α and γ measurements from BaBar

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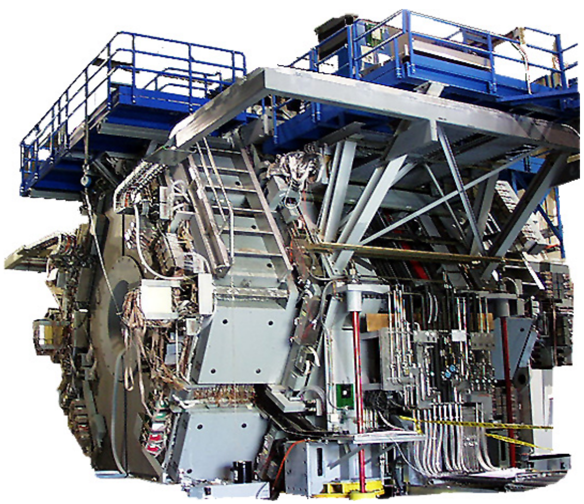

PANIC 2005
Santa Fe, New Mexico, USA
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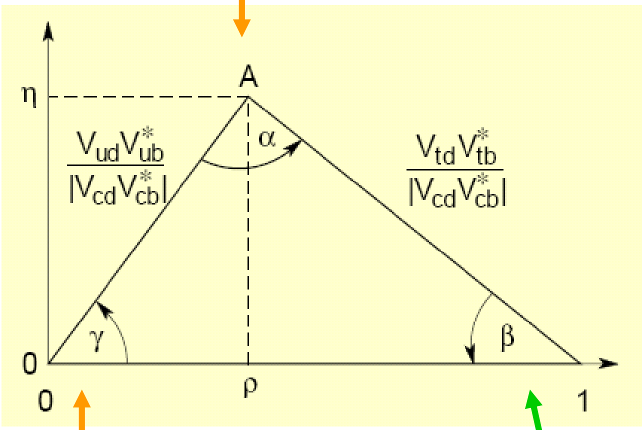
Introduction

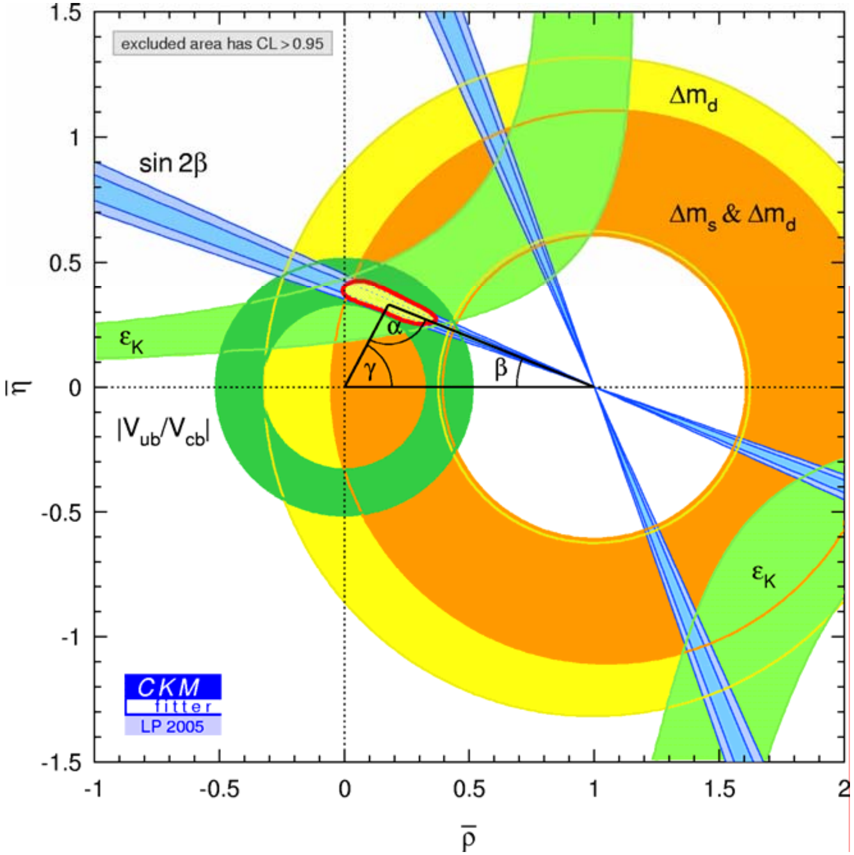
α and γ: challenging measurements

α from $\pi\pi$, $\rho\rho$, $(\rho\pi)^0$:
"penguin pollution"



γ from $B^+ \rightarrow D^{(*)0}K^{(*)+}$:
small interferences

β precisely measured with golden modes J/ ψ K_S, D^*D^*,…
$\sin(2\beta+\gamma)$ from $B^0 \rightarrow D\pi/\rho$



CKM standard fit without α and γ measurements:

$$\alpha = (97^{+13}_{-19})^\circ$$

$$\gamma = (57.3^{+7.3}_{-12.9})^\circ$$

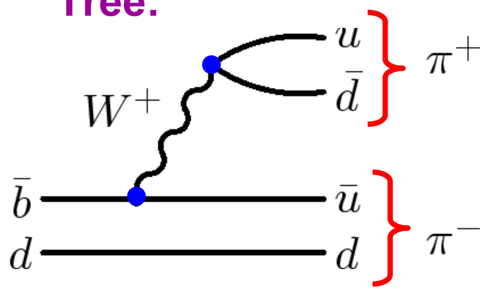
Measuring α with $B\to\pi\pi$, $\rho\rho$: SU(2) symmetry

Time dependent asymmetries in h^+h^-:
$$\boxed{A(\Delta t) = S\sin(\Delta m_d \Delta t) - C\cos(\Delta m_d \Delta t)}$$

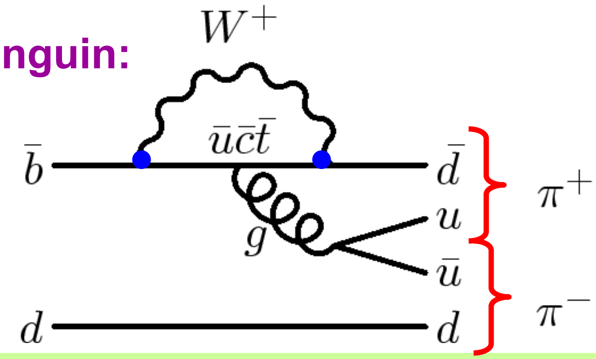
"Penguin pollution":

Tree:

$\propto V_{ub}V_{ud}^*$
$\propto \lambda^3$



Penguin:



$\propto V_{tb}V_{td}^*$
$\propto \lambda^3$

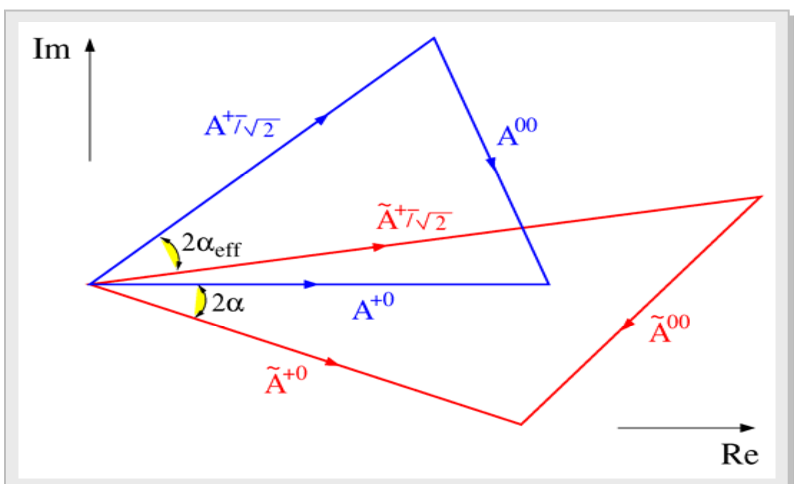
Neglecting P, S measures α:
$$C = 0 \qquad S = \sin(2\alpha)$$

In reality it measures α_{eff} $\Rightarrow$ additional info. needed for α
$$\boxed{C \neq 0 \qquad S = \sqrt{1-C^2}\sin(2\alpha_{eff}) \neq \sin(2\alpha)}$$

Isospin analysis: Gronau-London, PRL, 65, 3381 (1990)
Lipkin *et al.*, PRD 44, 1454 (1991)

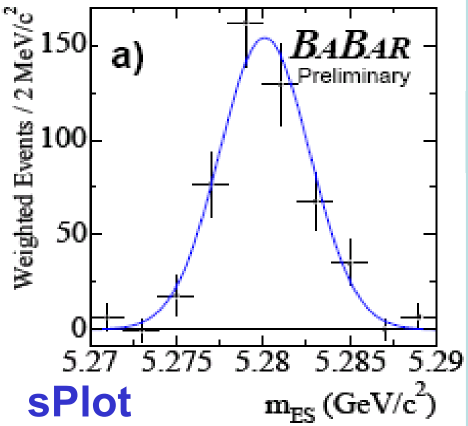
$$\boxed{A^{+0} = 1/\sqrt{2}\cdot A^{-+} + A^{00}}$$

Neglecting EWP,
$h^+ h^0$ (I=2)=pure tree $\qquad A^{+0} = A^{-0}$



Triangle relations allow determination of penguin induced shift in α: $|\alpha - \alpha_{eff}|$

Results for B→ππ



sPlot

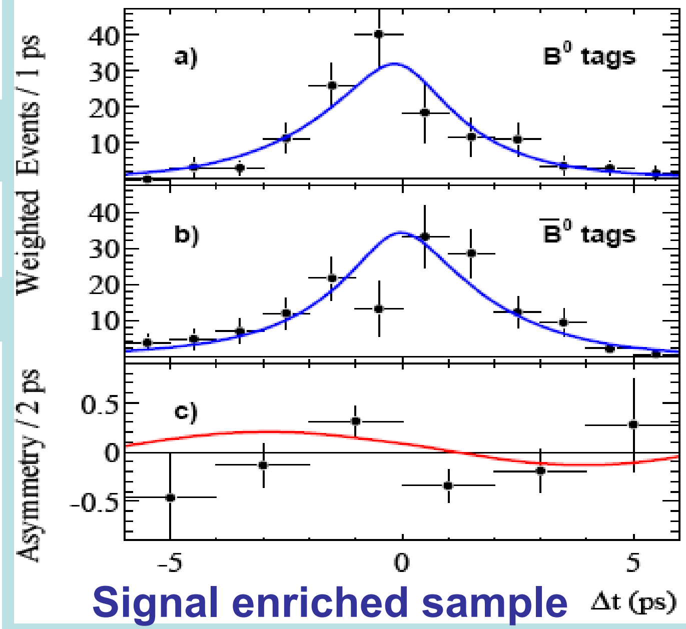
HEP-EX 0508046 (2005)

$\pi^+ \pi^-$

$$BF(\pi^+\pi^-) = (5.5 \pm 0.4 \pm 0.3)\times 10^{-6}$$

PRL, 95, 151803 (2005)

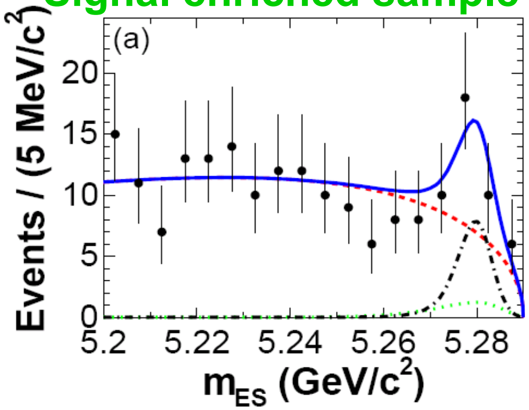
$$C_{\pi\pi} = -0.09 \pm 0.15 \pm 0.04$$
$$S_{\pi\pi} = -0.30 \pm 0.17 \pm 0.03$$



Signal enriched sample

- All measurements with 227×10^6 B pairs
- No observation of CP violation
- $\pi^0\pi^0$ observation (indicates non-negligible contribution of penguin) and measurement of C_{00}
- New meas. BR($\pi^+\pi^-$) with efficiency corrected for the effects of final-state radiation

Signal enriched sample



$\pi^0 \pi^0$

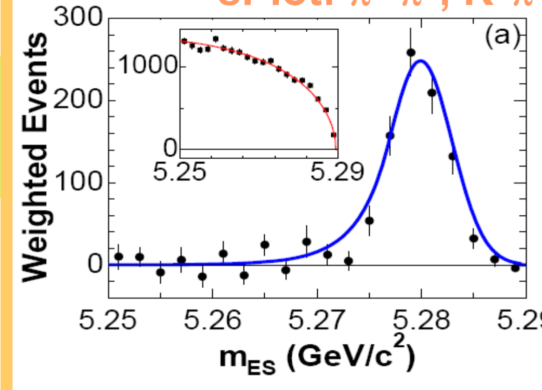
PRL, 94, 181802 (2005)

$\pi^+ \pi^0$

$$BF(\pi^0\pi^0) = (1.17 \pm 0.32 \pm 0.10)\times 10^{-6}$$
$$C_{00} = -0.12 \pm 0.56 \pm 0.06$$

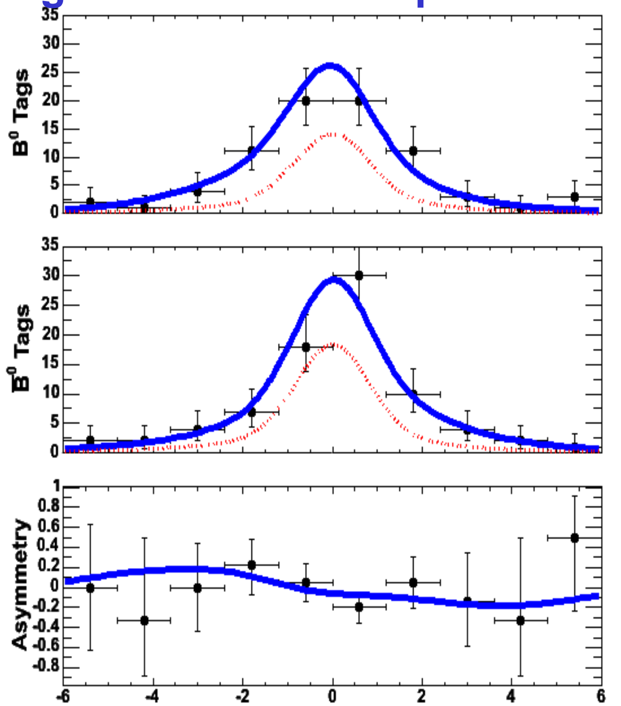
$$BF(\pi^\pm\pi^0) = (5.8 \pm 0.6 \pm 0.4)\times 10^{-6}$$
$$A^{CP}_{\pm 0} = -0.01 \pm 0.10 \pm 0.02$$

sPlot: $\pi^+ \pi^0$, $K^+\pi^0$



Results for $B \to \rho\rho$

Signal enriched sample



$\rho^+\rho^-$

Data: 232 $\times 10^6$ B pairs

PRL 95, 041805, (2005)

$$f_L(\rho^+\rho^-) = 0.978 \pm 0.014^{+0.021}_{-0.029}$$

$$S_L(\rho^+\rho^-) = -0.33 \pm 0.24^{+0.08}_{-0.14}$$

$$C_L(\rho^+\rho^-) = -0.03 \pm 0.18 \pm 0.09$$

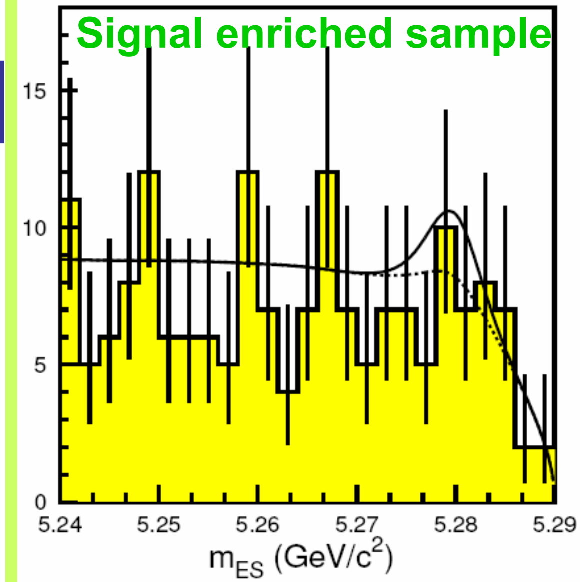
V-V state: need angular analysis: more difficult

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1 d\cos\theta_2} = \frac{9}{4}\left\{\underbrace{\frac{1}{4}(1-f_L)\sin^2\theta_1\sin^2\theta_2}_{\text{transverse}} + \underbrace{f_L\cos^2\theta_1\cos^2\theta_2}_{\text{longitudinal}}\right\}$$

- $f_L \sim 1 \Rightarrow \rho \sim 100\%$ longitudinally polarized~pure CP even state
- interference with $a_1\pi$, $\rho\pi\pi$, $\pi\pi\pi\pi$ neglected ($\Rightarrow$small syst.)
- B bkg = main source of syst.

$\rho^0\rho^0$

Data: 227$\times 10^6$ B pairs



- No significant signal seen
- f_L=1 assumed for most conservative upper limit
- small BR $\Rightarrow$ small penguin contribution in $\rho\rho$ modes
  $\Rightarrow$ good sensitivity to α expected

PRL, 94, 131801 (2005)

$$B(B^0 \to \rho^0\rho^0) = (0.54^{+0.36}_{-0.32} \pm 0.19)\cdot 10^{-6}$$

$$< 1.1\cdot 10^{-6} \quad 90\% \text{ C.L.}$$

Measuring α with $B\to(\rho\pi)^0\to\pi^+\pi^-\pi^0$: Dalitz analysis

Isospin analysis:

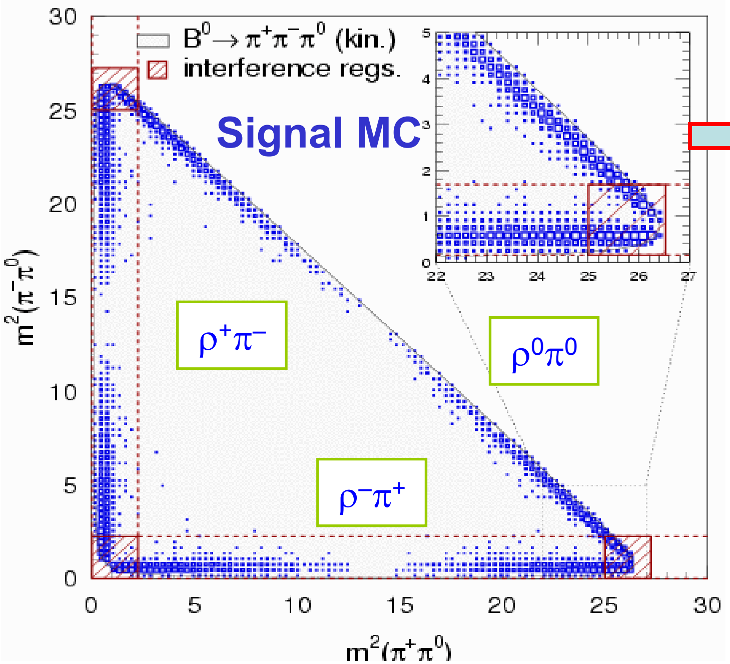
Not a CP eigenstates $\Rightarrow$ pentagonal relations
EWP neglected: 12 unknowns for 13 observables $\Rightarrow$ in principle possible
Unfruitful with the present statistics: current data does not constraint α

Time dependent Dalitz analysis assuming Isospin symmetry:

A. Snyder and H. Quinn, PRD, 48, 2139 (1993)

$$\boxed{\begin{aligned} A(B^0\to\pi^+\pi^-\pi^0) &= f_+A(\rho^+\pi^-)+f_-A(\rho^-\pi^+)+f_0A(\rho^0\pi^0)\\ \overline{A}(\overline{B}^0\to\pi^+\pi^-\pi^0) &= f_+\overline{A}(\rho^+\pi^-)+f_-\overline{A}(\rho^-\pi^+)+f_0\overline{A}(\rho^0\pi^0)\end{aligned}}$$

f_k relativistic Breit-Wigner form factors



Interference between the ρ resonances at equal masses-squared gives information on **strong phases** between resonances $\Rightarrow$ **α can be constrained without ambiguity**

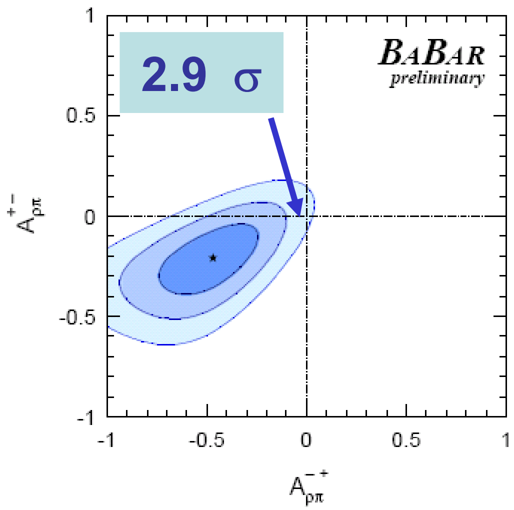
Direct CP asymmetries:

$$\mathcal{A}_{\rho\pi}^{+-} = \frac{|\kappa^{+-}|^2-1}{|\kappa^{+-}|^2+1}$$

$$\mathcal{A}_{\rho\pi}^{-+} = \frac{|\kappa^{-+}|^2-1}{|\kappa^{-+}|^2+1}$$

$$\kappa^{+-} = (q/p)(\overline{A}^-/A^+)$$

$$\kappa^{-+} = (q/p)(\overline{A}^+/A^-)$$



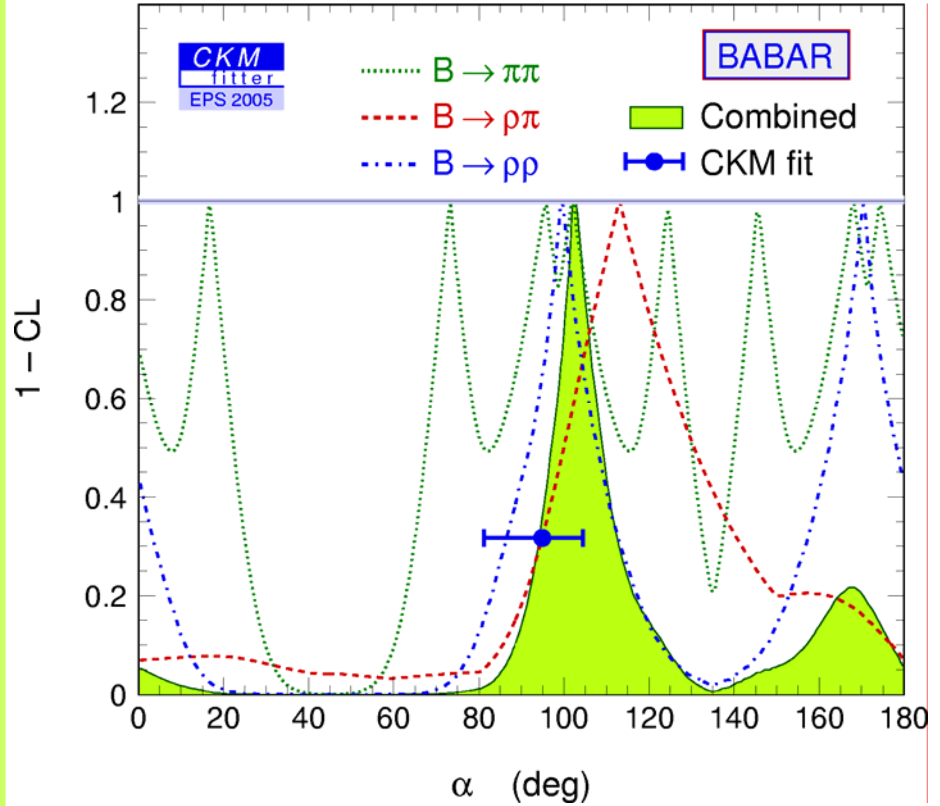
Constraints on α

- $\pi\pi$
  - 8 solutions within [0, π]
  - Need more statistics
- $\rho\rho$
  - Golden mode for α (smaller penguin contribution in $\rho\rho$ modes wrt $\pi\pi$)
  - Additional assumption: neglect possible I=1 amplitudes (quasi2body assumption)
- $\rho\pi$:

  α constrained with no ambiguity at 1σ

  $$\alpha = (113\ ^{+27}_{-17} \pm 6)^{o}$$
- Combined constraint:

  in very good agreement with CKM fit value

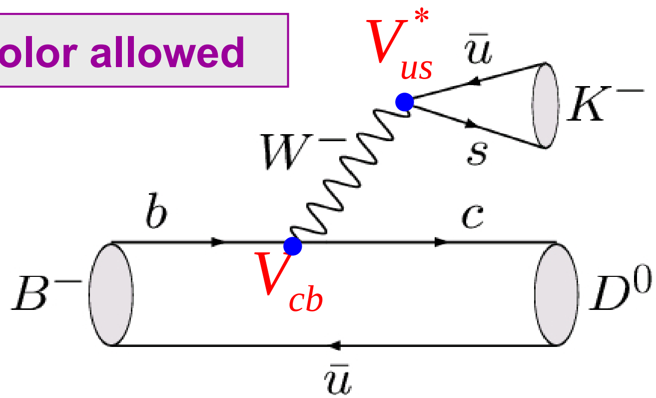


$$\alpha_{\rho\rho,\ \pi\pi,\ \pi\rho}^{\text{CKMfitter}} = (103^{+10}_{-9})^{o}$$

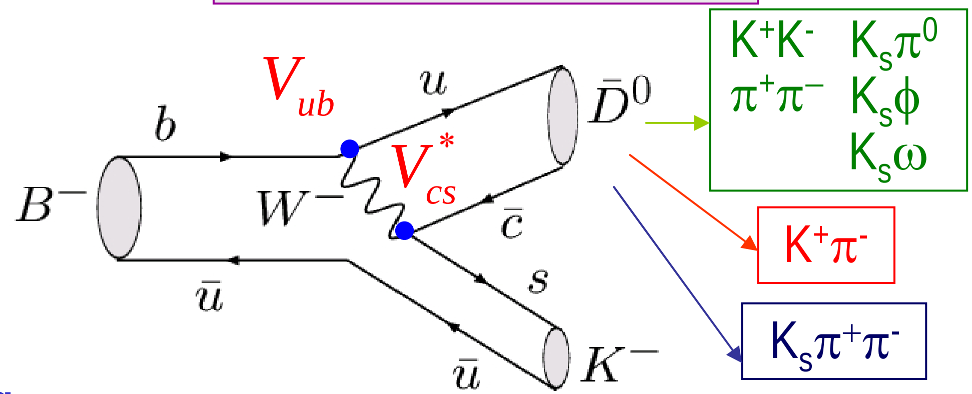
γ from direct CP violation: $B^- \to D^{(*)}K^{(*)-}$

Idea: using interference between $B^- \to D^0K^-$ and $B^- \to \bar{D}^0K^-$ decays where the D^0 and the $\bar{D}^0$ decay to a common final state *f*

b → c color allowed



b → u color suppressed



$$A \propto V_{cb}V_{us}^* \propto \lambda^3$$

Relative strong phase δ_B unknown

Rel. weak phase γ

$$A \propto V_{ub}V_{cs}^* \propto \lambda^3\sqrt{\rho^2+\eta^2}\,e^{i\delta_B}e^{-i\gamma}$$

Size of CP asymmetry depends on

$$r_B^{(*)} \equiv \frac{|A(B^- \to \overline{D}^{(*)0}K^-)|}{|A(B^- \to D^{(*)0}K^-)|} \sim 0.1-0.3$$

Critical parameter: r_B

Larger r_B, larger interference, better sensitivity to γ

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

Atwood-Dunietz-Soni: Phys. Rev. Lett. 78, 3257 (1997)
DCSD D^0 and CA D^0 ex. : $B^- \to (K^+\pi^-)_D K^-$

Giri-Grossman-Soffer-Zupan: Phys. Rev. D68 054018 (2003)
$D^0 \to K_s\,\pi^+\,\pi^-$ Phys. Rev. Lett. 78, 3257 (1997)

Results for GLW *(f=CP eigenstates)*

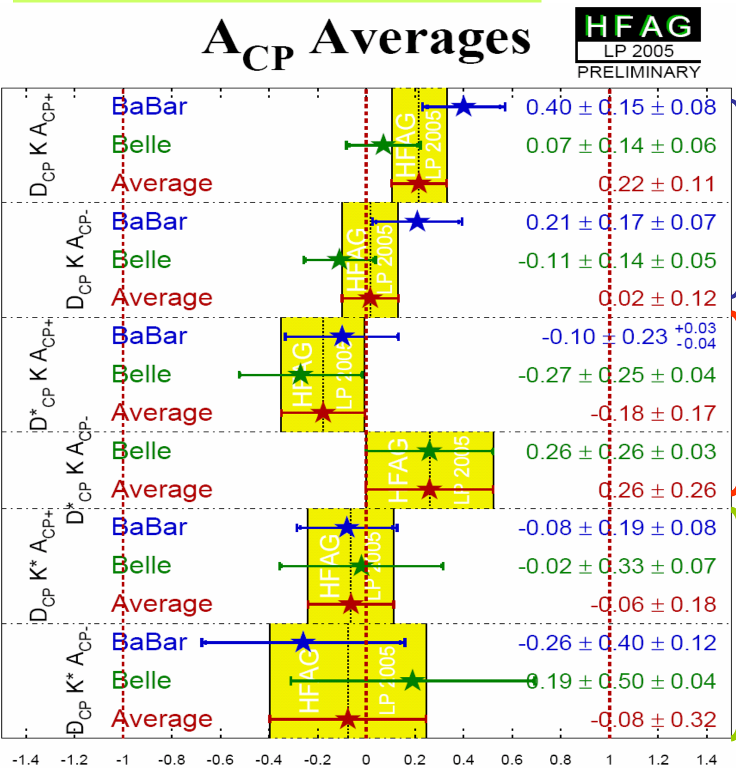
- **3 independent observables:**

$A_{CP+}R_{CP+}=-A_{CP-}R_{CP-}$

- **3 unknowns: γ, δ, $r_B^{(*)}$**

$$A_{CP\pm}=\frac{\Gamma(B^-\to D_{CP\pm}K^{(*)-})-\Gamma(B^+\to D_{CP\pm}K^{(*)+})}{\Gamma(B^-\to D_{CP\pm}K^{(*)-})+\Gamma(B^+\to D_{CP\pm}K^{(*)+})}=\frac{\pm 2r_B\sin\delta\sin\gamma}{R_{CP\pm}}$$

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



214×10⁶ B pairs

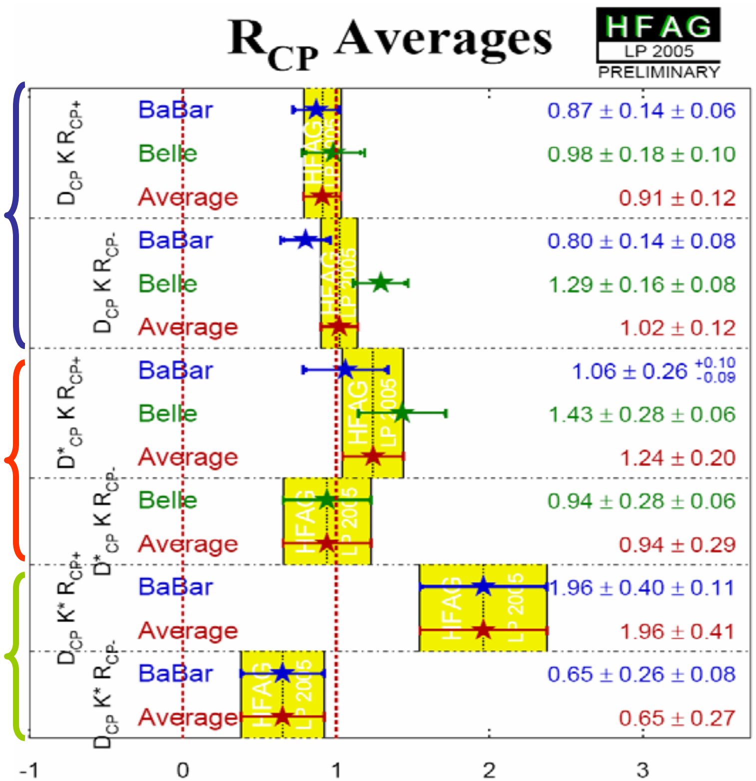
hep-ex/0408082

123×10⁶ B pairs

PRD 71, 031102 (2005)

214×10⁶ B pairs

PRD 72, 71103 (2005)



- Theoretically very clean
- No strong constraints yet on γ because $r_B^{(*)}$ small
- Need more statistics

Results for ADS ($f=K^+\pi^-$)

- **Small branching fractions**
- **Amplitudes ~ comparable**
- **2 observables for 3 unknowns**

favored

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

suppressed

Interference

suppressed

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

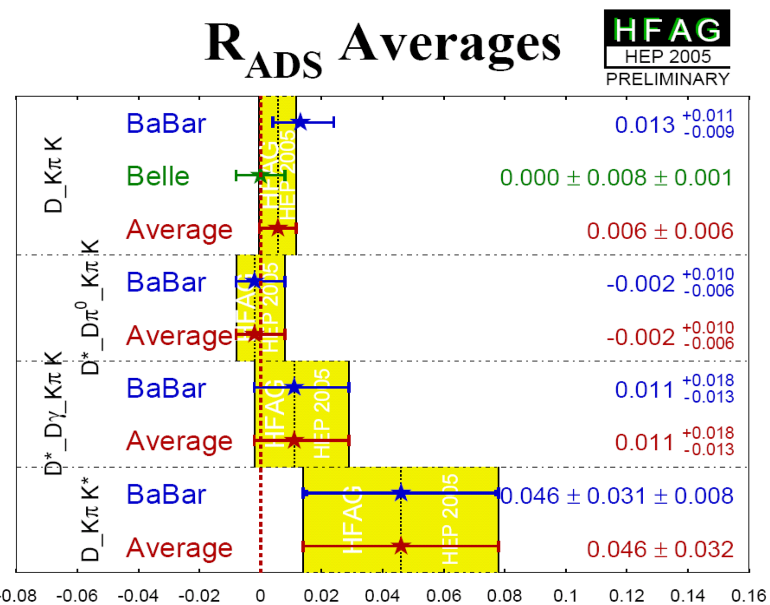
favored

$$R_{ADS} = \frac{\Gamma(B^- \to D_{ADS}K^{(*)-}) + \Gamma(B^+ \to D_{ADS}K^{(*)+})}{\Gamma(B^- \to D^0K^{(*)-}) + \Gamma(B^+ \to \overline{D}^0K^{(*)+})} = r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D)\cos\gamma$$

- **Input: $r_D=0.06\pm0.002$**

$$A_{ADS} = \frac{\Gamma(B^- \to D_{ADS}K^{(*)-}) - \Gamma(B^+ \to D_{ADS}K^{(*)+})}{\Gamma(B^- \to D_{ADS}K^{(*)-}) + \Gamma(B^+ \to D_{ADS}K^{(*)+})} = \frac{2r_B r_D \sin(\delta_B + \delta_D)\sin\gamma}{R_{ADS}}$$

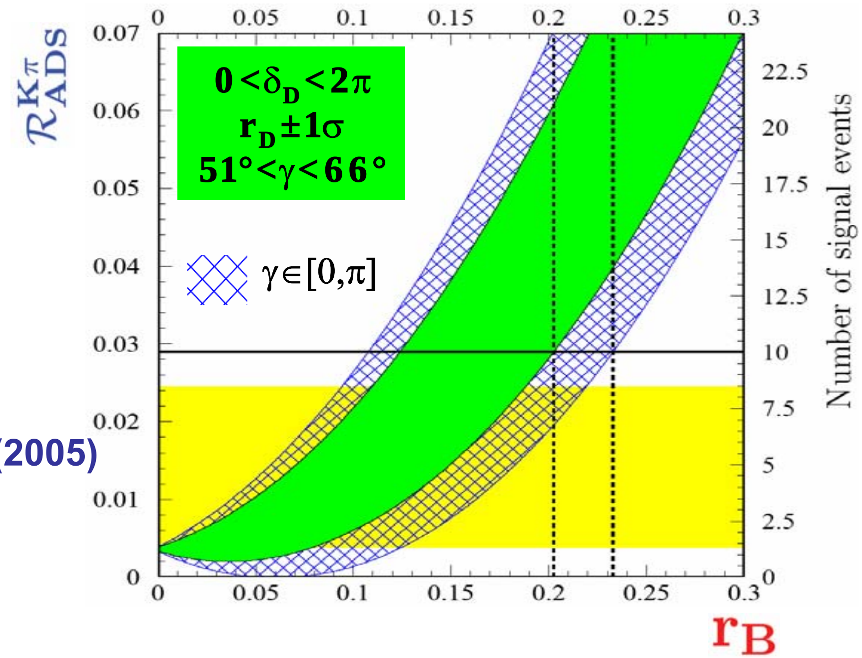
$$r_D = \left|\frac{A(D^0 \to K^+\pi^-)}{A(D^0 \to K^-\pi^+)}\right|$$



232×10^6 B pairs

hep-ex/0504047

PRD 72, 71104 (2005)



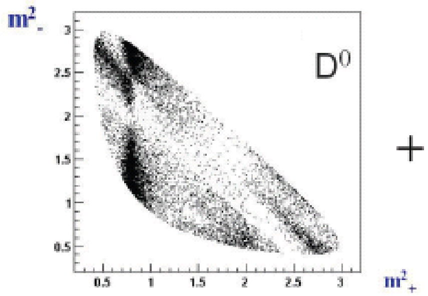
No signal seen

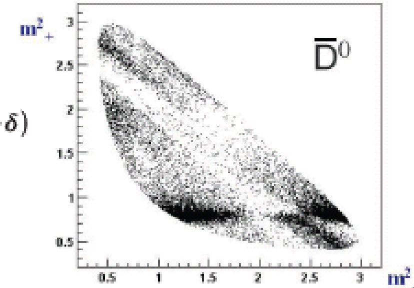
$D^{(*)}K$: $r_B<0.23$ and $r_B^{*2} <0.16^2$ @ 90%CL

Results for GGSZ: $(f=K_S\,\pi^+\pi^-)$

PRL 95, 121802 (2005)
hep-ex/0507101

- Final state accessible through many different decays $\Rightarrow$ need Dalitz analysis
- Weak phase γ, strong phase δ and magnitude of suppressed-to-favored amplitudes $r_B^{(*)}$ extracted from a fit to the interference pattern between D^0 and $\overline{D}^0$ in the Dalitz plot





$$A^{\pm} = \left| A_D(m_\mp^2, m_\pm^2) + r_B e^{i(\pm\gamma+\delta)} A_D(m_\pm^2, m_\mp^2) \right|^2$$

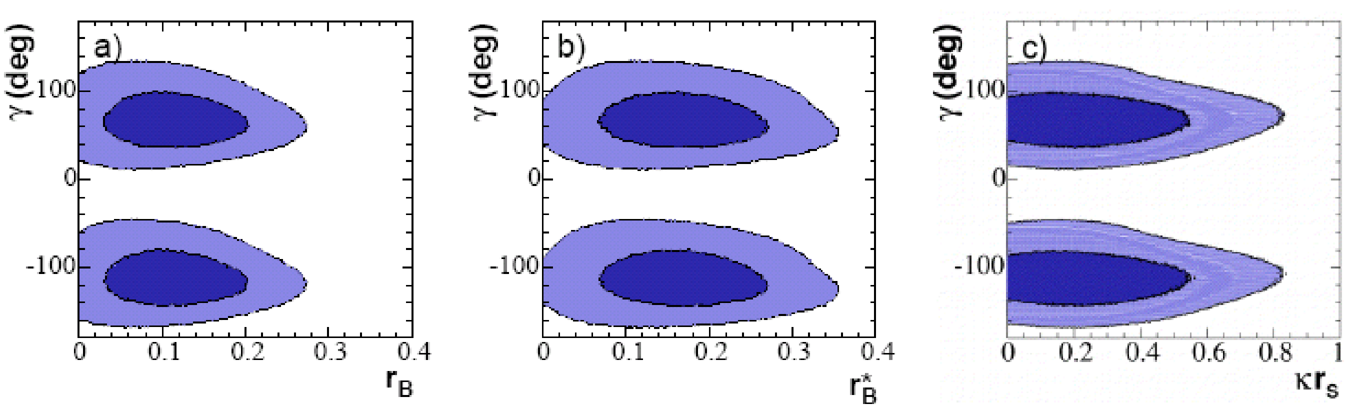
$m_+^2 = M(K_S^0\pi^+)$
$m_-^2 = M(K_S^0\pi^-)$

- 12 $x_\pm$, $y_\pm$ measured for three modes: DK^-, D^*K^-, DK^{*-}
- can be converted into constraints on γ, $\delta_B^{(*)}$, $r_B^{(*)}$

CP fit gives:

$$(x_\pm, y_\pm)^{(*)} \equiv (\mathbf{Re}, \mathbf{Im})\{\mathbf{r}_\mathrm{B}^{(*)} e^{\mathbf{i}(\delta_\mathrm{B}^{(*)} \pm \gamma)}\}$$

$\gamma = (67 \pm 28 \pm 13 \pm 11)°$



(GLW+ADS: $r_s=0.28^{+0.06}_{-0.10}$)

1 and 2σ level contours in the planes (γ, suppressed-to-favored ratio) from the three modes DK^-, D^*K^-, DK^{*-} taking all 3 modes results simultaneously

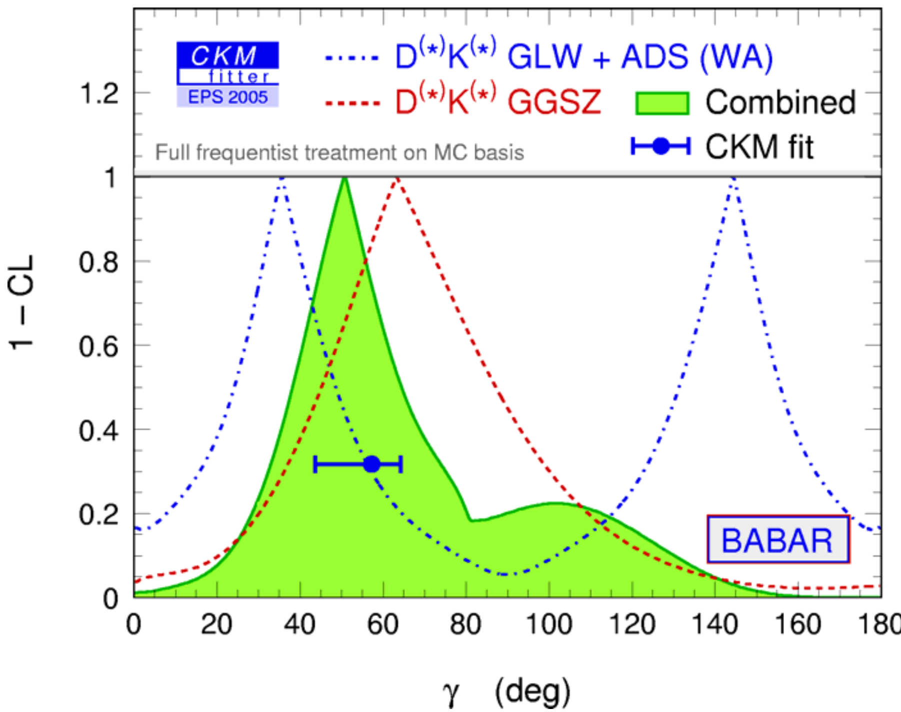
Constraints on γ

- GGSZ method: powerful tool: the golden mode for γ

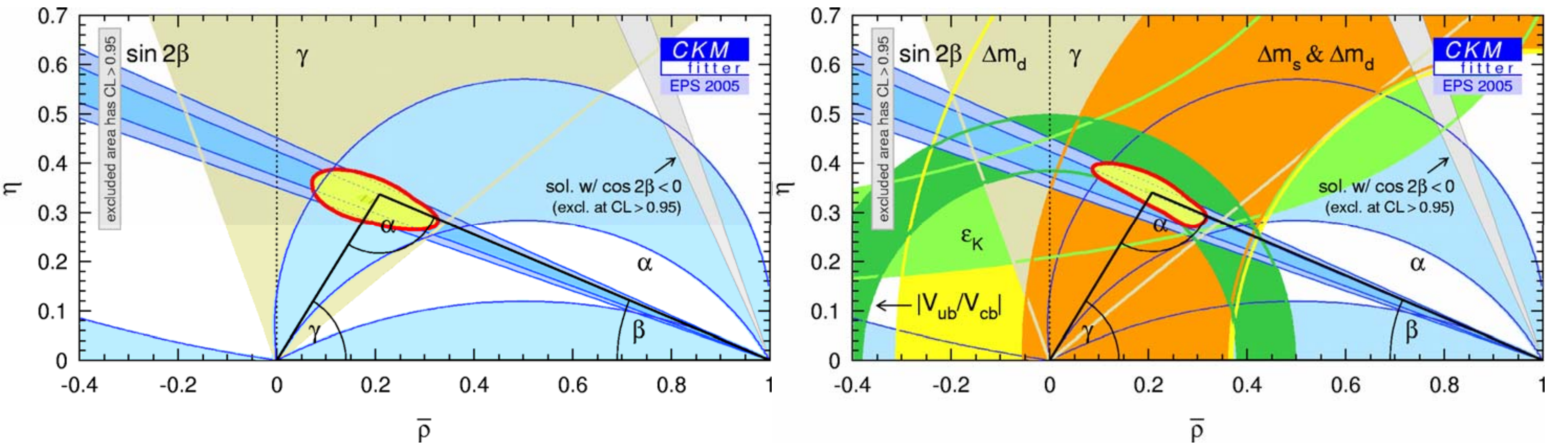
$$\gamma_{GGSZ} = (67 \pm 28 \pm 13 \pm 11)^\circ = (67 \pm 33)^\circ$$

- GLW and ADS methods:
  - limits on suppressed-to-favored ratios $r_B^{(*)}$
  - more statistics needed to really constraint γ
  - combining different measurements helps: combination of GLW/ADS (WA) and GGSZ(BaBar) with all measured modes:

$$\gamma_{GLW,ADS,GGSZ}^{CKMfitter} = (51^{+23}_{-18})^\circ$$



Conclusions



- Best α measurement: $\rho\rho$ (Lucky^2: longitudinal polarization dominates and small penguin pollution)

- Best γ measurement: Dalitz analysis GGSZ

$\alpha_{\rho\rho,\,\pi\pi,\,\pi\rho}^{WA} = (98.6^{+12.6}_{-8.1})^o$

$\gamma_{GLW,ADS,GGSZ}^{WA} = (63^{+15}_{-12})^o$

- All results in good agreement with the global CKM fit
- Measure γ at B-factories considered ~ impossible few years ago!
- SM fit: α, β and γ determine (ρ,η) nearly as precisely as all data combined
- New era: constraints from angles surpass the rest with increasing statistics

Backup slides:

- CKM matrix and unitarity triangle
- PEP-II performances
- The BaBar detector
- Analysis techniques:
    - ΔT measurement
    - B kinematical variables: m_{ES} and ΔE
    - Event shape variables
    - Cherenkov angle
    - General common features
- Further details on $\rho\rho$, $\pi\pi$ isospin analysis
- $\rho^+\rho^-$ the golden mode for measuring α
- Method for $B\to(\rho\pi)^0$ Dalitz analysis
- Extrapolations for $B\to\rho\pi$ isospin analysis
- π^0 efficiency measurement
- sPlots technique
- Combined results for GLW and ADS in $B^-\to D^0K^{*-}$
- GGSZ fit results

CKM matrix and unitarity triangle

Quark sector: masses eigenstates ≠ gauge eigenstates
Mixing between flavour and weak eigenstates described by
3 × 3 matrix with 3 real parameters and one single phase

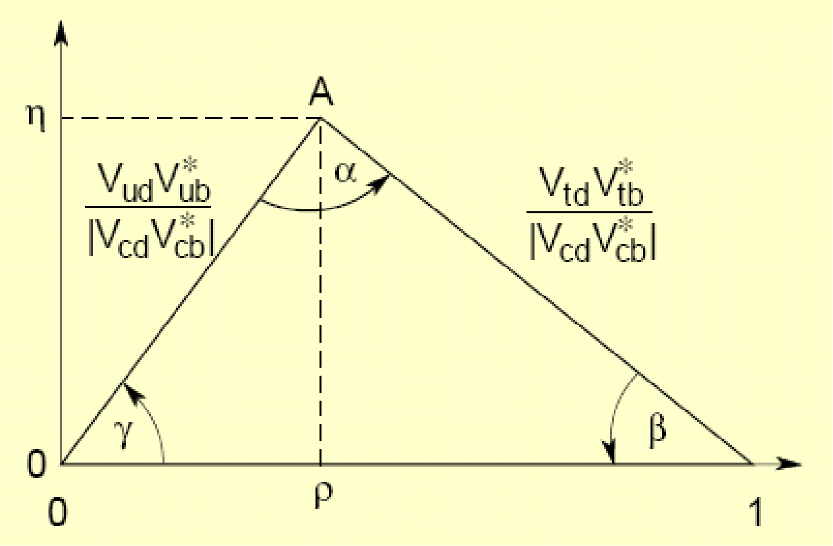
CKM matrix — Wolfenstein parameterization:

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \simeq \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

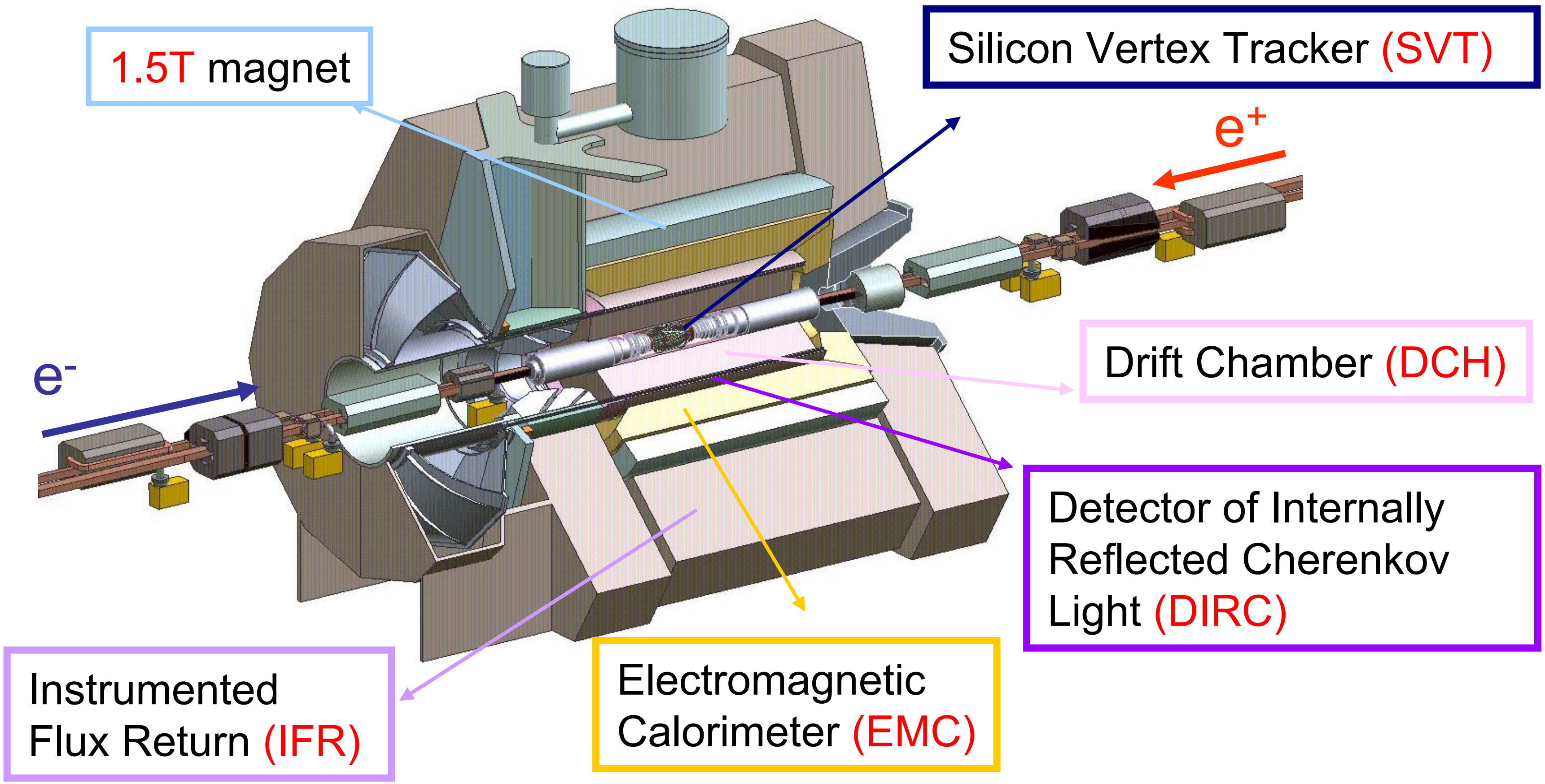
CP violation possible in the SM only if CKM matrix is complex i.e. UT area non zero i.e. $\eta \neq 0$

V_{CKM} Unitarity:

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



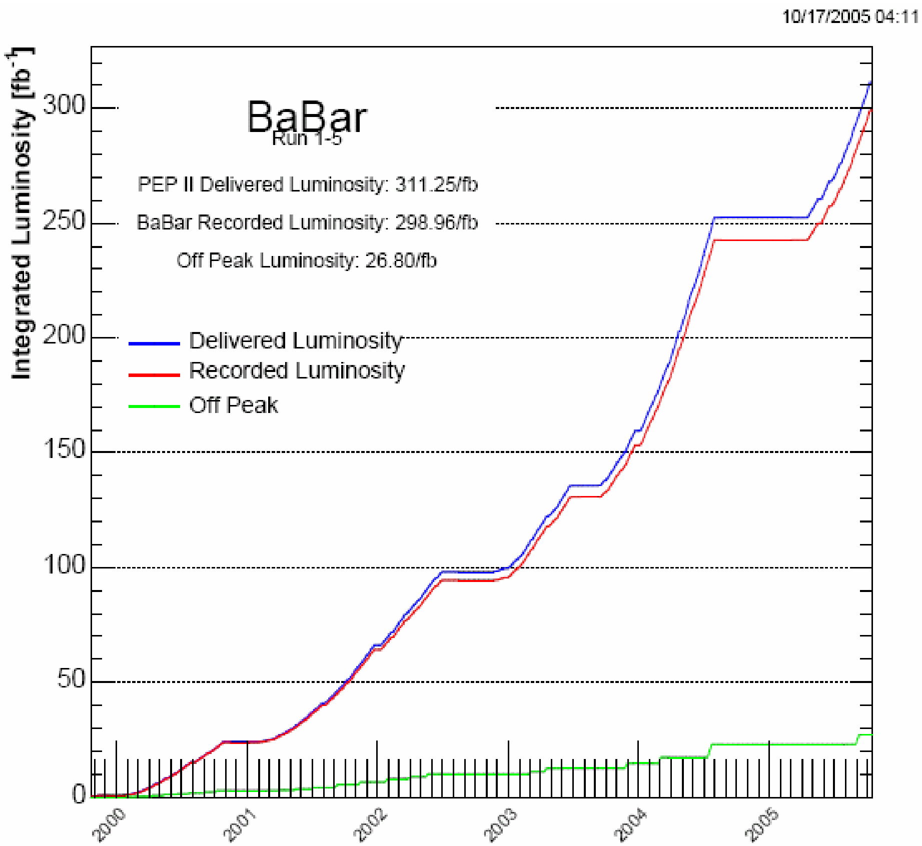
The BaBar detector

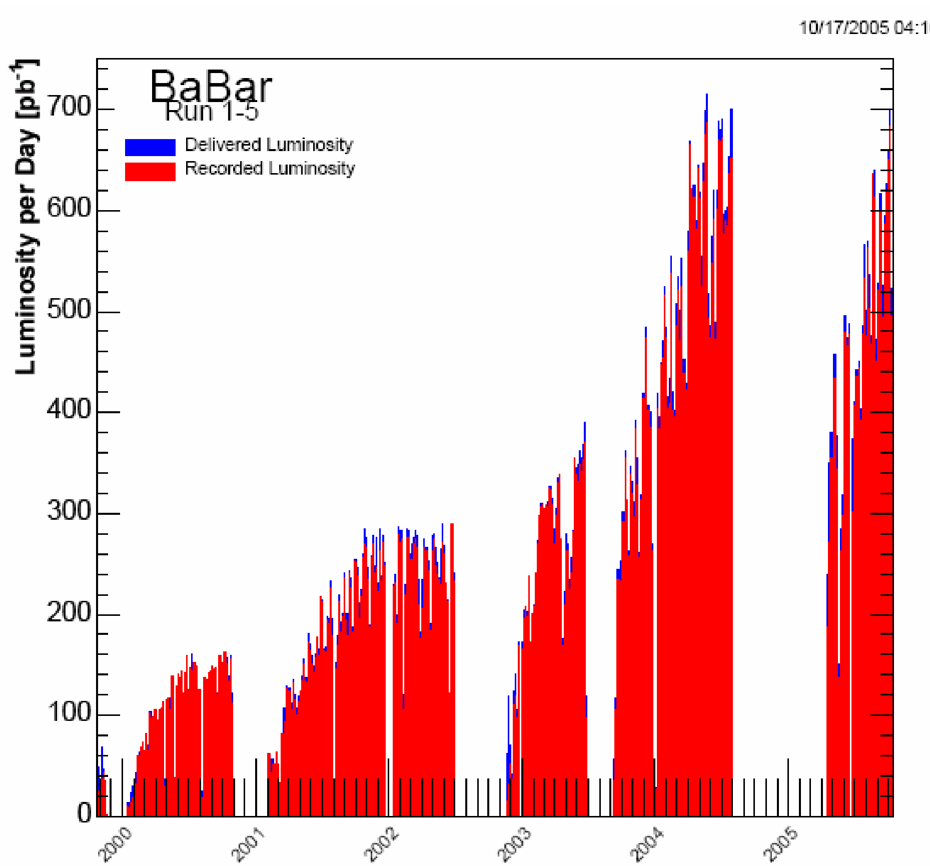


Pairs of B mesons from $\Upsilon(4S)$ decays: $\Upsilon(4S)\rightarrow B^0 B^0$, $B^+ B^-$

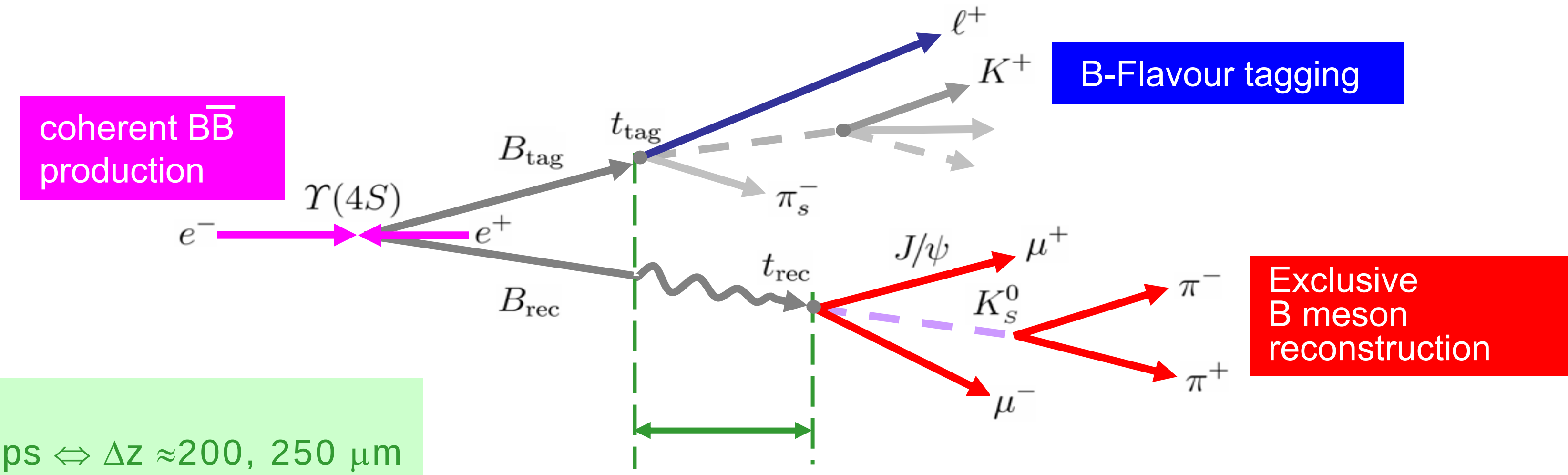
Boost of $\Upsilon(4S)$ in the lab frame: $bg \approx 0.56$

PEP-II performances





Analysis techniques: time dependent measurements



$\beta\gamma \sim 0.55$
$\Delta t = 1.6$ ps $\Leftrightarrow$ $\Delta z \approx 200, 250\ \mu$m

$$\Delta t \equiv t_{rec} - t_{tag} \approx \Delta z / \beta\gamma c$$

Time dependent measurements, flavor tagging:

- B$\overline{\text{B}}$ are in a coherent state at production
- There is a coherent evolution until B_{tag} decays
- B_{reco}'s flavour determined from B_{tag}'s flavour and Δt
- Boost: Δt measured via space length measurement between B_{tag} and B_{reco} Δz
- Flavor of the B_{tag} is determined by its decay product: charge of leptons, kaons, pions

Analysis techniques: kinematics and event shape

Beam Energy-substituted mass

$$m_{ES} = \sqrt{E_{beam}^{*2} - p_B^{*2}}$$

Energy difference

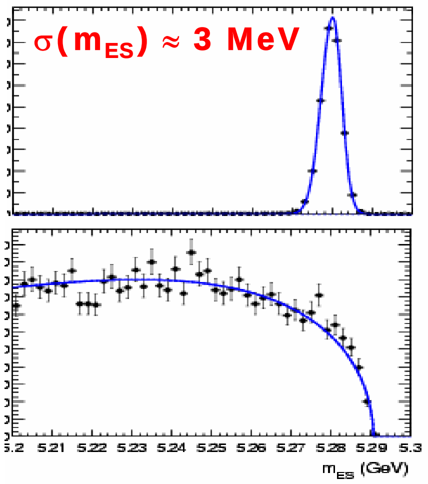
$$\Delta E = E_B^* - E_{beam}^*$$

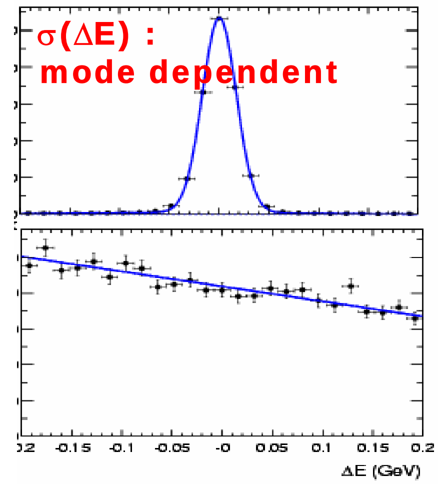
Event shape

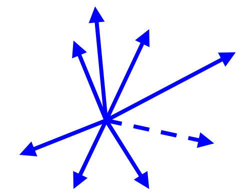
$\Upsilon(4S)$ rest frame

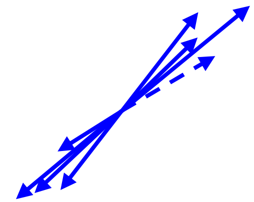
$B\bar{B}$ events

$q\bar{q}$ events (q=u,d,s,c)

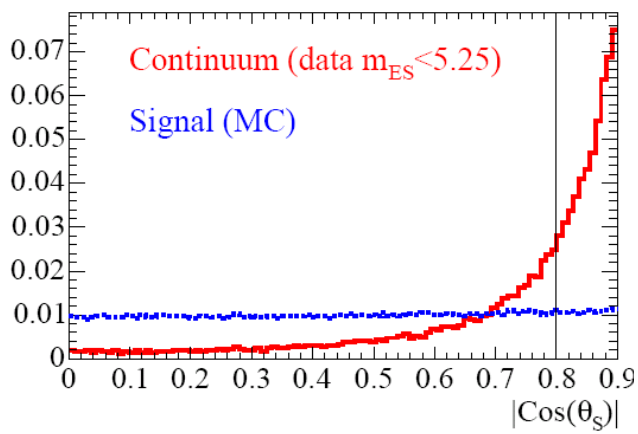


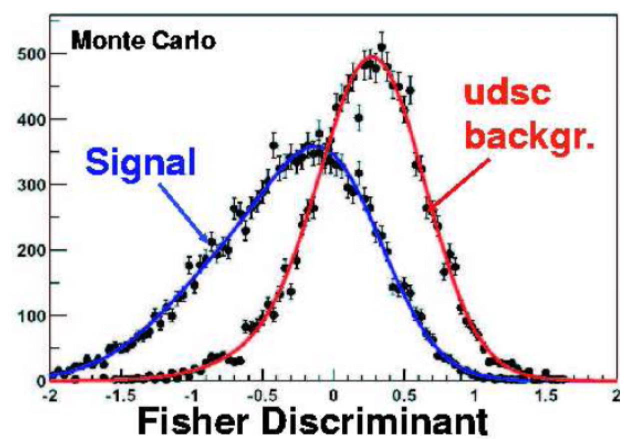






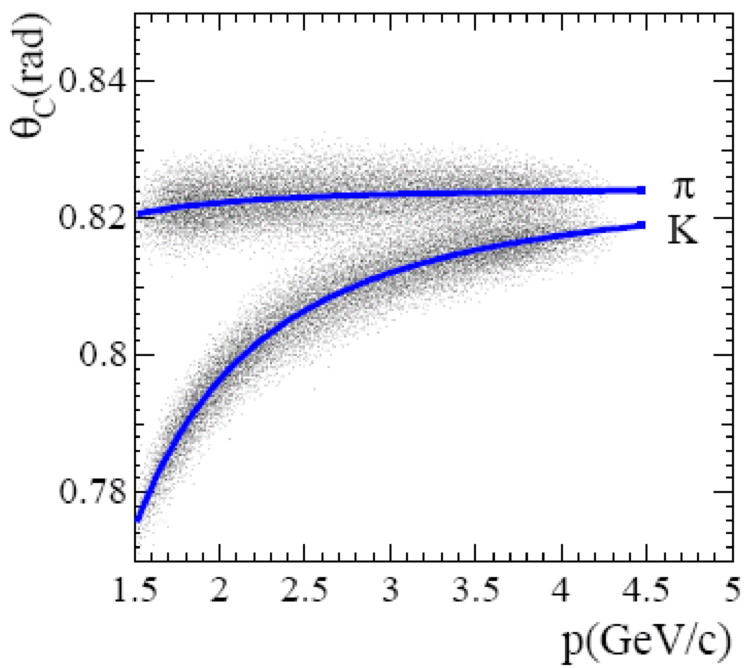
Event shape variables examples:



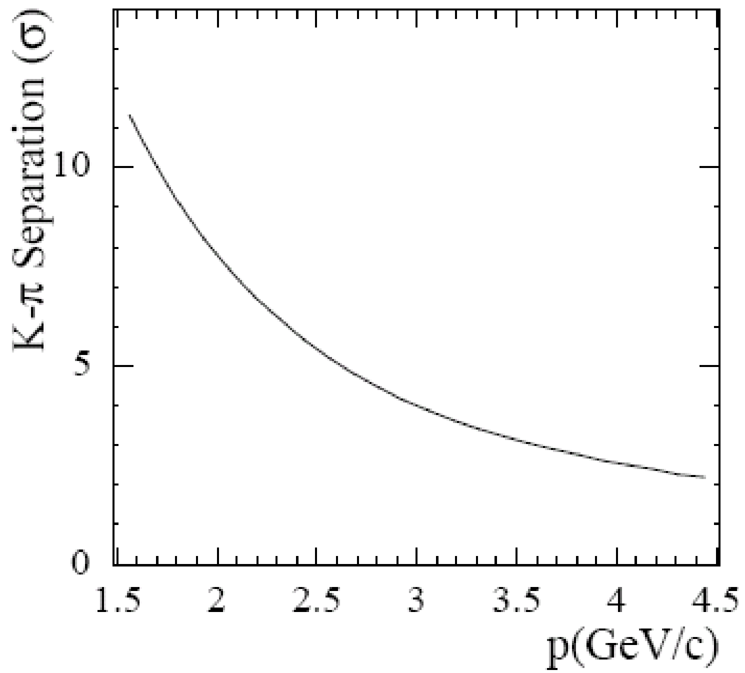


Analysis techniques: K/π discrimination

Cherenkov angle versus momentum:



K/ π separation versus momentum:



K/ π >2.5 σ up to 4 GeV/c

Analysis techniques: common features for $\pi\pi$, $\rho\rho$, $\rho\pi$

The 3 analyses ($B \to \pi\pi$, $B \to \rho\rho$, $B \to \rho\pi$ (Dalitz $\pi\pi\pi$)) share **the same philosophy and use the same techniques**:

- **Unbinned maximum likelihood** fit using m_{ES}, ΔE, NN/F, Δt, θ_c for $\pi\pi/K\pi$, Dalitz variables for $\rho\pi$, resonance mass and helicity for $\rho\rho$.

- Each component has **its own modeling** in the likelihood:
  - Correctly and misreconstructed signal events.
  - Continuum, charmed and charmless B backgrounds (up to 20 modes for $\rho\rho$).

- **Simultaneous fit** of Signal/background yields, free parameters describing the backgrounds, CP parameters and (polarization).

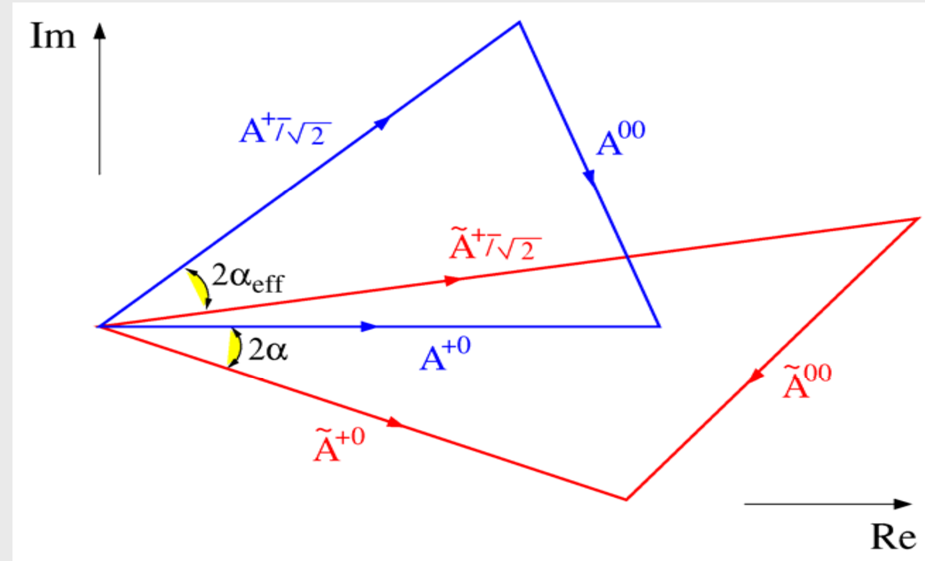
- Determination of Δt resolution function and mistag rates with **fully reconstructed events**.

- **Better statistical sensitivity than traditional “cut and count” approaches.**
- **Better control of the systematics thanks to this global likelihood technique.**

Further details on ρρ, ππ isospin analysis

Amplitudes under SU(2) symmetry:

$$A^{+-}/\sqrt{2} = Te^{i\gamma} + Pe^{-i\beta}$$
$$A^{00} = T_C e^{i\gamma} - Pe^{-i\beta}$$
$$A^{+0} = (T_C + T)e^{i\gamma}$$



α can be resolved up to an 8-fold ambiguity within [0,π]

Assumptions:

- neglect EW penguins
  (shifts α by ~ +2°) penguins
- neglect SU(2) breaking
- in ρρ: Q2B approx.
  (neglect interference)

Unknowns	Observables	Constraints	Account
α, T^{+-}, P^{+-}, T^{+0}, P^{+0}, T^{00}, P^{00}	B^{+-}, $S_{\pi\pi}$, $C_{\pi\pi}$ B^{+0}, A_{CP} B^{00}, (S_{00}), C_{00}	2 isospin triangles and one common side	13 unknowns – 7 observ. – 5 constraints – 1 glob. phase = 0 ☺

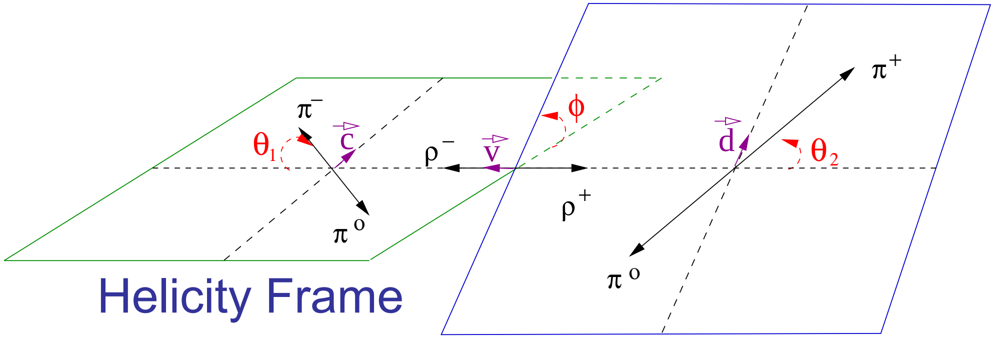
$\rho^+\rho^-$ the golden mode for measuring α

Analysis more difficult:

- 2 π^0 in the final state.
- Wide ρ resonances.
- V-V decay:

L=0,1,2 partial waves components:

$\Rightarrow$ **Need angular analysis.**



Helicity Frame

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1 d\cos\theta_2} = \frac{9}{4}\left\{\underbrace{\frac{1}{4}(1-f_L)\sin^2\theta_1\sin^2\theta_2}_{\text{Transverse (Mixed CP state)}} + \underbrace{f_L\cos^2\theta_1\cos^2\theta_2}_{\text{Longitudinal (CP-even state)}}\right\}$$

But eventually the best mode:

- First measurement of α performed by *BABAR* in ρρ: ***PRL, 93, 231801 (2004).***
- Branching fraction ~ **6 times larger** than for B→ ππ.
- Penguin pollution much smaller than in B→ππ
- f_L ~1.0 ⇒ ρ are ~100% longitudinally polarized, transverse part suppressed at the tree level: $(m_\rho/M_B)^2$ ⇒ **$B^0\to\rho^-\rho^+$ is almost a pure CP-even state!**

Method for B→(ρπ)^0 Dalitz analysis

hep-ex/0408099

213×10^6 B pairs

2 steps analysis:

- Fit 16 Breit-Wigner parameters related to the quasi two body parameters *S*, *C*,…
- Fit results + correlation matrix:

⇒ simultaneous extraction of weak and strong phases α, δ

$$|\mathcal{A}_{3\pi}|^2 \pm |\overline{\mathcal{A}}_{3\pi}|^2 = \sum_{\kappa\in\{+,-,0\}} |f_\kappa|^2 U_\kappa^\pm + 2\sum_{\kappa<\sigma\in\{+,-,0\}} \left(\mathrm{Re}\left[f_\kappa f_\sigma^*\right] U_{\kappa\sigma}^{\pm,\mathrm{Re}} - \mathrm{Im}\left[f_\kappa f_\sigma^*\right] U_{\kappa\sigma}^{\pm,\mathrm{Im}}\right)$$

$$\mathrm{Im}\left(\overline{\mathcal{A}}_{3\pi}\mathcal{A}_{3\pi}^*\right) = \sum_{\kappa\in\{+,-,0\}} |f_\kappa|^2 I_\kappa + \sum_{\kappa<\sigma\in\{+,-,0\}} \left(\mathrm{Re}\left[f_\kappa f_\sigma^*\right] I_{\kappa\sigma}^{\mathrm{Im}} + \mathrm{Im}\left[f_\kappa f_\sigma^*\right] I_{\kappa\sigma}^{\mathrm{Re}}\right),$$

$$C^+ = \frac{U_+^-}{U_+^+}, \quad C^- = \frac{U_-^-}{U_-^+}, \quad S^+ = \frac{2I_+}{U_+^+}, \quad S^- = \frac{2I_-}{U_-^+}, \quad \mathcal{A}_{\rho\pi} = \frac{U_+^+ - U_-^+}{U_+^+ + U_-^+}$$

$$\begin{aligned}
U_\kappa^\pm &= |A^\kappa|^2 \pm |\overline{A}^\kappa|^2, \\
U_{\kappa\sigma}^{\pm,\mathrm{Re(Im)}} &= \mathrm{Re(Im)}\left[A^\kappa A^{\sigma*} \pm \overline{A}^\kappa \overline{A}^{\sigma*}\right], \\
I_\kappa &= \mathrm{Im}\left[\overline{A}^\kappa A^{\kappa*}\right], \\
I_{\kappa\sigma}^{\mathrm{Re}} &= \mathrm{Re}\left[\overline{A}^\kappa A^{\sigma*} - \overline{A}^\sigma A^{\kappa*}\right], \\
I_{\kappa\sigma}^{\mathrm{Im}} &= \mathrm{Im}\left[\overline{A}^\kappa A^{\sigma*} + \overline{A}^\sigma A^{\kappa*}\right].
\end{aligned}$$

$$\mathcal{A}_{\rho\pi}^{+-} = \frac{|\kappa^{+-}|^2 - 1}{|\kappa^{+-}|^2 + 1} = -\frac{\mathcal{A}_{\rho\pi} + C + \mathcal{A}_{\rho\pi}\Delta C}{1 + \Delta C + \mathcal{A}_{\rho\pi} C},$$

$$\mathcal{A}_{\rho\pi}^{-+} = \frac{|\kappa^{-+}|^2 - 1}{|\kappa^{-+}|^2 + 1} = \frac{\mathcal{A}_{\rho\pi} - C - \mathcal{A}_{\rho\pi}\Delta C}{1 - \Delta C - \mathcal{A}_{\rho\pi} C},$$

$$\boxed{\begin{aligned}
\mathcal{A}_{\rho\pi} &= -0.088 \pm 0.049 \pm 0.013 \\
C &= 0.34 \pm 0.11 \pm 0.05, \\
S &= -0.10 \pm 0.14 \pm 0.04, \\
\Delta C &= 0.15 \pm 0.11 \pm 0.03 \\
\Delta S &= 0.22 \pm 0.15 \pm 0.03
\end{aligned}}$$

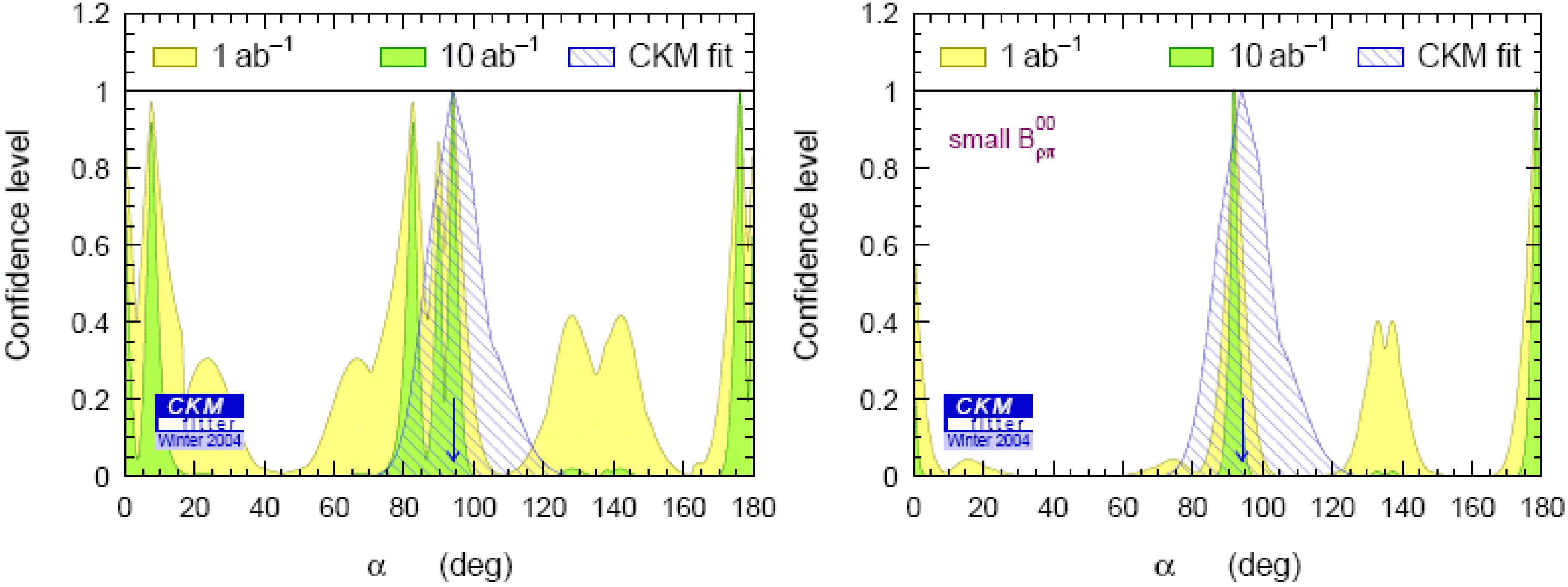
$$\boxed{\begin{aligned}
\mathcal{A}_{\rho\pi}^{+-} &= -0.21 \pm 0.11 \pm 0.04 \\
\mathcal{A}_{\rho\pi}^{-+} &= -0.47\,^{+0.14}_{-0.15} \pm 0.06
\end{aligned}}$$

Extrapolations for B→ρπ isospin analysis

$$
\begin{aligned}
2A^{00} &\equiv 2A(B^0 \to \rho^0\pi^0) &=& \; V_{ud}V_{ub}^*T_C^{00} - V_{td}V_{tb}^*\left(P^{+-}+P^{-+}\right) \,, \\
\sqrt{2}A^{0+} &\equiv \sqrt{2}A(B^+ \to \rho^0\pi^+) &=& \; V_{ud}V_{ub}^*T^{0+} - V_{td}V_{tb}^*\left(P^{+-}-P^{-+}\right) \,, \\
\sqrt{2}A^{+0} &\equiv \sqrt{2}A(B^+ \to \rho^+\pi^0) &=& \; V_{ud}V_{ub}^*\left(T^{+-}+T^{-+}+T_C^{00}-T^{0+}\right) \\
&&& + V_{td}V_{tb}^*\left(P^{+-}-P^{-+}\right) \,,
\end{aligned}
$$

Eur. Phys. J. C41, 1-131, CKMfitter group, (2005)

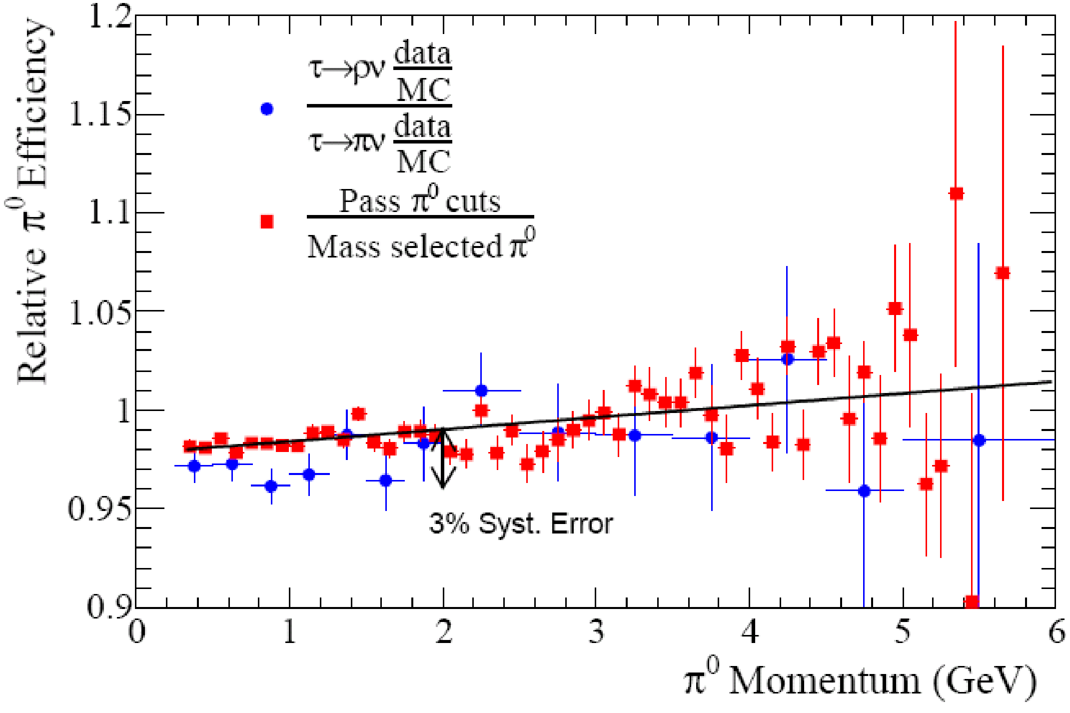
$$
\boxed{
\begin{aligned}
\sqrt{2}\left(A^{+0}+A^{0+}\right) &= 2A^{00}+A^{+-}+A^{-+} \,, \\
\sqrt{2}\left(\bar{A}^{+0}+\bar{A}^{0+}\right) &= 2\bar{A}^{00}+\bar{A}^{+-}+\bar{A}^{-+} \,.
\end{aligned}
}
$$



Analysis techniques: π^0 efficiency

Method:

- Select $e^+e^- \to \tau^+\tau^-$ with $\tau^+ \to e^+\nu\bar{\nu}$ and $\tau^- \to \pi^-(\text{or}\,\rho^-)\nu$
- $N(\tau^\pm \to \pi^\pm\nu) \propto \epsilon(\pi^\pm)$ and $N(\tau^\pm \to \rho^\pm\nu) \propto \epsilon(\pi^\pm)\epsilon(\pi^0)$
- π^0 momentum dependent double ratio: $\frac{\tau\to\rho\nu\,\frac{\text{data}}{\text{MC}}}{\tau\to\pi\nu\,\frac{\text{data}}{\text{MC}}}(p_{\pi^0}) \Rightarrow \frac{\epsilon(\pi^0)_{data}}{\epsilon(\pi^0)_{MC}}$
- Comparison with efficiencies of standard π^0 cuts $\Rightarrow$ discrepancy $< 3\%$ at 2 GeV



sPlot technique

Reference: François Le Diberder and Muriel Pivk, physics/0402083

Method:

- Fit without the variable x we want to plot
- We build the distribution by defining a weight for each event and for each species we want to plot with the covariance matrix

Definition of the statistical weight for one event and for a species k:

$$\mathbb{P}_k(y_e) = \frac{1}{N_k} \frac{\sum_{j=1}^{N_{es}} V_{kj} \mathcal{P}_j(y_e)}{\sum_{i=1}^{N_{es}} N_i \mathcal{P}_i(y_e)}$$

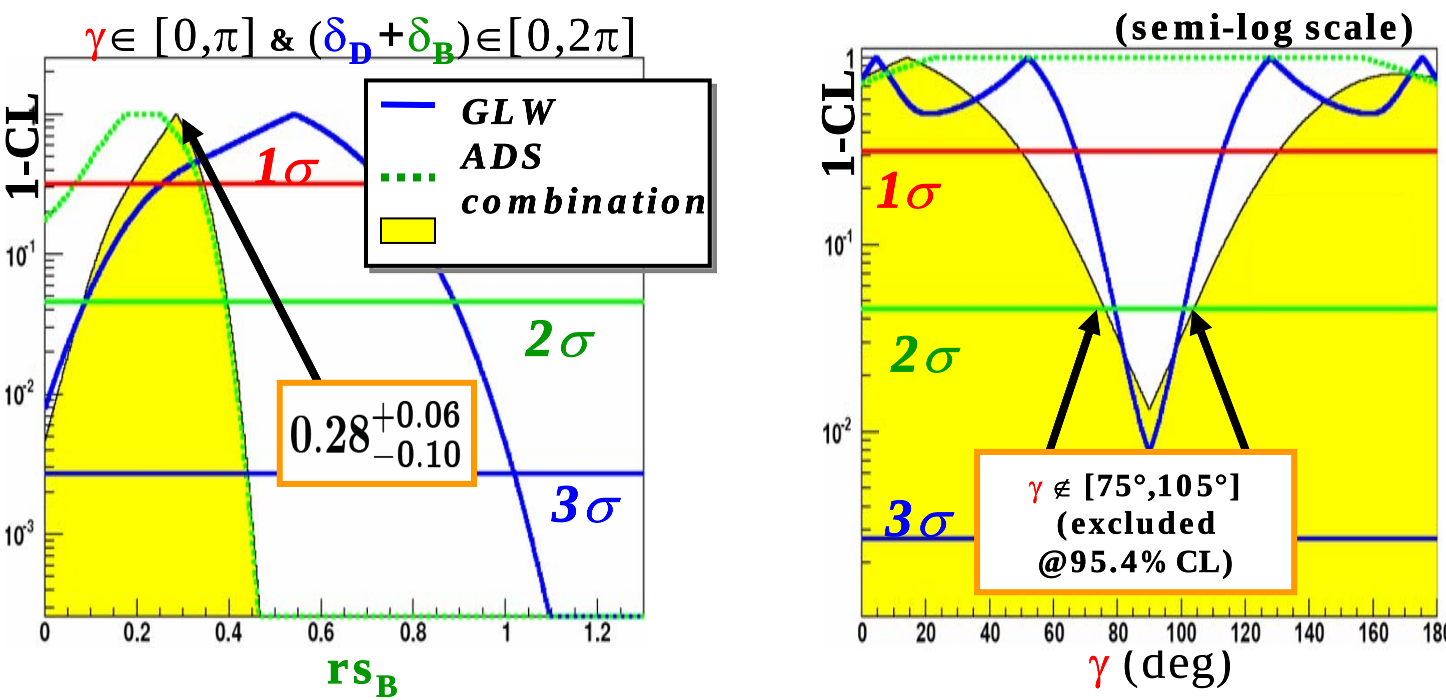
$\Rightarrow$ x Weighed distribution $x \notin \{y\}$ = real distribution of $x \notin \{y\}$

Interest:

- All the events are used
- No information taken from the x pdf $\mathcal{P}(x)$

Combined results for GLW and ADS $B^- \to D^0 K^{*-}$

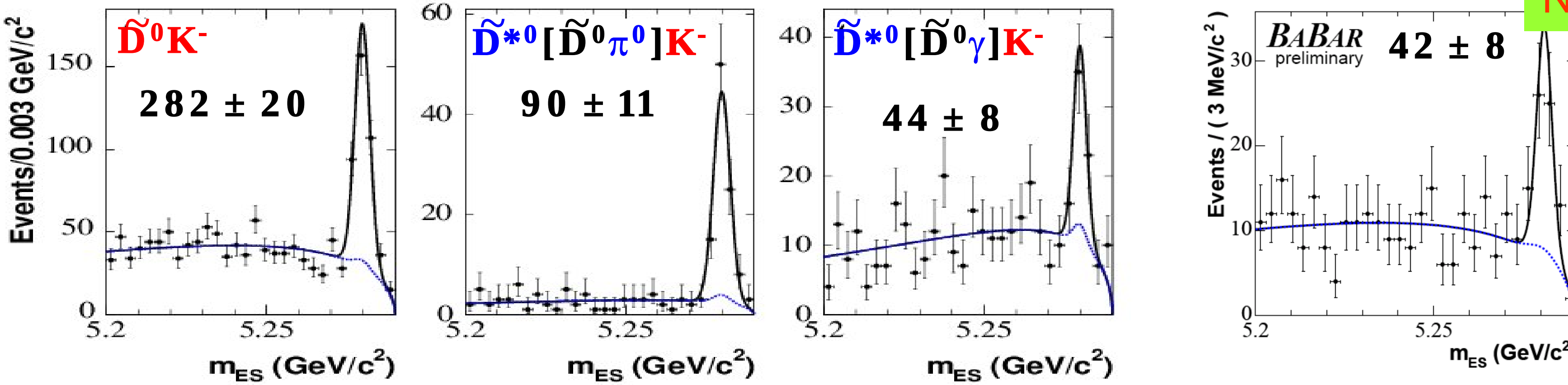
Frequentist approach (CKM-Fitter EPJ,C41,1 (2005)) to extract γ and r_b from ADS/GLW combination for $B^- \to D^0 K^{*-}$ modes:



$\gamma \notin$ [75º, 105º]
@95.4% CL

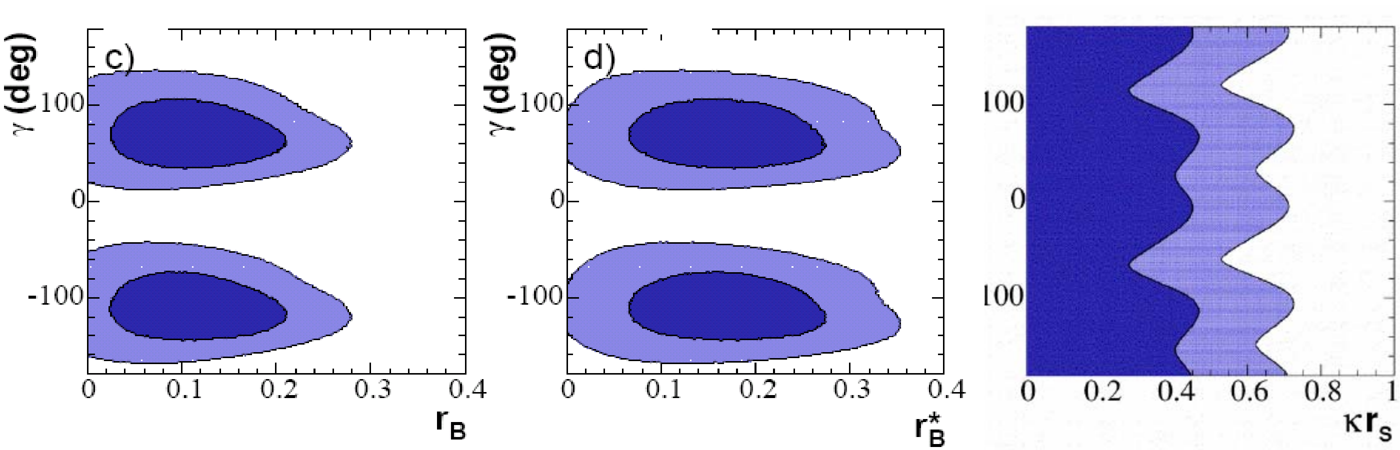
Results for GGSZ: $(f=K_S\,\pi^+\pi^-)$

NEW



	$x_\pm^{(*)}$	$y_\pm^{(*)}$
z_-	$0.08 \pm 0.07 \pm 0.03 \pm 0.02$	$0.06 \pm 0.09 \pm 0.04 \pm 0.04$
z_+	$-0.13 \pm 0.07 \pm 0.03 \pm 0.03$	$0.02 \pm 0.08 \pm 0.02 \pm 0.02$
z_-^*	$-0.13 \pm 0.09 \pm 0.03 \pm 0.02$	$-0.14 \pm 0.11 \pm 0.02 \pm 0.03$
z_+^*	$0.14 \pm 0.09 \pm 0.03 \pm 0.03$	$0.01 \pm 0.12 \pm 0.04 \pm 0.06$

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



$x_\pm$, $y_\pm$:
- **~ gaussian distributions**
- **Small statistical correlations**
- **Frequentist treatment to convert them into constraints on**

γ, $\delta_B^{(*)}$, $r_B^{(*)}$