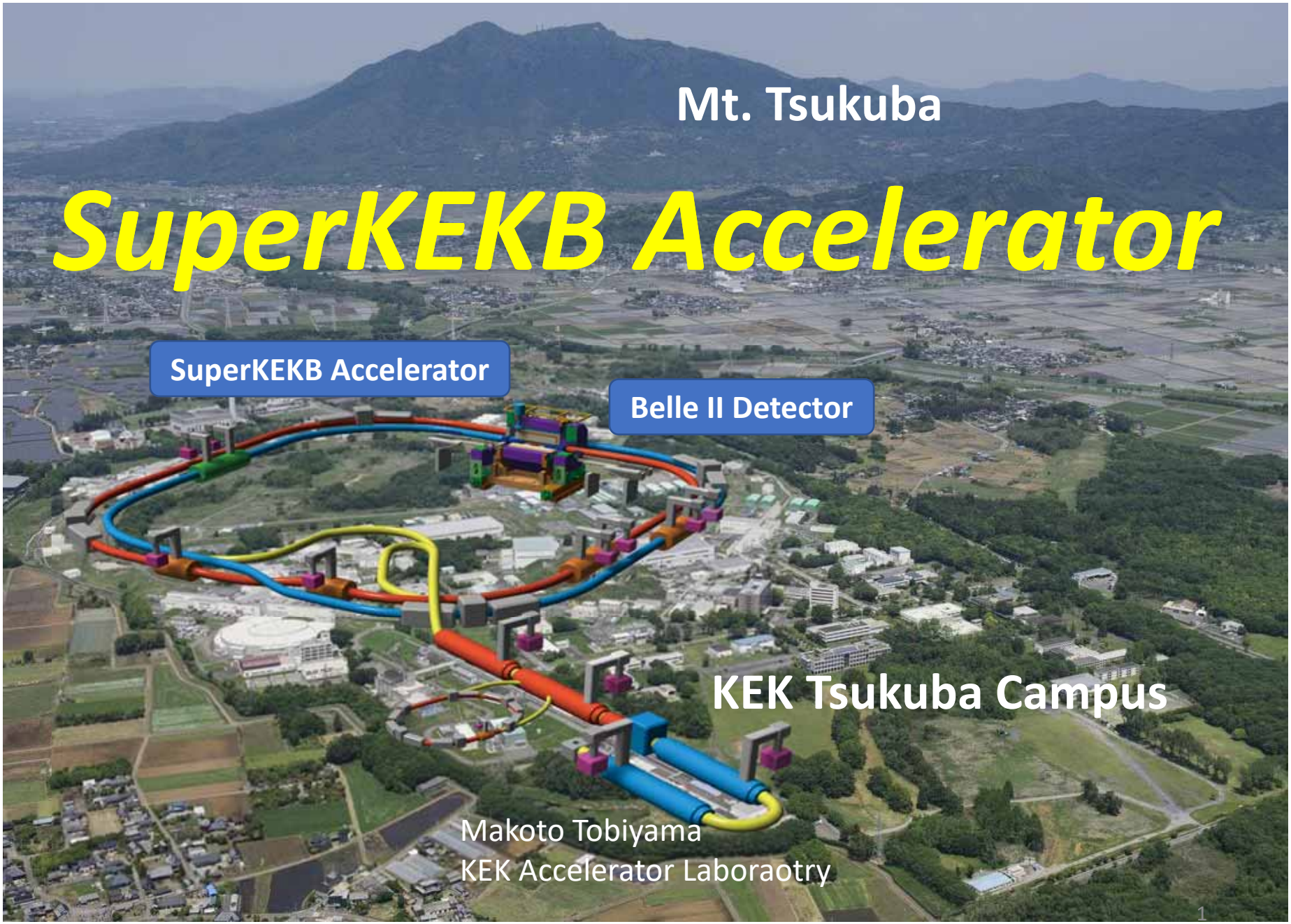
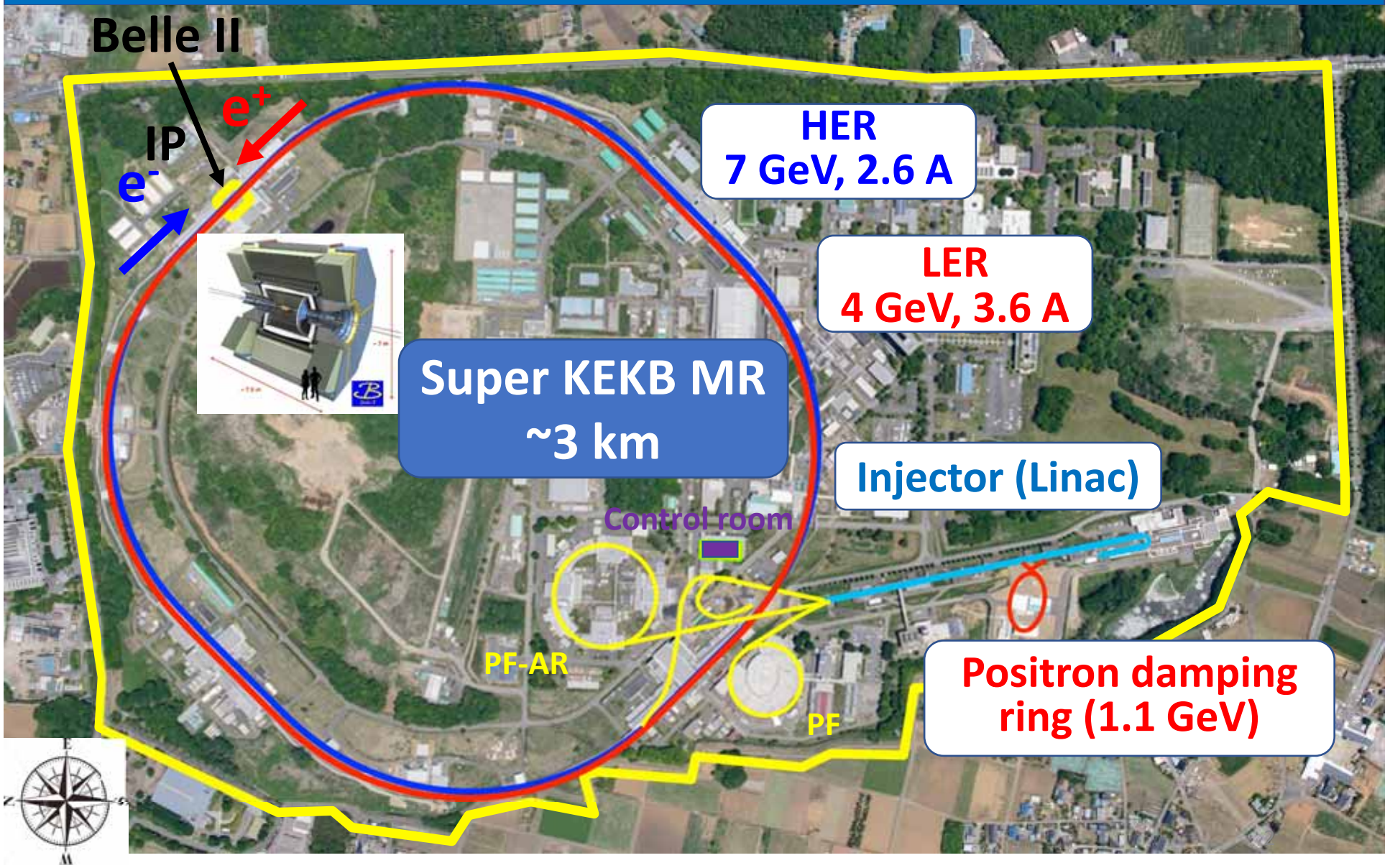

Mt. Tsukuba
SuperKEKB Accelerator
SuperKEKB Accelerator
Belle II Detector
KEK Tsukuba Campus
Makoto Tobiyama
KEK Accelerator Laboraotry

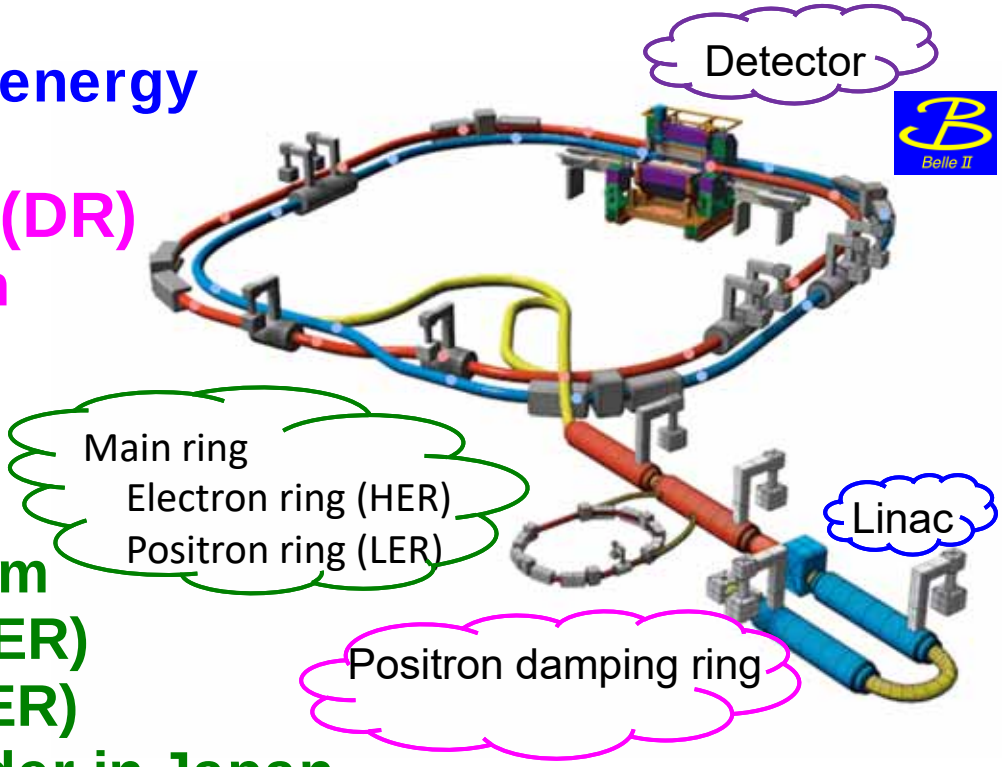
Layout


Belle II
IP
e+
e-
HER
7 GeV, 2.6 A
LER
4 GeV, 3.6 A
Super KEKB MR
~3 km
Injector (Linac)
Control room
PF-AR
PF
Positron damping
ring (1.1 GeV)

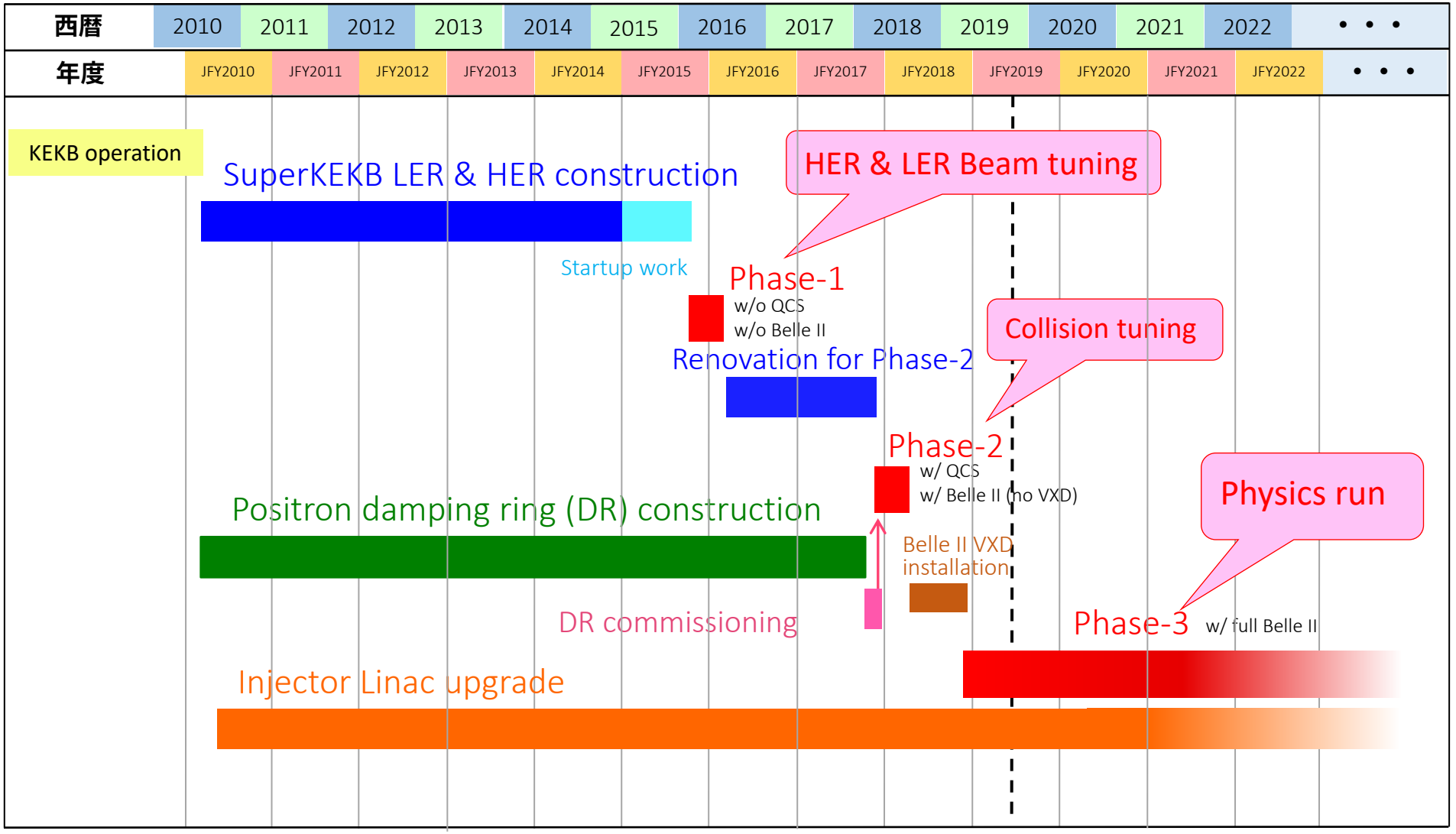
Configuration

- **Injector (Linac)**
  - **Length∼700 m**
  - **Generate e^- and e^+**
  - **Accelerate to the final energy**
- **Positron damping ring (DR)**
  - **Circumference ∼136m**
  - **1.1 GeV positron**
- **Main ring (MR)**
  - **Circumference∼3016 m**
  - **7 GeV electron ring (HER)**
  - **4 GeV positron ring (LER)**
  - **The largest e^- - e^+ collider in Japan**

- **Belle II Particle detector**



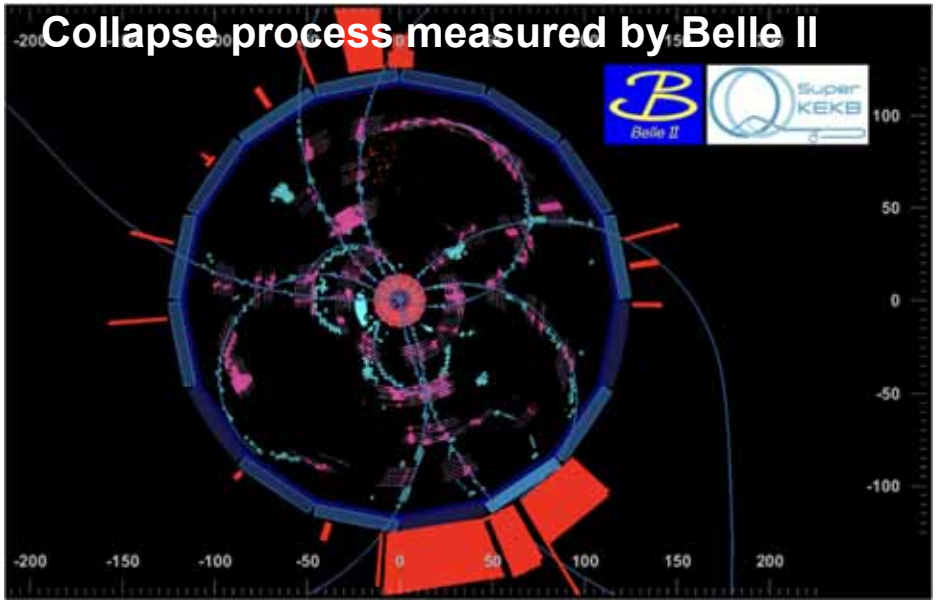
Timeline

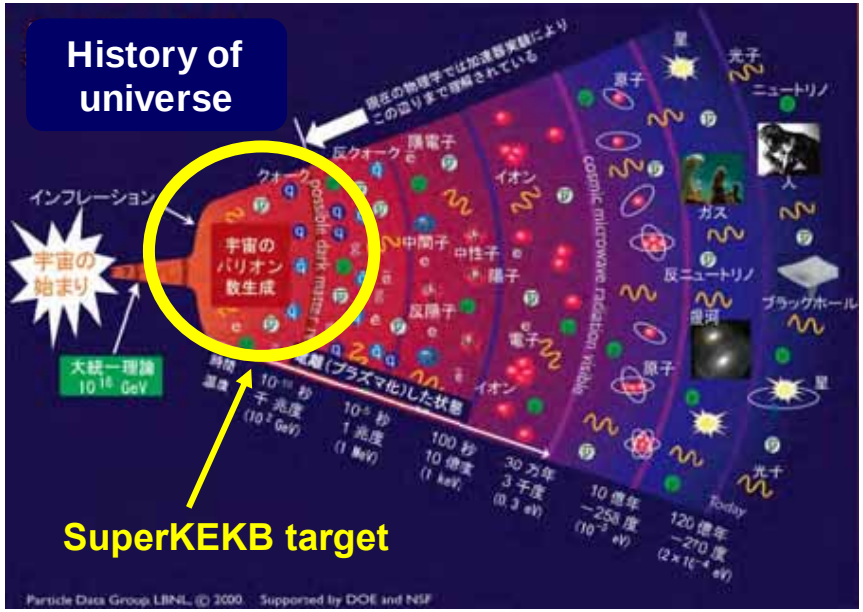


Based on K. Akai, Mar. 14, 2018 @KEKB review

Goal

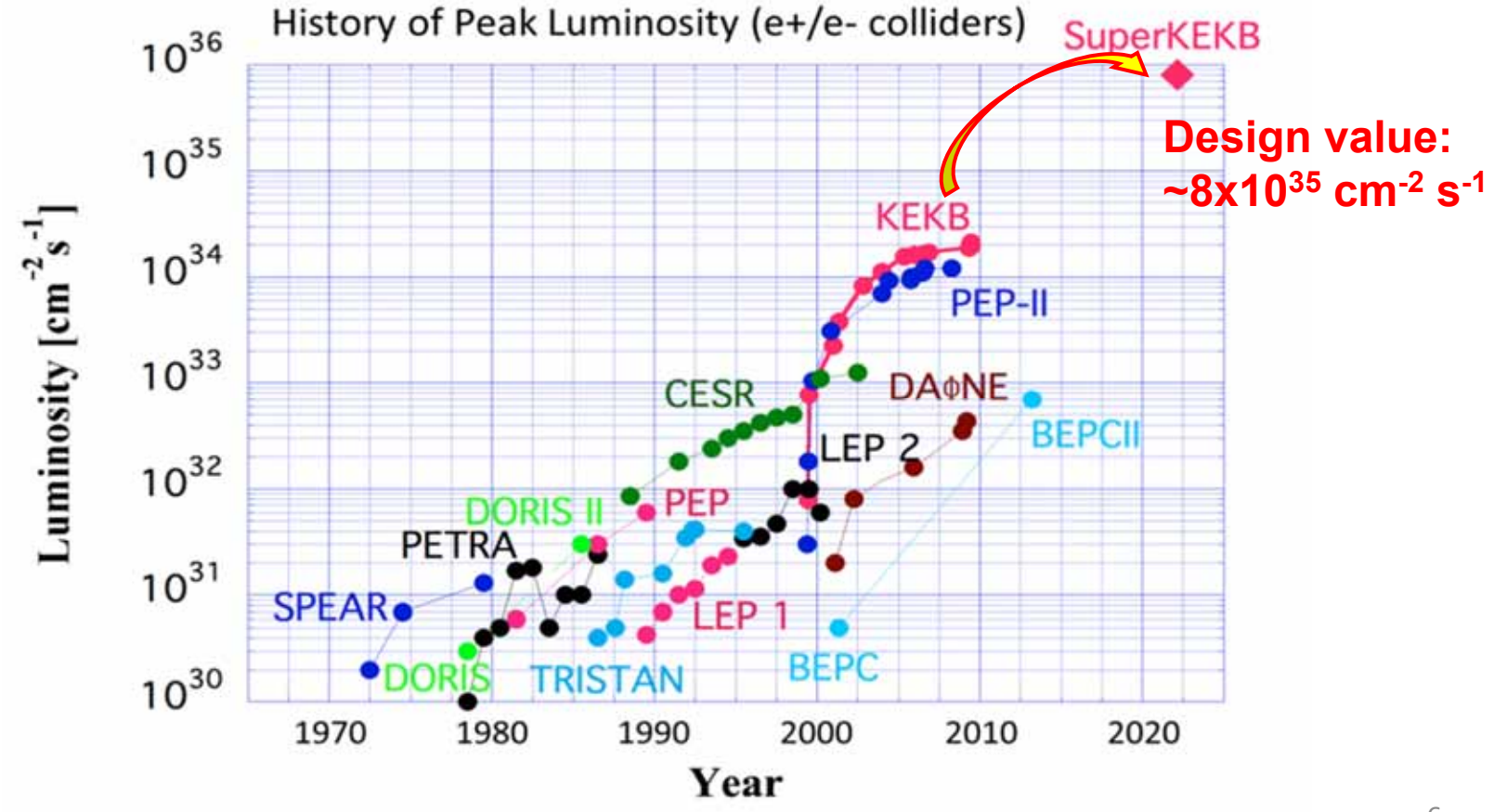
To find a new elementary-physics theory beyond the standard model by investigating the collapse process of B-mesons in detail produced by the collision of e+ and e-.





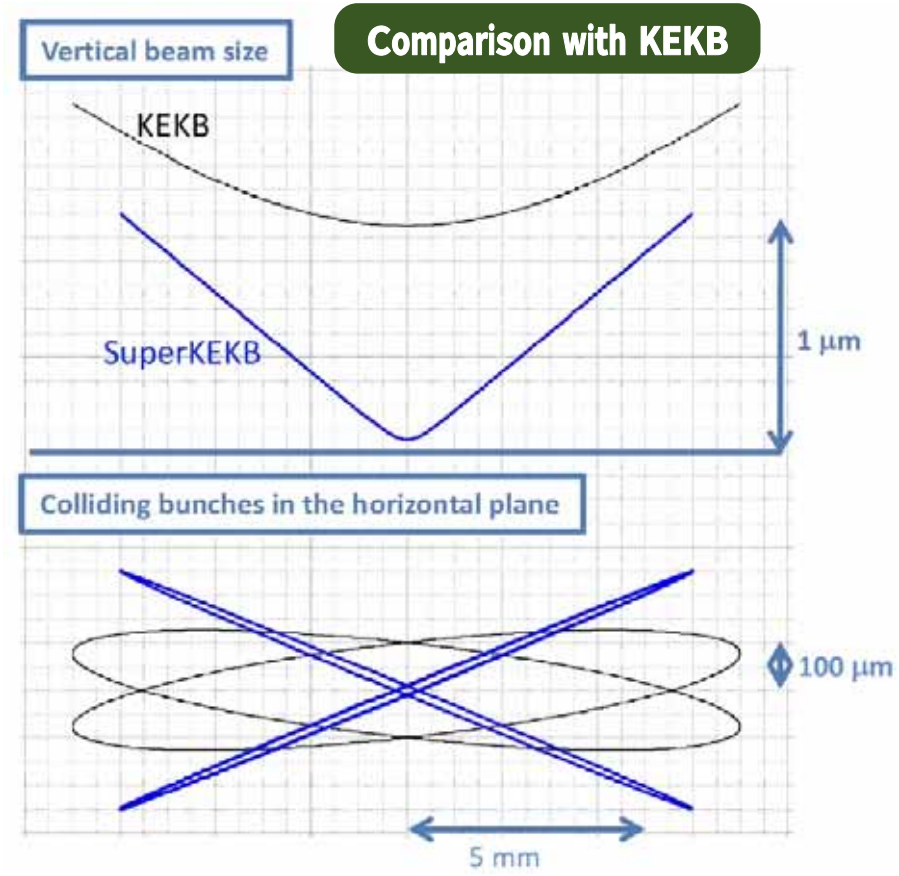
Feature

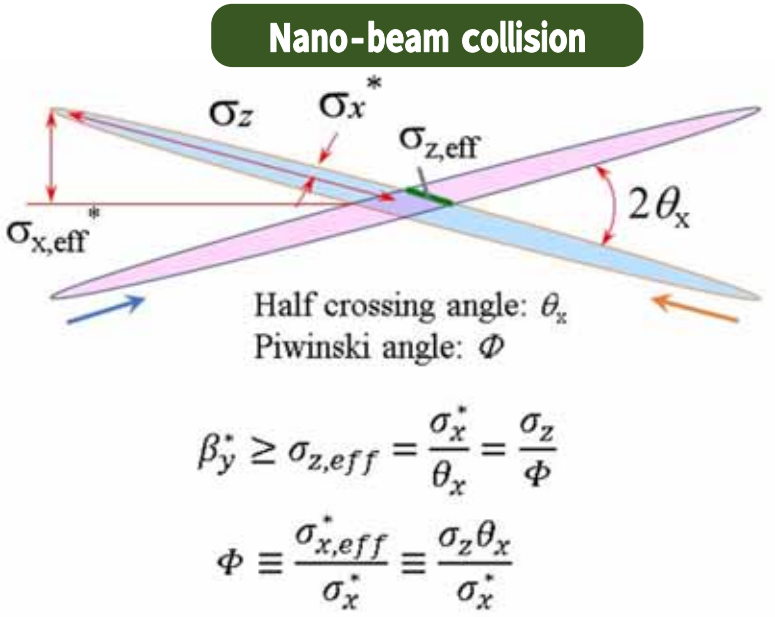
Aim the world-highest luminosity (a measure of collision frequency) by using a novel "nano-beam scheme" collision.



Nano-beam scheme

Squeeze beams down to ~50 nm height and ~10 μm width at the collision point with a large crossing angle to avoid the hour-glass effect.





$$\beta_y^* \geq \sigma_{z,eff} = \frac{\sigma_x^*}{\theta_x} = \frac{\sigma_z}{\Phi}$$

$$\Phi \equiv \frac{\sigma_{x,eff}^*}{\sigma_x^*} \equiv \frac{\sigma_z \theta_x}{\sigma_x^*}$$

β_x^* and β_y^* are squeezed to ~30 mm and ~0.3 mm, respectively, in the design.

Many challenges

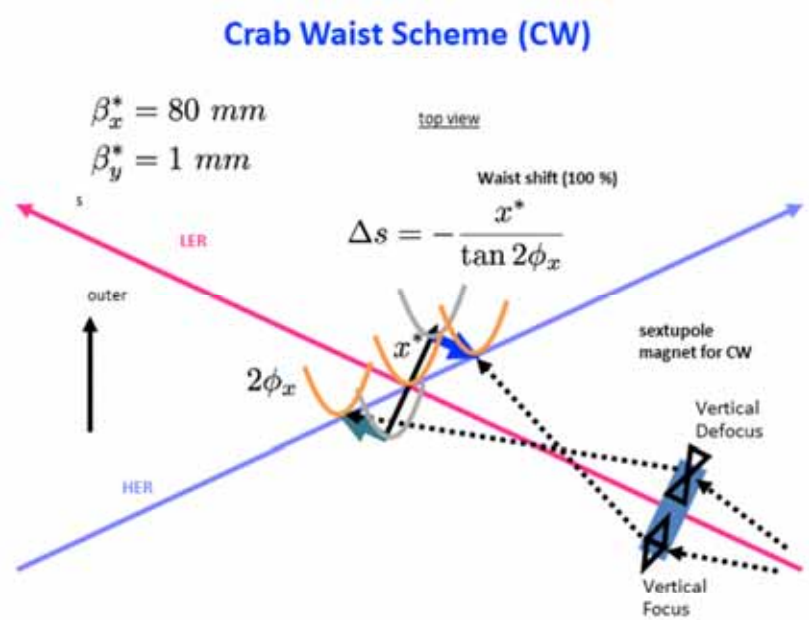
Low emittance, small beam size at IP

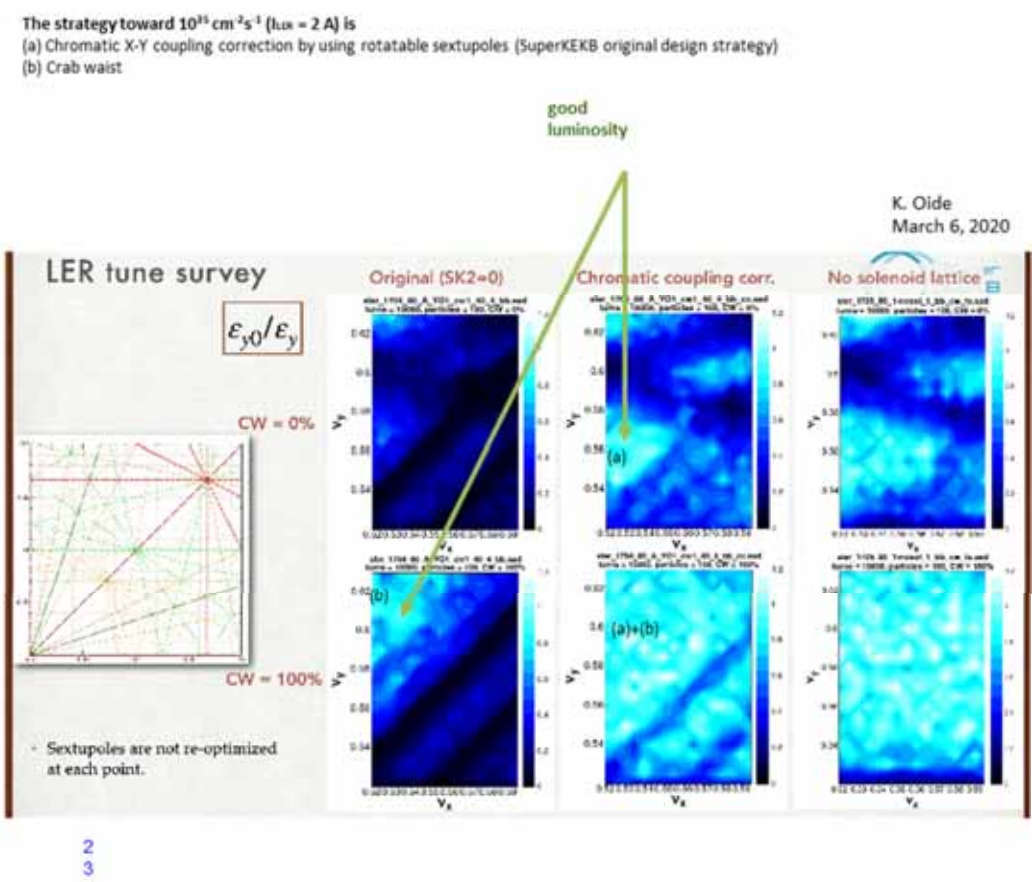
- Realize the low emittance optics using existing lattice as much as possible (to reduce construction costs)
- Sevier non-linear effect, small dynamic aperture
- Strong, ultra-fine tunable superconducting final focus
- Strong, stable and high-quality injector
  - Positron damping ring, Photo cathode RF gun
- Wideband, fast IP feedback system
- Beam instrumentations

High beam current

- **Strong injector**
- **Low impedance vacuum components**
- **Strong RF systems**
- **Bunch feedback systems to suppress coupled-bunch instabilities**

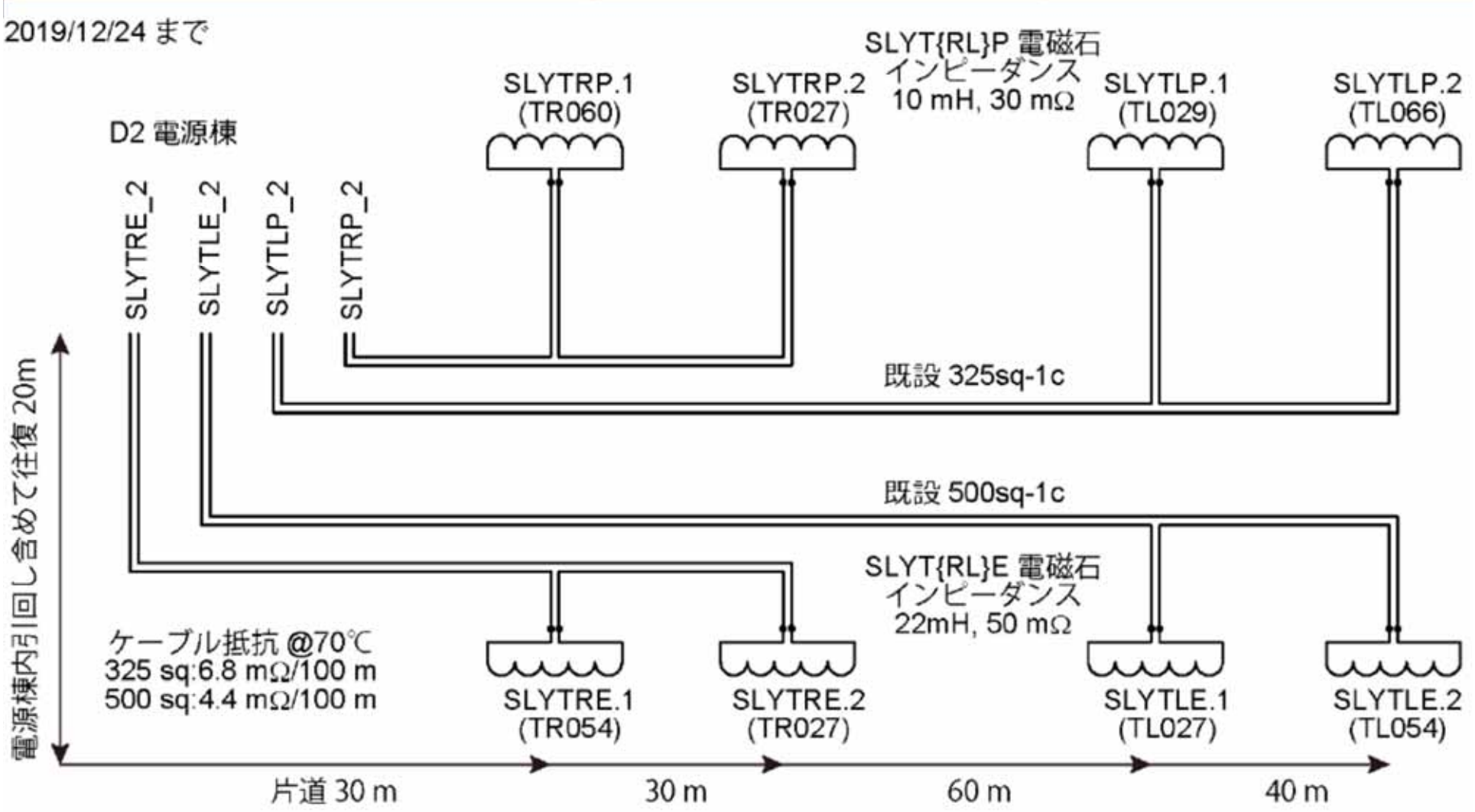
Crab waist mode



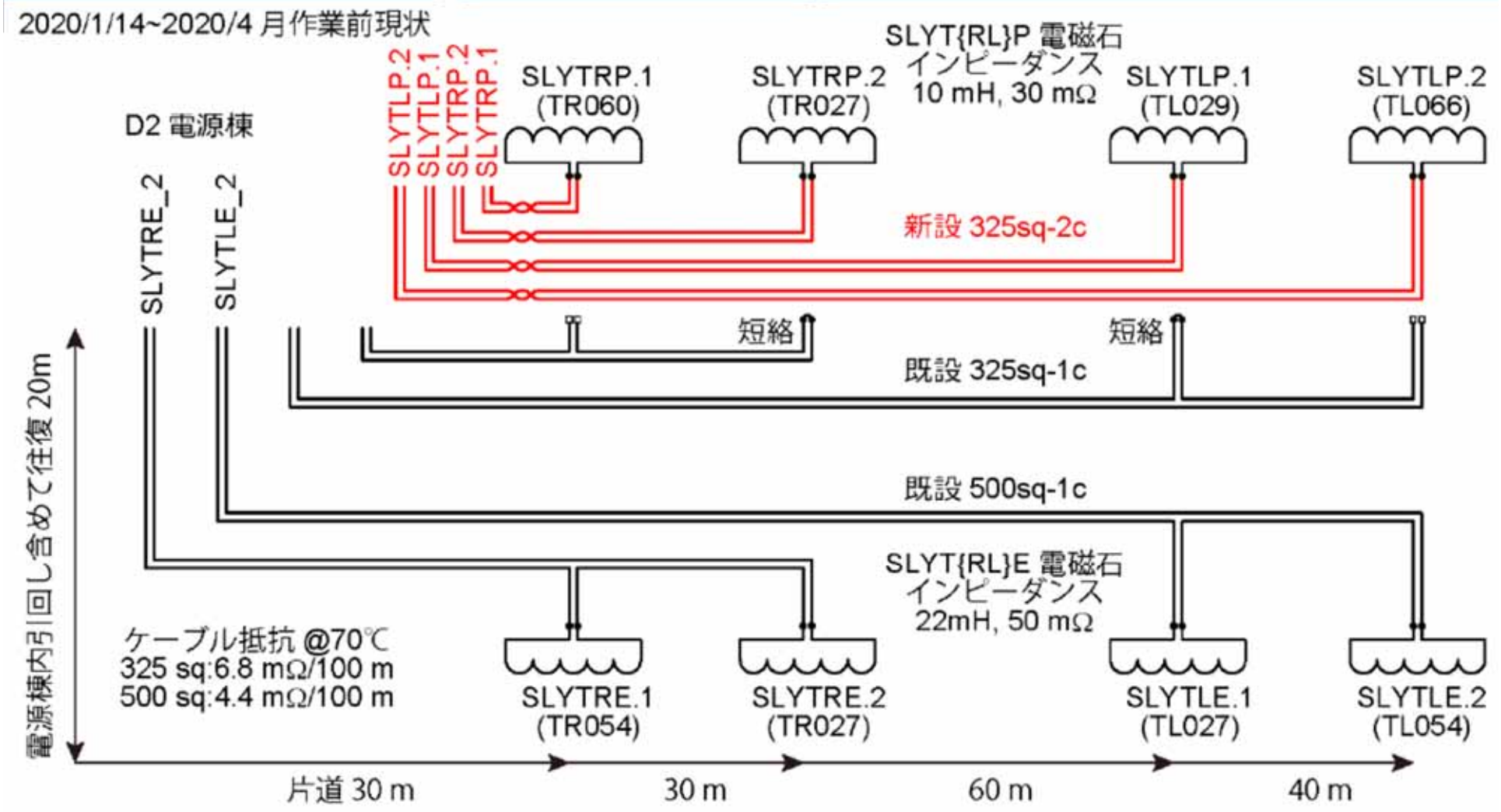


2
3

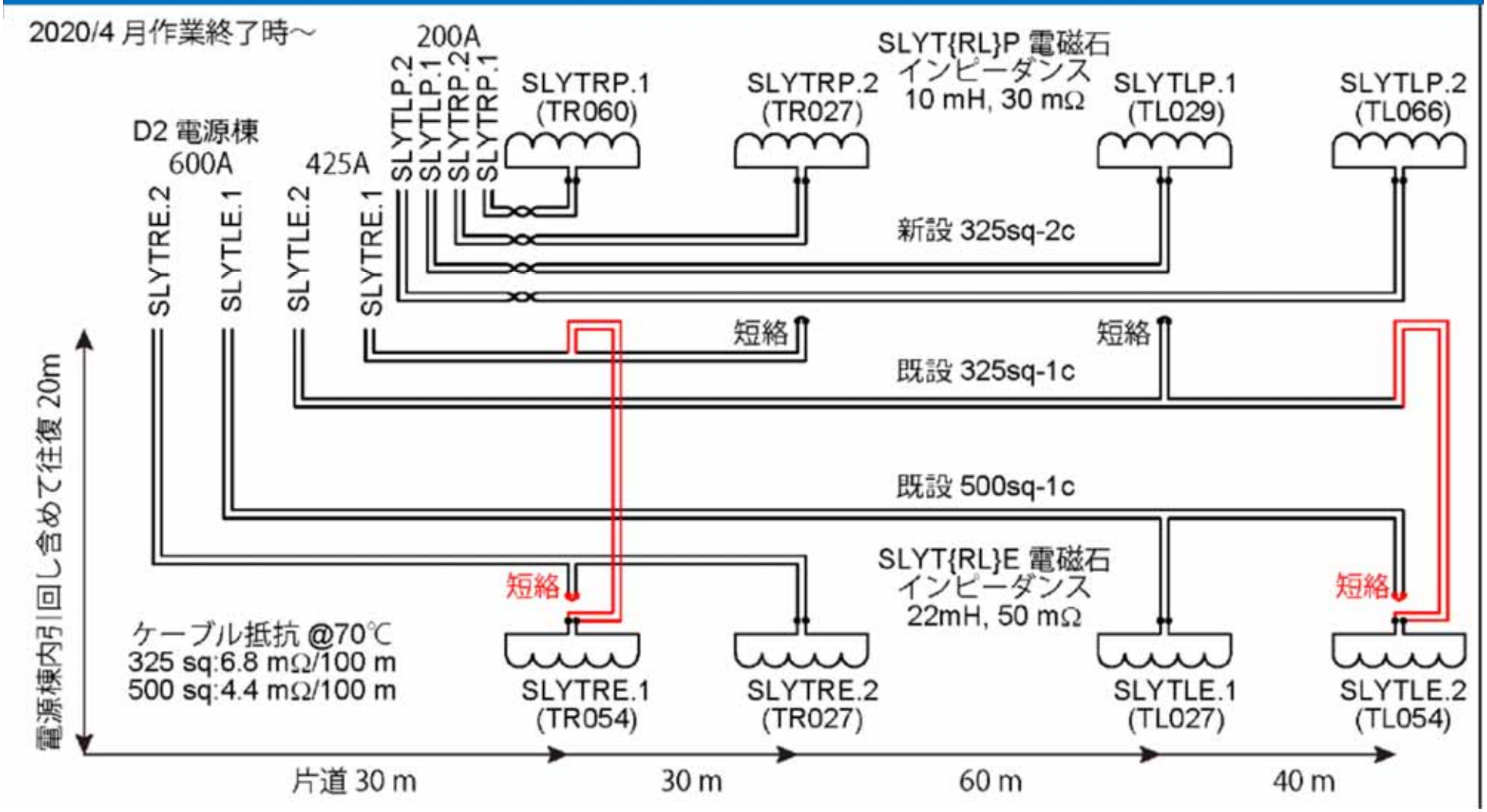
Cabling of Sextupoles for LCC



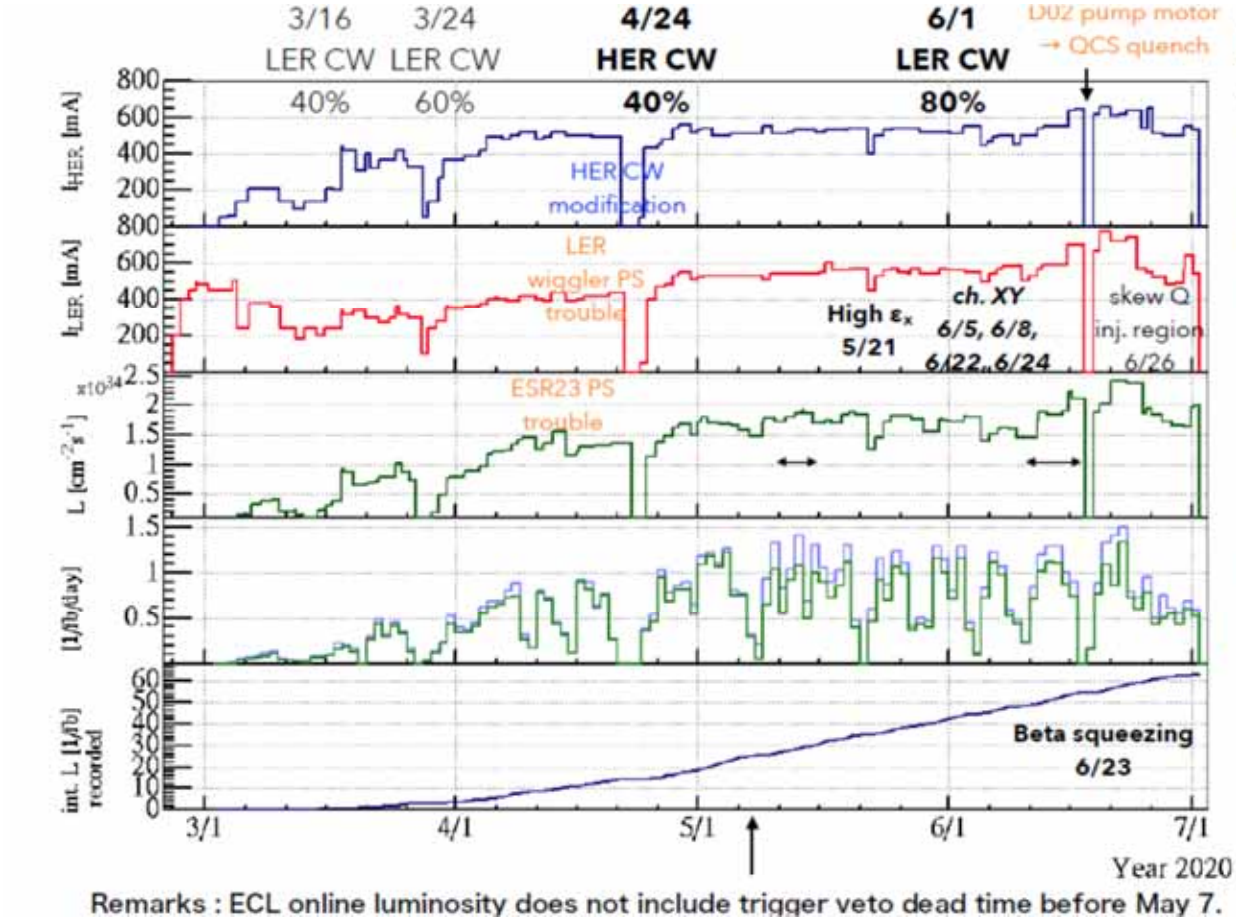
Cabling of Sextupoles for LCC



Cabling of Sextupoles for LCC



2020a,b operation



LER started on Feb. 25

HER started on March. 2

Max. current
LER : 770 mA
HER : 660 mA

Peak luminosity : 2.4 x 10^{34} $cm^{-2}s^{-1}$

Int. luminosity/day : 1.346 / 1.498 fb^{-1}

5/11-5/14 off-resonance

6/10-6/17 off-resonance

LER :

$\beta_x^*/\beta_y^* = 80\ mm/1\ mm$

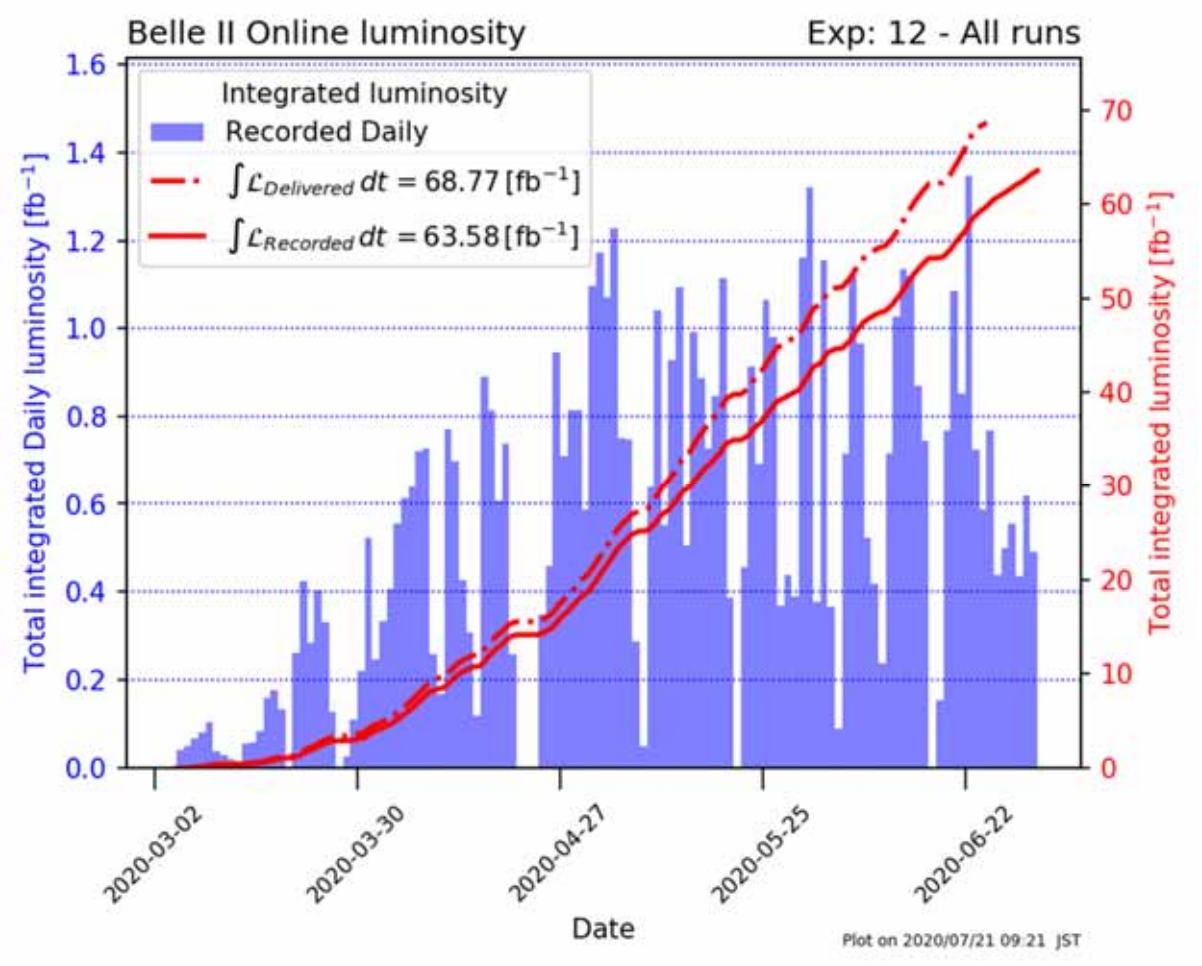
$\rightarrow \beta_x^*/\beta_y^* = 60\ mm/0.8\ mm$

HER :

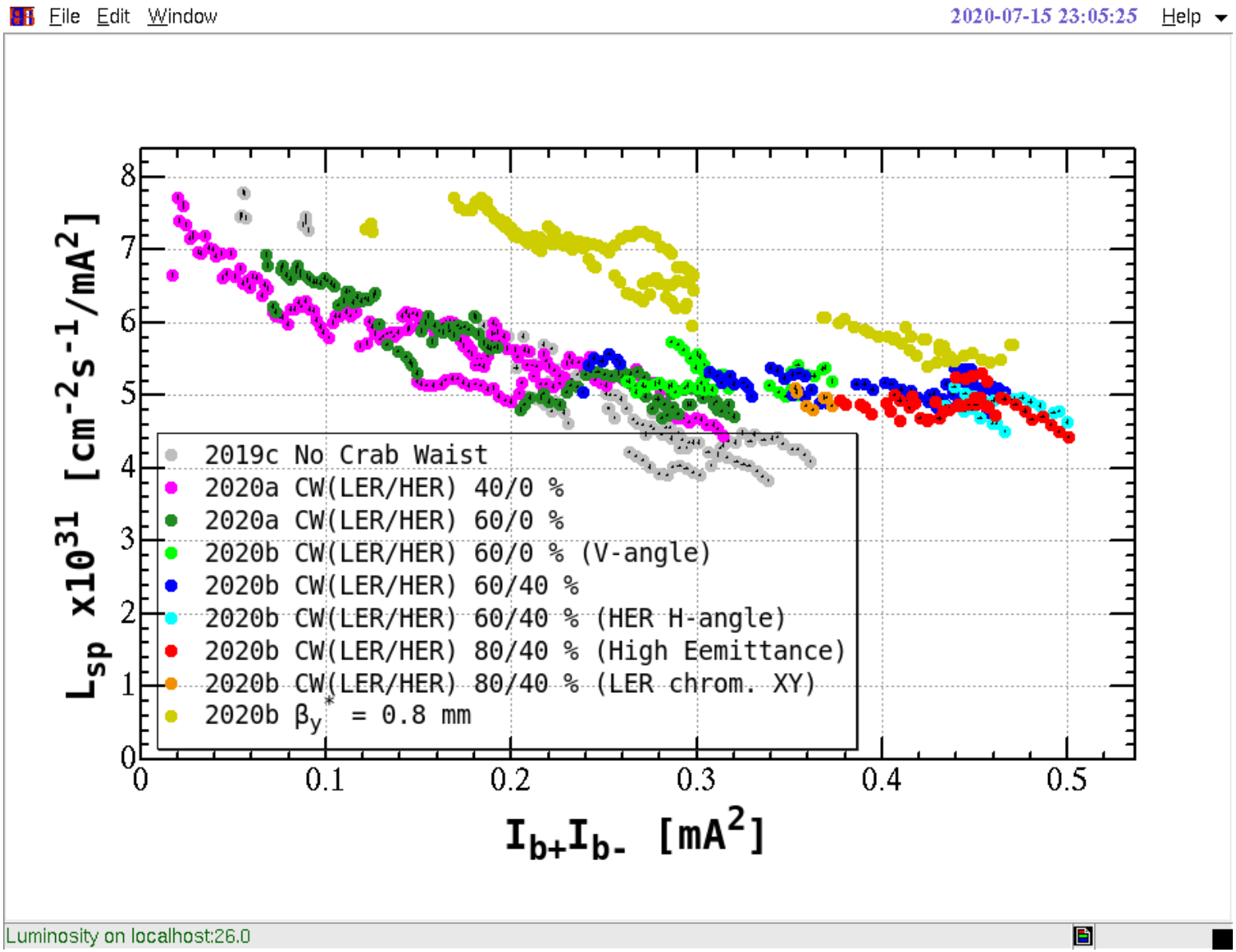
$\beta_x^*/\beta_y^* = 60\ mm/1\ mm$

$\rightarrow \beta_x^*/\beta_y^* = 60\ mm/0.8\ mm$

Integrated luminosity

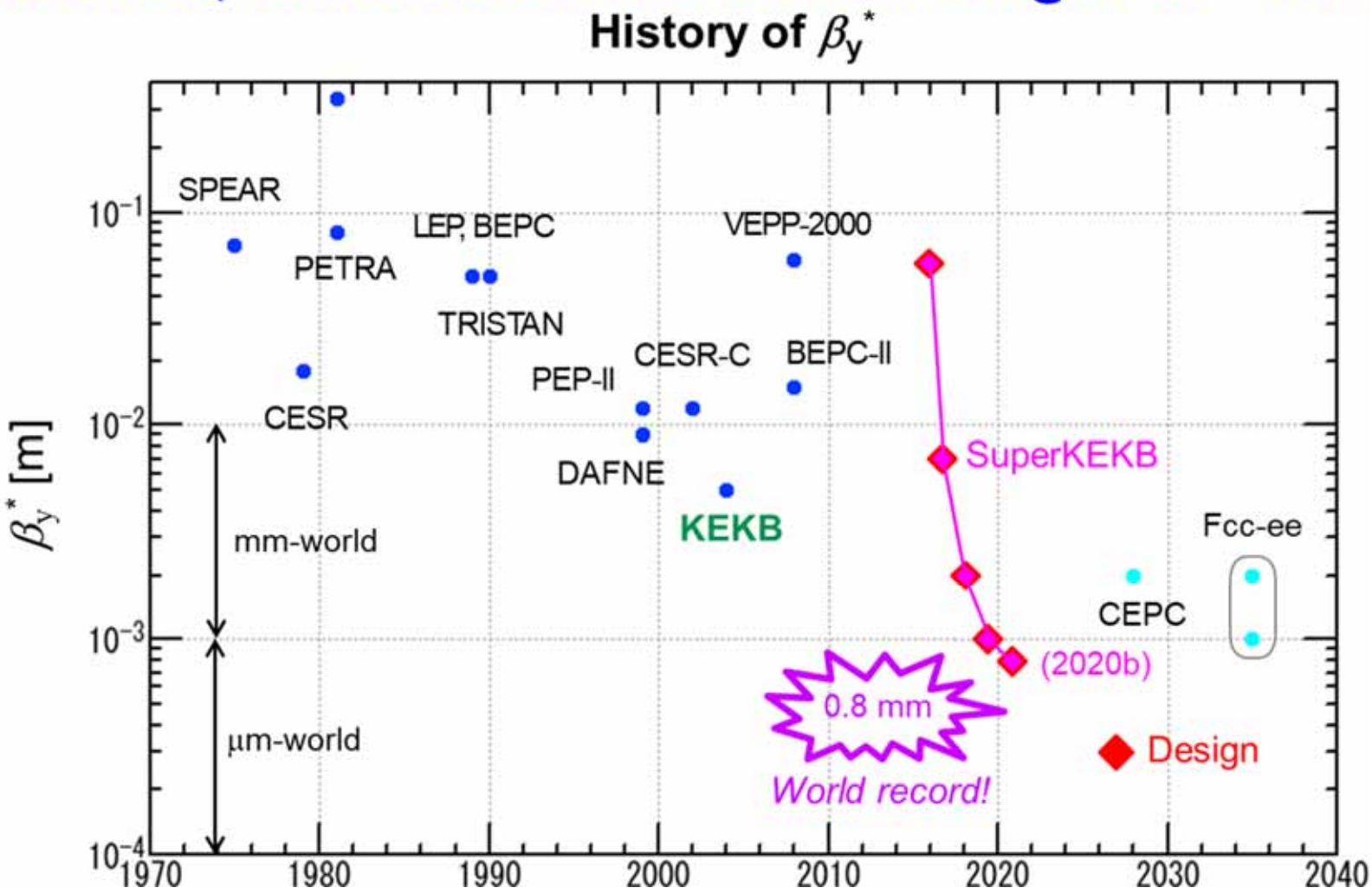


Specific Luminosity



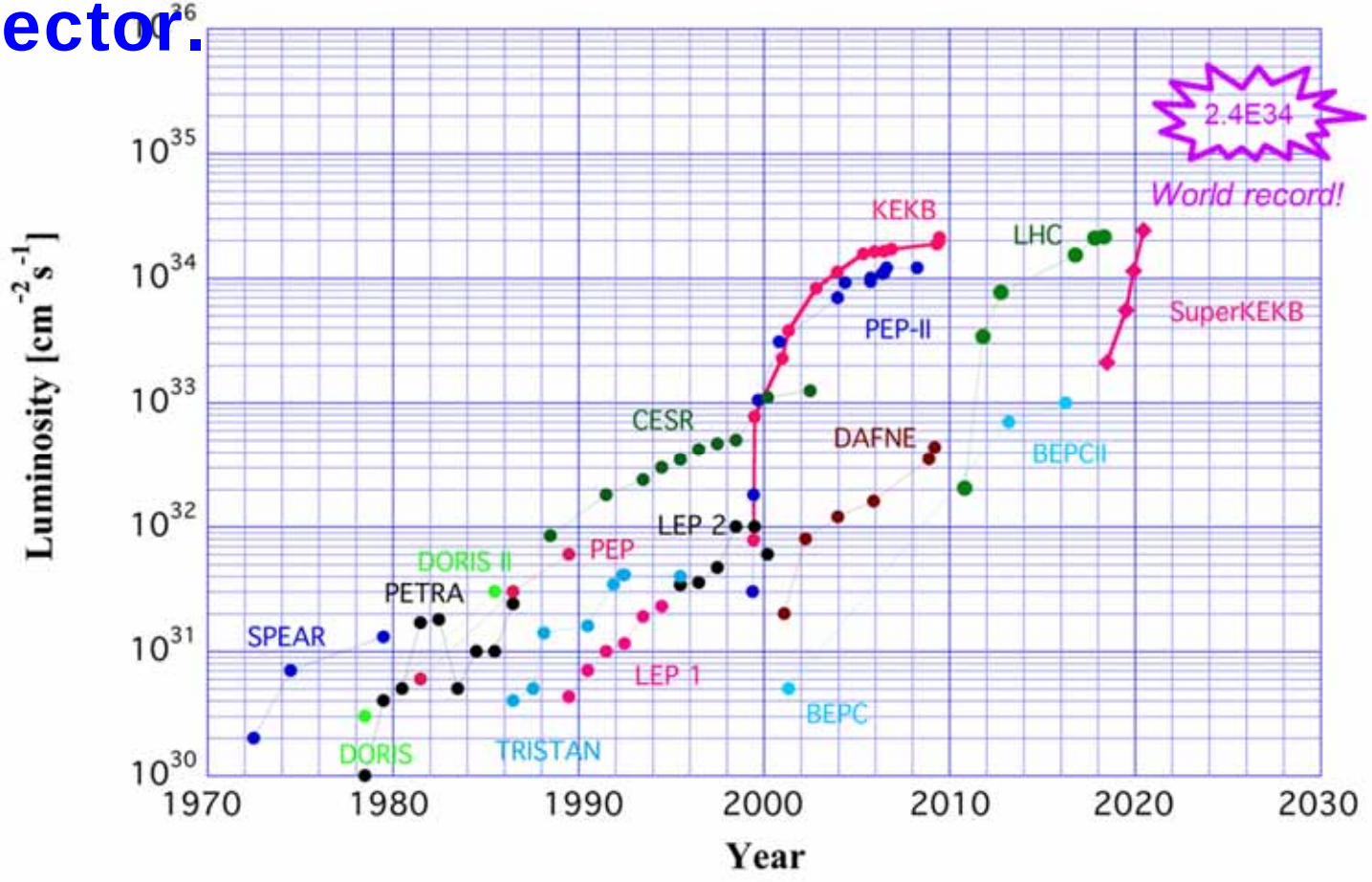
Present status

Now operating with the world's smallest β_y^* of 0.8 mm, lower than the bunch length of ~6 mm.



Present status

We are now struggling every day to increase luminosity and deliver more data to Belle II detector.

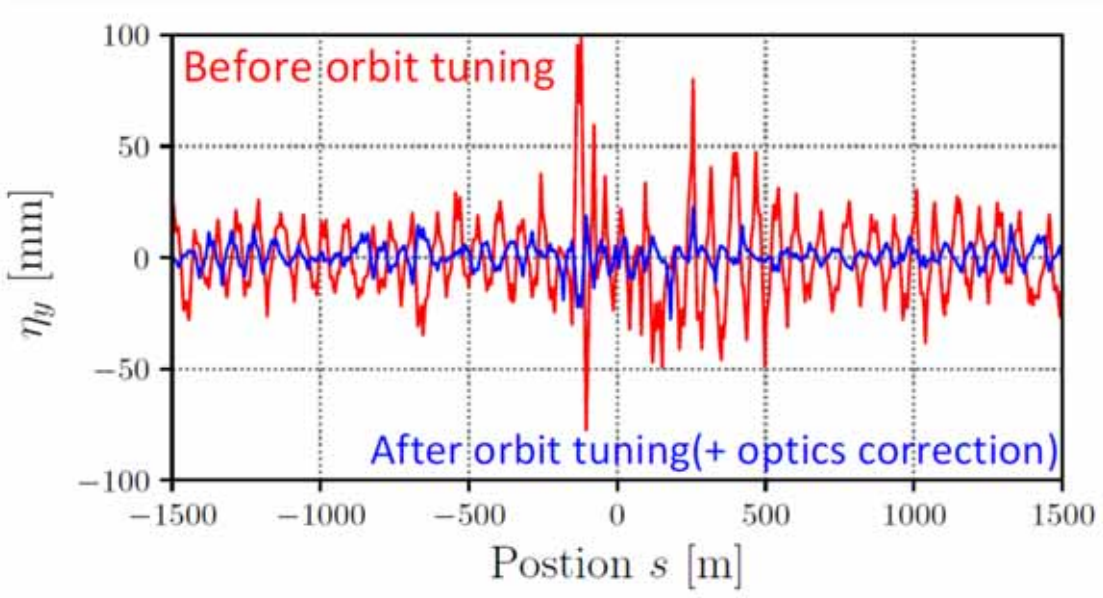


International collaboration on SuperKEKB accelerator commissioning and developments

- **R&D for high luminosity colliers [MNPP-01]**
  - **IJCLab: Fast luminosity monitor (LumiBelle2)**
  - **CERN: Beam Commissioning**
    - **Salim Ogur, Dima El Khechen, Marian Luckhof, Andreas Wegscheider, Jacqueline Keintzel, Frank Zimmerman, Renjin Yang, Adam Koval..**
  - **IHEP Beijing: Beam commissioning**
- **US-Japan collaboration in HEP**
  - **SLAC/Stanford:**
    - **IP feedback, Beam background, Collimators, HOM suppression, BxB feedback, X-ray monitor**
  - **University of Hawaii**
    - **X-ray monitor**
  - **Wayne State University : LABM**
  - **BNL, FNAL: Superconducting final Quads**

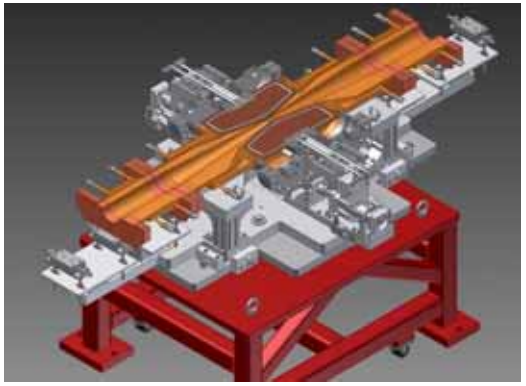
Challenges (1)

- **Difficulties in optical correction of the rings**
  - **Errors coming from the misalignment of the magnets have been enhanced with the lower βy***
  - **Non-linear optics, momentum-dependent effect of the lattice makes the corrections much difficult.**

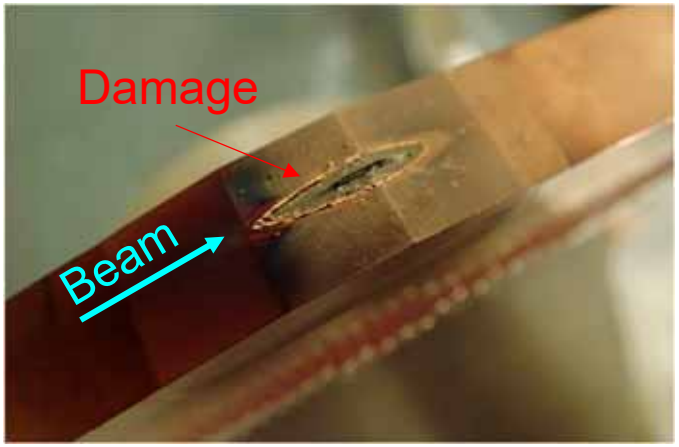


Challenges (2)

- **Background noise to the detector**
  - **Beam gas, Tousheck effect, Injection related background, + Radiative Bhaba**
  - **Need to protect the detector (and final focus Qs) by using the beam collimators placed around the rings.**
  - **Narrow gaps of the collimator increase beam impedance (mode coupling instability) and the possibilities of the damage of the heads.**

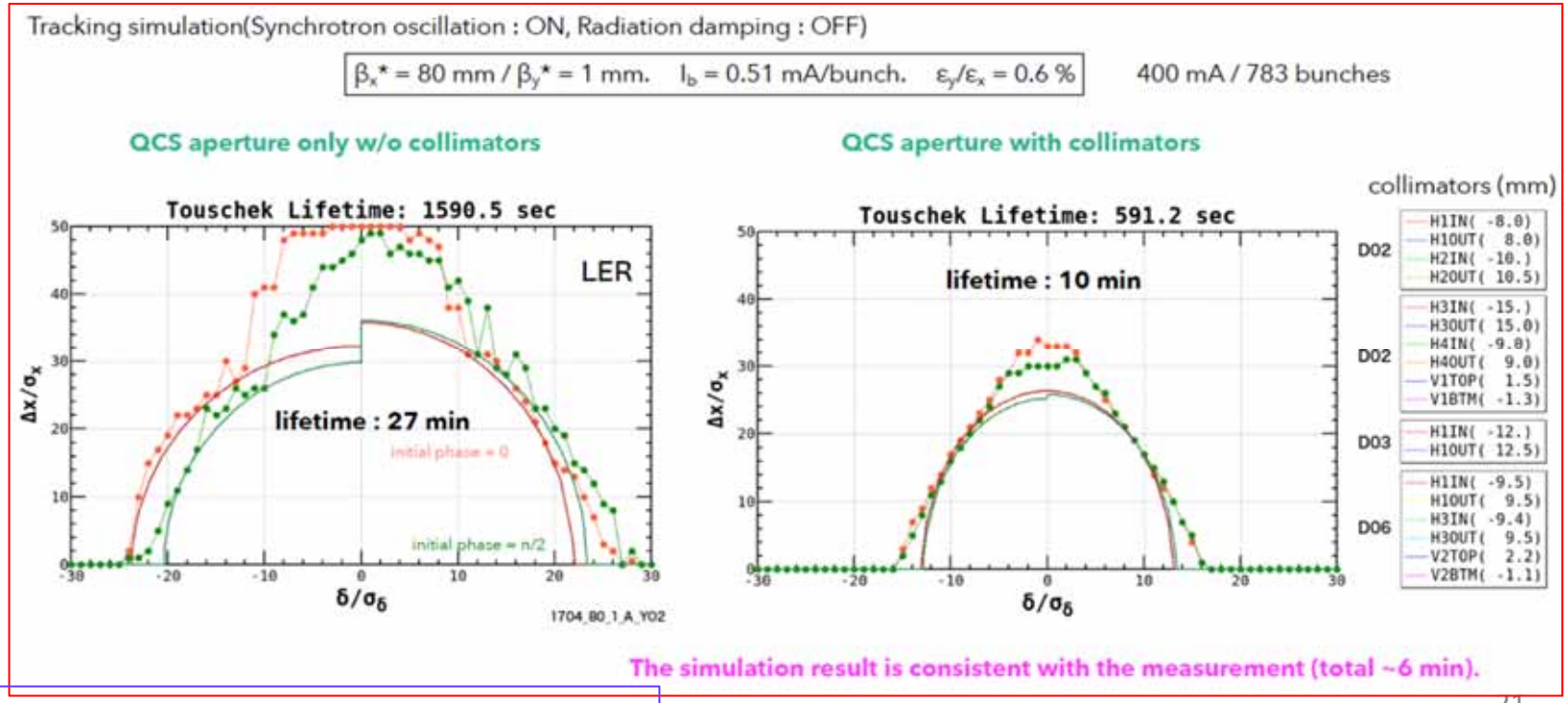


Damage of head (D02_V1) generated 2019b run



Challenges (3)

- **Very short beam lifetime**
  - **Physical aperture is strongly limited by the narrow gaps of the collimators.**
  - **Beam-beam effect also reduces the beam lifetime**



Ohnishi_SuperKEKB_Workshop_202003

Challenges (4)

- **Maintaining (very) aged hardware including buildings**
  - **Most of the hardware have been used since KEKB time (>20 years), some has been used since TRISTAN time (>30 years)**

Summary

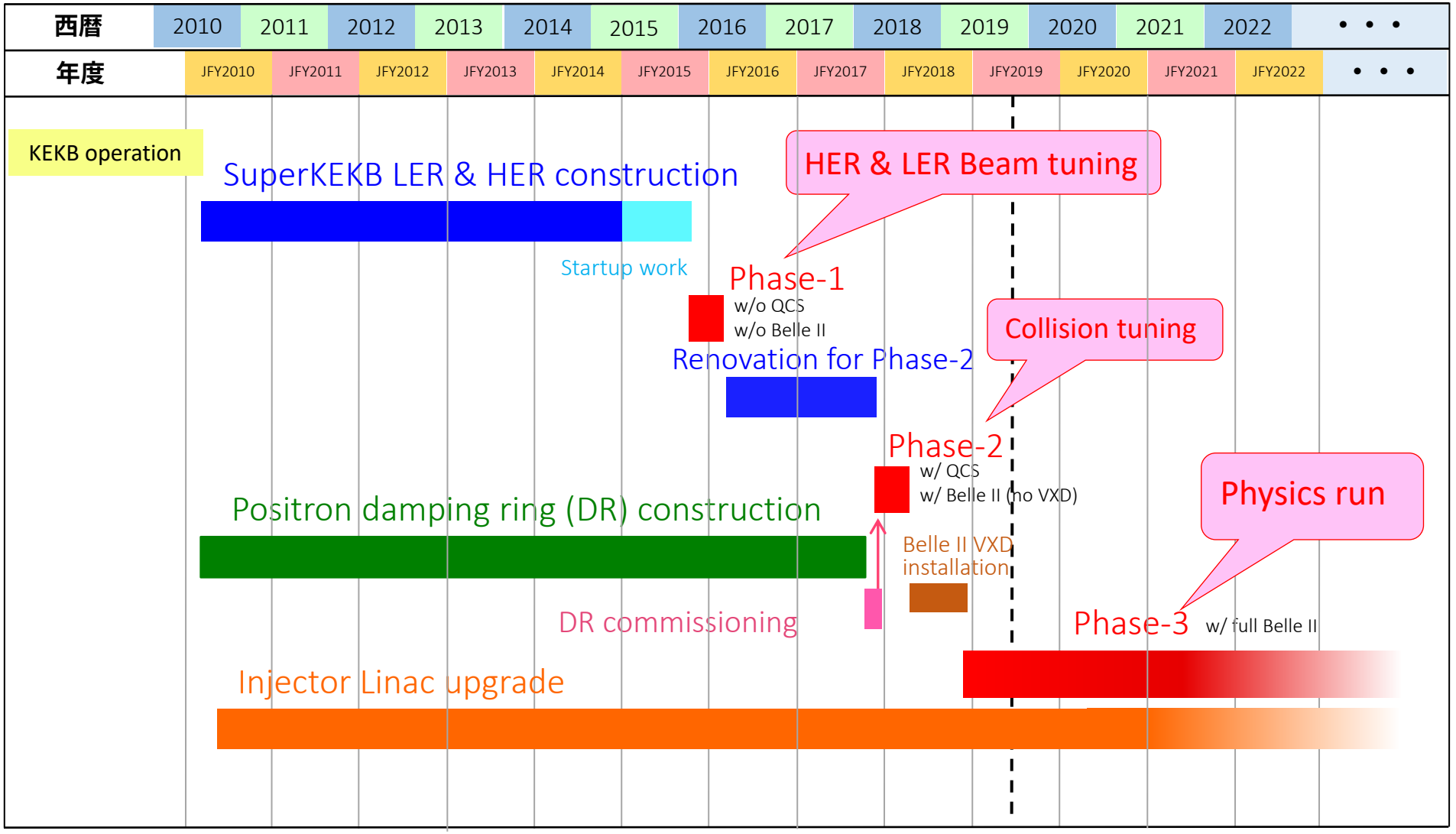
Achieved world highest luminosity of $2.4 \times 10^{34}/cm^2/s$

- **Nano-beam scheme works.**
- **Crab-waist scheme helped to operate the ring with higher bunch current**
- **Smallest IP vertical beam size (0.22um)**
  - **IP vertical beam size of SLC was 0.7um**

Try to reduce the βy^*, increase beam current, discover better optics– to achieve higher luminosity. Your cooperation is surely welcome!

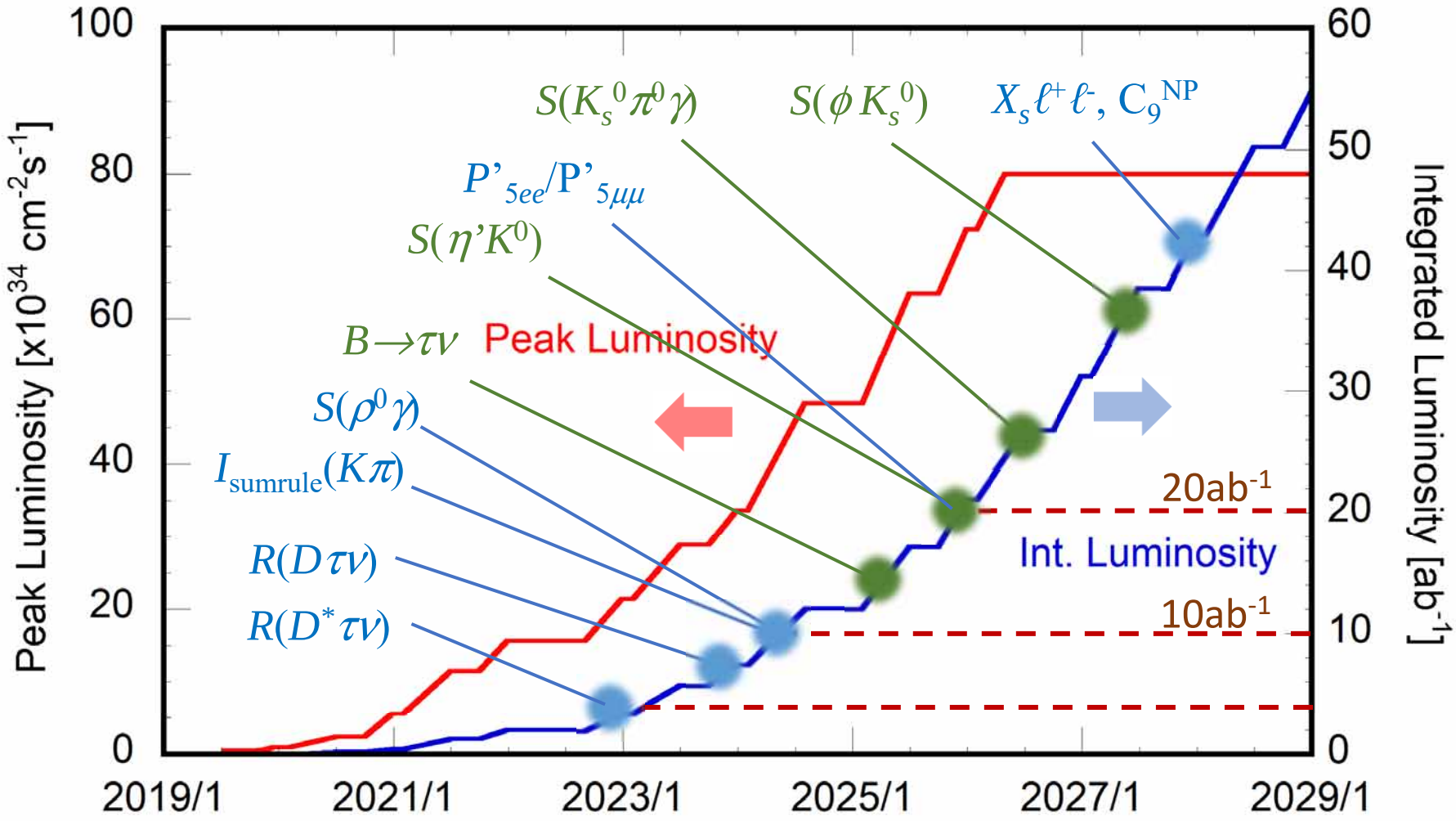
Backup

Timeline

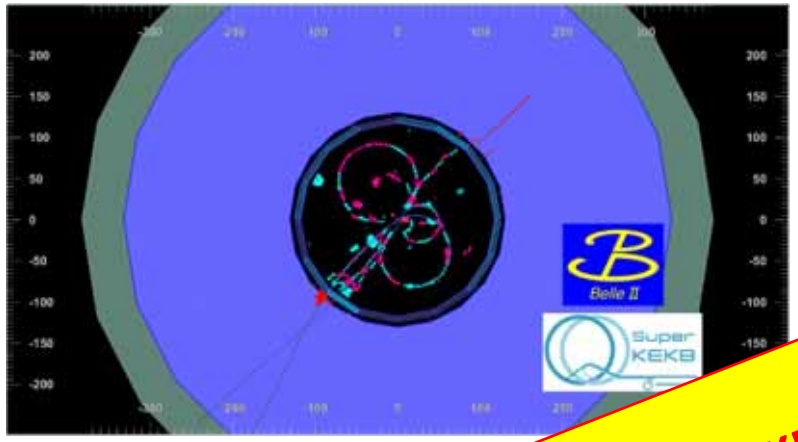


Based on K. Akai, Mar. 14, 2018 @KEKB review

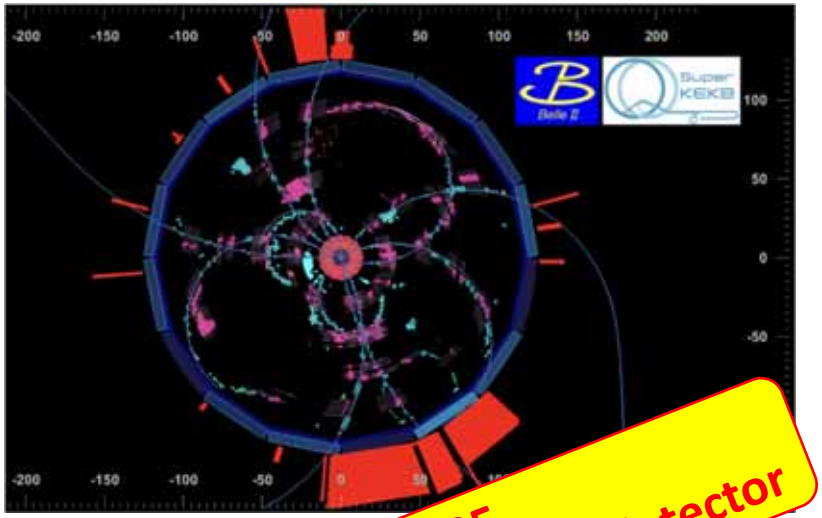
Luminosity projection and expected physics



Milestones



2018/04/26
First collision event at SuperKEKB



2019/03/25
First B-anti_B event with full detector