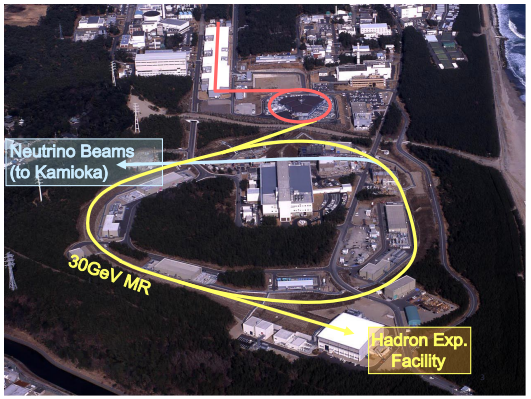


October 10th, 2022
@ESS (through Zoom)
The Commissioning Workshop of ESS-J-PARC collaboration

J-PARC Hadron, Neutrino facility construction, commissioning and operation

Takeshi K. KOMATSUBARA (KEK)
for
J-PARC Particle & Nuclear Physics Division

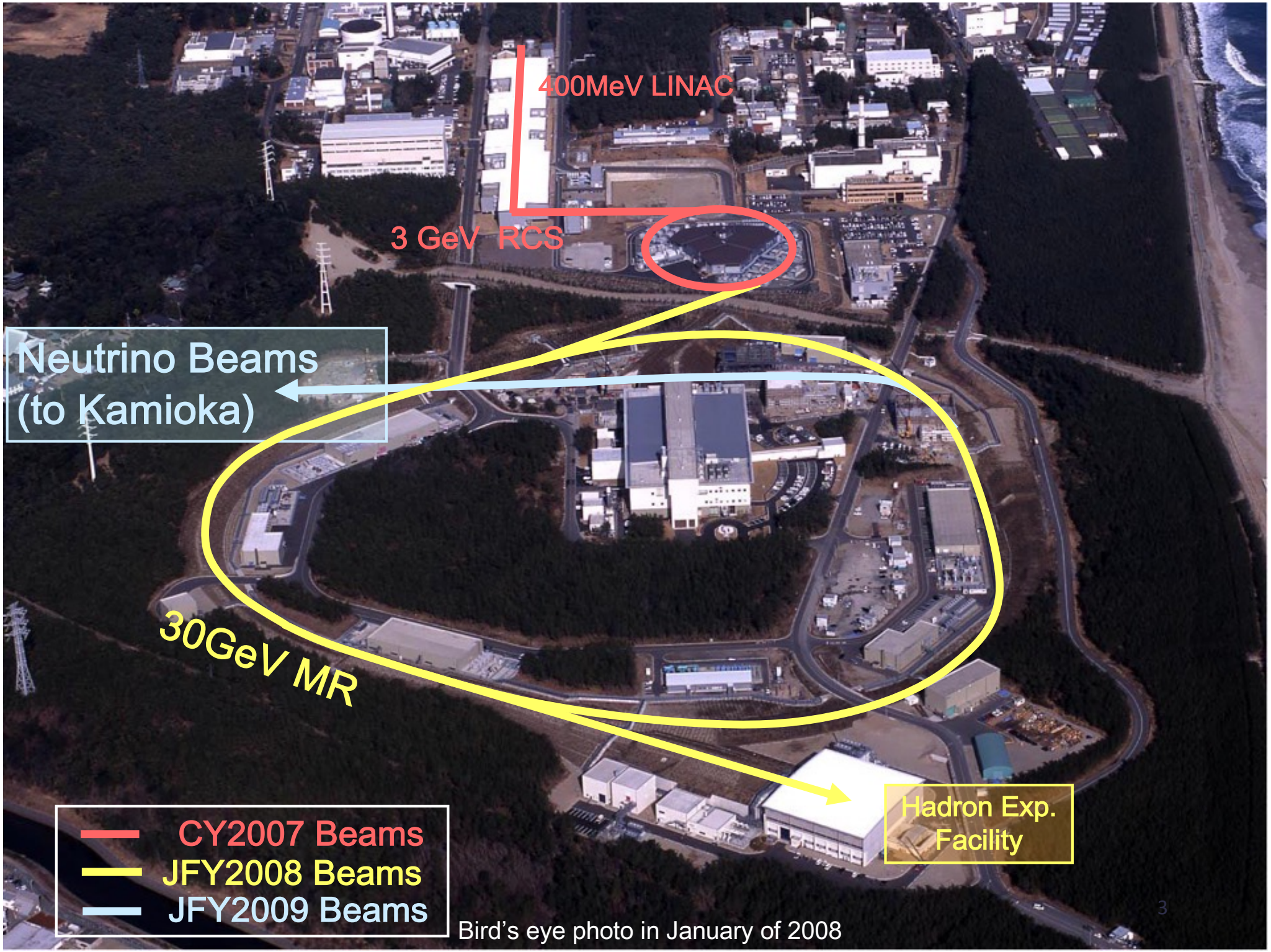
- I apologize I was unable to come to ESS for the workshop.

- The Great East Japan Earthquake in 2011 and
  Radioactive material leak incident at the Hadron Experimental Facility in 2013
  will be covered by Kotaro BESSHO in his talk tomorrow.

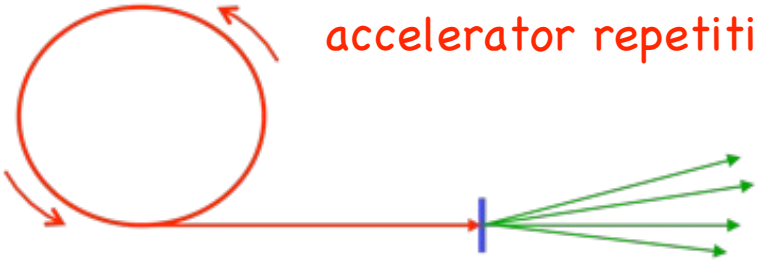
- Though the title of my talk is

J-PARC Hadron, Neutrino facility construction, commissioning and operation

I would focus on
the operation and facility upgrades after the initial construction.

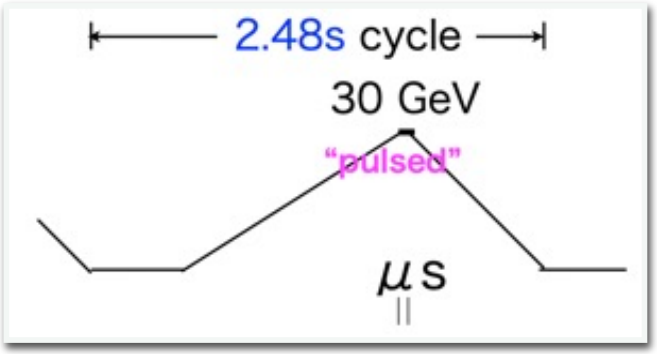


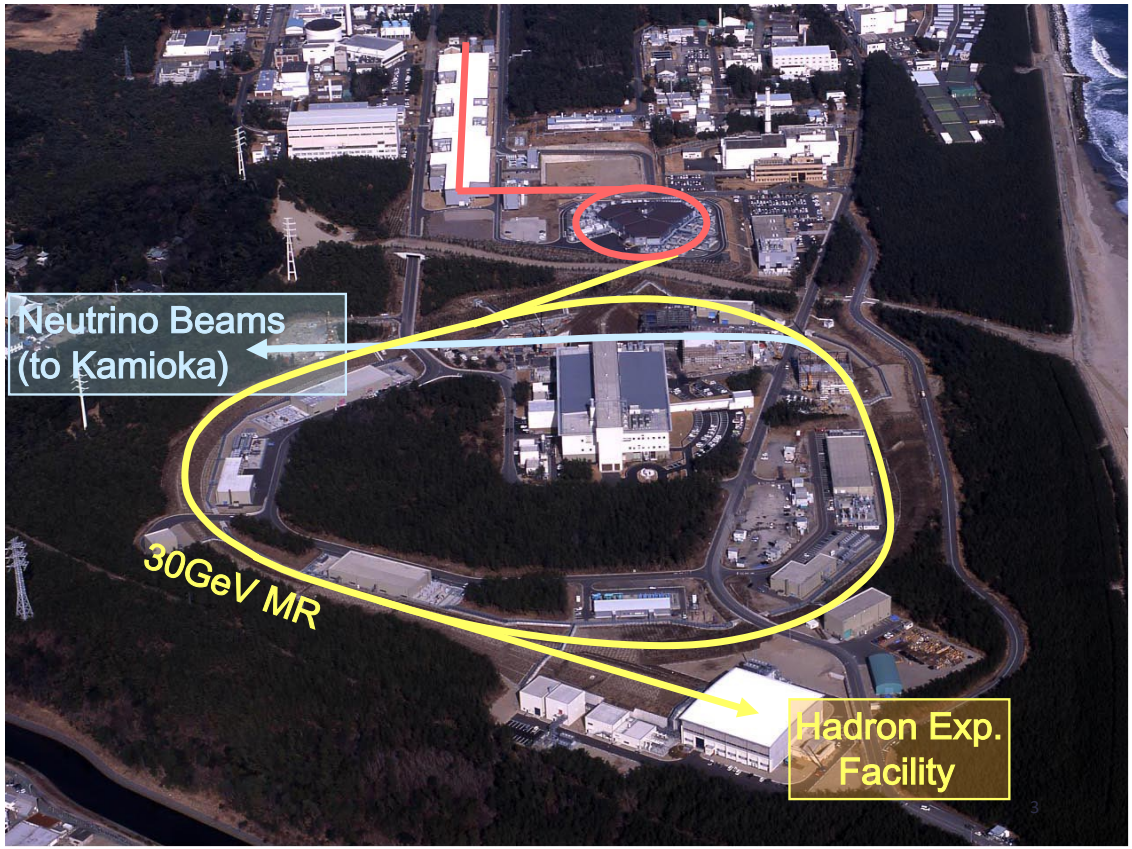
Bird's eye photo in January of 2008



Fast extraction

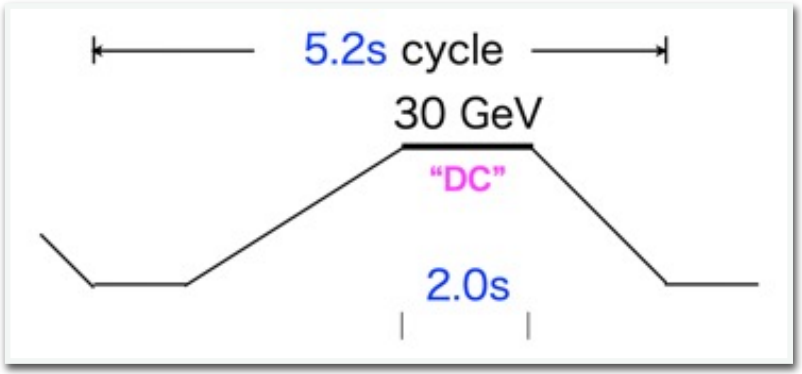
by kicker magnet





Slow extraction

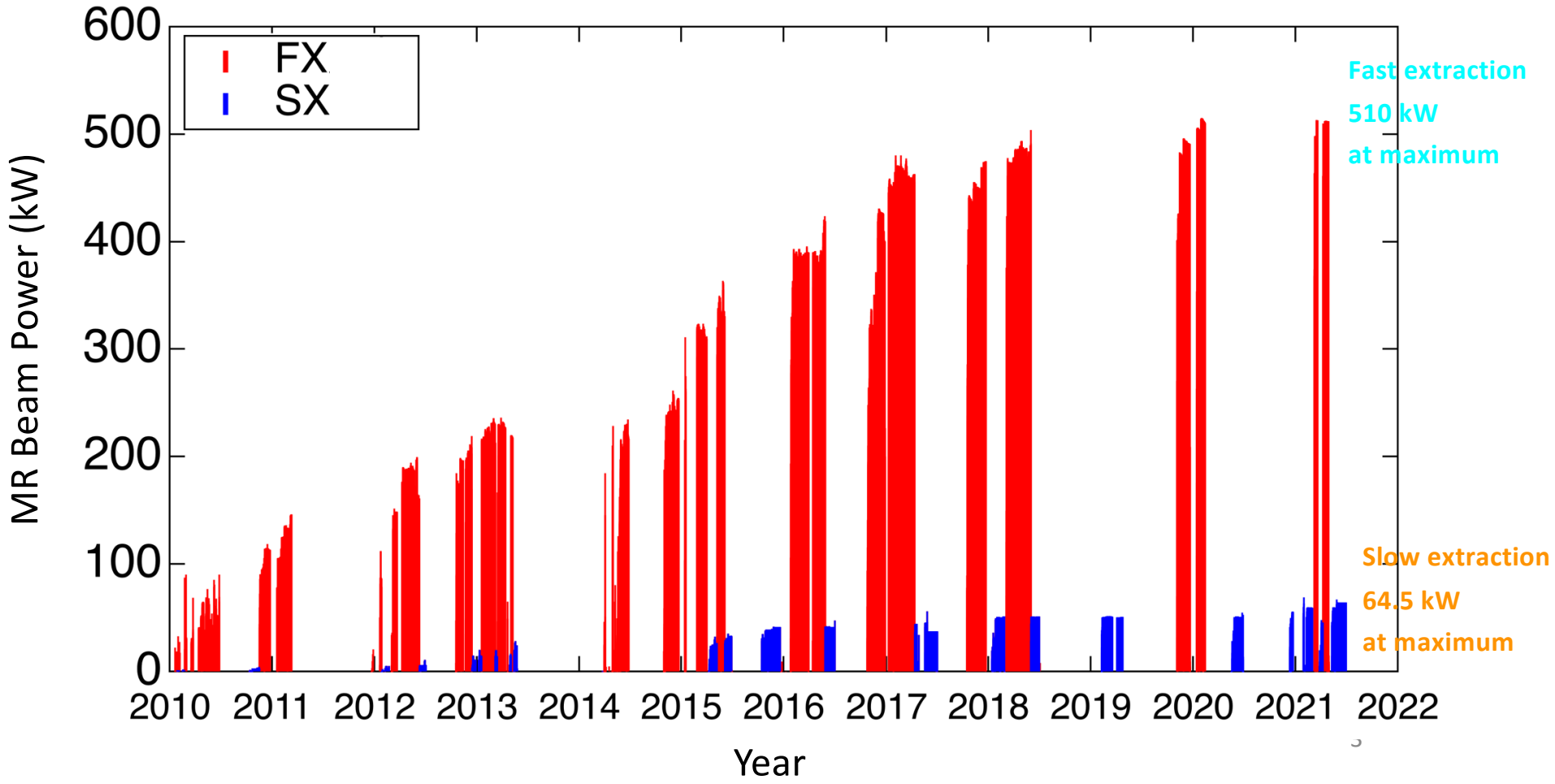
by extraction device

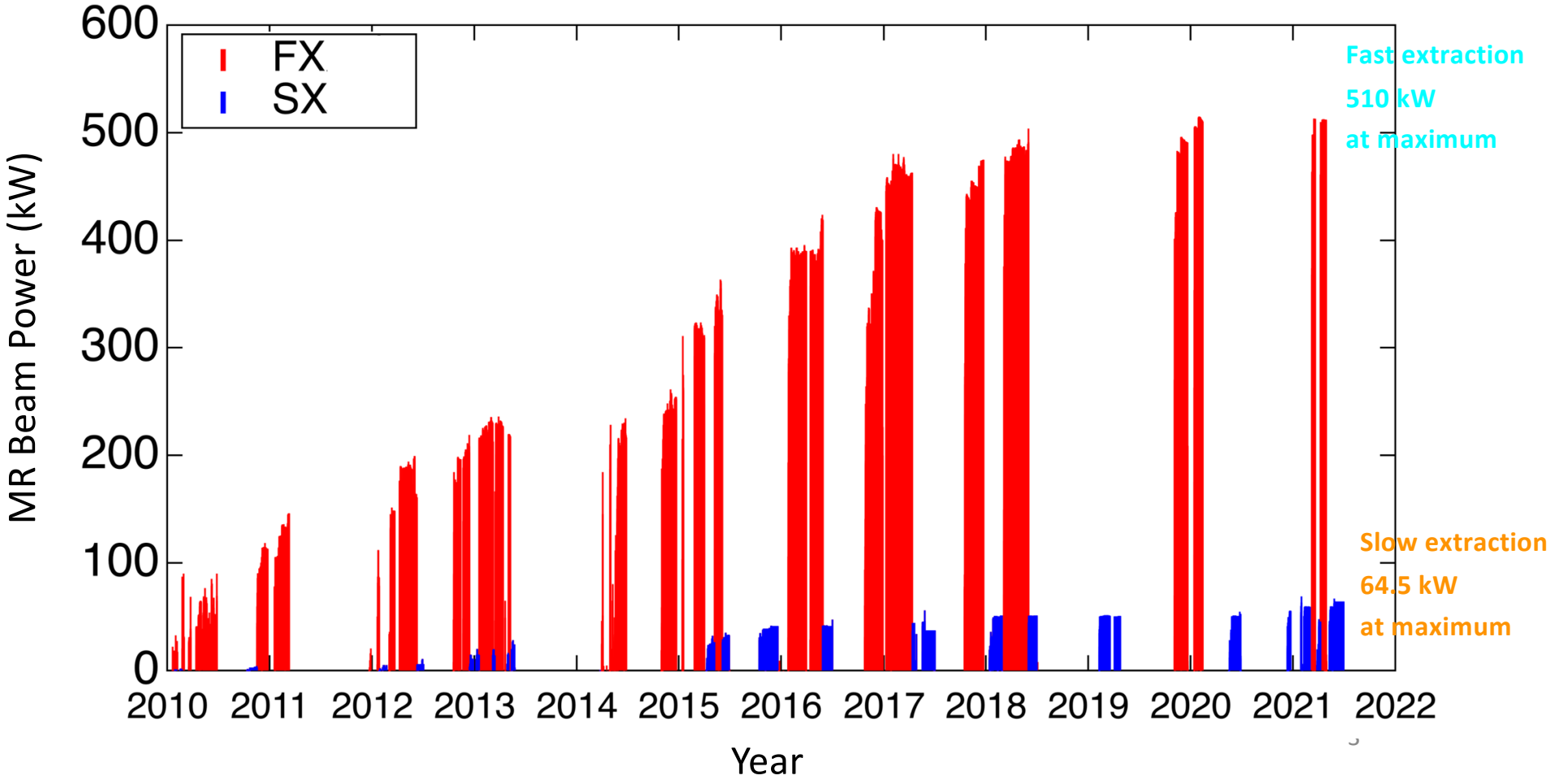


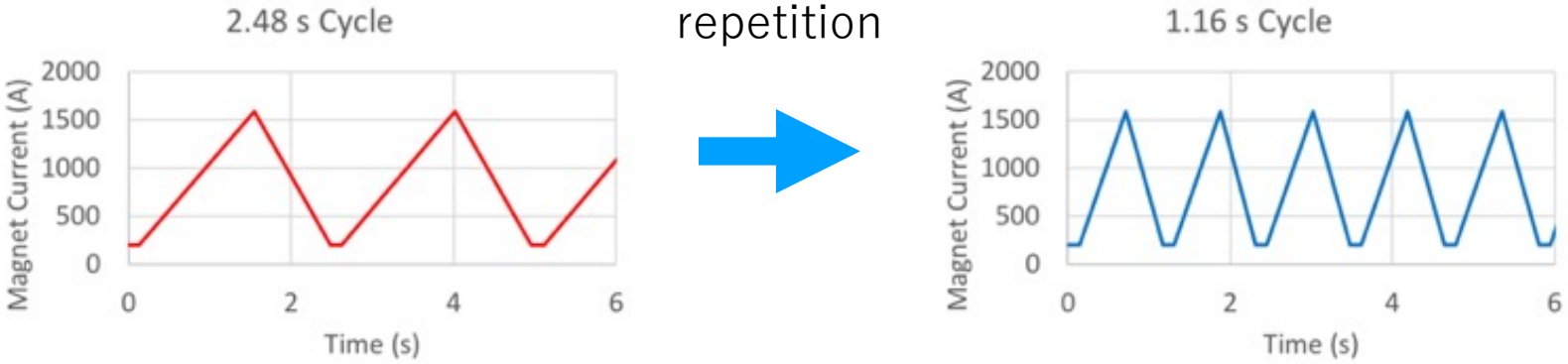
beam power

(beam energy) x (protons per pulse)/(cycle)

- The beam power was 510 kW with 2.6×10^{14} protons per pulse for the FX operation.
- The beam power was achieved to 64.5 kW for the SX operation with the extraction efficiency of 99.5 %.

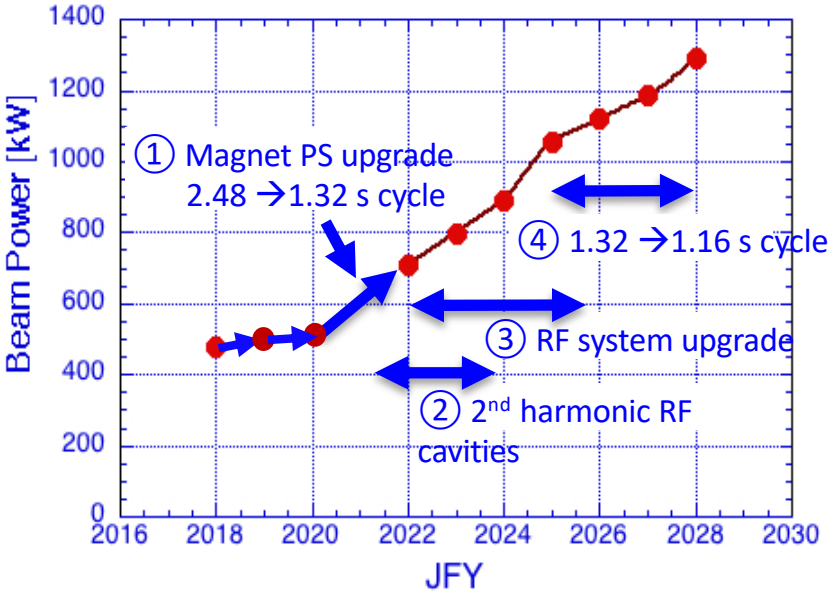


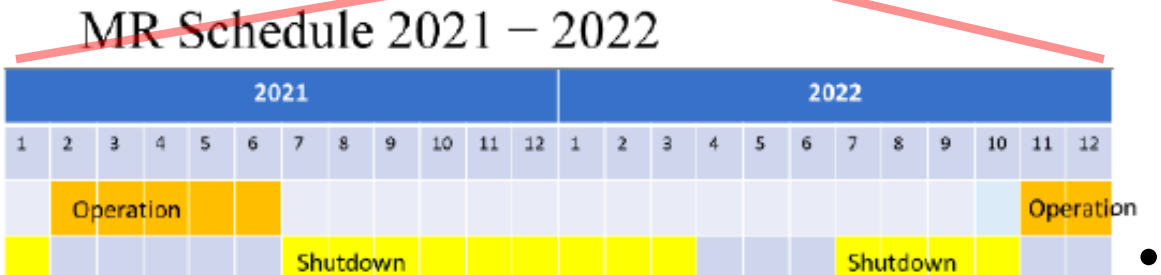

FX
SX
MR Beam Power (kW)
600
500
400
300
200
100
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Year
Fast extraction
510 kW
at maximum
Slow extraction
64.5 kW
at maximum


2.48 s Cycle
repetition
1.16 s Cycle
Magnet Current (A)
2000
1500
1000
500
0
0
2
4
6
Time (s)

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	Mass Production Installation/Test	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		Kicker PS improvement Septa manufacture Test							
Beam Monitors (BPM circuits)									



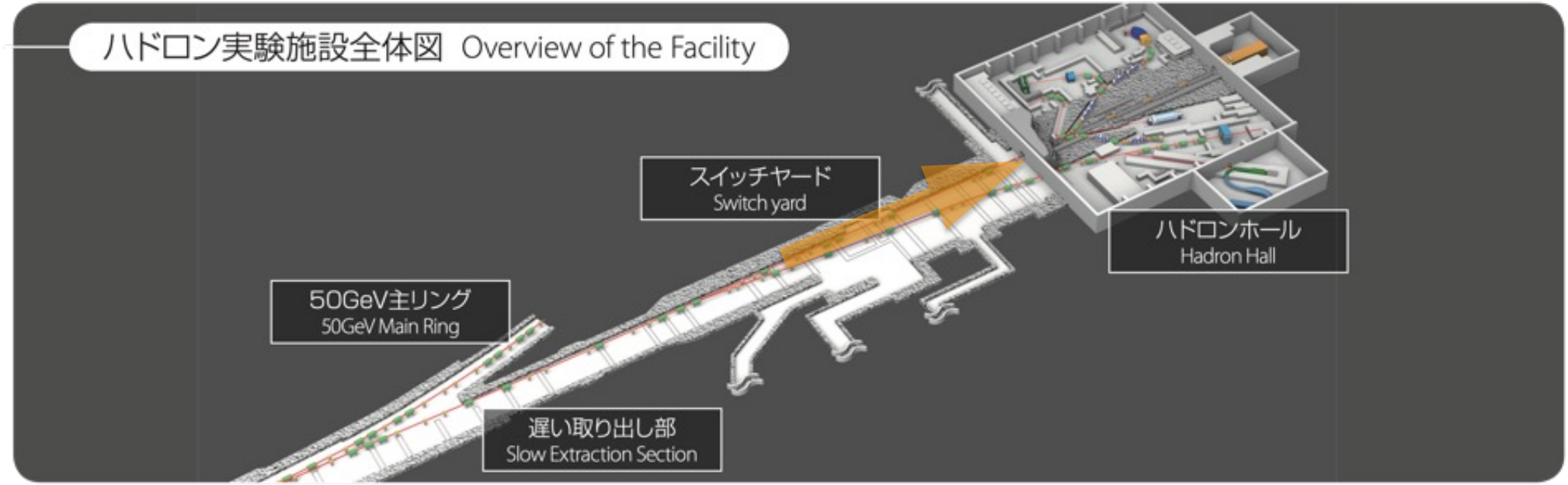


- 2022 June: Beam circulation (3GeV-DC)
- 2022 Nov.: 30GeV acceleration commissioning.

intense proton beam
from the Main Ring

upstream

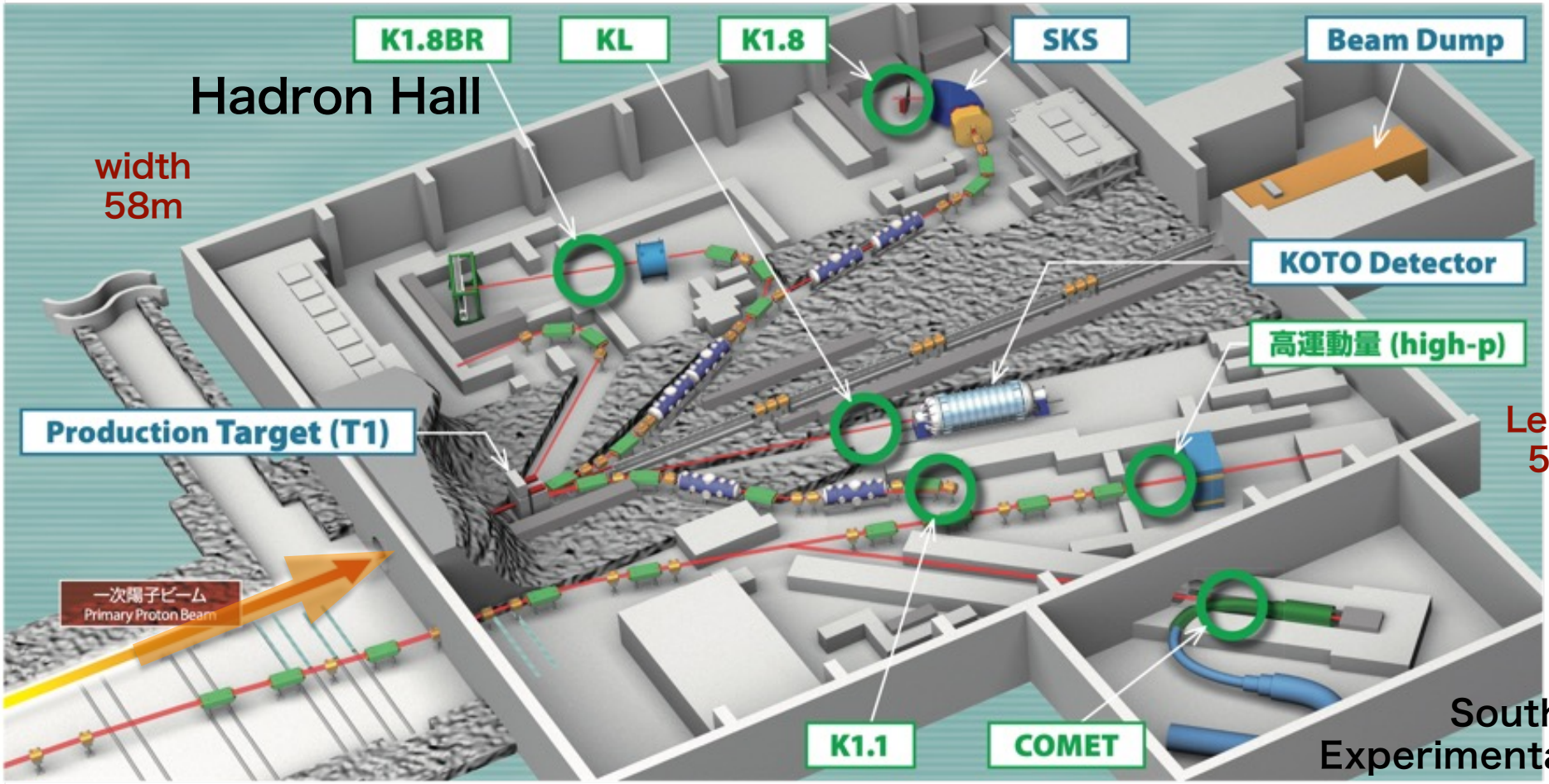
downstream



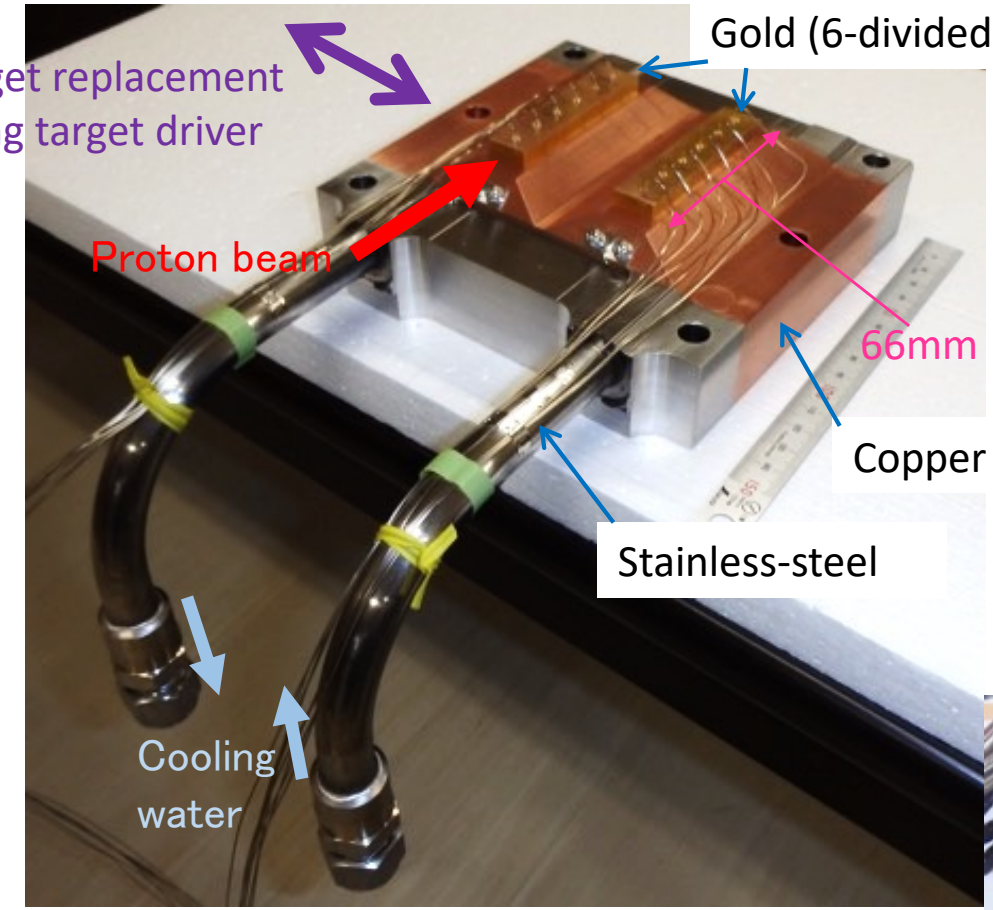
intense proton beam
from the Main Ring

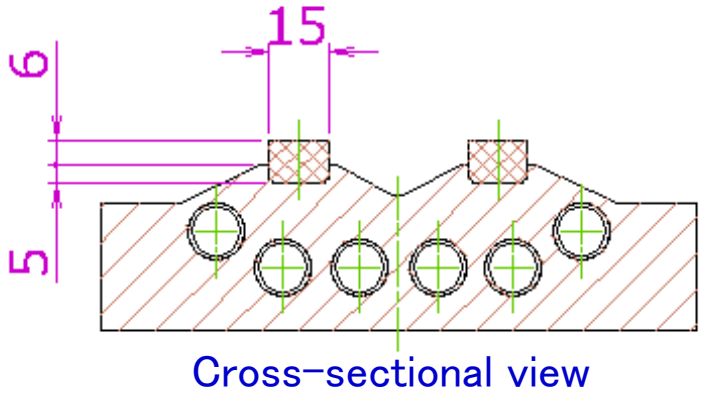
upstream

downstream

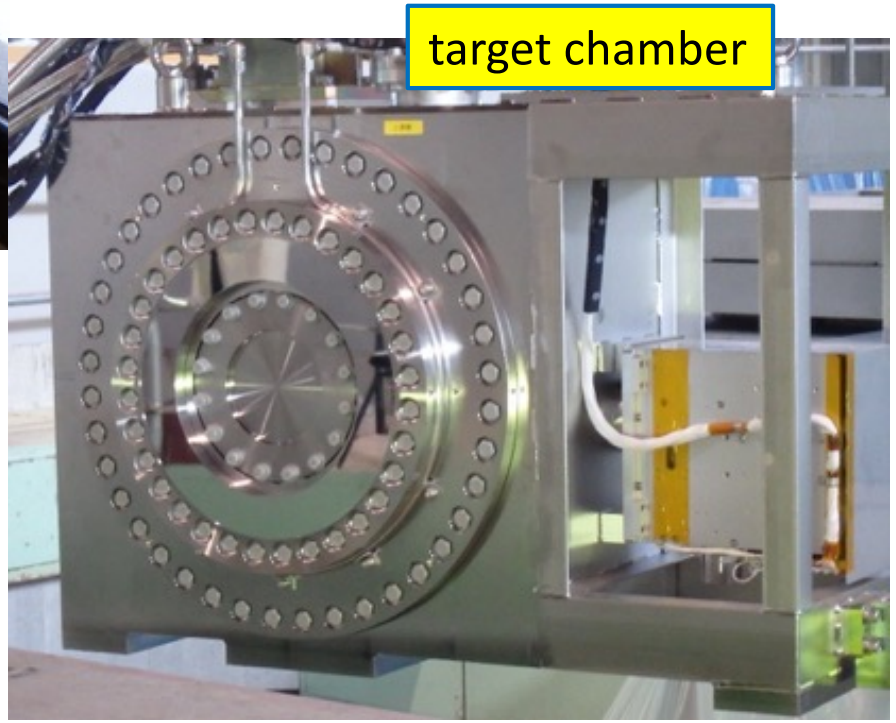


Hadron Target from 2015, after the incident



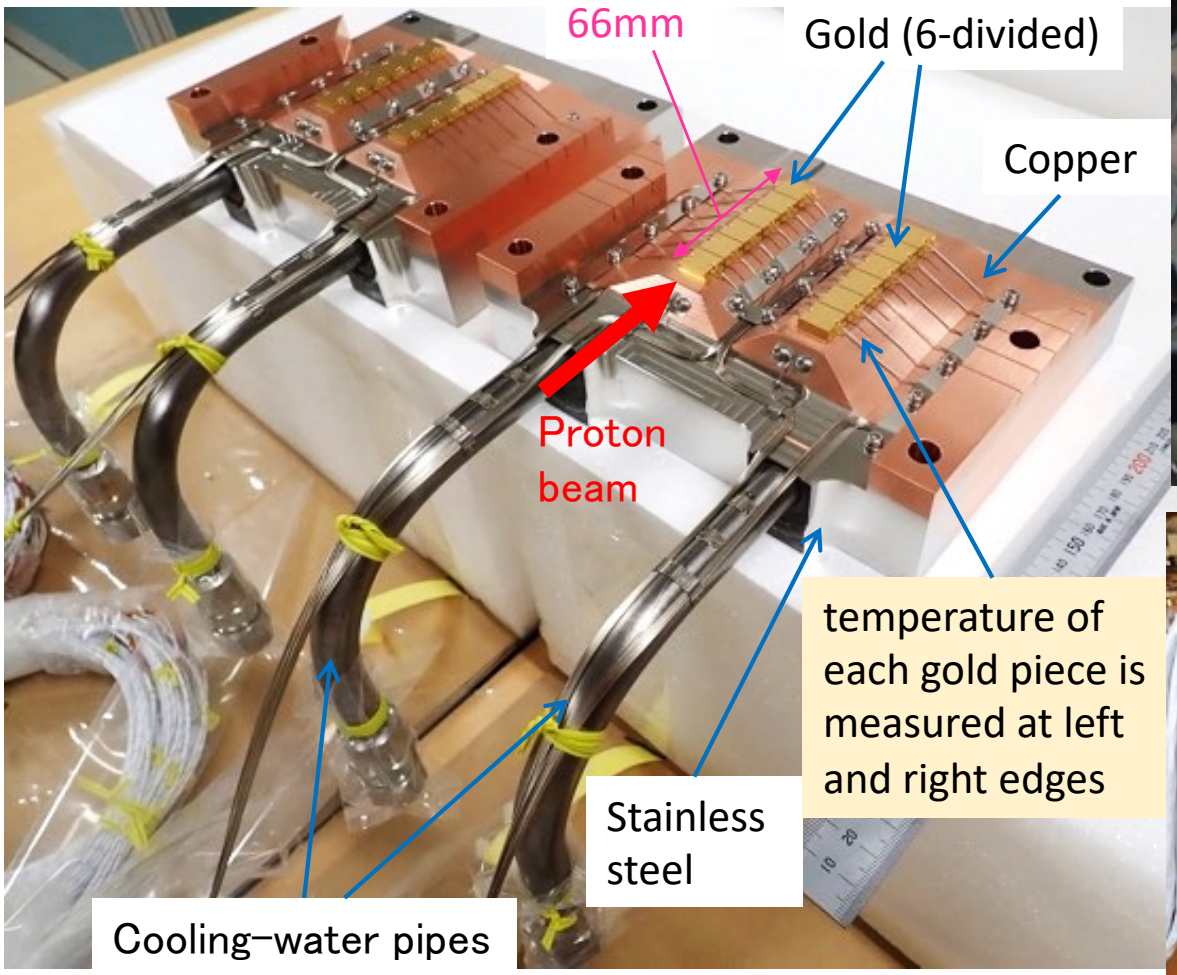


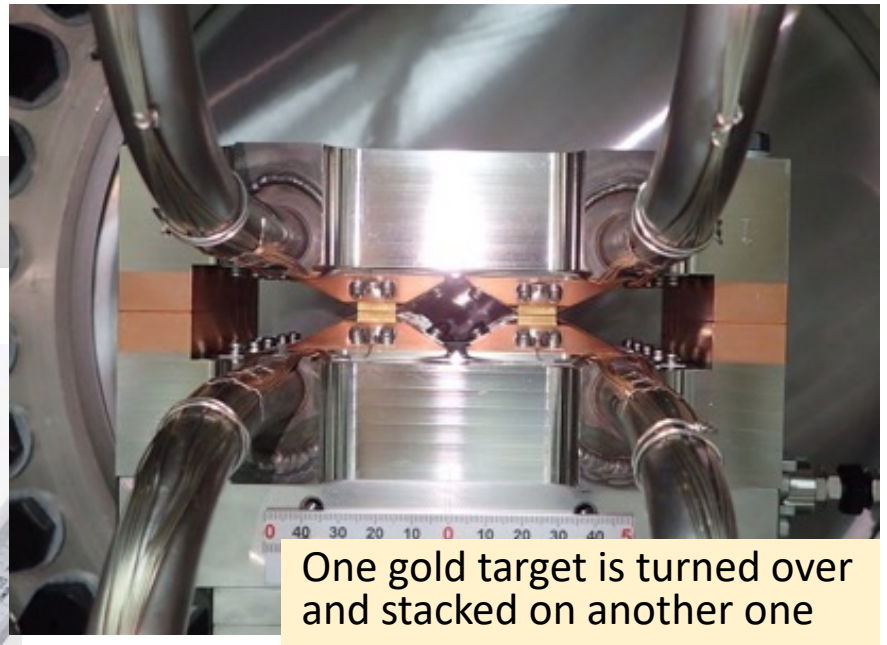
*Gold, copper, and stainless-steel are bonded by HIP (Hot Isostatic Pressing)



- Up to 57 kW beam
- Indirectly water-cooled
- Gold was chosen due to the good thermal conductivity and thermal expansion coefficient close to that of copper
- Involved in airtight chamber and He gas is circulated to monitor the target soundness

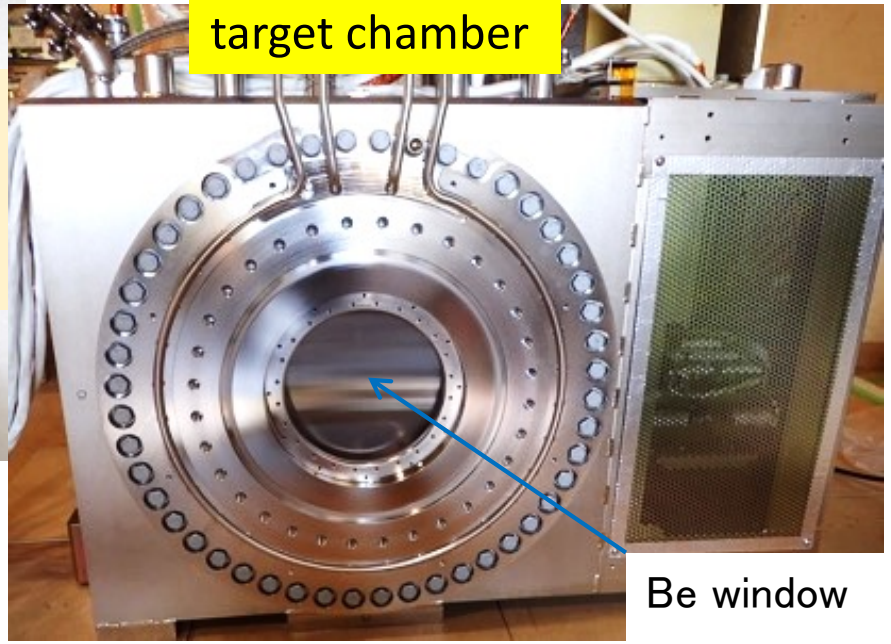
Present Target from 2019





One gold target is turned over and stacked on another one

target chamber



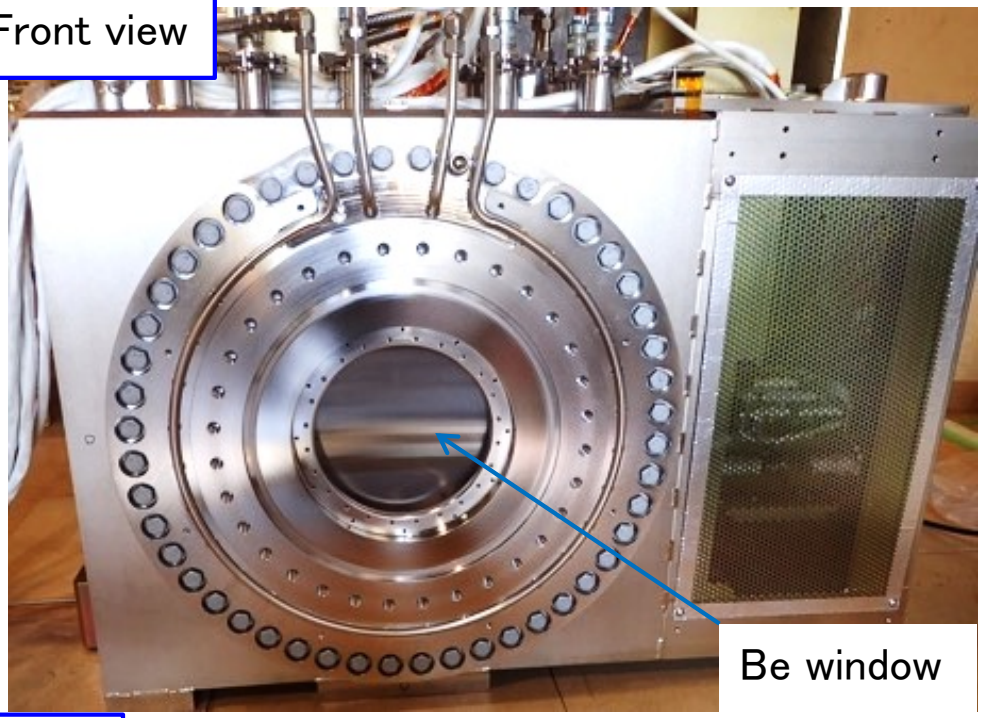
Be window

- Up to 95 kW beam (5.2-sec cycle)
- Indirectly water-cooled
- Gold was chosen due to the good thermal conductivity and thermal expansion coefficient close to that of copper
- Involved in airtight chamber and He gas is circulated to monitor the target soundness

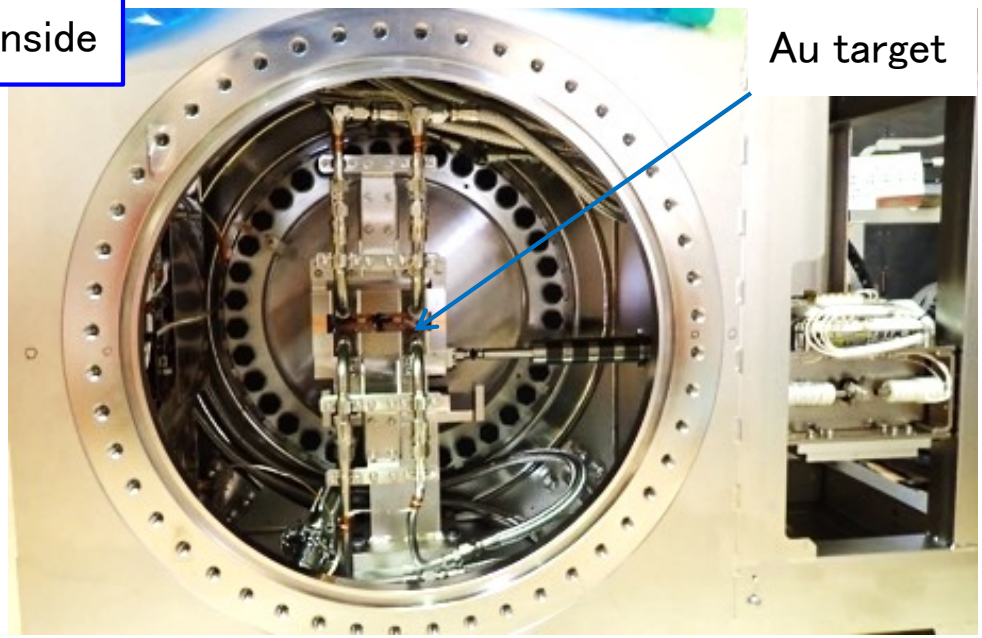
- installed in November 2019.
- first beam commissioning was performed in May 2020.

Target Chamber and Windows from 2019

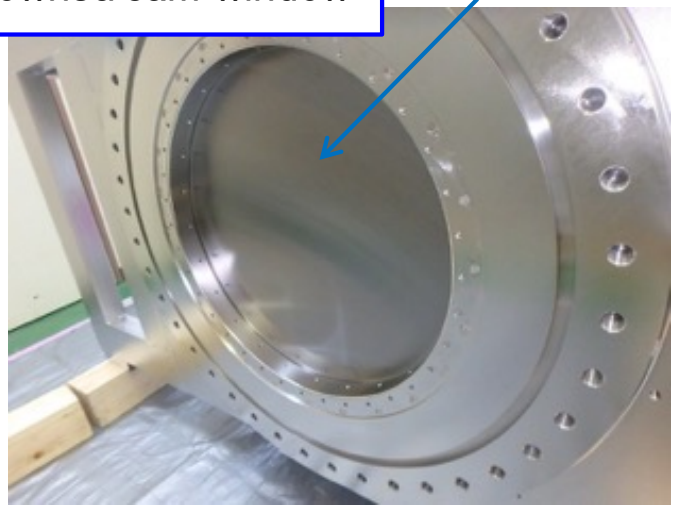
Front view

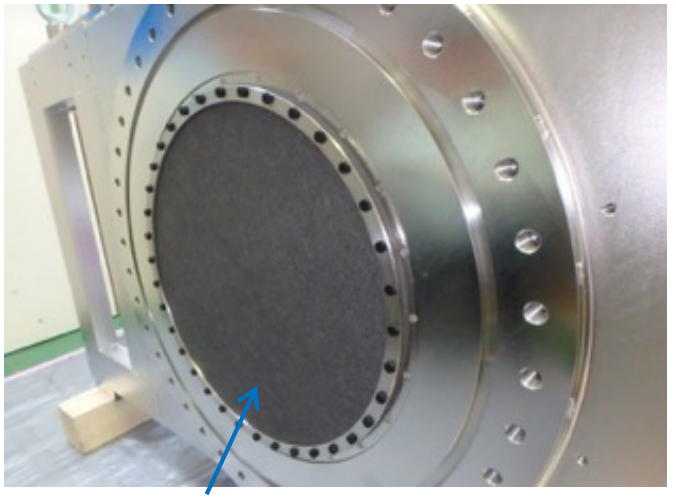


Inside



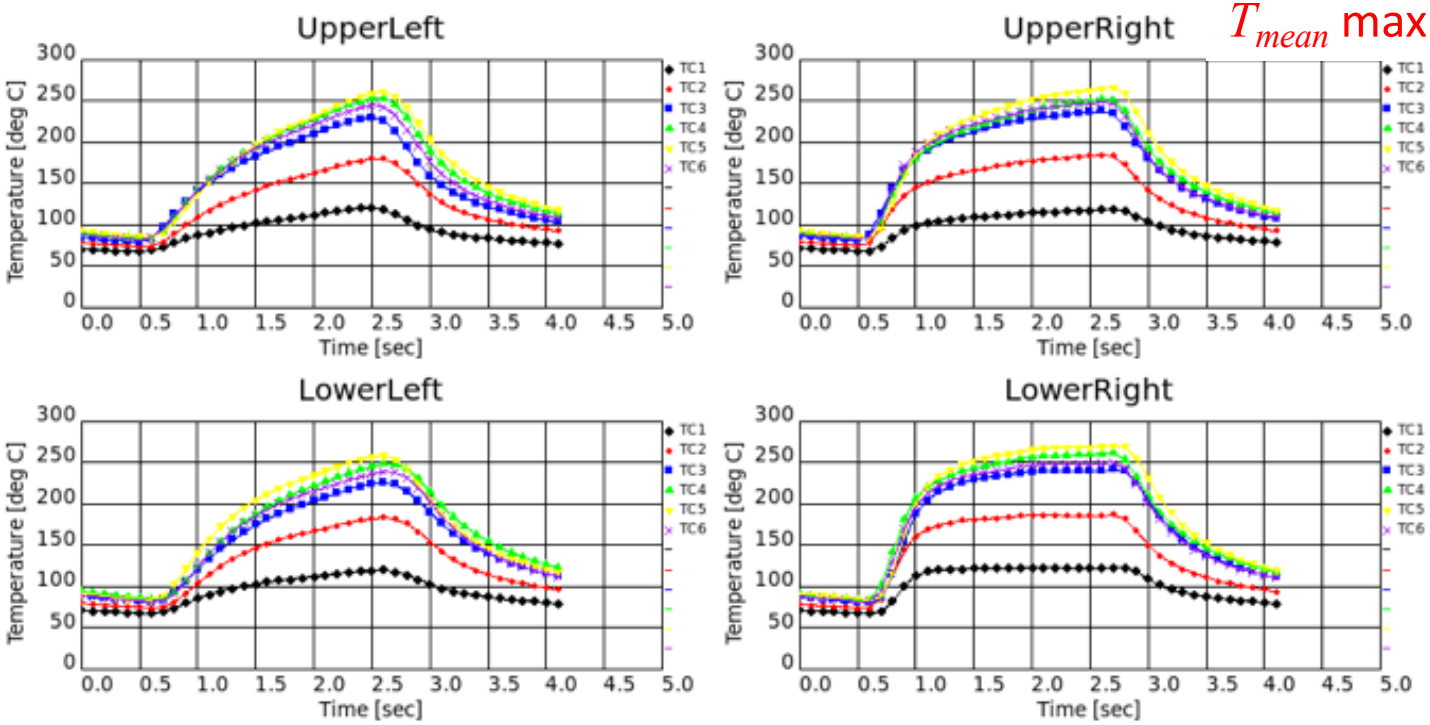
Downstream window





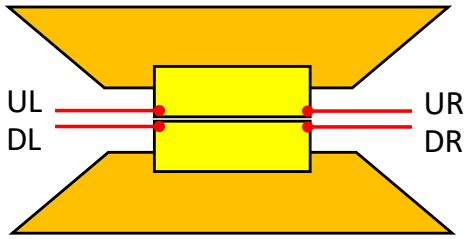
C/C composite partition wall
to prevent Be fragments from scattering

Target Temperature @64.5kW



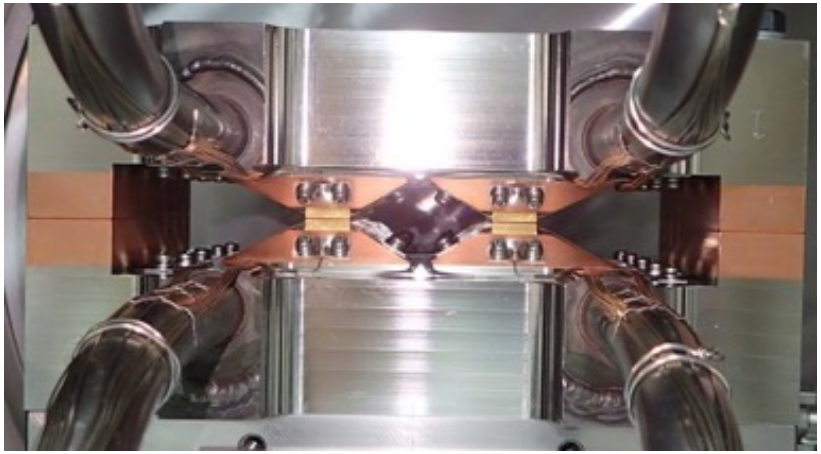
T_{mean} max 263℃ (ΔT=228K)

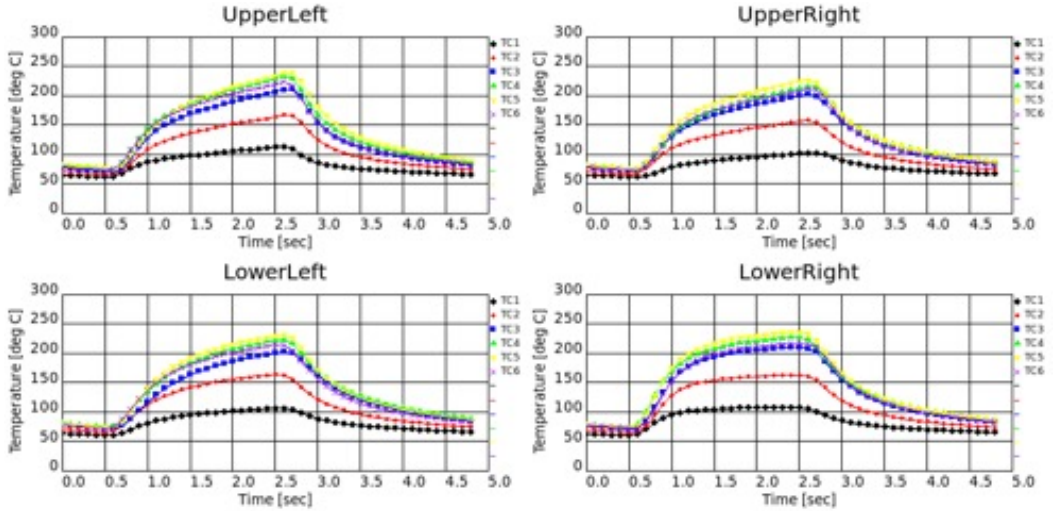
$$T_{mean} = \frac{T_{UL} + T_{UR} + T_{DL} + T_{DR}}{4}$$



(c.f.) Dec., 2020, 55.6kW

T_{mean} max 232℃ (ΔT=197K)





PHYSICAL REVIEW ACCELERATORS AND BEAMS **25,** 063001 (2022)

Indirectly cooled secondary-particle production target at J-PARC Hadron Experimental Facility

Masayoshi Saito,[1,*] Keizo Agari,[2] Hironobu Akiyama,[2] Kazuya Aoki,[2] Erina Hirose,[2] Masaharu Ieiri,[2] Yohji Katoh,[2] Yusuke Komatsu,[2,§] Ruri Kurasaki,[2] Michifumi Minakawa,[2] Yuhei Morino,[2] Fumimasa Muto,[2] Yoshinori Sato,[2] Shinya Sawada,[2] Hitoshi Takahashi,[2,†] Toshiyuki Takahashi,[2] Kazuhiro Tanaka,[2] Akihisa Toyoda,[2] Hiroaki Watanabe,[2,‡] and Yutaka Yamanoi[2]

[1]*Tohoku University, 6-3 Aramaki Aza-Aoba, Aoba-ku, Sendai 980-8578, Japan*
[2]*High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan*

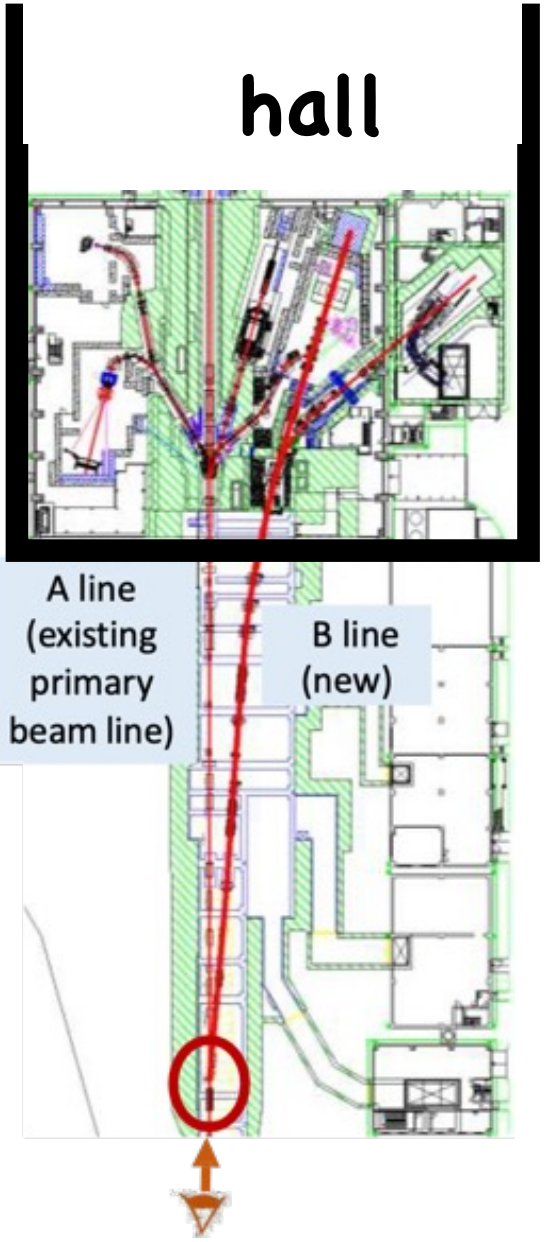
(Received 20 December 2021; accepted 25 April 2022; published 3 June 2022)

The Hadron Experimental Facility at the Japan Proton Accelerator Research Complex is used for various nuclear and elementary particle physics experiments that use secondary particle beams. The secondary-particle production target is a key element for the generation of particles such as kaons and pions. To increase beam power, a new target was developed and installed. The target, which is made of gold and indirectly cooled with water, was designed so that the maximum stresses do not exceed the allowable stresses determined based on the pressure vessel standard. 95 kW is considered to be the maximum power of the primary proton beam for a 5.2-s beam duration. The new target was stably operated up to a power of 65 kW. In addition, beam position estimation based on multipoint temperature measurements of the target was demonstrated.

DOI: 10.1103/PhysRevAccelBeams.25.063001

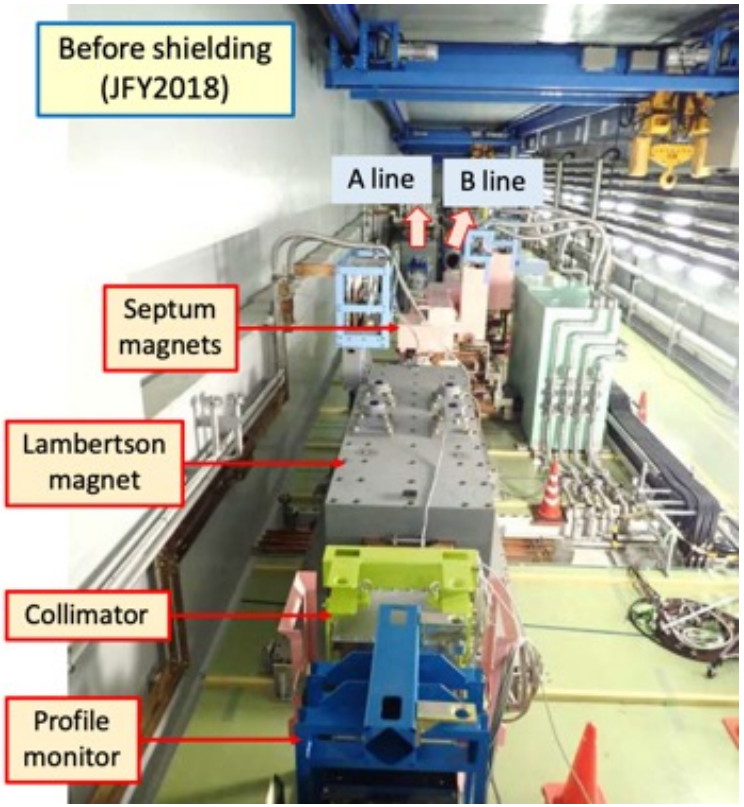
New Primary Beam Line (B-Line)

downstream

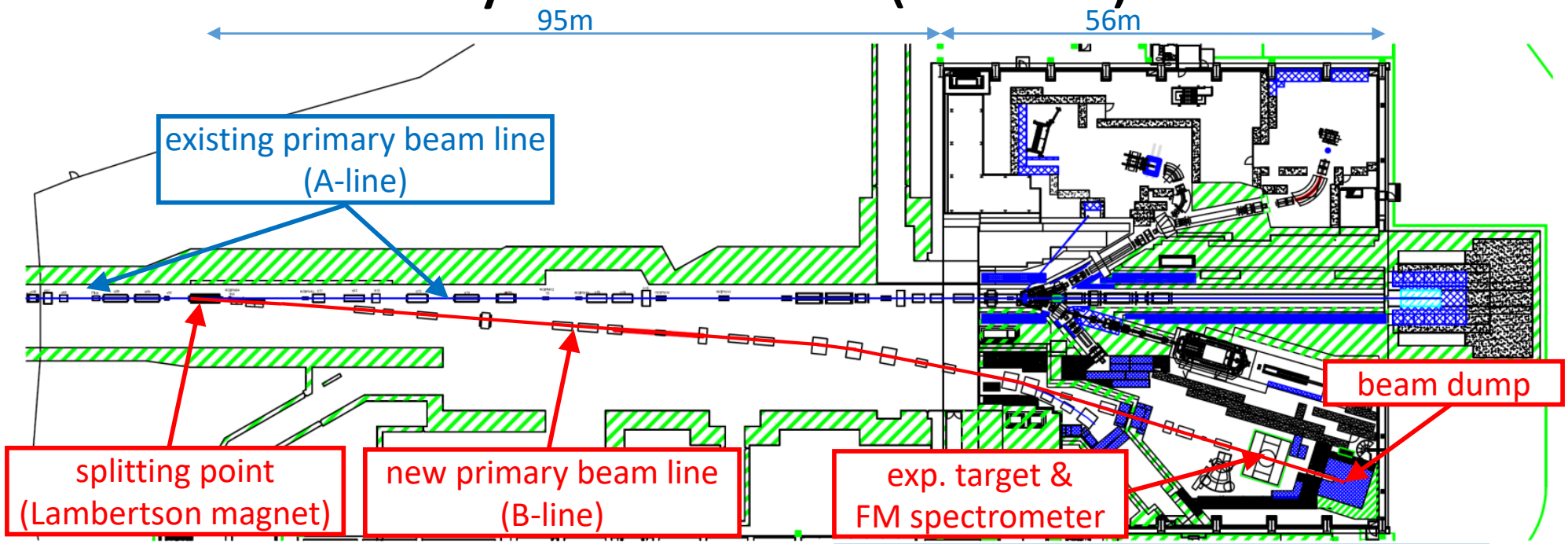


Switchyard

upstream

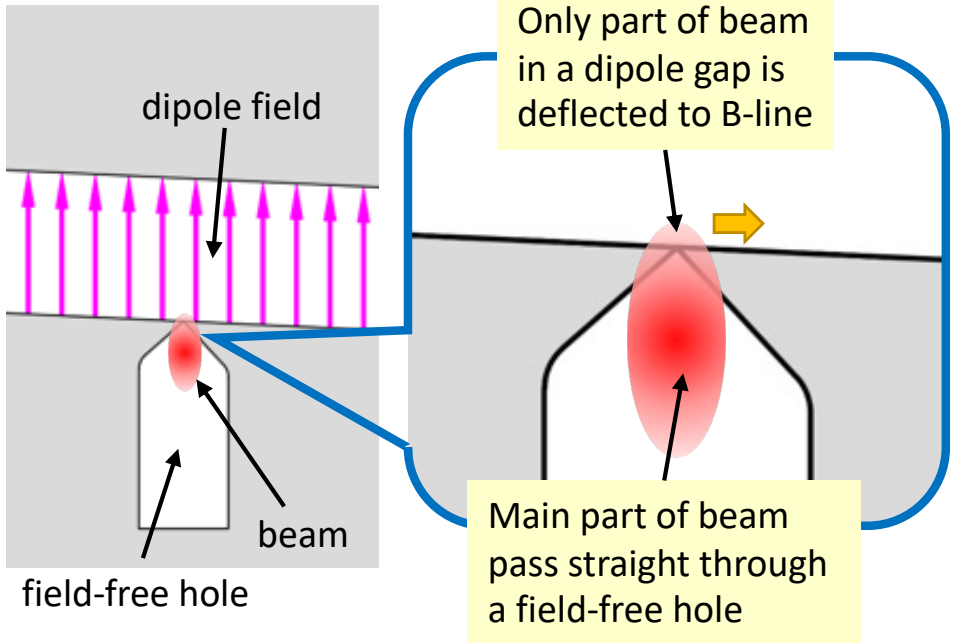


New Primary Beam Line (B-Line)

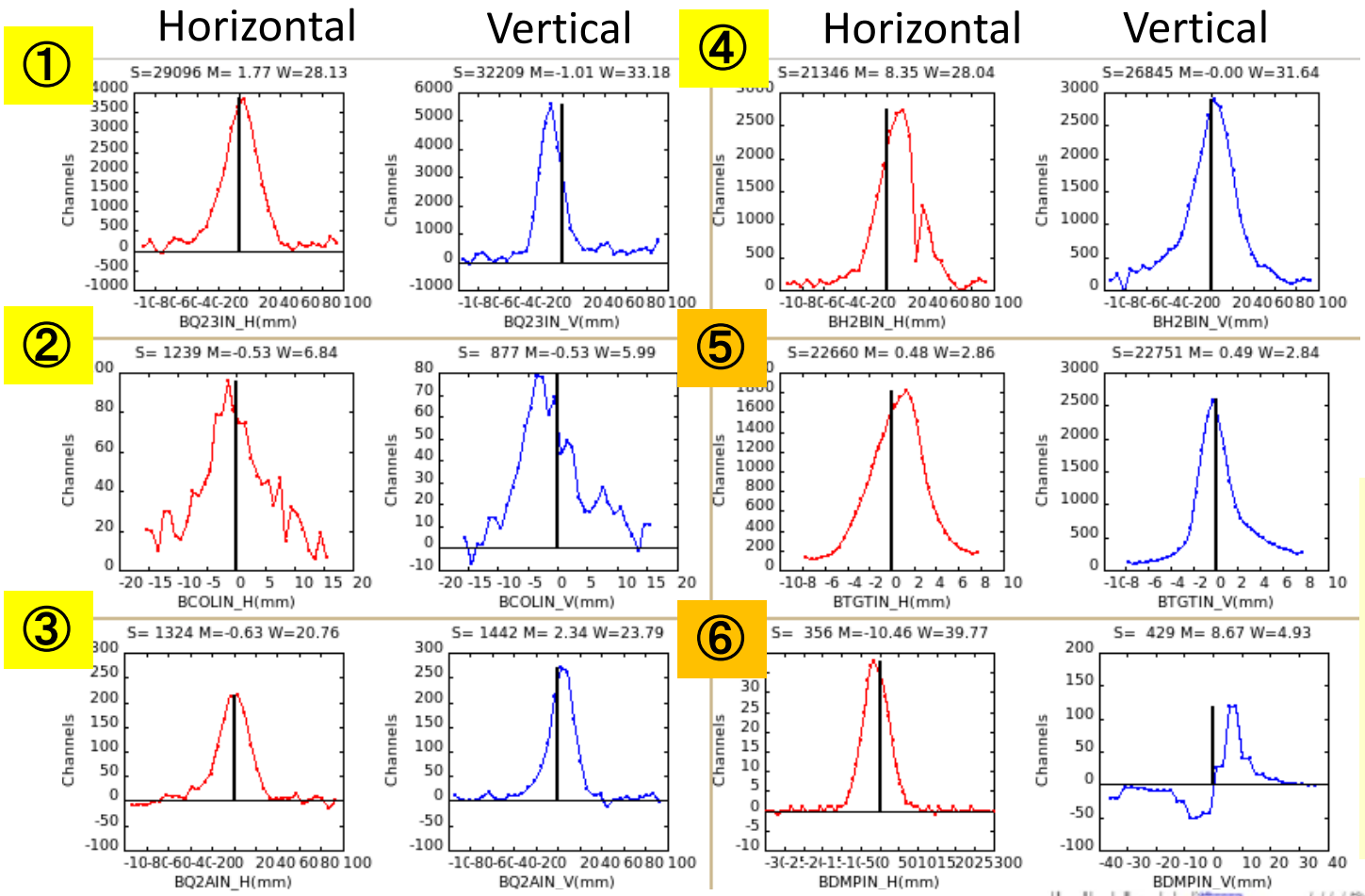


- Part of primary proton beam is split from existing primary beam line (A-line) and is directly used for user experiments.
- Max intensity: 2.6 x 10^{10} protons/spill (24W equivalent)
- Beam splitting is made with Lambertson magnet.

Cross section of Lambertson magnet poles



B-line Beam Profiles



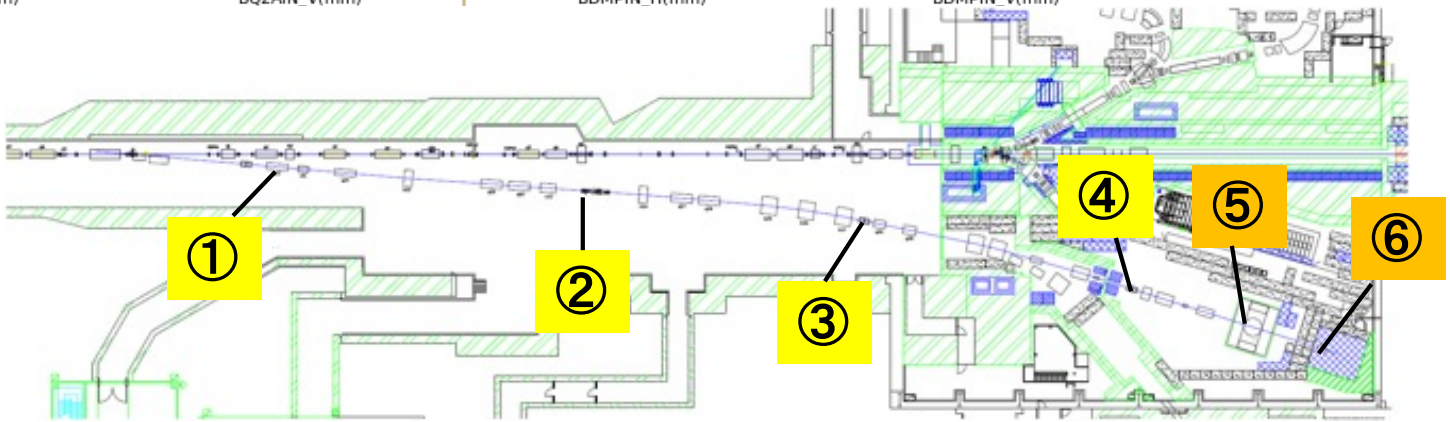
RGIPM
(Residual-gas ion profile monitor)

Ion Chamber

intensity: ~3x10^9 /spill

vacuum: ~100Pa

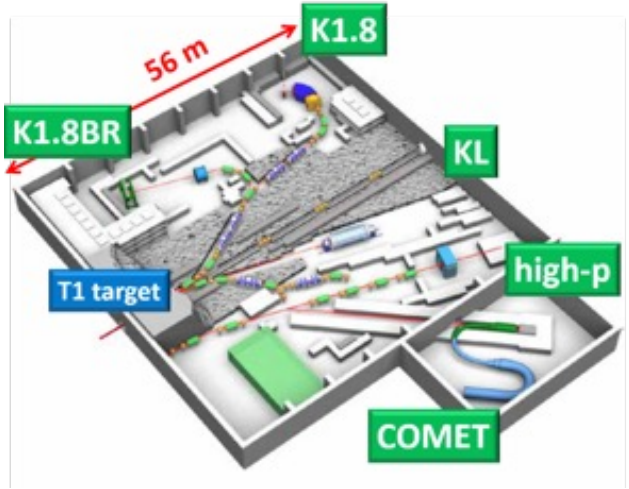
Even though intensity was 3-4 orders of magnitude lower than that of A-line, beam profiles could be measured with RGIPMs by controlling vacuum pressure.



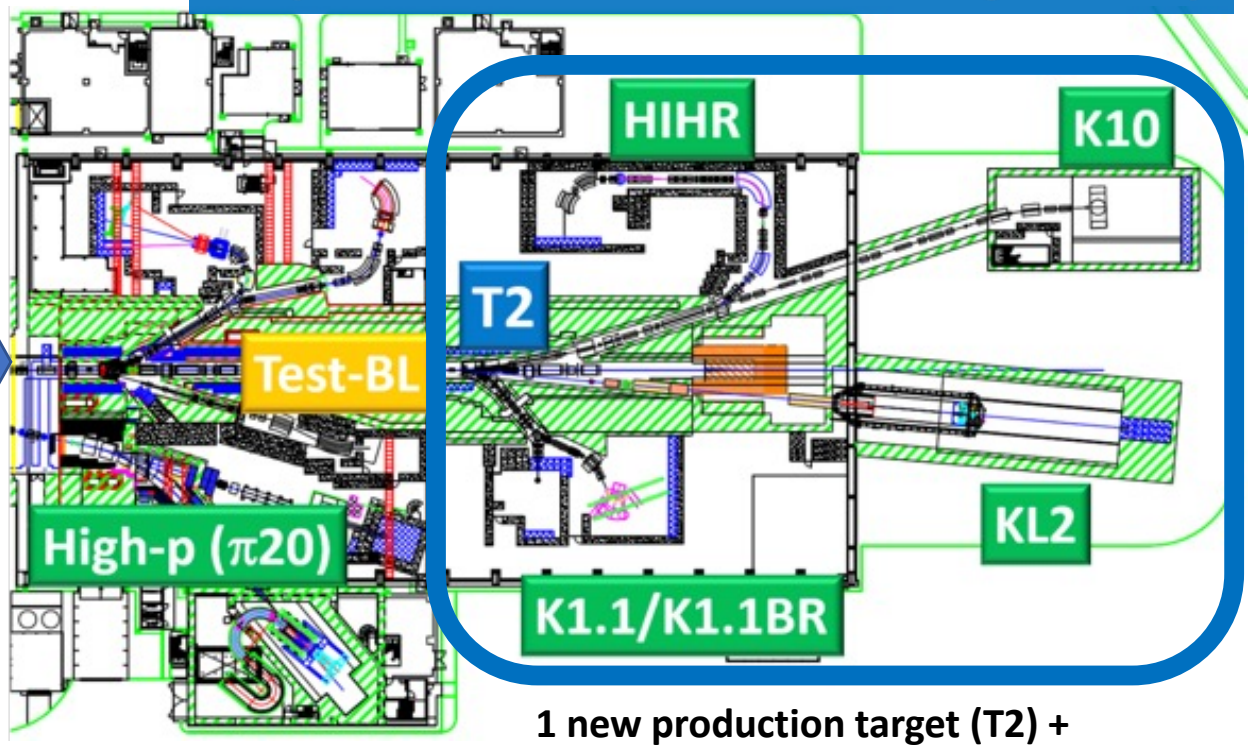
Hadron Experimental Facility Extension (HEF-ex) project

Open new physics that cannot be implemented at the existing facility

Present facility



1 production target (T1) +
2 charged beamlines (K1.8/1.8BR, High-p)
1 neutral beamline (KL)
1 muon beamline (COMET)



1 new production target (T2) +
4 new beamlines (HIHR, K1.1/K1.1BR, KL2, K10) +
2 modified beamlines (High-p (π20), Test-BL)

T2K (Tokai to Kamioka) experiment

$$Prob.(\nu_\mu \to \nu_e)$$

same?

$$Prob.(\bar{\nu}_\mu \to \bar{\nu}_e)$$

- Precise measurement of ν_e appearance
- Precise meas. of ν_μ disappearance

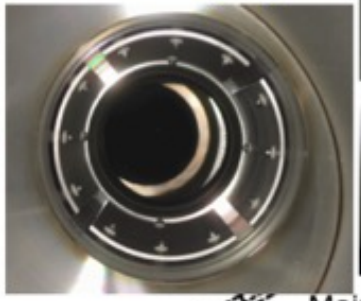
➔ Measure CPV phase, contribution to mass hier. determ.

primary proton beam line for T2K

Beam monitors are install along the proton beam transport

Profile (19)

Position (21)

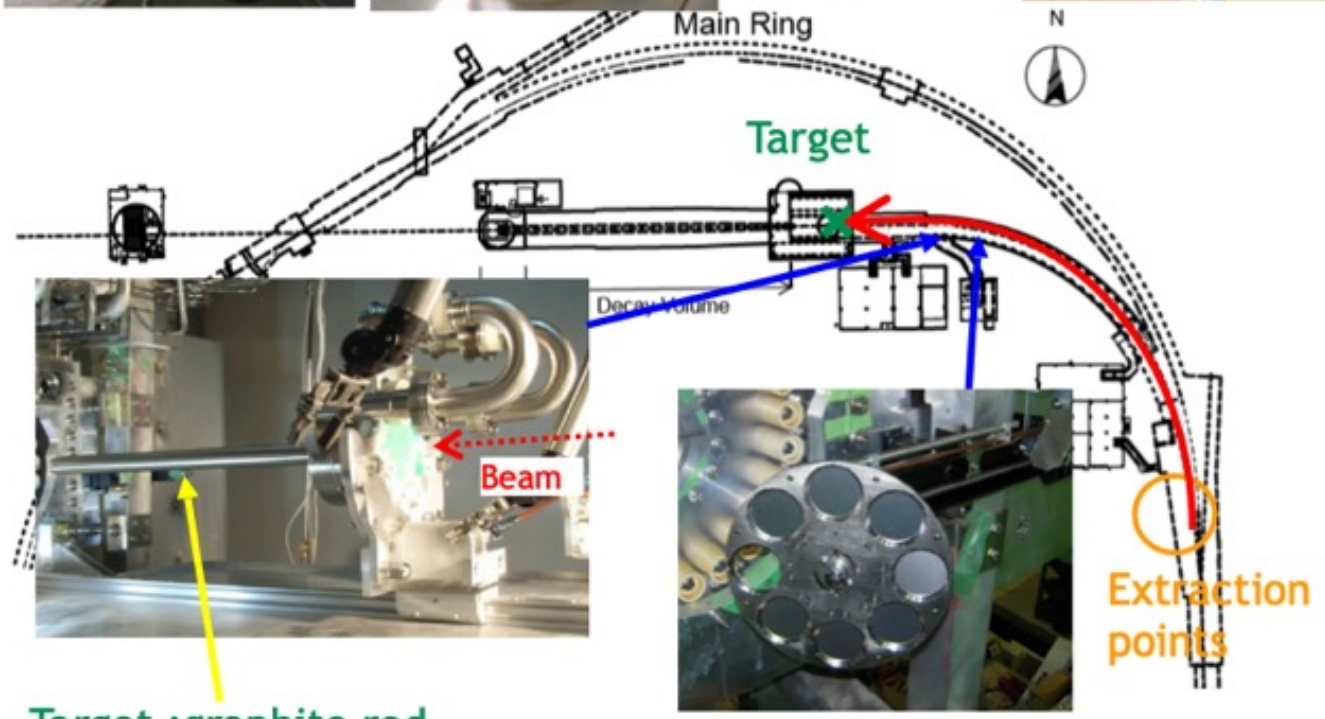


Intensity (5)

Beam loss (50)

Primary proton transport line

Super-conducting combined-function magnets

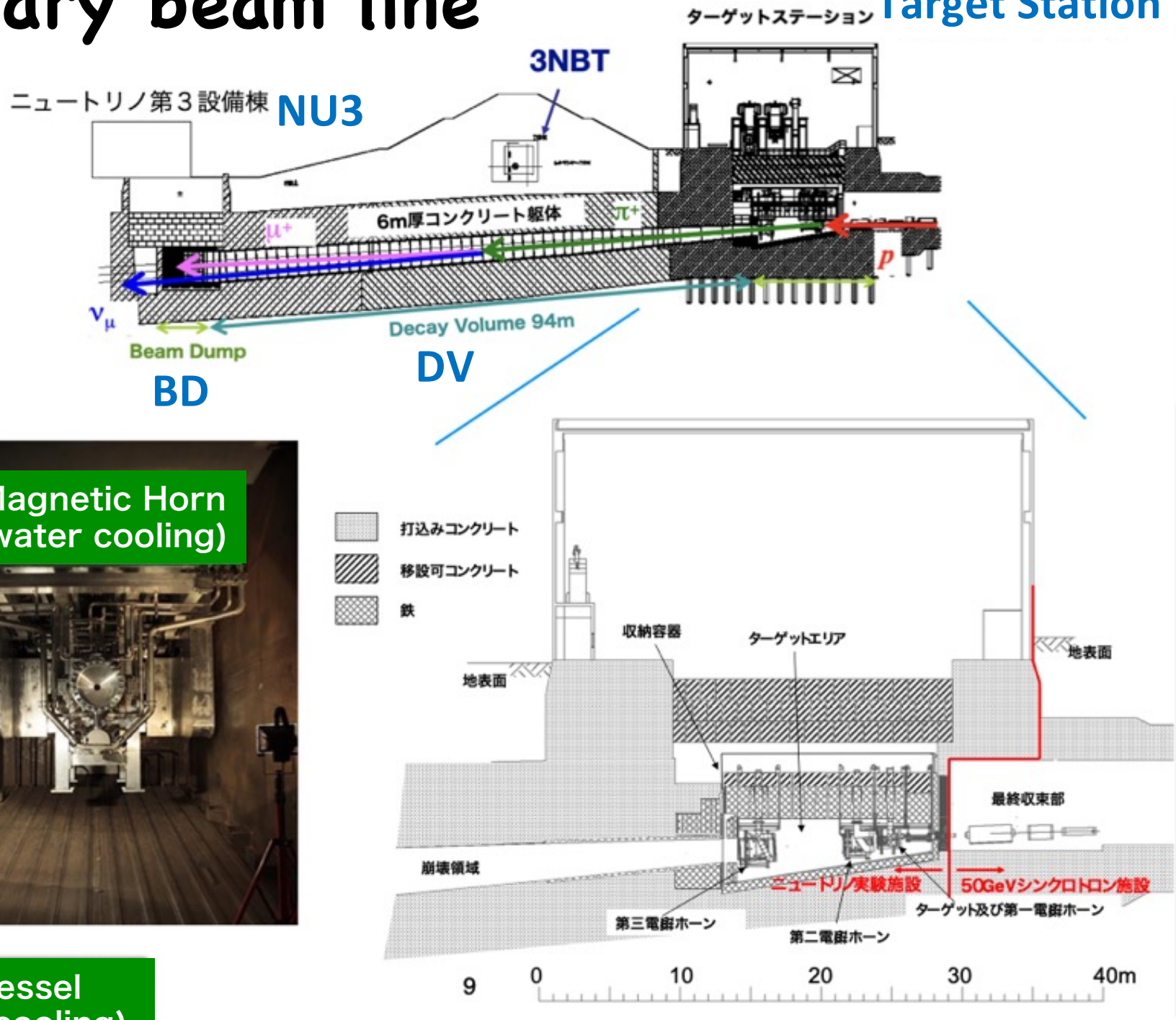


Normal-conducting magnets

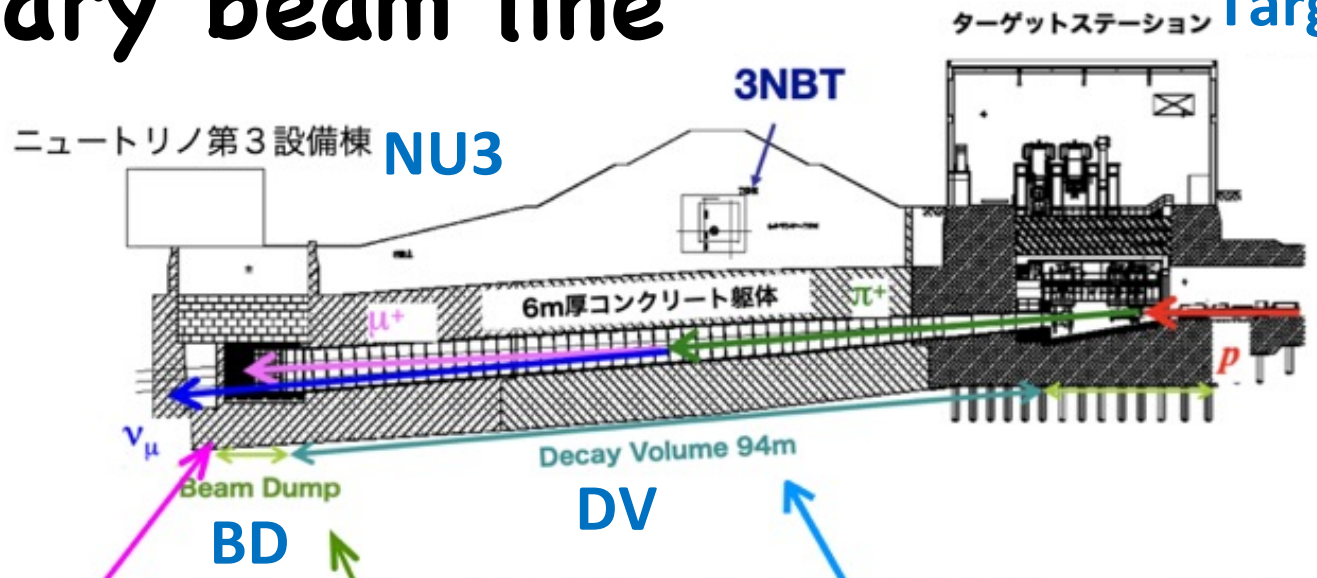
Target :graphite rod
ϕ26mm,L=900mm

Optical Transition Radiation (OTR)
Profile monitor

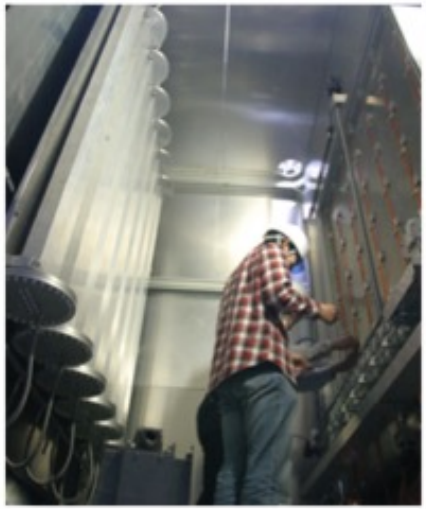
secondary beam line

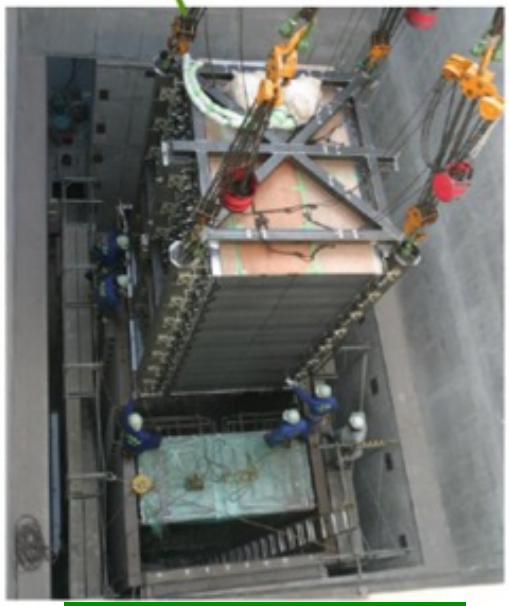


secondary beam line



Muon monitor



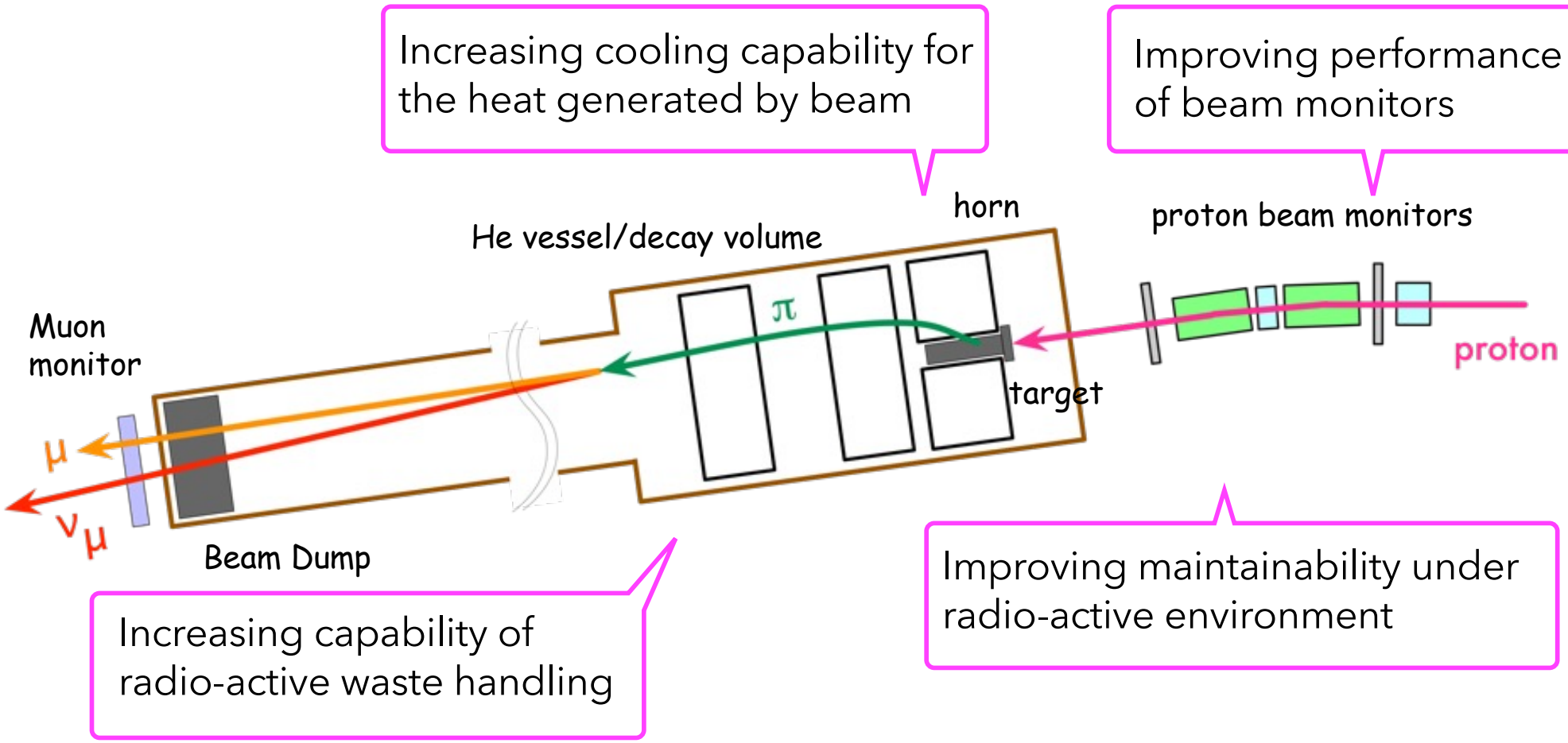


Beam Dump
(water cooling)

Decay Volume
(water cooling)

Overview of beamline upgrade

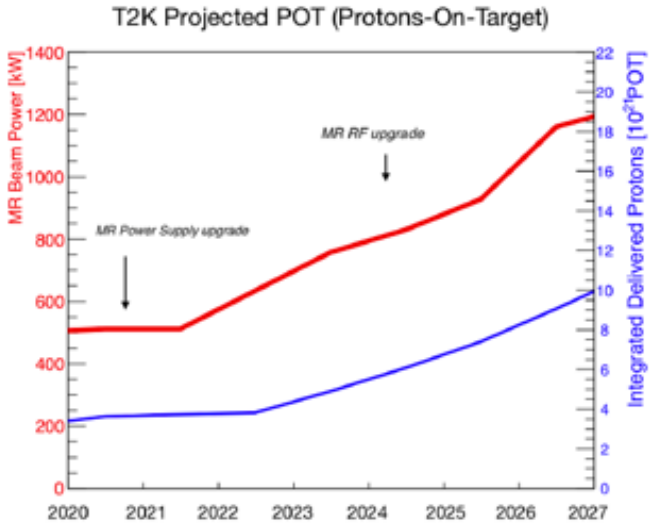
- Improvements necessary for some beamline components to accept 1.3MW beam



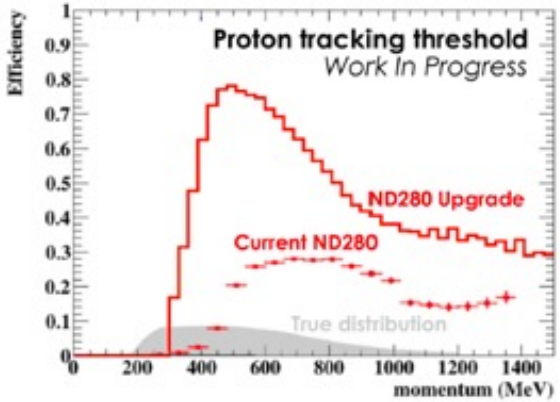
+ Accepting high repetition rate (~1Hz) beam

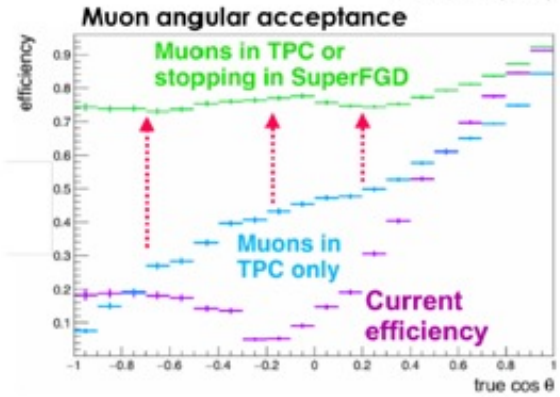
Technical Design Report : arXiv:1908.05141

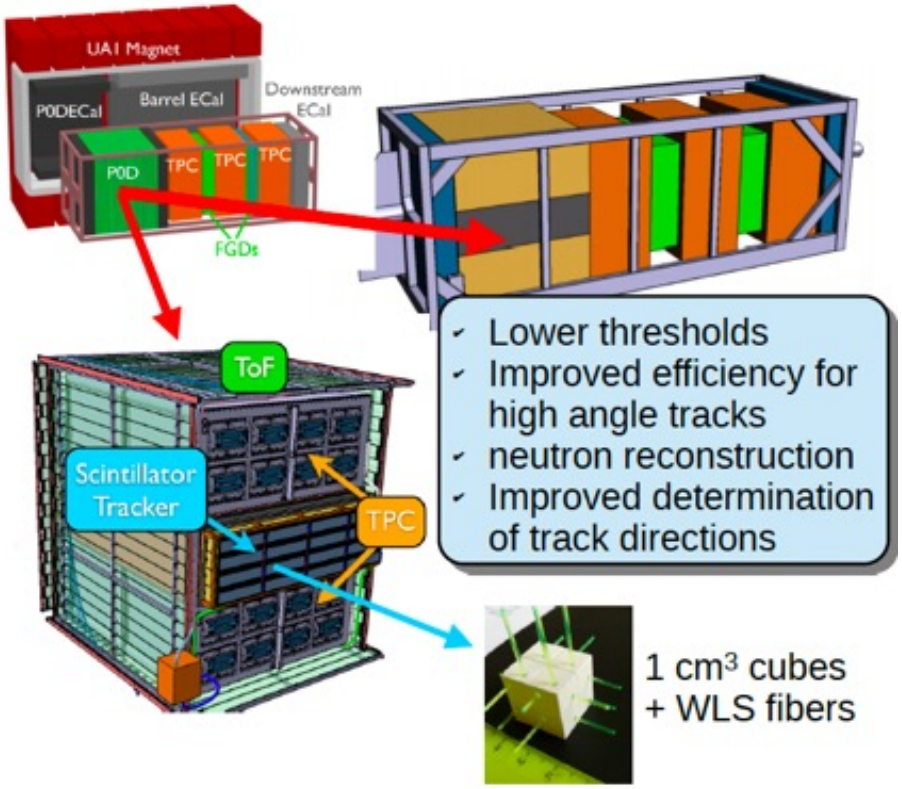
T2K prospects



- 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.



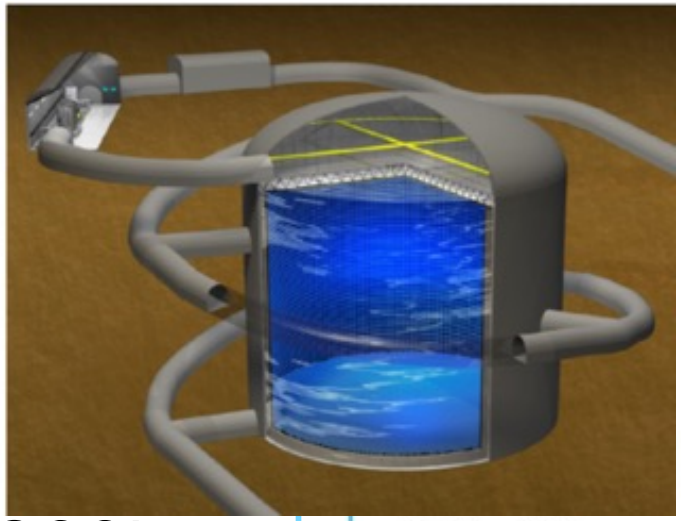




Future Project: **Hyper-Kamiokande**

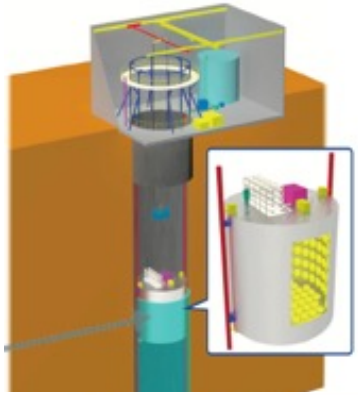
- Main physics goal : Discovery of CP violation in lepton sector with >5 σ significance by accumulating ~2000 $\nu_\mu \rightarrow \nu_e$ events and ~2000 events in ~10 years.
- Construction started in 2020. Exp. start in 2027.

Hyper-Kamiokande

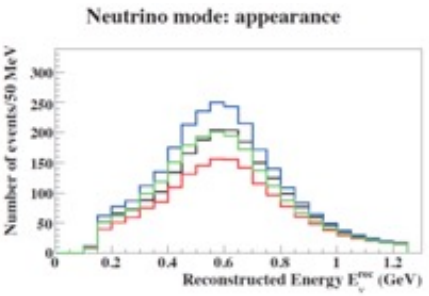


260kt
Cf: SK=50kt

New near-detector

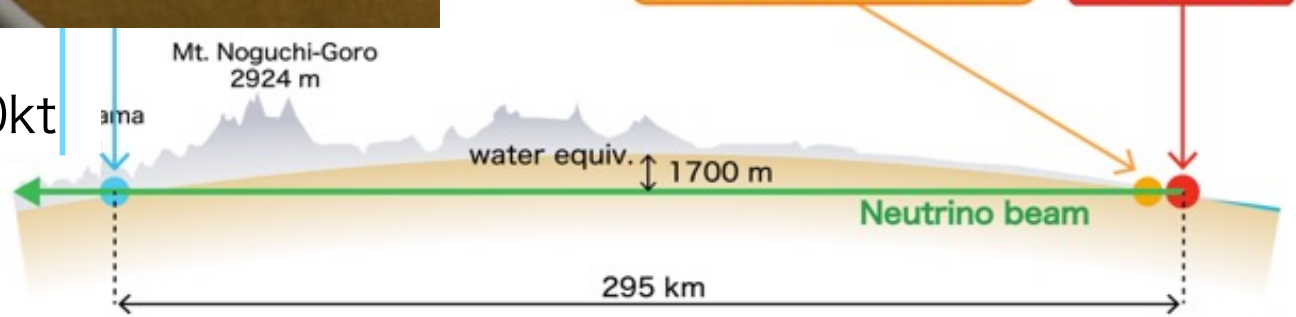


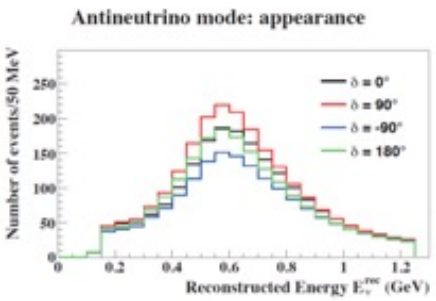
Beam power upgrade
750kW → 1.3MW



Near Detector

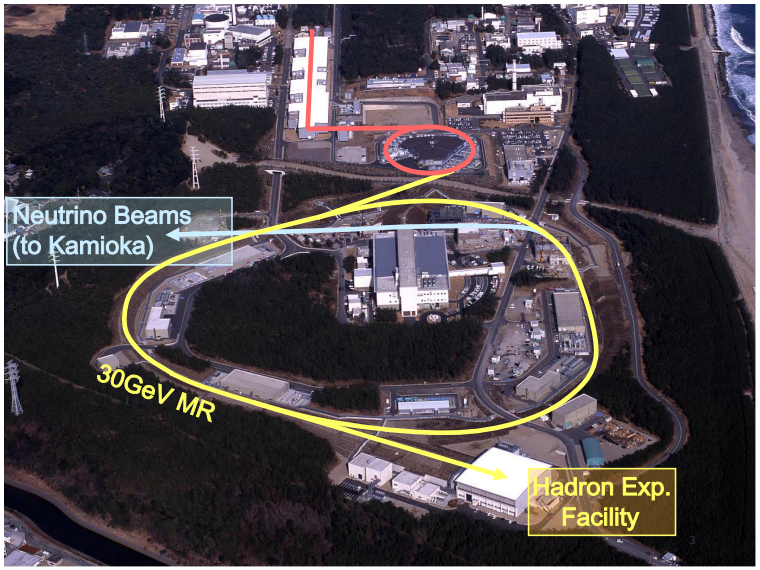
J-PARC





Intensity upgrade of J-PARC neutrino beam is essential.

Particle and Nuclear physics at J-PARC



- intense beams
- rare processes,
  precise measurements

to observe New Physics

international collaborations