CP asymmetry in $B \to$ Vector PseudoScalar decays

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on behalf of the

Belle Collaboration

Outline

- Introduction
- Signal selection and Branching fraction determination for
  - $B^0 \to J/\psi\pi^0$ (BELLE-CONF-0209)
  - $B^0 \to D^{\mp}D^{*\pm}$
  - $B^0 \to \phi K_S$ (BELLE-CONF-0232)
  - $B^0 \to K^+K^-K_S$ (BELLE-CONF-0225)
- CP violation study
- Summary

The results are obtained using data sample of $78\,\mathrm{fb}^{-1}$ at $\Upsilon(4S)$ resonance corresponding to 85M $B\bar{B}$ pairs

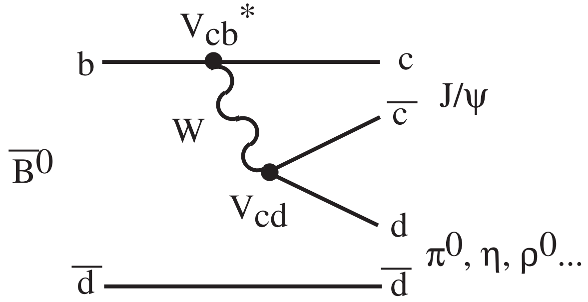
Introduction

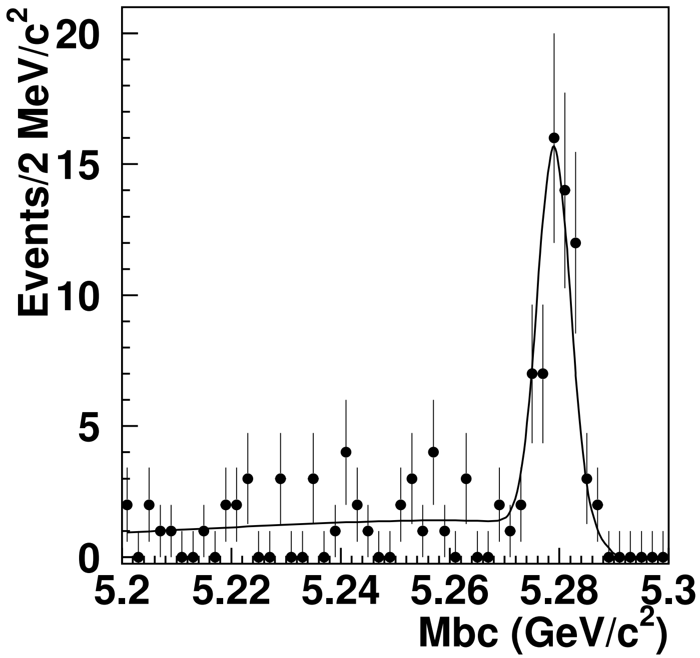
- The observation of CPV followed by the accurate measurement of $\sin 2\phi_1$ in $B^0 \to (c\bar{c})K^0$ by BaBar and Belle is an important test of the SM.
- CP violation in $B^0 \to J/\psi\pi^0$, $B^0 \to D^\pm D^{*\mp}$, $B^0 \to \phi K^0$ and $B^0 \to K^+K^-K^0$ is governed by the same angle ϕ_1, but in different transitions $\Rightarrow$ Check different sectors of CKM matrix:
  - $B^0 \to J/\psi\pi^0$ and $B^0 \to D^\pm D^{*\mp}$ via $\bar{b} \to c\bar{c}\bar{d}$
  - $B^0 \to \phi K^0$ and $B^0 \to K^+K^-K^0$ via $\bar{b} \to s\bar{s}\bar{s}$
- $\sin 2\phi_1(J/\psi K_S) \equiv \sin 2\phi_1(J/\psi\pi^0) \equiv \sin 2\phi_1(\phi K_S)$ in the SM with possible small deviations due to penguin contribution.
- Large difference can be a signature of a New Physics contribution

$B^0 \to J/\psi\pi^0$

Cabibbo and color suppressed: $b \to c\bar{c}d$ transition

- Combine J/ψ and π^0 candidates
- Look at M_{bc} and ΔE distributions





- Signal yield: 52.3 ± 8.7 events
- Purity: 84%

Preliminary:

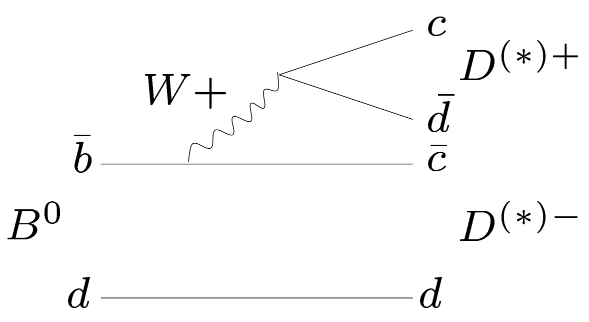
$$\boxed{\mathcal{B}(B^0 \to J/\psi\pi^0) = (1.8 \pm 0.3 \pm 0.2) \times 10^{-5}}$$

BaBar'02: $\mathcal{B} = (2.0 \pm 0.6 \pm 0.2) \times 10^{-5}$

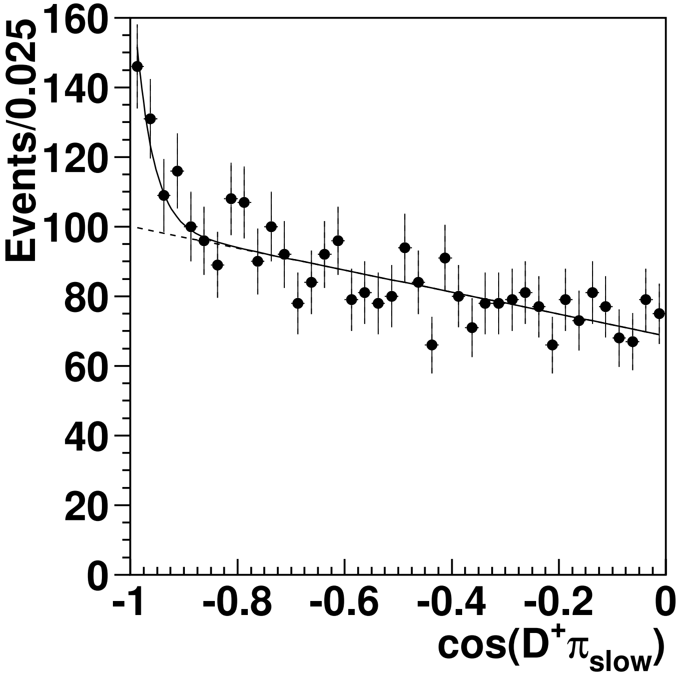
CLEO'00: $\mathcal{B} = (2.5^{+1.1}_{-0.9} \pm 0.2) \times 10^{-5}$

$B^0 \to D^{\pm} D^{*\mp}$

- To increase statistics partial reconstruction is used
  - D^+ is reconstructed in $K^-\pi^+\pi^+$ mode
  - Only π^-_{slow} from D^{*-} is required
  - Due to small energy release in $D^{*-} \to \bar{D}^0 \pi^-_{slow}$ decay the D^+ and π^-_{slow} are almost back-to-back in CMS



- Require lepton in the event to suppress continuum and provide flavor tag



- Signature: angle between D^+ and π_{slow} from D^{*-}
- Signal yield: 102 ± 23 events with lepton tag

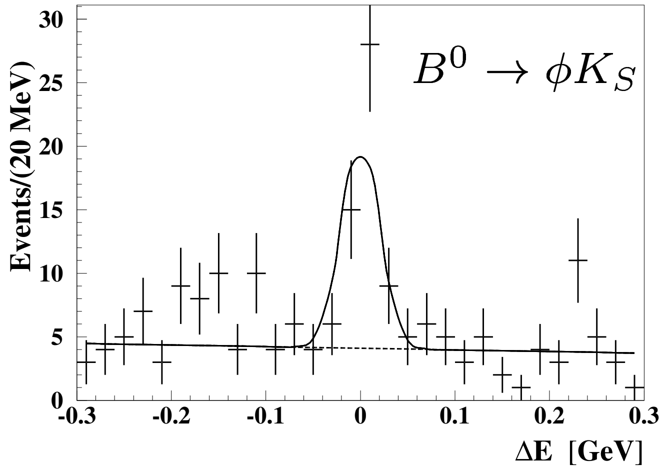
Preliminary:

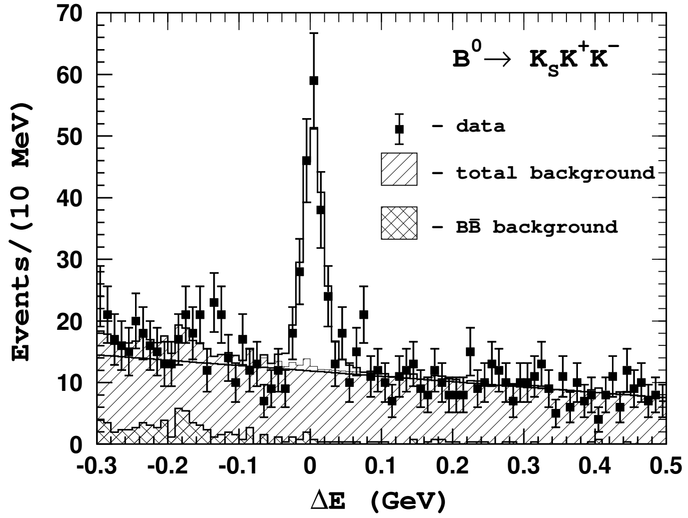
$$\mathcal{B}(B^0 \to D^{\pm} D^{*\mp}) = (1.25 \pm 0.28) \times 10^{-3}$$

Belle (full recon.) (29 fb^{-1}): $(1.17 \pm 0.26^{+0.22}_{-0.25}) \times 10^{-3}$

CLEO'00 Upper Limit: $< 0.63 \times 10^{-3}$ CL=90%

$B^0 \to \phi K_S, K^+K^-K_S$





- Signal yield:
  - $B^0 \to \phi K_S$: $39.4^{+7.5}_{-6.5}$
  - $B^0 \to K^+K^-K_S$: 149 ± 15

    ($B^0 \to \phi K_S$ events are NOT removed from $B^0 \to K^+K^-K_S$)
- Branching fractions (preliminary):

  $B^0 \to \phi K^0$: $(1.00^{+0.19+0.09}_{-0.17-0.13}) \times 10^{-5}$

  $B^0 \to K^+K^-K^0$: $(2.93 \pm 0.34 \pm 0.40) \times 10^{-5}$
- BaBar'01: $B^0 \to \phi K^0$: $(0.81^{+0.31}_{-0.25} \pm 0.08) \times 10^{-5}$

Summary of Branching fractions

Mode	# events	$\mathcal{B}$, (78 fb^{-1})	$\mathcal{B}$, (29 fb^{-1}) (2001)
$J/\psi\pi^0$	55.5 ± 8.6	$(2.0 \pm 0.3 \pm 0.2) \times 10^{-5}$	$(2.3 \pm 0.5 \pm 0.2) \times 10^{-5}$
$D^{\pm}D^{*\mp}$ full	–	–	$(1.17 \pm 0.26^{+0.22}_{-0.25}) \times 10^{-3}$
$D^{\pm}D^{*\mp}$ part.	102 ± 23	$(1.25 \pm 0.28) \times 10^{-3}$	$(1.48 \pm 0.38^{+0.28}_{-0.31}) \times 10^{-3}$
ϕK^0	$39.4^{+7.5}_{-6.5}$	$(1.00^{+0.19+0.09}_{-0.17-0.13}) \times 10^{-5}$	–
$K^+K^-K^0$	149 ± 15	$(2.93 \pm 0.34 \pm 0.40) \times 10^{-5}$	$(3.48 \pm 0.67 \pm 0.65) \times 10^{-5}$

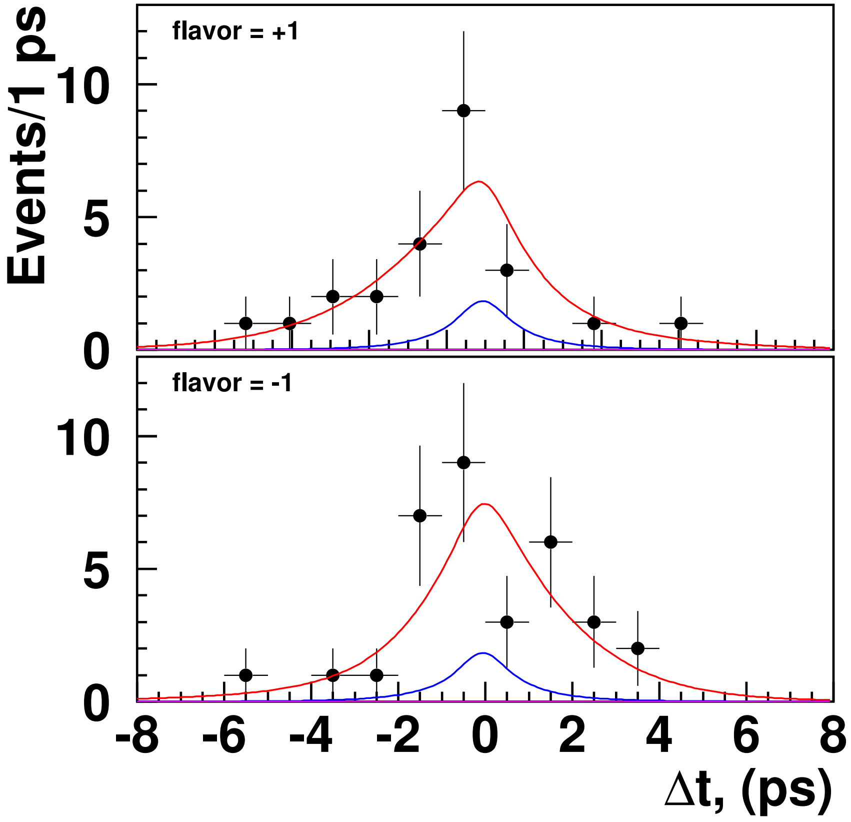
CP fit

- Standard Belle tagging procedure: multi-dimensional flavor likelihood
- Unbinned maximum likelihood fit
- For all channels the signal PDF is:

$$\frac{1}{4\tau_{B^0}} e^{-\frac{|\Delta t|}{\tau_{B^0}}} \{1 + q[S\sin(\Delta m \Delta t) + A\cos(\Delta m \Delta t)]\},$$

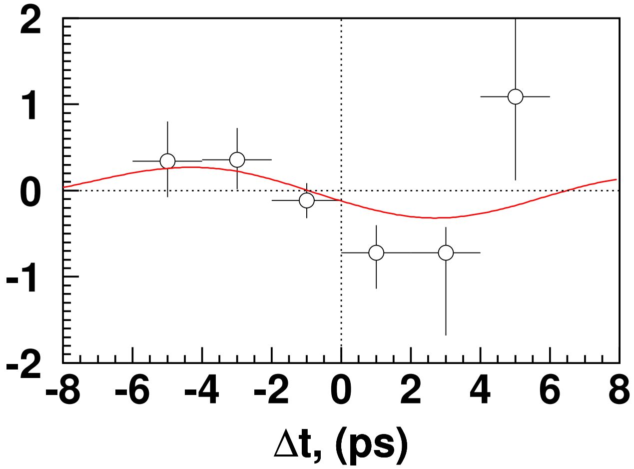
  where A accounts for the direct CP violation
- $''\sin 2\phi_1'' = -\xi_f S$

CP violation in $B^0 \to J/\psi\pi^0$



CP = +1

- # of fitted events: 57
- Purity: 86%

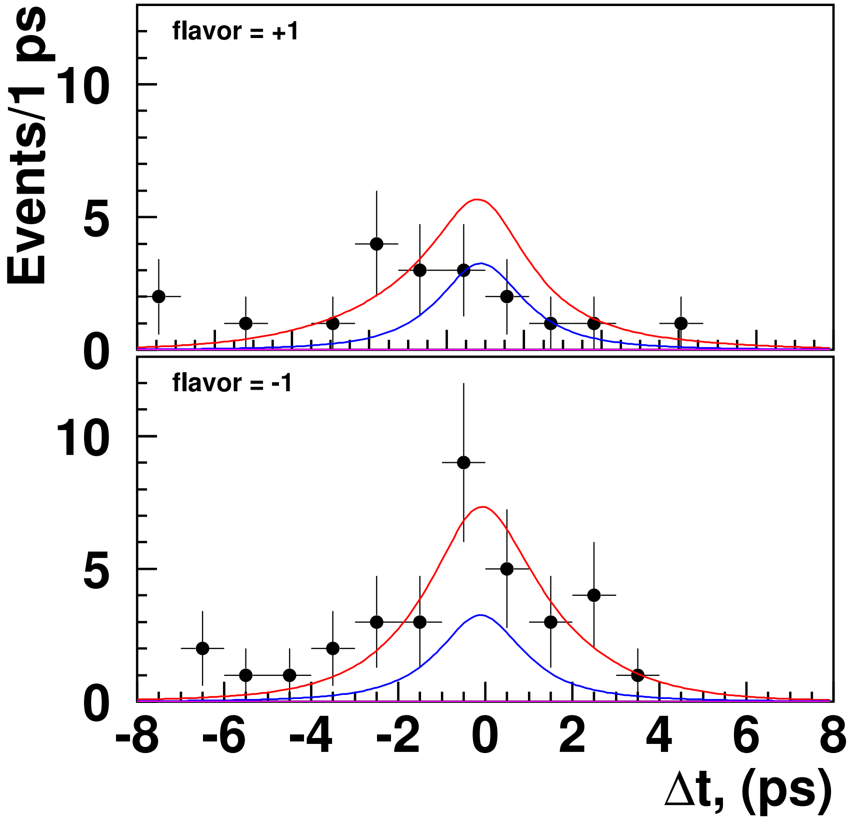


Preliminary:

$$''\sin 2\phi_1'' = +0.93 \pm 0.49 \pm 0.08$$

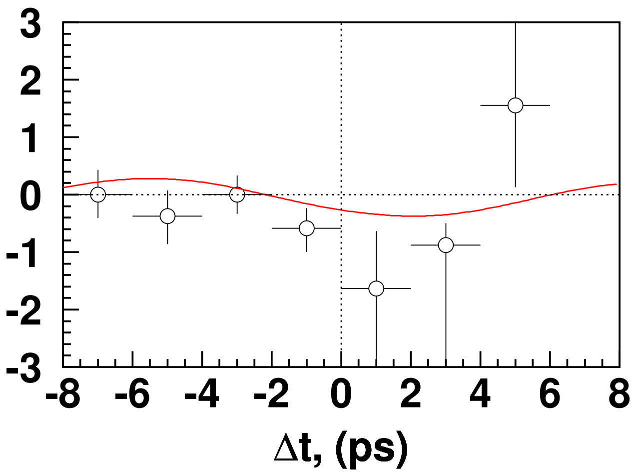
$$A = -0.25 \pm 0.39 \pm 0.06$$

CP violation in $B^0 \to \phi K_S$



CP = -1

- # of fitted events: 53
- Purity: 67%



Preliminary:

$$\text{"}\sin 2\phi_1\text{"} = -0.73 \pm 0.64 \pm 0.18$$

$$A = -0.56 \pm 0.41 \pm 0.12$$

CP violation in $B^0 \to K^+K^-K_S$

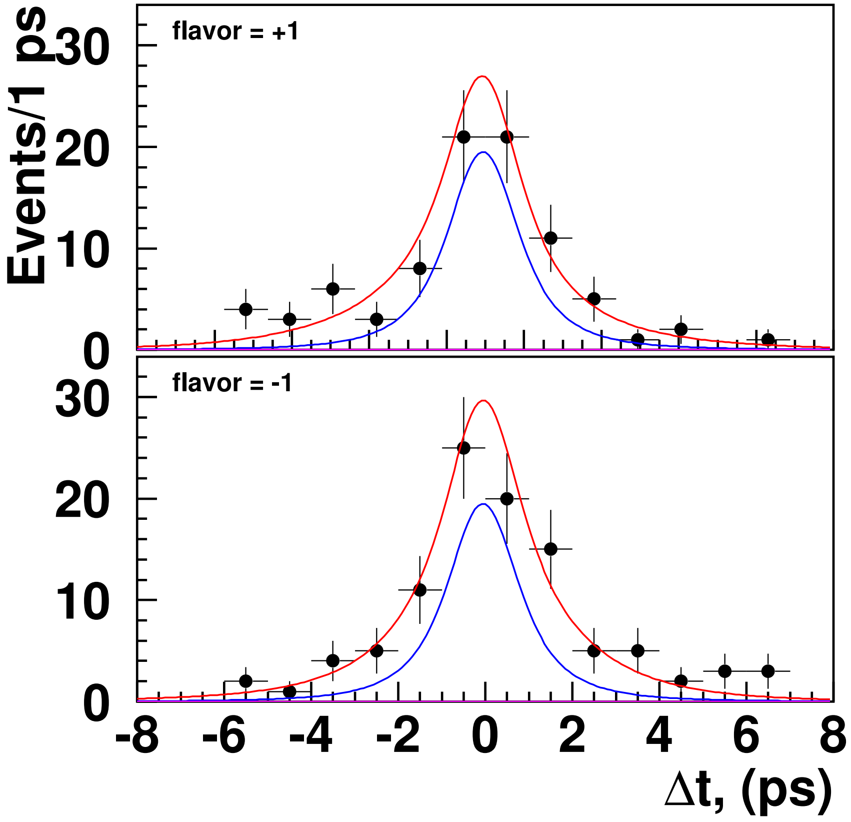
- $B^0 \to \phi K_S$ events are removed by selection $|M_{KK} - M_\phi| > 15$ MeV/c^2
- $K^+K^-K_S$ is a mixture of CP-even and -odd eigenstates
- Isospin violating tree $\bar{b} \to u\bar{u}\bar{s}$ contribution is small and estimated by the $\mathcal{B}(B \to KK\pi)$ $(< 3.1\%)$
- Penguin $\bar{b} \to q\bar{q}\bar{s}$ transitions are isospin conserving:
  $|K^+K^-K_S >= \alpha|_{CP=+1} + \beta|_{CP=-1}$

  $|K^0\bar{K}^0K^+ >= \alpha\frac{|K^+K_SK_S>+|K^+K_LK_L>}{\sqrt{2}} + \beta|K^+K_SK_L >$
- Take into account $\mathcal{B}(B^+ \to K^+K_SK_S)$ and $\mathcal{B}(B^+ \to K^+K^+K^-)$:

$$\alpha^2_{\text{non }\phi} = 2\frac{\mathcal{B}(B^+ \to K^+K_SK_S)}{\mathcal{B}(B^+ \to K^+K^+K^-)} = 0.97 \pm 0.15 \pm 0.07$$

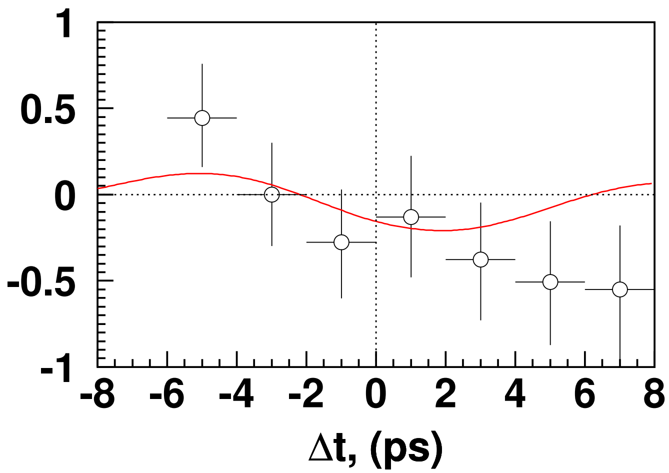
$B^0 \to K^+K^-K_S$ final state is dominated by CP-even component.

CP violation in $B^0 \to K^+K^-K_S$



Mostly $CP = +1$ (0.97 ± 0.15)

- # of fitted events: 191
- Purity: 49%



Preliminary:

$$''\sin 2\phi_1'' = +0.52 \pm 0.46 \pm 0.11$$

$$A = -0.42 \pm 0.36 \pm 0.09$$

Systematic errors for $J/\psi\pi^0$

Source	$\sin 2\phi_1$	A
Background shape	± 0.071	± 0.046
Charge asymmetry	± 0.003	± 0.001
Ip	± 0.004	± 0.001
Physics	± 0.010	± 0.012
Resolution	± 0.010	± 0.006
Rnp	± 0.009	± 0.007
Scale error	± 0.005	± 0.025
Signal fraction	± 0.031	± 0.027
Vertex selection	± 0.007	± 0.002
Wrong tag	± 0.022	± 0.014
Systematic Total	± 0.083	± 0.062

Summary

- Branching fractions for $B^0 \to J/\psi\pi^0, D^\pm D^{*\mp}, \phi K^0$ and $K^+K^-K_S$ decays have been measured
- We have measured $\sin 2\phi_1$ in $B^0 \to J/\psi\pi^0$, ϕK_S and $K^+K^-K_S$ decays.

Decay mode	$''\sin 2\phi_1''$	A
$J/\psi\pi^0$	$+0.93 \pm 0.49 \pm 0.08$	$-0.25 \pm 0.39 \pm 0.06$
ϕK_S	$-0.73 \pm 0.64 \pm 0.18$	$-0.56 \pm 0.41 \pm 0.12$
$K^+K^-K_S$	$+0.52 \pm 0.46 \pm 0.11^{+0.27}_{-0.03}$	$-0.42 \pm 0.36 \pm 0.09^{+0.03}_{-0.22}$
WA (Moriond'02)	$+0.79 \pm 0.10$	

Errors are still large but new statistics is coming.

CP study for $B^0 \to D^\pm D^{*\mp}$ is in progress.