Commissioning and Operation Status of Belle II and SuperKEKB

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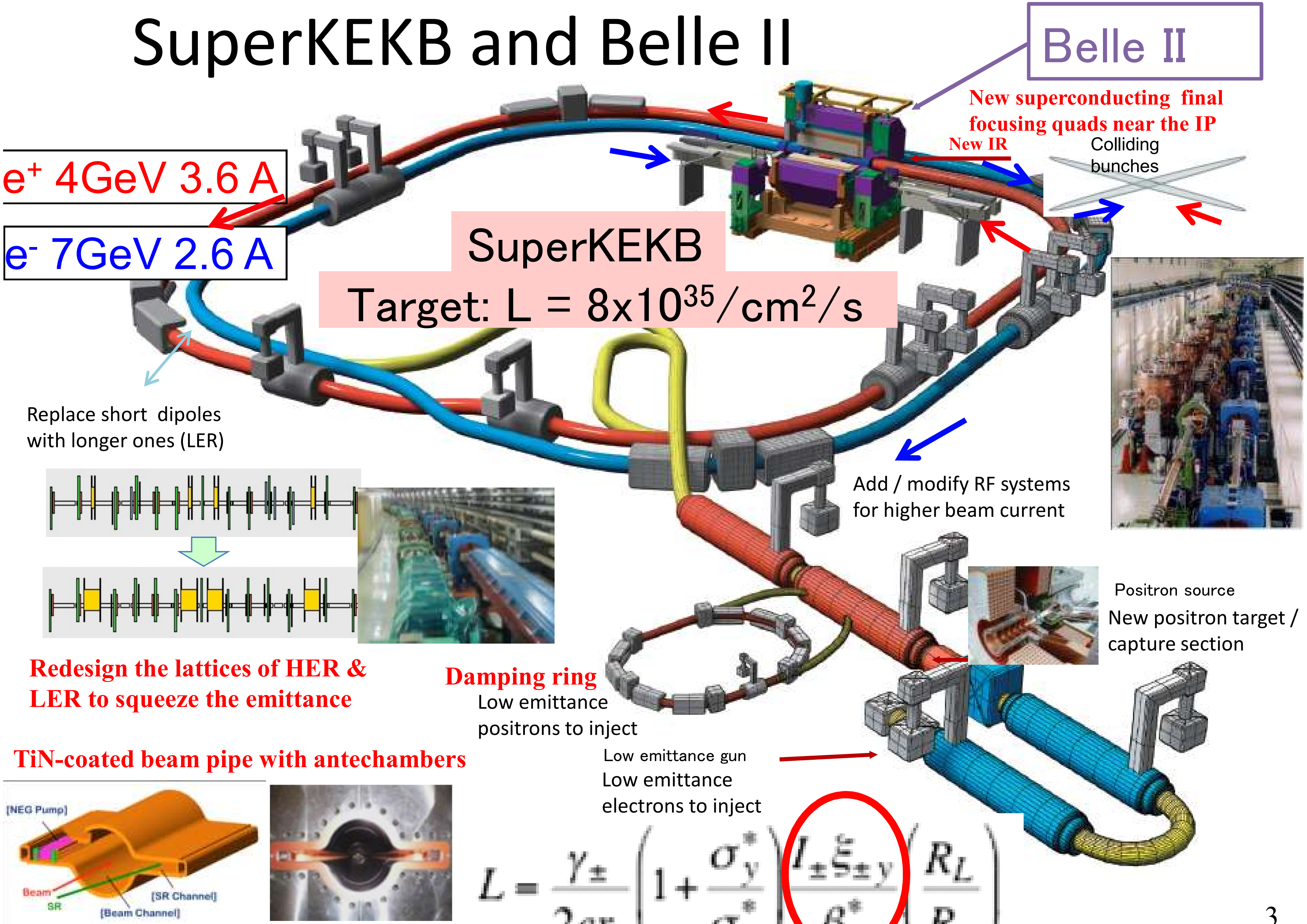
Heavy Quarks and Leptons 2018

SuperKEKB

SuperKEKB and Belle II



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

Key points for SuperKEKB

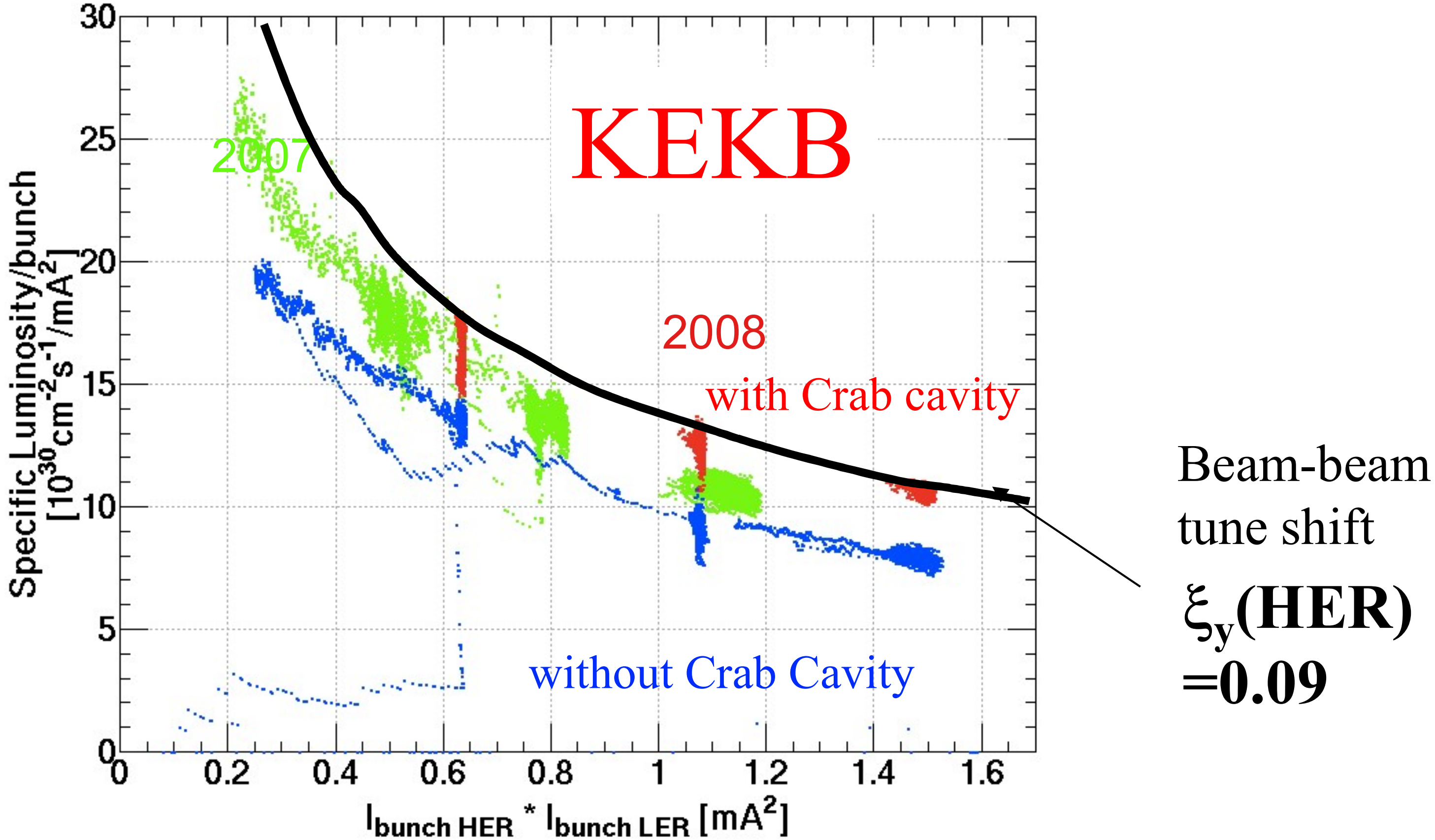
- Smaller beam size with moderate current
  - Nano beam option
    - Very low emittance
    - Stronger final focusing magnet closer to IP
- Complete new LER ring
  - New antechamber to reduce electron cloud
  - New longer and more bending magnets
- Optimized HER parameters (KEKB ring)
- Complete new IR

Why nano beam?

- Bunch luminosity is limited by several reasons.
  - Beam-beam tune shift limit.
  - Bunch lengthening.
  - Higher bunch current → damage hardware component
  - $1.2 \times 10^{31} cm^{-2} sec^{-1}$ at KEKB
    - It is not so high as compared with other machines.
- Higher luminosity means larger number of bunches.
  - Factor 2 at TRISTAN
  - Factor ~50 or more thanks for pretzel scheme at CESR and LEP
  - Factor ~1600 thanks for double rings at KEKB and PEPII (also BEPC II, LHC).
- We only need to improve the number of bunches by factor of three.
  - 5000 (~1600 at KEKB) is real maximum due to RF frequency.

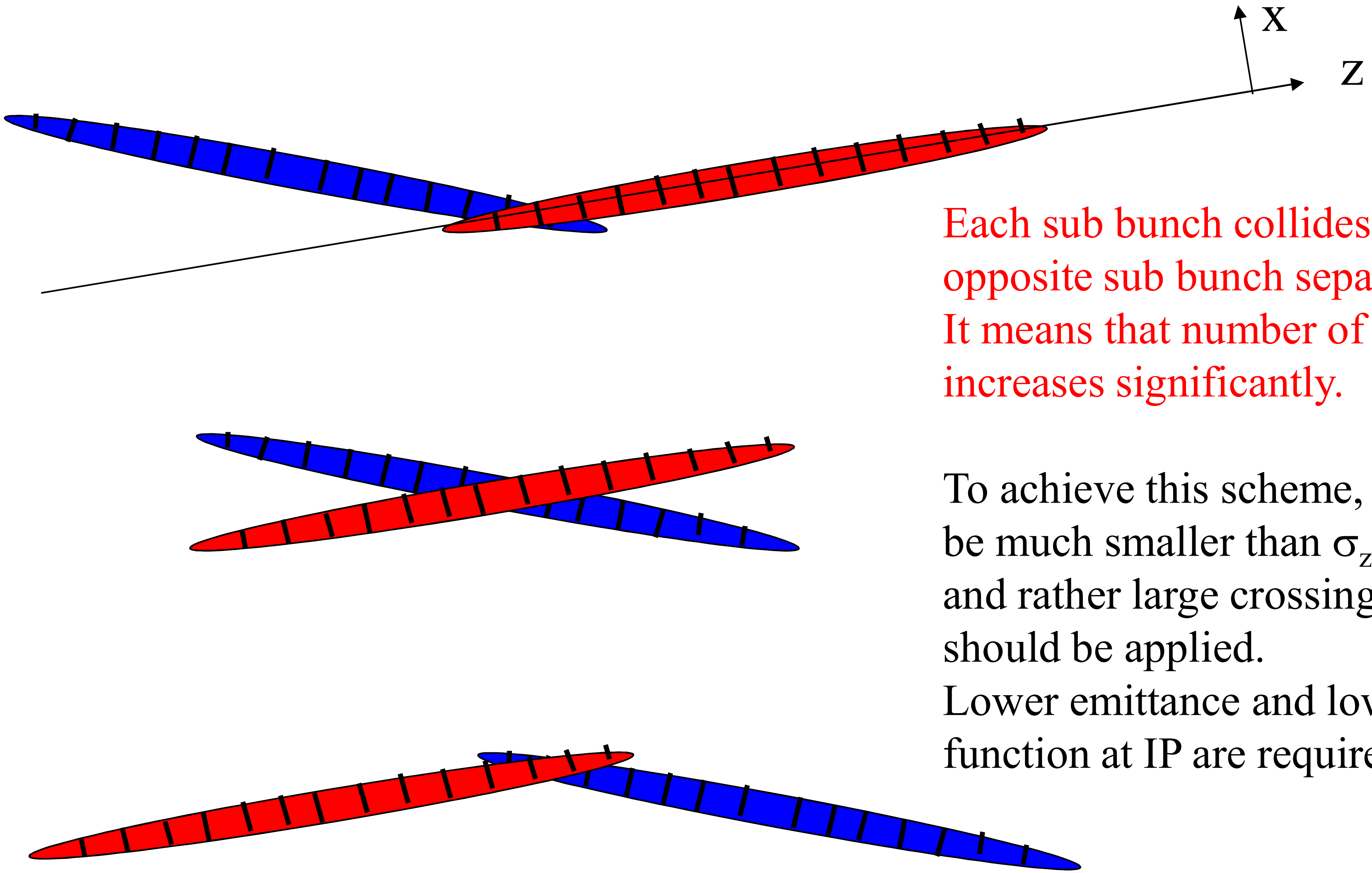
- Super bunch (nano beam) idea improves number of bunches, significantly.

Specific Luminosity



The beam beam shift could not exceed 0.09 even for higher bunch current and even with the crab cavity.

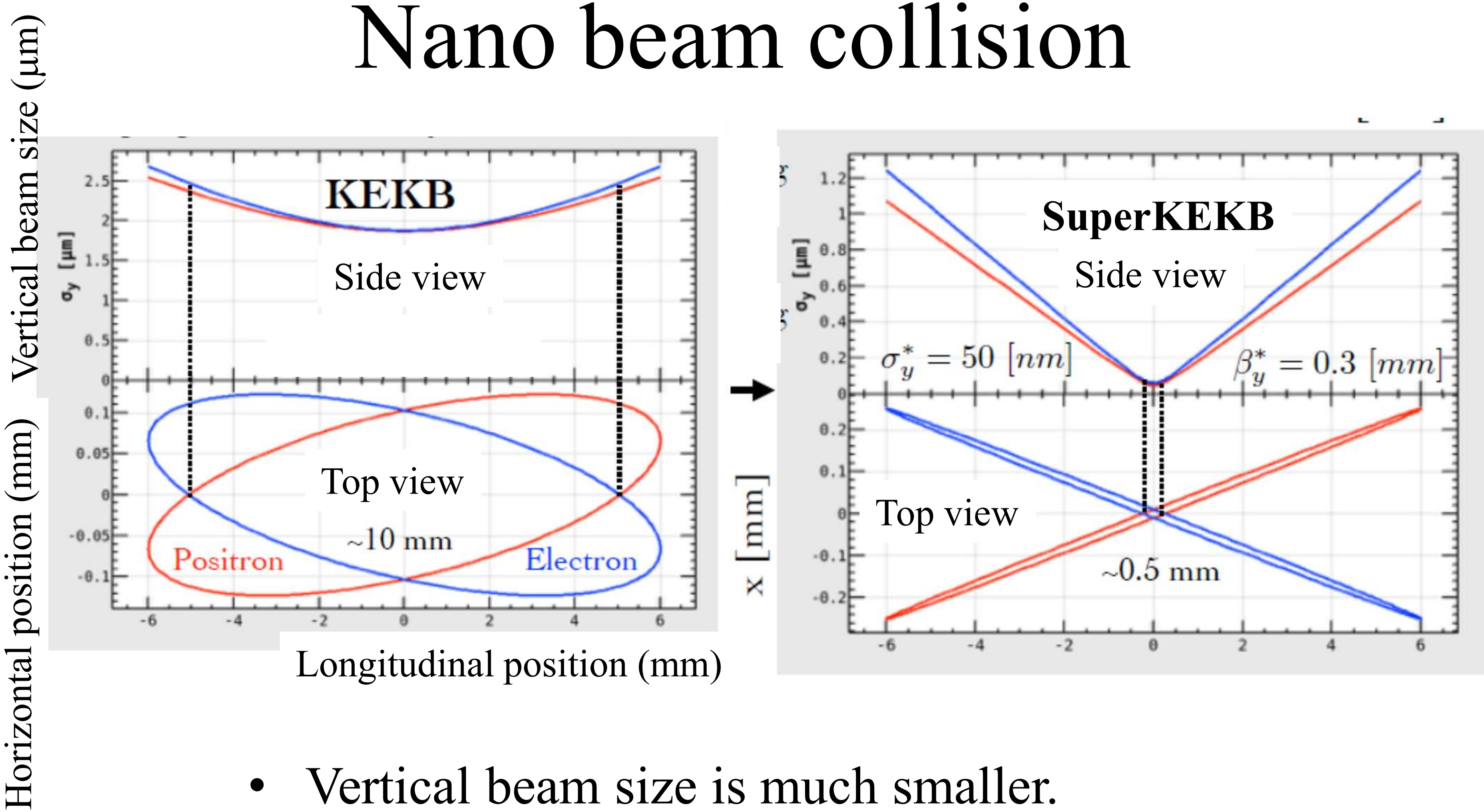
Super bunch (Nano beam)



Each sub bunch collides on opposite sub bunch separately.
It means that number of bunches increases significantly.

To achieve this scheme, σ_x should be much smaller than σ_z
and rather large crossing angle should be applied.
Lower emittance and lower β function at IP are required.

Nano beam collision



- Vertical beam size is much smaller.
  - 2 μm → 50 nm
- Collision area is much smaller.
  - Even if bunch lengths are similar.
  - ~10 mm → ~0.5 mm

Belle II

Requirements for Belle II detector

Target luminosity : L= 8 x 10^{35}/cm^2/sec

Larger beam-related background (×20)

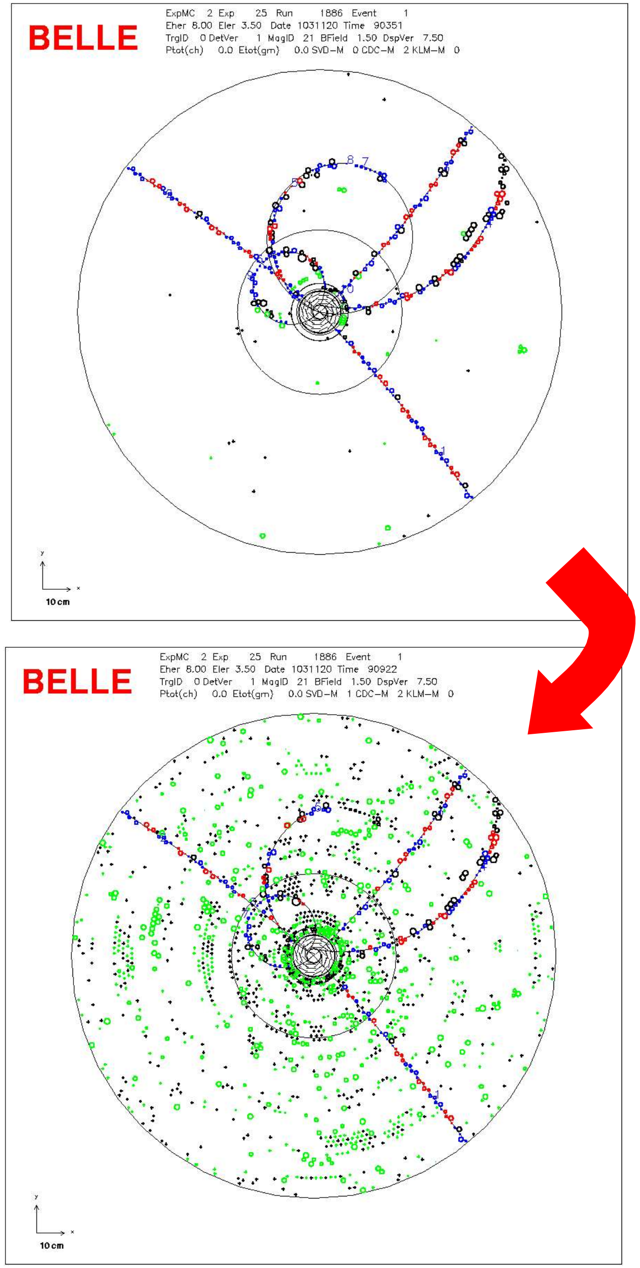
- Finer granularity
- Better timing separation

High trigger rate (×20)

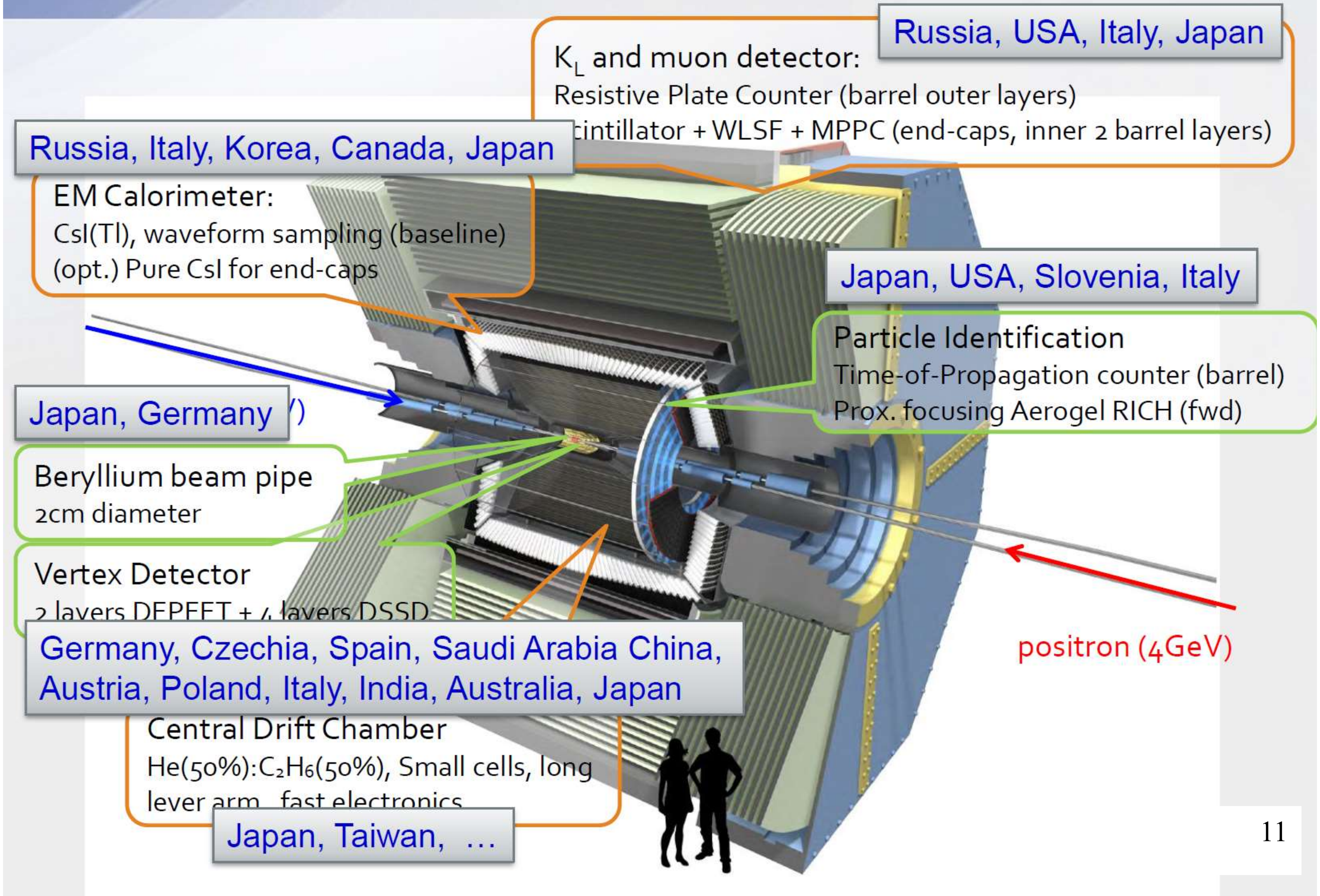
- Pipeline readout

Improvements

- Better particle ID devices
- Better vertex resolution



Belle II Detector



Belle II Collaboration

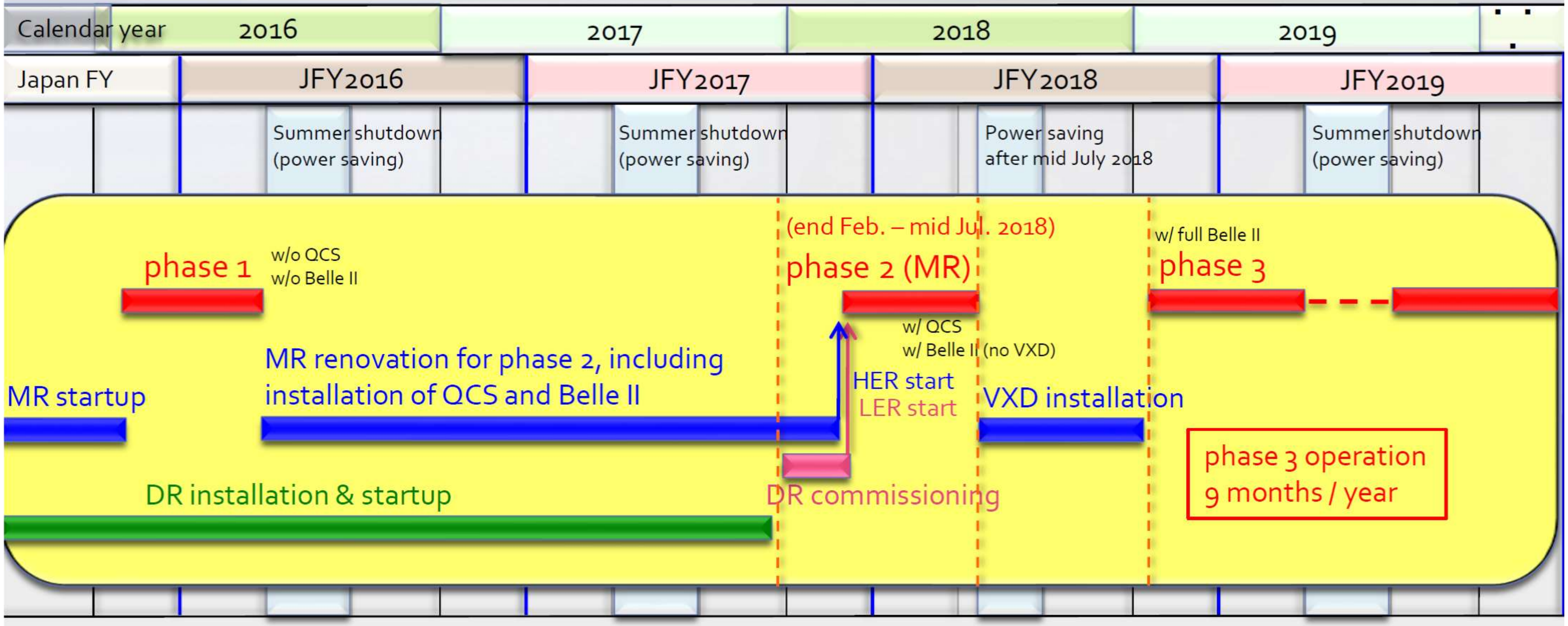
25 countries/regions
108 institutions
~750 researchers

Europe	320
Austria	10
Czechia	7
France	22
Germany	138
Israel	5
Italy	65
Poland	12
Russia	38
Slovenia	14
Spain	5
Ukraine	4

Asia			313
Saudi Arabia	1	Korea	40
Australia	33	Malaysia	5
China	37	Vietnam	2
India	31	Taiwan	27
Japan	133	Thailand	1
		Turkey	3

America	123
Canada	26
Mexico	13
USA	84

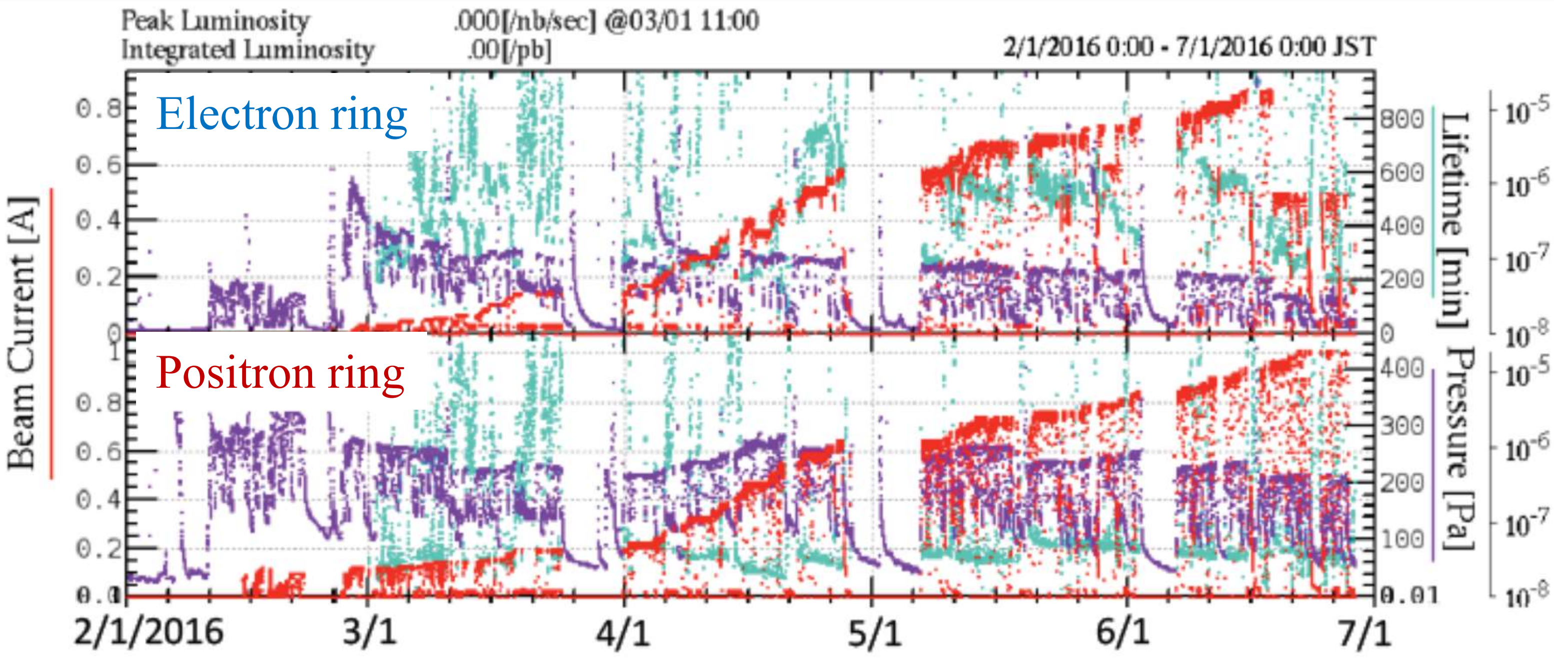
SuperKEKB/Belle II schedule



Phase 1 (w/o final focusing Q, w/o Belle II):
- Accelerator system test and basic tuning,
- **Vacuum scrubbing**,
- **Low emittance tuning**, and
- **Beam background studies**

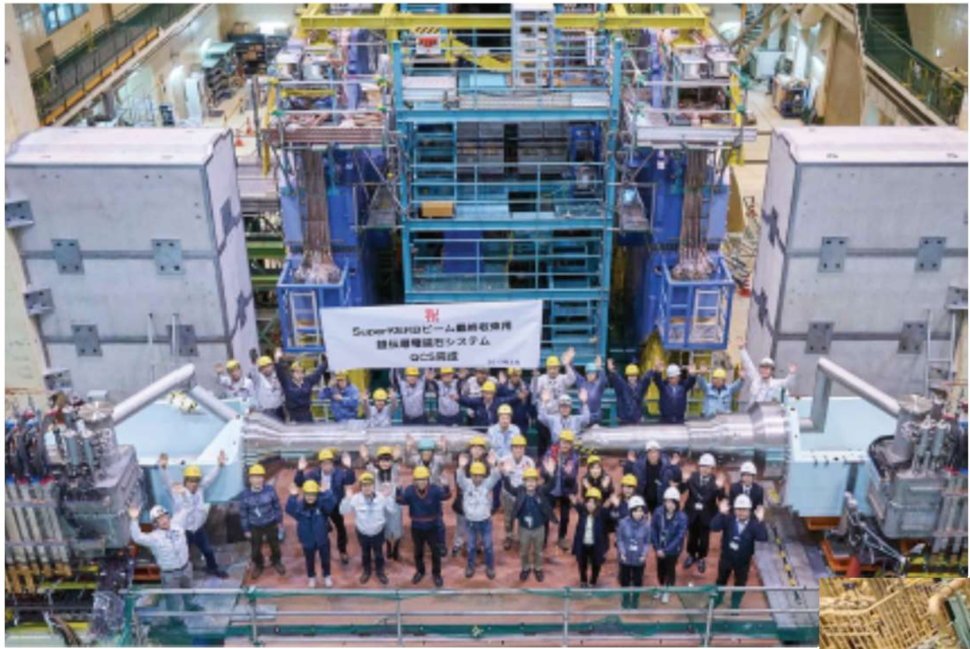
Phase 2 (w/ final focusing Q, w/Belle II but background monitors instead of vertex detectors)
- **Verification of nano-beam scheme**
  target: $L>10^{34}\ cm^{-2}s^{-1}$
- Understand **beam background** especially in vertex detector volume

Phase 1 operation in 2016

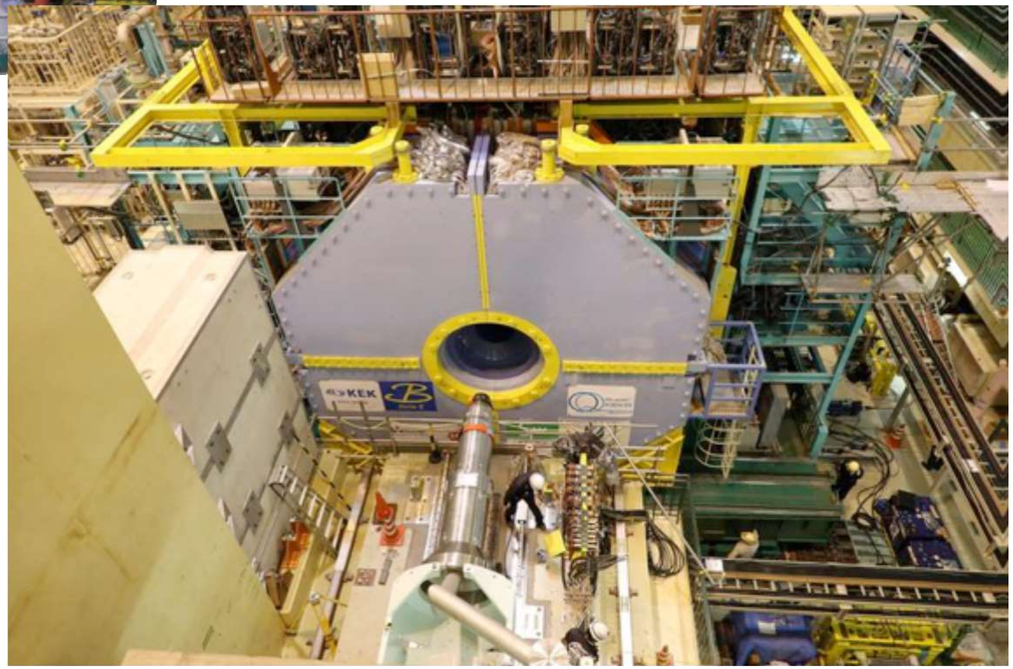


- Without Belle II and the final focusing magnets (QCS)
  - No collisions
  - Several sensors to measure the beam background.
- Hardware check and vacuum scrubbing
  - 0.85A and 1A were successfully stored in the electron and positron rings.

After Phase 1



Roll-in on April 11th , 2017

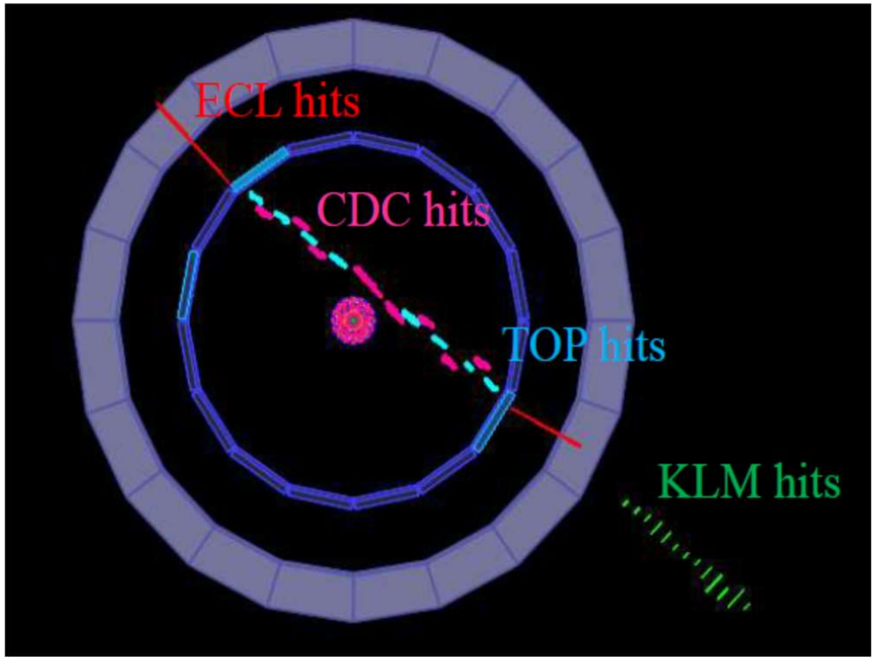


Construction and installation
of the final focusing magnets (QCS)
were done.

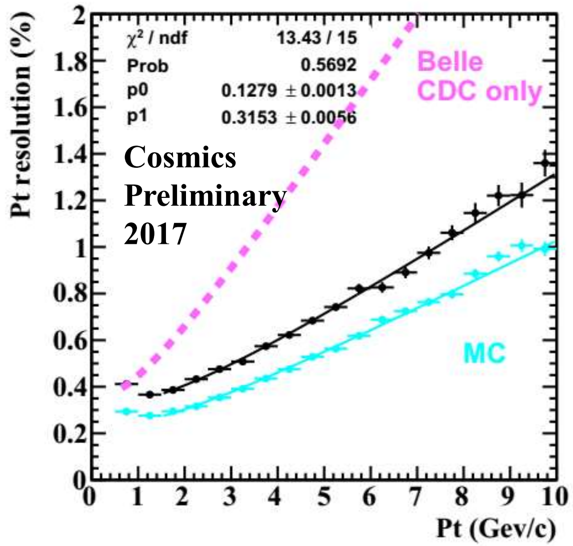
Damping ring construction
and commissioning
were performed, also.

Before Phase 2

Global cosmic ray run under 1.5 T magnetic field



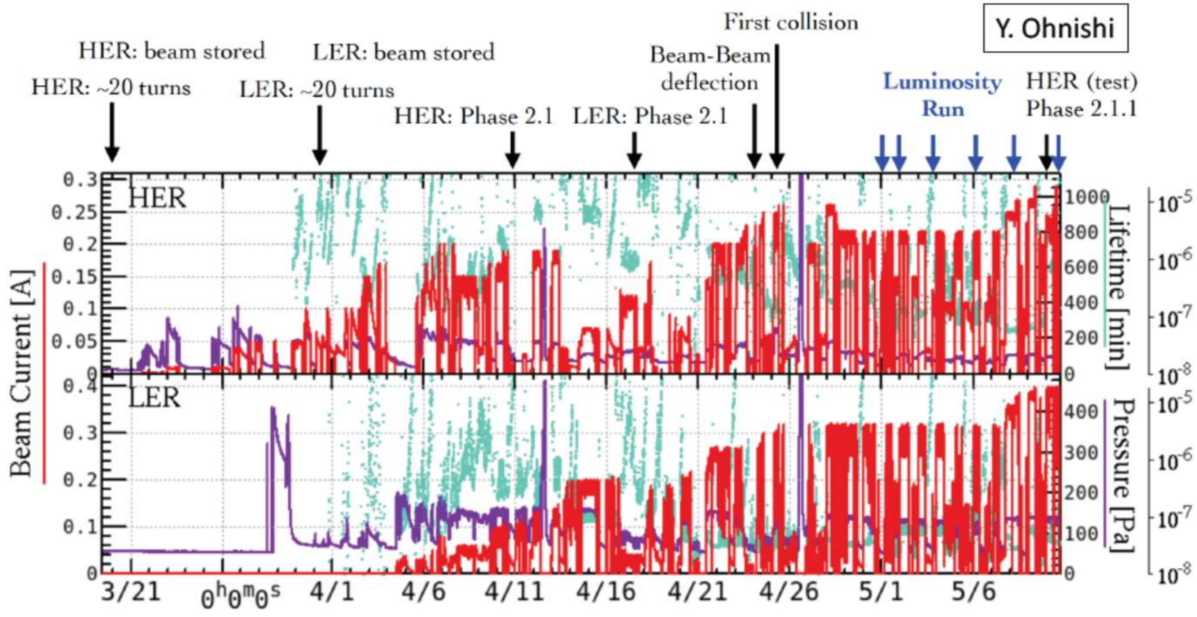
Drift chamber performance



Final construction and installation of ARICH

Partial vertex detector
and beam background monitors
were installed in the CDC.

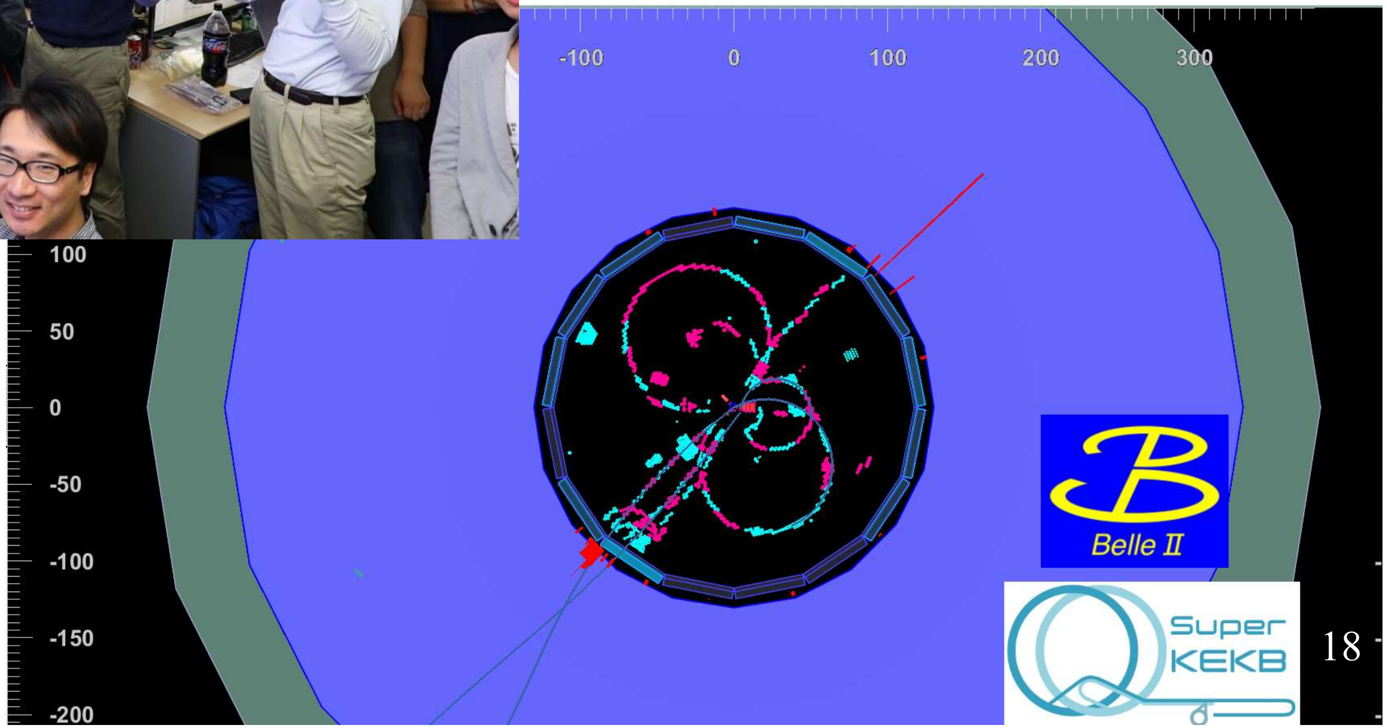
Phase 2 operation from March



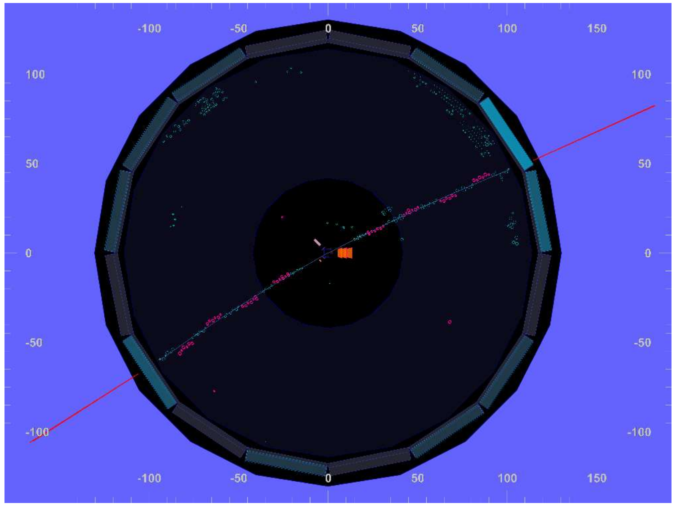
- It started with Belle II just two months ago.
  - The beam currents are increasing gradually.
  - The beams have been squeezed gradually (smaller β*) .
- First collision occurred just one month ago.

Events for first collision on April 26, 2018

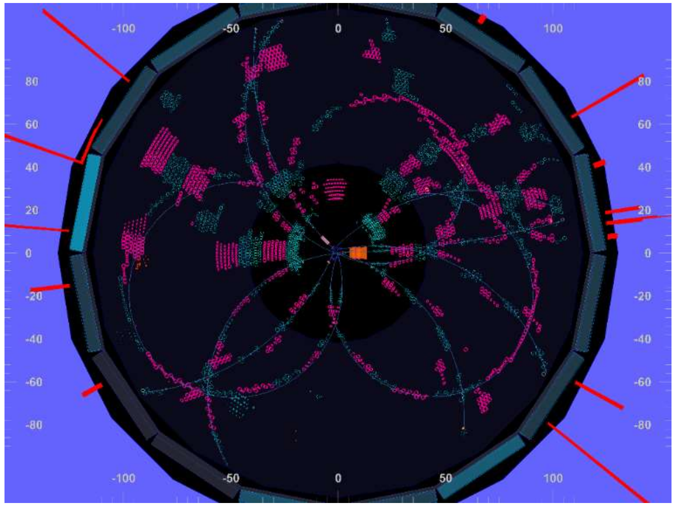
First hadronic event



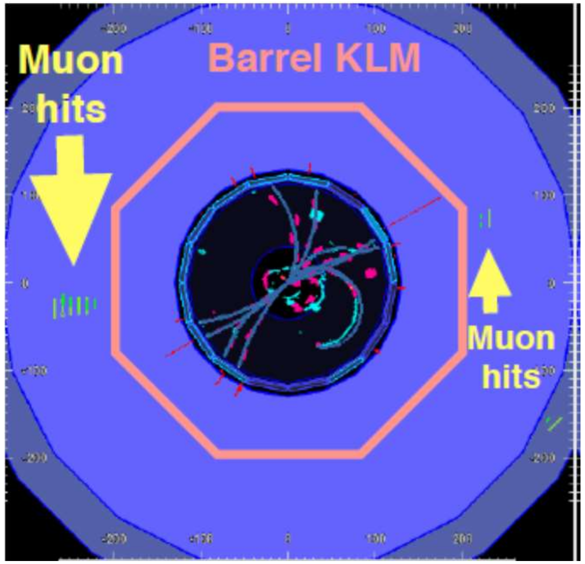
More Events



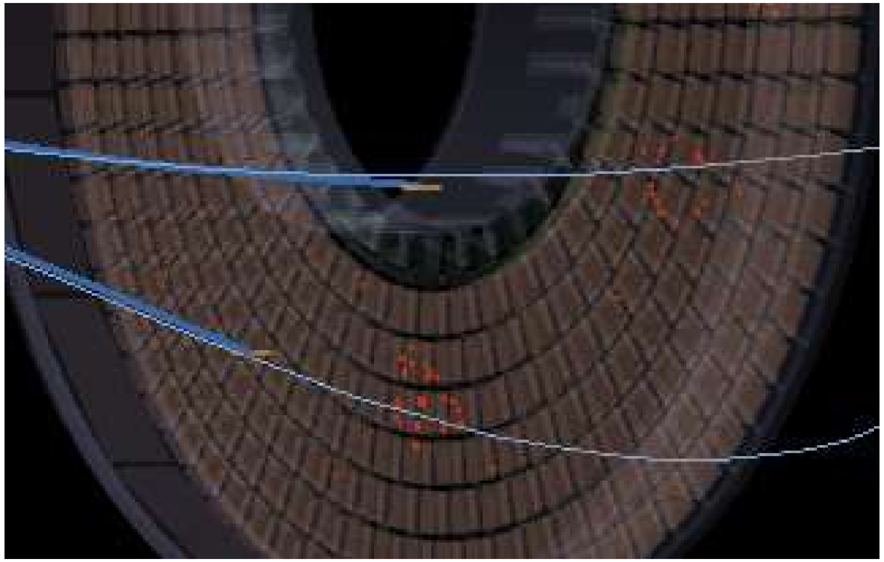
Bhabha event



$B\overline{B}$ like event



KLM is working.

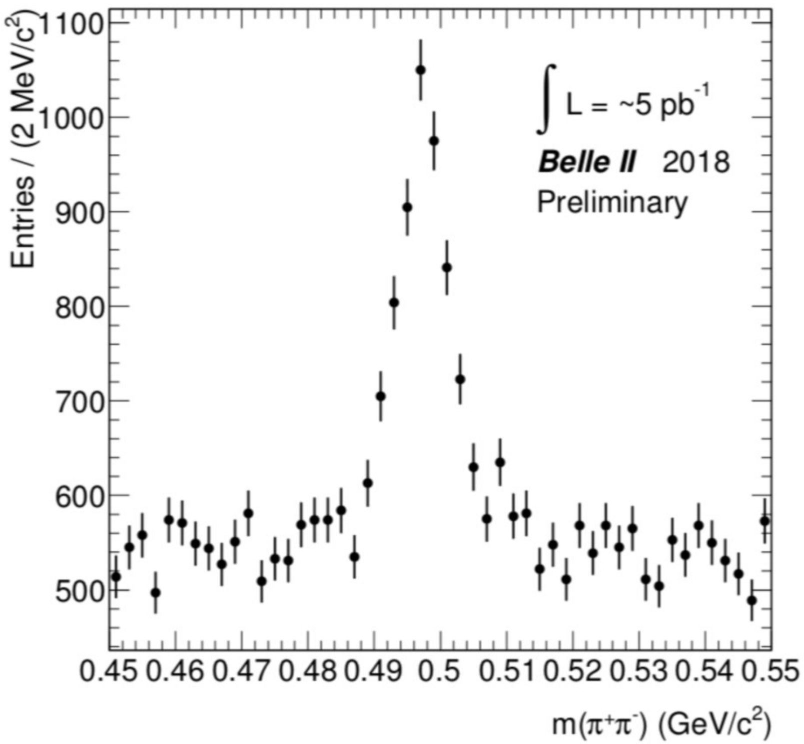


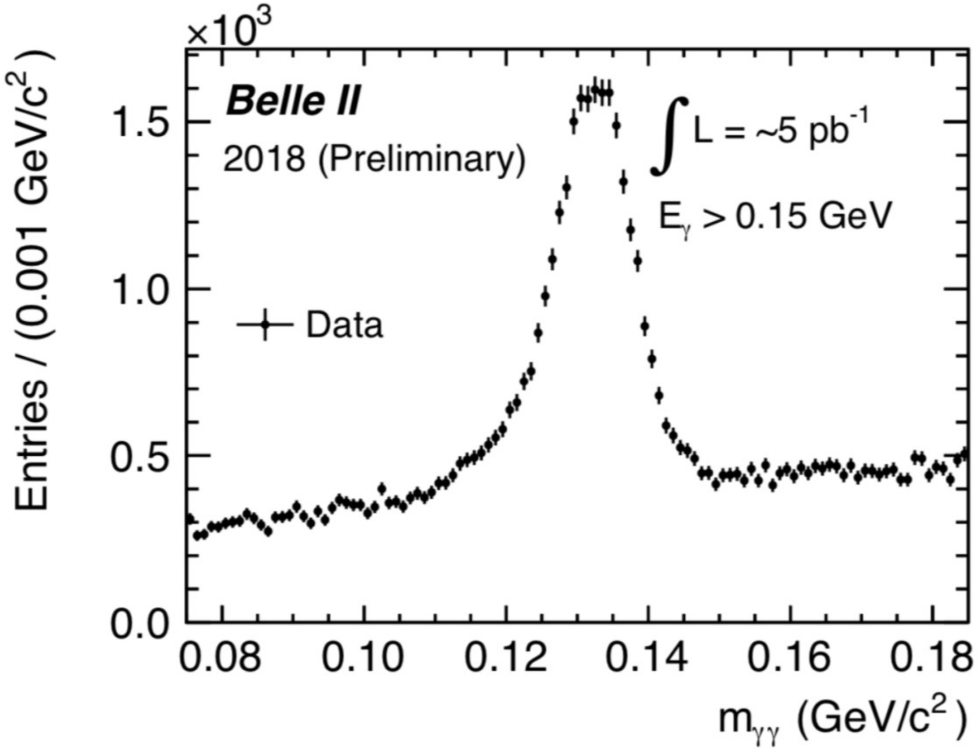
ARICH is working.

Present status

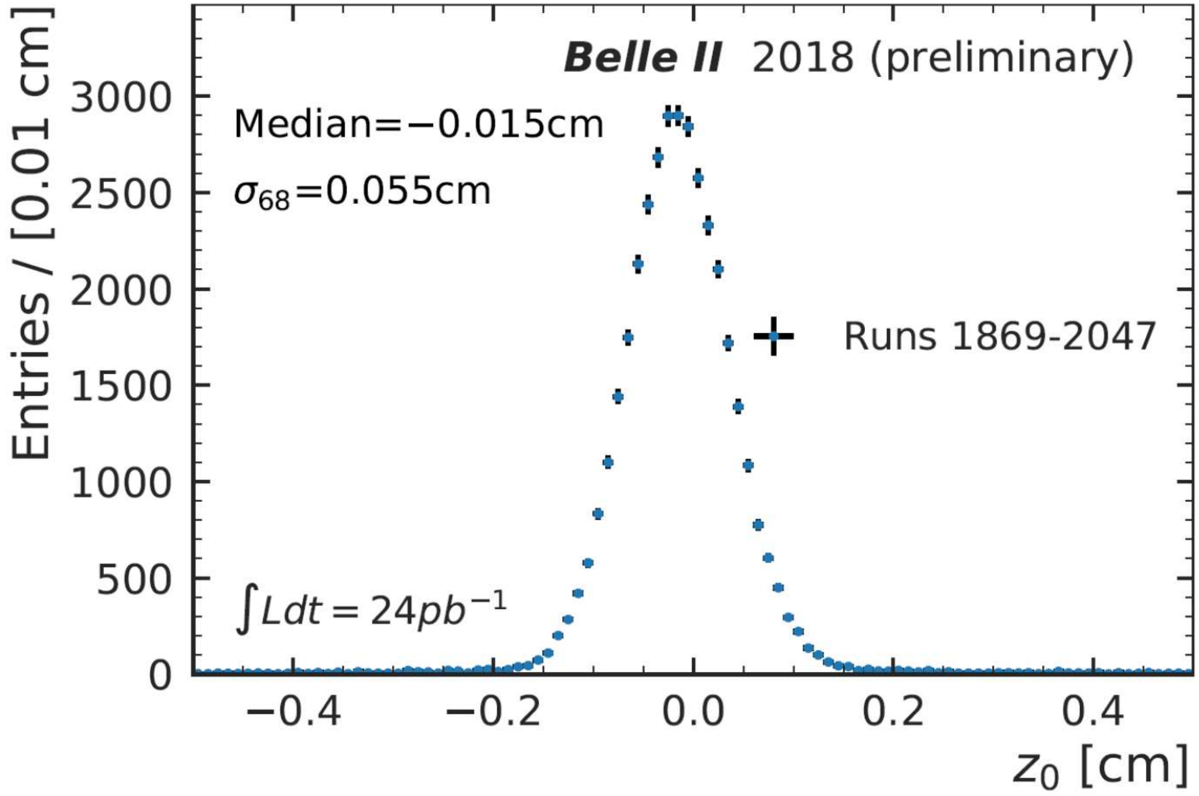
- Belle II is still the debugging and calibration stage.
  - SuperKEKB needs a lot of time for squeezing beams and other machine tuning (reducing the beam background).
- Present luminosity
  - Peak L ~ $1.3 \times 10^{33} cm^{-2} sec^{-1}$
  - Integrated L ~ 100 pb^{-1}
- At least,
  - K_s, K*, Λ, D and D* peaks can be seen for charged tracks.
  - π^0 and η peaks can be seen for gammas.
  - R_2 distribution for hadronic events is reasonably good.
    - The beam energies are consistent with Υ(4S) peak.
  - Longitudinal vertex distribution is smaller.

Mass peaks for charged tracks and gammas





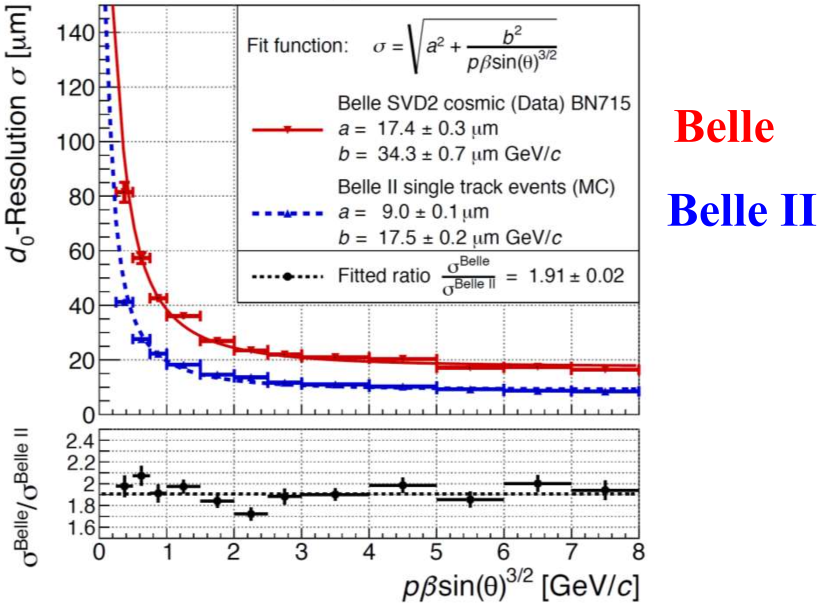
The longitudinal component of the interaction vertex



- The distribution is much smaller than the bunch length.
- **The nano beam scheme is working!!!**

Preparation for Phase 3 operation

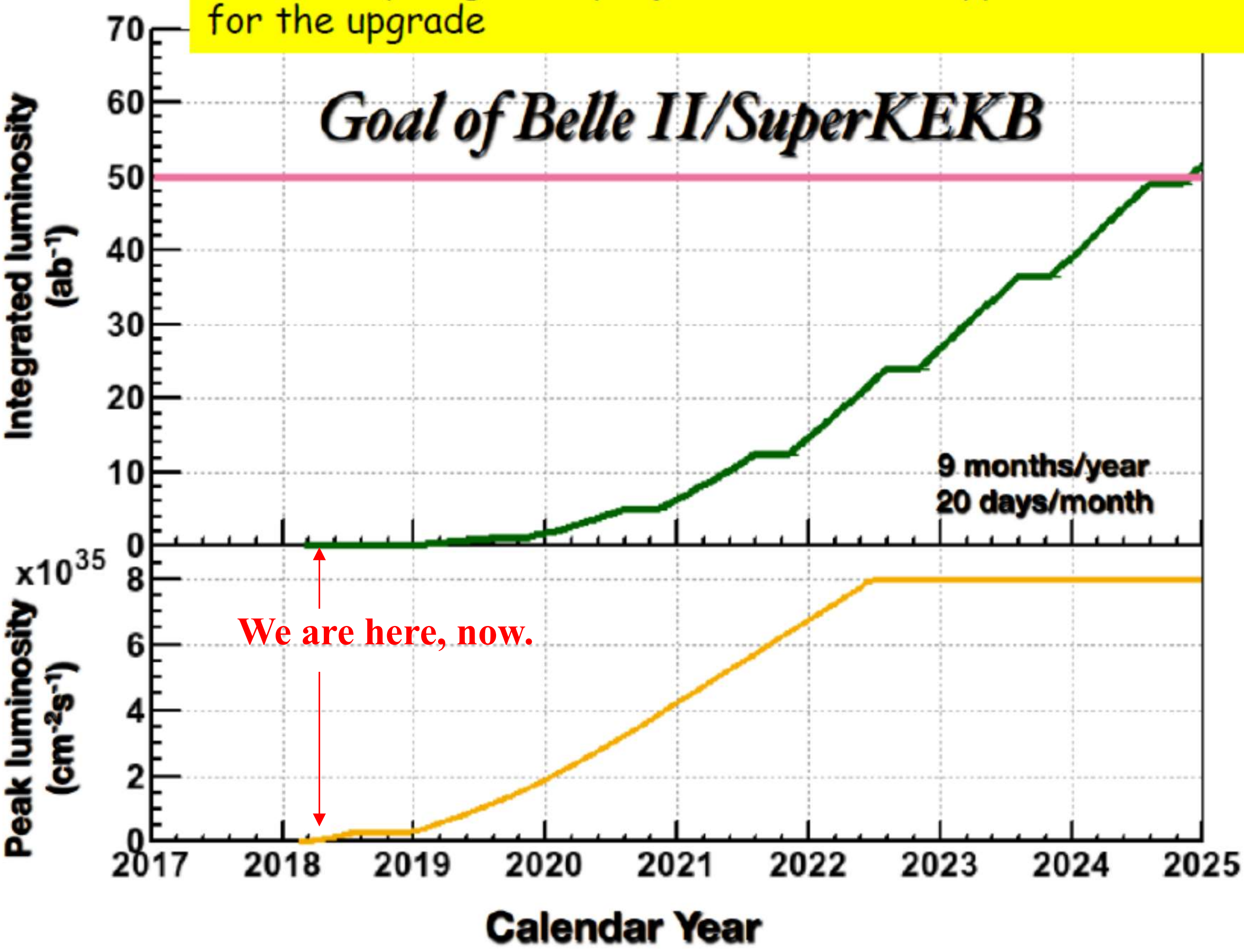
- Phase 2 operation will continue until July 17th.



- After that, full vertex detector will be installed.
  - Now, the construction is full swing.

SuperKEKB luminosity projection

It is a very long term project and various opportunities for the upgrade



Summary

- After several years construction, Belle II successfully observed first collision events from the SuperKEKB machine on April 26th, 2018.
  - But, it is just the starting point of a long experiment.
- The vertex detector will be installed this summer.
  - The phase 3 operation will start in February, 2019.
- Fruitful physics will come soon.
  - Belle II collaboration is still growing.
  - Please join us.

Backup

World highest luminosity

40 times higher than present record

L= $8 \times 10^{35}/cm^2/sec$