Belle II - Status and Prospects

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On behalf of the

Belle II Collaboration

Bound states in QCD and beyond III | St. Goar, Germany | 9th - 12th April 2019

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Belle II

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JG|U

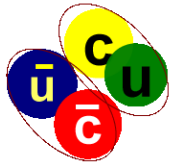
QCD – As You Like It

Pentaquark

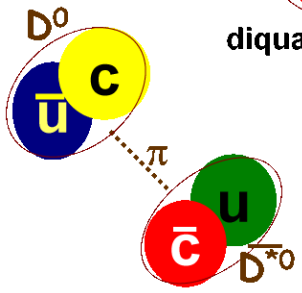
Tetraquark

Glueball

Hybrid meson



diquark-diantiquark



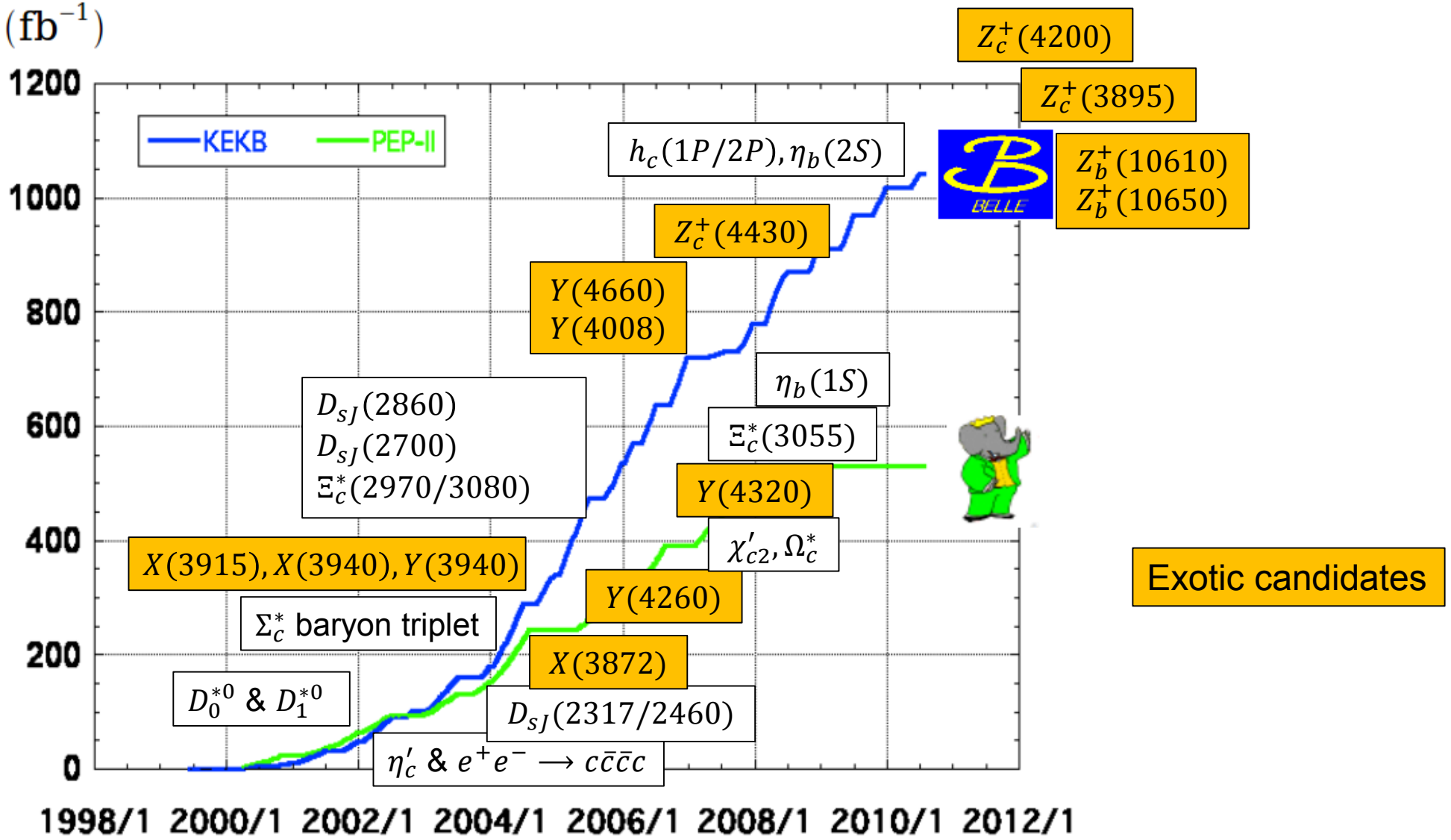
$D^0 - \bar{D}^{*0}$ "molecule"

H-dibaryon

Normal baryon

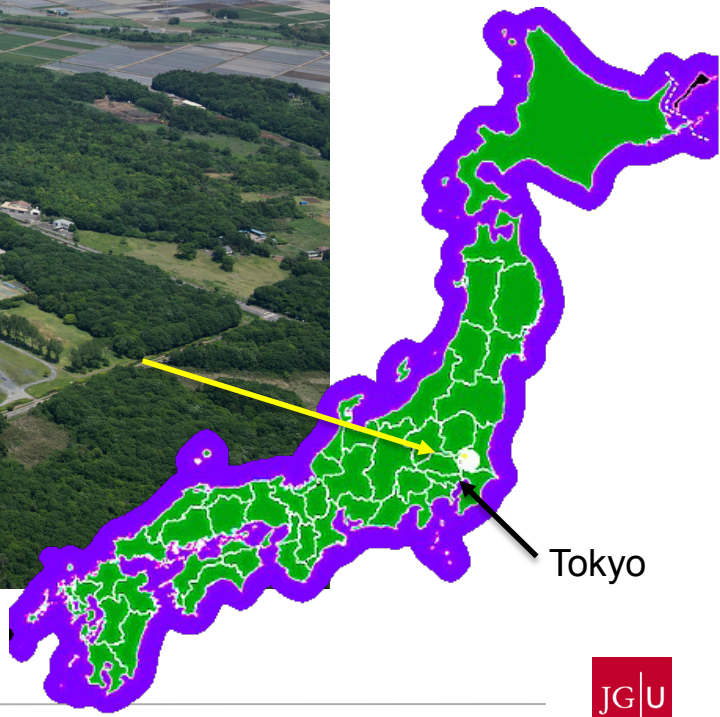
Normal meson

New Hadrons at 1st Generation B-Factories

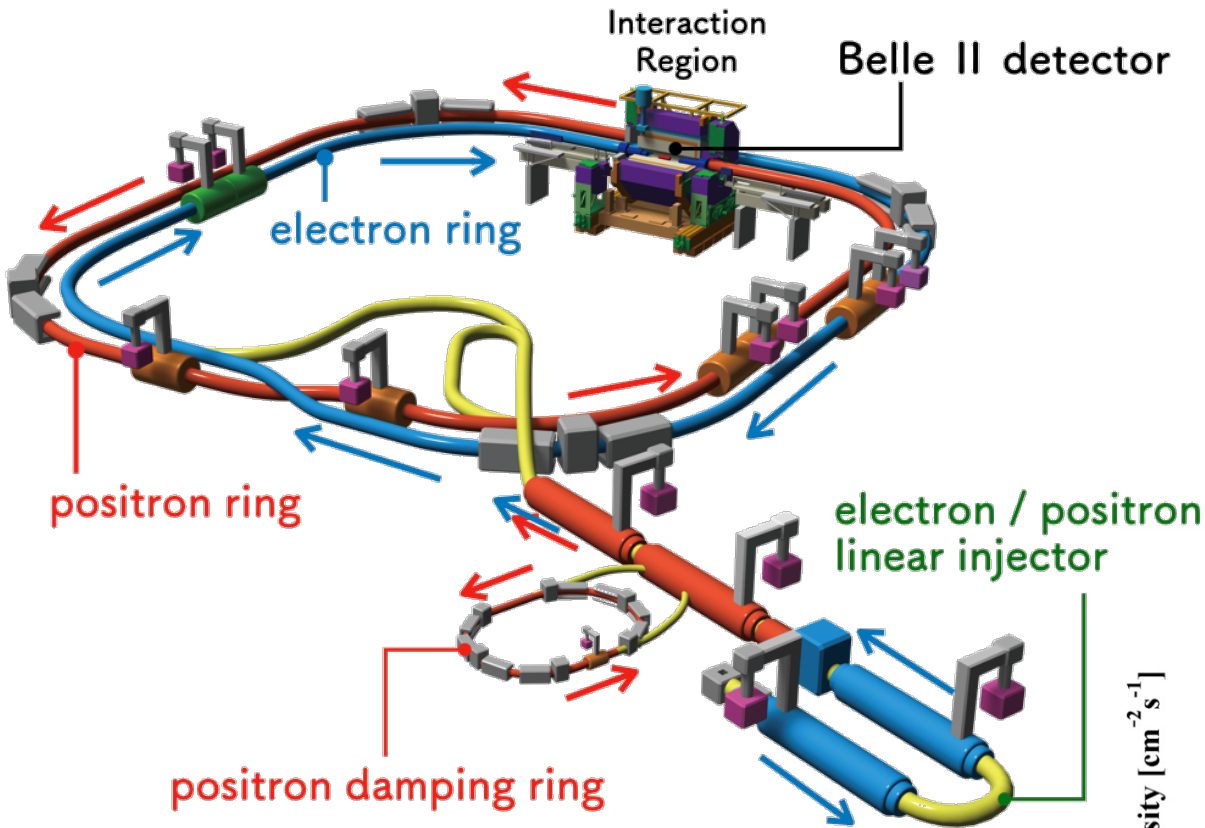


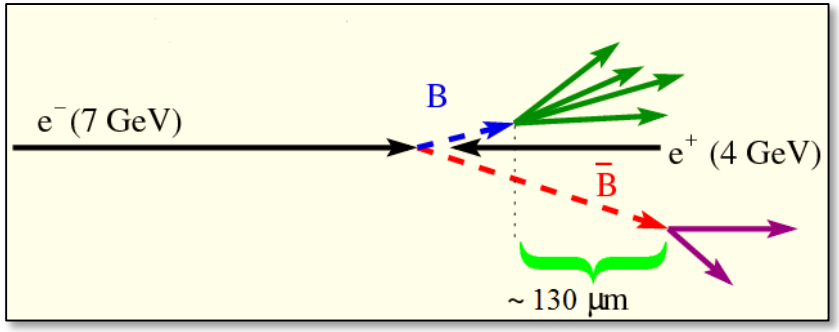
Exotic candidates

Where the Future starts – KEK (Tsukuba, Ibaraki)

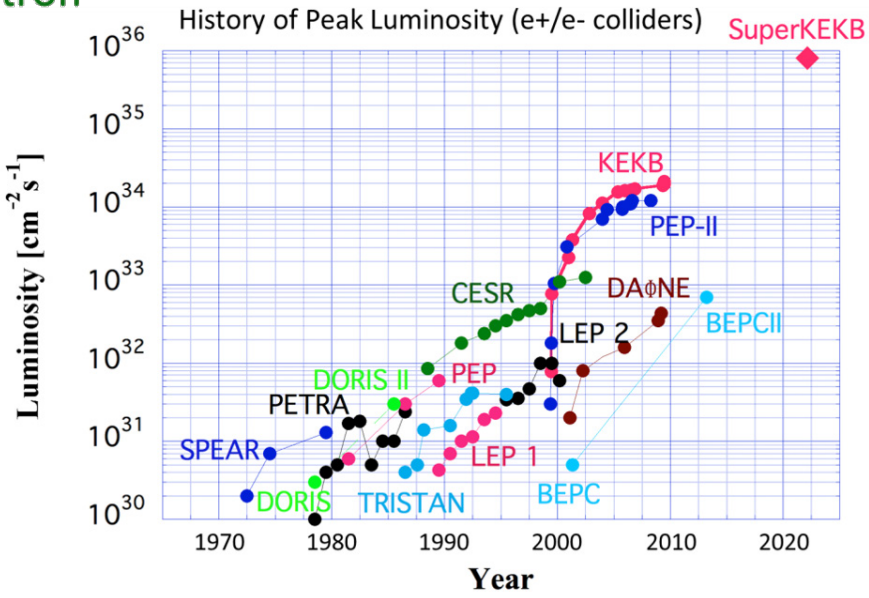


SuperKEKB - Overview

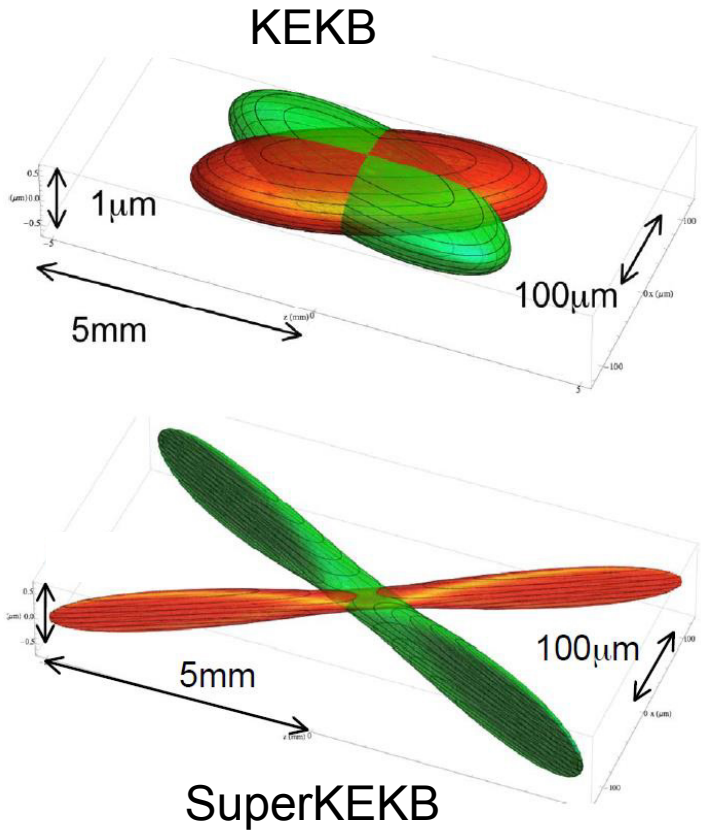


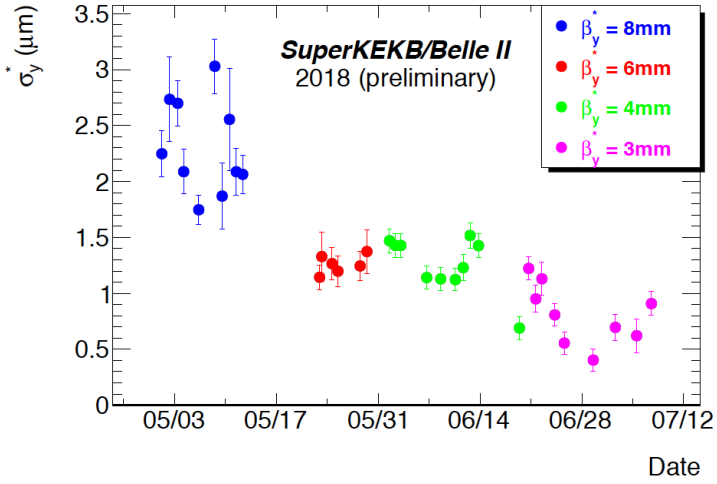


- Asymmetric e^+e^- collider
  - 7 GeV e^- (2.6A)
  - 4 GeV e^+ (3.6A)
- 40 times KEKB luminosity
  - $\mathcal{L} = 8 \times 10^{35} cm^{-2} s^{-1}$



SuperKEKB – Increasing Luminosity





	E (GeV) LER/HER	β^*_y (mm) LER/HER	β^*_x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1×10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80×10^{34}

Belle II Detector - Overview

Pixel Detector (PXD)

Silicon Vertex Detector (SVD)

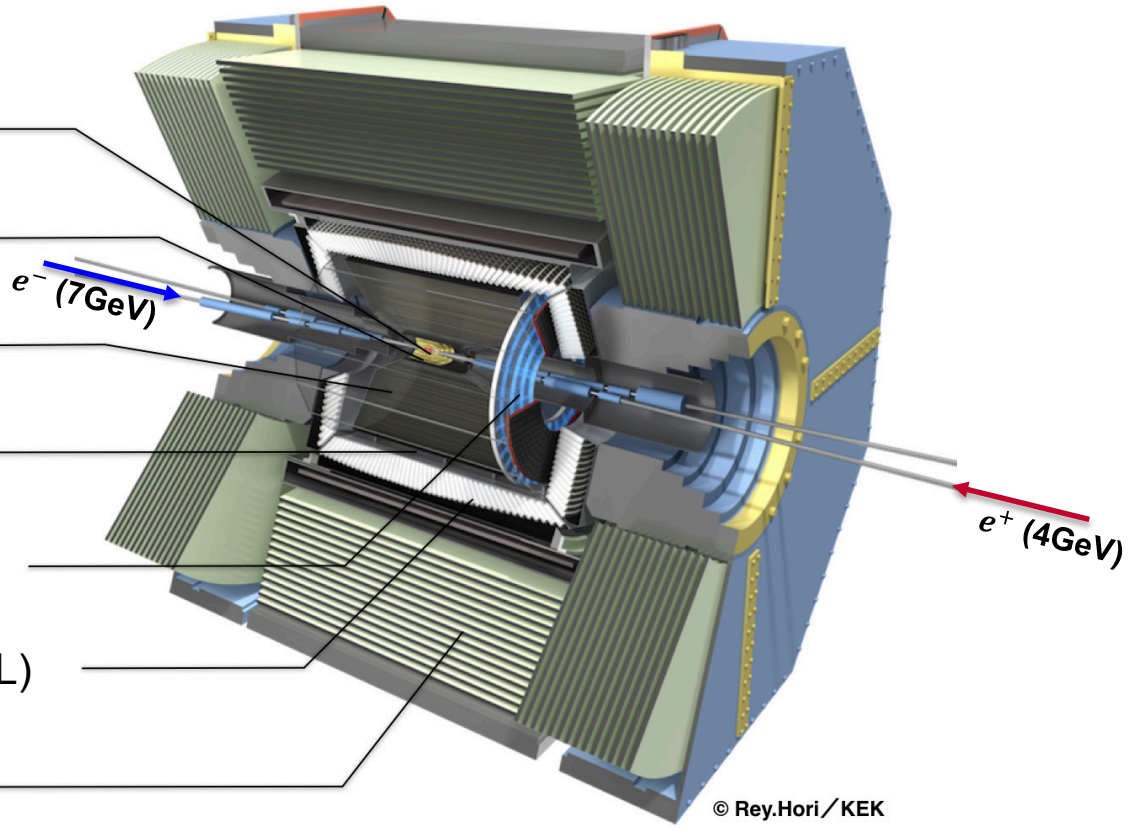
Central Drift Chamber (CDC)

TOP counter (TOP)

Aerogel RICH counter (ARICH)

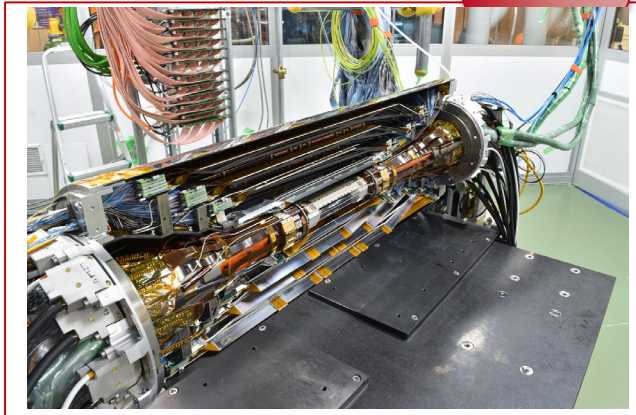
Electromagnetic Calorimeter (ECL)

K_L^0/Muon Detector (KLM)



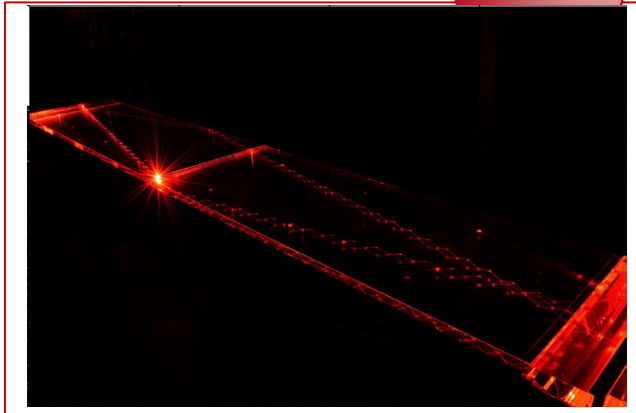
Belle II Detector – New Developments

VXD



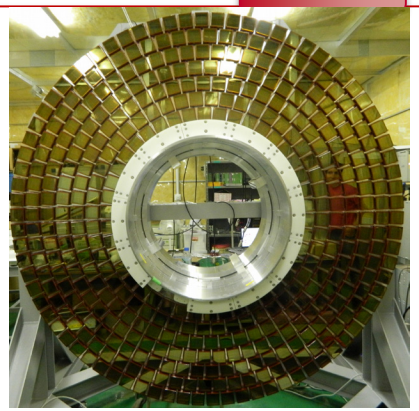
- PiXel Detector
  - Two layers DEPFET
  - $75\mu m$ thickness
  - ~0.19% X_0
- Silicon Vertex Detector
  - Four layers DSSD
  - ~0.7% X_0
- CO_2 cooling
- Improve resolution by factor 2

TOP



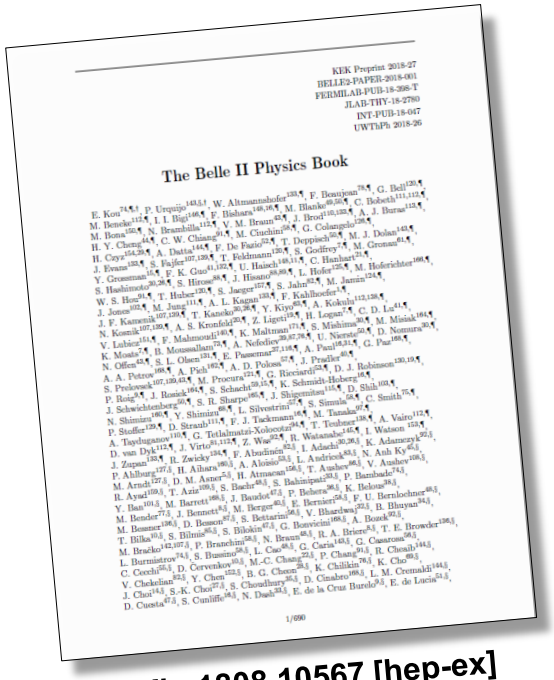
- Time-of-Propagation Cherenkov counter
  - 2D + Time
- Extreme timing precision
  - ~100ps single photon
- Fused Silica radiator
- MCP-PMT photo sensors
- Sampling readout + feature extraction
  - IRSX ASIC

ARICH



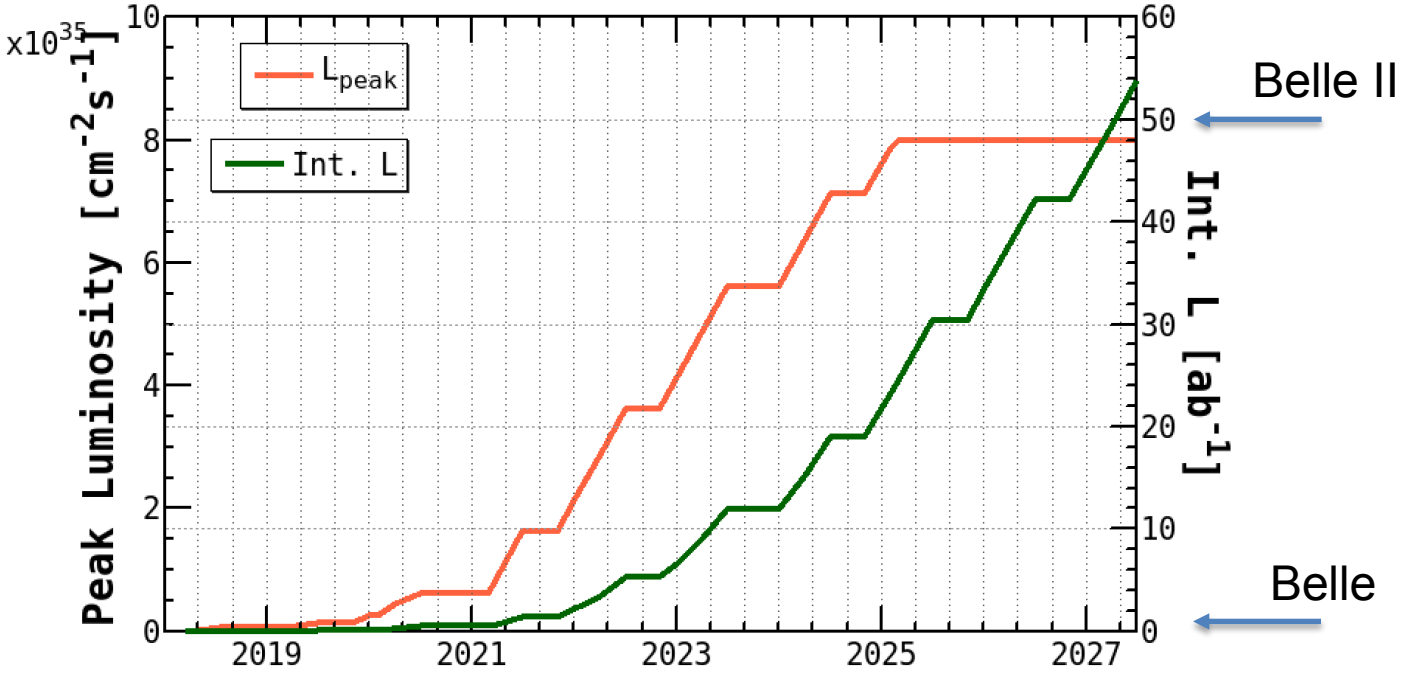
- Aerogel RICH with novel "focussing" radiator
  - Different Aerogel densities
- HAPD photo sensors for single-photon detection
- ~80k read-out channels
- Custom ASIC

Belle II Physics Plan


KEK Preprint 2018-27
BELLE2-PAPER-2018-001
FERMILAB-PUB-18-398-T
JLAB-THY-18-2780
INT-PUB-18-047
UWThPh 2018-26

The Belle II Physics Book

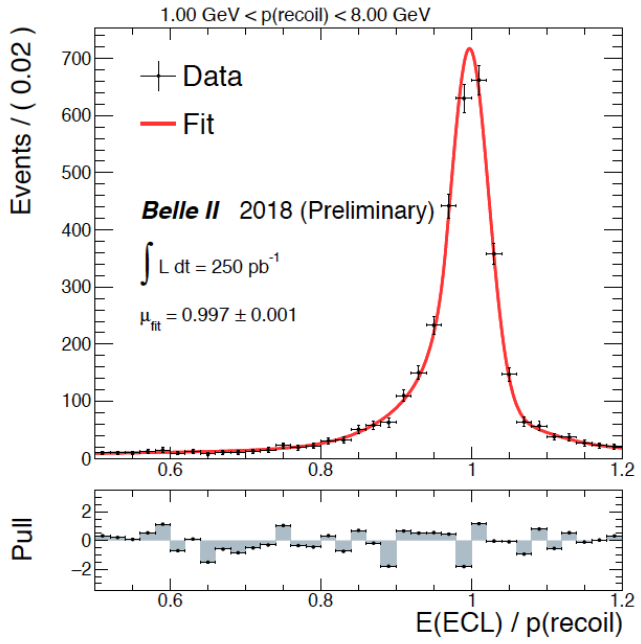
arXiv:1808.10567 [hep-ex]

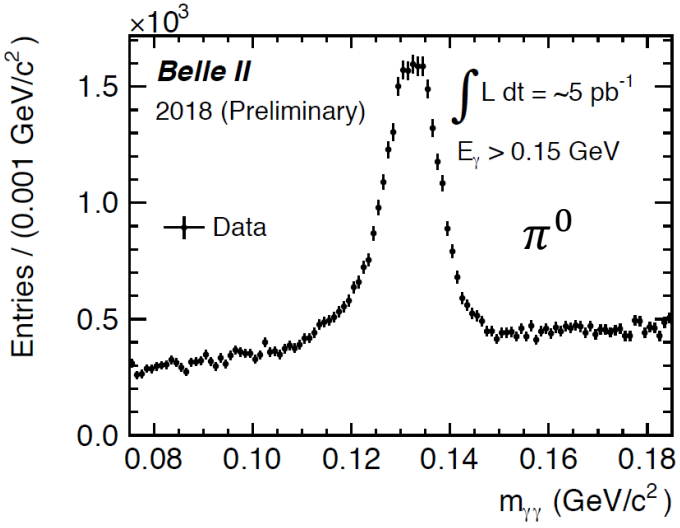


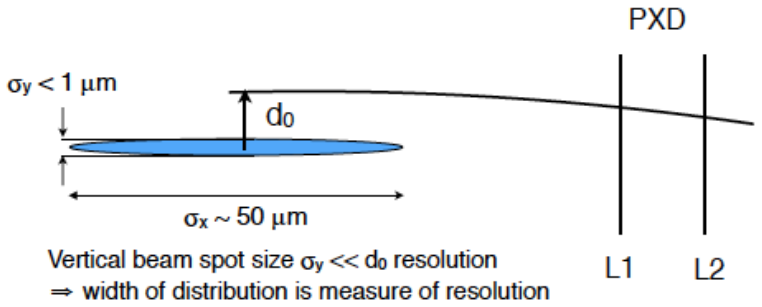
Current samples in fb^{-1} (millions of events), and the proposal for Belle II

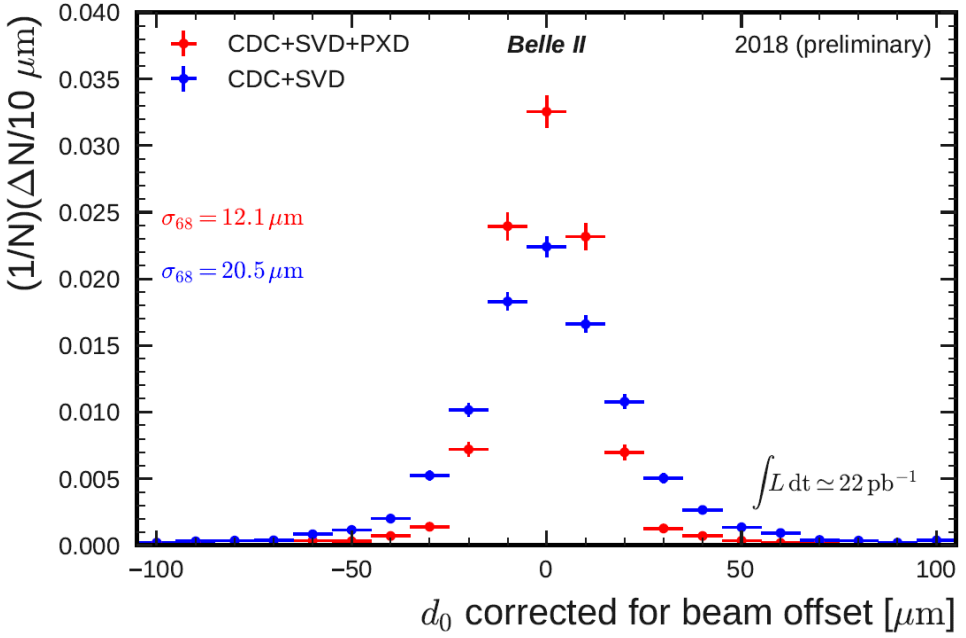
Experiment	$\Upsilon(1S)$	$\Upsilon(2S)$	$\Upsilon(3S)$	$\Upsilon(4S)$	$\Upsilon(5S)$	$\Upsilon(6S)$	$\frac{\Upsilon(nS)}{\Upsilon(4S)}$
CLEO	1.2 (21)	1.2 (10)	1.2 (5)	16 (17.1)	0.1 (0.4)	-	23%
BaBar	-	14 (99)	30 (122)	433 (471)	R_b scan	R_b scan	11%
Belle	6 (102)	25 (158)	3 (12)	711 (772)	121 (36)	5.5	23%
BelleII	-	-	300 (1200)	5×10^4 (5.4×10^4)	1000 (300)	100+400(scan)	3.6%

Results from Phase II – Detector Performance

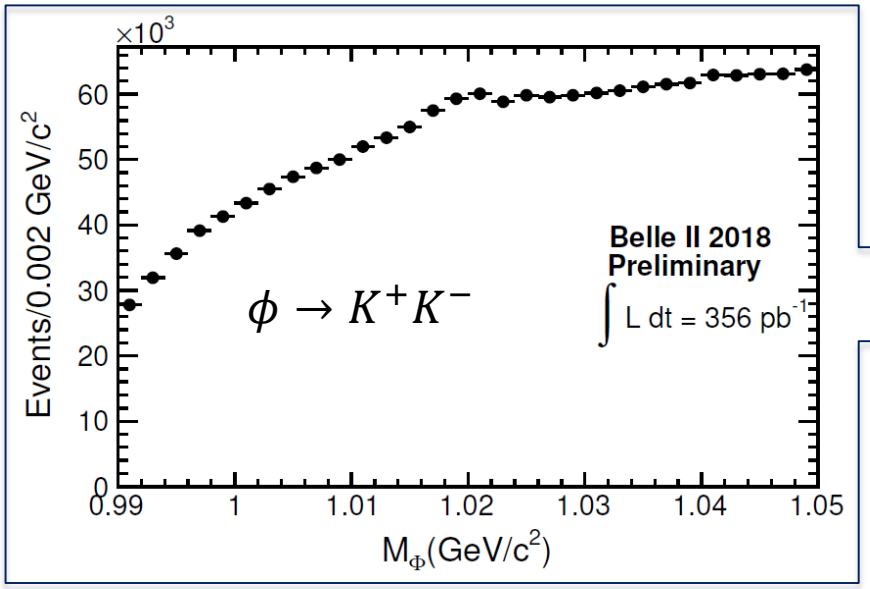


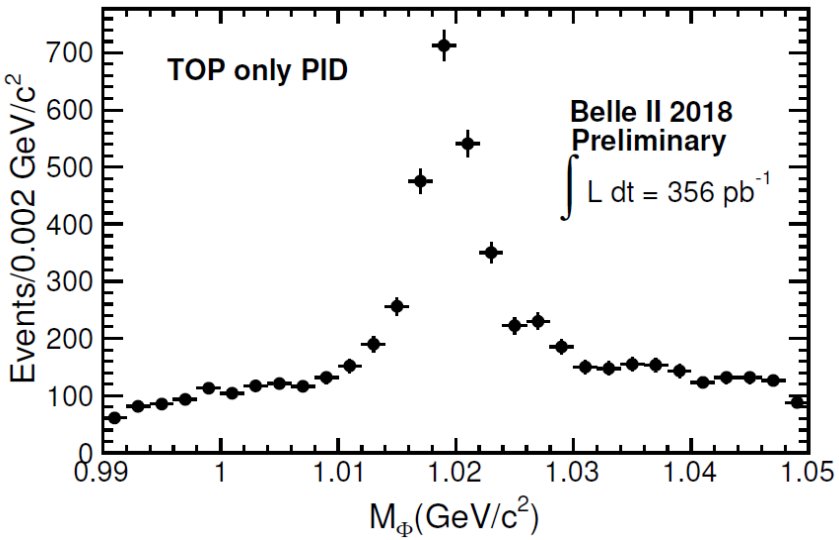


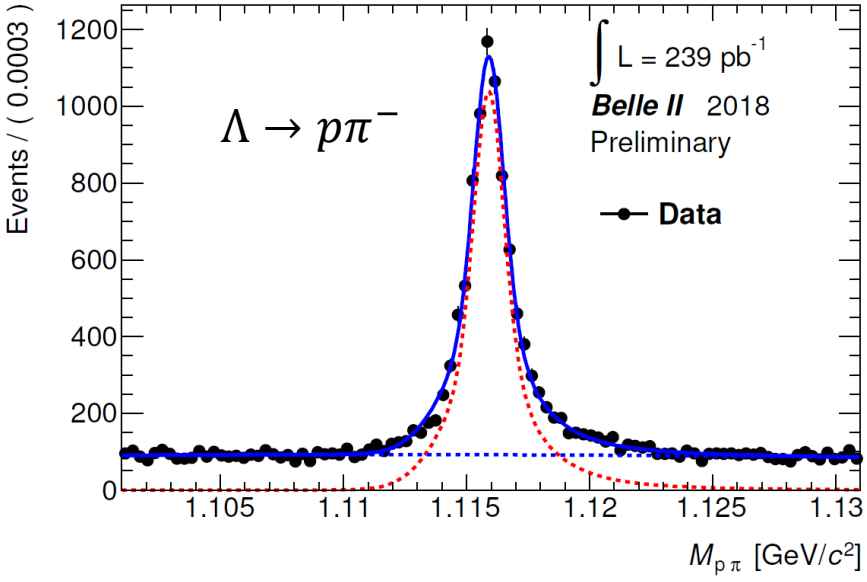


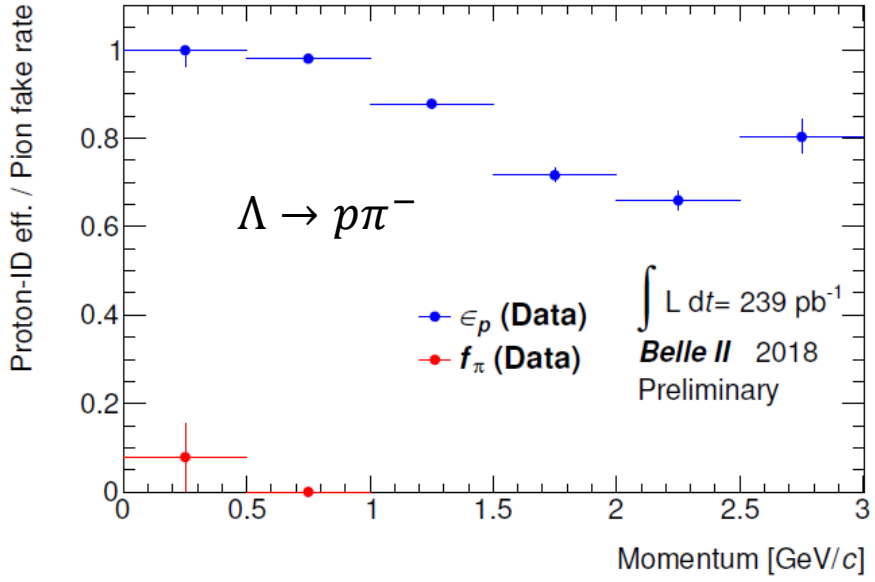


Results from Phase II – PID Performance

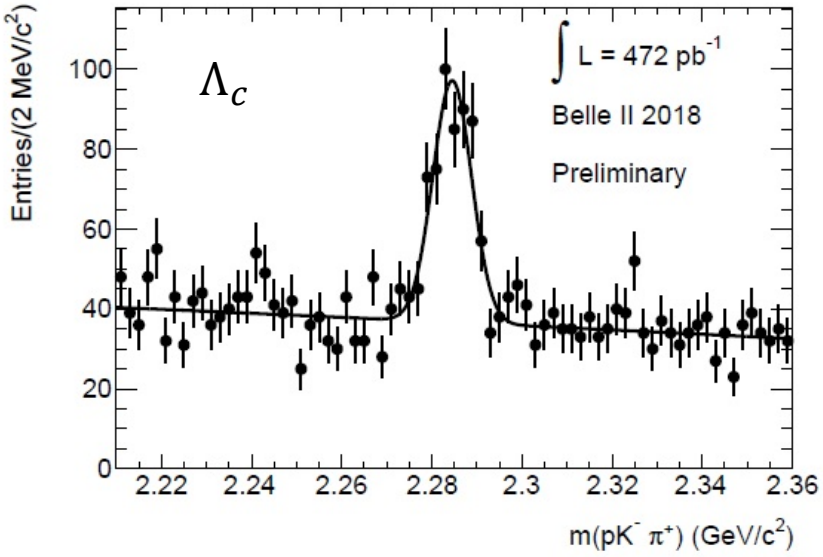


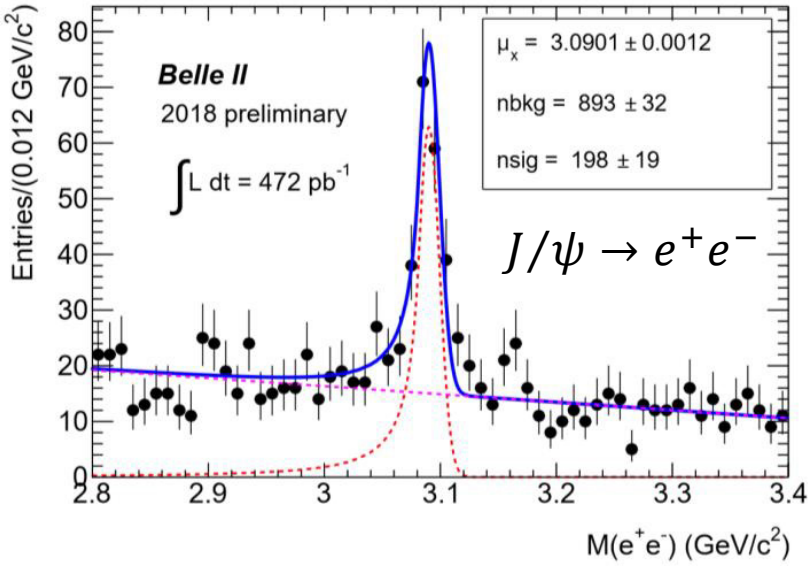


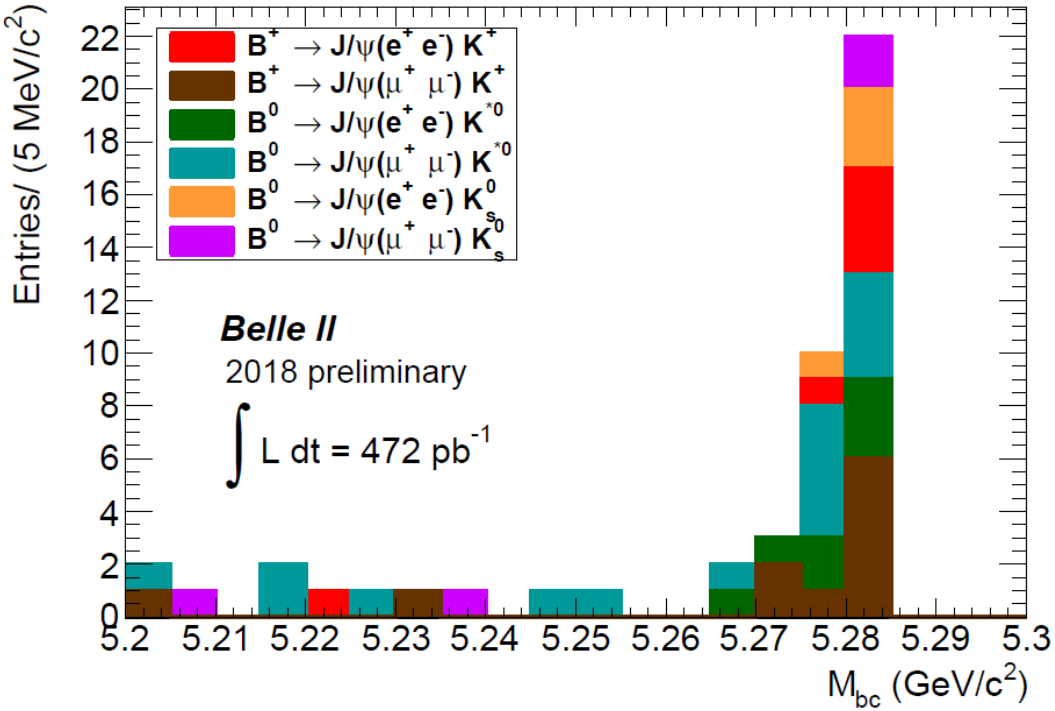




Results from Phase II – 'Rediscoveries'

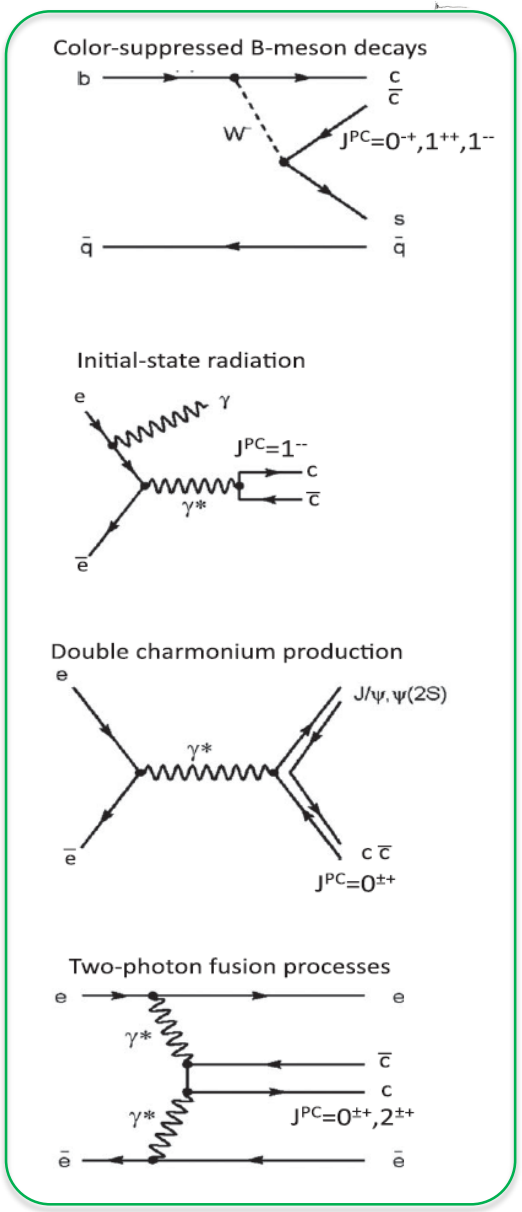






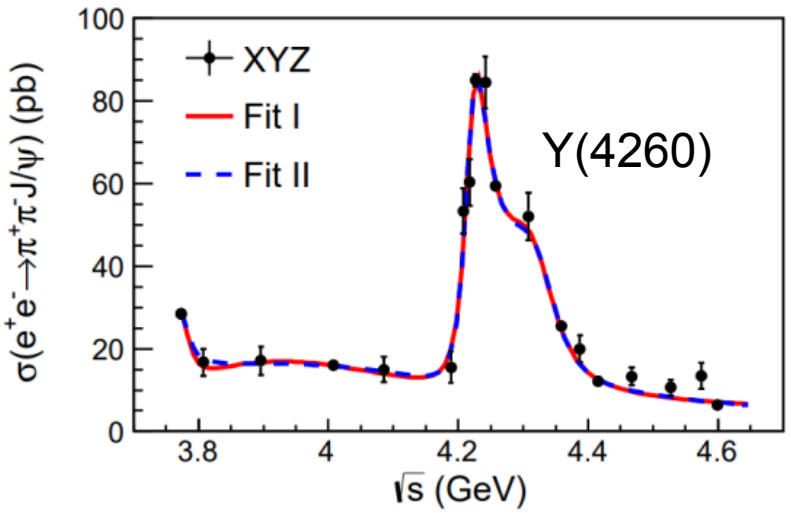
Quarkonium Production at B-Factories

- B decays
  - Charmonium only
  - All quantum numbers available
- Direct production / Initial State Radiation (ISR)
  - E_{CM} or below
  - $J^{PC} = 1^{--}$
- Double charmonium production
  - Absolute BR and cross sections
  - Seen for $J^{PC} = 1^{--}$ $(J/\psi, \psi(2S))$ plus $J = 0$ states
- Two-photon interaction
  - $J^{PC} = 0^{-+}, 0^{++}, 2^{++}$
- Quarkonium transitions
  - Hadronic/radiative decays between states



Charmonium at Belle II – ISR

- Access to line shape of vector states
- Y(4230), Y(4260), Y(4360) could all be explored
- Unexpected Y(4260) line-shape measured at BESIII, inconsistent among different modes. Could explore w/ ISR
- Cross sections of exclusive ($c\bar{c}$) + hadrons
- Search for strange partner of Z(3900) in K^+K^-J/ψ



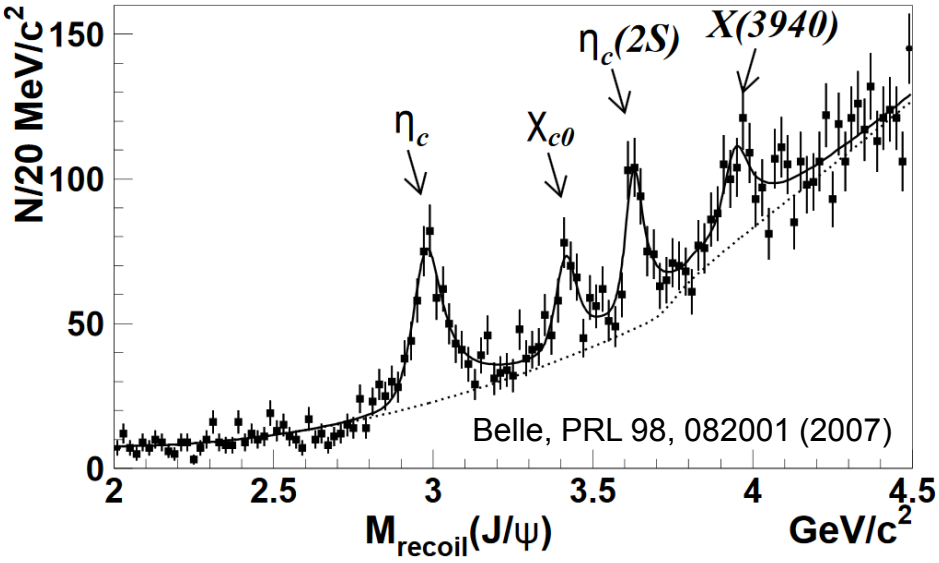
BES III, PRL 118, 092001 (2017)

Golden Channels	$E_{c.m.}$ (GeV)	Statistical error (%)	Related XYZ states
$\pi^+\pi^- J/\psi$	4.23	7.5 (3.0)	$Y(4008)$, $Y(4260)$, $Z_c(3900)$
$\pi^+\pi^-\psi(2S)$	4.36	12 (5.0)	$Y(4260)$, $Y(4360)$, $Y(4660)$, $Z_c(4050)$
$K^+K^- J/\psi$	4.53	15 (6.5)	Z_{cs}
$\pi^+\pi^- h_c$	4.23	15 (6.5)	$Y(4220)$, $Y(4390)$, $Z_c(4020)$, $Z_c(4025)$
$\omega\chi_{c0}$	4.23	35 (15)	$Y(4220)$

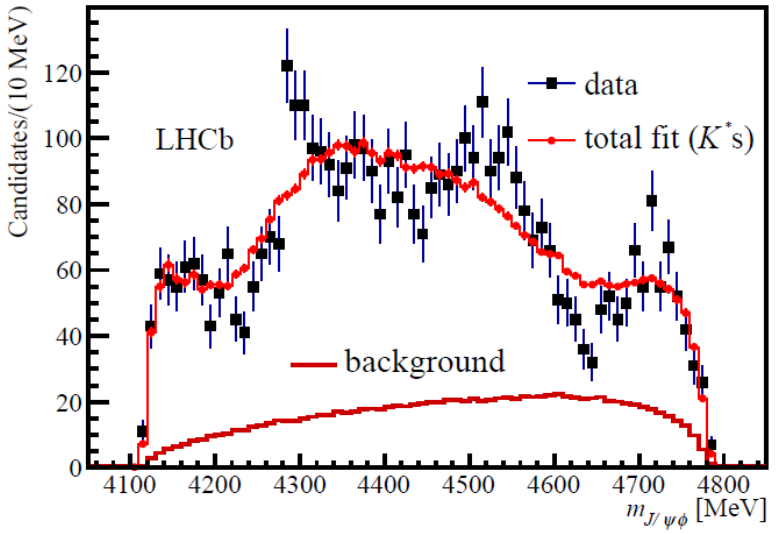
10ab^{-1} (50ab^{-1})

Charmonium at Belle II – Other Production Modes

- Double charmonium
  - Uniquely measurable at Belle II!
  - Absolute branching fractions.
  - Cross sections.
  - Spectroscopy



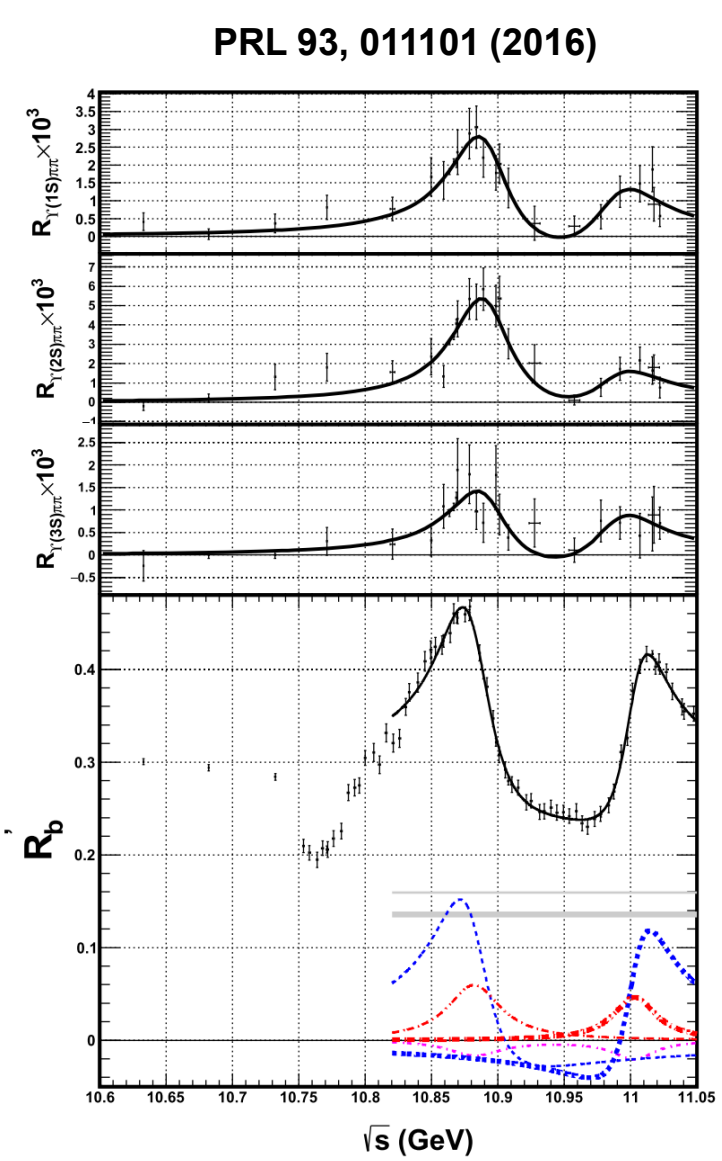
- Two photon
  - Also uniquely measurable at Belle II.
  - Could disentangle two of the four states seen by LHCb in $\phi J/\psi$



PRL 118, 022003 (2017)

In addition, B physics program will provide ~50x more data for expansion of studies in B → charmonium

Bottomonium at Belle II – Above $\Upsilon(4S)$

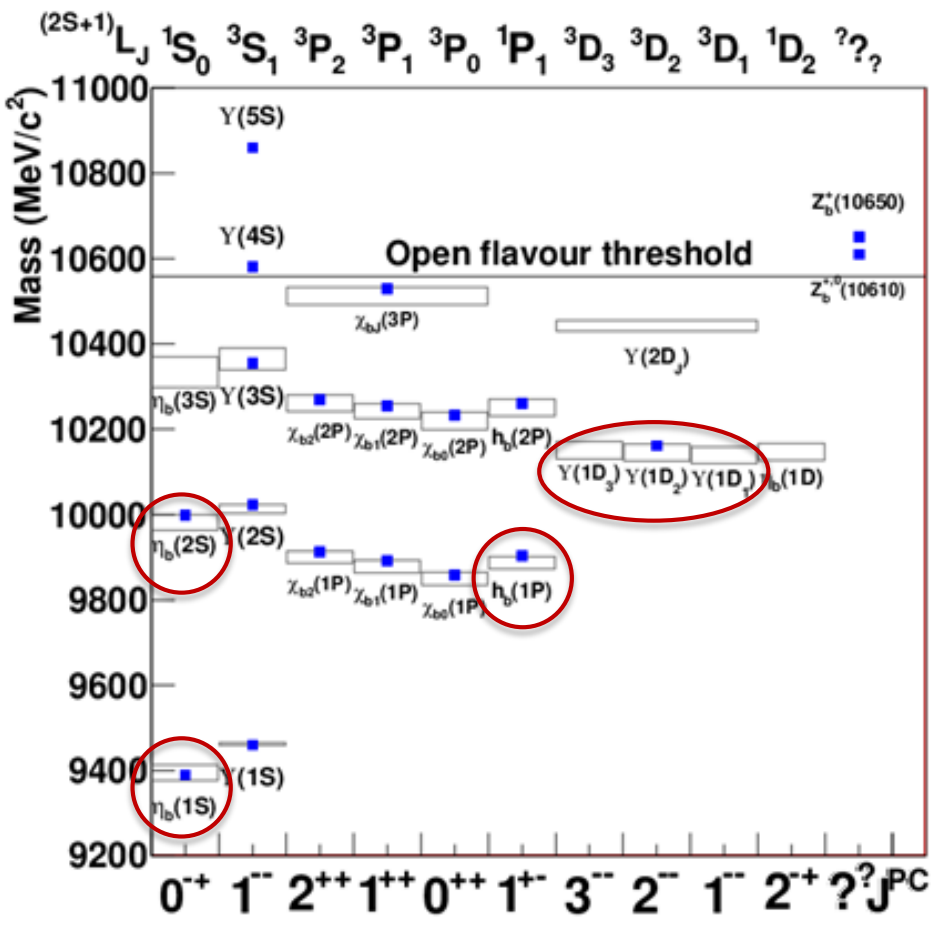


- Settle the nature of the $\Upsilon(5S)$!
- $\Upsilon(5S)$ line shapes
  - Apparent discrepancies in shape in $\pi\pi\Upsilon$ modes vs. $\pi\pi h$ modes
- Is Z_b above/below $B^{(*)}B^*$ threshold?
- $\Upsilon(5S)$ and $\Upsilon(6S)$ provide windows to search for missing narrow states in the bottomonium spectrum
  - Understand $\Upsilon(6S) \rightarrow Z_b$ decay
  - Evidence Z_b is a molecular state
  - Should have partners ("W_b ")

These runs require dedicated scans and/or samples on specific resonances!

Bottomonium at Belle II – Below $\Upsilon(4S)$

- Could collect 10-fold BaBar data set at $\Upsilon(3S)$ resonance
- Focus on conventional $b\bar{b}$ physics
  - $\Upsilon(1\ ^3D_J\ )$ triplet: discover $J = 1,3$
  - $\eta_b(1S, 2S)$: confirm $m(\eta_b(1S, 2S))$
  - Hadronic $(\pi^0, \pi^+\pi^-, \eta, \omega)$ decays
  - Radiative transitions
- Z_b^+ exotic contributions?

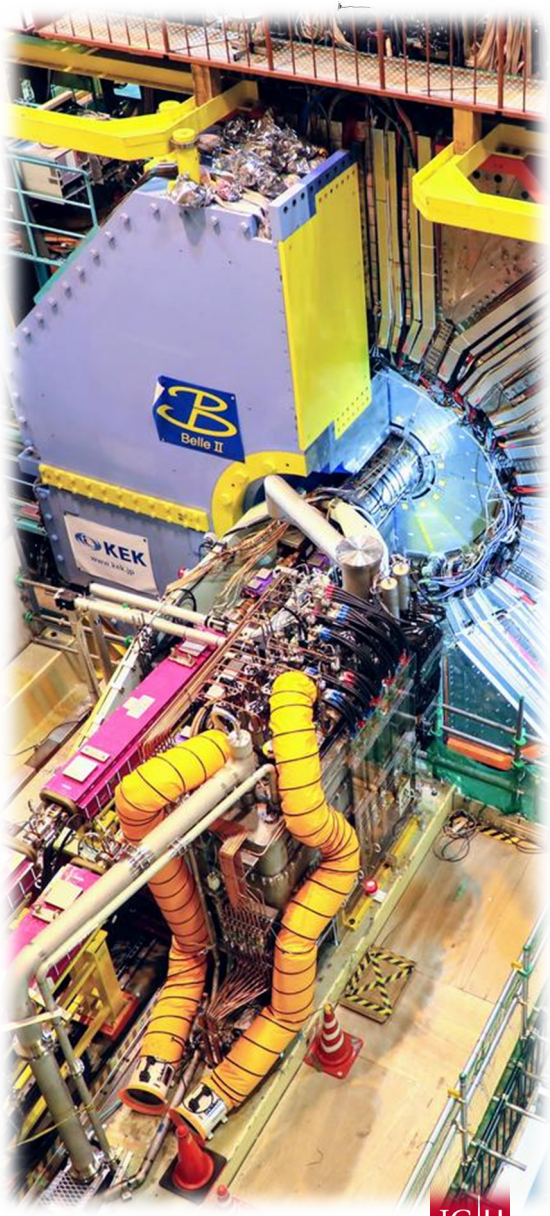


- Even more Exotics
  - Probing $\Lambda\Lambda$ interaction
  - Search for H dibaryon in missing mass from $\Upsilon(3S) \rightarrow H\ \Lambda\Lambda$ + hadrons
  - (Anti-)Deuteron production: Get the world best estimate of the coalescence parameter
- BSM-Physics (Dark Sector)

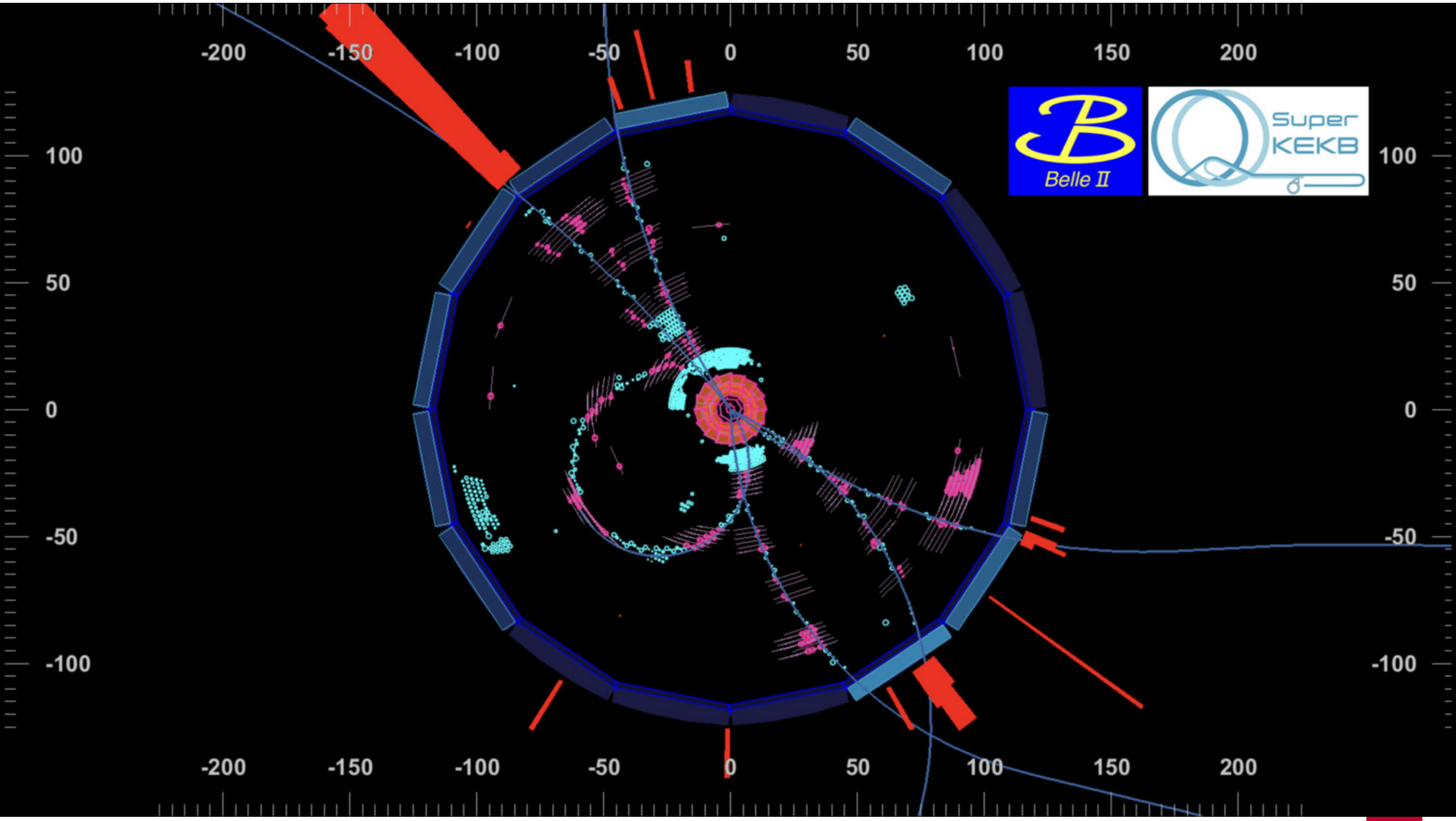
Conclusions

- SuperKEKB and Belle II Detector status
  - Detector installation finished
  - Phase 3 just started

- Belle II promises to collect a huge data sample in $\Upsilon(4S)$ but also increase data on others areas
- Search for New Physics via high-statistics precision measurement
- Potential for understanding exotic hadrons and quarkonium
- Unique production methods to probe charmonium(-like) system
- Only experiment able to address nature of bottomonium(-like) states
- BSM Searches in Dark Sector



Questions?


-200
-150
-100
-50
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50
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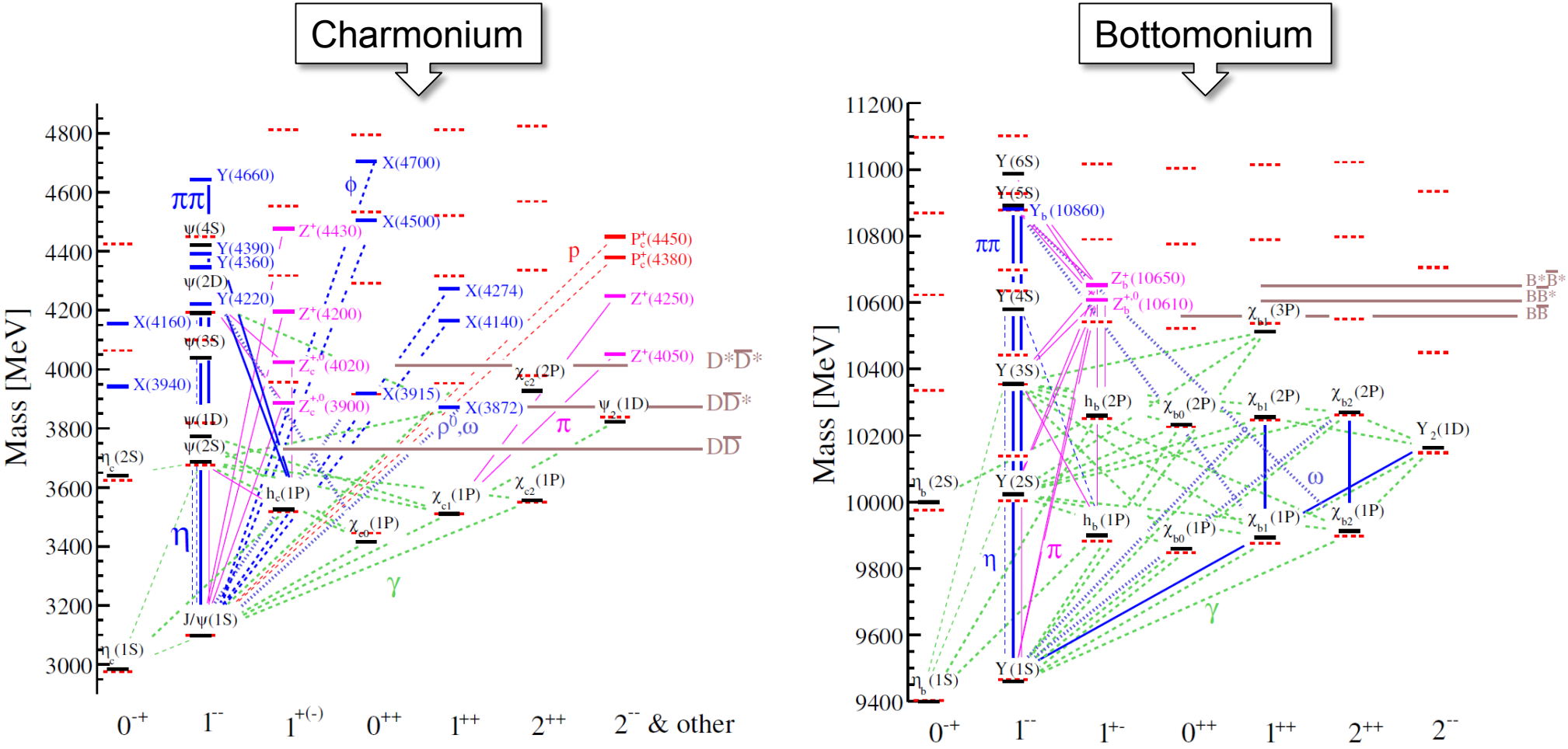
50
0
-50
-100
Belle II
Super KEKB

Backup Slides

Quarkonium Spectroscopy today



S. L. Olsen, T. Skwarnicki, and D. Zieminska, *Rev. Mod. Phys.*, Vol. 90, no. 1 (2018)