Time dependent CP violation in penguin dominated B decays

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for the Belle Collaboration

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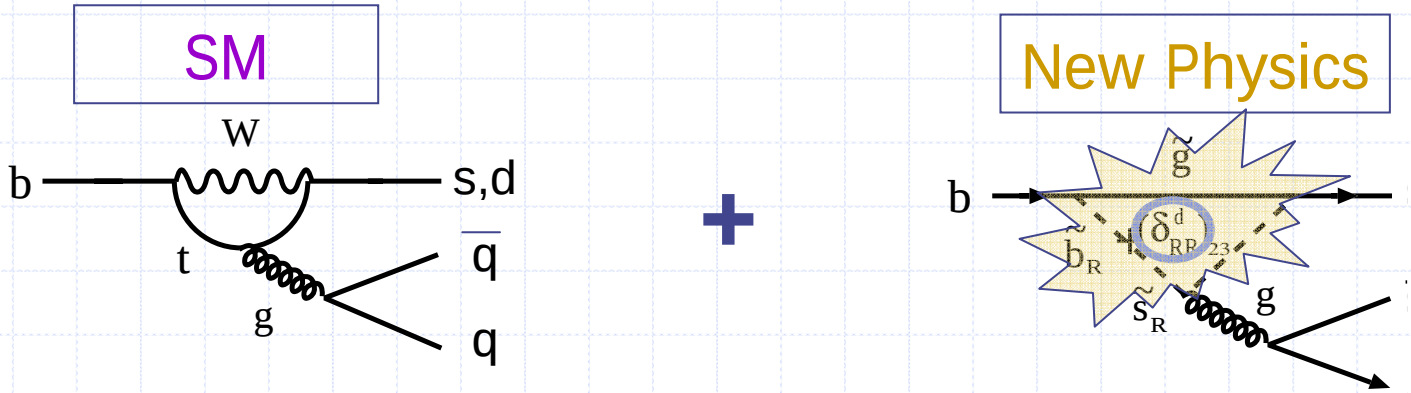
- Introduction
- New measurement of time-dependent CP violation (tCPV) in $B^0 \rightarrow K_S \pi^0 \pi^0$
- New tCPV result for $B^0 \rightarrow K_S K_S$

Introduction

- Penguin dominated B decays are sensitive to new physics beyond the SM

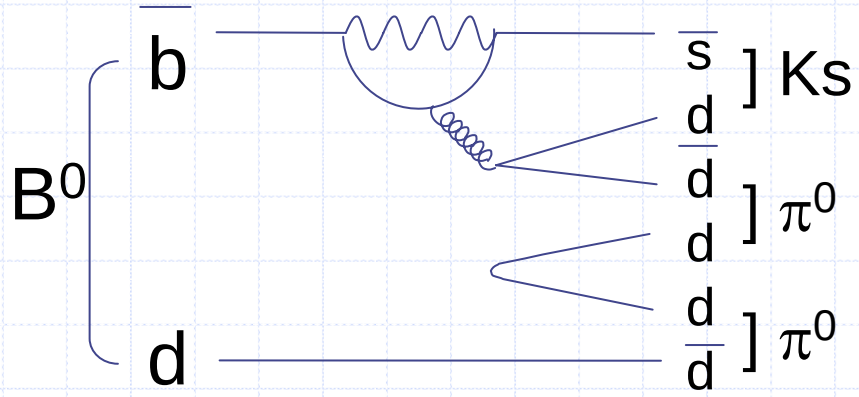


- New Physics may introduces extra CP phase in the decay
- Deviation of Time-dependent CP violation parameters from the SM expectation → Hint of New Physics

$$A_{CP}(t) \equiv \frac{\Gamma_{\overline{B}^0 \to f_{CP}}(t) - \Gamma_{B^0 \to f_{CP}}(t)}{\Gamma_{\overline{B}^0 \to f_{CP}}(t) + \Gamma_{B^0 \to f_{CP}}(t)} = S \sin \Delta m_d t + \mathcal{A} \cos \Delta m_d t$$

tCPV in $B^0 \to K_S \pi^0 \pi^0$

- Dominated by $b \to s\bar{q}q$ penguin decay
  - In the SM, no CP phase in the decay



- CP even, regardless of any resonance structure

  [T. Gershon and M. Hazumi, PLB 596 163 (2004)]

SM expectation

$\mathcal{S} = -\sin 2\phi_1$

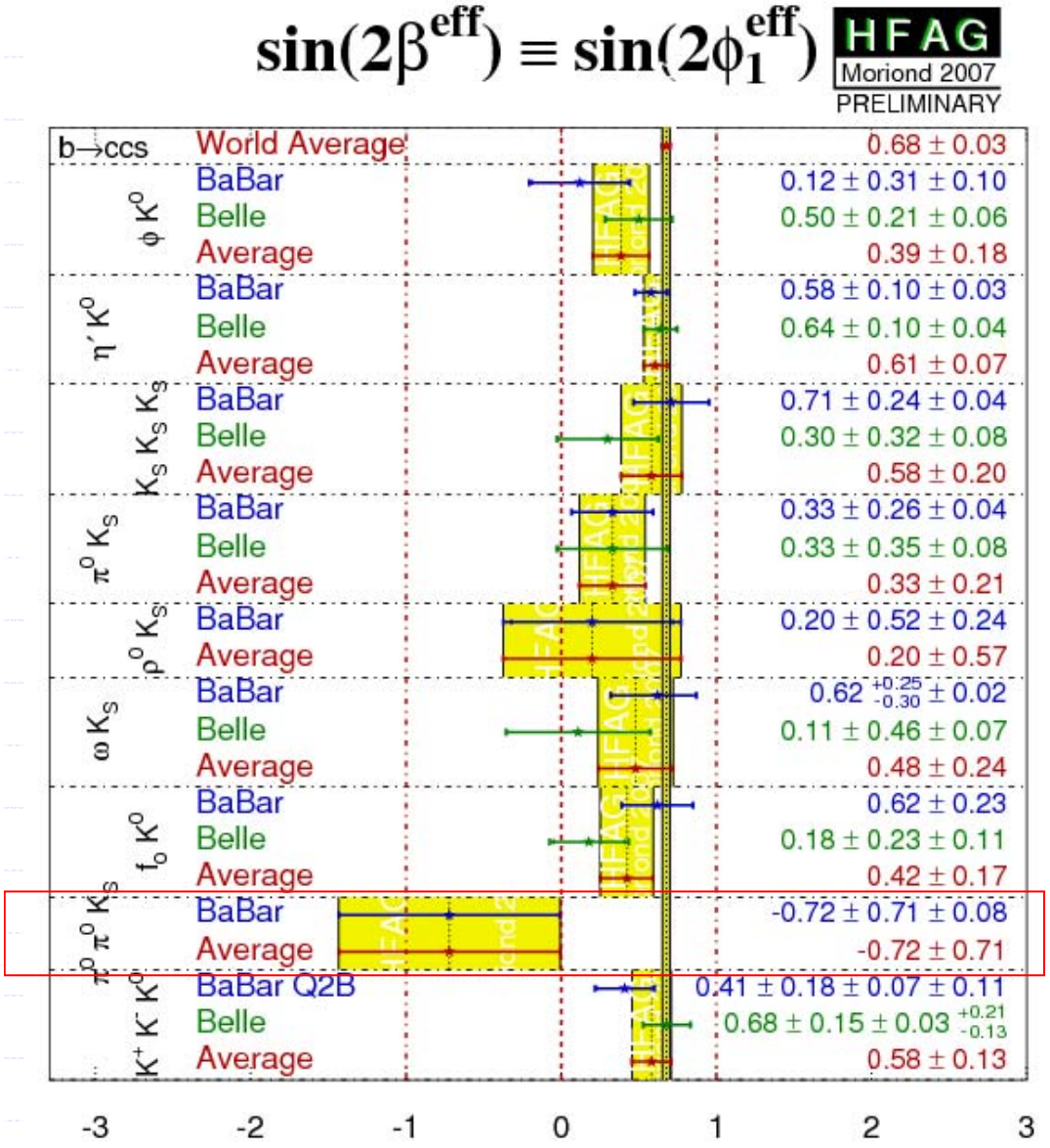
$\mathcal{A} = 0$

With small SM error

$\Delta \sin 2\beta_{K_S \pi^0 \pi^0} = 0.034^{+0.020}_{-0.025}$

[Hai-Yang Cheng, hep-ph/0702252]

b→sq̄q Situation as of Winter 2007



b→sq̄q naïve average

$\sin2\phi_1^{eff}=0.53\pm0.05$

2.6 sigma from the SM

- So far the only result available for $K_S\pi^0\pi^0$ is from BaBar, based on 227x10^6 B pairs
  - Sign of $\mathcal{S}$ is opposite to the SM expectation

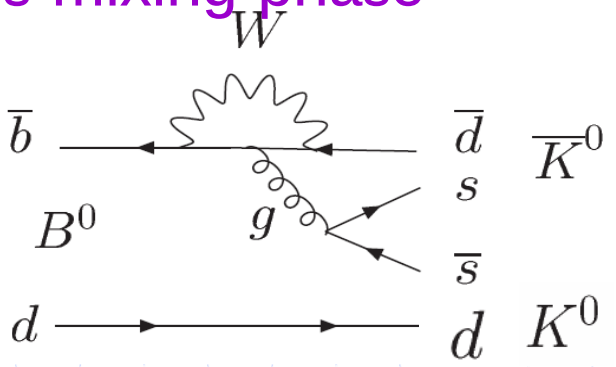
tCPV in $B^0 \rightarrow K_S K_S$

- $b \rightarrow d\bar{q}q$ penguin
  - Assuming top-quark dominance:
    $b \rightarrow t \rightarrow d$ penguin phase cancels mixing phase

SM expectation

$\mathcal{S} = 0$

$\mathcal{A} = 0$



Considering small contributions from *u*- and *c*-penguins:

$0.02 < \mathcal{S}(\mathrm{SM}) < 0.13$

$0.15 < \mathcal{A}(\mathrm{SM}) < 0.17$

Predictions (using QCD FA):
R. Fleischer and S. Recksiegel,
Eur.Phys.J.C38:251-259,2004

- BaBar has measured tCPV using 348×10^6 B pairs

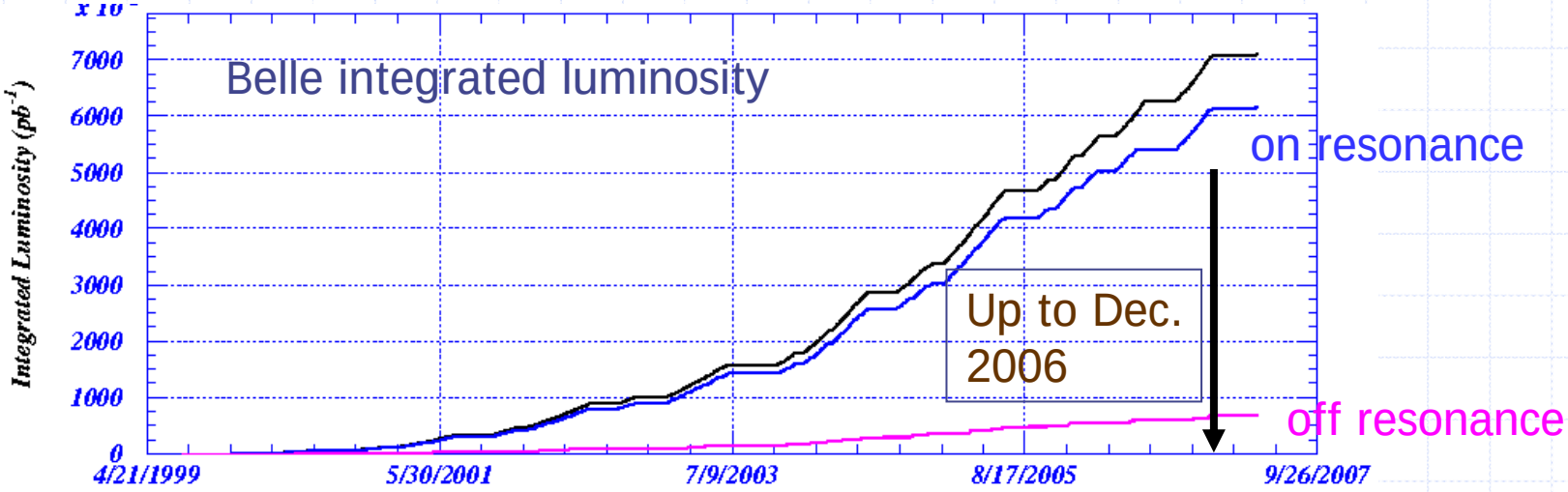
$\mathcal{S} = -1.28^{+0.80+0.11}_{-0.73-0.16}$ [PRL 97 (2006) 171805]

C=-$\mathcal{A}$= -0.40+/-0.41+/-0.06

We report first Belle results for

- tCPV in $B^0 \rightarrow K_S\pi^0\pi^0$
- tCPV in $B^0 \rightarrow K_SK_S$

based on a data sample of 657×10^6 $B\bar{B}$ pairs

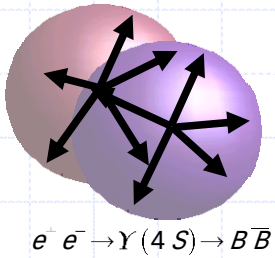


All results are preliminary

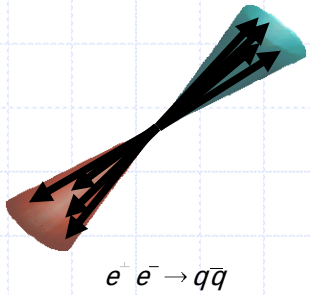
New tCPV result for $B^0 \rightarrow K_S \pi^0 \pi^0$

Signal Extraction

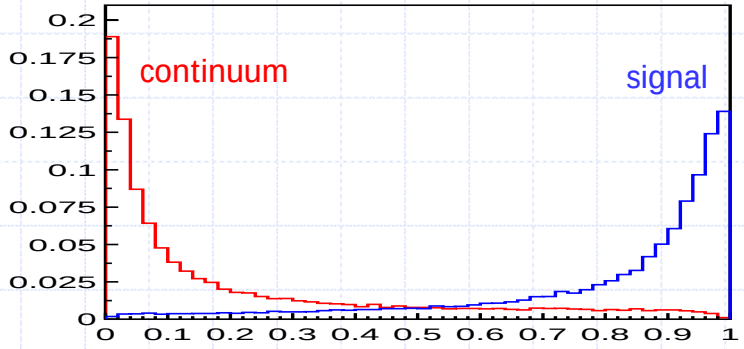
- B^0 decay candidates are selected by
  Energy difference : $\Delta E = E_B - E_{beam}$
  Beam constrained mass: $M_{bc} = (E_{beam} - P_B^2)^{1/2}$
- Dominant Background is e^+e^- → $q\bar{q}$ continuum
  → Distinguished from signal using a Likelihood Ratio(LR) based on event shape variables.



(Spherical)



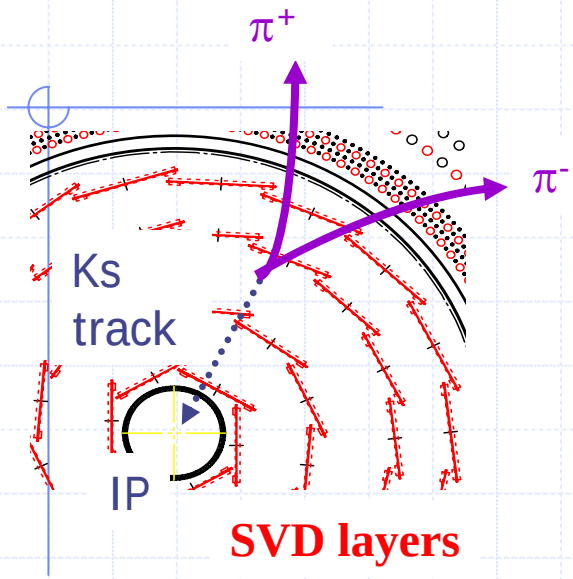
(Jet-like)



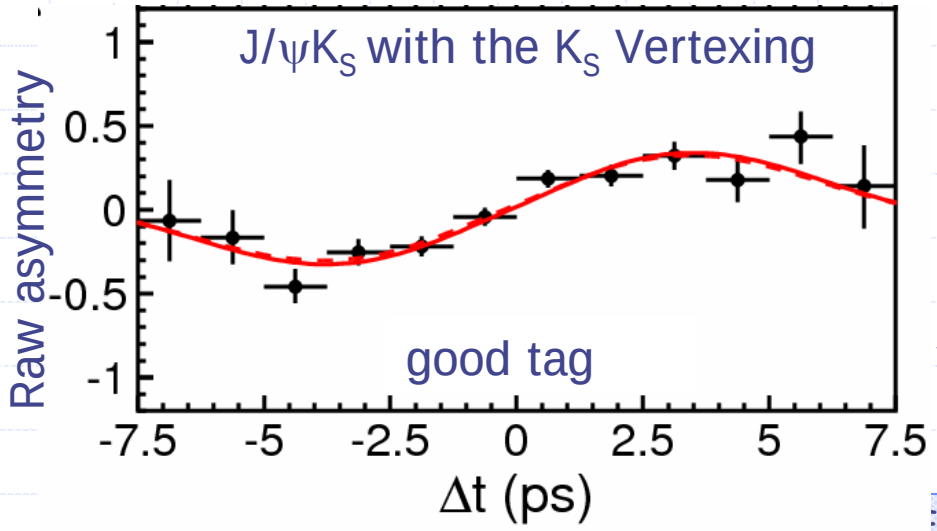
LR

- Vetoes to suppress other B decays
  - b→c Veto: $D^0 \to K_S\pi^0$ $(1.77 < M_{K\pi} < 1.94 GeV/c^2)$ $\chi_{c0} \to \pi^0\pi^0$ $(3.27 < M\pi\pi < 3.49 GeV/c^2)$
  - $B \to K_S\pi^0$ veto: $M_{K\pi} > 4.8 GeV/c^2$
  - $B \to K_SK_S$ veto: $M\pi\pi < 0.51 GeV/c^2$

Vertex Reconstruction with K_S



- No primary tracks from B vertex
- Use K_S track with the constraint to the Interaction Point profile
  - Require daughter pions to have SVD hits
  - Vertex reconstruction efficiency ~40%
    = Probability of Ks decay within SVD.
- Events without a vertex can still be used for $\mathcal{A}$ measurement.



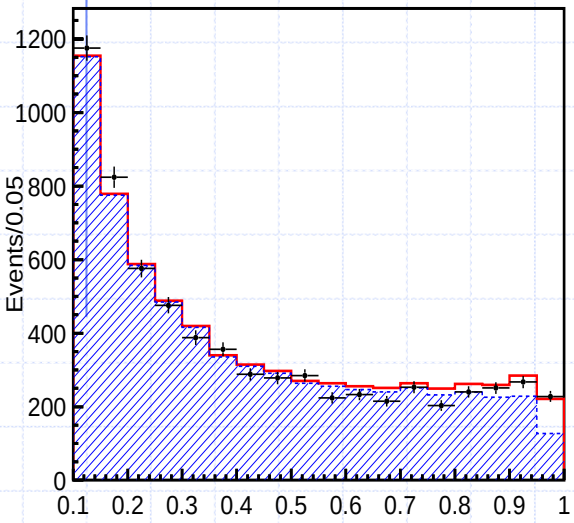
- The validity is confirmed using the $J/\psi K_S$ control sample.

B^0 Lifetime 1.503+/-0.036 ps

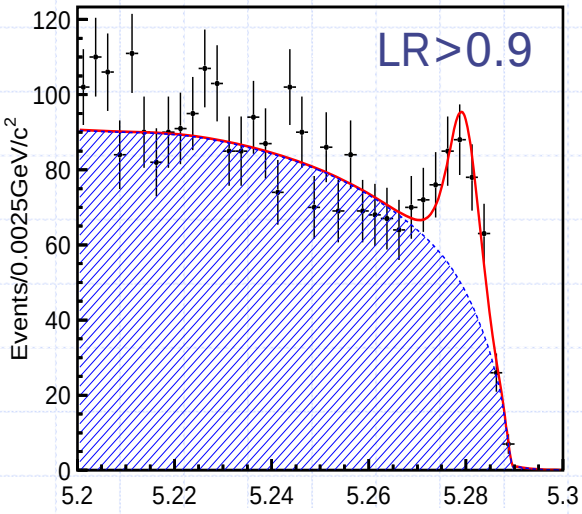
$\sin 2\phi_1 = +0.68 +/- 0.06$

$B^0 \rightarrow K_S \pi^0 \pi^0$ Signal Yield

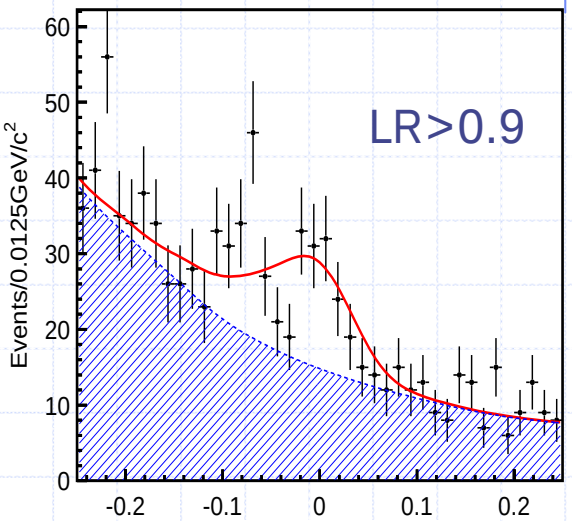
Event-by-event signal fractions extracted from 3D M_{bc}-ΔE-LR fit.



LR



$M_{bc}(GeV/c^2)$

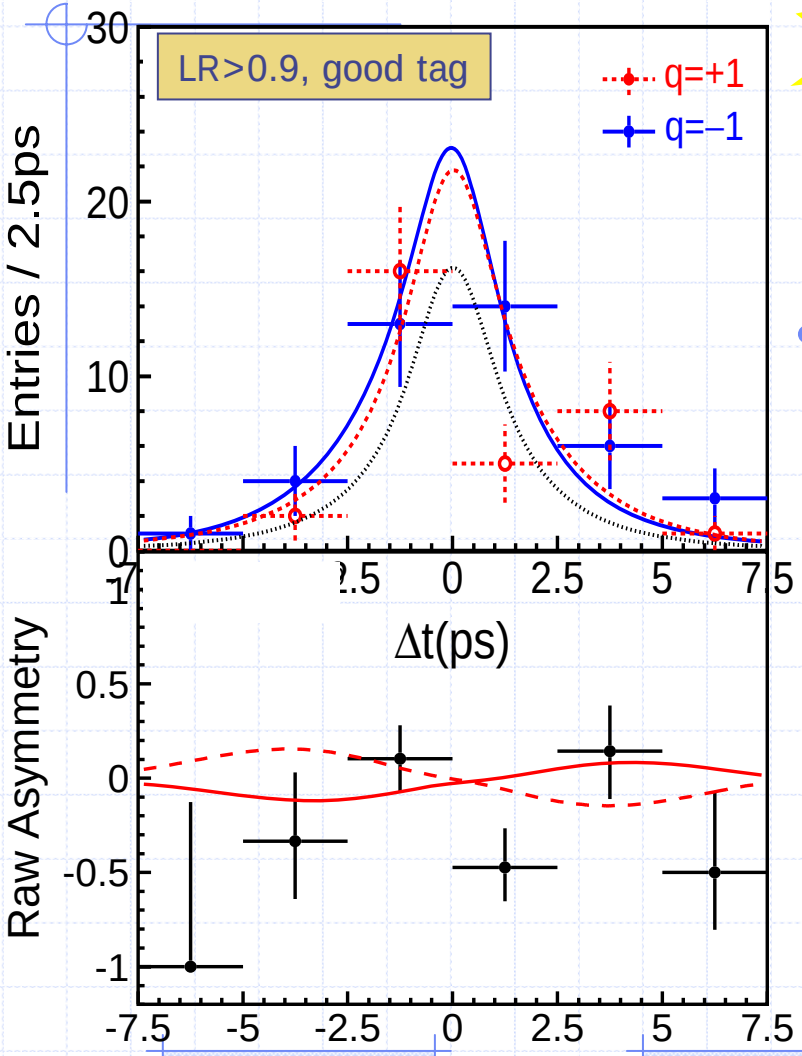


$\Delta E(GeV)$

Total Signal Yield 307+/-32

With vertex measurement 129+/-21

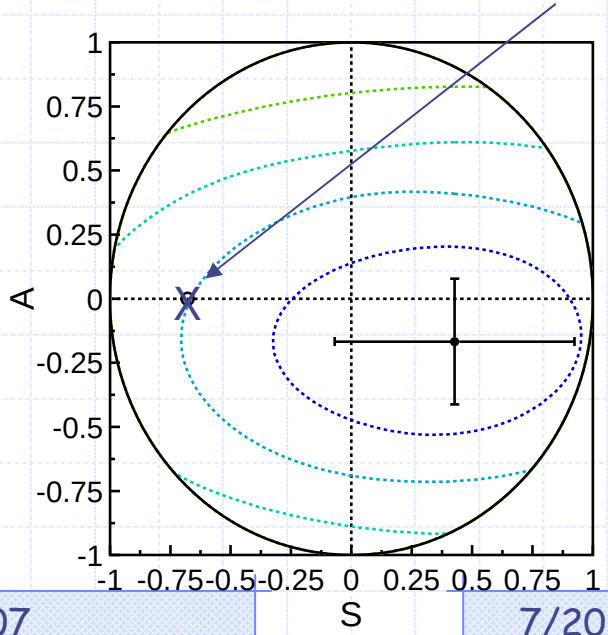
$B^0 \to K_S \pi^0 \pi^0$ tCPV Result



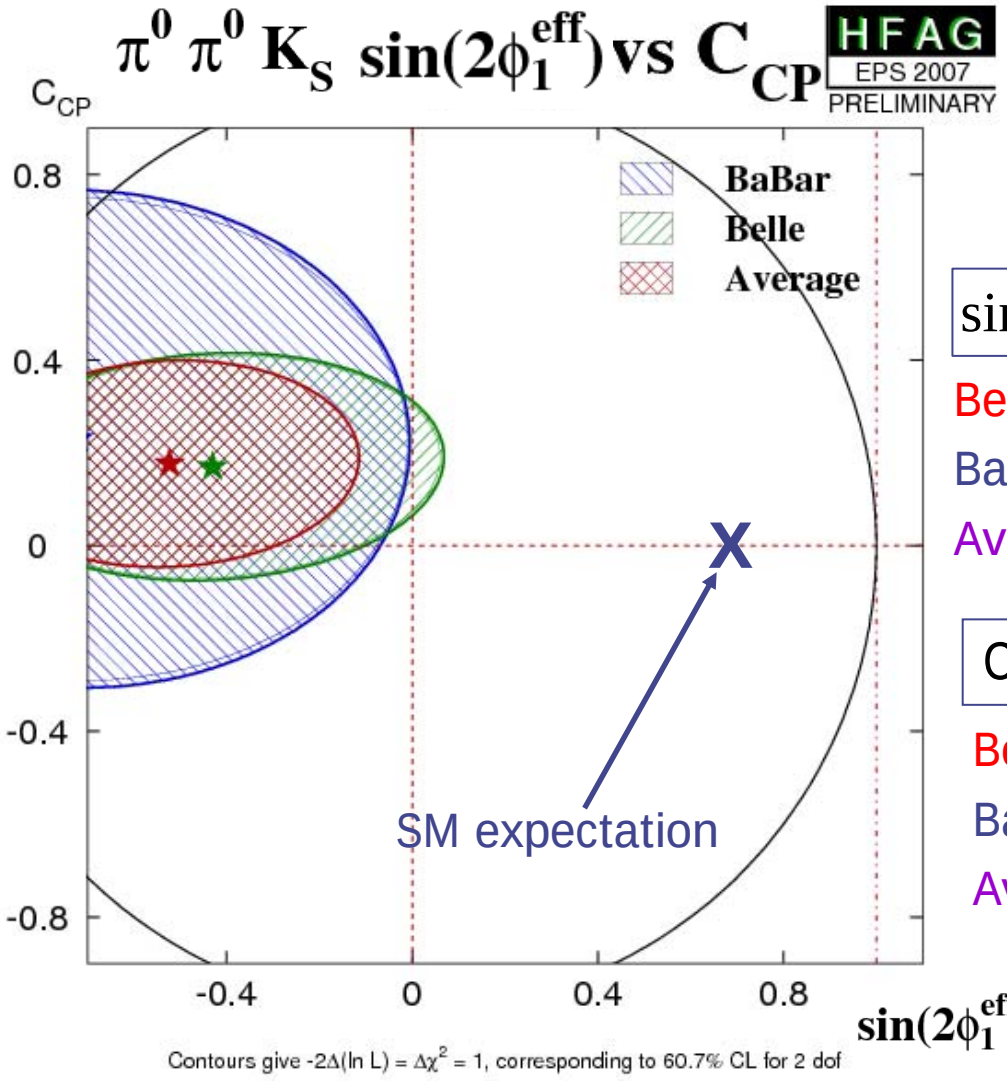
New !

$$\mathcal{S} = +0.43 \pm 0.49 \pm 0.09$$
$$\mathcal{A} = -0.17 \pm 0.24 \pm 0.05$$

- 2.0 sigma from the SM expectation $(A,S)=(0,-\sin 2\phi_1)$



$K_S\pi^0\pi^0$ tCPV Comparison



$\sin 2\phi_1^{eff} = -S$

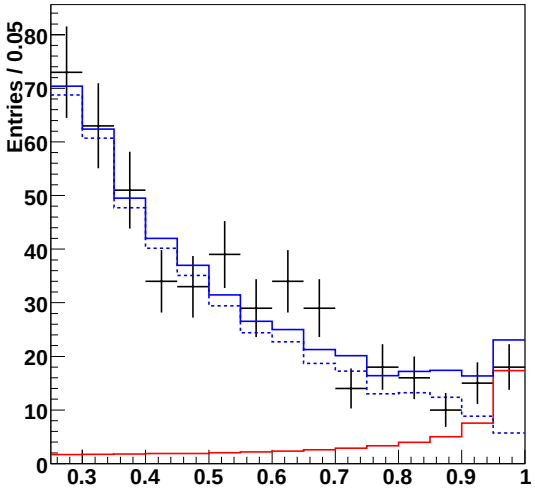
Belle	-0.43+/-0.49+/-0.09
BaBar[hep-ex/0702010]	-0.72+/-0.71+/-0.08
Average	-0.52+/-0.41

$C_{CP} = -\mathcal{A}$

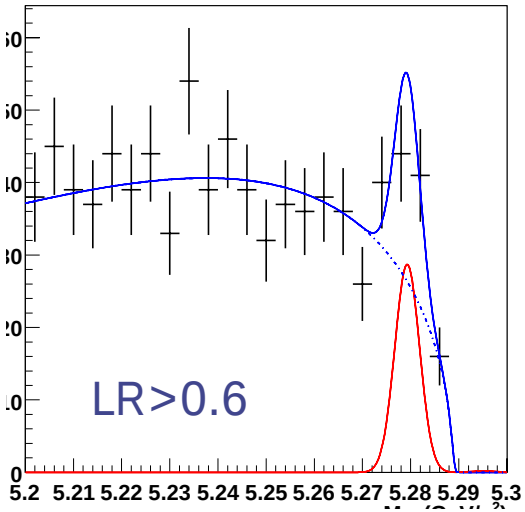
Belle	0.17+/-0.24+/-0.05
BaBar	0.23+/-0.52+/-0.13
Average	0.18+/-0.22

New tCPV result for $B^0 \to K_S K_S$

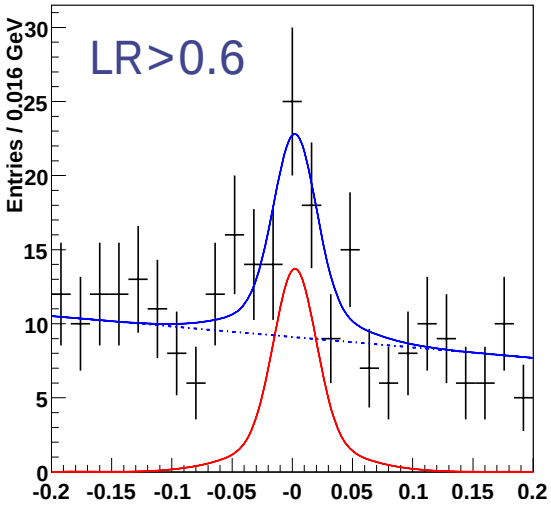
$B^0 \rightarrow K_S K_S$ Signal Yield



LR



$M_{bc}(GeV/c^2)$

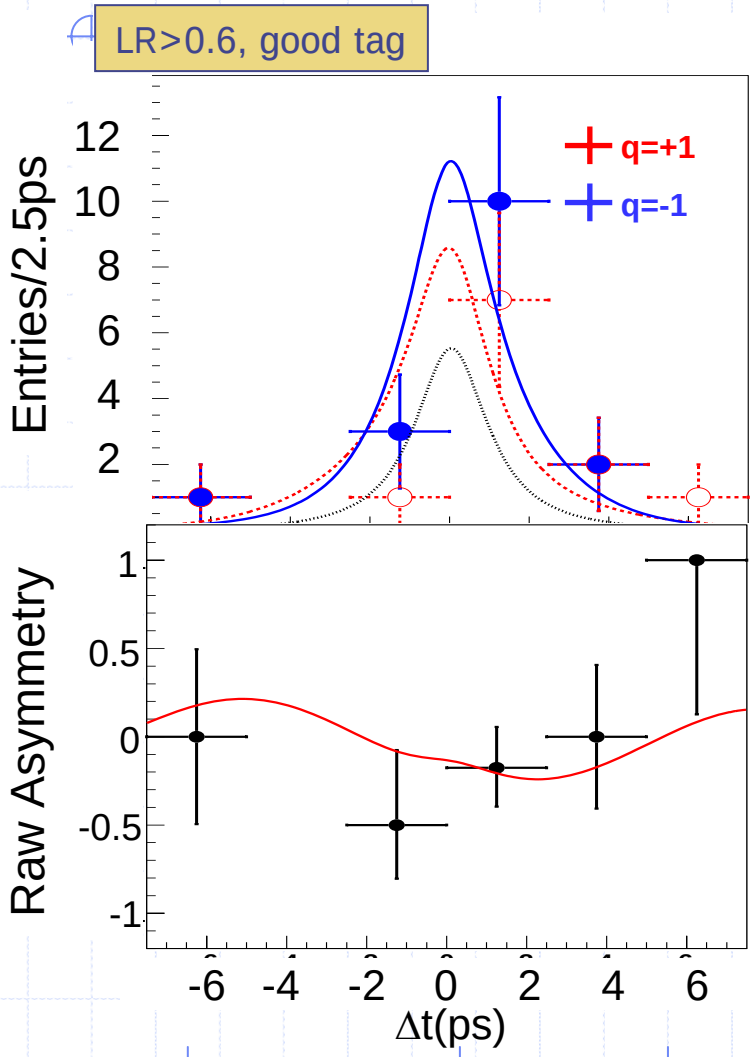


$\Delta E(GeV)$

Total Signal yield: 58+/-11

With vertex measurement: 33+/-6

$B^0 \to K_S K_S$ tCPV Result

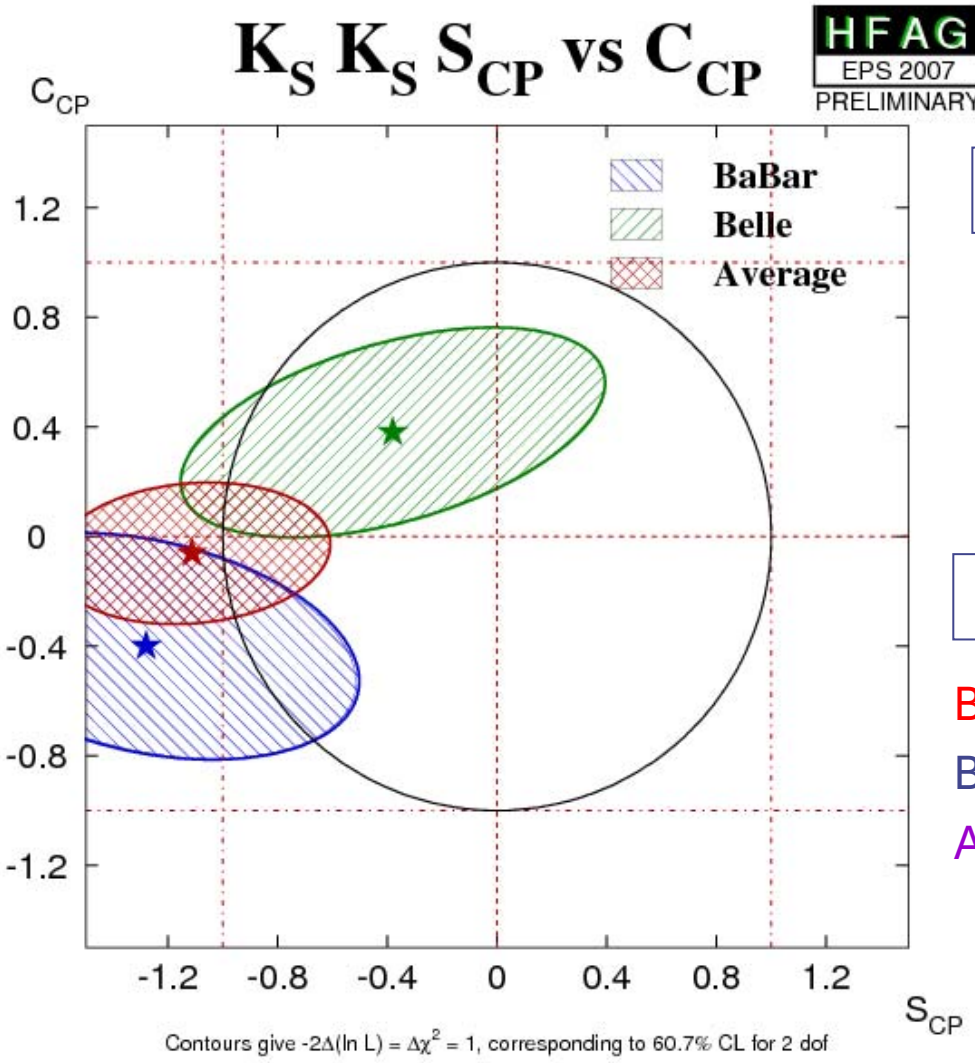


New !

$$S = -0.38 \pm 0.77 \pm 0.08$$
$$\mathcal{A} = -0.38 \pm 0.38 \pm 0.05$$

- First Belle tCPV result on b→d penguin

$K_S K_S$ tCPV Comparison



$\mathcal{S}$

Belle	-0.38+/-0.77+/-0.08
BaBar[PRL 97 (2006) 171805]	$-1.28^{+0.80+0.11}_{-0.73-0.16}$
Average	−1.11+/-0.50

$C_{CP}=-\mathcal{A}$

Belle	+0.38+/-0.38+/-0.05
BaBar	-0.40+/-0.41+/-0.06
Average	-0.06+/-0.26

Summary

- We report first Belle results for tCPV in $B^0 \to K_S\pi^0\pi^0$ and KsKs decays based on a data sample of 657×10^6 $B\bar{B}$ pairs

$B^0 \to K_S\pi^0\pi^0$ $\quad b\to s\bar{q}q$

$$\mathcal{S} = +0.43 \pm 0.49 \pm 0.09$$
$$\mathcal{A} = -0.17 \pm 0.24 \pm 0.05$$

2.0 sigma from the SM expectation

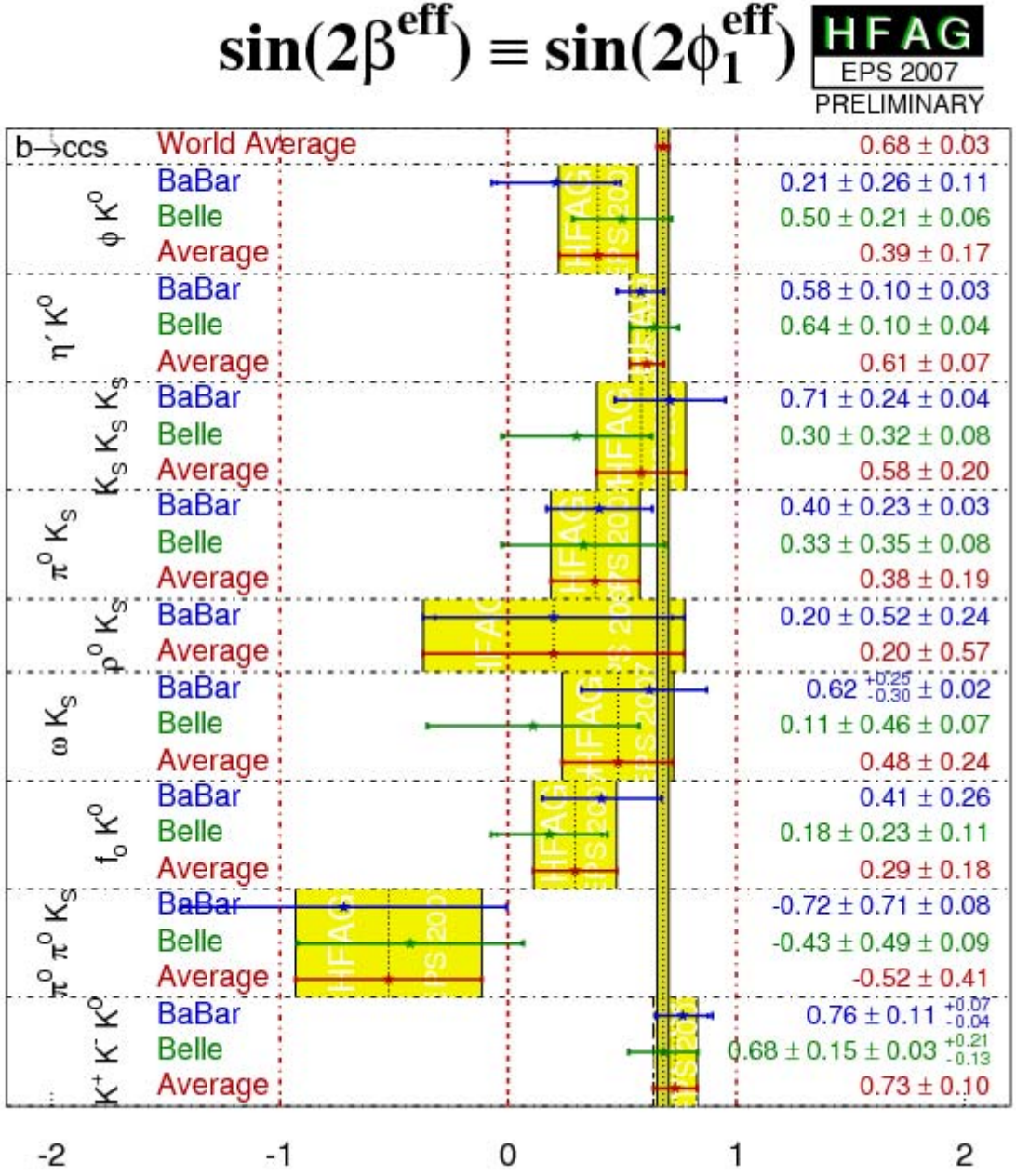
$B^0 \to K_S K_S$ $\quad b\to d\bar{q}q$

$$\mathcal{S} = -0.38 \pm 0.77 \pm 0.08$$
$$\mathcal{A} = -0.38 \pm 0.38 \pm 0.05$$

First Belle tCPV result on b→d penguin

All results are preliminary

b→sq$\bar{q}$ New World Average



New HFAG naïve Average

$$\sin 2\phi_1^{eff} = 0.56 \pm 0.05$$

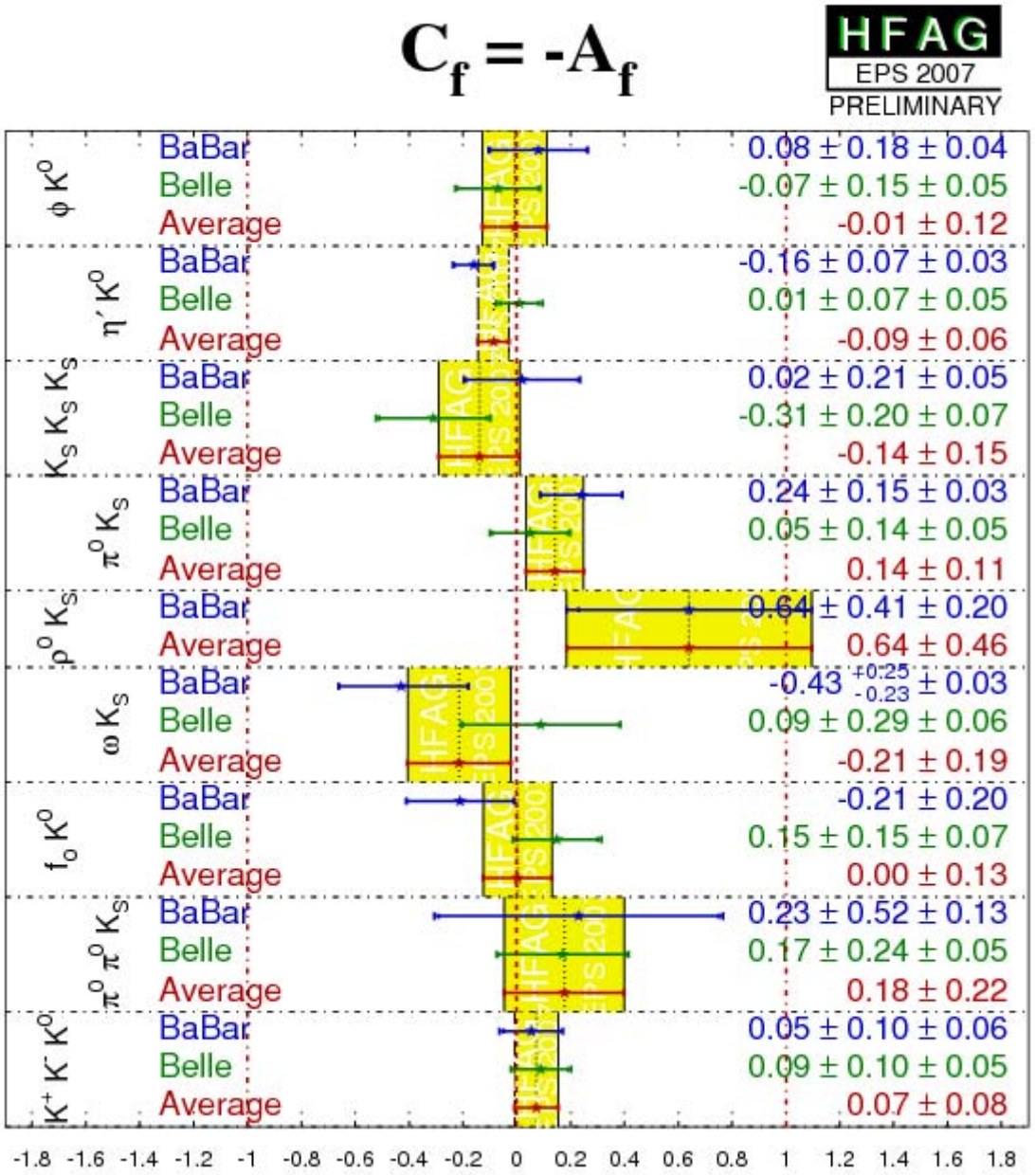
2.1 sigma from the SM

Note that theoretical uncertainties and correlations of systematic errors are neglected in the naïve average.

Backup slides

Systematic Errors

	$K_S\pi^0\pi^0$		K_SK_S	
	dS	dA	dS	dA
Vertexing	0.01	0.02	0.01	0.02
Flavor tagging	0.01	0.01	0.02	0.01
Resolution	0.03	0.02	0.06	<0.01
Physics	<0.01	<0.01	0.01	0.01
Possible Fit bias	0.02	0.01	0.02	0.01
BG fraction	0.05	0.03	0.04	0.02
BG dt shape	0.05	0.02	0.04	0.02
Tag-side interference	<0.01	0.04	<0.01	0.03
Total	0.09	0.05	0.08	0.05


$C_f = -A_f$
HFAG
EPS 2007
PRELIMINARY
ϕK^0
BaBar 0.08 ± 0.18 ± 0.04
Belle -0.07 ± 0.15 ± 0.05
Average -0.01 ± 0.12
$\eta' K^0$
BaBar -0.16 ± 0.07 ± 0.03
Belle 0.01 ± 0.07 ± 0.05
Average -0.09 ± 0.06
$K_S K_S K_S$
BaBar 0.02 ± 0.21 ± 0.05
Belle -0.31 ± 0.20 ± 0.07
Average -0.14 ± 0.15
$\pi^0 K_S$
BaBar 0.24 ± 0.15 ± 0.03
Belle 0.05 ± 0.14 ± 0.05
Average 0.14 ± 0.11
$\rho^0 K_S$
BaBar 0.64 ± 0.41 ± 0.20
Average 0.64 ± 0.46
ωK_S
BaBar -0.43 +0.25 -0.23 ± 0.03
Belle 0.09 ± 0.29 ± 0.06
Average -0.21 ± 0.19
$f_0 K^0$
BaBar -0.21 ± 0.20
Belle 0.15 ± 0.15 ± 0.07
Average 0.00 ± 0.13
$\pi^0 \pi^0 K_S$
BaBar 0.23 ± 0.52 ± 0.13
Belle 0.17 ± 0.24 ± 0.05
Average 0.18 ± 0.22
$K^+ K^- K^0$
BaBar 0.05 ± 0.10 ± 0.06
Belle 0.09 ± 0.10 ± 0.05
Average 0.07 ± 0.08
-1.8 -1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8

$K_S\pi^0\pi^0$ Dalitz plot