KEK and its plans

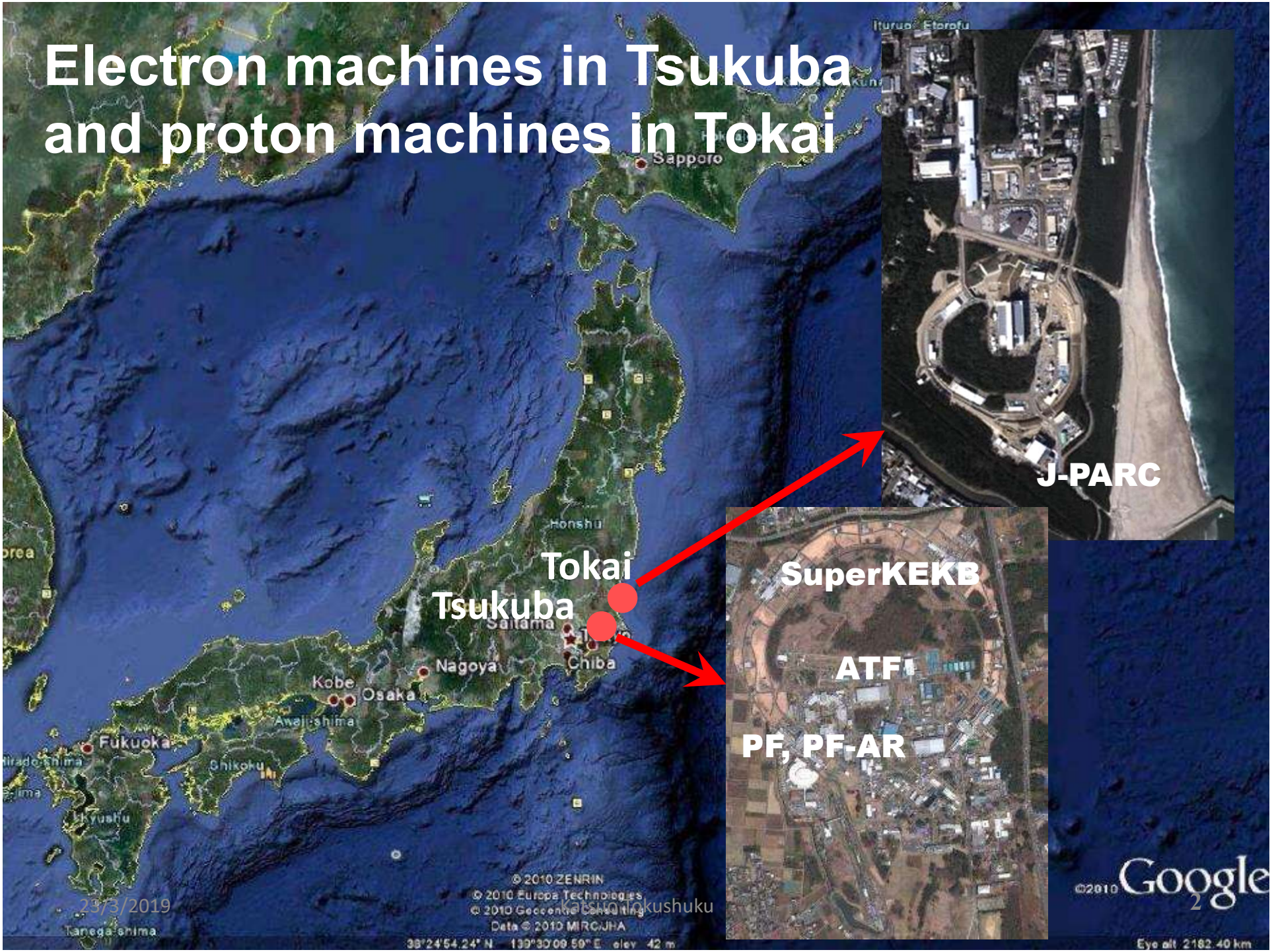
Shoji Uno (KEK)

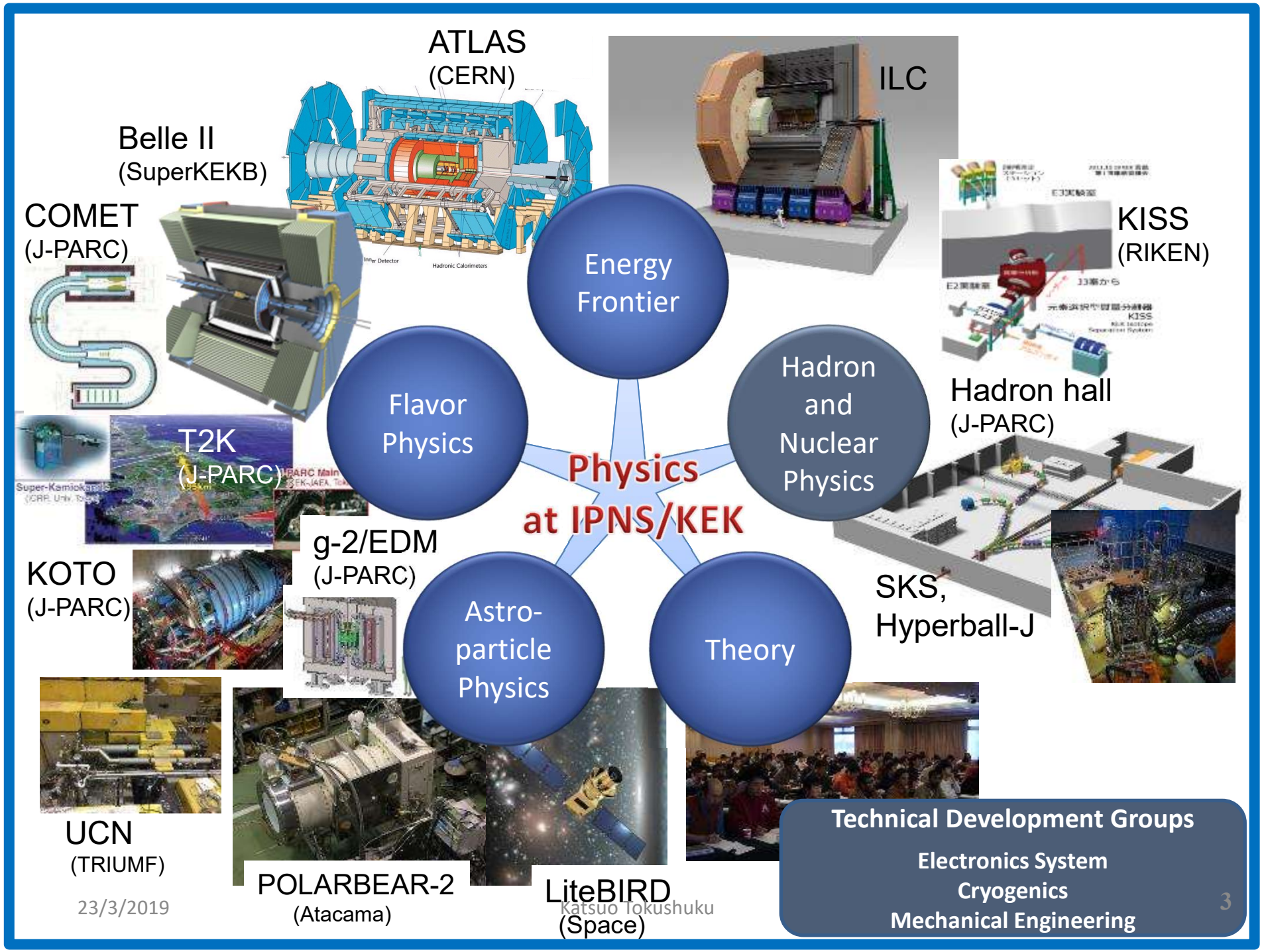
Feb-24th, 2020

INSTR' 20

BINP, Russia

Electron machines in Tsukuba and proton machines in Tokai




ATLAS
(CERN)
ILC
Belle II
(SuperKEKB)
COMET
(J-PARC)
KISS
(RIKEN)
Energy Frontier
Flavor Physics
Hadron and Nuclear Physics
Physics at IPNS/KEK
Astro-particle Physics
Theory
Hadron hall
(J-PARC)
T2K
(J-PARC)
g-2/EDM
(J-PARC)
KOTO
(J-PARC)
SKS,
Hyperball-J
UCN
(TRIUMF)
POLARBEAR-2
(Atacama)
LiteBIRD
(Space)
Technical Development Groups
Electronics System
Cryogenics
Mechanical Engineering

SuperKEKB

SuperKEKB and Belle II

Belle II

New superconducting final focusing quads near the IP

New IR

Colliding bunches

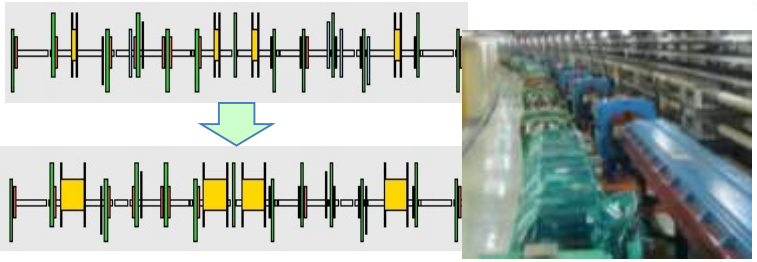
e^+ 4GeV 3.6 A

e^- 7GeV 2.6 A

SuperKEKB

Target: $L = 8 \times 10^{35}/cm^2/s$

Replace short dipoles with longer ones (LER)



Add / modify RF systems for higher beam current

Positron source

New positron target / capture section

Redesign the lattices of HER & LER to squeeze the emittance

Damping ring

Low emittance positrons to inject

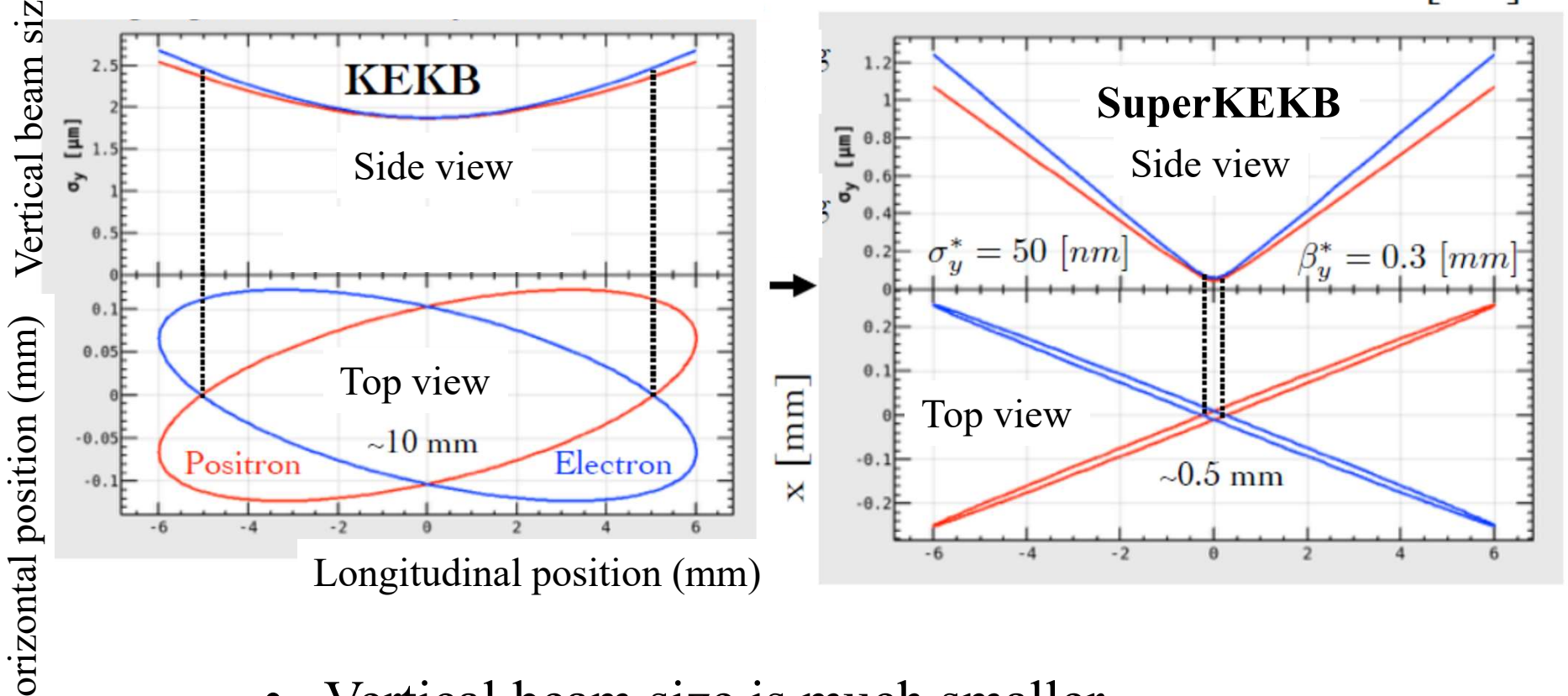
Low emittance gun

Low emittance electrons to inject

TiN-coated beam pipe with antechambers

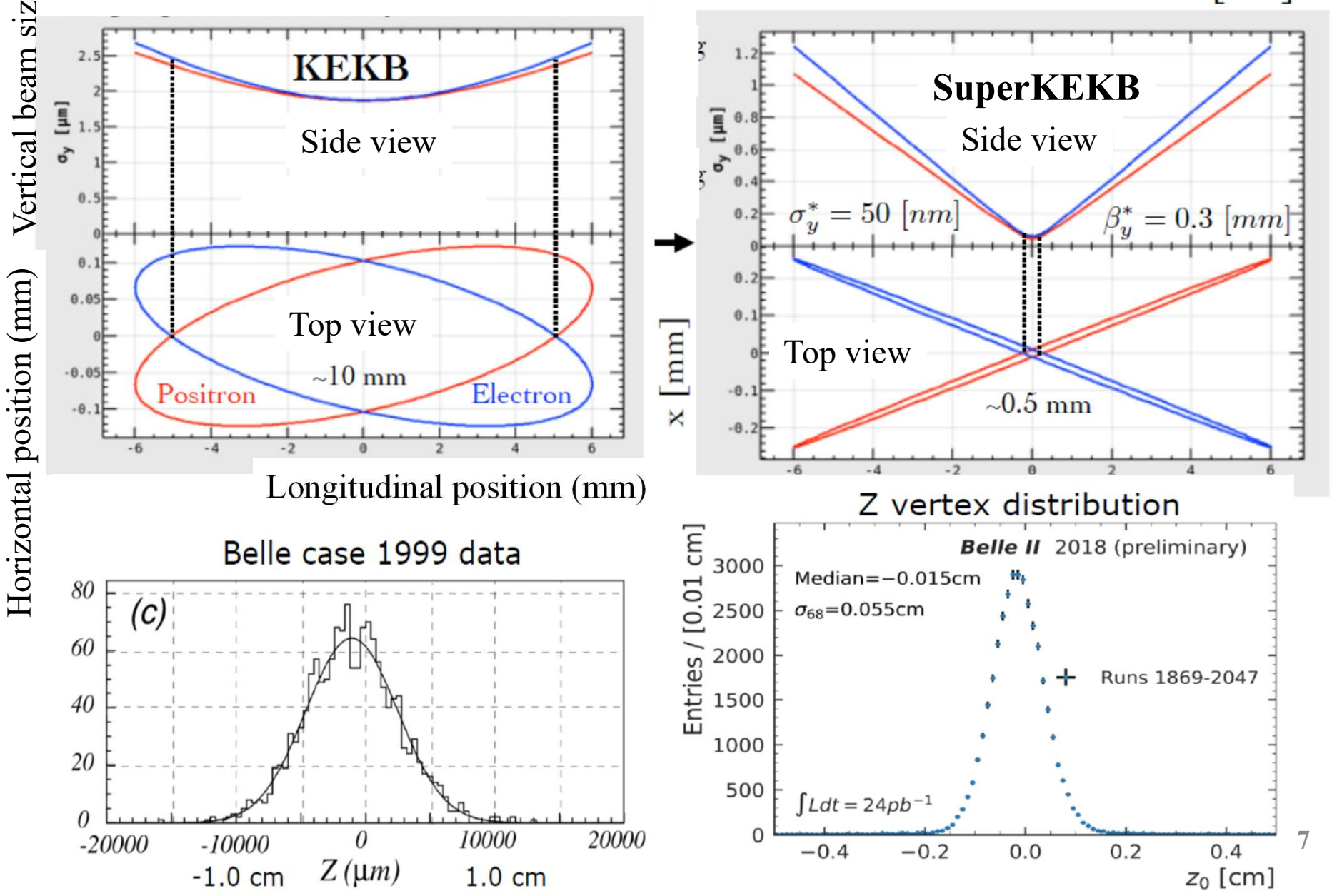
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

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

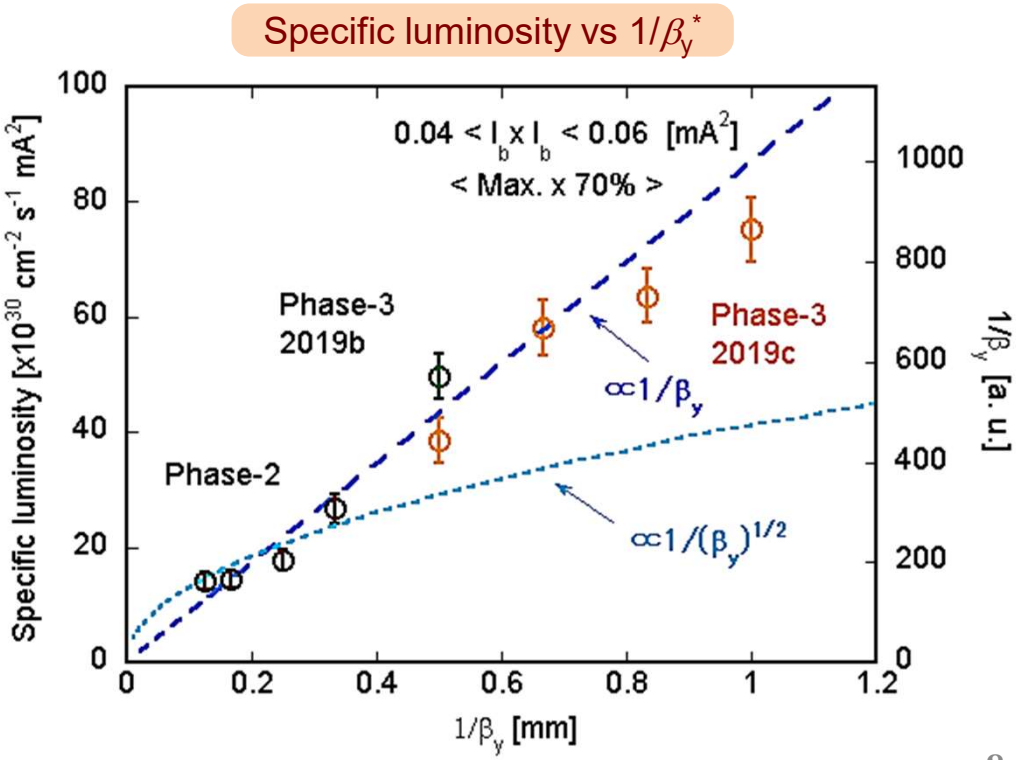
Nano beam collision



Specific luminosity

- Specific luminosity is increasing as a function of $1/\beta_y^*$ as expected, thanks to the nano beam collision scheme.
- Similar luminosity was obtained with lower beam current, already.
- In near future, higher luminosity will be obtained with higher beam current after the vacuum scrubbing.

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



Belle II

Belle II Collaboration

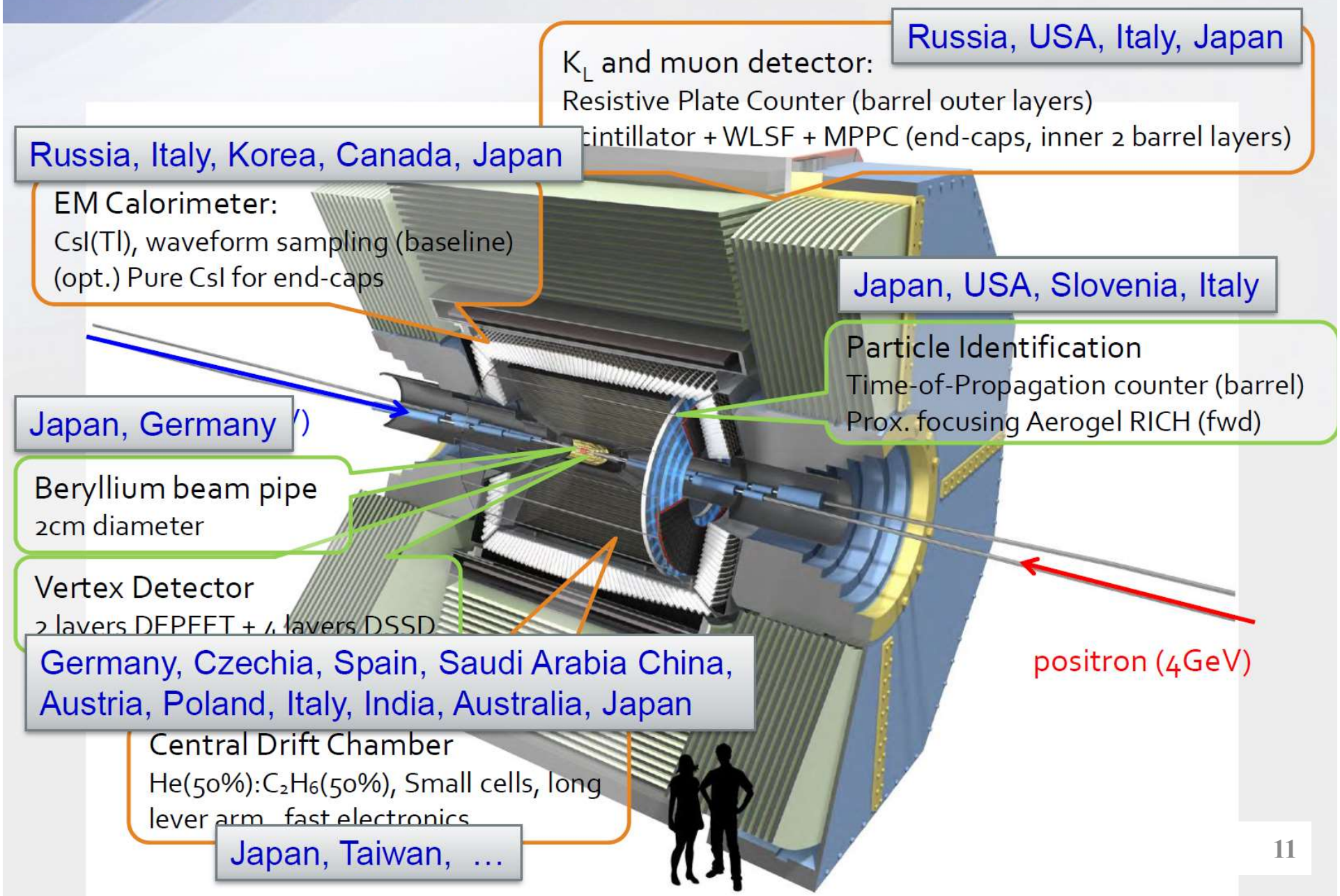
26 countries/regions
119 institutions
1029 researchers

Europe	451
Austria	21
Czechia	11
France	41
Germany	209
Israel	7
Italy	82
Poland	11
Russia	45
Slovenia	13
Spain	6
Ukraine	8

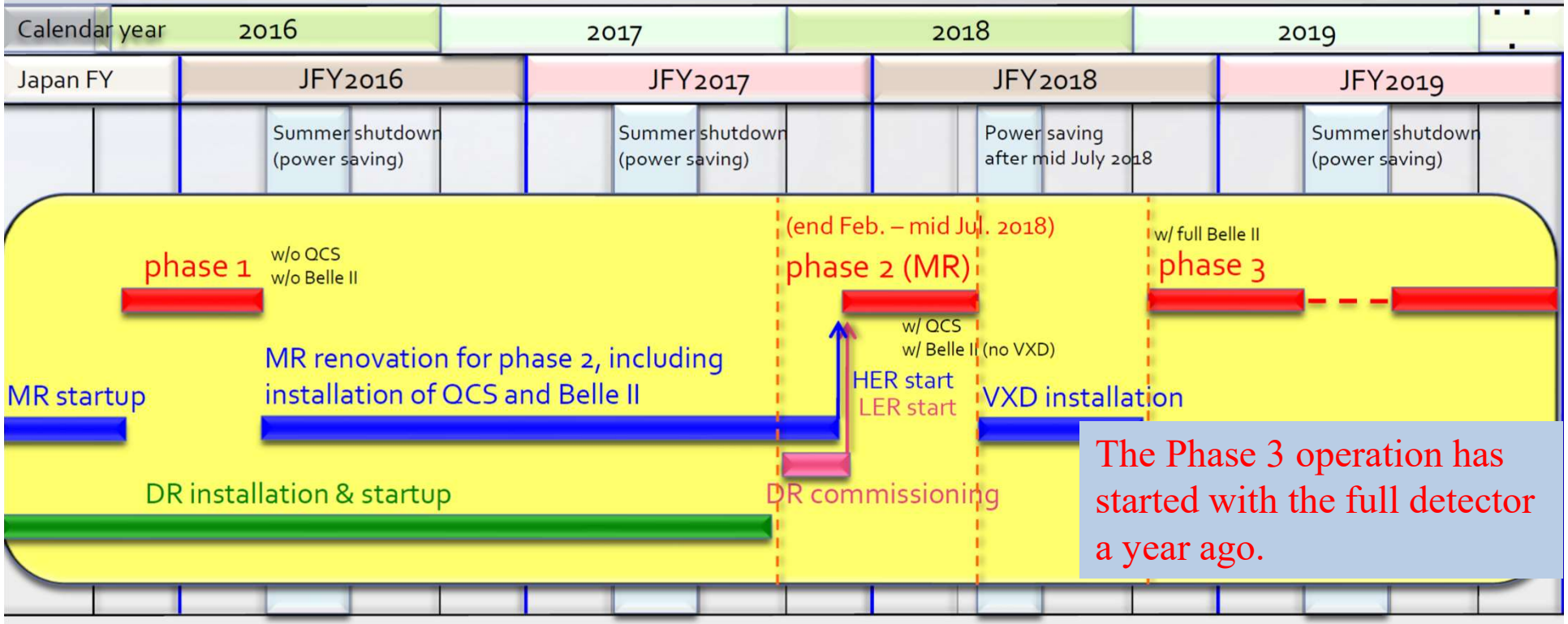
Asia			405
Saudi Arabia	3	Korea	47
Australia	29	Malaysia	4
Armenia	4	Vietnam	4
China	58	Taiwan	31
India	45	Thailand	5
Japan	170	Turkey	2

America	173
Canada	31
Mexico	15
USA	127

Belle II Detector



SuperKEKB/Belle II schedule

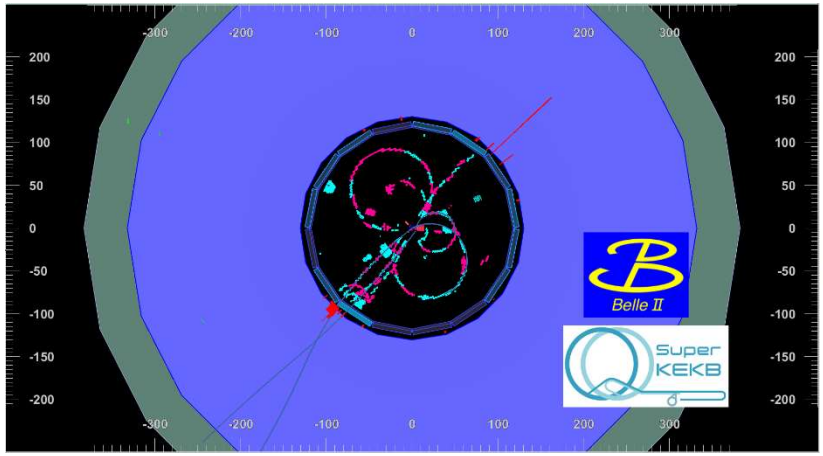


Phase 1 (w/o final focusing Q, w/o Belle II):
- Accelerator system test and basic tuning,
- **Vacuum scrubbing**,
- **Low emittance tuning**, and
- **Beam background studies**

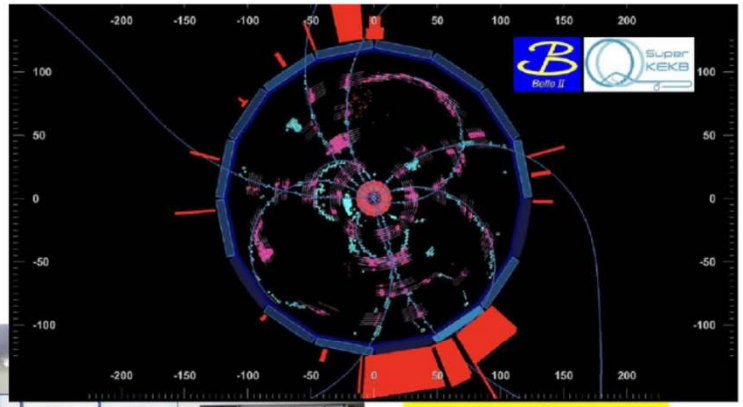
Phase 2 (w/ final focusing Q, w/Belle II but background monitors instead of vertex detectors)
- **Verification of nano-beam scheme**
  target: $L>10^{34}\ cm^{-2}s^{-1}$
- Understand **beam background** especially in vertex detector volume

First collision

First hadronic event on April 26, 2018



Another first collision
with full detector
on March 25, 2019

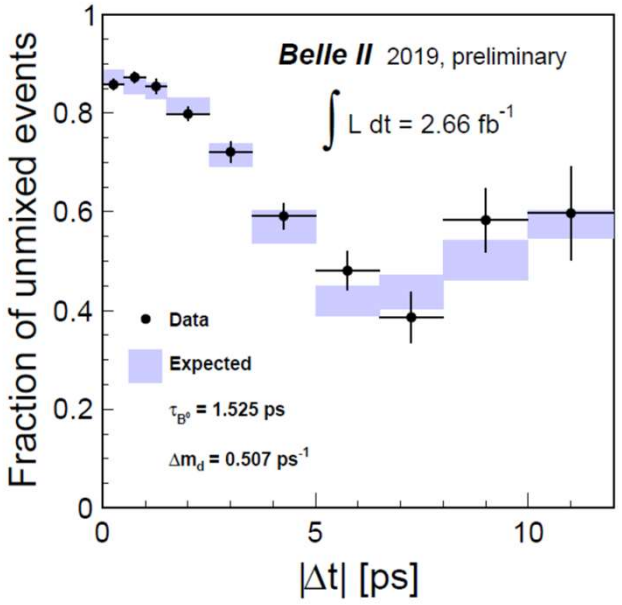


Present status

- Luminosity
  - Peak L ~ $1.1 \times 10^{34} cm^{-2} sec^{-1}$
    - with smaller beam current (HER:360mA, LER:500mA) than KEKB and PEPII, thanks to smaller β^*_y (1mm).
    - Higher luminosity is expected after enough vacuum scrubbing.
  - Integrated L ~ 10 fb^{-1}

- Detector is basically working.
  - The performance is good enough to do physics.
    - Please hear each subdetector talk.
  - The beam background is still high as compared with KEKB/Belle.

    due to lack of vacuum scrubbing time



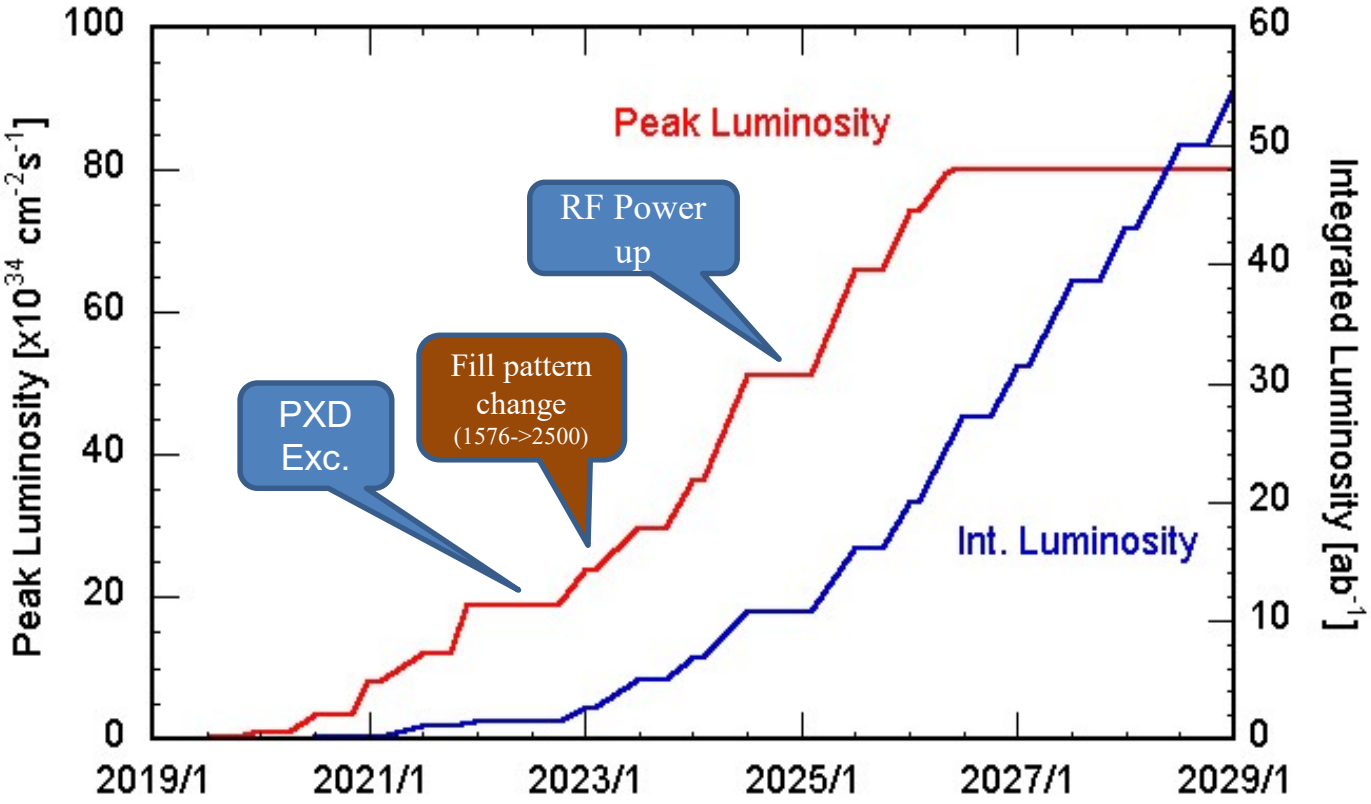
Physics

- Physics capability is documented as following paper.
  - PTEP 2019, no.12 123C01(2019)
  - arXiv:1808.10567
- First physics paper was already submitted to Phys. Rev. Lett.
  - arXiv:1912.11276

Search for an invisibly decaying Z' boson at Belle II in $e^+e^- \to \mu^+\mu^-(e^\pm\mu^\mp)$ plus missing energy final states

- More papers will come soon.

Long term projection

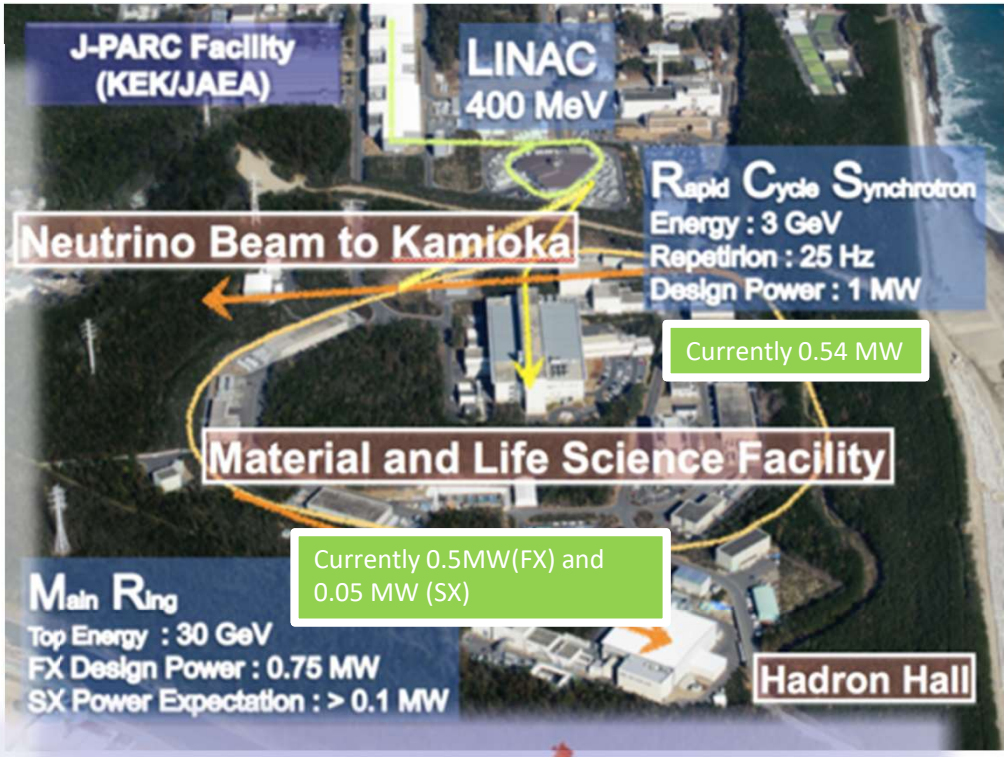


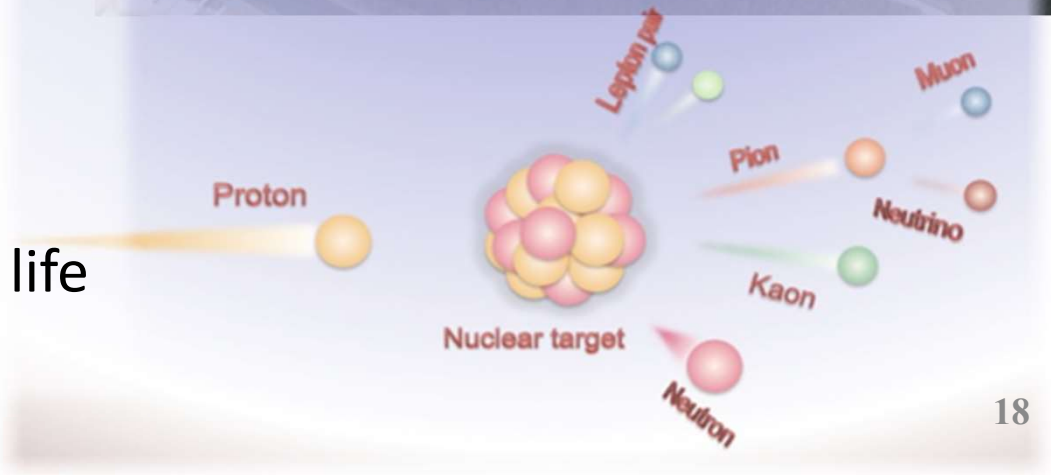
- Luminosity will increase due to more stored beam current(× 6), further squeezing beam at IP (× 3), and better beam-beam tune shift (× 4), after more machine study.
- The beam background will be reduced due to more vacuum scrubbing, more movable masks, more shield near detector and more machine tuning.
- Some upgrades are planed both for detector and accelerator.

J-PARC

J-PARC

- Multi-purpose research facility with hi-intensity proton driver:
  - Particle and Nuclear Physics
  - Material and Life Science
  - ADS R&D
- Jointly operated by two organizations:
  - KEK, and
  - JAEA
- For origin of
  - Matter and Universe
  - Diversity of material and life





T2K experiment

T2K collaboration

Asia	109
Japan	107
Vietnam	2

Europe	265
France	38
Germany	4
Italy	24
Poland	32
Russia	24
Spain	14
Switzerland	29
UK	100

America	102
Canada	31
U.S.A	71

Total 476
(12 countries)

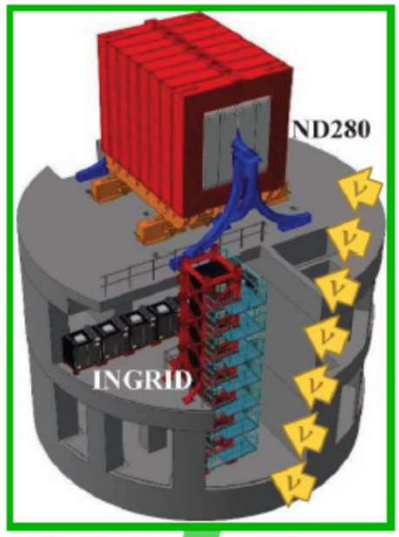
Apr. 2019

T2K experiment

- Long-baseline neutrino oscillation experiment
  - ν mode: 1.78 (+ ~0.2) $\times 10^{21}$ POT
  - $\bar{\nu}$ mode: 1.65 $\times 10^{21}$ POT
- Indication of CP violation at 2σ.

Super-Kamiokande
(ICRR, Univ. Tokyo)

Near detector

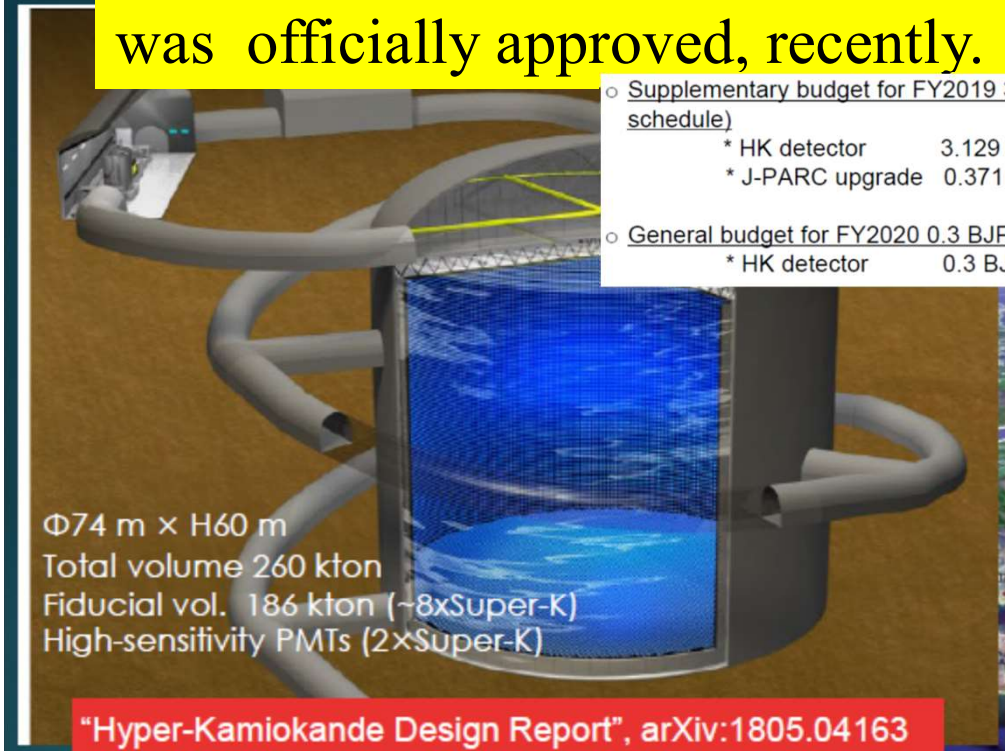


J-PARC Main Ring
(KEK-JAEA, Tokai)

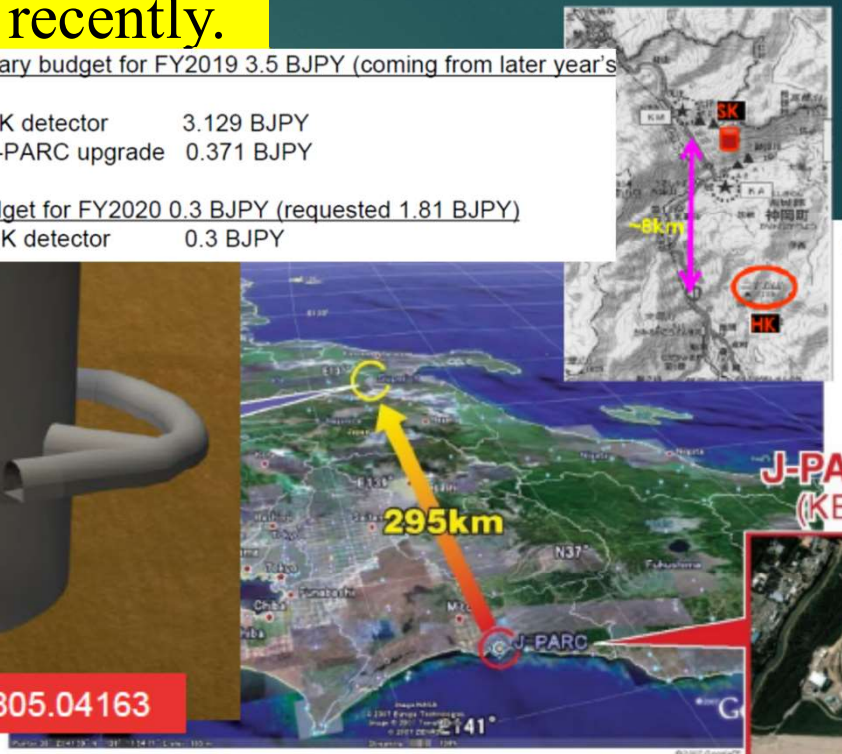
The "Hyper-Kamiokande" project

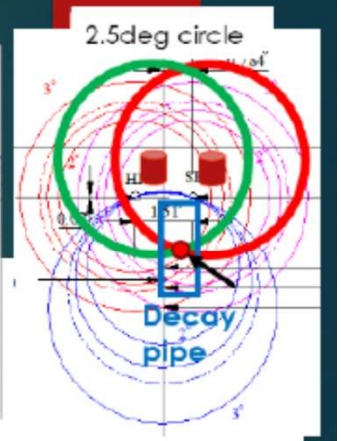
was officially approved, recently.

- Supplementary budget for FY2019 3.5 BJPY (coming from later year's schedule)
  - * HK detector 3.129 BJPY
  - * J-PARC upgrade 0.371 BJPY
- General budget for FY2020 0.3 BJPY (requested 1.81 BJPY)
  - * HK detector 0.3 BJPY



"Hyper-Kamiokande Design Report", arXiv:1805.04163



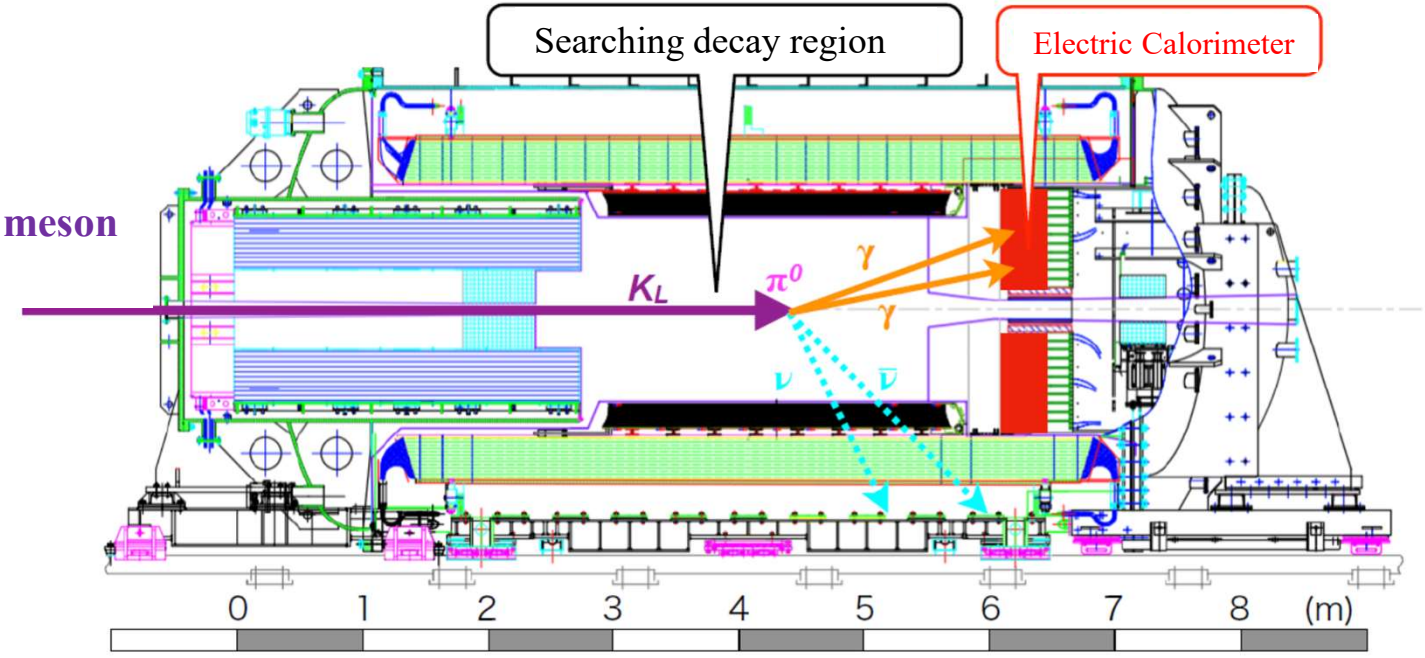


J-PARC Main Ring
(KEK-JAEA, Tokai)

- Construct Hyper-Kamiokande detector (U.Tokyo)
  - 190kt fiducial mass (SK:22.5kt) × 8
  - 40,000 photo sensors
- J-PARC neutrino facility (KEK)
  - Upgrade to 1.3MW J-PARC beam × 2.6
  - Near/intermediate detector complex
- Start construction in 2020 and aim to start operation in 2027

Rare K decay in Hadron hall

- KOTO experiment : $K_L \rightarrow \pi^0\nu\nu$
  - CP violation process and FCNC
  - BR(SM) = 3×10^{-11} : small theoretical uncertainty (~2%)
  - Challenging experimentally
    - Small Br and no charged particles



Results

2015 data

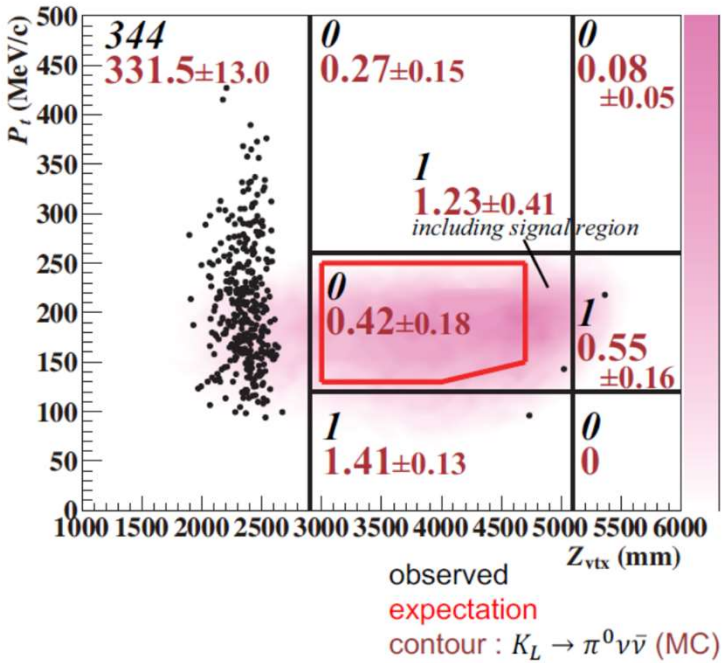
PHYSICAL REVIEW LETTERS 122, 021802 (2019)

Search for $K_L \to \pi^0\nu\bar{\nu}$ and $K_L \to \pi^0 X^0$ Decays at the J-PARC KOTO Experiment

J. K. Ahn,[1] B. Beckford,[2] J. Beechert,[2] K. Bryant,[2] M. Campbell,[2] S. H. Chen,[3] J. Comfort,[4] K. Dona,[2] N. Hara,[5] H. Haraguchi,[5] Y. B. Hsiung,[3] M. Hutcheson,[2] T. Inagaki,[6] I. Kamiji,[7] N. Kawasaki,[7] E. J. Kim,[8] J. L. Kim,[1,†] Y. J. Kim,[9] J. W. Ko,[9] T. K. Komatsubara,[6,10] K. Kotera,[5] A. S. Kurilin,[11,*] J. W. Lee,[5,‡] G. Y. Lim,[6,10] C. Lin,[3] Q. Lin,[12] Y. Luo,[12] J. Ma,[12] Y. Maeda,[7,§] T. Mari,[5] T. Masuda,[7,‖] T. Matsumura,[13] D. Mcfarland,[4] N. McNeal,[2] J. Micallef,[2] K. Miyazaki,[5] R. Murayama,[5,¶] D. Naito,[7,¶] K. Nakagiri,[7] H. Nanjo,[7,**] H. Nishimiya,[5] T. Nomura,[6,10] M. Ohsugi,[5] H. Okuno,[6] M. Sasaki,[14] N. Sasao,[15] K. Sato,[5,††] T. Sato,[6] Y. Sato,[5] H. Schamis,[2] S. Seki,[7] N. Shimizu,[5] T. Shimogawa,[16,¶] T. Shinkawa,[13] S. Shinohara,[7] K. Shiomi,[6,10] S. Su,[2] Y. Sugiyama,[5,¶] S. Suzuki,[16] Y. Tajima,[14] M. Taylor,[2] M. Tecchio,[2] M. Togawa,[5,¶] Y. C. Tung,[12] Y. W. Wah,[12] H. Watanabe,[6,10] J. K. Woo,[9] T. Yamanaka,[5] and H. Y. Yoshida[14]

(KOTO Collaboration)

$$BR_{K_L\to\pi^0\nu\bar{\nu}} < 3.0\times10^{-9}(90\,\%\,\mathrm{C.L.})$$



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2015 data

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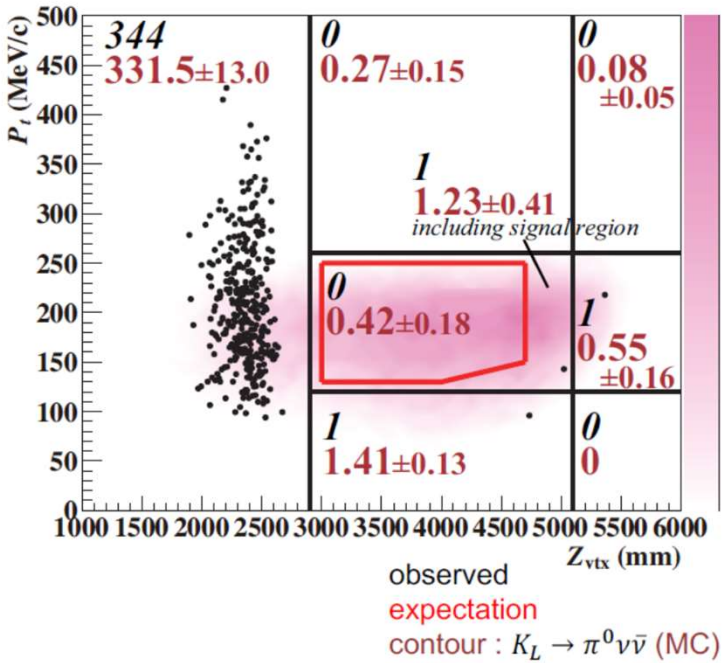
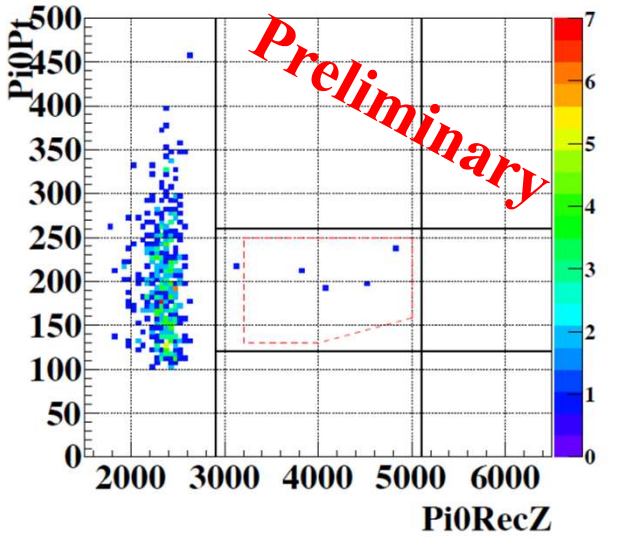


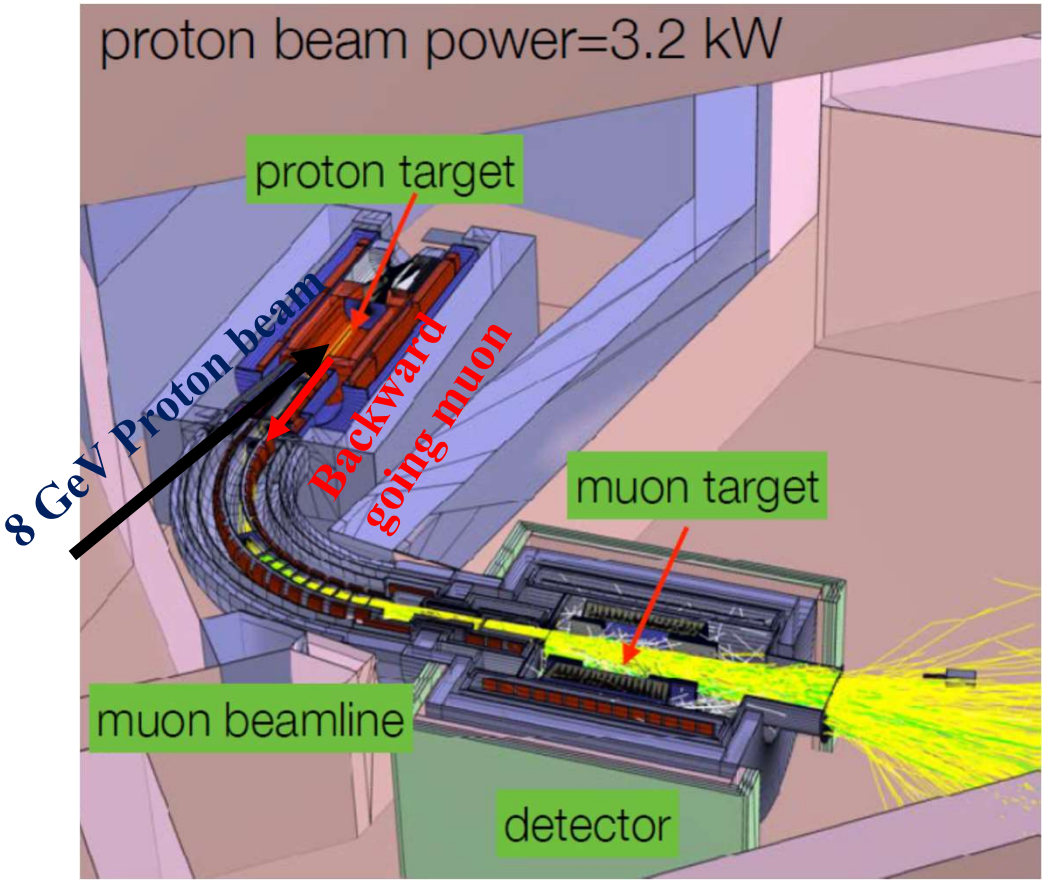
- New data (2016-2018) was unblinded and the preliminary result was presented at KAON2019.
- 4 events were found in the signal box.
- Experimental group is now checking those events carefully and has a plan to investigate the background further with the special setup in coming run period.



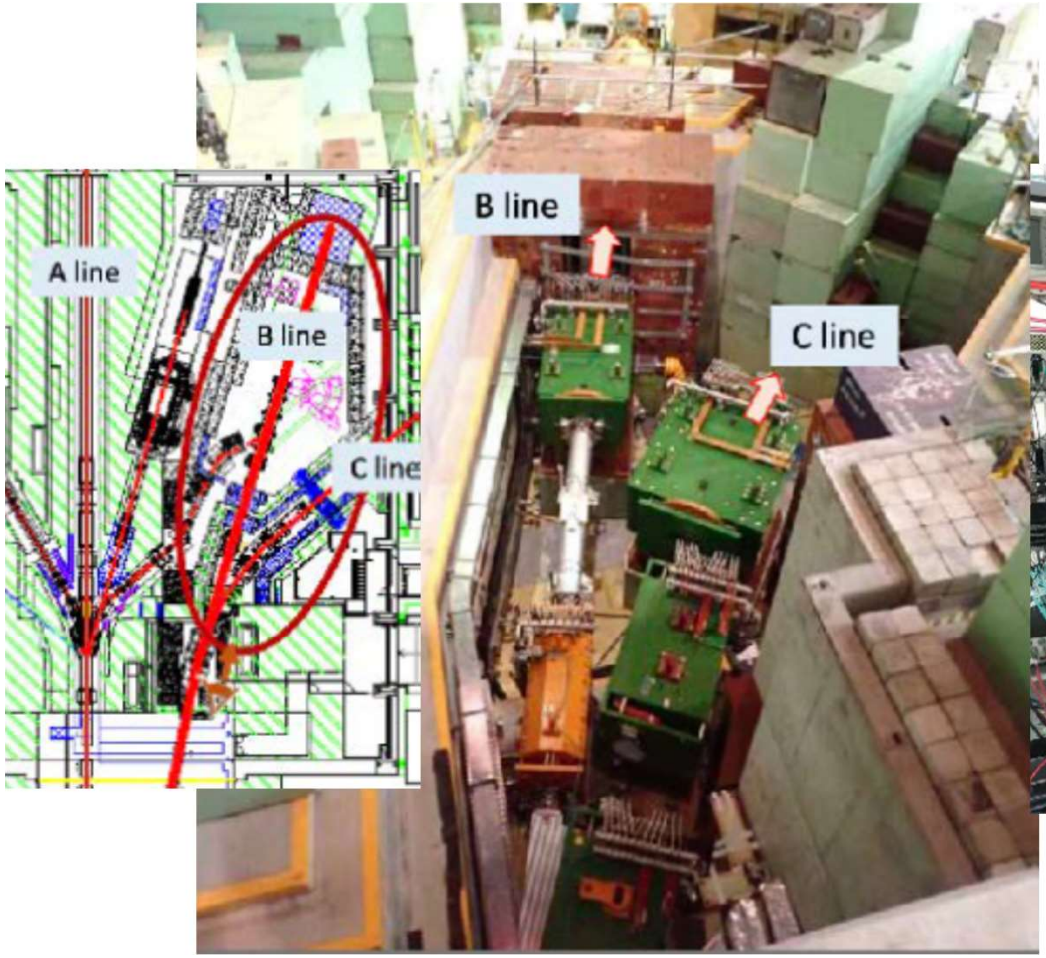
CLFV experiment in Hadron hall

- COMET Phase I experiment : μ → e conversion in a muonic atom
  - Charged Lepton Flavor Violation (CLFV)
  - Current limit < 7×10^{-13} → Aimed sensitivity < 6×10^{-15} × 100 improvement

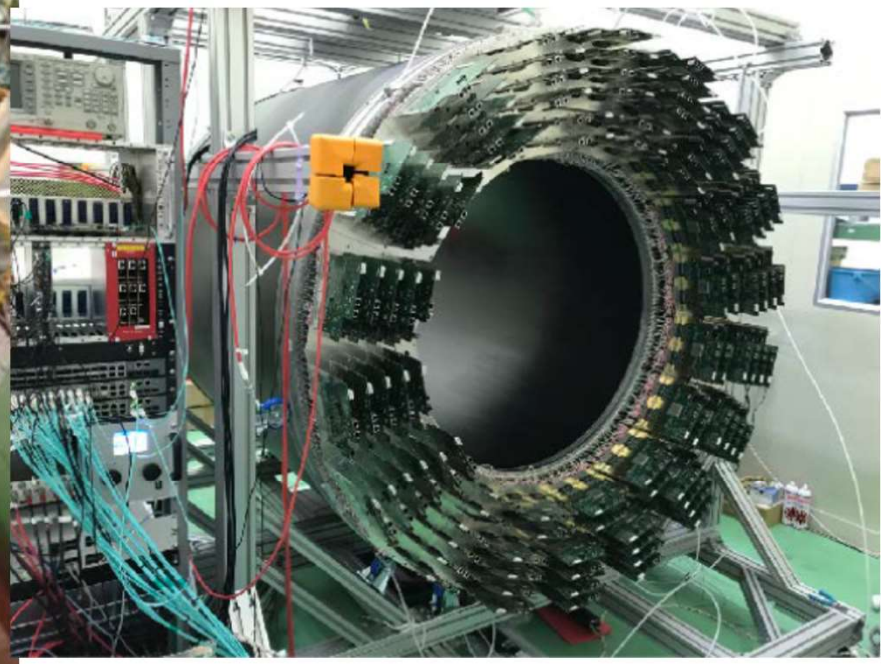
- The time structure (muon decay time) is important to reduce prompt beam background.
  - Small proton extinction was confirmed in the beam test.
- The detector is almost ready.
- Need to construct the proton target and the surrounding equipment.
- The first data taking will start in 2023.



Construction status



Upstream beam line is almost ready.
It will be tested soon.



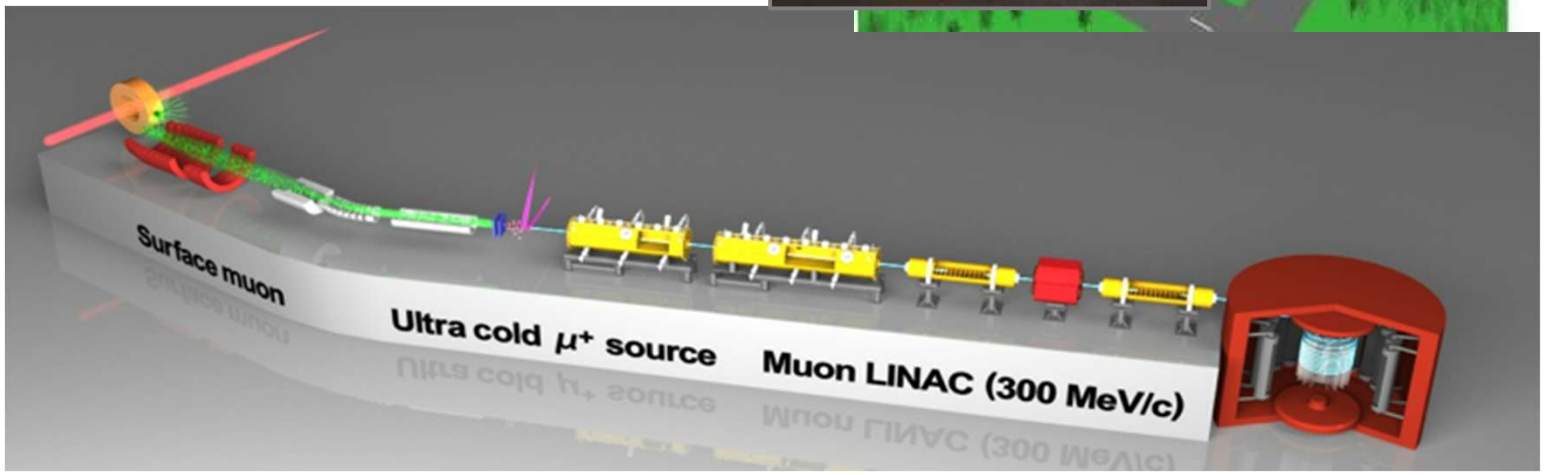
Main tracking detector in Phase I (CyDet) is almost ready.
Comic ray test is underway with full FE electronics.

IPNS supported Particle Physics at MLF

- Sterile Neutrino Search JSNS^2, E56

Data taking will start soon.
The time structure is important
to reduce the background.
25Hz bunch structure

- Muon g-2/EDM, E34



- And neutron fundamental physics, e.g. life, EDM …

Mid-term plan of MR

J-PARC mid-term plan

FX: The higher repetition rate scheme : Period 2.48 s —> 1.32 s for 750 kW.
(= shorter repetition period) —> 1.16 s for 1.3 MW
SX: Mitigation of the residual activity for 100kW

JFY	2017	2018	2019	2020	2021	2022	2023	2024
Event	New buildings		HD target		Long shutdown			
FX power [kW]	475	>480	>480	>480		>700	800	900
SX power [kW]	50	50	50	70		> 80	> 80	> 80
Cycle time of main magnet PS New magnet PS	2.48 s	2.48 s	2.48s	2.48s		1.32 s	<1.32s	<1.32s
High gradient rf system 2nd harmonic rf system								
Ring collimators	Add.collimators (2 kW)				Add.colli. (3.5kW)			
Injection system FX system								
SX collimator / Local shields								
Ti ducts and SX devices with Ti chamber	Ti-ESS-1	(Ti-ESS-2)						

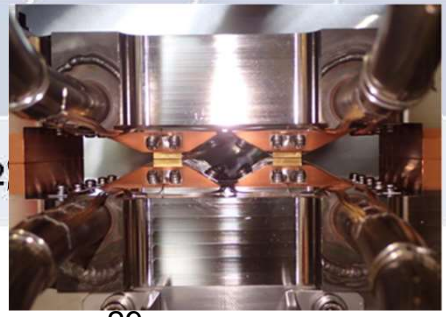
Mass production installation/test

Manufacture, installation/test

Kicker PS improvement, Septa manufacture /test

Kicker PS improvement, FX septa manufacture /test

Local shields



2028

1300

1.16

29

ILC

- International Linear Collider project
  - to study Higgs boson in detail.
- Japanese high energy community wants to host the project.
  - Some diet members strongly support us.
  - MEXT is also interesting in the project.
  - Those people are discussing the cost sharing and so on with US and European counties.
  - But, the cost is so huge. Not so easy to get the green light.

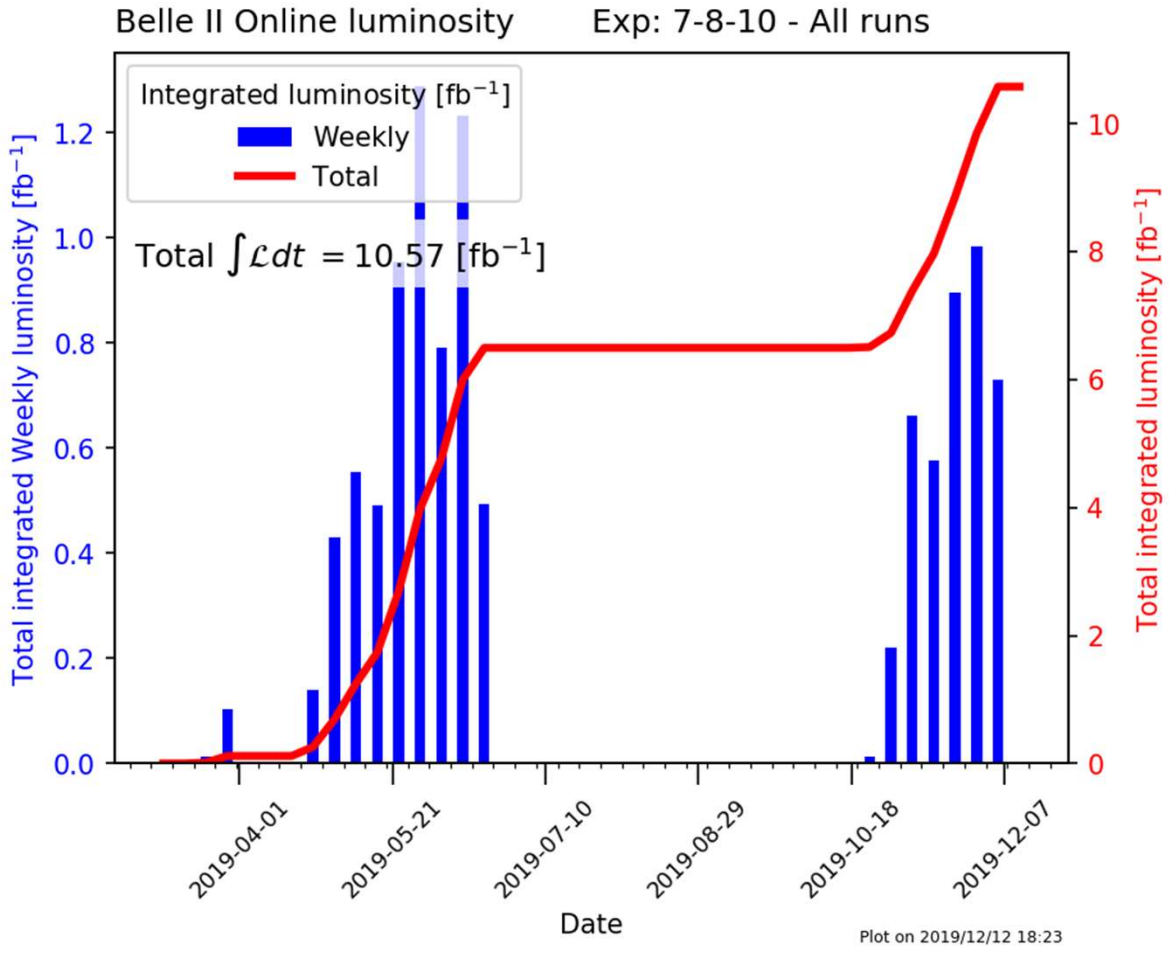
Summary

- KEK/IPNS has various on going projects and plans for flavor physics, energy frontier and others.
- SuperKEKB/Belle II has just started a year ago with full detector.
  - The nano collision scheme is working to get higher luminosity with smaller beam current.
  - Fruitful physics results will come soon.
- J-PARC has been running for 10 years.
  - T2K experiment shows 2σ indication of CP violation in the neutrino sector.
    - Hyper-Kamiokande project was officially approved, recently.
    - Data taking will start in 2027.
  - Several interesting projects are on going and will start soon.
    - Rare Kaon decay, Sterile neutrino search, CLFV experiment (COMET), etc.

Backup

KEK

IPNS is also collaborating with other world-wide institutes for various world top class projects.


Belle II Online luminosity
Exp: 7-8-10 - All runs
Integrated luminosity [fb^{-1}]
Weekly
Total
Total $\int \mathcal{L} dt = 10.57$ [fb^{-1}]
Total integrated Weekly luminosity [fb^{-1}]
Total integrated luminosity [fb^{-1}]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
2019-04-01
2019-05-21
2019-07-10
2019-08-29
2019-10-18
2019-12-07
Date
Plot on 2019/12/12 18:23

More Power at MR → 750 kW → 1.3 MW

More Rapid Cycle:

2.48 s → 1.32 s → 1.16 s

- Main Power Supply to be renewed
- High gradient RF Cavity
- Improve Collimator
- Rapid cycle pulse magnet for injection/extraction

More Protons / Pulse :

- Improve RF Power
- More RF Systems
- Stabilize the beam with feedback