Measurement Of
Sin2α (Sin2ϕ_2) And Rare Hadronic B Decays At BaBar and Belle

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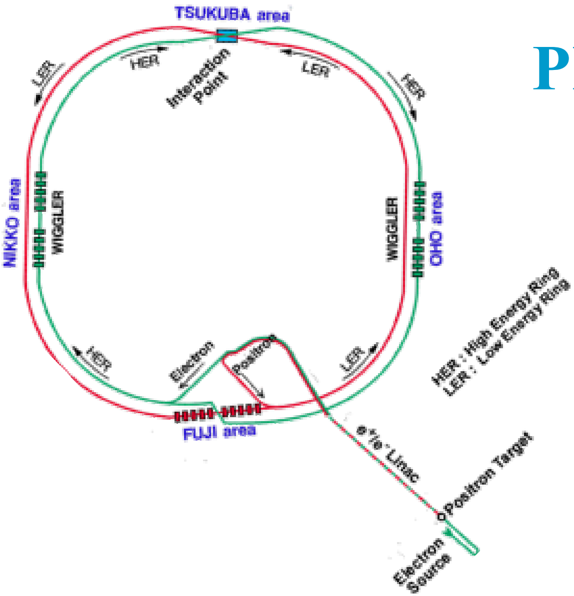
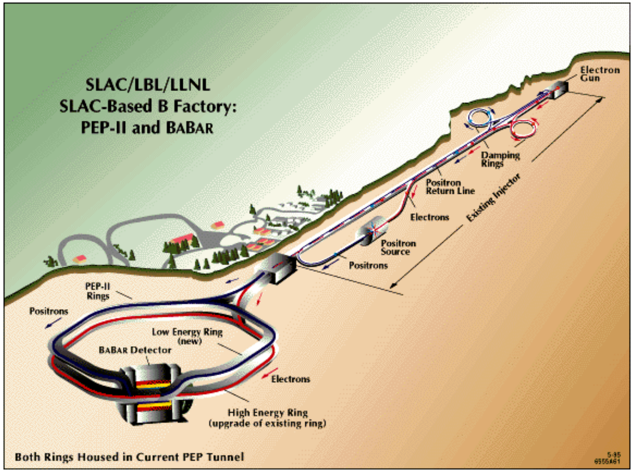
Physics In Collision XXIII
Zeuthen



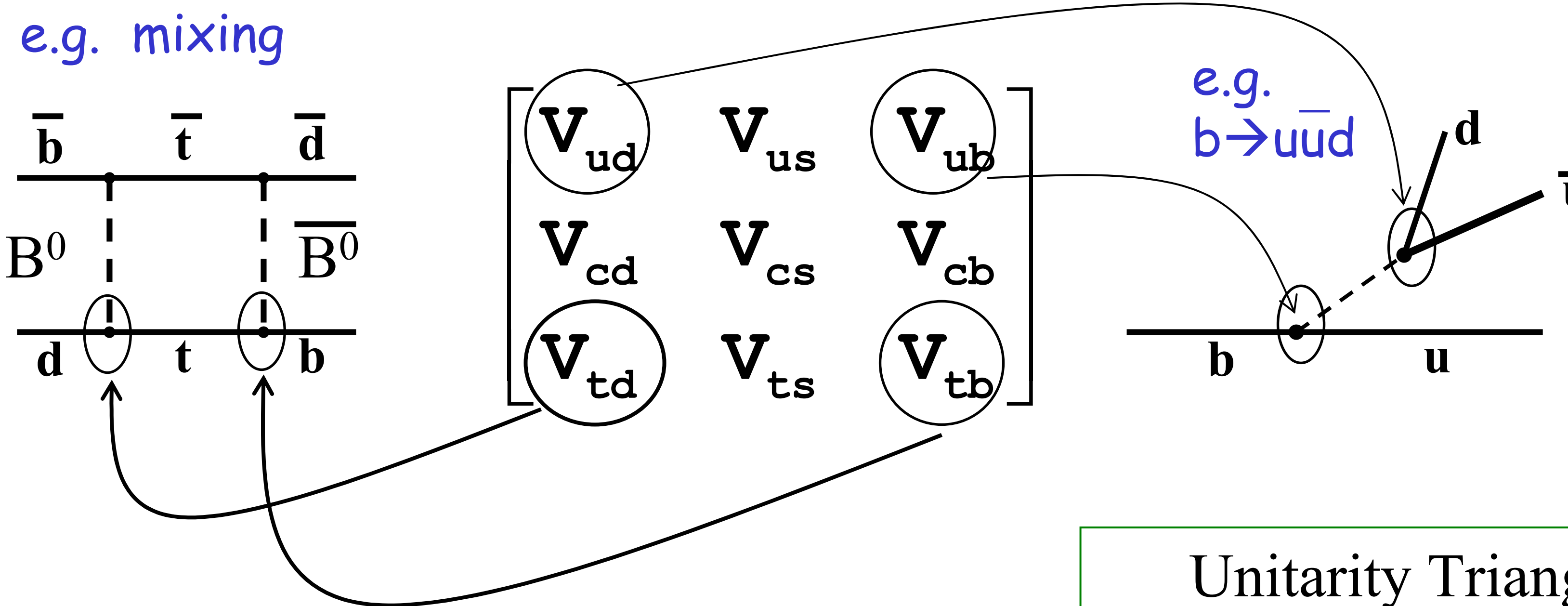


Outline

- Introduction
- $\sin 2\alpha_{eff}$ measurements in $B \rightarrow \pi\pi$
- $\sin 2\alpha_{eff}$ measurements in $B \rightarrow \rho\pi$
- Branching Fractions For Rare Hadronic B Decays
- Charge asymmetries.
- Summary

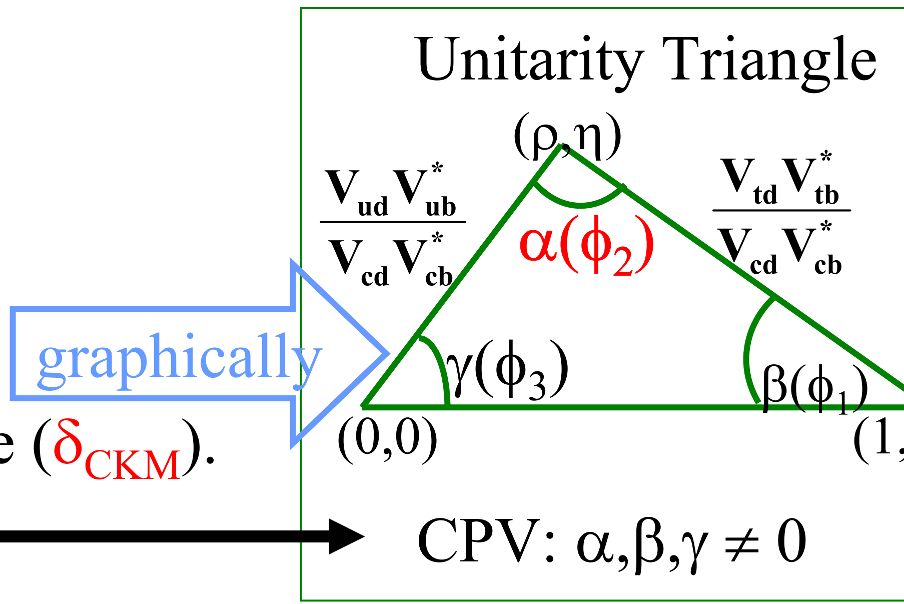
CP Violation And The Standard Model

SM weak interactions among quarks are controlled by CKM matrix:



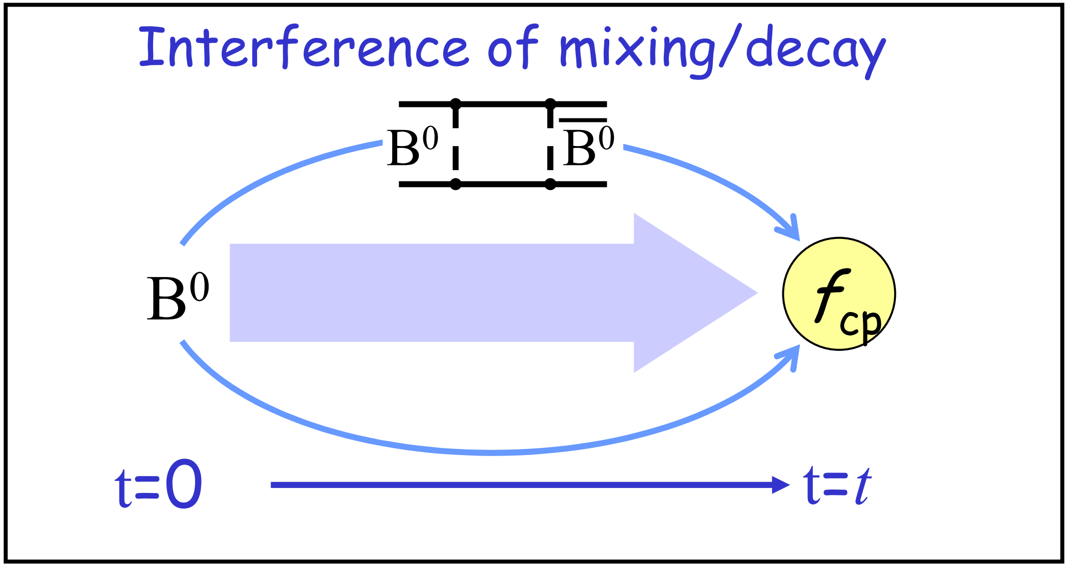
Constraints on the CKM matrix:

- unitarity:
  e.g. $V_{ud}V_{ub}^{*}+V_{cd}V_{cb}^{*}+V_{td}V_{tb}^{*}=0$
- only 4 free parameters left, including an undetermined phase (δ_{CKM}).



CPV ⇔ $\delta_{CKM} \neq 0$

CP Violation In Neutral B System



Interference term λ_{fcp}

$$\lambda_{f_{CP}} = \frac{q}{p} \cdot \frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}}$$

"Mixing Phase" ($\frac{q}{p}$)

Decay Amplitu[de] Ratio ($\frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}}$)

$\lambda_{fcp} \neq 1$ ➔ CPV

$$A_{CP}(t) \equiv \frac{\Gamma(\overline{B}^0(t) \to f_{CP}) - \Gamma(B^0(t) \to f_{CP})}{\Gamma(\overline{B}^0(t) \to f_{CP}) + \Gamma(B^0(t) \to f_{CP})} = -C_{fcp}\cos(\Delta m t) + S_{fcp}\sin(\Delta m t)$$

$$C_{f_{CP}} = \frac{1 - |\lambda_{f_{CP}}|^2}{1 + |\lambda_{f_{CP}}|^2}$$

Probe of "direct CP violation"

$|\lambda_{fcp}| \neq 1$ ➔ CPV

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

Sensitive to the phase of λ

Im (λ) ≠ 0 ➔ CPV

Rare Hadronic Decays

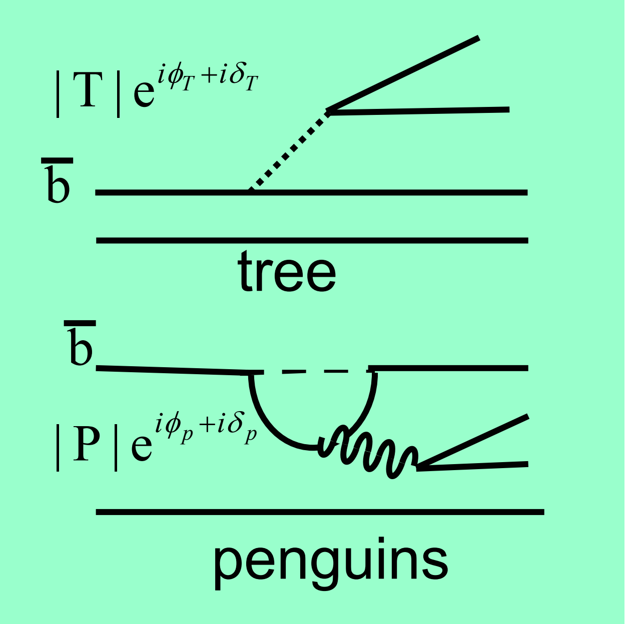
- Suppressed at tree(T) level due to Cabbibo, FCNC, etc.
- Significant Penguin (P) contribution.
- Broad physics interests:
  - Measure CP phases:

    Angle $\alpha(\phi_2)$: $B \to \pi\pi$, $\rho\pi$, $\rho\rho$

    Angle $\beta(\phi_1)$: $B \to \eta' K$, ϕK (see K. Abe's talk)

    Angle $\gamma(\phi_3)$: $B \to K\pi$, $\pi\pi$
  - Direct CPV via $A_{CP} = (\overline{B}-B)/(\overline{B}+B)$
  - Probes new physics in the loop.
  - Test hadronic models:

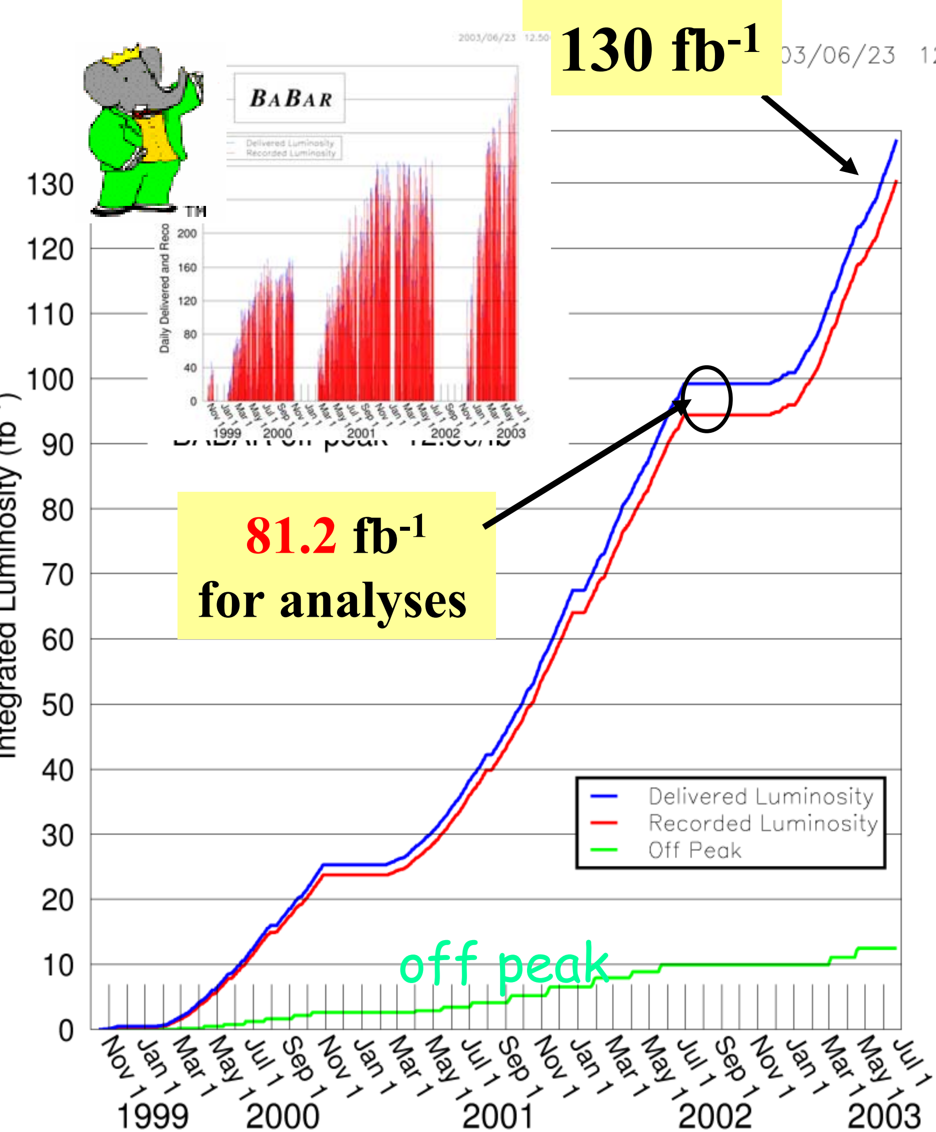
    SU(2)/SU(3) symmetry, QCD factorization, FSI…

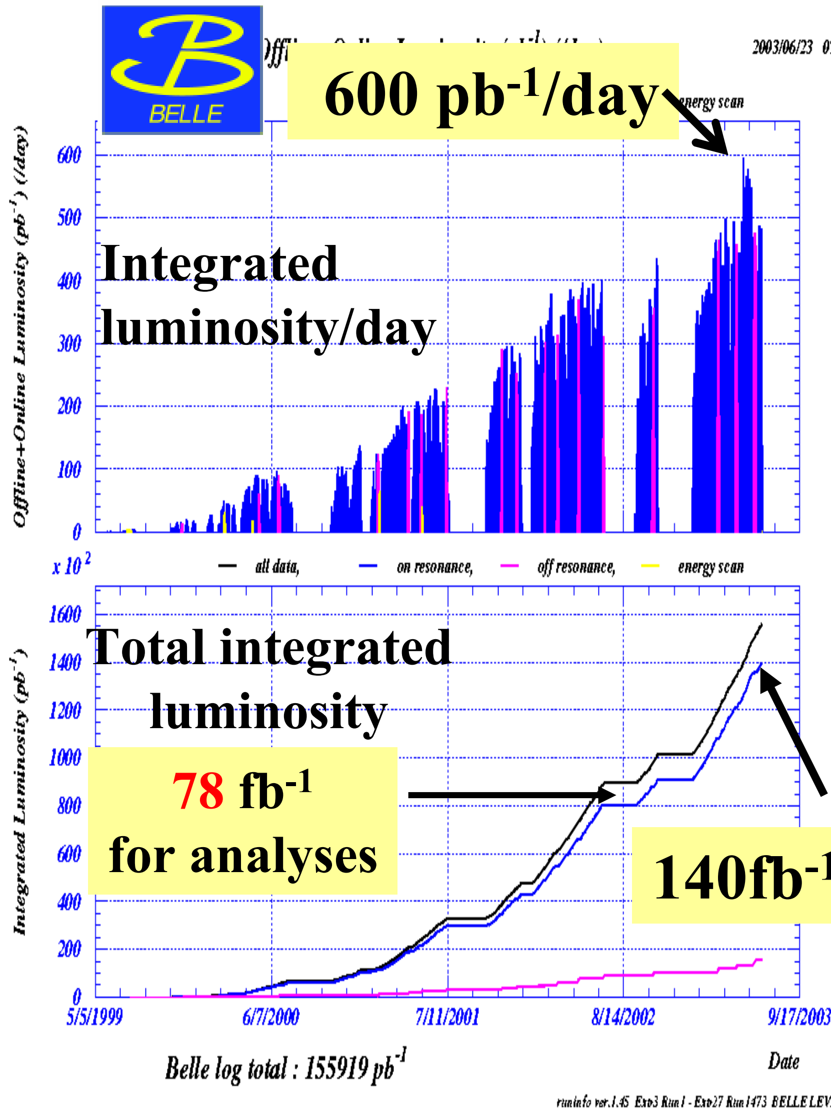


- Modes of interests (all charmless):
  - $B \to hh$ ($h=K,\pi$)
  - $B \to \rho\ \pi/K^{(*)}/\rho$
  - $B \to \eta^{(\prime)}/\omega/\phi\ K^{(*)}/\pi$
  - Also: $B \to$ baryons

This talk:
More slides on
CPV in $B \to \pi\pi$ and $\rho\pi$

Luminosity





>130 fb^{-1}/exp for analyses by summer

CP Violation In $B^0 \to \pi^+\pi^-$ ← CP=+1

- Time dependent asymmetry:
  $A_{CP}(t) = -C_{\pi\pi}\cos(\Delta m t) + S_{\pi\pi}\sin(\Delta m t)$

$$e^{i2\alpha} = \frac{V_{tb}^* V_{td} V_{ud}^* V_{ub}}{V_{tb} V_{td}^* V_{ud} V_{ub}^*}$$

$$C_{\pi\pi} = \frac{1-|\lambda_{\pi\pi}|^2}{1+|\lambda_{\pi\pi}|^2}, \quad S_{\pi\pi} = \frac{2\,\mathrm{Im}\,\lambda_{\pi\pi}}{1+|\lambda_{\pi\pi}|^2}, \quad \lambda_{\pi\pi} = e^{i2\alpha}\frac{1+|P/T|e^{i\delta}e^{i\gamma}}{1+|P/T|e^{i\delta}e^{-i\gamma}}$$

$$= \lambda_{\pi\pi}(\alpha, \beta, |P/T|, \delta)$$

δ: strong phase difference

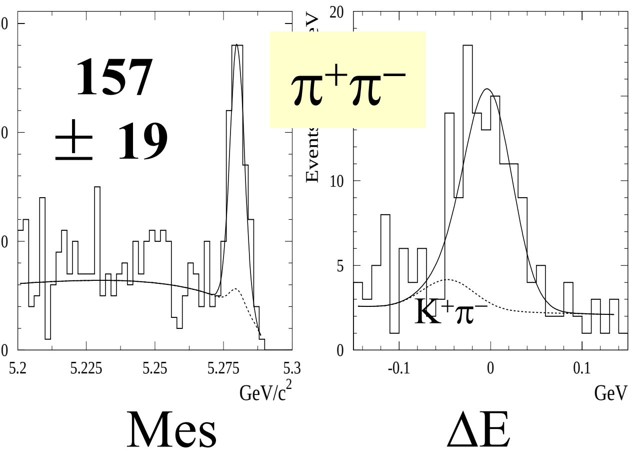
- Tree only: $\lambda_{\pi\pi} = e^{i2\alpha}$, $C_{\pi\pi} = 0$, $S_{\pi\pi} = \sin(2\alpha)$

- With penguin: $C_{\pi\pi} \neq 0$, $S_{\pi\pi} = 2\sin(2\alpha_{eff})/(1+|\lambda_{\pi\pi}|^2)$
  if $\delta \neq 0$

α to be extracted from α_{eff} with additional information.

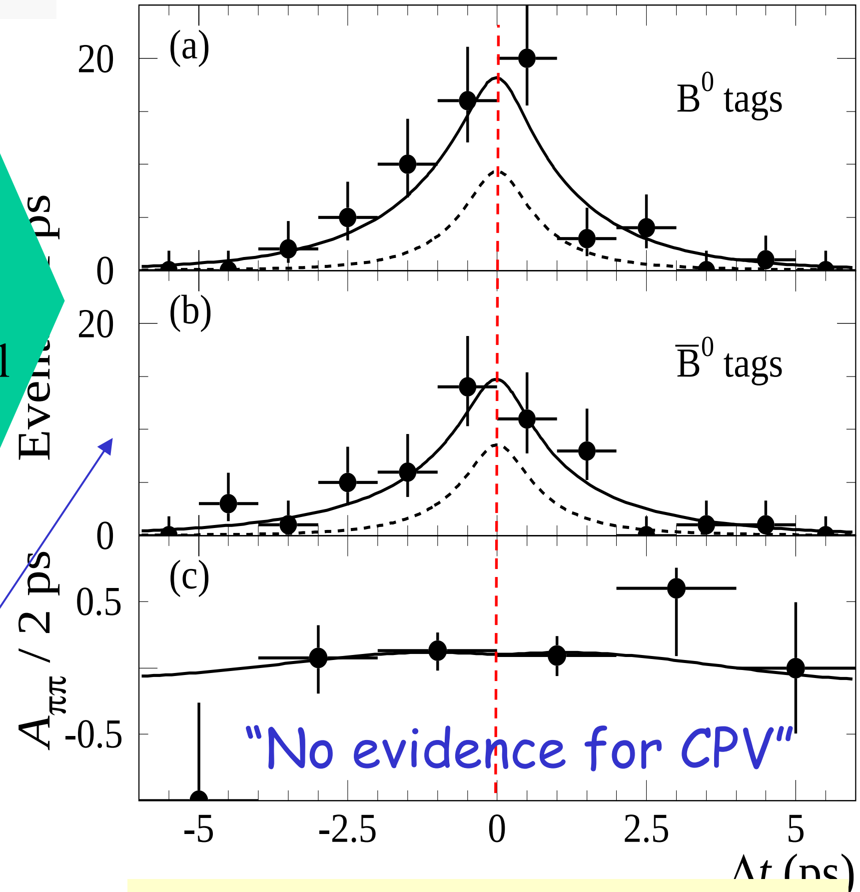
$B^0 \to \pi\pi$ Results: BaBar(81 fb^{-1})

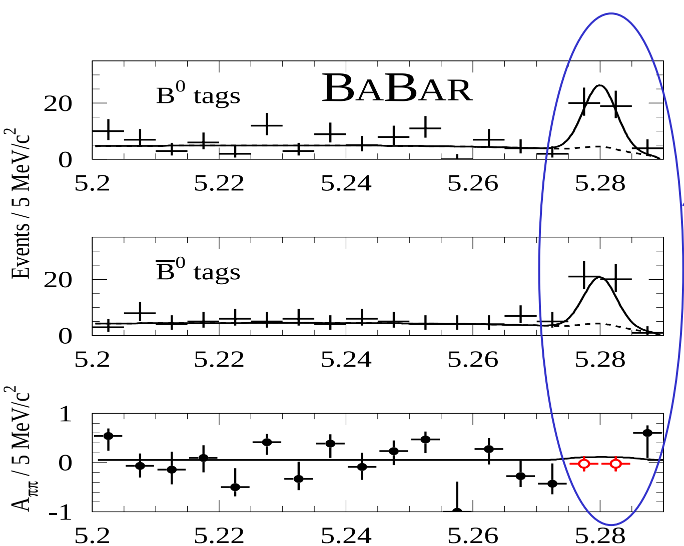
BF($B^0 \to \pi^+\pi^-$): $(4.7 \pm 0.6 \pm 0.2) \times 10^{-6}$



time distribution for ππ signal

Phys. Rev. Lett. **89** (2002) 281802





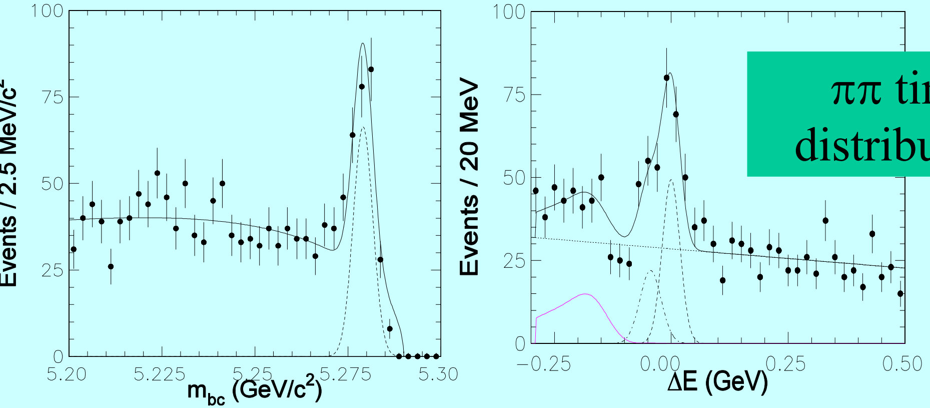
$C_{\pi\pi} = -0.30 \pm 0.25 \pm 0.04$

$S_{\pi\pi} = +0.02 \pm 0.34 \pm 0.05$

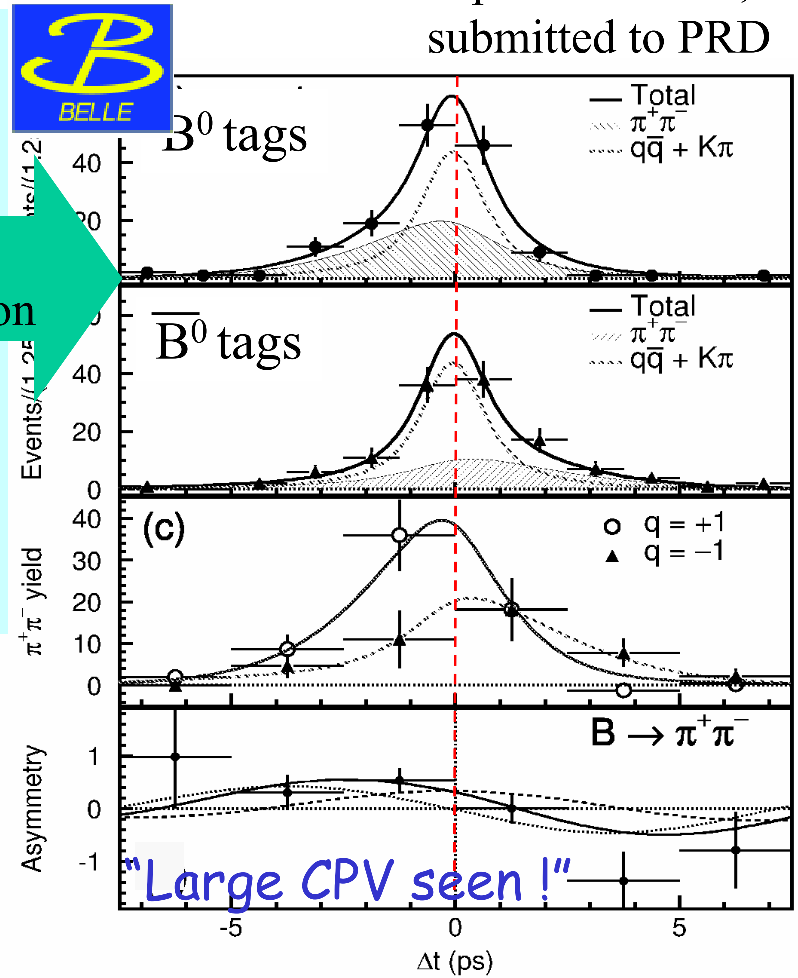
$B^0 \to \pi\pi$ Results: Belle (78 fb^{-1})

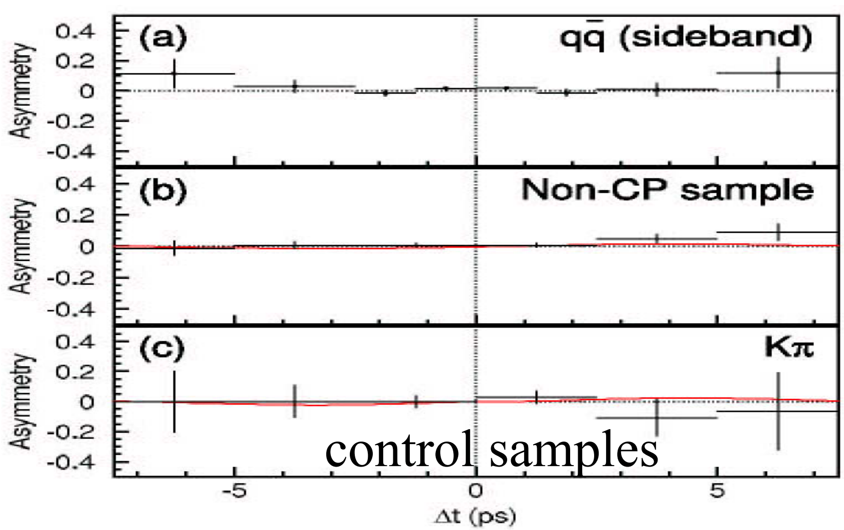
hep-ex/0301032,
submitted to PRD

760 in signal box
163 ± 24 ππ signals



ππ time distribution



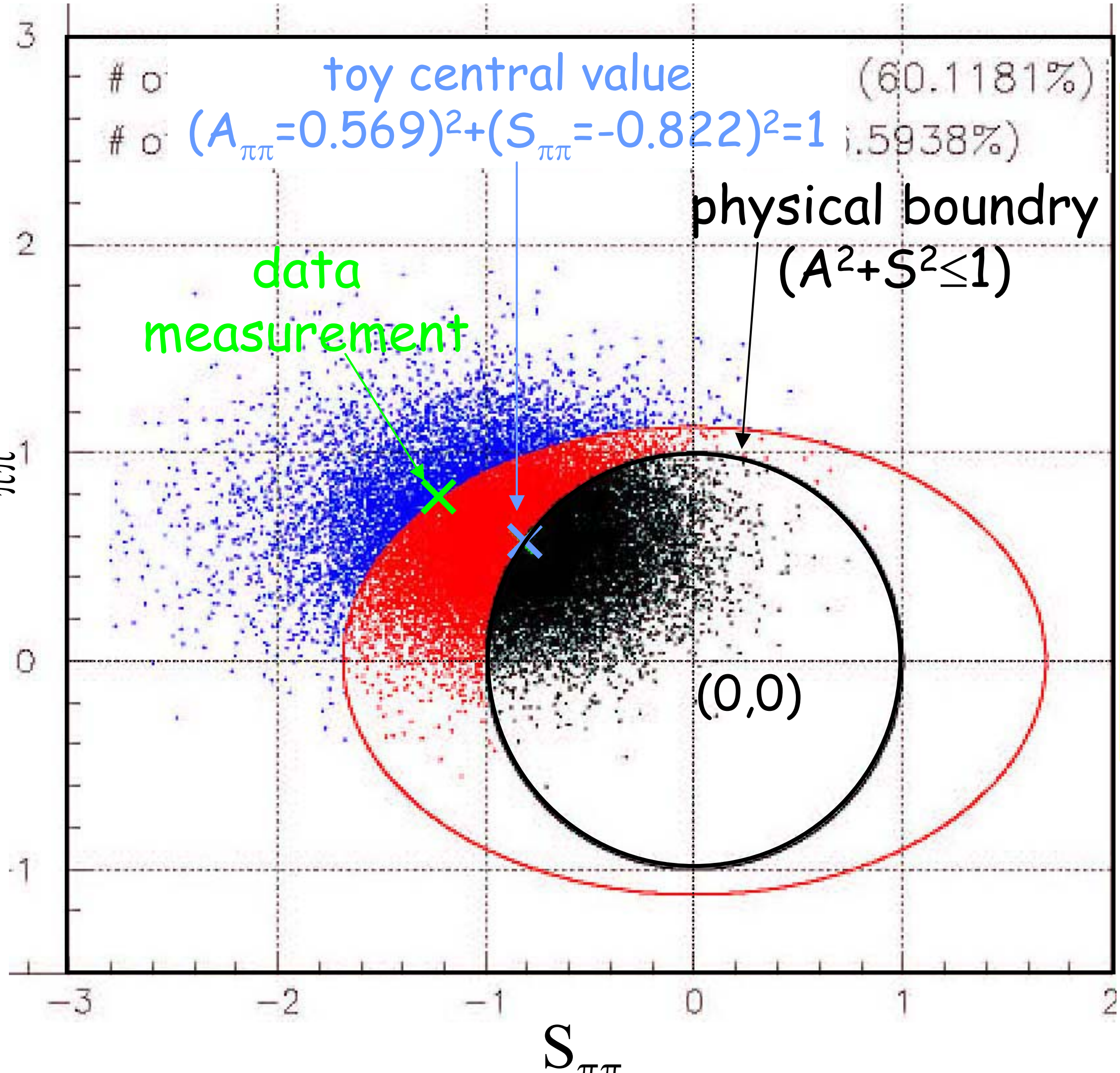


control samples

$C_{\pi\pi}$=-0.77 ± 0.27 ± 0.08
$S_{\pi\pi}$=-1.23 ± 0.41 $^{+0.08}_{-0.07}$

note: A = -C

Physical Boundary Condition Test



Belle's test

For $(A_{\pi\pi},S_{\pi\pi})=(0.569,-0.822)$

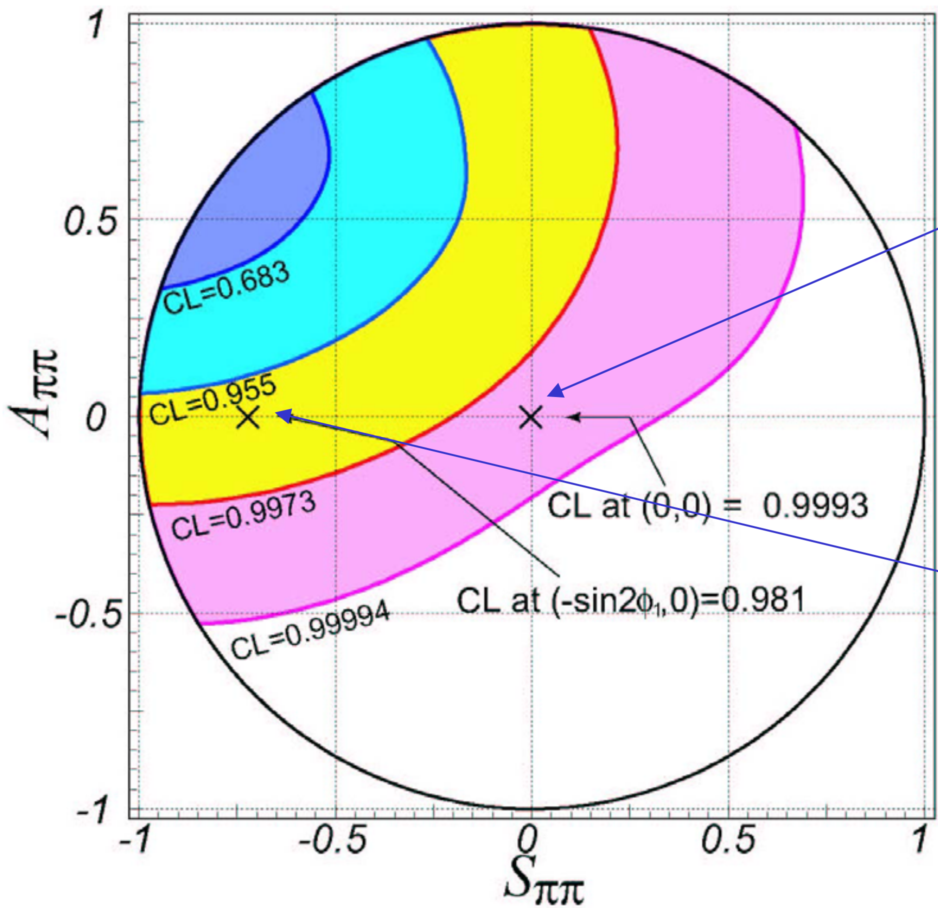
- probability of out-of-boundary measurement =60.1%
- 16.6% of measurements further from(0,0) than data.

➢It is possible to obtain out-of-boundary values

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

Belle's $B^0 \to \pi\pi$ CP Asymmetry: Confidence Regions

❑ Confidence level calculated with Feldman-Cousins frenquentist approach

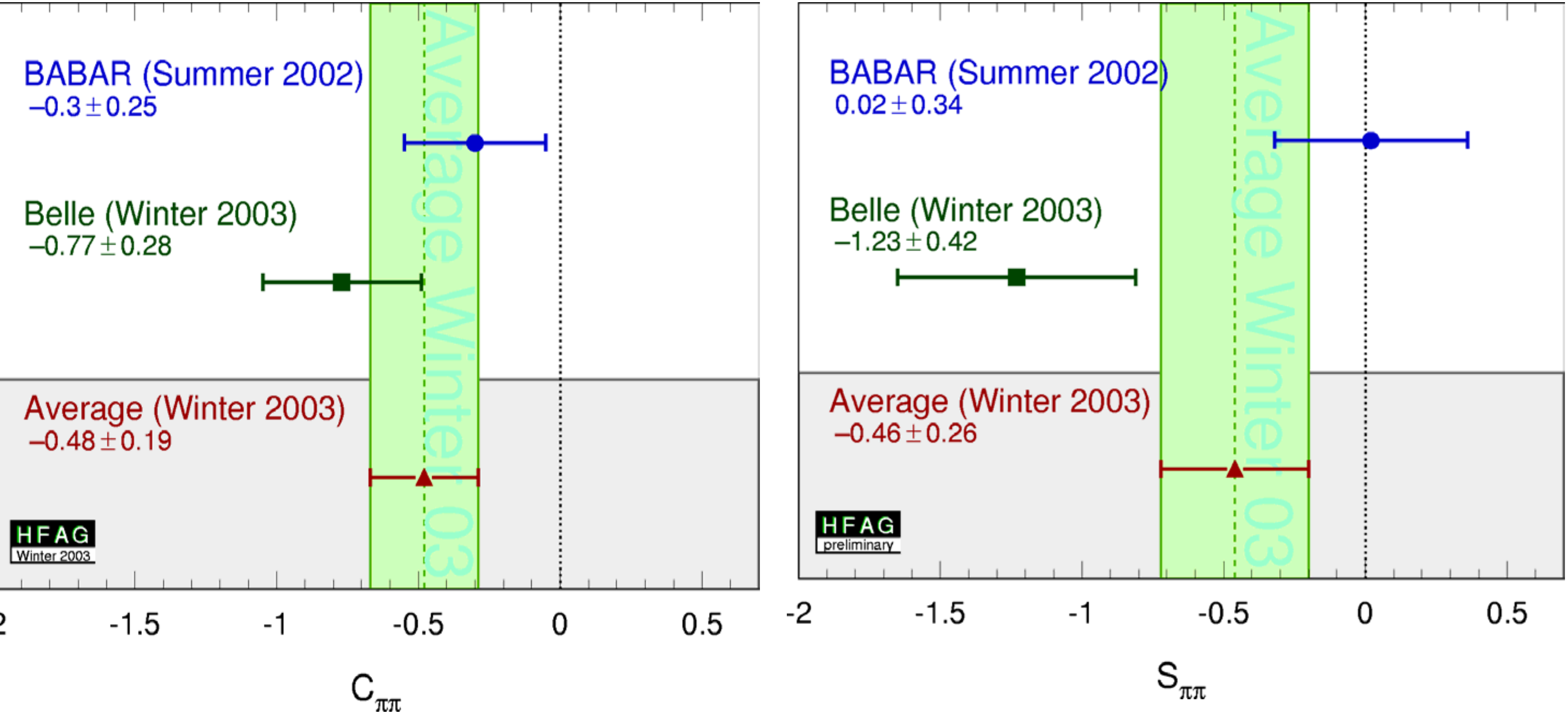


➢CP conserving hypothesis $(S_{\pi\pi}, A_{\pi\pi})$=(0.0) excluded at CL=99.93%. (3.4σ)

➢data inconsistent with no direct CPV ($A_{\pi\pi}$=0) at CL=98.1%. (2.2σ)

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

$B^0 \rightarrow \pi^+\pi^-$ CPV Results: BaBar and Belle



Compatibility (BaBar, Belle) =2.2σ
(CKMFitter group: CL=2.8%)

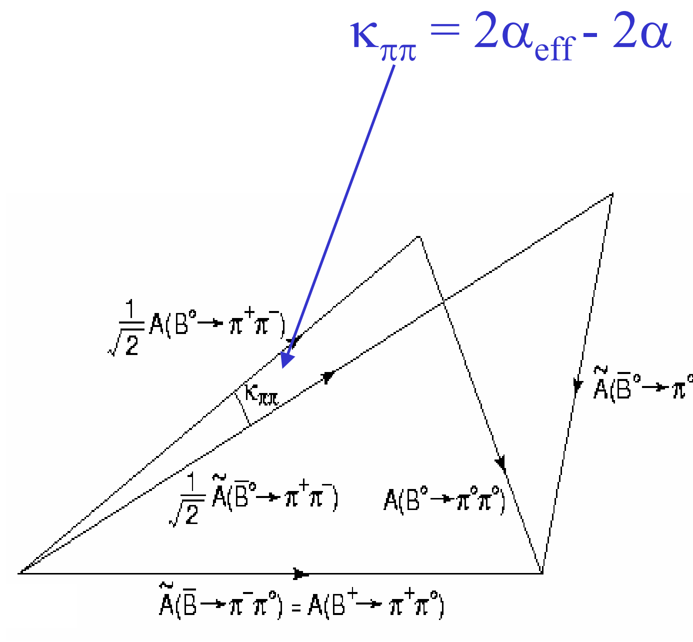
- Waiting for summer updates...

Constraints On α

- B→ $\pi^+\pi^-$, $\pi^+\pi^0$, $\pi^0\pi^0$ related by SU(2)
- Isospin triangles yields α.
  (up to eight-fold ambiguity)

Mode	BFs (10^{-6})	
	BaBar	Belle
$\pi^+\pi^-$	$4.7 \pm 0.6 \pm 0.2$	$4.4 \pm 0.6 \pm 0.3$
$\pi^+\pi^0$	$5.5^{+1.0}_{-0.9} \pm 0.6$	$5.3 \pm 1.3 \pm 0.5$
$\pi^0\pi^0$	$1.6^{+0.8+0.6}_{-0.9-0.3} < 3.6$	$1.8^{+1.4+0.5}_{-1.3-0.7} < 4.4$

90% CL limits so far.



Isospin Triangles
(Gronau and London)

Grossman-Quinn bound

$$\left|2\alpha_{eff} - 2\alpha\right| \le \cos^{-1}\left[1 - 2\frac{BR(B^0 \to \pi^0\pi^0)}{BR(B^\pm \to \pi^\pm\pi^0)}\right]$$

→

90%CL

$|\alpha_{eff} - \alpha| < 51^0$ (BaBar)

$|\alpha_{eff} - \alpha| < 68^0$ (Belle)

Also available: Gronau/London/Sinha/Sinha, Charles Bounds

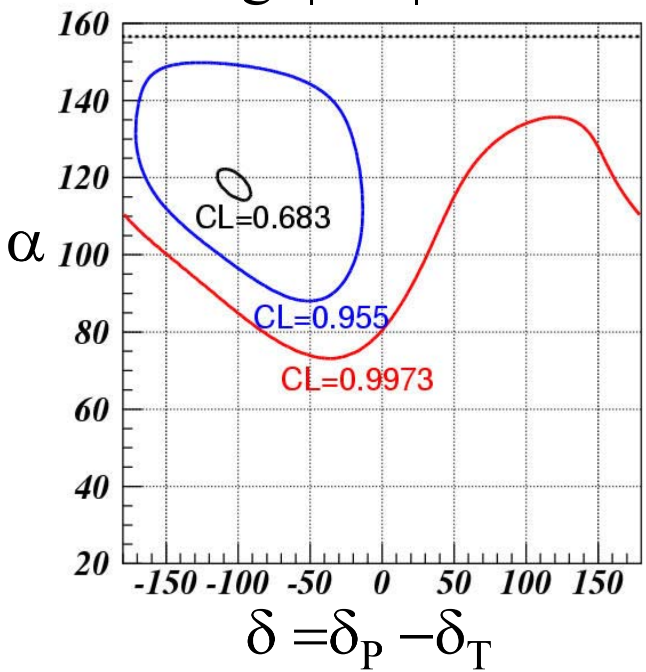
Constraints On α : Another Approach

0.15<|P/T|<0.45

- Gronau & Rosner presciption:
  - $A_{\pi\pi}$, $S_{\pi\pi}$ = function of (α, β, |P/T|, δ)
  - Convert ($A_{\pi\pi}$, $S_{\pi\pi}$) to (α,δ) with β and |P/T| as parameters

world average
$(23.5 +2.4/-2.2)^0$

e.g. |P/T|=0.3



Belle finds:
$78^o < \alpha < 121.6^o$ (95% C.L.)
insensitive to δ

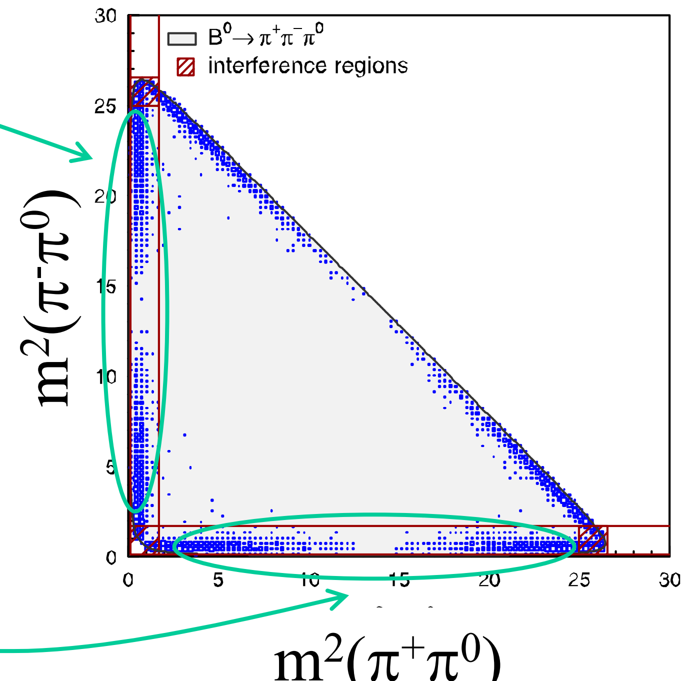
Compatible with prediction from CKMfitter: $101^o \pm 15^o$

Measuring CPV With $B^0 \rightarrow \rho\pi$ (3π)

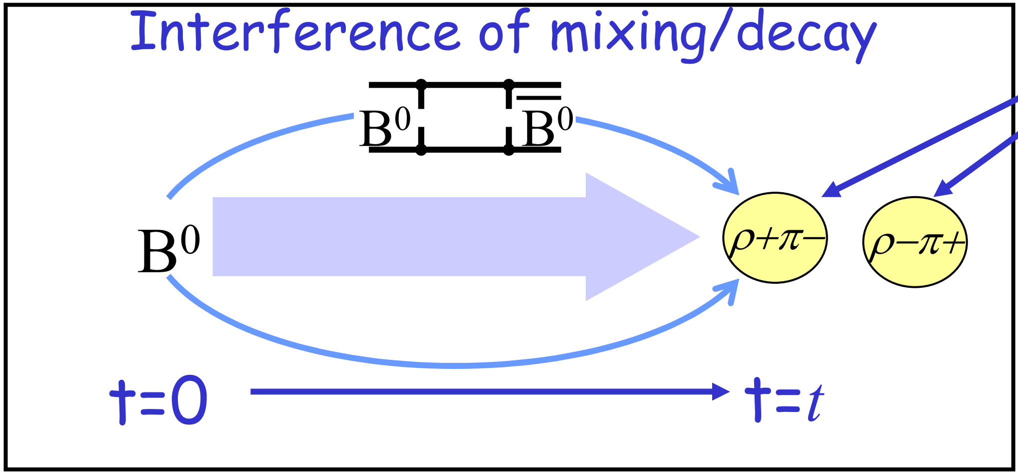
- $B \rightarrow \pi^+\pi^-\pi^0$ is also a $b \rightarrow uud$ process which probes α.
- It receives both tree(T) and penguin(P) contributions so α must be extracted out of phase confusion. This can be done via a full time-dependent Dalitz analysis.
- Experimentally this is challenging so a convenient first step is to look only at the quasi-two-body regions.

Quasi-two-body analyses

- performed on $\rho^+\pi^-$, and $\rho^-\pi^+$ bands
- interference region excluded
- ρK fit simultaneously, helped by PID



B→ρπ Time Dependent Asymmetry



Two non-CP, final state can be combined to reveal time dependent CP contents

$$A_{\rho^+\pi^-}(t) \equiv \frac{\Gamma(\overline{B}^0(t)\to\rho^+\pi^-)-\Gamma(B^0(t)\to\rho^+\pi^-)}{\Gamma(\overline{B}^0(t)\to\rho^+\pi^-)+\Gamma(B^0(t)\to\rho^+\pi^-)} = -C^+\cos(\Delta m t)+S^+\sin(\Delta m t)$$

$$A_{\rho^-\pi^+}(t) \equiv \frac{\Gamma(\overline{B}^0(t)\to\rho^-\pi^+)-\Gamma(B^0(t)\to\rho^-\pi^+)}{\Gamma(\overline{B}^0(t)\to\rho^-\pi^+)+\Gamma(\overline{B}^0(t)\to\rho^-\pi^+)} = -C^-\cos(\Delta m t)+S^-\sin(\Delta m t)$$

Redefinition : $C \equiv \frac{C^+ + C^-}{2}$, $S \equiv \frac{S^+ + S^-}{2}$, and $\Delta C \equiv \frac{C^+ - C^-}{2}$, $\Delta S \equiv \frac{S^+ - S^-}{2}$

C,S, CP parameters:
CPV if $C \neq 0$ or $S \neq 0$

$\Delta C, \Delta S$:
reflect final-state difference

B→ρπ: Yields And Charge Asymmetry (BaBar, 82 fb^{-1})

$$N_{\rho\pi} = 428 \pm 34 \pm 25$$

$$N_{\rho K} = 120 \pm 21 \pm 18$$

direct CPV?

$$A_{CP}^{\rho\pi} \equiv \frac{N_{\rho^+\pi^-} - N_{\rho^-\pi^+}}{N_{\rho^+\pi^-} + N_{\rho^-\pi^+}} = -0.18 \pm 0.08 \pm 0.03$$

$$A_{CP}^{\rho K} \equiv \frac{N_{\rho^+K^-} - N_{\rho^-K^+}}{N_{\rho^+K^-} + N_{\rho^-K^+}} = 0.28 \pm 0.17 \pm 0.08$$

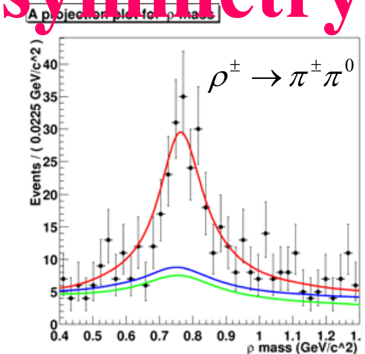
Branching Fractions:

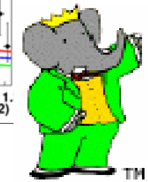
$$BF(B \to \rho^\pm\pi^\mp) = (22.6 \pm 1.8 \pm 2.2) \times 10^{-6}$$

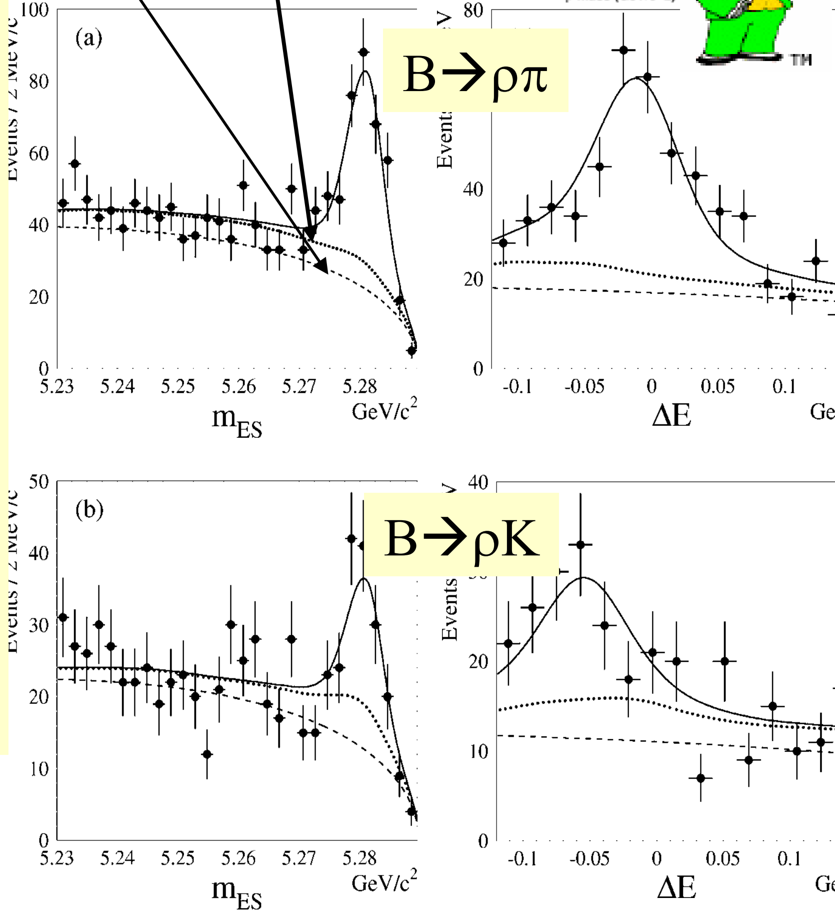
$$BF(B \to \rho^\pm K^\mp) = (7.3\ {}^{+1.3}_{-1.2} \pm 1.3) \times 10^{-6}$$

$$BF(B \to \rho^\pm\pi^\mp) = (20.8\ {}^{+6.0}_{-6.3}\ {}^{+2.8}_{-3.1}) \times 10^{-6}$$

(Belle)







B→ρπ: Time Distribution and Asymmetry (BaBar, 82 fb^{-1})

direct CPV?

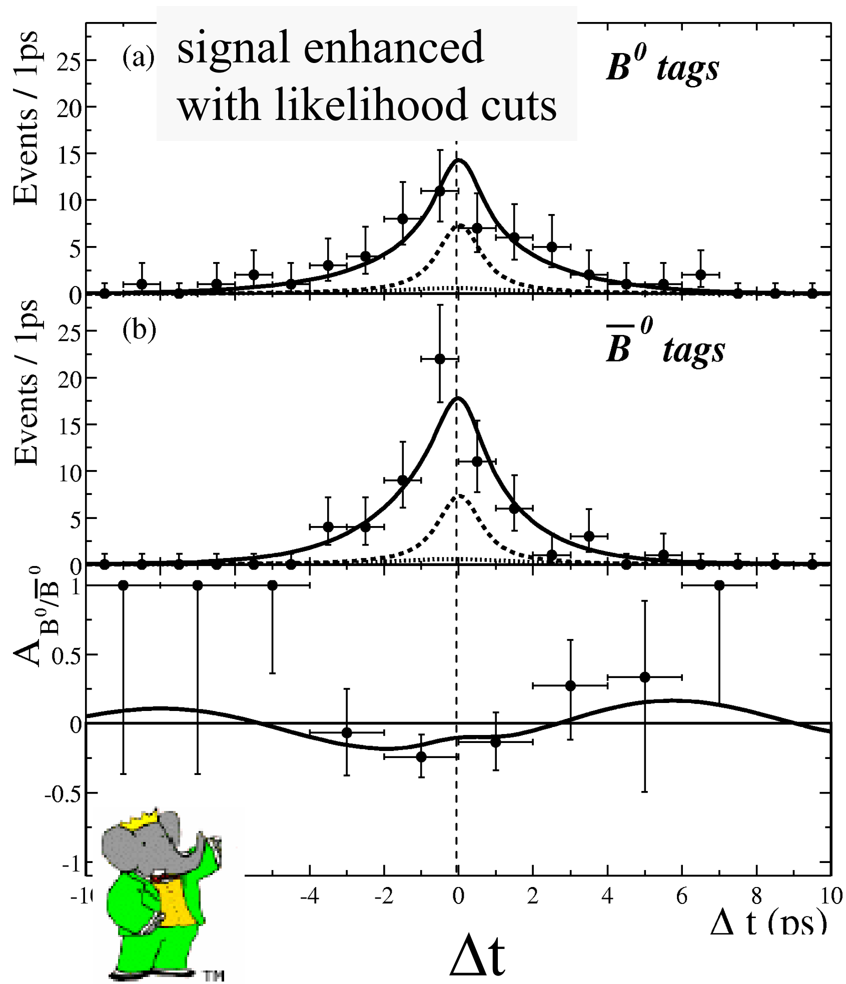
$$C_{\rho\pi} = 0.36 \pm 0.18 \pm 0.04$$

$$S_{\rho\pi} = 0.19 \pm 0.24 \pm 0.03$$

$$\Delta C_{\rho\pi} = 0.28\,^{+0.18}_{-0.19} \pm 0.04$$

$$\Delta S_{\rho\pi} = 0.15 \pm 0.25 \pm 0.03$$

Note:
naïve factorization predicts $\Delta C_{\rho\pi} \sim 0.4$.



hep-ex/0207068
submitted to PRL

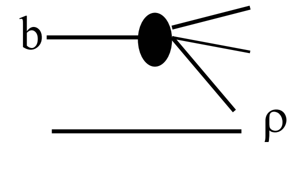
B→ρπ: Direct CPV?

A_{CP}, $C_{\rho\pi}$, $\Delta C_{\rho\pi}$ translated into 2 pairs of CP conjugated rates ($\propto |\mathcal{A}|^2$)

CP

$$N(B^0 \to \rho^-\pi^+) \equiv \frac{dN(B^0 \to \rho^-\pi^+)}{dt}\Big|_{t=0} \int e^{-t/\tau}dt = \frac{1}{4}(1+A_{CP}^{\rho\pi})(1+(C+\Delta C))N_{\rho\pi} = 137\,^{+34}_{-32} \pm 11$$

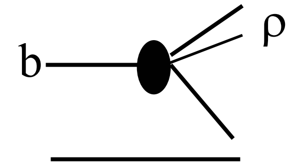
$$N(\overline{B}^0 \to \rho^+\pi^-) \equiv \frac{dN(\overline{B}^0 \to \rho^+\pi^-)}{dt}\Big|_{t=0} \int e^{-t/\tau}dt = \frac{1}{4}(1-A_{CP}^{\rho\pi})(1+(C-\Delta C))N_{\rho\pi} = 32\,^{+26}_{-25} \pm 6$$



CP

$$N(B^0 \to \rho^+\pi^-) \equiv \frac{dN(B^0 \to \rho^+\pi^-)}{dt}\Big|_{t=0} \int e^{-t/\tau}dt = \frac{1}{4}(1+A_{CP}^{\rho\pi})(1+(C+\Delta C))N_{\rho\pi} = 144\,^{+30}_{-27} \pm 11$$

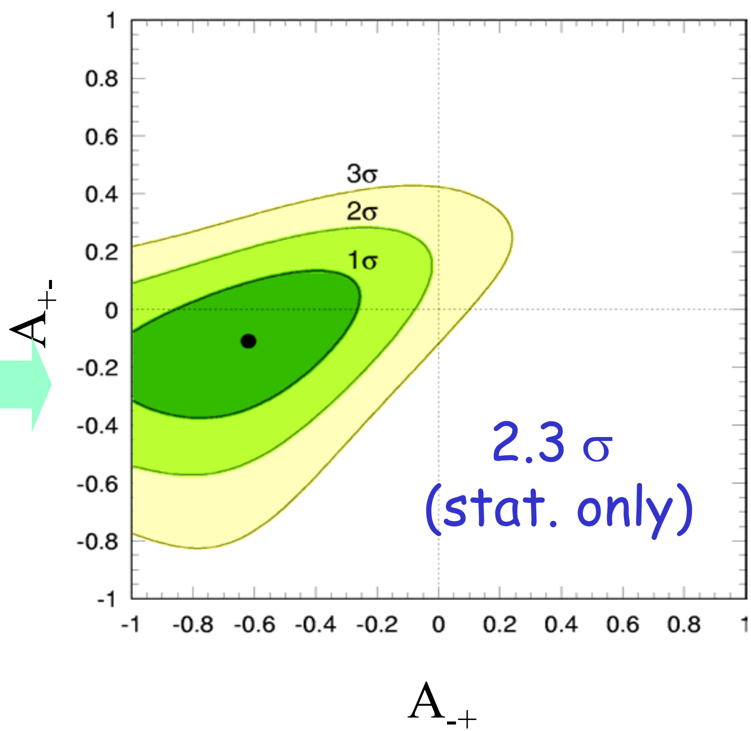
$$N(\overline{B}^0 \to \rho^-\pi^+) \equiv \frac{dN(\overline{B}^0 \to \rho^-\pi^+)}{dt}\Big|_{t=0} \int e^{-t/\tau}dt = \frac{1}{4}(1-A_{CP}^{\rho\pi})(1+(C-\Delta C))N_{\rho\pi} = 116\,^{+33}_{-31} \pm 10$$



Define two asymmetries:

$$_{-+} = \frac{N(\overline{B}^0 \to \rho^+\pi^-) - N(B^0 \to \rho^-\pi^+)}{\Sigma} = -0.62\,^{+0.24}_{-0.28} \pm 0.06$$

$$_{+-} = \frac{N(\overline{B}^0 \to \rho^-\pi^+) - N(B^0 \to \rho^+\pi^-)}{\Sigma} = -0.11\,^{+0.16}_{-0.17} \pm 0.04$$



More statistics is needed

Branching Fractions (BF) And A_{CP}

$$A_{CP} \equiv \frac{\Gamma(\overline{B} \to \bar{f}) - \Gamma(B \to f)}{\Gamma(\overline{B} \to \bar{f}) + \Gamma(B \to f)}$$

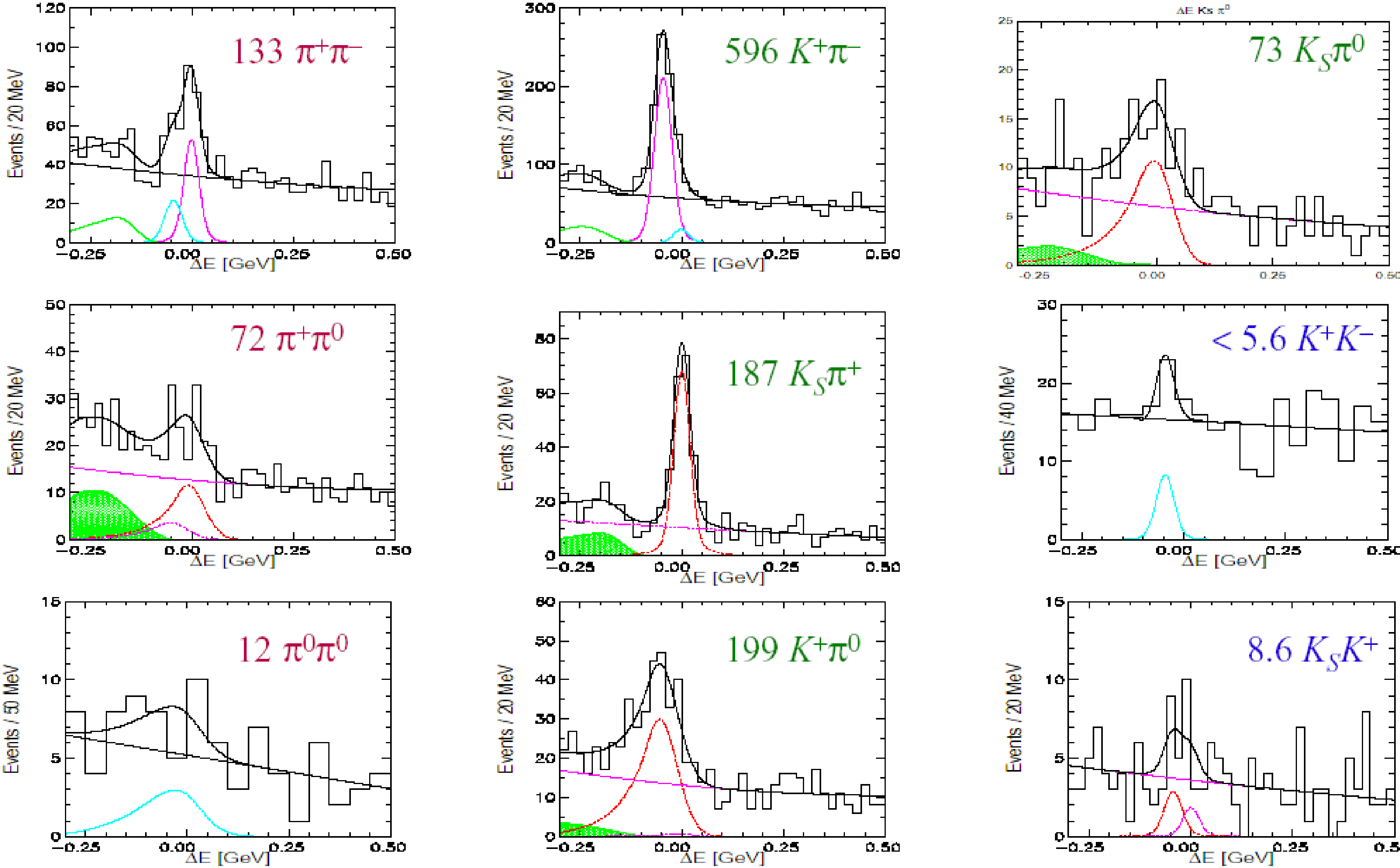
$$= \frac{2\,|\mathrm{P}|\,|\mathrm{T}|\sin\Delta\phi\sin\Delta\delta}{|\mathrm{P}|^2 + |T|^2 + 2\,|\mathrm{P}|\,|\mathrm{T}|\cos\Delta\phi\cos\Delta\delta}$$

The game:

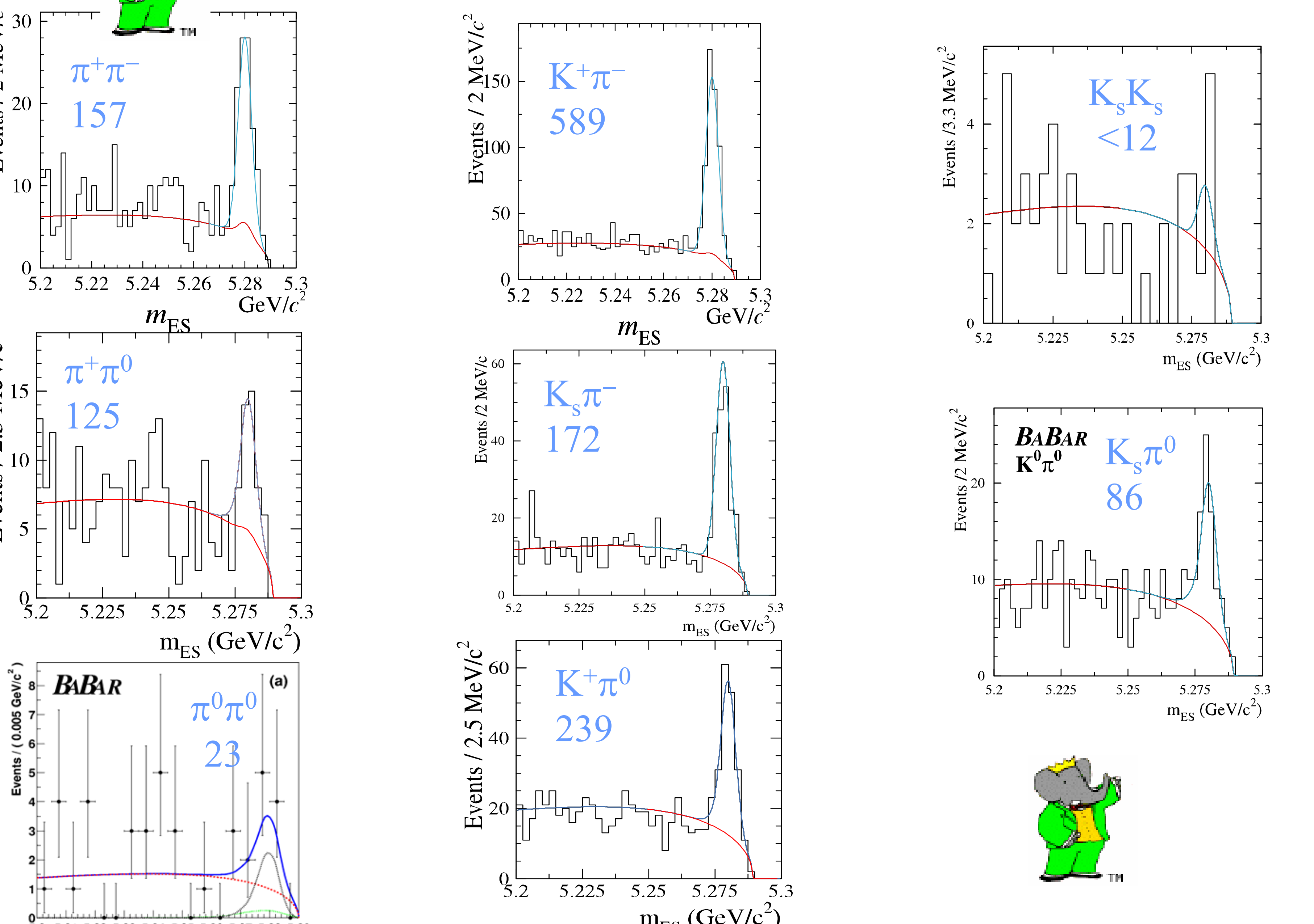
- Collect(reconstruct) signals
- Understand efficiency
- Calculate BF and A_{CP}

Note: Most of the BF results presented here are preliminary

$K\pi$ And $\pi\pi$ Yields: Belle



Kπ And ππ Yields: BaBar

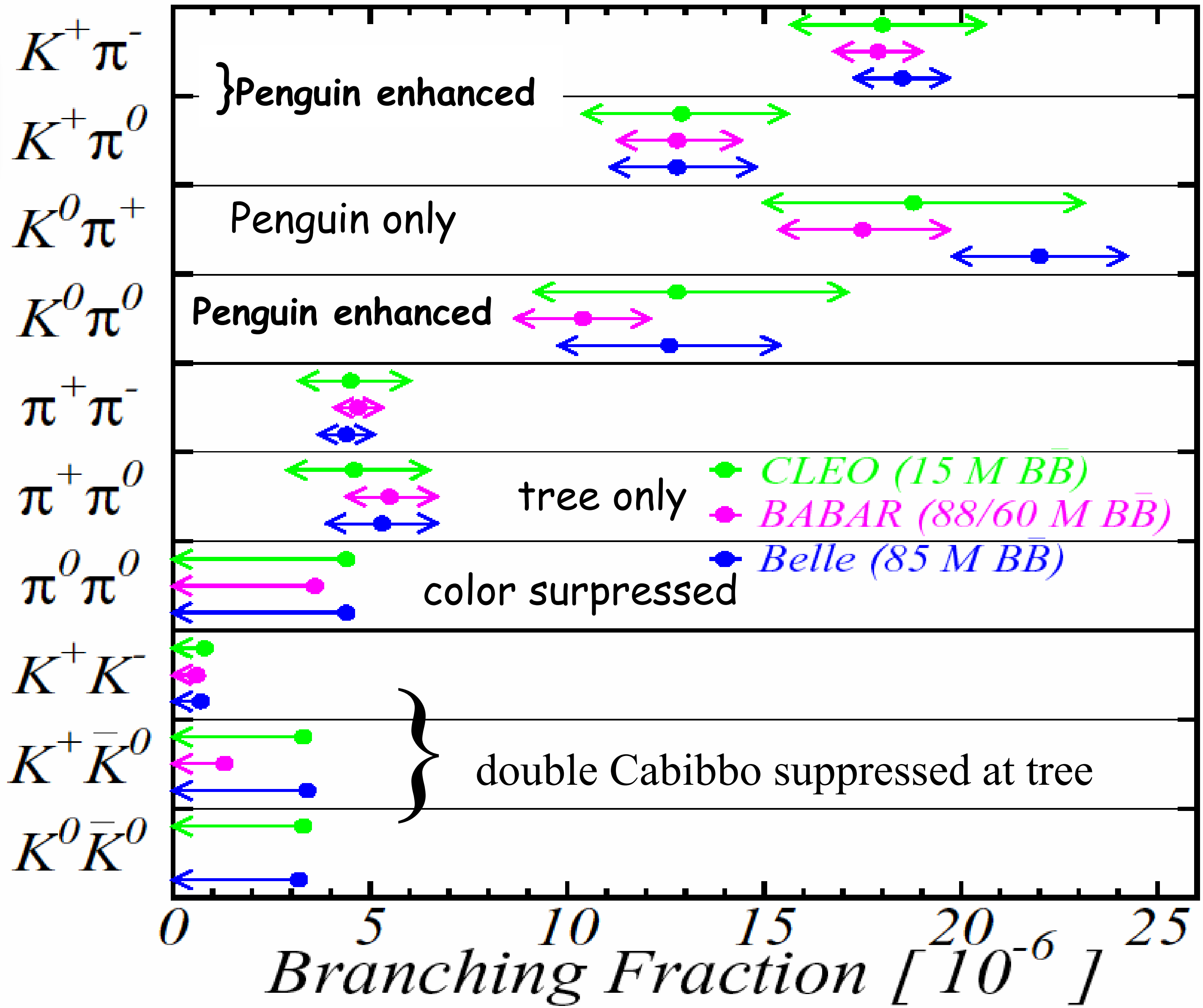


Summary Of
Kπ And ππ Branching Fractions

	BaBar(81.2 fb^{-1})		Belle(78 fb^{-1})	
Mode	**Nsignal**	**BF(10^{-6})**	**Nsignal**	**BF(10^{-6})**
$K^+\pi^-$	$589 \pm 30 \pm 17$	$17.9 \pm 0.9 \pm 0.7$	$595.9^{+33.2}_{-32.5}$	$18.5 \pm 1.0 \pm 0.7$
$K^+\pi^0$	$239^{+21}_{-22} \pm 6$	$12.8^{+1.2}_{-1.1} \pm 1.0$	198.9 ± 21.5	$12.8 \pm 1.4^{+1.4}_{-1.0}$
$K^0\pi^+$	$172 \pm 17 \pm 9$	$17.5^{+1.8}_{-1.7} \pm 1.3$	187.0 ± 16.3	$22.0 \pm 1.9 \pm 1.1$
$K^0\pi^0$	$86 \pm 13 \pm 3$	$10.4 \pm 1.5 \pm 0.8$	72.6 ± 14.0	$12.6 \pm 2.4 \pm 1.4$
$\pi^+\pi^-$	$157 \pm 19 \pm 7$	$4.7 \pm 0.6 \pm 0.2$	$132.7^{+18.9}_{-18.2}$	$4.4 \pm 0.6 \pm 0.3$
$\pi^+\pi^0$	$125^{+23}_{-21} \pm 17$	$5.5^{+1.0}_{-0.9} \pm 0.7$	72.4 ± 17.4	$5.3 \pm 1.3 \pm 0.5$
$\pi^0\pi^0$	$23^{+10}_{-9}{}^{+8.4}_{-4.4}$	$1.6^{+0.7}_{-0.6}{}^{+0.6}_{-0.3} < 3.6$	$12.0^{+9.1}_{-8.6}$	$1.8^{+1.4}_{-1.3}{}^{+0.5}_{-0.7} < 4.4$
K^+K^-	1 ± 8 (<16)	<0.6	$0.0^{+5.7}_{-0.0}$	<0.7
K^+K^0	$-5.6^{+2.8}_{-5.5} \pm 2.5$	$-0.6^{+0.6}_{-0.7} \pm 0.3 < 1.3$	8.6 ± 5.9	$1.7 \pm 1.2 \pm 0.1 < 3.4$
K^0K^0	$4.3^{+5.2}_{-4.1} \pm 1.1$	<1.6	2.0 ± 1.9	$0.8 \pm 0.8 \pm 0.1 < 3.2$

- Good agreement between BaBar and Belle (and CLEO)

Kπ And ππ BFs: Consistent Results



$K\pi$ And $\pi\pi$: BF Ratios

- $\pi^+\pi^-$ and $K^+\pi^-$:

	BaBar	Belle	
$\Gamma(\pi^+\pi^-)/\Gamma(K^+\pi^-)$	$0.26 \pm 0.04 \pm 0.02$	$0.24 \pm 0.04 \pm 0.02$	$\ll 1/\lambda$ (if tree onl

- Isospin ratios:

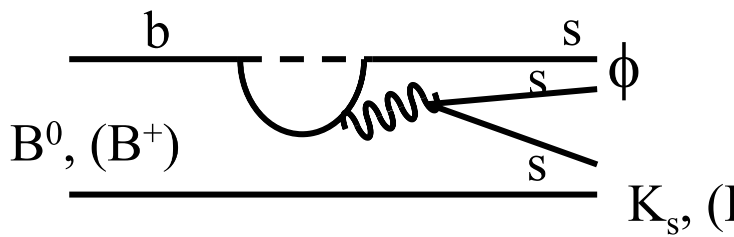
	BaBar	Belle	
$\Gamma(K^+\pi^-)/\Gamma(K^0\pi^+)$	$1.11 \pm 0.13 \pm 0.09$	$0.91 \pm 0.09 \pm 0.06$	~ 1
$2\Gamma(K^+\pi^0)/\Gamma(K^0\pi^+)$	$1.46 \pm 0.20 \pm 0.16$	$1.16 \pm 0.16 \pm 0.14$	~ 1
$\Gamma(K^+\pi^0)/2\Gamma(K^0\pi^0)$	$0.86 \pm 0.13 \pm 0.07$	$0.74 \pm 0.15 \pm 0.09$	~ 1
$\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^0)$	$0.46 \pm 0.10 \pm 0.05$	$0.45 \pm 0.13 \pm 0.05$	$\neq 1$

what we have learned:

- Penguin seems to be strong.
- Isospin symmetry holds well for penguin dominated (→ EW penguin small)
- Need more statistics for further constraint

Preliminary

B→φK Branching Fractions



b→sss

"sin2β" with b→sss

$S_{\phi K} \neq \sin 2\beta$?

See: K. Abe's talk

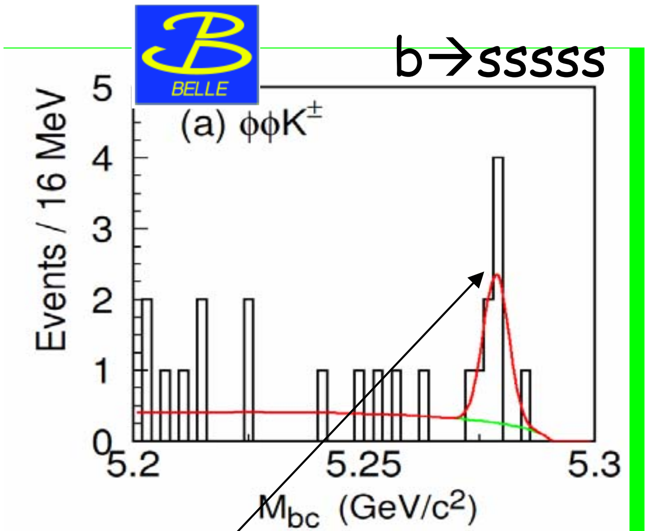
Angular Analysis: $\Gamma_L \sim \Gamma_T$

$|A_0|^2 = 0.43 \pm 0.09 \pm 0.04$

$|A_\perp|^2 = 0.41 \pm 0.10 \pm 0.04$ (Belle)

$\Gamma_L/\Gamma = 0.65 \pm 0.07 \pm 0.04$ (BaBar)

	BF(10^{-6})	
Mode	BaBar	Belle
ϕK^+	$10.0^{+0.9}_{-0.8} \pm 0.5$	$9.4 \pm 1.1 \pm 0.7$
ϕK^0	$7.6^{+1.3}_{-1.3} \pm 0.5$	$9.0^{+2.2}_{-1.8} \pm 0.7$
ϕK^{*+}	$12.1 \pm 2.0 \pm 1.5$	$6.7^{+2.1}_{-1.9} \pm 0.7$
ϕK^{*0}	$11.1 \pm 1.2 \pm 1.1$	$10.0^{+1.6}_{-1.5}$
$\phi\pi^+$	<0.38	
$\phi\phi K$		$2.6^{+1.1}_{-0.9} \pm 0.3$



first observation

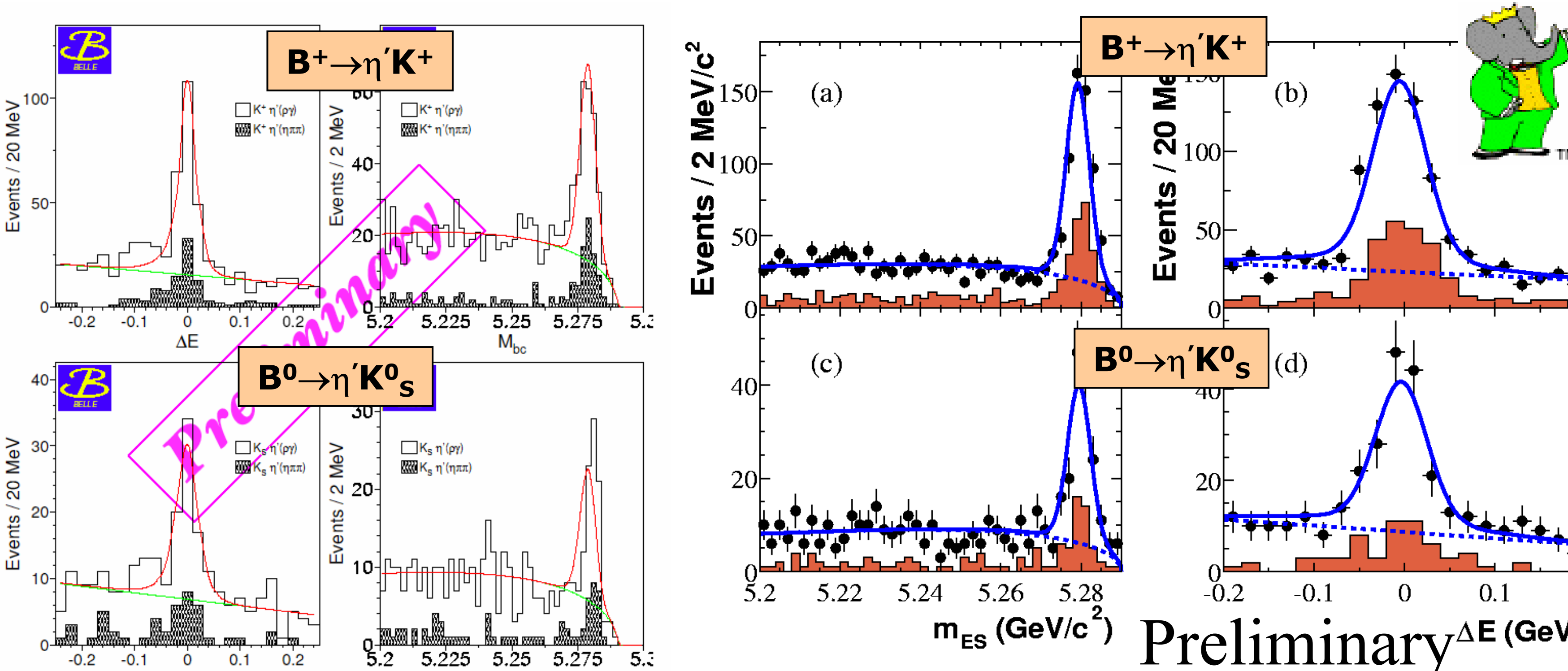
Preliminary

Another b→sss process: B→η′K

large BFs to be understood
BF(η′K) ~ 6x BF(πK)!

another test bed for "sin2β"

	BF(10^{-6})		
Mode	BaBar	Belle	CLEO
$\eta' K^+$	$76.9 \pm 3.5 \pm 4.4$	$77.9 \pm 6.0 \pm 9.0$	$80^{+10}_{-9} \pm 7$
$\eta' K^0$	$55.4 \pm 5.2 \pm 4.0$	$68 \pm 10^{+9}_{-8}$	$89^{+18}_{-16} \pm 9$
also obtained: limits on $\eta' K^{*+}$, $\eta' K^{*0}$, $\eta' \pi^+$, $\eta' \rho^0$			



Preliminary

Preliminar

More BFs: B→ρK and Inclusive hhh

Mode	BF(10^{-6}) BaBar	BF(10^{-6}) Belle
ρ^0K^{*+}	$7.7\,^{+2.1}_{-2.0}\pm1.4$	
ρ^-K^+	$7.3^{+1.3}_{-1.2}\pm1.3$	
$\rho^+\pi^-$	$22.7\pm1.8\pm2.2$	$20.8\,^{+6.0}_{-6.3}\,^{+2.8}_{-3.1}$
$\rho^0\pi^+$	$24\pm8\pm3$	$8.0\,^{+2.3}_{-6.3}\pm0.7$
$\rho^+\rho^0$	$22.5\,^{+5.7}_{-5.4}\pm4.9$	$31.7\pm7.1\,^{+3.7}_{-6.4}$

new

Angular Analysis
$\Gamma_L/\Gamma = (94.8\pm10.6\pm2.1)\%$ (Belle)
$\Gamma_L/\Gamma = (97\pm7\pm4)\%$ (BaBar)

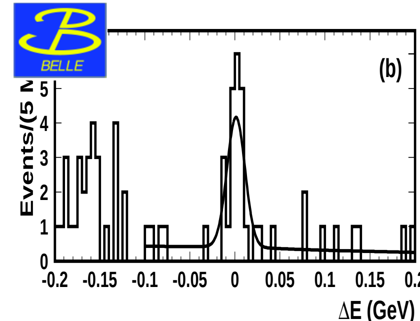
modes	BF(10^{-6})
$B^+\to K^+K_sK_s$	$13.4\pm1.9\pm1.5$
$B^0\to K_sK_sK_s$	$4.3\,^{+1.6}_{-1.4}\pm0.8$
$B^0\to K^+K^-K^0$	$29.3\pm3.4\pm4.1$
$B^+\to K^+\pi^+\pi^-$	$53.9\pm3.1\pm5.7$
$B^+\to K^+K^+K^-$	$33.0\pm1.8\pm3.2$

modes	BF(10^{-6})
$B^+\to\pi^+\pi^-\pi^+$	$10.9\pm3.3\pm1.6$
$B^+\to K^+\pi^-\pi^+$	$59.1\pm3.8\pm3.2$
$K^{*0}\pi+$	$10.3\pm1.2\pm1.8$
f_0K+	$9.2\pm1.2\pm2.4$
χ_cK^+	$1.46\pm0.35\pm0.12$
"higher" $K^{*0\prime}\pi+$	$25.1\pm2.0\pm9.0$
"higher" f_0K^+	<12
ρ^0K^+	<6.2
$K\pi\pi$ non-res.	<17
$B^+\to KKK$	$29.6\pm2.1\pm1.6$
$B^+\to KK\pi^+$	<6.3
$B^+\to K^-\pi^+\pi^+$	<1.8
$B^+\to K^+K^+\pi^-$	<1.3

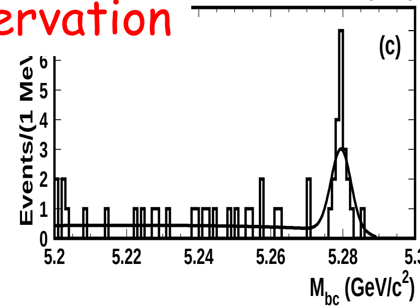
Preliminary

Still More BFs

	BF(10^{-6})	
Mode	BaBar	Belle
$\eta\pi^+$	$4.2 \pm 1.0 \pm 0.3$	$5.4\ ^{+2.0}_{-1.7} \pm 0.3$
ηK^+	$2.8 \pm 0.8 \pm 0.2$	$5.3\ ^{+1.8}_{-1.5} \pm 0.6$
ηK^0	<4.6	<12
ηK^{*+}	$22.1\ ^{+11.1}_{-9.2} \pm 3.3$	$26.5\ ^{+7.8}_{-7.0} \pm 3.0$
ηK^{*0}	$19.8\ ^{+6.5}_{-5.6} \pm 1.7$	$16.5\ ^{+4.6}_{-4.2} \pm 1.2$
$\omega\pi^+$	$5.4 \pm 1.0 \pm 0.5$	$5.9\ ^{+1.4}_{-1.3} \pm 0.6$
ωK^+	$5.0 \pm 1.0 \pm 0.4$	$6.7\ ^{+1.3}_{-1.2} \pm 0.6$
ωK^0	$5.3 \pm 1.3 \pm 0.5$	<7.6

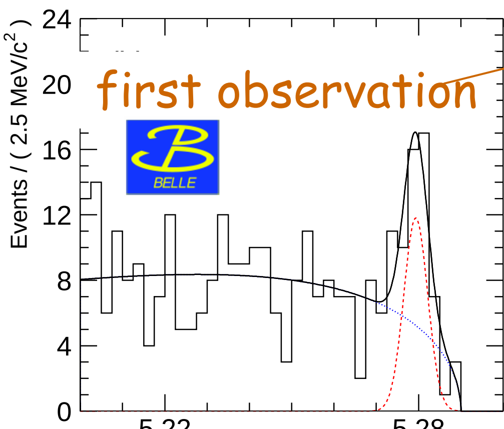


first observation

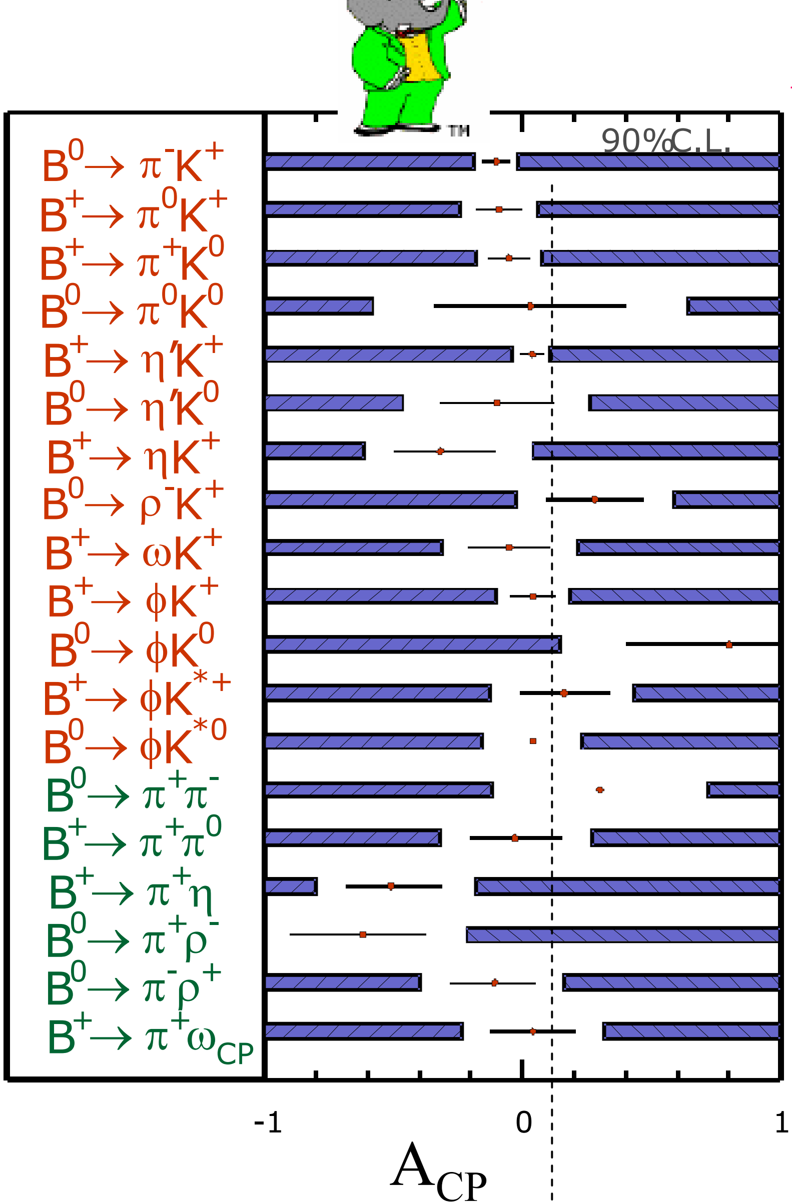


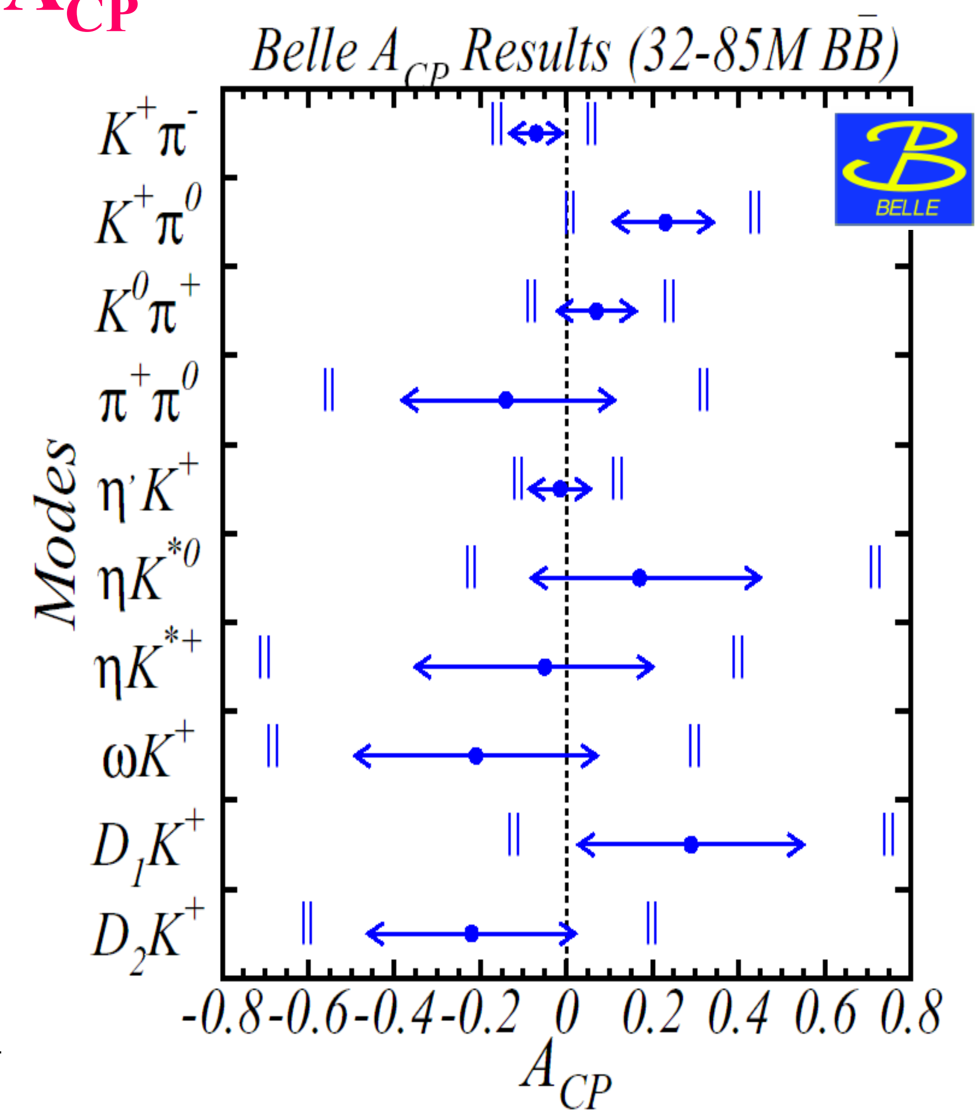
B→baryons (Belle)

Mode	BF(10^{-6})
$\Lambda_C \bar{P}$	$2.2\ ^{+0.6}_{-0.5} \pm 0.3 \pm 0.6$
$\Lambda \bar{P} \pi^+$	$3.97\ ^{+1.00}_{-0.80} \pm 0.56$
$P\bar{P}\pi^+$	$3.06\ ^{+0.73}_{-0.62} \pm 0.40$
$P\bar{P}K^+$	$5.66\ ^{+0.67}_{-0.57} \pm 0.74$
$P\bar{P}K_S$	$0.94 \pm 0.5 \pm 0.1$
$P\bar{P}K^{*+}$	$10.3\ ^{+1.0}_{-0.8} \pm 1.6$
$P\bar{P}K^{*0}$	<7.6



A_{CP}





No evidence of direct CPV from time-independent A_{CP}

preliminary

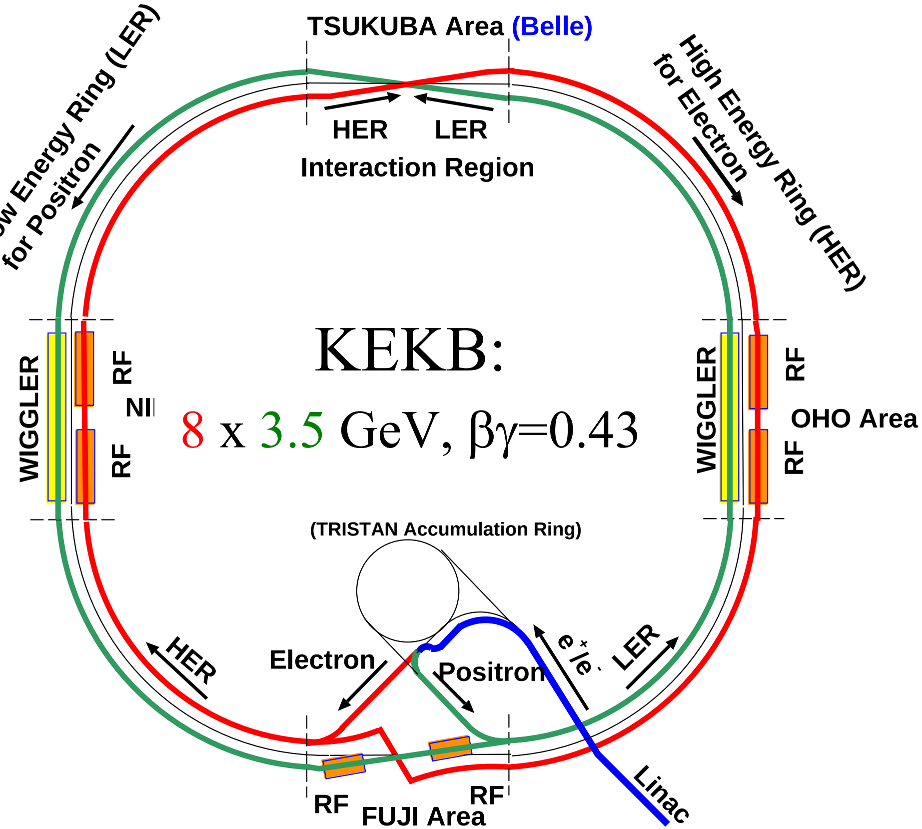
Summary

- **Rare hadronic decays are no longer so "rare" (think yields), thanks to large amount B mesons produced at B-factories.**

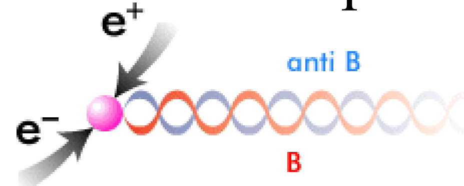
- **CP measurements in rare decays became a reality**
  - **B→ $\pi^+\pi^-$:**
    $C_{\pi\pi}$=-0.30 ± 0.25 ± 0.04, $S_{\pi\pi}$=+0.02 ± 0.34 ± 0.05 (BaBar)
    $C_{\pi\pi}$=-0.77 ± 0.27 ± 0.08, $S_{\pi\pi}$=-1.23 ± 0.41 $^{+0.08}_{-0.07}$ (Belle)
  - **B→$\rho^+\pi^-$:**
    $$A_{-+} = -0.63\,^{+0.24}_{-0.28} \pm 0.06\,,\; A_{+-} = -0.11\,^{+0.16}_{-0.17} \pm 0.04$$
    $$S_{\rho\pi} = 0.19 \pm 0.25 \pm 0.03$$
    (BaBar)
  - **also: "sin2β" in ϕK_s, $\eta' K_s$ (see K. Abe's talk)**
- **New modes observed, adding to a large pool of existing ones. BFs became more precise.**
- **No sign of new physics yet, but we are more sensitive than ever.**
- **Lots of achievement and we expect more.**

Backup slides

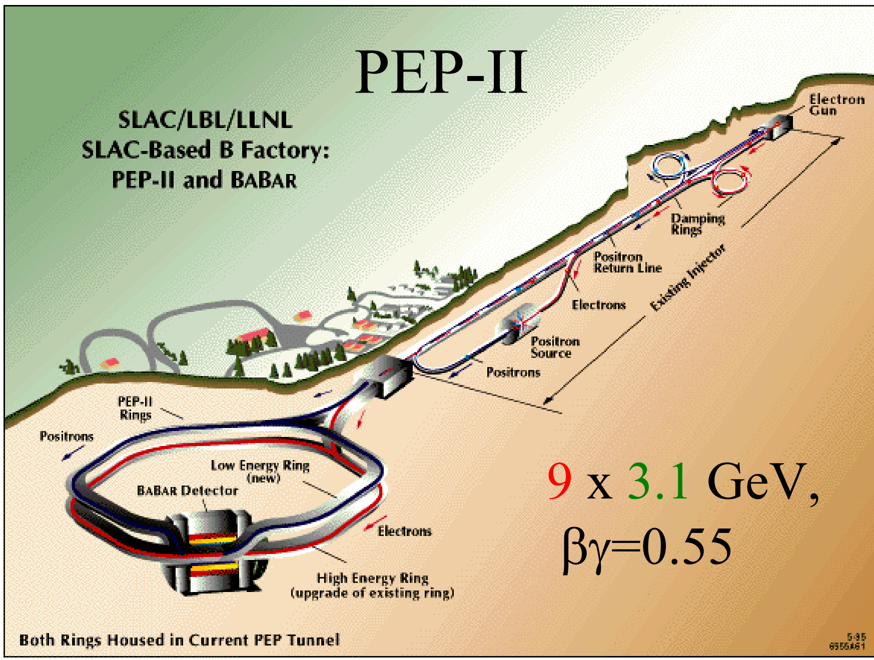
B-Factories: Asymmetric e^-e^+ Colliders@ $\Upsilon(4s)$

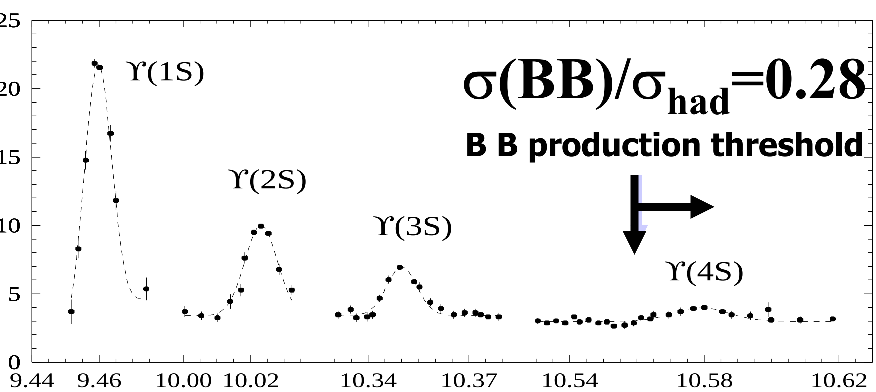


Coherent $B\overline{B}$ production

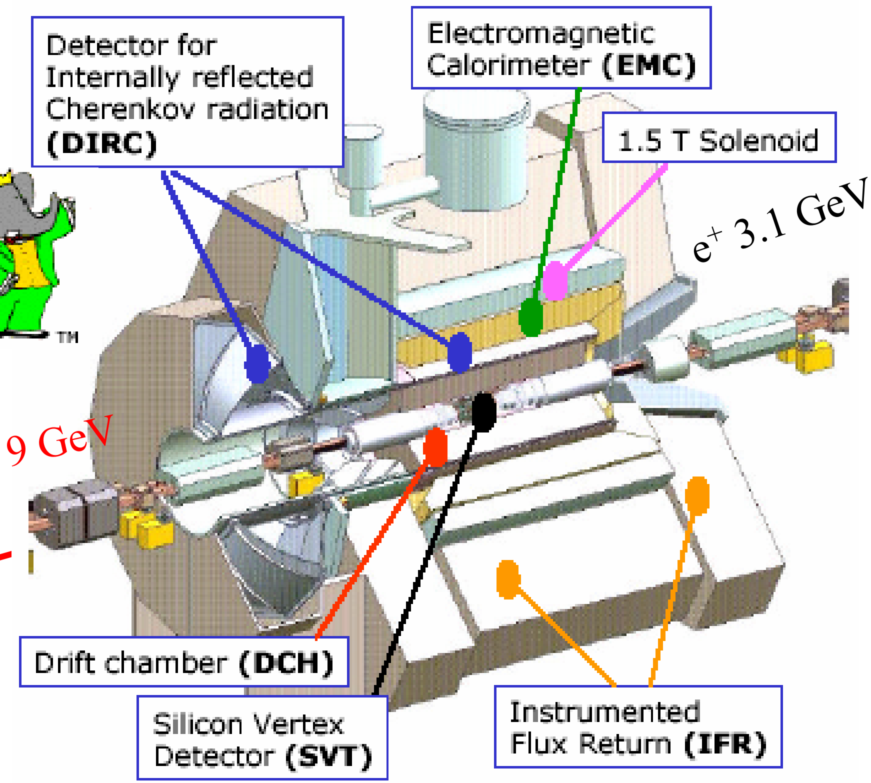


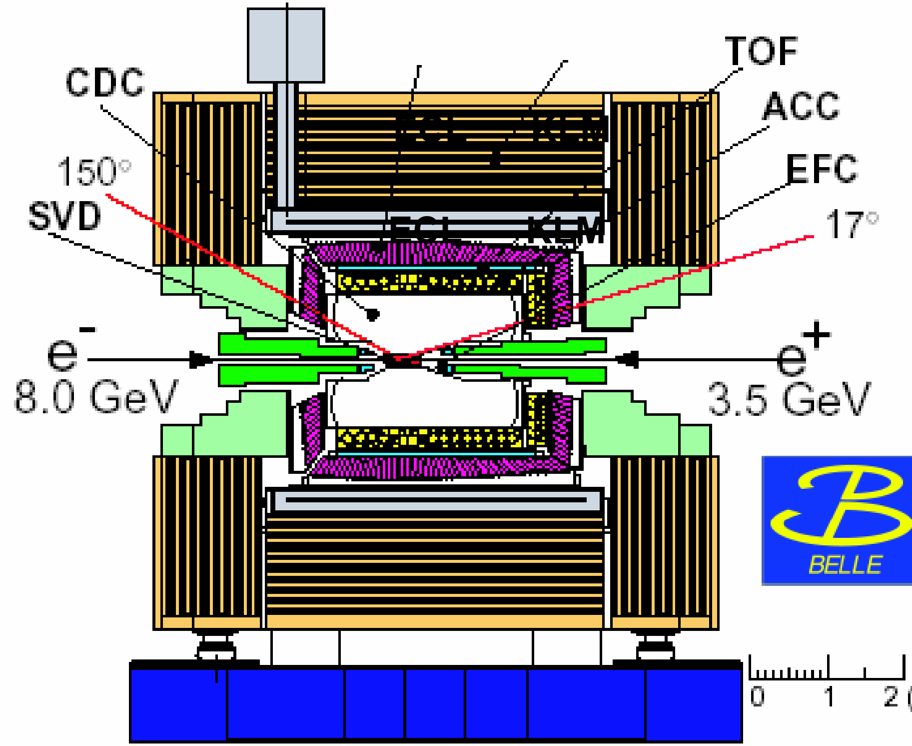
$$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B^0\overline{B^0}, B^+B$$





BaBar and Belle





DIRC: Quartz bar + water tank

SVT: 5-layer

…

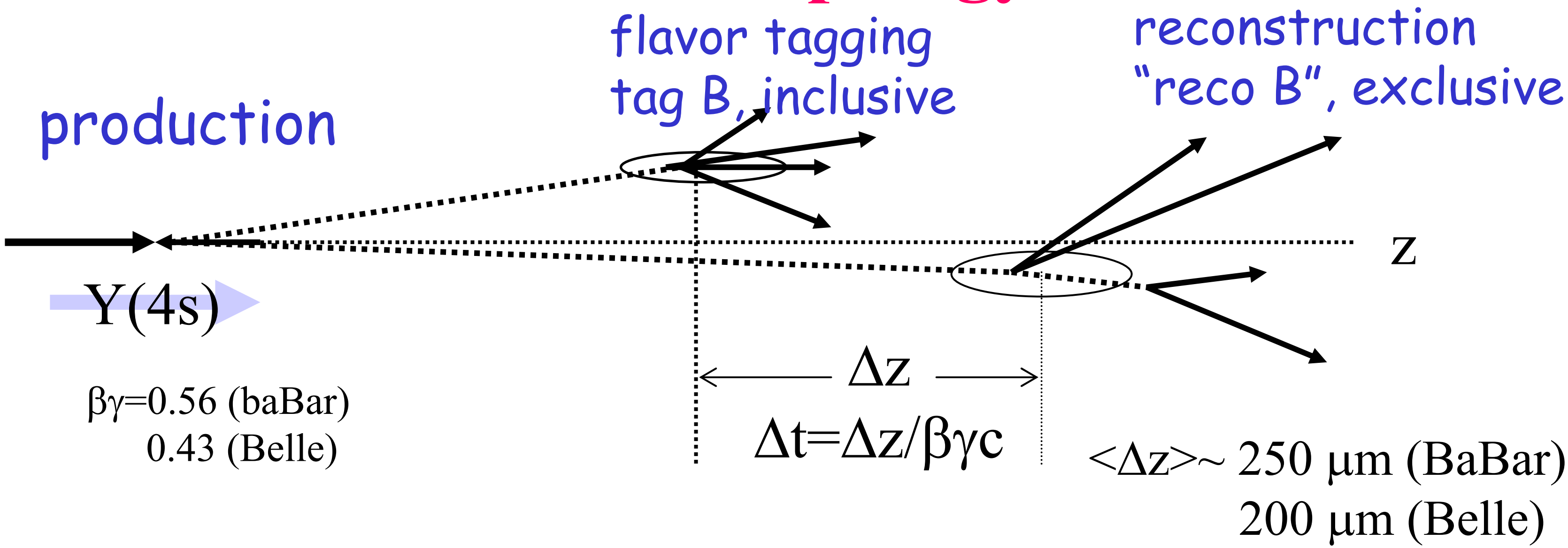
ACC: aerogel Cherenkov counters

SVD: 3-layer. (4-layer soon)

…

→high performance vertexing and PID←

Event Topology



Exclusively reconstructed B (reco B)

- Use daughter tracks to fit for decay vertex
- algorithms and resolutions decay mode dependent
- $\sigma_z \approx$ 65-90 μm

Inclusively reconstructed B (Tag B)

- Inclusive vertexing for all remaining good tracks
- use additional beam spot constraint if available.
- $\sigma_z \approx$ 140-160 μm