b→s transition CP measurements and γ extraction in B→ DK

Gianluca Cavoto

INFN - Roma La Sapienza

LHC Flavour Workshop

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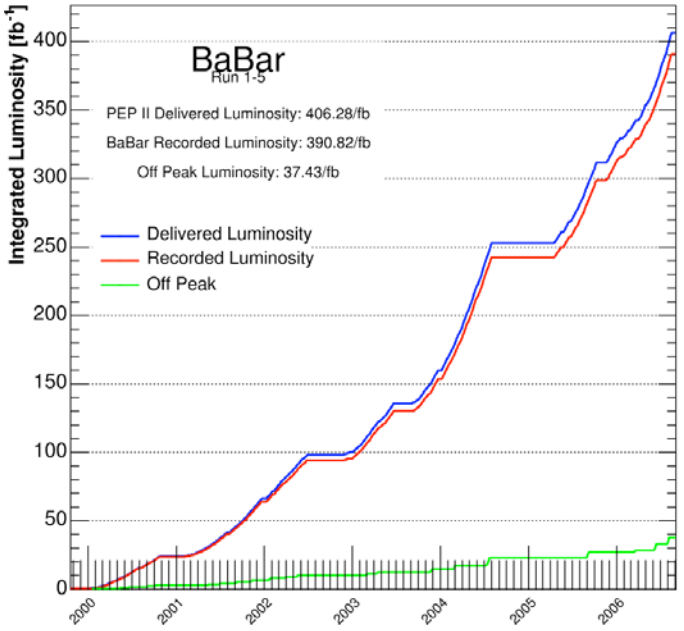
Summary

- b→ s penguin transition
  - time-dependent CP measurements
    - Is New Physics or just Standard Model ?
    - Summary of experimental results in several channels
      $B^0 \to K^+K^-K^0$, $\eta' K^0$, $K_S K_S K_S$, ωK_S, ρK_S, $\pi^0 K_S$

- γ extraction
    - Various method: GLW, ADS, Dalitz
  - Concentrate on some detail
    - Dalitz Model
    - systematics for γ

2006 summer results



Is there New Physics in b→s?

– b → c measure sin(2β) with small theoretical unc. (0.1-1%)

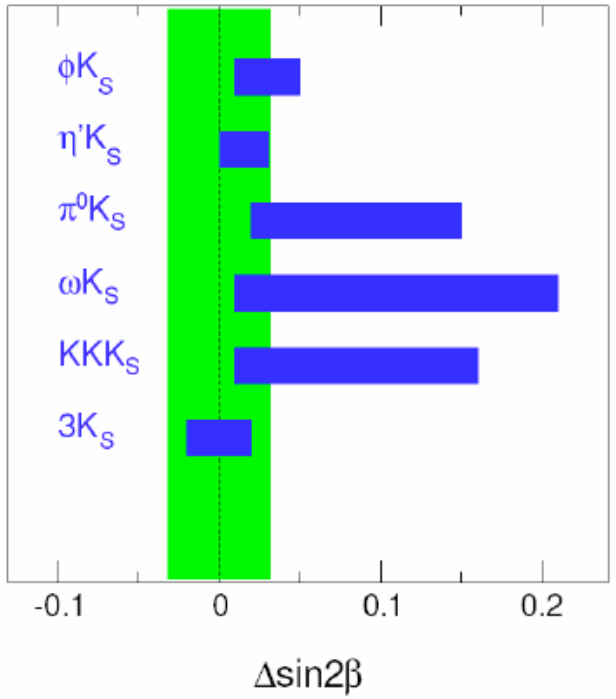
In the SM:

$S_f = -\eta_{CP} \sin 2\beta^f_{eff} \sim -\eta_{CP} \sin 2\beta$

$C_f \sim 0$

$\Delta S_f = \sin 2\beta^f_{eff} - \sin 2\beta \neq 0$ can be explained inside the SM

- Positive deviation ? (in QCDF)



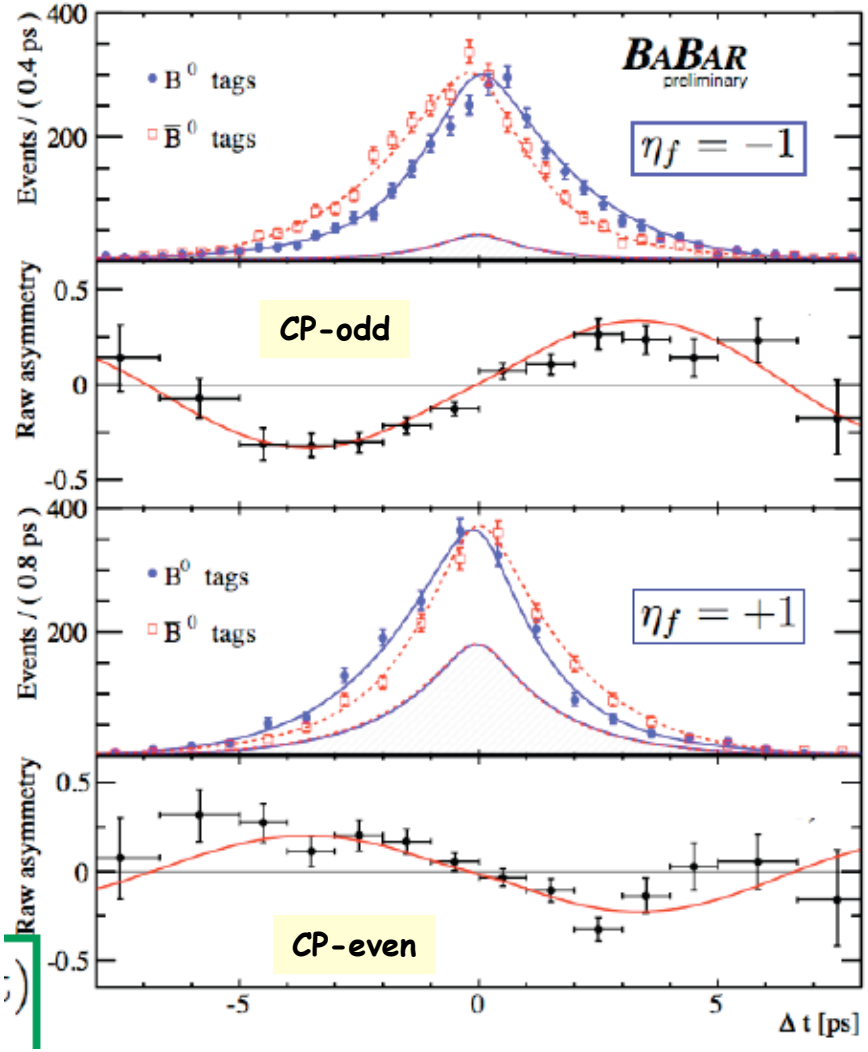
QCDF (Beneke, PLB620 (2005) 143-150; Cheng, Chua, Soni, PRD72 (2005) 094003; …) and SCET (Williamson, Zupan, hep-ph/0601214) allows to estimate ΔS:

Analysis technique

- Particle ID to separate charged particles (kaons and pions)
- K^0_L candidates reconstructed in EMC or IFR
- *B*-flavor tagging: NN-based, output sorted in 6 independent categories (plus untagged events)
- Unbinned maximum-likelihood fit using m_{ES} (m_B), ΔE (m_{miss}), the resonance mass and decay angle, the MVA, and Δt
- Likelihood components are signal (corrected and misreconstructed), continuum background, charmed and charmless *B*-related backgrounds

sin(2β) in (c$\bar{c}$)s BaBar

347M $B\bar{B}$



$B^0 \to J/\psi K^0$,
$\psi(2S)K_S$,
$\eta_c K_S$,
$\chi_{c1} K_S$,
$J/\psi K^{*0}$

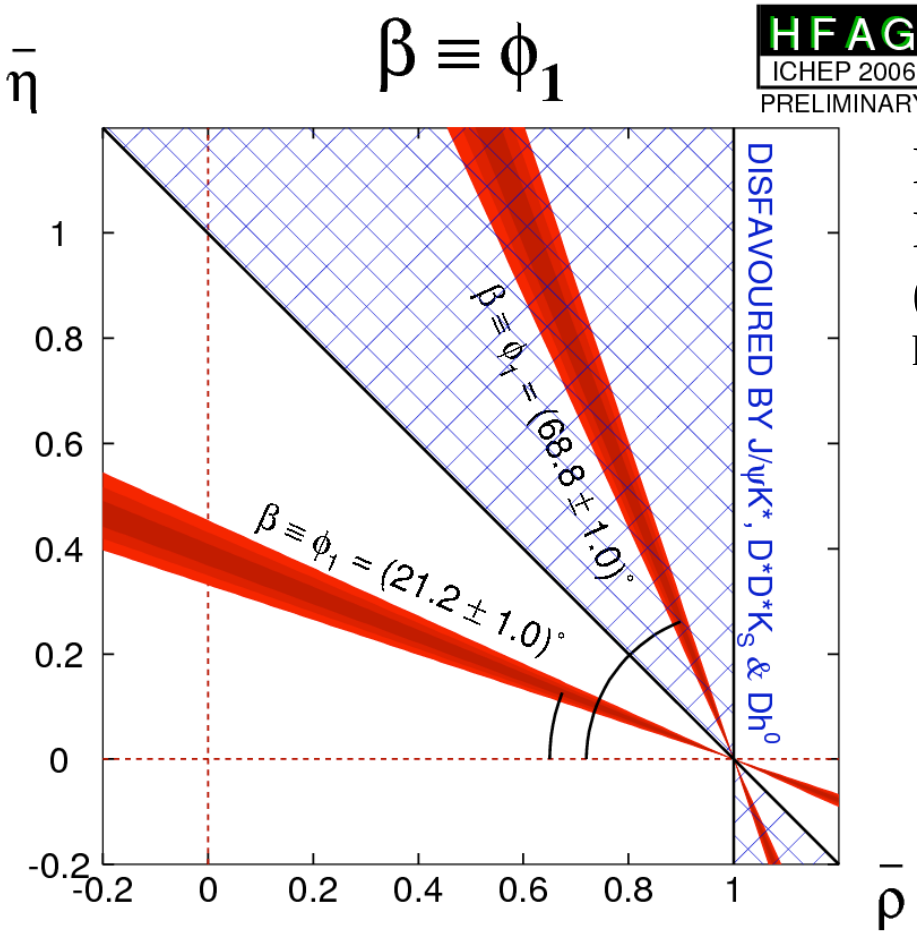
$$\sin(2\beta) = 0.710 \pm 0.034 \pm 0.019$$

$$A = -0.070 \pm 0.028 \pm 0.018$$

Averages over all modes,
In the process of splitting them…

$$\sin(2\beta)_{WA} = 0.674 \pm 0.026$$

Measuring β



$B^0 \rightarrow D^{*+} D^{*-} Ks$

Dalitz time dependent CP analysis

(94%CL, model-dependent)

hep-ex/0608016

$B^0 \rightarrow D h^0$ ($h^0 = \pi^0$ etc.)

Dalitz time dependent CP analysis

→ $\cos 2\beta > 0$ BaBar 87% CL

hep-ex/0607105

hep-ex/0607112

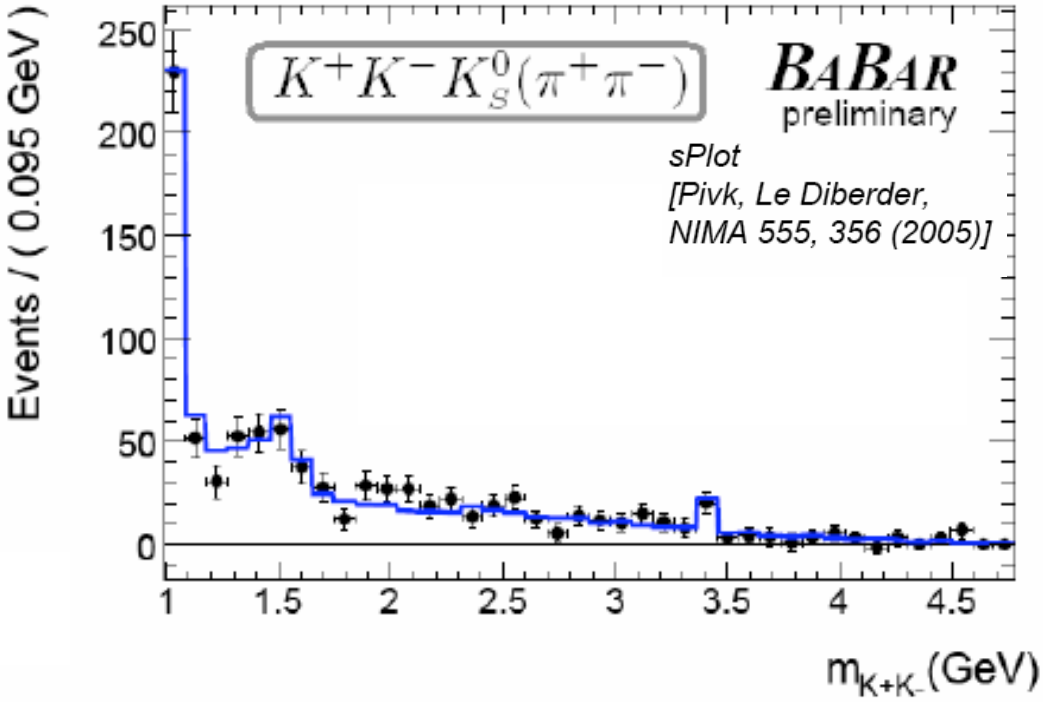
Dalitz TD *CP*V in $B^0 \to K^+K^-K^0$

347M $B\bar{B}$

- Obtain CP parameters for 2-body and 3-body modes simultaneously by time-dependent Dalitz fit
  - Isobar model ($\phi(1020)K^0$, $f_0(980)K^0$, $X_0(1550)K^0$, Non-resonant, $\chi_{c0}K^0$, D^+K^-, $D_S^+K^-$)

$K^+K^-K_S \to \pi^+\pi^-$
$K^+K^-K_S \to \pi^0\pi^0$
$K^+K^-K_L$

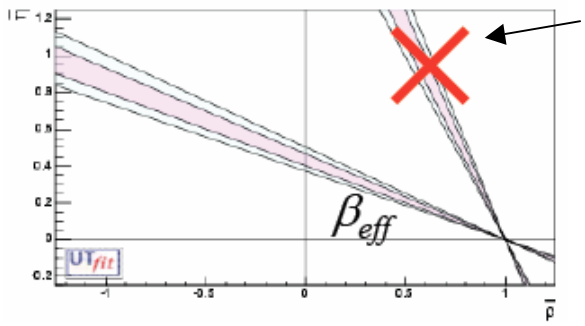
1516 ± 65
$K^+K^-K^0$ signal



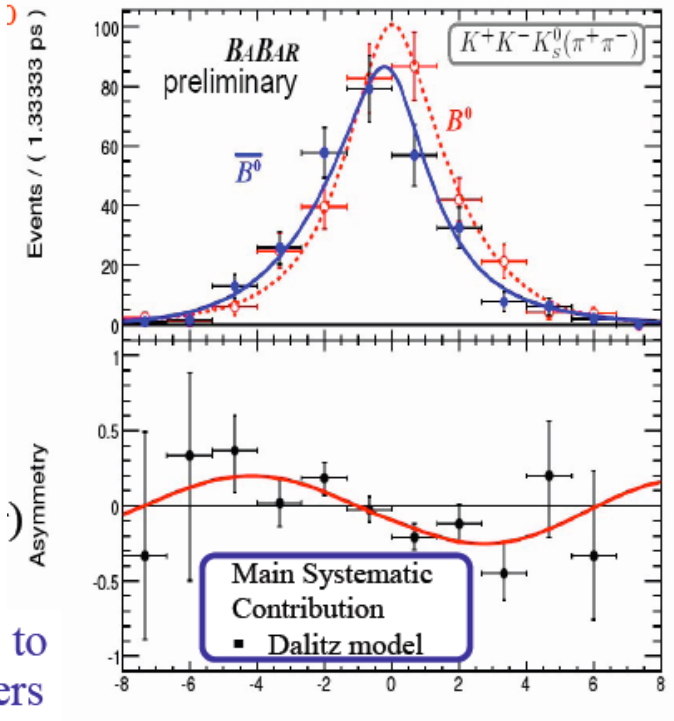
TD *CP*V in $B^0 \to K^+K^-K^0$: results

β measurement (not sin2β)

$$A_{CP} = -0.034 \pm 0.079 \pm 0.025$$
$$\beta_{eff} = 0.361 \pm 0.079 \pm 0.037$$



Rejected (within SM) 4.6σ



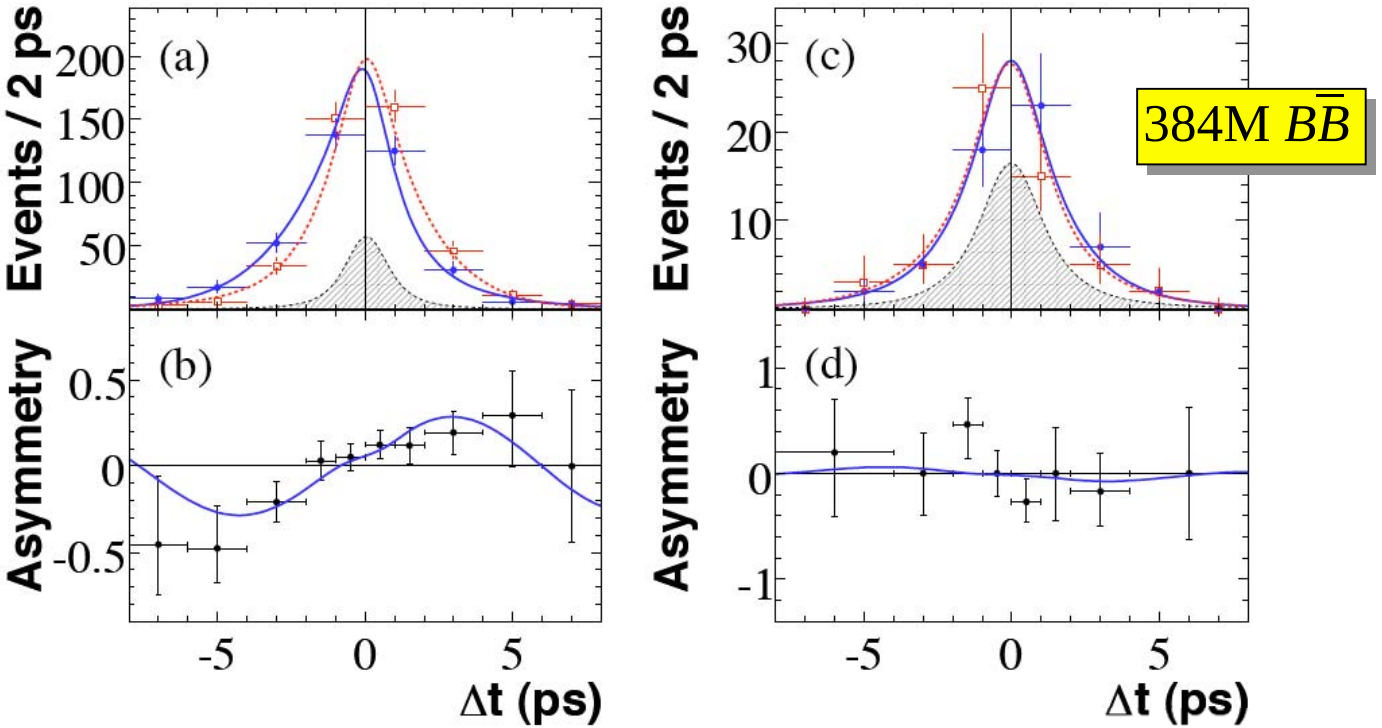
Fit to low mass K^+K^- region (<1.1 GeV) to extract ϕK^0 and $f_0(980)K^0$ CPV parameters

$\mathcal{A}_{CP}(\phi K^0)$	$-0.18 \pm 0.20 \pm 0.10$
$\beta_{eff}(\phi K^0)$	$0.06 \pm 0.16 \pm 0.05$
$\mathcal{A}_{CP}(f_0 K^0)$	$0.45 \pm 0.28 \pm 0.10$
$\beta_{eff}(f_0 K^0)$	$0.18 \pm 0.19 \pm 0.04$

ϕK^0: $\sin 2\beta_{eff} = +0.12 \pm 0.31(\text{stat}) \pm 0.10\ (\text{syst})$

TD *CP*V in $B^0 \to \eta' K^0$

Reconstructed 6 sub-decays: 5 with $K^0 \to K^0_S$ ($\eta_{CP} = -1$) and 1 with $K^0 \to K^0_L$ ($\eta_{CP} = +1$), with $\eta \to \gamma\gamma$, $\pi^+\pi^-\pi^0$, and $\eta' \to \eta\pi^+\pi^-$, $\rho^0\gamma$, and $K^0_S \to \pi^+\pi^-$, $\pi^0\pi^0$



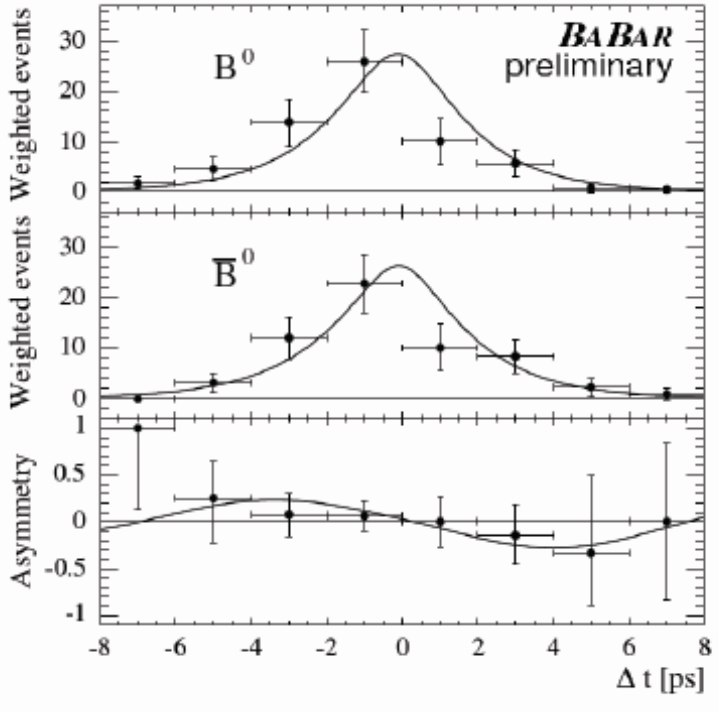
"sin2β" = +0.58 ± 0.10(stat) ± 0.03(syst)

$\mathcal{A}$ = –0.16 ± 0.07(stat) ± 0.03(syst)

- **Observation** of t*CP*V ($>5\sigma$) in a single $b \to s$ mode

TD *CPV* in $B^0 \to K_S K_S K_S$ Even CP eigenvalue (+1)

require at least 4 SVT hits for both K^0_S pions (~60% of events) for Δt measurement
determine Δt from a geometric fit to the $\Upsilon(4S) \to B^0 \bar{B}^0$ system taking in account the Interaction Point and by imposing a Gaussian constrain on the sum of the two B decay times to be equal to $2\tau_B$
keep remaining "no-Δt "events for direct CPV measurement

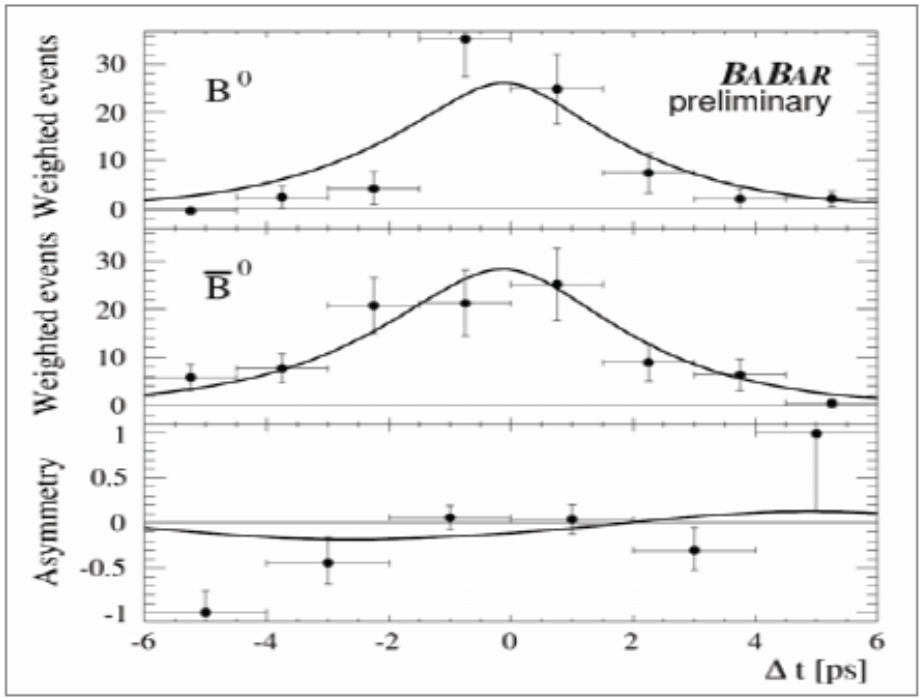


347M $B\bar{B}$

176 ± 17
$K_S K_S K_S$ signal

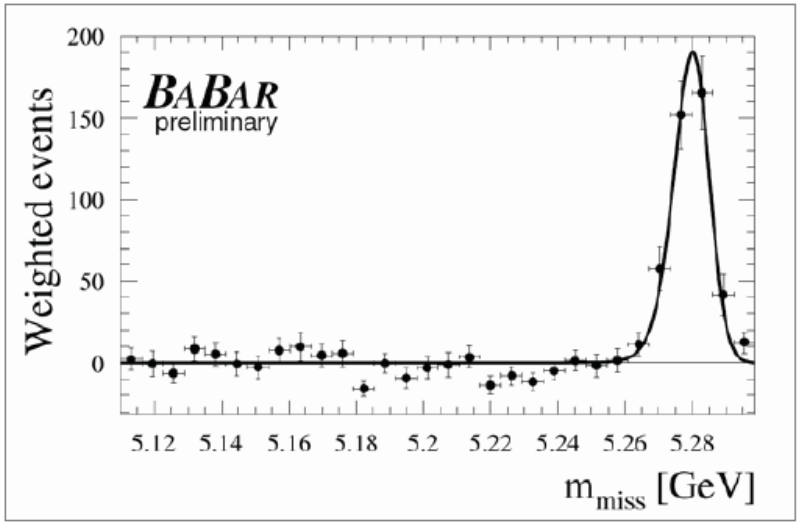
"sin2β" = +0.66 ± 0.26(stat) ± 0.08(syst)
$\mathcal{A}$ = +0.14 ± 0.22(stat) ± 0.05(syst)

TD *CP*V in $B^0 \to \pi^0 K_S$



347M $B\bar{B}$

425 ± 28
$\pi^0 K_S$ signal

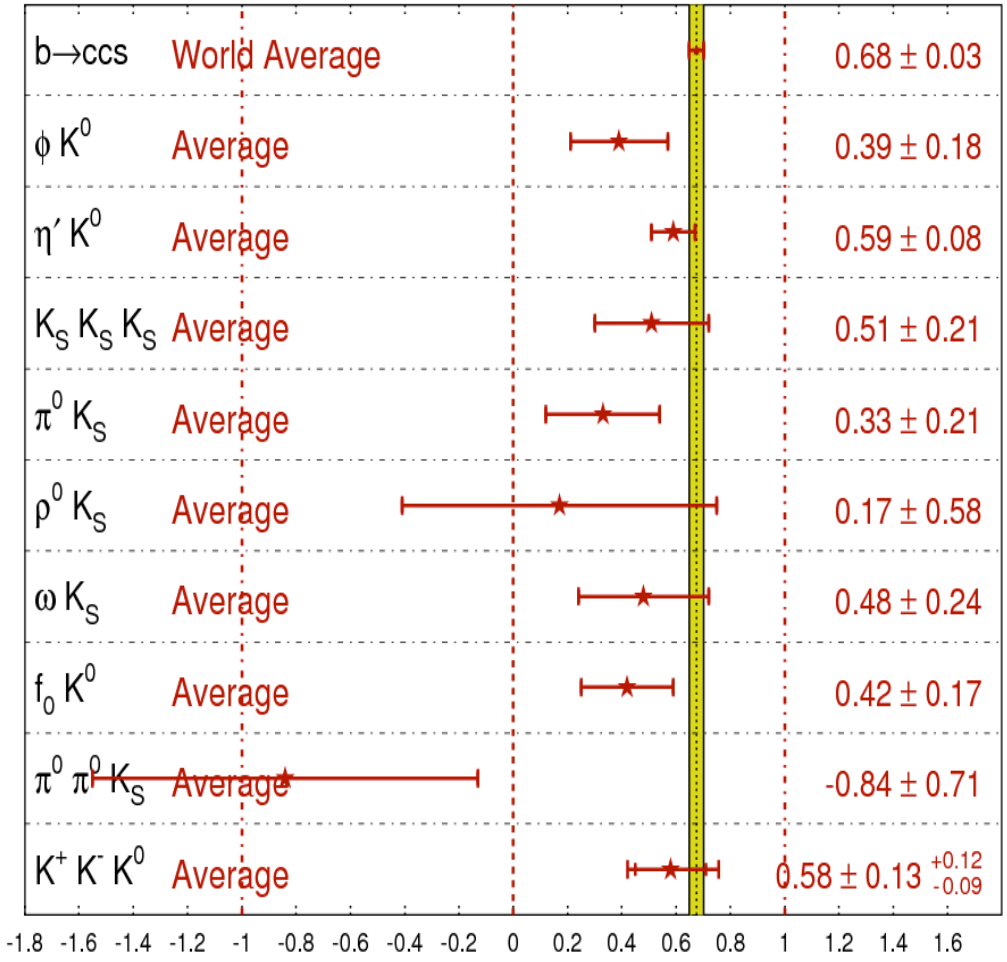


"sin2β" = +0.33 ± 0.26(stat) ± 0.04(syst)
$\mathcal{A}$ = –0.20 ± 0.16(stat) ± 0.03(syst)

”sin2β” with *b* → *s* penguins

$$\sin(2\beta^{\text{eff}}) \equiv \sin(2\phi_1^{\text{eff}})$$

HFAG
ICHEP 2006
PRELIMINARY



Is there a negative trend?

Naïve average of all b → s modes

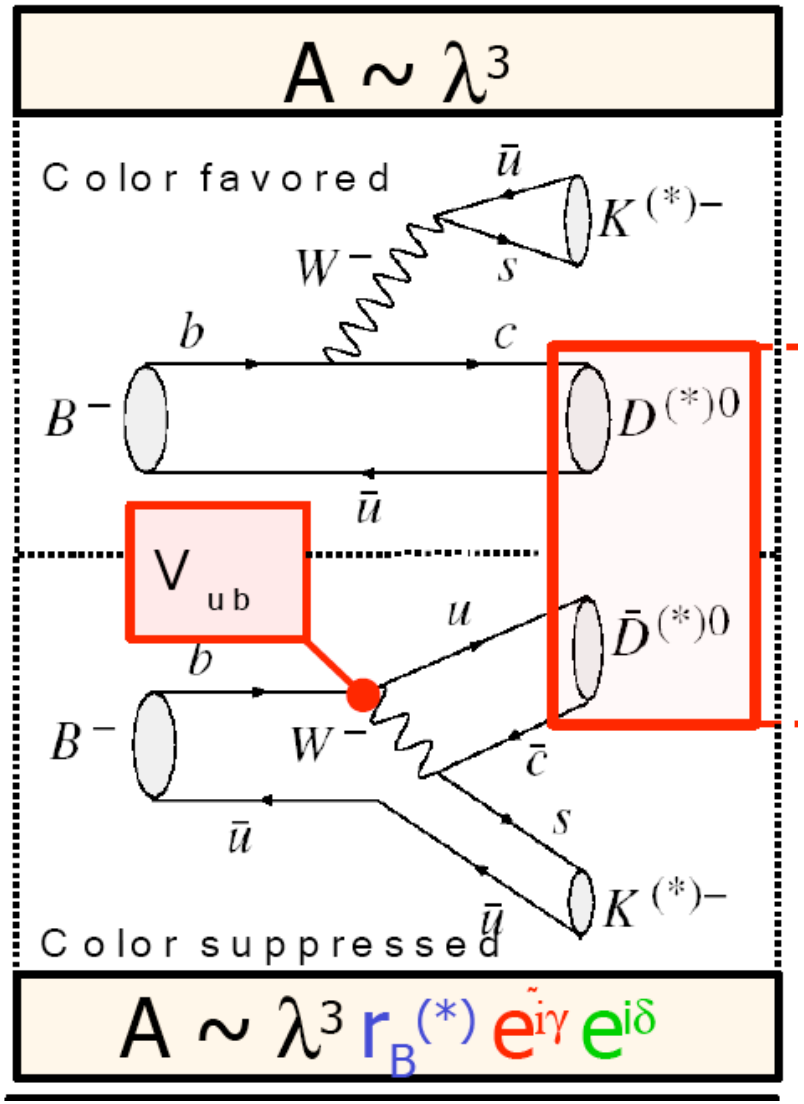
$\sin2\beta^{\text{eff}} = 0.52 \pm 0.05$

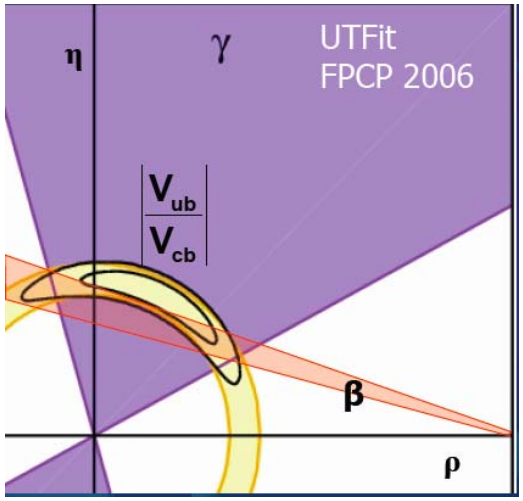
$\sin2\beta^{\text{ccs}} = 0.674 \pm 0.026$

Most of channels have ~0.20 stat error: more statistics !!!

Need full Dalitz analysis

γ extraction





Tree-only process,
Constraint for all New Physics scenarios

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

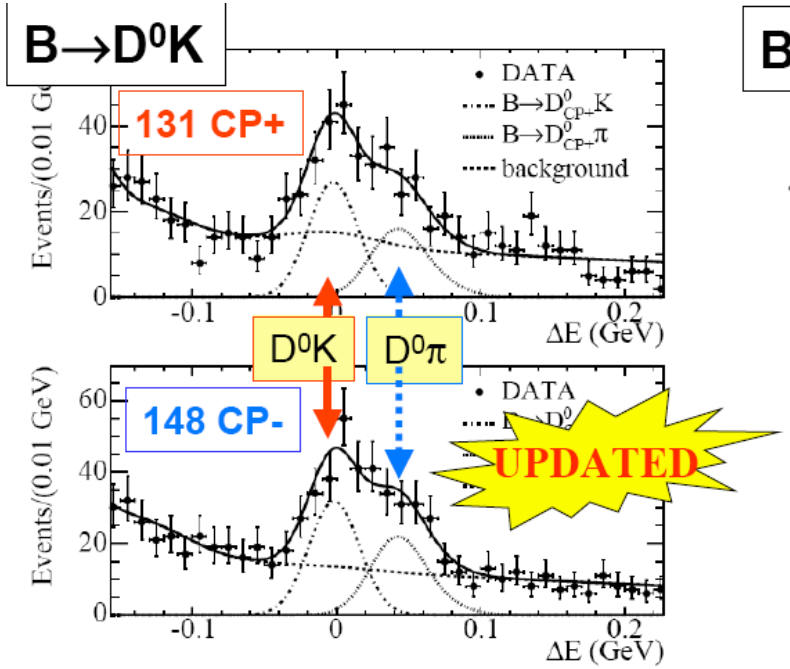
Gronau London Wyler

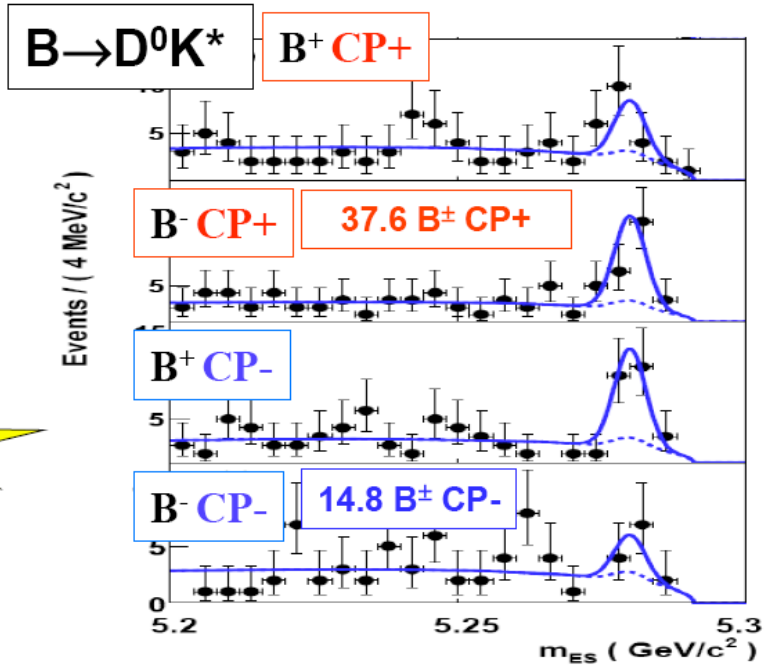
Reconstruct $D^{(*)0}$ to CP eigenstates $f_{CP\pm}$

$$R_{CP\pm} \equiv \frac{\Gamma(B^- \to D^0_{CP\pm} K^-) + \Gamma(B^+ \to D^0_{CP\pm} K^+)}{2\Gamma(B^- \to D^0 K^-)} = 1 \pm 2 r_B \cos\gamma \cos\delta_B + r_B^2$$

$$A_{CP\pm} \equiv \frac{\Gamma(B^- \to D^0_{CP\pm} K^-) - \Gamma(B^+ \to D^0_{CP\pm} K^+)}{\Gamma(B^- \to D^0_{CP\pm} K^-) + \Gamma(B^+ \to D^0_{CP\pm} K^+)} = \pm 2 r_B \sin\gamma \sin\delta_B / R_{CP\pm}$$

$B \to D^0_{CP\pm} K$, $D^0_{CP\pm} K^*$, $D^{*0}_{CP+} K$ $\quad f_{CP+}=KK, \pi\pi$ $\quad f_{CP-}=K_S\pi^0, K_S\phi, K_S\omega$





hep-ex/0607065 - 226 *10^6 BB pairs

Atwood Dunietz Soni

Color favored $B^- \to D^0 K^-$

Color suppressed $B^- \to \overline{D}^0 K^-$

Doubly CKM suppressed $D^0 \to K^+\pi^-$

CKM allowed $\overline{D}^0 \to K^+\pi^-$

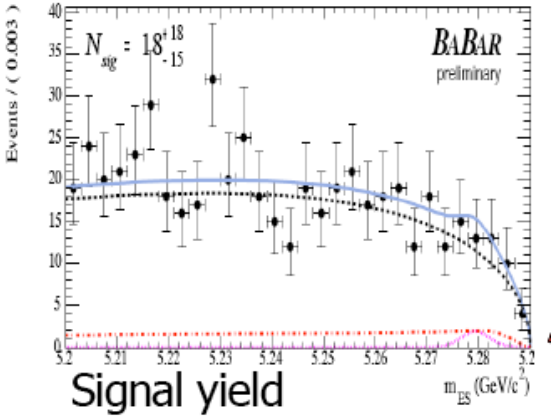
$[K^+\pi^-]_D K^-$

Signature = opposite sign kaons

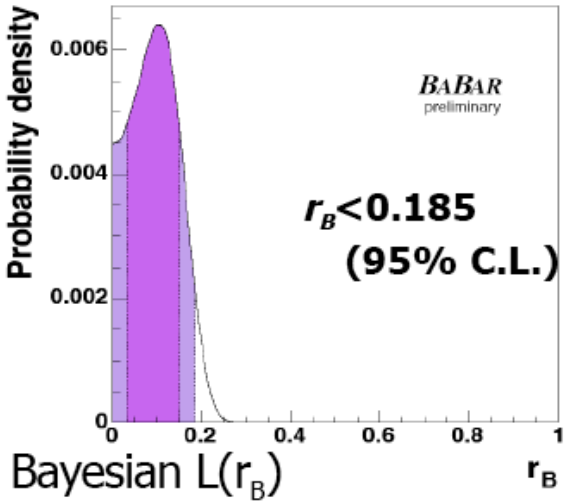
$$R_{ADS} = \frac{Br([K^+\pi^-]K^-) + Br([K^-\pi^+]K^+)}{Br([K^-\pi^+]K^-) + Br([K^+\pi^-]K^+)} = r_D^2 + r_B^2 + 2r_B r_D \cos(\delta_D + \delta_B)\cos\gamma$$

$$A_{ADS} = \frac{Br([K^+\pi^-]K^-) - Br([K^-\pi^+]K^+)}{Br([K^+\pi^-]K^-) + Br([K^-\pi^+]K^+)} = 2r_B r_D \sin(\delta_D + \delta_B)\sin\gamma \; / \; R_{ADS}$$

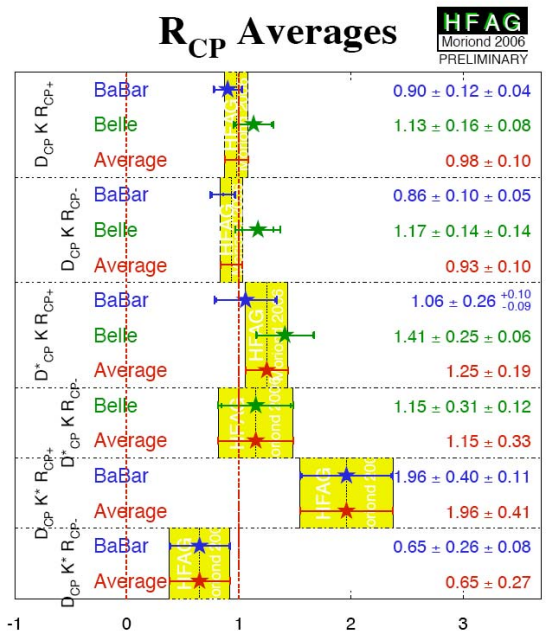
$B \to D^0[K^+\pi^-\pi^0]K$

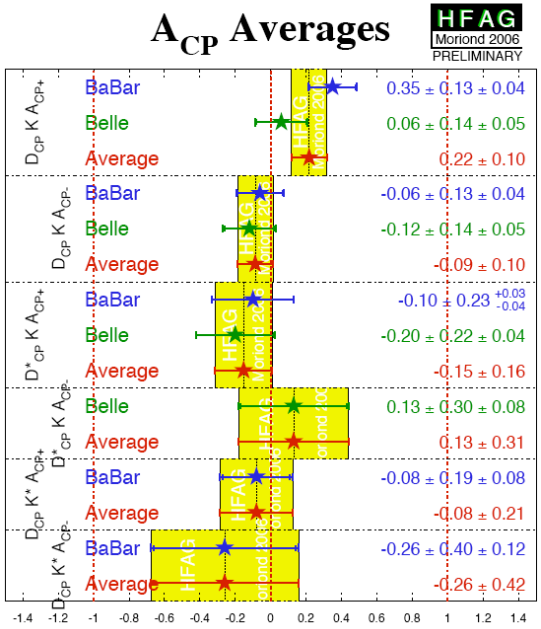


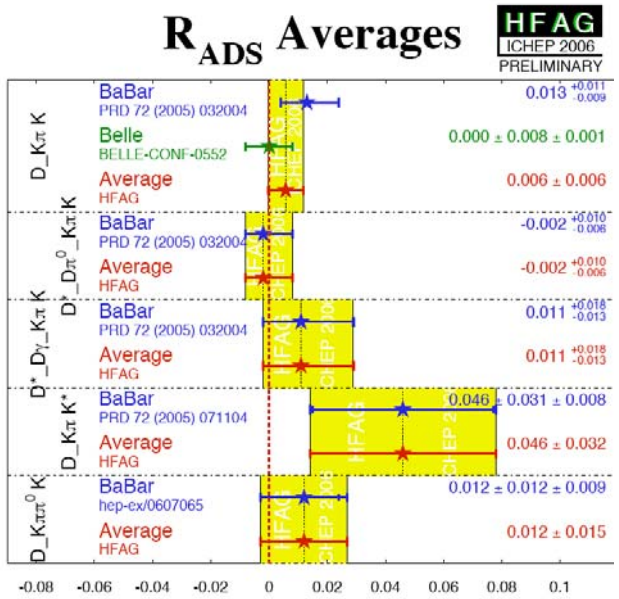
Signal yield from fit



Sensitivity only by combining…







– No constraint on γ with current statistics

$B \to D^{0(*)}(K_S\pi^+\pi^-)$ K Dalitz

Dalitz model $f_\pm(m_+^2, m_-^2)$ $\quad m_\pm^2 = m(K_S^0\pi^\pm)^2$

$$\Gamma_{B^\mp}(m_-^2, m_+^2) \propto \left|f_\mp\right|^2 + r_B^{(*)2}\left|f_\pm\right|^2 + 2\eta\left\{x_\mp^{(*)}\,\mathrm{Re}\left[f_\pm^* f_\mp\right] + y_\mp^{(*)}\,\mathrm{Im}\left[f_\mp f_\pm^*\right]\right\}$$

$\eta = +1$ (D^0K, $D^{*0}[D^0\pi^0]K$), -1 ($D^{*0}[D^0\gamma]K$)

No mixing and CP violation in charm decay

$$x^{(*)}_\pm = r^{(*)}_B \cos(\delta^{(*)}_B \pm \gamma)$$

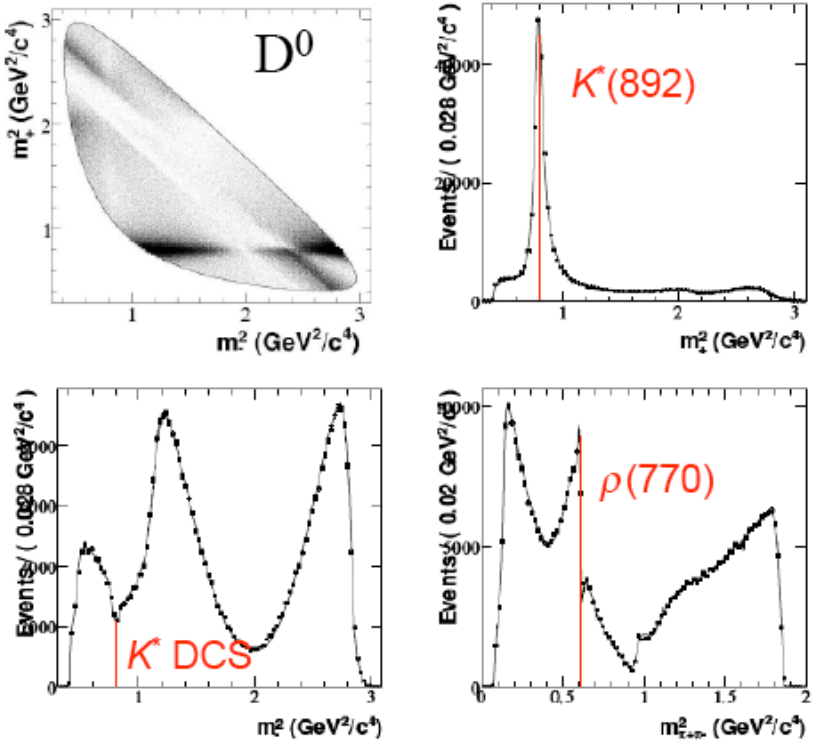
$$y^{(*)}_\pm = r^{(*)}_B \sin(\delta^{(*)}_B \pm \gamma)$$

$$r_B^{(*)2} = x_\pm^{(*)2} + y_\pm^{(*)2}$$

hep-ex/0607104 - 347 *10^6 B$\underline{\text{B}}$ pairs

$D^0 \to K_S\pi^+\pi^-$: Dalitz model

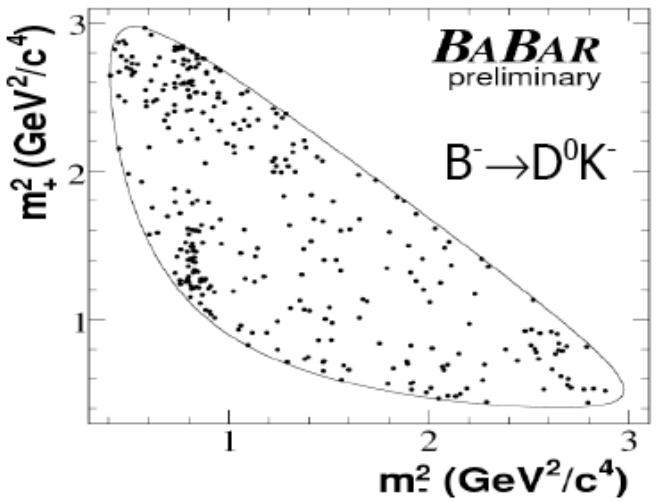
- From 390000 $D^{*+}\to D^0\pi^+$, $D^0\to K_S\pi\pi$ candidates (98% purity)
- ISOBAR model : 16 Breit-Wigner functions + a constant term
  - –parameters from PDG/other experiments (except for σ, σ', fit from data)
  - –K-Matrix formalism to estimate S-wave ππ systematic
  - –8 alternative models to fully evaluate model systematic

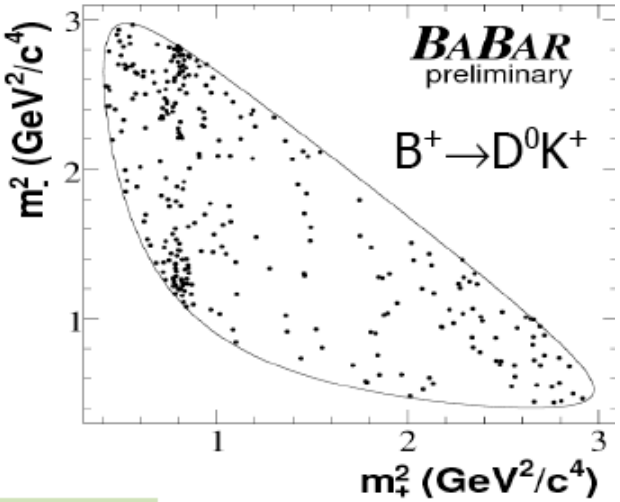


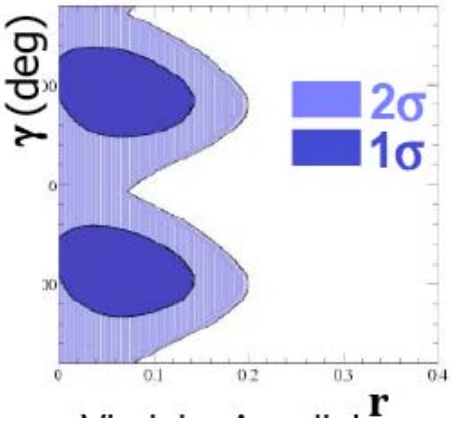
Component	$Re\{a_r e^{i\phi_r}\}$	$Im\{a_r e^{i\phi_r}\}$	Fit fraction (%)
$K^*(892)^-$	-1.223 ± 0.011	1.3461 ± 0.0096	58.1
$K_0^*(1430)^-$	-1.698 ± 0.022	-0.576 ± 0.024	6.7
$K_2^*(1430)^-$	-0.834 ± 0.021	0.931 ± 0.022	6.3
$K^*(1410)^-$	-0.248 ± 0.038	-0.108 ± 0.031	0.1
$K^*(1680)^-$	-1.285 ± 0.014	0.205 ± 0.013	0.6
$K^*(892)^+$	0.0997 ± 0.0036	-0.1271 ± 0.0034	0.5
$K_0^*(1430)^+$	-0.027 ± 0.016	-0.076 ± 0.017	0.0
$K_2^*(1430)^+$	0.019 ± 0.017	0.177 ± 0.018	0.1
$\rho(770)$	1	0	21.6
$\omega(782)$	-0.02194 ± 0.00099	0.03942 ± 0.00066	0.7
$f_2(1270)$	-0.699 ± 0.018	0.387 ± 0.018	2.1
$\rho(1450)$	0.253 ± 0.038	0.036 ± 0.055	0.1
Non-resonant	-0.99 ± 0.19	3.82 ± 0.13	8.5
$f_0(980)$	0.4465 ± 0.0057	0.2572 ± 0.0081	6.4
$f_0(1370)$	0.95 ± 0.11	-1.619 ± 0.011	2.0
σ	1.28 ± 0.02	0.273 ± 0.024	7.6
σ'	0.290 ± 0.010	-0.0655 ± 0.0098	0.9

hep-ex/0607104 - 347 *10^6 BB pairs

B→ D$^{0(*)}$K: results on γ







x_-	$0.041 \pm 0.059 \pm 0.018 \pm 0.011$
y_-	$0.056 \pm 0.071 \pm 0.007 \pm 0.023$
x_+	$-0.072 \pm 0.056 \pm 0.014 \pm 0.029$
y_+	$-0.033 \pm 0.066 \pm 0.007 \pm 0.018$
x_-^*	$-0.106 \pm 0.091 \pm 0.020 \pm 0.009$
y_-^*	$-0.019 \pm 0.096 \pm 0.022 \pm 0.016$
x_+^*	$0.084 \pm 0.088 \pm 0.015 \pm 0.018$
y_+^*	$0.096 \pm 0.111 \pm 0.032 \pm 0.017$

$\gamma \bmod 180^\circ = (92 \pm 41 \pm 11 \pm 12)^\circ$

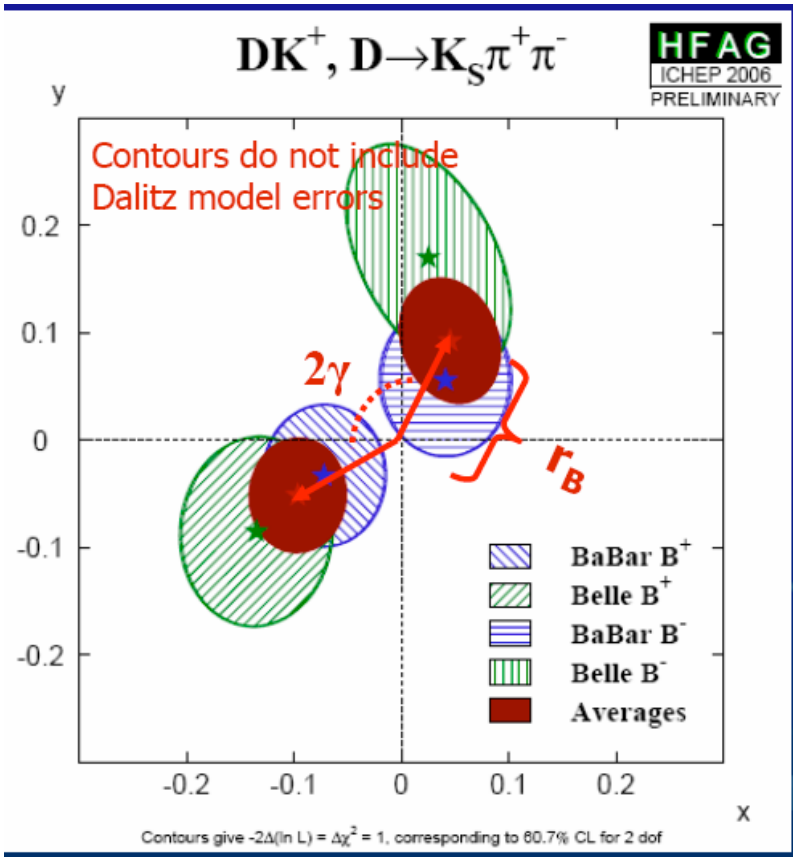
Stat Syst Dalitz

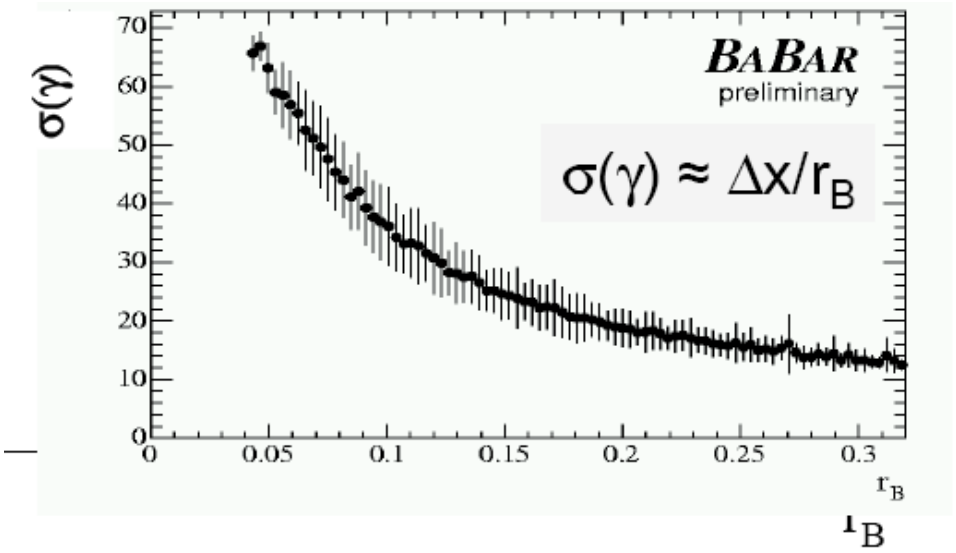
$r_B < 0.142$ ($r_B < 0.198$)

$0.016 < r_B^* < 0.206$ ($r_B^* < 0.142$)

1σ (2σ)

Statistical sensitivity to γ





Error on γ depends on true value of r_b

Model Systematics

ππ S-wave: Use K-matrix ππ S-wave model instead of the nominal BW model

ππ P-wave:

- Change ρ(770) parameters according to PDG
- Replace Gounaris-Sakurai by regular BW

ππ and Kπ D-wave: Zemach Tensor as the Spin Factor for $f_2(1270)$ and $K^*_2(1430)$ BW

Kπ S-wave:

- Allow $K^*_0(1430)$ mass and width to be determined from the fit
- Use LASS parameterization with LASS parameters

Kπ P-wave:

- Use $B \rightarrow J/\psi\, K_S\, \pi^+$ as control sample for K*(892) parameters
- Allow K*(892) mass and width to be determined from the fit

Blatt-Weisskopf penetration factors

Running width: consider a fixed value

Remove $K_2^*(1430)$, K*(1680), K*(1410), ρ(1450)

- Generate MC experiments with different models
- Evaluate $\Delta x = \sqrt{\Sigma_{i=1}^{8} \Delta x_i^2}$ for each coord.

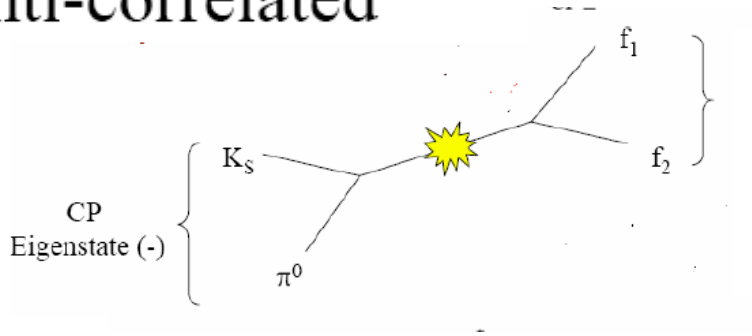
CP-tagged sample

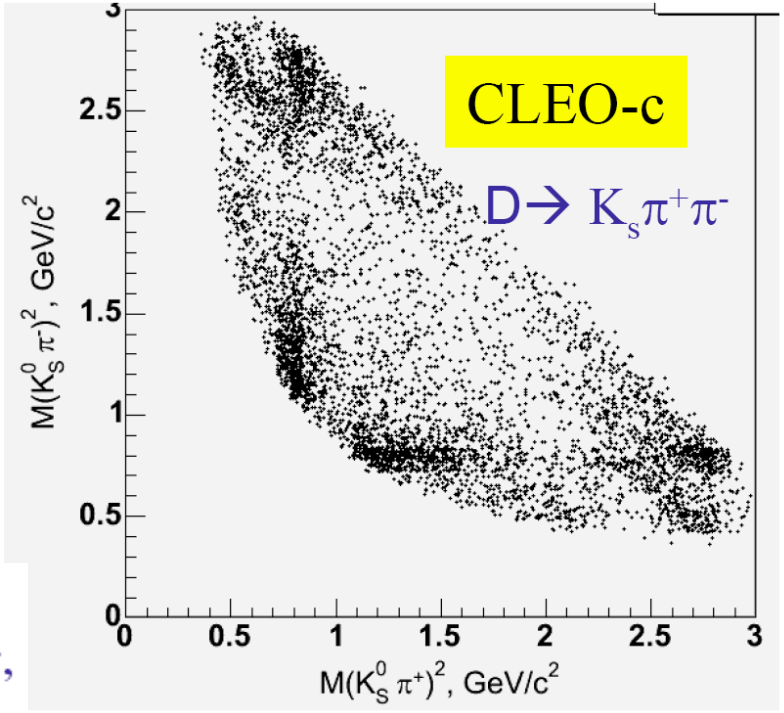
$$|D_{CP\pm}\rangle = \frac{1}{\sqrt{2}}\left[|D^0\rangle \pm |\overline{D^0}\rangle\right] \qquad \sqrt{2}A(D_{CP\pm} \to f) = A(D^0 \to f) \pm (\overline{D^0} \to f)$$

CP invariance

$\psi(3770)$L=1 C=-1

CP anti-correlated



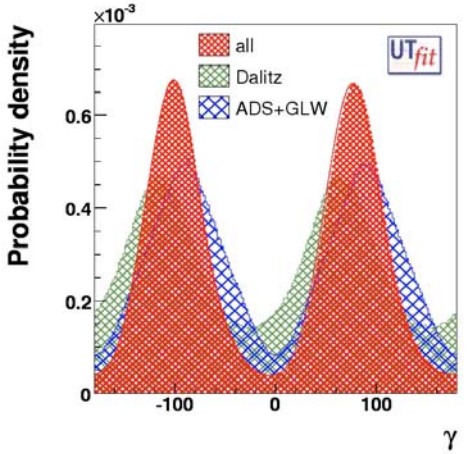


– CLEO-c CP tagged D's reduce Dalitz plot model dependence, compare CP+←DD→ $K_s\pi^+\pi^-$, CP-←DD→ $K_s\pi^+\pi^-$, & untagged D→ $K_s\pi^+\pi^-$, Extrapolation of Belle study CLEO-c 285 pb^{-1}/6fb^{-1} (3770 + DsDs) reduce model error to ~7^0, ~1^0

Ian Shipsey
CKM 2005

Conclusion & Outlook

- Two B-factories analyzed almost 1 ab-1
  - Still 1 ab^{-1} (at least) to come
- Many b→ s transitions channels analyzed
    - Observation of CP violation in $\eta'K^0$ transition
  - No clear deviation from SM (Stat errors ~0.20)
    - Statistically limited, theory model uncertainties!
- γ extraction
  - Large statistical error
    - Some sensitivity from combination of modes
  - Dalitz approach
    - Stat limited: Babar ±41 (small fitted r_b)
    - Dalitz model systematics (10 deg)
    - Model indipendent approach
      - synergy with charm factory (1 deg ?)



± 30 deg (WA)