

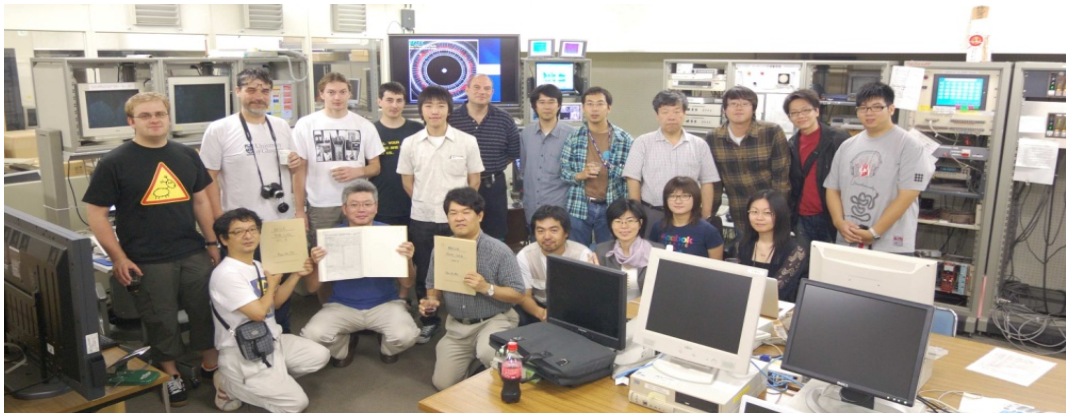
# A01: Research of exotic hadrons at B-factory experiment

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2011 Feb. 28<sup>th</sup>, Riken  
New Hadron WS

# Outline

- Status of KEKB and Belle
- Highlights during FY2010
- New Postdocs
- New computer
- New organization
- New analysis attempts
- Summary

# KEKB operation completed on June 30, 2010

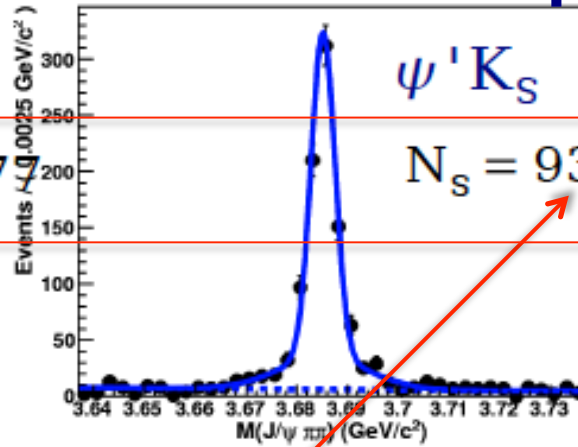
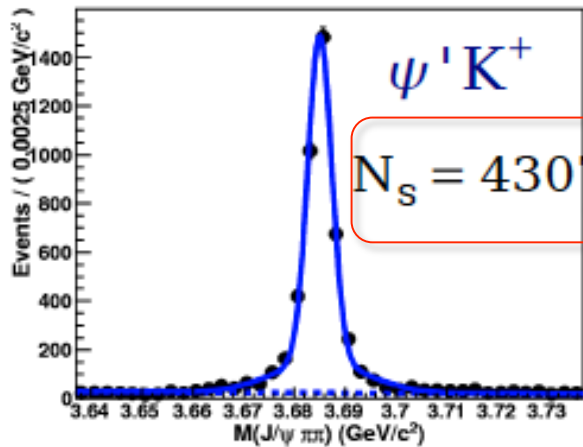


First physics run on June 2, 1999  
Last physics run on June 30, 2010  
 $L_{\text{peak}} = 2.1 \times 10^{34} / \text{cm}^2 / \text{s}$   
 $L_{\text{int}} > 1 \text{ ab}^{-1}$

# Belle Data Grand Reprocess

- New charged track finding algorithm.
  - Hit threshold tuned as a func. of  $\theta$  in Csl cal.
- ↓
- “SVD2” data(2003 autumn ~, 620M  $\overline{BB}$ ) have been reprocessed by the updated software.
  - Started from 2009 July, completed 2010 Feb.
  - Total  $\Upsilon(4S)$  corresponds to 772M  $\overline{BB}$ .

# Effects of Grand Reprocess

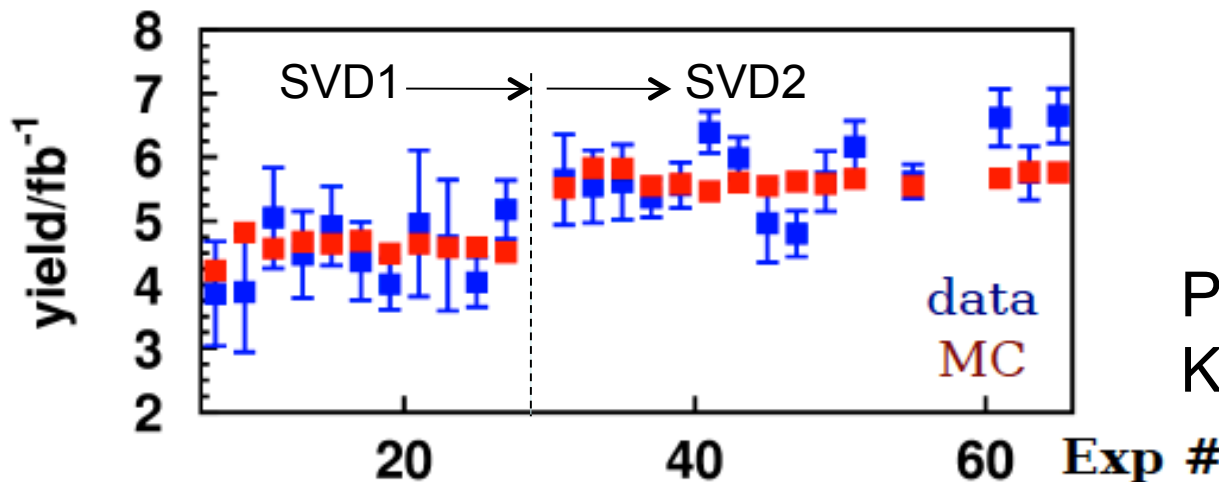


After grand reprocess

(Before grand reprocess)  
 $N_s = 2916 \pm 61$  (+50%)  
 $N_s = 559 \pm 25$  (+66%)

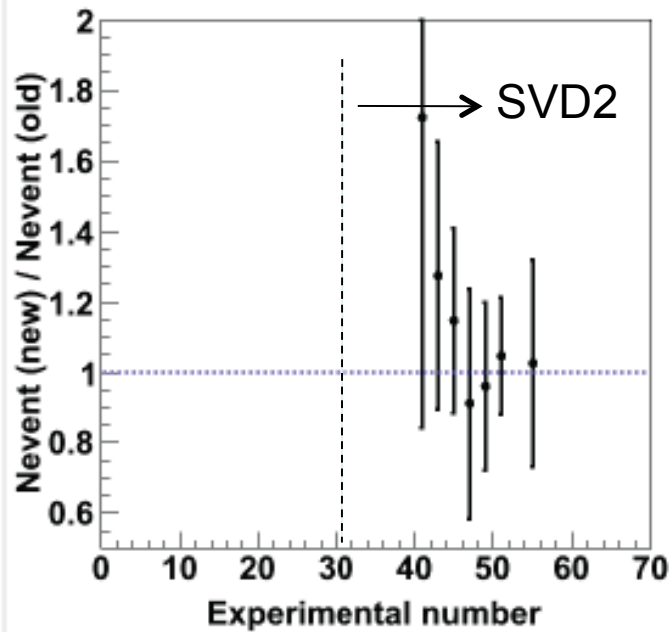
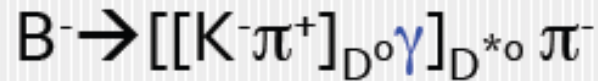
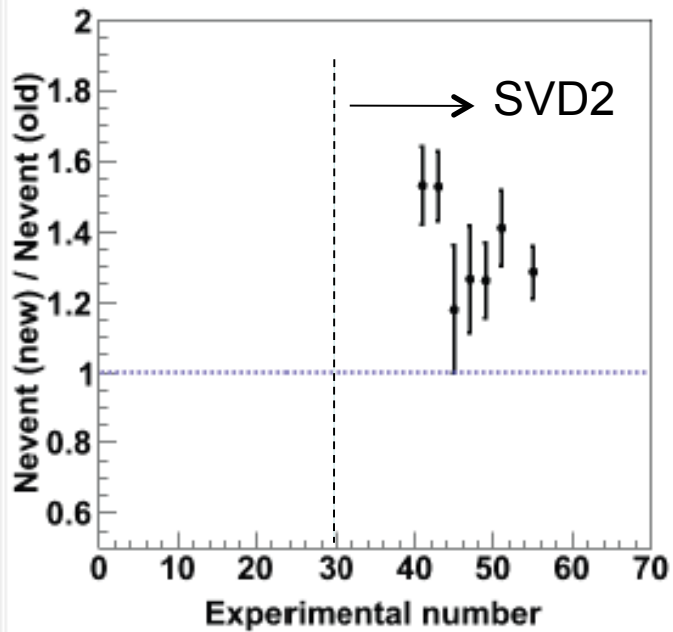
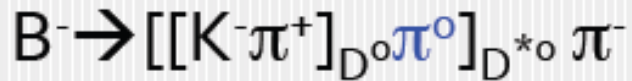
Significant improvement in reconstruction efficiency.

$\psi(2S) (J/\psi \pi^+ \pi^-) K^+$



Plots given by K.Trabelsi

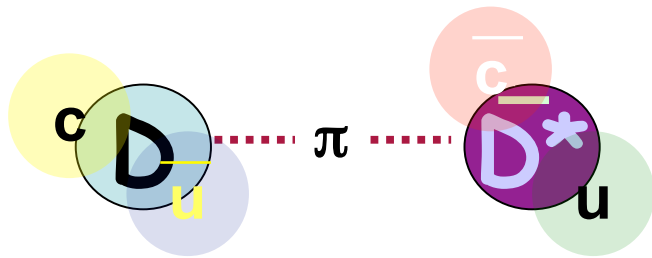
# Effects of Grand Reprocess (cont.)



For the B decays containing  $\pi^0/\gamma$ , improvement is also clearly seen.

Plots made by Y.Horii

$$X(3872) \rightarrow J/\psi \gamma, \psi' \gamma$$



If  $X(3872)$  is pure  $D^0 D^{*0}$  molecule,  
 $\text{Br}(X(3872) \rightarrow \psi' \gamma) < \text{Br}(X(3872) \rightarrow J/\psi \gamma)$   
 cf. Phys.Rept.429, 243(2006)

$X(3872) \rightarrow J/\psi \gamma$  has been confirmed by both Belle and BaBar.  
 cf. arXiv:0505037, PRD74,071101(2006), PRL102,132001(2009).

BaBar reported an evidence for  $X(3872) \rightarrow \psi' \gamma$

$$\frac{\text{Br}(X(3872) \rightarrow \psi' \gamma)}{\text{Br}(X(3872) \rightarrow J/\psi \gamma)} = 3.5 \pm 1.4 \quad \text{cf. PRL102,132001(2009)}$$

Belle should check if it is confirmed.

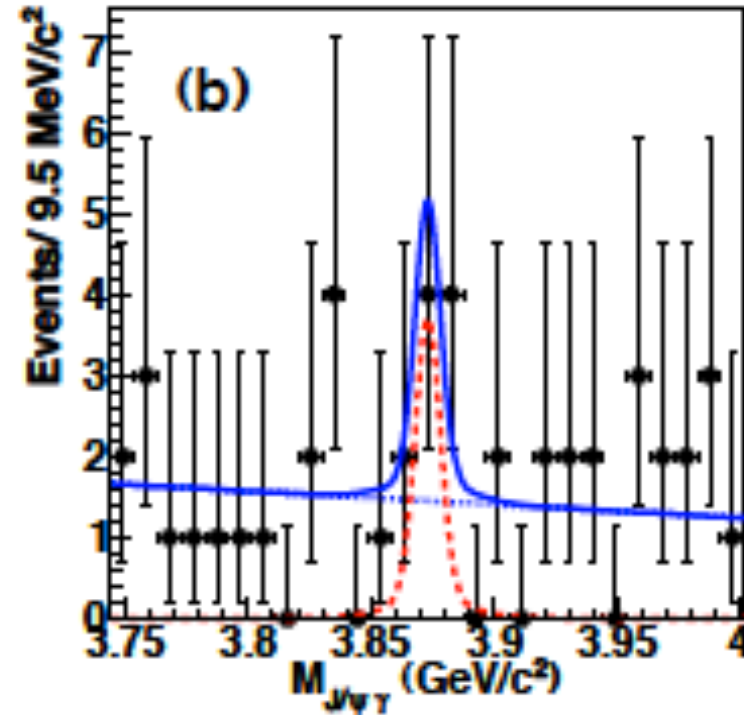
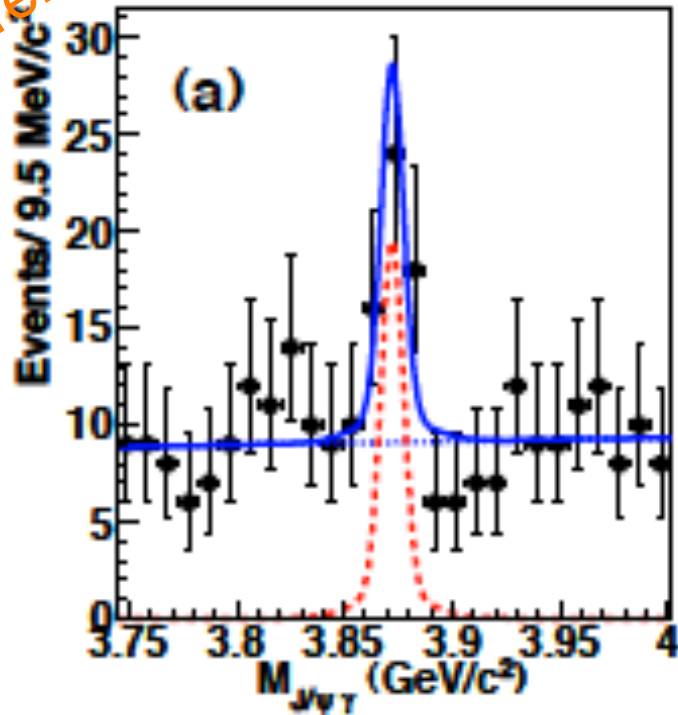
# Revisit $X(3872) \rightarrow J/\psi \gamma$

772M  $B\bar{B}$

Belle preliminary

$B^\pm \rightarrow J/\psi \gamma K^\pm$

$B^0 \rightarrow J/\psi \gamma K_S$



$$B^\pm \rightarrow J/\psi \gamma K^\pm \text{ signal : } 30 \text{ } ^{+8.2}_{-7.4} \text{ events, } 4.9\sigma$$

$$\frac{\text{Br}(X(3872) \rightarrow J/\psi \gamma)}{\text{Br}(X(3872) \rightarrow J/\psi \pi^+ \pi^-)} = 0.22 \pm 0.05$$



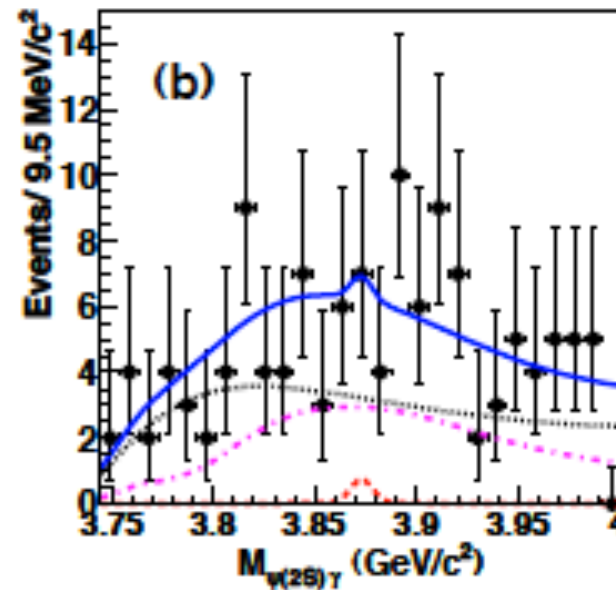
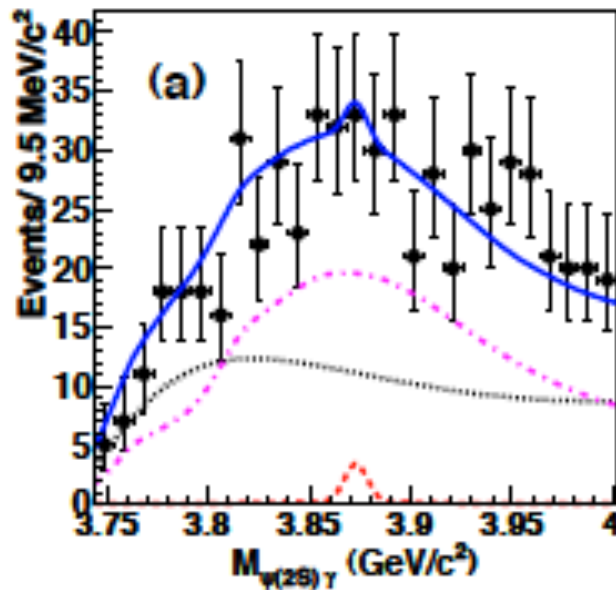
# How about $X(3872) \rightarrow \psi' \gamma$ ?

Belle preliminary

$B^\pm \rightarrow \psi' \gamma K^\pm$

$B^\pm \rightarrow \psi' \gamma K_S$

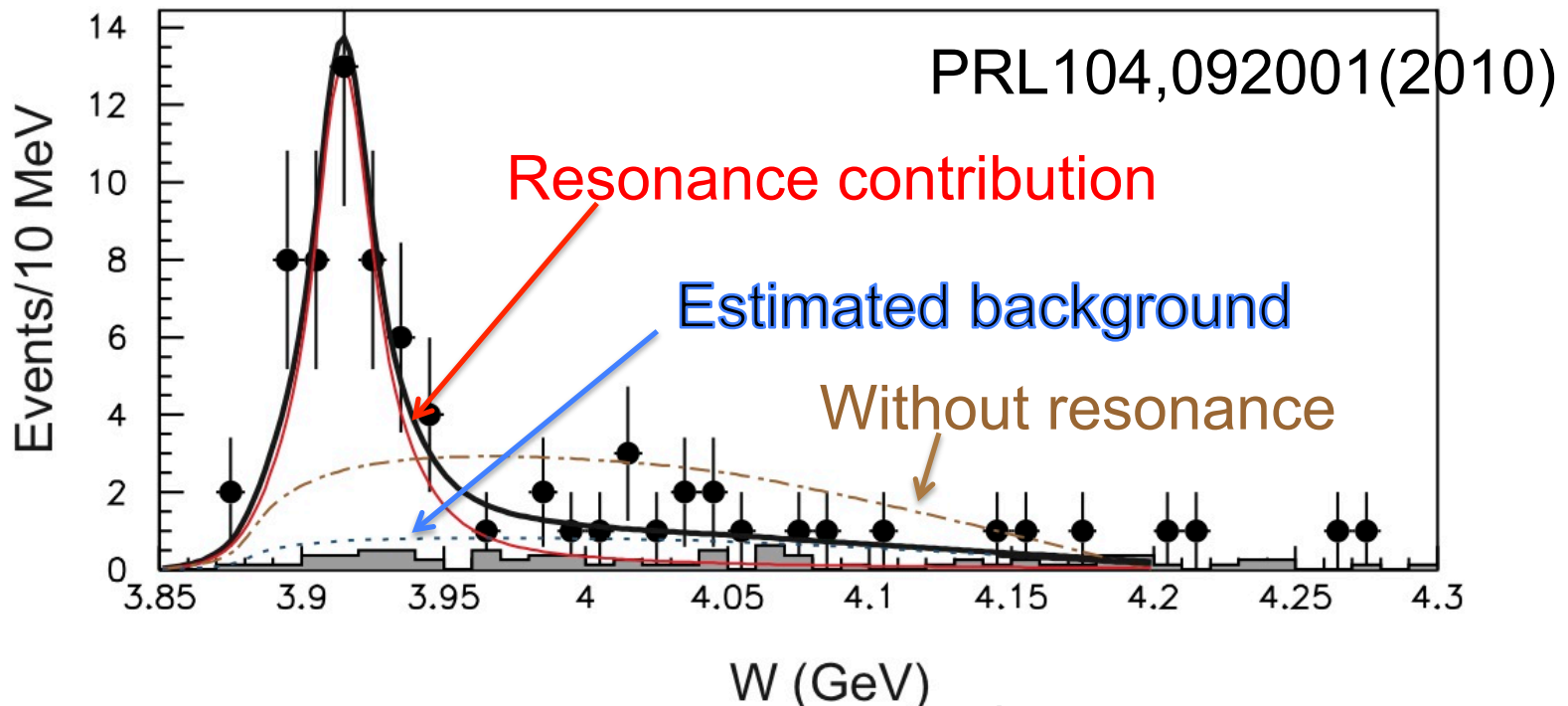
772M  $B\bar{B}$



No significant signal (← contradicting with BaBar).

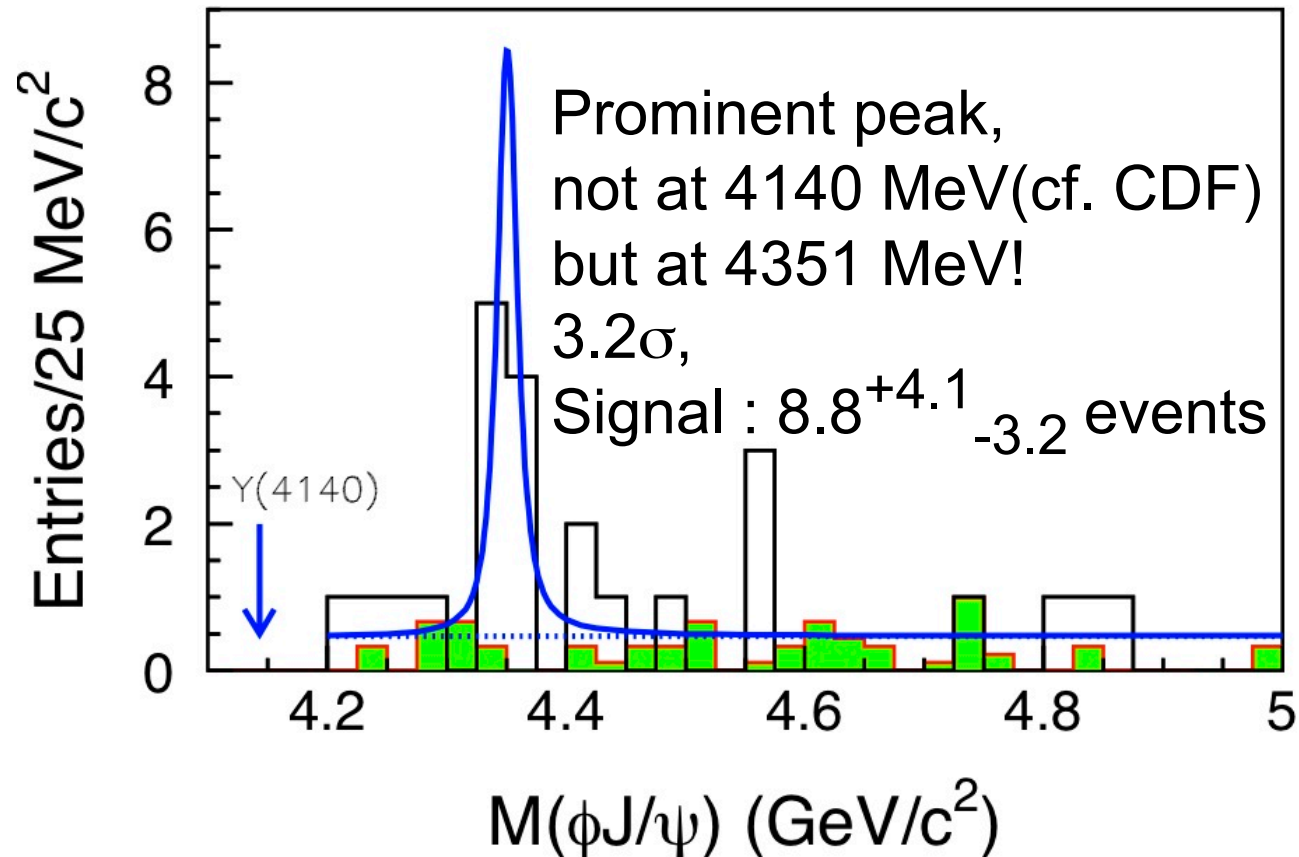
$$\frac{\text{Br}(X(3872) \rightarrow \psi' \gamma)}{\text{Br}(X(3872) \rightarrow J/\psi \gamma)} < 2.1 \text{ @90\% C.L.}$$

# $M(J/\psi \omega)$ in $\gamma\gamma$ ( $P_t < 0.1$ GeV)



Clear enhancement seen just above  $J/\psi \omega$  threshold!  
Statistical significance =  $7.7\sigma$ , Signal =  $49 \pm 14(\text{stat}) \pm 4$  events.  
 $M = 3915 \pm 3(\text{stat}) \pm 2(\text{syst})$  MeV,  $\Gamma = 17 \pm 10(\text{stat}) \pm 3(\text{syst})$  MeV  
 $J^{PC}$  not yet determined (need much more statistics).  
→ Revisit  $Y(3940)$  mass, width,  $J^{PC}$  in  $B \rightarrow J/\psi \omega K$  going on.

# M(J/ψ φ) in γγ collision at Belle



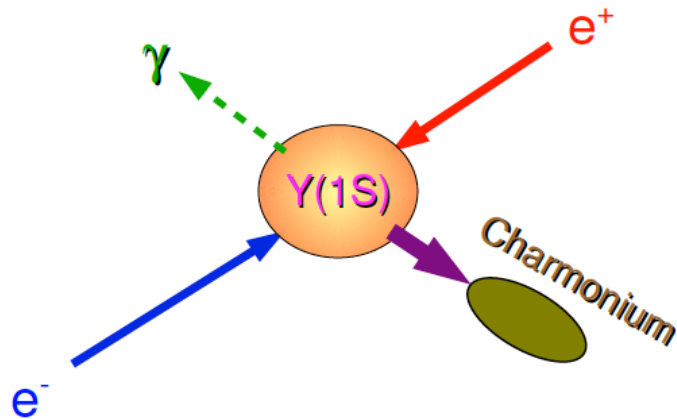
M=4350.6 +4.6/-5.1(stat) ±0.7 MeV

Γ=13 +18/-13(stat) ±4 MeV

PRL104,112004(2010)

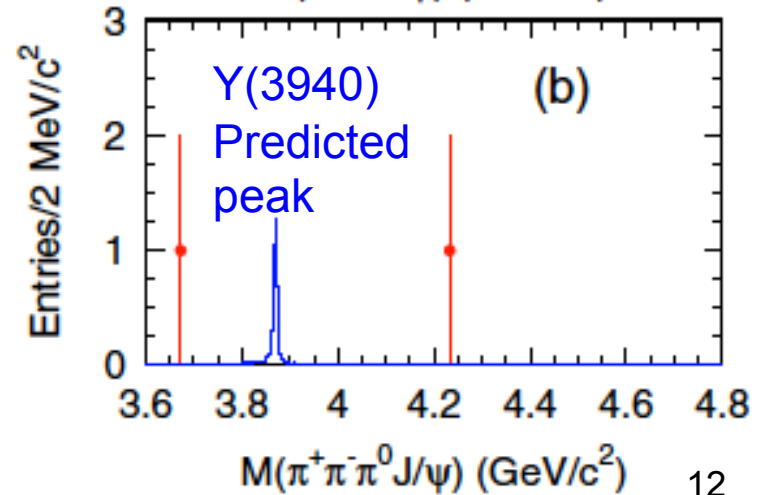
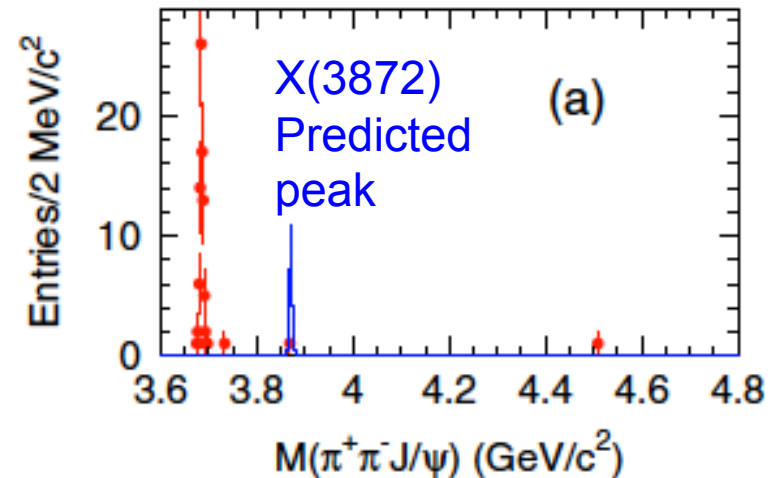
# $\Upsilon(1S) \rightarrow \gamma$ charmonium(-like)

102M  $\Upsilon(1S)$



- The produced charmonium(-like) particle has  $C=+1$ .
- $X(3872)$ ,  $Y(3940)$  are looked for as well as  $C=+1$  charmonium (i.e.  $\chi_{c0,1,2}$ ).
- No signal seen.

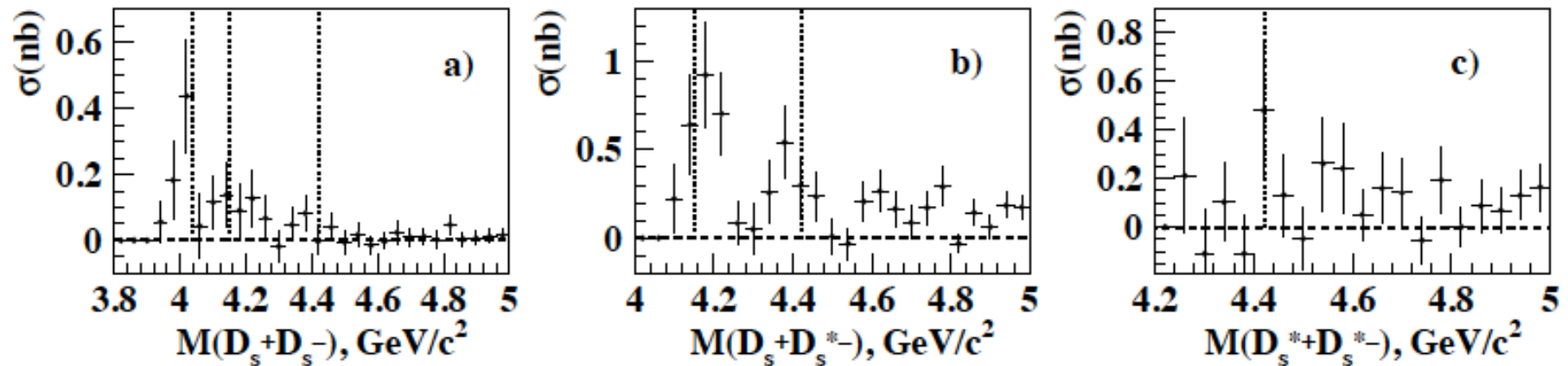
(PRD82,051504(R)(2010))



# $D_s^{(*)+}D_s^{(*)-}$ in Initial State Radiation

Initial state radiation is suitable process to have  $J^{PC}=1^{--}$  particle.  
 $e^+e^- \rightarrow \gamma D_s^{(*)+}D_s^{(*)-}$  cross section was measured to hunt the new state decaying into  $D_s^{(*)+}D_s^{(*)-}$ .

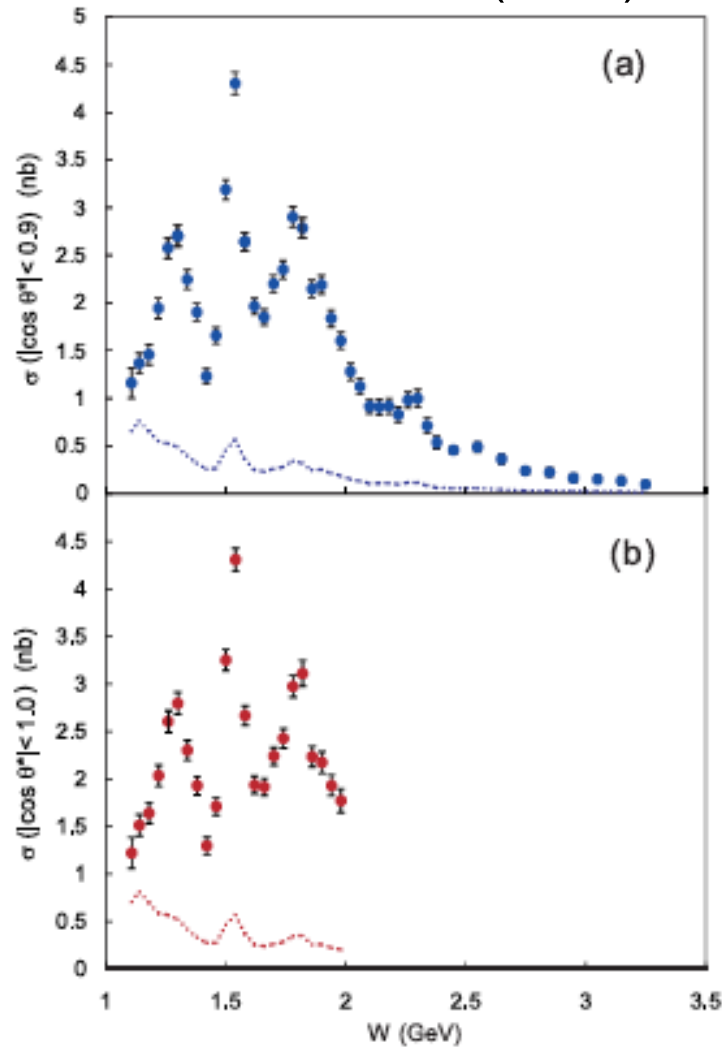
The  $\gamma$  escapes from acceptance along beam,  $M_{\text{miss}} \sim 0$ .



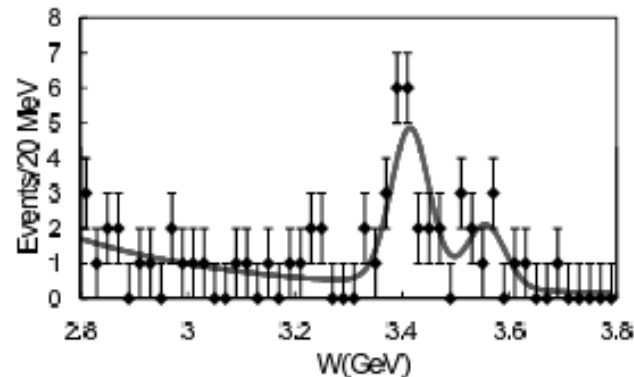
Peaks seen only at known  $\psi$ s.  
(PRD83,011101(R)(2011).

# $\gamma\gamma \rightarrow \eta\eta$

PRD82,114031(2010)



- Light exotic hadrons may appear in  $\eta\eta$  mass spectrum.
- $f_2(1270)$ ,  $f_2'(1525)$  clearly seen.
- From angular distribution, S- and D-wave contributions were extracted.
- $f_0(Y)$  at 1262 MeV,  $f_2(X)$  at 1737 MeV were gotten.
- $\chi_{c0}$  and  $\chi_{c2} \rightarrow \eta\eta$  seen.



# New Postdocs

- Kazuyuki Sakai (A01, KEK)
  - Tackle with  $B \rightarrow X_{cc} K$  total rate measurement.
- Vishal Bhardwaj (A01, Nara WU)
  - Did  $X(3872) \rightarrow J/\psi \gamma, \psi' \gamma$ .
- Chengping Shen (D01, Nagoya)
  - Did  $\gamma\gamma \rightarrow J/\psi \phi, \Upsilon(1S) \rightarrow \gamma$  charmonium search



# New Computer



- 2×Xeon(2.6GHz QuadCore)/Node
- 12 Nodes.
- 80TB RAID6+1
- 64TB RAID6+1 has been added.

- Belle data transfer still going on.  
(cf. all hadronic events ~80TB)
- Current bandwidth is 100Mbps.



SINET4 Nara DC to Osaka becomes  
2.4Gbps from 2011 April. Preparation  
to utilize it is also going on.



# New organization

- A01 and Nuclear Physics Consortium (NPC) members began to have a series of meetings to discuss, exchange ideas and encourage each other about Belle Physics analysis.

## “Belle New Hadron Meeting”

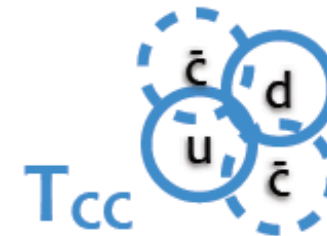
- As for NPC, listen Muramatsu-san's talk.
- So far 4 meetings have been held, chaired by M.Uchida(T.I.T.) and KM.

# Tcc search

by Oksu Seon (Nagoya)



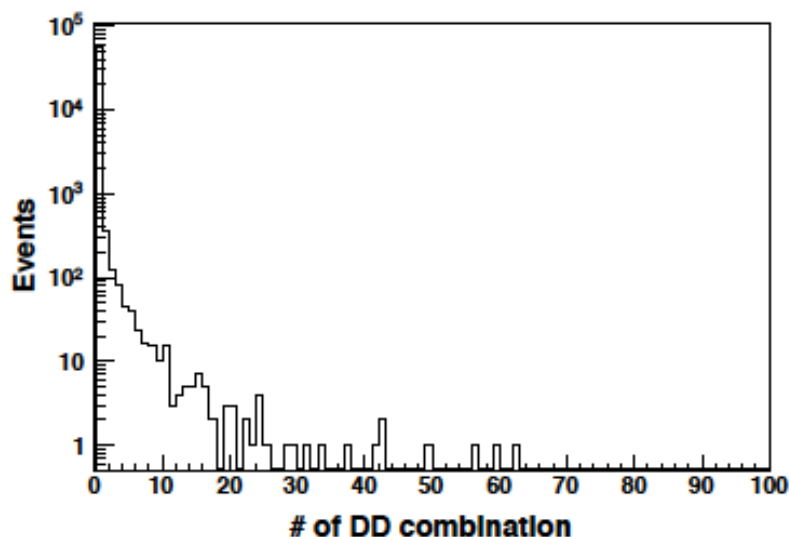
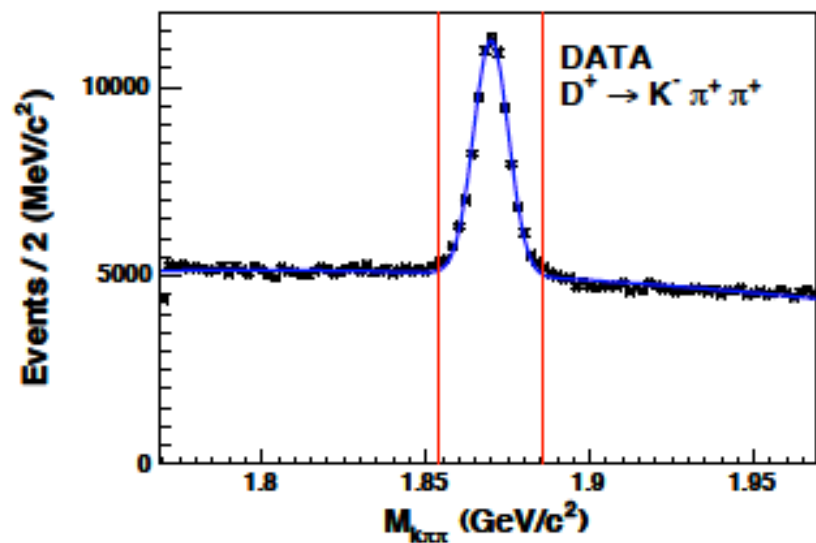
- Tetraquark : **explicit** exotic hadron ( $\bar{Q}\bar{Q}qq$ )  
 $q = u, d, s / Q = c, b$   
 (Not like “X Y Z” of  $Q\bar{Q}q\bar{q}$ )



- **$T_{cc}$  :  $ud\bar{c}\bar{c}$**
- Spin-color interaction :  $C_H \sum_{i>j} \vec{s}_i \cdot \vec{s}_j \frac{1}{m_i m_j}$
- Binding energy w.r.t. pseudoscalar(D) and vector meson ( $D^*$ ) final state :  $B_{T_{cc}} = m_{T_{cc}} - (m_D + m_{D^*}) \sim -79.3 \text{ MeV}$

**stable!**

# Now D and D\* are reconstructed



- Established way for reconstruction.
- Large number of same flavor DD<sup>(\*)</sup> combination, further selection to be considered.

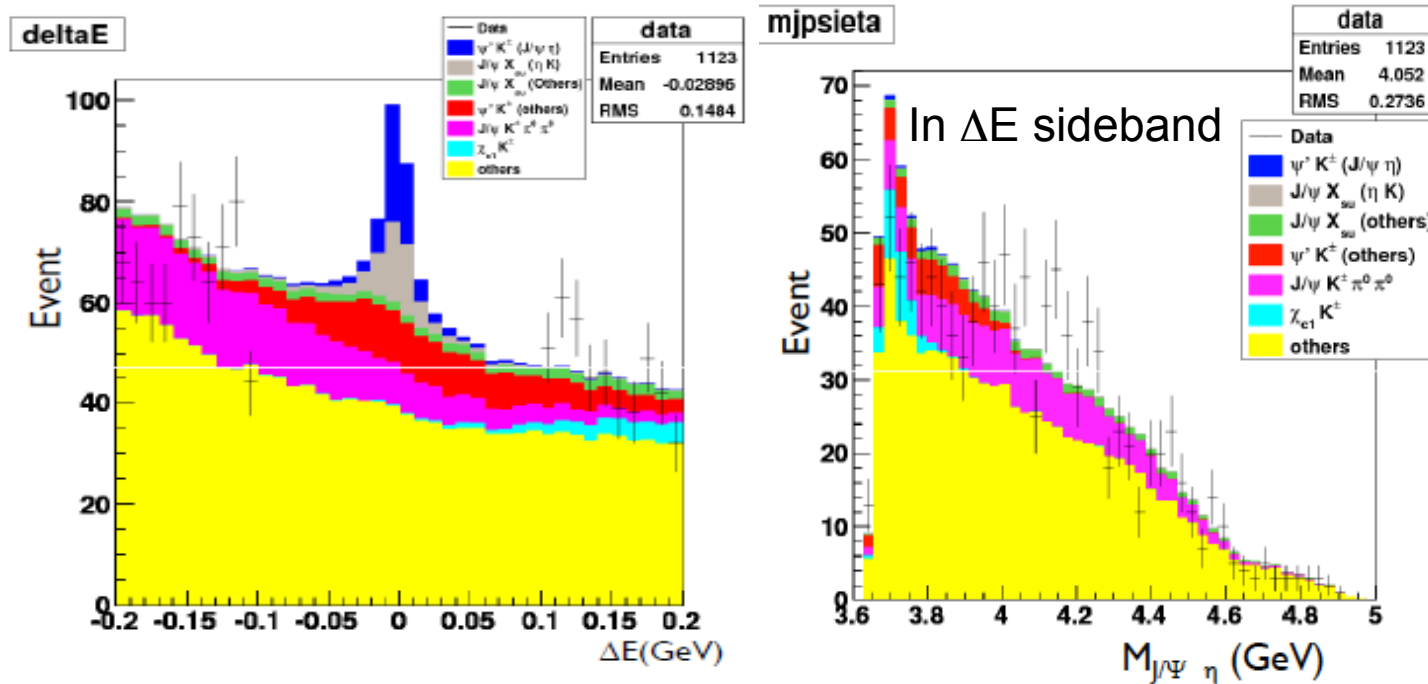
# $B^\pm \rightarrow J/\psi \eta K^\pm$

by Tomoko Iwashita  
(Nara WU)

Aiming to hunt  $c\bar{c}s\bar{s}$  tetraquark to  $J/\psi \eta$ .  
(cf. Karim Trabelsi is working on  $B \rightarrow J/\psi \phi K$ .)

$\eta$  is reconstructed by  $\gamma\gamma$ .

$\psi' \rightarrow J/\psi \pi^+ \pi^-$  and  $\chi_{c1(2)} \rightarrow J/\psi \gamma$  are vetoed for background reduction.



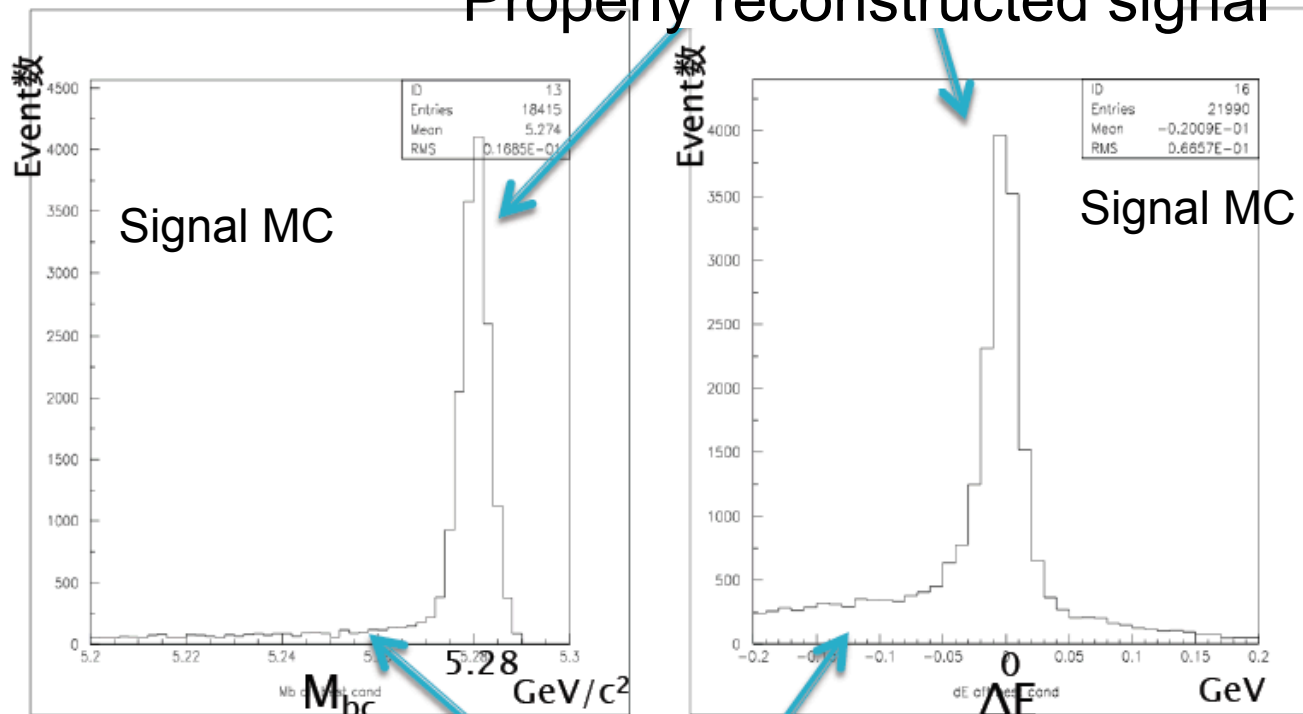
Sideband data have been checked, plan to open the box first to obtain br., then let's see  $M(J/\psi \eta)$  spectrum.

$$B^{\pm} \rightarrow \psi' \pi^0 K^{\pm}$$

by Miyuki Ishizuka  
(Nara WU)

Aiming to search for neutral partner of Z(4430).  
Reconstruction routine has been composed.

Properly reconstructed signal



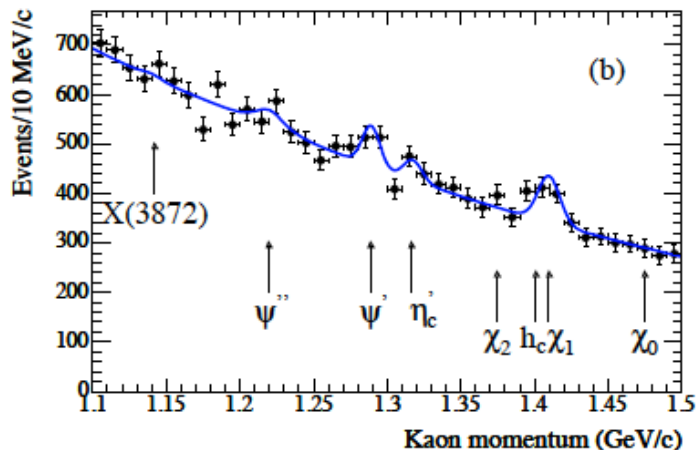
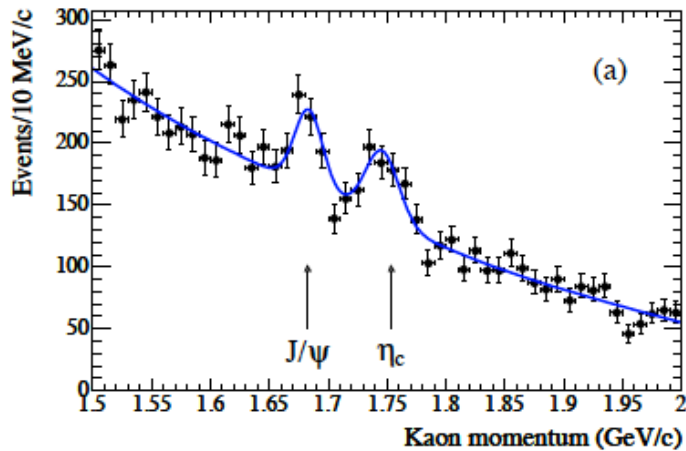
Next step would  
be background  
estimation

for  $-0.06 \text{ GeV} < \Delta E < +0.04 \text{ GeV}$

$5.27 < M_{bc} < 5.29 \text{ (GeV)}$

Need to think about suppression of wrong combination.

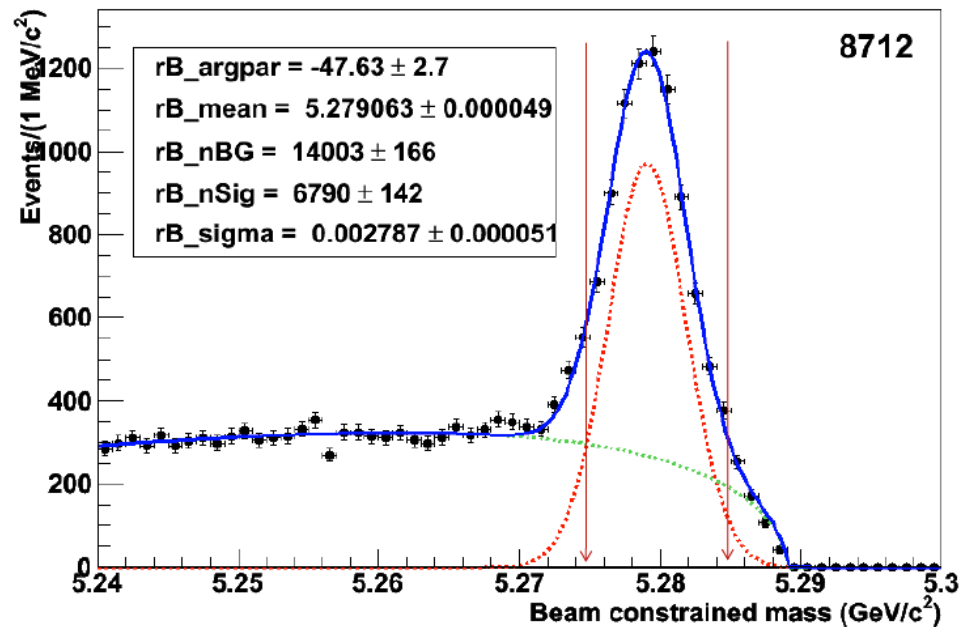
# $B \rightarrow X_{cc} K$ total rate by Kazuyuki Sakai (KEK)



cf. BaBar, PRL96,052002(2006)  
232M BB.

- Using fully reconstructed B meson sample, looking for peaks in Kaon momentum spectrum.
- Absolute branching fraction for  $B \rightarrow X_{cc} K$  is obtained by the event yield in the peak.
- $\text{Br}(B^\pm \rightarrow X(3872) K^\pm)$  is the most interesting quantity to be gotten.

# Now fully reconstructed B sample is carefully checked



- Charged K selection criteria and continuum suppression are now under optimization.

# Summary and prospect

- During 2010, Belle brought several highlights
  - $X(3872) \rightarrow J/\psi \gamma, \psi' \gamma$ .
  - $J/\psi \omega, J/\psi \phi$  in  $\gamma\gamma$  collisions.
  - $\Upsilon(1S) \rightarrow \gamma$  charmonium,  $D_s^{(*)+} D_s^{(*)-}$  in ISR,  $\gamma\gamma \rightarrow \eta\eta$ .
- New Postdocs, New Computer
- Enjoying collaborating efforts with NPC friends.
- Several new attempts started.
  - Tcc search,  $B \rightarrow J/\psi \eta K, \psi' \pi^0 K$ , total  $B \rightarrow X_{cc} K$  rate.
- And more will come!
  - $X(3872) \rightarrow \chi_{c1(2)} \gamma, \chi_{c1} \pi^0$ , etc. for example.