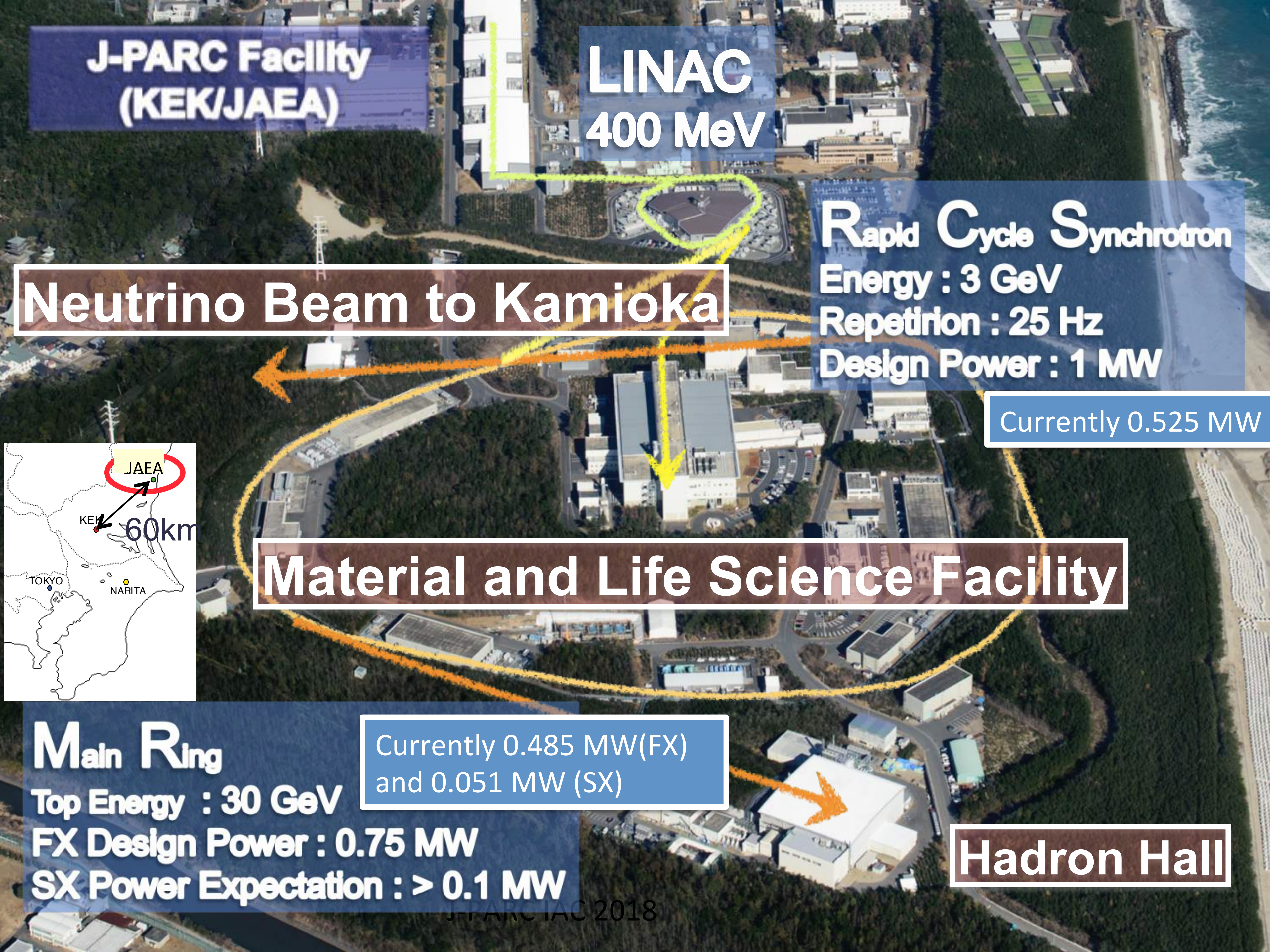
180921
TMEX2018
@Warsaw

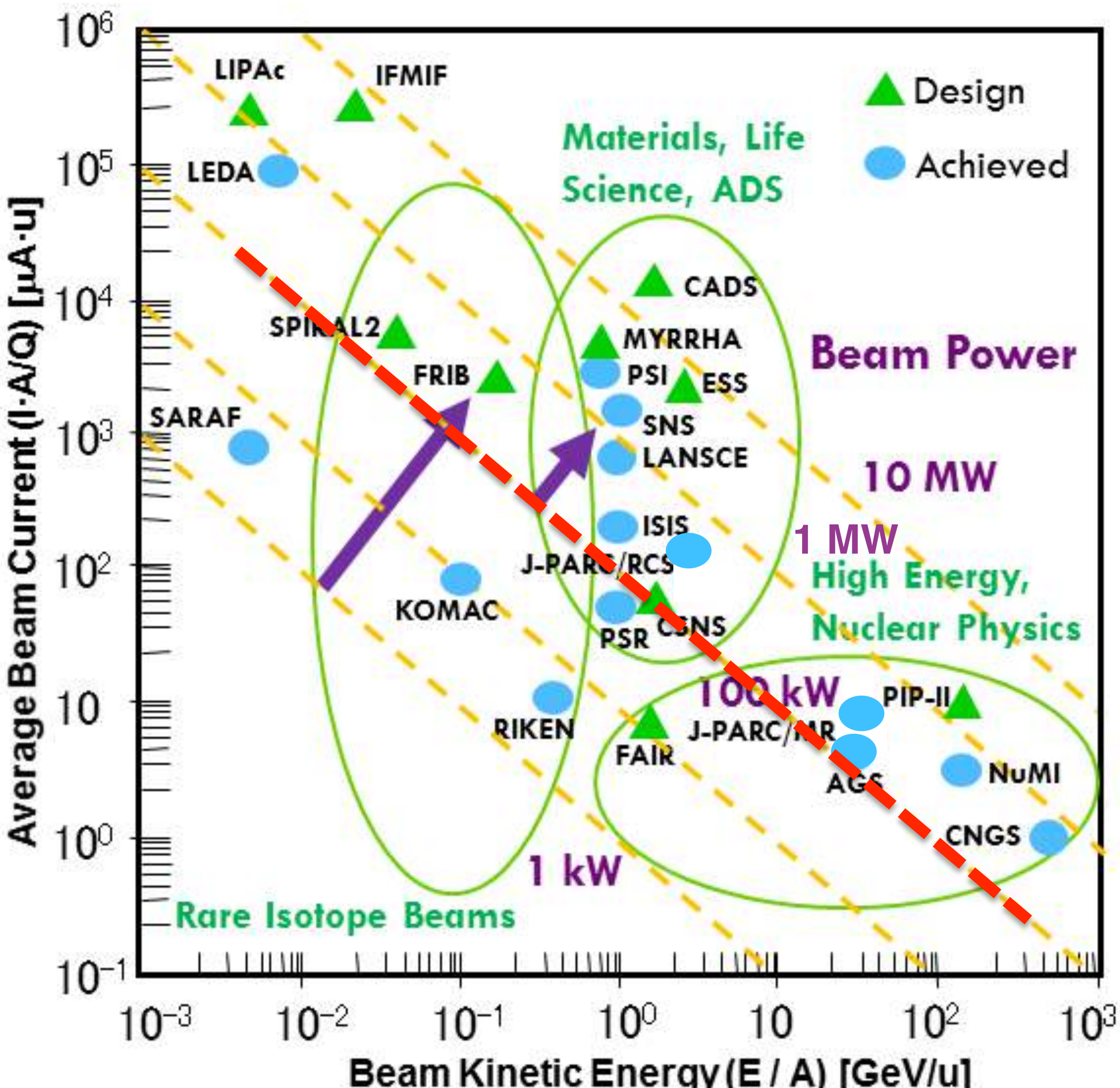
J-PARC: Japan Proton Accelerator Research Complex
Status and outlook

TAKASHI KOBAYASHI

IPNS/KEK, J-PARC


J-PARC Facility
(KEK/JAEA)
LINAC
400 MeV
Rapid Cycle Synchrotron
Energy : 3 GeV
Repetirion : 25 Hz
Design Power : 1 MW
Currently 0.525 MW
Neutrino Beam to Kamioka
JAEA
KEK
60km
TOKYO
NARITA
Material and Life Science Facility
Main Ring
Top Energy : 30 GeV
FX Design Power : 0.75 MW
SX Power Expectation : > 0.1 MW
Currently 0.485 MW(FX)
and 0.051 MW (SX)
Hadron Hall

A Quest for High Intensity



High Intensity

High Statistics

- More Precision
- More Rare Searches
- More Materials

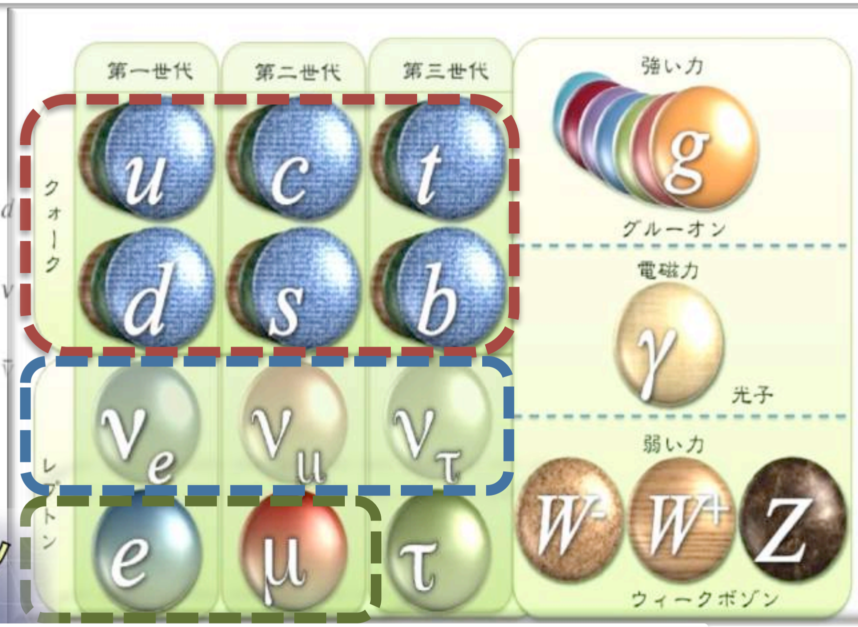
Discovery!

Jie Wei / Y. Yamazaki

Particle−Nuclear Physics explored at J-PARC

Search for CPV beyond CKM theory

KOTO@Hadron Hall



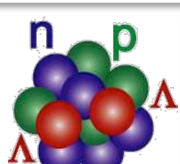
Neutrino Mixing thru PMNS matrix

T2K Exp.

CPV in neutrino sector?

Charged Lepton Flavor violated?

Explore role of strangeness in neutron stars



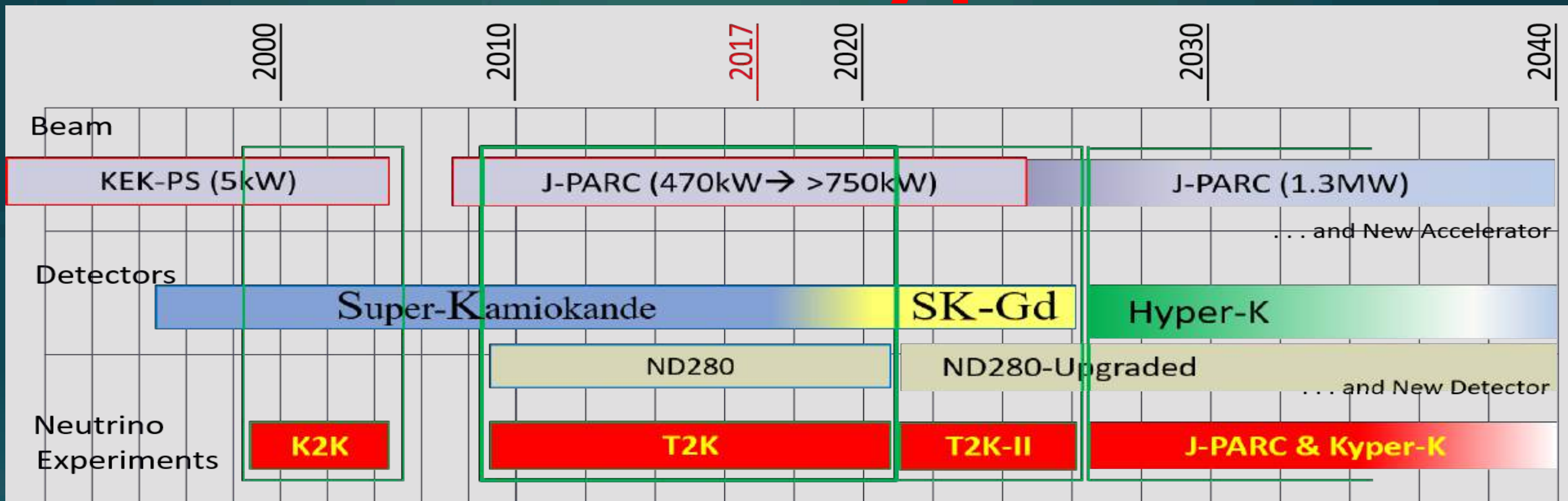
ΛΛ-Hyper Nuclei

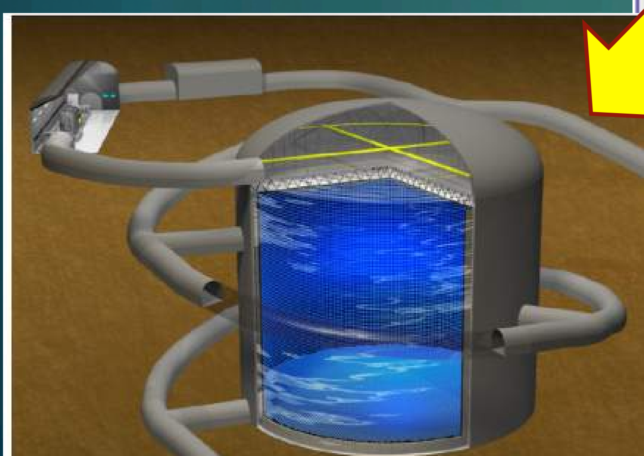
Strange quark may play an important roles in an extreme high density matter, aka neutron star.

CPV in Charged Lepton?

g_μ-2/μEDM

Accelerator-based neutrino program in Japan: K2K → T2K → HyperK





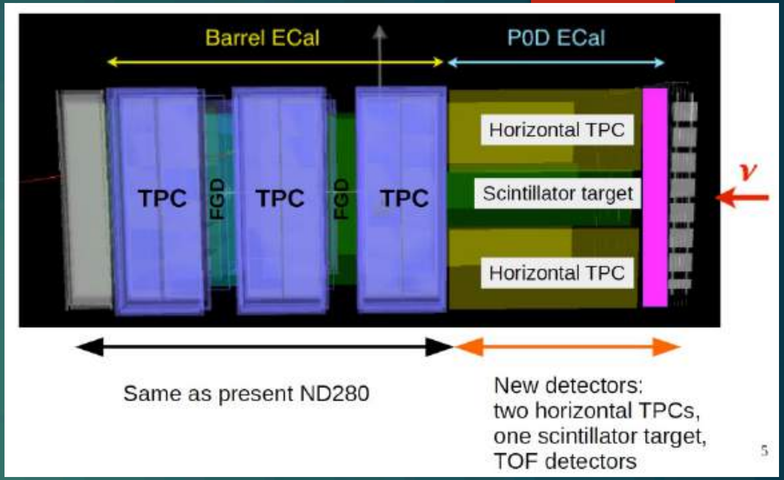
Hyper-Kamiokande (260kt)

T2K-II

https://j-parc.jp/researcher/Hadron/en/pac_1601/pdf/EoI_2016-10.pdf

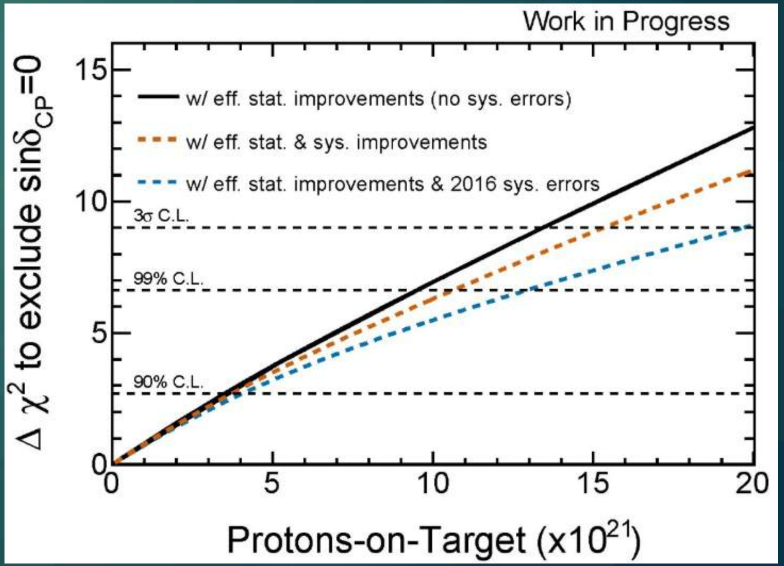
- Upgrade of T2K
  - **Beam power → 1.3MW**
    - Near detector upgrade
- POT goal : **20×10^{21} by ~2026**
- Physics goal
  - **Evidence of CP violation at > 3σ ($\delta=-\pi/2$)**
- Stage-1 status at J-PARC PAC
- Strong participation/commitment of French collaborators

Baseline design of ND upgrade

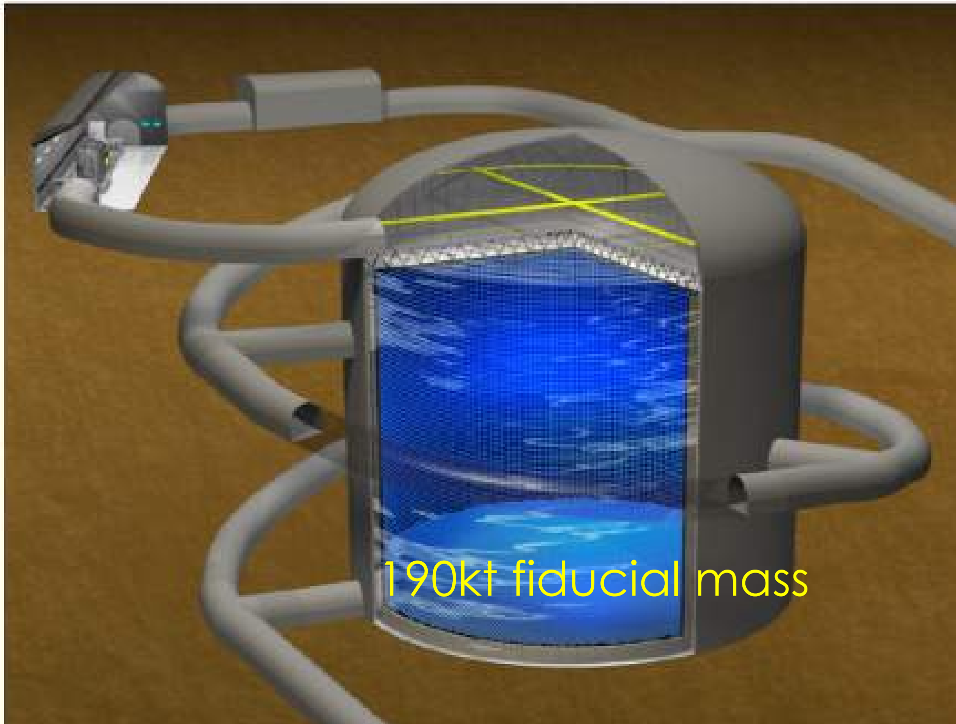


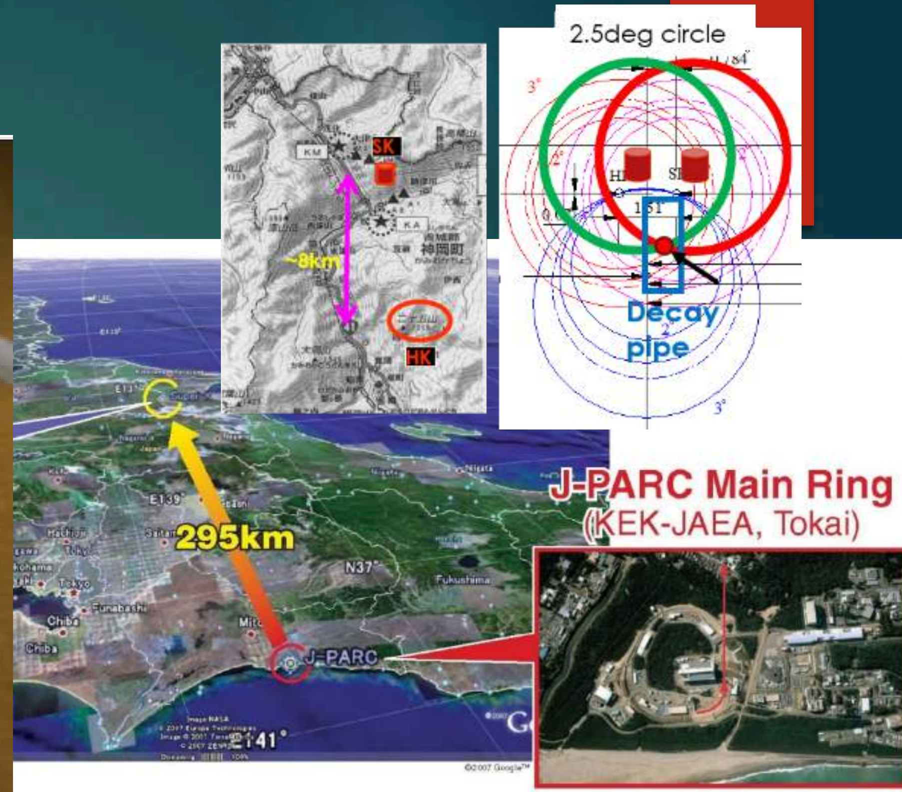
With CERN SPSC EoI-015

https://cds.cern.ch/record/2240188/files/SPSC-EOI-015.pc



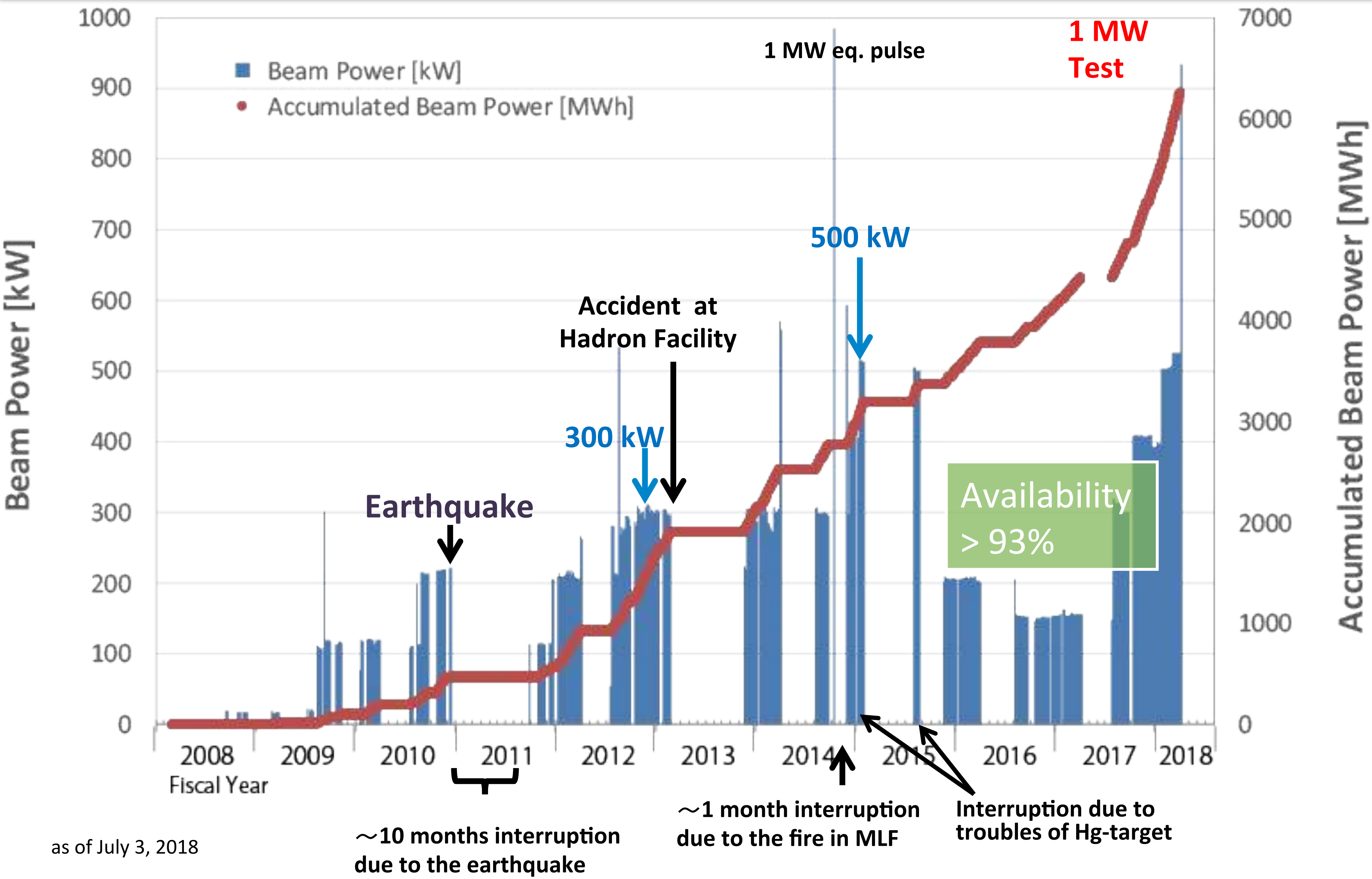
Hyper-Kamiokande





- "Hyper-Kamiokande Project"
  - **Upgraded J-PARC with >1.3MW**
  - Intermediate detector
  - Hyper-Kamiokande detector
  - Option to place 2nd detector in Korea in the future
- **Physics goals**
  - **Acc nu: CPV**
  - **Atm nu: mass hierarchy**
  - **Astronomical nu: SN, solar nu**
  - **Discover Proton decay!**

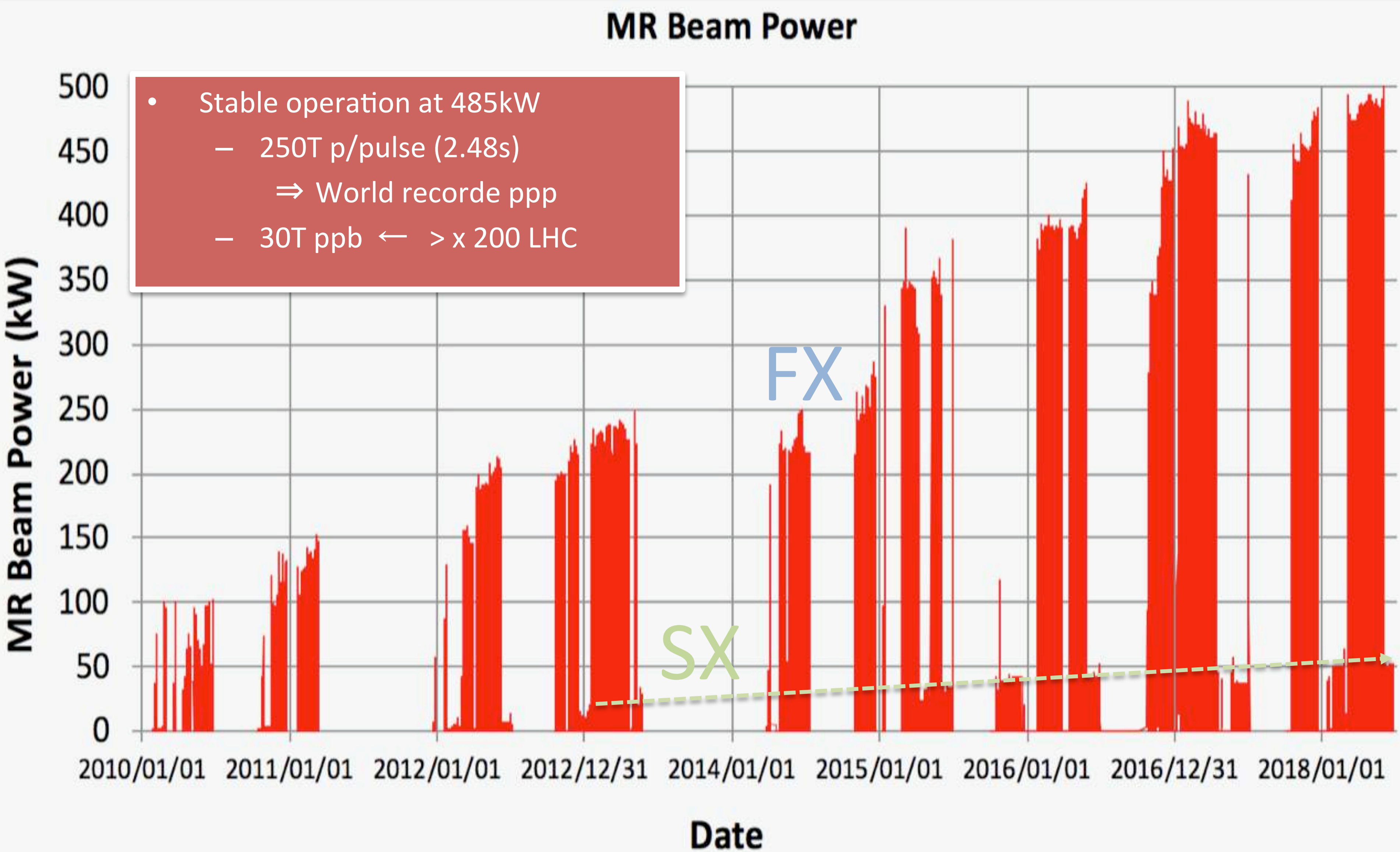
Beam Power History at MLF



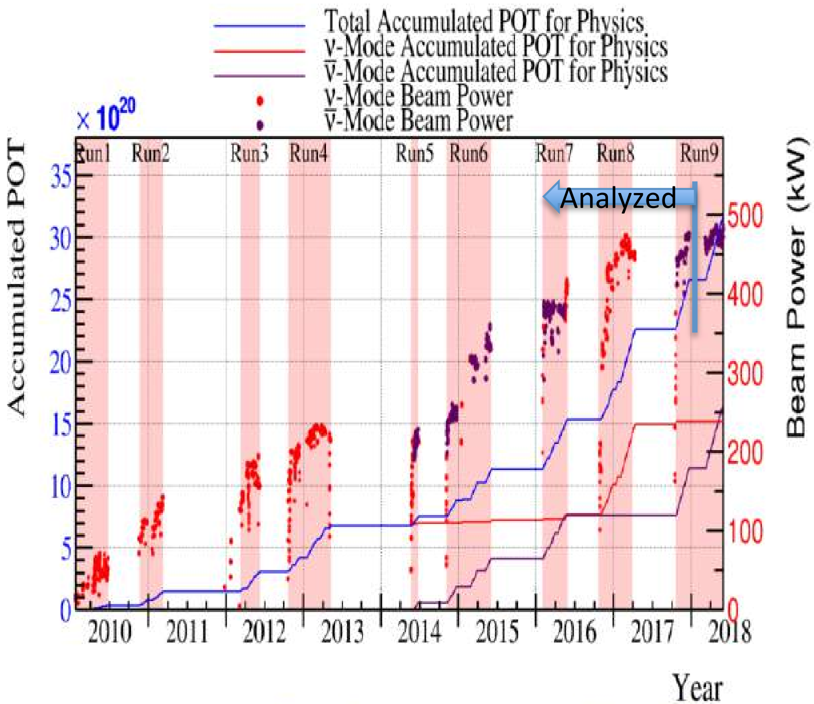
as of July 3, 2018

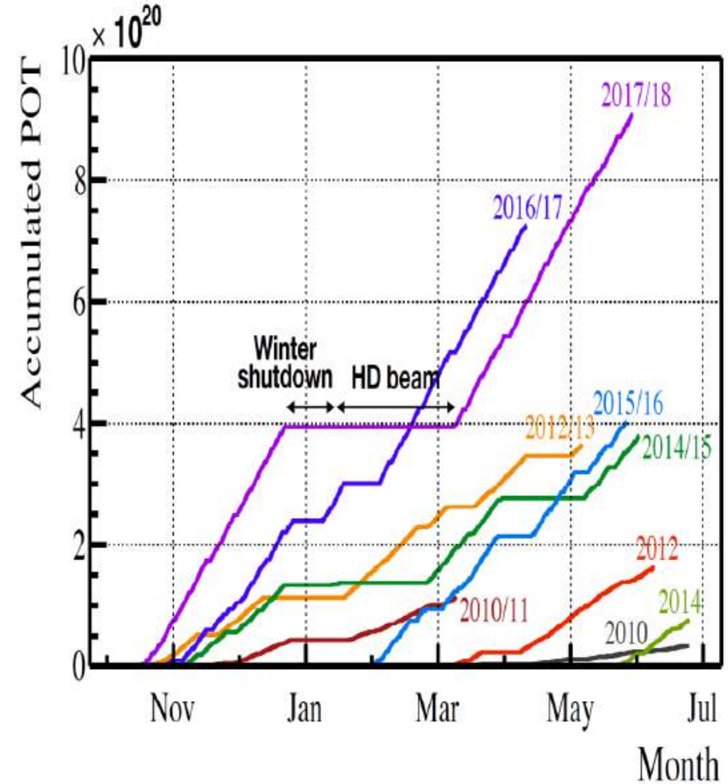

消火器
1MW安定運転に成功！
平成30年7月3日
J-PARC
J-PARC MLF

Beam Power History of Main Ring



T2K history





- Data taking period : Oct.-Dec. 2017 and Mar.-May 2018
- 485 kW stable operation
- Total delivered POT to T2K : 3.16×10^{21}
  - ν-mode POT : 1.51×10^{21} (47.83%)
  - $\bar{\nu}$-mode POT : 1.65×10^{21} (52.17%)

Analyzed data
2.62×10^{21} POT
ν-mode : 1.49×10^{21} POT
$\bar{\nu}$-mode : 1.12×10^{21} POT

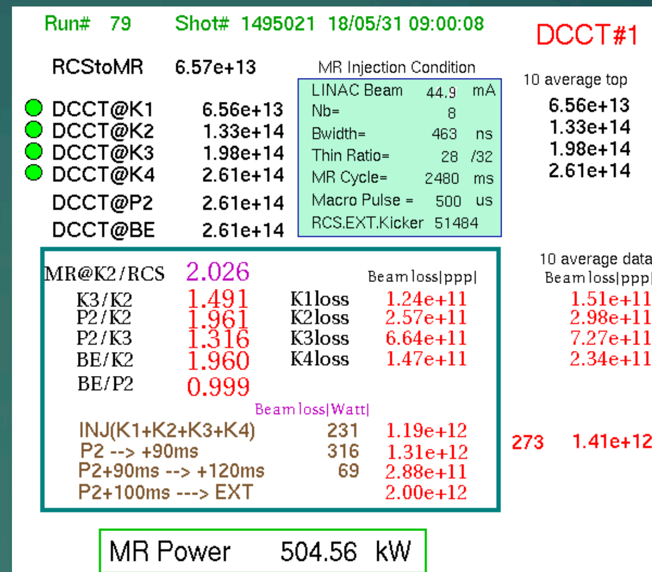
- Anti-neutrino data is doubled from 2017
  - (~50% increase of analyzed data for now)

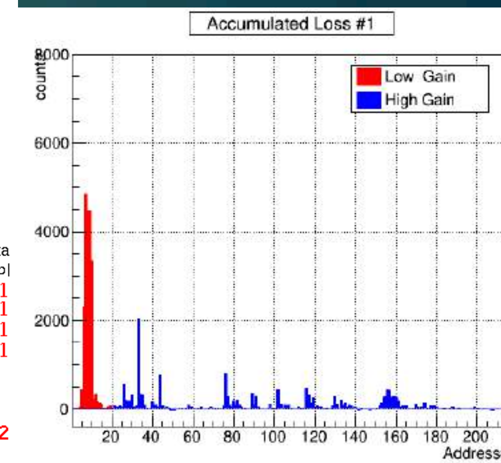
High intensity trial

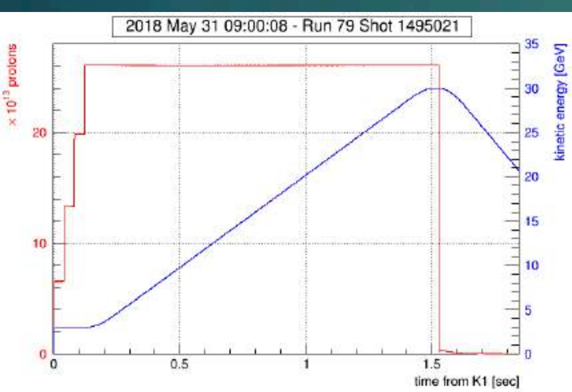
Sato-san's slide
@T2K collab M.

Successful 50 straight shots to NU at 500 kW

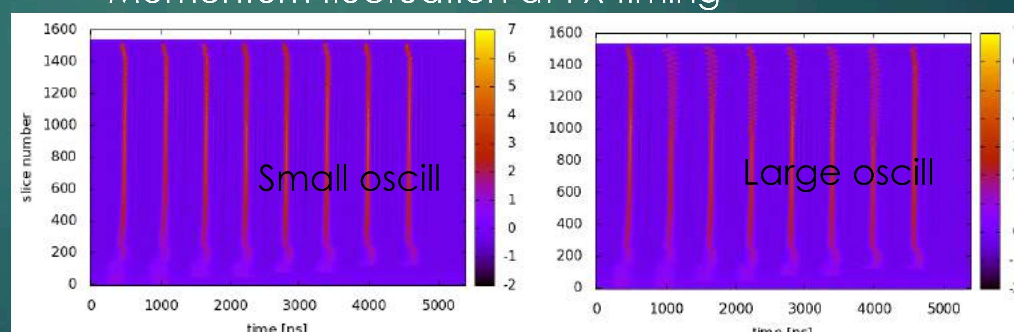
- Tune scan to suppress beam loss
- RF Vtop 310 kV → 320 kV
- MR 700 W loss
- RF#3 anode current 100~102A
- NU loss, dp/p acceptable







Momentum fluctuation at FX timing

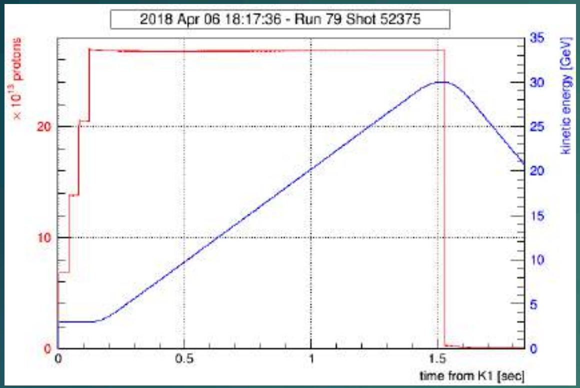


→ Shot by shot difference is acceptable at NU

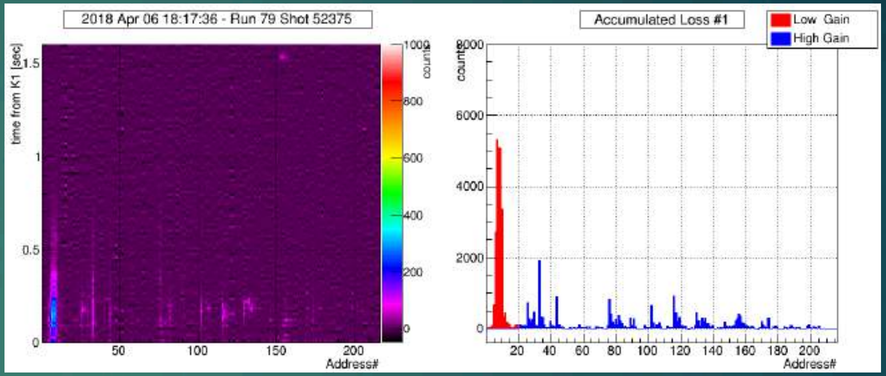
Sato-san's slide
@T2K collab M.

High intensity trial: **520kW** 1 shot

- The beam power of 520 kW was achieved by a single shot with the cycle time of 2.48 s.



Extracted beam: 2.68e14 ppp



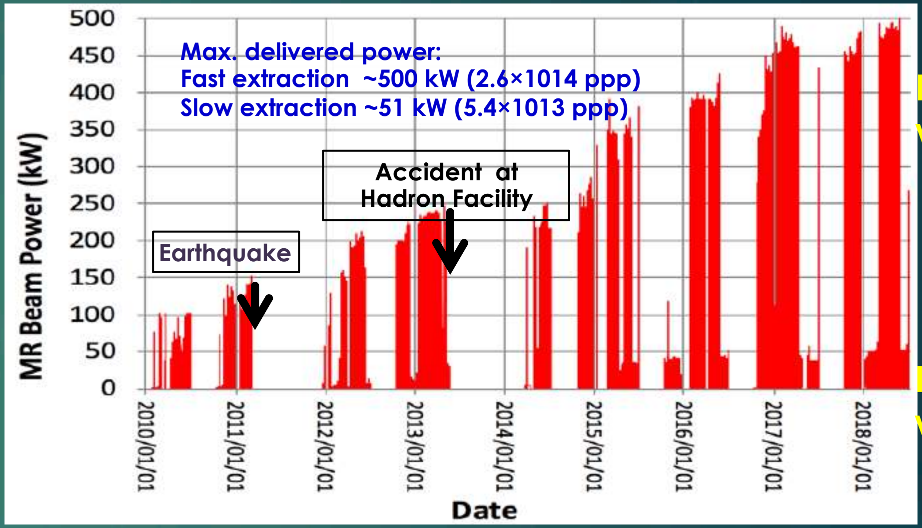
Total beam loss ~ 1.0 kW in the cycle of 2.48 s

	Protons per pulse	Bunch number	Repetition period (sec)	Beam power (kW)	Beam loss (kW)	Notes
1	2.68e14	8	2.48	520	1.0	measurement
2	2.68e14	8	1.16	1110	2.1	estimation

- **Equivalent to ~1.1 MW when 1.16s cycle with the beam loss of 2.1 kW.**
- **Beam study necessary to reduce/localize the beam losses**

Summary of MR achievements and plans

Beam Power History MR to NU (FX) / HD (SX)



Achievements
- **Stable 490 kW** operation with 500 W loss
- **50 series shots @ 500 kW** successfully with 700 W loss
- **1 shot @ 520kW** with 1kW loss

Plan for near future

Transverse:
- Enough for 500 kW, but having good keys un-optimized yet.
- **New operation points are under R&D for > 500 kW**

Longitudinal:
- For stable 500 kW, realizing Feedback system is essential.
- **Current limit of the anode power supplies is an issue.**


祝　ニュートリノPOT達成
＆MR 500 kW 越え
平成29年4月13日

Future prospect

Upgrade to 1.3MW

- Strategy

Beam Power (kW)	485 (Achieved)	(940)	1,300 (Goal for T2K-II)
#p/p(10^{12})	250	250	320
Rep T (s)	2.48	1.28	1.16

+25%

Funding started

-10%

- Method
  - Higher rep rate: **Funding started**
    - MR magnet power supply upgrade
    - MR RF upgrade (High grad/PS)
    - MR Fast Extraction Kicker upgrade
  - Higher #p/p
    - MR RF upgrade (PS)

After funding for 750kW design power is secured, No big step to >1.3MW

More Power at MR

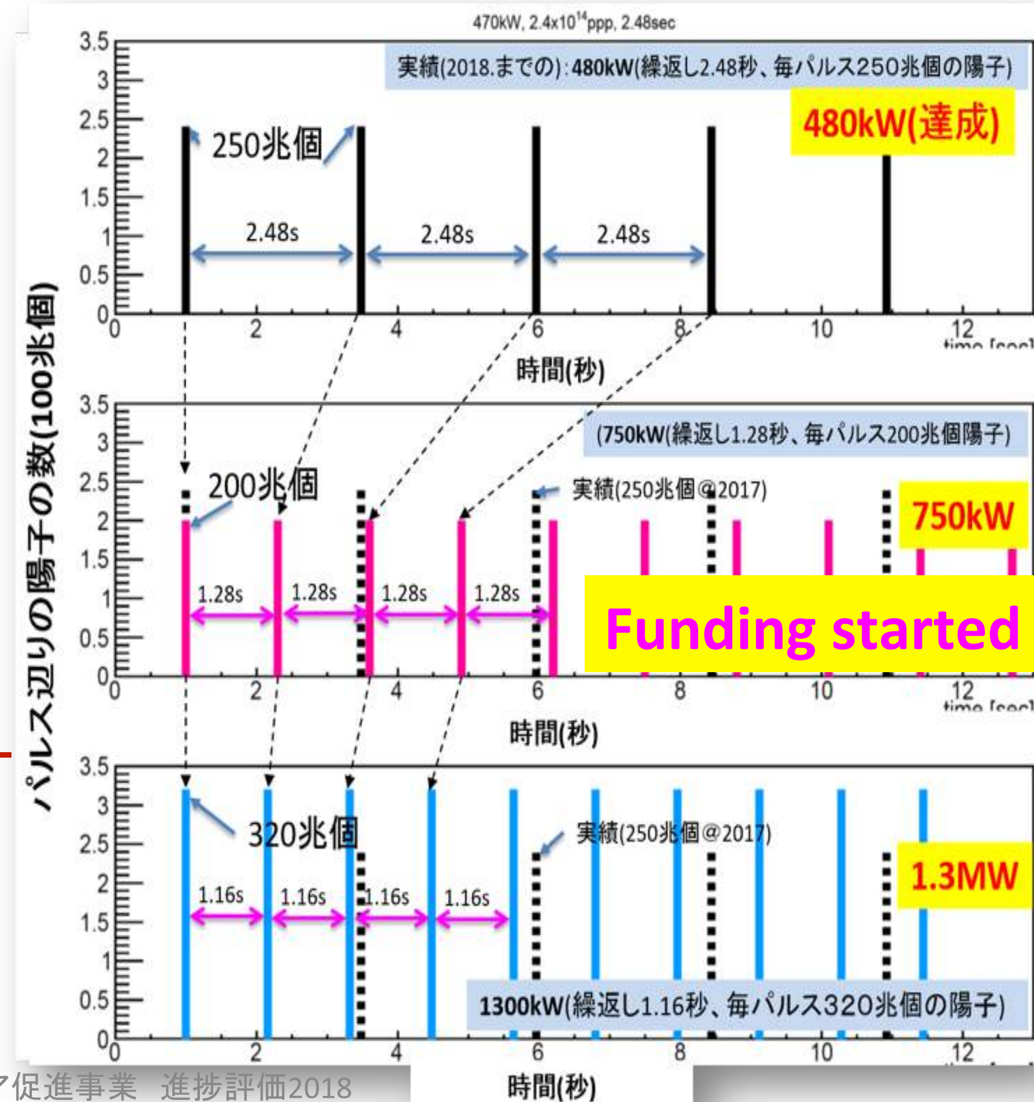
More Rapid Cycle:

2.48 s → 1.28 s → 1.16 s

- Main Power Supply to be re-newed
- High gradient RF Cavity
- Improve Collimator
- Rapid cycle pulse magnet for injection/extraction

More Protons / Pulse :

- Improve RF Power
- More RF Systems
- Stabilize the beam with feedback

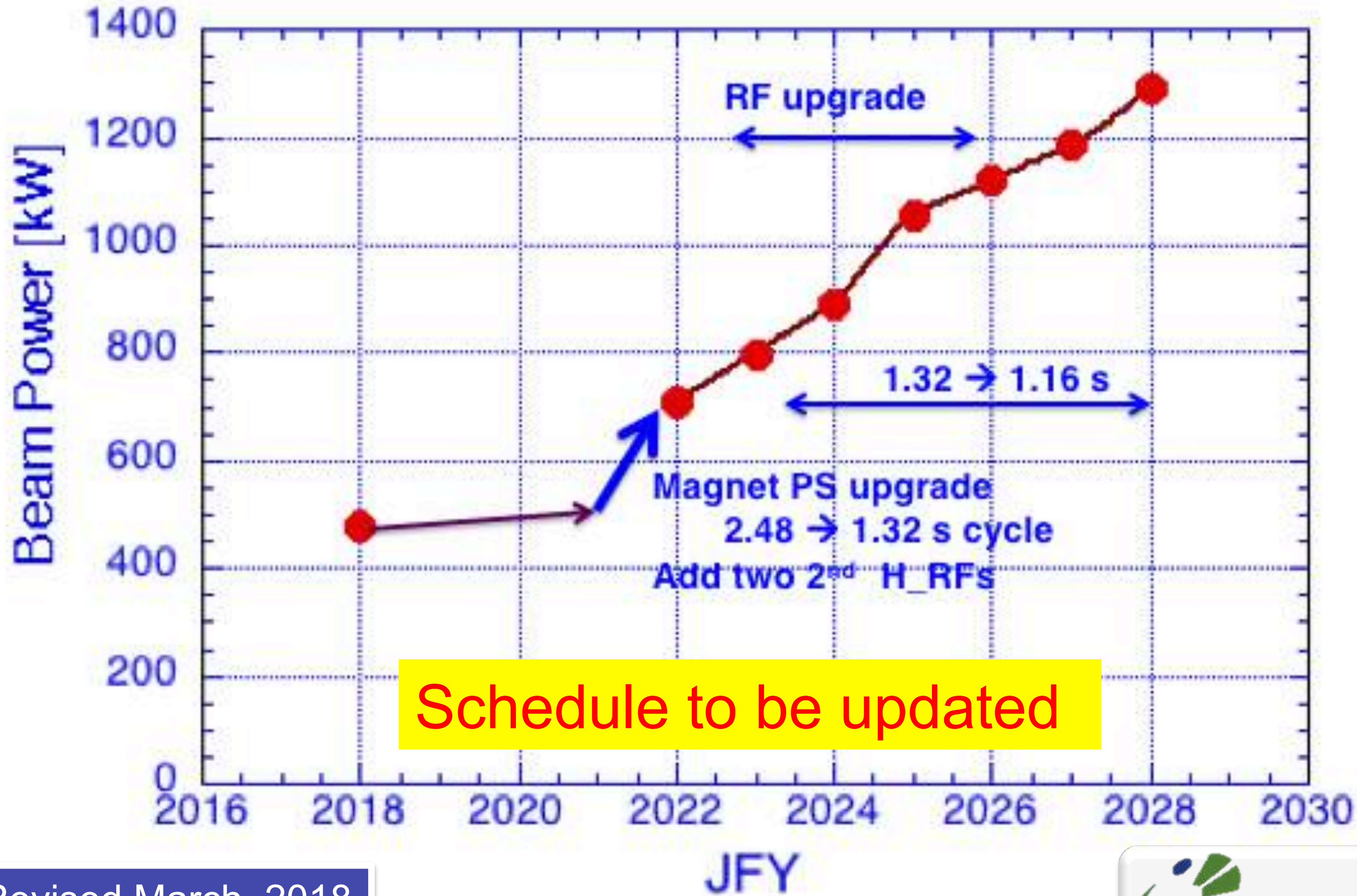


Projected Schedule of MR new Power Supply

JFY	2017	2018	2019	2020	2021	2022	2023	2024
Event	New buildings		HD target		Long shutdown			
FX power [kW]	475	>480	>480	>480		>700	800	900
SX power [kW]	50	50	50	70		> 80	> 80	> 80
Cycle time of main magnet PS	2.48 s	2.48 s	2.48s	2.48s		1.32 s	<1.32s	<1.32s
New magnet PS		Mass production installation/test						
High gradient rf system								
2nd harmonic rf system		Manufacture, installation/test						
Ring collimators	Add.collimators (2 kW)				Add.colli. (3.5kW)			
Injection system	Kicker PS improvement, Septa manufacture /test							
FX system	Kicker PS improvement, FX septa manufacture /test							
SX collimator / Local shields						Local shields		
Ti ducts and SX devices with Ti chamber	Ti-ESS-1	(Ti-ESS-2)						

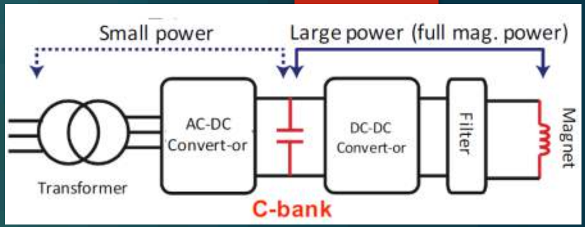
利用者協議会
20180320

J-PARC Main Ring (30 GeV) operates beyond 1 MW

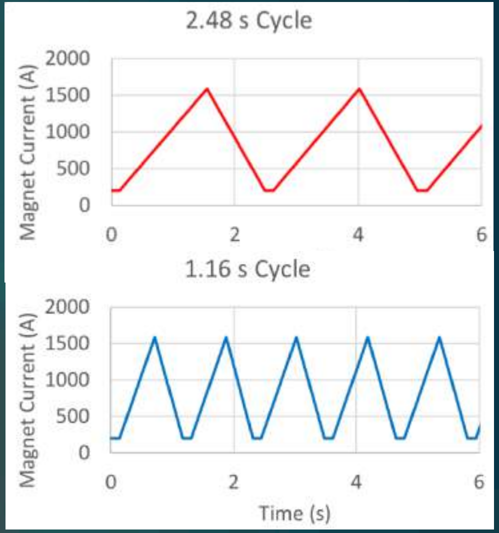


Revised March, 2018

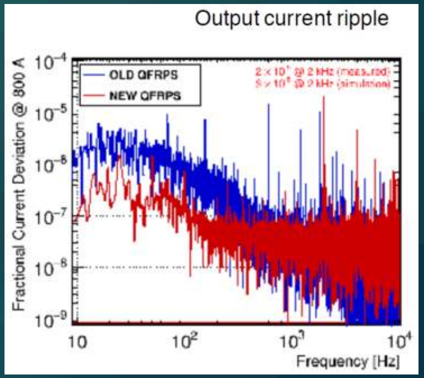
MR magnet power supply upgrade for higher rep rate



- Large capacitor bank for energy recovery
- Construction started
  - Buildings to be completed in 2017
  - First mid scale PS installed and being operated successfully



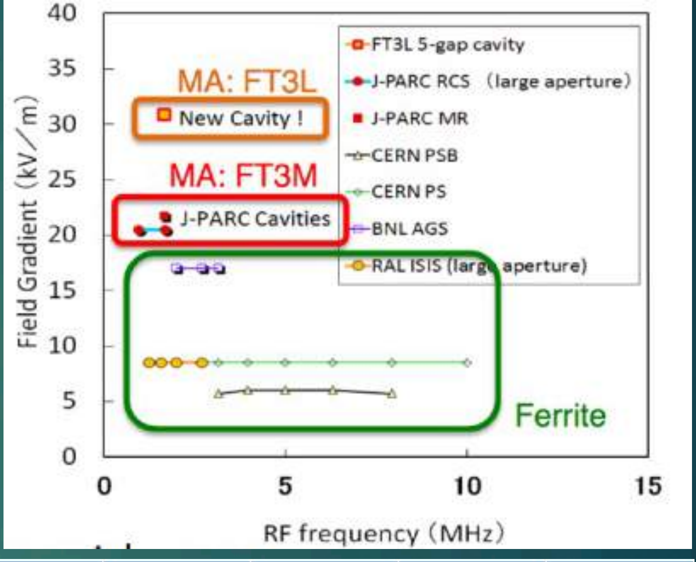
New Power Supply for Rapid Cycle

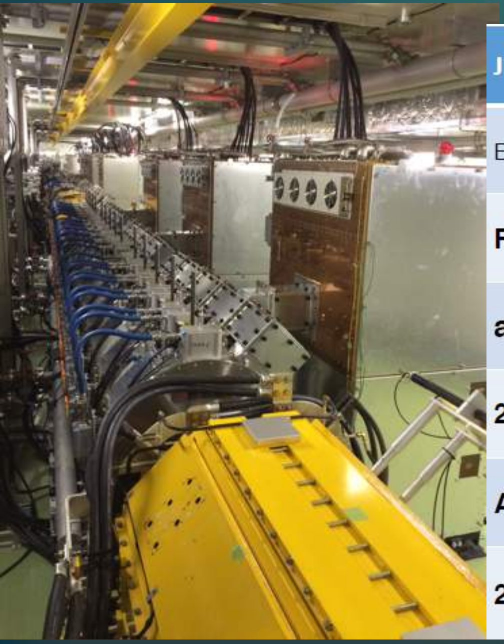


RF upgrade status and plan

- All 9 cavities are FT3L now
  - 7 for fundamental
  - 2 for 2nd H.
- For 1.3MW 600 kV accelerating voltage needed for 1.16 s operation.
  - 11 accelerating systems
  - 2 2nd harmonic

  Needed
- Anode power supply upgrade required to increase output current





JFY	2018	2019	2020	2021	2022	202X
Events				Long shutdown	MR 1.3-sec operation	MR 1.16-sec operation
FT3L 4GAP Cavity	7	7	7	9	9	9
additional 4GAP Cavity	-	-	-	-	-	2
2nd Harmonic Cavity	2	2	2	2	2	2
Accelerating Voltage	300-390kV	300-390kV	300-390kV	510kV	510kV	600kV
2nd Harmonic Voltage	110kV	110kV	110kV	120kV	120kV	120kV

Neutrino beam facility upgrade

- Original design principle/specification
  - 750kW for replaceable components
  - >3MW for irreplaceable parts (Decay volume, Dump, etc)
  - 750kW = 30GeV x **(330Tp/5us pulse)** x (2.10s cycle)
- Goal
  - 1.3MW = 30GeV x **(320Tp/5us pulse)** x (1.16s cycle)
    - Similar impulse thermal shock!
- Main upgrades
  - Horn current 250kA → 320kA (+10% nu flux)
  - Cooling power
  - Radio-active waste (water,..) processing power

Beam Power	# of protons/pulse	Rep. rate
350 kW (achieved)	1.8×10^{14}	2.48 sec.
750 kW (proposed) [original plan]	2.0×10^{14} [3.3×10^{14}]	1.30 sec. [2.10 sec.]
1.3 MW (proposed)	3.2×10^{14}	1.16 sec.

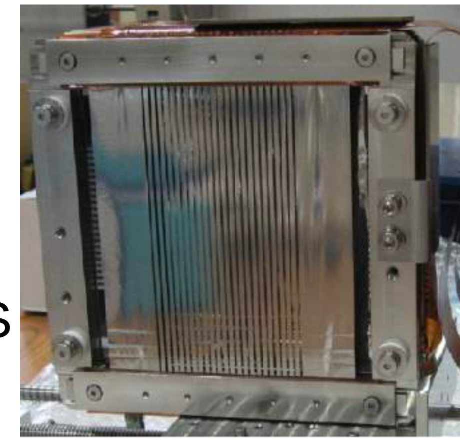
Present capability of 2ndary beam line

Component	Limiting factor	Current acceptable value
Target/Beam window	Thermal shock	3.3×10^{14} ppp
	Cooling capacity	0.9MW
Horn	Conductor cooling	2MW
	Stripline cooling	0.75MW
	Hydrogen production	1MW
	Operation	250kA, 2.48s
He Vessel	Thermal stress	4MW
	Cooling capacity	1MW
Decay Volume	Thermal stress	4MW
	Cooling capacity	1MW
Beam Dump	Oxidization	3MW
	Cooling capacity	1MW
Radiation	Radiation shielding	0.75MW
	Radioactive water disposal	8.4×10^{20} POT/y (0.4MW-equiv)

Beam Monitor Upgrade

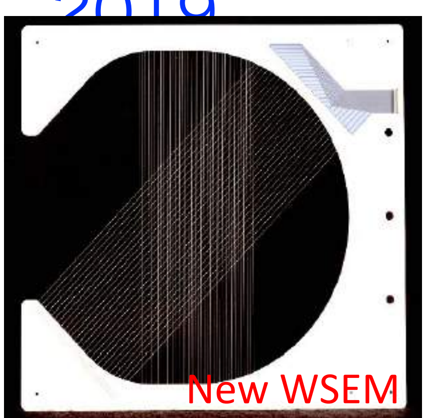
SSEM (profile monitor) ⇒ Beam intercepting monitors

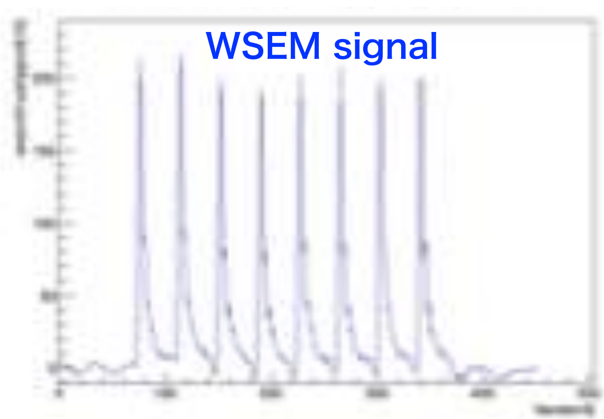
- Cause beam loss ⇒ only most downstream SSEM19 used continuously
- Radiation tolerance is also an issue

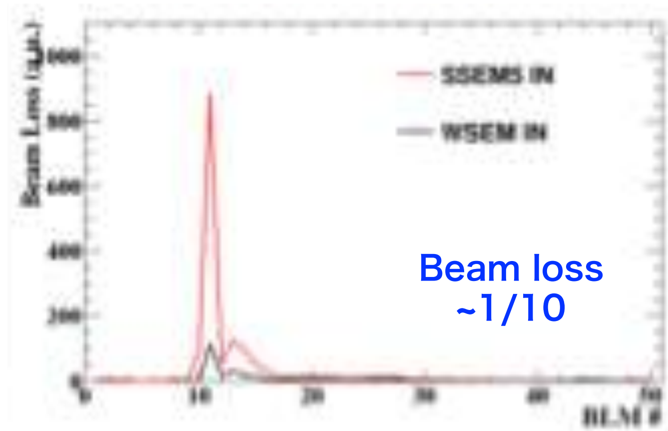


Wire Secondary Emission Monitor

- Use Ti wires instead of thin Ti foils
- First prototype installed ⇒ worked well as
  - Beam loss reduced by 1/10 of current SSEM
  - Resolution and precision equivalent to SSEM
  - No problem at long-term (160H) continuous operation
- SSEM18 to be exchanged to WSEM in summer 2018 or 2019







Target Upgrade

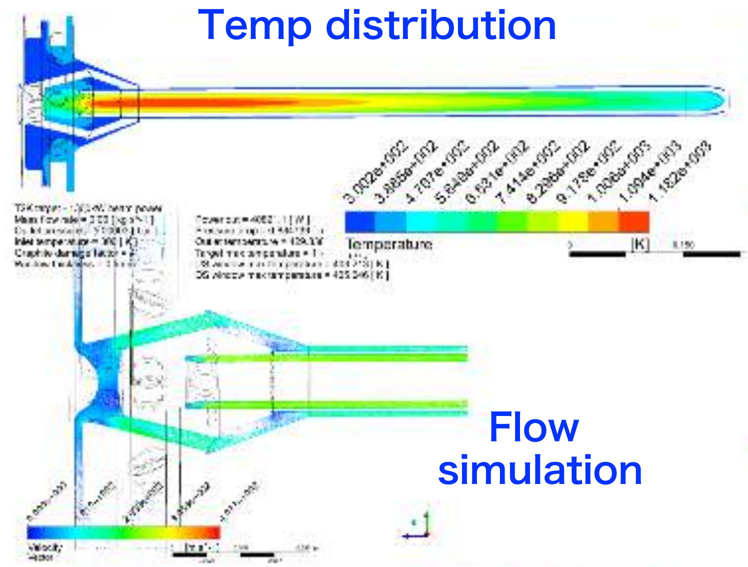
Current target

- Solid graphite can accommodate **3.2×10^{14} ppp**
  - Radiation damage is an open question
- Cooling capacity: **900kW**

Improvement

- **Double mass flow rate** (32→60g/s)

  ⇒ Need higher pressure (1.6→**5bar**)
  - **Upgrade of He compressor** is needed
  - Titanium container to be optimized for high He pressure
- FEM simulation for 1.3 MW ⇒ **909℃** expected (assuming 1/4 thermal conductivity due to radiation damage)
  - Higher temp. requires lower O_2 contamination



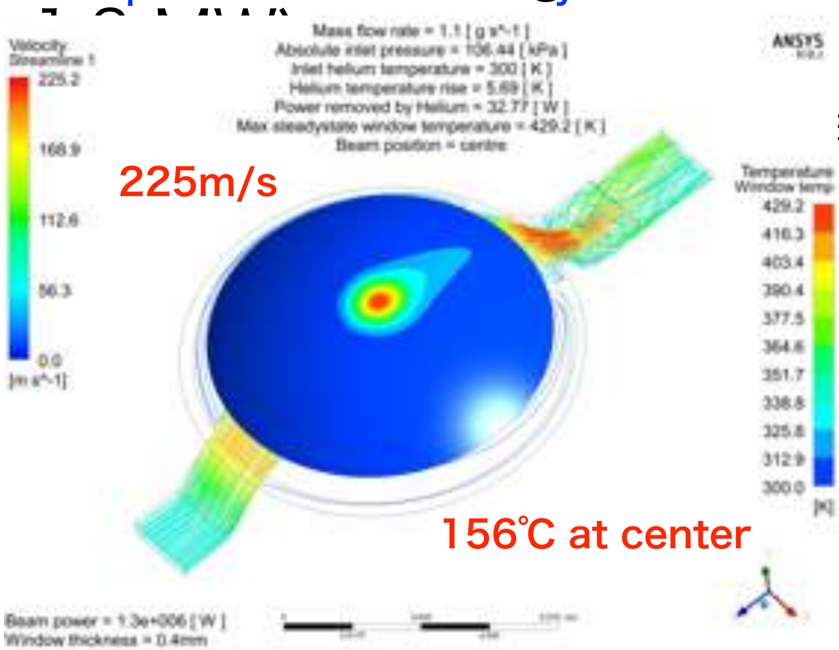
	0.75 MW	1.3 MW
He pressure	1.6 bar	5 bar
Pressure drop	0.83 bar	0.88 bar
He mass flow	32 g/s	60 g/s
Heat load	23.5 kW	40.8 kW
US window temp	105 ℃	157 ℃
DS window temp	120 ℃	130 ℃
Target core temp	736 ℃	909 ℃

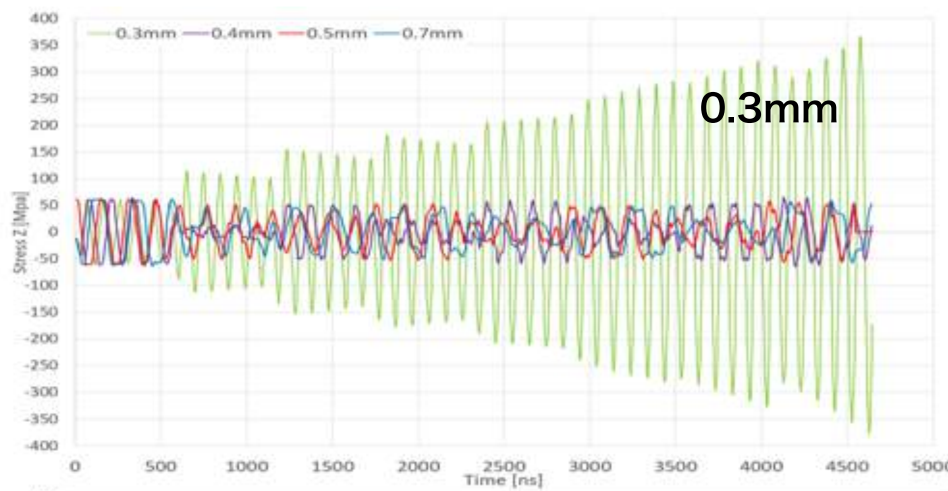
Beam Window Upgrade

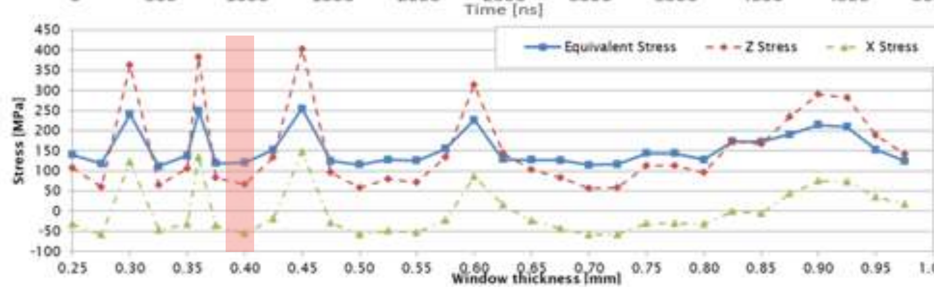
Thickness change to increase tolerance of beam window

- 0.3→0.4 mm ⇒ Stress reduction to half (250 MPa → ~125 MPa)
- Operation at 1.3 MW appears feasible for upgraded window
- Radiation damage is an sig

Temperature and He velocity for 1.3 MW



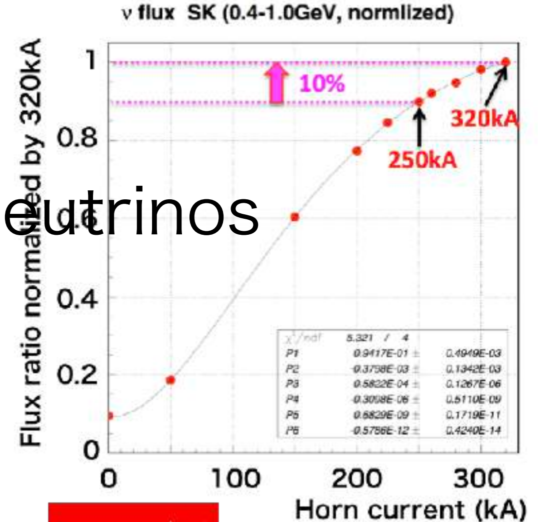


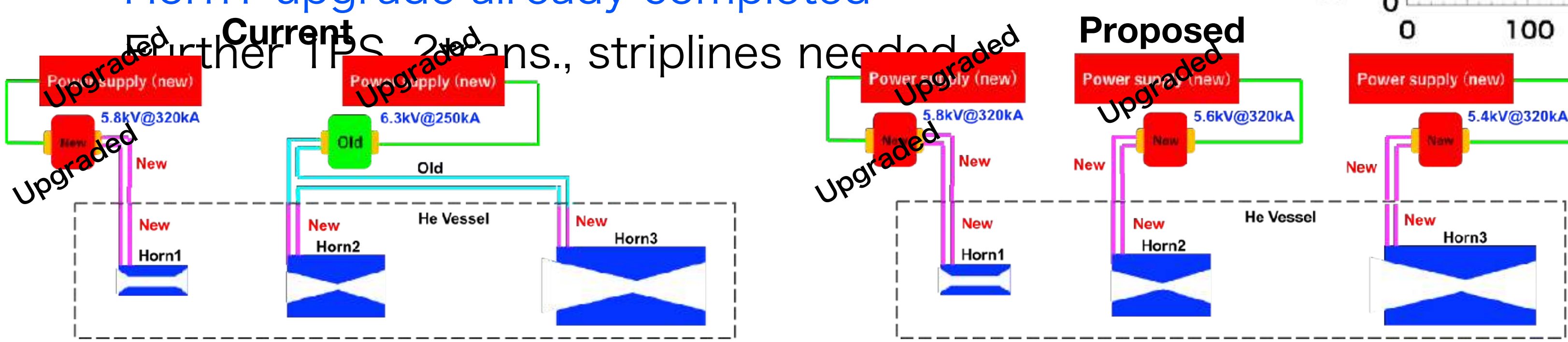


Horn System Upgrade

Horn current increase: 250 kA → 320 kA (design)

- **~10% flux gain** for right-sign neutrinos
- **5~10% flux reduction** for wrong-sign neutrinos
- **3 power supply** system is adopted
    - New PS, new transformer, new striplines developed
    - Horn1 upgrade already completed
    - Further TPS, 2 trans., striplines needed






Two new power supplies produced


New striplines installed to HV


New transformer

Radioactive Water Disposal

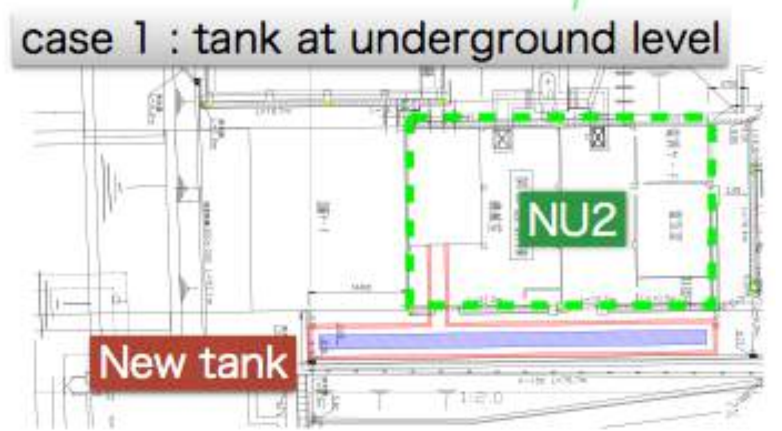
Radioactive water disposal

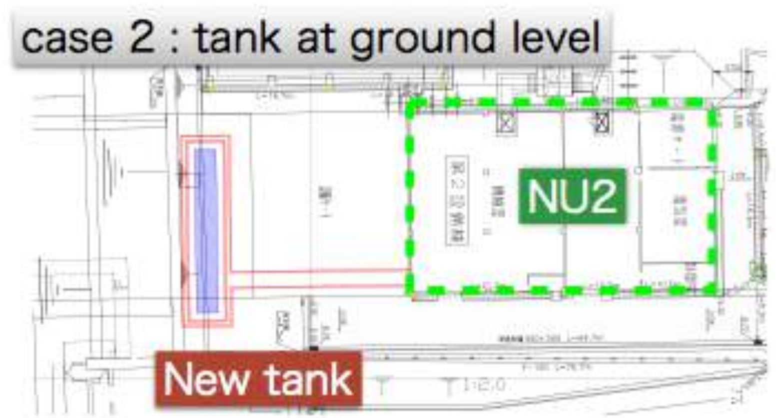
- ^{3}**H** (Tritium) → **dilution**, ^{7}**Be** → 99.9% removed by ion-exchange

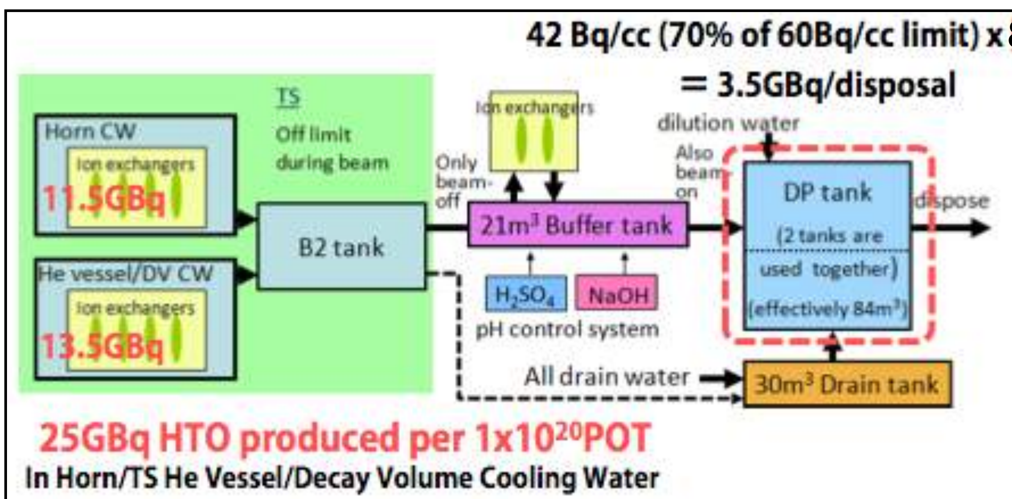
HTO disposal by dilution

- Current dilution tanks (84m^3)
  ⇒ **400kW** (8.4x10^{20} POT/year)
- Toward >1.3MW
  ⇒ **Construct a new tank with O(400)m^3**
  - Design in FY2018~2019
  - Construction in FY2020~2021

Proposed location of new tank







Timeline

JFY	2018	2019	2020	2021	2022	2023	2024	2025	2026
Beam power assumption (kW)	>480	>480	>480	Long shutdown	900	1100	1300	1300	1300
Acceptable beam power (kW)	750	750	750		>1300	>1300	>1300	>1300	>1300
Acceptable POT (POT/year)	8.4×10^{20}	8.4×10^{20}	8.4×10^{20}		3.2×10^{21}	3.2×10^{21}	3.2×10^{21}	3.2×10^{21}	3.2×10^{21}
Primary beamline				Ti duct, large aperture magnet					
WSEM upgrade		Replace SSEM 18, 19							
OTR upgrade	OTR-III			OTR-IV					
Muon monitor upgrade									
Target for 1.3 MW	Manufacturing			Install					
Target He system			Manufacture, install						
Beam window upgrade	Manufacturing			Install					
Horn for high power operation	Horn1	Horn2		Install	Horn3		Install		
Horn electrical system		Manufacture, install							
Horn stripline cooling			Water cooling						
Hydrogen removal system	System upgrade								
Remote maintenance reinforcement			Monitor replace	Horn cask					
Radiation shielding			Manufacture, install						
Cooling capacity upgrade			Manufacture, install						
Radioactive water disposal	Tank truck	New tank/building construction							
Beamline DAQ upgrade	Manufacture, install								
Beamline interlock improvement	Manufacture, install								
GPS upgrade	Manufacture, install								

Earlier realization by 1 year is technically feasible

KEK Project Implementation plan (KEK-PIP)

- Prioritization of projects which require new funding requests
- External review (May 22,23, 2016)
  - Recommendations
  - https://www.kek.jp/ja/About/OrganizationOverview/Assessment/Roadmap/KEK-PIP_Evaluation.pdf
- KEK-PIP taking into account the recommendations
  - https://www.kek.jp/ja/About/OrganizationOverview/Assessment/Roadmap/KEK-PIP.pdf

Project to be prioritized:
- COMET II
- J-PARC upgrade for Hyper Kamiokande
- Hadron Hall Extension
- H-line and g-2/EDM
- LHC and ATLAS
- Super Computer
- RNB

Separate prioritization
- Light Source

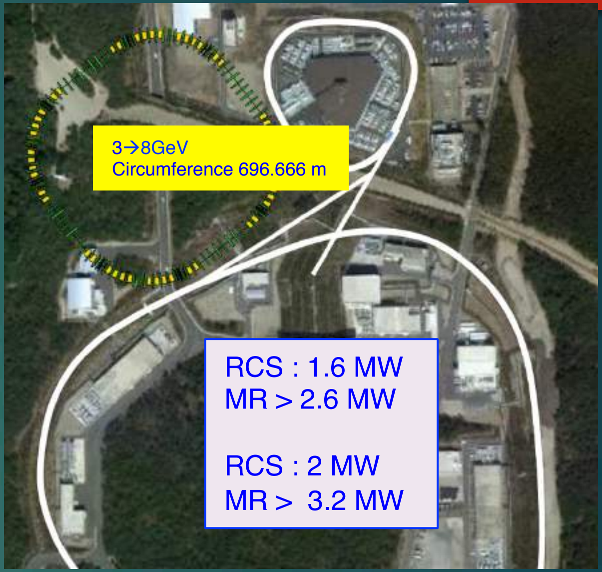
Upgrade of J-PARC for Hyper-K is highest priority

Funding situation

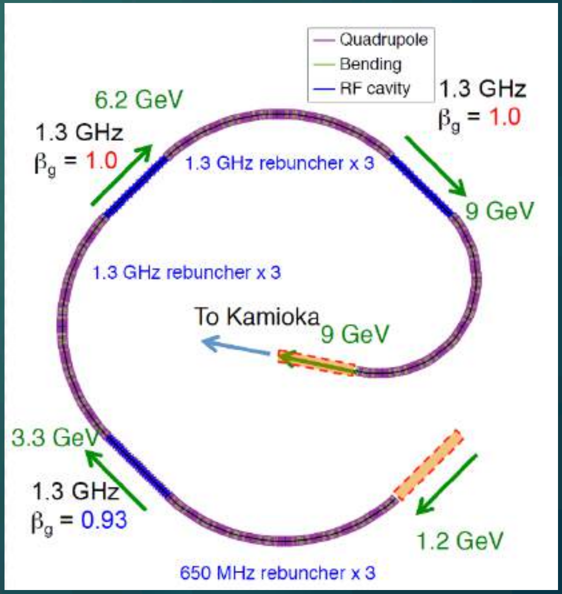
- Funding for 750kW upgrade started
  - Power supply
- Budget request from KEK to MEXT for FY2019
  - Upgrade for 1.3MW
  - Intermediate detector facility
- Budget request from MEXT to MOF
  - Power supply + alpha for power upgrade
- Will make funding request for 1.3MW again for JFY2020 (around June 2019)

Ideas for even higher power

- Second booster in J-PARC
  - Introduce new 8GeV booster for MR injection to “eliminate” space charge effect at injection
  - Upto 3.2MW when RCS is 2MW



- “Circular” Linear accelerator
  - Utilize TRISTAN/KEKB tunnel at Tsukuba campus
  - 9GeV, 100mA, 1%duty = 9MW



Summary

- J-PARC neutrino beam achieved 490kW stable operation
  - Accelerator demonstrated 1100kW equiv. shot
- J-PARC plan to upgrade to 750kW and then 1.3MW
  - Funding for 750kW is started (FY2016-)
  - Modest upgrade and budget from 750kW to 1.3MW
  - **Highest priority project in KEK-PIP**
- 1.3MW is challenging goal but technically achievable
- Higher beam power should also be pursued
- → Big impact on the long baseline neutrino physics
- Your participation and challenge are highly welcome!!

Spare

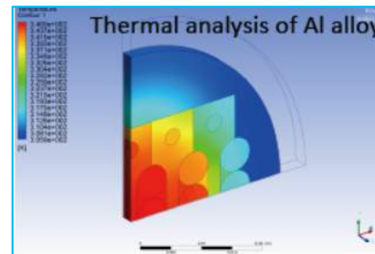
RaDIATE

Radiation Damage In Accelerator Target Environments

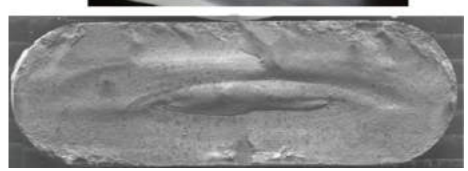
radiate.fnal.gov

- To solve a world's common problem to understand the effect of radiation damage on target/window materials, accelerator & fission/fussion communities' researchers & engineers work together.
- J-PARC neutrino was an active partner since 2014
- From JFY2016 J-PARC plan to join officially

Neutrino Beam Window
Ti Alloy ~1x10^{21} pot
~1 Displacement Per Atom
(Existing data up to ~0.3DPA)



Fermilab
UNIVERSITY OF OXFORD
Science & Technology Facilities Council
BROOKHAVEN NATIONAL LABORATORY
Pacific Northwest NATIONAL LABORATORY
Los Alamos NATIONAL LABORATORY EST.1943
FRIB
EUROPEAN SPALLATION SOURCE
OAK RIDGE National Laboratory
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
2016~
CERN
GSI
Argonne NATIONAL LABORATORY

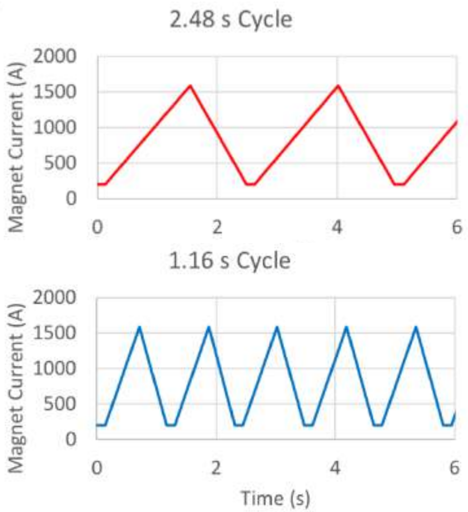


NuMI graphite broken target Post-Irradiation Examination (PIE) at PNNL: Swelling effect observed

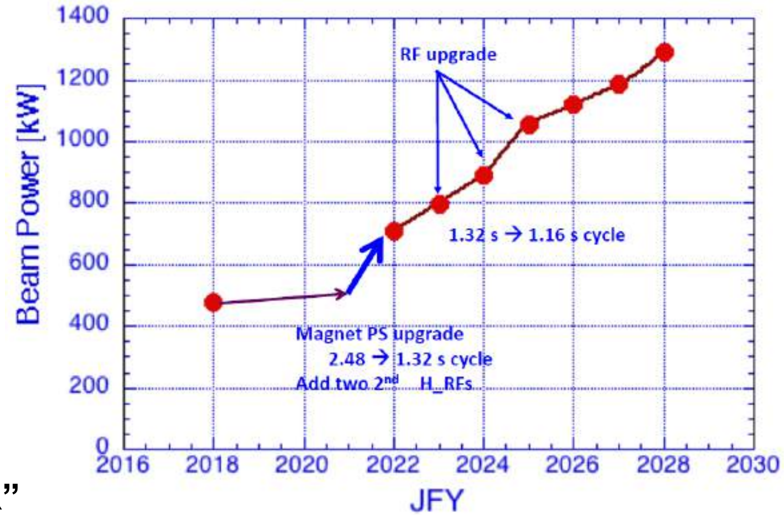
New Irradiation Run at BNL (2017 February ~)

Beam Power Upgrade Concept

- Stable operation of 490 kW has been achieved so far with
  the cycle time of 2.48 s and
  the accelerated protons of 2.5e14 ppp.
- The beam power of 1.3 MW is planned with
  the faster cycling of 1.16 s and
  the accelerated protons of 3.3e14 ppp.
- Hardwares (Magnet PS/ RF/ Colli/ Inj&FX/…) are under preparation
- The most powerful neutrino beam can be realized in several years.



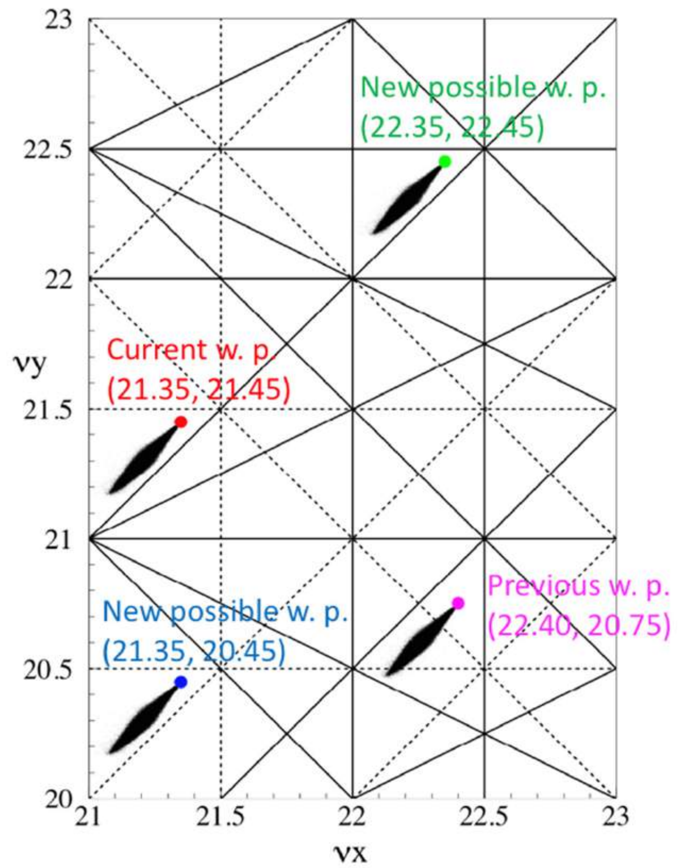
Beam Power	Cycle time	Protons per pulse (ppp)	Protons per bunch (ppb)	Eq. beam power in RCS
490 kW	2.48 s	2.5 e14	3.1 e13	760 kW
520 kW	2.48 s	2.7 e14	3.4 e13	810 kW
750 kW	1.3 s	2.0 e14	2.5 e13	610 kW
1.3 MW	1.16 s	3.3 e14	4 e13	1 MW



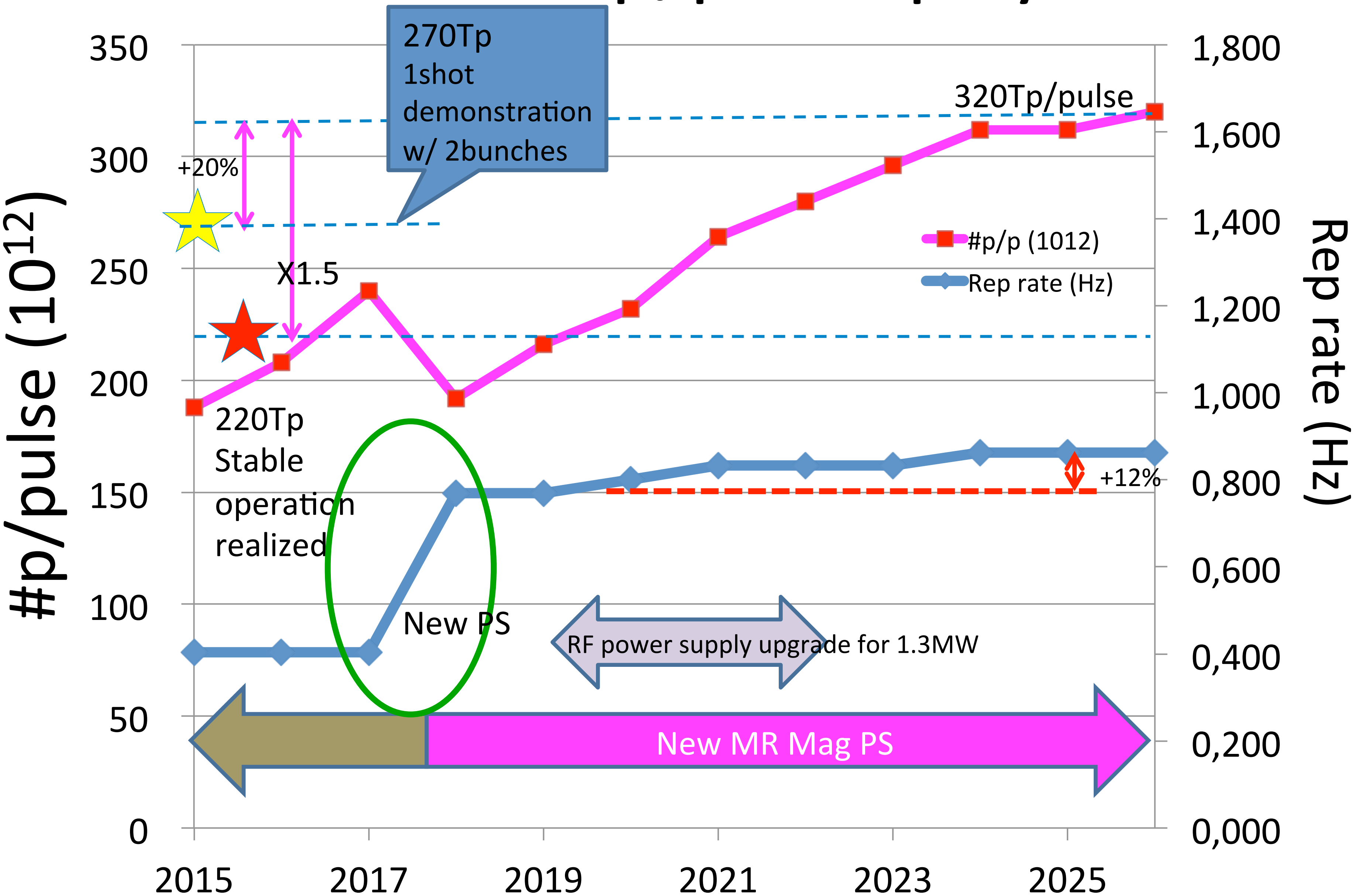
T. Koseki: TUPAK005, IPAC2018, "Upgrade Plan of J-PARC MR"

Possible operation points

- (21.35, 21.45) demonstrated 1.1 MW capability in 1.16 s cycle.
- However, it is affected by the structure resonances of 2vx−2vy=0 and vx−2vy = −21.
- Working points of **(22.35, 22.45)** and **(21.35, 20.45)** may be free from the structure resonances.



Assumed #p/p & rep cycle



Next big goal: CPV

Neutrino and anti-neutrino behave same?

Origin of Matter

- Mass hierarchy
- Precision measurements
- Any new phenomena

J-PARC Overview and Future

July 8, 2018

ICHEP2018 Satellite Meeting for Hyper-Kamiokande and KNO

Naohito SAITO (nsaito@post.j-parc.jp)

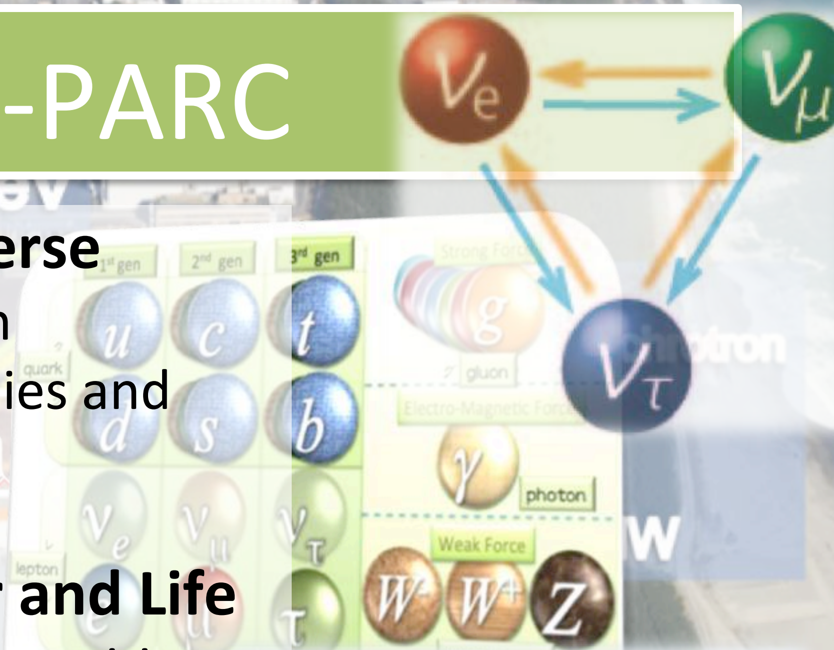
High Energy Accelerator Research Organization

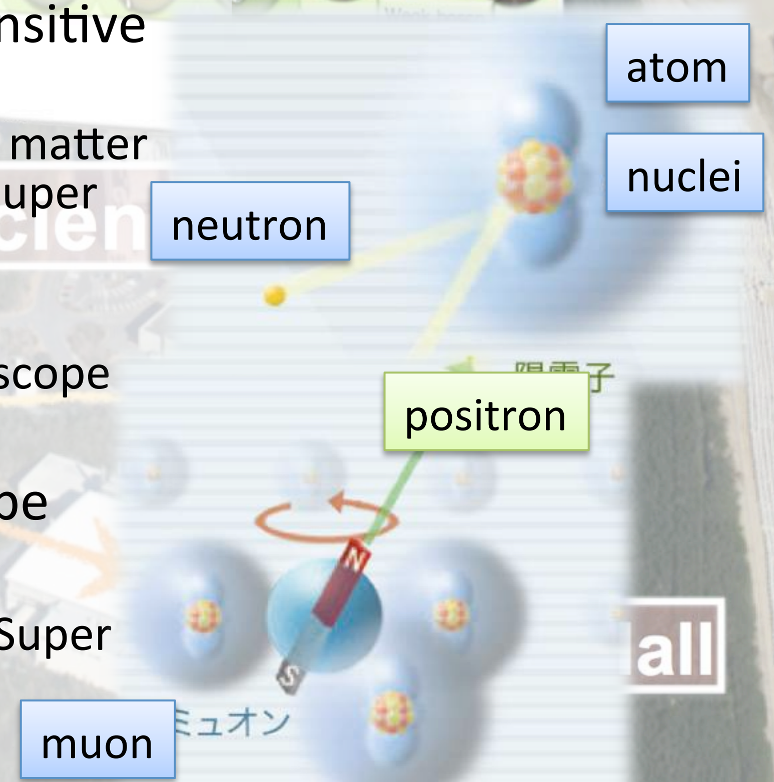
Japan Atomic Energy Agency

J-PARC

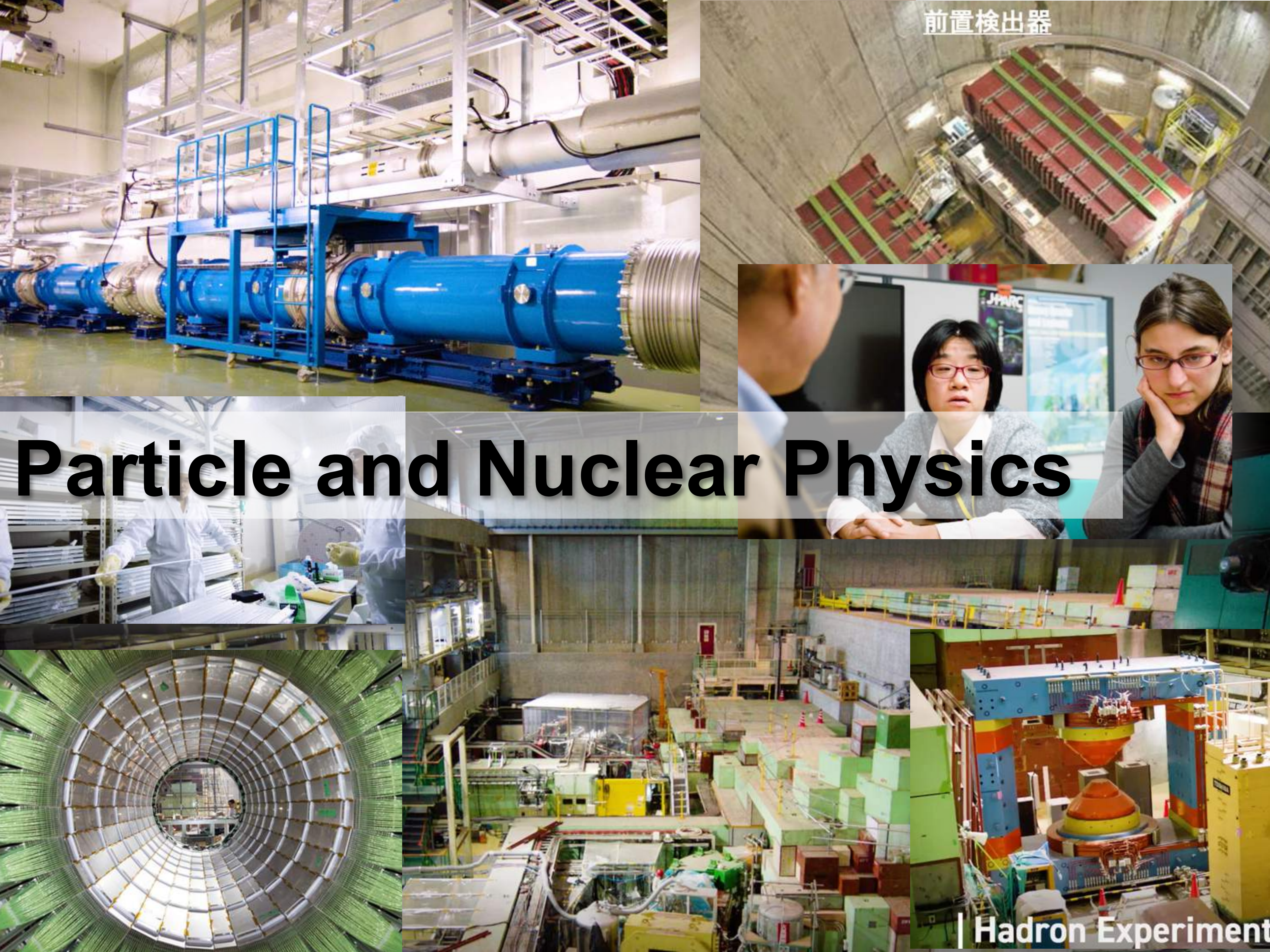
Science at J-PARC

- **Elucidate Origin of Matter and Universe**
  - Neutrino Oscillation and its CPV search
  - Charged Lepton and Quark Flavor studies and CPV search
  - Strong Interaction studies
- **Explore Origin of Diversity in Matter and Life**
  - Neutron as penetrating and hydrogen sensitive probe
    - Energy materials (e.g.bettery), Life and soft matter (e.g. proteins, polymer), Hard matter (e.g. super conductor)
  - Muon as a micro magnetic probe
    - μSR, X-ray from muonic atom, muon microscope
    - Fundamental physics
  - Create core of innovation with multi-probe
  - Industrial Application
    - Synergetic use of SPring-8/PF and J-PARC, Super Computer "Kei"
- **R&D for Nuclear Transmutation**





Particle and Nuclear Physics

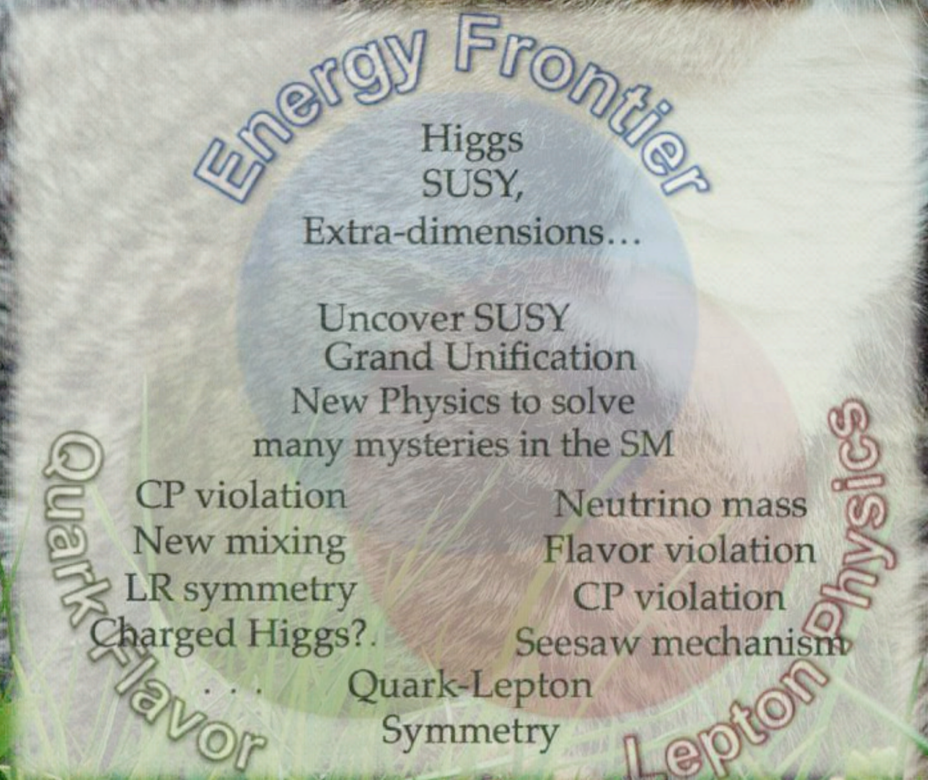


Hi-Energy Frontier

New phenomena may exist in the unprecedented energy region

→LHC, ILC and future colliders

Astrophysics

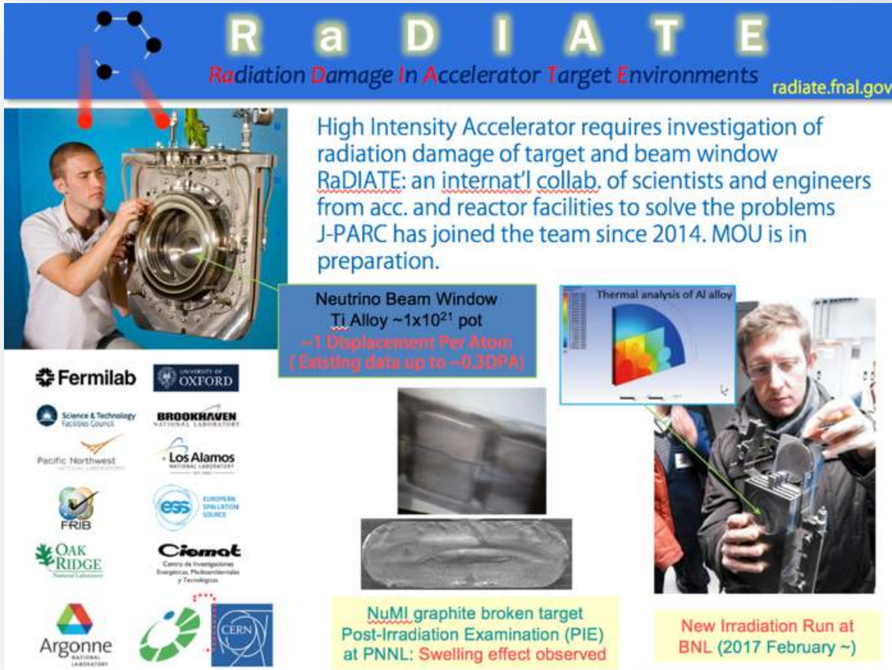


Hi-Intensity Frontier

Ultra-precision measurements may provide a hint for New Physics!

→Hi-Luminosity lepton colliders, Hi-Intensity Proton Drivers

Now a member of RaDIATE September, 2017



Collaborators gathered for MoU signing and Workshop

Collaboration with Academia & Industry

Domestic University

New Graduate Course Established to include J-PARC science

Oversea Institutions

Collaboration with ANSTO

For improving user environment, sample environment, e.g. deuterization lab, and exchange program for researchers.

Collaboration with TRIUMF

Experimental Collaboration and exchange program of researchers; share the know-how on facility and safety management

Collaboration with ESS

Contribute to the newly constructed major facility based on the experience of J-PARC construction.

Osaka U@J-PARC

Kyoto U@J-PARC

Kyushu U@J-PARC

University branches at J-PARC

Education and training of students and young researchers at the very front of J-PARC operation, especially to raise the next generation who can create a future cutting edge facilities

Industrial Sector

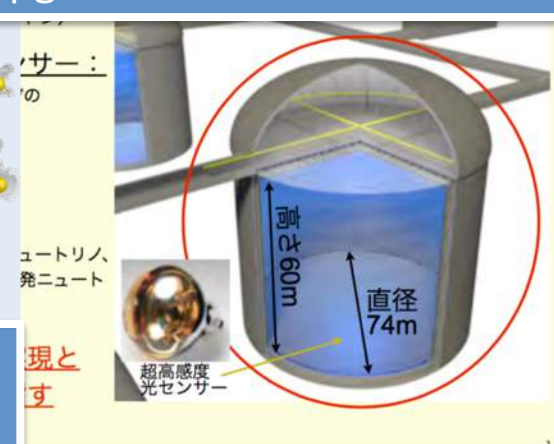
J-PARC/Sumitomo rubber Inc. Fellowship is been enlarged

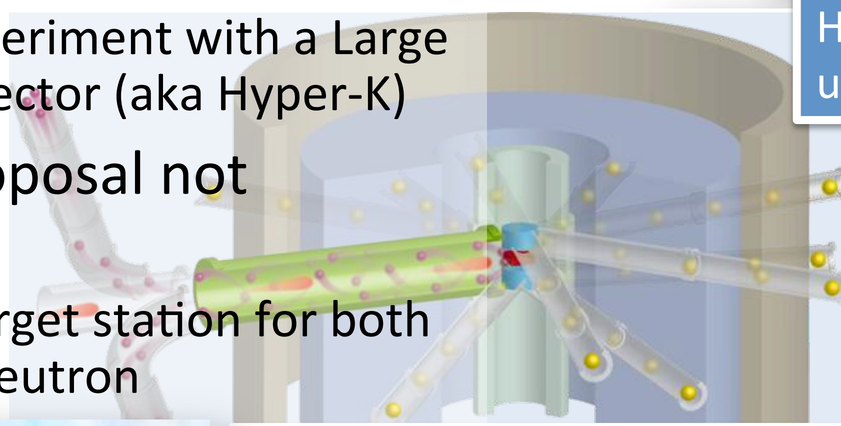
Japan Science Council Master Plan 2017

- JSC selected 28 important projects from 166 proposals
- Two J-PARC related proposals are selected as important projects:
  - Elucidation of the origin of matter with an upgrade of the J-PARC experimental facility
  - Nucleon Decay and Neutrino Oscillation Experiment with a Large Advanced Detector (aka Hyper-K)
- One J-PARC proposal not selected
  - MLF the 2nd target station for both neutron and neutron

g-2/EDM

Hyper-K and relevant J-PARC upgrade





MLF the 2nd target station for neutron x 10+muon x 50

Science Council of Japan

APS TV for J-PARC Particle & Nuclear Physics

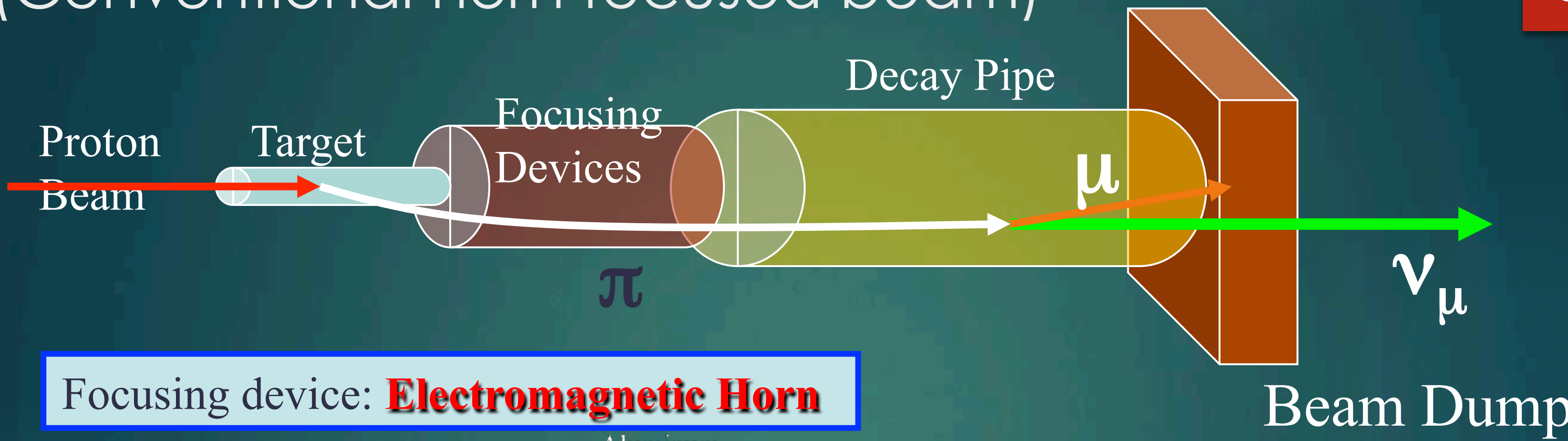
Summary

- J-PARC is a multi-purpose facility based on high-intensity proton driver.
- High power frontier is further explored
  - MLF reached 500 kW ops; 1 MW test successfully done.
  - MR-FX reached 485 kW! SX is pushed to 51 kW.
  - Targetry activities will be strengthened further (cf. RaDIATE)
- Whole purpose of J-PARC is to produce exciting scientific results with world-wide users: both academia and industries. We invite YOUNG SCIENTISTS to work with us for more excitements to share world-wide!

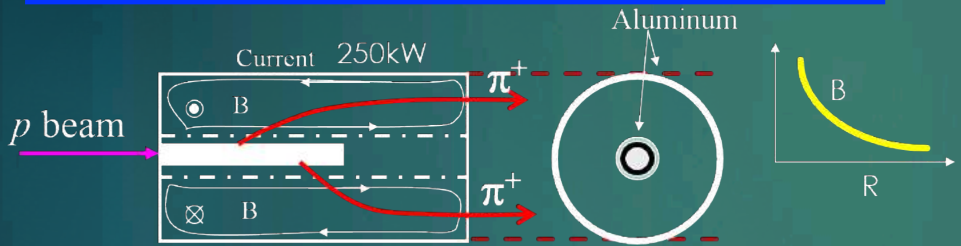
Including Young at Heart!

J-PARC

How to make ν_μ beam
(Conventional horn focused beam)



Focusing device: **Electromagnetic Horn**



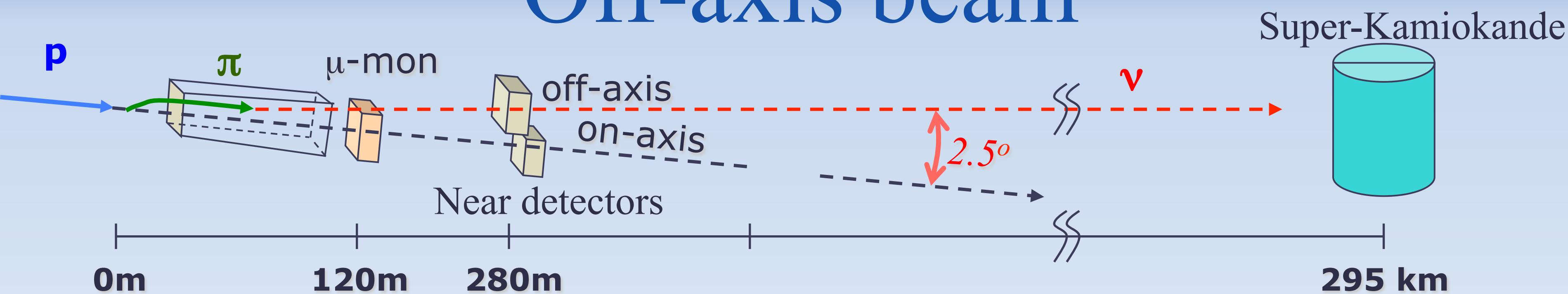
- Pure ν_μ beam (≳99%)
- ν_μ / ν_μ can be switched by flipping polarity of Horns

For high sensitivity/precise experiment

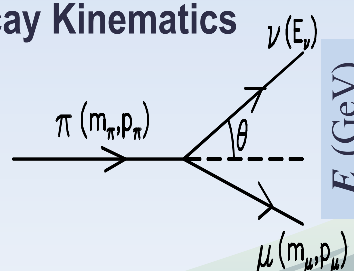
→ More neutrinos

→ Higher proton beam power
x machine operation time
x running efficiency

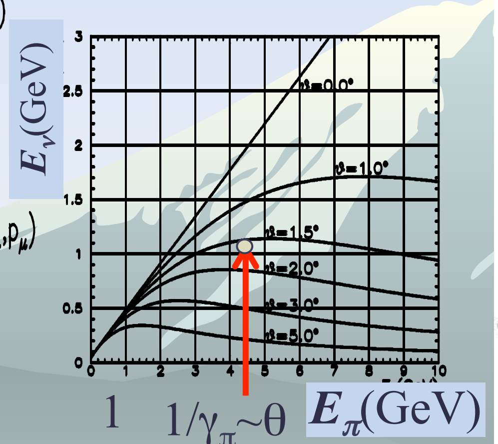
Off-axis beam



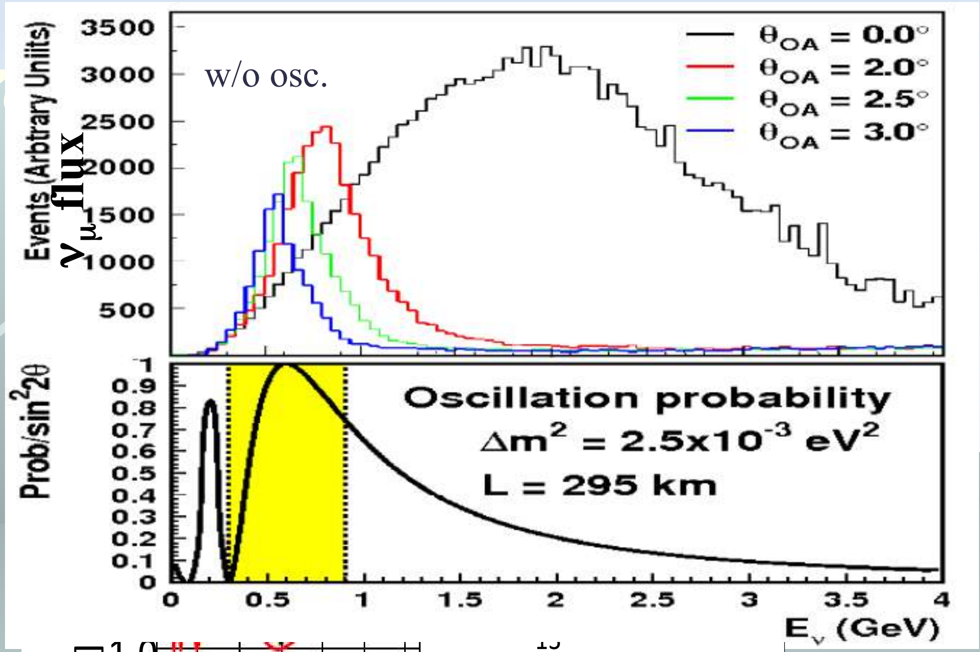
Decay Kinematics

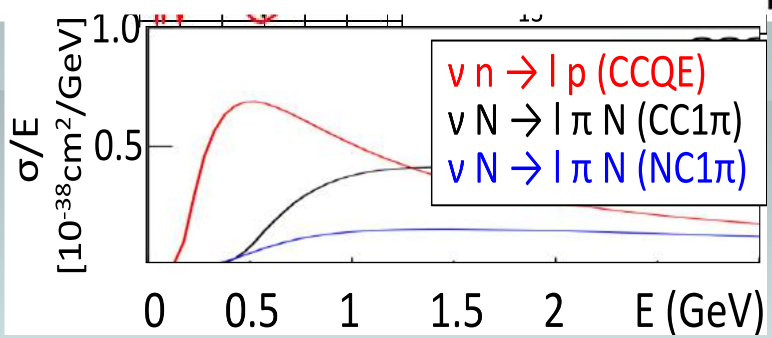


$$E_\nu = \frac{m_\pi^2 - m_\mu^2}{2(E_\pi - p_\pi \cos\theta)}$$



$$E_\nu^{\max}[\mathrm{GeV}] \approx \frac{30}{\theta[\mathrm{mrad}]}$$



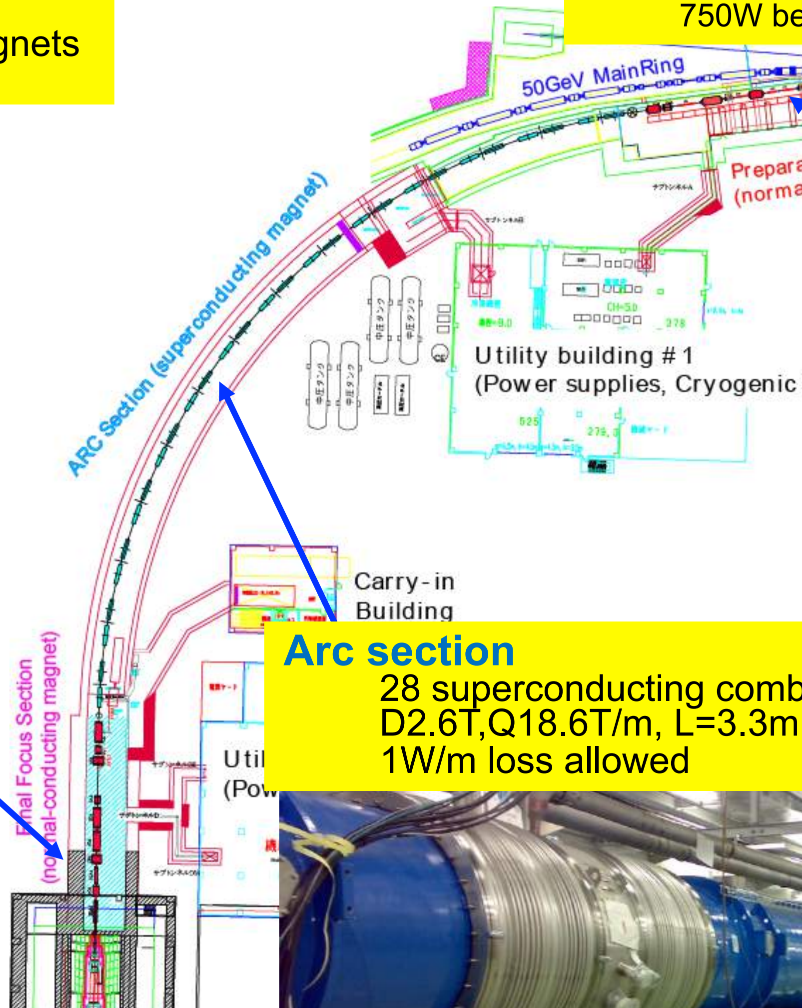


- **High intensity/narrow band/ tunable LE beam**
- **First application for T2K**

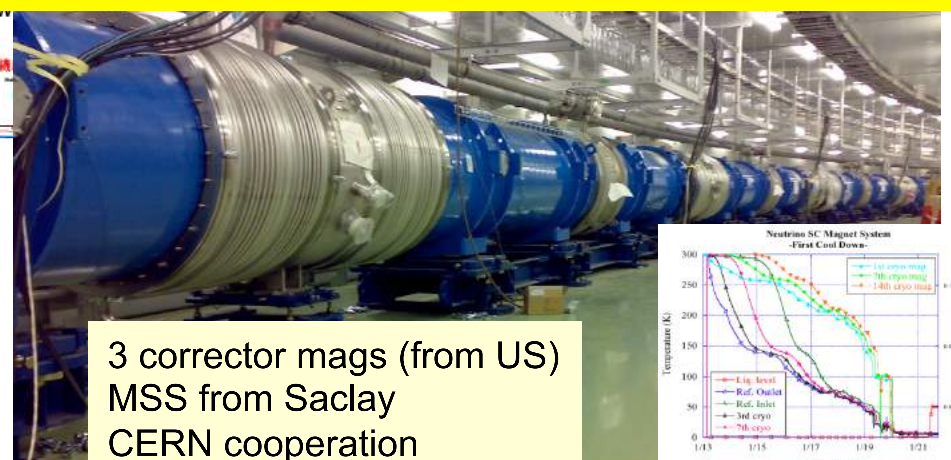
Primary beamline

Final focusing (FF) section
10 normal conducting magnets
250W loss shield

Preparation section
11 normal conducting magnets
750W beam loss shield



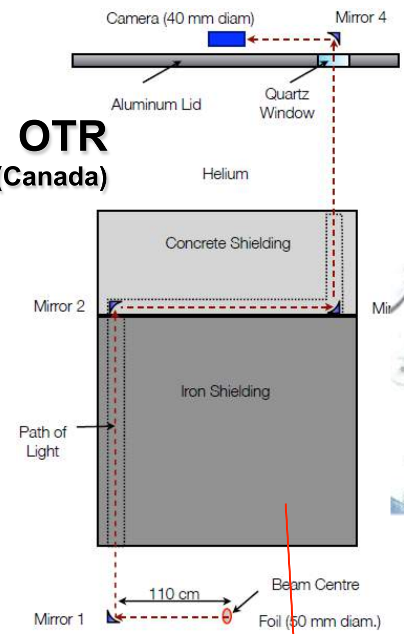
Arc section
28 superconducting combined function magnets
D2.6T,Q18.6T/m, L=3.3m
1W/m loss allowed



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

Beam Monitors

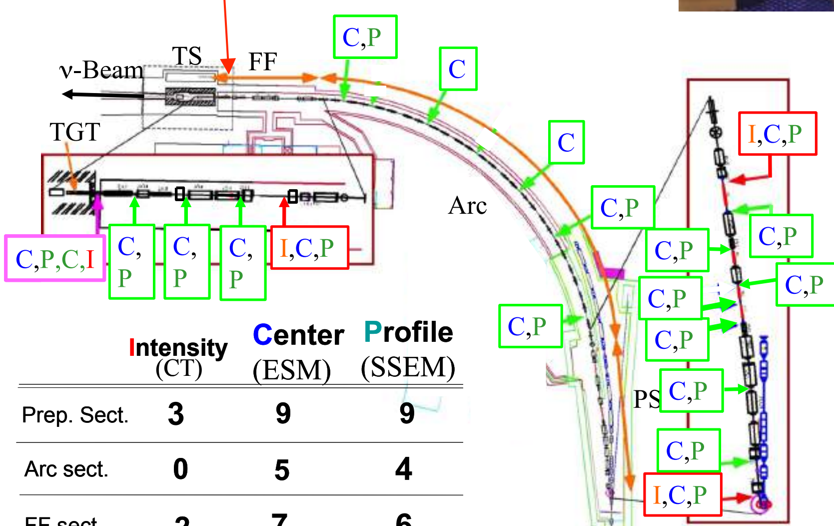
OTR
(Canada)



ESM

CT

- Position:
  - 21 x Electrostatic monitors
- Profile
  - 19 x Segmented Secondary Emission monitors
- Intensity
  - 5x Current Transformers
- Loss
  - 50 x proportional counters
- Targetting
  - Optical Transition Radiation detector (Canada)
- Elec.: from US/Korea/Jp
- Beam timing: GPS (US)



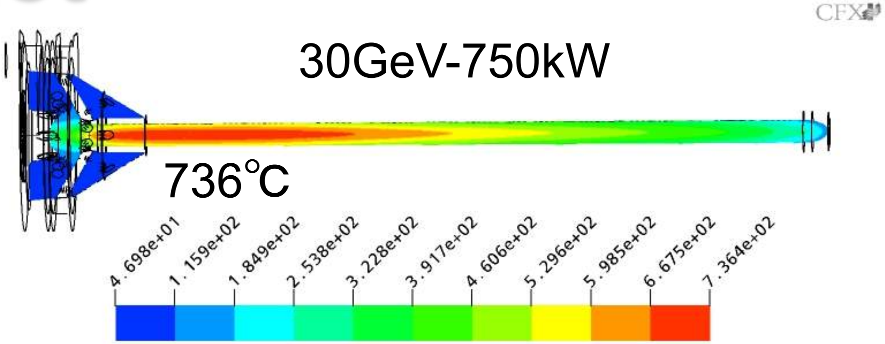
	Intensity (CT)	Center (ESM)	Profile (SSEM)
Prep. Sect.	3	9	9
Arc sect.	0	5	4
FF sect.	2	7	6

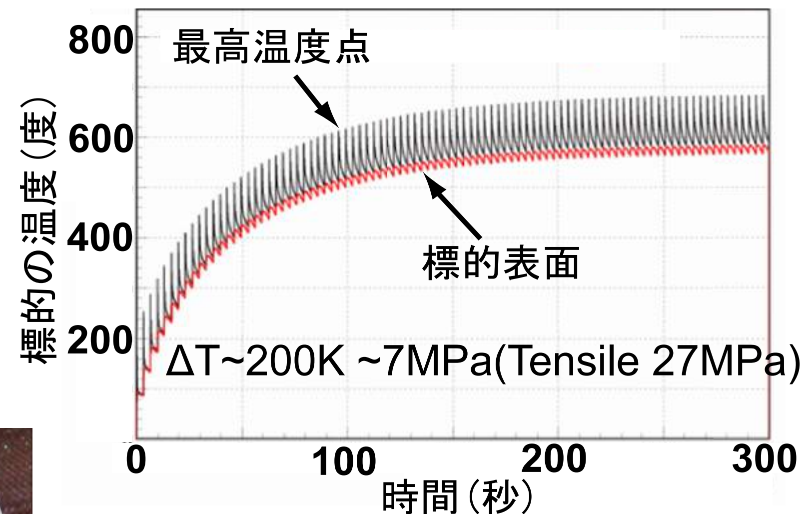
Beam loss monitor will be placed along the beam line.

SSEM $5\mu m^t$ Ti foil strips

Target

- Isotropic Graphite (IG-430) 1.8g/cm3
- 26mm(D)x900mm(L)
  - 1.9 int len. (70% int.),
- Heat load: 58kJ/spill (~20kW)
- Thermal shock stress (ΔT~200K) ~ 7MPa (< tensile strength 37MPa)
- Forced flow Helium gas cooling in Ti-alloy(Ti-6 A1-4V) container
  - Higher temp = less rad. damage
  - O2 < 100ppm to avoid Oxidization (burn!) → to keep S.F.>2 for 5 yrs
- Remote maintenance
- Design done by KEK/RAL





Electromagnetic horns

- 3 horn system
- 320kA design (now 250kW)
  - 0.7ms for 1st horn
  - 2ms for 2nd/3rd (series)
- Max field: 2.1T
- Al alloy (A6061-T6)
- Heat load ~11kW@1st horn (beam +Joule)
- Water cooled.
- Design max thermal stress: 25MPa (Lorentz+Thermal) (cf. tensile stren. 282MPa)
- Fully remote maintenance

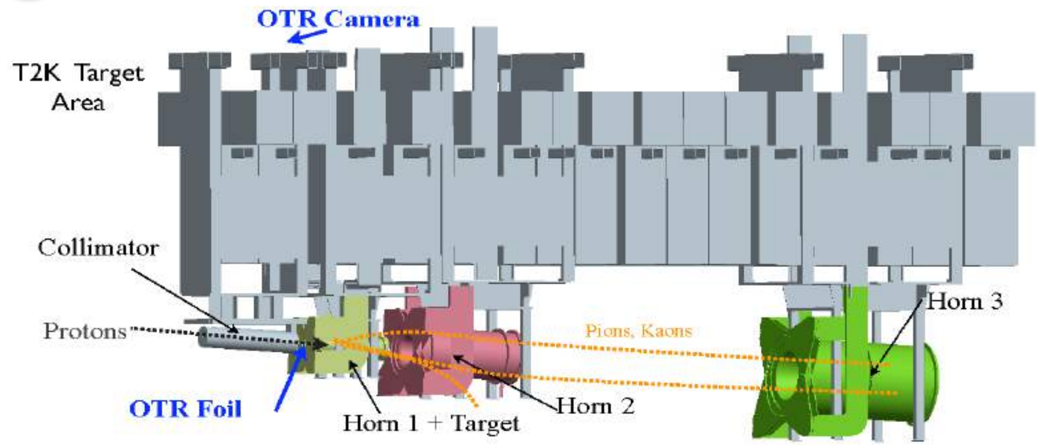
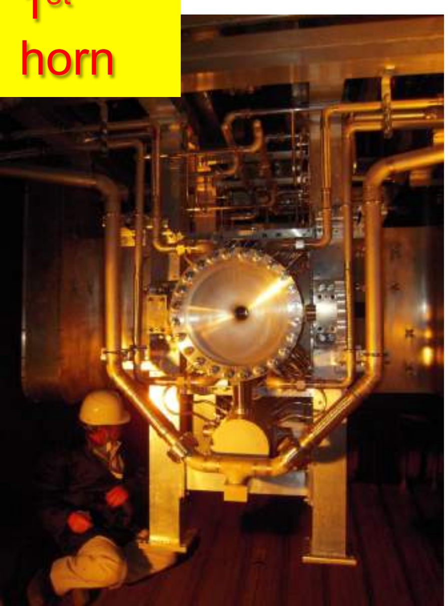


Table 3.8: Heat Load to the horns in unit of kJ/pulse.

	radiaion		Joel's heat	total
	inner-conductor	outer-conductor		
1st horn	23.6	15.6	3.3	42.5(11kW)
2nd horn	6.7	12.3	3.8	22.8(6.3kW)
3rd horn	2.0	4.0	2.5	8.5(2.4kW)

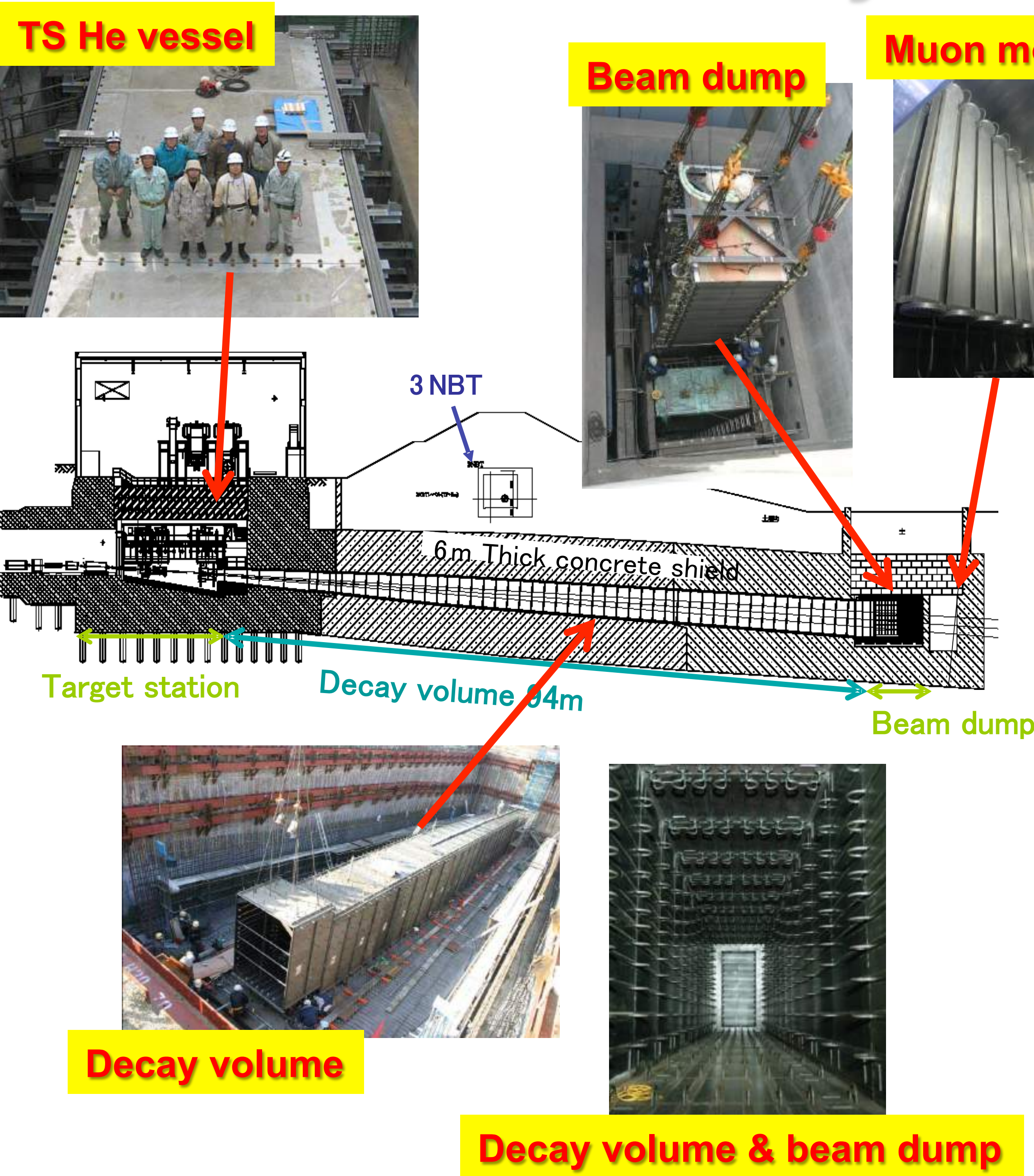
1st horn



2nd horn (US)

3rd horn

Secondary beamline



- Heat load (@750kW)
  - TS ~300kW
  - DV ~150kW
  - BD ~240kW
- Whole volume filled w/ He gas (~1000m^3)
  - Reduce NOx & ^{3}H
  - Reduce pion abs.
- All inner surfaces water cooled
  - Concrete upto ~100deg
  - Periodically waste with dilution (obey law)
- Beam dump
  - Graphite blocks
  - Water-pipe casted Al block attached to both side
  - Upto 3MW beam
- Muon monitor
  - 5GeV thresh.
  - Ionization chamber & Si
  - 7x7 grid each
  - Monitor dir/int spill-by-spill
  - Emulsion

Neutrino Beam Upgrade Status

Tetsuro Sekiguchi
KEK, IPNS/J-PARC Center
on behalf of
J-PARC Neutrino Beamline Group

2018.9.13

7th Hyper-Kamiokande proto-collaboration meeting

Contents

J-PARC Neutrino Facility

Primary Beamline

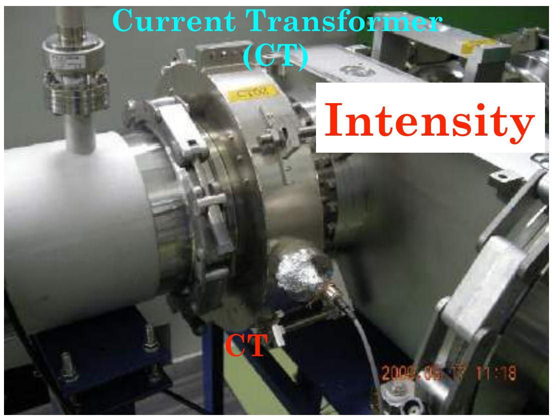
Arc section
(SC magnet)

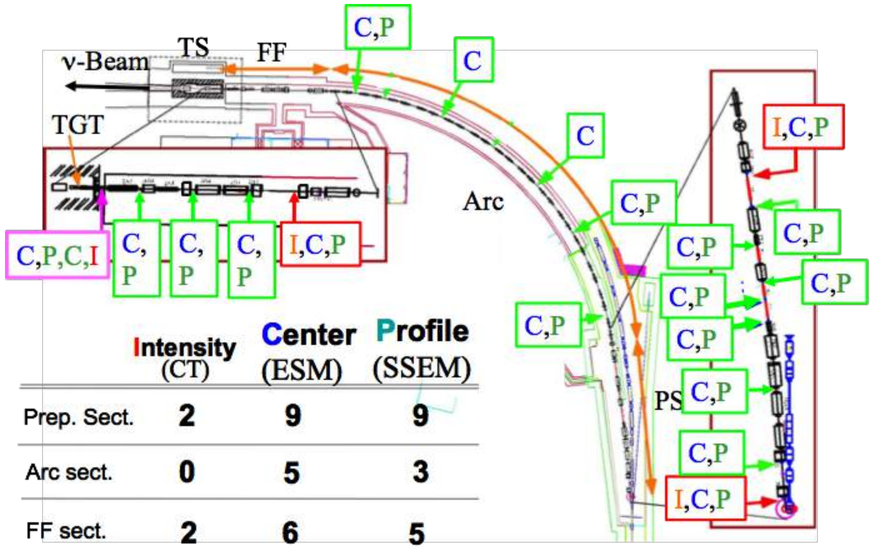
Final focus section
(NC magnet)

Preparation section
(NC magnet)

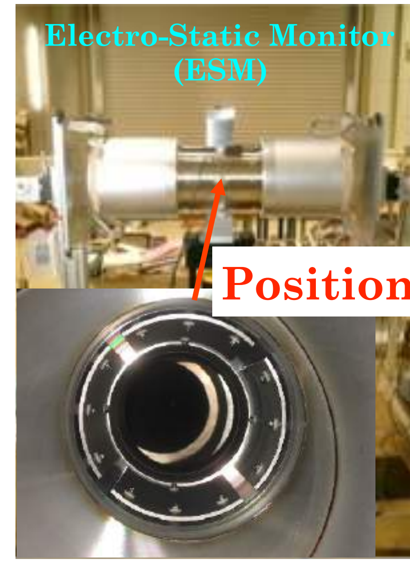
Beam Monitors

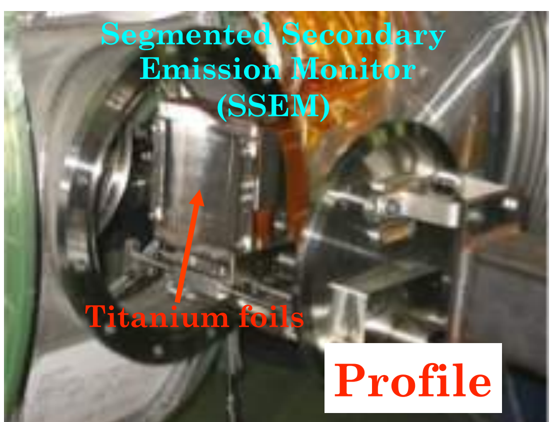
- Proton beam measurements and control
  - Precise beam control is crucial for high intensity beam

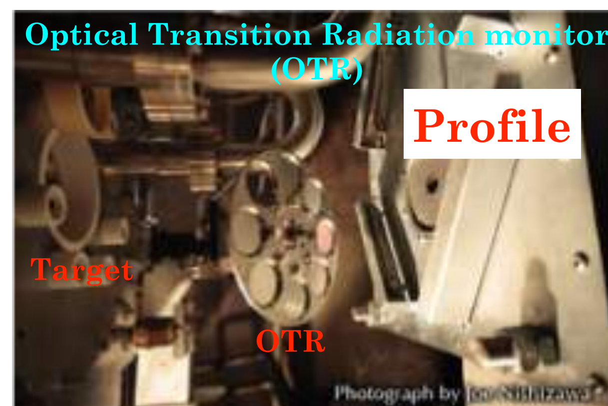




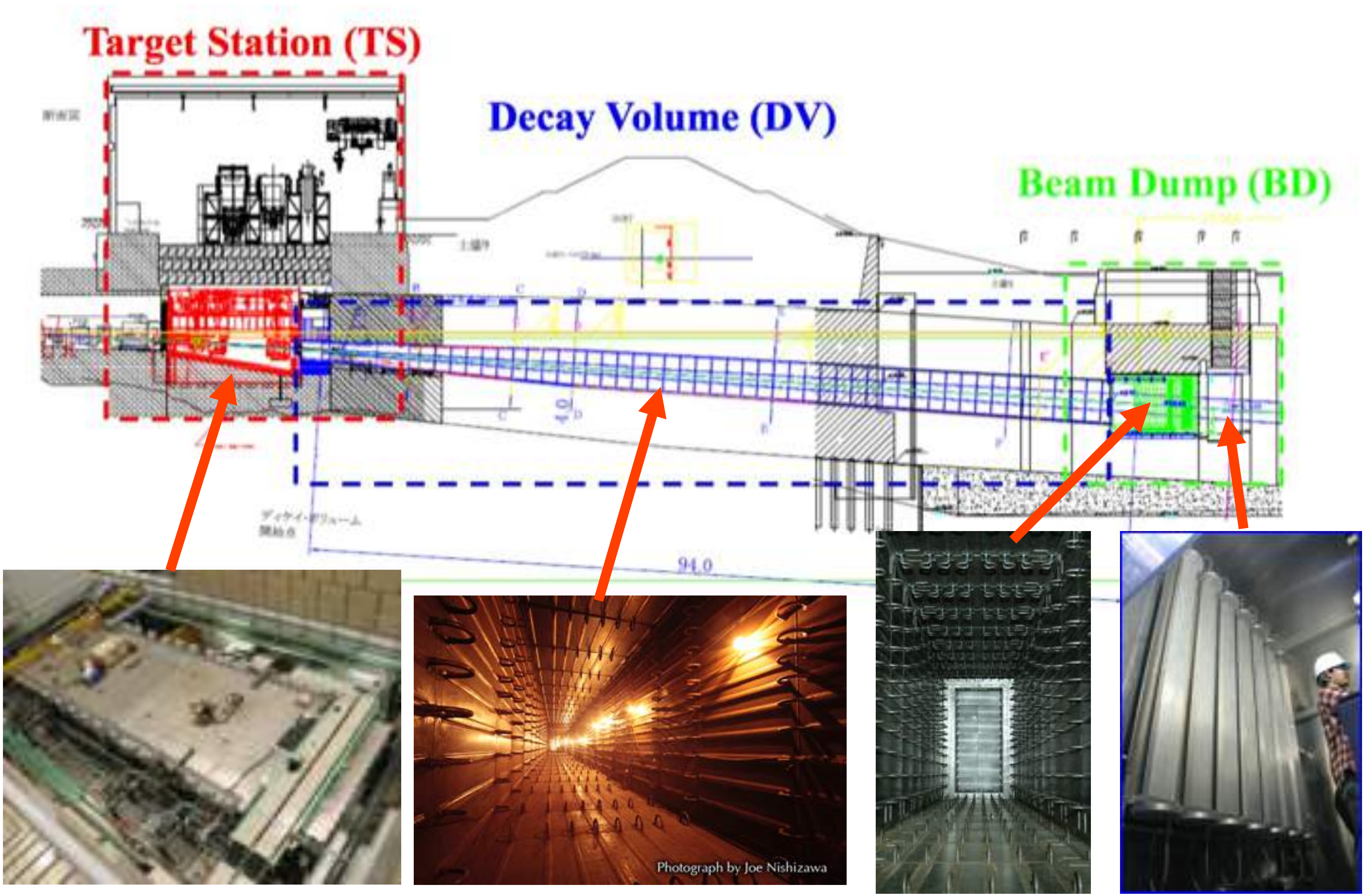
	Intensity (CT)	Center (ESM)	Profile (SSEM)
Prep. Sect.	2	9	9
Arc sect.	0	5	3
FF sect.	2	6	5







Secondary Beamline



Target Station

All equipments inside Helium Vessel can be replaceable

Horn1

Target

Contents

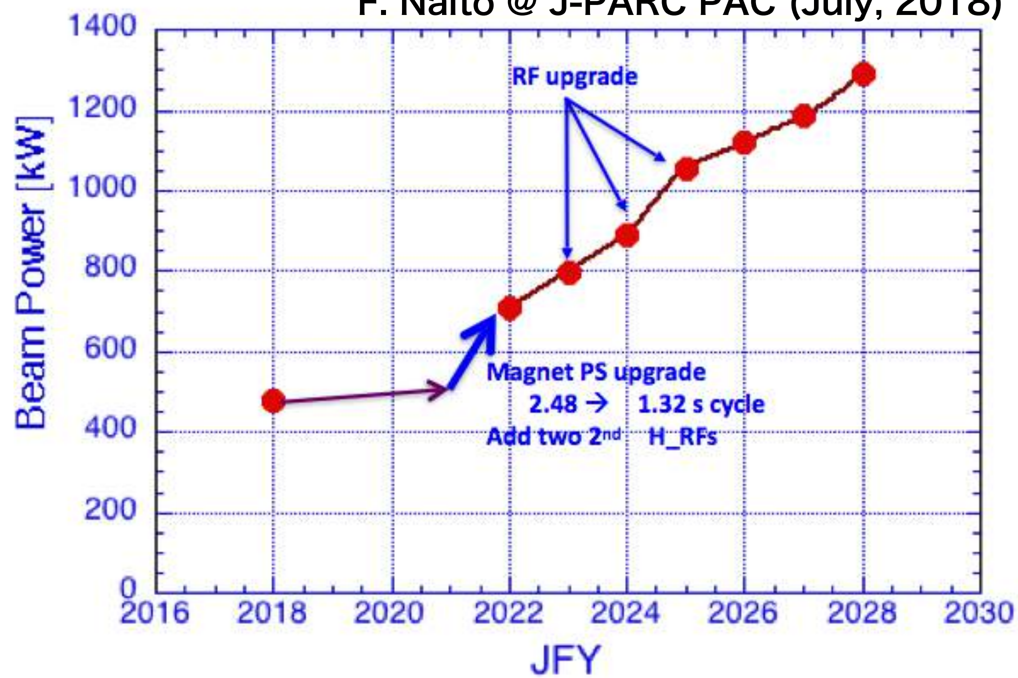
MR Beam Power Upgrade Plan

	2.5 x 10^{14}	2.0×10^{14} [3.3×10^{14}] +26%	2.7×10^{14} [2.6×10^{14}]	+19% 3.2×10^{14}
	2.48 s	1.32 s [2.1 s]	1shot [50shots]	1.16 s

Method

- Increase repetition rate
  - 2.48s → 1.3s → 1.16s
  - MR magnet PS upgrade
- Increase beam intensity
  - $2.5\times10^{14} \rightarrow 3.2\times10^{14}$ ppp
  - MR RF system upgrade

F. Naito @ J-PARC PAC (July, 2018)



Neutrino Beamline Upgrade

Necessary upgrade toward >1.3MW

- **Primary beamline**
  - **Beam monitor upgrade**
  - Remote maintenance in FF section
  - Larger aperture magnets and/or upgraded collimators may be needed
- **DAQ**
  - **DAQ/control system upgrade** for higher rep. rate and safety operation
- **Secondary beamline**
  - **Target/beam window upgrade**
  - **Higher current** horn operation (250kA → **320kA**)
  - **Cooling capacity** upgrade
  - Upgrade for **radiation protection/treatment**
  - Radiation damage studies and develop more radiation-resistant beamline components (target/beam window, etc)

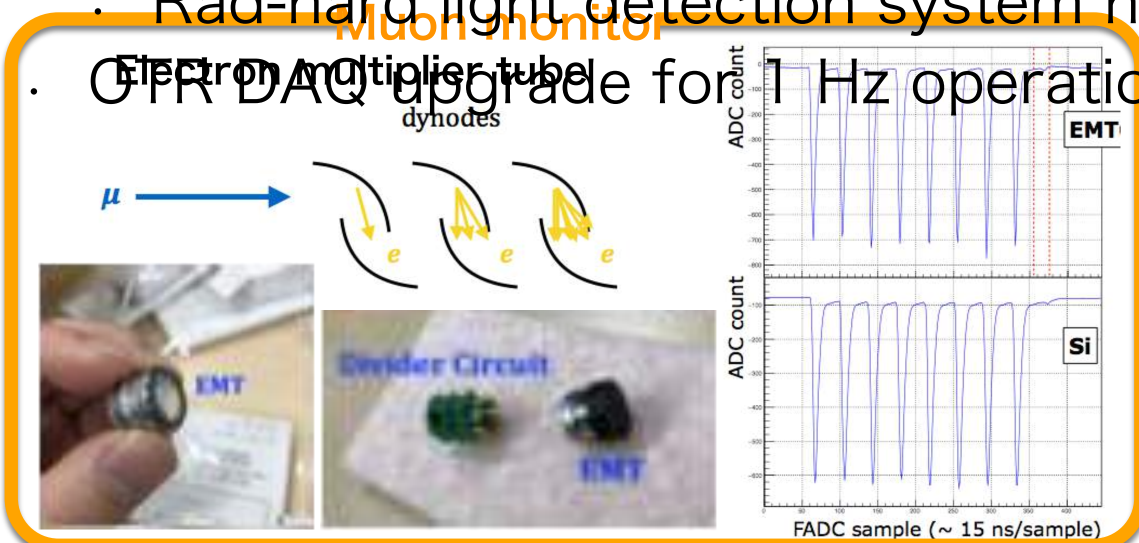
Beam Monitor Upgrade

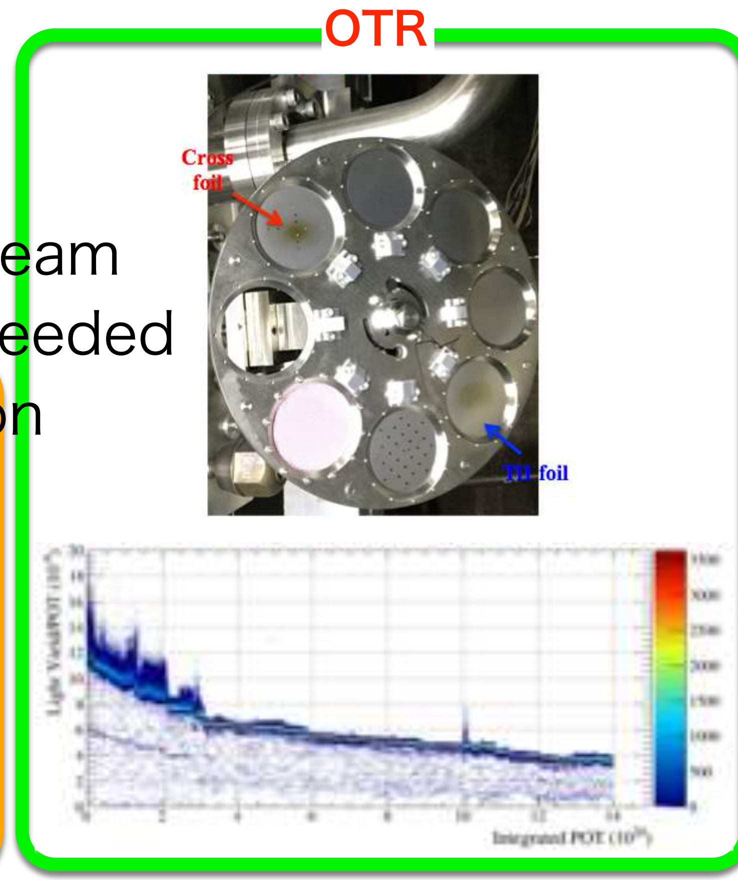
Muon monitor upgrade

- Si detectors and Ion Chambers ⇒ **Si degradation** at high beam power
- Developing new type of muon monitors (**electron multiplier tube**, EMT)

OTR upgrade

- Problem on rotation system
  - Develop more redundant system
- Issue on light yield degradation by beam
  - Rad-hard light detection system needed
- OTR DAQ upgrade for 1 Hz operation





Control/DAQ Upgrade for THz Operation

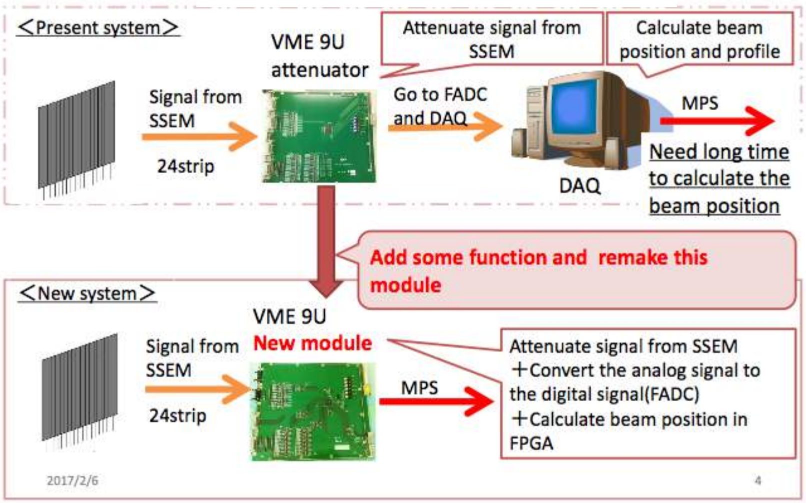
Upgrade strategy

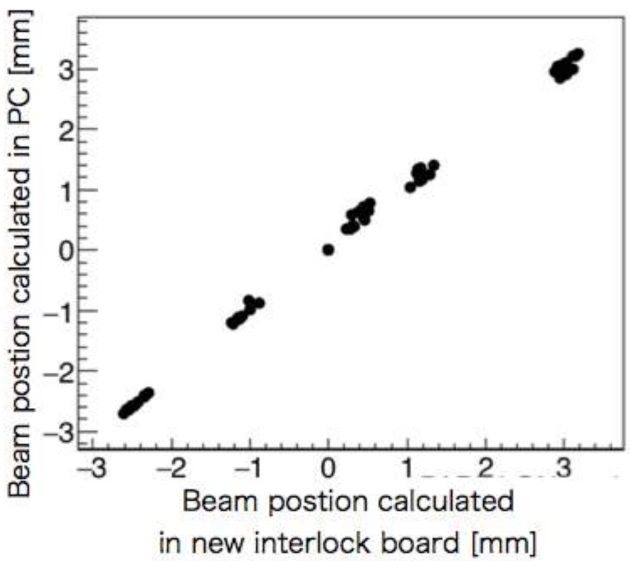
- DAQ upgrade for shorter cycle
- Reinforcement of interlock system safe operation

Status

- DAQ upgrade
  - Hardware (New FADC) and softv development
  - To be done in summer 2018
- New hardware interlock ⇒ New interlock module
  - Prototype boards showed good performance
    - Position measurement comparable to offline analysis
  - To be installed at SSEM19 for testing in summer 2018
- Improve latency for beamline magnet current interlock

New hardware interlock

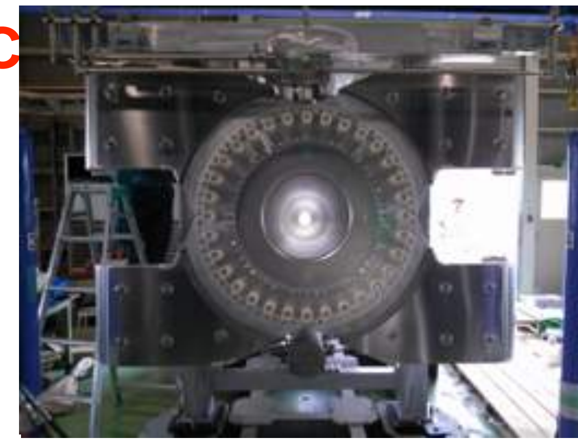


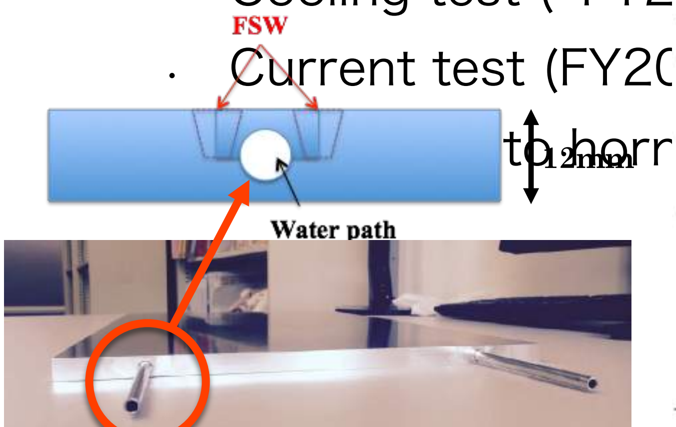


Horn System Upgrade

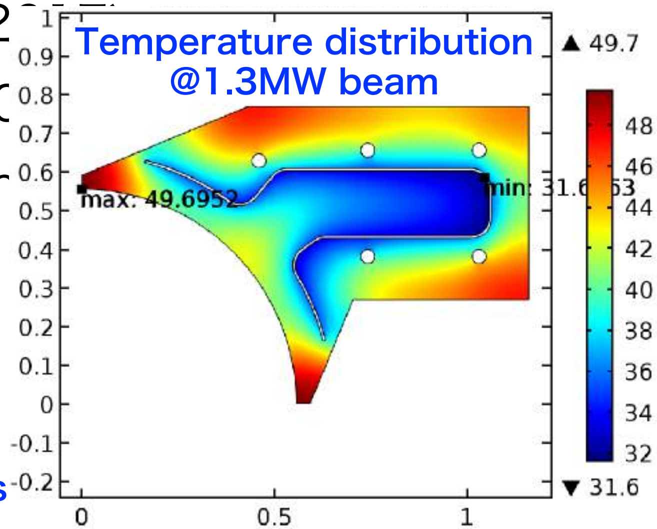
Stripline cooling improvement

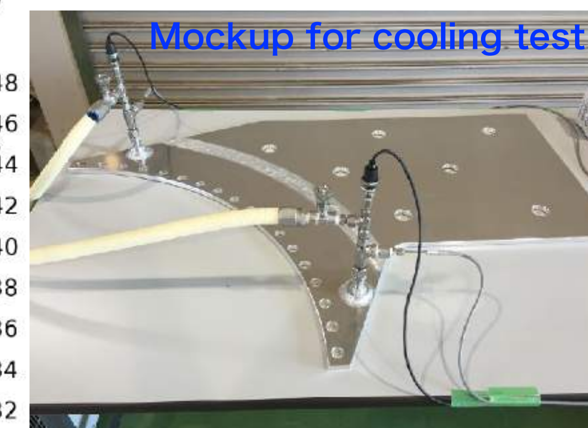
- Heat deposit by defocused pions ⇒ Cooling w/ forced He flow (**750kW**)
- Upgrade toward 1.3MW ⇒ **Water-c**
striplines
    - Water-tube embedded in Al plates using FSW
        - **Can be acceptable >3MW**
    - Schedule
        - Cooling test (~FY2
        - Current test (FY20
        - to horn





Test piece of water-cooled striplines





Mockup for cooling test

Other Improvement

Cooling for secondary beamline

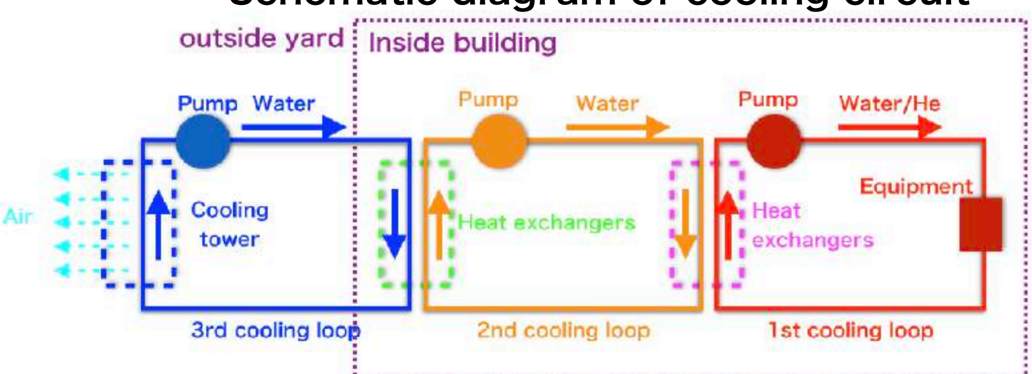
- Current cooling capacity = 1 MW
- Upgrade circulation pumps, heat exchangers and cooling towers/chillers
- Problem on clogging in water system for iron vessel ⇒ Need investigation

Radiation shielding

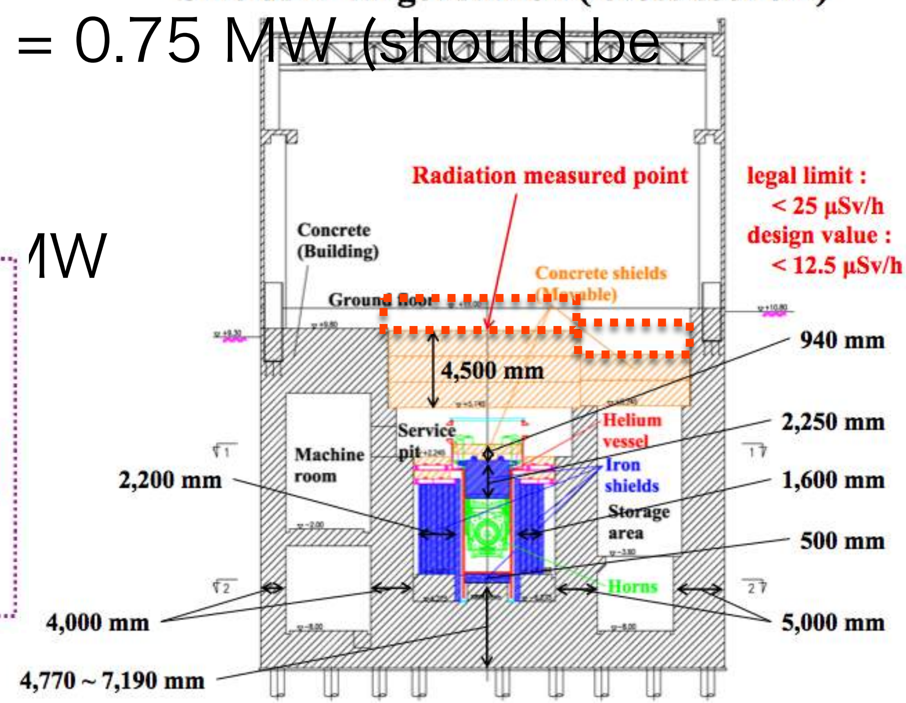
- Upper shields in Target Station = 0.75 MW (should be upgraded)
  - Additional one more layer needed

MW

Schematic diagram of cooling circuit



Shields in target station (cross section)



Maintenance Scenario

Remote maintenance for highly radio-activated equipment

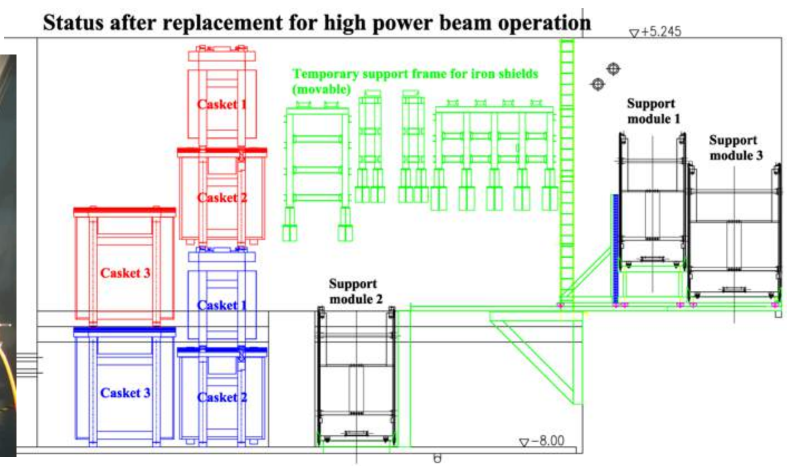
- Already established : Target, Beam window, Horn
- Need development : Beam monitors in TS and FF section

Long-term maintenance scenario (>10years) for HK era

- Target/horn replacement

Horn remote handling

Target remote handling



Beamline Upgrade Technical Review

Neutrino beamline upgrade technical advisory meeting

- Held on June 21-22, 2018
- Reviewers
  - K. Tanaka (chair, J-PARC), J. Hylen (FNAL), M. Calviani (CERN), N. Fukunishi (Riken), Y. Kasugai, M. Hagiwara, K. Haga (J-PARC), H. Noumi (RCNP/KEK)
- Beamline upgrade TDR submitte

- Many useful comments/suggestions
  - Very positive comments
  - Some additional simulations (radiation, thermal analysis) suggested
- TDR to be revised for submission at next J-PARC PAC

Further improvement for HK?

Baseline upgrade scenario for 1.3 MW determined

Further improvement of neutrino flux is really beneficial

- Target, magnetic horns can be replaceable
  - Any new design can be adopted.
  - For example,
    - Denser target material w/ hybrid structure can give ~10% flux gain
    - Longer target (~1.7m) can also give ~10% gain
      - In addition, horn shape optimization gives further gain
  - Target/horn design optimization is a good topic for collaboration
- Upgrades of other equipments
  - Primary beamline configuration change
  - Beam monitors (WSEM, Beam induced fluorescent monitor, etc)
  - Control/DAQ

Summary

Neutrino beamline upgrade toward 1.3 MW for Hyper-K

- **Accelerator upgrade**
  - Higher rep. rate (2.48 s → 1.3 s → **1.16 s**) : PS upgrade, RF upgrade
  - Higher intensity (2.4×10^{14} ppp → $\mathbf{3.2\times10^{14}}$ ppp) : RF upgrade
- **Beamline upgrades**
  - Beam monitor upgrade
  - Control/DAQ upgrade
  - Target and beam window upgrade
  - Horn current to 320kA and stripline cooling upgrade
  - Upgrade of radioactive water disposal
  - Higher cooling capacity
  - Radiation shielding upgrade
- **Neutrino beamline upgrade technical advisory meeting**
  - Many useful comments and TDR will be revised

Secondary beam line upgrade

Component	Limiting Factor	Current Acceptable Value	Upgraded Acceptable Value
Target	Thermal Shock	3.3×10^{14} ppp	3.3×10^{14} ppp
	Cooling Capacity	0.75 MW	>1.5 MW
Horn	Conductor Cooling	2 MW	2 MW
	Stripline Cooling	0.54 MW	>1.25 MW
	Hydrogen Production	1 MW	>1 MW
	Operation	2.48 s & 250 kA	1 s & 320 kA
He Vessel	Thermal Stress	4 MW	4 MW
	Cooling Capacity	0.75 MW	>1.5 MW
Decay Volume	Thermal Stress	4 MW	4 MW
	Cooling Capacity	0.75 MW	>1.5 MW
Beam Dump	Thermal Stress	3 MW	3 MW
	Cooling Capacity	0.75 MW	>1.5 MW
Radiation	Radioactive Air Disposal	1 MW	>1 MW
	Radioactive Water	0.5 MW	0.75→1.3 or 2 MW