Current Status of the α measurement

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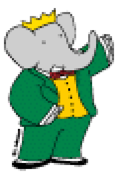
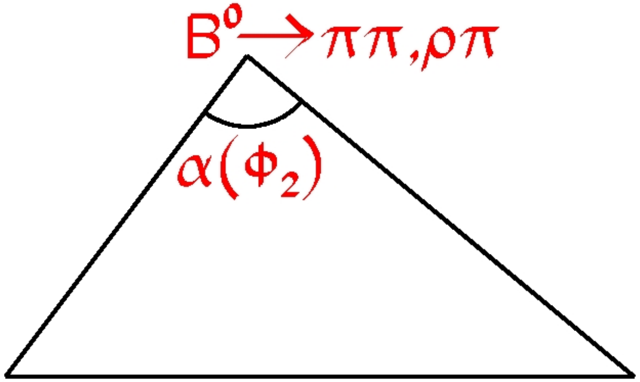
on behalf of BaBar Collaboration

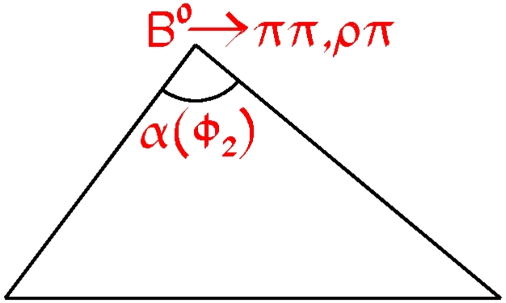
http://www.slac.stanford.edu/BF



CERN Flavour Workshop
May 17th 2006



α: collecting the ingredients



ππ and ρρ from the diagrams

- considering only the tree (T):

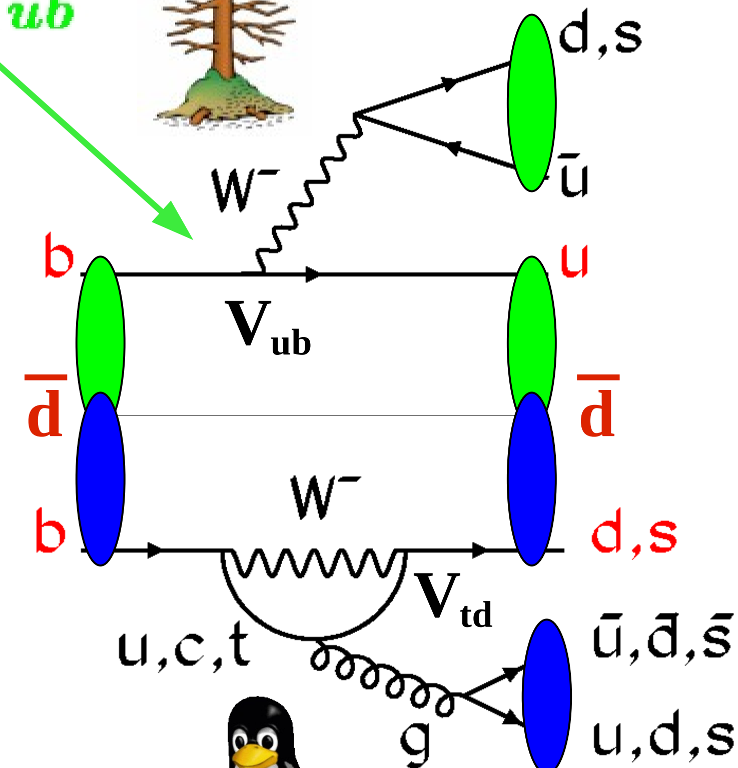
$$\lambda_{\pi\pi} = \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \frac{V_{ud}^* V_{ub}}{V_{ud}^* V_{ub}}$$

mixing

$\lambda_{\pi\pi} = e^{2i\alpha}$

$C_{\pi\pi} = 0$

$S_{\pi\pi} = \sin(2\alpha)$

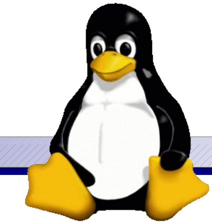


- adding the penguins (P):

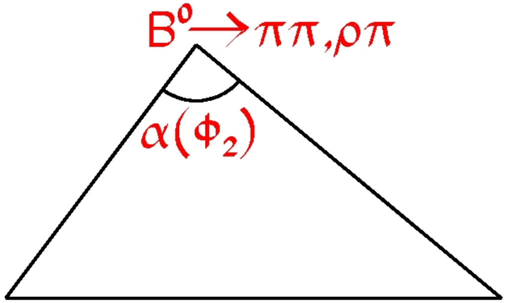
$$\lambda_{\pi\pi} = e^{2i\alpha} \frac{1 + |P/T| e^{i\delta} e^{i\gamma}}{1 + |P/T| e^{i\delta} e^{-i\gamma}}$$

$C_{\pi\pi} \propto \sin(\delta)$

$S_{\pi\pi} = \sqrt{1 - C_{\pi\pi}^2} \sin(2\alpha_{eff})$



α: collecting the ingredients (II)



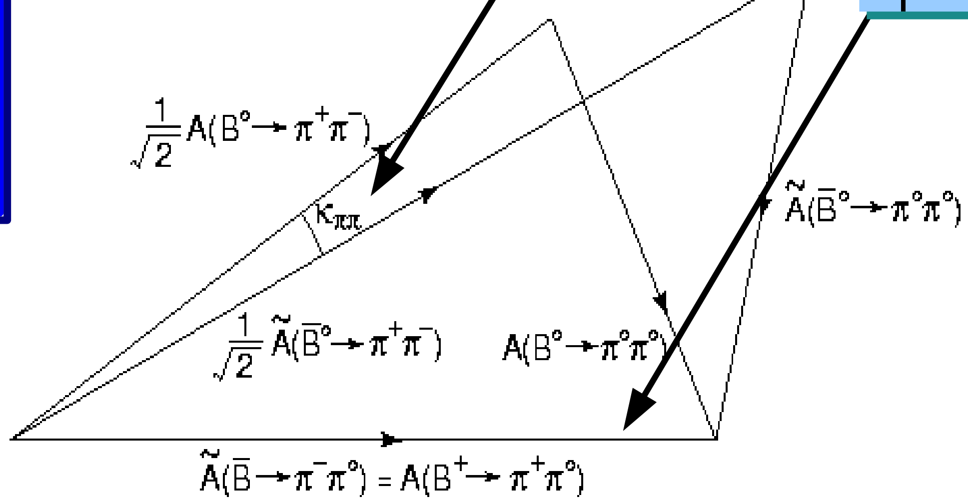
from $\alpha_{eff} \rightarrow$ to α: isospin analysis

- $B \rightarrow \pi^+\pi^-, \pi^+\pi^0, \pi^0\pi^0$ decays are connected from isospin relations
- $\pi\pi$ states can have I = 2 or I = 0
  - the gluonic penguins contribute only to the I = 0 state ($\Delta I=1/2$)
  - $\pi^+\pi^0$ is a pure I = 2 state ($\Delta I = 3/2$) and it gets contribution only from the tree diagram
  - triangular relations allow for the determination of the phase difference induced on α:

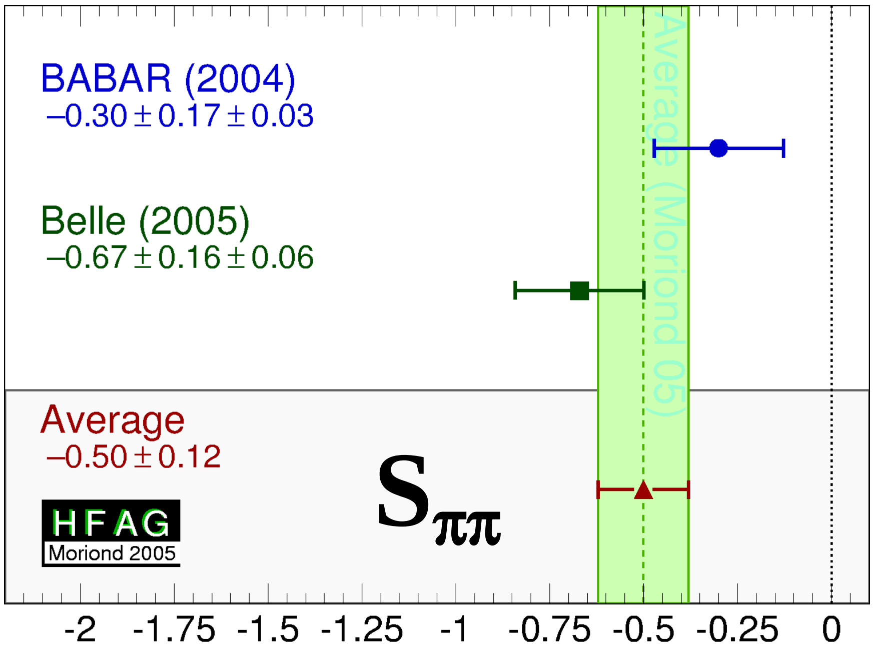
$$2\alpha_{eff} = 2\alpha + \kappa_{\pi\pi}$$

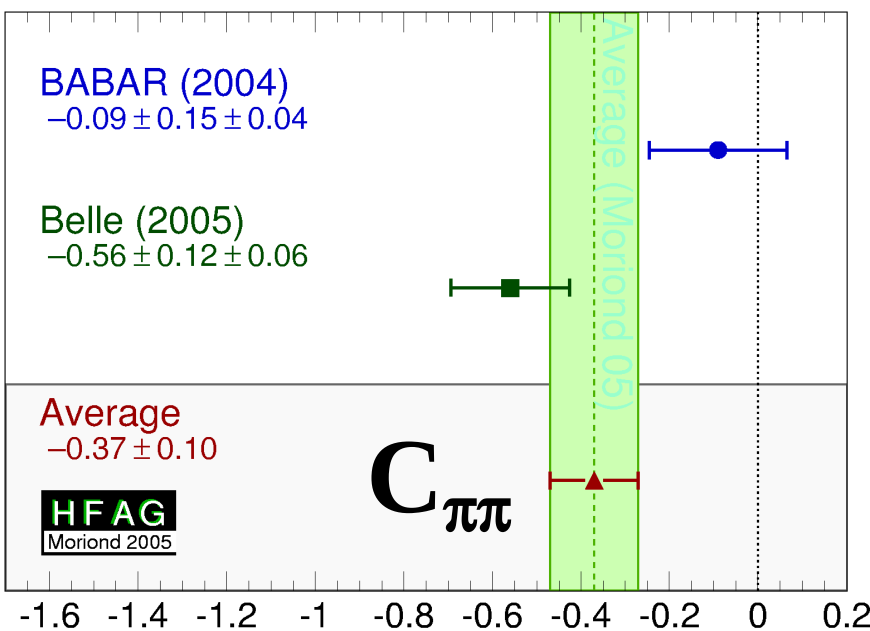
$$|A^{+0}|=|A^{-0}|$$

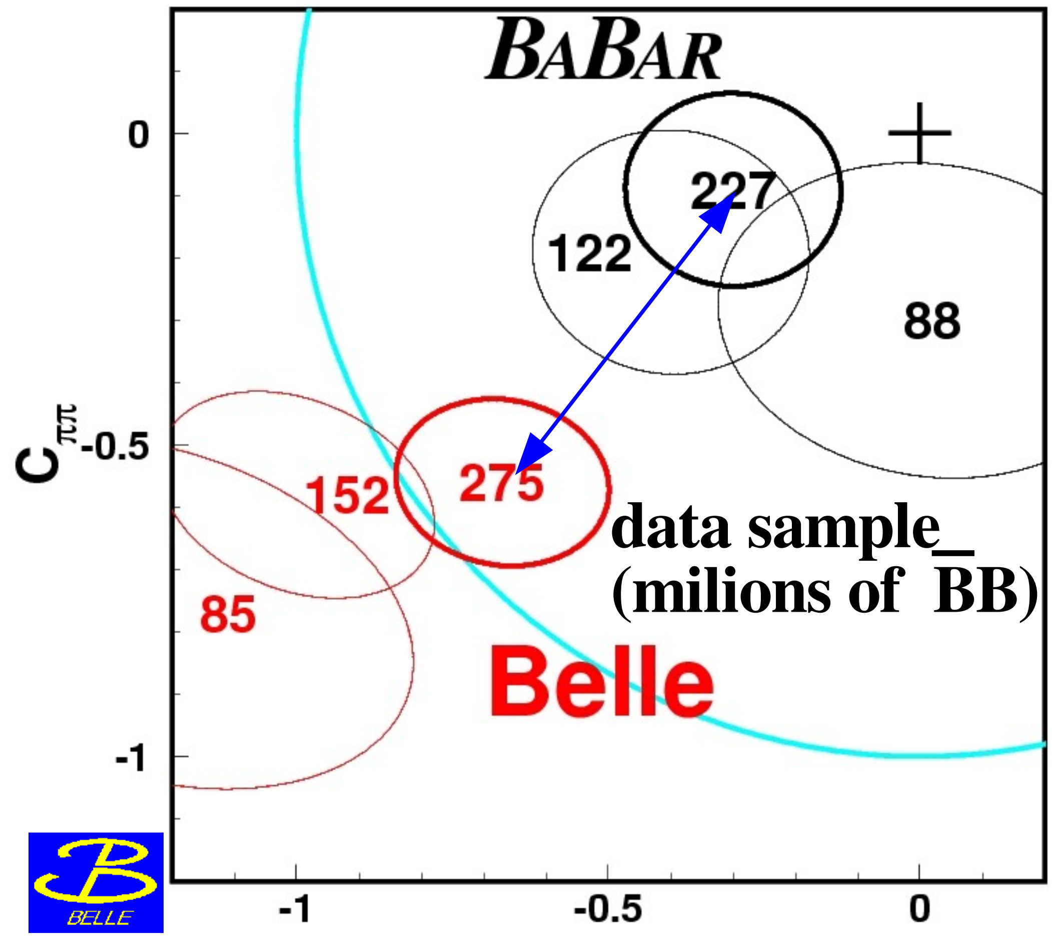
Both BR(B^0) and BR($\overline{B}^0$) have to be measured in all the $\pi\pi$ channels



towards α: time dependent analysis

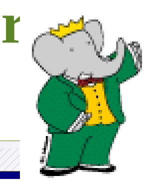






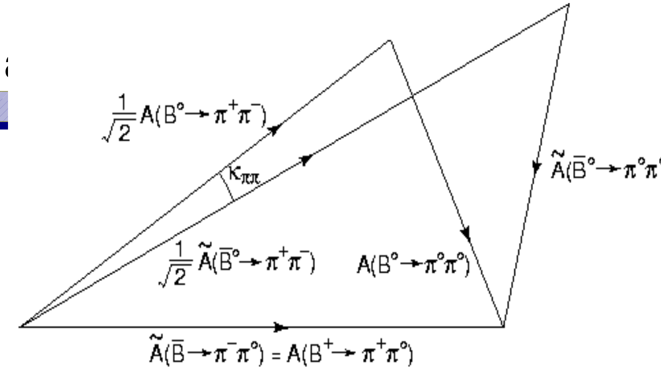
Belle: evidence of CP violation

not confirmed by BaBar



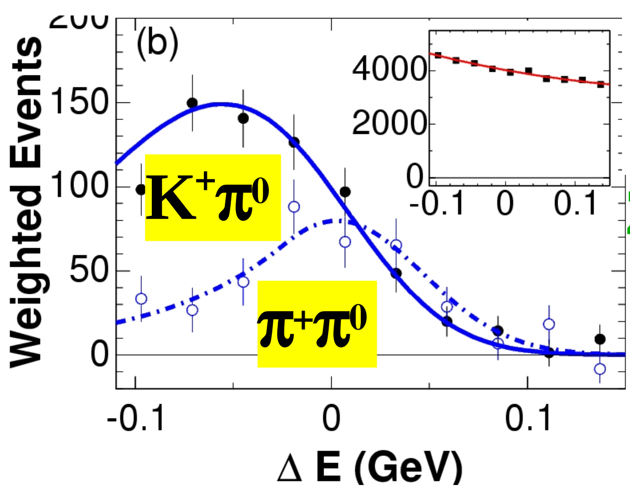
2.2σ discrepancy BaBar-Belle

towards α: isospin analysis

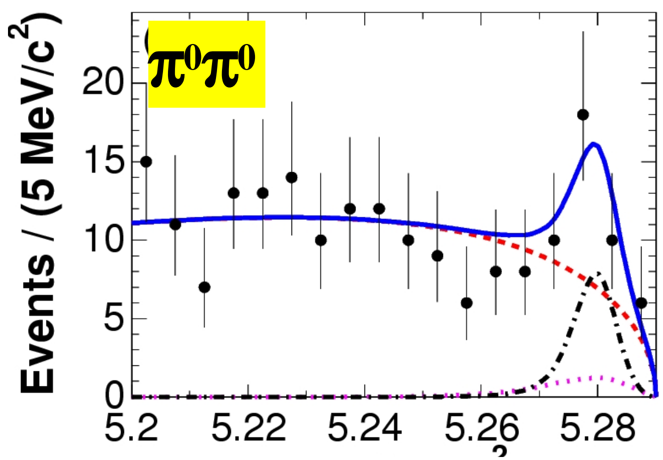


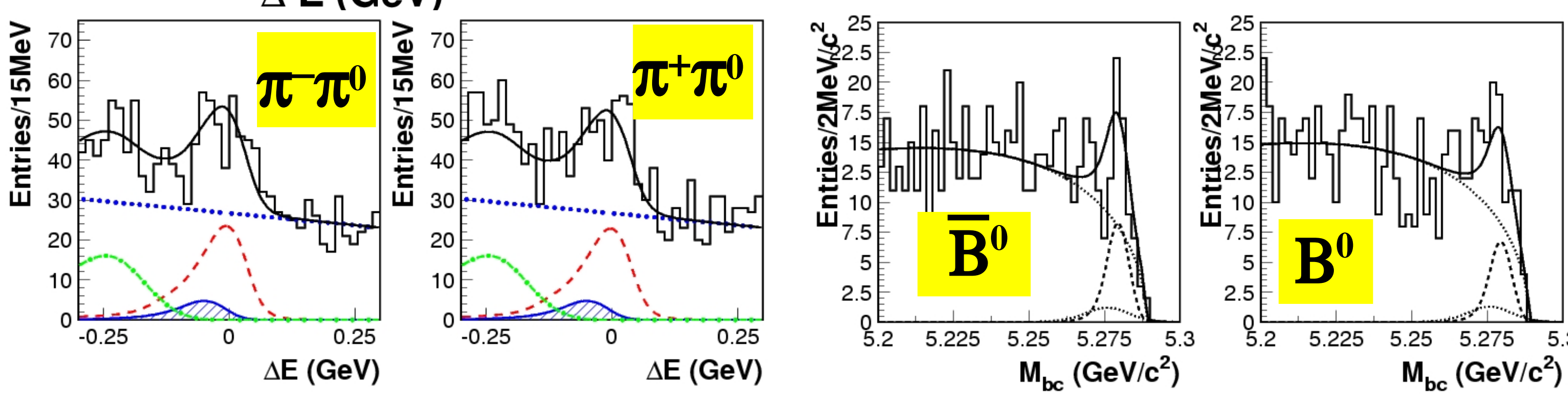
to complete the isospin analysis

	BaBar	Belle
$B \to \pi^+\pi^0$:	$BR(\pi^+\pi^0) = (5.8 \pm 0.6 \pm 0.4) \cdot 10^{-6}$	$BR(\pi^+\pi^0) = (5.0 \pm 1.2 \pm 0.5) \cdot 10^{-6}$
	$A(\pi^+\pi^0) = -0.01 \pm 0.10 \pm 0.02$	$A(\pi^+\pi^0) = 0.02 \pm 0.08 \pm 0.01$
$B \to \pi^0\pi^0$:	$BR(\pi^0\pi^0) = (1.17 \pm 0.32 \pm 0.10) \cdot 10^{-6}$	$BR(\pi^0\pi^0) = (2.3 \pm 0.5 \pm 0.3) \cdot 10^{-6}$
	$C(\pi^0\pi^0) = -0.12 \pm 0.56 \pm 0.06$	$C(\pi^0\pi^0) = 0.44 \pm 0.53 \pm 0.17$



208 fb^{-1}

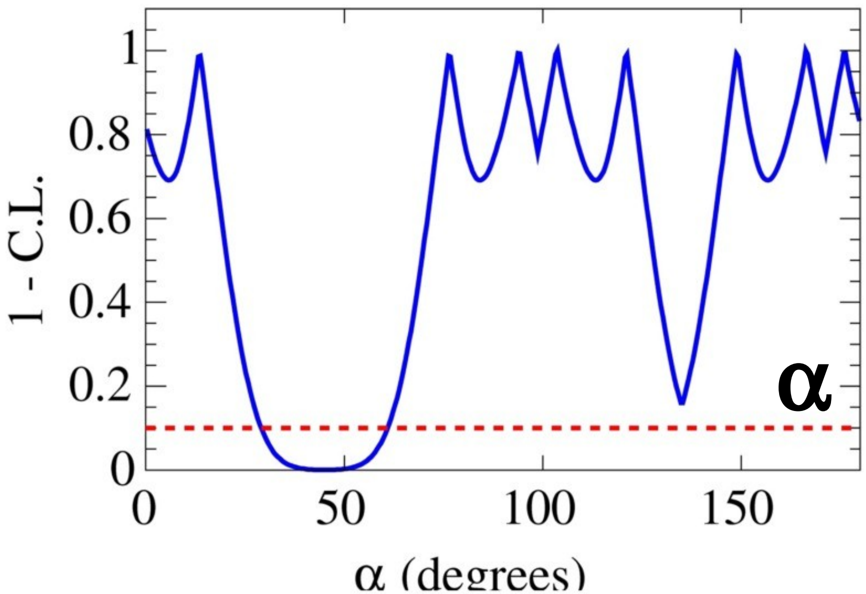




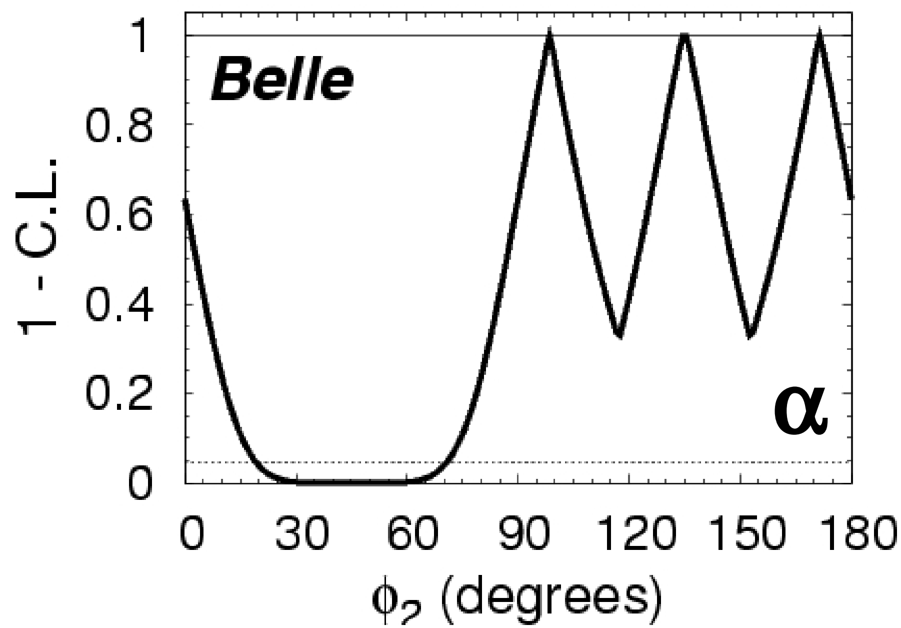
253 fb^{-1}

α: from B → ππ

PRL 95, 151803 (2005)



PRL 95, 101801 (2005)

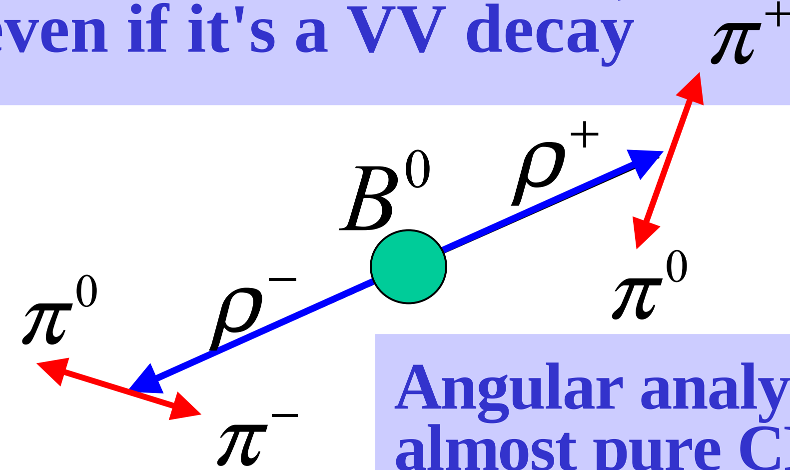


[29°, 61°] excluded @ 90% CL

[19°, 71°] excluded @ 95% CL

more on α_{eff}: from $B \to \rho^+\rho^-$

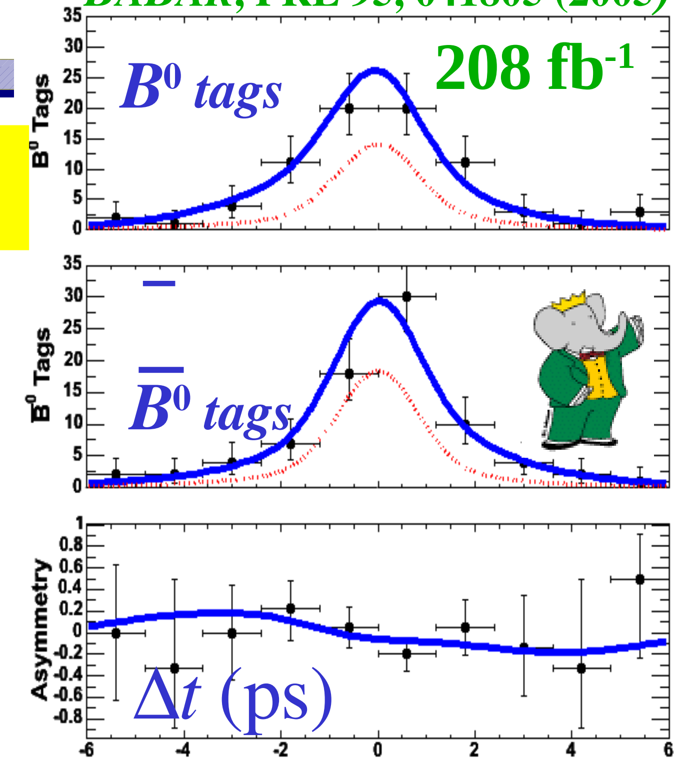
3 polarizations → mixed CP state:
but we are lucky → there is just one!
no additional dilution,
even if it's a VV decay

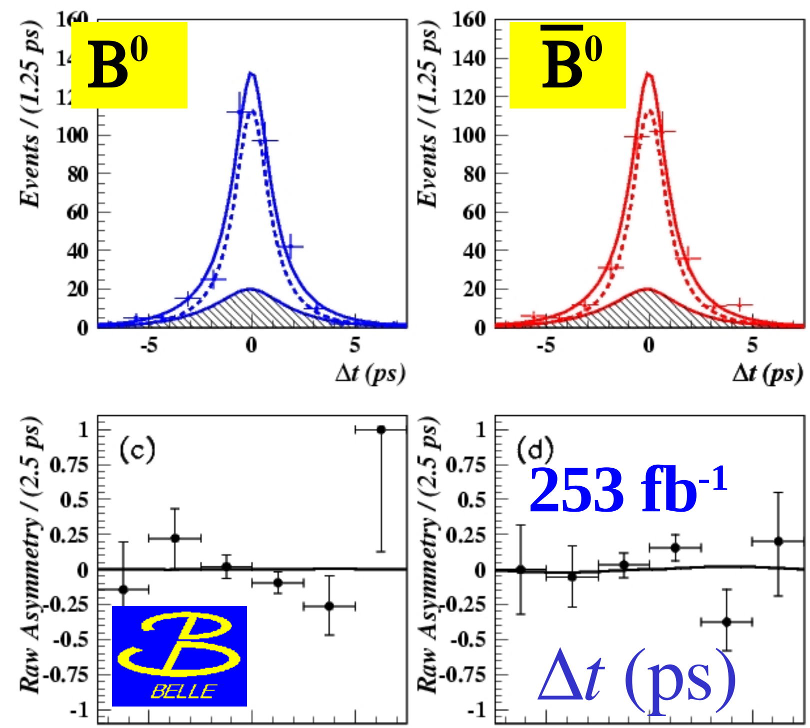


Angular analysis →
almost pure CP=+1 !

	BABAR	Belle	HFAG
f_L	$0.978 \pm 0.014^{+0.021}_{-0.029}$	$0.941^{+0.034}_{-0.040} \pm 0.030$	$0.967^{+0.023}_{-0.028}$
$S_{\rho\rho}$	$-0.33 \pm 0.24^{+0.08}_{-0.14}$	$0.08 \pm 0.41 \pm 0.09$	-0.21 ± 0.22
$C_{\rho\rho}$	$-0.03 \pm 0.18 \pm 0.09$	$0.00 \pm 0.30^{+0.09}_{-0.10}$	-0.03 ± 0.17

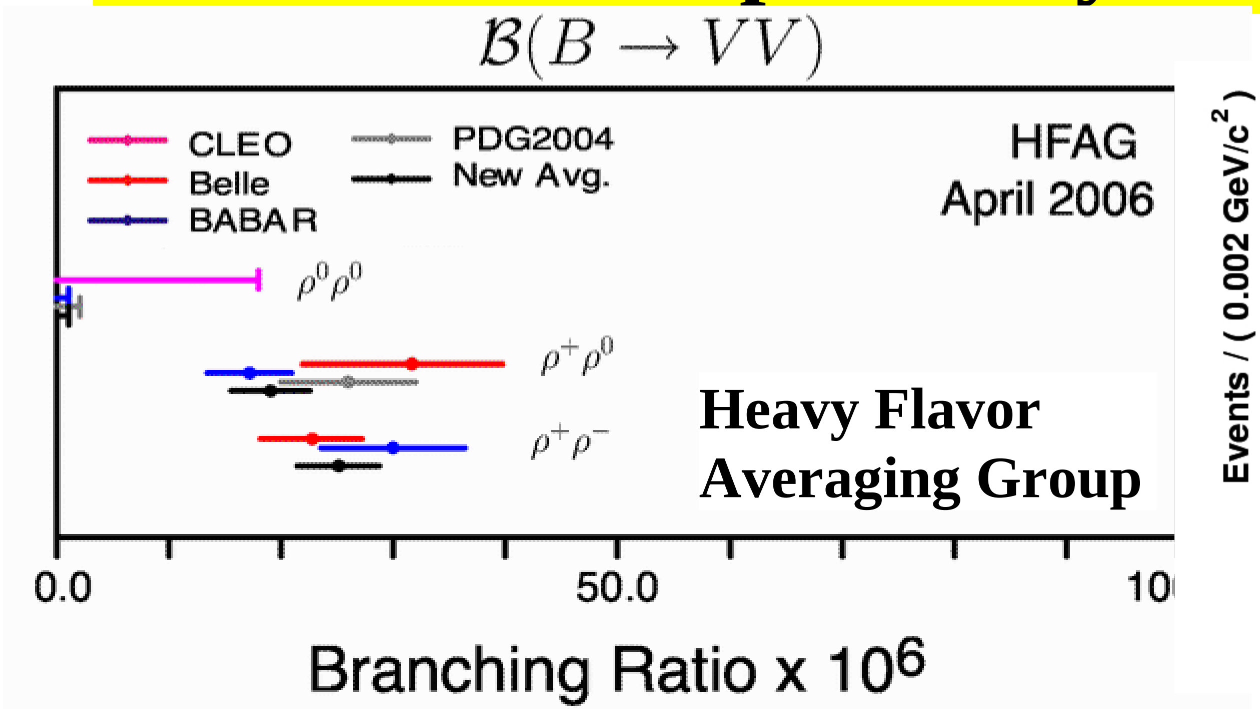
BABAR, PRL 95, 041805 (2005)

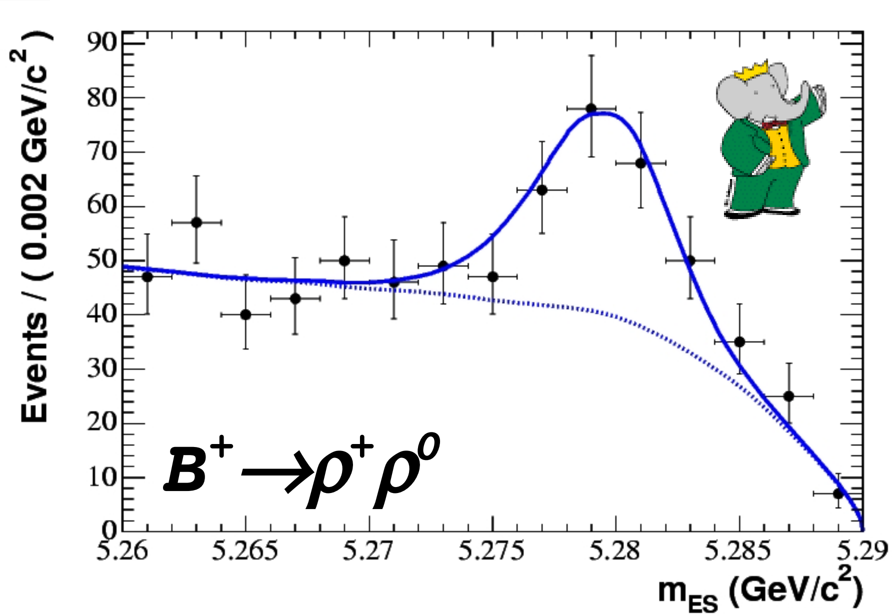




BELLE, hep-ex/0601024 (2006)

towards α: isospin analysis from B → ρρ



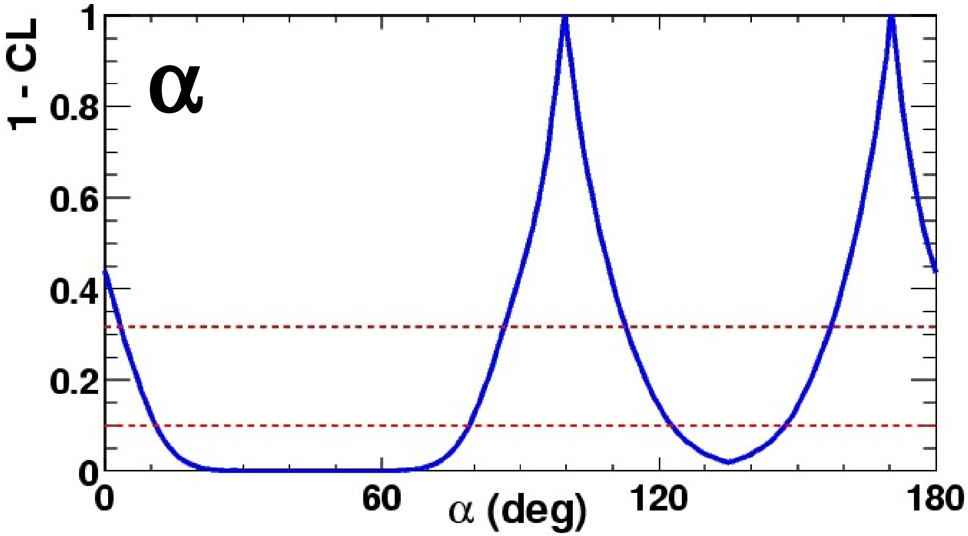


Mode	B/10^{-6} (*BABAR*)		B/10^{-6} (Belle)	
$B^0 \to \rho^0\rho^0$	<1.1(@90%C.L.)	[230 M $\bar{B}$B]	–	
$B^+ \to \rho^+\rho^0$	$17.2 \pm 2.5 \pm 2.8$	[230 M $\bar{B}$B]	$31.7 \pm 7.1 \pm 6.7$	[85 M $\bar{B}$B]
$B^0 \to \rho^+\rho^-$	$30 \pm 4 \pm 5$	[89 M $\bar{B}$B]	$22.8 \pm 3.8 \pm 2.6$	[275 M $\bar{B}$B]

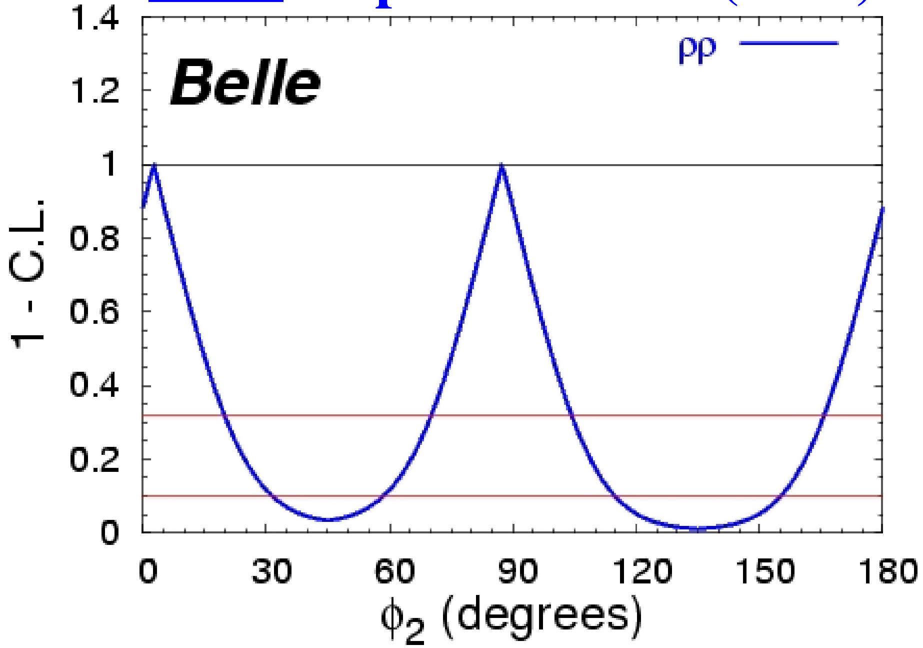
if 00 channel → 0 $|\alpha-\alpha_{eff}| \to 0$
from data: $|\alpha-\alpha_{eff}|_{\rho\rho} < |\alpha-\alpha_{eff}|_{\pi\pi}$

α: from B → ρρ

PRL 95, 041805 (2005)



hep-ex/0601024 (2006)

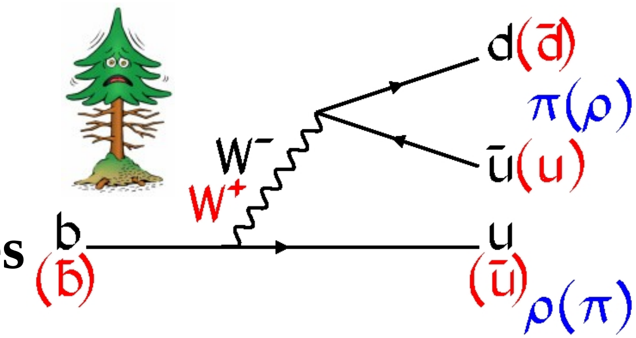


$\alpha_{SM} = [100 \pm 13]°$

$\alpha_{SM} = [88 \pm 17]°$

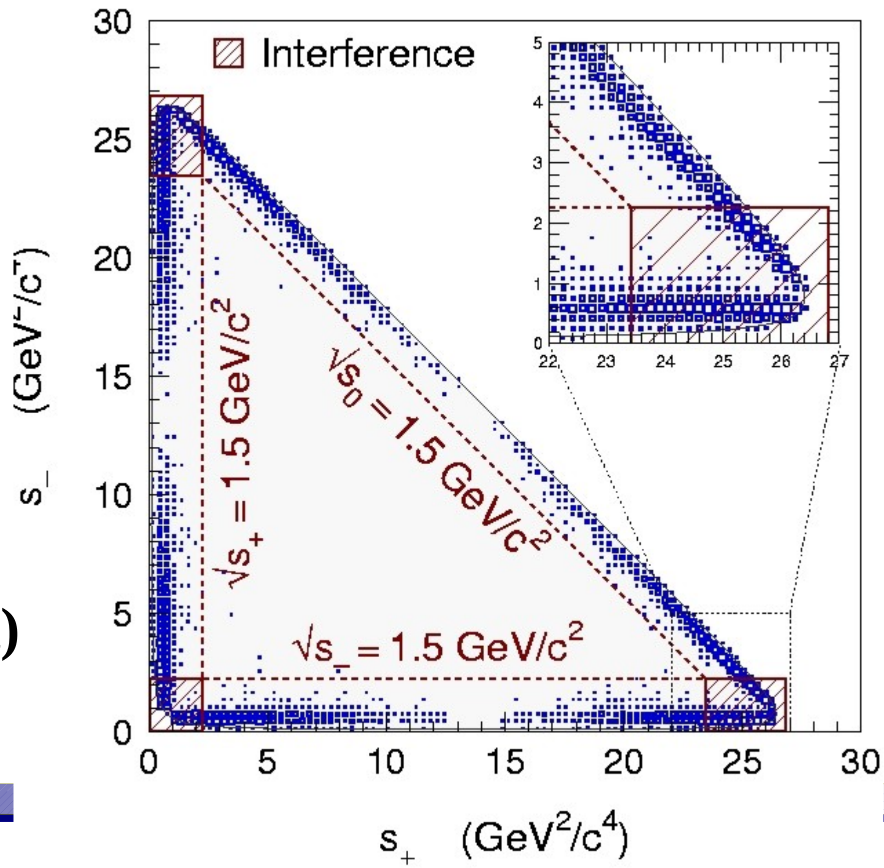
dominant contribution to the error: 11° from the Grossman-Quinn bound with the $\rho^0\rho^0$ limit

Still α: time-dipendent analysis $B^0 \rightarrow (\rho\pi)^0$



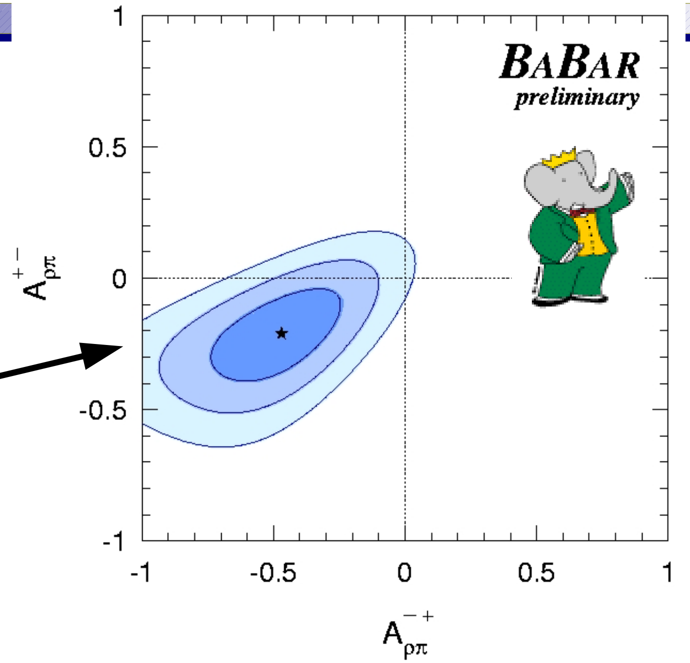
- method Snyder-Quinn
  - *Phys. Rev. D48 2139 (1993)*
- α extraction together with the strong phases exploiting the amplitude interference
- the amplitude $A_{3\pi}$ is dominated by $\rho^+\pi^-$, $\rho^-\pi^+$, $\rho^0\pi^0$ and by the radial component
  - $A_{3\pi} = f_+A^{+-} + f_-A^{-+} + f_0\, A^{00}$
  - $A^k = T^{\,k}e^{-i\alpha} + P^{\,k}$
- with this one can define time-dependent coefficients as functions of

  $\cos(\Delta m_d\, \Delta t)$ and $\sin(\Delta m_d\, \Delta t)$

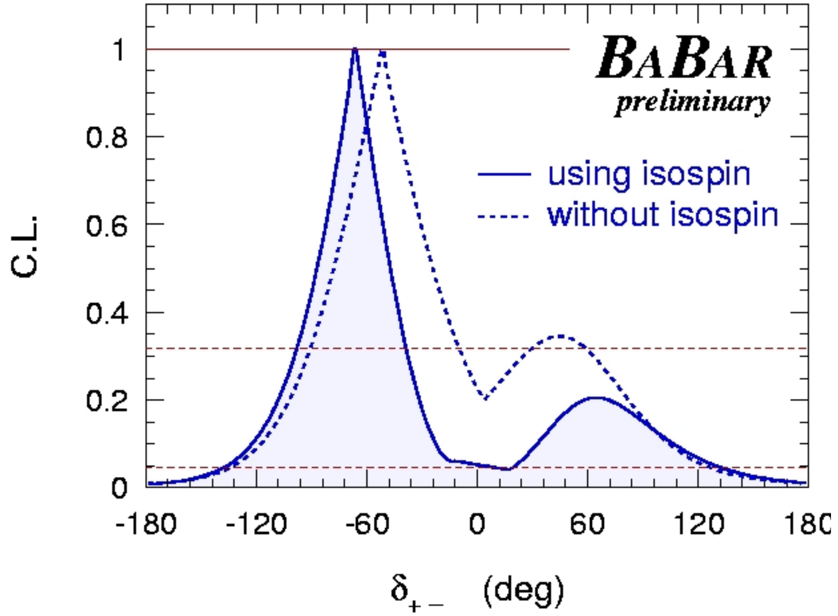


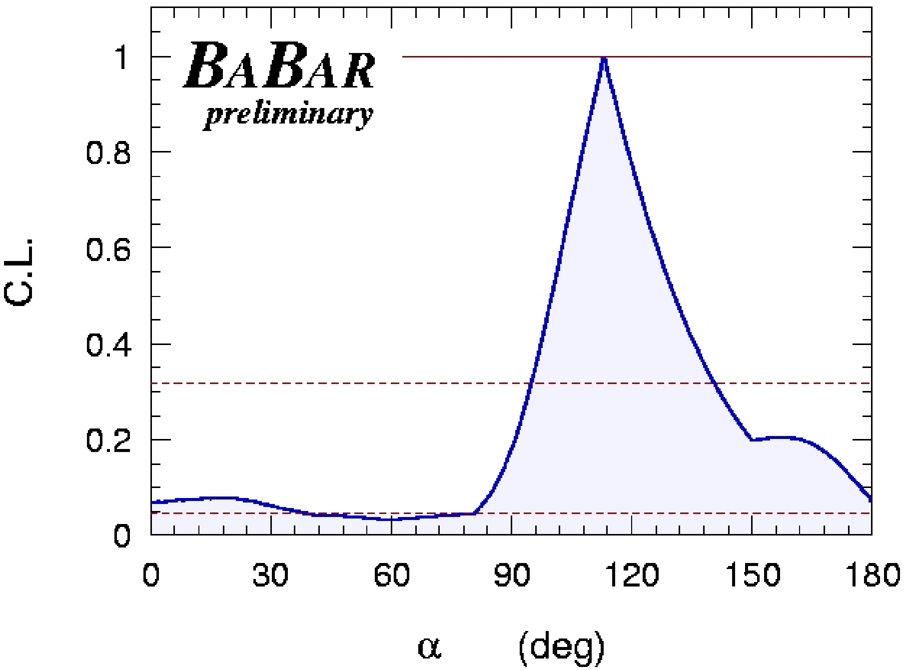
$B^0 \to (\rho\pi)^0$ results

- direct asymmetry measurement:
  - $A^{+-} = -0.21 \pm 0.11 \pm 0.04$
  - $A^{-+} = -0.47 \pm 0.15 \pm 0.06$
- defining $\delta_{+-} = \arg(A^{+*}A^{-})$
  and using SU(2) relation in $P^0 = -(P^+ + P^-)/2$
  - one can extract



$\alpha = (113^{+27}_{-17} \pm 6)°$





α from isospin analysis: $\pi\pi$, $\rho\rho$, $\rho\pi$

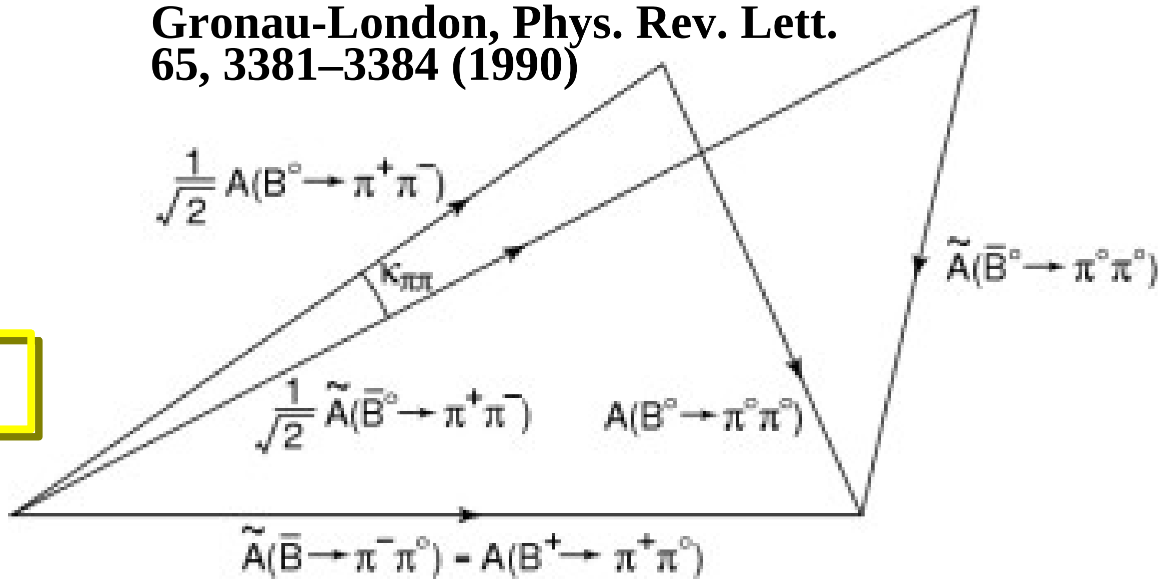
Starting from the SU(2) amplitudes ($\pi\pi$, $\rho\rho$):

$A^{+-} = -Te^{-i\alpha} + Pe^{i\delta P}$

$A^{+0} = -1/\sqrt{2}\, e^{-i\alpha}\, (T + T_C\, e^{i\delta C})$

$A^{00} = -1/\sqrt{2}\, (T_C\, e^{i\delta C}\, e^{-i\alpha} + Pe^{i\delta P})$

Gronau-London, Phys. Rev. Lett. 65, 3381–3384 (1990)



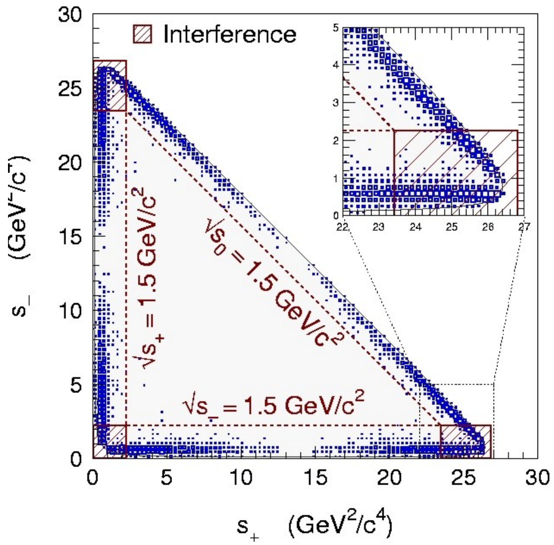
unknowns: T, P, T_C, δ_P, δ_{T_C}, α
observable: 3x BR, C_{+-}, S_{+-}, C_{00}

Similar analysis for $(\rho\pi)^0$ on the Dalitz plane

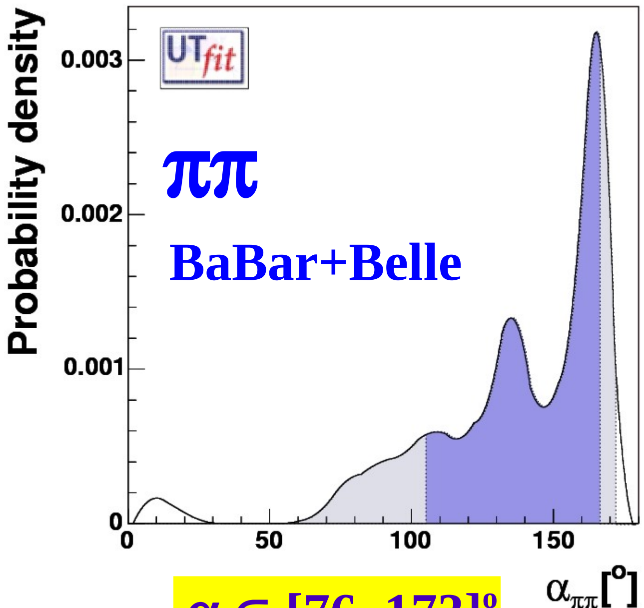
$A^k = T^k e^{-i\alpha} + P^k$

$\bar{A}^k = T^{\bar{k}} e^{i\alpha} + P^{\bar{k}}$

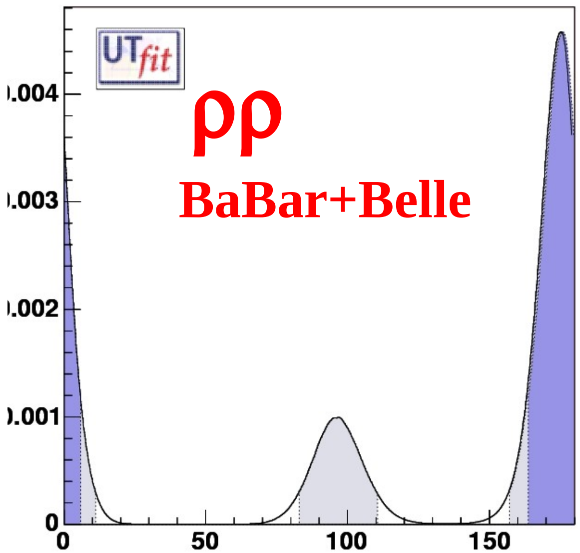
with k=+- for $\rho^+\pi^-$, -+ for $\rho^-\pi^+$, e 00 for $\rho^0\pi^0$



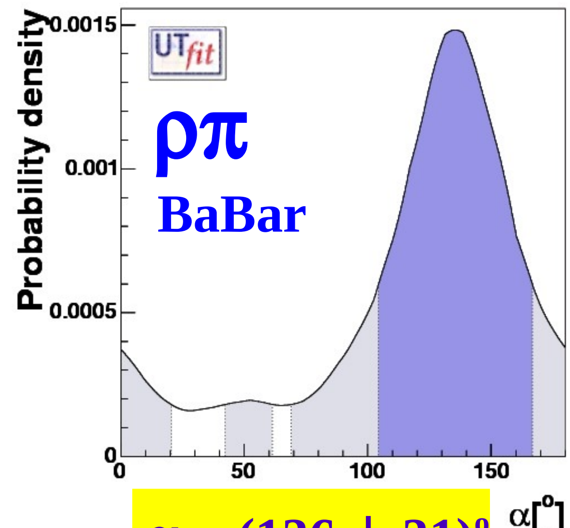
α from isospin analysis: ρρ, ππ and ρπ



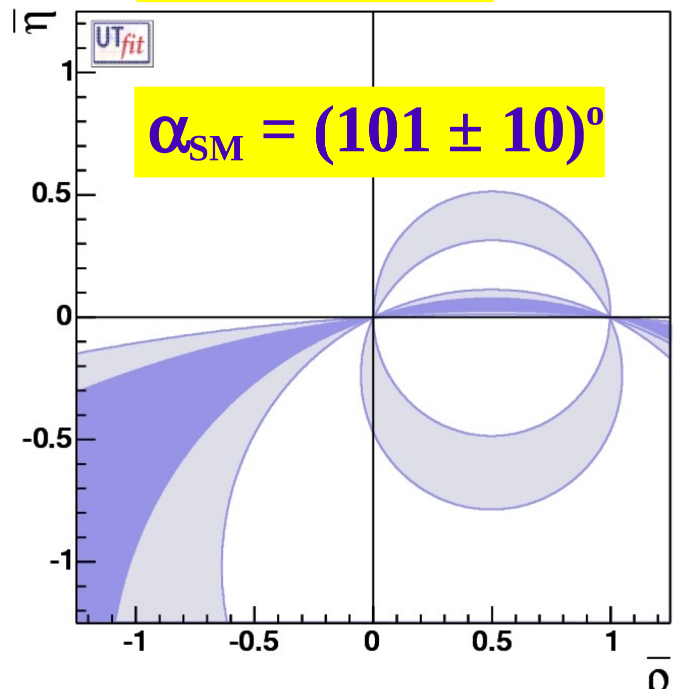
$\alpha \in [76, 173]^o$



$\alpha \in [83, 111]^o U[157, 191]^o$



$\alpha = (136 \pm 31)^o$



$\alpha_{SM} = (101 \pm 10)^o$

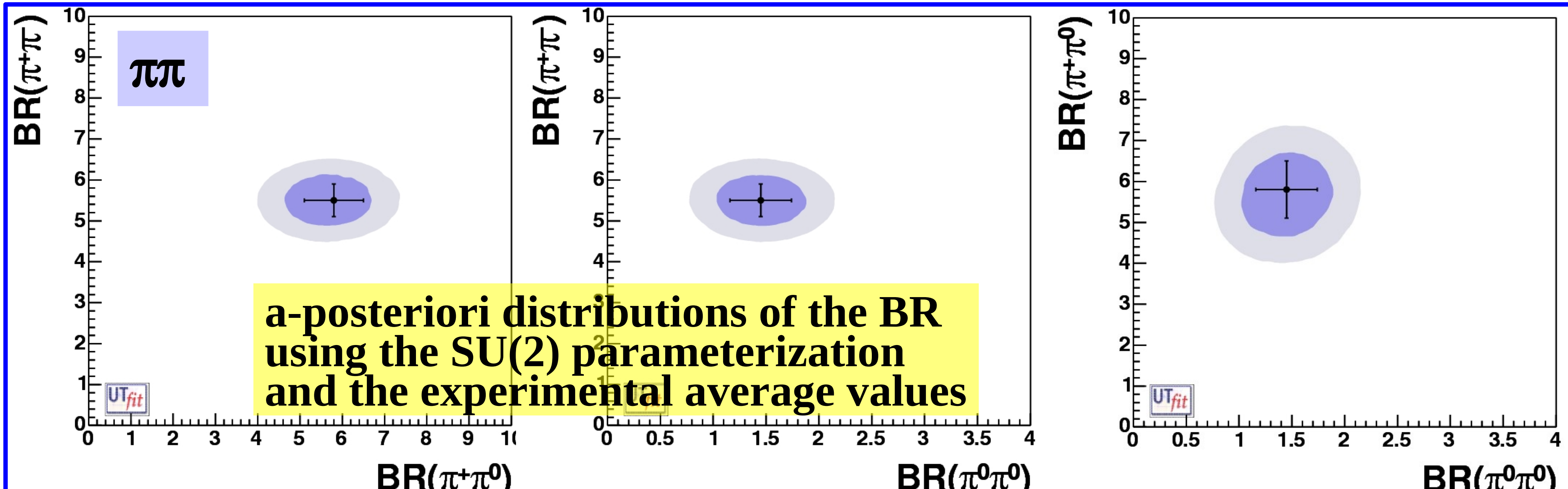
$C_{\pi\pi} = -0.37 \pm 0.10$
$S_{\pi\pi} = -0.50 \pm 0.12$

$C_{\rho\rho} = -0.03 \pm 0.17$
$S_{\rho\rho} = -0.21 \pm 0.22$

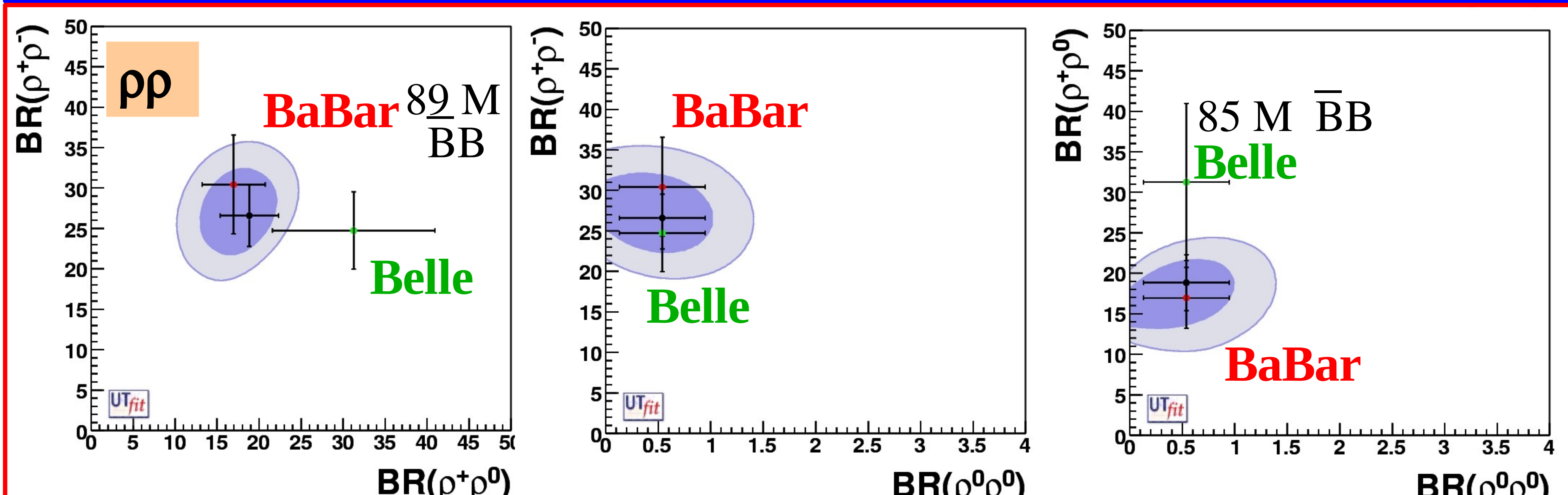
$C_{\pi\pi}$ and $S_{\pi\pi}$ equal to 0 are excluded

$C_{\rho\rho}$ and $S_{\rho\rho}$ equal to 0 are preferred

Test of the isospin assumption in ππ and ρρ

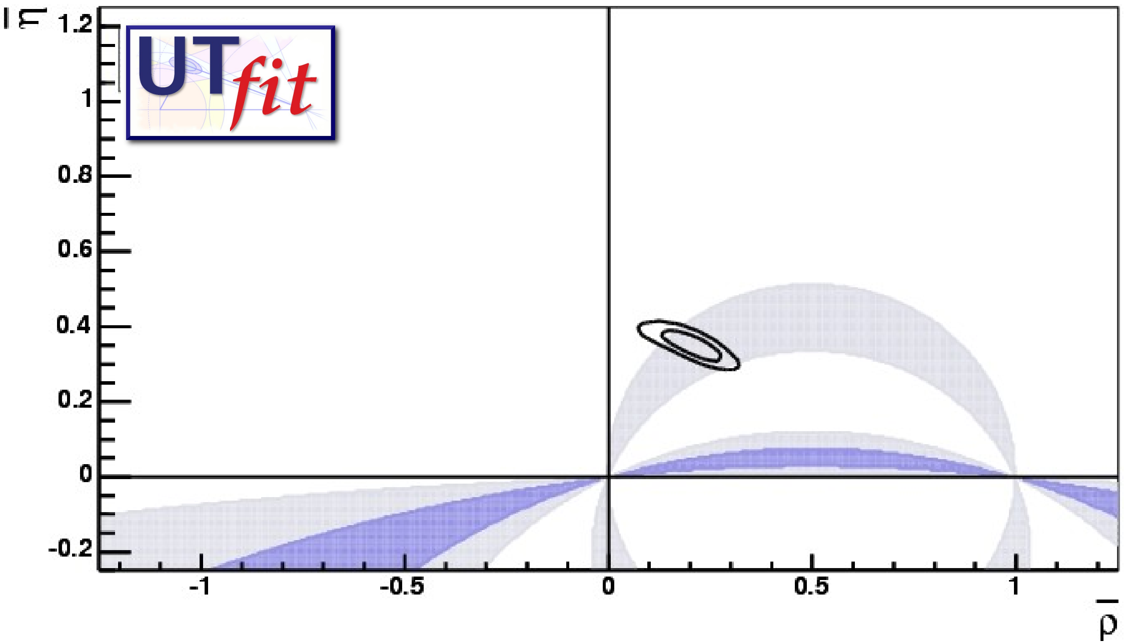


a-posteriori distributions of the BR using the SU(2) parameterization and the experimental average values

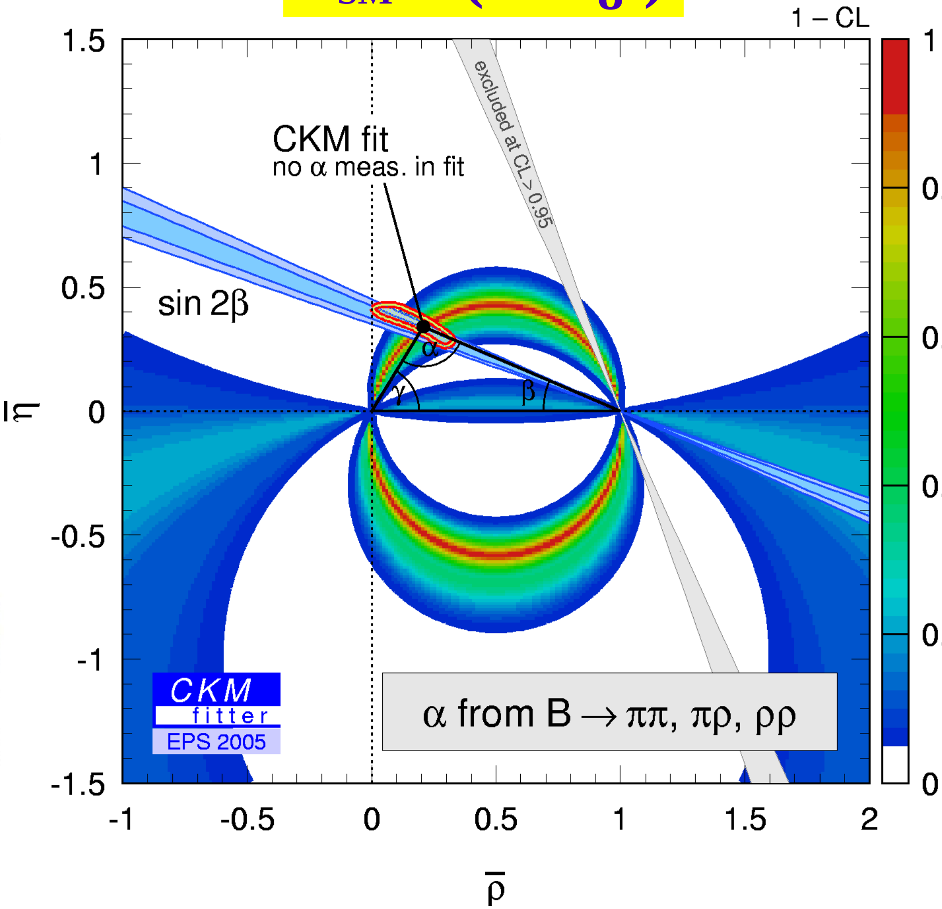


α from isospin analysis: summary

$\alpha_{SM} = (101 \pm 10)^o$

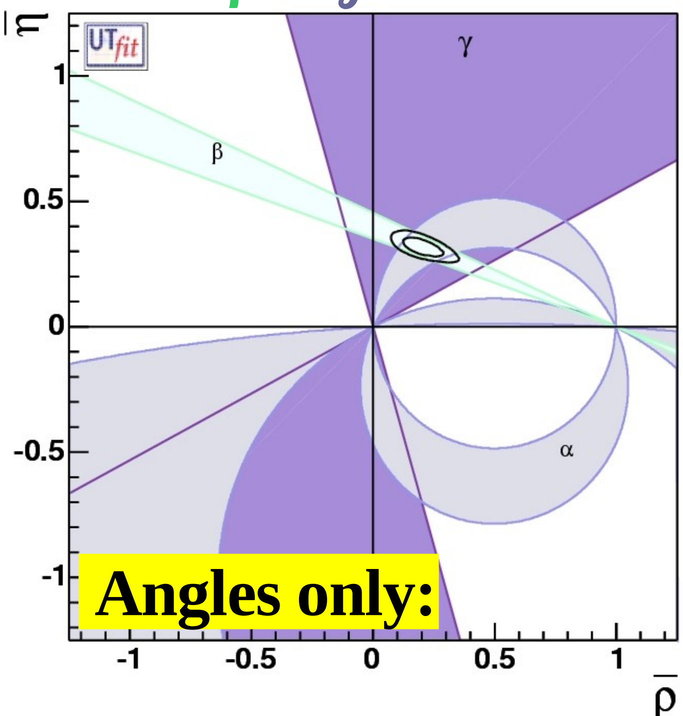


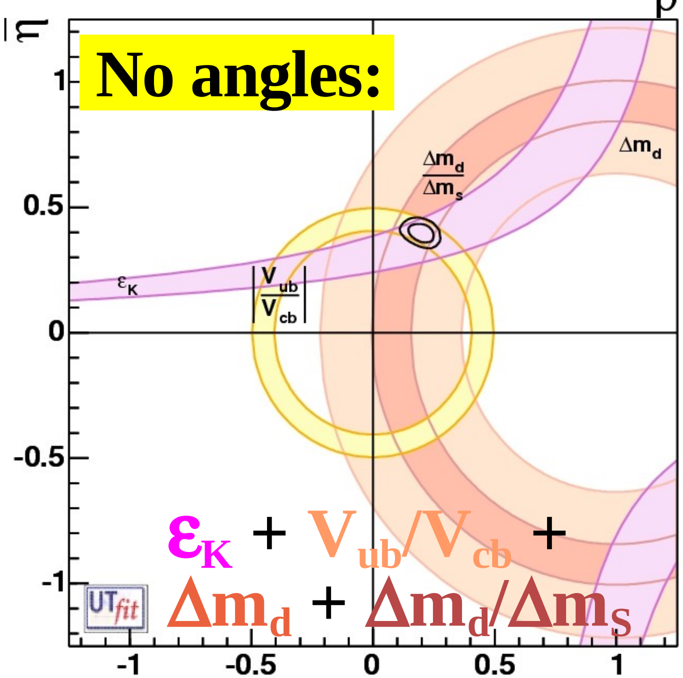
$\alpha_{SM} = (99\,^{+13}_{-8})^o$

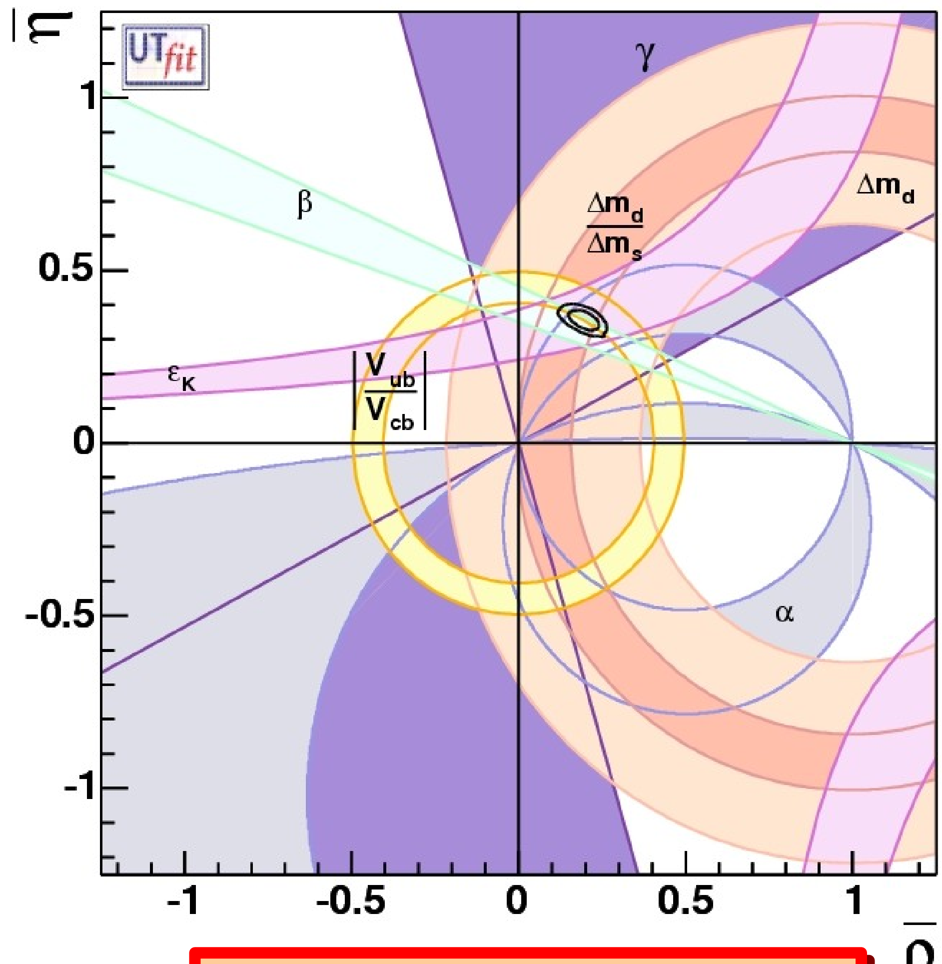


Including all the constraints

$\beta + \gamma + \alpha$



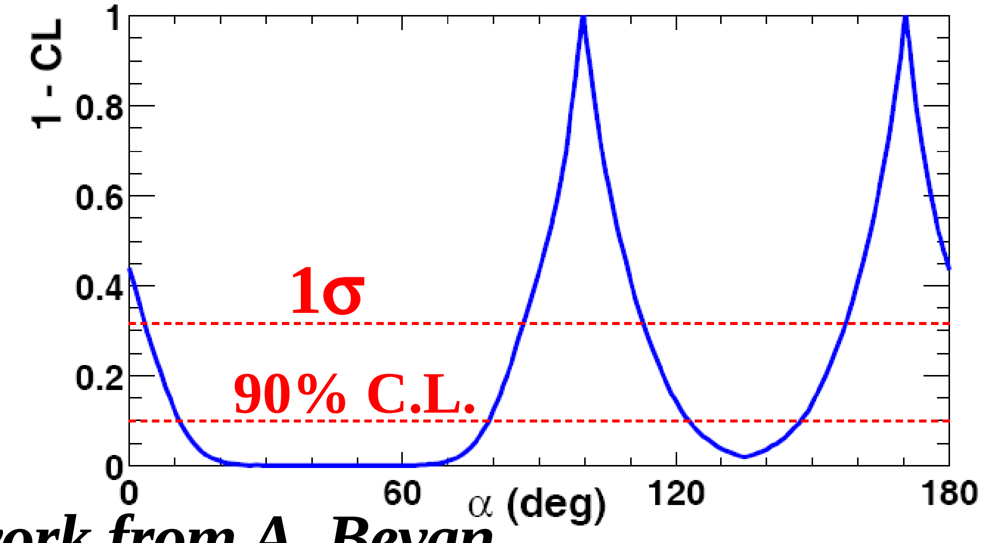




$\bar{\rho} = 0.193 \pm 0.029$
[0.133, 0.248] @ 95% Prob.

$\bar{\eta} = 0.355 \pm 0.019$
[0.318, 0.393] @ 95% Prob.

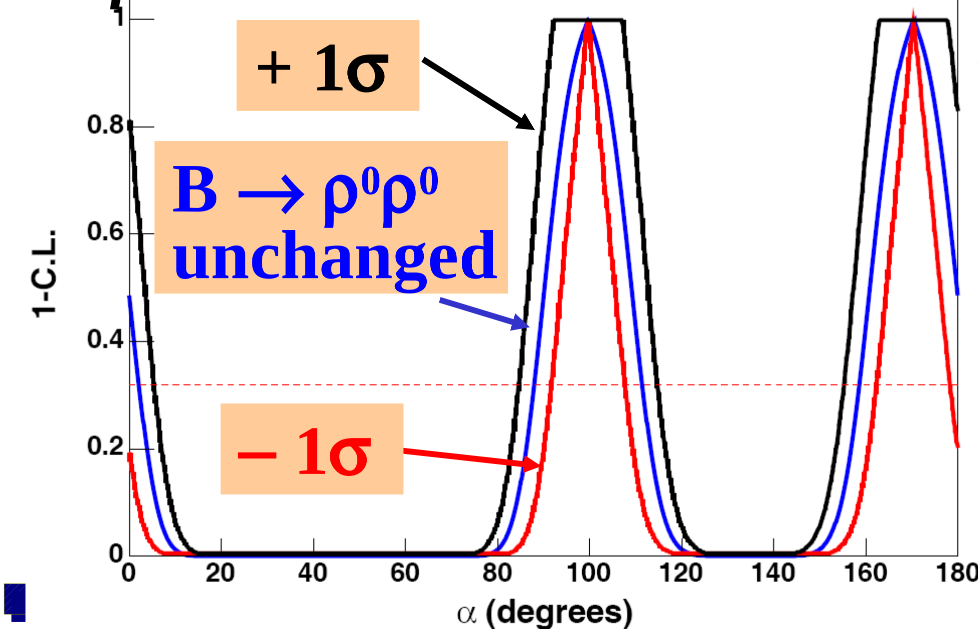
Physics Reach with 1 ab^{-1} scenario



Current α measurement from B→ ρρ:

multiple unresolved solutions within each peak

work from A. Bevan



Projected α measurement from B→ ρρ for 1 ab^{-1}

the uncertainty on α depends critically on BR($B \to \rho^0\rho^0$)

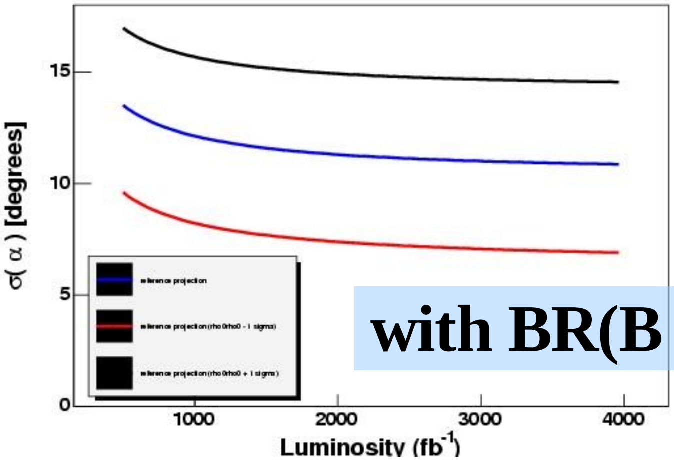
Scenarios:

- use the current value
- + 1σ
- – 1σ

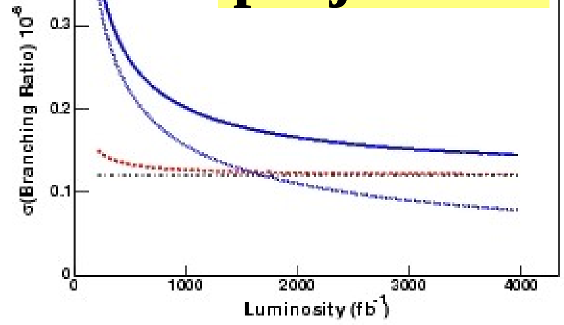
Physics Reach with 1 ab^{-1} scenario

critical issue: $B \to \rho^0\rho^0$
but also $B \to \rho^+\rho^0$

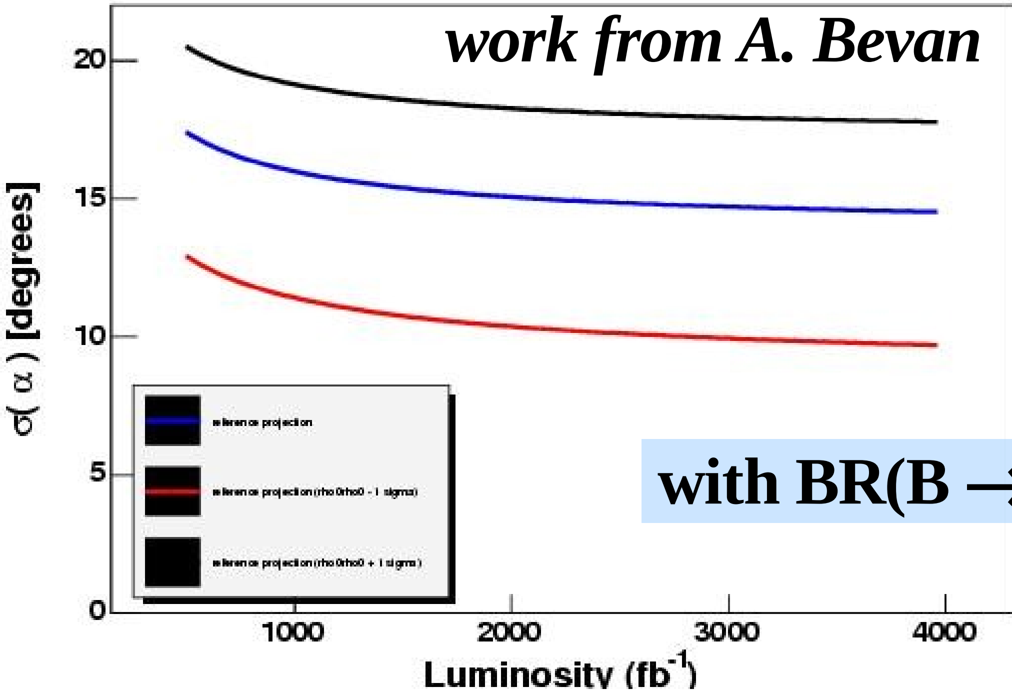
$B \to \rho^0\rho^0$ error projection



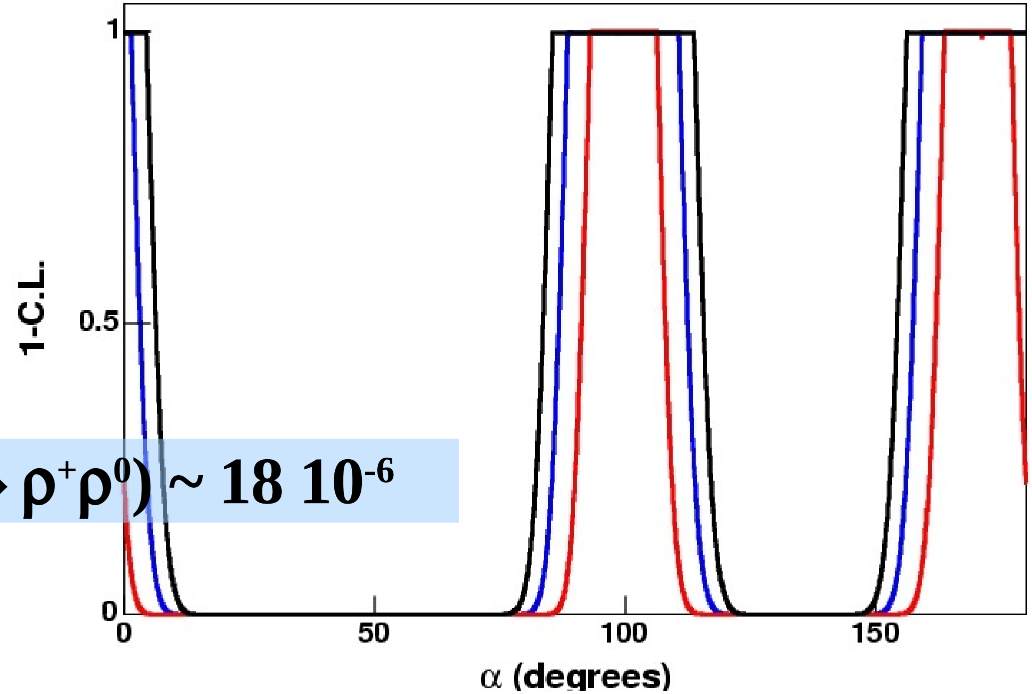
with BR($B \to \rho^+\rho^0$) ~ 26.4 10^{-6}



work from A. Bevan



with BR($B \to \rho^+\rho^0$) ~ 18 10^{-6}



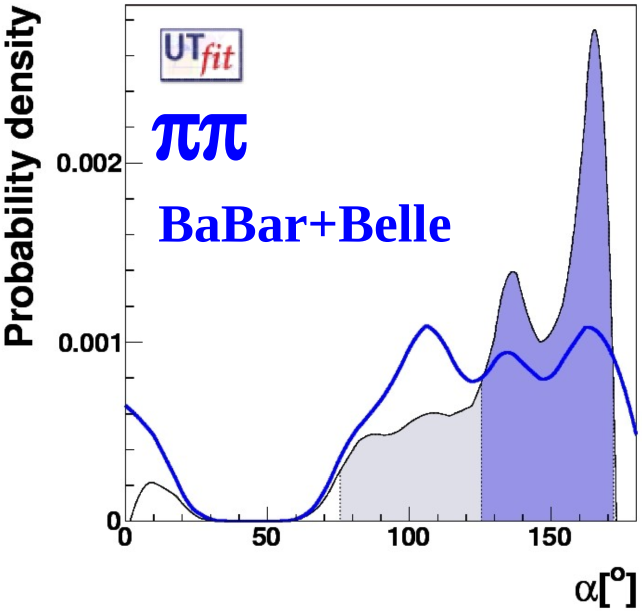
Conclusions:

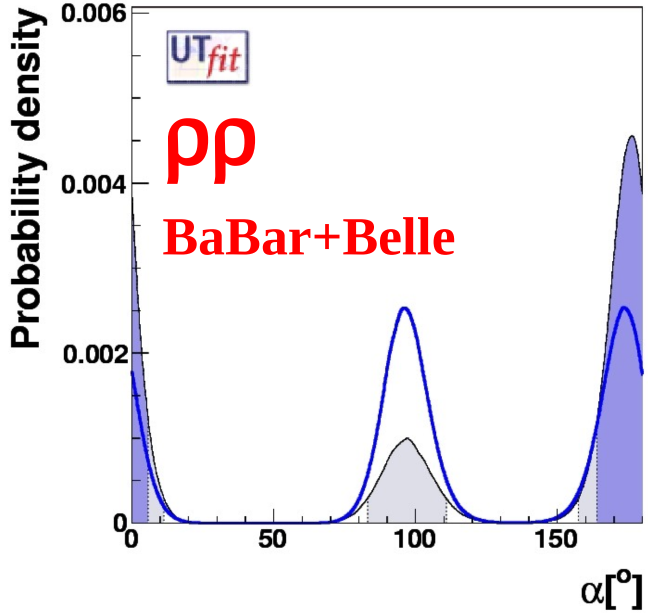
α is still a land open for discussion even if the SM solution already reaches the 10^{o} precision

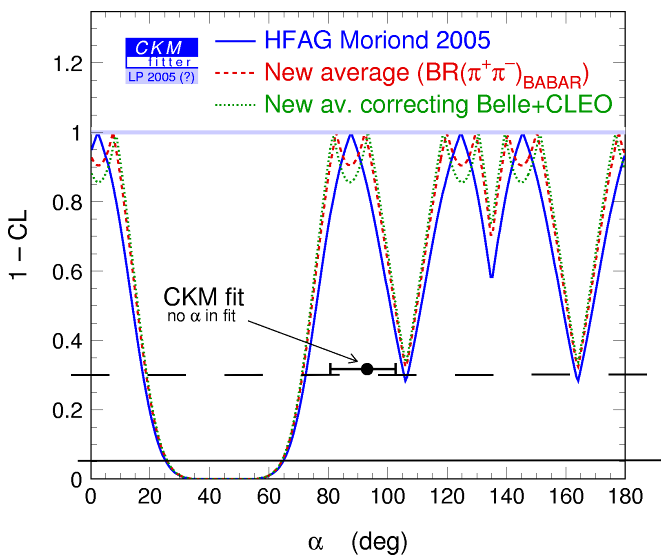
I keep the conclusions short this time!

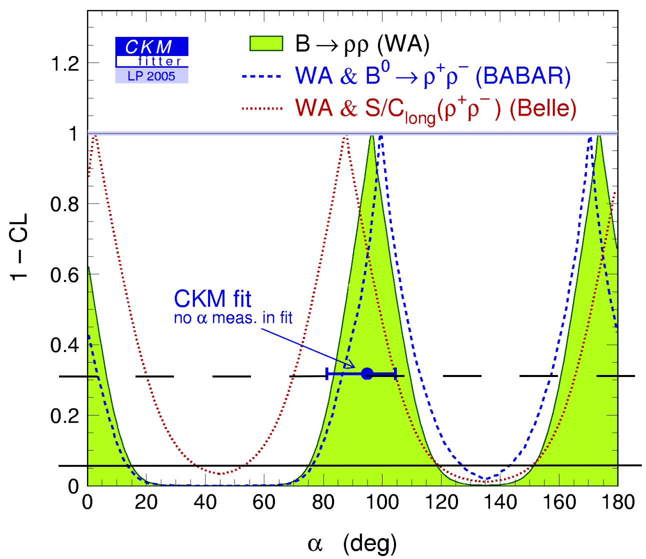
Back up slides

α from isospin analysis (III): ππ and ρρ









$C_{\pi\pi}$ and $S_{\pi\pi}$ equal to 0 are excluded

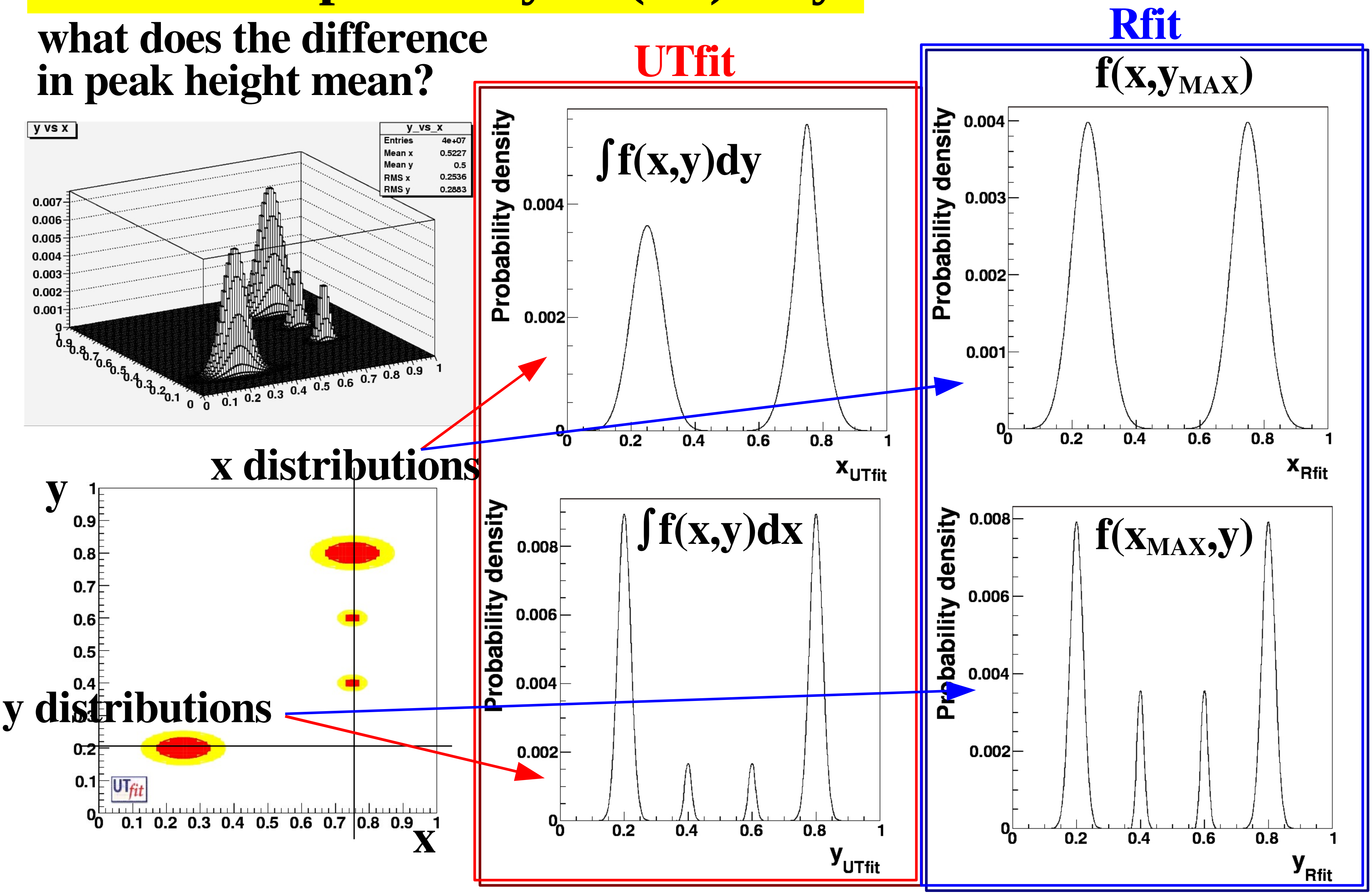
$C_{\pi\pi} = -0.37 \pm 0.10$
$S_{\pi\pi} = -0.50 \pm 0.12$

$C_{\rho\rho} = -0.03 \pm 0.17$
$S_{\rho\rho} = -0.21 \pm 0.22$

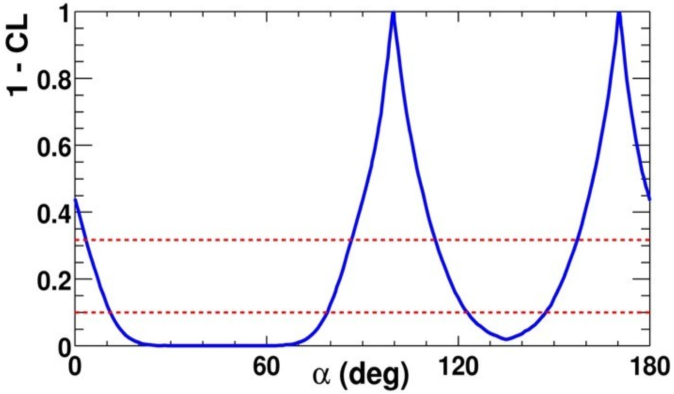
$C_{\rho\rho}$ and $S_{\rho\rho}$ equal to 0 are preferred

α from isospin analysis (IV): toy

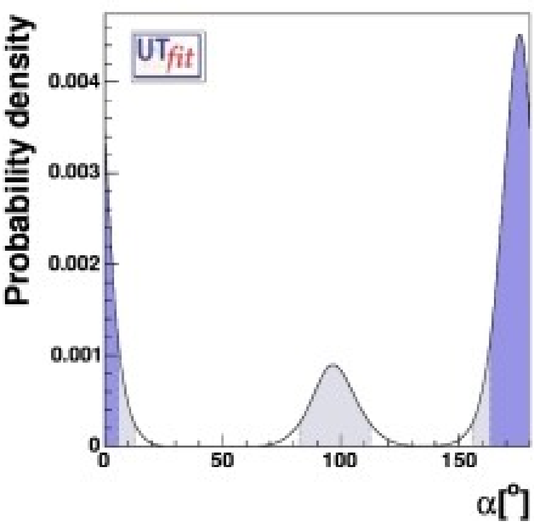
what does the difference in peak height mean?

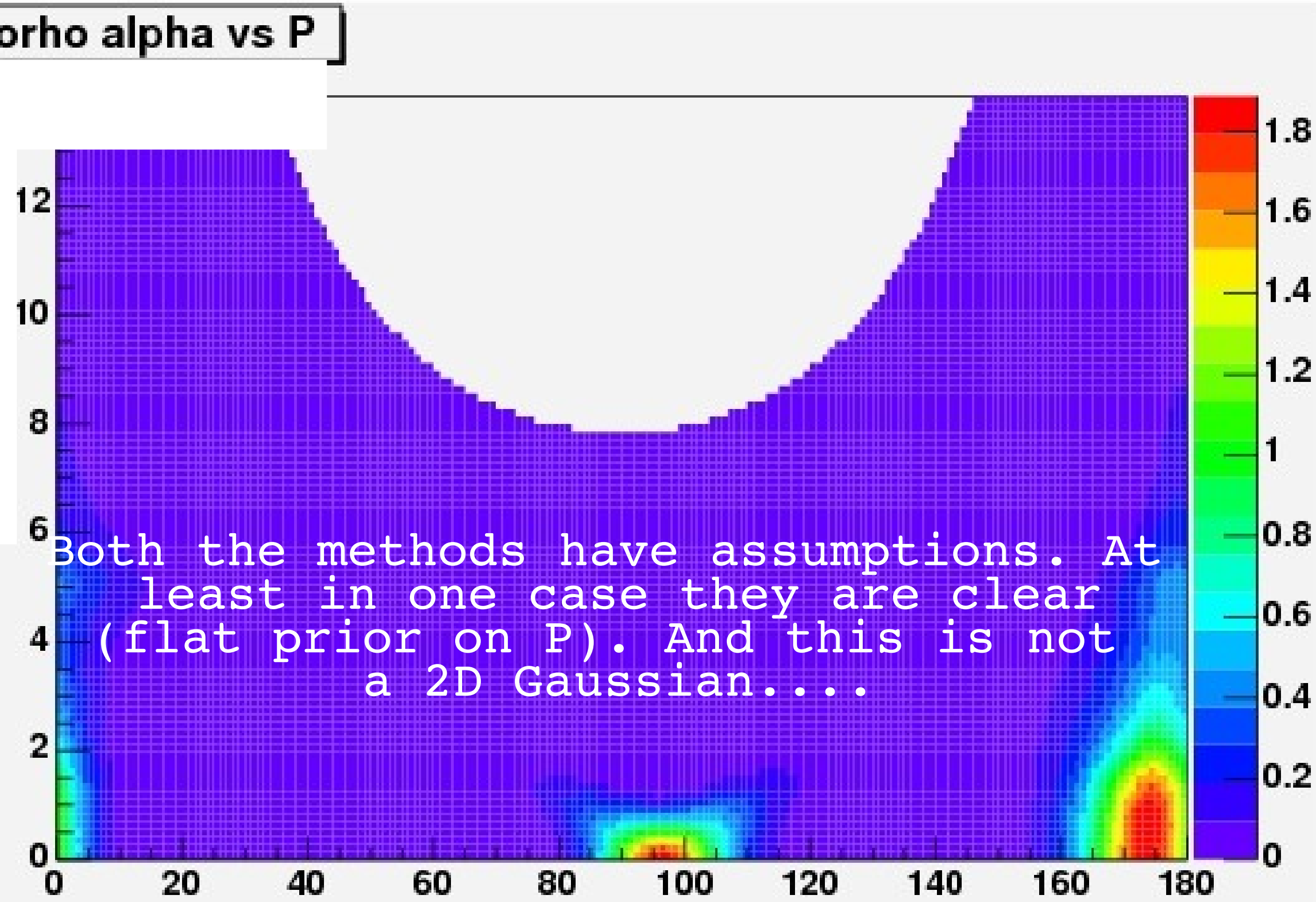


Taking the maximum



Integrating





Both the methods have assumptions. At least in one case they are clear (flat prior on P). And this is not a 2D Gaussian....