Study of charmoniumlike states with initial state radiation at Belle II

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Introduction

- Potential model works very well for charmonium states below $D\bar{D}$ threshold.
- A lot of charmonium(-like) states above $D\bar{D}$ threshold were observed in the past decade.
- XYZ particles – Charmonium-like states with many exotic properties! What is their nature?

Example potential from Barnes, Godfrey, Swanson:

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

(Coulomb + Confinement + Contact)

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

(Spin-Orbit + Tensor)

PRD72, 054026 (2005)

The charmonium(-like) states observed via ISR: $Y(4008)$, $Y(4260)$, $Y(4360)$, $Y(4660)$, $X(4630)$, $\psi(4040)$, $\psi(4160)$, $\psi(4415)$, ...
KEK, Tsukuba (near Tokyo), Japan
Belle data sample

All the data samples can be used for ISR studies.
Published ISR results at Belle

<table>
<thead>
<tr>
<th>Process</th>
<th>Reference</th>
<th>Int. Lum.</th>
<th>c.m. ene.</th>
<th>Physics Covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D^{(<em>)}\pm D^{(</em>)}\mp$</td>
<td>PRL 98.092001(2007)</td>
<td>547.8 fb$^{-1}$</td>
<td>3.9-5.0 GeV</td>
<td>Cross sections</td>
</tr>
<tr>
<td>$DD_{2}^{*}(2460)$</td>
<td>PRL 100, 062001 (2008)</td>
<td>673 fb$^{-1}$</td>
<td>4.0-5.0 GeV</td>
<td>$\psi(4415)$</td>
</tr>
<tr>
<td>$\Lambda_{c}^{+}\Lambda_{c}^{-}$</td>
<td>PRL101,172001 (2008)</td>
<td>695 fb$^{-1}$</td>
<td>4.8-5.4 GeV</td>
<td>$Y(4630)$</td>
</tr>
<tr>
<td>$D^{0}D^{*-}\pi^{+}$</td>
<td>PRD 80, 091101(R) (2009)</td>
<td>695 fb$^{-1}$</td>
<td>41.-5.2 GeV</td>
<td>$Y(4260)$</td>
</tr>
<tr>
<td>$DD$</td>
<td>PRD 77, 011103 (2008)</td>
<td>673 fb$^{-1}$</td>
<td>3.8-5.0 GeV</td>
<td>Cross sections</td>
</tr>
<tr>
<td>$\pi^{+}\pi^{-}J/\psi$</td>
<td>PRL 99, 182004 (2007)</td>
<td>548 fb$^{-1}$</td>
<td>3.8-5.5 GeV</td>
<td>$Y(4008), Y(4260)$</td>
</tr>
<tr>
<td>$\pi^{+}\pi\psi(2S)$</td>
<td>PRL 99, 142002 (2007)</td>
<td>673 fb$^{-1}$</td>
<td>4.0-5.5 GeV</td>
<td>$Y(4360), Y(4660)$</td>
</tr>
<tr>
<td>$K^{+}K^{-}J/\psi$</td>
<td>PRD 77, 011105(R) (2008)</td>
<td>673 fb$^{-1}$</td>
<td>4.2-6.0 GeV</td>
<td>$Y(4260)$</td>
</tr>
<tr>
<td>$\phi\pi^{+}\pi^{-}$</td>
<td>PRD 80, 031101 (2009)</td>
<td>673 fb$^{-1}$</td>
<td>1.3-3.0 GeV</td>
<td>$Y(2175), \phi(1680)$</td>
</tr>
<tr>
<td>$\eta J/\psi$</td>
<td>PRD 87, 051101(R) (2013)</td>
<td>980 fb$^{-1}$</td>
<td>3.8-5.3 GeV</td>
<td>$\psi(4040),\psi(4160)$</td>
</tr>
<tr>
<td>$\pi^{+}\pi J/\psi$</td>
<td>PRL 110, 252002 (2013)</td>
<td>980 fb$^{-1}$</td>
<td>3.8-5.5 GeV</td>
<td>$Y(4008), Y(4260),Zc(3900)$</td>
</tr>
<tr>
<td>$KKJ/\psi$</td>
<td>PRD 89,072015 (2014)</td>
<td>980 fb$^{-1}$</td>
<td>4.4-5.2 GeV</td>
<td>$Y(4260)$</td>
</tr>
<tr>
<td>$\pi^{+}\pi\psi(2S)$</td>
<td>PRD 91, 112007 (2015)</td>
<td>980 fb$^{-1}$</td>
<td>4.0-5.5 GeV</td>
<td>$Y(4260), Y(4360), Y(4660)$</td>
</tr>
<tr>
<td>$\gamma \chi_{cJ}$</td>
<td>PRD 92, 012011 (2015)</td>
<td>980 fb$^{-1}$</td>
<td>3.8-5.6 GeV</td>
<td>$\psi(4040,4160,4415);$ $Y(4260, 4360, 4660)$</td>
</tr>
</tbody>
</table>

ISR is a successful story at Belle, while it’s similar to BaBar.

Black font means the significance is low
Example I: Cross section measurements via ISR at Belle

Contribution of exclusive cross sections to the total cross section

$\sigma(e^+e^- \rightarrow D^{(*)}D^*)$


e$^+e^- \rightarrow D^0D^-\pi^+$


e$^+e^- \rightarrow D_s^{(*)}D_s^{(*)}$


$e^+e^- \rightarrow \Lambda_c^+\Lambda_c^-$


**BES:** $R_{tot} - R_{uds}$

**Belle:** $R_{excl}$
Example I: Cross section measurements via ISR at Belle

Contribution of exclusive cross sections to the total cross section

BES: $R_{tot} - R_{uds}$
Belle: $\sum R_{excl}$
Example II: updated $e^+ e^- \rightarrow \pi^+ \pi^- \psi(2S)$ at Belle

Unbinned simultaneous maximum likelihood fit for $Y(4360)$ and $Y(4660)$:

$$Amp = BW_1 + e^{i\phi} \cdot BW_2.$$ 

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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Solution I</th>
<th>Solution II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{Y(4360)}$ (MeV/$c^2$)</td>
<td>4347 ± 6 ± 3</td>
<td>4358 ± 6 ± 3</td>
</tr>
<tr>
<td>$\Gamma_{Y(4360)}$ (MeV)</td>
<td>103 ± 9 ± 5</td>
<td>103 ± 9 ± 5</td>
</tr>
<tr>
<td>$\mathcal{B} \cdot \Gamma_{Y(4360)}^{e^+ e^-}$ (eV)</td>
<td>9.2 ± 0.6 ± 0.6</td>
<td>10.9 ± 0.6 ± 0.7</td>
</tr>
<tr>
<td>$M_{Y(4660)}$ (MeV/$c^2$)</td>
<td>4652 ± 10 ± 11</td>
<td>4668 ± 10 ± 11</td>
</tr>
<tr>
<td>$\Gamma_{Y(4660)}$ (MeV)</td>
<td>68 ± 11 ± 5</td>
<td>68 ± 11 ± 5</td>
</tr>
<tr>
<td>$\mathcal{B} \cdot \Gamma_{Y(4660)}^{e^+ e^-}$ (eV)</td>
<td>2.0 ± 0.3 ± 0.2</td>
<td>8.1 ± 1.1 ± 1.0</td>
</tr>
<tr>
<td>$\phi$ (°)</td>
<td>32 ± 18 ± 20</td>
<td>272 ± 8 ± 7</td>
</tr>
</tbody>
</table>

- $N^{sig}$ doubled in the updated study.
- Consistent with previous measurement. PRL99,142002(2007)
- $M_{Y(4360)} = 4361 \pm 9 \pm 9$ MeV/$c^2$,
- $M_{Y(4660)} = 4664 \pm 11 \pm 11$ MeV/$c^2$.
- No obvious signal above $Y(4660)$.
- Some events accumulate at $Y(4260)$, especially in $\pi^+ \pi^- J/\psi$ mode.
ISR at Belle vs. BESIII

- BESIII: 16 energy points, $L_{tot} = 5.1 \, \text{fb}^{-1}$
- $\psi(2S)$ reconstructed modes:
  - Mode I: $\psi(2S) \rightarrow \pi^+ \pi^- J/\psi, J/\psi \rightarrow e^+ e^- / \mu^+ \mu^-$
  - Mode II: $\psi(2S) \rightarrow \text{neutrals} + J/\psi, \text{neutrals} = (\pi^0 \pi^0, \pi^0, \eta \& \gamma \gamma), J/\psi \rightarrow e^+ e^- / \mu^+ \mu^-$

BESIII: arXiv/1703.08787
**Advantage of new accelerator: SuperKEKB**

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

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

**Beam size:**

\[ 100 \mu m (H) \times 2 \mu m (V) \rightarrow 10 \mu m (H) \times 59 \text{nm} (V) \]

40 times higher luminosity:

\[ 2.1 \times 10^{34} \rightarrow 8 \times 10^{35} \text{cm}^{-2} \text{s}^{-1} \]

**KEKB → SuperKEKB**

- Nano-Beam scheme, extremely small \( \beta^*_y \), low emittance
- Beam current \( (I_\pm) \times 2 \)

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

**Reinforce RF systems for higher beam currents**

**Improve monitors and control system**

**Injector Linac upgrade:**

- Upgrade positron capture section
- Low emittance RF electron gun

**New \( e^+ \) Damping Ring constructed**

**DR tunnel**

**X.L. Wang (Fudan Univ.)**
**Belle II detector**

**BEAST** (Background commissioning detector)

**KL and muon detector:** (KLM)
- Resistive Plate Counter (barrel outer layers)
- Scintillator + WLSF + MPPC (end-caps, inner 2 barrel layers)

**EM Calorimeter:** (ECL)
- CsI(Tl), waveform sampling (barrel)
- Pure CsI + waveform sampling (end-caps)

**Particle Identification**
- Time-of-Propagation counter (barrel): (TOP)
- Prox. focusing Aerogel RICH (fwd): (ARICH)

**Beryllium beam pipe**
- 2 cm diameter

**Vertex Detector:** (VXD=PKD+SVD)
- 2 layers DEPFET + 4 layers DSSD

**Central Drift Chamber:** (CDC)
- He(50%):C₂H₅(50%), small cells, long lever arm, fast electronics

Electrons (7 GeV)

Positrons (4 GeV)

~7.5 m

~7.2 m

~1400 Ton

For more details, see Dr. Jake BENNETT’s talk on 3rd, Sept.
The tracking system

<table>
<thead>
<tr>
<th>Component</th>
<th>Type</th>
<th>Configuration</th>
<th>Readout</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam pipe</td>
<td>Beryllium double-wall</td>
<td>Cylindrical, inner radius 10 mm, 10 µm Au, 0.6 mm Be, 1 mm coolant (paraffin), 0.4 mm Be</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PXD</td>
<td>Silicon pixel (DEPFET)</td>
<td>Sensor size: 15×100 (120) mm² pixel size: 50×50 (75) µm² 2 layers: 8 (12) sensors</td>
<td>10 M</td>
<td>impact parameter resolution ( \sigma_{x0} \approx 20 \mu m ) (PXD and SVD)</td>
</tr>
<tr>
<td>SVD</td>
<td>Double sided Silicon strip</td>
<td>Sensors: rectangular and trapezoidal Strip pitch: 50(p)/160(n) - 75(p)/240(n) µm 4 layers: 16/30/56/85 sensors</td>
<td>245 k</td>
<td></td>
</tr>
<tr>
<td>CDC</td>
<td>Small cell drift chamber</td>
<td>56 layers, 32 axial, 24 stereo ( r = 16 - 112 \text{ cm} ), ( -83 \leq z \leq 159 \text{ cm} )</td>
<td>14 k</td>
<td>( \sigma_{r\phi} = 100 \mu m, \sigma_{z} = 2 \text{ mm} )  ( \sigma_{p_t}/p_t = \sqrt{(0.2%p_t)^2 + (0.3%/\beta)^2} )  ( \sigma_{p_t}/p_t = \sqrt{(0.1%p_t)^2 + (0.3%/\beta)^2} ) (with SVD)</td>
</tr>
</tbody>
</table>

X.L. Wang (Fudan Univ.)
Barrel PID: image Time Of Propagation (iTOP)

Cherenkov ring imaging with precision time measurement (better than 100ps)

Installation completed! 2016, May 11
Expected performance of Belle II

From Prof. Ushiroda’s talk at LP2017.

IP resolution

Belle II works similar to or better than Belle despite ~20 times higher beam background

Tracking efficiency vs. $p_t$

Energy resolution
Better w/ no background, worse w/ background

$K/\pi$ PID

$B^0 \rightarrow \rho^0 \gamma$ vs. $K^{*0} \gamma$

w/o PID

w/ PID

From Prof. Ushiroda’s talk at LP2017.
The schedule of Belle II
In 2018, launch SuperKEKB for the first collision in Feb., and start physics operation later!!!

Commissioning:
- SuperKEKB: Clean beam pipe, monitor, tuning optics, collimators, ...
- Belle II: Safe operation, bkg study, beam abort system, calibration, ...

We are here
(Commissioning)

Start of phase II

DR installation & startup

MR renovation for phase 2, including installation of QCS and Belle II

Belle II roll-in 11st, April

phase 1

w/o QCS
w/o Belle II

phase 2 (MR)
(mid Feb. – mid Jul. 2018)

w/ QCS
w/ Belle II (no VXD)

w/ full Belle II

phase 3

VXD installation

DR commissioning

HER start
LER start

phase 3 operation 9 months / year
Profile of SuperKEKB luminosity and Belle II data sample

Goal of Belle II/SuperKEKB

1 ab$^{-1}$ (Belle data size)
ISR at Belle II vs. direct scan at BESIII

**Effective lum at Belle II**

At 4.26 GeV/c² for $\pi^+\pi^- J/\psi$

- $\varepsilon_{BESIII} = 46\%$
- $\varepsilon_{BelleII} = 10\%$

**ISR**

- ISR: many $\sqrt{s}$ simultaneously
- reduced point-to-point systematics
- mass resolution limited by detector performance
- boost of hadronic system vs. $\gamma_{ISR}$ may actually help efficiency

**Direct scan**

- (very) high luminosity at a few selected $\sqrt{s}$
- better resolution in $\sqrt{s}$ — relevant for direct production of $1^{-}\bar{1}^{-}$ states
- much higher efficiency

- ISR produces events at all CM energies BESIII can reach
- With $> 5(10)$ ab$^{-1}$ data sample, Belle II can do ISR studies on $e^+e^- \rightarrow$ charmonium + light hadrons and charm meson pair + light hadrons.
  - charmonium+light hadrons: $\pi^+\pi^- J/\psi$, $\pi^+\pi^- \psi(2S)$, $K^+K^- J/\psi$, $K^+K^- \psi(2S)$, $\gamma X(3872)$, $\pi^+\pi^- X(3872)$, $\pi^+\pi^- h_c$, $\pi^+\pi^- h_c(2P)$, $\omega \chi_{cJ}$, $\phi \chi_{cJ}$, $\eta J/\psi$, $\eta' J/\psi$, $\eta \psi(2S)$, $\eta h_c$, ...
  - charm meson pair + light hadrons: $D\bar{D}$, $DD^*$, $DD^*\pi$, ...
Solve the single-channel puzzle

- **PRL110, 252002(2013)**
  \[ \sigma[e^+ e^- \rightarrow \pi^+ \pi^- J/\psi] \]
  \( Y(4260) \)

- **PRD91, 112007(2015)**
  \[ \sigma[e^+ e^- \rightarrow \pi^+ \pi^- \psi(2S)] \]
  \( Y(4360) + Y(4660) \)

- **PRD87, 051101(R)(2013)**
  \[ \sigma[e^+ e^- \rightarrow \eta J/\psi] \]
  \( \psi(4040) + \psi(4160) \)

- **PRD89, 072015(2014)**
  \[ \sigma[e^+ e^- \rightarrow K^+ K^- J/\psi] \]
  New peaks?

- Different final states have different peaks.
- Each \( Y \) or \( \psi \) state decays to only one channel.
- Need Belle II data!
Sensitivity study: \( Y(4260) \to \pi^+\pi^-\psi(2S) \)

\[ \text{Amp} = BW_1 + e^{i\phi_1} \cdot BW_2 + e^{i\phi_2} \cdot BW_3. \]

\begin{align*}
\mathcal{B} \cdot \Gamma_{Y(4260)}^{e^+e^-} &\quad 1.5 \pm 0.6 \pm 0.4 & 1.7 \pm 0.7 \pm 0.5 & 10.4 \pm 1.3 \pm 0.8 & 8.9 \pm 1.2 \pm 0.8 \\
M_{Y(4360)} &\quad 4365 \pm 7 \pm 4 & 74 \pm 14 \pm 4 \\
\Gamma_{Y(4360)} &\quad 21.1 \pm 3.5 \pm 1.4 & 17.7 \pm 2.6 \pm 1.5 \\
\mathcal{B} \cdot \Gamma_{Y(4360)}^{e^+e^-} &\quad 4.1 \pm 1.0 \pm 0.6 & 4.9 \pm 1.3 \pm 0.6 \\
M_{Y(4660)} &\quad 4660 \pm 9 \pm 12 & 74 \pm 12 \pm 4 \\
\Gamma_{Y(4660)} &\quad 9.3 \pm 1.2 \pm 1.0 & 2.4 \pm 0.5 \pm 0.3 \\
\mathcal{B} \cdot \Gamma_{Y(4660)}^{e^+e^-} &\quad 2.2 \pm 0.4 \pm 0.2 & 8.4 \pm 0.9 \pm 0.9 \\
\phi_1 (^{\circ}) &\quad 304 \pm 24 \pm 21 & 294 \pm 25 \pm 23 & 130 \pm 4 \pm 2 & 141 \pm 5 \pm 4 \\
\phi_2 (^{\circ}) &\quad 26 \pm 19 \pm 10 & 238 \pm 14 \pm 21 & 329 \pm 8 \pm 5 & 117 \pm 23 \pm 25
\end{align*}

- Significance of \( Y(4260) \) is 2.4\( \sigma \)—low, but affects the parameters of \( Y(4360) \) and \( Y(4660) \)!
- FOUR solutions with equally good fit quality, which is \( \chi^2/ndf = 14.8/19 \).
- Fit w/o \( Y(4260) \):
  - \( M_{Y(4360)} = 4347 \pm 6 \pm 3 \text{ MeV}/c^2, \Gamma_{Y(4360)} = 103 \pm 9 \pm 5 \text{ MeV} \);
  - \( M_{Y(4660)} = 4652 \pm 10 \pm 11 \text{ MeV}/c^2, \Gamma_{Y(4660)} = 68 \pm 11 \pm 5 \text{ MeV} \).
Sensitivity study: $Y(4360)/Y(4660) \to \pi^+\pi^-\psi(2S)$

Search for and study the intermediate states of the decays

$Z_c(4050)\pm \to \pi^±\psi(2S)$ 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: $> 3.5\sigma$

$Z_c(3900)\pm$

- $M = 3894.5 \pm 6.6 \pm 4.5$ MeV/$c^2$
- $\Gamma = 6 \pm 24 \pm 26$ MeV

$Z(4430)\pm$ in B decays

Belle with ISR: PRL100, 142001(2008)

PRL91, 112007(2015)

$M_{\max}[\pi\psi(2S)]$ (GeV/$c^2$)

Events/20 MeV/$c^2$

Belle with ISR: PRL110, 252002(2013)
Sensitivity study: $Y(4360)/Y(4660) \rightarrow \pi^+\pi^-\psi(2S)$

Structure of $Y(4660)$

- $f_0(980)$ dominates in $Y(4660)$ decay, which is quite different to other $Y$ states.
- 10 $ab^{-1}$ data sample can yield 10 times number of signals.
- Searching for intermediate state like $Z_c(4050)^\pm$ in $Y(4360)$ decay is possible.

PRD91, 112007(2015)
Scan on $e^+e^- \to K^+K^-J/\psi$

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.
ISR simulation at Belle II

Preliminary study

PHOKHARA generator is used to do the ISR simulation at Belle II.

**Y(4360) mass**

- @Belle II

**ISR characteristics**

- @Belle II

**M_{\pi^+\pi^-} in Y(4360) decay**

- @Belle II

More studies are ongoing.
Summary

- ISR is a successful story at Belle, a lot of results were obtained.
- Belle II is going to take data in 2018, and we are going to get a huge data sample, which can be used for ISR studies again.
- The schedule of Belle II is ongoing well.
- With about \(10 \text{ ab}^{-1}\) data, Belle II plans to study \(e^+e^- \rightarrow \text{charmonium+light hadrons and charm meson pair+light hadrons.}\)
- There are still problems in some studies, such as \(e^+e^- \rightarrow \pi^+\pi^- J/\psi, \pi^+\pi^- \psi(2S), K^+K^- J/\psi, \eta J/\psi, \text{etc.}\)
- The nature of exotic states should be clear via studying with Belle II data.

Thank you!
Backup
Initial State Radiation

Advantages:

- Cover a wide region below the $E_{cm}$ of collider smoothly. Good for broad structures.
- Avoid the point-to-point systematic error.
- Low beam-wall and beam-gas backgrounds.
- The $J^{PC}$ of final state is still $1^{--}$.

Disadvantages:

- Low effective luminosity, especially when $\sqrt{s}$ is far away from $E_{cm}$ of the collider.
- Low efficiency because $\gamma_{ISR}$ and its recoil CMS fly along the $e^+e^-$ beams.
- $\gamma_{ISR}$ has very high energy and not very good resolution.
SuperKEKB can exceed the peak luminosity of KEKB when we achieve $\xi_y > 0.05$.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Phase 2.2 (8x8)</th>
<th>Phase 2.3 (4x8)</th>
<th>Phase 2.4 (4x4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_x \times L_y$, $n_b$</td>
<td>1000 mA x 800 mA, 1576 bunches (3-bucket spacing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_x^*$ [mm]</td>
<td>256</td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>$\beta_y^*$ [mm]</td>
<td>2.16</td>
<td>2.16</td>
<td>1.08</td>
</tr>
<tr>
<td>$\varepsilon_y/\varepsilon_x$ [%]</td>
<td>5.0</td>
<td>1.4</td>
<td>0.7*</td>
</tr>
<tr>
<td>$\xi_x$</td>
<td>0.0104</td>
<td>0.0053</td>
<td>0.0053</td>
</tr>
<tr>
<td>$\xi_y$</td>
<td>0.0257</td>
<td>0.0484</td>
<td>0.0496</td>
</tr>
<tr>
<td>$I_{bunch}$ [mA]</td>
<td>0.64</td>
<td>0.64</td>
<td>0.64</td>
</tr>
<tr>
<td>$L$ [$cm^2s^{-1}$]</td>
<td>$1 \times 10^{34}$ (tentative target)</td>
<td>$2 \times 10^{34}$</td>
<td>$4 \times 10^{34}$</td>
</tr>
<tr>
<td>$L_{sp}$ [$cm^2s^{-1}$/mA]</td>
<td>$1.97 \times 10^{31}$</td>
<td>$3.94 \times 10^{31}$</td>
<td>$7.88 \times 10^{31}$</td>
</tr>
</tbody>
</table>

* conserve $\beta_y^*/\varepsilon_y$.
Cosmic ray run (June, 2017)

- Systems included: CDC, TOP, ECL, KLM
- Magnetic field: 1.5T
Phase II

Belle II roll in, 11/4/2017

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

Commissioning of accelerator and sub-detectors

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

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

- Readout integration of installed sub-detectors and central DAQ is in progress.
- Control room built; shift started
- Combined data taking established, though low rate
More about Belle II

**Readout (TRG, DAQ)**

- Max. 30kHz L1 trigger \(\sim\) 100% efficient for hadronic events.
- 1MB(PXD) + 100kB(others) per event \(\rightarrow\) over 30GB/sec before reduction, 2-3GB/s to record (&further compression offline)

**Offline computing:**

- A globally-distributed computing and data-storage system via GRID.