Exotic states from $\pi^+\pi^-/\pi^\pm/\eta$ + quarkonium and Belle II status

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Belle&Belle II Collaborations

北大高能物理系列，2017年12月1日

十分感谢李强老师的邀请！
十分感谢北大诸位老师多年的帮助！

Outline

- Some exotic states in hadronic transitions.
- Belle II experiment.
- Some important contributions during Belle II construction.
- Belle II at Fudan.

Exotic states in hadronic transitions

更多前沿信息，参考苑老师的报告

New knowledge of the XYZ states

(charmonium(-like) only)

苑长征

中国科学院高能物理研究所

北京大学，2017年10月26日

Quarkonium Spectroscopy

- The quarkonium spectrum is similar to atom spectrum.
- Below $D\bar{D}/B\bar{B}$ thresholds – Both charmonium and bottomonium are successful stories of QCD.
- The potential model.

Example potential from Barnes, Godfrey, Swanson:

$$V_0^{(c\bar{c})}(r) = -\frac{4}{3}\frac{\alpha_s}{r} + br + \frac{32\pi\alpha_s}{9m_c^2}\,\tilde{\delta}_\sigma(r)\vec{S}_c\cdot\vec{S}_{\bar{c}}$$

(Coulomb + Confinement + Contact)

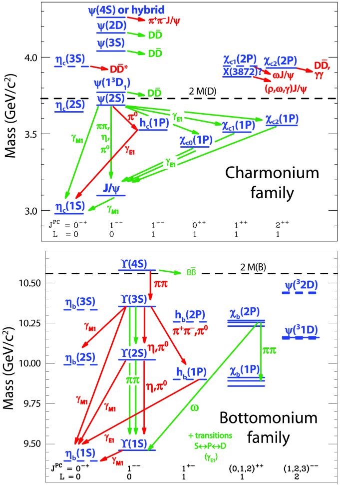
$$V_{\text{spin-dep}} = \frac{1}{m_c^2}\left[\left(\frac{2\alpha_s}{r^3} - \frac{b}{2r}\right)\vec{L}\cdot\vec{S} + \frac{4\alpha_s}{r^3}\mathrm{T}\right]$$

(Spin-Orbit + Tensor)

PRD72, 054026 (2005)

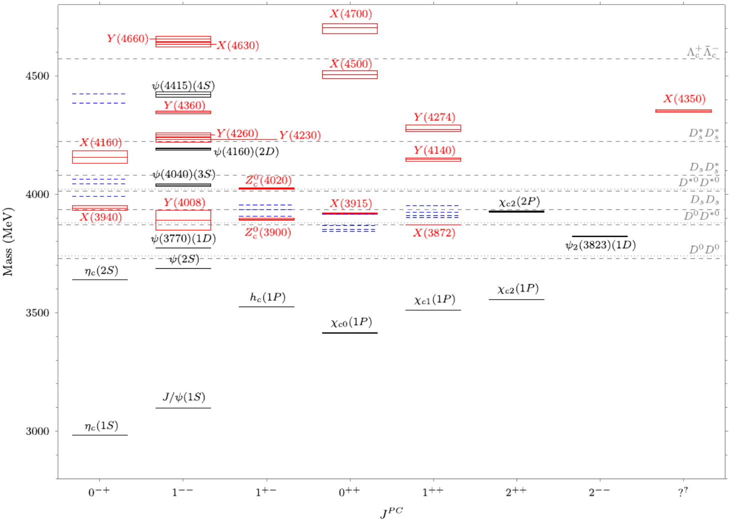
A. Esposito *et al.*, Int.J.Mod.Phys. A30, 1530002 (2014).

- The first two hadronic transitions: $\pi^+\pi^-$-transition and η-transition



Eichten *et al.*, Rev. Mod. Phys.80,1161(2008)

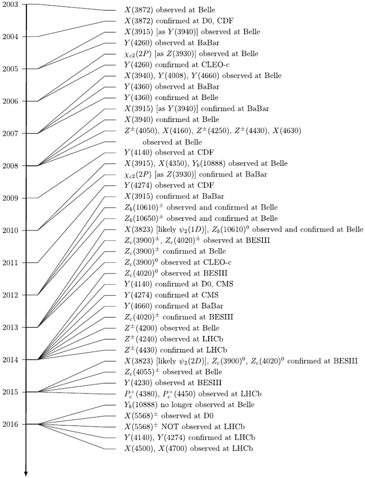
Particle “Zoo" about open-charm threshold



R. F. Lebed *et al.*, Prog. Part. Nucl. Phys 93, 143(2017)

Timeline of the discoveries

From Prog. Part. Nucl. Phys 93, 143(2017)



A lot of achievements!

So ...

It's hard to cover all the topics. Let's focus on those from hadronic transitions, especially from Belle.

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

HEAVY QUARKONIUM PHYSICS

Eur. Phys. J. C (2011) 71: 1534
DOI 10.1140/epjc/s10052-010-1534-9

THE EUROPEAN PHYSICAL JOURNAL C

Review

Heavy quarkonium: progress, puzzles, and opportunities

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QWG Yellow Report: 505 pages

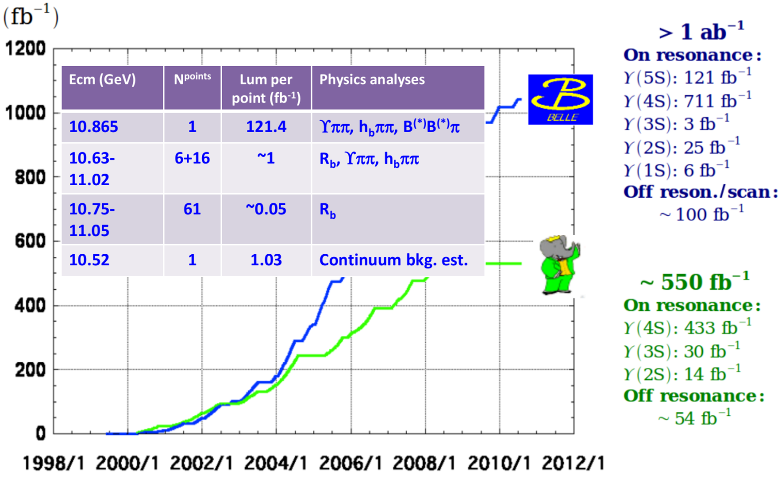
QWG Report, 2011: 178 pages

Mostly focus on Belle results.

KEKB and Belle

KEK, Tsukuba (near Tokyo), Japan

The data samples



Ecm (GeV)	N^{points}	Lum per point (fb^{-1})	Physics analyses
10.865	1	121.4	$\Upsilon\pi\pi$, $h_b\pi\pi$, $B^{(*)}B^{(*)}\pi$
10.63-11.02	6+16	~1	R_b, $\Upsilon\pi\pi$, $h_b\pi\pi$
10.75-11.05	61	~0.05	R_b
10.52	1	1.03	Continuum bkg. est.

Huge data samples for quarkonium(-like) state.

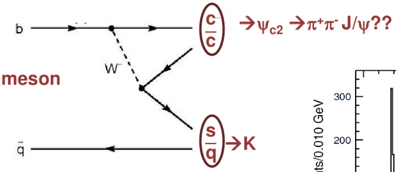
Outline

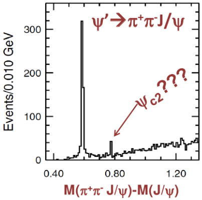
- $X(3872) \to \pi^+\pi^- J/\psi$
- $e^+e^- \to \pi^+\pi^- J/\psi$
- $e^+e^- \to \pi^+\pi^- \psi(2S)$
- η-transitions
- $\pi^+\pi^-$-transitions and η-transitions in $\Upsilon(4S, 5S)$

The start: $X(3872)$

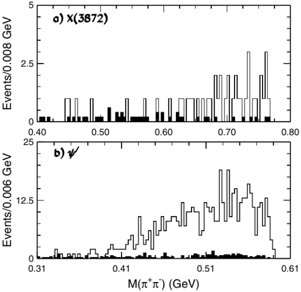
In the search for ψ_{c2} in $B \to K\psi_{c2} \to K\pi^+\pi^- J/\psi$. (Prof. Stephen Olsen's talk at a summer school.)

Eichten *et al.*, PRL98, 162002(200)





Belle PRL **91**, 262001 (2003)

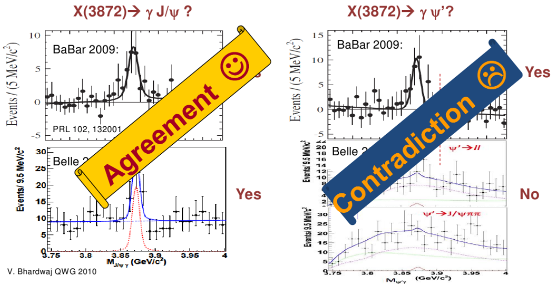


$M_X = 3872.0 \pm 0.6$ MeV$/c^2$ and $\Gamma_X < 2.3$ MeV$/c^2$.

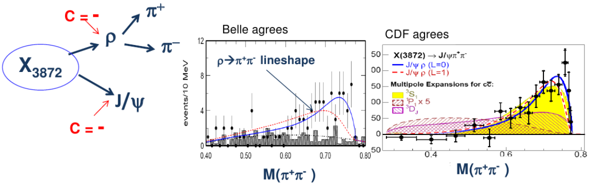
(ψ_{c2} : 1^3D_2 state, $J^{PC} = 2^{--}$)

$C(X(3872)) = +$

Not $X(3872) \to \gamma\chi_c$, but $X(3872) \to \gamma J/\psi$ decay found.



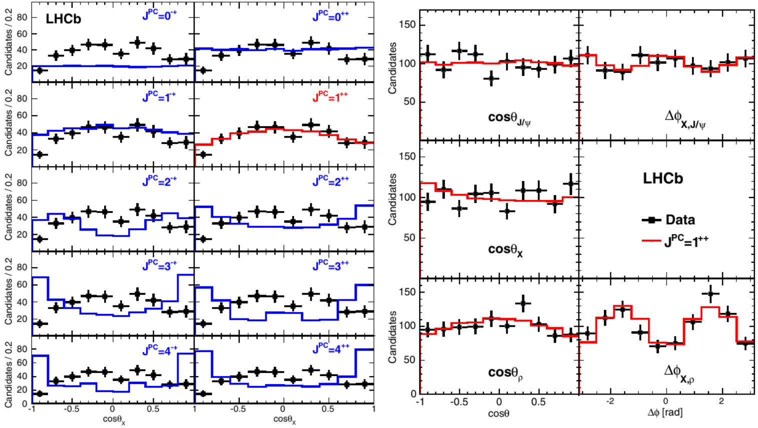
$C(X) = C(\gamma) \times C(J/\psi) = (-) \times (-) = +$, it must be not ψ_{c2}!



$J^{PC} = 1^{++}$ or 2^{-+} from angular analysis by CDF and Belle. (CDF: PRL98, 132002(2007); Belle: PRD84, 052004(2011))

LHCb determined J^{PC} of $X(3872)$

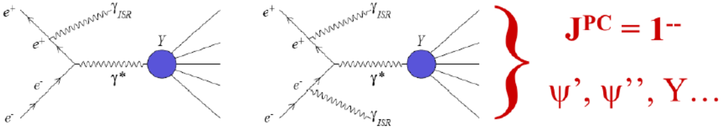
- Angular correlations in $B^+ \to X(3872)K^+$.
- $X(3872) \to \rho^0 J/\psi$, $\rho^0 \to \pi^+\pi^-$ and $J/\psi \to \mu^+\mu^-$.
- Measure orbital angular momentum contributions and determine the J^{PC}.



LHCb: PRD92, 011102(R)(2015)

$J^{PC} = 1^{++}$!!!

Initial State Radiation



- $J^{PC} = 1^{--}$ of the final states!

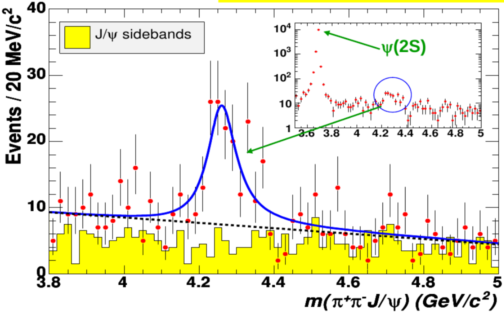
$e^+e^- \to \pi^+\pi^- J/\psi$: $Y(4260)$, $Y(4008)$, $Z_c(3900)^+$, $Y(4220)$ and $Y(4320)$

$Y(4260)$ from ISR

Once $\pi^+\pi^- J/\psi$ again, but in $e^+e^- \to \pi^+\pi^- J/\psi$ via Initial State Radiation (ISR). $Y(4260)$ found at BaBar: (2005).

PRL95, 142001 (2005)

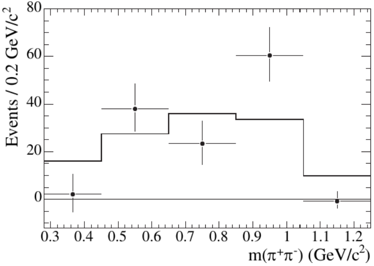
$\pi^+\pi^- J/\psi$ Mass



BaBar: 232 fb^{-1}

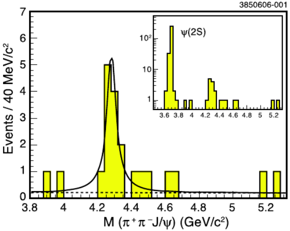
>8σ significance structure called $Y(4260)$

M(J/ψππ) of ψ(2S) with J/ψ constraint is well described by Cauchy shape funct.



Confirmed at CLEO

$Y(4260)$ was confirmed by CLEO at first.



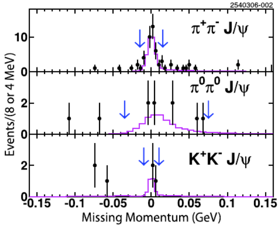


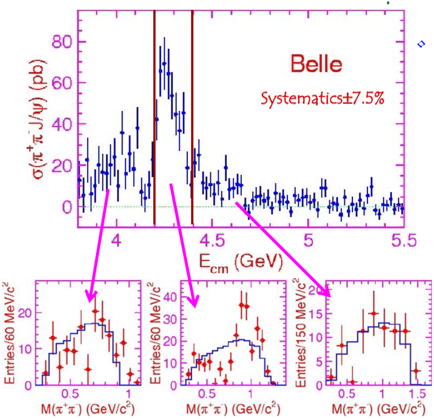
FIG. 2 (color online). The missing momentum (k) distribution for $\pi^+\pi^- J/\psi$ (top), $\pi^0\pi^0 J/\psi$ (middle), and $K^+K^- J/\psi$ (bottom) in the data at $\sqrt{s} = 4.26$ GeV (circles), and the signal shape as predicted by MC simulation (solid line histogram) scaled to the net signal size.

1. With data taken in $\Upsilon(1S-4S)$, via ISR:
Q. He *et al.* PRD74, 091104(R)(2006)

2. With data taken on $\sqrt{s} = 4.26$ GeV. Three decay modes: $\pi^+\pi^- J/\psi$, $\pi^0\pi^0 J/\psi$ and $K^+K^- J/\psi$.
T. E. Coan *et al.*, PRL96, 162003(2006)

$Y(4260)$ at Belle

With 550 fb^{-1} data, Belle got much better line shape of $Y(4260)$. It started from the background of $e^+e^- \to \gamma_{\mathrm{ISR}} + \pi^+\pi^-\pi^+\pi^-$. No $\psi(4040)$, $\psi(4160)$ or $\psi(4415)$ observed!

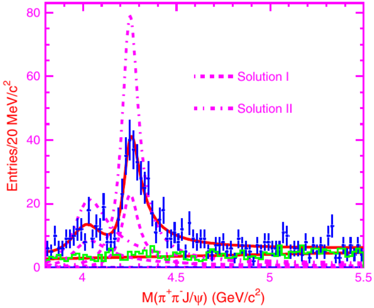


- $M_{\pi\pi}$ spectra in different $\sqrt{s}$ regions:
  - $\sqrt{s}$ = 3.8 −4.2 & 4.4−4.6 GeV in agreement with 3−body phase space.
  - Y(4260) region $\sqrt{s}$ = 4.2 −4.4 GeV: two clusters at low and high masses. Cluster around 1 GeV. (scalars?).

- Asymmetry shape of $Y(4260)$.
- Strange $M_{\pi^+\pi^-}$ distribution from $Y(4260)$ decays.

Looks not only one component of $Y(4260)$ signal.
C. Z. Yuan *et al.*, PRL99,182004(2007)

Fit for $Y(4260)$ at Belle

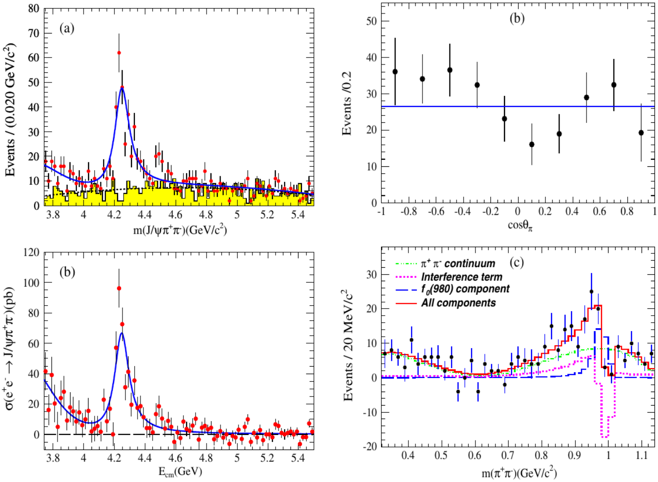


Parameters	Solution I	Solution II
$M(R1)$	$4008 \pm 40^{+114}_{-28}$	
$\Gamma_{\rm tot}(R1)$	$226 \pm 44 \pm 87$	
$\mathcal{B}\Gamma_{e^+e^-}(R1)$	$5.0 \pm 1.4^{+6.1}_{-0.9}$	$12.4 \pm 2.4^{+14.8}_{-1.1}$
$M(R2)$	$4247 \pm 12^{+17}_{-32}$	
$\Gamma_{\rm tot}(R2)$	$108 \pm 19 \pm 10$	
$\mathcal{B}\Gamma_{e^+e^-}(R2)$	$6.0 \pm 1.2^{+4.7}_{-0.5}$	$20.6 \pm 2.3^{+9.1}_{-1.7}$
ϕ	$12 \pm 29^{+7}_{-98}$	$-111 \pm 7^{+28}_{-31}$

Fit with two BWs can describe the lineshape of $Y(4260)$ well.

Update on $e^+e^- \to \pi^+\pi^- J/\psi$ from BaBar

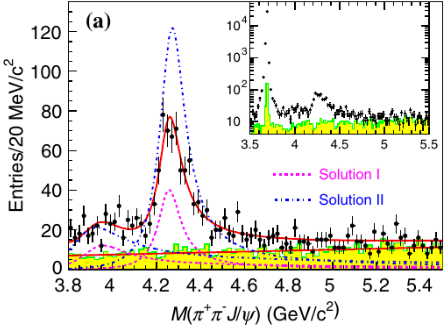
BaBar updated the measurement with 454 fb^{-1} full data sample. BaBar: PRD86, 051102(R)(2012)



- Enhancement at 4.01 GeV$/c^2$ not confirmed.
- Fit with $f_0(980)$ to describe the $M_{\pi^+\pi^-}$ distribution for $Y(4260)$ decays.
  - $\pi^+\pi^-$ system is in a predominantly S-wave state.
  - $f_0(980)$ branching ratio: $0.17 \pm 0.13(stat.)$

Update on $e^+e^- \to \pi^+\pi^- J/\psi$ at Belle

With 980 fb^{-1} full Belle data sample.



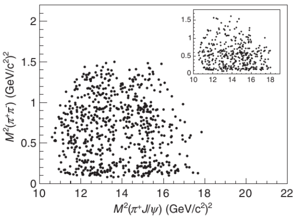
Parameters	Solution I	Solution II
$M(R_1)$	$3890.8 \pm 40.5 \pm 11.5$	
$\Gamma_{\rm tot}(R_1)$	$254.5 \pm 39.5 \pm 13.6$	
$\Gamma_{ee}\mathcal{B}(R_1 \to \pi^+\pi^- J/\psi)$	$(3.8 \pm 0.6 \pm 0.4)$	$(8.4 \pm 1.2 \pm 1.1)$
$M(R_2)$	$4258.6 \pm 8.3 \pm 12.1$	
$\Gamma_{\rm tot}(R_2)$	$134.1 \pm 16.4 \pm 5.5$	
$\Gamma_{ee}\mathcal{B}(R_2 \to \pi^+\pi^- J/\psi)$	$(6.4 \pm 0.8 \pm 0.6)$	$(20.5 \pm 1.4 \pm 2.0)$
ϕ	$59 \pm 17 \pm 11$	$-116 \pm 6 \pm 11$

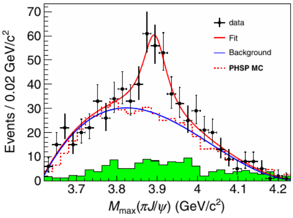
- $N_{\rm sig}^{\rm obs}$ doubled.
- Still asymmetry shape of $Y(4260)$.
- Notice the bin near 4.3 GeV$/c^2$.

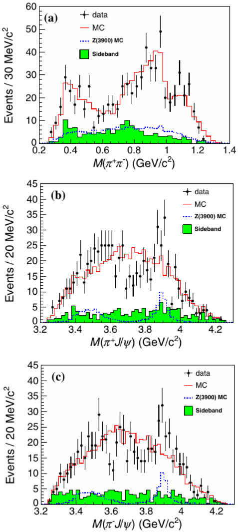
Z. Q. Liu et al, Belle: PRL110,252002(2013)

$Zc(3900)^+$ **from Belle**

Intermediate state searched for.

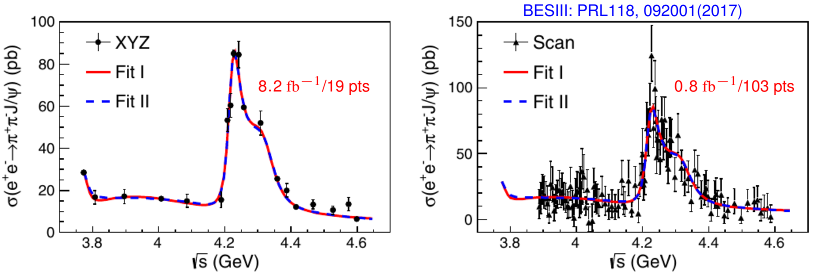






- $M_{\pi^+\pi^-}$: $f_0(980)$, $f_0(500)$ and nonresonant S-wave amplitudes.
- S-wave amplitude can not reproduce the structure at 3.9 GeV$/c^2$. $\rightarrow Z_c(3900)$

Energy scan on $Y(4260)$ at BESIII



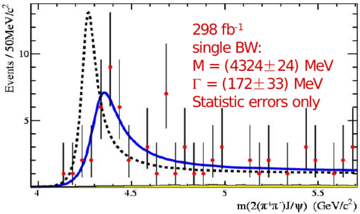
Parameters	Fit result
$M(R_1)$	$3812.6^{+61.9}_{-96.6}$ $(\cdots)$
$\Gamma_{tot}(R_1)$	$476.9^{+78.4}_{-64.8}$ $(\cdots)$
$M(R_2)$	4222.0 ± 3.1 (4220.9 ± 2.9)
$\Gamma_{tot}(R_2)$	44.1 ± 4.3 (44.1 ± 3.8)
$M(R_3)$	4320.0 ± 10.4 (4326.8 ± 10.0)
$\Gamma_{tot}(R_3)$	$101.4^{+25.3}_{-19.7}$ $(98.2^{+25.4}_{-19.6})$

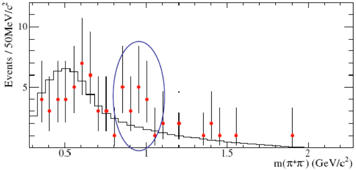
- Two structures: $Y(4220)$ and $Y(4320)$ (7.6σ)

$e^+e^- \to \pi^+\pi^-\psi(2S)$: $Y(4360)$, $Y(4660)$, $Z(4050)^+$

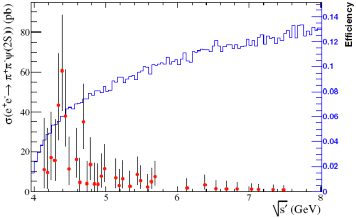
$\pi^+\pi^-\psi(2S)$ scan at BaBar

BaBar searched for $Y(4260)$ in $\pi^+\pi^-\psi(2S)$ final states later.



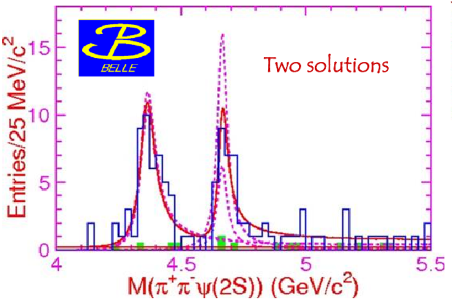


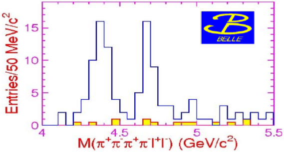
Significant enhancement but with a mass inconsistent with Y(4260).

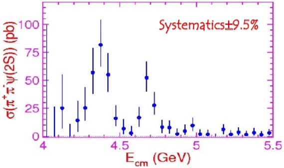


BaBar: B. Aubert *et al.*, PRL98, 212001(2007).

$\pi^+\pi^-\psi(2S)$ at Belle







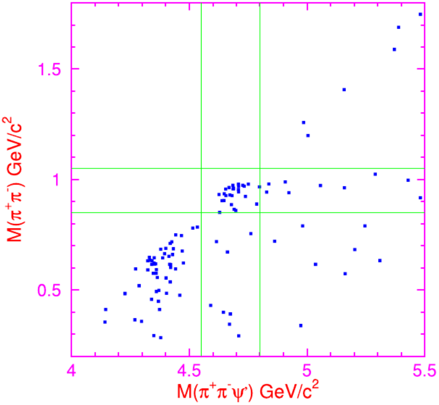
Parameters	Solution one	Solution two
$M(Y(4360))$	$4361 \pm 9 \pm 9$	
$\Gamma_{\rm tot}(Y(4360))$	$74 \pm 15 \pm 10$	
$\mathcal{B} \cdot \Gamma_{e^+e^-}(Y(4360))$	$10.4 \pm 1.7 \pm 1.5$	$11.8 \pm 1.8 \pm 1.4$
$M(Y(4660))$	$4664 \pm 11 \pm 5$	
$\Gamma_{\rm tot}(Y(4660))$	$48 \pm 15 \pm 3$	
$\mathcal{B} \cdot \Gamma_{e^+e^-}(Y(4660))$	$3.0 \pm 0.9 \pm 0.3$	$7.6 \pm 1.8 \pm 0.8$
ϕ	$39 \pm 30 \pm 22$	$-79 \pm 17 \pm 20$

- $e^+e^- \rightarrow \pi^+\pi^-\psi(2S)$ via ISR, with $\psi(2S)\pi^+\pi^- J/\psi$ and $J/\psi \rightarrow e^+e^-/\mu^+\mu^-$
- Backgrounds quite clean!
- $Y(4360)$ - confirmed for the first time with much better resonance parameters.
- $Y(4660)$ - A 5.8σ narrow state discovered.

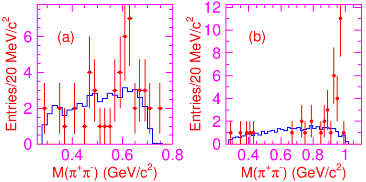
Two solutions: constructive and destructive interference.

Belle: X. L. Wang *et al.*, PRL99,142002(2007)

$Y(4360)$ and $Y(4660)$



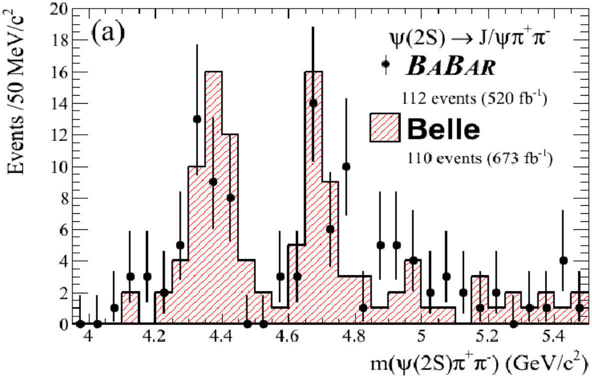
The scatter plot of $M_{\pi^+\pi^-\psi(2S)}$ vs. $M_{\pi^+\pi^-}$

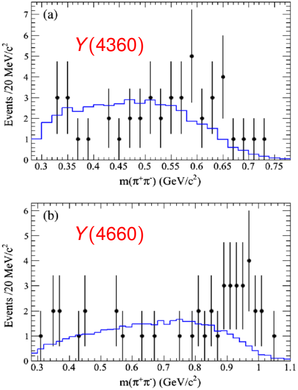


- Blue histograms: MC simulation based on phase space mode.
- $Y(4360)$: $M_{\pi^+\pi^-}$ tends to be large, different from phase space.
- $Y(4660)$: like a $f_0(980)$ signal dominates in $\pi^+\pi^-$ system. Somebody considered $Y(4660)$ to be a $f_0(980)\psi(2S)$ molecular state.

BaBar updates on ISR

BaBar 520 fb^{-1}
PRD89,111103(R)(2014)



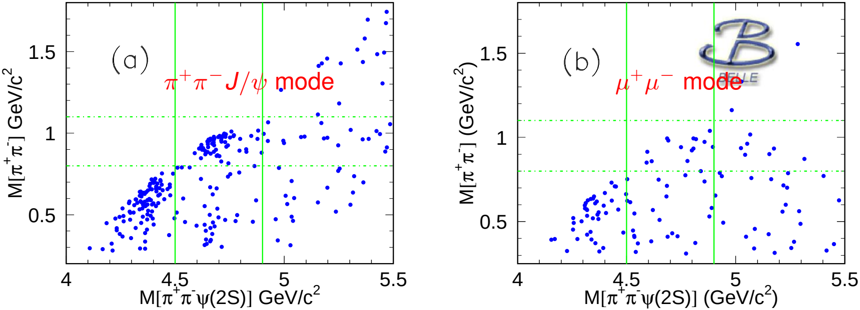


- $\psi(2S) \to \pi^+\pi^- J/\psi$ with $J/\psi \to e^+e^-/\mu^+\mu^-$, or $\psi(2S) \to \mu^+\mu^-$
- $Y(4660)$ confirmed.
- $M_{\pi^+\pi^-}$ for $Y(4660)$ in the vicinity of $f_0(980)$.

$e^+e^- \to \pi^+\pi^-\psi(2S)$ update at Belle

- Two modes used in reconstructing $\psi(2S)$ signals: $\psi(2S) \to \pi^+\pi^- J/\psi$, $\psi(2S) \to \mu^+\mu^-$
- Selection criteria improved comparing to previous measurement.

980 fb^{-1}



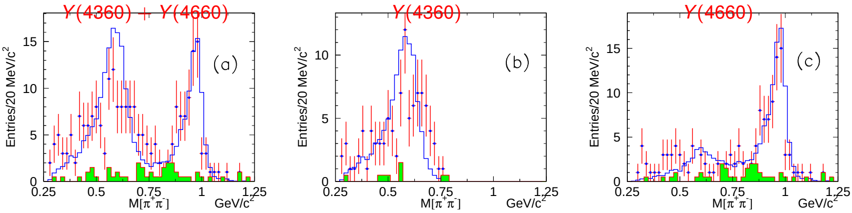
- **Purity:** 245 candidate events with a purity of 96% from $\pi^+\pi^- J/\psi$ mode, and 118 events with a purity of 60% from $\mu^+\mu^-$ mode.
- $M_{\pi^+\pi^-}$**:** tends to the phase space boundary; $f_0(980)$ belts.

PRD91, 112007(2015)

$M_{\pi^+\pi^-}$ projections in $\pi^+\pi^- J/\psi$

It's not so clean in $\mu^+\mu^-$ mode, due to the width of sidebands:

Mass resolution: $\sigma_{\pi^+\pi^- J/\psi} = 2.7 \pm 0.2$ MeV$/c^2$, $\sigma_{\mu^+\mu^-} = 13.8 \pm 2.1$ MeV$/c^2$.

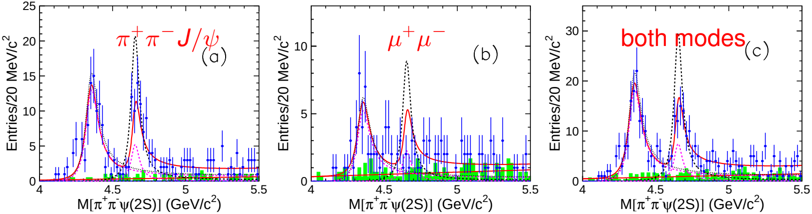


- Dots: data; Blank hist: MC simulations; Shaded hist: bkg from $\psi(2S)$ sidebands.
- **(a)** with $4.0 < M_{\pi^+\pi^-\psi(2S)} < 5.5$ GeV$/c^2$.
- $Y(4360)$**:** $4.0 < M_{\pi^+\pi^-\psi(2S)} < 4.5$ GeV$/c^2$, looks like $f_0(500)$
- $Y(4660)$**:** $4.5 < M_{\pi^+\pi^-\psi(2S)} < 4.9$ GeV$/c^2$, could only be $f_0(980)$.

MC simulation with an incoherent sum of the $f_0(500)$ and $f_0(980)$.

Fit of $M_{\pi^+\pi^-\psi(2S)}$ spectrum with two resonances

Unbinned simultaneous maximum likelihood fit for $Y(4360)$ and $Y(4660)$: $Amp = BW_1 + e^{i\phi} \cdot BW_2$.

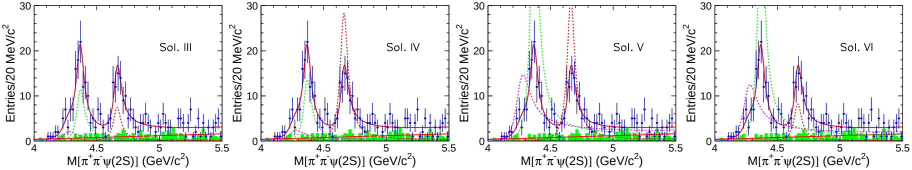


Parameters	Solution I	Solution II
$M_{Y(4360)}$ (MeV$/c^2$)	$4347 \pm 6 \pm 3$	
$\Gamma_{Y(4360)}$ (MeV)	$103 \pm 9 \pm 5$	
$\mathcal{B} \cdot \Gamma^{e^+e^-}_{Y(4360)}$ (eV)	$9.2 \pm 0.6 \pm 0.6$	$10.9 \pm 0.6 \pm 0.7$
$M_{Y(4660)}$ (MeV$/c^2$)	$4652 \pm 10 \pm 11$	
$\Gamma_{Y(4660)}$ (MeV)	$68 \pm 11 \pm 5$	
$\mathcal{B} \cdot \Gamma^{e^+e^-}_{Y(4660)}$ (eV)	$2.0 \pm 0.3 \pm 0.2$	$8.1 \pm 1.1 \pm 1.0$
ϕ ($^\circ$)	$32 \pm 18 \pm 20$	$272 \pm 8 \pm 7$

$\chi^2/ndf = 18.7/21$.

- Consistent with previous measurement
- No obvious signal above $Y(4660)$.
- 12 events accumulate at $Y(4260)$, especially the $\pi^+\pi^- J/\psi$ mode.
- If $Y(4260)$ is included in the fit, ...

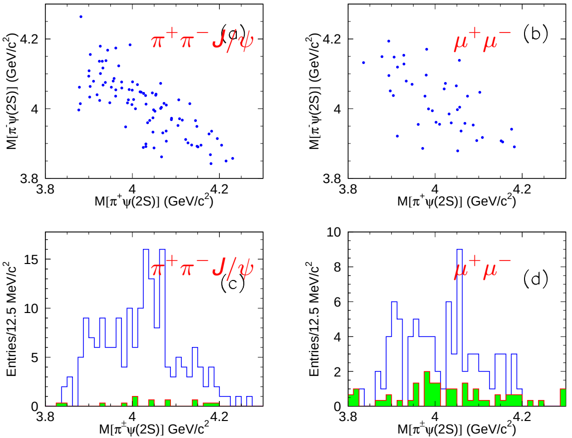
Fit of $M_{\pi^+\pi^-\psi(2S)}$ spectrum with three resonances



	Sol. III	Sol. IV	Sol. V	Sol. VI
$\mathcal{B}\cdot\Gamma^{e^+e^-}_{Y(4260)}$ (eV)	$1.5\pm0.6\pm0.4$	$1.7\pm0.7\pm0.5$	$10.4\pm1.3\pm0.8$	$8.9\pm1.2\pm0.8$
$M_{Y(4360)}$ (MeV$/c^2$)	$4365\pm7\pm4$			
$\Gamma_{Y(4360)}$ (MeV)	$74\pm14\pm4$			
$\mathcal{B}\cdot\Gamma^{e^+e^-}_{Y(4360)}$ (eV)	$4.1\pm1.0\pm0.6$	$4.9\pm1.3\pm0.6$	$21.1\pm3.5\pm1.4$	$17.7\pm2.6\pm1.5$
$M_{Y(4660)}$ (MeV$/c^2$)	$4660\pm9\pm12$			
$\Gamma_{Y(4660)}$ (MeV)	$74\pm12\pm4$			
$\mathcal{B}\cdot\Gamma^{e^+e^-}_{Y(4660)}$ (eV)	$2.2\pm0.4\pm0.2$	$8.4\pm0.9\pm0.9$	$9.3\pm1.2\pm1.0$	$2.4\pm0.5\pm0.3$
ϕ_1 ($^\circ$)	$304\pm24\pm21$	$294\pm25\pm23$	$130\pm4\pm2$	$141\pm5\pm4$
ϕ_2 ($^\circ$)	$26\pm19\pm10$	$238\pm14\pm21$	$329\pm8\pm5$	$117\pm23\pm25$

- Significance of $Y(4260)$ is 2.4σ—low, but affects the parameters of $Y(4360)$ and $Y(4660)$!
- FOUR solutions with equally good fit quality, which is $\chi^2/ndf = 14.8/19$.
- Mathematical solutions with n Y states: 2^{n-1}

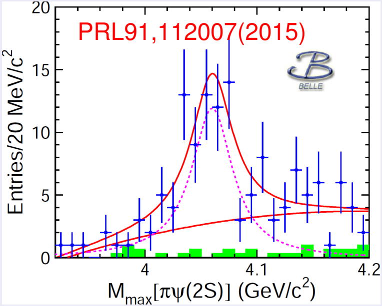
Search for intermediate states in $Y(4360)$ decays



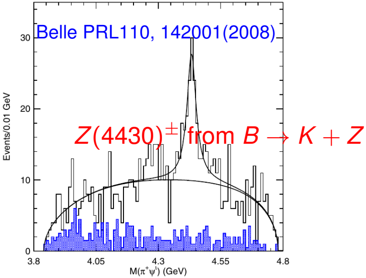
- $M_{\pi^\pm \psi(2S)}$: sum of the $M_{\pi^+\psi(2S)}$ and $M_{\pi^-\psi(2S)}$
- An excess at both $\pi^+\pi^- J/\psi$ and $\mu^+\mu^-$ modes, and both $M_{\pi^+\psi(2S)}$ and $M_{\pi^-\psi(2S)}$!
- A new Z_c at 4.05 GeV$/c^2$?
- No excess found at previous measurement of Belle, because only 110 signal events observed then.

$Y(4360) \to \pi + Z_c(4050)$

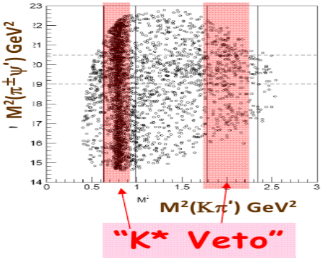
$Z_c(4050)^{\pm} \to \pi^{\pm}\psi(2S)$ in Y(4360) decays



- $Y(4360)$ signal region
- $M = (4054 \pm 3 \pm 1)$ MeV$/c^2$
- $\Gamma = (45 \pm 11 \pm 6)$ MeV
- About 45 signal events.
- Significance: $> 3.5\sigma$

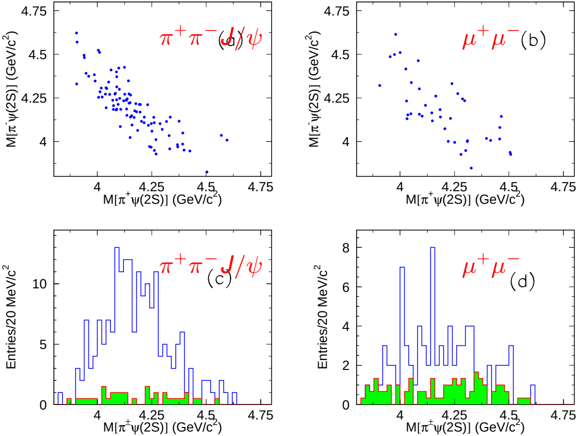


- $M = 4433 \pm 4 \pm 2$ MeV$/c^2$
- $\Gamma = \sim 45$MeV



Search for intermediate states in $Y(4660)$ decays

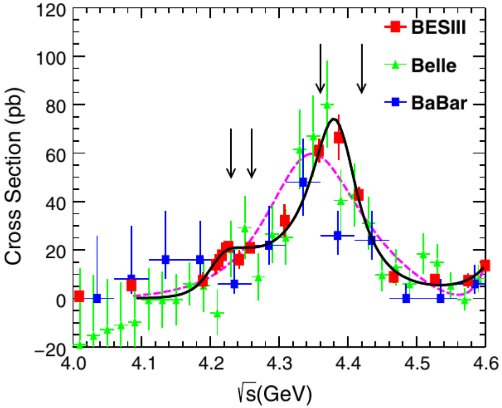
No obvious excess found in $Y(4660)$ decays.



- $f_0(980)\psi(2S)$ dominates in $Y(4660)$ decays.
- However, looks no-$f_0(980)$ component exists.
- Relationship between Z_c and $Y(4660)$ would be interesting at BelleII.

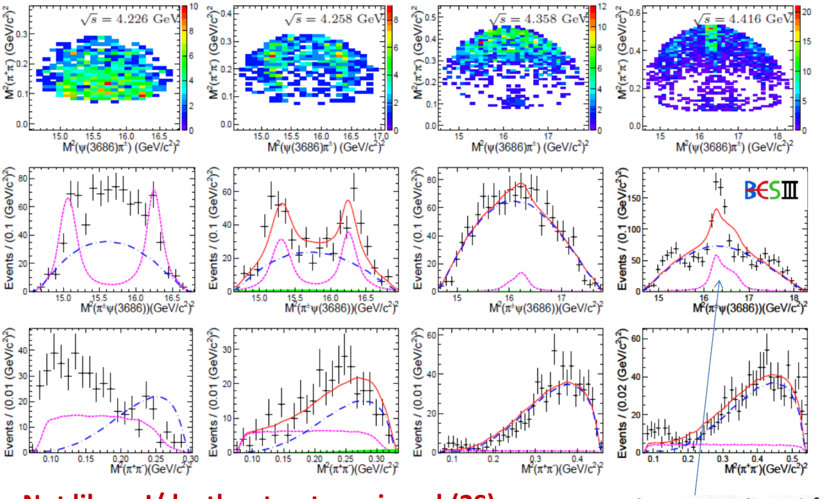
Measurement from BESIII

- BESIII: 16 energy points, $L_{tot} = 5.1\ \mathrm{fb}^{-1}$
- $\psi(2S)$ reconstructed modes:
  - Mode I: $\psi(2S) \to \pi^+\pi^- J/\psi, J/\psi \to e^+e^-/\mu^+\mu^-$
  - Mode II: $\psi(2S) \to neutrals + J/\psi$, $neutrals = (\pi^0\pi^0, \pi^0, \eta\ \&\ \gamma\gamma)$, $J/\psi \to e^+e^-/\mu^+\mu^-$
- Fit with $Y(4360) + Y(4220)$, the significance of $Y(4220)$ is 5.8σ.



BESIII: PRD96, 032004 (2017)

Search for $Z_c \to \pi\psi(2S)$ at BESIII



Not like π J/ψ, the structures in π ψ(2S) vs. Ecm are much more complicated !

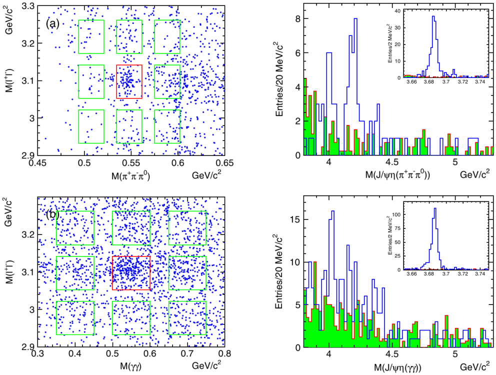
- M = (4032.1 ± 2.4) MeV/c²
- Γ = (26.1 ± 5.3) MeV

BESIII: PRD96, 032004 (2017)

η-transitions: $\psi(4040)$, $\psi(4160)$, Υ's

$\eta J/\psi$ via ISR

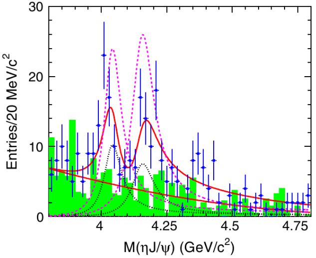
- Via emitting η should have large partial width of hadronic transition of charmonium.
- Belle searches for $e^+e^- \to \eta J/\psi$ via ISR for the first time.
- $\eta \to \gamma\gamma/\pi^+\pi^-\pi^0$, and $J/\psi \to e^+e^-$ or $\mu^+\mu^-$ in the reconstructions.



- $\sigma(\psi(2S)) = 13.9 \pm 1.4$ pb in $\eta \to \pi^+\pi^-\pi^0$ mode; $\sigma(\psi(2S)) = 14.0 \pm 0.8$ pb in $\eta \to \gamma\gamma$ mode. The expectation: $\sigma(\psi(2S)) = 14.7$ pb.
- Clear $\psi(4040)$ and $\psi(4160)$, but no Y state found! Really Y???

Belle: Wang *et al.*, PRD87, 051101(R)(2013).

$\eta J/\psi$ via ISR

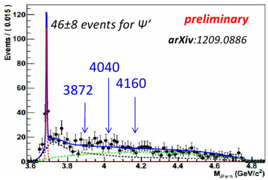


- This is the first time to found ψ states in charmonium transition!
  $> 6.0\sigma$ for $\psi(4040)$; $> 6.5\sigma$ for $\psi(4160)$.
- Large $\mathcal{B}(\psi \to \eta J/\psi)$!
  $\mathcal{B}(\psi(2S) \to \eta J/\psi) = (3.28 \pm 0.07)\%$
- Unlike $\pi^+\pi^-$ transition, no significant Y signal!!!
- Fit with parameters of $\psi(4040)$ and $\psi(4160)$ free, first time in an exclusive channel:
  - $\psi(4040)$: $M = 4012 \pm 5$ MeV$/c^2$, $\Gamma = 54 \pm 13$ MeV.
  - $\psi(4160)$: $M = 4157 \pm 10$ MeV$/c^2$, $\Gamma = 84 \pm 20$ MeV.

Parameters	Solution I	Solution II
$M_{\psi(4040)}$	4039 (fixed)	
$\Gamma_{\psi(4040)}$	80 (fixed)	
$\mathcal{B}\cdot\Gamma^{\psi(4040)}_{e^+e^-}$	$4.8 \pm 0.9 \pm 1.5$	$11.2 \pm 1.3 \pm 2.1$
$M_{\psi(4160)}$	4153 (fixed)	
$\Gamma_{\psi(4160)}$	103 (fixed)	
$\mathcal{B}\cdot\Gamma^{\psi(4160)}_{e^+e^-}$	$4.0 \pm 0.8 \pm 1.4$	$13.8 \pm 1.3 \pm 2.1$
ϕ	$336 \pm 12 \pm 14$	$251 \pm 4 \pm 7$

$\Gamma_{e^+e^-}(\psi(4040)) = (0.86 \pm 0.07)$ keV from PDG $\to$ $\mathcal{B}(\psi(4040) \to \eta J/\psi) = (0.56 \pm 0.10 \pm 0.18)\%$ or $(1.30 \pm 0.15 \pm 0.26)\%$.
$\Gamma_{e^+e^-}(\psi(4160)) = (0.83 \pm 0.07)$ keV from PDG $\to$ $\mathcal{B}(\psi(4160) \to \eta J/\psi) = (0.48 \pm 0.10 \pm 0.17)\%$ or $(1.66 \pm 0.16 \pm 0.29)\%$.
The $\Gamma(\psi \to \eta J/\psi)$ is about 1 MeV.

$B^+ \to J/\Psi\eta K^+$



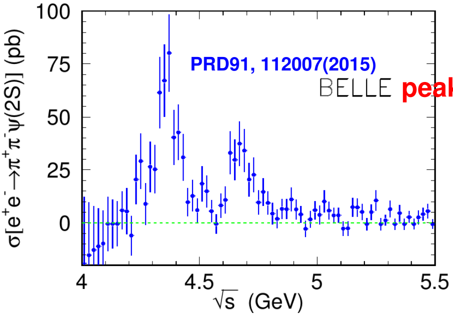
Meanwhile, no $\psi(4040)$ or $\psi(4160)$ in $\eta J/\psi$ seen in $B \to K + \eta J/\psi$.

Cross sections of $e^+e^- \to \pi^+\pi^-\psi(2S)$, $\pi^+\pi^-J/\psi$ and $\eta J/\psi$

$e^+e^- \to$ *final states* cross section is calculated with

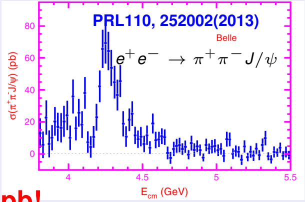
$$\sigma_i = \frac{n_i^{\rm obs} - n_i^{\rm bkg}}{\mathcal{L}_i \sum_{j=1}^{2} \varepsilon_{ij}\mathcal{B}_j},$$

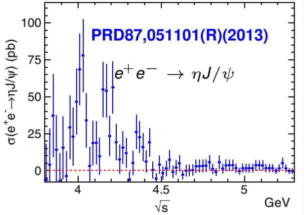
where i indicates the mass bin and j indicates the $\psi(2S)$ decay mode.



peaks $\sim$ 75 pb!

Other cross sections from ISR:



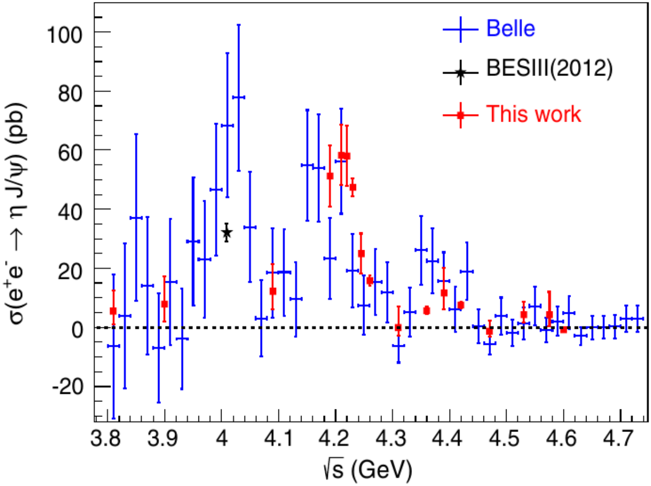


The $\sigma(e^+e^- \to \pi^+\pi^-J/\psi)$ at $Y(4260)$, $\sigma(e^+e^- \to \pi^+\pi^-\psi(2S))$ at $Y(4360)$ and $\sigma(e^+e^- \to \eta J/\psi)$ at $\psi(4040)$ are almost the same!!! WHY?

$\to$ Need Belle II data, or more BESIII data.

$e^+e^- \to \eta J/\psi$ at BESIII

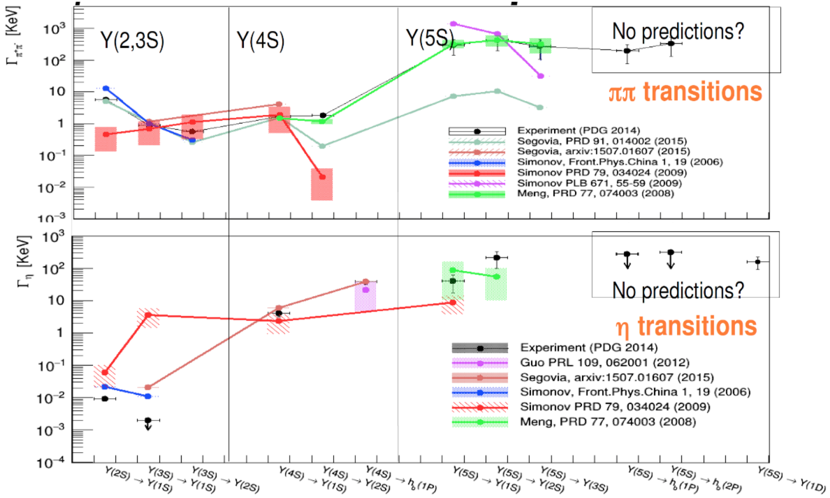
BESIII: PRD91, 112005(2015)



- Confirm Belle's measurement.
- No Y, but ψ!
- Need to measure the resonant parameters of $\psi(4040)$ and $\psi(4160)$ in the future.

η and $\pi^+\pi^-$ transitions from bottomonium(-like) states.

The η vs $\pi^+\pi^-$ transitions from $\Upsilon(nS)$: theory vs exp



More hadronic transitions

The partial width in units of keV:

Limited by available channels

$\Upsilon(4S) \to$	
$\Upsilon(1S)\pi^+\pi^-$	1.7 ± 0.2
$\Upsilon(1S)\eta$	4.0 ± 0.8
$\Upsilon(2S)\pi^+\pi^-$	1.8 ± 0.3
$h_b(1P)$	45 ± 7

$\mathcal{B}(\Upsilon(4S) \to \eta\Upsilon(1S)) > \mathcal{B}(\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S))$!!!

Limited by available statistics

$\Upsilon(6S) \to$	
$\Upsilon(1S)\pi^+\pi^-$	137 ± 32
$\Upsilon(2S)\pi^+\pi^-$	183 ± 43
$\Upsilon(3S)\pi^+\pi^-$	77 ± 28
$Z_b(10610, 10650)^\pm\pi^\mp$	$1300 - 6600$

$\Upsilon(5S)$ transitions

$\Upsilon(5S) \to$	
$\Upsilon(1S)\pi^+\pi^-$	238 ± 41
$\Upsilon(1S)\eta$	39 ± 11
$\Upsilon(1S)K^+K^-$	33 ± 11
$\Upsilon(2S)\pi^+\pi^-$	428 ± 83
$\Upsilon(2S)\eta$	204 ± 44
$\Upsilon(3S)\pi^+\pi^-$	153 ± 31
$\chi_{b1}(1P)\omega$	84 ± 20
$\chi_{b1}(1P)(\pi^+\pi^-\pi^0)_{\mathrm{non}-\omega}$	28 ± 11
$\chi_{b2}(1P)\omega$	32 ± 15
$\chi_{b2}(1P)(\pi^+\pi^-\pi^0)_{\mathrm{non}-\omega}$	33 ± 20
$\Upsilon_J(1D)\pi^+\pi^-$	~ 60
$\Upsilon_J(1D)\eta$	150 ± 48
$Z_b(10610)^\pm\pi^\mp$	2070 ± 440
$Z_b(10650)^\pm\pi^\mp$	1200 ± 300

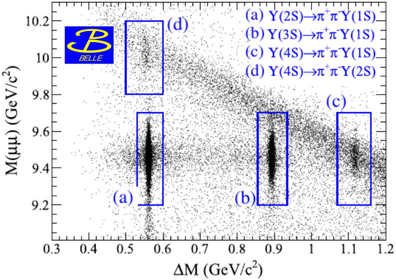
$\pi^+\pi^-$-transition is enhanced by Z_b states.

A full scan (10 MeV$/c^2$ steps, $\int \mathcal{L}dt$) from the $B\bar{B}$ threshold to the maximum availabe energy will give Belle II a unique opportunity to shed light on the hadronization mechanism.

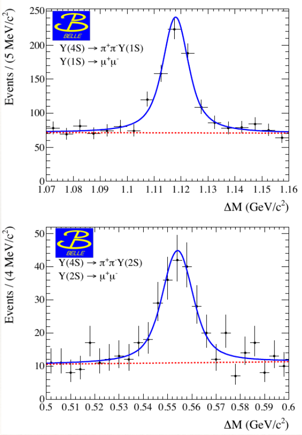
Bondar et al. **Mod. Phys. Lett. A32(2017), 1750025**

Dipion transitions

- Measurement of dipion transitions also provided
- Fit to $\Delta M = M_{\pi^+\pi^-\mu^+\mu^-} - M_{\mu^+\mu^-}$



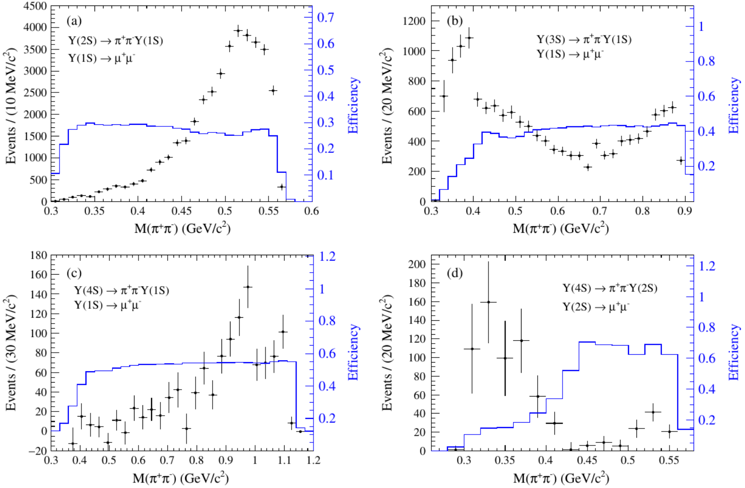
Belle: PRD96, 052005(2017)



Measurement	Result	PDG value
$\mathcal{B}(\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S))$	$(8.2 \pm 0.5 \pm 0.4) \times 10^{-5}$	$(8.1 \pm 0.6) \times 10^{-5}$
$\mathcal{B}(\Upsilon(4S) \to \pi^+\pi^-\Upsilon(2S))$	$(7.9 \pm 1.0 \pm 0.4) \times 10^{-5}$	$(8.6 \pm 1.3) \times 10^{-5}$
$\sigma_{\rm ISR}(\Upsilon(2S))$	$(17.36 \pm 0.19 \pm 0.69)$ pb	(17.1 ± 0.3) pb
$\sigma_{\rm ISR}(\Upsilon(3S))$	$(28.9 \pm 0.5 \pm 1.3)$ pb	(28.6 ± 0.5) pb

The ISR cross section $\sigma_{\rm ISR}$ is based on $\mathcal{B}^{\rm PDG}(\Upsilon(2S, 3S) \to \pi^+\pi^-\Upsilon(1S))$

$M_{\pi^+\pi^-}$ in the $\pi^+\pi^-$-transitions

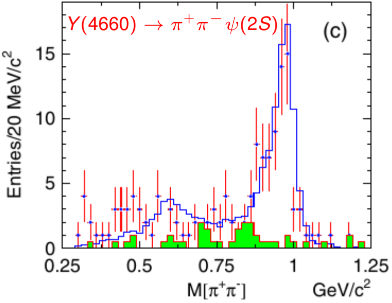


- Double peaked structure in $\Upsilon(4S) \to \pi^+\pi^-\Upsilon(2S)$ and $\Upsilon(3S) \to \pi^+\pi^-\Upsilon(1S)$, enhancement near $M_{\pi^+\pi^-}$ threshold.
- $f_0(980)$ in $\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S)$???

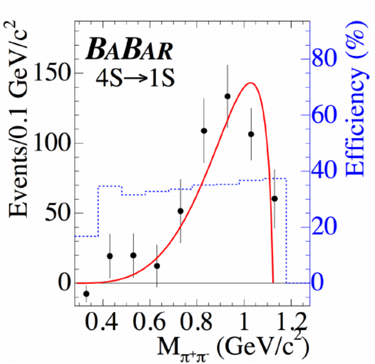
Belle: PRD96,052005(2017)

$f_0(980)$ in $\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S)$

- Behaviour not seen in previous data at the $\Upsilon(4S)$.
- However, $f_0(980)$ signals were observed in $Y(4260) \to \pi^+\pi^- J/\psi$ and $Y(4660) \to \pi^+\pi^-\psi(2S)$.



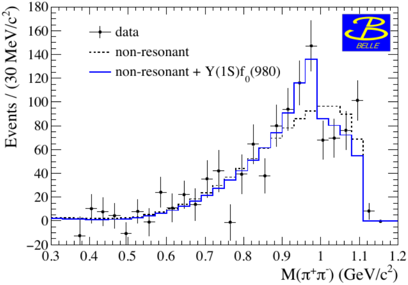
Belle: PRD91,112007(2015)



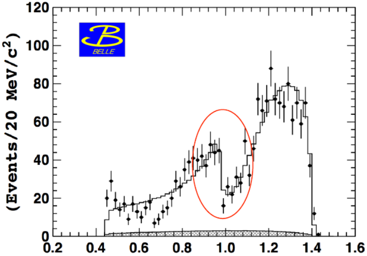
BaBar: PRL96, 232001(2006)

$f_0(980)$ in $\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S)$

- Major interest comes from $\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S)$ dipion invariant mass.
- very similar to what observed at the $\Upsilon(5S)$:



Belle: PRD96,052005(2017)

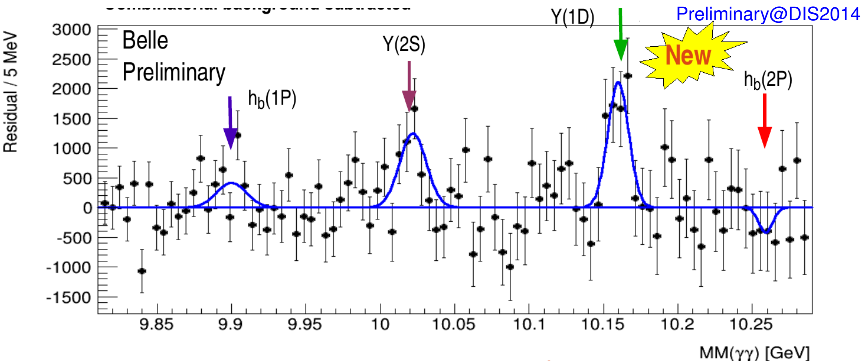


Belle: PRL108, 122001(2012)

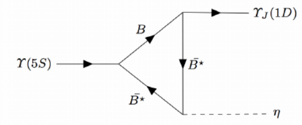
- Recently predicted by theory: Chen et al., PRD95, 034022(2017)
- An amplitude model including a resonant $f_0(980)$ contribution is preferred by data (2.8σ)
- Addition of $f_2(1270)$ does not improve the description

η transitions from $\Upsilon(5S)$

- η reconstructed in $\eta \to \gamma\gamma$, look at the missing mass spectrum, after combinatorial background subtraction



- In particular, $\mathcal{B}(\Upsilon(5S) \to \eta\Upsilon(1D))$ in compatible with the prediction (via triangular meson loops)
  Wang et al., PRD94, 094039(2016)
- Observation of $\Upsilon(5S) \to \eta\Upsilon(1D)$
  $\mathcal{B}(\Upsilon(5S) \to \eta\Upsilon(1D)) = (2.8 \pm 0.7 \pm 0.4) \times 10^{-3}$
- Now finalizing the result on the branching fractions



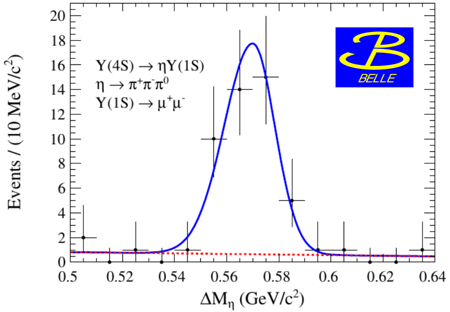
$\Upsilon(4S) \to \eta\Upsilon(1S)$

Belle: PRD96,052005(2017)

- With the same approach and a similar event selection.
- Fit to $\Delta M_\eta = M_{\pi^+\pi^-\gamma\gamma\mu^+\mu^-} - M_{\mu^+\mu^-} - M_{\pi^+\pi^-\gamma\gamma}$
- Confirmation of the enhancement with respect to dipion transition

$$\mathcal{R} = \frac{\mathcal{B}(\Upsilon(4S) \to \eta\Upsilon(1S))}{\mathcal{B}(\Upsilon(4S) \to \pi^+\pi^-\Upsilon(1S))} \quad (1)$$

- Confirm the enhancement of $\Upsilon(4S) \to \eta\Upsilon(1S)$ via spin-flip transition.



Measurement	Result	PDG value
$\mathcal{B}(\Upsilon(4S) \to \eta\Upsilon(1S))$	$(1.70 \pm 0.23 \pm 0.08) \times 10^{-4}$	$(1.96 \pm 0.28) \times 10^{-4}$
$\mathcal{R}$	$2.07 \pm 0.30 \pm 0.11$	2.41 ± 0.42

Very good processes on exotic states.

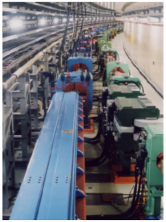
But, Question: What is the nature of the exotic states?

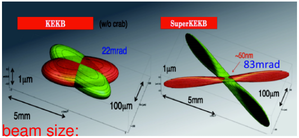
- Multi-quark states?
- Molecule?
- glueball?
- hybrid?

We need more data!!!

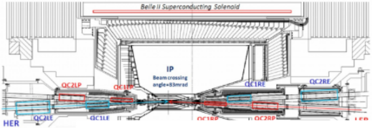
SuperKEKB and Belle II

Advantage of new accelerator: SuperKEKB





beam size:
$100\mu m(H) \times 2\mu m(V) \rightarrow$
$10\mu m(H) \times 59nm(V)$

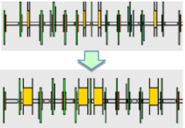


New superconducting final focusing magnets near the Interaction Point (IP)

e^+ 3.6A

e^- 2.6A

Redesign the lattice to reduce the emittance (replace short dipoles with longer ones, increase wiggler cycles) (being tuned)

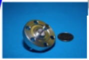


KEKB→SuperKEKB

- Nano-Beam scheme, extremely small β_y^*, low emittance
- Beam current ($I_\pm$) ×2

$$L = \frac{\gamma_\pm}{2e\gamma_e}\left[1 + \frac{\sigma_y^*}{\sigma_x^*}\right]\frac{I_\pm \xi_{y\pm}}{\beta_{y\pm}^*}\left[\frac{R_L}{R_{\xi y}}\right]$$

40 times higher luminorsity:
$2.1 \times 10^{34} \rightarrow 8 \times 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$



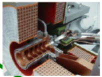
Reinforce RF systems for higher beam currents

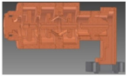
Improve monitors and control system

Injector Linac upgrade:

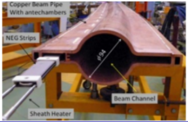
Upgrade positron capture section

Low emittance RF electron gun





Replace beam pipes with TiN-coated beam pipes with antechambers (works well)



New e^+ Damping Ring constructed

Belle II Collaboration

25countries/regions
105 institutions
~750 researchers

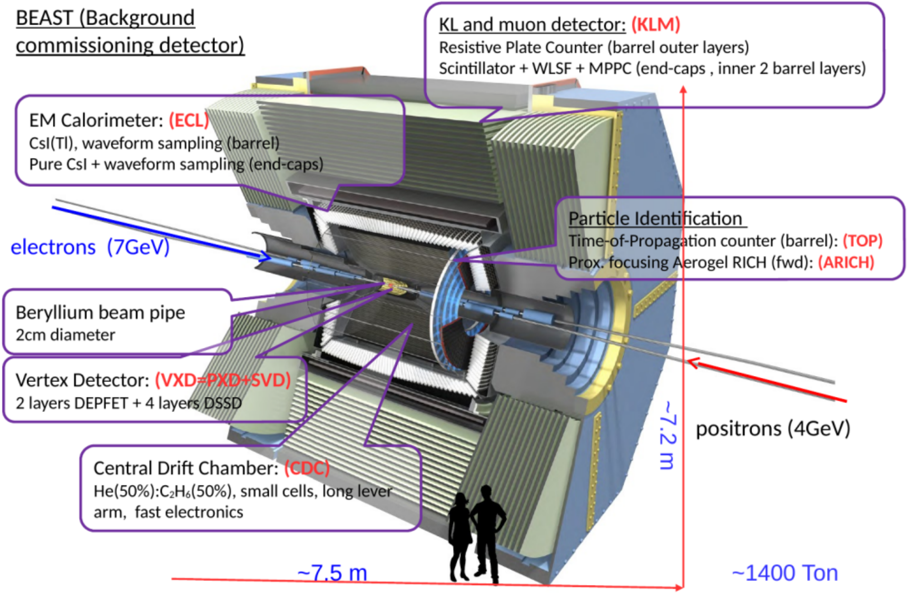
Europe	300
Austria	13
Czechia	6
France	14
Germany	110
Israel	3
Italy	76
Poland	13
Russia	42
Slovenia	16
Spain	4
Ukraine	3

Asia			346
Saudi Arabia	1	Korea	43
Australia	33	Malaysia	6
China	33	Vietnam	3
India	44	Taiwan	28
Japan	150	Thailand	2
		Turkey	3

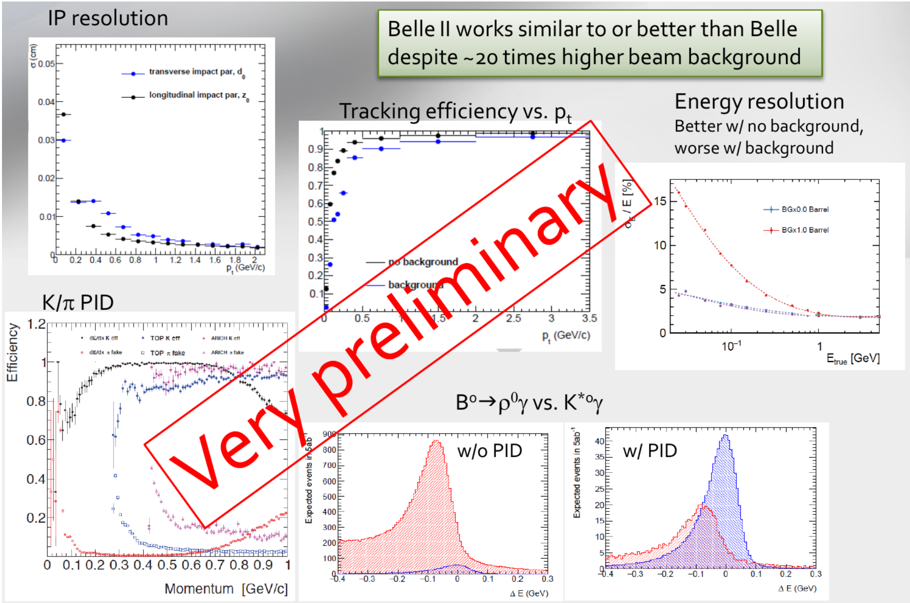
America	129
Canada	28
Mexico	12
USA	89

Recently, France (June) and Israel (Oct) joined.

Belle II detector



Expected performance of Belle II



From Prof. Ushiroda's talk at LP2017.

Projecte ambient neutron rate in Belle II means that endcap RPCs would **never see muons**

Efficiency in Belle

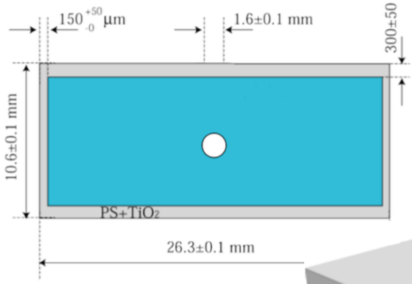
Layer	Barrel	Forward Endcap	Backward Endcap
0	0.97	0.91	0.9
1	0.98	0.93	0.9
2	0.99	0.94	0.9
3	0.99	0.94	0.9
4	0.99	0.94	0.89
5	0.99	0.92	0.88
6	0.99	0.93	0.89
7	0.99	0.92	0.87
8	0.99	0.92	0.86
9	0.99	0.9	0.85
10	0.99	0.87	0.82
11	0.99	0.82	0.8
12	0.99	0.78	0.81
13	0.99	0.77	0.76
14	0.99	—	—

Efficiency in Belle II

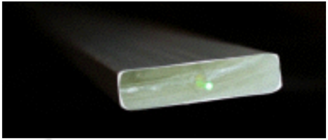
Layer	Barrel	Forward Endcap	Backward Endcap
0	0.9	0	0
1	0.94	0	0
2	0.96	0	0
3	0.97	0	0
4	0.98	0	0
5	0.98	0	0
6	0.98	0	0
7	0.99	0	0
8	0.98	0	0
9	0.99	0	0
10	0.99	0	0
11	0.99	0	0
12	0.99	0	0
13	0.99	0	0
14	0.99	—	—

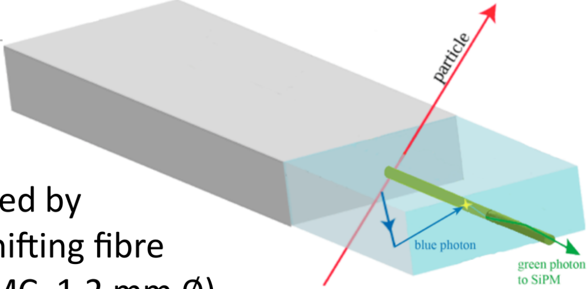
KLM scintillator strip

Scintillator (with TiO_2 reflective coating) delivers blue light to central-bore WLS fibre.



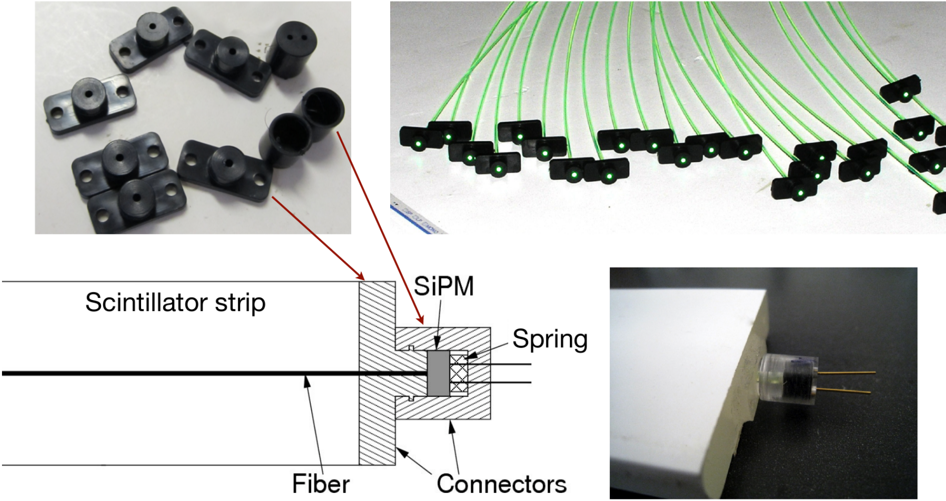
FNAL scintillator for barrel



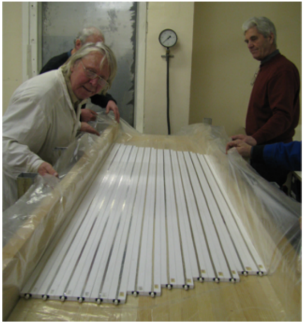


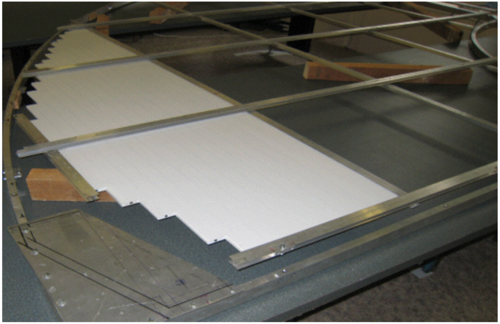
Light is captured by
wavelength-shifting fibre
(Kuraray Y11 MC, 1.2 mm Ø)

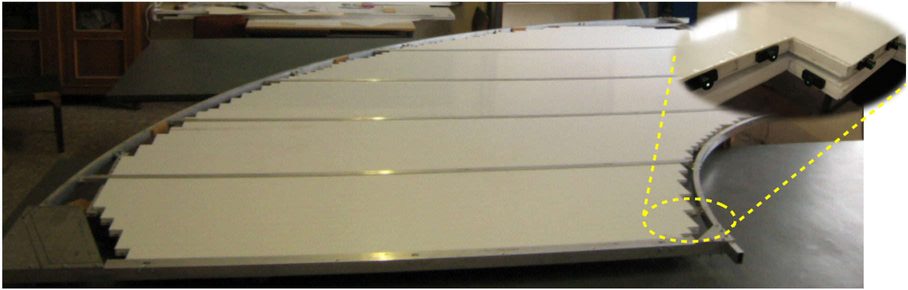
WLS fibre is epoxied to a ferrule that is epoxied to the scintillator strip



An endcap scintillator superlayer

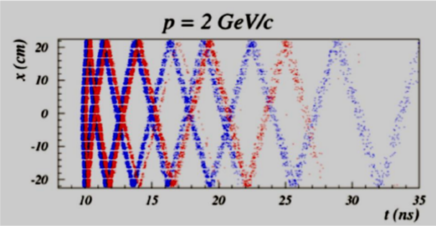


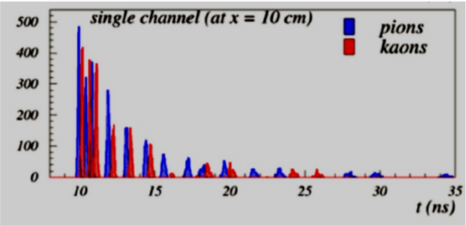




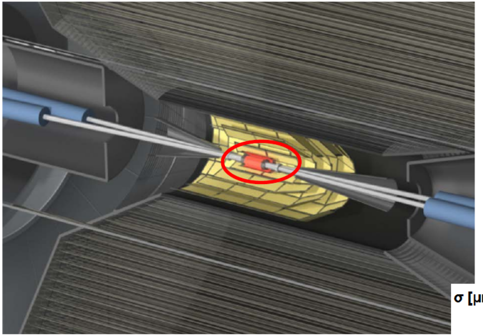
Barrel PID: image Time Of Propagation (iTOP)

Quartz Property	Requirement
Flatness	<6.3μm
Perpendicularity	<20 arcsec
Parallelism	<4 arcsec
Roughness	< 0.5nm (RMS)
Bulk transmittance	> 98%/m
Surface reflectance	>99.9%/reflection





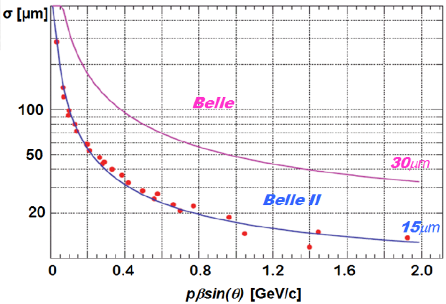
The Belle II vertex detector



- 2 DEPFET pixel detector (PXD) layers
- 4 Double Sided Si-Strip Detector (DSSD) (SVD) layers

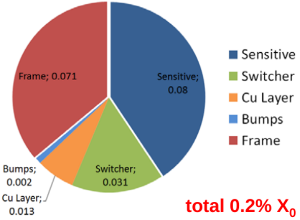
→ *Improvement in the impact parameter resolution*

- Fast detector to keep small occupancy
- High spatial resolution
- Very short distance from the IP
- Minimum thickness

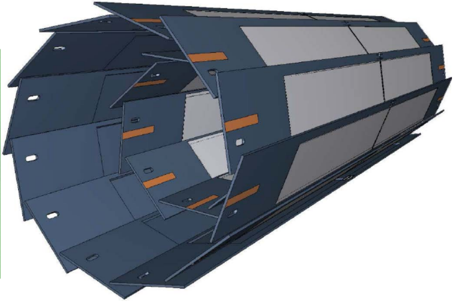


PXD: DEPFET pixel detector

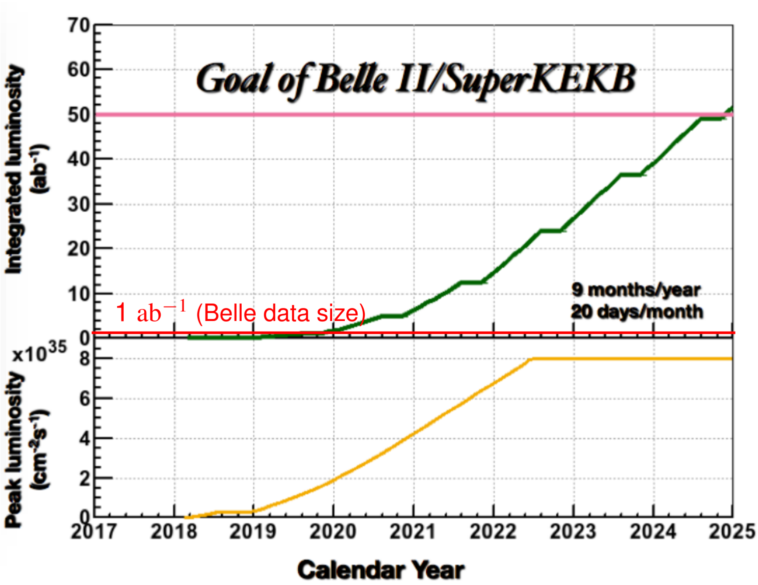
	Inner layer (L1)	Outer layer (L2)
# modules	8	12
Distance from IP (cm)	1.4	2.2
Thickness (μm)	75	75
# pixels	768 x 250	768 x 250
Total # pixels	3.072 M	4.608 M
Pixel size (μm^2)	55 x 50 60 x 50	70 x 50 85 x 50
Sensitive area (mm^2)	44.8 x 12.5	61.44 x 12.5



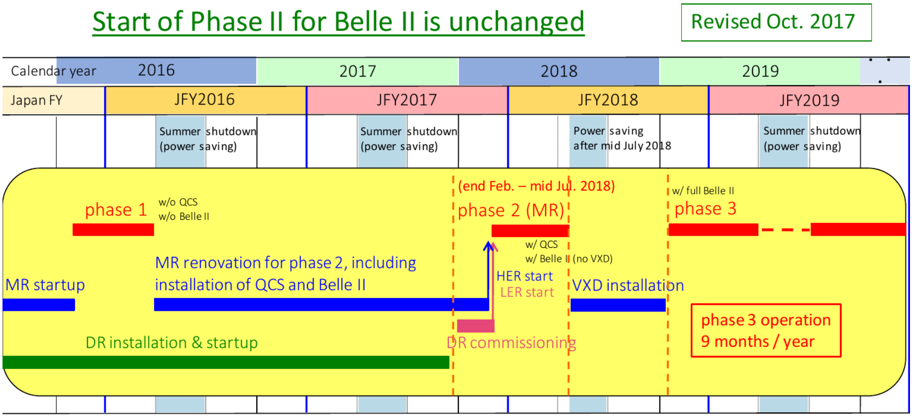
total 0.2% X_0



Profile of SuperKEKB luminosity and Belle II data sample



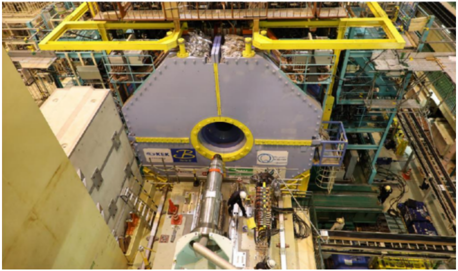
Updated SuperKEKB/Belle II schedule



Change in the start of DR commissioning (due to problem with linac waveguides)
Shutdown for VXD installation ∼ 6 months (mistakenly ∼ 5 months was allocated in earlier schedules)

Phase II

Belle II roll in, 11/4/2017



Commissioning of accelerator and sub-detectors

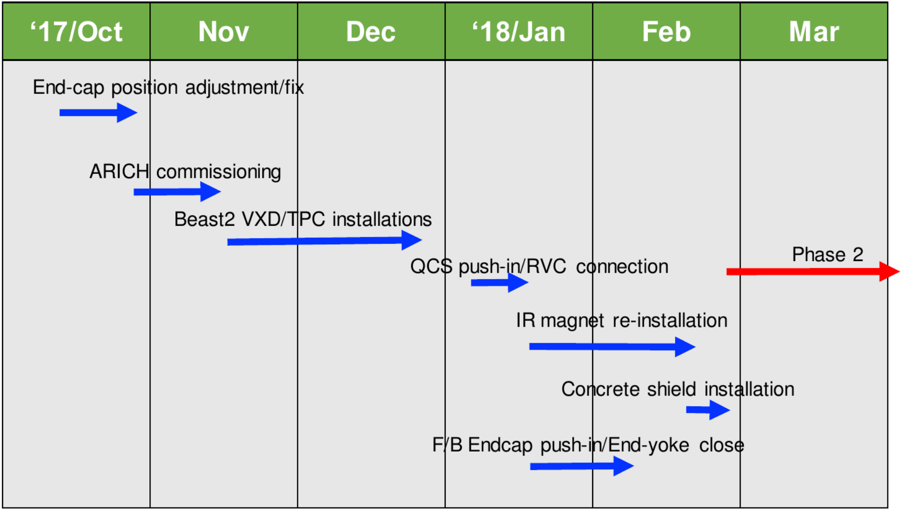
- Start beginning of 2018, duration about 5 months.
- Beam collisions with focusing magnets (QCS).
- Target luminosity is $10^{34}\ cm^{-2}s^{-1}$, which is KEKB level.
- 20-40 fb^{-1} data for physics analyses.
- W/o vertex detector dependent measurements.

What can be done with Phase 2 data?

- Background studies
- Detector and trigger performance studies
- Simulation validation
- Exercising of calibration and alignment procedures
- Reconstruction algorithm tuning
- Physics measurements

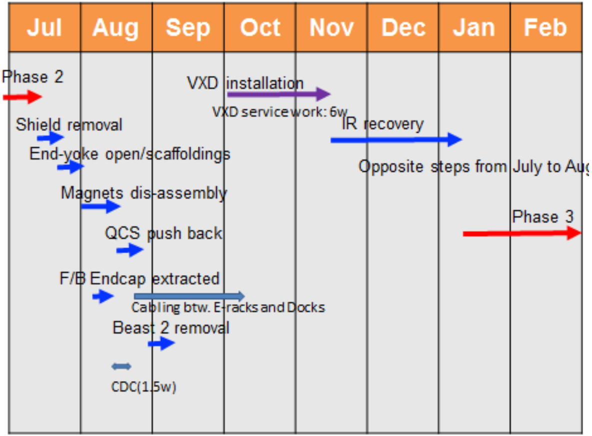
The first collision is expected in Feb. 2018, about 8 years after KEKB being shut down.

IR construction toward phase 2



6 months shutdown for VXD installation and transition to phase III

- Belle II management: total shutdown must be 6 months or shorter
- Appears to be possible by clever arrangement of work in parallel.



The “Big Picture” now

- The first “Global” Cosmic ray running took place during two periods in July and August 2017.
- Very rocky start with many more problems than anticipated. Tracks, momentum, energy, timing resolutions and efficiencies from nearly all outer detector subsystems were obtained in the end. Shakedown of many problems (e.g. but firmware of TOP, KLM are not ready for high rates). EKLM is not connected.
  - The last parts of the outer detector were installed (ARICH and forward ECL). RPC readout electronics was finished. BKLM scintillator readout has issues.
  - First high rate tests of the VXD part of the Global DAQ were successful.
  - The PHASE II VXD was put together at KEK in a new clean room at Tsukuba Hall.
- **Amazing progress continues ! We will be ready for Phase II but much hard work is still ahead.**

Slides from Tom Browder.

Some guys working for Belle II.

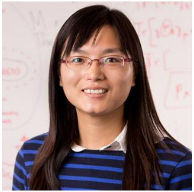
王博群： 美国Cincinnati大学博士后，2012年——

北大班勇老师培养的学生！！！已经在Cincinnati大学工作五年。

Work on iTOP subdetector

- Hardware:
  - The acceptance tests of the quartz radiator of the iTOP detector.
  - The alignment and gluing of the iTOP optics components.
  - Assembly and commissioning of the iTOP detector.
  - Participated in the beam test of the prototype iTOP detector in SPring-8, Japan.
- Software:
  - Develop and implement DQM histograms for iTOP detector.
  - Manage the source code repository for the Belle II DQM software package.

李春花： 澳大利亚Melbourne大学博士后，2014年——



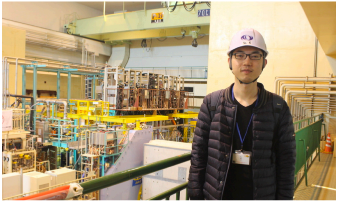
- Leading the development of the High Level Trigger (HLT)
  - The HLT group convenor.
  - Develop the HLT software, trigger menu, and the integration of the online software.
  - Coordinate the DAQ, trigger, software and physics groups for HLT.

HLT: New for Belle II

- Physics Trigger: suppress event rates from 30 kHz to 10 kHz on DAQ
- PXD RoI: provide HLT trigger and tracking information of SVD and CDC to calculate RoI of PXD
- Calibration: Flag samples for the calibration of sub-detectors
- DQM: Information from reconstruction of data quality monitoring

- Leading the development of the simulation of hardware trigger (TSIM)
  - Co-coordinator of the TSIM group
  - Simulation of hardware trigger of each sub-detector
  - Coordinate the work between trigger and physics groups

叶桦： DESY 博士后，2014年——



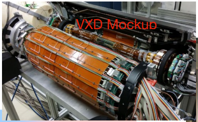
2-pahse CO2 cooling and VXD mechanics

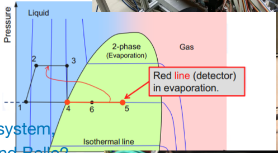
- MARCO is universal 2-pahse CO2 cooling system, and is the base design for the ATLAS IBL and Belle2 VXD cooling systems.
- The full size VXD mockup is built to verify the thermal and mechanical performance of the VXD detector and CO2 cooling system.

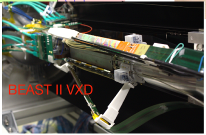
DEPFET PXD commissioning and integration

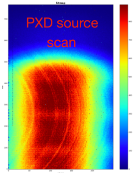
- Beam tests of the VXD system including full DAQ chain.
- PERSY (Permanently running system) testing setup at DESY, including PXD, SVD, and BEASTII subdetectors.
- Mass-testing for Phase3 PXD
- Preparing for the half-shell commissioning at DESY

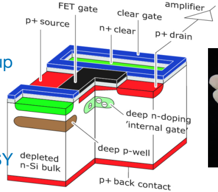
hua.ye@desy.de

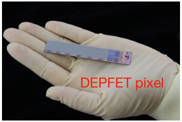








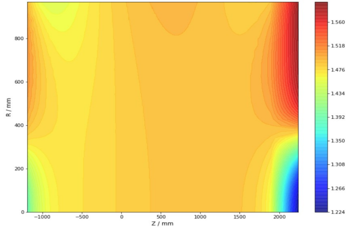




郭爱强： 中德联合，DESY博士后，2014年——

Magnetic field measurement for BelleII

- ➢ How does B-field affect physics analysis?
  - Momentum measurement
  - Trajectory extrapolation
  - Particle identification
- ➢ Accuracy requirement:
  - <0.1%
- ➢ Method
  - 3D Hall probe
- ➢ Procedure
  - Map CDC volume with BelleII solenoid only (Before CDC installed)
  - Map VXD volume with BelleII solenoid and QCS (after CDC installed)



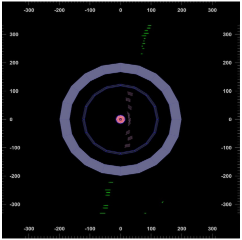
- ➢ The B field measurement campaigns were successfully finished in August of 2017
- ➢ Intrinsic quality of data is sufficient to reach 0.1% precision goal
- ➢ Discrepancy between data and calculation was observed and the measurements provided essential information to improve the simulation

管颖慧： 美国**Indiana**大学和西北太平洋国家实验室（**PNNL**）博士后，**2015**年——

Work on KLM detector at BelleII

- Work for the commissioning of the K_L-Muon (KLM) detector at BelleII
  - Electronic boards installation, cabling, debugging the electronics and data acquisition (DAQ) chain.
  - Analyze the cosmic-ray data to investigate the performance of the hardware and software of the KLM.
  - Implementation of slow control software and GUI for controlling and monitoring high voltage (HV) system and run control software controlling DAQ for KLM.
- Development and maintenance of the simulation/reconstruction software of KLM
  - KLM stand-alone tracking
  - Alignment
  - Manage KLM data in data base

2017. June. cosmic ray test



罗涛： 2015-2017 匹茨堡大学博士后，现复旦青年研究员

罗涛研究员团队在Belle II实验上的工作

➢ 参加硬件研发和探测器建造：

- ✓ 领导了iTOP探测器在KEK富士厅的宇宙线测试工作。
- ✓ 搭建测试平台，开发测试和数据获取工具; 负责iTOP探测器前端电子学板IRSX ASIC，数据读出系统等的测试。
- ✓ 被认命为iTOP测试的协调人。
- ✓ 目前是ARICH 探测器上的束流本底研究负责人。

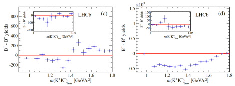
➢ 物理分析工作：

- ✓ 2017年11月开始被认命为B介子的不含粲介子末态衰变物理组(B2charmless group) 中EVTGEN 产生子工作相关负责人
- ✓ 在研物理分析课题
  - ▪ 从B介子的不含粲介子末态衰变中测量直接CPV和寻找新的CPV来源， 比如：$B^0 \to K_S K_S \pi^0$等
  - ▪ 寻找稀有衰变：$B^0 \to K_S \pi^0$

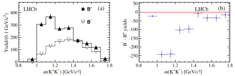
在KEK工作时领导的团队

Results from LHCb (Big Local CPV)

$B^\pm \to K^\pm K^+ K^-$



$B^\pm \to \pi^\pm K^+ K^-$



Belle II at Fudan

复旦大学Belle II研究计划: Physics analysis, hardware and software

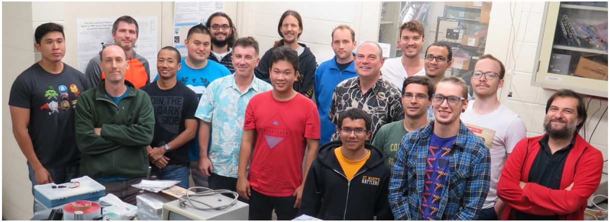
- Physics analyses in the future, to match the goals of Belle II experiment.
- Build a computing center, and join Belle II Grid: 320 cores and 200TB
  - Join Belle II GRID.
  - Support from LNPIA: needs a computing center and can share the cost. the resources to have a more powerful computing center.
  - 我们正在购买208个核，36 TB的服务器设备。
- Operation and Maintenance of KLM.
  - Based on my work on KLM construction at VPI(弗吉尼亚理工).
  - FDU will share responsibility with VPI and Indiana.
  - Easy travel from 复旦 to KEK.
- R&D for KLM upgrade: replace the legacy RPC modules.
  - Take this opportunity to build a hardware lab mainly for Belle II experiment.
  - Set up the R&D facility, prepare to participate in upgrade if it happens.
- Calibrations for iTOP and KLM: important before Phase III data taking.
  - 我在负责TBC时间刻度(30 ps)。
  - 正带着Cincinnati的一个博士生工作。
- Work for ARICH(罗涛).

Getting post-docs and students to establish our group.

Our lab

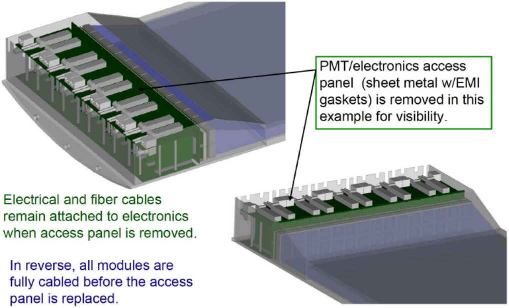
- 电子学设备，NIM/VME，高压机箱。。。
- 正在搭建一套宇宙线测试系统。
- 正在把一块KLM模板从KEK运到复旦。

- 正在考虑与夏威夷大学Gary Varner的ID Lab的合作。



KLM upgrade

Integrate the readout electronics in the module, like iTOP module.



Avoid the headache troubles from the long ribbon cables.

组织结构

- 黄焕中教授：千人计划，重离子对撞实验与double-beta实验。
- Belle II实验：王小龙(PI)，罗涛(青年研究员)与张翼(学生)。团队建设中
- 理论方面：黄旭光（物理系，青千），Daekyoung Kang(青年研究员，MIT和Los Alamos博士后)

支持力度

- 复旦大学校领导非常重视。
- 院系的具体支持。
- 大学各职能部门很配合。
- 更多资源正在配备中：实验室，办公室，经费，人员。

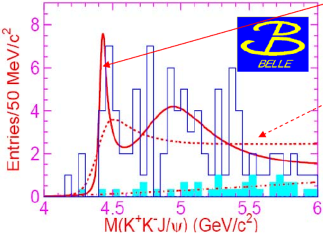
Summary

- The exotics from the $\pi^+\pi^-$ and η hadronic transitions:
  1. There have been a lot of exotic states observed in the past decades.
  2. $\pi^+\pi^-$-transitions and η-transitions performed the major roles in the discoveries of exotic states.
  3. Studying the $\pi^+\pi^-$-transitions and η-transitions may help us to understand the nature of the exotic state.
  4. Need to pay more attention to
     - $f_0(980)$ in $\pi^+\pi^-$-transitions
     - Enhancement of η-transition
  5. Belle II data are coming, and there will be a unique data sample for exotic states.
- Belle II is going to take data soon.
- Work plan at Fudan Univ. for Belle II is reported.

Thank you!

Back-up

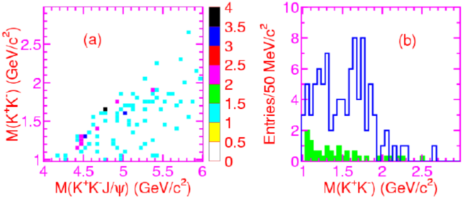
$e^+e^- \to K^+K^-J/\psi$ via ISR at Belle



PDG $\psi(4415)$ + 1 BW:
M = (4875 ± 132) MeV
Γ = (630 ± 126) MeV

single BW:
M = (4430 ± 38) MeV
Γ = (254 ± 49) MeV

The figure is still not clear. New resonance or just continuum production, or other mechanism? Larger data sample from future B factories should give an answer.



Similarly, KK invariant mass tends to be large!

$$\Gamma\left(Y(4260) \to e^+e^-\right) \cdot B\left(Y \to K^+K^- J/\psi\right) < 1.2 \text{ eV @ 90\% C.L.}$$

Belle: C.Z.Y & C.P. Shen et al., PRD77,011105(RC)

Belle Quantum Number of $X(3872)$

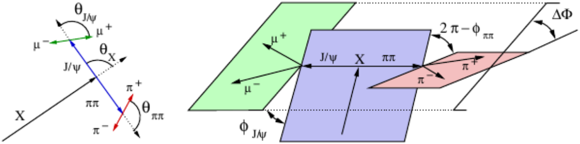
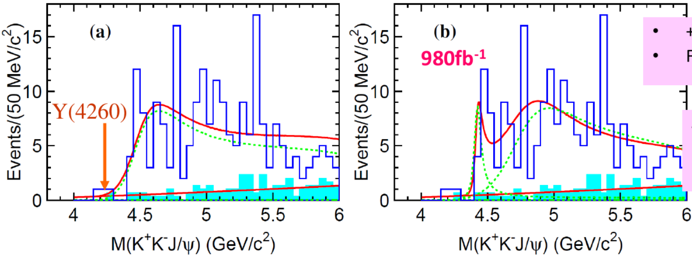


TABLE I. Result of the $X(3872)$ particle angular analysis. Listed are the state, the decay mode, the L and S quantum numbers of the J/ψ-$(\pi^+\pi^-)$ system, the χ^2 with 11 degrees of freedom and the χ^2 probability.

J^{PC}	decay	LS	χ^2 (11 d.o.f.)	χ^2 prob.
1^{++}	$J/\psi\rho^0$	01	13.2	0.28
2^{-+}	$J/\psi\rho^0$	11,12	13.6	0.26
1^{--}	$J/\psi(\pi\pi)_S$	01	35.1	2.4×10^{-4}
2^{+-}	$J/\psi(\pi\pi)_S$	11	38.9	5.5×10^{-5}
1^{+-}	$J/\psi(\pi\pi)_S$	11	39.8	3.8×10^{-5}

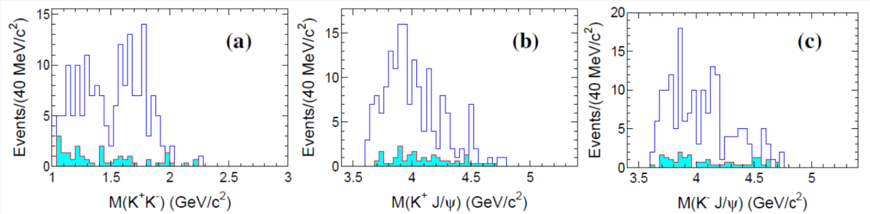
Scan on $e^+e^- \to K^+K^-J/\psi$



- +one resonance.
- Fit with $\psi(4415)$

$\chi^2/ndf=30/11$
➢ $M=4747\pm117$MeV
➢ $\Gamma=671\pm86$ MeV

Dalitz analysis performed

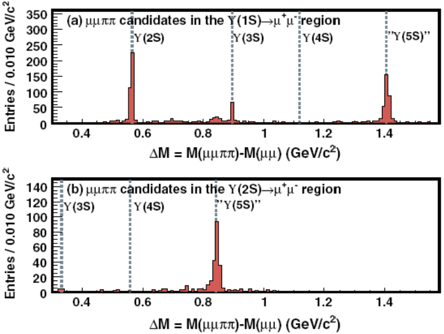


- Not clear on a structure produced in $e^+e^- \to K^+K^-J/\psi$.
- No evident structure in $K^\pm J/\psi$ mass distribution under current statistics.

PRD89, 072015(2014)

Y_b: b-quark version of $Y(4260)$

- $\Upsilon(5S) \to \Upsilon(nS) + \pi^+\pi^-$ searched at Belle with 21.87 fb^{-1}@10.87 GeV$/c^2$ data.
- $\pi^+\pi^-$ transition of $\Upsilon(5S)$ has much large partial width. (Like $Y(4260) \to \pi^+\pi^- J/\psi$)
- A b-quark version of $Y(4260)$ — Y_b? Or something not understood?
- The abnormal $\mathcal{B}$ needed more study! So Belle took more data after then.
  120 fb^{-1}, including scan data.



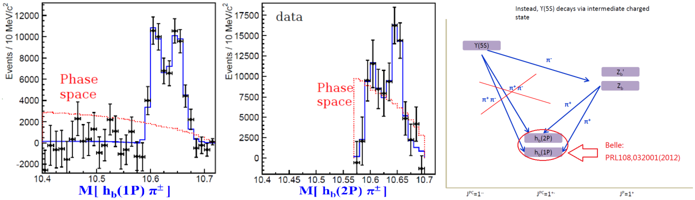
$\mathcal{B}(\Upsilon(5S) \to \Upsilon(2S)\pi^+\pi^-) =$
$0.85 \pm 0.07(stat.) \pm 0.16(syst.)$ MeV$/c^2$.

Process	Γ_{total}	$\Gamma_{e^+e^-}$	$\Gamma_{\Upsilon(1S)\pi^+\pi^-}$
$\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$	0.032 MeV	0.612 keV	0.0060 MeV
$\Upsilon(3S) \to \Upsilon(1S)\pi^+\pi^-$	0.020 MeV	0.443 keV	0.0009 MeV
$\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-$	20.5 MeV	0.272 keV	0.0019 MeV
$\Upsilon(10\,860) \to \Upsilon(1S)\pi^+\pi^-$	110 MeV	0.31 keV	0.59 MeV

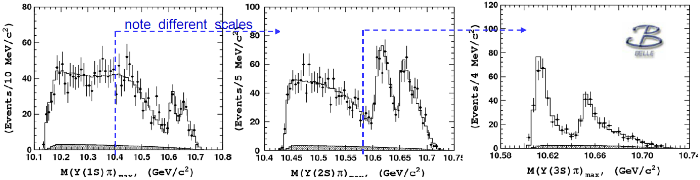
K. F. Chen *et al.*, PRL100,112001(2008)

Charged Z_b's in $\Upsilon(5S) \to (b\bar{b})\pi^+\pi^-$

- π^+ and π^- reconstructed only, $M_{miss}(\pi^+\pi^-) \sim b\bar{b}$.
- Structures in $\pi^\pm h_b$ modes:



- Structures in $\pi^\pm\Upsilon$ modes:



- $Z_b(10610)/Z_b(10650) \to (b\bar{b}) + \pi^\pm$: PRL108,122001(2012).
  - $Z_b(10610)$: $M_1 = (10607.2 \pm 2.0)$ MeV$/c^2$, $\Gamma_1 = (18.4 \pm 2.4)$ MeV.
  - $Z_b(10650)$: $M_2 = (10652.2 \pm 1.5)$ MeV$/c^2$, $\Gamma_2 = (11.5 \pm 2.2)$ MeV.

Need to pay more attention to η-transitions