CP Violation in tree-dominated processes and Determination of UT Angles

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On behalf of
BaBar and Belle Collaborations

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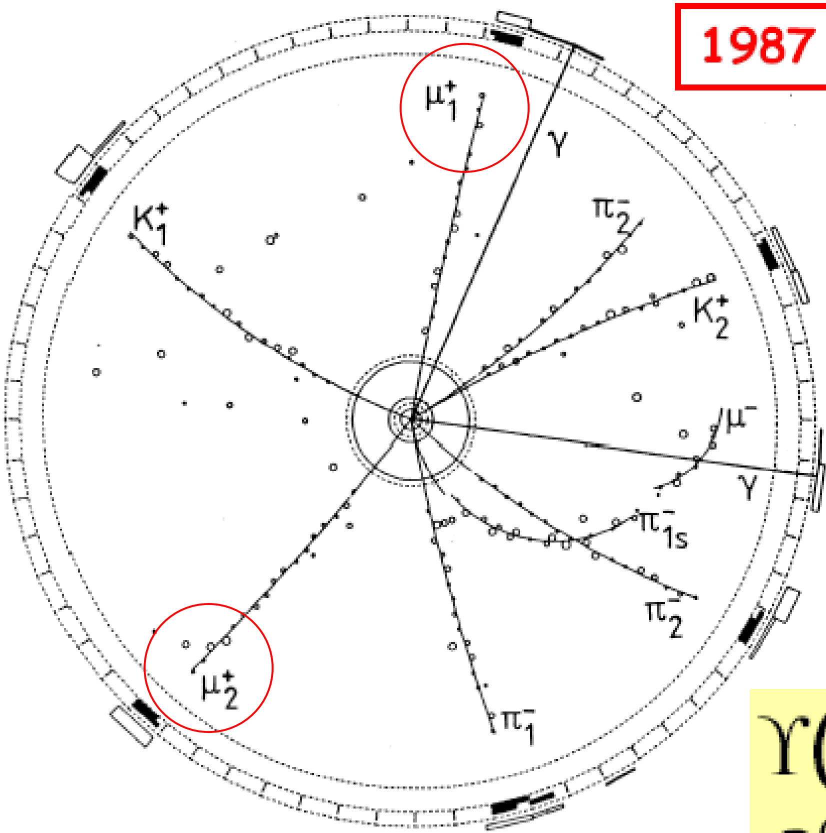
B-Physics in recent past
(only 17 years ago)



$\chi_d = 0.17 \pm 0.05$

ARGUS, PL B **192**, 245 (1987)

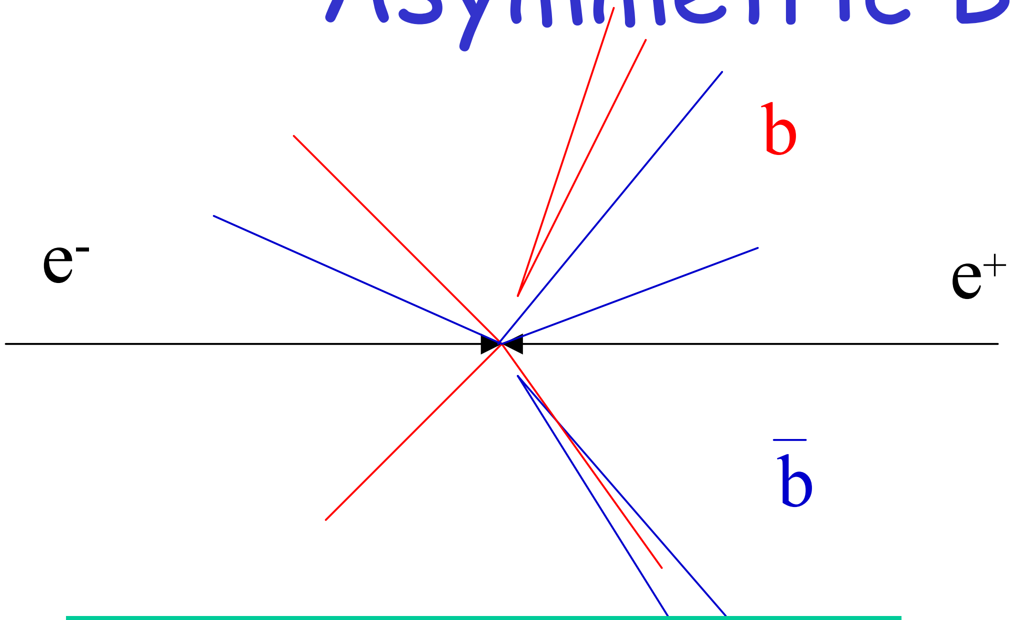
1987

Measurement Of B° oscillations. Found large and

$\Delta m/\Gamma \approx 1$

$$\Upsilon(4S) \to B^0 \bar{B}^0 \to B_1^0 B_2^0$$
$$B_1^0 \to D_1^{*-} \mu_1^+ \nu_1,\ D_1^{*-} \to \bar{D}^0 \pi_1^-$$
$$B_2^0 \to D_2^{*-} \mu_2^+ \nu_2,\ D_1^{*-} \to D^- \pi^0$$

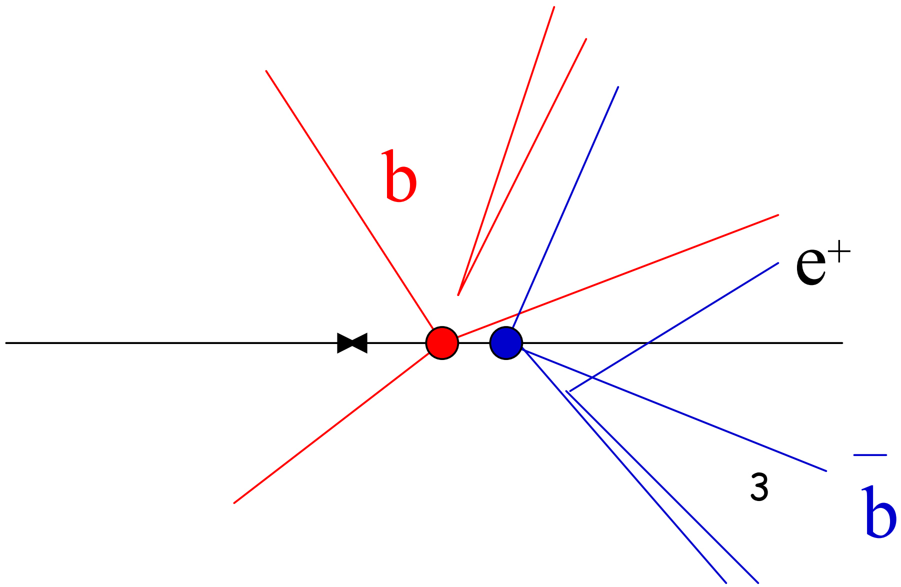
From Symmetric to Asymmetric B-Factory



Symmetric (CESR)
B travel ≈ 30μm

$e^+e^- \rightarrow \Psi(4s) \rightarrow B\bar{B}$

Asymmetric (boosted):
(First ideas in 1987)
PEPII, KEKB
<Δz> about 250 μm



Measuring CP Violation in B decays

- The e^+e^- asymmetric way
- Sin 2β: a precise measurement
- Measuring angle α
- Toward a γ determination
- Summary and Conclusions

More details in Parallel Sessions

See also A.Satpathy on direct CP violation recent results. More than 4s effect found!!

CP Violation and Standard Model

- CP violation generated by complex coupling constant
- Quark mixing matrix $\lambda = \sin(\theta_{Cabibbo})$

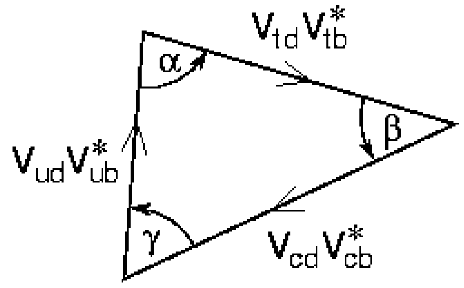
  Cabibbo Kobayashi Maskawa matrix

- 3quark generations -> one non-removable phase

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

Wolfenstein parameterization

The 'Triangles'

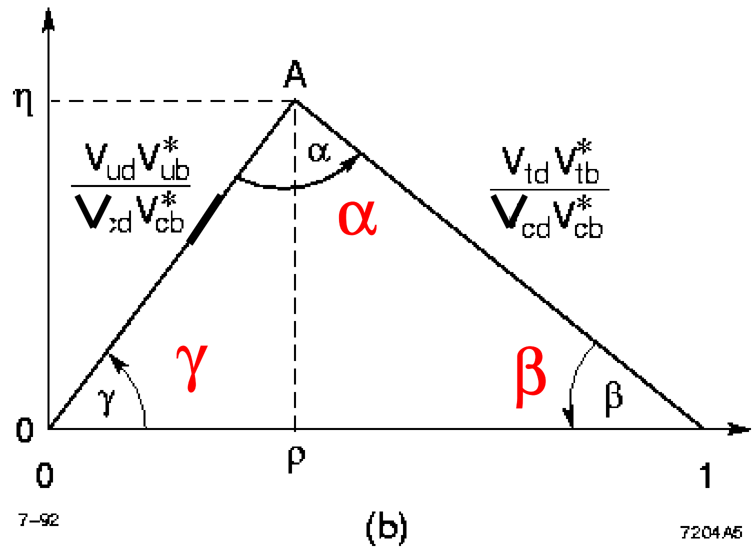


(a)

- CKM matrix is unitary

B_d system

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



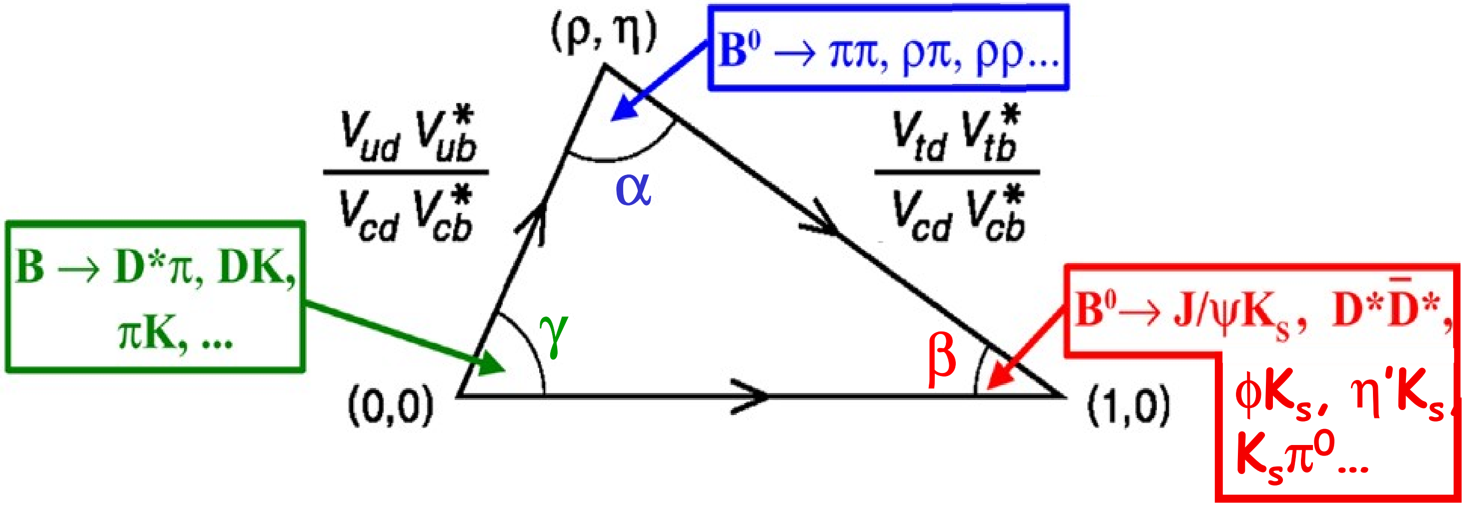
(b)

Phases-> angles α,β,γ
or in this side of Pacific
ϕ2,ϕ1,and ϕ3

CP violation proportional to triangle area:

measure sides and angles independently

Constraints on the UT angles



'new' results on these B decays:

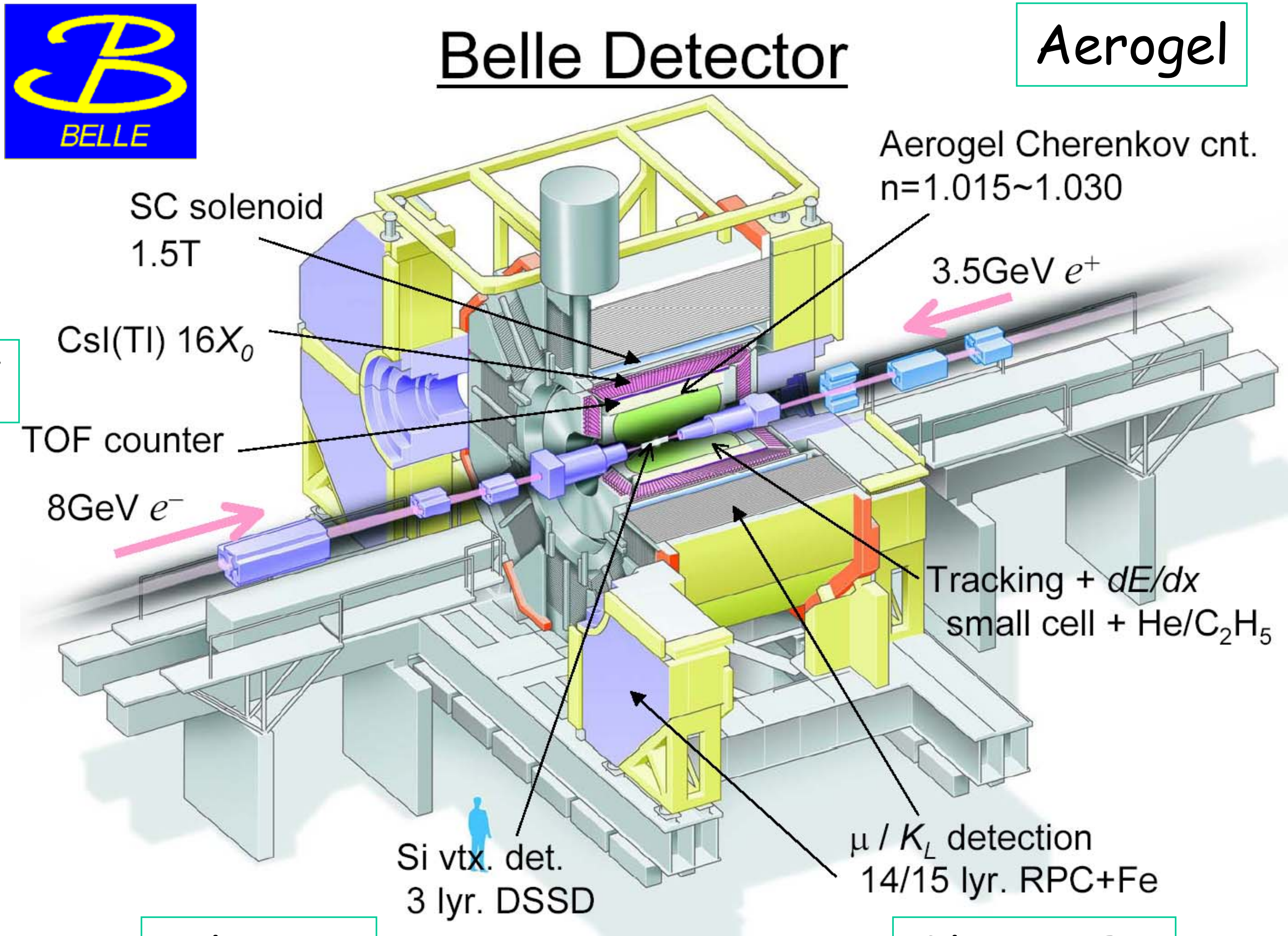
$B^0 \to \rho^+\rho^-$ ➔ α

$B^- \to D^0[K^+\pi^-]K^-$ ➔ γ

$B^0 \to J/\Psi K^{*0}$ ➔ β

Decay rates are small
Need high luminosity !

Belle Detector



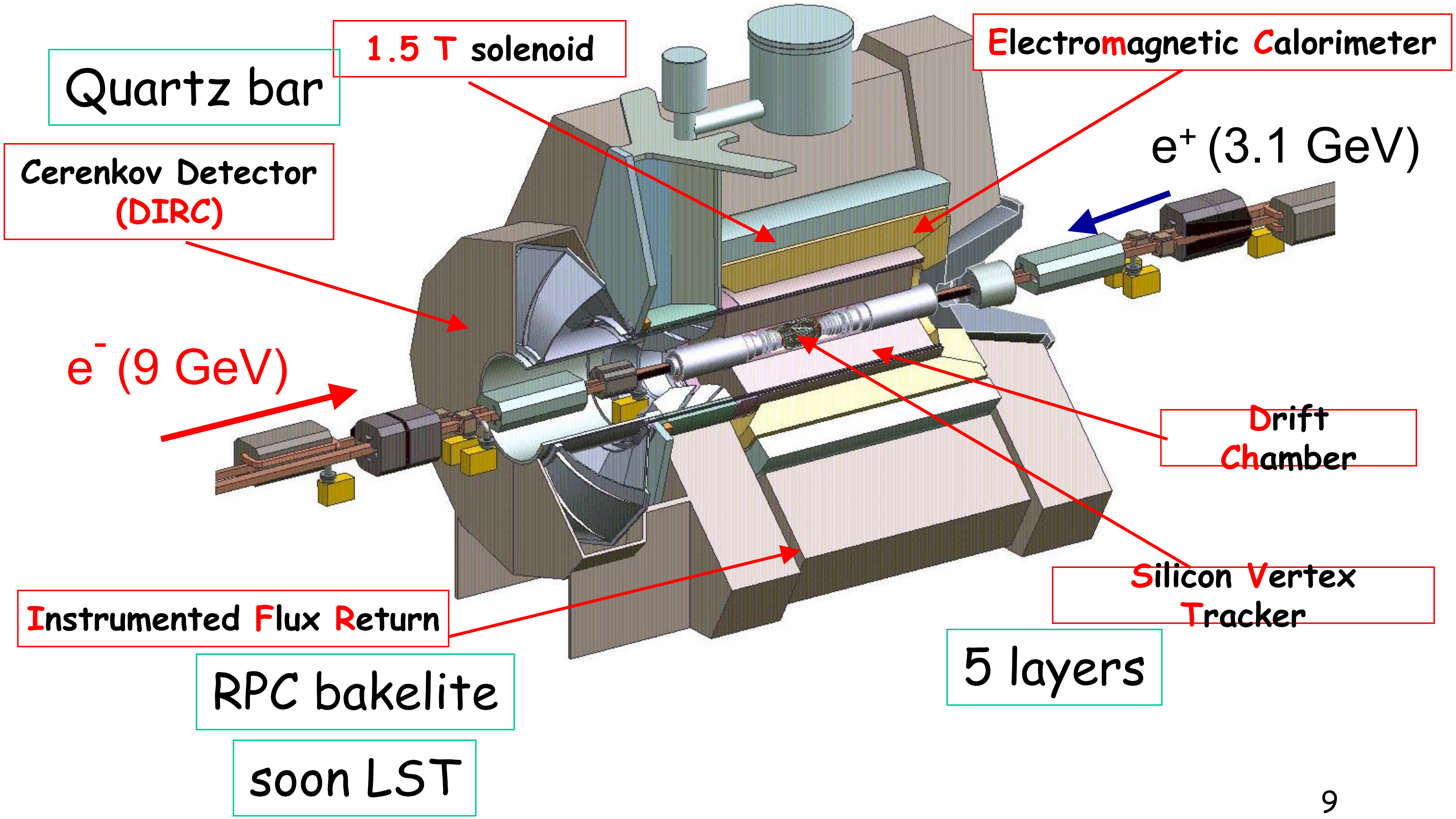
Aerogel

TOF

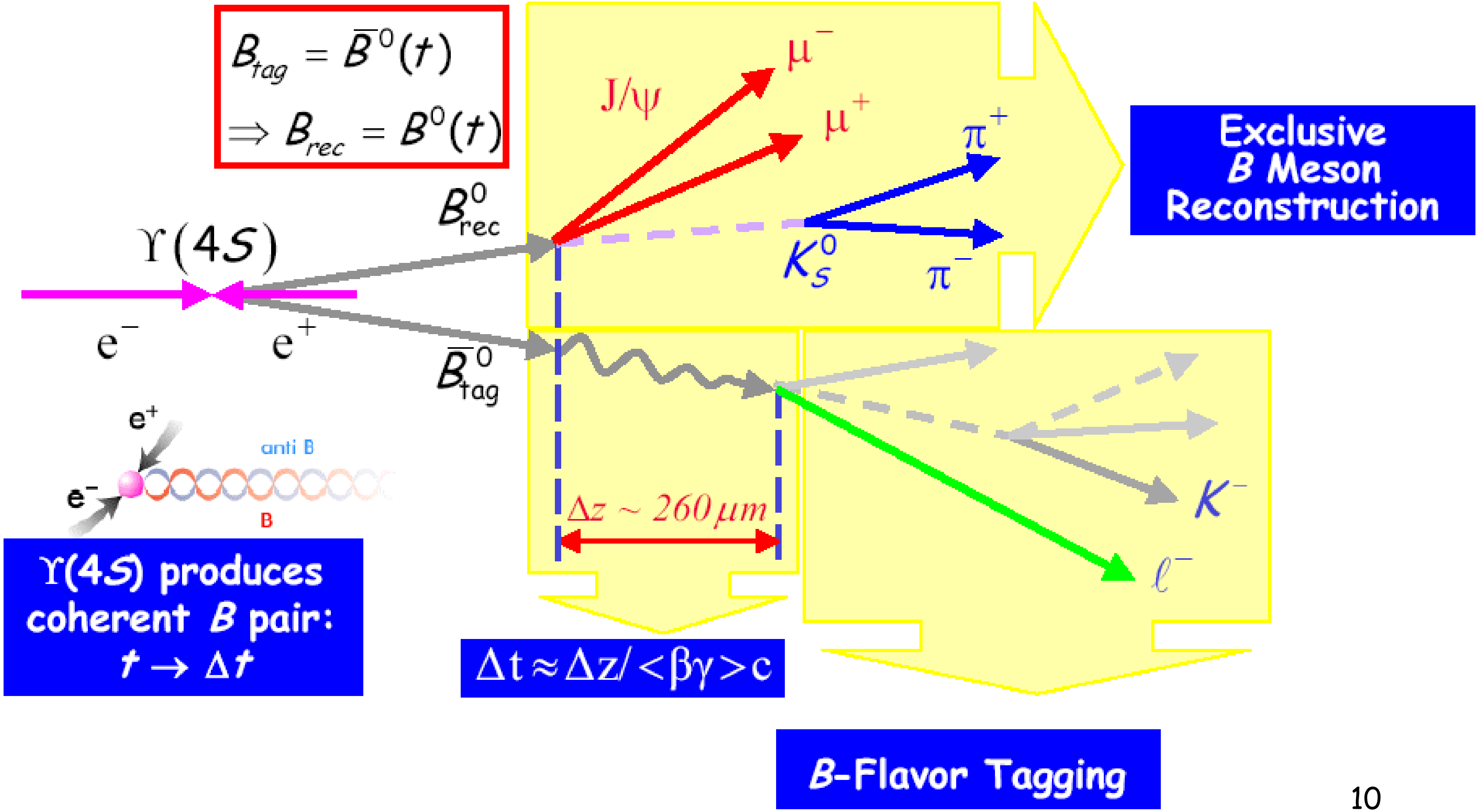
3 layers

Glass-RPC

BABAR Detector

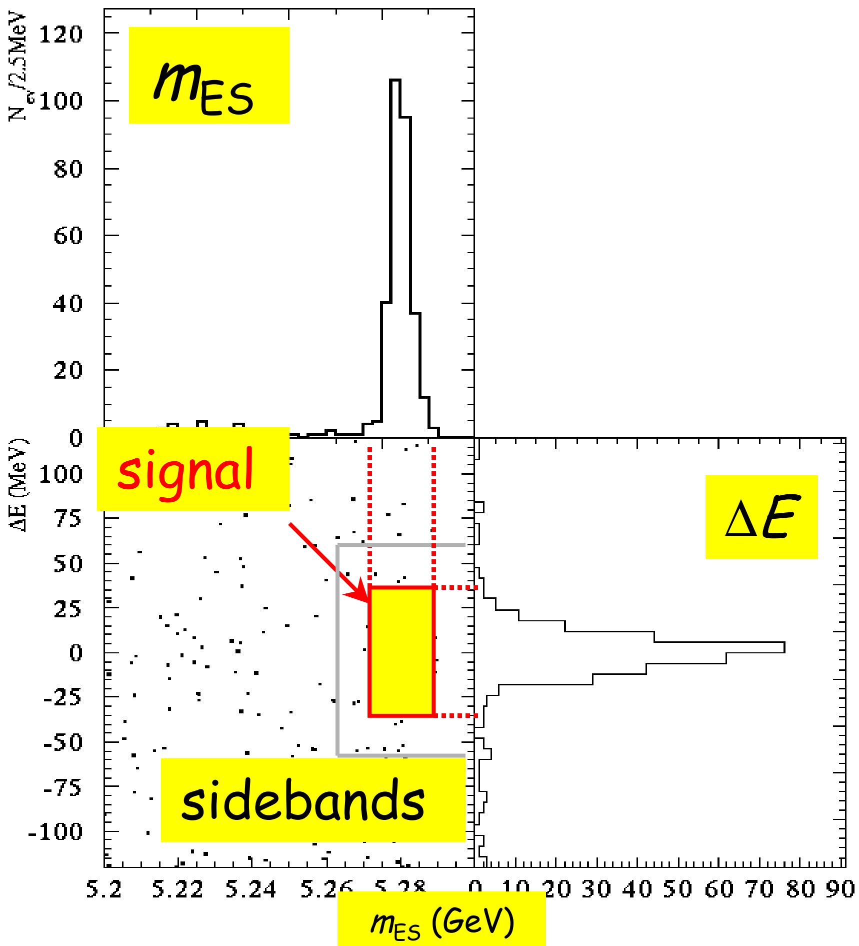


Experimental Technique



B Reconstruction at Υ(4S)

$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\overline{B}$$



Kinematic signature for B decays:

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

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

Typical resolutions:

$\sigma(m_{ES}) \approx$ 2.5 MeV

$\sigma(\Delta E) \approx$ 15 - 30 MeV

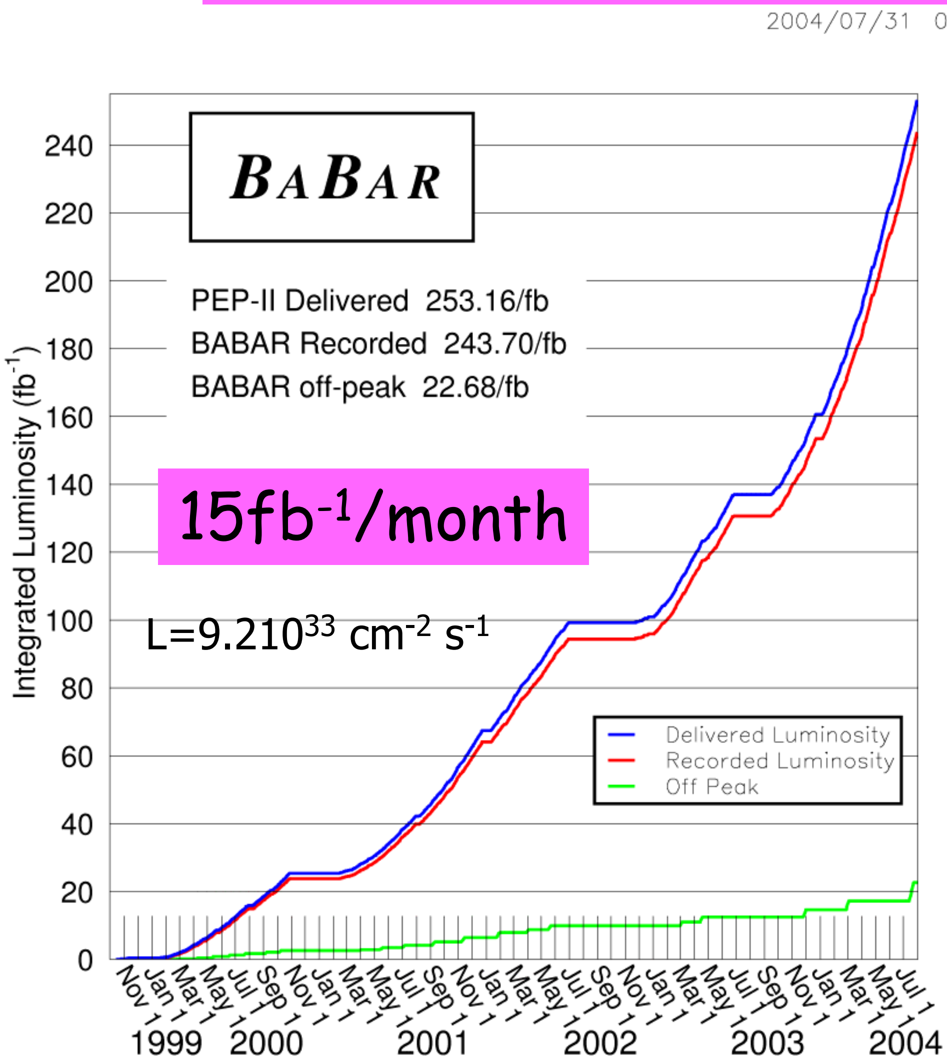
measured in Υ(4S) rest frame

B signal: $\Delta E=0$, $m_{ES}= m_B$

- Define 2 regions in ΔE, m_{ES} plane:
  - Signal region
  - Sideband region

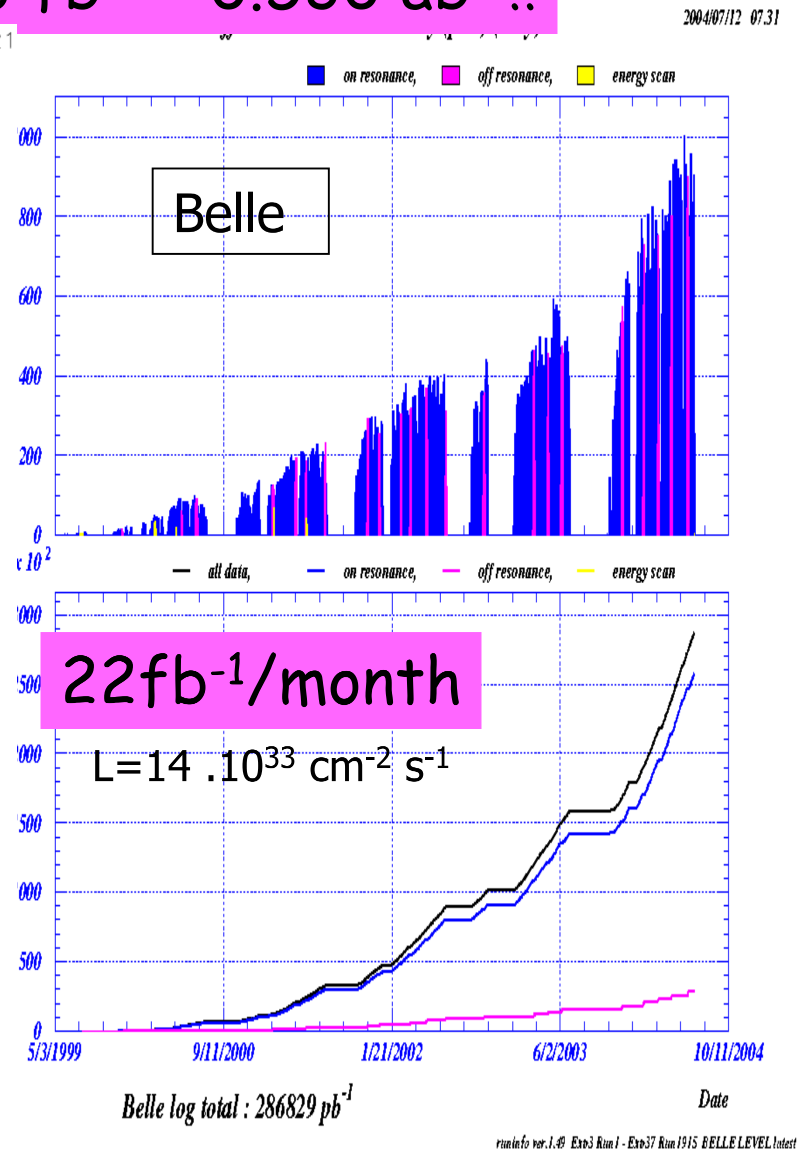
Current Luminosities

Tot 244 + 286 fb^{-1} = 0.530 ab^{-1}!!



15fb^{-1}/month

L=9.2 10^{33} cm^{-2} s^{-1}



22fb^{-1}/month

L=14 .10^{33} cm^{-2} s^{-1}

General CP Formalism

Decay distributions $f_+(f_-)$ when tag = $B^0(\bar{B}^0)$

$$f_{CP,\pm}(\Delta t) = \frac{\Gamma}{4} e^{-\Gamma \Delta t}[1 \pm S_{f_{CP}} \sin \Delta m_d \Delta t \mp C_{f_{CP}} \cos \Delta m_d \Delta t]$$

Asymmetry

$$A_{f_{CP}}(\Delta t) = C_{f_{CP}} \cos(\Delta m_d \Delta t) - S_{f_{CP}} \sin(\Delta m_d \Delta t)$$

$$C_{f_{CP}} = \frac{1-|\lambda_{f_{CP}}|^2}{1+|\lambda_{f_{CP}}|^2} \qquad S_{f_{CP}} = \frac{-2\,\mathrm{Im}\,\lambda_{f_{CP}}}{1+|\lambda_{f_{CP}}|^2}$$

For single amplitude: $C_{f_{CP}} = 0$, $S_{f_{CP}} = -\mathrm{Im}\,\lambda_{f_{CP}}$

***CP* parameter**

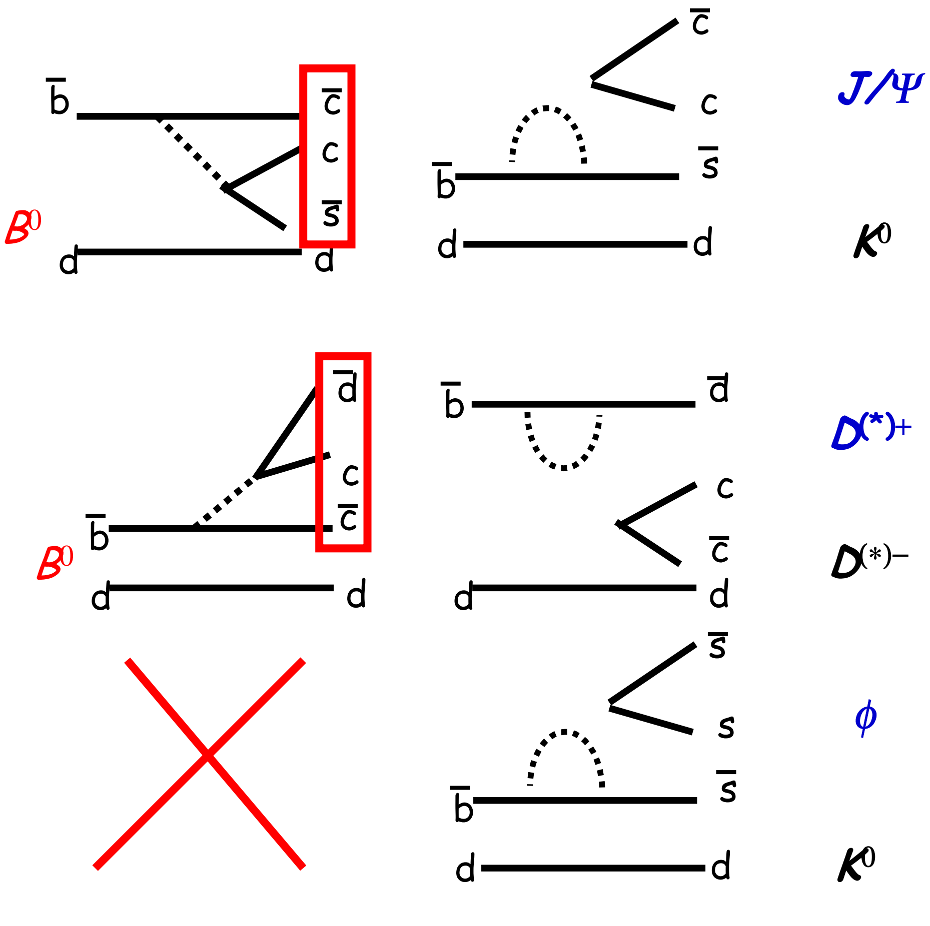
$$\lambda_{f_{CP}} = \eta_{f_{CP}} \frac{q}{p} \frac{\bar{A}_{\bar{f}_{CP}}}{A_{f_{CP}}}$$

- $\eta_{f_{CP}}$: *CP* eigenvalue
- $\frac{q}{p} \approx e^{-2i\beta}$ from mixing (Wolfenstein convention)
- $\frac{\bar{A}_{\bar{f}_{CP}}}{A_{f_{CP}}}$: Amplitude ratio

Decay	$Arg(\bar{A}/A)$	$\lvert\lambda\rvert$	phase
$B^0 \to J/\Psi, K^0$	0	1	$\sin 2\beta$
$B^0 \to \pi^0 \pi^0$	$\approx$ (-2γ)	≈ 1	$\sin 2\alpha$

Measurements of β

See also N.Barlow talk



Charmonium K^0

Penguin and tree have the same weak phase

$D^{(*)}D^{(*)}$ and $J/\Psi\pi^0$

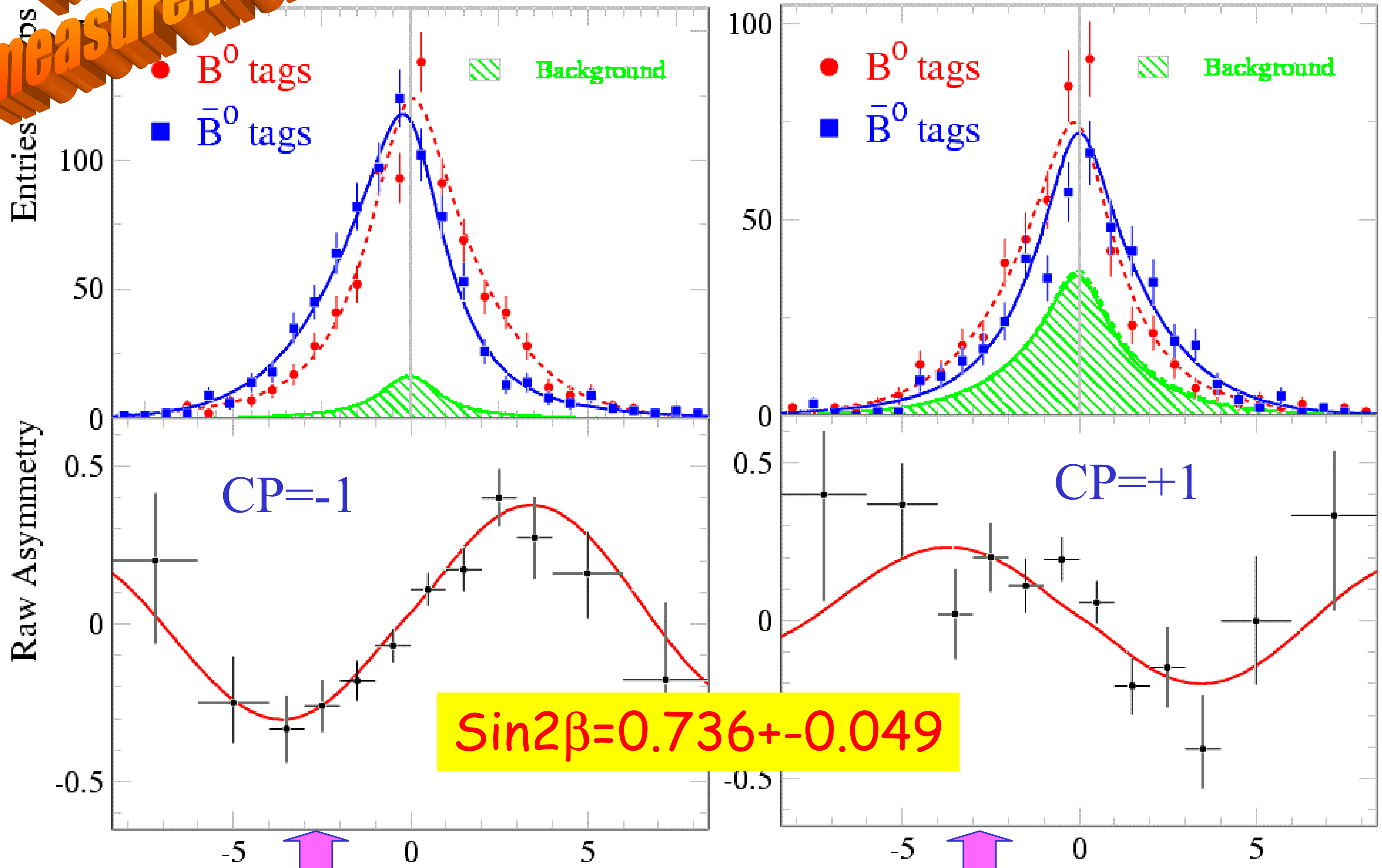
Penguin and tree have different weak phases: asymmetry not necessarily = sin2β

ϕK^0 and $\eta^{(')}K^0$

Mostly penguin. In principle measures sin2β, but sensitive to new physics

Charmonium K°

precision measurement

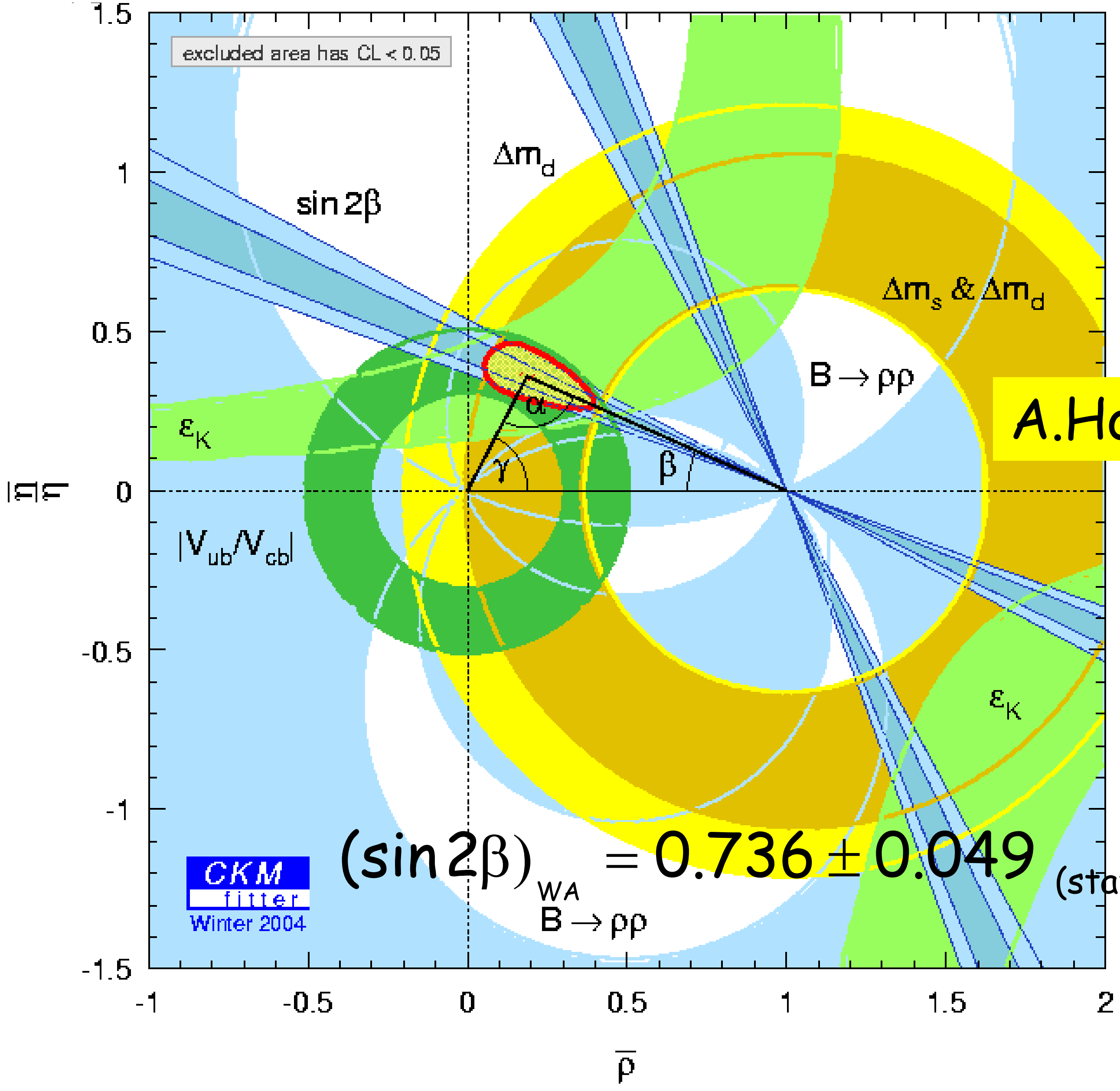


Sin2β=0.736+-0.049

Events with K_S

Events with K_L

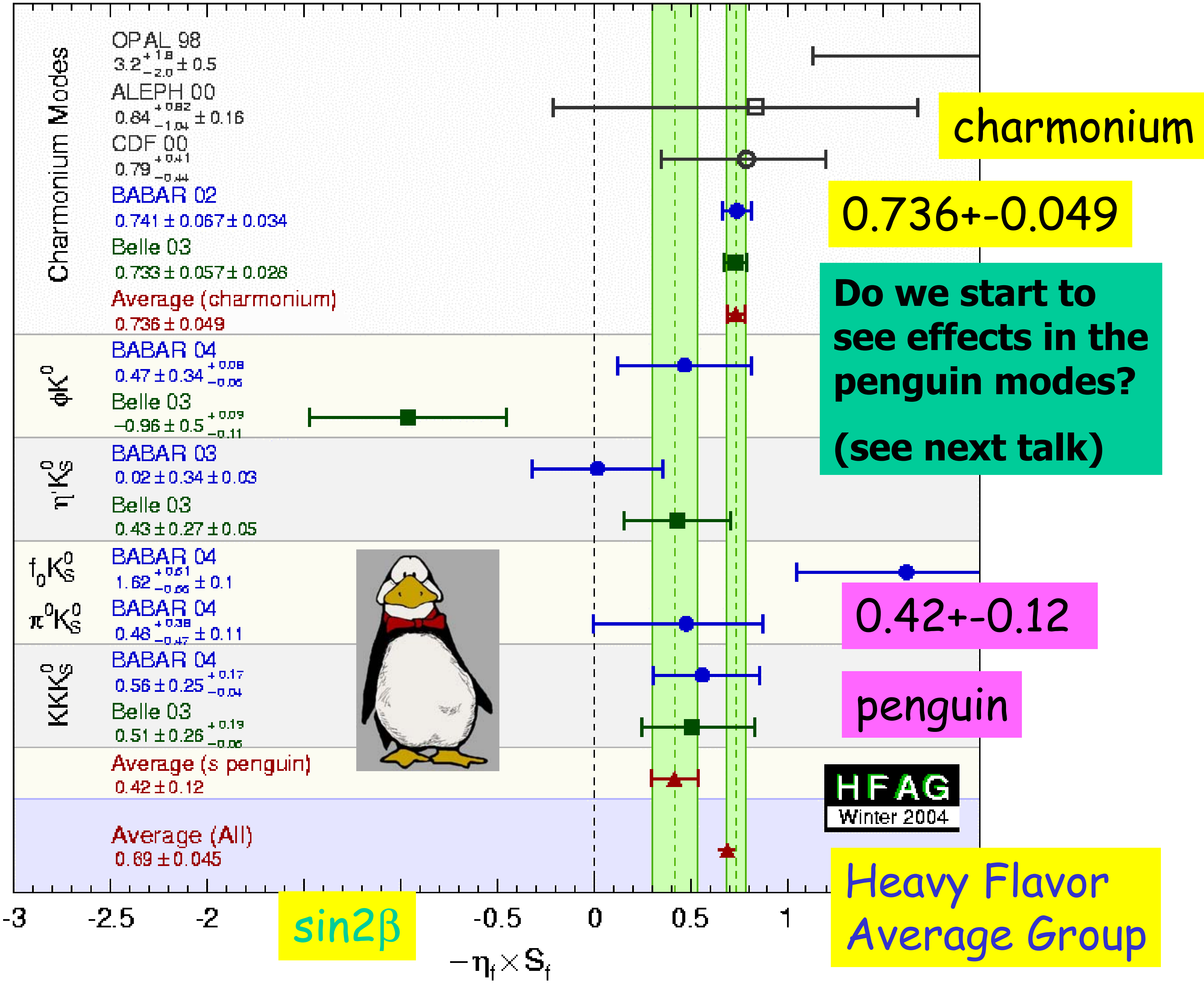
Unitarity Triangle Fit



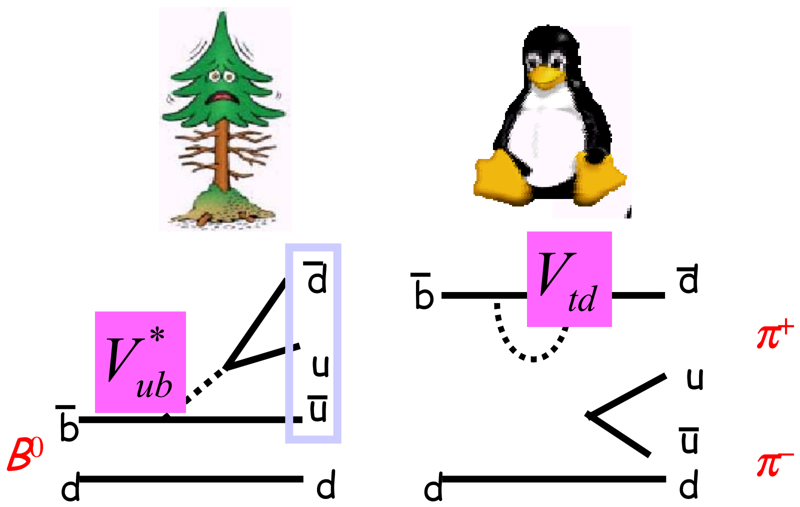
CKMfitter

A.Hoecker et al

$$(\sin 2\beta)_{WA} = 0.736 \pm 0.049 \text{ (stat+syst)}$$


Charmonium Modes
OPAL 98
$3.2^{+1.8}_{-2.0} \pm 0.5$
ALEPH 00
$0.84^{+0.82}_{-1.04} \pm 0.16$
CDF 00
$0.79^{+0.41}_{-0.44}$
BABAR 02
$0.741 \pm 0.067 \pm 0.034$
Belle 03
$0.733 \pm 0.057 \pm 0.028$
Average (charmonium)
0.736 ± 0.049
ϕK^0
BABAR 04
$0.47 \pm 0.34^{+0.08}_{-0.06}$
Belle 03
$-0.96 \pm 0.5^{+0.09}_{-0.11}$
$\eta' K_S^0$
BABAR 03
$0.02 \pm 0.34 \pm 0.03$
Belle 03
$0.43 \pm 0.27 \pm 0.05$
$f_0 K_S^0$
BABAR 04
$1.62^{+0.51}_{-0.56} \pm 0.1$
$\pi^0 K_S^0$
BABAR 04
$0.48^{+0.38}_{-0.47} \pm 0.11$
KKK_S^0
BABAR 04
$0.56 \pm 0.25^{+0.17}_{-0.04}$
Belle 03
$0.51 \pm 0.26^{+0.19}_{-0.05}$
Average (s penguin)
0.42 ± 0.12
Average (All)
0.69 ± 0.045
HFAG
Winter 2004
-3
-2.5
-2
-0.5
0
0.5
1
$-\eta_f \times S_f$
charmonium
0.736+-0.049
Do we start to see effects in the penguin modes?
(see next talk)
0.42+-0.12
penguin
sin2β
Heavy Flavor Average Group

Measurements of α



See also M.Pierini talk

$\pi^+\pi^-$, $\rho^+\pi^-$, $\pi^+\pi^-\pi^0$,$\rho\rho$

Penguin and tree have different weak phases.

$$A = e^{i\gamma} T + e^{-i\beta} P$$

$$\overline{A} = e^{-i\gamma} T + e^{i\beta} P$$

$$\alpha = \pi - (\beta + \gamma)$$

Strong phases different

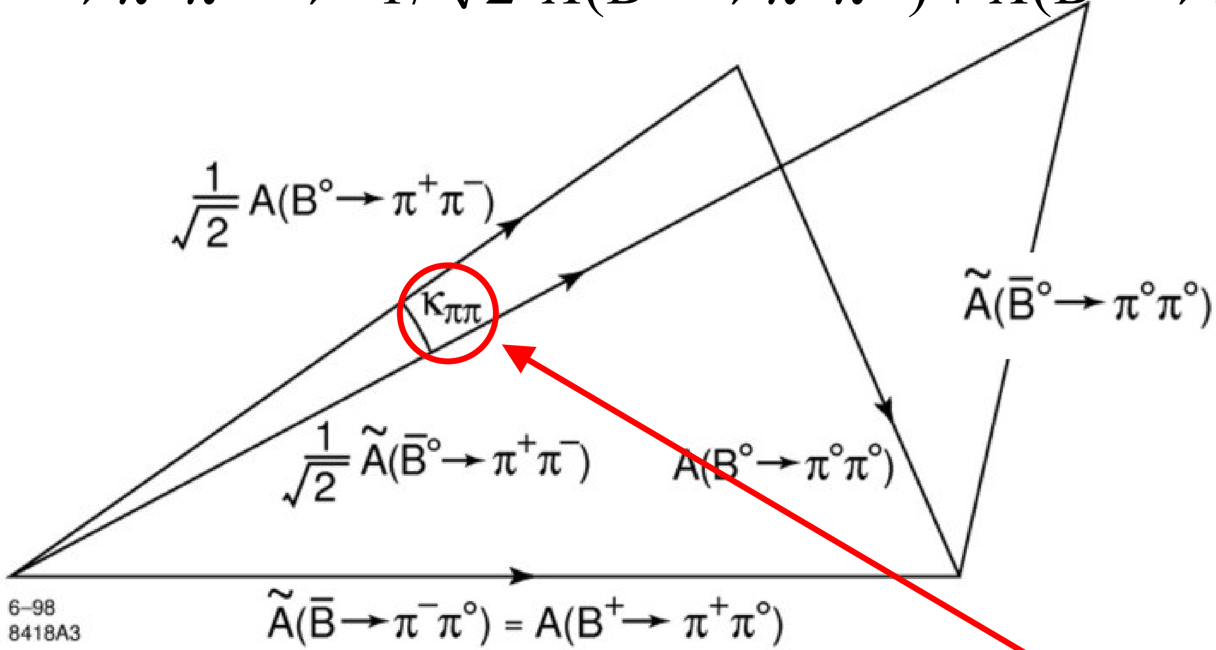
$$\lambda = \frac{q}{p}\frac{\overline{A}}{A} = |\lambda| e^{2i\alpha}$$

$$2\alpha_{eff} = 2\alpha + \kappa_{\pi\pi}$$

- $\pi^+\pi^-$, $\rho^+\pi^-$,$\rho^+\rho^-$ require isospin analysis

Isospin analysis

$$A(B^+ \to \pi^+\pi^0 \to = 1/\sqrt{2}\cdot A(B^0 \to \pi^-\pi^+) + A(B^0 \to \pi^0\pi^0)$$



- Asymmetry in $\pi^+\pi^-$ → $\sin 2\alpha_{eff} = \sin(2\alpha + \kappa_{\pi\pi})$
- Isospin analysis determines $\kappa_{\pi\pi}$.

  Needs $B^0 \to \pi^0\pi^0$ and $\bar{B}^0 \to \pi^0\pi^0$.

  Or, use $\pi^0\pi^0$ rate to bound $\kappa_{\pi\pi}$.

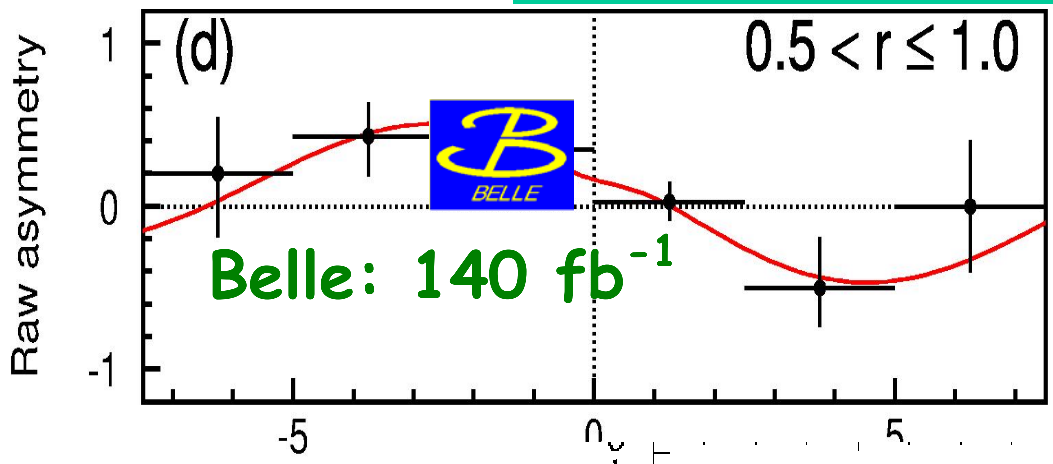
  Small $\pi^0\pi^0$ rate → small $\kappa_{\pi\pi}$.

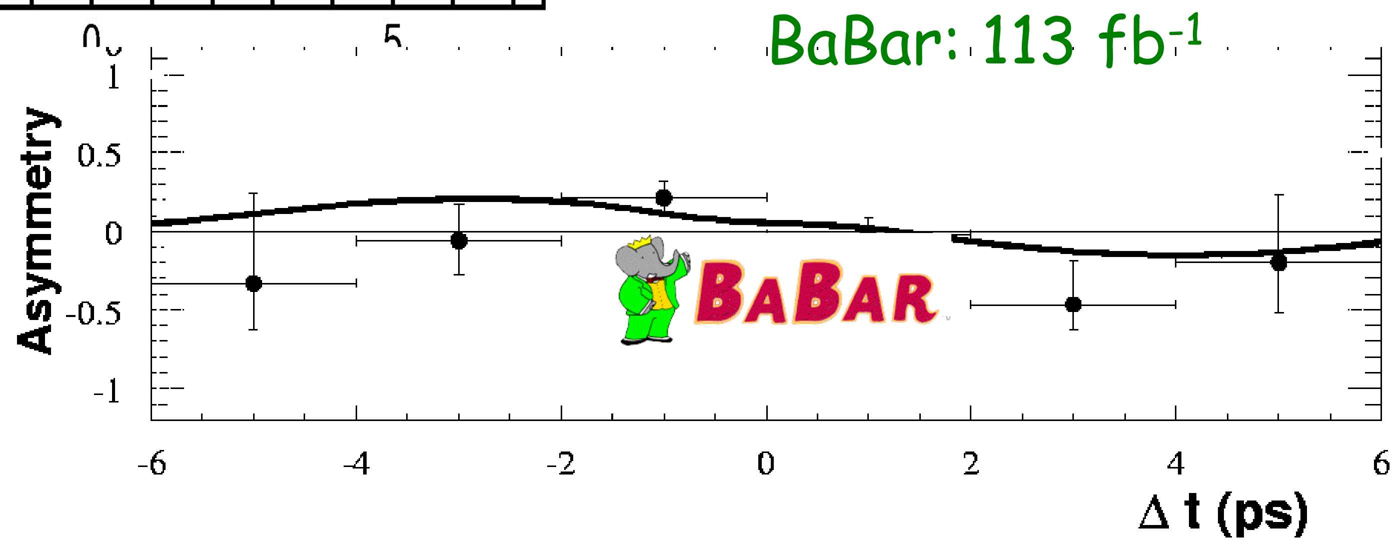
$\pi^+\pi^-$ CP Asymmetries

S, C

$$A_{CP}(\Delta t) = \frac{2\,\mathrm{Im}\lambda}{1+|\lambda|^2}\sin\Delta m\Delta t - \frac{1-|\lambda|^2}{1+|\lambda|^2}\cos\Delta m\Delta t$$

$$= \frac{N(\overline{B}^\circ(\Delta t)\to\pi^+\pi^-) - N(B^\circ(\Delta t)\to\pi^+\pi^-)}{N(\overline{B}^\circ(\Delta t)\to\pi^+\pi^-) + N(B^\circ(\Delta t)\to\pi^+\pi^-)}$$



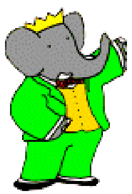


Comparison of $A_{\pi\pi}=-C_{\pi\pi}$ and $S_{\pi\pi}$

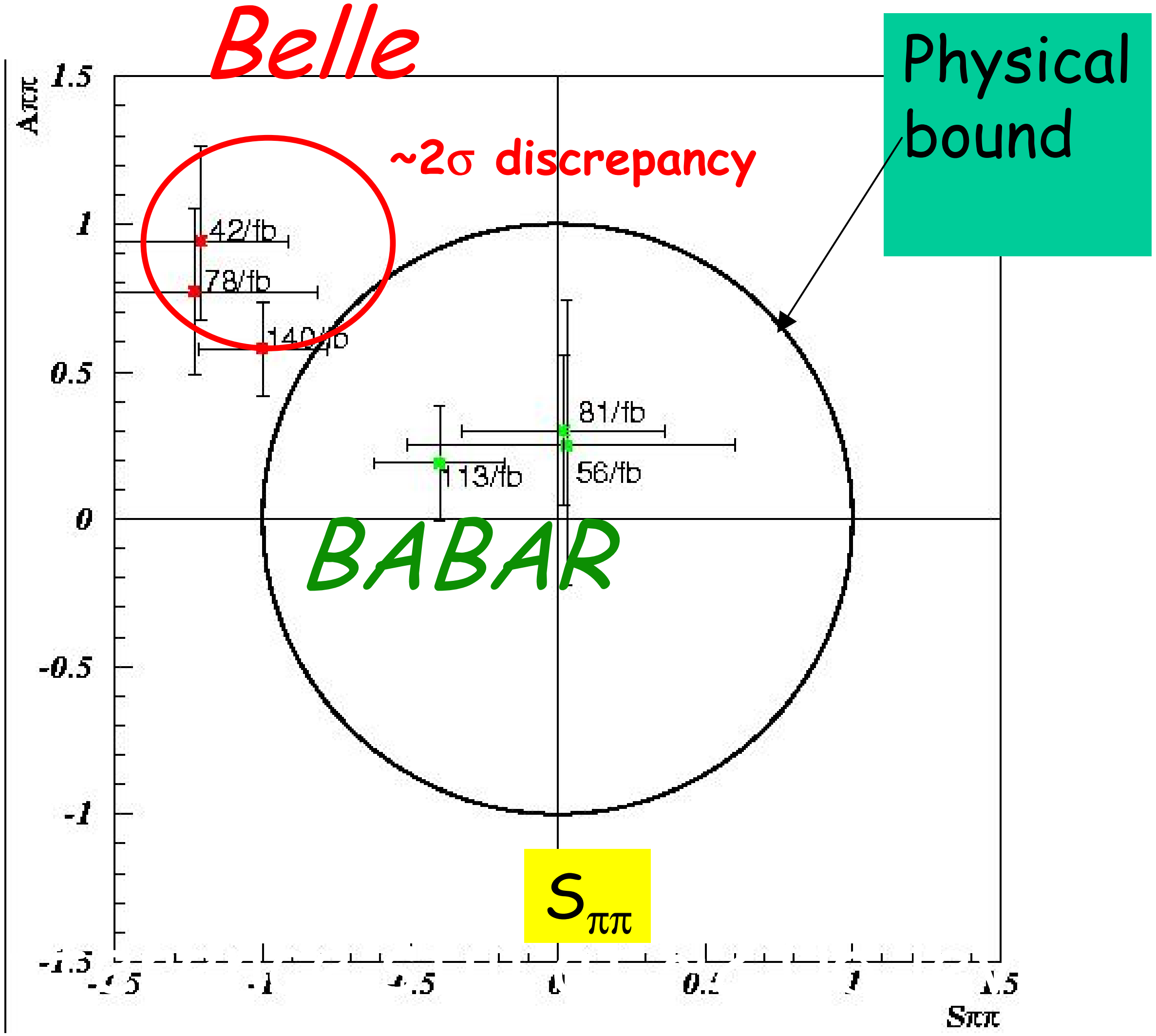
$A_{\pi\pi}=-C_{\pi\pi}$

5.2σ CPV

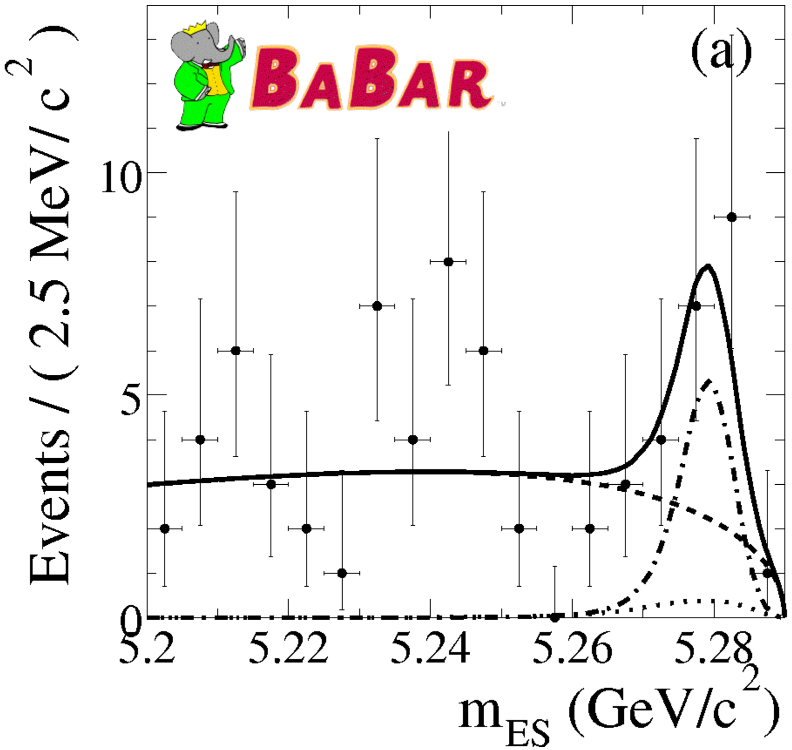
BELLE



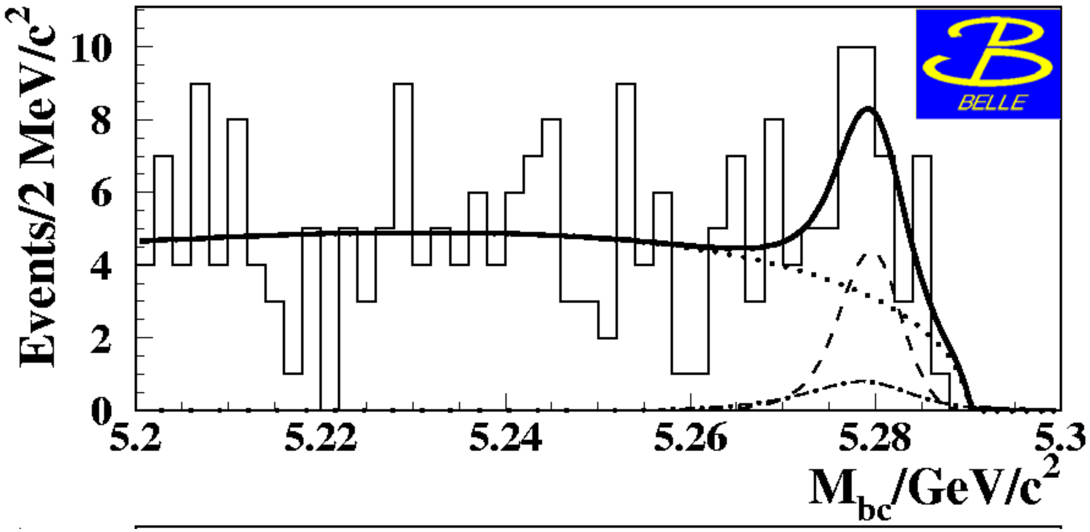
2σ CPV



$\pi^0\pi^0$ has now been seen……



46 +- 13 events
BR = (2.1 +- 0.6 +- 0.3) 10^{-6}
4.2σ significance



26 +- 9 events
BR = (1.7+-0.6+- 0.2) 10^{-6}
3.4σ significance

……but we don't like it !

- Penguin pollution
- Too small for isospin analysis with the present samples
- Too large for useful bound

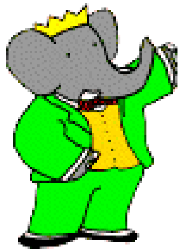
e.g. Grossmann-Quinn bound

$$\sin^2(\alpha_{eff} - \alpha) < \frac{BR(B^0/\overline{B}^0 \to \pi^0\pi^0)}{BR(B^{+-} \to \pi^{+-}\pi^0)}$$

Gives $|\alpha_{eff} - \alpha| < 47°$

90% C.L.
World average

B→ρρ: it gets better….



Mode	BR
$B^0/\bar{B}^0 \to \rho^+\rho^-$	$(30 \pm 4 \pm 5) \times 10^{-6}$
$B^\pm \to \rho^\pm\rho^0$	$(26.4 \pm 6.4) \times 10^{-6}$
$B^0/\bar{B}^0 \to \rho^0\rho^0$	$(0.62^{+0.72}_{-0.60} \pm 0.12) \times 10^{-6}$

Found almost fully longitudinally polarized

- $B \to \rho^0\rho^0$ is <u>very</u> small!
- Grossman-Quinn bound is useful

$|\alpha_{eff} - \alpha| < 16^\circ\ (13^\circ)$ @ 90% (68.3%) C.L.

Belle also has similar measurements

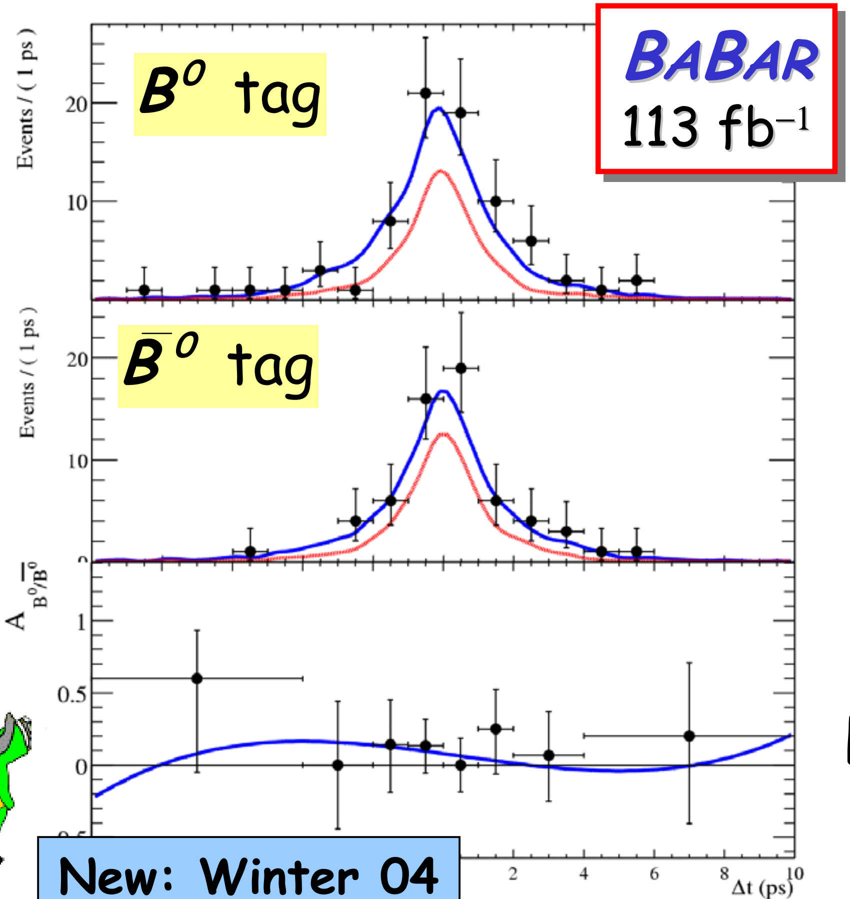
$B^0 \to \rho^+\rho^-$

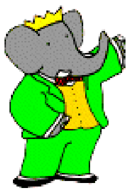
$$S_{long} = -0.19 \pm 0.33_{(stat)} \pm 0.11_{(syst)}$$
$$C_{long} = -0.23 \pm 0.24_{(stat)} \pm 0.14_{(syst)}$$

$BF(B^0 \to \rho^0\rho^0) <$
2.1×10^{-6} (90% CL)

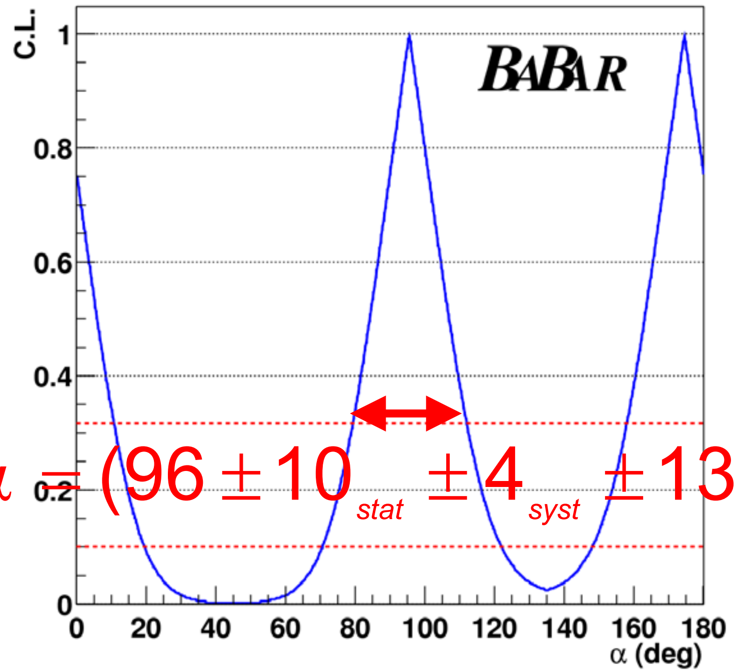
Small!

BABAR
113 fb^{-1}





New: Winter 04



$$\alpha = (96 \pm 10_{stat} \pm 4_{syst} \pm 13_{peng})^\circ$$

Belle $\alpha = 102^{+16+5}_{-12-4} \pm 13(peng)$

- Isospin analysis: interference, NR contributions, I=1 amplitudes neglected

$B\to\pi\pi\pi^0$: Full Dalitz Analysis

Snyder-Quinn Method

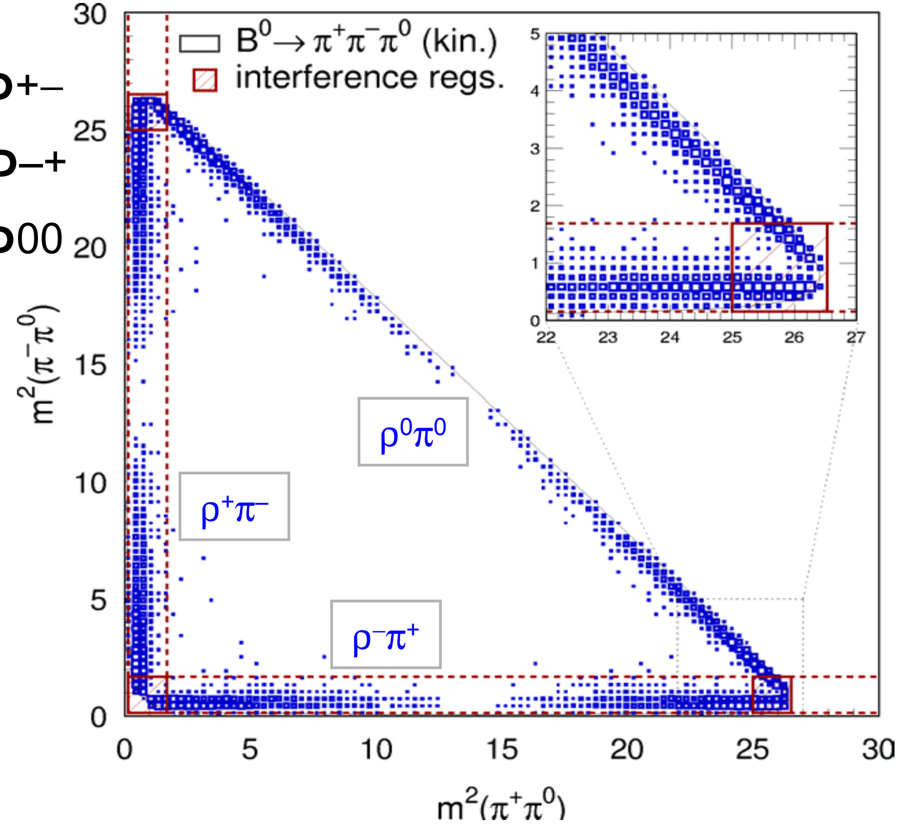
Extract α and the strong phases
using the interference between $B^0 \to \pi^+\pi^-\pi^0$ amplitudes

$$A(B^0\to\rho^+\pi^-) \equiv A^{+-} = T^{+-}e^{-i\alpha} - P^{+-}$$
$$A(B^0\to\rho^-\pi^+) \equiv A^{-+} = T^{-+}e^{-i\alpha} - P^{-+}$$
$$A(B^0\to\rho^0\pi^0) \equiv A^{00} = T^{00}e^{-i\alpha} - P^{00}$$

$\pi^+\pi^-\pi^0$ amplitude parametrization:

$$A_{3\pi} = f_+A^{+-} + f_-A^{-+} + f_0A^{00}$$
$$\overline{A}_{3\pi} = f_+\overline{A}^{+-} + f_-\overline{A}^{-+} + f_0\overline{A}^{00}$$

- The $f_{+,-,0}$ are relativistic Breit-Wigner form factors



σ_α~25° in 113 fb^{-1} without ambiguity (BaBar estimate)

α status and prospects

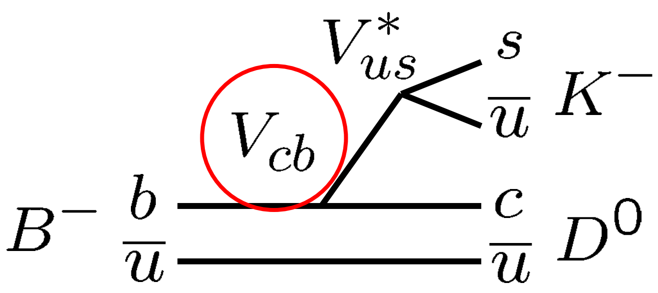
- Too much penguin pollution in $B \to \pi\pi$
- Observed $B \to \pi^0\pi^0$ but
  - More statistics needed for Isospin analysis
  - Too large for useful $|\alpha_{eff} - \alpha|$ bound
- Situation looks better in $B \to \rho\rho$
  - Longitudinally polarized, CP eigenstate
  - Very small $B \to \rho^0\rho^0$ indicate small penguin pollution
- Other approaches also in the works.

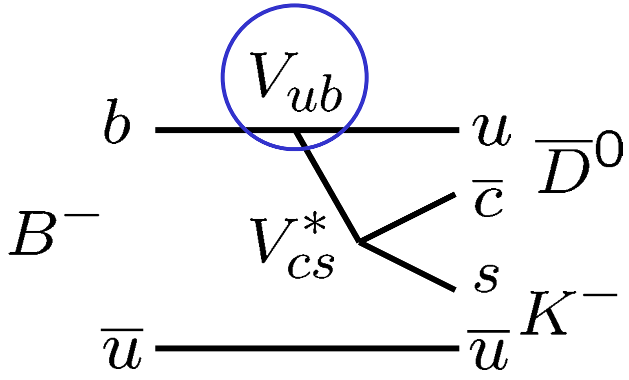
Toward a γ determination

See also M.Rama talk

- *The challenge*: directly measure the $b \to u$ phase (γ) relative to the $b \to c$ phase (0).

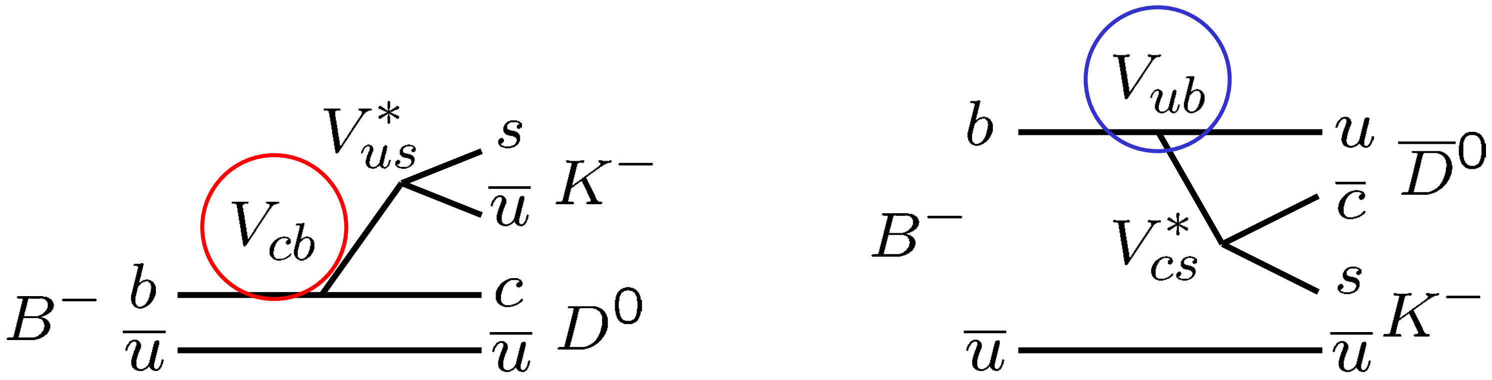
- Most straightforward tool: $B \to DK$





- These amplitudes *interfere* for D final states that both D^0 and $\overline{D}^0$ can decay to.

γ from B→DK

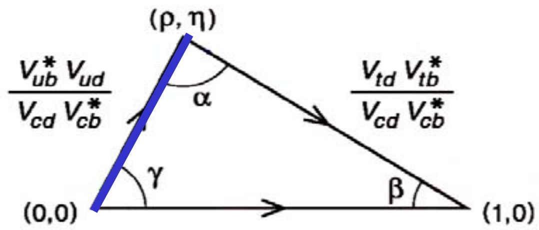


- Relative size of B decay amplitudes

$$r_b \equiv \left| \frac{A(b \to u)}{A(b \to c)} \right| = R_u\, F_{cs}$$

R_u is the left side of the Unitarity Triangle (~0.4).

F_{cs} is an *unknown* color-suppression factor. Expected to be in the range [0.2,0.5].



- Want r_b to be large to get more interference.

γ from B→DK: GLW method

- Gronau, London, and Wyler: use D decays to CP eigenstates.

Equal D^0 and $\overline{D}^0$ decay amplitudes by construction.

$$\begin{cases} D_+^0 = (D^0 + \overline{D}^0)/\sqrt{2} \\ D_-^0 = (D^0 - \overline{D}^0)/\sqrt{2} \end{cases}$$

CP even: $\pi^+\pi^-, K^+K^-$

CP odd: $K_s\pi^0$, $K_s\rho^0$

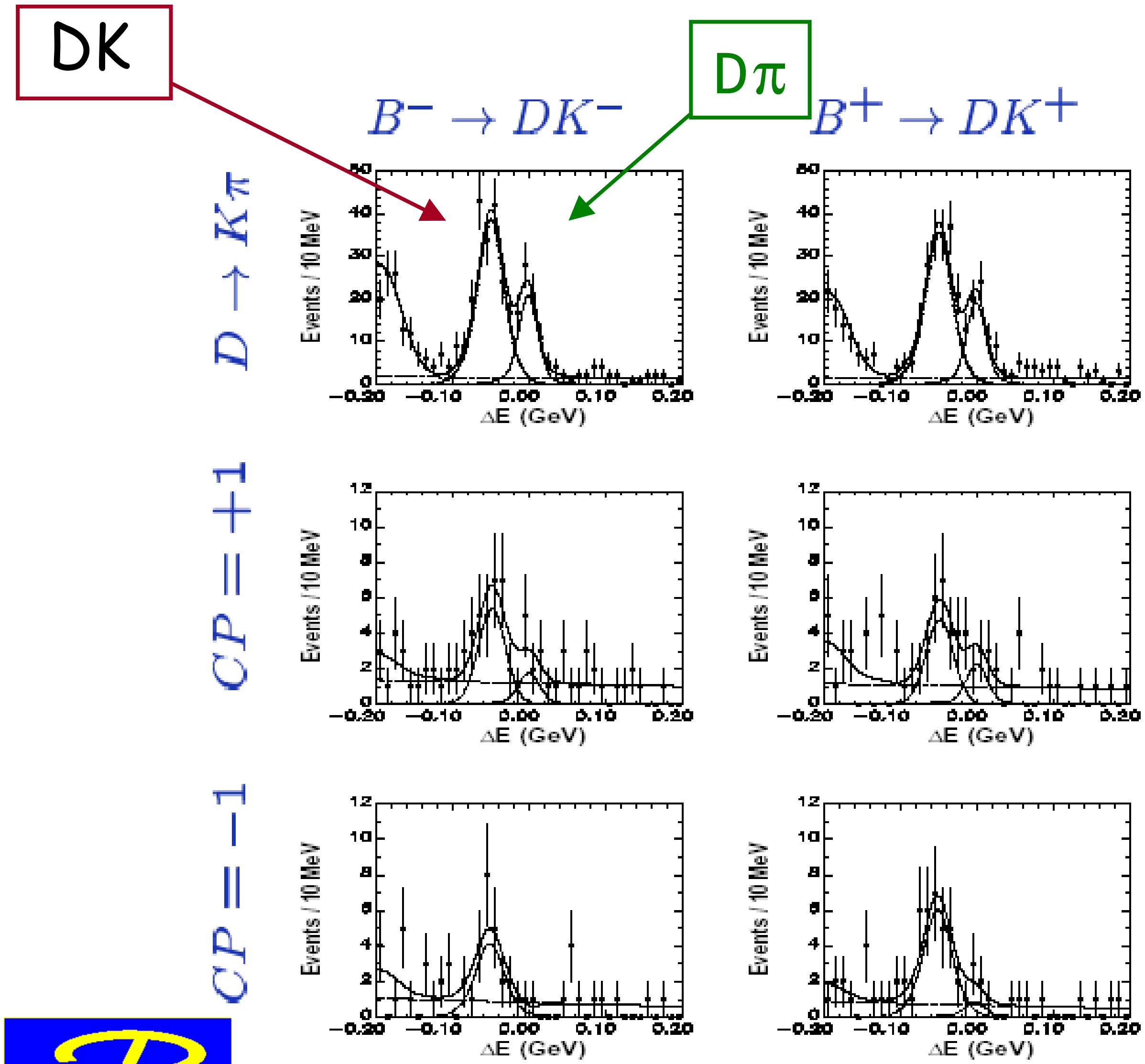
$$R_\pm = \frac{\mathcal{B}(D_\pm^0 K^-) + \mathcal{B}(D_\pm^0 K^+)}{\mathcal{B}(D^0 K^-) + \mathcal{B}(D^0 K^+)} = 1 + r_b^2 \pm 2\, r_b \cos\delta_b \cos\gamma$$

$$A_\pm = \frac{\mathcal{B}(D_\pm^0 K^-) - \mathcal{B}(D_\pm^0 K^+)}{\mathcal{B}(D_\pm^0 K^-) + \mathcal{B}(D_\pm^0 K^+)} = \pm\, 2\, r_b \sin\delta_b \sin\gamma / R_\pm$$

4 equations, 3 unknown

δ_b = strong phase diff

GLW Method: Belle Analysis



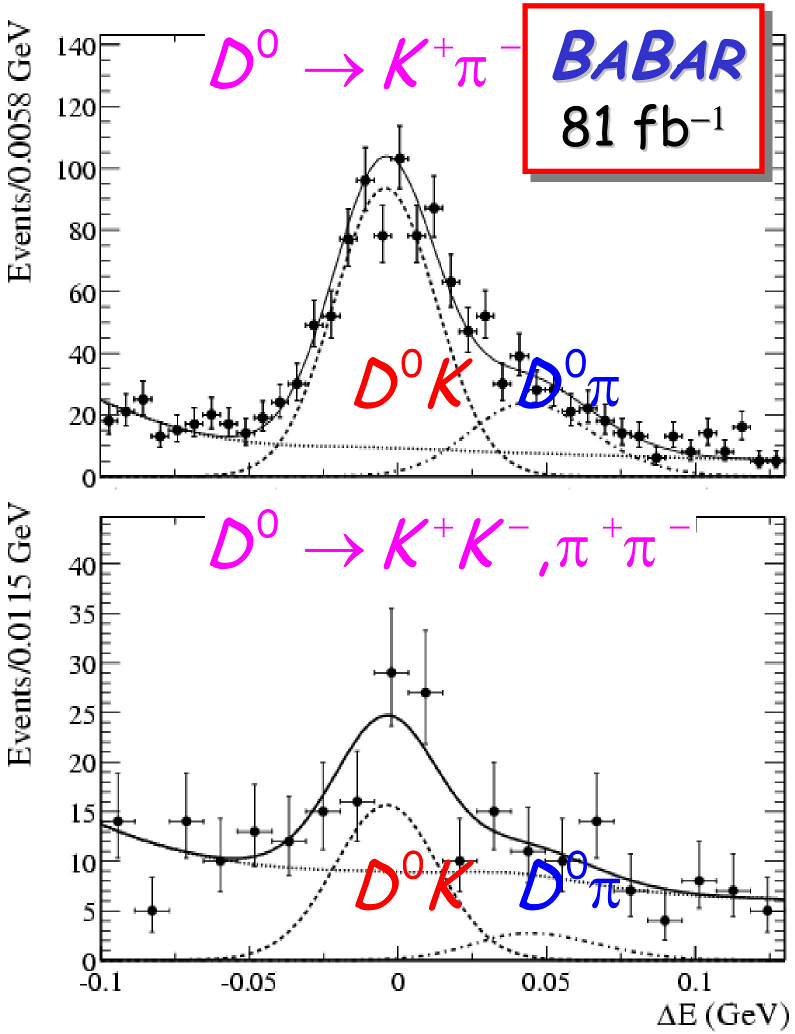
$D \to K\pi$

$D \to K^+K^-, \pi^+\pi^-$

$D \to K_S\pi^0, K_S\phi, K_S\omega, K_S\eta, K_S\eta'$

O(90M) BB pairs

GLW: BaBar Analysis



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

Comparing BaBar vs Belle

	BABAR [81fb^{-1}]	Belle [78 fb^{-1}]
R_+	1.06±0.19±.06	1.21±0.25±0.1
A_{CP+}	0.07±0.17±.06	0.06±.19±.04
R_-	*	1.41±.27±0.15
A_{CP-}	*	0.19±.17±0.05

*Coming soon

Good agreement within large errors

γ from B→DK: ADS method

- Atwood, Dunietz, and Soni: equalize the interfering amplitudes

favored: $B^- \to D^0 K^-$ — suppressed: $D^0 \to K^+\pi^-$

suppressed: $B^- \to \overline{D}^0 K^-$ — favored: $\overline{D}^0 \to K^+\pi^-$

→ $[K^+\pi^-]_D K^-$

$$R_{ADS} = \frac{\mathcal{B}([K^+\pi^-]K^-) + \mathcal{B}([K^-\pi^+]K^+)}{\mathcal{B}([K^-\pi^+]K^-) + \mathcal{B}([K^+\pi^-]K^+)} = r_d^2 + r_b^2 + 2\, r_b r_d \cos(\delta_b + \delta_d) \cos\gamma$$

$$A_{ADS} = \frac{\mathcal{B}([K^+\pi^-]K^-) - \mathcal{B}([K^-\pi^+]K^+)}{\mathcal{B}([K^-\pi^+]K^-) + \mathcal{B}([K^+\pi^-]K^+)} = 2\, r_b r_d \sin(\delta_b + \delta_d) \sin\gamma / R_{ADS}$$

δ_d charm strong phase

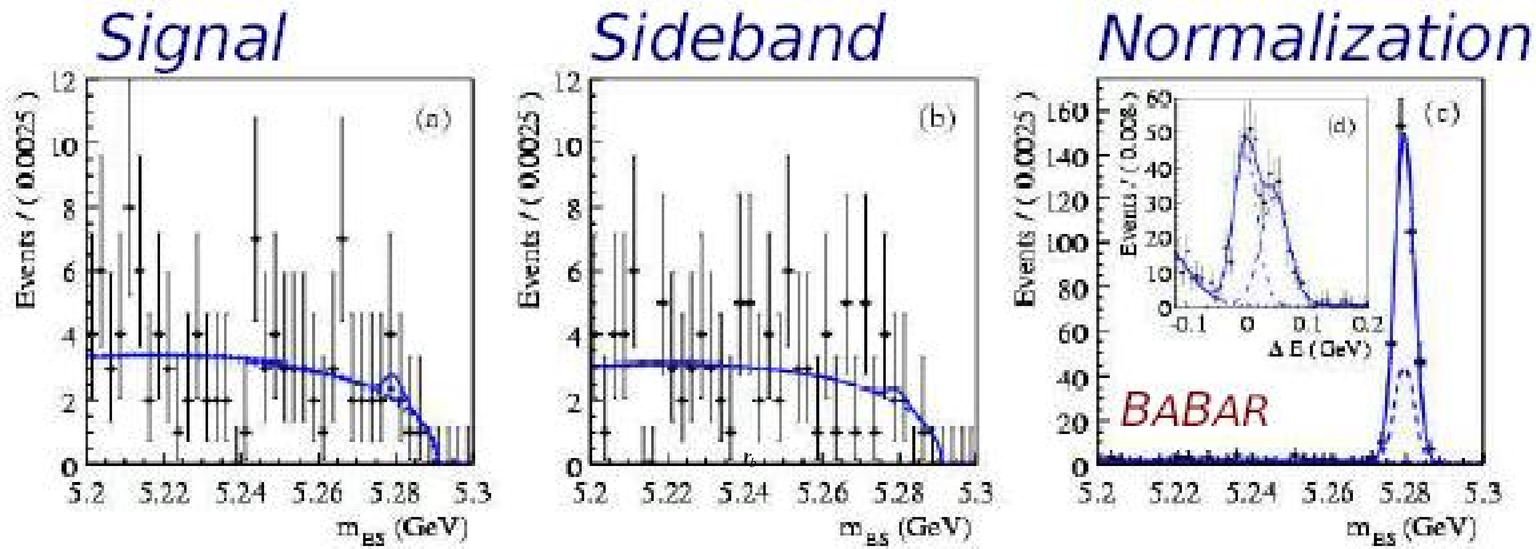
$$r_d^2 = \frac{BR(D^0 \to K^+\pi^-)}{BR(D^0 \to K^-\pi^+)} \cong 4 \cdot 10^{-3}$$

GLW	ADS
$R_\pm \; \mathcal{O}(1 \pm r_b)$	$R_{ADS} \; \mathcal{O}(r_b^2)$
$A_\pm \; \mathcal{O}(\pm r_b)$	$A_{ADS} \; \mathcal{O}(1)$

Complementary to GLW

ADS: $B^- \to D^{(*)0}K^-$

109 fb-1

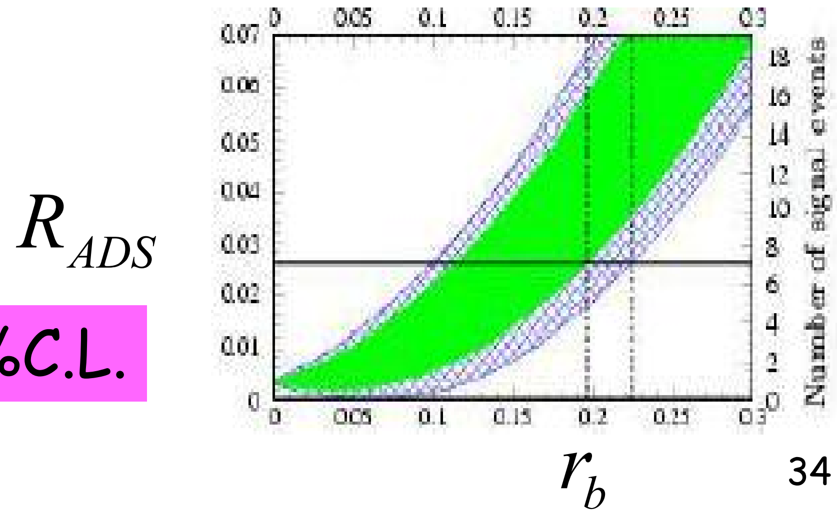


Signal consistent with zero N=1.1+-3.0

$R_{ADS} < 0.026$

$r_b < 0.22$

90%C.L.



A promising method

Giri, Grossman,Soffer,Zupan+ Belle

Interference in the Dalitz plot of

$B^- \to D^0/\bar{D}^0 K^-$ with $D^0/\bar{D}^0 \to K_S \pi^+ \pi^-$.

$B^- \to D^0 K^-$ $\qquad$ $B^- \to \bar{D}^0 K^-$

$$A(B^-) = f(M_-^2, M_+^2) + r_B e^{i(\delta - \gamma)} f(M_+^2, M_-^2)$$

$$A(B^+) = f(M_+^2, M_-^2) + r_B e^{i(\delta + \gamma)} f(M_-^2, M_+^2)$$

$B^+ \to \bar{D}^0 K^+$ $\qquad$ $B^+ \to D^0 K^+$

$M^\pm$=invariant mass($K_s\pi^\pm$)
f =Dalitz D decay amplitude

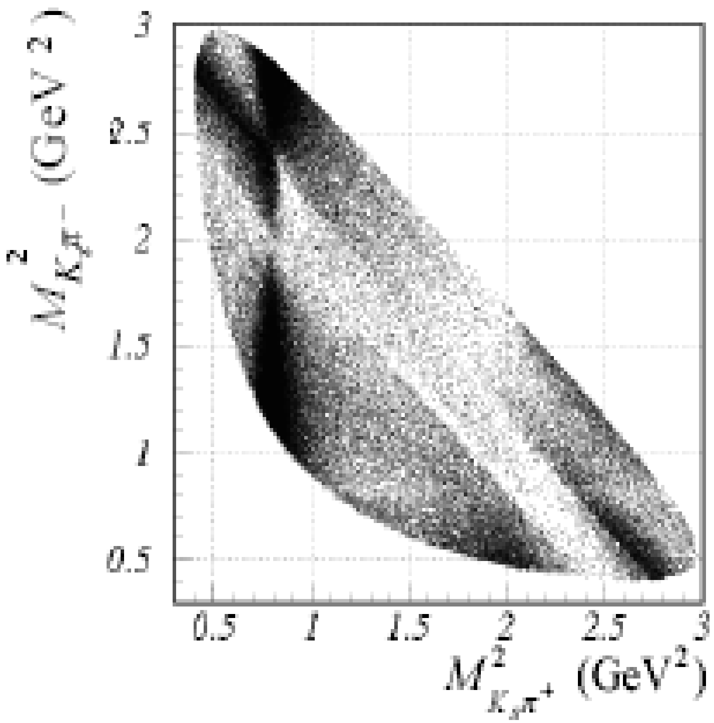
Both interfering D° amplitudes Cabibbo-favored

No CP violation in D° assumed

Determining the $D^0 \to K_s\pi^+\pi^-$ amplitude

High statistics $D^{*-} \to D^0\pi^-$ from $e^+e^- \to c\bar{c}$ process

f = sum of resonances



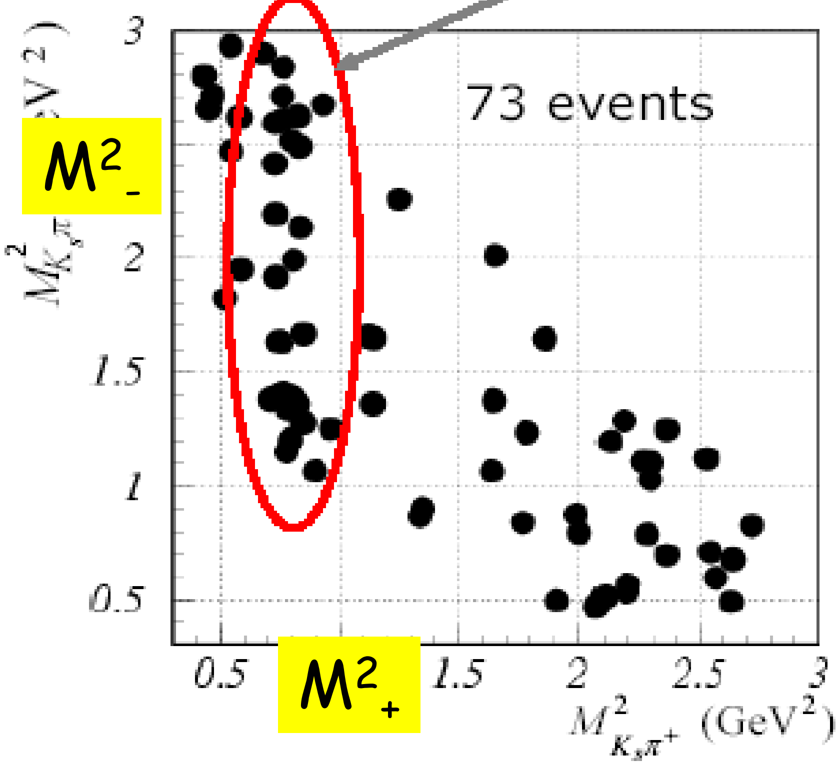
Resonance	Our fit		
	Amplitude	Phase, °	Fit fraction
$\sigma_1 K_s$	1.66±0.11	218.0±3.8	11%
$\rho(770) K_S$	1	0	21%
ωK_s	(3.30±1.13)·10^{-2}	114.3±2.3	0.4%
$f_0(980) K_s$	0.405±0.008	212.9±2.3	4.8%
$\sigma_2 K_s$	0.31±0.05	236±11	0.9%
$f_2(1270) K_s$	1.36±0.06	352±3	1.5%
$f_0(1370) K_s$	0.82±0.10	308±8	0.9%
$K^*(892)^-\pi^+$	1.656±0.012	137.6±0.6	60%
$K^*(892)^+\pi^-$	0.149±0.007	325.2±2.2	0.5%
$K^*_0(1430)^-\pi^+$	1.96±0.04	357.3±1.5	5.8%
$K^*_0(1430)^+\pi^-$	0.30±0.05	128±8	0.1%
$K^*_2(1430)^-\pi^+$	1.32±0.03	313.5±1.8	2.8%
$K^*_2(1430)^+\pi^-$	0.21±0.03	281.5±9	0.07%
$K^*(1680)^+\pi^-$	2.56±0.22	70±6	0.4%
$K^*(1680)^-\pi^+$	1.02±0.22	102±11	0.07%
Non resonant	6.1±0.3	146±3	24%

some model dependency

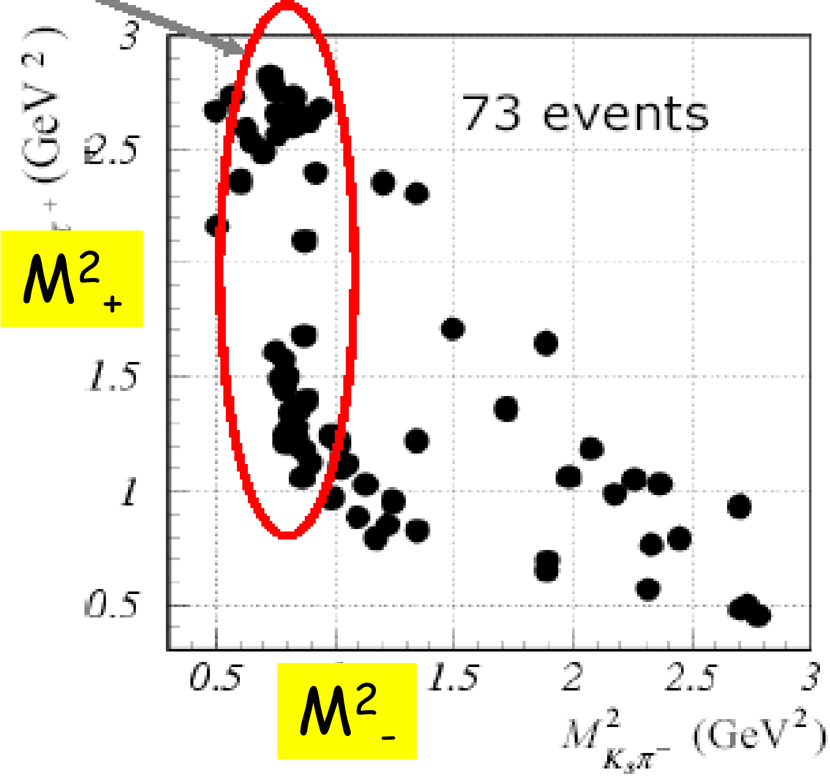
$B^{\pm} \rightarrow D^0 \overline{D^0} K$

$D^0 \overline{D^0} \rightarrow K_s \pi^+ \pi^-$

$K^*(892)$ bands



D^0 from $B^+ \rightarrow D^0 K^+$



D^0 from $B^- \rightarrow D^0 K^-$
(π^+ and π^- interchanged)

$\Phi_3 = (86 \pm 23)^0$ 1σ $r_b = 0.26^{+0.10}_{-0.14}$

In agreement with Babar

$(77^{+17}_{-19} \pm 13 \pm 11)°$ combining with D* sample

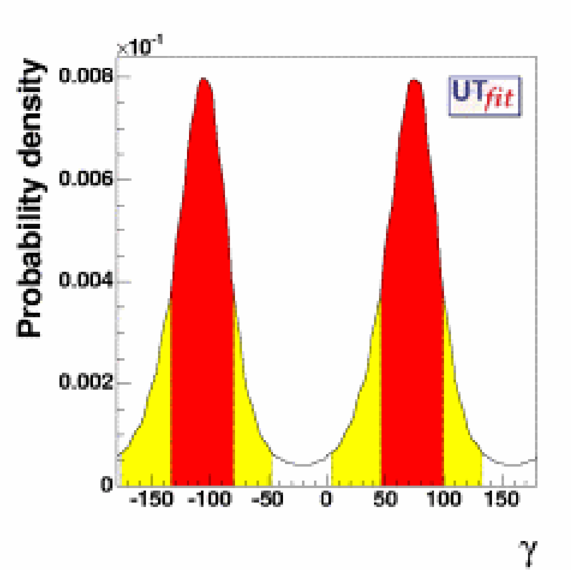
Fitting All Together (GLW+ADS+DALITZ)

Probability Density function

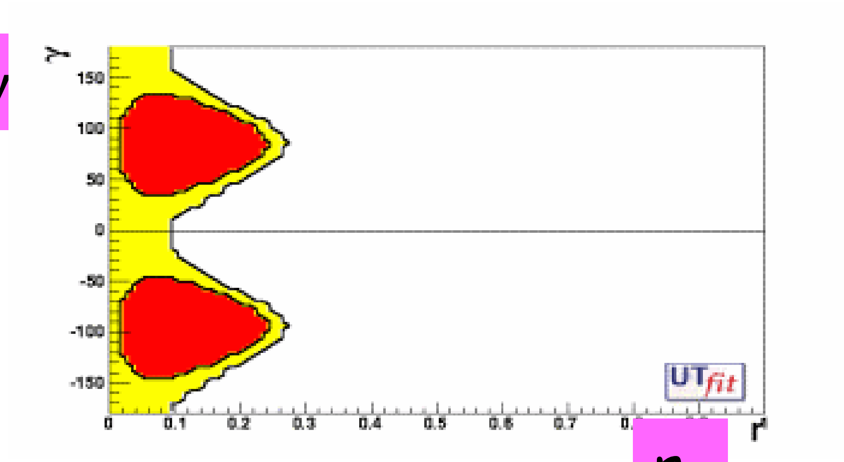
courtesy of

www.utfit.org

68% 95%

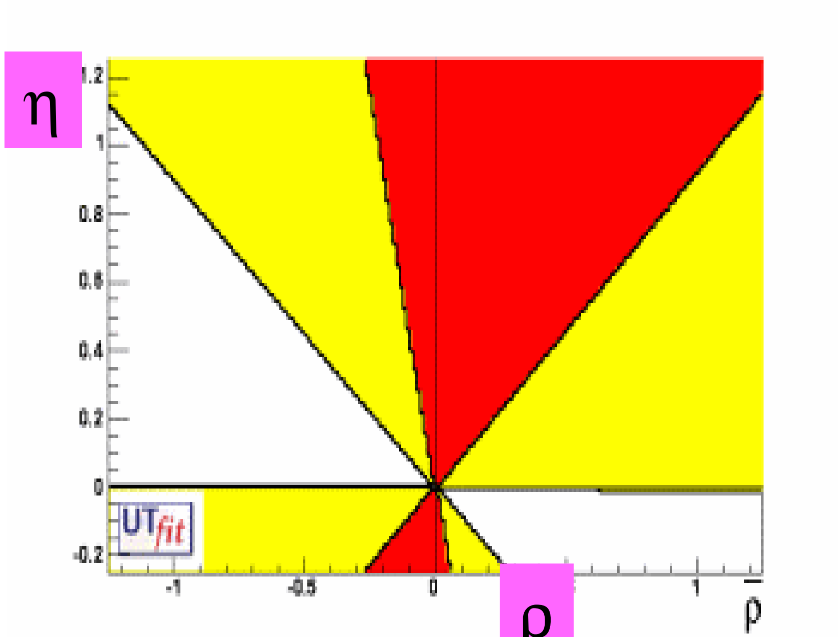


γ

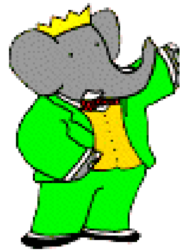


r_b

Drawn into the ρ–η plane



Summary and Conclusions



- sin2β in charmonium modes is now a precision measurement

  sin2β=0.736±0.049 world av.

- Hints of discrepancy between charmonium and penguin modes ? (see next talk)
- First measurement of α (with assumptions):

  $\alpha = 96^{o} \pm 10^{o}$ (stat.) $\pm 4^{o}$ (syst.) $\pm 13^{o}$ (penguin)

  Very preliminary, neglecting interference, NR contribution

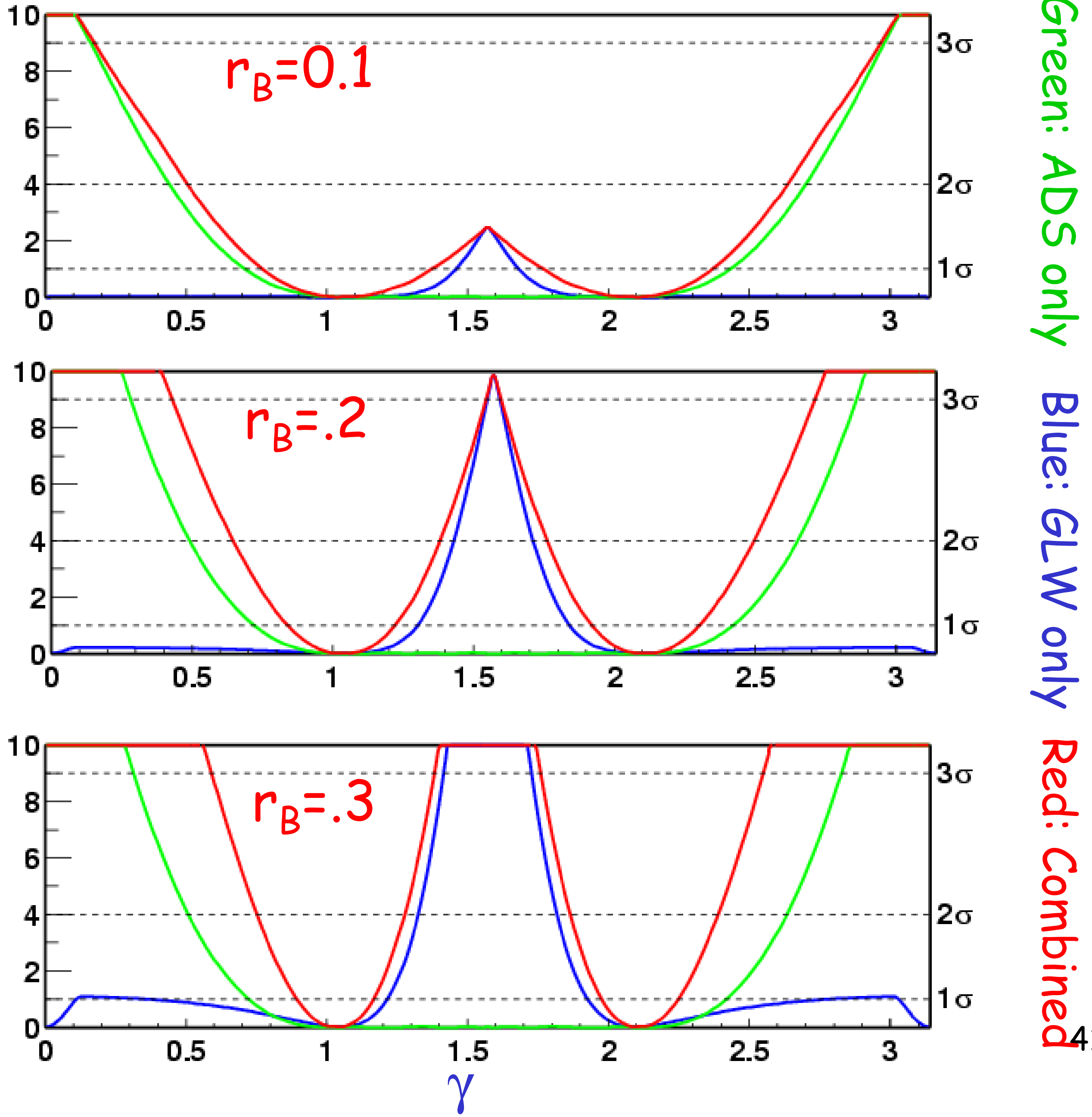
- New techniques to measure γ being developed

  -γ determination looks difficult

  -need huge statistics

Back-up Slides

Some extrapolations: good scenario



Inputs:

γ = 60°

δ_B = 0°

δ_D=250°

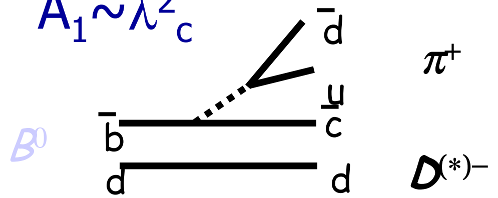
500 fb^{-1}

Measurements of γ

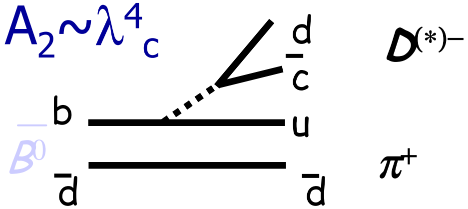
See M.Rama talk

- Contributions from $b \rightarrow u$ transitions bring a dependence of CPV from γ
  - *Measure γ in direct CP asymmetries in charged B decay rates*
  - *Measure $2\beta+\gamma$ with CPV in mixing*
- Two cases

$A_1 \sim \lambda^2{}_c$

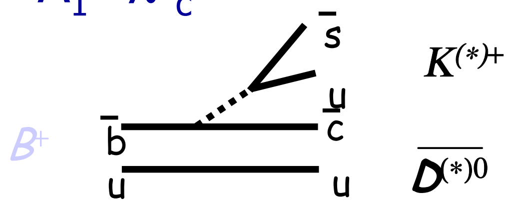


$A_2 \sim \lambda^4{}_c$

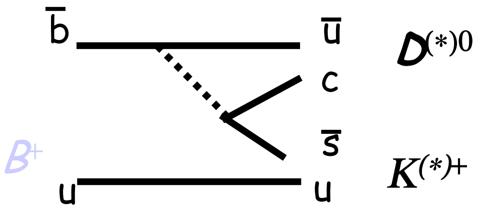


$\sin 2\beta+\gamma$: A_2 doubly cabibbo suppressed

$A_1 \sim \lambda^3{}_c$



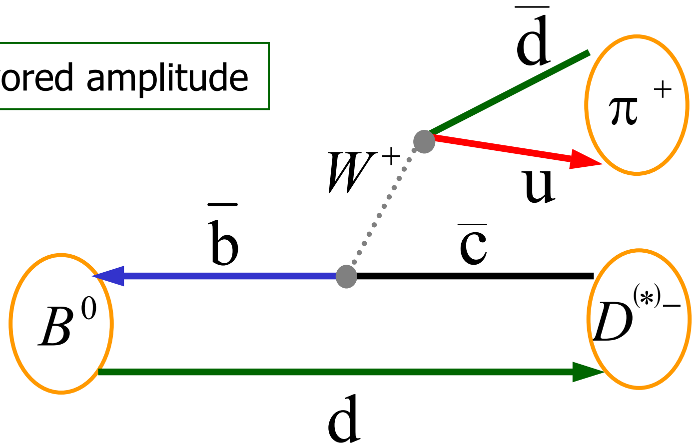
$A_2 \sim \lambda^3{}_c$



$\sin\gamma$: A_2 colour suppressed

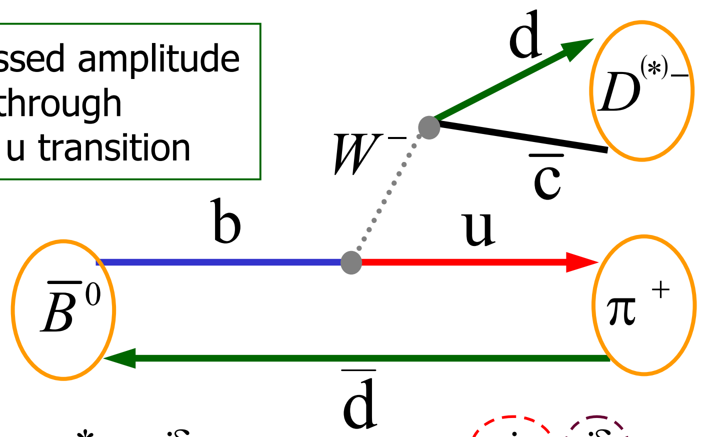
Measuring γ in B->D(*)π

Favored amplitude



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

Suppressed amplitude through b → u transition

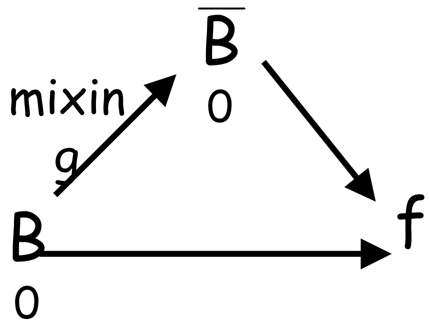


$$V_{ub}V_{cd}^{*}\, e^{i\delta} = r_{(*)}\, A\, e^{-i\gamma} e^{i\delta}$$

CKM angle

Strong phase difference

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



Sin(2β+γ)>0.89 @68.3% C.L.
Sin(2β+γ)>0.76@ 90.0% C.L.

B^0 system

Evidences of from $D^{(*)}K^{(*)0}$

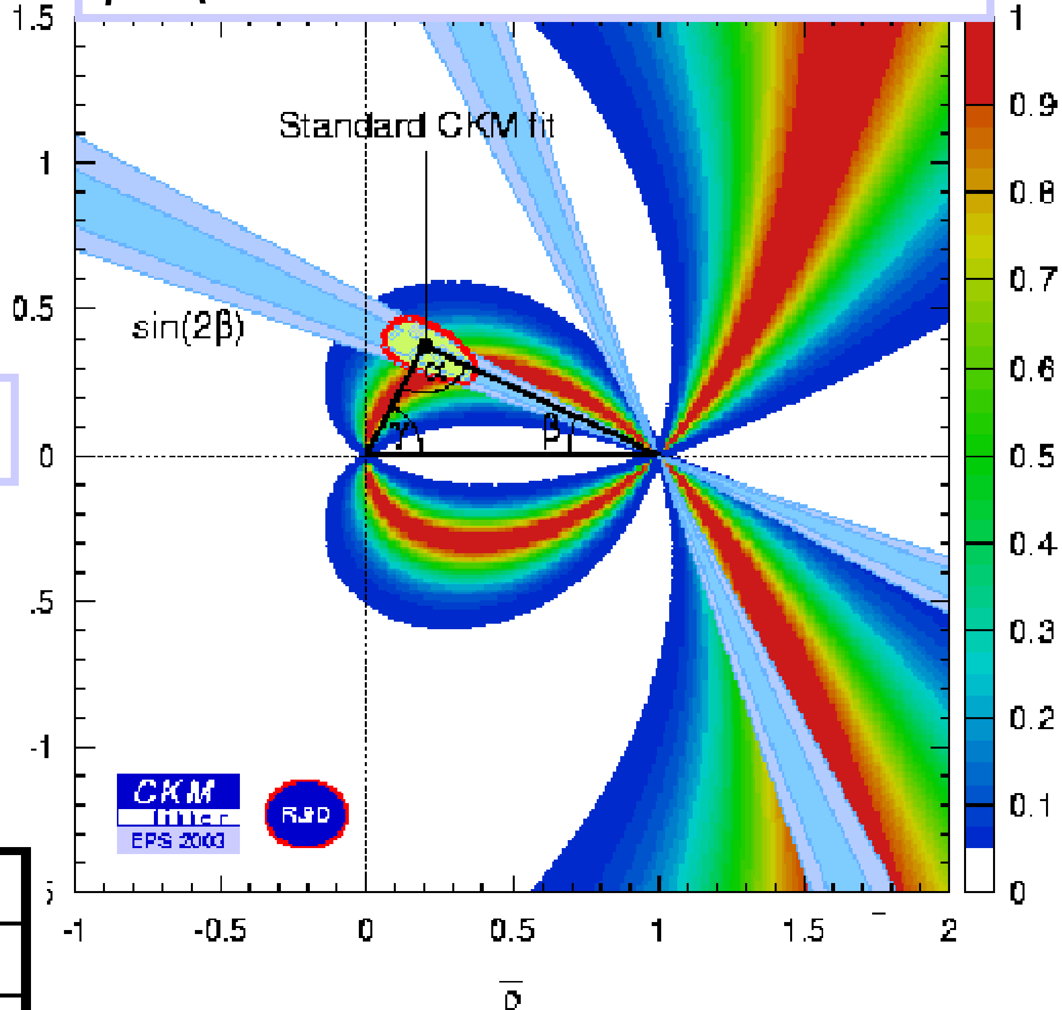
Mode	Br(x10^{-5}) Belle	Br(x10^{-5}) BaBar
$B^0 \to \bar{D}^0 K^{*0}$	4.8 ±1.1 ±0.5	3.0 ±1.3 ±0.6
$B^0 \to \bar{D}^0 K^0$	5.0 ±1.3 ±0.6	3.4 ±1.3 ±0.6

BELLE

V_{ub}

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

ρ–η constraints from $D^{(*)}\pi$



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

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

BaBar