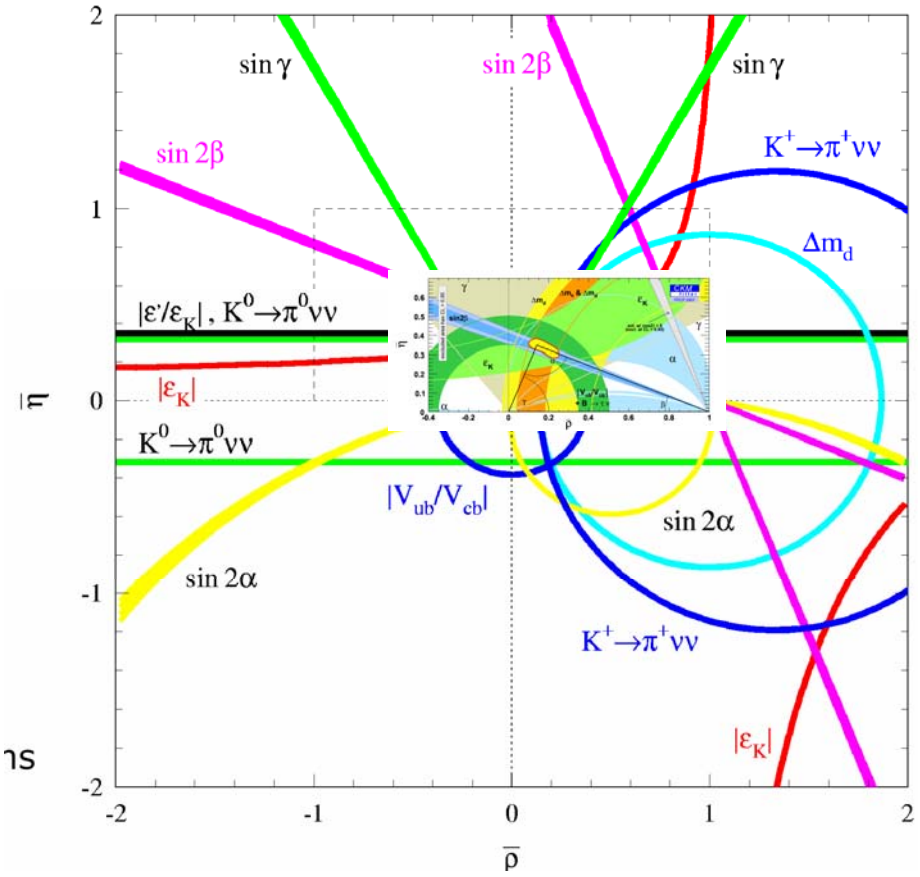
λ~ 0.23 (0.5%), **A ~ 0.8** (2%), ρ~**0.2** (20%), η ~ **0.4** (7%).

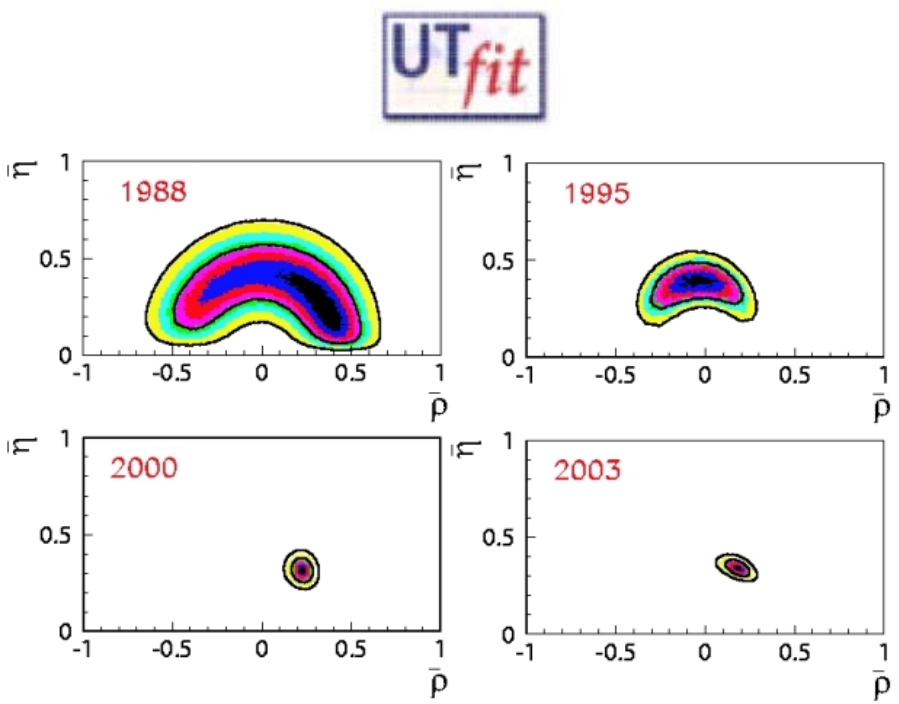


(b)

Look for new physics as a correction to the CKM picture

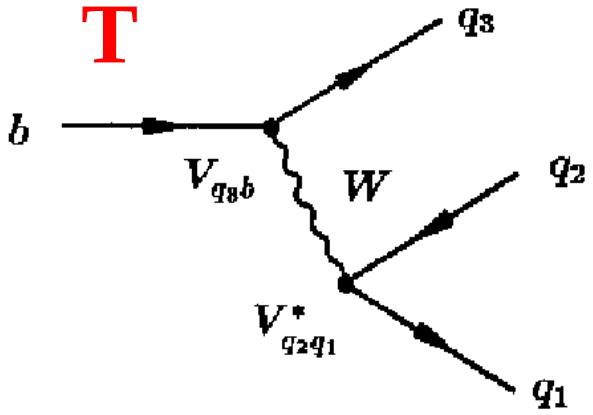
CKM matrix and UT



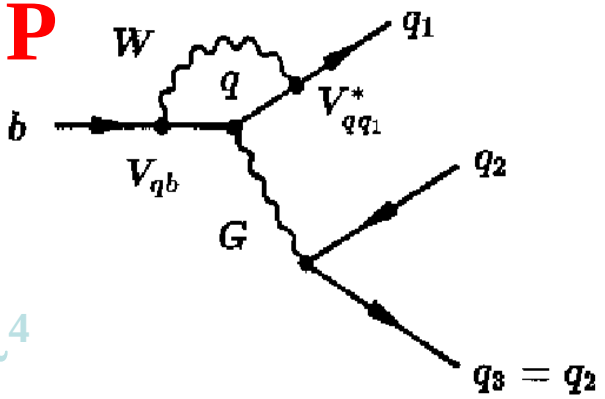


Amplitude structure in the SM

T



P



EWP

Cabibbo and color suppression

λ^2 λ^4

$A_{ccs} \sim V_{cb} V_{cs}^* \mathbf{T}_{ccs} + V_{ub} V_{us}^* \mathbf{P}_s$

$A_{sss} \sim V_{cb} V_{cs}^* \mathbf{P} + V_{ub} V_{us}^* \mathbf{P}$

$A_{ccd} \sim V_{tb} V_{td}^* \mathbf{P} + V_{cb} V_{cd}^* \mathbf{T}_{ccd}$

$A_{uud} \sim V_{tb} V_{td}^* \mathbf{P} + V_{ub} V_{ud}^* \mathbf{T}_{uud}$

λ^3

GOLDEN

Charmonium $K_{S,L}$	β
ΦK_S	β_{eff}
D^+D^-	$\beta+\phi$
$\pi^+ \pi^-$	α_{eff}

$(\mathbf{T}_{cus} + \mathbf{T}_{ucs})$ common D decay modes — DK — γ

Time dependent CP Asymmetries

For B decaying to f_{CP} (CP eigenstate) .

$$\mathcal{A}_f(\Delta t) \equiv \frac{\Gamma_{\bar{B}^0\to f}(\Delta t) - \Gamma_{B^0\to f}(\Delta t)}{\Gamma_{\bar{B}^0\to f}(\Delta t) + \Gamma_{B^0\to f}(\Delta t)}$$

$$= S_f \sin(\Delta m \Delta t) - C_f \cos(\Delta m \Delta t)$$

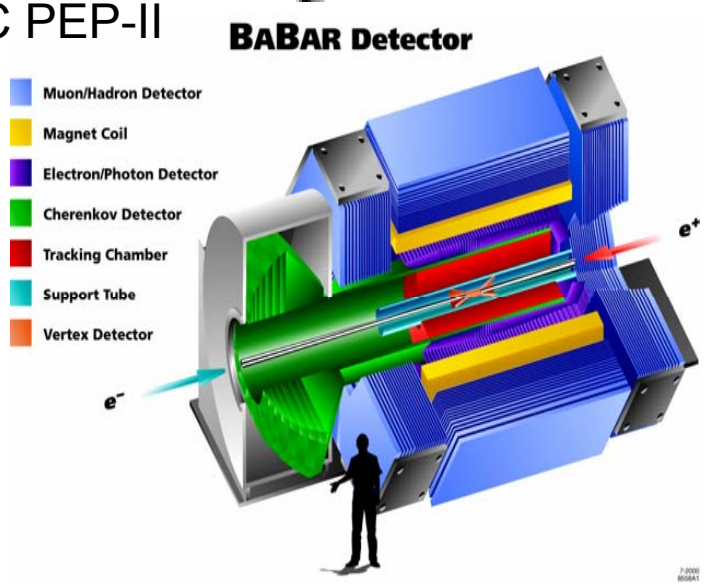
$\eta \sin 2\varphi_{eff}$

$$\lambda_f = \frac{q}{p}\frac{\bar{A}_f}{A_f} \qquad S_f \equiv \frac{2\,\mathrm{Im}(\lambda_f)}{1+|\lambda_f|^2} \qquad C_f \equiv -A_f \equiv \frac{1-|\lambda_f|^2}{1+|\lambda_f|^2}$$

- Statistics (low B.R.) — **B factory**
- Exclusive B mesons reconstruction — **tracking/calorimetry**
- Δt measurement — **asymmetric collider, vertexing**
- Flavor tagging — **particle identification**

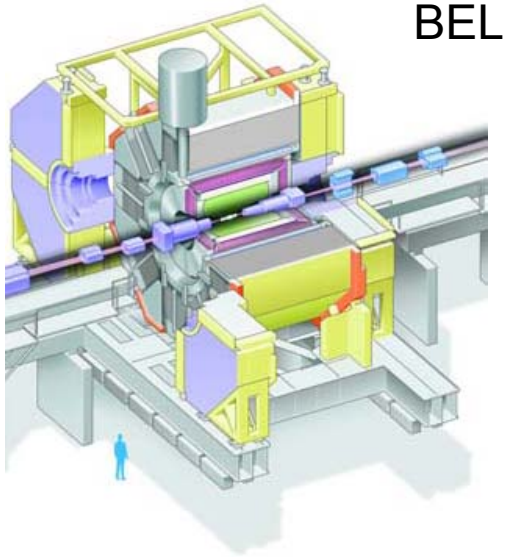
Experiments

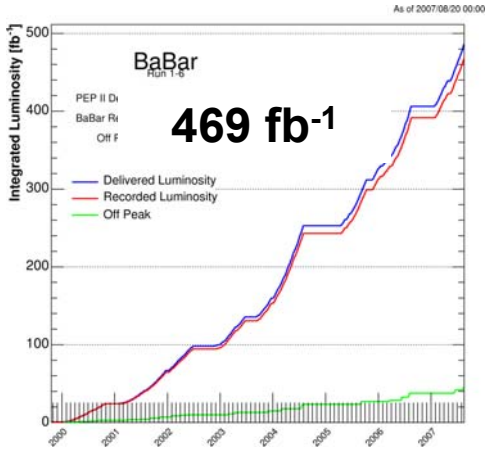
SLAC PEP-II



KEK-B

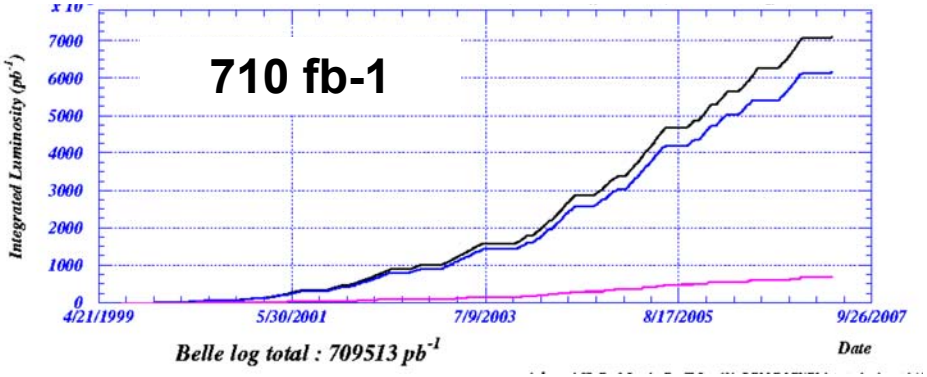
BELLE



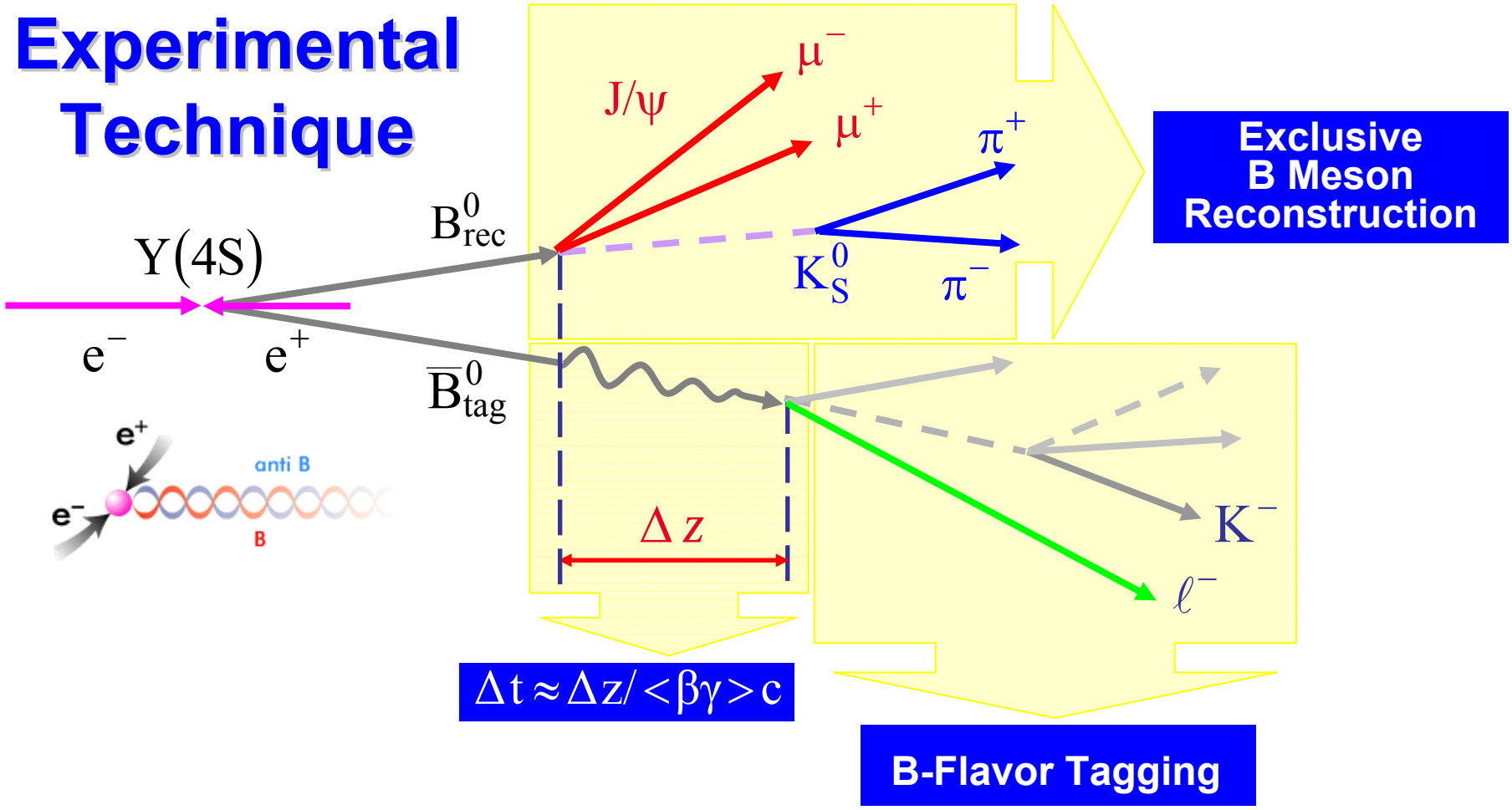


August 21

TeVatron now contributes



Experimental Technique



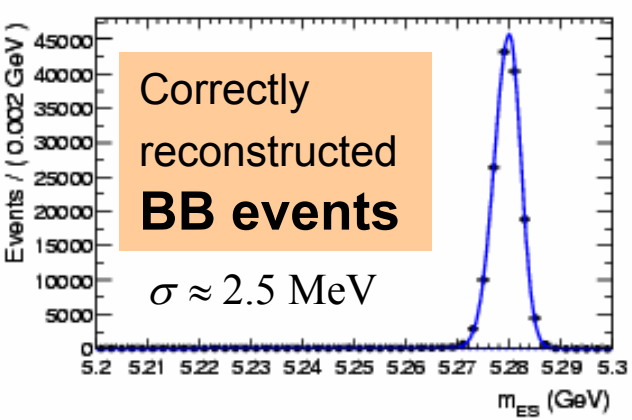
$B^0_{rec} = B^0_{flav}$ (flavor eigenstates) ➡ lifetime, mixing analyses

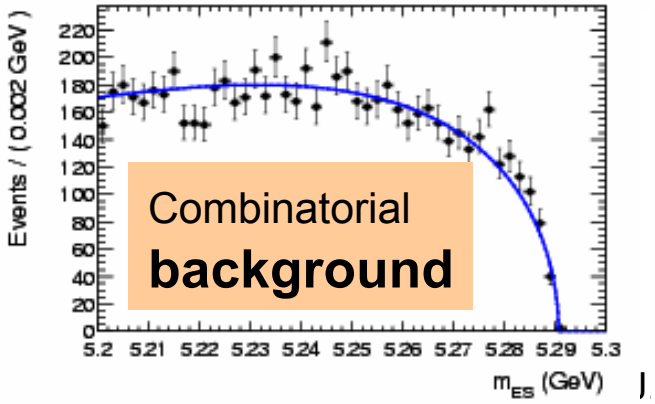
$B^0_{rec} = B^0_{CP}$ (CP eigenstates) ➡ CP analysis

B Meson Reconstruction

Beam-energy substituted mass

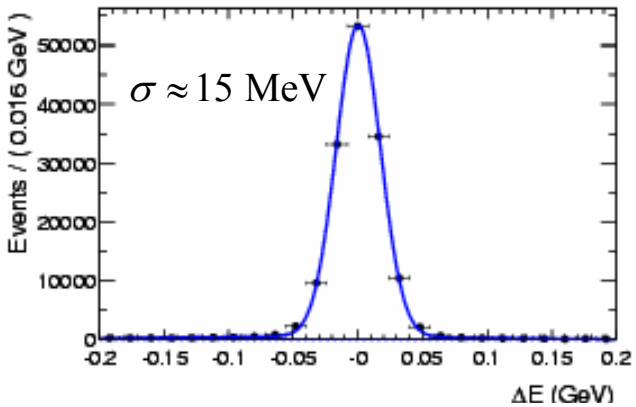
$$m_{ES} = \sqrt{E^{*}_{beam}{}^{2} - p^{*2}_{B}}$$

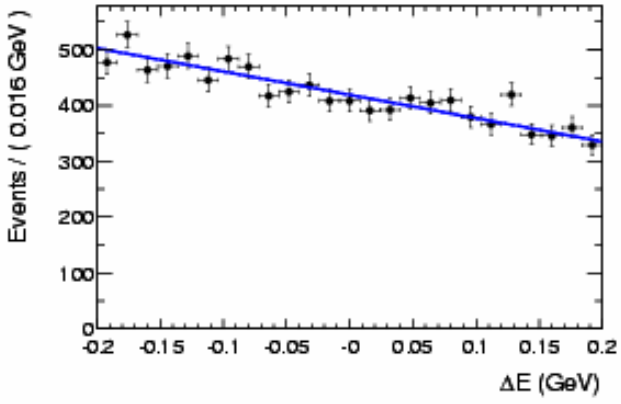




Energy difference

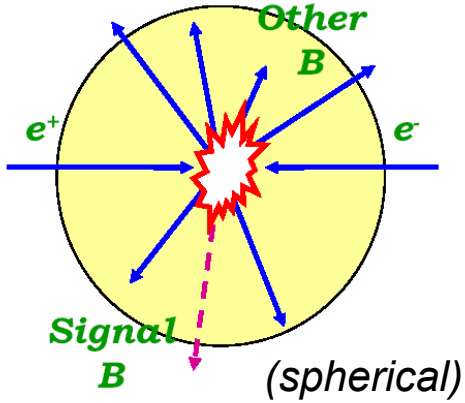
$$\Delta E = E^{*}_{B} - E^{*}_{beam}$$



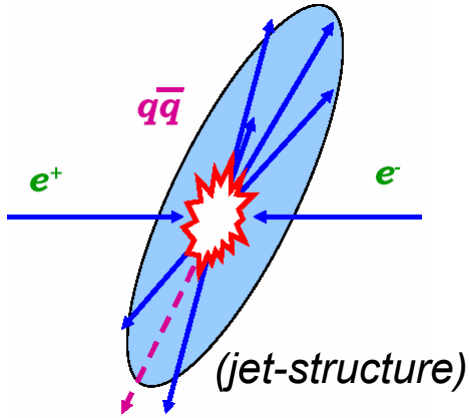


Event topology

(multivariate methods)



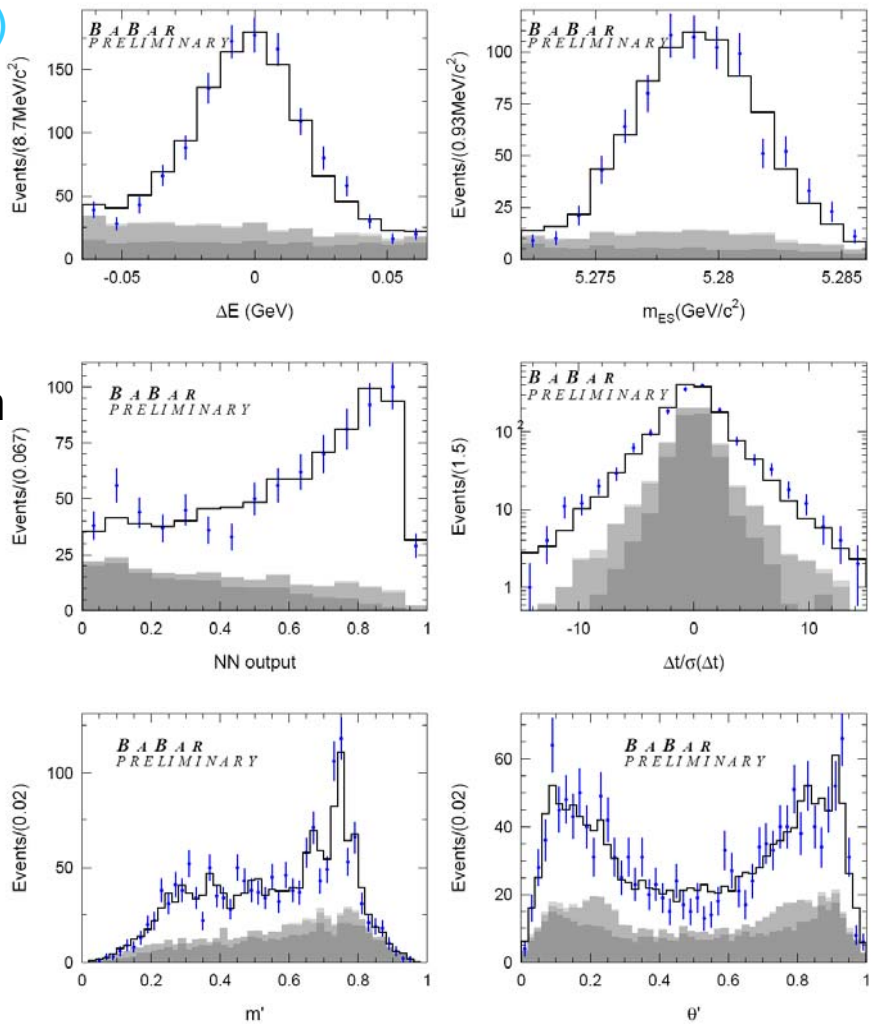
(spherical)



(jet-structure)

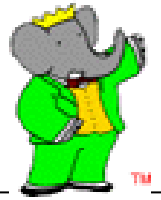
Amplitude analyses

- Use kinematics at BB threshold (Mes, ΔE)
- Fight combinatorial (mainly continuum with MVA) and peaking backgrounds.
- Can use Δt and tagging information, **TDCPA analyses**
- Isobar expansion to model amplitude for B(bar)→3bodies with a non resonant term and resonances.
- Each term is a complex amplitude multiplied by a complex (isobar coefficient) whose argument incorporates the CKM phase.
- Extended UML fits to the isobar coefficients and yields
- Misreconstructed signal events included



β

- b→c cbar s
- b→s,d gluon (b→ qqbar s,d)
- b→c ubar d
- b→c cbar d
- b to s γ by Tulay Donszelmann this afternoon

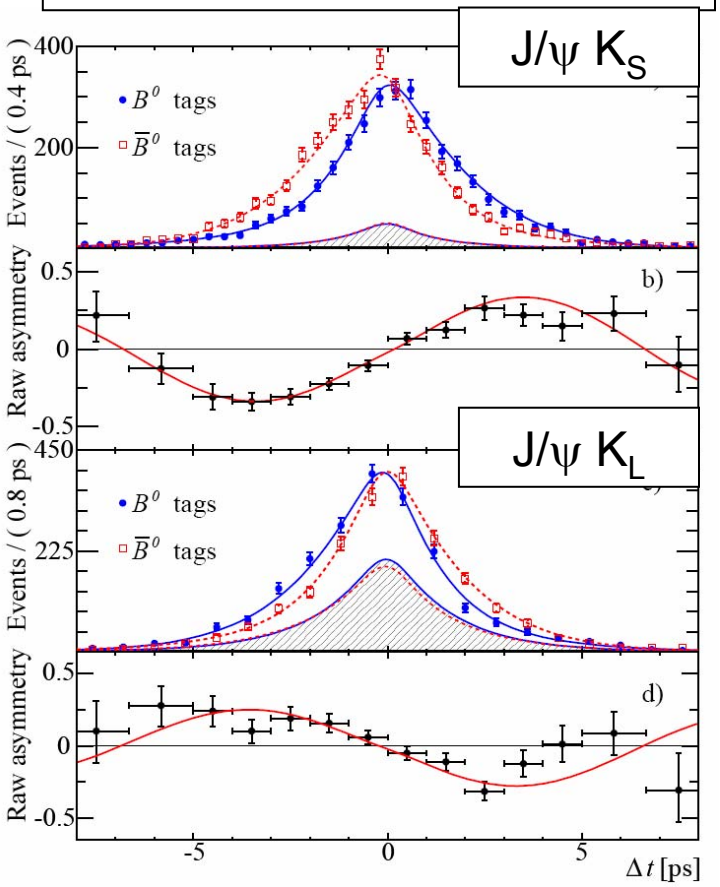


b → c cbar s

S=0.714 ± 0.032 ± 0.018

C=0.049 ± 0.022 ± 0.017

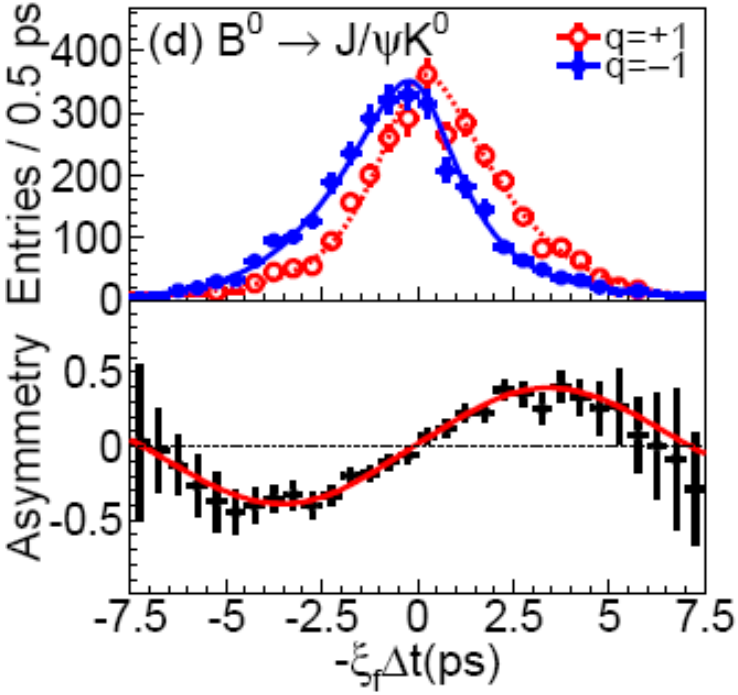
Preliminary arXiv: 0703021



S=0.642 ± 0.031 ± 0.017

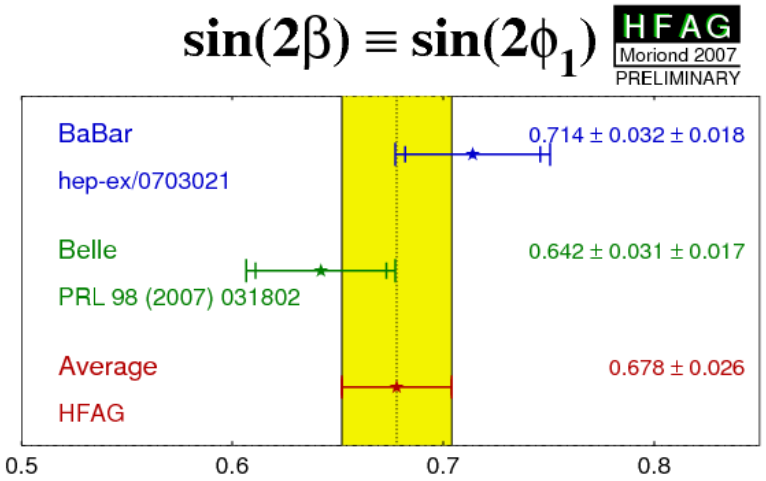
C=0.018 ± 0.021 ± 0.014

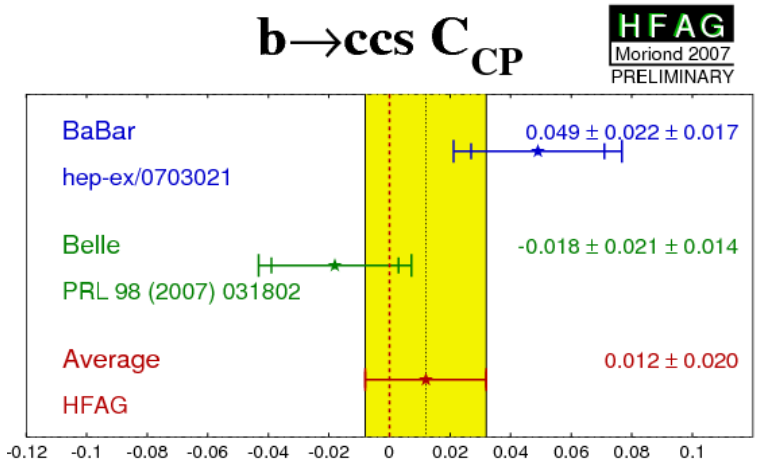
PRL 031802 (2007)



In SM, expect, S=ηsin2β, C=0

Status of charmonium K0

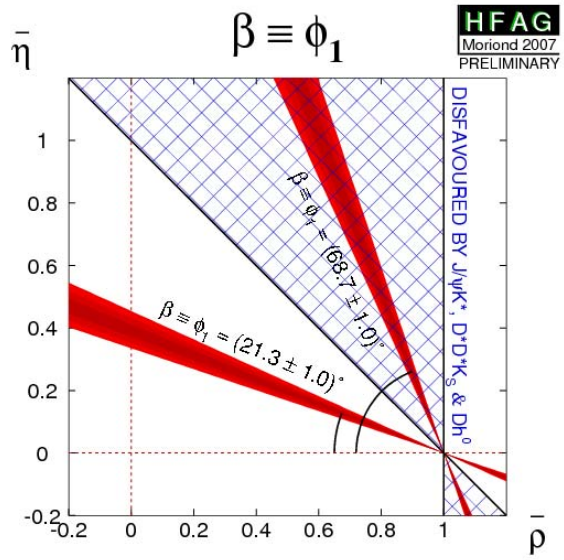




All charmonium (HFAG)

sin2β=0.678±0.025

β=(21.3 ± 1.0)° or (68.7 ± 1.0)°



cos2β

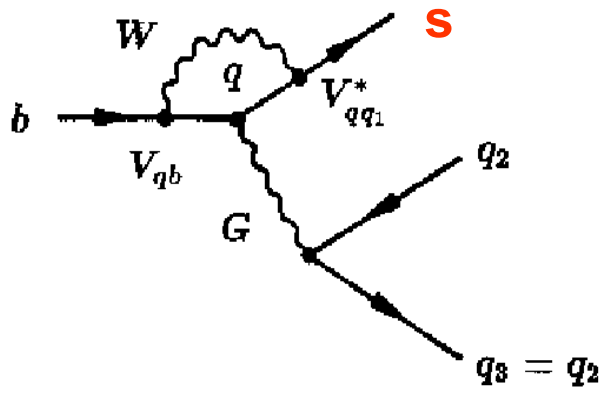
•J/Psi K*
3.32 +0.76 −0.96 ± 0.27 BABAR *PRD 71, 032005 (2005)*
0.56 ± 0.79 ± 0.11 *PRL 95 091601 (2005)*

• Bd → D0(kspi+pi-) h0 (NEW!) *arXiv: 0708.1549 preliminary*
• cos2b>@84% c.l. (assumptions)

• D*D*Ks
• cos2b>0 @94% c.l. (assumptions) *Phys.Rev. D74 (2006) 091101*
• Not conclusive *arXiv:0706.2045 preliminary*

Now, amplitude analyses measure β!

b → qq-bar s (penguin)

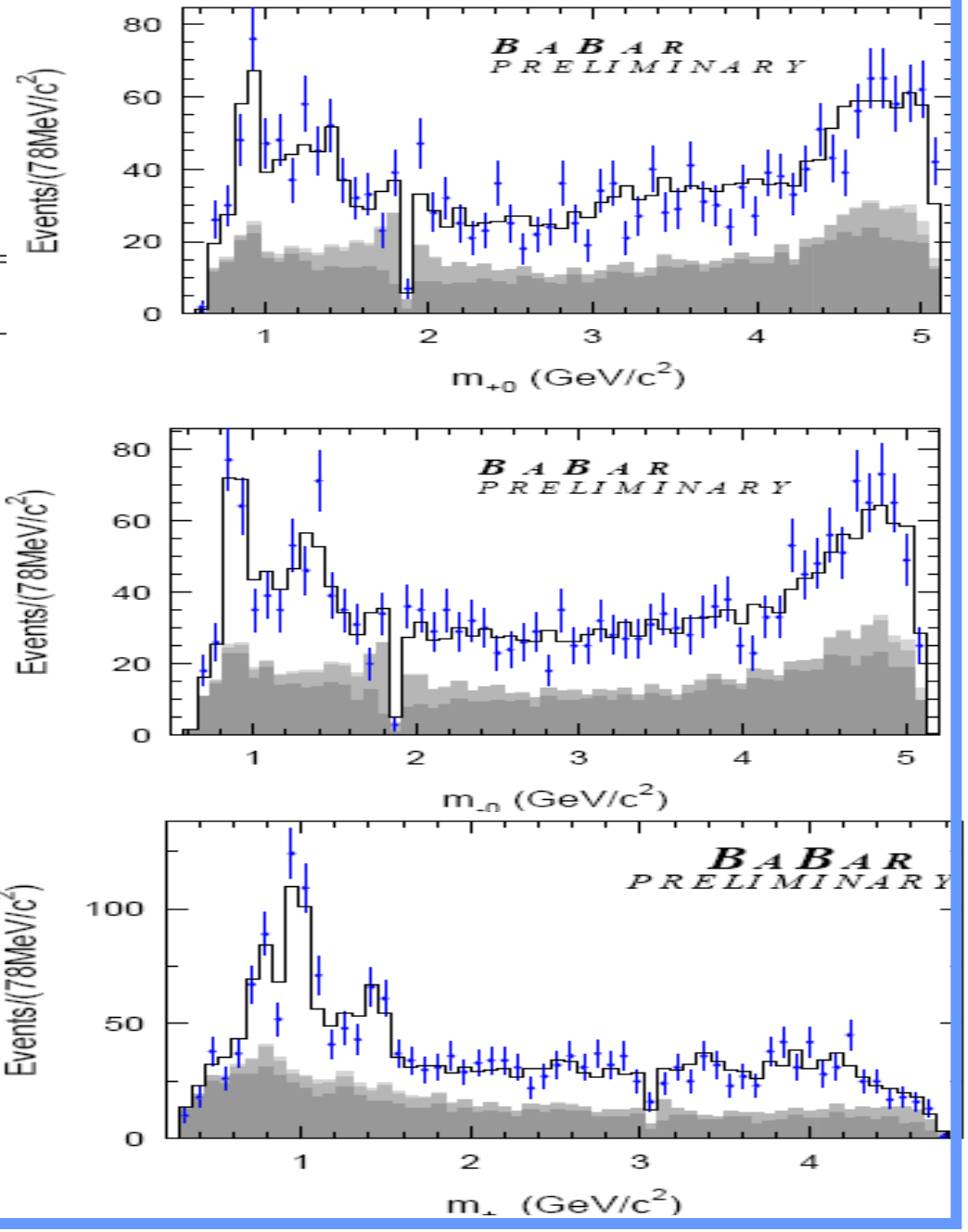


- Loop diagrams with same weak phase as ccbar s in SM
- new physics in loops ?
- New results available, in particular from amplitude analyses

Ksπ+π– (1)

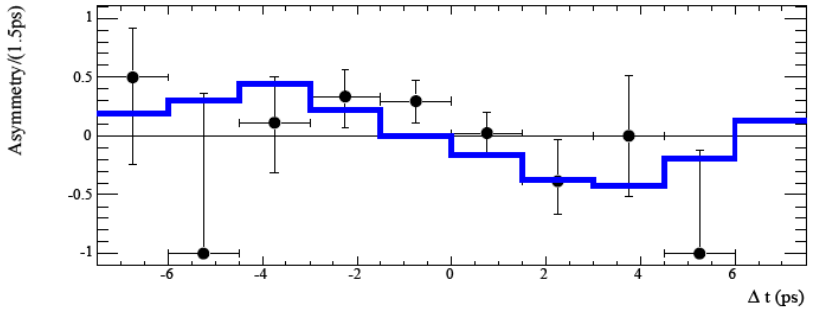
Preliminary arXiv: 0708.2097

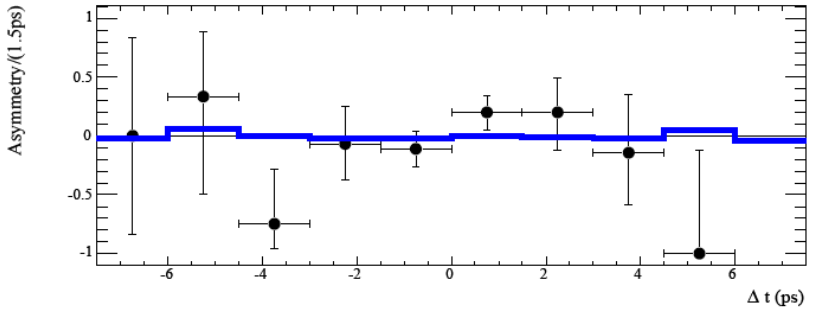
Resonance	Parameters	Form Factor
f_0	mass $= 965 \pm 10$	Flatté
	$g_\pi = 165 \pm 18$	
	$g_K = 695 \pm 93$	
ρ^0	mass $= 775.5 \pm 0.4$	GS
	width $= 146.4 \pm 1.1$	
$K^{*+}(892)$	mass $= 891.66 \pm 0.26$	RBW
$K^{*-}(892)$	width $= 50.8 \pm 0.9$	
$K^{*+}(1430)$	mass $= 1415 \pm 3$	LASS
$K^{*-}(1430)$	width $= 300 \pm 6$	
	cutoff $= 2000$	
	$a = 2.07 \pm 0.1\,(\mathrm{GeV}^{-1})$	
	$r = 3.32 \pm 0.34\,(\mathrm{GeV}^{-1})$	
$f_X(1300)$	mass $= 1449 \pm 13$	RBW
	width $= 126 \pm 25$	
$f_2(1270)$	mass $= 1275.4 \pm 1.1$	RBW
	width $= 185.2^{+3.1}_{-2.5}$	
$\chi_{c0}(1P)$	mass $= 3414.75 \pm 0.35$	RBW
	width $= 10.4 \pm 0.7$	
NR decays		flat phase spac



b → qq-bar s Ksπ+π−

Parameter	Value	Parameter	Value
$C(f_0(980)K^0_S)$	$0.35 \pm 0.27 \pm 0.07 \pm 0.04$	$C(\rho^0(770)K^0_S)$	$0.02 \pm 0.27 \pm 0.08 \pm 0.06$
$^\dagger 2\beta_{\rm eff}(f_0(980)K^0_S)$	$(89^{+22}_{-20} \pm 5 \pm 8)^\circ$	$^\dagger 2\beta_{\rm eff}(\rho^0(770)K^0_S)$	$(37^{+19}_{-17} \pm 5 \pm 6)^\circ$
$^\dagger S(f_0(980)K^0_S)$	$-0.94^{+0.07+0.05}_{-0.02-0.03} \pm 0.02$	$^\dagger S(\rho^0(770)K^0_S)$	$0.61^{+0.22}_{-0.24} \pm 0.09 \pm 0.08$
$f(f_0(980)K^0_S)$	$14.3^{+2.8}_{-1.8} \pm 1.5 \pm 0.6$	$f(\rho^0(770)K^0_S)$	$9.0 \pm 1.4 \pm 1.1 \pm 1.1$
$A_{CP}(K^{*+}(892)\pi^-)$	$-0.18 \pm 0.10 \pm 0.03 \pm 0.03$	$^\dagger\Delta\phi(f_0K^0_S, \rho^0K^0_S)$	$(-59^{+16}_{-17} \pm 6 \pm 6)^\circ$
$^\dagger\Delta\phi(K^*(892)\pi)$ [a]	$(-164 \pm 24 \pm 12 \pm 15)^\circ$		
$f(K^*(892)\pi)$	$11.7 \pm 1.3 \pm 1.3 \pm 0.6$		
$f(K^*(1430)\pi)$	$38.9 \pm 2.5 \pm 0.7 \pm 1.3$	$f(NR)$	$25.6 \pm 2.5 \pm 1.9 \pm 0.5$
$f(f_0(1300)K^0_S)$	$6.3 \pm 1.3 \pm 0.6 \pm 0.3$	$f(f_2(1270)K^0_S)$	$2.1 \pm 0.8 \pm 0.0 \pm 0.2$
$f(\chi_{c0}(1P)K^0_S)$	$1.2 \pm 0.5 \pm 0.0 \pm 0.1$		

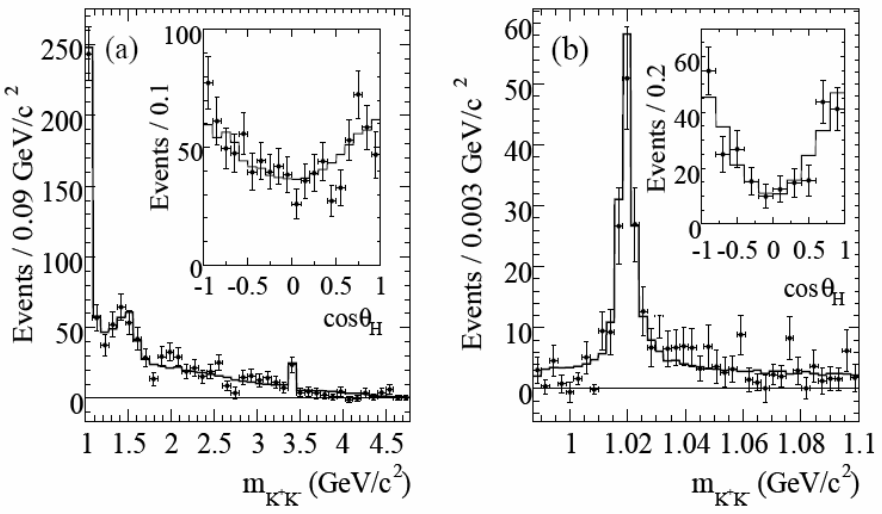




f0Ks β=44.5 ±11 ± 2.5 ± 4 degrees

Preliminary arXiv: 0708.2097 18.5 ± 6 ± 2.5 ± 4 ρ0Ks

b → qq-bar s (penguin) KsK+K-



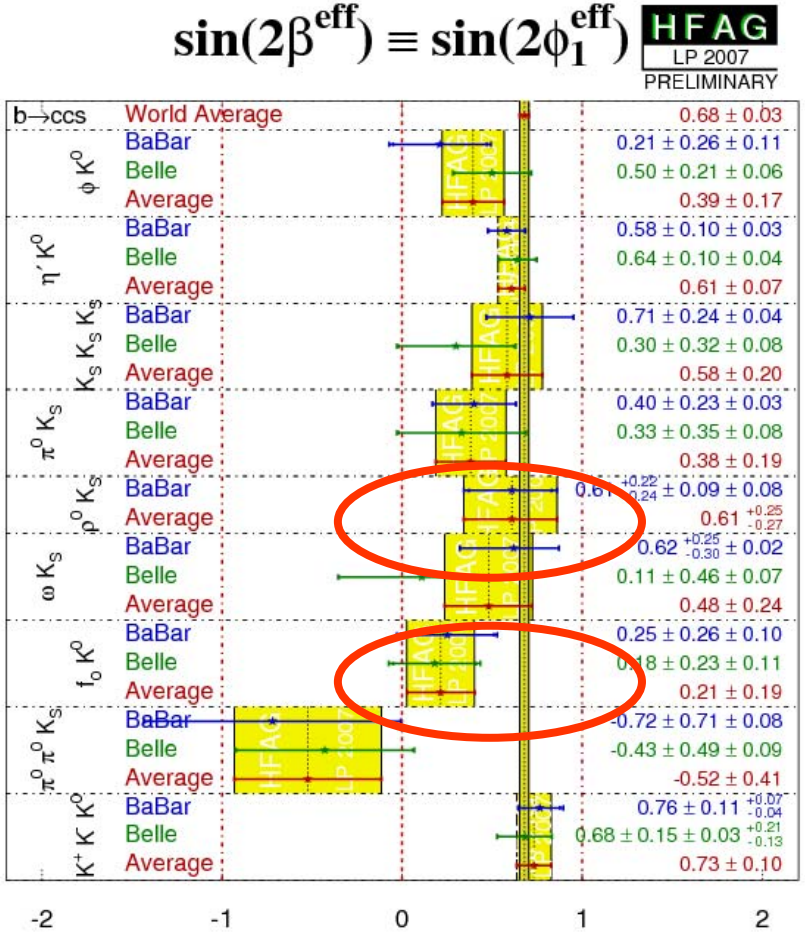
Measures β_{eff} for

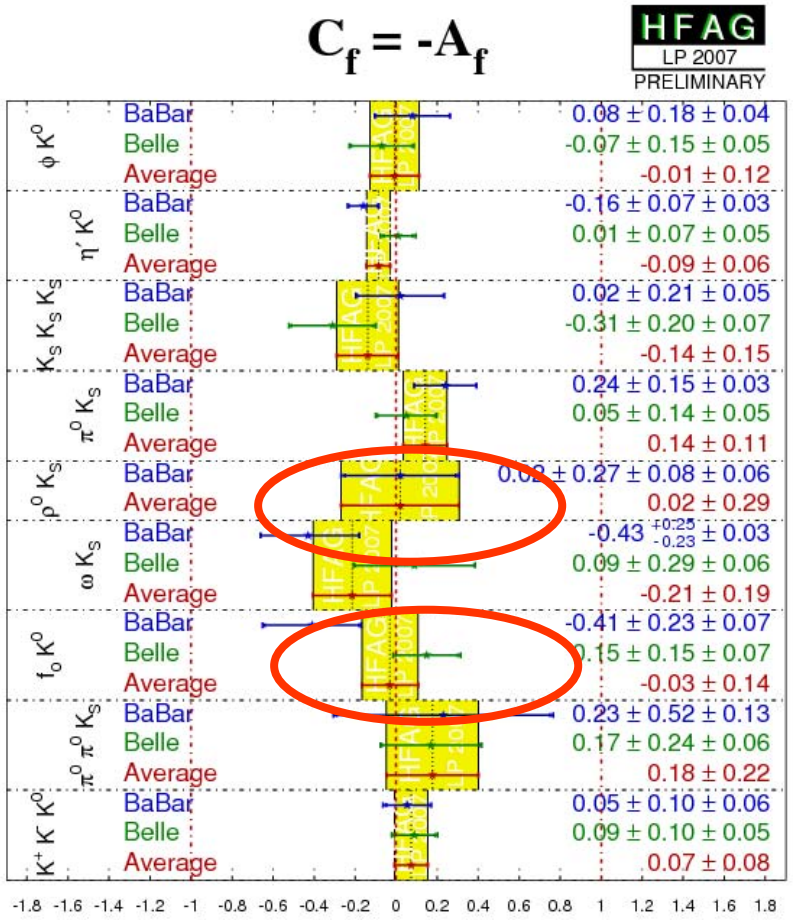
- ϕKs
- f0Ks with f0→K+K-
- K+K-Ks in the high mass region [M(K+K-)>1.1 GeV/c2]

	A_{CP}	β_{eff} (rad)	(degrees)
Whole DP	$-0.015 \pm 0.077 \pm 0.053$	$0.352 \pm 0.076 \pm 0.026$	20.2±4.3±1.5
High-mass	$-0.054 \pm 0.102 \pm 0.060$	$0.436 \pm 0.087\ ^{+0.055}_{-0.031}$	25.0
(1) ϕK^0	$-0.08 \pm 0.18 \pm 0.04$	$0.11 \pm 0.14 \pm 0.06$	6±8
(1) $f_0 K^0$	$0.41 \pm 0.23 \pm 0.07$	$0.14 \pm 0.15 \pm 0.05$	8±8
(2) ϕK^0	-0.11 ± 0.18	0.10 ± 0.13	6±7
(2) $f_0 K^0$	-0.20 ± 0.31	3.09 ± 0.19	177 ± 11

CPV established at 4.8 σ; $\pi-\beta_{eff}$ disfavored at 4.5 σ

b→s gluon (LP07)



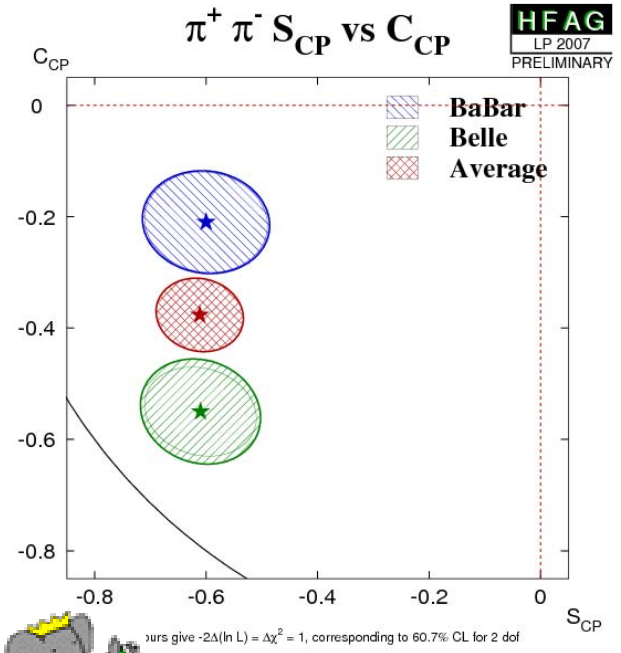


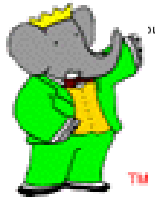
Without the outlying $B \to K_S$ f0($\pi^+\pi^-$)

α

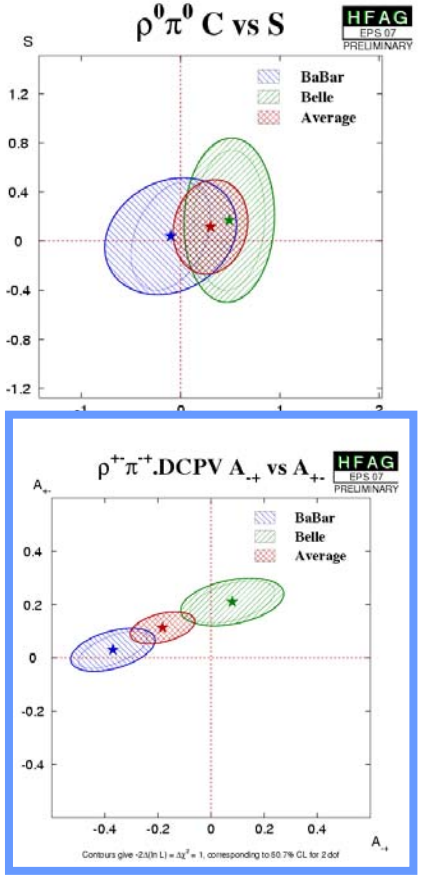
- Original idea B→$\pi\pi$.
  - Penguin pollution.
  - Gronau London (GL) isospin scheme.
  - Big BF($\pi 0 \pi 0$)
- B→ 3 pion Dalitz.
  - Snyder Quinn et al.
  - Babar and now Belle
- B→ $\rho\rho$
  - like $\pi\pi$ but twice lucky (polarization, B→ $\rho 0 \rho 0$ small)
- new (recent) b1 pi, K1 pi, a1 pi

b → uu-bar d

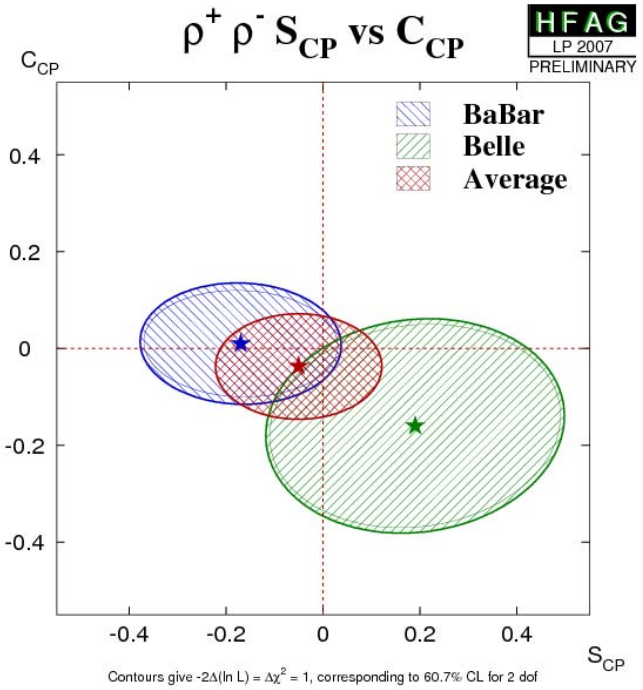




[PRL 99 (2007) 021603](#)
[PRL 98 (2007) 211801](#)



[PRD 76 (2007) 012004](#)
[PRL 98 (2007) 221602](#)



preliminary [arXiv:0705.2157](#)
[PRD 76 (2007) 011104](#)

$(\rho\pi)^0$

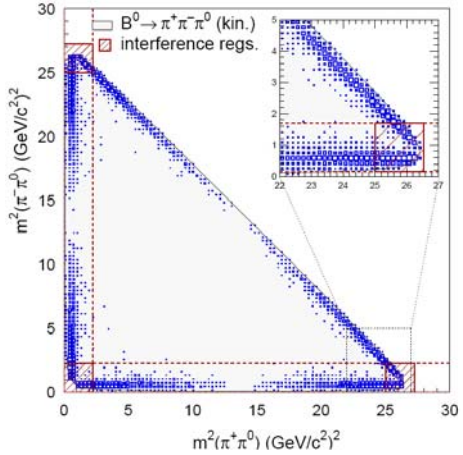
BABAR PRD 76 (2007) 012004
BELLE PRL 98 (2007) 221602

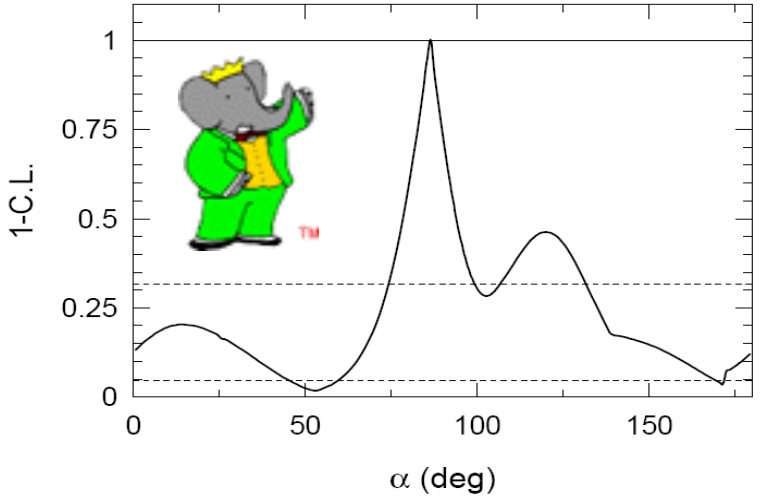
TDCPA analysis

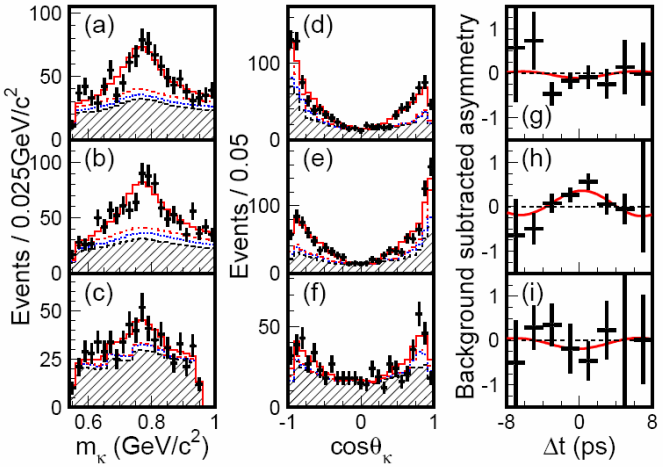
3 ρ charge states intefere

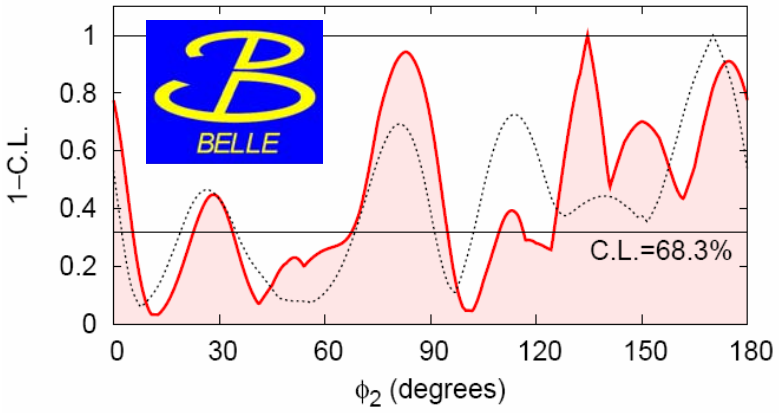
in the corners

Fit bilinear form factors

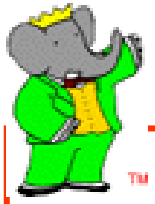








New ρρ GL isospin analysis



TDCP $\rho^0\rho^0$

Preliminary arXiv:0708.1630v1 [hep-ex]

$10^6 \times BF = 0.84 \pm 0.29 \pm 0.17$

$f_L = 0.70 \pm 0.14 \pm 0.05$

$S_{CP} = 0.5 \pm 0.9 \pm 0.2$

$C_{CP} = 0.4 \pm 0.9 \pm 0.2$

+

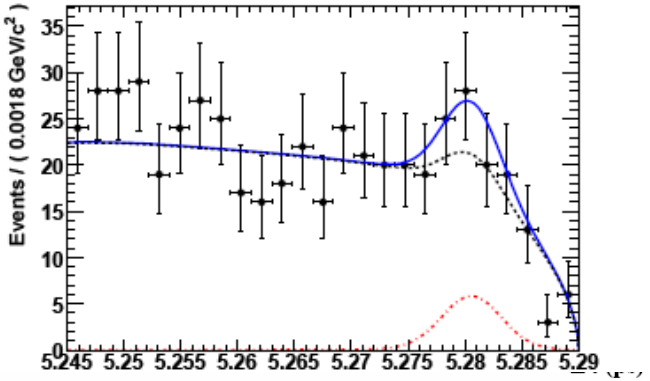
$\rho^+\rho^-$

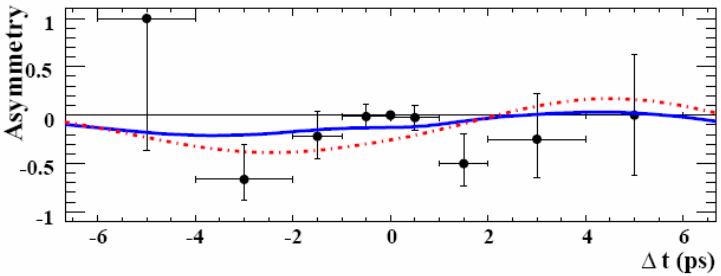
Babar preliminary arXiv:0705.2157

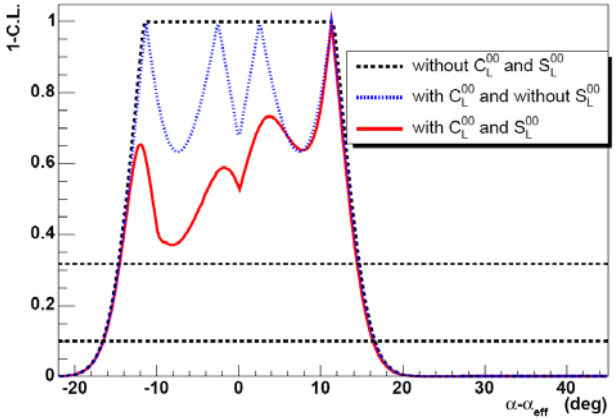
Belle PRD 76 (2007) 011104

=

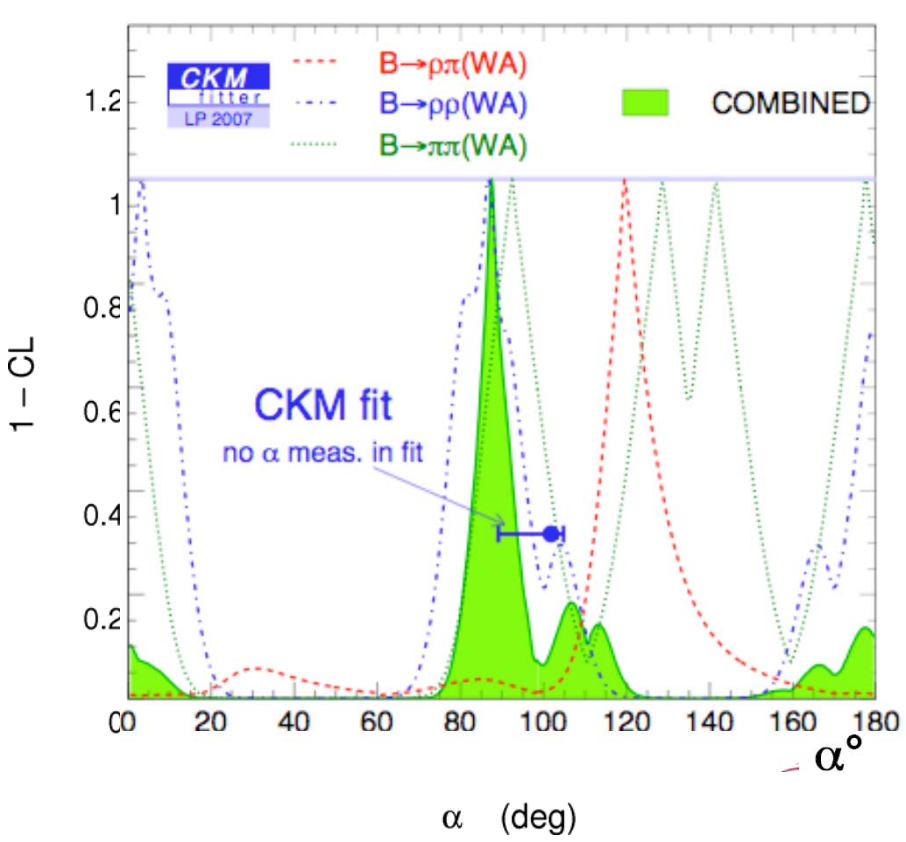
$|\alpha - \alpha_{eff}| = 16.5$ deg. @ 90% c.l.

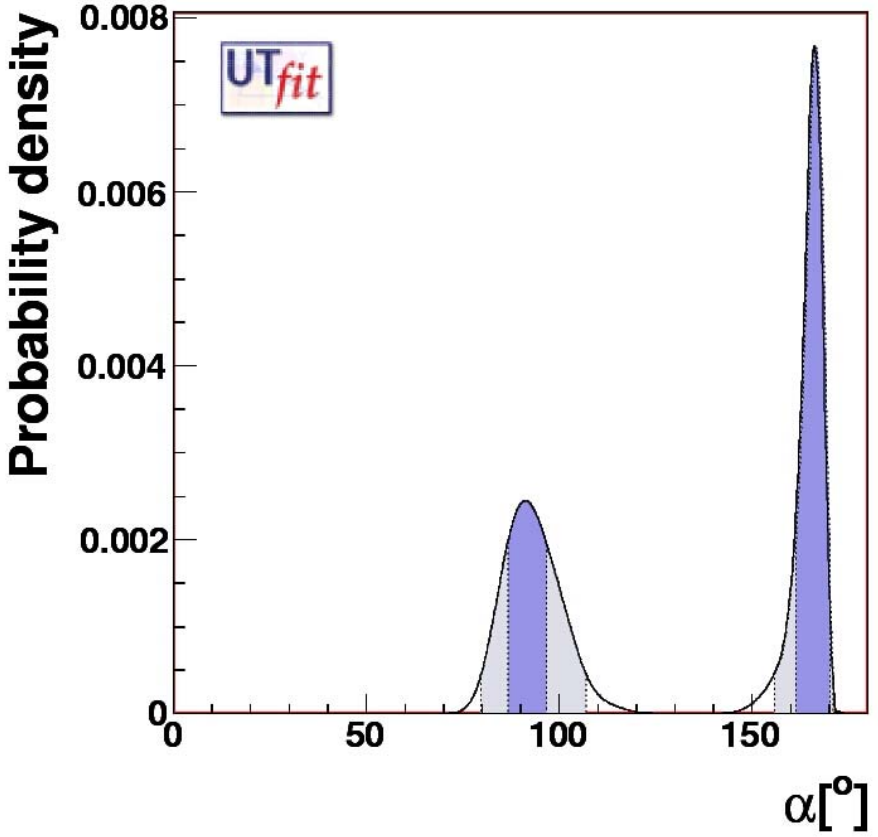






α combined





α=[80,107] or [156,171] deg @95%c.l.

γ

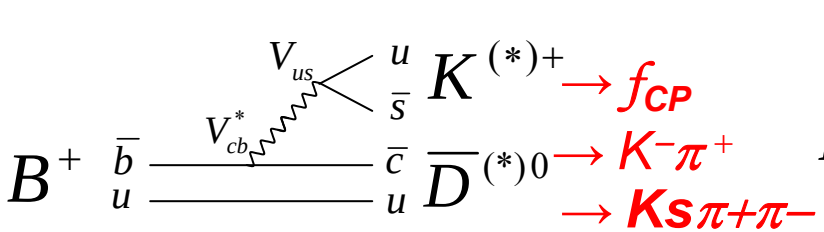
- Tree by GLW, ADS, GGSZ B→ D(*)K(*)
- sin(2b+γ) measurable via B0 → D(*)+/- $\pi(\rho)$-/+
- **new result GLW B+/-→D_CP K+/-**

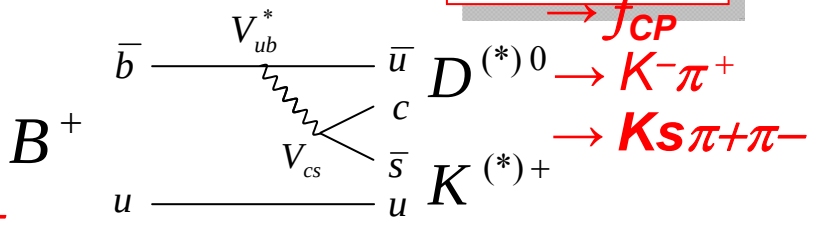
GLW,ADS, GGSZ

GGZS method

GLW method

ADS method $\rightarrow f_{CP}$





Colour **favoured** b→c amplitude ⊗ Cabibbo **suppressed** c→d amplitude	Colour **suppressed** b→u amplitude ⊗ Cabibbo **favoured** c→s amplitude

	GLW analysis
$R_{CP\pm}$	$1 + r_B^2 \pm 2r_B \cos(\delta_B)\cos(\gamma)$
$A_{CP\pm}$	$\pm 2r_B \sin(\delta_B)\sin(\gamma) / R_{CP\pm}$
	ADS analysis
$R_{\rm ADS}$	$r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D)\cos(\gamma)$
$A_{\rm ADS}$	$2r_B r_D \sin(\delta_B + \delta_D)\sin(\gamma) / R_{\rm ADS}$
	Dalitz analysis
$x_\pm$	$r_B \cos(\delta_B \pm \gamma)$
$y_\pm$	$r_B \sin(\delta_B \pm \gamma)$

$$\mathcal{A} = \frac{2r_B r_D \sin(\delta_B + \delta_D)\sin(\gamma)}{r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D)\cos(\gamma)}$$

$$r_B = \frac{|A(B^- \to \overline{D}^0 K^-)|}{|A(B^- \to D^0 K^-)|}$$

$$r_D = \frac{|A(D^0 \to f)|}{|A(\overline{D}^0 \to f)|}$$

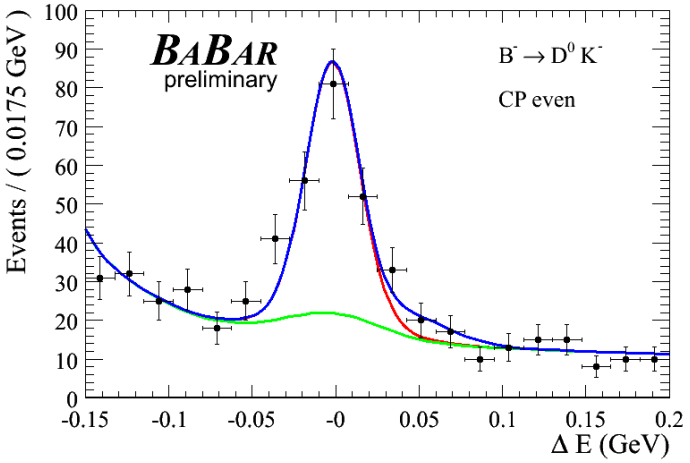
B→DK GLW update

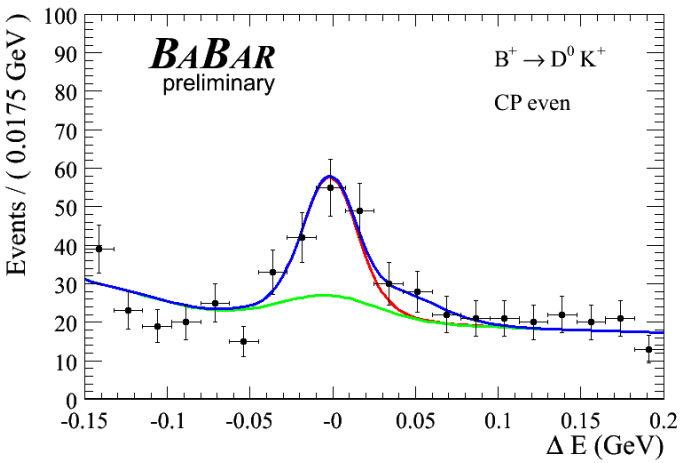
Preliminary arXiv:0708.1534

Table 3: Comparison of the preliminary results of this analysis to the previous measurements by *BABAR* [3] and Belle [4]. The decay mode $D^0 \to K^0_S\phi$, used in the previous analyses, is not included in the present measurement.

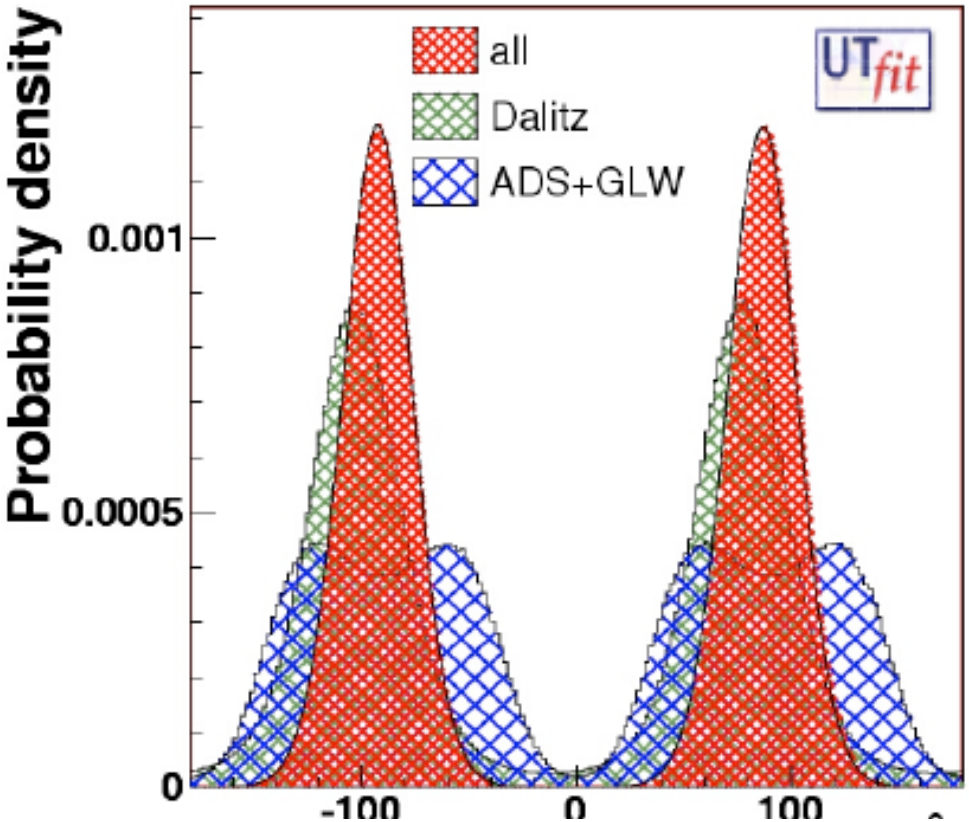
Parameter	Present analysis	*BABAR* (2006) [3]	Belle (2006) [4]
R_{CP-}	$0.81 \pm 0.10 \pm 0.05$	$0.86 \pm 0.10 \pm 0.05$	$1.17 \pm 0.14 \pm 0.14$
R_{CP+}	$1.07 \pm 0.10 \pm 0.04$	$0.90 \pm 0.12 \pm 0.04$	$1.13 \pm 0.16 \pm 0.08$
A_{CP-}	$-0.19 \pm 0.12 \pm 0.02$	$-0.06 \pm 0.13 \pm 0.04$	$-0.12 \pm 0.14 \pm 0.05$
A_{CP+}	$0.35 \pm 0.09 \pm 0.05$	$0.25 \pm 0.13 \pm 0.04$	$0.06 \pm 0.14 \pm 0.05$

3.4 σ





γ from tree processes



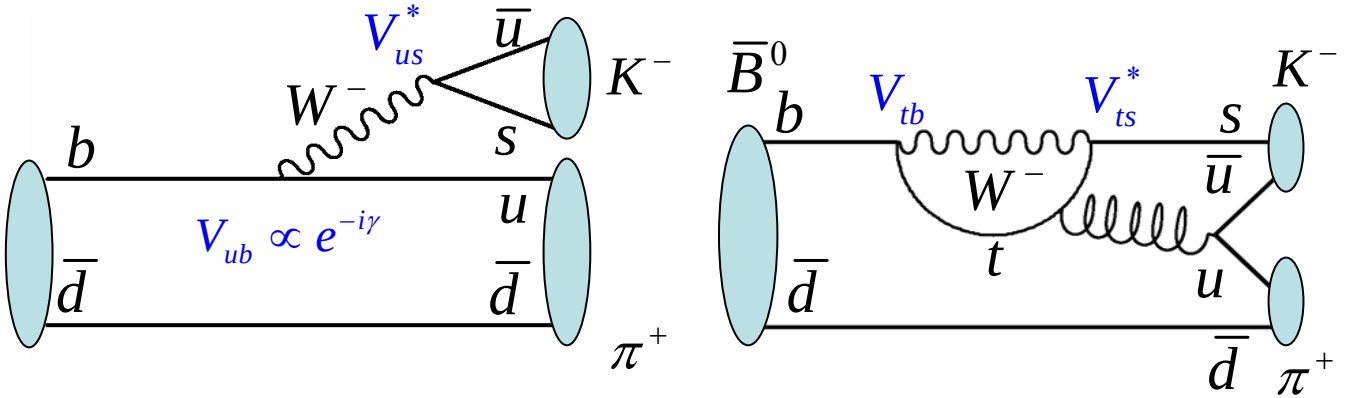
$\gamma = 88 \pm 16\ ^\circ$

Includes a new preliminary result:

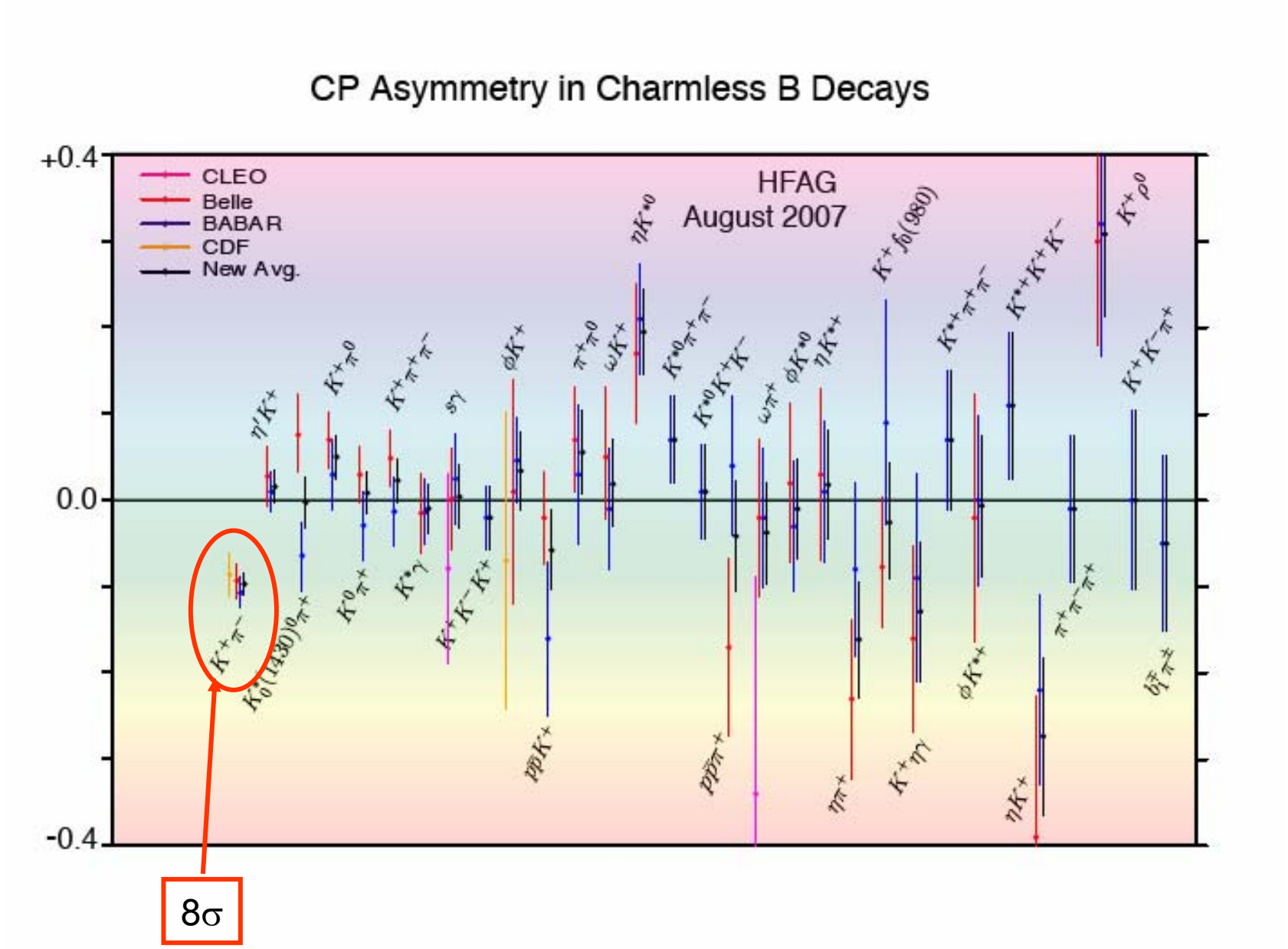
$B^\pm \to D^0 K^\pm$ **GLW**
(BaBar)

Direct CP violation in $B \rightarrow K^-\pi^+$

Interference between tree and penguin amplitudes produces a CP asymmetry in $B \rightarrow K^-\pi^+$.



ACP(K+π–)= -0.133 ±0.030 ±0.009
ACP(K+π0)= 0.030 ±0.039 ± 0.10


CP Asymmetry in Charmless B Decays
HFAG
August 2007
CLEO
Belle
BABAR
CDF
New Avg.
+0.4
0.0
-0.4
8σ

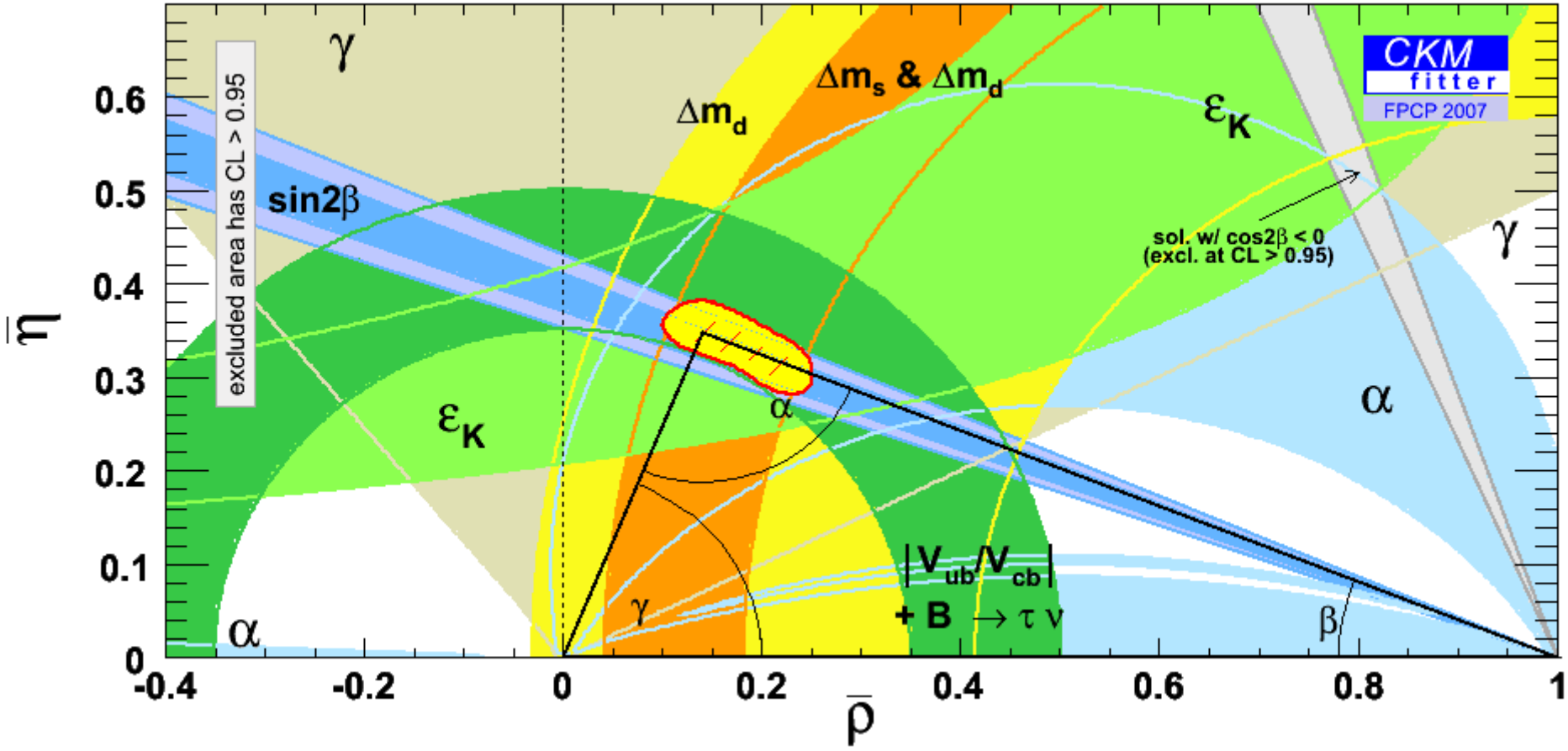
CKM fits

http://www.slac.stanford.edu/xorg/ckmfitter/plots_fpcp07/ckmEval_results_fpcp07.html

http://utfit.roma1.infn.it/ckm-results/ckm-results.html#summ

- synthesize the measurements with different statistical assumptions
- Other measurements not covered here are input to the fits, among which:
  - Bs mixing, UT sides

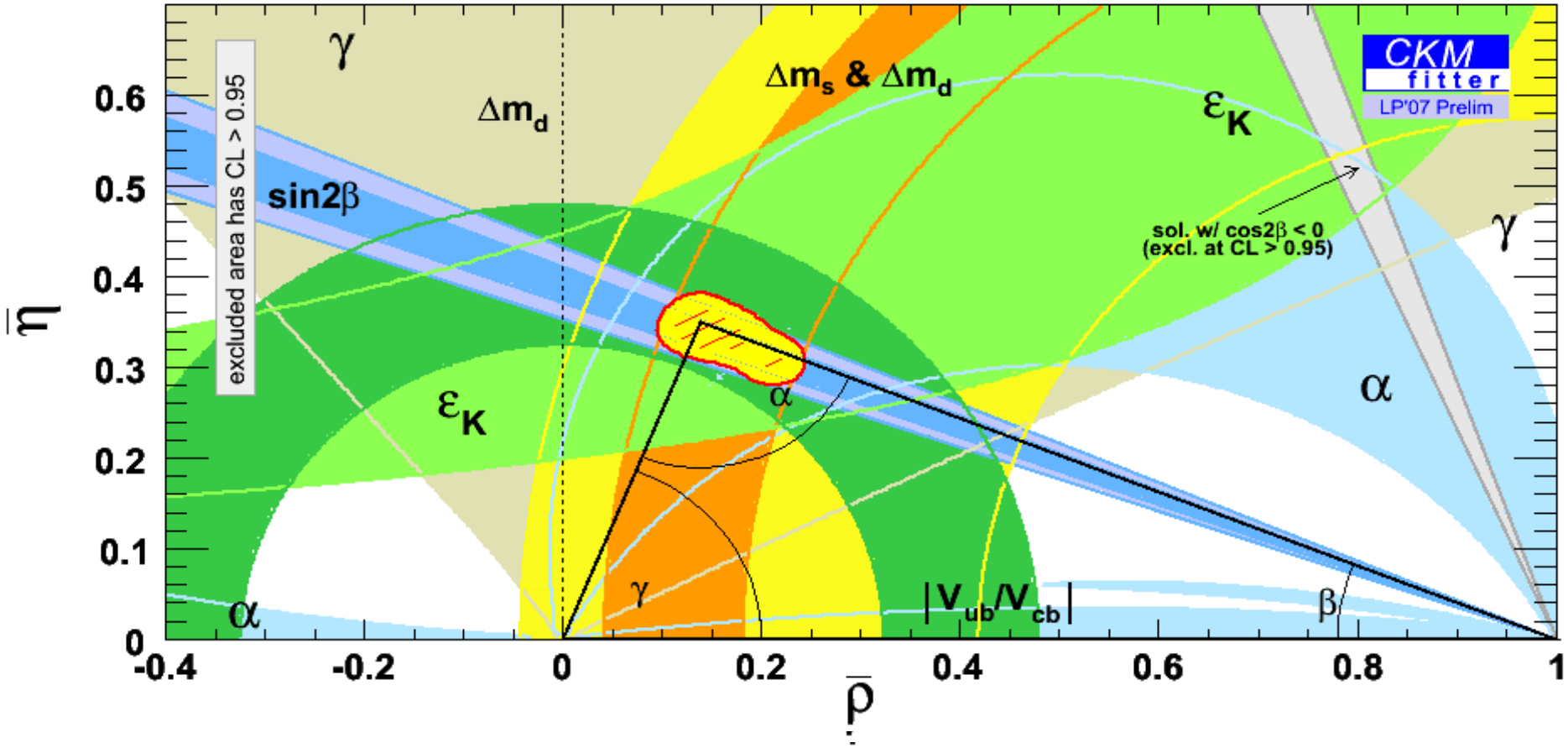
CKM fits



CP conserving quantities CP violating quantities Loops **Full fit**

CKMfitter at LP07

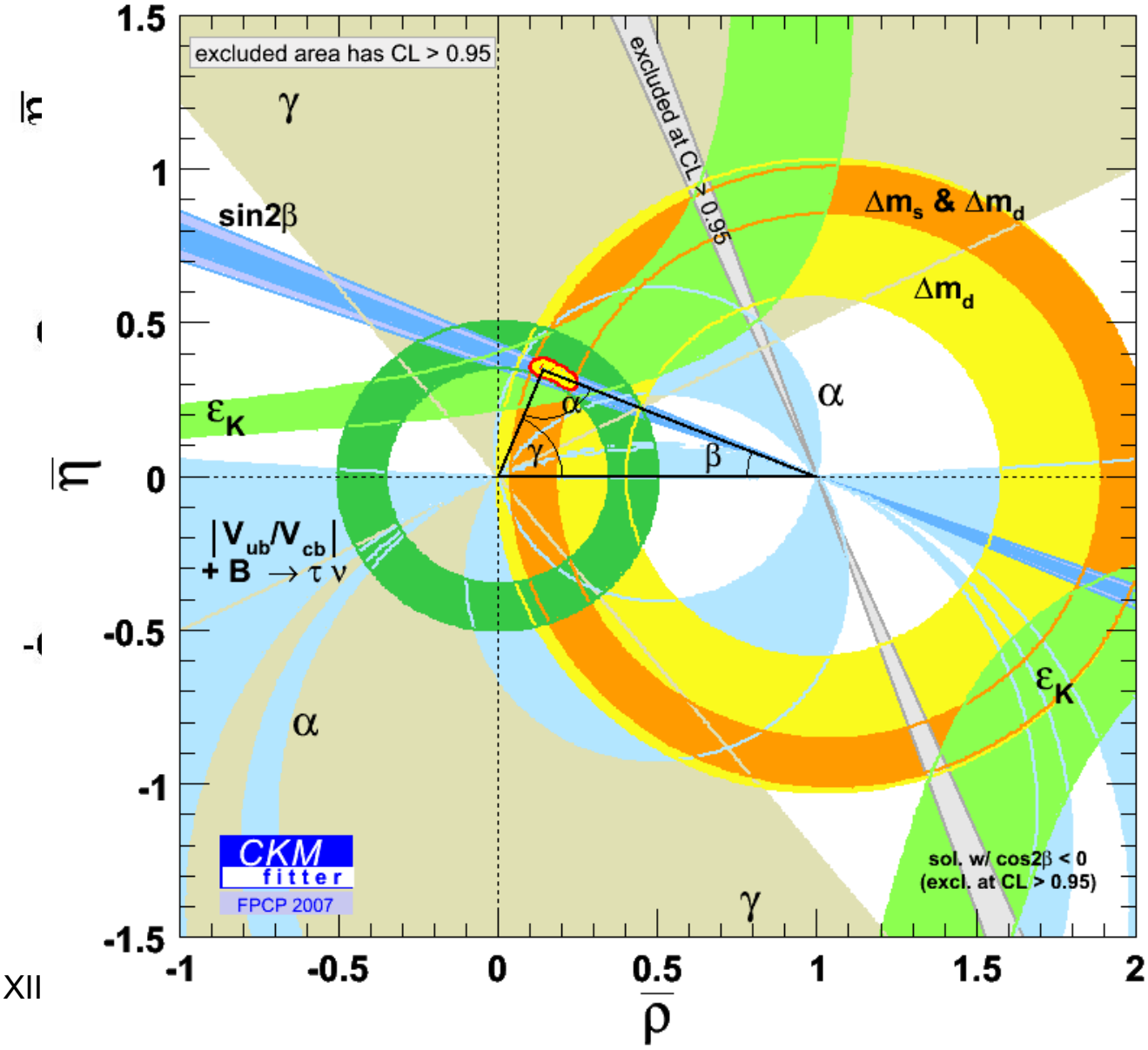
Full Fit LP07



Angles only

Full fit

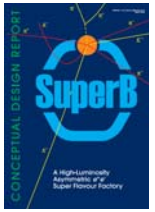
Global CKM Fits



Summary and perpectives

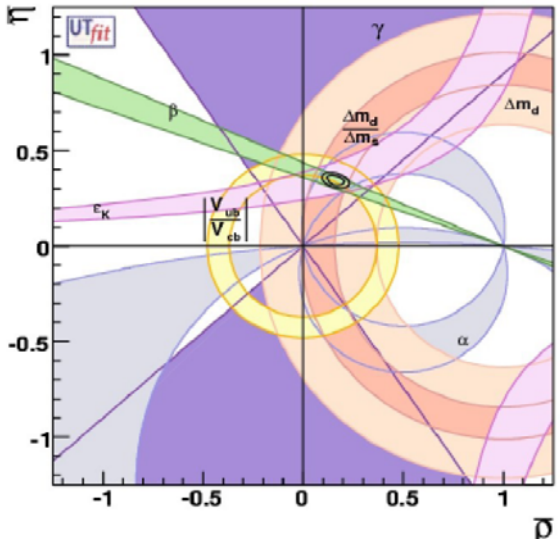
- With 1.15 ab-1 the B factories have validated the CKM model.
- NP effects actively looked for have not shown up.
- Amplitudes analyses bring precision on quasi-2-body final states.
- PEP2/BABAR: one more year. 1st generation B factories ending.
  Expect final results 2009-12.

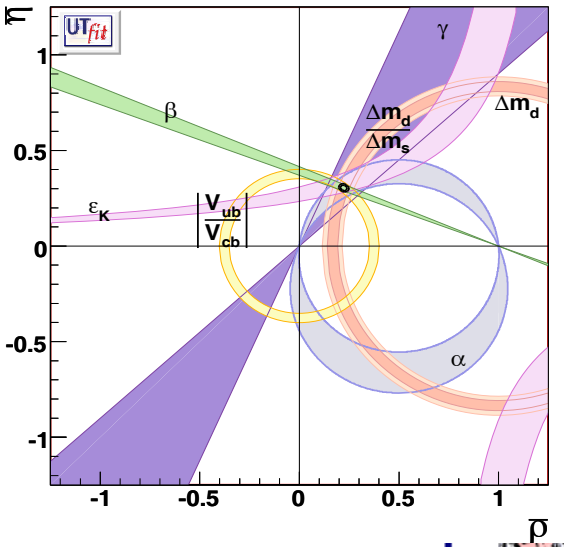
- TeVatron impact via Δm_s and now more.
- LHCb: major contributions forthcoming.
- New e+e- machines (Super B, or SFF) under study.



Outlook at LP07

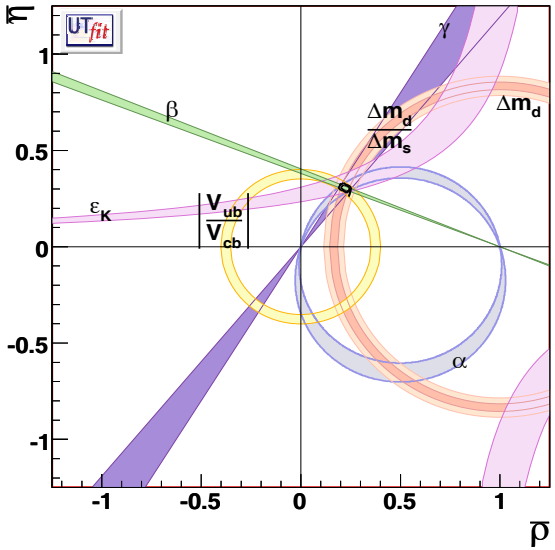
Now

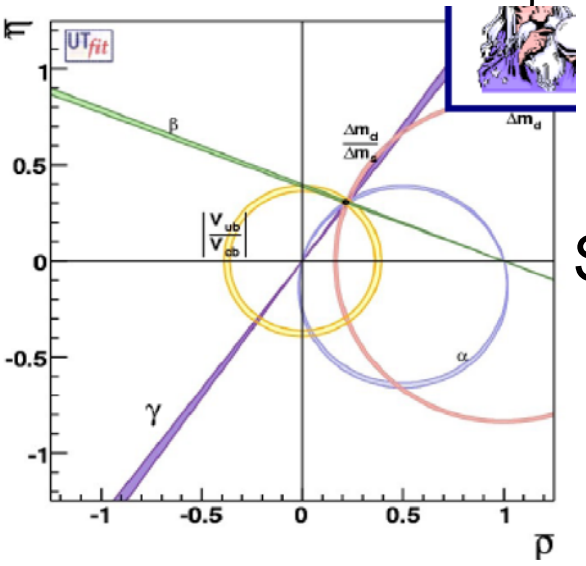




B factory

LHCb





Super B

Talk by Gino Isidori and Yuanning Gao

Backup slides

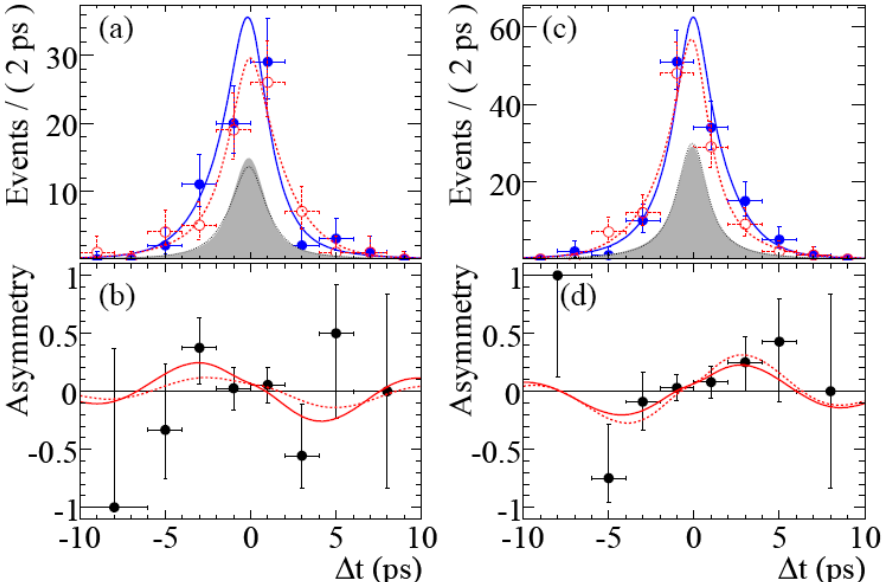
b → c u-bar d B→ D0h0

No Penguin !

Fleischer, NPB 659, 321 (2003), PLB 562,234 (2003).

D0→ CP eigenstate

CP even CP odd



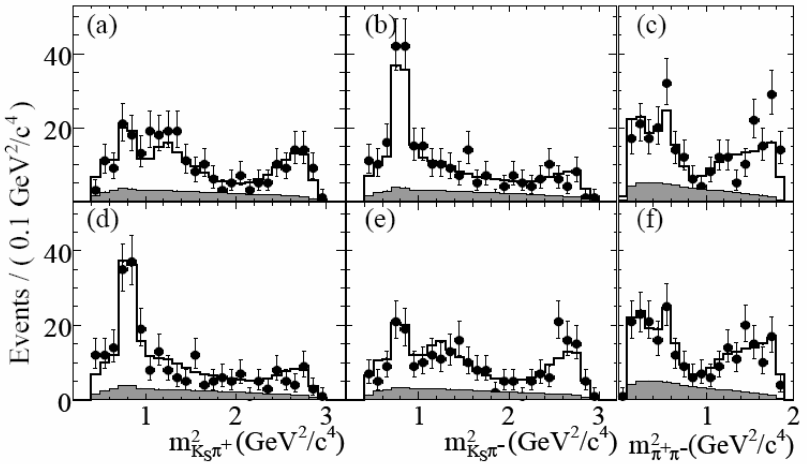
Preliminary, hep-ex/0703019

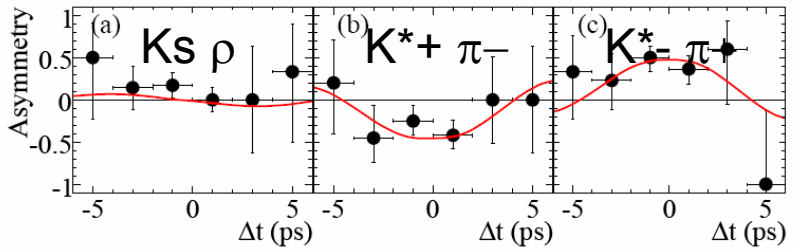
S=-0.56 ± 0.23 ± 0.05

C=-0.23 ± 0.15 ± 0.04

SM expectation S=-sin2β

D0 → Ks π+π− Dalitz





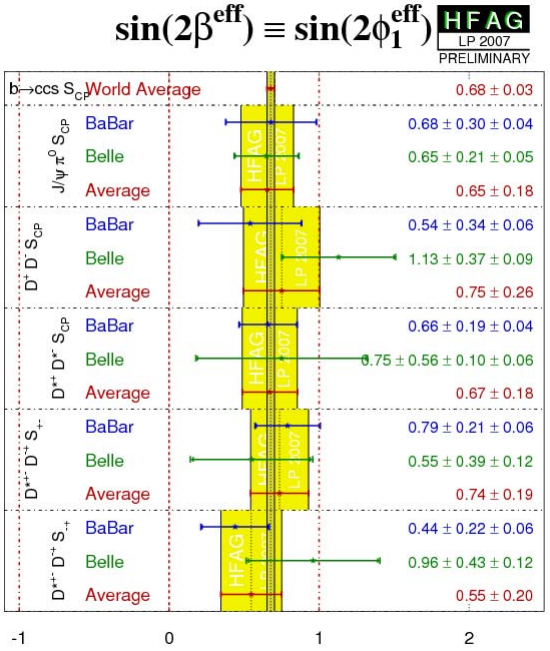
Preliminary, arXiv: 0708.1549

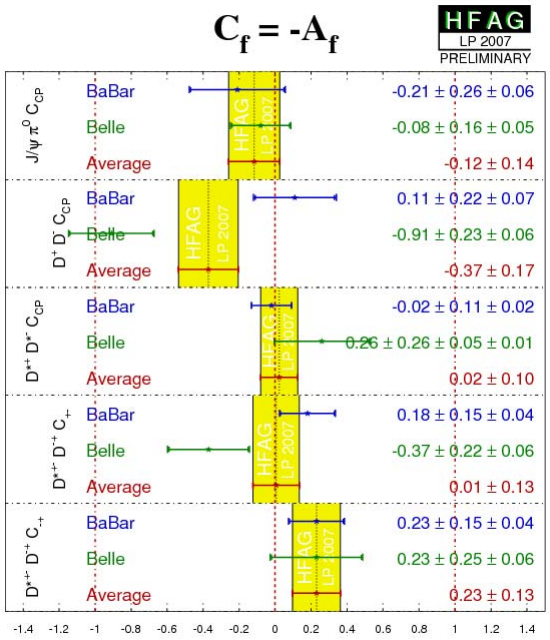
S=0.29±0.34 ±0.03 ±0.05

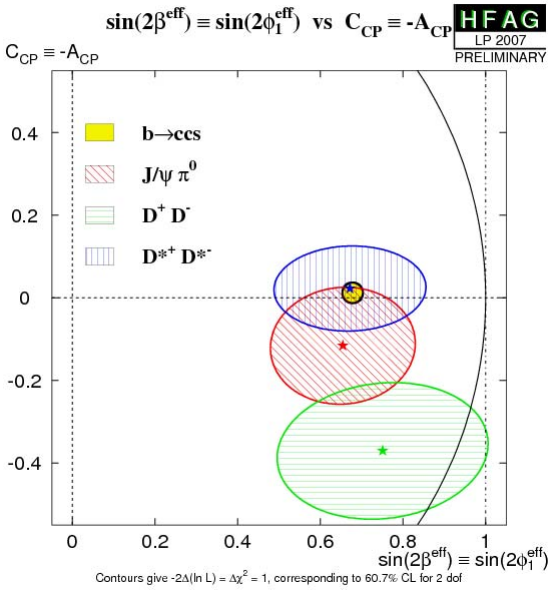
C=0.42 ±0.49 ±0.09 ±0.13

cos2b>0 @86% c.l.

b → cc-bar d


sin(2β^eff) ≡ sin(2φ1^eff)
HFAG
LP 2007
PRELIMINARY
b→ccs S_CP World Average 0.68 ± 0.03
J/ψ π0 S_CP
BaBar 0.68 ± 0.30 ± 0.04
Belle 0.65 ± 0.21 ± 0.05
Average 0.65 ± 0.18
D+ D- S_CP
BaBar 0.54 ± 0.34 ± 0.06
Belle 1.13 ± 0.37 ± 0.09
Average 0.75 ± 0.26
D*+ D- S_CP
BaBar 0.66 ± 0.19 ± 0.04
Belle 0.75 ± 0.56 ± 0.10 ± 0.06
Average 0.67 ± 0.18
D*+- D+ S+-
BaBar 0.79 ± 0.21 ± 0.06
Belle 0.55 ± 0.39 ± 0.12
Average 0.74 ± 0.19
D*+- D+ S+-
BaBar 0.44 ± 0.22 ± 0.06
Belle 0.96 ± 0.43 ± 0.12
Average 0.55 ± 0.20
-1 0 1 2


C_f = -A_f
HFAG
LP 2007
PRELIMINARY
J/ψ π0 C_CP
BaBar -0.21 ± 0.26 ± 0.06
Belle -0.08 ± 0.16 ± 0.05
Average -0.12 ± 0.14
D+ D- C_CP
BaBar 0.11 ± 0.22 ± 0.07
Belle -0.91 ± 0.23 ± 0.06
Average -0.37 ± 0.17
D*+ D- C_CP
BaBar -0.02 ± 0.11 ± 0.02
Belle 0.26 ± 0.26 ± 0.05 ± 0.01
Average 0.02 ± 0.10
D*+- D+ C+-
BaBar 0.18 ± 0.15 ± 0.04
Belle -0.37 ± 0.22 ± 0.06
Average 0.01 ± 0.13
D*+- D+ C+-
BaBar 0.23 ± 0.15 ± 0.04
Belle 0.23 ± 0.25 ± 0.06
Average 0.23 ± 0.13
-1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4


sin(2β^eff) ≡ sin(2φ1^eff) vs C_CP ≡ -A_CP
HFAG
LP 2007
PRELIMINARY
C_CP ≡ -A_CP
b→ccs
J/ψ π0
D+ D-
D*+ D*-
0.4
0.2
0
-0.2
-0.4
0 0.2 0.4 0.6 0.8 1
sin(2β^eff) ≡ sin(2φ1^eff)
Contours give -2Δ(ln L) = Δχ² = 1, corresponding to 60.7% CL for 2 dof

b → qq-bar s (penguin) KsK+K-

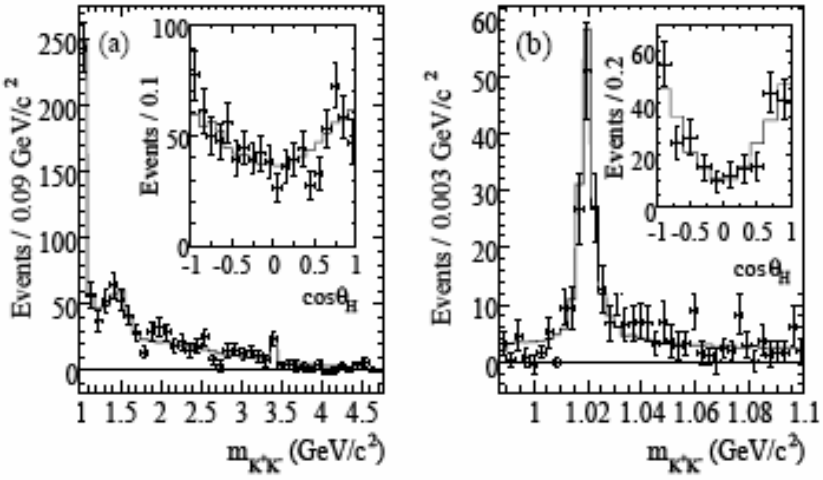


FIG. 2: The distributions of $m_{K^+K^-}$ for signal-weighted [23] $B^0_{(+-)}$ data in (a) the entire DP and (b) the low-mass region. Insets show distributions of $\cos\theta_H$. The histograms are projections of the fit function for the corresponding result.

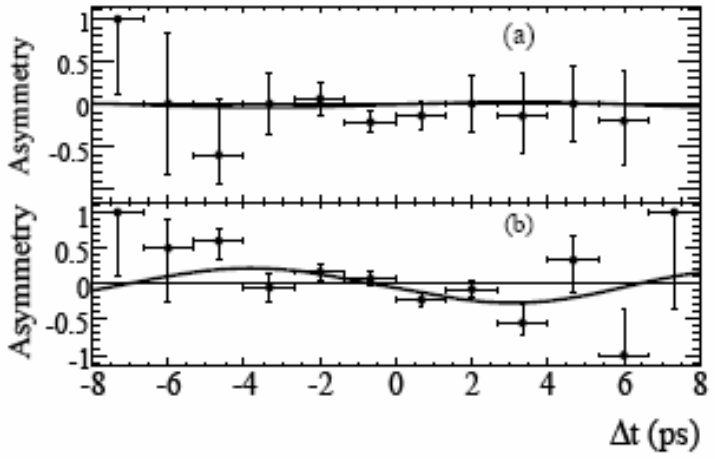


FIG. 3: The raw asymmetry between B^0- and $\overline{B}^0$-tagged signal-weighted [23] events for $B^0_{(+-)}$, in (a) the low-mass region and (b) the high-mass region. The curves are projections of the corresponding fit results.

TABLE II: The *CP*-asymmetries for $B^0 \to K^+K^-K^0$ for the entire DP, in the high-mass region, and for ϕK^0 and f_0K^0 in the low-mass region. The first errors are statistical and the second are systematic. The solutions (1) and (2) from the low-mass fit are discussed in the text.

	A_{CP}	β_{eff} (rad)
Whole DP	$-0.015 \pm 0.077 \pm 0.053$	$0.352 \pm 0.076 \pm 0.026$
High-mass	$-0.054 \pm 0.102 \pm 0.060$	$0.436 \pm 0.087\ ^{+0.055}_{-0.031}$
(1) ϕK^0	$-0.08 \pm 0.18 \pm 0.04$	$0.11 \pm 0.14 \pm 0.06$
(1) f_0K^0	$0.41 \pm 0.23 \pm 0.07$	$0.14 \pm 0.15 \pm 0.05$
(2) ϕK^0	-0.11 ± 0.18	0.10 ± 0.13
(2) f_0K^0	-0.20 ± 0.31	3.09 ± 0.19

20.2±4.3±1.5 degrees

25.0

6±8

8±8

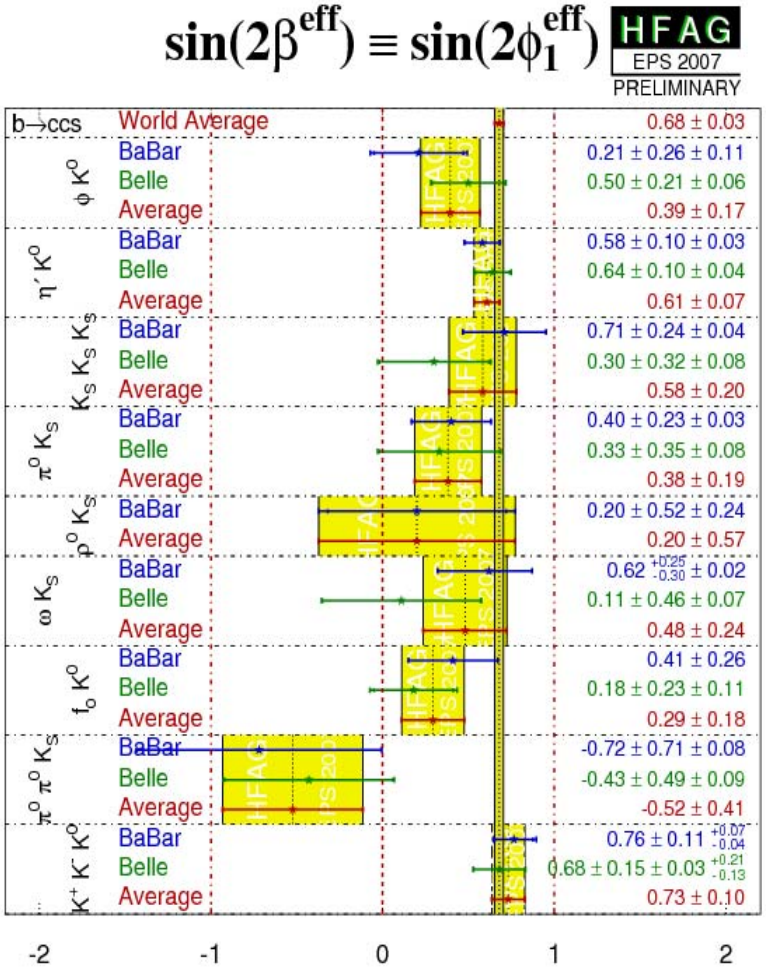
6±7

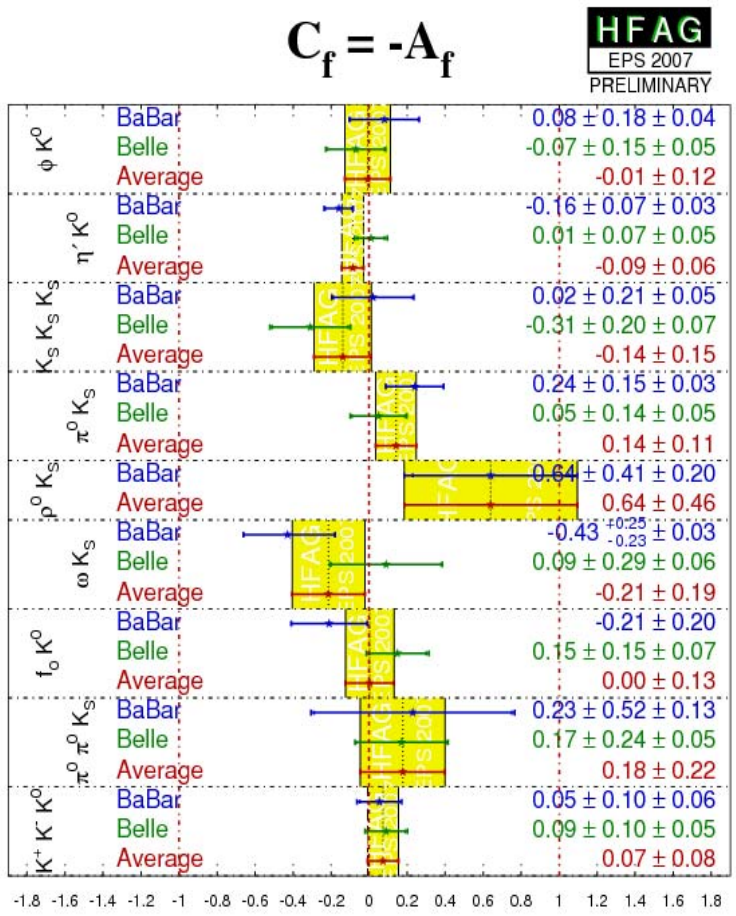
177±11

CPV established at 4.8 σ

$\pi-\beta_{eff}$ disfavored at 4.5 σ

b →q qbar s vs c cbar s (EPS)





b → qq-bar s (penguin)
Ksπ0π0

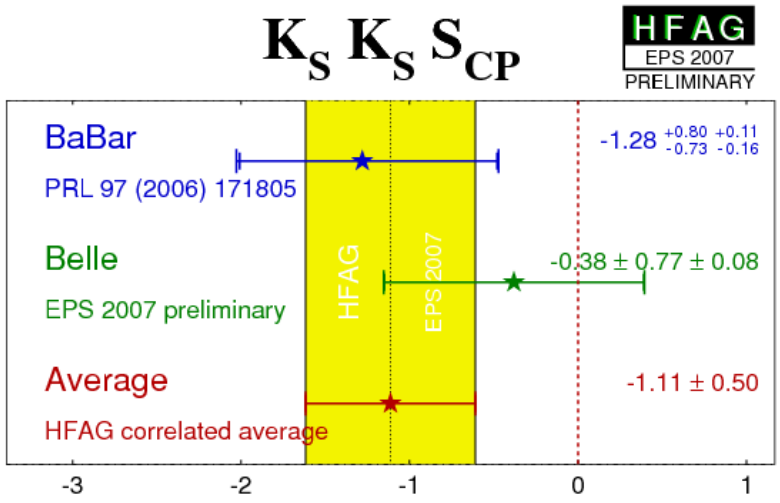
S=-0.43+0.25-023±0.03 (expectation =+0.7)

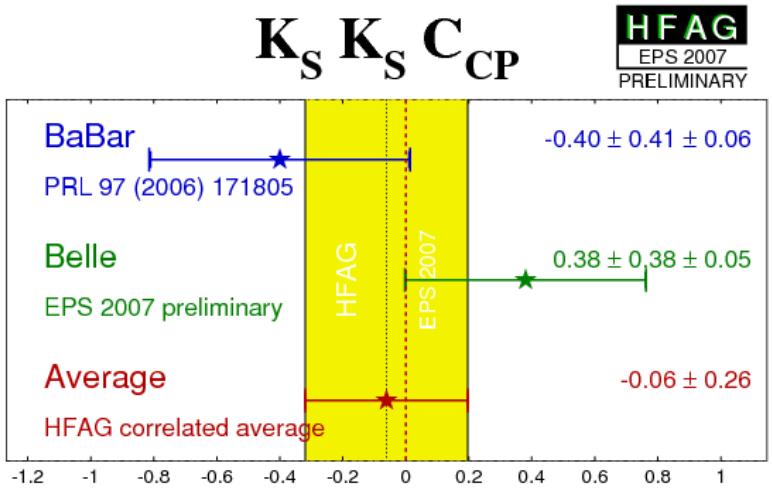
C=0.17 ± 0.24 ± 0.05

arXiv:0708.1845v2 [hep-ex]

b ⟶ qq-bar d (penguin)

- Add the results on KsKS new from BELLE at EPS

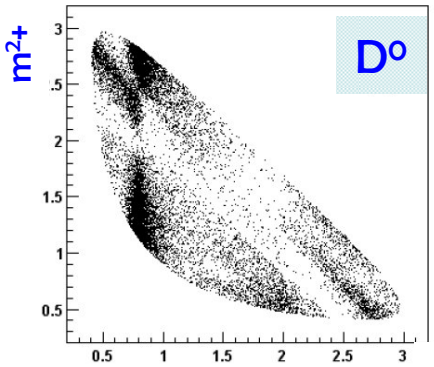
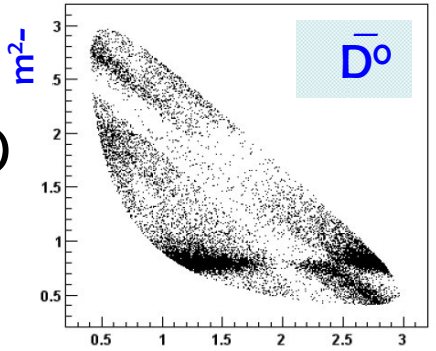




- B to s gamma covered by Tulay Donszelmann this afternoon

GGSZ

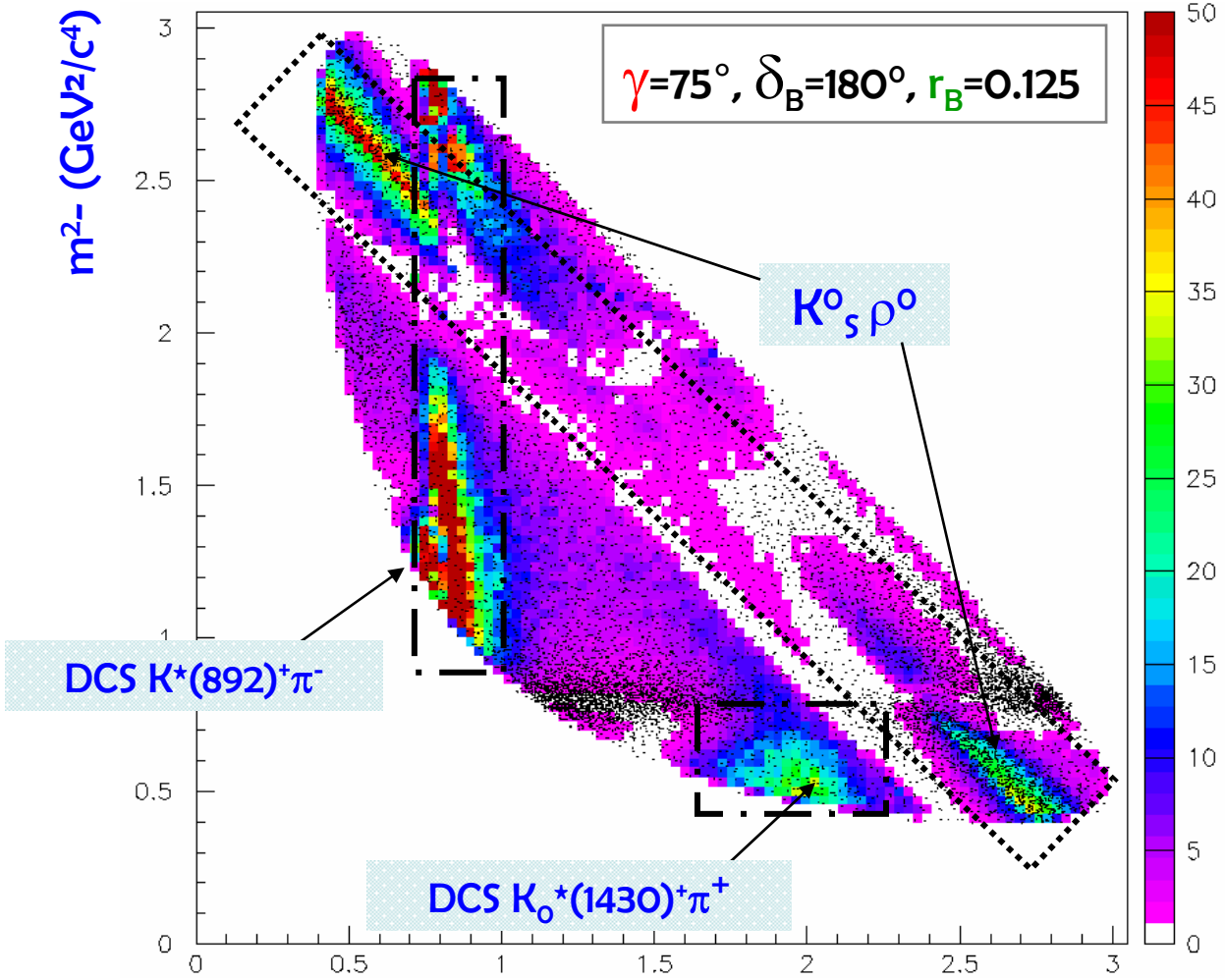
D0→ Ks $\pi+\pi-$

$$\mathcal{A}(B^-) = |\mathcal{A}_B(D^0K^-)|\times \left(\text{  } \times \mathcal{A}_D(m^2_-,m^2_+) + r_B e^{i(\delta_B - \gamma)} \text{  } \times \mathcal{A}_D(m^2_+,m^2_-) \right)$$

Also D0→ $\pi+\pi-\pi0$

Dalitz method: sensitivity to γ

... varies strongly across the Dalitz $K_S^0\pi^+\pi^-$ plot !



Relative event weight:

$W = 1/(d^2\mathcal{L} / d\gamma^2)$ and

$\sigma^2(\gamma) \sim 1/W$

Interference of

$B^- \to D^0 K^-$, $D^0 \to K^0_S\rho^0$

with

$B^- \to \bar{D}^0 K^-$, $\bar{D}^0 \to K^0_S\rho^0$

$\equiv$ GLW like

Interference of

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

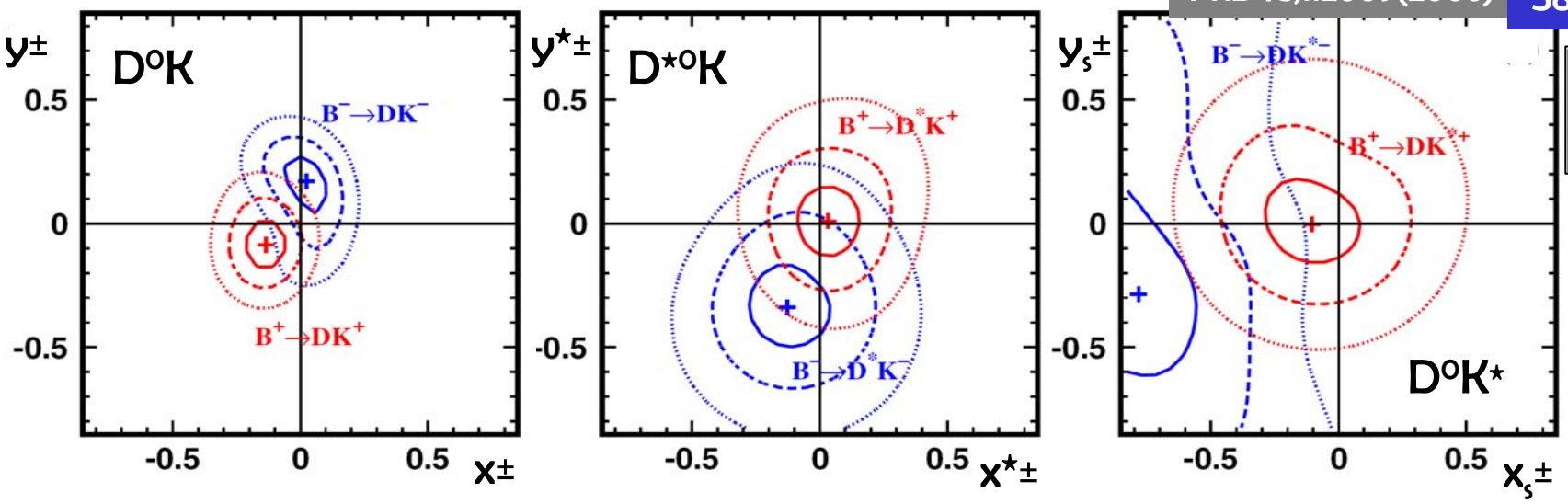
(suppressed) with

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

$\equiv$ ADS like

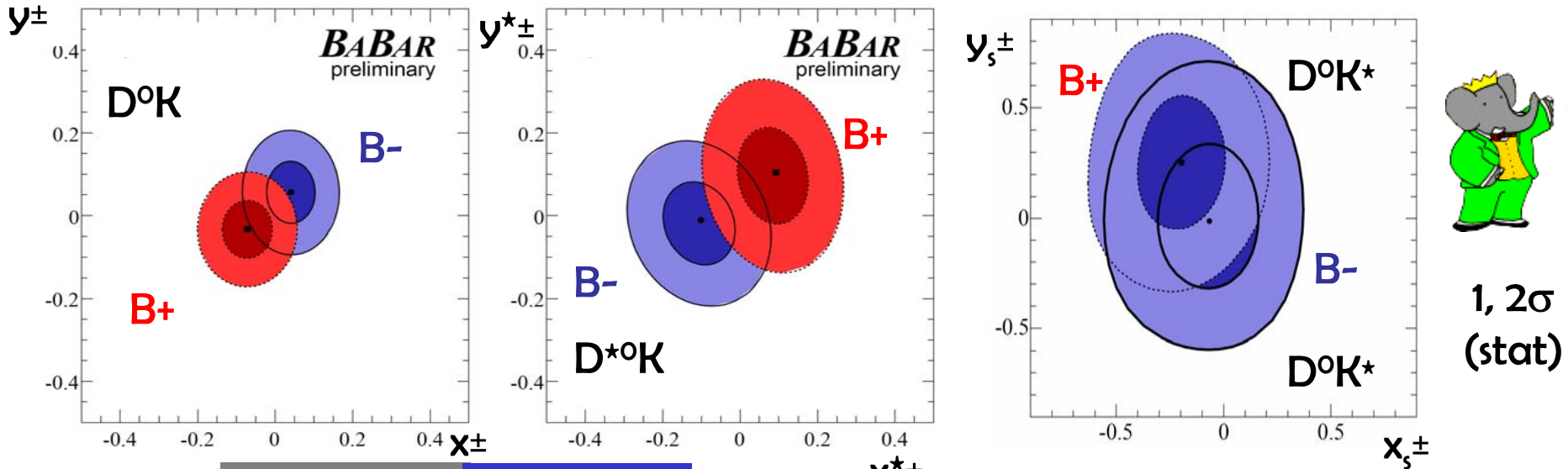
$(x_\pm, y_\pm)$: Fits results BABAR and Belle

PRD 73,112009(2006) | 386x10⁶ $B\bar{B}$



BELLE

1, 2, 3σ (stat)

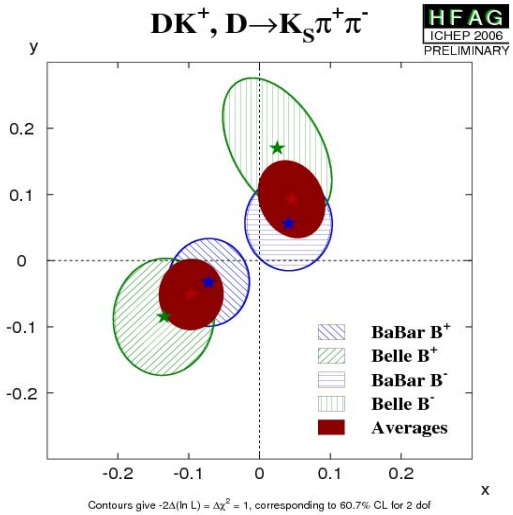


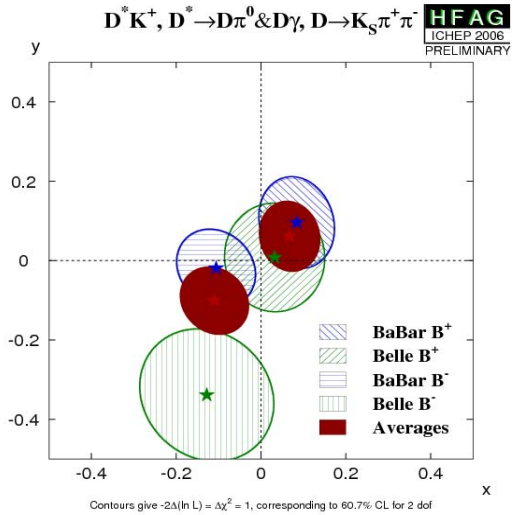
1, 2σ (stat)

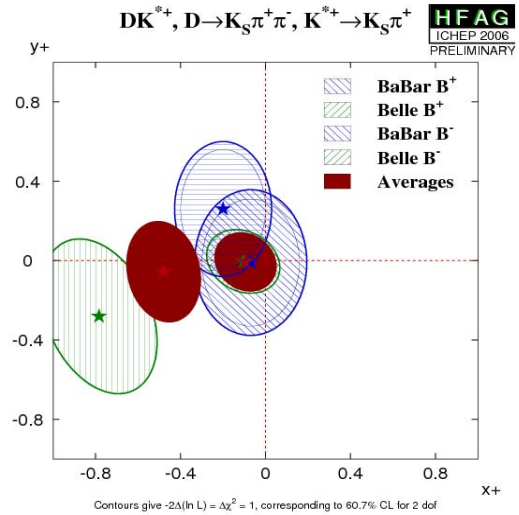
25/8/07 X hep-ex/0607104 | 347x10⁶ $B\bar{B}$ eau CPV in B and CKM

hep-ex/0507101 | 227x10⁶ $B\bar{B}$

HFAG Compilation



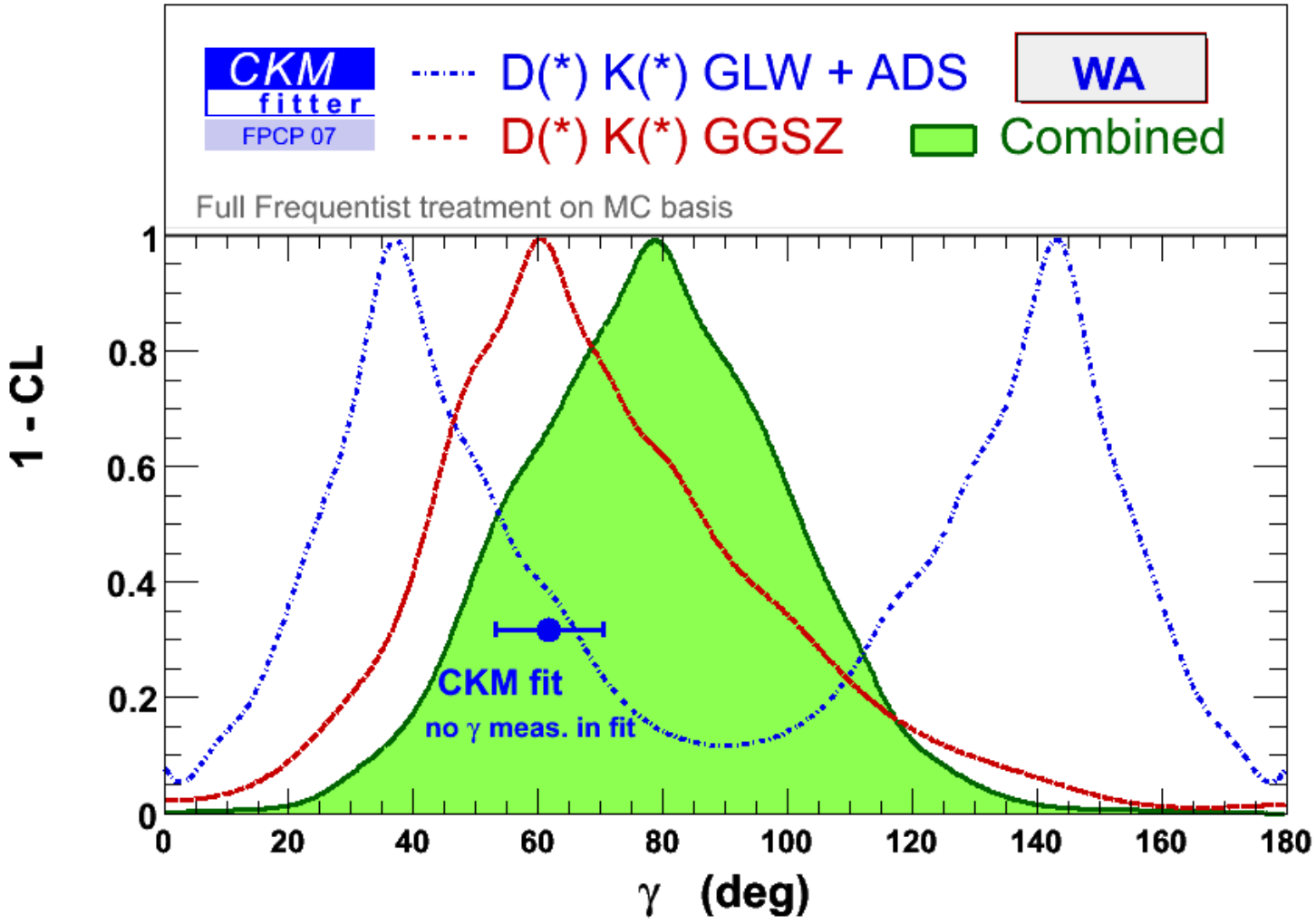




	X+	Y+	X-	Y-
D0→ Ks π+π−	−0.097 ± 0.045	−0.051 ± 0.053	0.045 ± 0.047	0.093 ± 0.058
	0.067 ± 0.071	0.061 ± 0.088	−0.110 ± 0.080	−0.101 ± 0.085
	−0.094 ± 0.144	−0.007 ± 0.146	−0.480 ± 0.173	−0.056 ± 0.253

	ρ+	**θ+**	**ρ−**	**θ−**
D0→ π+π−π0	0.75 ± 0.12	(147 ± 23)°	0.72 ± 0.12	(173 ± 42)°

γ combined


CKM fitter
FPCP 07
D(*) K(*) GLW + ADS
D(*) K(*) GGSZ
WA
Combined
Full Frequentist treatment on MC basis
1 - CL
CKM fit
no γ meas. in fit
γ (deg)
0
0.2
0.4
0.6
0.8
1
0
20
40
60
80
100
120
140
160
180

http://www.slac.stanford.edu/xorg/ckmfitter/plots_fpcp07/ckmEval_results_fpcp07.html

http://utfit.roma1.infn.it/ckm-results/ckm-results.html#summ

CKM

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

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

$$\alpha \equiv \phi_2 = \arg\left[-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right], \quad \beta \equiv \phi_1 = \arg\left[-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right], \quad \gamma \equiv \phi_3 = \arg\left[-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right]$$

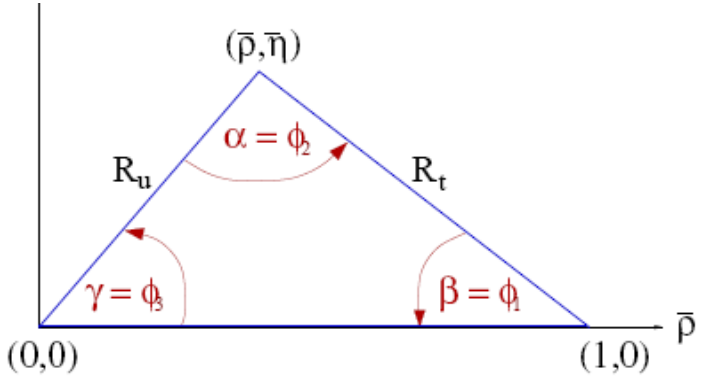
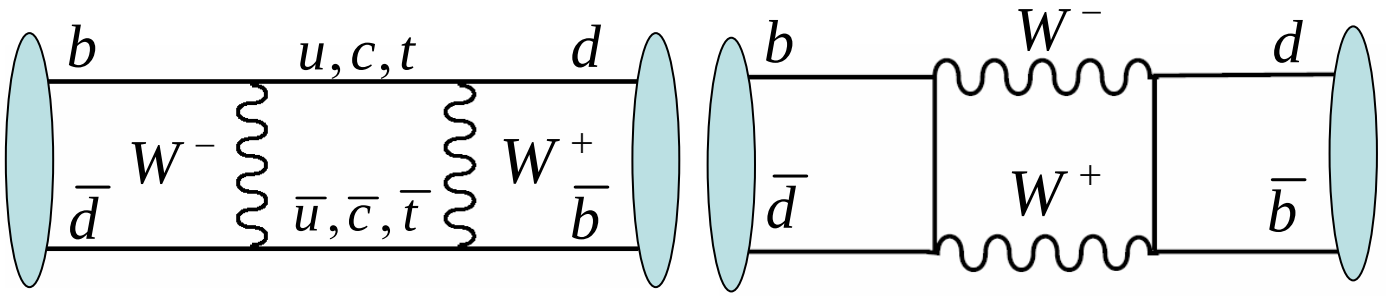
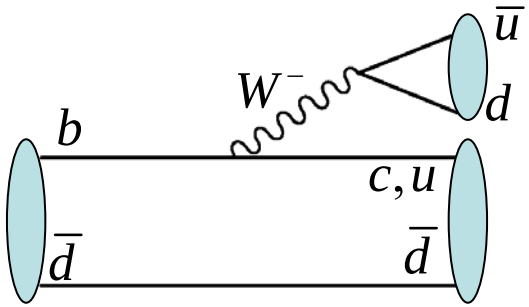
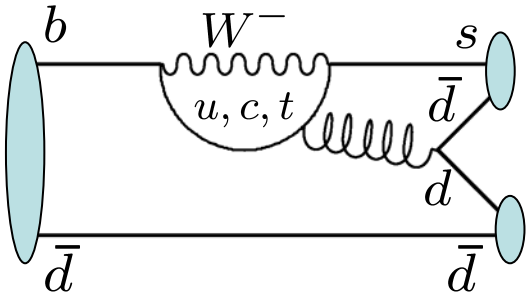


Figure 9: The Unitarity Triangle.


b
u,c,t
d
W⁻
W⁺
d̄
ū,c̄,t̄
b̄
b
W⁻
d
d̄
W⁺
b̄


ū
W⁻
d
b
c,u
d̄
d̄


b
W⁻
s
u, c, t
d̄
d
d̄
d̄

Calculating λ for specific final states

$B^0 \to \pi^+\pi^-$ $(b \to u\bar{u}d)$

$$\lambda = \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \cdot \frac{V_{ud}^* V_{ub}}{V_{ud} V_{ub}^*} \qquad \mathrm{Im}(\lambda) = \sin(2\alpha)$$

(assuming only tree diagram for illustration)

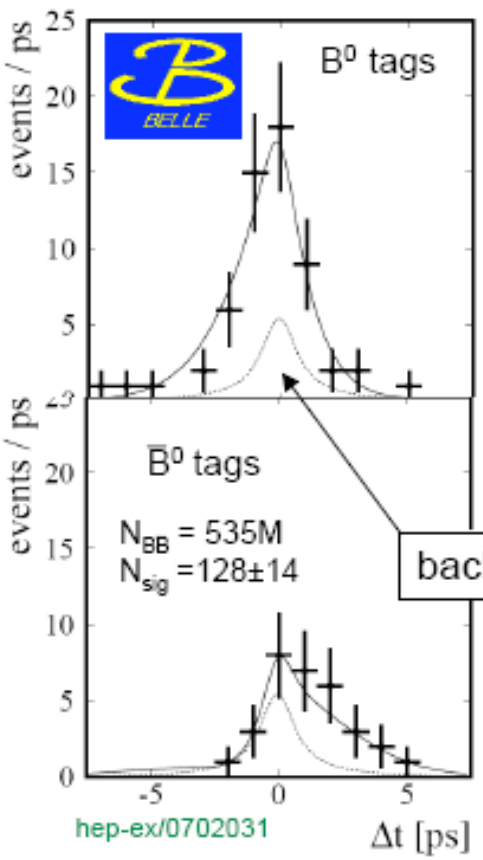
$B^0 \to J/\psi K_S^0$ $(b \to c\bar{c}s) \times (K^0 \to K_S^0)$

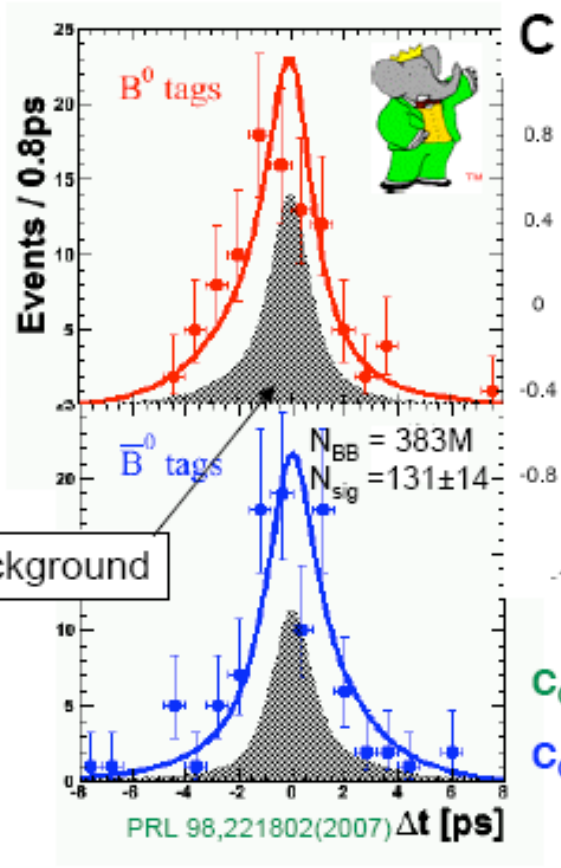
$$\lambda = (-1) \cdot \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \cdot \frac{V_{cs}^* V_{cb}}{V_{cs} V_{cb}^*} \cdot \frac{V_{cd}^* V_{cs}}{V_{cd} V_{cs}^*} \qquad \mathrm{Im}(\lambda) = \sin(2\beta)$$

$B^0 \to J/\psi K_L^0$ $(b \to c\bar{c}s) \times (K^0 \to K_L^0)$

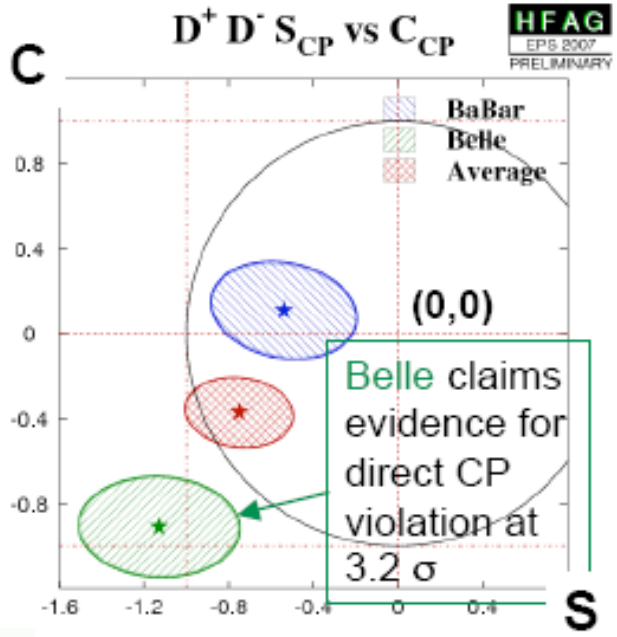
$$\lambda = (+1) \cdot \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \cdot \frac{V_{cs}^* V_{cb}}{V_{cs} V_{cb}^*} \cdot \frac{V_{cd}^* V_{cs}}{V_{cd} V_{cs}^*} \qquad \mathrm{Im}(\lambda) = -\sin(2\beta)$$

S and C in $B^0 \to D^+D^-$: $b \to c\bar{c}d$





background



$C_{CP}(B^0 \to D^+D^-) = -0.91 \pm 023 \pm 0.06$

$C_{CP}(B^0 \to D^+D^-) = +0.11 \pm 022 \pm 0.07$

New Belle Result:

Agreement on C has CL=0.003

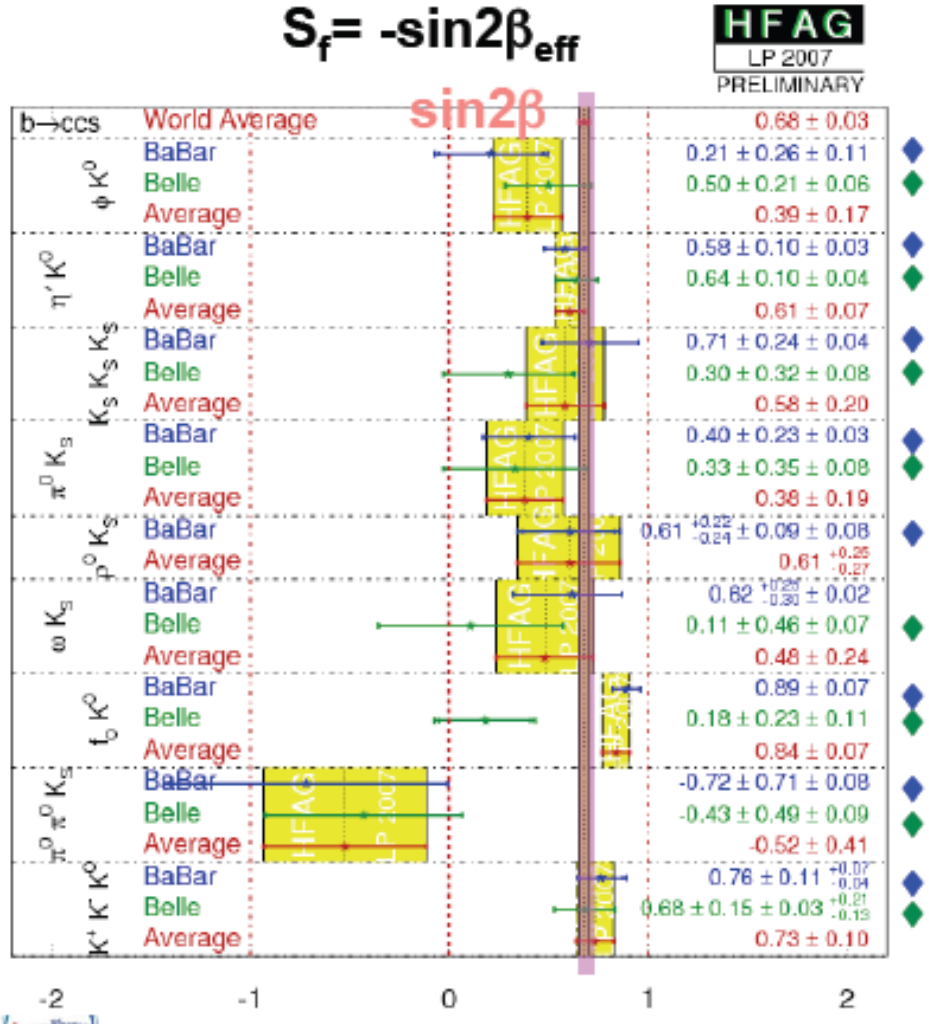
⇒ **>3.0σ discrepancy**

$A_{CP}(B^+ \to D^+D^0) = 0.01 \pm 0.08 \pm 0.02$

BELLE-CONF-0762 Preliminary

sin2β in b→sq̄q Penguins

$S_f = -\sin 2\beta_{eff}$



$$\left\langle \sin 2\beta_{eff} \right\rangle = 0.67 \pm 0.04$$

1% CL for the average

New naïve HFAG average <1σ from the naïve golden mode sin2β value

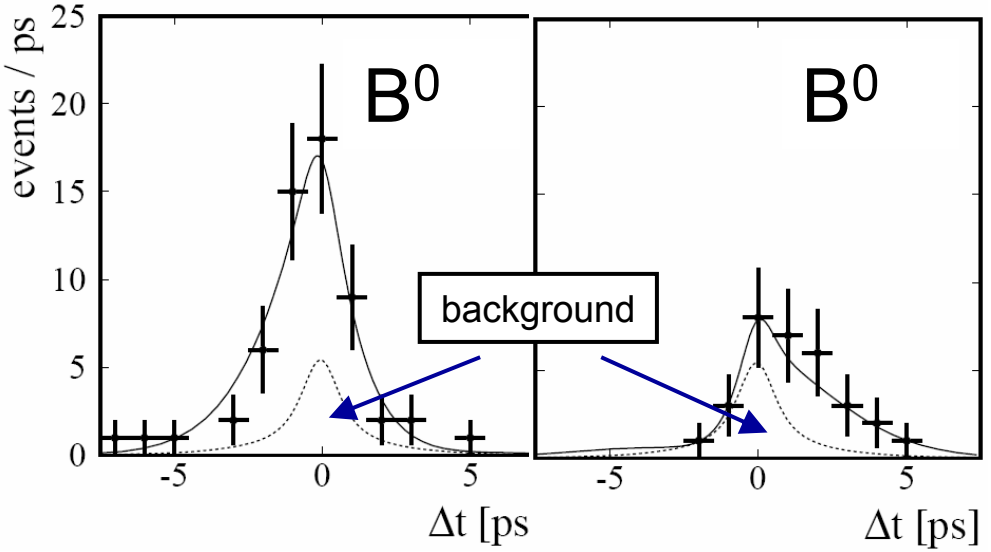
♦≡ New/Updated BaBar/Belle Result

Belle's CPV in $B^0 \to D^+D^-$

Belle @ CKM 2006
(N_{BB} = 535M):

Different decay rate for $B^0 \to D+D-$ and $B^0 \to D+D-$!

Evidence for large direct CP violation in $B \to D+D-$
(hep-ex/0702031)



$$\eta S = 1.13 \pm 0.37 \pm 0.09$$
$$C = -0.91 \pm 0.23 \pm 0.06 \ (3.2\sigma)$$

Belle @ LP 2007
(N_{BB} = 657M):

$$A_{CP} = (B^+ \to D^+ \bar{D}^0) = 0.01 \pm 0.08 \pm 0.02$$

(expect same direct CPV in charged B mode)

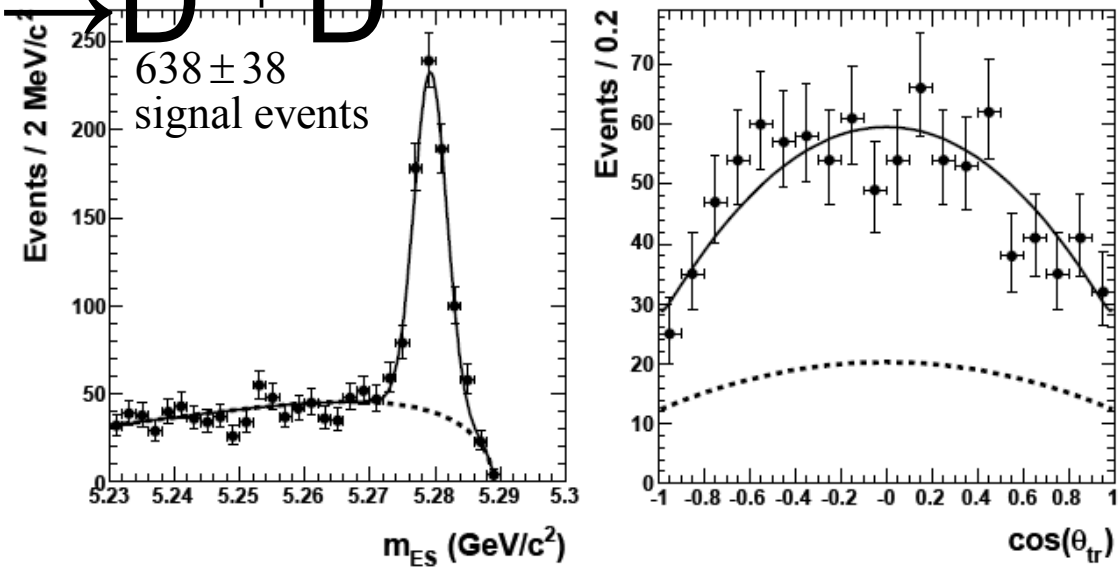
NEW!

$B^0 \to D^{*+} D^{*-}$

Same quark diagram as $B^0 \to D^+D^-$

- VV final state (not a CP eigenstate)
- Determine effective CP-even contribution: η_{CP} using D^* decay analysis)

$$R_\perp = 0.143 \pm 0.034 \pm 0.008$$



CP asymmetries from CP-even amplitudes

$$\eta S_+ = 0.72 \pm 0.19 \pm 0.05$$
$$C_+ = -0.05 \pm 0.14 \pm 0.02$$

ηS consistent with sin2β ! No direct CPV!