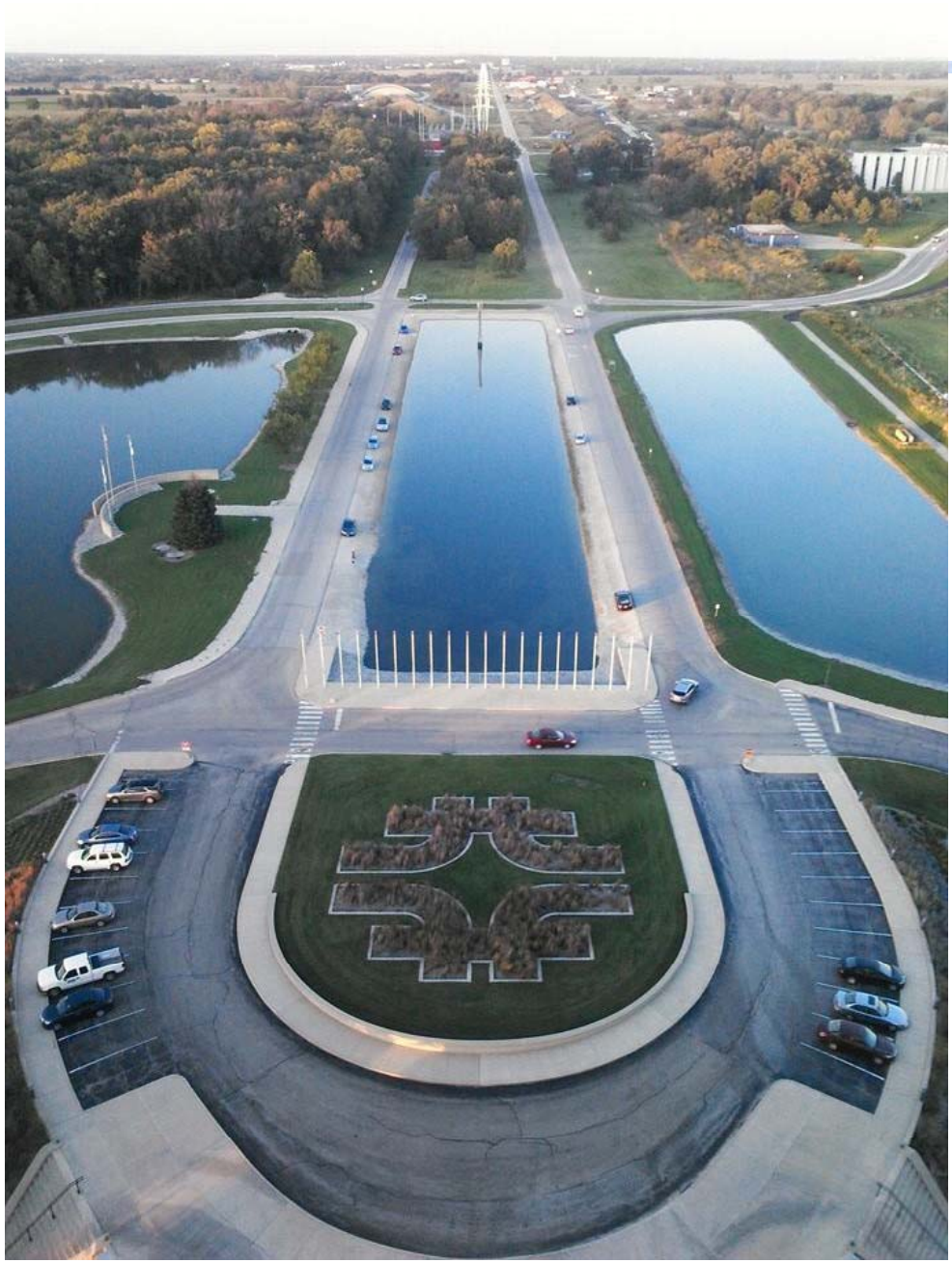

Operational Status of Decay Volume Helium Vessel at J-PARC Neutrino Experimental Facility

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on behalf of the neutrino beam group

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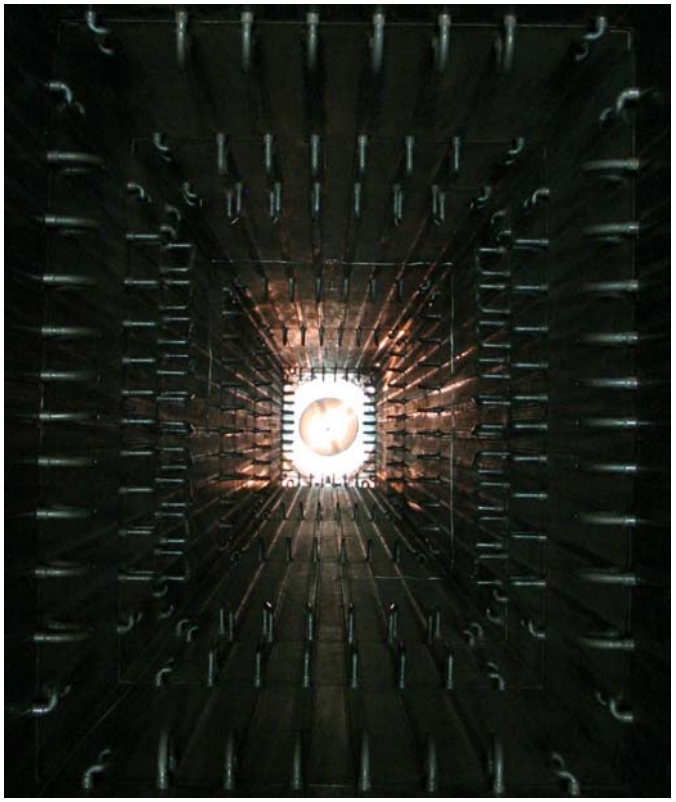
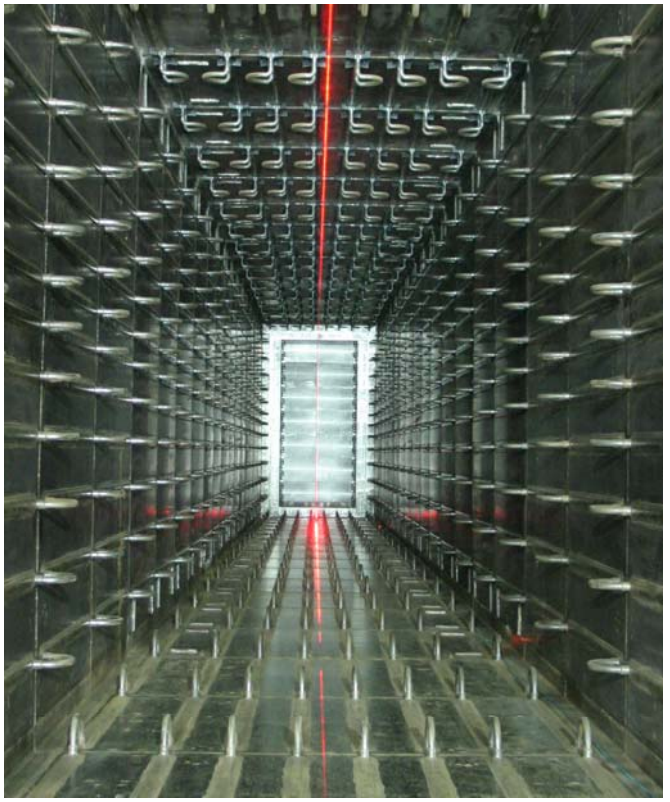
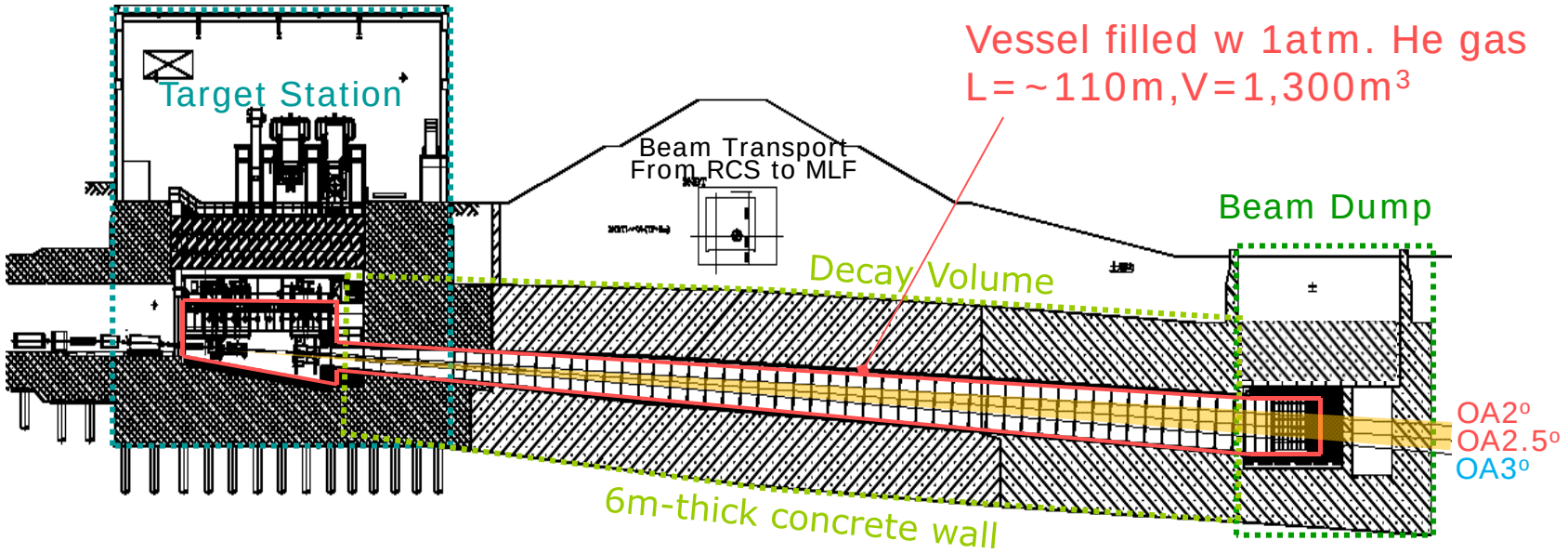


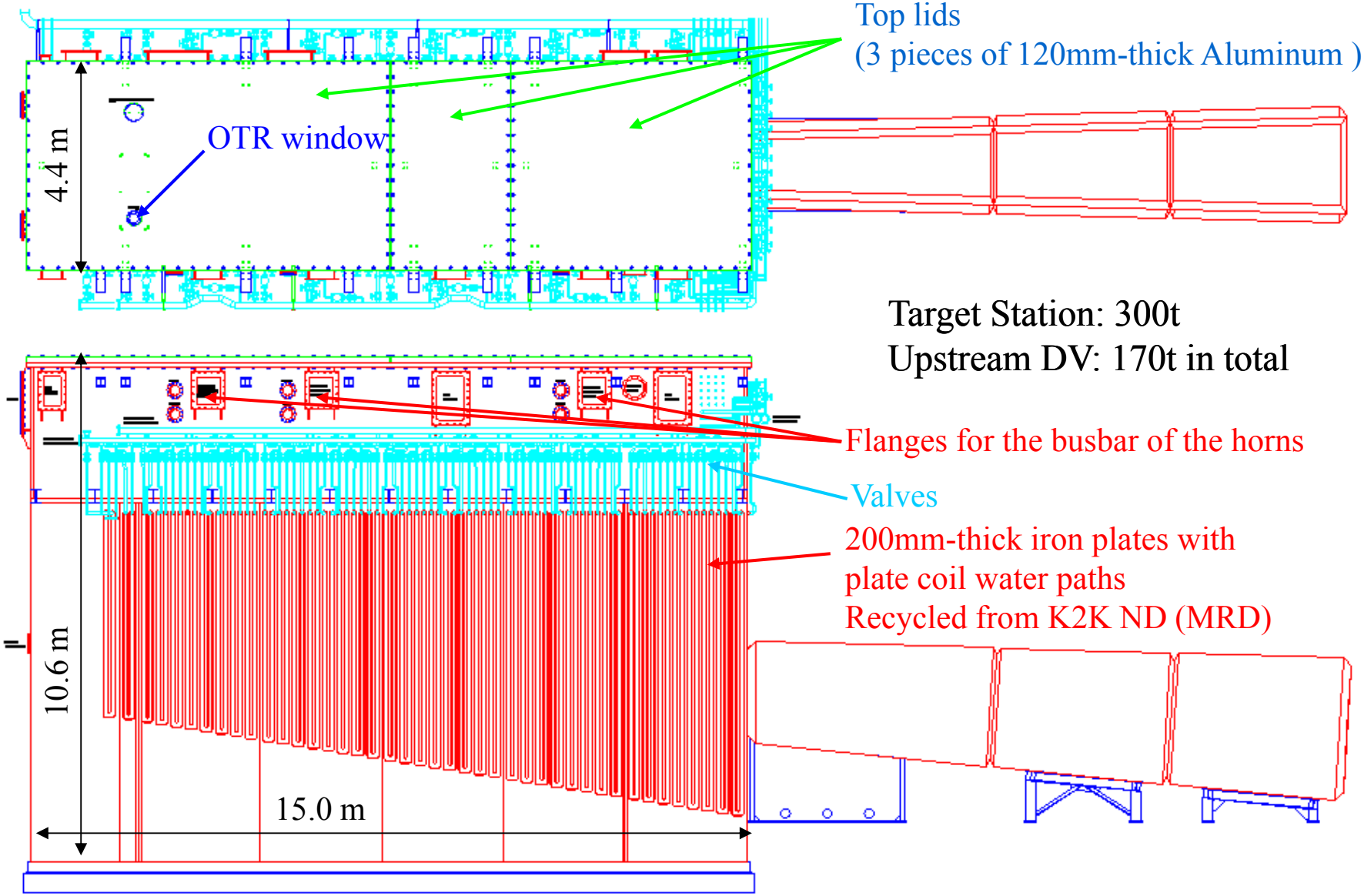


1. The Helium Vessel at J-PARC neutrino beam-line

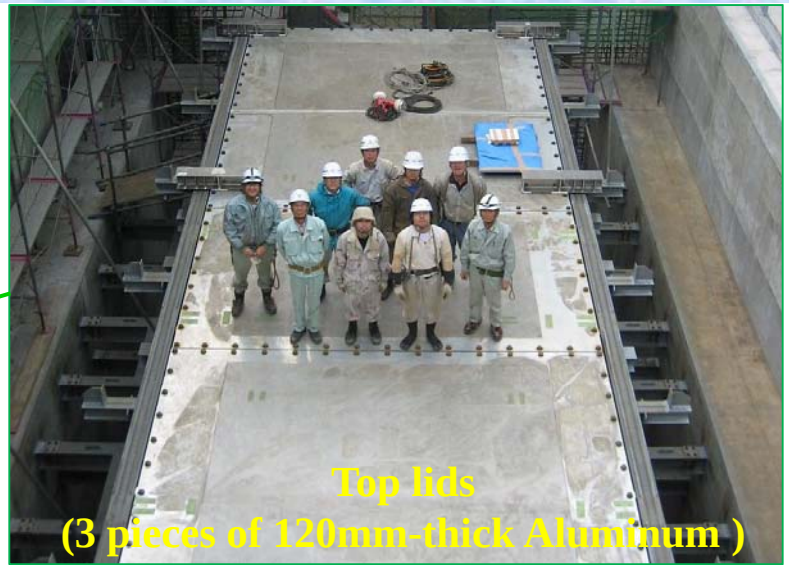


- Target Station(TS), Decay Volume(DV) & Beam Dump(BD) all enclosed in a gigantic vacuum/helium vessel, made of carbon steel plates.
  - Water cooling through plate coils welded on surface
  - Upstream cooling system at TS / downstream system at a utility bldg. (NU3)
- He gas filling after evacuation
  - Entire structures were rigidly built with thick plates (100mm for TS / 16mm + anchors for DV / 200mm for BD), welded together with deep grooves.
- He circulation by a helium compressor at TS: Flow rate = ~1,600Nm^3/h
  - Inlet plays role as coolant of horn strip-line cooling duct.
  - No forced circulation for DV/BD (piping at BD exist for future use)

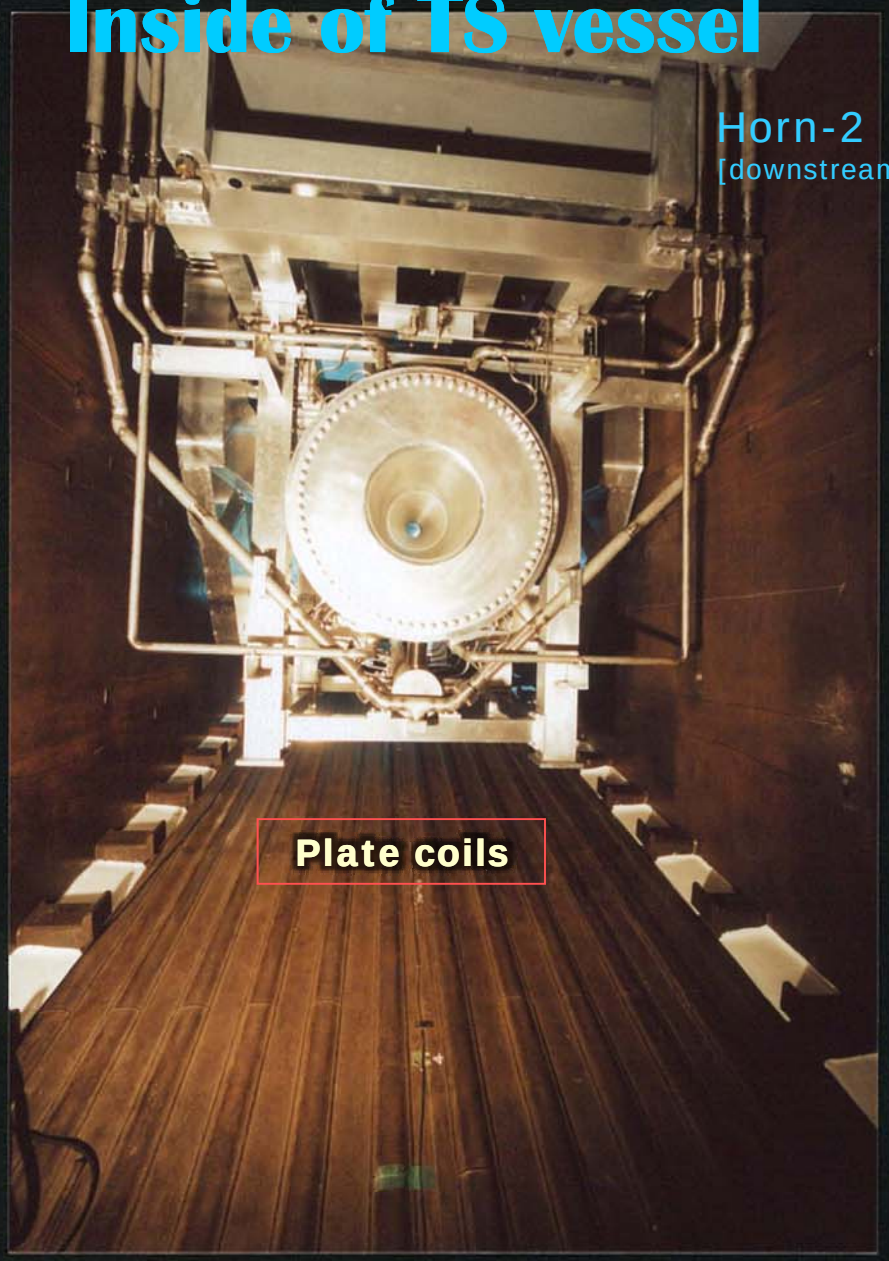
Helium Vessel at TS



TS/DV Helium Vessel Construction

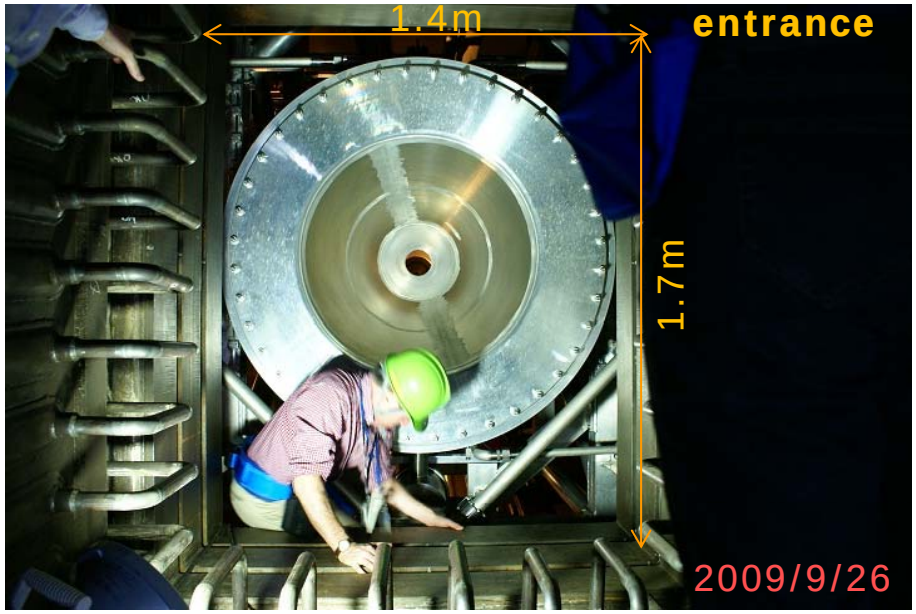


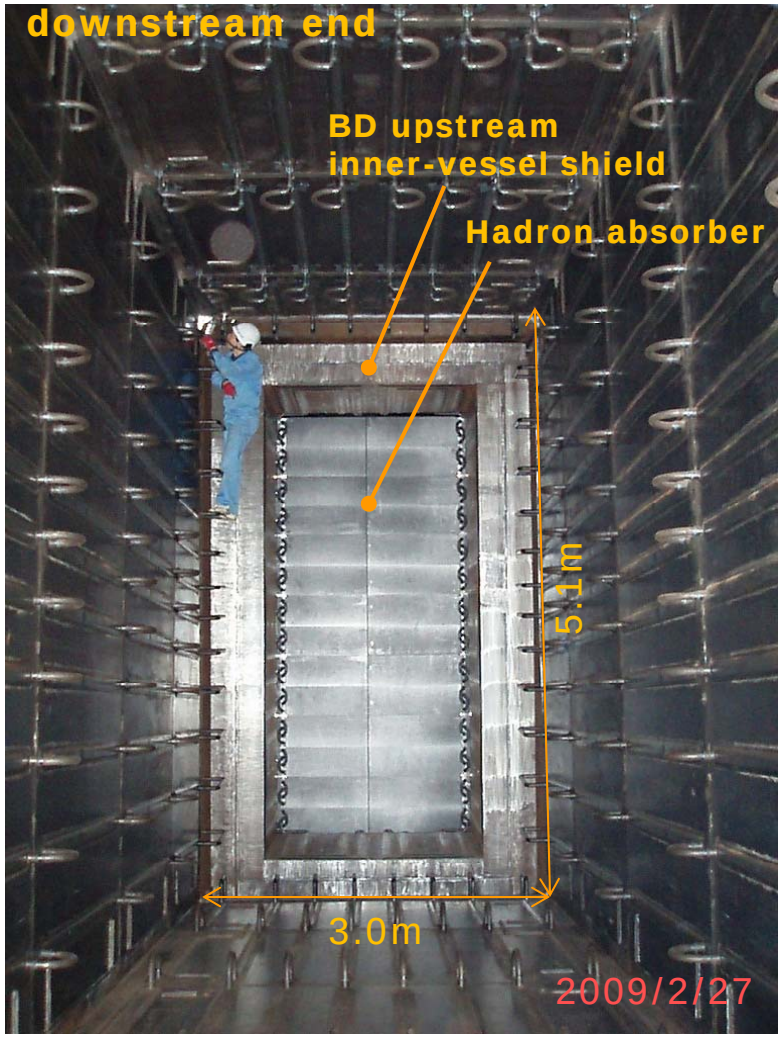
Inside of TS vessel

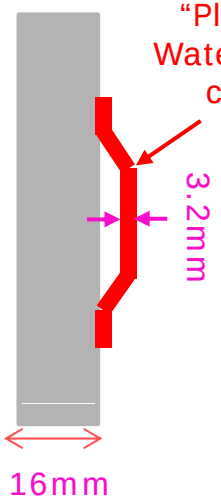


Photos on Sep., 2009 (before Physics Run)

Inside of decay volume



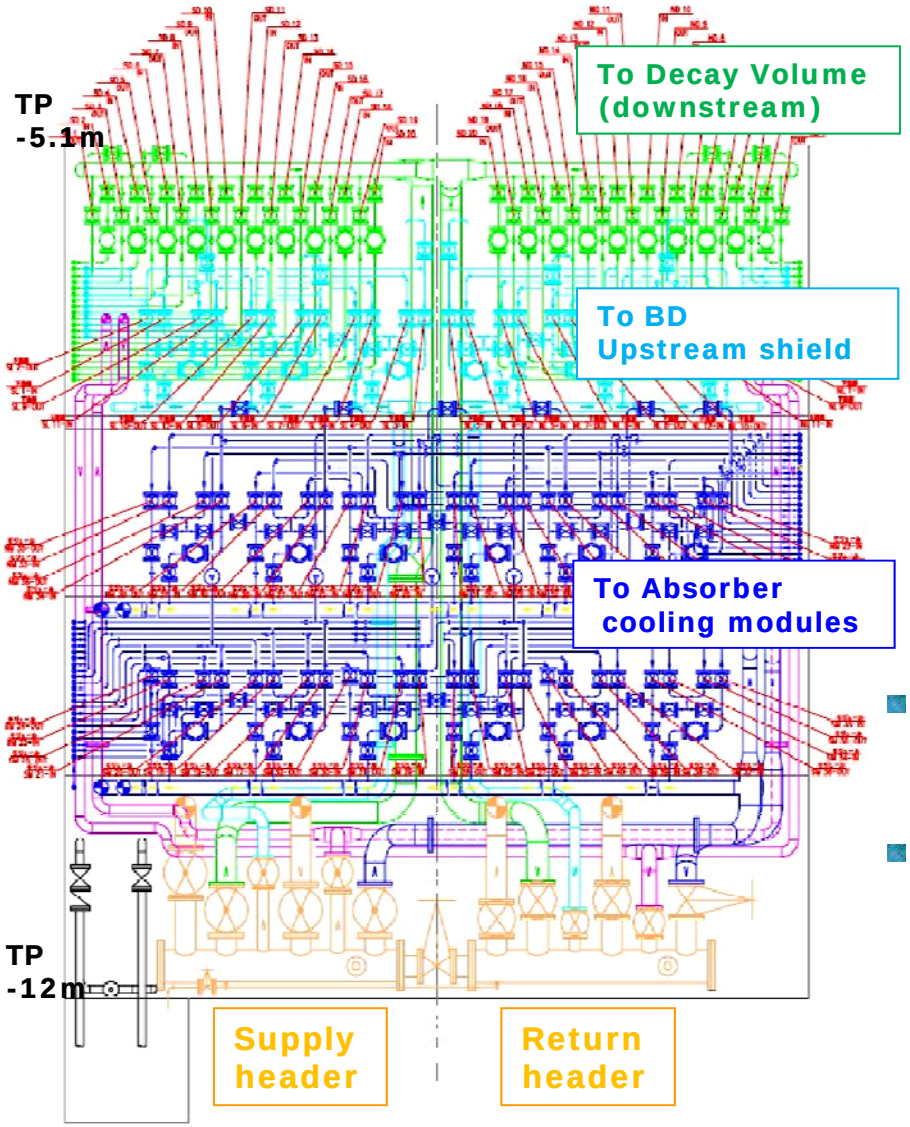




- Water circuits are separated to upstream and downstream.
- Each composed of 20 circuits – 40 water channels.

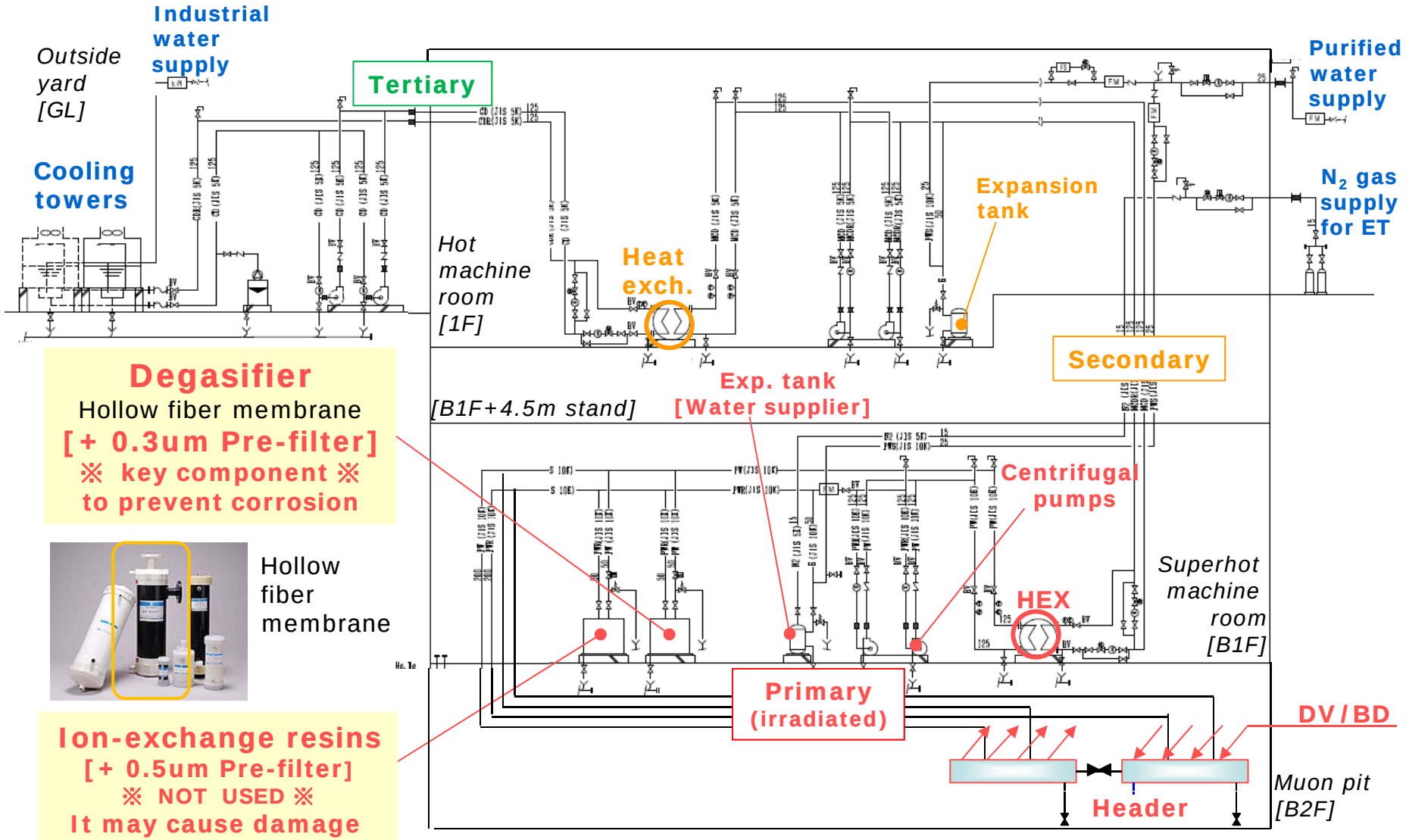
Plumbing at muon pit

[West side wall]



- Control water flow of 260water channels (130 circuits), ~500 Valves (25A)
- Though it is designed to use half of the circuits for 750kW beam, we forced to use all channels with low flow rate.
  - It may cause troubles for carbon steel, if we remove water from the channels.

Cooling Water System [NU3: downstream DV+BD]

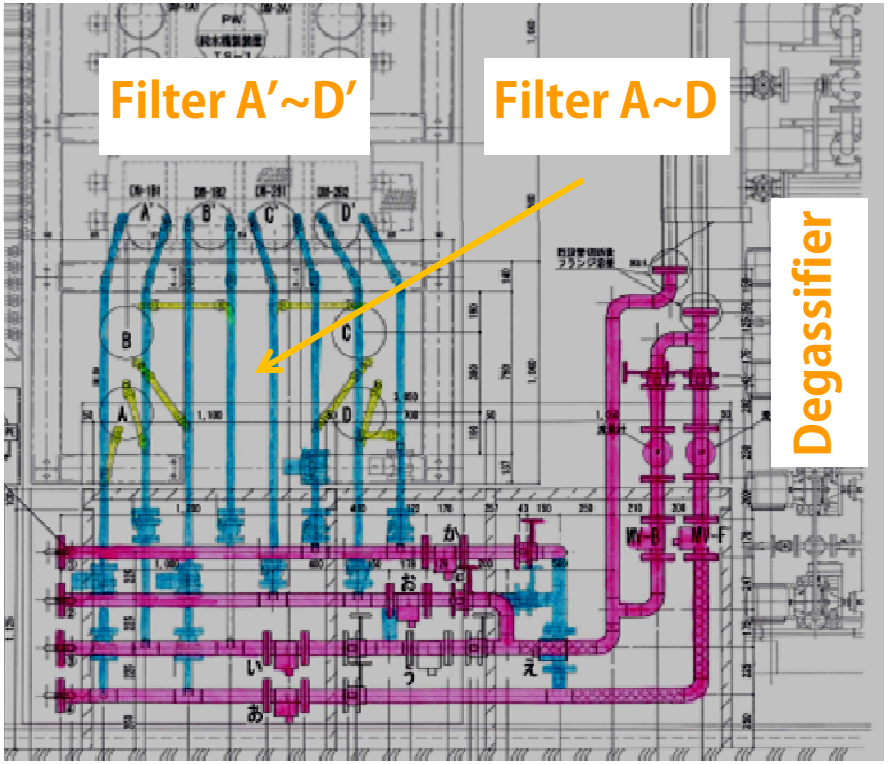


Degasifier
Hollow fiber membrane
[+ 0.3um Pre-filter]
※ key component ※
to prevent corrosion

Hollow fiber membrane

Ion-exchange resins
[+ 0.5um Pre-filter]
※ NOT USED ※
It may cause damage to carbon steel

2. Status of Water cooling [after NBI2012]

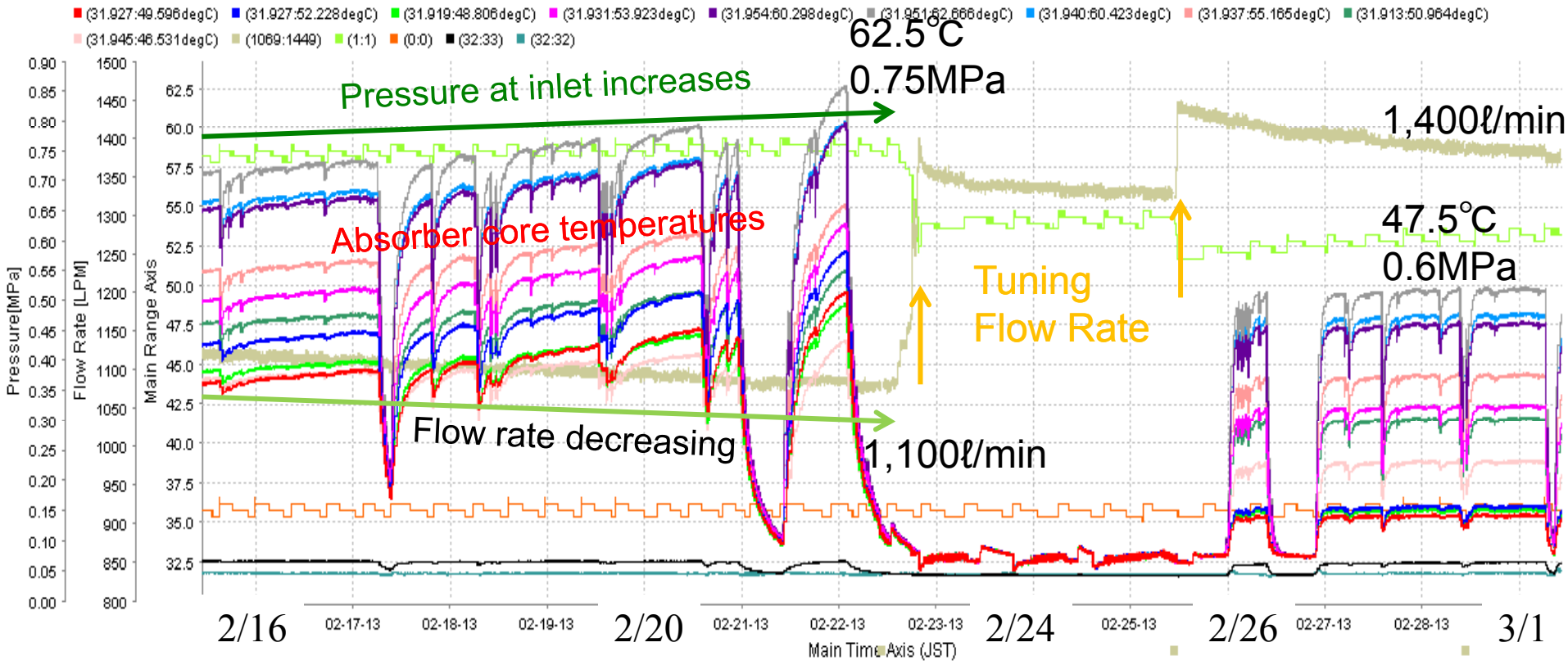


- Pre-filters for the degassifier (5um⇒1um) was installed to TS CW system in summer 2012 (similar system to NU3)
- They effectively absorb the radio-active particulate in the water (^{7}Be), but frequently clog up.
  - Powder of carbon steel (black skin)
- Exchange/tuning of filters caused 8hrs x 2 beam loss in Nov. 2012 runs (Run-4)

⇓

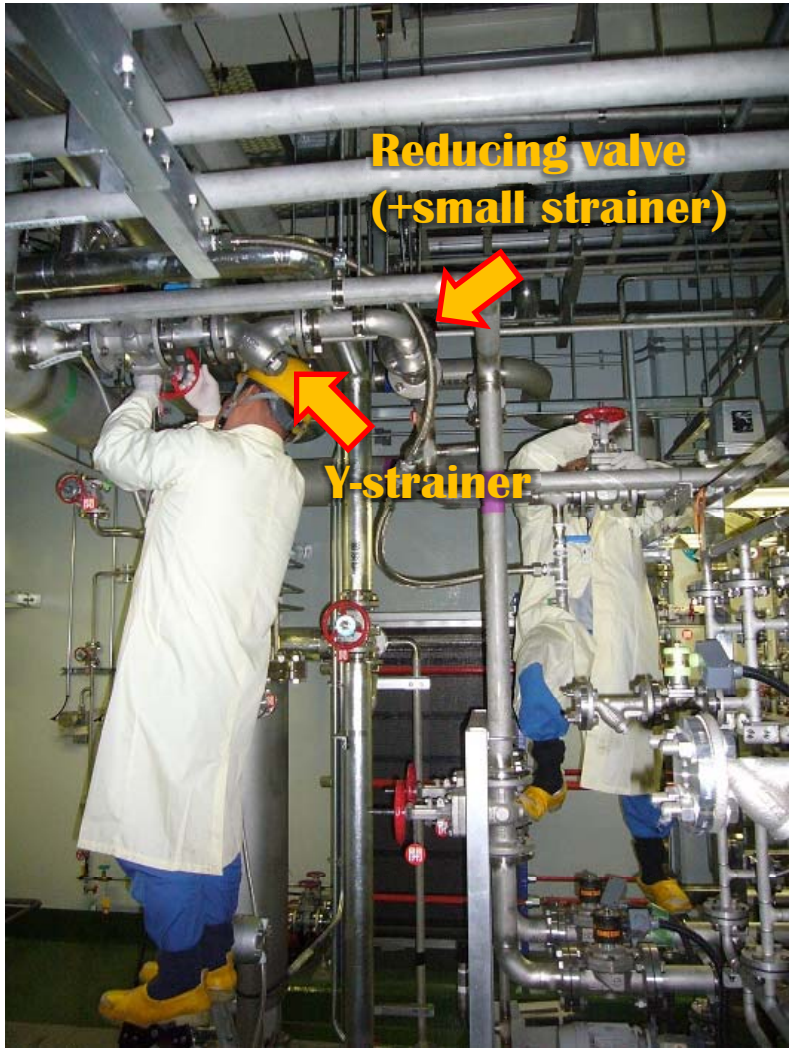
- New system was installed during the 2012 winter shut-down.
  - Remote controls, such as switching to a spare set of reserve filters / opening bypass line, are possible without disturbing beam runs.

Decrease of cooling water flow rate at NU3 (Feb.2013)



- Drop of cooling water flow rate observed for DV He vessel and beam dump.
- The black powder may clog up the water paths / valves.
- It was found that flow rate ~0 for some of channels
  - After adjusting the flow rate of each channel, flow rate stabilized.

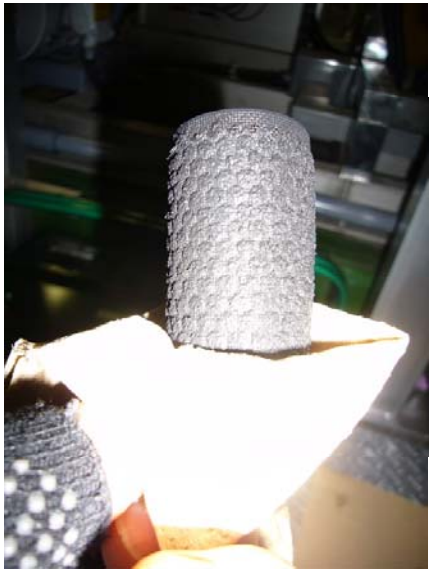
Flow rate decrease at degasiffier (NU3) [Mar 2014]



Y-strainer

- Flow rate <100l/min
- (nominal 135)
- Pressure after reducing valve 0.1MPa (0.3MPa)

Small strainer



Radioactivity in cooling water (NU3)

- Radioactive nuclei in the primary cooling water
  - Run-4: Oct. 2012 ~ May. 2013, 3.6x10^{20}pot, ~230kW
  - On Dec. 2012 we disposed some amount of water to boot up water dilution process and to prepare for the summer maintenance in 2013.

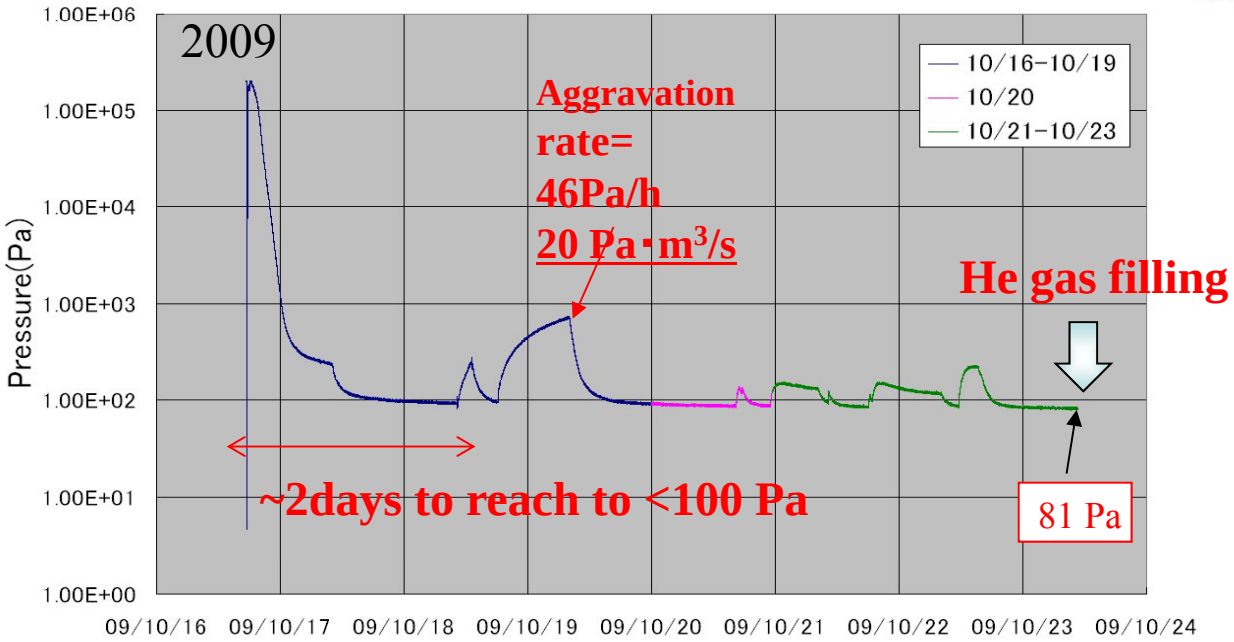
  - Only ^{3}H is beyond limit for disposal.
  - The 0.3um pleats filters in front of degasiffier seems to be very effective to adsorb/concentrate ^{7}Be

  - So far daughters of Fe is not serious problems.
  - In sometime future it will be necessary to use ion exchanging resins before drainage.

Spc.	3H	7Be	22Na	43K	52Mn	54Mn
Bq/cc (Dec.2012)	740	1.0	0.045	-	0.046	0.12
Bq/cc (May.2013)	500	1.2	0.045	0.1	0.11	0.13
Disp.limit	60	30	0.3	3	0.5	1
Life	12.3y	53.2d	2.6y	22.3h	5.6d	312d

3. Status of Helium atmosphere in the vessel

Mechanical-booster pumps
@ TS B1 stand



- By evacuation we reach to <100Pa (0.1%) with a few days ~ a week
  - Vacuum was saturated by outgas (20 Pa·m³/s), possibly from vessel surface / concrete shield blocks in the TS vessel
- Tiny amount of air leak at BD vessel: 10^{-2}~10^{-1} Pa·m³/s=1~10ppmO_2/day.
  - air contamination suppressed by keeping slightly positive pressure wrt. atmosphere.
  - O_2 contamination < 100ppm for entire beam period
- The dew point (humidity) in the vessel was saturated in a week after gas filling
  - Source of Tritium (HTO) production
  - From concrete surface ? Water leaking ?
  - ⇒ From Oct. 2012, we faced to water leak from Horn(s)

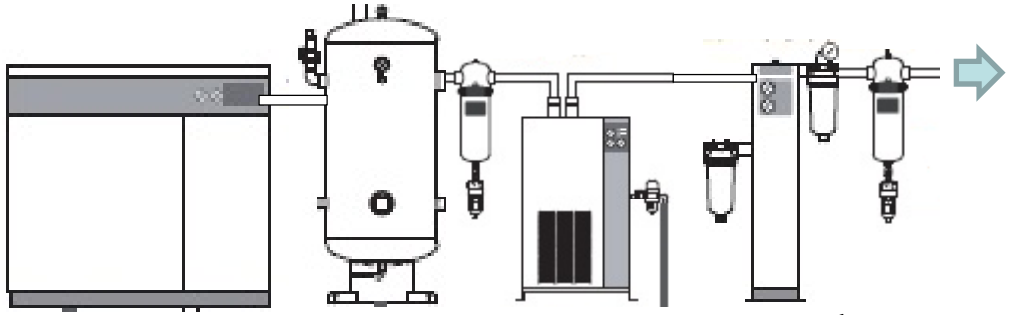
Gas chromatograph measurement [Apr.2013]

- On Feb.~Mar.2013 gas chromatograph was installed to TS
- Helium vessel(Apr.2013):
  - N_2 1,500 ppm
  - O_2 20 ppm
  - CH_4 30 ppm
  - CO_2 /CO 0 ppm
- Consistent to the reach of evacuation
- Oxygen is low enough.

gas chromatograph at TS-1F
• Coolant Helium gas for target, beam window, and He vessel
• Cover gas of horn cooling water

Dried Air Supplier @ NU3

- Before opening He vessel, we need to dry up inside of vessel to avoid suffering internal exposure by ^{3}H (HTO).
- ^{3}H level in the vessel is much higher than that in 2011.
  - 2011: ~1300mBq/cm^3 after 1.4x10^{20} POT
  - 2012: ~1100mBq/cm^3 after 1.6x10^{20} POT
  - 2013: ~1900mBq/cm^3 after 3.6x10^{20} POT
- In 2011, it took 3 weeks to reduce ^{3}H level from 1.3Bq/cc to 0.2Bq/cc
- We have reinforced dried air supplier at NU3: higher flow rate & lower dew point.

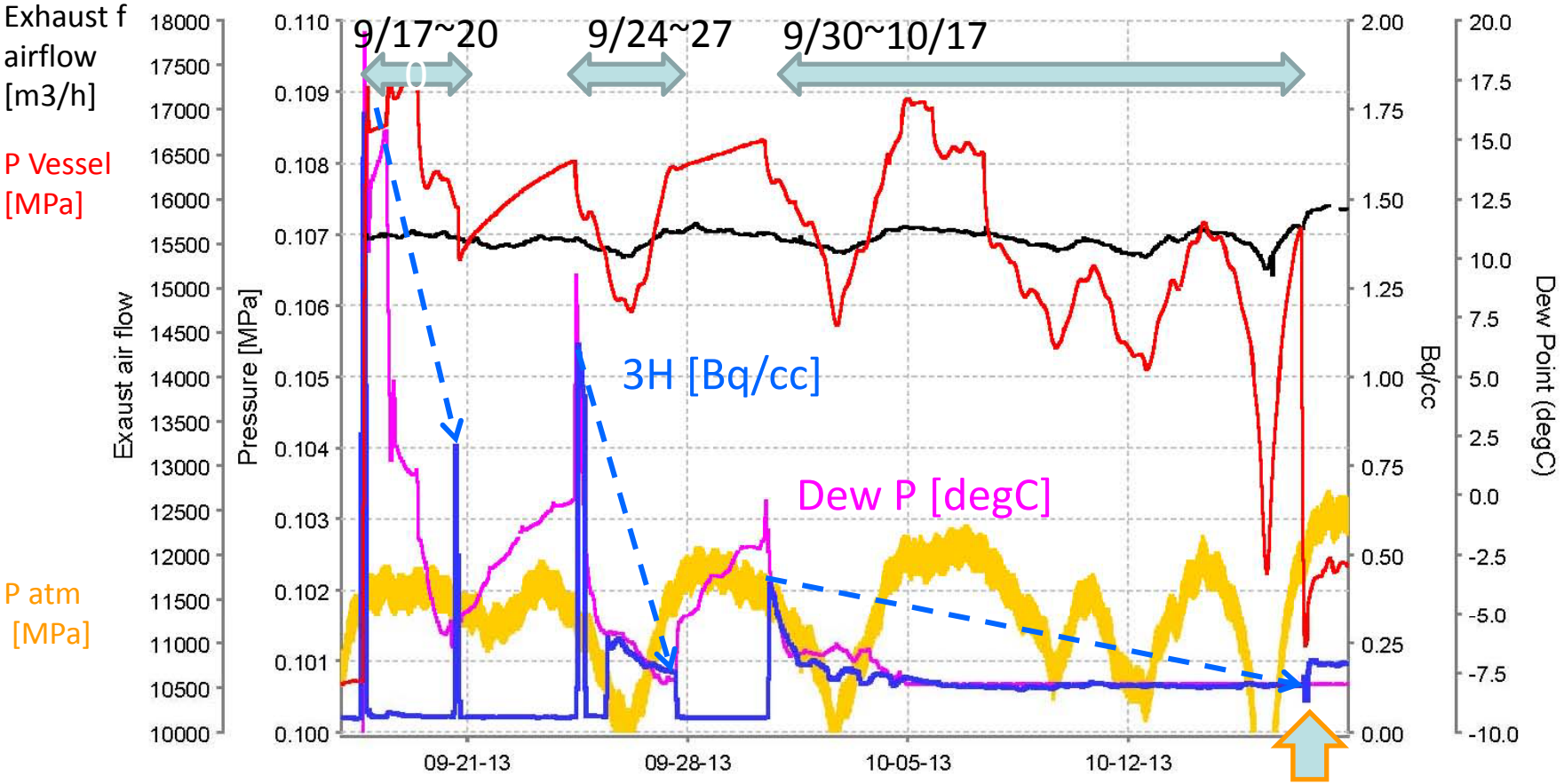


Compressor 2.4m^3/min (was 1m^3/min) | 400 L Air tank | Refrigerated Air Dryer | Heatless Air Dryer (new)

Low dew point clean air

Filtration rating	Pressure dew point	Remaining oil content
0.01 μm	−40℃	0.01 wt ppm
	−20℃	

Drying He Vessel [Sep. 2013 -]

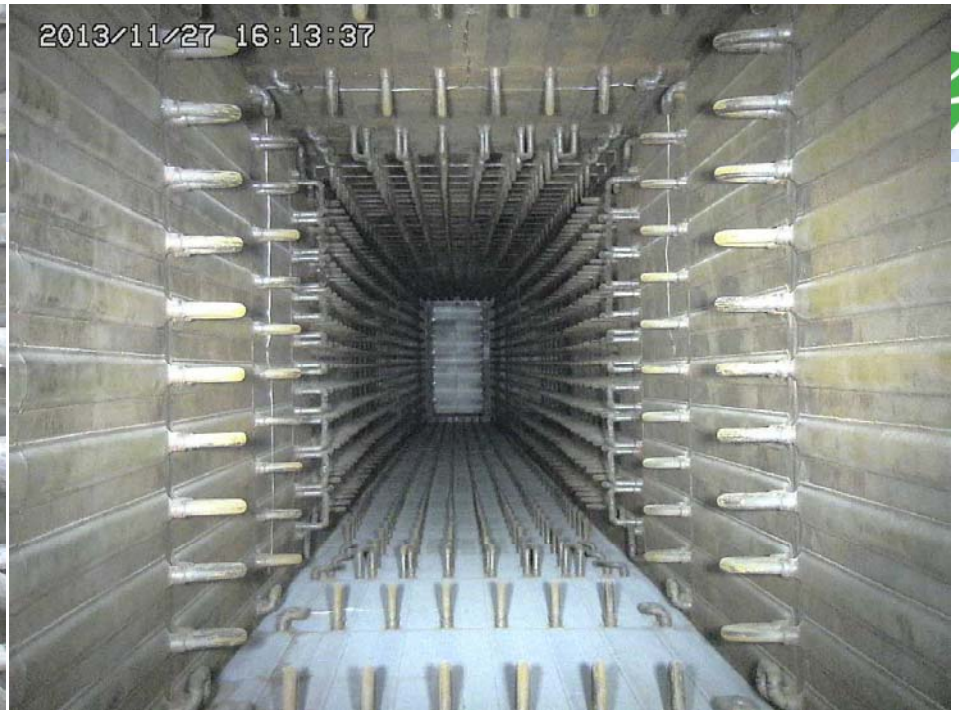


- Vessel evacuation on Sep.12-13, drying vessel by air supplier at NU3 started on Sep.17.
  - Dew point >20℃→-20℃,
  - ^{3}H 1.8 Bq/cc → 100mBq/cc (2011: 210mBq/cc)
- Vessel was opened on Oct.17 (One month)

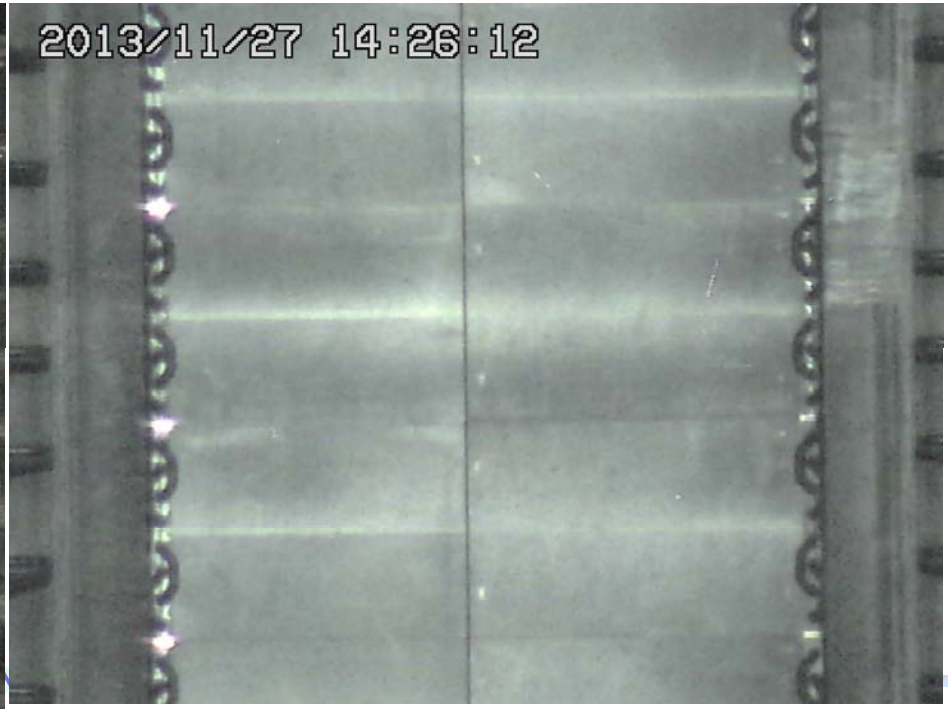
BD/DV Inspection [Nov.27, 2013]

- After old Horn-3 was moved to maintenance area, we set web camera on the beam-line and inspect DV/BD status


2013/11/27 16:13:09


2013/11/27 16:13:37


2013/11/27 14:30:29


2013/11/27 14:26:12


2013/11/27 14:30:13


2013/11/27 14:30:57


2013/11/27 14:31:16


2013/11/27 14:31:50


2013/11/27 15:01:43

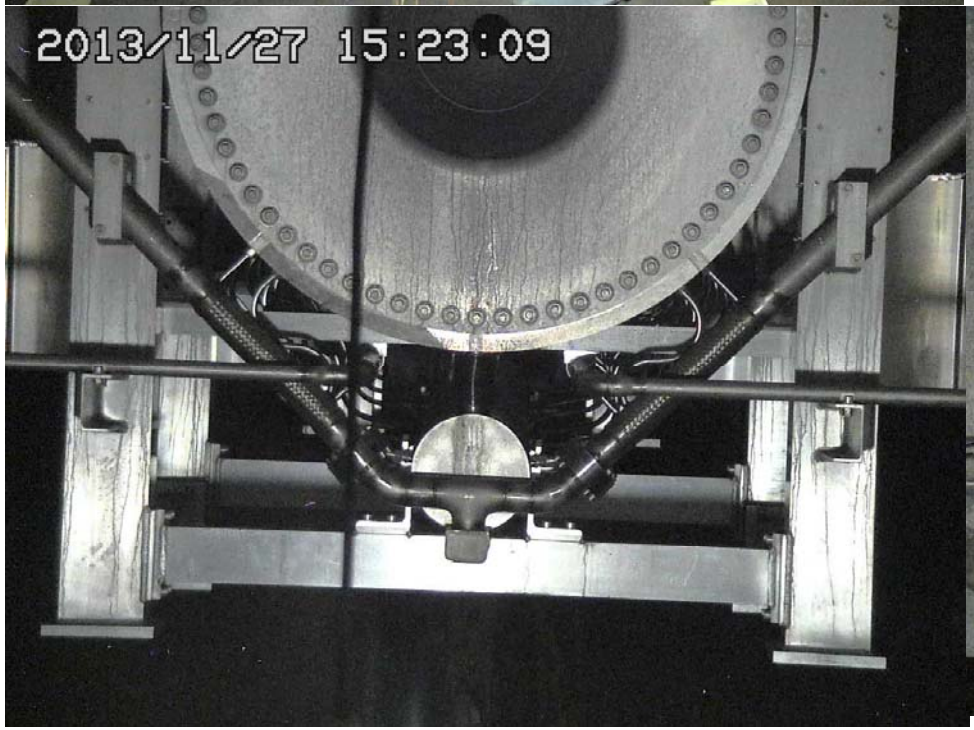

2013/11/27 15:02:26


2013/11/27 15:02:03

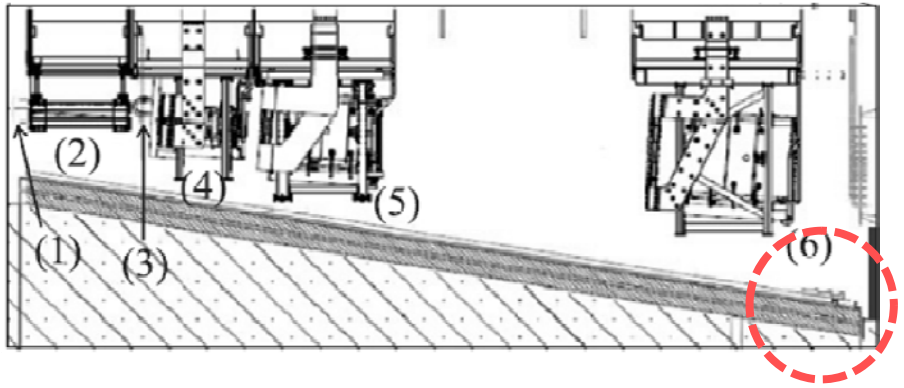

2013/11/27 15:00:28

Horn-2 dew condensation

- Imprint of dew condensation was clearly identified at the surface of Horn-2
- It was acting as dehumidifier of the helium vessel...



Imprint of puddle at bottom of TS vessel



- Dirty powder layer due to water drainage from horn leak plus dew condensation (?)

Replacing Heat Exchanger (TS) [Dec.2013]

- ΔP became >0.4MPa, possibly due to clogging of black iron powder
  - Residual dose: O(100uSv/h)
- We replaced with new one.

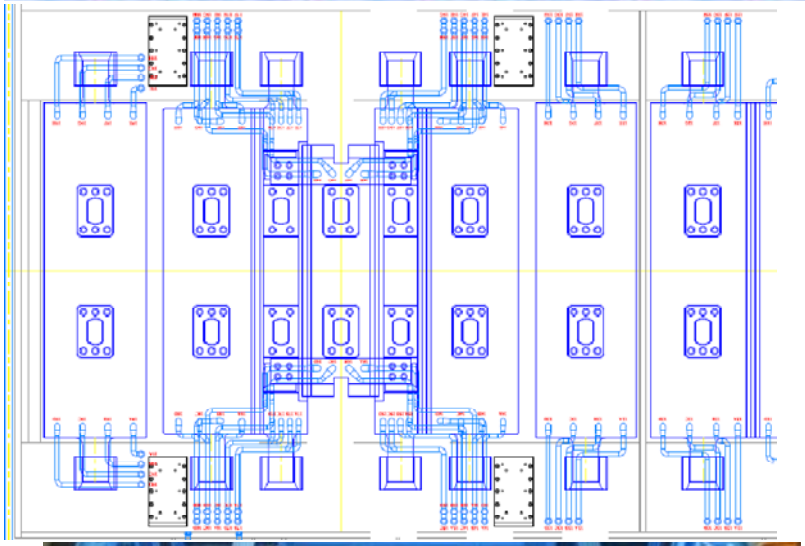
  →ΔP < 0.1MPa

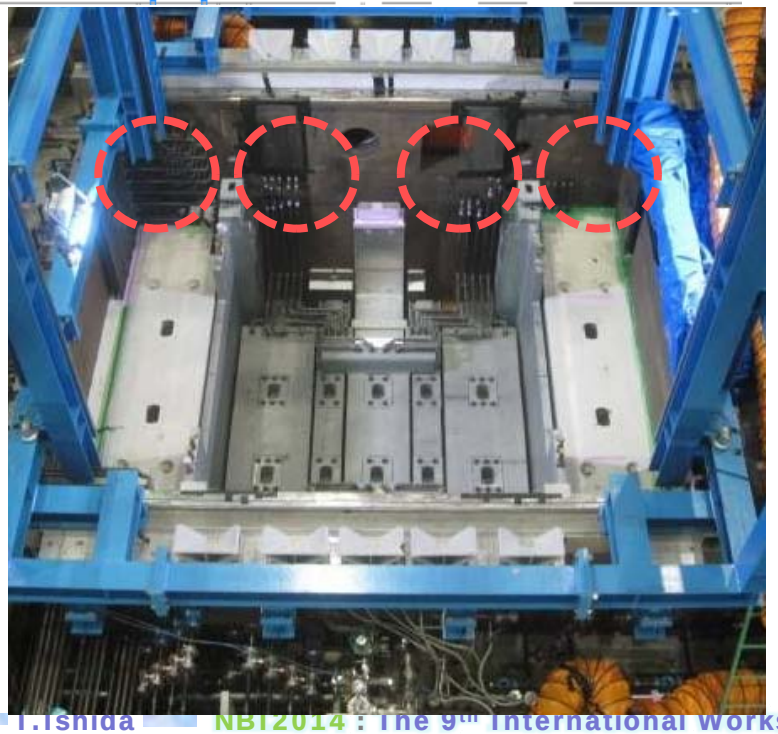
Source of Vessel Humidity ?

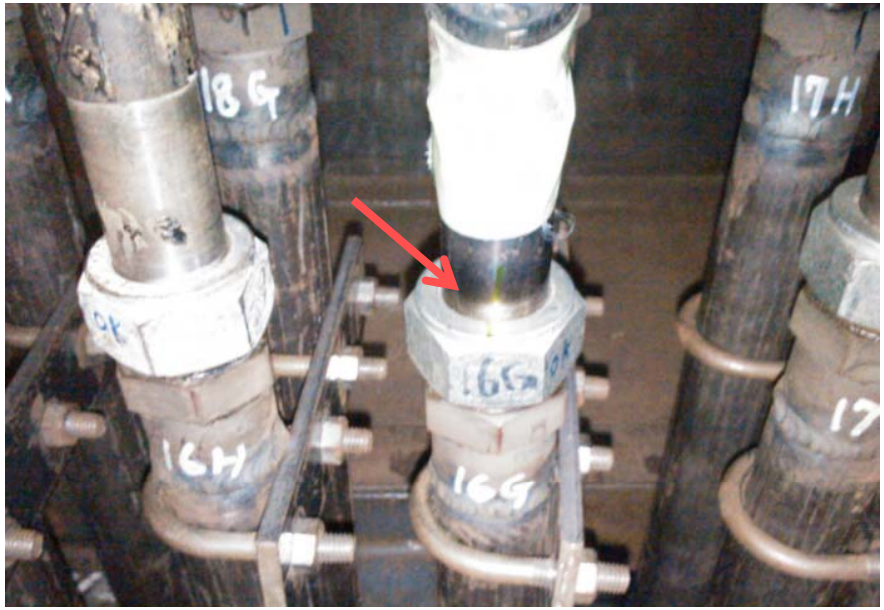
- Dew point= 25~26 deg.C.
  - Outgas from surface of wall/concrete blocks ?
    - Wall: ~3x10^{-4} Pa･m^3/s/m^2 → Vessel (1,700m^2) 0.6 Pa･m^3/s
    - Concrete Block: ~1x10^{-2} Pa･m^3/s/m^2 → Shield(240m^2) 3 Pa･m^3/s
    - The values are still not so consistent to 20 Pa･m^3/s.
    - It is curious that the outgas lasts whole the run ?
- Run-4: horn water leak = the source of the humidity !
  - The humidity cause dew condensation to horns
  - It can become critical problem on its performance and life limitation!
- During 2013 maintenance we realized many bad SWL connections for the iron shield blocks in the TS vessel.
  - We tried to fix them all but not in perfect manner.
  - Typical dew point: 14℃(May.28)⇒25℃(Jun.26, 2014)

※ For Run-5 we raised up temperature of coolant water to horn H/X and after cooler of He compressors from 22→25℃ (Aug. 2013) to avoid dew condensation (temporal solution)

Bad SWL connections for iron shields



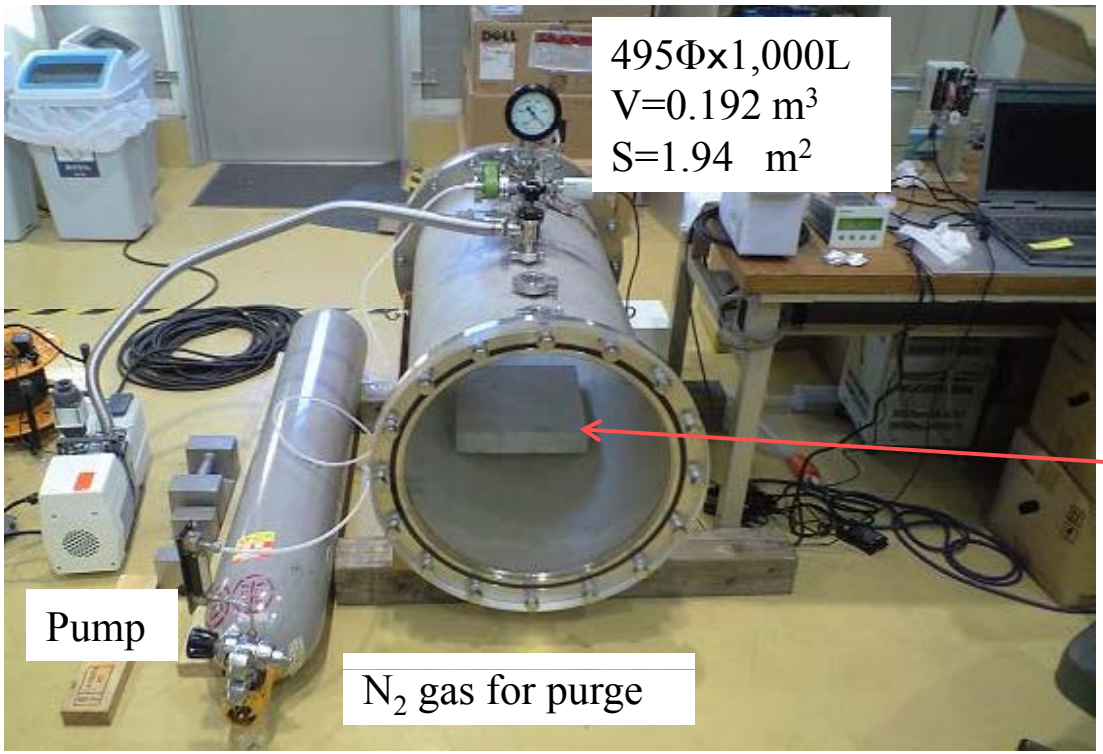




Summary

- Evacuation and He filling: it takes a week to make vacuum level < 100 Pa (~1,000ppm of air).
  - Oxygen < 100 ppm for entire beam periods: prevent NOX production and oxidation of the apparatus inside.
  - Validated by gas-chromatograph measurements.
  - We successfully used 1st set of horns, target, window, OTR, DV for 5 years.
- Due to the saturation of humidity in the vessel helium, before opening vessel to start maintenance, we need to dry HTO.
  - We improved the dried air supplier at NU3 and finish the process in a month.
  - Situation will be improved by fixing bad SWL connections of shield blocks.
  - We raised up horn cooling water temperature to stop dew condensation.
- For cooling water circuits (made of carbon steel), powder of iron black skin clogs up filters/HX.../strainers/valves not a few times.
  - We continuously reinforce the system (automated filter exchange etc.)

Test Outgas Measurements



60 kg scale
dM =1g

Block w paint
$V=6e^{-3}$ m³
13 kg
Reduced
-3g /day by evacuation

- BG 12Pa/h $=3.3\times10^{-4}$ Pa·m³/s/m² → Vessel (1,700m²) 0.6 Pa·m³/s
- Block 47(-12)Pa/h = 1.0×10^{-2} Pa·m³/s/m² → Shield(240m²) 3 Pa·m³/s
- The values are still not consistent to 20 Pa·m³/s, but maybe comparable.
  Cf. Block weight: 0.023%/d →Shield(130t) 45 Pa·m³/s (assume all vapors remain)

Cooling water flow at TS