Violazione diretta di CP e decadimenti rari del mesone B a BaBar

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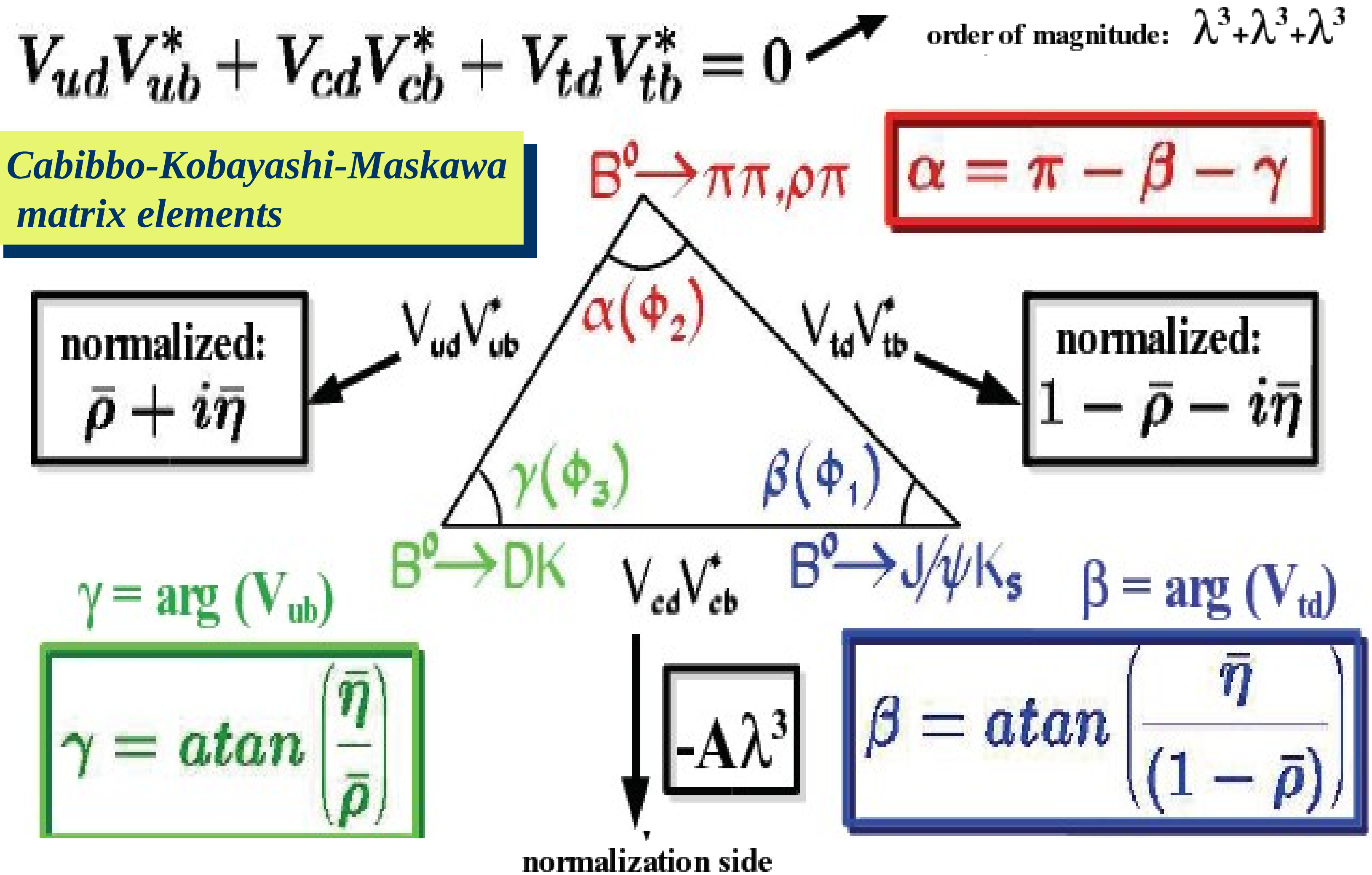
The CKM Unitarity Triangle



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Outline

- Selection of charmless hadronic B decays
  - **First observation** of **direct CP violation in B physics**
    - Charge asymmetry in **B $\rightarrow$Kπ**
  - New non-leptonic B decays
    - B $\rightarrow$ **$K_S K_S$, $K_S K$**

Understand hadronic physics in weak decays

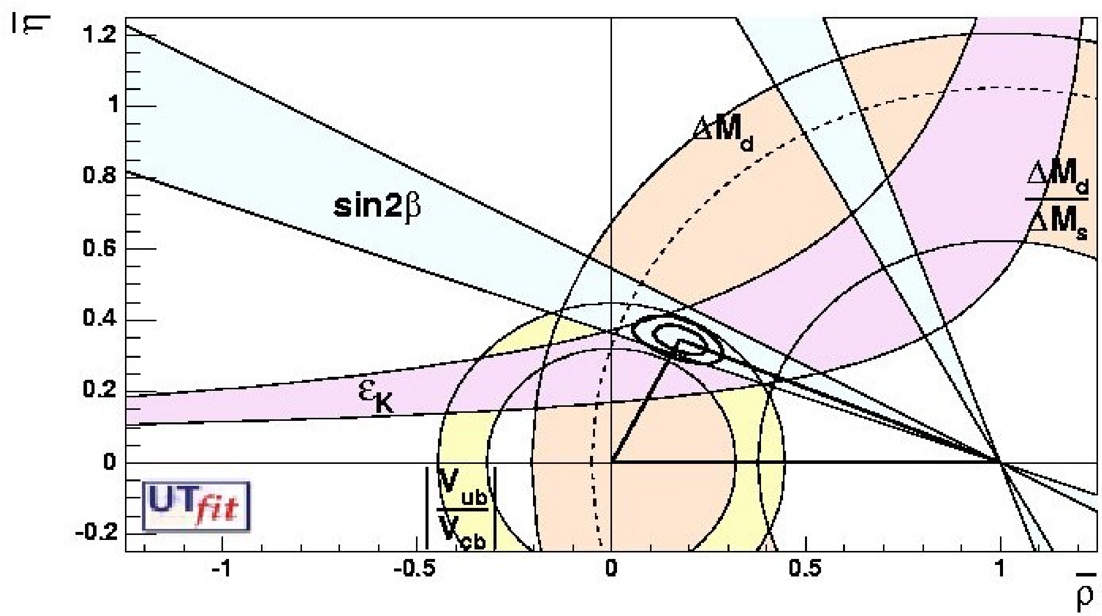
  - Experimental measurement of **CKM angle α**
  - **Time-dependent CP asymmetries**
    - B $\rightarrow \pi\pi$
    - B $\rightarrow \pi^+\pi^-\pi^0$ ($\rho\pi$) Dalitz
    - B $\rightarrow \rho\rho$

New powerful constraint on CKM UT (ρ,η)

Many results not covered here, you will hear about them in few weeks www.utfit.org.

Where we started from

hep-ph/0408079



Inputs from kaon Physics, B physics, Lattice QCD,HQET

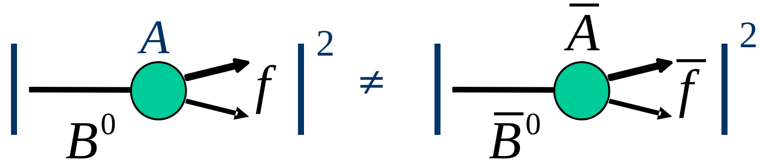
$\bar{\eta} = 0.348 \pm 0.028$

$\bar{\rho} = 0.172 \pm 0.047$

$\eta \neq 0 \rightarrow$ CP violation in B physics

The challenge is to constrain the triangle with "angle" measurements only

Direct CP violation



Direct CP **violation has been observed in Kaon system**

We had not yet observed direct *CP* violation in *B* meson system arising from *decay amplitude*

$$A_{CP} \equiv \frac{\left|\bar{A}_{\bar{f}}\right|^2 - \left|A_f\right|^2}{\left|\bar{A}_{\bar{f}}\right|^2 + \left|A_f\right|^2} \neq 0 \rightarrow \text{Direct } CPV$$

It took more than 30 years to establish DCPV in Kaon system!

PRL ***83****, 22 (1999)*

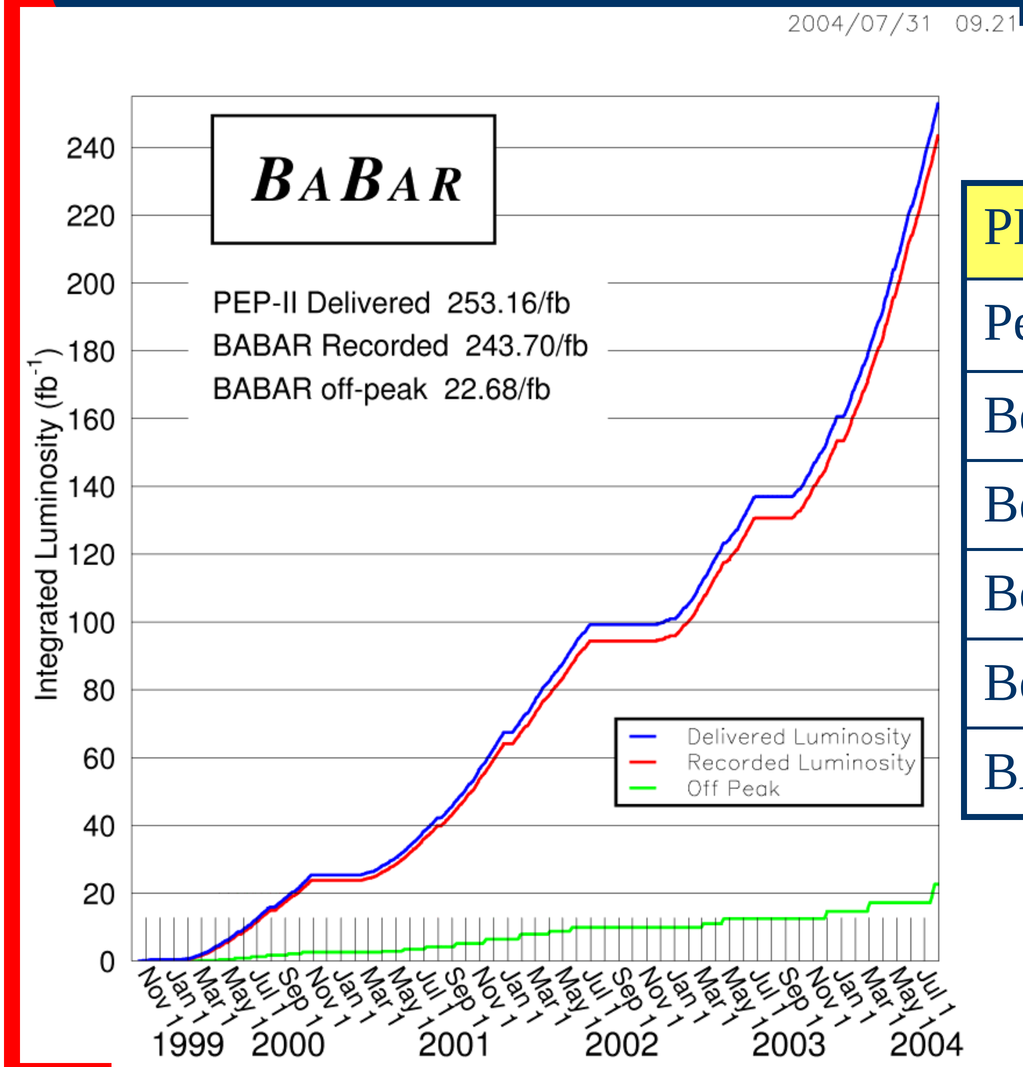
$$\mathrm{Re}\left(\varepsilon'/\varepsilon\right) \sim 28\times10^{-4}$$

Experimentally:
look for *charge* asymmetries
(in rare decays though…)

$$A_{CP} = \frac{Br\left(\bar{B}\rightarrow\bar{f}\right) - Br\left(B\rightarrow f\right)}{Br\left(\bar{B}\rightarrow\bar{f}\right) + Br\left(B\rightarrow f\right)}$$

BaBar at PEP-II

Rare decays, need a B-factory!

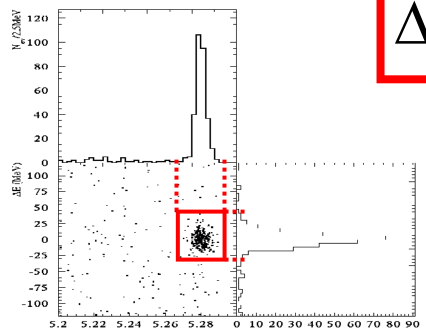


PEP-II Records	
Peak luminosity	**0.921×10^{34} cm^{-2} s^{-1}**
Best shift (8 hours)	246.3 pb^{-1}
Best day	710.5 pb^{-1}
Best week	4.200 fb^{-1}
Best 30 days	16.05 fb^{-1}
BABAR logged	**243.7 fb^{-1}**

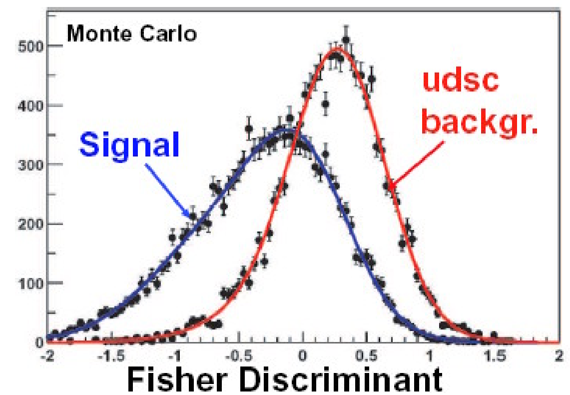
Analysis techniques

High reconstruction efficiency

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



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



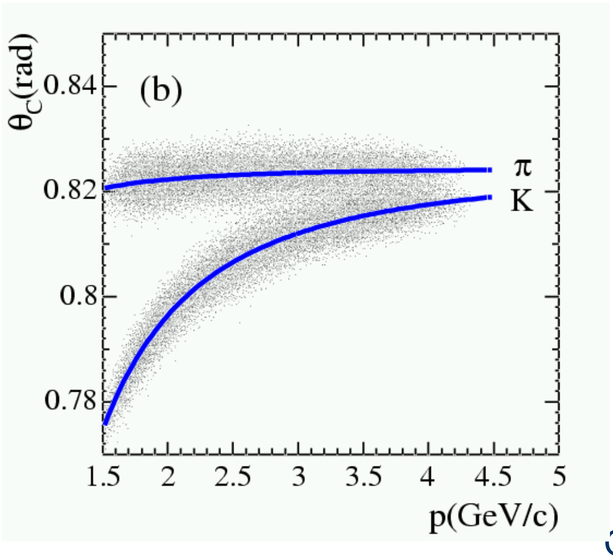
Reject

$$e^+e^- \to q\bar{q}$$

events
topological variables
in
Neural Network or
Fisher discriminant

Cerenkov angle

- No charge confusion.
- separation π/K **at high momentum**



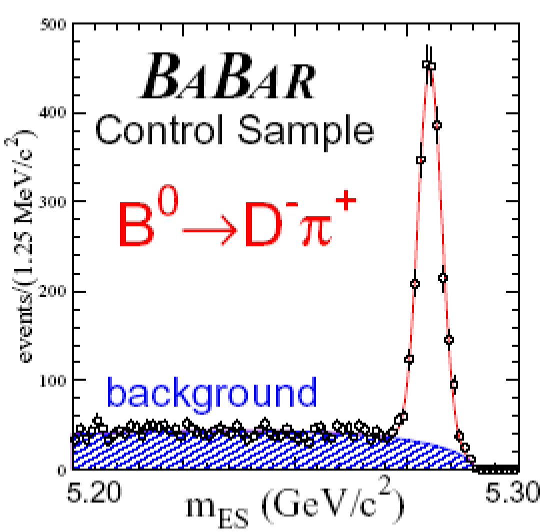
Extracting rare decays

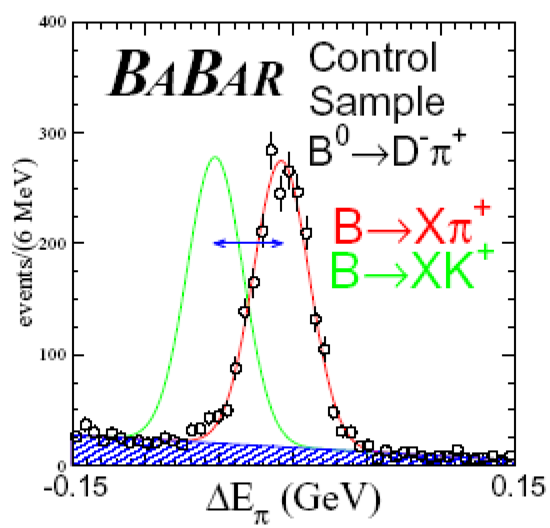
- Small BF (10^{-5} – 10^{-6})

– Need high efficiency analysis

– Detailed parametrization of discriminant variables

- Global maximum likelihood fit





Count how many K^+ and how many K^-…

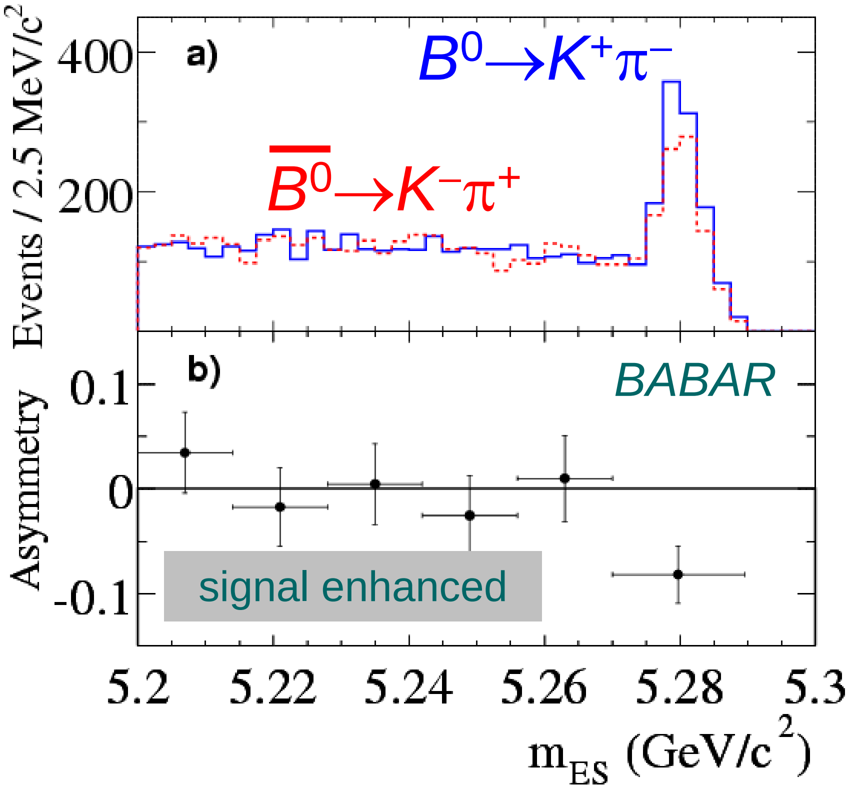
First Observation of Direct CPV in B decay

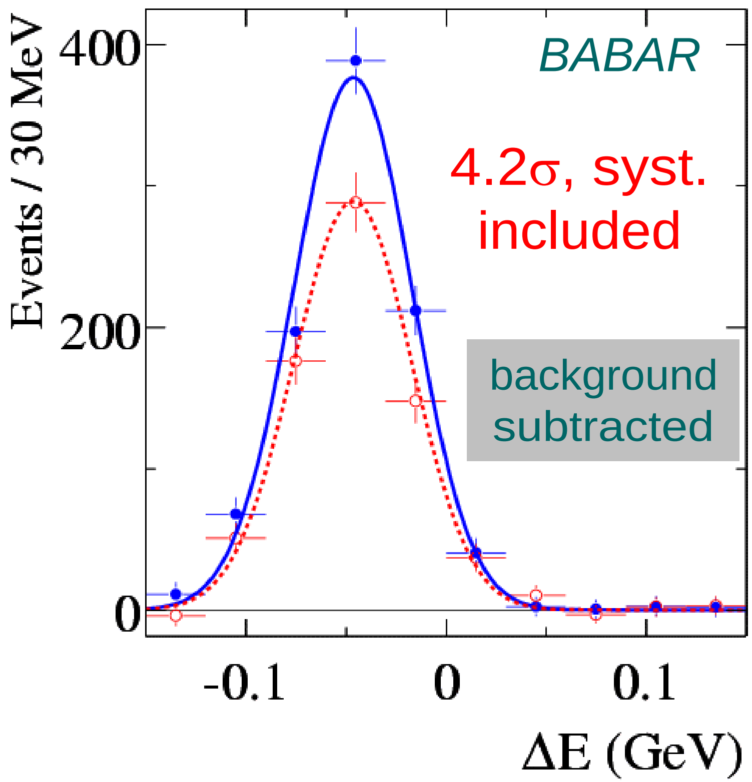
$$n_{K\pi} = 1606 \pm 51$$

$$A_{K\pi} = -0.133 \pm 0.030 \pm 0.009$$

$$n\left(B^0 \to K^+\pi^-\right) = 910$$

$$n\left(\bar{B}^0 \to K^-\pi^+\right) = 696$$





$A_{K\pi}$: systematics and cross-checks

- ✓ *CPV due to mixing ruled out*

  *PRL **89**, 281802 (2002)*

- ✓ *Asymmetries consistent in different Kaon momentum ranges*
- ✓ *Asymmetries consistent when including decay time information*
- ✓ *Asymmetries consistent in different running period*
- ✓ *Asymmetries consistent with SM predictions*

Systematics:

Source	Error
Signal fisher PDF	0.001
θ_c PDF	0.001
Potential MC bias	0.003
Potential Charge bias	0.008
Total	0.009

Background charge asymmetry free in the fit:

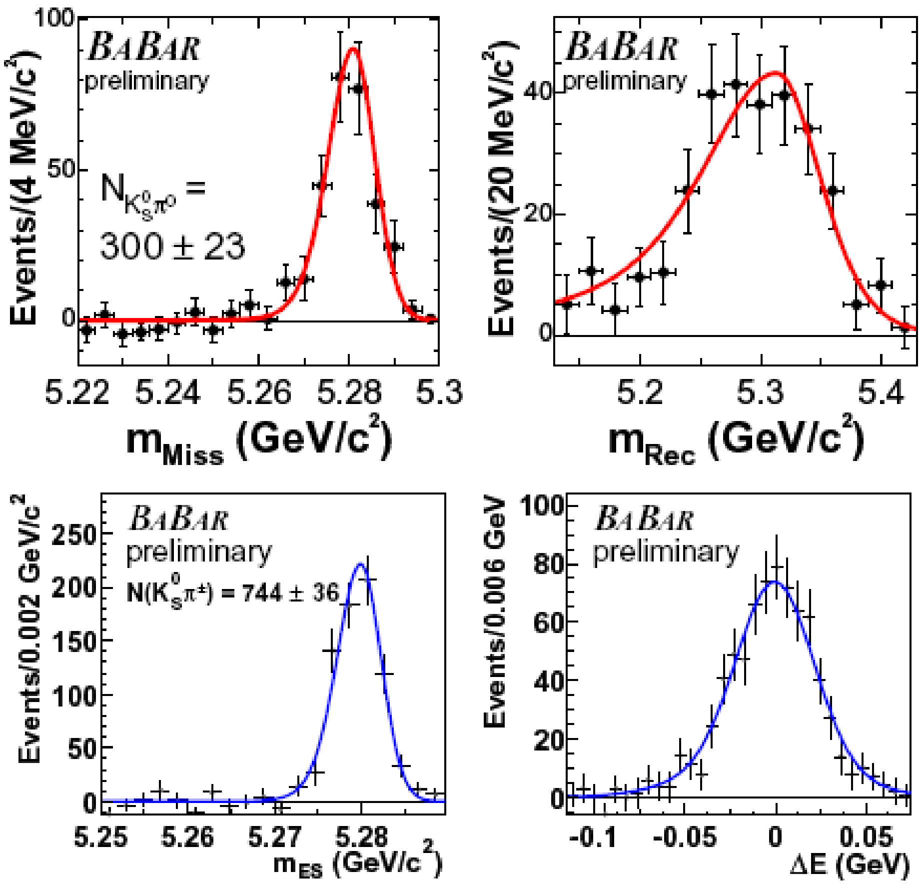
$$A^b_{K\pi} = 0.001 \pm 0.008$$

Running period:

Sample	$N_{B\bar{B}}$	$n_{K\pi}$	$A_{K\pi}$	$A^b_{K\pi}$
1999–2001	21.1	142 ± 15	-0.240 ± 0.102	0.006 ± 0.026
2002	66.4	479 ± 27	-0.102 ± 0.055	-0.008 ± 0.015
2003	34.1	241 ± 19	-0.109 ± 0.079	0.007 ± 0.021
2004	104.9	743 ± 33	-0.142 ± 0.044	0.004 ± 0.012

Branching fraction measurements

224M BB pairs



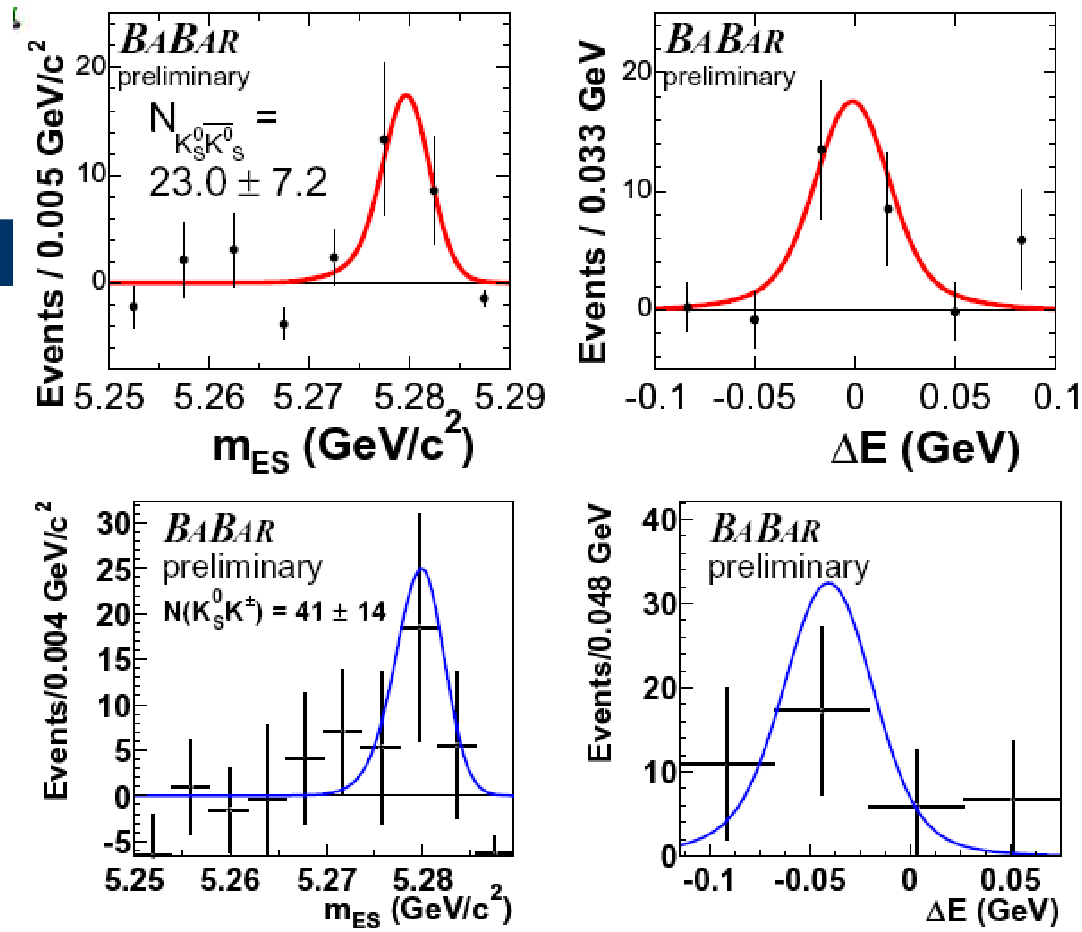
Mode	branching ratio (10^{-6})
$B^+ \to K^+\pi^0$	$12.0 \pm 0.7 \pm 0.6$
$B^0 \to K^0\pi^0$	$11.4 \pm 0.9 \pm 0.6$
$B^+ \to K^0\pi^+$	$26.0 \pm 1.3 \pm 1.0$
$B^0 \to K^+\pi^-$	$17.9 \pm 0.9 \pm 0.7$

Mode	asymmetry (%)
$B^+ \to K^+\pi^0$	$6 \pm 6 \pm 1$
$B^+ \to K^0\pi^+$	$-8.7 \pm 4.6 \pm 1.0$

$B \to KK$

224M BB pairs

- First evidence for K^0K^0
- Hint of a signal for K^+K^0

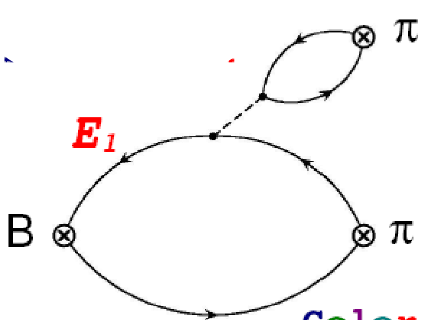


Mode	Signal	σ	Branching ratio (10^{-6})	Asymmetry
$B^0 \to K^0\bar{K}^0$	$23.0 \pm 7.2 \pm 2.0$	4.5	$1.19 \pm 0.38 \pm 0.13$	
$B^+ \to K^+\bar{K}^0$	$41 \pm 14 \pm 3$	90% C.L.	< 2.35	[-0.43,0.68]
		3.5	$1.45 \pm 0.50 \pm 0.11$	
$B^0 \to K^+K^-$	< 16	-	< 0.6	

How can we translate all this into CKM phases?

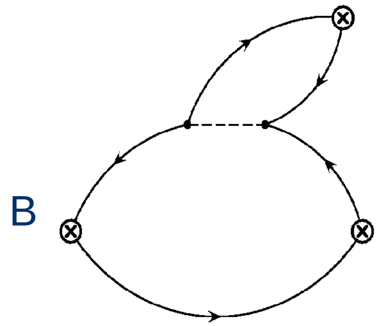
M.Pierini talk at ICHEP04

Hadronic interactions hassles



$\sim \mathcal{O}(1)$

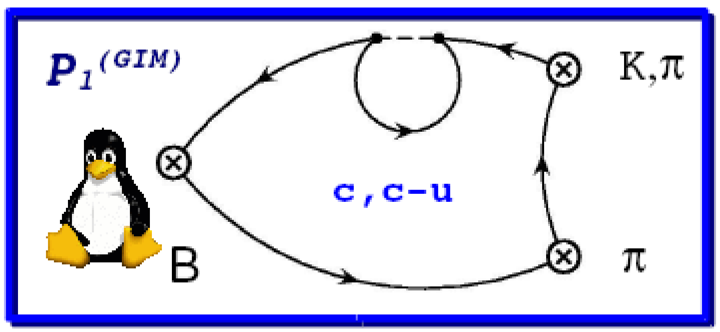
Color allowed



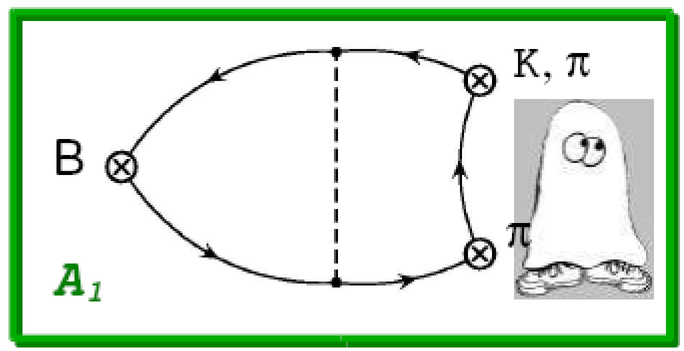
CE

Color suppressed

Renormalization Group Invariant quantities (Buras & Silvestrini, hep-ph/9812392)



Charming and GIM penguins(c−u)



Connected Annihilation (a.k.a. W−exchange)

Perturbative calculation of hadronic contributions too naïve.

Λ_{QCD}/mb Non-perturbative terms

M.Pierini talk at ICHEP04

A working phenomenological model

Complex parameters (strong phases!)

$E_1 \sim 1$ *Evaluated with Factorization technique*

Weak Amplitudes

Charming Penguin $\sim \lambda^2$ | $V_{us} V_{ub}^* \sim \lambda^4$

$$\mathcal{A}(B^0 \to K^+ \pi^-) = V_{ts} V_{tb}^* \times P_1(c) - V_{us} V_{ub}^* \times \{E_1 - P_1^{GIM}(u-c)\}$$

$$\mathcal{A}(B^+ \to K^0 \pi^+) = -V_{ts} V_{tb}^* \times P_1(c) + V_{us} V_{ub}^* \times \{A_1 - P_1^{GIM}(u-c)\}$$

$$\sqrt{2} \cdot \mathcal{A}(B^+ \to K^+ \pi^0) = V_{ts} V_{tb}^* \times P_1(c) - V_{us} V_{ub}^* \times \{E_1 + E_2 + A_1 - P_1^{GIM}(u-c)\}$$

$$\sqrt{2} \cdot \mathcal{A}(B^0 \to K^0 \pi^0) = -V_{ts} V_{tb}^* \times P_1(c) - V_{us} V_{ub}^* \times \{E_2 + P_1^{GIM}(u-c)\}$$

$P_I(c) \sim \Lambda_{QCD}/m_b$

sensitivity to the angle γ

- **Parametrize** Λ_{QCD}/m_b terms
- Global fit to BF and ACP, statistical test for **consistency** of theory with experiment
- Two terms with different CKM elements: ***interference!*** **sensitivity to γ**

M.Pierini talk at
ICHEP04

B $\to$ KK system

Charming Penguin $\sim \lambda^3$ $\qquad$ $V_{ud}V_{ub}^* \sim \lambda^3$

$$\mathcal{A}(B^0 \to K^+K^-) = - V_{ud}V_{ub}^* \times A_2$$

$$\mathcal{A}(B^+ \to K^+K^0) = -V_{td}V_{tb}^* \times P_1(c) + V_{ud}V_{ub}^* \times \{A_1 - P_1^{GIM}(u-c)\}$$

$$\mathcal{A}(B^0 \to \overline{K}^0K^0) = -V_{td}V_{tb}^* \times P_1(c) - V_{ud}V_{ub}^* \times \{P_1^{GIM}(u-c)\}$$

Different CKM matrix element as Kπ
Different amplitudes (different quark contents)

Pure penguin, ***sensitive to new physics effect!!!***

Given the small yields, application for a super B-factory?

M.Pierini talk at
ICHEP04

Constraining the big picture

Good agreement data/theory

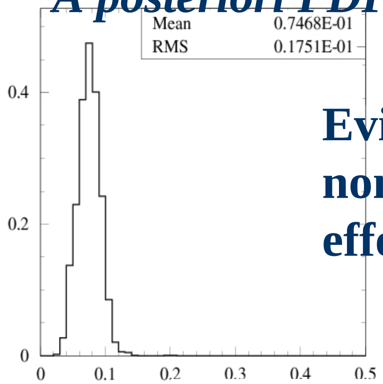
Input from HFAG averages

Channel	$BR^{th} \times 10^6$	$BR^{exp} \times 10^6$	$\mathcal{A}_{CP}^{th}$	$\mathcal{A}_{CP}^{exp}$
$K^+\pi^-$	19.1 ± 0.7	18.2 ± 0.8	-0.07 ± 0.02	-0.11 ± 0.02
$K^+\pi^0$	12.5 ± 0.5	12.0 ± 0.9	-0.07 ± 0.02	0.06 ± 0.04
$K^0\pi^+$	23.5 ± 0.9	24.6 ± 1.3	0.00 ± 0.05	-0.02 ± 0.03
$K^0\pi^0$	9.0 ± 0.4	11.4 ± 1.0	-0.01 ± 0.04	0.09 ± 0.16

$A(K^+\pi^-)$ predicted!

Hints of discrepancy??

A posteriori PDF

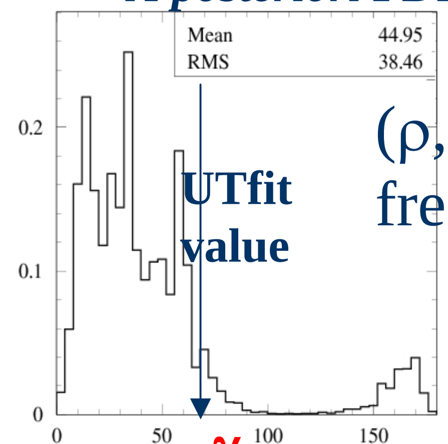


Evidence of non-perturbative effects

$P_I(c)$

(normalized to E_1)

A posteriori PDF



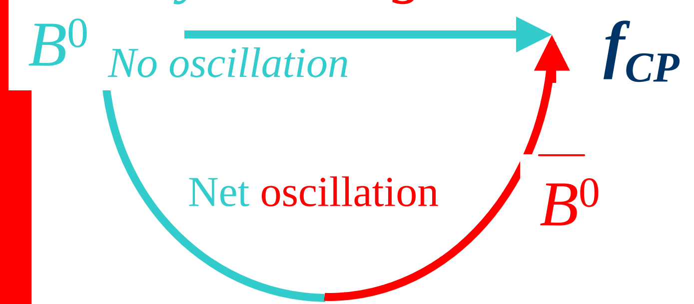
UTfit value

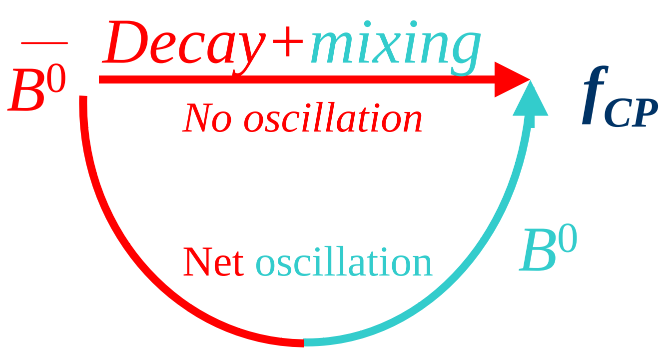
γ

(ρ,η)
free input

Charmless 2body decays still within SM framework

Decay-mixing interference





$$\Gamma\left(B^0_{phys}(t) \to f_{CP}\right) \neq \Gamma\left(\overline{B}^0_{phys}(t) \to f_{CP}\right)$$

$$A_{f_{CP}}(t) = \frac{\Gamma\left(\overline{B}^0_{phys}(t) \to f_{CP}\right) - \Gamma\left(B^0_{phys}(t) \to f_{CP}\right)}{\Gamma\left(B^0_{phys}(t) \to f_{CP}\right) + \Gamma\left(\overline{B}^0_{phys}(t) \to f_{CP}\right)}$$

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

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

Amplitude ratio

$\frac{q}{p} \approx e^{-2i\beta}$

CP parameter

$$C_{f_{CP}} = \frac{1 - |\lambda_{f_{CP}}|^2}{1 + |\lambda_{f_{CP}}|^2} \quad = 0$$

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

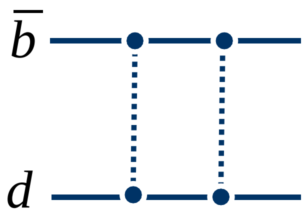
For single amplitude

$C_{f_{CP}} \neq 0$ implies Direct *CP* Violation

α from mixing- decay inteference

$b \to u\bar{u}\, d$ transition

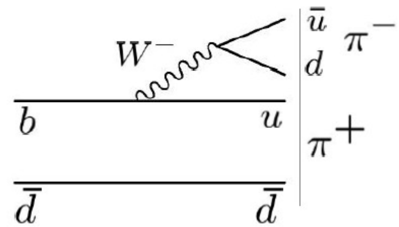
B^0 mixing



$$q/p \propto V^*_{tb} V_{td} / V_{tb} V^*_{td}$$

⊕

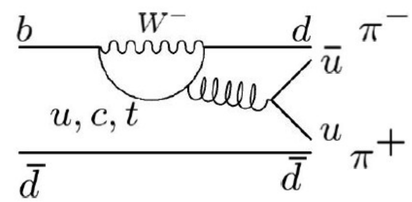
B^0 decay: tree



$$A \propto V^*_{ub} V_{ud} \quad \propto \lambda^3$$

⊕

B^0 decay: penguin



$$A \propto V^*_{td} V_{tb} \quad \propto \lambda^3$$

In fact: $\alpha = \pi - (\beta + \gamma)$

$$\lambda_{hh} = \frac{q}{p}\frac{\bar{A}}{A} = e^{2i\alpha}\frac{1 - P/T\, e^{-i\alpha}}{1 - P/T\, e^{+i\alpha}} = |\lambda| e^{i2\alpha_{eff}}$$

$$\frac{q}{p} = e^{-2i\beta}$$

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

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

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Current predictions

Charming Penguin $\sim \lambda^3$ $\qquad$ $V_{ud} V_{ub}^* \sim \lambda^3$

$$\mathcal{A}(B^0 \to \pi^+ \pi^-) = V_{td} V_{tb}^* \times P_1(c) - V_{ud} V_{ub}^* \times \{E_1 + A_2 - P_1^{GIM}(u\text{-}c)\}$$

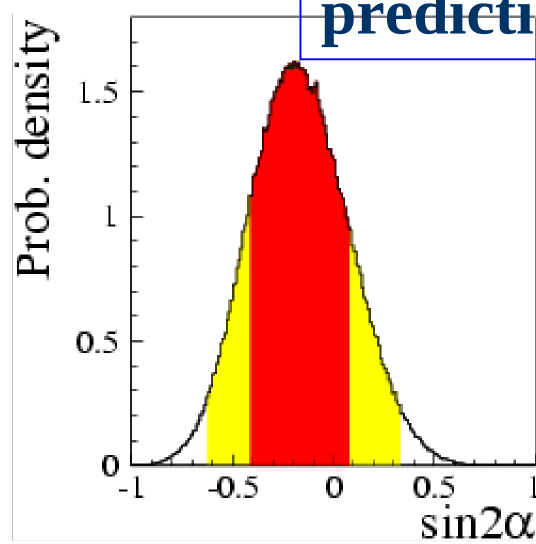
$$\sqrt{2} \cdot \mathcal{A}(B^+ \to \pi^+ \pi^0) = - V_{ud} V_{ub}^* \times \{E_1 + E_2\}$$

$$\sqrt{2} \cdot \mathcal{A}(B^0 \to \pi^0 \pi^0) = - V_{td} V_{tb}^* \times P_1(c) - V_{ud} V_{ub}^* \times \{E_2 - A_2 + P_1^{GIM}(u\text{-}c)\}$$

$P_1(c) \sim \Lambda_{QCD}/m_b$

- You fit for $\sin(2\alpha_{eff})$
  - Time dependent CP asymmetries
- You'd like to extract α
  - ***Isospin analyses***
- Eventually you want (ρ,η) constraints.

UT fit prediction

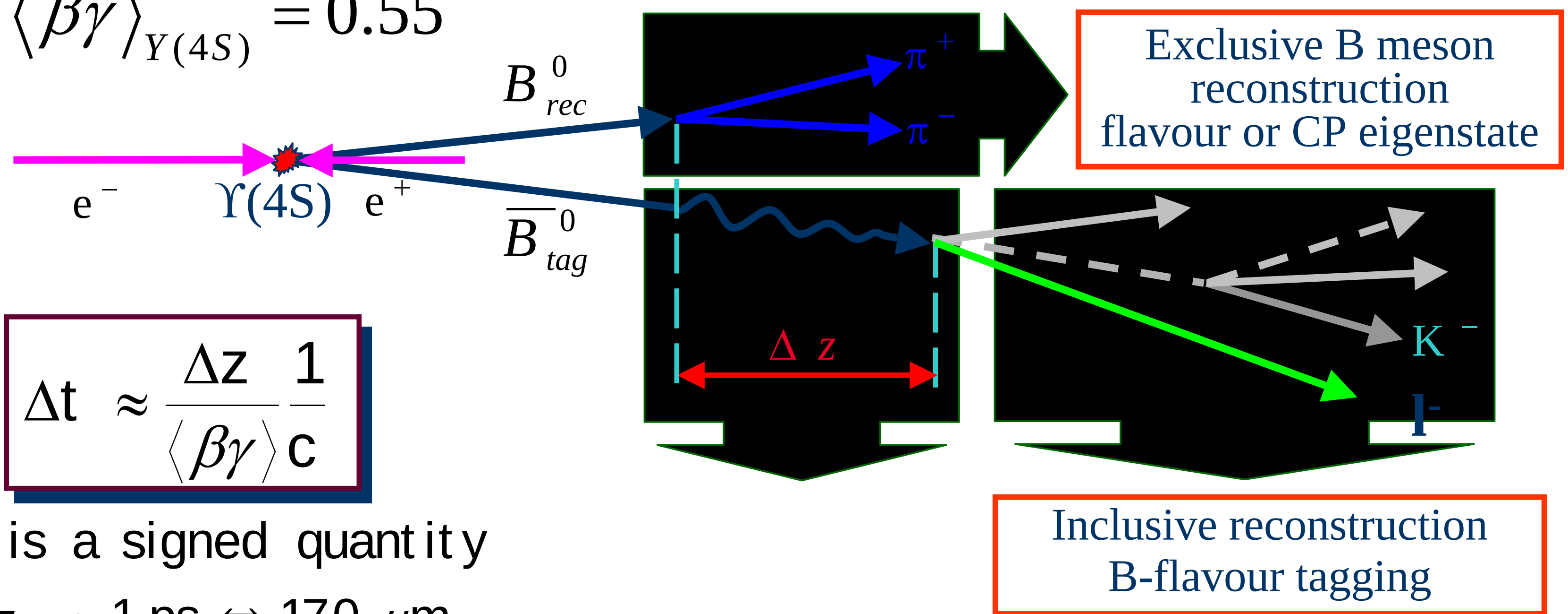


$\sin(2\alpha) = -0.16 \pm 0.26$

Time- dependent analysis

Asymmetric B-factory

$$\langle \beta\gamma \rangle_{\Upsilon(4S)} = 0.55$$



$$\Delta t \approx \frac{\Delta z}{\langle \beta\gamma \rangle} \frac{1}{c}$$

Δt is a signed quantity

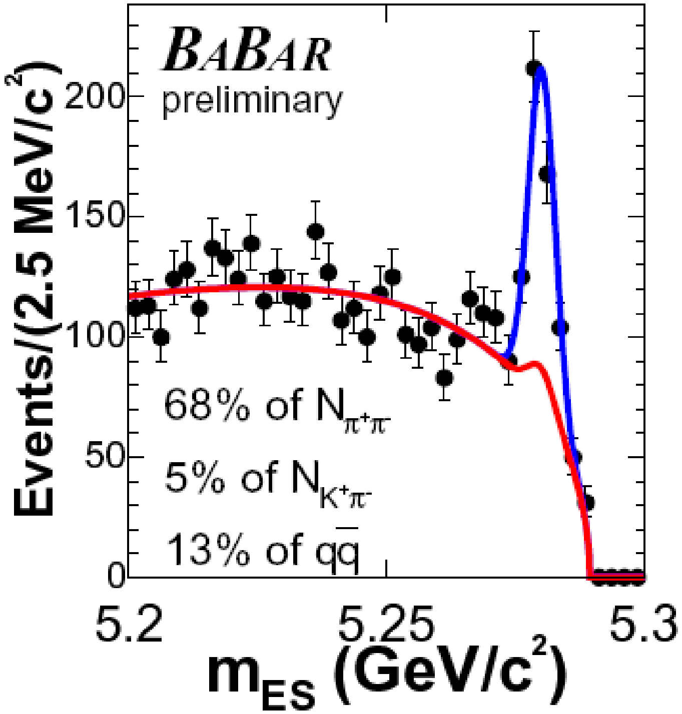
$\sigma_{\Delta t} \sim 1\ ps \Leftrightarrow 170\ \mu m$

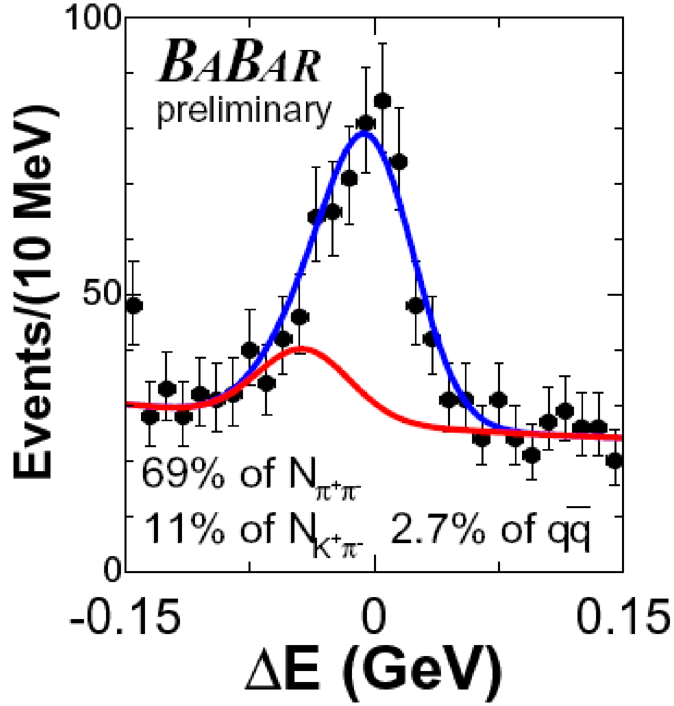
$\tau_B \sim 1.6\ ps \Leftrightarrow 250\ \mu m$

Tagging performance: Q = 30.5%

$B^0 \to \pi^+\pi^-$ sample

Likelihood ratio cuts



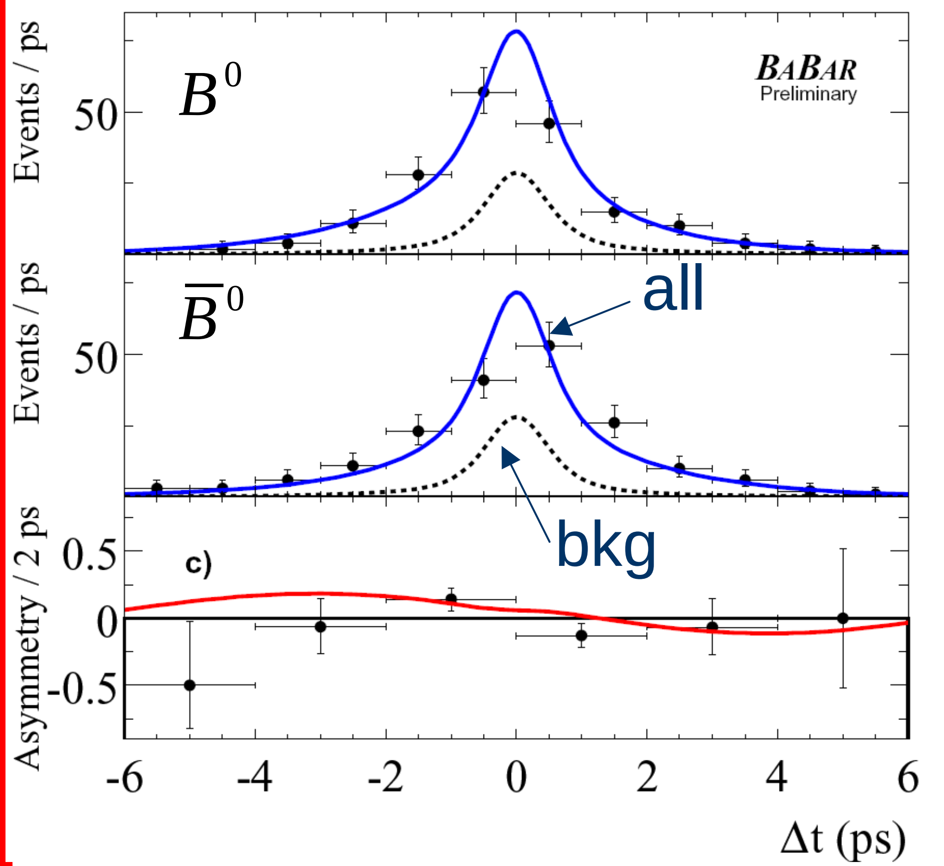


3body Background negligible

224 M BB pairs

$$N_{\pi\pi} = 467 \pm 33$$

$B^0 \to \pi^+\pi^-$ time-dependent CP asymmetry



224 M BB pairs

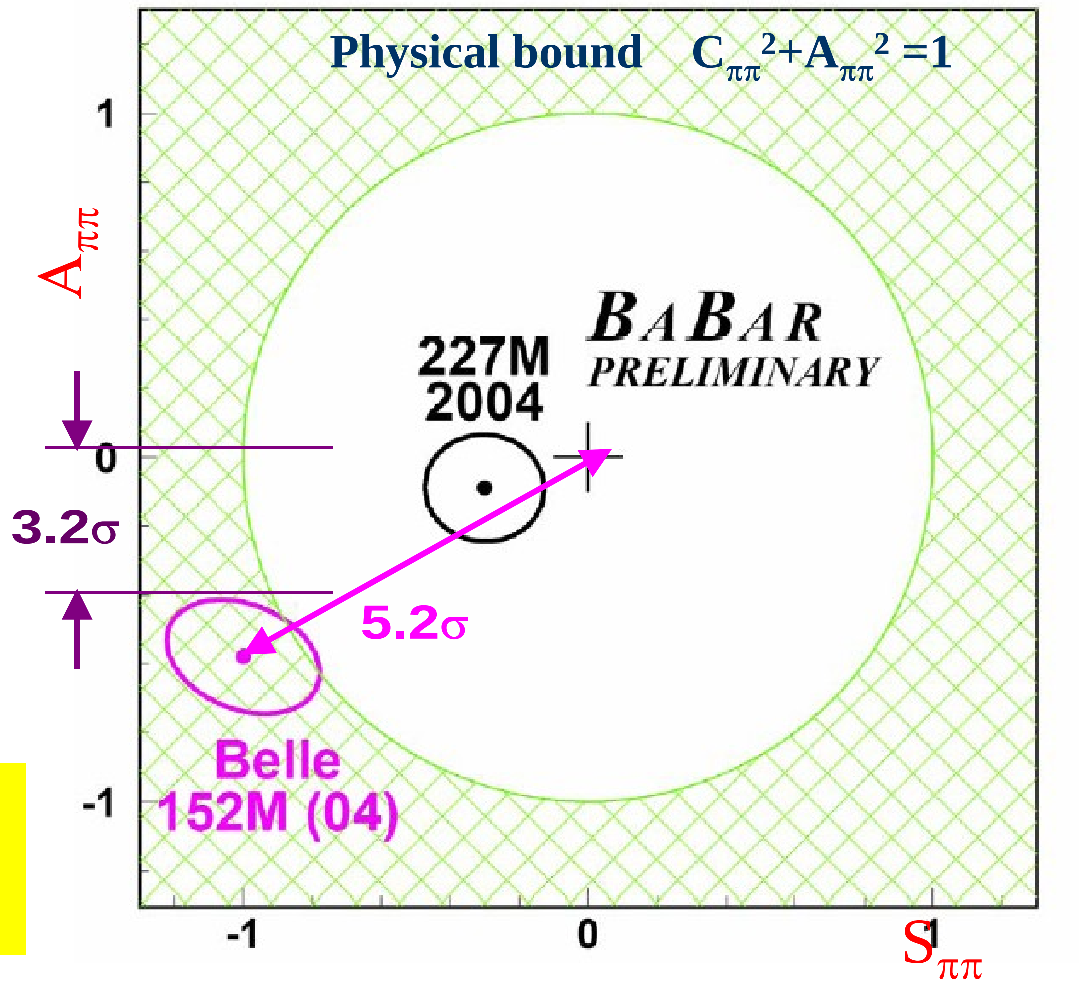
$$S_{\pi\pi} = -0.30 \pm 0.17 \pm 0.03$$
$$C_{\pi\pi} = -0.09 \pm 0.15 \pm 0.04$$

No evidence of CP violation

Belle versus BaBar

- Belle claims 3.2σ observation of direct CP
  - Based on Feldman-Cousins analysis (ensemble of toyMC experiments)

Belle evidence for Direct CP violation not supported by BABAR measurements

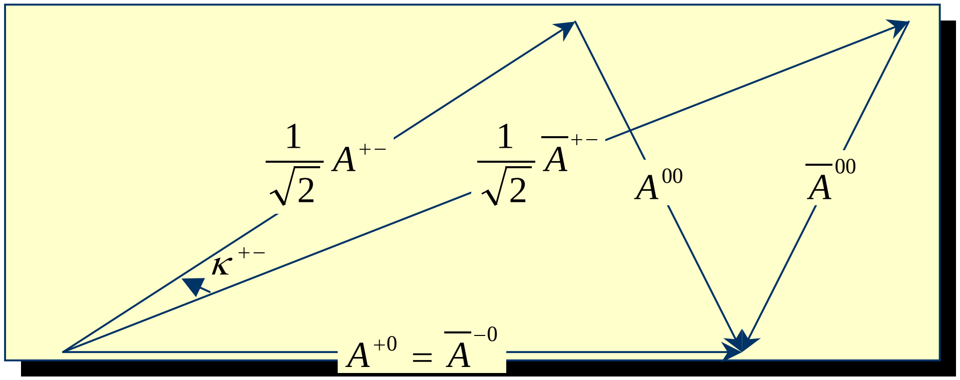


Trapping the penguins

Isospin analysis

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

$$S^{+-} = \sin(2\alpha + \kappa^{+-})\sqrt{1 - C^{+-2}}$$



Need to measure $C_{\pi 0\pi 0}$ too! (and still do not solve ambiguities!)

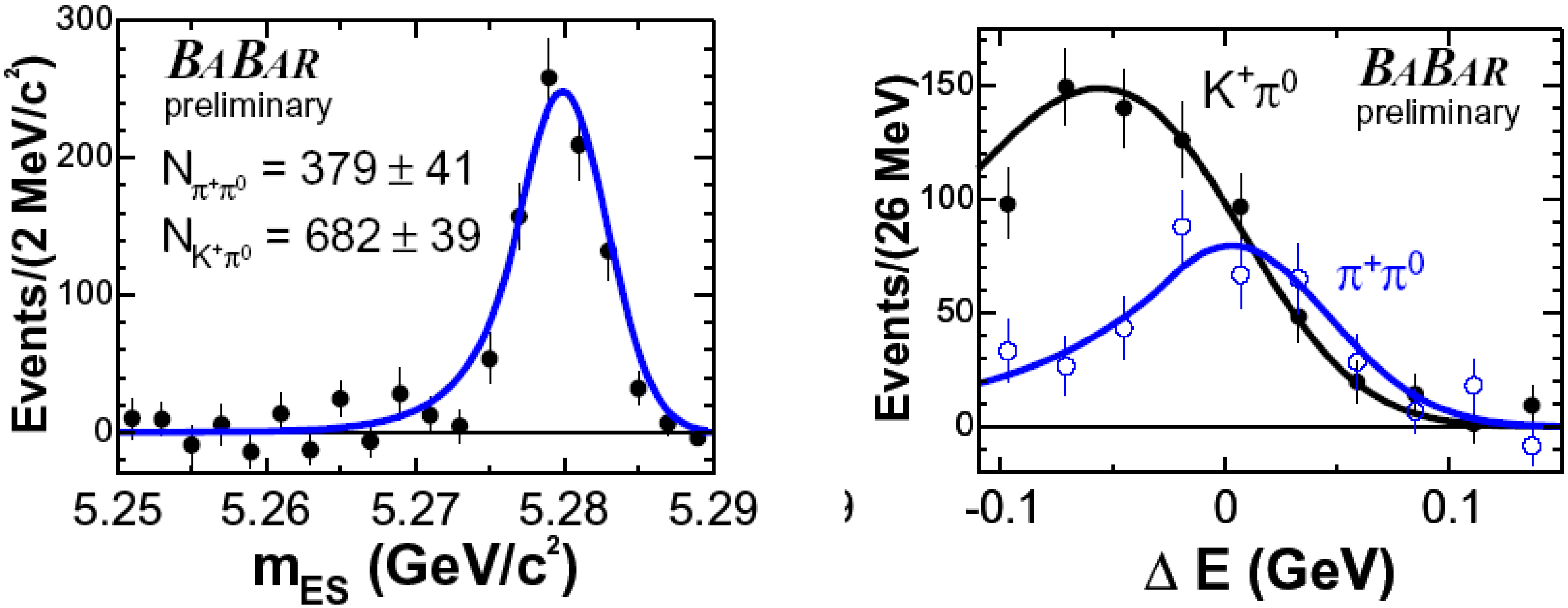
Bound the penguins:

- Grossman-Quinn

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

But pure SU(2) could not be the end of the story…!

$B^- \rightarrow \pi^-\pi^0 / K^- \pi^0$



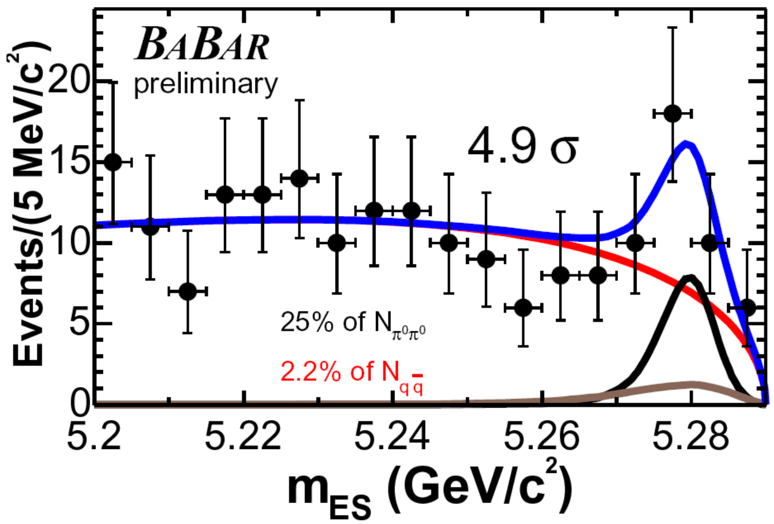
$$\mathcal{B}(B^+ \rightarrow \pi^+\pi^0) = (5.8 \pm 0.6 \pm 0.4) \times 10^{-6}$$

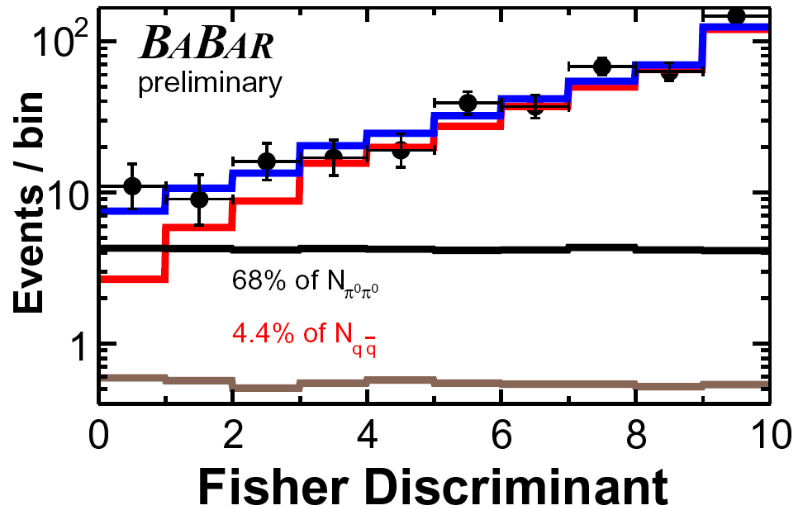
$$\mathcal{A}_{\pi^+\pi^0} = -0.01 \pm 0.10 \pm 0.02$$

$B^0 \to \pi^0\pi^0$

Fisher discriminant
(topology + flavour tagging)

Large continuum background
3body contamination





Fit $= q\bar{q}$ bkgd + $B^0 \to \rho^\pm\pi^0$ + signal

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

First measurement

GQ bound (WA)

$$|\alpha - \alpha_{eff}| \le 21^o \ at \quad 68\%CL$$

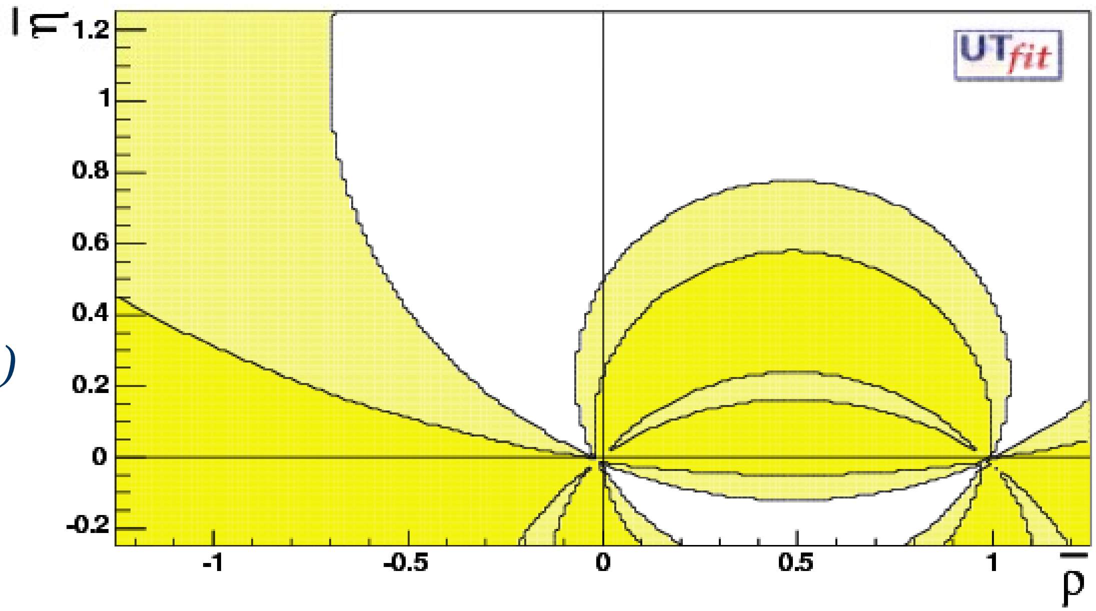
Our experimental knowledge from ππ

BaBar ππ

dark yellow: 68%
light yellow:95%

$\alpha = 103 \pm 19$

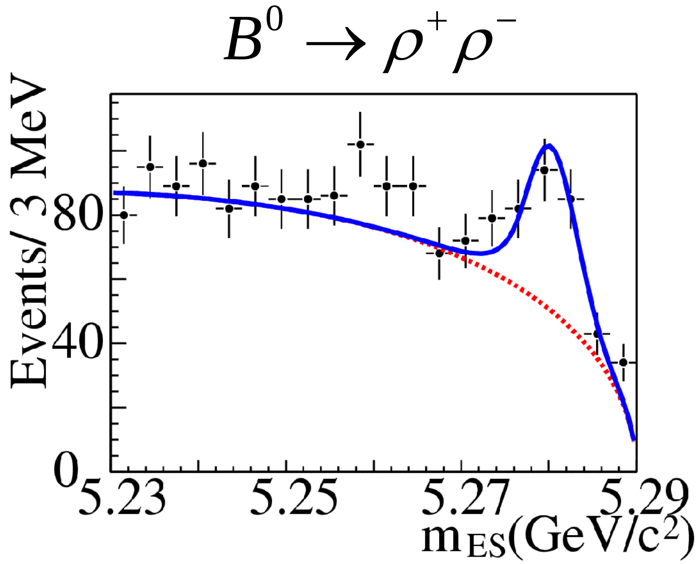
(selecting one solution)

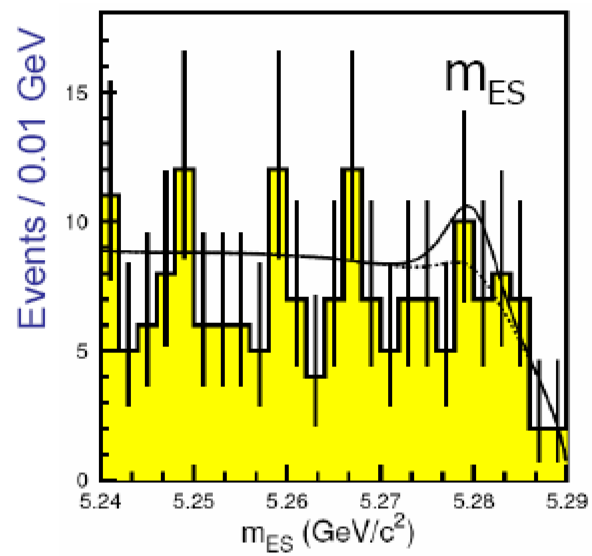


Relatively large penguin
→ BF($\pi^0\pi^0$) large →loose (ρ,η) constraints…

A clean mode? : $\rho^+\rho^-$

What about a small $BF(B^0 \to \rho^0\rho^0)$?





$$BF(\rho^+\rho^-) = (30 \pm 4_{stat} \pm 5_{syst})10^{-6}$$

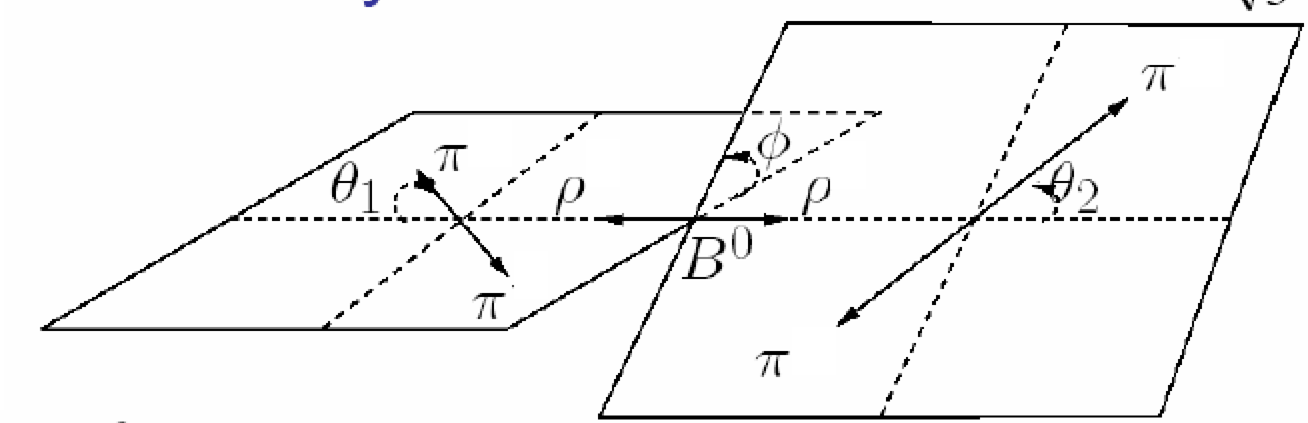
$$BF(\overline{B}^0 / B^0 \to \rho^0\rho^0) < 1.1\times10^{-6} \quad @\,90\%\,\mathrm{CL}$$

$$BF(B^{\pm} \to \rho^{\pm}\rho^0) = (26.4 \pm 6.4)\times10^{-6} \quad (HFAG)$$

Penguins are smaller!!!
$|\alpha_{eff} - \alpha| < 11°$ (68% CL)

Angular analysis

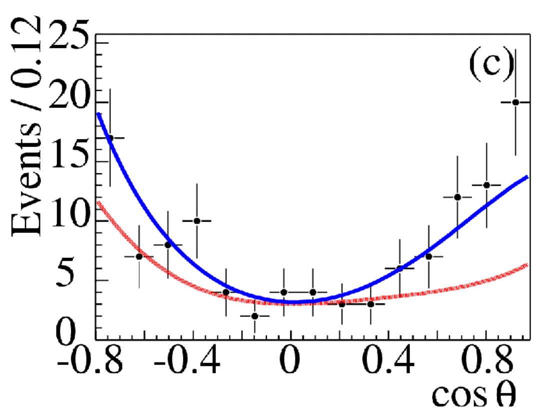
- VV mode
- S,P,D wave components,
  - need angular analysis to determine CP contents



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

Longitudinal
(CP even)
SLong & CLong

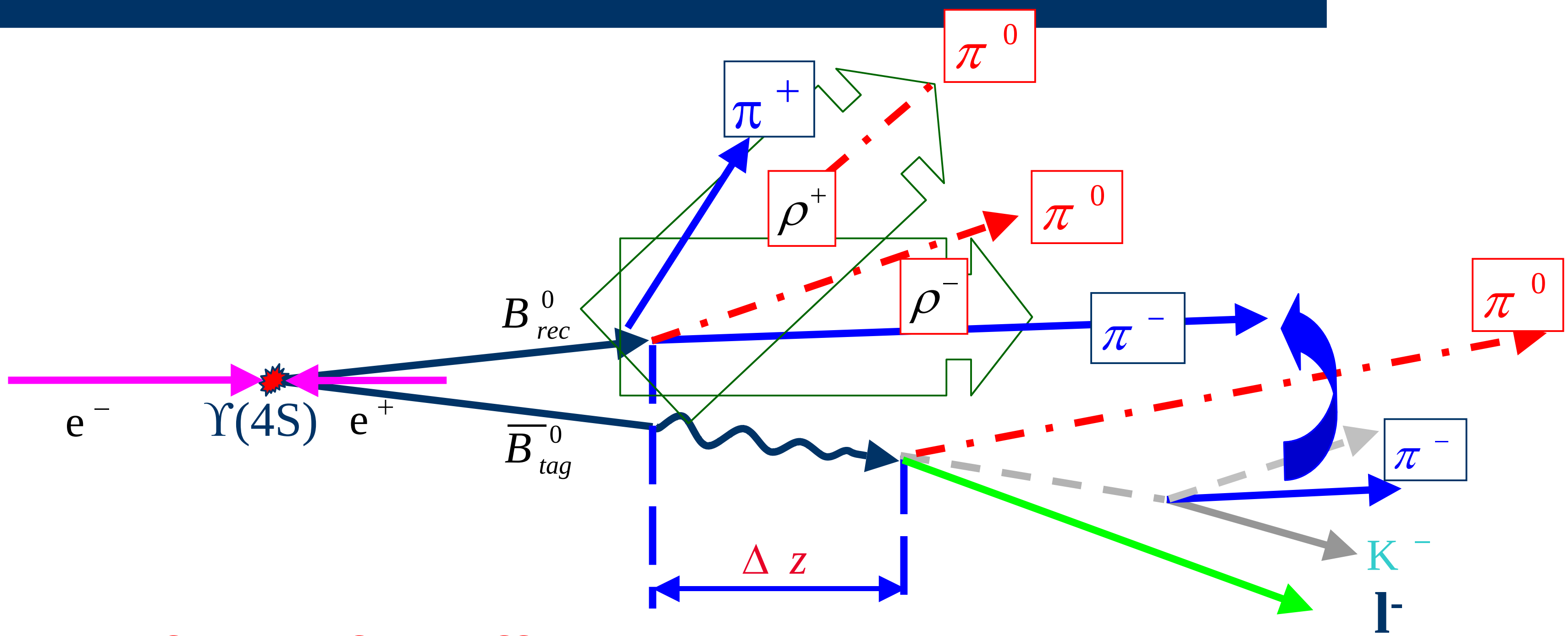
Transverse
(Mixed CP state)
Set $S_{Tran}=C_{Tran}=0$
& vary for systematics



$$f_{long} = 0.99 \pm 0.03(stat)^{+0.04}_{-0.03}(syst)$$

Pure CP eigenstate!

A tough job



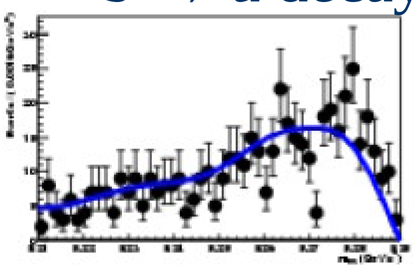
Self-cross-feed effects (39% longitudinal signal events)

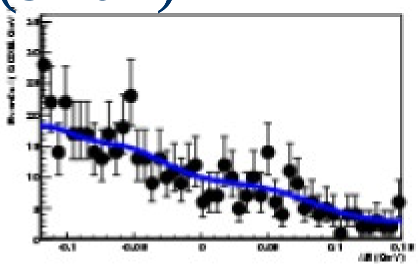
Possible dilutions effect, careful studies reveals few percents effect (accounted for)

Systematics

- Detailed description of B-background
  - 200 exclusive channels studied…

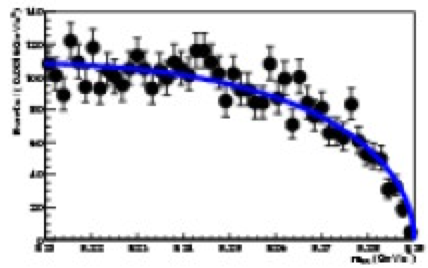
$b \to u$ decays (small)

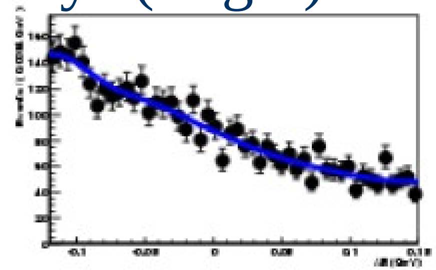




m_{ES} $a_1\rho$ ΔE

$b \to c$ decays (large!)





m_{ES} ΔE

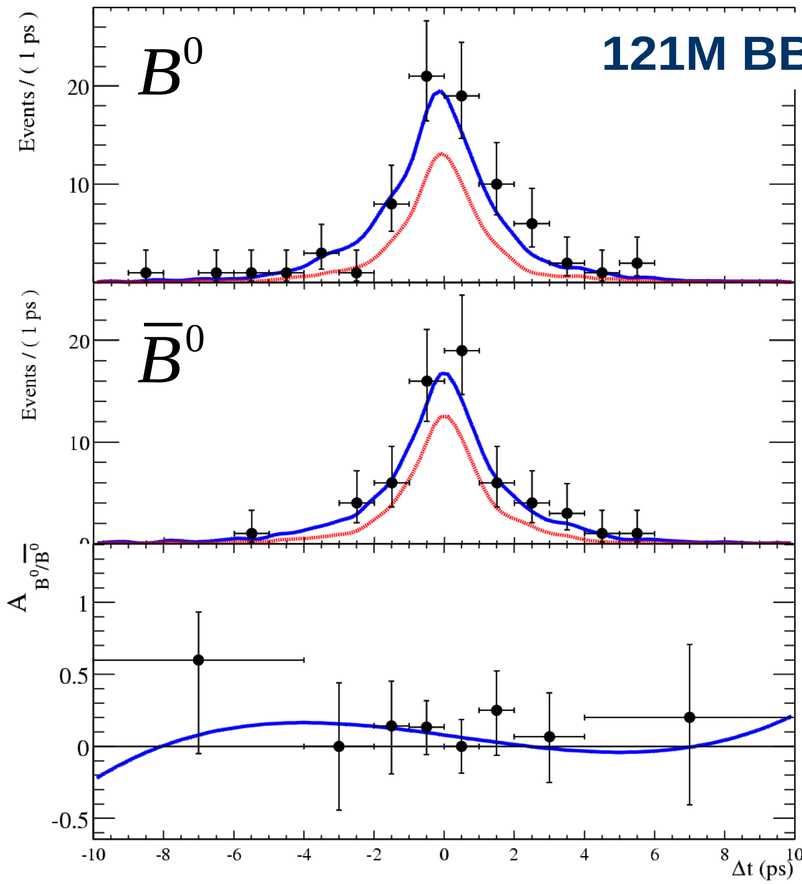
Largest systematics on S and C come from unknown CP properties of BB background.

- Sensitivity to other wave?
  - Systematic error interference of signal with $a_1\pi$, $\rho\pi\pi$, $\pi\pi\pi\pi$:0.02 for both S and C

$B \to \rho^+\rho^-$ time-dependent asymmetry

Maximum likelihood fit to m_{ES}, ΔE, NN, $\cos\theta$, ρ mass

121M BB pairs



$$S_{\rho\rho}^{long} = -0.19 \pm 0.33_{stat} \pm 0.11_{syst}$$

$$C_{\rho\rho}^{long} = -0.23 \pm 0.24_{stat} \pm 0.14_{syst}$$

Likelihood projections

Bounding α

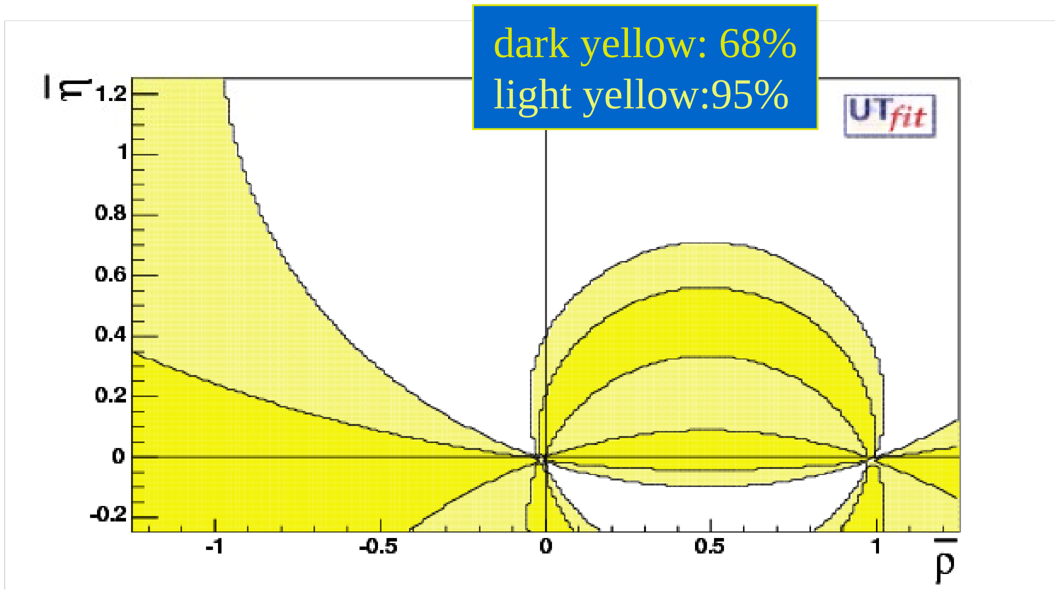
$121M\ B\bar{B}$ pairs

BaBar $\rho^+\rho^-$

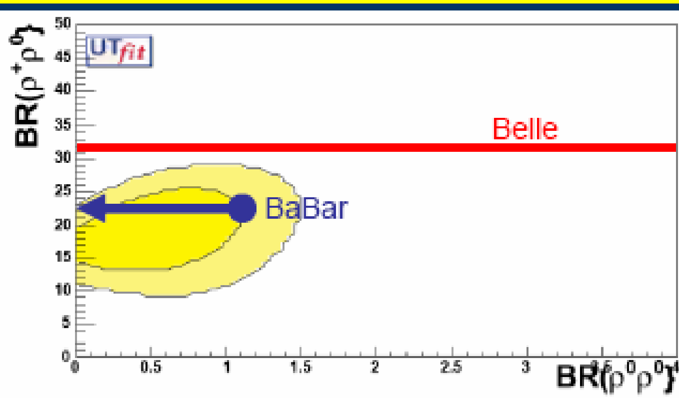
$\alpha = 97 \pm 14$

(selecting one solution)

Neglect I=1 component of amplitude



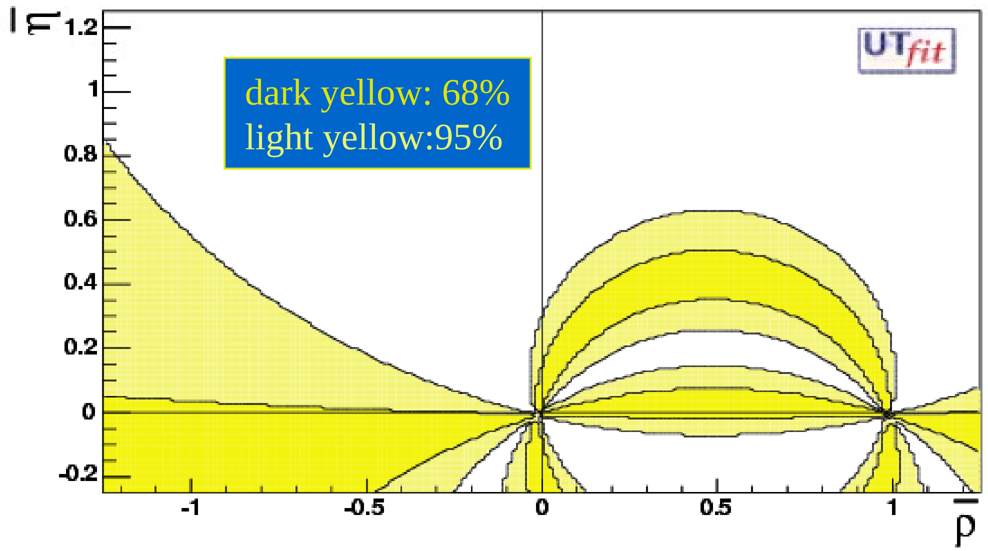
Validity of isospin analysis approach under scrutiny though…



Internal crosscheck of SU(2) assumption in UT fit

Constraints from ππ and ρρ

Indirect UT fit constraints: $\alpha = (95 \pm 8)°$



These measurements: $\alpha = (98 \pm 9)°$

But there is more…

$B^0 \rightarrow \pi^+\pi^-\pi^0$ with Dalitz analysis

– Idea: Extract α and strong phases using interference between amplitudes.

Dalitz variables:

$$s_+ = (p_+ + p_0)^2 , \qquad s_- = (p_- + p_0)^2 ,$$

Form factors + Rel. Breit-Wigner

$$\mathcal{A}_{3\pi} = f_+ A^+ + f_- A^- + f_0 A^0$$
$$\overline{\mathcal{A}}_{3\pi} = f_+ \overline{A}^+ + f_- \overline{A}^- + f_0 \overline{A}^0$$

Contain CP violating phase

Time dependance:

$$|\mathcal{A}_{3\pi}^{\pm}(\Delta t)|^2 = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}} \Big[|\mathcal{A}_{3\pi}|^2 + |\overline{\mathcal{A}}_{3\pi}|^2 \mp \left(|\mathcal{A}_{3\pi}|^2 - |\overline{\mathcal{A}}_{3\pi}|^2 \right) \cos(\Delta m_d \Delta t) \pm 2\mathrm{Im}\left[\overline{\mathcal{A}}_{3\pi} \mathcal{A}_{3\pi}^* \right] \sin(\Delta m_d \Delta t) \Big] ,$$

Coefficients are function of α (26 parameters)

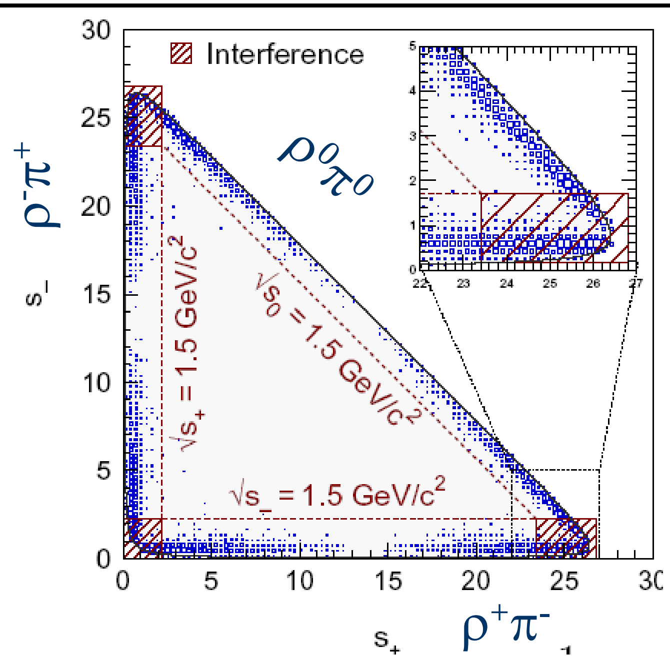
No quasi-2 body approximation, interference effects in!

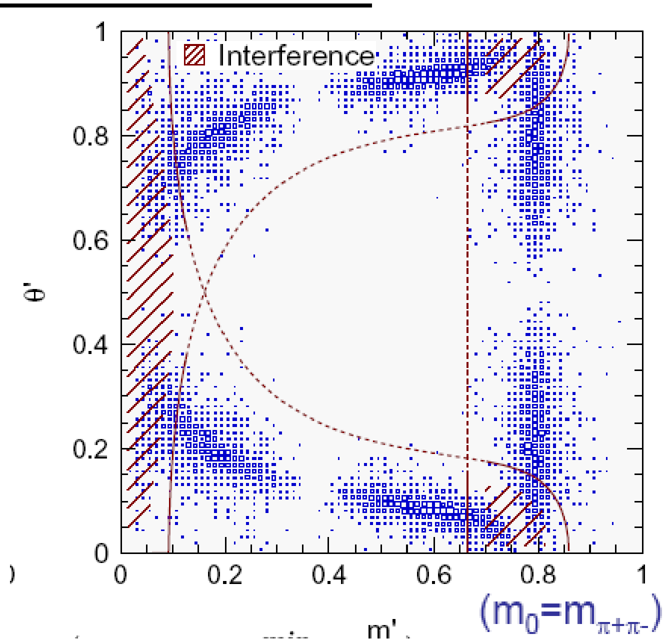
$\pi^+\pi^-\pi^0$ Dalitz distribution

- **Isobar** model dominated by vectors [ρ(770), ρ(1450), ρ(1700)]
  - Scalar contribution assumed to be negligible
- **Small** $\rho^0\pi^0$ signal, 26 →16 parameters
- Reparametrize Dalitz distribution (better handling of background)

$$m' \equiv \frac{1}{\pi}\arccos\left(2\frac{m_0 - m_0^{\min}}{m_0^{\max} - m_0^{\min}} - 1\right) \quad \text{and} \quad \theta' \equiv \frac{1}{\pi}\theta_0$$

θ_0 : *π helicity angle*





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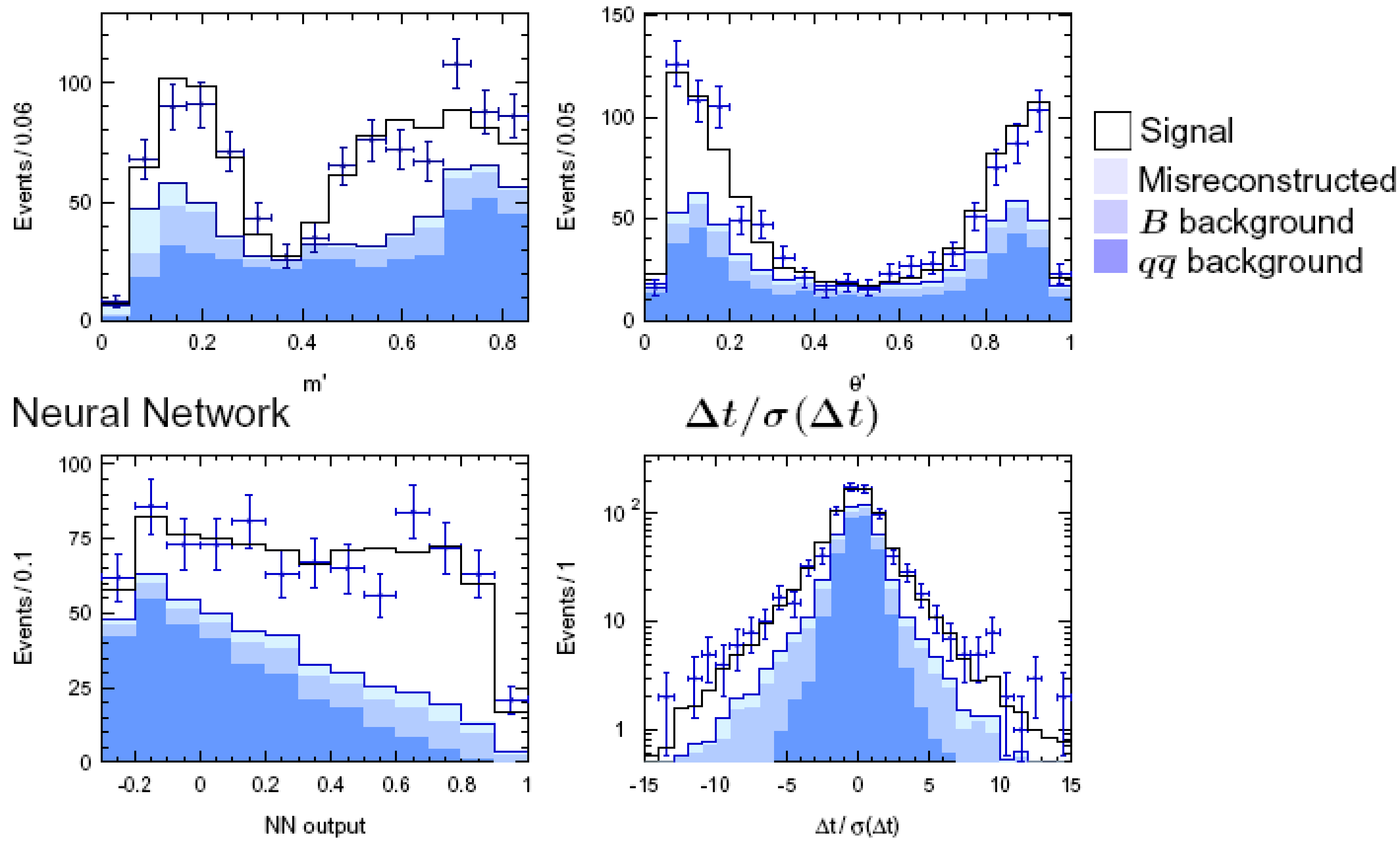
$\pi^+\pi^-\pi^0$ data sample

Dalitz plot variables:

$213 \times 10^6 B\bar{B}$ pairs



Yield $B^0 \rightarrow \pi^+\pi^-\pi^0$: 1184 ± 58

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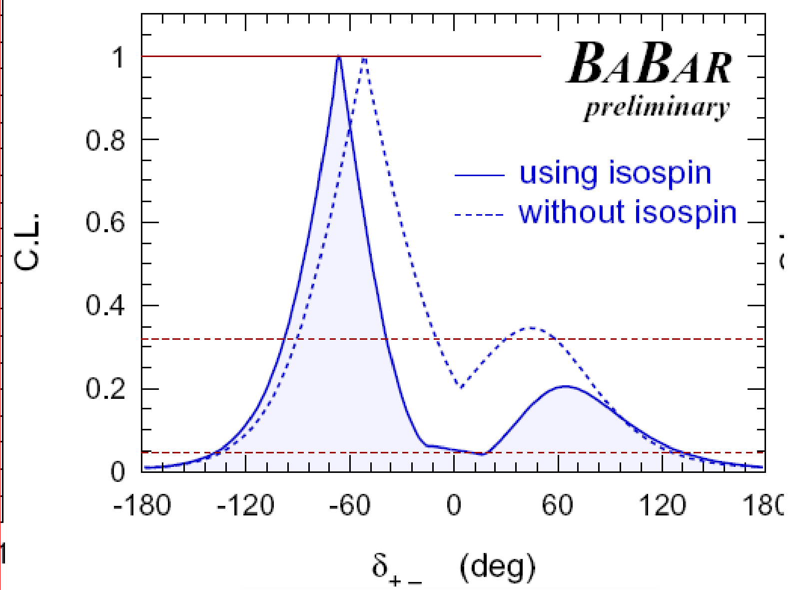
Time dependent fit results

213M BB pairs

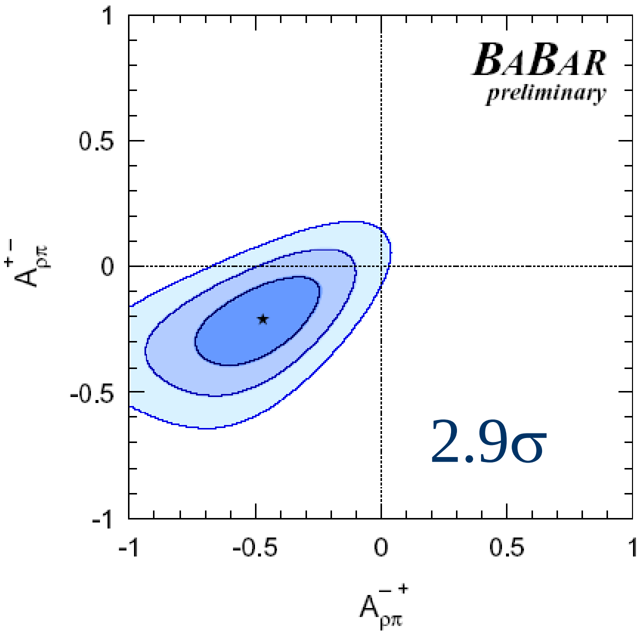
Constraint on strong phase difference
Between $B^0 \to \rho^+\pi^-$ and $B^0 \to \rho^-\pi^+$

$$\delta_{+-} = \arg\left(A^{+*}A^{-}\right)$$



$$\delta_{+-} = (-67^{+28}_{-31} \pm 7)^{\circ}$$

Direct CP asymmetry

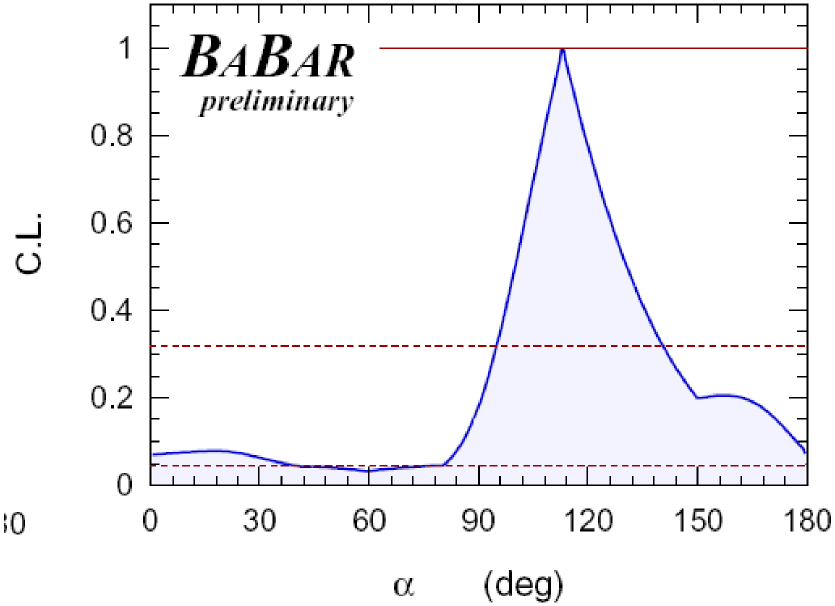


$C(\rho^+\pi^-)$and $C(\rho^-\pi^+)$
(including interference effect)

α from $\pi^+\pi^-\pi^0$

Assuming SU(2)

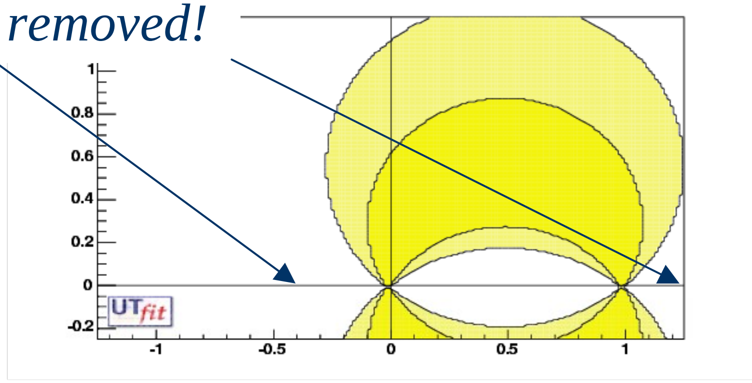
213M BB pairs



$$\alpha = (113^{+27}_{-17} \pm 6)^\circ$$

Dalitz model systematics

Ambiguities removed!



A promising channel

Conclusions

- In 224M BB pairs BaBar has observed direct CP violation in $B^0 \rightarrow K^+\pi^-$

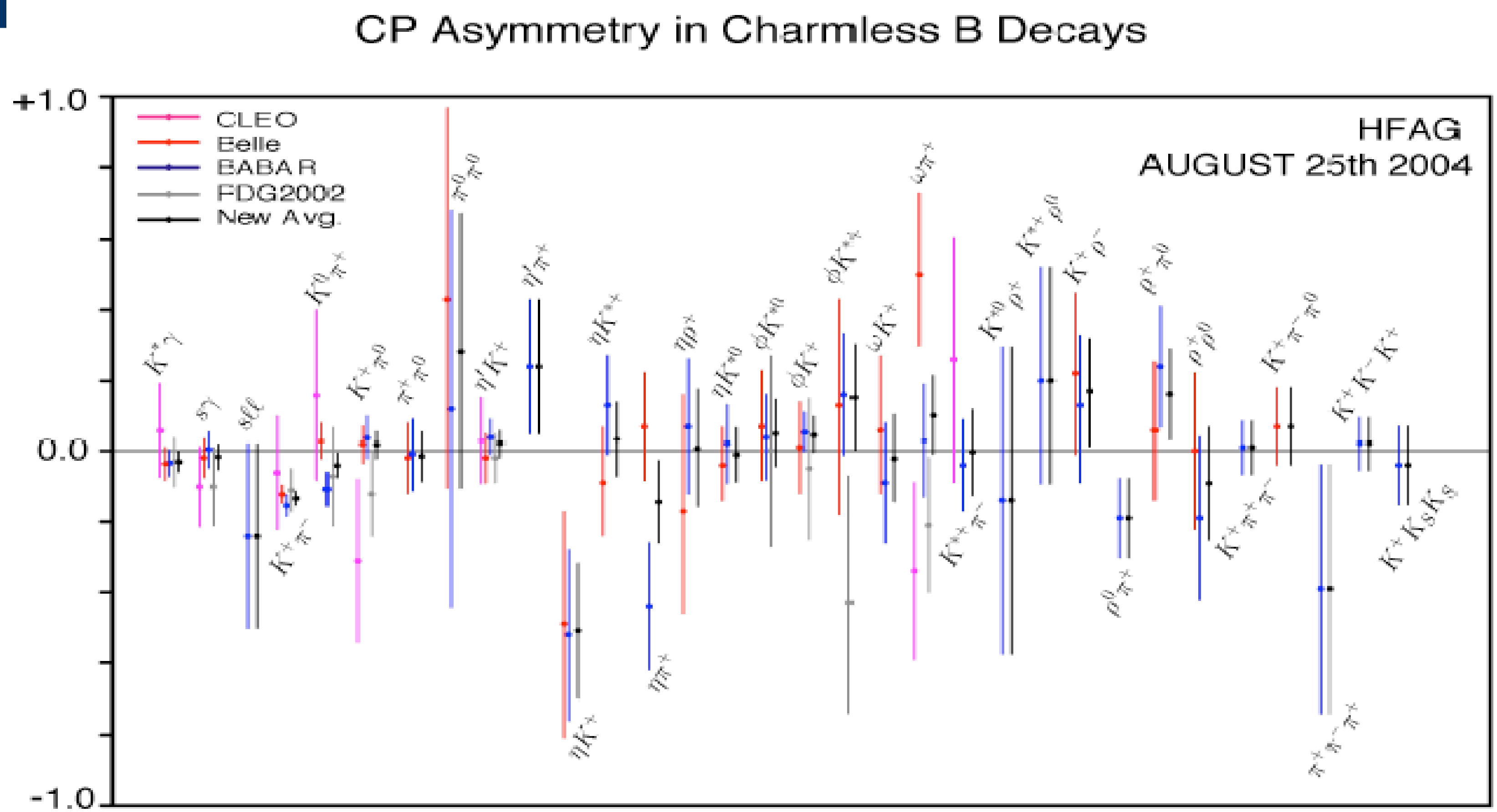
$$A_{K\pi} = -0.133 \pm 0.030 \pm 0.009$$

  - Indications for direct CP in $\pi\pi$
- Non-leptonic charmless 2-body B-decays
  - Well explained by phenomenolgical models within SM
  - New state observed ($K^0\bar{K}^0$), good for future?
- α extraction was never straightforward.
  - Need full isospin analysis for $\pi\pi$ (first measurement of $C\pi^0\pi^0$) in $\rho\rho$ smaller penguins
  - First time-dependent Dalitz analysis in ($\rho\pi$) $\pi^+\pi^-\pi^0$

BaBar: α known to 10°

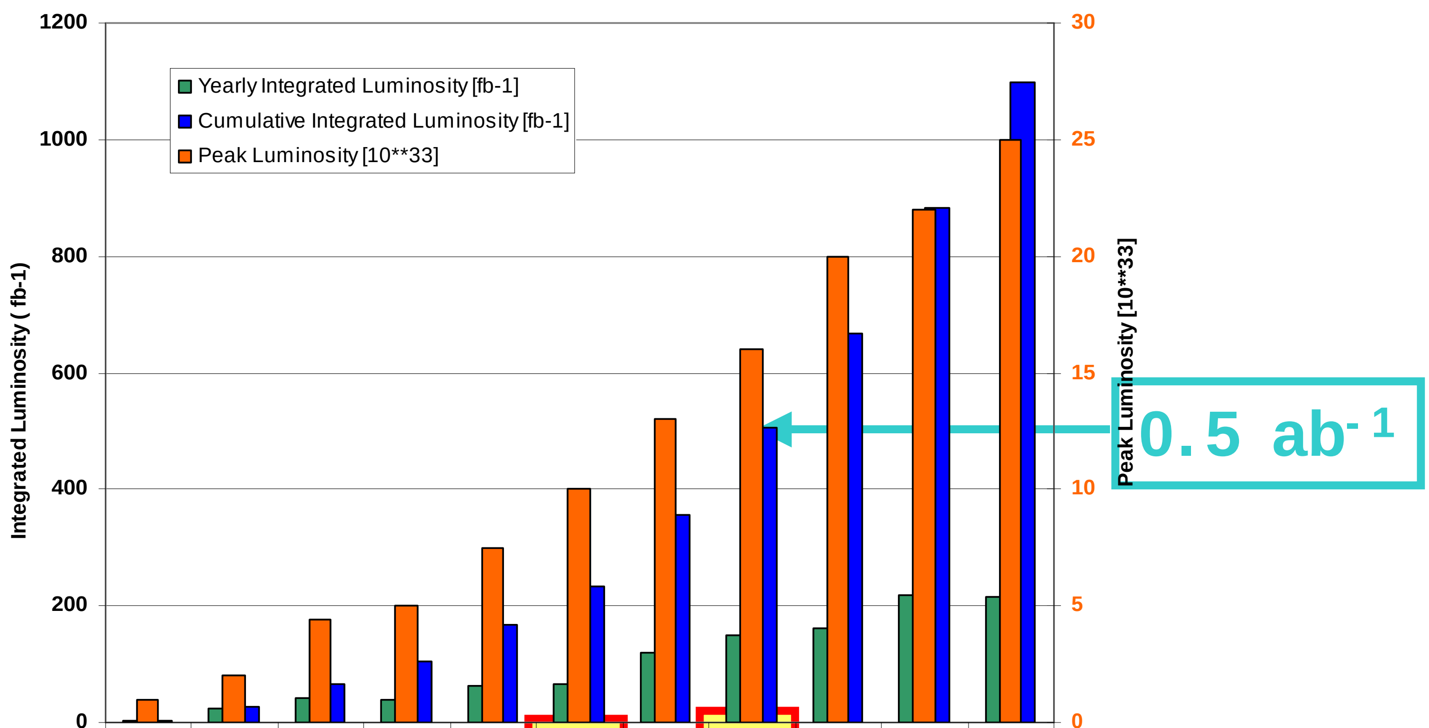
No big surprise, SM seems rock solid!

Many more…!!!



New physics could hide in some of them!!!

PEP II Luminosity Projections



Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Yearly Integrated Luminosity [fb-1]	3	23	41	39	62.6	66.1	120.1	151	160.1	217	216
Cumulative Integrated Luminosity [fb-1]	3	26	67	106	168.6	234.7	354.8	505.8	665.9	882.9	1098.9
Peak Luminosity [10**33]	1	2	4.4	5	7.5	10	13	16	20	22	25

2004 2006 ← **1.6×10^{34}**

G.Cavoto

Outlook

- Next future will see experiments at hadron colliders take over B-physics (larger cross sections, B_s physics)
- Nevertheless e^+e^- environment is unique
  - Final states with many neutrals, high flavour tagging efficiency, ultra-pure samples (recoil), coherent state
- **Measurement of α at 1° possible only at e^+e^-**
- ***And many other accurate B_d physics measurements to spot New Physics***

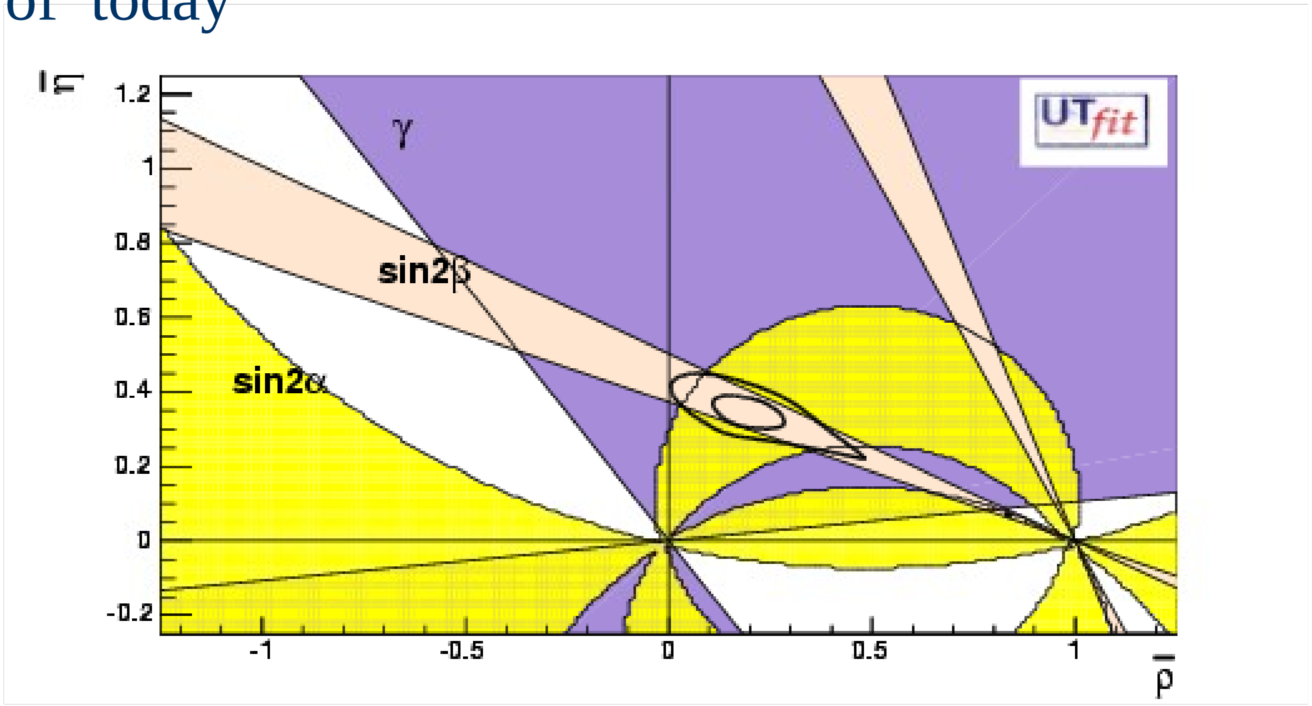
A super B-factory?

10 ab^{-1}/year
Detector and machine challenging…

LHC measures NP masses, super B-factory couplings and phases?

Angles only, as promised

(ρ,η) plane from measurements of sin(2β), sin(2α), and γ only as of today



Many thanks to M.Bona and M.Pierini for UT fit support

Backup slides

$B^0 \to \rho^+\pi^-$ quasi- twobody

$$f_{B^0}^{\rho^\pm h^\mp}(\Delta t) = (1 \pm A_{CP}(\rho h))e^{-|\Delta t|/\tau}(1 + \left[(S_{\rho h} \pm \Delta S_{\rho h})\sin(\Delta m \Delta t) - (C_{\rho h} \pm \Delta C_{\rho h})\cos(\Delta m \Delta t)\right]$$

$$f_{\overline{B}^0}^{\rho^\pm h^\mp}(\Delta t) = (1 \pm A_{CP}(\rho h))e^{-|\Delta t|/\tau}(1 - \left[(S_{\rho h} \pm \Delta S_{\rho h})\sin(\Delta m \Delta t) - (C_{\rho h} \pm \Delta C_{\rho h})\cos(\Delta m \Delta t)\right]$$

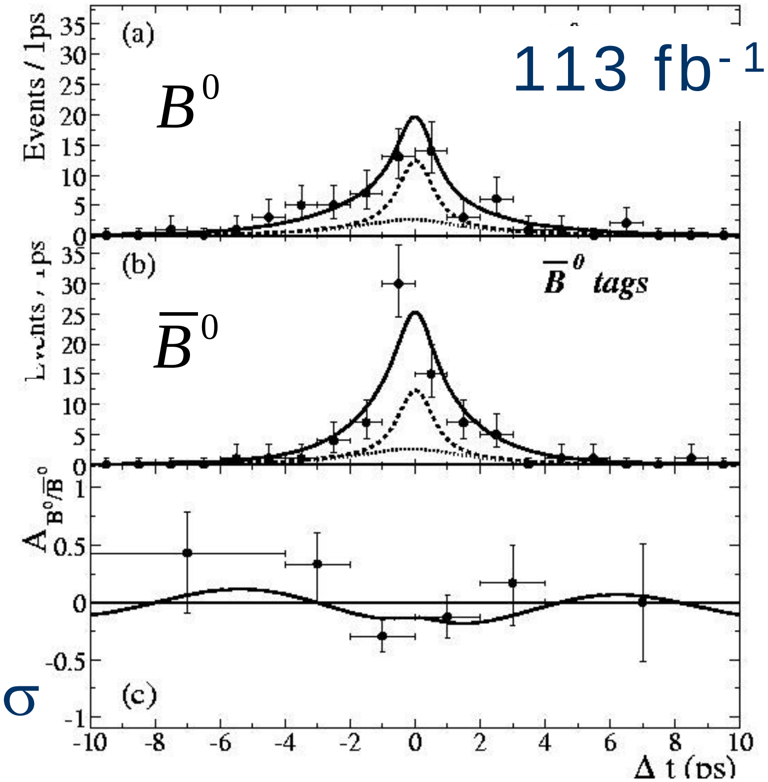
$$S_{\rho\pi} = -0.13 \pm 0.18 \pm 0.04$$

$$C_{\rho\pi} = 0.35 \pm 0.13 \pm 0.05$$

$$\Delta S_{\rho\pi} = 0.33 \pm 0.18 \pm 0.03$$

$$\Delta C_{\rho\pi} = 0.20 \pm 0.13 \pm 0.05$$

$$A_{CP}^{\rho\pi} = -0.114 \pm 0.062 \pm 0.027$$



Significance for direct CPV: 2.5σ

More promising: perform full Dalitz plot analysis;

ρπ Dalitz analysis parameters

Parameter	Coefficient of	Fit Result
I_-	$\|f_-\|^2 \sin(\Delta m_d \Delta t)$	$-0.19 \pm 0.11 \pm 0.02$
I_+	$\|f_+\|^2 \sin(\Delta m_d \Delta t)$	$0.06 \pm 0.11 \pm 0.02$
U_0^+	$\|f_0\|^2$	$0.16 \pm 0.05 \pm 0.05$
U_-^-	$\|f_-\|^2 \cos(\Delta m_d \Delta t)$	$0.22 \pm 0.16 \pm 0.05$
U_-^+	$\|f_-\|^2$	$1.19 \pm 0.12 \pm 0.03$
U_+^-	$\|f_+\|^2 \cos(\Delta m_d \Delta t)$	$0.50 \pm 0.17 \pm 0.06$
$U_{+-}^{-,\Im m}$	$\Im m[f_+ f_-^*] \cos(\Delta m_d \Delta t)$	$0.3 \pm 1.4 \pm 0.3$
$U_{+-}^{-,\Re e}$	$\Re e[f_+ f_-^*] \cos(\Delta m_d \Delta t)$	$2.0 \pm 1.2 \pm 0.2$
$U_{+-}^{+,\Im m}$	$\Im m[f_+ f_-^*]$	$0.16 \pm 0.70 \pm 0.14$
$U_{+-}^{+,\Re e}$	$\Re e[f_+ f_-^*]$	$-0.26 \pm 0.65 \pm 0.17$
$I_{+-}^{\Im m}$	$\Im m[f_+ f_-^*] \sin(\Delta m_d \Delta t)$	$-5.2 \pm 1.9 \pm 0.7$
$I_{+-}^{\Re e}$	$\Re e[f_+ f_-^*] \sin(\Delta m_d \Delta t)$	$-0.3 \pm 2.0 \pm 0.5$
$U_{+0}^{+,\Im m}$	$\Im m[f_+ f_0^*]$	$0.25 \pm 0.35 \pm 0.18$
$U_{+0}^{+,\Re e}$	$\Re e[f_+ f_0^*]$	$-0.34 \pm 0.39 \pm 0.15$
$U_{-0}^{+,\Im m}$	$\Im m[f_- f_0^*]$	$0.34 \pm 0.43 \pm 0.17$
$U_{-0}^{+,\Re e}$	$\Re e[f_- f_0^*]$	$-0.98 \pm 0.44 \pm 0.18$

U_κ^+ : branching fraction and charge asymmetry

U_κ^- : dilution and time-dependent CP asymmetry

I_κ : mixing-induced asymmetry (strong phase shifts)

$U_{\kappa\kappa'}^\pm$ and $I_{\kappa\kappa'}$: interference in Dalitz plot