J-PARC Neutrino Facility Upgrade

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on behalf of
J-PARC Neutrino Group

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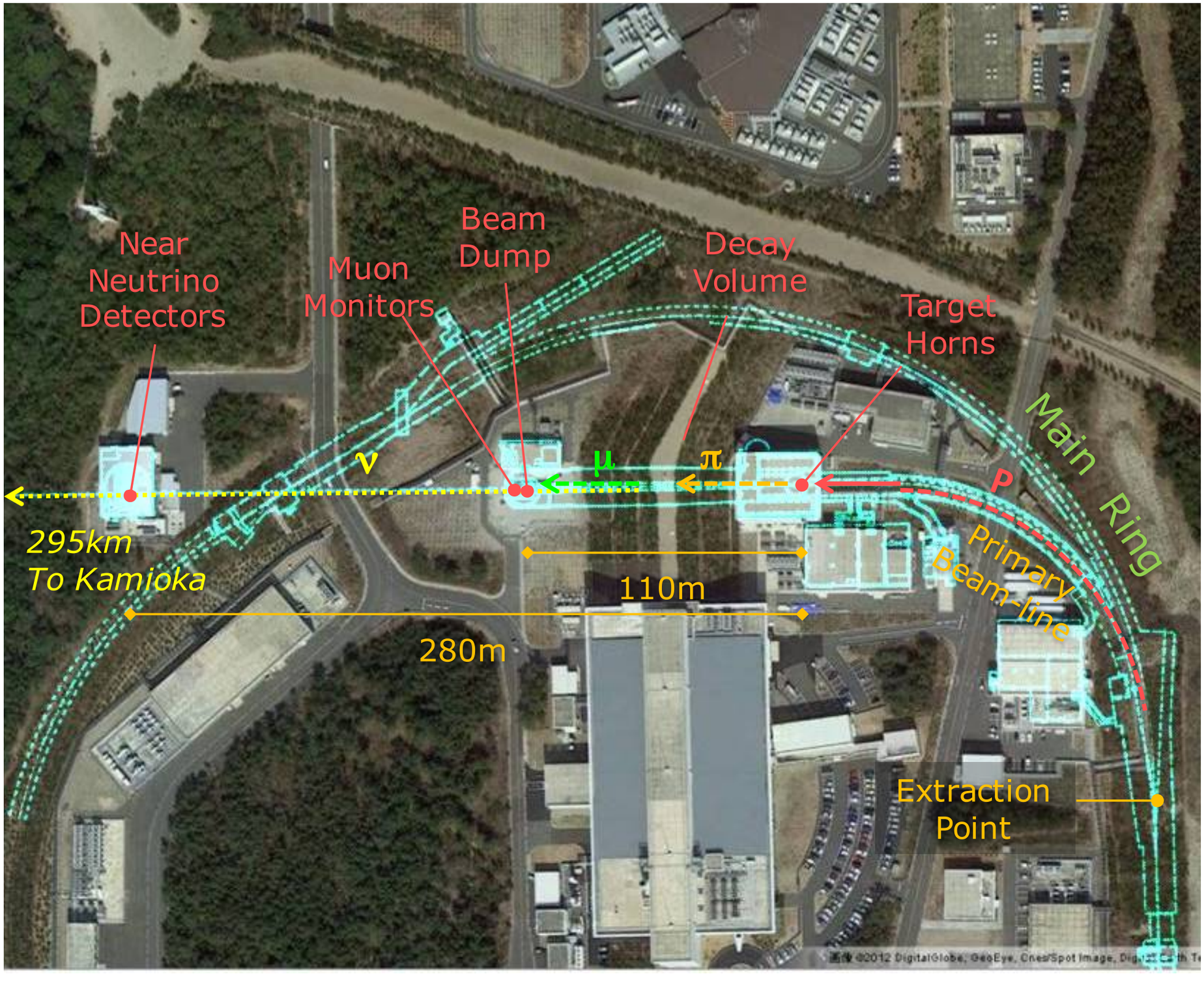
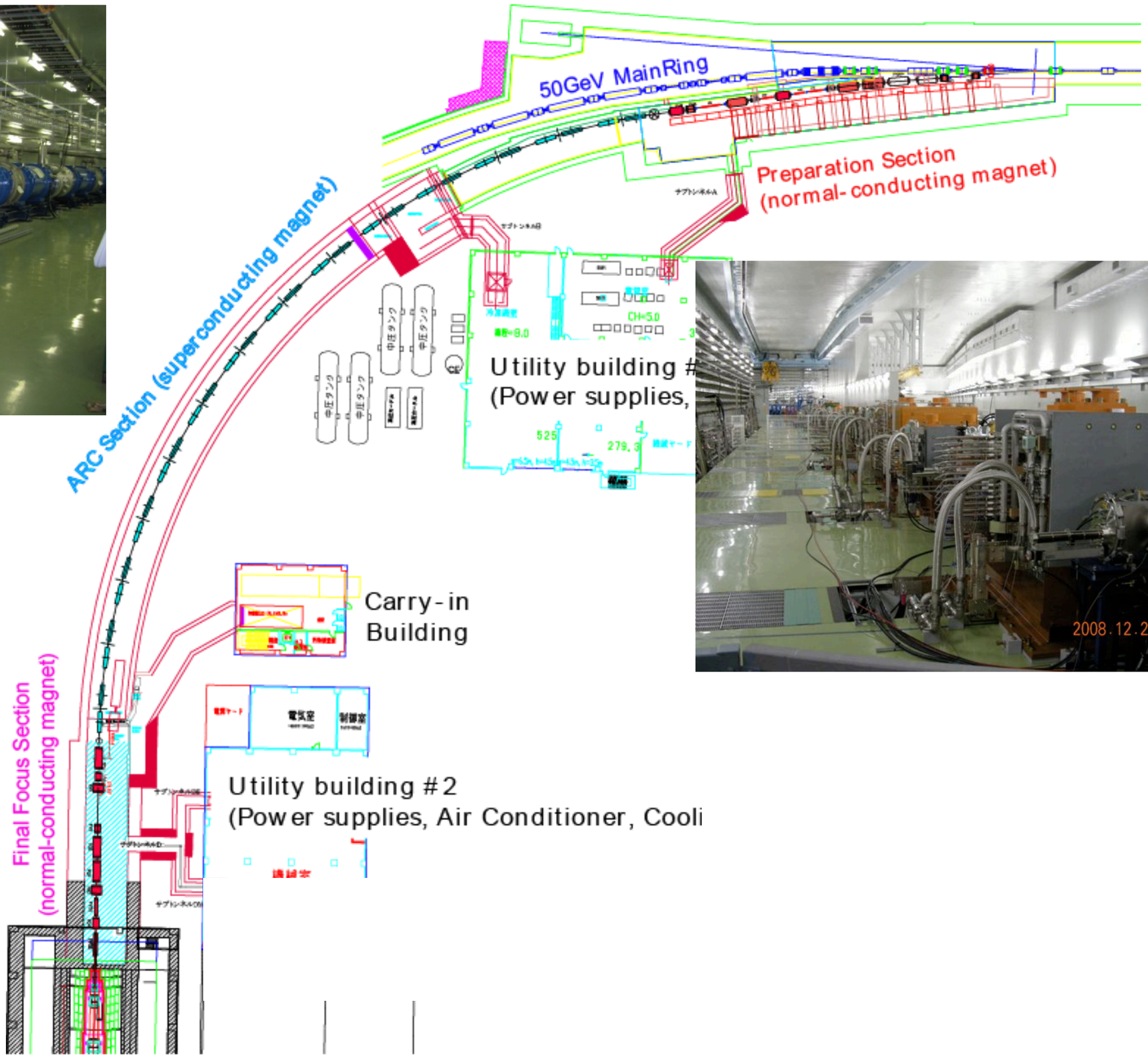
NBI2017:
10th International Workshop on Neutrino Beams and Instrumentation

Contents

J-PARC Neutrino Facility

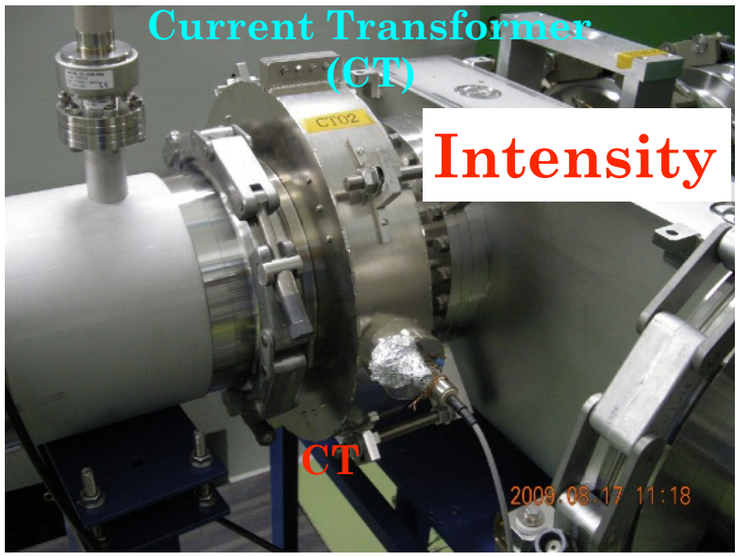


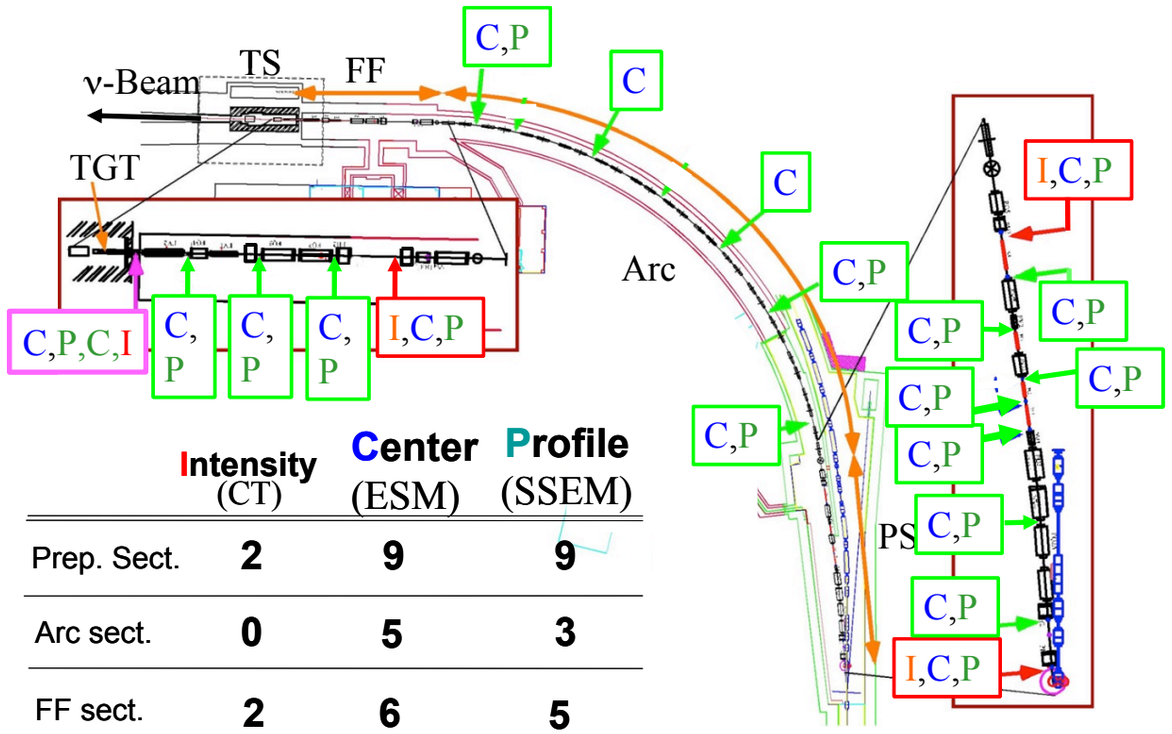
Primary Beamline



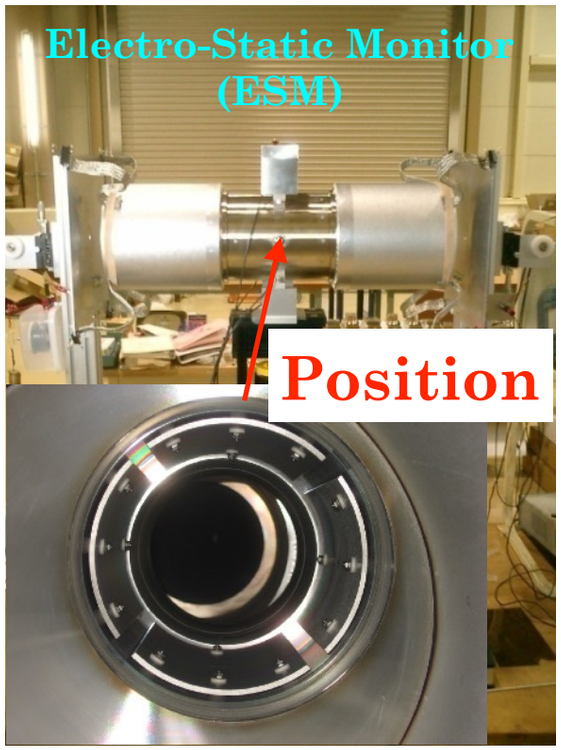
Beam Monitors

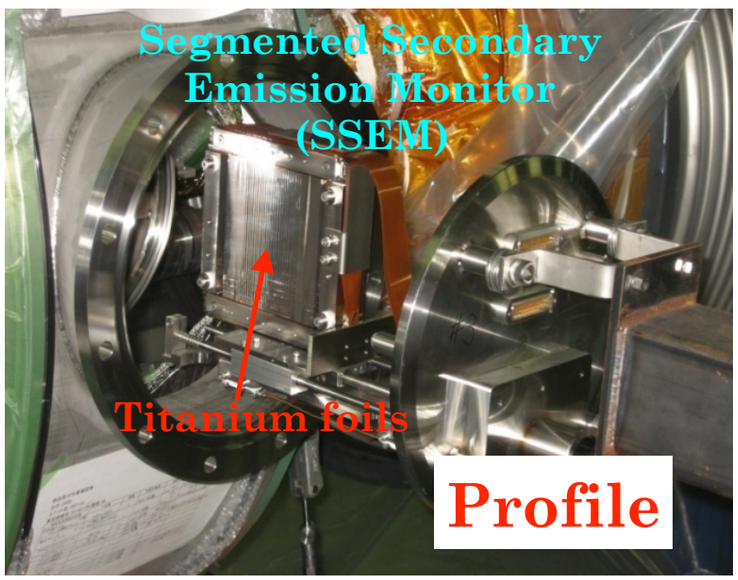
- Proton beam measurements and control
  - **Precise beam control is crucial for high intensity beam**

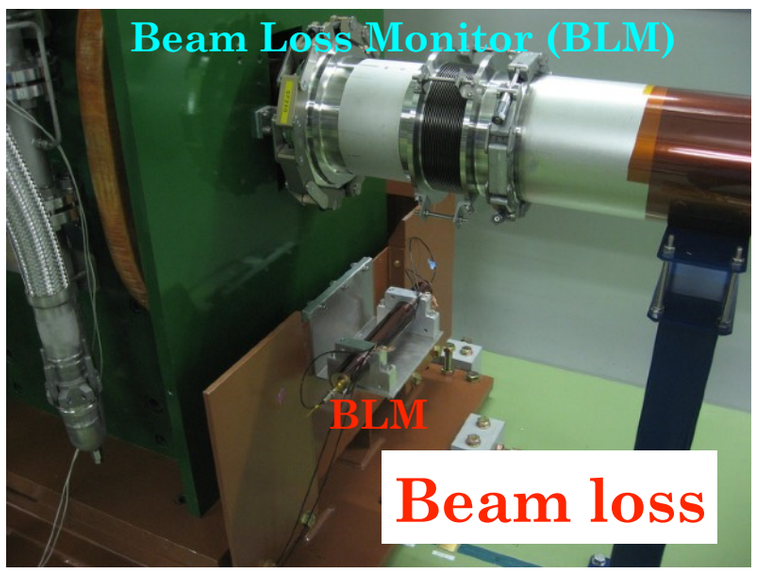


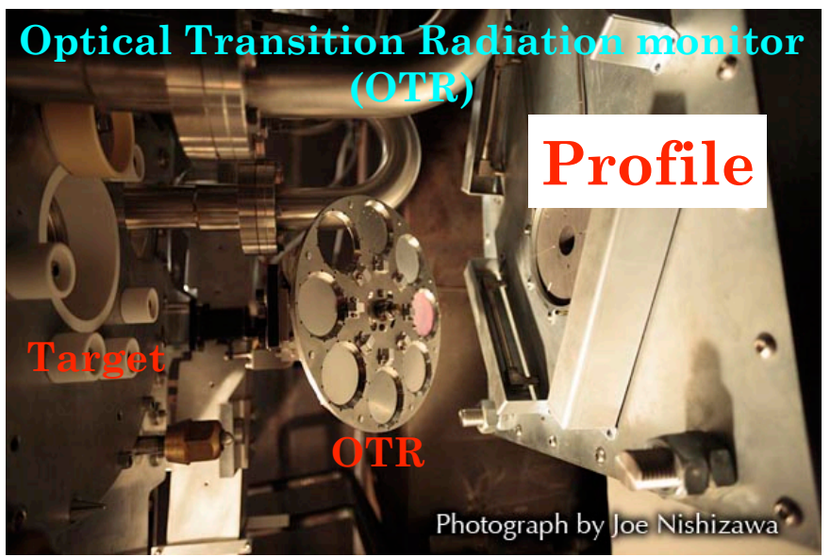


	Intensity (CT)	Center (ESM)	Profile (SSEM)
Prep. Sect.	2	9	9
Arc sect.	0	5	3
FF sect.	2	6	5

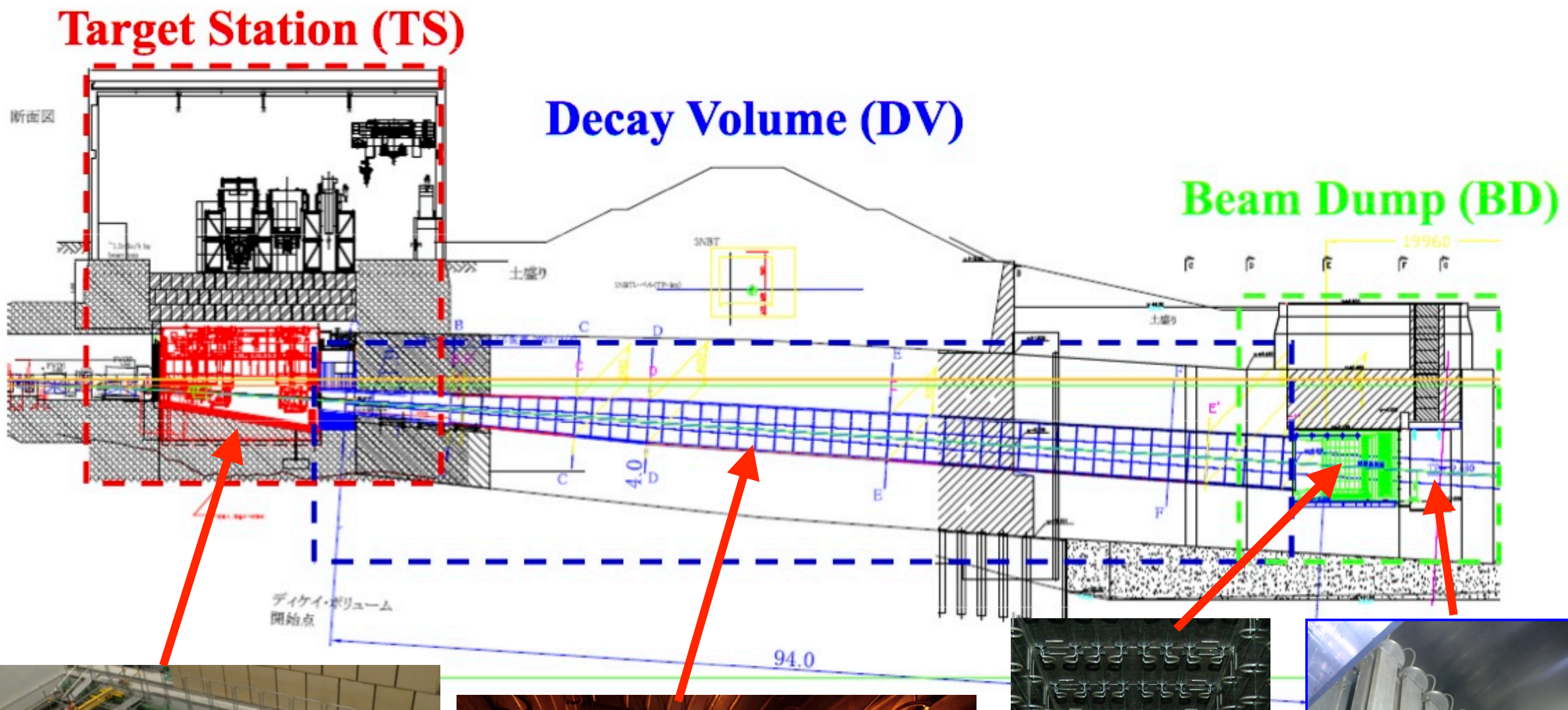


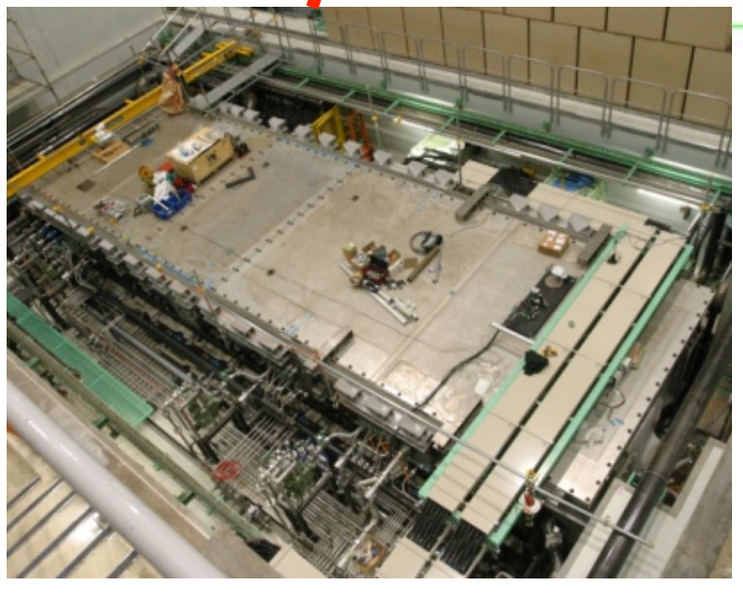


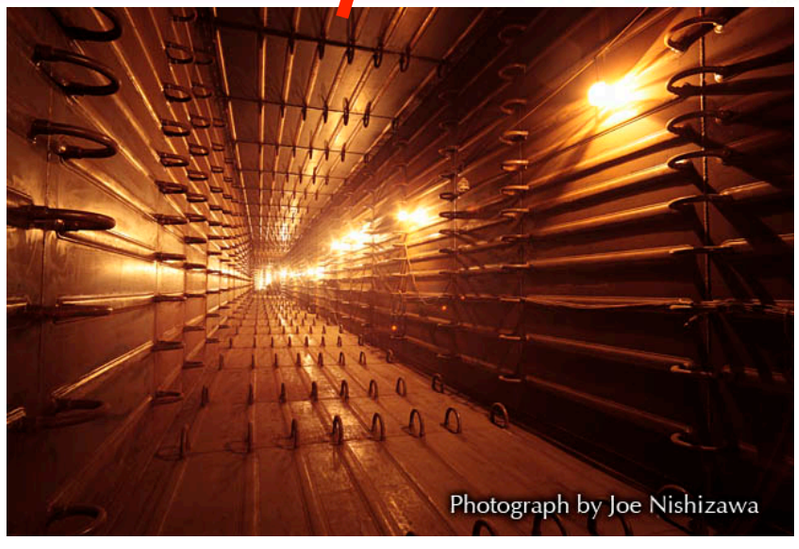


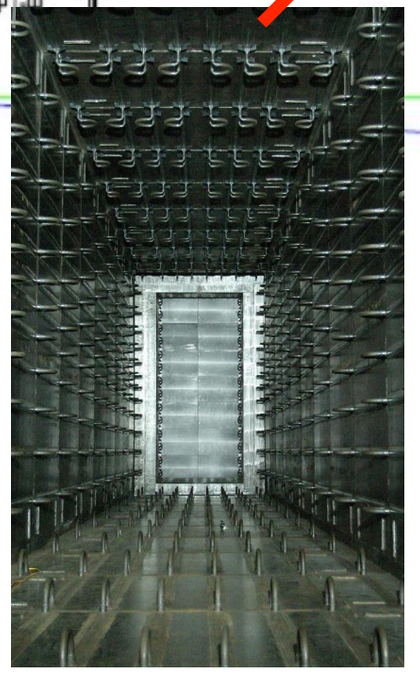


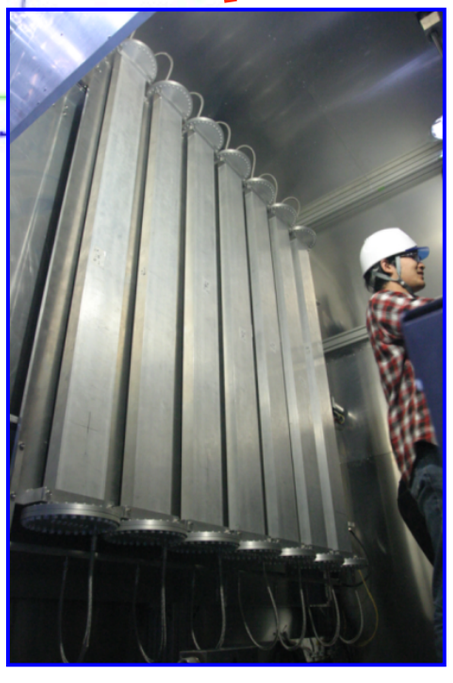
Secondary Beamline





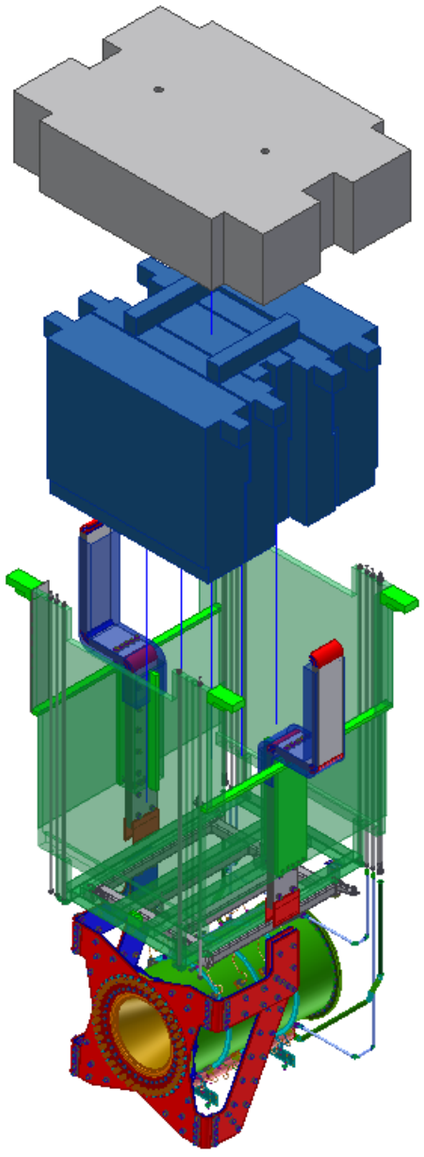


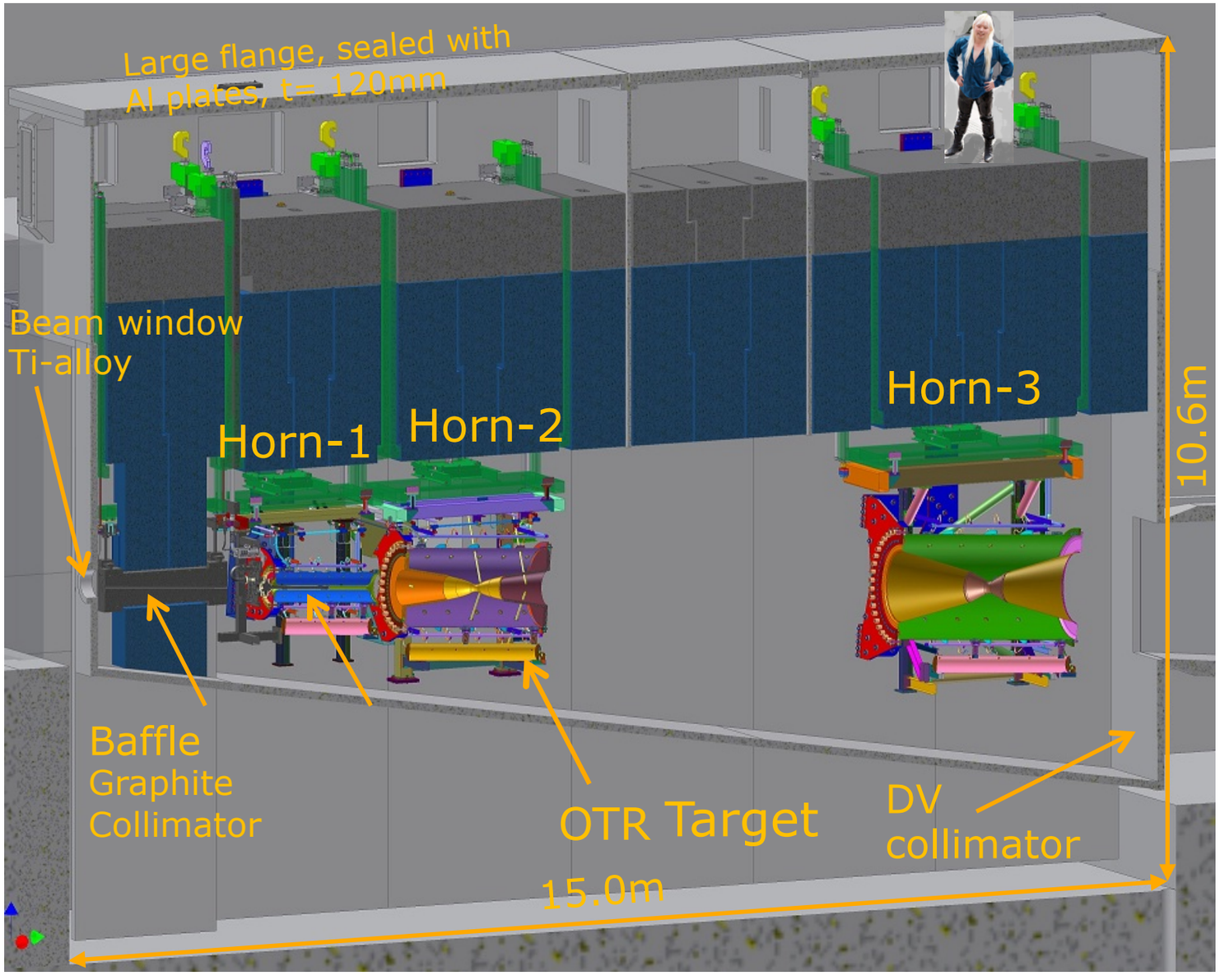


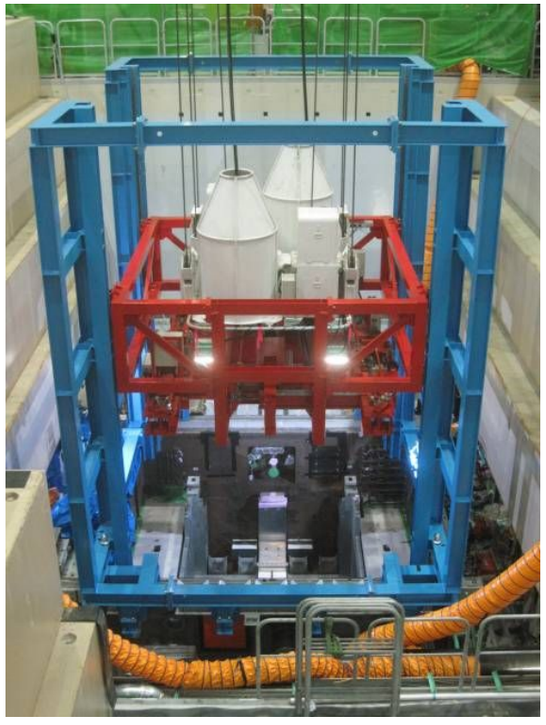


Target Station

All equipments inside Helium Vessel can be replaceable







- All beamline equipments are highly irradiated at O(10) Sv/h
- Exchangeable with remote handling.
- Guide system for precision alignment during movement.

Talk by M. Tada

Contents

MR Beam Power Upgrade Plan

Beam Power	470 (achieved)	750kW (proposed) [original]	1MW (demonstrated)	1.3MW (proposed)
# of protons/ pulse	2.4 x 10^{14}	2.0x10^{14} [3.3x10^{14}]	2.6x10^{14}	3.2x10^{14}
Operation cycle	2.48 s	1.3 s [2.1 s]	1shot	1.16 s

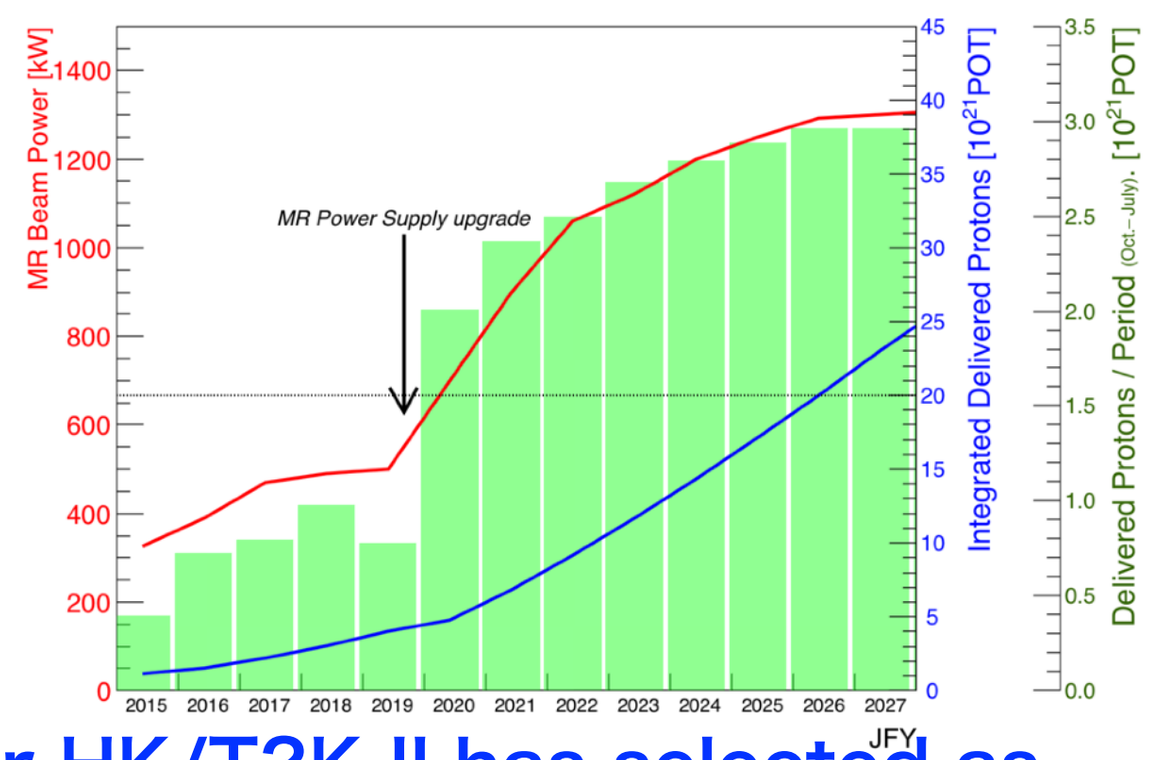
+25% (2.4 x 10^{14} → 3.2x10^{14})

+18% (2.6x10^{14} → 3.2x10^{14})

T2K-II Protons-On-Target Request

Method

- Increase repetition rate for 750kW
- Increase beam intensity for >1.3MW



- Accelerator/beamline upgrade for HK/T2K-II has selected as the highest priority project in KEK PIP

MR Upgrade Plan

Courtesy of T. Koseki

Revised in Jan. 2017

JFY	2015	2016	2017	2018	2019	2020	2021	2022
		New buildings →			Long shutdown			
FX power [kW]	390	470	480-500	> 500	700	800	900	1060
SX power [kW]	42	42	50	50-60	60-80	80	80-100	100
Cycle time of main magnet PS New magnet PS	2.48 s		Mass production installation/test →		1.3 s →	1.3 s	1.3 s	1.3 s
High gradient rf system 2nd harmonic rf system	Installation →		Manufacture, installation/test →				→	→
Ring collimators	Add.collimators (2 kW)				Add.colli. (3.5kW)		Upgrade for 1.3MW	
Injection system FX system	Kicker PS improvement, Septa manufacture /test →							
	Kicker PS improvement, FX septa manufacture /test →						→	
SX collimator / Local shields					Local shields →			
Ti ducts and SX devices with Ti chamber			ESS					

Neutrino Beamline Upgrade

- **Basic philosophy for beamline design**
  - Most of components were designed to accept **3.3x10^{14} ppp**
  - Replaceable components designed for **750kW** (can be upgraded later)
  - Non-replaceable components (HV, DV, BD) designed for **3~4MW**
- **Necessary upgrade toward >1.3MW**
  - **Primary beamline**
    - Upgrade beam monitors
    - Produce larger aperture magnets
    - Remote maintenance for equipment in final focusing section
  - **DAQ**
    - Upgrade DAQ/control system for higher rep. rate and safety operation
  - **Secondary beamline**
    - Upgrade Horn system for higher current operation (250kA → **320kA**)
    - Increase **cooling capacity** for secondary beamline components
    - Increase capacity for **radioactive water disposal**
    - Understand **radiation damage** and develop more radiation-resistant beamline components (target/beam window, etc)

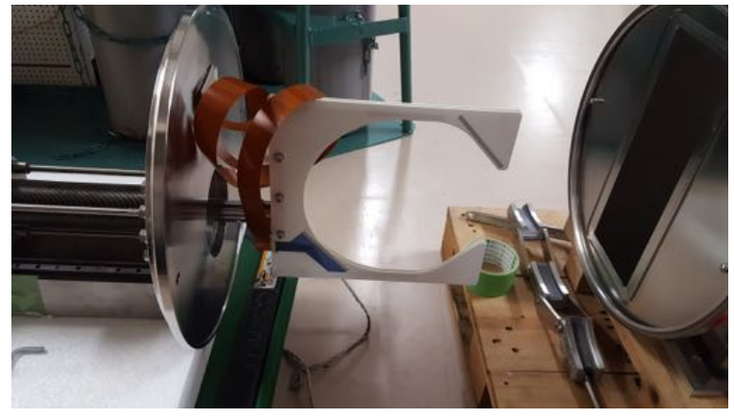
Current Acceptable Beam Power

Component	Limiting factor	Current acceptable value	
Target/ Beam window	Thermal shock	3.3x10^{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	0.75MW	
Decay Volume	Thermal stress	4MW	
	Cooling capacity	0.75MW	
Beam Dump	Oxidization	3MW	
	Cooling capacity	0.75MW	
Radiation disposal	Radioactive air	>2MW	
	Radioactive water	0.4MW	

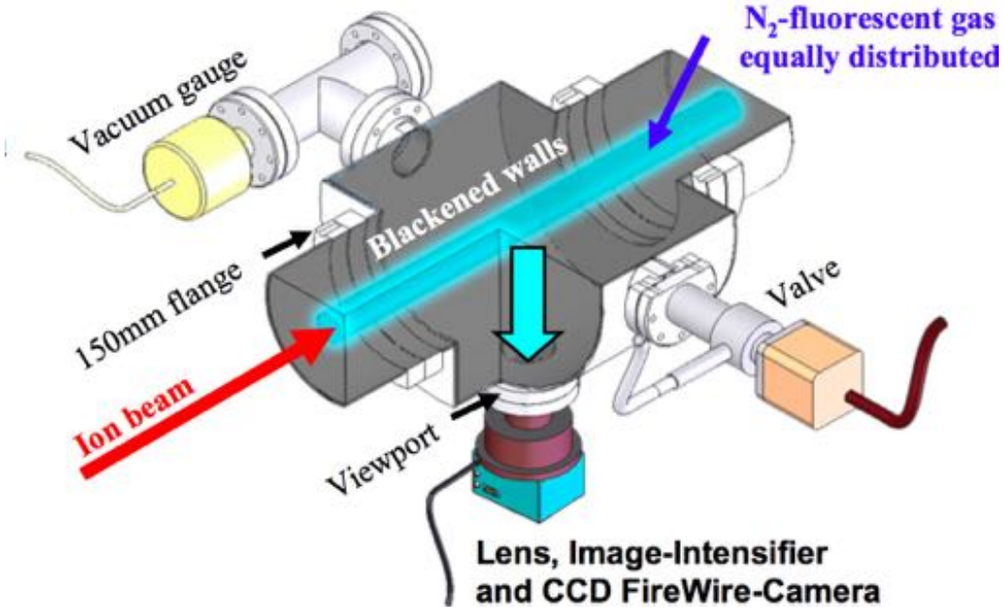
Beam Monitor Upgrade

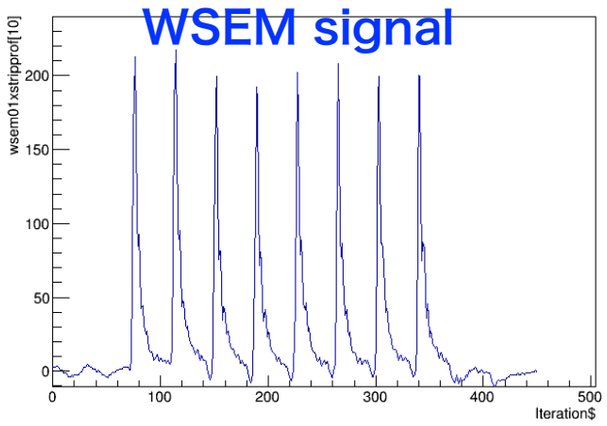
- **Wire Secondary Emission Monitor (WSEM)**
  - First prototype installed ⇒ worked well as expected
  - Beam loss reduced by 1/10 of current SSEM
- **Beam Induced Fluorescent Monitor (BIF)**
  - Light emission from beam-gas interaction
  - Various component tests ongoing
- **Schedule**
  - Aim to install
    - WSEM in ~2018
    - BIF in ~2020

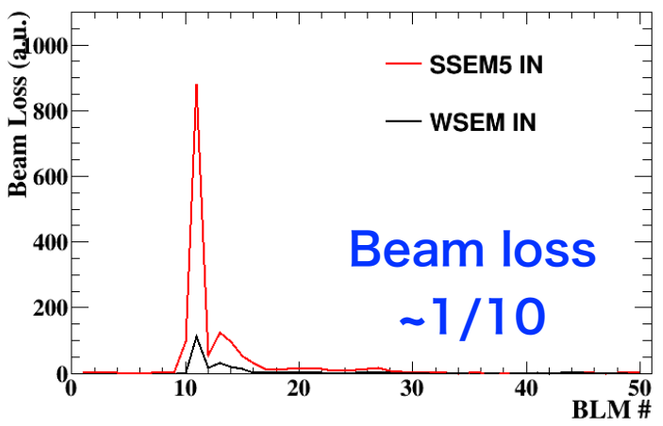
Talk by M. Friend



WSEM Mounted on Mover

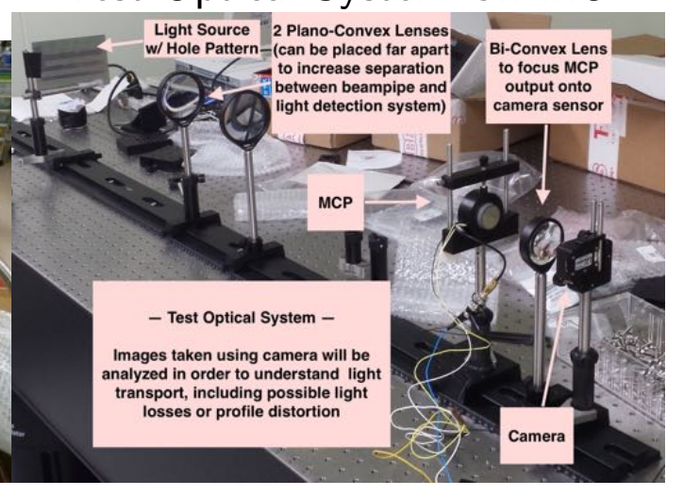






Test Vacuum Vessel @Tokai

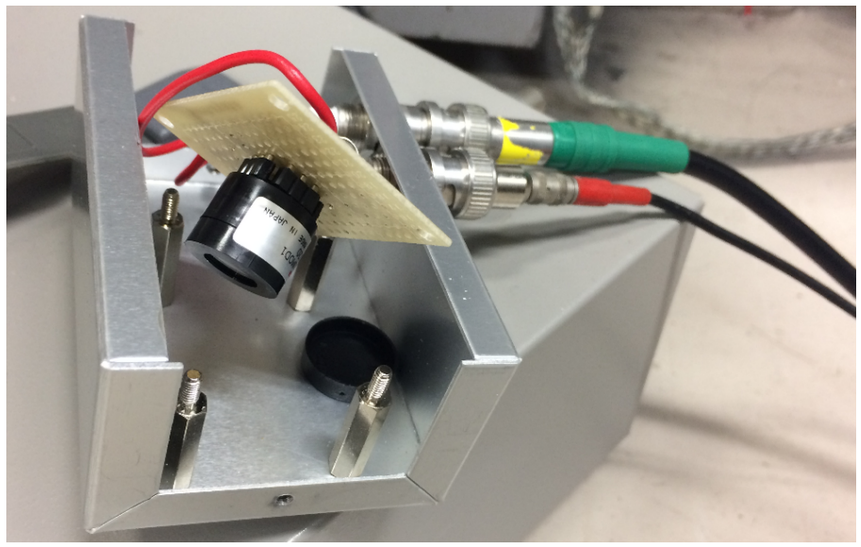
Test Optical System @IPMU

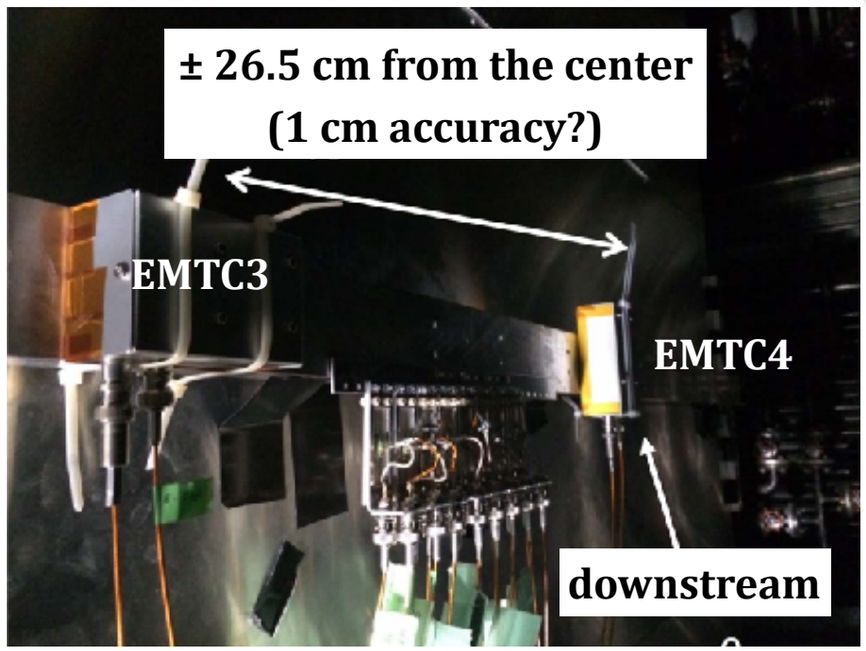


Other Monitors

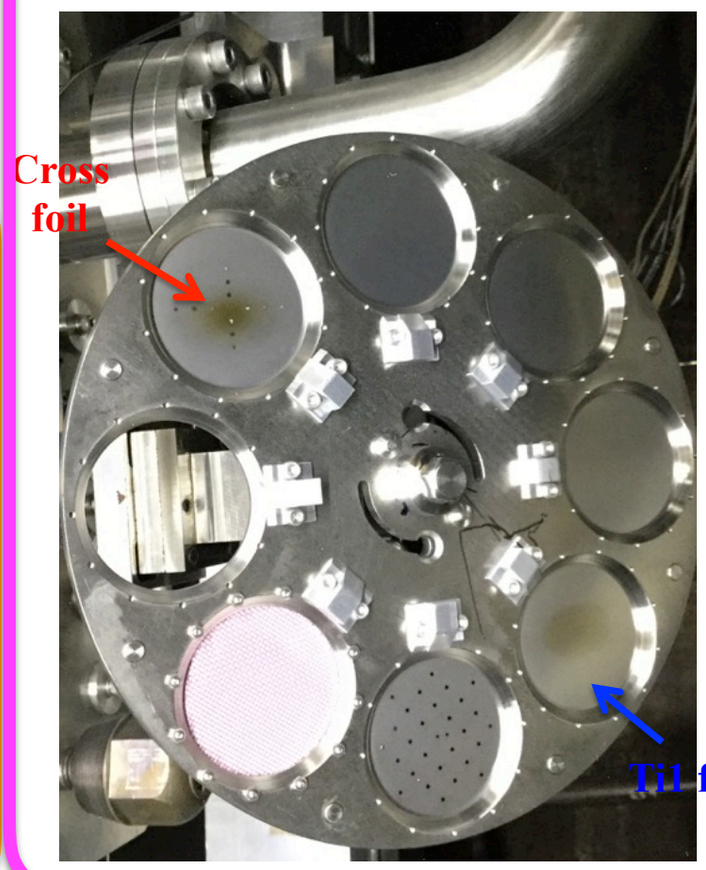
- **Muon monitor upgrade** Talk by Y. Ashida
  - Existing: Si and Ion Chamber ⇒ Si is not high radiation tolerant
  - Developing new type of muon monitors (electron multiplier tube, EMT)
- **OTR upgrade** Talk by M. Yu
  - Problem on rotation system
    - Develop more redundant system
  - Radiation damage is an issue
    - New Ti material to be used

MUMON



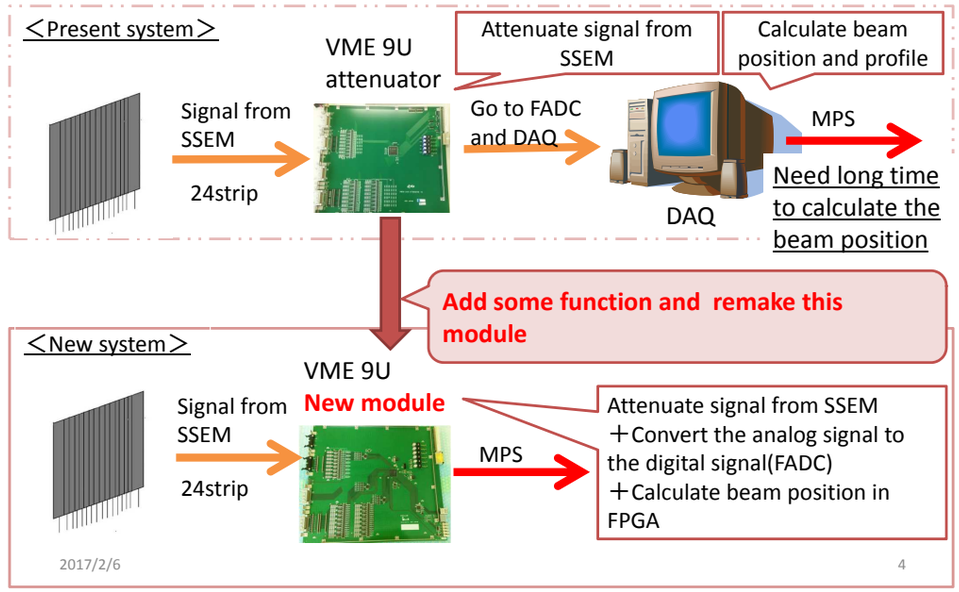


OTR

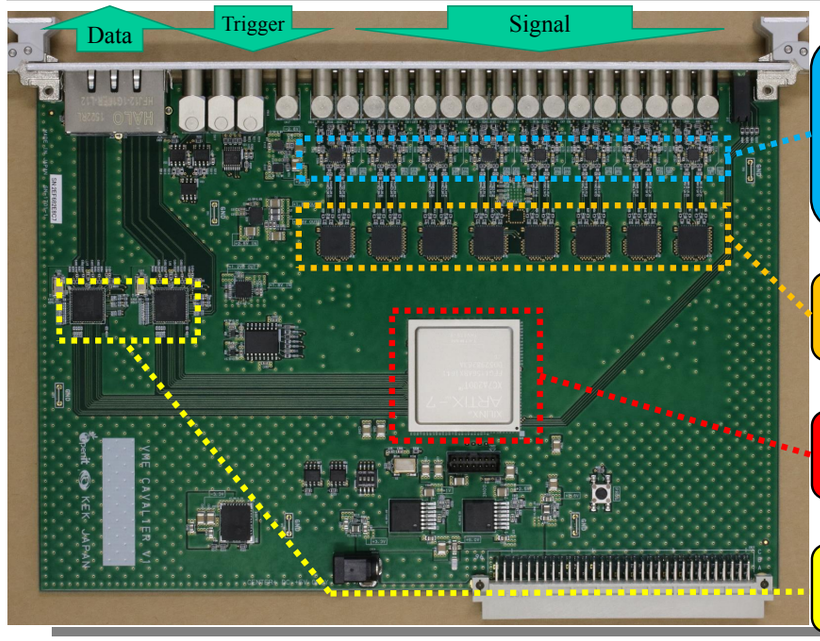


Control/DAQ Upgrade for 1Hz Operation

- Faster DAQ for high rep. rate ⇒ New FADC (by Hamada@KEK)
- New hardware interlock for safe beam operation ⇒ New interlock module (by Yamasu@Okayama U)
- Prototype boards under development
- Aim to implement in FY2019 or earlier



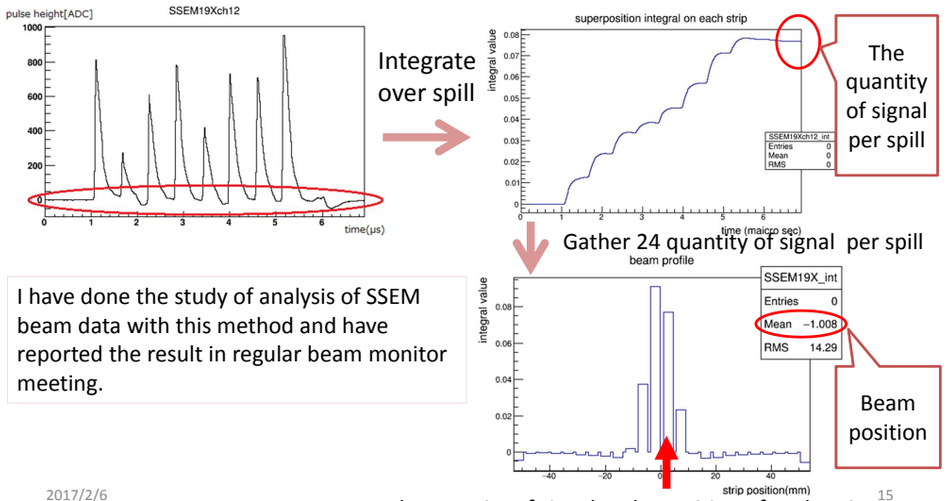
CAVALIER
(16 ChAnnel Vme Adc moduLe for neutrIno ExpeRiment)



Future prospect

Beam position calculation method in FPGA

I'm making beam position calculation firmware now.



I have done the study of analysis of SSEM beam data with this method and have reported the result in regular beam monitor meeting.

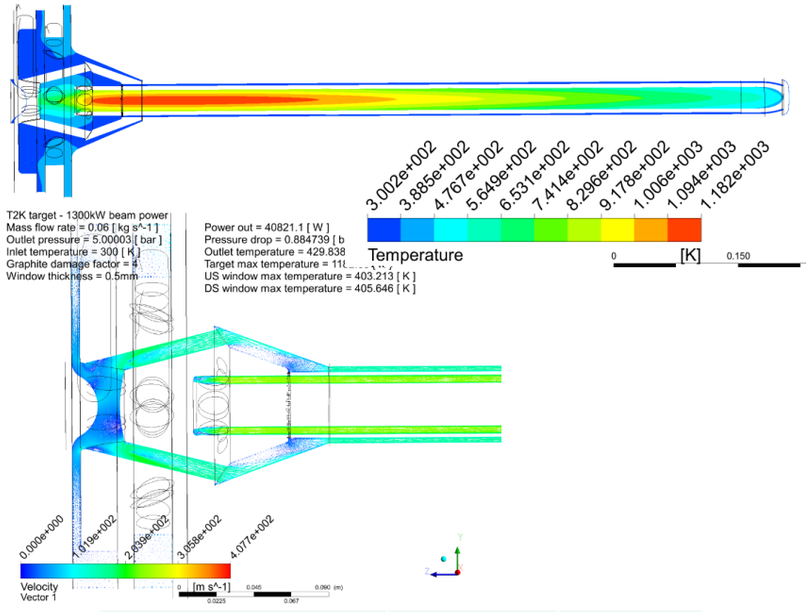
Make quantity of signal and a position of each strip agree

Target Upgrade

Talk by T. Nakadaira

- **Original target design**
  - Design intensity = 3.3×10^{14} ppp → **3.2×10^{14} ppp** should be no problem
    - Understanding radiation damage is crucial
  - Cooling capacity: 750kW + 20% margin → **900kW**
- **Improvement**
  - **Higher flow rate** needed → higher pressure tolerance

  - **Upgrade of He compressor** is needed to increase flow rate
- FEM simulation for 1.3 MW ⇒ max temp. = 909℃ (should be reduced)
  - Further study is ongoing

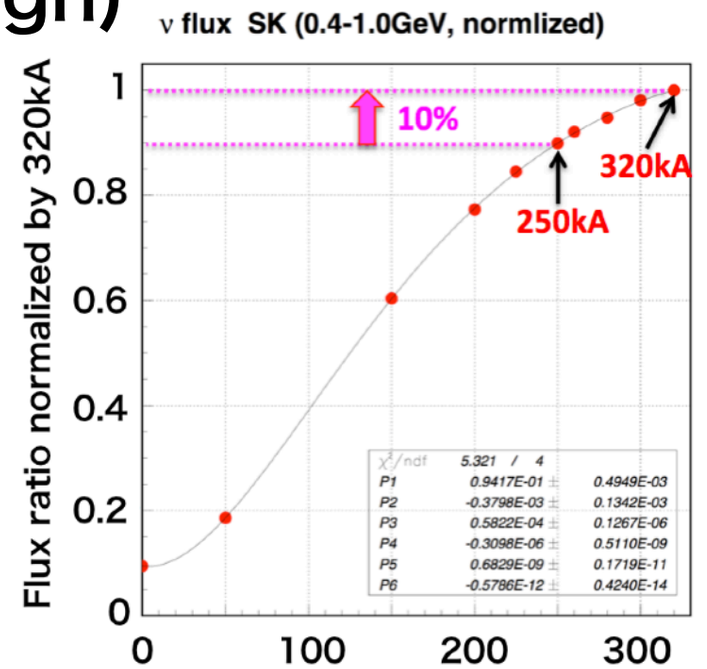


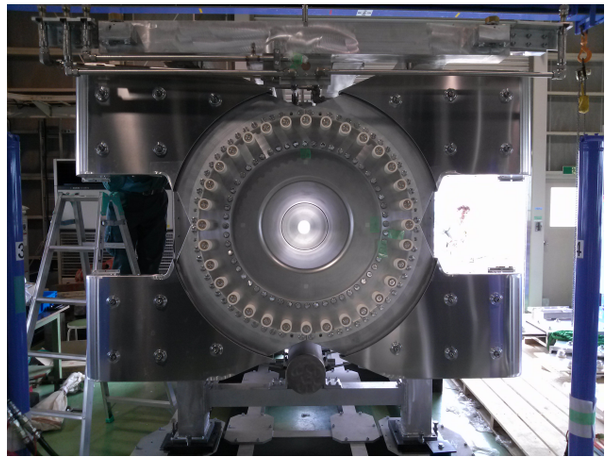
	0.75 MW	1.3 MW
Helium pressure	1.6 bar	5 bar
Pressure drop	0.83 bar	0.88 bar
Helium mass flow	32 g/s	60 g/s
Heat load	23.5 kW	40.8 kW
US window temp	105 ° C	157 ° C
DS window temp	120° C	130° C
Targe core temp	736 ℃	909 ℃

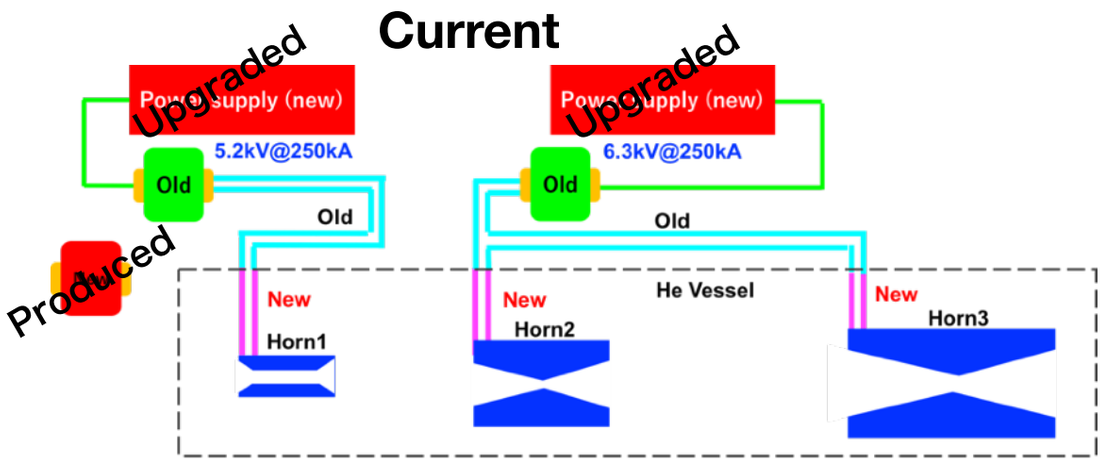
Horn System Upgrade

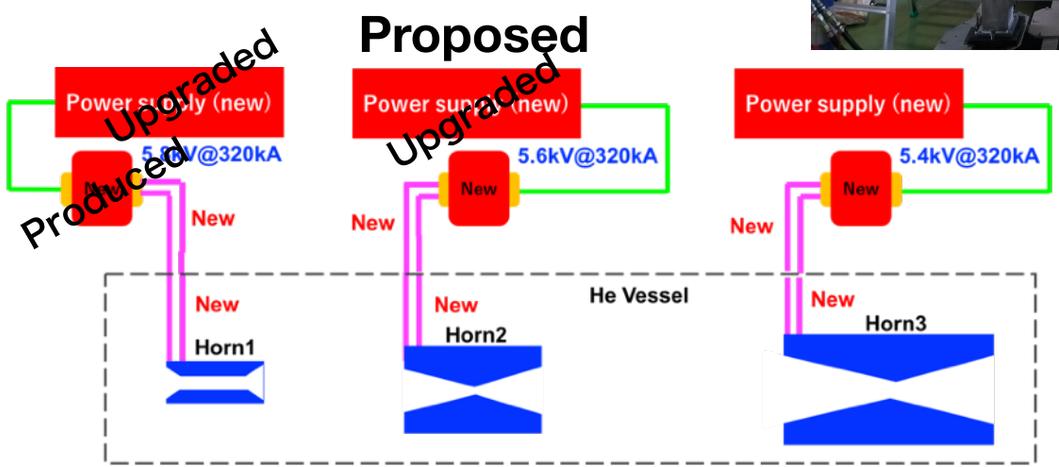
Talk by T. Sekiguchi

- **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
    - Further 1PS, 2trans., striplines needed
- **Stripline cooling improvement**
  - Higher He flow rate (>750kW) ⇒ He compressor upgrade
  - **Water-cooled striplines** to developed for >1.3MW
    - R&D ongoing ⇒ to be implemented to horn by FY2020
- **Spare horn production is also important**





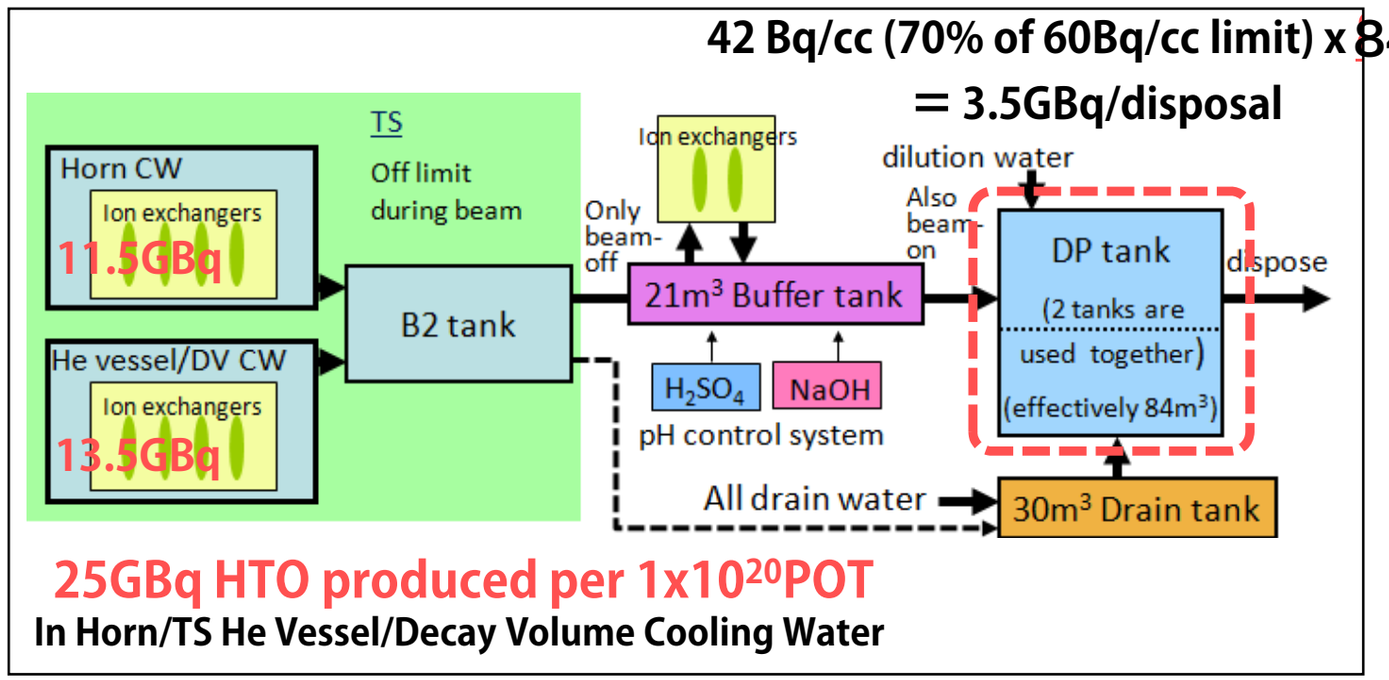




Radioactive Water Disposal

Talk by Y. Oyama

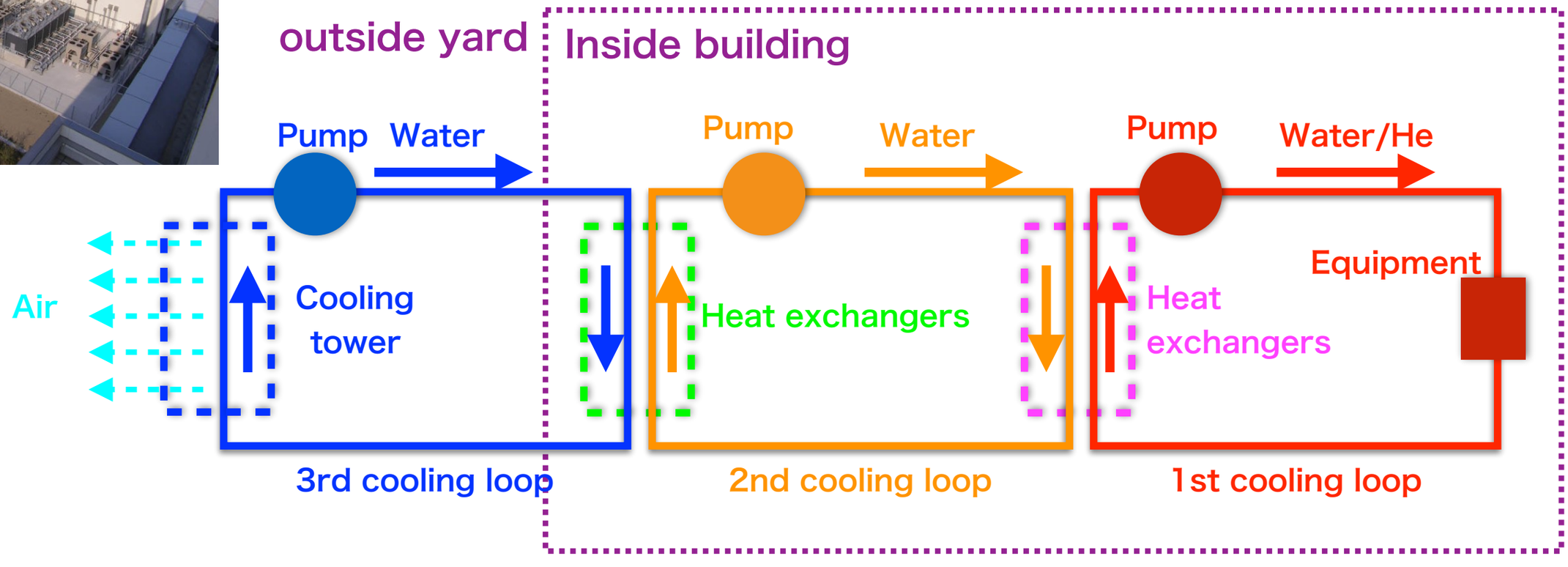
- **Radioactive water disposal**
  - **^{3}H** (Tritium) → **dilution**, **^{7}Be** → 99.9% removed by ion-exchange
- **HTO disposal by dilution**
  - Current dilution tanks (84m^3) : **400kW** (8.4x10^{20} POT/year) acceptable
  - Toward >1.3MW, following will be adopted step by step
    - **Increase disposal cycle** ⇒ needs some technical improvements
    - A portion of radioactive water is taken by **tanker truck**
    - Construct an **additional dilution tank** with O(200)m^3, entailing construction of new dedicated building



Cooling Capacity Improvement

- Secondary beamline
  - Designed for 750kW → higher capacity needed for > 1.3MW
- Improvement
  - Higher flow rate → replace with larger pumps
  - Higher cooling capacity → larger heat exchangers/cooling tower

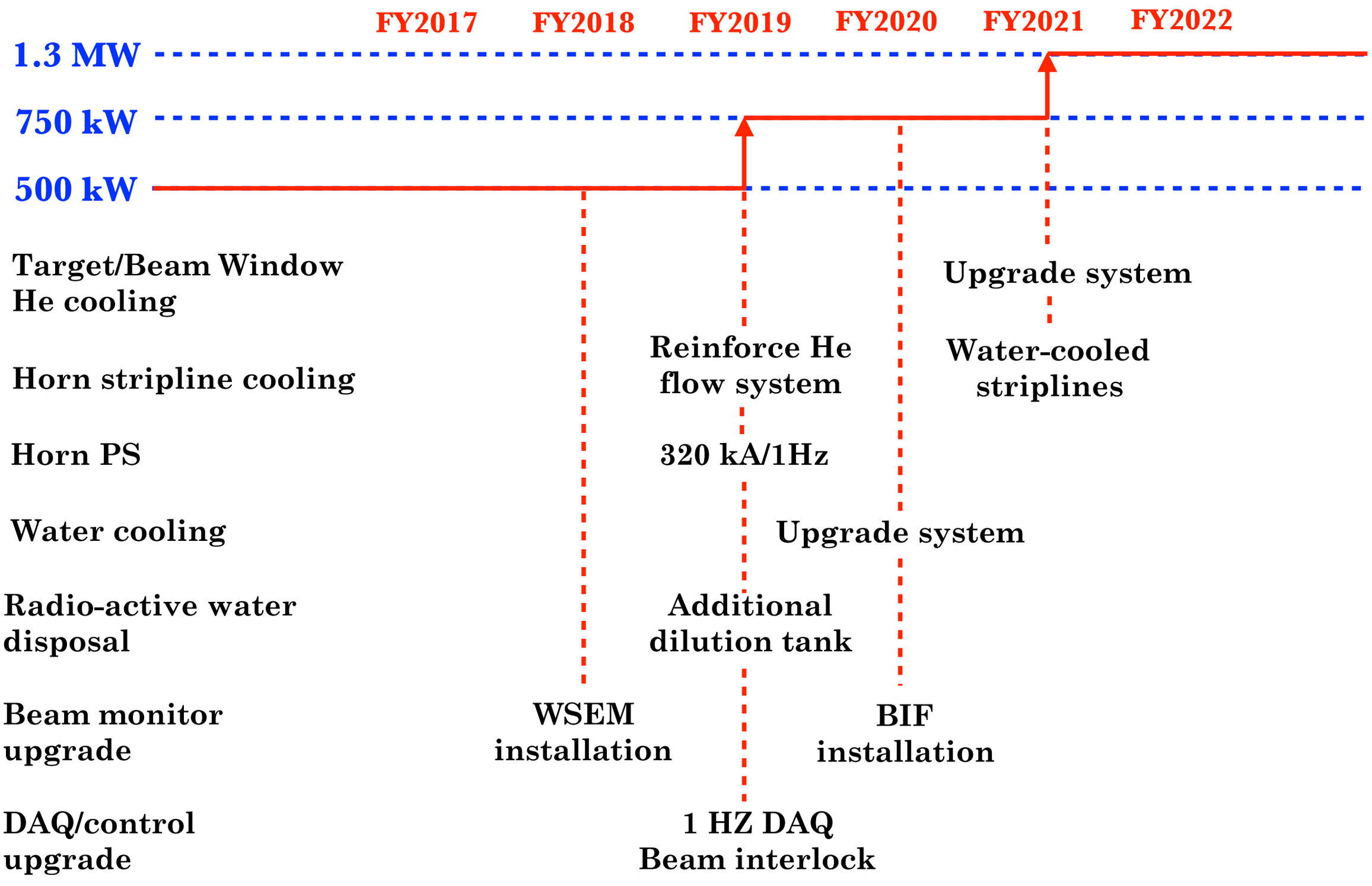
Detailed design is needed soon



Acceptable Beam Power

Component	Limiting factor	Current acceptable value	Upgraded acceptable value
Target/ Beam window	Thermal shock	3.3×10^{14} ppp	3.3×10^{14} ppp
	Cooling capacity	0.9MW	>1.5MW
Horn	Conductor cooling	2MW	2MW
	Stripline cooling	0.75MW	>3MW
	Hydrogen production	1MW	>1.5MW
	Operation	250kA, 2.48s	320kA, 1s
He Vessel	Thermal stress	4MW	4MW
	Cooling capacity	0.75MW	>1.5MW
Decay Volume	Thermal stress	4MW	4MW
	Cooling capacity	0.75MW	>1.5MW
Beam Dump	Oxidization	3MW	3MW
	Cooling capacity	0.75MW	>1.5MW
Radiation disposal	Radioactive air	>2MW	>2MW
	Radioactive water	0.4MW	>1.5MW

Timeline


FY2017
FY2018
FY2019
FY2020
FY2021
FY2022
1.3 MW
750 kW
500 kW
Target/Beam Window
He cooling
Upgrade system
Reinforce He
flow system
Water-cooled
striplines
Horn stripline cooling
Horn PS
320 kA/1Hz
Water cooling
Upgrade system
Radio-active water
disposal
Additional
dilution tank
Beam monitor
upgrade
WSEM
installation
BIF
installation
DAQ/control
upgrade
1 HZ DAQ
Beam interlock

Contents

Summary

- **Upgrade toward 1.3 MW**
  - **Accelerator upgrade**
    - Higher rep. rate (2.48 s → 1.3 s → **1.16 s**) : PS upgrade, RF upgrade
    - Higher intensity (2.4x10^{14} ppp → **3.2x10^{14}** ppp) : RF upgrade
  - **Beamline upgrades**
    - Beam monitor upgrade
    - Control/DAQ upgrade for higher rep. rate operation
    - Target upgrade
    - Horn current upgrade to 320kA
    - Higher cooling capacity for secondary beamline
    - Upgrade of radioactive water disposal