Skyshine and Other Dose Evaluation

1. Radiation design targets
2. Skyshine evaluation
3. Proton beam line shield
4. Air and water activation and waste

JAERI
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Radiation Design Targets

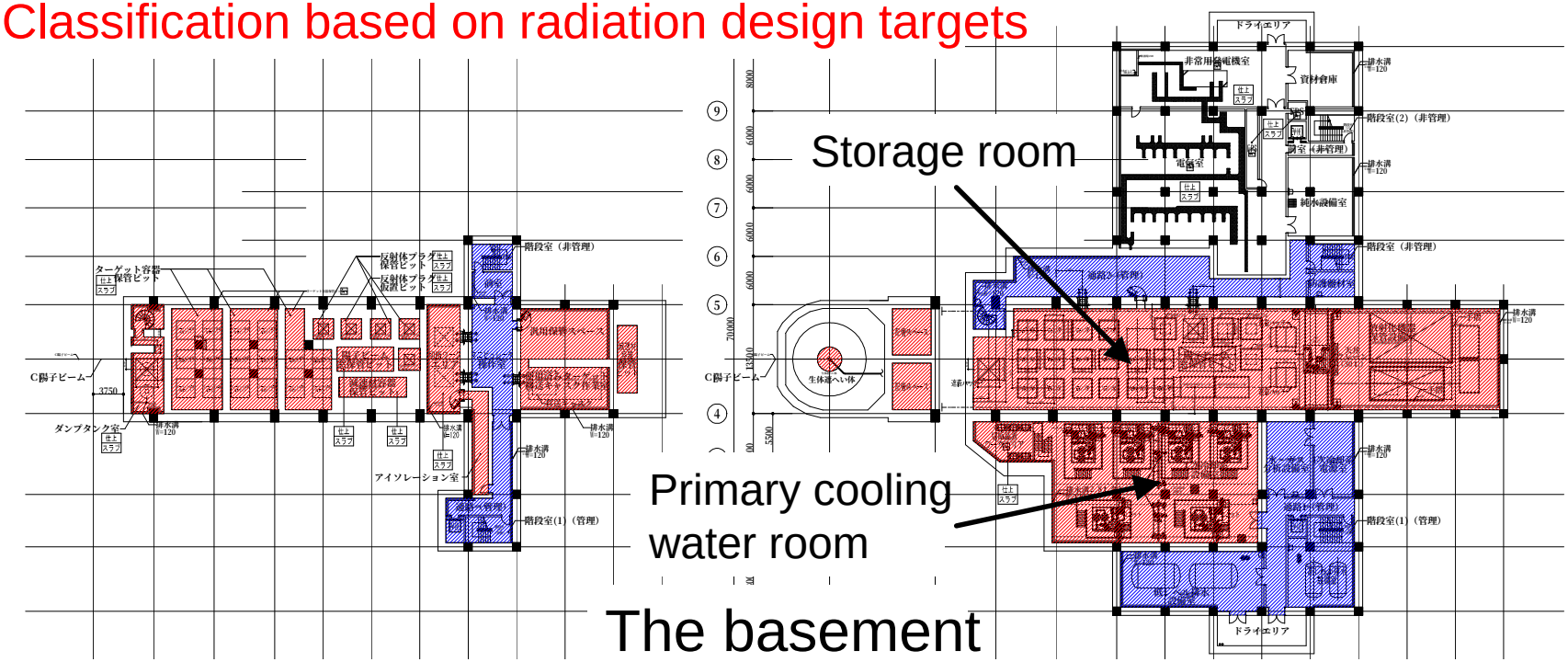
Item	Design target*	Japanese Law
Dose rate at Site boundary	? 50 μSv/year (? 35 μSv/year for Phase-I)	? 250 μSv/3 months
Dose rate at General area	? 0.25 μSv/hour	? 20 μSv/week**
Dose rate at Radiation controlled area I***	? 12.5 μSv/hour	? 1 mSv/week
Radioactive concentration at discharge	1/2 of Japanese law	
Ground water activation****	? 5 mSv/hour for line loss ? 11mSv/hour for point loss	

* : Design targets are smaller (1/2 ~ 1/20) than Japanese law.
**: 1week = 40 hours
***: Registered radiation workers can enter freely any time.
**** : This corresponds to ?10μSv/y if one drinks ground water at site boundary for one year.

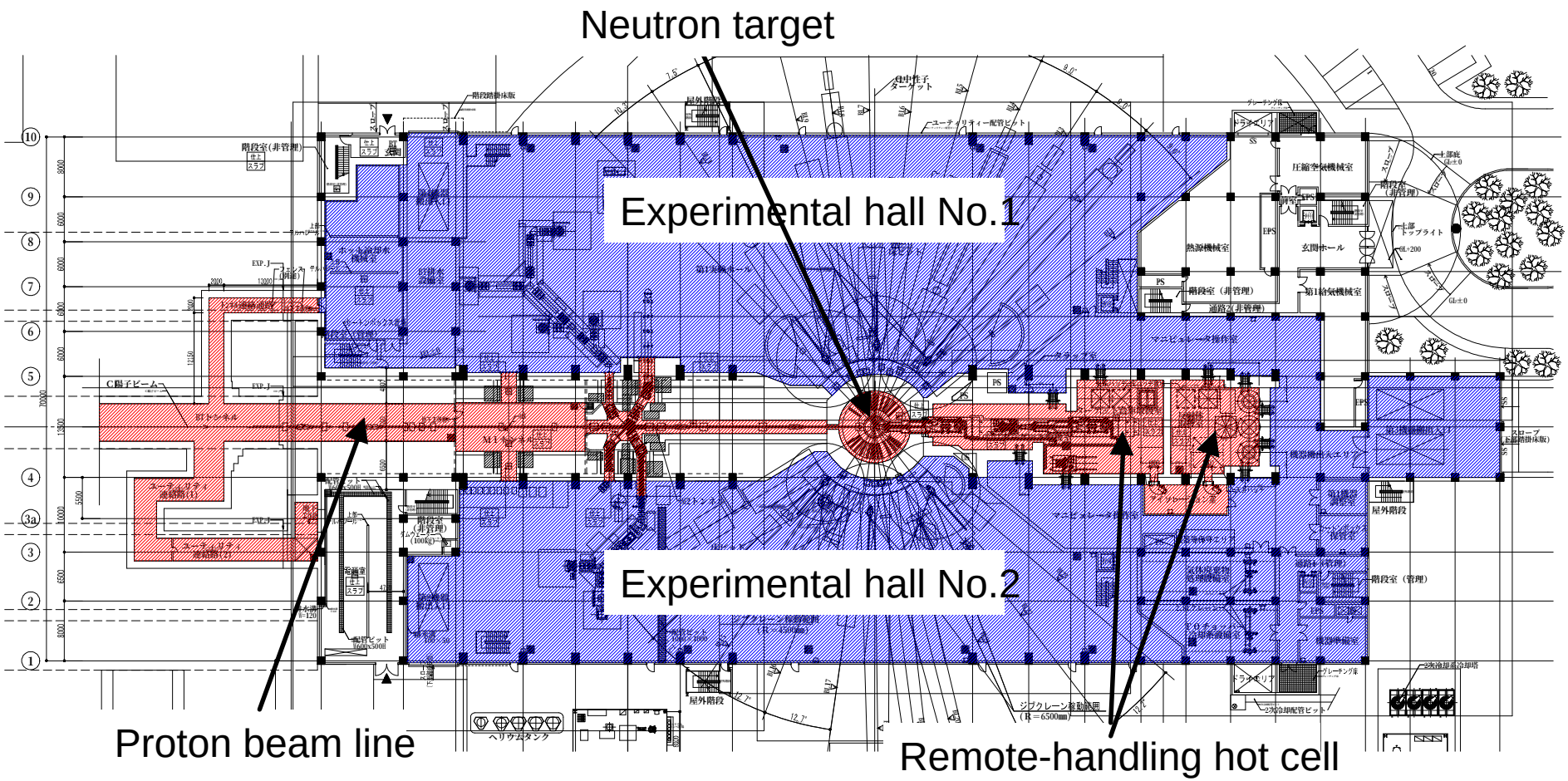
MLF Area Classification -(1)

General area : No color	- Dose rate is always less than 0.25 μSv/h.
No-restricted radiation controlled area : Blue	- Dose rate is always less than 12.5 μSv/h. - Radiation workers can freely enter any time. - There can exist radioactive contamination in the air or on the surface.
Restricted radiation controlled area : Red	- Dose rate is always or occasionally higher than 12.5 μSv/h. - Even radiation workers are restricted to enter. - There can exist radioactive contamination in the air or on the surface.

Classification based on radiation design targets

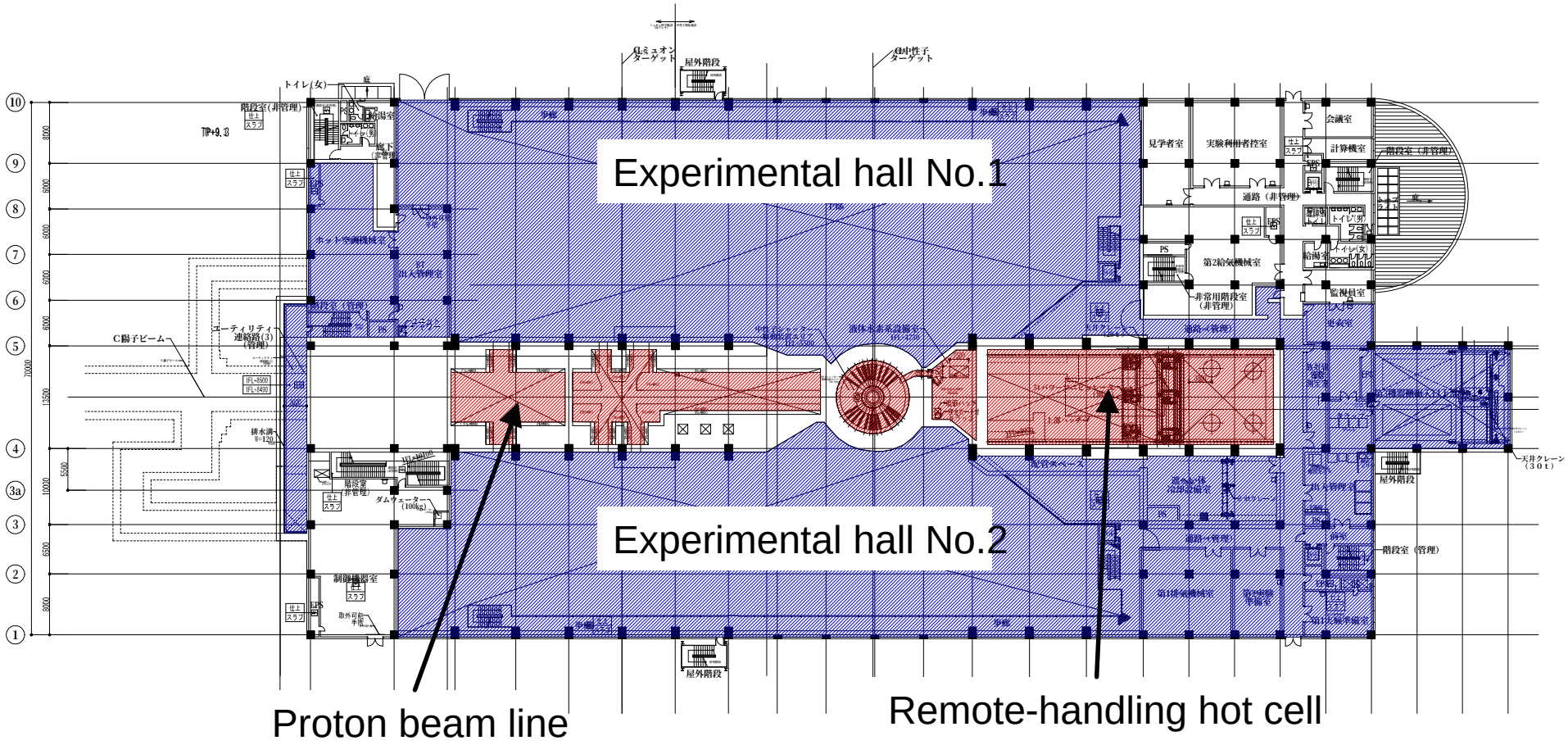


MLF Area Classification -(2)



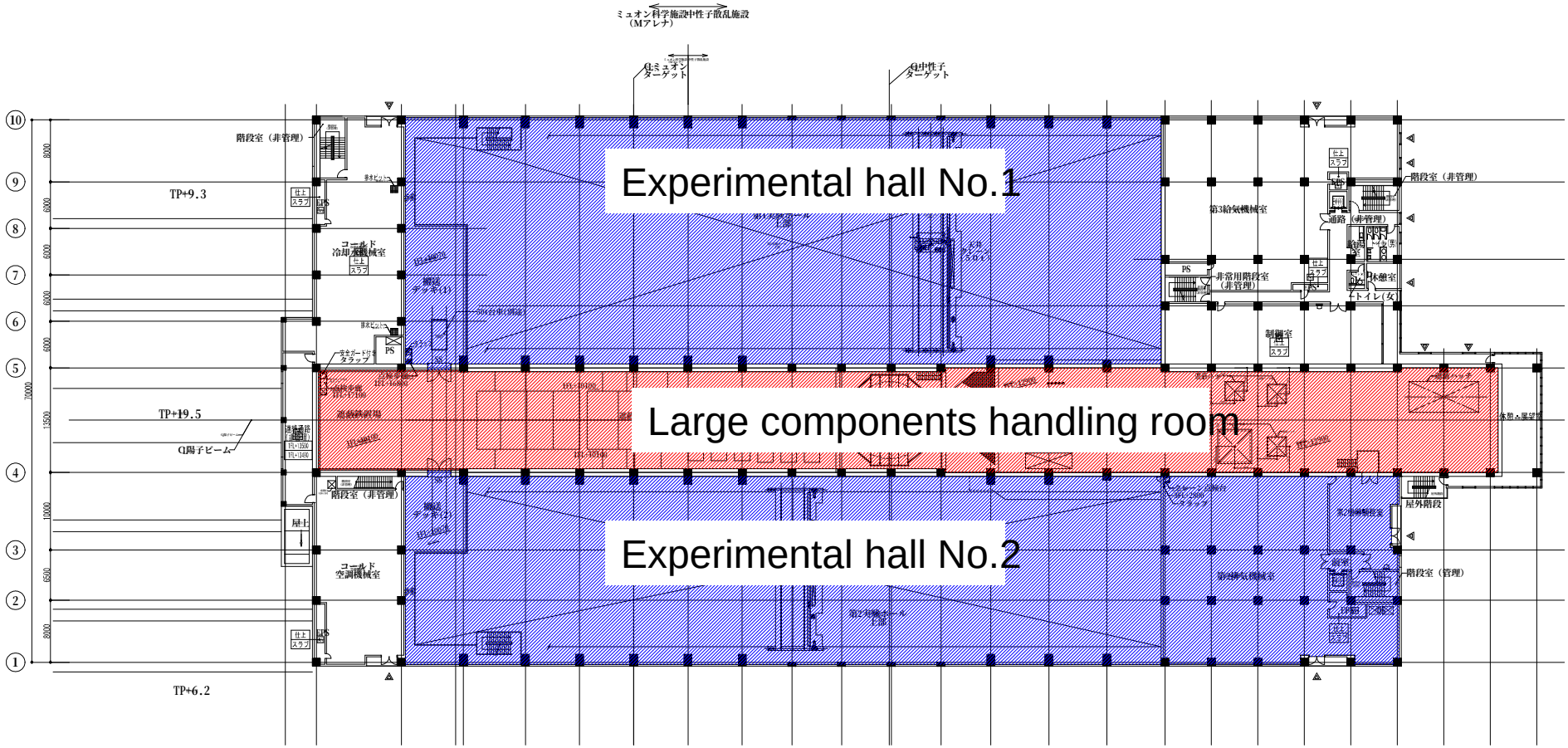
The first floor

MLF Area Classification -(3)



The second floor

MLF Area Classification -(4)



The third floor

Dose and Activation Evaluation Methods

- Evaluation methods :
  - Dose : Moyer's model, NMTC/JAM, MCNPX2.1.5
  - Activation : NMTC/JAM and DCHAIN-SP
  - Evaluation accuracy --> Reports by Meigo and Kai
  - Evaluation margin :
    - ✓Moyer's model-->none (Moyer's model overestimates)
    - ✓Monte Carlo calculation --> Factor 2
      (None for activation evaluation)

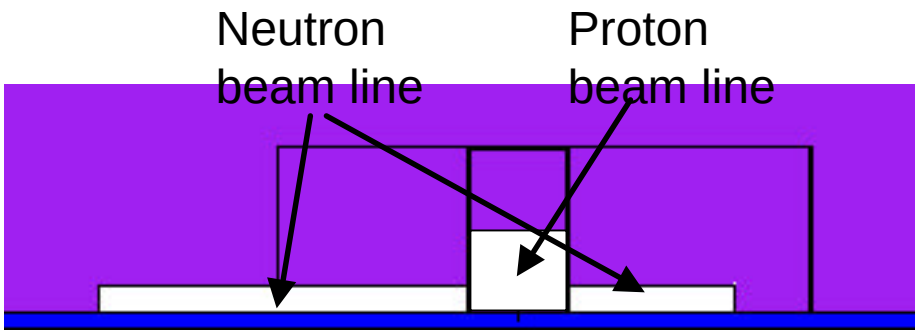
- Evaluation Conditions
  - Proton beam operation time : 5000 h/year
    (20 days/cycle, 12 cycles/year)
  - Proton beam power : 1 MW

Dose and Activation Evaluation Items

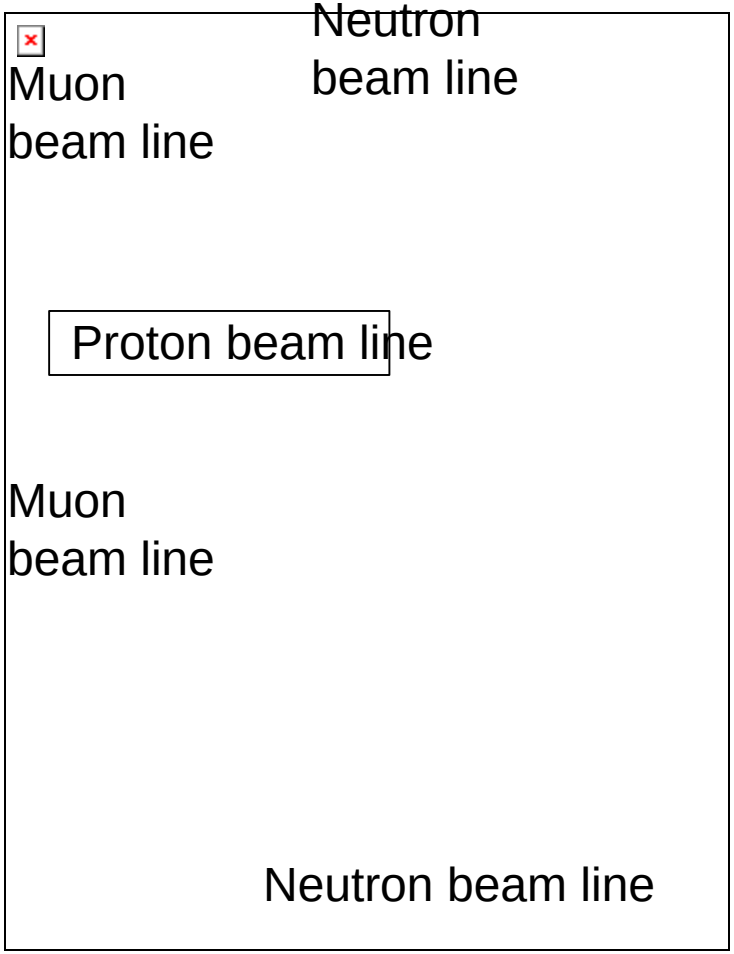
- Shield for neutrons and gammas : total dose
  - Bulk shield and Streaming
    - ✓Neutron target-->presentation by Maekawa
    - ✓Muon target -->presentation by Miyake
    - ✓Collimator-->presentation by Miyake
    - ✓Magnets [1W/m and 1kW]
    - ✓Skyshine
- Activation : air, water and apparatus
  - gamma dose in processing room for air and water
  - gamma dose at maintenance
  - radioactive concentration at discharge of air and water

Skyshine Evaluation- (1)

- Calculation code : MCNPX
- Calculation conditions
  (Average dose rate on the outer surface of shield)
  - neutron beam line : 2 μSv/h
  - muon beam line : 2 μSv/h
  - proton beam line : 6 μSv/h
    (including a margin of 2)

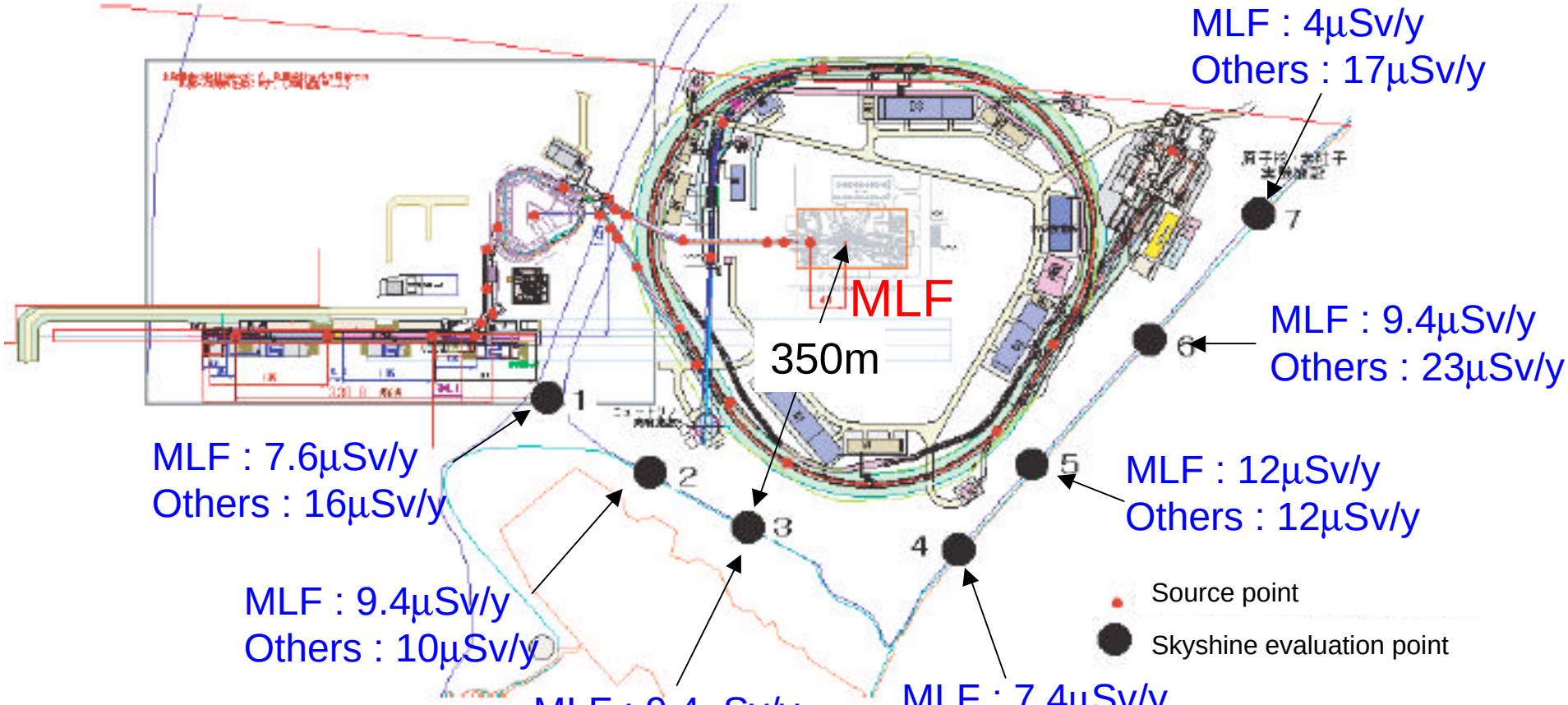


Vertical model



Horizontal model

Skyshine Evaluation- (2)



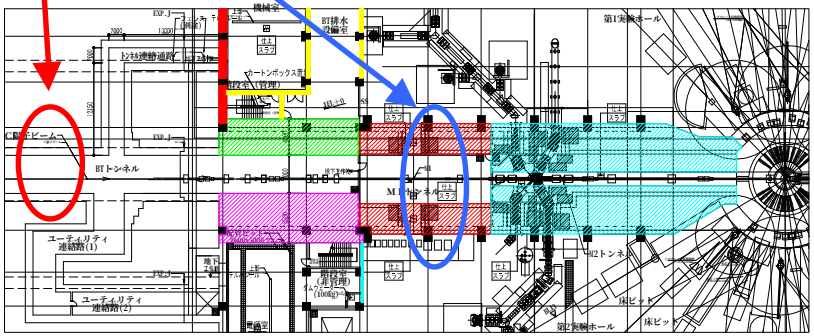
Skyshine dose from others is tentative.

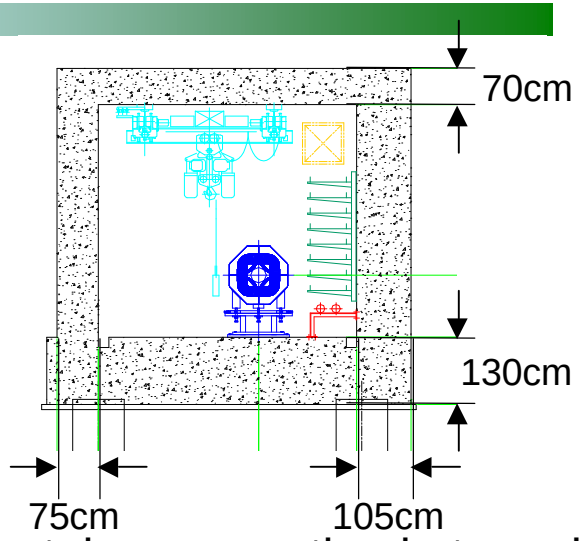
Total skyshine dose will be less than 35 μSv/y.

Proton Beam Line Shield (1)

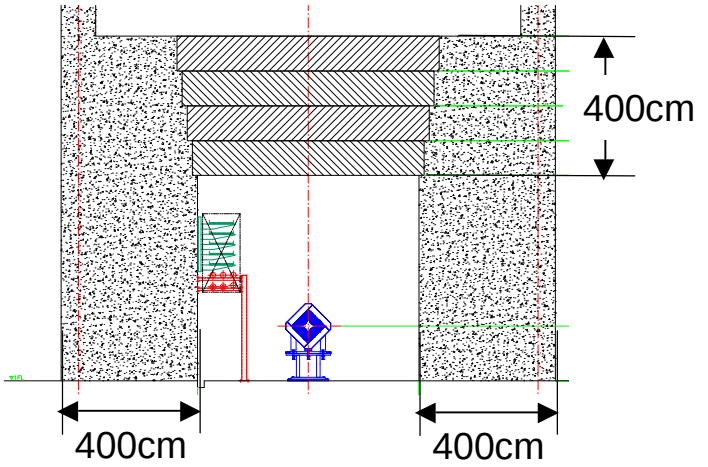
- 1W/m beam loss -

- Calculation method : Moyer's model
- Tunnel : criteria is soil activation (5mSv/h).
  - ceiling : concrete 70cm
  - floor : concrete 130cm
  - right side (from upstream) : concrete 105cm
  - left side (from upstream) : concrete 75cm
- In MLF : criteria is 12.5 μSv/h.
  - ceiling,side : concrete 400cm





Horizontal cross section in tunnel (from upstream)



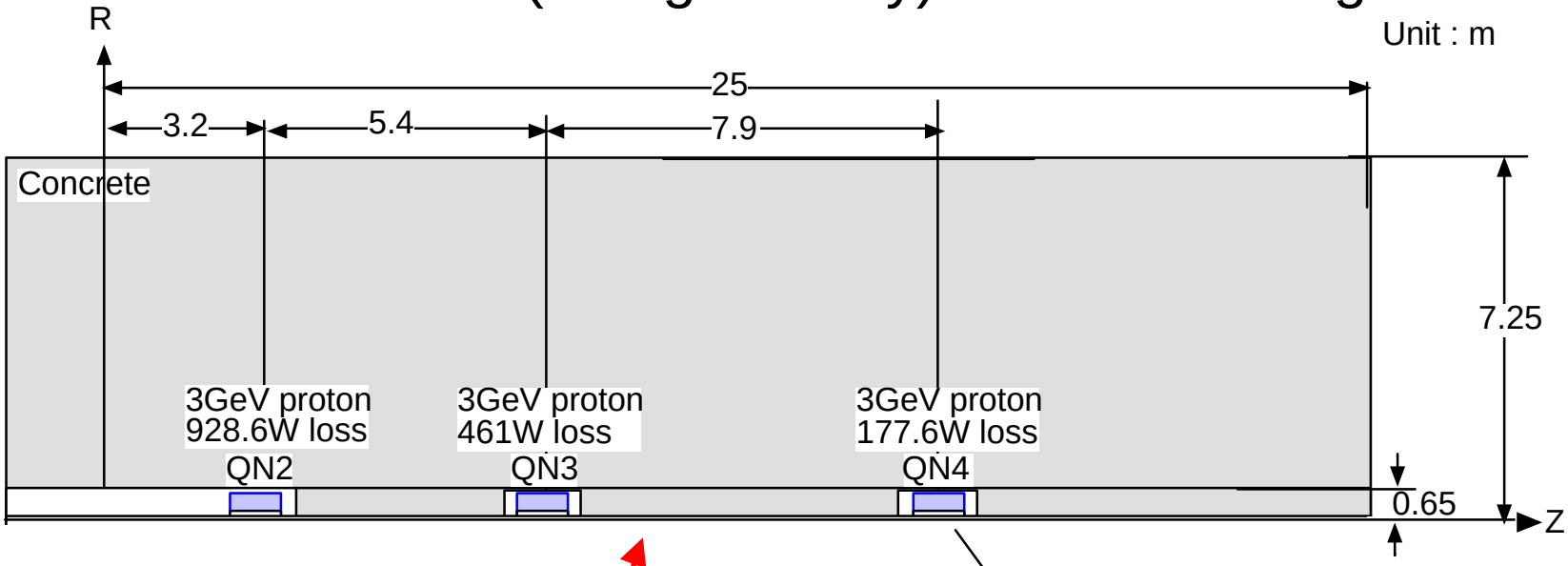
Horizontal cross section in MLF

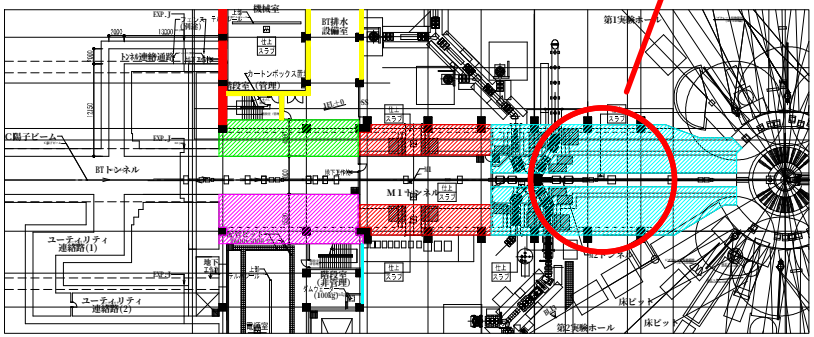
Proton Beam Line Shield (2)

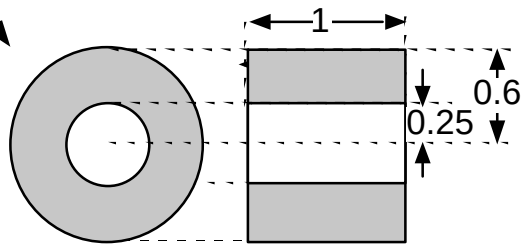
- proton beam line between muon and neutron target -

Beam loss at magnets is ~1kW.

Calculation model (R-Z geometry) after muon target





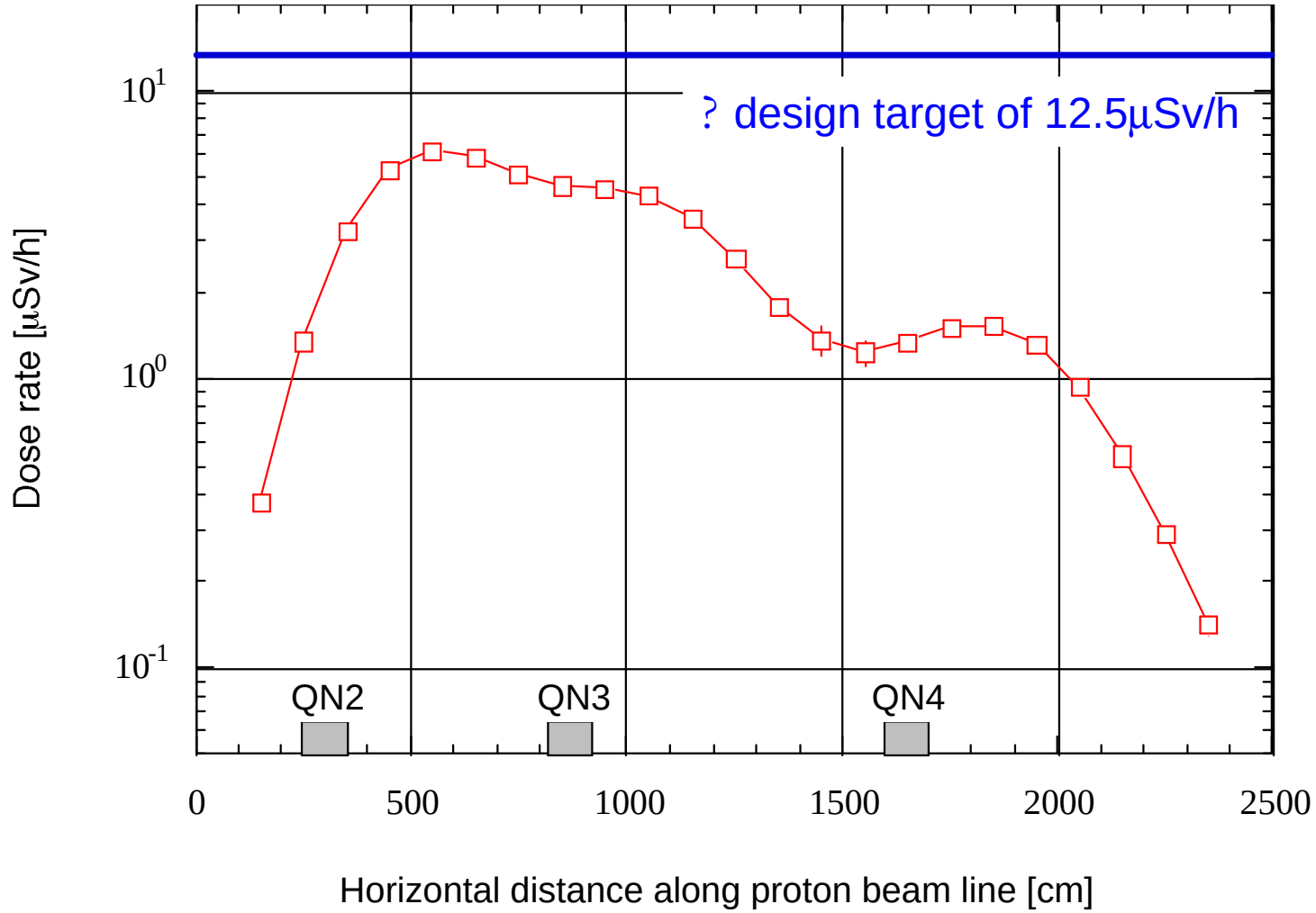


Magnet (Iron)

Proton Beam Line Shield (3)

- proton beam line between muon and neutron target -

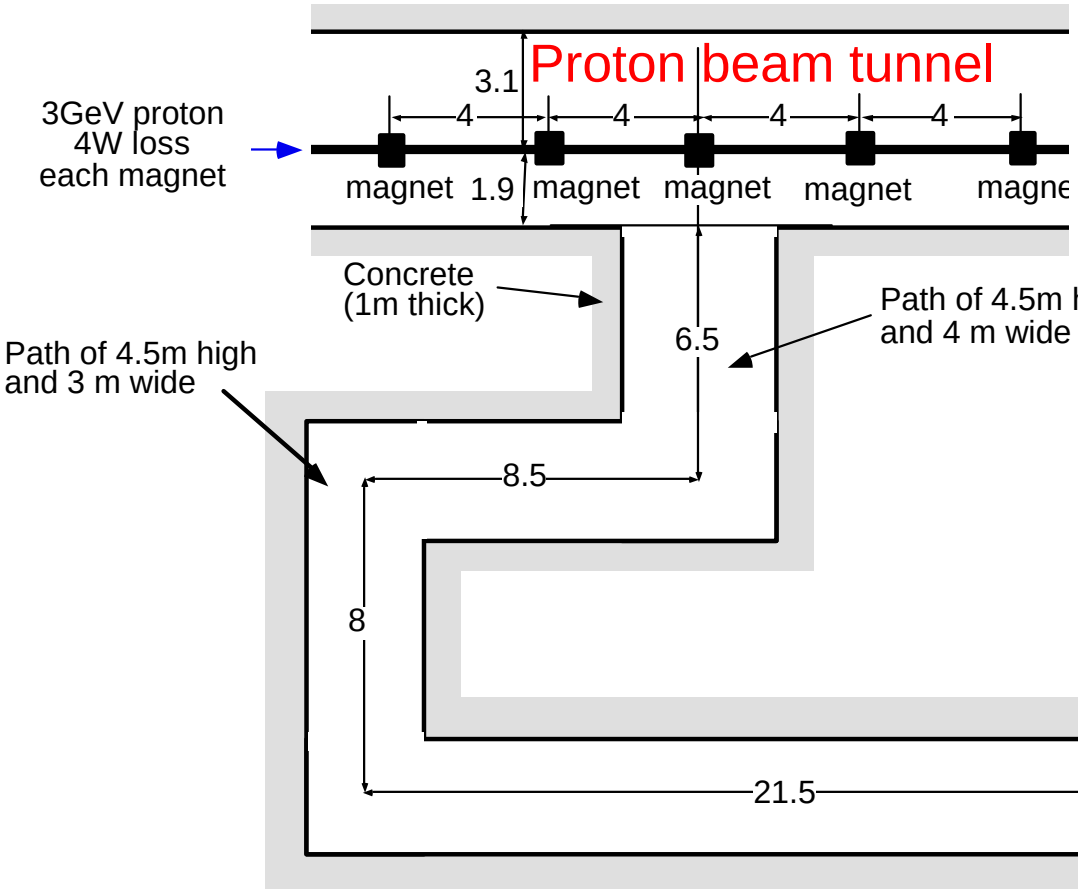
Calculated dose rate on outer surface of shield with MCNPX

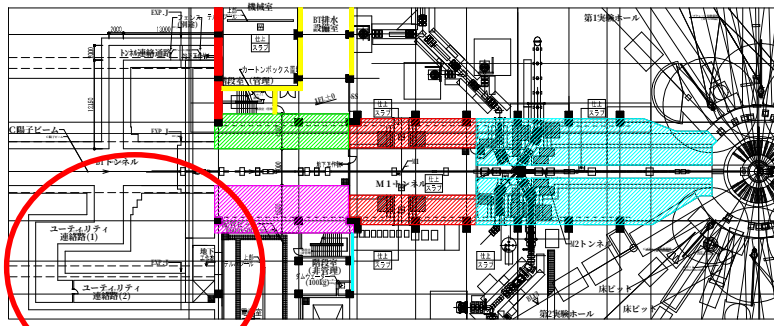


Proton Beam Line Shield (4)

- Streaming through Labyrinth -

Calculation model





utility connection path

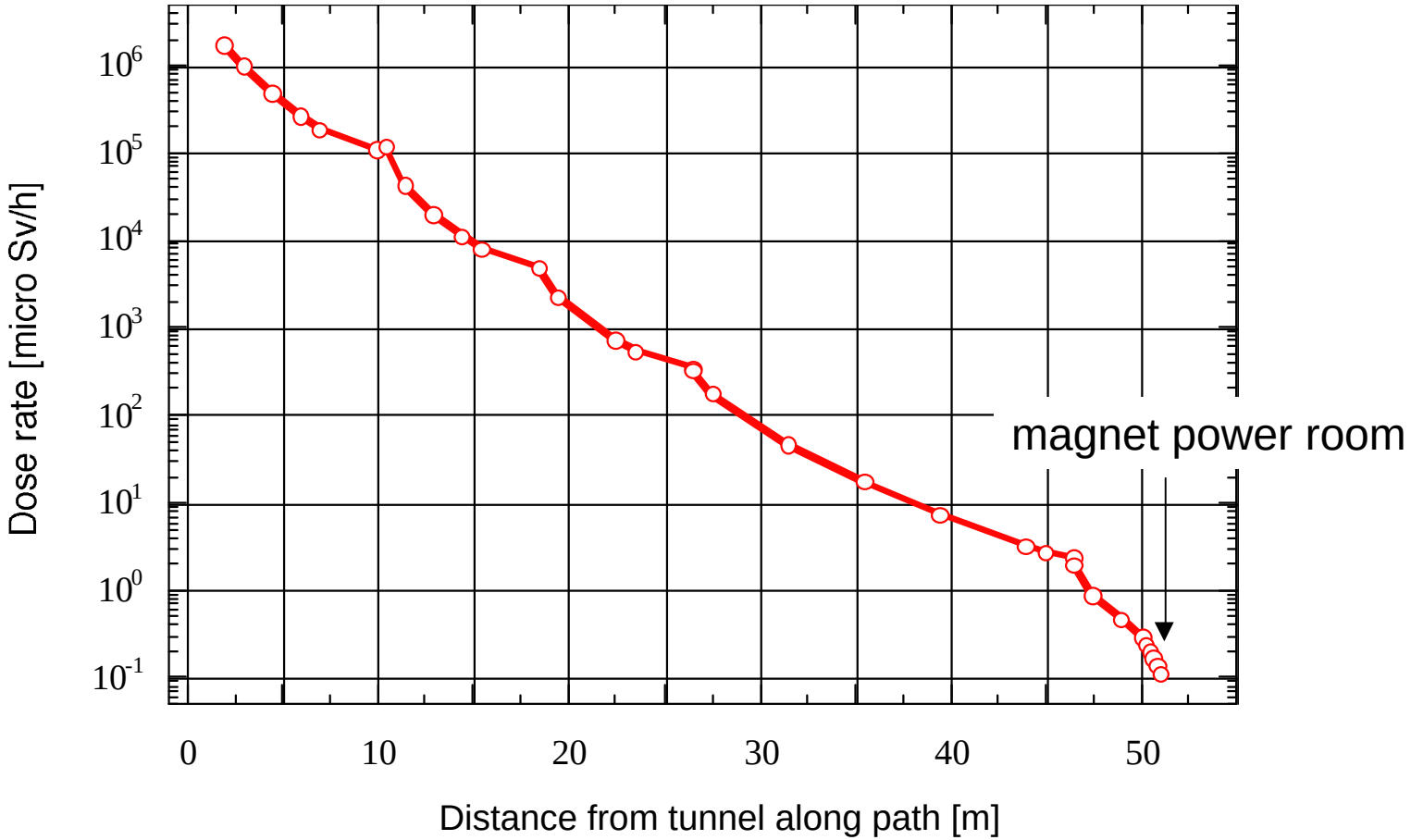
unit : m

Magnet power room
(general area)

Proton Beam Line Shield (5)

- Streaming through Labyrinth -

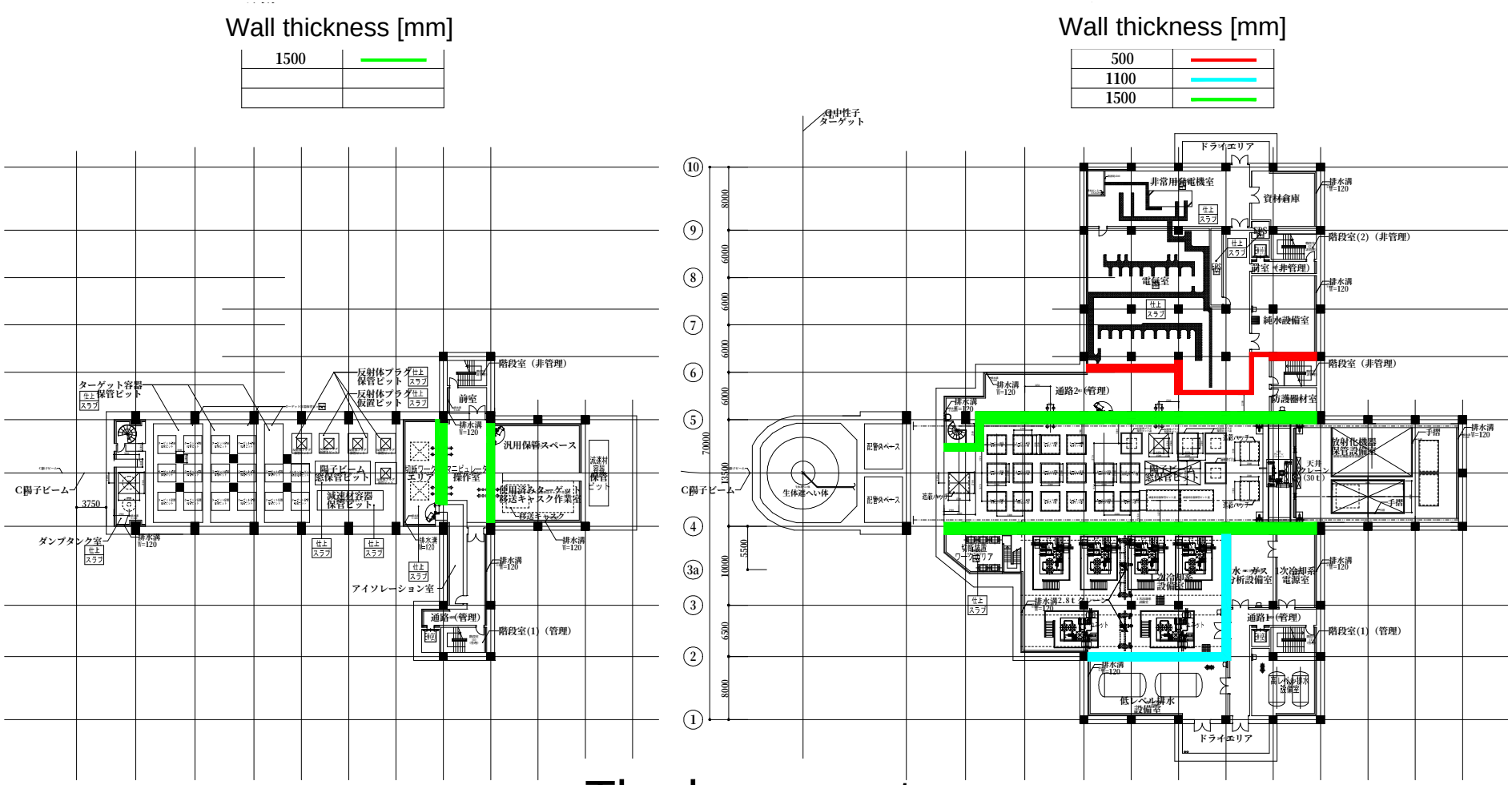
Calculated dose rate along path with MCNPX



Dose rate at magnet power room (general area) is less than the design target of 0.25μSv/h.

Shielding Walls -(1)

Concrete wall thickness required for neutron and/or gamma shield

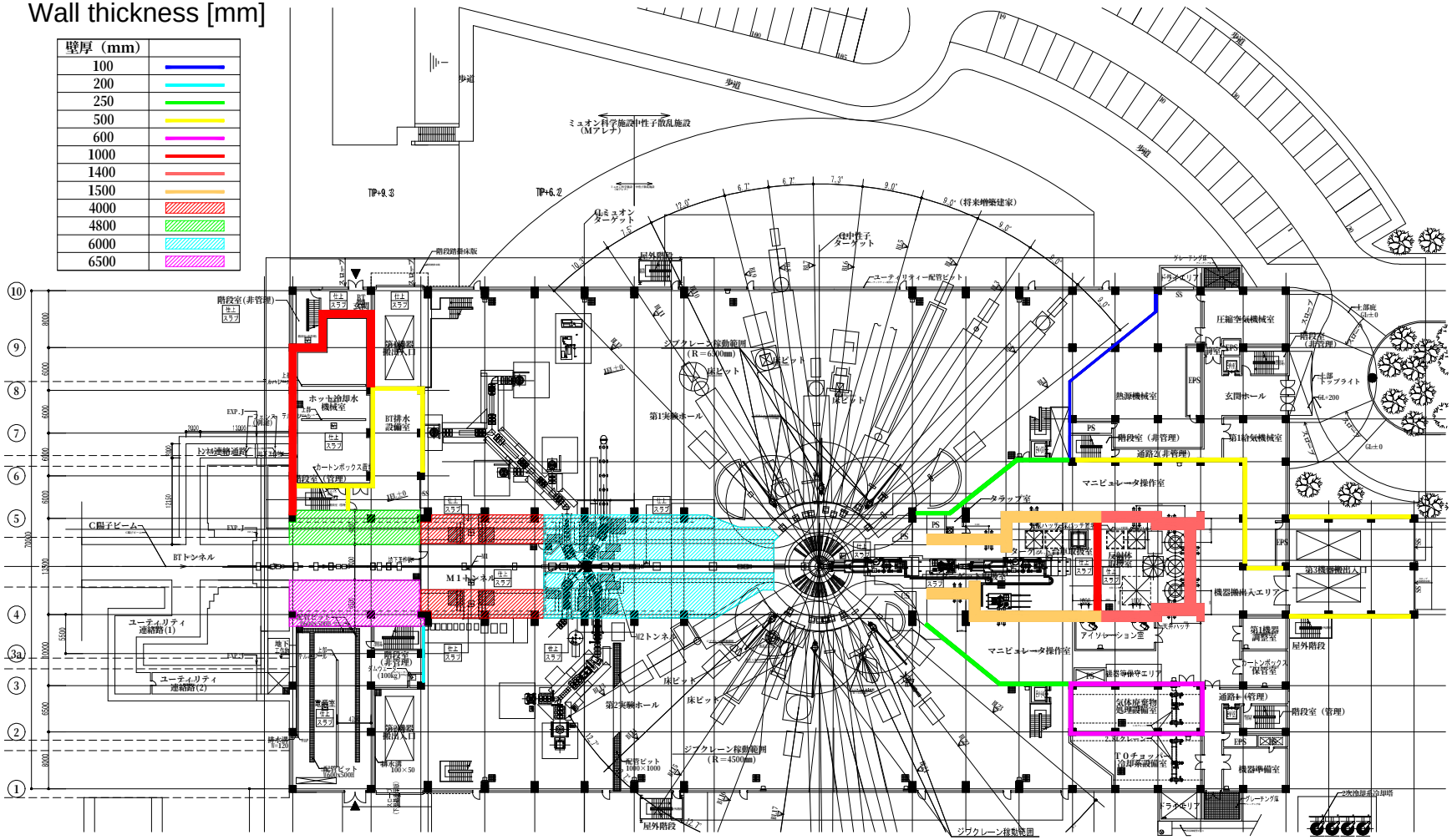


The basement

Shielding Walls -(2)

Wall thickness [mm]

壁厚（mm）
100
200
250
500
600
1000
1400
1500
4000
4800
6000
6500

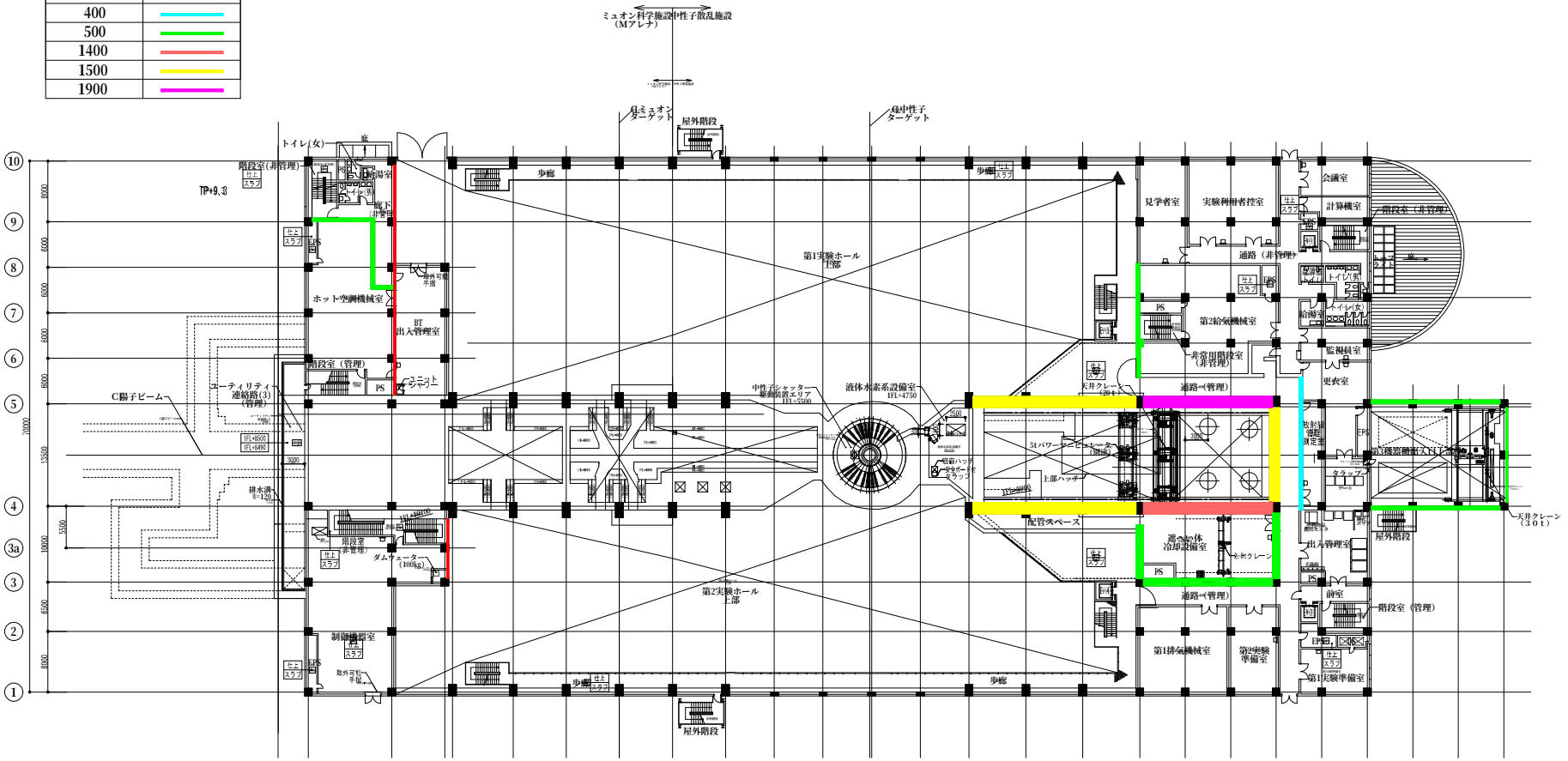


The first floor

Shielding Walls -(3)

Wall thickness [mm]

200	
400	
500	
1400	
1500	
1900	

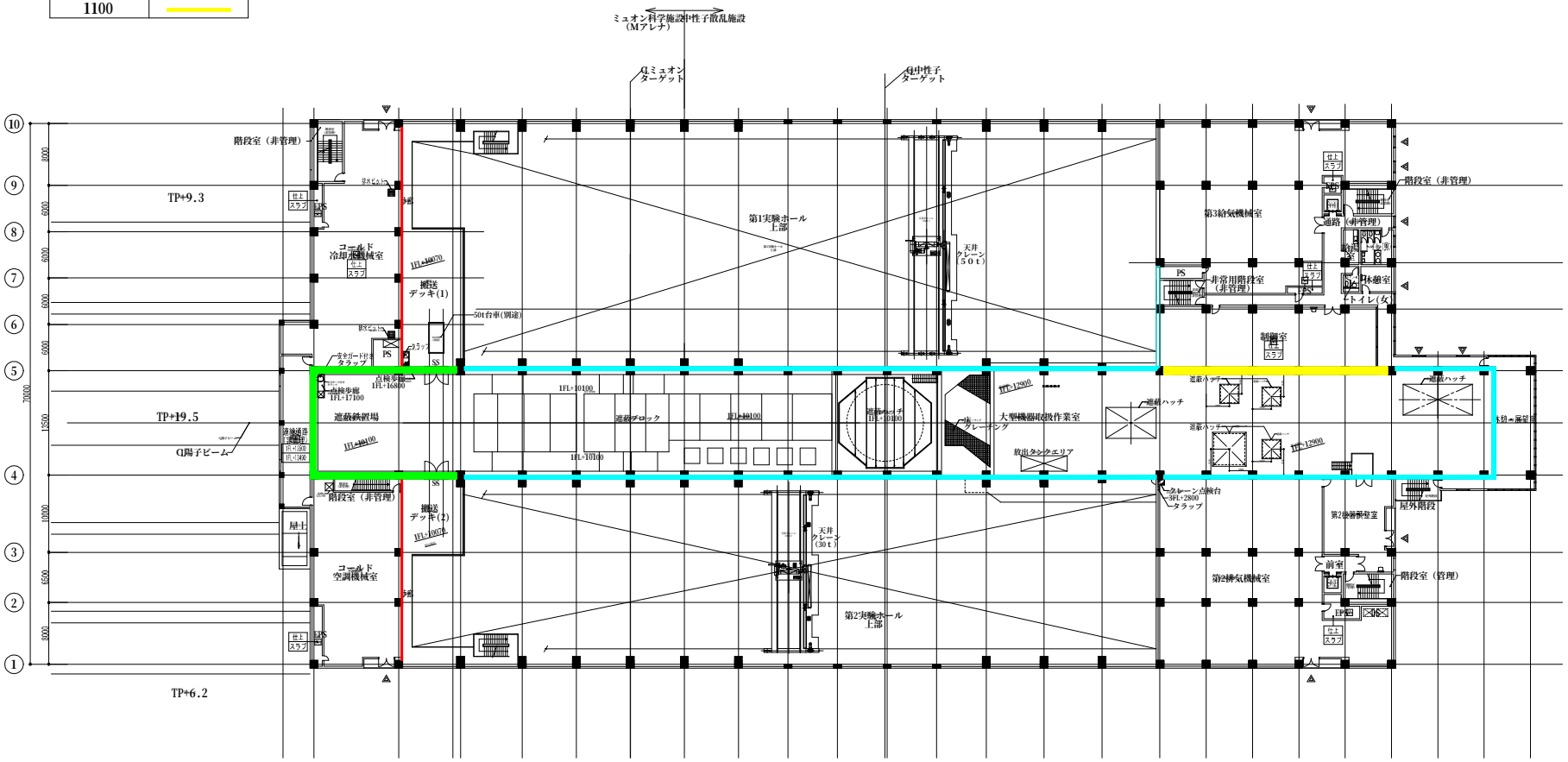


The second floor

Shielding Walls -(4)

Wall thickness [mm]

200	
500	
800	
1100	



The third floor

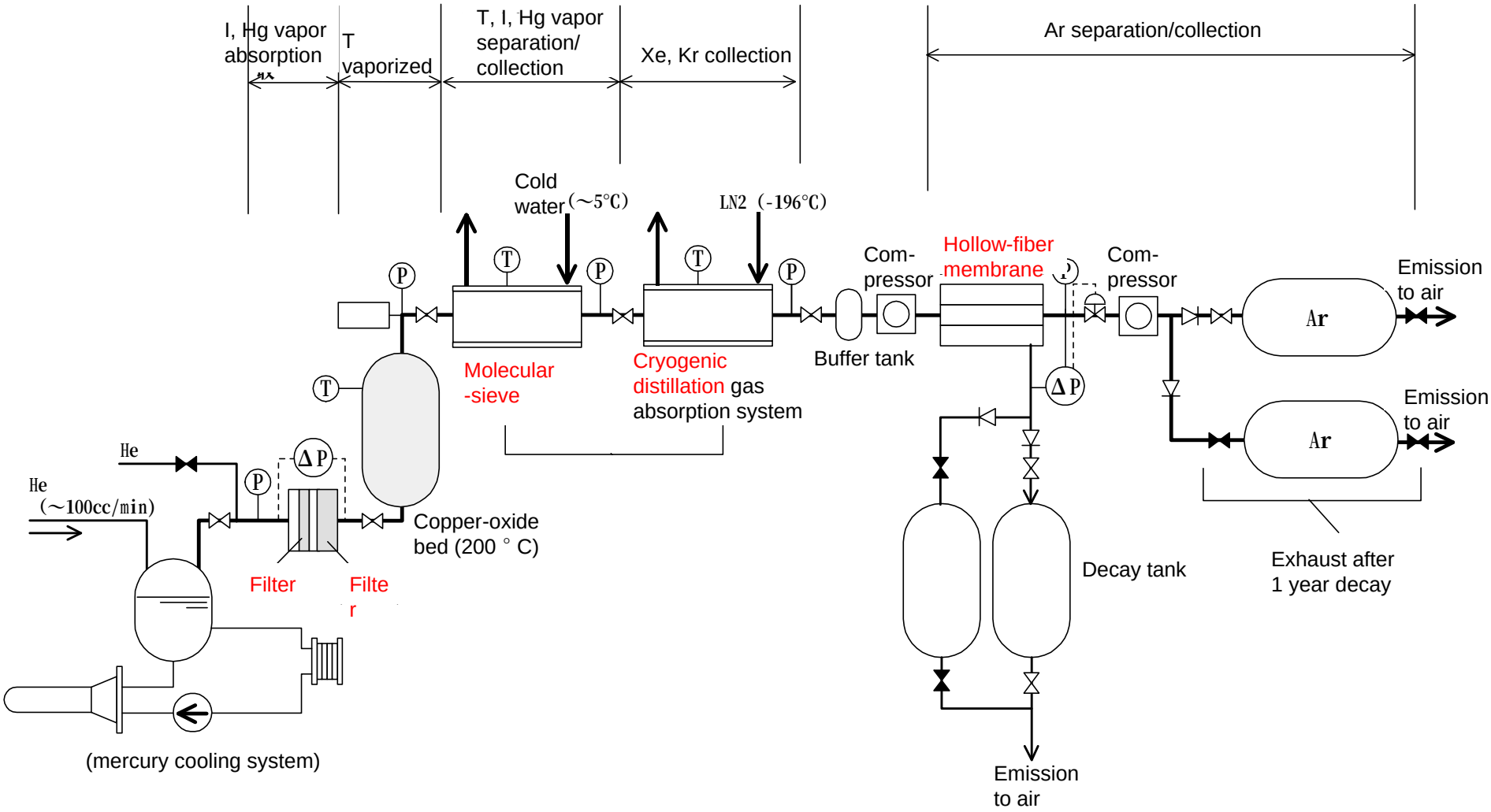
Radioactive Nuclides in Cover Gas

- Cover gas of mercury and water surge tanks will be batch-processed.Tritium, rare noble gases, iodine, radioactive mercury vapor will be included in cover gas.
- Quantity of radioactive nuclides in cover gas is very large.
  - ✓Tritium : 9.3 x 10^{13} Bq/y
  - ✓Xe-127 : 1.3 x 10^{13} Bq/y

    --> Off gas process system will be required.

Radioactive emissions	Source	Collection or separation equipment	Decontamination factor
Tritium	Tritium generated in mercury, H_2O, D_2O, structural material and air	Tritium collection system using molecular-sieve	1000
Rare noble gases	Rare noble gases generated in mercury, structural material	Ar : Hollow-fiber membrane	50
		Xe, Kr :Cryogenic distilation column	100
Iodine	Iodine generated in mercury (1/1000 of total amount of Iodine was assumed to release from mercury)	Iodine absorption filter	2000
Radioactive mercury vapor	Radiactive mercury (1/1000 of total amount of mercury was assumed to release)	Mercury vapor collection system	10000

Concept of Off Gas Process System



This system will be installed for 1MW operation.

Annual Emission of Radioactive Nuclides from MLF Stack

Nuclide		Total inventory after 1 year operation	Decontamination factor (DF) and Relaese rate (RR)	Annual emission	Emission concentration*	Limit of Emission concentration	Emission concentration / Limit
^{3}H		9.3×10^{13} Bq/y	DF : 10^{3}	9.3×10^{10} Bq/y	1.2×10^{-4} Bq/cm^3	5.0×10^{-3} Bq/cm^3	0.024
Ar	^{37}Ar	3.7×10^{12} Bq/y	DF : 5×10^{1}	7.4×10^{10} Bq/y	9.6×10^{-5} Bq/cm^3	7.0×10^{2} Bq/cm^3	1.4×10^{-7}
	^{39}Ar	7.7×10^{9} Bq/y		1.5×10^{8} Bq/y	2.0×10^{-7} Bq/cm^3	2.0×10^{-1} Bq/cm^3	1.0×10^{-6}
	^{42}Ar	5.6×10^{9} Bq/y		1.2×10^{8} Bq/y	1.6×10^{-7} Bq/cm^3	2.0×10^{-1} Bq/cm^3	8.0×10^{-7}
I	^{124}I	2.3×10^{12} Bq/y	DF : 2×10^{3}	1.2×10^{6} Bq/y	1.6×10^{-9} Bq/cm^3	9.0×10^{-6} Bq/cm^3	1.8×10^{-4}
	^{125}I	1.5×10^{13} Bq/y	RR : 1/1000	7.5×10^{6} Bq/y	9.8×10^{-9} Bq/cm^3	1×10^{-5} Bq/cm^3	9.8×10^{-4}
	^{126}I	9.0×10^{11} Bq/y		4.5×10^{5} Bq/y	5.9×10^{-10} Bq/cm^3	5.0×10^{-6} Bq/cm^3	1.2×10^{-4}
^{127}Xe		1.3×10^{13} Bq/y	DF : 10^{2}	1.3×10^{11} Bq/y	1.7×10^{-4} Bq/cm^3	3.0×10^{-3} Bq/cm^3	0.057
Kr	^{81}Kr	1.2×10^{7} Bq/y	DF :10^{2}	1.2×10^{5} Bq/y	1.6×10^{-10} Bq/cm^3	1.0×10^{-1} Bq/cm^3	1.6×10^{-9}
	^{85}Kr	2.3×10^{10} Bq/y		2.3×10^{8} Bq/y	3.0×10^{-7} Bq/cm^3	1.0×10^{-1} Bq/cm^3	3.0×10^{-6}
Hg	^{194}Hg	3.4×10^{11} Bq/y	DF :10^{4}	3.4×10^{4} Bq/y	4.4×10^{-11} Bq/cm^3	3.0×10^{-6} Bq/cm^3	1.5×10^{-5}
	^{195}Hg	2.1×10^{14} Bq/y	RR : 1/1000	2.1×10^{7} Bq/y	2.7×10^{-8} Bq/cm^3	9.0×10^{-5} Bq/cm^3	3.0×10^{-4}
	^{197}Hg	1.8×10^{15} Bq/y		1.8×10^{8} Bq/y	2.3×10^{-7} Bq/cm^3	3.0×10^{-5} Bq/cm^3	7.7×10^{-3}
	^{203}Hg	2.3×10^{15} Bq/y		2.3×10^{8} Bq/y	3.0×10^{-7} Bq/cm^3	2.0×10^{-5} Bq/cm^3	0.015
Total							0.096 **

* : Total air volume released from MLF stack for one year is assumed to be 7.7×10^{14} cm^3 (tentative).

** : Exclude contribution from 3NBT.

Annual emission of radioactive nuclides from MLF stack is smaller than Japanese law and design target.

Liquid Waste in MLF

- Most dominant radioactive nuclide generated in coolant water is tritium (> 99%).
  - Light water : 5.4 x 10^{11}Bq/year, 1.1 x 10^{13}Bq/30year
  - Heavy water : 6.8 x 10^{11}Bq/year, 1.3 x 10^{13}Bq/30year
  - Coolant inventory : ~10m^3
  - Concentration of tritium in light water will be over that (?1.2 x 10^3 Bq/cc) transferable to JAERI waste processing facility.
- Light water can not be discharged and transferred. If tritium concentration is too high, it is replaced and stocked in MLF.
- Heavy water is assumed to be used for a life time of the facility. If tritium concentration is too high, it is replaced and stocked in MLF.
- Mercury will be used for a life time of the facility, and will not be replaced.

Summary

- Shielding design has been finished.
  - Skyshine
  - Proton beam line shield
  - Air and water activation

  - The structure of MLF is almost fixed.

- Future work
  - Accident analysis
  - Off gas process system