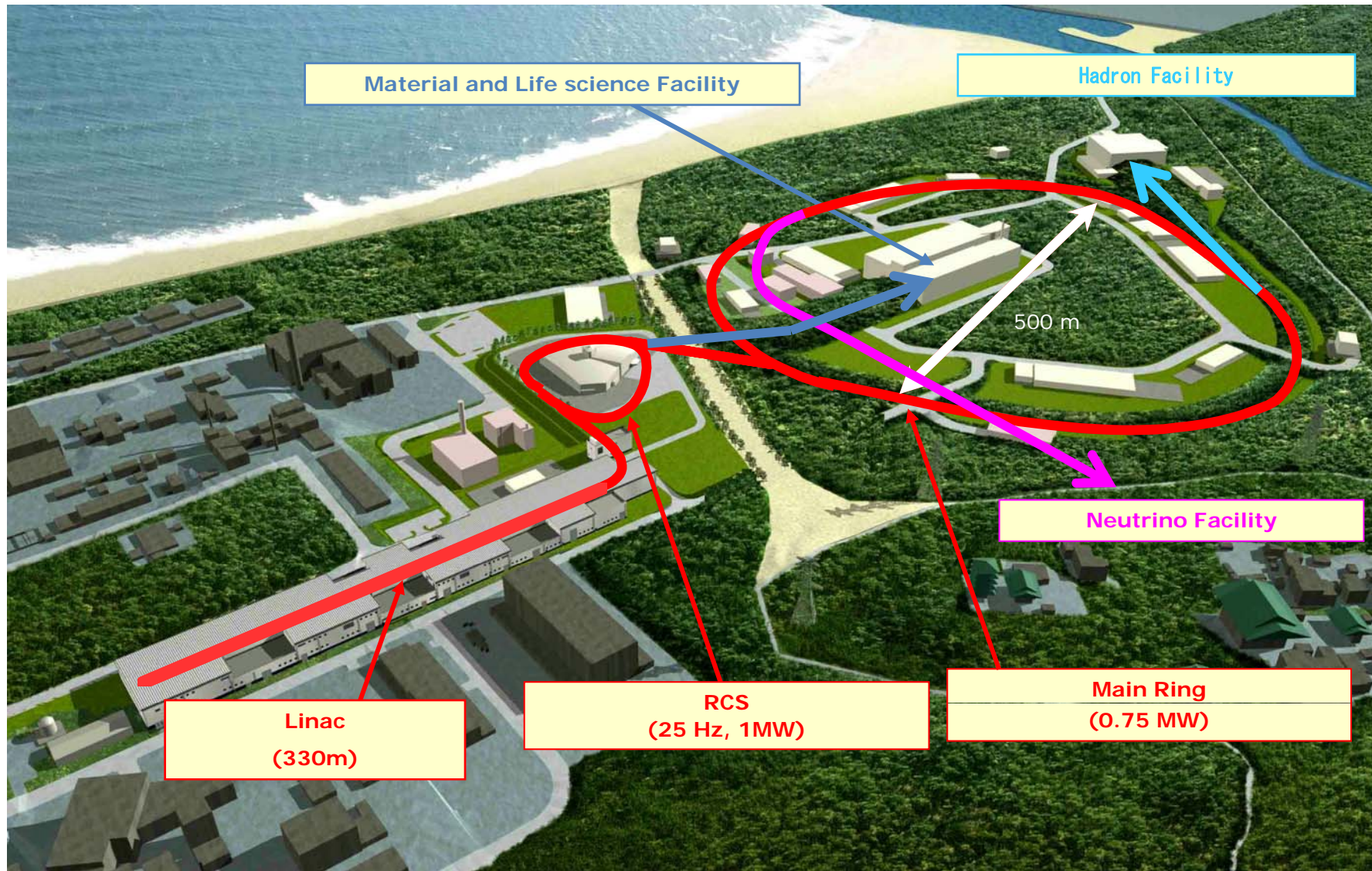


**J-PARC neutrino beamline**  
**~ Upgrade plan ~**

**2013.6.21**  
**KEK, IPNS**  
**Tada**

# J-PARC ( **J**apan **P**roton **A**ccelerator **R**esearch **C**omplex )



# J-PARC Neutrino Experimental Facility

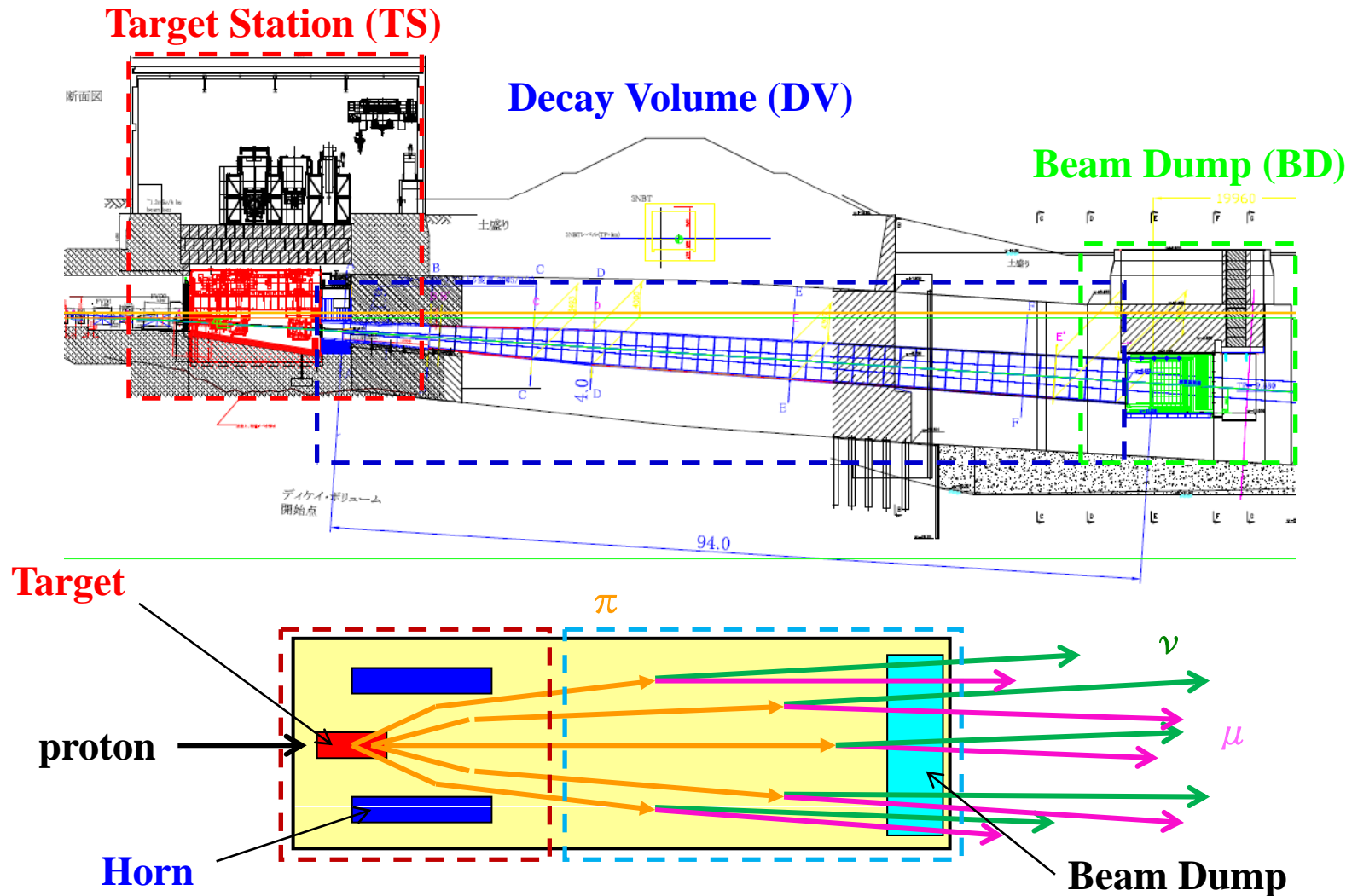
Conventional horn-focused beam-line, designed/constructed for T2K (Tokai-to-Kamioka) long base-line neutrino oscillation experiment and for its future upgrade.

J-PARC, Tokai



# Secondary Beam Line

Variable off-axis angle (2.0~2.5 degree) neutrino beam



Target

proton

Horn

$\pi$

Beam Dump

$\nu$

$\mu$

# Target Station

Remote-controlled Crane

Outer Concrete Shields (3,400t)



Outer Iron shields (2,400t)



Helium Vessel



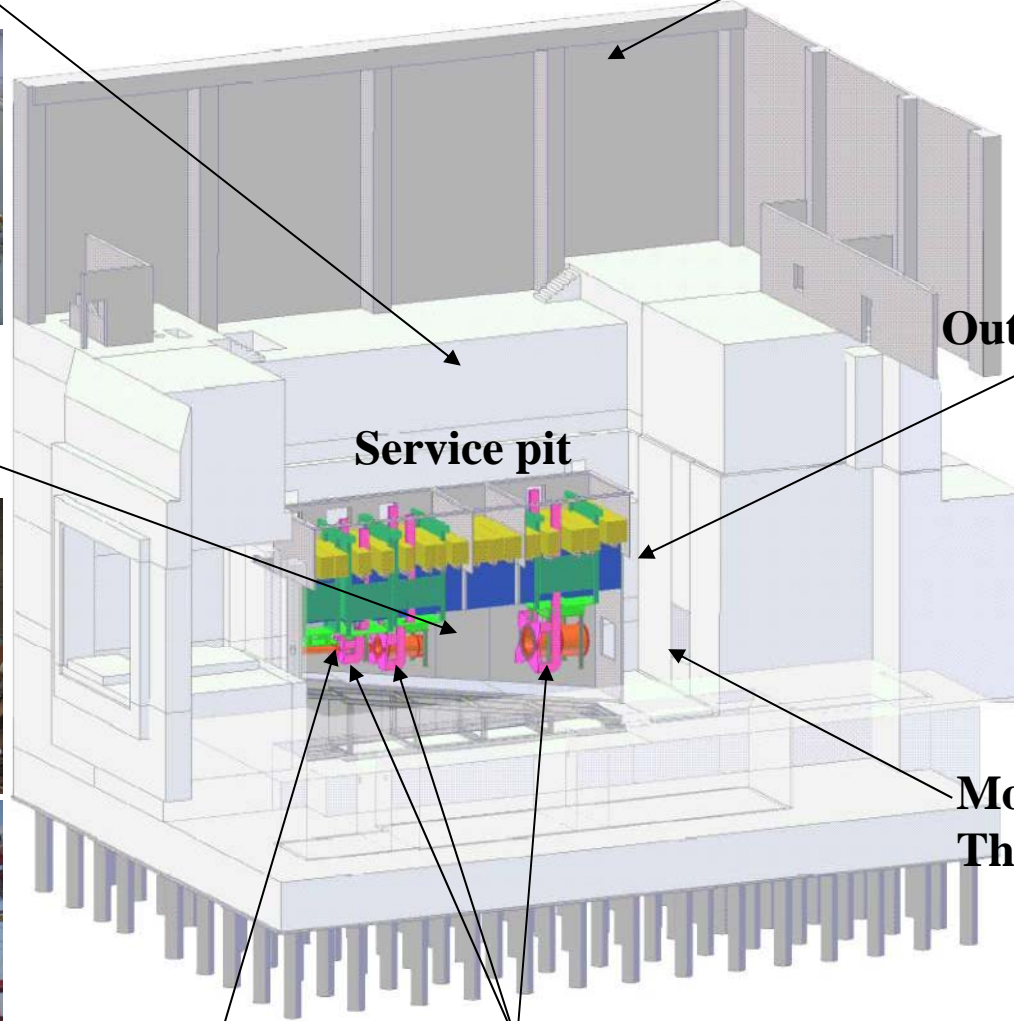
Service pit

Most Upstream Part of The Decay Volume



Target

Horn



# Inside of the Helium Vessel of the Target Station

**Horn Support Modules**

**Heart of the neutrino beamline**

**Upper Concrete Shields**

**Upper Iron Shields**

**Helium Vessel**

**15m**

**4m**

**11m**

**2.25m**

**Target (set inside of the 1st horn)**

**Horns (three)**

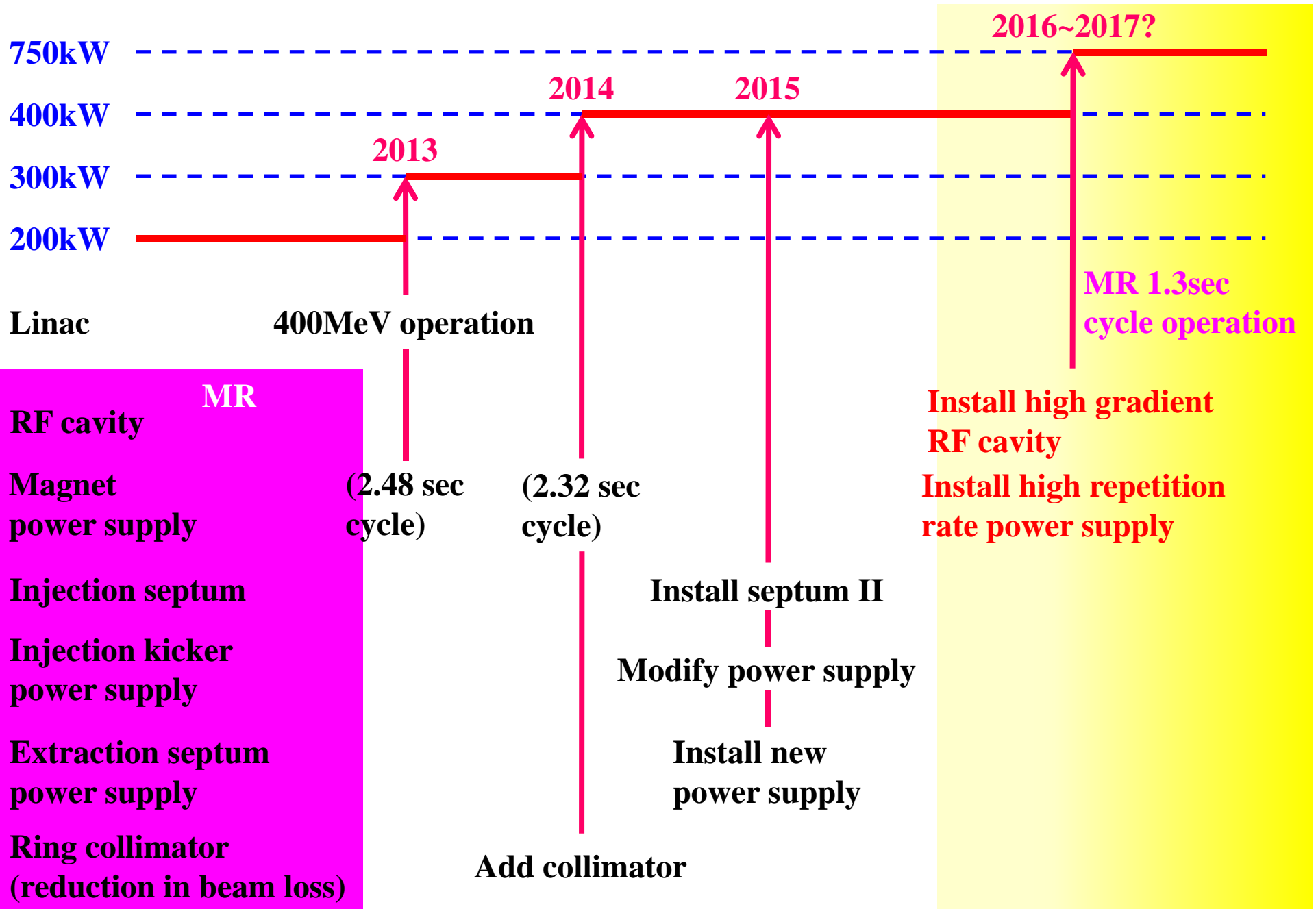
**Toroidal-type Magnet to focus the neutrino beam**

**Made of Graphite**

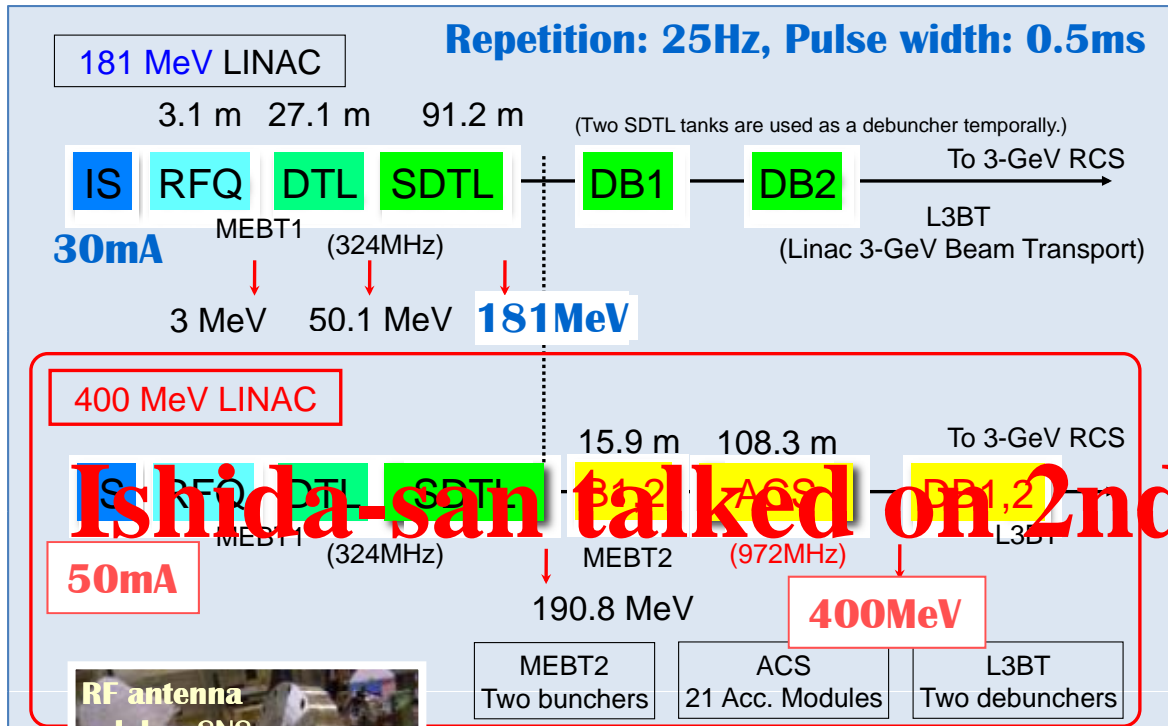
**The horns are driven by the current 320kA!  
Field : 4.3T @ r=15mm**

**Target, horns, shields are maintenance by the remote control system because of the high radioactivation of them.**

# Upgrade plan in accelerator towards high power operation



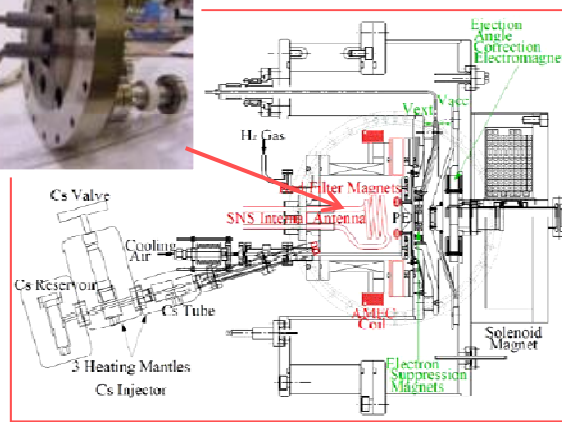
# LINAC Upgrade



- New accelerating structure, ACS, will be installed to increase the extracted beam energy from 181MeV to 400MeV
- Front-end part (IS+RFQ) will be replaced to increase peak current from 30mA to 50mA

**Ishida-san talked on 2nd open meeting**

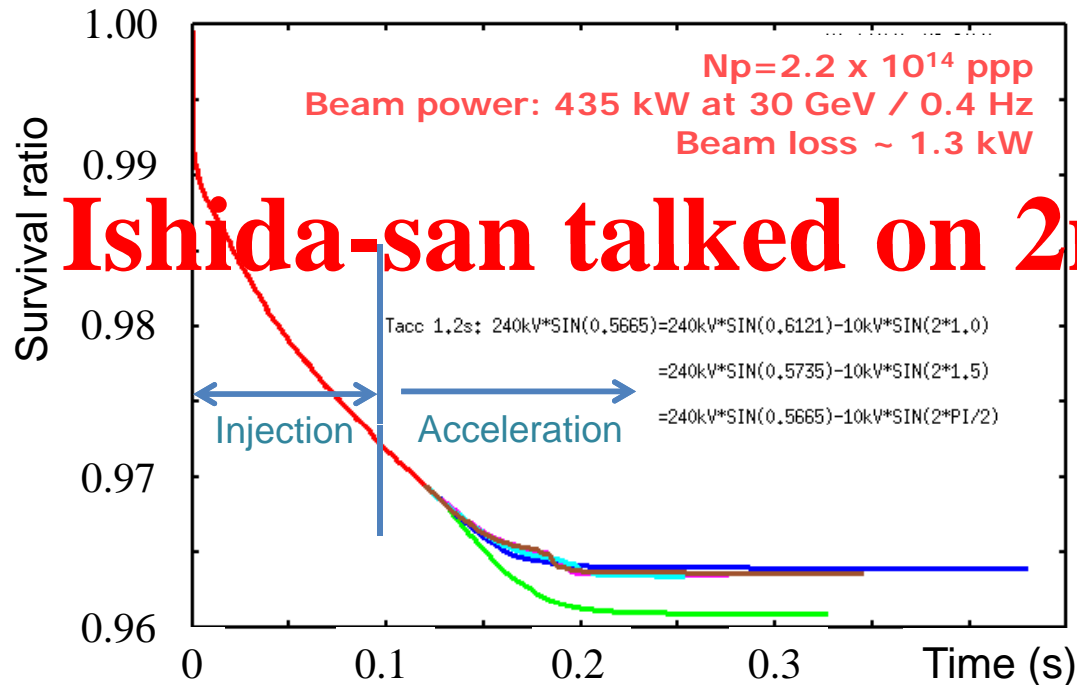
- These installations are scheduled in 2013





# For Higher Beam Power in MR Fast Extraction

Tracking simulation of the MR fast extraction with space charge effect



Ishida-san talked on 2nd open meeting

- Number of particles in one pulse is limited by the beam loss due to the space charge effect
  - **~450kW** is estimated upper limit with current apparatus
- To achieve higher beam power :
  1. Higher beam energy than 30 GeV (Original plan)
  2. Higher repetition rate than 0.4 Hz



\* The saturation effect deteriorates field quality of main magnets.

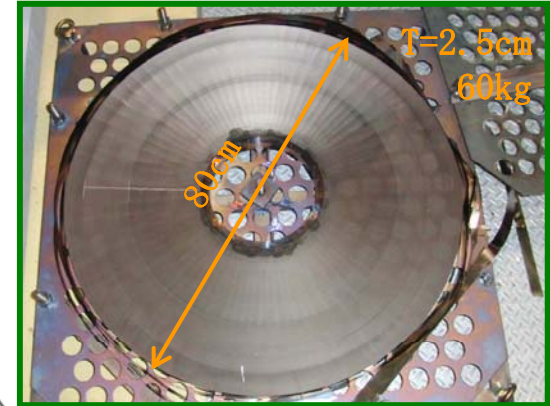
Total power consumption:

$$P_{50\text{GeV}} = 2 \times P_{40\text{GeV}} = 4 \times P_{30\text{GeV}}$$

# For 1 Hz Operation



**(3) Upgrade of injection and extraction devices**



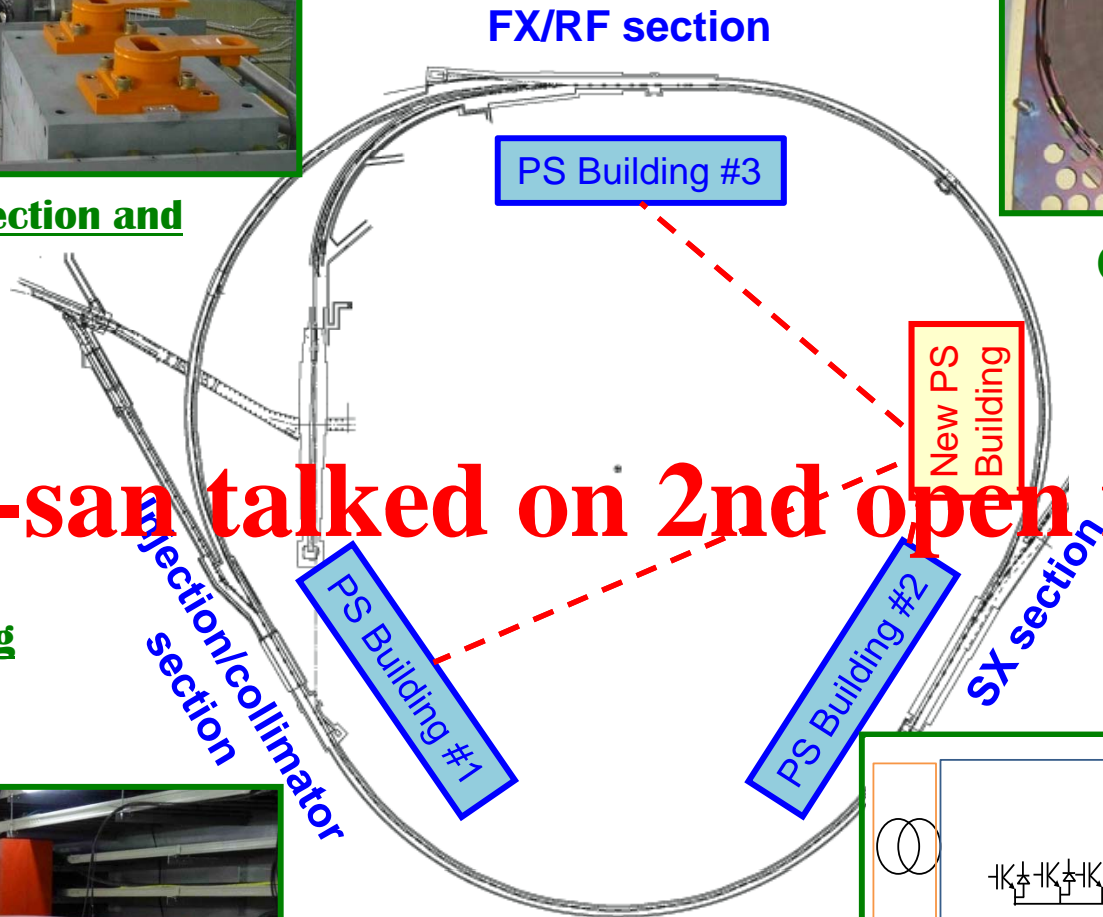
**(2) Replacement of the rf cavities**

New magnetic core material, which has x2 times higher impedance than present one, is developed.

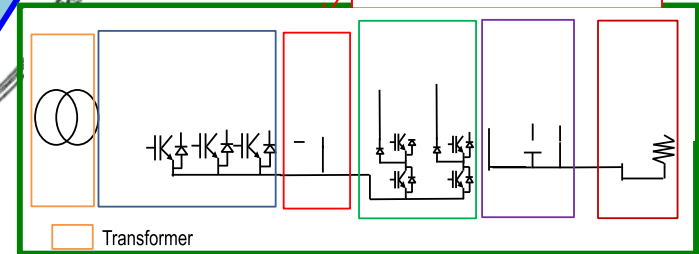
**Ishida-san talked on 2nd open meeting**

**(4) Upgrade of ring collimator section**

2kW → 3.5kW



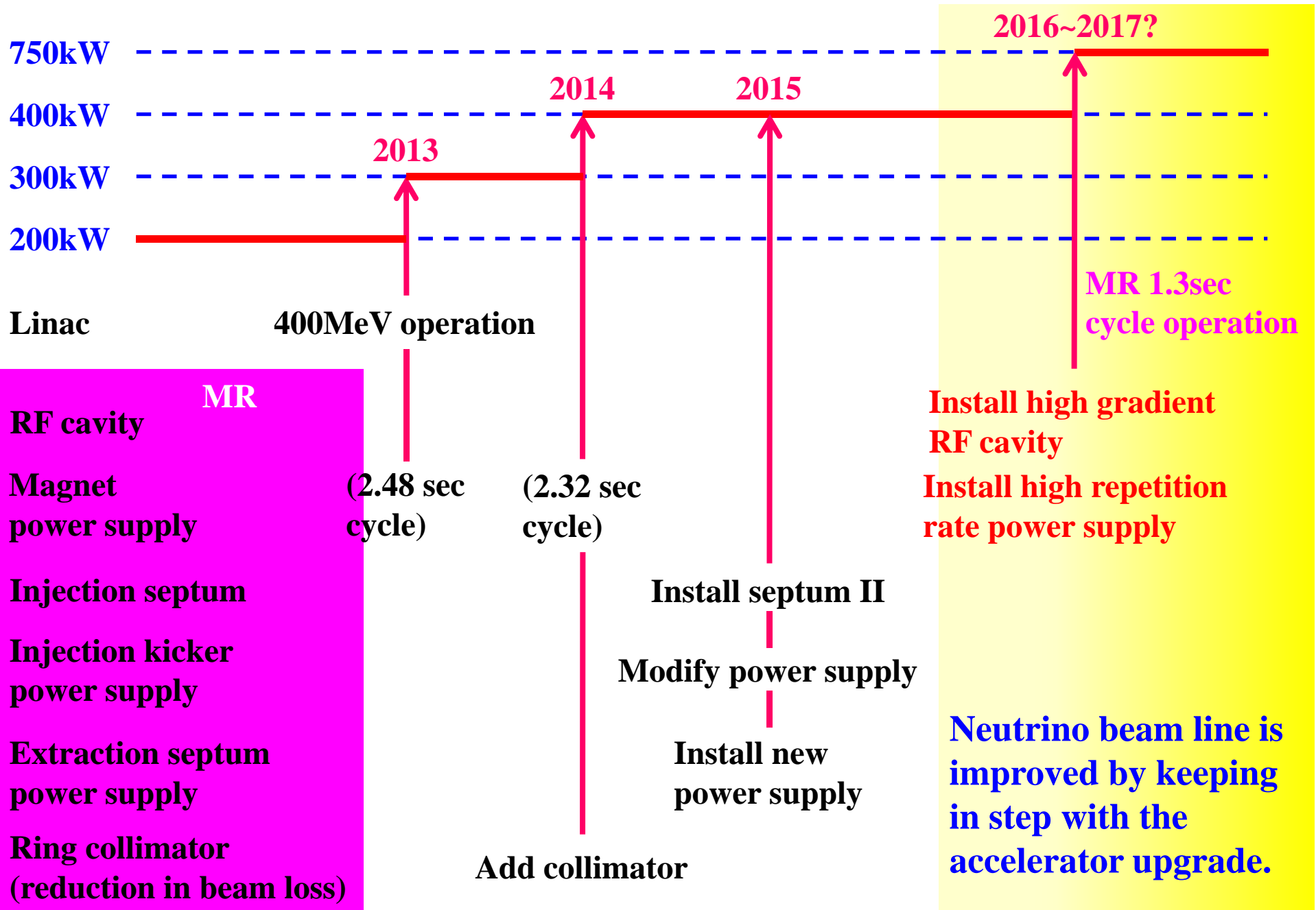
**Condenser bank For energy recovery**



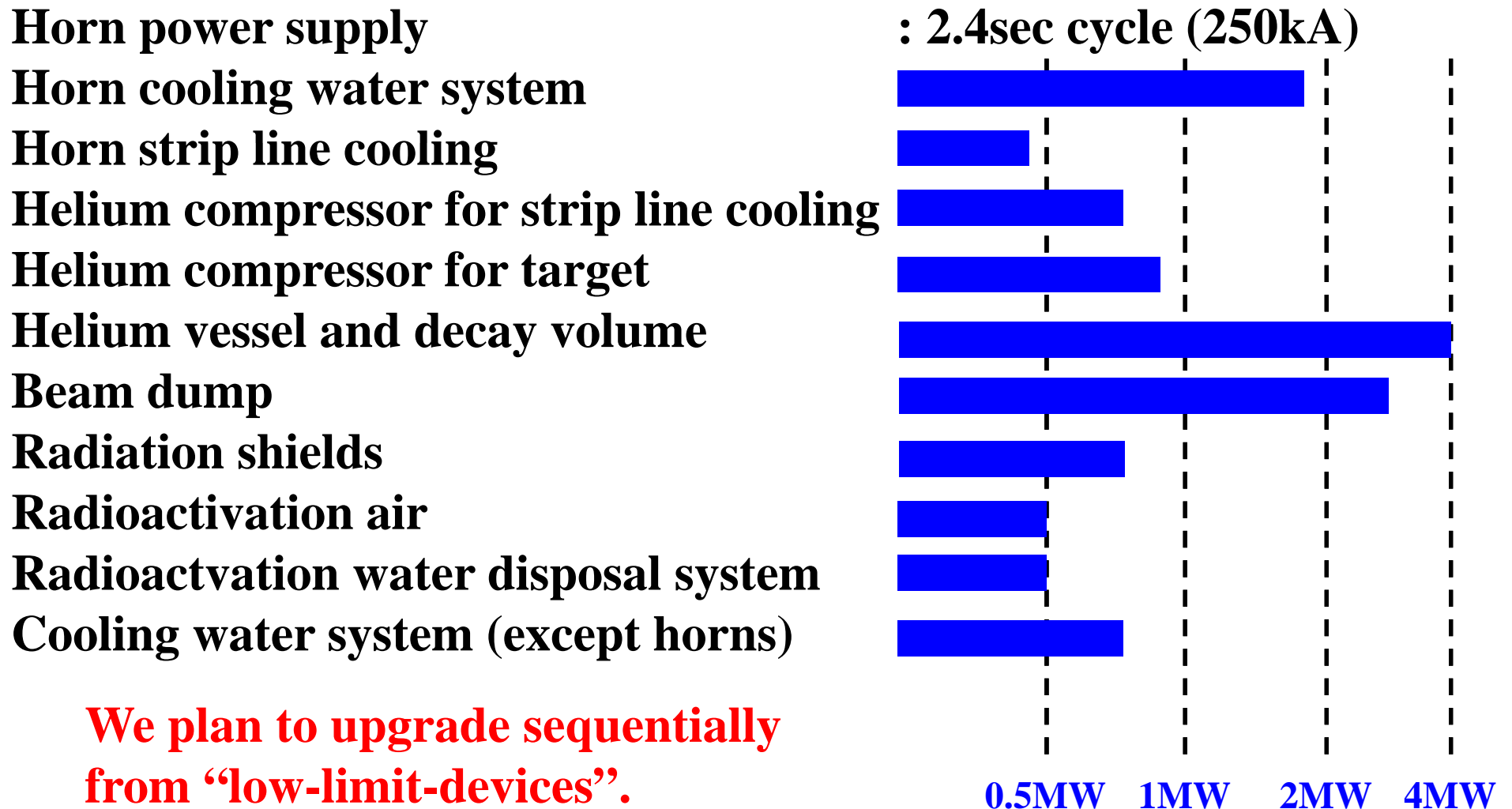
**(1) Replacement**

All the main magnet power supplies will be replaced with newly developed high rep./low ripple PS. A new PS building to be constructed.

# Upgrade plan in accelerator towards high power operation



# The limit of beam power that present devices can stand



## **Triad of the improvement plans for the beam line in this few years**

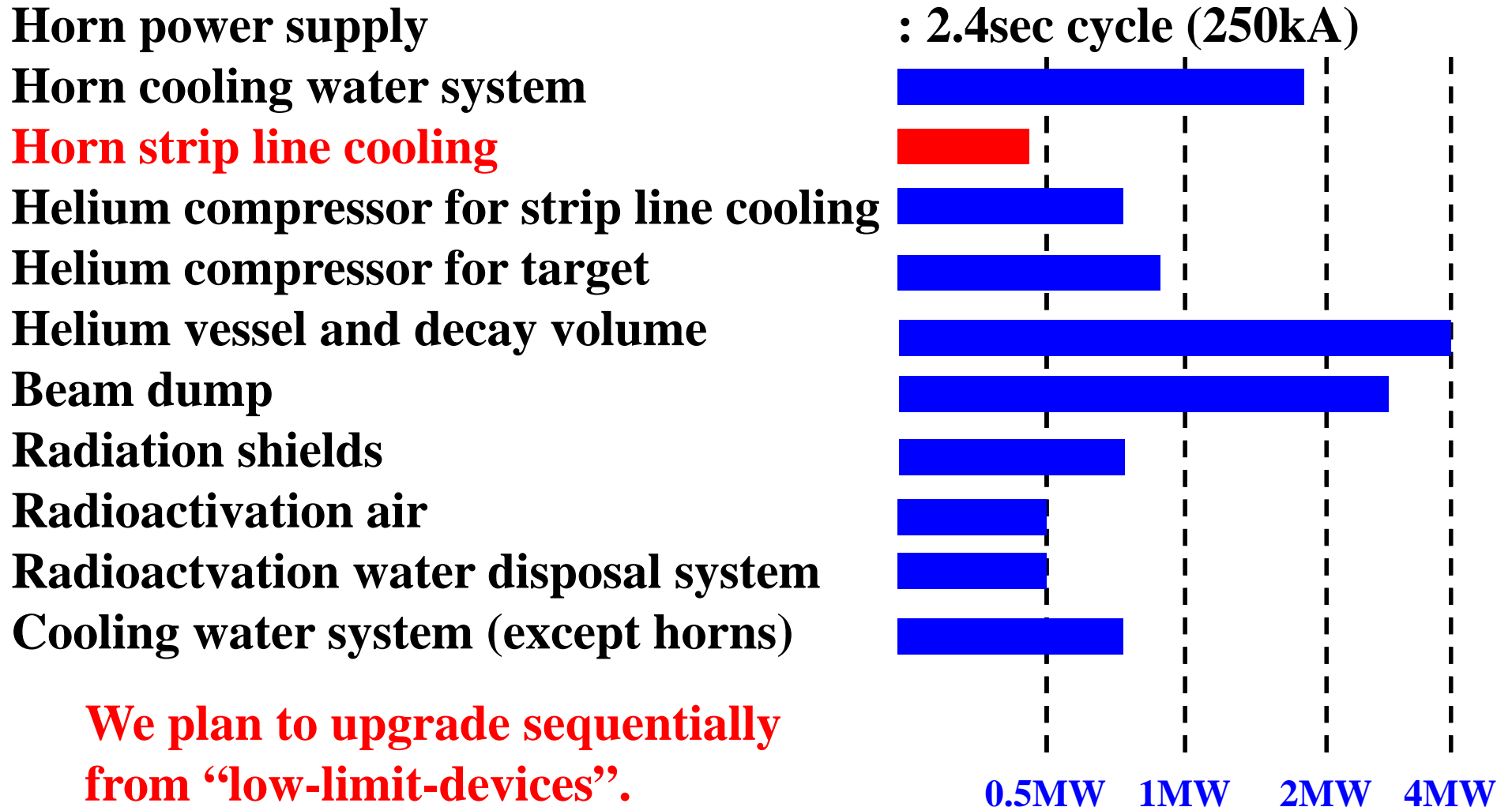
### **1) Replacement of the horns**

**New horns have the same conductor shapes  
and improved peripherals.**

### **2) Introduce new-horn-power-supply system using 3 power supplies**

### **3) Anti-radiation measure**

# The limit of beam power that present devices can stand

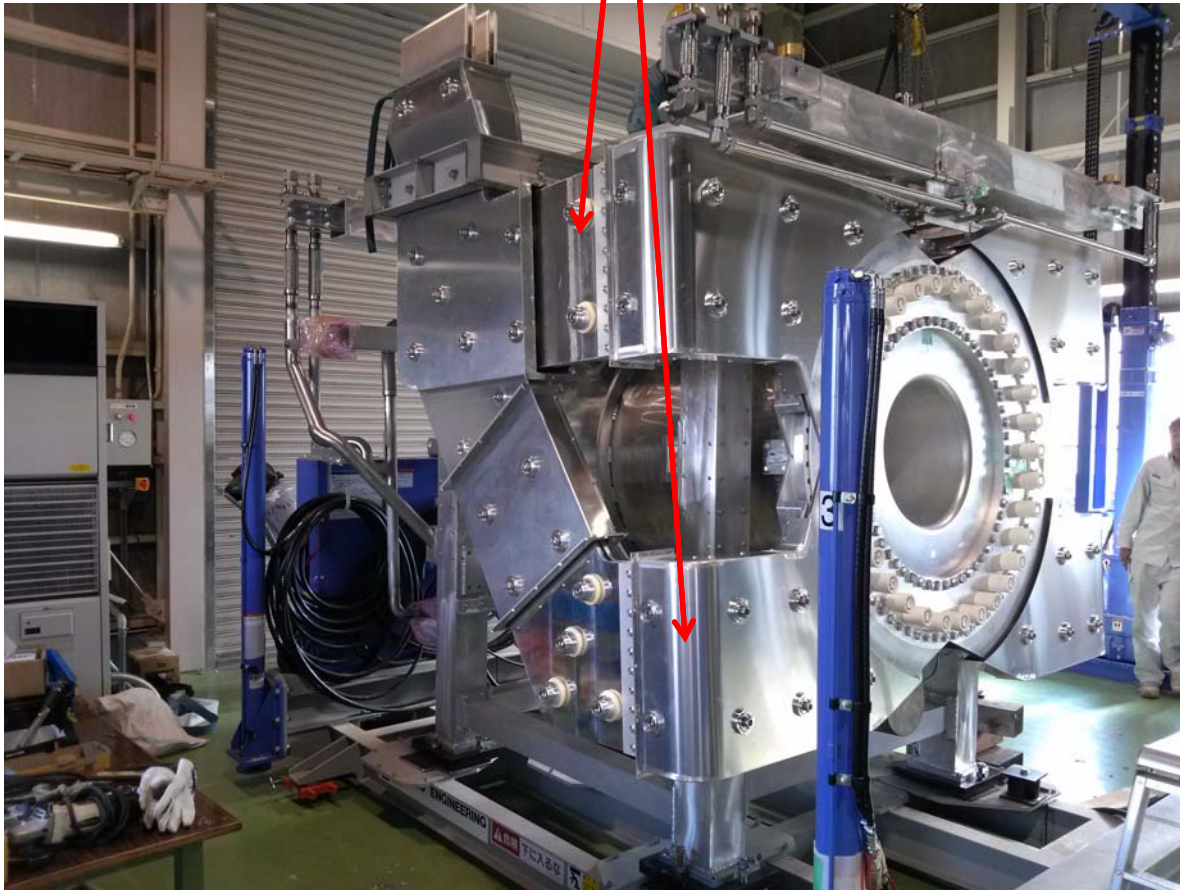


# Motivation for replacement of the horns

**1) To correspond to high-repetition rate operation on accelerator**

# Motivation for replacement of the horns

- 1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)





# Motivation for replacement of the horns

**1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)**

**2) To correspond to high-power beam**

# Motivation for replacement of the horns

**1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)**

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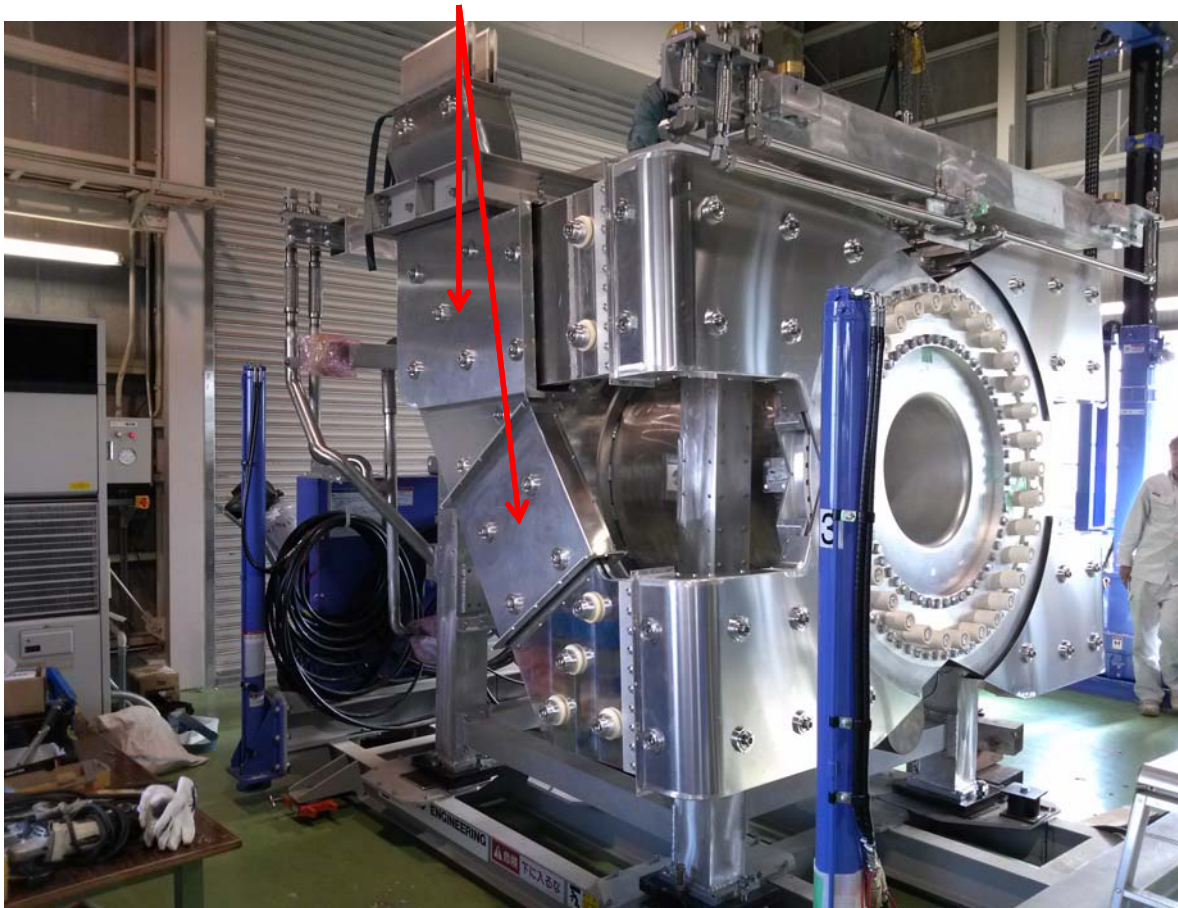
**Cooling performance  
for strip lines**

**Present horns :  
up to 400kW**

# Motivation for replacement of the horns

1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)

2) To correspond to high-power beam  
Have the high performance cooling duct for strip lines



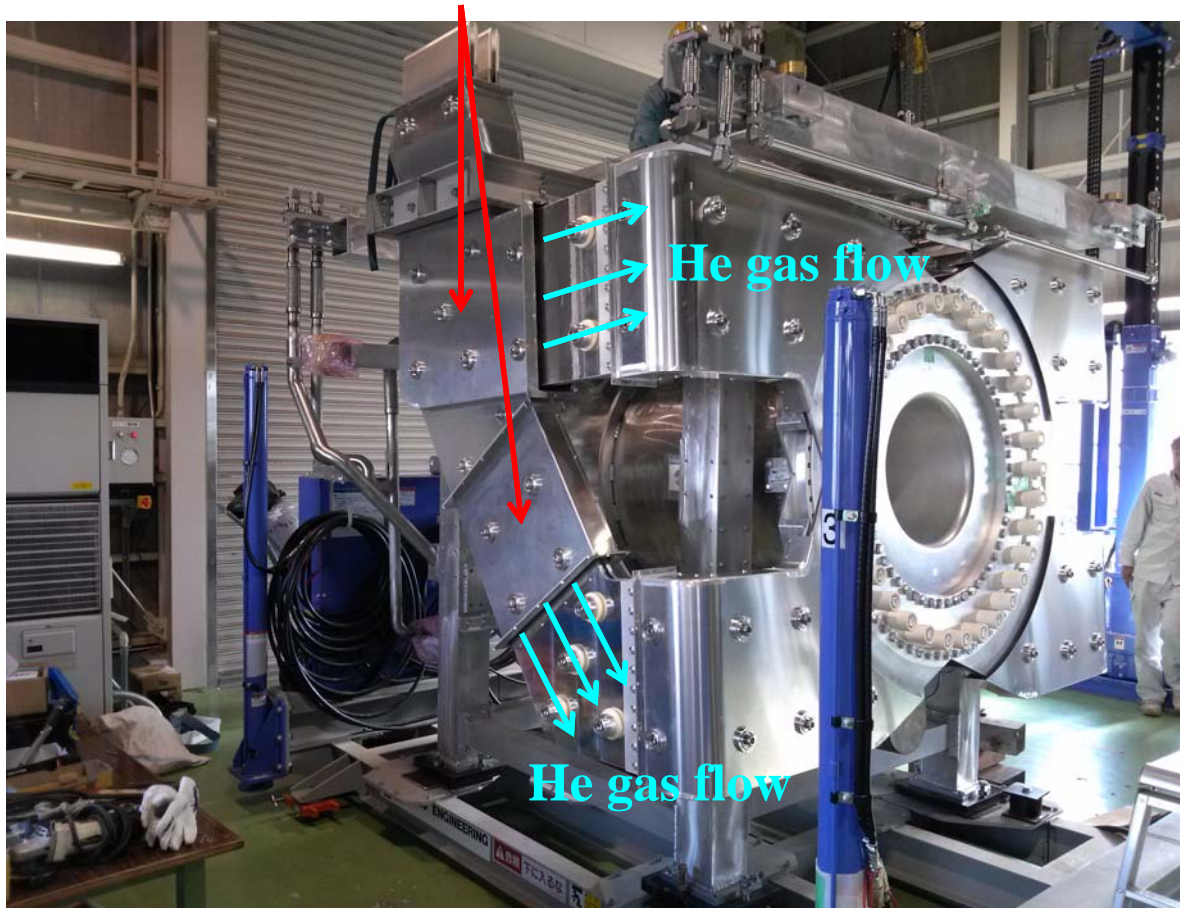
Cooling performance  
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Present horns :  
up to 400kW

# Motivation for replacement of the horns

1) To correspond to high-repetition rate operation on accelerator  
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Have the high performance cooling duct for strip lines



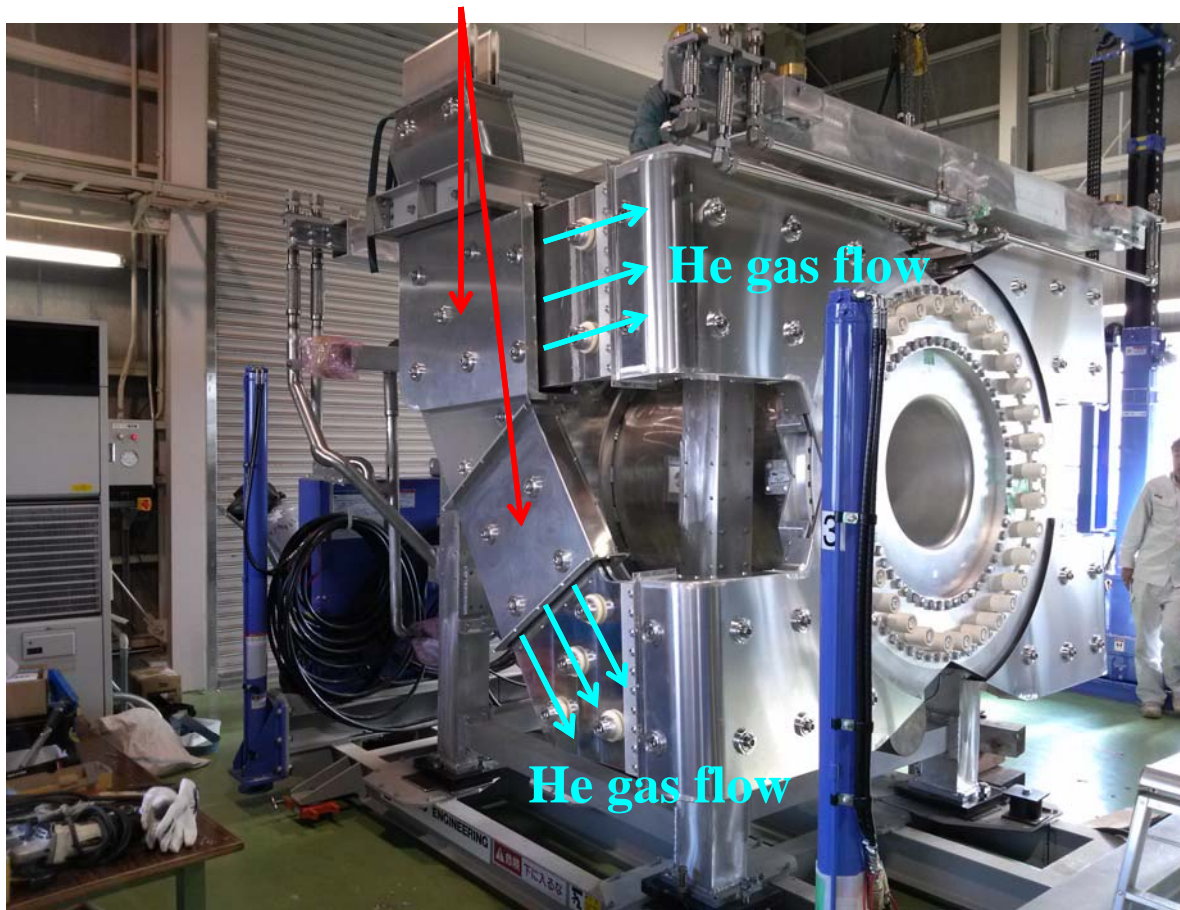
Cooling performance  
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# Motivation for replacement of the horns

1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)

2) To correspond to high-power beam  
Have the high performance cooling duct for strip lines



Cooling performance  
for strip lines

Present horns :  
up to 400kW

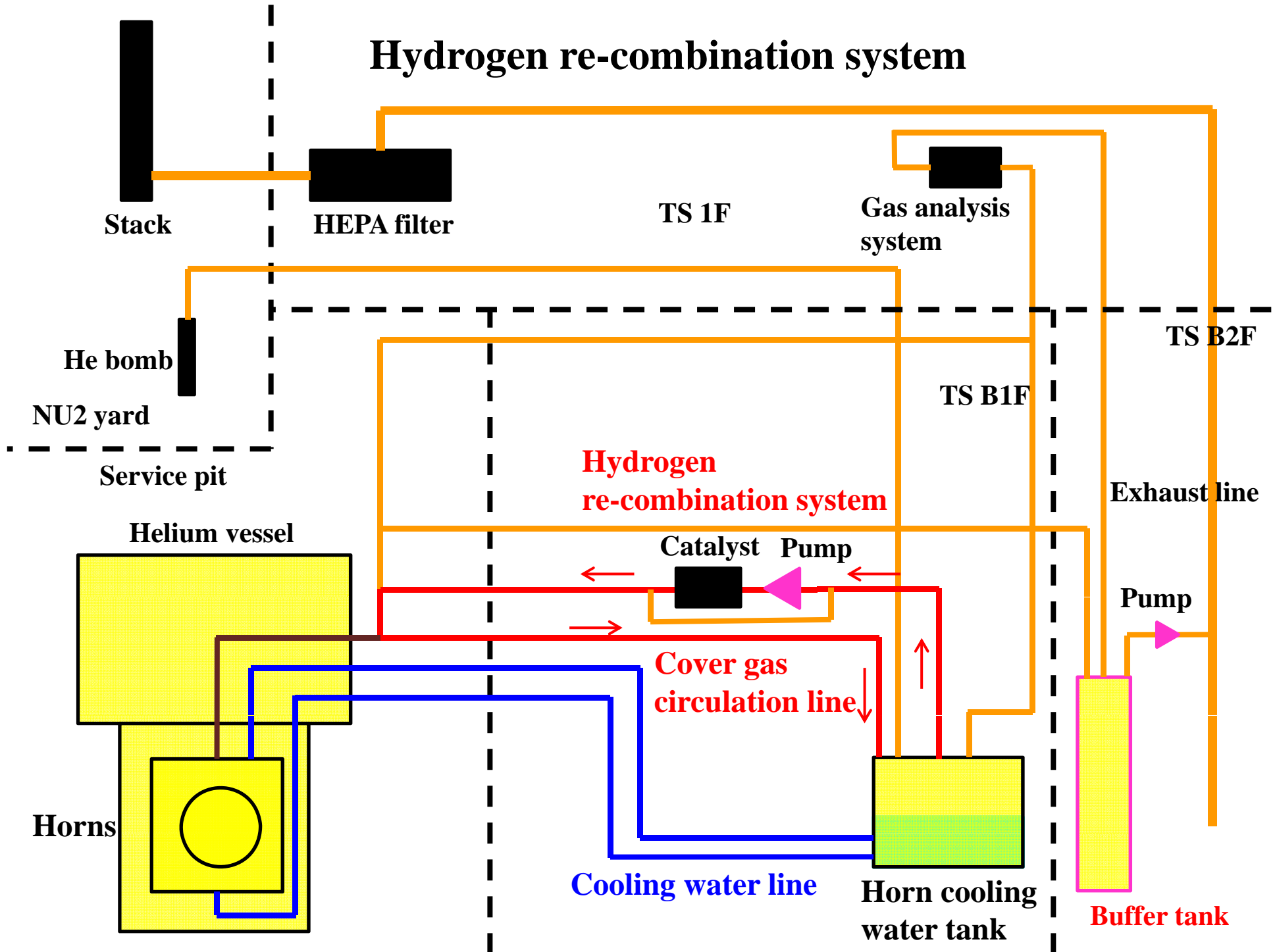


**New horns :**  
**up to 750kW**  
**with present He compressor**  
**up to a few MW**  
**adding He compressor**

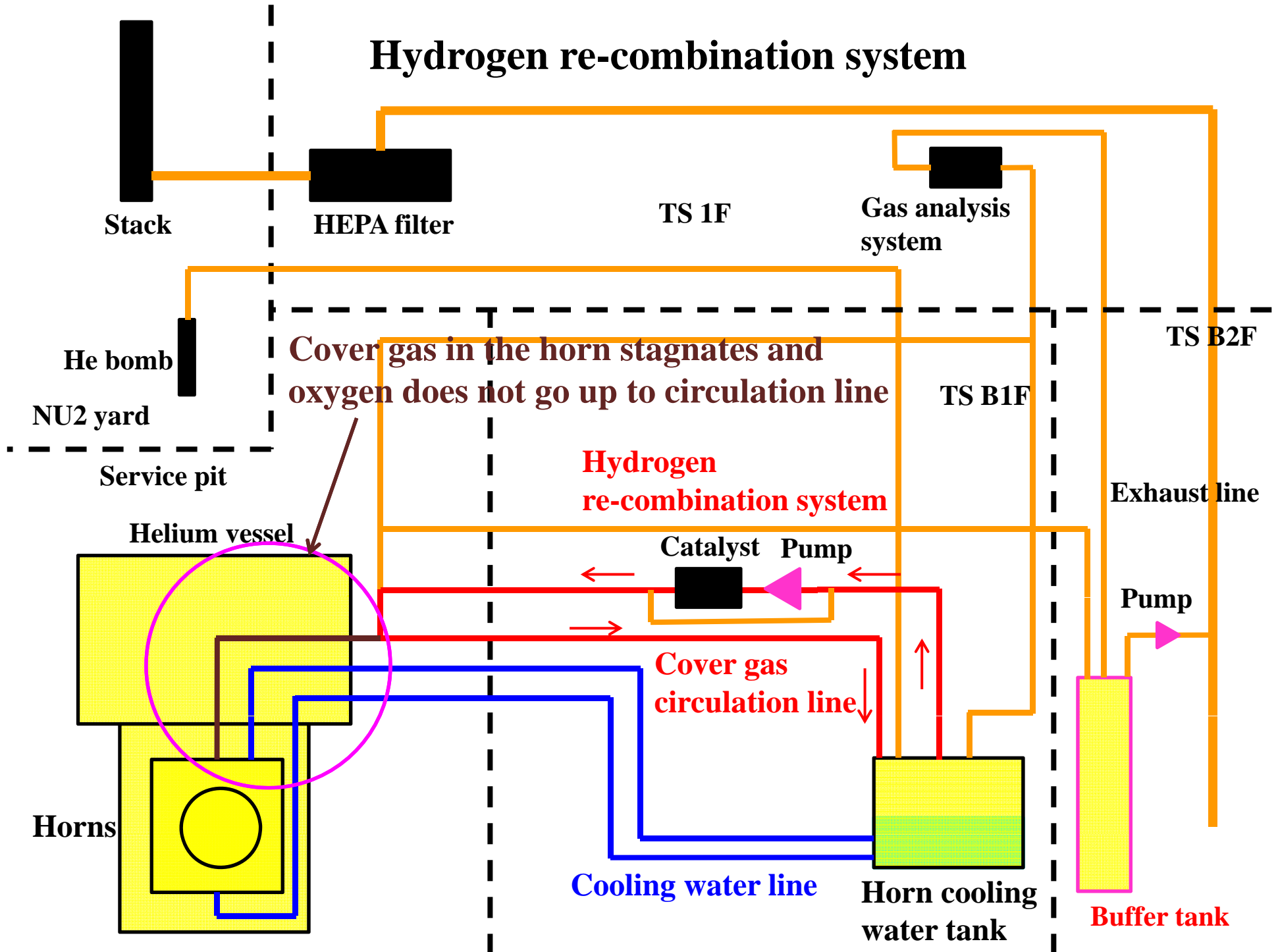
# Motivation for replacement of the horns

- 1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)**
- 2) To correspond to high-power beam  
Have the high performance cooling duct for strip lines**
- 3) To eliminate hydrogen efficiently in horn cover gas**

# Hydrogen re-combination system

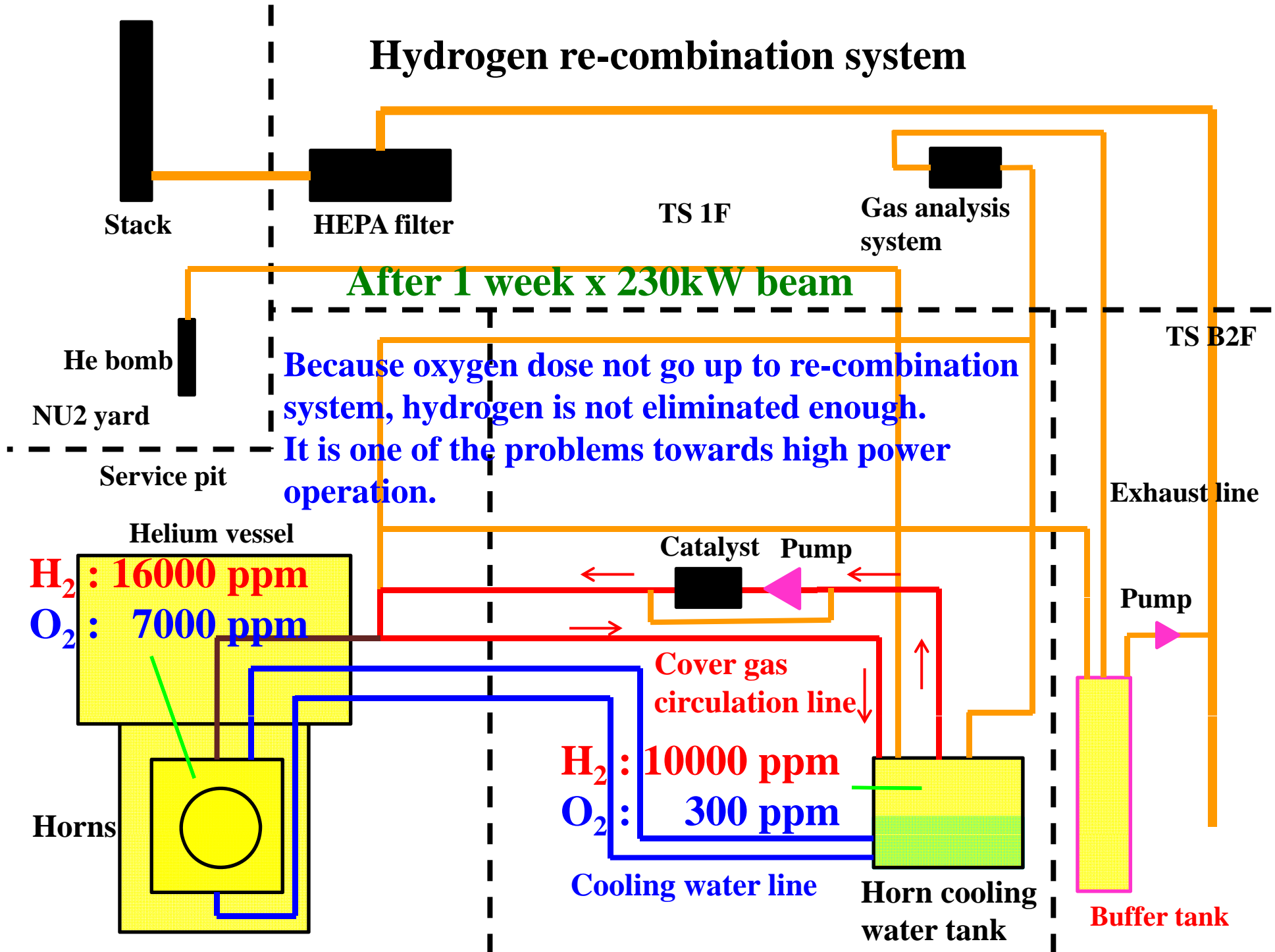


# Hydrogen re-combination system



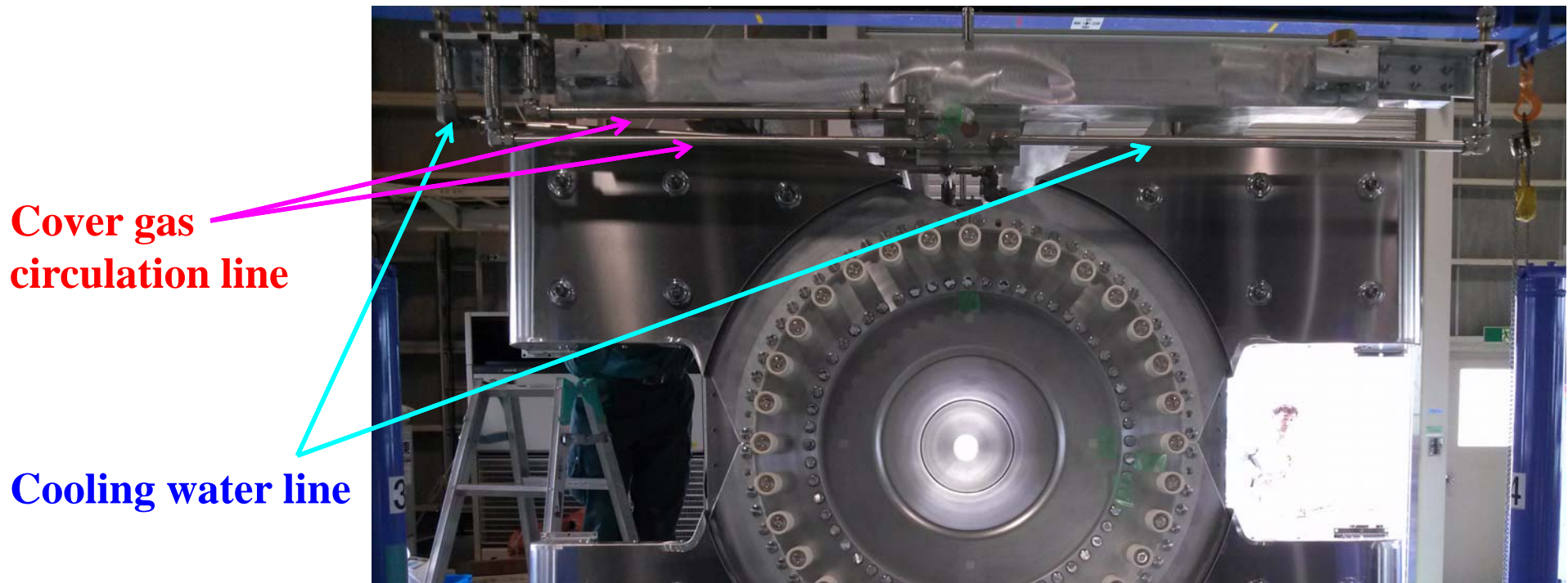


# Hydrogen re-combination system

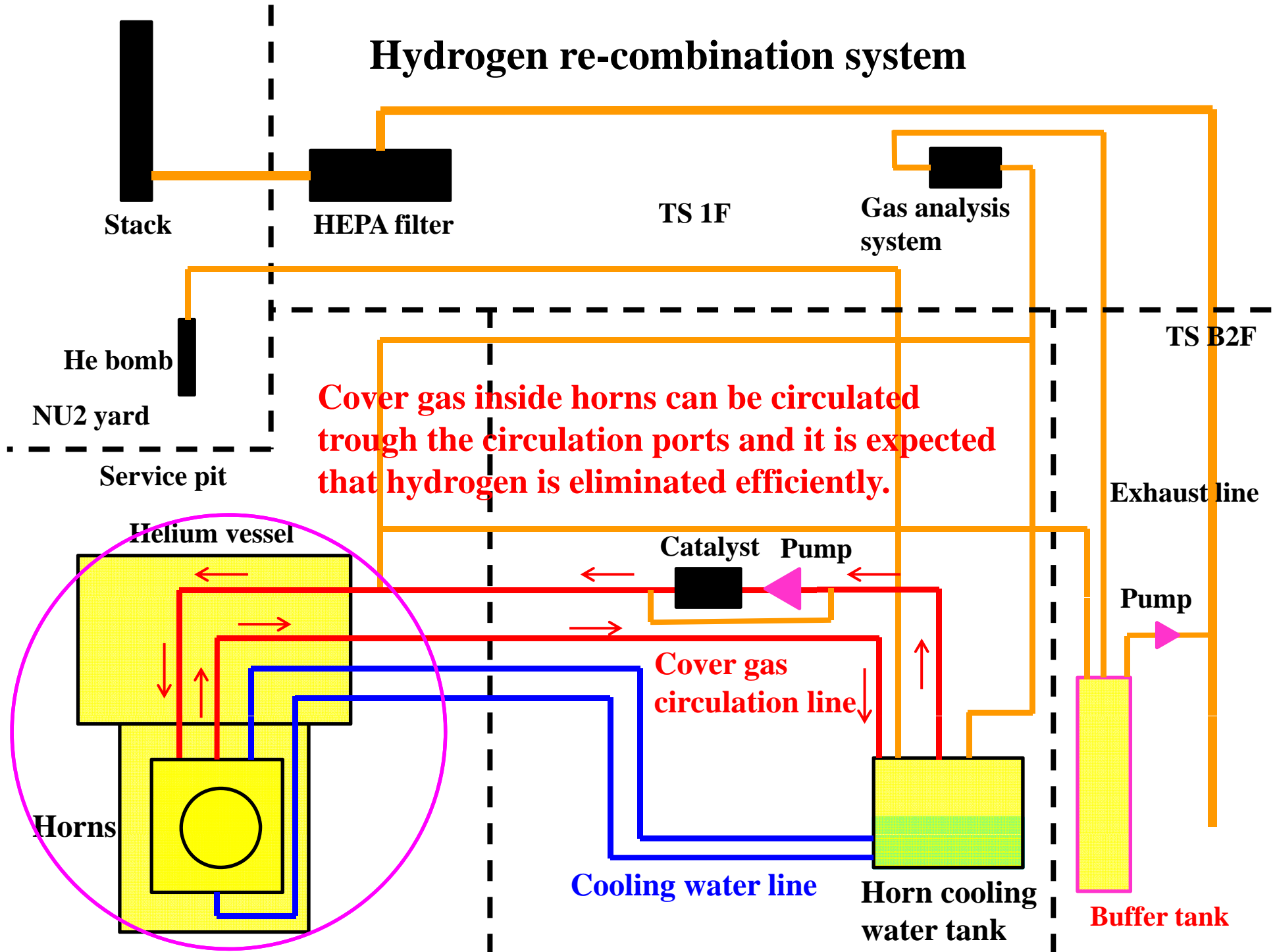


# Motivation for replacement of the horns

- 1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)
- 2) To correspond to high-power beam  
Have the high performance cooling duct for strip lines
- 3) To eliminate hydrogen efficiently in horn cover gas  
Have the circulation port for inner gas



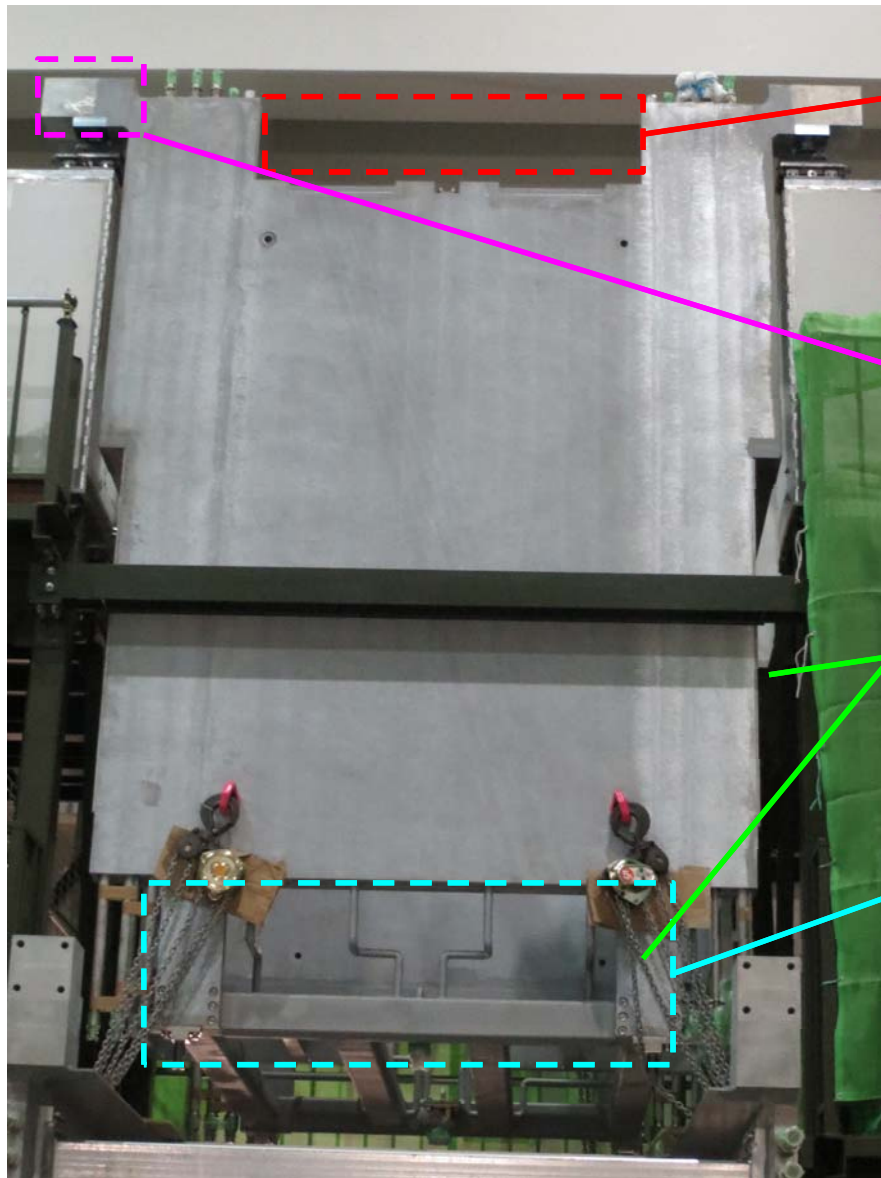
# Hydrogen re-combination system



# Motivation for replacement of the horns

- 1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)**
- 2) To correspond to high-power beam  
Have the high performance cooling duct for strip lines**
- 3) To eliminate hydrogen efficiently  
Have the circulation port for inner gas**
- 4) To exchange the new support module**

## New horn support module



**Inclination can be adjusted with counterweights**

**Handling point suitable for the remote maintenance (twist-lock)**

**Low deformation structure**

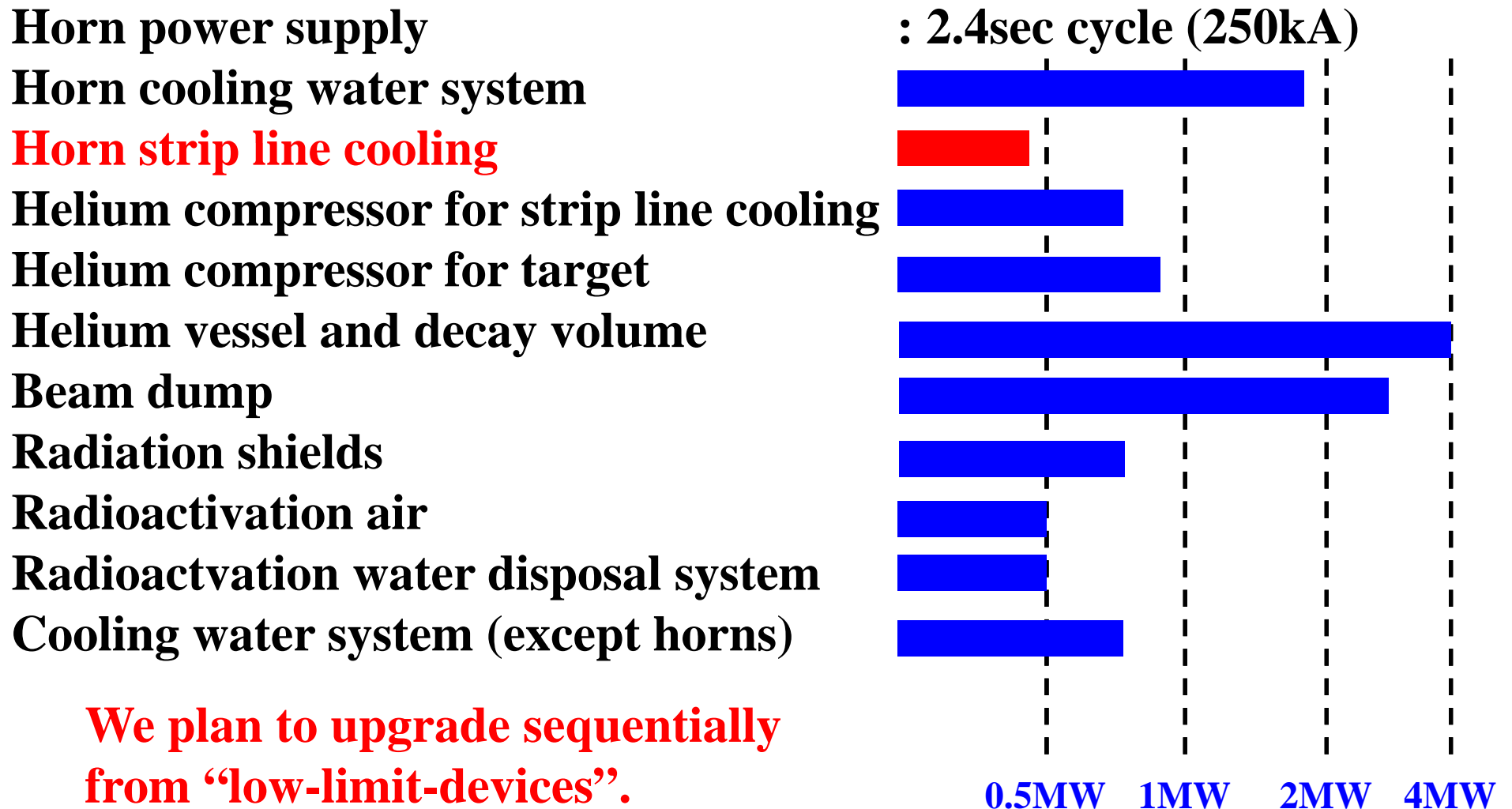
**The parts near the beam axis are water cooled to correspond to high power beam operation**

# Motivation for replacement of the horns

- 1) To correspond to high-repetition rate operation on accelerator  
Have low-inductance strip lines (wide and closed up)**
- 2) To correspond to high-power beam  
Have the high performance cooling duct for strip lines**
- 3) To eliminate hydrogen efficiently  
Have the circulation port for inner gas**
- 4) To exchange the new support module  
Have and the counter-weight balancer, the low deformation structure,  
and water cooled parts near the beam axis (New support module)  
Horn support modules are also exchanged only this time,  
but recycled at next horn-exchange and future.**

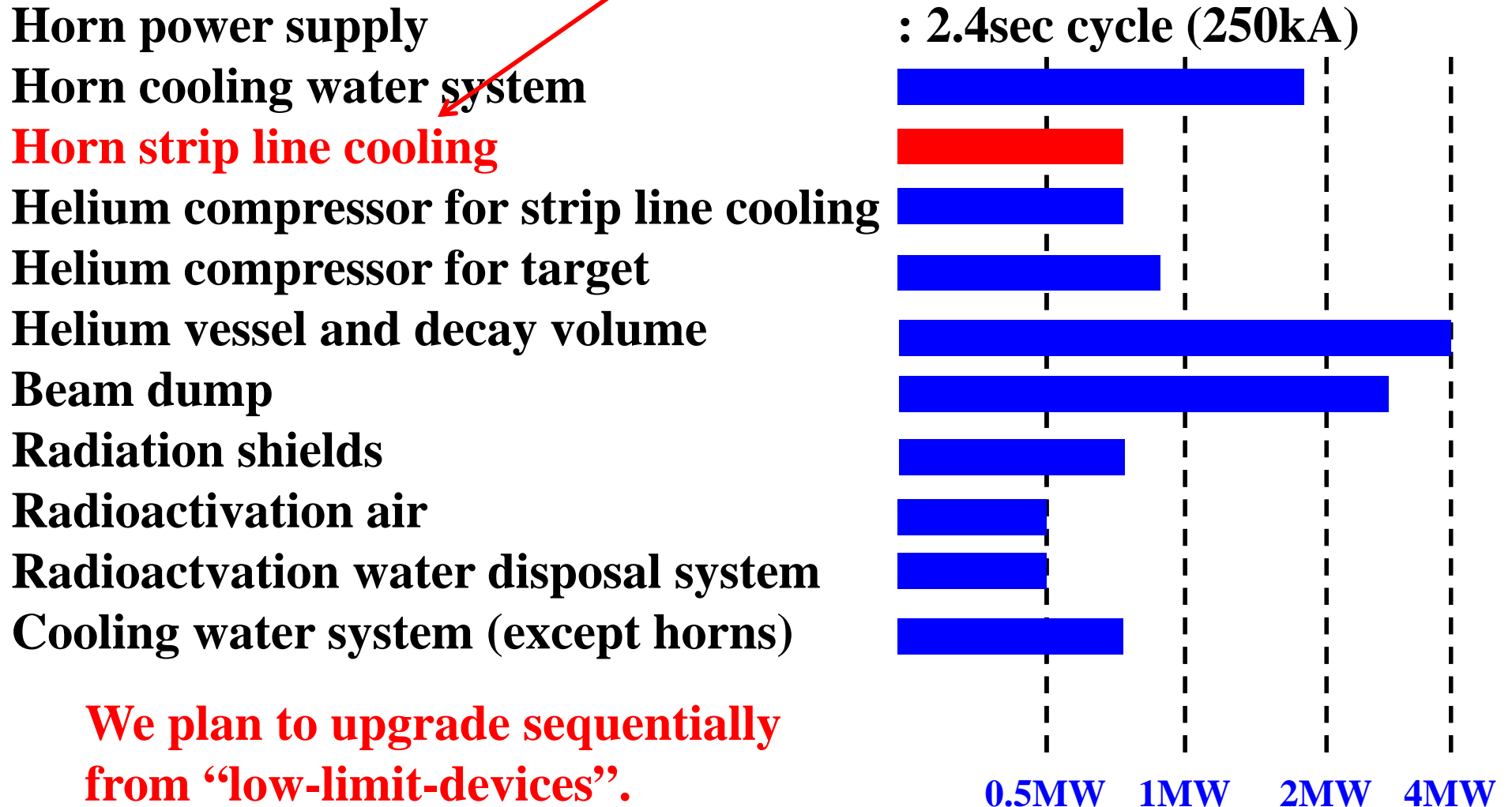
# The limit of beam power that present devices can stand

**Replace to the new horns**



# The limit of beam power that present devices can stand

Replace to the new horns



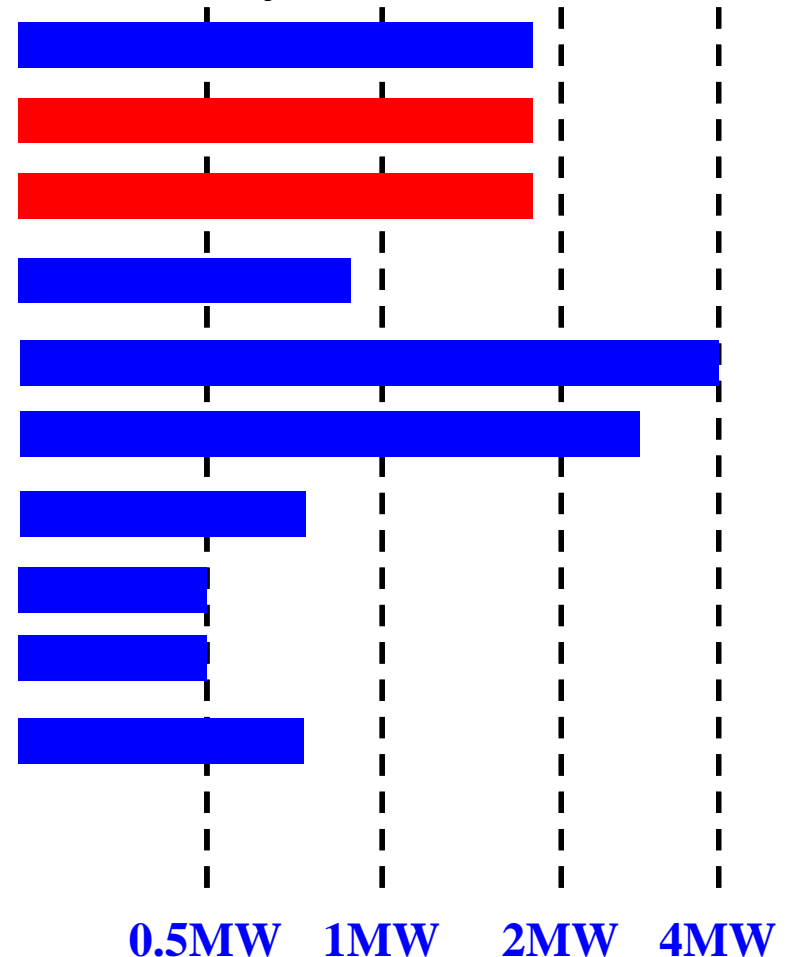


# The limit of beam power that present devices can stand

**Replace to the new horns**  
**Add helium compressor**

- Horn power supply
- Horn cooling water system
- Horn strip line cooling**
- Helium compressor for strip line cooling**
- Helium compressor for target
- Helium vessel and decay volume
- Beam dump
- Radiation shields
- Radioactivation air
- Radioactivation water disposal system
- Cooling water system (except horns)

: 2.4sec cycle (250kA)



**We plan to upgrade sequentially from “low-limit-devices”.**

# The limit of beam power that present devices can stand

**Horn power supply**

**: 2.4sec cycle (250kA)**

**Horn cooling water system**

**Horn strip line cooling**

**Helium compressor for strip line cooling**

**Helium compressor for target**

**Helium vessel and decay volume**

**Beam dump**

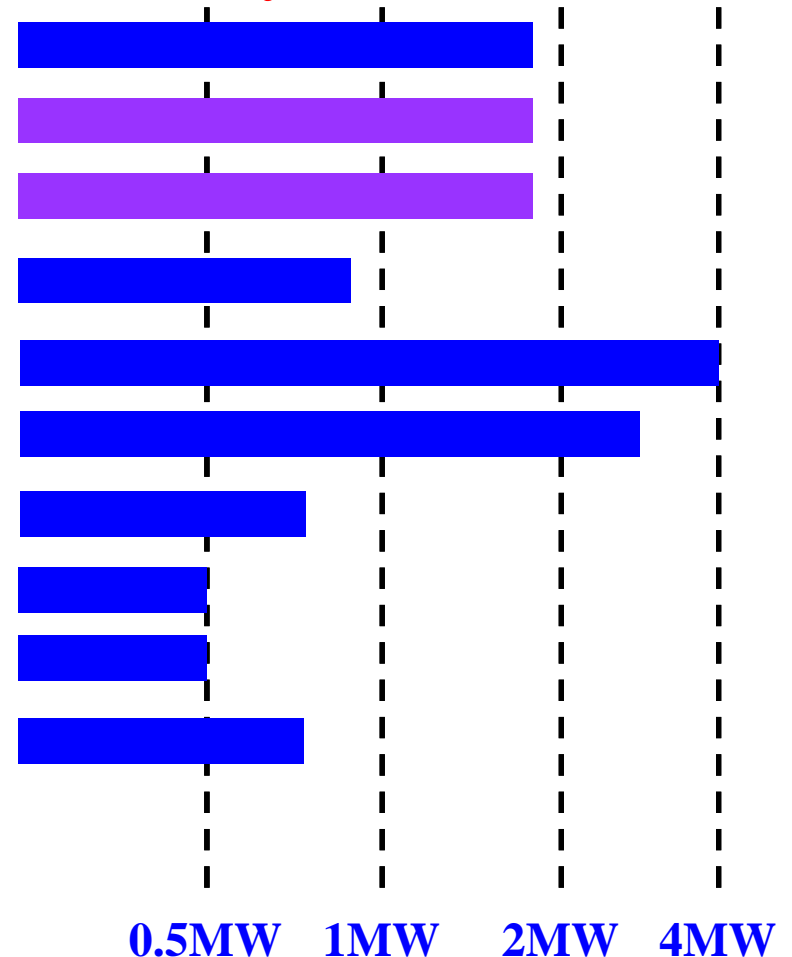
**Radiation shields**

**Radioactivation air**

**Radioactivation water disposal system**

**Cooling water system (except horns)**

**We plan to upgrade sequentially  
from “low-limit-devices”.**



# **Motivation for introduction new-horn-power-supply system**

- 1) To correspond to high-repetition rate operation on accelerator  
Up to 1sec-cycle operation**

# Motivation for introduction new-horn-power-supply system

**1) To correspond to high-repetition rate operation on accelerator  
Up to 1sec-cycle operation**

**2) To operate with 320kA current**

# Motivation for introduction new-horn-power-supply system

1) To correspond to high-repetition rate operation on accelerator  
Up to 1sec-cycle operation

2) To operate with 320kA current

3) To reduce the risk

We can operate with low voltage  
and get safety redundancy at 3-power supplies configuration

# Motivation for introduction new-horn-power-supply system

1) To correspond to high-repetition rate operation on accelerator  
Up to 1sec-cycle operation

2) To operate with 320kA current

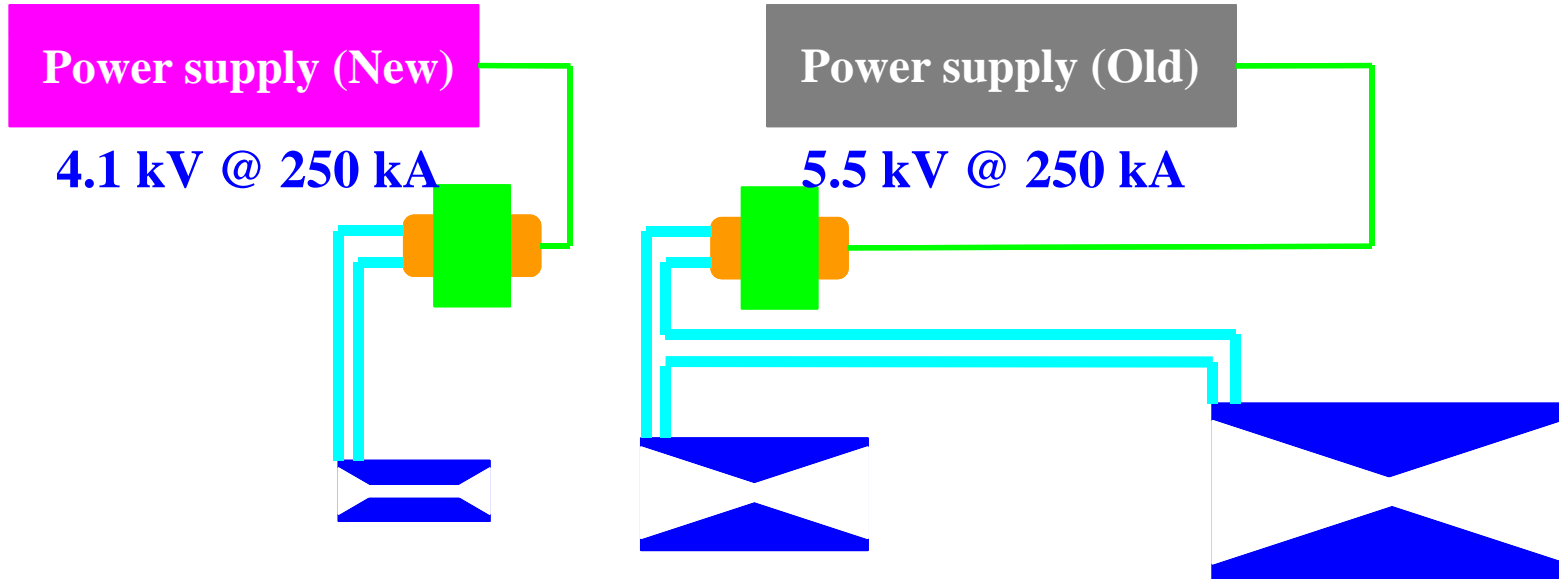
3) To reduce the risk

We can operate with low voltage  
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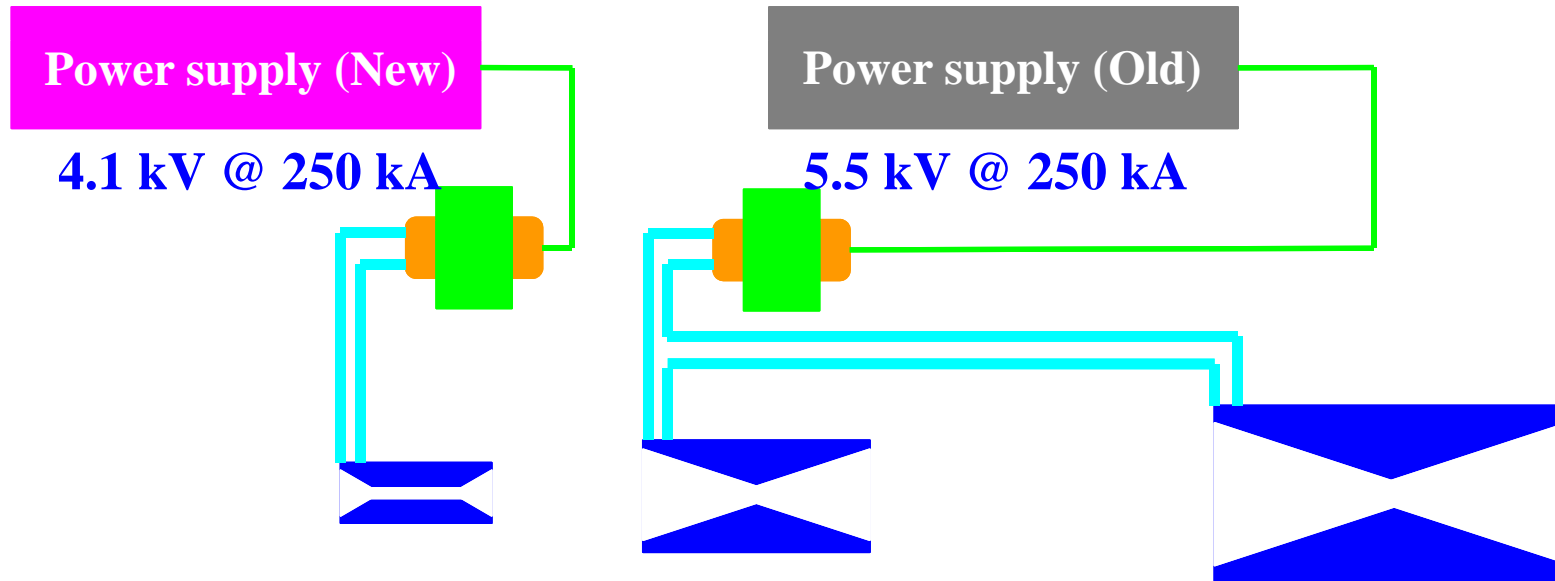
4) To replace the “old” horn power supply

“Old” power supply has been used since K2K experiment,  
so some of service parts stock face to shortage

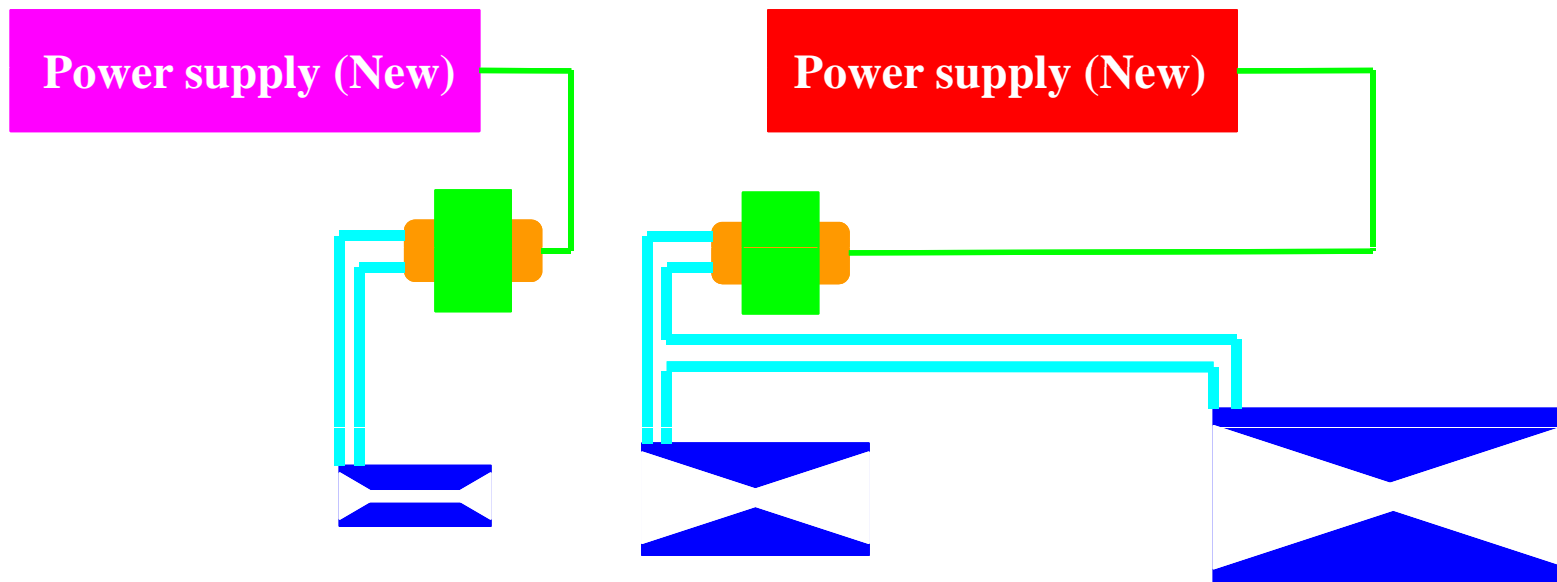
## Present configuration



## Present configuration

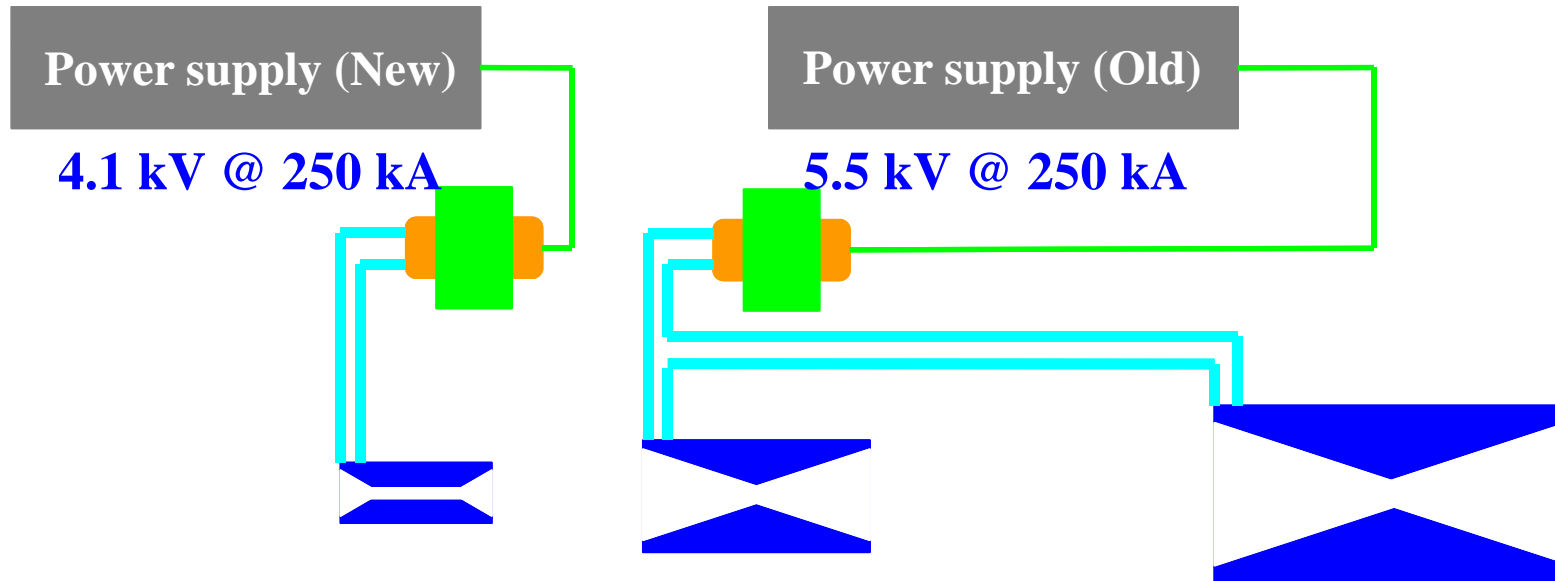


## Configuration 2014

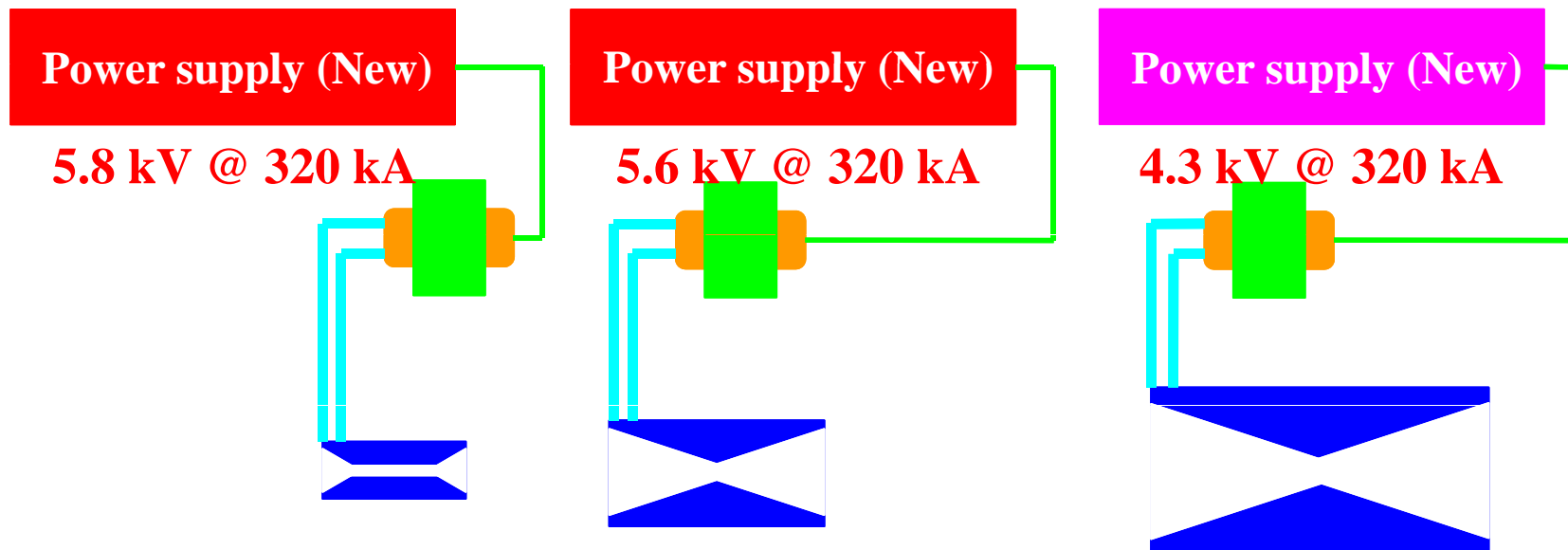




## Present configuration



## Configuration 2015~



# The limit of beam power that present devices can stand

**Introduce new-horn-power-supply system using 3 power supplies**

**Horn power supply**

**: 2.4sec cycle (250kA)**

Horn cooling water system

Horn strip line cooling

Helium compressor for strip line cooling

Helium compressor for target

Helium vessel and decay volume

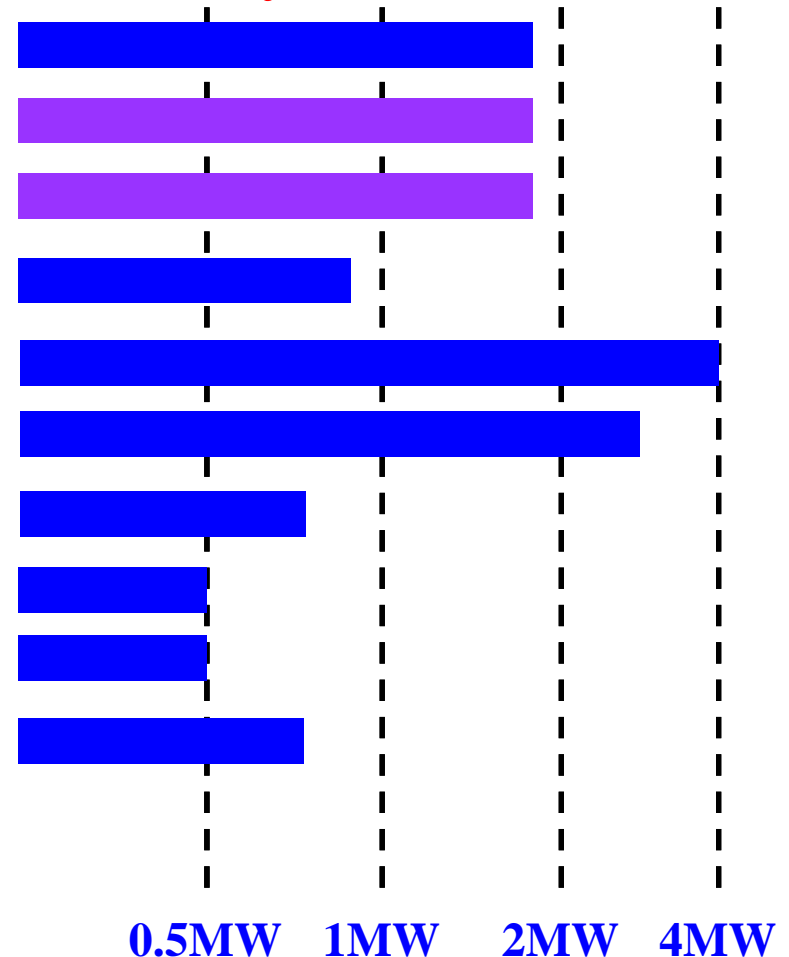
Beam dump

Radiation shields

Radioactivation air

Radioactivation water disposal system

Cooling water system (except horns)



**We plan to upgrade sequentially from “low-limit-devices”.**

# The limit of beam power that present devices can stand

**Introduce new-horn-power-supply system using 3 power supplies**

**Horn power supply**

**: 1.0sec cycle (320kA)**

Horn cooling water system

Horn strip line cooling

Helium compressor for strip line cooling

Helium compressor for target

Helium vessel and decay volume

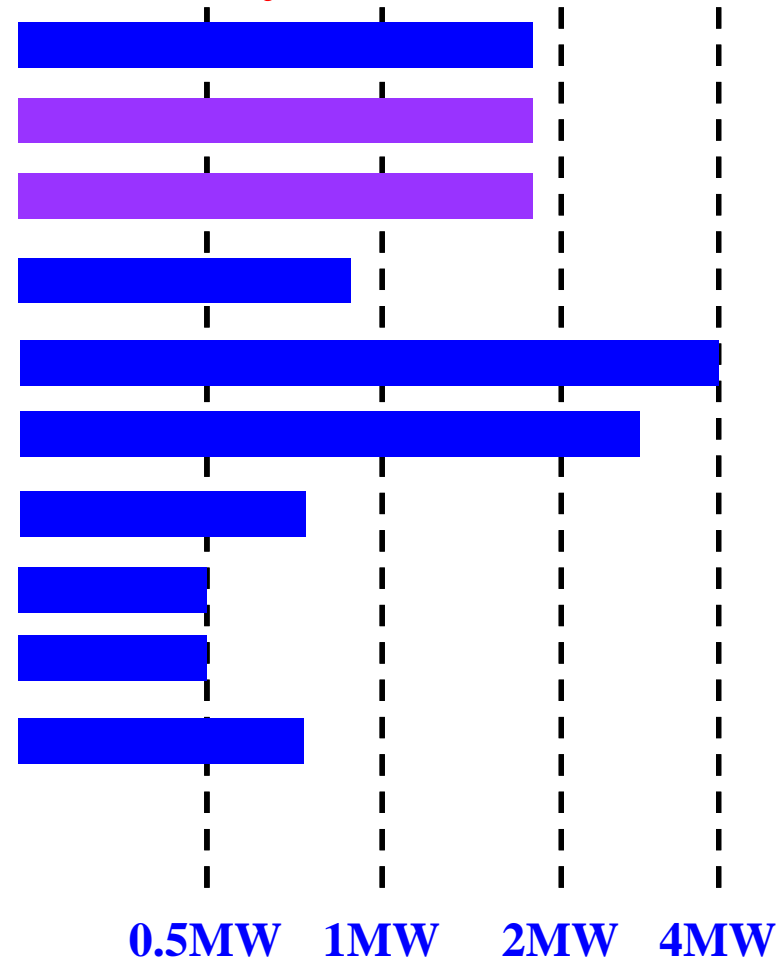
Beam dump

Radiation shields

Radioactivation air

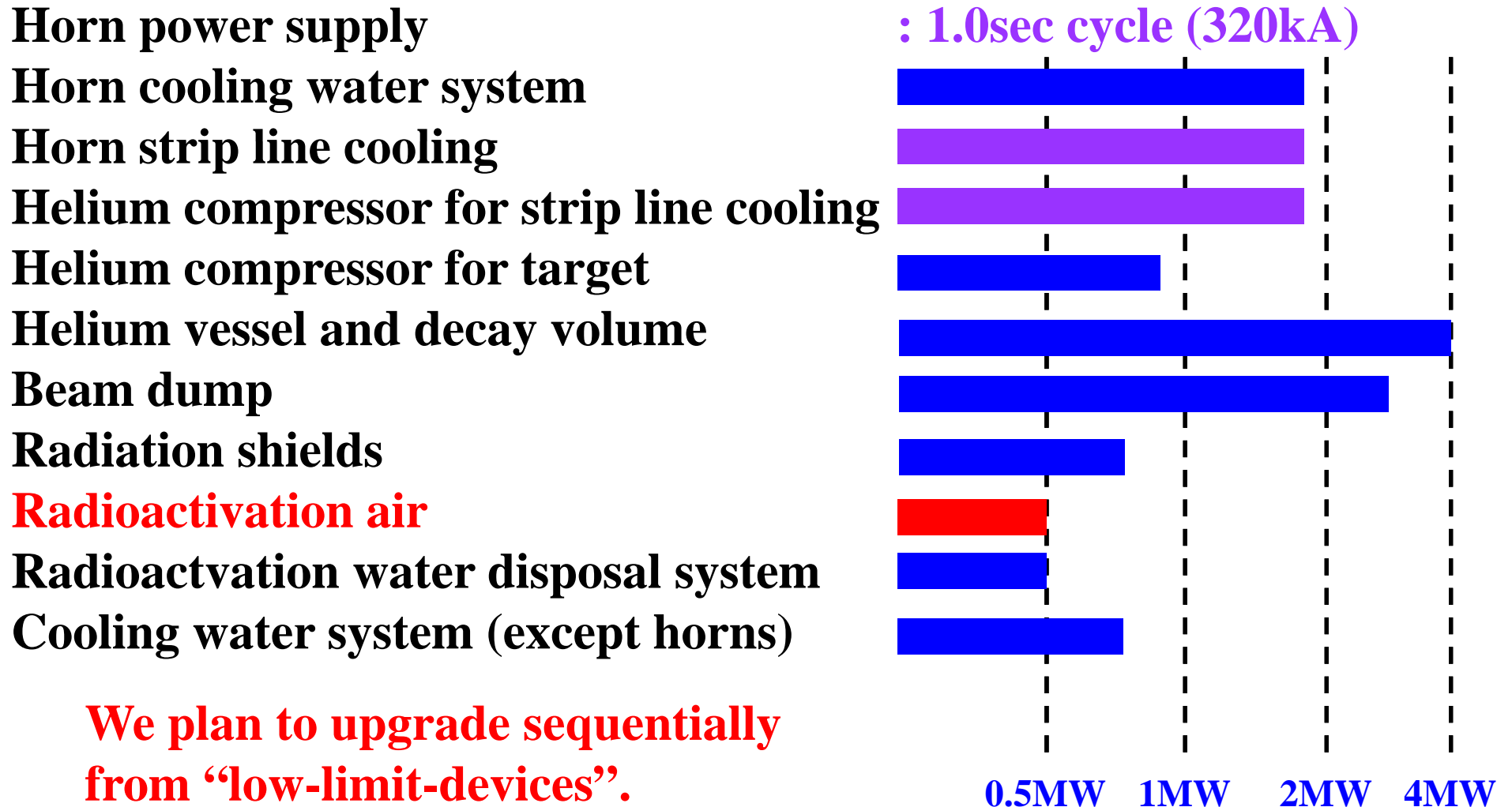
Radioactivation water disposal system

Cooling water system (except horns)



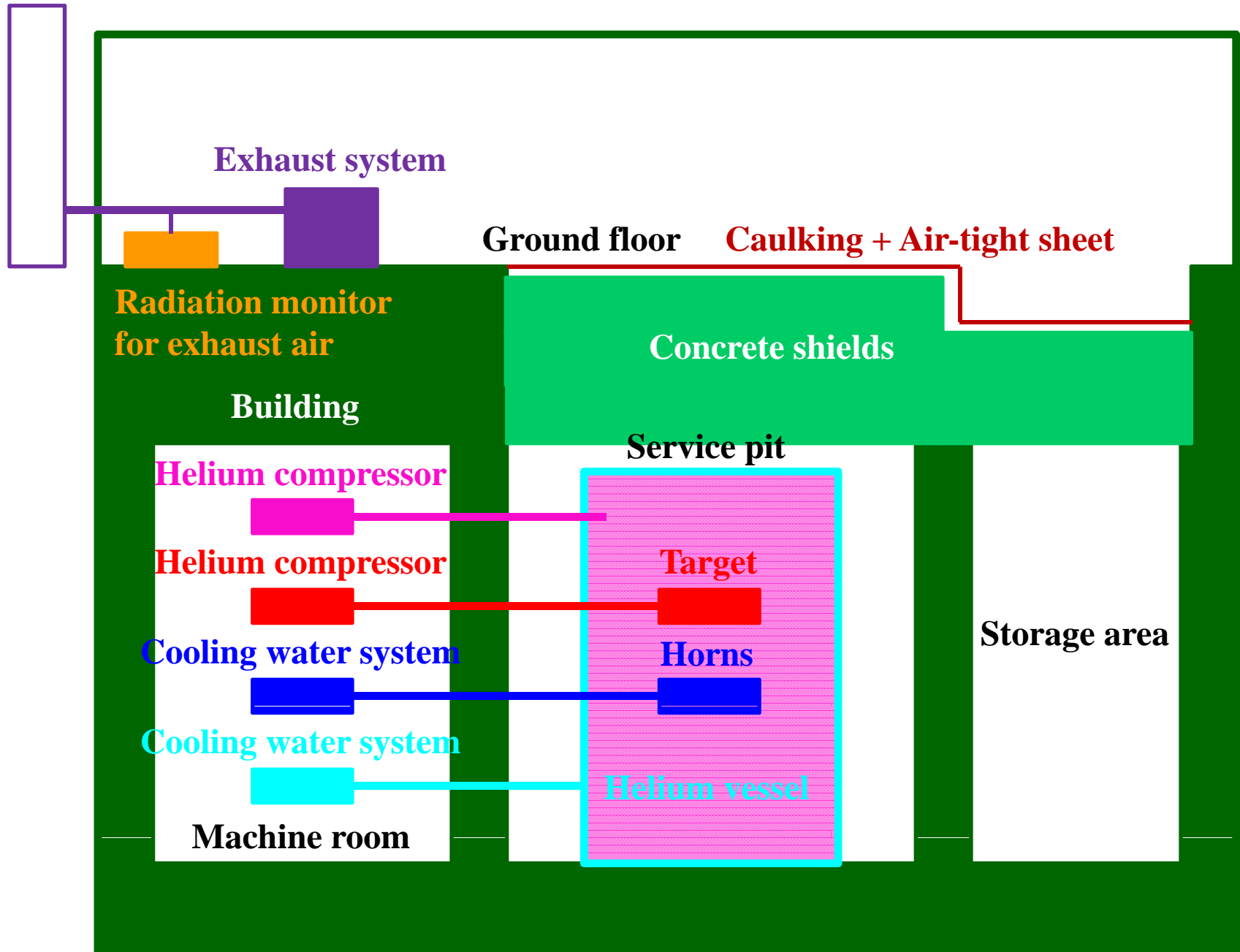
**We plan to upgrade sequentially from “low-limit-devices”.**

# The limit of beam power that present devices can stand



# Schematic diagram of target station

Chimney stack

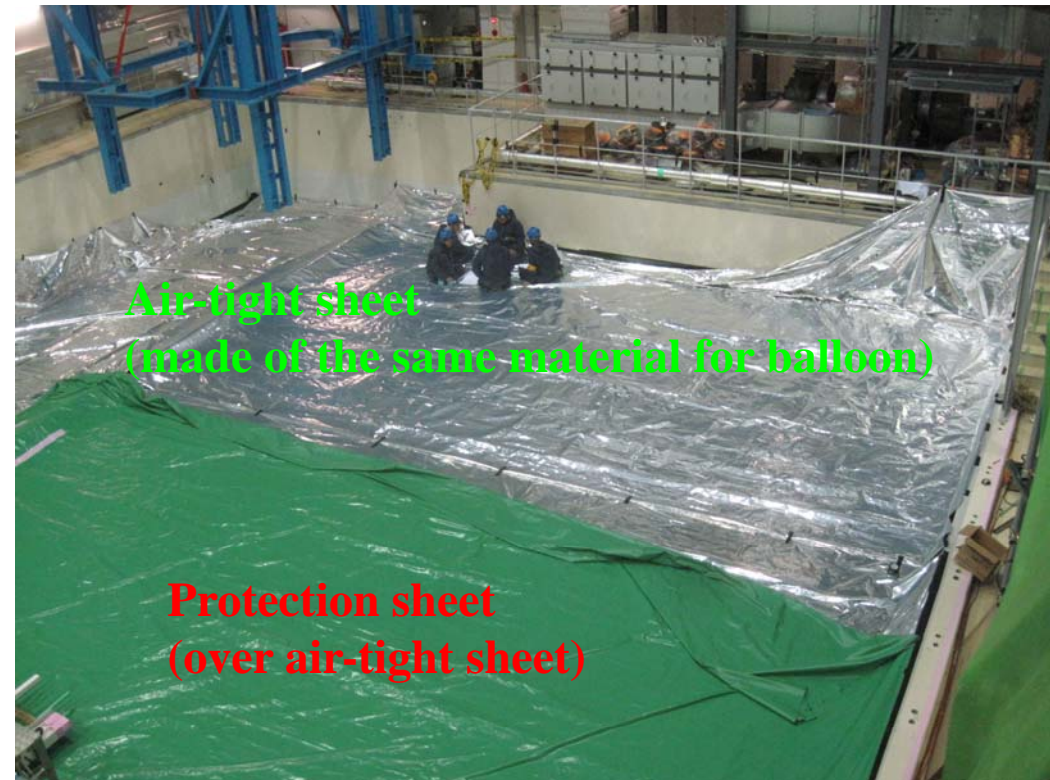


# Air-tight work in target station

## Caulking between concrete shields



## Lay the air-tight sheet



Air-tight sheet  
(made of the same material for balloon)

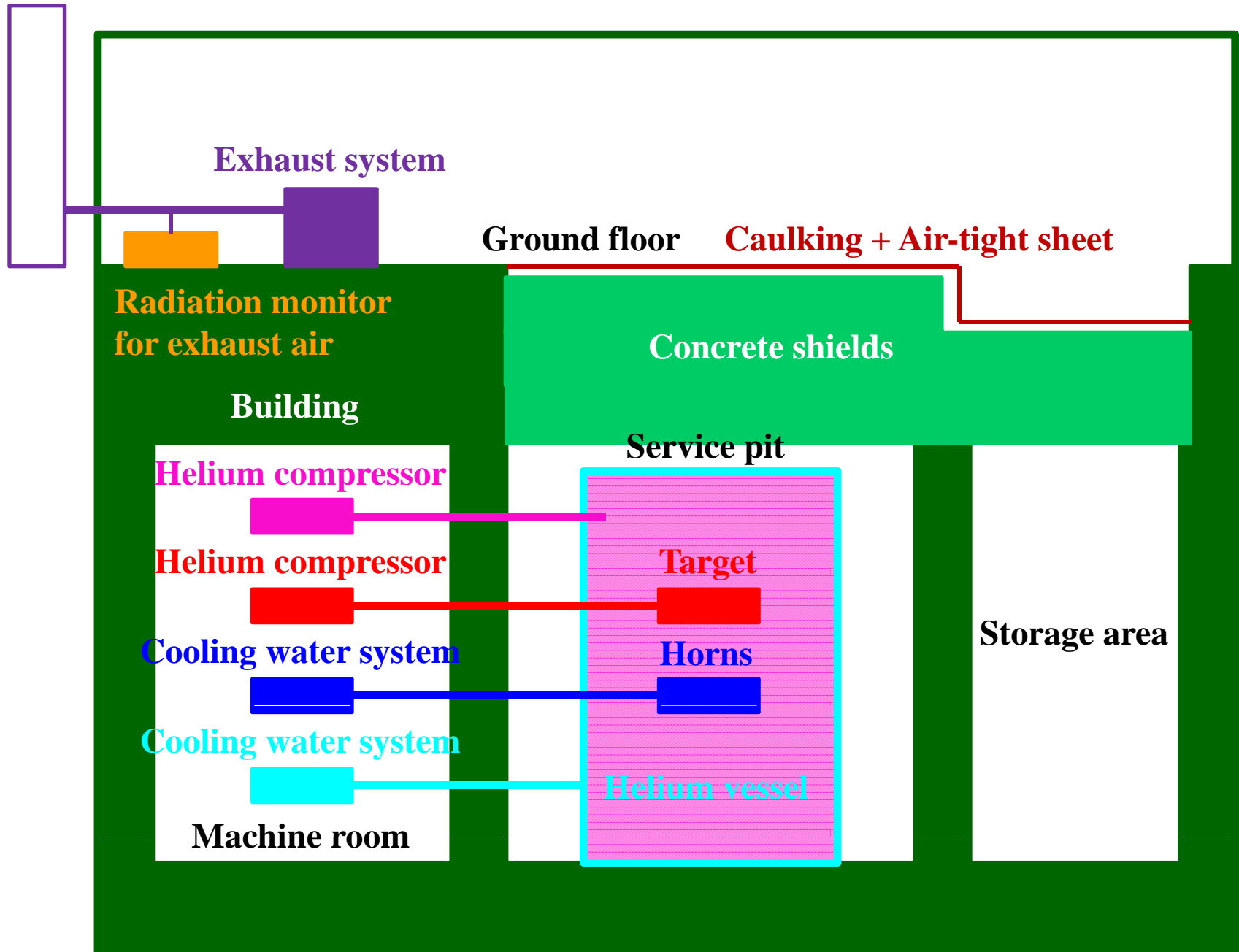
Protection sheet  
(over air-tight sheet)



## Lay the protection sheet under air-tight sheet

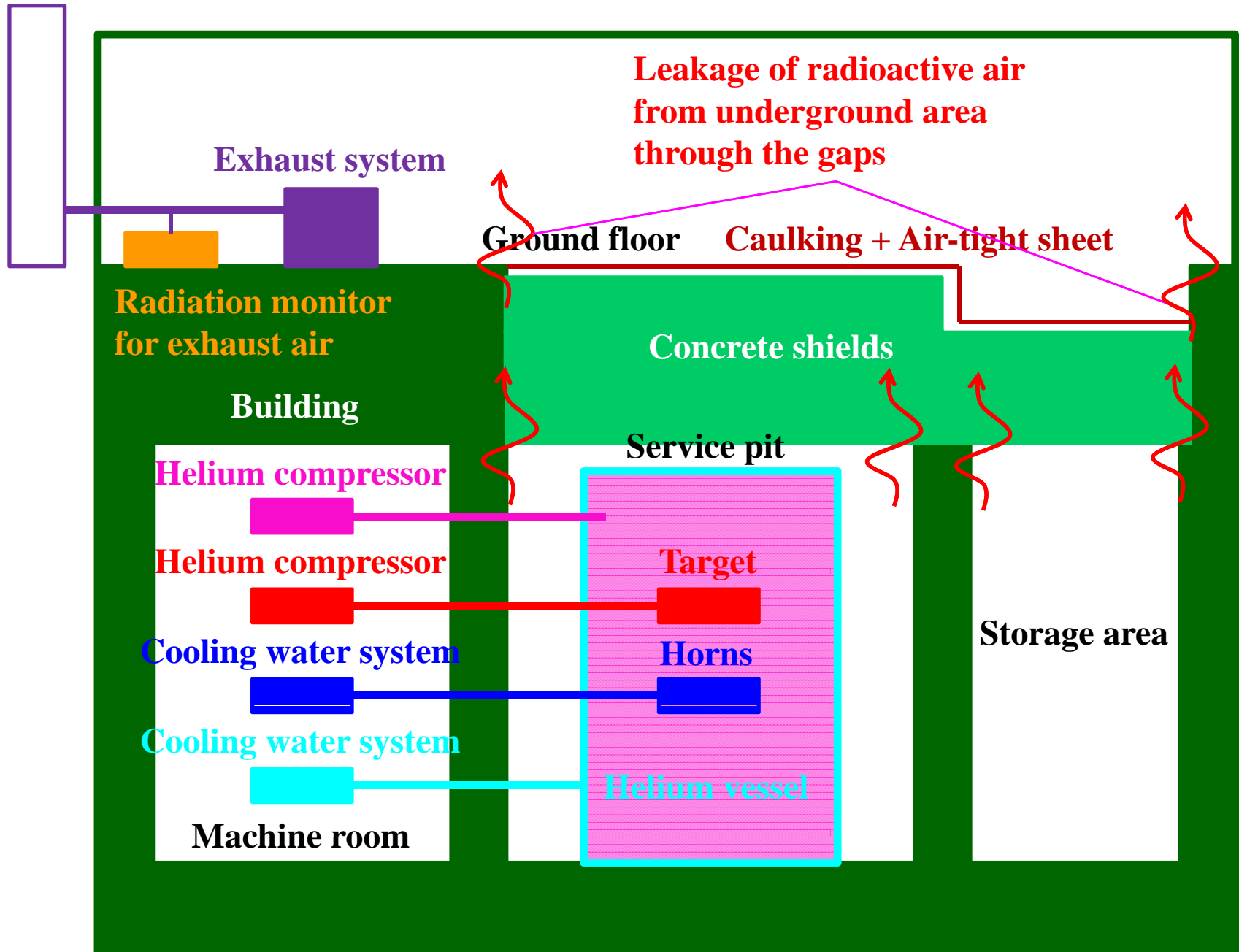
# Schematic diagram of target station

Chimney stack



# Schematic diagram of target station

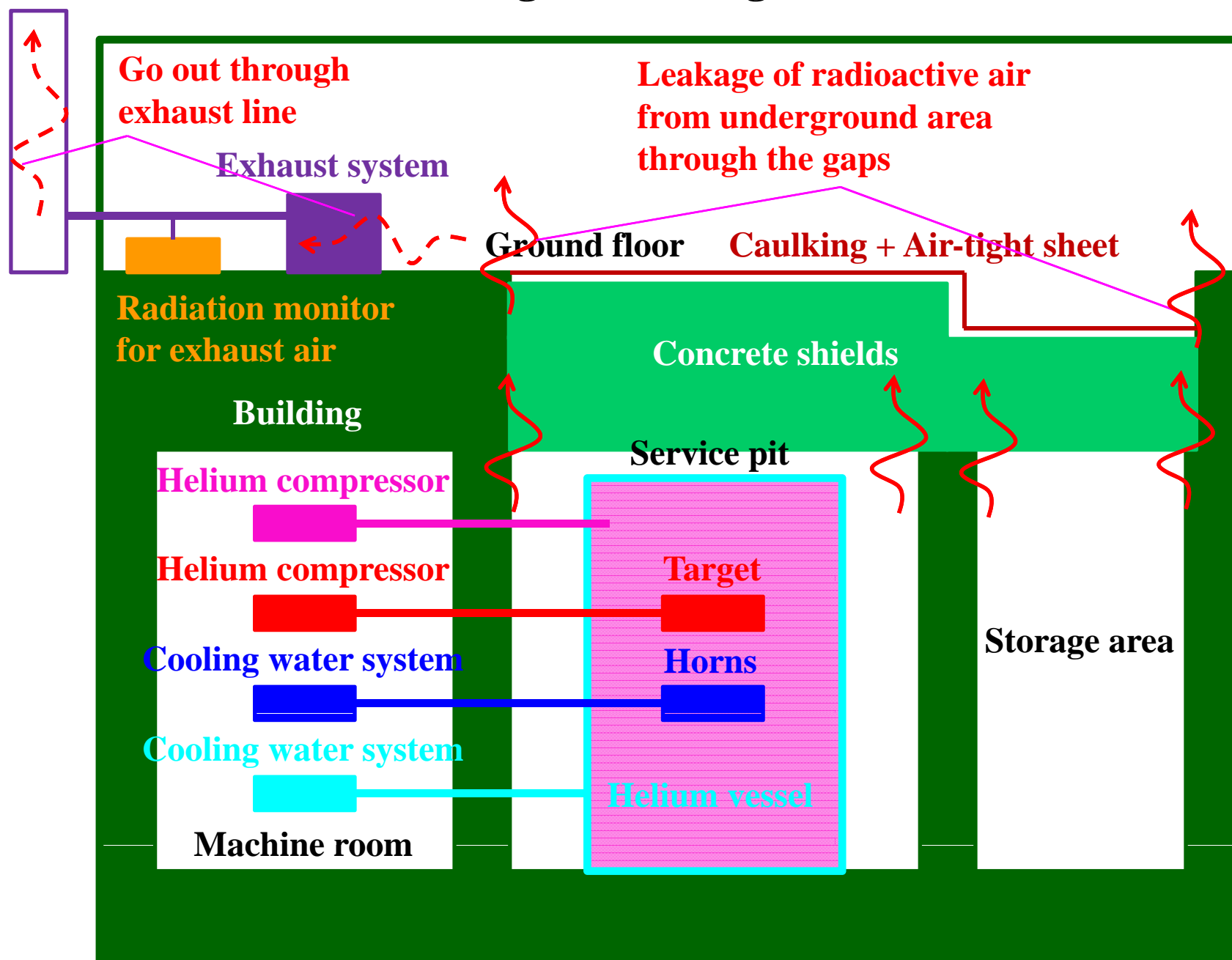
Chimney stack



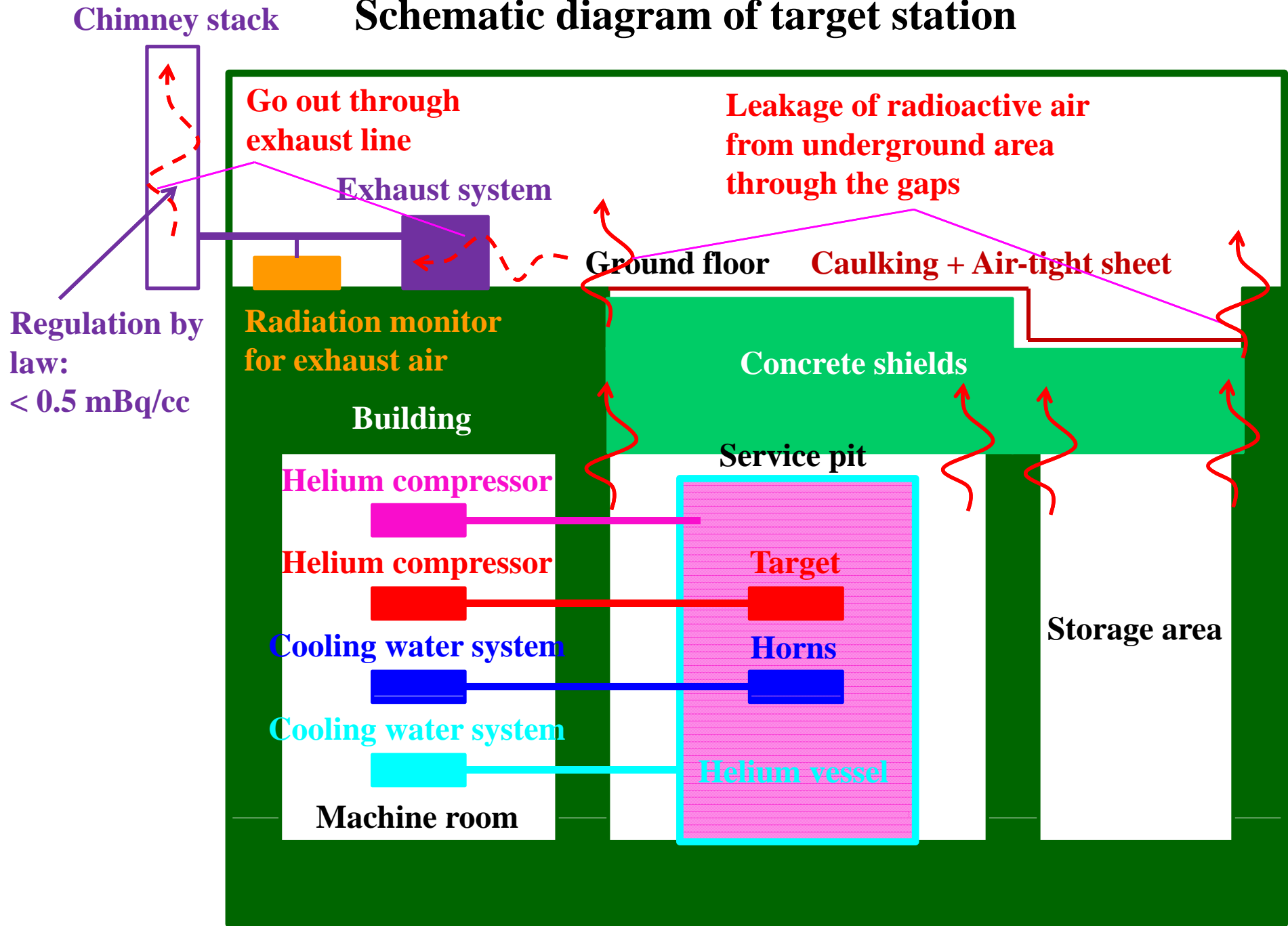


Chimney stack

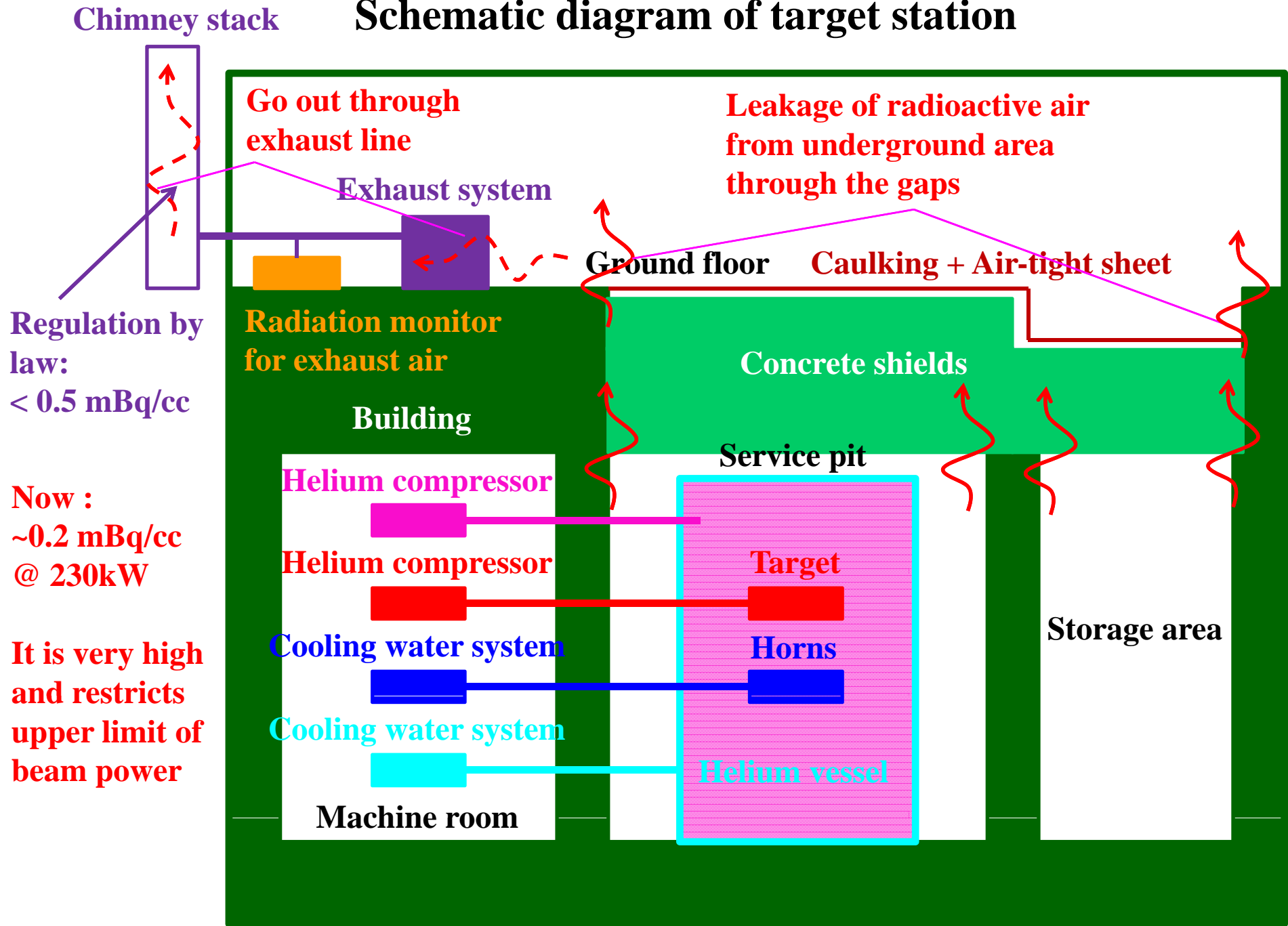
# Schematic diagram of target station



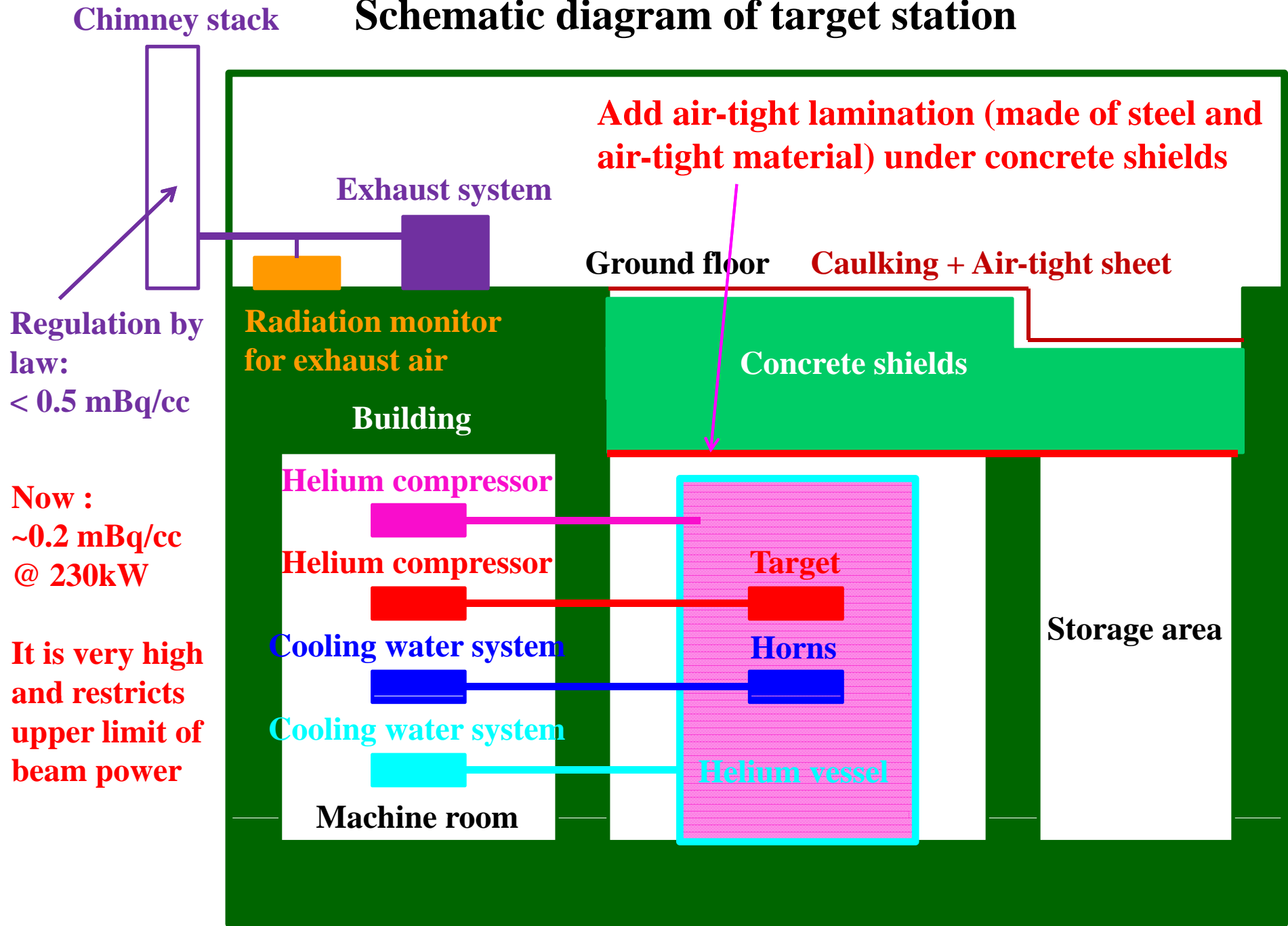
# Schematic diagram of target station



# Schematic diagram of target station

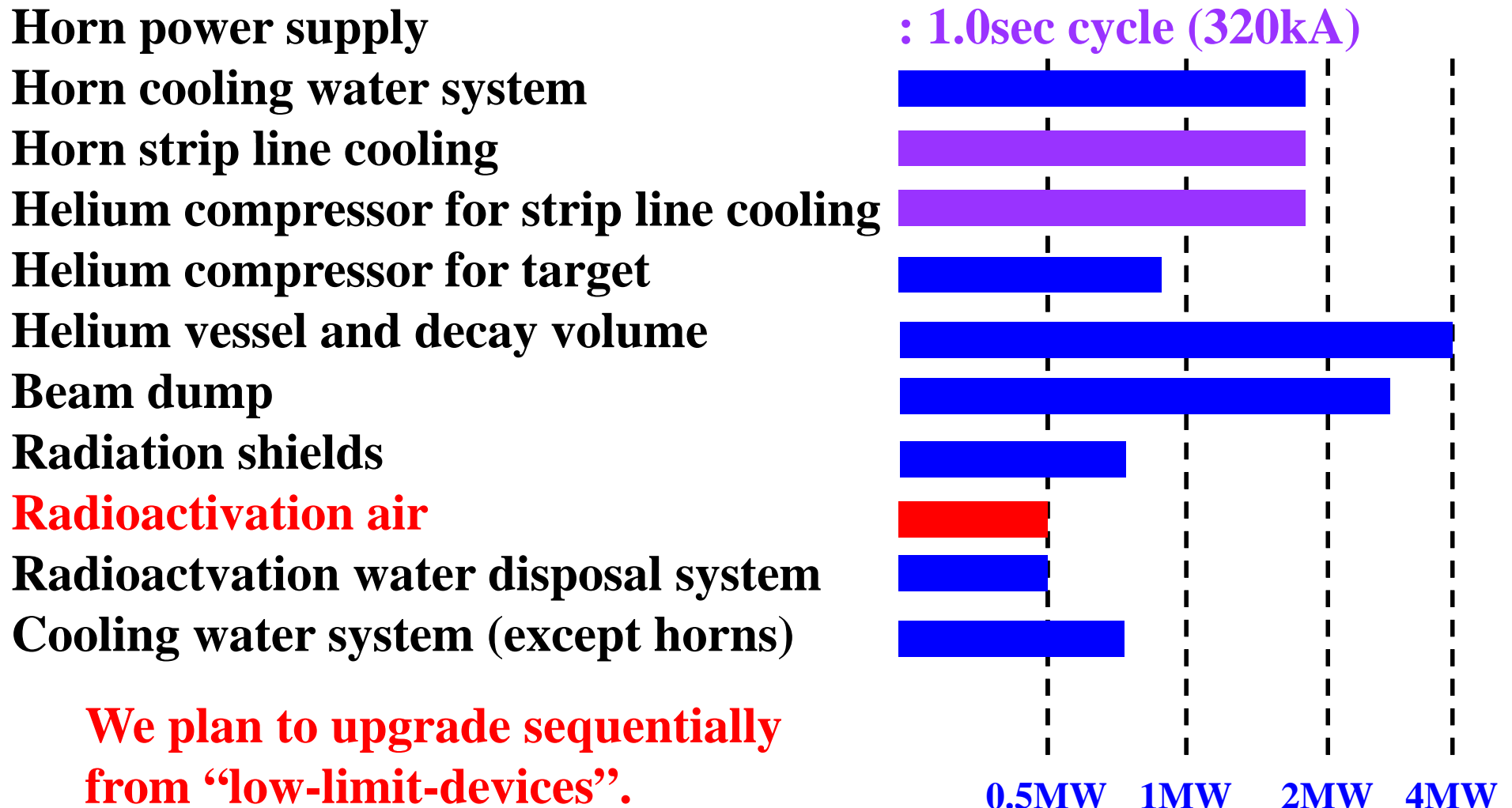


# Schematic diagram of target station



# The limit of beam power that present devices can stand

**Add air-tight lamination (made of steel and air-tight material) under concrete shields**



# The limit of beam power that present devices can stand

**Add air-tight lamination (made of steel and air-tight material) under concrete shields**

Horn power supply

Horn cooling water system

Horn strip line cooling

Helium compressor for strip line cooling

Helium compressor for target

Helium vessel and decay volume

Beam dump

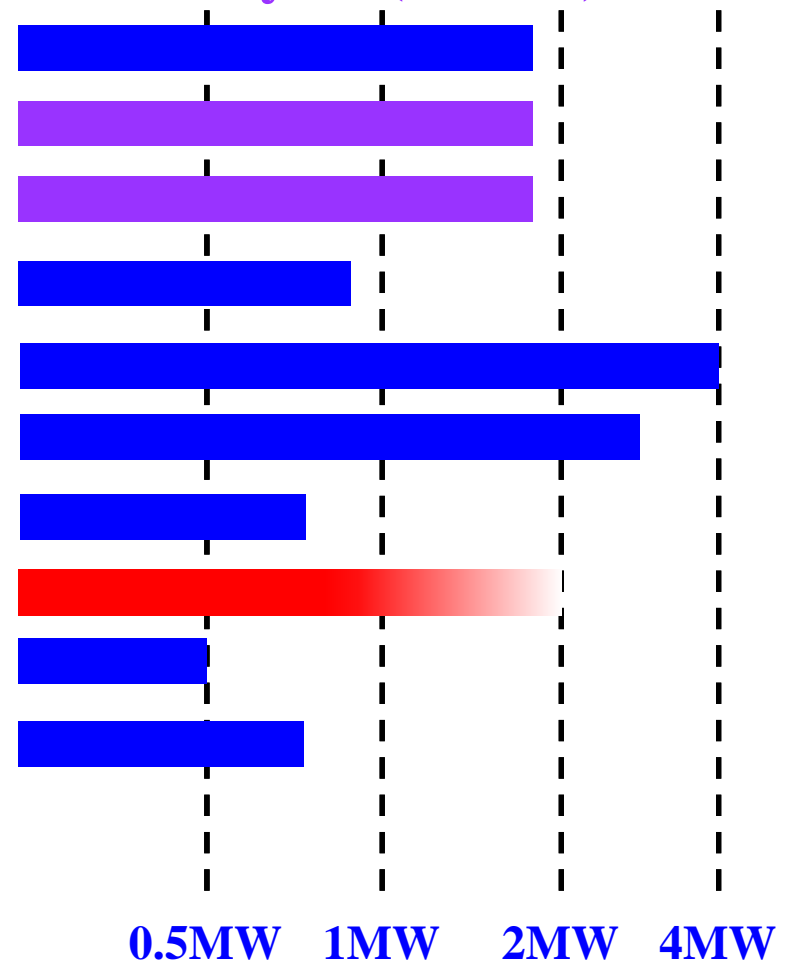
Radiation shields

**Radioactivation air**

Radioactivation water disposal system

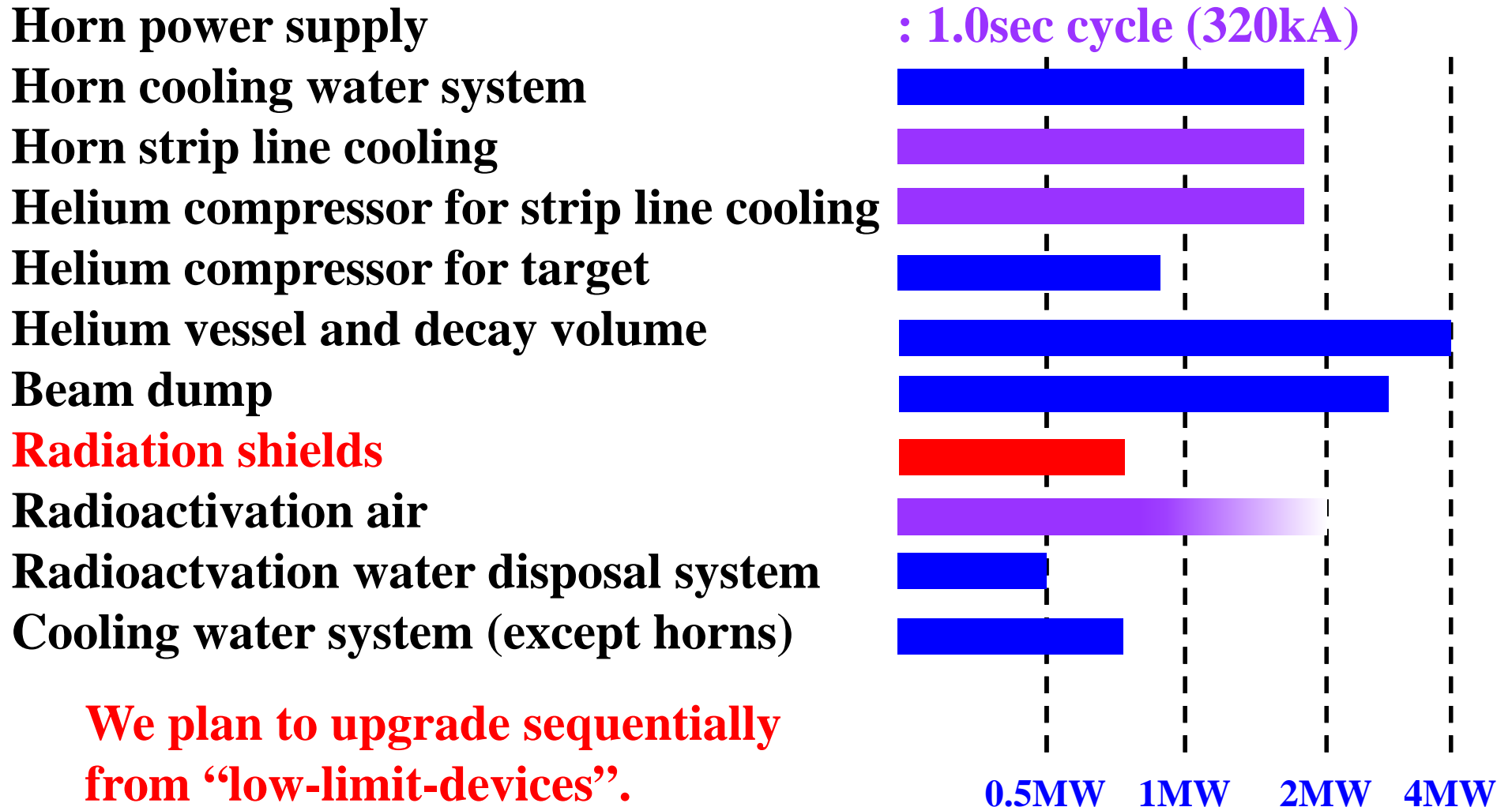
Cooling water system (except horns)

: 1.0sec cycle (320kA)



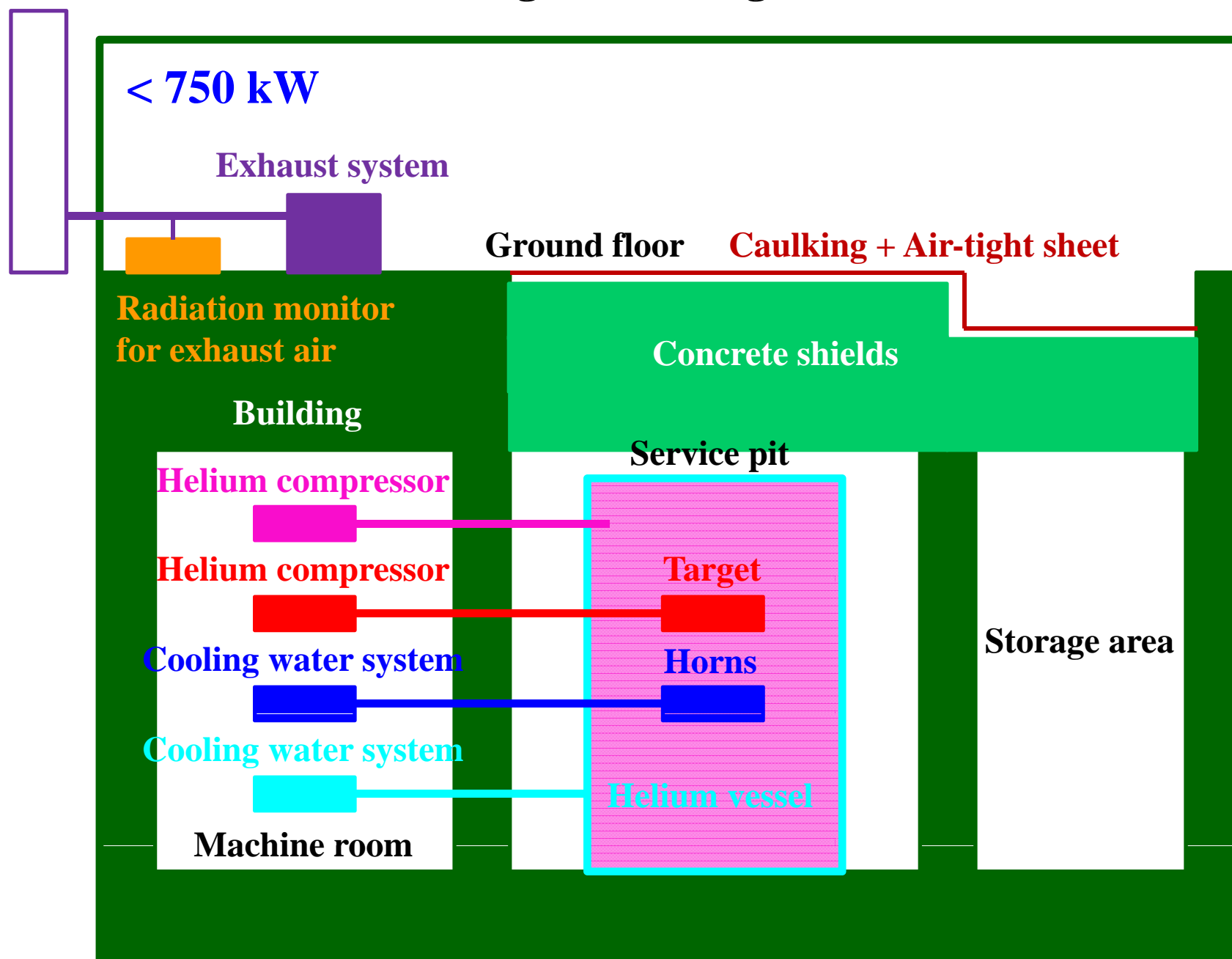
**We plan to upgrade sequentially from “low-limit-devices”.**

# The limit of beam power that present devices can stand



Chimney stack

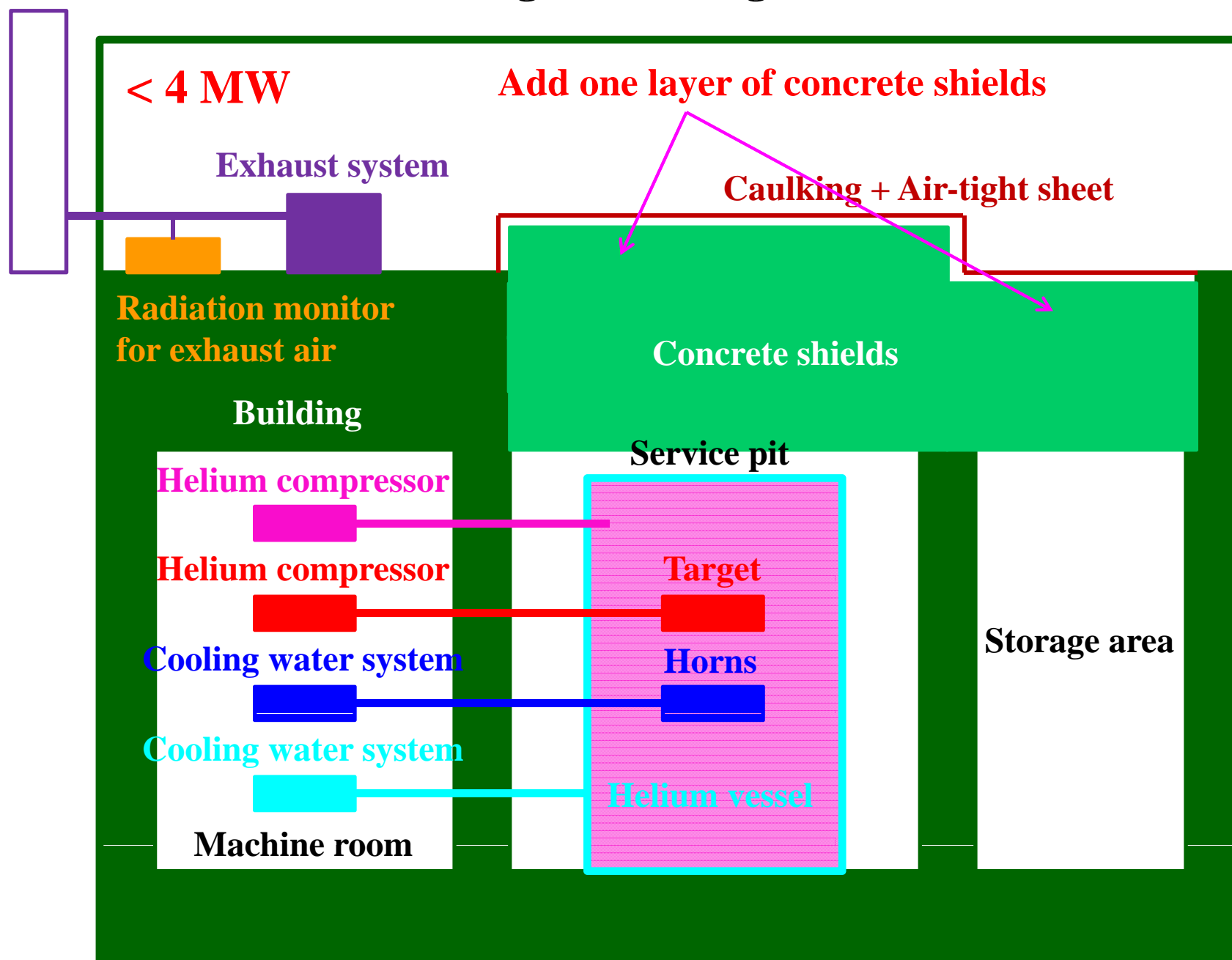
# Schematic diagram of target station





Chimney stack

# Schematic diagram of target station



$< 4 \text{ MW}$

Add one layer of concrete shields

Exhaust system

Caulking + Air-tight sheet

Radiation monitor  
for exhaust air

Concrete shields

Building

Service pit

Helium compressor

Helium compressor

Cooling water system

Cooling water system

Machine room

Target

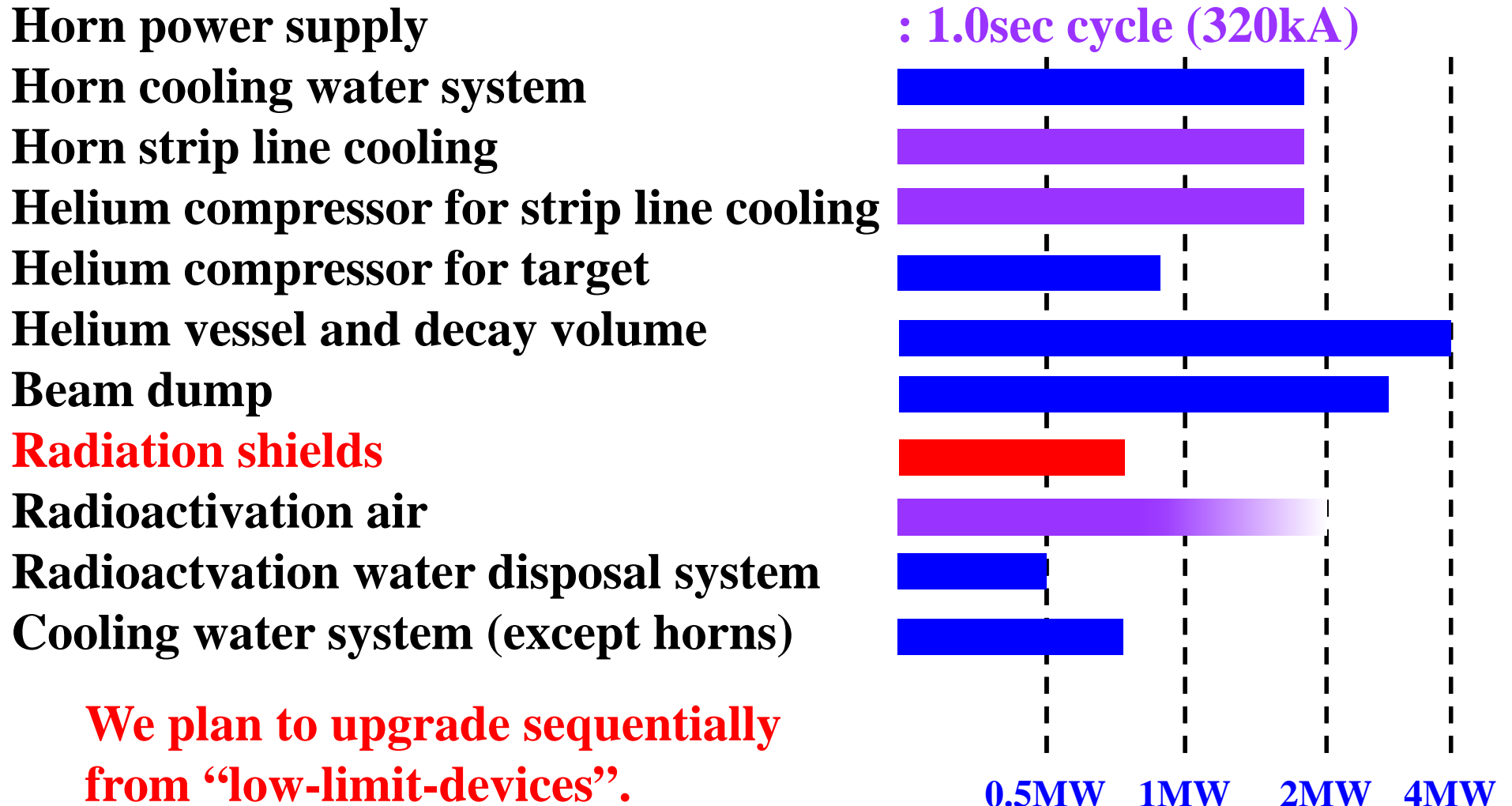
Horns

Helium vessel

Storage area

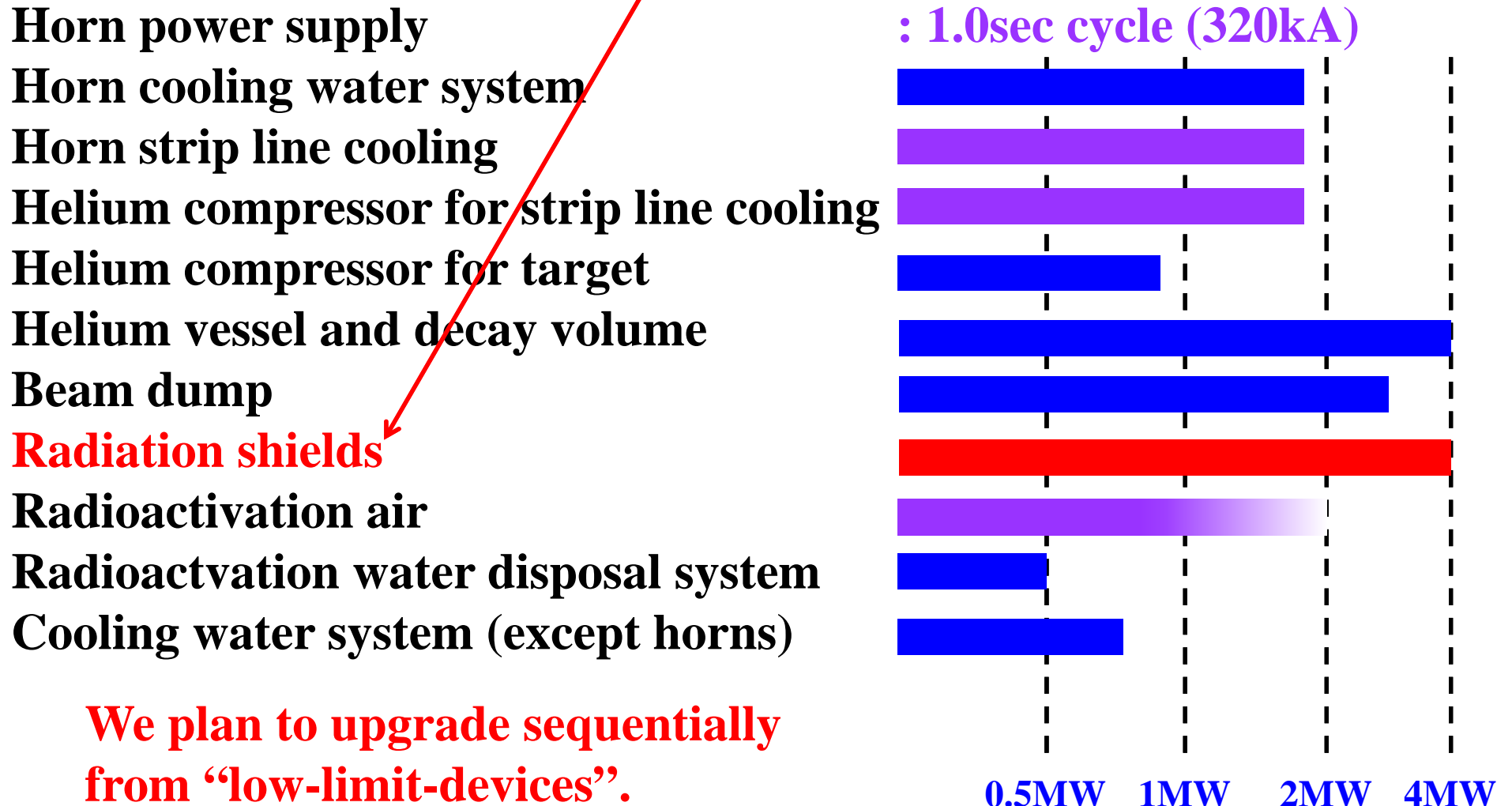
# The limit of beam power that present devices can stand

**Add one layer of concrete shields**

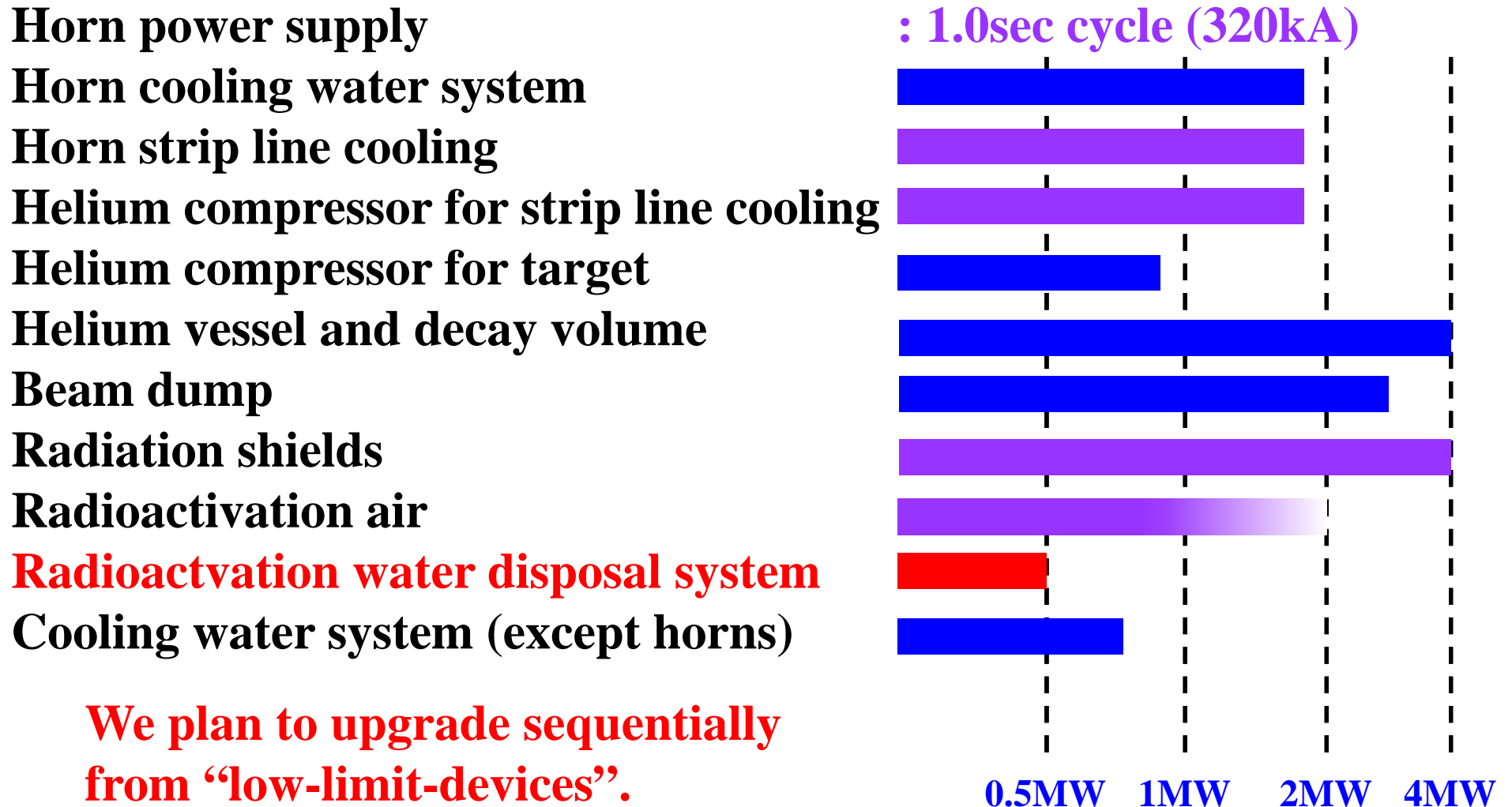


# The limit of beam power that present devices can stand

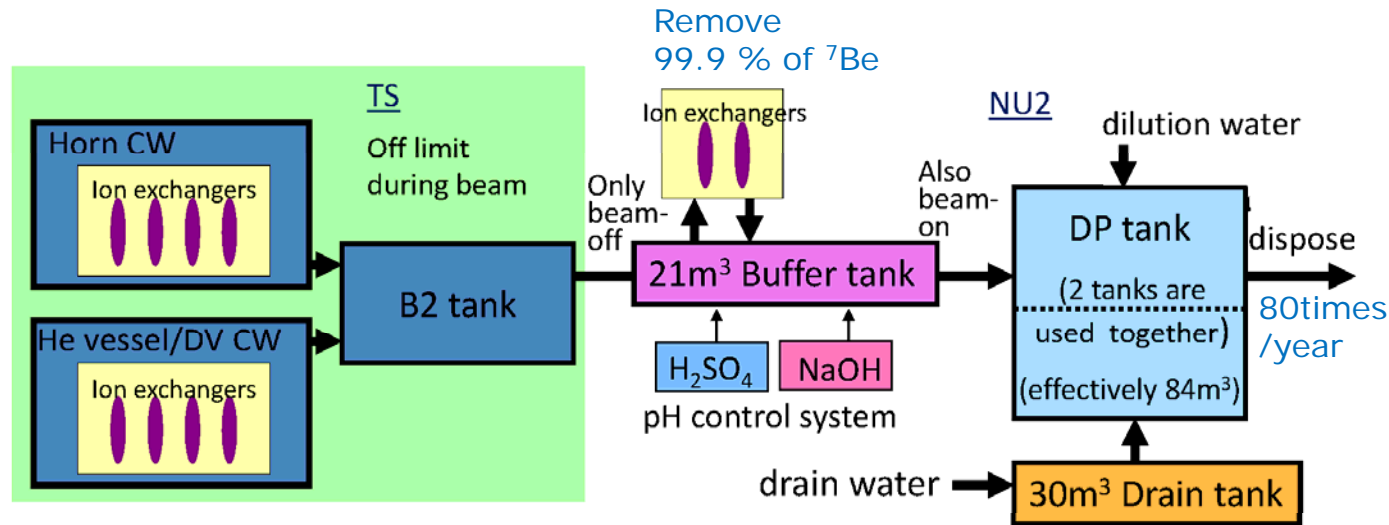
**Add one layer of concrete shields**



# The limit of beam power that present devices can stand



# Upgrade for Radioactive Water Disposal



**<sup>7</sup>Be and <sup>3</sup>H are produced by beam operation in the cooling water.**  
**<sup>7</sup>Be is removed by the ion exchanger and <sup>3</sup>H is diluted in tank to < 42 Bq/cc.**  
**The tank size restricts the disposal capacity, and**  
**the limit of the present dilution system corresponds to ~ 500kW beam.**  
**So we plan to use the tanker truck and/or add the tank.**  
**We test to use the tanker truck this summer shutdown.**

# The limit of beam power that present devices can stand

**Use tanker truck**

Horn power supply

Horn cooling water system

Horn strip line cooling

Helium compressor for strip line cooling

Helium compressor for target

Helium vessel and decay volume

Beam dump

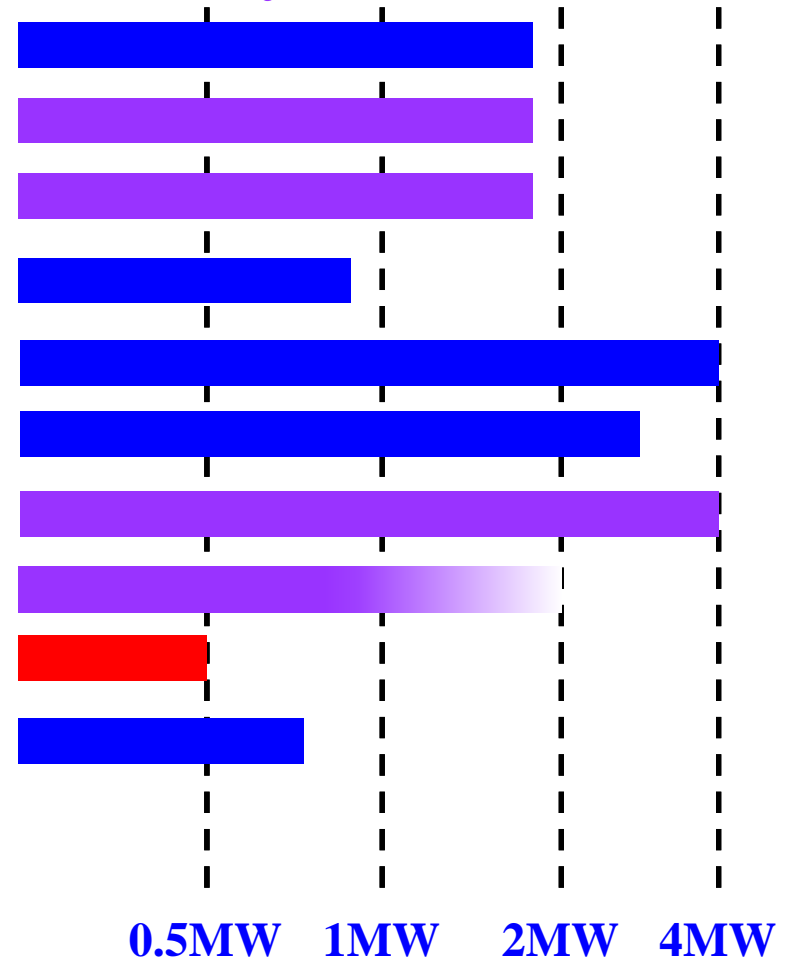
Radiation shields

Radioactivation air

**Radioactivation water disposal system**

Cooling water system (except horns)

**: 1.0sec cycle (320kA)**



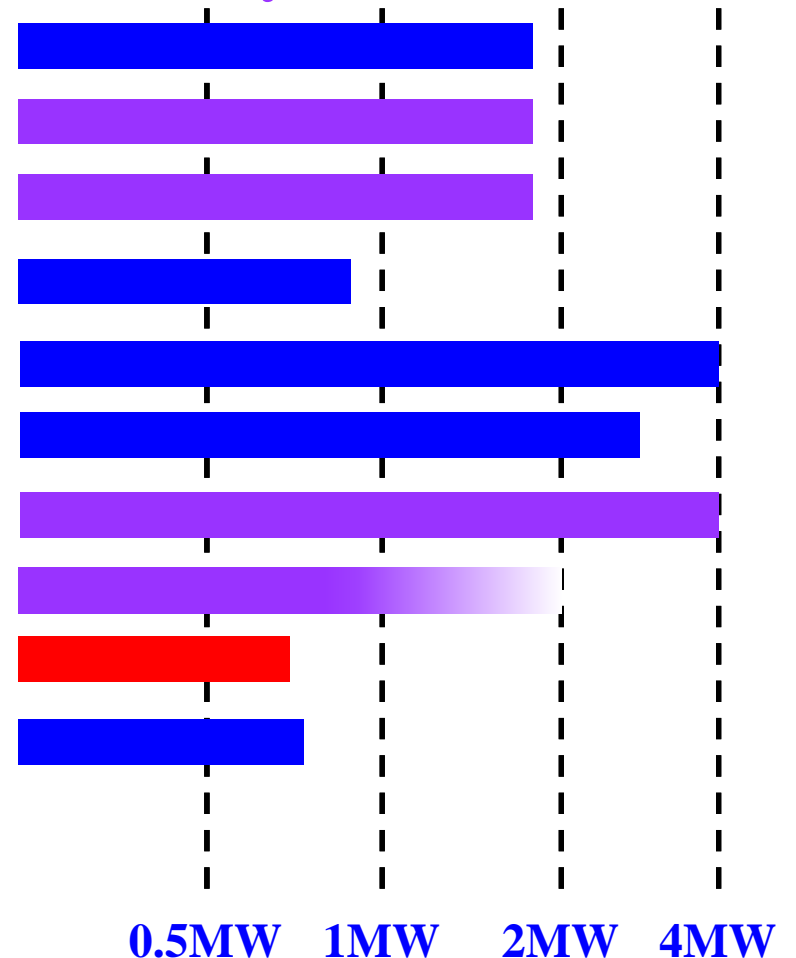
**We plan to upgrade sequentially from “low-limit-devices”.**

# The limit of beam power that present devices can stand

**Use tanker truck**

- Horn power supply
- Horn cooling water system
- Horn strip line cooling
- Helium compressor for strip line cooling
- Helium compressor for target
- Helium vessel and decay volume
- Beam dump
- Radiation shields
- Radioactivation air
- Radioactivation water disposal system**
- Cooling water system (except horn)

**: 1.0sec cycle (320kA)**



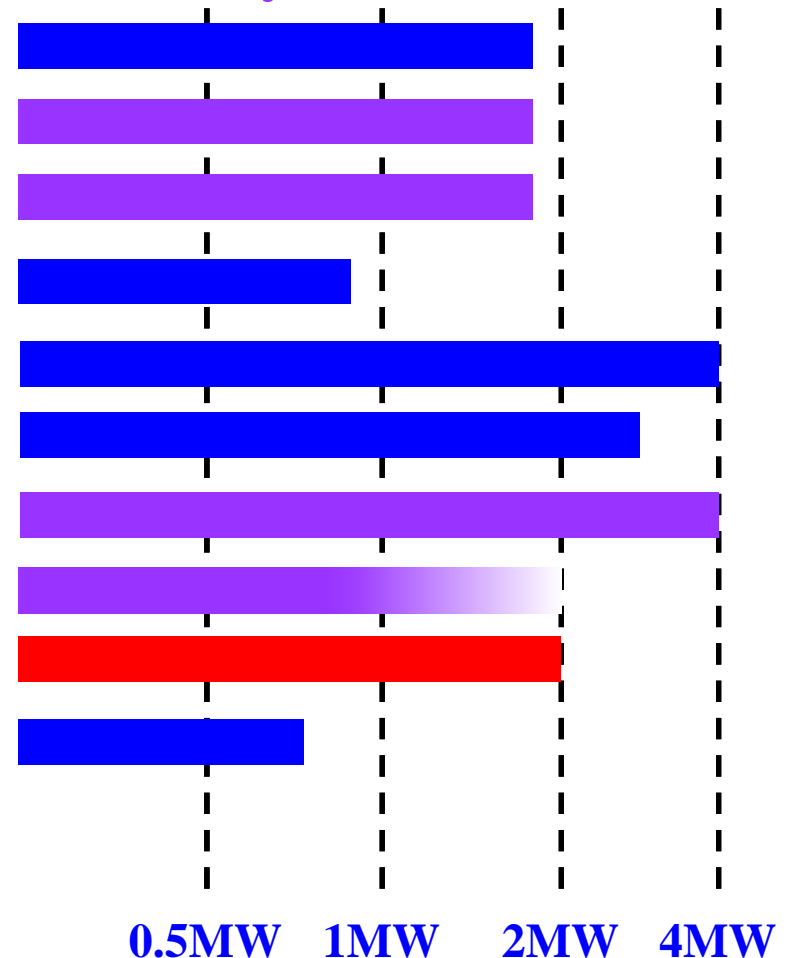
**We plan to upgrade sequentially from “low-limit-devices”.**

# The limit of beam power that present devices can stand

**Add buffer tank**

- Horn power supply
- Horn cooling water system
- Horn strip line cooling
- Helium compressor for strip line cooling
- Helium compressor for target
- Helium vessel and decay volume
- Beam dump
- Radiation shields
- Radioactivation air
- Radioactivation water disposal system**
- Cooling water system (except horns)

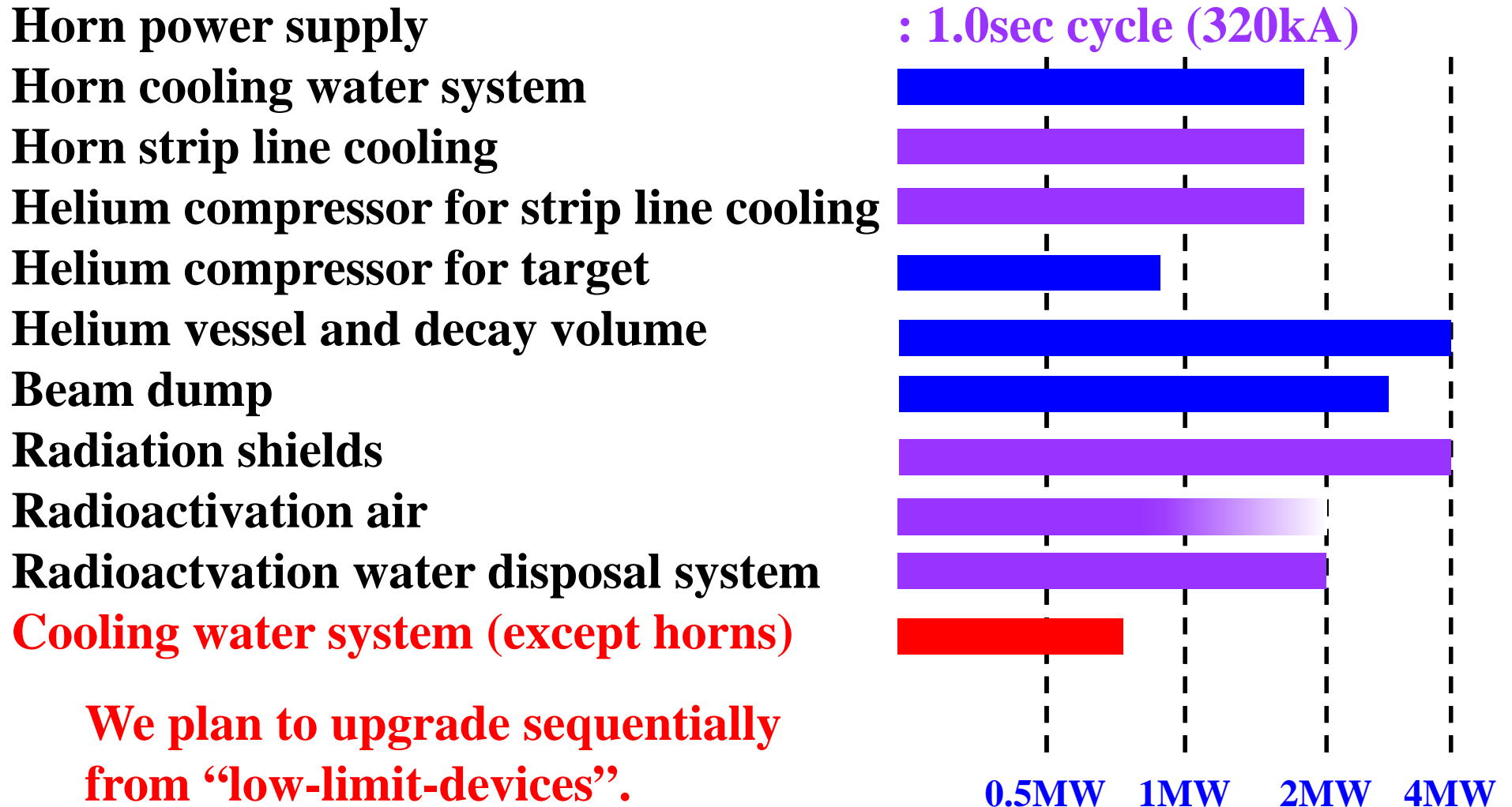
**: 1.0sec cycle (320kA)**



**We plan to upgrade sequentially from “low-limit-devices”.**



# The limit of beam power that present devices can stand



# The limit of beam power that present devices can stand

**Upgrade the system**

Horn power supply

Horn cooling water system

Horn strip line cooling

Helium compressor for strip line cooling

Helium compressor for target

Helium vessel and decay volume

Beam dump

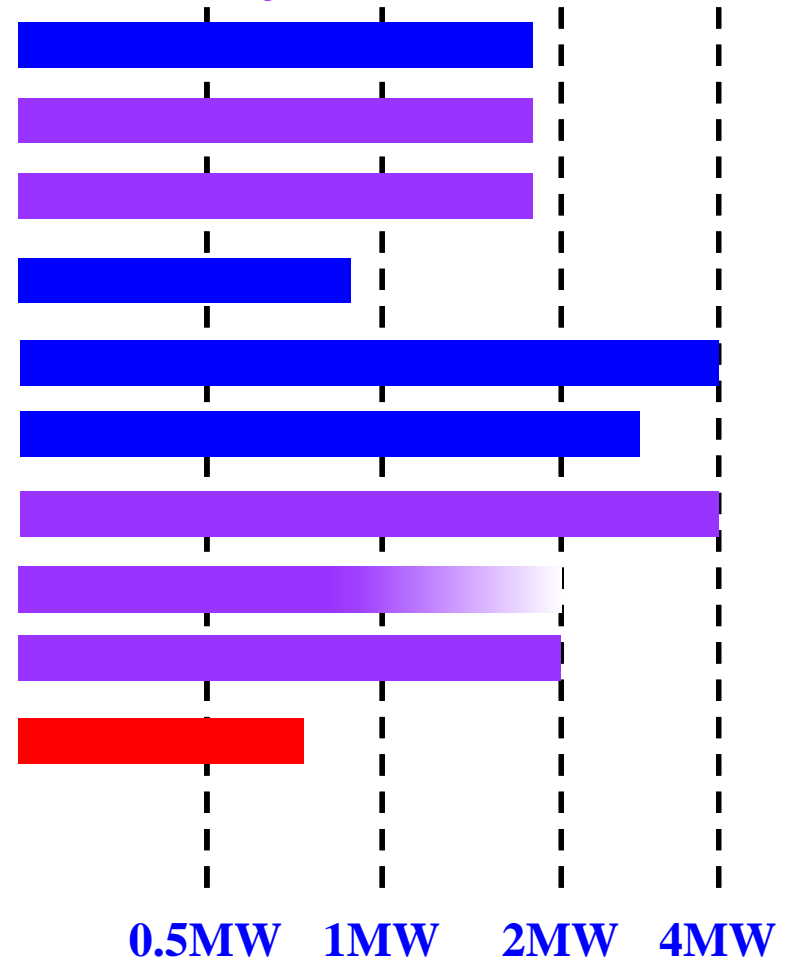
Radiation shields

Radioactivation air

Radioactivation water disposal system

**Cooling water system (except horns)**

**: 1.0sec cycle (320kA)**



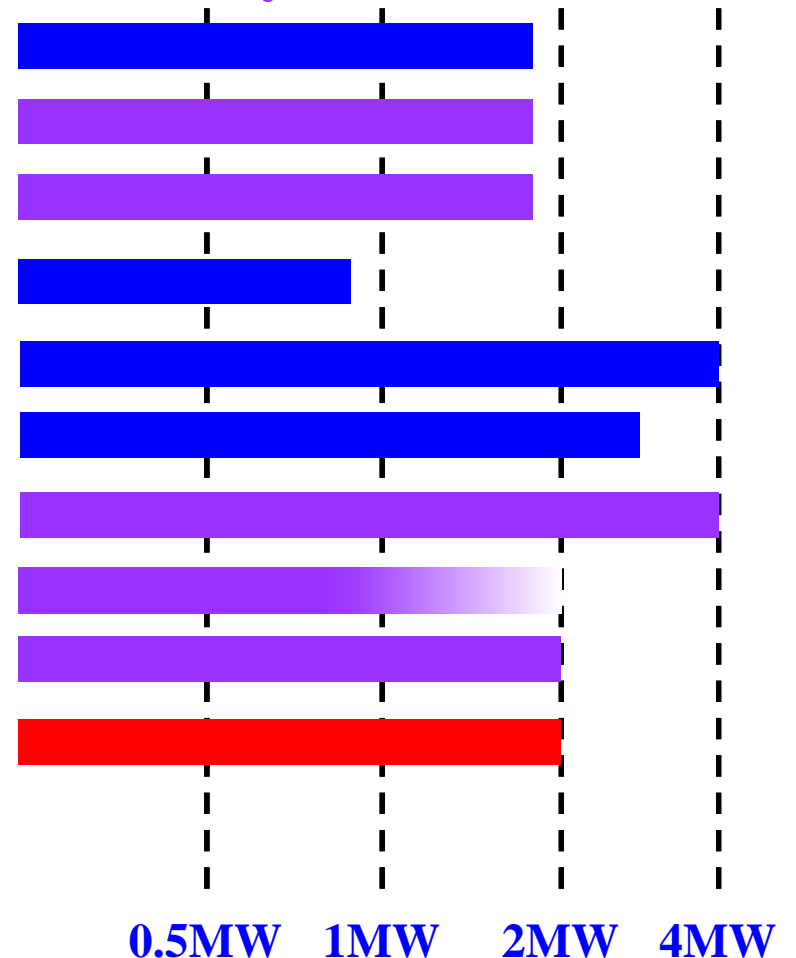
**We plan to upgrade sequentially from “low-limit-devices”.**

# The limit of beam power that present devices can stand

**Upgrade the system**

- Horn power supply
- Horn cooling water system
- Horn strip line cooling
- Helium compressor for strip line cooling
- Helium compressor for target
- Helium vessel and decay volume
- Beam dump
- Radiation shields
- Radioactivation air
- Radioactivation water disposal system
- Cooling water system (except horns)**

**: 1.0sec cycle (320kA)**

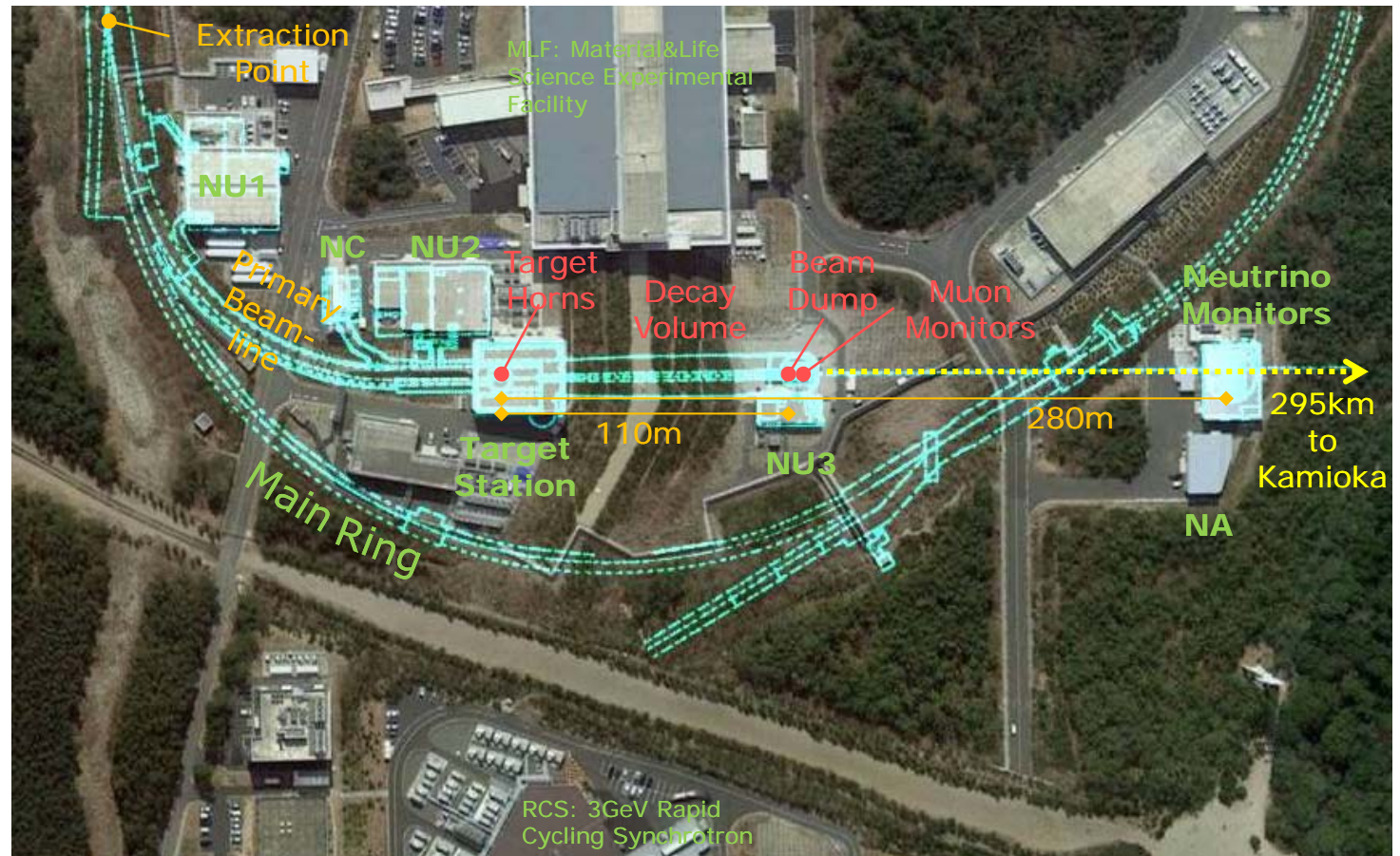


**We plan to upgrade sequentially from “low-limit-devices”.**

# J-PARC Neutrino Experimental Facility

Our facility buildings are too small to install upgraded facilities.

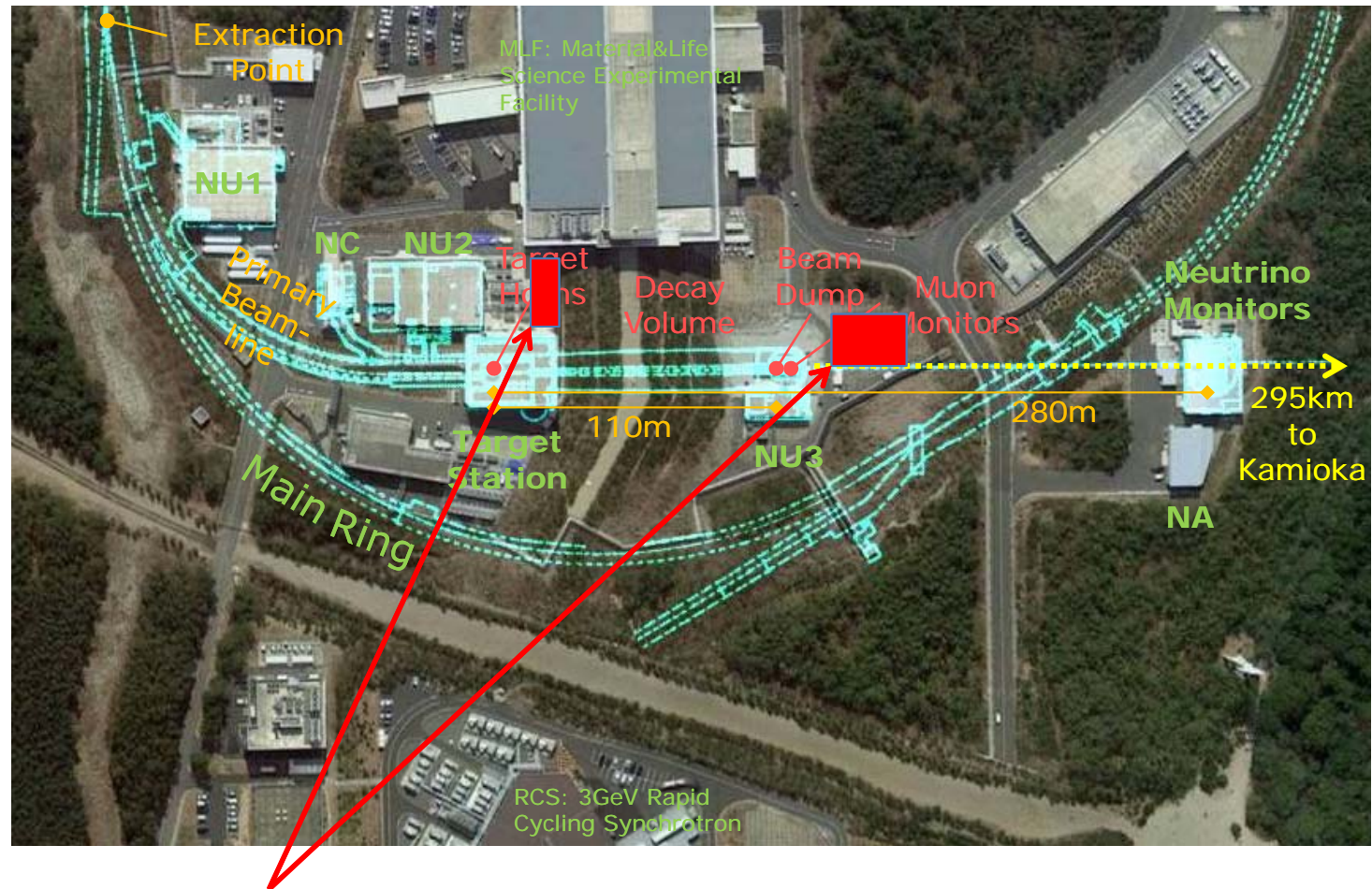
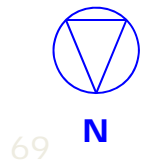
J-PARC, Tokai



N

# J-PARC Neutrino Experimental Facility

Our facility buildings are too small to install upgraded facilities.



**We plan to build new facility buildings for the new cooling water systems, the new buffer tanks, and other facilities.**

# Schedule in this few years

	FY 2013		FY 2014		FY 2015	
Horn		H2/H3 exchange		H1 exchange		
Horn power supply	PS manufacturing		PS exchange	Transformer manufacturing	3rd PS install	3 transformers install
Anti-radiation measure		Airtightness work				
New facility buildings			Design		Build?	

Work for horn exchange straddles in two years and for power supply in three years because of budget, time, and manpower.  
 (Also modification of water system and airtightness work)

# Upgrade plan in secondary beam line towards high power operation

