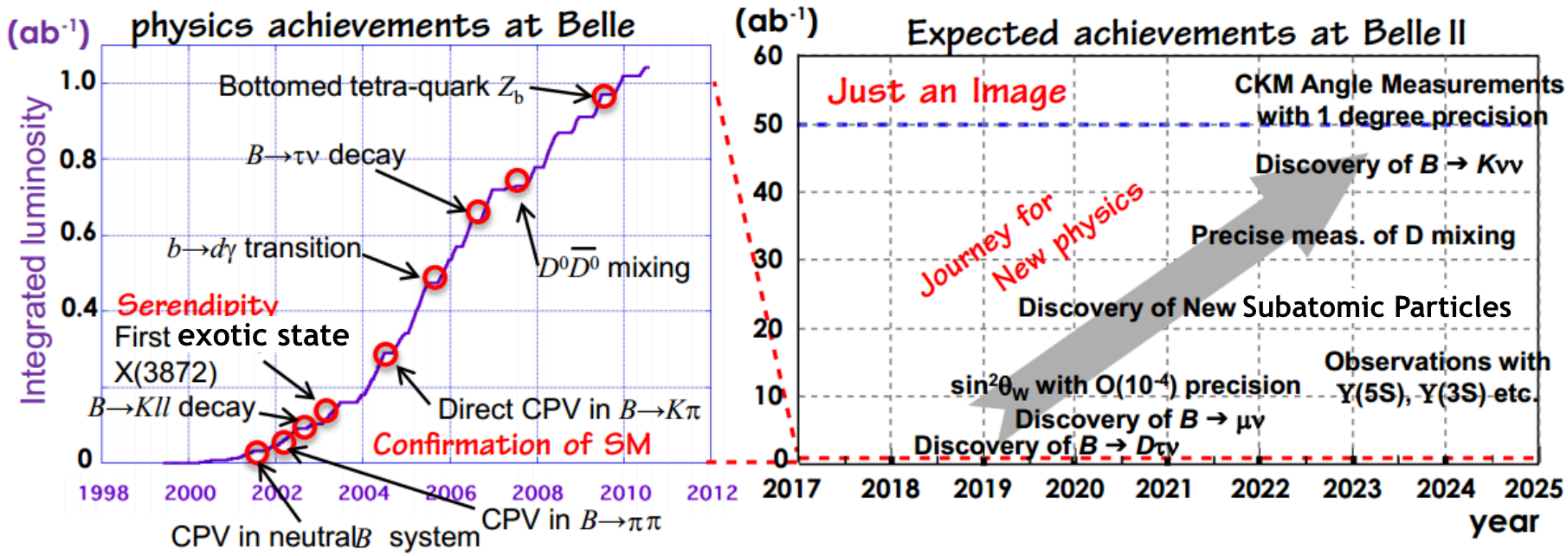
Status of SuperKEKB and Belle II

Hua Ye (DESY)

On behalf of the Belle II Collaboration

Quarkonium 2017
Nov.6-10, 2017 PKU

From Belle to Belle II



Belle achieves >500 Physics Journal Publications

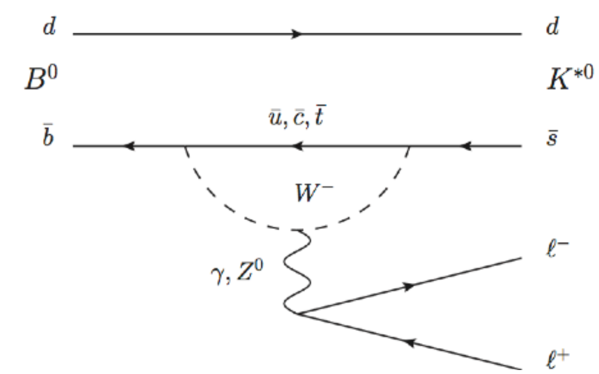
Expected to gain 50ab^{-1} sample in next decade

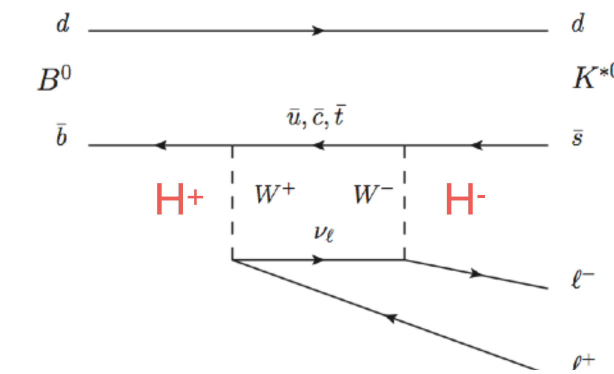
Accelerator	KEKB		SuperKEKB
Beam Energy (GeV)	3.5 x 8 ($\gamma = 0.425$)		4 x 7 ($\gamma = 0.28$)
CM energy	……, $\Upsilon(4S)$, ……		……, $\Upsilon(4S)$, ……
Luminosity (cm^{-2}s^{-1})	2.1×10^{34}	x 40 →	8×10^{35}
Total data (ab^{-1})	1	x 50 →	50

Flavour Physics @Belle II

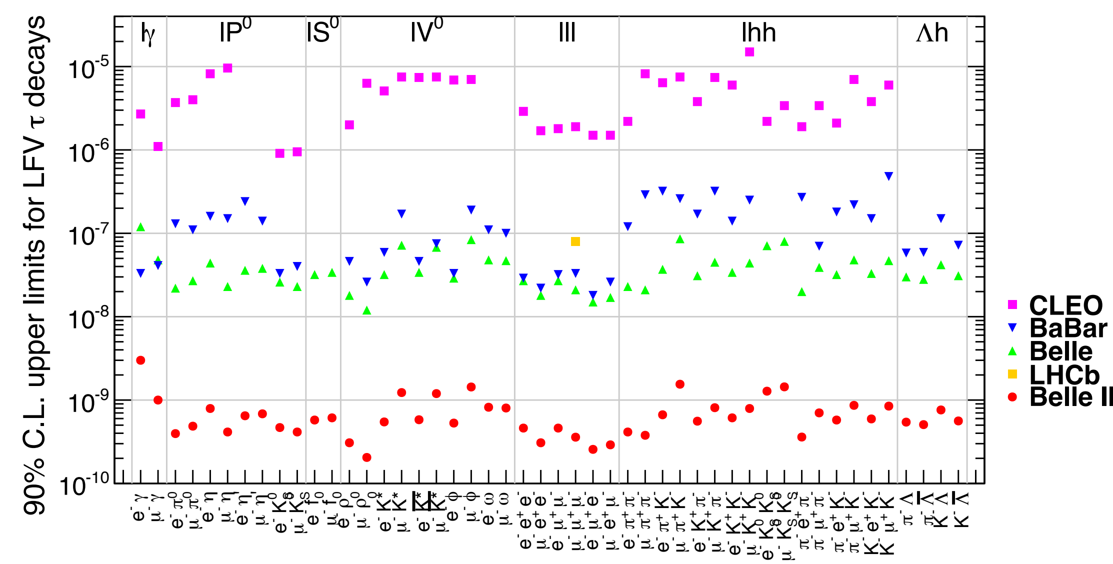
Flavour physics questions to be addressed by Belle II

- Rare B decays
    - Multiple Higgs bosons?
    - Flavour-changing neutral currents beyond the SM?
    - Are there new CP violating phases in the quark sector?

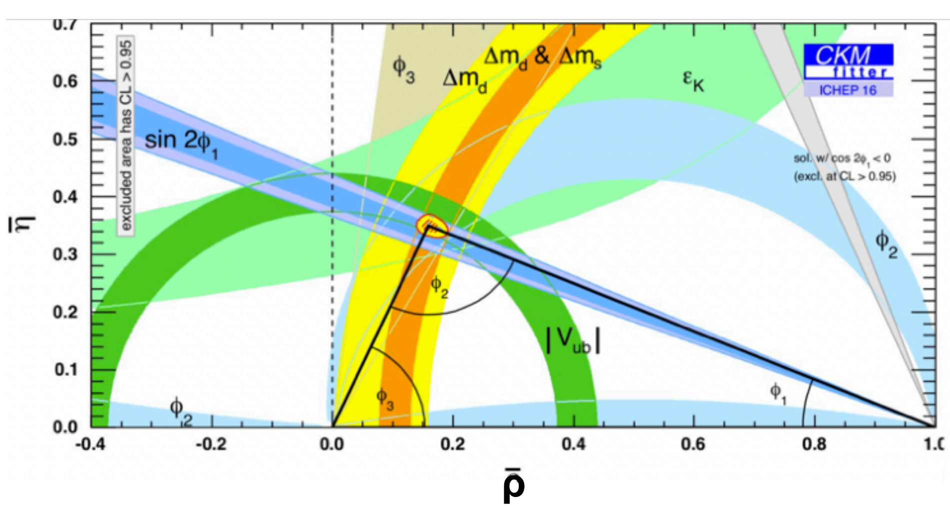


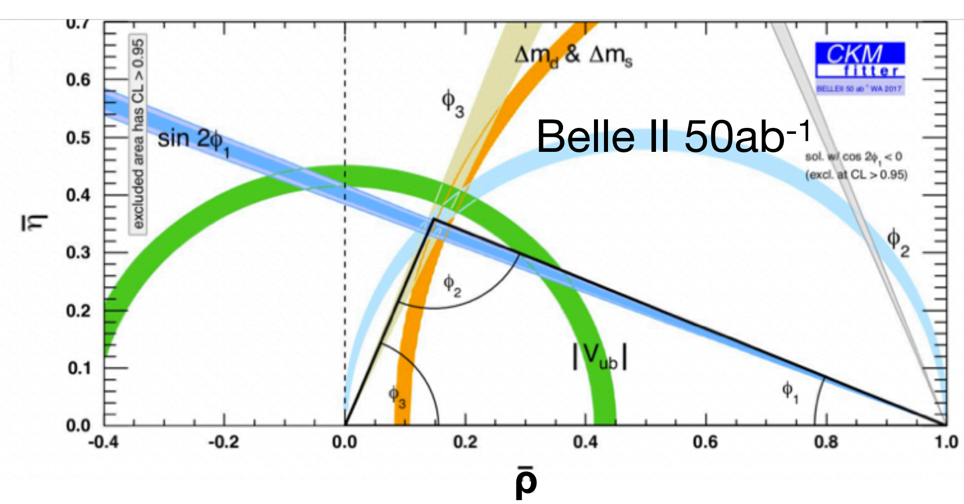


- Lepton flavour violation (LFV)?
    - Belle II provides unique sensitivity to study τ decays via missing energy.



- Precise measurements of CKM matrix elements and their phases.

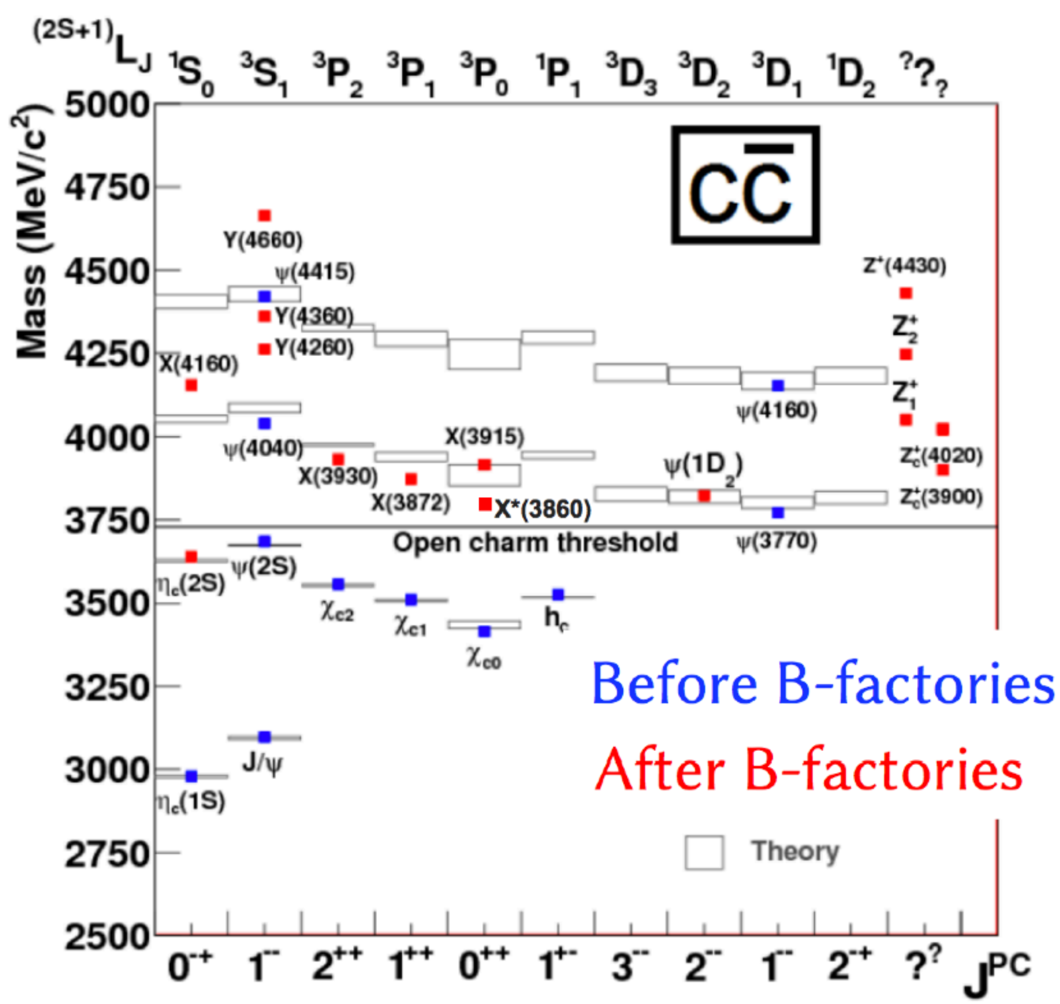


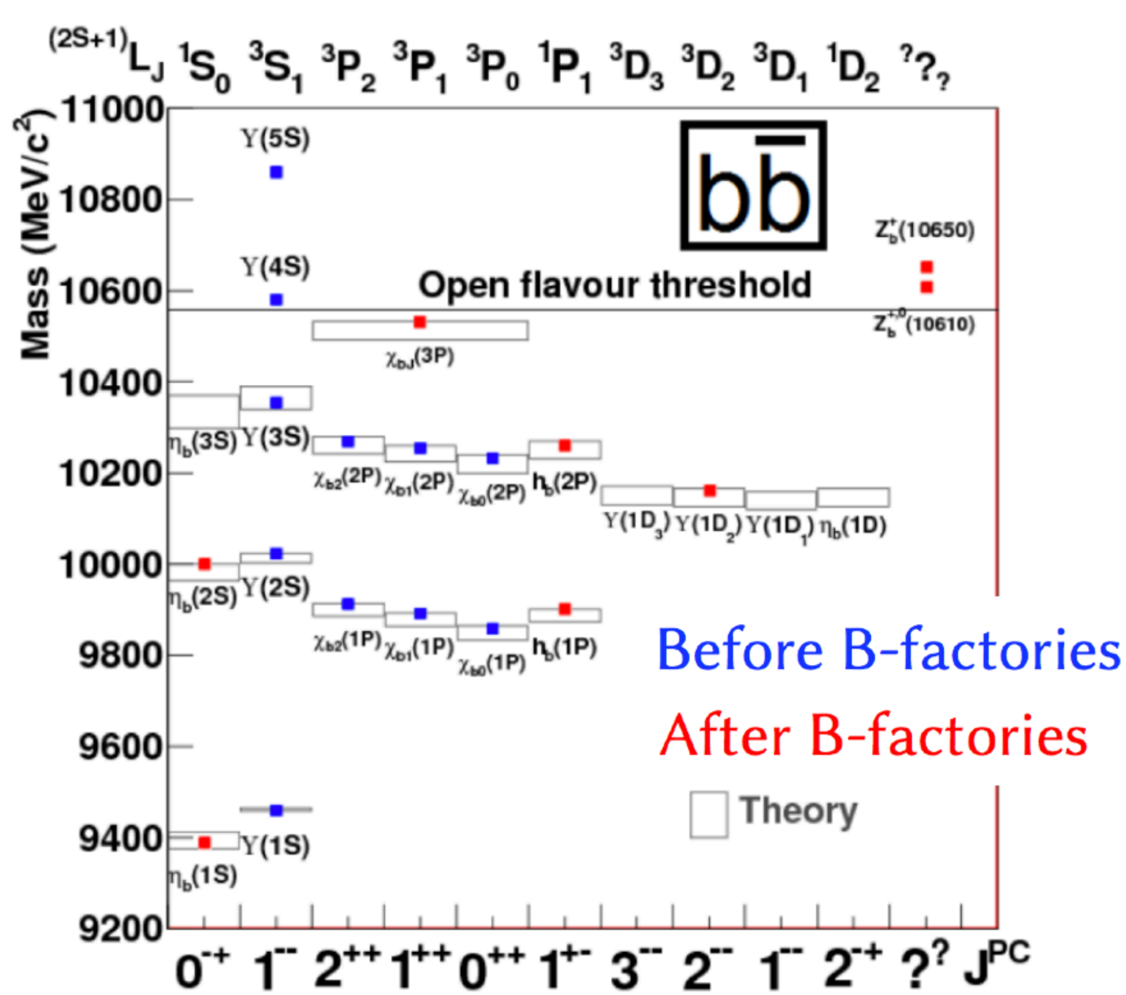


non-Flavour Physics @Belle II

- Is there a dark sector of particle physics at the same mass scale as ordinary matter?
  - Belle II has unique sensitivity to dark matter via missing energy decays.

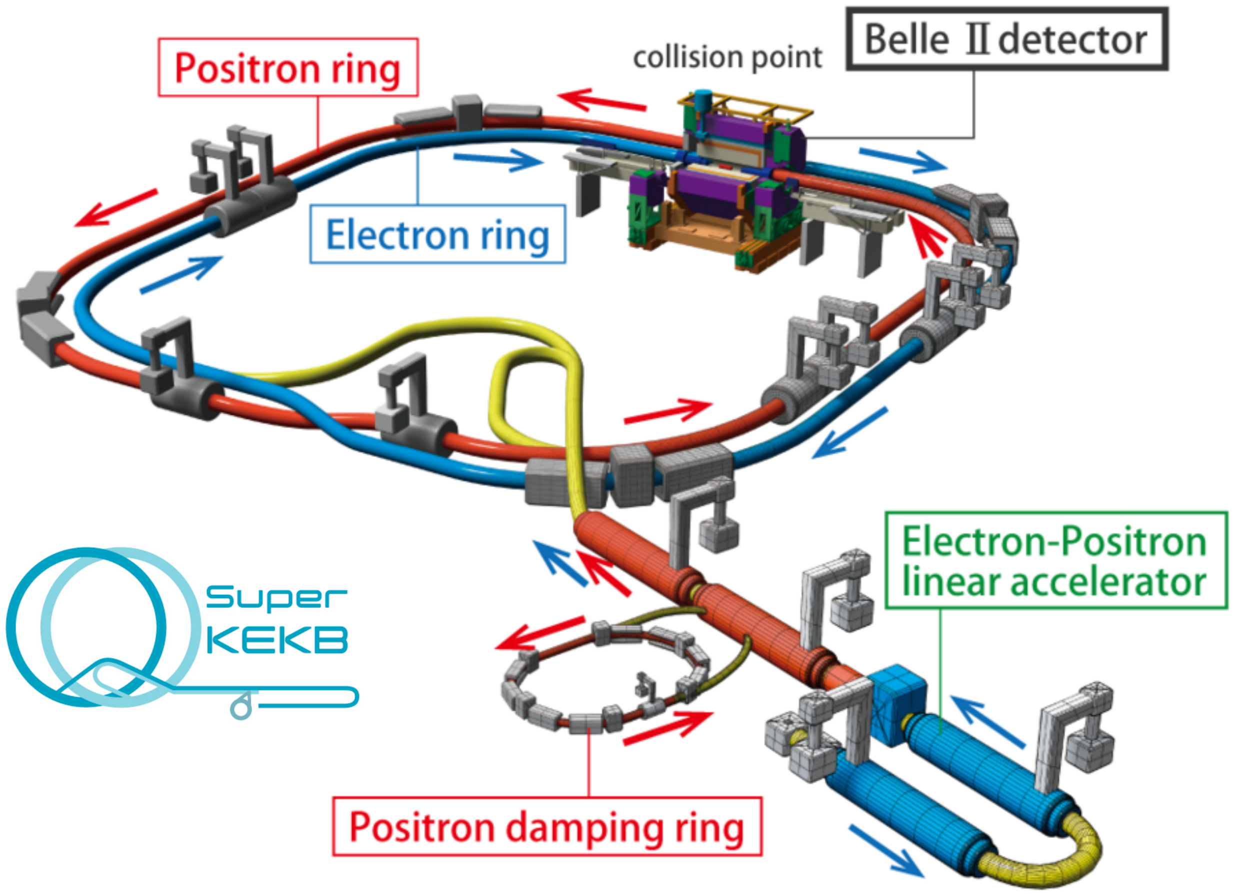
- What is the nature of the strong force in binding hadrons?
  - States not predicted by the conventional hadron interpretation.

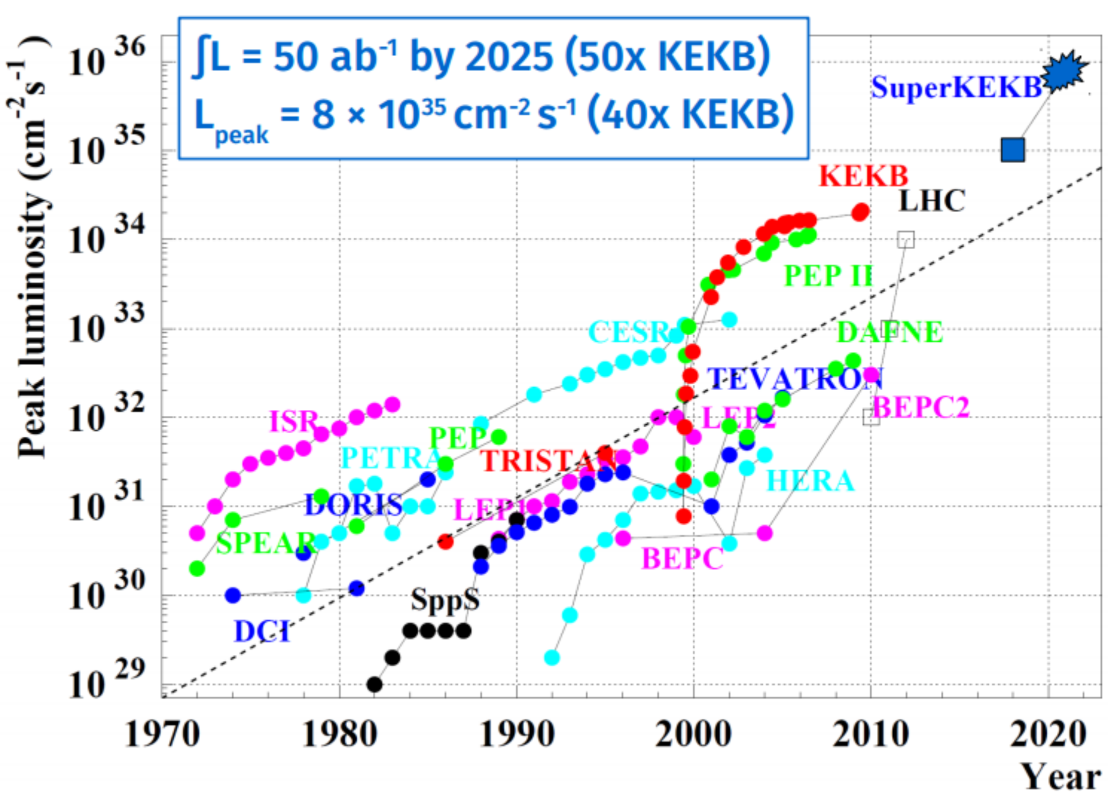




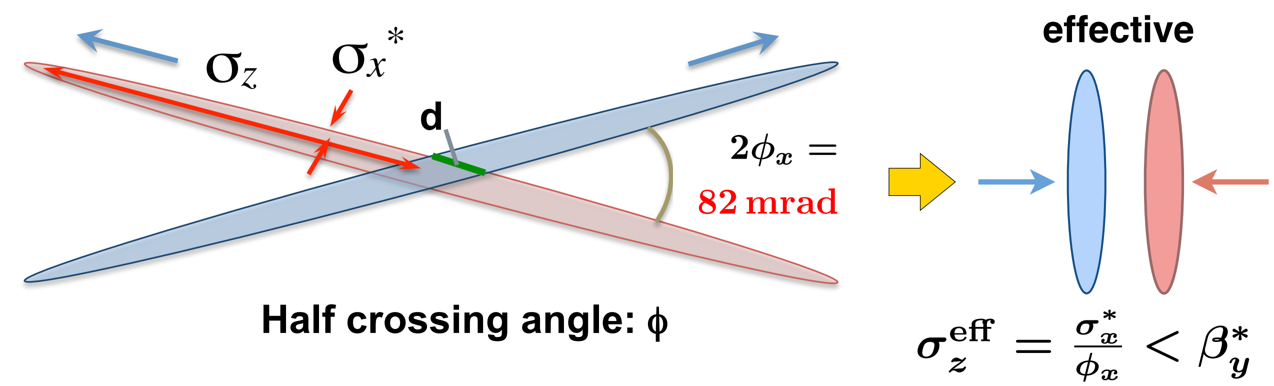
More info: Yiming Li's talk "Perspectives on spectroscopy study at Belle II"

SuperKEKB





Nano-Beam scheme (P. Raimondi, DAΦNE): Squeeze vertical beta function at the IP (β_y^*) and minimize longitudinal size of overlap region to avoid penalty from hourglass effect.



Strong focusing of beams down to vertical size of ~ **50nm** requires **low emittance beams**, very **sophisticated final focus** quadrupoles (QCS) and a **large crossing angle**.

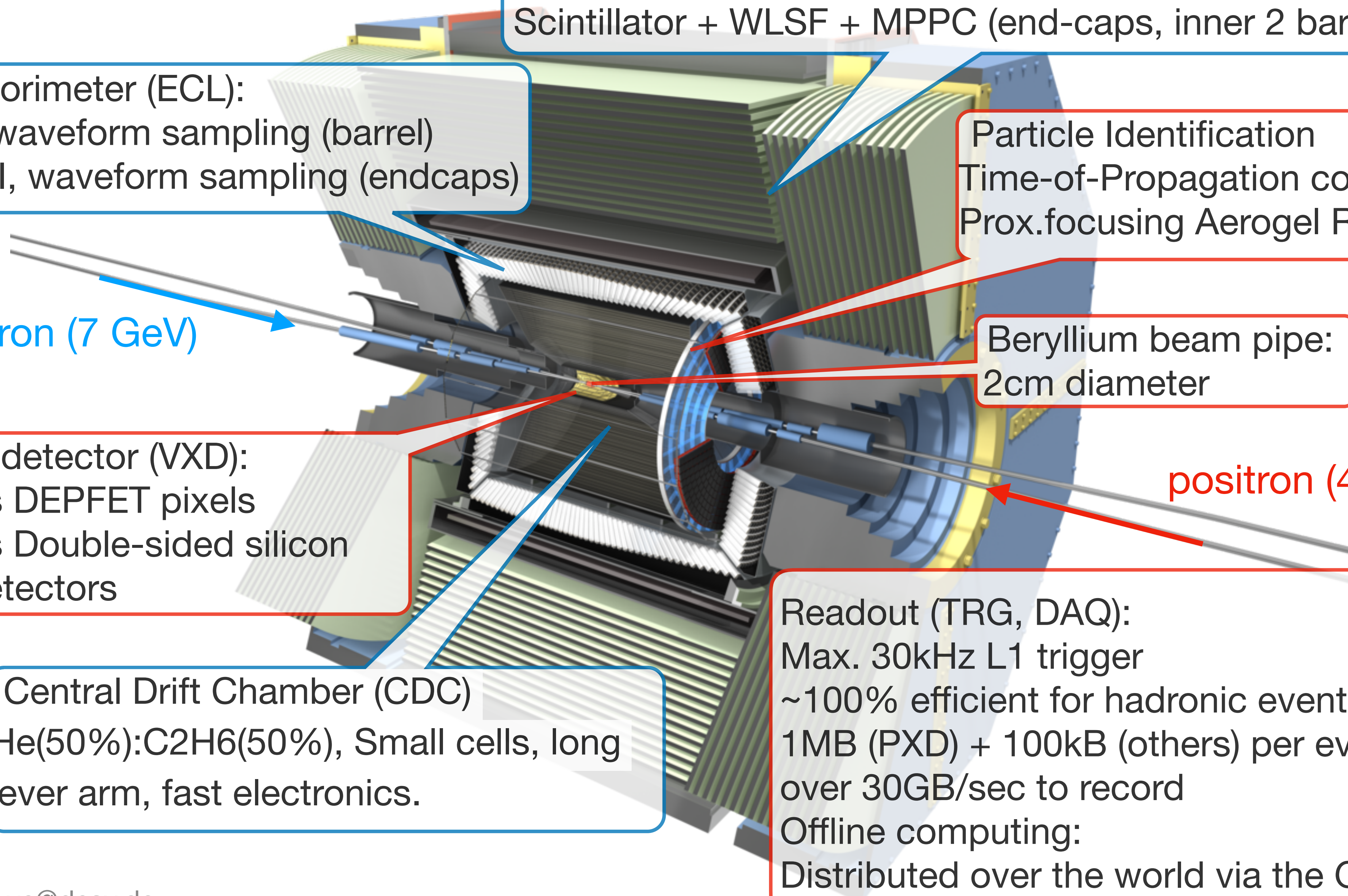
beam current **x2** beam-beam param. **x1**

$$L = \frac{\gamma_\pm}{2er_e}(1+a)\frac{R_L}{R_\xi}\left(\boxed{\frac{I_\pm \xi_{y\pm}}{\beta^*_{y\pm}}}\right)$$

vertical beta function **x20**

Belle II Detector

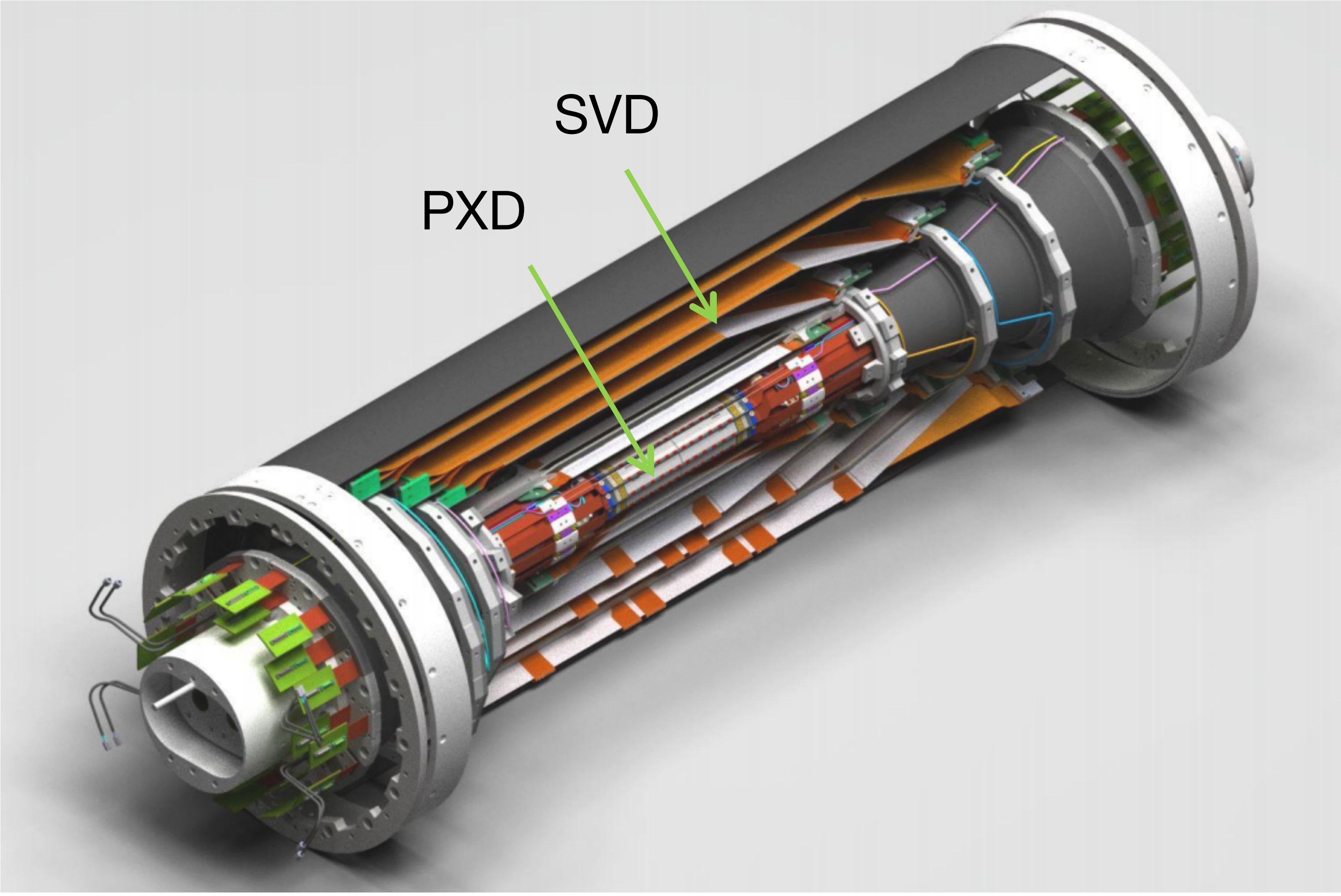
40x instantaneous luminosity is expected to represent significantly higher background levels in all Belle II subdetectors.



Belle II VXD

Challenges for vertex reconstruction:

- Higher backgrounds (lumi. increase, nano-beam)
  => higher occupancy
- Boost reduced from $\beta\gamma$=0.42 to 0.28
  => B-meson flight length of 125 μm



Pixel Detector (PXD)

- 40 DEPFET modules
- Pixel size: 50 x 55-85 μm^2
- Occupancy: 0.4 hits/μm^2/s (3% max)
- Integration time: 20 μs (rolling shutter)
- Thickness: 75 μm, 0.21% X_0 per layer

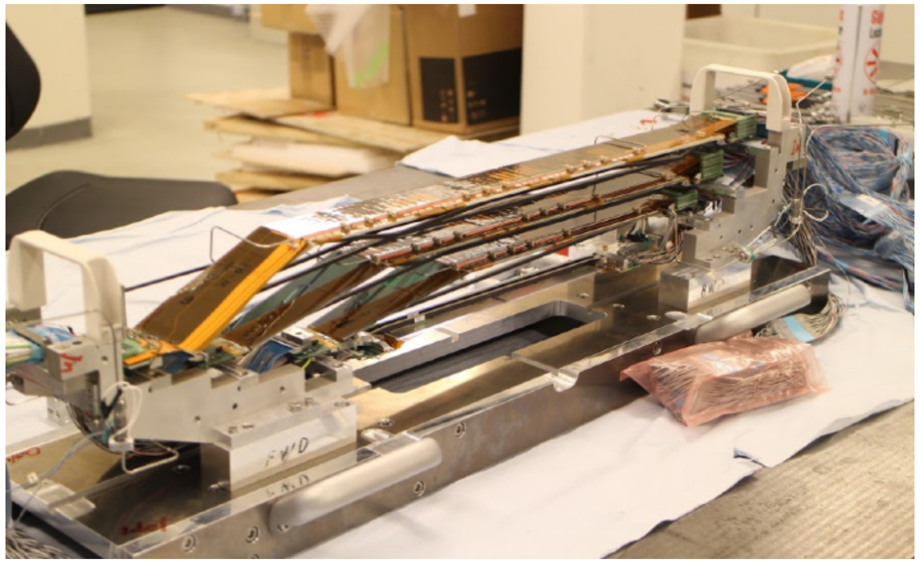
Silicon Vertex Detector(SVD)

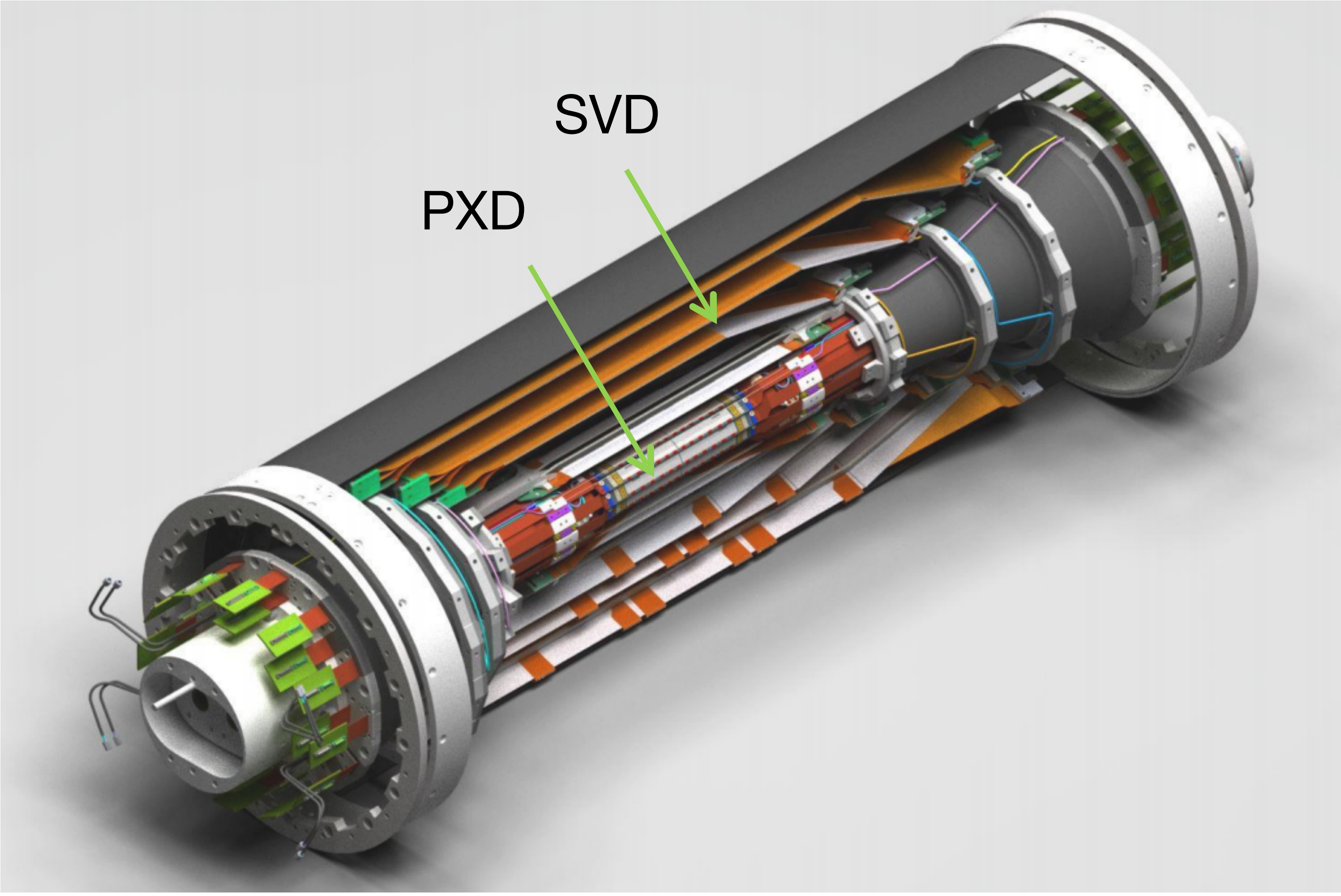
- 172 double-sided silicon strip detectors (DSSDs);
- Slant shapes in FWD region for the material budget reduction.
- material budget: 0.7% X_0 per layer

Belle II VXD

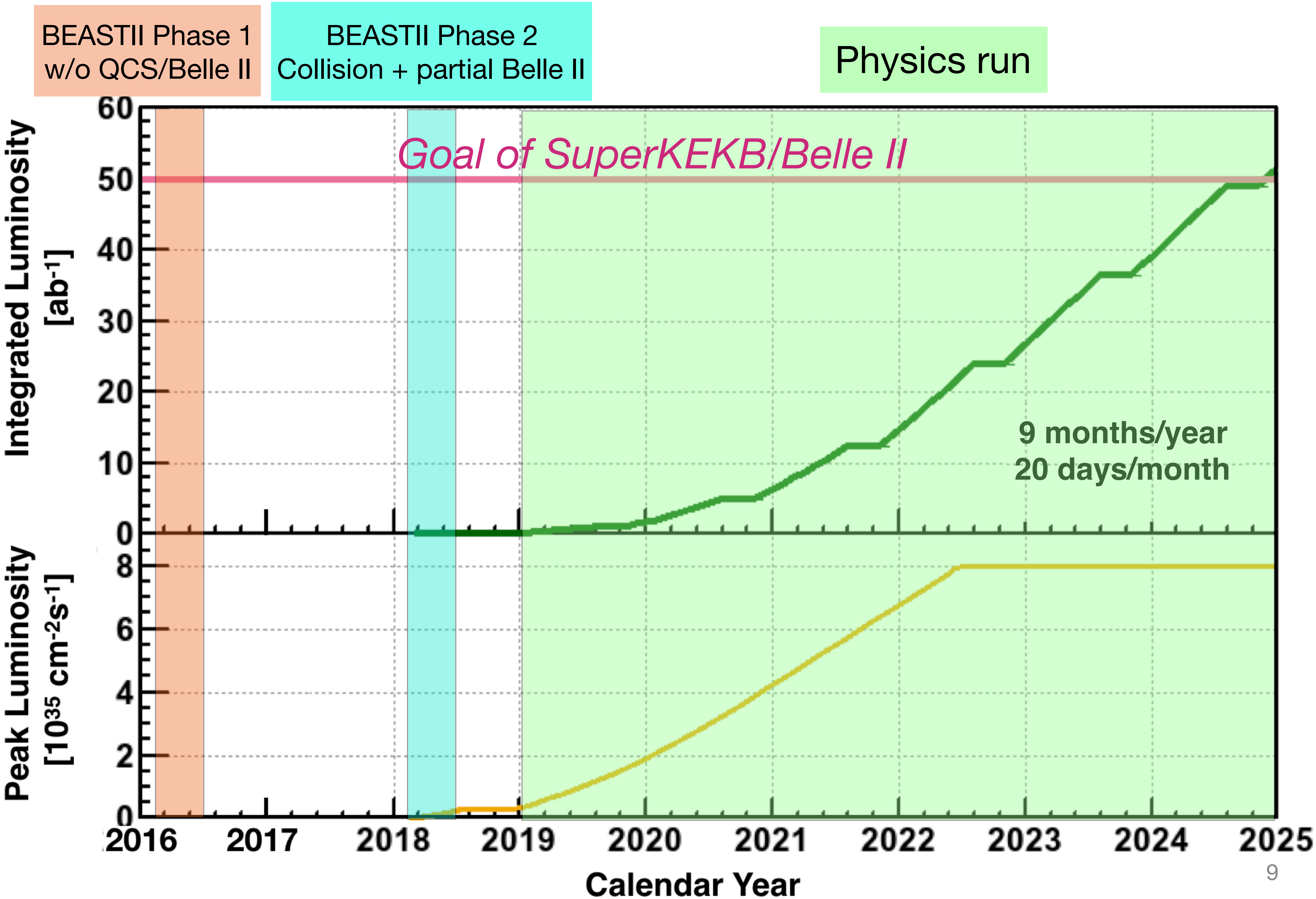
Challenges for vertex reconstruction:

- Higher backgrounds (lumi. increase, nano-beam)
  => higher occupancy
- Boost reduced from $\beta\gamma$=0.42 to 0.28
  => B-meson flight length of 125 μm



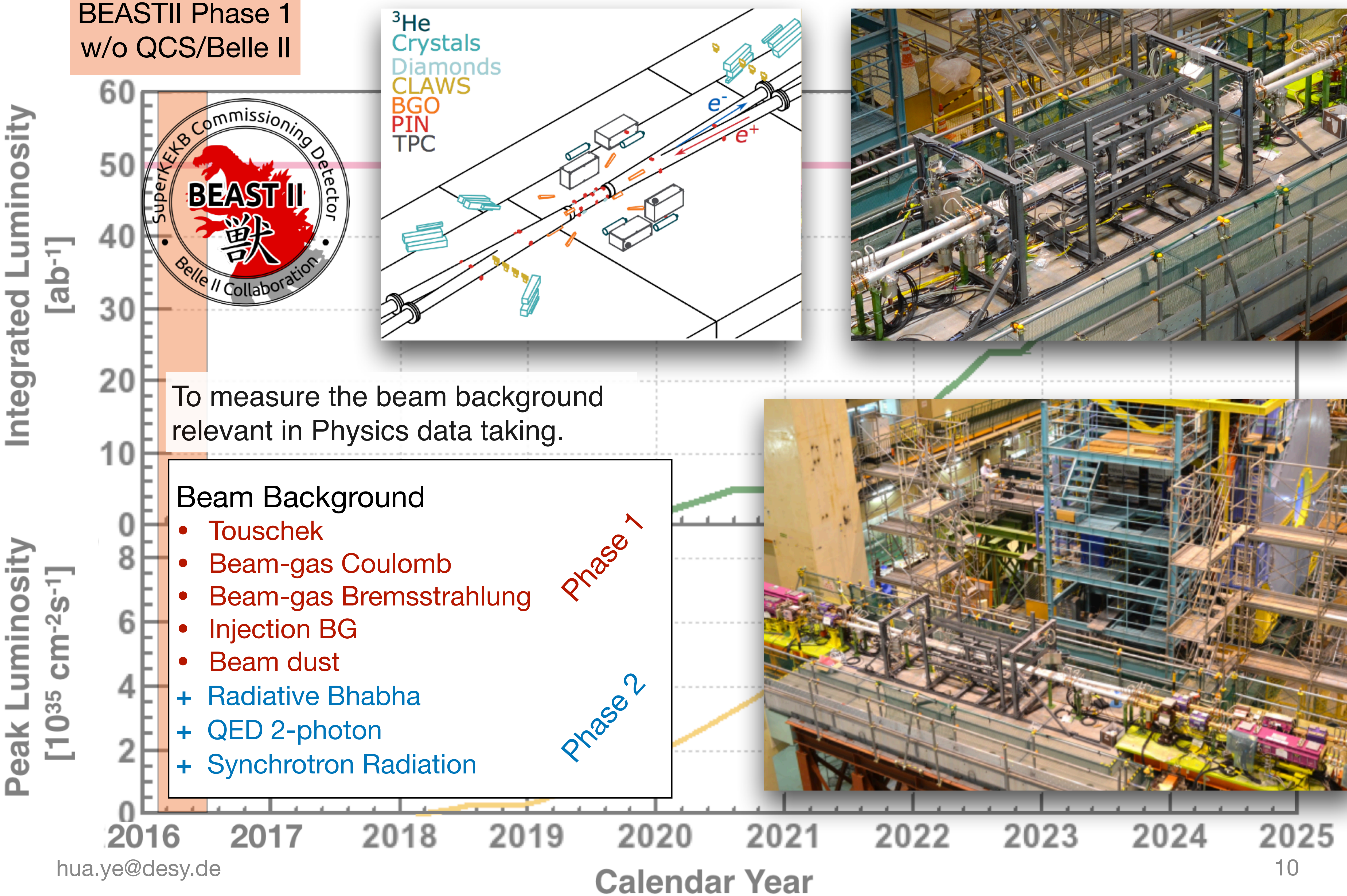


SuperKEKB&Belle II Commissioning



BEAST II Phase I

BEASTII Phase 1
w/o QCS/Belle II



To measure the beam background relevant in Physics data taking.

Beam Background

- Touschek
- Beam-gas Coulomb
- Beam-gas Bremsstrahlung
- Injection BG
- Beam dust

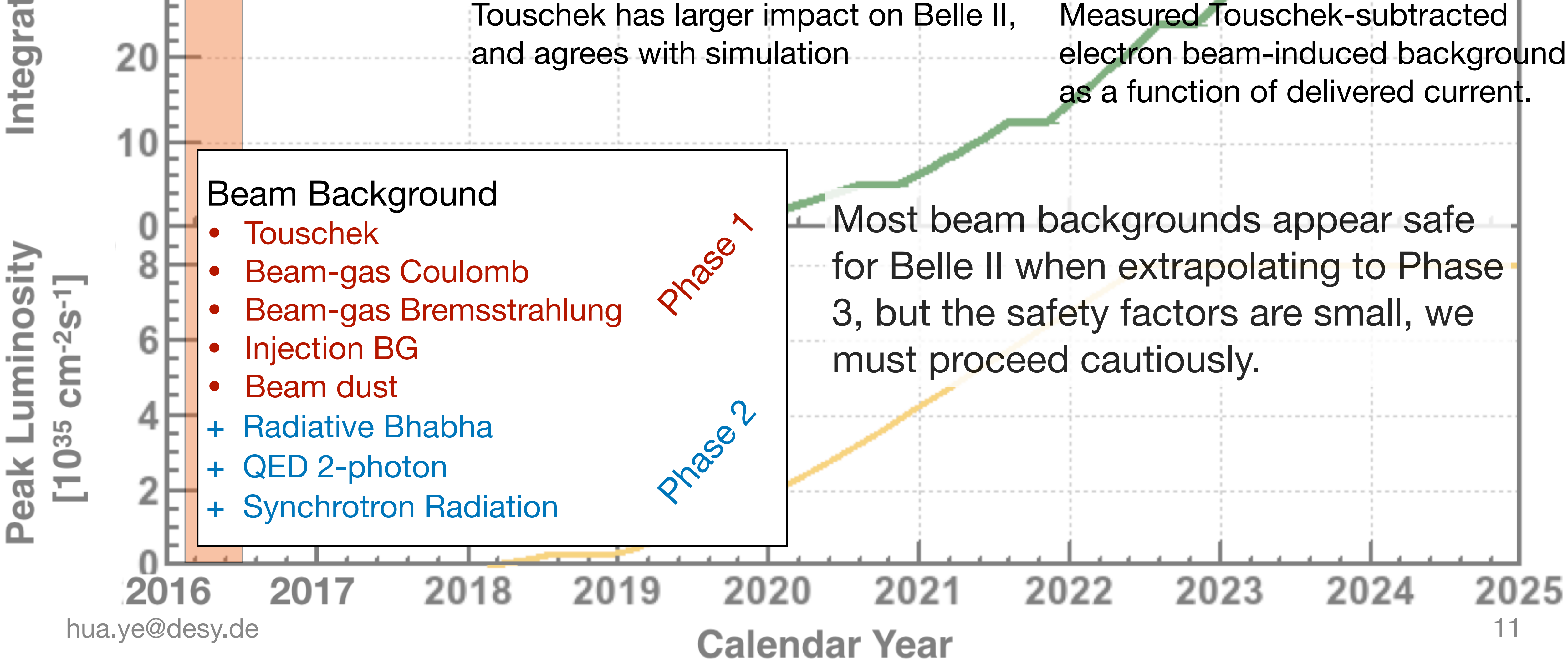
Phase 1

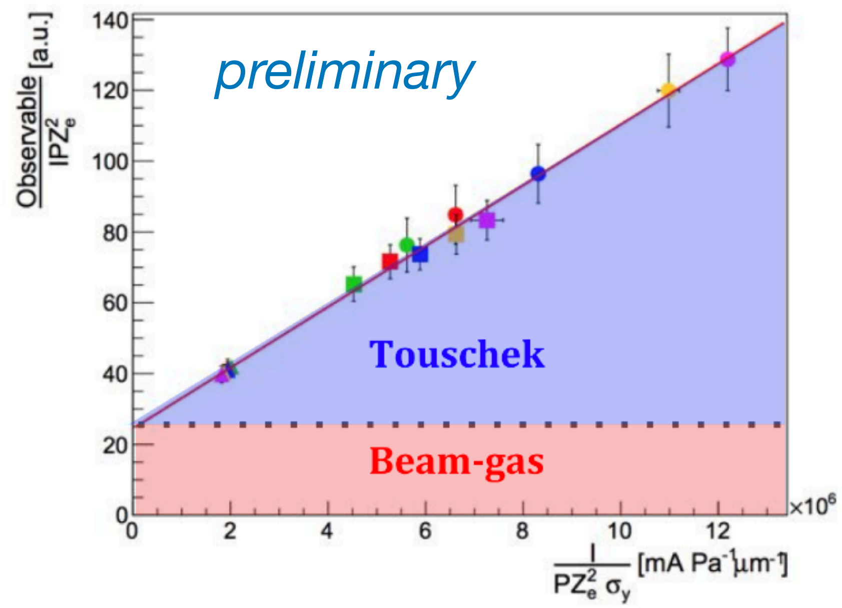
+ Radiative Bhabha
+ QED 2-photon
+ Synchrotron Radiation

Phase 2

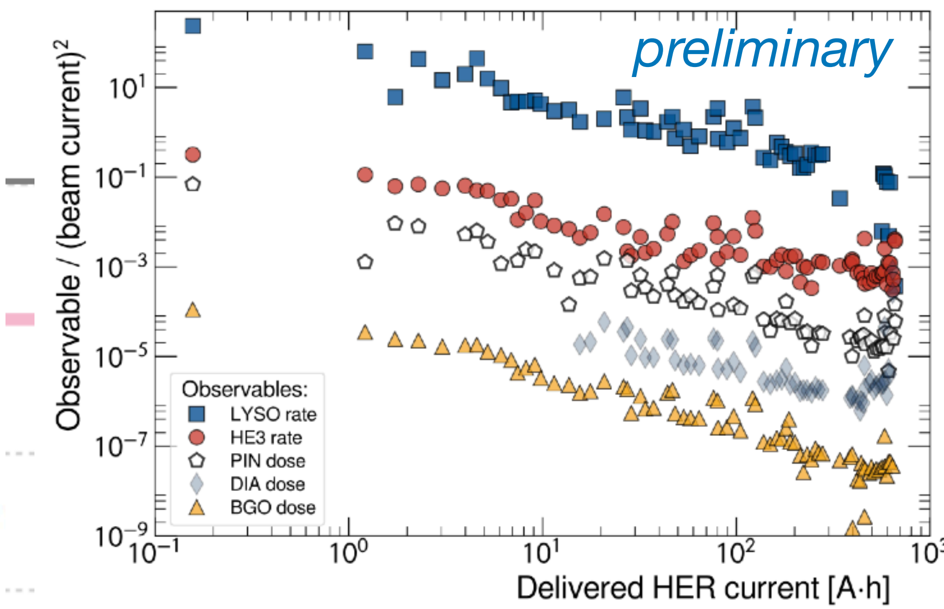
BEAST II Phase I

BEASTII Phase 1
w/o QCS/Belle II





Touschek has larger impact on Belle II, and agrees with simulation



Measured Touschek-subtracted electron beam-induced background as a function of delivered current.

Beam Background
- Touschek
- Beam-gas Coulomb
- Beam-gas Bremsstrahlung
- Injection BG
- Beam dust

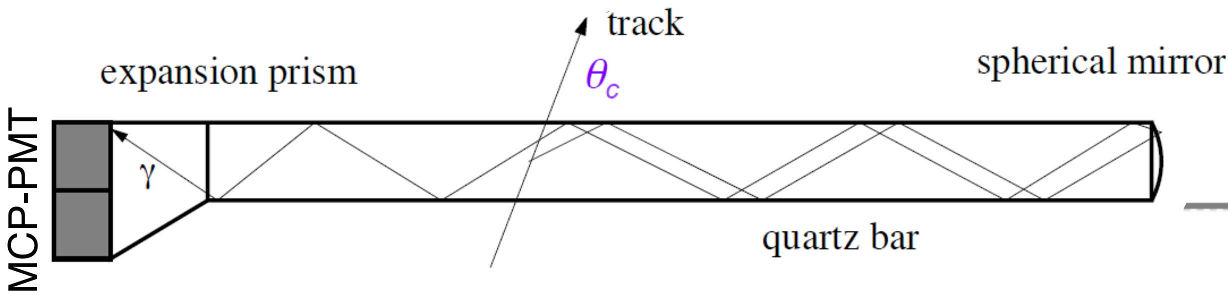
Phase 1

+ Radiative Bhabha
+ QED 2-photon
+ Synchrotron Radiation

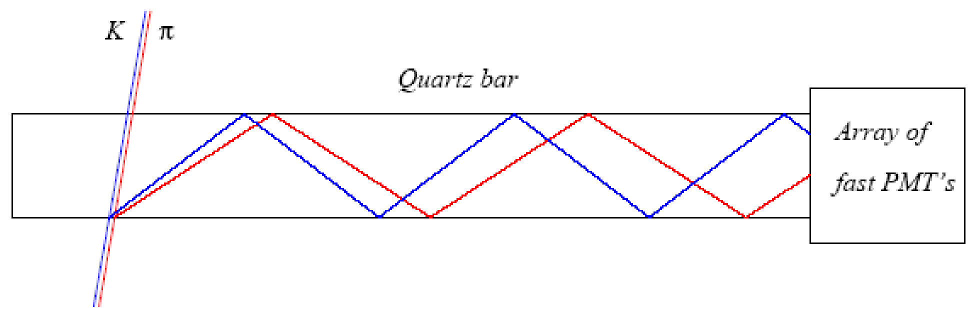
Phase 2

Most beam backgrounds appear safe for Belle II when extrapolating to Phase 3, but the safety factors are small, we must proceed cautiously.

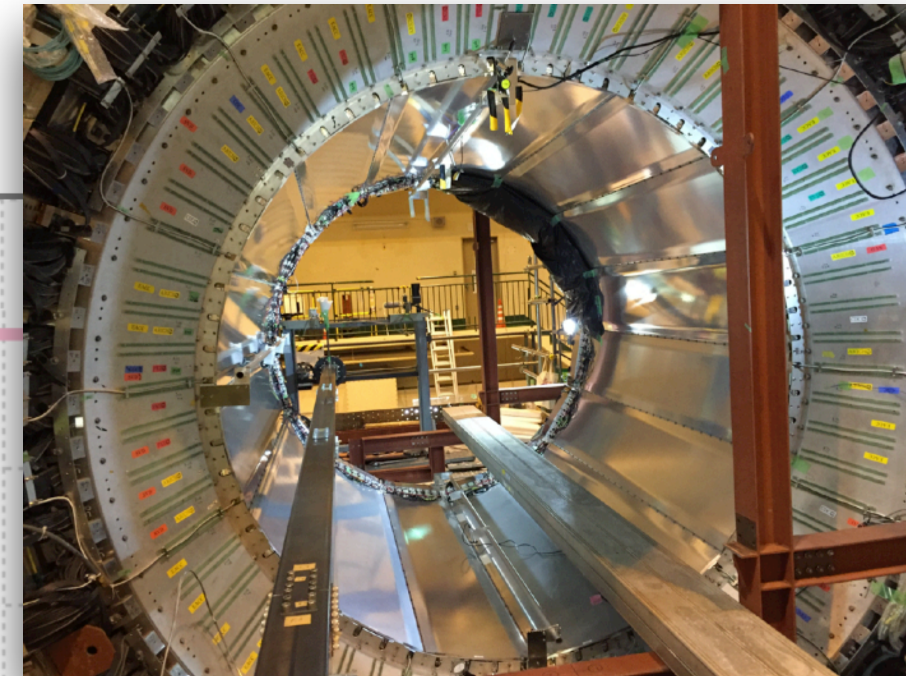
PID:iTOP



K/**π** different θ_c → different path length → different time of propagation.



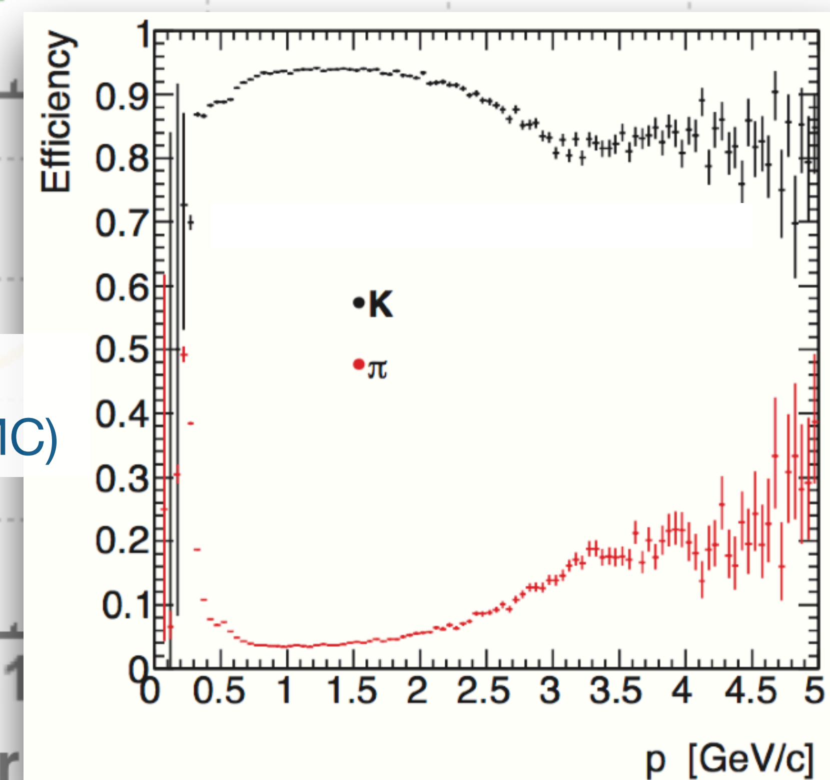
θ_c is reconstructed from: hit position (x,y) in the photo detector plane and time of propagation



- 16 quartz bars: 2x1.25 m x 0.45 m x 2 cm
- 32 (segmented anode 4x4) Micro-channel plate PMTs Hamamatsu SL-10 MCP PMT

iTOP installed into Belle II

iTOP K ID efficiency and π fake rate with beam bkg (MC)



Integrated Luminosity [ab-1]

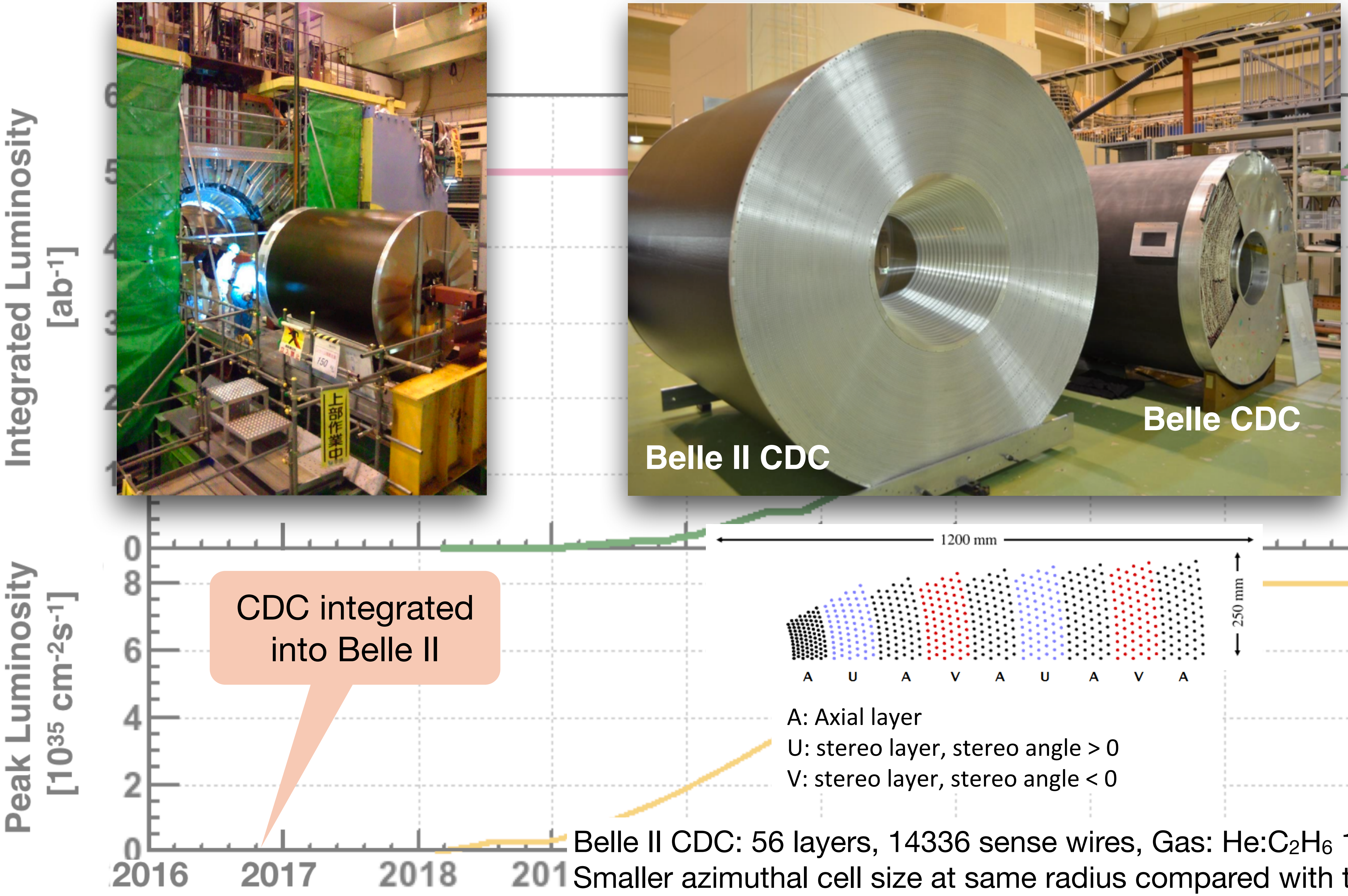
Peak Luminosity [10^{35} cm^{-2}s^{-1}]

0 8 6 4 2 0

2016 2017 2018 2019 2020 2021 2025

Calendar Year

Drift Chamber integration

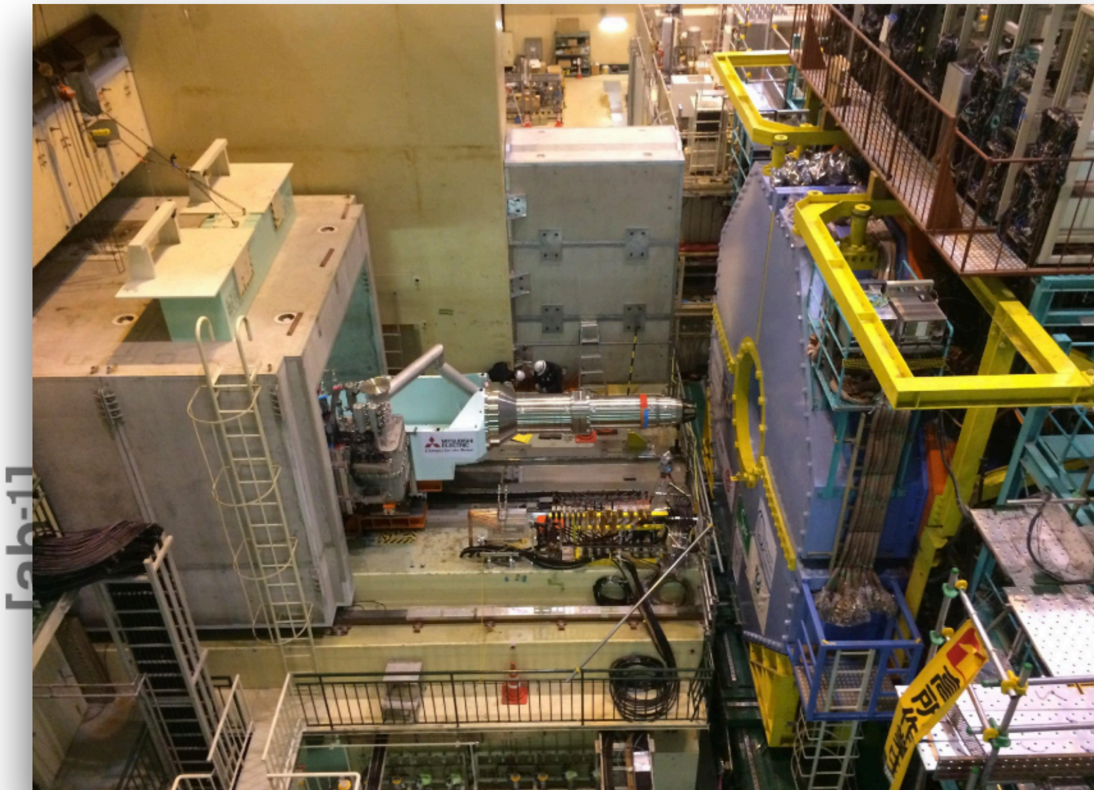


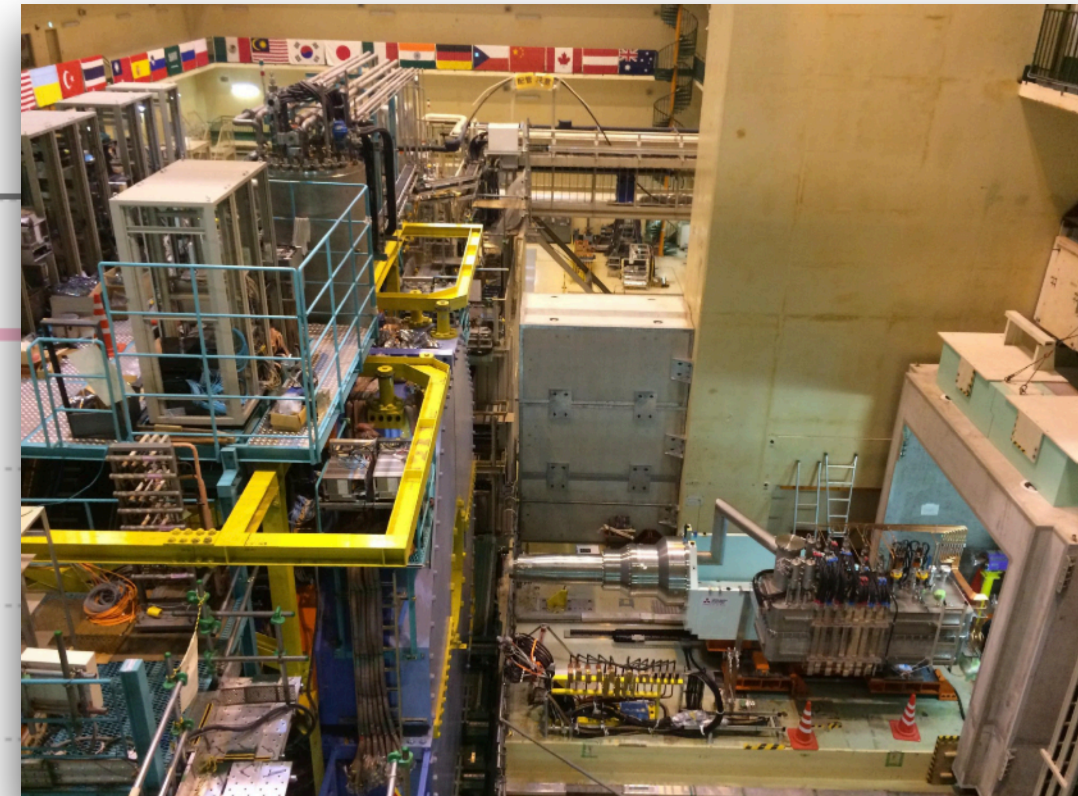
CDC integrated into Belle II

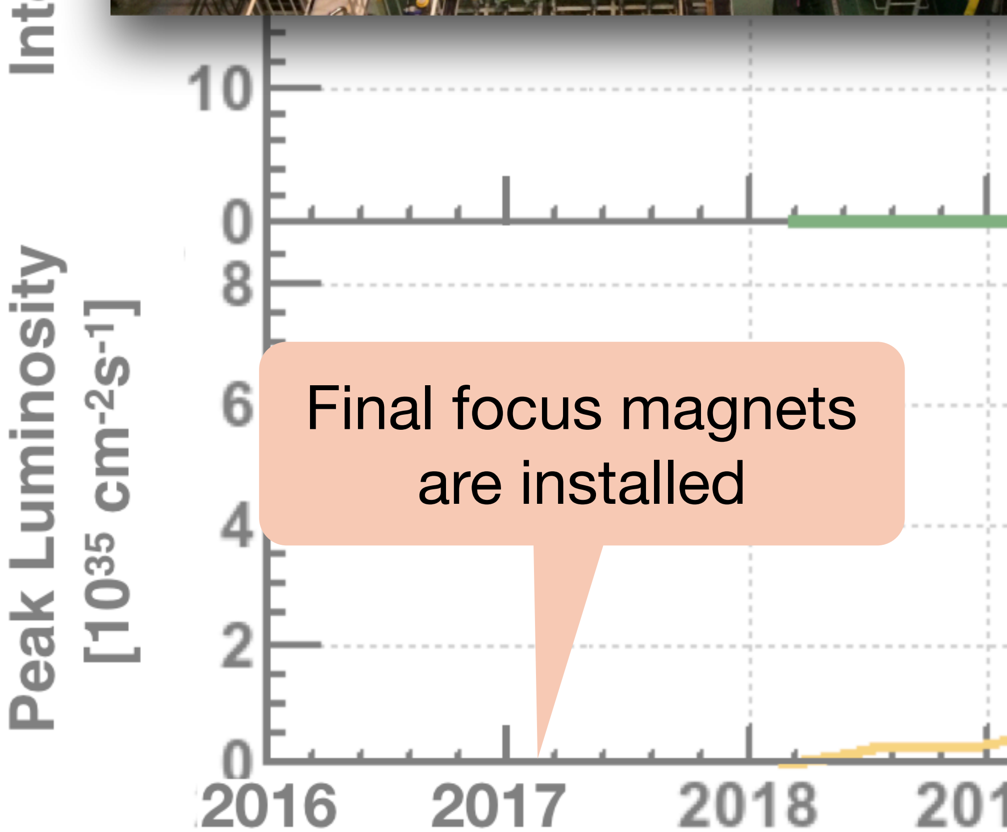
A: Axial layer
U: stereo layer, stereo angle > 0
V: stereo layer, stereo angle < 0

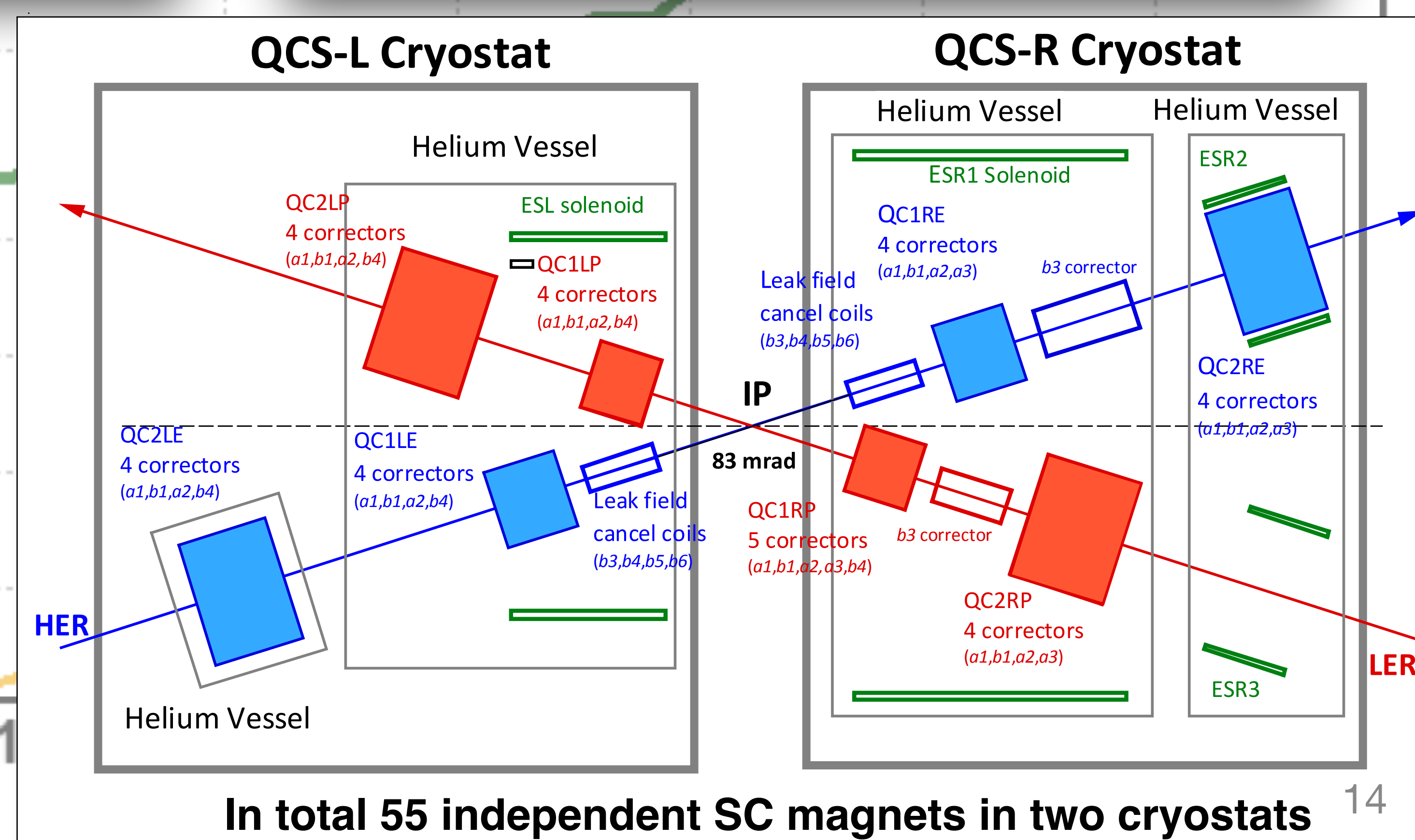
Belle II CDC: 56 layers, 14336 sense wires, Gas: He:C_2H_6 1:1
Smaller azimuthal cell size at same radius compared with the Belle CDC.

Final focus magnets









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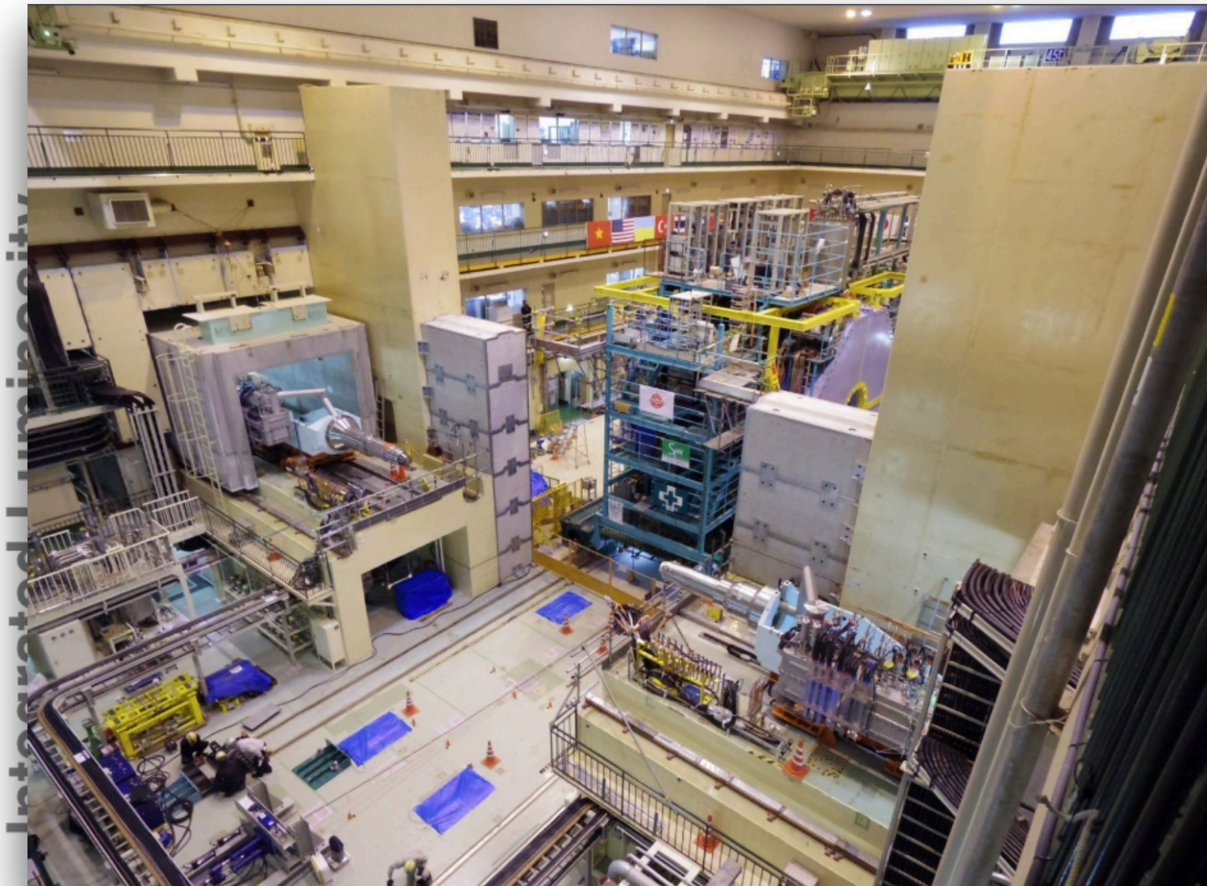
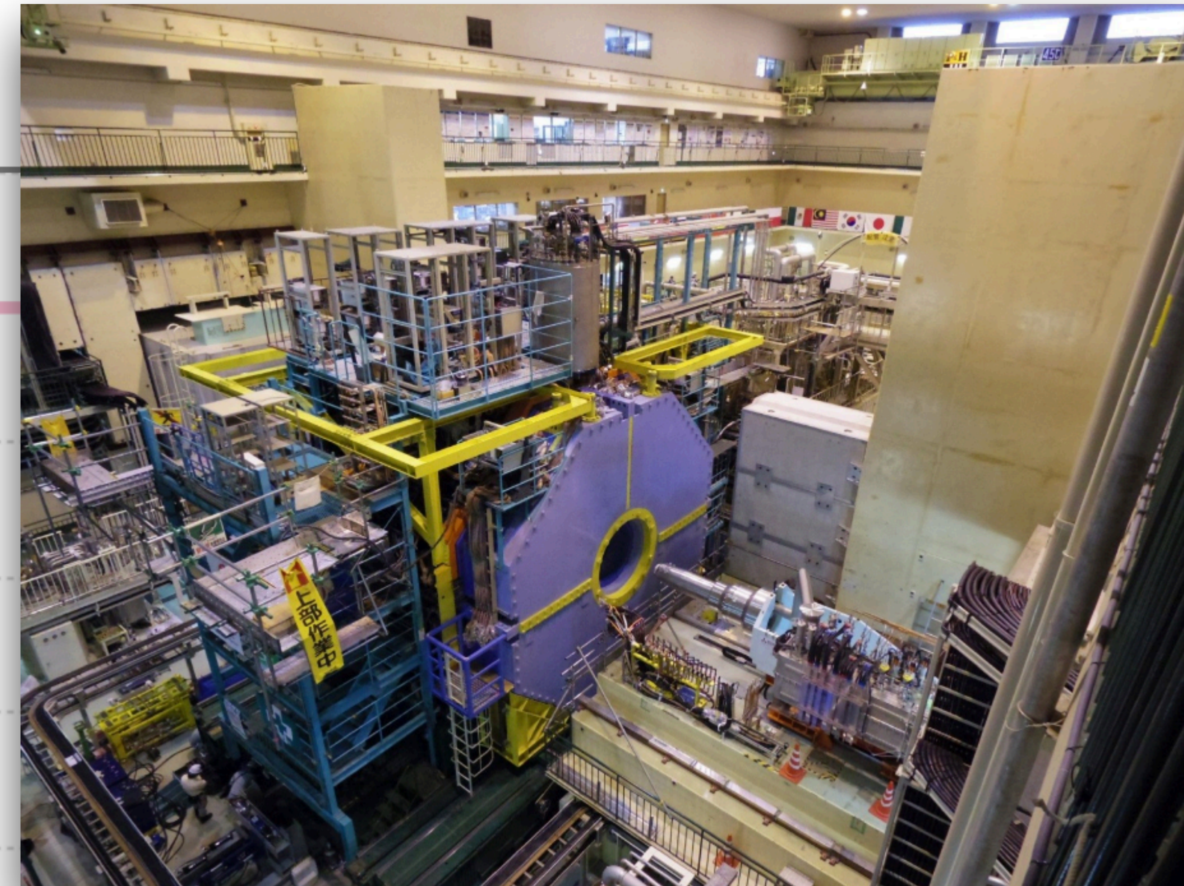
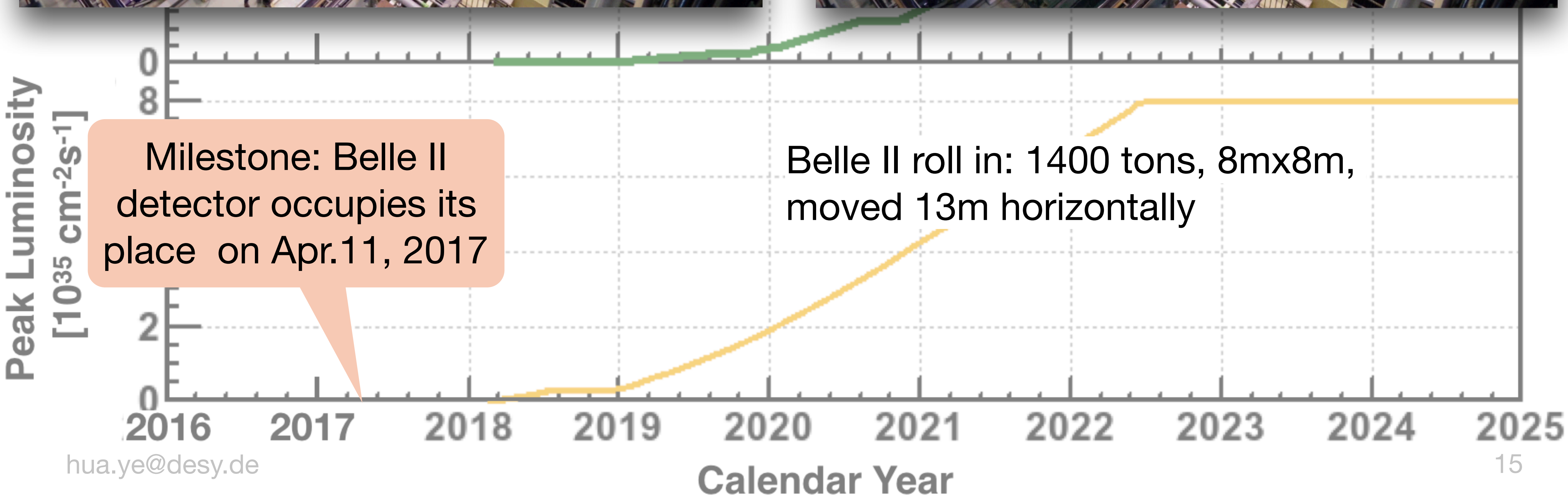
Belle II rolled in in April.2017



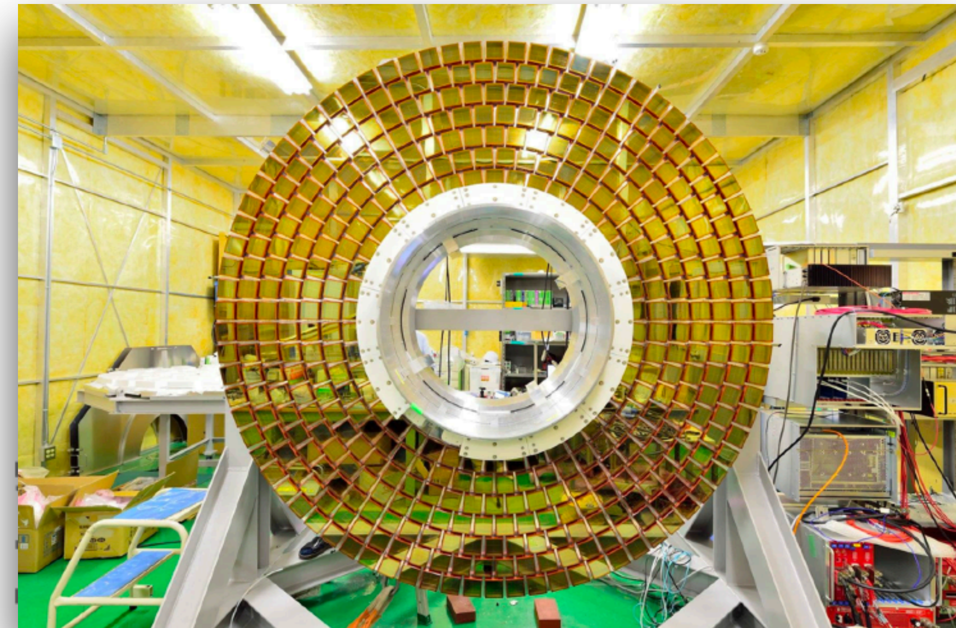


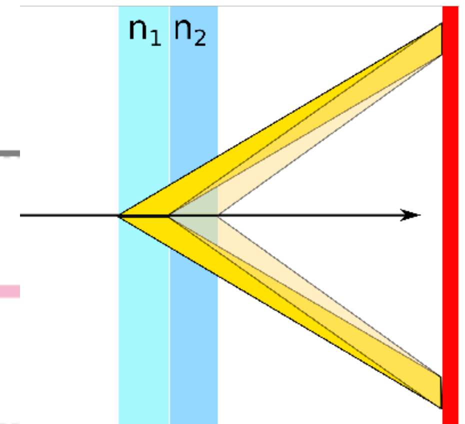


Milestone: Belle II detector occupies its place on Apr.11, 2017

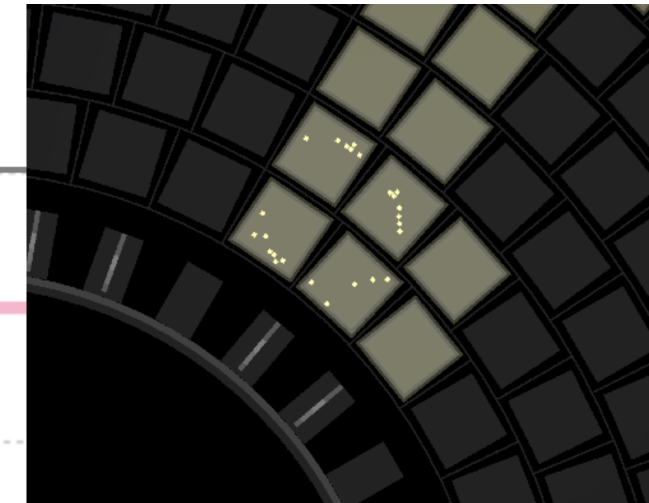
Belle II roll in: 1400 tons, 8mx8m, moved 13m horizontally

PID: ARICH





Proximity focussing



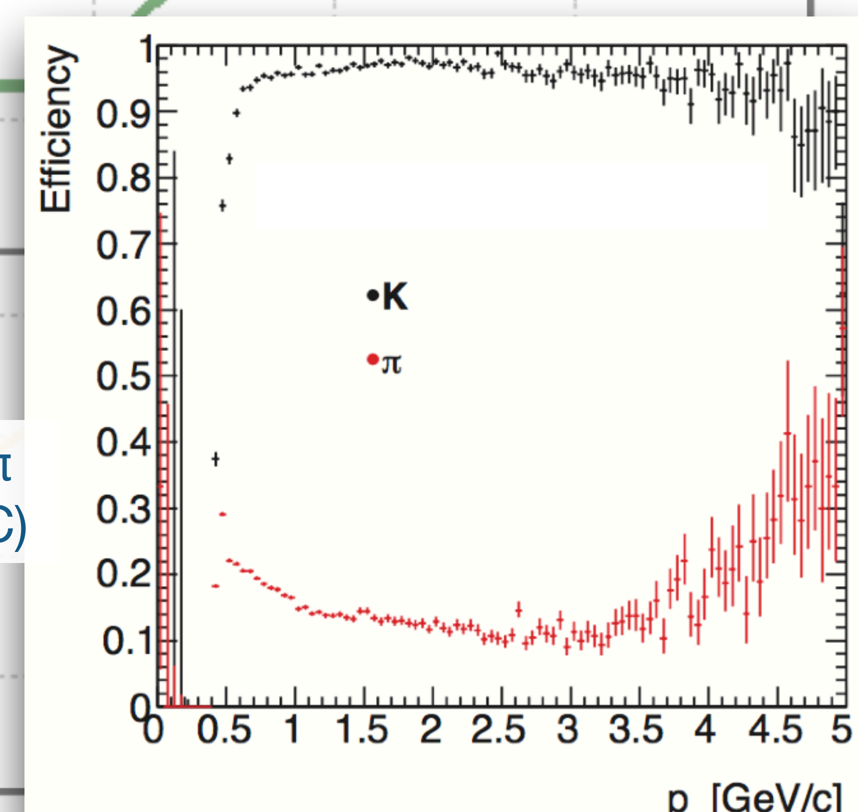
Cherenkov rings in one sector of the ARICH.

Radiator
- Silica Aerogel n = 1.045-1.055
- transmission length > 40 mm

Photon detection
- Hybrid Avalanche Photo Detectors
- 420 units, 144 channels each, 5 mm pixelated

ARICH is fully integrated into Belle II

ARICH K ID efficiency and π fake rate with beam bkg (MC)

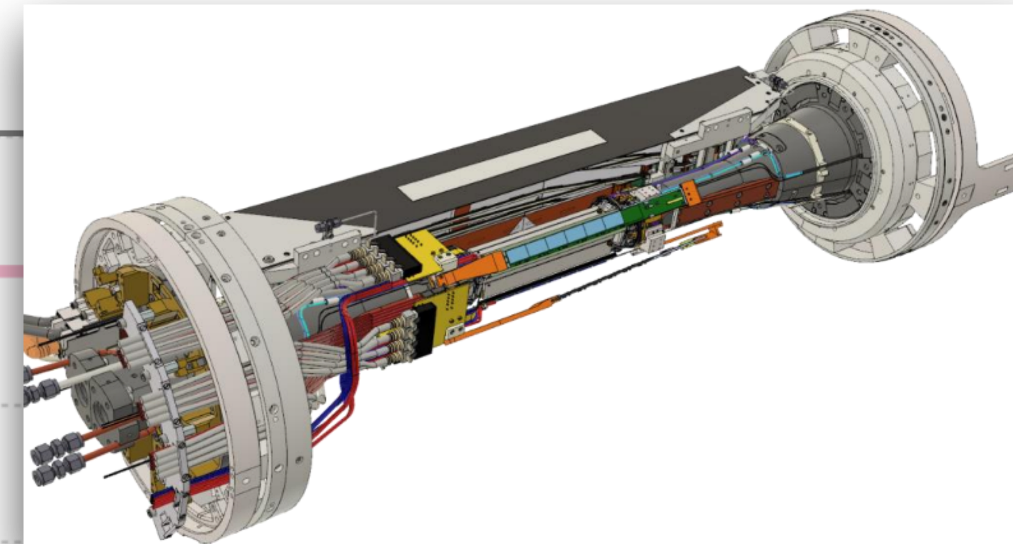


BEAST II Phase II

BEASTII Phase 2
Outer Belle II + “BEAST-VXD”

Motivation for BEAST II Phase II:

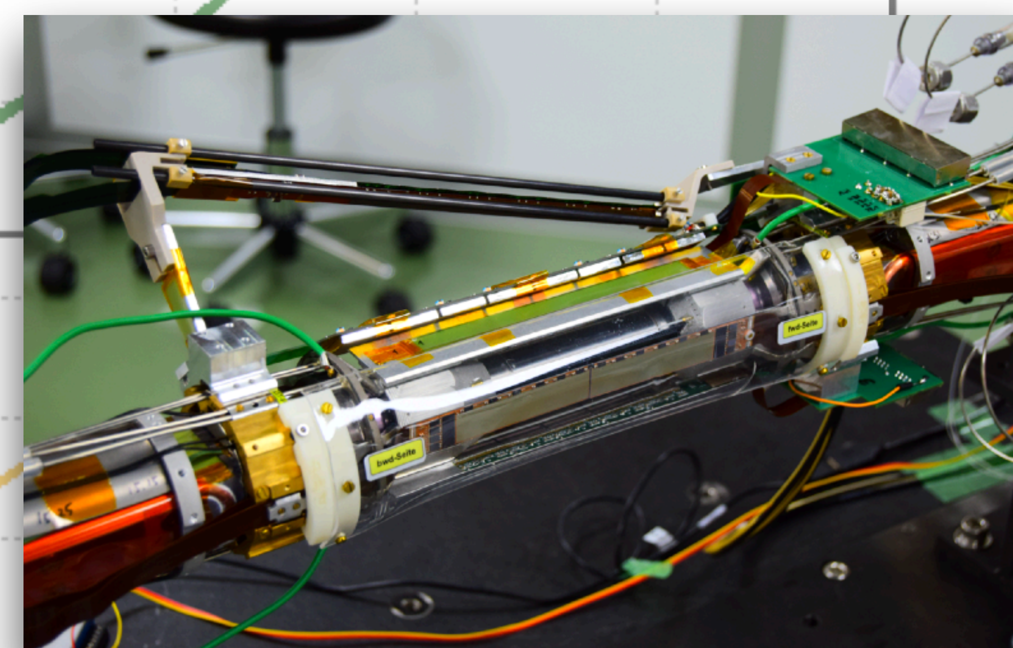
- **Machine commissioning**
- **Radiation safe environment for the full VXD.**
- **Target luminosity is $1X10^{34} cm^{-2}s^{-1}$.**



2 PXD and 4 SVD layers in +x sector where the highest backgrounds are expected.

Dedicated radiation monitors :

- **FANGS , FE-I4 based hybrid pixel to investigate the Synchrotron Radiation (SR) background.**
- **CLAWS, scintillators with SiPM to measure the time evolution of the injection background.**
- **PLUME, double-sided high granularity MIMOSA pixels**



BEAST II Phase II

BEASTII Phase 2
Outer Belle II + “BEAST-VXD”

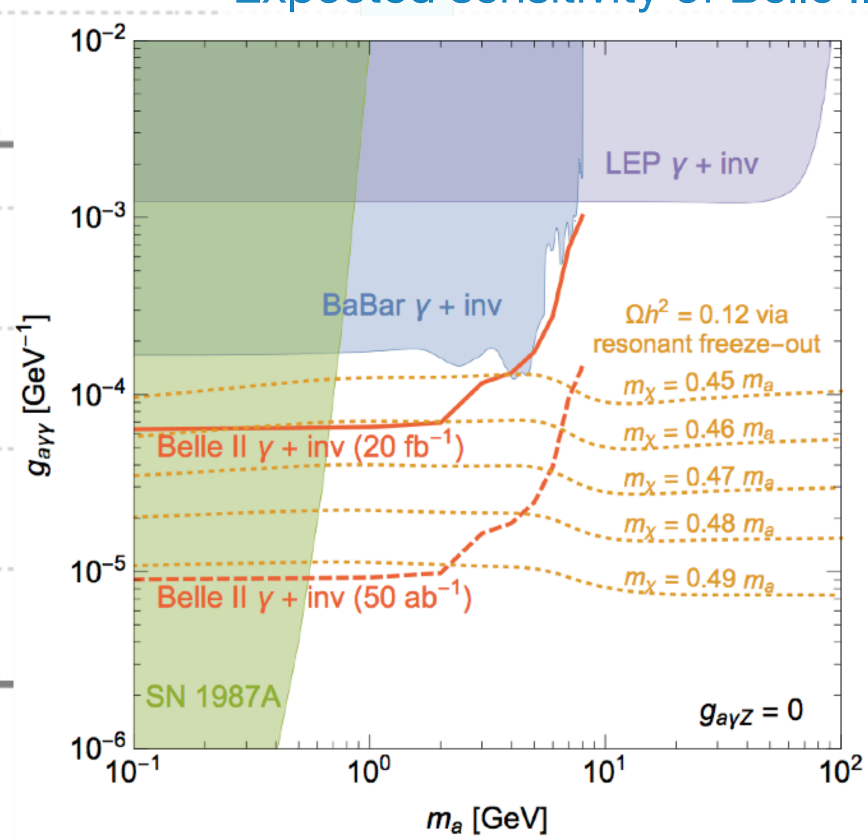
Early physics prospects

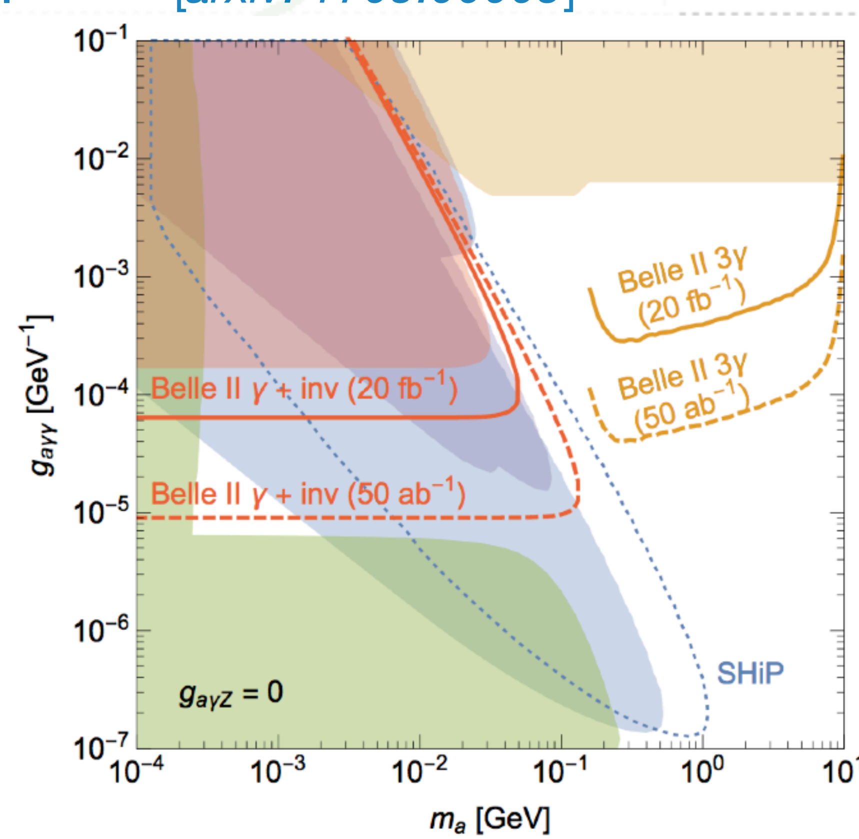
- Efficiency losses for low P_t particles,
- no appreciable losses in photon efficiency.
- **Estimate of integrated luminosity (20±20 fb^{-1})**
- Potential for low-multiplicity / dark channels studies.

Dark sector research

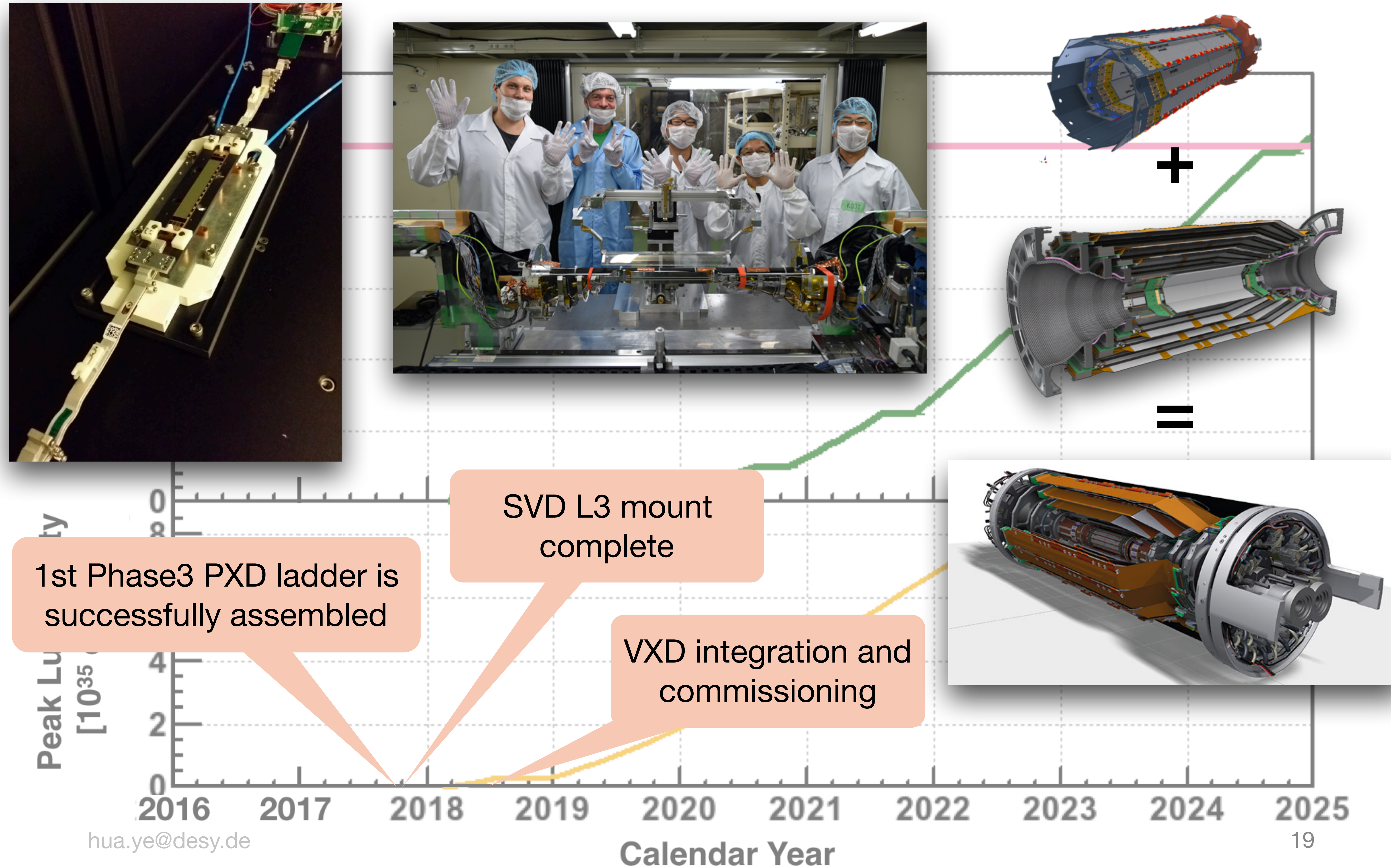
- Axion-like particles (ALPs) produced in ALP-strahlung, then decays into DM or into two photons.

Expected sensitivity of Belle II. [*arxiv: 1709.00009*]

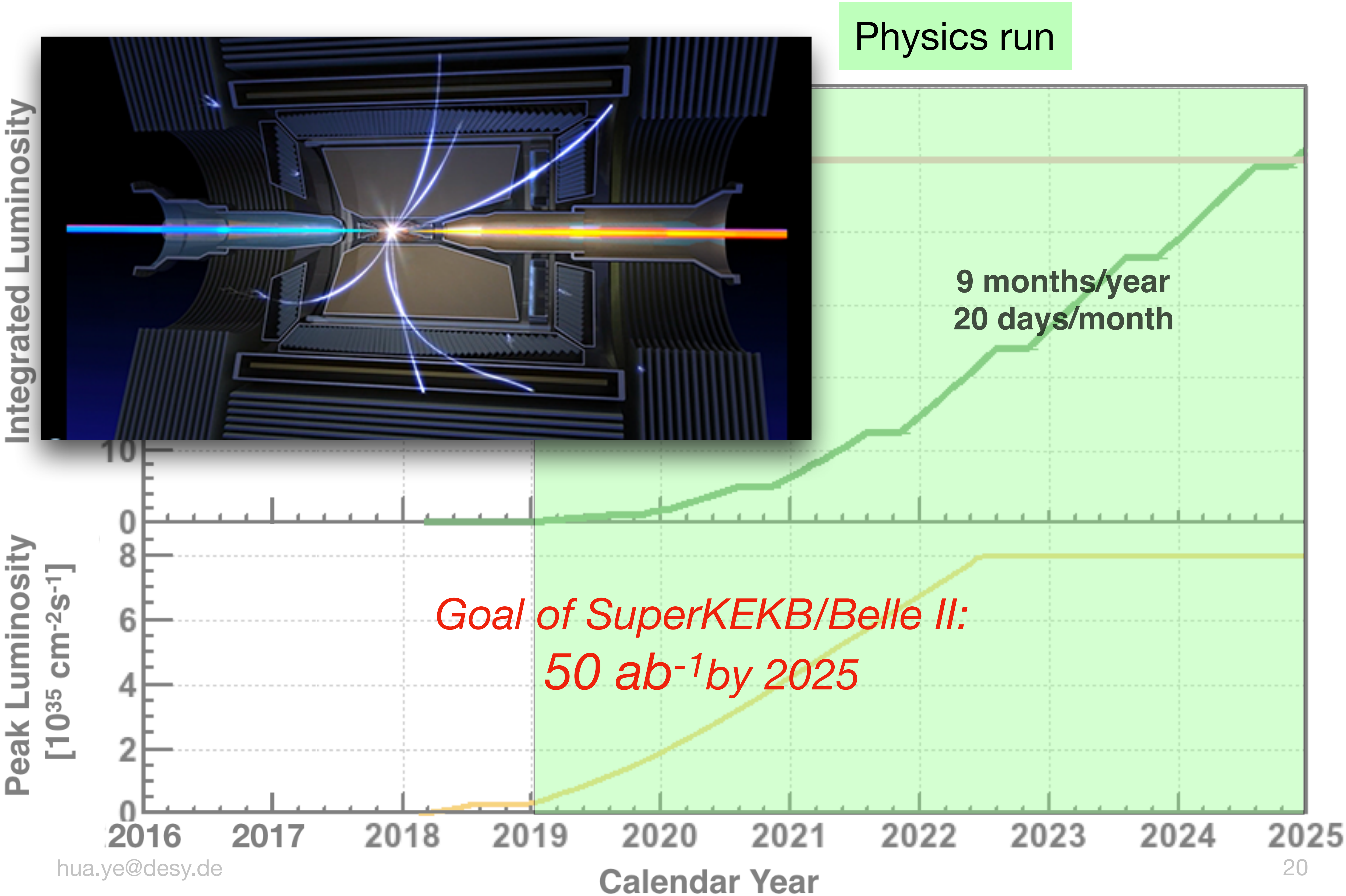




VXD Commissioning



Physics data taking



Goal of SuperKEKB/Belle II:

50 ab^{-1} by 2025

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Summary

- Belle II has a rich physics program.
- SuperKEKB upgrades are on-target, Belle II detector construction is on going.
- BEAST2 Phase2 will start in Feb.2018, to further investigate the beam background, and probably first data for physics studies.
- Physics data taking with full Belle II detector will start in the beginning of 2019!

Super KEKB

Belle II

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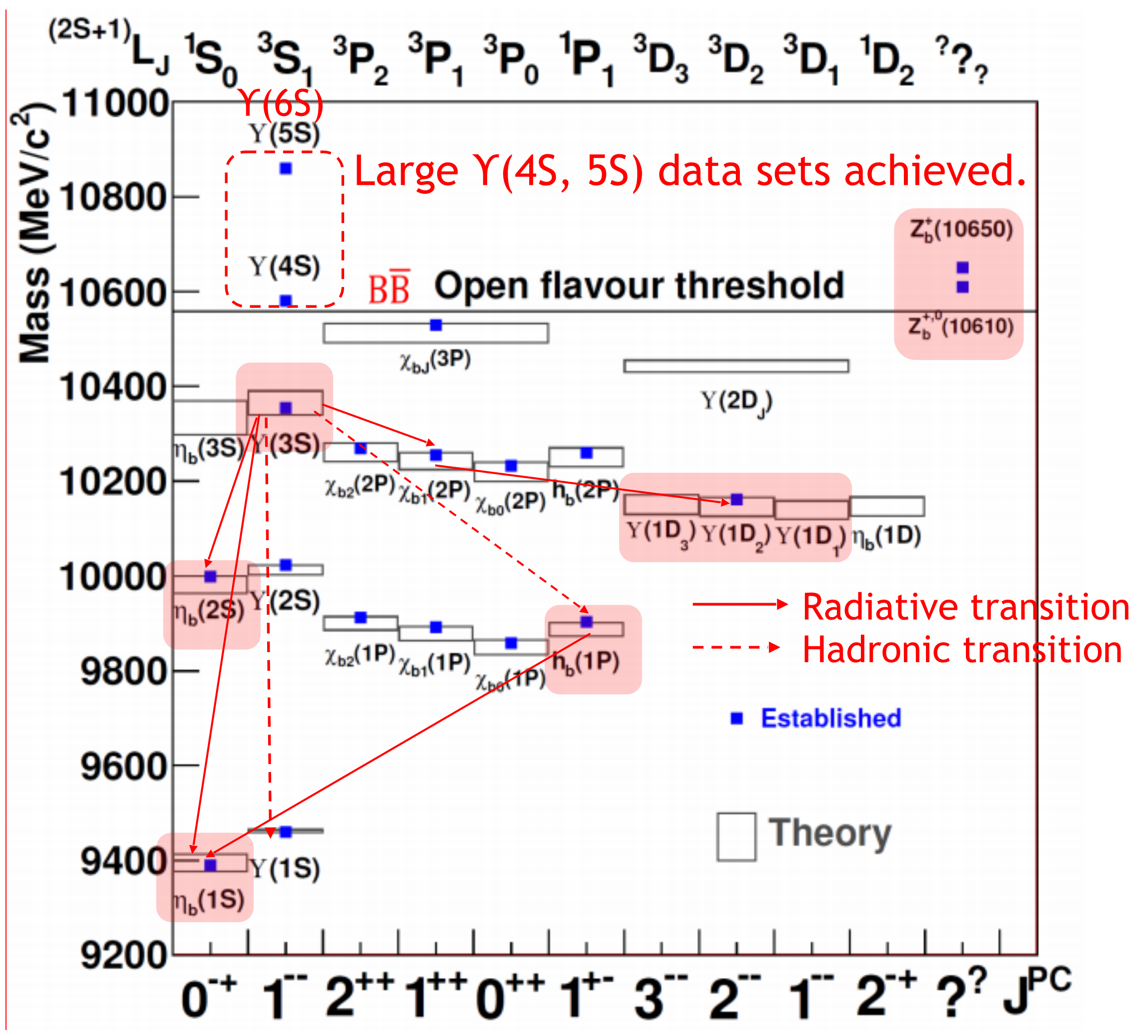
Backup

Early Physics of Bottomonium Spectroscopy

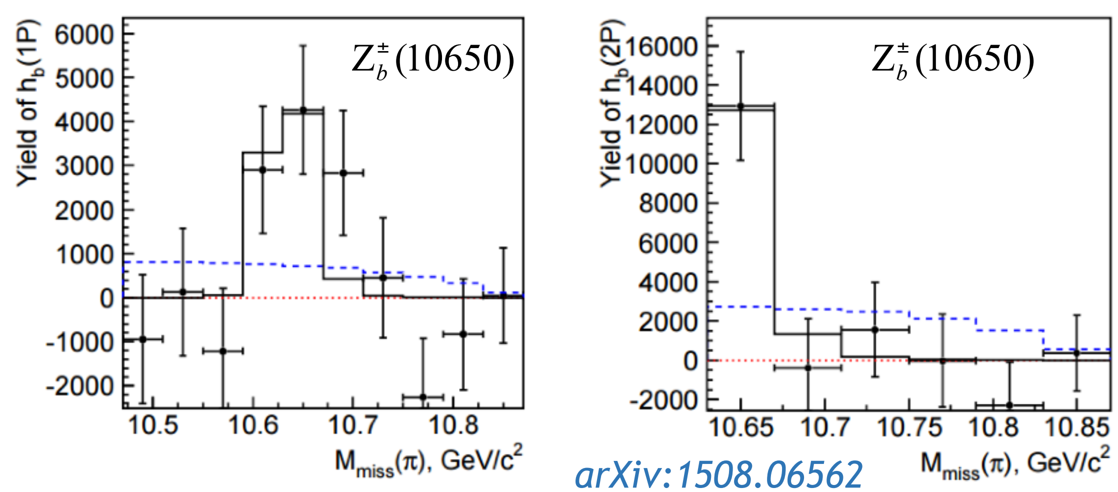
Existing e+e− datasets collected near Υ resonances.

Experiment	Scans/Off. Res.	$\Upsilon(5S)$ 10876 MeV		$\Upsilon(4S)$ 10580 MeV		$\Upsilon(3S)$ 10355 MeV		$\Upsilon(2S)$ 10023 MeV		$\Upsilon(1S)$ 9460 MeV	
	fb^{-1}	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6	fb^{-1}	10^6
CLEO	17.1	0.4	0.1	16	17.1	1.2	5	1.2	10	1.2	21
BaBar	54	R_b scan		433	471	30	122	14	99	–	
Belle	100	121	36	711	772	3	12	25	158	6	102

Potential impact above Υ(5S) and below Υ(4S) with $\mathcal{O}$(10-100) fb^{-1}



Base on the 6fb^{-1} **Υ(6S)** data of Belle
Zb is favored by 3.4σ and 4.7σ for the hb(1P) and hb(2P)
Υ (6S)→ππΥ(nS) decays are not fully studied.



arXiv:1508.06562

The **Υ(3S)** offers greatest access to lower bottomonium states

- η_b(1S,2S), h_b(1P) and Υ(n^3D_1) Studies
- Hadronic/Radiative transitions.
- …