Research on Charm Physics at Belle

Review meeting
for Sino-Japan Core-University Cooperative Program

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8 April 2009

1. **Physics motivation at Belle/KEKB**
2. **Search for $D^0\overline{D}^0$ mixing**
3. **Search for exotic states via $B^- \to J/\psi + \ldots$ decays**
4. **Search for X(1835) and X(1812) states**
5. **Summary**

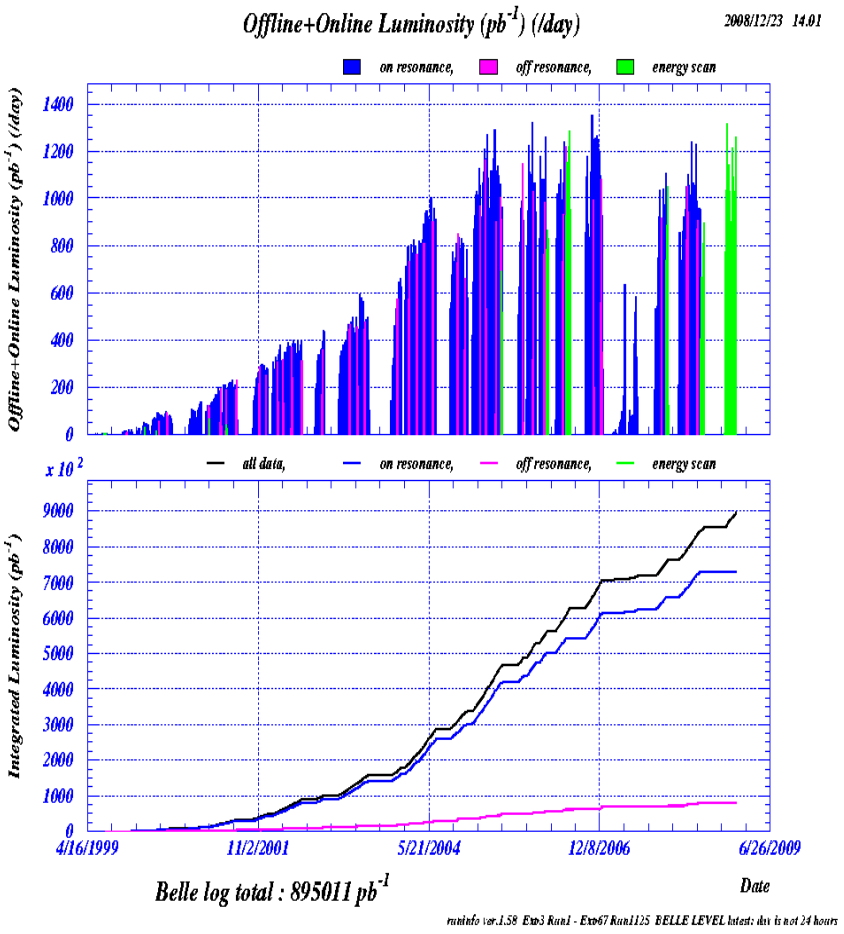
Introduction

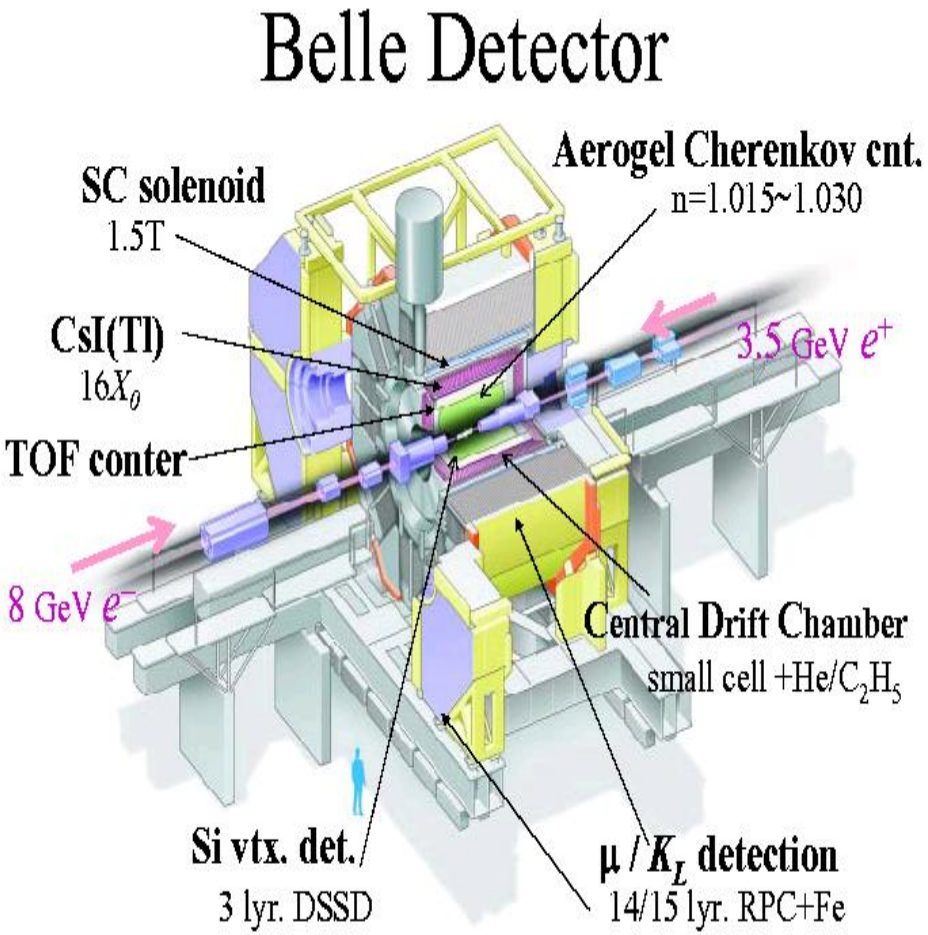
- Institutions and Members
  - Institute of High Energy Phys. (IHEP)
  - Peking University (PU)
  - Univ. of Science and Tech. of China (USTC)

Institute	staff	Post-doc	graduate
IHEP	3	1	1
PU	1		2
USTC	1	1	2
total	5	2	5

- Funds (General) from NSFC : 220K RMB (2002-2004)
  440K RMB (2006-2008)
- Funds (Innovation) from IHEP/CAS : 100K RMB (2001-2004)

KEKB and Belle detector





Belle collected total integrated luminosity : > 894.8 fb^{-1} till 2 Dec. 2008

Physics motivation

- Search for $D^0\overline{D^0}$ mixing
  - Mixing between different flavor quarks had observed in $K^0\overline{K^0}$ and $B^0\overline{B^0}$,

    but not observed in $D^0\overline{D^0}$ till 2007.
  - SM :$D^0\overline{D^0}$ mixing is at ≤1% level, and

    CPV in D^0 decay is at ≤0.1%.

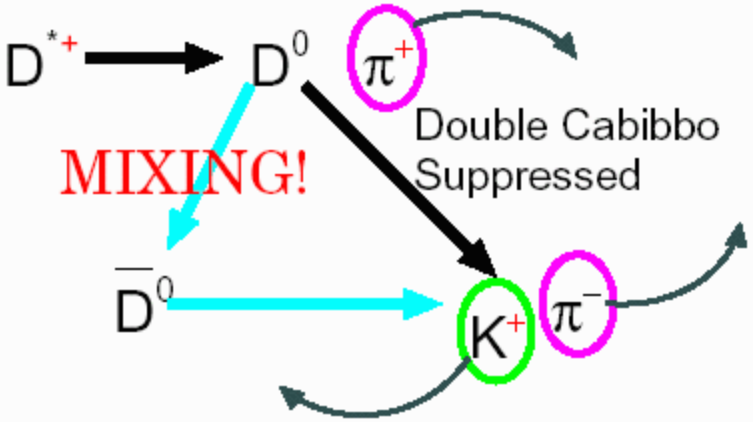
New physics, if observed CP is at 1% level.

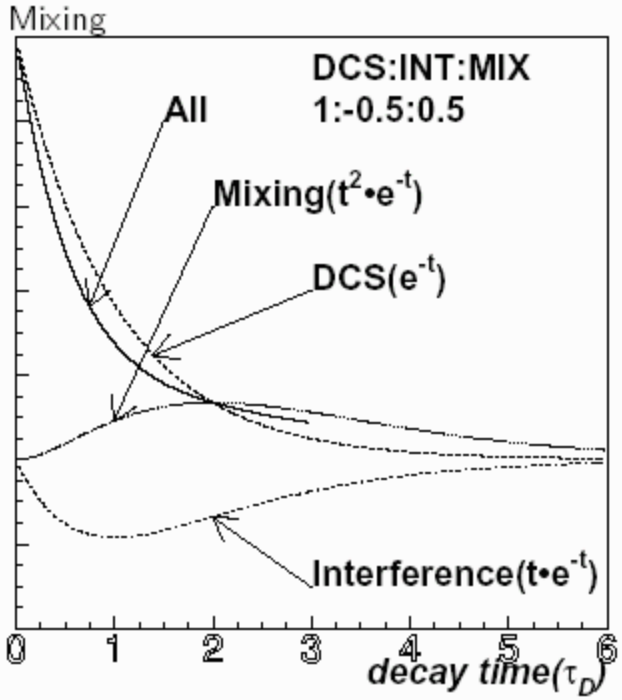
Search for $D^0\overline{D^0}$ mixing

Introduction: $D^0 \to K^+\pi^-$ time dependence

$$\frac{dN_{K^+\pi^-}}{dt} \propto \left[R_D + \underbrace{\sqrt{R_D}y't}_{\text{Interference}} + \underbrace{\frac{1}{4}(x'^2 + y'^2)t^2}_{\text{Mixing}}\right] e^{-t}$$

$$x' = x\cos\delta + y\sin\delta$$
$$y' = y\cos\delta - x\sin\delta$$
$$x = \Delta M/\Gamma \quad y = \Delta\Gamma/2\Gamma$$
δ = strong phase difference

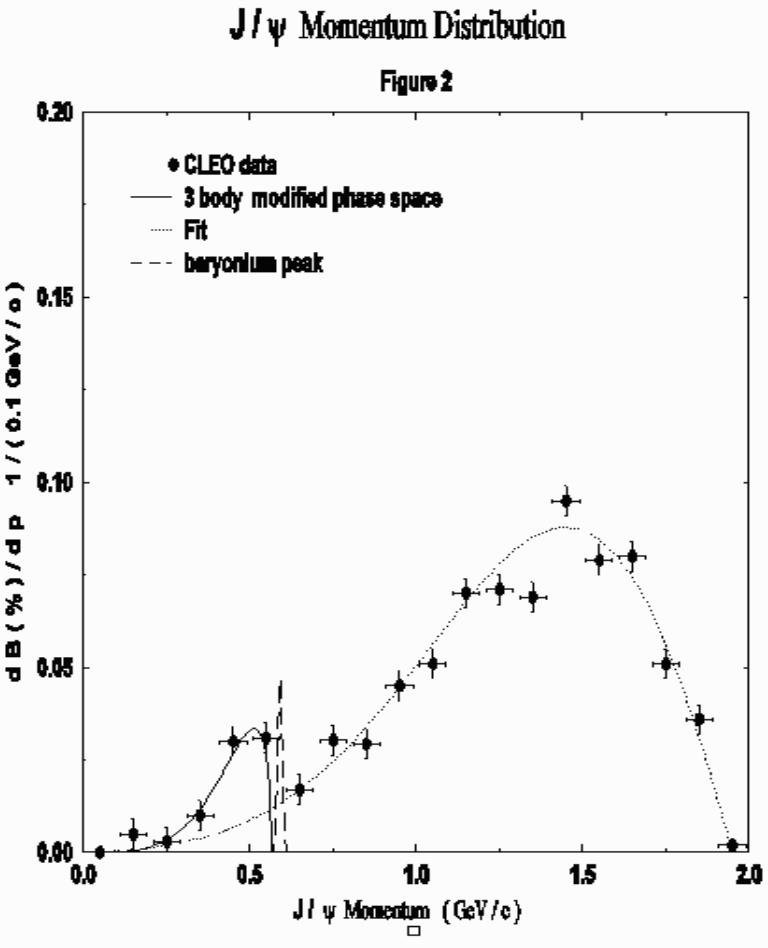




R_D is ratio of DCS to CF decay rates

Physics motivation

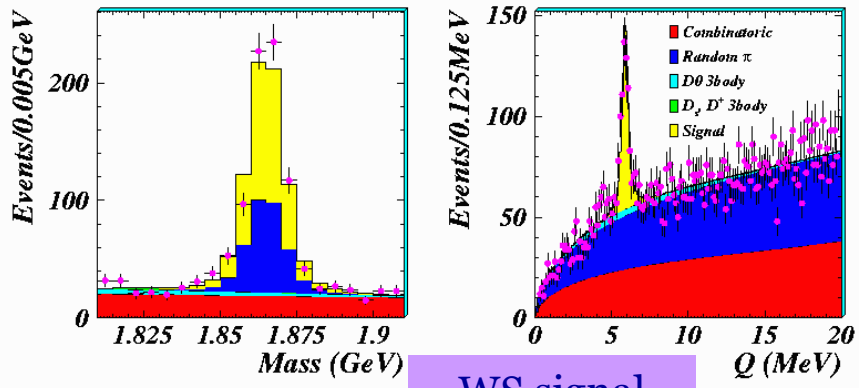
- Slow J/ψ bump observed by CLEO, and confirmed by BaBar and Belle.



- Search for source of the excess from B decays.
  - Intrinsic charm $(c\bar{c})$ inside of B meson.
  - Intermediate exotic state in $B^- \to J/\psi\, \Lambda \bar{p}$ decay
  - excited gluonic state in $B \to J/\psi\, \eta' K$ decay

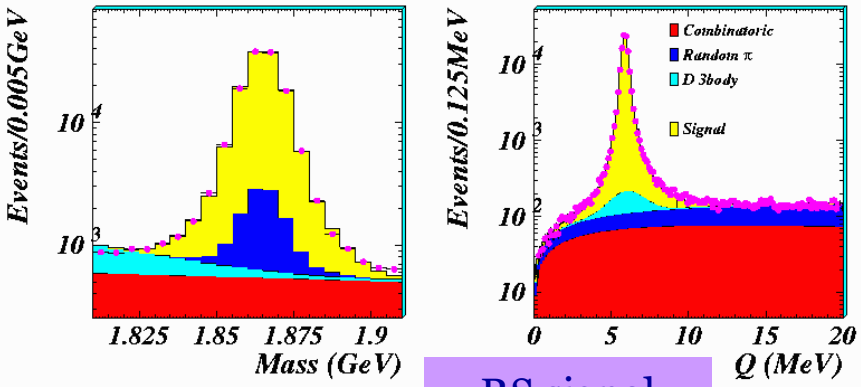
- Search for new resonances X(1835) and X(1810), observed by BES

First talk on $D^0\overline{D^0}$ mixing



WS signal

FIG. 6: Projections of M (left) and Q (right) for the wrong-sign data (points) and the fit functions (histograms), within a 3σ window in the complementary variable ($5.27 \leq Q < 6.47$ MeV and $1.8445 \leq M < 1.8845$ GeV respectively). The signal contribution is shaded yellow.



RS signal

FIG. 5: Projections of M (left) and Q (right) for the right-sign data (points) and the fit functions (histograms), for the region $1.81 \leq M < 1.91$ GeV and $0 \leq Q < 20$ MeV. Note the logarithmic scale.

BELLE CONF 0254
ICHEP02 Parallel 8
AHS744
hep-ex/0208051

A measurement of the rate of wrong-sign decays $D^0 \to K^+\pi^-$

K. Abe,[8] K. Abe,[44] N. Abe,[47] R. Abe,[30] T. Abe,[48] I. Adachi,[8] Byoung Sup Ahn,[18] H. Aihara,[49] M. Akatsu,[23] M. Asai,[10] Y. Asano,[51] T. Aso,[50] V. Aulchenko,[2] T. Aushev,[13] A. M. Bakich,[43] Y. Ban,[34] E. Banas,[28] S. Banerjee,[42] A. Bay,[19] I. Bedny,[2] P. K. Behera,[52] D. Beiline,[2] I. Bizjak,[14] A. Bondar,[2] A. Bozek,[28] M. Bračko,[21,14] J. Brodzicka,[28] T. E. Browder,[7] B. C. K. Casey,[7] M.-C. Chang,[27] P. Chang,[27] Y. Chao,[27] K.-F. Chen,[27] B. G. Cheon,[40] R. Chistov,[13] S.-K. Choi,[6] Y. Choi,[42] Y. K. Choi,[42] M. Danilov,[13] L. Y. Dong,[11] R. Dowd,[22] J. Dragic,[22] A. Drutskoy,[13] S. Eidelman,[2] V. Eiges,[13] Y. Enari,[23] C. W. Everton,[22] F. Fang,[7] H. Fujii,[8] C. Fukunaga,[46] N. Gabyshev,[8] A. Garmash,[2,8] T. Gershon,[8] B. Golob,[20,14] A. Gordon,[22] K. Gotow,[53] H. Guler,[7]

- Ratio of WS ($K^+\pi^-$) over RS ($K^-\pi^+$) is measured to be

$$R_{WS} = \frac{D^0 \to K^+\pi^-}{D^0 \to K^-\pi^+} = (0.372 \pm 0.025^{+0.009}_{-0.011})\%$$

T. Matsumoto,[48] Y. Mikami,[49] W. Mitaroff,[12] K. Miyabayashi,[24] Y. Miyabayashi,[23] H. Miyake,[32] H. Miyata,[30] L. C. Moffitt,[22] G. R. Moloney,[22] G. F. Moorhead,[22] S. Mori,[51] T. Mori,[4] A. Murakami,[37] T. Nagamine,[48] Y. Nagasaka,[10] T. Nakadaira,[49] T. Nakamura,[47] E. Nakano,[31] M. Nakao,[8] H. Nakazawa,[8] J. W. Nam,[40] S. Narita,[48] Z. Natkaniec,[28] K. Neichi,[44] S. Nishida,[17] O. Nitoh,[51] S. Noguchi,[24] T. Nozaki,[8] A. Ogiji,[22] S. Ogawa,[45] F. Ohno,[47] T. Ohshima,[23] Y. Ohshima,[47] T. Okabe,[23] S. Okuno,[18] S. L. Olsen,[7] Y. Onuki,[30] W. Ostrowicz,[28] H. Ozaki,[8] P. Pakhlov,[13] H. Palka,[28] C. W. Park,[18] H. Park,[18] K. S. Park,[40] L. S. Peak,[43] J.-P. Perroud,[19] M. Petric,[8] L. E. Piilonen,[53] E. Prebys,[22] J. L. Rodriguez,[7] F. J. Ronga,[19] N. Root,[2] M. Rozanska,[28] K. Rybicki,[28] J. Ryuko,[32] H. Sagawa,[8] S. Saitoh,[8] Y. Sakai,[8] H. Sakamoto,[17] H. Sakaue,[31] M. Satapathy,[52] A. Satpathy,[8,22] O. Schneider,[19] S. Schrenk,[9] C. Schwanda,[8,12] S. Semenov,[13] K. Senyo,[51]

- Contribution paper to ICHEP2002
- hep-ex/0208051, 30 Aug 2002

First paper on $D^0\overline{D^0}$ mixing

PRL 94, 071801 (2005) PHYSICAL REVIEW LETTERS week ending 25 FEBRUARY 2005

Search for D^0-$\overline{D}^0$ Mixing in $D^0 \to K^+\pi^-$ Decays and Measurement of the Doubly-Cabibbo-Suppressed Decay Rate

J. Li,[31] Z. P. Zhang,[31] A. J. Schwartz,[4] K. Abe,[8] ... A. M. Bakich,[34] A. Bay,[16] I. Bedny,[1] U. Bitenc,[13] ... T. E. Browder,[7] Y. Chao,[24] A. Chen,[22] K.-F. Chen, ... M. Danilov,[12] M. Dash,[44] L. Y. Dong, ... S. Eidelman,[1] V. Eiges,[12] ... Gabyshev,[1] A. Garmash,[30] T. Gershon, ... J. Haba,[8] K. Hayasaka,[20] ... H. Hoshi,[37] S. Ho... T. Iijima,[20] A. Imoto,[21] ... Iwasaki,[8] J. H. Kang,[45] J. S. Kang,[14] S. U. Kataoka,[21] N. Katayama,[8] H. Kawai,[2] ... T. Kawasaki, H. R. Khan, J. H. K... Y.-J. Kwon,[45] L. S. Lange,[5] G. Lede... J. MacNaughton,[11] G. Majumder,[35] F. M... Nagam... Olsen,[7] ... S. Ser... M. ... C. I... Y. Yu

Phys Rev Lett 94, 071801 (2005)

$$R_D = \frac{D^0 \to K^+\pi^-}{D^0 \to K^-\pi^+} = (0.381 \pm 0.017^{+0.008}_{-0.016})\%$$

90 fb^{-1}

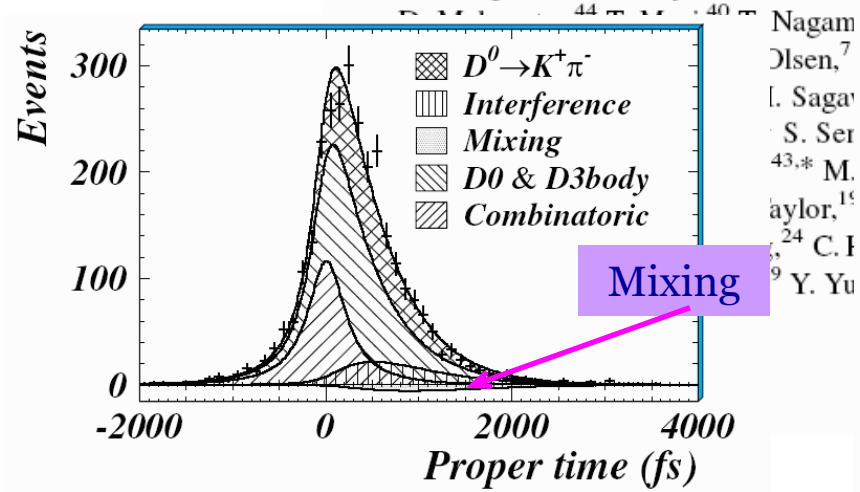


FIG. 2 (color online). The decay-time distribution for WS events satisfying $|m_{K\pi} - m_{D^0}| < 22\,\mathrm{MeV}/c^2$ and $|Q - 5.9\,\mathrm{MeV}| < 1.5\,\mathrm{MeV}$. Superimposed on the data (points with error bars) are projections of the decay-time fit.

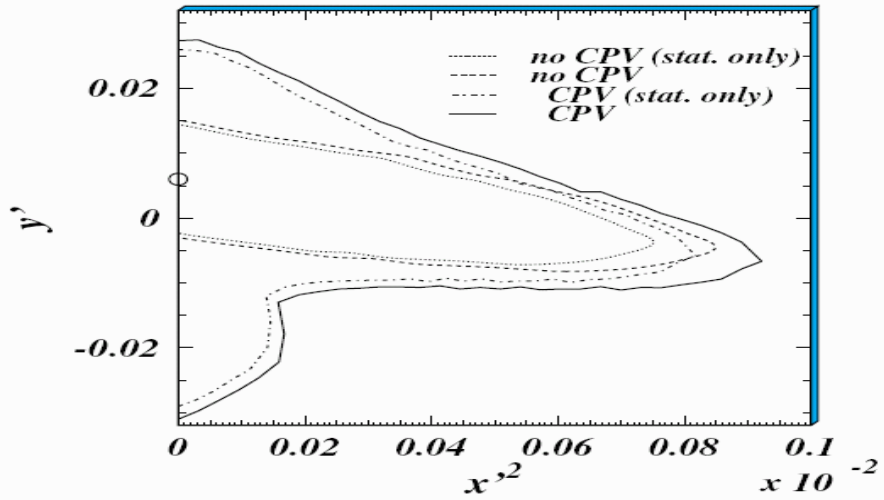


FIG. 3 (color online). 95% C.L. regions for (x'^2, y'). The dotted (dashed) contour is statistical (statistical and systematic) and corresponds to CP conservation. The dash-dotted (solid) contour is statistical (statistical and systematic) and allows for CPV. The open circle represents the most likely value when CP is conserved and x'^2 is constrained to be ≥ 0.

Search for $D^0\overline{D^0}$ mixing

- Results are consistent with no mixing and no CPV.
- More restrictive than previous limits.

No CPV (95%)	$y'(\times 10^{-3})$	$x'^2(\times 10^{-3})$
Belle	$-8.2 < y' < 16$	$x'^2 < 0.81$
BaBar2003	$-27 < y' < 22$	$x'^2 < 2.0$
CLEO2000	$-52 < y' < 2$	$x'^2 < 0.76$

- (When $x'^2 = 0$) y' prefer positive in the same direction as BaBar's result.
- $D^0 \to K^+\pi^-$ result is about two sigma away from "no mixing".
- The future: More precise measurement is needed, with more Belle/BaBar data or CLEO-c and BES-III.

Search for $D^0\overline{D^0}$ mixing

PRL 95, 231801 (2005) PHYSICAL REVIEW LETTERS week ending 2 DECEMBER 2005

Measurement of the Wrong-Sign Decays $D^0 \to K^+\pi^-\pi^0$ and $D^0 \to K^+\pi^-\pi^+\pi^-$, and Search for *CP* Violation

X. C. Tian,[32] Y. Ban,[32] K. Abe,[7] K. Abe,[42] H. Aihara,[44] K. Arinstein,[1] Y. Asano,[48] V. Aulchenko,[1] T. Aushev,[11] A. M. Bakich, A. Bondar,[1] A. ... izjak,[12] S. Blyth,[22] ... Chen,[22] K.-F. Chen,[24] W. T. Chen,[22] B. G. Cheon, R. Chistov, S.-K. Choi, Y. Choi, Y. K. Choi, A. Chuvikov, J. Dalseno,[19] M. Danilov,[11] M. Dash,[49] L. Y. Dong,[9] A. Drutskoy,[4] S. Eidelman,[1] Y. Enari,[20] F. Fang,[6] S. Fratina,[12] N. Gabyshev,[1] T. Gershon,[7] G. Gokhroo,[40] B. Golob,[17,12] A. Gorišek,[12] J. Haba,[7] T. Hara,[30] K... Y. Hoshi,[42] S. Hou,[22] W.-S. Hou,[24] T. Iijima,[20] K. Ikado,[20] A. In... J. H. Kang,[50] J. S. Kang,[14] P. Kapusta,[25] N. Katayama,[7] H. Kawai,... S. M. Kim,[38] K. Kinoshita,[4] S. Korpar,[18,12] P. Križan,[17,12] P. ... Y.-J. Kwon,[50] G. Leder,[10] S. E. Lee,[36] T. Lesiak,[25] J. Li,[35] S.-W... A. Matyja,[25] W. Mitaroff,[10] K. Miyabayashi,[21] H. Miyake,[30] H. ... T. Tsukamoto,[7] S. Uehara,[7] T. Uglov,[11] K. Ueno,[24] S. Uno,[7] ... C. C. Wang,[24] C. H. Wang,[23] M.-Z. Wang,[24] Q. L. Xie,[9] B. D. Yab... J. Ying,[32] Y. Yuan,[9] C. C. Zhang,[9] L. M...

Phys Rev Lett 95, 231801 (2005)

281 fb^{-1}

$$R_{WS}(K\pi\pi^0) = (0.229 \pm 0.015^{+0.013}_{-0.009})\%$$

$$R_{WS}(K3\pi) = (0.320 \pm 0.018^{+0.018}_{-0.013})\%$$

No CP violation is observed.

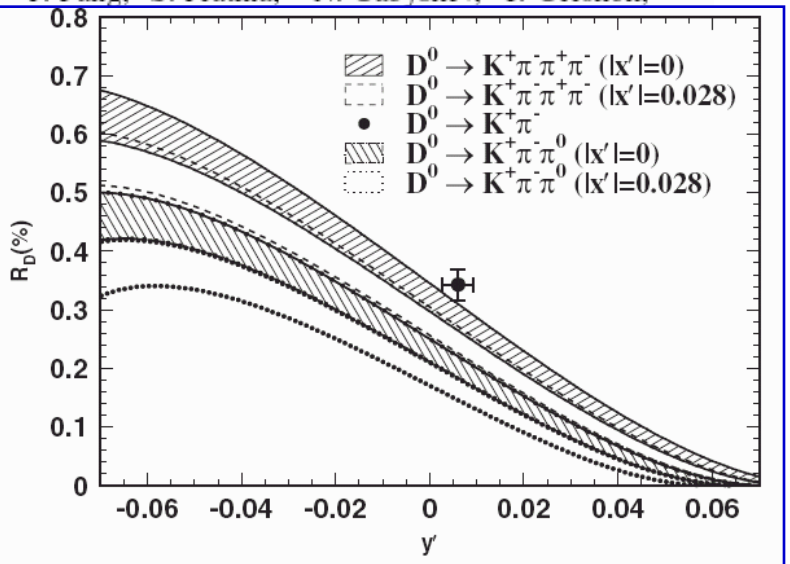


FIG. 3. 68.3% C.L. bands for R_D as a function of y' for $x' = 0$ and $|x'| = 0.028$. The latter value is the upper limit obtained from our analysis of $D^0 \to K^+\pi^-$ decays assuming no *CP* violation [6]. The point with 1σ error bars is the result from the $D^0 \to K^+\pi^-$ analysis for $x' = 0$ (and no *CP* violation). Note that δ and, thus, x', y' may differ for the three modes.

Search for $D^0\overline{D^0}$ mixing

PRL 96, 151801 (2006) PHYSICAL REVIEW LETTERS week ending 21 APRIL 2006

Improved Constraints on D^0-$\overline{D^0}$ Mixing in $D^0 \to K^+\pi^-$ Decays from the Belle Detector

L. M. Zhang,[35] Z. P. Zhang,[35] J. Li,[35] K. Abe,[7] K. Abe,[42] I. Adachi,[7] H. Aihara,[44] D. Anipko,[1] K. Arinstein,[1] Y. Asano,[48] T. Aushev,[11] S. B... Belous,[10] U. Bitenc,[12] I. Bizjak,[12] S. ... M.-C. Chang,[43] P. Chang,[24] Y. Chao,[24] A. Chen,[22] W. T. Chen,[22] B. G. Cheon,[3] R. Chistov,[11] S.-K. Choi,[5] Y. Choi,[38] Y. K. Choi,[38] ... Ha, ... Hou ... saki, ... S. M ... Ku ... Y. M ... T. Mo ... uno, ... N. Sat ... M. E ... hen, ... aka, ... Ueno ... E. ... hang

Phys Rev Lett 96, 151801 (2006)

400 fb^{-1}

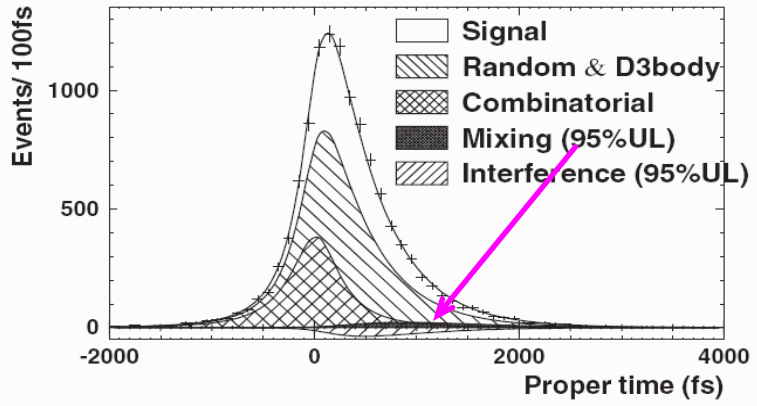


FIG. 2. The decay-time distribution for WS events satisfying $|m_{K\pi} - m_{D^0}| < 22$ MeV/c^2 and $|Q - 5.9| < 1.5$ MeV. Superimposed on the data (points with error bars) are projections of the decay-time fit when no *CPV* is assumed. The mixing and interference terms are shown at the 95% confidence level upper limit (95% UL) for mixing.

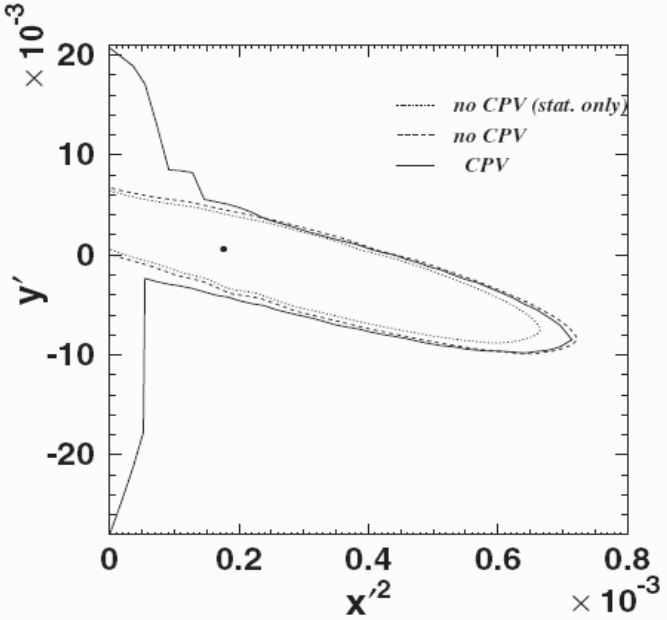


FIG. 3. 95% C.L. regions for (x'^2, y'). The point is the best fit resu... s the ... . The solid line is the statistical and systematic contour in the *CPV*-allowed case.

non−zero significance: 2.3σ

$$R_D = \frac{D^0 \to K^+\pi^-}{D^0 \to K^-\pi^+} = (0.377 \pm 0.008 \pm 0.005)\%$$

Search for $D^0\overline{D^0}$ mixing

PRL 99, 131803 (2007) PHYSICAL REVIEW LETTERS week ending 28 SEPTEMBER 2007

Measurement of $D^0 - \bar{D}^0$ Mixing Parameters in $D^0 \to K_s\pi^+\pi^-$ Decays

L. M. Zhang,[37] Z. P. Zhang,[37] I. Adachi,[7] H. Aihara,[45] V. Aulchenko,[1] T. Aushev,[18,13] A. M. Bakich,[40] V. Balagura,[13] E. Barberio,[21] A. [illegible] P. Chang,[26] Y. C[illegible] S. Cho,[50] Y. Choi,[39] Y. K. Choi,[39] J. Dalseno, [illegible] G. Gokhroo,[41] B. Golob,[19,14] H. Ha,[16] J. Haba,[7] T. Hara,[32] N. C. Hastings,[45] K. Hayasaka,[22] H. Hayashii,[23] M. Hazumi,[7] [illegible] Y. B. Hsiung, [illegible] Y. Iwasaki,[7] N. [illegible] H. J. Kim,[17] H[illegible] [33] C. C. Kuo,[24] [illegible] V. Lin,[26] Y. Liu [illegible] iyake,[32] H. Mi[illegible] [27] S. Nishida,[7] [illegible] P. Pakhlov,[13] G[illegible] ahoo,[6] Y. Saka[illegible] A. J. Schwartz,[3] R. Seidl,[9,35] K. Senyo,[22] M. E. Sevior,[21] M. Shapk[illegible] [illegible] omov,[3] N. Soni,[33] S. [illegible] T. [illegible] saki,[7] K. Tamai,[7] N. T[illegible] [illegible],[7] S. Uehara,[7] K. Uen[illegible] Y. [illegible] A. Vinokurova,[1] C. H. [illegible] amaguchi,[44] Y. Yama[illegible]

Phys Rev Lett 99, 131803 (2007)

$540\ fb^{-1}$

Direct measurement:

$$x = (0.80 \pm 0.29^{+0.09+0.10}_{-0.07-0.14})\%$$

$$y = (0.33 \pm 0.24^{+0.08+0.06}_{-0.12-0.08})\%$$

$$non-zero\ significance:\ 2.2\sigma$$

Allowing for CPV

$$|q/p| = 0.86^{+0.30+0.06}_{-0.29-0.03} \pm 0.08$$

$$\arg(q/p) = (-14^{+16+5+2}_{-18-3-4})^0$$

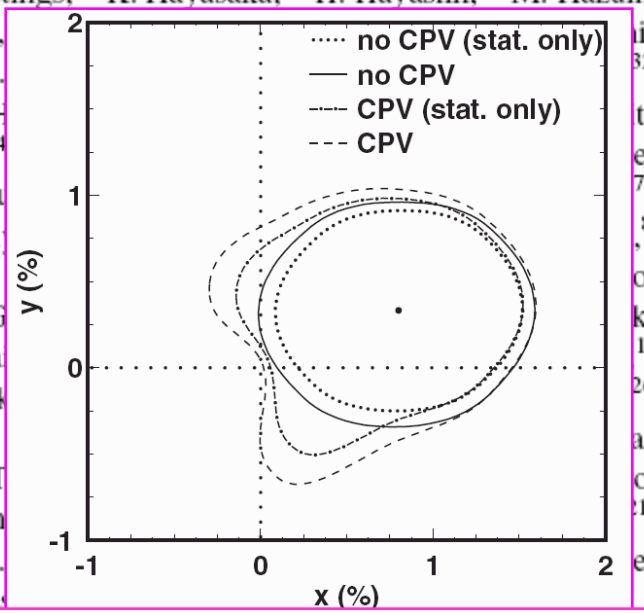


FIG. 4. 95% C.L. contours for (x, y): dotted (solid) corresponds to statistical (statistical and systematic) contour for no *CPV*, and dash-dotted (dashed) corresponds to statistical (statistical and systematic) contour for the *CPV*-allowed case. The point is the best-fit result for no *CPV*.

Search for $D^0\overline{D^0}$ mixing

- Our observations show：
  - Precise measurements of Rd agree with other experiments;
  - Significance for non-zero $D^0\overline{D^0}$ mixing

$$non-zero\ of\ x\ and\ y:\ \ 2.2\sigma\ \ for\ \ D^0 \to K_S\pi\pi^0$$

$$non-zero\ of\ x'^2\ and\ y':\ \ 2.3\sigma\ \ for\ \ D^0 \to K\pi$$

difference in significance is about 2σ effect

- Other observations：

$$3.9\sigma\ \ for\ \ D^0 \to K\pi\ \ (Babar)$$

$$3.2\sigma \text{ and } 3.0\sigma\ \ for\ \ D^0 \to KK, \pi\pi\ \ (Belle\ and\ Babar)$$

- Further study with 10 times more data are still required.

Search for $B^- \to J/\psi(\Lambda, \Sigma^0, p)\bar{p}$

PHYSICAL REVIEW D **69**, 017101 (2004)

Search for $B^- \to J/\psi \Lambda \bar{p}$ decay

S. L. Zang,[9] K. Abe,[7] K. Abe,[41] T. Abe,[7] I. Adachi,[7] Byoung Sup Ahn,[14] H. Aihara,[43] M. Akatsu,[20] Y. Asano,[48] T. Aso,[47] V. Aulchenko,[1] T. A… A. Boz…čko,[18,12] T. E. Browder,[6] P. Chang… Choi,[14] Y. K. Choi,[37] A. Chuvikov,[32] M. Danilov,[11] L. Y. Dong,[9] S. Eidelman,[1] V. Eiges,[11] Y. Enari,[20] C. Fukunaga,[45] N. Gabyshev,[7] … C. Hagner,[50] … W.-S. Hou,[24] R. Itoh,… vasaki,[7] J. H. Kang,[51] J. S. Kang,[14] P. Kapusta,[25] N. Katayama,[7] H. Kawai,[2] T. K… [51] J. H. Kim,[37] S. K. Kim,[36] K. Kinoshita,[3] P. Koppenburg,[7] S. Korpar,[18,12]

Phys Rev D 69, 017101 (2004)

78 fb^{-1}

No exotic state is found

$Br(B^- \to J/\psi \Lambda \bar{p}) < 4.1 \times 10^{-5}$ $(90\% CL)$

significance : 2.8σ

PHYSICAL REVIEW D **72,** 051105(R) (2005)

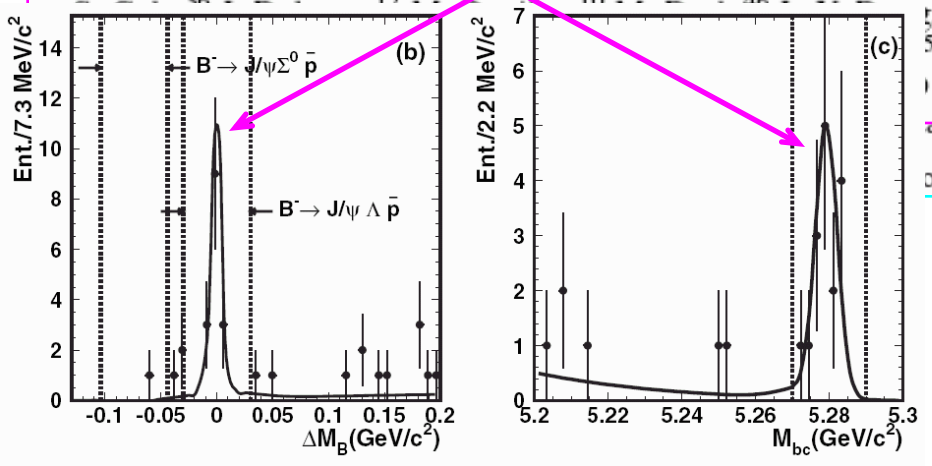
Observation of $B^- \to J/\psi \Lambda \bar{p}$ and searches for $B^- \to J/\psi \Sigma^0 \bar{p}$ and $B^0 \to J/\psi p \bar{p}$ decays

Q. L. Xie,[8,*] K. Abe,[6] K. Abe,[39] I. Adachi,[6] H. Aihara,[41] … E. Barberio,[17] … Bizja… J. Brodzicka,[23] … V. T. Chen,[20] B. G. Cheon,[3] R. Chistov,[10] Y. Choi,[35] A. Chuvikov,[31] … [8] A. Drutskoy,[4] S. Eidelman… S. Fratina,[11] … [5,11] A. Gorišek,[11] J. Haba,[6] K. … H. Hayashii,[19] … W.-S. Hou,[22] Y. B. Hsiung,[22] T. Iijima,[18] K. Ikado,[18]

Phys Rev D 72, 051105 (2005)

253 fb^{-1}

Signal for $B^- \to J/\psi \Lambda \bar{p}$



$Br(B^- \to J/\psi \Lambda \bar{p}) = 11.6 \pm 2.8^{+1.8}_{-2.3} \times 10^{-6}$

$Br(B^- \to J/\psi \Sigma^0 \bar{p}) < 11 \times 10^{-5}$ $(90\% CL)$

$Br(B^0 \to J/\psi p \bar{p}) < 8.3 \times 10^{-7}$ $(90\% CL)$

Search for $B^{0(+)} \to J/\psi \bar{D}^0 (\pi^+)$

PHYSICAL REVIEW D **71,** 091107 (2005)

Search for $B^0 \to J/\psi \bar{D}^0$ and $B^+ \to J/\psi \bar{D}^0 \pi^+$ decays

L. M. Zhang,[33] Z. P. Zhang,[33] K. Abe,[6] K. Abe,[39] I. Adachi,[6] H. Aihara,[41] Y. Asano,[45] T. Aushev,[10] S. Bahinipati,[4] A. M. Bakich,[36] M. Barber[...] M. Bračk[o] [...] zicka,[24] T. E. Browder,[5] Y. Chao,[23] [...] histov,[10] Y. C[...] vikov,[31] S. Cole,[36] J. Dalseno,[18] M. Danilov,[10] M. Dash,[46] A. Drutskoy,[4] S. Eidelman,[1] S. Fratina,[11] N. Gabyshev, T. Gershon,[6] G. Gokhroo,[37] B. Golob,[16,11] A. Gorišek,[11] T. Hara,[28] K. Hayasaka,[19] H. Hayashii,[20] M. Hazumi,[6] L. Hinz,[15] T. Hokuue,[19] [...] M. Nakao,[6] Z. Natkaniec,[24] S. Nishida,[6] O. Nitoh,[44] S. Ogawa,[38] [...] Y. Onuki,[26] W. Ostrowicz,[24] H. Ozaki,[6] H. Palka,[24] C. W. Park,[35] [...] H. Sagawa,[6] Y. Sakai,[6] N. Sato,[19] T. Schietinger,[15] O. Schneider,[15] [...] Somov,[4] R. Stamen,[6] S. Stanič,[45,*] M. Starič,[11] K. Sumisawa,[28] T. Sumiyoshi,[43] S. Suzuki,[32] S. Y. Suzuki,[6] O. Tajima,[6] F. Takasaki,[6] K. Tamai,[6] N. Tamura,[26] M. Tanaka,[6] Y. Teramoto,[27] X. C. Tian,[30] K. Trabelsi,[5] T. Tsukamoto,[6] S. Uehara,[6] T. Uglov,[10] K. Ueno,[23] S. Uno,[6] P. Urquijo,[18] G. Varner,[5] K. E. Varvell,[36] S. Villa,[15] C. C. Wang,[23] C. H. Wang,[22] M.-Z. Wang,[23] Q. L. Xie,[8] A. Yamaguchi,[40] H. Yamamoto,[40] Y. Yamashita,[25] M. Yamauchi,[6] J. Ying,[30] C. C. Zhang,[8] J. Zhang,[6] and D. Žontar[16,11]

(Belle Collaboration)

Phys Rev D 71, 091107 (2005)

140 fb^{-1}

- Consistent with Babar's
- Rule out possible charm content at 1% level in the B meson

$$Br(B^+ \to J/\psi \bar{D}^0 \pi^+) < 2.5 \times 10^{-5} \quad (90\% CL)$$

$$Br(B^0 \to J/\psi \bar{D}^0) < 2.0 \times 10^{-5} \quad (90\% CL)$$

Search for $B^{+,0} \to J/\psi\eta'(K^+, K_S^0)$

PHYSICAL REVIEW D 75, 017101 (2007)

Search for $B^+ \to J/\psi\eta' K^+$ and $B^0 \to J/\psi\eta' K_S^0$ decays

Q. L. Xie,[10] K. Abe,[8] I. Adachi,[8] H. Aihara,[46] D. Anipko,[1] K. Arinstein,[1] V. Aulchenko,[1] T. Aushev,[18,13] T. Aziz,[42] S. Bahinipati,[4] A. M. Baki... Bedny,[1] K. ...itenc,[14] I. Bizjak,[14] S. Blyth,[24] A. ... Chao,[26] A. ... Chen,[26] W. T. Chen,[24] B. G. Cheon,[3] R. Chistov,[13] Y. Choi,[40] Y. K. Choi,[40] S. Cole,[41] J. Dalseno,[21] M. Dash,[...] A. Drutskoy,[4] ... A. Go,[24] G. Gokhroo,[42] H. Ha,[16] J. Haba,[8] K. Hayasaka,[22] ... Y. Hoshi,[44] S. Hou,[24] W.-S. Hou,[26] T. Iijima,[22] K. Ikado,[22] ... oh,[8] Kin... J. K... W. ... [35] Y. Nagasaka,[9] E. Nakano,[31] M. Nakao,[8] Z. Natkaniec,[27] ... Olsen,[7] Y. Onuki,[36] H. Ozaki,[8] P. Pakhlov,[13] G. Pakhlova,[13] H. Park,[17] L. S. Peak,[41] R. Pestotnik,[14] L. E. Piilonen,[50] A. Poluektov,[1] H. Sahoo,[7] Y. Sakai,[8] N. Satovama,[39]

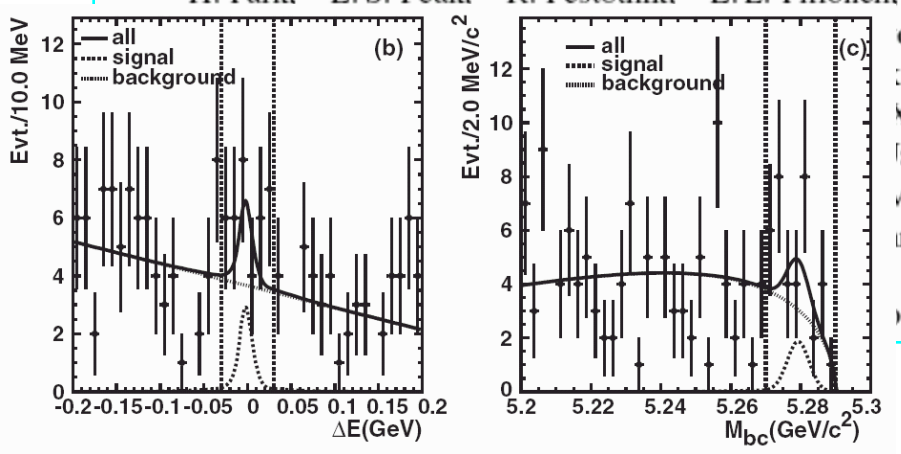
Phys Rev D 75, 017101 (2007)

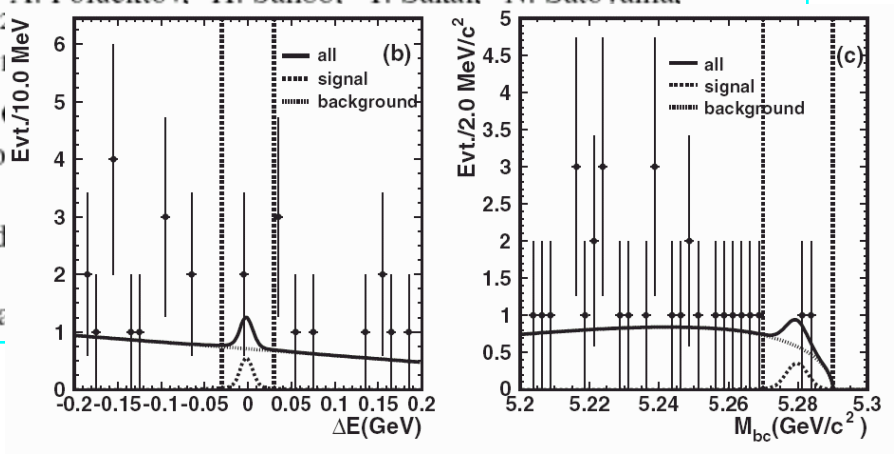
357 fb^{-1}

- No signal hybrid of $B \to \psi_g K$ is found
- Here ψ_g is excited gluonic $(c\bar{c}g)$ state

$Br(B^+ \to J/\psi\eta' K^+) < 8.8\times10^{-5}$ (90%CL)

$Br(B^0 \to J/\psi\eta' K_S^0) < 2.5\times10^{-5}$ (90%CL)





$B^+ \to J/\psi\eta' K^+$

$B^0 \to J/\psi\eta' K_S^0$

Search for $X(1812)$ in $B^{\pm} \to K^{\pm}\omega\phi$

Search for the $X(1812)$ in $B^{\pm} \to K^{\pm}\omega\phi$

C. Liu,[37] Z. P. Zhang,[37] I. Adachi,[9] H. Aihara,[43] K. Arinstein,[1,32] T. Aushev,[19,14] A. M. Bakich,[40] E. Barberio,[22]
T. E. Browder,[8] M.-C. Chen,[25] B. G. Cheon,[7]
W. Dungel,[12] S. Eid Gabyshev,[1,32]
P. Goldenzweig,[2] H. Ha,[17] J. Haba,[9] B.-Y. Han,
K. Inami,[23] A. Ishikawa,[36] R. Itoh,[9] M. Iwasaki,
N. Katayama,[9] T. Kawasaki,[30] H. O. Kim,[18] Y. I. K
P. Krokovny,[9] S.-H. Kyeong,[47] J. S. Lange,[5] M. J
Y. Liu,[23] D. Liventsev,[14] R. Louvot,[19] A. Matyja,
Y. Nagasaka,[10] E. Nakano,[33] M. Nakao,[9] H. Nakaz
S. Ogawa,[41] T. Ohshima,[23] S. Okuno,[16] H. Oza

To be submitted to Phys Rev D (RC)

$657\ fb^{-1}$

$Br(B^{\pm} \to K^{\pm} X(1812), X(1812) \to \omega\phi) < 3.2 \times 10^{-7}$ $(90\%CL)$

$Br(B^{\pm} \to K^{\pm}\omega\phi) < 1.9 \times 10^{-6}$ $(90\%CL)$

- Search for $X(1812) \to \omega\phi$ as possible tetra-quark state or hybrid.
- No significant signal is found.

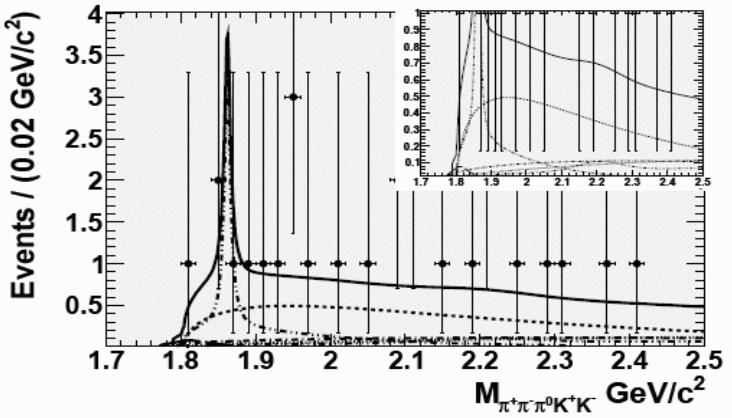


FIG. 2: Mass spectrum in the $\omega\phi$ fit with the following components: $B^+ \to K\omega\phi$ three-body (dotted), $B\overline{B}$ (dot-dashed), $q\overline{q}$ (dashed), D^0(dot-dot-dashed), D_s(dot-dot-dot-dashed), $B^{\pm} \to K^{\pm}X(1812)$(long-dashed), and total(solid). The spectrum is also shown in the inset with an expanded vertical scale

X(1835) observed by BESII

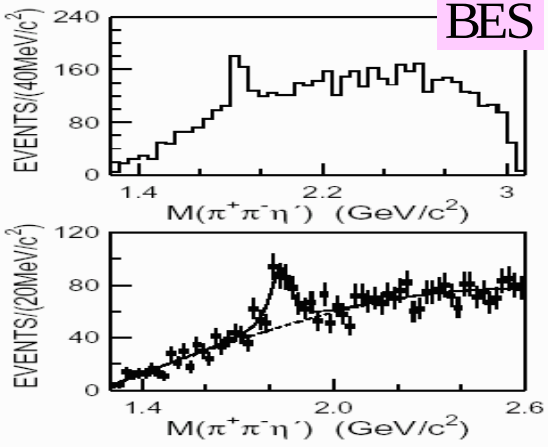
- Observation of X(1835)

$$M = 1833.7 \pm 6.1 \pm 2.7\ MeV/c^2$$

$$\Gamma = 67.7 \pm 20.3 \pm 7.7\ MeV/c^2$$

$$Br(J/\psi \to \gamma X) \cdot B(X \to \pi^+\pi^-\eta') = (2.2 \pm 0.4 \pm 0.4) \times 10^{-4}$$

See: Phys. Rev. Lett. 95, 262001 (2005)



$M_{\eta'\pi^+\pi^-}$

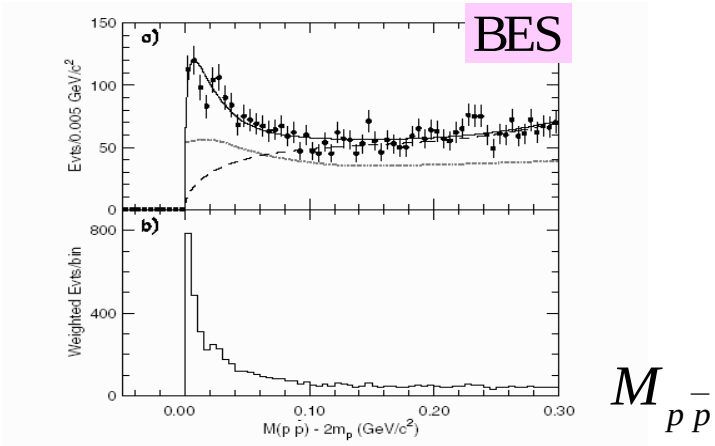
$J^{PC}: 0^{-+}$

- Enhancement near $p\bar{p}$ threshold

$$M = 1859^{+3+5}_{-10-25}\ MeV/c^2$$

$$Br(J/\psi \to \gamma X) \cdot B(X \to p\bar{p}) = (7.0 \pm 0.4^{+1.9}_{-0.8}) \times 10^{-5}$$

See : Phys. Rev. Lett. 91, 022001 (2003)



$M_{p\bar{p}}$

S-wave BW fit with FSI & zero isospin gives:

$$M = 1831 \pm 7\ MeV/c^2$$

$$\Gamma < 157\ MeV/c^2$$

$J^{PC}: 0^{++}$ or 0^{-+}

Search for X(1835) in $e^+e^- \to J/\psi\, X(1835)$

Search for $X(1835)$ in $e^+e^- \to J/\psi + X(1835)$ ~~in e^+e^- annihilation~~ at $\sqrt{s} \approx 10.6$ GeV

J. Wang[1], Y. Ban[1], C. C. Zhang[2], P. Wang[2], and X. C. Tian[2]

[1] Peking University, Beijing
[2] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing

(Dated: March 6, 2009)

Under referee process in Belle

We report the $X(1835)$ state via $e^+e^- \to J/\psi + X(1835)$ with a data sample of 673 fb^{-1} collected on and off $\Upsilon(4S)$ resonance with the Belle detector at KEKB collider. A significant evidence is found for $e^+e^- \to J/\psi + X(1835)$ produ...

673 fb^{-1}

$$\sigma_{Born}(e^+e^- \to J/\psi\, X(1835)) \cdot Br(X(1835) \to >2\ charged) < 0.76\ fb^{-1} \quad (90\%CL)$$

- Search for $X(1835) \to >2\ charged$ as glueball candidate.
- No significant evidence is found.

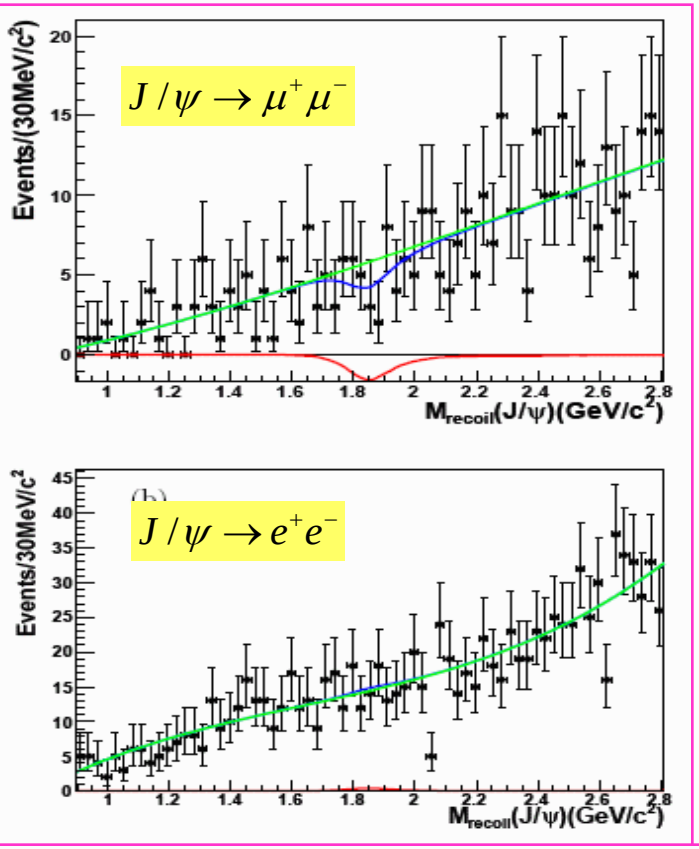
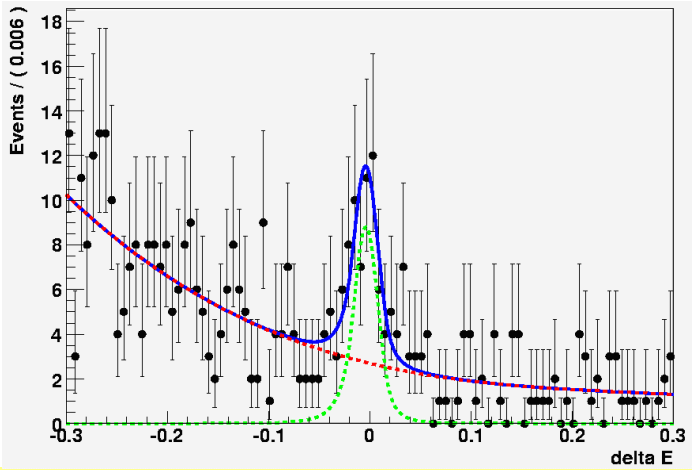


FIG. 3: Fitted results of low recoil mass region for $J/\psi \to \mu\mu$(a) and $J/\psi \to ee$(b) respectively. Red lines represent Monte Carlo signal shapes, green lines are background shapes.

Measurement of η_C and search for X(1835)

$$B^{\pm} \to K^{\pm}\eta_C,\ \eta_C \to \eta'\pi^+\pi^-$$

$L\,\mathrm{int} = 605 \quad fb^{-1}$



The fit yields $N_{obs} = 49.0 \pm 9.7$

- X(1835) is observed from J/psi decay by BESII.
- It could be produced in B decay and two-photon process, if it is an excited η' state.
- presented at physics group meeting.

No signal for $B^{\pm} \to K^{\pm}X(1835)$ with $X(1835) \to \eta'\pi^+\pi^-$ is found.

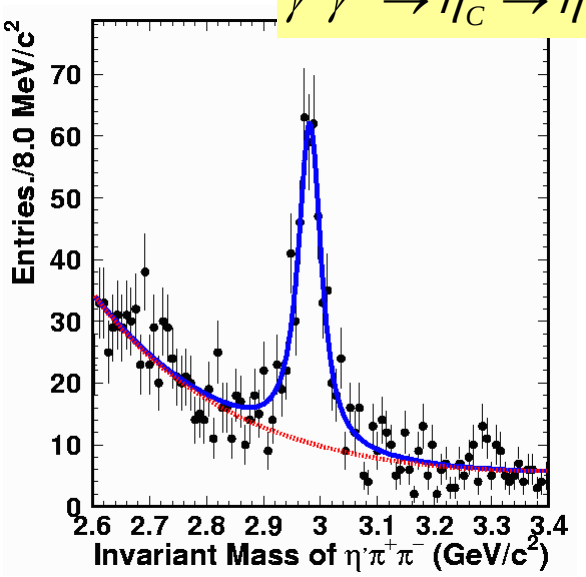
η_C signal for $B^{\pm} \to \eta_C K^{\pm}$ is observed. It is a first observation via $\eta_C \to \eta'\pi^+\pi^-$ decay mode.

- Preliminary and unpublished
- Internal report only.

Measurement of η_C and search for X(1835)

$via \;\; two-photon \;\; process: \;\; \gamma^*\gamma^* \to \eta_C, X(1835)$

$\gamma^*\gamma^* \to \eta_C \to \eta'\pi^+\pi^-$



$L\,\mathrm{int} = 673 \;\; fb^{-1}$

$M_{\eta_C} = 2981.9 \pm 1.8 \pm 2.0 \;\; MeV/c^2$

$\Gamma_{\eta_C} = 36.3^{+5.3}_{-4.4} \pm 2.6 \;\; MeV/c^2$

$\Gamma_{\gamma\gamma} Br(\eta_C \to \eta'\pi^+\pi^-) = 52.1 \pm 4.3 \pm 6.8 \;\; eV/c^2$

(PDG08: $194 \pm 98 \;\; eV/c^2$)

Direct measurement with improved precision

$\gamma^*\gamma^* \to X(1835) \to \eta'\pi^+\pi^-$

Preliminary search for $X(1835)$ is presented at Belle Analysis Meeting.

PhD thesis on Belle physics

1. Ye Yuan (IHEP)， 2002

   "Measurement of $B \to \chi_{c1,c2} K^{(*)}$ decays at Belle/KEKB"

2. Zshilei Zang (IHEP)， 2005

   "Search for $B^- \to J/\psi \Lambda \bar{p}$ decays at Belle"

3. Jin Li (USTC), 2004

   "Search for $D^0 \overline{D^0}$ mixing via $D^0 \to K^+ \pi^-$ "

4. Qilin Xie (SCU)， 2005

   "Search for $B^- \to J/\psi (\Lambda, \Sigma^0, p) \bar{p}$ and $B^{+,0} \to J/\psi \eta' (K^+, K_S^0)$ at Belle"

5. Xinchun Tian (PKU), 2006

   "Measurement of the wrong-sign decays $D^0 \to K^+ \pi^- (\pi^0, \pi^+ \pi^-)$ and search for CP violation"

6. Liming Zhang (USTC), 2006

   "Search for $D^0 \overline{D^0}$ mixing in $D^0 \to K^+ \pi^-$ and Measurements of $B^{0(+)} \to J/\psi \overline{D}^0 (\pi^+)$ "

Publication

1. "Search for $B^- \to J/\psi \Lambda \bar{p}$ decay",
   Phys. Rev. D69, 017101 (2004)
2. "Observation of $B^- \to J/\psi \Lambda \bar{p}$ and search for $B^- \to J/\psi \Sigma^0 \bar{p}$ decay",
   Phys. Rev. D72, 051105 (2005)
3. "Search for $B^{0(+)} \to J/\psi \bar{D}^0 (\pi^+)$ decay",
   Phys. Rev. D71, 091107 (2005)
4. "Search for $D^0 \bar{D}^0$ mixing in $D^0 \to K^+\pi^-$ decays",
   Phys. Rev. Lett. 94, 071801 (2005)
5. "Measurement of WS $D^0 \to K^+\pi^-(\pi^0, \pi^+\pi^-)$ decays and Search for CPV",
   Phys. Rev. Lett. 95, 231801 (2005)
6. "Improved Constraints on $D^0 \bar{D}^0$ mixing in $D^0 \to K^+\pi^-$ decays",
   Phys. Rev. Lett. 96, 151801 (2006)
7. "Proper-time resolution function in $D^0 \bar{D}^0$ mixing search",
   Nucl. Instrum. Meth. A553,483 (2005)
8. "Search for $B^{-(0)} \to J/\psi \eta' K^-(K_S^0)$ decays",
   Phys. Rev. D75, 017101 (2007)
9. "Measurement of $D^0 \bar{D}^0$ mixing parameters in $D^0 \to K_S\pi^+\pi^-$ decays",
   Phys. Rev. Lett., 99 131803 (2007)

PRL : 4 papers

PRD : 4 papers

NIM : 1 paper

Summary

- Contributions on Charm physics research to Belle experiment
  - 9 papers published（4 for PRL, 4 for PRD, 1 for NIM)
- Our results in $D^0\overline{D}^0$ mixing disfavor the non-mixing point with $2.3\sigma(2.2\sigma)$ significance for $D^0 \to K^+\pi^-(K_S\pi^+\pi^-)$.
  - Continue effort in the search is expected at Super Belle
- No evidence for exotic states from $B^{(-,0)} \to J/\psi(\Lambda\overline{p},\ \overline{D}^0(\pi^0))$ decays
  - $Br(B^- \to J/\psi\Lambda\overline{p})$ is measured, and upper limits for others are obtained.
- More papers on X(1812) and X(1835) search will be published.

My appreciations to
our colleagues at KEKB and Belle for their dedicate and successful works.

JSPS fund
NSFC fund
Innovation(IHEP,CAS) fund
CCAST fund

Thanks

Thanks

Research on charm Physics at Belle

Brief status (continue)

- Conf. talk (Yuan Ye/IHEP)

  "Branching fractions and Properties on B meson Decays to Charmonium"

  presented at the Annual Meeting of Chinese Association of High Energy Physics, Oct. 2002, Xinxiang, China

- Conf. talk (Ban Y/PU, Dong L.Y./IHEP)

  "Measurement of R_{WS} $D^0 \to K^+\pi^-$ using 11 fb^{-1}"

  presented at Inter. Conf. of Flavor Physics, 2001, Hunan, China

- Conf. talk (Yuan.Y./IHEP)

  "Selected topics from Belle experiment"

  presented at Workshop on B Physics at hadron colliders, 22-23 Nov. 2004, CCAST, Beijing