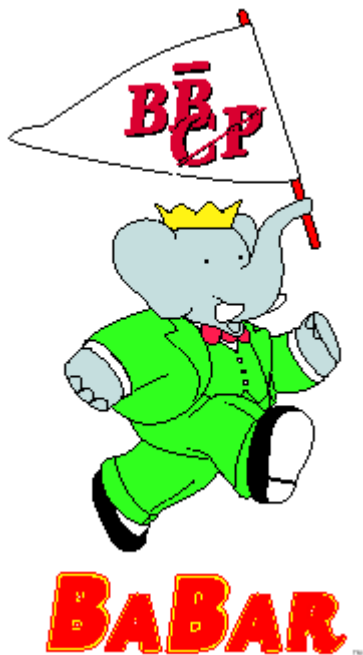


Processi FCNC nei decadimenti del B a BaBar



Emanuele Di Marco

Roma,

12 Novembre 2004

Transizioni $b \rightarrow s$

- Le asimmetrie di CP dipendenti dal tempo
 - $B \rightarrow \phi K^0$, $B \rightarrow K^+ K^- K_S$
 - Nuovi decadimenti $b \rightarrow s$: $B \rightarrow f_0(980) K_S$, $B \rightarrow \eta' K_S$,
 $B^0 \rightarrow K_S \pi^0$, $B^0 \rightarrow K^* \gamma$, $B^0 \rightarrow K_S K_S K_S$
 - Confronto con $\sin 2\beta$ di $b \rightarrow c$
- Asimmetrie dirette di CP in $b \rightarrow s$:
 - $B \rightarrow \phi K^+$, $B \rightarrow \phi K^{*0}(892)$
- Analisi angolare, osservazione di FSI:
 - $B \rightarrow \phi K^{*0}(892)$

Il triangolo unitario

- V_{CKM} unitaria complessa \Rightarrow 3 angoli e 1 fase
- Tutta la ~~CP~~ in SM determinata da δ_{CKM}

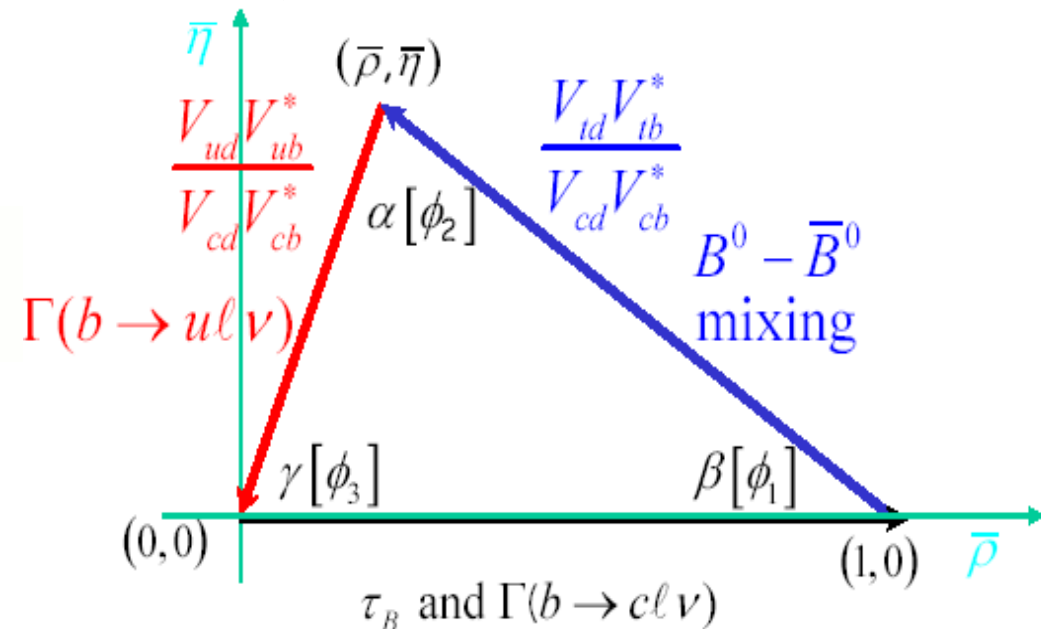
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \simeq \begin{pmatrix} 1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\bar{\rho} - i\bar{\eta}) \\ -\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1 - \bar{\rho} - i\bar{\eta}) & -A\lambda^2 & 1 \end{pmatrix}$$

parametrizzazione di Wolfenstein fino all'ordine λ^3

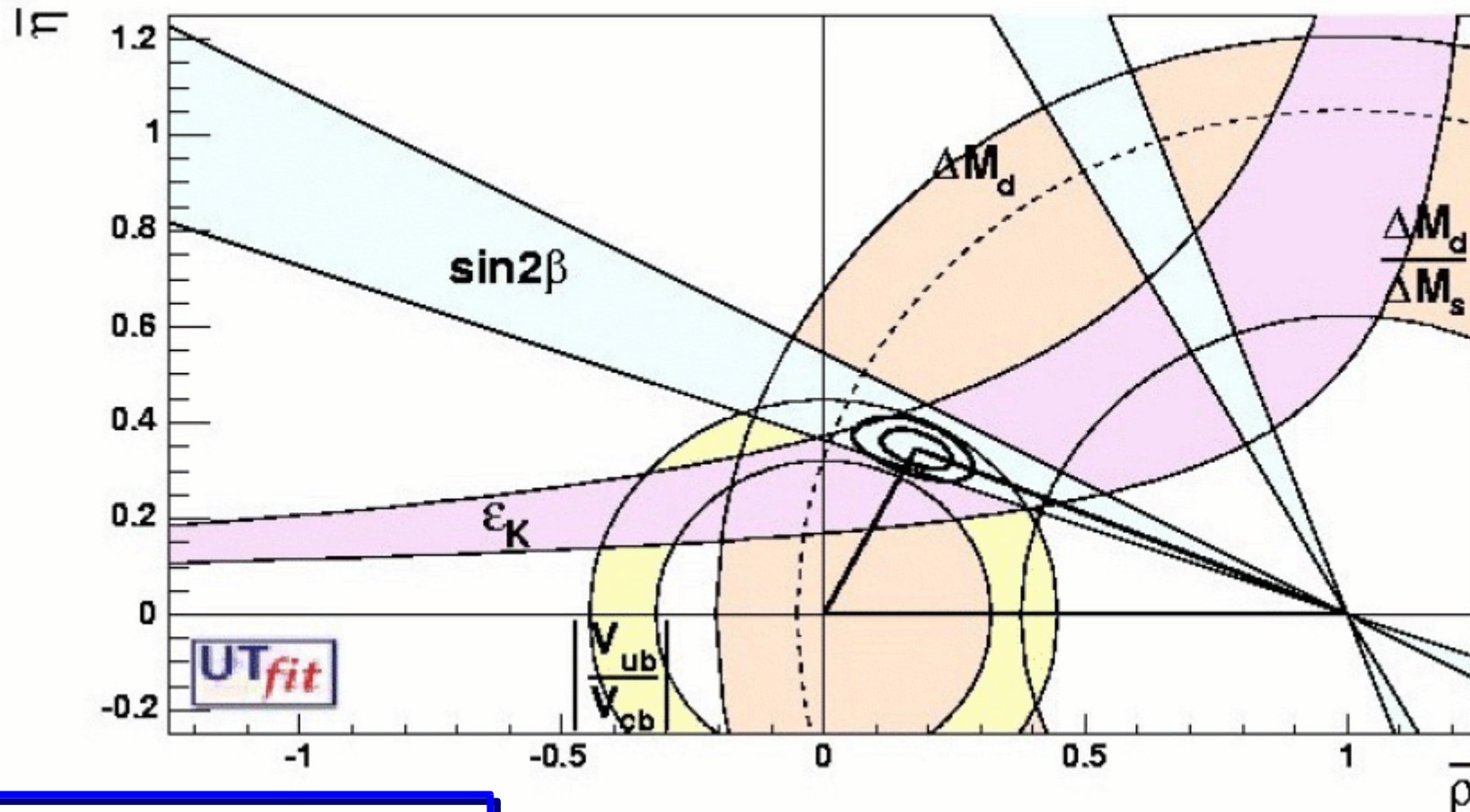
La relazione di unitarieta':

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

$$\begin{array}{ccc} \downarrow & \downarrow & \downarrow \\ \approx \lambda^3 & \approx \lambda^3 & \approx \lambda^3 \end{array}$$



- Vincoli da fisica del B e del K, reticolo.

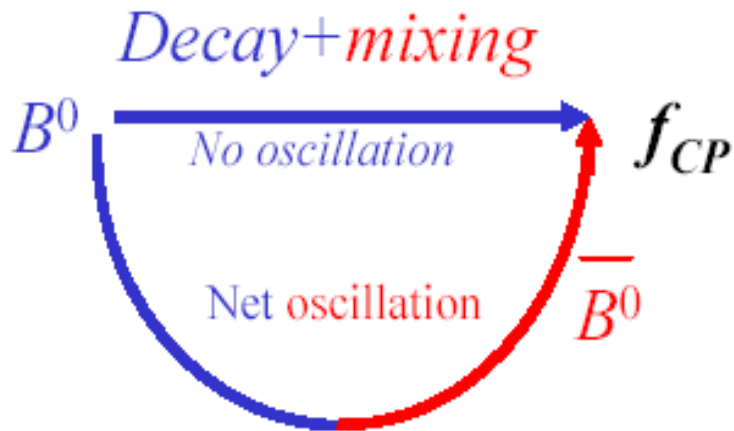


$$\begin{aligned} \bar{\rho} &= 0.172 \pm 0.047 \\ \bar{\eta} &= 0.348 \pm 0.028 \end{aligned}$$

La consistenza di misure CP cons. (lati) e ~~CP~~ (angoli) sono un vincolo forte sul Modello Standard

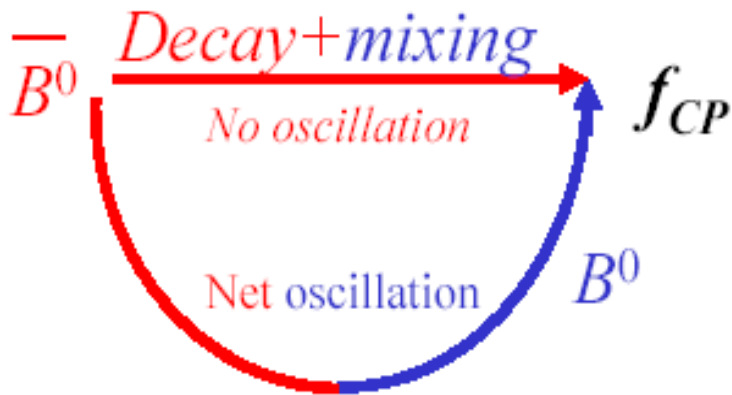
$A_{CP}(t)$: ~~CP~~ "time dependent"

Asimmetria di CP:



$$A_{f_{CP}}(t) = \frac{\Gamma(\bar{B}_{phys}^0(t) \rightarrow f_{CP}) - \Gamma(B_{phys}^0(t) \rightarrow f_{CP})}{\Gamma(B_{phys}^0(t) \rightarrow f_{CP}) + \Gamma(\bar{B}_{phys}^0(t) \rightarrow f_{CP})}$$

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



$$\Gamma(B_{phys}^0(t) \rightarrow f_{CP})$$

\neq

$$\Gamma(\bar{B}_{phys}^0(t) \rightarrow f_{CP})$$

$$\lambda_{f_{CP}} = \frac{q}{p} \frac{\bar{A}_{f_{CP}}}{A_{f_{CP}}} \approx e^{-2i\beta}$$

Amplitude ratio

CP parameter

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

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

For single amplitude
= 0

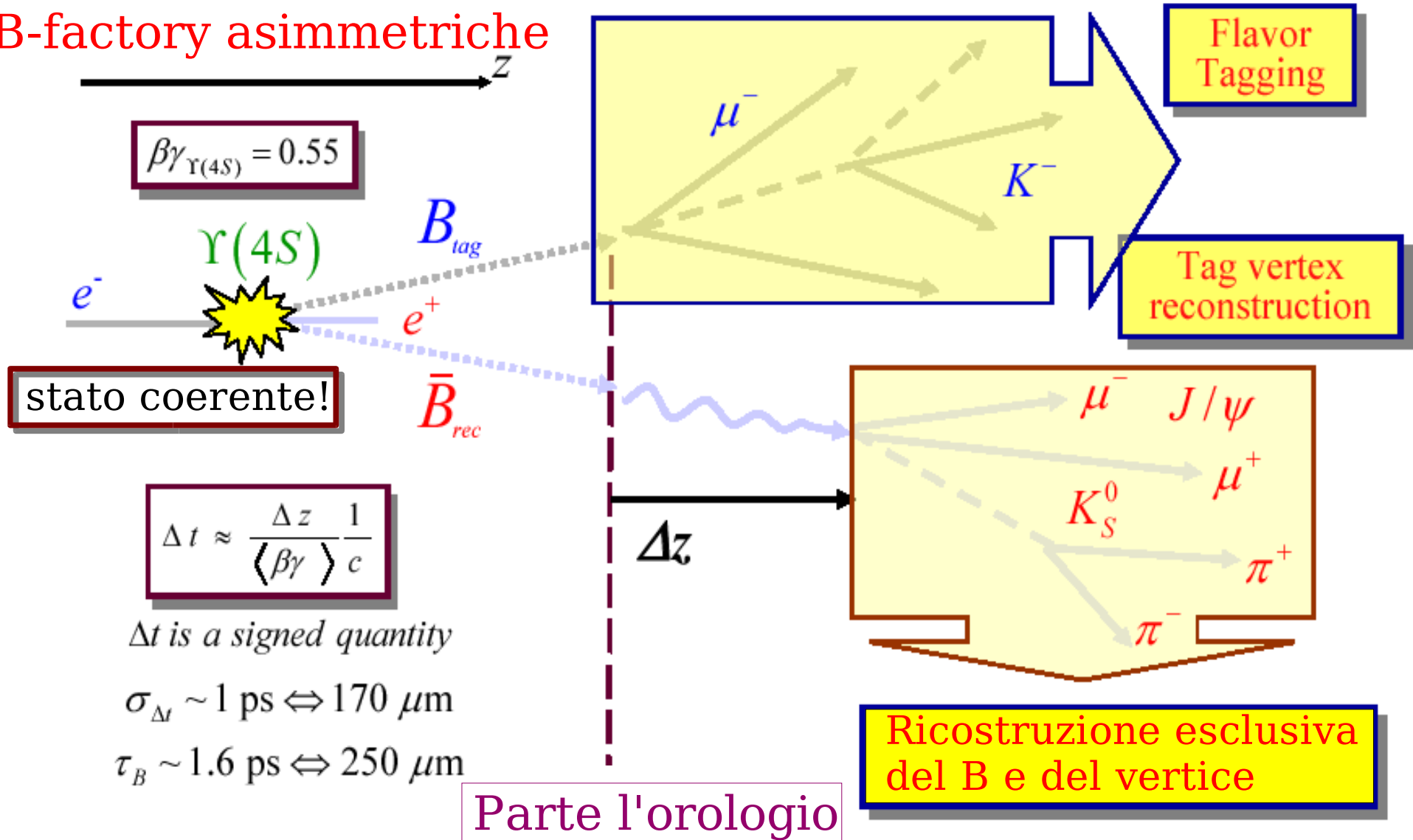
= $-\text{Im} \lambda_{f_{CP}}$

$C_{f_{CP}} \neq 0$ implica CPV diretta

Misura di $A_{CP}(t)$

BaBar – Belle:
B-factory asimmetriche

Tagging performance: $Q=30.5\%$



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

Δt is a signed quantity

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

$$\tau_B \sim 1.6 \text{ ps} \Leftrightarrow 250 \mu\text{m}$$

~~CP~~: $B \rightarrow J/\psi K_S$

- Mixing $\bar{B}_d - B_d$: fase $\Phi_M = 2\beta$
- Pinguino/Albero $\sim A\lambda^2$

$$a_{CP}(t) = C \cos(\Delta m_d t) + S \sin(\Delta m_d t)$$

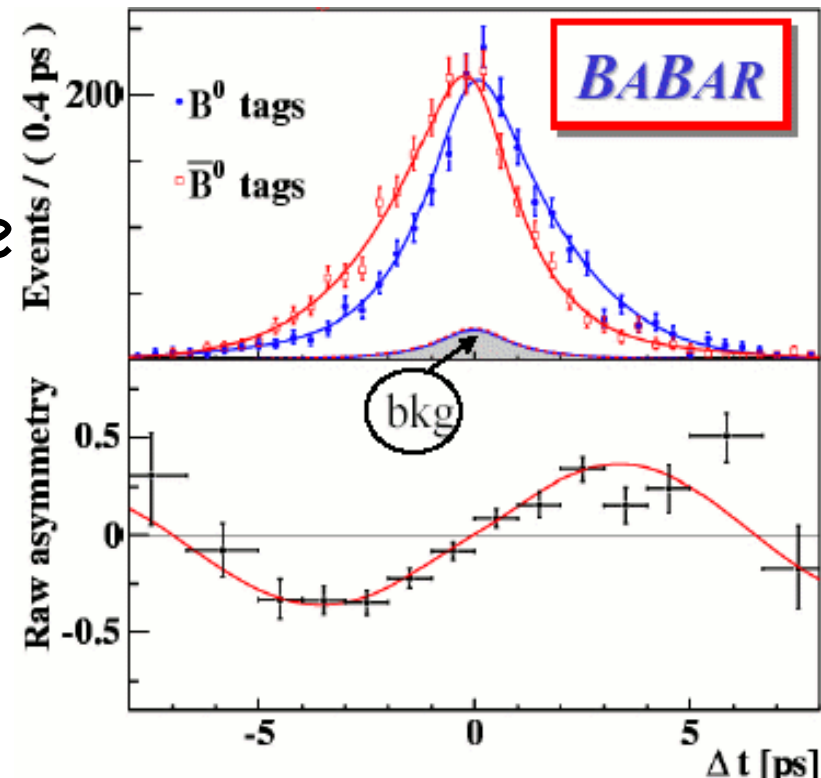
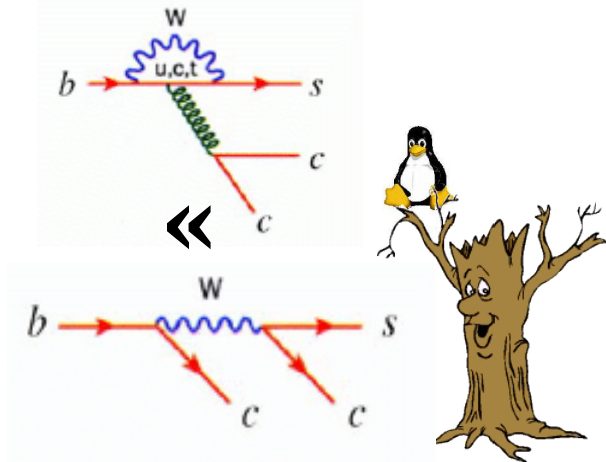
$$= 0$$

$$= \sin(2\beta)$$

- Piccole incertezze adroniche
- Constraint a UT
- BaBar (227×10^6 coppie):

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

$$\sin(2\beta) = 0.726 \pm 0.037$$

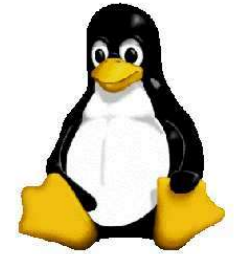
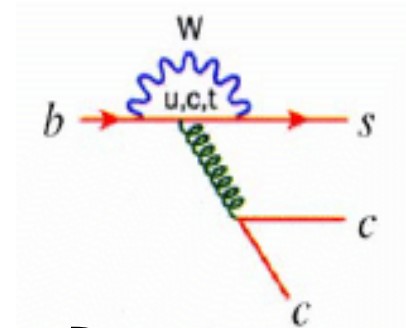


~~CP~~: $b \rightarrow s$

- Mixing $\bar{B}_d - B_d$: fase $\Phi_M = 2\beta$

- Assenza di FCNC nello SM:

- assenza di transizione albero
- decadimento attraverso il loop



} \Rightarrow una sola ampiezza

$$a_{CP}(t) = C \cos(\Delta m_d t) + S \sin(\Delta m_d t)$$

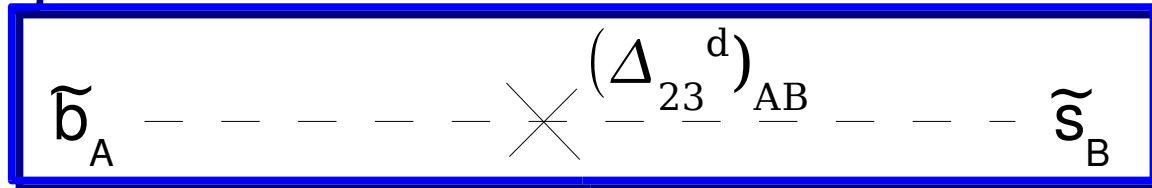
nello SM:
 $C=0$
 $S=\sin(2\beta)$

- Il loop e' sensibile alle masse di eventuali nuove particelle pesanti
- BF e soprattutto A_{CP} sensibili a Nuova Fisica
- Ma le incertezze adroniche nello SM non sono completamente sotto controllo...

Nuova Fisica in $b \rightarrow s$?

- *SUSY* introduce accoppiamenti quark-squark
- M_{squark} in generale:

– non diagonale \Rightarrow inserzioni di massa $((\Delta_{23}^d)_{AB})$:

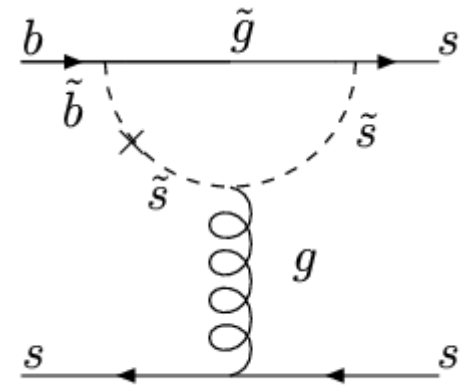


– complessa \Rightarrow nuove fasi (sorgenti di ~~CP~~)

- I contributi di Nuova Fisica sono:

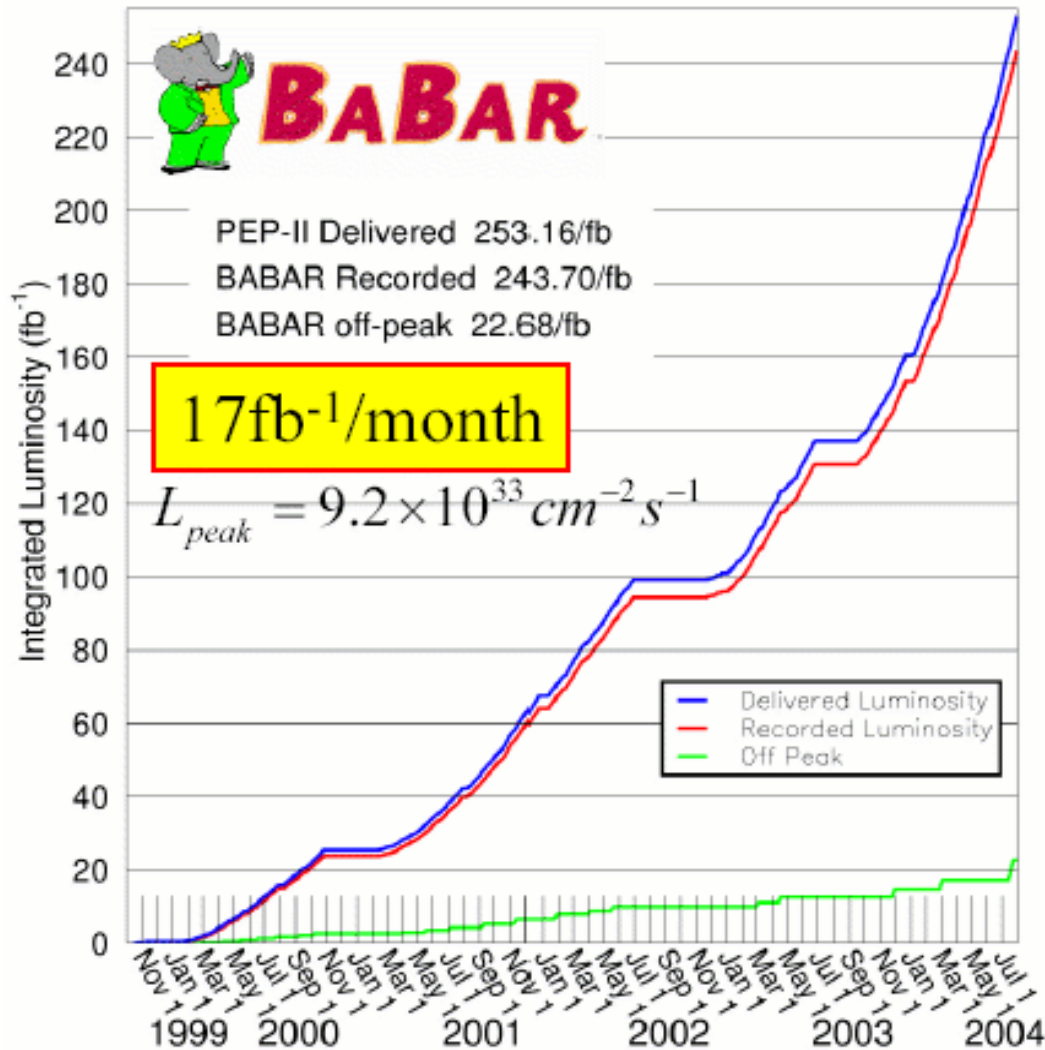
– soppressi per le alte masse delle particelle nel loop ($\propto 1/M^2$)

– favoriti rispetto allo SM per l'accoppiamento (di $\sim \alpha_s/\alpha_w$)

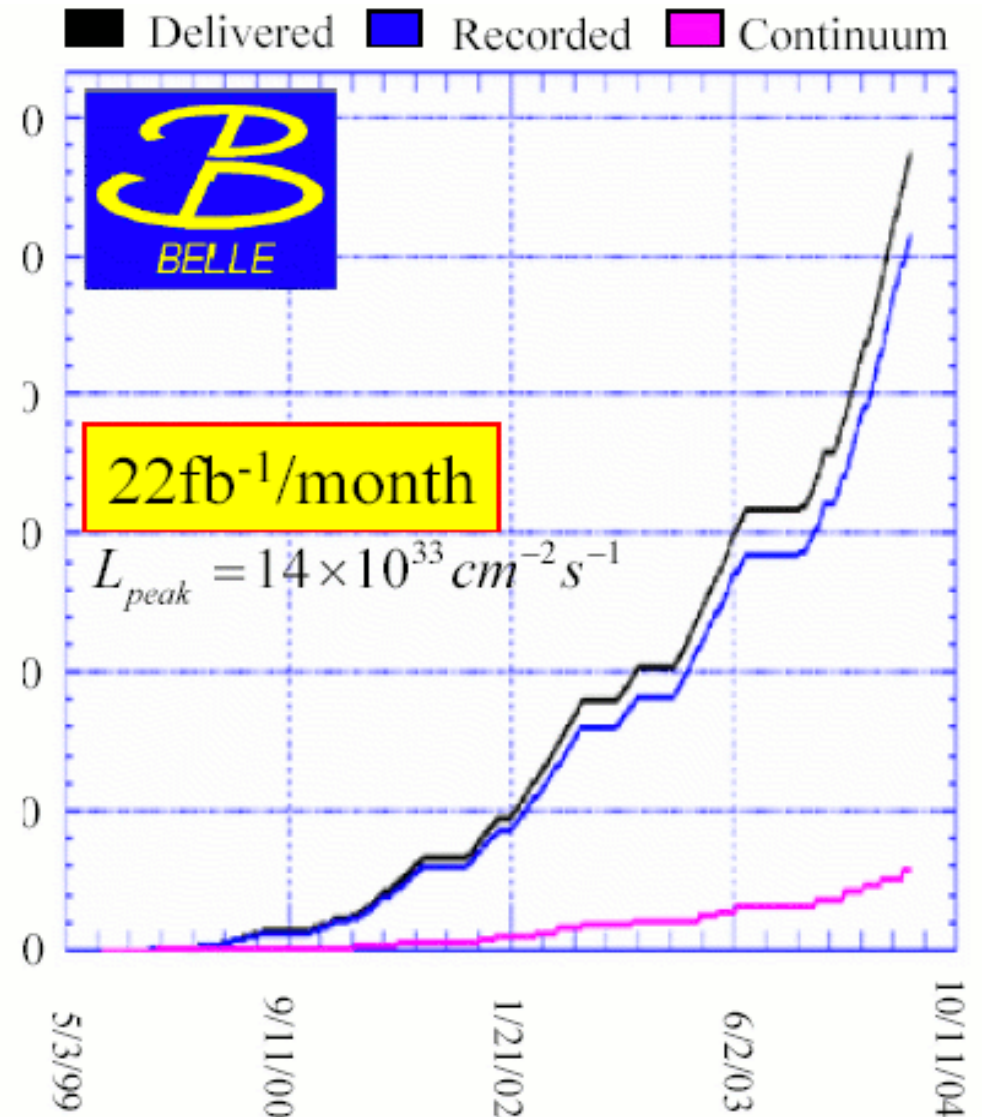


Il contributo delle B-factory

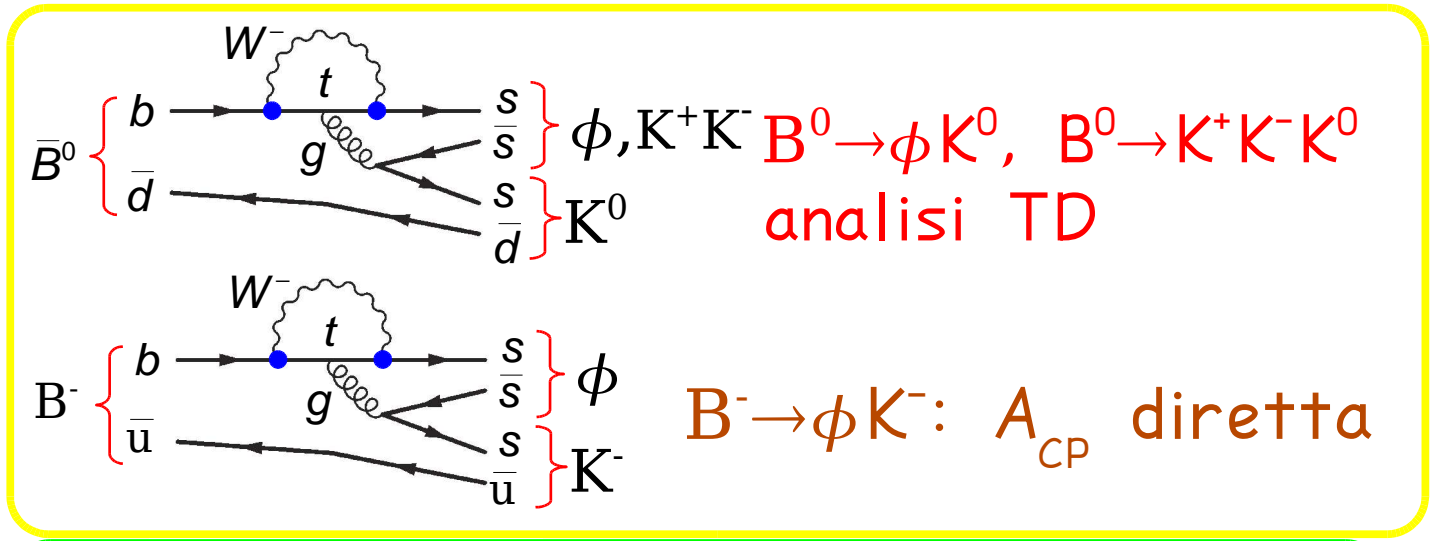
Luminosita' integrata:
244 fb⁻¹



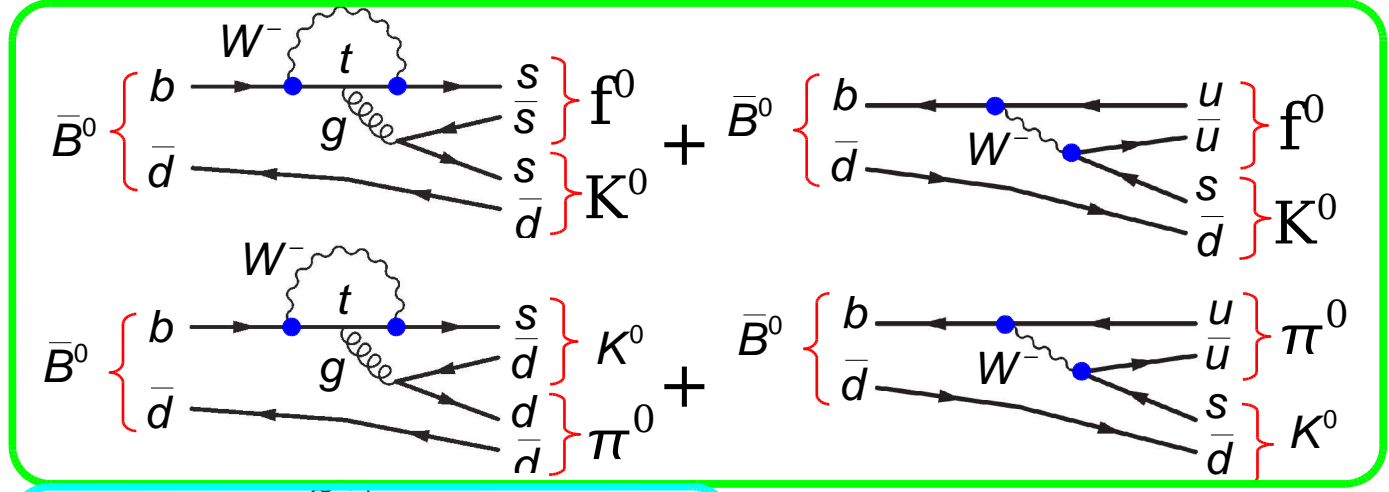
+ 286 fb⁻¹ = 0.530 ab⁻¹ !



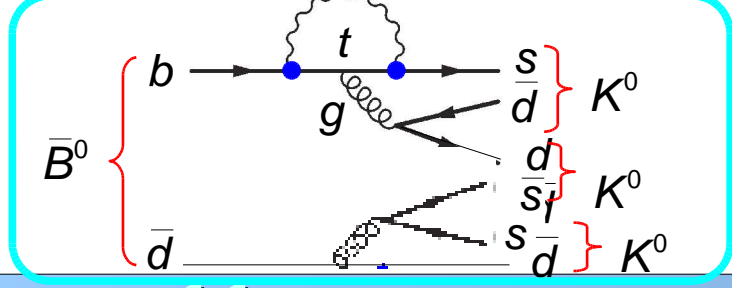
L'universo $b \rightarrow s$



$B \rightarrow \phi K$: golden mode
 incertezza $\sim 5\%$
 $B^0 \rightarrow K^+ K^- K^0$: incertezza
 sul contenuto di CP



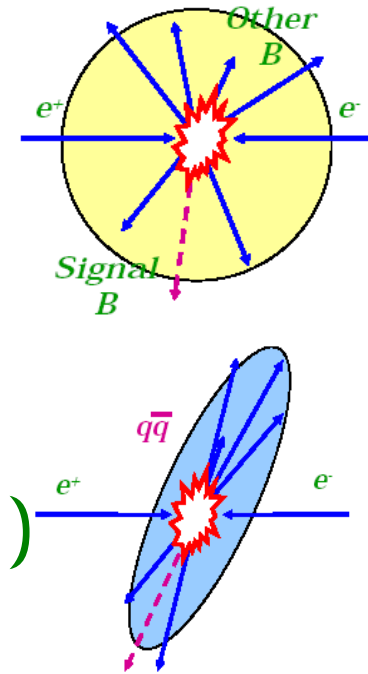
$B \rightarrow f^0 K$: incertezza
 dovuta alla componente
 albero: $\sim 10\%$
 $B \rightarrow K^0 \pi^0$:
 incertezza $\sim 20\%$



$B \rightarrow K_s K_s K_s$: dominato da pinguino,
 non color-soppresso

I fondi principali

- e^+e^- è un ambiente pulito, tuttavia:
 - $\sigma(e^+e^- \rightarrow \bar{b}b) \simeq 1.05 \text{ nb}$
 - $\sigma(e^+e^- \rightarrow \bar{u}u + \bar{d}d + \bar{s}s + \bar{c}c) \simeq 3.40 \text{ nb}$
 - Si sfrutta la differente forma degli eventi (sfericita', analisi multivariate...)



- Fondi da decadimenti simili di $\bar{B}B$:

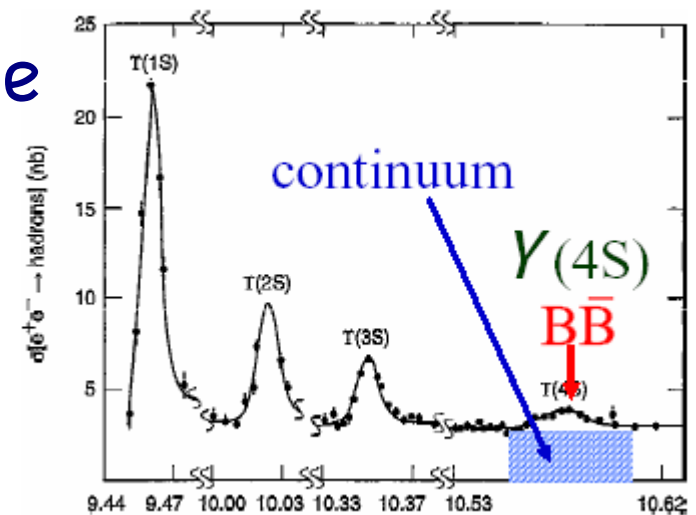
- selezione cinematica e angolare

- fondi irriducibili:

- stima da misure dirette

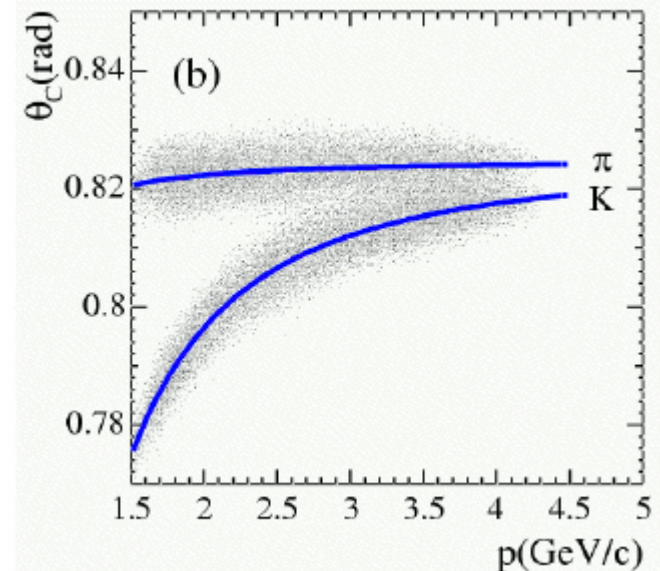
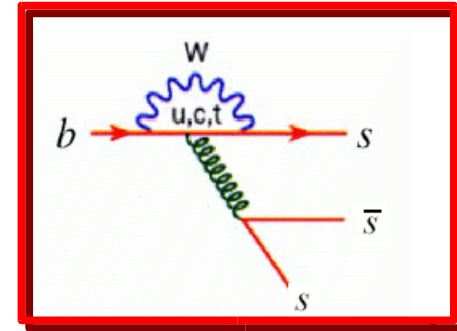
- sottrazione

- inclusione nell'errore sistematico



$B \rightarrow \phi K_S$: il "golden mode"

- $\phi = (\bar{s}s) \Rightarrow$ puro Pinguino
- $\phi \rightarrow K^+ K^-$ e $K_S \rightarrow \pi^+ \pi^-$ il canale con purezza maggiore (ma anche altri modi ricostruiti)
- Particle Identification (PID):
 - separazione $K - \pi$ (riv. Čerenkov), $p(K) \approx 1-2 \text{ GeV}/c$
- Fondo $\bar{B}B$: $f_0 K_S$, ϕK^{*0} , ϕK^{*+}
 - $f_0 K_S$ ($B \rightarrow SS$, CP opposta):
diversa distribuzione angolare
 - ϕK^* , $K^* \rightarrow (K_S \pi)$: sel. su $E(\pi)$ persa



$B \rightarrow \phi K_S$: risultati

227 × 10⁶ coppie

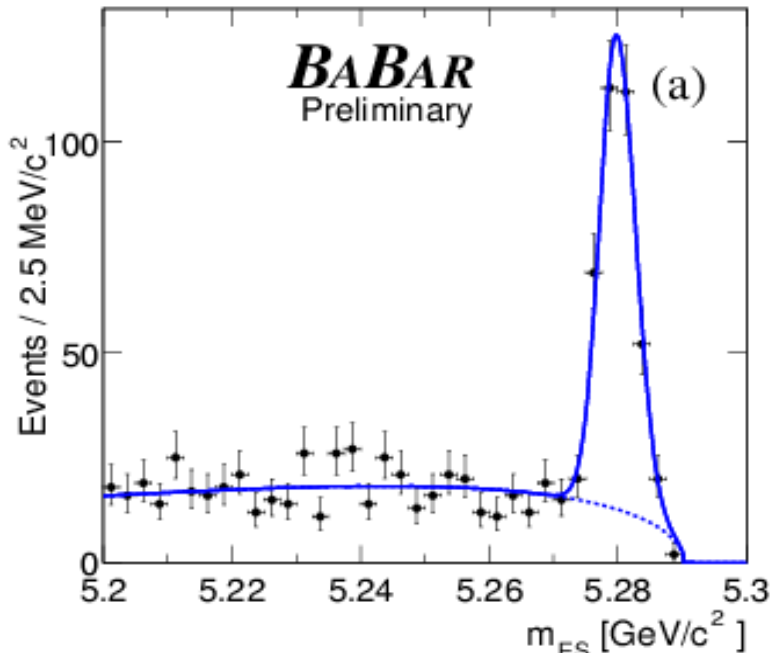
- $\mathcal{L}(m_{ES}, \Delta E, \mathcal{F}, |\cos\theta_H|, \Delta t, \sigma(\Delta t))$ per 3 componenti

Variabili cinematiche:

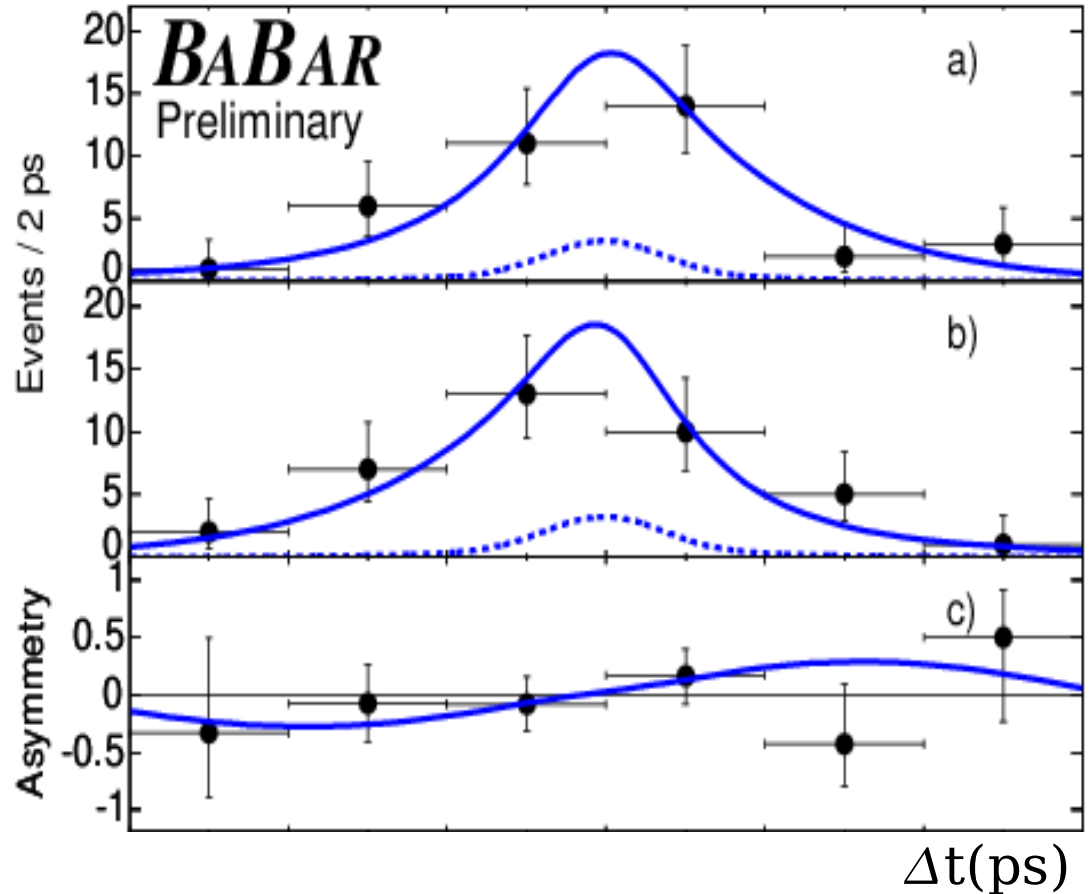
$$m_{ES} = \sqrt{E_{beam}^{*2} - P^{*2}}$$

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

Discriminante di Fisher \mathcal{F}



$$\sin(2\beta[\bar{c}c]) = 0.726 \pm 0.037 @ 1.3\sigma$$

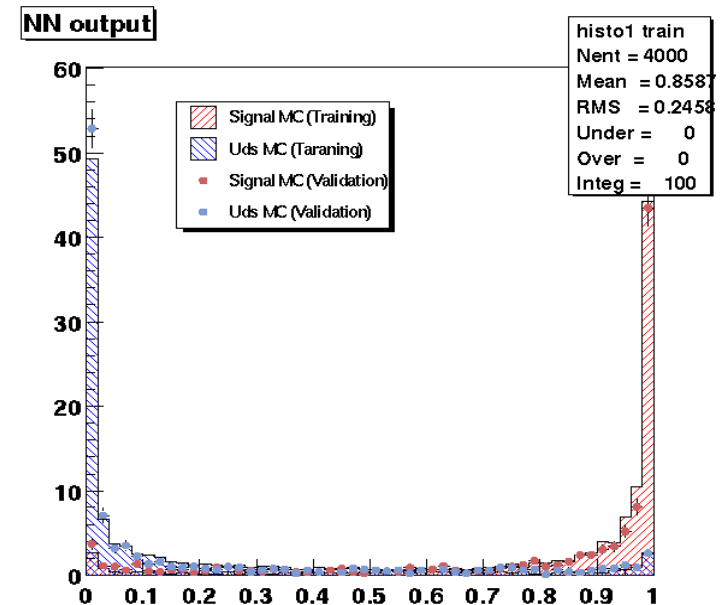


$$N(\phi K_S) = 114 \pm 12$$

$$C = -0.07 \pm 0.27 \quad S = 0.29 \pm 0.31$$

$$B \rightarrow \phi K_L$$

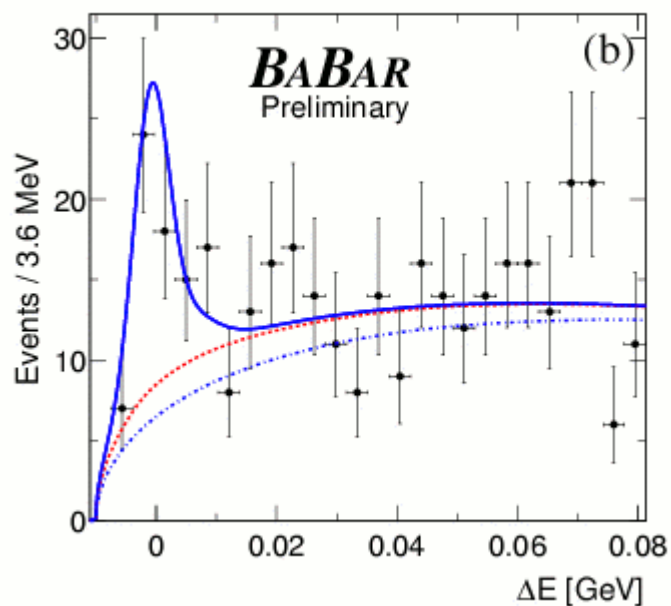
- Stesso processo, ma CP opposta a ϕK_S
- K_L riconosciuto dalle interazioni adroniche:
 - nei cristalli del calorimetro em
 - nel Fe del rivelatore di μ
- $p(K_L)$ non misurato, constraint sulla massa del B per chiudere la cinematica
- Fondo da γ :
 - Rete Neurale basata sulla forma dello sciame em vs. adr
- Fondo da μ :
 - veto sulle tracce



$B \rightarrow \phi K_L$: risultati

227×10^6 coppie

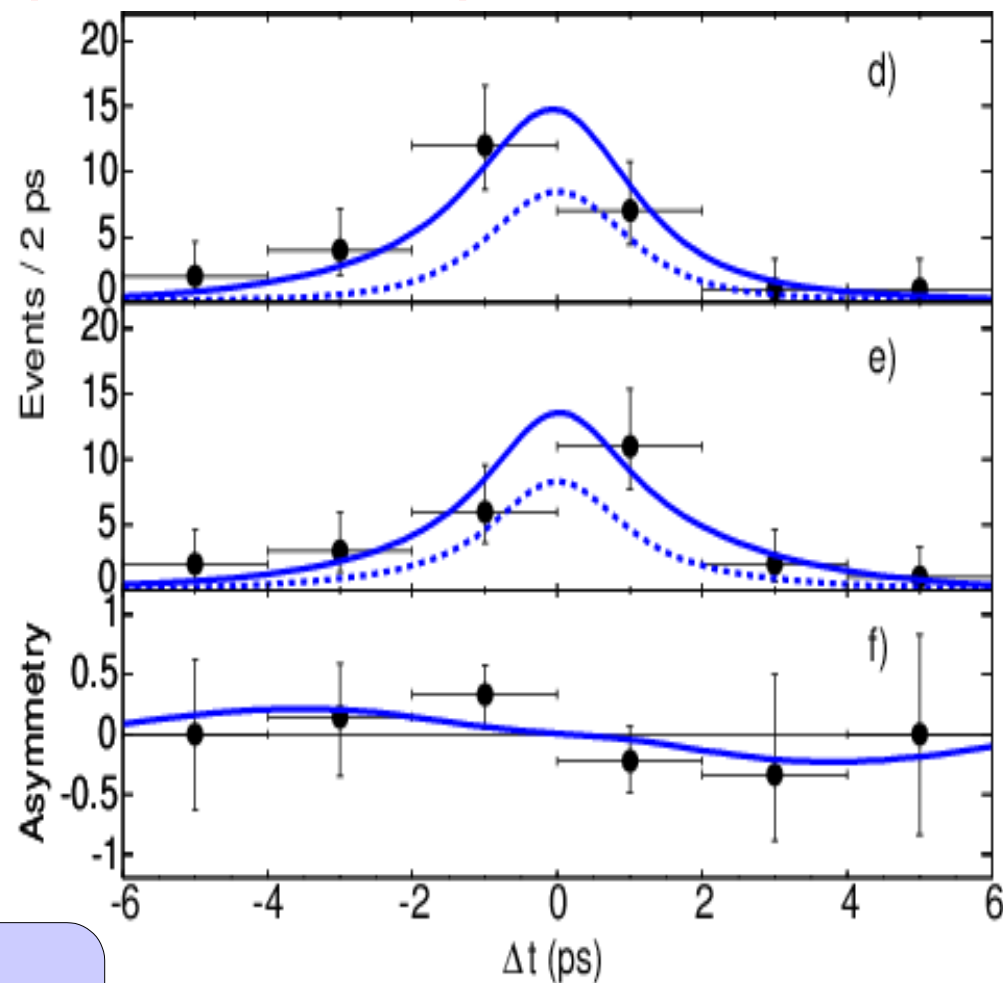
- $\mathcal{L}(\Delta E, \mathcal{F}, |\cos\theta_H|, \Delta t, \sigma(\Delta t))$ per 3 componenti



CP opposta a $j/\psi K_S - \phi K_S$!

$$N(\phi K_L) = 98 \pm 18$$

$$C = 0.31 \pm 0.49 \quad S = -1.05 \pm 0.51$$



$$\sin(2\beta[\bar{c}c]) = 0.726 \pm 0.037 @ 0.7\sigma$$

Combinazione $\phi K_S + \phi K_L$

- BaBar:

- su $n(\text{coppie BB})=227 \cdot 10^6$
- $S = +0.50 \pm 0.25(\text{stat})^{+0.08}_{-0.05}(\text{sist})$
- $C = 0.00 \pm 0.23(\text{stat}) \pm 0.09(\text{sist})$



- Belle:

- su $n(\text{coppie BB})=274 \cdot 10^6$
- $S = +0.06 \pm 0.33(\text{stat}) \pm 0.09(\text{sist})$
- $C = -0.08 \pm 0.22(\text{stat}) \pm 0.09(\text{sist})$

nello SM
 $S(\phi K_S) = \sin(2\beta)$



$$S = 0.34 \pm 0.20 \quad C = -0.04 \pm 0.17$$

HFAG
ICHEP 2004

$$\sin(2\beta[\bar{c}c]) = 0.726 \pm 0.037 @ 2.0\sigma$$

$B \rightarrow \phi K$: SUSY (I)

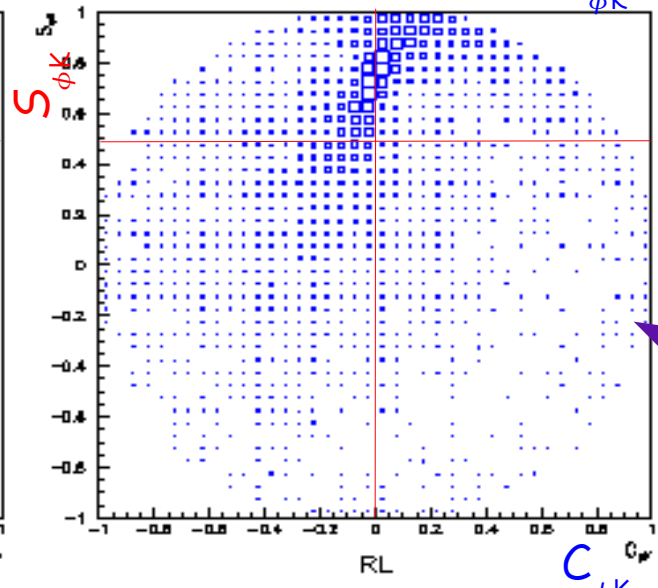
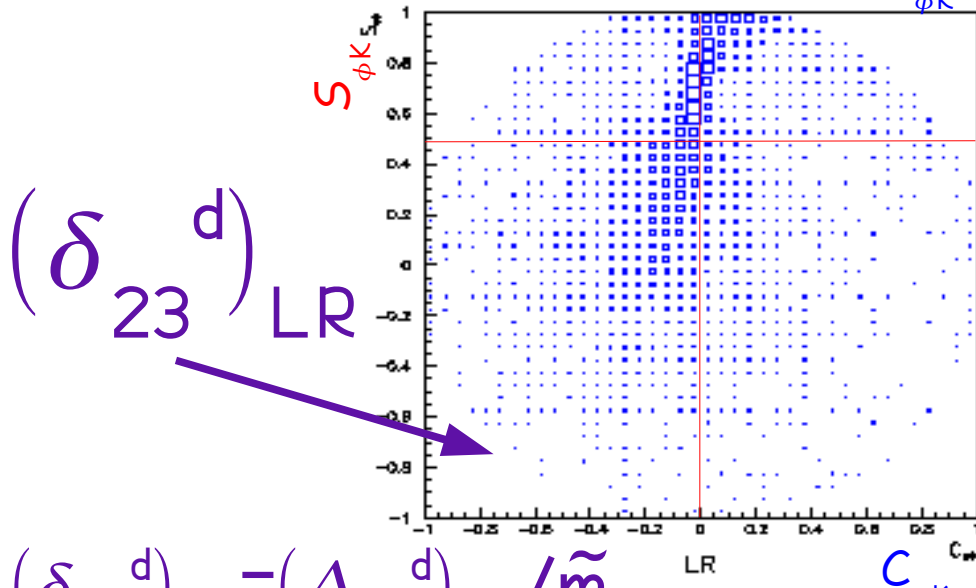
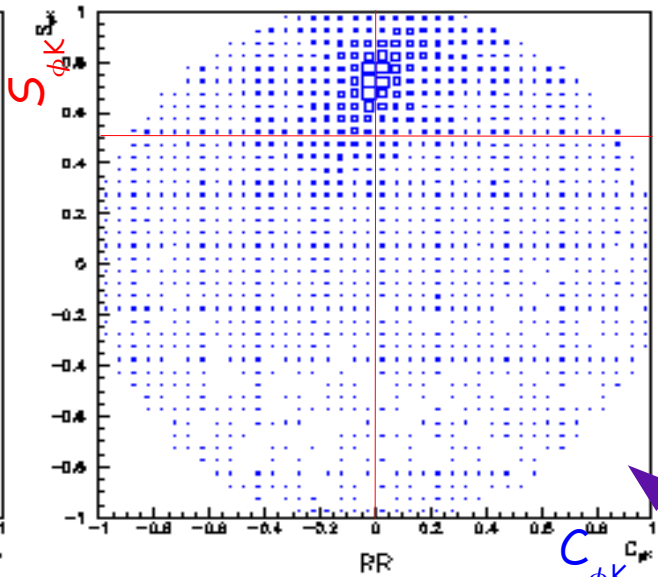
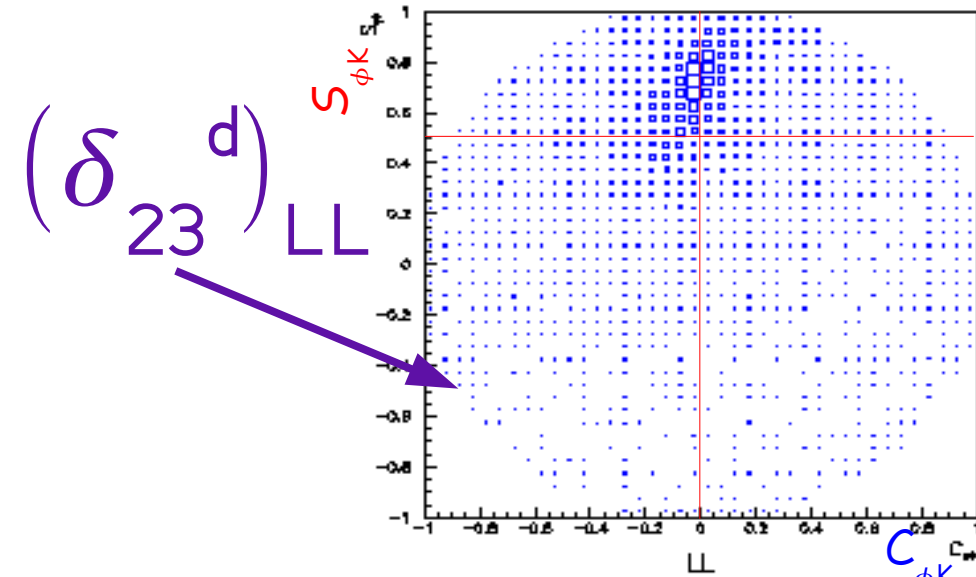
Ciuchini et al., hep-ph/0212397

- Gli elementi off-diagonal $(\Delta_{23}^d)_{AB}$ considerati come interazione
- Gli accoppiamenti degli squark possono essere $AB=LL, RL, LR, RR$
- Applicando i vincoli sperimentali da:
 - $\text{Br}(B \rightarrow X_s \gamma) = (3.29 \pm 0.34) \times 10^{-4}$
 - $A_{CP}(B \rightarrow X_s \gamma) = -0.02 \pm 0.04$
 - $\text{BR}(B \rightarrow X_s l^+ l^-) = (6.1 \pm 1.4 \pm 1.3) \times 10^{-6}$
 - $\Delta M_s > 14.4 \text{ps}^{-1}$

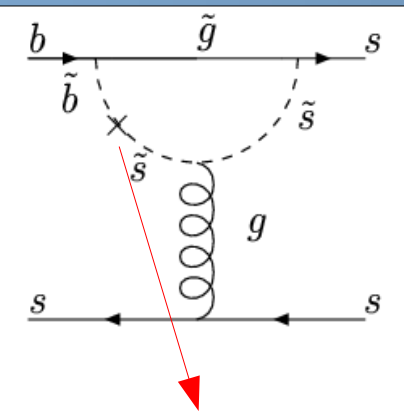
$$\tilde{b}_A \text{ --- } \times \text{ --- } (\Delta_{23}^d)_{AB} \text{ --- } \tilde{s}_B$$

B → φ K: SUSY (II)

Ciuchini et al., hep-ph/0212397



$$(\delta_{23}^d)_{LR} = (\Delta_{23}^d)_{LR} / \tilde{m}$$



Inserzione di massa $(\delta_{23}^d)_{AB}$

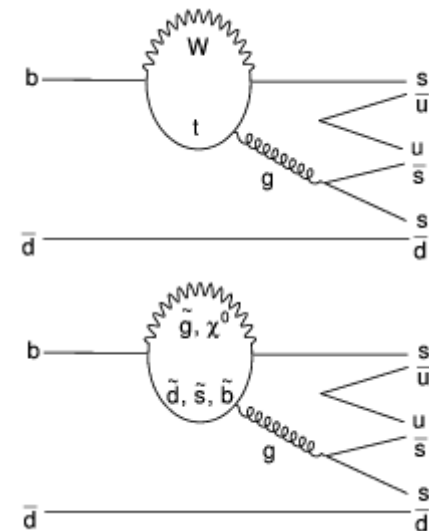
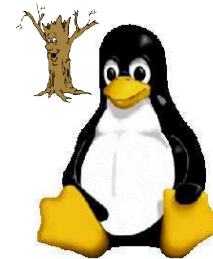
$(\delta_{23}^d)_{RR}$

$(\delta_{23}^d)_{RL}$

$B \rightarrow K^+ K^- K_S$

- Pinguino(ss) + $\lambda^4 \times$ albero

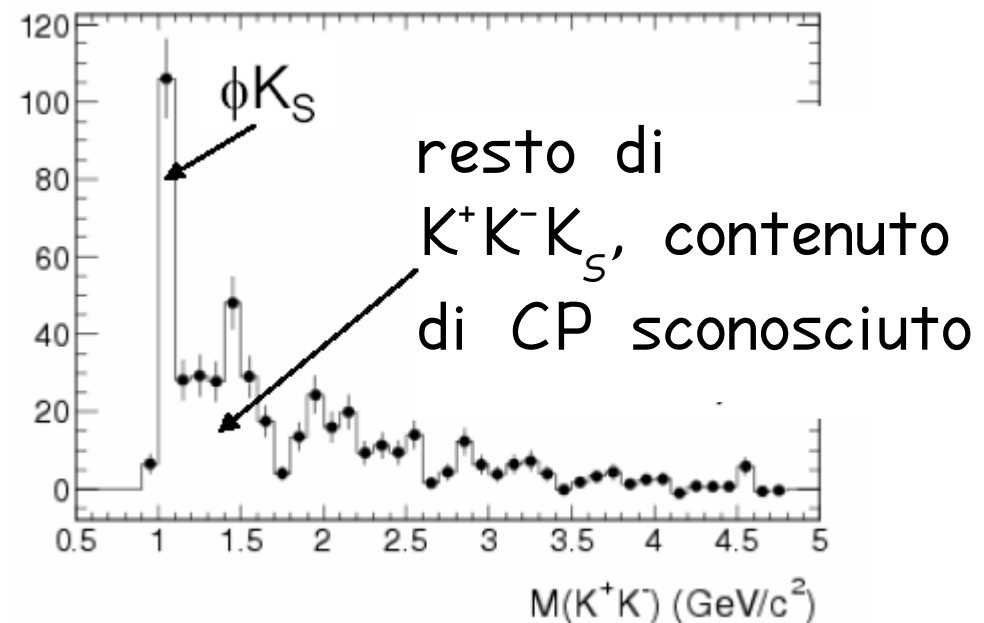
- $BR(K^+ K^- K_S) = (23.8 \pm 2.0 \pm 1.6) 10^{-6}$
 $\Rightarrow \sim 3 BF(\phi K_S)$



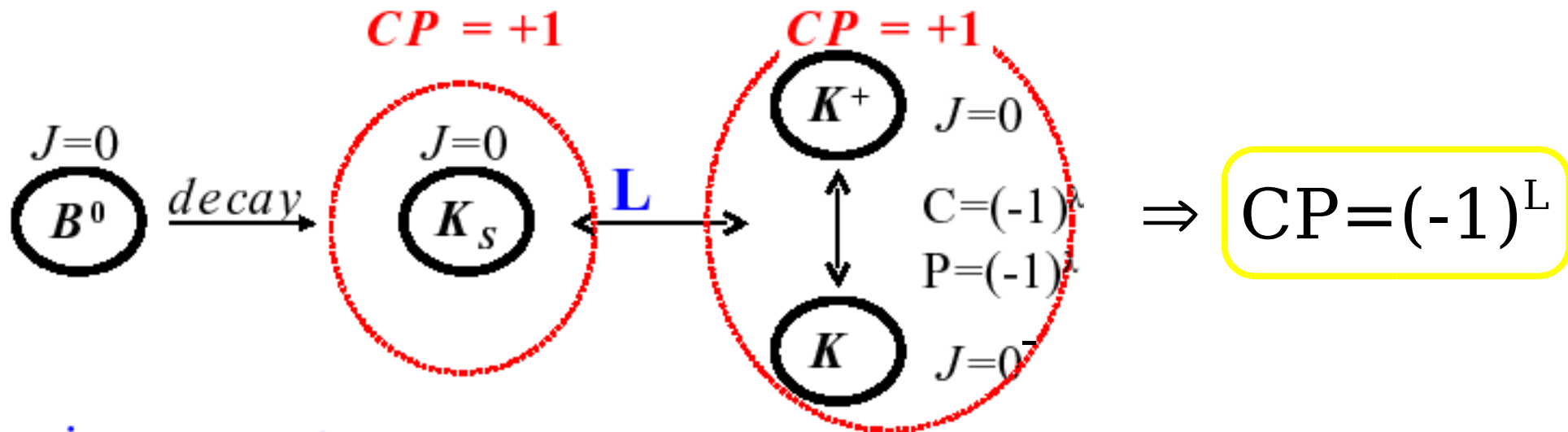
- tuttavia il contenuto di CP non è definito a priori, la frazione CP-pari si determina con:

- analisi di isospin
- analisi angolare

- Validazione di ϕK_S



$B \rightarrow K^+ K^- K_S$: contenuto di CP



- Ampiezza espansa in termini dei polinomi di Legendre:

$$|\mathcal{A}|^2 = \sum_l \langle P_l \rangle \cdot P_l(\cos \theta_H)$$

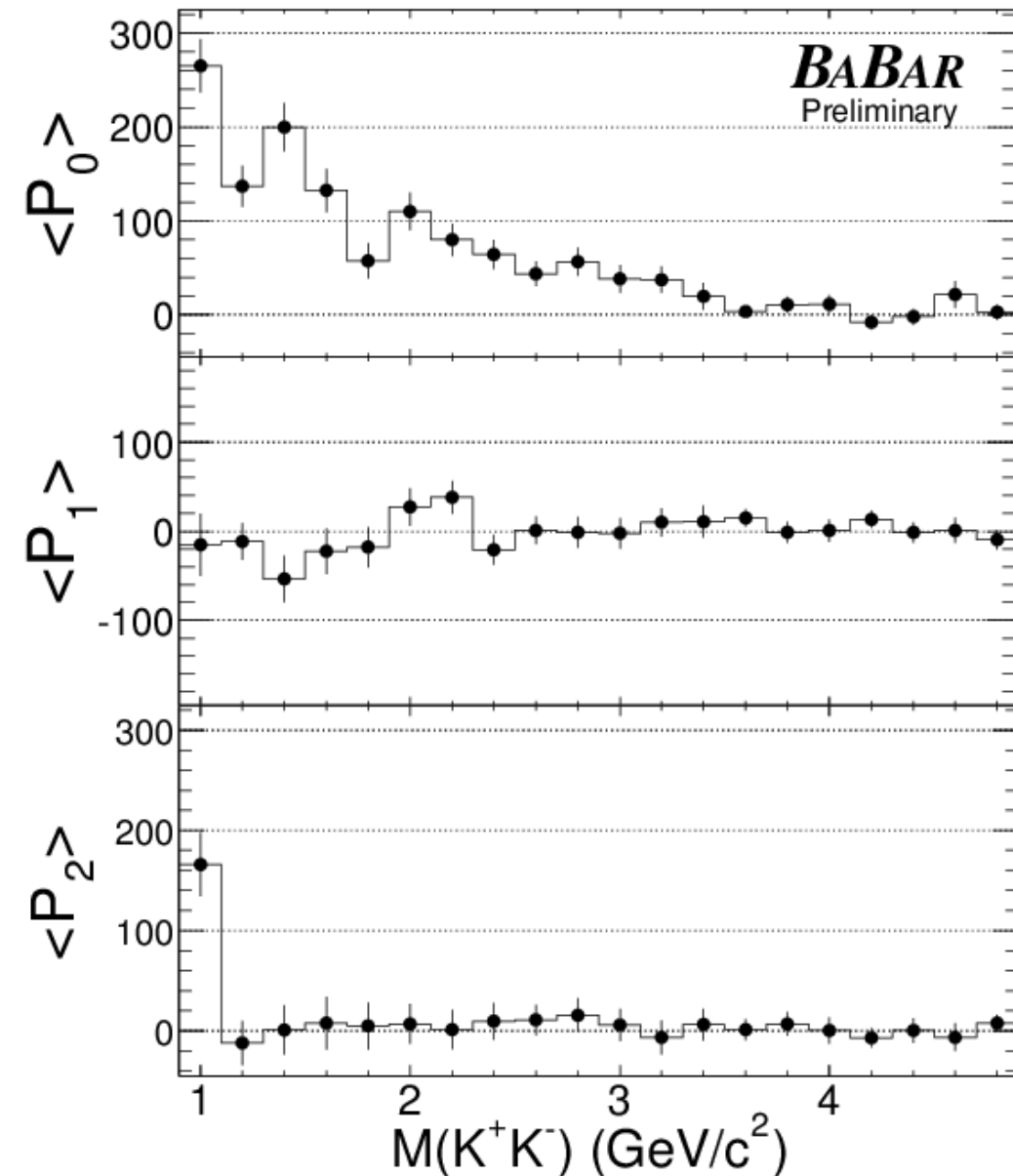
- La dinamica è sconosciuta, momenti estratti dagli eventi:

$$\langle P_l \rangle \approx \sum_j P_l(\cos \theta_{H,j}) \mathcal{W}_j / \varepsilon_j$$

prob(j=segnale),

estratta con la sottrazione del fondo mediante χ^2 Plot [Le Diberder, hep-ph/0402083]

$B \rightarrow K^+ K^- K_S$: momenti



Eventi totali

$$\langle P_0 \rangle = \frac{A_s^2 + A_p^2}{\sqrt{2}}$$

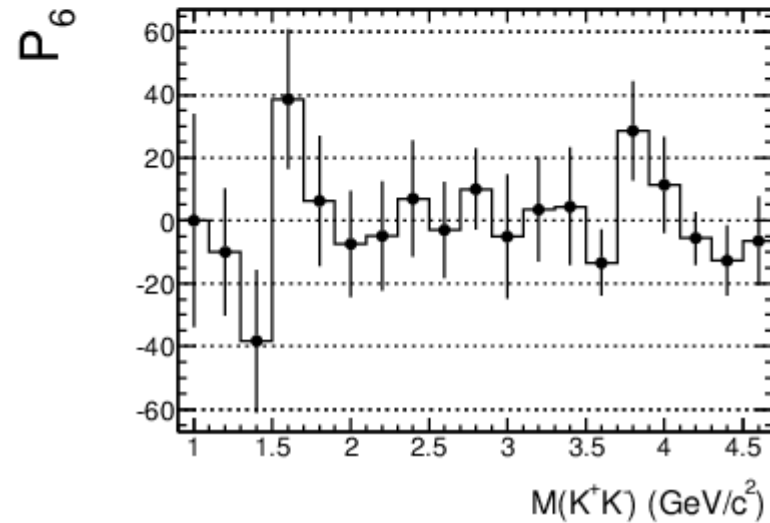
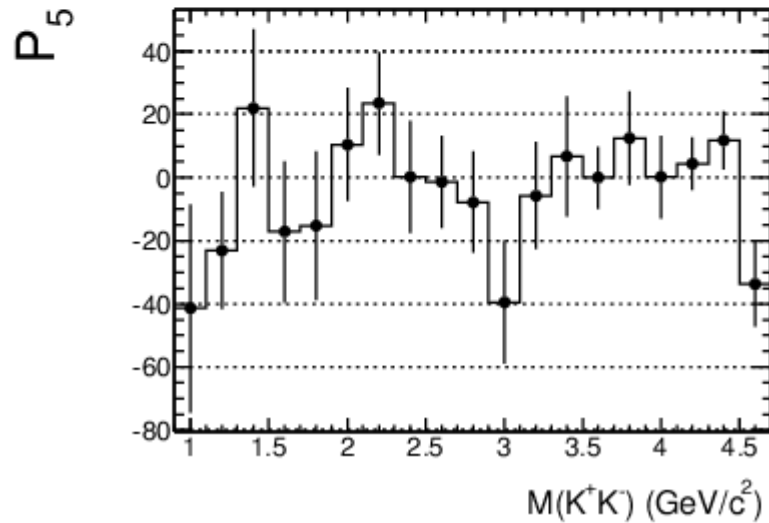
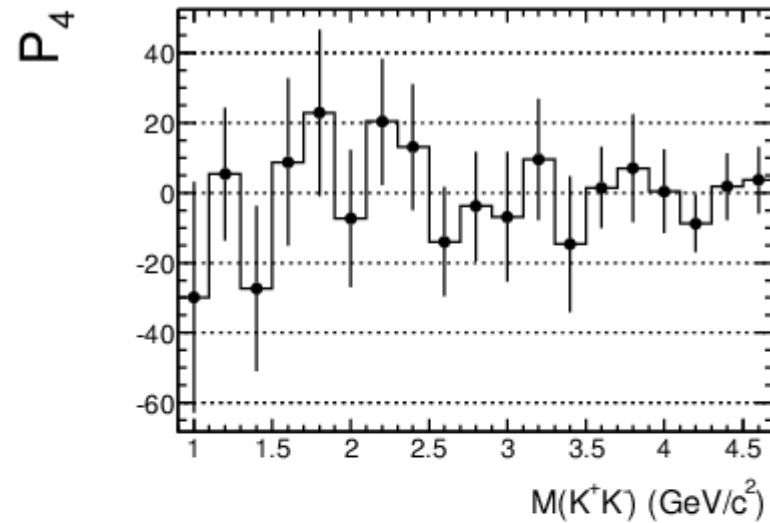
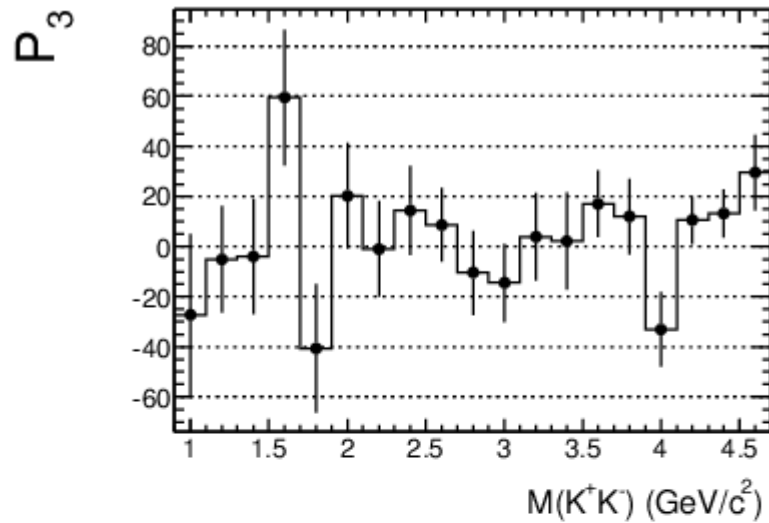
Interferenza S-P

$$\langle P_1 \rangle = \frac{2A_s A_p \cos \phi}{\sqrt{2}}$$

Onda P

$$\langle P_2 \rangle = \sqrt{\frac{2}{5}} A_p^2$$

$B \rightarrow K^+ K^- K_S$: momenti superiori



$P_3 = P_4 = P_5 = P_6 = 0 \Rightarrow$ assenza di decadimenti in onda-D

Estrazione $f_{CP\text{-pari}}$

- In funzione dei momenti

$$f_{\text{even}} = \frac{A_s^2}{A_s^2 + A_p^2} = 1 - \sqrt{\frac{5}{4}} \frac{\langle P_2 \rangle}{\langle P_0 \rangle},$$

Regione della ϕ

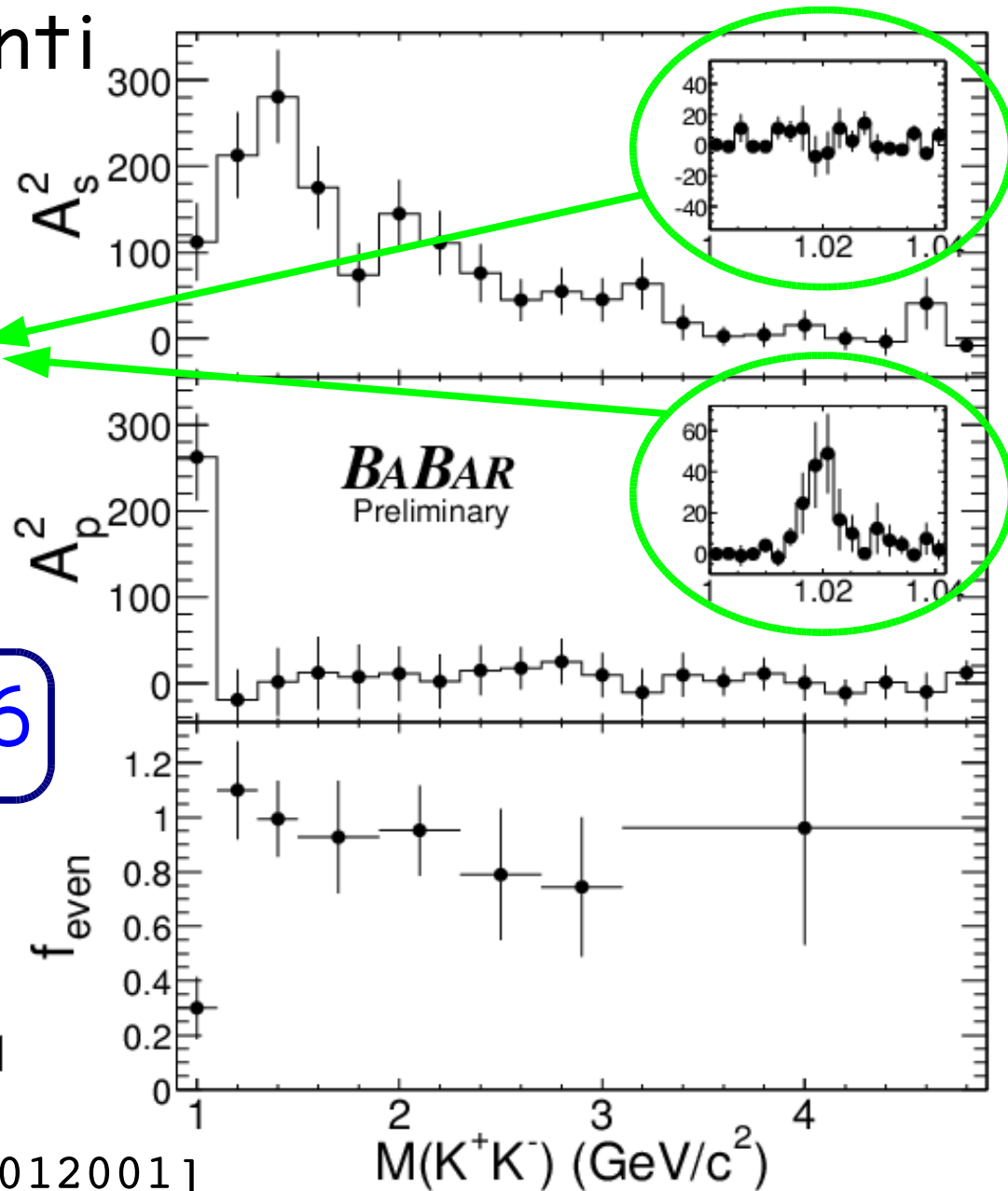
- Nella regione con meno onda-P: $|m_{K^+K^-} - m_\phi| > 15\text{MeV}$

$$f_{CP\text{-even}} = 0.89 \pm 0.08 \pm 0.06$$

- Cross-check con un'analisi di isospin:

$$f_{CP\text{-even}} = \frac{2\Gamma(B^+ \rightarrow K^+ K_S^0 K_S^0)}{\Gamma(B^0 \rightarrow K^+ K^- K^0)} = 0.75 \pm 0.11$$

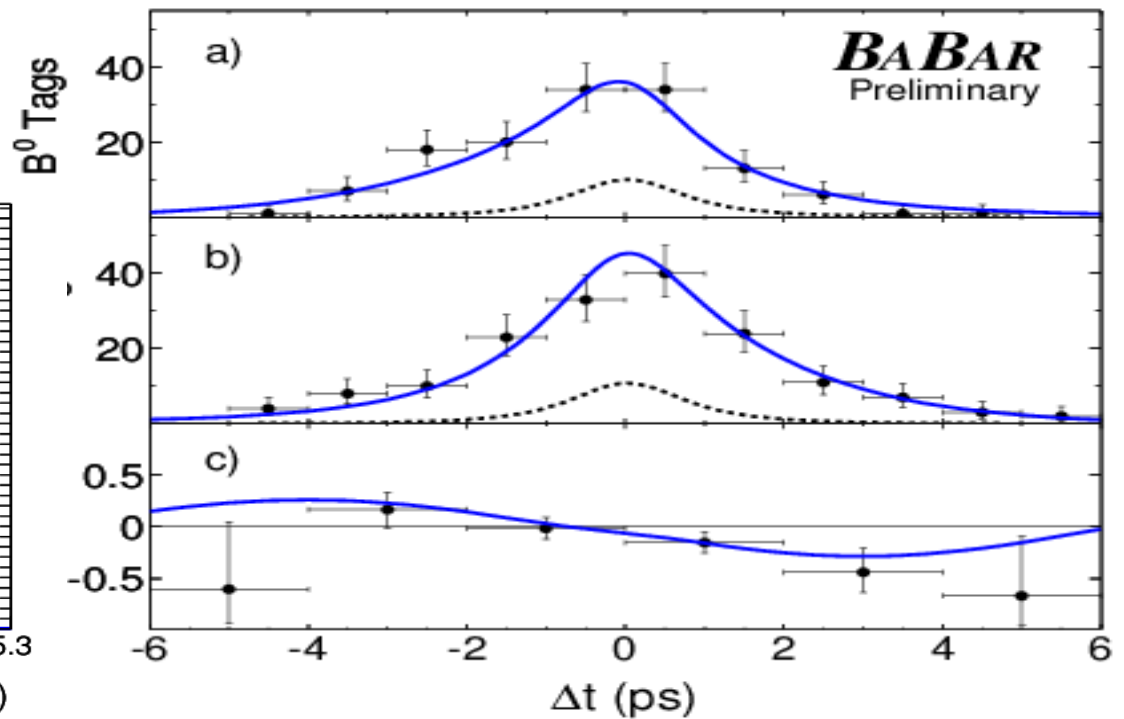
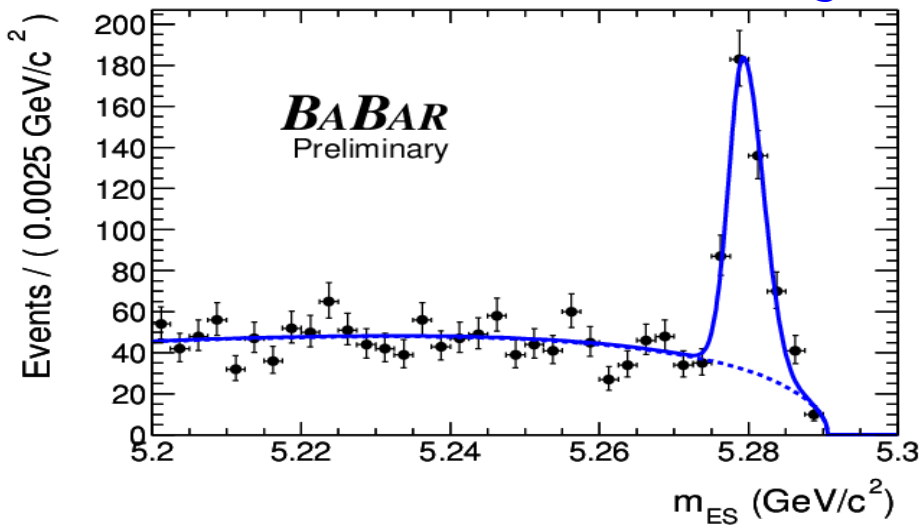
[Belle coll., Phys. Rev. D 69 012001]



$B \rightarrow K^+ K^- K_S$: asimmetria 227 × 10⁶ coppie

- $N = 452 \pm 28$

(escludendo gli eventi ϕK_S)



Dal CP-fit →

$$S = -0.42 \pm 0.17 \pm 0.04$$

$$C = 0.410 \pm 0.14 \pm 0.06$$

contenuto di CP

- La presenza di onda P e S introduce una diluizione
- Fissando $C=0$ nel fit

$$\sin(2\beta[\bar{c}c]) = 0.726 \pm 0.037 @ 0.7\sigma$$

→ $\sin 2\beta_{\text{eff}} = -S(2f_{\text{even}} - 1) = 0.55 \pm 0.22 \pm 0.04 \pm 0.11$

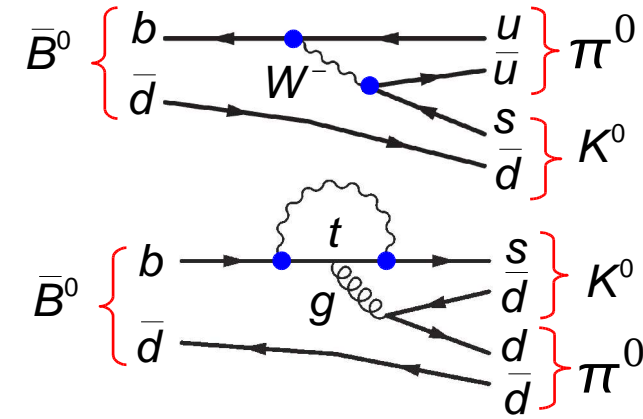
$B^0 \rightarrow K_S \pi^0$: il "silver mode"

- Contributo ad albero doppio CKM soppresso e color soppresso

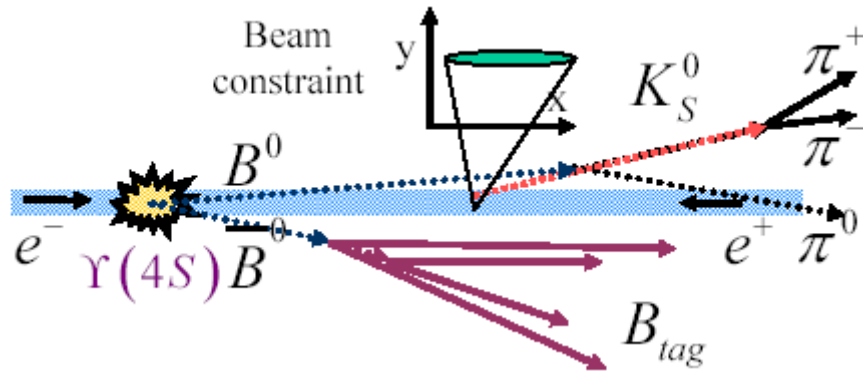
- Dominato dal Pinguino $b \rightarrow sdd$

misura $\sin 2\beta$, ma con incertezze adroniche:

$$O(\lambda^2 / \bar{\lambda}) \sim 20\%$$



- Scommessa sperimentale: vertice senza primari carichi



- Vertice con il $K_S \rightarrow \pi^+ \pi^-$
- Il K_S ha una lifetime non trascurabile

**vertice Beam Spot Constrained:
il K_S e' riportato al Beam Spot lungo l'asse z**

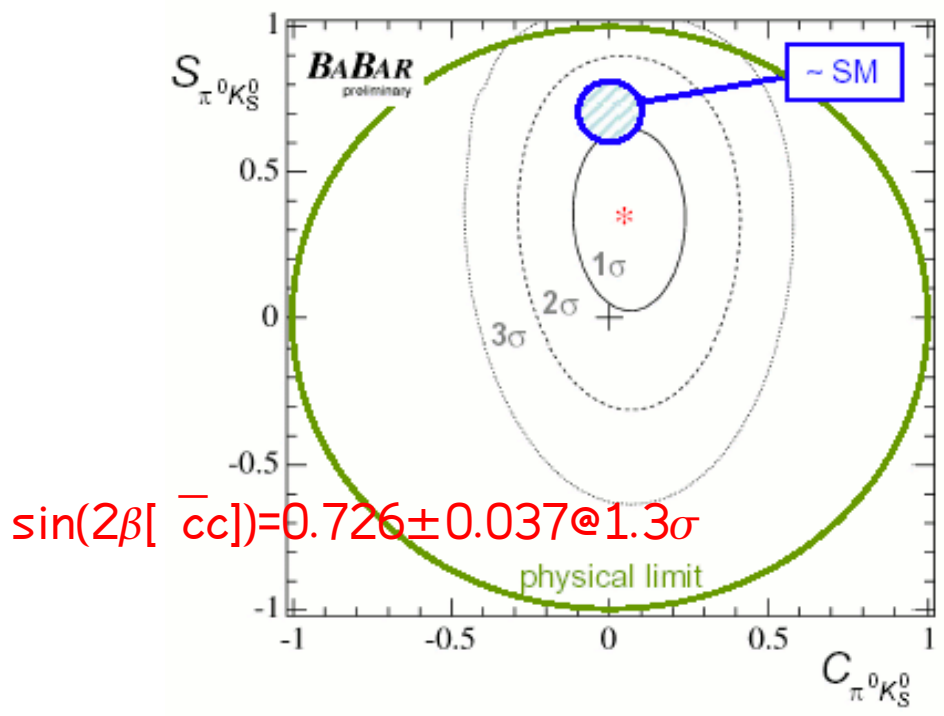
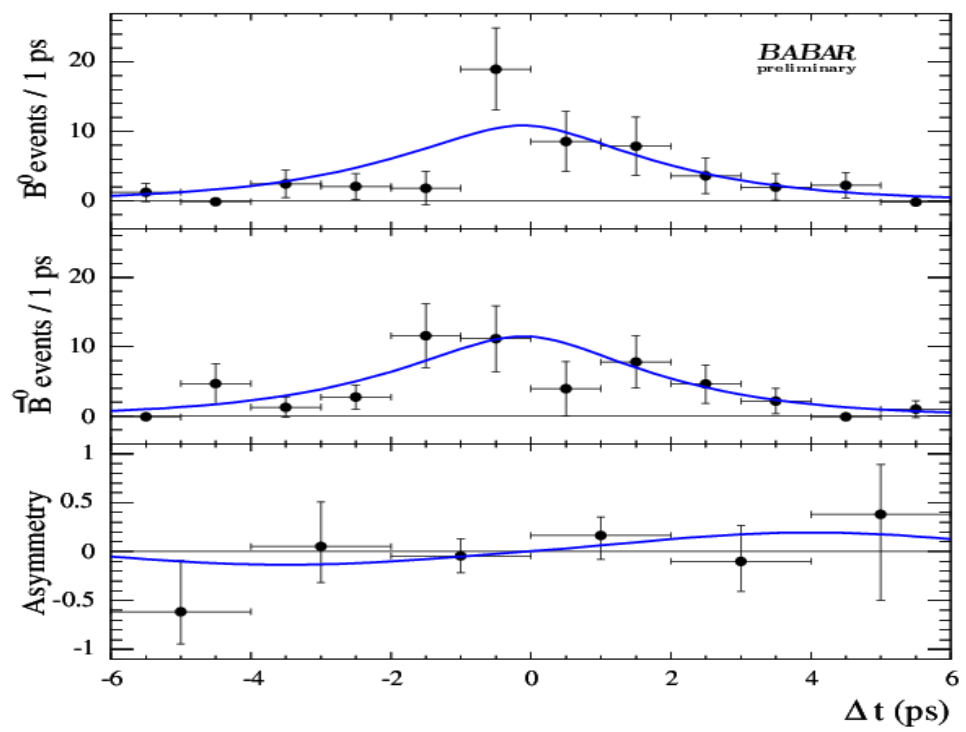
Validazione su $J/\psi K_S$:
rimosse le informazioni su $\mu^+ \mu^-$

	nominal	mangled
C	-0.009 ± 0.053	-0.024 ± 0.056
S	0.714 ± 0.075	0.702 ± 0.089

$B^0 \rightarrow K_S \pi^0$: ~~CP~~

227 × 10⁶ coppie

- Per la misura di Δt richiesti 4 SVT hits ($\epsilon \sim 60\%$)
- Gli altri eventi usati per CPV diretta



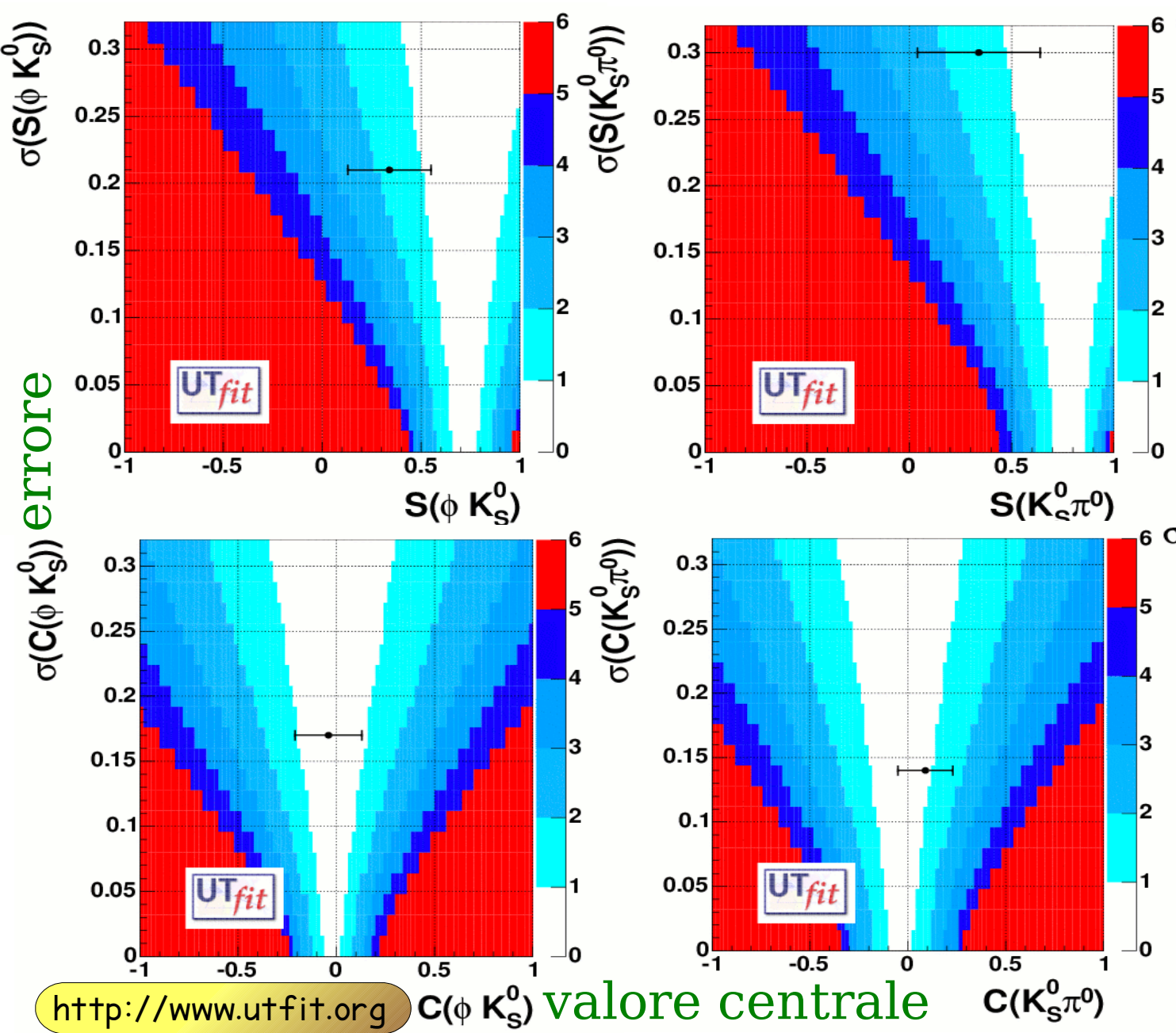
Eventi: $N(K_S \pi^0) = 300 \pm 23$

➔ $BF(K^0 \pi^0) = (11.4 \pm 0.9 \pm 0.6) \times 10^{-6}$

$C = 0.06 \pm 0.18 \pm 0.06$
 $S = 0.35^{+0.30}_{-0.33} \pm 0.04$

Sistematica principale
sull'allineamento dei layer SVT

Quanto bene conosciamo lo SM?



Confronto tra:

- La predizione del valore dei parametri CP (S e C) nello SM
- La misura sperimentale diretta

- L'errore statistico non permette di trarre conclusioni sull'incompatibilita' con lo SM
- Il "golden mode" e il "silver mode" hanno sensibilita' comparabile

<http://www.utfit.org>

valore centrale

Il "bronze mode": $B \rightarrow f_0(980)K_S$

- Contenuto di quark del mesone $f_0(980)$:

$$f_0 = \cos(\phi_s) \bar{s}s + \sin(\phi_s) \bar{n}n, \quad n = (\bar{u}u + \bar{d}d)/\sqrt{2}$$

$$\phi \rightarrow f_0 \gamma \quad (f^0 \rightarrow \gamma\gamma) \quad \longrightarrow \quad \phi_s = -48^\circ \pm 6^\circ$$

[Anisovich et al. hep-ph/0011191]

- L'albero:

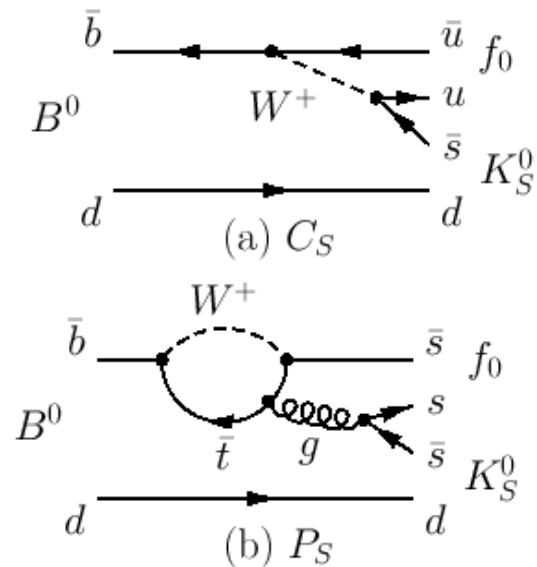
- doppio Cabibbo soppresso ($|V_{ub}|^2$)
- color soppresso

misura $\sin 2\beta$, ma con
incertezze adroniche
 $\sim 10\%$

- Stima del BF in fattorizzazione QCD da $f_0 K^+$

- Senza componente $\bar{n}n$
- In $f^0 K^+$ c'e' anche l'annichilazione

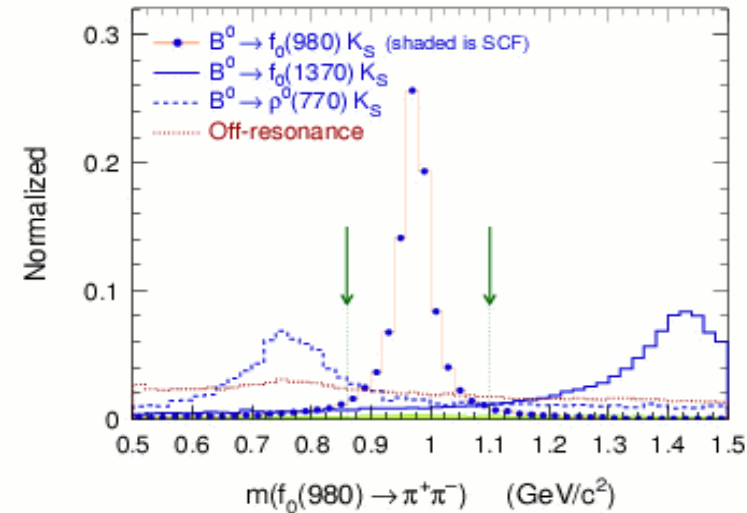
$$\longrightarrow \quad \text{BF}(f^0 K^0) \approx 6 \times 10^{-6}$$



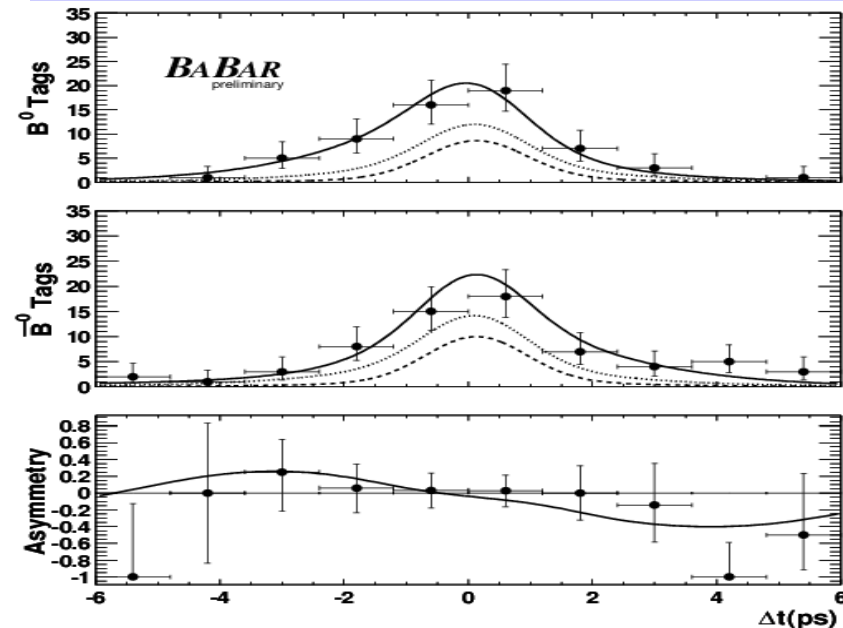
$B \rightarrow f_0(980) K_S$: BF & CP

209×10^6 coppie

- Approccio Q2B per $f_0 \rightarrow \pi^+ \pi^-$:
 $0.86 < m(\pi^+ \pi^-) < 1.10 \text{ GeV}/c^2$
- Stima della diluizione di CP dovuta all'interferenza con altri modi del Dalitz plot: $B^0 \rightarrow \pi^+ \pi^- K_S$



- Eventi: $N(f_0 K_S) = 152 \pm 19$ \longrightarrow $BF(f_0 K_S) = (6.0 \pm 0.6 \pm 0.9) 10^{-6}$



$$C = -0.24 \pm 0.31 \pm 0.15$$

$$S = -0.95^{+0.32}_{-0.23} \pm 0.10$$

$$\sin(2\beta[\bar{c}c]) = 0.726 \pm 0.037 @ 0.6\sigma$$

NB: Incompatibilita' a piu' di 2σ
 con il risultato di Belle:

$$C = +0.39 \pm 0.27 \pm 0.08$$

$$S = +0.47 \pm 0.41 \pm 0.08$$

Il "wooden mode": $B \rightarrow \eta' K_S$

227 × 10⁶ coppie

- Incertezza sulla composizione di η' (η_1, η_8)

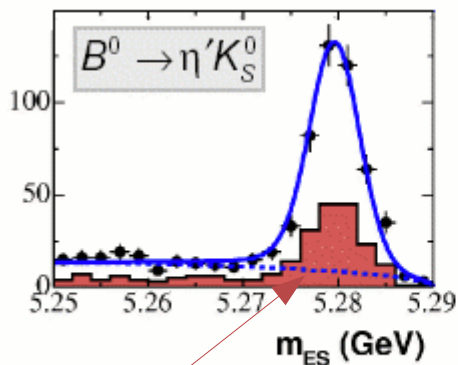
- albero soppresso →

misura $\sin 2\beta$, ma con incertezze adroniche di ~10%

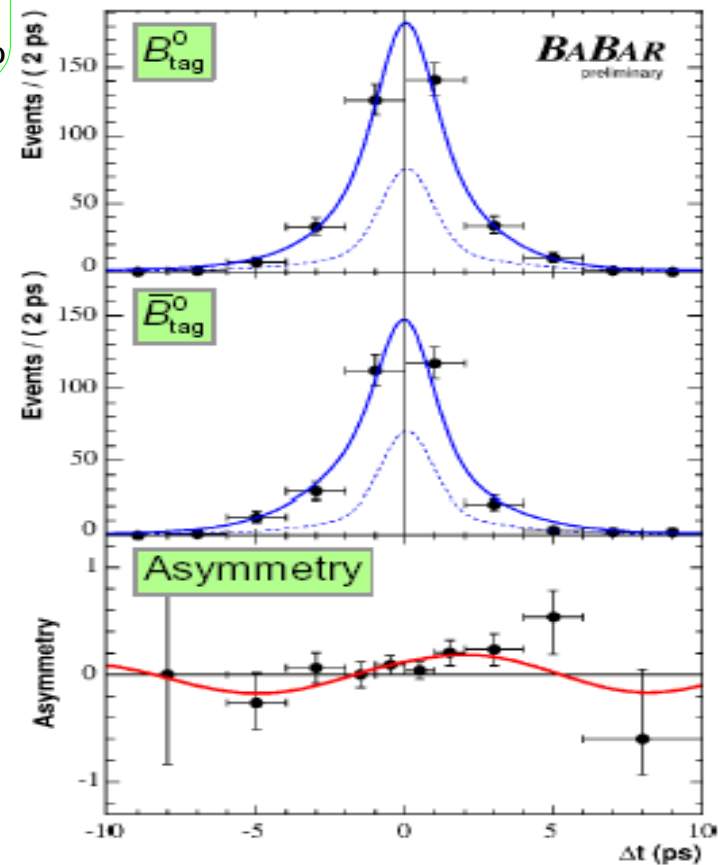
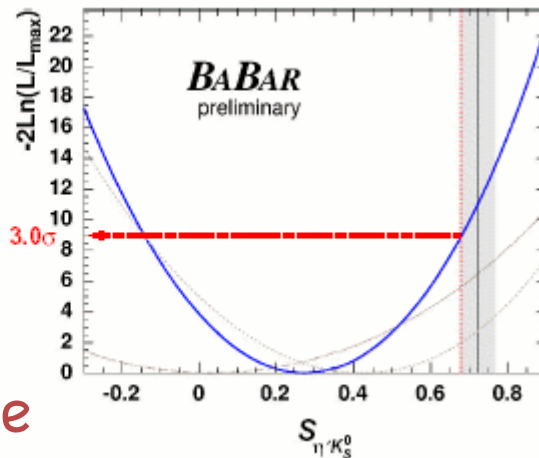
- Molti stati finali:

$$N(\eta' K_S) = 819 \pm 38$$

$\eta' \rightarrow \eta \pi^+ \pi^-, \rho \gamma$
 $\eta \rightarrow \gamma \gamma, \pi^+ \pi^- \pi^0$
 $K_S \rightarrow \pi^+ \pi^-, \pi^0 \pi^0$



$\eta' \rightarrow \rho \gamma$ subsample



Grande statistica: $BF(\eta' K_S) = (60.6 \pm 5.6 \pm 4.6) \times 10^{-6}$

- Il minore errore statistico nei pinguini
- $\sin(2\beta[\bar{c}c]) = 0.726 \pm 0.037 @ 3.0\sigma$

$$C = -0.21 \pm 0.10 \pm 0.03$$

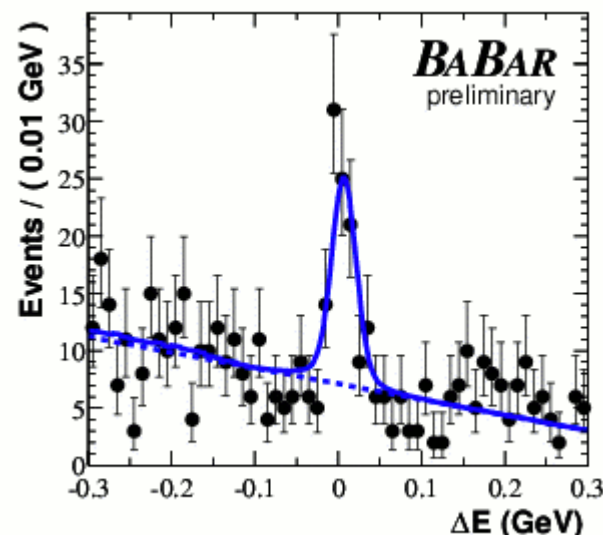
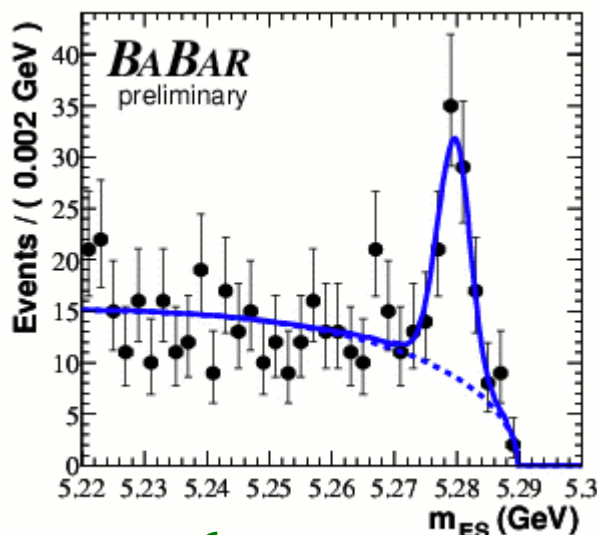
$$S = +0.27 \pm 0.14 \pm 0.03$$

- Tecnica del Vertice Beam Spot Constrained

- $N(K_S K_S K_S) = 71 \pm 9 (\text{stat})$

- $BF(B^0 \rightarrow K_S K_S K_S) = (6.5 \pm 0.8 \pm 0.8) 10^{-6}$

superiore di 2σ rispetto
 $BF(B^+ \rightarrow K^+ K^- K^+)$:
 stati intermedi risonanti?



- Belle (275×10^6 coppie):

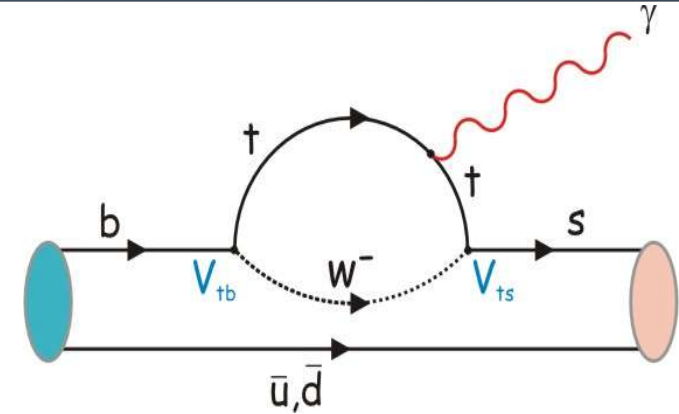
- $S = -1.26 \pm 0.68 \pm 0.18$

- $C = 0.54 \pm 0.34 \pm 0.08$

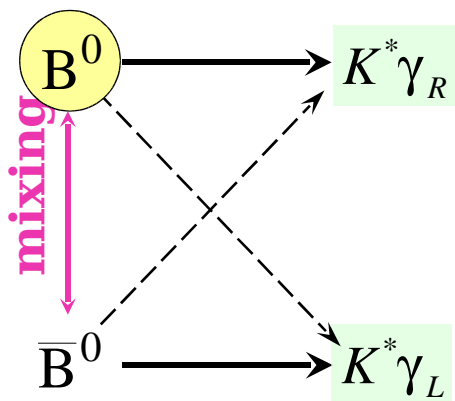
$$\sin(2\beta[\bar{c}c]) = 0.726 \pm 0.037 @ 2.8\sigma$$

Pinguini Radiativi: $B \rightarrow K^*(K^* \rightarrow K_s \pi^0) \gamma$

- Transizione elementare $b \rightarrow s \gamma$
- Stato finale $K_s \pi^0 \gamma$ accessibile sia a B^0 che a \bar{B}^0



- Nel limite di quark s a massa nulla, i fotoni sono completamente polarizzati con elicità opposte per B^0 e \bar{B}^0



~~CP~~ nell'interferenza tra mixing e decadimento
soppressa di un fattore $\sim \mathbf{m_s/m_b}$

- Nello SM: $S_{K^* \gamma} \approx (2m_s/m_b) \sin 2\beta \approx 0.05$ e $|C_{K^* \gamma}| < 1\%$

$B \rightarrow K^*(K^* \rightarrow K_S \pi^0) \gamma$: risultati

124×10^6 coppie

- Selezione dei fotoni:

- cluster energetici isolati nel calorimetro
- forma dello sciame
- veto su π^0 e η

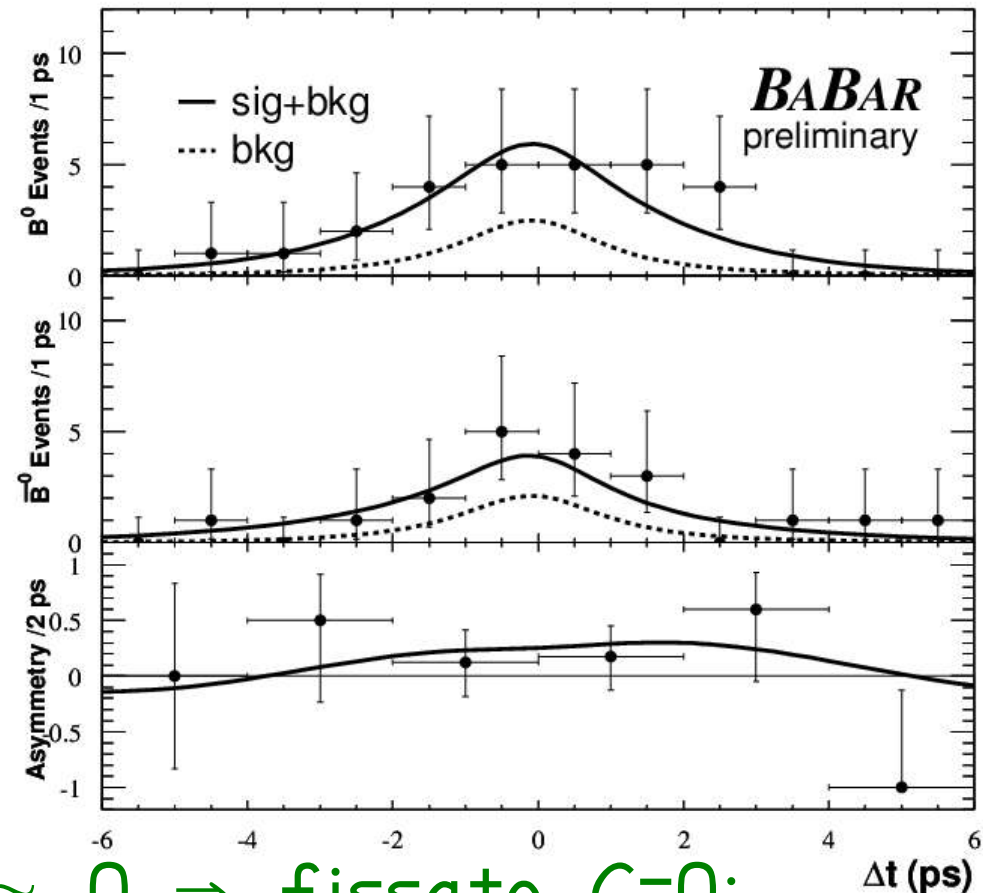
- Tecnica del vertice
Beam Spot Constrained

$$S = 0.25 \pm 0.63 \pm 0.14$$

$$C = -0.57 \pm 0.32 \pm 0.09$$

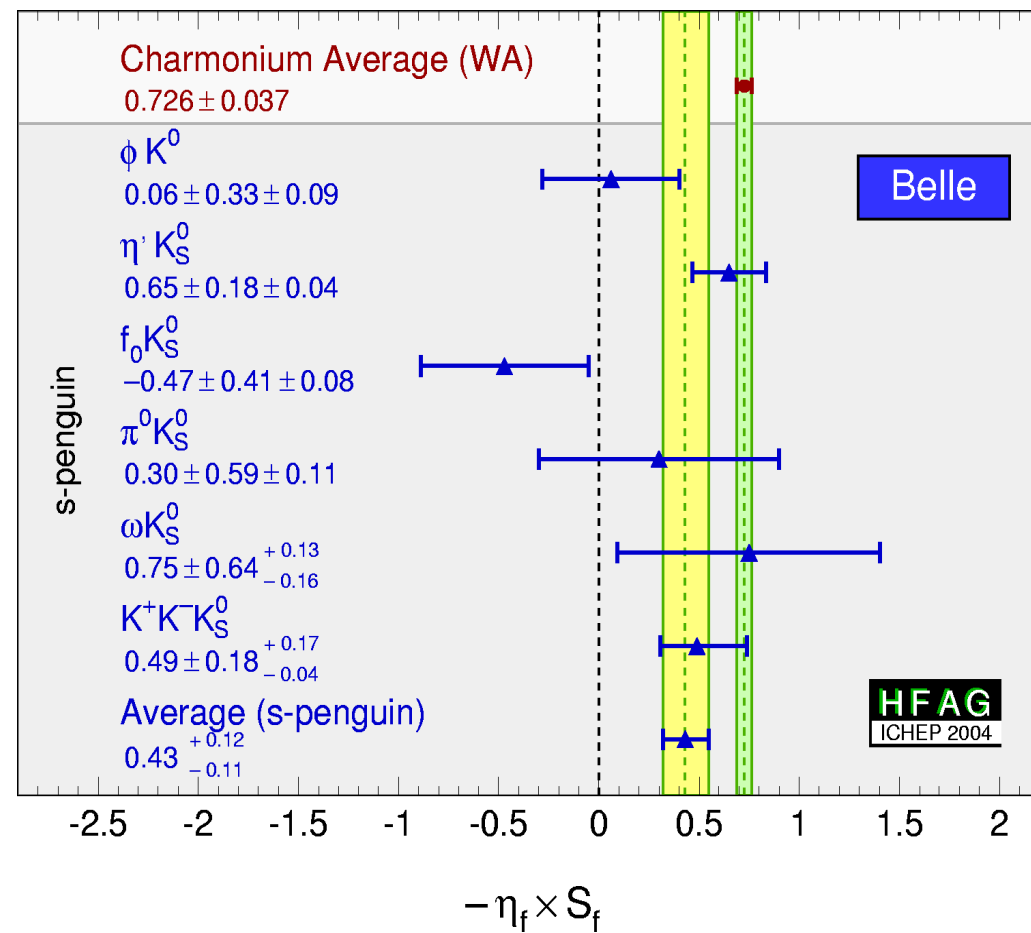
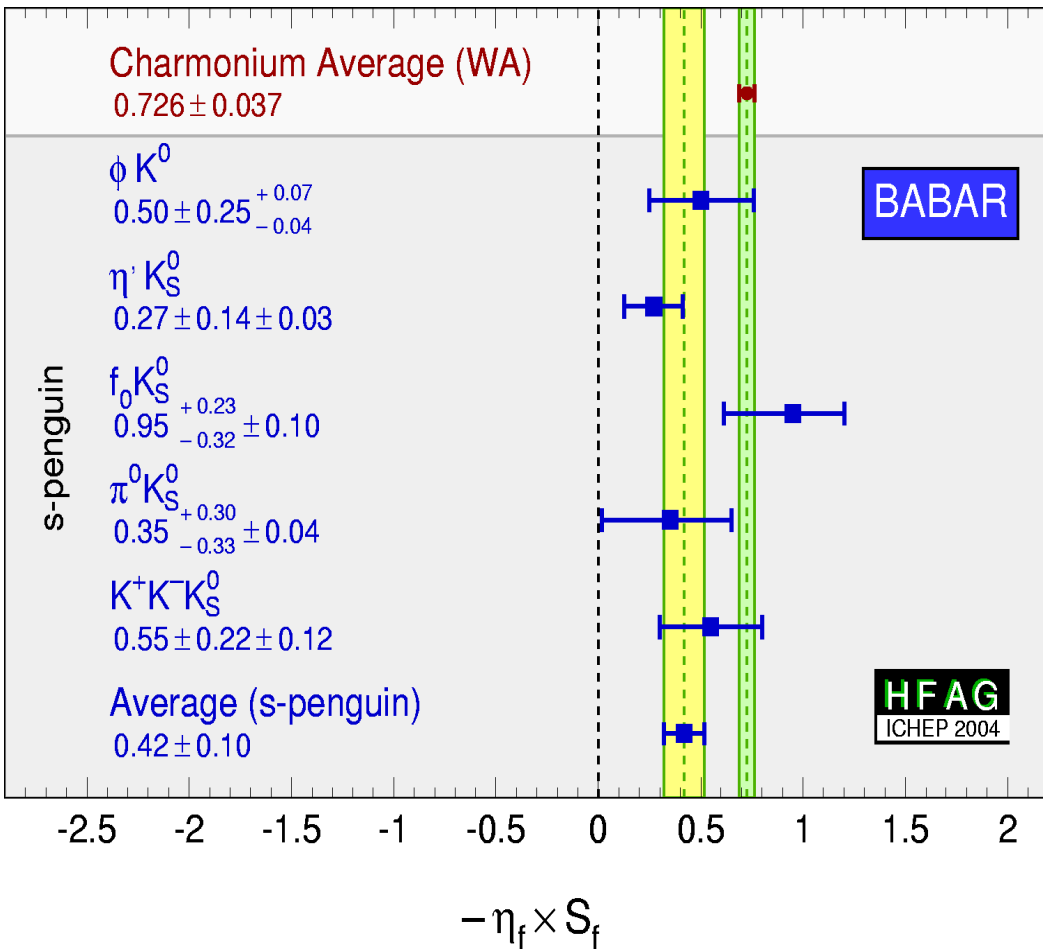
- In SM $C_{K^* \gamma} = -A_{K^* \gamma}(K^* \rightarrow K^+ \pi^-) \approx 0 \Rightarrow$ fissato $C=0$:

- $S = 0.25 \pm 0.65 \pm 0.14$



Prima misura "time dependent"
di $b \rightarrow s \gamma$

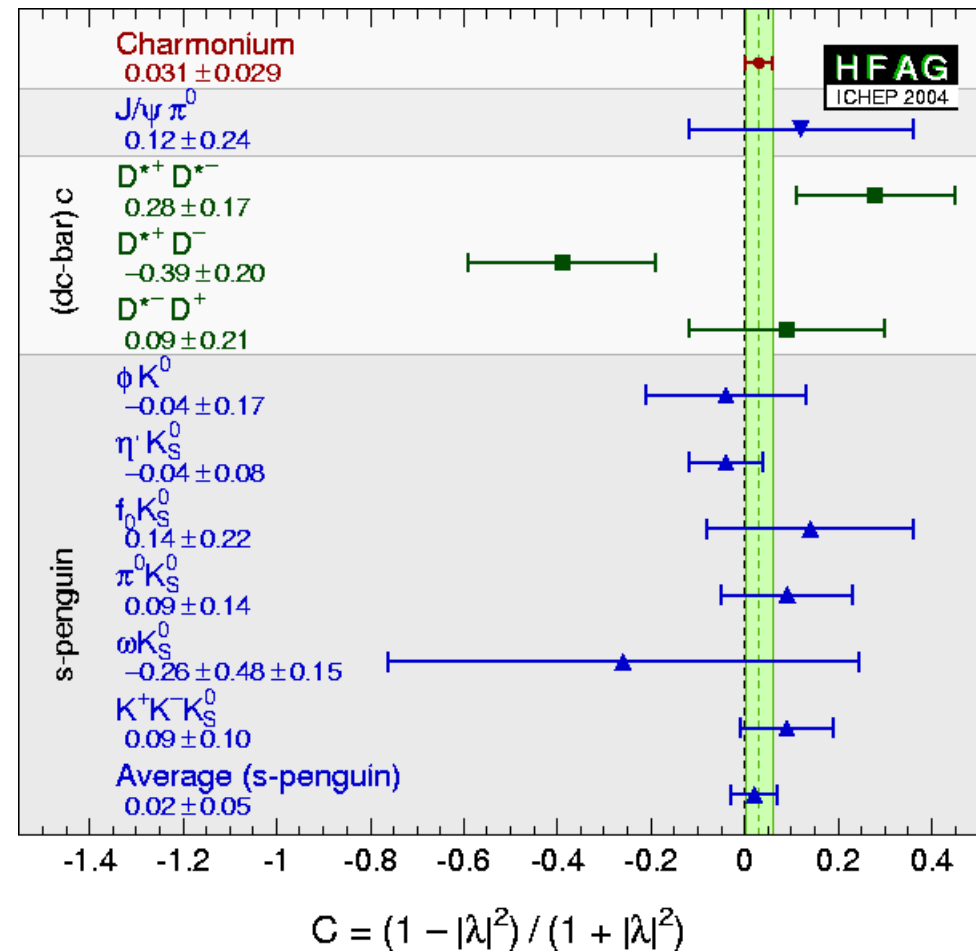
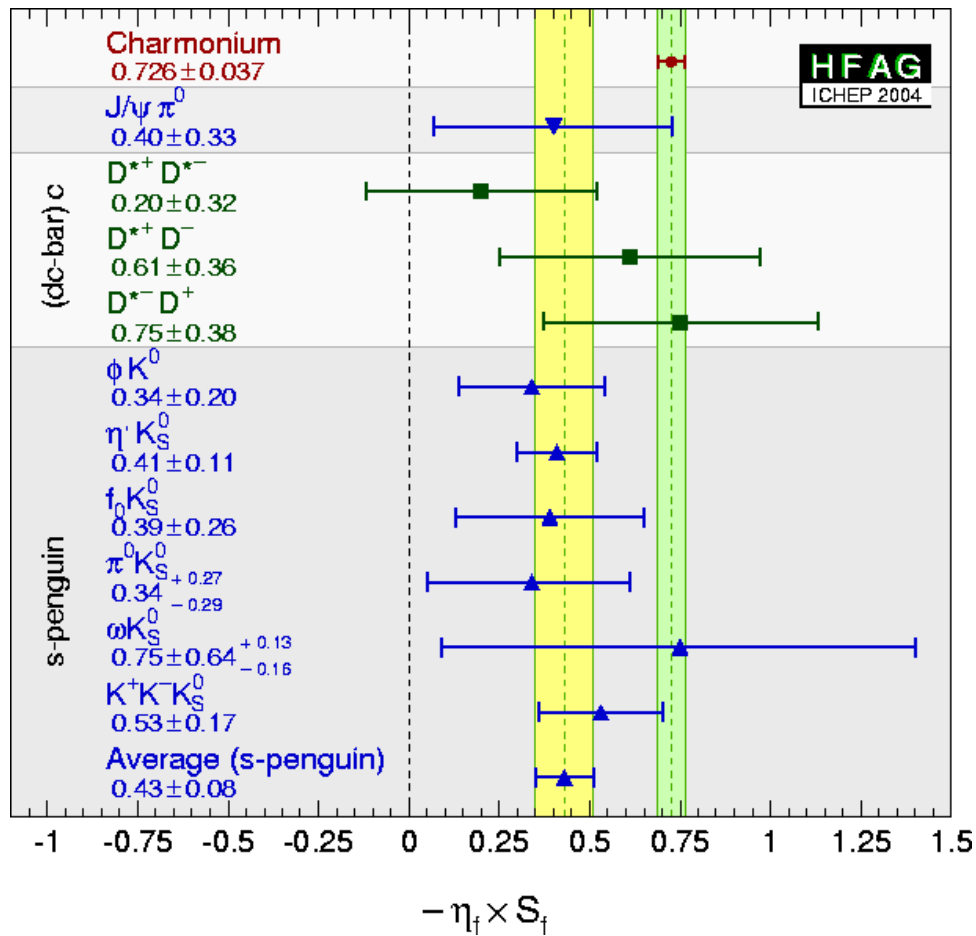
$\sin 2\beta_{eff}$: BaBar vs. Belle



- $S_{\phi K}$ consistent tra loro e con SM
- $S_{f_0 K}$ inconsistenti a piu' di 2σ
- $\sigma(K_S \pi^0)_{BaBar} \ll \sigma(K_S \pi^0)_{Belle}$

$$S_{charmonio} = 0.726 \pm 0.037$$

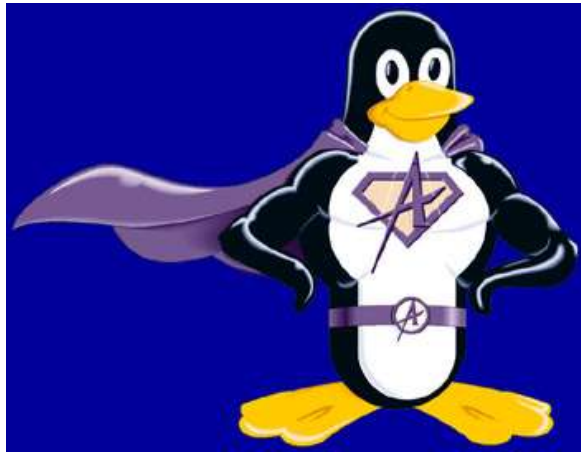
Media delle B-factory



- $S_{\text{pinguini}} = 0.41 \pm 0.07$
- $S_{\text{charmonio}} = 0.725 \pm 0.037$

- $C_{\text{pinguini}} = 0.02 \pm 0.05$
- $C_{\text{charmonio}} = 0.031 \pm 0.029$

Ma non solo
“Time Dependent”...



vs.



nella ricerca di fisica oltre SM

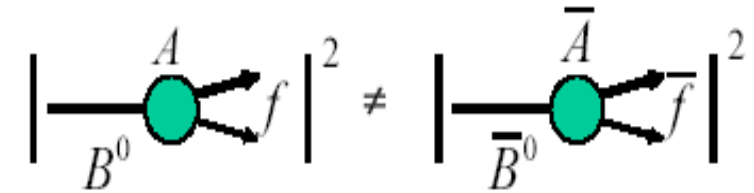
$B^+ \rightarrow \phi K^+$: ~~CP~~ diretta

- Nei decadimenti del B^+ si misura A_{CP} diretta:

$$A_{CP} = \frac{\text{Br}(\bar{B} \rightarrow \bar{f}) - \text{Br}(B \rightarrow f)}{\text{Br}(\bar{B} \rightarrow \bar{f}) + \text{Br}(B \rightarrow f)} \neq 0 \Rightarrow \text{CPV diretta}$$

- In pratica si misura l'asimmetria integrata di carica:

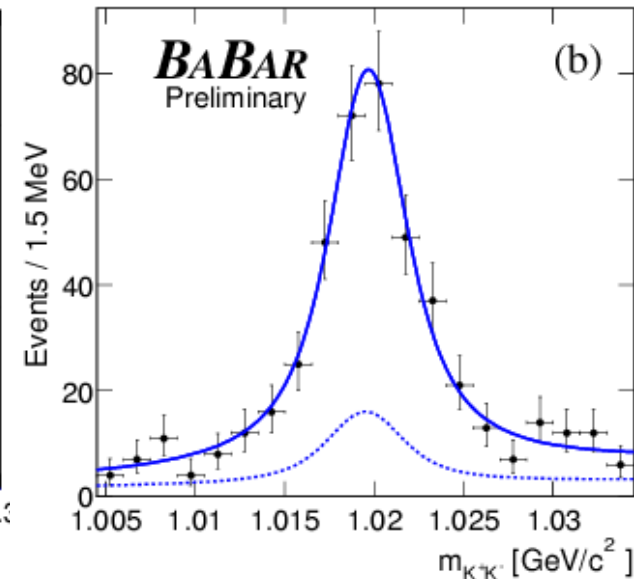
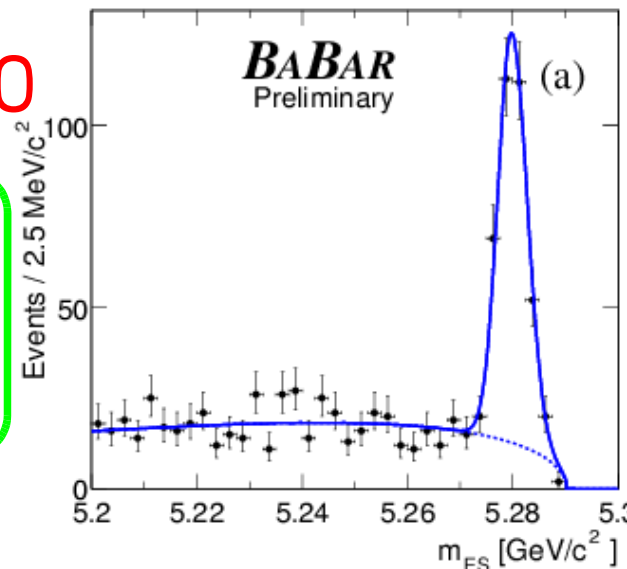
$$A_{CP} = 1 - 2f^+, \quad f^+ = N^+ / (N^+ + N^-)$$



- Nello SM: $A_{CP}(\phi K^+) = 0$

$$N(\phi K^+) = 400 \pm 23$$

$$A_{CP} = 0.054 \pm 0.056 \pm 0.012$$



$B^0 \rightarrow \phi K^{*0}$

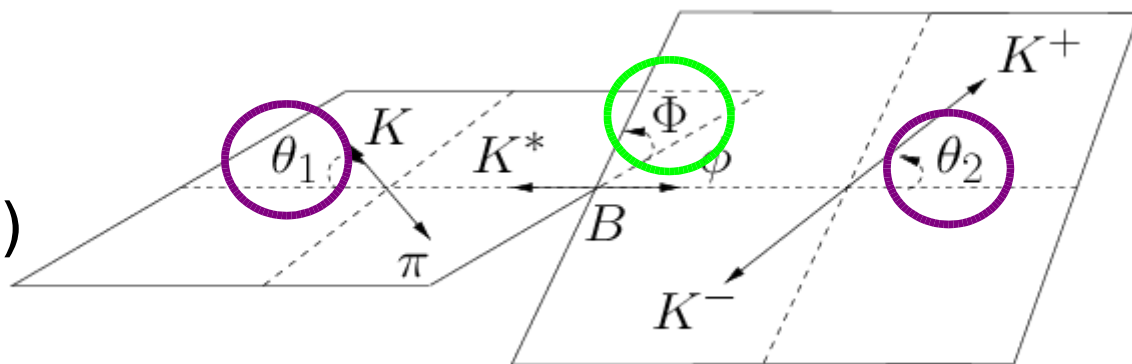
Decadimento $B \rightarrow VV$:

– il contenuto di CP dipende dallo stato angolare

$$\frac{d^3\Gamma}{d \cos \theta_1 d \cos \theta_2 d\Phi} \propto \left| \sum_{m=-1}^1 A_m \times Y_{1,m}(\theta_1, \Phi_1) \times Y_{1,-m}(\theta_2, \Phi_2) \right|^2$$



$$\Gamma(\phi K^*) = f(H_i = \cos \theta_i, \Phi, A_0, A_{\parallel}, A_{\perp})$$



L'ampiezza trasversa e' una combinazione CP+ e CP-:

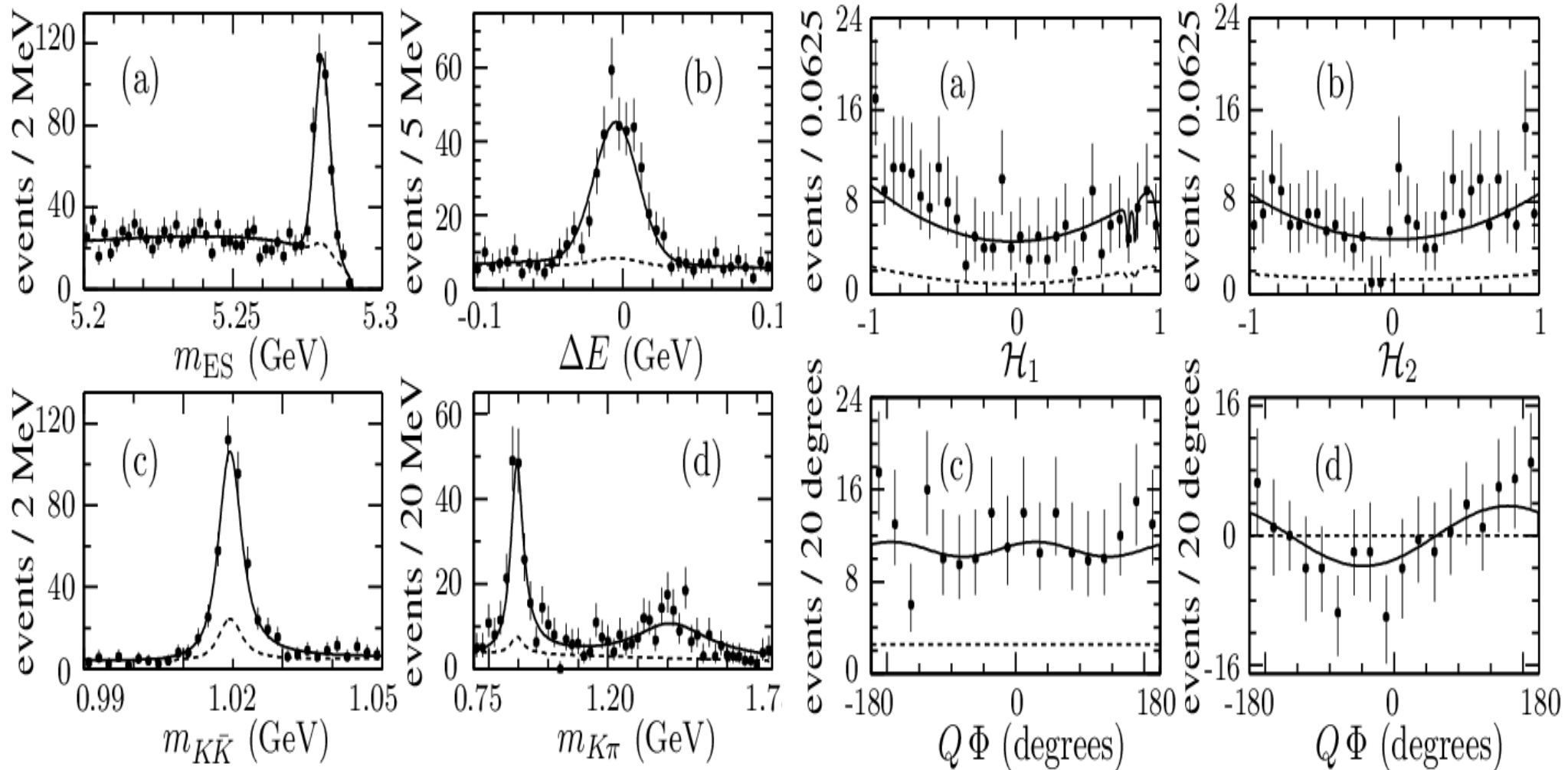
- A_0 : longitudinale (CP=+1)
- A_{\parallel} : trasversa (CP=+1)
- A_{\perp} : trasversa (CP=-1)

$$\begin{aligned} \Sigma_{\lambda\lambda} &= (|A_{\lambda}|^2 - |\bar{A}_{\lambda}|^2)/2 \\ \Lambda_{\perp i} &= -\text{Im}(A_{\perp} A_i^* - \bar{A}_{\perp} \bar{A}_i^*) \\ \Sigma_{//0} &= \text{Re}(A_{//} A_0^* - \bar{A}_{//} \bar{A}_0^*) \end{aligned}$$

~~CP~~ diretta

Triplo-prod.
(viol. di T)

$B^0 \rightarrow \phi K^{*0}$: sample



$N(\phi K^{*0}(892)) = 201 \pm 20 \pm 6$
 $BF(\phi K^{*0}) = (9.2 \pm 0.9 \pm 0.5) \times 10^{-6}$

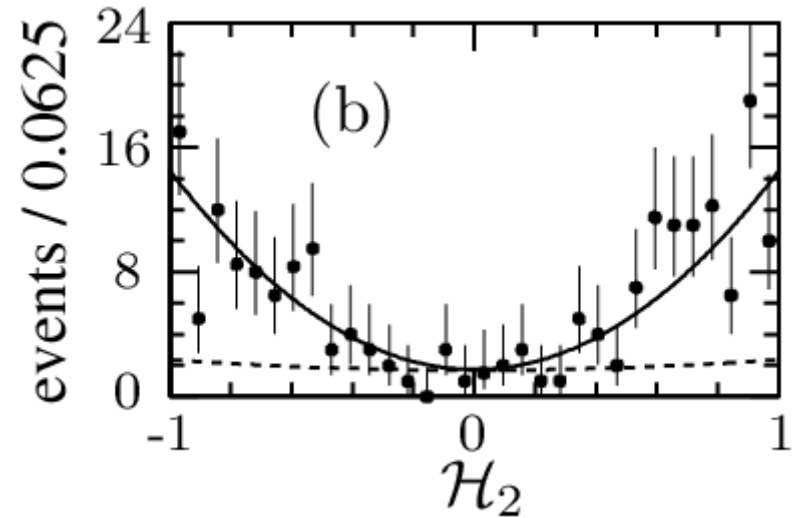
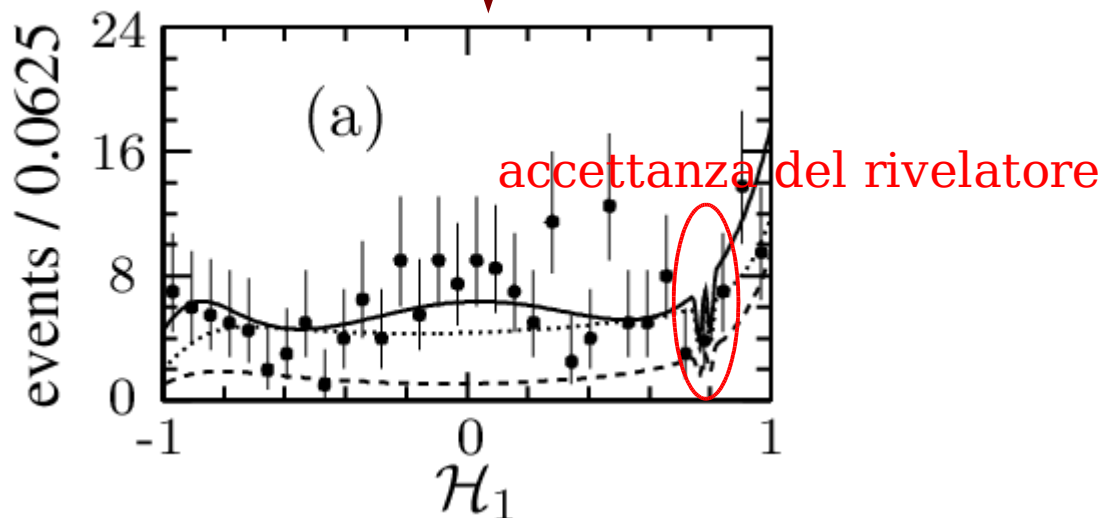
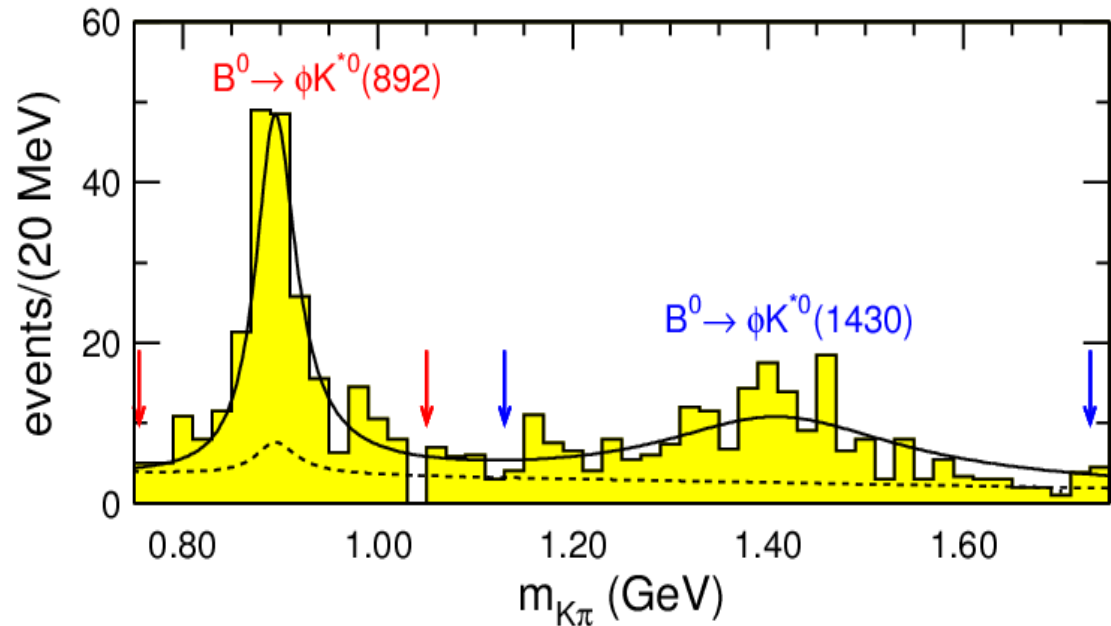
Osservazione di $B^0 \rightarrow \phi K^{*0}(1430)$

- Osservazione di 181 ± 17 eventi (19σ)

- 100% longitudinale (H_2)

- $K^{*0}(1430)$ composto da:

- $K_0^{*0}(1430)$ (scalare) (H_1)
- $K_2^{*0}(1430)$ (tensore)



$B^0 \rightarrow \phi K^{*0}$: polarizzazione

- Si misurano:

227×10^6 coppie

$$\begin{aligned} f_L^\pm &= |A_0^\pm|^2 & f_\perp^\pm &= |A_\perp^\pm|^2 \\ \phi_\parallel^\pm &= \arg(A_\parallel^\pm) & \phi_\perp^\pm &= \arg(A_\perp^\pm) \end{aligned}$$

e da queste si costruiscono le asimmetrie

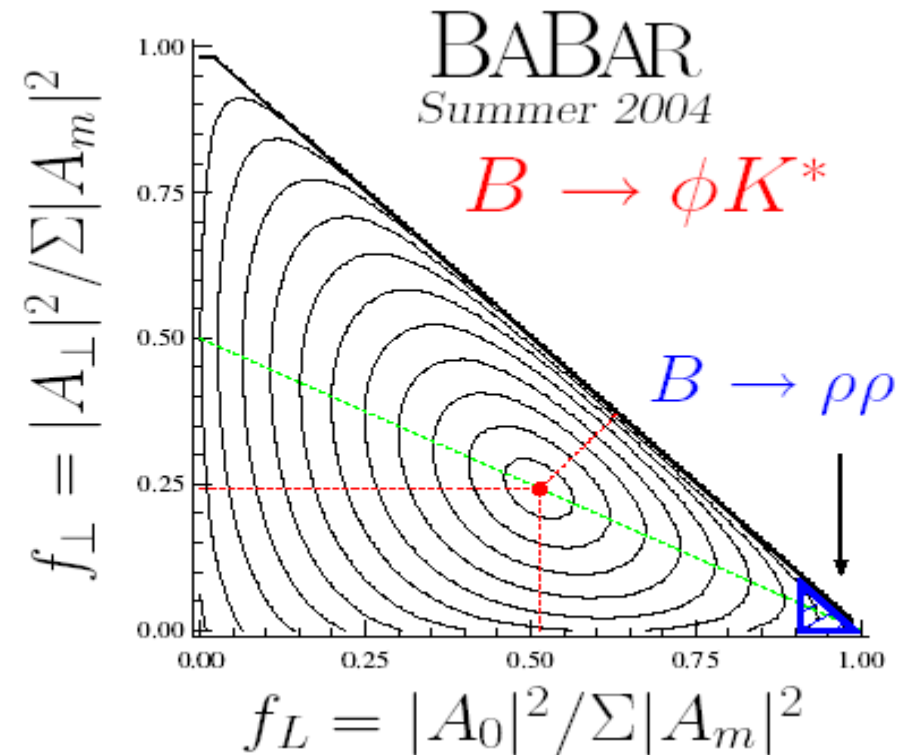
- In fattorizzazione naïve:

$$f_L \sim 1 - \frac{m_V^2}{m_B^2} \sim 0.96$$

– nei canali dominati da albero ($\rho^+\rho^-$, $\rho^+\rho^0$): $f_L \approx 1$

– Fit:

$$\begin{aligned} f_L &= 0.52 \pm 0.05 \pm 0.02 \\ f_\perp &= 0.22 \pm 0.05 \pm 0.02 \end{aligned}$$



Il "polarization puzzle"

- $f_{\perp}(\text{pinguino}) \approx 0.5$ vs. $f_{\perp}(\text{albero}) \approx 1 \Rightarrow$ NP?

- Ma interazioni a lunga distanza (FSI) introducono nuove fasi forti

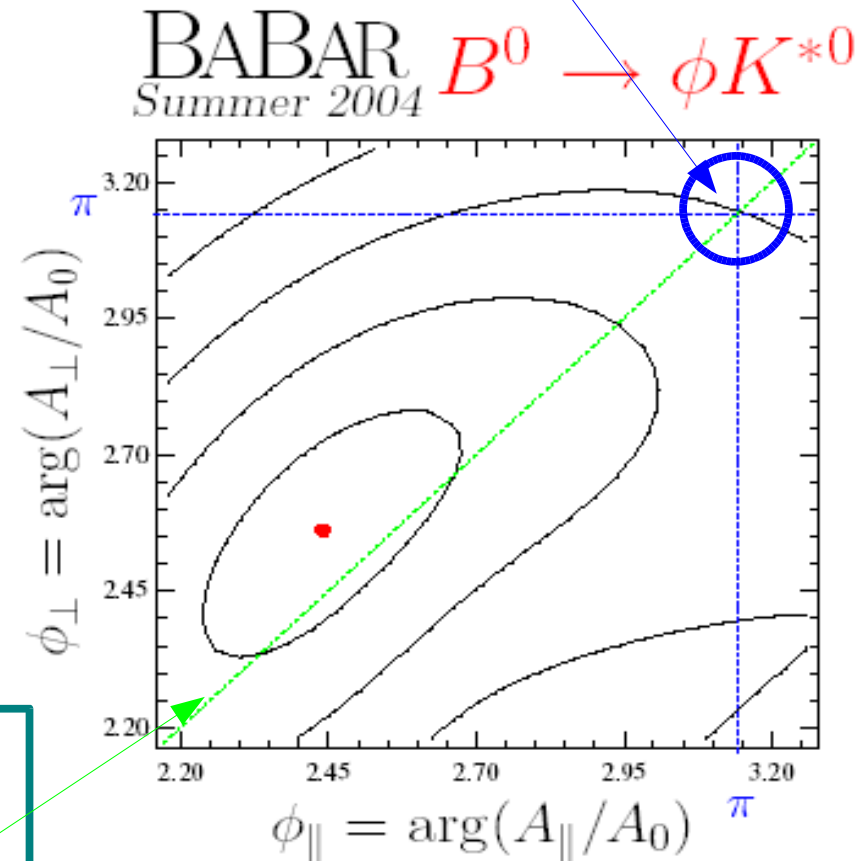
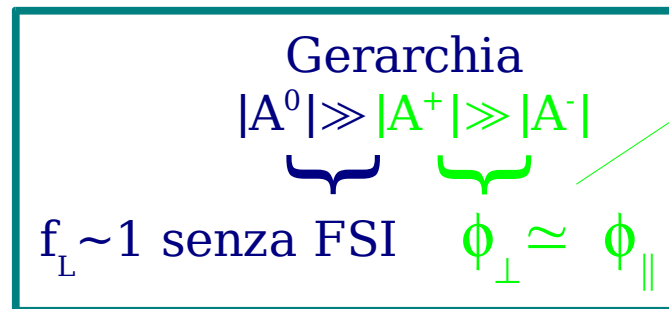
$\{\pi;\pi\}$ = SM senza contributi non fattorizzabili

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

Evidenza a 3.0σ di FSI

Belle [152×10^6 coppie]:

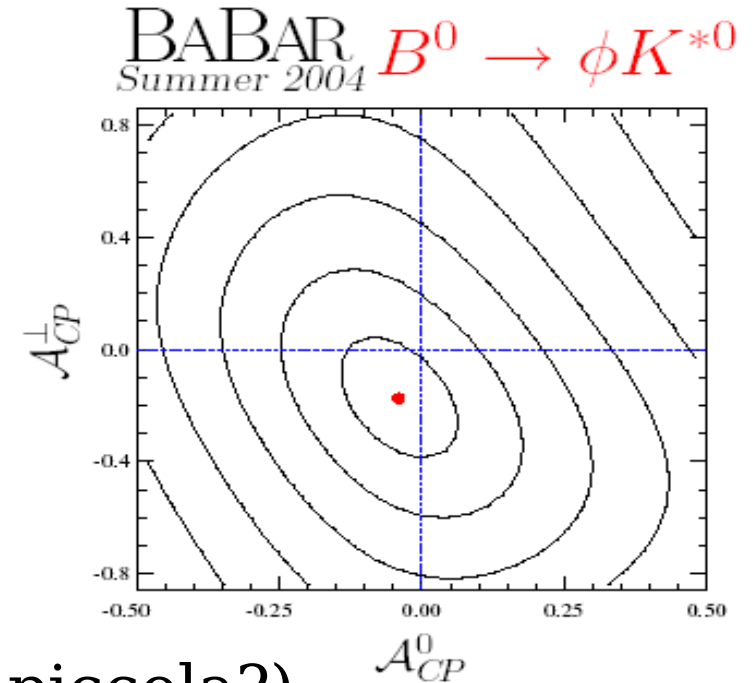
- $\phi_{\parallel} = -2.58 \pm 0.40$
- $\phi_{\perp} = 0.48 \pm 0.33$



$B^0 \rightarrow \phi K^{*0}$: ~~CP~~ e ~~T~~

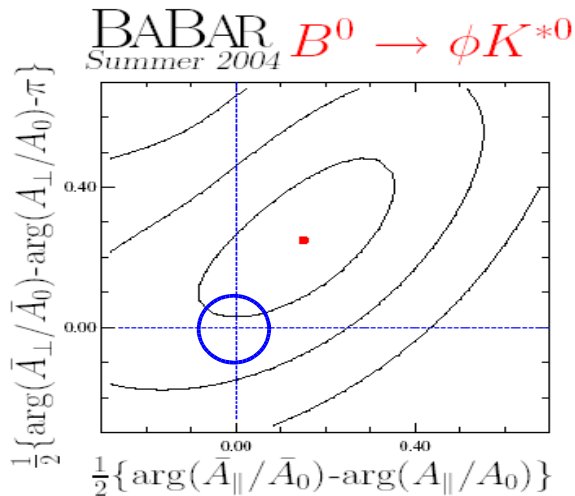
• ~~CP~~ dirette:

- $A_{CP} = -0.01 \pm 0.09 \pm 0.02$
- $A_{CP}^0 = -0.06 \pm 0.10 \pm 0.01$
- $A_{CP}^\perp = -0.10 \pm 0.24 \pm 0.05$



$$\propto \sin \Delta \delta_{\text{forte}} \sin \Delta \delta_{\text{debole}}$$

Nessuna evidenza di ~~CP~~ diretta ($\Delta \delta_{\text{forte}}$ piccola?)



Triplo prodotto (violazione di T):

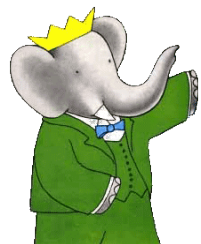
$$\Delta \phi_{\parallel} = 0.15^{+0.21}_{-0.24} \pm 0.05 \text{ (rad)}$$

$$\Delta \phi_{\perp} = 0.25^{+0.23}_{-0.22} \pm 0.05 \text{ (rad)}$$

$\neq \{0,0\} \Rightarrow \text{NP}$

$$\propto \cos \Delta \delta_{\text{forte}} \sin \Delta \delta_{\text{debole}}$$

$B^0 \rightarrow \phi K^{*0}$: BaBar vs. Belle



227M coppie $\bar{B}B$



152M coppie $\bar{B}B$

$\Lambda_{00} (= f_L)$

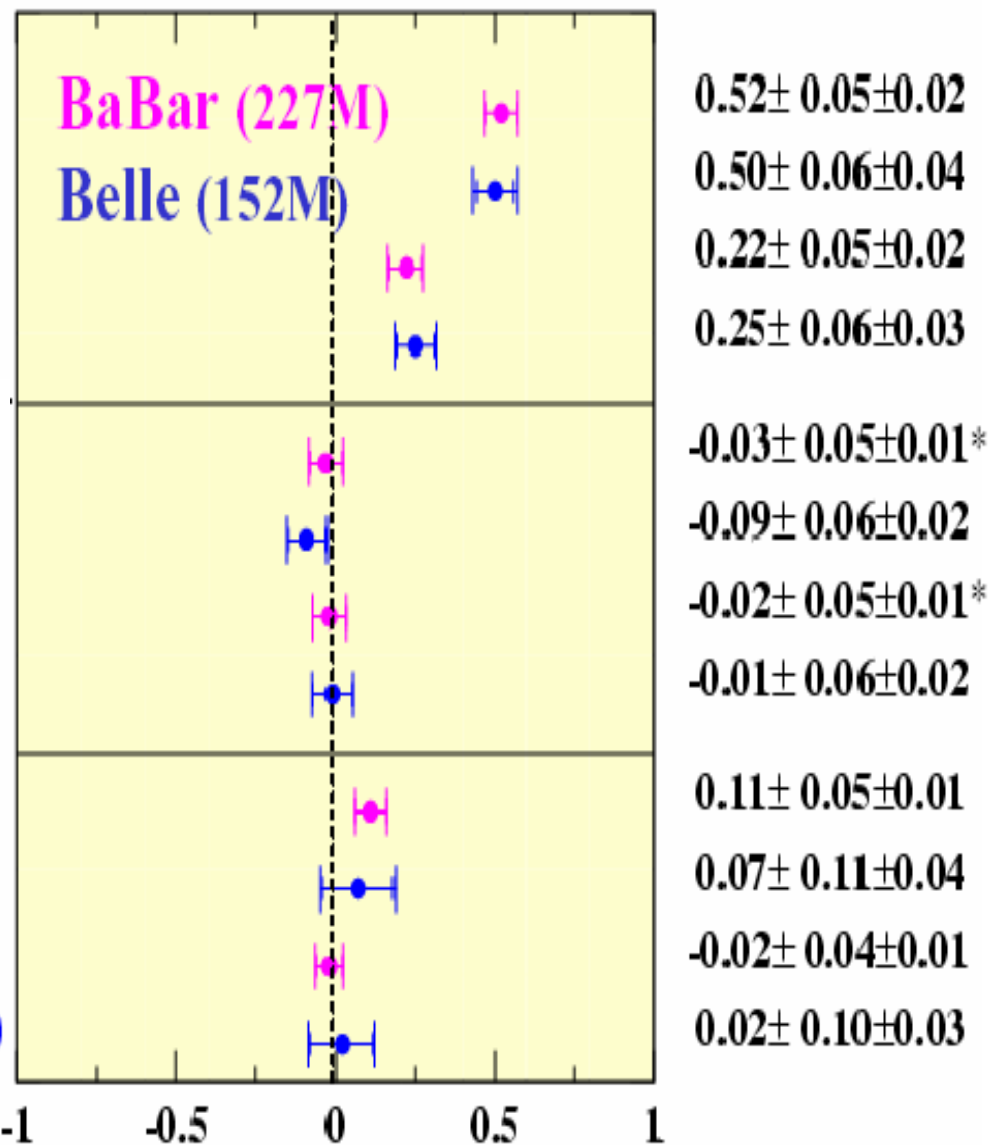
$\Lambda_{\perp\perp} (= f_{\perp})$

Σ_{00}

$\Sigma_{\perp\perp}$

$\Lambda_{\perp 0} (= A_T^0)$

$\Lambda_{\perp //} (= A_T^{//})$



* ricalcolati dai valori fittati

• Nello SM: $A, \Sigma = 0$

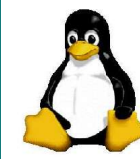
• BaBar e Belle consistenti

• Nessun segnale di NP eccetto il "f_L puzzle", ma ci sono le FSI

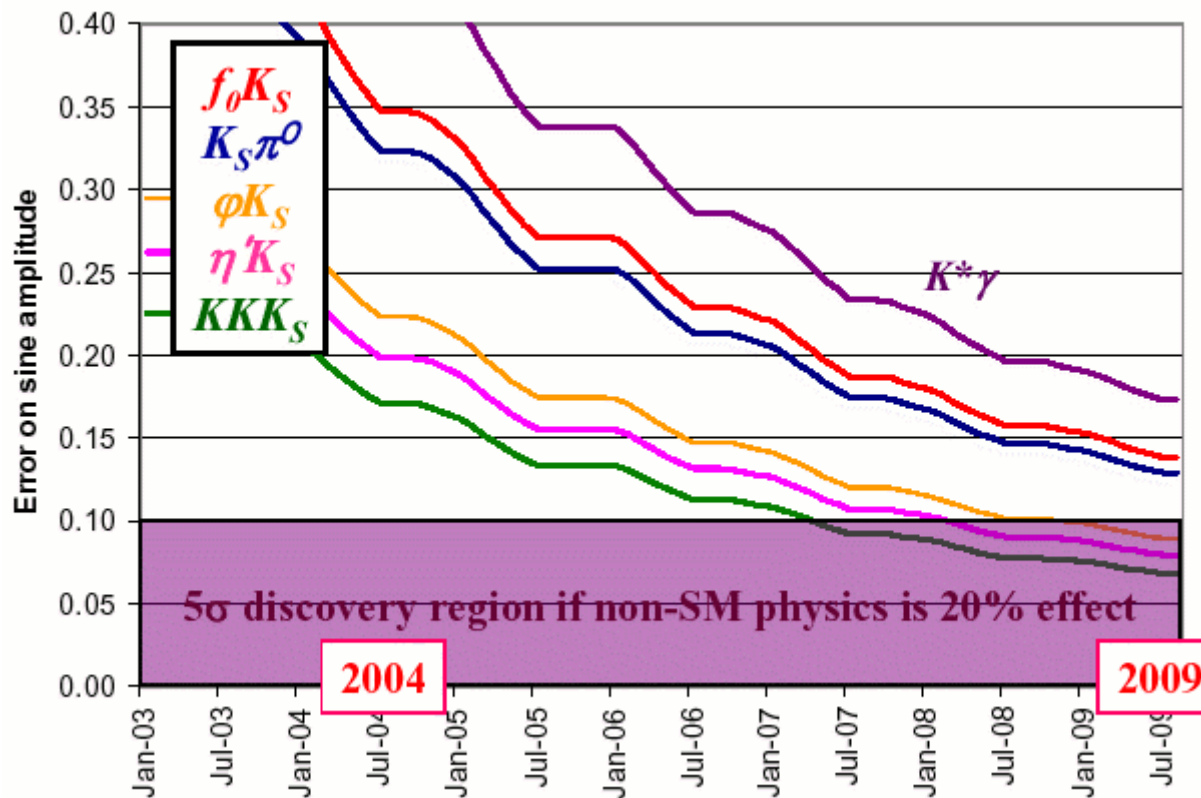
Conclusioni

- Molti decadimenti a pinguino studiati oltre $B \rightarrow \phi K$
- I risultati delle B-factory BaBar e Belle sono in accordo tra loro
- Gli esperimenti mostrano una discrepanza nei canali $b \rightarrow s \bar{q}q$ di $\sim 2.7\sigma$ [BaBar] e $\sim 2.4\sigma$ [Belle] dal charmonio $b \rightarrow \bar{c}cs$
- Con l'aumento della luminosita' ci si aspetta $\sigma(\sin 2\beta_{\text{eff}}(\phi K)) < 0.1 \Rightarrow$ test fondamentale della descrizione CKM della fisica del flavour.

Il futuro dei



L'aumento della statistica delle B-factory nei prossimi anni potrebbe condurre ad un'iniziale evidenza di nuova fisica oltre lo SM:



Luminosita'
aspettata:

2004 = 240 fb⁻¹
2009 = 1.5 ab⁻¹

L'errore proiettato e' solo statistico,
ma in tutti i canali l'errore sistematico e' ~1%