DPF2006 + JPS2006

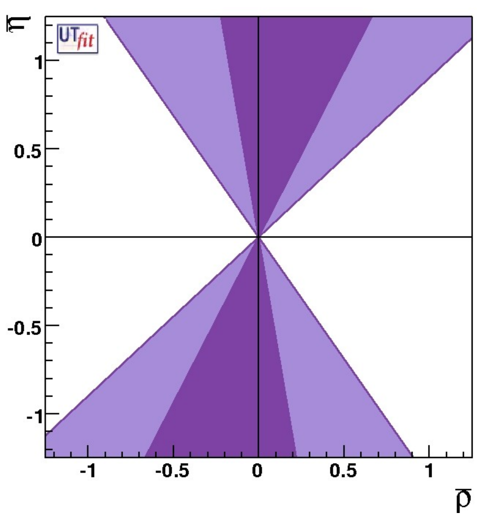
Joint Meeting of Pacific Region Particle Physics Communities

Measurement of the UT angle γ at BaBar

Virginia Azzolini

IFIC – Universitat de Valencia – CSIC

(on behalf of the BaBar Collaboration)



Outline:

Measurements of γ using $B^{\pm} \to D^{(*)}K^{(*)\pm}$

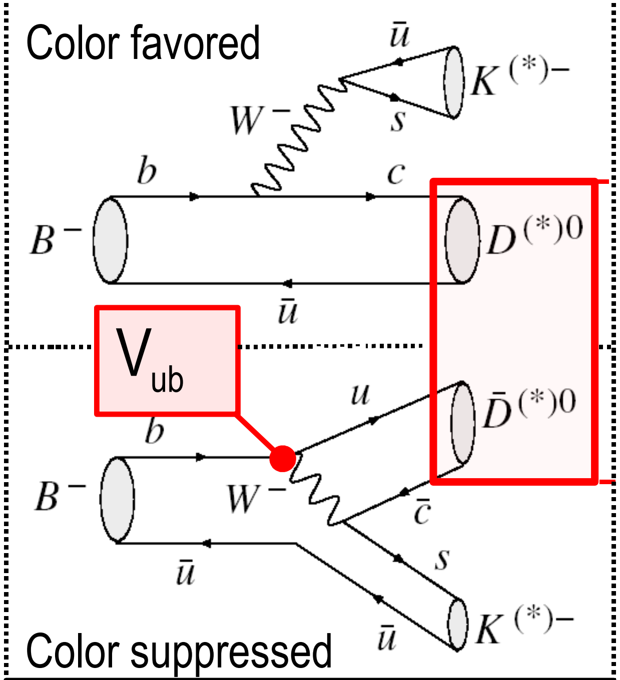
- GLW Method
- ADS Method
- D^0 Dalitz Method (GGSZ)

Methods overview

Access γ via interference between b→c<u>u</u>s and b→u<u>c</u>s decay processes

Reconstruct D in final states f accessible to both to D^0 and $\overline{D^0}$

$A \sim \lambda^3$



$A \sim \lambda^3 r_B^{(*)} e^{i\gamma} e^{i\delta}$

Theoretically clean:

contributions.

Three methods

GLW D^0 CP-modes	**ADS** DCSD mode	**GGSZ** Dalitz
K^+K^-, $\pi^+\pi^-$ [CP+] $K_S\pi^0$, $K_S\omega$, $K_S\phi$ [CP−]	$K^+\pi^-$ $\overline{D^0} \rightarrow K^+\pi^-$ suppr. $D^0 \rightarrow K^+\pi^-$ fav.	$K_S\pi^+\pi^-$

. δ = relative (unknown) strong phase

.. γ = weak phase

... $r_B^{(*)}$ = (critical) ratio of suppr./fav. amplitudes:

$$r_B^{(*)} = \frac{|A(B^- \rightarrow \overline{D}^{(*)0} K^-)|}{|A(B^- \rightarrow D^{(*)0} K^-)|} \sim 0.1 - 0.2$$

PL B265, 172 (1991)
PL B557, 198 (2003)

Larger r_B

→ Larger interference

→ better γ experimental precision

Gronau-London-Wyler method

Phys. Lett. B253, 483; Phys. Lett. B265, 172 (1991)

. Reconstruct D meson in CP-eigenstates (accessible to D^0 and $\underline{D}^0$)
even (CP = +1 $\pi^+\pi^-$, K^+K^-) & odd (CP = -1 $Ks^0\pi^0$, $Ks^0\phi$, $Ks^0\omega$)

.. Measure 4 observables $R_{CP\pm}$, $A_{CP\pm}$ (formulae for D^0K):

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

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

Theoretically clean
but
8-fold ambiguity

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

B→ D^0 K

PRD 73, 051105 - 232 $*10^6$ B$\underline{\text{B}}$ pairs

$R_{CP+} = 0.90 \pm 0.12(stat.) \pm 0.04(syst.)$ $R_{CP-} = 0.86 \pm 0.10(stat.) \pm 0.05(syst.)$
$A_{CP+} = 0.35 \pm 0.13(stat.) \pm 0.04(syst.)$ $A_{CP-} = -0.06 \pm 0.13(stat.) \pm 0.04(syst.)$
$x_+ = -0.082 \pm 0.053 \pm 0.018$, $x- = 0.102 \pm 0.062 \pm 0.022$, $r_B^2 = -0.12 \pm 0.08 \pm 0.03$

B→ D^0 K*

PRD 73, 071103 - 232 $*10^6$ B$\underline{\text{B}}$ pairs

$R_{CP+} = 1.96 \pm 0.40(stat.) \pm 0.11(syst.)$ $R_{CP-} = 0.65 \pm 0.26(stat.) \pm 0.08(syst.)$
$A_{CP+} = 0.08 \pm 0.19(stat.) \pm 0.08(syst.)$ $A_{CP-} = 0.26 \pm 0.40(stat.) \pm 0.12(syst.)$
$x_+ = 0.32 \pm 0.18 \pm 0.07$, $x- = 0.33 \pm 0.16 \pm 0.06$, $r_B^2 = 0.30 \pm 0.25$

B→ D^{*0} K

PRD 71, 031102 - 123 $*10^6$ BB pairs

$R_{CP+} = 1.06 \pm 0.26(stat.) \pm 0.10(syst.)$
$A_{CP+} = \tilde{0}.10 \pm 0.23(stat.) \pm 0.04(syst.)$

CP^- not reconstructed

Atwood-Dunietz-Sony method

Phys. Rev. Lett. 78, 3257 (1997)

Classic two body: Decays into non-CP state, where the color-favoured mode decays via Doubly-Cabibbo Suppressed (DCS) channels

Color favored $B^- \to D^0 K^-$ | Doubly CKM suppressed $D^0 \to K^+ \pi^-$

Color suppressed $B^- \to \overline{D}^0 K^-$ | CKM allowed $\overline{D}^0 \to K^+ \pi^-$

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

Signature = opposite sign kaons

Small BF (~10^{-7}), but amplitudes are similar → expected large CP symmetries

Observables R_{ADS} and A_{ADS} (based on opposite sign and same sign kaon decays):

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

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

with unknown parameters: r_B, δ and γ

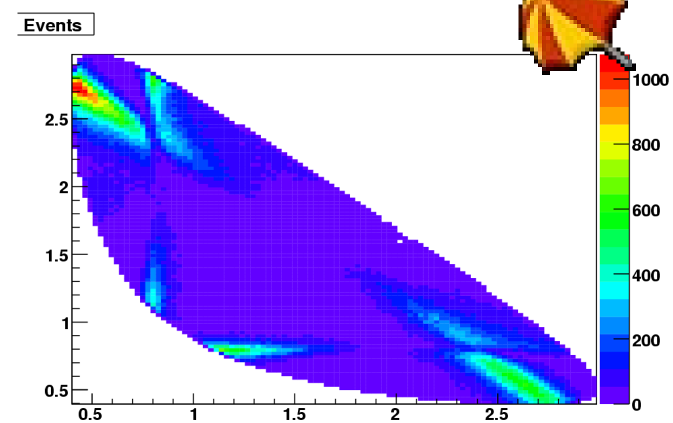
input :
$$r_D = \left|\frac{A(D^0 \to K^+\pi^-)}{A(D^0 \to K^-\pi^+)}\right| = 0.060 \pm 0.003$$
($D^{*+} \to D^0 (K\pi)\pi^+$ decays -- PRL91,171801(2003))

$D^{(*)0}K$: PRD 72, 032004 - 232 *10^6 $B\overline{B}$ pairs

$D^0 K^*$: PRD 72, 071104 - 232 *10^6 $B\overline{B}$ pairs

hep-ex/0607065 - 226 *10^6 $B\bar{B}$ pairs

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



Multi-body: similar to previous analysis with f = $K^+\pi^-\pi^0$. Complication for γ extraction from $|A_D|$, δ_D variation across the D^0 Dalitz plane:

$$R_{ADS} = \frac{\Gamma(B^+ \to [K^-\pi^+\pi^0]_{D^0}K^+) + \Gamma(B^+ \to [K^-\pi^+\pi^0]_{\overline{D}^0}K^+) + \Gamma(B^-)}{\Gamma(B^+ \to [K^+\pi^-\pi^0]_{D^0}K^+) + \Gamma(B^+ \to [K^+\pi^-\pi^0]_{\overline{D}^0}K^+) + \Gamma(B^-)}$$

we can express R_{ADS} as

$$R_{ADS} = \int \left| r_B e^{i(\delta_B+\gamma)} + r_D e^{i\delta_D} \right|^2 dm_{K\pi}\, dm_{K\pi^0} = r_B^2 + r_D^2 + 2\, r_B\, r_D\, C \cos\gamma$$

$$r_B^{(*)} = \frac{|A(B^- \to \underline{D}^{(*)0} K^-)|}{|A(B^- \to D^{(*)0} K^-)|} \sim 0.1 - 0.2$$

$r_D^2 \equiv \Gamma(D^0 \to K^+\pi^-\pi^0) / \Gamma(D^0 \to K^-\pi^+\pi^0)| = (0.214 \pm 0.011)\%$ (BaBar, preliminary)

$$C = \frac{1}{r_D\, BR(D^0 \to K^-\pi^+\pi^0)} \int A(D^0 \to K^-\pi^+\pi^0)\, A(D^0 \to K^+\pi^-\pi^0) \cos\Delta\, dm_{12}\, dm_{13}$$

$\Delta = \delta_B + \delta_D - \overline{\delta_D}$

hep-ex/0607065 - 226 *10^6 $B\bar{B}$ pairs

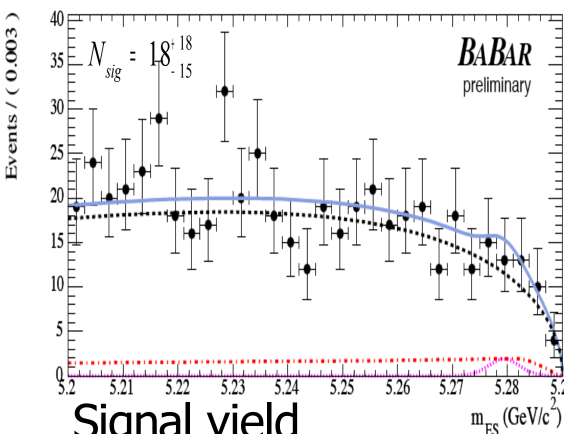
ADS $B \to D^0[K^+\pi^-\pi^0]K$

R_{ADS} and r_B distribution extraction

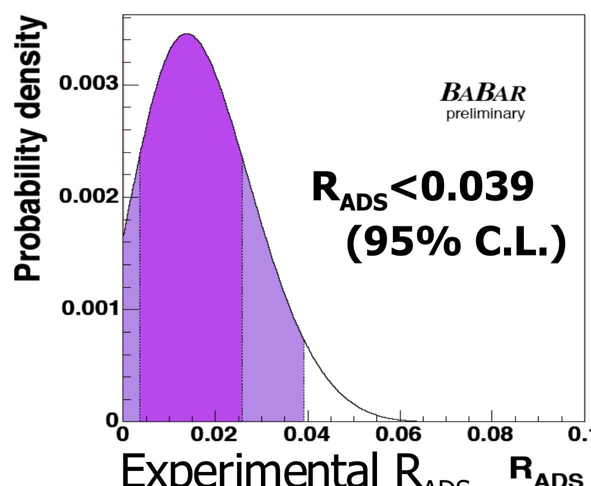
A priory probability is Gaussian consistent with $r_D^2 = (0.214 \pm 0.011)\%$ (BaBar,prel.)

$$R_{ADS} = r_B^2 + r_D^2 + 2 r_B r_D C \cos\gamma$$

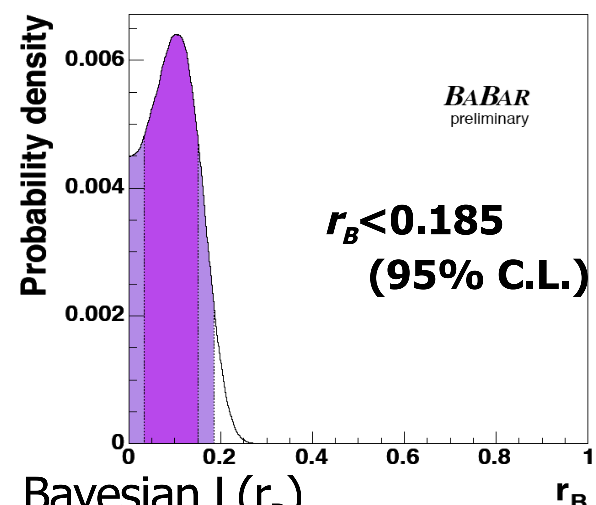
Distributed flat in [-1,1] and [0,1]



Signal yield from fit



Experimental R_{ADS} likelihood



Bayesian $L(r_B)$
(flat r_B and |Ccosγ| prior PDFs)

wrt $f=K^+\pi^-$:
more background
but smaller r_D

→ R_{ADS} <0.039 using | C cosγ | ≤ 1
r_B <0.185 95% C.L.

ADS averages

D(*)^{0}K: PRD 72, 032004 - 232 *10^6 $B\bar{B}$ pairs
$D^{0*}K^*$: PRD 72, 071104 - 232 *10^6 $B\bar{B}$ pairs
hep-ex/0607065 - 226 *10^6 $B\bar{B}$ pairs

Comparison with other analyses

Classical ADS

$B \rightarrow DK$

$R_{ADS} < 0.029$ 90% C.L

$r_B < 0.23$ 90% C.L.

$B \rightarrow [D\pi]_{D*}K$

$R_{ADS} < 0.023$ ($D^{*0} \rightarrow D^0\pi^0$)

< 0.045 ($D^{*0} \rightarrow D^0\gamma$) 90% C.L.

$r_B < 0.16$ 90% C.L.

$B \rightarrow [K^+\pi^-]_D K^{*-}$

$R_{ADS} = 0.046 \pm 0.032$ 1σ

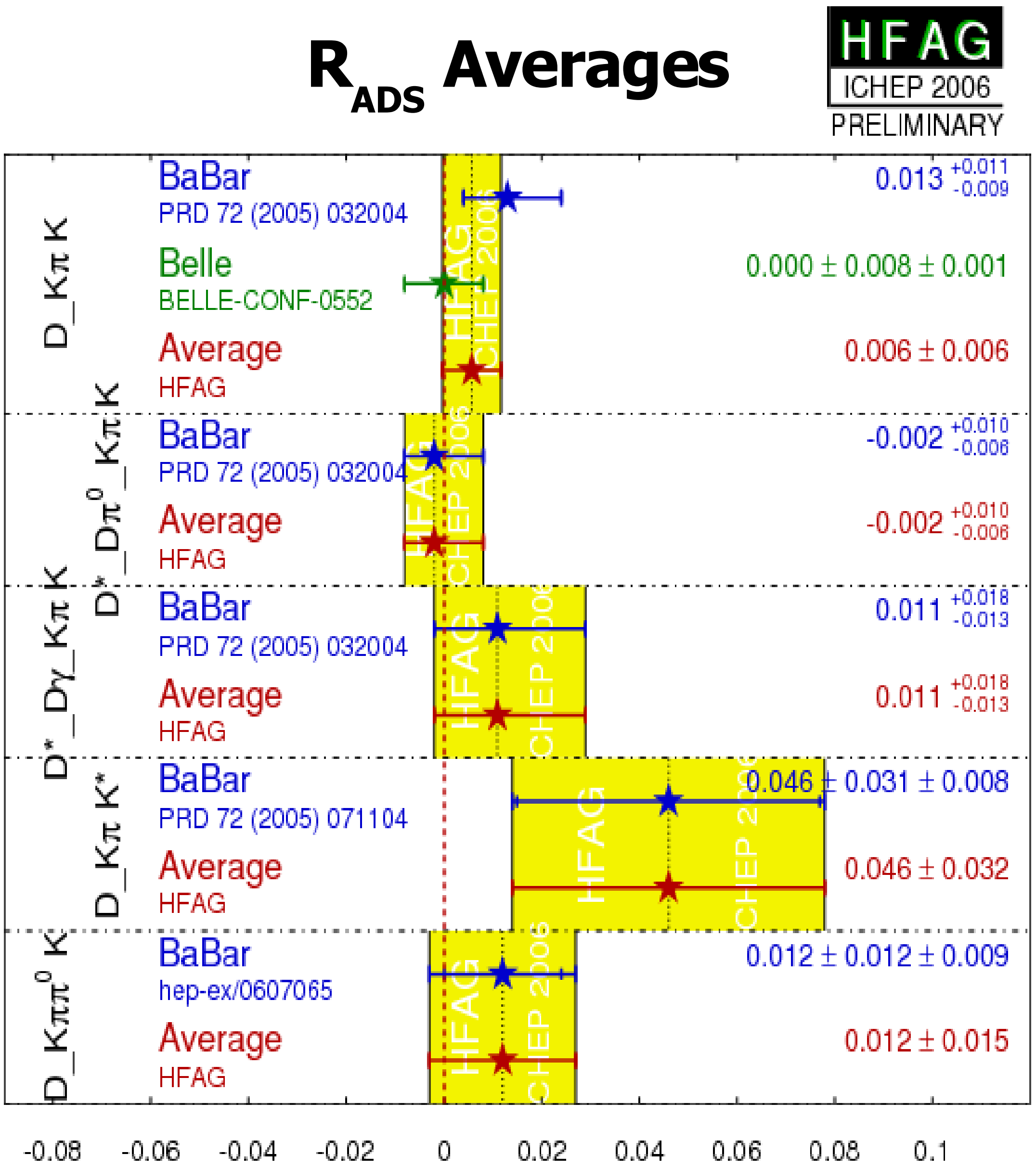
$r_B = 0.20 \pm 0.14$ 1σ

Dalitz ADS

$B \rightarrow [K+\pi- \pi0]$ DK-

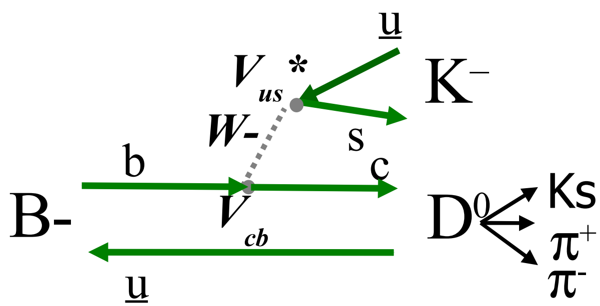
$R_{ADS} < 0.039$ 95% C.L.

$r_B < 0.185$ 95% C.L.

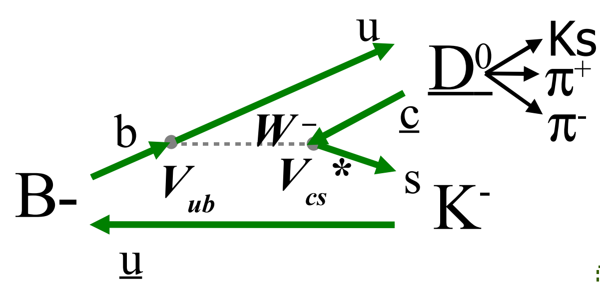


Giri-Grossman-Soffer-Zupan (Dalitz) method

$D^0, \bar{D}^0$ decay to 3 body final state $K_S\pi^+\pi^-$



Color-allowed $b\to c$ amplitude



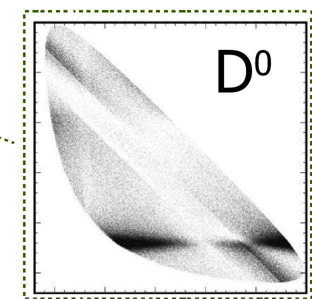
Color-suppressed $b\to u$ amplitude

The interference is a function of the Dalitz plot point :

$$B^-: \quad M_-(m_-^2, m_+^2) = \left|A(B^- \to D^0 K^-)\right| \left[f(m_-^2, m_+^2) + r_B e^{i\delta_B} e^{-i\gamma} f(m_+^2, m_-^2) \right]$$

$$B^+: \quad M_+(m_-^2, m_+^2) = \left|A(B^+ \to \bar{D}^0 K^+)\right| \left[f(m_+^2, m_-^2) + r_B e^{i\delta_B} e^{+i\gamma} f(m_-^2, m_+^2) \right]$$

$$m_-^2 = m(K_S^0\pi^-)^2$$
$$m_+^2 = m(K_S^0\pi^+)^2$$



No D mixing
No CP violation in D decays

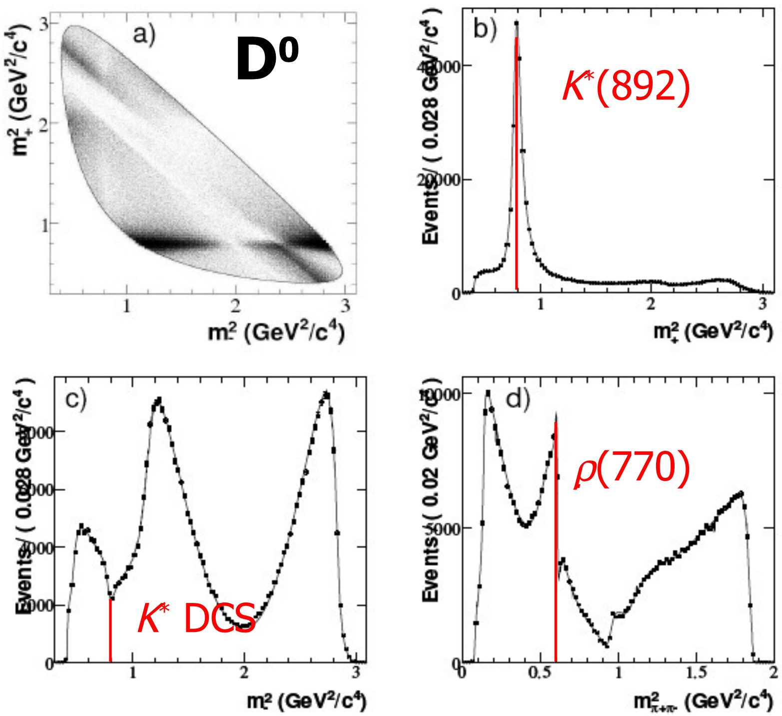
pros: Only Two-fold ambiguity $(\delta_B,\gamma)\to(\delta_B+\pi,\gamma+\pi)$

significantly larger statistical power $Br(D^0\to K_s\pi\pi) \sim 10*Br(D^0\to f_{CP})$

GGSZ $D^0 \to K_s\pi\pi$ method

$f(m_-^2, m_+^2)$ extracted from unbinned maximum likelihood fit to tagged D^0

(from $D^{(*)+} \to D^0\pi+$ decays, ~390k evts @97.7% purity).



Isobar model (≡ coherent Σ of **Breit-Wigner** (BW) amplitudes)

. 3-body D^0 decays proceed mostly via 2 -body decays

.. A_D = 16 distinct resonances + 1 NR term

... Not so good for ππ S-wave

.... σ(500) /σ'(1000) added to describe reasonably well the data

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	3.6
$K^*(1410)^-$	-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

K-matrix Model *

. include ππ S-wave terms

.. unitarity

...χ2 /dof similar to BW model

* I.J.R.Aitchison,Nucl.Phys. A189, 417 (1972)
V.V.Anisovitch, A.V. Sarantev EPJ A16, 229 (2003)

GGSZ $D^0 \to K_s \pi\pi$ method

Dalitz model systematic uncertainties:

. introduce 8 alternative models

.. generate high statistics toy MC (x100 data statistics) experiments according nominal (BW) model

... fit with both nominal & alternative model

.... take the maximum of the absolute value of the differences

$\pi\pi$ S-wave: Use K-matrix $\pi\pi$ S-wave model instead of the nominal BW model

$\pi\pi$ P-wave: Change $\rho(770)$ parameters according to PDG
Replace Gounaris-Sakurai by regular BW
Remove $\rho(1450)$

$\pi\pi$ D-wave: Zemach Tensor as the Spin Factor

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

$K\pi$ P-wave: Use $B \to J/psi\ Ks\ \pi+$ as control sample for K*(892) parameters
Allow K*(892) mass and width to be determined from the fit

$K\pi$ D-wave: Zemach Tensor as the Spin Factor

Blatt-Weiskopf penetration factors

No running width

Dalitz plot normalization

GGSZ $D^0 \to K_s \pi\pi$ method

Cartesian Coordinates:

From previous studies, parameters (r_B, γ, δ) badly behave statistically

No sensitivity to γ for r_B<0.1 *(+underestimated errors on γ and δ)*

$\rightarrow$ Fit 4 cartesian coordinates ($x\pm$, $y\pm$)

$$x_\pm = \mathrm{Re}\,(r_B e^{i(\delta\pm\gamma)}) \qquad y_\pm = \mathrm{Im}\,(r_B e^{i(\delta\pm\gamma)})$$

. Gaussian Errors on x, y (no unphysical zone)

.. (x^+, y^+) , (x^-,y^-) uncorrelated

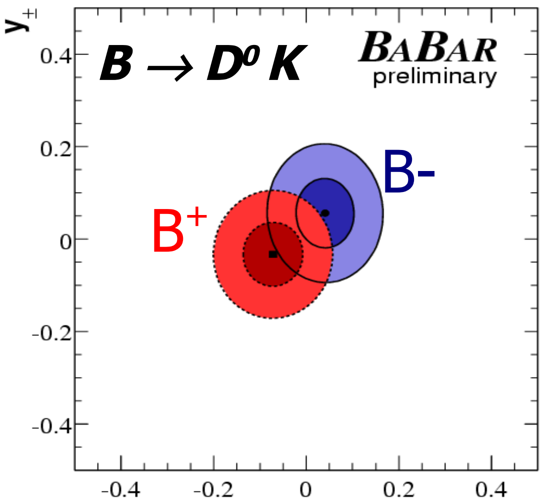
... Unbiased results $\forall$ r_B

.... Easier to combine different results

Note: GLW results also sensitive to $x_\pm$ and through the relations

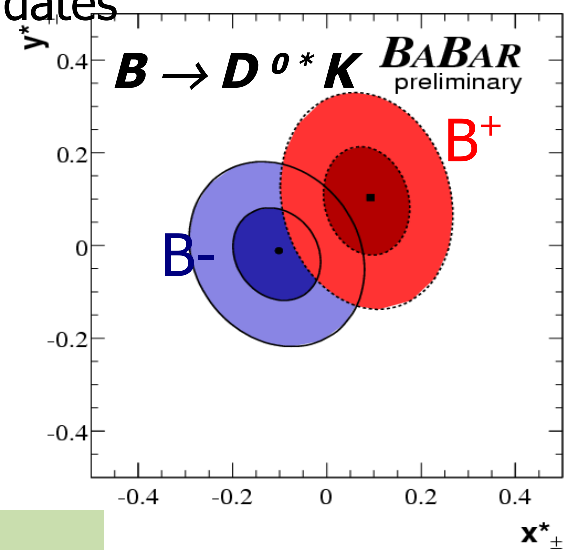
$$x_\pm = \frac{R_{CP+}(1\mp A_{CP+}) - R_{CP-}(1\mp A_{CP-})}{4} \qquad r_B^{\,2} = \frac{R_{CP+} + R_{CP-} - 2}{2}$$

GGSZ $D^0 \to K_s \pi\pi$ method



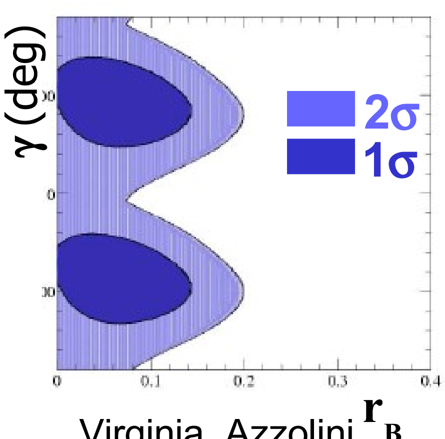
- Dalitz distribution of selected $B^{\pm}$ candidates
- Fitted values of $x^{(*)}_{\pm}$, $y^{(*)}_{\pm}$

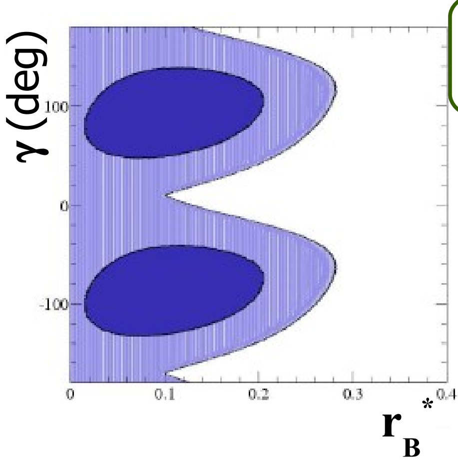
x_-	$0.041 \pm 0.059 \pm 0.018 \pm 0.011$
y_-	$0.056 \pm 0.071 \pm 0.007 \pm 0.023$
x_+	$-0.072 \pm 0.056 \pm 0.014 \pm 0.029$
y_+	$-0.033 \pm 0.066 \pm 0.007 \pm 0.018$
x^*_-	$-0.106 \pm 0.091 \pm 0.020 \pm 0.009$
y^*_-	$-0.019 \pm 0.096 \pm 0.022 \pm 0.016$
x^*_+	$0.084 \pm 0.088 \pm 0.015 \pm 0.018$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



frequentist [Neyman] approach used to build 5D confidence level on $(\gamma, r_B, \delta_B, r_B^*, \delta_B^*)$

1σ and 2σ projection contours on $r_B^{(*)}$, γ





γ mod $180^\circ = (92 \pm 41 \pm 11 \pm 12)^\circ$

Stat Syst Dalitz

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

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

1σ (2σ)

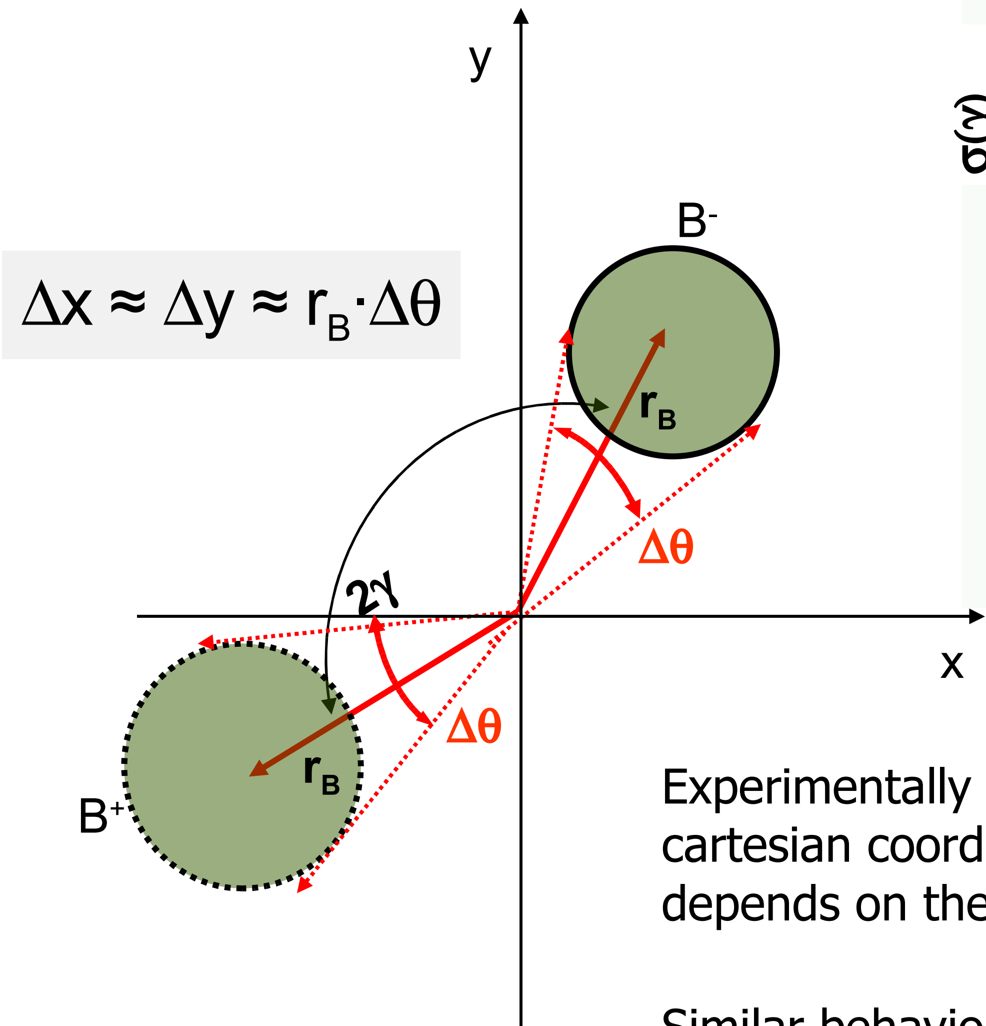
hep-ex/0607104 - 347 $*10^6$ $B\bar{B}$ pairs

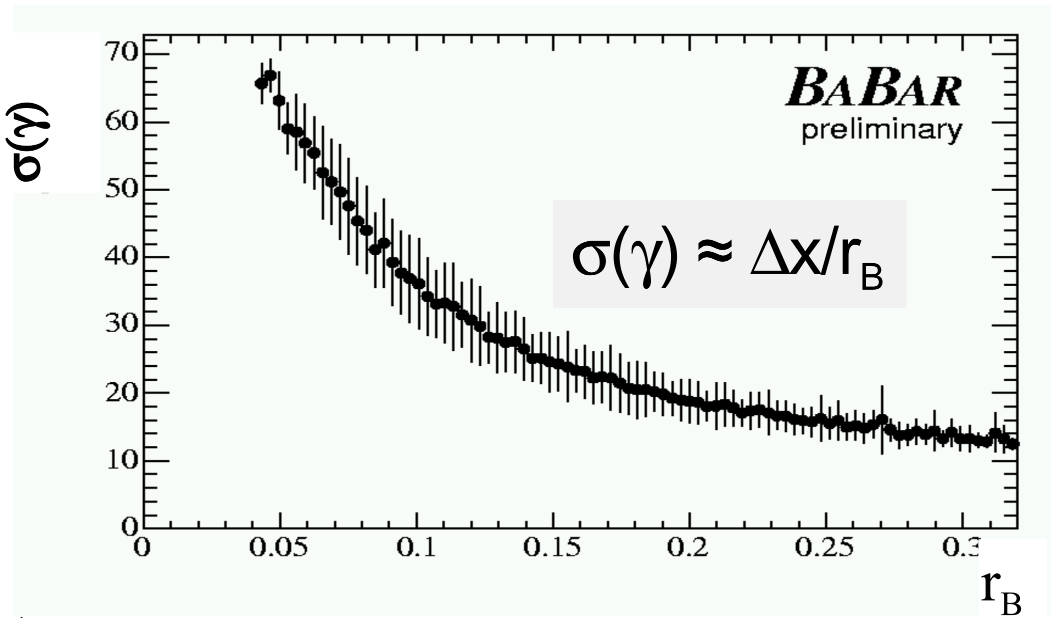
GGSZ $D^0 \to K_s \pi\pi$ method

Comments on the results:

Better precision on x,y wrt to Belle,

σ_γ worse due to smaller measured central value of $r^{(*)}_B$



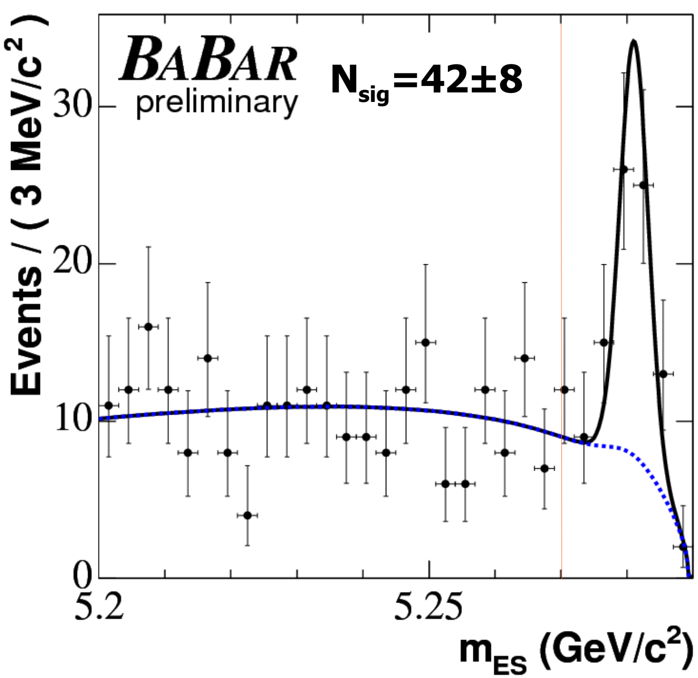


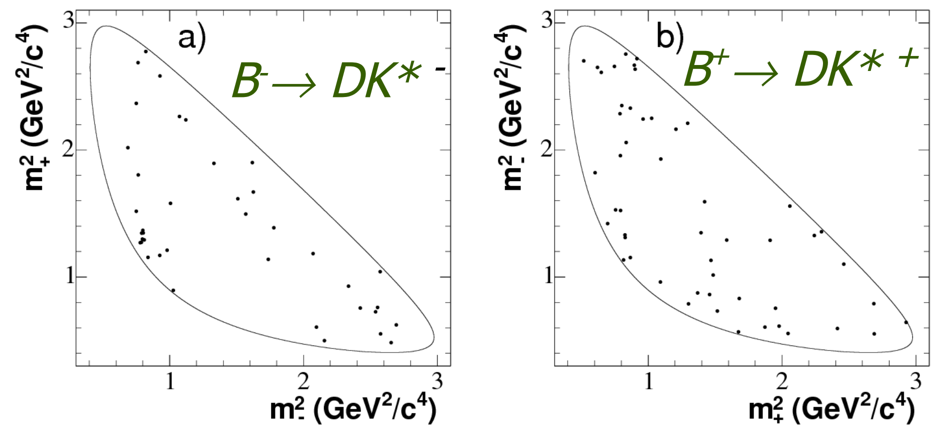
Experimentally we can improve the measurement of the CP cartesian coordinates but the improvement on error of γ depends on the true value of the r_B parameter.

Similar behavior for statistical and systematic error.

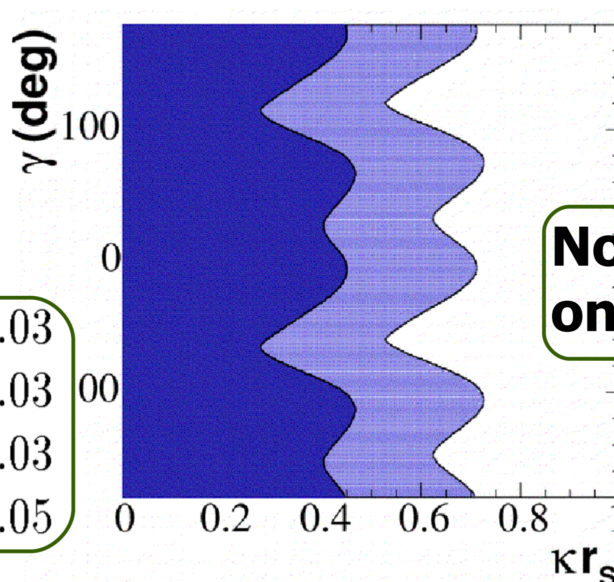
GGSZ $B\to D^0K^*$ $(K^*\to K_S\pi)$, $D^0\to K_s\pi\pi$ method

Analogous to previous analysis, one additional fit parameter *k* to take into account non- resonant $B\to D^0K_S\pi$ background and r_B, δ_B variation across B Dalitz plot.





$$x_{s-} \equiv \kappa r_s \cos(\delta_s - \gamma) \quad -0.20 \pm 0.20 \pm 0.11 \pm 0.03$$
$$y_{s-} \equiv \kappa r_s \sin(\delta_s - \gamma) \quad 0.26 \pm 0.30 \pm 0.16 \pm 0.03$$
$$x_{s+} \equiv \kappa r_s \cos(\delta_s + \gamma) \quad -0.07 \pm 0.23 \pm 0.13 \pm 0.03$$
$$y_{s+} \equiv \kappa r_s \sin(\delta_s + \gamma) \quad -0.01 \pm 0.32 \pm 0.18 \pm 0.05$$



No 1σ limit on γ (alone)

GLW+ADS+GGSZ + sin(2β+γ) : present and prospect

GGSZ method:

. powerful tool:

.. the golden mode for γ

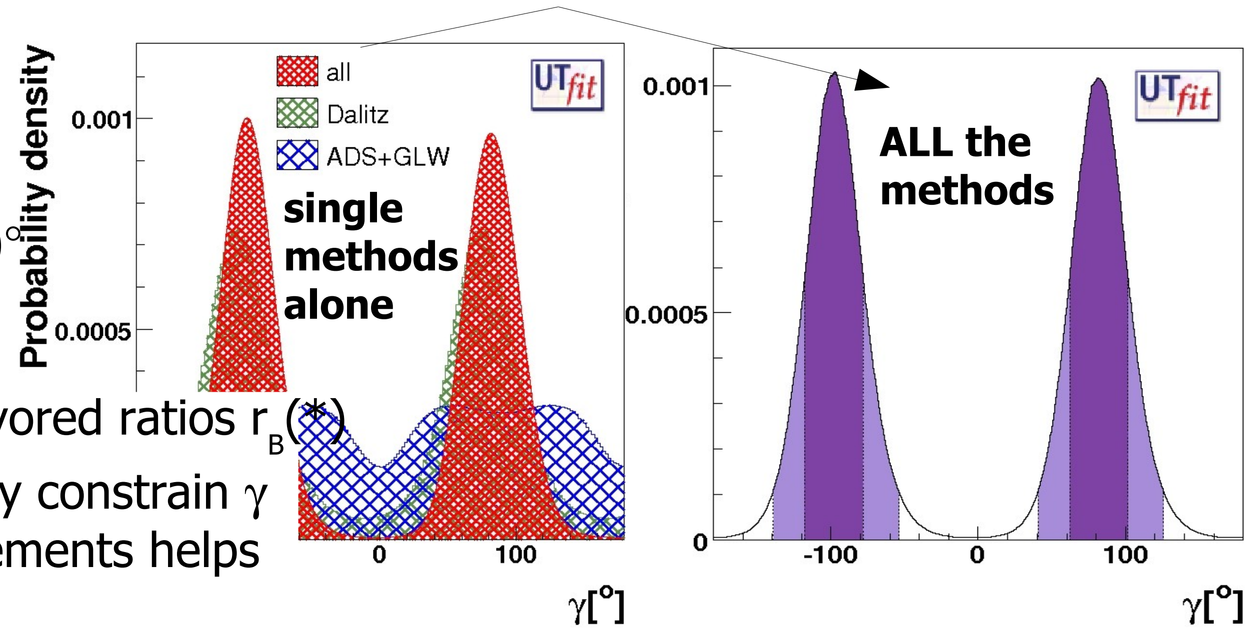
γ mod 180° = (92 ± 41 ± 11 ± 12)°

GLW & **ADS** methods:

.limits on the suppressed-to-favored ratios r_B(*)

.. more statistic needed to really constrain γ

... combining different measurements helps



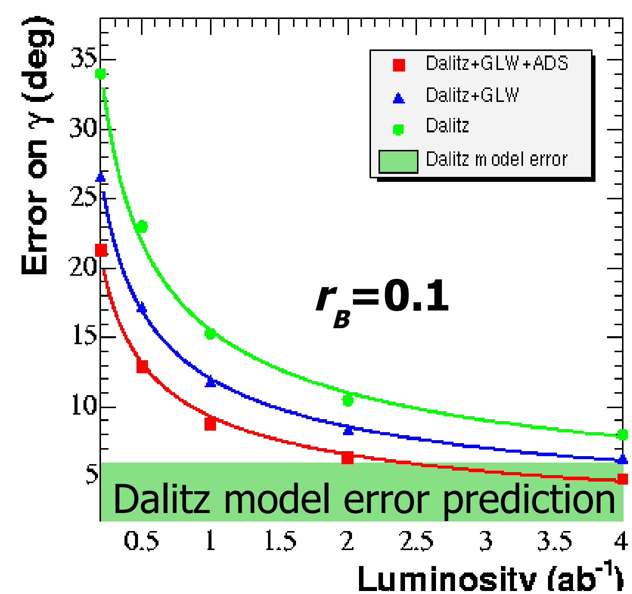
combination of all the measured modes:

$\gamma_{GLW,ADS,GGSZ}$ = 82 ± 20 ([41,126] @ 95% Prob.) [UTfit]

$\gamma_{GLW,ADS,GGSZ}$ = - 98 ± 20 ([-139,-33] @ 95% Prob.) [UTfit]

still crucial is combining methods & decay modes along with more statistics

If $r_B \geq 0.1$ at 1 ab^{-1} γ will be know with a precision close to 10°

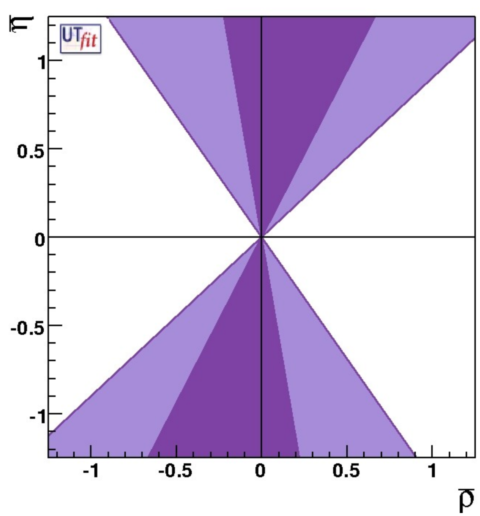


DPF2006 + JPS2006

Joint Meeting of Pacific Region Particle Physics Communities

Measurement of the UT angle γ at BaBar

Virginia Azzolini



Outline:

Measurements of γ using $B^{\pm} \to D^{(*)}K^{(*)\pm}$

GLW Method

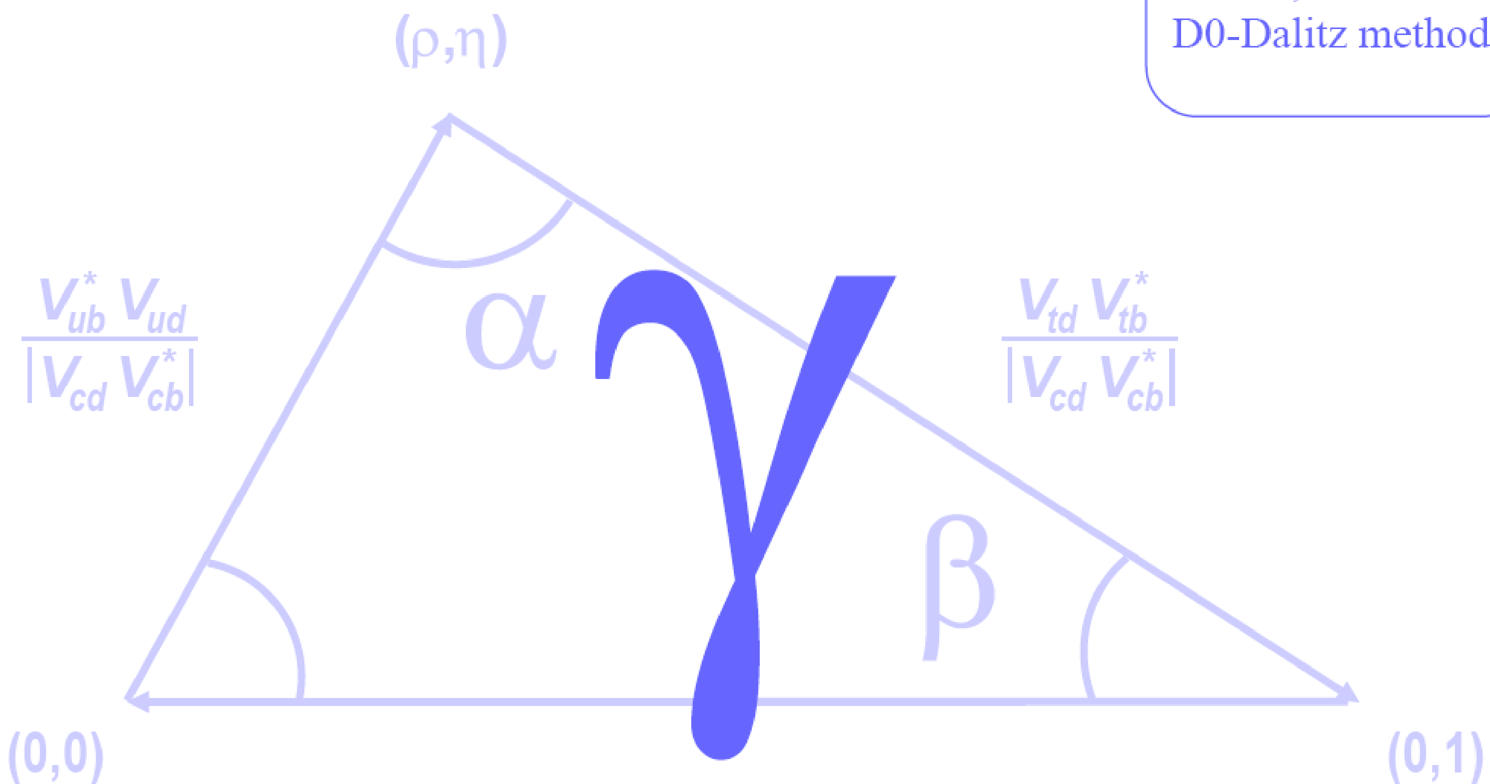
ADS Method

D^0 Dalitz Method (GGSZ)

backup

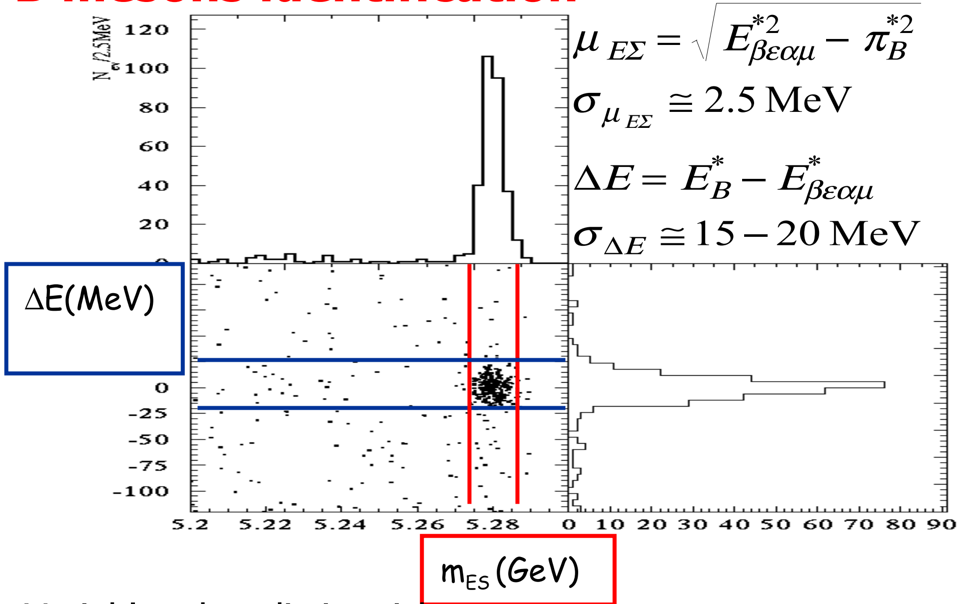
$B^{\pm} \longrightarrow D^{(*)}K^{(*)}$

GLW, ADS and D0-Dalitz methods



Selection of signal events

B mesons identification



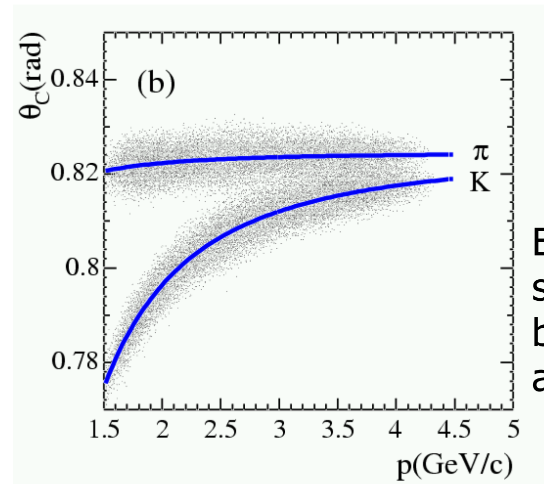
$$\mu_{E\Sigma} = \sqrt{E^{*2}_{\beta\varepsilon\alpha\mu} - \pi^{*2}_{B}}$$

$$\sigma_{\mu_{E\Sigma}} \cong 2.5\ \mathrm{MeV}$$

$$\Delta E = E^{*}_{B} - E^{*}_{\beta\varepsilon\alpha\mu}$$

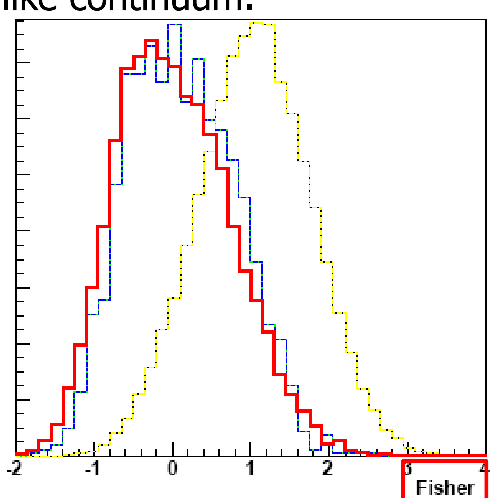
$$\sigma_{\Delta E} \cong 15 - 20\ \mathrm{MeV}$$

K/π : Cherenkov angle

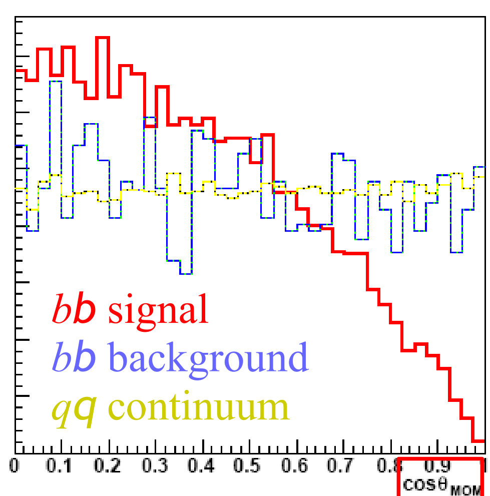


Excellent separation between 1.5 and 4 GeV/c

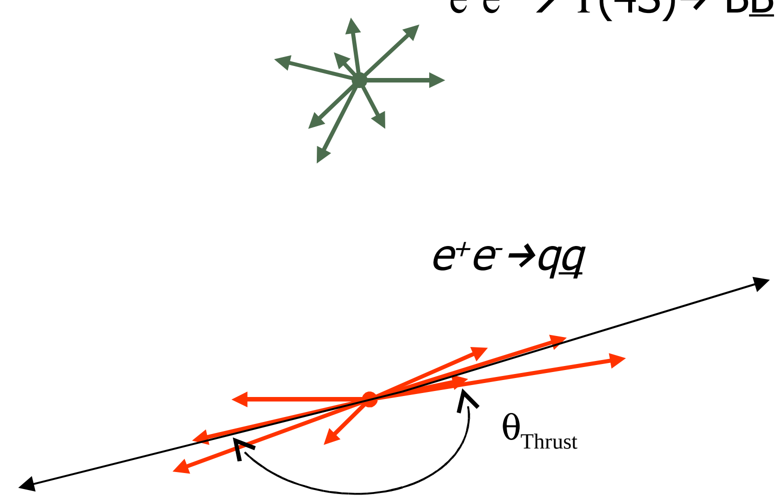
Variables that distinguish spherical B events from jet-like continuum.



Variables that distinguish $\Upsilon(4S) \to bb$ from $e^+e^- \to qq$



Thrust angle defines the jet-like event



Combinatorial $e^+e^- \to qq$ bkg suppression

Gronau-London-Wyler method

Phys. Lett. B253, 483; Phys. Lett. B265, 172 (1991)

D^0K : PRD 73, 051105 - 232 *10^6 B$\underline{B}$ pairs
D^0K^*: PRD 73, 071103 - 232 *10^6 B$\underline{B}$ pairs
$D^{*0}K$: PRD 71, 031102 - 123 *10^6 B$\underline{B}$ pairs

. Reconstruct D meson in CP-eigenstates (accessible to D^0 and $\underline{D}^0$)
even (CP = +1 $\pi^+\pi^-$, K^+K^-) & odd (CP = -1 $K_s^0\pi^0$, $K_s^0\phi$, $K_s^0\omega$)

.. Measure 4 observables $R_{CP\pm}$, $A_{CP\pm}$ (formulae for D^0K):

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

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

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

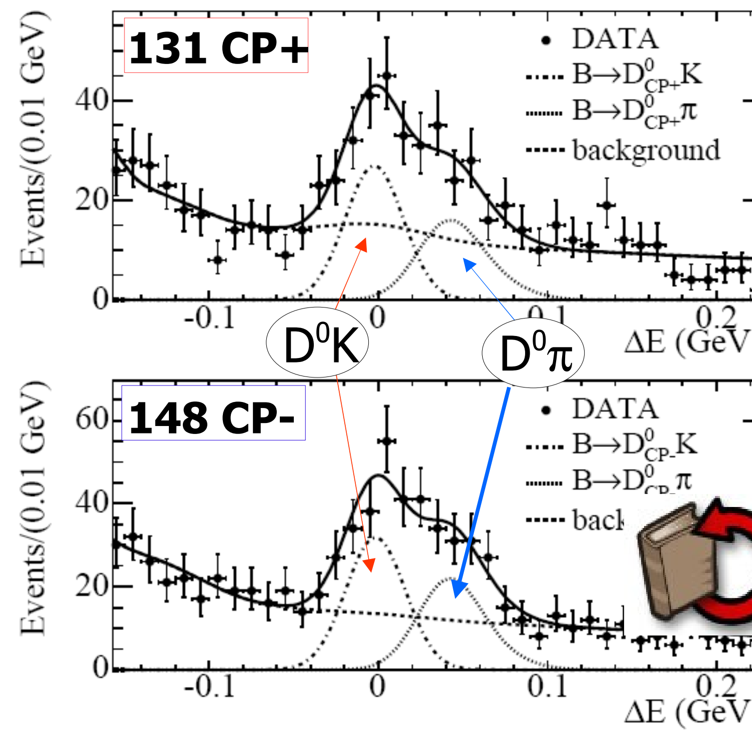
Theoretically clean
but
8-fold ambiguity

3 ind. observables
3 unknowns:

γ

δ = strong phase diff.
$A(B^- \to \underline{D}^0 K^-)$ &
$A(B^- \to D^0 K^-)$

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



GLW : results

$B \to D^0 K$

PRD 73, 051105 232*10^6 BB

$R_{CP+} = 0.90 \pm 0.12(stat.) \pm 0.04(syst.)$ $R_{CP-} = 0.86 \pm 0.10(stat.) \pm 0.05(syst.)$

$A_{CP+} = 0.35 \pm 0.13(stat.) \pm 0.04(syst.)$ $A_{CP-} = -0.06 \pm 0.13(stat.) \pm 0.04(syst.)$

$B \to D^0 K^*$

PRD 73, 071103 232*10^6 BB

$R_{CP+} = 1.96 \pm 0.40(stat.) \pm 0.11(syst.)$ $R_{CP-} = 0.65 \pm 0.26(stat.) \pm 0.08(syst.)$

$A_{CP+} = 0.08 \pm 0.19(stat.) \pm 0.08(syst.)$ $A_{CP-} = 0.26 \pm 0.40(stat.) \pm 0.12(syst.)$

$B \to D^{*0} K$

PRD 71, 031102 123*10^6 BB

$R_{CP+} = 1.06 \pm 0.26(stat.) \pm 0.10(syst.)$

$A_{CP+} = \tilde{0}.10 \pm 0.23(stat.) \pm 0.04(syst.)$

CP^- not reconstructed

. With current statistics, these DO NOT constrain (alone) γ / ϕ_3 nor $r^{(*)}_B$

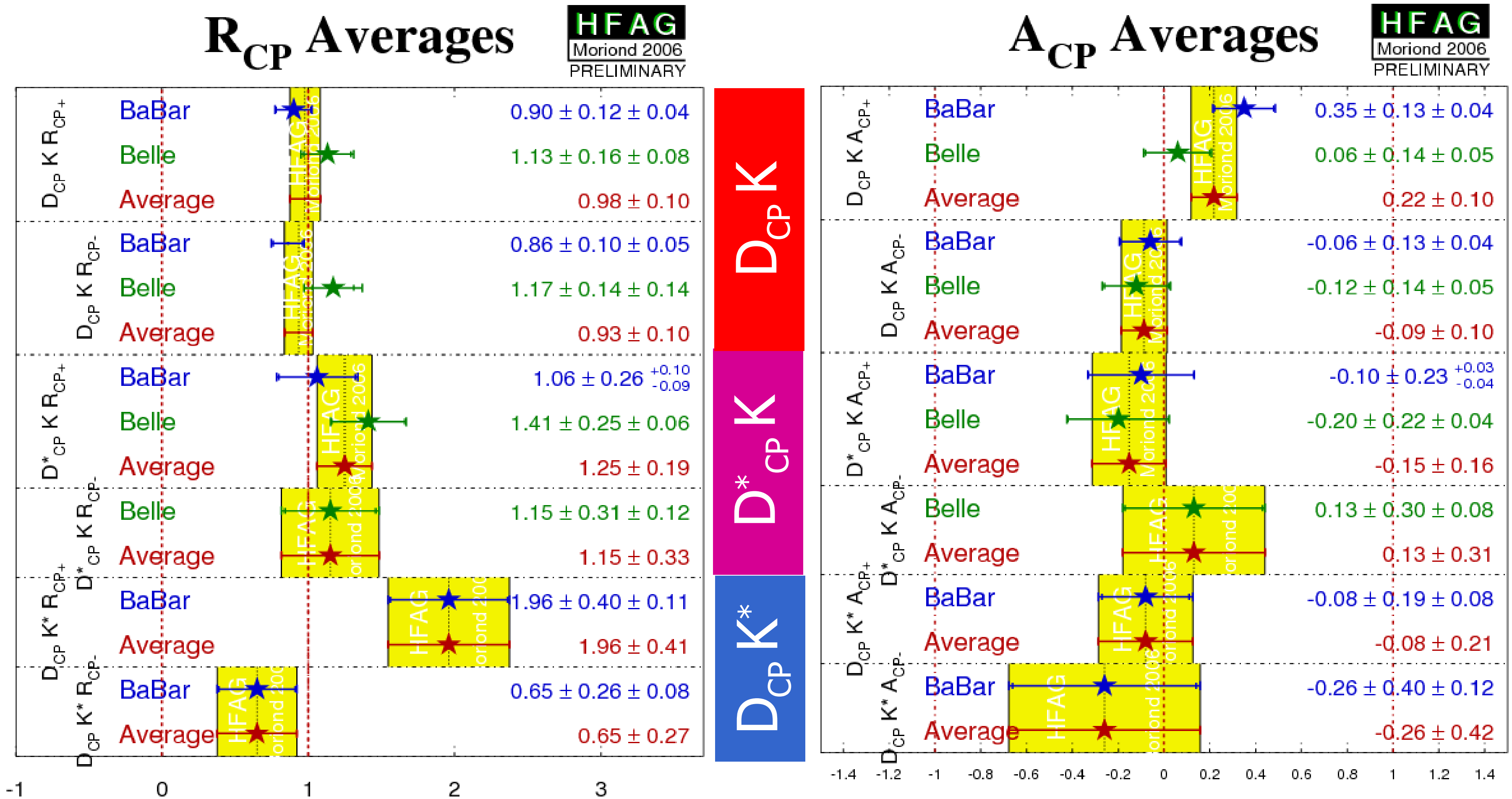
.. however, they provide competitive measurements of the cartesian coordinates $x_\pm$,

used by Dalitz, through the relations $x_\pm = \frac{R_{CP+}(1 \mp A_{CP+}) - R_{CP-}(1 \mp A_{CP-})}{4}$ $r_B^{\,2} = \frac{R_{CP+} + R_{CP-} - 2}{2}$

$x_+ = -0.082 \pm 0.053 \pm 0.018$, $x_- = 0.102 \pm 0.062 \pm 0.022$, $r_B^{\,2} = -0.12 \pm 0.08 \pm 0.03$ $B \to D^0 K$

$x_+ = 0.32 \pm 0.18 \pm 0.07$, $x_- = 0.33 \pm 0.16 \pm 0.06$, $r_B^{\,2} = 0.30 \pm 0.25$ $B \to D^0 K^*$

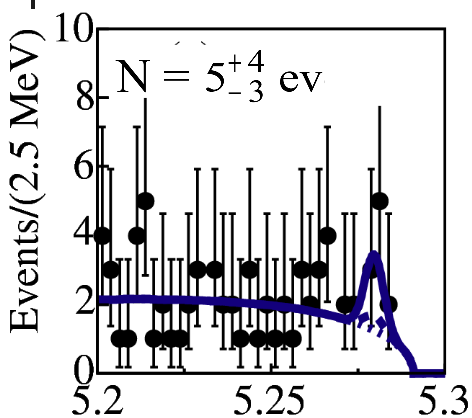
GLW averages



Implications for r_B and γ see body of the talk

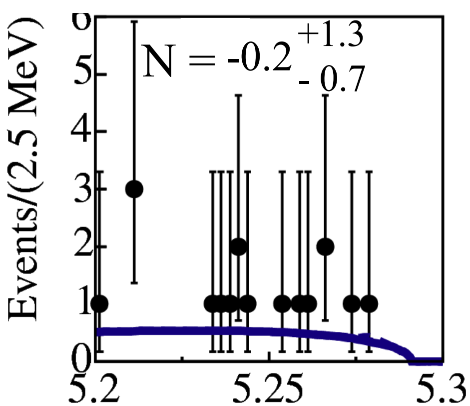
D(*)^{0}K: PRD 72, 032004 - 232 *10^6 B$\bar{B}$ pairs
D^{0*}K: PRD 72, 071104 - 232 *10^6 B$\bar{B}$ pairs

ADS results



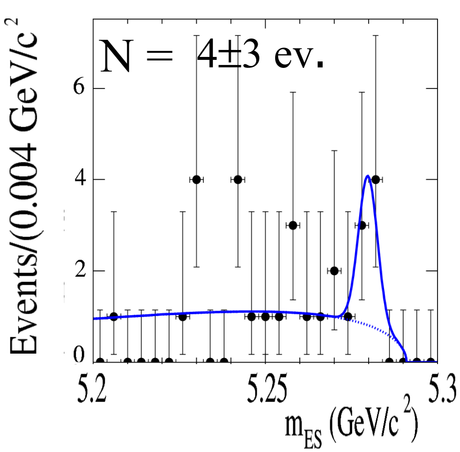
$B \to DK$

R_{ADS} <0.029 90% C.L



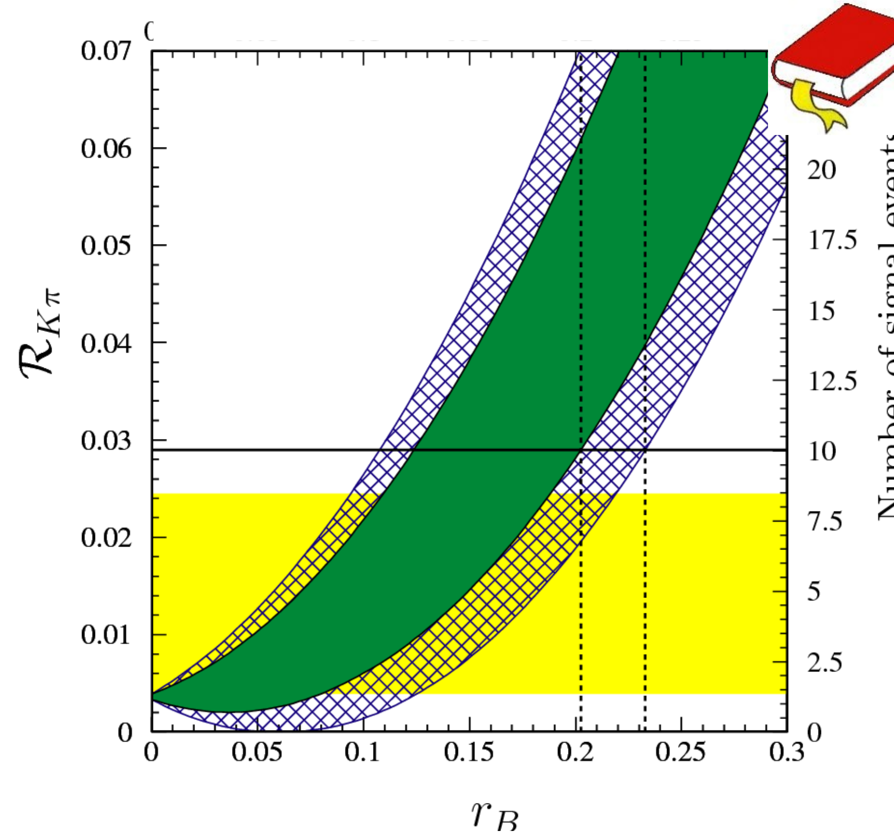
$B \to [D\pi]_{D*}K$

R_{ADS} <0.023 ($D^{*0} \to D^0\pi^0$)
<0.045 ($D^{*0} \to D^0\gamma$)
90% C.L.



$B \to [K^+\pi^-]_D K^{*-}$

R_{ADS} = 0.046±0.032 1σ



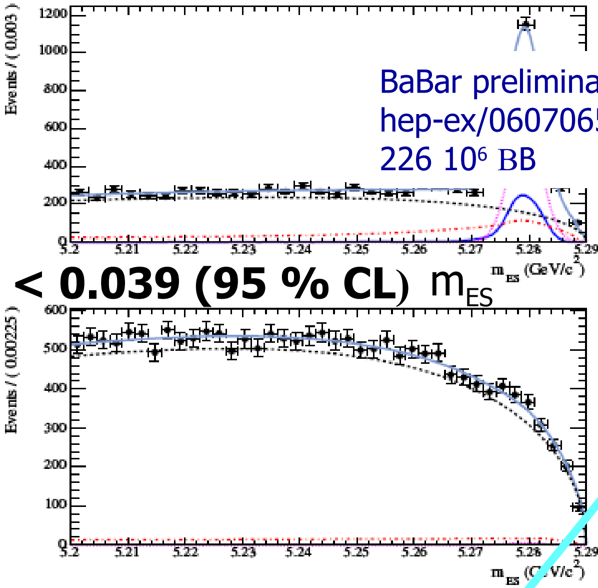
DK :	r_B < 0.23	90% C.L. at least
D*K:	r_B < 0.16	90% C.L.
DK*:	r_B = 0.20±0.14	1σ

No significant signal
→ A_{ADS} no measured
limit on R_{ADS}
limit on r_B using $|\cos(\delta_D + \delta_B)\cos\gamma| < 1$

Virginia Azzolini

ADS averages

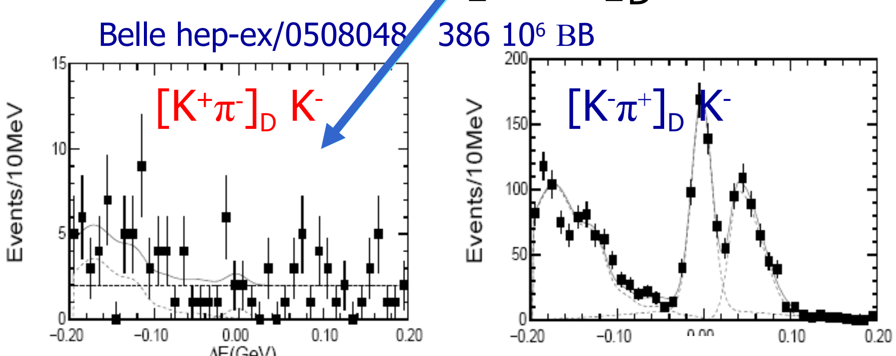
. New BaBar result in $[K^{+}\pi^{-}\pi^{0}]_{D}K^{-}$



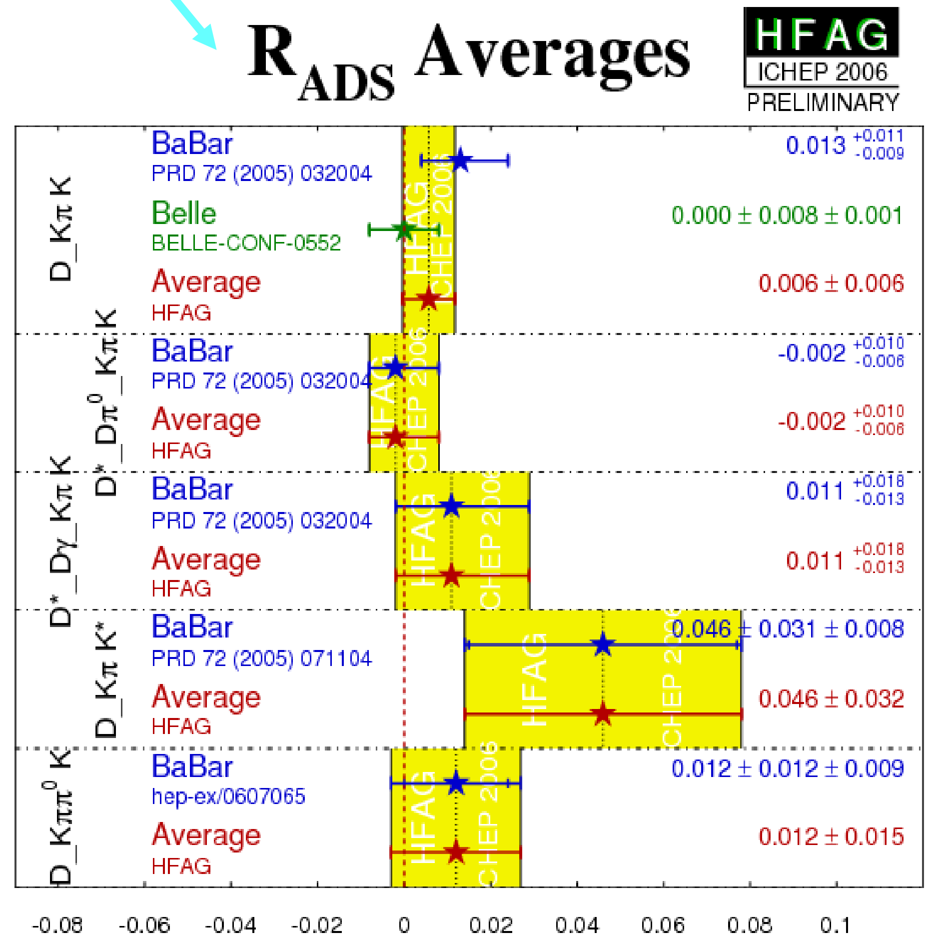
DK < 0.039 (95 % CL) m_{ES}

No signal yet in suppressed modes

. Belle result in $[K^{+}\pi^{-}]_{D}K^{-}$



DK<0.014 (90 % CL)



347 *10[6] $B\bar{B}$ pairs
BABAR-CONF-06/038

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

UPDATED

∀γ (and $r^{(*)}_B$, $\delta^{(*)}_B$) from

– known $D^0/\bar{D}^0\to K_S\pi^+\pi^-$ Dalitz model $f_\pm(m_+^2, m_-^2)$ $m_\pm^2 = m(K_S^0\pi^\pm)^2$

– B^-/B^+ decay rates vs m_+^2, m_-^2

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

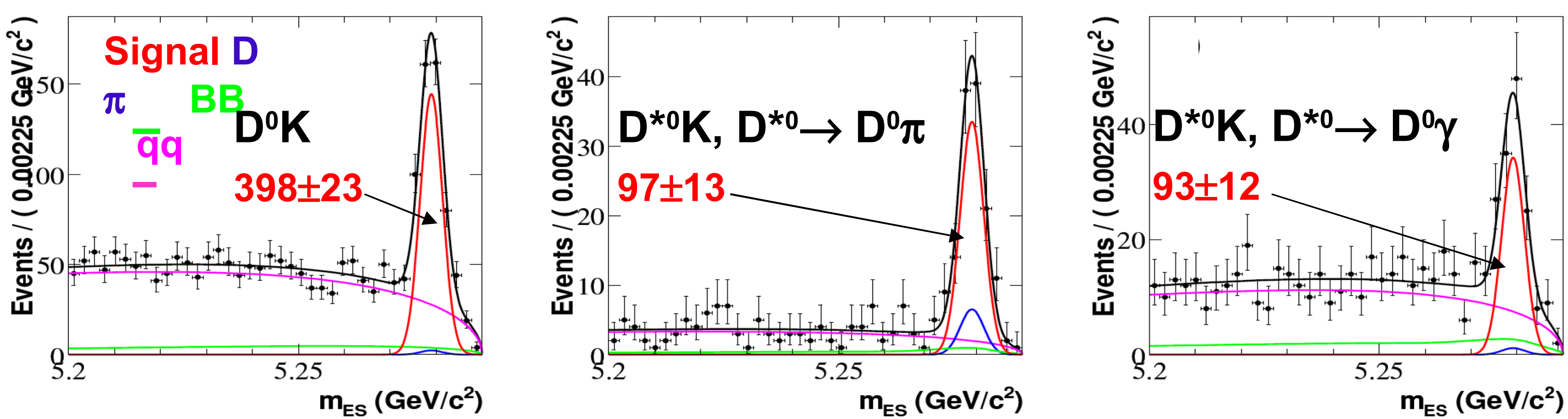
$\eta=+1$ (D^0K, $D^{*0}[D^0\pi^0]K$), -1 ($D^{*0}[D^0\gamma]K$)

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

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

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

- Update of previous analysis with:
  - 1.5x more statistics
  - More refined evaluation of systematic uncertainties (esp. Dalitz model one)
  - Same Dalitz model (apart from K*(1430) parameters), larger $D^0/\bar{D}^0\to K_S\pi\pi$ sample

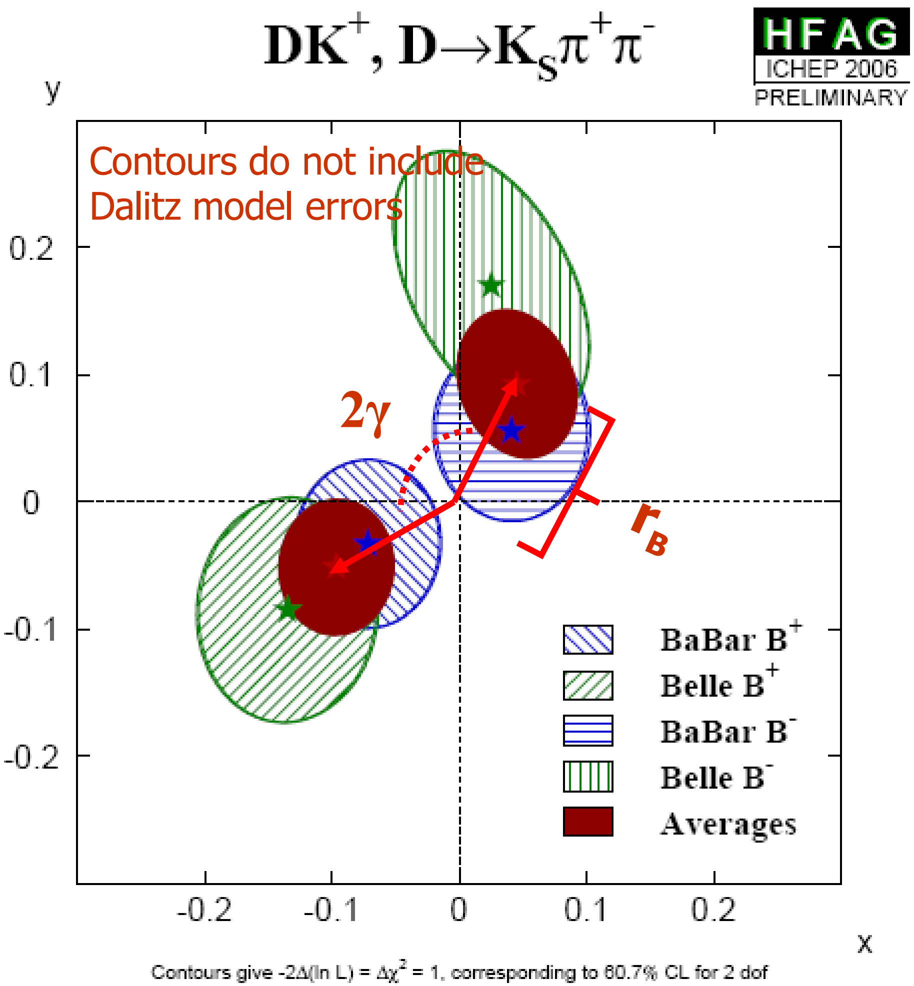


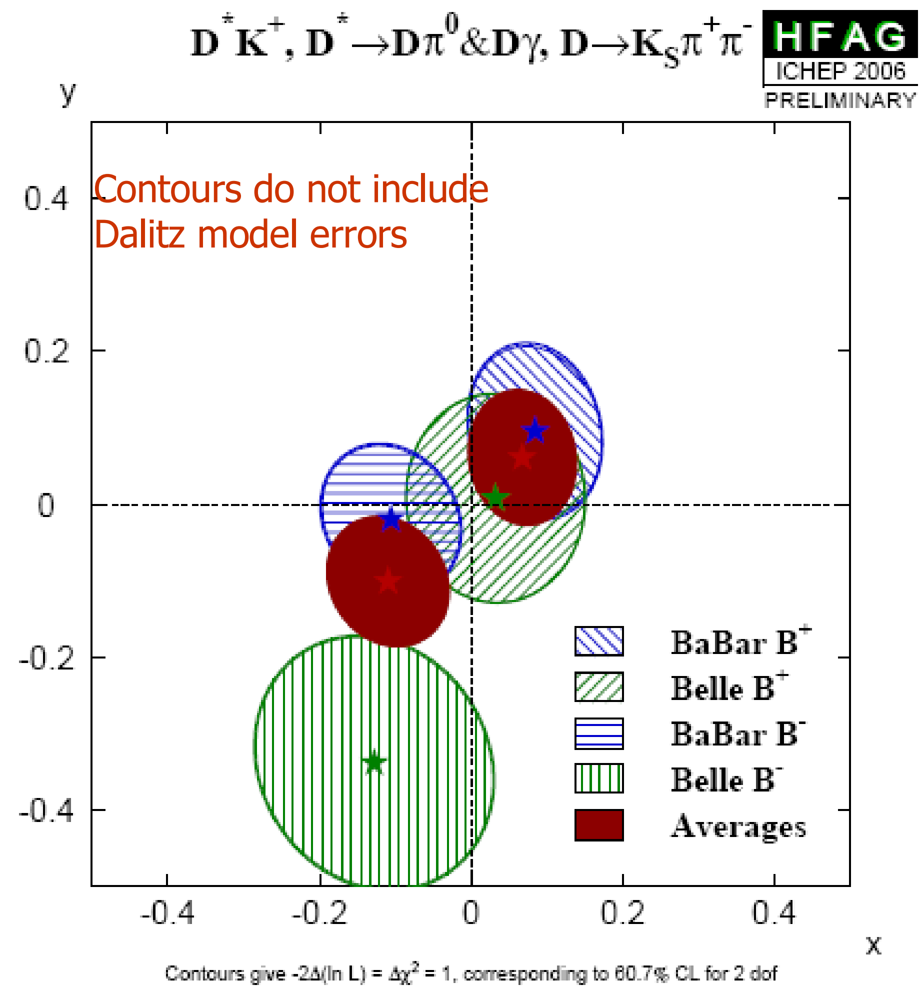
Results on γ

. HFAG averages for $x_\pm = r_B \cos(\delta_B \pm \gamma)$, $y_\pm = r_B \sin(\delta_B \pm \gamma)$

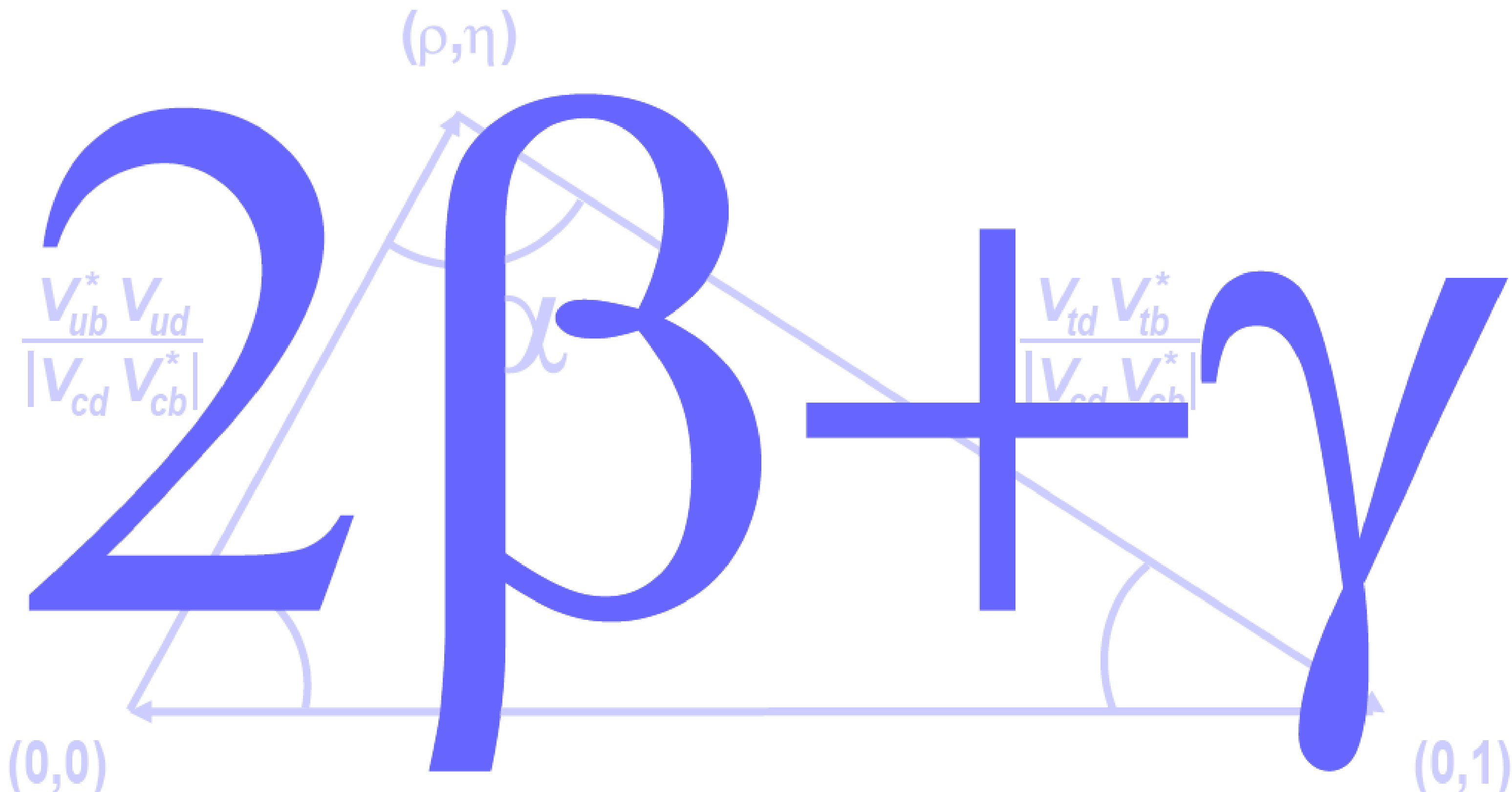
. UTfit find $\gamma = 78 \pm 30°$ based on $B^- \to D^{(*)} K^{(*)-}$ decays

. Note: σ_γ depends significantly on the value of r_B



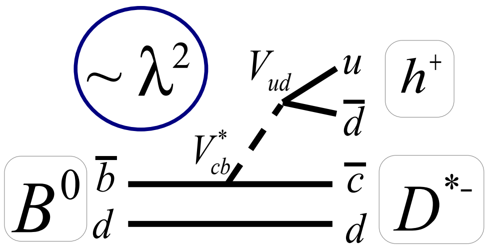


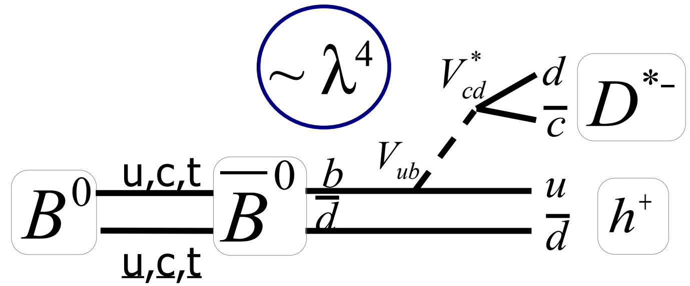
$2\beta+\gamma$

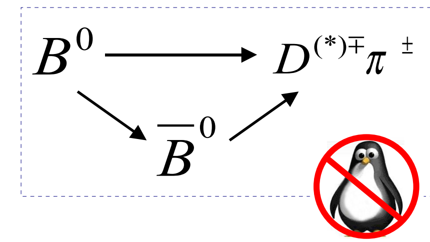


CP violation in neutral B^0 decays → time dependant

. Use interference b→c<u>u</u>d / b→u<u>c</u>d instead of b→c<u>u</u>s/u<u>c</u>s to extract $2\beta+\gamma$







.. Wrt DK, the favored b→c amplitude is $O(\lambda^2)$, the suppressed is $O(\lambda^4)$

- Higher yields
- $r_{D(*)\pi} \equiv |A(B^0 \to D^{(*)-}\pi^+)/A(B^0 \to D^{(*)-}\pi^+)| \approx |V_{ub}V_{cd}|/|V_{cb}V_{ud}|$
  - → Smaller asymmetries and sensitivity to γ

... $\sin(2\beta+\gamma)$ is measured from the time evolution:

$$P_\eta(B^0,\Delta t) \propto 1+\eta\cos(\Delta m_d \Delta t) + (a + \eta b - \eta c)\sin(\Delta m_d \Delta t)$$

$$P_\eta(\bar{B}^0,\Delta t) \propto 1-\eta\cos(\Delta m_d \Delta t) - (a - \eta b - \eta c)\sin(\Delta m_d \Delta t)$$

$$\eta = + \text{ for } D^{*-}\pi^+, \quad \eta = - \text{ for } D^{*+}\pi^-$$

strong phase between b→u and b→c

$$a = 2r\sin(2\beta+\gamma)\cos\delta$$

$$c_{lep} = 2r\cos(2\beta+\gamma)\sin\delta$$

Only B's with lepton tag

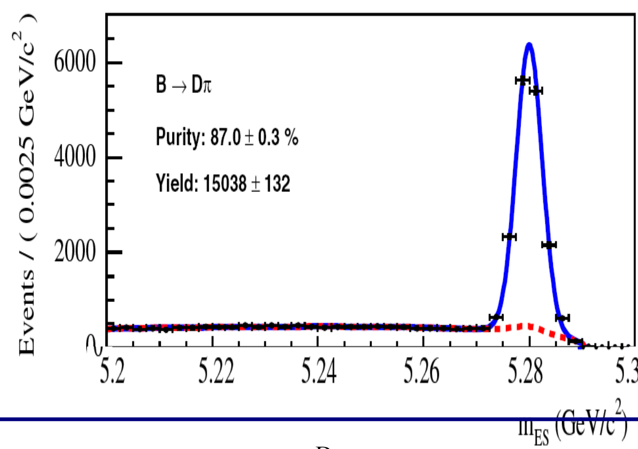
.... In present experiments no hope to fit for $r^{(*)}$

→determine elsewhere ($B^0 \to D_s^{(*)}\pi/\rho$ assuming SU(3), neglecting annihilation)

PRD73 :111101 - 232 *10^6 $B\bar{B}$ pairs
PRD71:112003- 232 *10^6 $B\bar{B}$ pairs

$\sin(2\beta+\gamma)$ from $B^0 \to D^{(*)} \pi/\rho$

38000 fully reconstructed $D^{(*)}\pi/D\rho$ (purity ~ 90%)

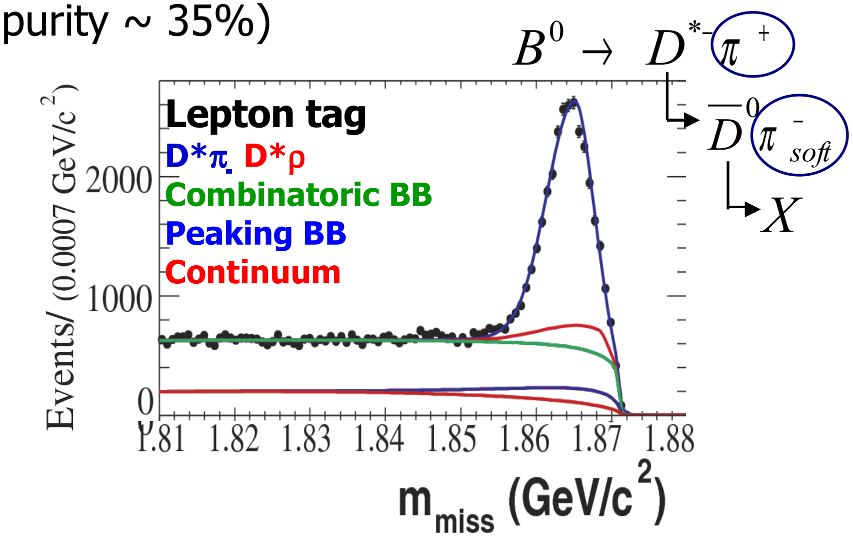


$a^{D\pi} = -0.010 \pm 0.023 \pm 0.007$ $\quad c^{D\pi}_{lep.} = -0.033 \pm 0.042 \pm 0.012$

$a^{D^*\pi} = -0.040 \pm 0.023 \pm 0.010$ $\quad c^{D^*\pi}_{lep.} = 0.049 \pm 0.042 \pm 0.015$

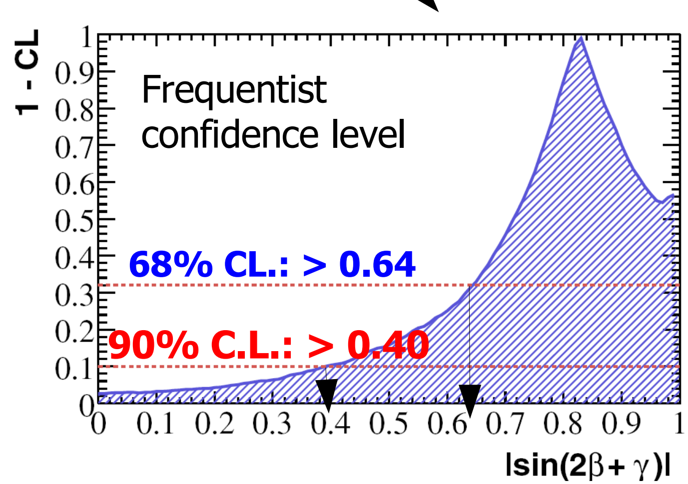
$a^{D\rho} = -0.024 \pm 0.031 \pm 0.009$ $\quad c^{D\rho}_{lep.} = -0.098 \pm 0.055 \pm 0.018$

90000 partially reco'ed $B^0 \to D^*\pi$ ($D^* \to D^0\pi$, $D^0 \to X$) (purity ~ 35%)



$a^{D^*\pi} = -0.034 \pm 0.014 \pm 0.009$

$c^{D^*\pi}_{lep.} = -0.025 \pm 0.020 \pm 0.013$



Using

$r_{D\pi} = 0.019 \pm 0.004$

$r_{D^*\pi} = 0.015 \pm 0.006$

$r_{D\rho} = 0.003 \pm 0.006$

$|\sin(2\beta+\gamma)| > 0.64(0.40)$ @ 68(90)% CL

Observation of $B^0 \to D_s^{(*)+} \pi^-$, $D_s^{(*)-} K^+$

sin(2β+γ) in $B^0 \to D^{(*)\mp} \pi^\pm$ needs $r(D^{(*)}\pi) = |A(B^0 \to D^{(*)+} \pi^-)/A(B^0 \to D^{(*)-} \pi^+)|$

but

current available data $\not\to$ direct BF measurement

SU(3)

$$r(D^{(*)}\pi) \stackrel{\text{SU(3)}}{=} \tan\theta_c \, \frac{f_{D^{(*)}}}{f_{D_s^{(*)}}} \sqrt{\frac{\mathcal{B}(B^0 \to D_s^{(*)+}\pi^-)}{\mathcal{B}(B^0 \to D^{(*)-}\pi^+)}}$$

$\tan\theta_c$: Cabibbo angle

$f_{D(*)}/f_{Ds(*)}$: ratio of D(*) and Ds(*) decay const

measured BF throught D_s^+ reco in

$D_s \to \phi\pi$, $K^0_S K^+$ and $K^{*0}K^+$ modes :

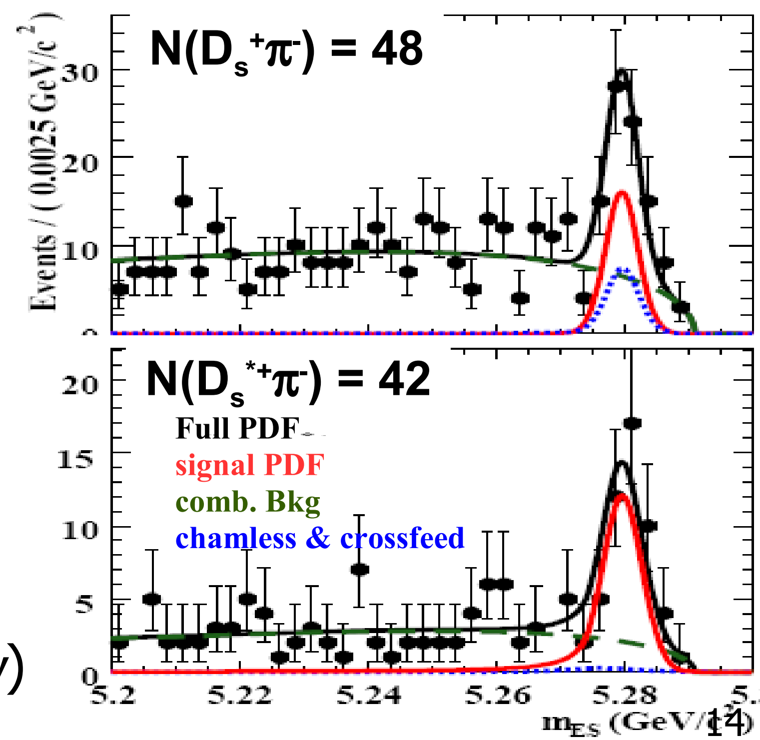
BF $(B^0 \to D_s^+ \pi^-) = (1.3 \pm 0.3 \pm 0.2) * 10^{-5}$
BF$(B^0 \to D_s^{*+} \pi^-) = (2.8 \pm 0.6 \pm 0.5) * 10^{-5}$

SU(3)

$r(D\pi) = (1.3 \pm 0.2 \pm 0.1) * 10^{-2}$ (30% smaller)
$r(D^*\pi) = (1.9 \pm 0.2 \pm 0.2) * 10^{-2}$ (25% larger)

$\to$ Improved σ_r but smaller <r>

$\to$ expect no big improvement on σ(2β+γ)

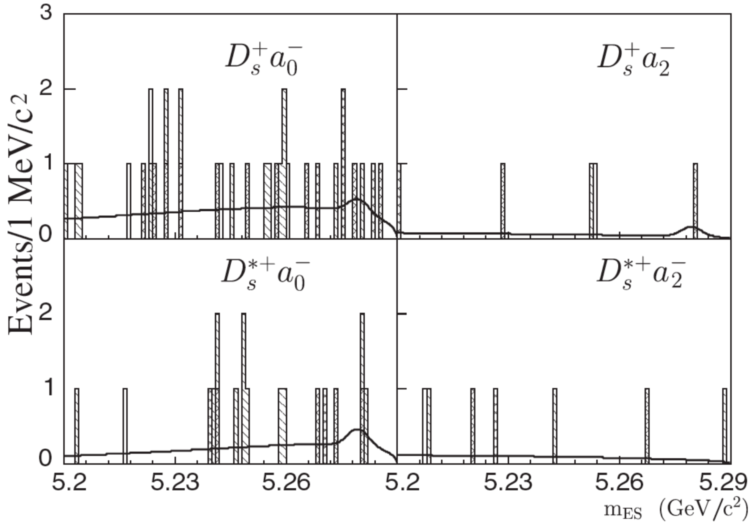


hep-ex/0604106 - 226 *10^6 $B\bar{B}$ pairs
PRD73:071103 - 230 *10^6 $B\bar{B}$ pairs

Sin(2β+γ) from $B \to D^{(*)0}K^0$ and $D^{(*)}a_{0(2)}$?

f = $D^{(*)0}K_s$

f = $D^{(*)}a_0(2)$

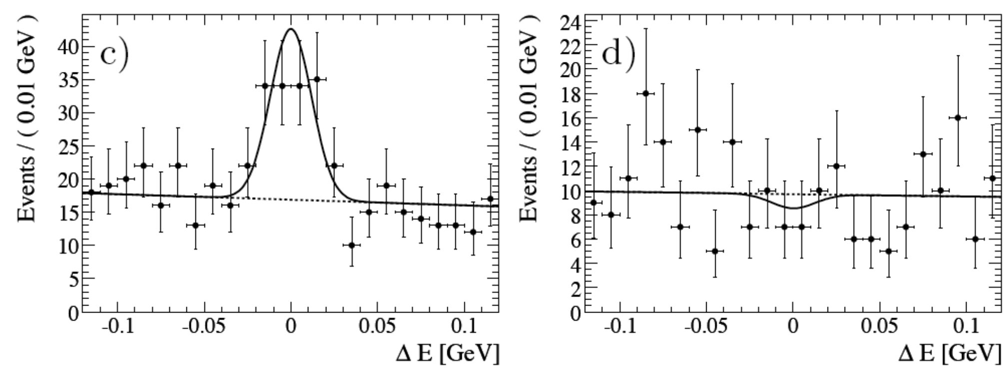


. Both b→ c and b→ u amplitudes are color-suppressed
→ BR ~ 10^{-5}, r ≈f *$|V_{ub}V_{cs}|/|V_{cb}V_{us}|$ ≈ f *0.4

(f: different strong interaction dynamics in b→c, u)

.. **$D^{(*)0}K^0$ ($K^0 \to K_s$) BF**s and **r** in the self-tagging final state

D^0K^{*0}, $K^{*0} \to K\pi$ *(assuming that r for DK^{*0} is the same as r for DK^0)*



$$\mathcal{B}(\tilde{B}^0 \to D^0\tilde{K}^0) = (5.3 \pm 0.7 \pm 0.3) \times 10^{-5}$$
$$\mathcal{B}(\tilde{B}^0 \to D^{*0}\tilde{K}^0) = (3.6 \pm 1.2 \pm 0.3) \times 10^{-5}$$
$$\mathcal{B}(\overline{B}^0 \to D^0\overline{K}^{*0}) = (4.0 \pm 0.7 \pm 0.3) \times 10^{-5}$$
$$\mathcal{B}(\overline{B}^0 \to \overline{D}^0\overline{K}^{*0}) = (0.0 \pm 0.5 \pm 0.3) \times 10^{-5}$$

We measure (SU(3)- related) $D^{(*)}_s a_{0(2)}$ BF upper limits:

$$BF(B \to D_s^+ a_0^-) < 1.9 \cdot 10^{-5} \qquad BF(B \to D_s^{*+} a_0^-) < 3.6 \cdot 10^{-5}$$
$$BF(B \to D_s^+ a_2^-) < 1.9 \cdot 10^{-4} \qquad BF(B \to D_s^{*+} a_2^-) < 2.0 \cdot 10^{-4}$$

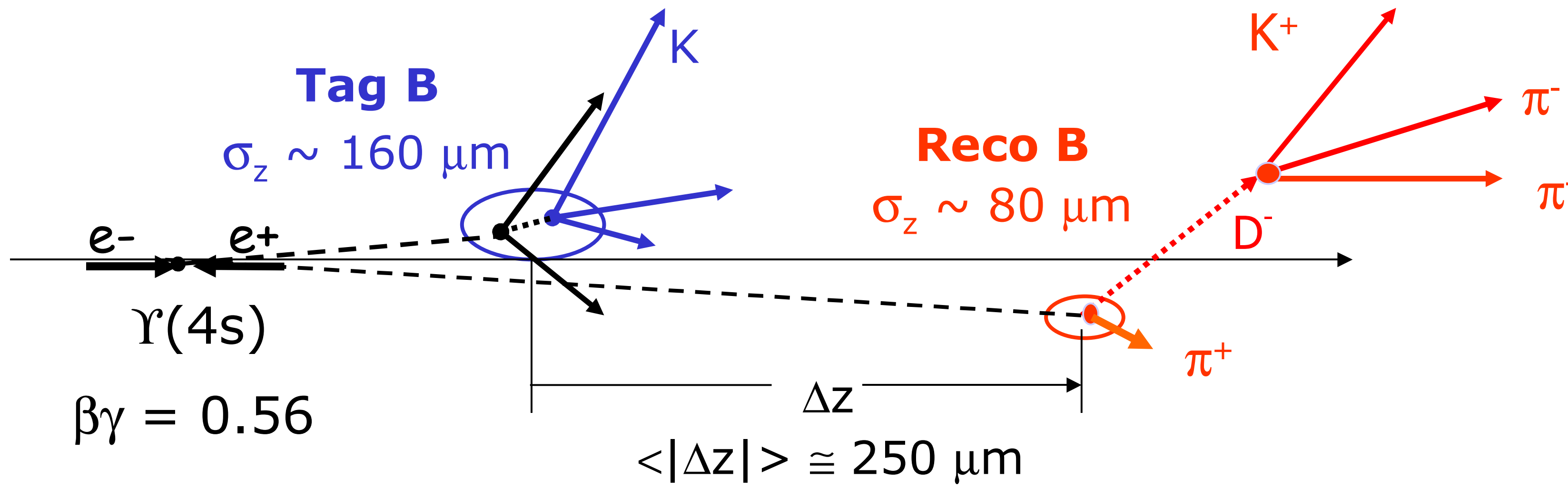
$r(D^0K^{*0})$<0.4 @ 90% C.L.:

r_B smallerthan theo. expected

BF($D^{(*)}_s a_{0(2)}$)<≈10^{-6}.
Since ε<≈10% and secondary BFs ~10%,
channel is not usable to measure sin(2β+γ) at BaBar

not useful to measure γ value yet

Experimental technique



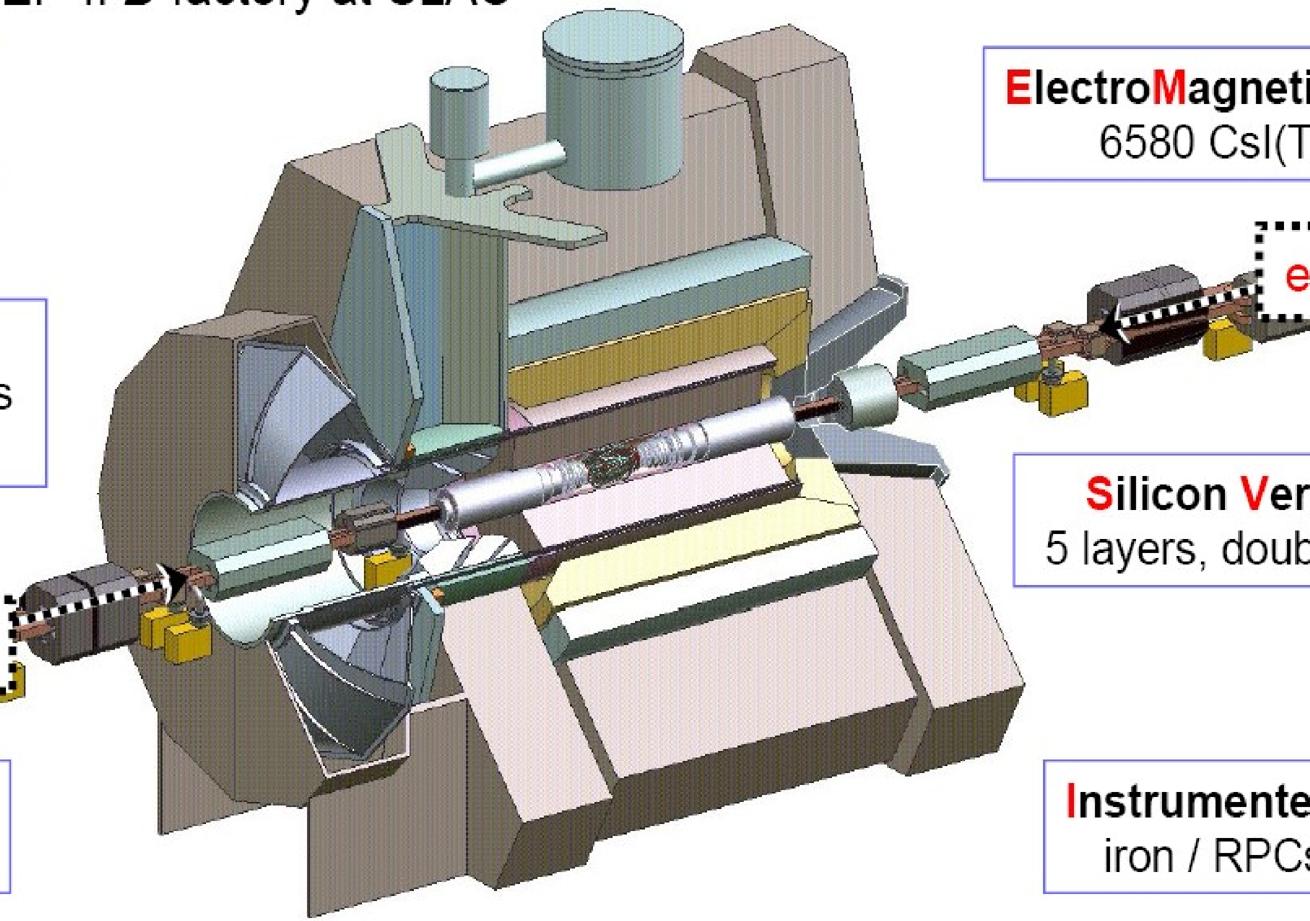
3. Reconstruct inclusively the vertex of the "other" B meson (B_{TAG})
4. Determine the flavor of B_{TAG}

1. Reconstruct one B meson (B_{REC}) in a final state of interest (e.g. $D^-\pi^+$)
2. Reconstruct the vertex position

5. Compute the proper time difference $\Delta t \cong \Delta z/\gamma\beta c$ (RMS ~1.1 ps)
6. Fit the Δt spectra

BABAR : where? what? who?

- At the PEP-II *B*-factory at SLAC



- *BABAR* collaboration consists 11 countries and ~590 physicists !

References

γ:

$r_B^{(*)}$, theoretical expectation value: Phys. Lett B265, 172 (1991), PL B557, 198 (2003)

Gronau-London-Wyler method: Phys. Lett. B253, 483; Phys. Lett. B265, 172 (1991)

. D^0K : PRD 73, 051105 – 232 $*10^6$ $B\underline{B}$

. D^0K^*: PRD 73, 071103 – 232 $*10^6$ $B\underline{B}$

. $D^{*0}K$: PRD 71, 031102 – 123 $*10^6$ $B\underline{B}$

Atwood-Dunietz-Sony method : Phys. Rev. Lett. 78, 3257 (1997)

. $D(*)^0K$: PRD 72, 032004 – 232 $*10^6$ $B\underline{B}$

. $D^{0*}K$: PRD 72, 071104 – 232 $*10^6$ $B\underline{B}$

. $D^0[K^+p^-p^0]K$: hep-ex/0607065 – 226 $*10^6$ $B\underline{B}$

Giri-Grossman-Soffer-Zupan (Dalitz) method: Phys. Rev. D68, 054018 (2003)

. $D(*)^0K$: hep-ex/0607104 – 347 $*10^6$ $B\underline{B}$

. DK^*: hep-ex/0507101 – 227 $*10^6$ $B\underline{B}$

$2\beta + \gamma$:

. $B^0 \rightarrow D^{(*)}\pi/\rho$: PRD73 :111101 - 232 $*10^6$ $B\underline{B}$, PRD71:112003- 232 $*10^6$ $B\underline{B}$

. $B^0 \rightarrow D_s^{(*)+}\pi-$, $D_s^{(*)-}K^+$: hep-ex/0604012 - 230 *106 $B\underline{B}$