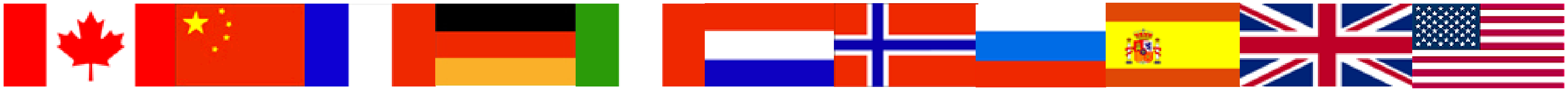
# Status and Perspectives of *BABAR* Experiment

Maurizio Pierini
University of Wisconsin, Madison



# The *BABAR* Collaboration

**11 Countries**
**80 Institutions**
**623 Physicists**

## USA [38/311]
California Institute of Technology
UC, Irvine
UC, Los Angeles
UC, Riverside
UC, San Diego
UC, Santa Barbara
UC, Santa Cruz
U of Cincinnati
U of Colorado
Colorado State
Harvard U
U of Iowa
Iowa State U
LBNL
LLNL
U of Louisville
U of Maryland
U of Massachusetts, Amherst
MIT
U of Mississippi
Mount Holyoke College
SUNY, Albany
U of Notre Dame
Ohio State U
U of Oregon
U of Pennsylvania
Prairie View A&M U
Princeton U
SLAC
U of South Carolina
Stanford U
U of Tennessee
U of Texas at Austin
U of Texas at Dallas
Vanderbilt
U of Wisconsin
Yale

## Canada [4/24]
U of British Columbia
McGill U
U de Montréal
U of Victoria

## China [1/5]
Inst. of High Energy Physics, Beijing

## France [5/53]
LAPP, Annecy
LAL Orsay
LPNHE des Universités Paris VI et VII
Ecole Polytechnique, Laboratoire Leprince-Ringuet
CEA, DAPNIA, CE-Saclay

## Germany [5/24]
Ruhr U Bochum
U Dortmund
Technische U Dresden
U Heidelberg
U Rostock

## Italy [12/99]
INFN, Bari
INFN, Ferrara
Lab. Nazionali di Frascati dell' INFN
INFN, Genova & Univ
INFN, Milano & Univ
INFN, Napoli & Univ
INFN, Padova & Univ
INFN, Pisa & Univ & Scuola Normale Superiore
INFN, Perugia & Univ
INFN, Roma & Univ "La Sapienza"
INFN, Torino & Univ
INFN, Trieste & Univ

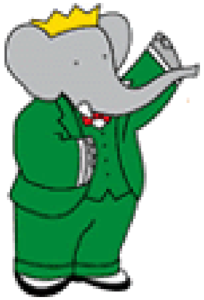
## The Netherlands [1/4]
NIKHEF, Amsterdam

## Norway [1/3]
U of Bergen

## Russia [1/13]
Budker Institute, Novosibirsk

## Spain [2/3]
IFAE-Barcelona
IFIC-Valencia

## United Kingdom [11/75]
U of Birmingham
U of Bristol
Brunel U
U of Edinburgh
U of Liverpool
Imperial College
Queen Mary , U of London
U of London, Royal Holloway
U of Manchester
Rutherford Appleton Laboratory
U of Warwick

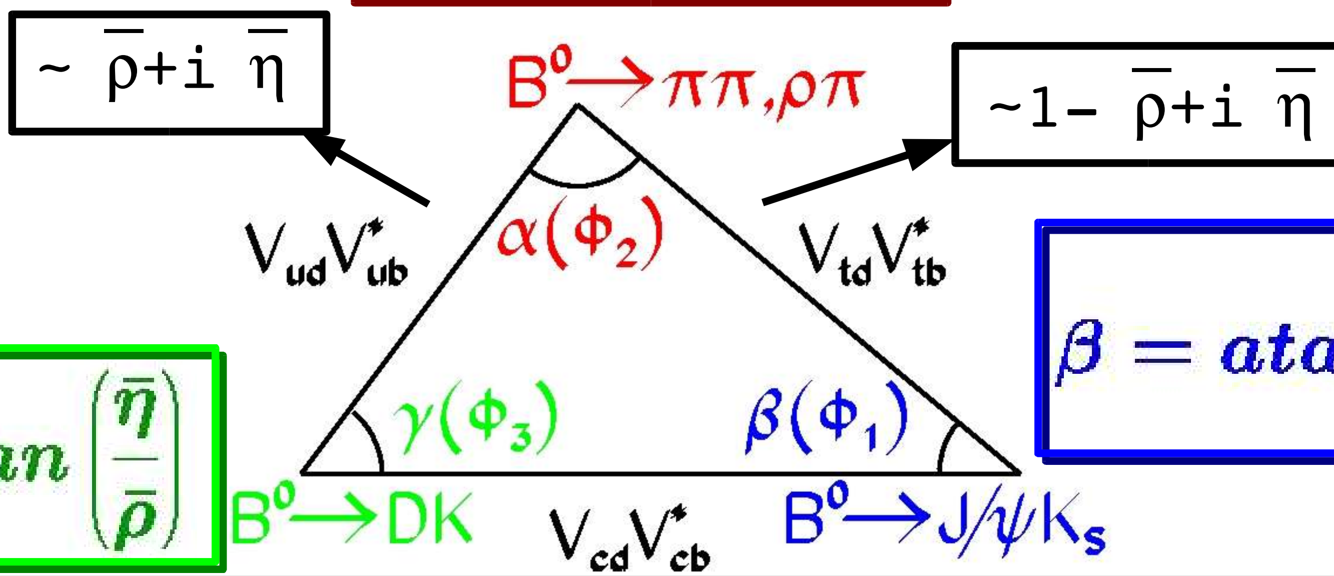


# Unitarity Triangle

Using the Unitarity of the CKM matrix in the SM we can build the Unitarity Triangle.

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

$$\alpha = \pi - \beta - \gamma$$

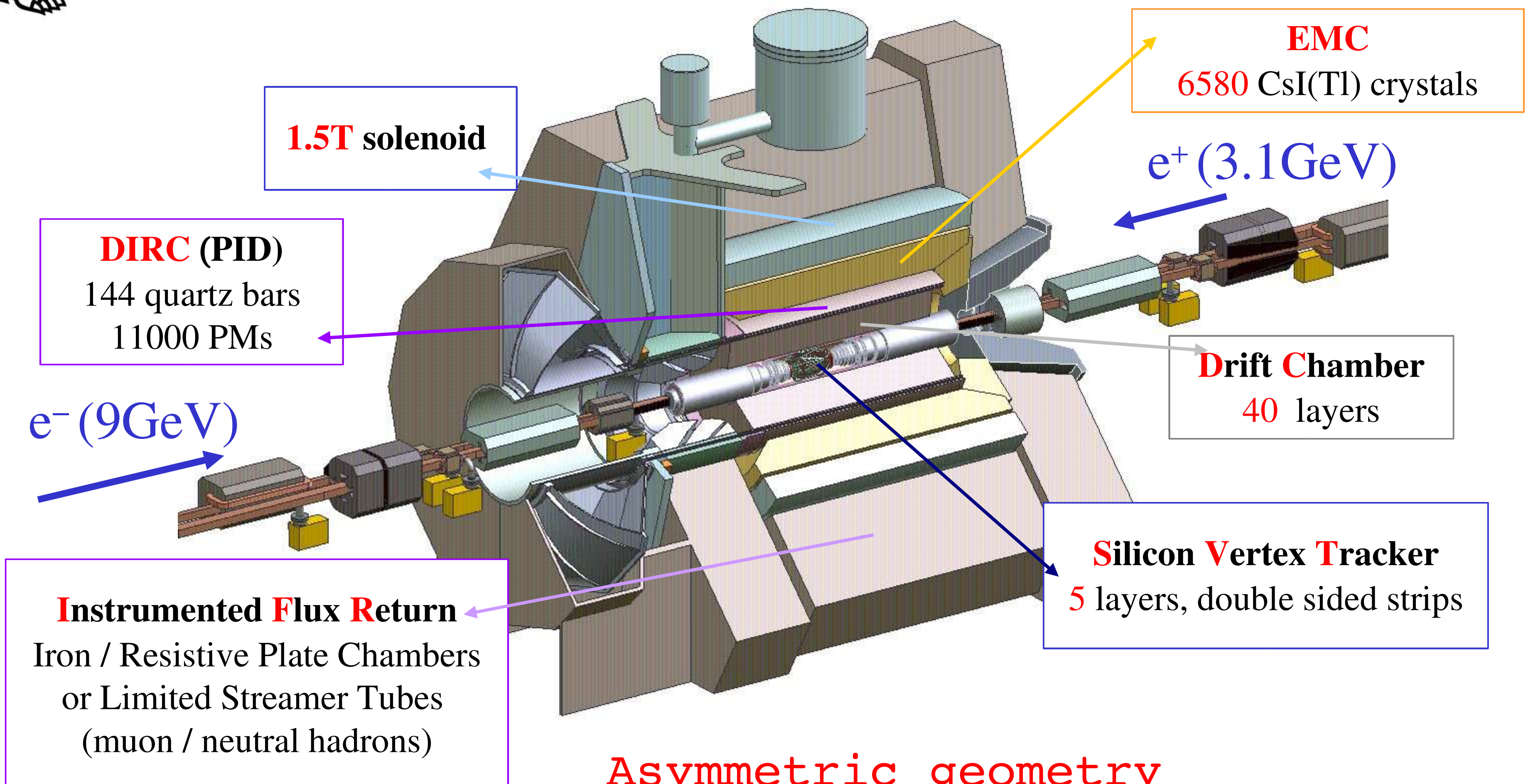



$$\gamma = atan\left(\frac{\bar{\eta}}{\bar{\rho}}\right)$$

$$\beta = atan\left(\frac{\bar{\eta}}{(1-\bar{\rho})}\right)$$

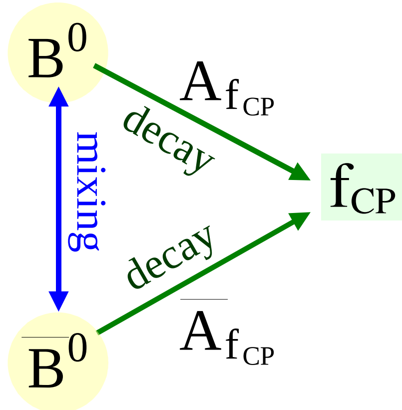
- **Angles** of triangle from CP **asymmetries** in $B$ decay
- **Sides** of triangle from **rates** for $b \to ul\nu$, $B^0\bar{B}^0$ mixing

# *BABAR* Detector




Asymmetric geometry
(in order to optimize performances for the boost of the rest-frame respect to LAB)

# Why the boost?CP asymmetry




decay

$$\lambda_{f_{CP}} = \frac{q}{p} \cdot \frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}} = |\lambda_{f_{CP}}| \cdot e^{-2i\phi_{CP}}$$

mixing

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

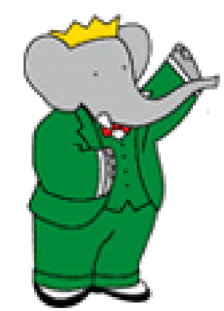
$$C_{f_{CP}} = \frac{1-|\lambda_{f_{CP}}|^2}{1+|\lambda_{f_{CP}}|^2}$$

$$A_{f_{CP}} = \frac{\Gamma(\overline{B}^0_{phys}(t)\rightarrow f_{CP}) - \Gamma(B^0_{phys}(t)\rightarrow f_{CP})}{\Gamma(\overline{B}^0_{phys}(t)\rightarrow f_{CP}) + \Gamma(B^0_{phys}(t)\rightarrow f_{CP})}$$
$$= C_{f_{CP}}\cos(\Delta m_d \Delta t) + S_{f_{CP}}\sin(\Delta m_d \Delta t)$$

With only one CKM term in the decay ($A = \overline{A}$)

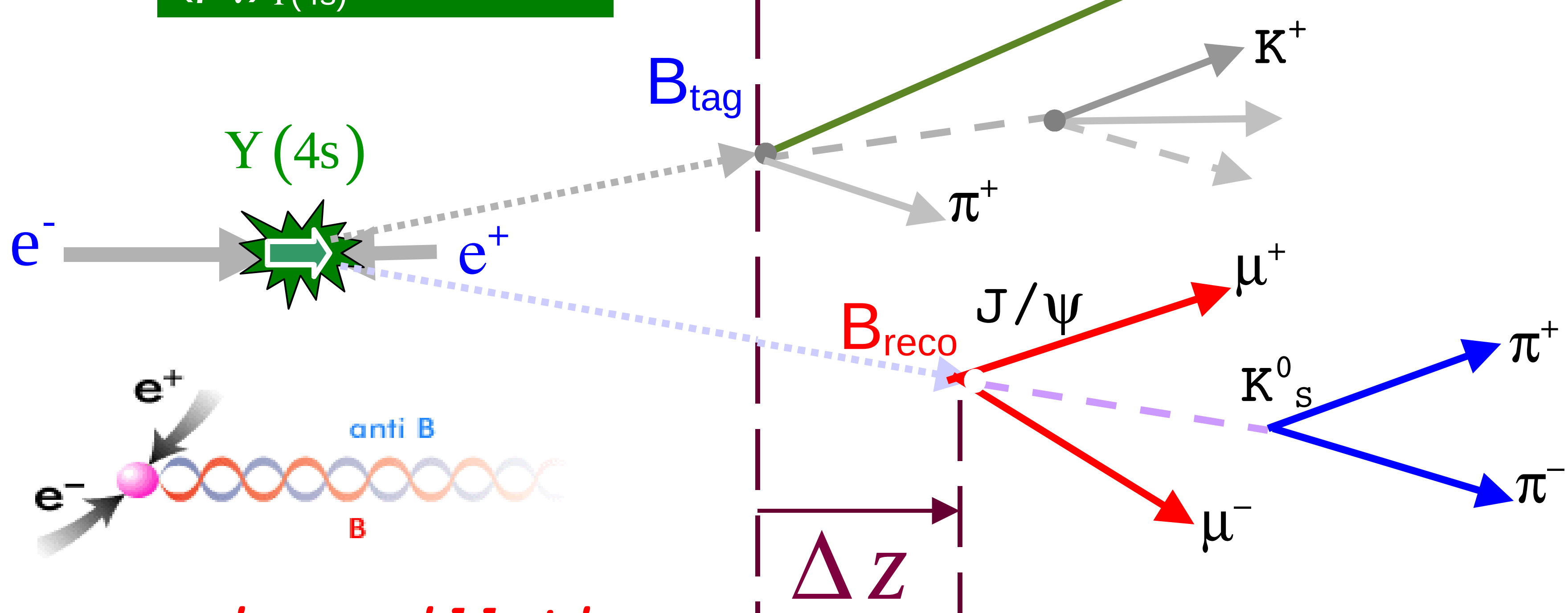
$$C = 0 \quad ; \quad S = \sin(2\beta)$$

Standard Model predictions



# Vertex Reconstruction

$(\beta\gamma)_{\Upsilon(4s)} = 0.56$



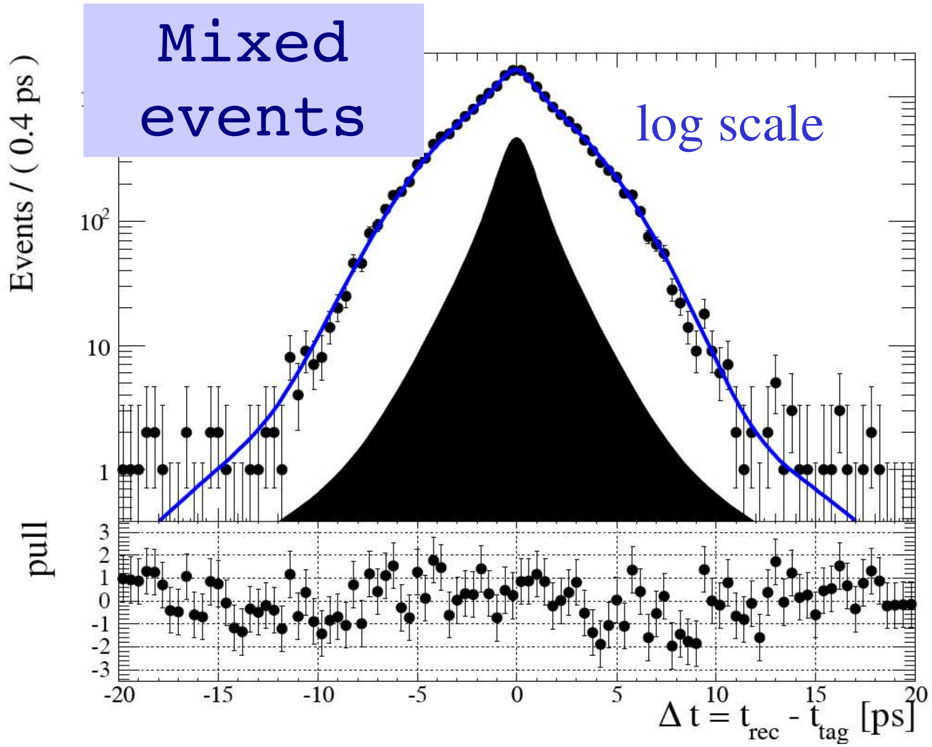

***B mesons pair oscillating in a coherent state***

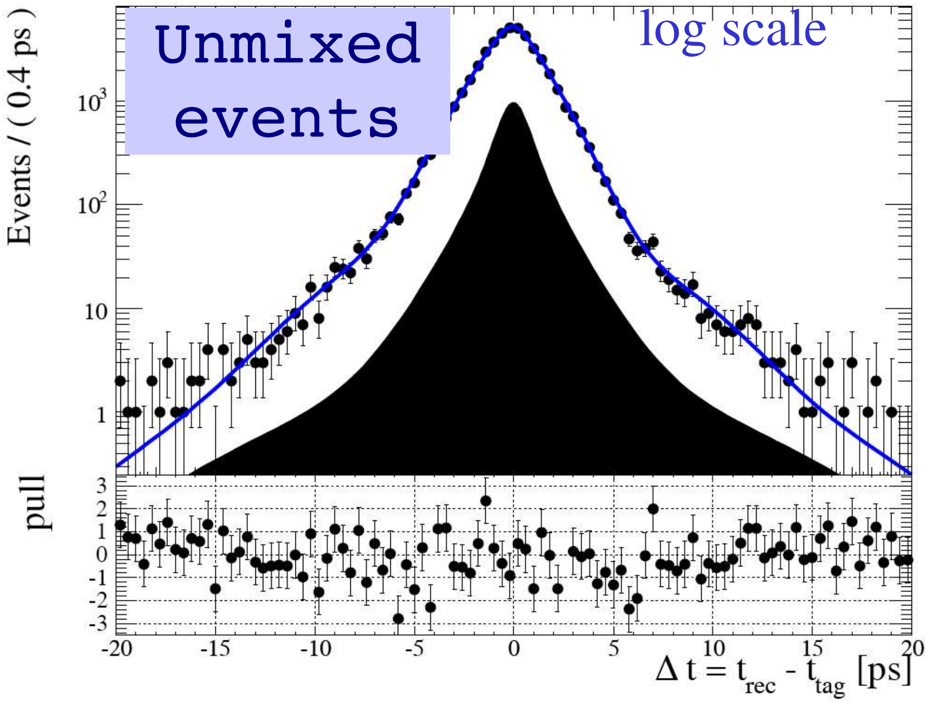
$$<|\Delta z|> \sim 200\,\mu m$$

$$\Delta t \approx \frac{\Delta z}{<\beta\gamma>c}$$

# $\Delta t$ p.d.f. (from data)

$\Delta t = t_{rec} - t_{tag}$

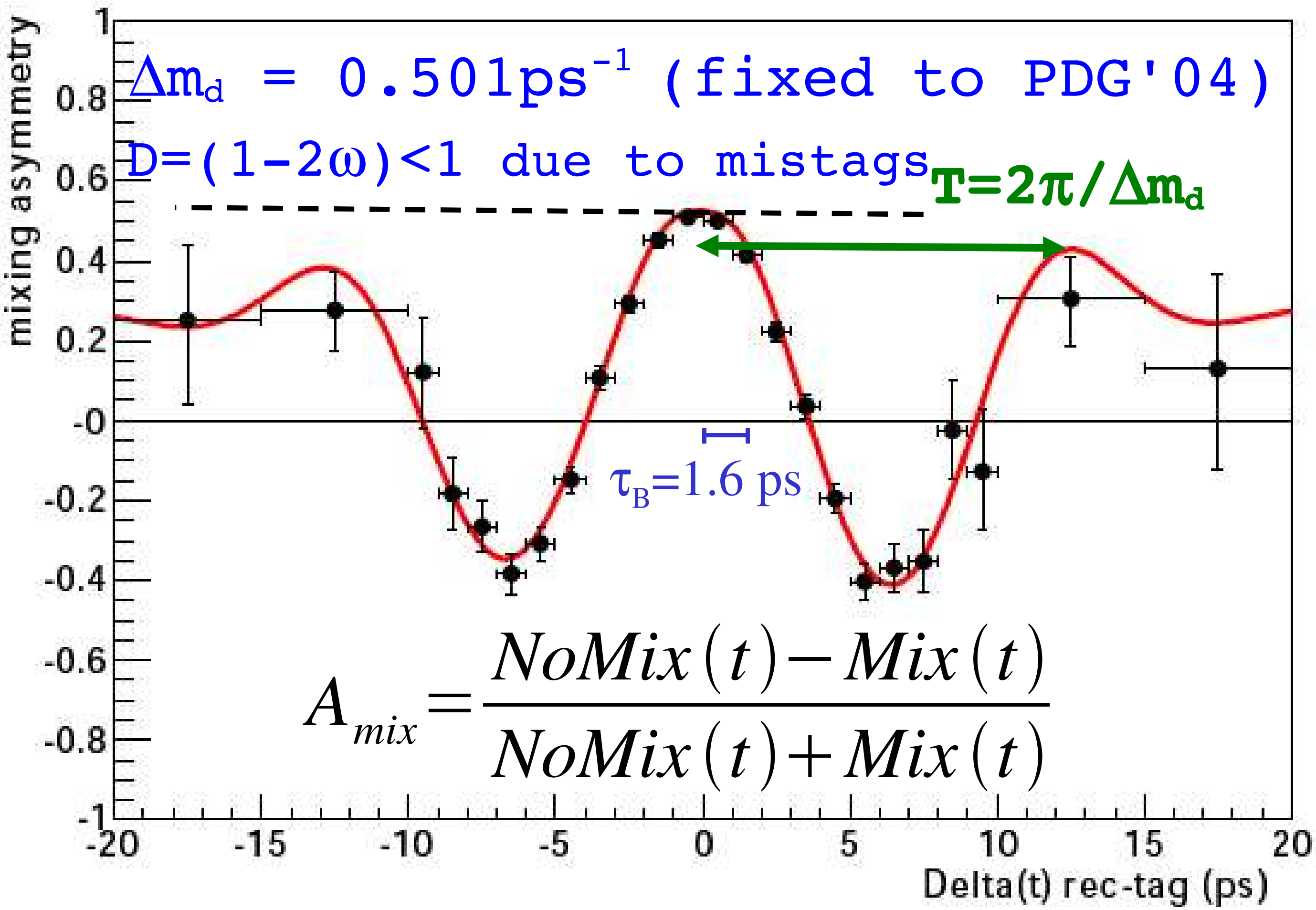



We can fit directly on data the parameterization of the Vertex resolution function, using a sample of fully reconstructed B events

# Mistag ($\omega$) measurement (from data)

$$f_{\substack{Unmixed\\Mixed}} = \left\{ \frac{e^{-|\Delta t|/\tau_B}}{4\tau_B} \left[1 \pm (1-2\omega)\cos(\Delta m_d \Delta t)\right] \right\} \otimes R(\Delta t)$$




Separately determine *D* for each tag category.

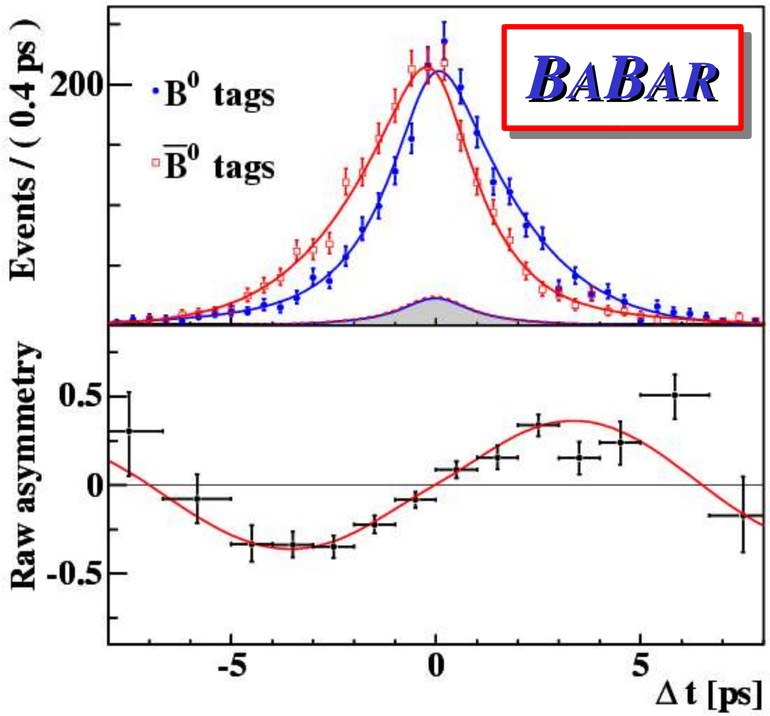
Overall tagging performance:

$\varepsilon = (74.9 \pm 0.2)\%$

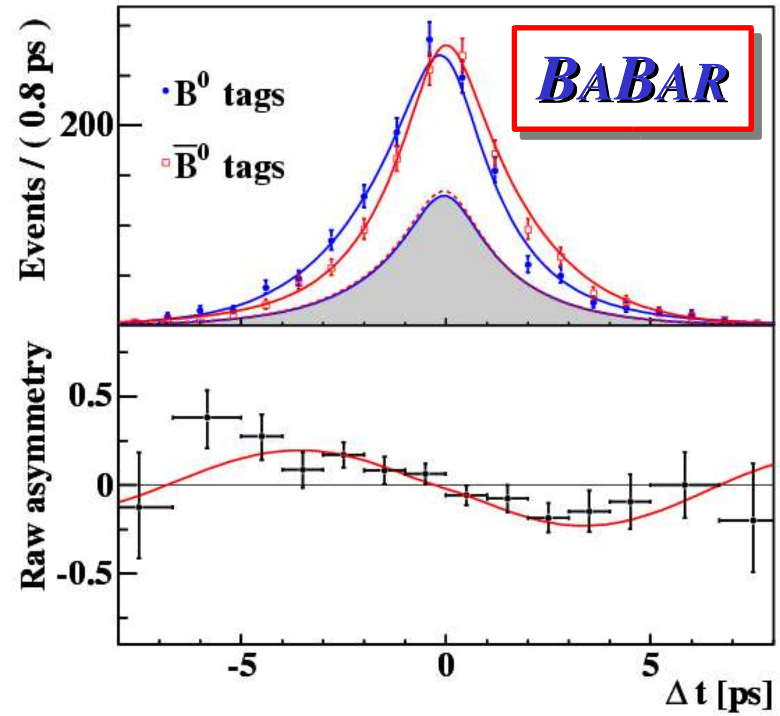
$Q = \varepsilon(1-2\omega)^2 = (30 \pm 0.4)\%$

# sin2β from charmonium modes

$(c\bar{c})K^0_S$ (CP odd) modes




$(c\bar{c})K^0_L$ (CP even) modes




**Update for ICHEP04**

$\sin 2\beta = 0.722 \pm 0.040 \pm 0.023$

$(c\bar{c})K^0_S + (c\bar{c})K^0_L$

Belle update for LP05

$S(J/\psi K^0) = 0.652 \pm 0.039 \pm 0.020$

386 M $B\bar{B}$ pairs

# Theory error on sin2β(I)

$$\mathcal{A}(B^0 \to J/\psi\, K^0) = \underbrace{-V_{cs} V_{cb}^* \times (E_2 - P_2)}_{\sim \lambda^2} + \underbrace{V_{us} V_{ub}^* \times (P_2^{GIM} - P_2)}_{\sim \lambda^4}$$

- $B^0 \to J/\psi K^0$ is considered the cleanest mode to measure sin2β
- Hadronic corrections coming from CKM suppressed terms are expected to be small
- Trying to fit them from data implies effects $\mathcal{O}(1)$ on S (no sensitivity from the BR)
- One can use $B^0 \to J/\psi \pi^0$ to obtain the bound on the hadronic parameters of $B^0 \to J/\psi K^0$

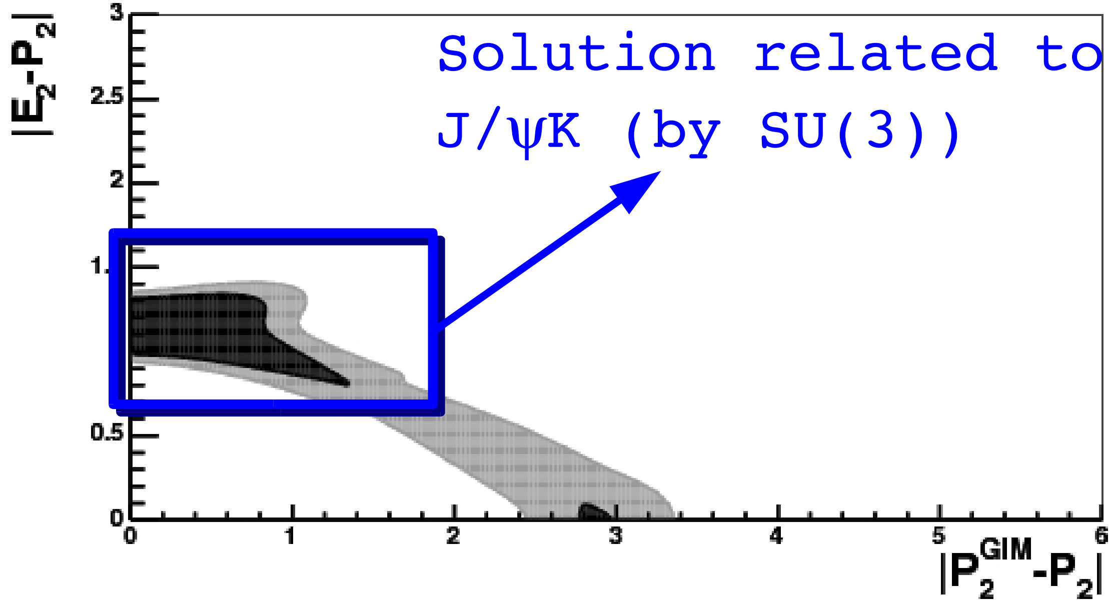
$$\mathcal{A}(B^0 \to J/\psi\, \pi^0) = \underbrace{-V_{cd} V_{cb}^* \times (E_2 - P_2)}_{\sim \lambda^3} + \underbrace{V_{ud} V_{ub}^* \times (P_2^{GIM} - P_2)}_{\sim \lambda^3}$$

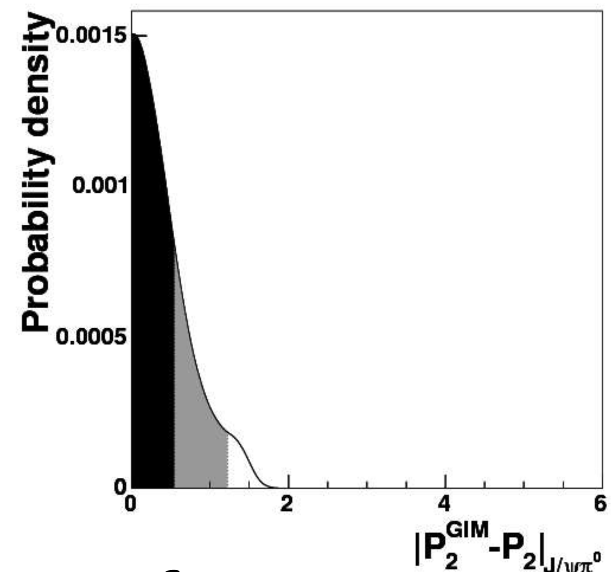
using the experimental informations (BR, S and C) as input

**Ciuchini, M.P. and Silvestrini hep-ph/0507290**

# Theory error on sin2β(II)

| | | | | | |
|---|---|---|---|---|---|
| $BR^{th} \times 10^5$ | $2.2 \pm 0.4$ | $BR^{exp} \times 10^5$ | $2.2 \pm 0.4$ | $\mathcal{C}_{CP}^{th}$ | $0.09 \pm 0.19$ |
| $\mathcal{C}_{CP}^{exp}$ | $0.12 \pm 0.24$ | $\mathcal{S}_{CP}^{th}$ | $-0.47 \pm 0.30$ | $\mathcal{S}_{CP}^{exp}$ | $-0.40 \pm 0.33$ |
| $\|E_2 - P_2\|$ | $\{1.22 \pm 0.15$ ; $0.15 \pm 0.15$ | $\|P_2^{GIM} - P_2\|$ | $\{0.43 \pm 0.43$ ; $2.87 \pm 0.43$ | $\delta_P$ | $\{(-24 \pm 41)^\circ$ ; $(-146 \pm 50)^\circ$ |



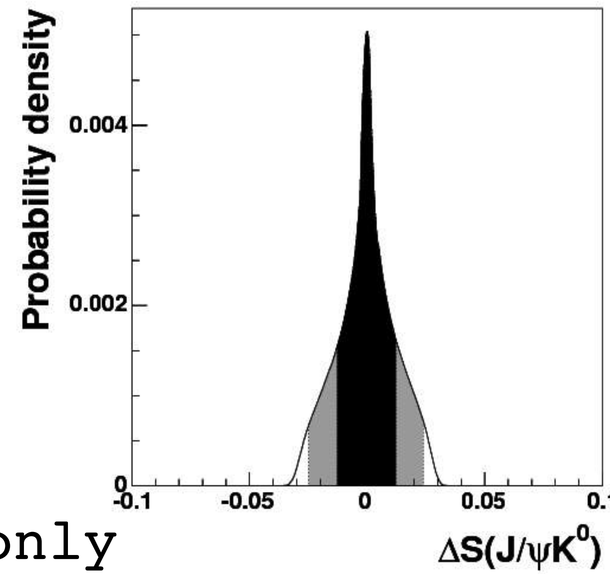




We can use SU(3) to **determine the range** of CKM suppressed contributions in J/ψ K. It is **weaker than** fixing the value of the parameter with **SU(3)**

# Theory error on sin2β(III)

One can then obtain model independent determination on the theoretical error on sin2β

**ΔS= 0.000 ± 0.012**




| | | | | | |
|---|---|---|---|---|---|
| $\mathrm{BR}^{\mathrm{th}} \times 10^5$ | $8.5 \pm 0.5$ | $\mathrm{BR}^{\mathrm{exp}} \times 10^5$ | $8.5 \pm 0.5$ | $\mathcal{C}_{\mathrm{CP}}^{\mathrm{th}}$ | $0.00 \pm 0.02$ |
| $\mathcal{C}_{\mathrm{CP}}^{\mathrm{exp}}$ | $-0.01 \pm 0.04$ | $\mathcal{S}_{\mathrm{CP}}^{\mathrm{out}}$ | $0.73 \pm 0.05$ | $\mathcal{S}_{\mathrm{CP}}^{\mathrm{in}}$ | $0.73 \pm 0.04$ |
| $\lvert E_2 - P_2 \rvert$ | $1.44 \pm 0.05$ | | | | |

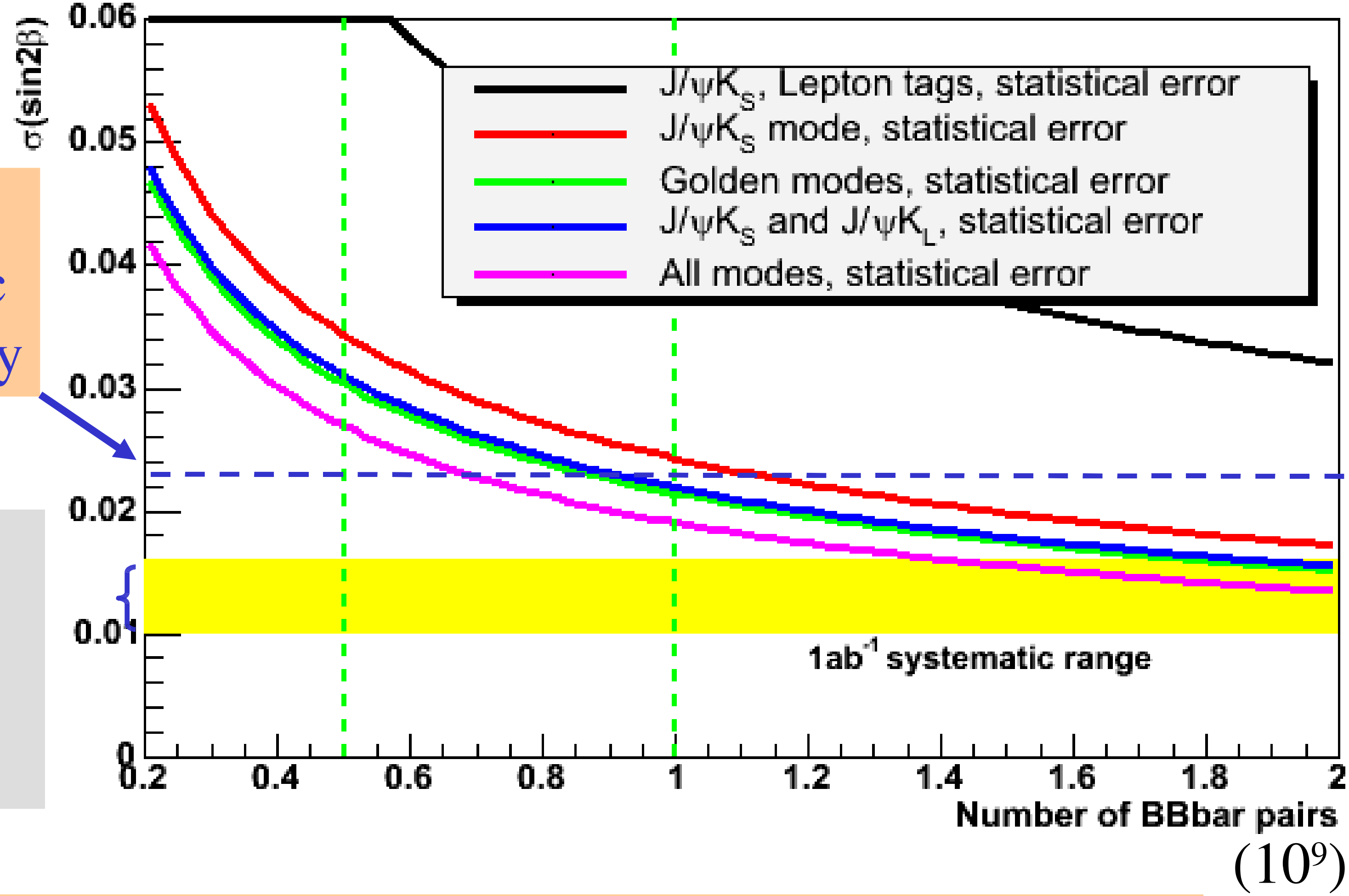
**The Lesson:**

- CKM suppressed contributions are relevant for CP asymmetries
- They are not crucial for a fit to BR only
- They cannot be bound without additional assumptions
- Flavor symmetries can be used to guess the order of magnitude (going further requires to control symmetry breaking effects)

**It is unrealistic for the other channels to be known better than the golden mode**

# sin2β error vs. luminosity

Current systematic uncertainty




Range of estimated systematic error: 1 $ab^{-1}$

At 1 $ab^{-1}$, we can improve sin2β by nearly a factor of 2.

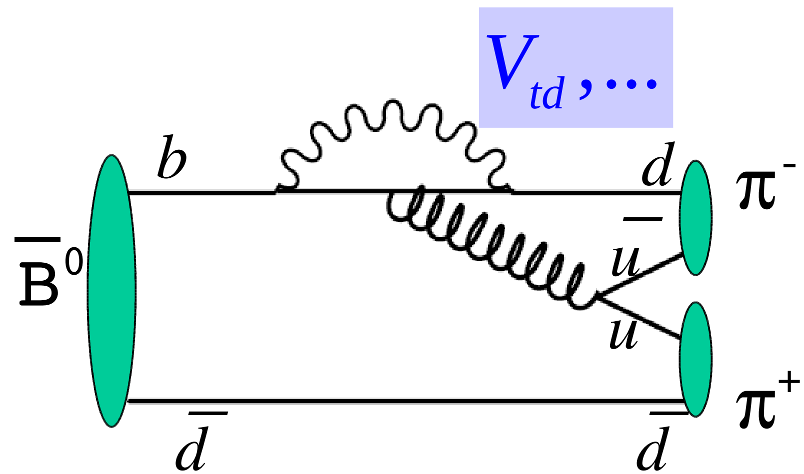
# α: A work in progress

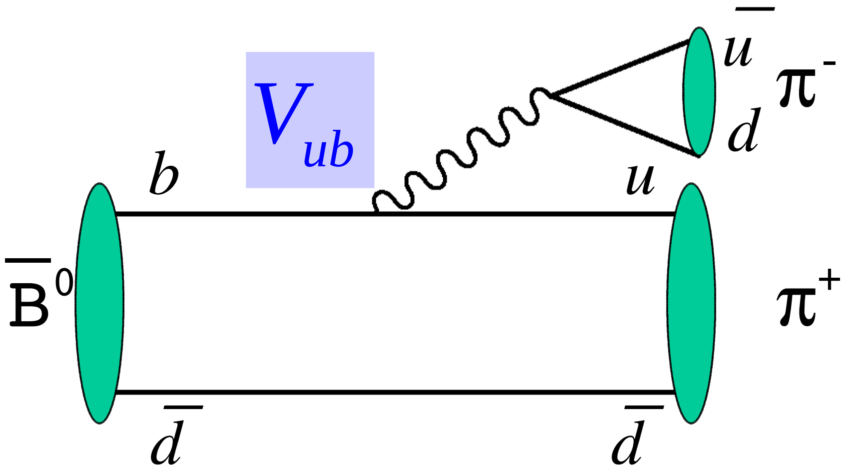
Original idea: if $B^0 \rightarrow \pi^+\pi^-$ amplitude is dominated by the $b \rightarrow u$ tree process, it is just like measuring sin2β

$$\lambda_{\pi^+\pi^-} = \frac{q}{p} \cdot \frac{\bar{A}_{\pi^+\pi^-}}{A_{\pi^+\pi^-}} = \eta_{CP}^{\pi^+\pi^-} e^{-2i\beta} e^{-2i\gamma} = e^{2i\alpha}$$

$$S_{\pi^+\pi^-} = \frac{2\Im(\lambda_{\pi^+\pi^-})}{1+|\lambda_{\pi^+\pi^-}|^2} = \sin 2\alpha \qquad C_{\pi^+\pi^-} = \frac{1-|\lambda_{\pi^+\pi^-}|^2}{1+|\lambda_{\pi^+\pi^-}|^2} = 0$$

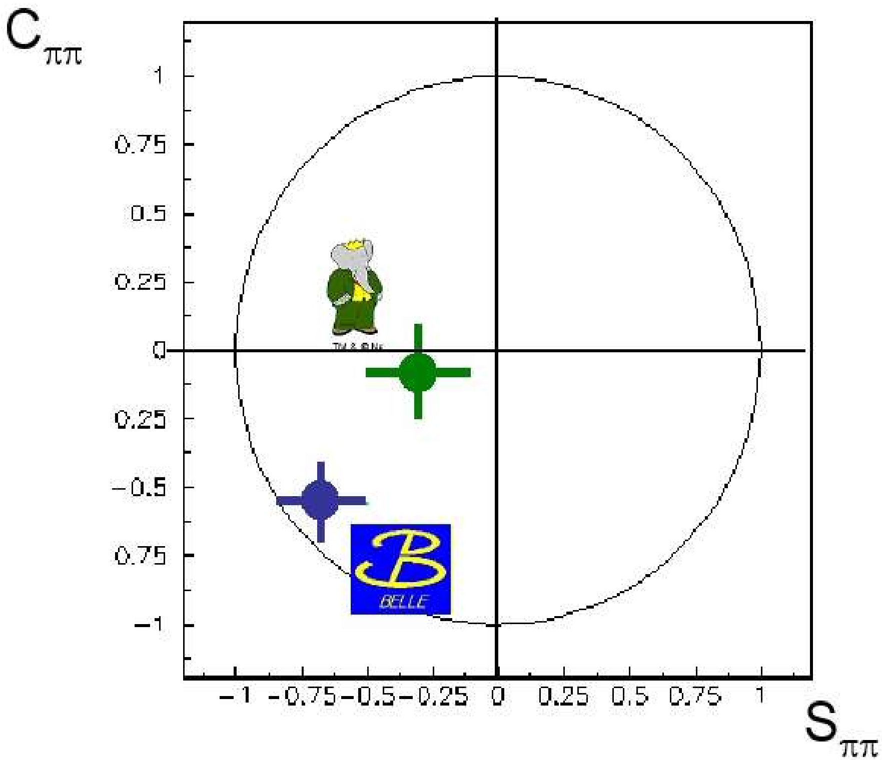
If penguins were negligible, we could extract α directly from the time-dependent CP asymmetry for $B^0 \rightarrow \pi^+\pi^-$. But penguins are there

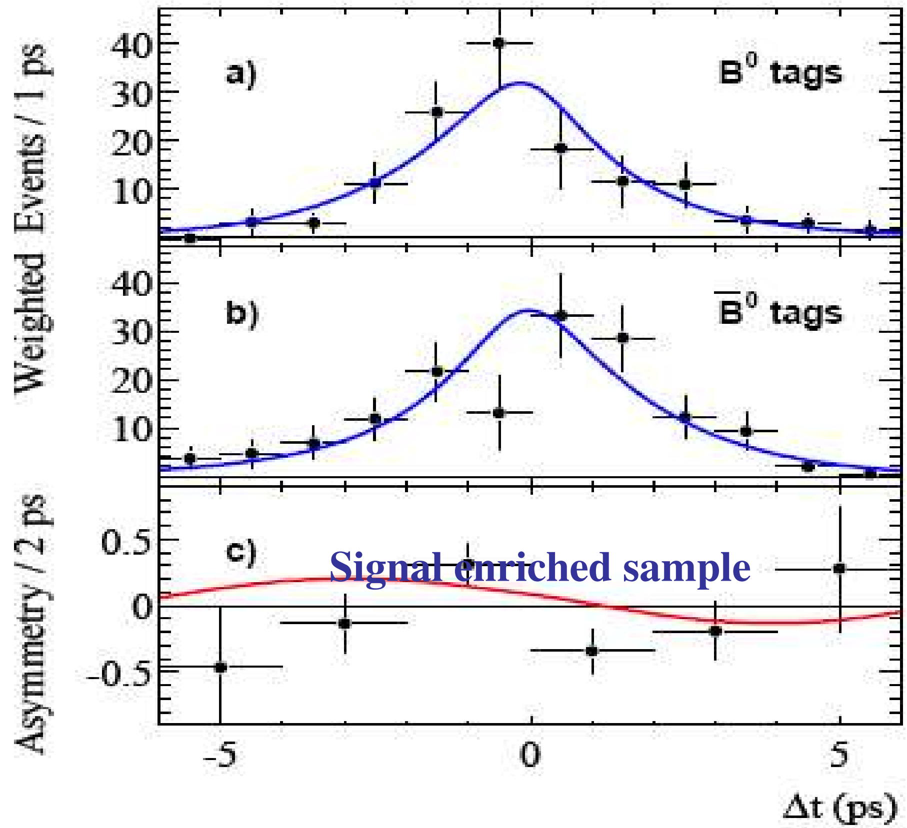


# Time dependent $A_{CP}$(II)

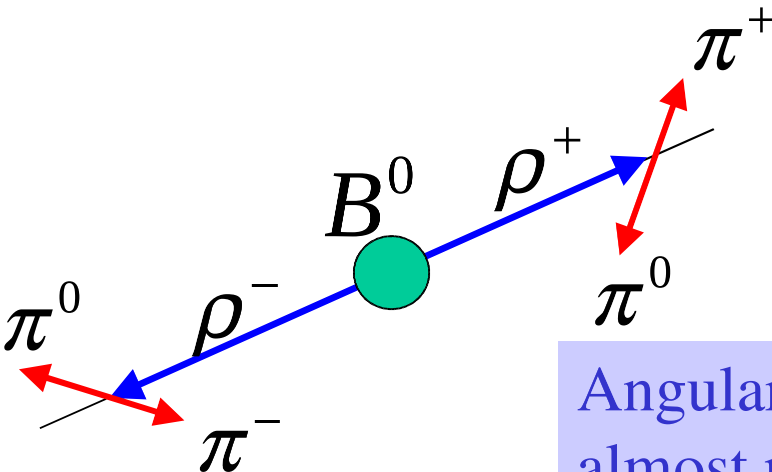
| | *BABAR* | BELLE |
|---|---|---|
| $S_{\pi\pi}$ | $-0.30\pm0.17\pm0.03$ | $-0.67\pm0.16\pm0.06$ |
| $C_{\pi\pi}$ | $-0.09\pm0.15\pm0.04$ | $-0.56\pm0.12\pm0.06$ |



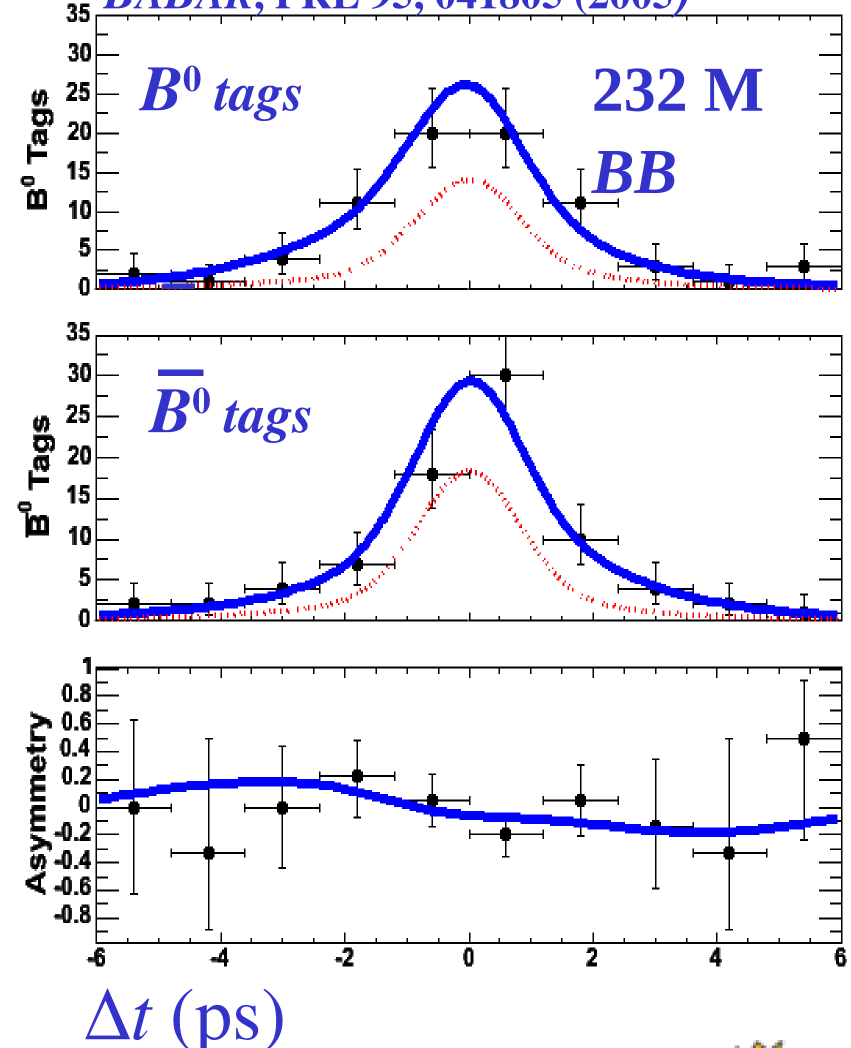
# Time dependent $A_{CP}$(II)

3 polarizations→mixed CP state
We are lucky (there is just one).
No additional dilution, even if it's a VV decay




Angular analysis → almost pure CP=+1 !

*BABAR*, PRL 95, 041805 (2005)



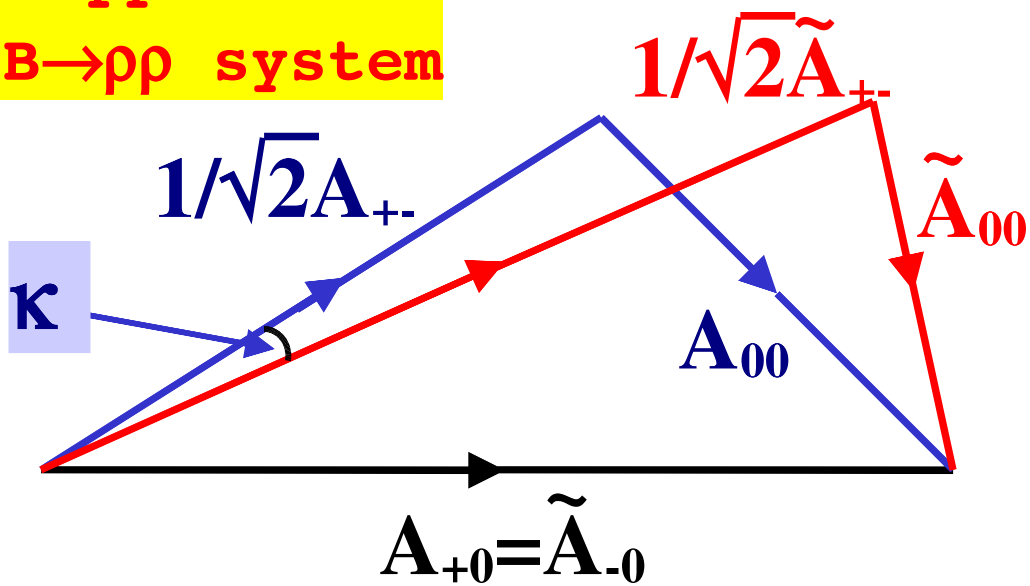

| | *BABAR* | BELLE (LP2005) |
|---|---|---|
| $f_L$ | $0.978\pm0.014^{+0.021}_{-0.029}$ | $0.951^{+0.033+0.029}_{-0.039-0.031}$ |
| $S_{\rho\rho}$ | $-0.33\pm0.24^{+0.08}_{-0.14}$ | $0.09\pm0.42\pm0.08$ |
| $C_{\rho\rho}$ | $-0.03\pm0.18\pm0.09$ | $0.00\pm0.30^{+0.09}_{-0.10}$ |

Would like to see *S*, *C* with 5x data!

# Isospin Analysis(I)

$B^+ \to \pi^+\pi^0$ is pure tree (no gluonic penguin)→triangles have common side after rescaling one set by $e^{2i\gamma}$:

**The same approach also for B→ρρ system**




- If penguin amp=0, triangles coincide.
- 4-fold discrete ambiguity (can flip both triangles)
- take worst case as "penguin error"

Grossman & Quinn, PRD 58, 017504 (1998)

$$\sin^2\kappa < \frac{BR(B^0\to\pi^0\pi^0)+BR(\bar{B}\to\pi^0\pi^0)}{BR(B^+\to\pi^+\pi^0)+BR(B^-\to\pi^-\pi^0)}$$

# Isospin Analysis(II)

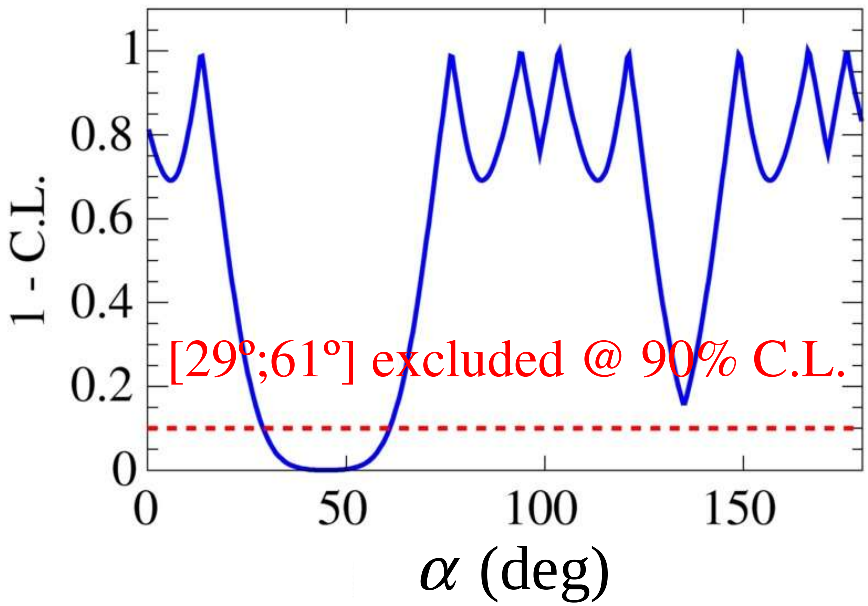
| Mode | B/10$^{-6}$ (*BABAR*) | B/10$^{-6}$ (Belle) |
|---|---|---|
| $B^0 \to \pi^0\pi^0$ | $1.17 \pm 0.32 \pm 0.10$ | $2.3^{+0.4+0.2}_{-0.5+0.3}$ |
| $B^+ \to \pi^+\pi^0$ | $5.8 \pm 0.6 \pm 0.4$ | $5.0 \pm 1.2 \pm 0.5$ |
| $B^0 \to \pi^+\pi^-$ | $5.5 \pm 0.4 \pm 0.3$ | $4.4 \pm 0.6 \pm 0.3$ |
| $C_{\pi^0\pi^0}$ | $-0.12 \pm 0.56 \pm 0.06$ | |

| Mode | B/10$^{-6}$ (*BABAR*) | | B/10$^{-6}$ (Belle) | |
|---|---|---|---|---|
| $B^0 \to \rho^0\rho^0$ | <1.1(@90%C.L.) | [230 M $B\bar{B}$] | – | |
| $B^+ \to \rho^+\rho^0$ | $23^{+5}_{-6} \pm 6$ | [89 M $B\bar{B}$] | $32 \pm 7^{+4}_{-7}$ | [85 M $B\bar{B}$] |
| $B^0 \to \rho^+\rho^-$ | $30 \pm 4 \pm 5$ | [89 M $B\bar{B}$] | $24.4 \pm 2.2^{+3.8}_{-4.1}$ | [275 M $B\bar{B}$] |

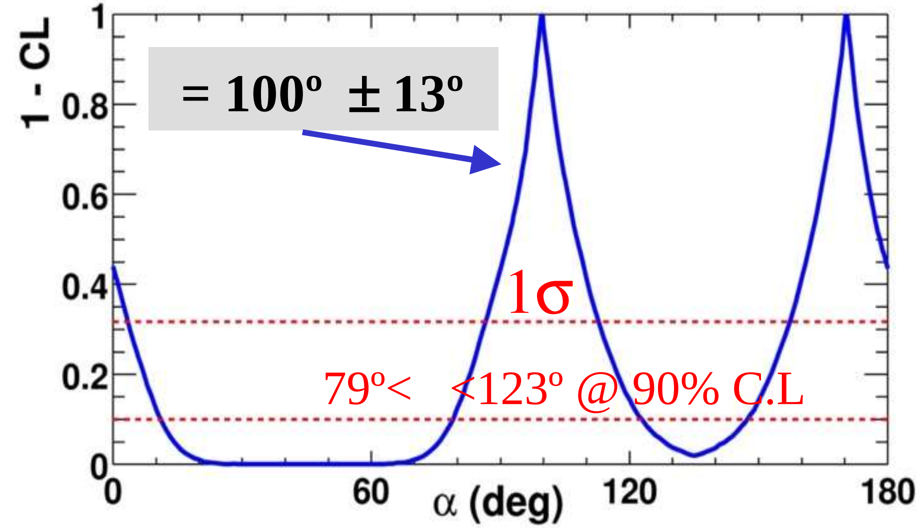
$\pi^0\pi^0$ amp. isn't small compared to the others, while $\rho^0\rho^0$ is small. This means that $\rho\rho$ is better $|\Delta\alpha_{\pi\pi}|<35°$(90%CL) vs $|\Delta\alpha_{\rho\rho}|<14°$(90%CL)

# Isospin Analysis(III)

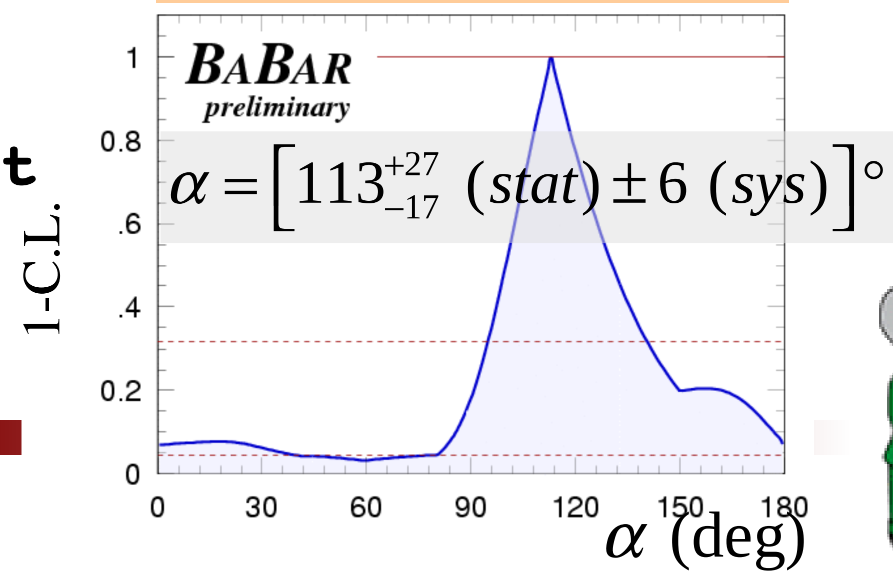
$B \to \pi\pi$ PRL, 94, 181802 (2005)



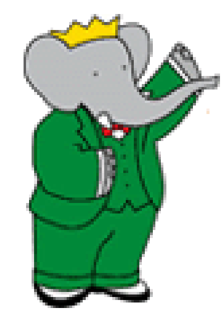

$B \to \rho\rho$ PRL 95, 041805 (2005)




$B \to \pi^+\pi^-\pi^0$ Dalitz hep-ex/0408089




**Complementary information from $B \to \pi^+\pi^-\pi^0$ time dependent Dalitz analysis**



# $\alpha$ from $B \to \pi^+\pi^-\pi^0$

Not a CP eigenstates $\Rightarrow$ pentagonal relations

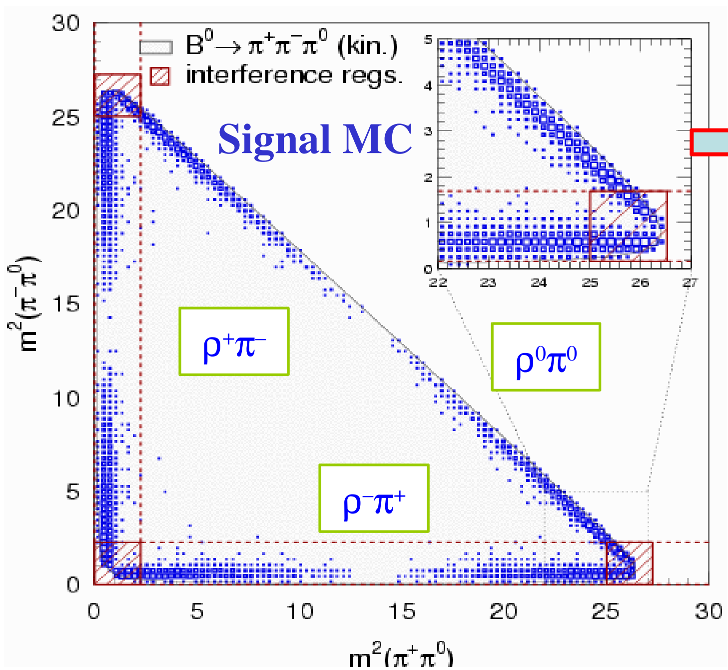
A. Snyder and H. Quinn, PRD, 48, 2139 (1993)

EWP neglected: 12 unknowns for 13 observables $\Rightarrow$ in principle possible

Unfruitful with the present statistics: current data does not constraint $\alpha$

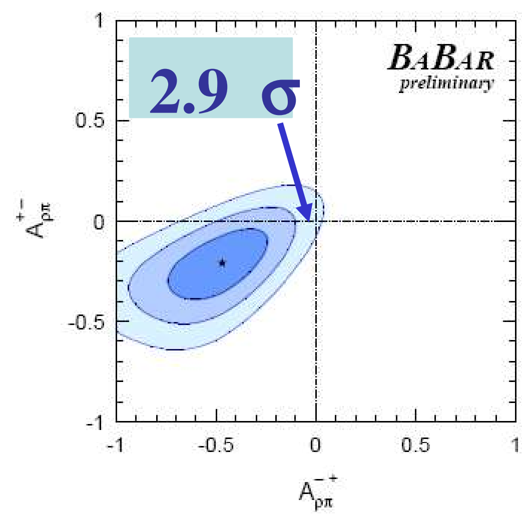
Time dependent Dalitz analysis assuming Isospin symmetry

*use relativistic Breit-Wigner form factors*

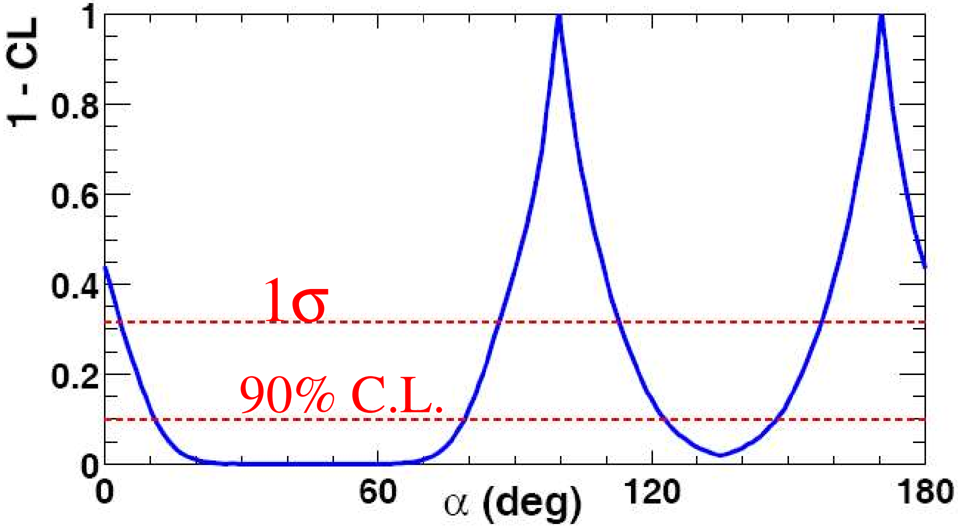



Interference between the ρ resonances at equal masses-squared gives information on **strong phases** between resonances $\Rightarrow$ **$\alpha$ can be constrained without ambiguity**

Direct CP asymmetries:

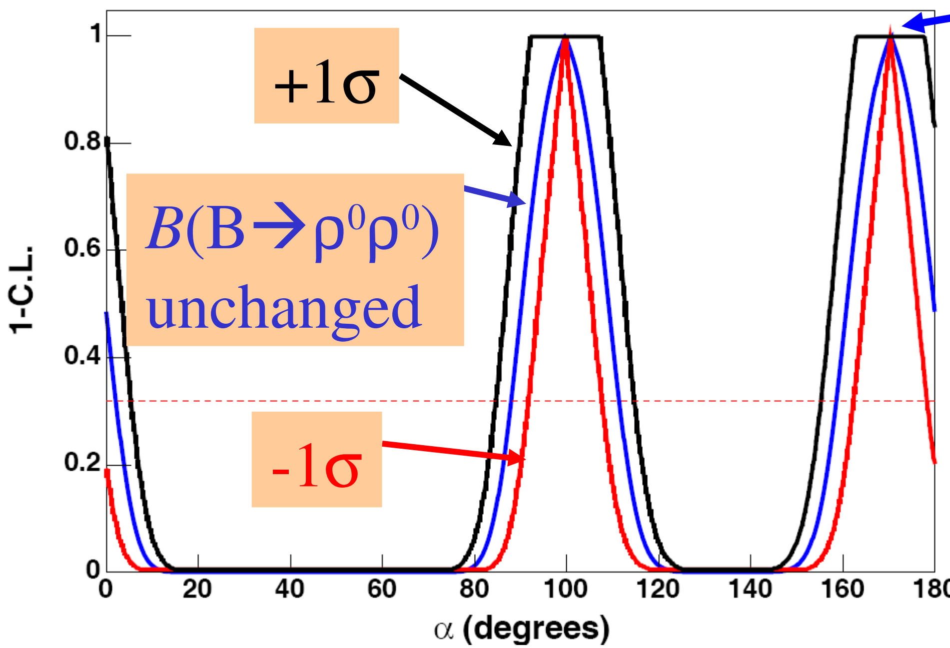


# Projections for α from $B \to \rho^+\rho^-$




Current α measurement from $B \to \rho\rho$

Multiple unresolved solutions within each peak.



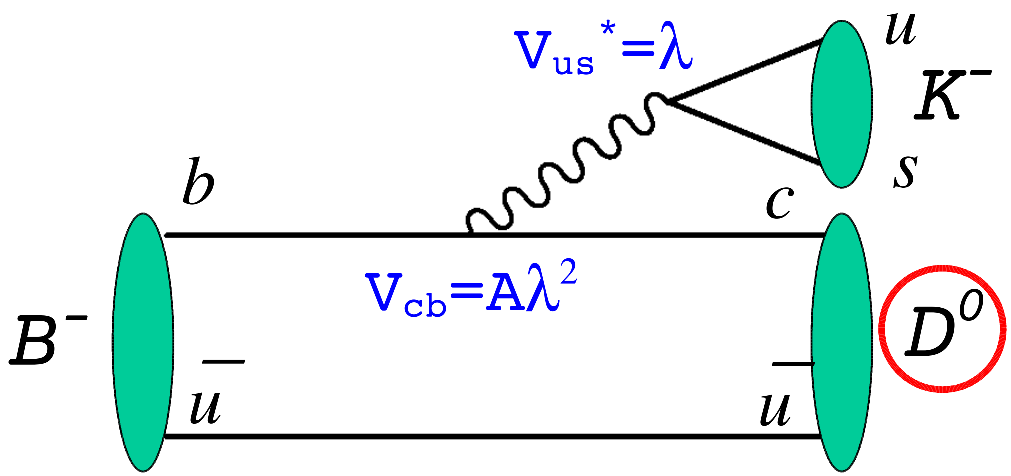

Projected α measurements from $B \to \rho\rho$ for 1 $ab^{-1}$

The uncertainty on α depends critically on $\mathcal{B}(B \to \rho^0\rho^0)$. Scenarios:

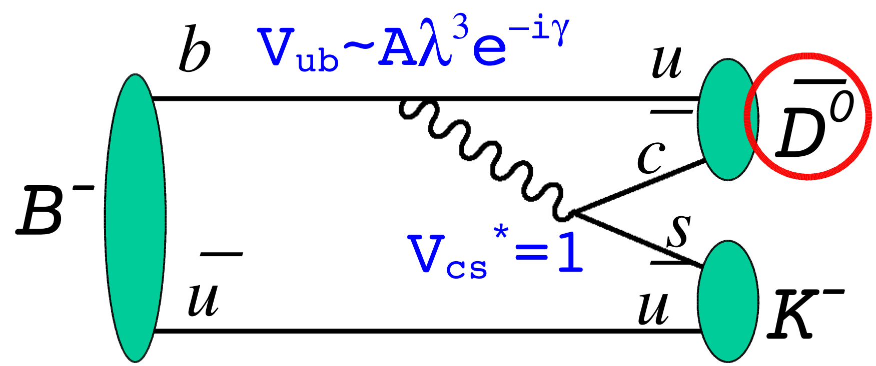
- use current central val
- +1σ ———
- - 1σ ———

# $\gamma$ from $B^+ \to \overset{(-)}{D}{}^{(*)} K^{(*)+}$

$A(B^- \to D^0 K^-) = A_B$



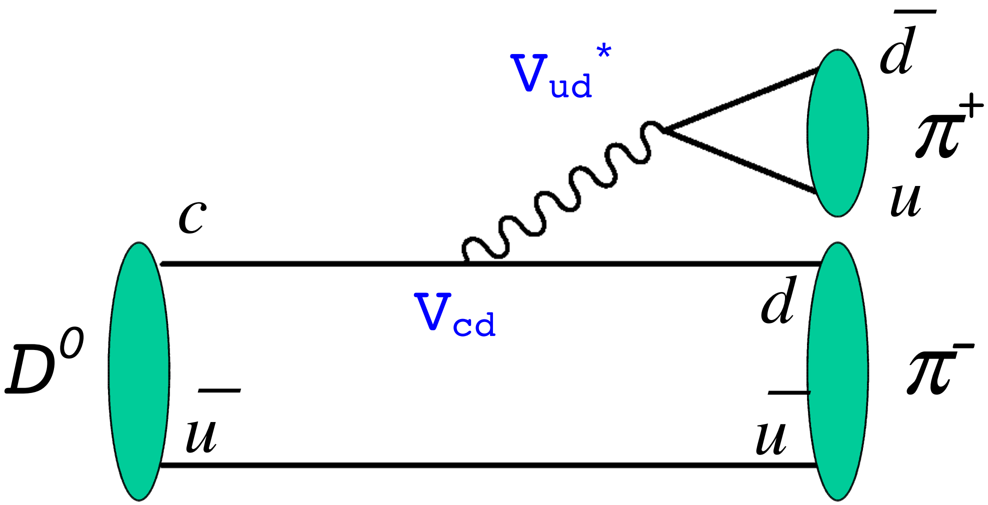

$A(B^- \to \bar{D}^0 K^-) = A_B r_B e^{i(\delta_B - \gamma)}$

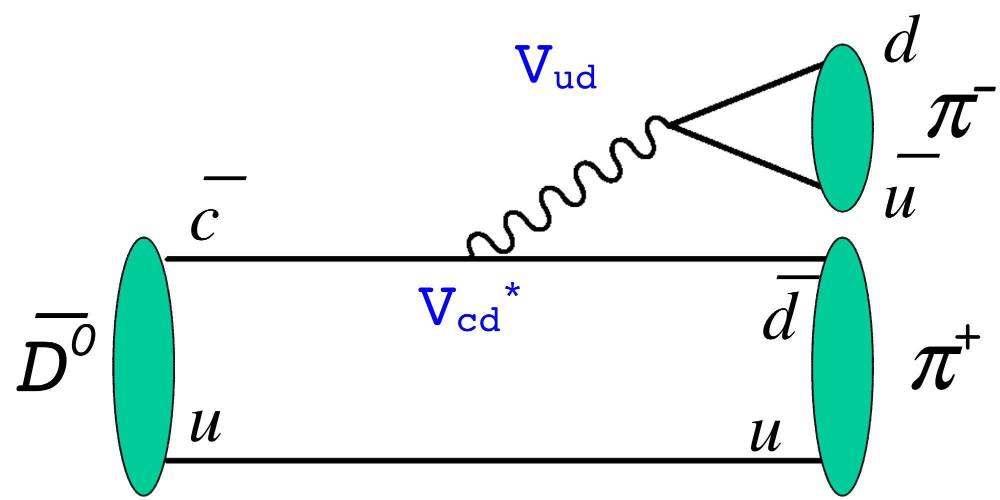



- We can exploit the interference between these two amplitudes in several ways
- Anyhow, the interference is ruled by the parameter $r_B$, which is
  - 0.2 (~CKM factors) if the two diagrams are of the same order of magnitude
  - even smaller, if color suppression works at a certain level

# $\gamma$ (GLW method): $B^- \to D_{CP} K^-, D_{CP} \to f_{CP}$

$D^0$ ($\overline{D}^0$) → $f_{CP}$ = CP eigenstate from singly-Cabibbo-suppressed decay.
[Gronau & London, PLB 253, 483 (1991), Gronau & Wyler, PLB 265, 172 (1991)].




$CP = +1 \quad \pi^+\pi^-, K^+K^-$

$CP = -1 \quad K^0_S\pi^0, K^0_S\phi, K^0_S\omega, K^0_S\eta, K^0_S\eta'$

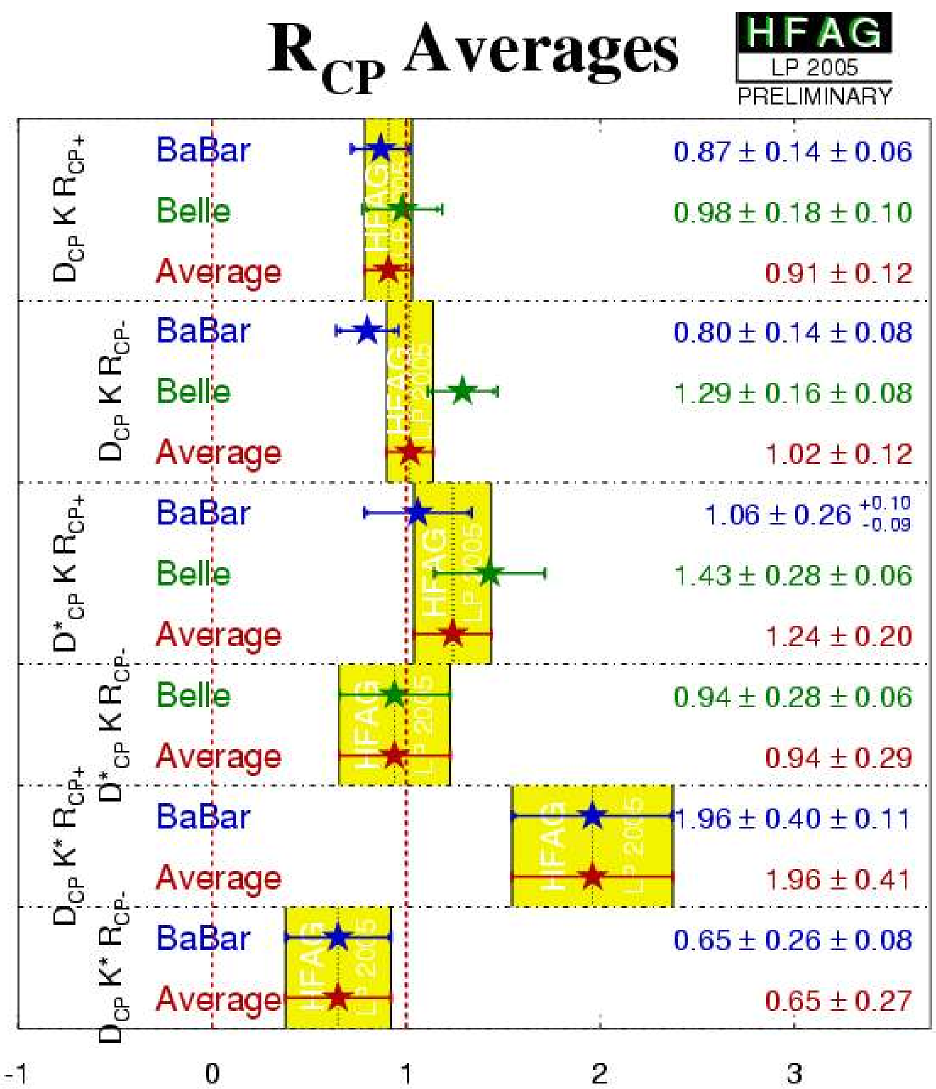
Large rate, but <u>interference is small</u>: $r_B << 1$

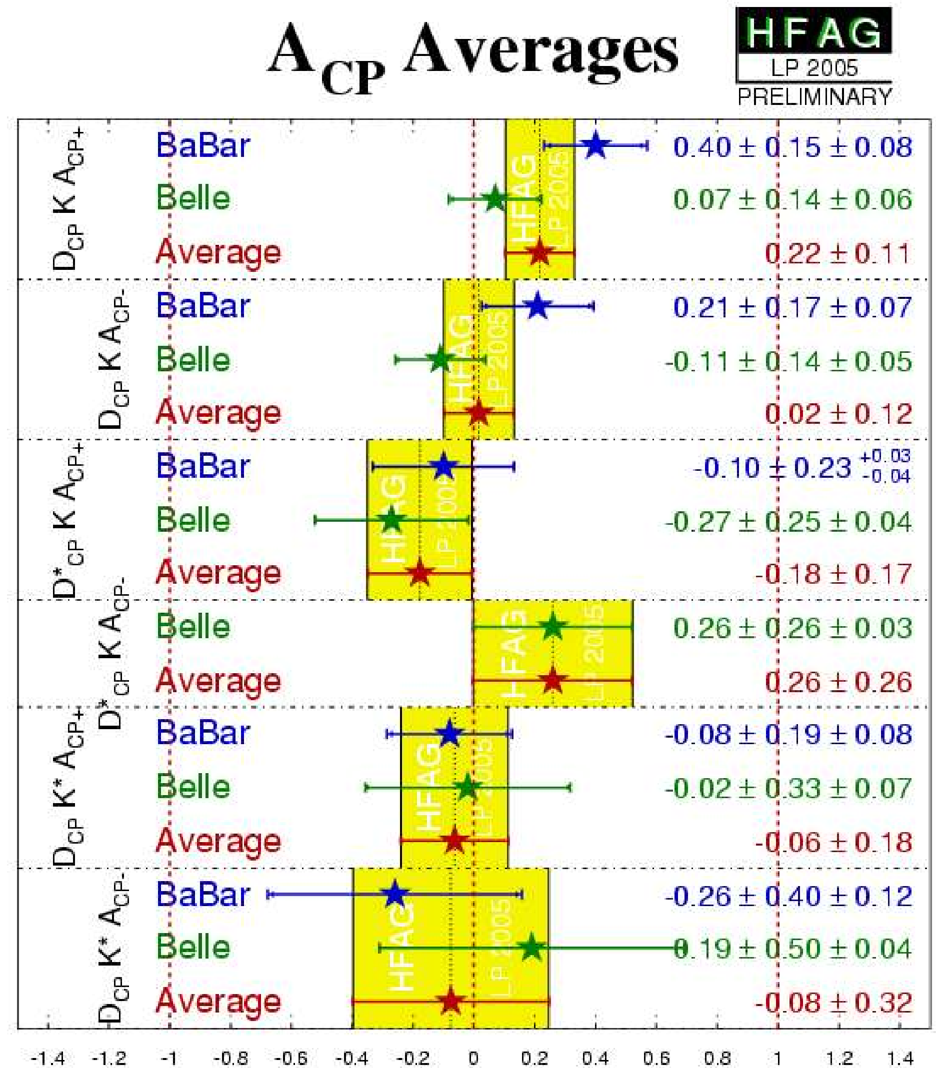
$$\mathrm{Amp}(B\pm, CP_{D^0}=\eta_D) \propto A_B[1+\eta_D r_B e^{i(\delta_B \pm \gamma)}]]$$

# $\gamma$ (GLW method): $B^- \to D_{CP} K^-, D_{CP} \to f_{CP}$

$$A_{CP\pm} = \frac{\Gamma(B^+ \to D^0_{CP\pm}K^+) - \Gamma(B^- \to D^0_{CP\pm}K^-)}{\Gamma(B^+ \to D^0_{CP\pm}K^+) + \Gamma(B^- \to D^0_{CP\pm}K^-)} = \frac{\pm 2r \sin\gamma \sin\delta}{1 + r^2 \pm 2r\cos\gamma\cos\delta}$$

$$R_{CP\pm} = \frac{\Gamma(B^+ \to D^0_{CP\pm}K^+) + \Gamma(B^- \to D^0_{CP\pm}K^-)}{\Gamma(B^+ \to \overline{D}^0 K^+) + \Gamma(B^- \to D^0 K^-)} = 1 + r^2 \pm 2r\cos\gamma\cos\delta$$

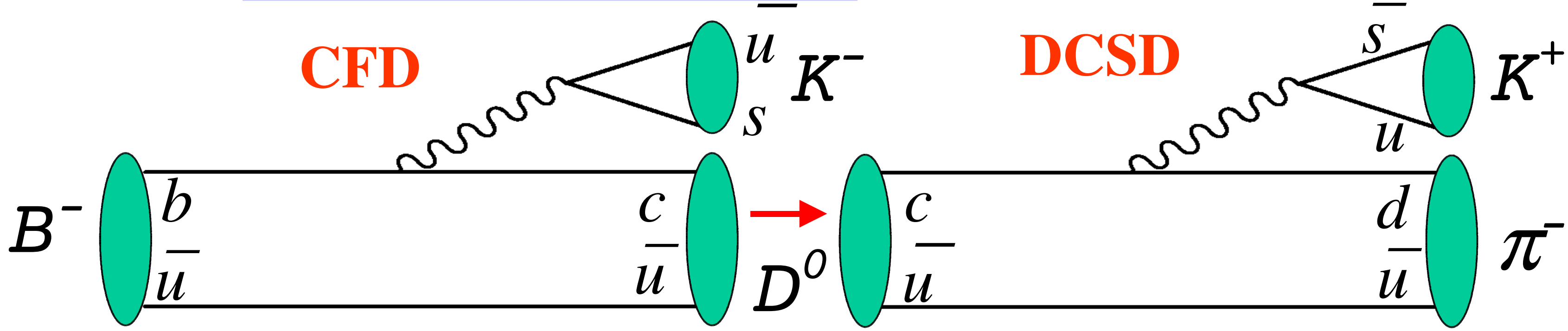


# $\gamma$ (ADS method): $B^- \to K^+[D^0 \to K^+\pi^-; D^0 \to K^+\pi^-]$

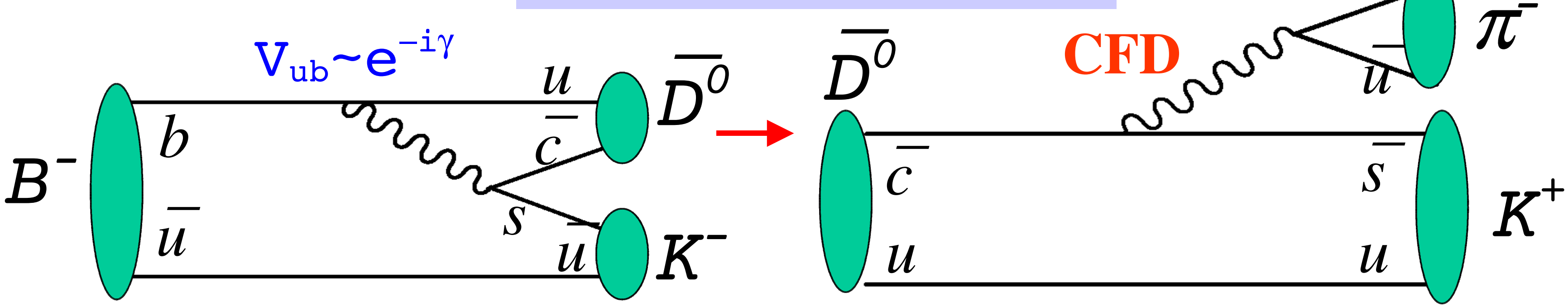
$B^- \to D^0 K^-; D^0 \to K^+\pi^-$

Atwood, Dunietz, & Soni, PRL 78, 3257 (1997), PRD 63, 036005 (2001)




DCSD

$B^- \to \bar{D}^0 K^-; \bar{D}^0 \to K^+\pi^-$



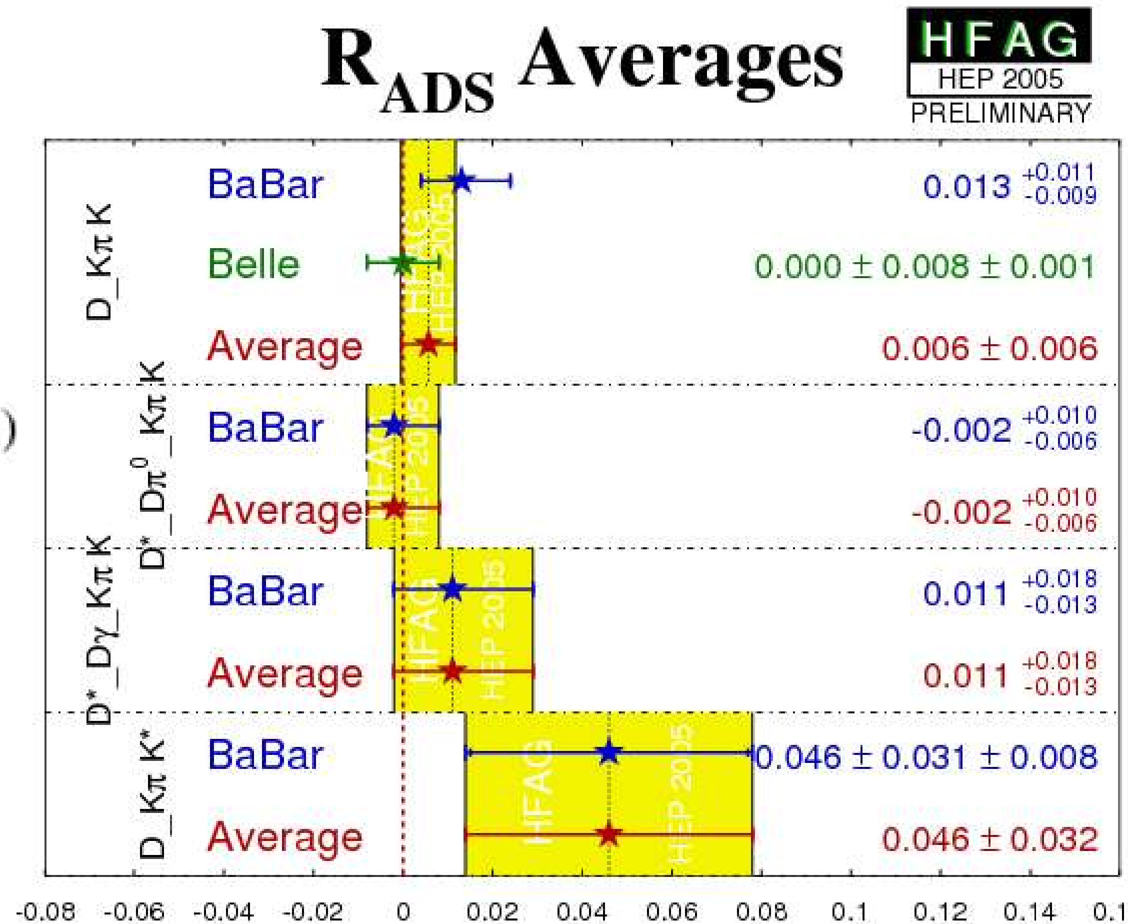

$$A(B^\pm, D^0 \to K^\pm\pi^\mp) = A_B A_D [r_D e^{i\delta_D} + r_B e^{i(\delta_B \pm \gamma)}]$$

Interference is large: $r_B$, $r_D$ comparable, but overall rate is small!

# $\gamma$ (ADS method): $B^- \to K^+[D^0 \to K^+\pi^-; D^0 \to K^+\pi^-]$

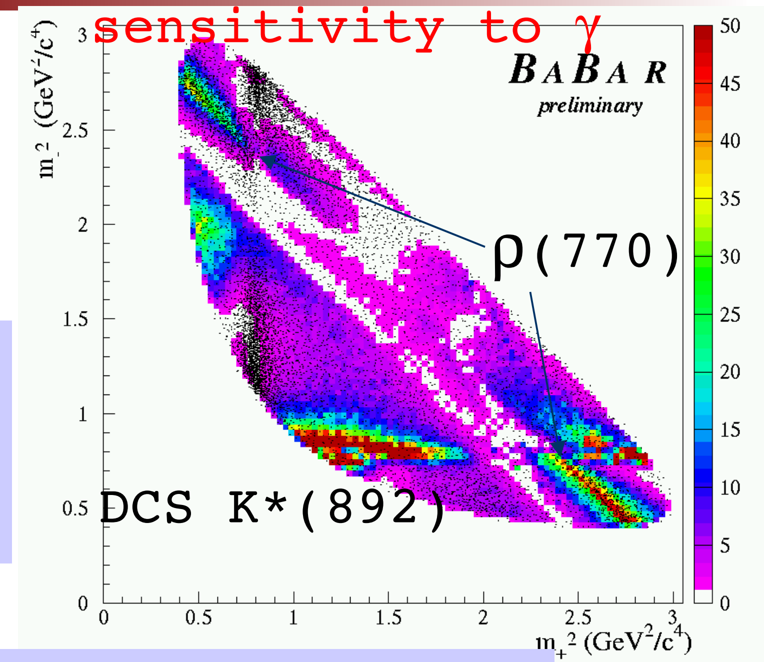
$$R_{ADS} = r_B^2 + r_{DCS}^2 + 2 r_B\, r_{DCS} \cos\gamma \cos(\delta_B + \delta_D)$$

$$r_{DCS} \equiv \sqrt{\frac{BR(D^0 \to K^+\pi^-)}{BR(D^0 \to K^-\pi^+)}}$$




**Most measurements using interference with DCSD $D^0$ decay indicate $r_B$<0.2.**

# $\gamma$(Dalitz plot): $B^- \to [\overset{(-)}{D}{}^0 \to K_s \pi^+ \pi^-] K^-$




Atwood, Dunietz, & Soni, PRL 78, 3257 (1997),
PRD 63, 036005 (2001)
Giri, Grossman, Soffer, & Zupan, PRD 68, 054018 (2003),
Bondar (Belle), PRD 70, 072003 (2004)

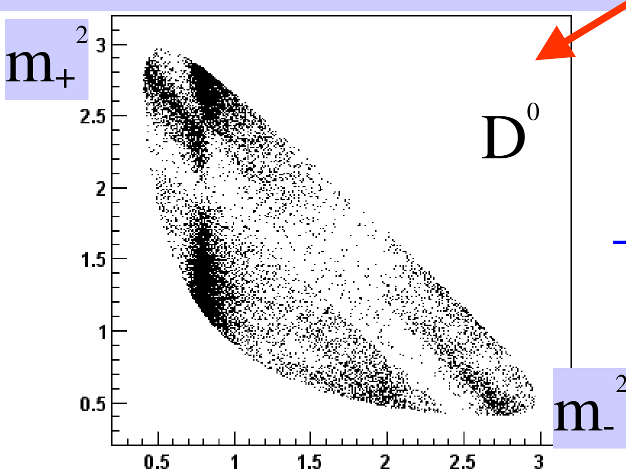
Relatively large BFs
only 2-fold ambiguity
Interference depends
on Dalitz region

$m_+^2 = m^2(K^0_s \pi^\pm)^2$

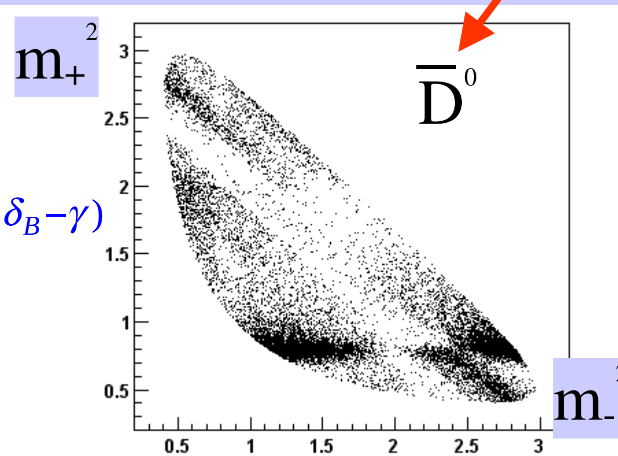
$$M_-(m_-^2, m_+^2) = |A(B^- \to D^0 K^-)| [f(m_-^2, m_+^2) + r_{Be}^{i\delta_B} e^{-i\gamma} f(m_+^2, m_-^2)]$$

$$M_+(m_-^2, m_+^2) = |A(B^+ \to \bar{D}^0 K^+)| [f(m_+^2, m_-^2) + r_{Be}^{i\delta_B} e^{i\gamma} f(m_-^2, m_+^2)]$$

$|M_-|^2 =$ |

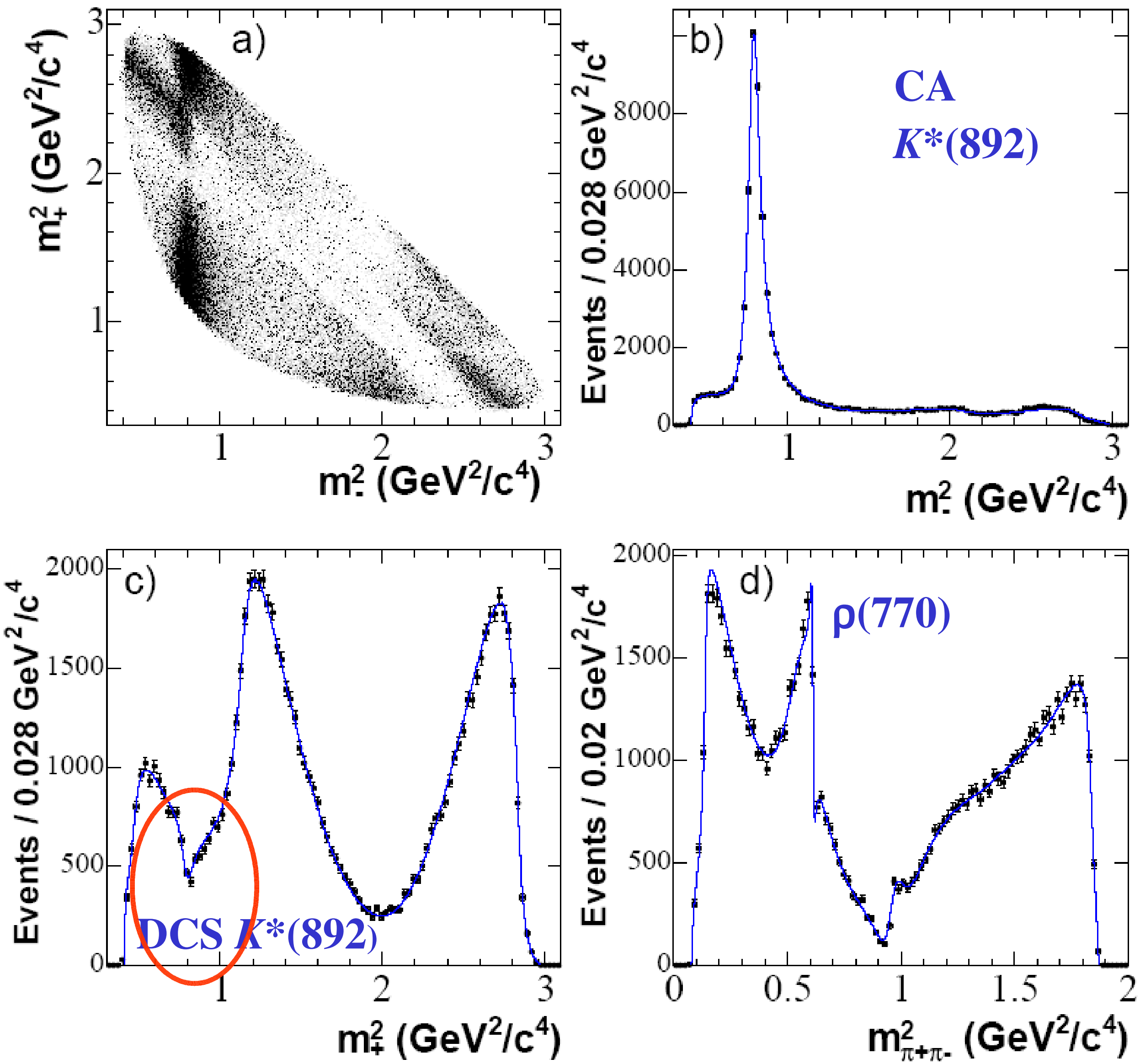



$+ r_B e^{i(\delta_B - \gamma)}$




$|^2$

# Fitting the $D^0 \to K_S \pi^+ \pi^-$ Dalitz plot




$$m_+^2 \equiv m^2(K_S^0 \pi^+)$$
$$m_-^2 \equiv m^2(K_S^0 \pi^-)$$

$D^{*+} \to D^0 \pi^+$ (91.5 fb$^{-1}$)

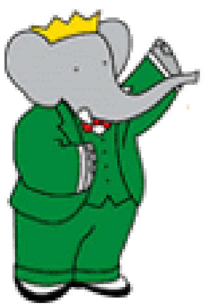
$N_{evts}$ = 82 K
Purity: 97%

*BABAR*
hep-ex/0504039

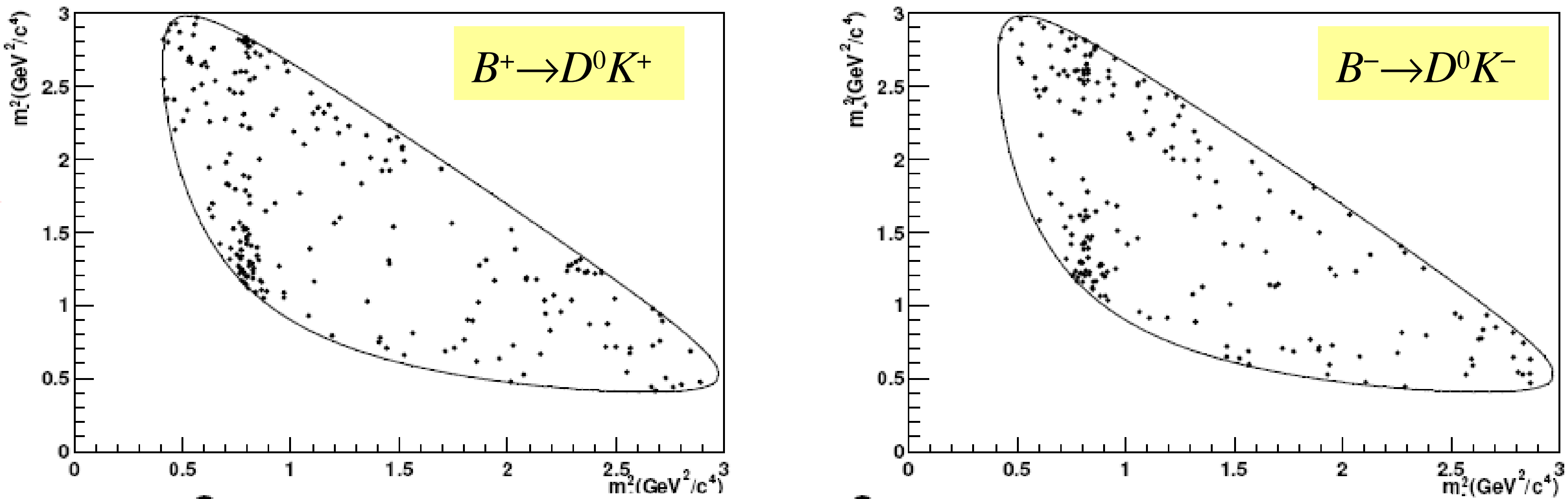
Issue: contribution of broad, s-wave resonances
(3) Orig. method: 2 BWs
(4) New: K-matrix

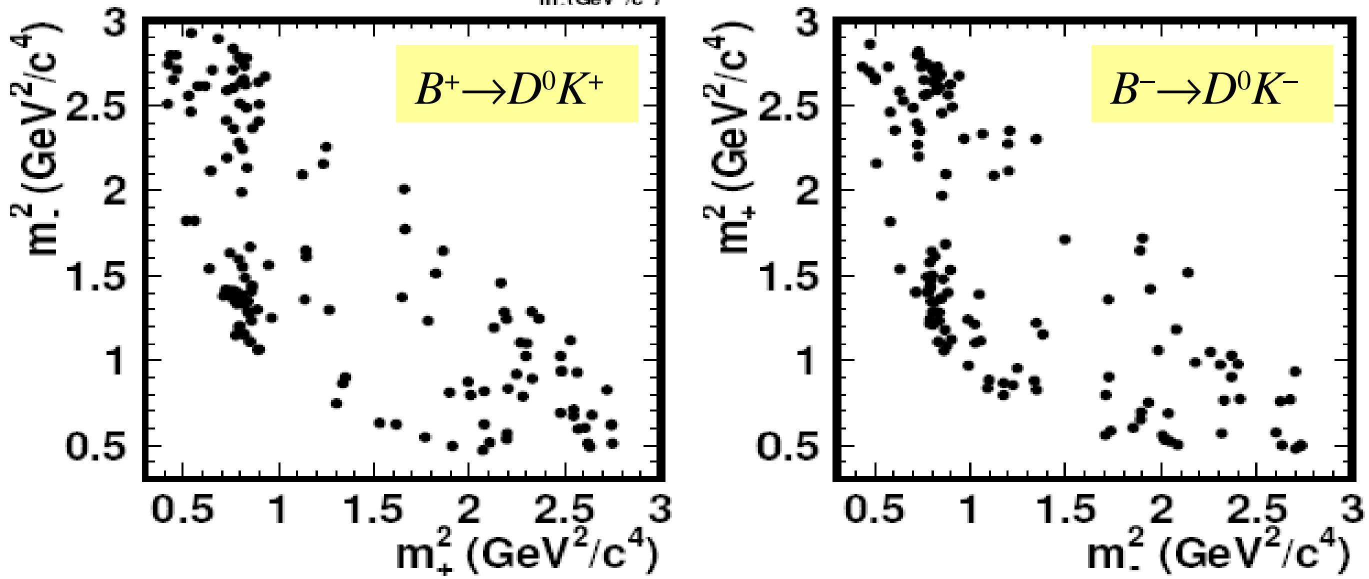
Anisovich & Saratev
Eur. Phys. J A16, 229 (2003)

$\chi^2$/dof≈3824/3022=1.27



# $B^{+/-} \to D^0 K^{+/-}$ Dalitz distributions



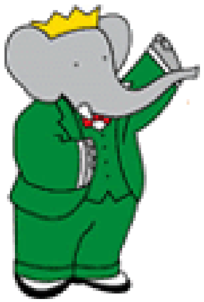

Differences between $B^+$ and $B^-$ signifies direct CP violation. Good S/B, but needs more data.

Above, $D^0$ is super-position of $D^0$ and $\overline{D^0}$

# $\gamma$: *BABAR* and Belle Dalitz results

| | *BABAR* (+stat+sys+model) hep-ex/0504039, 0507101 | Belle (+stat+sys+model) hep-ex/04110439, 0504013 |
|---|---|---|
| $r_B(D^0K)$ | $0.12 \pm 0.08 \pm 0.03 \pm 0.04$ | $0.21 \pm 0.08 \pm 0.03 \pm 0.04$ |
| $r_B(D^{*0}K)$ | $0.17 \pm 0.10 \pm 0.03 \pm 0.03$ | $0.12^{+0.16}_{-0.11} \pm 0.02 \pm 0.04$ |
| $r_B(D^0K^*)$ | $< 0.50\ (0.75)$ @ $1\sigma\ (2\sigma)$ | $0.25 \pm 0.18 \pm 0.09 \pm 0.04 \pm 0.08$ non-$K^*$ |
| $\gamma$ | $(67 \pm 28 \pm 13 \pm 11)^\circ$ | $(68 \pm 15 \pm 13 \pm 11)^\circ$ |
| direct CP significance | $2.4\sigma$ | $2.3\sigma$ |

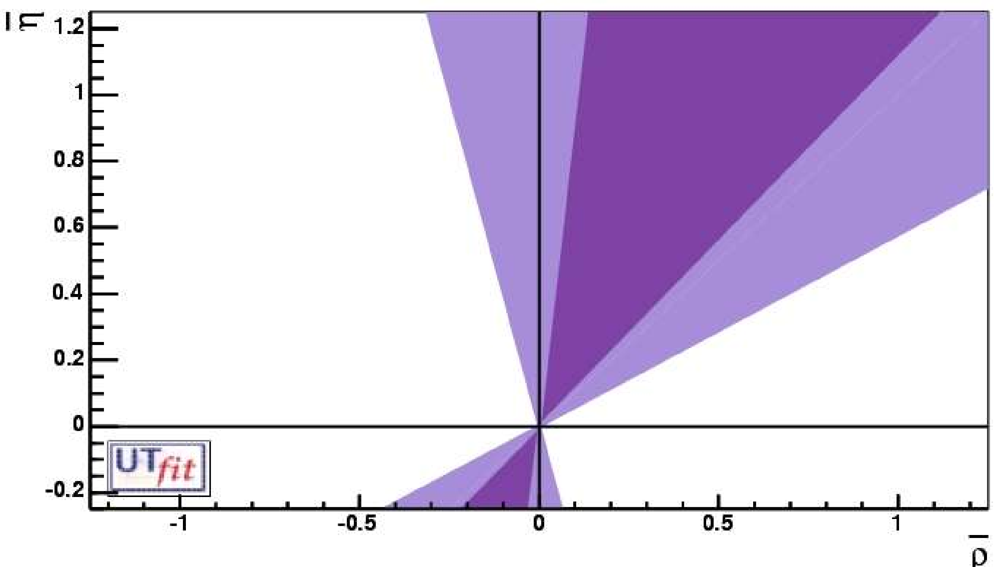
**The error on $\gamma$ is very sensitive to the value of $r_B$.**
**The other methods (ADS, GLW) help us to measure $r_B$.**

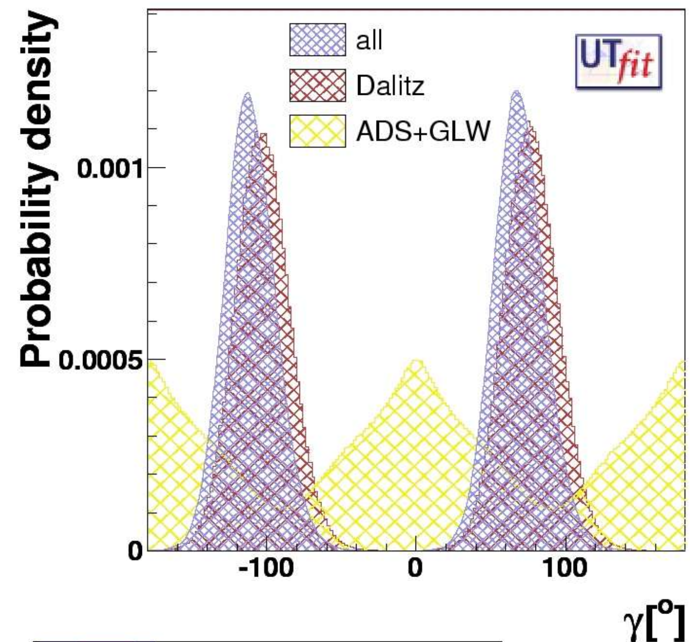


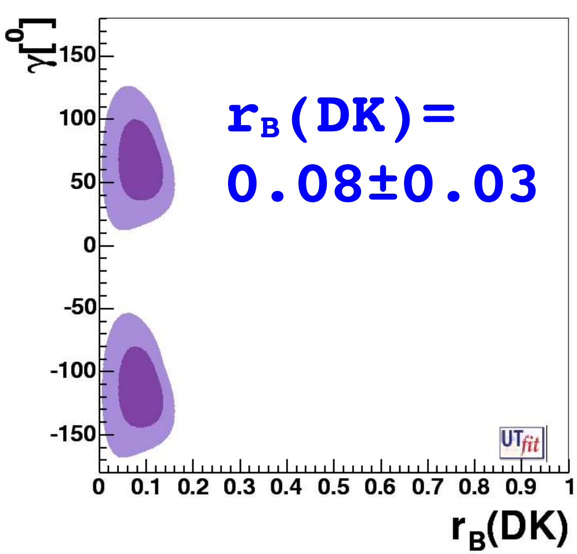
# Combining all the methods

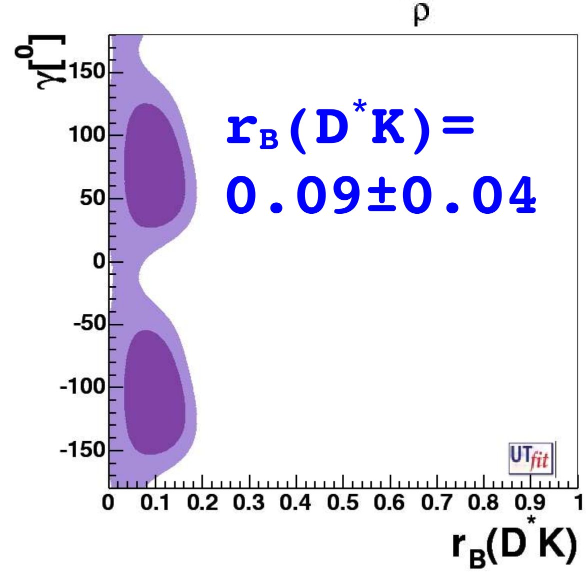
$\gamma = \quad 68 \pm 17 ([36,103] \quad @95\% \text{ Prob})$

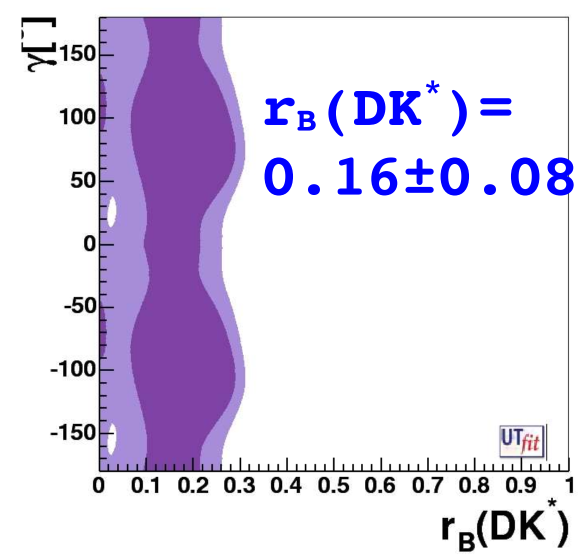
$\gamma = -112 \pm 17 ([-144,-77] @95\% \text{ Prob})$



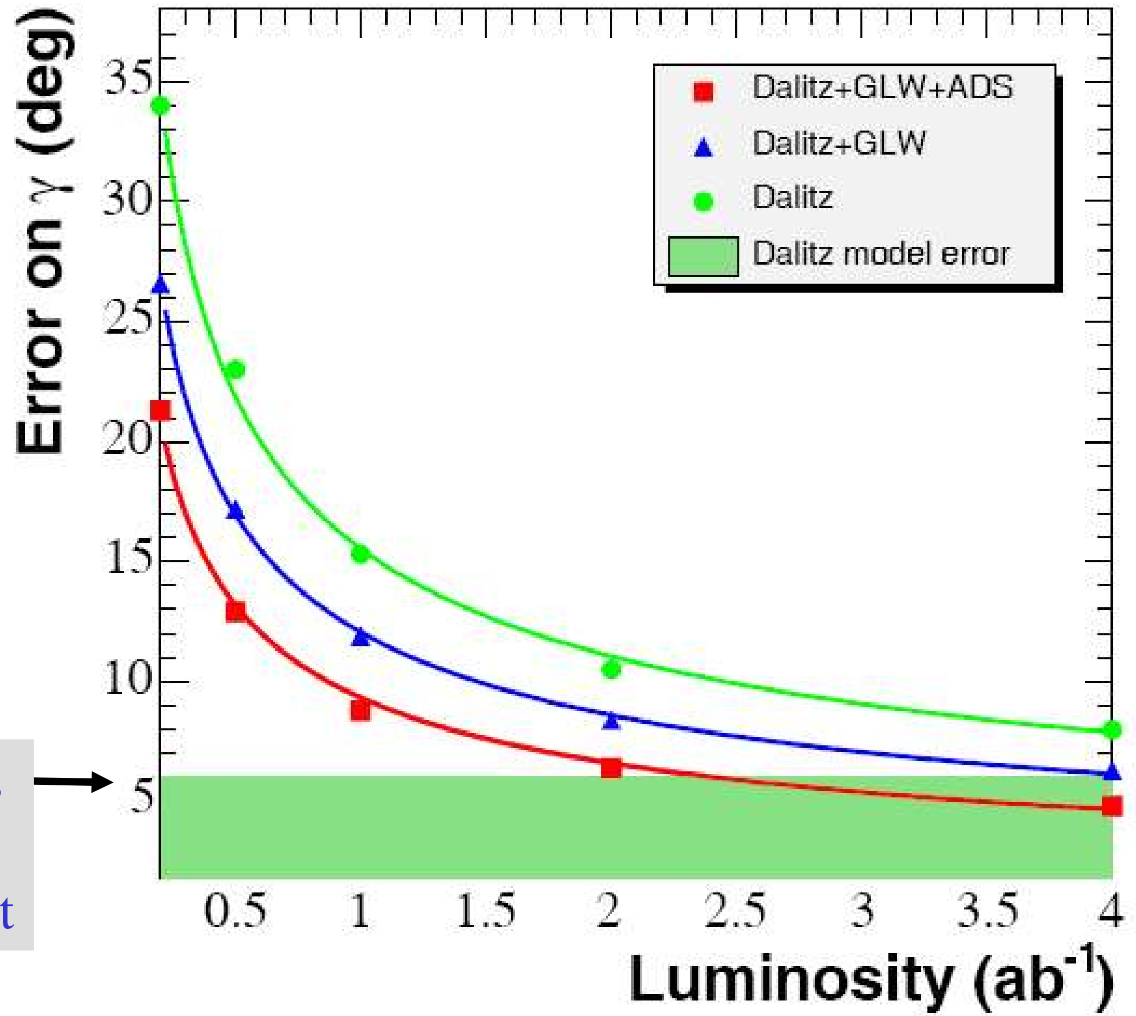



# Projected error on $\gamma$ for $r_B$=0.1

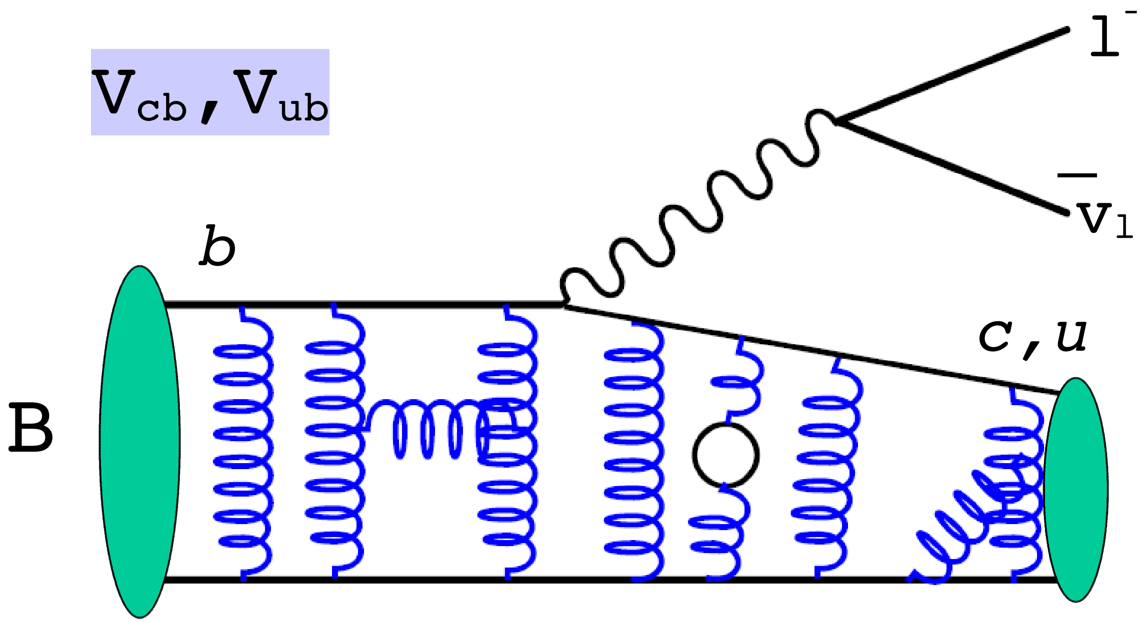



Projected sys error due to $D^0$ Dalitz plot

We will be able to improve the error on $\gamma$ by at least a factor of 2.

# Semileptonic B Decays

$V_{cb}, V_{ub}$




**b→c:**
D, D*, D**,...
**b→u:**
π, ρ, η,
η',ω,a₁,...

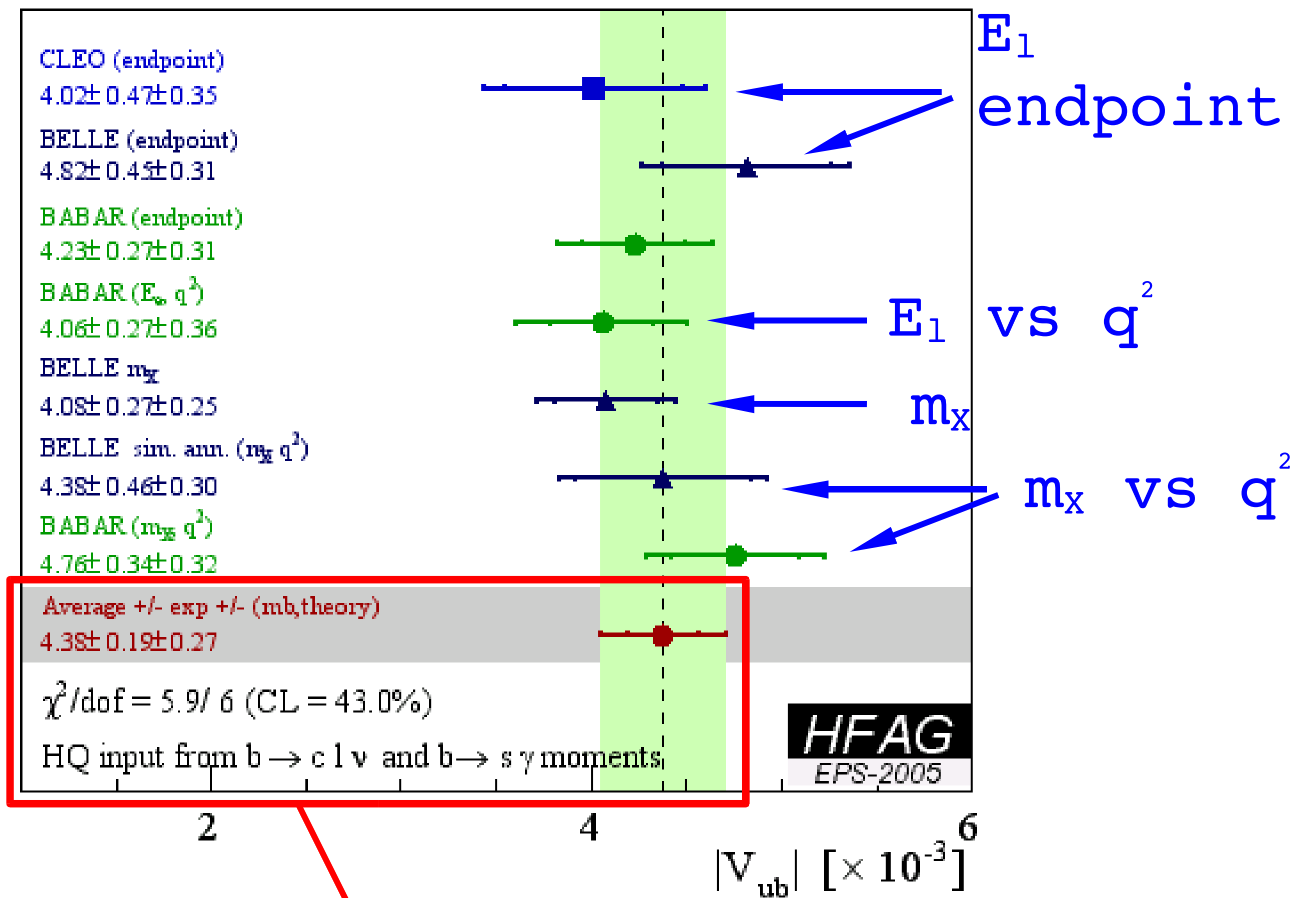
- Two complementary experimental and theoretical approaches
  - ➢ *Exclusive decays*: measure (and predict) the rate for specific exclusive modes, usually in restricted region of phase space.
  - ➢ *Inclusive decays*: use as much of phase space as possible to minimize theoretical input. **Extract non-perturbative QCD parameters from data.** Goal: $|V_{ij}|$(exclusive) = $|V_{ij}|$ (inclusive)!

# $|V_{ub}|$: inclusive measurements

- Key CKM constraint

$$\left|\frac{V_{ub}}{V_{cb}}\right| = \sqrt{\bar{\rho}^2 + \bar{\eta}^2}$$

- Use $m_b$ and QCD parameters extracted from inclusive $B \to X_c \, l \, \nu$ and $B \to X_s \, \gamma$ spectra.
- Many methods with uncertainties around 10%.
- Uncertainty from $m_b$ has been reduced to 4.5%.
- With more data, the $|V_{ub}|$ uncertainties could be pushed down to 5%-6.5%.

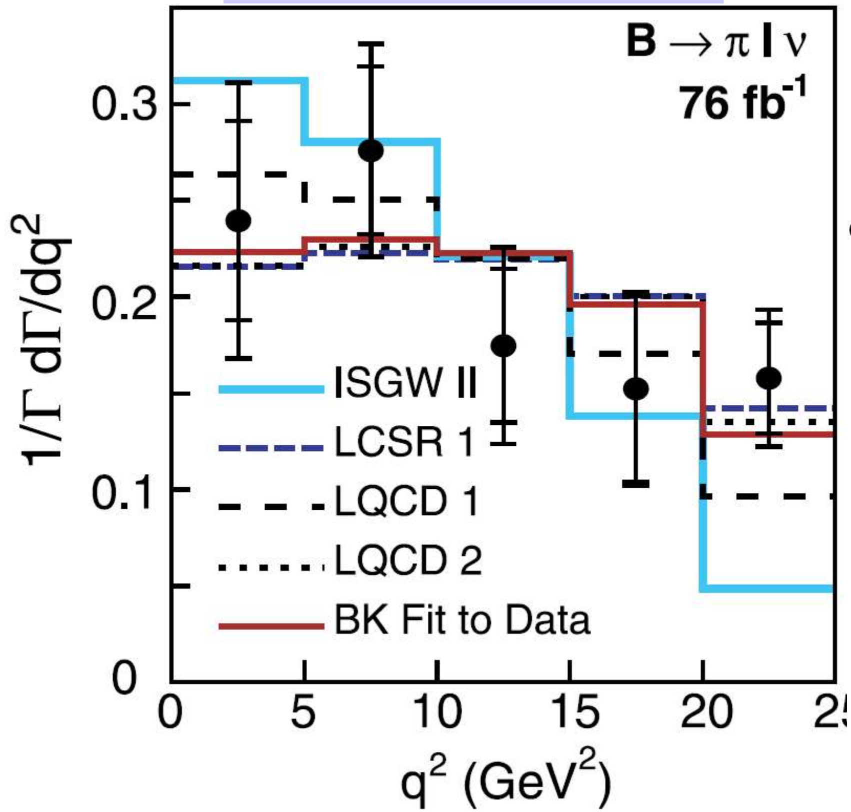



$$|V_{ub}|_{WAvg} = (4.38 \pm 0.19 \pm 0.27)\,10^{-3}$$

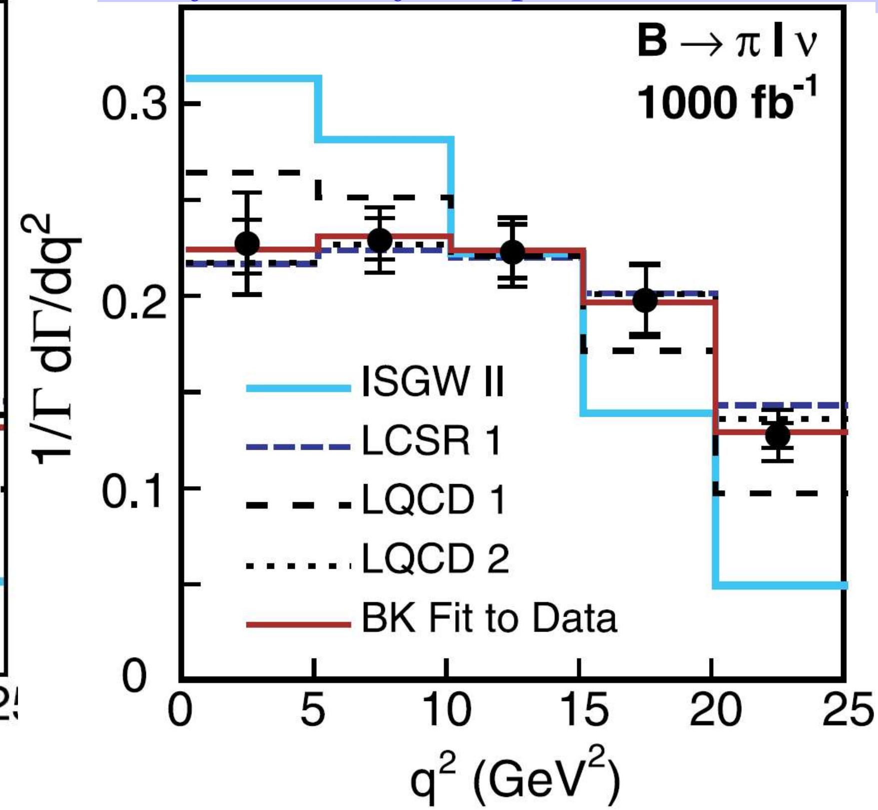
expt theory

# $|V_{ub}|$:exclusive measurements

Present data
PRD 72, 051102 (2005)




Projection to 1 ab⁻¹ *(data taken to be on BK fit curve from present measurement).*

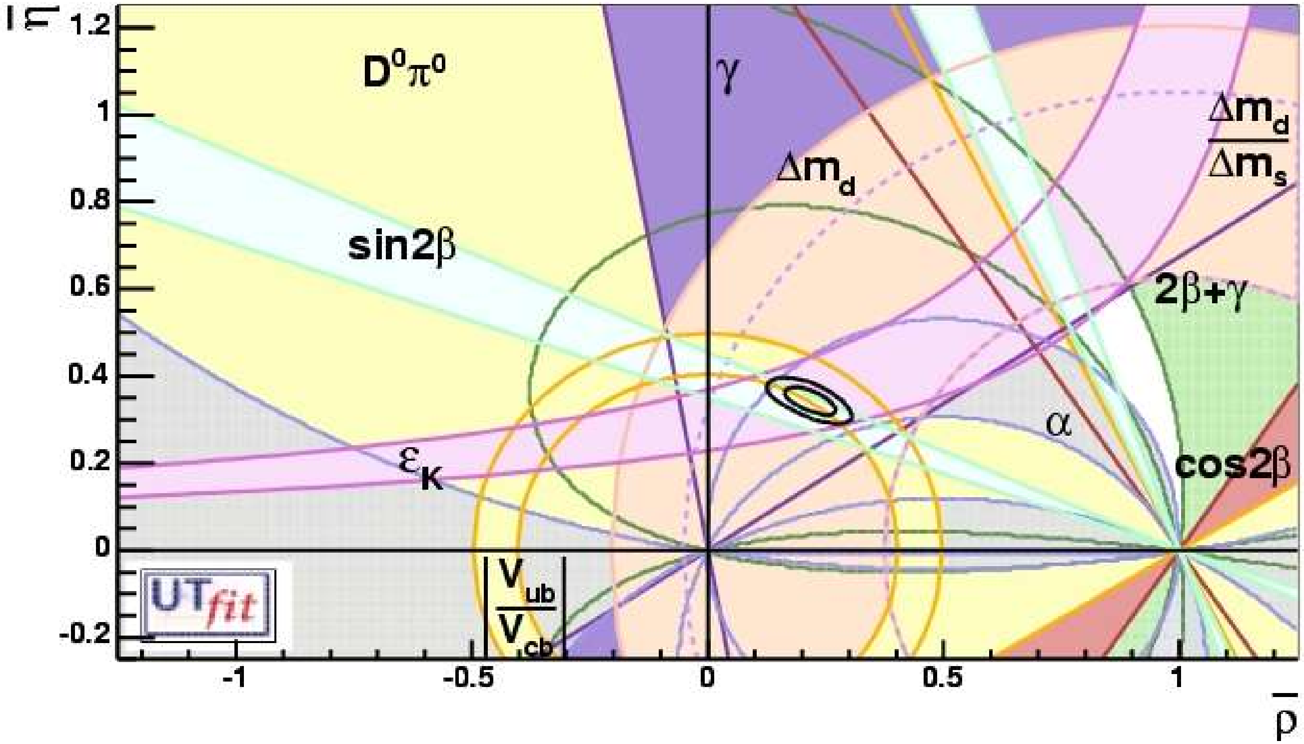



In the high $q^2$ region alone, we will measure the branching fraction with an uncertainty of (6-7)% , or (3-3.5)% uncertainty on $|V_{ub}|$. Lattice theorists expect to reach 6%, so exclusive/inclusive will be similar.

# Combining all the constraints

$V_{ub}/V_{cb} + \Delta m_d + \Delta m_d/\Delta m_s + \varepsilon_K +$
$\cos 2\beta + \beta + \gamma + \alpha + 2\beta+\gamma + \sin 2\beta$

sides+
Kaon physics+
angles




$\bar{\rho} = 0.216 \pm 0.036$
[0.143, 0.288] @ 95% Prob.

$\bar{\eta} = 0.342 \pm 0.022$
[0.300, 0.385] @ 95% Prob.

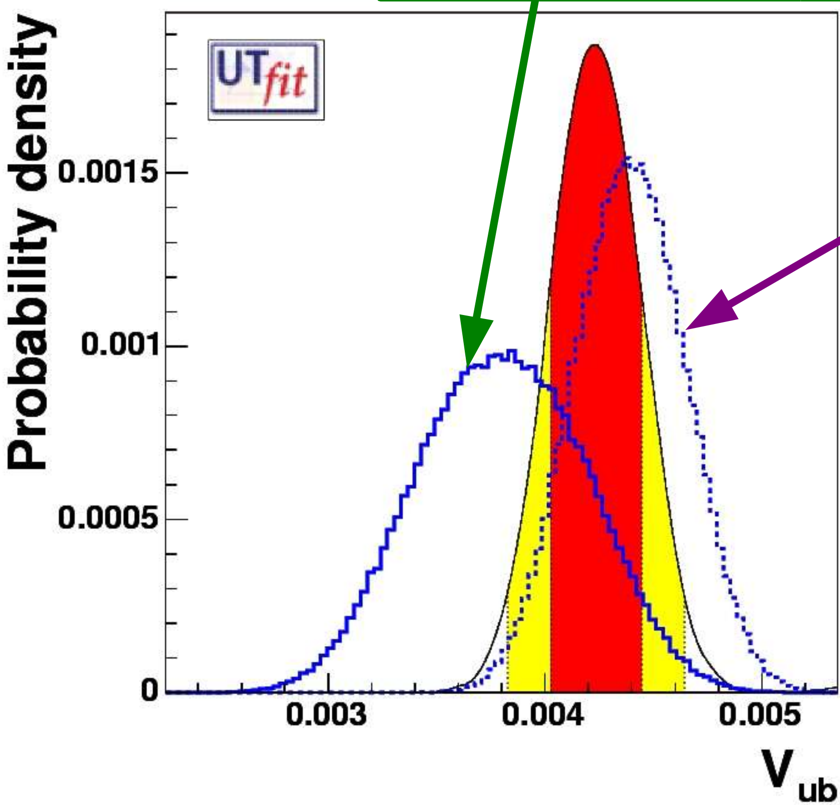
# Tension in the fit

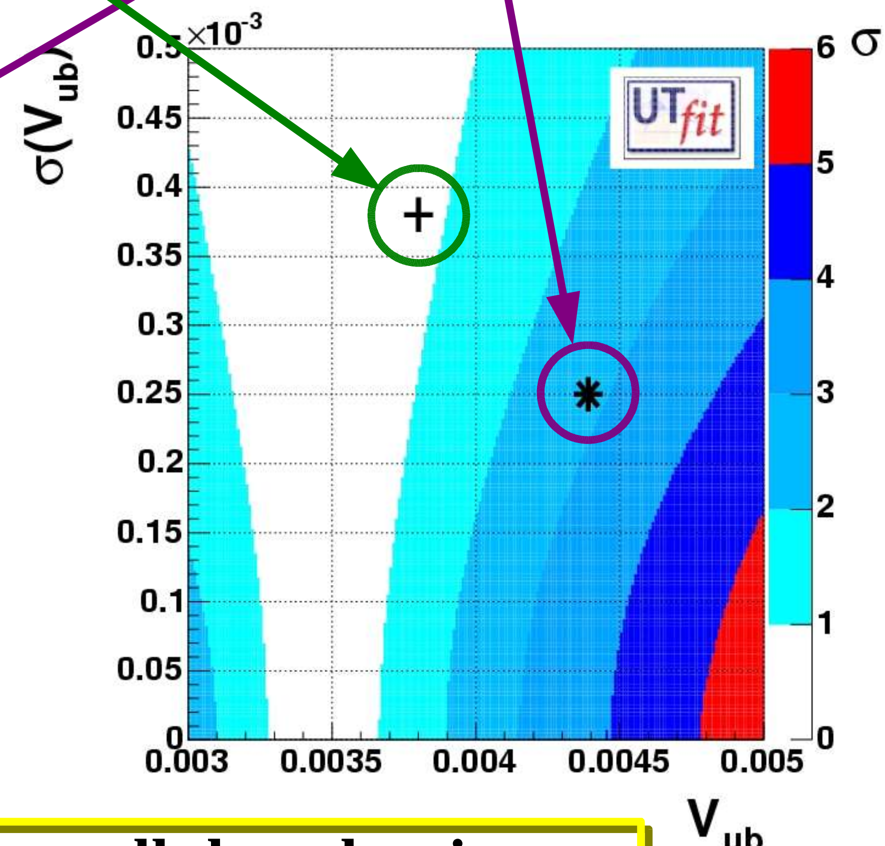
**exclusive: BRs from HFAG; form factor from quenched LQCD**

$V_{ub}=(3.80\pm0.27\pm0.47)10^{-3}$

**inclusive from HFAG**

$V_{ub}=(4.38\pm0.19\pm0.27)10^{-3}$



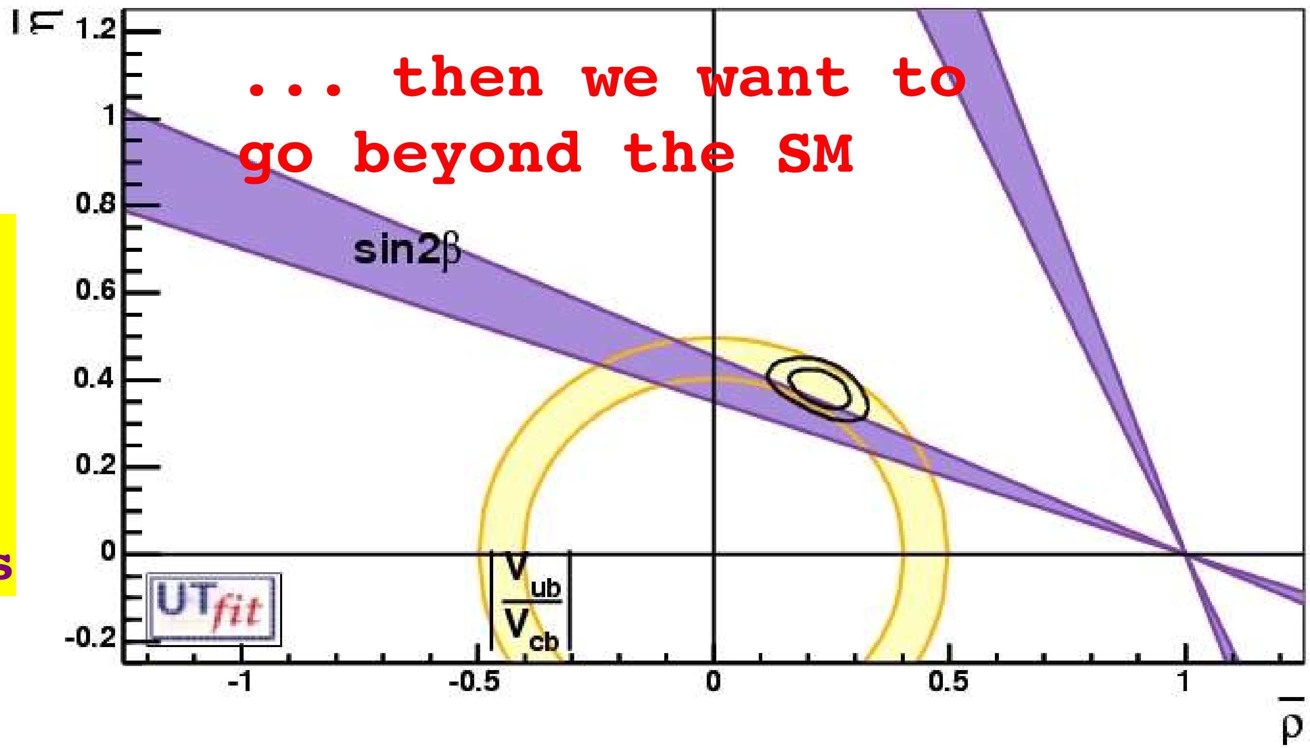

**incl.+excl.**

$V_{ub} = (4.22 \pm 0.20)\ 10^{-3}$

**from all the other inputs:**

$V_{ub} = (3.48 \pm 0.20)\ 10^{-3}$

# But if you believe the numbers...




Ciuchini, M.P, Silvestrini hep-ph/0507290 Model independent estimation of theoretical errors

$\sin 2\beta = 0.791 \pm 0.034$ from indirect determination

$\sin 2\beta = 0.687 \pm 0.032 \pm 0.017$ From direct measurement

# Fit with NP-independent constraints

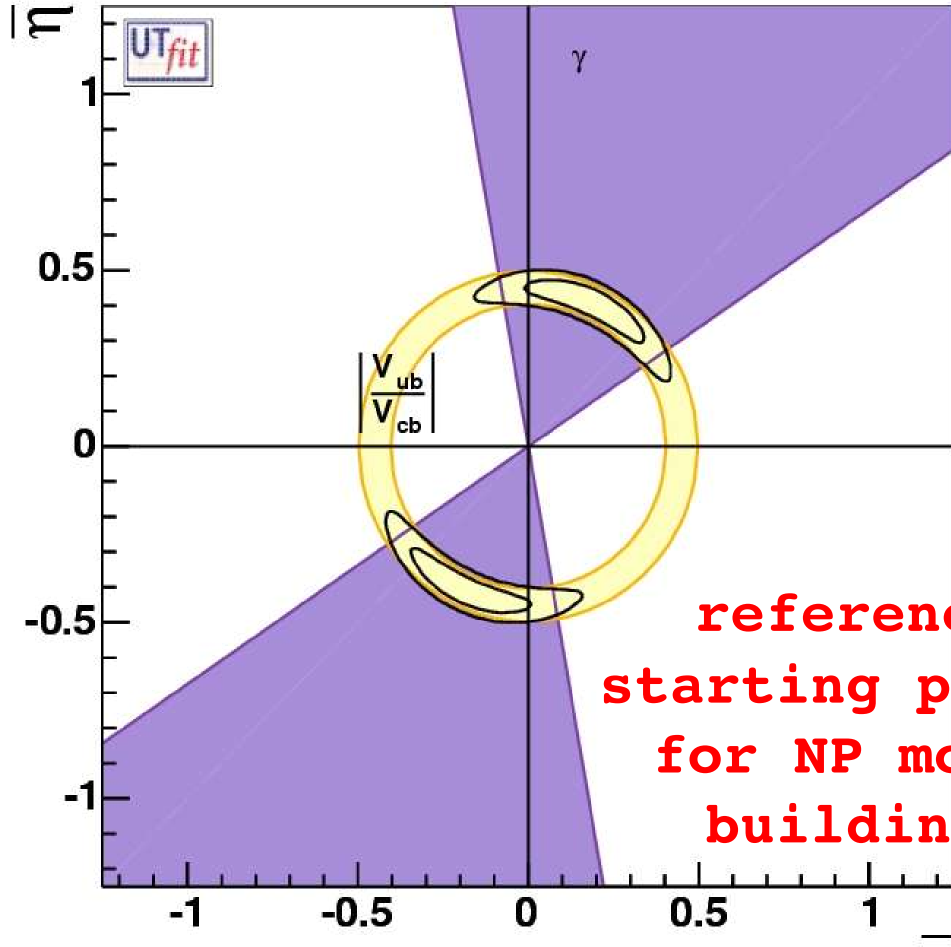
Assuming no NP at tree level

- *the effect of the $D^0$-$\bar{D}^0$ mixing to $\gamma$ is negligible wrt the actual error*
- *semileptonic decays are clean*

We have a NP free determination of $\bar{\rho}$ and $\bar{\eta}$

$\bar{\rho} = \pm\, 0.18 \pm 0.11$

$\bar{\eta} = \pm\, 0.41 \pm 0.05$




reference starting point for NP model building

# NP: model independent approach

We can generalize the analysis beyond the Standard Model parameterizing the deviations in $|\Delta F|=2$ processes in a model independent way:

- $|\varepsilon_K|^{EXP} = C_\varepsilon \cdot |\varepsilon_K|^{SM}$
- $\Delta m_s^{EXP} = C_s \cdot \Delta m_s^{SM}$
- $\alpha^{EXP} = \alpha^{SM} - \phi_{Bd}$
- $\Delta m_d^{EXP} = C_d \cdot \Delta m_d^{SM}$
- $A_{CP}(J/\psi K^0) = \sin(2\beta + 2\phi_{Bd})$

5 unknowns

| | $\rho, \eta$ | $C_d, \varphi_d$ | $C_{\varepsilon K}$ | $C_s, \varphi_s$ |
|---|---|---|---|---|
| $V_{ub}/V_{cb}$ | X | | | |
| $\Delta m_d$ | X | X | | |
| $\varepsilon_K$ | X | | X | |
| ACP ($J/\Psi$ K) | X | X | | |
| $\alpha$ ($\rho\rho,\rho\pi,\pi\pi$) | X | X | | |
| $\gamma$ (DK) | X | | | |
| $\Delta m_s$ | | | | X |
| ACP ($J/\Psi$ $\phi$) | ~X | | | X |
| $\gamma$ ($D_sK$) | X | | | X |

6 available constraints

not yet available

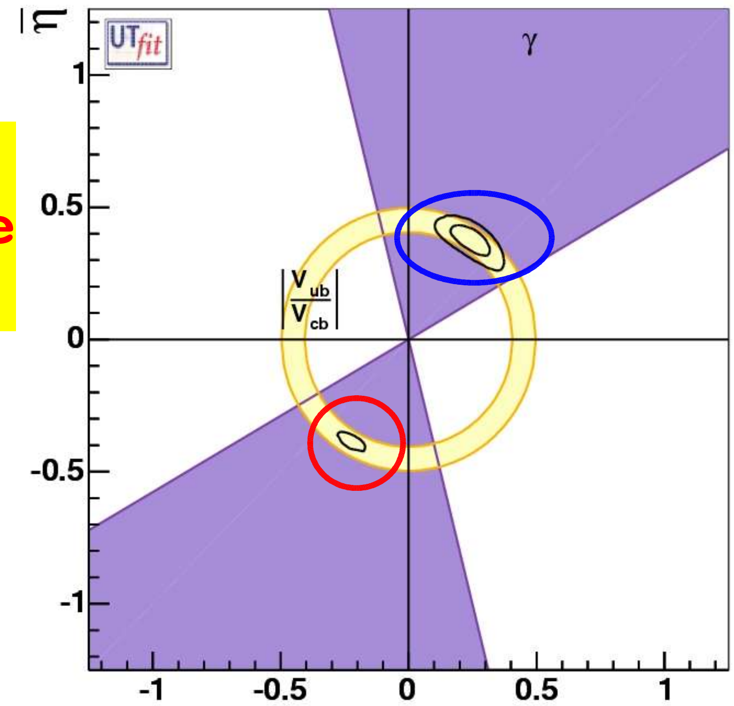
**model indepentent assumptions**

J. M. Soares and L. Wolfenstein, Phys. Rev. D 47 (1993) 1021;
N. G. Deshpande, B. Dutta and S. Oh, Phys. Rev. Lett. 77 (1996) 4499 [arXiv:hep-ph/9608231]
J. P. Silva and L. Wolfenstein, Phys. Rev. D 55 (1997) 5331 [arXiv:hep-ph/9610208]
A. G. Cohen *et al.*, Phys. Rev. Lett. 78 (1997) 2300 [arXiv:hep-ph/9610252]
Y. Grossman, Y. Nir and M. P. Worah, Phys. Rev. Lett. B 407 (1997) 307 [arXiv:hep-ph/9704287]

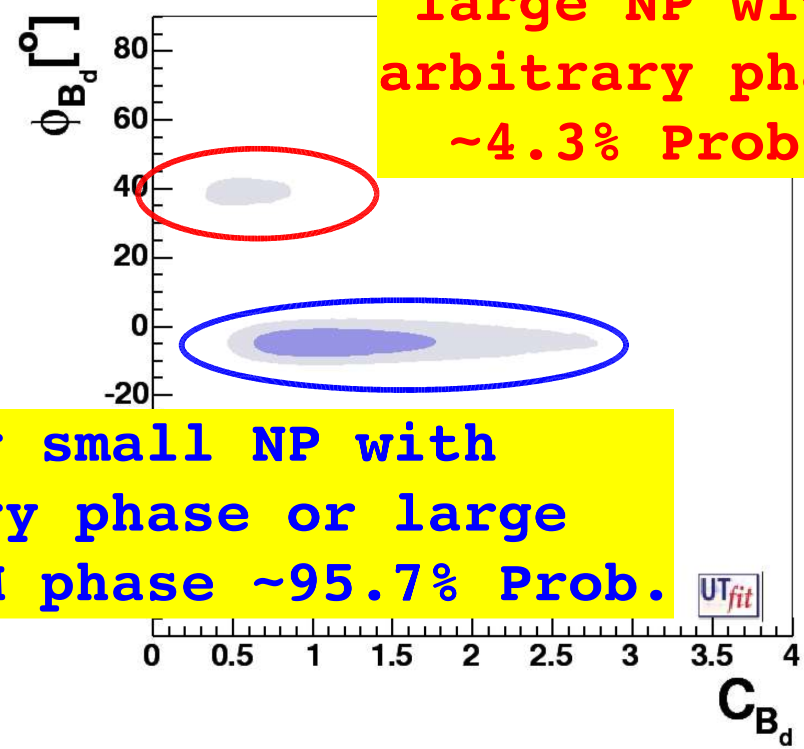
# The $UT_{fit}$ beyond the SM

“SM” $\bar{\rho} = 0.246 \pm 0.053$
“NP” [-0.230, -0.212] @ 95% Prob.

“SM” $\bar{\eta} = 0.379 \pm 0.039$
“NP” [-0.398, -0.381] @ 95% Prob.



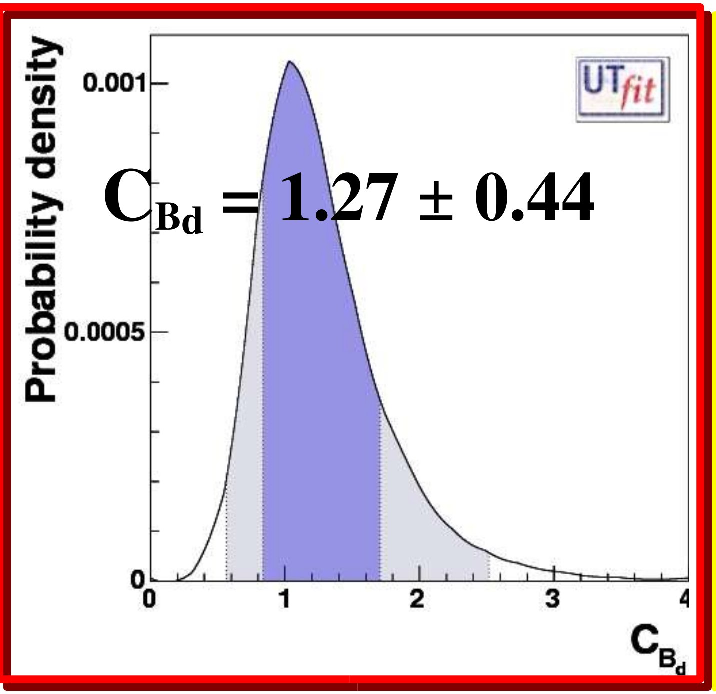

large NP with arbitrary phase ~4.3% Prob.

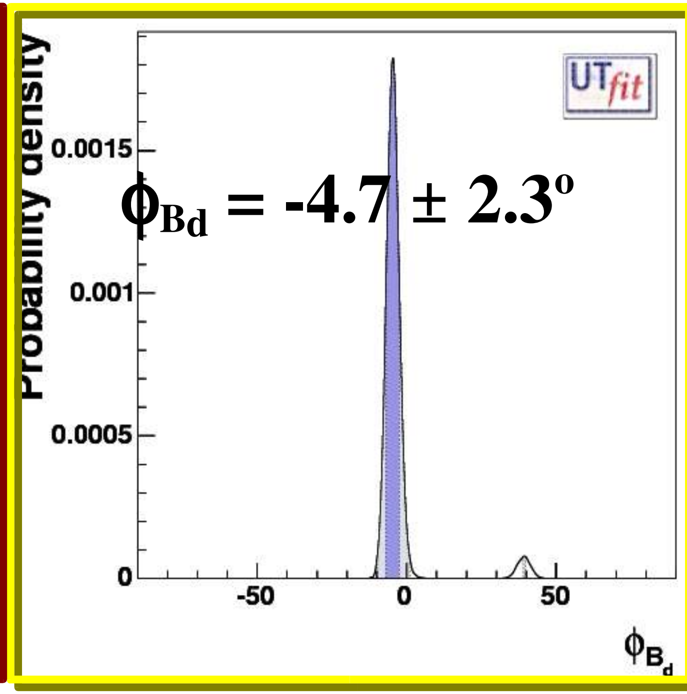


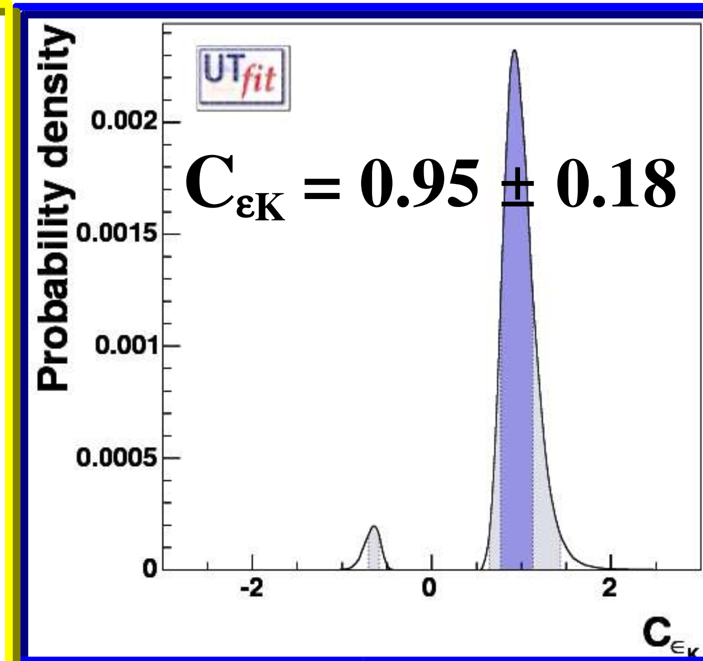

SM or small NP with arbitrary phase or large NP with SM phase ~95.7% Prob.

# Bounds on NP parameters

NP in $\Delta B_d=2$ and $\Delta S=2$ is going in the direction of **Minimal Flavor Violation**, while **$B_s$ sector is still unexplored**



# Where do we go from here?

**In any scenario, BaBar will probe New Physics in the pre-LHC era**

## *Are there new sources of CPV?*

- *New sources of CPV in $s \to d$ and/or $b \to d$ transitions are*
  - *strongly constrained by the UT fit*
  - *"unnecessary", given the great success and consistency of the fit*

**From L.Silvestrini's talk at LP05**

- *New sources of CPV in $b \to s$ transitions are*
  - *much less (un-) constrained by the UT fit*
  - *natural in many flavour models, given the strong breaking of family SU(3)*

    Pomarol, Tommasini; Barbieri, Dvali, Hall; Barbieri, Hall; Barbieri, Hall, Romanino; Berezhiani, Rossi; Masiero et al; …
  - *hinted at by $\nu$'s in SUSY-GUTs*

    Baek et al.; Moroi; Akama et al.; Chang, Masiero, Murayama; Hisano, Shimizu; Goto et al.; …

# First Case: New Physics brings additional CP violation in the $b \to s$ sector

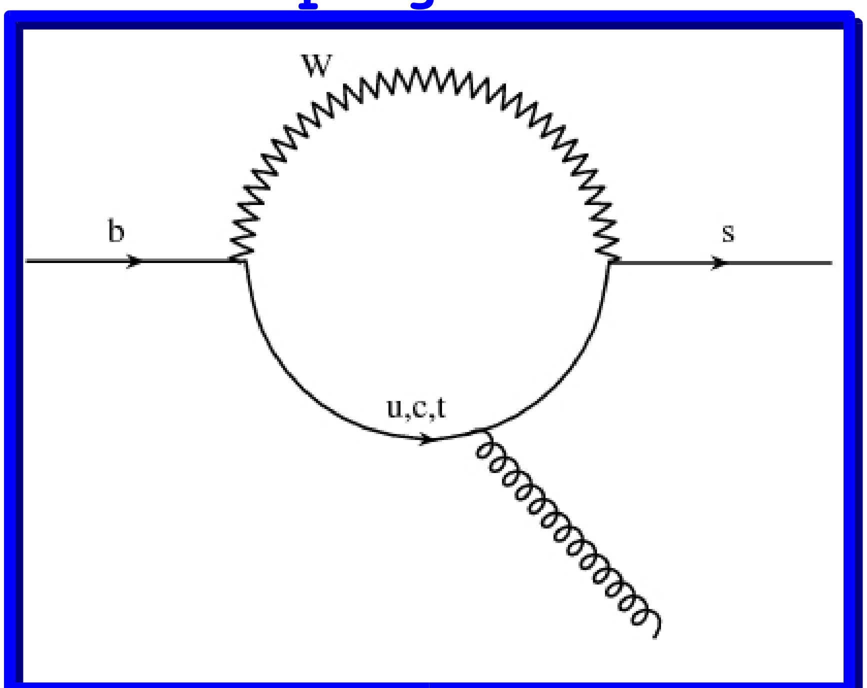
# Testing b→s: Time Dependent $A_{CP}$

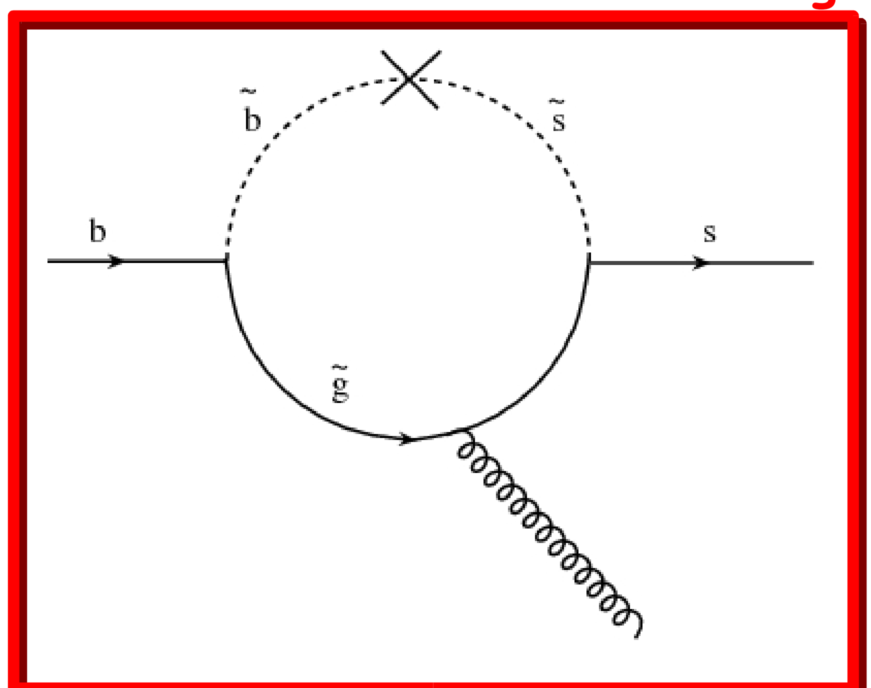
From an experimental point of view

- Same approach than sin2β analysis for $J/\psi K^0$
- Special care to additional background sorces (these are rare decays, $BR \sim 10^{-5}$)

From a theoretical point of view

- SM predicts S~sin2β and C~0 if only one amplitude is present
- For b→s channels, the **dominant SM amplitude is a penguin** and **NP can enters at the leading order**



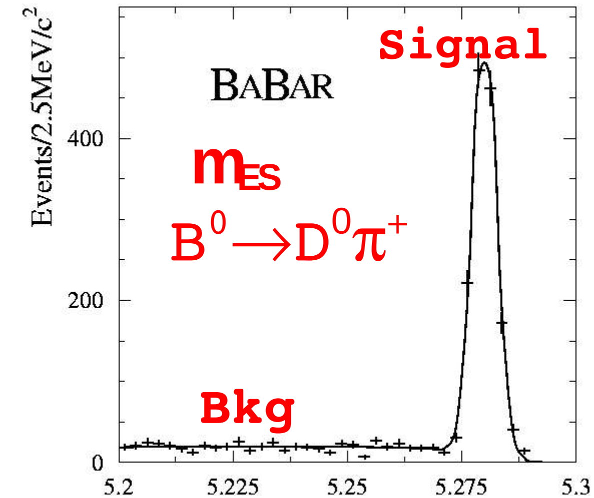
# Experimental strategy (I)

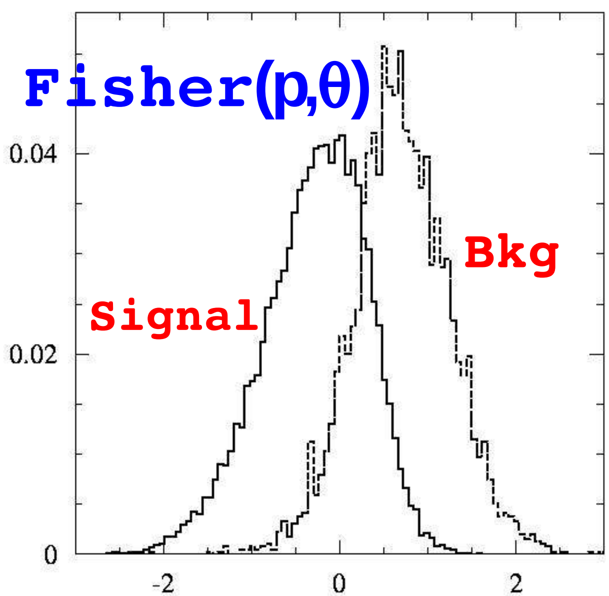
We reduce background by

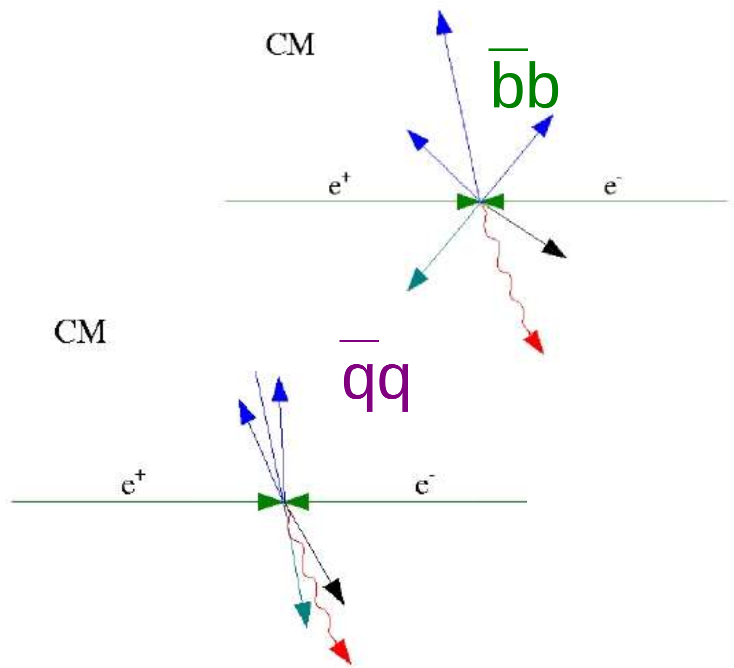
- Using kinematic variables

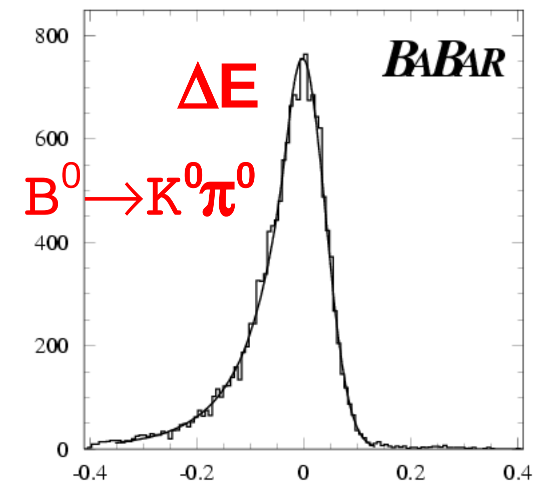
$$m_{ES}=\sqrt{(\sqrt{s}/2)^2-p_B^{*2}} \qquad \Delta E=E_B^*-\sqrt{s}/2$$

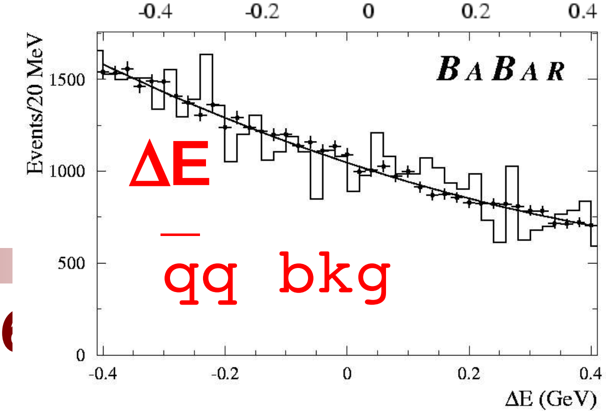
- Exploiting the different topology (isotropic vs jet-like)



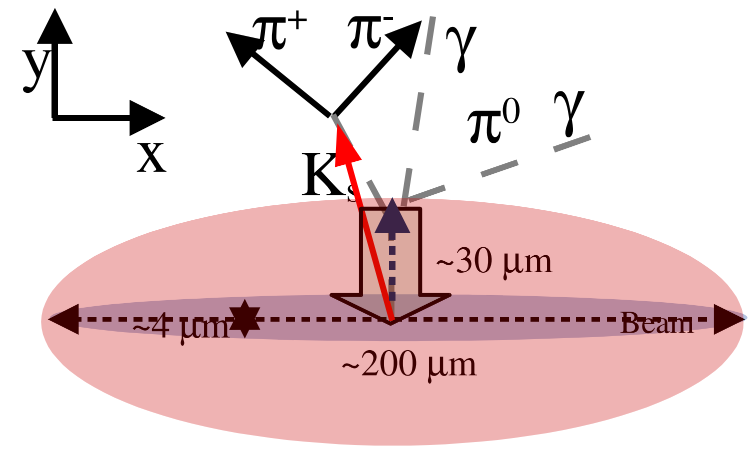



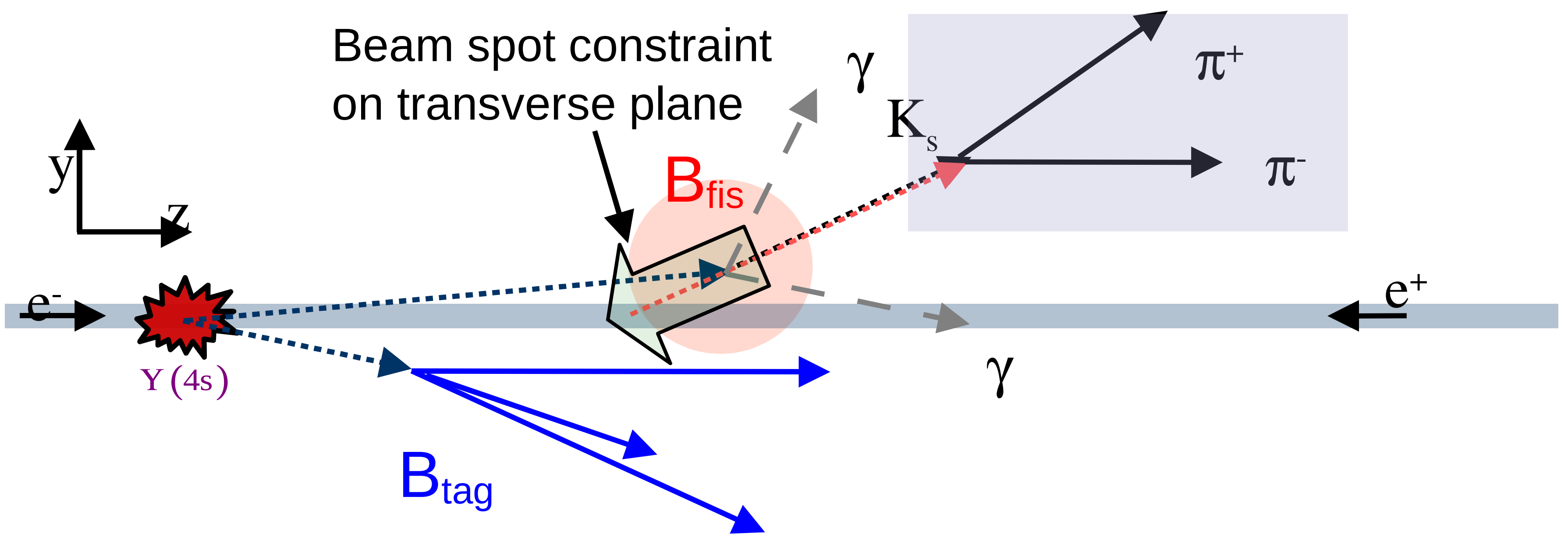



# Experimental issues(II)

Several of these channels do not have charged tracks from the vertex. But we can extrapolate back the $K_S$:

- Using the constraint of the beam spot on the transverse plane
- Requiring the $K_S$ to decay in the inner part of the SVT



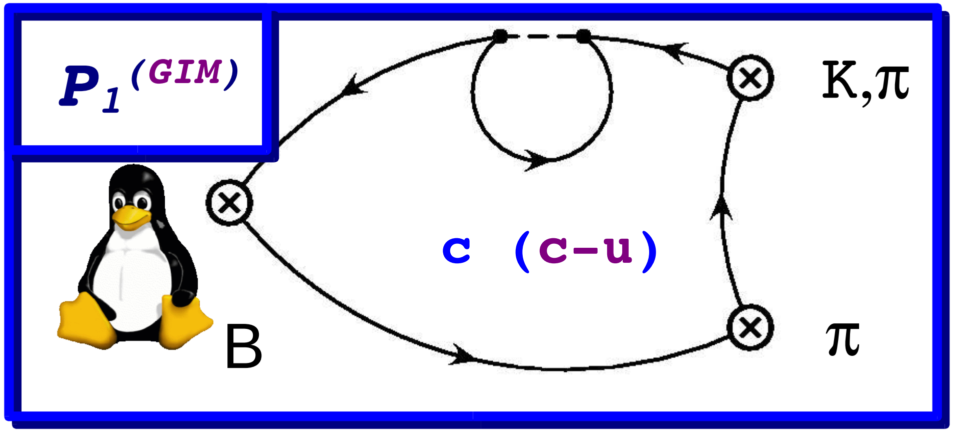



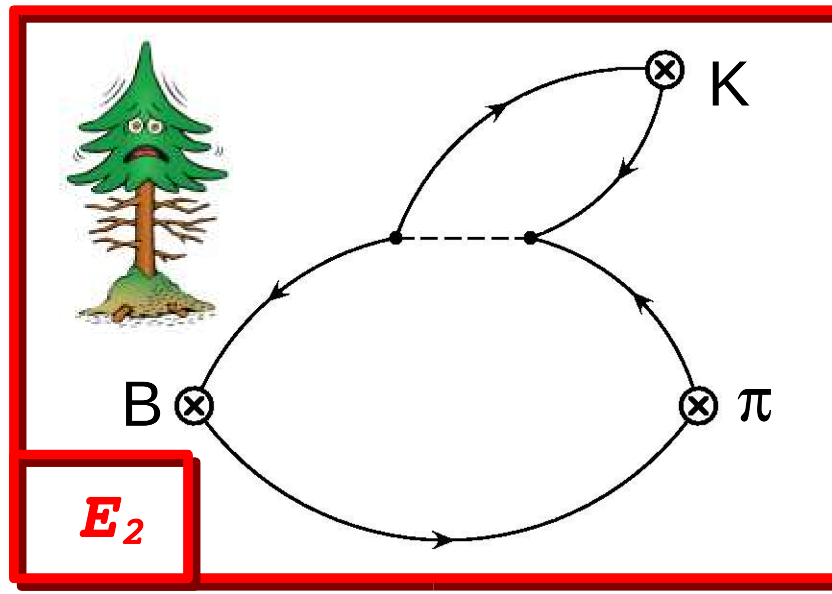
# Theory problem: CKM suppressed terms

CKM enhanced($\sim \lambda^2$) CKM suppressed($\sim \lambda^4$)

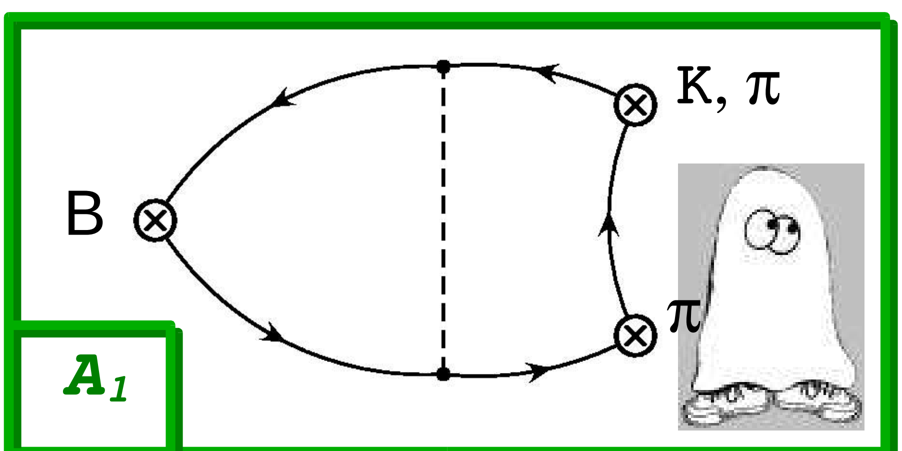
$$\mathcal{A}(B^0 \to f^s{}_{CP}) = V_{ts} V_{tb}^* \times P + V_{us} V_{ub}^* \times \{\ldots\}$$

GIM penguins(c-u)

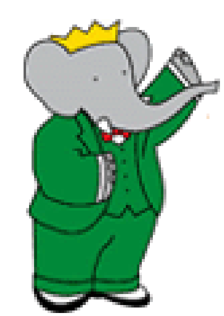



"Color suppressed" tree



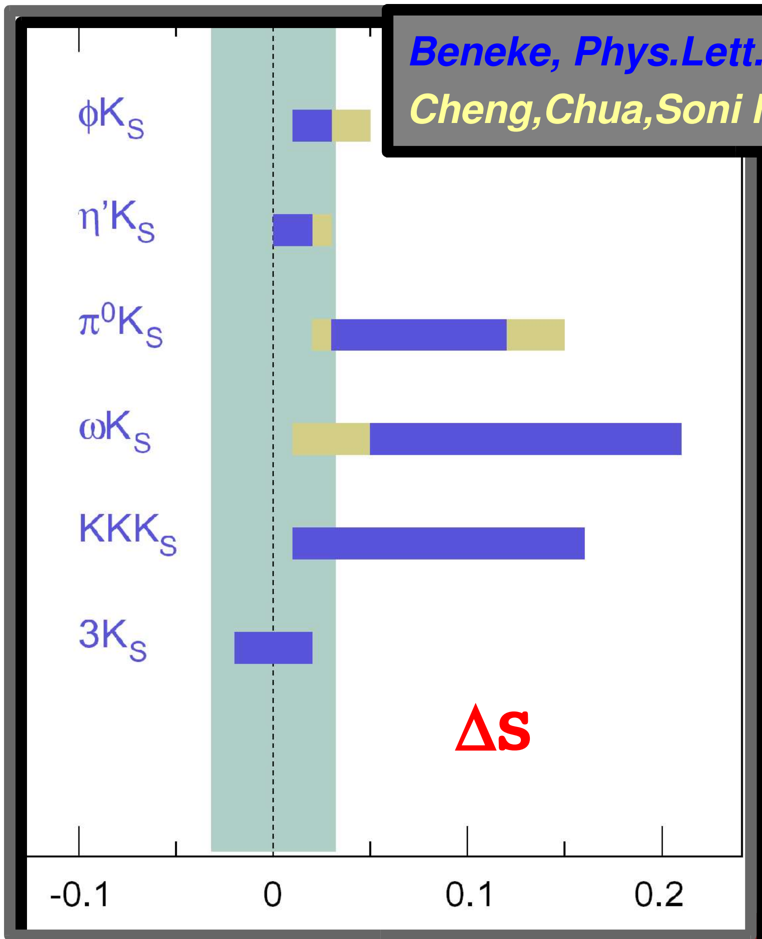

Connected Annihilation



# ΔS: Calculation vs flavor symmetry

The corrections can be calculated or can be extracted from data. Because of the large amount of free parameters, SU(3) is needed to get competitive estimations respect to QCD factorization, in the case of $\phi K^0$ and $\eta' K^0$

*Beneke, Phys.Lett. B620, 143,*
*Cheng,Chua,Soni hep-ph/0506268*




Open issues:

- Do the penguins factorize (i.e, are **charming penguins** important?)
- What is the error associated to **SU(3) breaking**?
- Can we follow a **"data driven" approach** to reduce the uncertainties?

# How can experiments help?

BaBar and Belle will provide more measurements than the only time dependent asymmetries

**Neutral decays are not well reproduced**

| Mode | *BABAR* | Belle | World Average | QCD FA | pQCD |
|---|---|---|---|---|---|
| $\pi^+\pi^-$ | $4.7 \pm 0.6 \pm 0.2$ | $4.4 \pm 0.6 \pm 0.3$ | $4.5 \pm 0.4$ | $4.6 - 9.5$ | $5.9 - 11.0$ |
| $\pi^0\pi^0$ | $1.17 \pm 0.32 \pm 0.10$ | $2.3^{+0.4+0.2}_{-0.5-0.3}$ | $1.45 \pm 0.29$ | $0.4 - 0.9$ | $0.1 - 0.7$ |
| $\pi^+\pi^0$ | $5.8 \pm 0.6 \pm 0.4$ | $5.0 \pm 1.2 \pm 0.5$ | $5.5 \pm 0.6$ | $5.1 - 6.0$ | $2.7 - 4.8$ |
| $K^+\pi^-$ | $17.9 \pm 0.9 \pm 0.7$ | $18.5 \pm 1.0 \pm 0.7$ | $18.2 \pm 0.8$ | $18.4 - 20.0$ | $12.6 - 19.3$ |
| $K^0\pi^0$ | $11.4 \pm 0.9 \pm 0.6$ | $11.7 \pm 2.3^{+1.2}_{-1.3}$ | $11.5 \pm 1.0$ | $6.5 - 9.3$ | $4.4 - 8.1$ |
| $K^0\pi^+$ | $26.0 \pm 1.3 \pm 1.0$ | $22.0 \pm 1.9 \pm 1.1$ | $24.1 \pm 1.3$ | $18.8 - 24.8$ | $14.4 - 26.3$ |
| $K^+\pi^0$ | $12.0 \pm 0.7 \pm 0.6$ | $12.0 \pm 1.3^{+1.3}_{-0.9}$ | $12.1 \pm 0.8$ | $11.7 - 14.0$ | $7.8 - 14.3$ |
| $K^+K^-$ | $< 0.6$ | $0.06^{+0.12+0.03}_{-0.10-0.02}$ | $0.06^{+0.12}_{-0.10}$ | $< 0.08$ | $0.06$ |
| $K^0\overline{K^0}$ | $1.19^{+0.40}_{-0.35} \pm 0.13$ | $0.8 \pm 0.3 \pm 0.1$ | $0.96^{+0.25}_{-0.24}$ | $1.5 - 2.2$ | $1.4$ |
| $K^+\overline{K^0}$ | $1.45^{+0.53}_{-0.46} \pm 0.11$ | $1.0 \pm 0.4 \pm 0.1$ | $1.19^{+0.32}_{-0.30}$ | $1.4 - 2.2$ | $1.4$ |

**With precise measurements we will be able to defintly rule out models. The survivour will give us ΔS. And we can help more "data driven" approaches**

| Mode | $\sigma$ (stat) | $\sigma$ (syst) | $\sigma$ (tot) | $\sigma$ (WA) |
|---|---|---|---|---|
| $\pi^+\pi^-$ | 3.5 | 2 | 4 | 3 |
| $\pi^0\pi^0$ | 14 | 6 | 15 | 11 |
| $\pi^+\pi^0$ | 5.5 | 3 | 6 | 4 |
| $K^+\pi^-$ | 1.5 | 2 | 2.5 | 2 |
| $K^0\pi^0$ | 4 | 3 | 5 | 4 |
| $K^0\pi^+$ | 2.5 | 3 | 4 | 3 |
| $K^+\pi^0$ | 3 | 3 | 4 | 3 |
| $K^+K^-$ | – | – | – | $< 10^{-7}$ |
| $K^0\overline{K^0}$ | 17 | 6 | 18 | 13 |
| $K^+\overline{K^0}$ | 15 | 3 | 15 | 11 |

# The Charming penguins Model

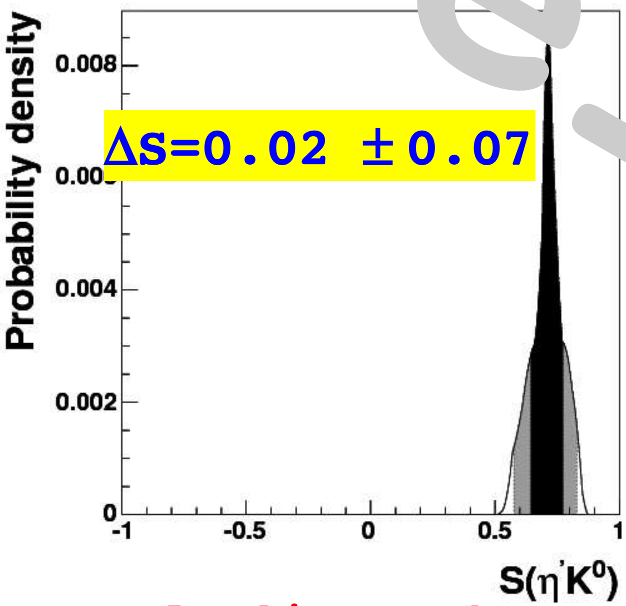
- We express the decay amplitudes in terms of RGI
- We fix the CKM matrix to the output of **UT***fit*
- We calculate the perturbative contribution to each RGI using QCD factorization
- **We add a complex unknown for each RGI which is $\Lambda_{QCD}/m_b$ suppressed** (i.e. we allow the breaking of factorization ansatz)
- We use experimental data to determine the unknown quantities
- Expected differences respect to QCD fact: large BR($\pi^0\pi^0$) and sizable CP violation in $B \to K\pi$ (**Ciuchini et al. hep-ph/0104126**). Both recently verified by experiments

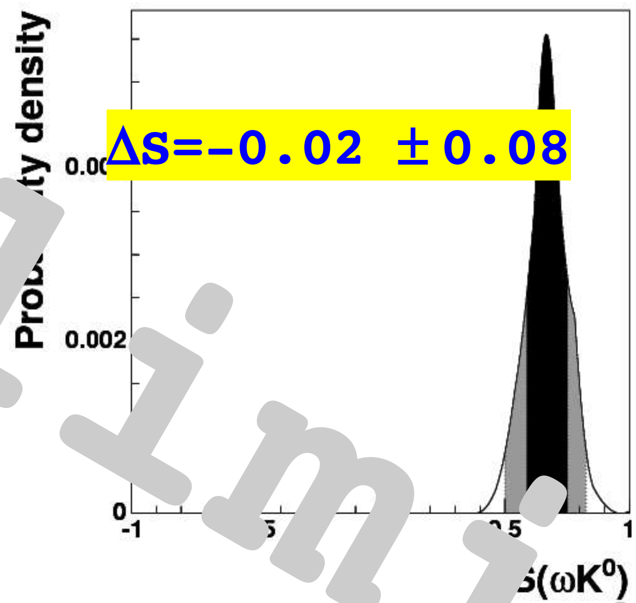
**Good news:** We still have predictive power on CP parameters

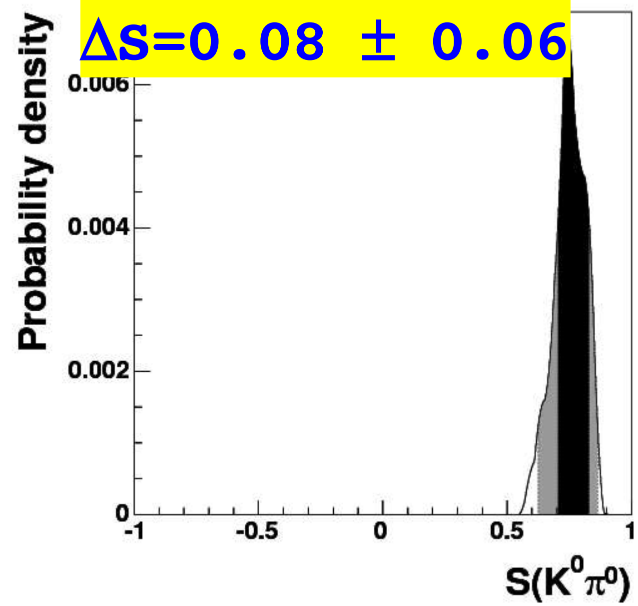
**Bad news:** BR are not sensitive to CKM suppressed RGI. We have to limit the allowed parameter space.

# S Parameters in the SM

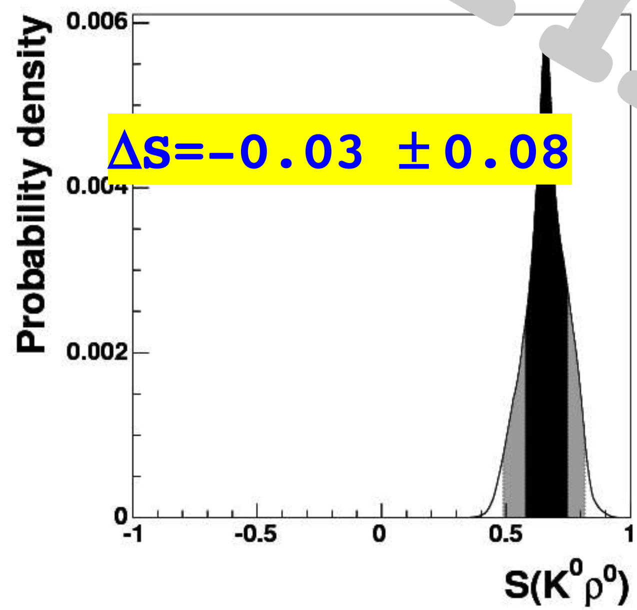


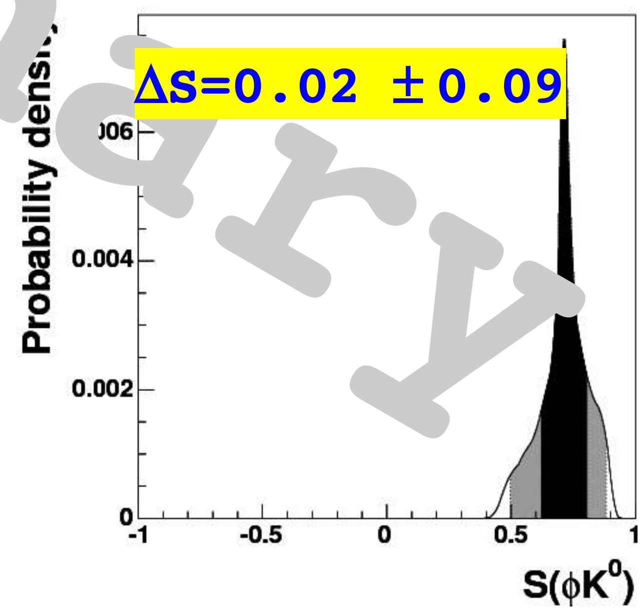



Including the errors, deviations are ≤10% level



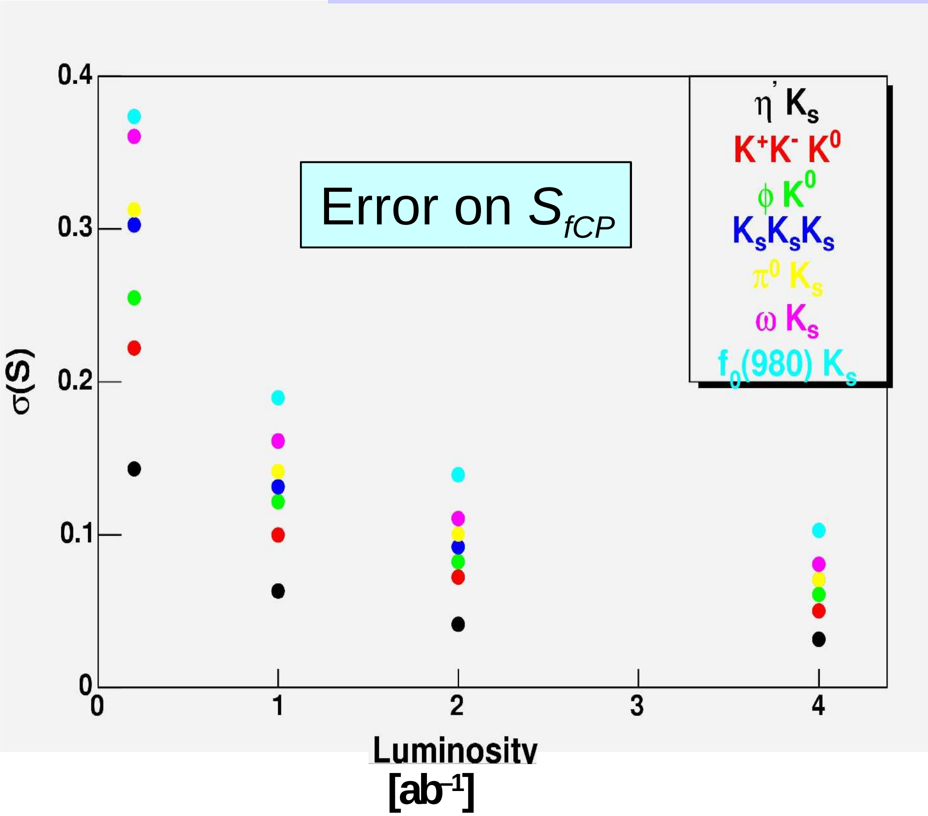



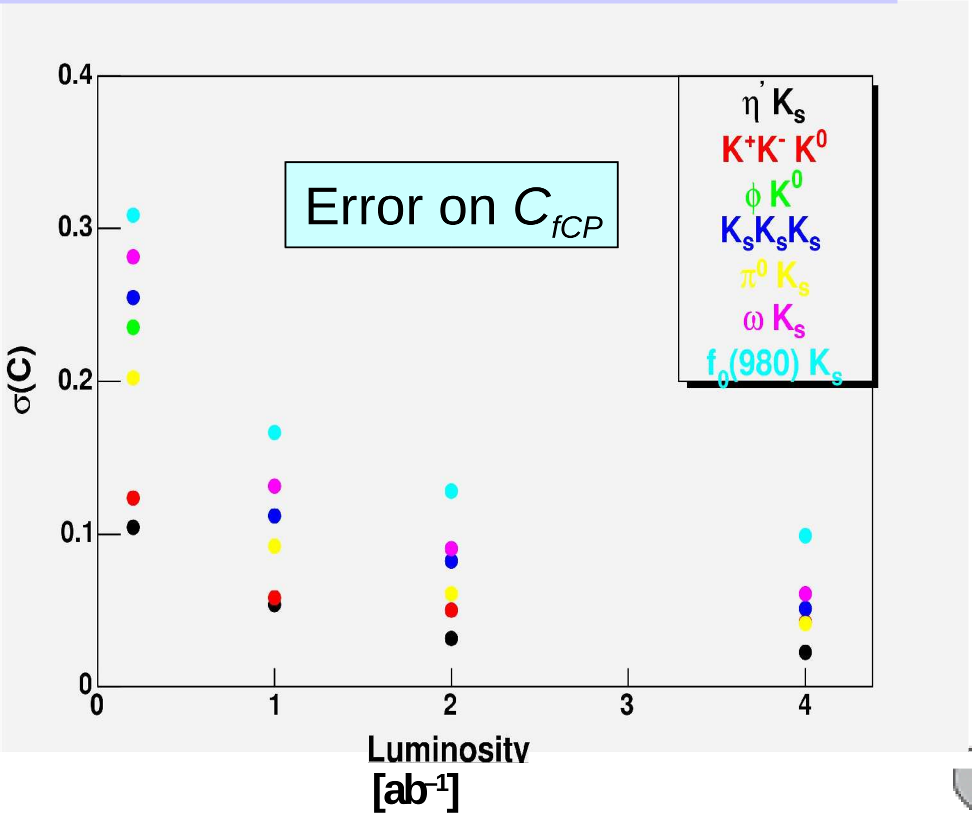
# S error vs. luminosity

Expect >2 $ab^{-1}$ dataset from combined B Factories by end 2008

⇒ ~0.1 errors on $S_{fCP}$ and $C_{fCP}$ from individual $b\to s\bar{s}s$, $q\bar{q}s$ modes

⇒ potential to discover significant deviation from $b\to c\bar{c}s$ modes



# SUSY Mass Insertions

$$\begin{pmatrix} m_{11} & m_{21} & m_{31} \\ m_{12} & m_{22} & m_{32} \\ m_{13} & m_{23} & m_{33} \end{pmatrix} \rightarrow \begin{pmatrix} m_d & 0 & 0 \\ 0 & m_s & 0 \\ 0 & 0 & m_b \end{pmatrix}$$

quark rotation ( generating CKM matrix)

$$\begin{pmatrix} \tilde{m}^2_{11} & \tilde{m}^2_{21} & \tilde{m}^2_{31} \\ \tilde{m}^2_{12} & \tilde{m}^2_{22} & \tilde{m}^2_{32} \\ \tilde{m}^2_{13} & \tilde{m}^2_{23} & \tilde{m}^2_{33} \end{pmatrix}_{AB} \rightarrow \begin{pmatrix} m^2_{\tilde{d}} & 0 & 0 \\ 0 & m^2_{\tilde{s}} & 0 \\ 0 & 0 & m^2_{\tilde{b}} \end{pmatrix}_{AB} + m^2_{\tilde{q}} \begin{pmatrix} 0 & \delta^{*BA}_{12} & \delta^{*BA}_{13} \\ \delta^{AB}_{12} & 0 & \delta^{*BA}_{23} \\ \delta^{AB}_{13} & \delta^{AB}_{23} & 0 \end{pmatrix}$$

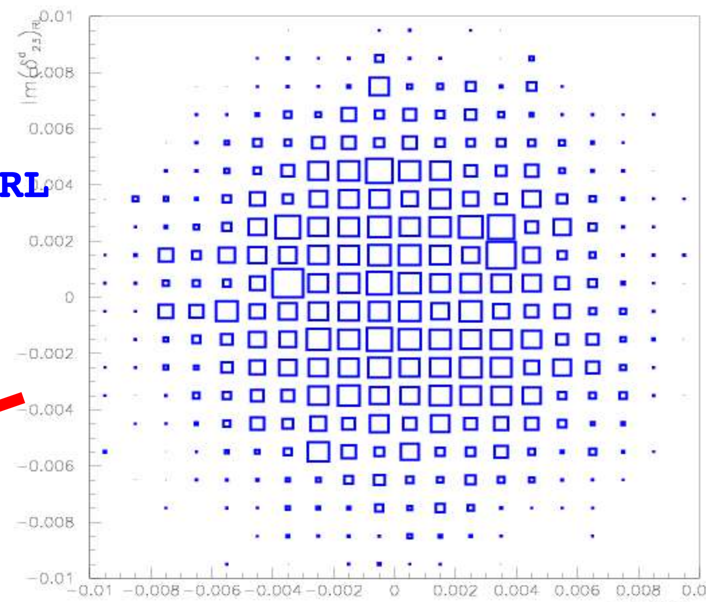
average squark mass

chirality of incoming and outgoing squark (**LL,LR,RL,RR**)

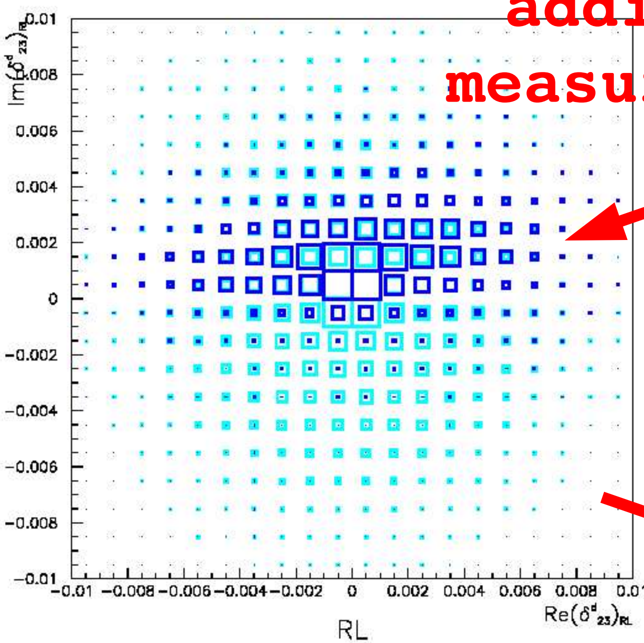
**Effective interaction (mass insertion) between second and third family**

# And how $A_{CP}$ will help

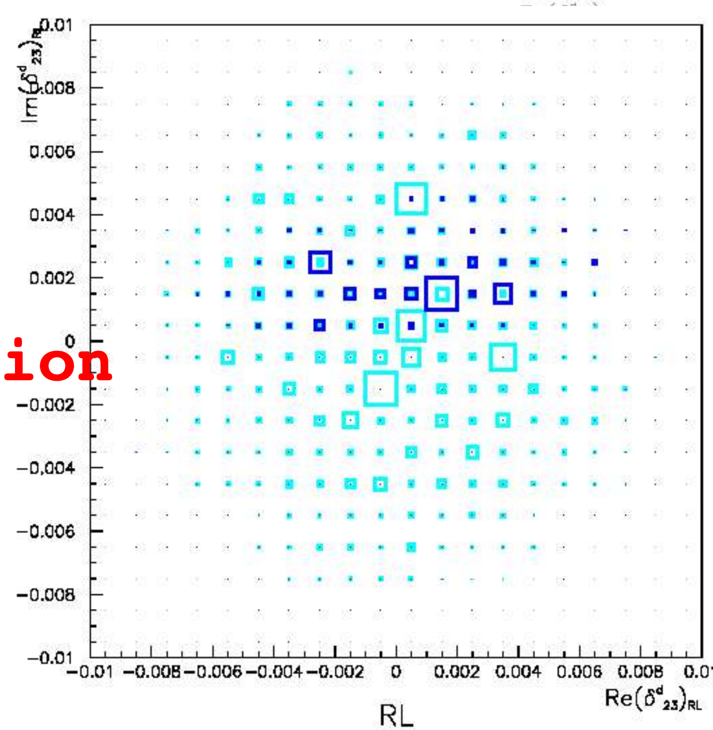
## $Re(\delta^d_{23})_{RL}$ vs $Im(\delta^d_{23})_{RL}$




adding S measurements




extrapolation to 2008




No b→s time dep.
With b→s time dep.

# Testing b→s: Polarization in B→VV

Large amount of experimental information:

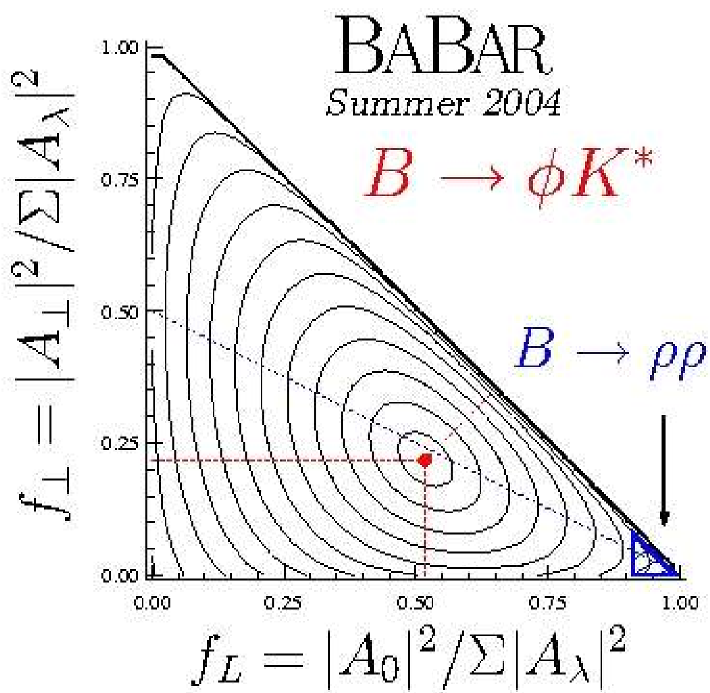
- BR and $A_{CP}$ for different polarizations
- Polarization fractions
- Triple products (~cos of strong phase rather than sin)

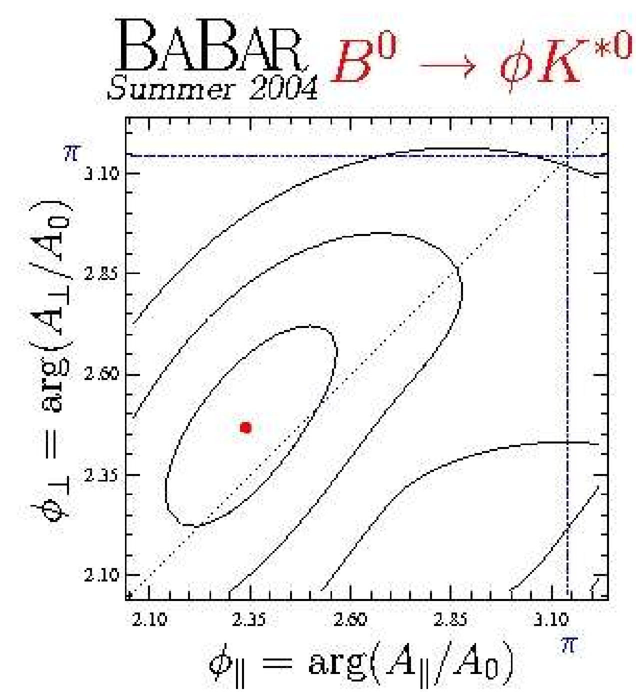
- Observe $|A_0|$, $|A_\perp|$, $|A_\parallel|$ $>5\sigma$ each

$$f_L = 0.52 \pm 0.05 \pm 0.02$$
$$f_\perp = 0.22 \pm 0.05 \pm 0.02$$

- Observe FSI $>3\sigma$

$$\phi_\parallel = 2.34\ ^{+0.23}_{-0.20} \pm 0.05\ \text{(rad)}$$
$$\phi_\perp = 2.47 \pm 0.25 \pm 0.05\ \text{(rad)}$$

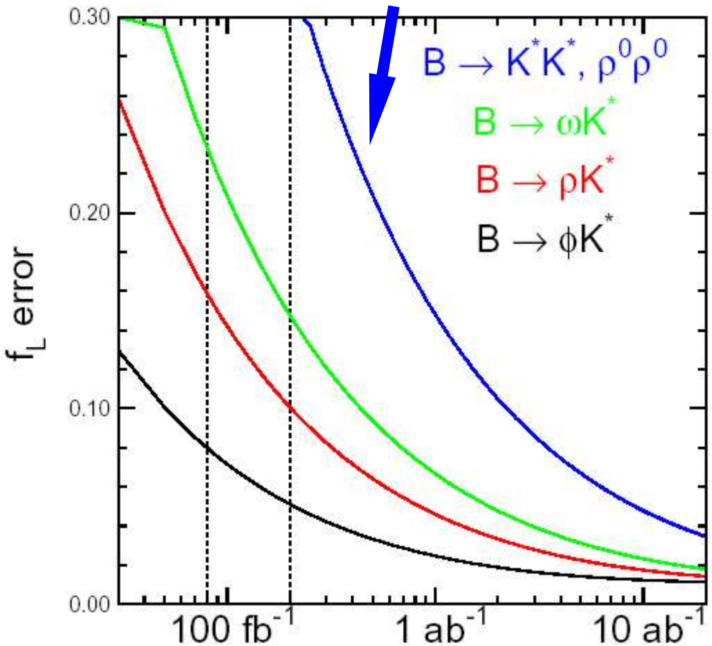


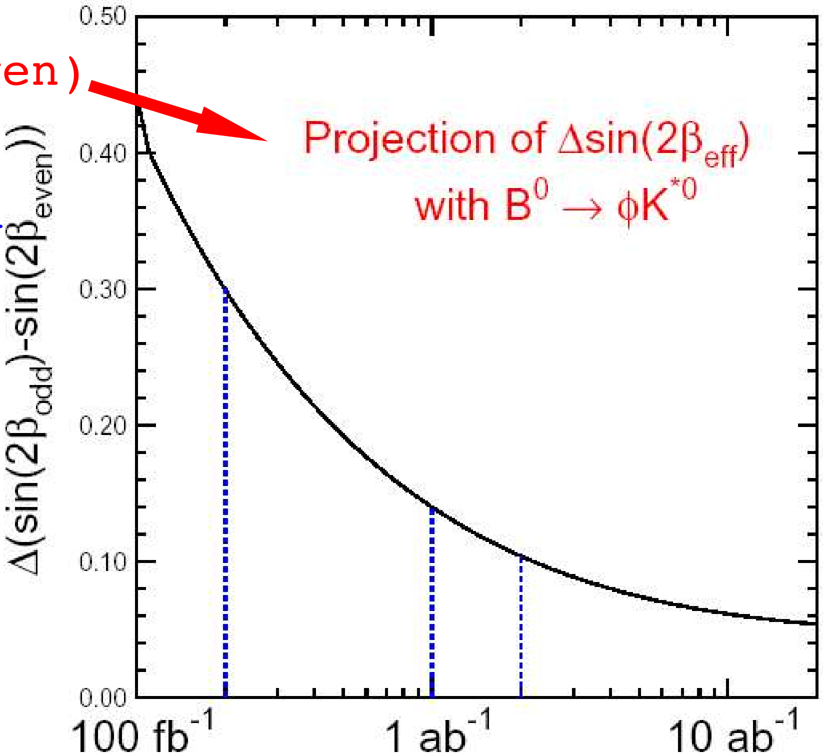



# Improvement of B→VV Decays

Improving the precision:

- Theoretically clean access to phases
  - Measure $\Delta S = \sin 2\beta(odd) - \sin 2\beta(even)$
- Triple-product asymmetries
  - Able to separate right handed currents (which are null in SM)



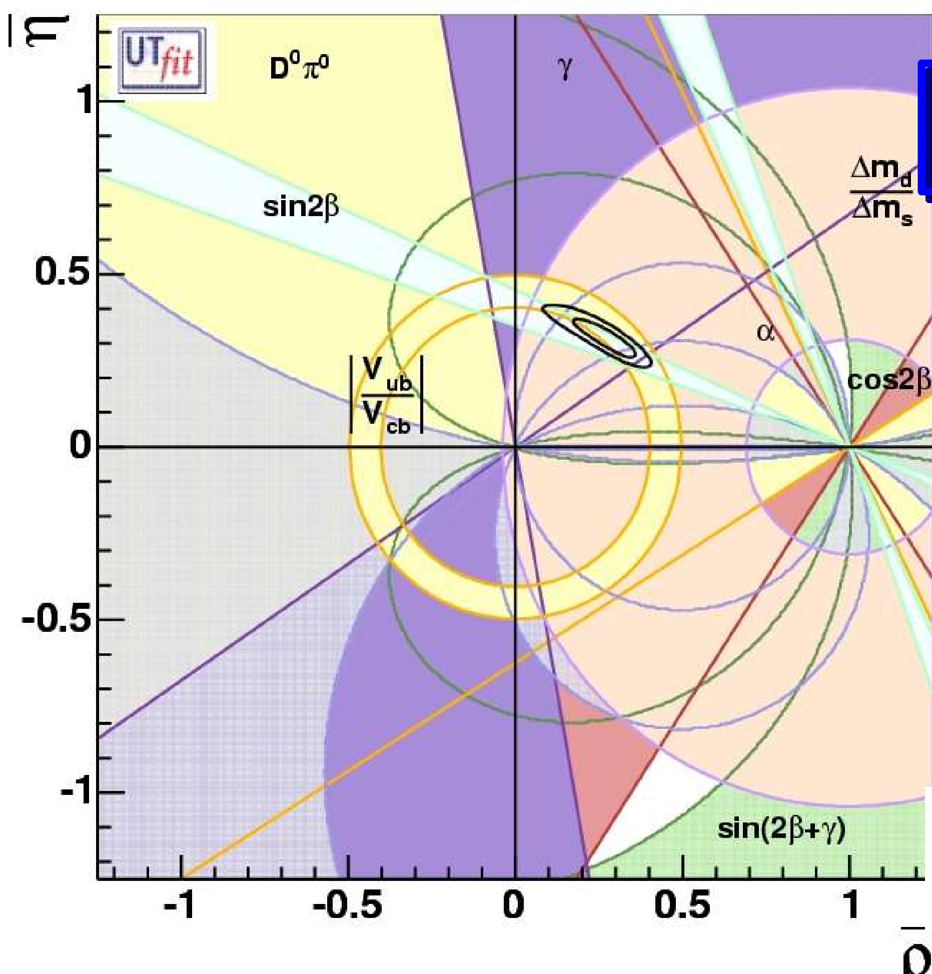



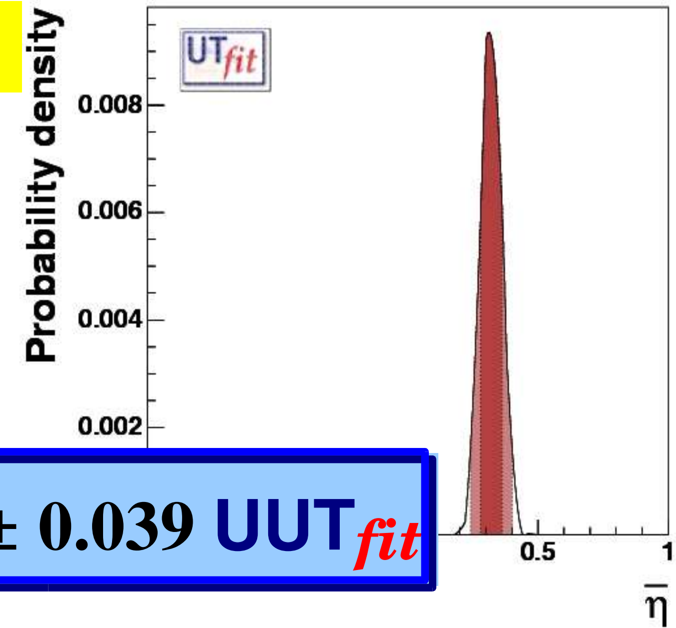
# Second Case: New Physics is Minimal Flavor Violating in the b→d sector. No additional CP violation

# The Starting Point

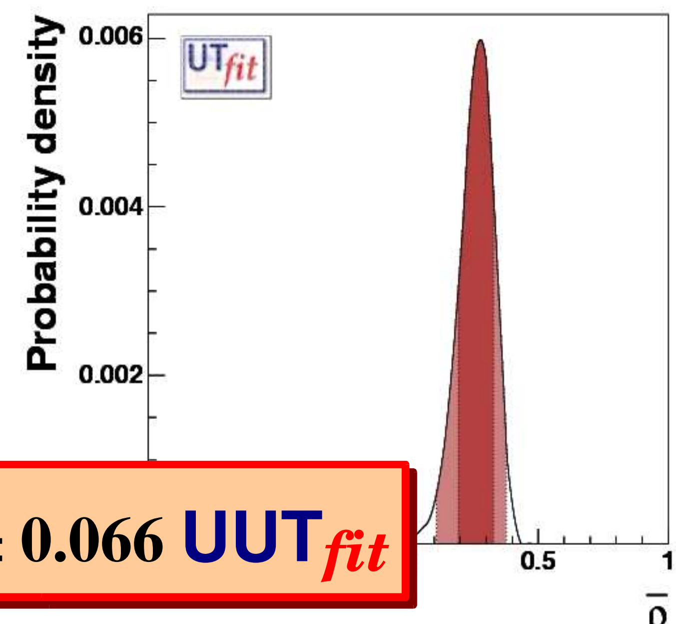
**Buras et al. hep-ph/0007085**

**We can determine $\bar{\rho}$ and $\bar{\eta}$ in a universal way for (MFV) NP and SM.**
**$\varepsilon_K$ and $\Delta m_d$ are not used.**




$\bar{\eta} = 0.319 \pm 0.039$ UUT$_{fit}$




$\bar{\rho} = 0.258 \pm 0.066$ UUT$_{fit}$

# From UT to Rare decays

Starting from **UUT** it is possible to constrain NP quantities and to study their effect on rare B and K decays

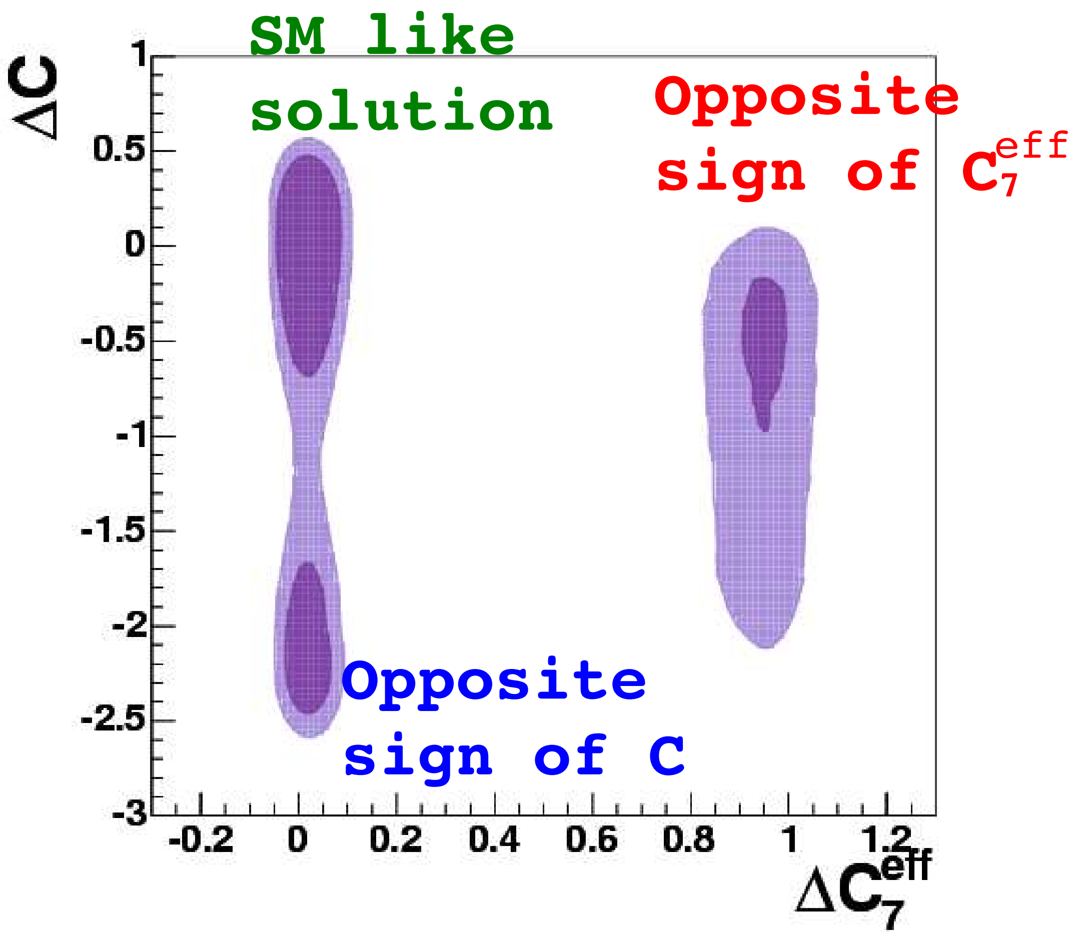
- Dimension 4 operators: FCNC effective Z vertex
  $\Rightarrow$ $C=C_{SM}+\Delta C$ (constrained by $BR(B\rightarrow X_s l^+ l^-)$ and $BR(K^+\rightarrow \pi^+ \nu\nu)$)

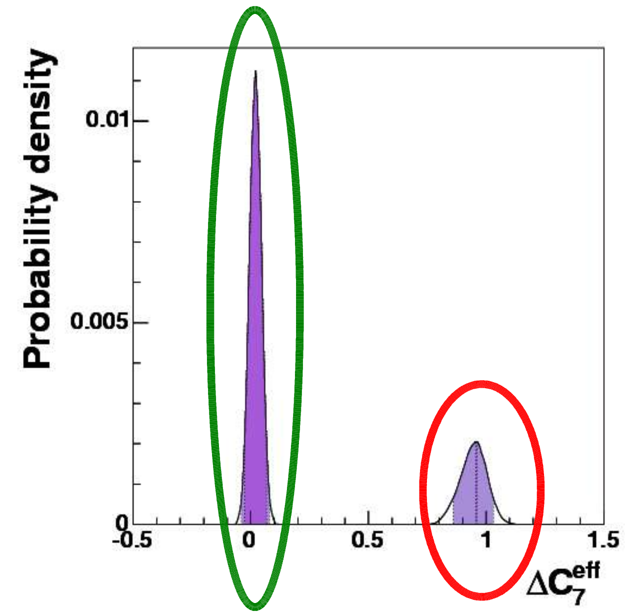
- Dimension 5 operators: (chromo)magnetic penguin
  $\Rightarrow$ $C_7^{eff}=(C_7^{eff})_{SM}+\Delta C_7^{eff}$ (constrained by $BR(B\rightarrow X_s\gamma)$)

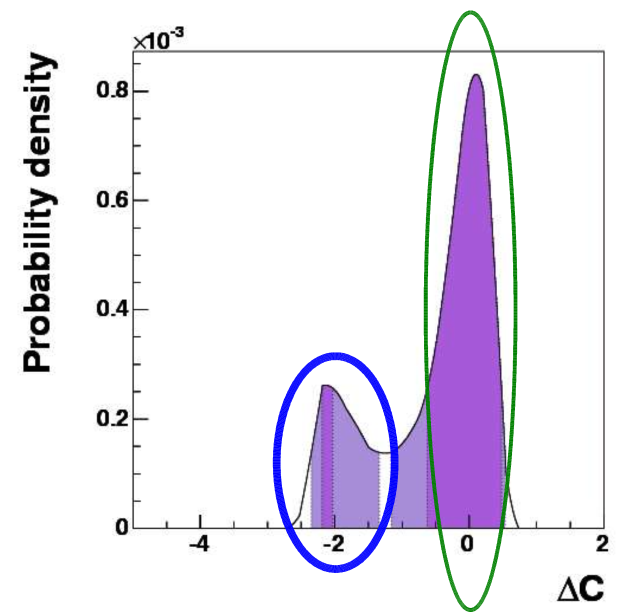
- Dimension 6 operators: penguins, boxes
  $\Rightarrow$ subleading NP contributions to rare decays

Rare decays $\Leftrightarrow$ SM functions + $\Delta C$, $\Delta C_7^{eff}$

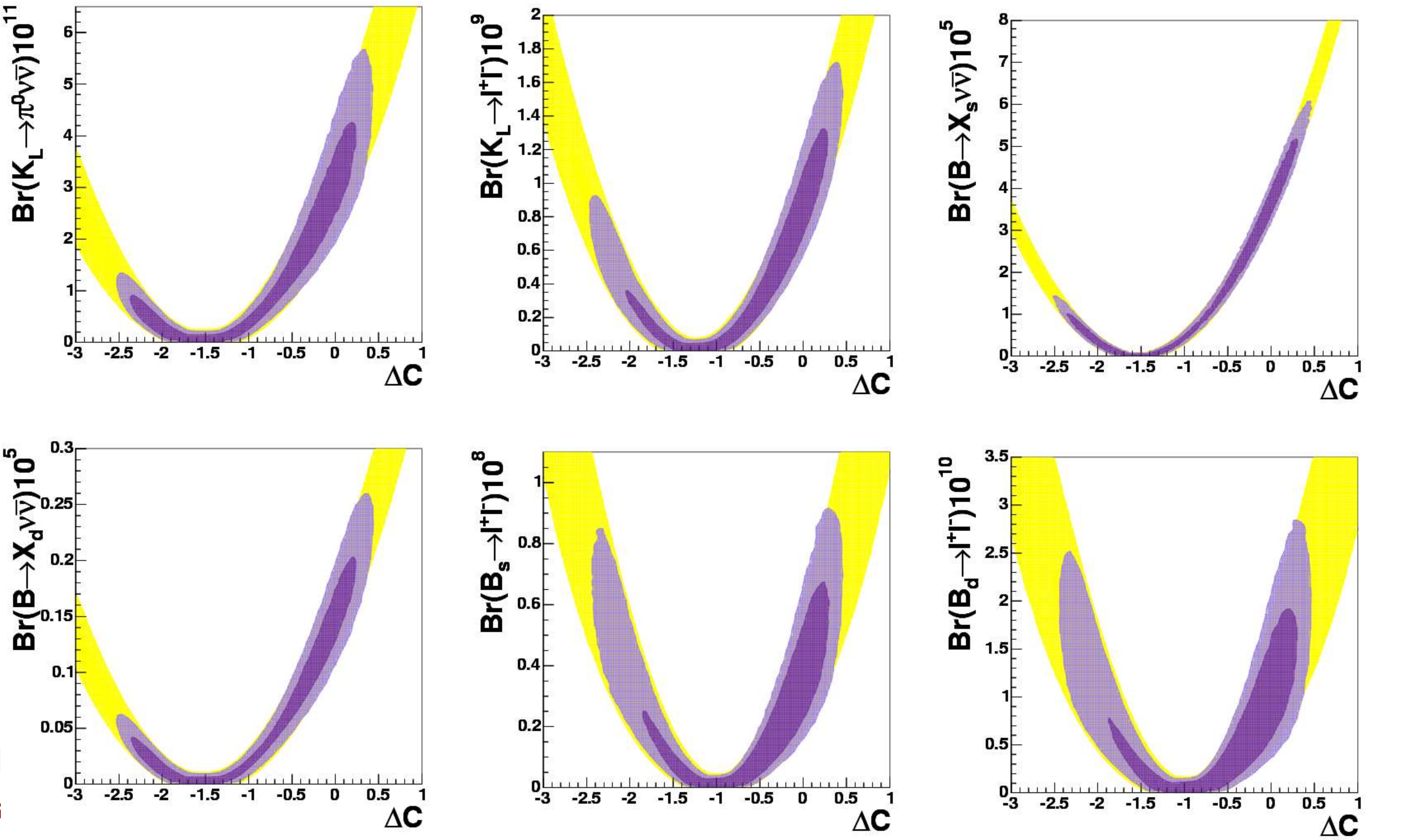
# Constraint on NP contributions



# Predictions for Rare K and B Decays



# The Lesson from MFV

In MFV models (at low/moderate tanβ) rare decays can be only slightly enhanced w.r.t the SM. Strong suppressions still possible at present.

| Branching Ratios | MFV (95%) | SM (68%) | SM (95%) | exp |
|---|---|---|---|---|
| $Br(K^+ \to \pi^+ \nu\bar{\nu}) \times 10^{11}$ | $< 11.9$ | $8.3 \pm 1.2$ | $[6.1, 10.9]$ | $(14.7^{+13.0}_{-8.9})$ [19] |
| $Br(K_L \to \pi^0 \nu\bar{\nu}) \times 10^{11}$ | $< 4.59$ | $3.08 \pm 0.56$ | $[2.03, 4.26]$ | $< 5.9 \cdot 10^4$ [37] |
| $Br(K_L \to \mu^+\mu^-)_{SD} \times 10^9$ | $< 1.36$ | $0.87 \pm 0.13$ | $[0.63, 1.15]$ | - |
| $Br(B \to X_s \nu\bar{\nu}) \times 10^5$ | $< 5.17$ | $3.66 \pm 0.21$ | $[3.25, 4.09]$ | $< 64$ [38] |
| $Br(B \to X_d \nu\bar{\nu}) \times 10^6$ | $< 2.17$ | $1.50 \pm 0.19$ | $[1.12, 1.91]$ | - |
| $Br(B_s \to \mu^+\mu^-) \times 10^9$ | $< 7.42$ | $3.67 \pm 1.01$ | $[1.91, 5.91]$ | $< 2.7 \cdot 10^2$ [39] |
| $Br(B_d \to \mu^+\mu^-) \times 10^{10}$ | $< 2.20$ | $1.04 \pm 0.34$ | $[0.47, 1.81]$ | $< 1.5 \cdot 10^3$ [39] |

**If this is the case, we need very high statistics**

# Where we stand

## *Expected Upper Limits*

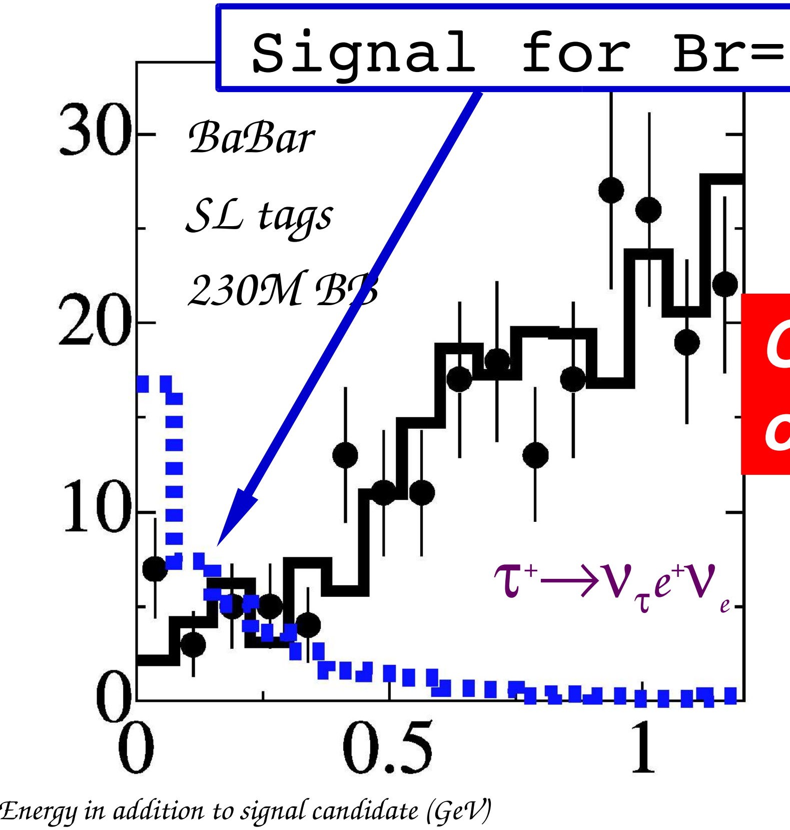
| *Mode* | $BR_{SM}$ | $BR_{NP}$ | $0.5ab^{-1}$ | $1ab^{-1}$ | $2ab^{-1}$ |
|---|---|---|---|---|---|
| $B \to Xll$ | $\sim 10^{-6}$ | $\sigma(A_{CP})$ | 16% | 11% | 8% |
| $B \to Kll$ | $\sim 10^{-6}$ | Up to $10^{-5}$ | $610^{-5}$ | $410^{-5}$ | $310^{-5}$ |
| $D \to Xll$ | $\sim 10^{-6}$ | Up to $10^{-5}$ | $\sim 10^{-5}$ | ? | ? |
| $B \to ll$ | $<10^{-11}$ | Up to $10^{-5}$ | $310^{-8}$ | $210^{-8}$ | $10^{-8}$ |
| $D \to ll$ | $<10^{-9}$ | Up to $10^{-6}$ | $310^{-7}$ | $210^{-7}$ | $10^{-7}$ |

**If NP cancels the SM contribution, we need a large increase of statistics to have useful bounds on NP**

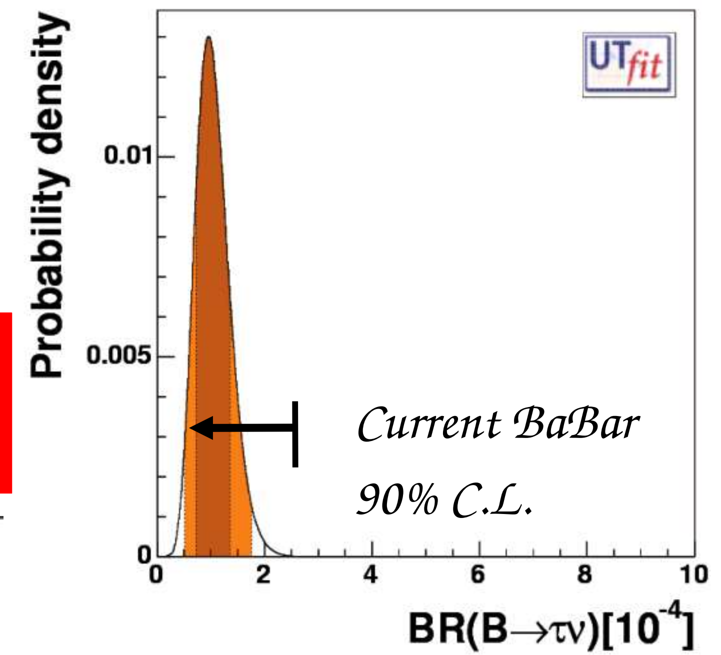
# The Next Step: $B \to \tau\nu$

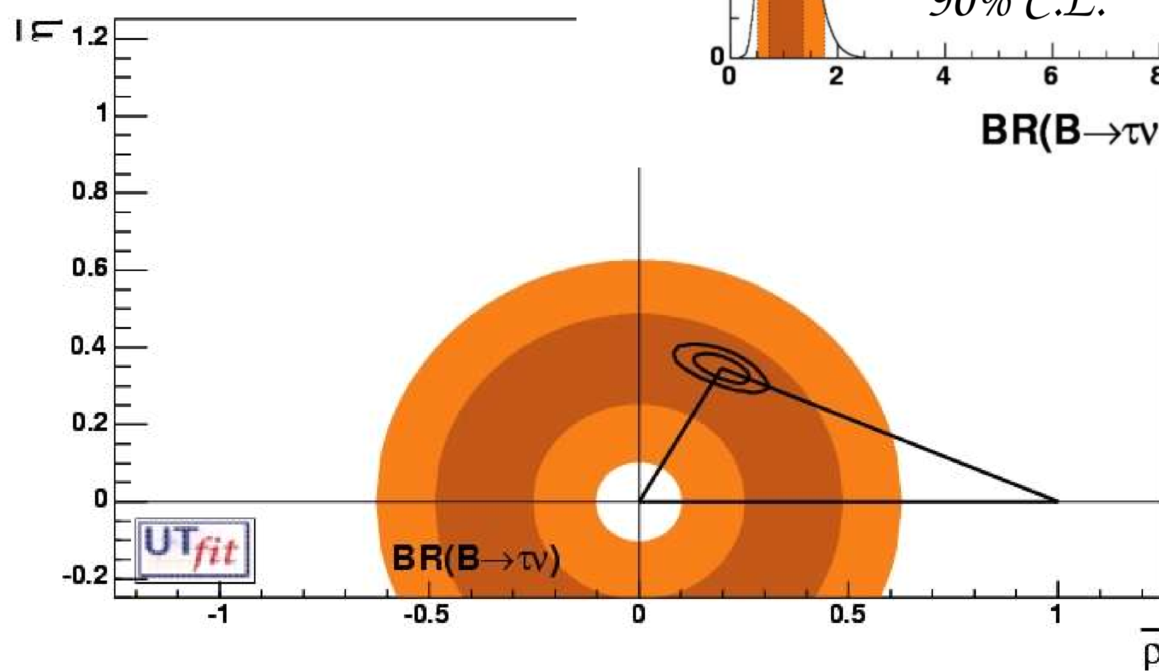
$$\mathcal{B}(B \to \ell\nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

**$< 1.8\ 10^{-4}$ @ 90% CL**




***Close to discovery of the mode or of NP***



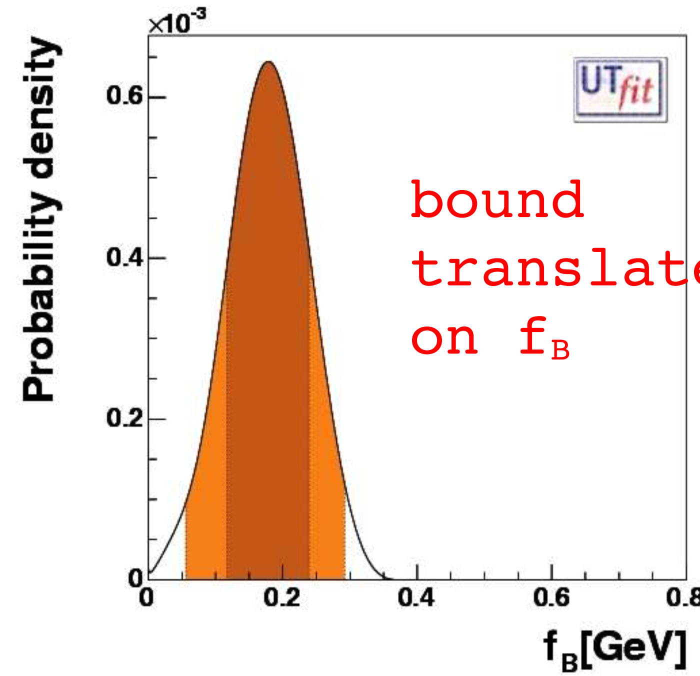



# What can happen

If we measure it, in agreement with the Standard Model, we will have an experimental way to extract $f_B$

- Test of the Lattice
- Improvement of the ($f_B$ dominates the spread of $\Delta m_d$ bound)

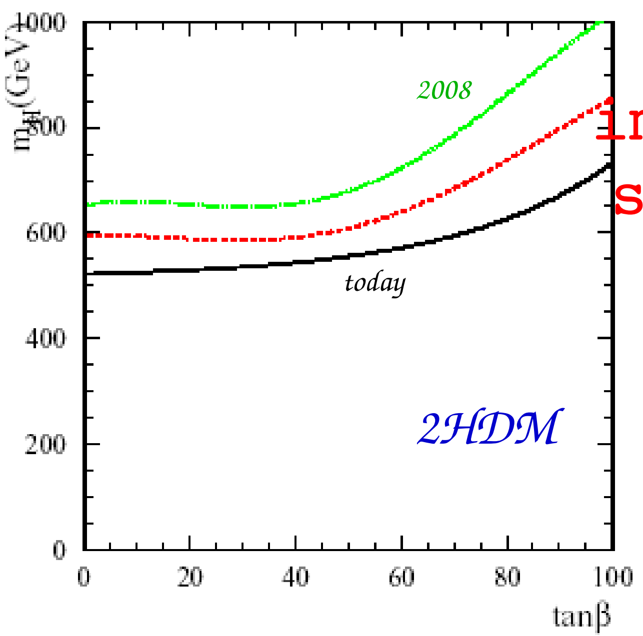
If we don't see it, we have evidence of new Physics and a constraint on models




bound translated on $f_B$

$f_{Bd} = 0.178 \pm 0.062$ GeV

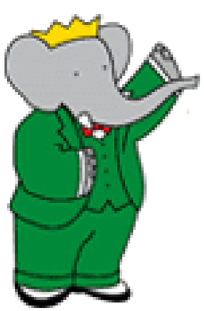
$f_{Bd} = 0.192 \pm 0.026 \pm 0.009$ GeV from lattice QCD




Example of impact on Higgs sector in 2DHM model

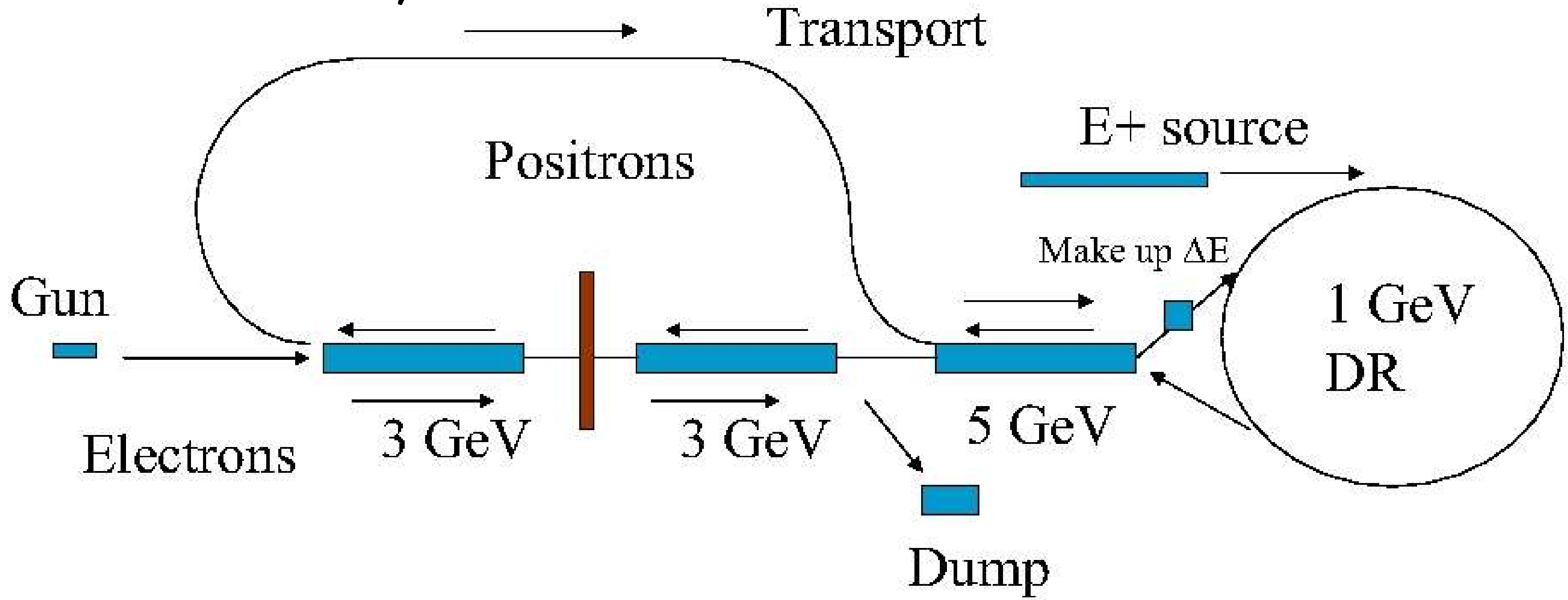
# Conclusion?

- The B-factories are in the era of high precision measurements
- With ~1$ab^{-1}$ in 2008, BaBar will test CKM mechanism and the presence of NP in a more stringent way (~0.1 for S and C, ~10°-15° for $\alpha$ from $\rho\rho$ alone and ~5°-10° for $\gamma$)
- Even in the case of small deviations, we will obtain very useful information from the combination of constraints from several decay modes
- We can also help theorists to improve the models and reduce the theoretical errors, by providing a large set of precise measurements on similar channels (BR and CP asymmetries)
- We can use additional ways to test $b \to s$ decays, such as $B \to VV$ modes
- But if we want to scan all the possibilities, we need a new generation of experiment **(i.e. this is not the conclusion)**



# A new design for a Super B-factory

Using the present technology and the R&D for the ILC, we have a new kind of machine to build




A small version of the ILC that runs at the Υ(4s), with a reduced boost (bg~0.1-0.2) and a better vertex resolution (thanks to smaller beam-spot and limited multiple scattering).

- We can have luminosity as large as $\sim 10^{37}$ (now it is $\sim 10^{34}$)
- We will have a poor knowledge of the energy of the initial state (not a big deal...)

# Luminosity

The luminosity for a linear collider is:

$L = Hd\ Np\ P / 4\pi E\ \sigma_x \sigma_y$

Hd : disruption enhancement

P : average beam power

## Scaling laws

- Disruption:

$$D \approx \frac{N\sigma_z}{(\sigma_x \sigma_y)}$$

Decrease $\sigma_z$ + decrease N
Increase spotsize

- Luminosity

$$L \approx \frac{N^2}{(\sigma_x \sigma_y)}$$

Increase N
Decrease spotsize

Contraddicting requests!

- Energy spread:

$$\delta_E \approx \frac{N^2}{(\sigma_x^2 \sigma_z)}$$

Increase $\sigma_z$ + decrease N
Increase spotsize

| | Linear B | SuperPeP |
|---|---|---|
| $N_b$ | 24000 | 5000 |
| $f_o$ | 120Hz | 136KHz |
| $\varepsilon_x$ | 0.6nm | 20nm |
| $\varepsilon_y$ | 0.006nm | 1nm |
| $\beta_x$ | 1mm | 100mm |
| $\beta_y$ | 1mm | 3.0mm |
| $\sigma_z$ | 0.7mm | 3.0mm |
| $\sigma_x$ | 0.8um | 45um |
| $\sigma_y$ | 0.08 um | 1.7um |
| $\tau_d$ | 1.4ms | 20ms |
| I+ | 7.2 A | 10 A |
| I- | 7.2 A | 20 A |
| N+ | 4 e10 | 1.3 e11 |
| N- | 4 e10 | 2.6 e11 |
| Hd | 2.3 | 1.0 |
| L | $1.1\ 10^{36}$ | $1.7\ 10^{36}$ |

# Situation is evolving

INFN Super B group

INFN has setup a roadmap program to evaluate future options and commitments in major physics projects.

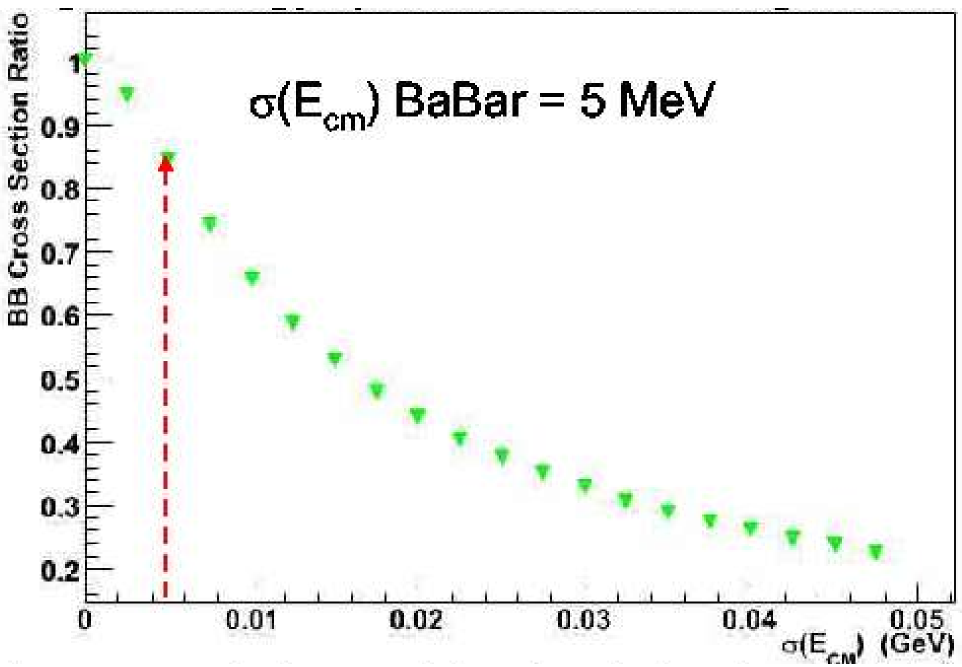
Groups (as a sort of advisory bodies) have been setup to collect informations in a coherent way to be presented to the INFN management.

In the area covered by Gruppo I (Particle Physics with accelerators) a group has been setupto study the possibility of a SuperB Factory in Italy .

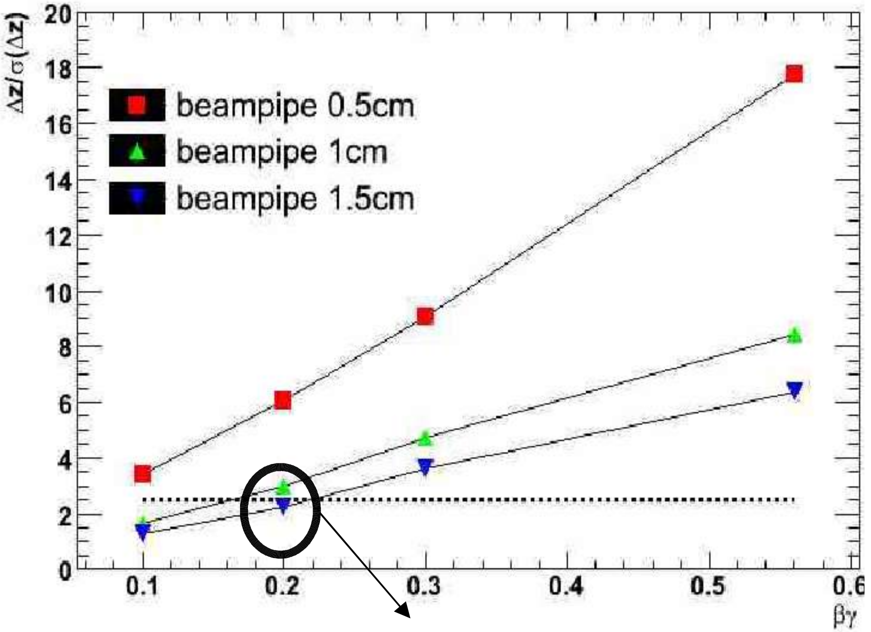
11.11,2005 LNF Marcello A Giorgi Superb

# Effect of Energy spread on analyses

Effective number of events




*Vertex difference resolution vs boost*




even in this situation same
Δz resoultion as now

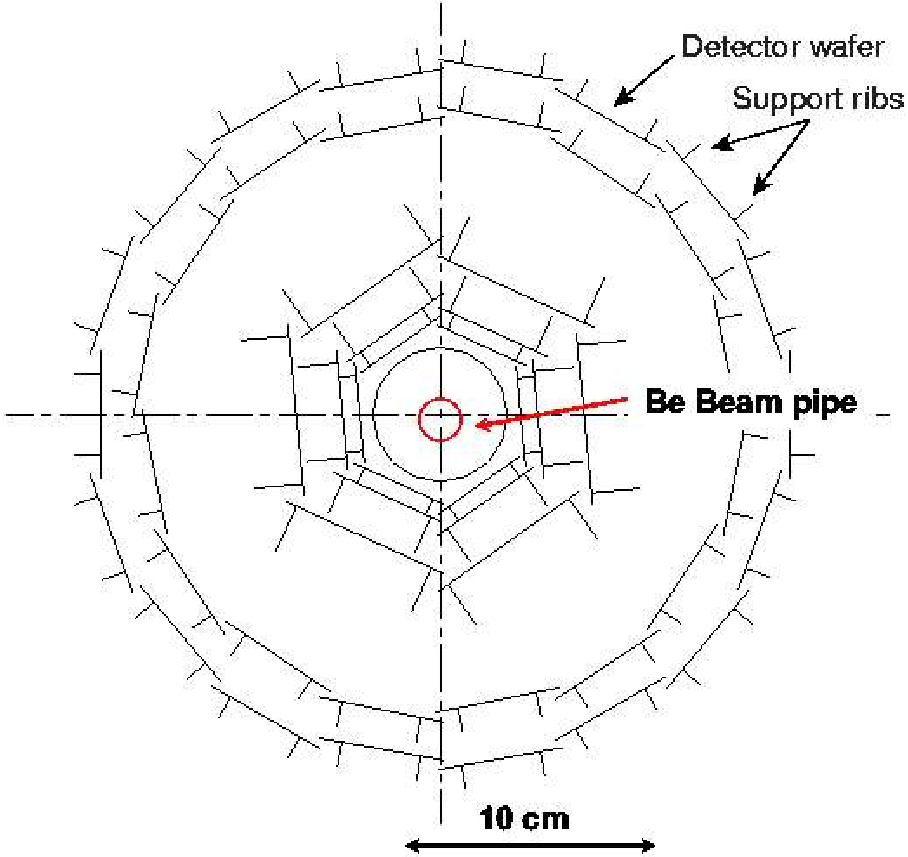
Furthermore

- better angular acceptance: $e^-$=7.0 GeV $e^+$=4.0 GeV $\beta\gamma$=0.28 and for $\theta$=100 (300) mrad correspond to 99% (92%) coverage in the CM. BaBar has 88% coverage.

# SuperB SVT Geometry

ADDED → 0

| Layer | Radius |
|---|---|
| 0 | 1.05 cm |
| 1 | 3.3 cm |
| 2 | 4.0 cm |
| 3 | 5.9 cm |
| 4 | 9.1 to 12.7 cm |
| 5 | 11.4 to 14.6 cm |




(Arched wedge wafers not shown)

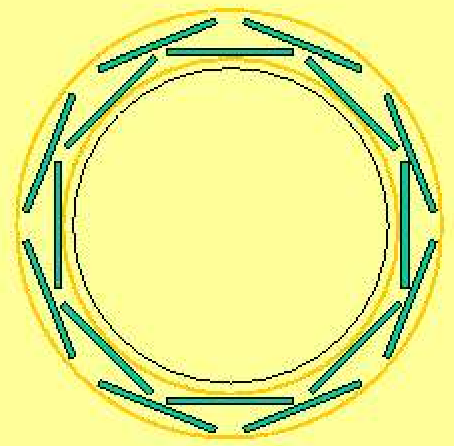
- Added layer0
- Reduced beampipe radius 2.5→1cm
- Reduce Be thickness 1.3→0.3mm
- 5 μm Au foil before layer0

Nicola Neri - SuperB WorkShop

# Pixel concept

Forti

- Monolithic Active Pixels
- Thinned to 50um
  - Possible because active region is only about 10um thick
- With 5mm BP, 3mm2 chip could be OK.
- Glue on kapton foil
- Support kapton off BP
- Reduce thickness of Au shield
  - How much can we thin it ?
- Many issues to resolve
  - Feasibility of a MAPS system
  - z overlap
  - Cables, cooling
  - Mechanical support



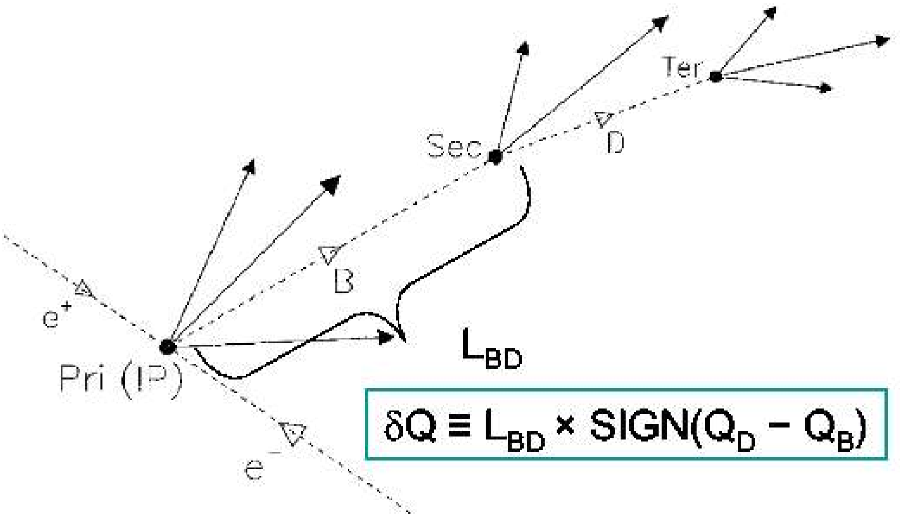
x10 scale with 5mm radius BP, 3mm pixel chip

Lots of MAPS R&D in many places

Nov 12, 2005 WG2 Summary

# Benefits of a better vtx detector

- Better vertex determination not only impacts the time dependent measurements but all the analysis in general.
- The $\Delta z$ helps rejecting continuum uds events.
- One can think about *"ad-hoc"* topological algorithm to further discriminate against combinatorial bkg.
- If you are able to separate the D vertex from the B vertex. You can determine the flavor of the tag B decay from the charge difference between the B and the D.
- SLD tagging "dipole based" ($\delta Q$) technique could be helpful. $\delta Q>0$ ($\delta Q<0$) means B0bar (B0).

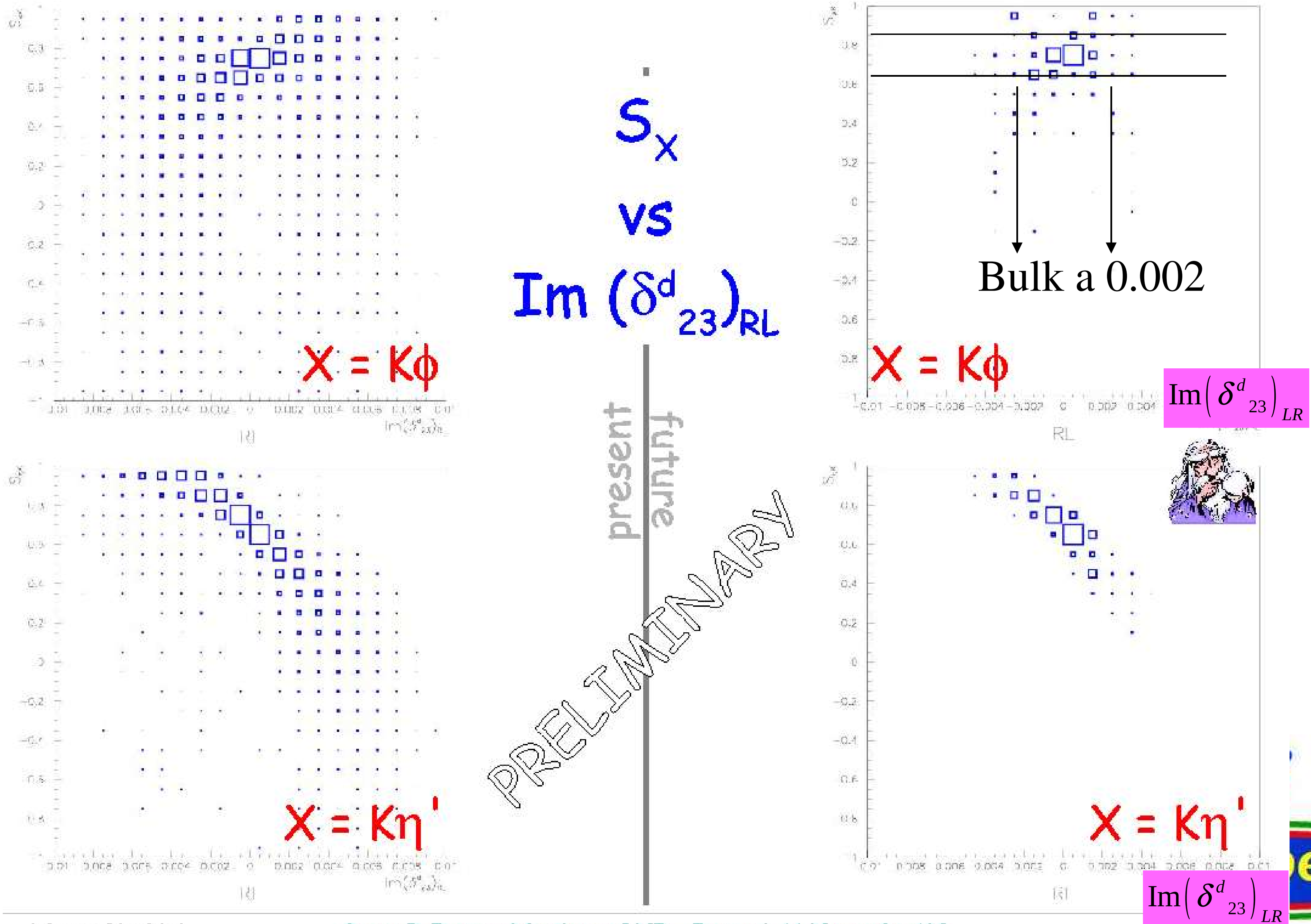



$$\delta Q \equiv L_{BD} \times \mathrm{SIGN}(Q_D - Q_B)$$

- ***REDUCE BKG***
- ***IMPROVE TAGGING PERFORMANCES***

Nicola Neri - SuperB WorkShop

# Impact on SUSY search



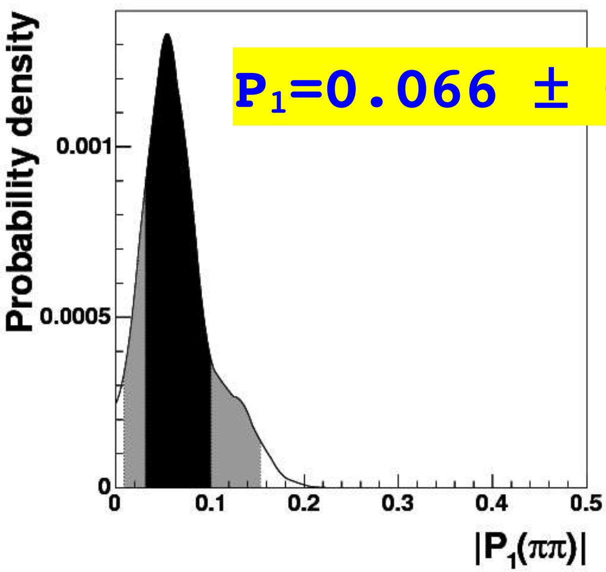
# Maybe the story will continue...

Superb

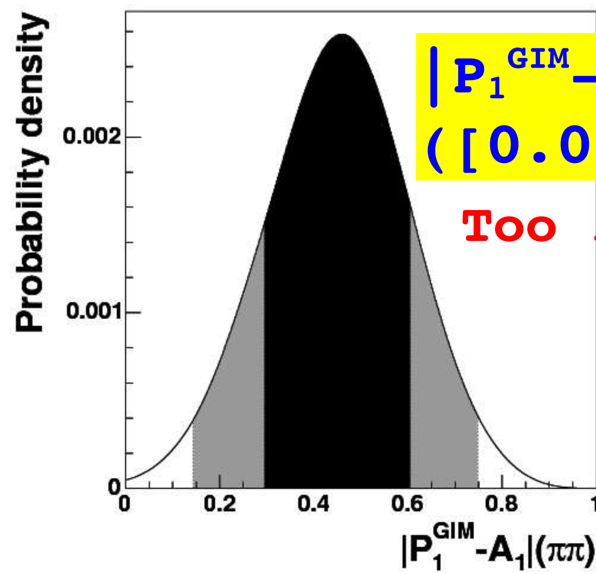
# Backup Slides

# Fit to B→ππ

| Channel | $BR^{th} \times 10^6$ | $BR^{exp} \times 10^6$ | $\mathcal{A}_{CP}^{th}$ | $\mathcal{A}_{CP}^{exp}$ | $\mathcal{S}^{th}$ | $\mathcal{S}^{exp}$ |
|---|---|---|---|---|---|---|
| $\pi^+\pi^-$ | $5.5 \pm 0.4$ | $5.4 \pm 0.4$ | $0.33 \pm 0.11$ | $0.37 \pm 0.10$ | $-0.54 \pm 0.12$ | $-0.50 \pm 0.12$ |
| $\pi^+\pi^0$ | $5.7 \pm 0.6$ | $5.8 \pm 0.6$ | 0 | $0.01 \pm 0.06$ | - | - |
| $\pi^0\pi^0$ | $1.42 \pm 0.29$ | $1.45 \pm 0.29$ | $0.07 \pm 0.24$ | $0.28 \pm 0.39$ | - | - |




**$P_1 = 0.066 \pm 0.035$**




**$|P_1^{GIM} - A_1| = 0.45 \pm 0.15$**
**([0.08,0.90] at 95%)**

**Too large to be $\Lambda_{QCD}/m_b$. Problems with factorization?**

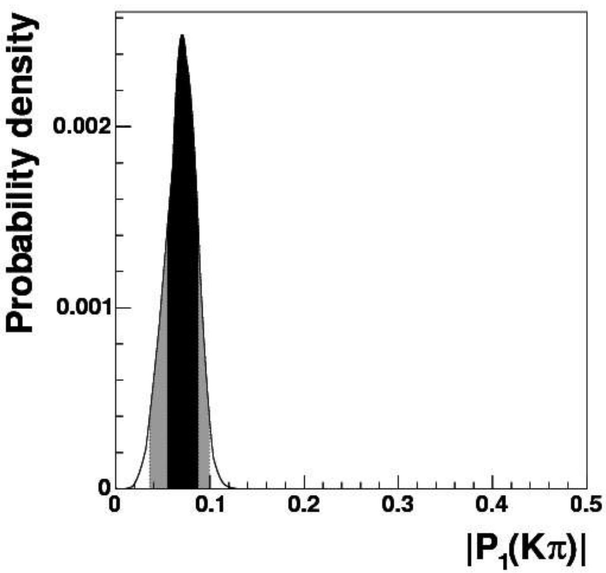
- **Values are given in units of $E_1$**
- We will use **[0.0,0.90]** for the **Kπ fit** (to be conservative)

# Fit to B→Kπ

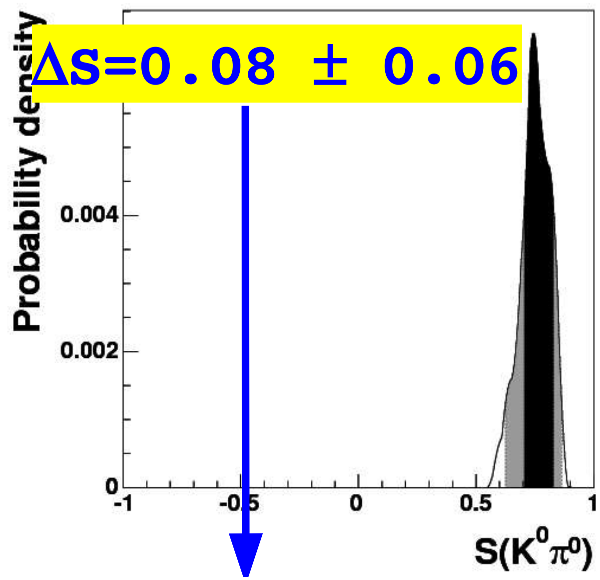


| Channel | $BR^{th} \times 10^6$ | $BR^{exp} \times 10^6$ | $\mathcal{A}_{CP}^{th}$ | $\mathcal{A}_{CP}^{exp}$ |
|---|---|---|---|---|
| $K^+\pi^-$ | $20.1 \pm 0.6$ | $19.7 \pm 0.7$ | $-0.107 \pm 0.018$ | $-0.115 \pm 0.018$ |
| $K^+\pi^0$ | $12.9 \pm 0.5$ | $12.2 \pm 0.8$ | $0.00 \pm 0.04$ | $0.04 \pm 0.04$ |
| $K^0\pi^+$ | $24.9 \pm 1.0$ | $25.3 \pm 1.4$ | $0.00 \pm 0.04$ | $-0.02 \pm 0.02$ |
| $K^0\pi^0$ | $9.9 \pm 0.4$ | $11.5 \pm 1.0$ | $-0.09 \pm 0.06$ | $0.02 \pm 0.13$ |

$P_1 = 0.071 \pm 0.016$




$\Delta S = 0.08 \pm 0.06$




Prediction in the Standard Model (exp error on sin2β not included)

Including the radiative corrections, the discrepancy in the BR is gone. **No more Kπ puzzle!!!!**