J-PARC NU Radioactive Waste Treatment

Yuichi Oyama
(KEK/J-PARC)

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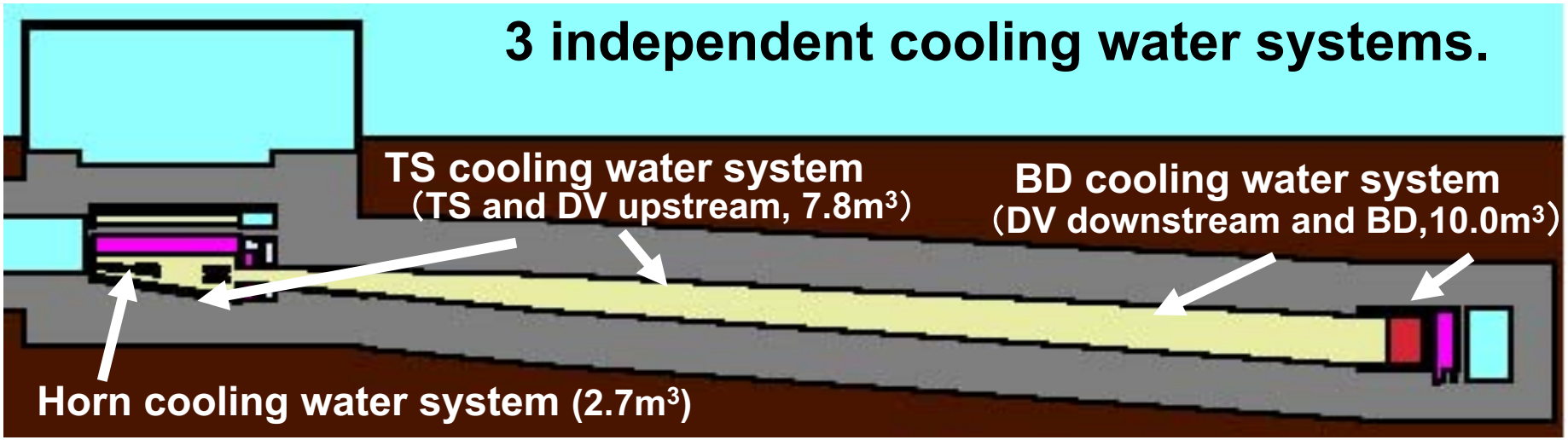
Overview

- In NBI2014, radioactive waste treatment in J-PARC neutrino facility was reported with a title "T2K water drainage and exhaust air". Treatment of ^{3}H, ^{7}Be and ^{22}Na in the radioactive water, and reduction of radiation in exhaust air were reported.
- Please visit following pages for details.
  https://indico.fnal.gov/conferenceOtherViews.py?view=standard&confId=8791
  http://www-nu.kek.jp/~oyama/nbi2014.oyama.ppt
- Fortunately, we do not have any additional difficulties in ^{7}Be and ^{22}Na in radioactive water, and radiation in exhausted air.
- In this talk, I would like to focus on the ^{3}H problem.
- Sorry but some of the contents overlap with the talk in NBI2014.

Cooling water systems in T2K neutrino beam line



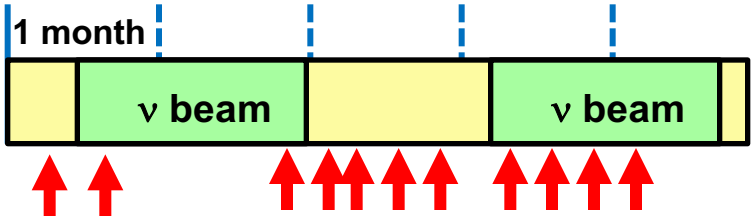
- Horn and TS cooling water are disposed from facilities in an upstream building (NU2), and BD cooling water are disposed from downstream NU3 building.
- Most of products from Oxygen decay within several ten minutes, or have extremely long life. Disposal scenario of only ^{3}H ($\tau_{1/2}$=12.3y) and ^{7}Be ($\tau_{1/2}$=53.3d) must be considered.
- Metal ions from beam-line components/pipes are resolved in water. ^{22}Na ($\tau_{1/2}$=2.6y) from Aluminum must be considered.

Regulations about radioactive water drainage

- When we dispose radioactive water, there are very strict constraints on both concentration and total radioactivity.

	concentration	Total disposal from neutrino
^{3}H	< 60 Bq/cc (< 42Bq/cc for safety)	< 120 GBq/year (< 800 GBq/year) < 5000 GBq/year in J-PARC
^{7}Be	< 30 Bq/cc	< 1.2 GBq/year < 3.6GBq/year in J-PARC
^{22}Na	< 0.3Bq/cc	< 0.06 GBq/year

Disposal Scenario of Radioactive Cooling Water in the Target Station



Target Station (off-limits)

NU2 building

Until ^{7}Be removed satisfactory a few days

3 days/cycle

clean water

Ion exchangers

Horn cooling water system (2.7m^3)

TS/DV cooling water system (7.8m^3)

clean water

Ion exchangers

B2 tank (~4m^3)

~80%

pH control system

H_2SO_4

NaOH

Buffer tank (19.5m^3)

pH<7

Ion exchangers

clean water

2 Dilution tanks (42m^{3}x 2)

drainage

Drain tank (20.5m^3)

drain water from air-conditioner etc

Disposal of radioactive water In FY2016

Total POT (Proton on Target) : 7.26×10^{20}

- ^{3}H from cooling water

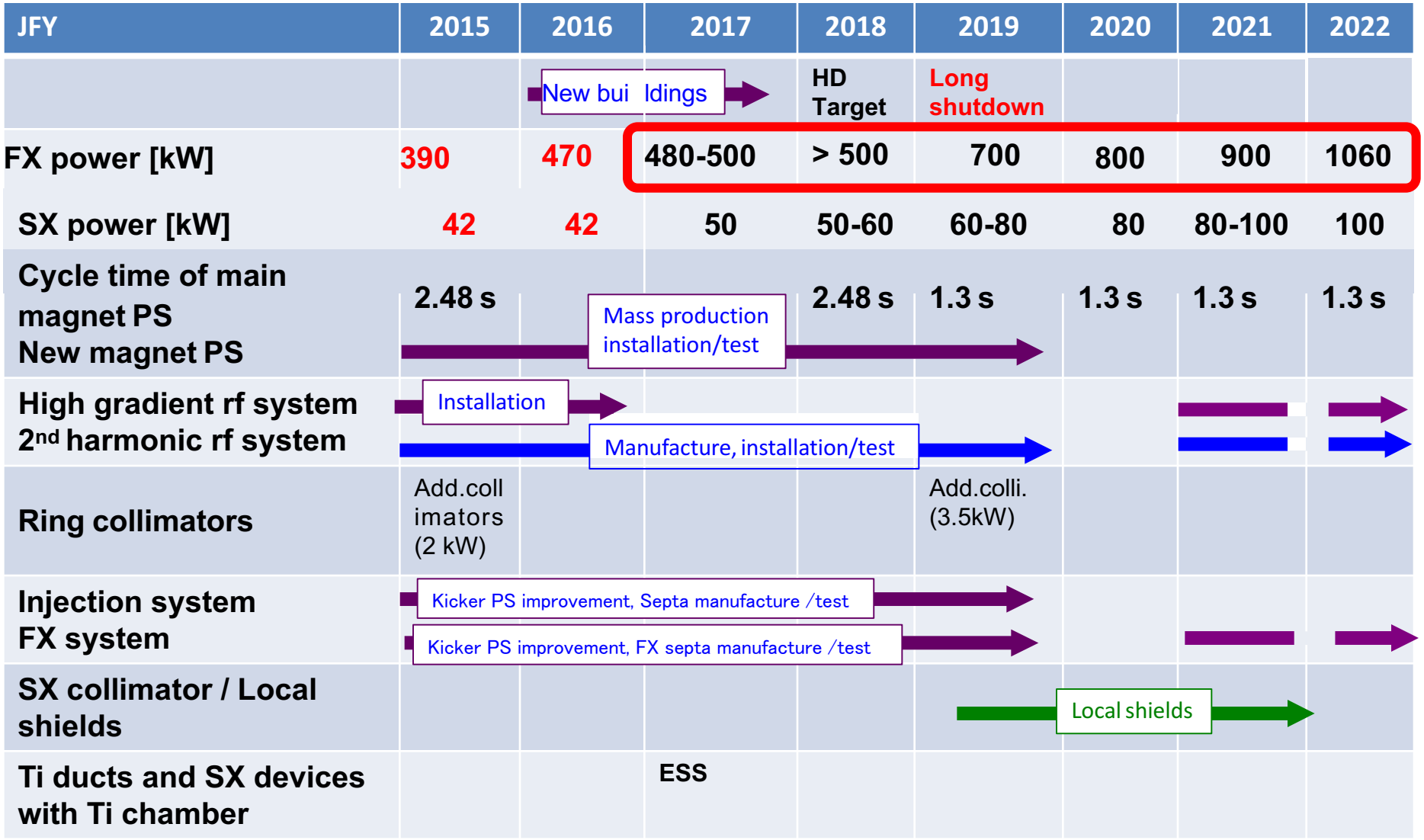
facility	^{3}H
Upstram total (NU2)	136.5GBq
Horn	62.3GBq
TS+upstream DV	74.2GBq
BD+downstream DV (NU3)	21.5GBq
Grand Total	158.0GBq

- Disposal

facility	Disposal	^{3}H in one disposal	
Upstream(NU2)	Drainage	$84m^3$ x 42Bq/cc = 3.5GBq	42
Downstream (NU3)	Drainage	$17m^3$ x 42Bq/cc = 0.7GBq	8
	Tank track	10GBq (maximum)	2

The disposal cycle is every 3 business days.
"50 times in a year" It is almost full.

Mid-term plan of MR (Revised in Jan. 2017)



MR Power supply upgrade delayed to 2019 or later due to funding situation

Future beam power and disposal of radioactive water

- Overburden for the disposal of the radioactive water is proportional not to beam power but to POT or (beam power x beam time).
- In October 2016 – April 2017 beam period, the maximum beam power was 470kW. However, the POT in this period was 7.26×10^{20} and it corresponds to ~360kW x 10^7 s equivalent.

The beam season is from fall to early summer.

- In the radiation management, drainage of radioactive water from NU2 is the most critical issue. From the experience in FY2016, the present capability of the NU2 water drainage is

~400kW x 10^7 s equivalent

- In 2017-2018, small upgrade of the beam power
  In 2018-2019, beam time will be short because of shutdown of SK
  In 2019-2020, beam time will be short because of shutdown of MR
  Upgrade of radioactive water drainage must be prepared for 2020-2021 beam.

Upgrade of radioactive water disposal

- Present system can dispose ^{3}H from ~400kW x 10^{7} s beam.
  In near future, we must dispose ^{3}H from ~1300 kW x 10^{7} s beam.
  Final goal will be ~2000 kW x 10^{7} s beam.

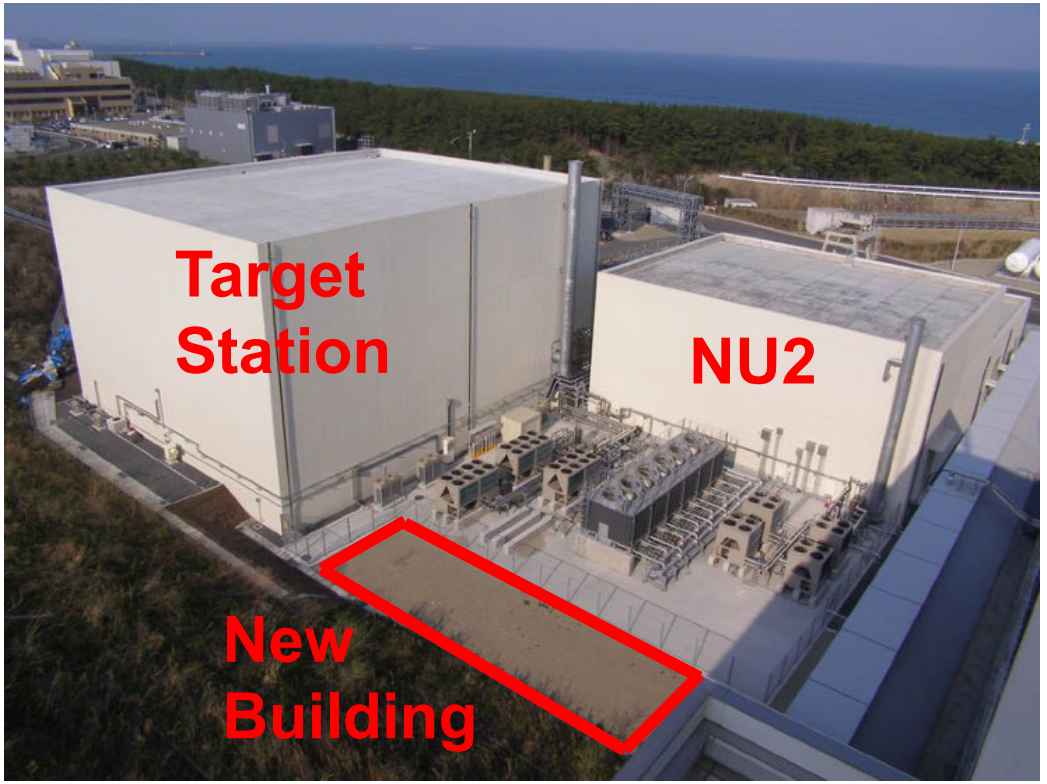
- Following upgrade are under consideration in parallel.

  1. Larger dilution/drainage tank
  2. Improvement of the frequency of drainage
  3. Tank track
  4. Shortcut in cooling water circuit

- At least, some of them must be ready by 2020 summer.
  We hope that the upgrades are completed, and we can enjoy Tokyo Olympic without worry….

(1)Larger dilution/drainage tanks

- The inside volume of present tank is 100m^3, and the effective volume is 84m^3.
- We request a new dilution/drainage tank in a new building.
  We need at least 300m^3 tank.
- However, it is quite expensive.
  The total cost is order of oku-yen (~M US$).
- We will continue the budget request, but
  we cannot be optimistic.



(2)Improvement of the frequency of drainage

- A strong constraint about the drainage work is that it should be done during daytime of business days. Officers in the local government occasionally monitor the drainage.

- We should change the drainage cycle from every three business days to every other business day, and finally every business day.
  1)Manpower is required (costs for the manpower is not linear)
  2)For radiation measurement, instruments and operators only for drainage work would be necessary. In the case of daily drainage, measurements of radioactivity must be done during night.

- The limit will be extended to
  ~600kW x 10^7 s/year for 1 drainage/2 business days
  ~1200kW x 10^7 s/year for 1 drainage/every business day

- Another manpower is needed.

I hope to resign the overseer!

(3)Tank Truck

- The back-end section of JAEA provides a service to take over radioactive water by a tank truck.
- The takeover by the tank truck in NU3 started, successfully.

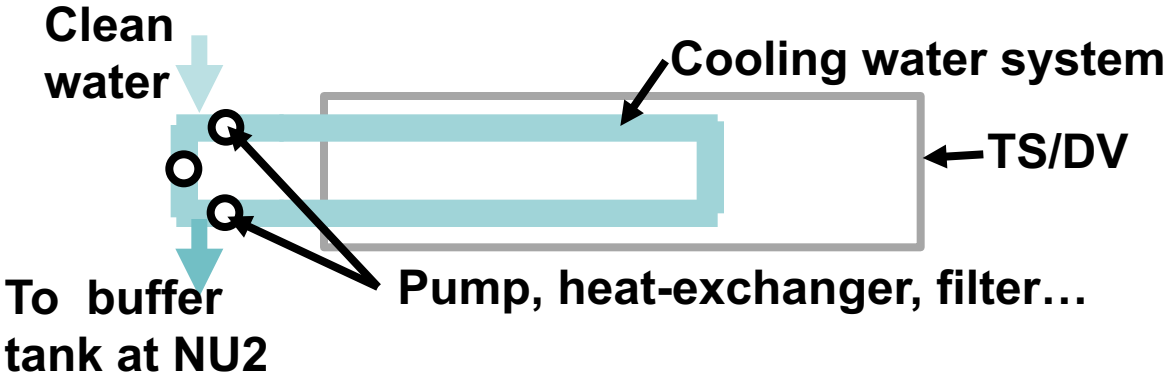
(photo in NU3)

- This can be also done in NU2 after a change of the water circuit.
- If present agreement between neutrino group and JAEA is considered, radioactive water corresponding to
  3×10^{20} pot/year (~150kW x 10^7 s/year)
  can be disposed by the tank truck.
- We would like to negotiate the frequency after the regular takeover become stable.

Maintenance of cooling water system in summer shutdown

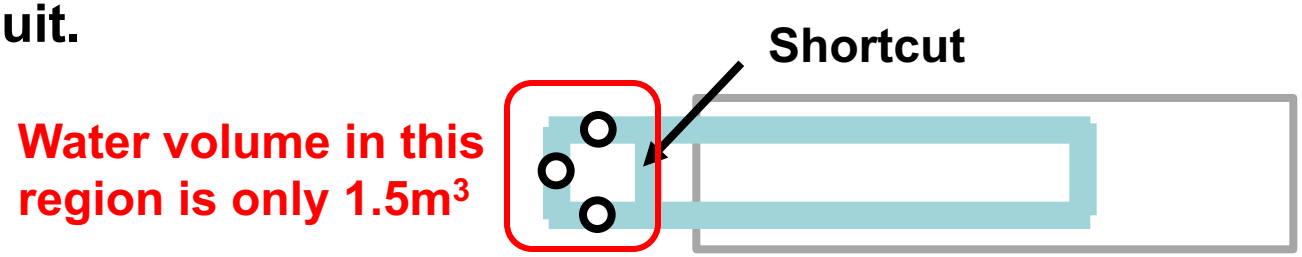
- During the summer shutdown, maintenance works for the cooling water components (pumps, heat-exchangers, filters….) are needed. For the safety reason, radioactivity of the water must be reduced. After the long beam period, the ^{3}H concentration is thousands Bq/cc, and it must be reduced to be less than ~60Bq/cc.

- Total volume of TS/DV cooling water system is 7.8m^3. After 7.8m^3 of replacement dilution, the concentration become 1/e. Even after the NU2 buffer tank become full, the concentration become ~1/10. Since additional space for dilution is needed, radioactive water in buffer tank must be disposed first. The maintenance works cannot be started.



(4)Shortcut in cooling water circuit

- In summer 2018, we will construct a shortcut in the cooling water circuit.



- We can start the maintenance work after the replacement dilution of only 1.5m^3. With the capacity of buffer tank in NU2, we can reduce the ^{3}H concentration with more than 5 orders of magnitude.

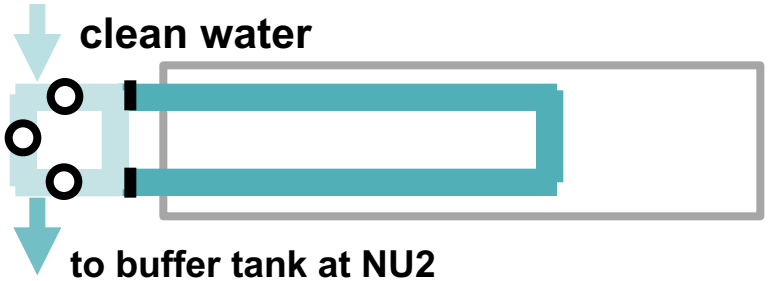
- In 2017, the summer shutdown started on April 12, but the maintenance became possible on September 6. The maintenance period was very short. After the construction of the shortcut, we can keep longer maintenance period.

The maintenance scenario

When the beam period is finished in early summer, ^{3}H concentration is high.

darkness of the water shows concentration of ^{3}H

Open the short cut and close the full water circuit.



Partial replacement dilution by clean water. The maintenance become possible very soon after the beam stop.

After the maintenance, close the short cut and open the full water circuit.

Replacement dilution again just before the new beam season. Dilution/drainage from NU2 can be done after the beam start.

Total ^{3}H problem

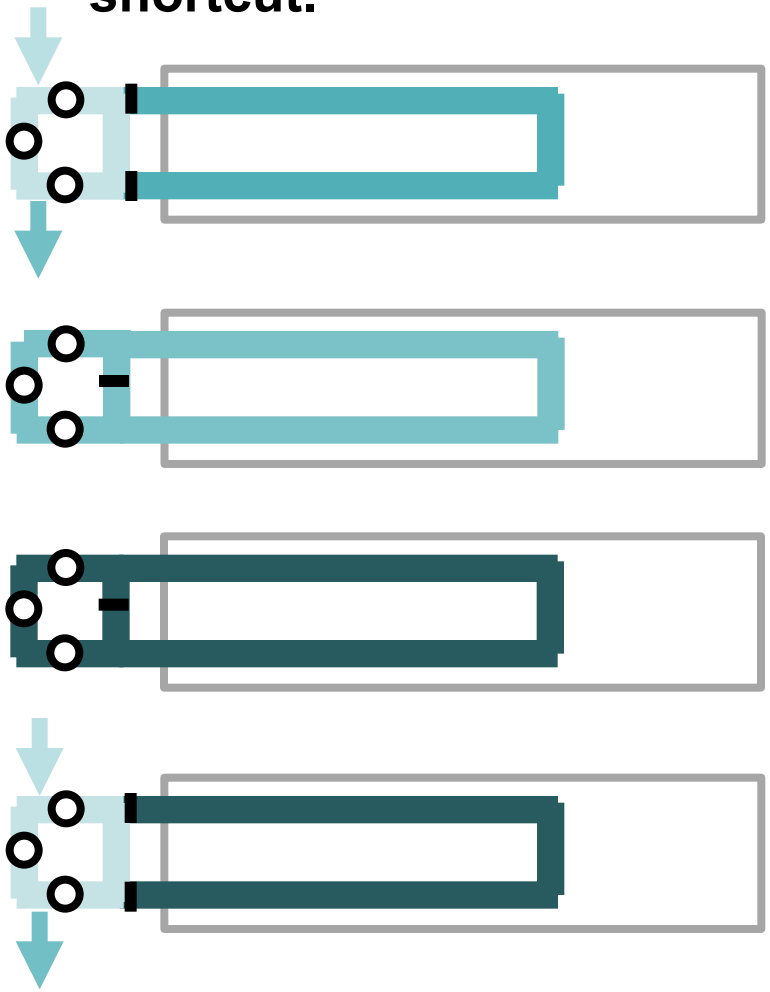
- The beam in FY2016 was ~360kW x 10^7 s equivalent.
  The total ^{3}H from the neutrino facility in FY2016 was 158 GBq.
- From regulations, the disposal limit on ^{3}H is 5000 GBq/year from J-PARC. Since J-PARC consists of 6 facilities (Linac, RCS, MR, MLF, Hadron, neutrino), the quota for the neutrino facility is 800 GBq/year.
- If the results in FY2016 is scaled, ^{3}H from ~1700 kW x 10^7s equivalent beam can be disposed within the 800GBq/year limit.
  If we can borrow additional quota from other facilities, the quota is enough even for ~2000kW x 10^7s equivalent beam.
  We thought that special care is not needed for the total ^{3}H …….
- However, the local government must agree with the drainage even if the ^{3}H is less than the quota.
- In addition, we have a historical condition.
  When J-PARC started in 2008, we reported to the local government that expected ^{3}H from neutrino facility was 120 GBq/year. This is unofficial and soft constraints.

Total ^{3}H problem

- When a drastic facility upgrade will be made in future, update of the document will be requested by the local government.
- The J-PARC head quarter suggested that we must make some efforts to reduce total ^{3}H in the drainage. At least “Total ^{3}H is in proportional the beam power” is not accepted.

“Confinement” of ^{3}H rich water

- We can reduce ^{3}H to outside of the cooling water system by using the shortcut.



After the partial dilution and maintenance works….

Close the shortcut, open the full water circuit, and wait for the beam restart.
Additional dilution is not done.

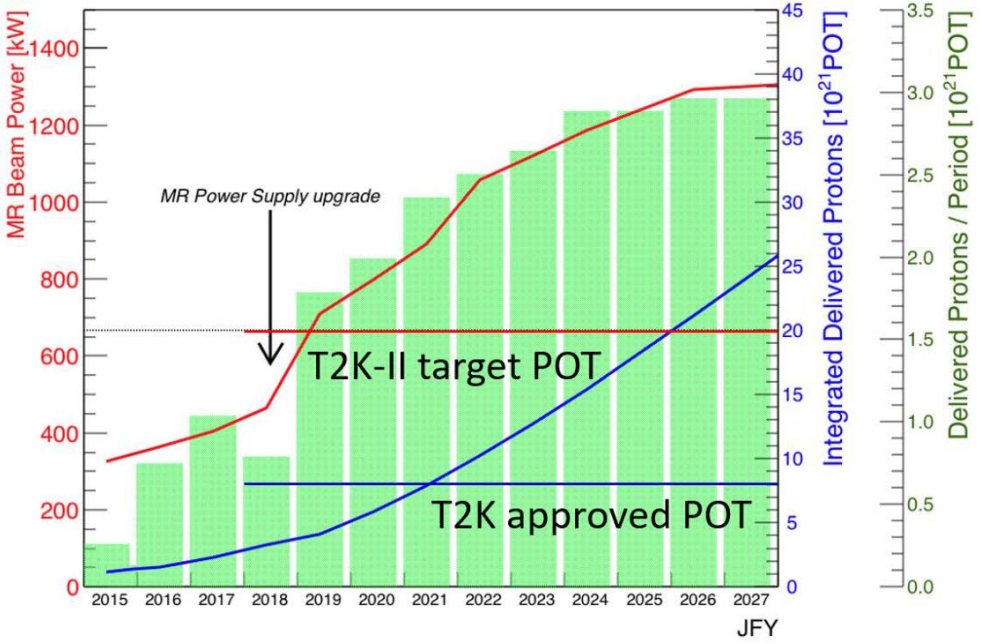
Concentration of ^{3}H become larger by larger every year……..

We will dilute only the shortcut region.

- The concentration become larger and larger, and finally, approach to (yearly ^{3}H production) = (yearly ^{3}H disposal) equilibrium.

We can reduce ^{3}H!

- Based on (relatively old) beam upgrade plan, drainage of the radioactive water using the confinement over 12 years is calculated.



- About 9% of ^{3}H decay in the water circulation system. Note that the half life of ^{3}H is 12.3 years. Certainly, we can claim that the disposal of ^{3}H is reduced by 9%.

- About 18% of them remains in the water circulation system after the 12 years beam operation. The ^{3}H concentration is larger than 100000Bq/cc. We will insist that 18% is also reduced (as MLF do). In total, we can reduce by 27%!

- In the first couple of years, number of drainages can be small. Construction of larger dilution/disposal tank can be delayed. However, it will be certainly needed in a longer time period.

Summary

- In the present radioactive water drainage cycle, the disposal capability corresponds to ~400kW x 10^7s equivalent beam per year.
- Although large manpower/cost/overburden are necessary, we can improve the drainage cycle to every business day.
  The limit can be extended to ~1200kW x 10^7s equivalent.
- Tank truck will help to reduce number of drainage. However, it is equivalent to only ~150kW x 10^7s beam.
- Shortcut of the water circuit will contribute to secure long maintenance period during the summer shutdown.
- Confinement of ^{3}H employing the shortcut water circuit will reduce the drainage of total ^{3}H from the neutrino facility by 27%.
- Although the ^{3}H confinement will also allows possible delay of construction, larger dilution/disposal tank is definitely needed.

End