Vienna, September 16, 2014

Belle II and hadron spectroscopy

Peter Križan

University of Ljubljana and J. Stefan Institute

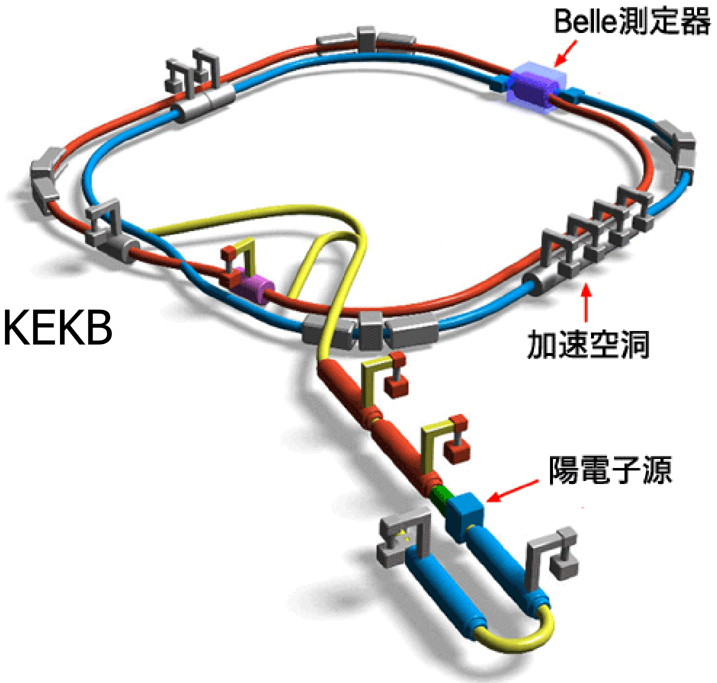
University of Ljubljana

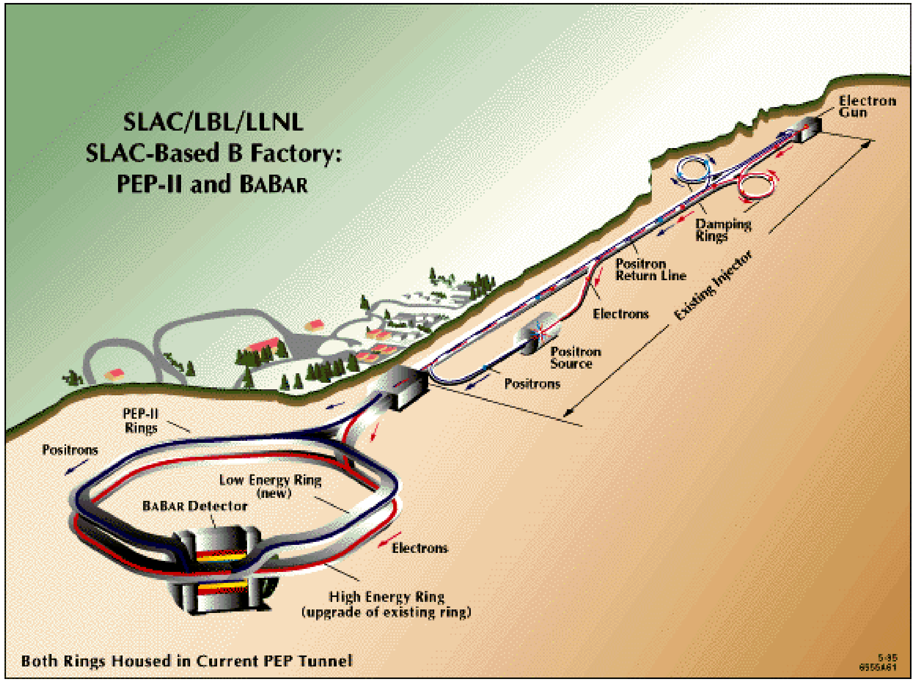
"Jožef Stefan" Institute

Contents

- B factories: contribution to hadron spectroscopy and searches for exotic states (selected topics)
- Super B factory: advantages
- Super B factory: accelerator and detectors
- Summary: status and outlook

Asymmetric B factories: flavour physics at the luminosity frontier





$\sqrt{s}=10.58$ GeV

$e^+ \rightarrow \Upsilon(4s) \leftarrow e^-$

$\Upsilon(4s) \rightarrow B\,\bar{B}$

$\Delta z \sim c\beta\gamma\tau_B \sim 200\mu m$

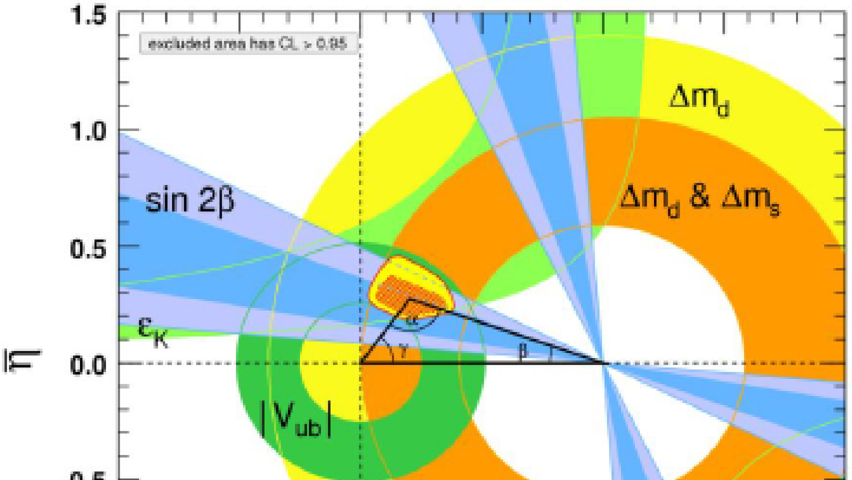
BaBar	$p(e^-)=9$ GeV	$p(e^+)=3.1$ GeV	$\beta\gamma=0.56$
Belle	$p(e^-)=8$ GeV	$p(e^+)=3.5$ GeV	$\beta\gamma=0.42$

To a large degree shaped flavour physics in the previous decade

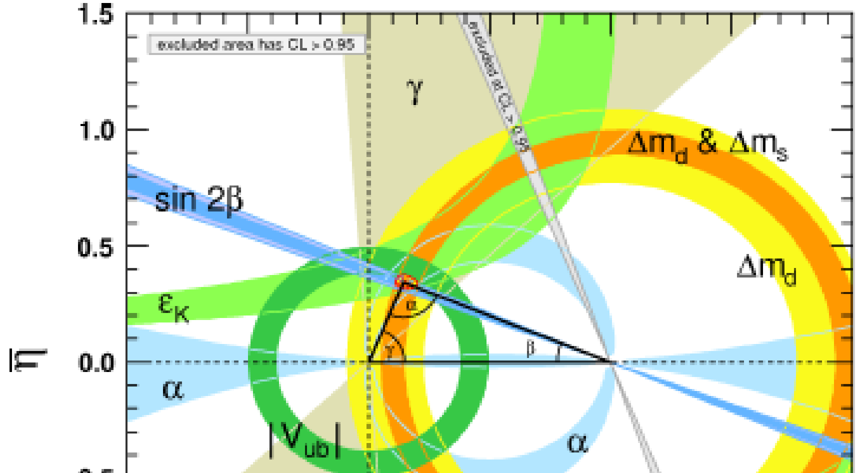
B factories: CP violation in the B system

CP violation in the B system: from the discovery (2001) to a precision measurement (2011).

EPS 2001



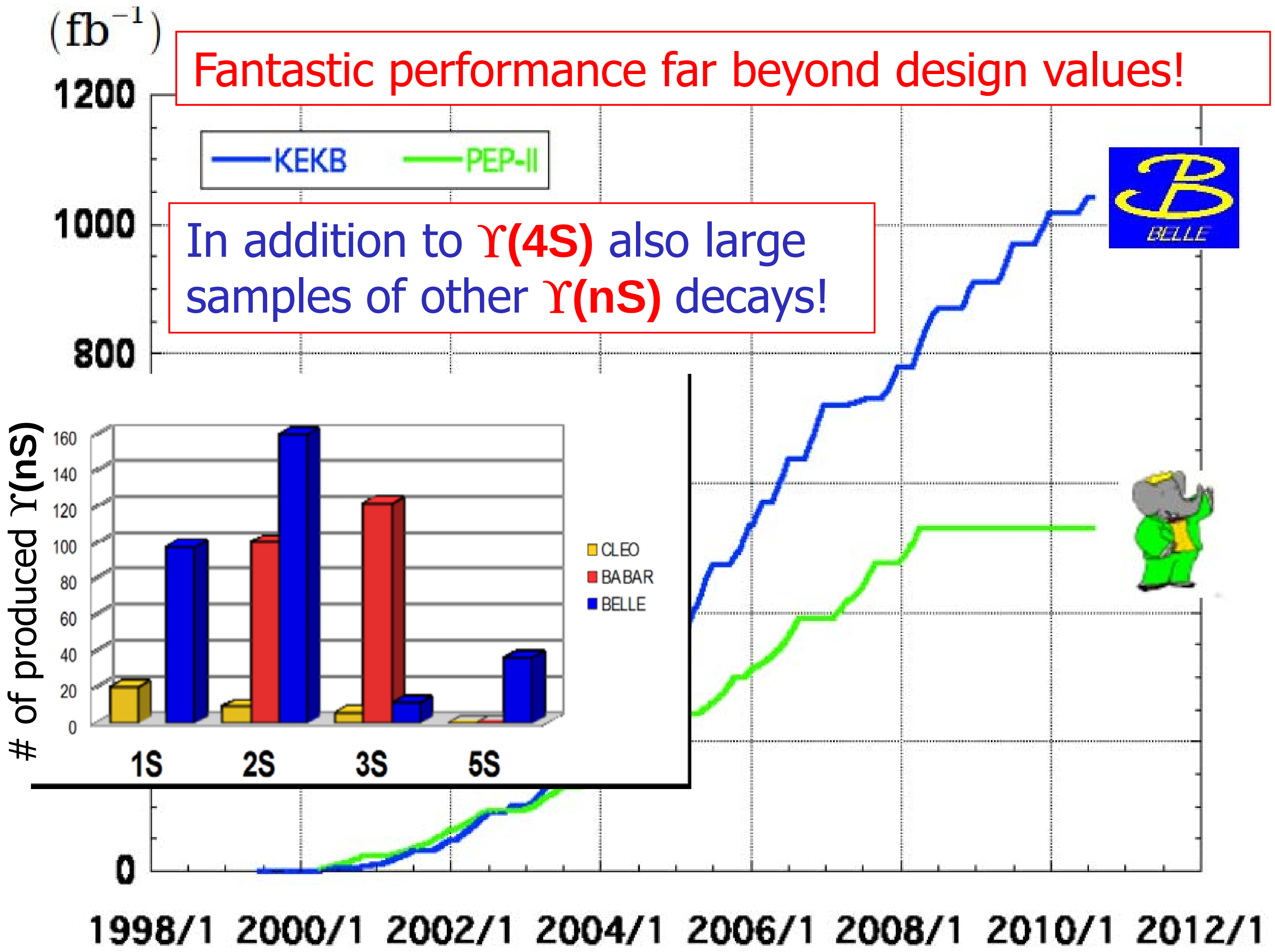
EPS 2011



B factories: a success story

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decay modes (e.g., $B \rightarrow \tau\nu$, $D\tau\nu$)
- $b \rightarrow s$ transitions: probe for new sources of CPV and constraints from the $b \rightarrow s\gamma$ branching fraction
- Forward-backward asymmetry (A_{FB}) in $b \rightarrow s l^+ l^-$
- Observation of D mixing
- Searches for rare τ decays
- Discovery of exotic hadrons including charged charmonium- and bottomonium-like states

Integrated luminosity at B factories



$> 1\ ab^{-1}$

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1}

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 25 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan:

$\sim 100\ fb^{-1}$

$\sim 550\ fb^{-1}$

On resonance:

$\Upsilon(4S)$: 433 fb^{-1}

$\Upsilon(3S)$: 30 fb^{-1}

$\Upsilon(2S)$: 14 fb^{-1}

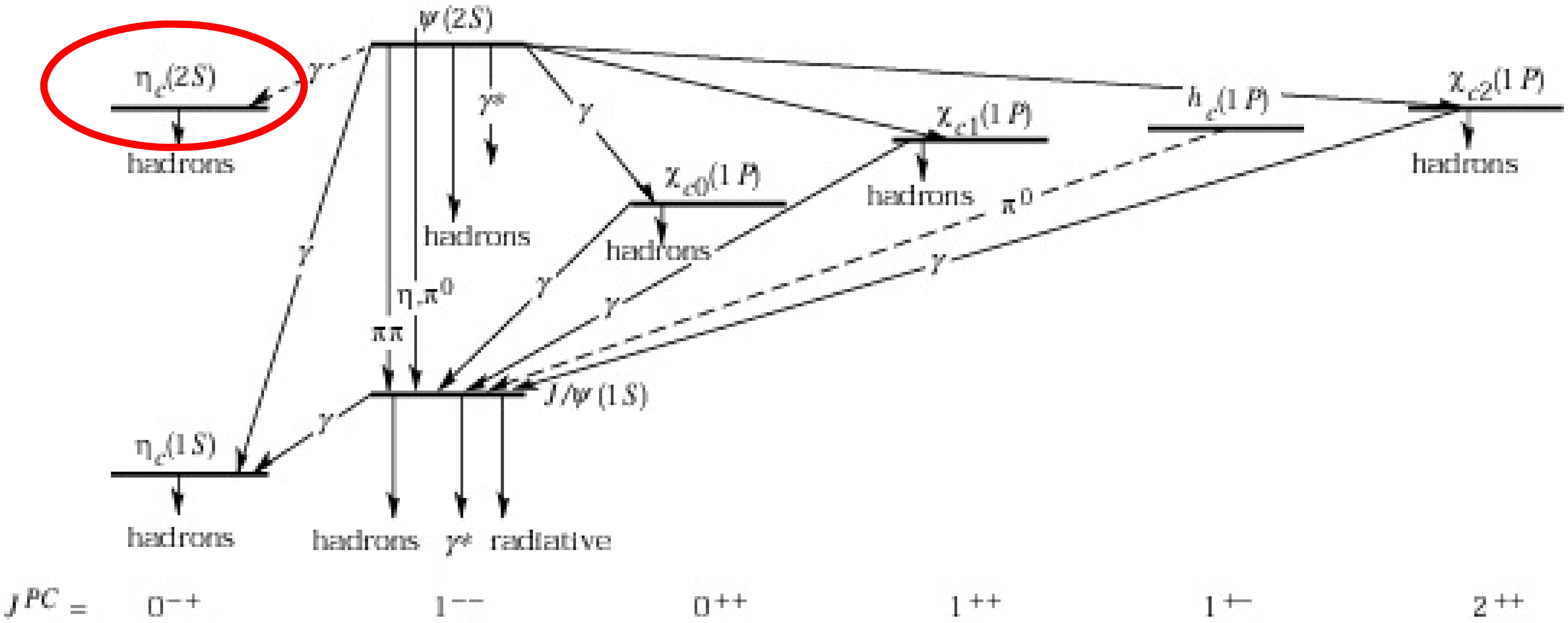
Off resonance:

$\sim 54\ fb^{-1}$

B factories and hadron spectroscopy

The series of discoveries started with the observation of the η_c' meson in $B \rightarrow K\,\eta_c'$ decays.

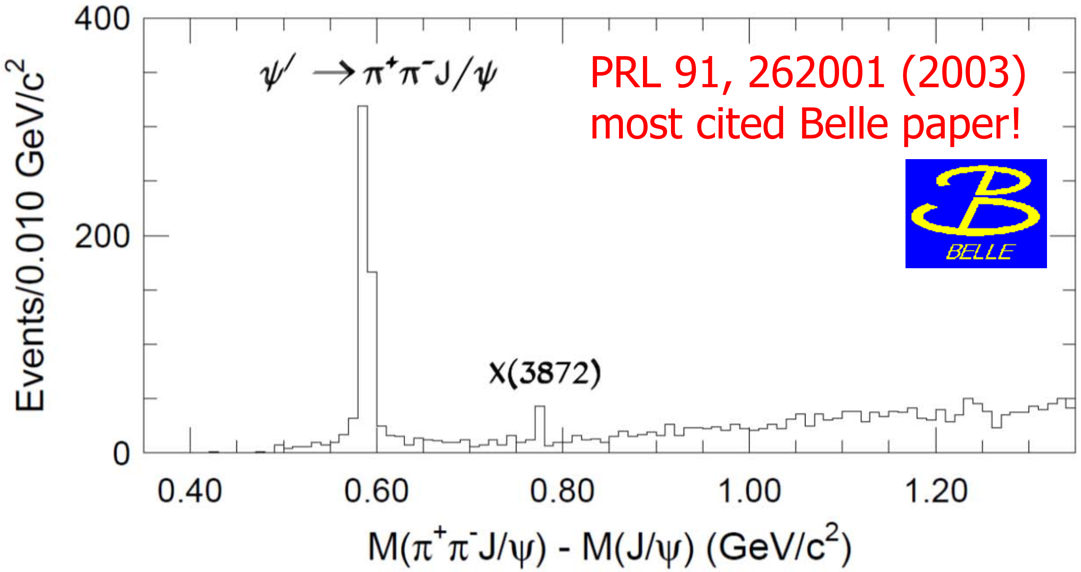
$\eta_c' = \eta_c(2S)$ the first radially excited state of para-charmonium



B factories and hadron spectroscopy

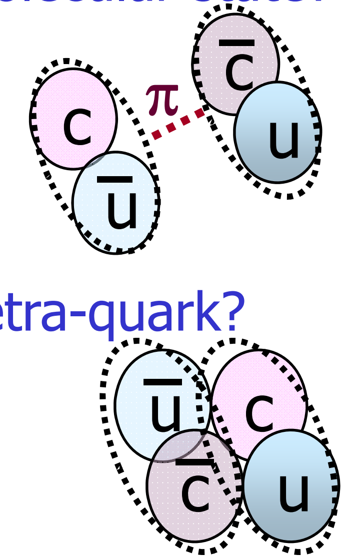
The series of discoveries started with the observation of the η_c' meson in $B \to K\ \eta_c'$ decays. →

The first exotic state was X(3872) – again found in $B \to K$ X(3872) decays



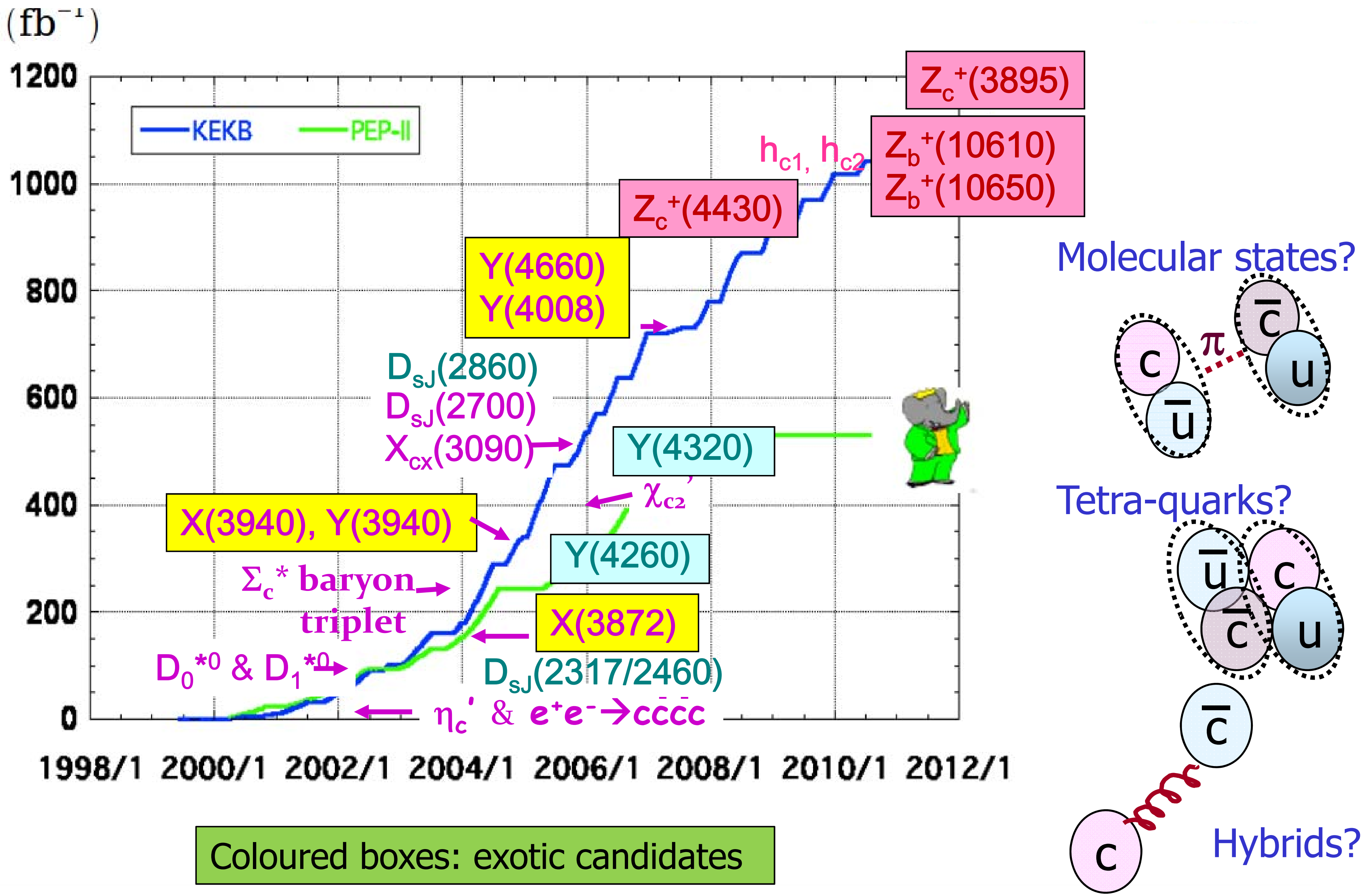
Molecular state?

Tetra-quark?



It turned out that we have just opened a door to a gold mine!

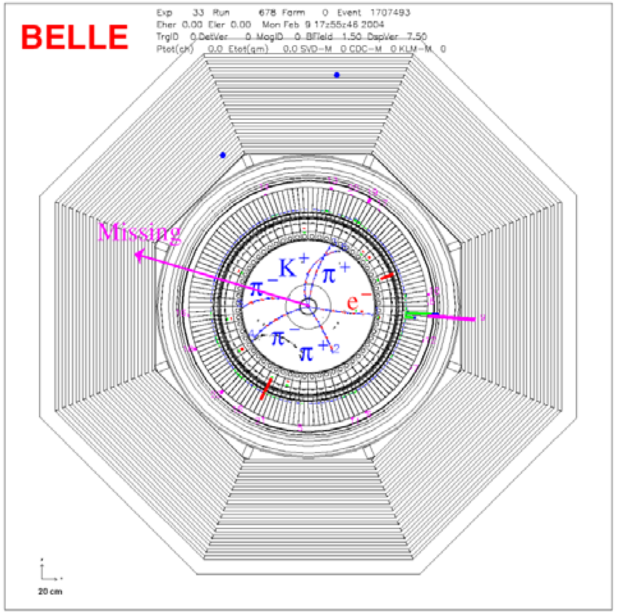
New hadrons at B-factories



Coloured boxes: exotic candidates

Advantages of B factories in the LHC era

$$B^+ \to D^0\pi^+$$
$$(\to K\pi^-\pi^+\pi^-)$$
$$B^- \to \tau(\to e\nu\bar{\nu})\nu$$



Unique capabilities of B factories:

→ Exactly two B mesons produced (at Υ(4S))

→ High flavour tagging efficiency

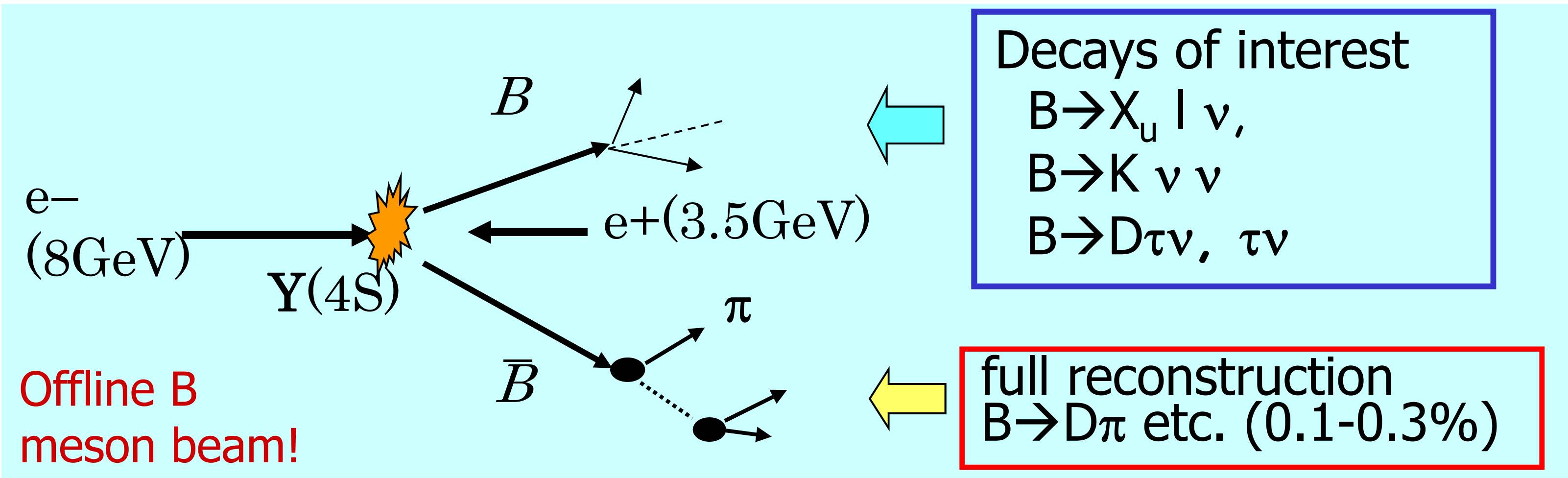
→ Detection of gammas, π^0s, K_Ls

→ Very clean detector environment (can observe decays with several neutrinos in the final state!)

→ Well understood apparatus, with known systematics, checked on control channels

Full reconstruction tagging

An example of the power of a B factory: fully reconstruct one of the B's to tag B flavor/charge, determine its momentum, and exclude decay products of this B from further analysis (exactly two B's produced in Υ(4S) decays)



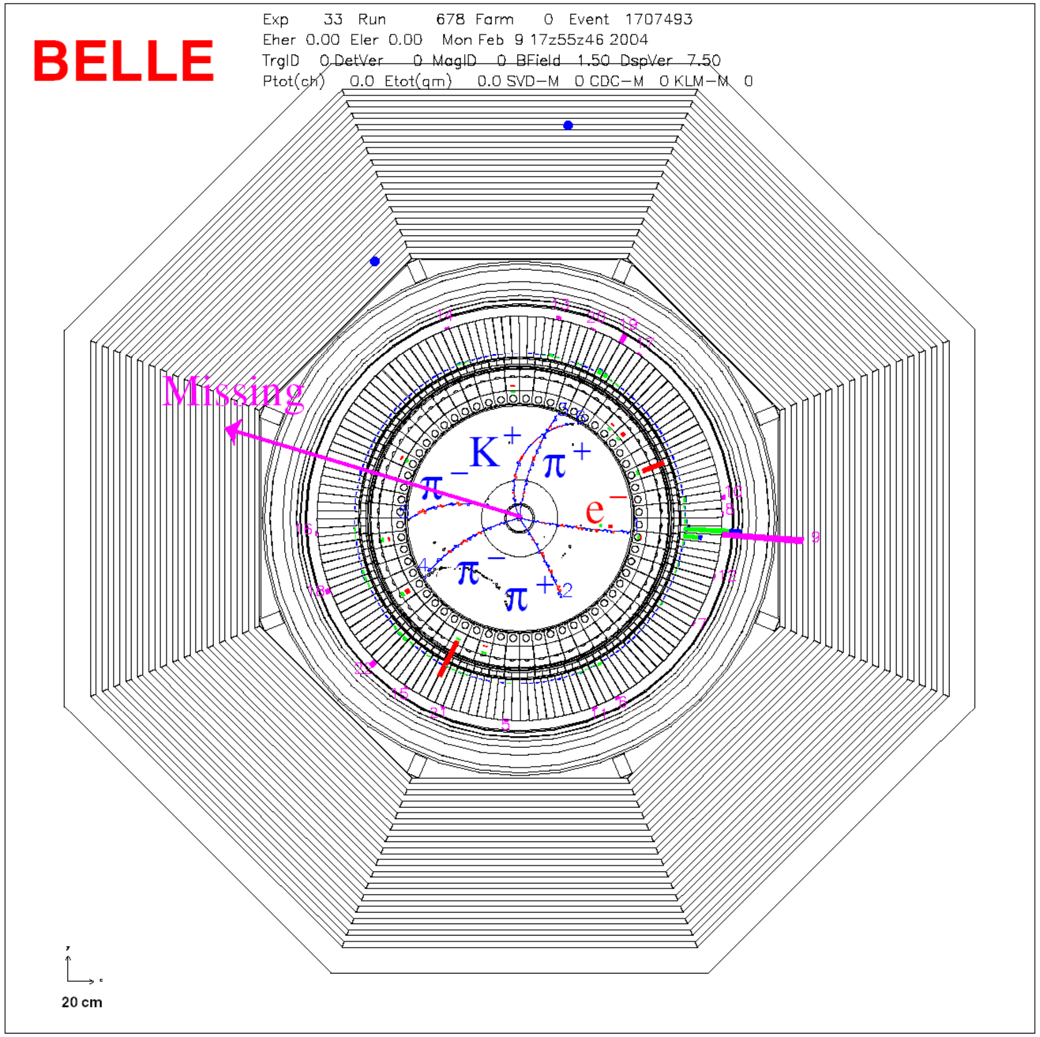
Powerful tool for B decays with neutrinos, used in several analyses

→unique feature at B factories

$B^- \to \tau^- \nu_\tau$

Example of a missing energy decay

$$B^+ \to D^0 \pi^+ \\ (\to K\pi^-\pi^+\pi^-) \\ B^- \to \tau(\to e\nu\bar{\nu})\nu$$



Advantages in searches for new hadrons

Clean environment:

- Can look for new states in an inclusive way (e.g. $\Upsilon(5S) \rightarrow h_c \pi \pi$)

$\rightarrow$

- Can reconstruct one resonance, look for the recoiling system (e.g. $e^+ e^- \rightarrow J/\psi + X$)

$\rightarrow$

- Detection of gammas, π^0s

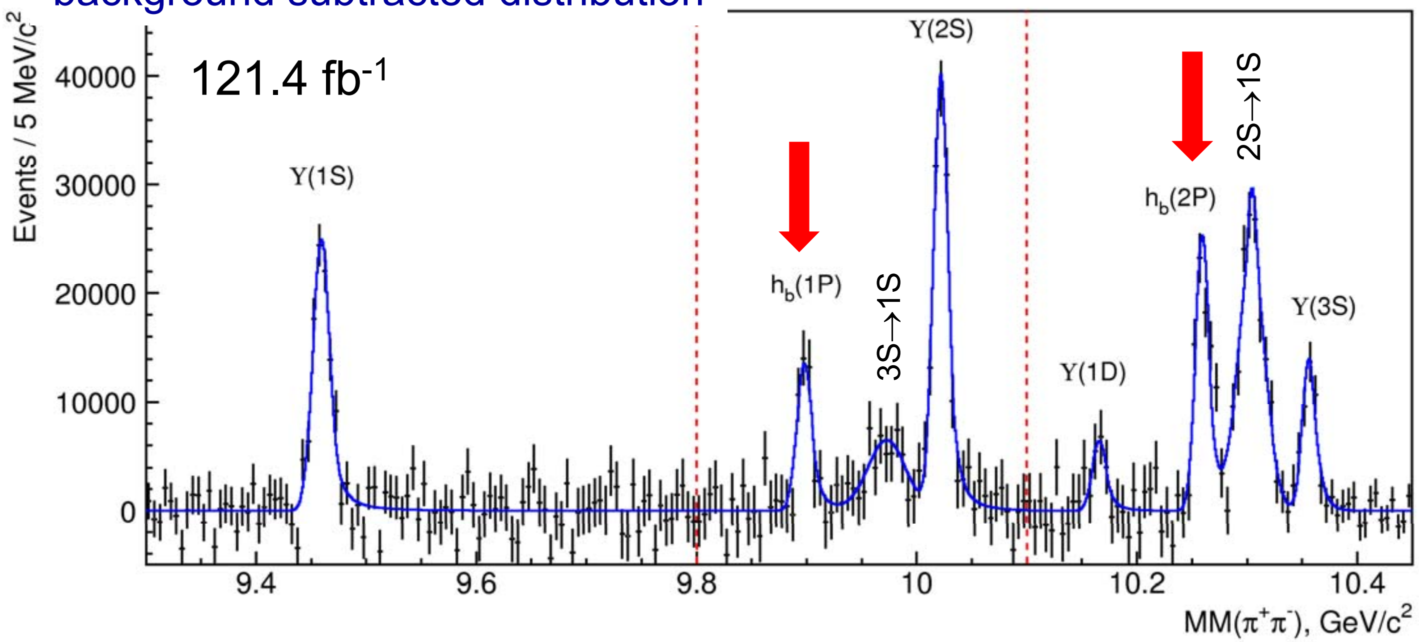
Observation of $h_b(nP)$ in $\Upsilon(5S)$ decays

$h_b(nP)$: $(b\bar{b})$, S=0, L=1, $J^{PC}=1^{+-}$

Inclusive search in $\Upsilon(5S) \rightarrow \pi^+\pi^- \ldots$ ← Only two charged pions used

$$MM(\pi^+\pi^-) = \sqrt{(P_{\Upsilon(5S)} - P_{\pi^+\pi^-})^2}$$

background subtracted distribution



Significance w/ systematics

$h_b(1P)$ 5.5σ
$h_b(2P)$ 11.2σ

PRL108, 032001

h_b production is enhanced (despite of the spin flip between Υ(5S) and h_b)
→ the mechanism of production is exotic → look for resonances in π **h_b**

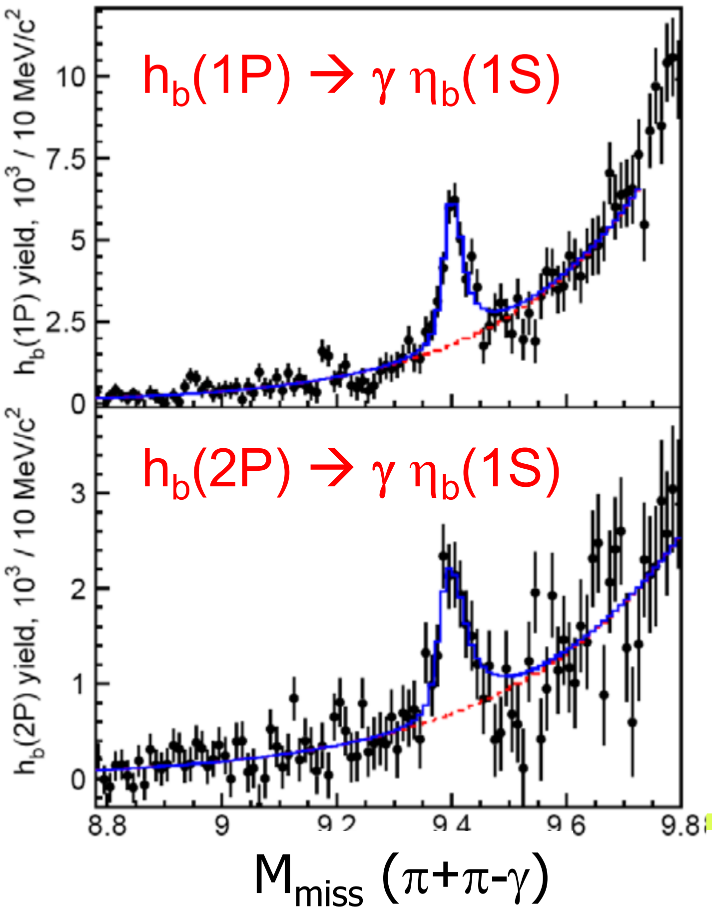
Observation of $\eta_b(nS)$ in h_b decays

Inclusive search in $\Upsilon(5S) \to \pi^+\pi^- \gamma$ ....

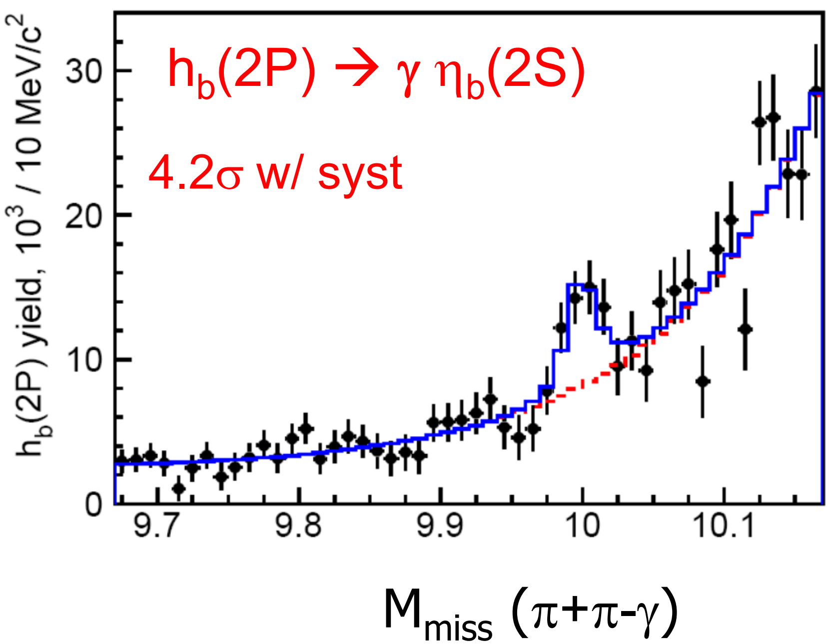
Use only two charged pions and a gamma

para-bottomonium
$\eta_b(nS)$: $(b\bar{b})$, S=0, L=0, $J^{PC}=0^{-+}$

$\Upsilon(5S) \to h_b(nP)\ \pi\ \pi$,
$h_b(nP) \to \gamma\ \eta_b(n'S)$

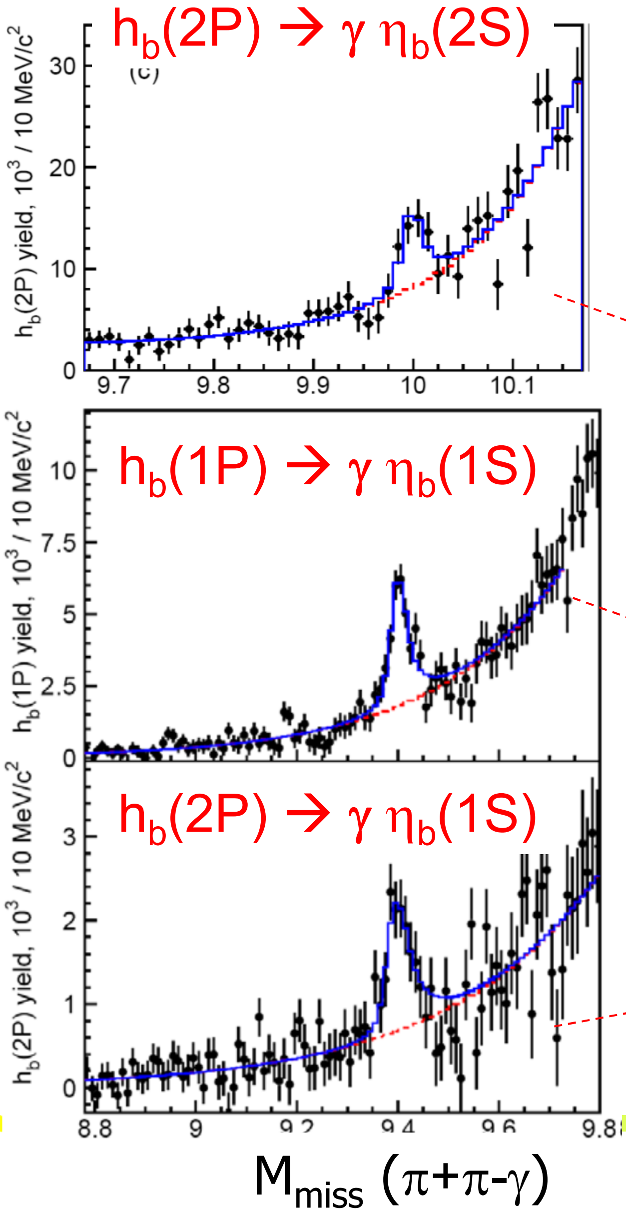


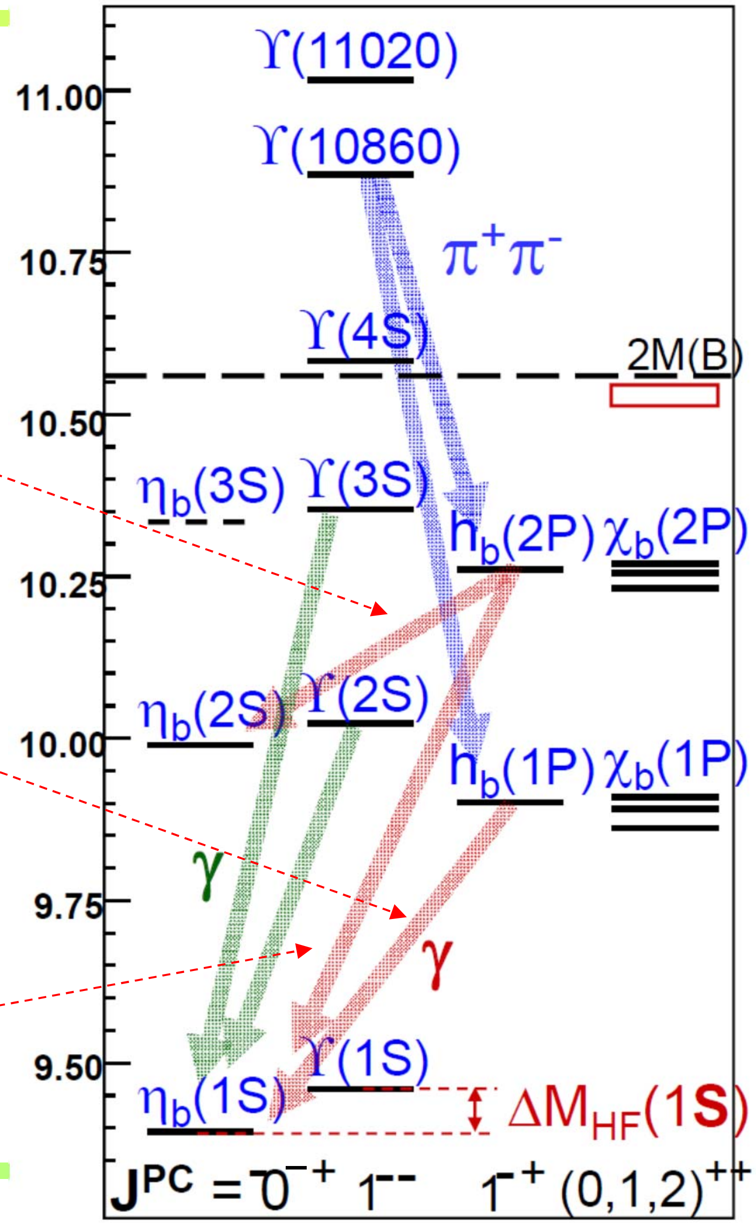
First evidence for $\eta_b(2S)$



Mizuk et al. Belle PRL 109 (2012) 232002

Observation of $\eta_b(nS)$ in h_b decays

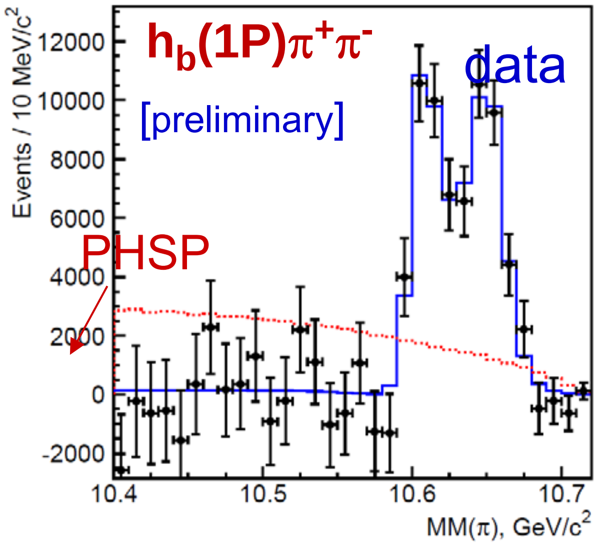




Observation of charged Z_b states: resonant substructure in $\Upsilon(5S) \to h_b(nP)\,\pi^+\pi^-$

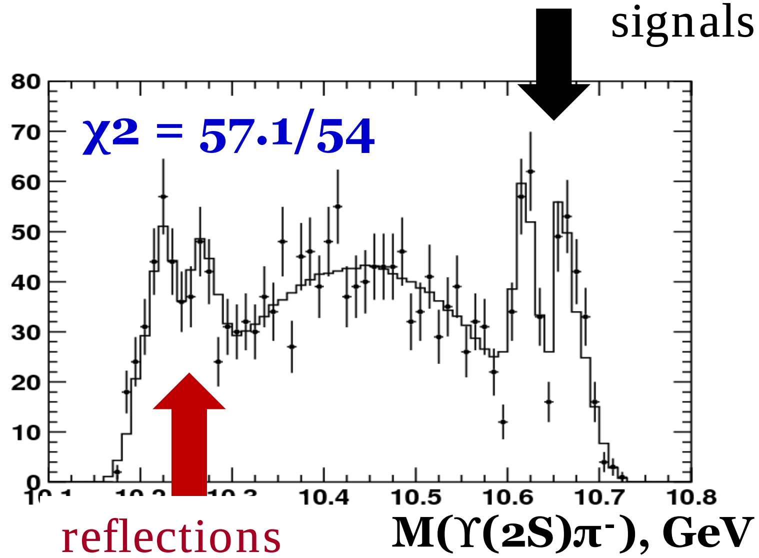
Inclusive search in $M(h_b\pi^+) = MM(\pi^-)$

measure $\Upsilon(5S) \to h_b\pi\pi$ yield in bins of $MM(\pi)$



Exclusive searches:

Observed in $\Upsilon(5S) \to$ **$\Upsilon(1S)$** $\pi+\pi-$, **$\Upsilon(2S)$** $\pi+\pi-$ and **$\Upsilon(3S)$** $\pi+\pi-$



$Z_b(10610)$ $M = 10608.1 \pm 1.7$ MeV, $\Gamma = 15.5 \pm 2.4$ MeV

$Z_b(10650)$ $M = 10653.3 \pm 1.5$ MeV, $\Gamma = 14.0 \pm 2.8$ MeV

Seen in 5 different final states, parameters are consistent

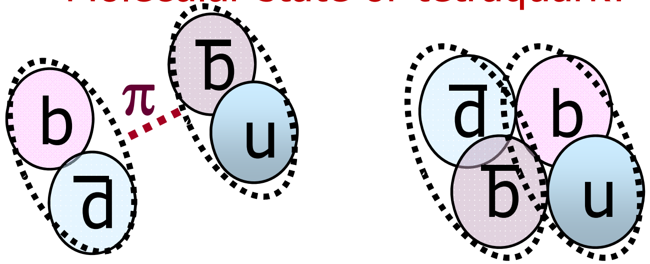
$J^P=1^+$ in agreement with data; other J^P are disfavored

→ What is the nature of Z_b^+? Molecules, tetraquarks, cusps, ... ?

Z_b^+ properties

Must be an exotic state (charged bottomonium-like state must at least have the $b\bar{b}u\bar{d}$ content)

Molecular state or tetraquark?



- Z_b^+(10610): mass very close to the BB* threshold
- Z_b^+(10650): mass very close to the B*B* threshold

Analysis of angular distributions suggests JP=1^+ for both states.

Observation of dominant Z_b decays to BB* and B*B*

Belle preliminary

- $Z_b^+(10610) \rightarrow$ BB*, BR = (86.0 +- 3.6)%
- $Z_b^+(10650) \rightarrow$ B*B*, BR = (73.4 +- 7.0)%

consistent with a molecular nature of the charged bottomonia (Bondar, Garmash, Milstein, Mizuk, Voloshin, PRD84 054010)

Evidence of neutral partner of Z(10610) in

- $Z_b^0 \rightarrow \Upsilon \pi^0$ decays with 4.9 sigma significance

PRD 88, 052016 (2013) (arXiv:1308.2646)

B(*)B* molecular interpretation

Bondar, Garmash, Milstein, Mizuk, Voloshin
PRD84 054010 (arXiv:1105.4473)

$$|Z'_b\rangle = \frac{1}{\sqrt{2}} 0^-_{b\bar b} \otimes 1^-_{Q\bar q} - \frac{1}{\sqrt{2}} 1^-_{b\bar b} \otimes 0^-_{Q\bar q}$$

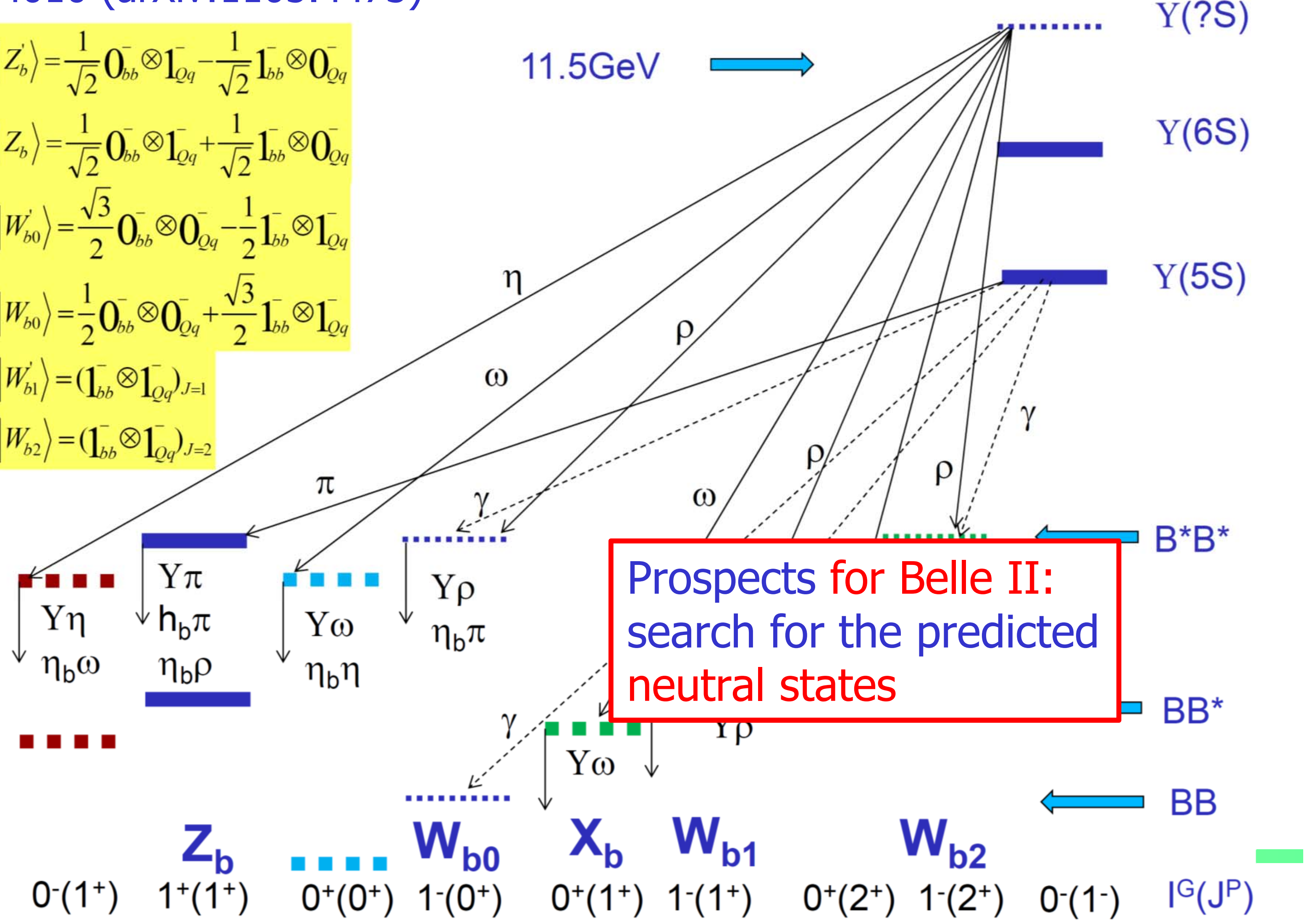
$$|Z_b\rangle = \frac{1}{\sqrt{2}} 0^-_{b\bar b} \otimes 1^-_{Q\bar q} + \frac{1}{\sqrt{2}} 1^-_{b\bar b} \otimes 0^-_{Q\bar q}$$

$$|W'_{b0}\rangle = \frac{\sqrt{3}}{2} 0^-_{b\bar b} \otimes 0^-_{Q\bar q} - \frac{1}{2} 1^-_{b\bar b} \otimes 1^-_{Q\bar q}$$

$$|W_{b0}\rangle = \frac{1}{2} 0^-_{b\bar b} \otimes 0^-_{Q\bar q} + \frac{\sqrt{3}}{2} 1^-_{b\bar b} \otimes 1^-_{Q\bar q}$$

$$|W'_{b1}\rangle = (1^-_{b\bar b} \otimes 1^-_{Q\bar q})_{J=1}$$

$$|W_{b2}\rangle = (1^-_{b\bar b} \otimes 1^-_{Q\bar q})_{J=2}$$



Prospects for Belle II:
search for the predicted
neutral states

Charmonium-like vs bottomonium like

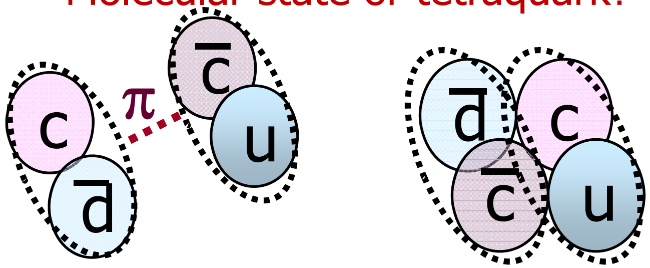
Interesting to compare the observed exotic charmonium-like states with bottomonium-like states.

If the molecular interpretation is right, the spectra close to the open charm and beauty thresholds should be similar.

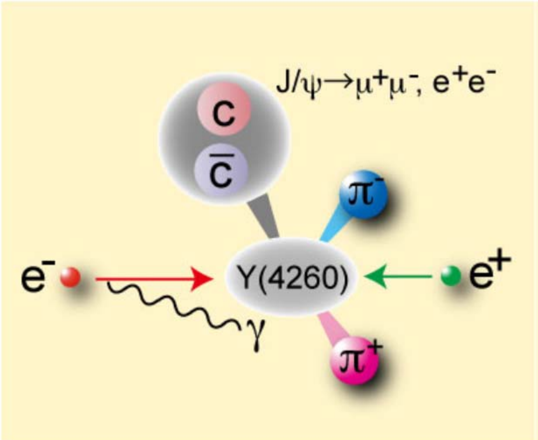
→ Investigate charged charmonia

… again have to be exotic (such a state must at least have the $c\bar{c}u\bar{d}$ content)

Molecular state or tetraquark?

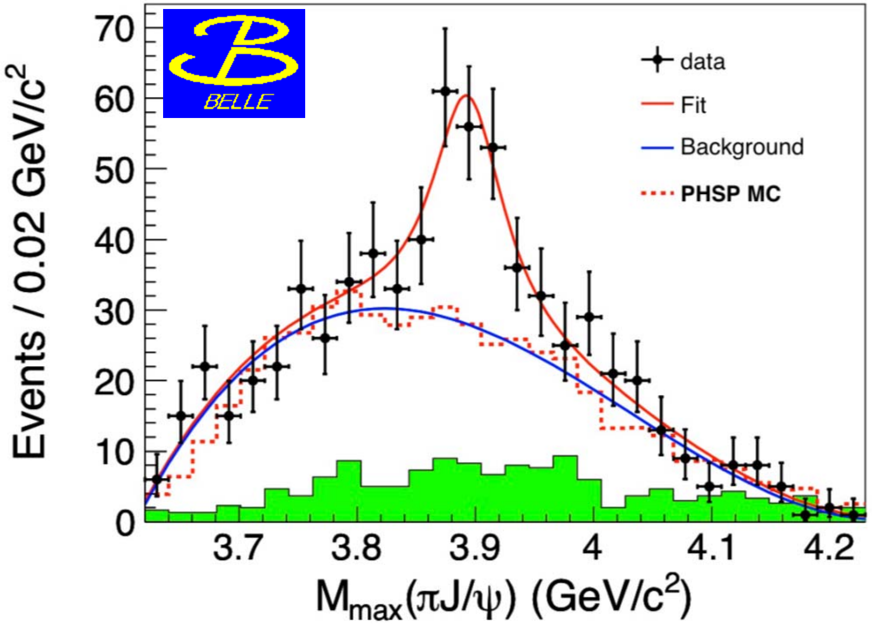


Charged charmonium in Y(4260) → $J/\psi\ \pi^+\pi^-$



Y(4260) produced via ISR
(Initial State Radiation)

Look for a resonance in $J/\psi\ \pi^+$



Found! → $Z_c^+(3895)$

Observed also by BES III.
They also recently found a peak in $(DD^*)^+$ at 3885 MeV
PRL110, 252001 (2013)
PRL112, 022001 (2014)

PRL110, 252002 (2013)

very similar to
$\Upsilon(5S) \to Z_b^+\pi^- \to \Upsilon(1s)\ \pi^+\pi^-$

Charged charmonia in B → charmonium + π + K

More charged charmonium-like states!

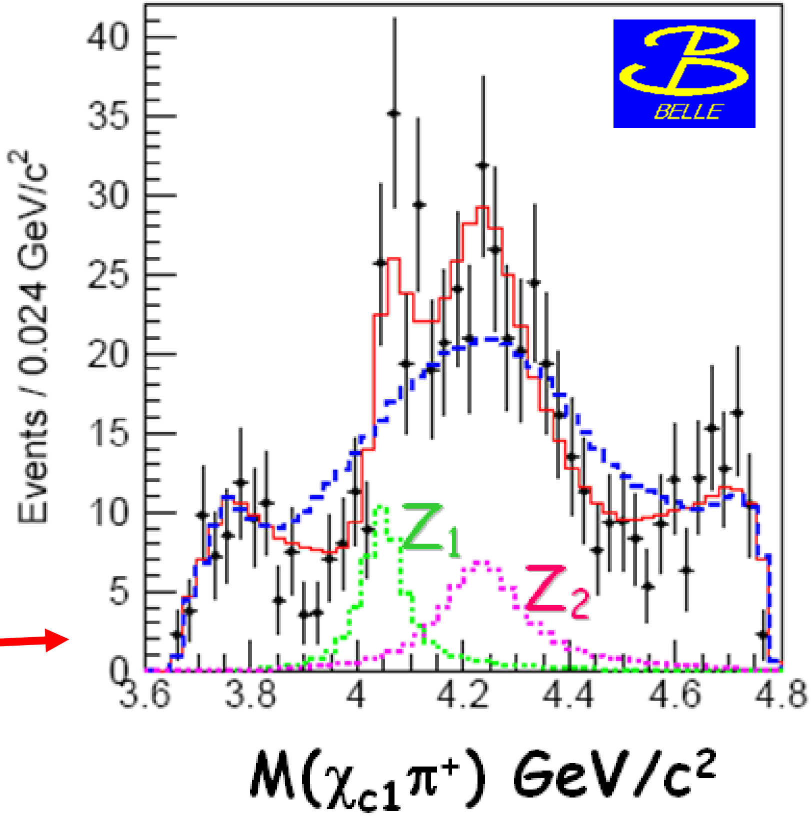
B → K X: an excellent tool for production of charmonia and charmoniumlike states; essential in observation of η_c' and X(3872)

Belle observed 3 charged peaks in B decays to charmonium + π + K

cc=Ψ' → $Z_c^+(4430)$

cc=χ_{c1} → $Z_c^+(4050)$, $Z_c^+(4250)$

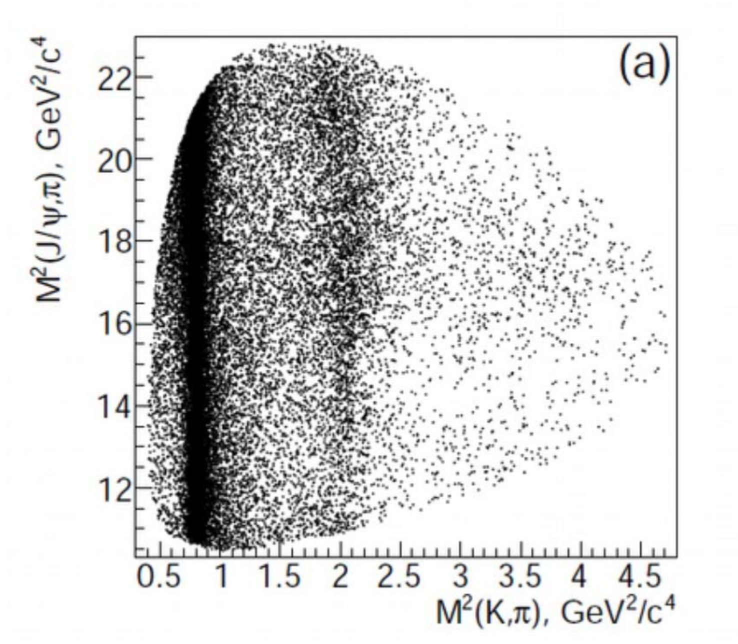
=Z_1 =Z_2

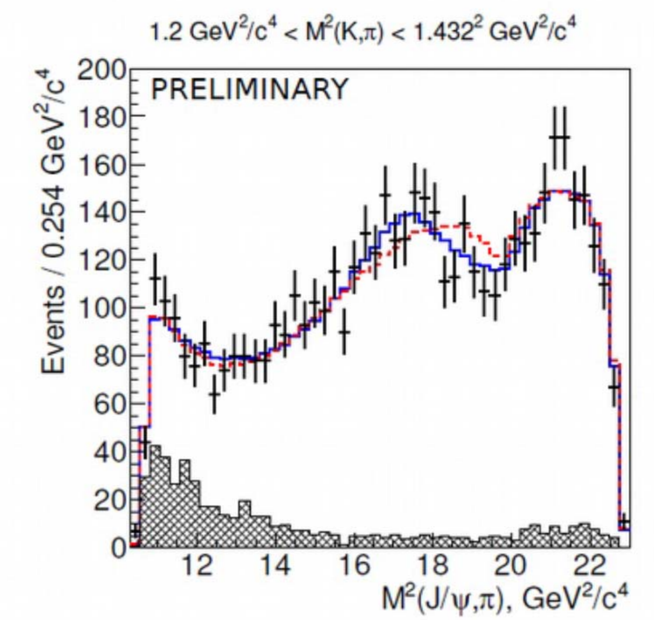


R. Mizuk et al. (Belle) PRD 78, 072004

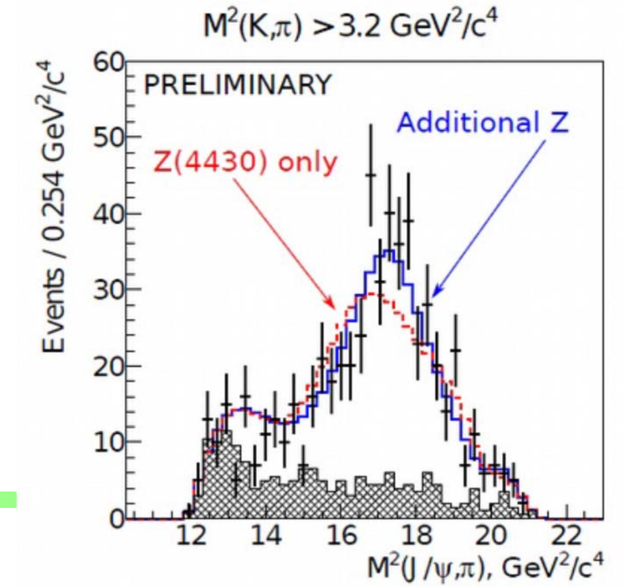
$Z_c^+(4430)$ recently confirmed by LHCb.

A new charged charmonium in B → J/ψ π^+ K





- 4D amplitude analysis
- 10 K* resonances, $Z^+(4430)$, $Z^+(4200)$ → new
- 6.6σ significance
- $M = 4196\ ^{+31}_{-29}\ ^{+17}_{-13}$ MeV/c2
- $\Gamma = 370 \pm 70\ ^{+70}_{-132}$ MeV
- $J^P = 1^+$



http://arxiv.org/abs/1408.6457 (submitted to PRD)

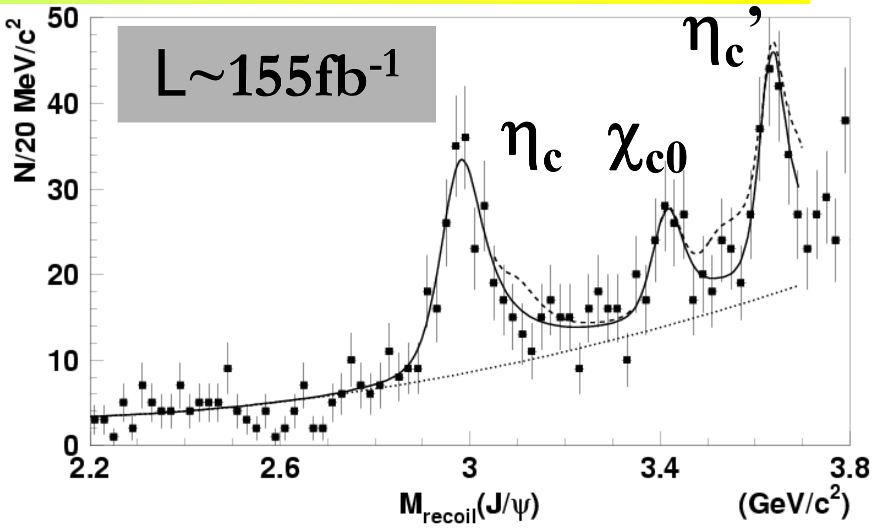
J/ψ recoil method

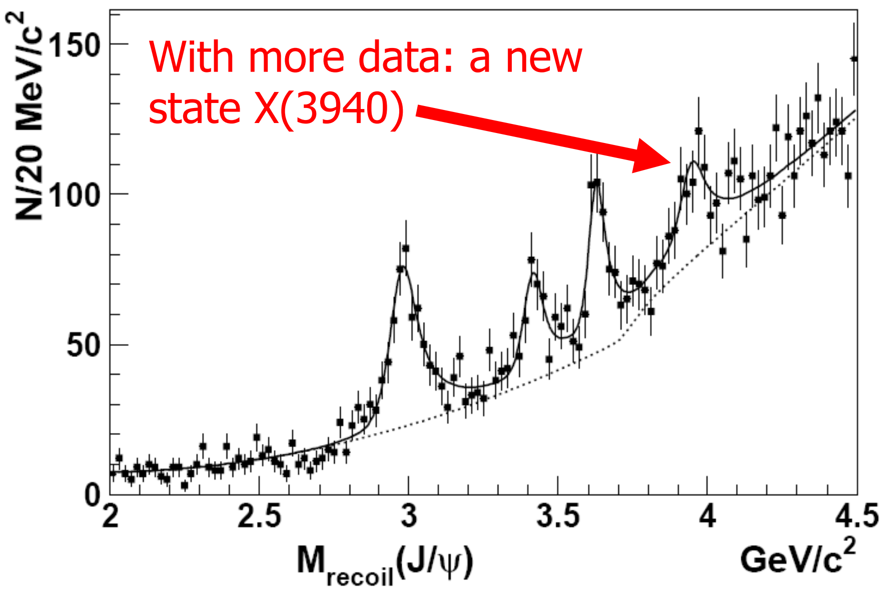
The idea: reconstruct J/ψ, calculate the mass of the recoiling system.

First used in the discovery of an unexpectedly large double charmonium production in $e^+e^- \rightarrow cccc$

In the recoil mass spectrum, Belle observed the peaks of charmonium C=0 states and discovered X(3940).

This reaction challenged our understanding of perturbative QCD. Leading order prediction was O(0.1) the observed value. NLO calculations 'almost' solved the discrepancy.



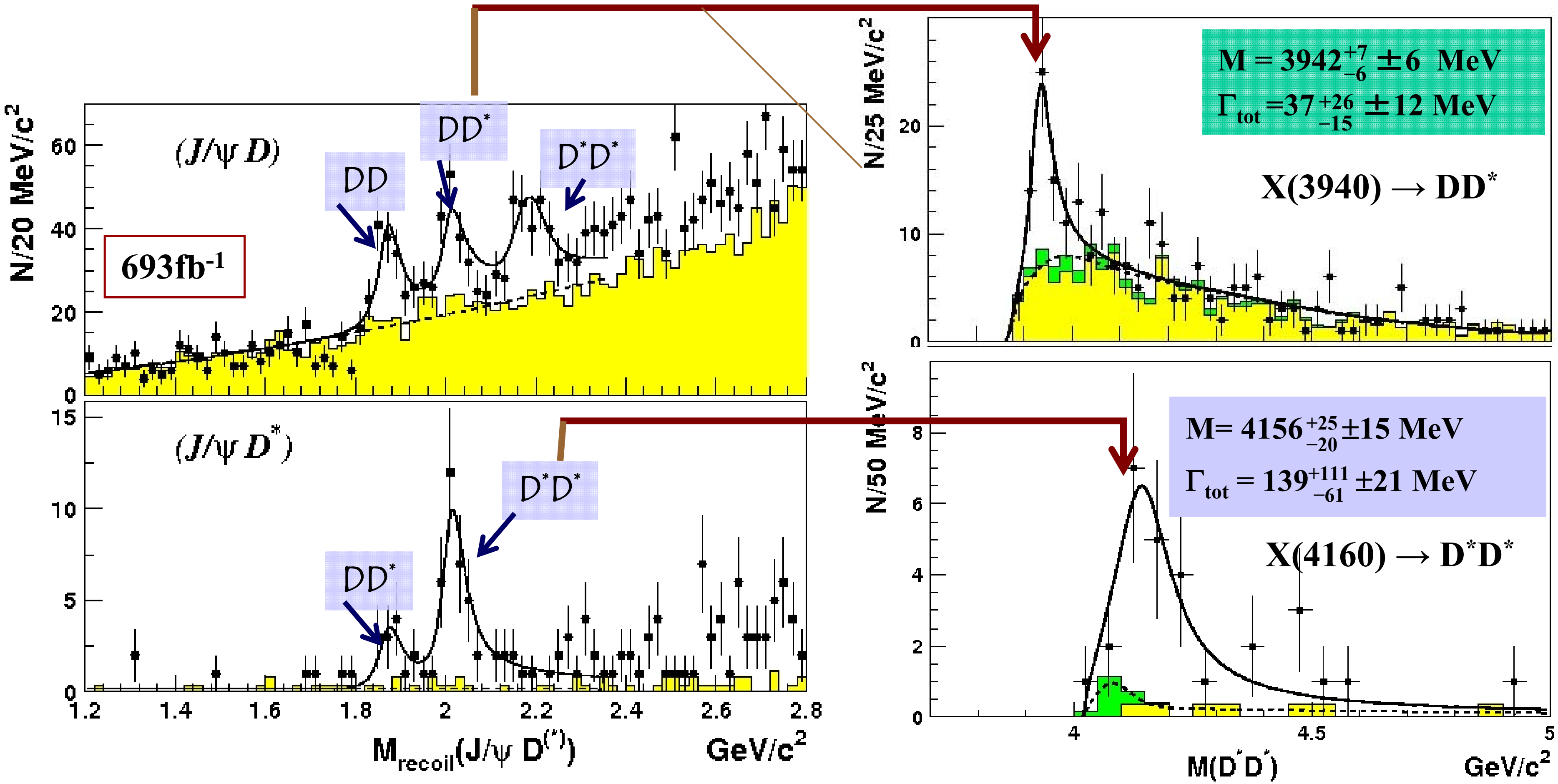


N.B. Such a study can only be done at a B factory!

$e^+e^- \rightarrow J/\psi\ D^{(*)}\ D^{(*)}$

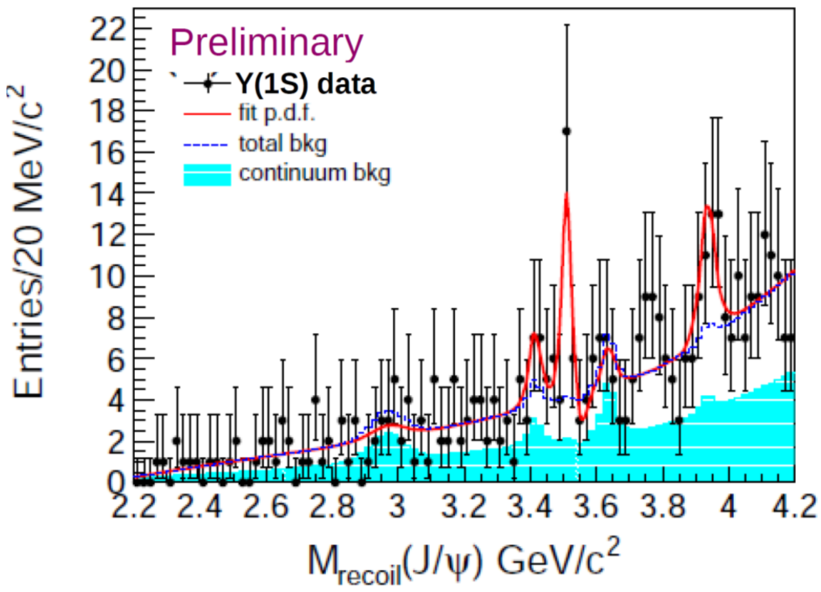
Reconstruct J/ψ and D or D*, calculate the mass of the recoiling system.

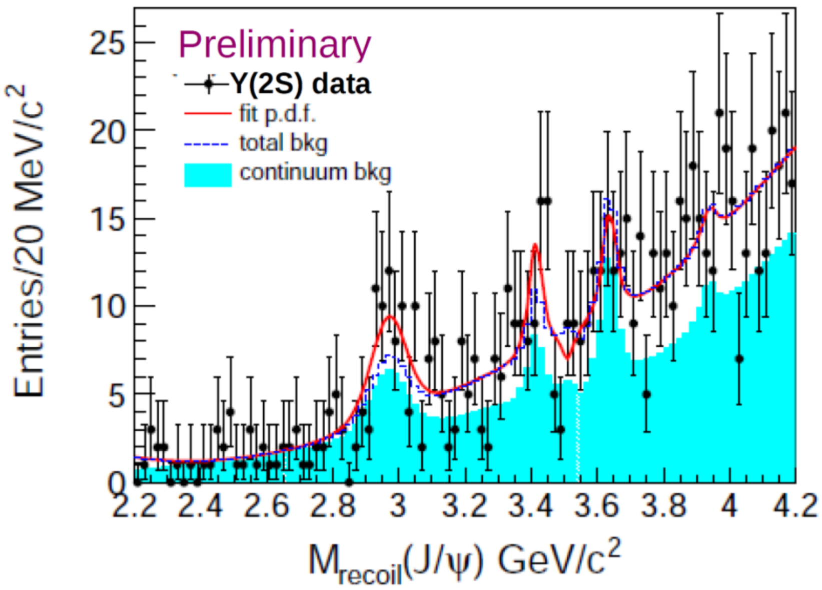
→ Confirmed X(3940) and found one more state at 4156 MeV.



Future prospects at Belle-II: Full reconstruction of χ_c or η_c will allow to exploit the recoil technique and scan the charmonium(-like) C=-1 states.

Double-charmonium production in Υ(1,2S) decays





- Reconstruct J/ψ, look at the recoil mass
- One significant channel observed
- In good agreement with theory (NRQCD)

Channels	N_{fit}	$\Sigma\,(\sigma)$	$\mathcal{B}_R(\times 10^{-6})$	$\mathcal{B}_{th}(\times 10^{-6})$
$\Upsilon(1S) \to J/\psi + \eta_c$	-5.0 ± 6.3	–	< 2.2	$3.9^{+5.6}_{-2.3}$
$\Upsilon(1S) \to J/\psi + \chi_{c0}$	6.0 ± 5.6	1.3	< 3.4	1.3
$\Upsilon(1S) \to J/\psi + \chi_{c1}$	19.9 ± 6.2	4.6	$3.98 \pm 1.24 \pm 0.22$	4.9
$\Upsilon(1S) \to J/\psi + \chi_{c2}$	-3.2 ± 4.0	–	< 1.4	0.20
$\Upsilon(1S) \to J/\psi + \eta_c'$	-2.1 ± 6.0	–	< 2.2	$2.0^{+3.4}_{-1.4}$
$\Upsilon(1S) \to J/\psi + X(3940)$	19.0 ± 8.7	2.8	< 5.4	–
$\Upsilon(1S) \to \psi' + \eta_c$	-5.0 ± 3.9	–	< 3.6	$1.7^{+2.4}_{-1.0}$
$\Upsilon(1S) \to \psi' + \chi_{c0}$	2.1 ± 4.1	0.6	< 6.5	–
$\Upsilon(1S) \to \psi' + \chi_{c1}$	0.2 ± 3.6	0.1	< 4.5	–
$\Upsilon(1S) \to \psi' + \chi_{c2}$	-6.7 ± 2.3	–	< 2.1	–
$\Upsilon(1S) \to \psi' + \eta_c'$	-5.7 ± 3.3	–	< 3.2	$0.8^{+1.4}_{-0.6}$
$\Upsilon(1S) \to \psi' + X(3940)$	-5.9 ± 4.0	–	< 2.9	–
$\Upsilon(2S) \to J/\psi + \eta_c$	16.3 ± 11.9	1.9	< 5.4	$2.6^{+3.7}_{-1.6}$
$\Upsilon(2S) \to J/\psi + \chi_{c0}$	7.8 ± 9.5	1.1	< 3.4	1.1
$\Upsilon(2S) \to J/\psi + \chi_{c1}$	-4.4 ± 6.6	–	< 1.2	4.1
$\Upsilon(2S) \to J/\psi + \chi_{c2}$	2.1 ± 7.4	0.4	< 2.0	0.17
$\Upsilon(2S) \to J/\psi + \eta_c'$	-3.8 ± 10.8	–	< 2.5	$1.3^{+2.1}_{-0.9}$
$\Upsilon(2S) \to J/\psi + X(3940)$	0.7 ± 12.1	0.0	< 2.0	–
$\Upsilon(2S) \to \psi' + \eta_c$	-0.4 ± 7.9	–	< 5.1	$1.1^{+1.6}_{-0.7}$
$\Upsilon(2S) \to \psi' + \chi_{c0}$	2.6 ± 5.7	0.6	< 4.7	–
$\Upsilon(2S) \to \psi' + \chi_{c1}$	-2.8 ± 4.2	–	< 2.5	–
$\Upsilon(2S) \to \psi' + \chi_{c2}$	-13.3 ± 4.8	–	< 1.9	–
$\Upsilon(2S) \to \psi' + \eta_c'$	-3.0 ± 5.9	–	< 3.3	$0.5^{+0.9}_{-0.4}$
$\Upsilon(2S) \to \psi' + X(3940)$	-0.3 ± 7.1	–	< 3.9	–

B factories and hadron spectroscopy

B factories have found most of the still missing pieces in bottomonium and charmonium spectra.

Belle, Babar, BES-III and LHCb are studying a plethora of new states, the so called XYZ mesons, which require a spectroscopy with new degrees of freedom (tetraquarks, molecules, hybrids).

Many new questions arose from unexpected states near the open charm/beauty thresholds.

A lot more to be explored with considerably larger data sets!

N	Title	Year	Cites
1	X(3872)	2003	739
2	Large CPV	2001	618
3	$B \to X_s \gamma$	2001	381
4	CP in $B^0 \bar{B}^0$	2002	326
5	D0 mixing	2007	292
6	Y(3945)	2005	290
7	$B \to \tau \nu$	2006	277
8	$2c\bar{c}$	2002	272
9	$b \to s \gamma$	2004	265
10	$D_s^*(2317)$, $D_{s1}(2460)$	2003	258
11	D^{**}	2004	249
12	Z(4430)	2008	235
13	D_{sJ}	2006	221
14	$X(3940)$ in $2c\bar{c}$	2007	204

8 out of 14 most cited Belle papers are spectroscopy related

N.B. Table needs updating…

What next?

Next generation: Super B factories → Looking for New Physics

→ Need much more data (almost two orders!)

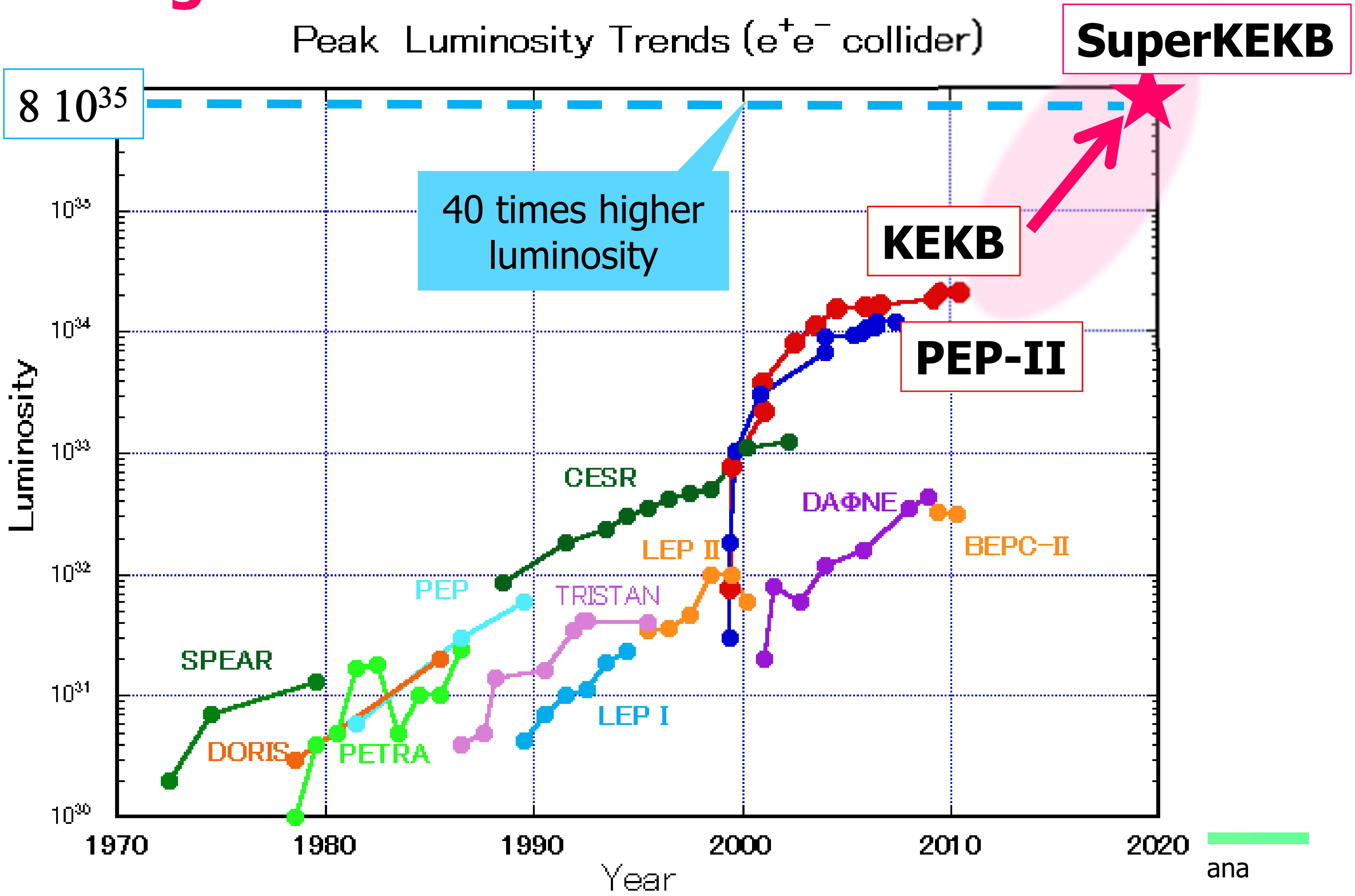
Super B factory: also an excellent tool for studies of exotic hadrons

A new feature: very strong competition from LHCb and BESIII

Still, e^+e^- machines running at (or near) Υ(4s) will have considerable advantages in several classes of measurements, and will be complementary in many more

→ Physics at Super B Factory, arXiv:1002.5012 (Belle II)
→ SuperB Progress Reports: Physics, arXiv:1008.1541 (SuperB)

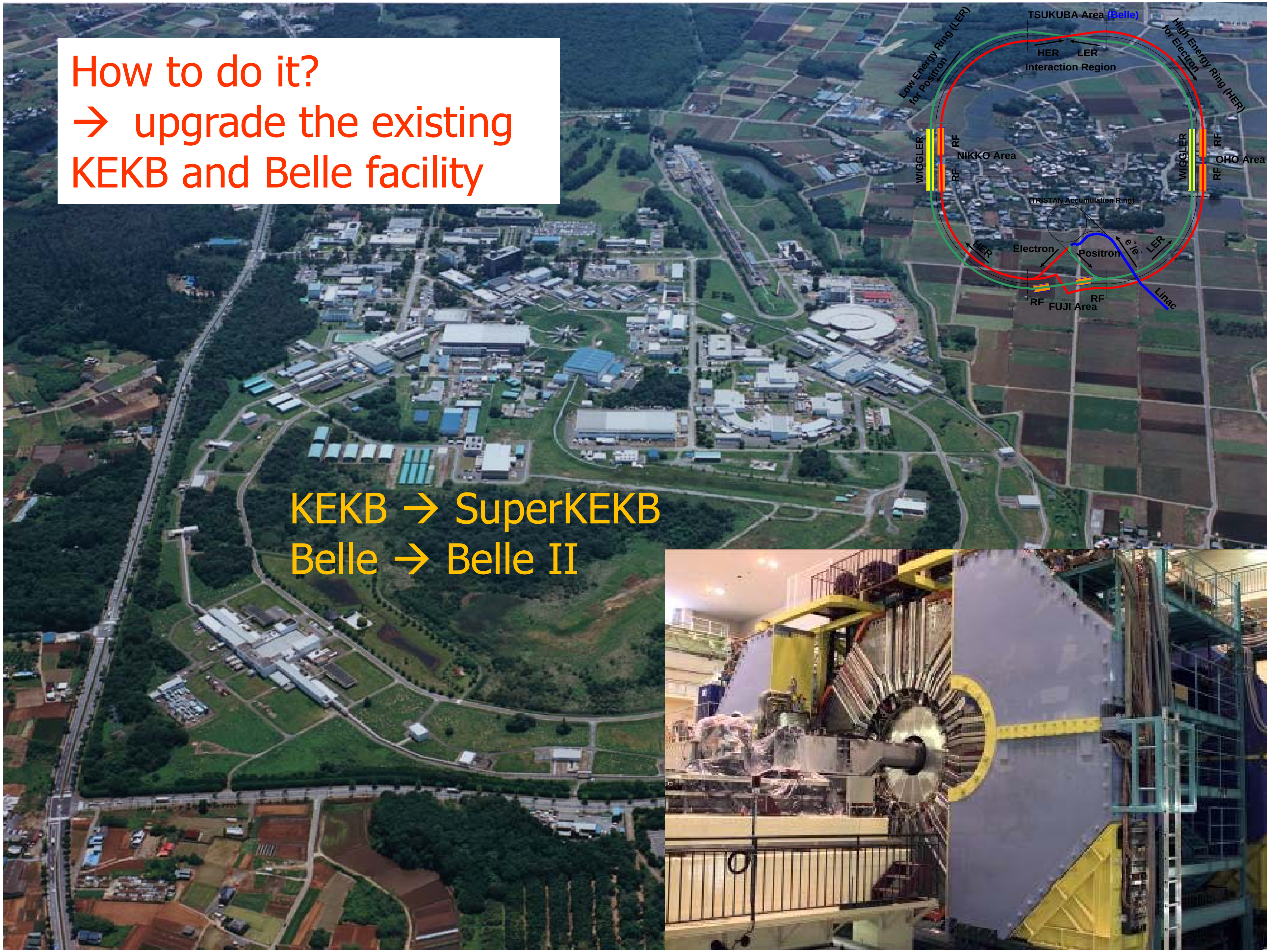
Need O(100x) more data →Next generation B-factories



ana

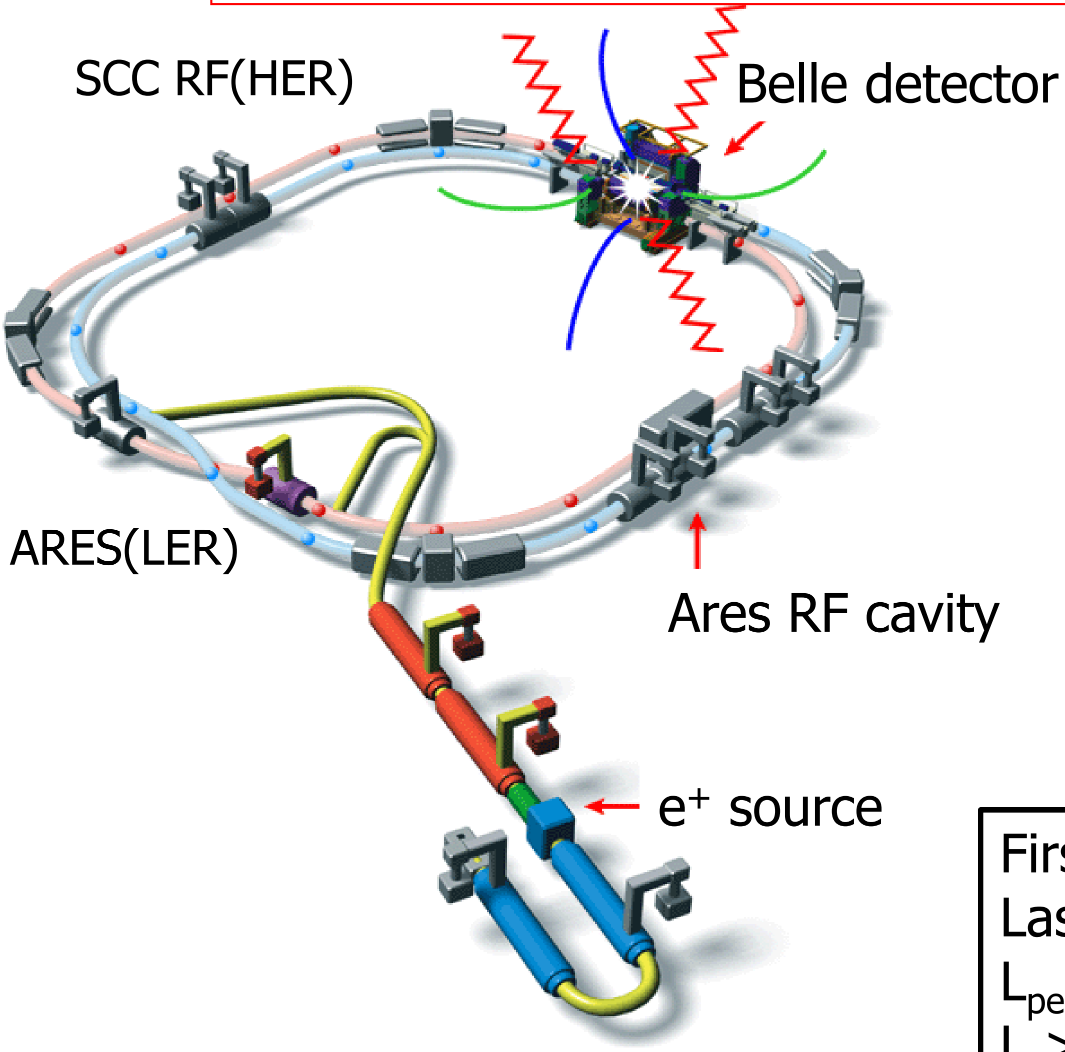
How to do it?
→ upgrade the existing KEKB and Belle facility

KEKB → SuperKEKB
Belle → Belle II



The KEKB Collider

Fantastic performance far beyond design values!



- e^- (8 GeV) on e^+(3.5 GeV)
  - $\sqrt{s} \approx m_{\Upsilon(4S)}$
  - Lorentz boost: $\beta\gamma$=0.425
- 22 mrad crossing angle

Peak luminosity (WR!) :

2.1×10^{34} cm^{-2}s^{-1}

=2x design value

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

How to increase the luminosity?

Beam-beam parameter

Beam current

Lorentz factor

$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

Lumi. reduction factor (crossing angle)& Tune shift reduction factor (hour glass effect) 0.8 - 1 (short bunch)

Classical electron radius

Beam size ratio@IP 1 - 2 % (flat beam)

Vertical beta function@IP

(1) Smaller β_y^*

(2) Increase beam currents

(3) Increase ξ_y

"Nano-Beam" scheme

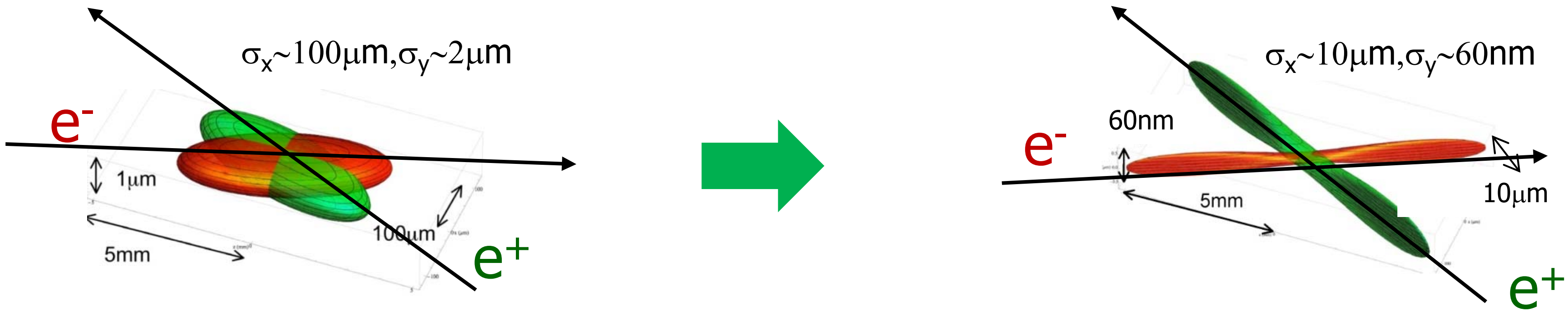
Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

How big is a nano-beam ?

How to go from an excellent accelerator with world record performance – KEKB – to a 40x times better, more intense facility?

In KEKB, colliding electron and positron beams are much thinner than a human hair...



... For a 40x increase in intensity you have to make the beam as thin as a few x100 atomic layers!

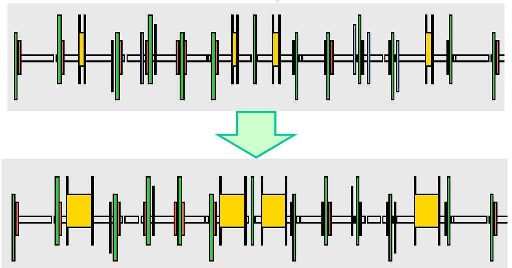
Machine design parameters

parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.37	0.40	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0881	0.0807	
Luminosity	**L**	**2.1×10^{34}**		**8×10^{35}**		**$cm^{-2}s^{-1}$**

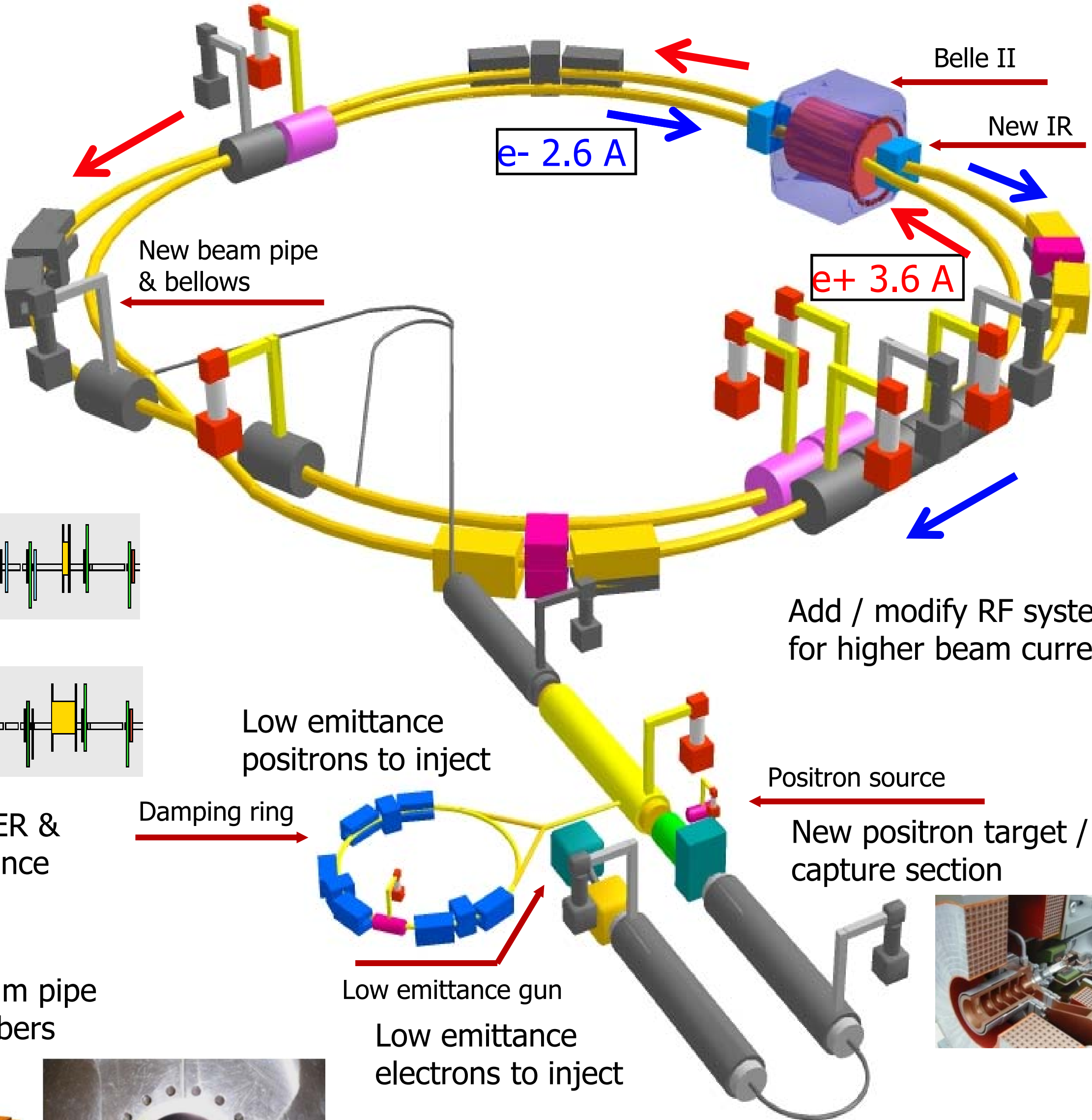
- **Nano-beams and a factor of two more beam current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of short lifetime for the LER

KEKB → SuperKEKB

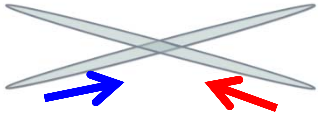
Replace short dipoles with longer ones (LER)



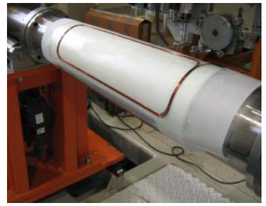
Redesign the lattices of HER & LER to squeeze the emittance



Low emittance electrons to inject



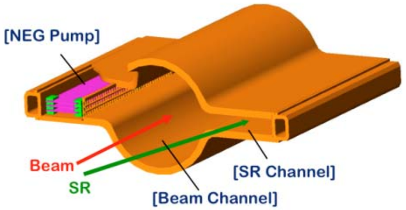
New superconducting /permanent final focusing quads near the IP

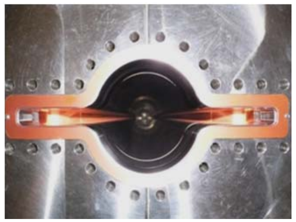


Add / modify RF systems for higher beam current

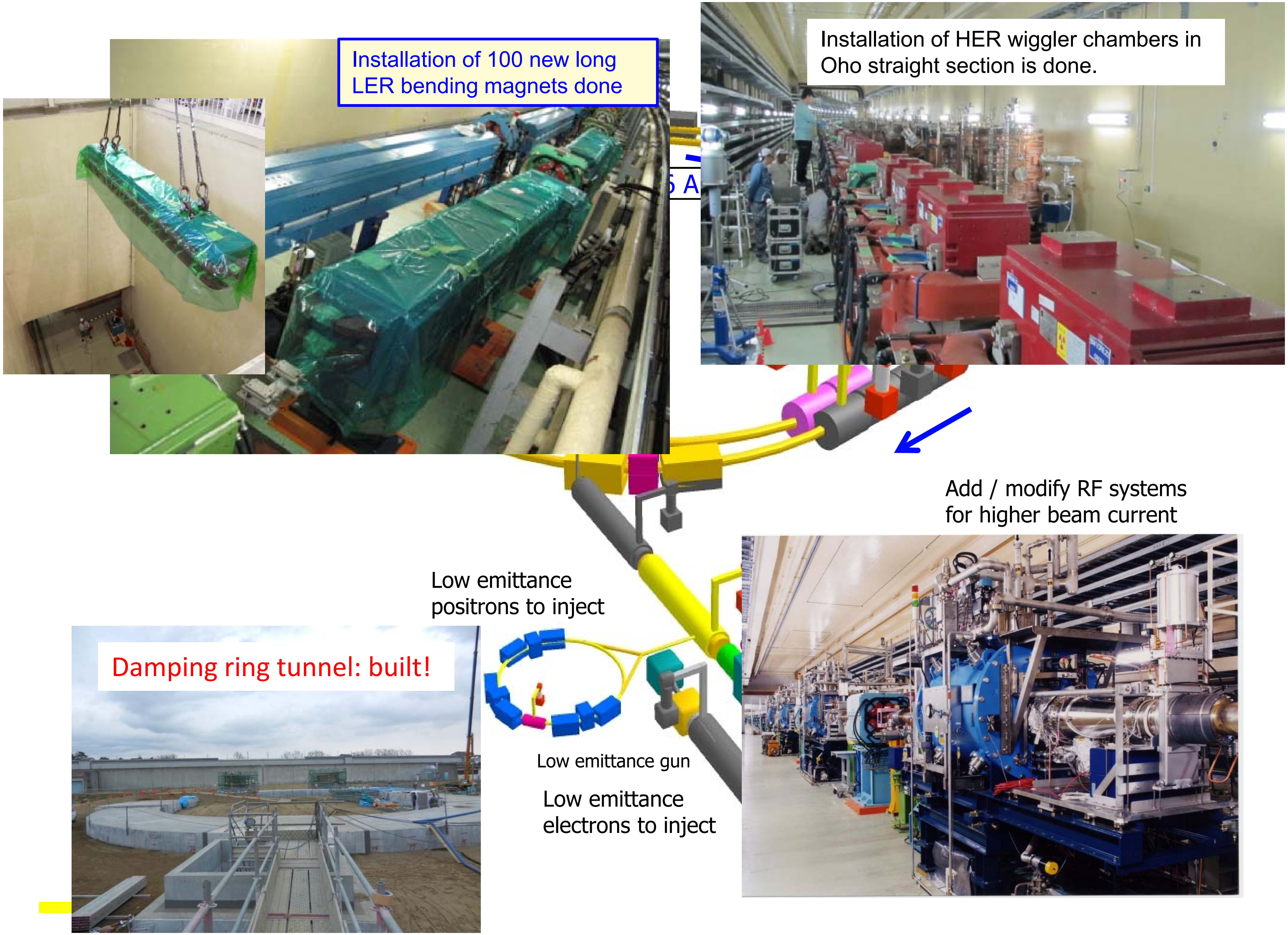
New positron target / capture section

TiN-coated beam pipe with antechambers





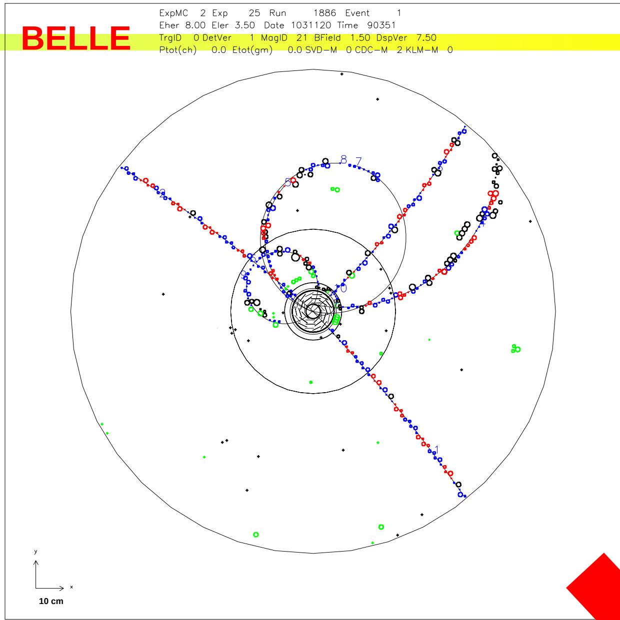
To get x40 higher luminosity

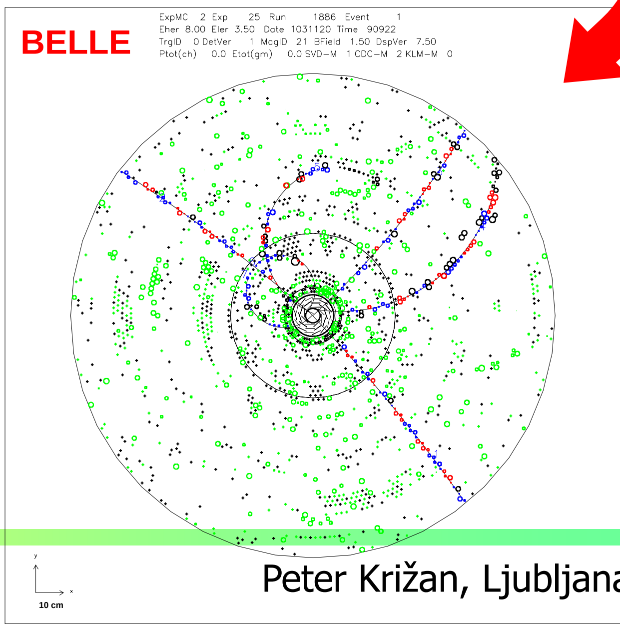

Installation of 100 new long
LER bending magnets done
Installation of HER wiggler chambers in
Oho straight section is done.
Add / modify RF systems
for higher beam current
Low emittance
positrons to inject
Damping ring tunnel: built!
Low emittance gun
Low emittance
electrons to inject

Requirements for the Belle II detector

Critical issues at L= 8 x 10^{35}/cm^2/sec

- **Higher background (×10-20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low *p* μ identification ← sμμ recon. eff.
  - hermeticity ← ν "reconstruction"



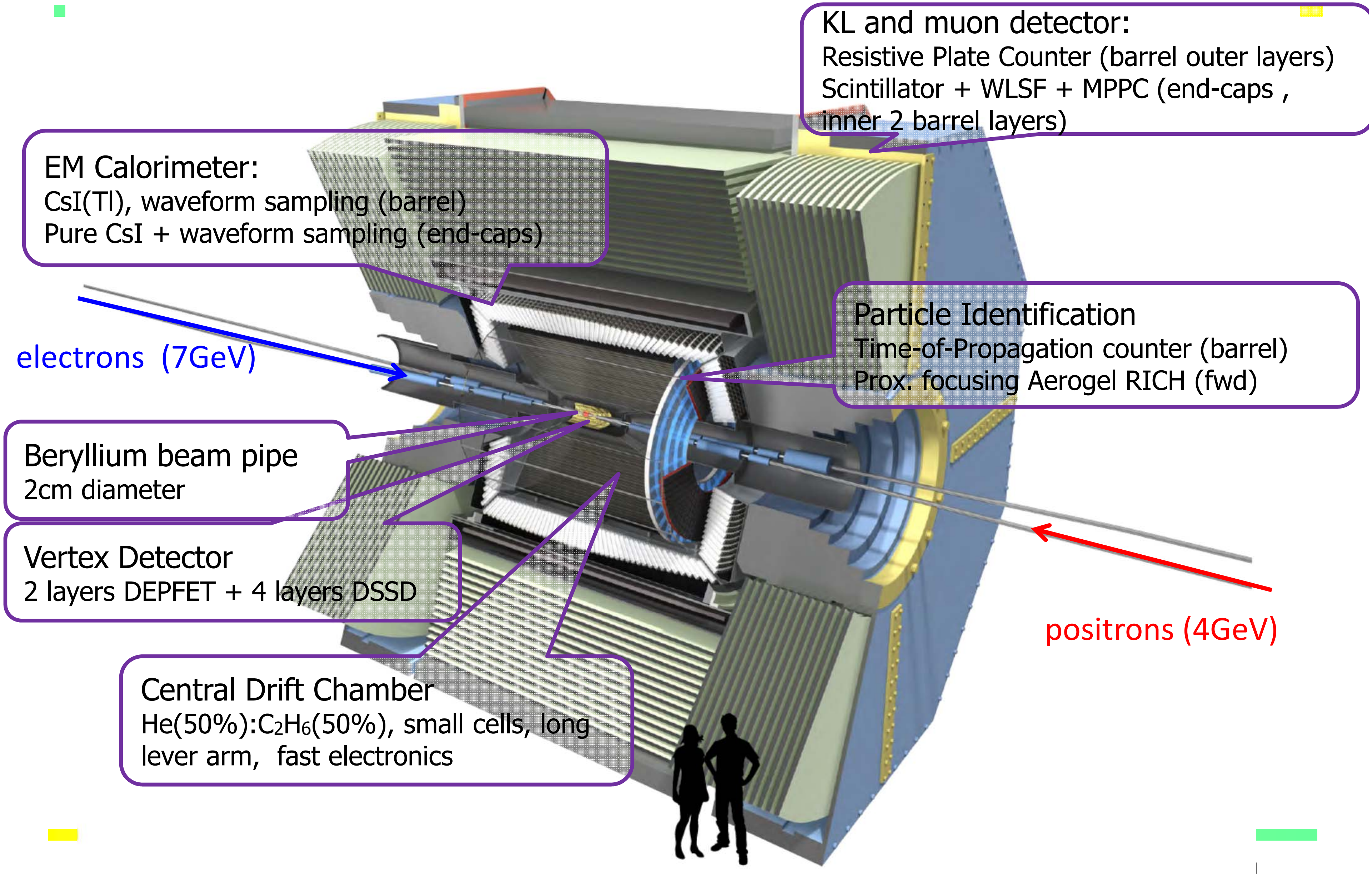


Solutions:

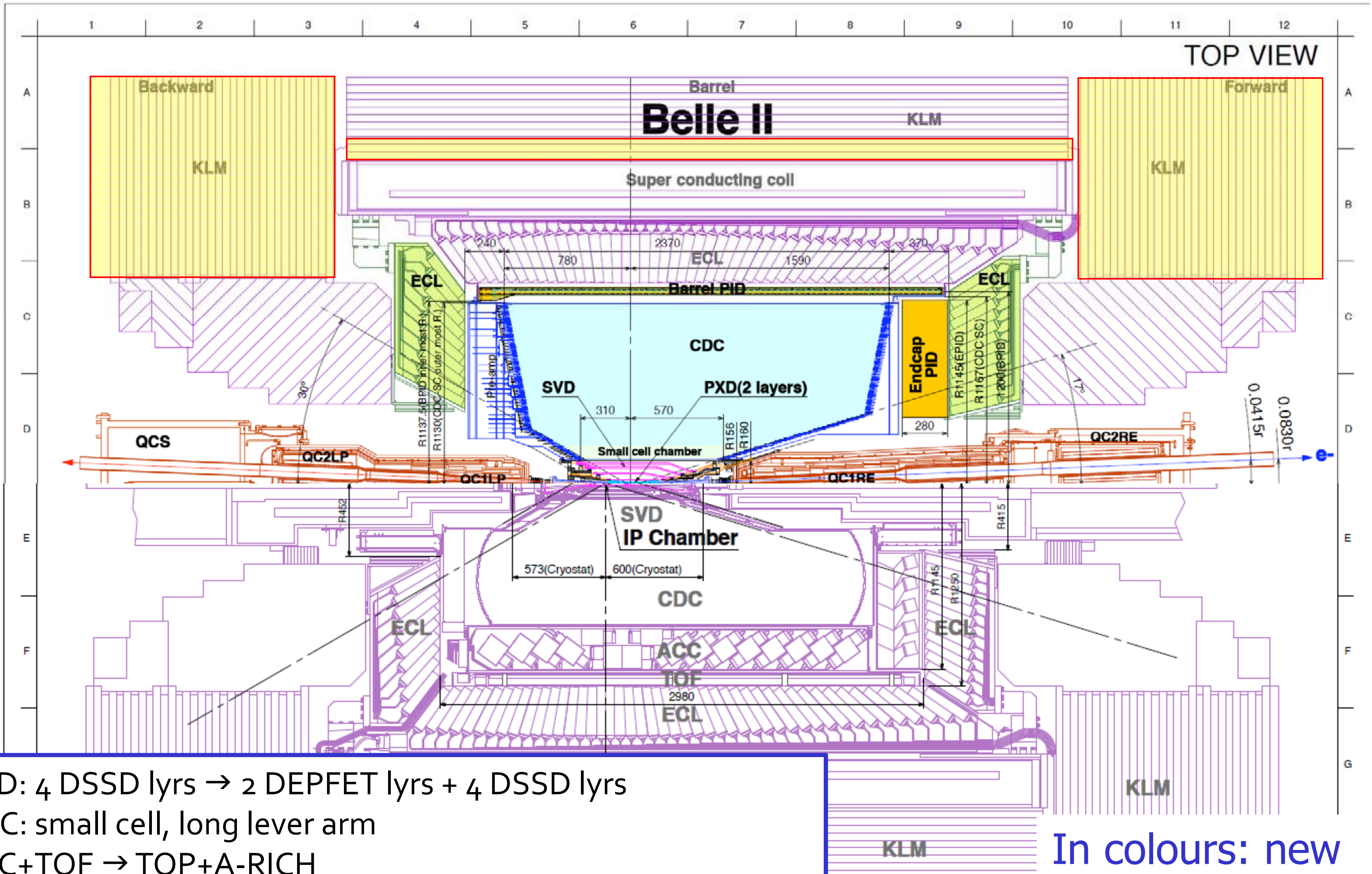
- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter crystals
- Faster readout electronics and computing system.

Belle II TDR, arxiv:1011.0352v1[physics.ins-det]

Belle II Detector



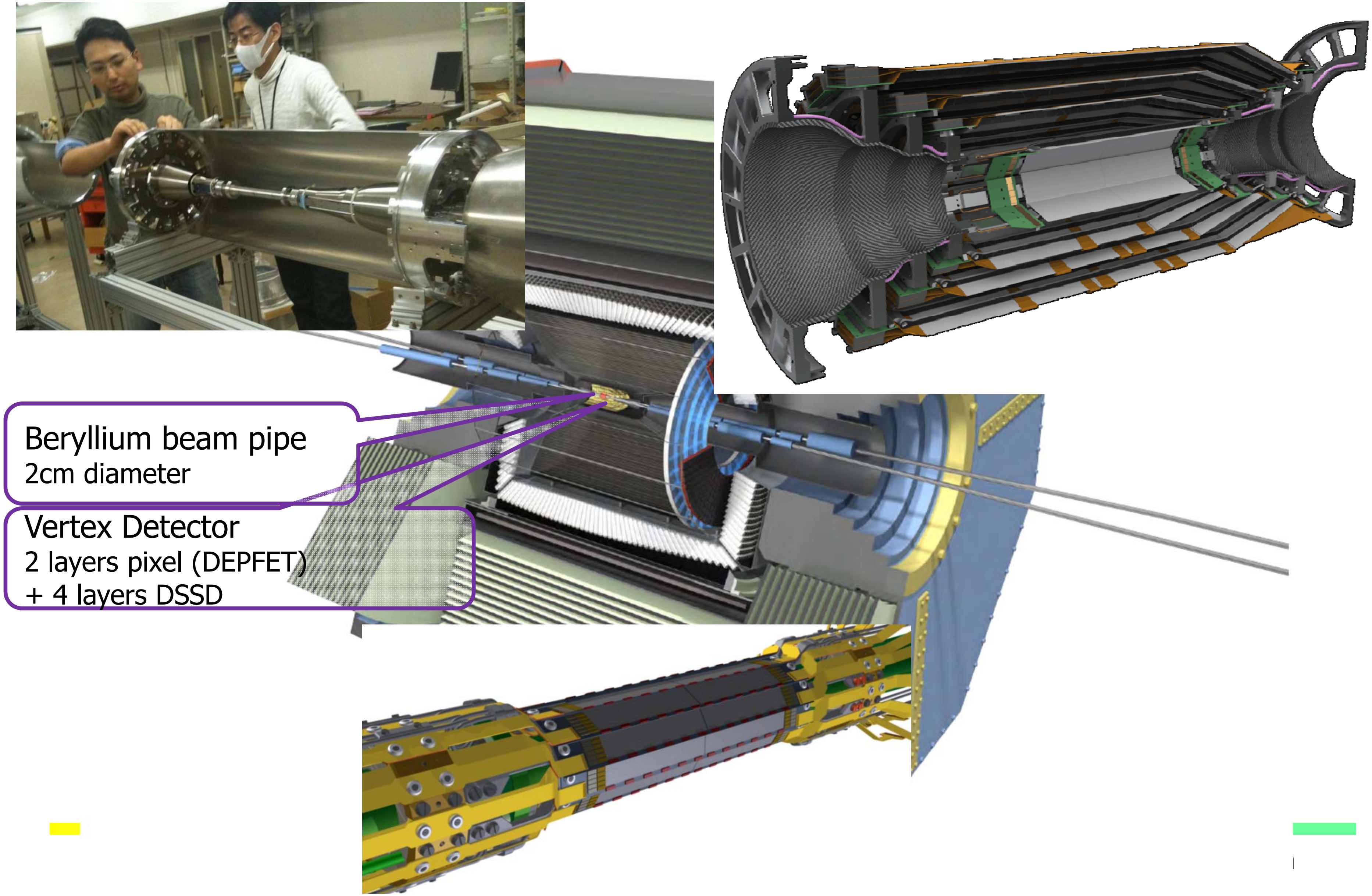
Belle II Detector (in comparison with Belle)



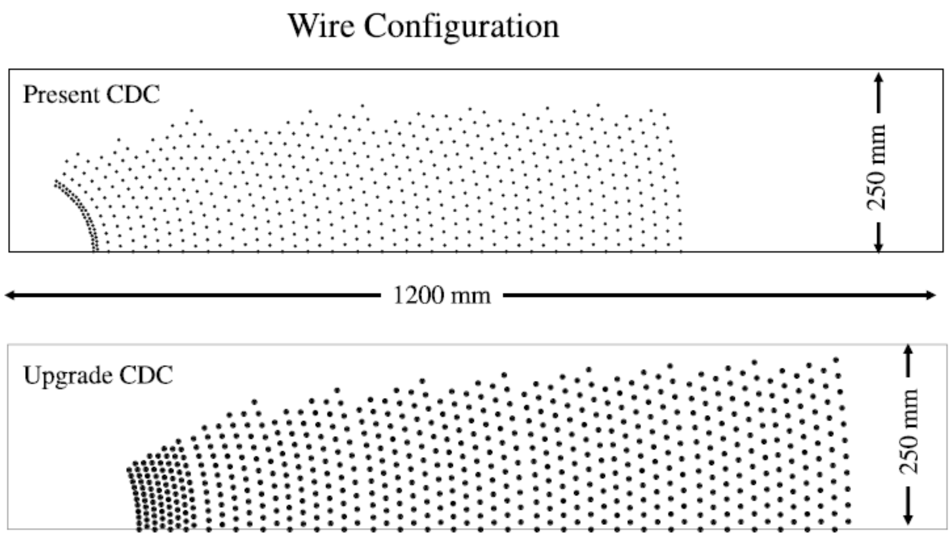
SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling (+pure CsI for endcaps)
KLM: RPC → Scintillator +MPPC (endcaps, barrel inner 2 lyrs)

In colours: new components

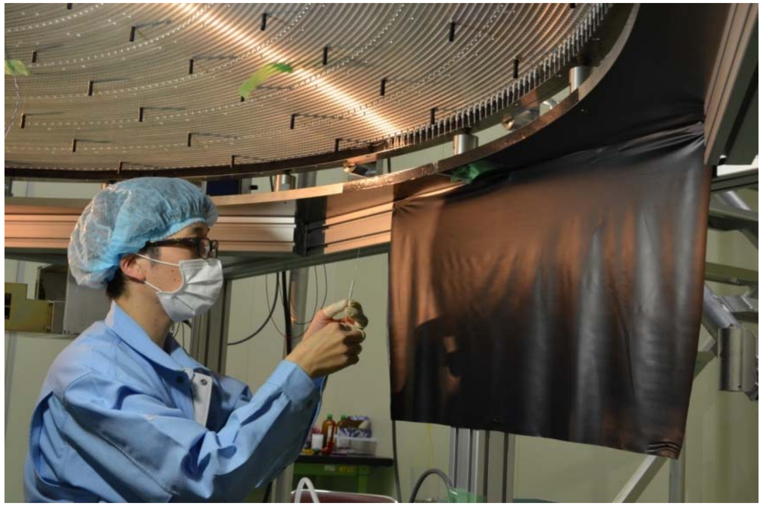
Belle II Detector – vertex region



Belle II CDC



Much bigger than in Belle!



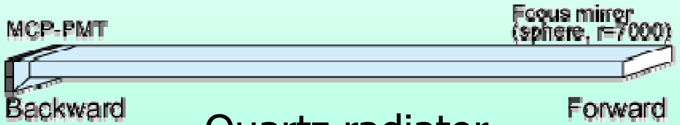
Wire stringing in a clean room

- thousands of wires,
- 1 year of work...

- Done!

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



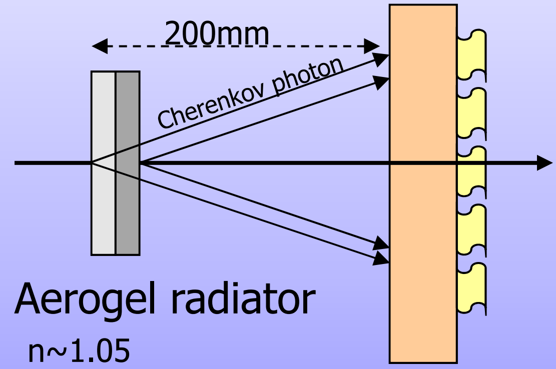
Quartz radiator

Focusing mirror

Small expansion block

Hamamatsu MCP-PMT (measure t, x and y)

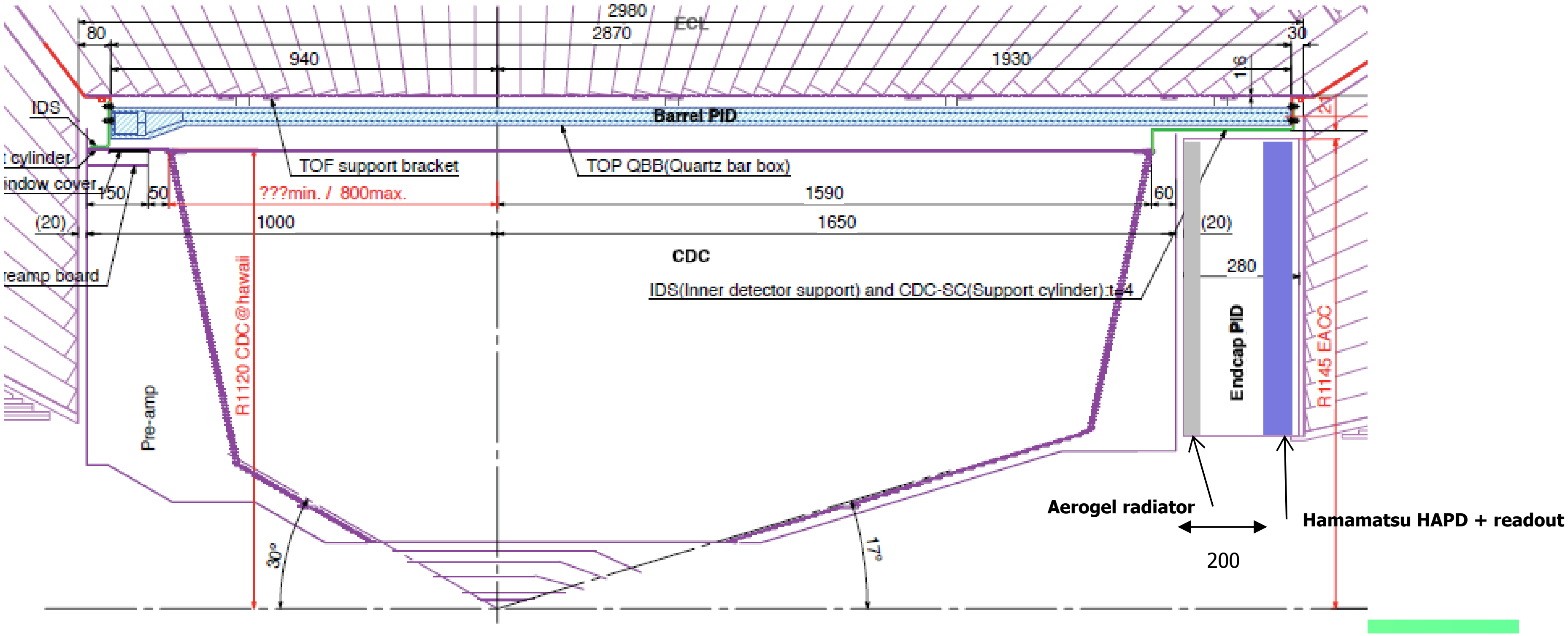
Endcap PID: Aerogel RICH (ARICH)



Aerogel radiator

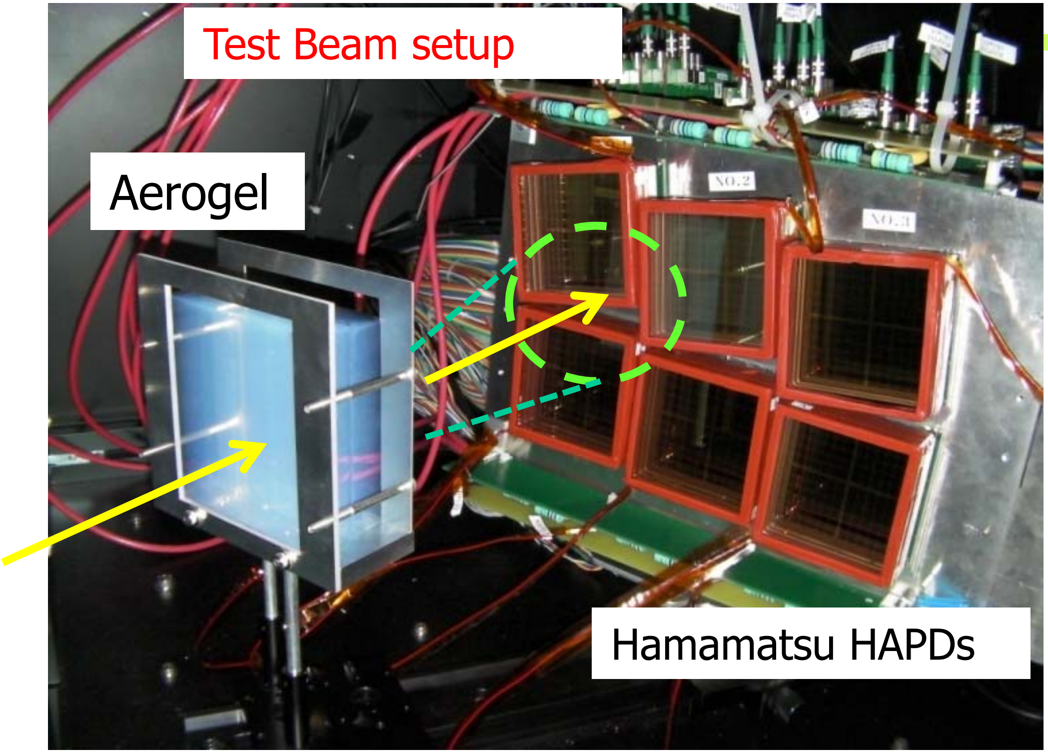
n~1.05

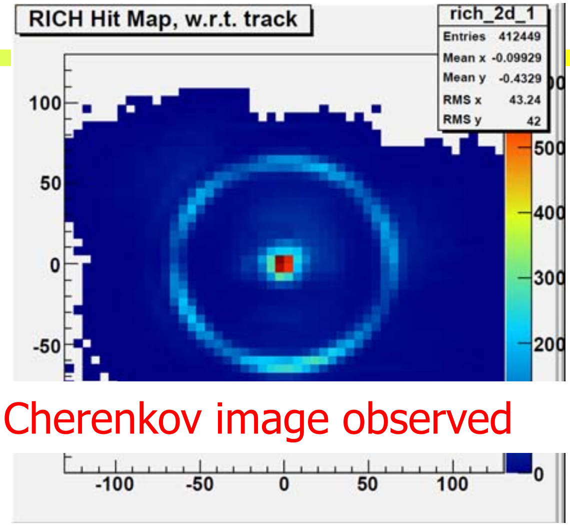
Hamamatsu HAPD



Peter Križan, Ljubljana

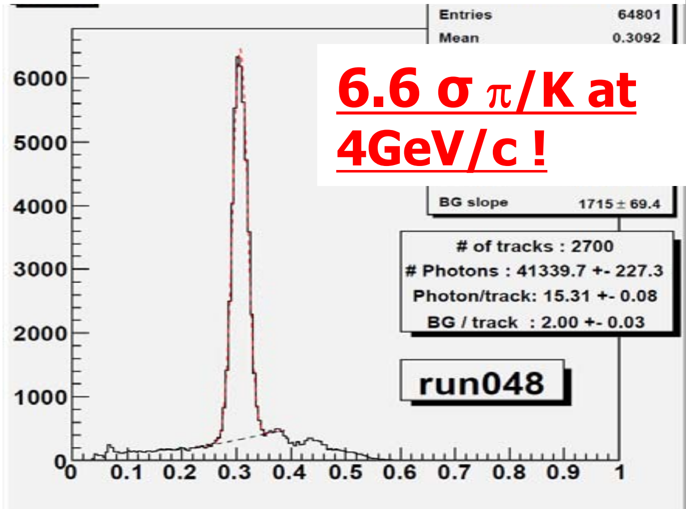
Aerogel RICH (endcap PID)





Clear Cherenkov image observed

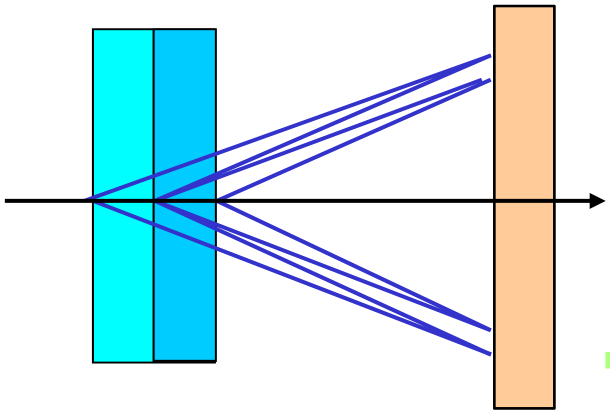
Cherenkov angle distribution



6.6 σ π/K at 4GeV/c !

RICH with a novel "focusing" radiator – a two layer radiator

Employ multiple layers with different refractive indices→ Cherenkov images from individual layers overlap on the photon detector.



Peter Križan, Ljubljana

The Belle II Collaboration

A very strong group of ~600 highly motivated scientists!

SuperKEKB/Belle II Status

Funding

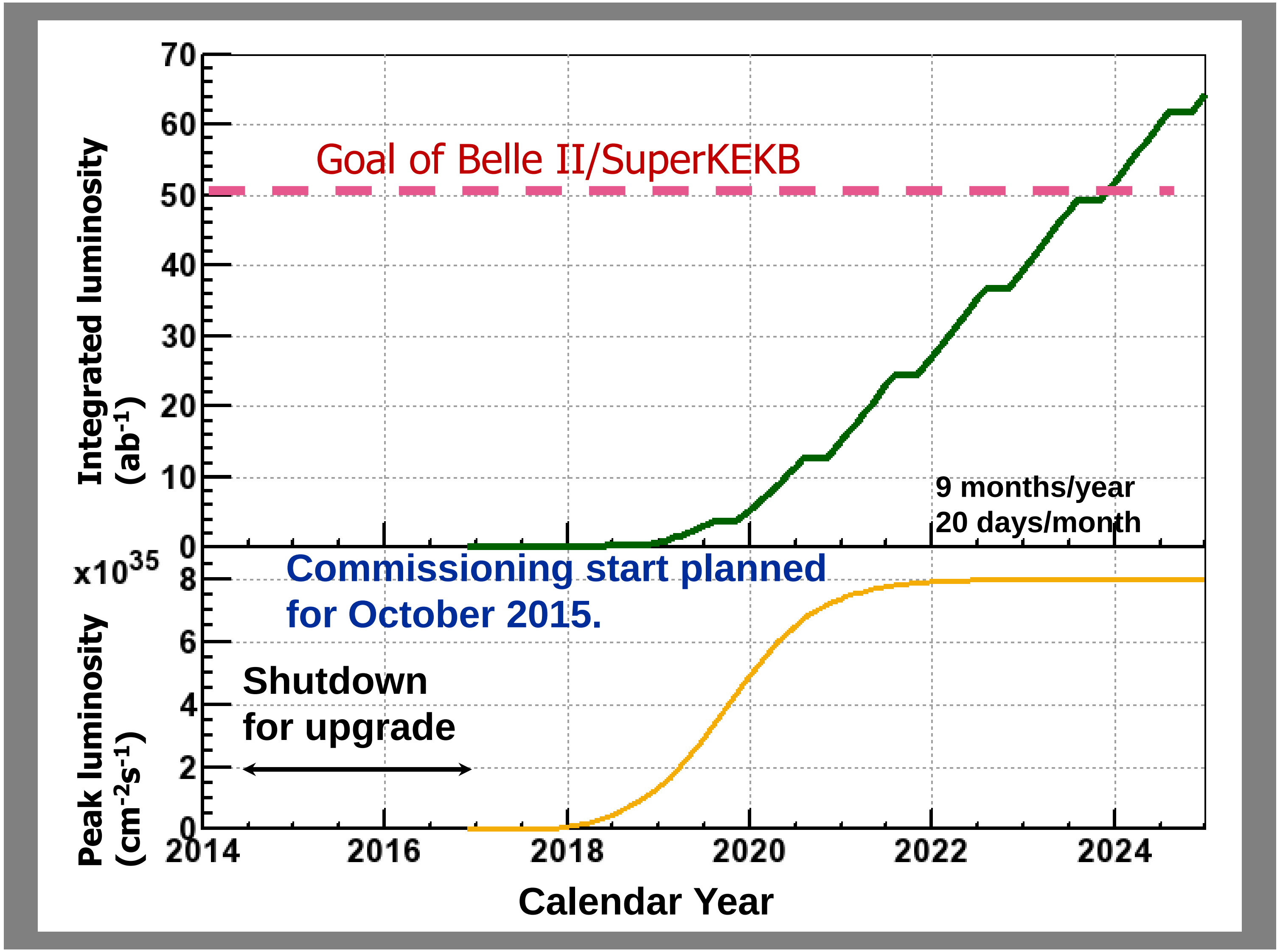
- ~100 MUS for machine approved in 2009 -- Very Advanced Research Support Program (FY2010-2012)
- Full approval by the Japanese government in December 2010; the project was finally in the JFY2011 budget as approved by the Japanese Diet in 2011
- Non-Japanese funding agencies have also allocated sizable funds for the upgrade of the detector.

SuperKEKB and Belle II construction proceeding, nearly on schedule.

5

Commissioning start delayed 9 months from original plan, now scheduled for October 2015.

SuperKEKB luminosity projection



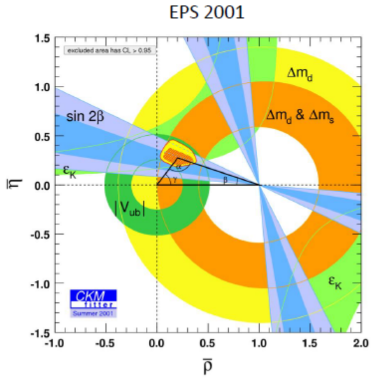
Summary 1

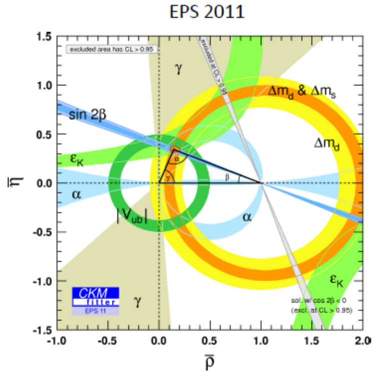
- In the last decade, B-factories have found most of the missing pieces in the bottomonium and charmonium spectra.
- Belle, Babar and BES-III are discovering a plethora of new states, the so called XYZ mesons, which require a spectroscopy with new degrees of freedom (tetraquarks, molecules, hybrids).
- Many new questions arose from unexpected states across and above thresholds.
- Precise tests of NRQCD will require $O(10^9)$ samples of Y(1,2,3S) decays or larger.

Summary 2

- Charged bottomonia (Z_b states) have provided unique pathways to discover the missing spin singlet states. Their understanding is tightly coupled to the study of the charmonium-like counterparts (Z_c states) observed by Belle, BES-III and LHCb. Running at or above Υ(5S) is compulsory for making further progress on this topic (SuperKEKB can reach E_{cms} = 11.25 GeV).
- Bottomonia provide also a unique environment for the study of hyperon-nucleon interactions, as their annihilations produce slow hyperons in large quantities, and are the only mesons which can produce nuclei (from deuteron to He-4).
- Possible studies include further searches for the long sought H-dibaryon.
- The physics program of Belle II during the early running periods is under preparation; it is very likely to include a very sizable fraction of data taking at Υ(nS) resonances above and below Υ(4S).

Summary





- B factories have proven to be an excellent tool for flavour physics as well for searches for new hadronic states, with reliable long term operation, constant improvement of the performance, achieving and surpassing design performance
- Super B factory at KEK under construction 2010-15 → SuperKEKB+Belle II, L x40, construction at full speed – the biggest particle physics project under preparation
- Expect a new, exciting era of discoveries in hadron spectroscopy, complementary to the LHCb, BESIII, PANDA, JLAB