Misure di α alle B-factory

G.Cavoto

Princeton University Univ.Roma
La Sapienza e INFN Roma

Incontri di Fisica delle Alte Energie

XVI Ciclo di Incontri

14-16 Aprile 2004 Torino

Outline

- α extraction
  - Isospin analysis
- B_d decay modes time-dependent asymmetry
  - $\mathbf{B_d \rightarrow \pi\pi, \rho\pi, \rho\rho.}$
- Experimental challenges
- Current results
  - BaBar and Belle most recent measurements
- Outlook

What's α ??

Pictures for illustrations

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

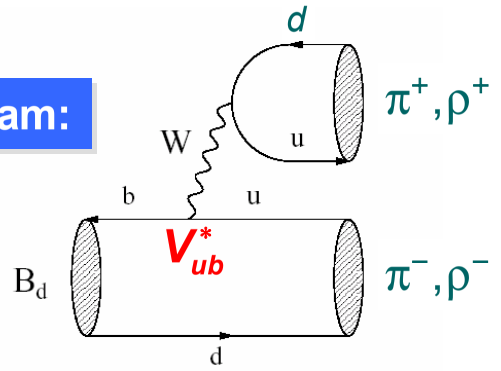
In fact: $\alpha = \pi - (\beta + \gamma)$

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

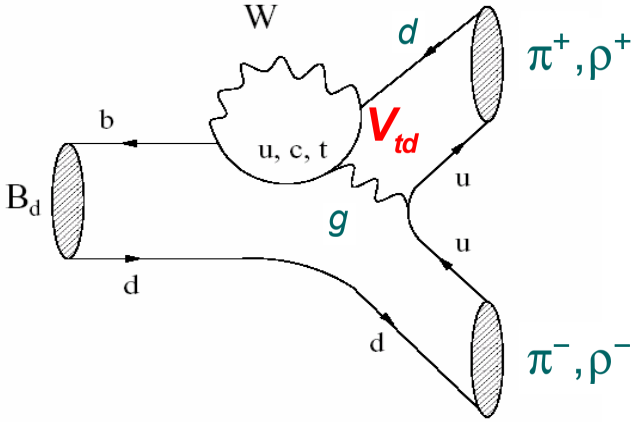
$$\frac{q}{p} = e^{-2i\beta}$$

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

Tree diagram:

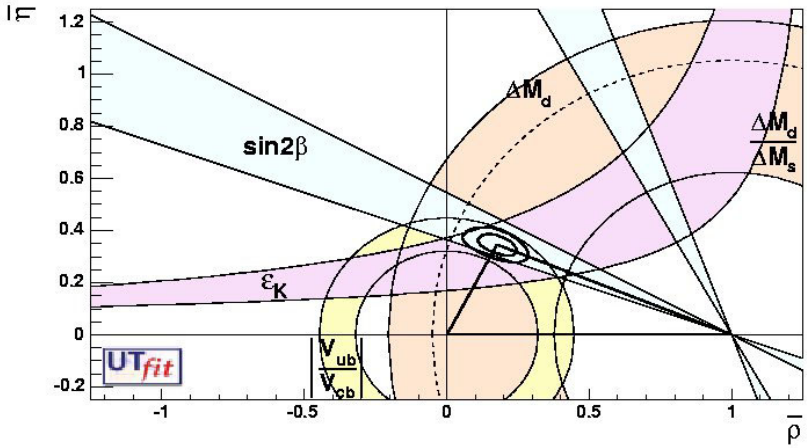


Penguin diagram:

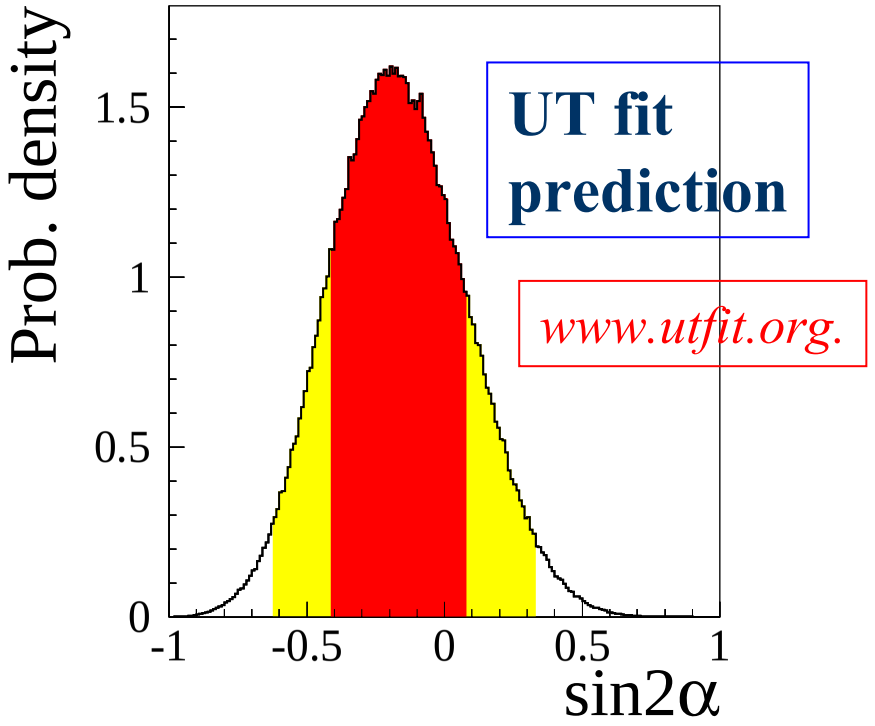


Current predictions

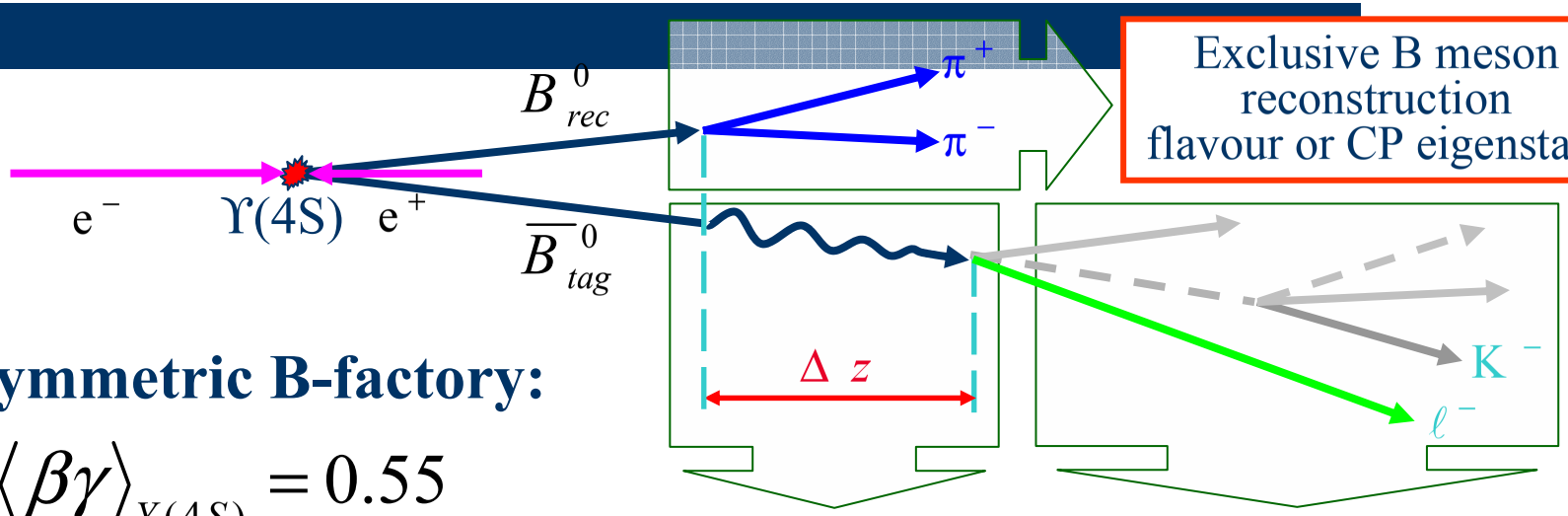
- You fit for sin(2α_{eff})
  - Time dependent CP asymmetries
- You'd like to extract α
  - Isospin analyses
- Eventually you want (ρ,η) constraints.



Sin(2α) = -0.19 ± 0.25



Time dependent analysis



Exclusive B meson reconstruction flavour or CP eigenstate

Asymmetric B-factory:

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

$\Delta t \approx \Delta z / c \langle \beta\gamma \rangle_{\Upsilon(4S)}$

$\langle \Delta z \rangle_{B\bar{B}} \approx 260\,\mu\text{m}$

Inclusive reconstruction B-flavour tagging

$$A_{CP}(t) = \frac{N(\bar{B}^0(t) \to h^+h^-) - N(B^0(t) \to h^+h^-)}{N(\bar{B}^0(t) \to h^+h^-) + N(B^0(t) \to h^+h^-)} = S_{hh}\sin(\Delta m t) - C_{hh}\cos(\Delta m t)$$

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

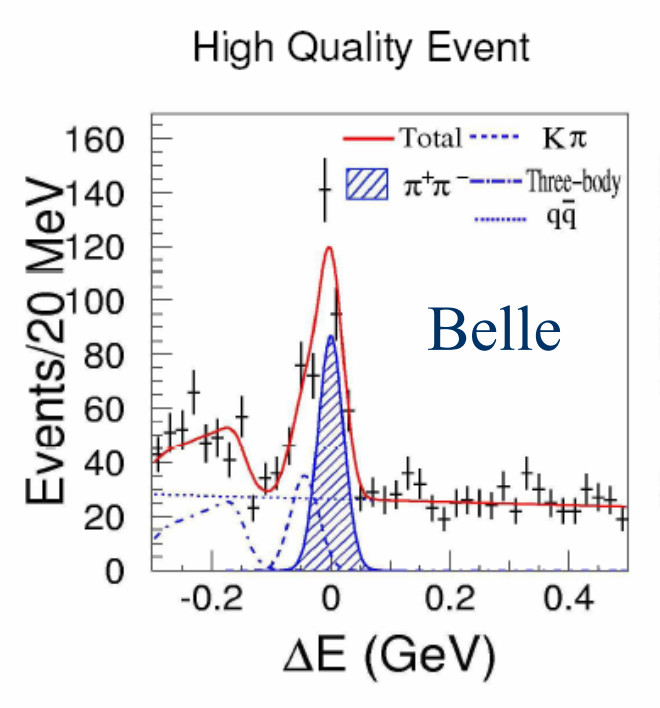
$$C_{hh} = \frac{1-|\lambda_{hh}|^2}{1+|\lambda_{hh}|^2}$$

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

Cerenkov detector to separate pions from kaons
Continuum suppression technique (Fisher discr.)

140 fb^{-1}

- 1529 candidates
- 372±32 $\pi^+\pi^-$ signal events

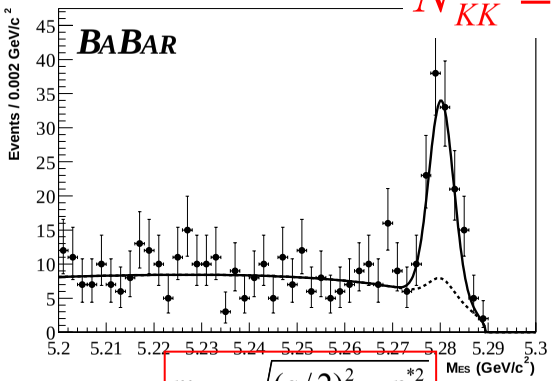


113 fb^{-1}

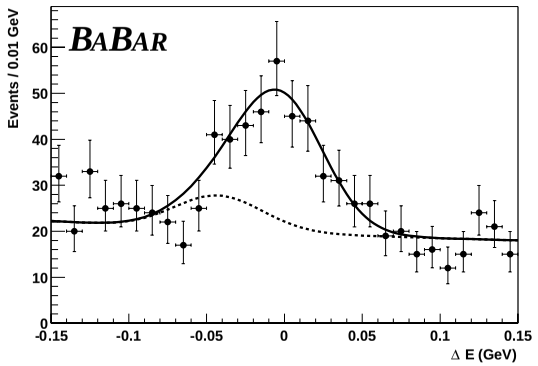
$N_{\pi\pi} = 265.9 \pm 24.0$

$N_{K\pi} = 873.3 \pm 37.5$

$N_{KK} = 12.5 \pm 10.4$

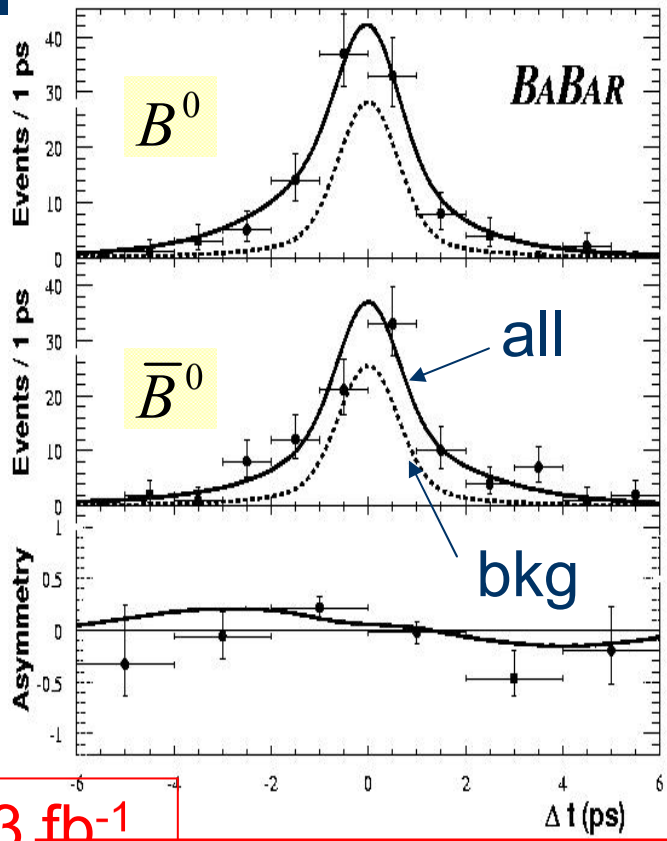


$$m_{ES} = \sqrt{(s/2)^2 - p_B^{*2}}$$



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

CP asymmetry results.

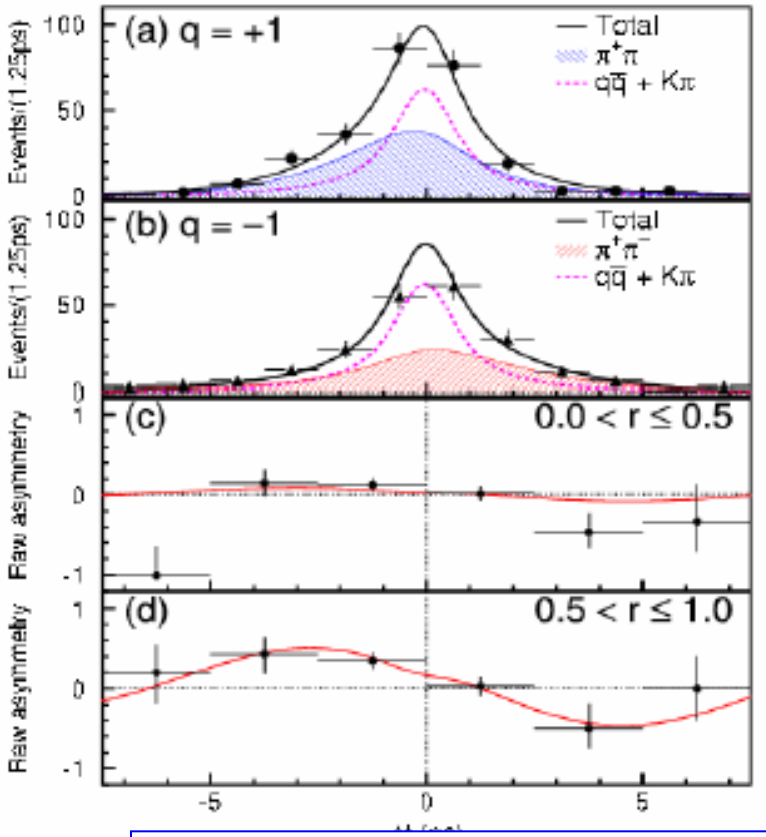


113 fb^{-1}

$S_{\pi\pi} = -0.40 \pm 0.22 \pm 0.03$

$C_{\pi\pi} = -0.19 \pm 0.19 \pm 0.05$

$A_{CP}^{K\pi} = -0.107 \pm 0.041 \pm 0.013$



$-C_{\pi\pi} =$

$S_{\pi\pi} = -1.00 \pm 0.21 \pm 0.07$

$A_{\pi\pi} = 0.58 \pm 0.15 \pm 0.07$

140 fb^{-1}

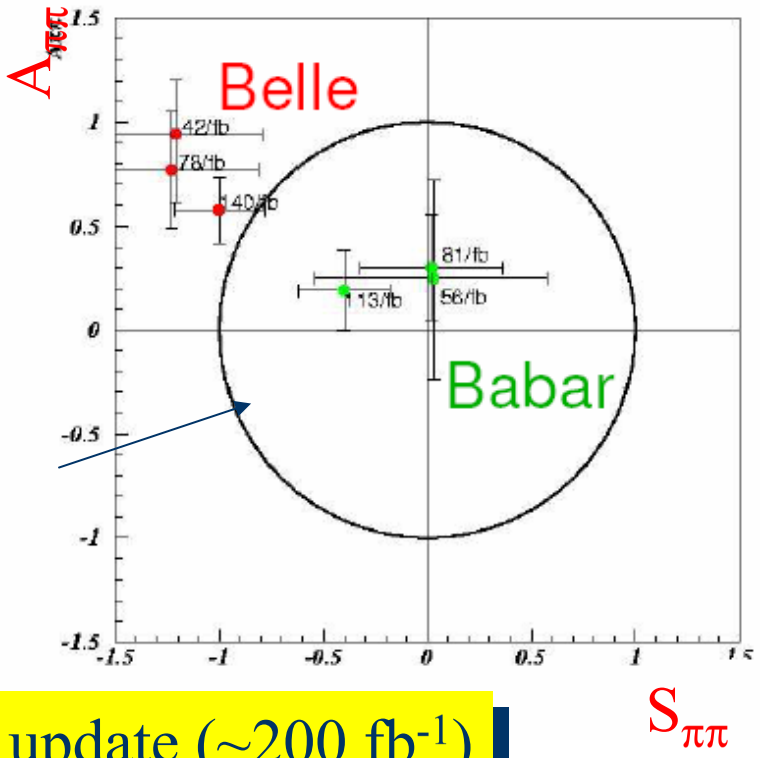
Belle versus BaBar

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

History of $S_{\pi\pi}$ and $C_{\pi\pi}$

Physical bound:

$\mathrm{sqrt}(C_{\pi\pi}^2+S_{\pi\pi}^2) = 1$

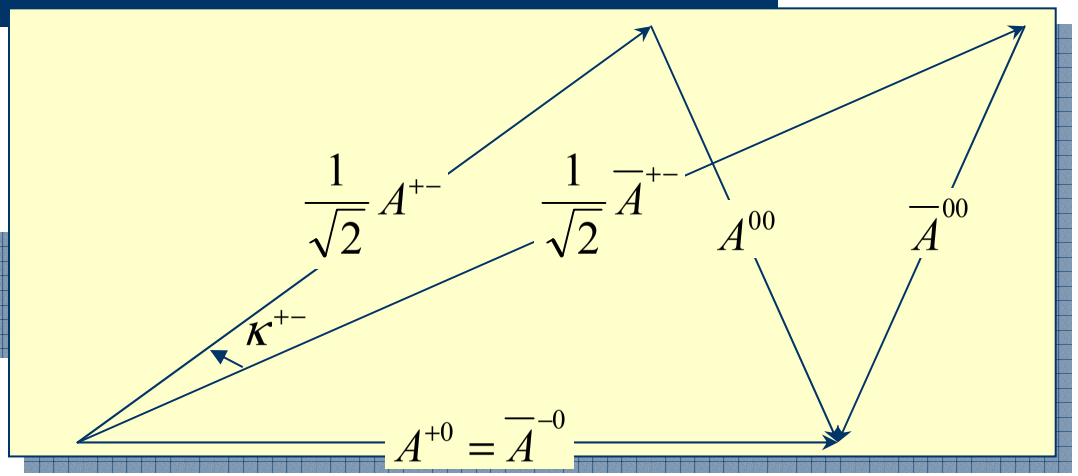


Stay tuned for BaBar's summer update (~200 fb^{-1})

Trapping the penguins

- Isospin analysis

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



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

- Bound the penguins:
  - Grossman-Quinn

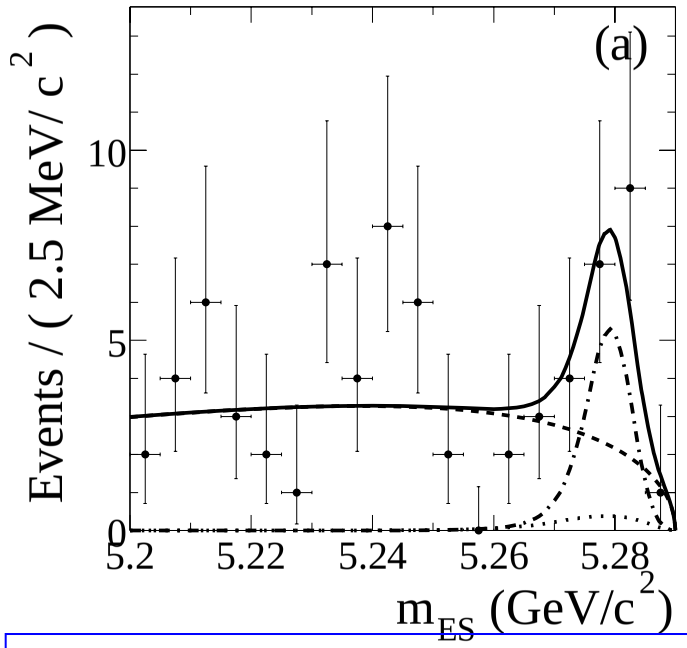
$$\sin^2(\alpha_{eff} - \alpha) < \frac{BR(B^0 \to \pi^0\pi^0)}{BR(B^+ \to \pi^+\pi^0)}$$

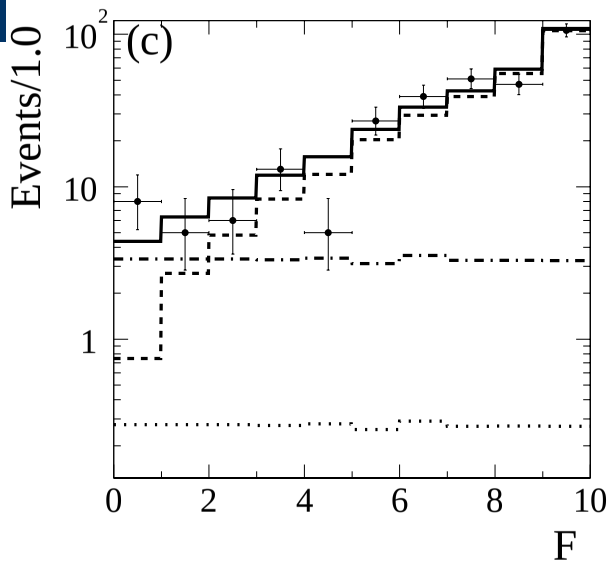
Theorists start to argue this is not the end of the story…!

$B^0 \rightarrow \pi^0\pi^0$

Fisher discriminant
(topology + flavour tagging)

Large continuum background
3body contamination





GQ bound (WA)

$$\left|\alpha - \alpha_{eff}\right| \leq 43^{o} \ at \quad 95\% CL$$

$$N(\pi^0\pi^0) = 45.6^{+13.9}_{-12.5}$$

$$BF(B^0 \rightarrow \pi^0\pi^0) = 2.10 \pm 0.6 \pm 0.3 \times 10^{-6}$$

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

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

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

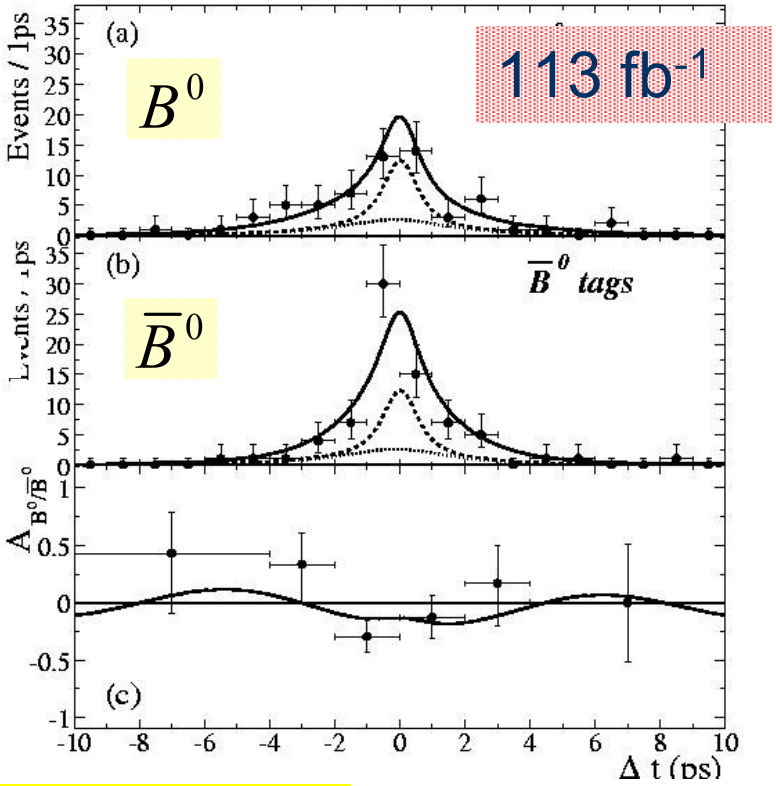
$$S_{\rho\pi} = -0.13 \pm 0.18 \pm 0.04$$

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

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

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

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



Significance for direct CPV: 2.5σ

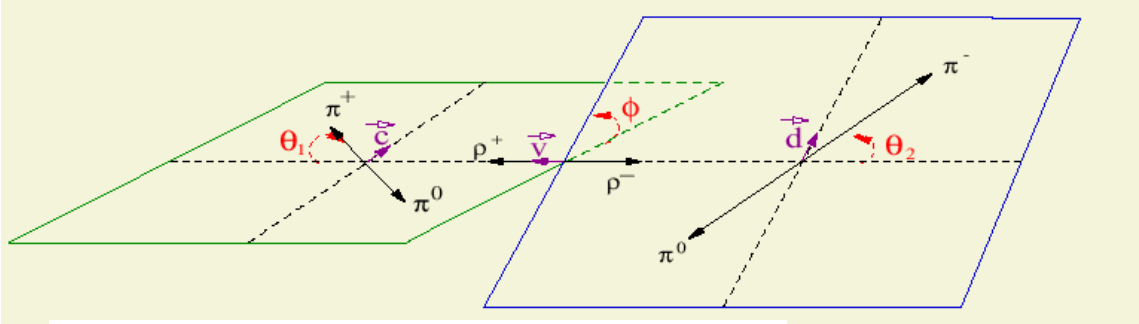
More promising: perform full Dalitz plot analysis;

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

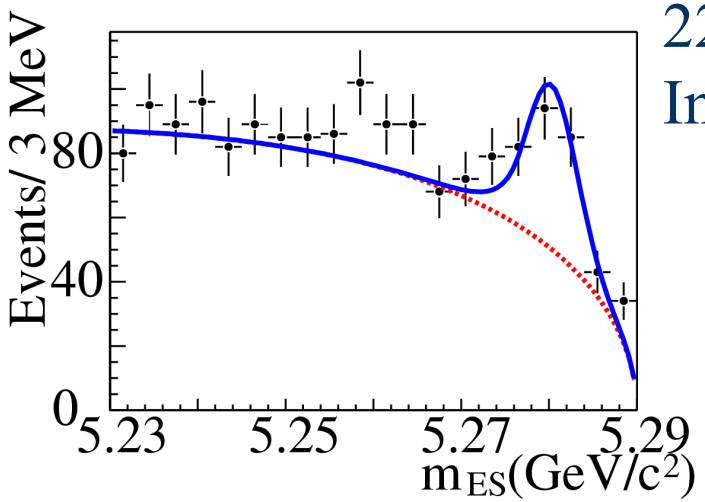
BF($B^0 \to \rho^0\rho^0$) small?

$$BF(B^{\pm} \to \rho^{\pm}\rho^0) = (26.4 \pm 6.4) \times 10^{-6}$$

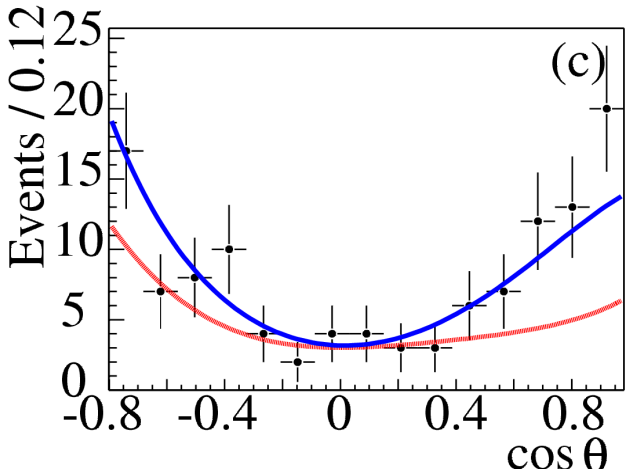
$$BF(\overline{B}^0 / B^0 \to \rho^0\rho^0) < 2.1 \times 10^{-6} \quad @\ 90\%\ \mathrm{CL}$$



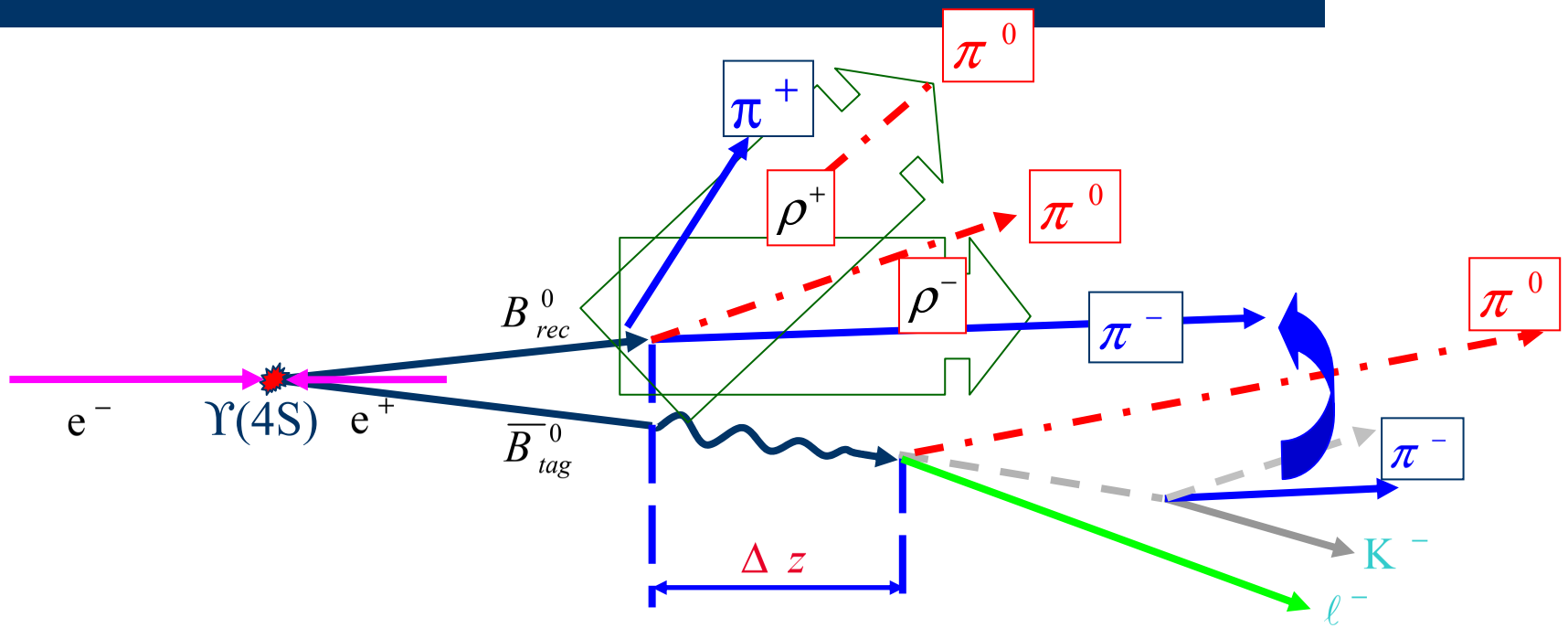
BF ~ 3 10^{-5}
VV mode:
need angular
decomposition



220 signal events
In 81 fb^{-1}



A tough job



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

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

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

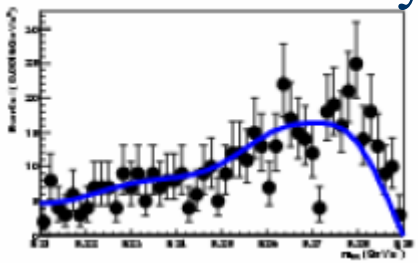
$$f_{long} = 0.99 \pm 0.03(stat)^{+0.04}_{-0.03}(syst)$$

Pure CP eigenstate!

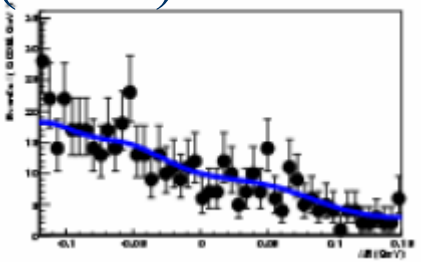
Systematics

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

$b \to u$ decays (small)

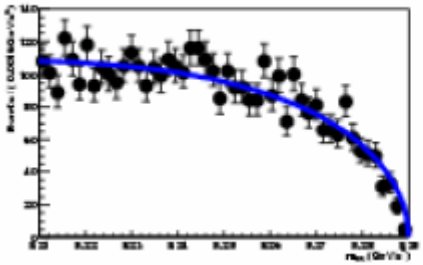


m_{ES} $a_1\rho$

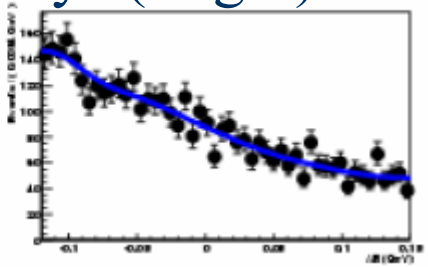


ΔE

$b \to c$ decays (large!)



m_{ES}



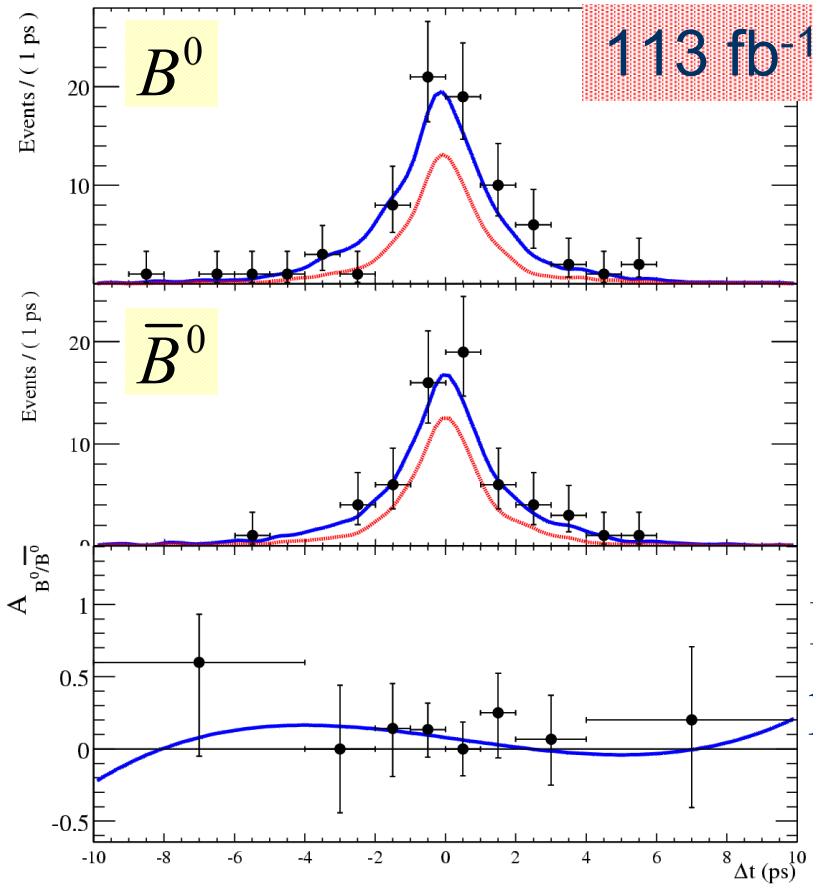
ΔE

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

- Sensitivity to other wave?
  - Small effect from allowing for "non-resonant" component ($\rho\pi\pi$)

A partial wave decomposition could settle this out.

Results



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

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

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

Likelihood projections

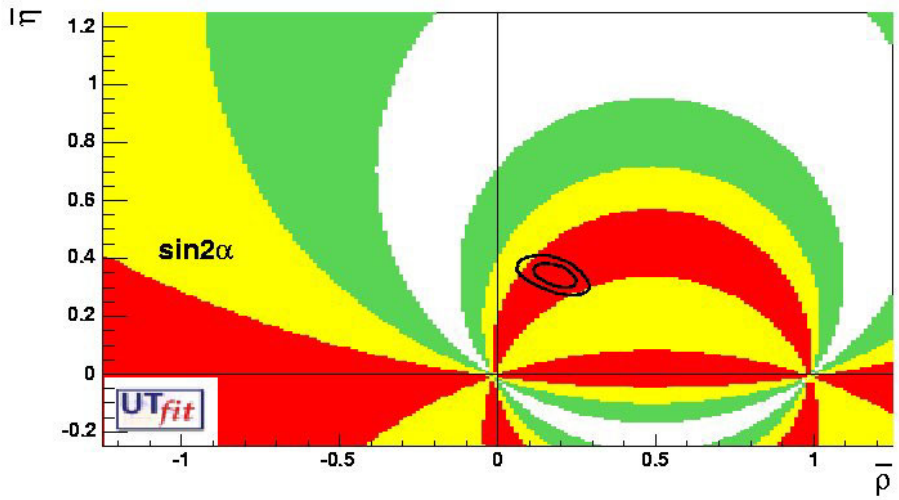
Bounding α

GQ bound (WA)

$$\left|\alpha - \alpha_{eff}\right| \leq 17^{o} \ at \quad 95\% CL$$

Translating into (ρ,η)

BaBar
$\rho^{+}\rho^{-}$

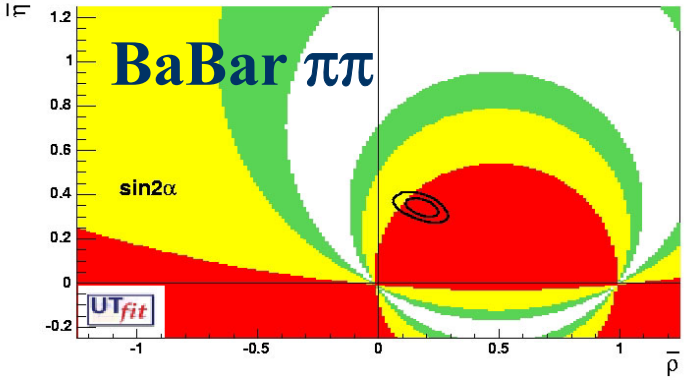


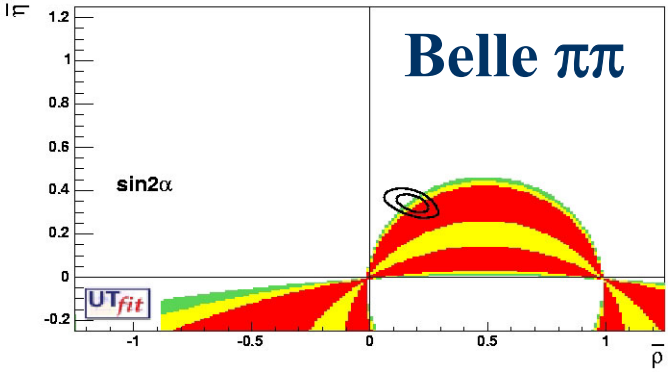
Red: 68%
Yellow:95%

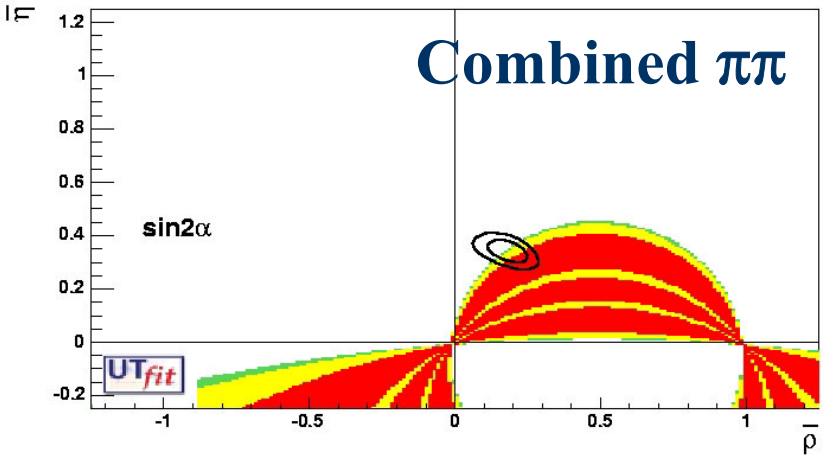
Validity of isospin analysis approach under scrutiny though…

Our experimental knowledge from ππ

Including Grossman-Quinn bound



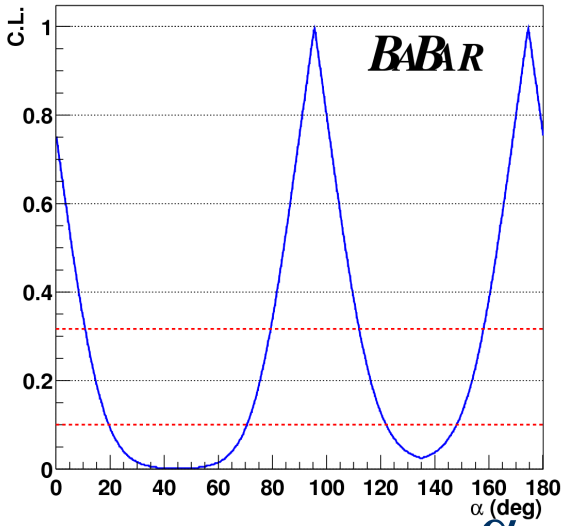




Conclusions

- α extraction never straightforward.
  - Need full isospin analysis for $\pi\pi$
    $\rho\rho$ looking better (valid GQ bound)

BaBar Winter04 $\rho\rho$ results:
One solution in agreement
With SM/UT fit prediction



α_{eff}

- Experimental indication of direct CP in $\pi\pi$
  - Need to be confirmed by both exp's

Outlook

Luminosity projection:

	L_{peak} (10^{33})	L_{int} fb^{-1}	I_{her} (mA)	I_{ler} (mA)
2004	12.5	260	1600	2700
2005	18.2	395	1800	3600
2006	23	580	2000	3600
2007	30	880	2200	4500

- This summer about 200 fb^{-1} for BaBar
- Updates of $\pi\pi$ and $\rho\rho$ analyses.
  - Evidence for direct CP in $\pi\pi$
  - First measurement of $C_{\pi 0 \pi 0}$
  - New limit (or discovery??) on $\rho^0\rho^0$.
- Full Dalitz analysis for $\rho\pi$
  - It would disentangle penguin contribution and measure α !
- Theorists do not like SU(2) anymore
  - More measurements needed? Clever combination of current data to extract α.

Stay tuned, the story of α is not yet over…!