J-PARC Accelerator and Neutrino Beamline Upgrade Program

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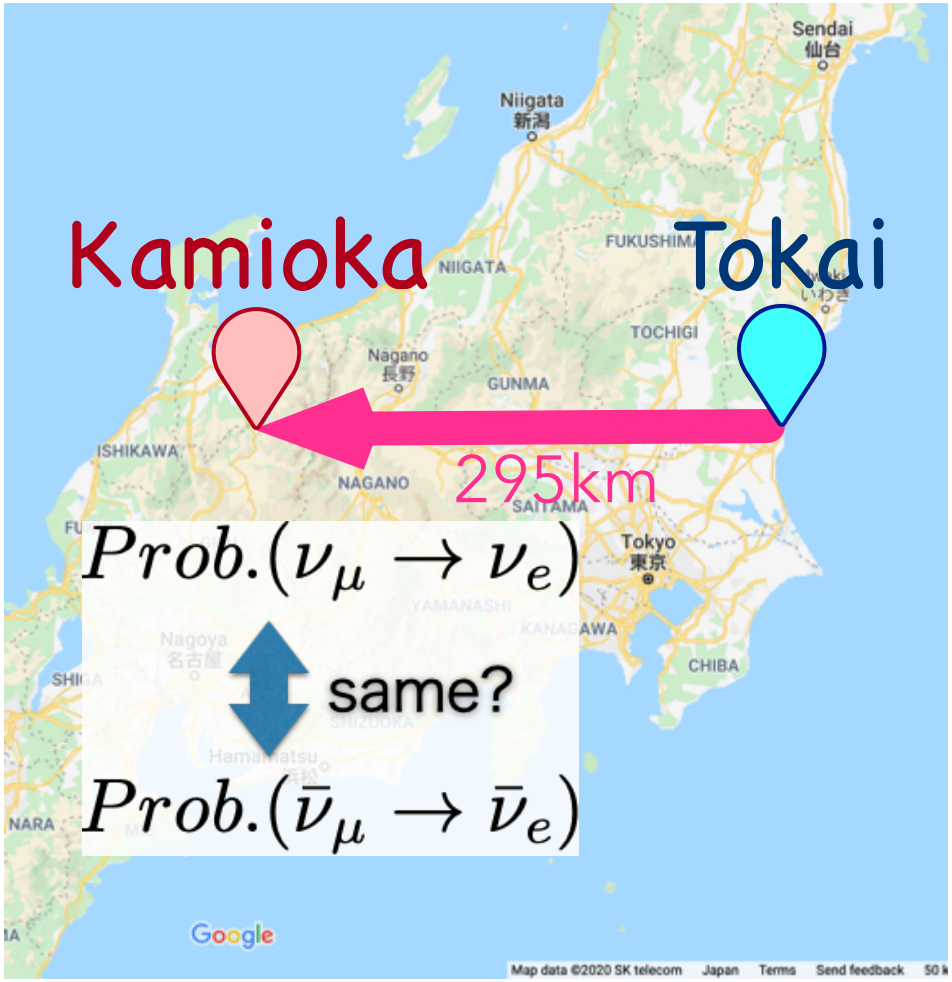
on behalf of the J-PARC neutrino facility group

The XXIX International Conference on
Neutrino Physics and Astrophysics
Neutrino 2020, June 29, 2020

Accelerator-based long-baseline neutrino oscillation experiments at Japan

Main physics target is CP violation in neutrino oscillation



T2K

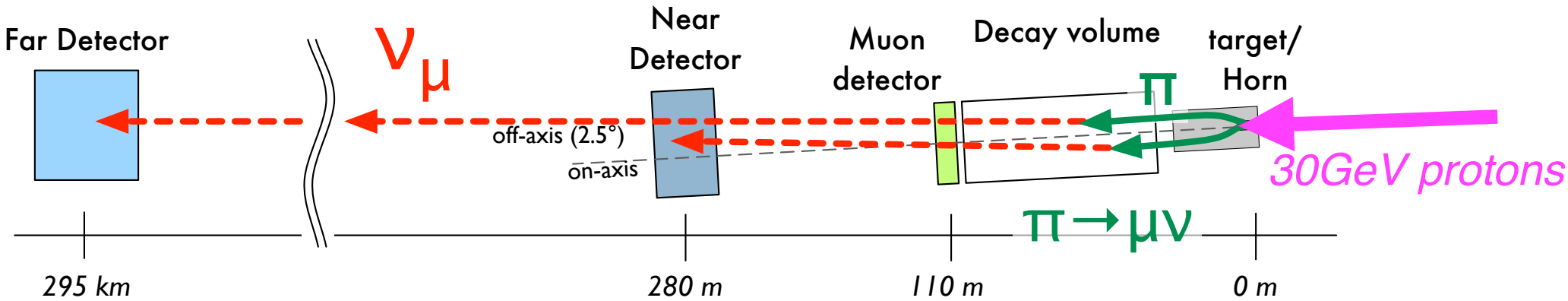
- Recently, T2K results showed a hint of large CP violation
  DOI:10.1038/s41586-020-2177-0
- Latest results will be shown at July/ 2nd Session
- Upgrade of beam and near detector is in progress

Hyper-Kamiokande (data taking 2027~)

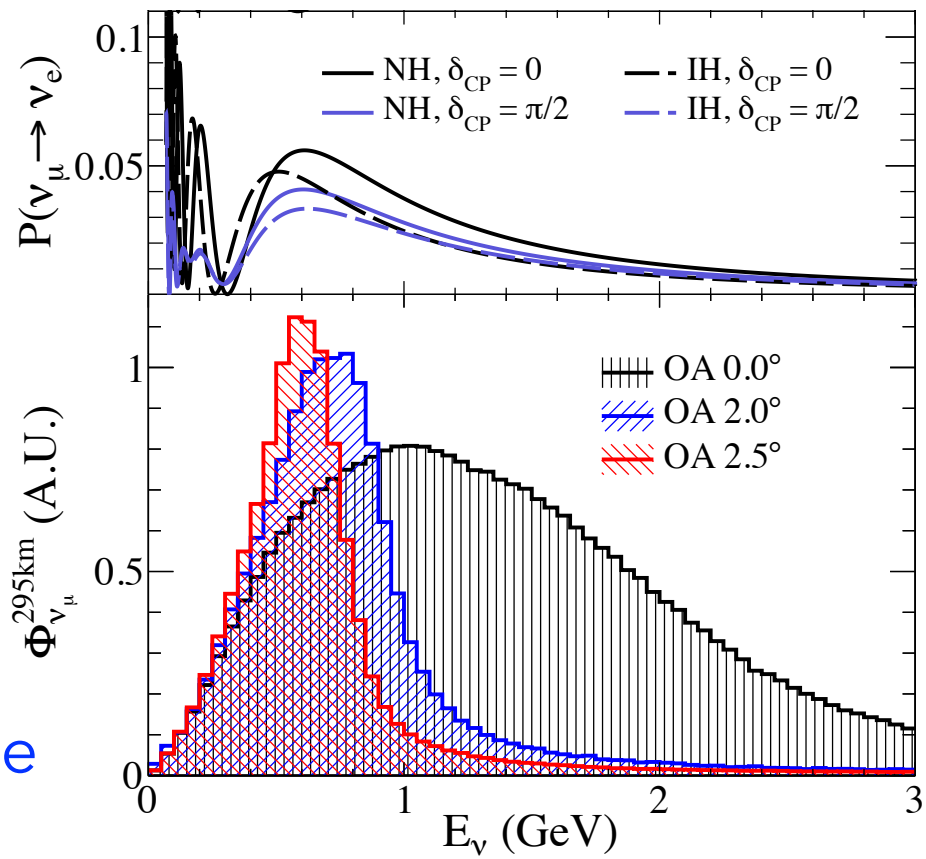
M.Ishitsuka will discuss in next talk

High intense neutrino beam is essential to study $\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$

High intense neutrino beam for T2K and HK



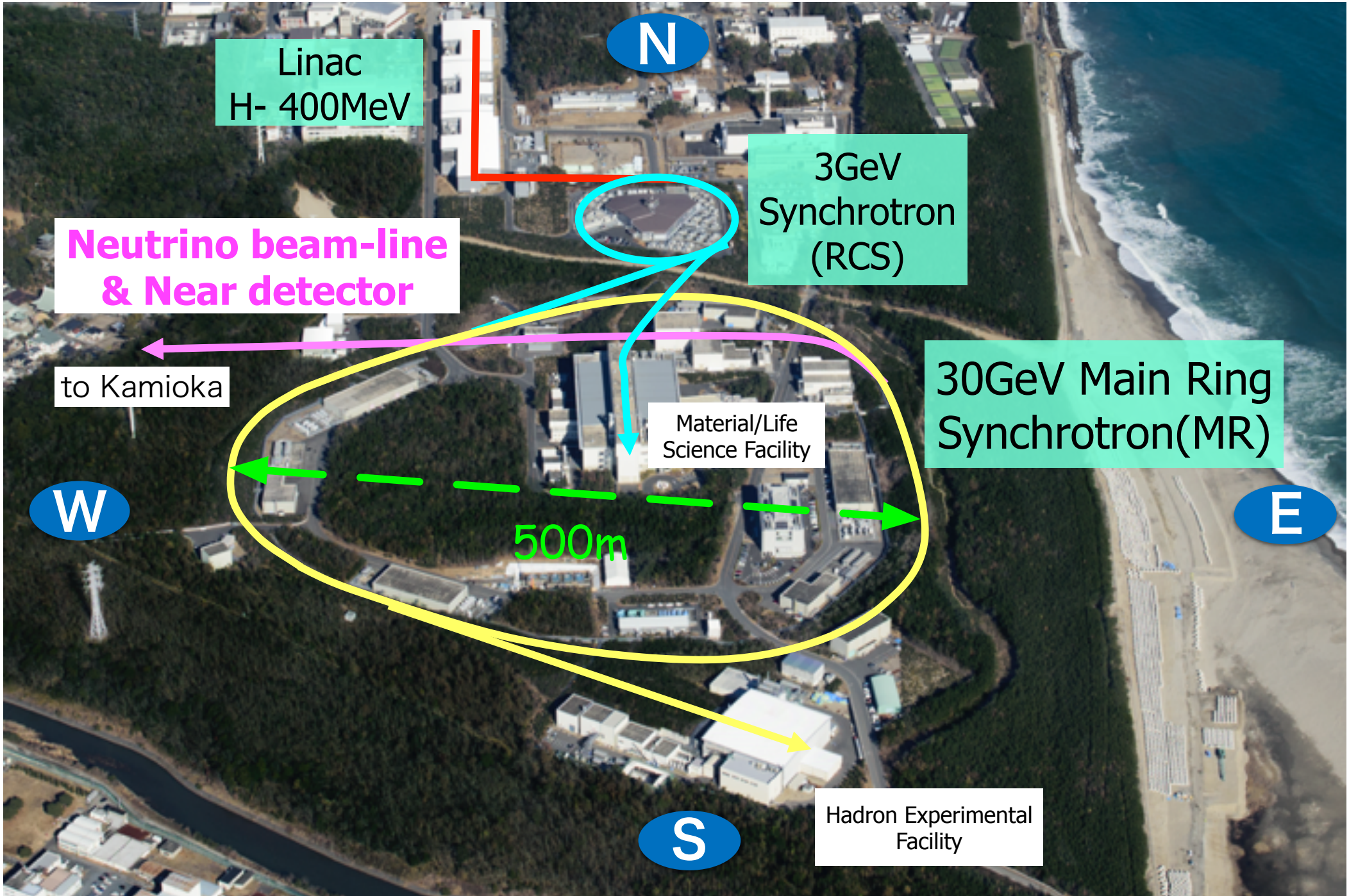
- ν energy is narrow with off-axis method
  L = 295km → oscillation peak at 0.6GeV
- small ν_e contamination (~1%)
- ν / $\bar{\nu}$ can be switched by flipping horn polarity



Key points:

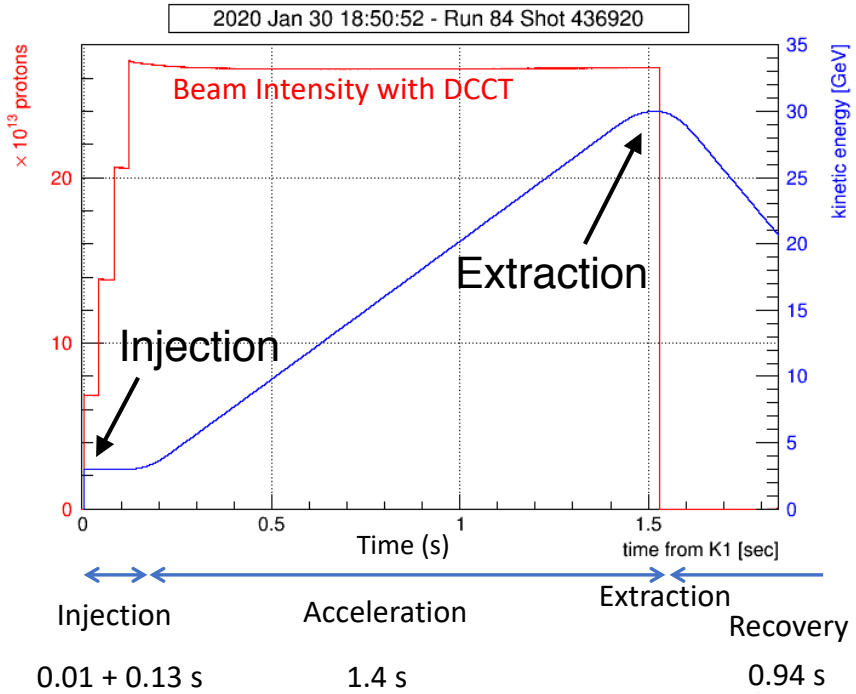
- ~Mega-Watt class proton driver
- Neutrino beamline which can handle the high intense beam

J-PARC accelerators at Tokai

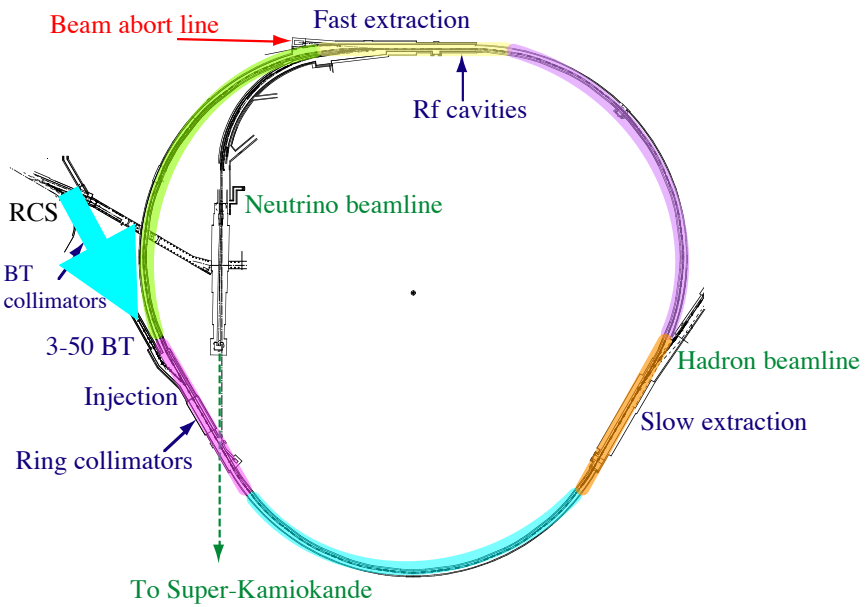


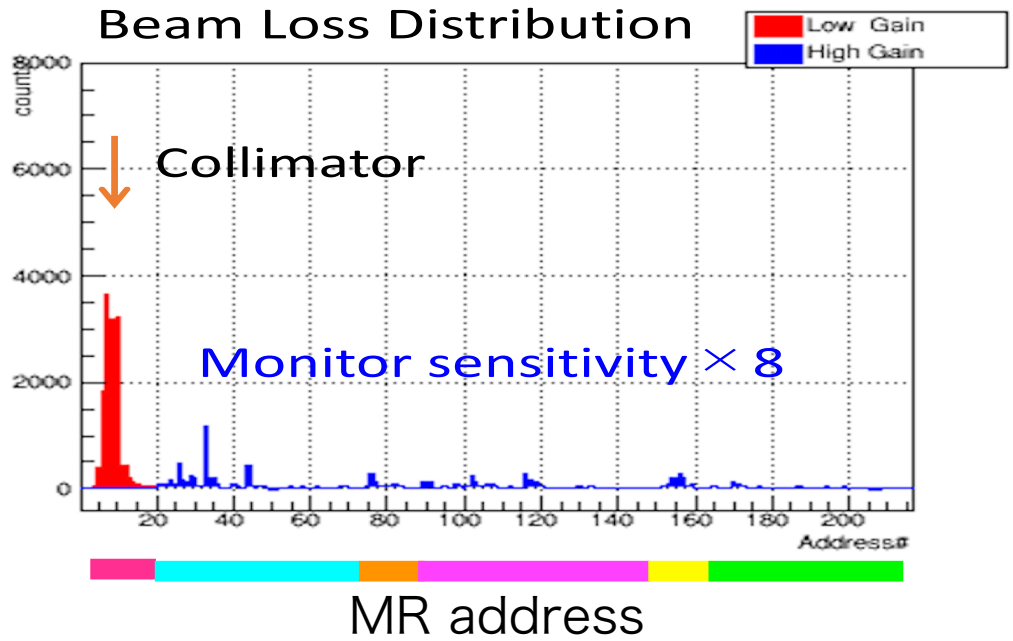
Status of MR operation

- Stable operation at 515kW w/ 2.48sec repetition has been achieved
  - 3.4×10^{13} protons per bunch (ppb) x 8 bunch at injection (=2.72×10^{14} protons per pulse(ppp))
  - 2.66×10^{14} ppp at the end of acceleration (~2% loss)



Minimizing and localizing of beam loss is critical to keep availability of maintenance





- **Sufficient localization and reasonable size of loss have been achieved.**
- **Further reduction of beam loss is in progress with beam dynamics study etc.**

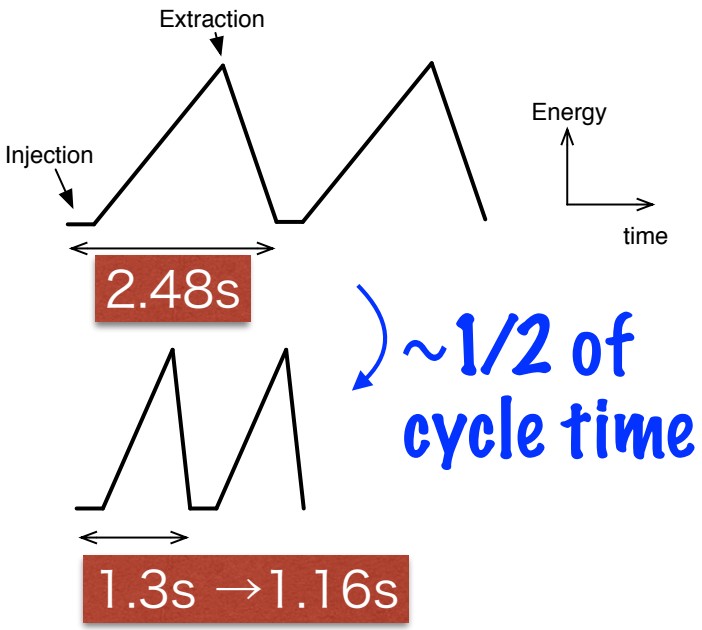
How can we increase beam power ?

Power ∝ 30GeV x # of protons x $1/T_{rep.}$

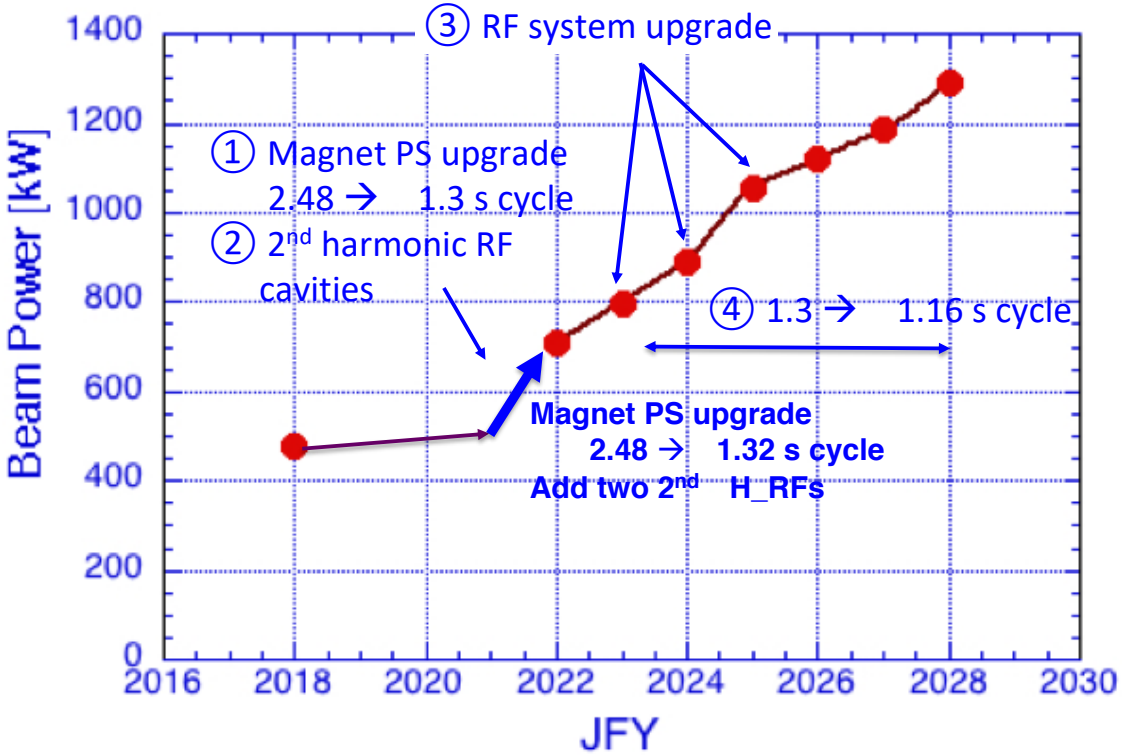
now 0.5MW 2.5×10^{14}

target 1.3MW 3.2×10^{14}

+30% protons per pulse



❖Upgrade of magnet power supply and RF



❖Also, upgrade of

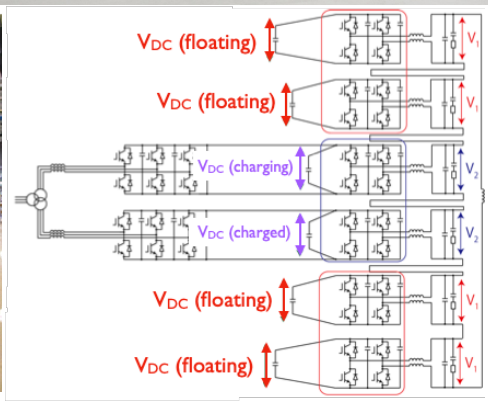
- Collimators
- Beam dump
- Inj./Ext. devices
- Beam monitors

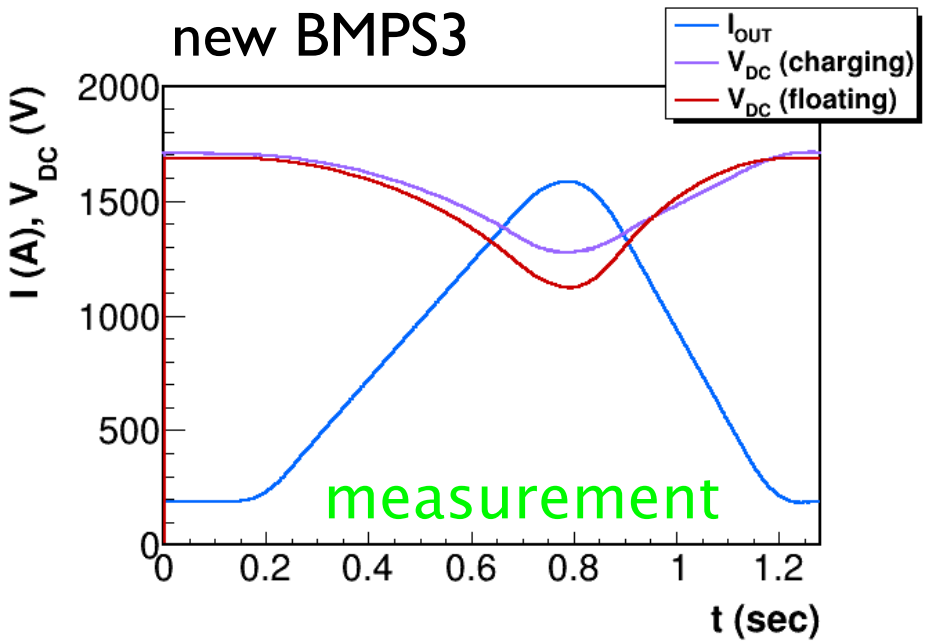
are planned

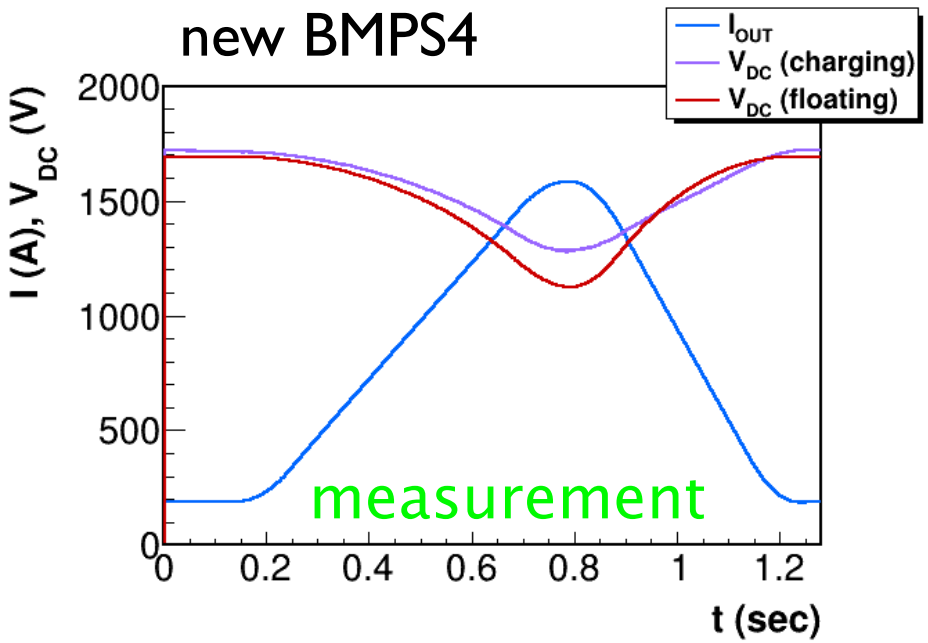
New Power Supply

- A new power supply was developed with capacitor banks for the energy recovery
- 4 of 6 power supplies were constructed and installed
- Commissioning w/ two actual bending magnets (BM) was successfully performed
  →more than 50 hours continuous operation with 1.32 sec cycle was confirmed without any failures
- Installation of remaining PS in 2021

Capacitor Banks for BMPS3

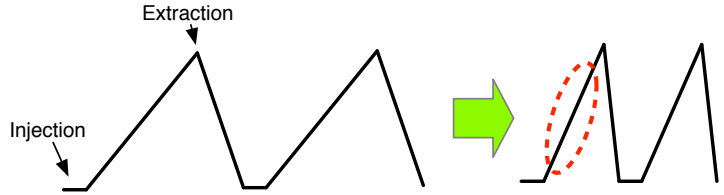






small current ripple@1580A is also confirmed

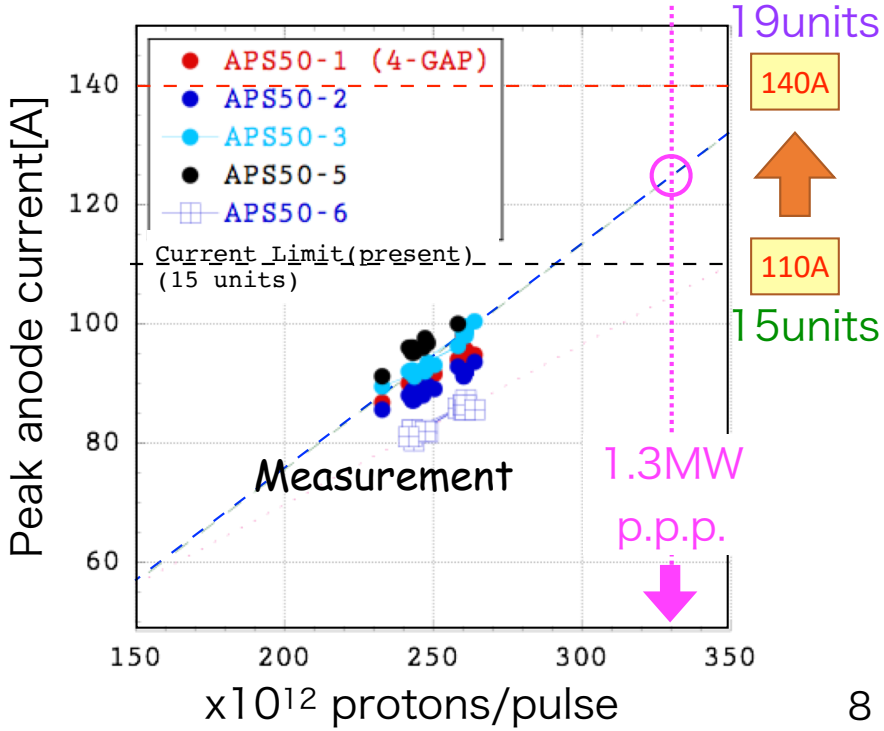
Upgrade plan of MR RF



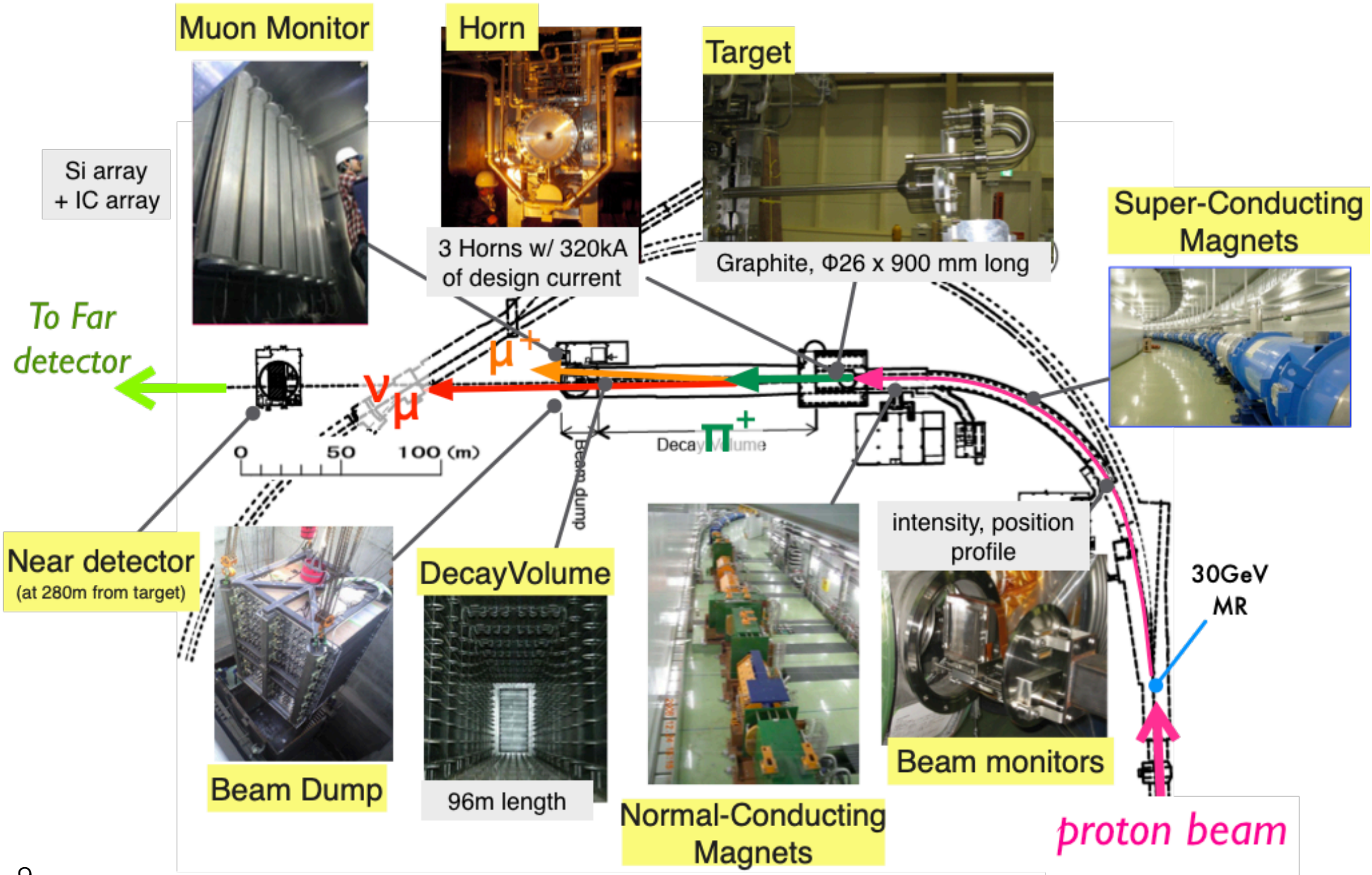
- Add RF cavities for higher RF voltages (faster cycling)
  - with newly developed high gradient RF core

	2019	2021	202X
MR Cycle	2.48 s	1.32 s	1.16 s
FT3L 4GAP Cavities	7	9	11
2nd Harmonic Cavities	2	2	2
Accelerating Voltage	300 kV	510 kV	600 kV
2nd Harmonic Voltage	110 kV	110 kV	110 kV

- Upgrade of the anode power supply (APS) for the beam loading compensation

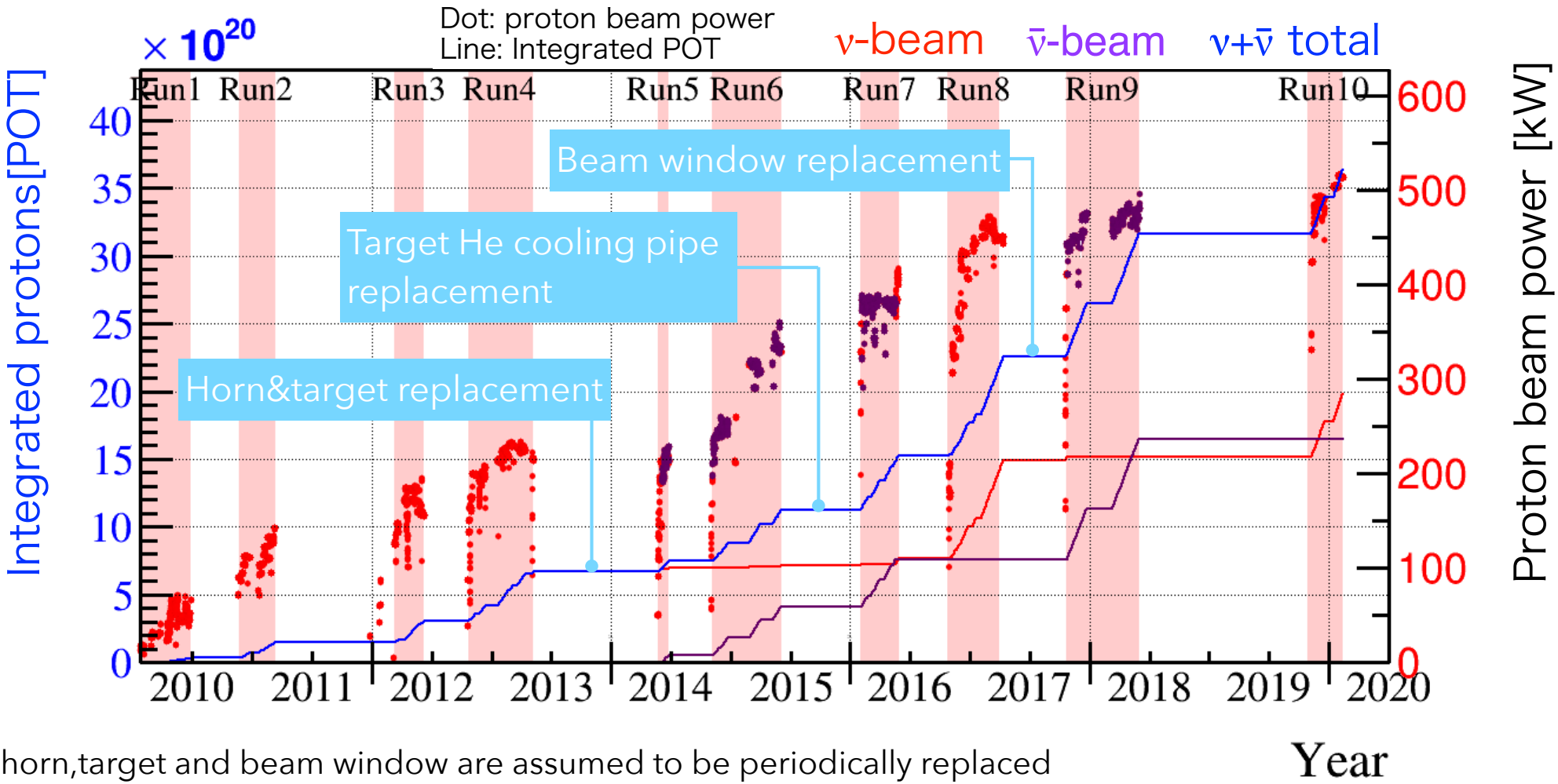


J-PARC neutrino beamline



Neutrino beamline operation

- Accumulated 3.64×10^{21} Protons On Target (2010 Jan. ~ 2020 Feb.)
  - Corresponds to ~46% of original proposal
- Replacement of radio-activated equipments(*) were successfully performed several times
- Stable operation at 515kW has been achieved with no major issues



(*) horn,target and beam window are assumed to be periodically replaced

How can we realize 1.3MW operation ?

- Upgrade is necessary for components which were designed with original beam config.
  - Accepting high repetition rate (~1Hz) beam
  - Increasing cooling capability for the heat generated by beam
  - Increasing capability of radio-active waste handling
  - Improving maintainability under radio-active environment
- Also, improving some components for further stable and safe operation based on experience of operation so far

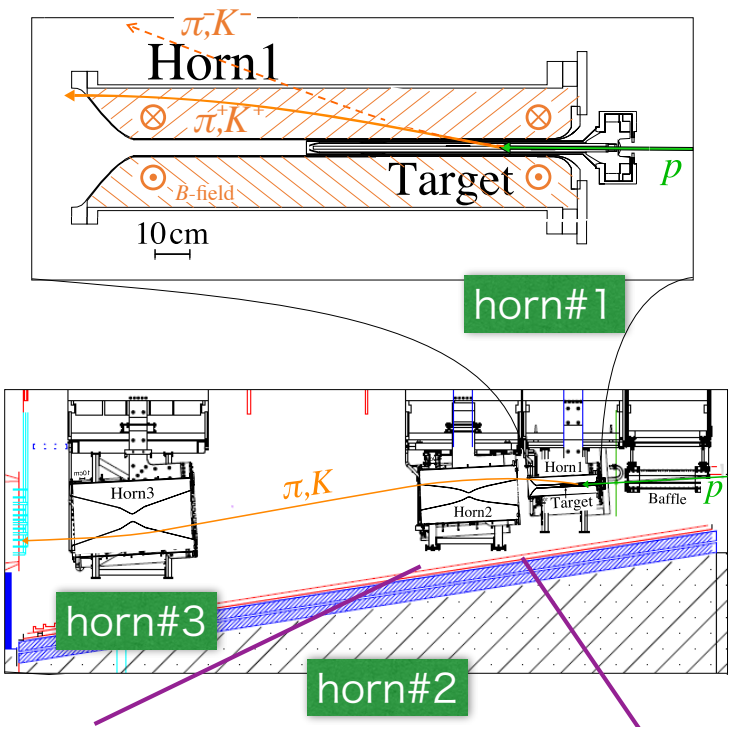
	Original	New
Beam power [MW]	0.75	1.3
# of protons per pulse	3.3×10^{14}	3.2×10^{14}
Rep. Time [sec]	2.1	1.16

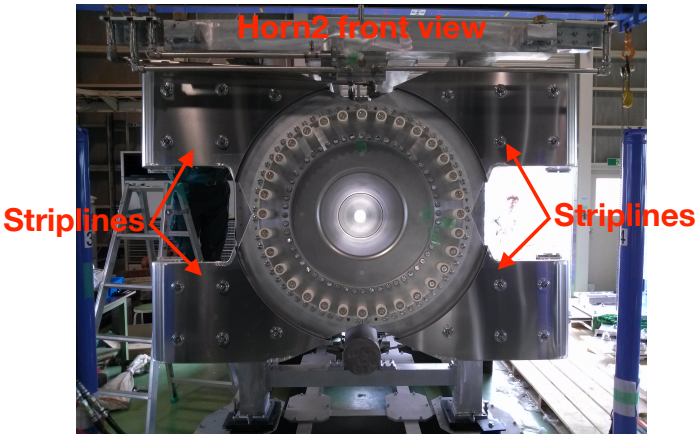
These are modest improvements.
Ready to accept 1.3MW beam after these improvements.

Technical Design Report : arXiv:1908.05141

Please see also Poster#186
[by S.Cao (KEK) for T2K]

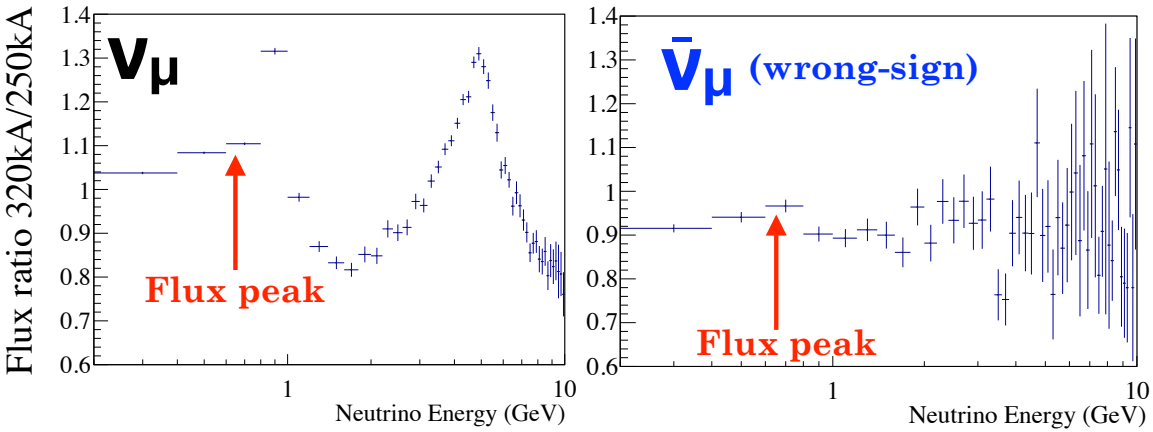
Electromagnetic horn



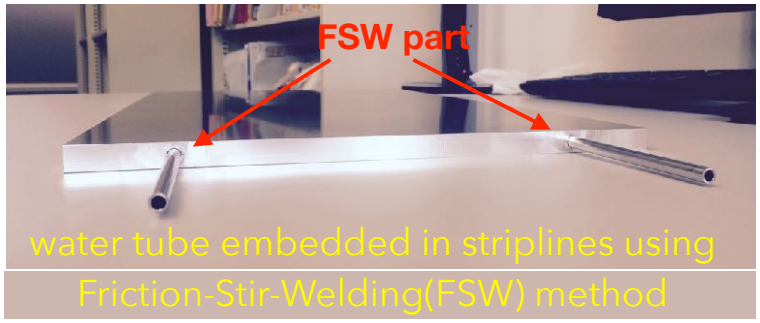


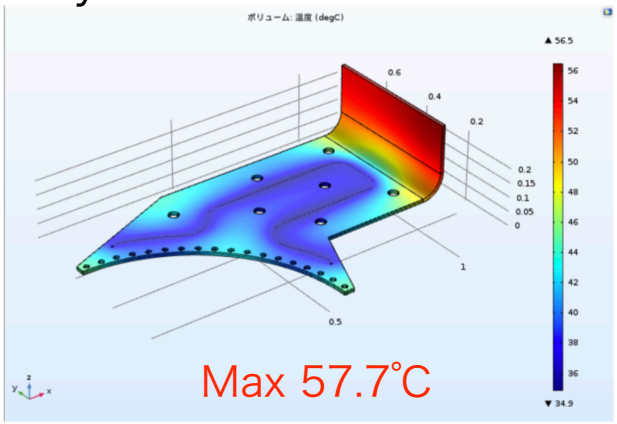
Currently, the He gas cooling method limits acceptable power to 750kW

- Power supply system will be slightly modified for 1Hz op.
  - also, increase the current from 250kA to 320kA
  - +10% increase of ν flux, 5-10% reduction of wrong sign ν



- Need to improve cooling capability of horn#2 stripline for the heat generated by beam





(< acceptable temp.)

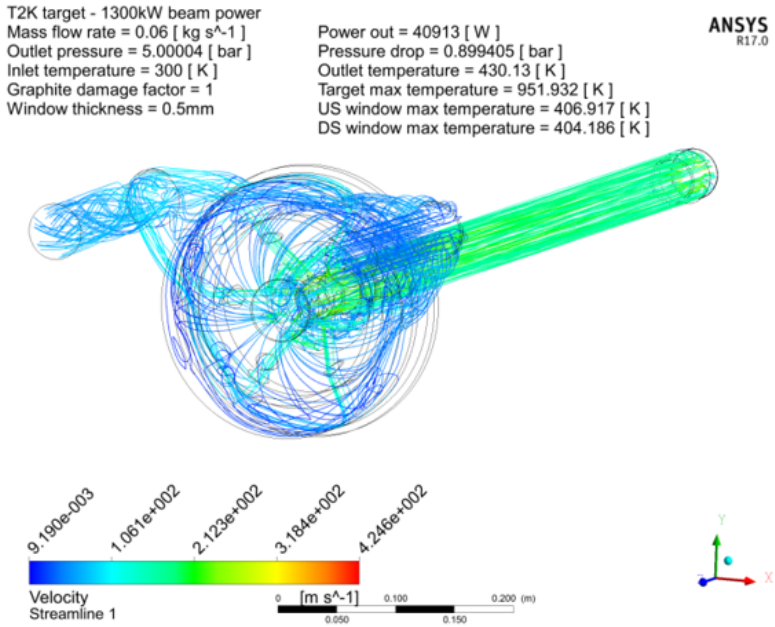
Developed a new water cooled stripline which can accept up to 2.1MW → **ready to install**

- Collaboration with Colorad U. and FNAL

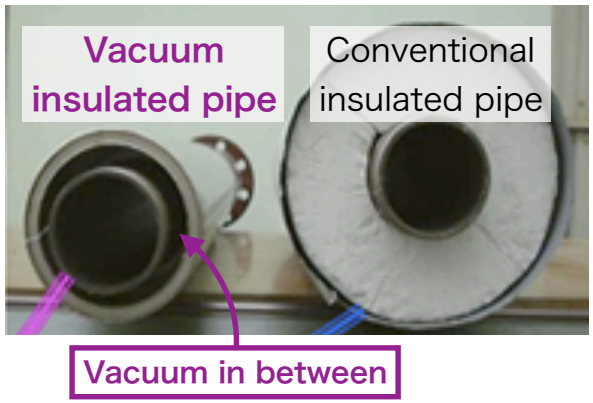
Target

- Designed for 3.3 x 10^{14} p.p.p. → should be OK for 3.2 x 10^{14} p.p.p. (1.3MW)
  - no damage on target observed after 1.3MW x 6month equivalent POT exposure
- Need to improve the He gas cooling capability for the heat generated by beam (x1.7 : 24kW@750kW → 41kW@1.3MW)

→ increase He mass flow rate to accept this



https://www.enoah.co.jp/



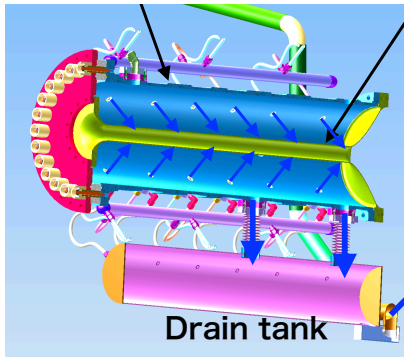
- Design of new target for 1.3MW
- Collaboration with RAL group on the target as well as the beam window

- Developing improved He cooling system for high flow rate and high pressure tolerance
- Collaboration with FNAL for He circulation system for target cooling

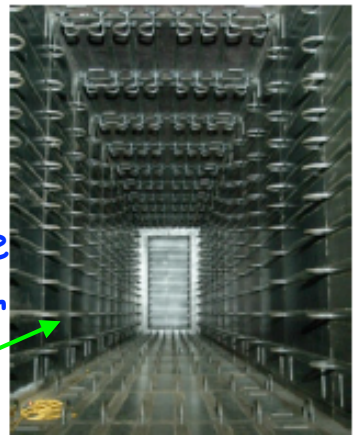
Radio-active water disposal

- Cooling water activated by ^{3}H (Tritium) should be diluted and drained
- Tritium contamination increases as increasing beam exposures but the capability of water disposal is limited by size of the dilution tank
- Increase the size of the dilution tank to increase the capability of water disposal : 84m^3 → 484m^3

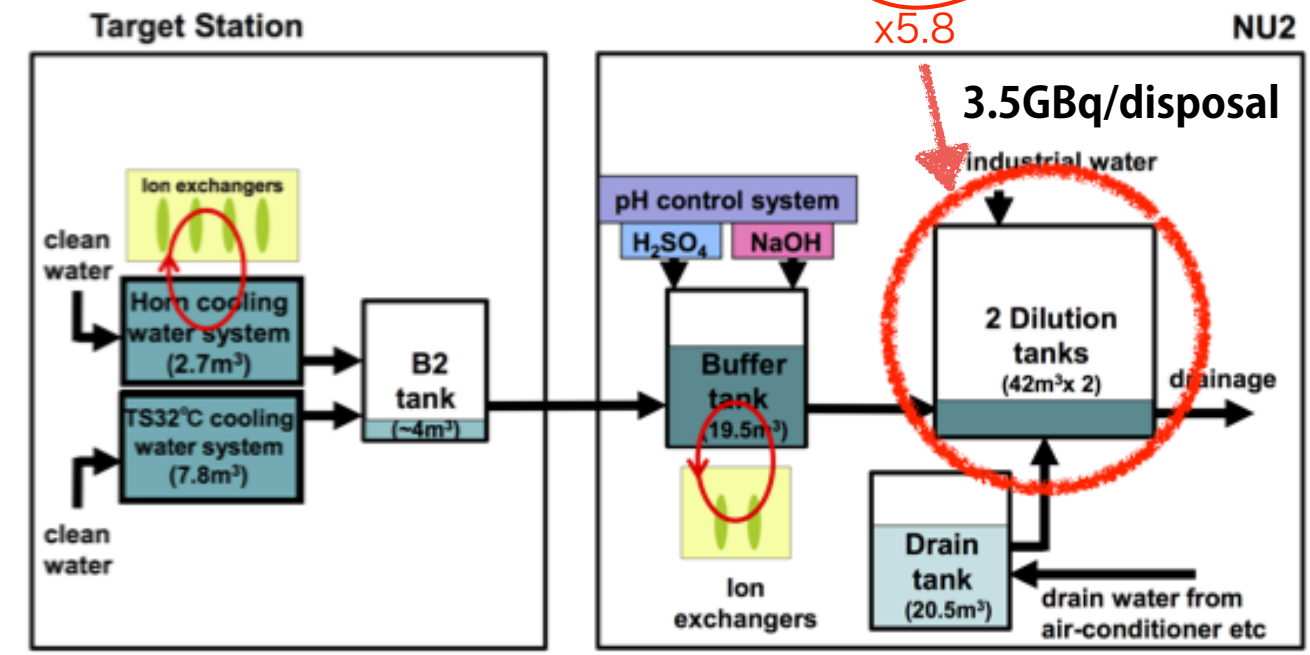
x5.8



Horn cooling water



Decay volume cooling water pipes



Under construction (~2022)

~25GBq HTO produced per 1x10^{20}POT

In Horn/TS He Vessel/Decay Volume Cooling Water

R&D to understand Tritium production and knowledge sharing on Tritium treatment are in progress among US-Japan collaboration

Beam monitor

Please see also Poster#186
[by S.Cao (KEK) for T2K]

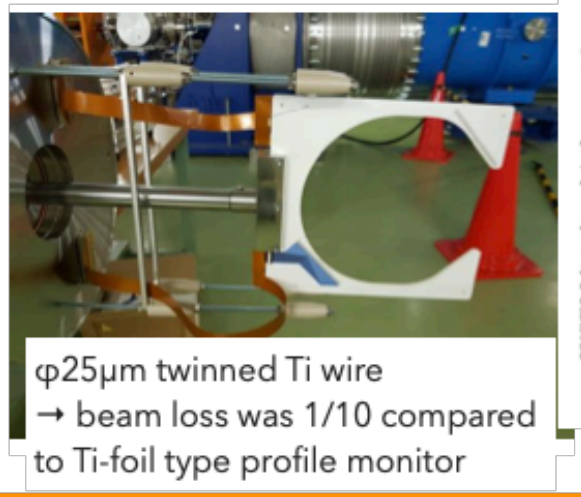
Proton beam profile measurement is important to properly tune the beam size at the target, but beam loss caused by the monitor becomes an issue for MW beam power

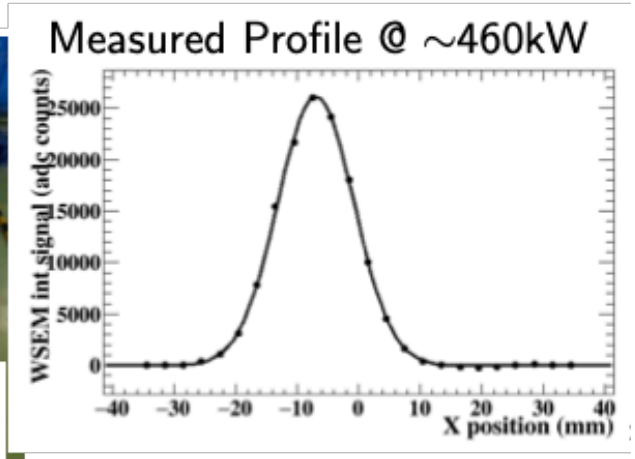
- ❖ A new wire-based profile monitor was successfully developed with US-Japan collaboration
- ❖ Non-destructive beam profile monitor is also under development toward continuous monitoring w/o any beam loss

In addition, secondary muon beam direction monitoring is important

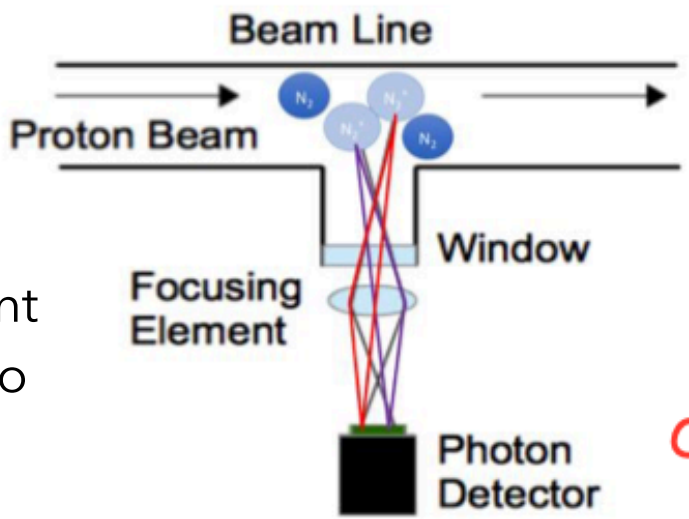
- ❖ A new muon monitor device is under development with domestic Universities and US-Japan collaboration

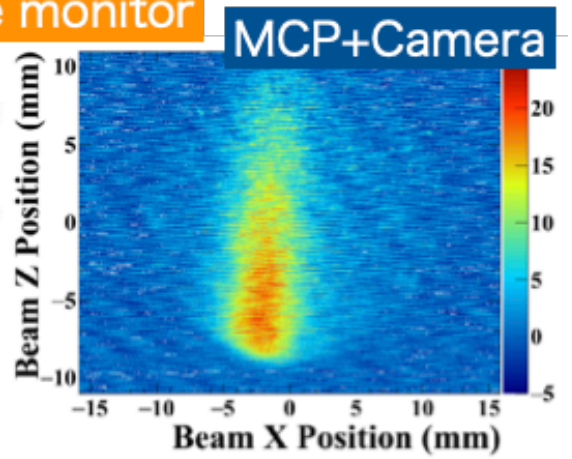
Wire-type Secondary-emission profile monitor



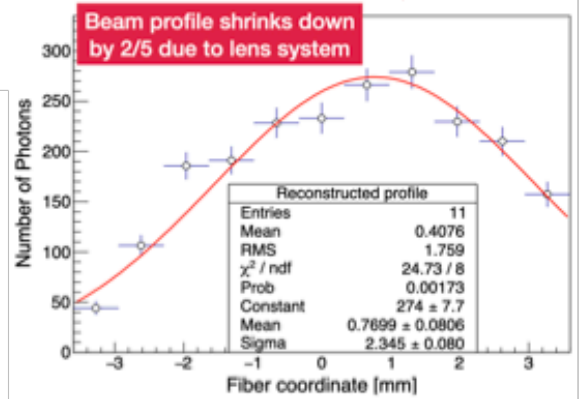


Beam induced fluorescence monitor





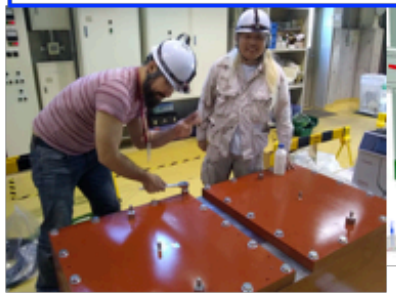
Observed beam profile



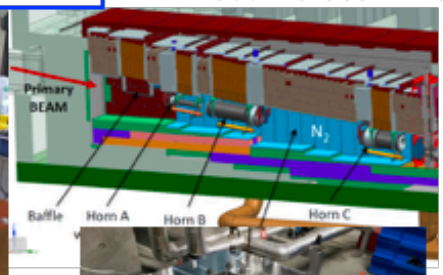
International cooperation for high intensity facility

In addition to the neutrino beamline components, we also promote strong & world-wide cooperation for common technical challenges toward high intensity facility (both Accelerator + Beamline)

KEK/J-PARC - FNAL cooperation for LBNF

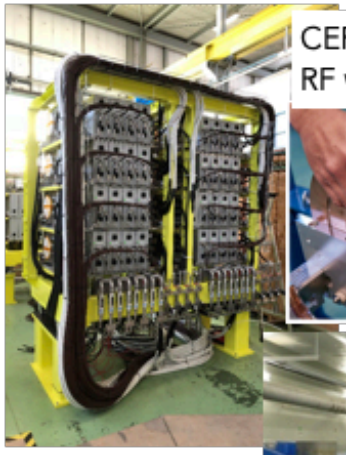


LBNF neutrino beamline



Air-tight hatch cover, feedthrough for horn stripline etc. R&D based on ~10 years experience at J-PARC

KEK/J-PARC - CERN



CERN PS booster RF w/ J-PARC RF core

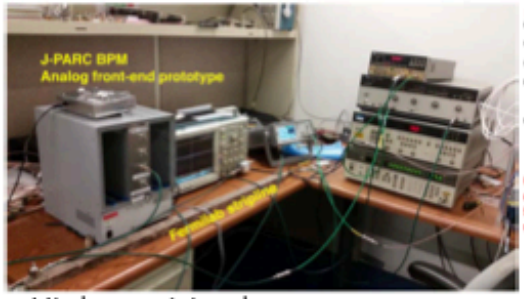
J-PARC neutrino beamline SC magnets

3 corrector mags (from US)
MSS from Saclay
CERN cooperation

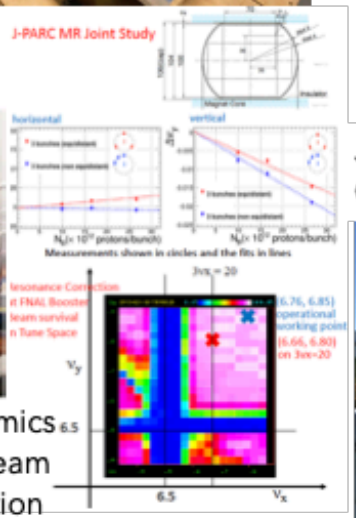
RaDIATE collaboration

Study radiation response of materials

US-Japan

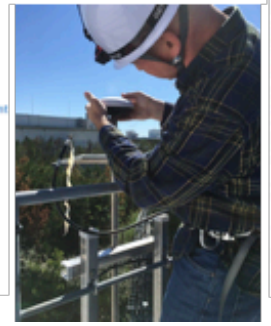


High precision beam position monitor measurement



Beam dynamics study for beam loss reduction

J-PARC-Kamioka GPS



KEK/J-PARC - TRIUMF

Remote maintenance

KEK/J-PARC - RAL

Beam window

Summary

- J-PARC accelerator and neutrino beamline upgrade program is essential for T2K and Hyper-K experiments
- Upgrade program for higher power is ongoing in good shape
  - Achieved >500kW with sufficient beam loss reduction
  - Upgrade for higher repetition rate is scheduled in JFY2021
- Some of upgrade program is performed under strong international and domestic collaboration

J-PARC accelerator and neutrino beamline is ready for >1MW before Hyper-K start