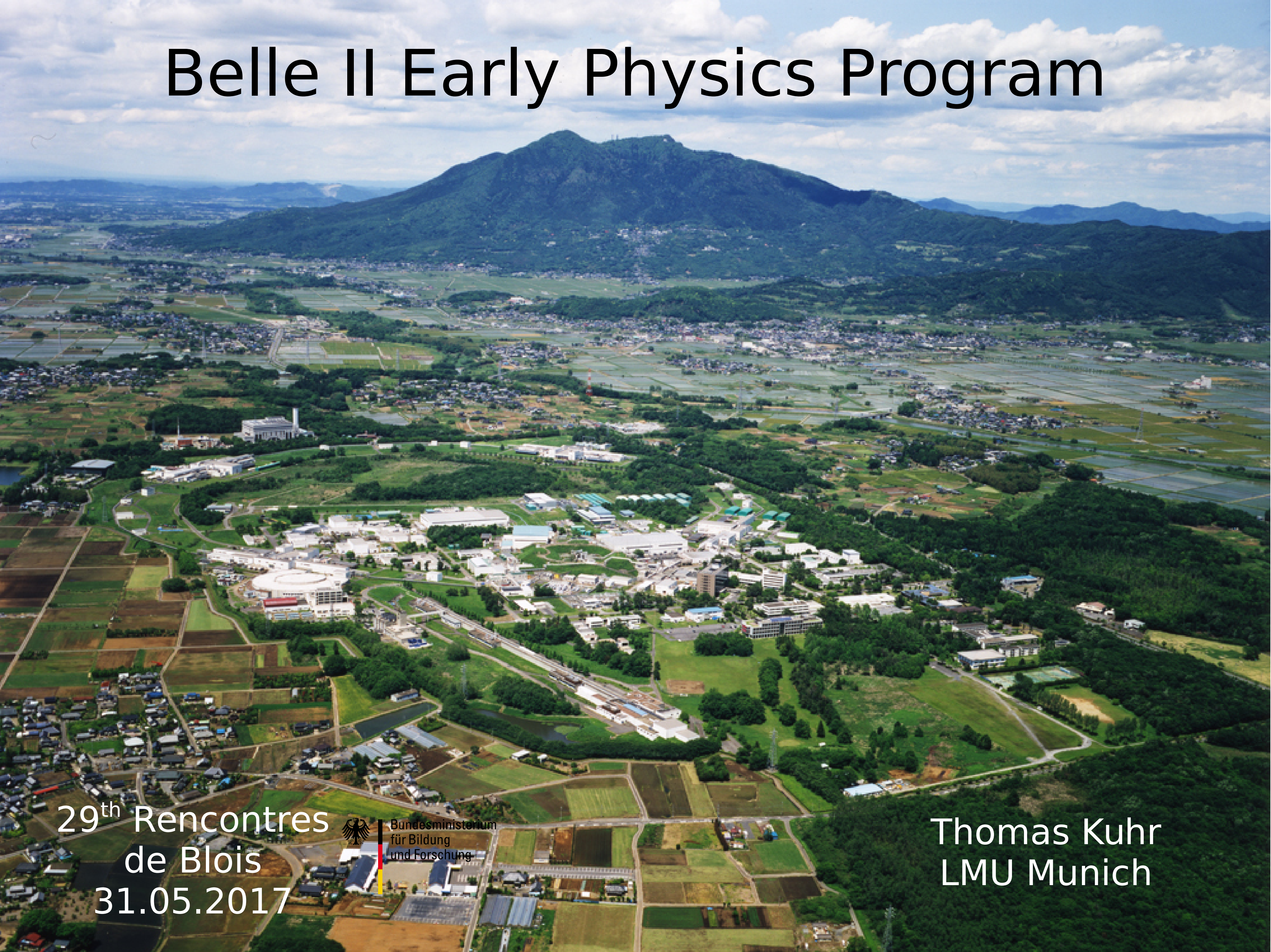
Belle II Early Physics Program



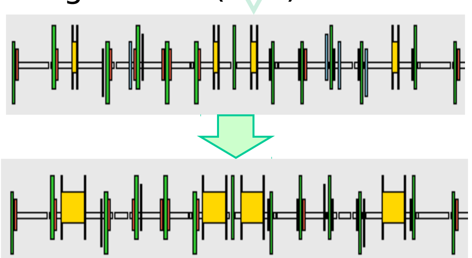
29th Rencontres de Blois
31.05.2017

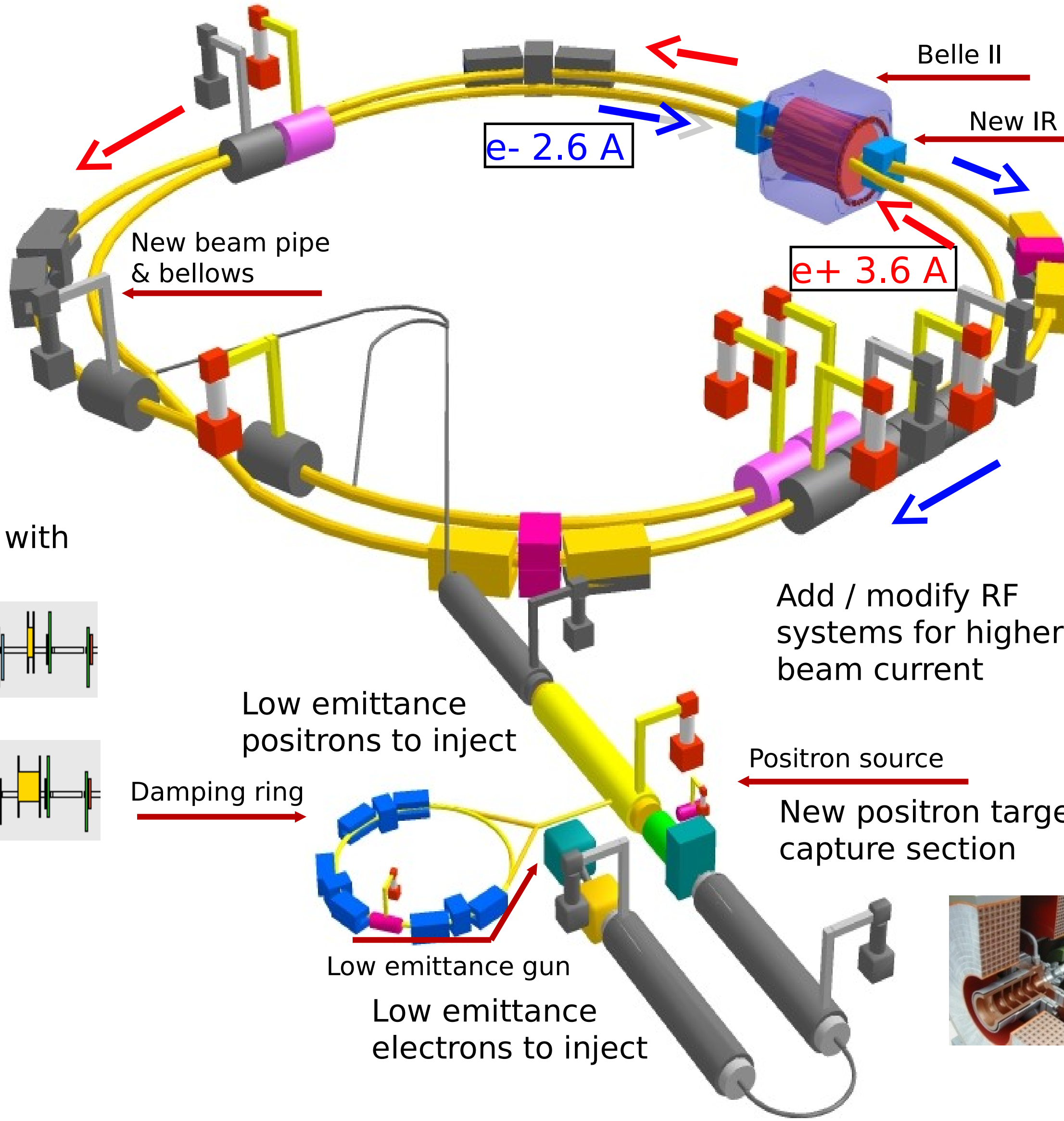
Bundesministerium für Bildung und Forschung

Thomas Kuhr
LMU Munich

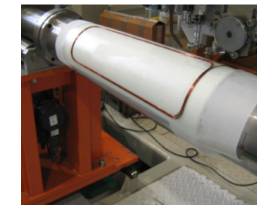
SuperKEKB Upgrade

Replace short dipoles with longer ones (LER)

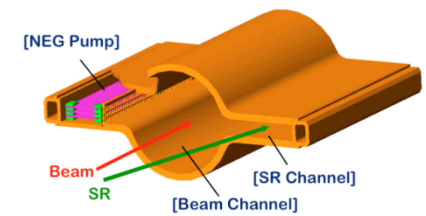




New superconducting /permanent final focusing quads near the IP



TiN-coated beam pipe with antechambers

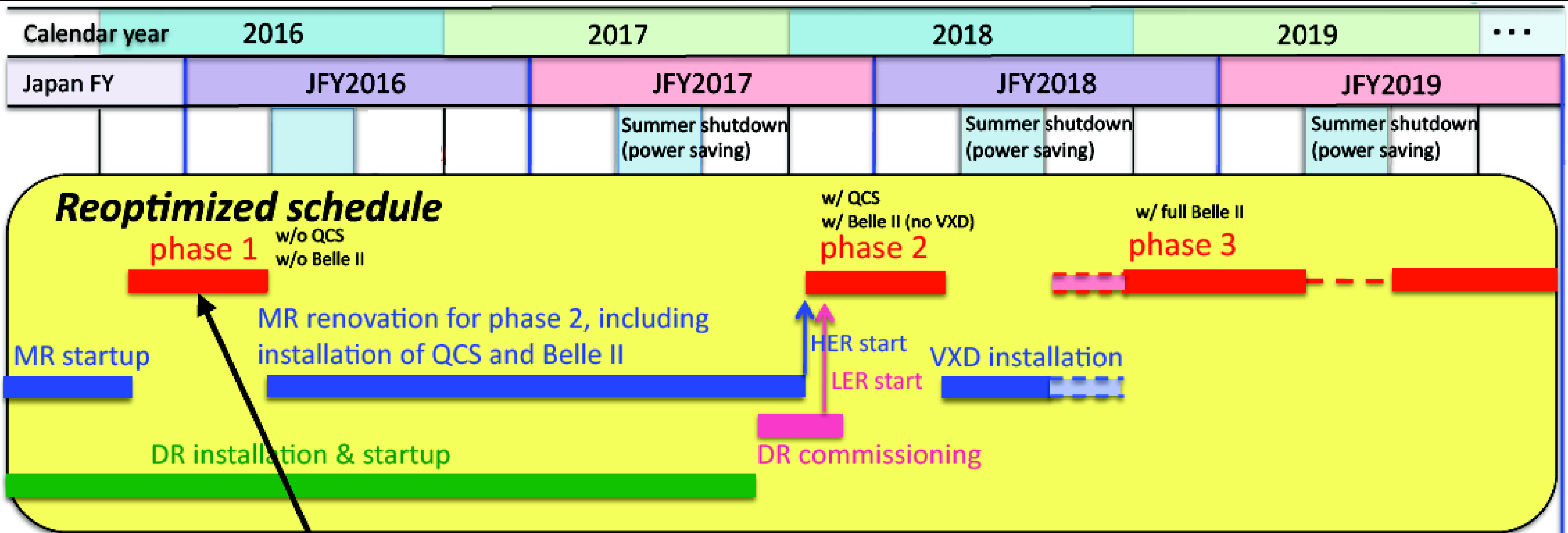


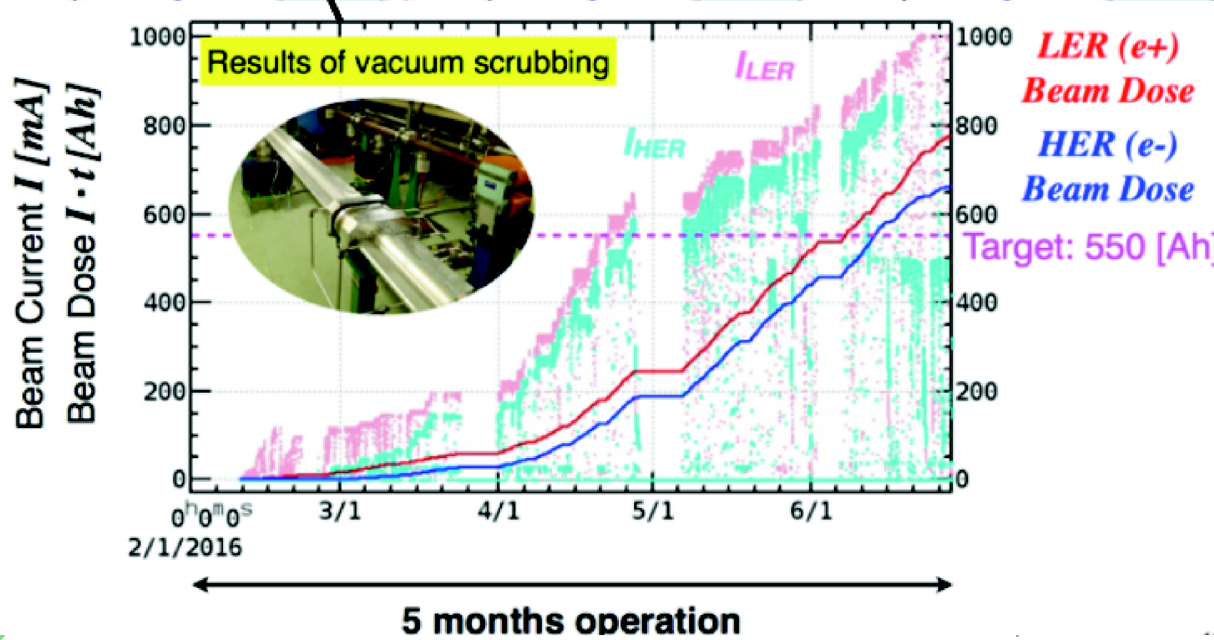
Add / modify RF systems for higher beam current

Redesign the lattices of HER & LER to squeeze the emittance

New positron target / capture section

SuperKEKB / Belle II Schedule

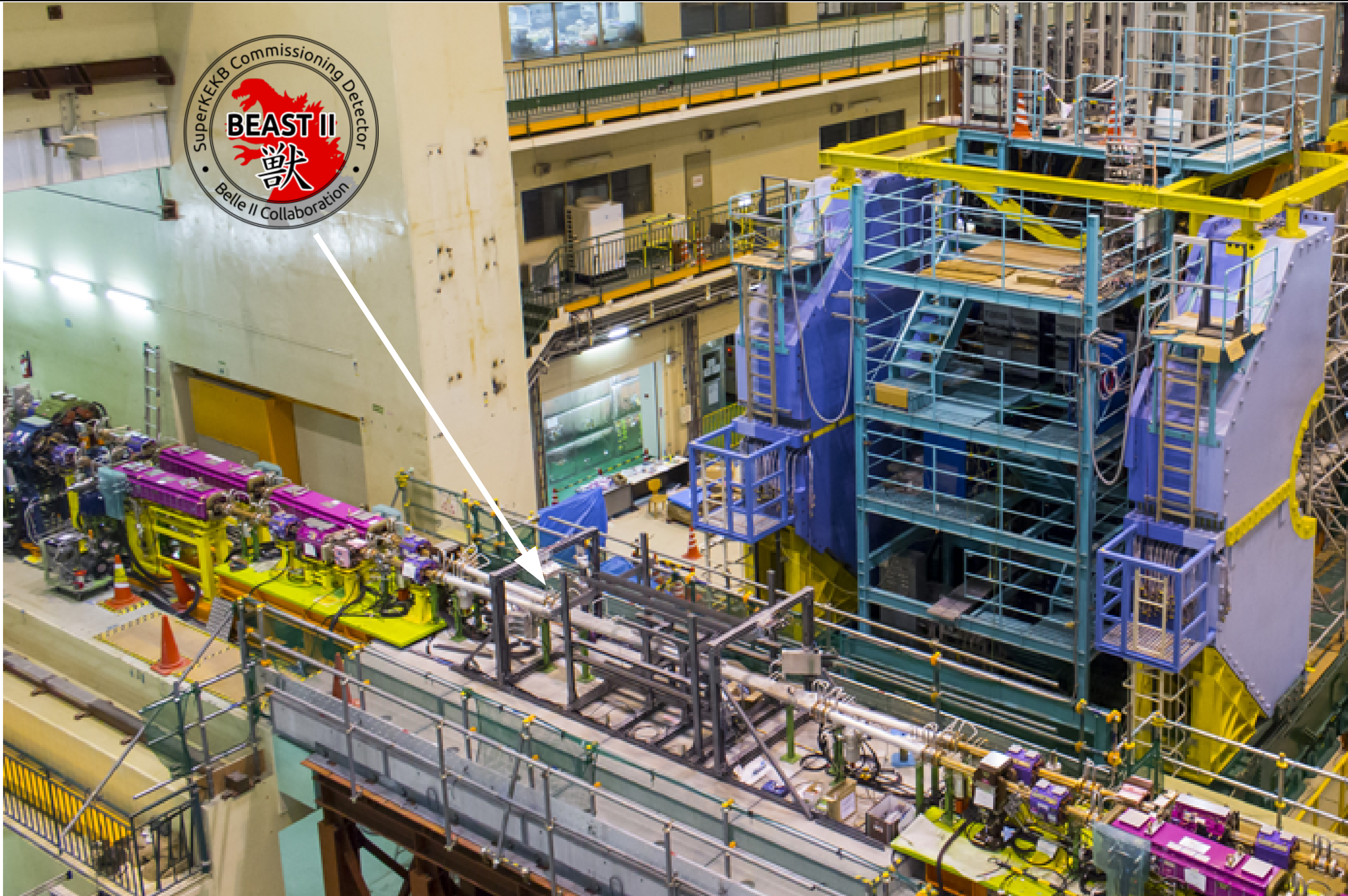


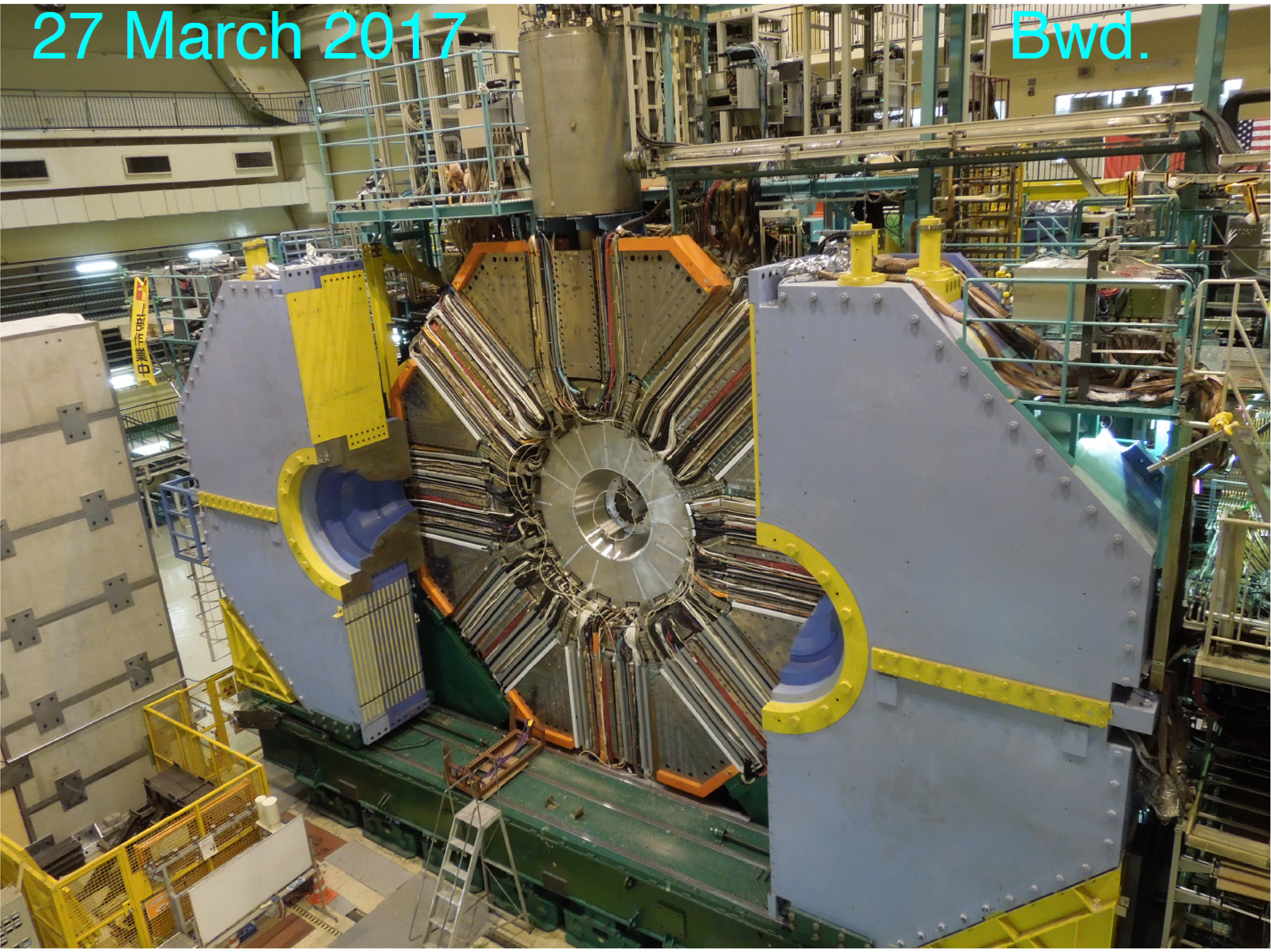


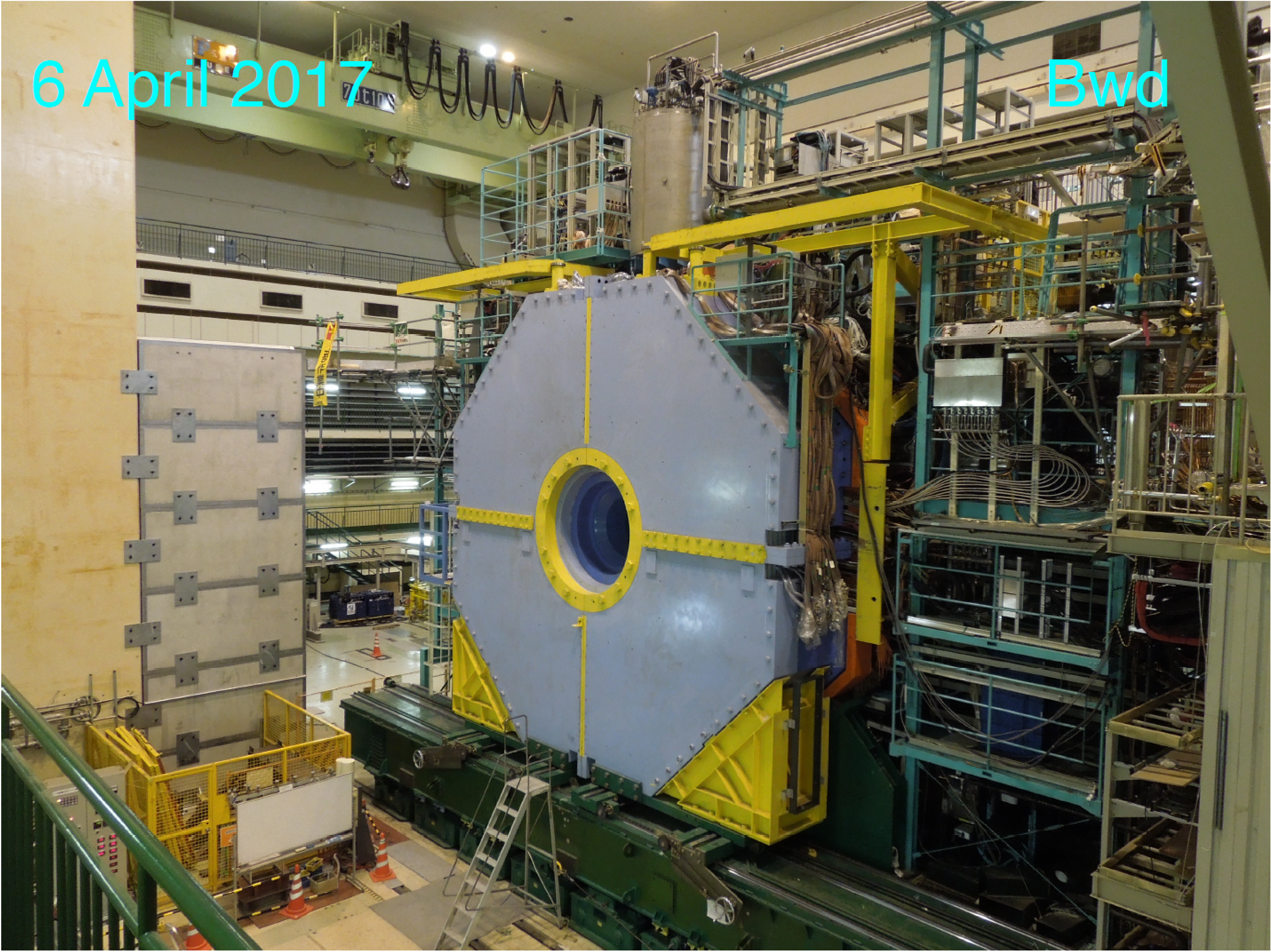
Phase 1

- No collisions
- Beast II detector for background measurements

BEAST II: Background Measurements

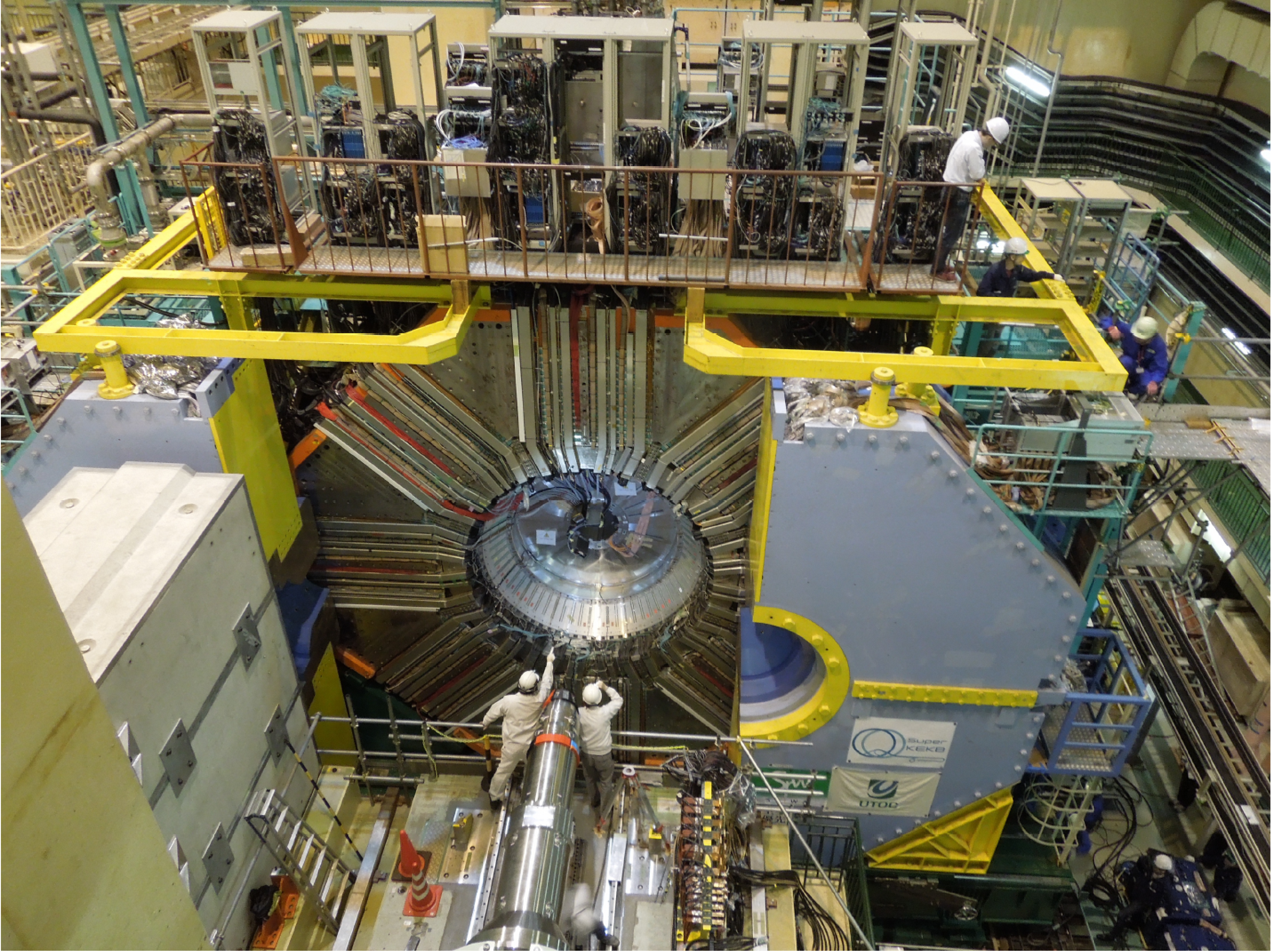



27 March 2017
Bwd.


6 April 2017
Bwd


危険高電圧
感電注意
200V
100V
足場の組立て等
作業主任者の職務
UTOC
KEK


P&H
危険高電圧
感電注意
200V
100V
足場の組立て等
作業主任者の職務
UTOC
昇降階段あり

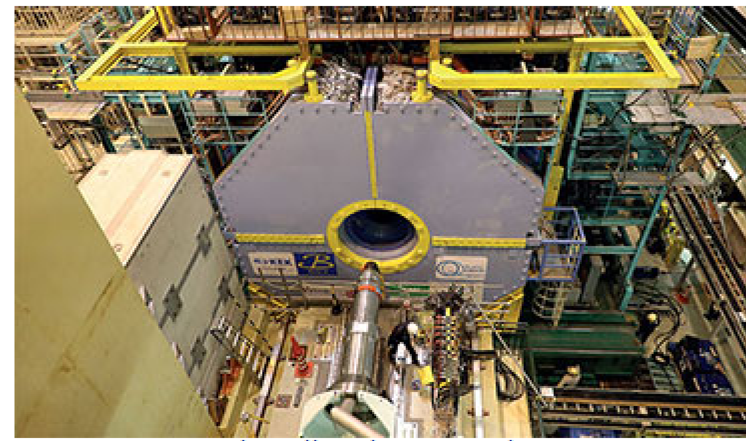

Super
KEKB
UTOC

Belle II Roll In

CERN COURIER

May 19, 2017

Belle II rolls in



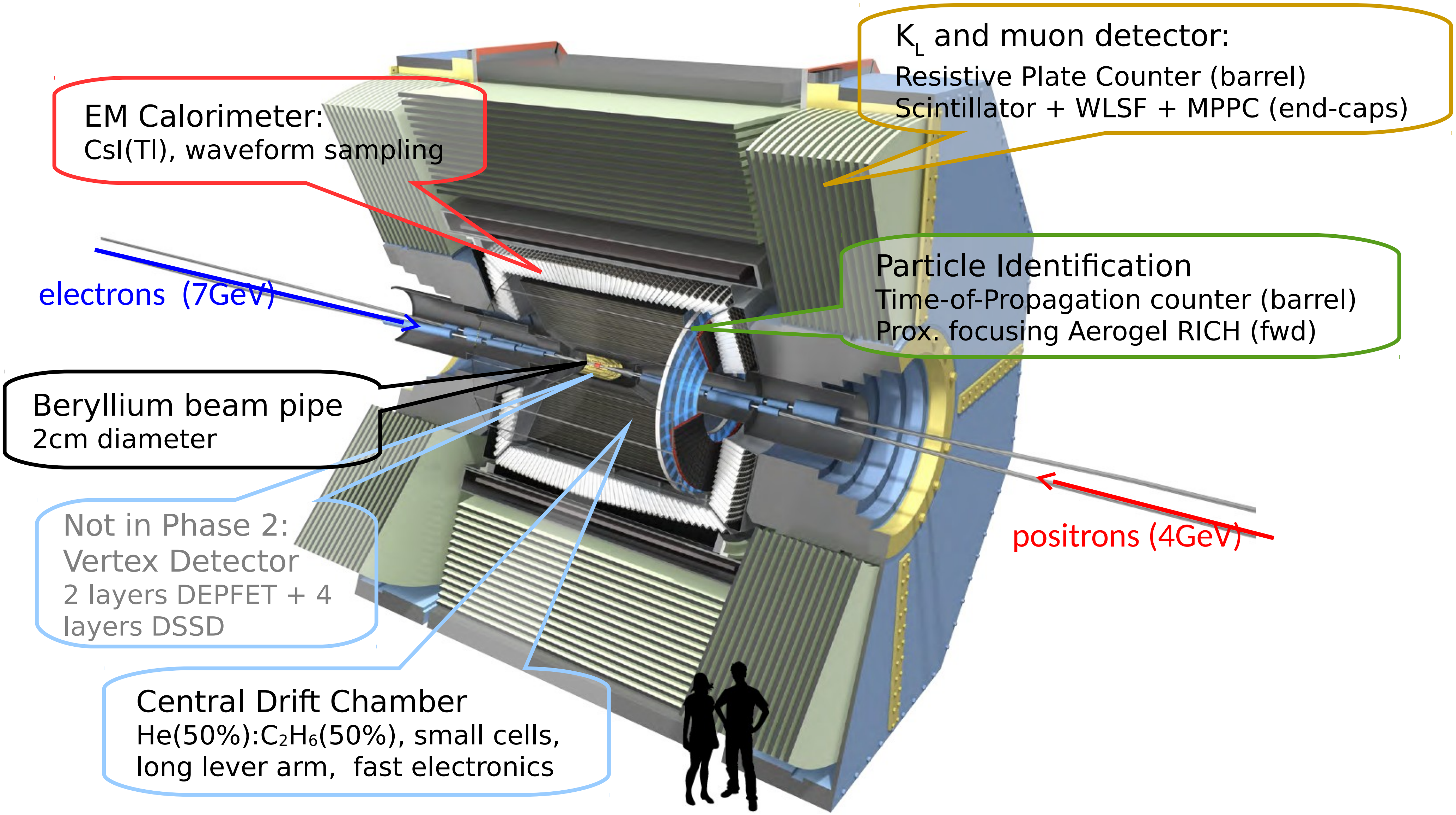
The Belle II detector in place

On 11 April, the Belle II detector at the KEK laboratory in Japan was successfully "rolled-in" to the collision point of the upgraded SuperKEKB accelerator, marking an important milestone for the international B-physics community. The Belle II experiment is an international collaboration hosted by KEK in Tsukuba, Japan, with related physics goals to those of the LHCb experiment at CERN but in the pristine environment of electron-positron collisions. It will analyse copious quantities of B mesons to study CP violation and signs of physics beyond the Standard Model (*CERN Courier* September 2016 p32).

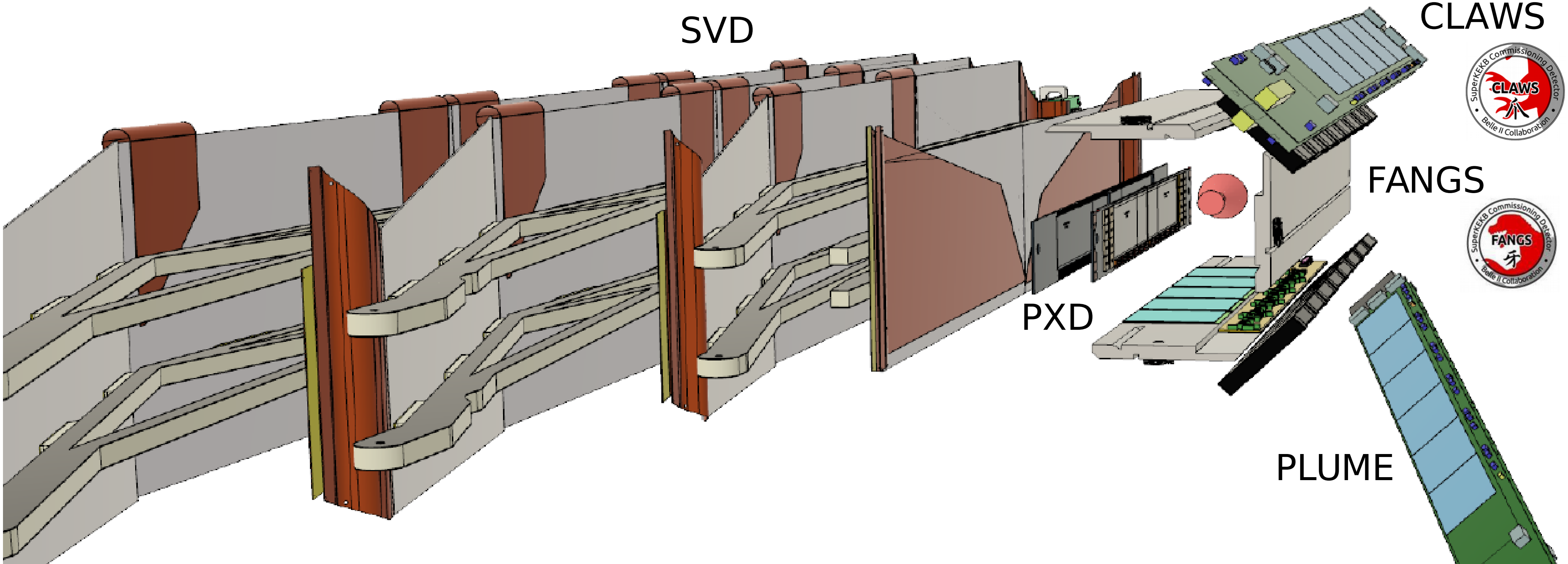
"Roll-in" involves moving the entire 8 m-tall, 1400 tonne Belle II detector system from its assembly area to the beam-collision point 13 m away. The detector is now integrated with

Belle II Detector

TDR: arXiv:1011.0352

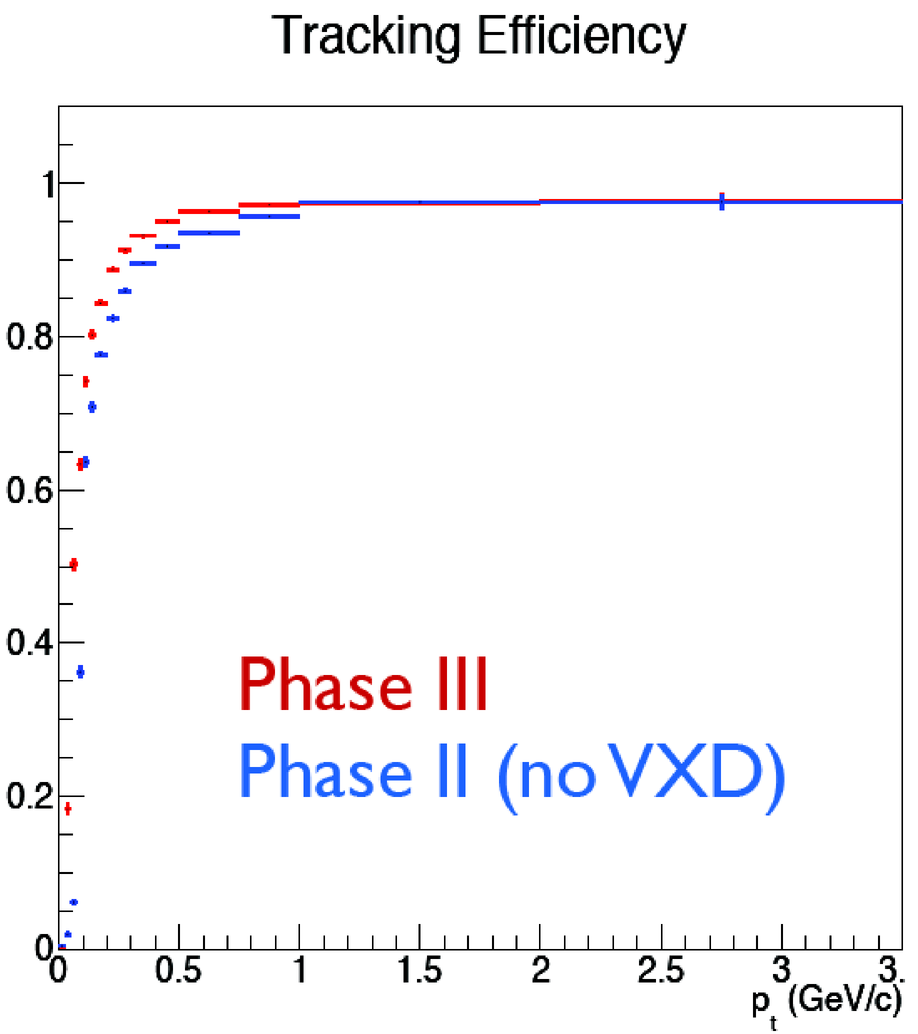


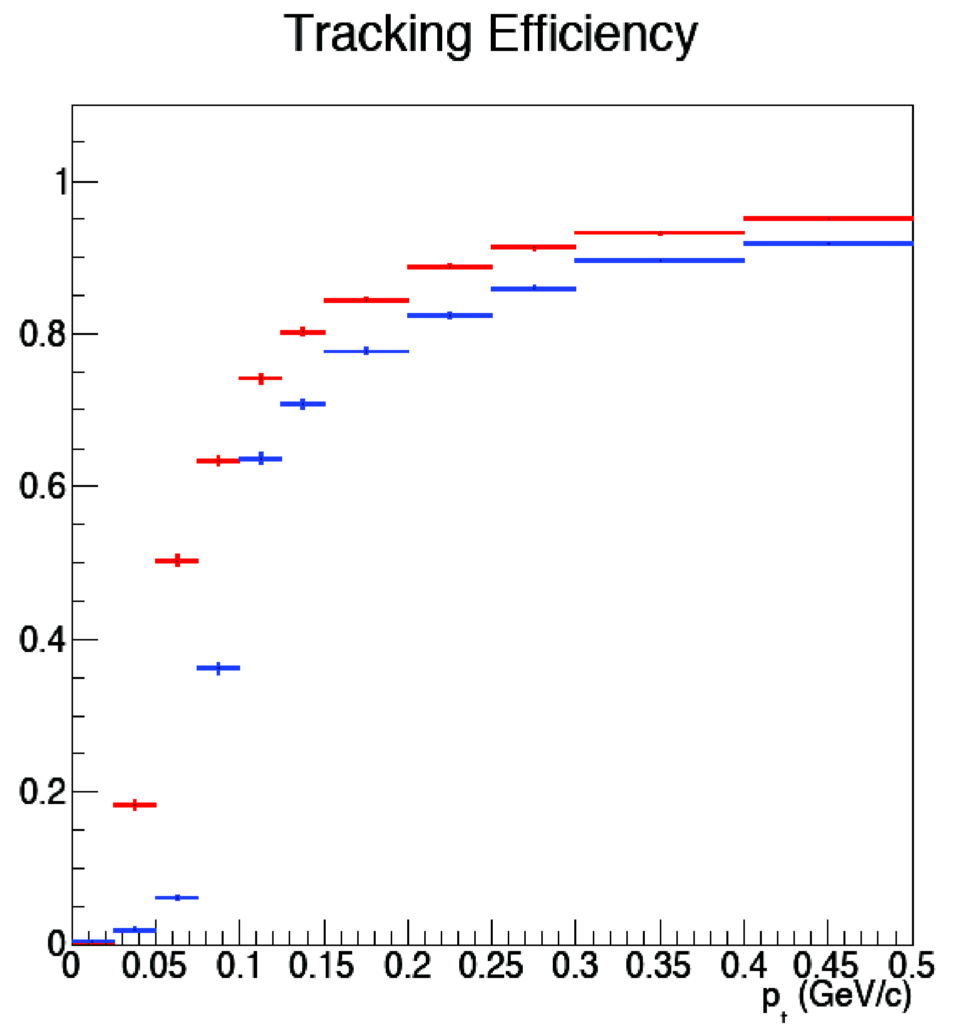
BEAST Silicon Detectors



- One sector of PXD + SVD
- FANGS: Hybrid silicon pixel detectors with ATLAS IBL readout
- CLAWS: Plastic scintillators with SiPM readout
- PLUME: Double sided staves with CMOS pixel sensors

Tracking w/o VXD





Phase 2

Commissioning of accelerator and outer detectors

- Start beginning of 2018, duration ~5 months
- With focusing magnets (QCS) → beam collisions
- Target luminosity 10^{34} $cm^{-2}s^{-1}$ → (20 ± 20) fb^{-1} for physics analyses
- No vertex detector → no time dependent measurements, no low momentum tracking

What can we do with Phase 2 data?

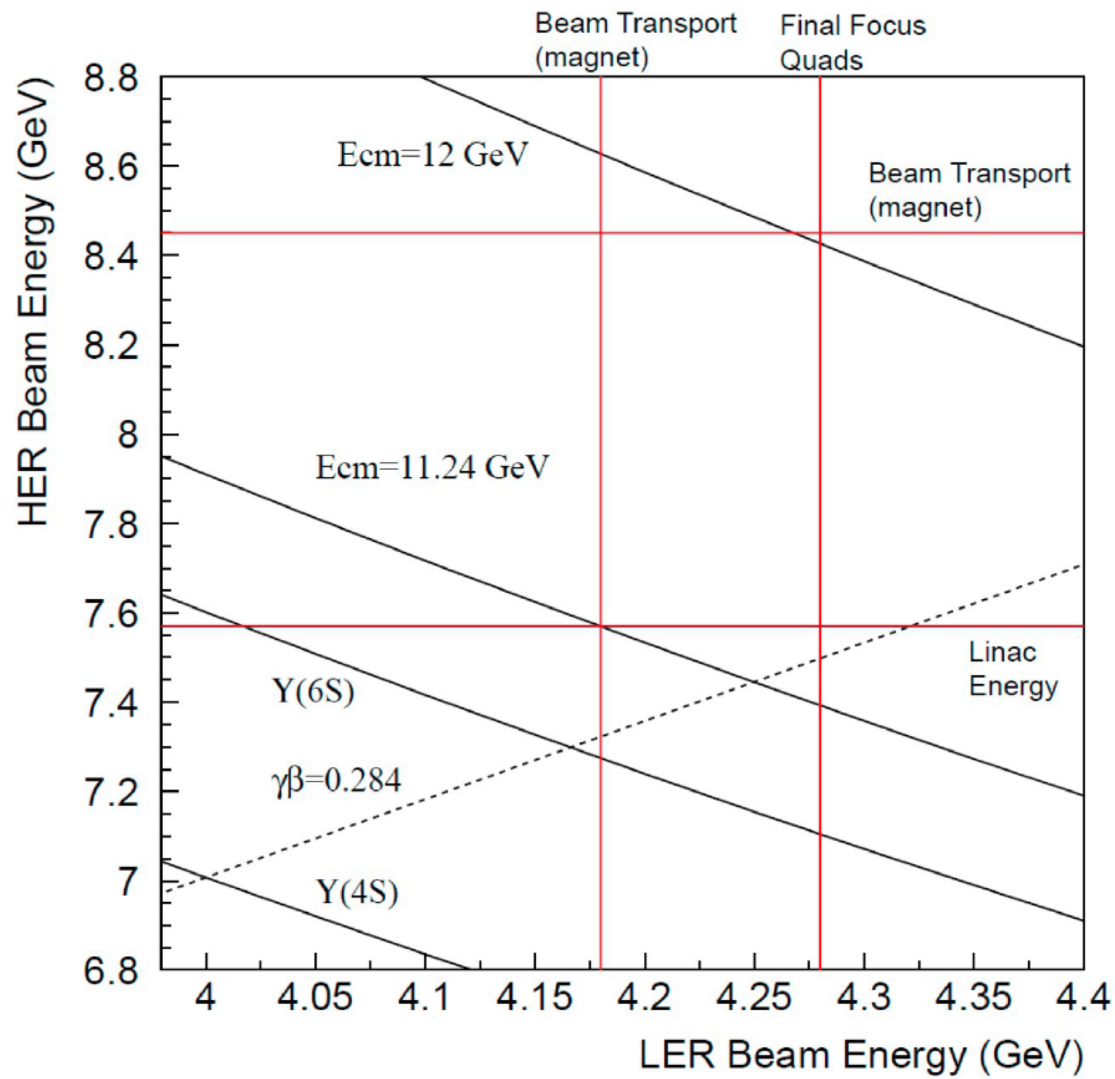
- Background studies
- Detector and trigger performance studies
- Simulation validation
- Exercising of calibration and alignment procedures
- Reconstruction algorithm tuning
- Physics measurements

Center of Mass Energy

Existing datasets [fb^{-1}]:

	CLEO	BaBar	Belle
Υ(1S)	1.2	-	6
Υ(2S)	1.2	14	25
Υ(3S)	1.2	30	3
Υ(4S)	16	433	711
Υ(5S)	0.1	R_b scan	121
Υ(6S)	-		5.5
Off res.	17	54	100

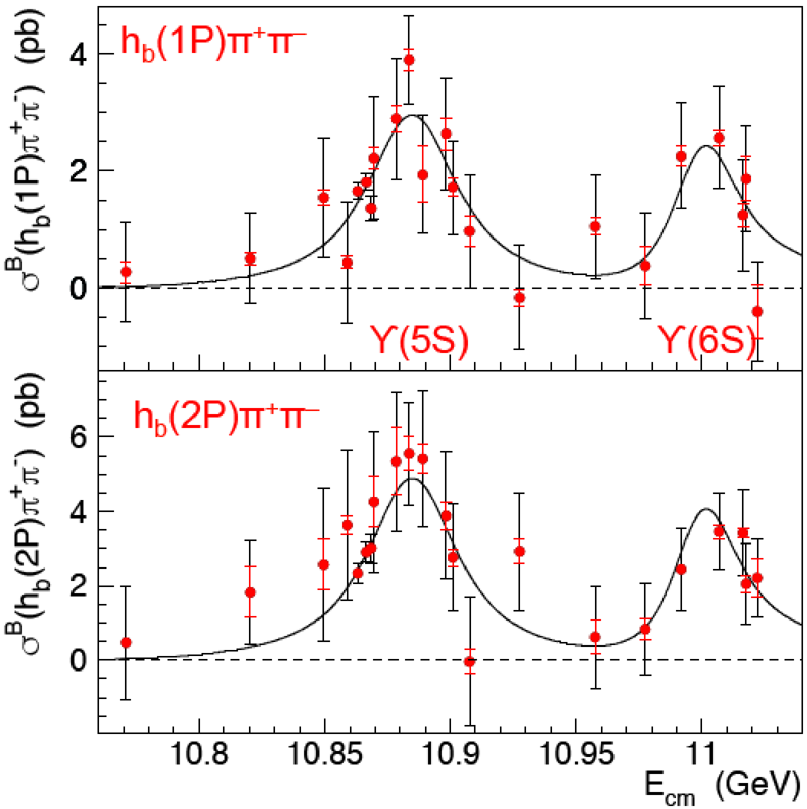
➔ High √s most promising

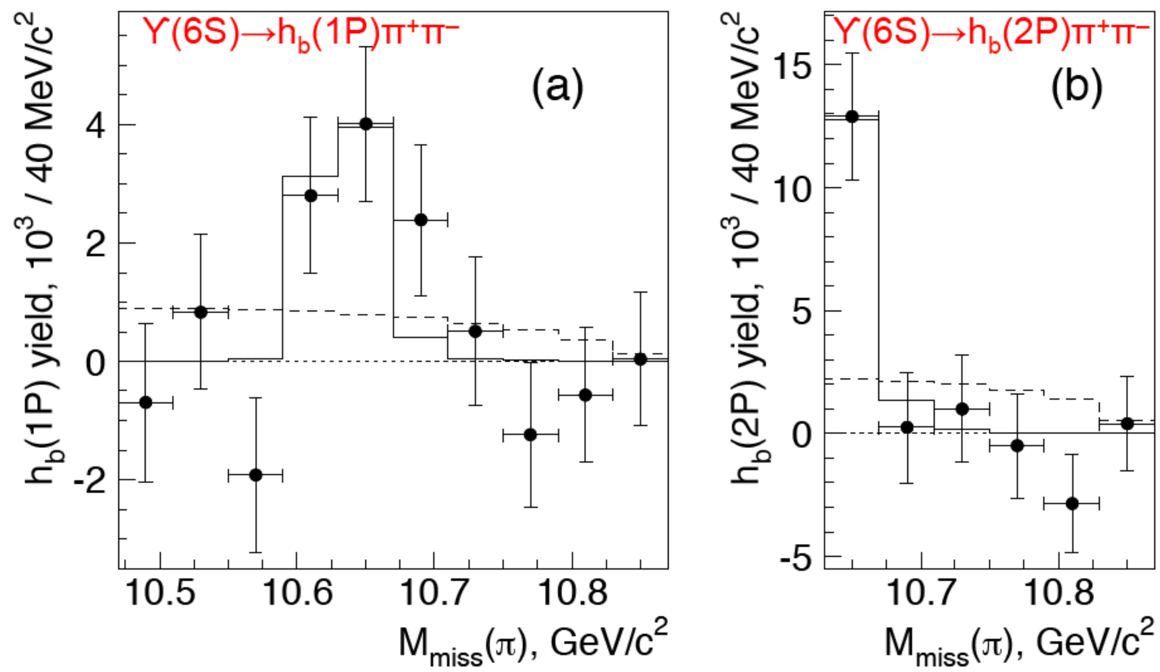


Z_b @ Belle

- $Z_b^{\pm}(10610)$ and $Z_b^{\pm}(10650)$ discovered in $\Upsilon(nS)\,\pi^{\pm}$ and $h_b(mP)\,\pi^{\pm}$ at $\Upsilon(5S)$
  PRL 108, 122001 (2012)
- $Z_b^0(10610)$ discovered in $\Upsilon(nS)\,\pi^0$ at $\Upsilon(5S)$ PRD 88, 052016 (2013)
- $Z_b^{\pm}(10610) \rightarrow B^*B$ and $Z_b^{\pm}(10650) \rightarrow B^*B^*$ observed at $\Upsilon(5S)$ (dominant)
  PRL 116, 212001 (2016)

3.3σ for $Z_b^{\pm}(10610)$ at $\Upsilon(6S)$ PRL 117, 142001 (2016)





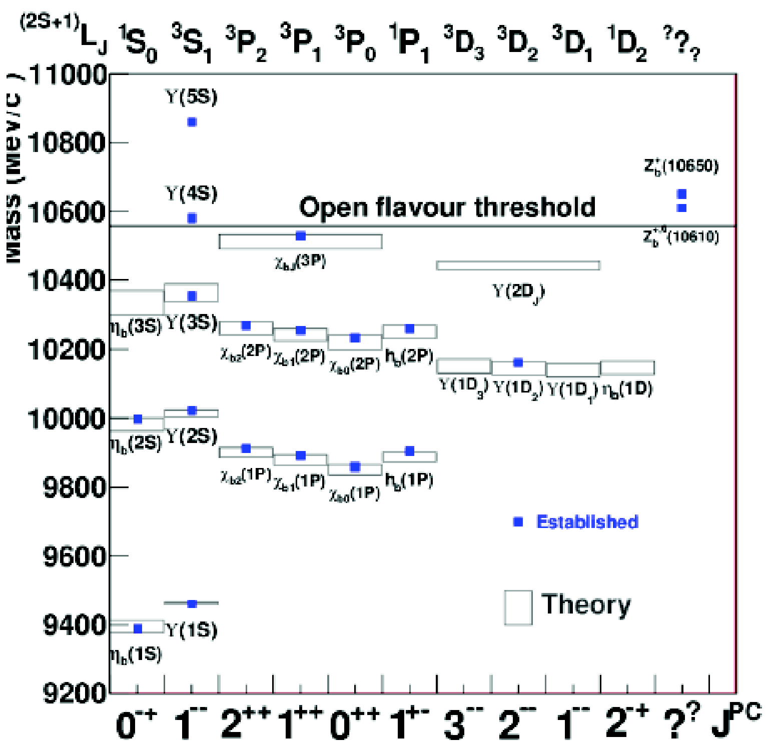
Υ(6S): Exotic States

- Search for Z_b, isovector W_b, isoscalar X_b, and QCD hybrids

		Feasibility x Interest
1	$\Upsilon(6S) \rightarrow Z_b^+ \pi^- \rightarrow h_b(1P, 2P) \pi^+ \pi^-$	***
2	$\Upsilon(6S) \rightarrow Z_b^+ \pi^- \rightarrow \Upsilon(1S, 2S, 3S) \pi^+ \pi^-$	***
3	$\Upsilon(6S) \rightarrow Z_b^+ \pi^- \rightarrow \eta_b \rho$	*
4	$\Upsilon(6S) \rightarrow W_b^0 \gamma$, $W_b \rightarrow \eta_b \pi, \chi_b \pi, \Upsilon\rho$	*
5	$\Upsilon(6S) \rightarrow W_b^0 \pi^+ \pi^-$, $W_b \rightarrow \eta_b \pi, \chi_b \pi, \Upsilon\rho$	**
6	$\Upsilon(6S) \rightarrow \gamma X_b (\rightarrow \omega \Upsilon(1S))$	**
7	$\Upsilon(6S) \rightarrow \pi \pi X_b (\rightarrow \omega \Upsilon(1S))$	*
8	QCD hybrids in BB*	*

Υ(6S): Conventional Bottomonium

- ➔ So far unseen states may be discovered
- But limited by data size



1* due to stat limitation

Quarkonia transitions

1	Υ(6S) → π π Υ(n^3D_J)	*
2	Υ(6S) → η Υ(pS) and η Υ(n^3D_J)	*
3	Υ(6S) → $K^+ K^-$ Υ(pS), strangeness unexplored	*
4	Υ(6S) → ω χ_b(1P)	*

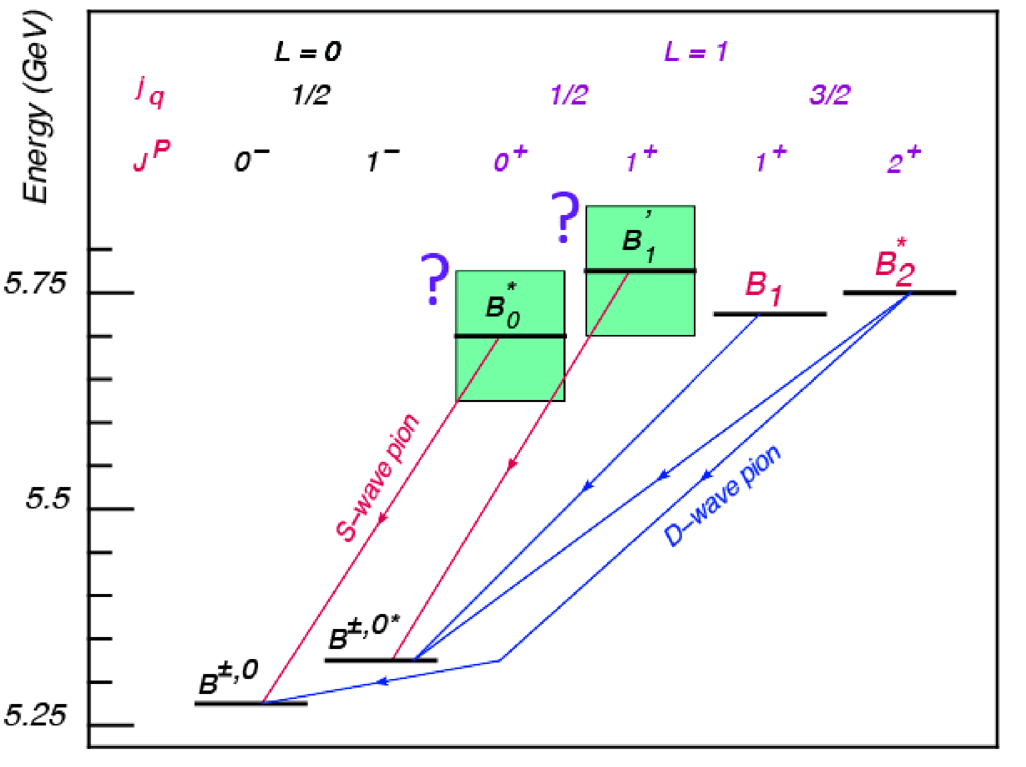
Bottomonium discovery

5	Υ(6S) → $\pi^+ \pi^-$ h_b(3P)	*
6	Υ(6S) → $\pi^+ \pi^-$ Υ(2D) or η Υ(2D)	*
7	Υ(6S) →1F bottomonium multiplet via dipion transition	?

Spectroscopy

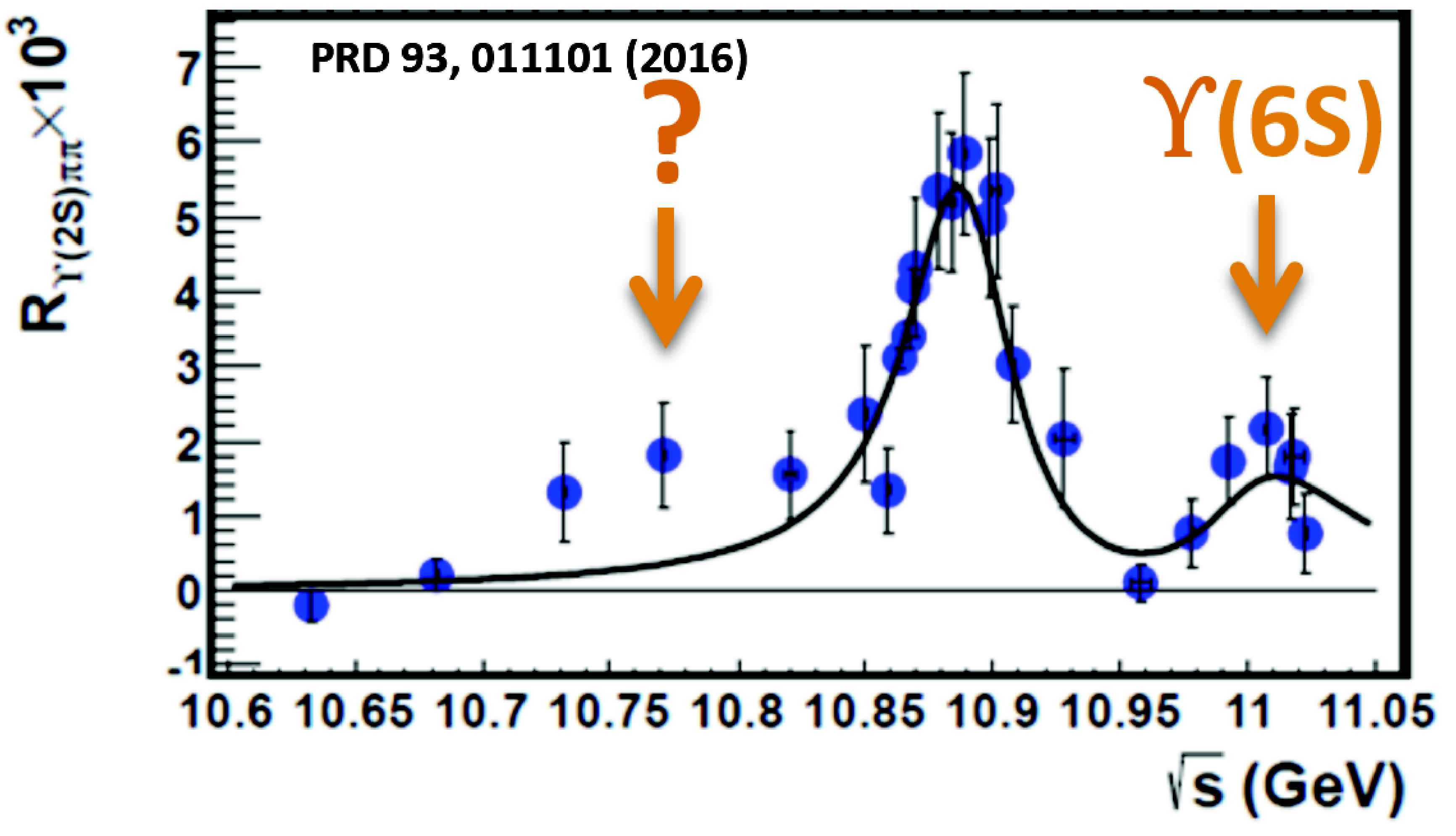
- Υ(6S) at BB** threshold

Particles	Threshold, GeV/c^2
$B^{(*)}\bar{B}^{**}$	11.00 – 11.07
$B_s^{(*)}\bar{B}_s^{**}$	11.13 – 11.26
$\Lambda_b\,\bar{\Lambda}_b$	11.24
$B^{**}\bar{B}^{**}$	11.44 – 11.49
$B_s^{**}\bar{B}_s^{**}$	11.48 – 11.68
$\Lambda_b\,\bar{\Lambda}_b^{**}$	11.53 – 11.54
$\Sigma_b^{(*)}\,\bar{\Sigma}_b^{(*)}$	11.62 – 11.67
$\Lambda_b^{**}\,\bar{\Lambda}_b^{**}$	11.82 – 11.84



Alternative Operating Points

- Anomaly in Υ(2S)$\pi\pi$



Low Multiplicity Events

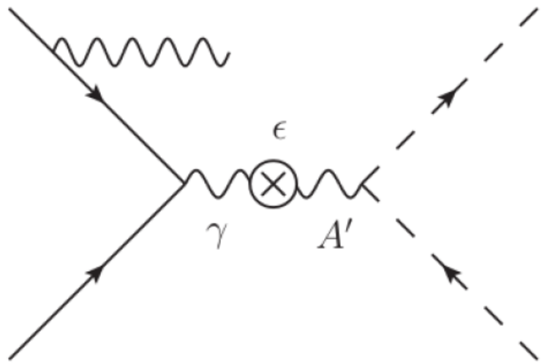
Trigger:

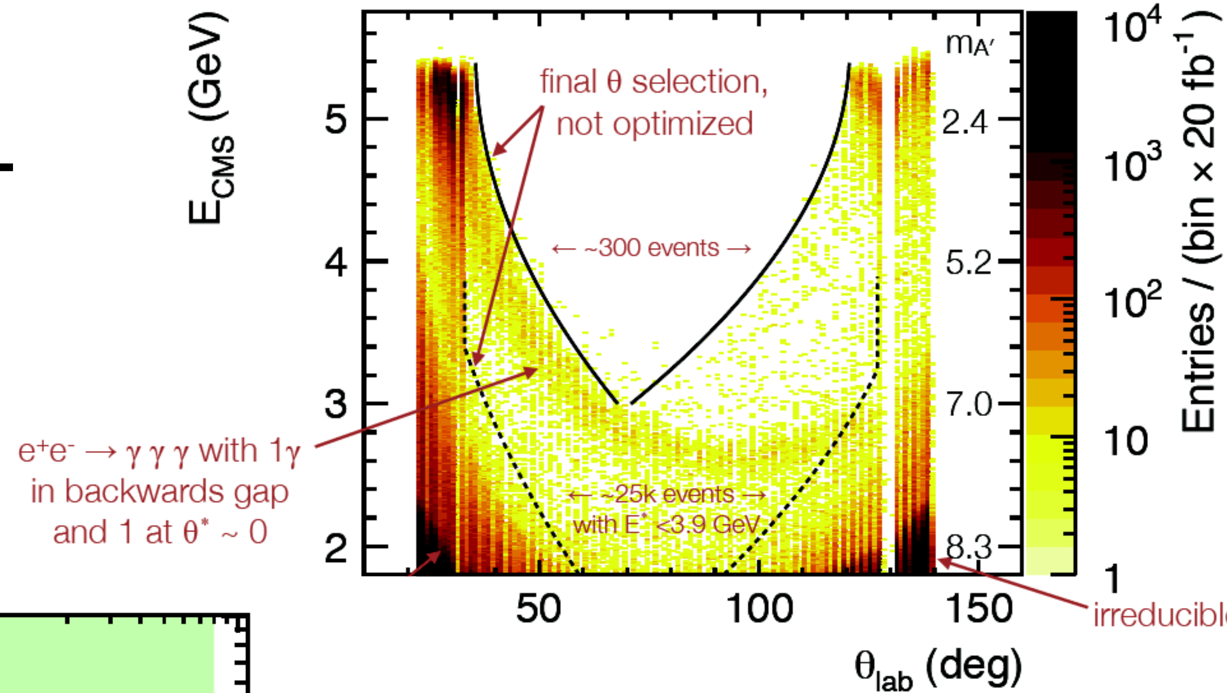
- ~100% efficient for B and charm decays
- ➢ Low multiplicity events challenging because of large QED background
- Belle trigger was not optimized for low multiplicity
- Improvements of level 1 (L1) hardware trigger at Belle II:
  - Data rate increased from 16 to 190 Mbps
  - Logic implemented in FPGAs instead of hard coded
- Software based high level trigger (HLT) runs full reconstruction

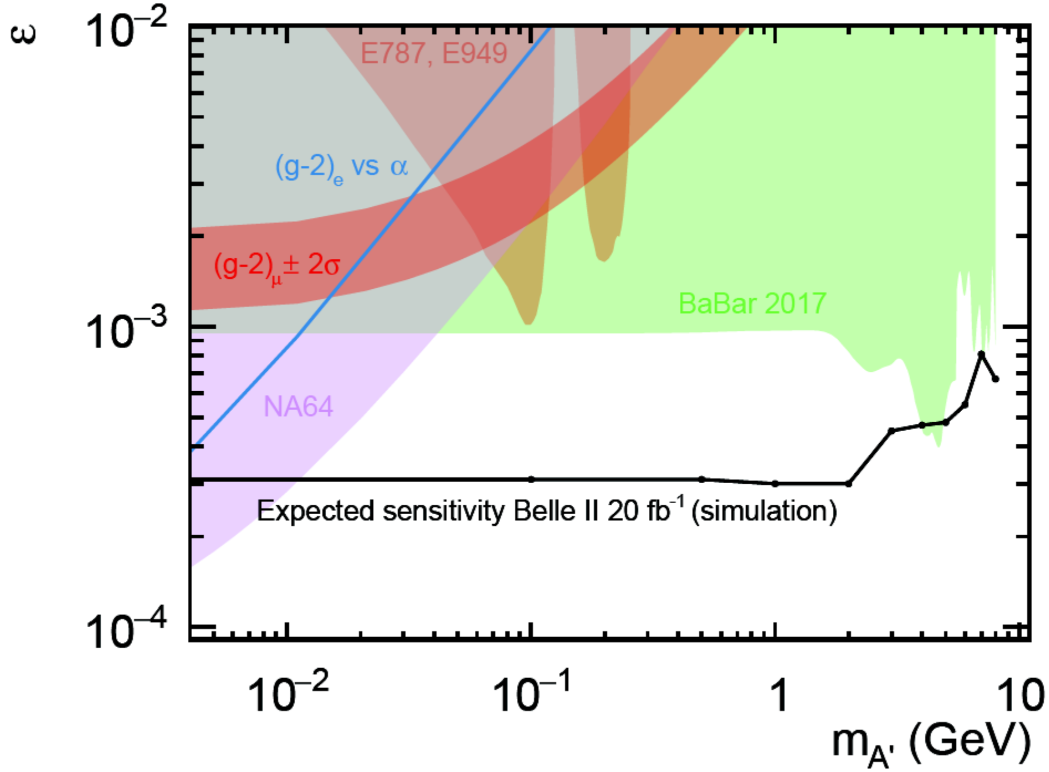
Development of triggers for low multiplicity:

➔ Search for new physics in low multiplicity events with phase 2 data

Dark Photon A’







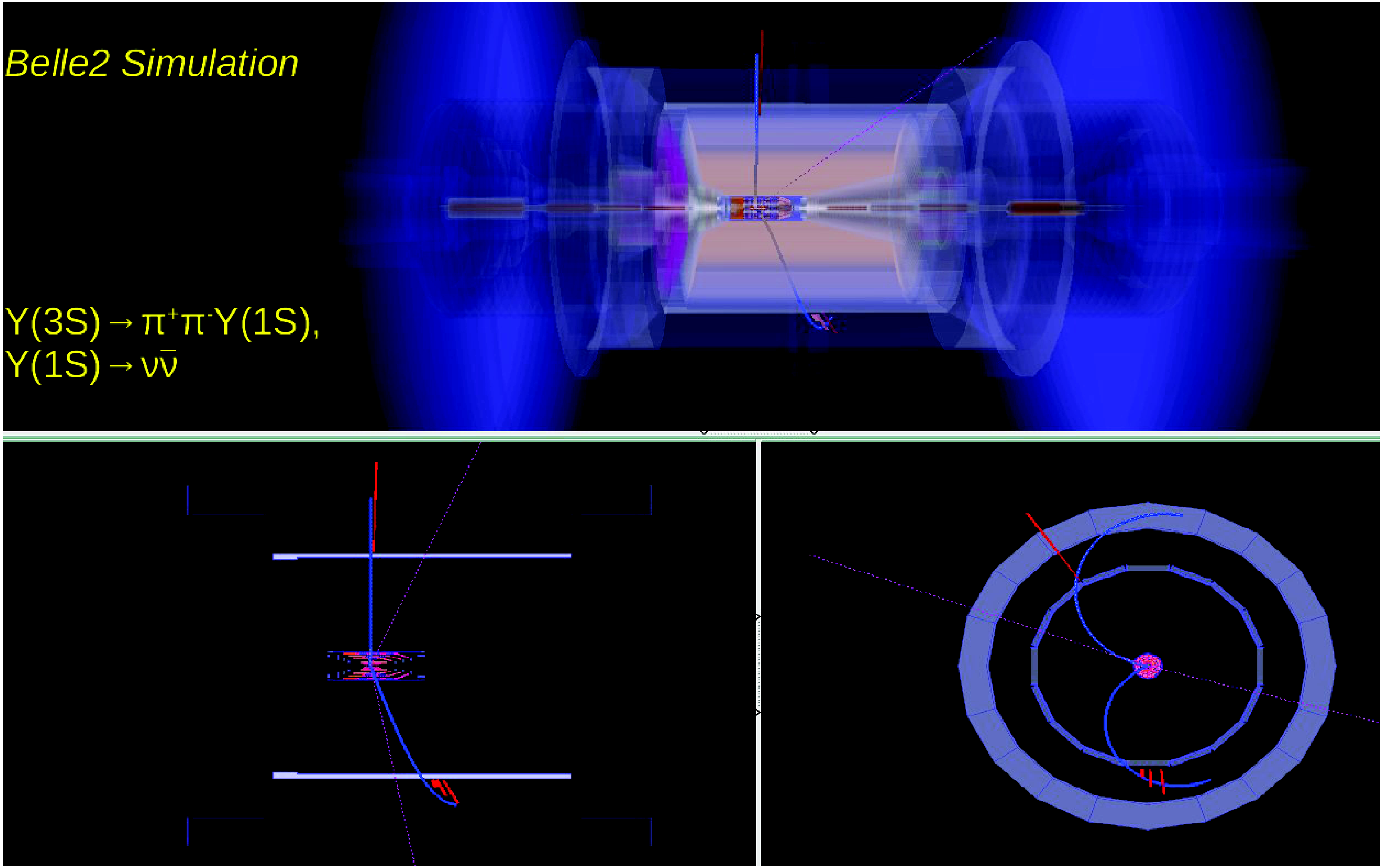
- Kinetic mixing with SM photon

$$\sigma \propto \varepsilon^2 \alpha^2 \left(1 - m_{A'}^2 / E_{CM}^2\right) / E_{CM}^2$$

➢ Relevant for phase 2:
Decay A’ → invisible

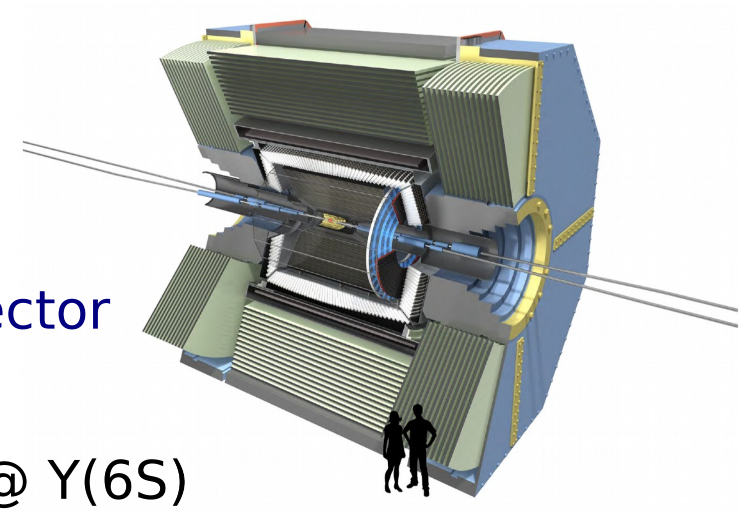
➔ Requires single photon trigger
→ Challenge: background

Invisible Υ(1S) or Υ(2S) Decays



Summary

- Belle II phase 2 starts in about half a year
- ➔ Accelerator and detector commissioning



- Expect (20 ± 20) fb^{-1} of data w/o vertex detector
- ➔ Some exciting first physics opportunities
  - Exotic states and bottomonium studies @ Υ(6S)
  - Dark photon search with single photon trigger
- More details in B2TIP report: *The Belle II Physics Book* (to be submitted to PTEP)

- Stay tuned for news from Belle II
  - https://twitter.com/belle2collab
  - https://www.facebook.com/belle2collab

Backup

Accelerator Design: Nano Beam Scheme

Invented by Pantaleo Raimondi for SuperB

Lorentz factor

Beam current

Beam-Beam parameter $\xi_y \propto \sqrt{(\beta_y^*/\varepsilon_y)}$

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

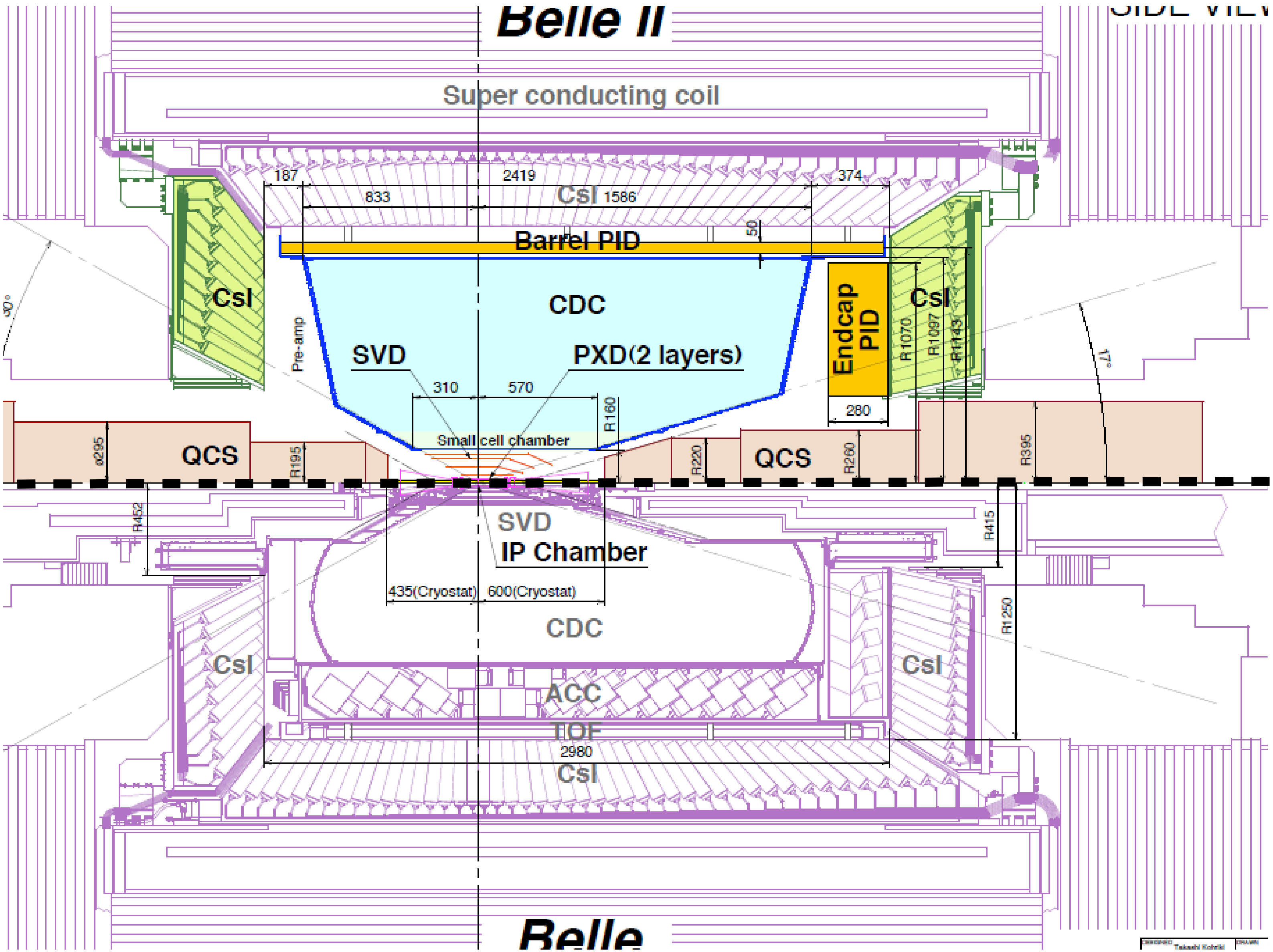
Geometrical reduction factors (crossing angle, hourglass effect)

Vertical beta function at IP

Beam aspect ratio at IP

	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 Compared with Belle



Belle II Collaboration

~700 members
100 institutions
23 countries

Molecular States

$I^G(J^P)$	Name	Composition	Co-produced particles [Threshold, GeV/c^2]	Decay channels
$1^+(1^+)$	Z_b	$B\bar{B}^*$	π [10.75]	$\Upsilon(nS)\pi$, $h_b(nP)\pi$, $\eta_b(nS)\rho$
$1^+(1^+)$	Z'_b	$B^*\bar{B}^*$	π [10.79]	$\Upsilon(nS)\pi$, $h_b(nP)\pi$, $\eta_b(nS)\rho$
$1^-(0^+)$	W_{b0}	$B\bar{B}$	ρ [11.34], γ [10.56]	$\Upsilon(nS)\rho$, $\eta_b(nS)\pi$
$1^-(0^+)$	W'_{b0}	$B^*\bar{B}^*$	ρ [11.43], γ [10.65]	$\Upsilon(nS)\rho$, $\eta_b(nS)\pi$
$1^-(1^+)$	W_{b1}	$B\bar{B}^*$	ρ [11.38], γ [10.61]	$\Upsilon(nS)\rho$
$1^-(2^+)$	W_{b2}	$B^*\bar{B}^*$	ρ [11.43], γ [10.65]	$\Upsilon(nS)\rho$
$0^-(1^+)$	X_{b1}	$B\bar{B}^*$	η [11.15]	$\Upsilon(nS)\eta$, $\eta_b(nS)\omega$
$0^-(1^+)$	X'_{b1}	$B^*\bar{B}^*$	η [11.20]	$\Upsilon(nS)\eta$, $\eta_b(nS)\omega$
$0^+(0^+)$	X_{b0}	$B\bar{B}$	ω [11.34], γ [10.56]	$\Upsilon(nS)\omega$, $\eta_b(nS)\eta$
$0^+(0^+)$	X'_{b0}	$B^*\bar{B}^*$	ω [11.43], γ [10.65]	$\Upsilon(nS)\omega$, $\eta_b(nS)\eta$
$0^+(1^+)$	X_b	$B\bar{B}^*$	ω [11.39], γ [10.61]	$\Upsilon(nS)\omega$
$0^+(2^+)$	X_{b2}	$B^*\bar{B}^*$	ω [11.43], γ [10.65]	$\Upsilon(nS)\omega$