

The Belle II/SuperKEKB project

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on behalf of the Belle II Collaboration

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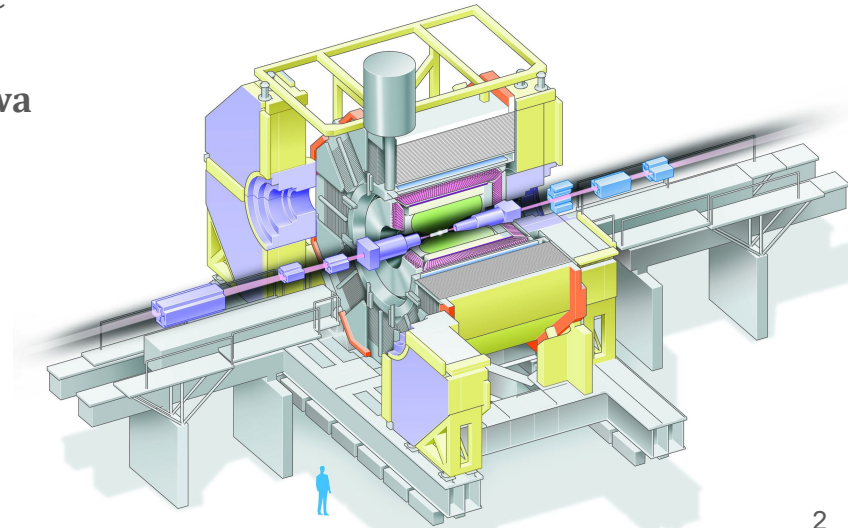
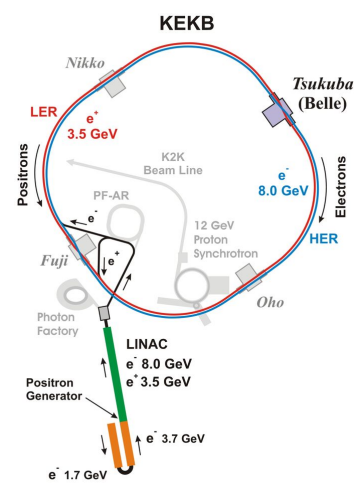


Belle/KEKB

The B -factory at KEK (Tsukuba, Ibaraki, Japan)

- Targeted **CP -violation** using 771 million B meson pairs
- Operated from **1999 to 2010**
- The KEKB accelerator delivered **over 1ab^{-1}** to the Belle detector, a huge success (mostly at $Y(4S)$ resonance)
- Along with BaBar, **confirmed Kobayashi and Maskawa model** of CP violation, leading to 2008 Nobel Prize
- Additional unique datasets at $Y(1S)$, $Y(2S)$, $Y(5S)$ resonances, leading to **unexpectedly rich additional results**

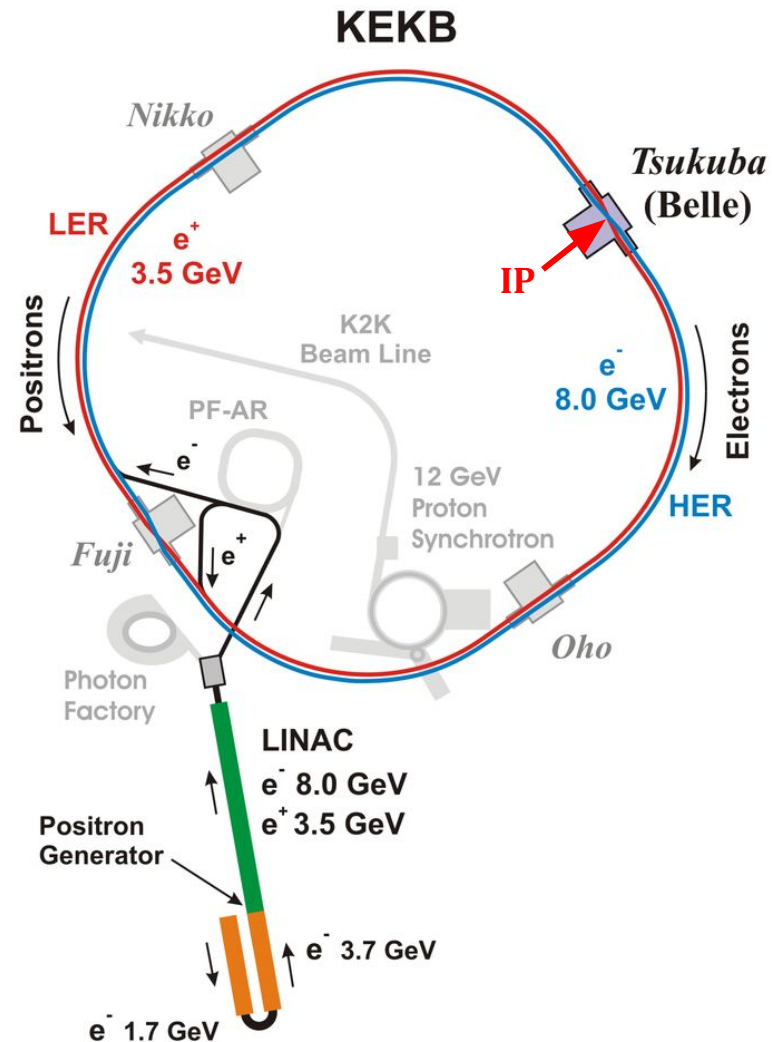
New results still coming out: see **Min-Zu Wang**, *Recent results of rare B/D decays from Belle*, tomorrow



Belle/KEKB

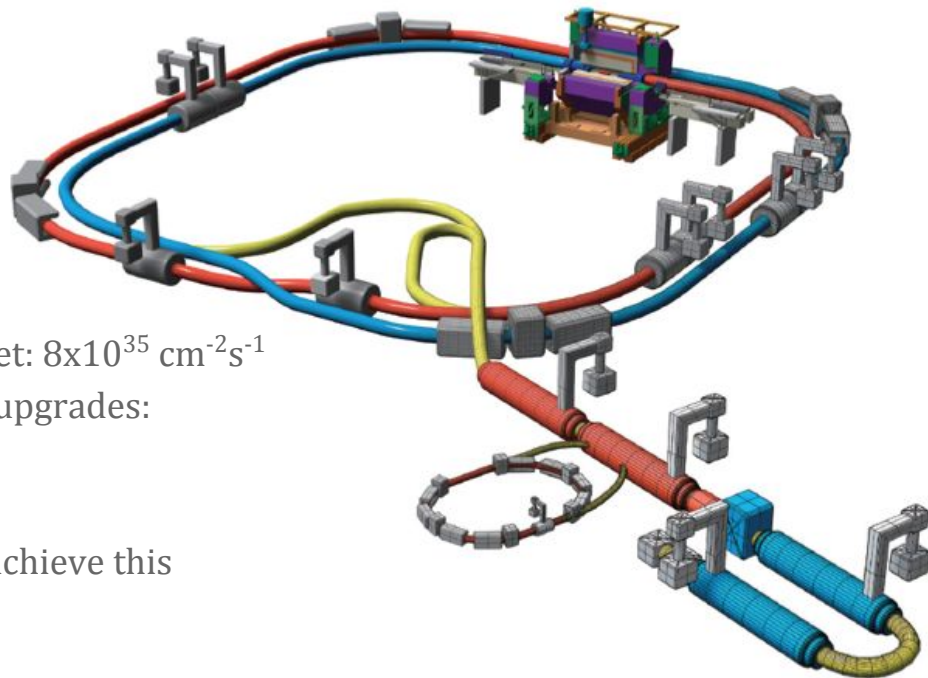
How it worked

- Electrons accelerated to **8 GeV** in linac
- Positrons generated and accelerated to **3.5 GeV**
- The two beams are **injected** in opposite directions into the 3km circumference storage ring in **bunches**
- **Quadrupole** magnets **contain** beams
- **Dipole** magnets **steer** beams
- Final focusing **quadrupole** magnets **focus** and cross the beams at the “interaction point” (**IP**)
- Belle detectors at IP detect products of the (asymmetric) collisions

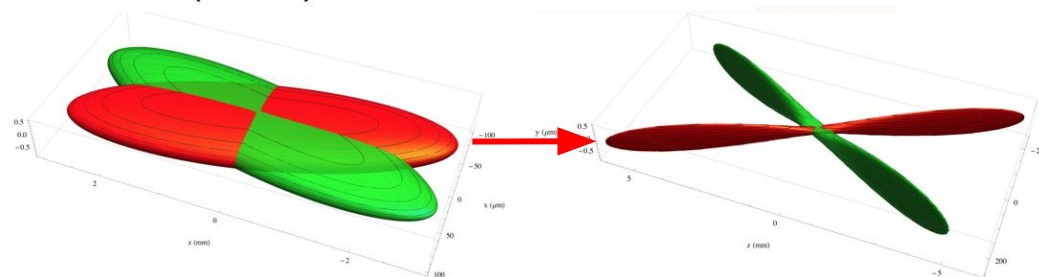


Belle II/SuperKEKB

The **super** B -factory at KEK (2019 start)



- A **40-fold** increase in luminosity over KEKB (target: $8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ instantaneous, 50 ab^{-1} integrated), due to major upgrades:
 - “Nano-beam” scheme (below)
 - Doubled beam currents
 - Both projects require **major upgrades** to achieve this
- **First turns Feb. 10, 2016! Exciting times!**

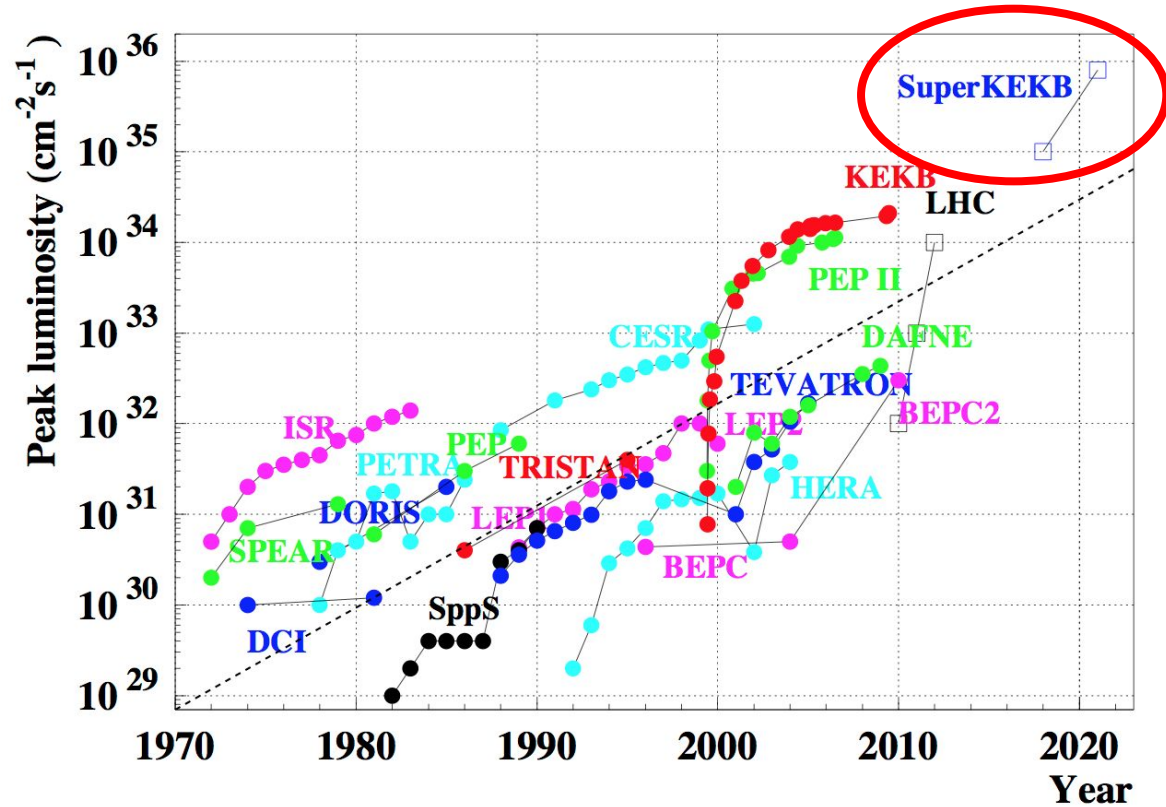


Factor of **2**

$$L = \frac{\gamma_{\pm}}{2e r_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*} \right) \left(\frac{I_{\pm} \zeta_{\pm y}}{\beta_y^*} \right) \left(\frac{R_L}{R_y} \right) = 8 \times 10^{35} \text{ cm}^2 \text{ s}^{-1}$$

Factor of **20**

SuperKEKB is the next luminosity frontier



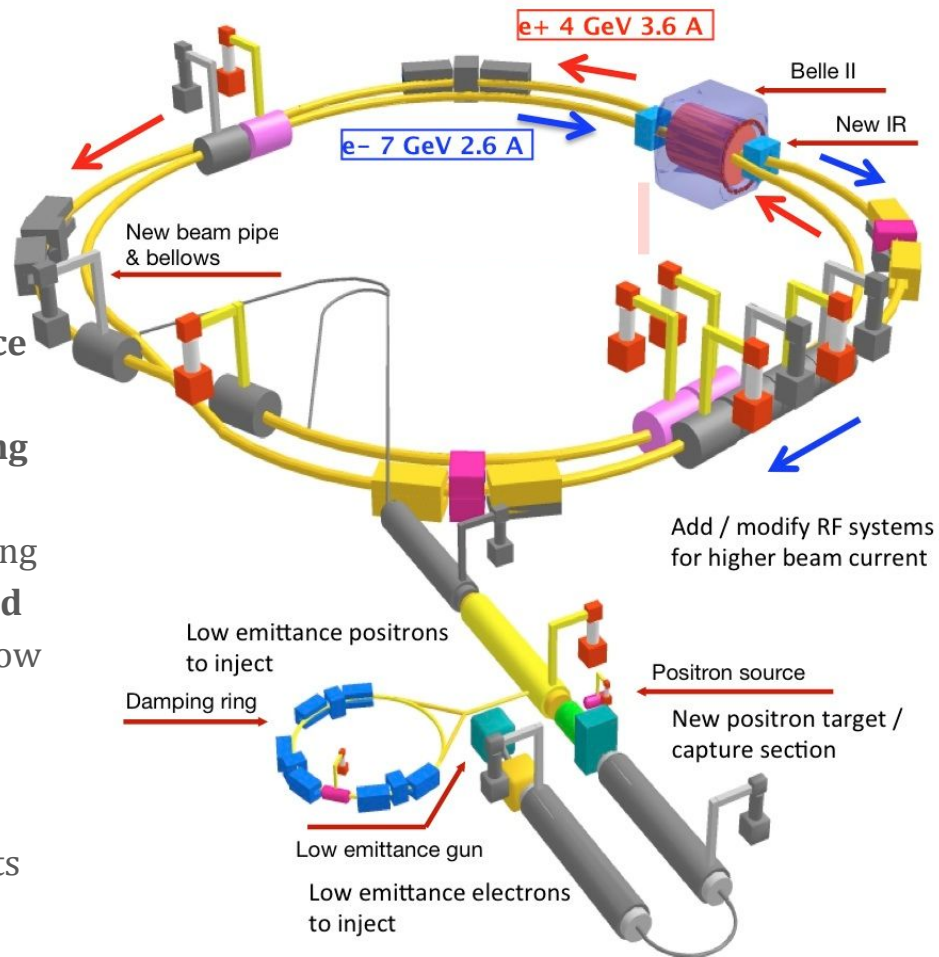


SuperKEKB upgrades

SuperKEKB upgrades

Overview

- Accelerate and store **high-current, low-emittance** beams
 - New 135m diameter **positron damping ring**
 - Upgraded **RF** system
 - New **beam pipe** in low energy (positron) ring with TiN coating to suppress **electron-cloud**
 - Longer **quadrupole focusing magnets** in low energy ring to squeeze emittance during transport
- Focus to **nanobeams** at interaction point
 - New superconducting final focusing magnets

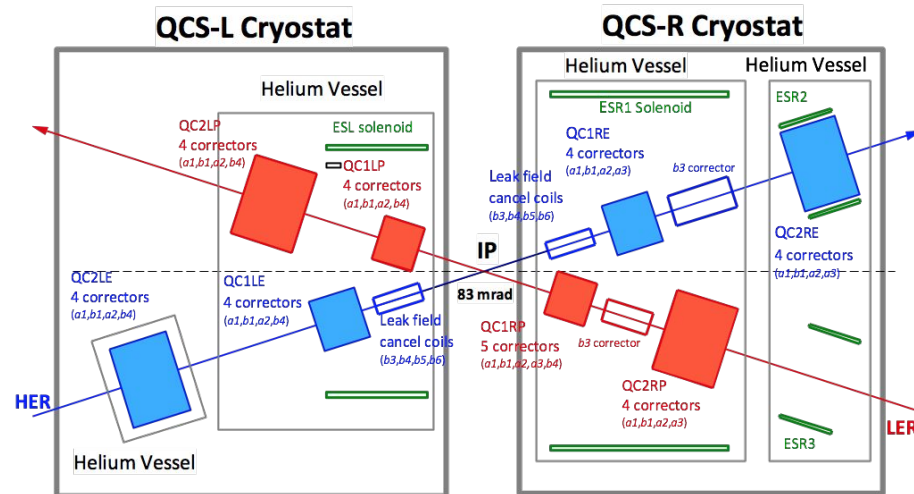


SuperKEKB upgrades



New final focusing magnets

- “The world’s most complicated superconducting magnet system” (QCS):
 - 55 superconducting coils in two cryostats (dipoles, quads, sextupoles, compensating solenoids, ...)
 - A **large crossing angle** (4.8 degrees) keeps beams separated in quads while having focusing elements very near interaction point
- Key to **nanobeam** magic!





Belle II upgrades

For **physics** prospects, see **K. Suzuki**, *Belle II Physics Prospects*, tomorrow

Belle II upgrades

Central beam pipe: decreased diameter from 3cm to 2cm (Beryllium)

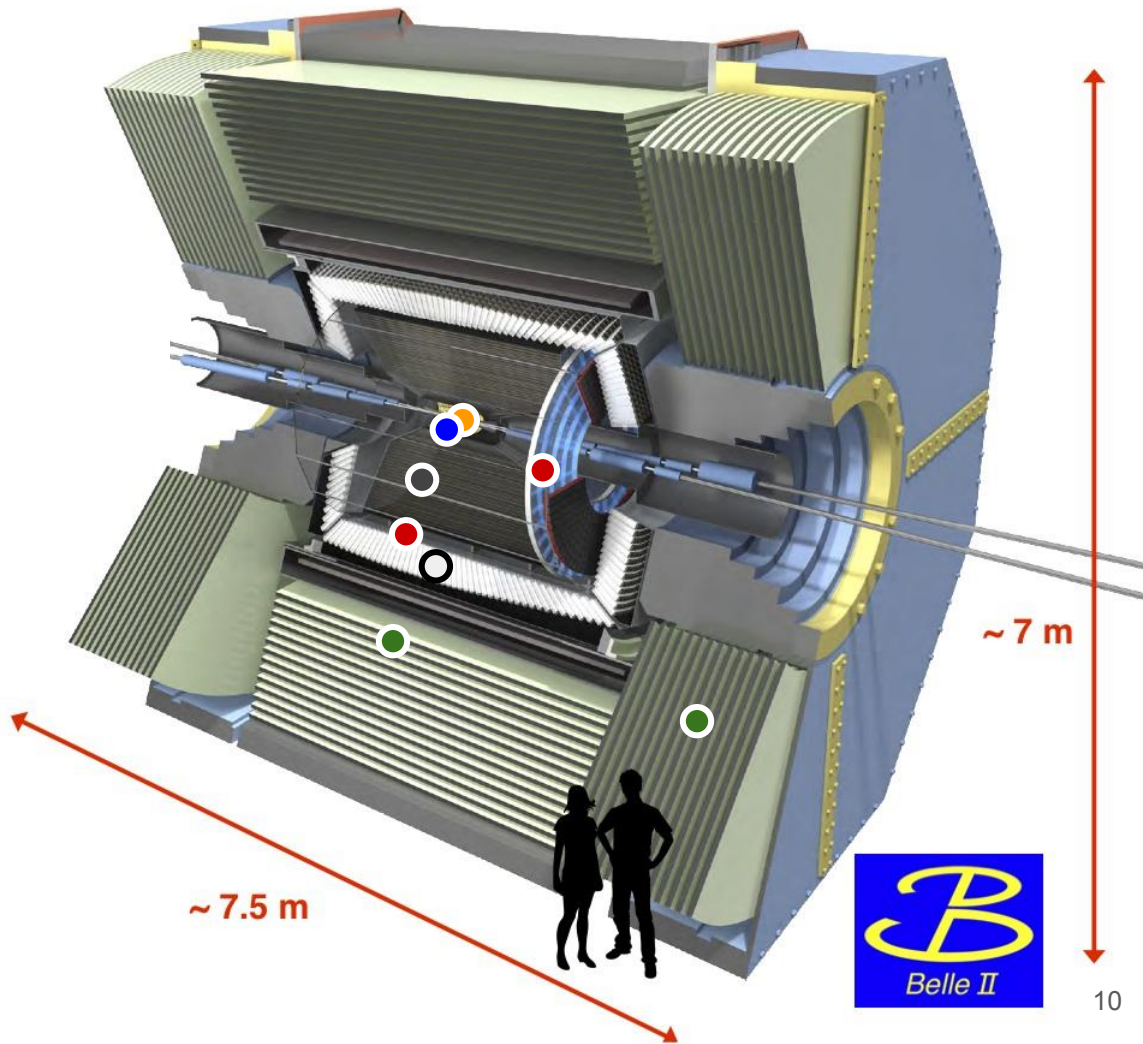
Vertexing: new 2 layers of pixels, upgraded 4 double-sided layers of silicon strips

Tracking: drift chamber with smaller cells, longer lever arm, faster electronics

PID: new time-of-flight (barrel) and proximity focusing aerogel (endcap) Cherenkov detectors

EM calorimetry: upgrade of electronics and processing with legacy CsI(Tl) crystals

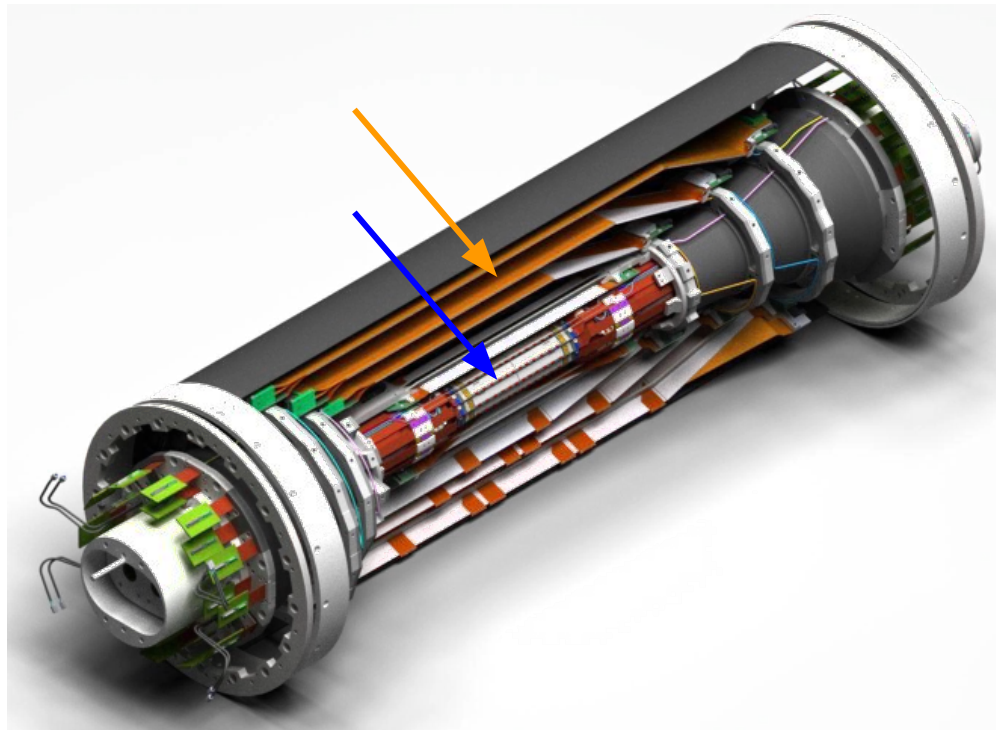
K_L and μ : scintillators replace RPCs (endcap and inner two layers of barrel)



Belle II upgrade details

New vertexing system

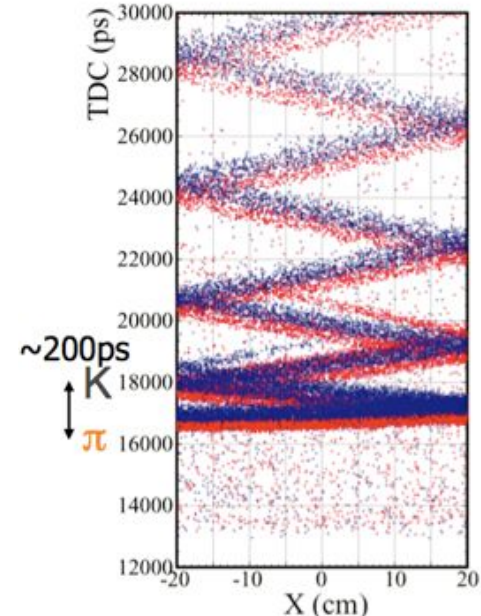
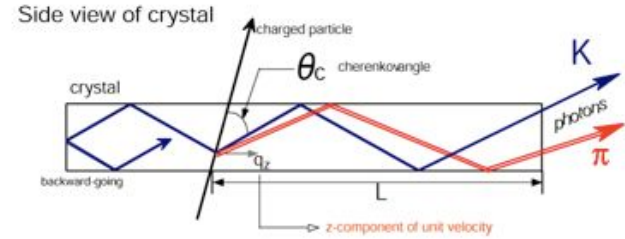
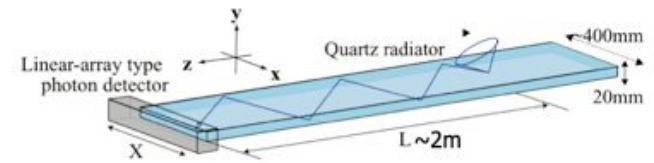
- **Critical** component of *CP*-violation studies (for tagging of *B* mesons with displaced decay vertices)
- Two subdetector systems:
 - All-new: two layers of DEPFET pixels at extreme low-*r* (**PXD**)
 - Upgrade: four layers of double-sided silicon strip sensors (**SVD**)
- Major challenges: limit material budget, increased radiation environment
- Vertexing resolution **improved by factor of ~2** compared to Belle



Belle II upgrade details

Barrel PID detector

- All-new Cherenkov time-of-propagation (TOP) detector
 - Compact DIRC variant
 - For K/π discrimination in the barrel
 - Cherenkov **angle** depends on **velocity**
 - **Time of propagation** of light to photodetectors identifies **mass**
- Design
 - Interleaved quartz bars between drift chamber and calorimeter
 - Linear array of microchannel plate PMTs at end of bar
 - Requires picosecond timing (bottom)





SuperKEKB/Belle II
commissioning

2016

2017

2018

1 2 3 4 5 6 7 8 9 10 11 12

1 2 3 4 5 6 7 8 9 10 11 12

1 2 3 4 5 6 7 8 9 10 11 12

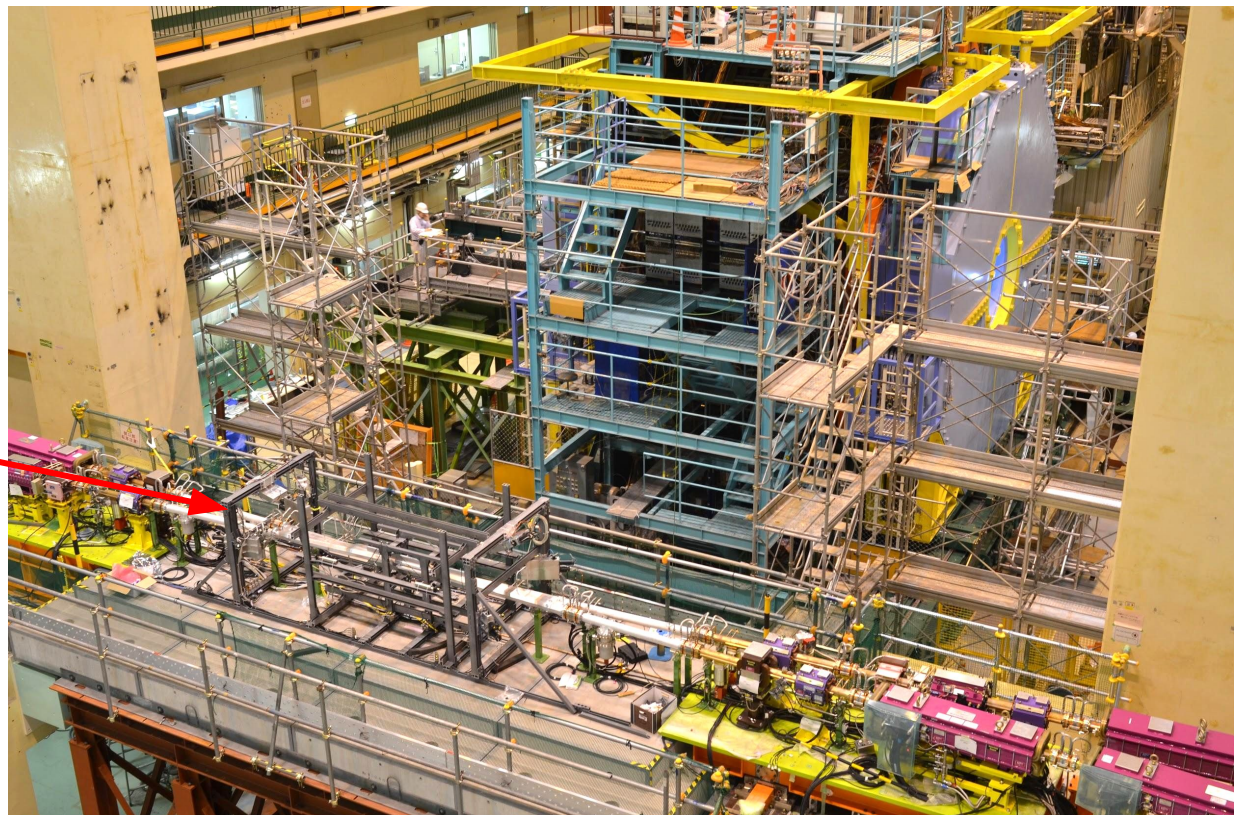
Phase 1

Phase 2



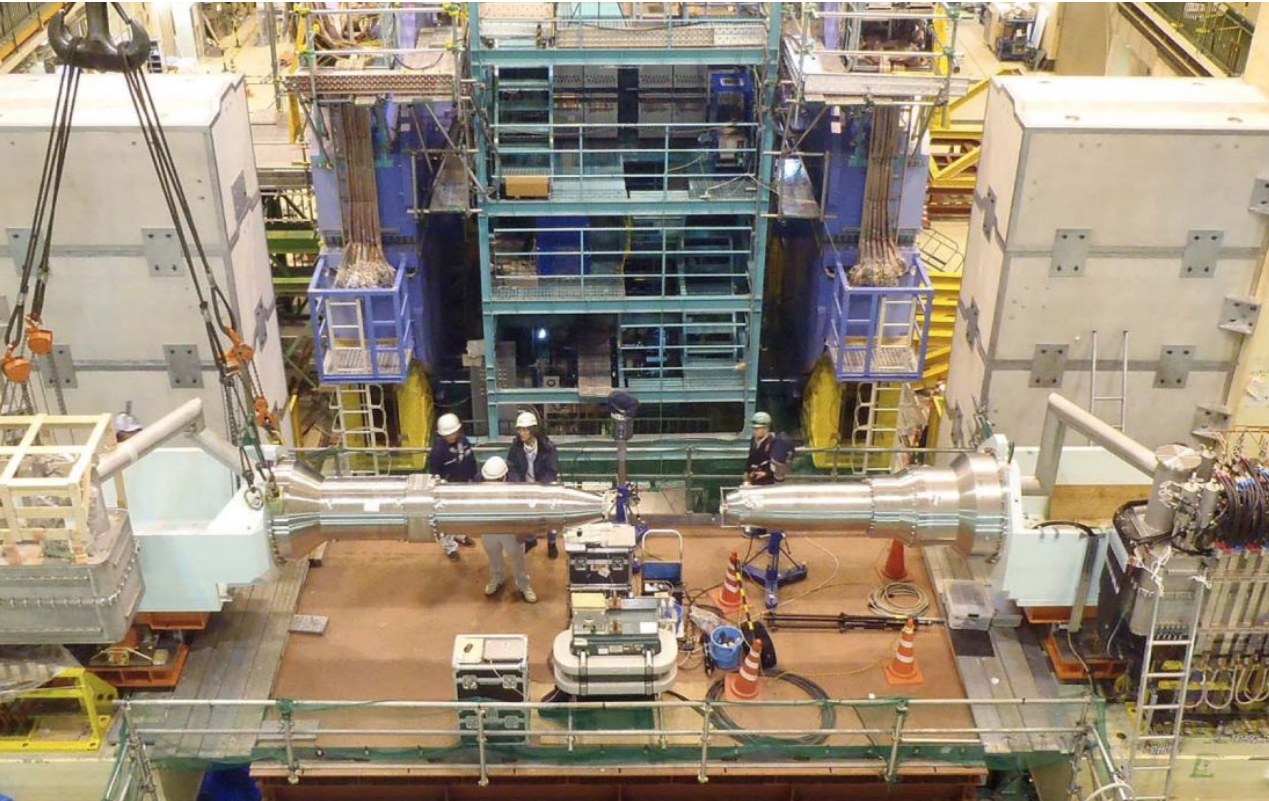
Phase I (complete)

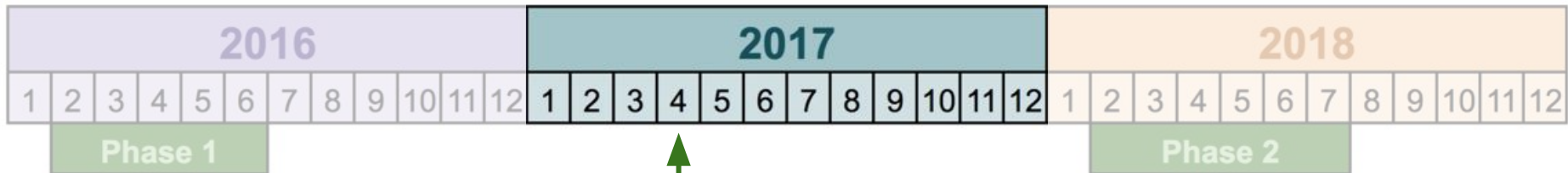
- Circulate both beams; **no collisions, no Belle**
- Tune accelerator optics, etc.
- Vacuum scrub
- Beam studies with **"BEAST II"**





Install final focusing magnet systems (**complete**)





Belle roll-in (**complete**)



2016

2017

2018

1 2 3 4 5 6 7 8 9 10 11 12

1 2 3 4 5 6 7 8 9 10 11 12

1 2 3 4 5 6 7 8 9 10 11 12

Phase 1

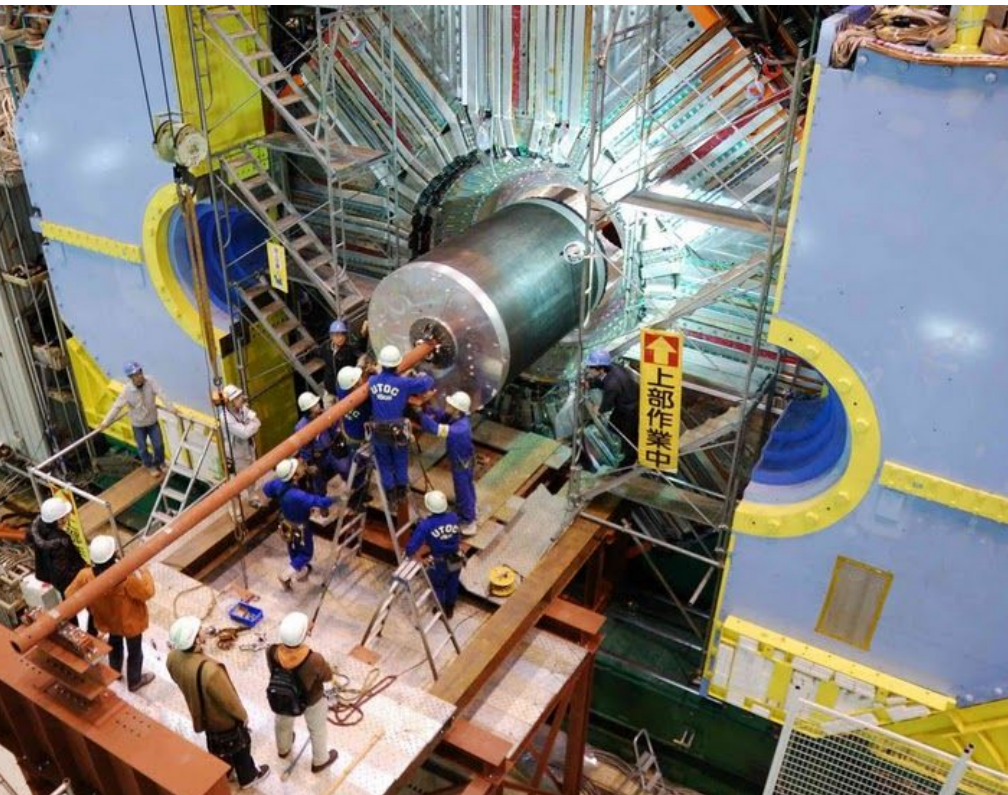
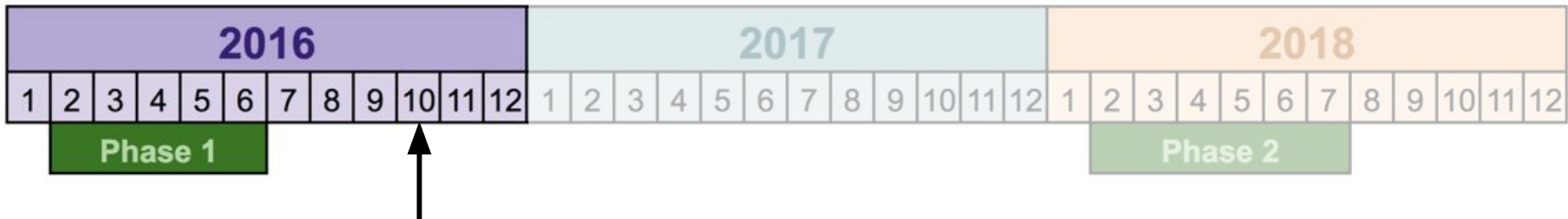
Phase 2



Belle subdetector installation

- Barrel Cherenkov PID detector (TOP) installed **May 2016**





Belle subdetector installation

- Barrel Cherenkov PID detector (TOP) installed May 2016
- Drift chamber (CDC) installed **October 2016**



2016

2017

2018

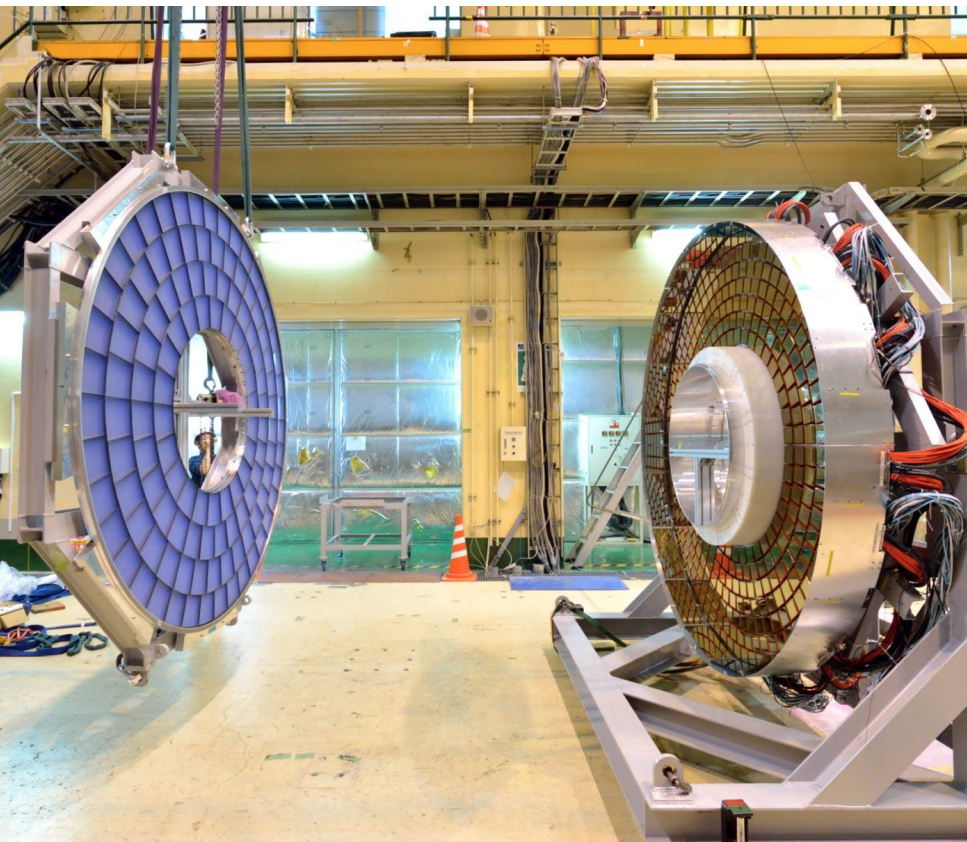
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Phase 1

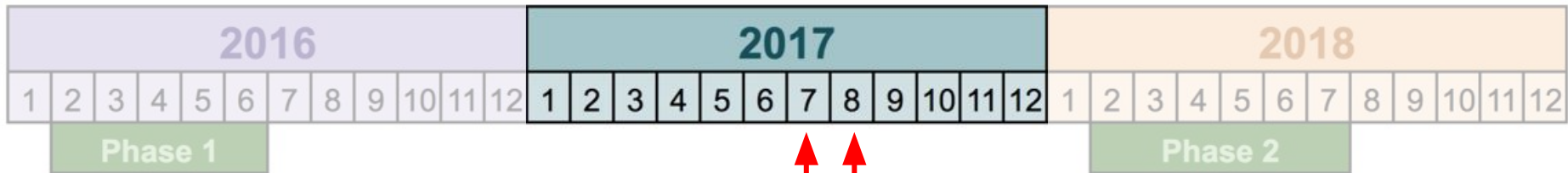
Phase 2



Belle subdetector installation

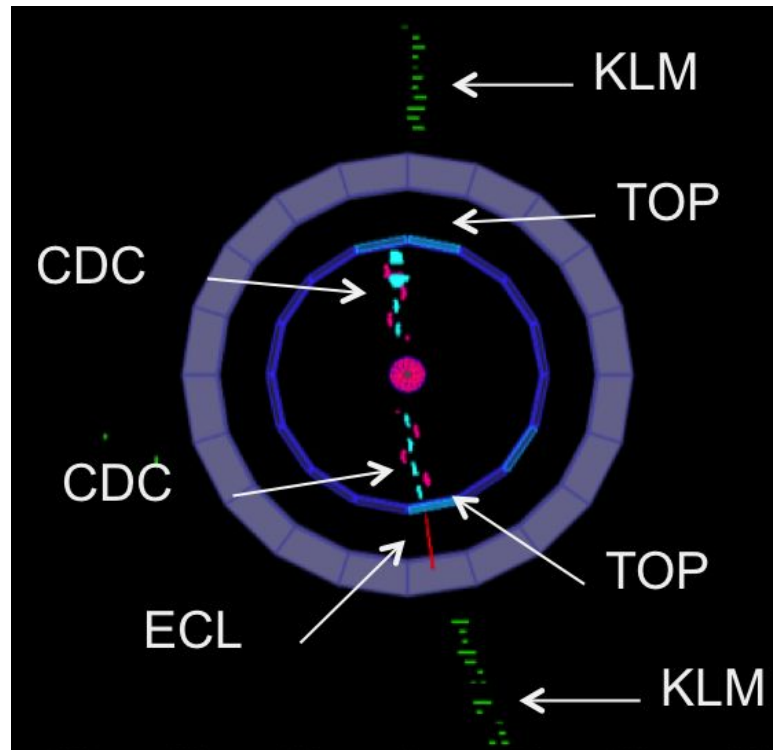
- Barrel Cherenkov PID detector (TOP) installed **May 2016**
- Drift chamber (CDC) installed **October 2016**
- Endcap Cherenkov PID detector (ARICH) integration completed **last week** (left)
- Central vertexing detectors (SVD+PXN) assembling; will be integrated after Phase 2
- Other installation and upgrade work ongoing

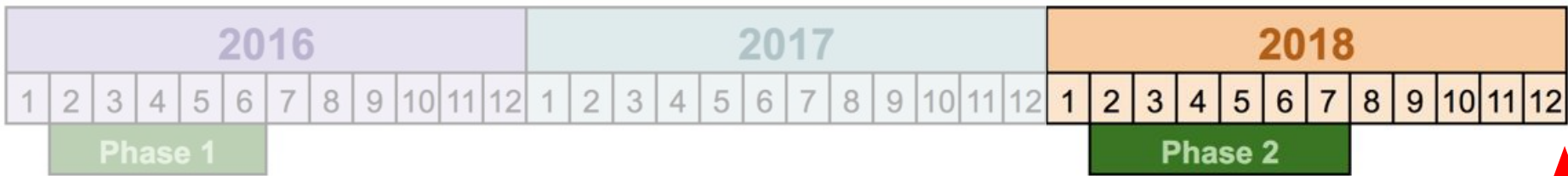




Belle II global cosmic run (one in **July**, one **right now**)

- Outer detectors participating
 - Test of **readout integration**, event reconstruction, shifting, etc.
 - Final 1.5T solenoid field on
 - Pictured (from July run): hits in four outer subdetectors



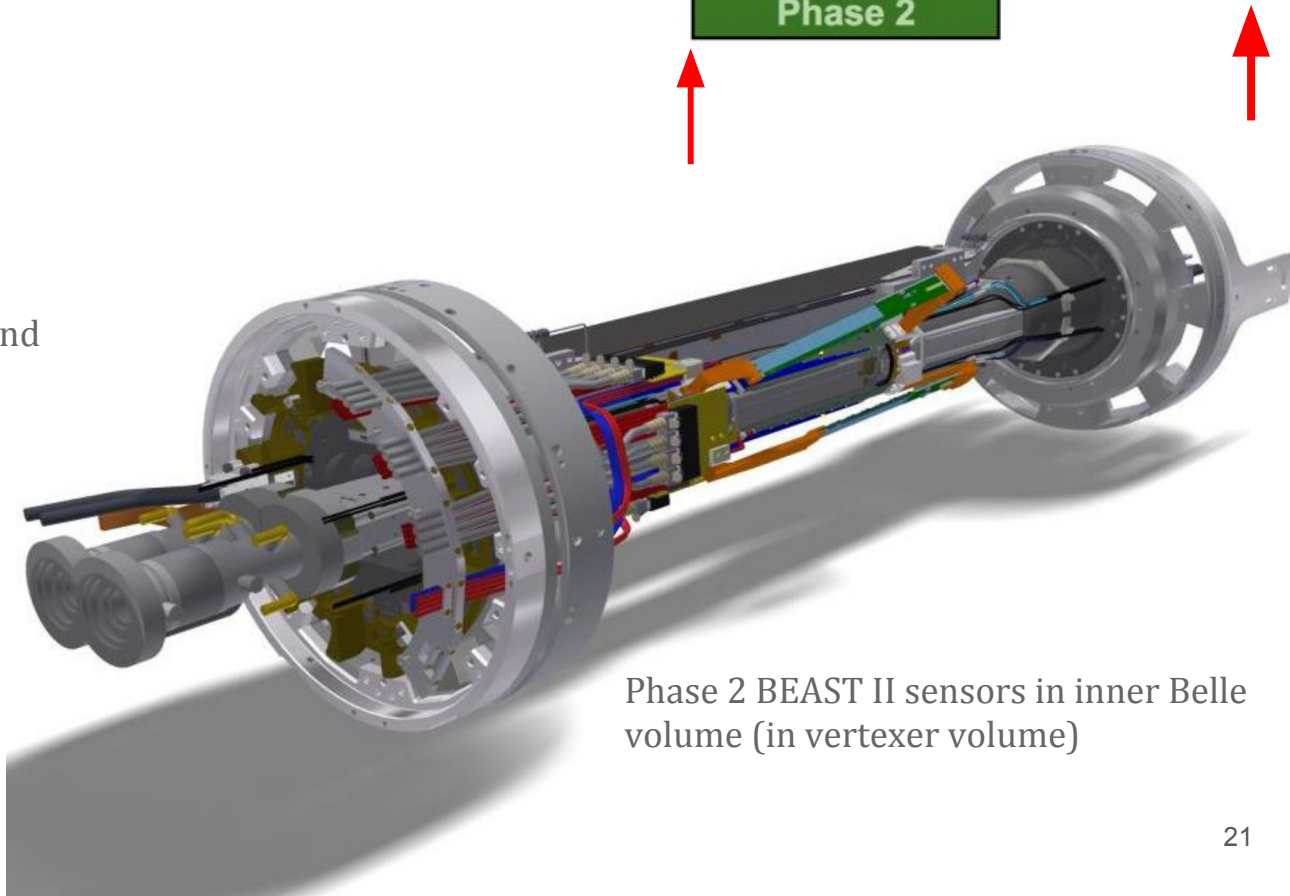


Phase 2

- First **collisions**
- First **nanobeam**
- Beam studies with **BEAST II** and **partial Belle II**

Phase 3

- **Complete** Belle II, **complete** SuperKEKB
- First real physics run!
- **Early 2019**



Phase 2 BEAST II sensors in inner Belle volume (in vertexer volume)

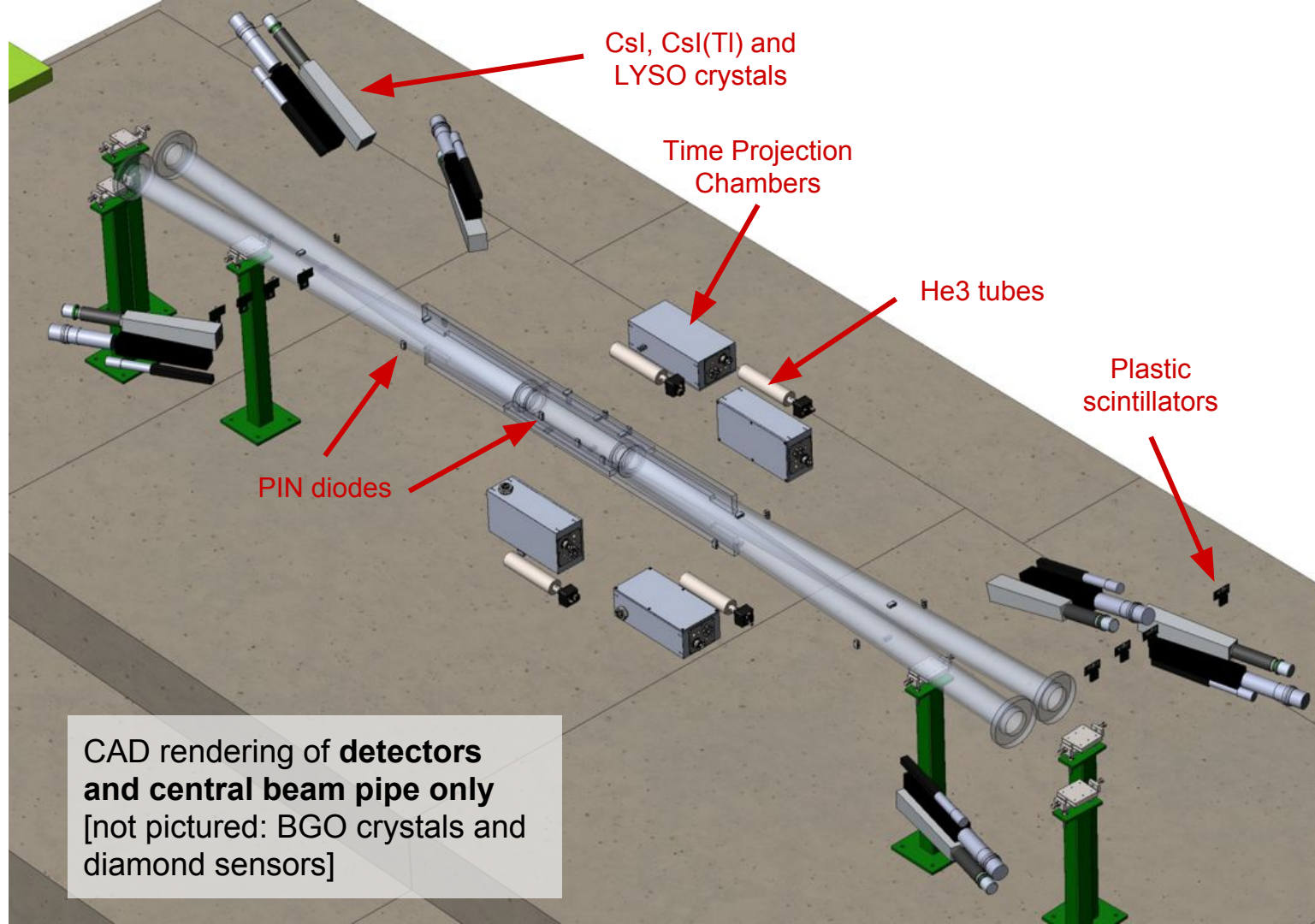
BEAST II

Beam background monitoring in **Phase 1**

- 7 detector systems providing:
 - Thermal neutron rate
 - Fast neutron tracking
 - Neutral and charged dose rates
 - EM spectrum and dose
 - Bunch-by-bunch injection backgrounds
 - More...
- Provided **real-time feedback** to SuperKEKB controllers
- Analysis ongoing to inform Phase 2 + 3 run conditions, masking, collimation, etc.





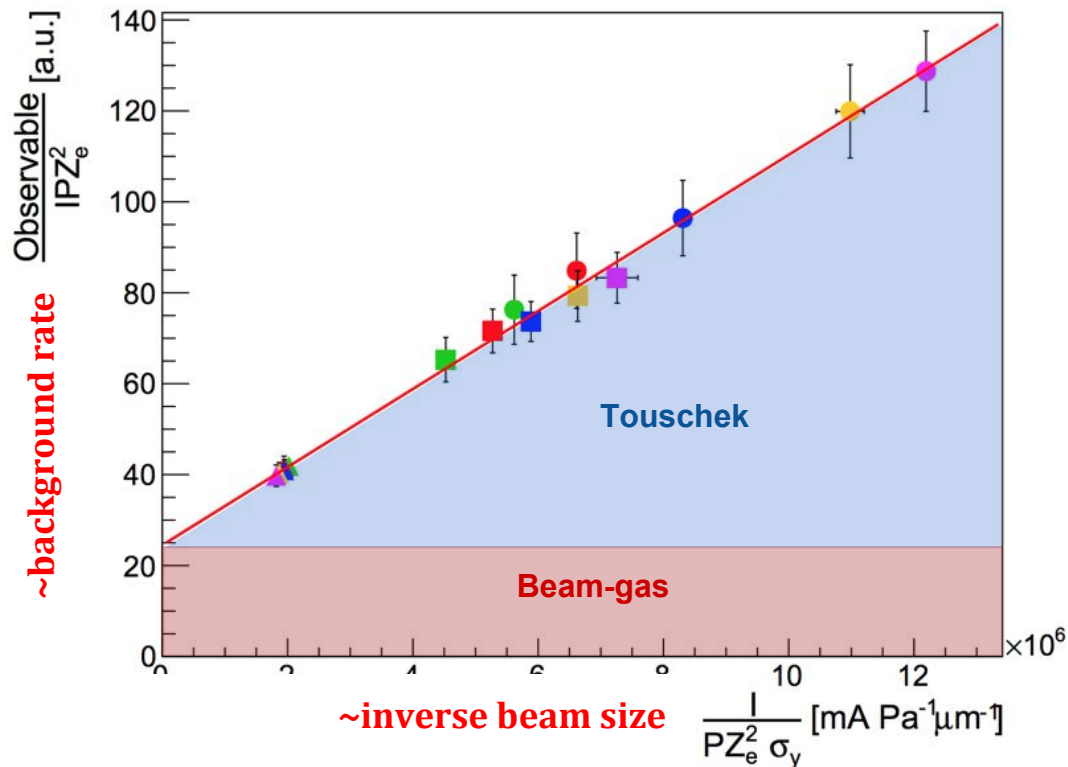


CAD rendering of **detectors**
and **central beam pipe** only
[not pictured: BGO crystals and
diamond sensors]

BEAST II: some results from phase 1

Touschhek scattering

- Intra-beam scattering increases as beam is **squeezed**
- Key background in Belle II
- Phase 1 result: **parameterization** of Touschek as function of beam size and position
 - Can be extrapolated to Phase II
 - Informs masking/collimation choices

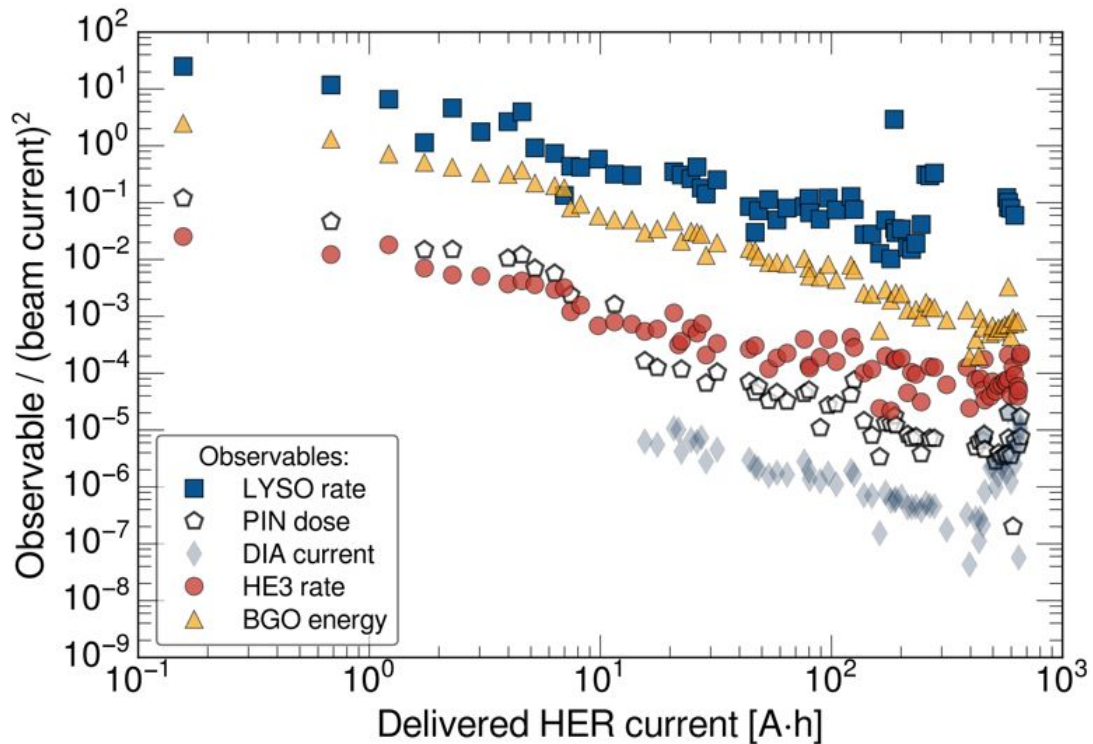




BEAST II: some results from phase 1

Beam scrubbing

- Cleaning beam pipes with beams
- Clear progress over time
- Findings: HER scrubbing adequate, LER **not yet**

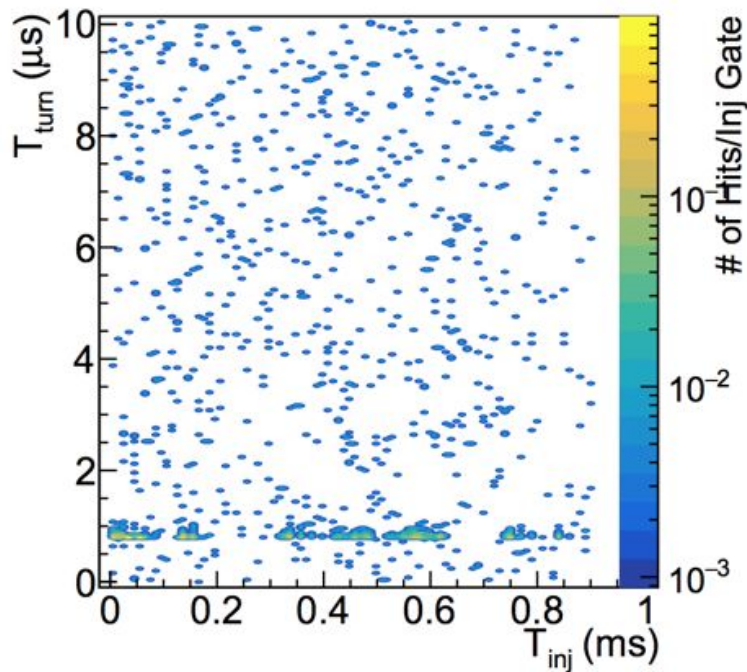




BEAST II: some results from phase 1

Injection

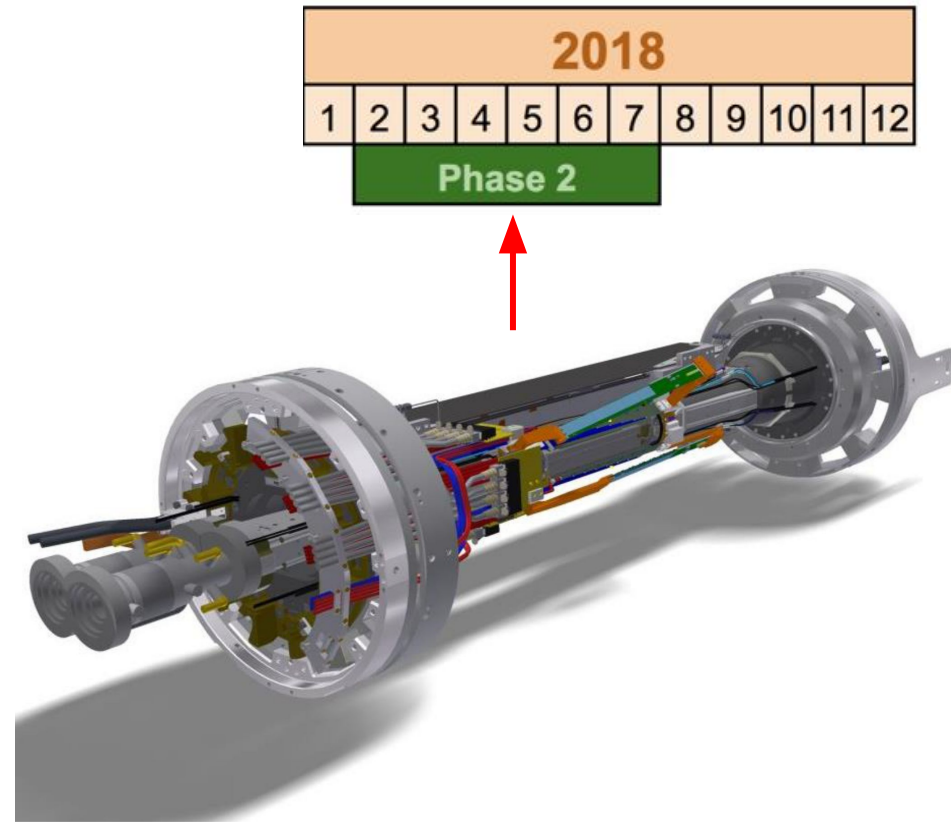
- Principle
 - Newly topped-off bunches are “**hot**” for \sim ms
 - Bunches circulate with 10 μ s period
 - Fast detectors (\sim ns) measure **bunch-by-bunch** background time structure at IP
- **Critical** to pixel vertexer performance
 - Electronic gating may be necessary for short window after injection
- **Results:** real-time feedback to SuperKEKB *artists* and detailed characterization of injection backgrounds



BEAST II

Beam background monitoring in **Phase 2**

- Detectors:
 - Some BEAST II detectors from Phase 1
 - **New** BEAST II detectors (right) in Belle II's vertex detector volume
 - Some Belle II detectors
- Goal: study beam backgrounds with **luminosity** and **nanobeams**
 - Ensure that vertex detectors are safe to install
 - Measure **synchrotron radiation at IP**
- Installation already underway





Summary

Overall project status

SuperKEKB and Belle II

- On-target for **Feb. 2018 first collisions** (Phase 2)
 - SuperKEKB upgrades are on-target (currently commissioning new positron damping ring)
 - Phase 2 BEAST II is starting installation work **~now**
 - Belle II outer subdetectors are in-place and currently participating in a **global cosmic run**
- First physics runs with vertex detector (full Belle II) **~January 2019**
- **It is a very busy and exciting time!**





Спасибо!