J-PARC Neutrino Beam Upgrade Plans and Possibilities

2020/12/2, NF09 workshop

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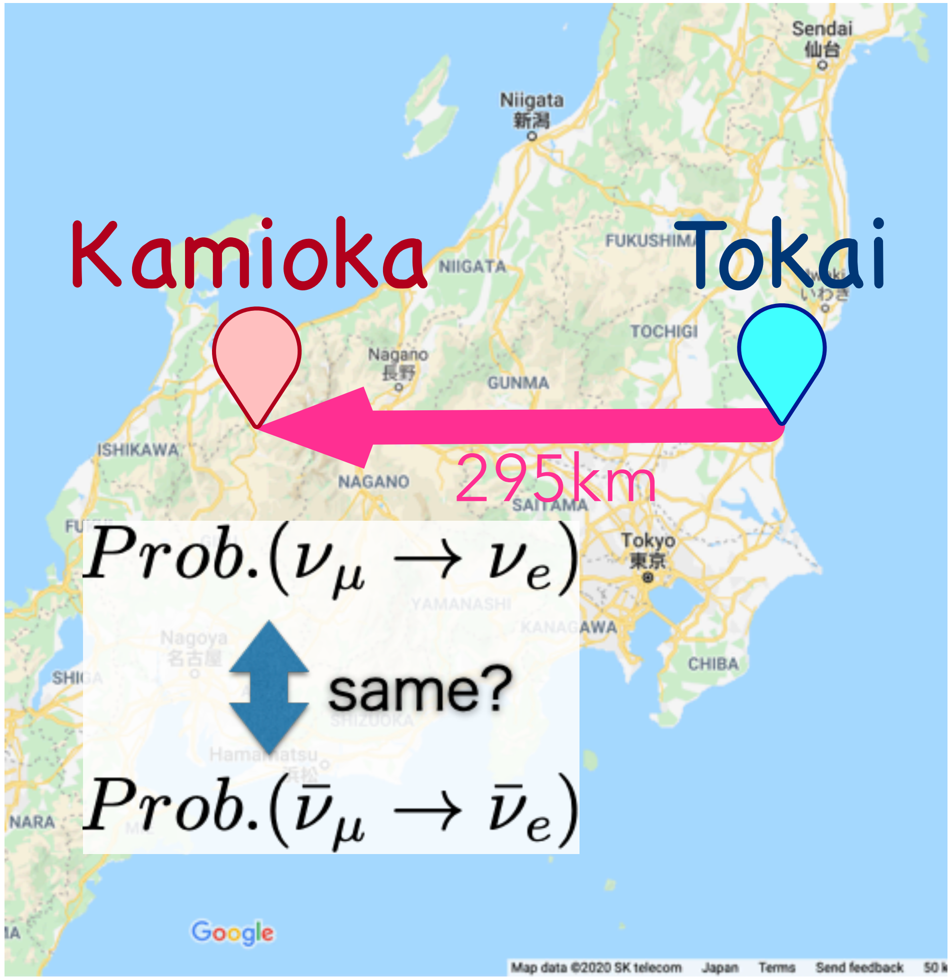
on behalf of the J-PARC neutrino facility group

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

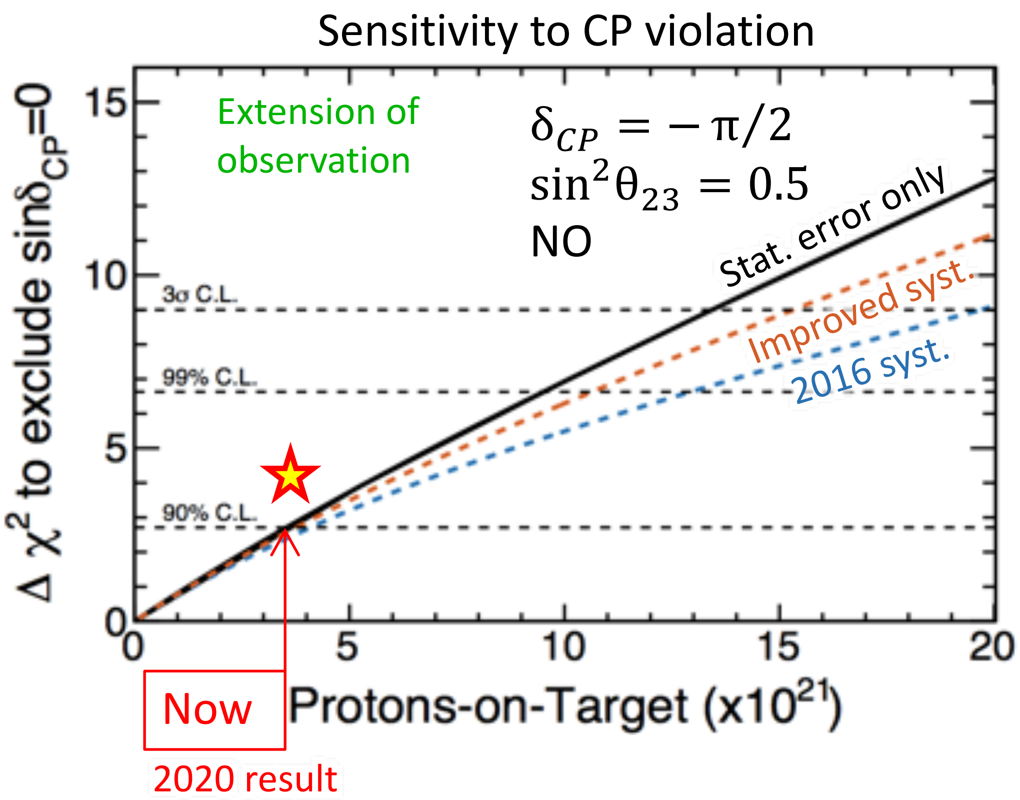
- ❖ Extension of data taking (T2K-II) was approved
- ❖ Upgrade of beam and near detector is in progress

Hyper-Kamiokande

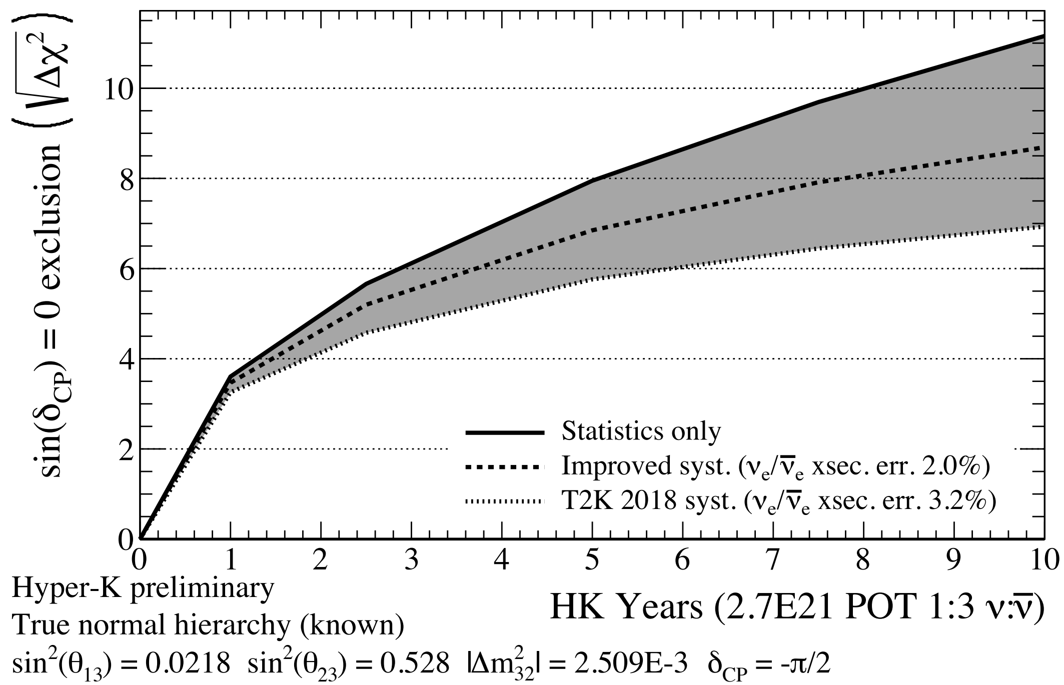
- ❖ Construction started
- ❖ will begin operation in 2027

Sensitivity to CPV

~3σ sensitivity for δ_{CP}=-π/2 case

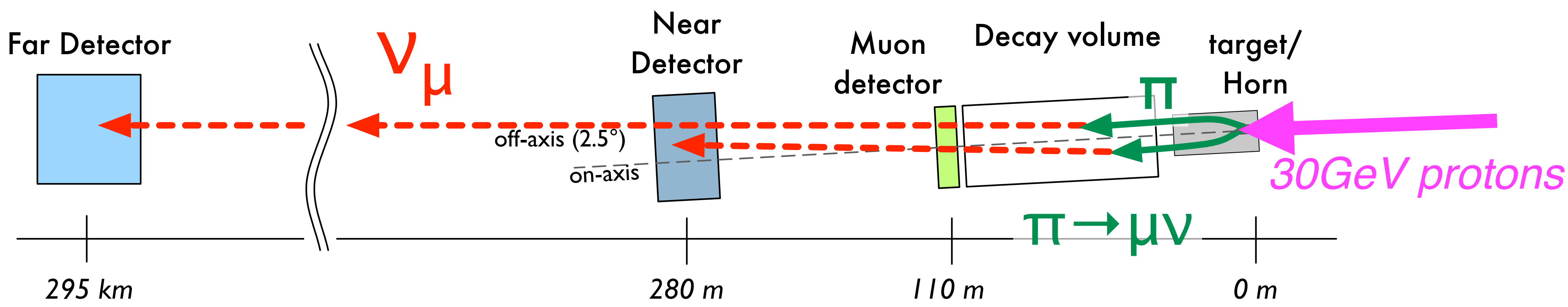


$\sin\delta_{CP}$=0 can be excluded in 2-3years if δ_{CP}=-π/2

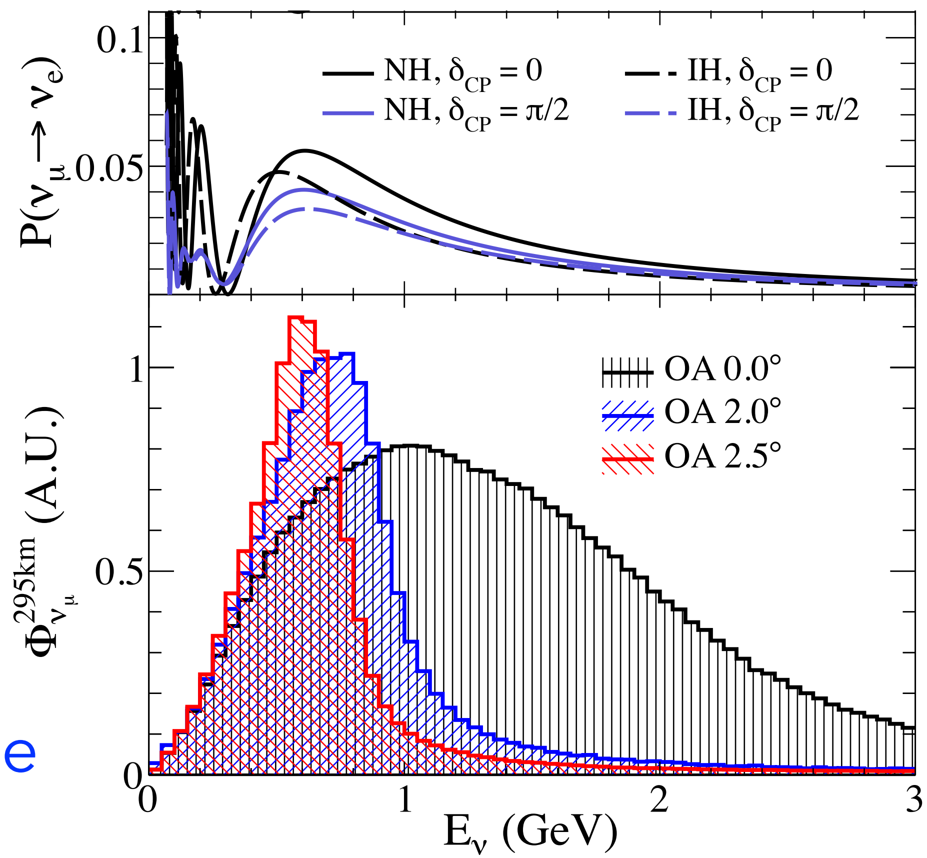


High intense neutrino beam and reduction of syst. error are essential

High intense neutrino beam for T2K and HK



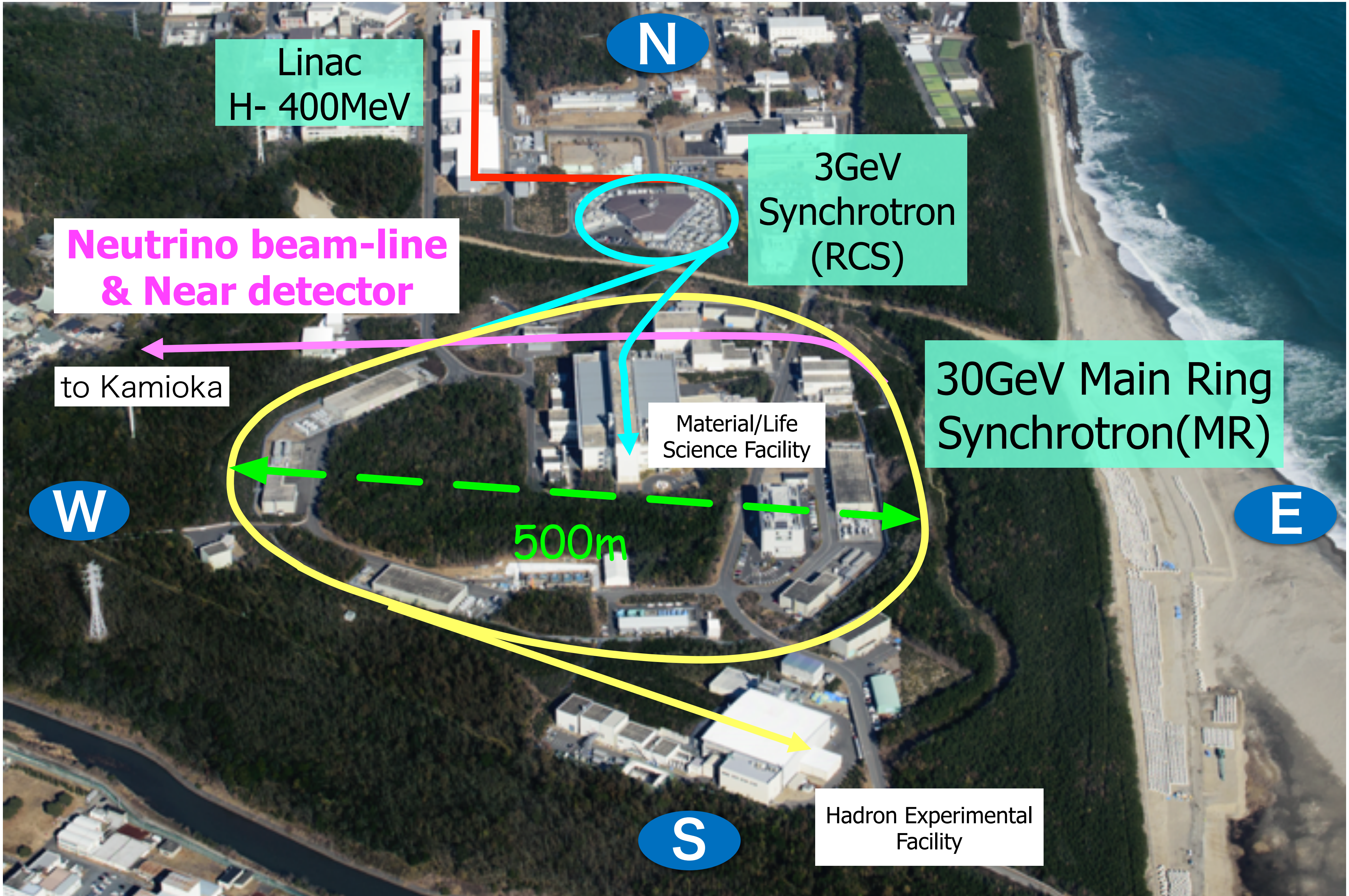
- ν energy is narrow with off-axis method
  L = 295km → oscillation peak at 0.6GeV
- small ν_e contamination (~1%)
- ν / $\overline{\nu}$ can be switched by flipping horn polarity



Key points:

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

J-PARC accelerators at Tokai

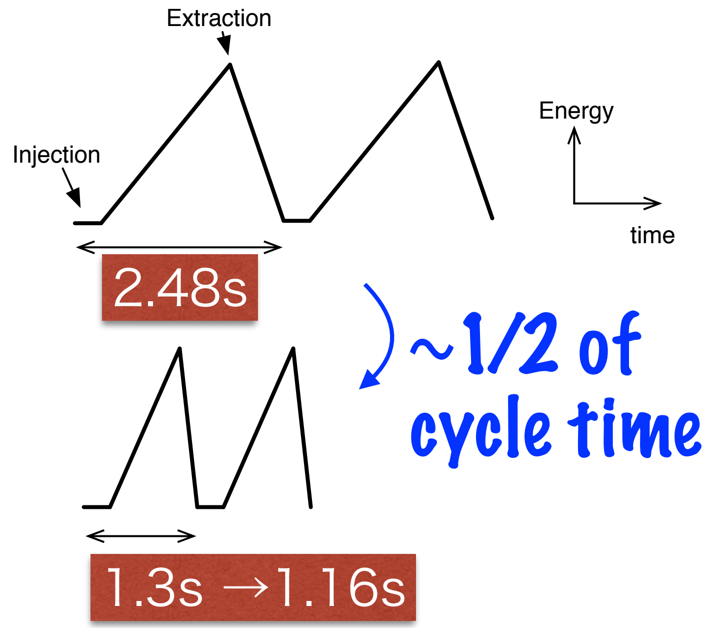


How can we increase beam power ?

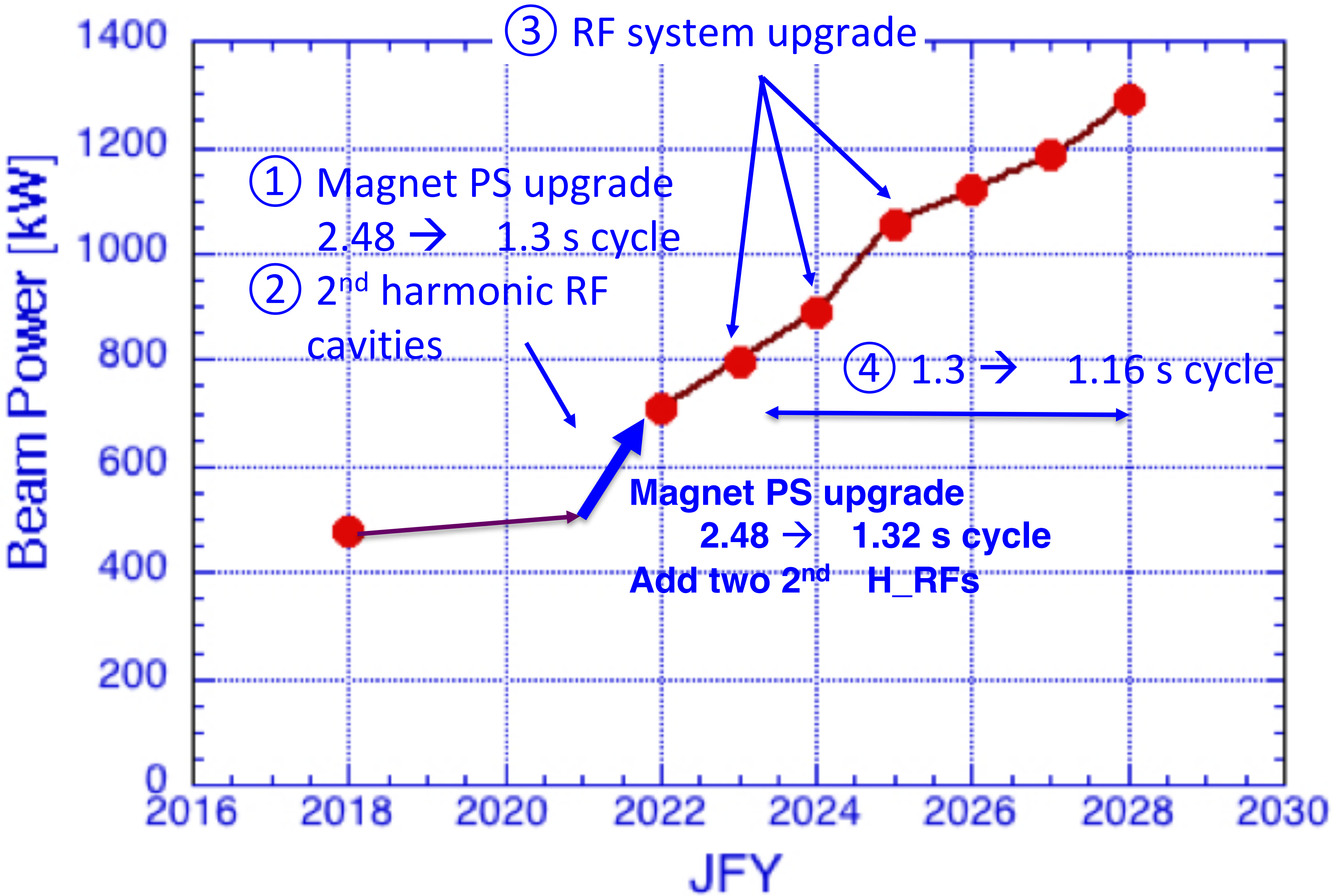
Power ∝ 30GeV x # of protons x 1/T$_{rep.}$

	Power	# of protons
now	0.5MW	2.5×10^{14}
target	1.3MW	3.2×10^{14}

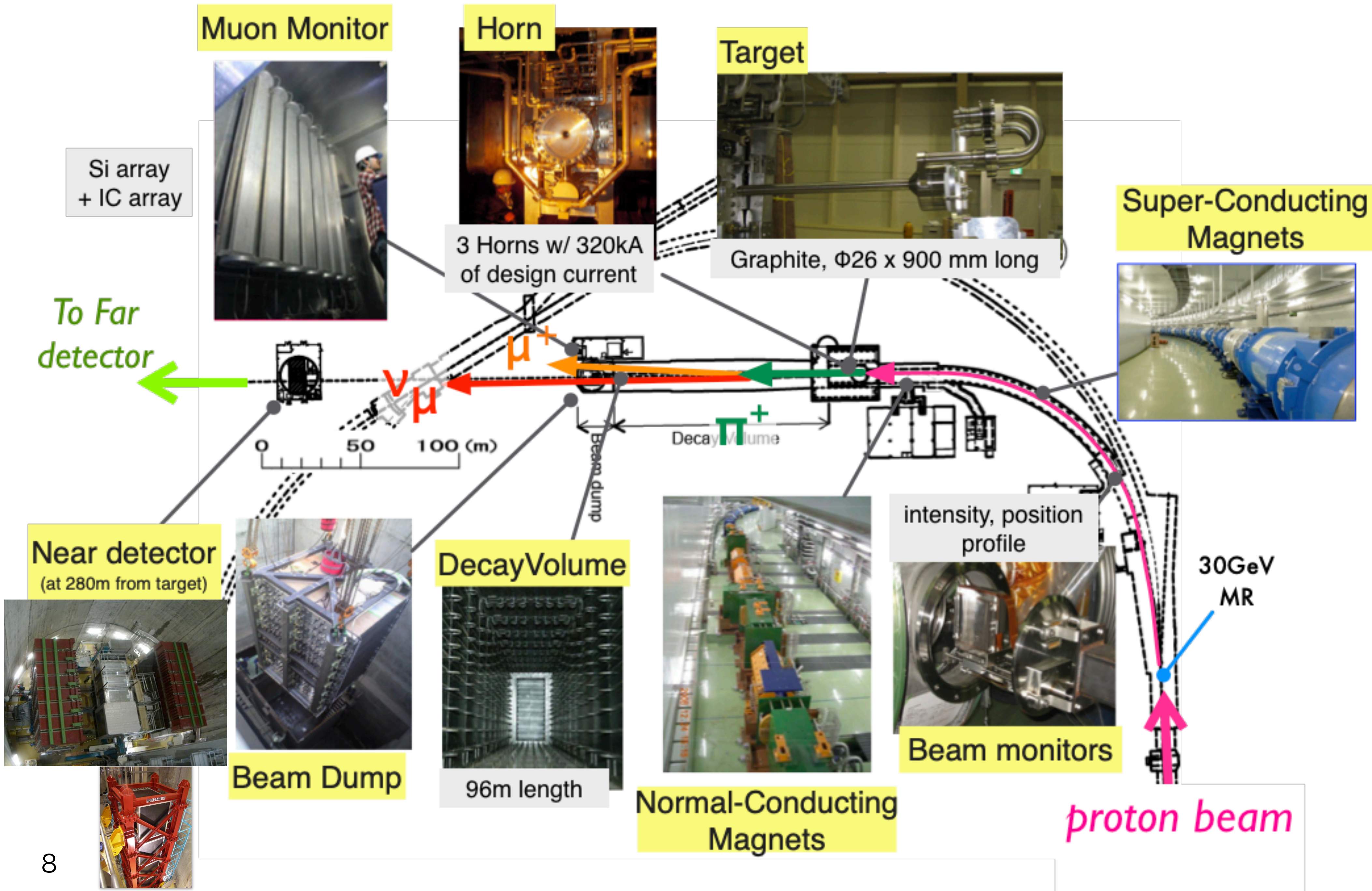
+30% protons per pulse



J-PARC MR Power Upgrade Plan

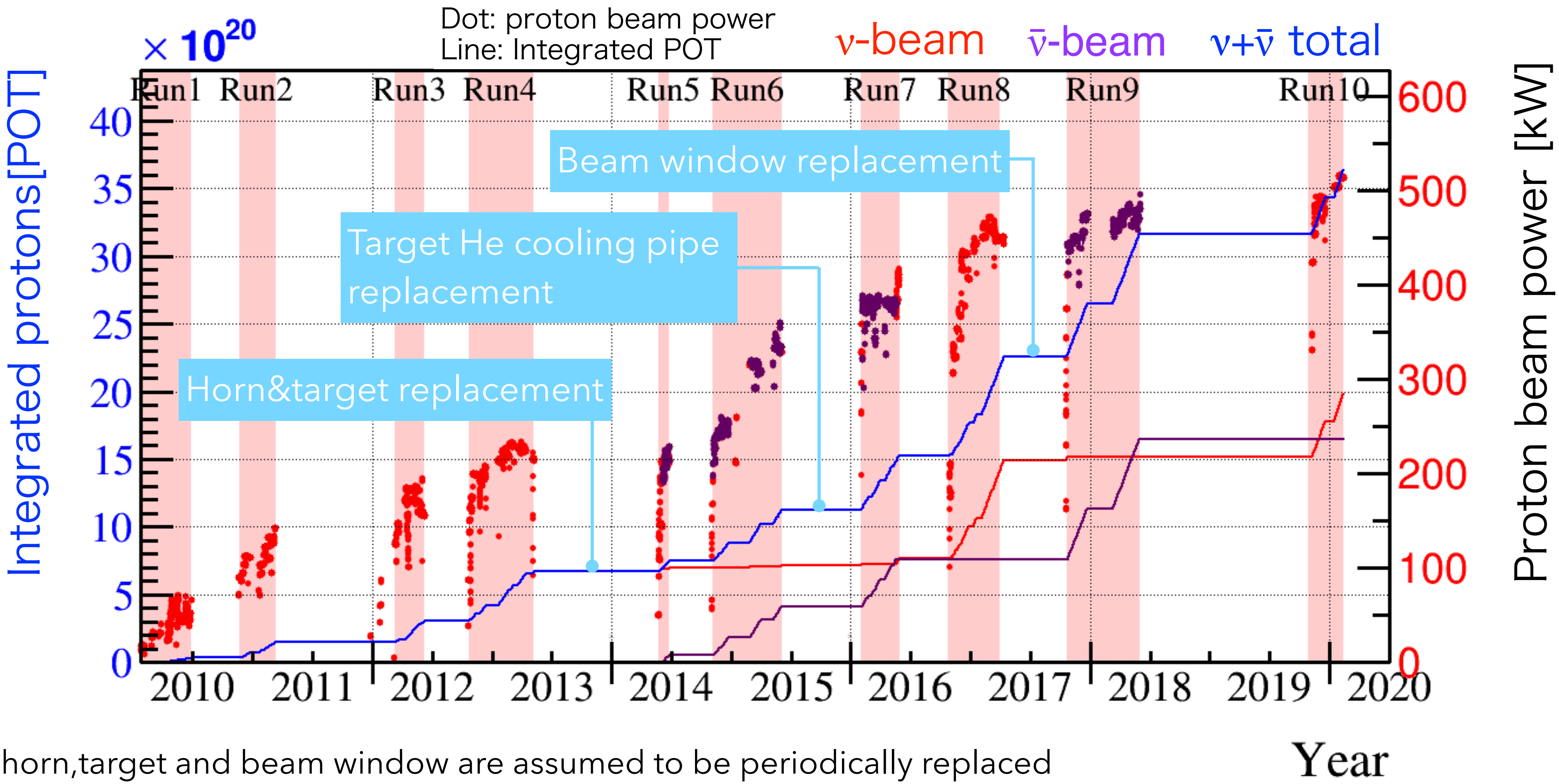


J-PARC neutrino beamline



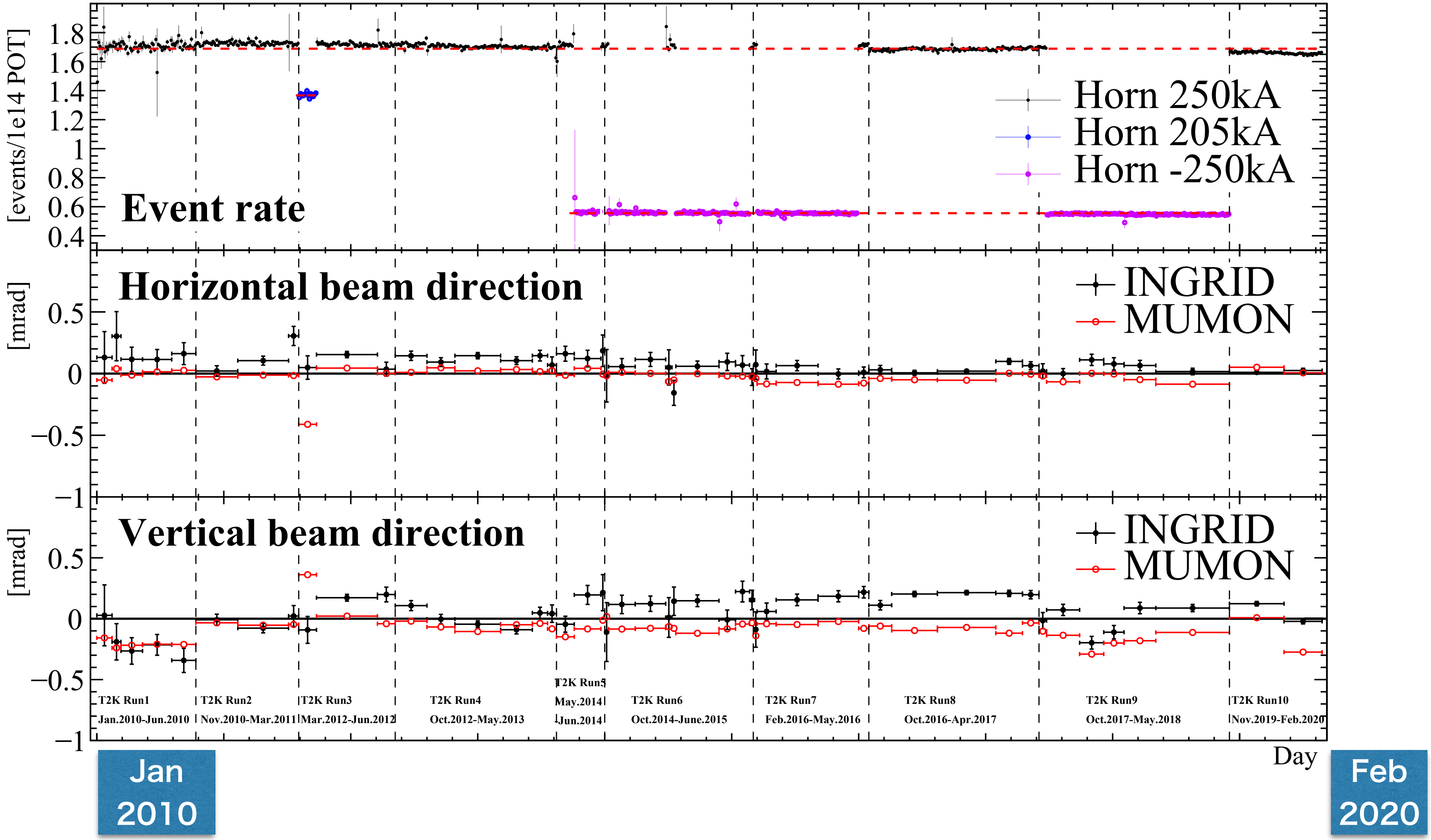
Neutrino beamline operation

- 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

Beam stability

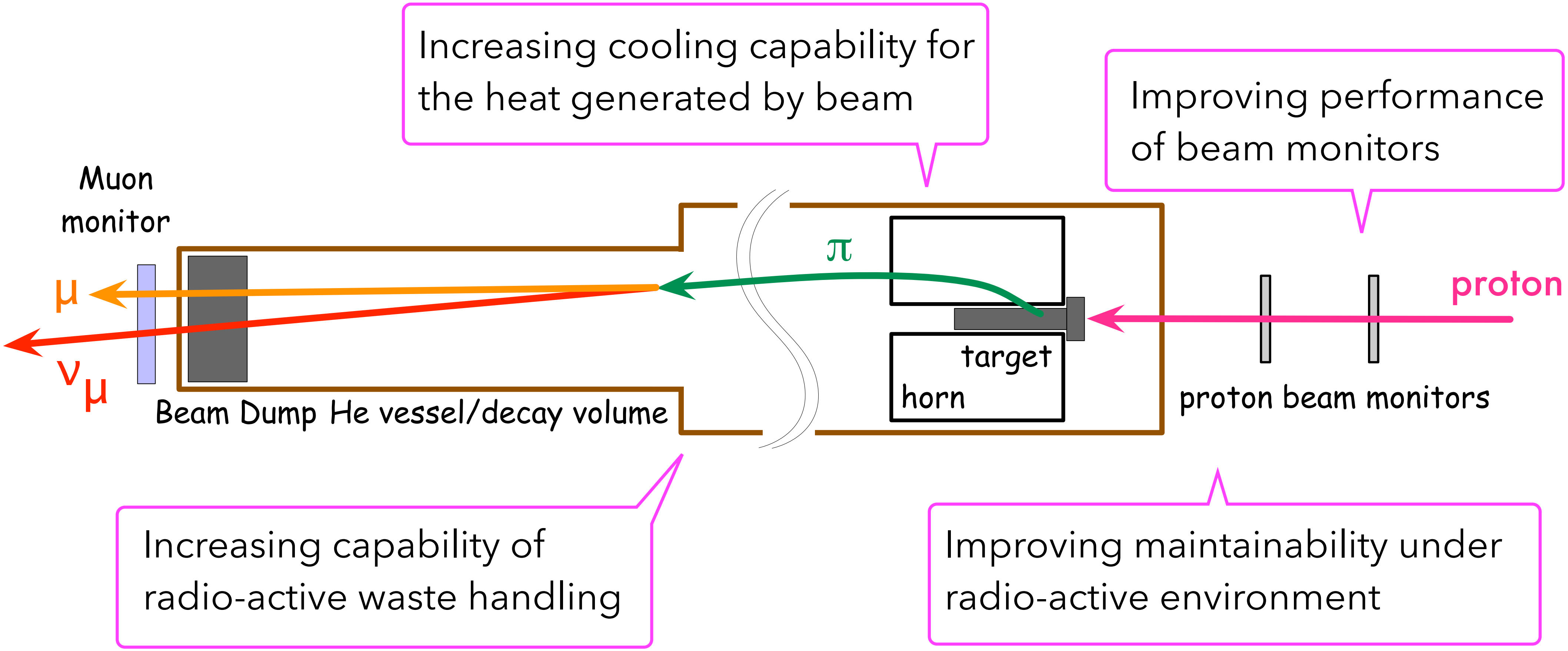


- Beam direction is stable within much better than 1mrad
  - 1mrad corresponds to a 2% shift of peak ν energy at SK

Need to keep this stability even at 1.3MW beam

How can we realize 1.3MW operation ?

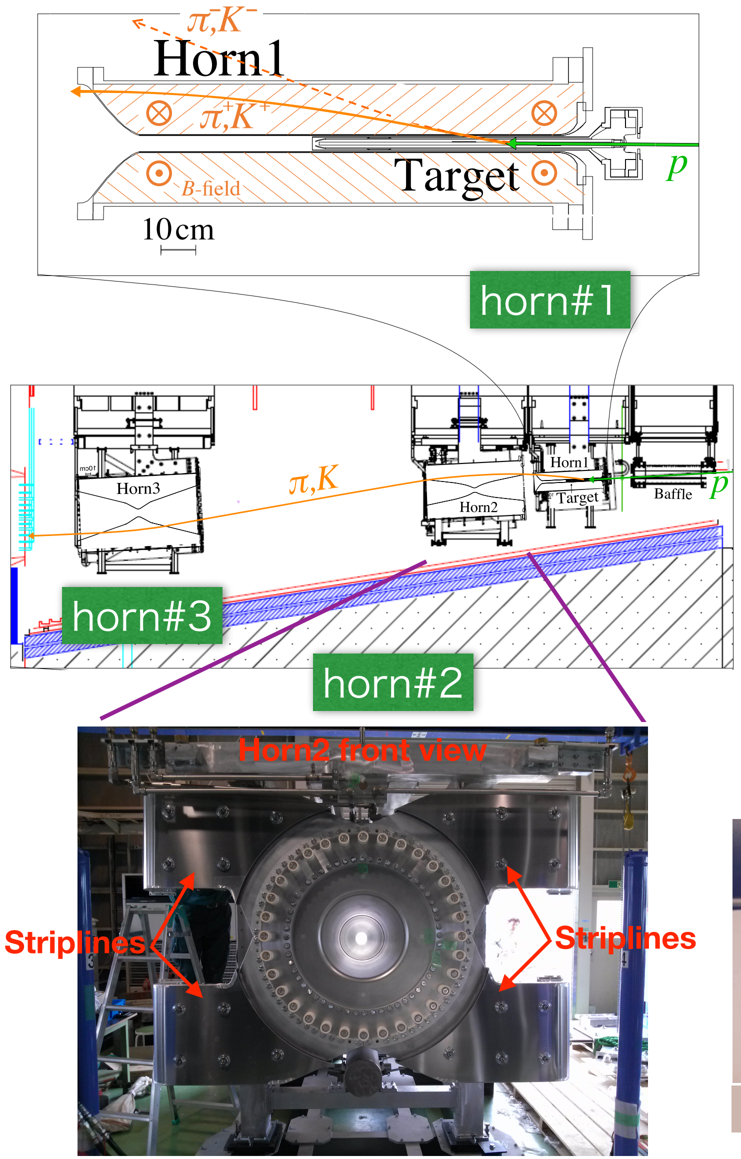
- Modest improvement is necessary for some beamline components



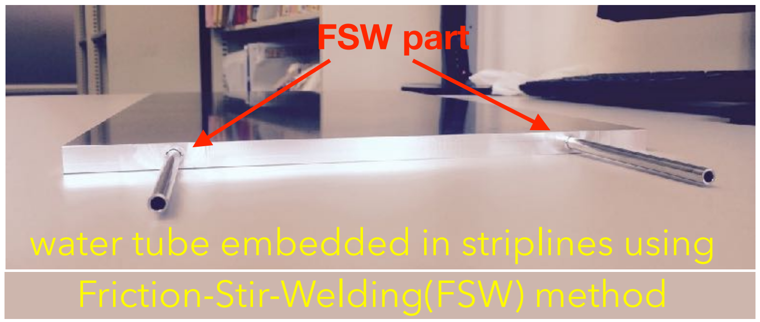
+ Accepting high repetition rate (~1Hz) beam

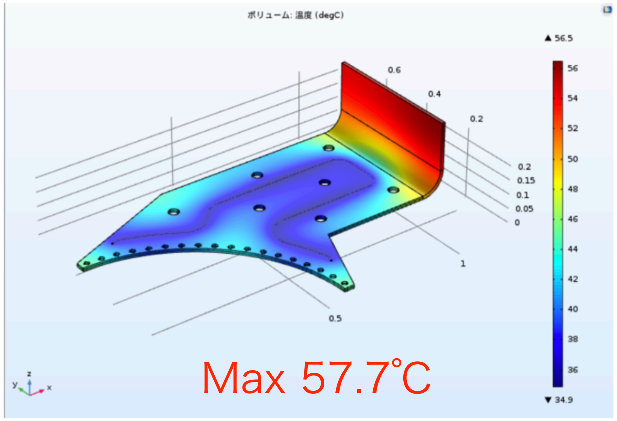
Technical Design Report : arXiv:1908.05141

Electromagnetic horn



- Power supply system will be slightly modified for 1Hz operation
- 250kA → 320kA operation
- Improving cooling capability of horn#2 stripline for the heat generated by beam
- Collaboration with Colorad U. and FNAL



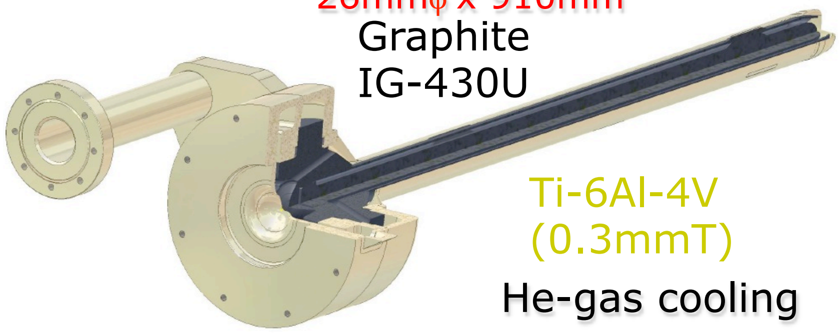


(< acceptable temp.)

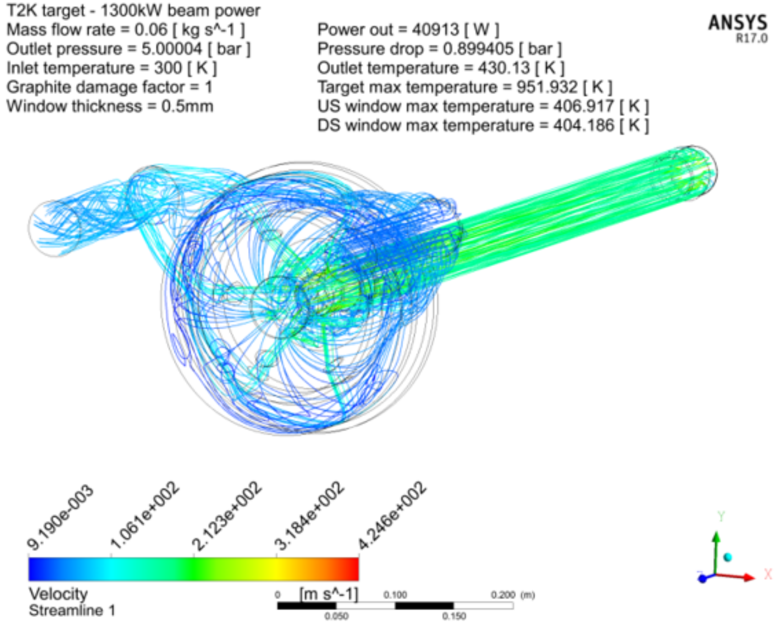
Currently, the He gas cooling method limits acceptable power to 750kW

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

Target



Target



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

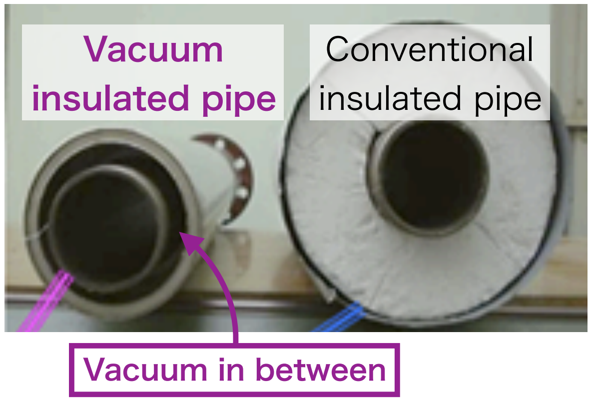
❖ Designed for 3.3 x 10^{14} p.p.p. → should be OK for 3.2 x 10^{14} p.p.p. (1.3MW)

- 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/

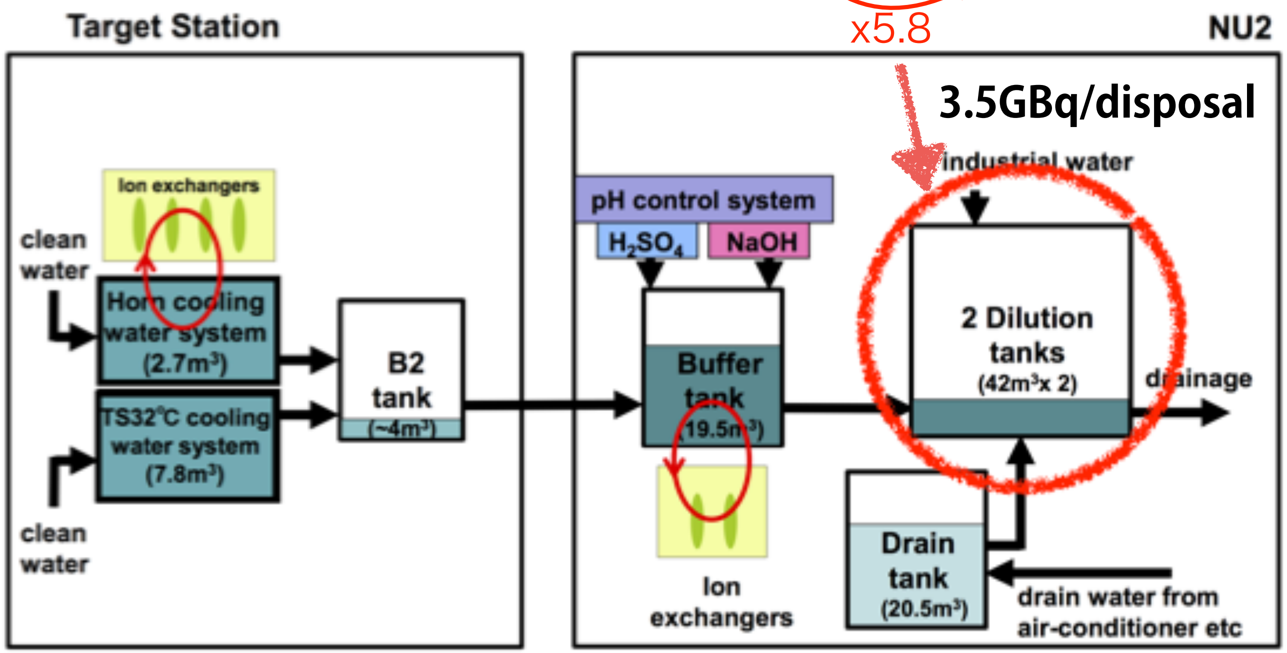


- Developing improved He cooling system for high flow rate and high pressure tolerance
- Collaboration with FNAL for He circulation system for target cooling

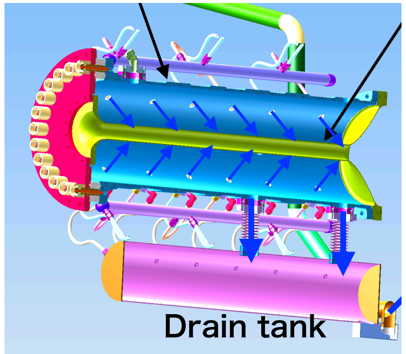
Radio-active water disposal

- 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

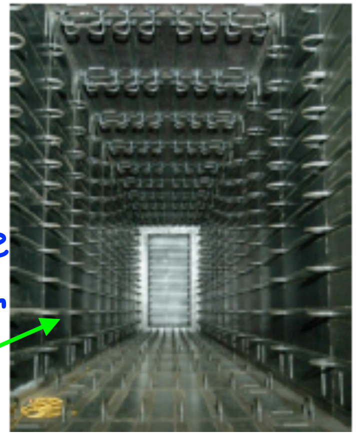
x5.8



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

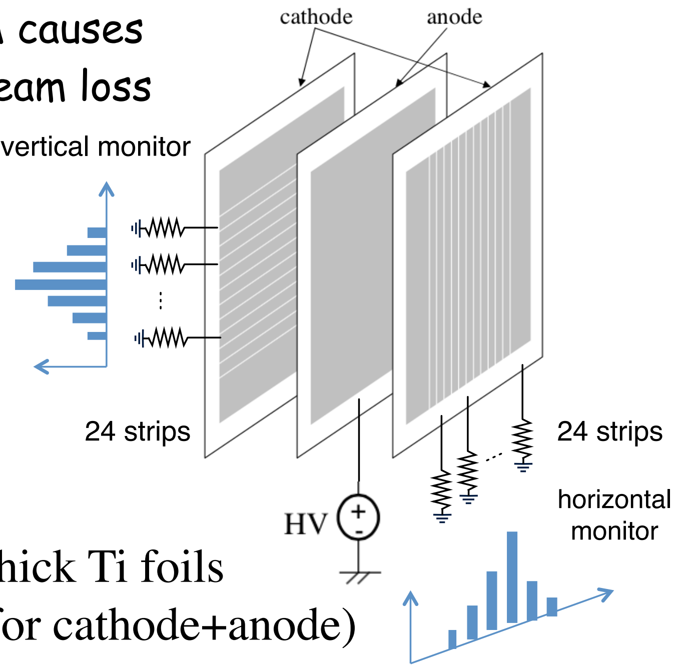
R&D to understand Tritium production and knowledge sharing on Tritium treatment are in progress among US-Japan collaboration

Proton beam monitor

- Important to properly tune the beam position, direction and size at the target
- Segmented Secondary Emission Monitors (SSEM) are utilized in the neutrino beamline
- Beam loss becomes an issue for MW beam power

→ **New type monitors are developed**

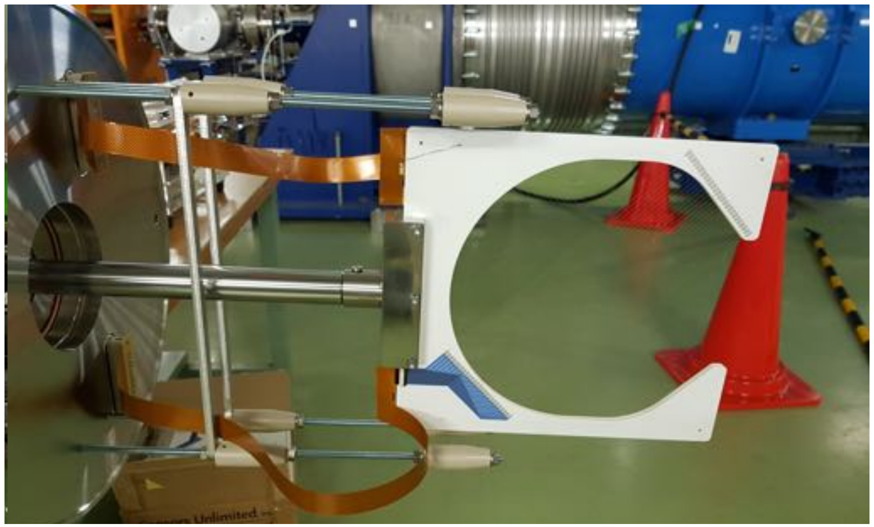
each SSEM causes ~0.005% beam loss



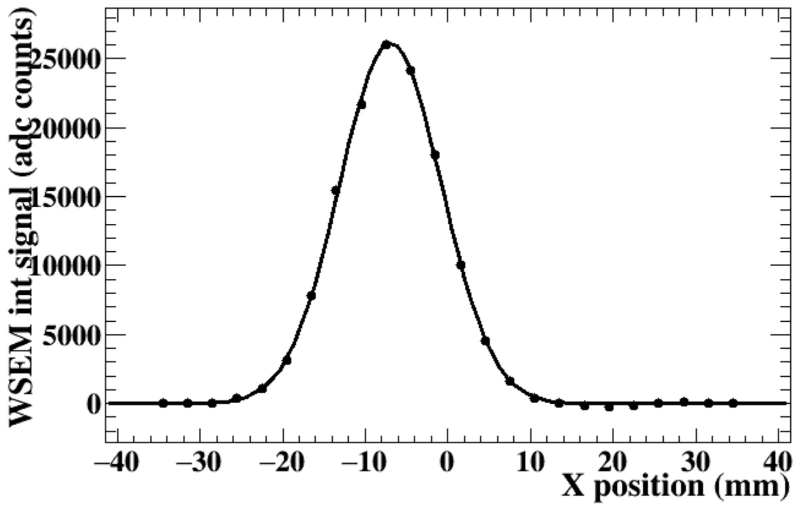
5μm thick Ti foils
(total 15μm for cathode+anode)

(1) Wire-type Secondary-emission profile monitor

US-Japan collaboration



Measured Profile @ ~460kW

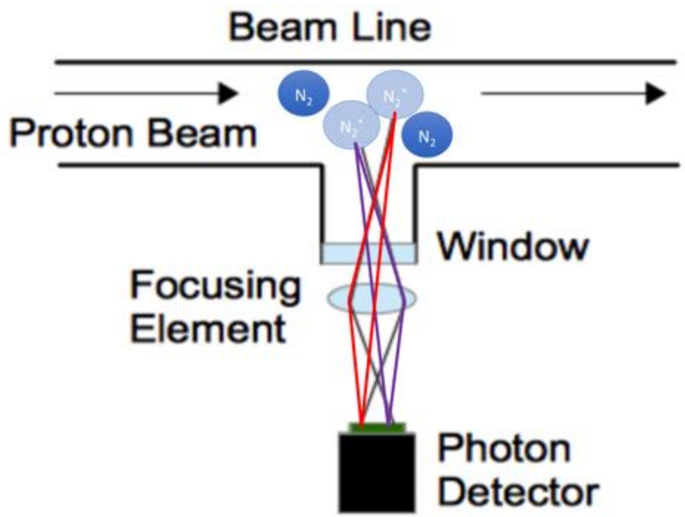


φ25μm twinned Ti wire

→ beam loss was 1/10 compared to Ti-foil type profile monitor

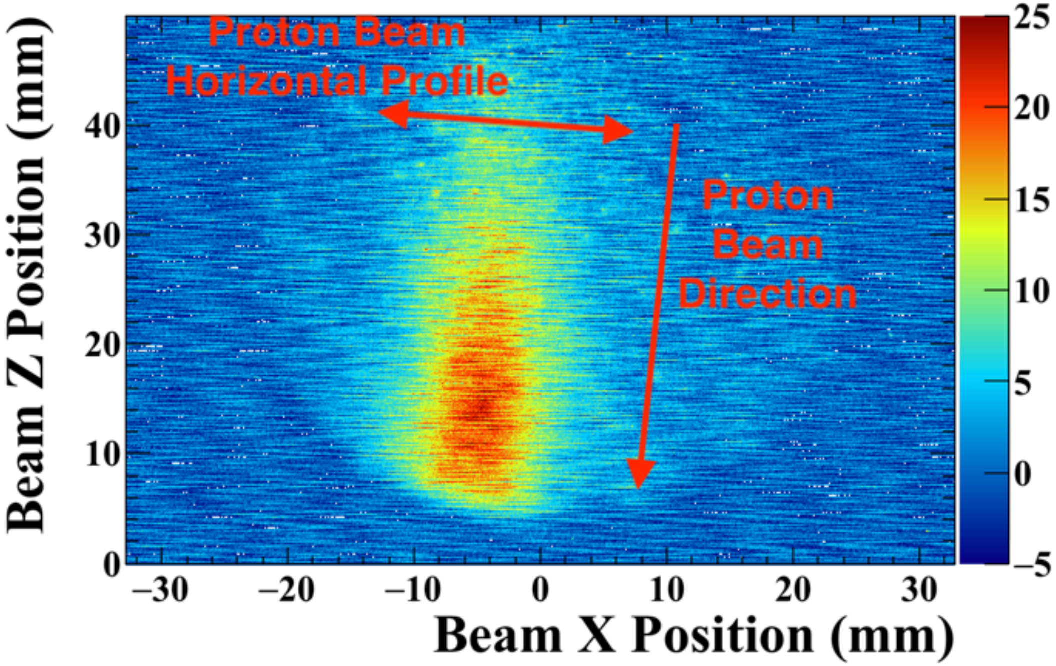
(2) Beam induced fluorescence monitor

- Beam induced fluorescence profile monitor is under development as a non-destructive beam profile monitor toward continuous monitoring w/o any beam loss

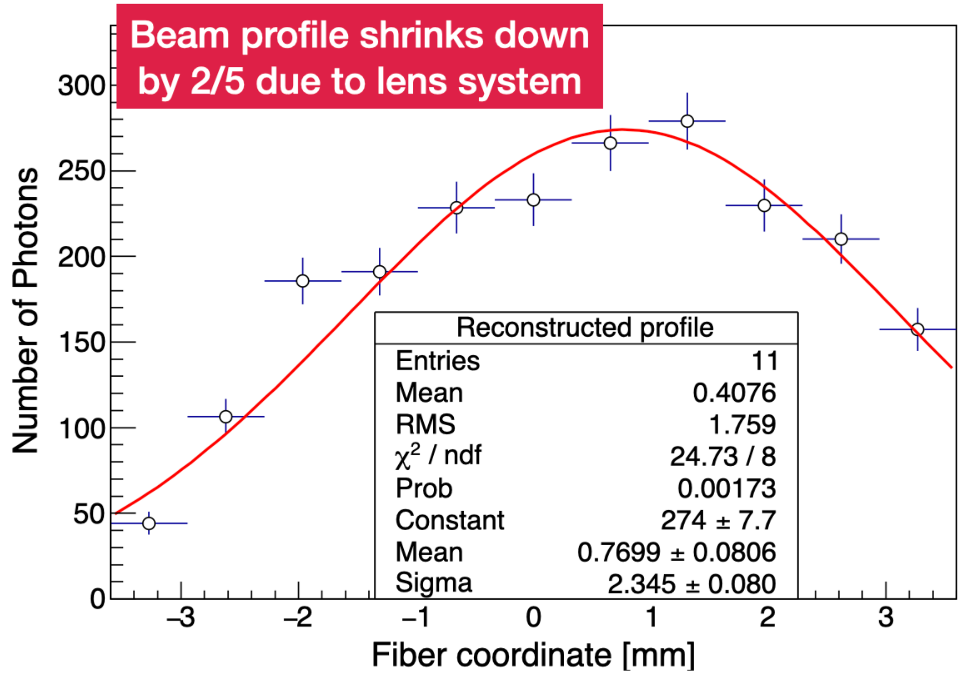


Successfully Observed beam profile w/ Prototype monitor

MCP+Camera

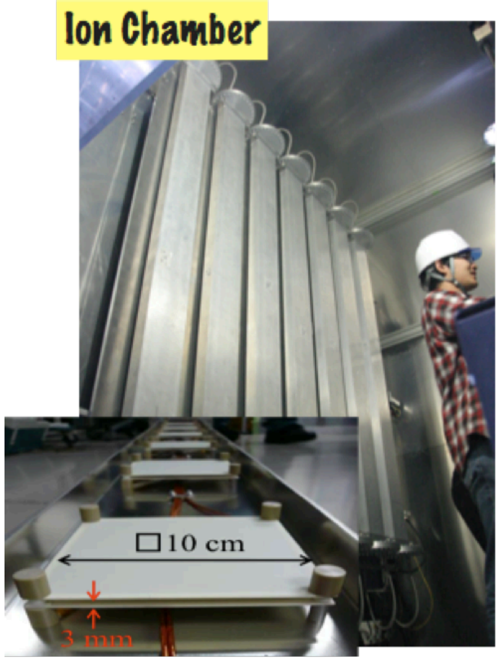


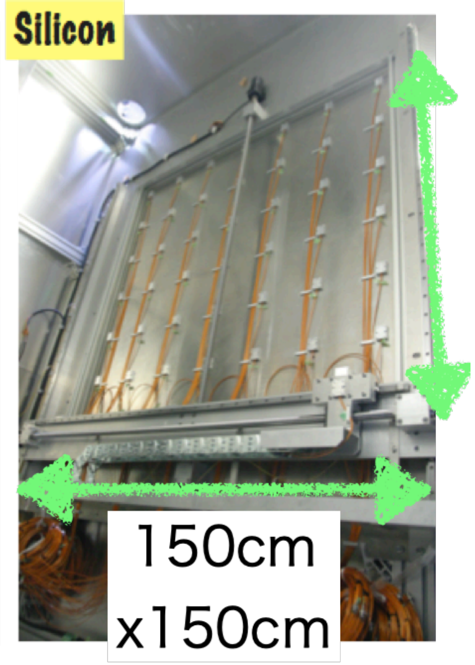
SiPM array



Muon monitor upgrade

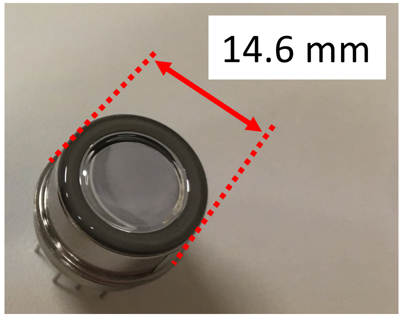
- ❖ Important to properly monitor spill-by-spill muon beam direction and profile
- ❖ Signal degradation was observed (e.g. ~1%/5E20 POT for Si)
- ❖ A new detector w/ radiation tolerance is under development → EMT

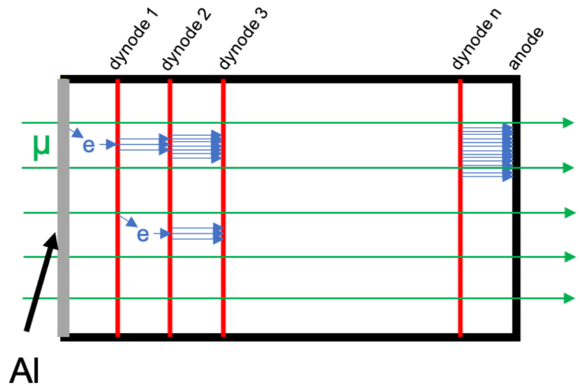




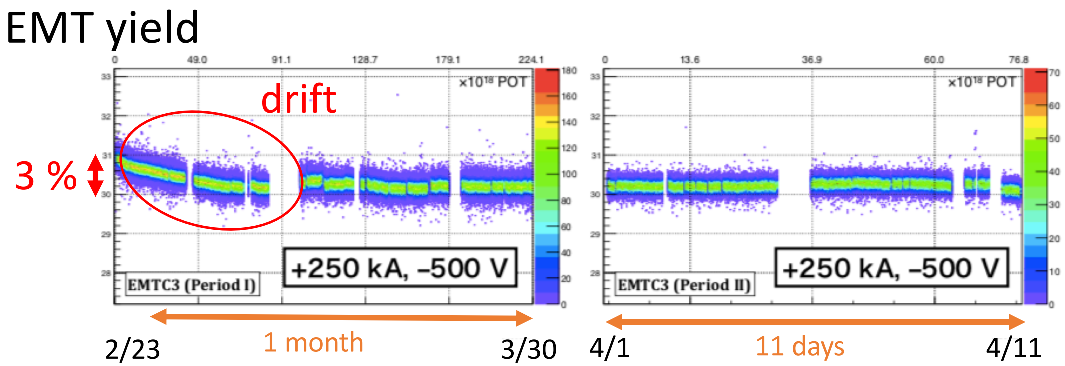
EMT R&D

- Initial study of linearity, stability was checked at J-PARC → it looks promising
- Test beam experiments to evaluate radiation tolerance were performed
- Development with domestic Universities and US-Japan collaboration





EMT



Summary

- J-PARC accelerator and neutrino beamline upgrade program is essential for T2K and Hyper-K experiments
- Upgrade program for high power is ongoing under strong international and domestic collaboration

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