

Mid-Term Plans of J-PARC Accelerator for Neutrinos

T. Koseki

Accelerator Laboratory, KEK
J-PARC Center, KEK&JAEA

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**J-PARC Facility
(KEK/JAEA)**

**LINAC
400 MeV**

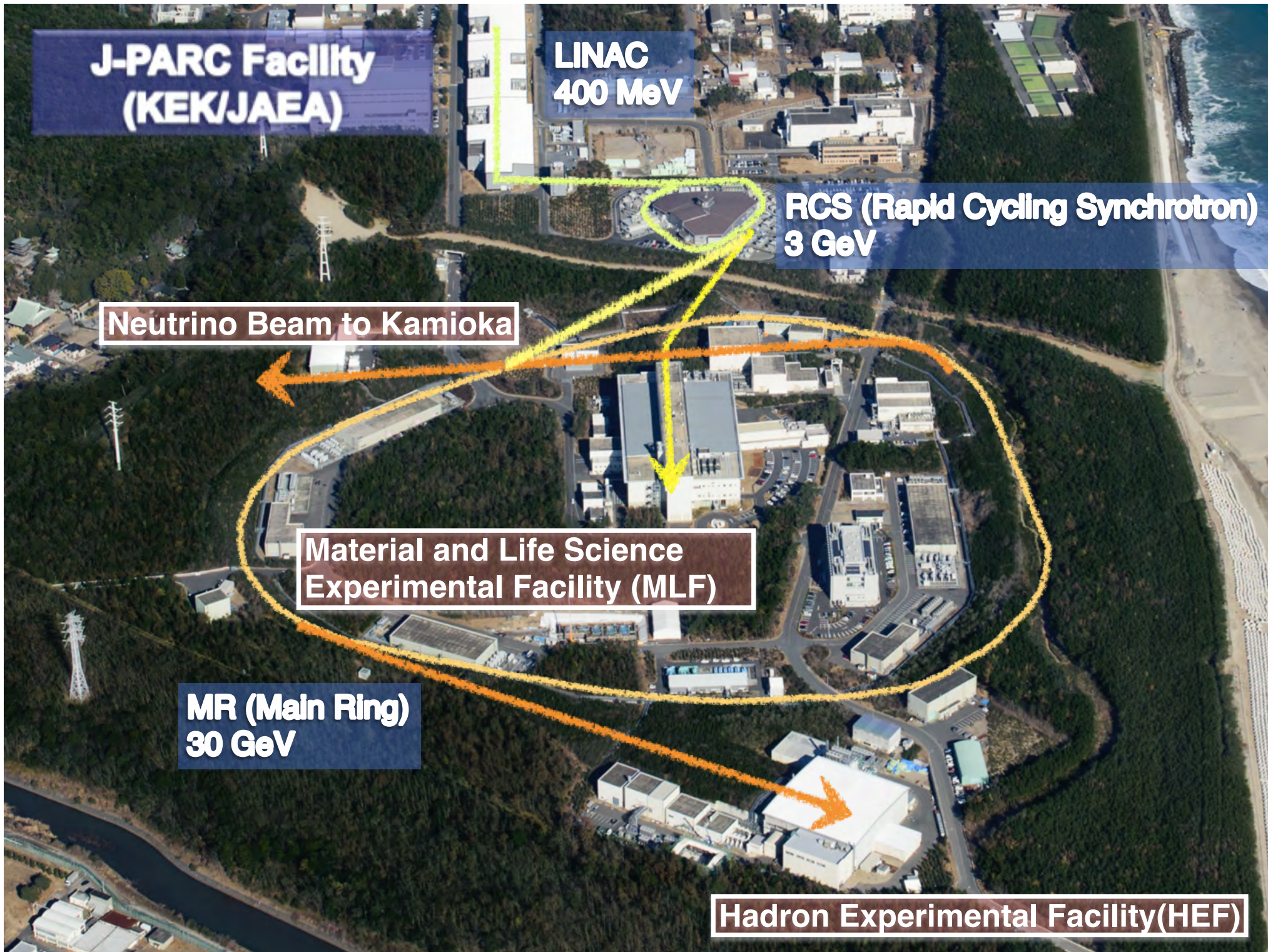
**RCS (Rapid Cycling Synchrotron)
3 GeV**

Neutrino Beam to Kamioka

**Material and Life Science
Experimental Facility (MLF)**

**MR (Main Ring)
30 GeV**

Hadron Experimental Facility(HEF)



Neutrino Beamline and T2K experiment

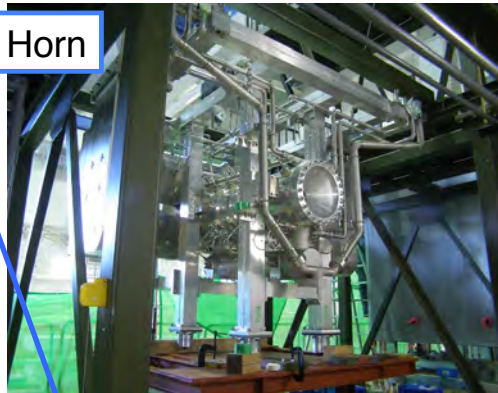
Neutrino monitor bld.



Super-Kamiokande
(ICRR, Univ. Tokyo)



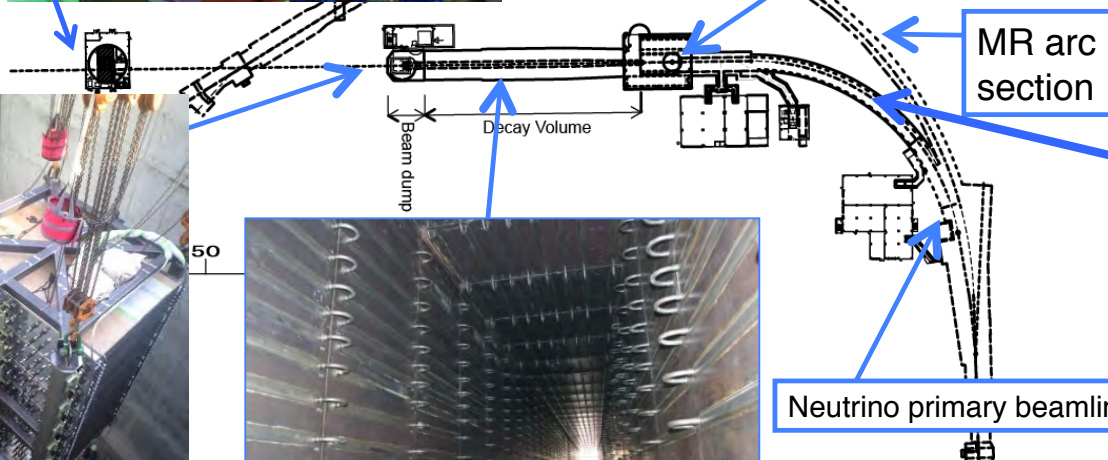
Horn



Target



Main R



Combined function
superconducting magnet



Beam dump

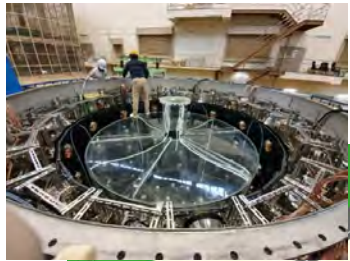


Decay volume

Neutrino primary beamline

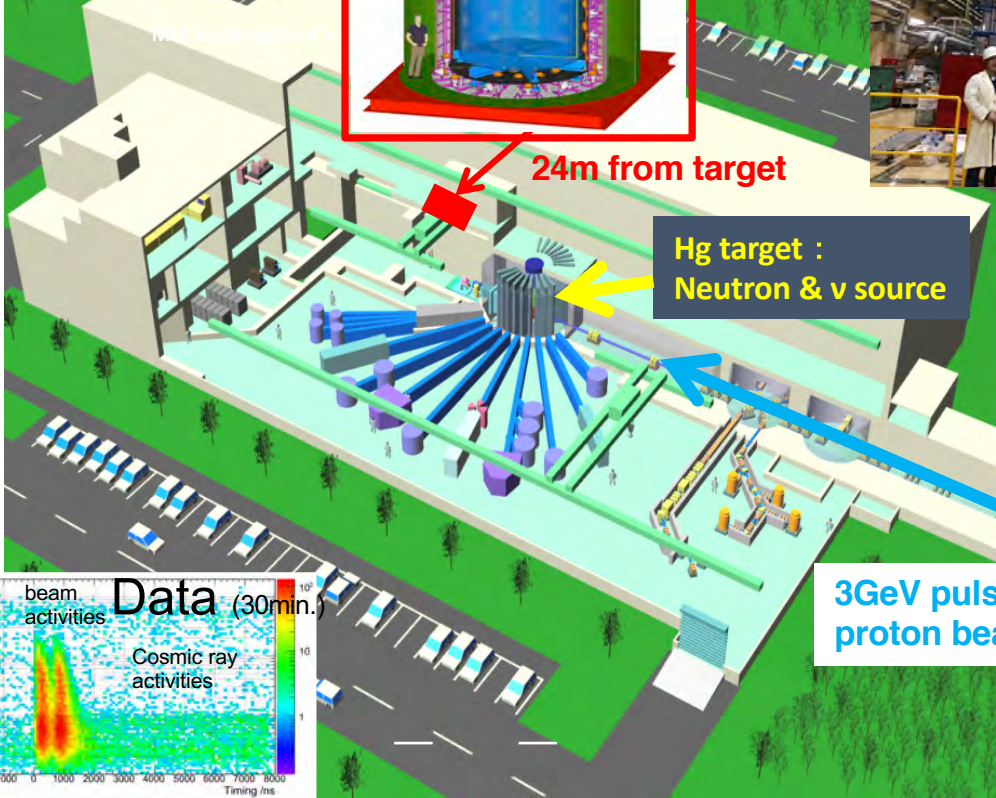
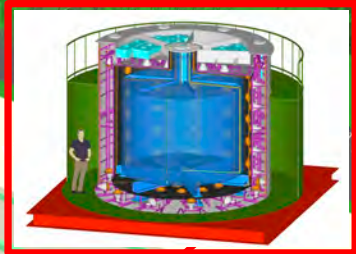
T2K excluded $\theta_{13}=0$ at 7.3σ level of significance in 2014.
 First observation of ν_e appearance from ν_μ beam.
 → Next target is CP-violation discovery in neutrino sector.

JSNS² experiment : Search for sterile neutrino

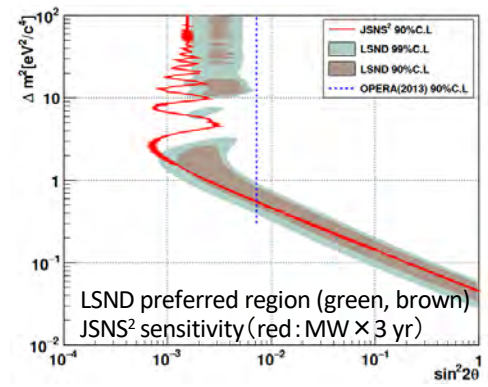
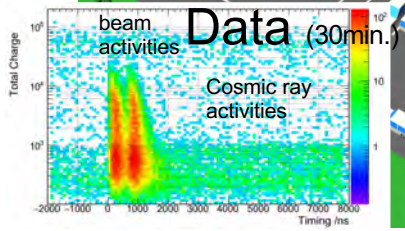


50 ton liquid scintillator + ~120PMTs

First data taking @ MLF (2020/June)



JSNS2 experiment searches for sterile neutrino in the region implied by LSND (90%CL, 1 MW \times 3 yr)

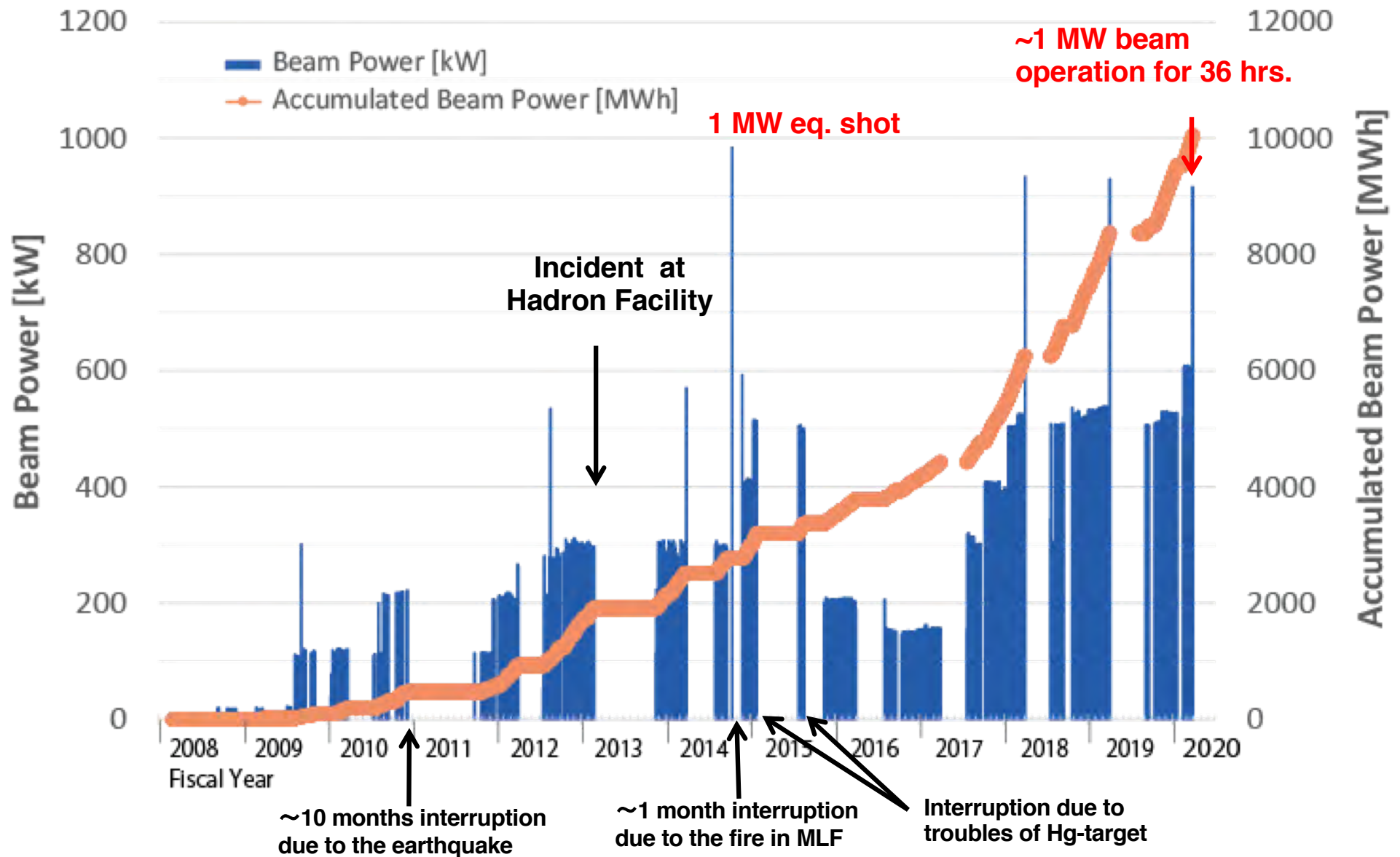


Short-baseline neutrino oscillation $\nu_\mu \rightarrow \nu_e$ is studied by a liquid scintillator detector at 24 m from the source.

- Data taking was started from June 2020 (0.8% of approved POT)

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Beam Power History at MLF

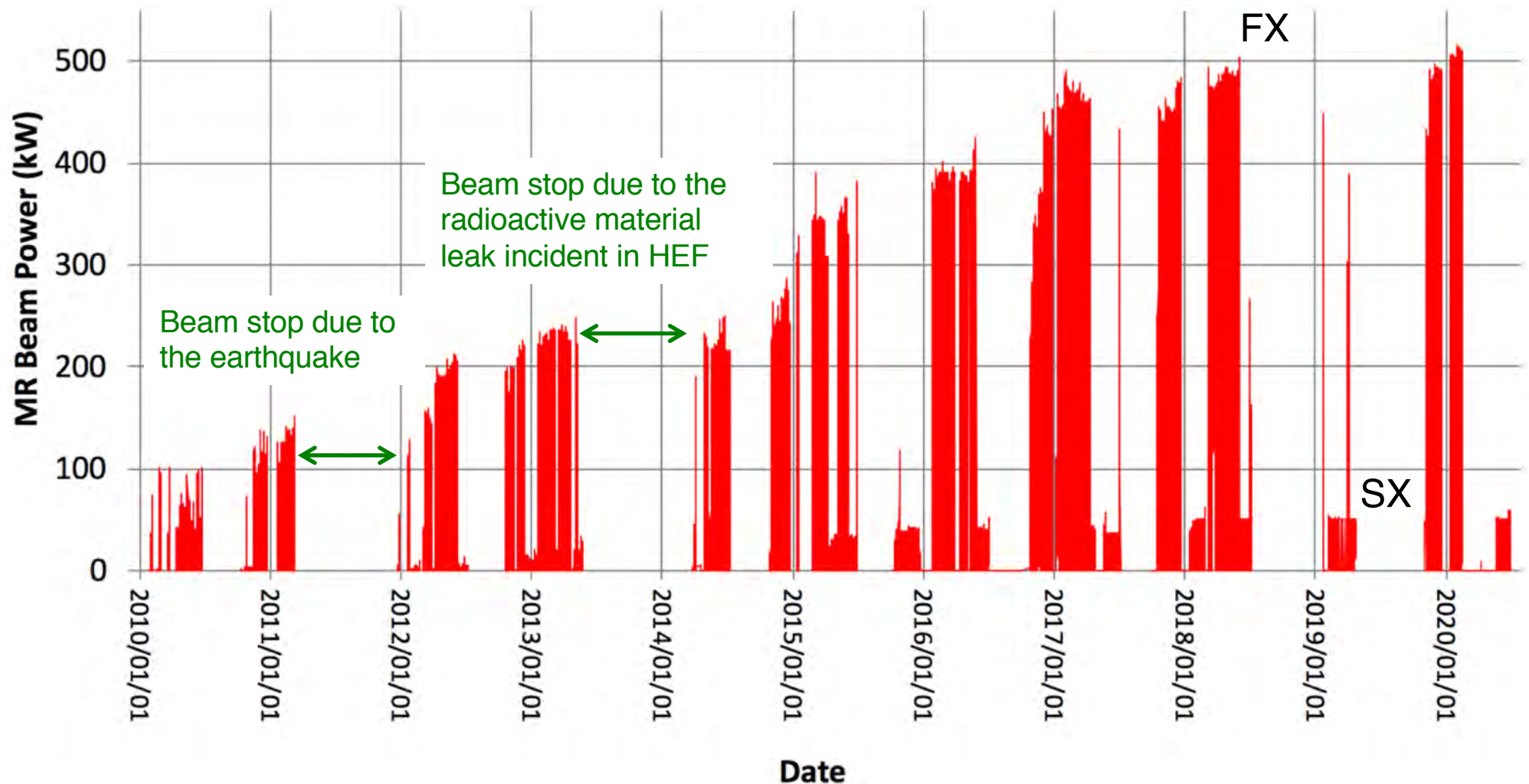


as of June 27, 2020

Accelerator is ready to start 1 MW operation for MLF.

Beam power history of MR

As of June 27, 2020



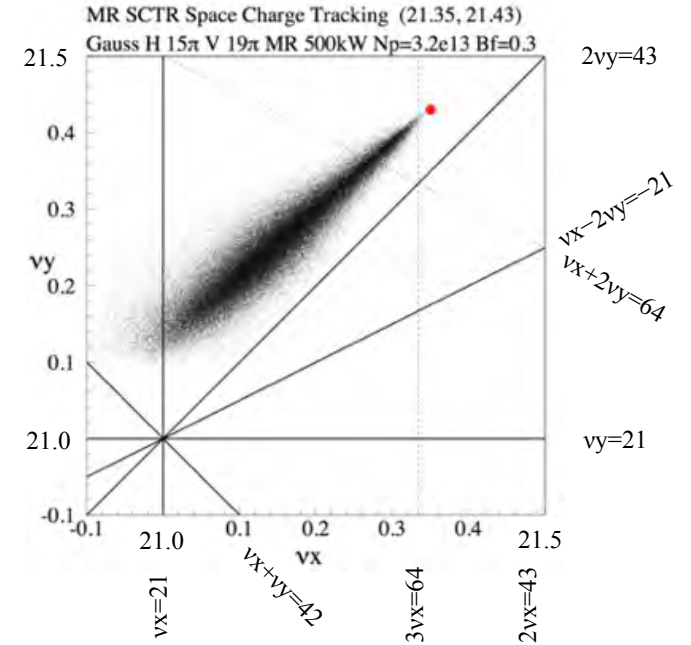
Max. beam power :

Fast extraction ~ 515 kW (2.66×10^{14} ppp), the world highest ppp in synchrotrons.

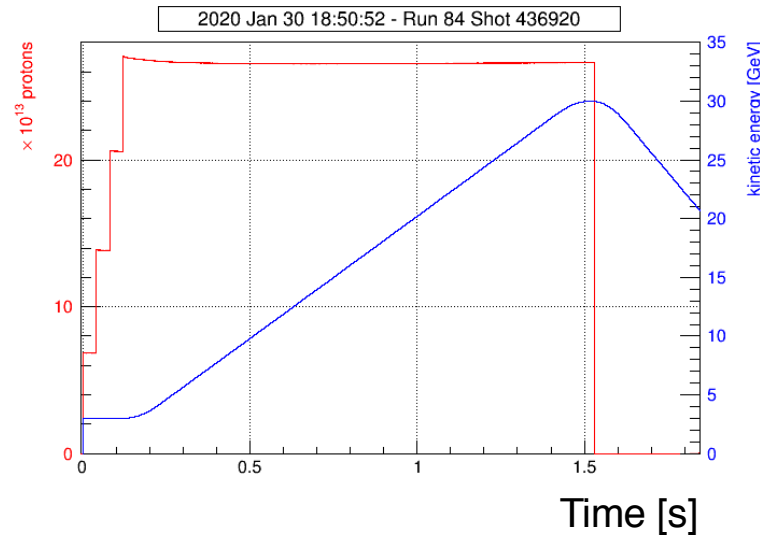
Slow extraction ~ 51 kW (5.5×10^{13} ppp) for users with the world highest extraction efficiency of 99.5 %, ~ 60 kW for demonstration.

FX operation with high power beam

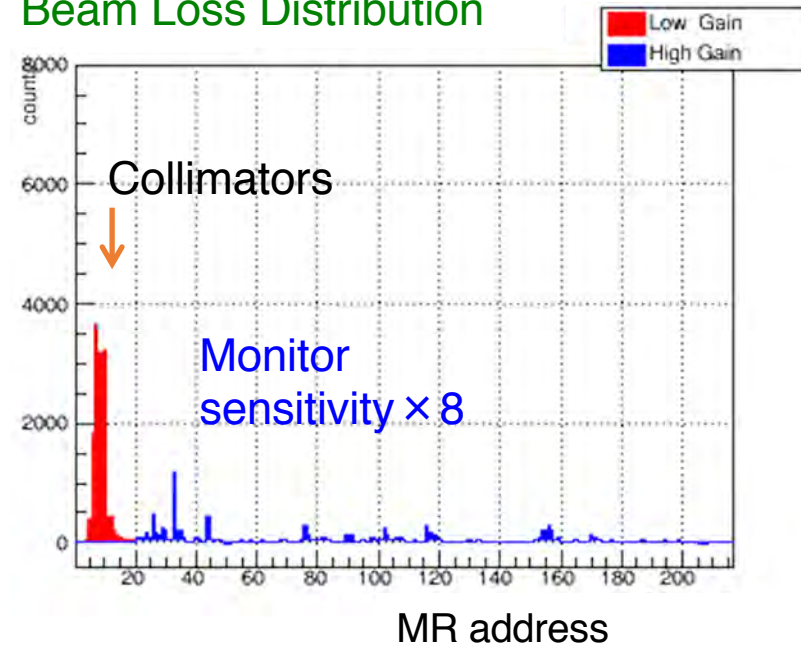
- Beam Power : 515 kW
- Number of extracted protons : 2.66×10^{14} ppp
- Beam Loss in MR : ~ 800 W < Collimator Capacity (2 kW)
- Beam Loss in 3-50BT collimator :
 ~ 100 W < Collimator Capacity (2 kW)



Beam Intensity



Beam Loss Distribution

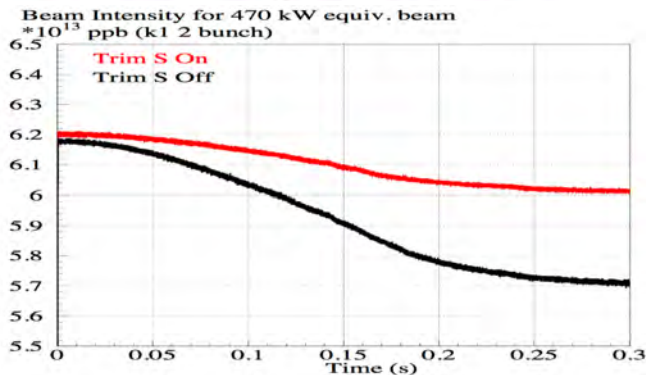
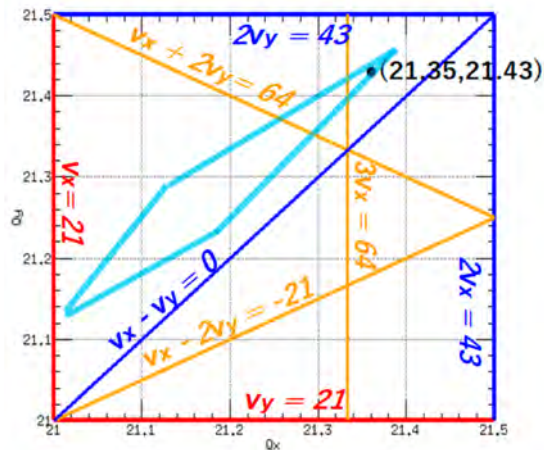


FX operation with high power beam(cont'd)

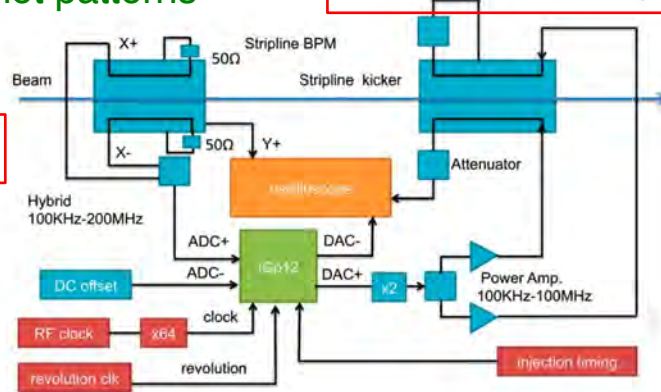
For the high power routine operation

- 3rd order resonance correction
- 2nd harmonic rf voltage
- Tune optimization at injection/acceleration
- Optimization of chromaticity correction pattern
- Intra-bunch feedback for trans. instabilities
- Optimization of octupole magnet patterns
- ...etc.

3rd order resonance correction

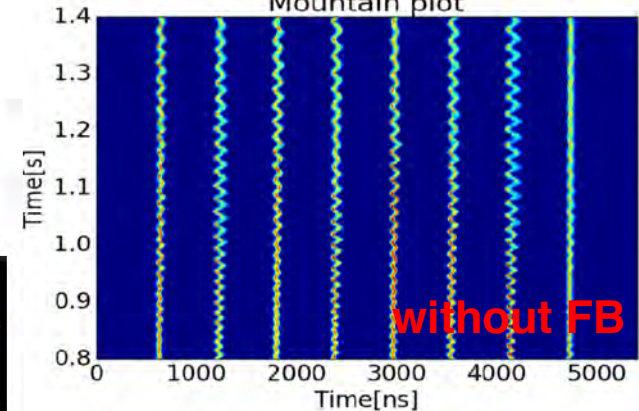


Intra-bunch FB system



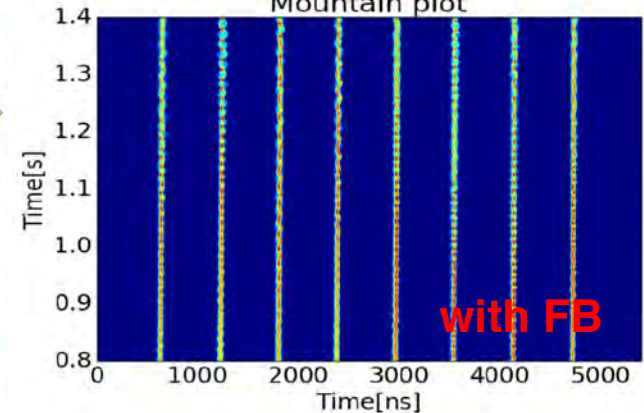
Suppression of CBI by rf feedback system

Bunch Oscillation (480 kW) Mountain plot



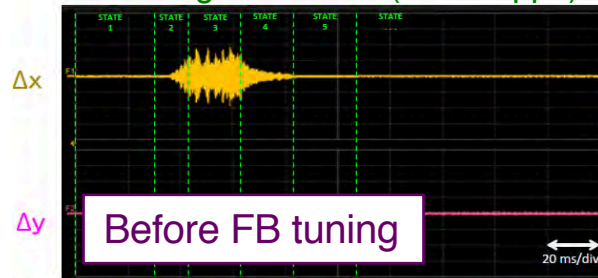
without FB

Mountain plot

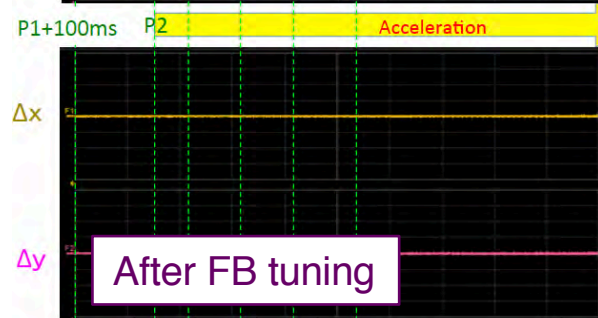


with FB

Delta signal of BPM (2.4e13 ppb)



Before FB tuning



After FB tuning

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Mid-term plan of MR

High rep. rate operation

FX cycle time : 2.48 s for 500 kW → 1.30 s for > 750 kW → 1.16 s for 1.3 MW

JFY	2017	2018	2019	2020	2021	2022	2023	2024
Event	New buildings →		HD target		Long shutdown			
FX power [kW]	475	500	500	500		>700	800	900
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			Mass production/installation/test		→			
2 nd harmonic rf system			Manufacture, installation/test		→			
Ring collimators	Capacity 2 kW				Capacity 3.5kW			
Injection system			Kicker PS improvement, Septa manufacture /test		→			
FX system			Kicker PS improvement, FX septa manufacture /test		→			
BPM Circuits			→					
Intra-bunch feedback system			→					

The long shutdown from July 2021 to September 2022 for high rep. rate operation is planned. Some of magnet power supplies and FX septa will be replaced, and second harmonic RF systems and collimators will be reinforced.

Power upgrade scenario for FX

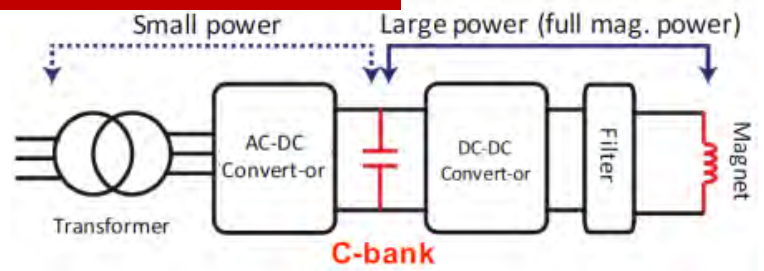
	Beam Power	Cycle Time	Number of accelerated protons	Equivalent beam power in RCS
Achieved	500 kW	2.48 s	2.6×10^{14} ppp	780 kW
Original design power	750 kW	1.32 s	2.1×10^{14} ppp	610 kW
Goal	1.3 MW	1.16 s	3.3×10^{14} ppp	1 MW

- Factor 2 gain by shorter cycle time
- 30% gain by ppp increasing

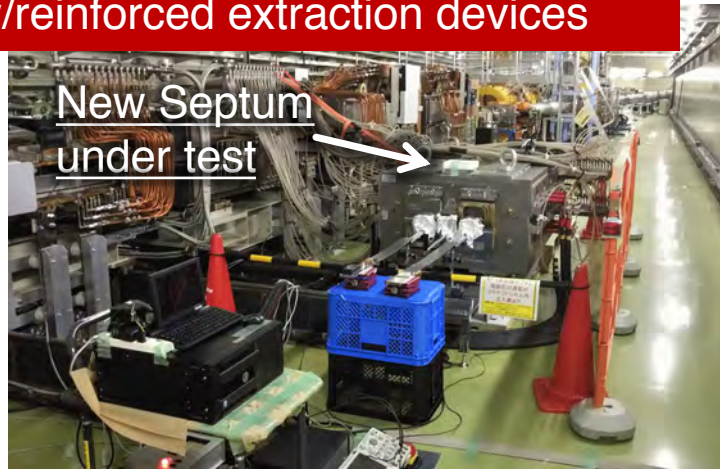
Reinforcement of rf system



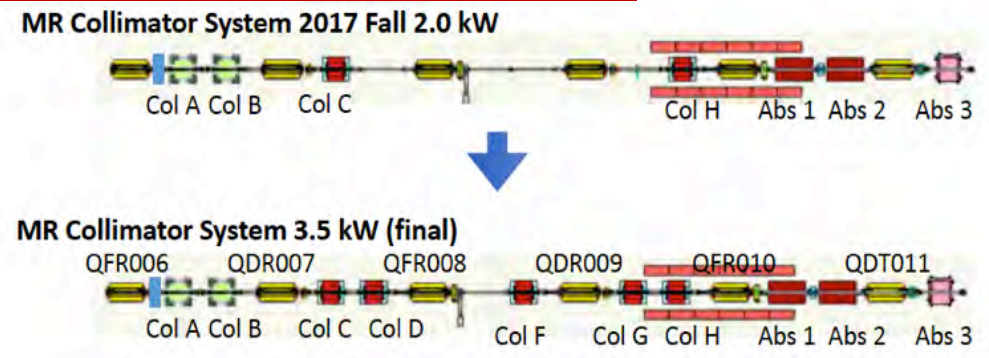
New main magnet power supplies



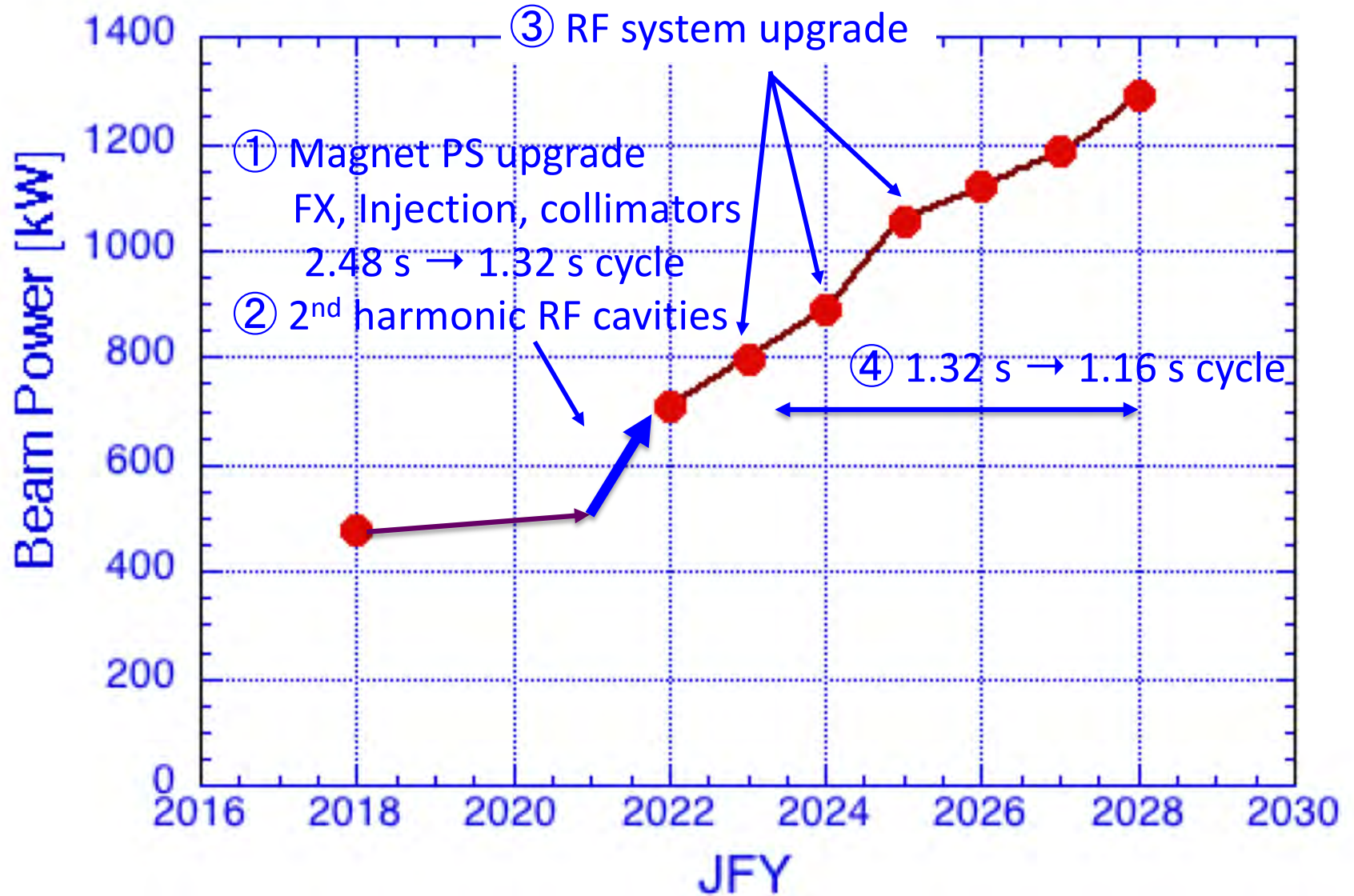
New/reinforced extraction devices



Upgrade of collimator capacity



Expected beam power for FX

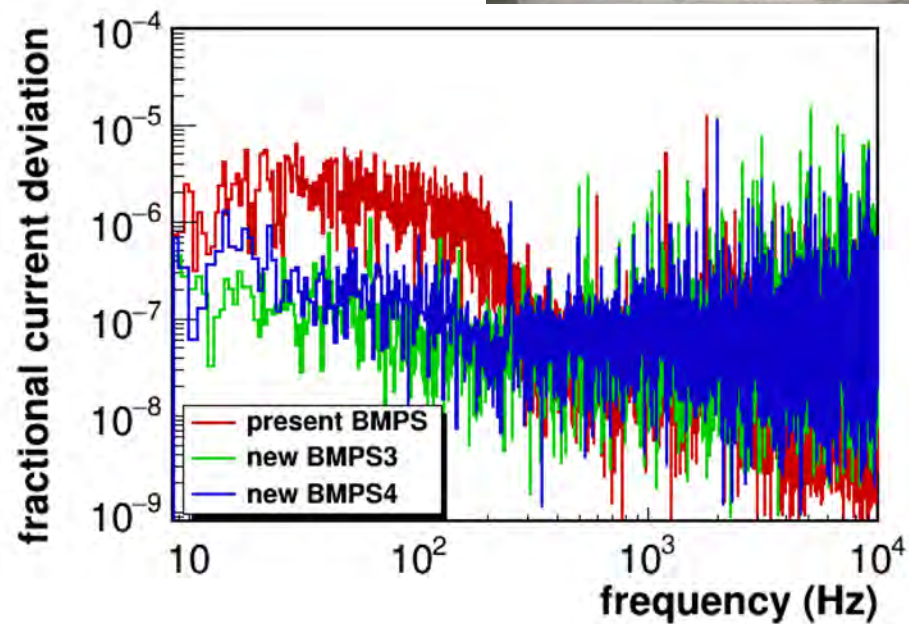
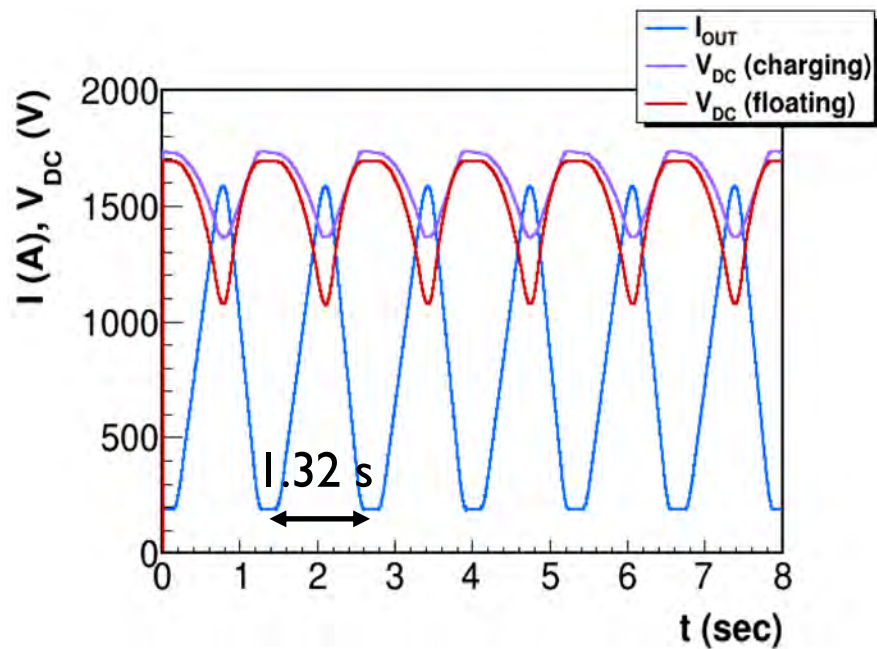


New power supply for high repetition rate operation

- Construction of new three buildings for the PS's has been completed.
- Mass production of the PS's is in progress.



Test results with a real magnet family



Reinforcement of rf System

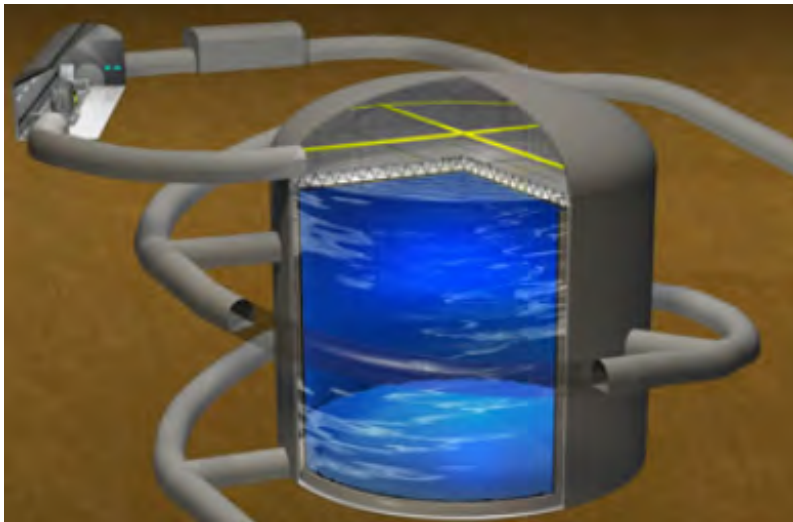
- Two 2nd harmonic cavities
- Two fundamental cavities
- Upgrade of anode power supplies for beam loading compensation

	2019	2021	2027
MR cycle time	2.48 s	1.32 s	1.16 s
Fundamental cavities	7	9	11
2 nd harmonic cavities	2	2	2
Acc. voltage	300 kV	510 kV	600 kV
2 nd harm. voltage	110 kV	110 kV	110 kV



The upgrade plan of rf system after 2021 is a part of the Hyper-Kamiokande project, which is approved by the Japanese government in JFY 2019.

Hyper-Kamiokande



The Hyper-Kamiokande project

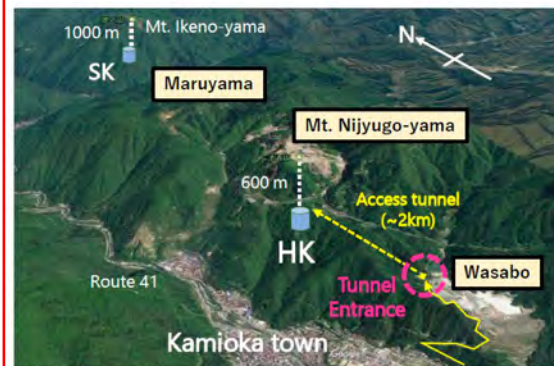
- Construction of Hyper-Kamiokande
- J-PARC beam power upgrade and construction of Intermediate Water Cerenkov Detector

Operation will start 2027.

T. Kobayashi

Hyper-Kamiokande:
190 kton Water Cerenkov detector
With new PMTs have x2 better
photon sensitivity

Entrance yard construction in Kamioka cite



Construction of entrance yard in Wasabo was completed.

Construction of the waste water treatment facility at the entrance yard has started.



Summary

The RCS is delivering 600 kW beam for MLF users.

The design power 1 MW will be started within the next few years with new Liq.-Hg targets.

The JSNS² experiment started data taking from June 2020.

MR delivers 515 kW beam for T2K.

The long shutdown and upgrade for high-rep rate operation are scheduled from July 2021 to Sep. 2022.

The Hyper-Kamiokande project has been approved by the government in JFY2019 and launched.

The beam upgrade plan of MR from 750 kW to 1.3 MW is a part of the Hyper-Kamiokande project.

Manufacturing of the RF systems for 1.3 MW operation started in JFY2020.