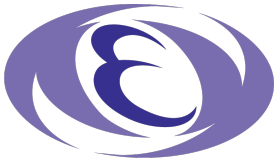
T2K / J-PARC status

T. Nakadaira
High Energy Accelerator Research Organization (KEK)



IPNS / J-PARC
for
T2K collaboration

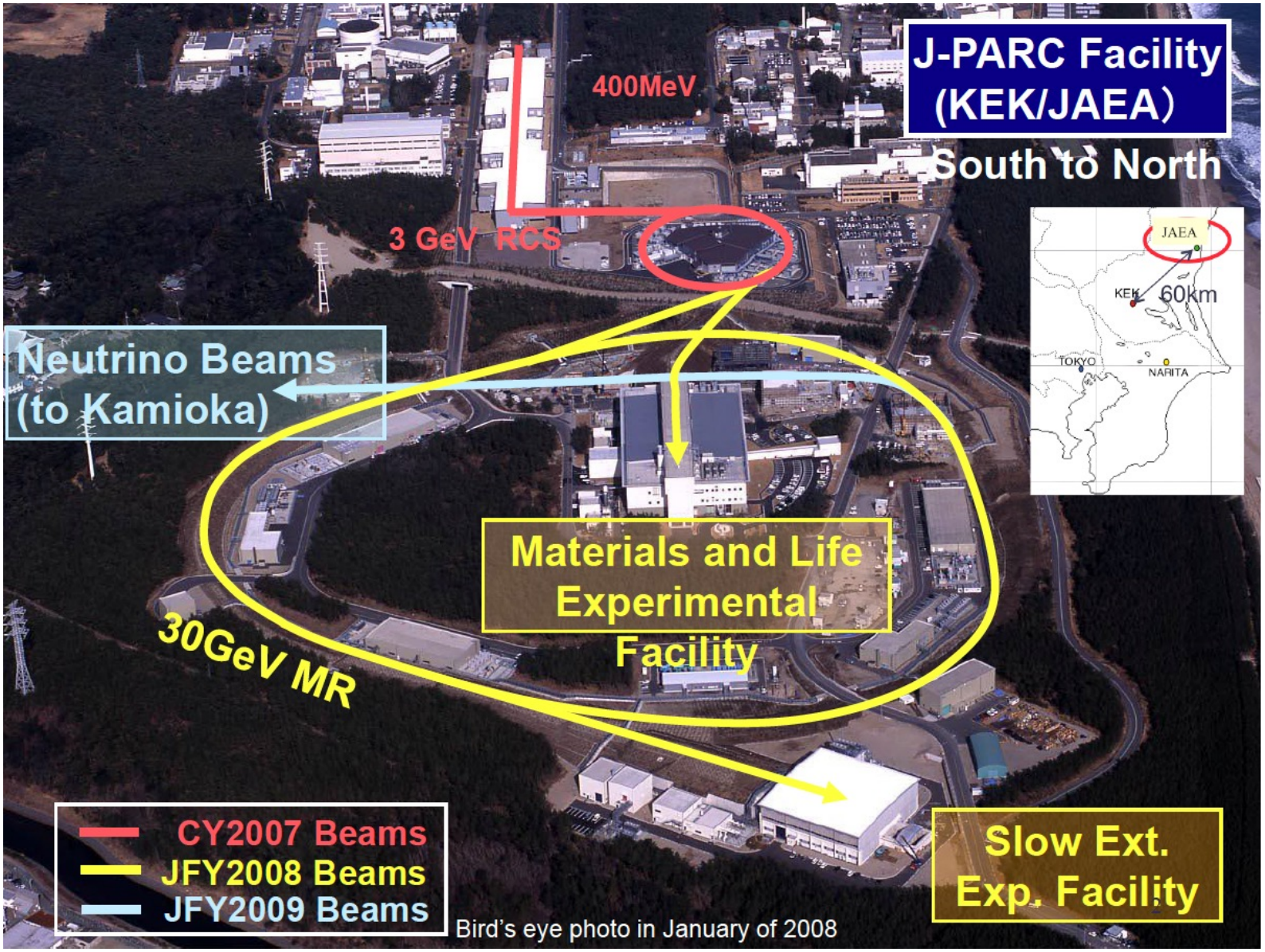
J-PARC neutrino facility

Contents

- Overview of J-PARC and J-PARC neutrino facility
- J-PARC Accelerator status
- Operation status of J-PARC neutrino facility
- Recent T2K physics results & Prospects
- Future Project: Hyper-Kamiokande

J-PARC: Japan Proton Accelerator Research Complex

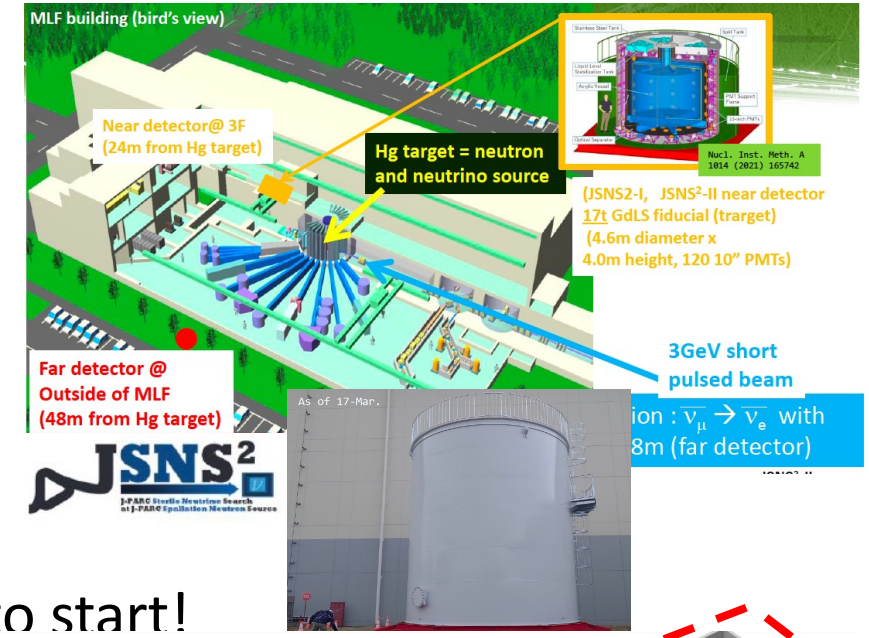
- 3 accelerators and 3 experimental facility



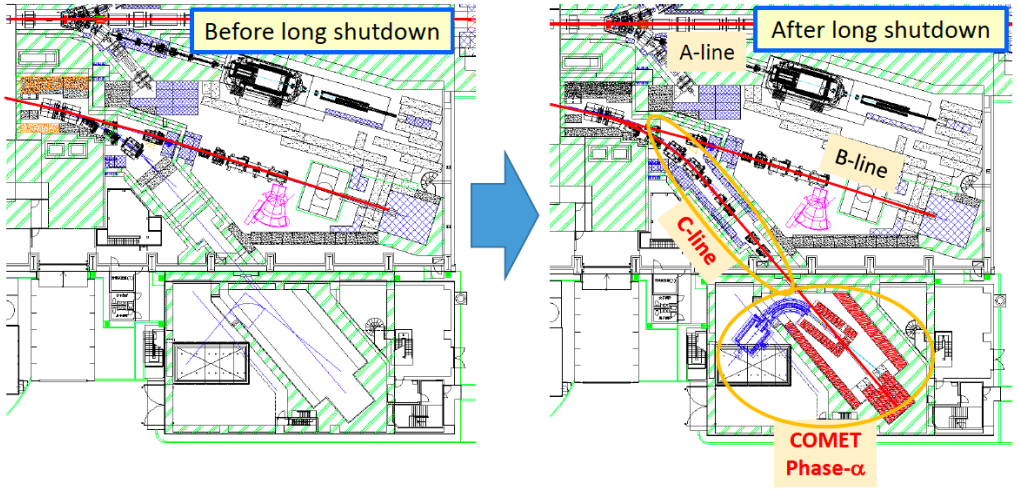
Experimental Facilities @ J-PARC

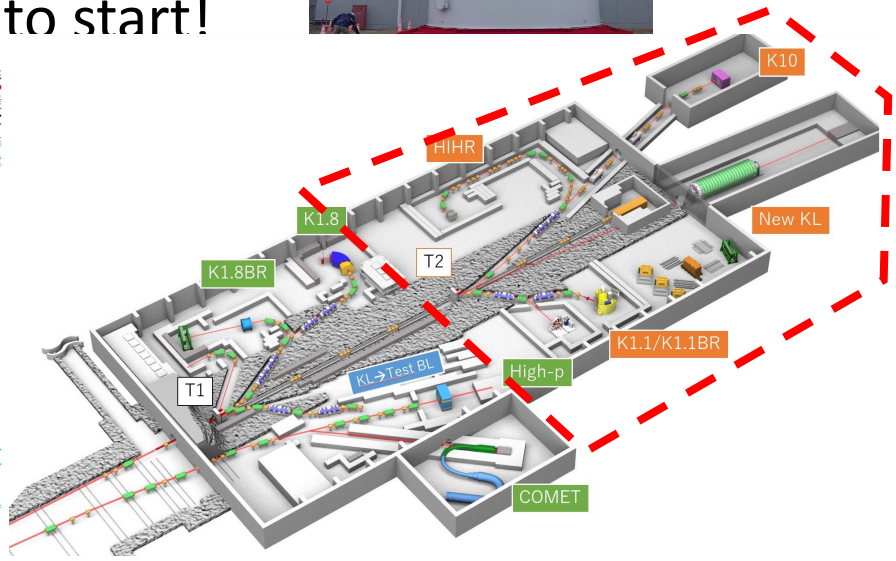
- **MLF**: Material & Life science
  - JSNS^2(E56: Short-baseline neutrino experiment) is running.
  - JSNS^2-II (E82: w/ 2nd detector) is under preparation.

T. Maruyama @ 34th J-PARC PAC



- Hadron experimental Facilities
  - COMET (E21) experiment is about to start!

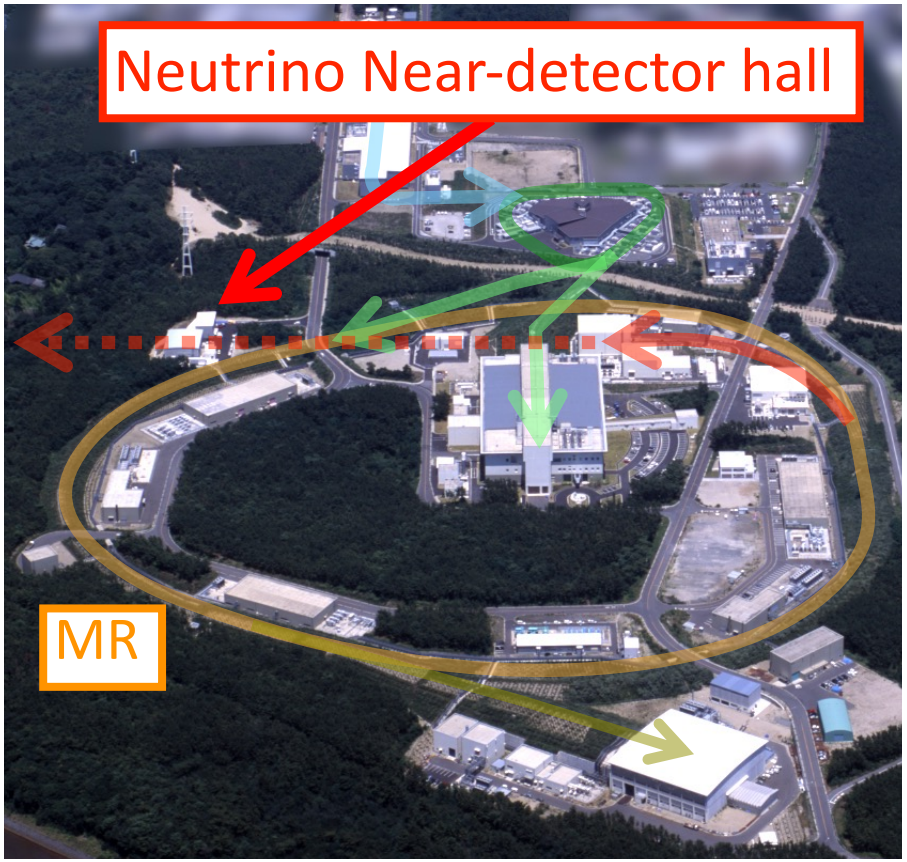




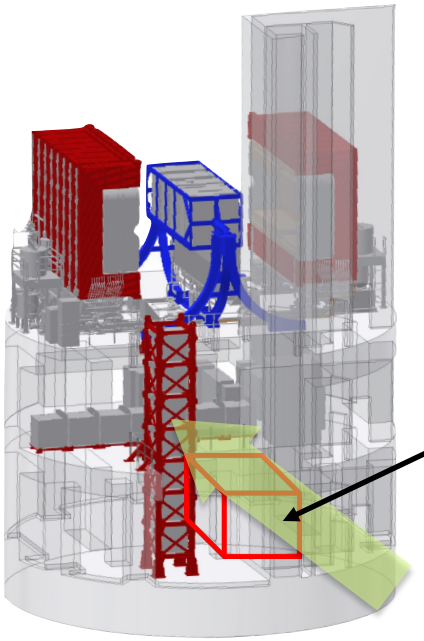
- **Hadron hall extension** : high-prioritized project in KEK-PIP 2022.

J-PARC neutrino experimental facility

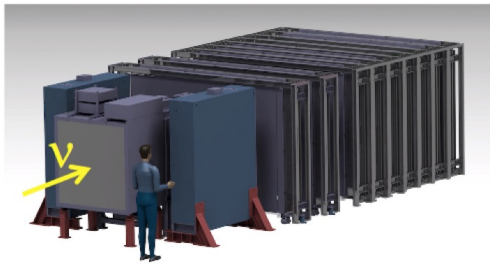
- High intensity neutrino beam by MR-FX 30GeV protons
  for Long base-line neutrino experiments: **T2K** (E11/E65) and **Hyper-K**.
  - Operation start @ 2009: Original design
    - 750 [kW]: 3.3×10^{14} [p/pulse], Repetition 2.1[s]
      → Upgraded goal: **1.3 [MW]** 3.3×10^{14} [p/pulse], Rep. 1.16[s]



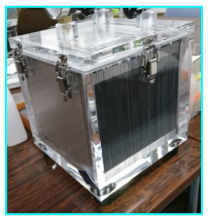
- T2K near detectors
- NINJA (E71): Running
- SUBMET (P83:)

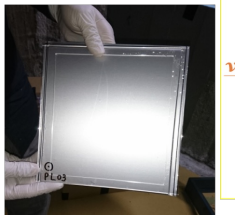


E69/T2K WAGASCI



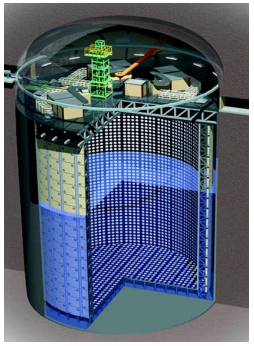
E71 Emulsion

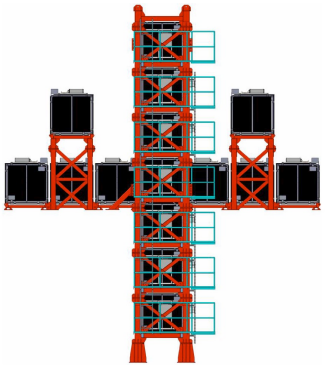


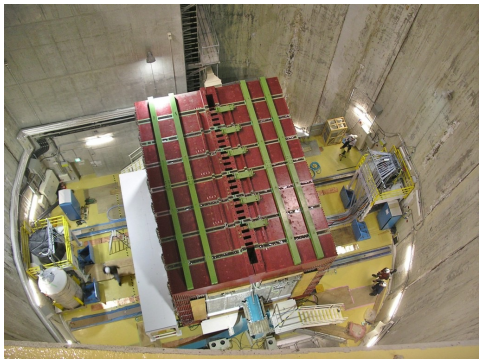


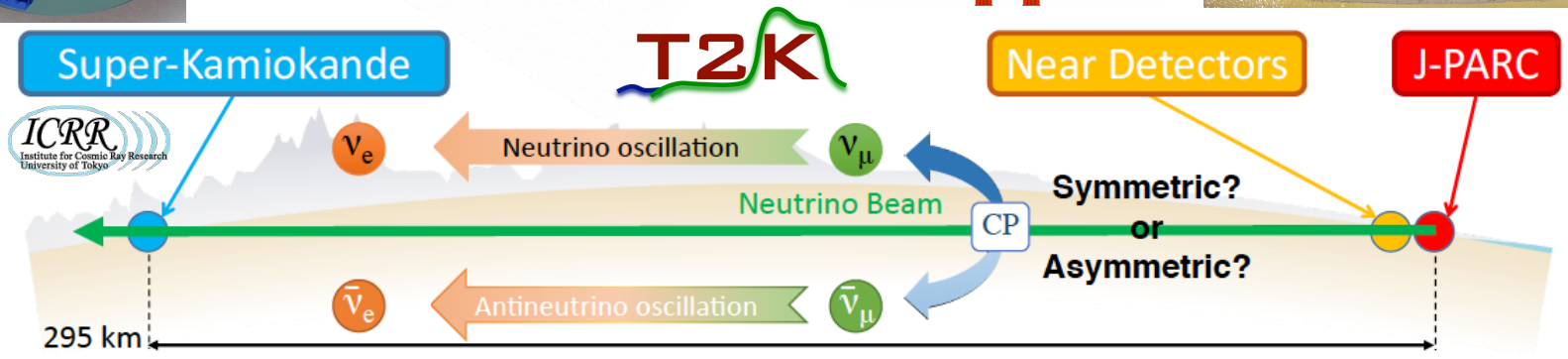
T2K: LBL neutrino oscillation experiment

- **Physics goals**
  - Search for the new neutrino oscillation: $\nu_\mu \rightarrow \nu_e$ (~2013)
  - **Search for CP violation in lepton sector (2014~)**





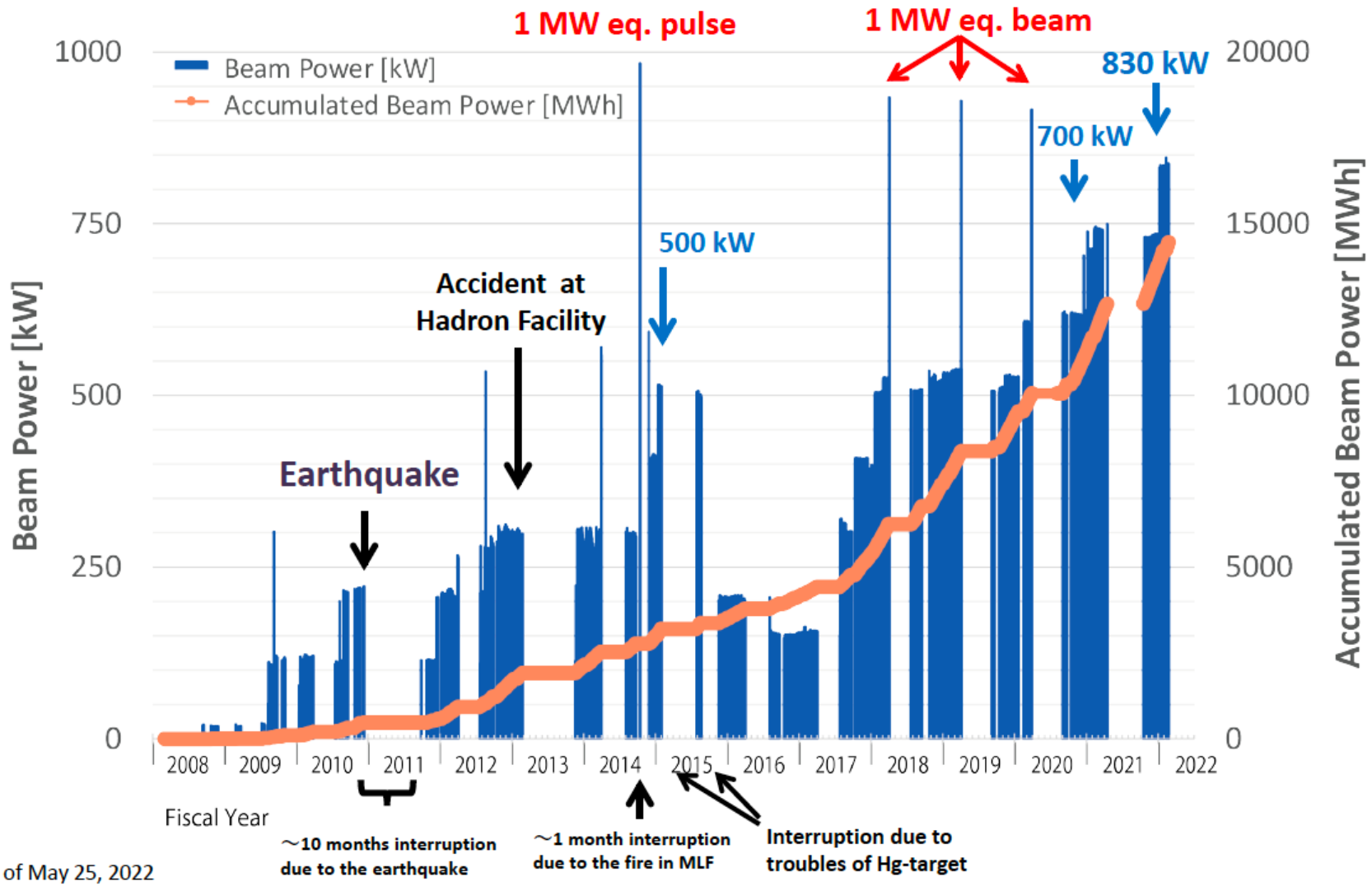




~528 members, 70 Institutes, 14 countries

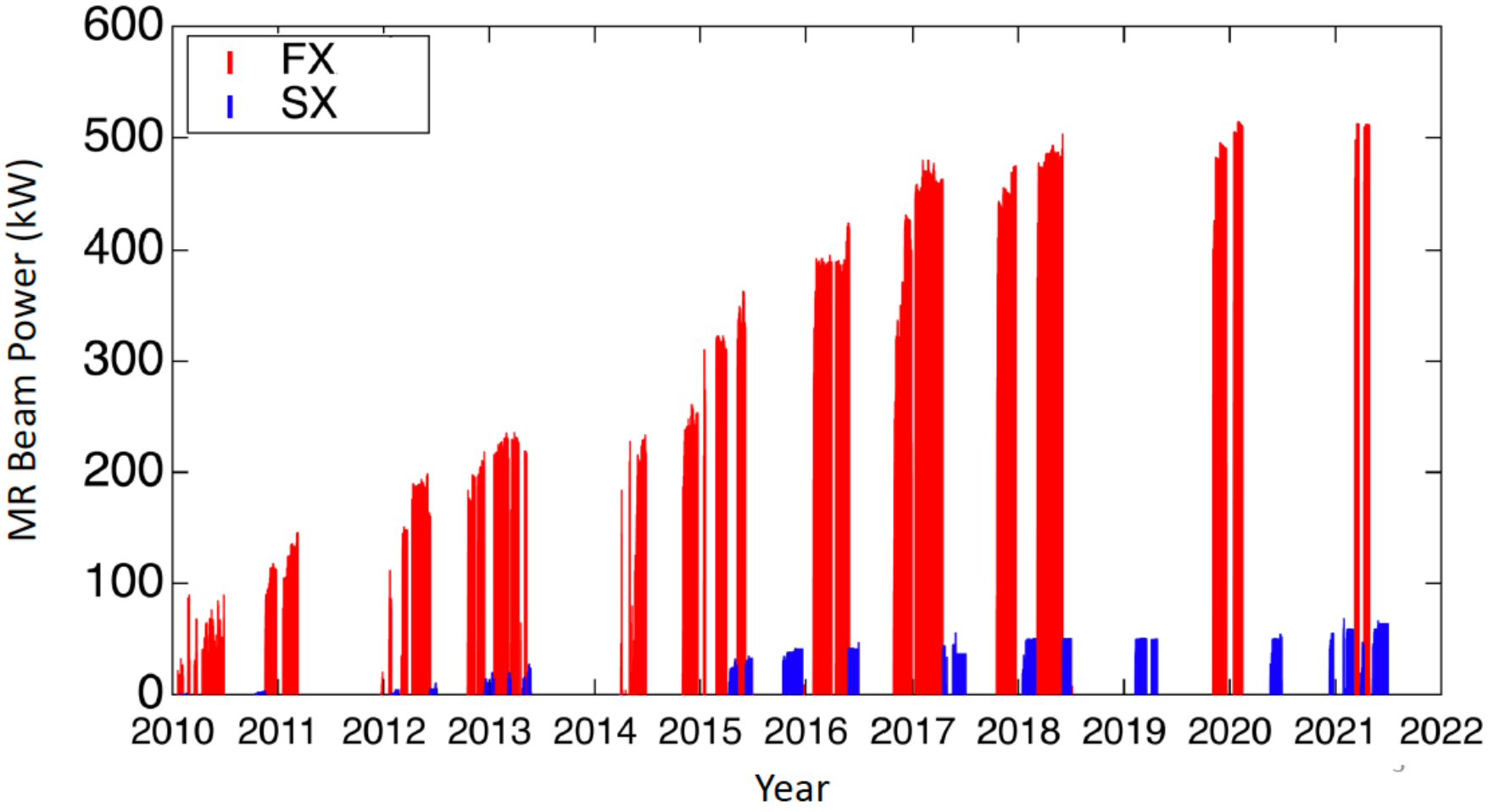
J-PARC Accelerator status: LINAC+RCS

- RCS beam power to MLF (Design: 1MW)
  → **830kW** stable beam has been achieved!

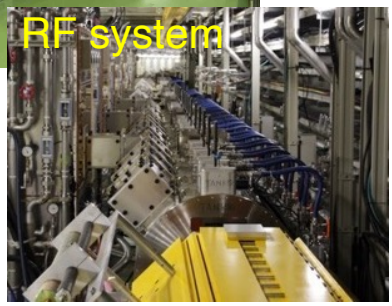


J-PARC Accelerator: MR beam power

- ~510kW for NU/FX user
  - 2.6×10^{14} proton/pulse w/ 2.48s repetition .
- ~65kW for HD/SX user
  - Extraction efficiency of 99.5%



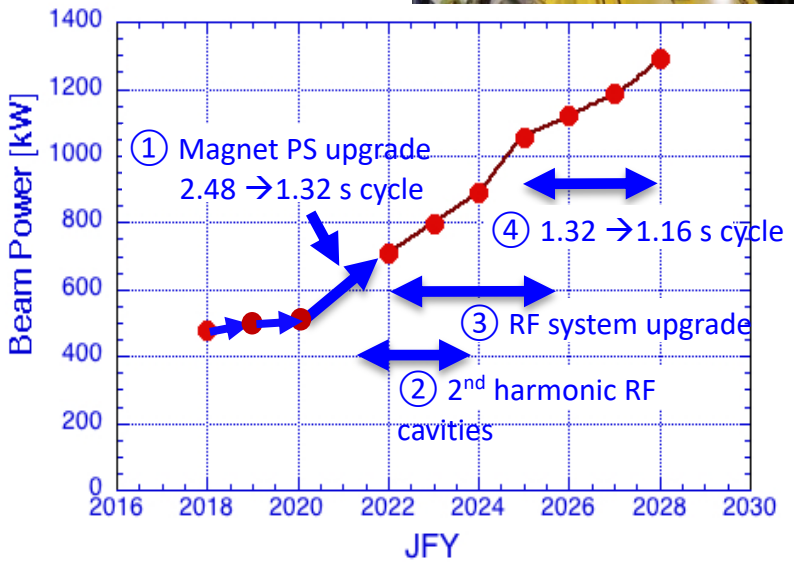
J-PARC MR Mid-term plan



JFY	2020	2021	2022	2023	2024	2025	2026	2027	2028
Event		Long Shutdown							
FX power [kW]	515	-	>700	800	900	>1000	>1100	>1200	1300
SX power [kW]	55	60–70	>80	>80	>80	>80	~100	~100	~100
Cycle time for Fast Extraction New Magnet PS	2.48s		1.32s	1.32s	1.32s	1.32s	<1.32s	<1.32s	1.16s
RF system upgrade									
2nd RF system upgrade									
Collimator system		Add.colll. (3.5kW)							
Injection system FX system									
Beam Monitors (BPM circuits)									

Mass Production Installation/Test

Kicker PS improvement Septa manufacture Test

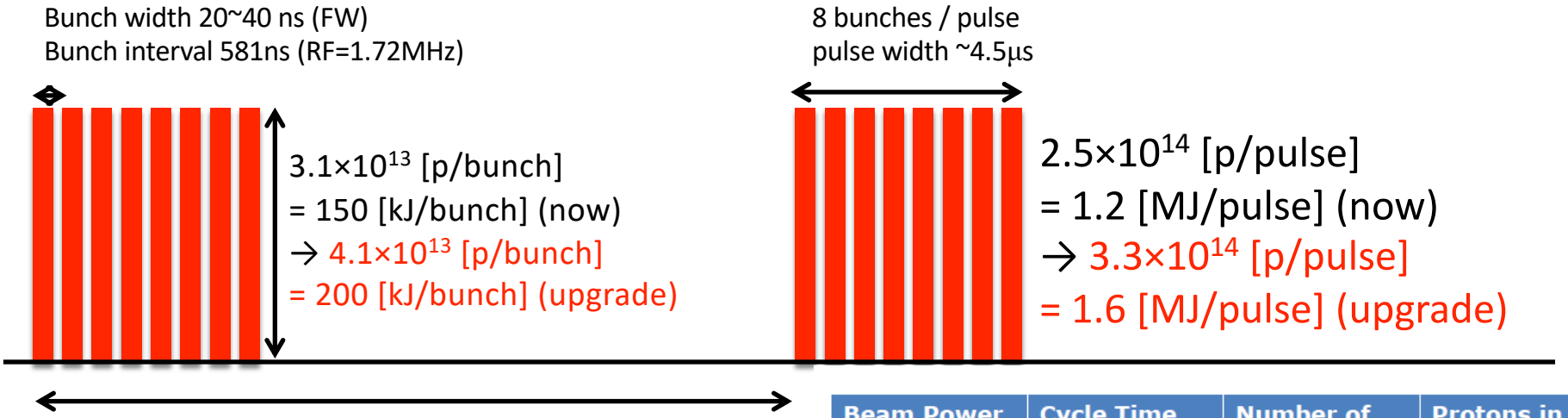


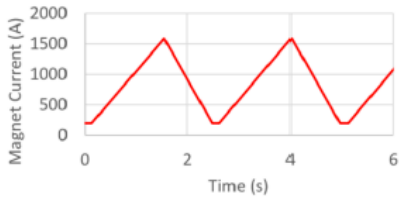
MR Schedule 2021 – 2022

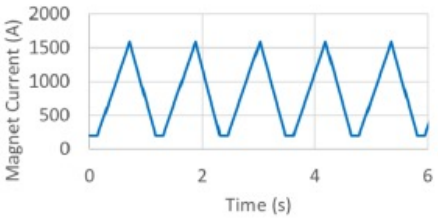
- 2022 June: Beam circulation (3GeV-DC)
- 2022 Nov.: 30GeV acceleration commissioning.

J-PARC MR-FX Beam structure

- Operation rate of beam-line equipment should be increased.
  - Horn, Beam-monitor DAQ, Beam interlock, etc
- Target protons/pulse is same as J-PARC original design.
  → Requirement for a single spill is not changed.
  - Thermal shock tolerance of target, beam window, etc
- Beam heat load, Radiation, Radio-activation will be increased w.r.t beam power or POT.
  - Cooling capability, radiation shields, radioactive waste treatment, etc





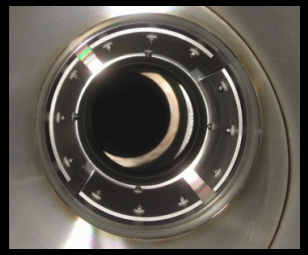
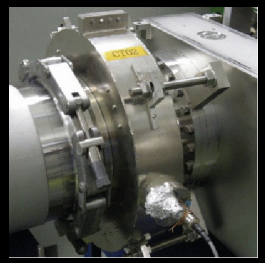
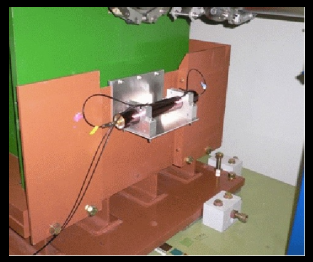


Beam Power	Cycle Time	Number of accelerated protons	Protons in each bunch
500 kW	2.48 s	2.6×10^{14} ppp	3.3×10^{13} ppb
750 kW	1.32 s	2.1×10^{14} ppp	2.6×10^{13} ppb
1.3 MW	1.16 s	3.3×10^{14} ppp	4×10^{13} ppb

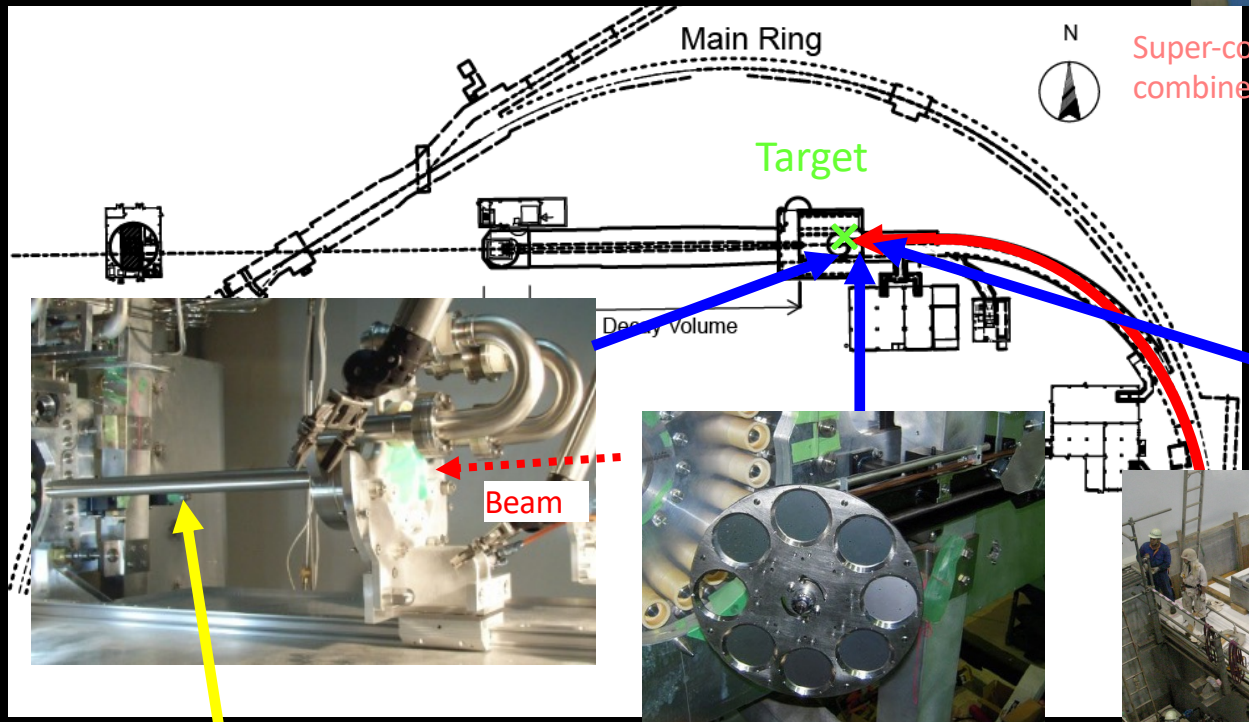
J-PARC ν beam line :Primary-line

Beam monitors are install along the proton beam transport

Profile (19) Position (21) Intensity (5) Beam loss (50)

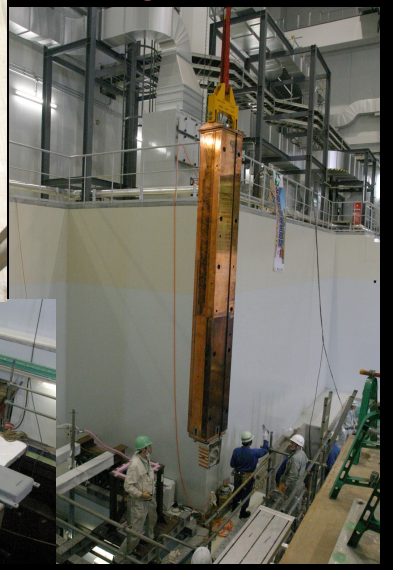





Primary proton transport line

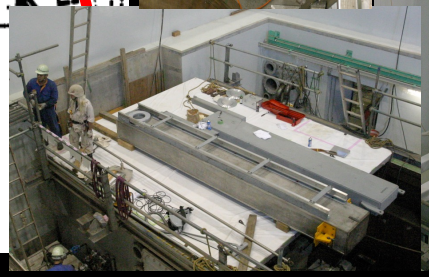
Super-conducting combined-function magnets

Normal-conducting magnets



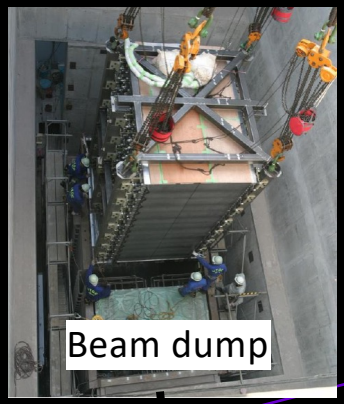
Target :graphite rod
ϕ26mm,L=900mm

Optical Transition Radiation (OTR)
Profile monitor

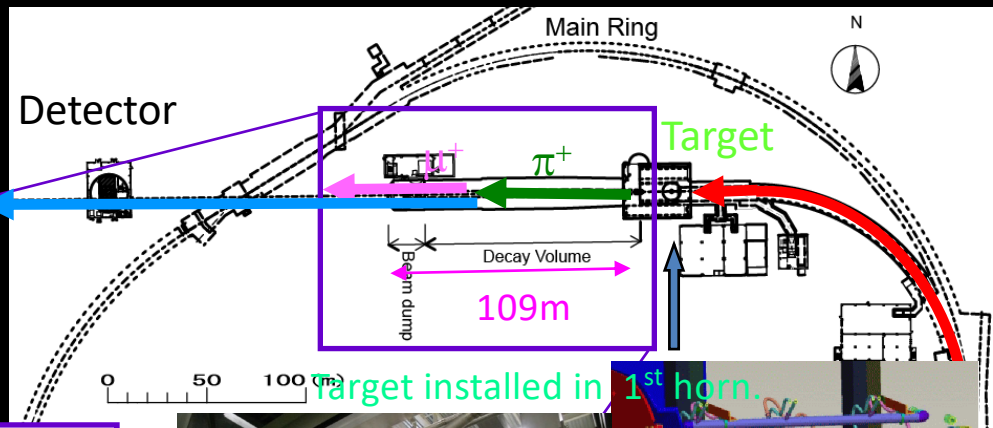


Vacuum chamber and structure
for most downstream beam monitors

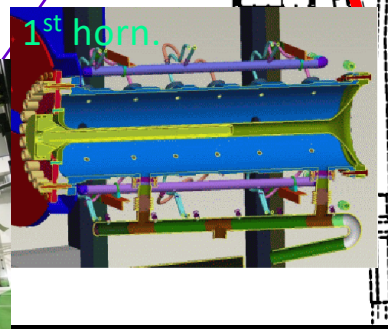
J-PARC ν beam line: secondary line

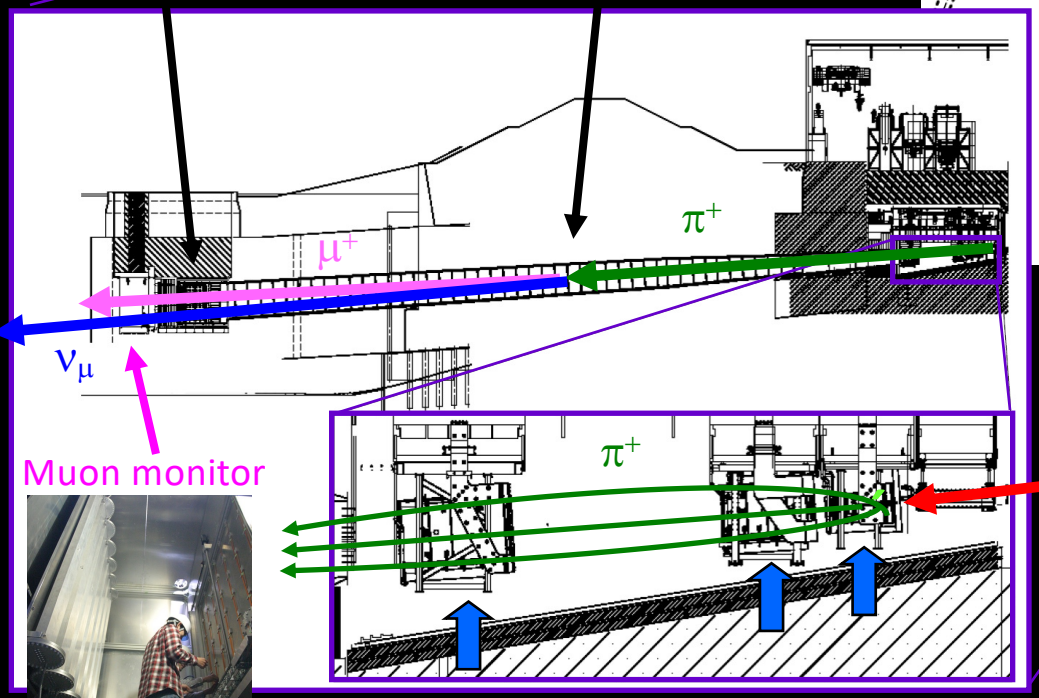


Decay volume (He gas filled)



Target installed in 1st horn.

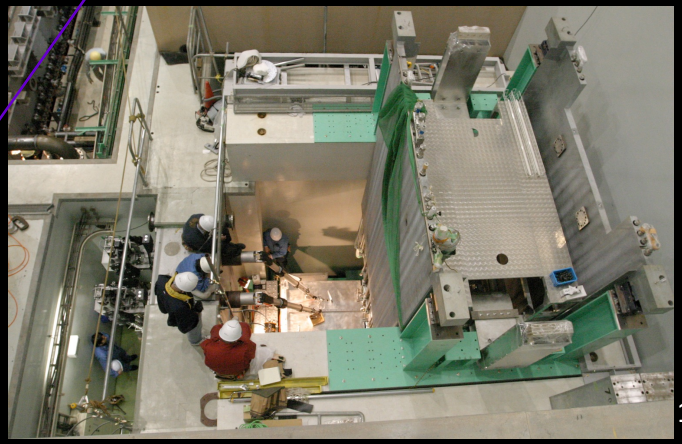




Muon monitor

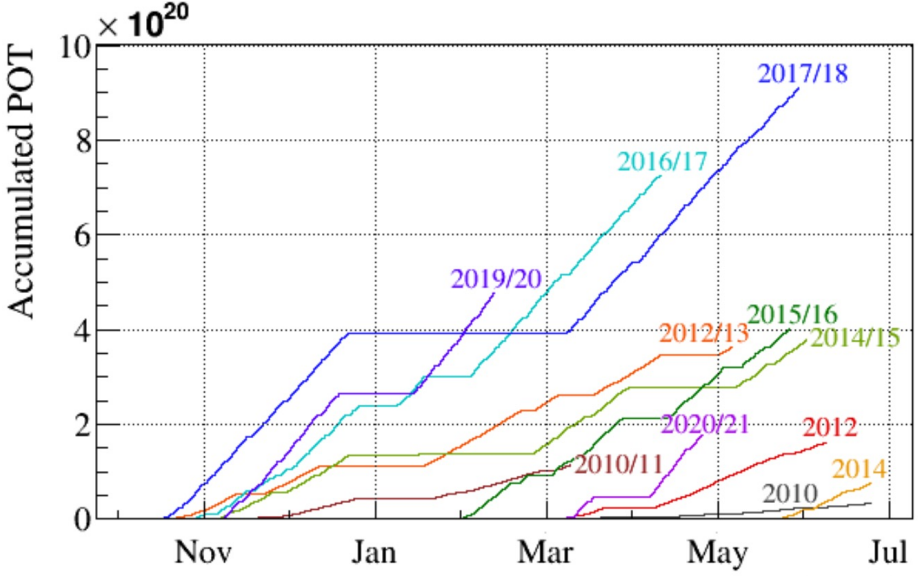
Pions are focused by 3 electromagnetic Horns.

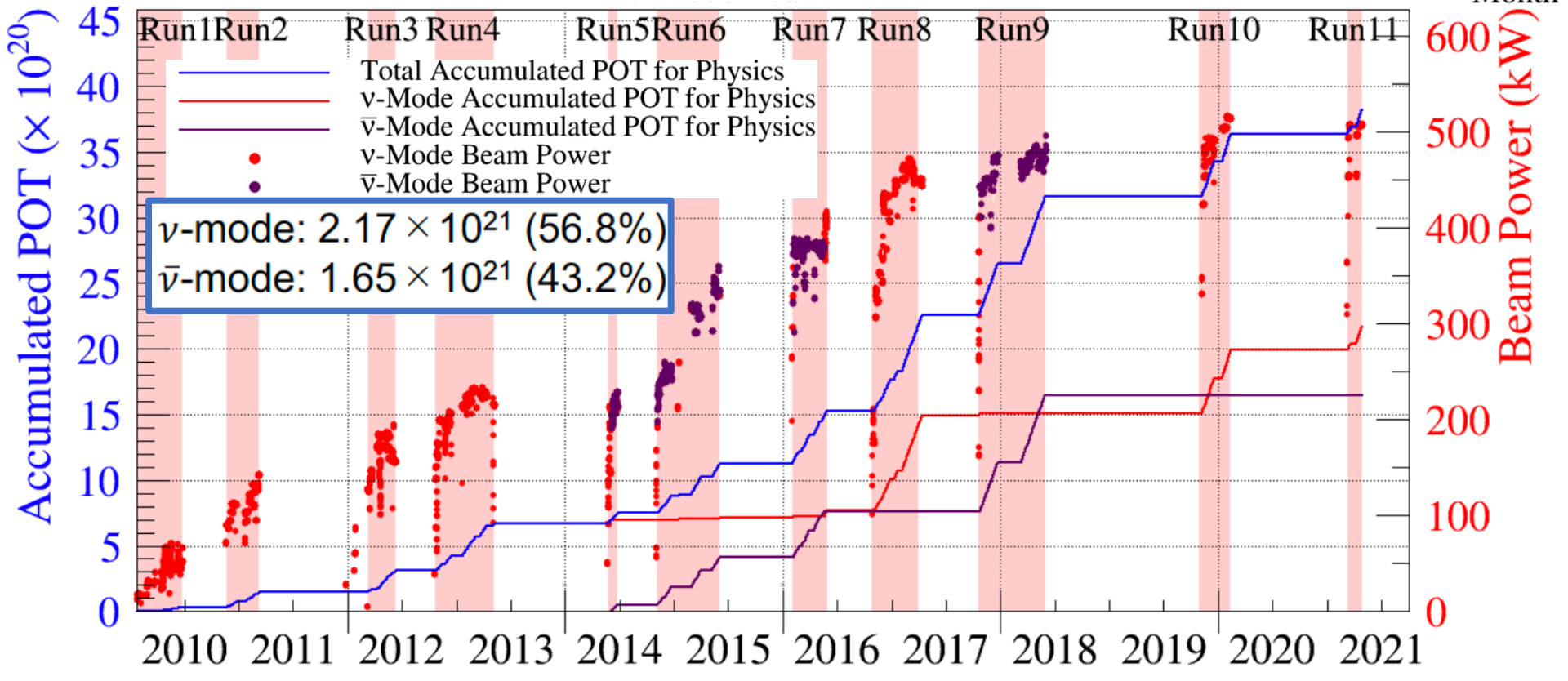
Target/Horn Remote Maintenance area.



Operation history

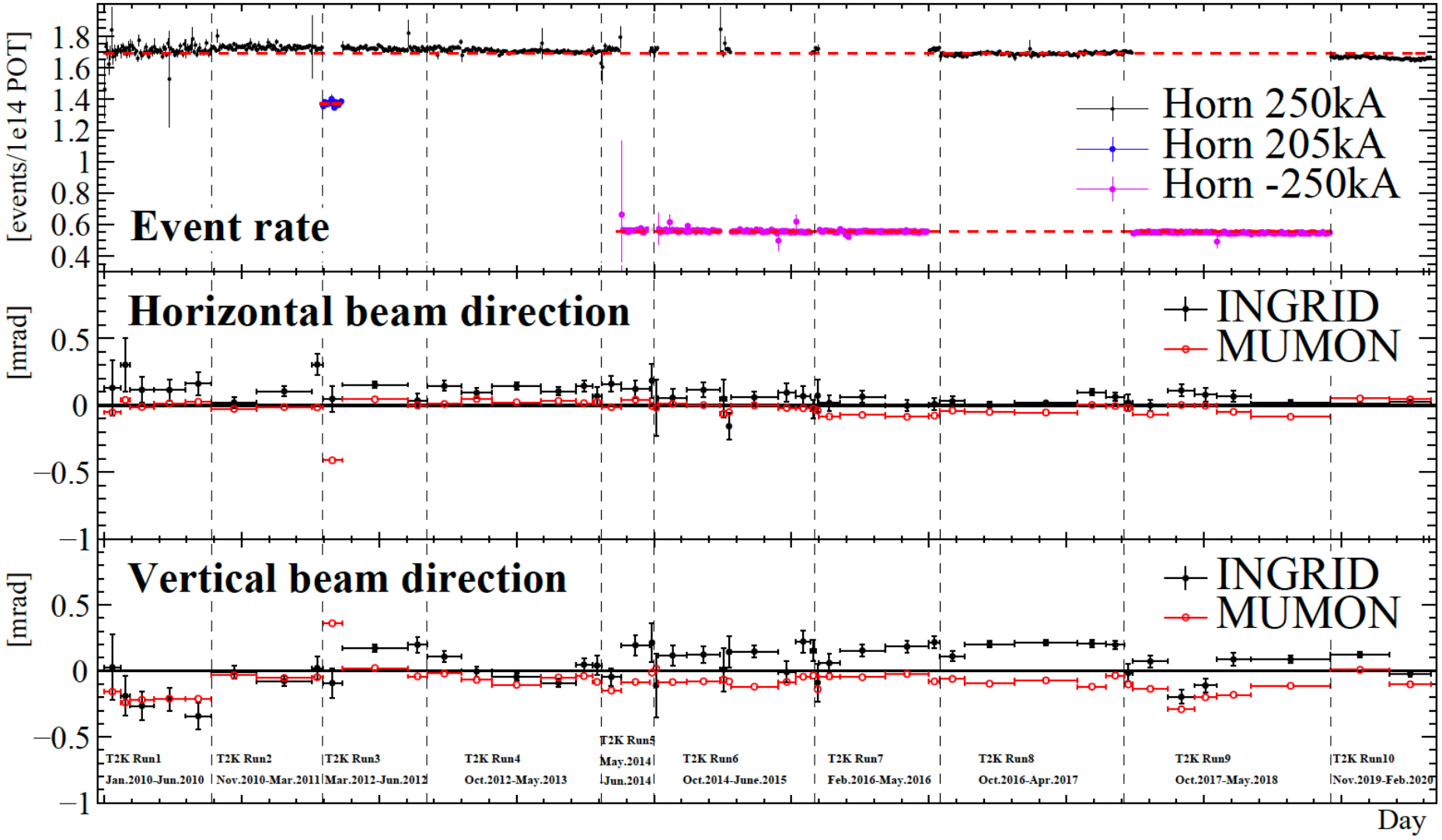
- >510kW stable neutrino beam is achieved.
- Total: 3.82×10^{21} POT





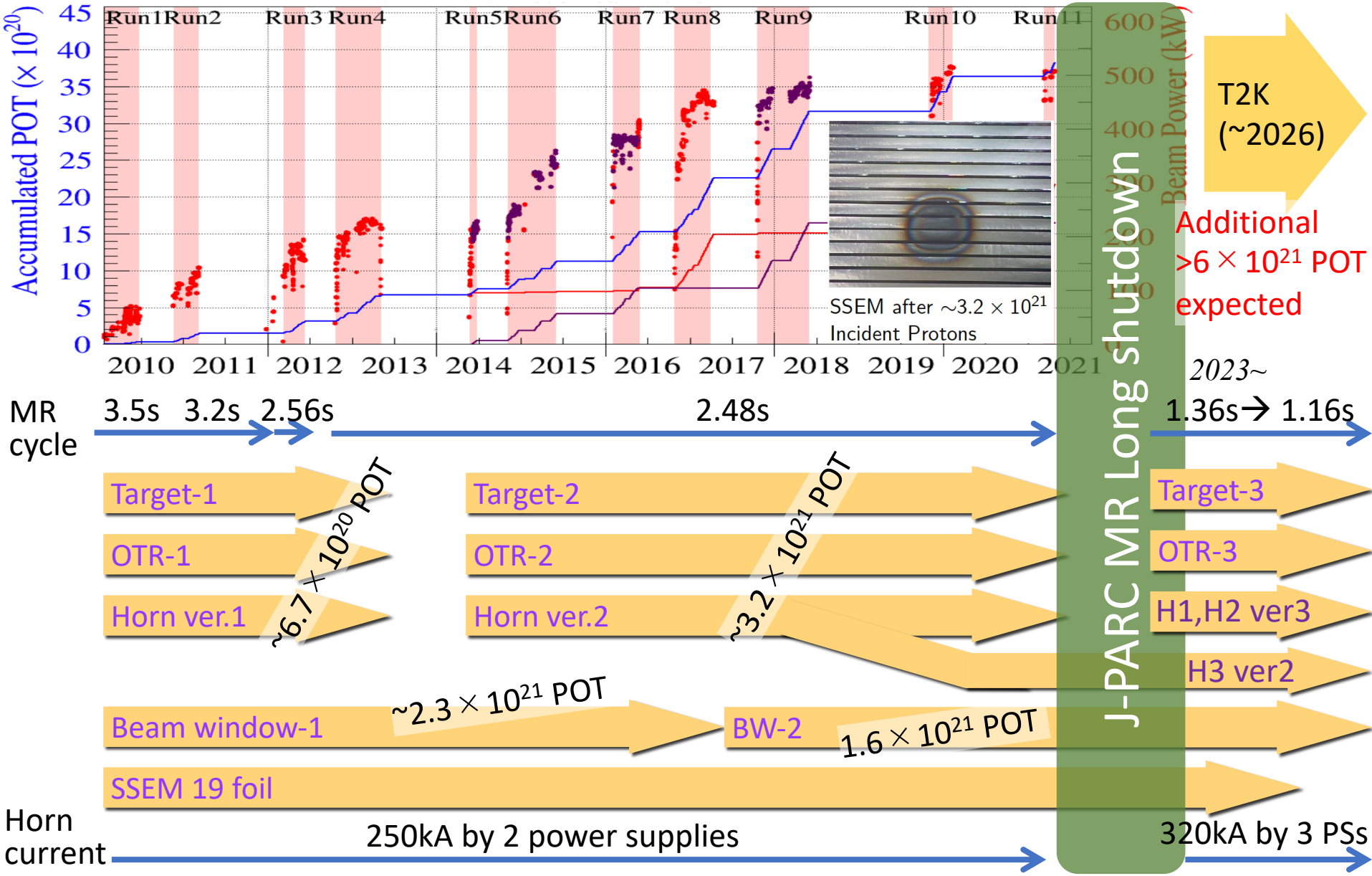
Neutrino beam stability

- We have successfully tuned neutrino beam direction within << 1mrad.



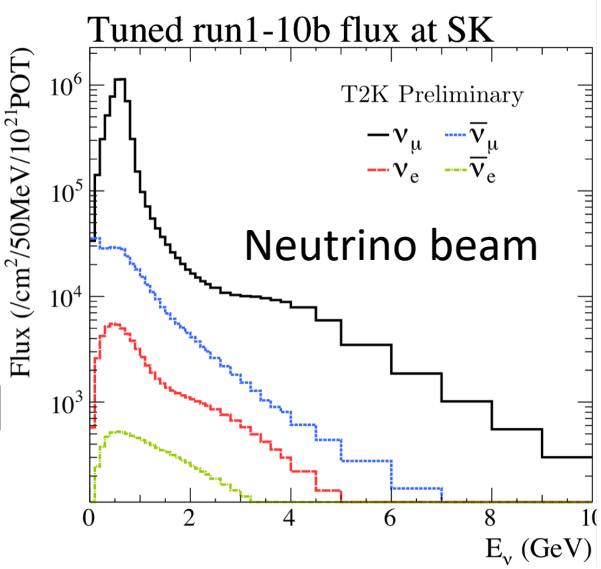
Operation & maintenance history

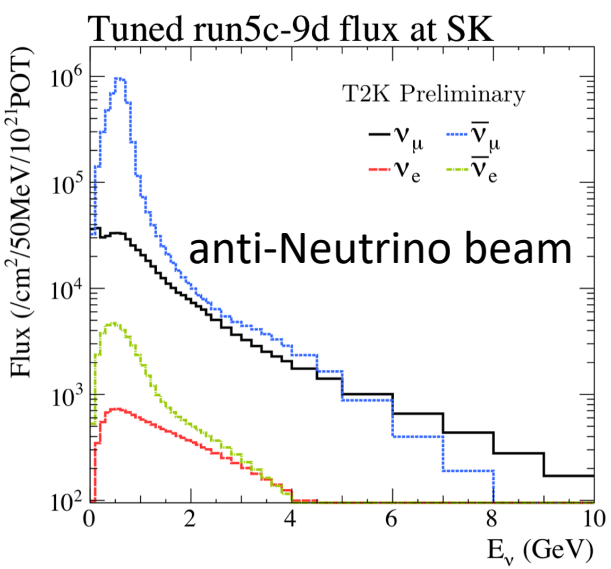
J-PARC ν-beam-line equipment has survived up to 2~3 × 10^{21} POT!



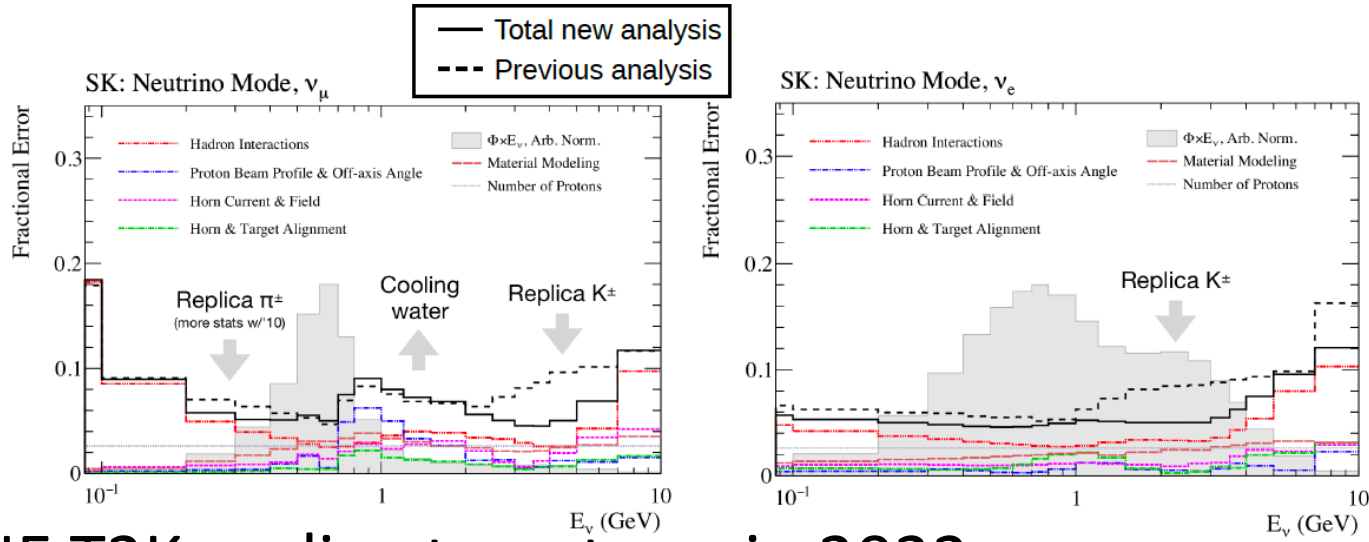
Neutrino flux

- Flux is estimated using dedicated hadron production measurement: CERN NA61/SHINE.





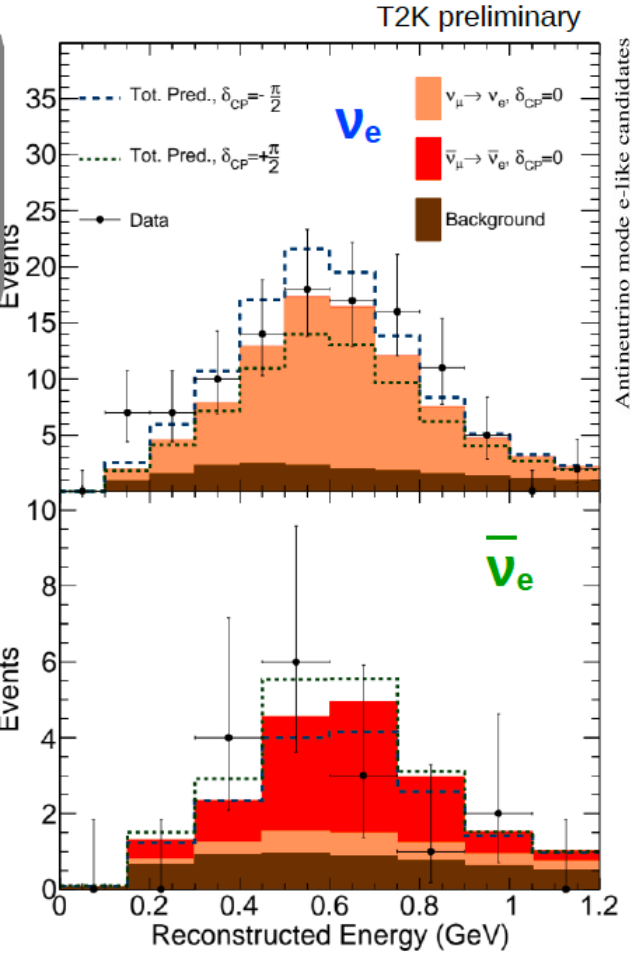
- Flux uncertainty is improved using NA61/SHINE replica-target data in 2010. But, more conservative treatment due to material modeling is necessary.

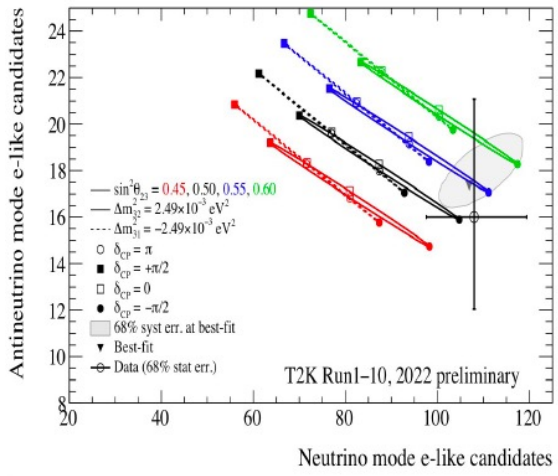


- New NA61/SHINE T2K replica-target run in 2022 summer.
  → Further high-statistics data has been obtained.

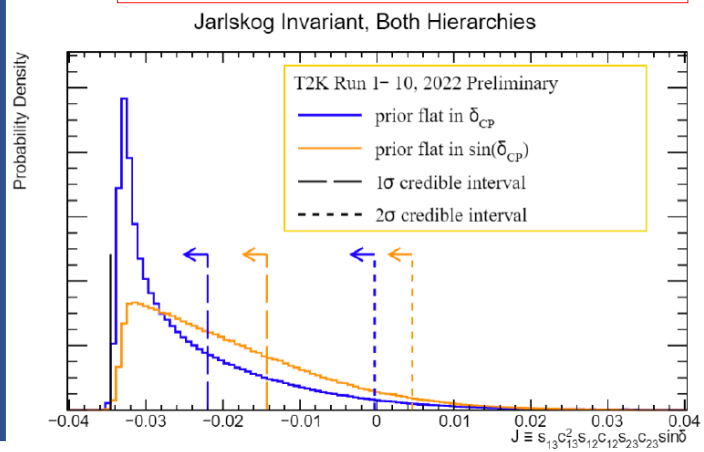
Recent results from T2K

- New results by improved analysis using 2010-2020 data.
  - Improved neutrino flux, using ND280 event samples with new categories, increasing new SK event samples, …
- Hint for Lepton CPV w/ 90% CL.

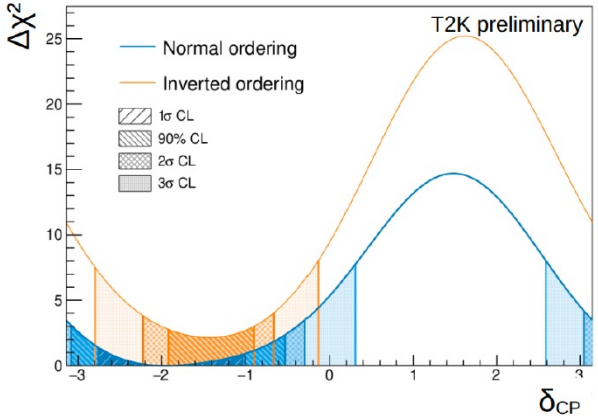




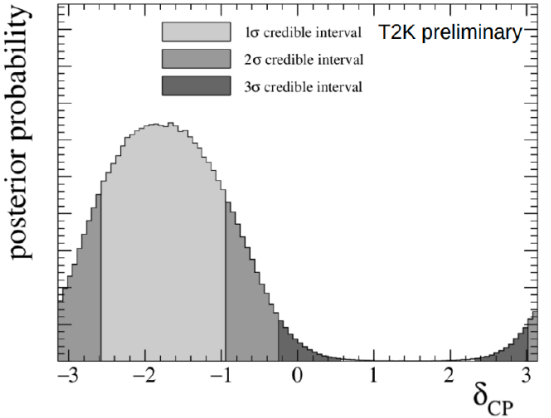
$$J = s_{13}c_{13}^2 s_{12}c_{12}s_{23}c_{23}\sin\delta_{CP}$$



Frequentist
(Feldman-Cousins method)

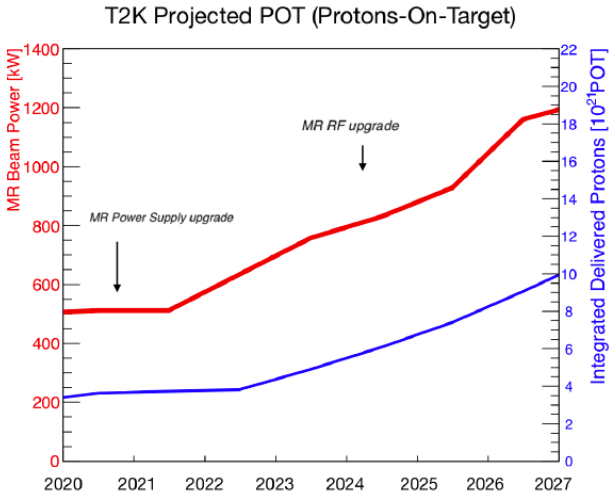


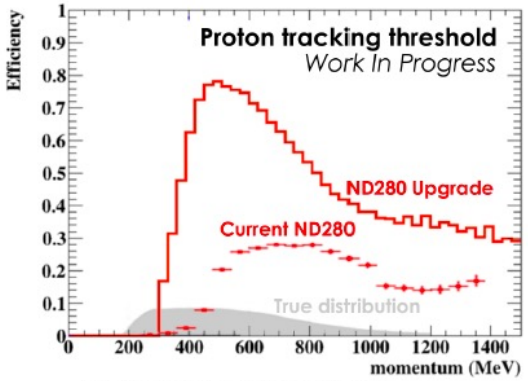
Bayesian
(marginalized over MO)

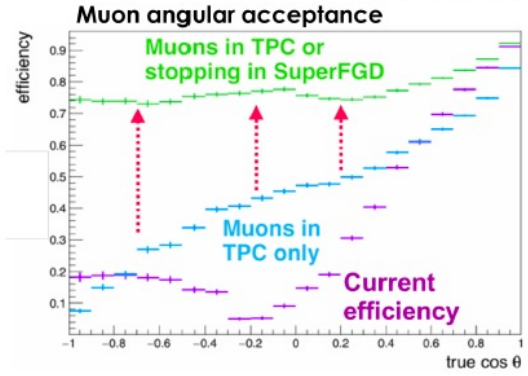


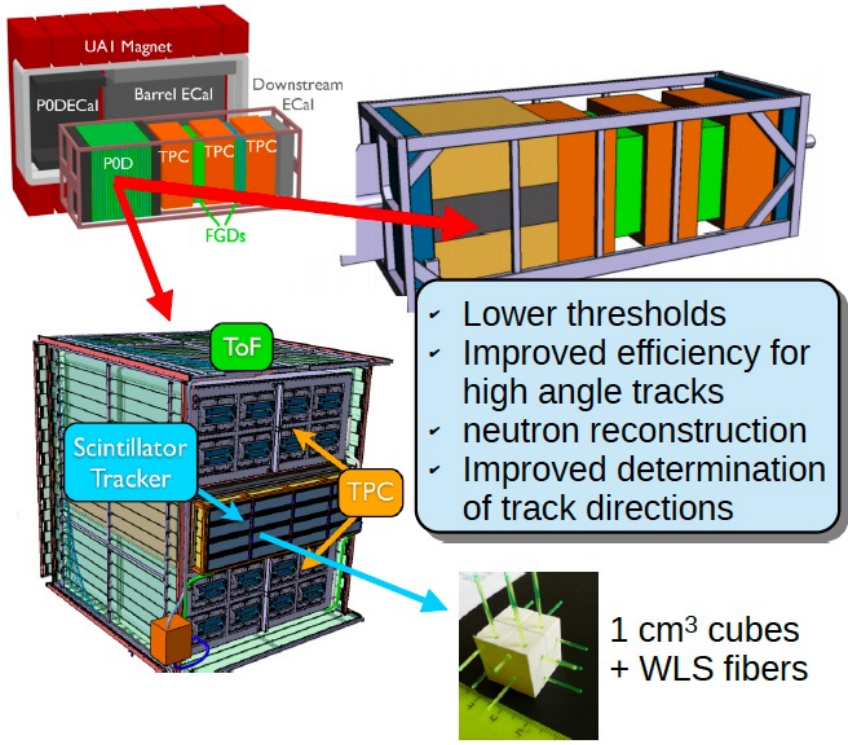
T2K prospects

- Aiming CPV search with >3σ sensitivity for largest CPV
  - Accumulating Total ~1 × 10^{22} POT (3 times statistics)
    + Horn current 250kA → 320kA (~10% increase ν flux/proton)
  - Upgrading ND280 with new Detectors: SuperFGD and HA-TPC.





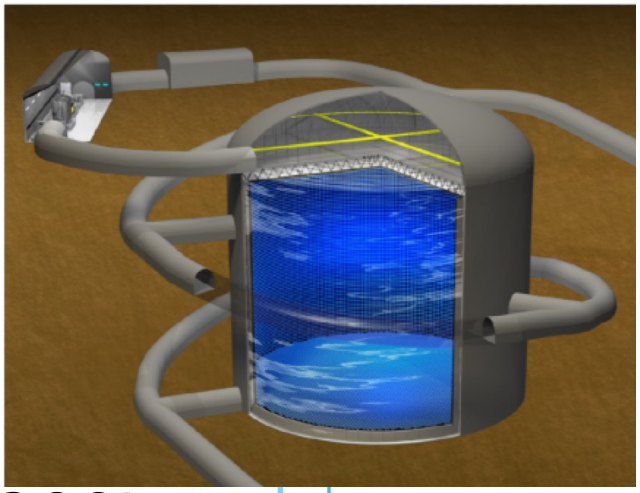




Future Project: **Hyper-Kamiokande**

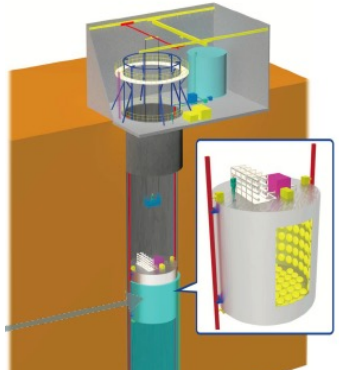
- Main physics goal : Discovery of CP violation in lepton sector with >5 σ significance by accumulating ~2000 $\nu_\mu \rightarrow \nu_e$ events and ~2000 events in ~10 years.
- Construction started in 2020. Exp. start in 2027.

Hyper-Kamiokande

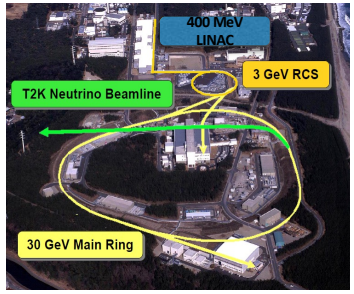


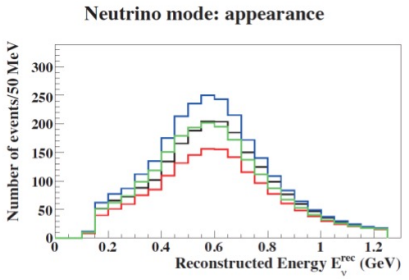
260kt
Cf: SK=50kt

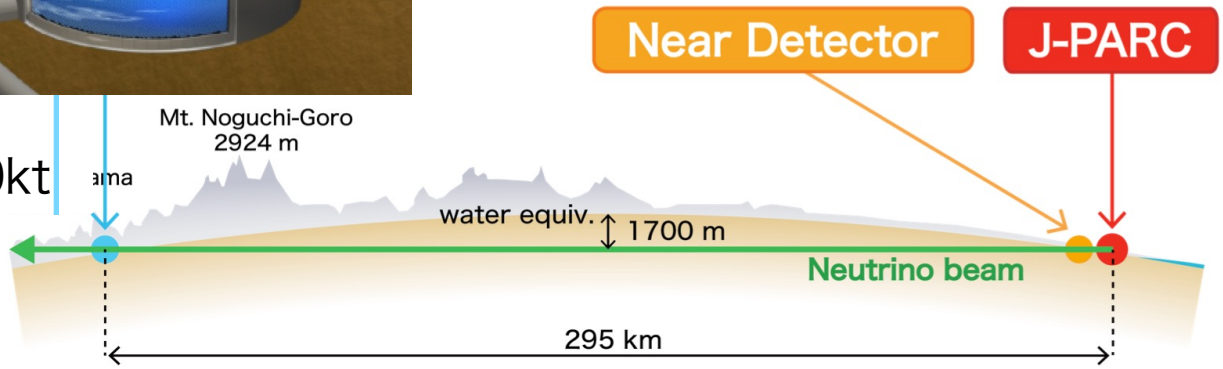
New near-detector

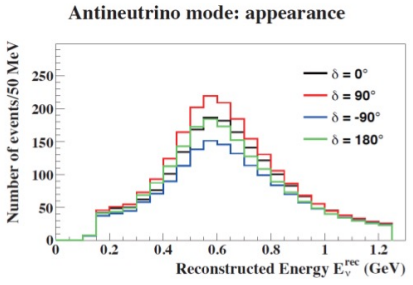


Beam power upgrade
750kW → 1.3MW









Intensity upgrade of J-PARC neutrino beam is essential.

Summary

- J-PARC is multi-purpose facility using MW-class high-intensity proton accelerator.
  → Many neutrino-related experiments are running.
  → Accelerator performance is now approaching to original design after 13 years operation.
- Upgrade of J-PARC MR and Neutrino beam facility is on-going.
  → J-PARC MR operation has beam resumed after ~1 year long shutdown from 2021 July.
- Recent T2K results shows exciting hints for lepton CPV.
  → Resumed T2K running from 2023 and future Hyper-K from 2027 is very promising.