[FJPPN-A_RD_30]

Measurement and simulation of injection losses and resulting detector backgrounds at SuperKEKB

H. Kaji, N. Iida, Y. Funakoshi, H. Nakayama, Y. Ohnishi,
T. Koga, K. Uno, S. Uehara (KEK)
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The SuperKEKB/Belle II project

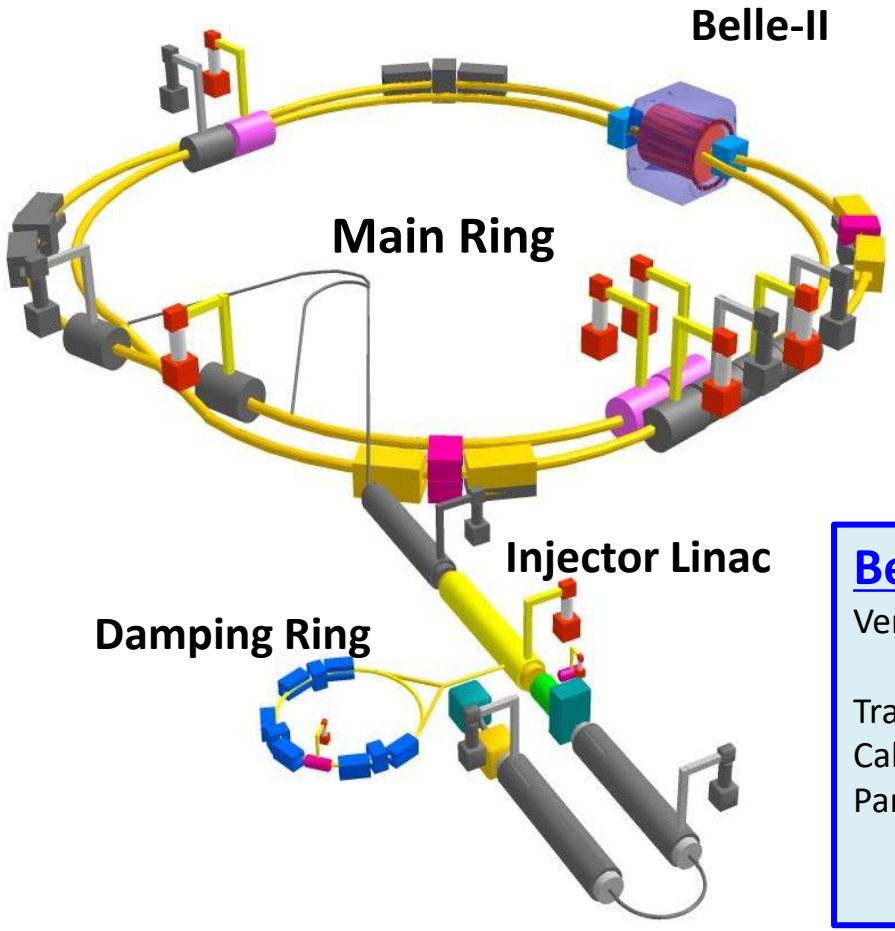
SuperKEKB (Electron-Positron Collider)

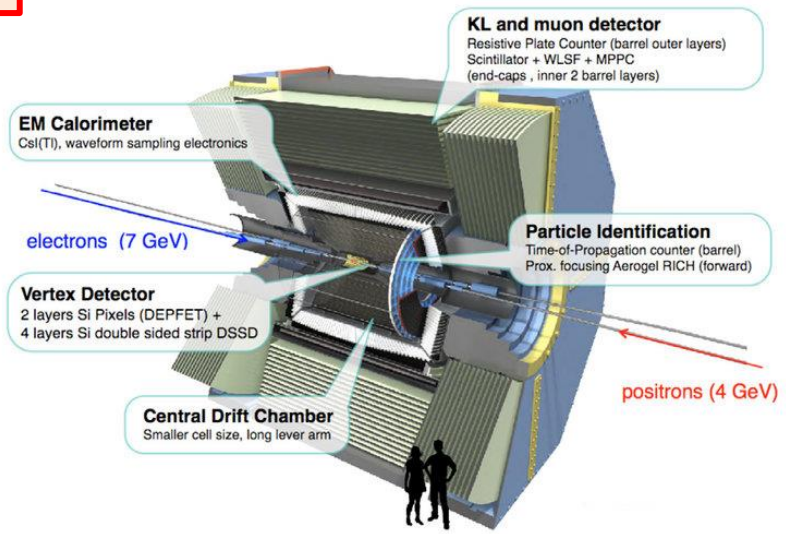
C.M.S. Energy: √s = 10.58 GeV

Luminosity: **L = 6 x 10^{35} $cm^{-2}s^{-1}$**

（Luminosity Frontier Machine）

	Electron	Positron
Energy (GeV)	7	4
Current (A)	3.6	2.6





Belle II (General purpose detector)

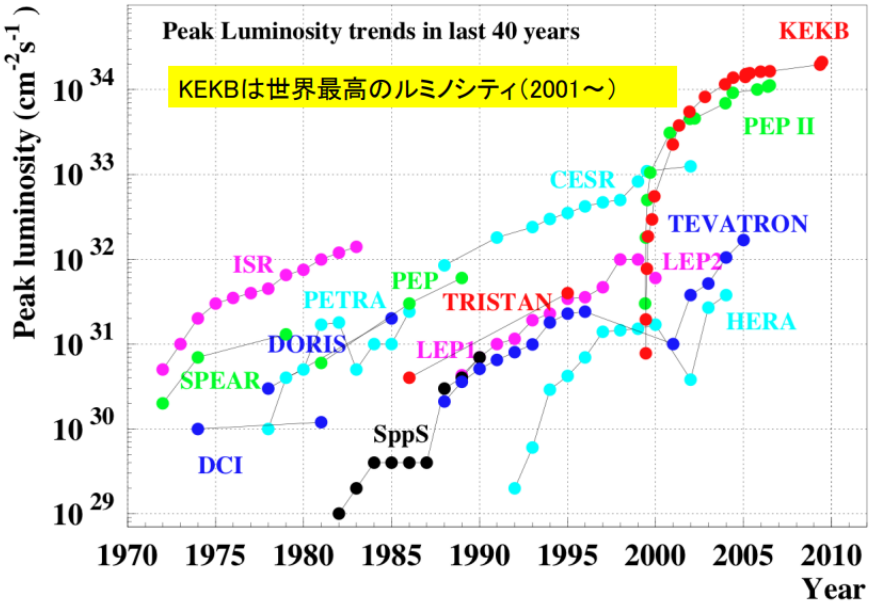
Vertex detectors: Pixel Vertex Detector (PXD),
Silicon strip Vertex Detector (SVD)
Tracking: Central Drift Chamber (CDC)
Calorimeter: Electromagnetic CaLorimeter (ECL)
Particle ID: Aerogel Ring Image CHerenkov detector (ARICH)
K-Long and Muon detector (KLM)
Time-Of-Propagation counter (TOP)

Luminosity Frontier

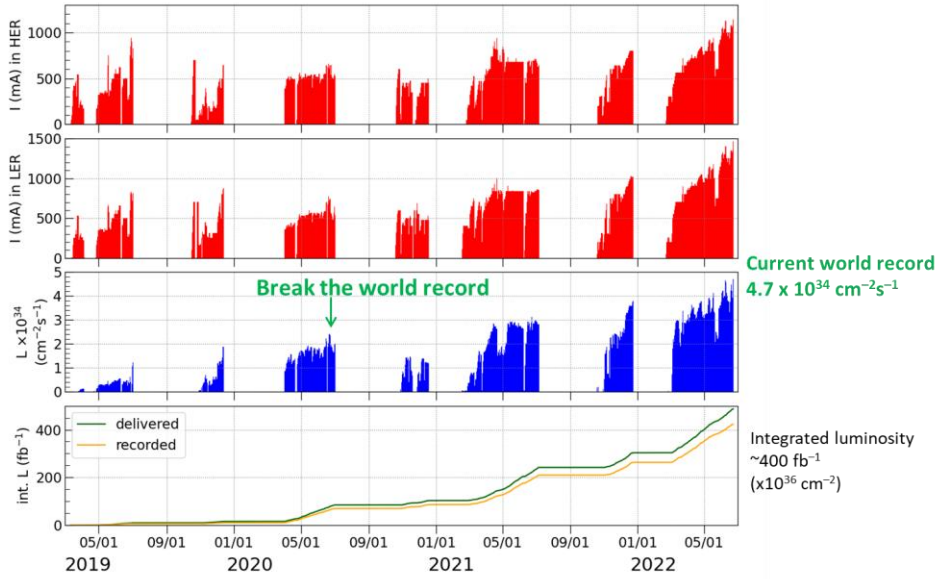
The B-pair production rate (pair/sec) is: $N = \sigma \times L$

where σ is the cross-section for the B pair production, 1.1nb. L is luminosity.
Note, 110 pairs of B mesons are produced in a second when L = 10^{35} $cm^{-2}s^{-1}$.

World's history before SuperKEKB



Our history, current record: 4.7x10^{34} $cm^{-2}s^{-1}$



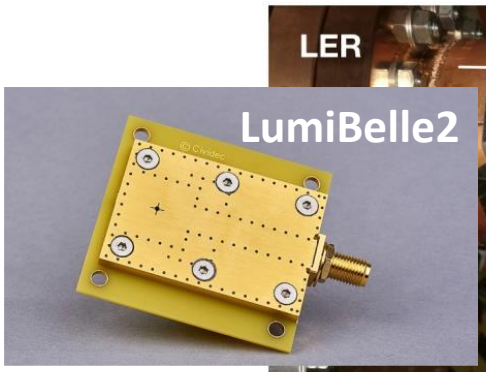
SuperKEKB aims the untrodden luminosity.

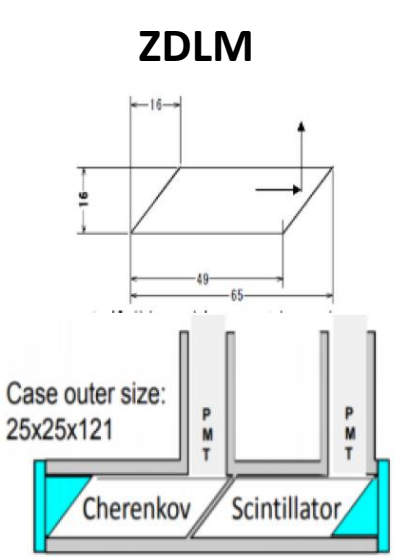
Orsay-KEK in 2012-2019

The fast luminosity monitors has been developed with the support by FJPPN-TYL.

LumiBelle2:
Single crystal Chemical Vapor Deposition (sCVD) diamond detector

ZDLM (Zero Degree Luminosity Monitor):
Cherenkov and scintillator detector





C. G. Pang, P. Bambade, Y. Funakoshi, S. Uehara, et al., Nucl.Instrum.Meth. A931 (2019) 225-235

Now is the time to set sail to the sea of the untrodden luminosity.
The dream team is re-formed!

IJCLab-KEK in 2024-

Understanding of the injection-related background at SuperKEKB

- beam simulation for the electron injection beam
- orbit measurement of the electron injection
- beam loss measurement fo the electron injection beam
- combined analysis of the above items.

Luminosity monitoring

- maintain the 1kHz luminosity monitoring with accuracy of 1% for

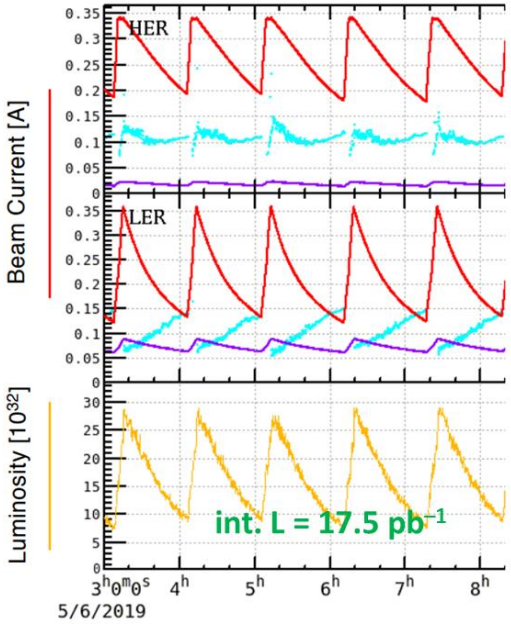
  Luminosity feedback system based on “dithering”

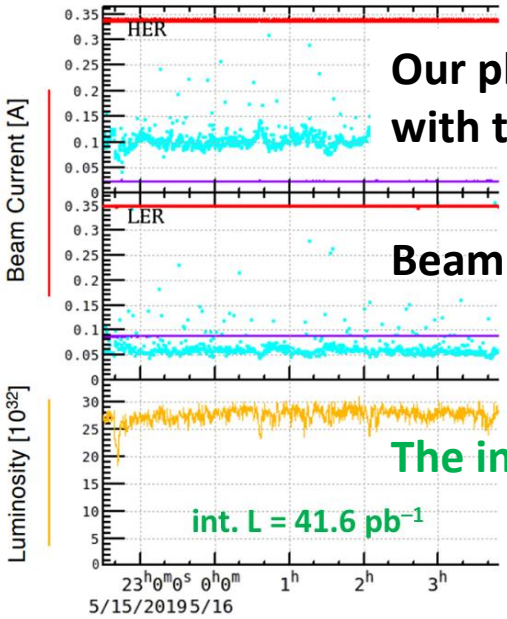
  investigation of the ground motion effect

  elucidation of mystery of the luminosity dependence on bunch space

  and so on ...

Injection background and DAQ dead time



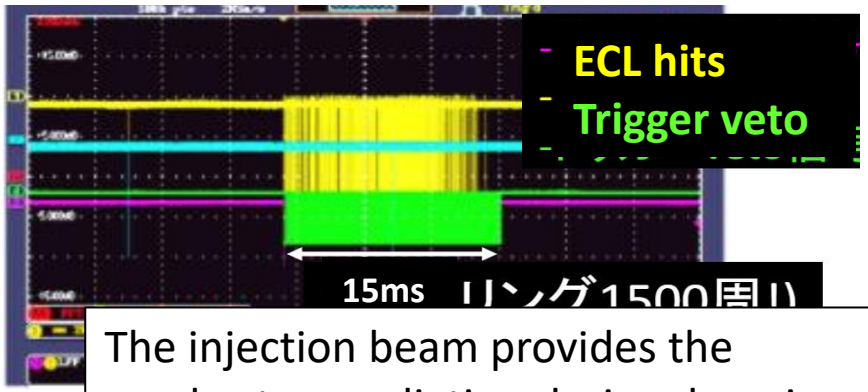


Our physics run carries out with the top-up filling since 2019.

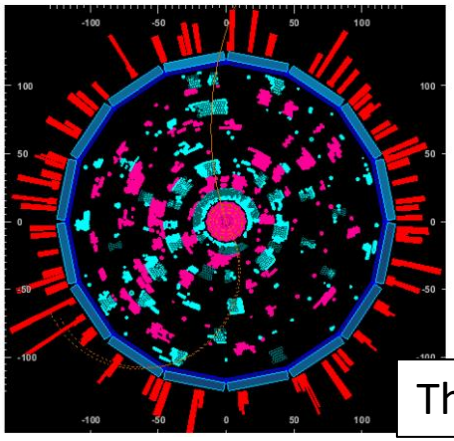
Beam is added from the injector in 50Hz.

The integrated luminosity is 2.4 times larger!

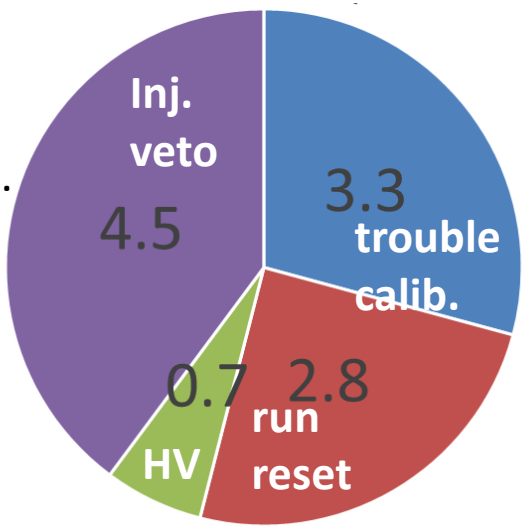
However, the Belle II detector suffered from the injection background.
We employ the veto time in the Belle II DAQ. **Frustrating data loss!**



The injection beam provides the synchrotron radiation during damping.



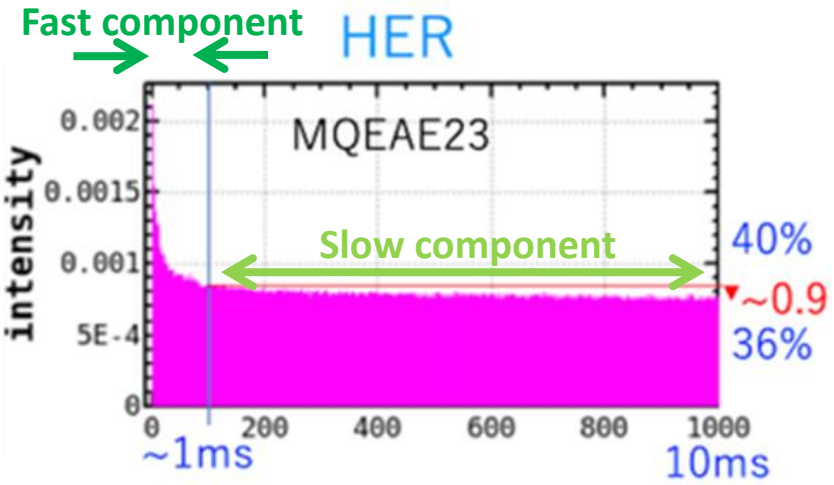
They hit Belle II.



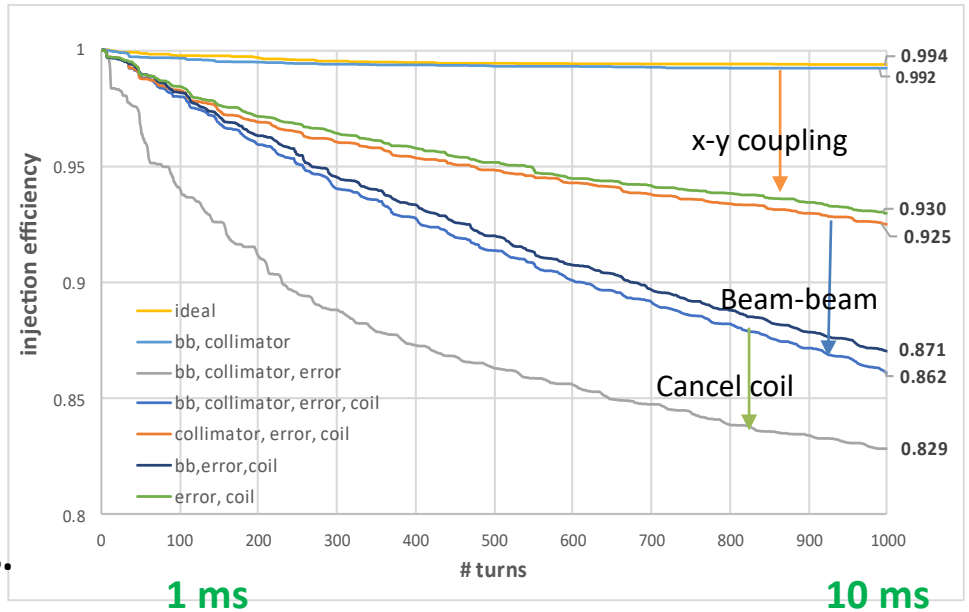
DAQ dead time (%) in 2022

Beam simulation for electron injection

Fast and slow components of the charge decay are observed in the injection.
- Fast component affects the injection efficiency
- Slow component affects the dead time of the Belle II DAQ.



Turn by turn beam charge of the injected electrons.



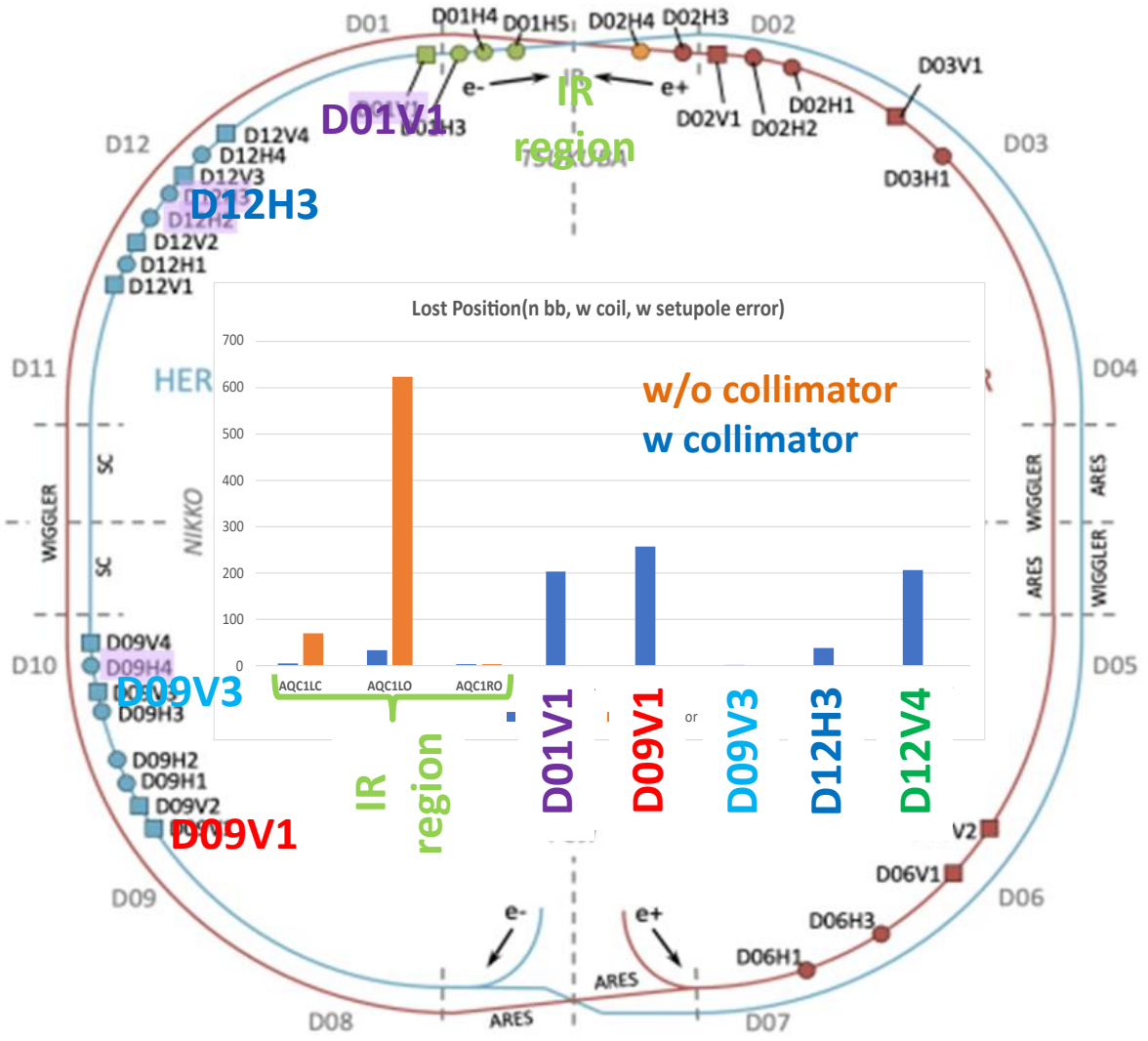
The 10% of the injected beam is lost with some slow effects and causes the beam background at the Belle II detector.

The development of the beam simulation is on-going.
Some slow components of the injection beam loss are reproduced.

Beam Loss distribution (simulation)

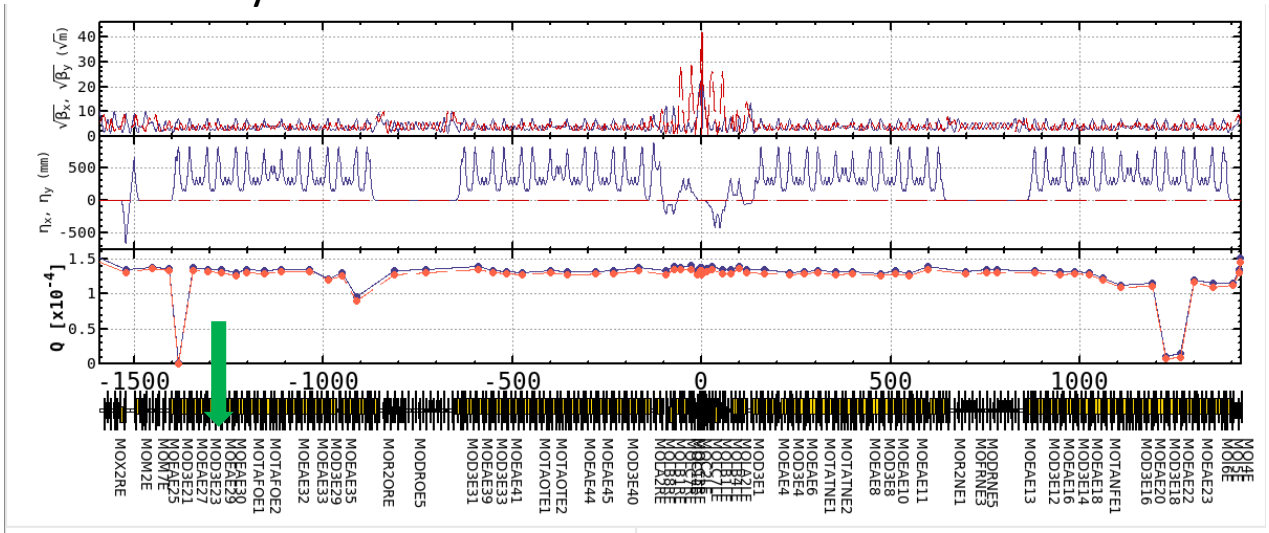
The aperture of the collimator is introduced in the simulation.

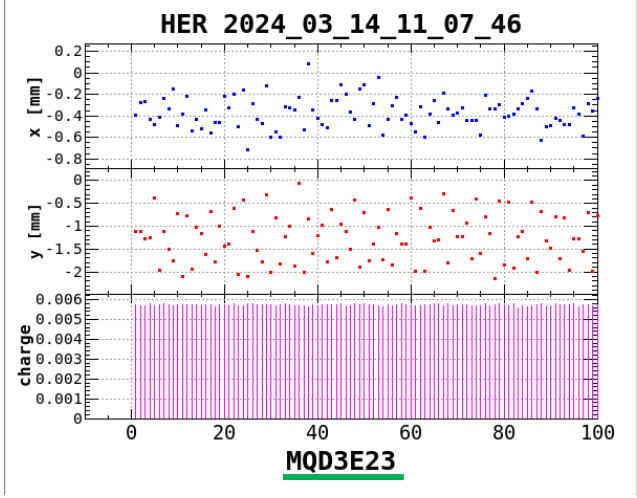
The mitigation of the beam background at the IR region can be simulated by changing the collimator aperture.

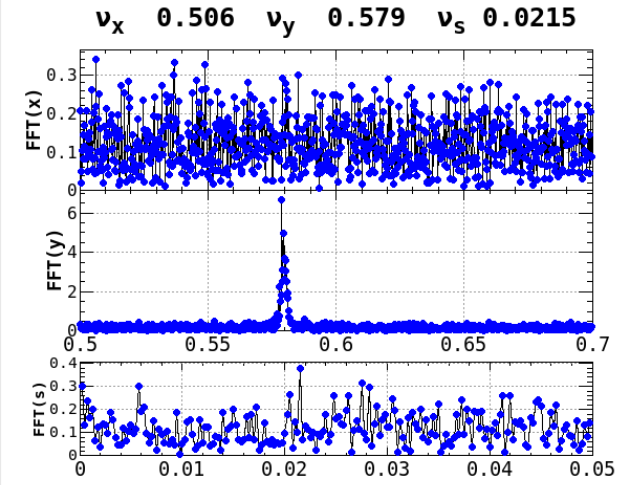


TbT beam orbit measurement system

Turn-by turn beam orbit measurement with 70 Beam Position Monitors







The upgraded trigger system is utilized since 2024
- data acquisition for both injection and stored beams.

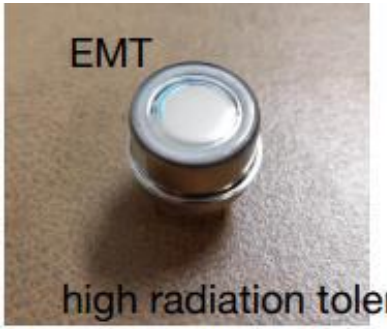
Stimulation for str. beam in three directions
- horizontal kick
- vertical kick
- longitudinal kick (RF kick)

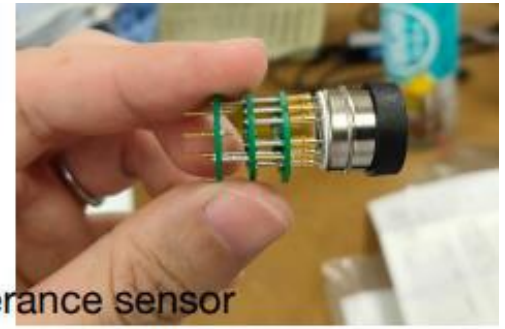
Measurement for more than 1000 turns. can be utilized for
- detailed comparison between the real beam behavior and the simulation.
- frequency domain analysis to investigate the error source in our accelerator model.

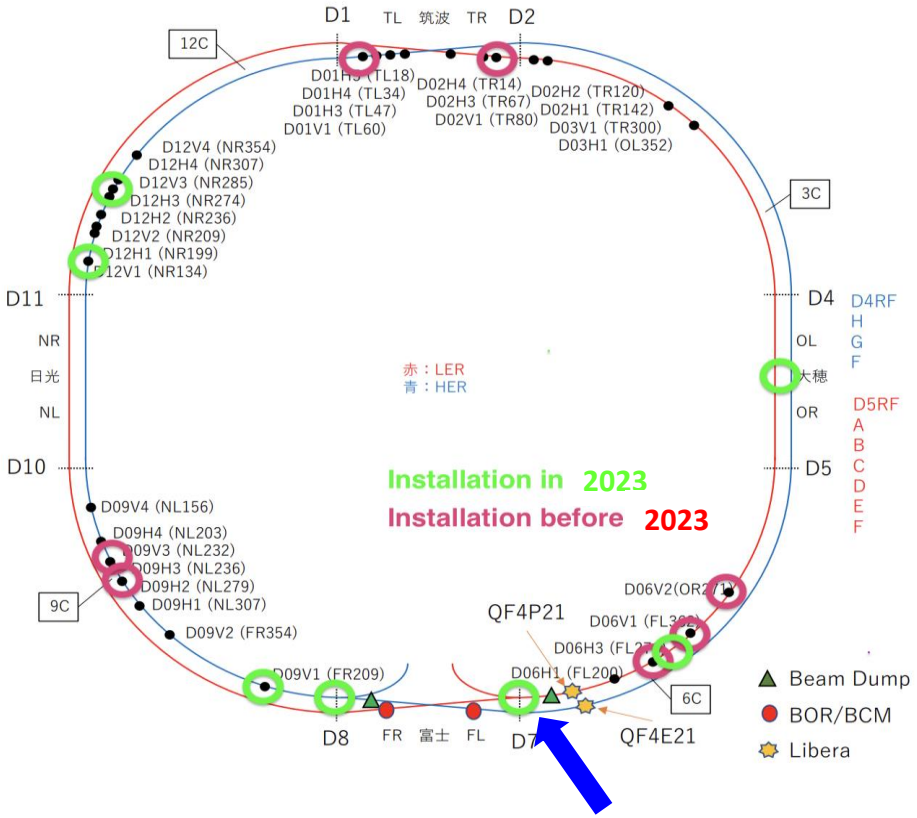
Loss monitor system

We installed the precise time-resolution loss monitor made of the CsI scintillator and EMT into the SuperKEKB tunnel.

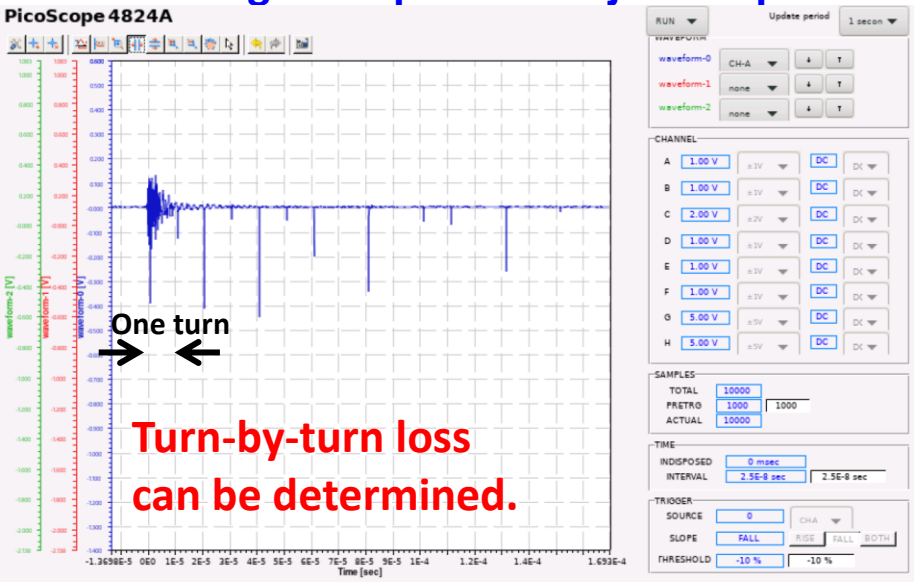
Most of the beam loss points (main collimators) are covered.







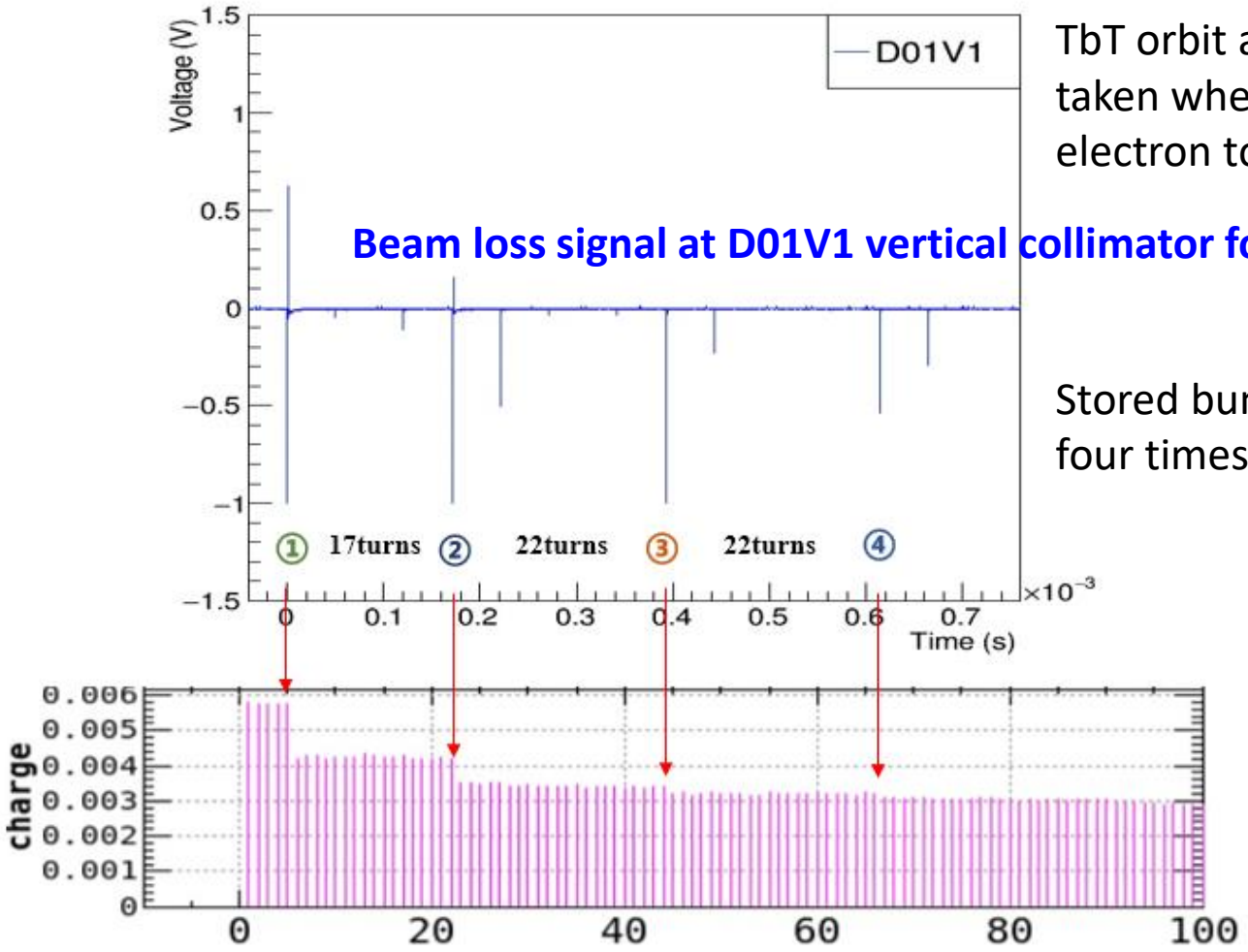
Beam loss signal at positron injection point



The data acquisition can be implemented with the injection or TbT triggers.

Combined analysis

Data acquisition of the loss monitor with TbT trigger enable us the combined analysis.



Beam loss signal at D01V1 vertical collimator for electron beam

TbT orbit and loss monitor data are taken when we kick the stored electron to the vertical direction.

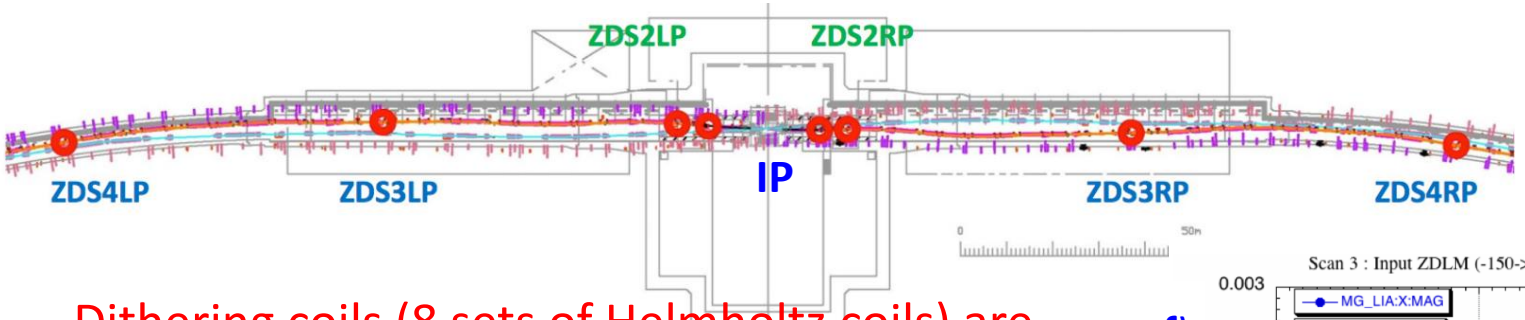
Stored bunch hit vertical collimator four times and lost its charge.

We can evaluate the absolute calibration of loss monitor data without GEANT simulation.

In the detailed comparison with the beam simulation, we unveil the nature of the electron injection.

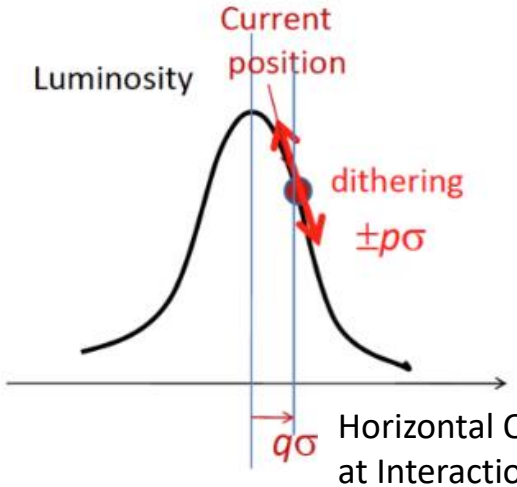
Luminosity feedback

Y. Funakoshi, S. Uehara, P. Bambade, *et al.*,
doi:10.18429/JACoW-eeFACT2018-WEXBA04

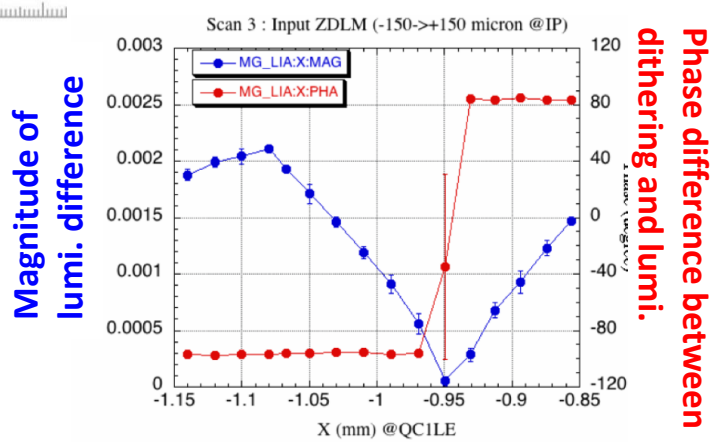


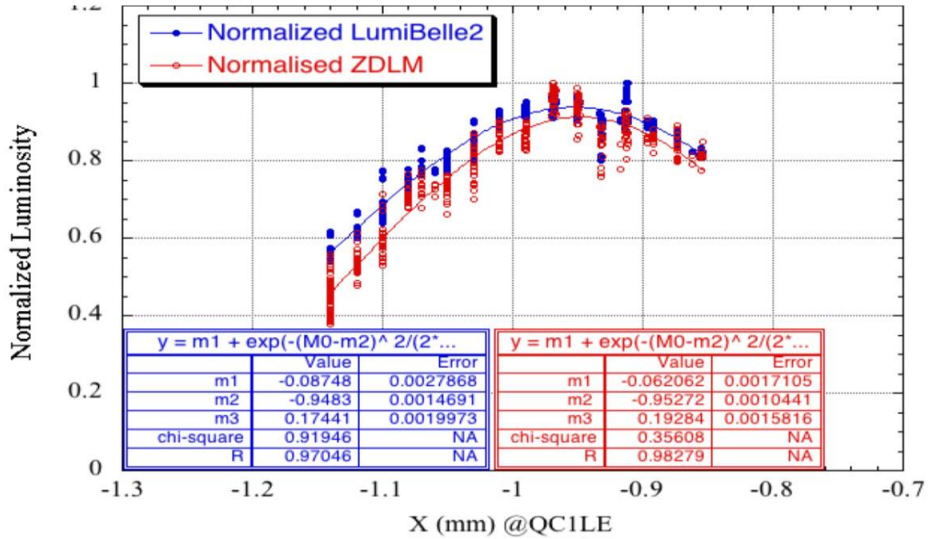
Dithering coils (8 sets of Helmholtz coils) are installed in the positron beamline.

Positron beam is kicked in 79Hz and monitor the luminosity.



Horizontal Orbit at Interaction Point



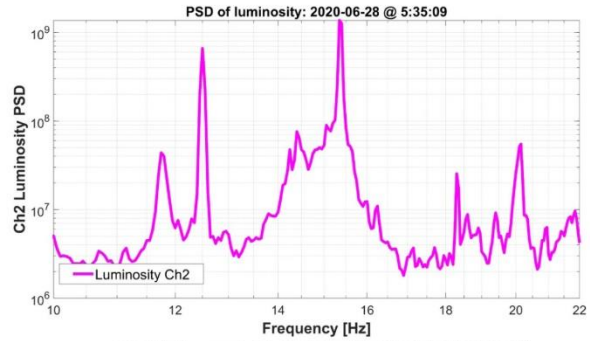


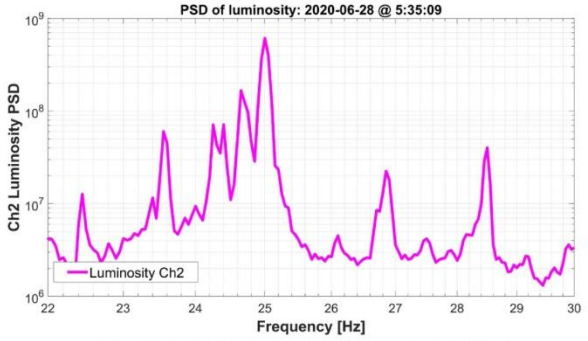
Ground motion

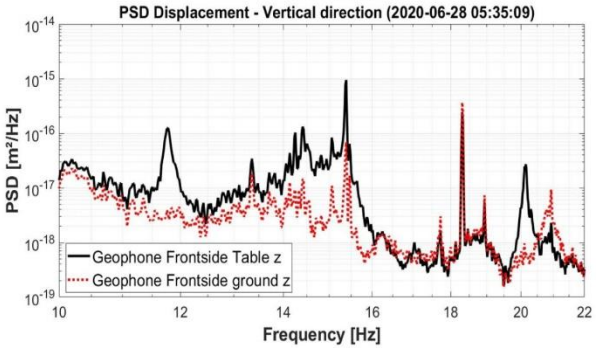
M. Serluca, P. Bambade, S. Uehara, et al., Nucl.Instrum.Meth. A1025 (2022) 166123.

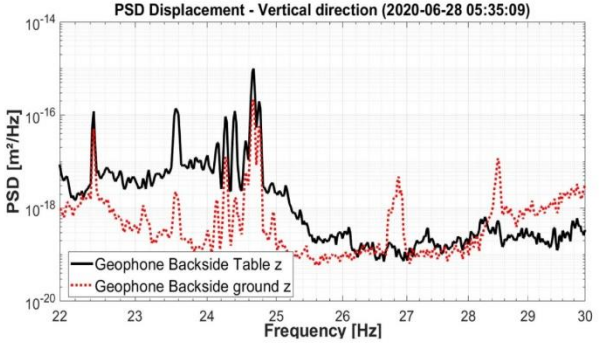
The ground motion in the IP region is measured with the seismic sensor.

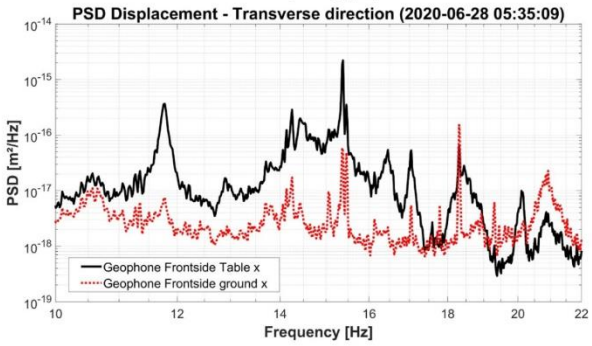
Power Spectral Density is compared with Luminosity.

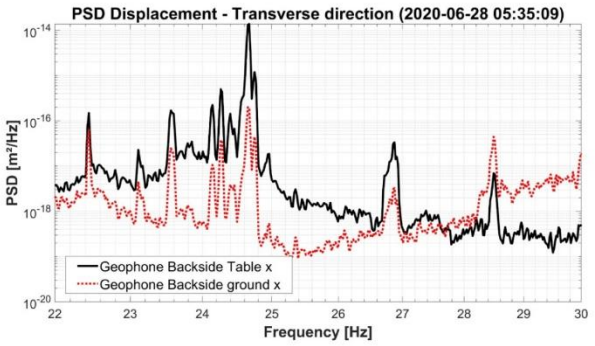








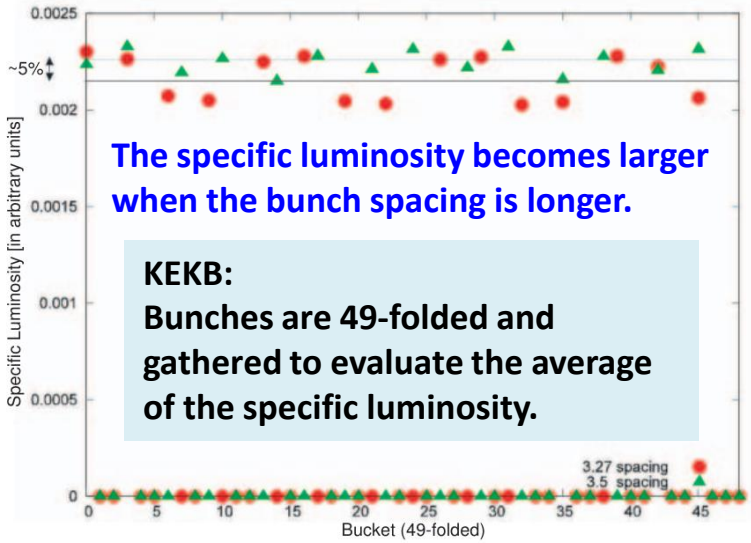


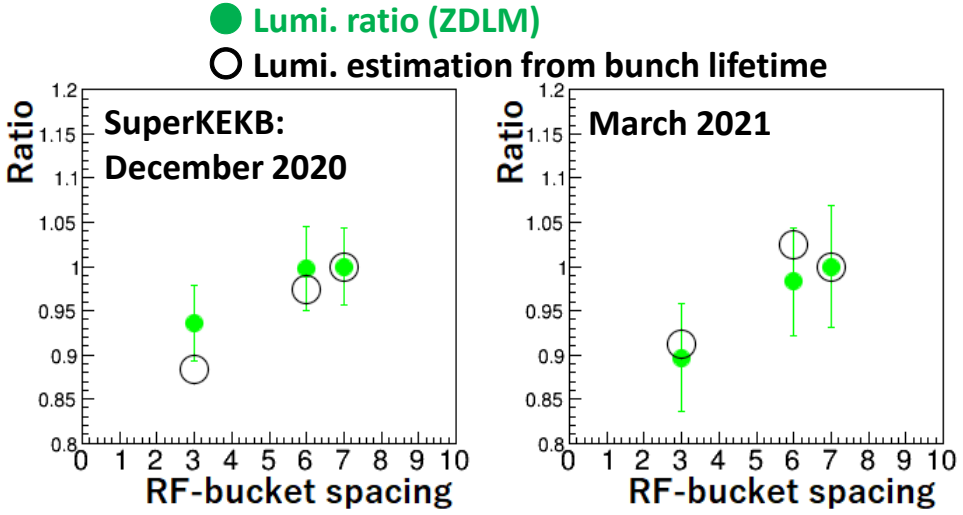


Mystery of luminosity dependence on bunch space

The fast luminosity monitor give us the bunch-by-bunch luminosity.
It address the mystery of the luminosity dependence on the bunch spacing.

Note, our RF frequency is 509MHz. **One RF-bucket space corresponds to 2ns.**





Y. Funakoshi, *et al.,* 2006 *Proc. EPAC 2006* (Edinburgh, UK)
Recent Progress of KEKB

H. Kaji, Y. Funakoshi, S. Uehara,
J. Phys.: Conf. Ser. **2687** 022009 (2024)
DOI 10.1088/1742-6596/2687/2/022009

Further study with the cross-check between LumiBelle2 and ZDLM.

Conclusion

The dream team is re-formed!

We started studying for understanding of the electron injection background.
- We unveil the nature of the electron injection with the beam simulation, the TbT measurement of the orbit and beam loss.
- It hope to be suppress the DAQ deadtime of Belle II.

We maintain the luminosity monitor which is one of the most important system in the SuperKEKB/Belle II project.
- Continue to break the world's record luminosity
- Plenty of beam physics programs are available.