Shielding design for the installation of Non-linear collimator at SuperKEKB

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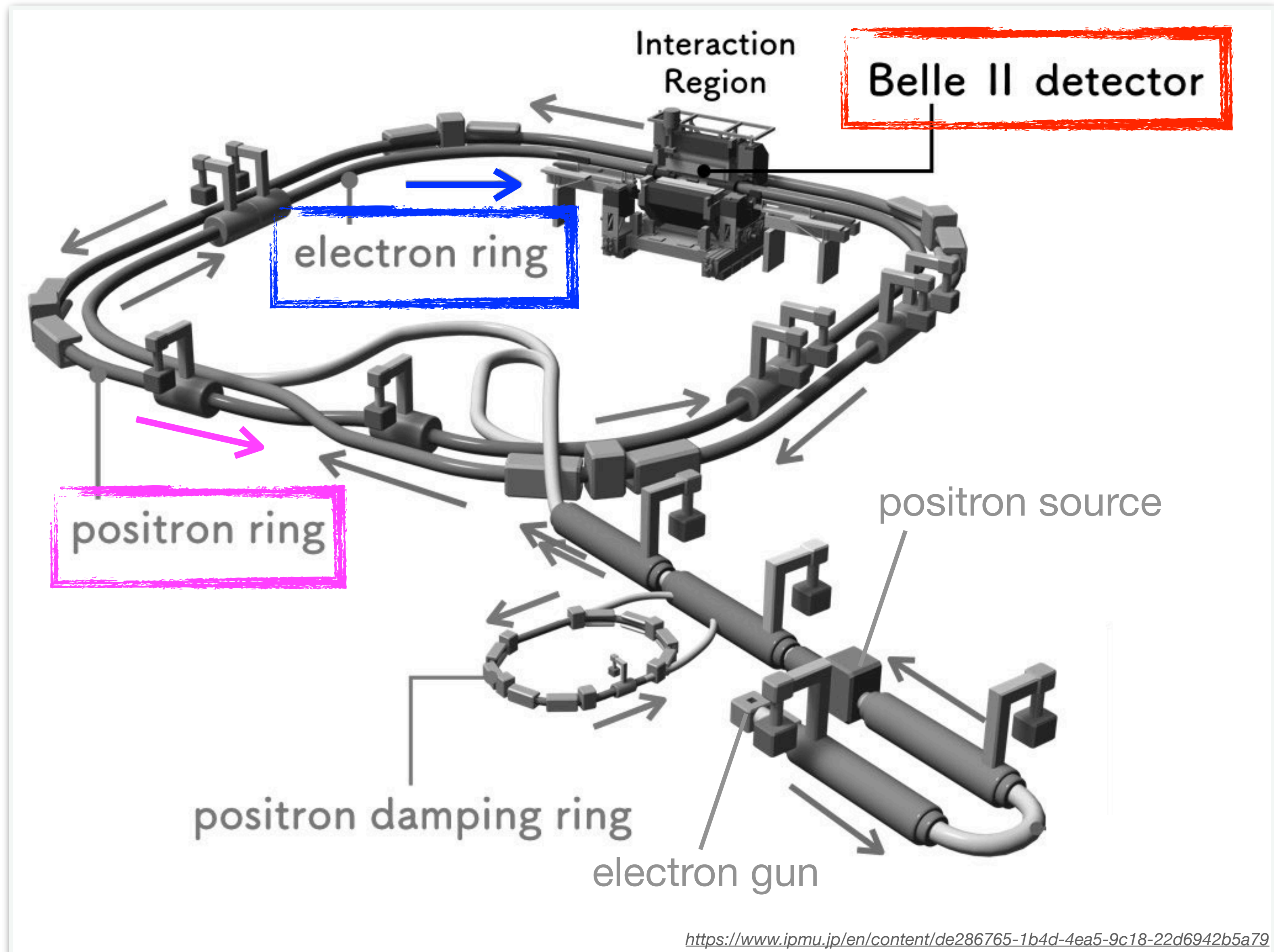
RadSynch'23, 30 May - 2 June 2023, ESRF, Grenoble

Introduction

- **SuperKEKB** is an e+e- collider consisting of e- ring (7 GeV) and e+ ring (4 GeV) at KEK.

- A large amount of B mesons are produced and their decay phenomena are measured by the Belle II detector.



- The main goals are to study CP Violation in detail and to search for physics beyond the Standard Model.

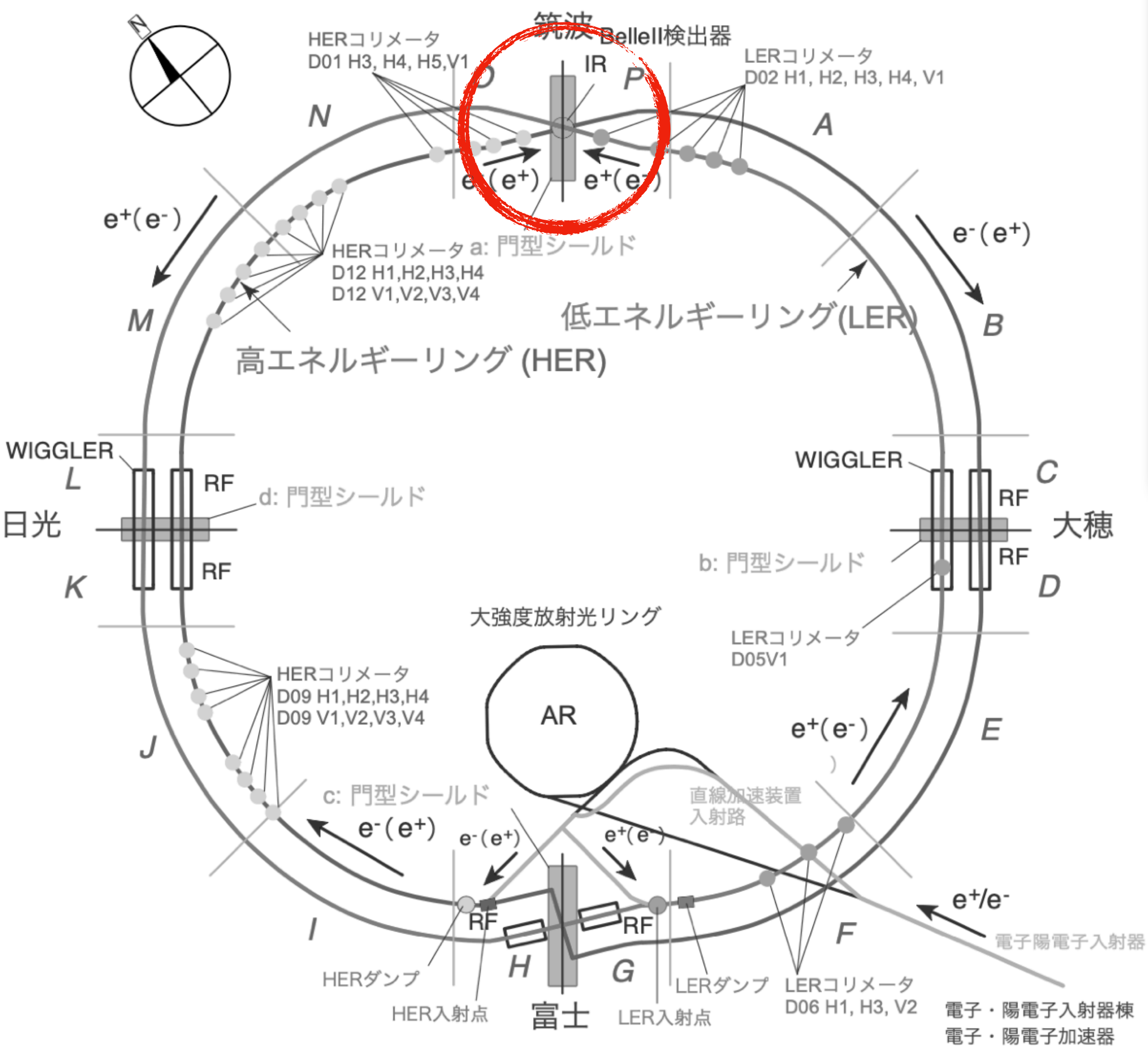
Super-KEKB schedule

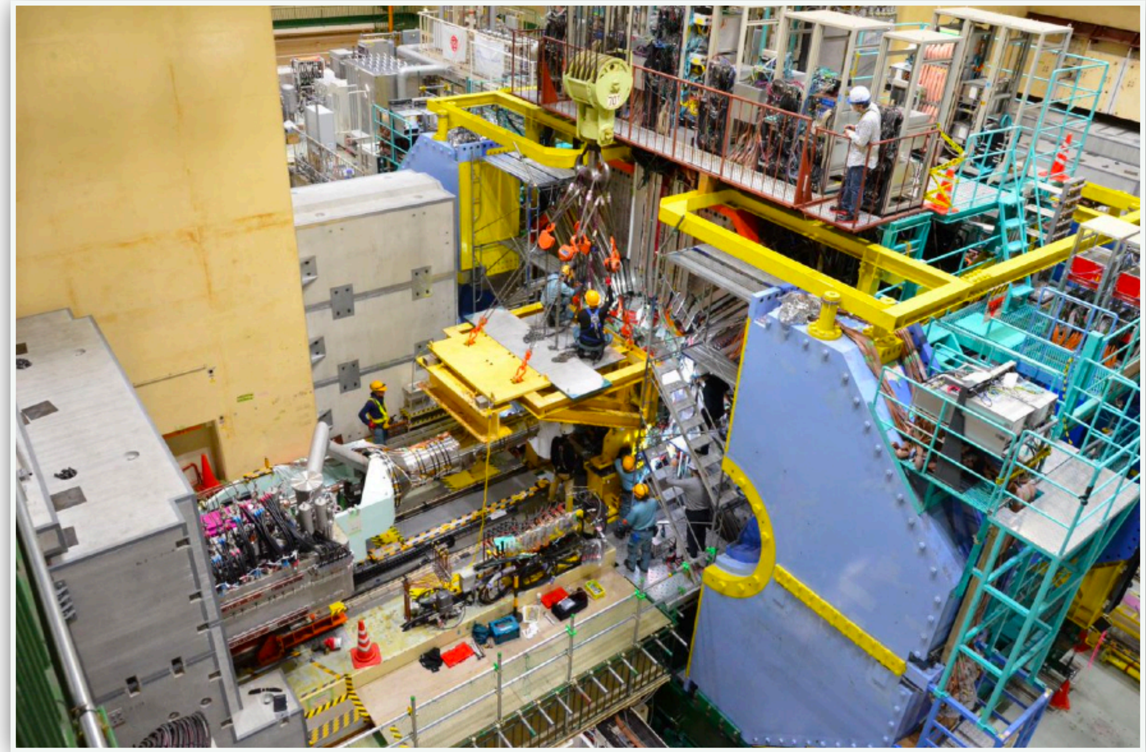
	KEKB (1998-2010)	SuperKEKB (Phase1)	SuperKEKB (Phase2)	SuperKEKB (Phase3)
beam energy and intensity	LER 3.5GeV / 2.9A HER 8 GeV / 1.2A	LER 4GeV / 1A HER 7 GeV / 1A	LER 4GeV / 1.8A HER 7 GeV / 1.3A	LER 4GeV / 3.6A HER 7 GeV / 2.6A
luminosity (1/cm2/s)	1×10^{34}	0	1×10^{34}	80×10^{34}
duration	11y	5m	5m	long
purpose	Belle etc.	beam injection adjust, vacuum	Belle2 adjust wighout VXD wighout some cavities with e+ dumping ring	Belle2 with VXD with cavities with e+ dumping ring

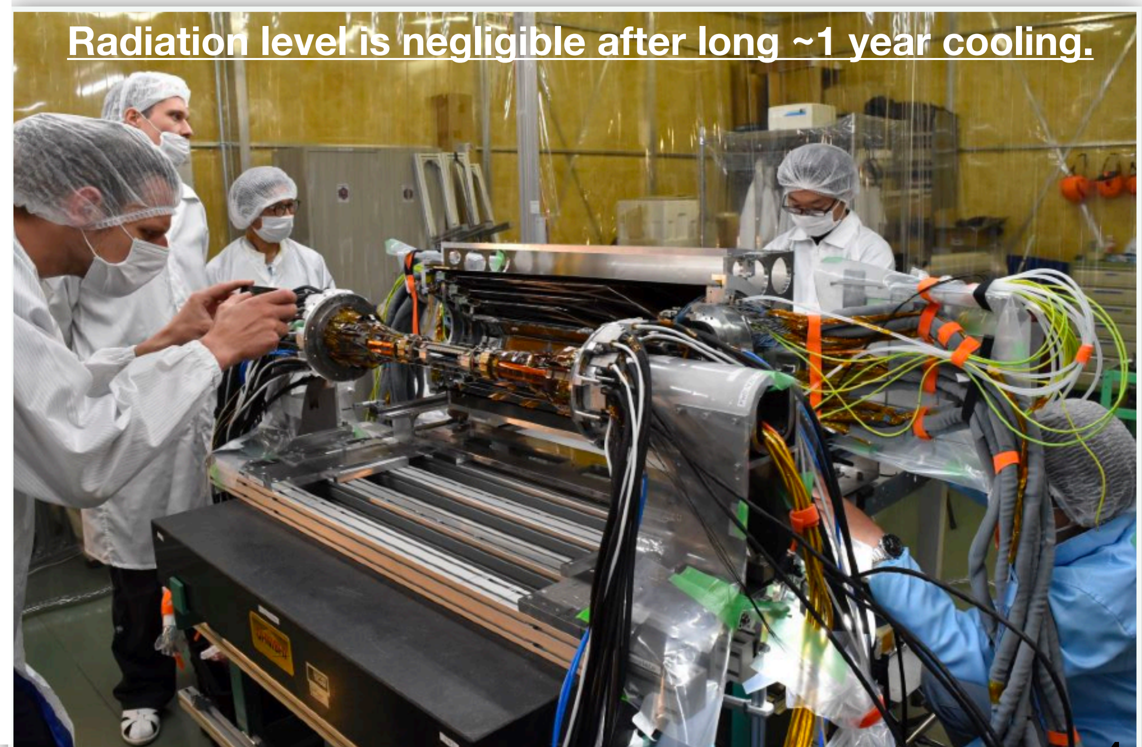
Higher luminosity by squeezing beams to nanometer-scale

Current Status

- The equipments are being improved during the long shutdown to maximize luminosity.
- The major changes are the upgrade of Belle's vertex detector and the construction of a non-linear collimation system.







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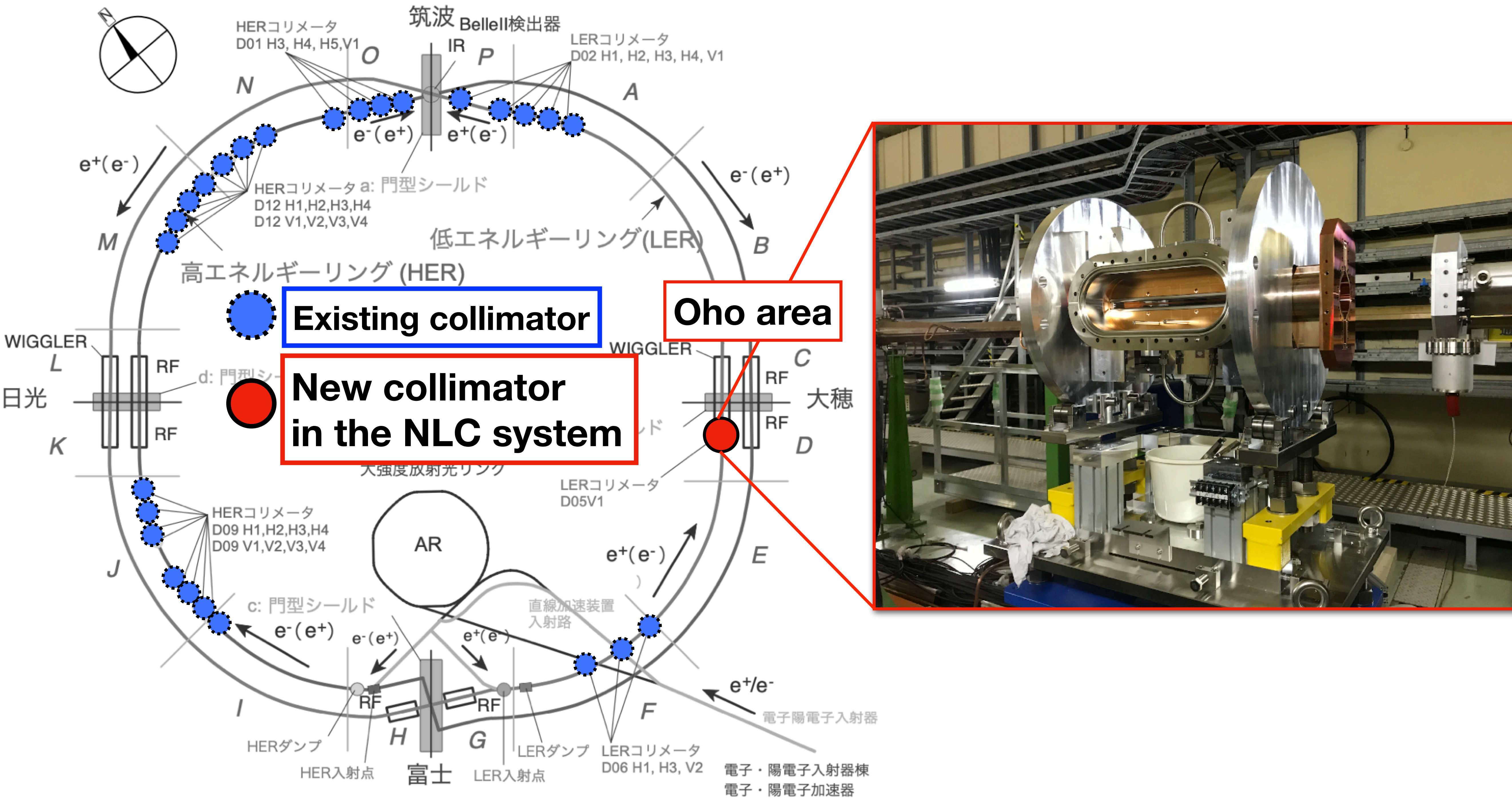
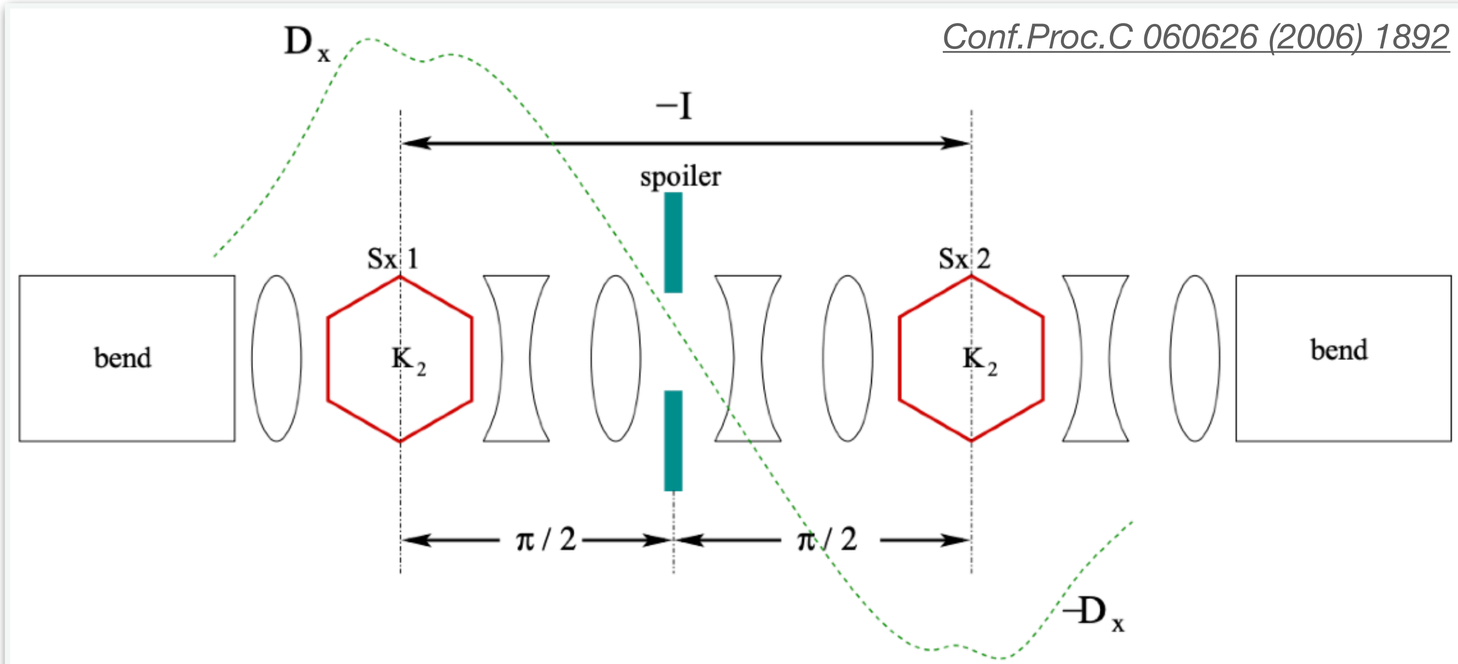


Non-linear Collimation (NLC)



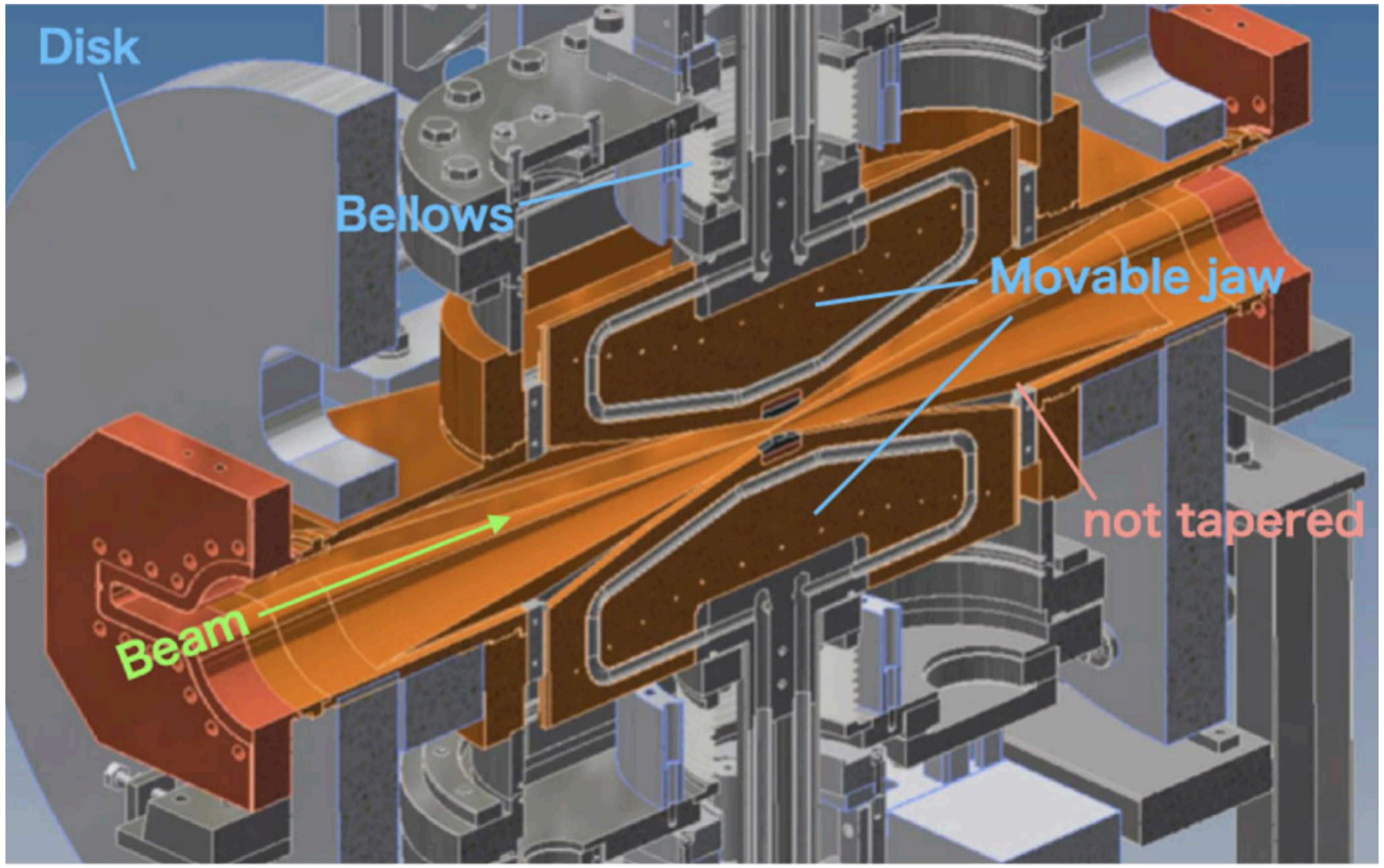
- In the NLC system, a pair of sextupole magnets are used, and the time evolution of the beam orbit is described by a non-linear differential equation.

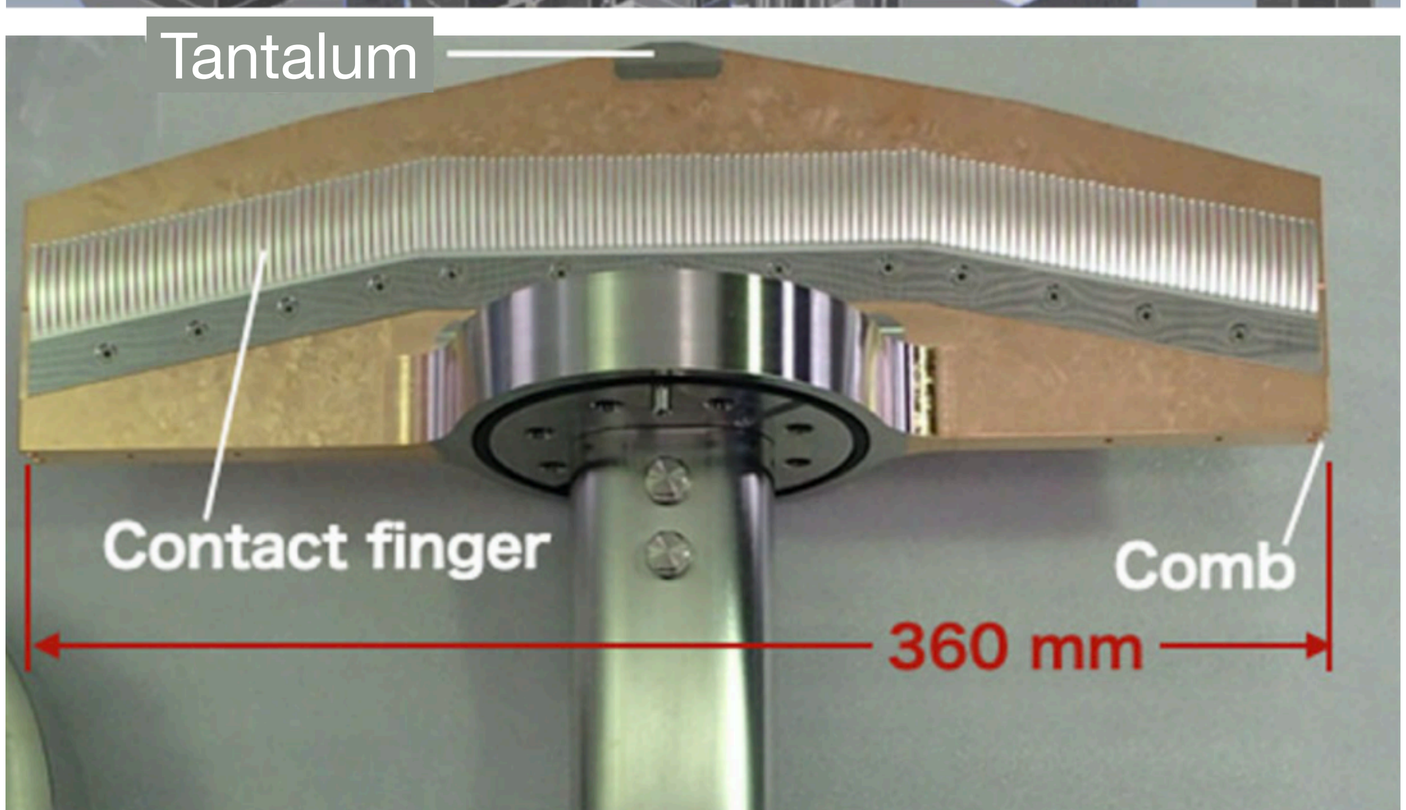
- The sextapole magnets deflect the beam halo away from the center orbit significantly, and the beam halo is efficiently removed by a collimator.

- One of the most important issues for improving luminosity is reducing the beam background, and the NLC system contributes to this.

The collimator in the system becomes **a new radiation source**, and increases the dose rate in the surrounding facilities.

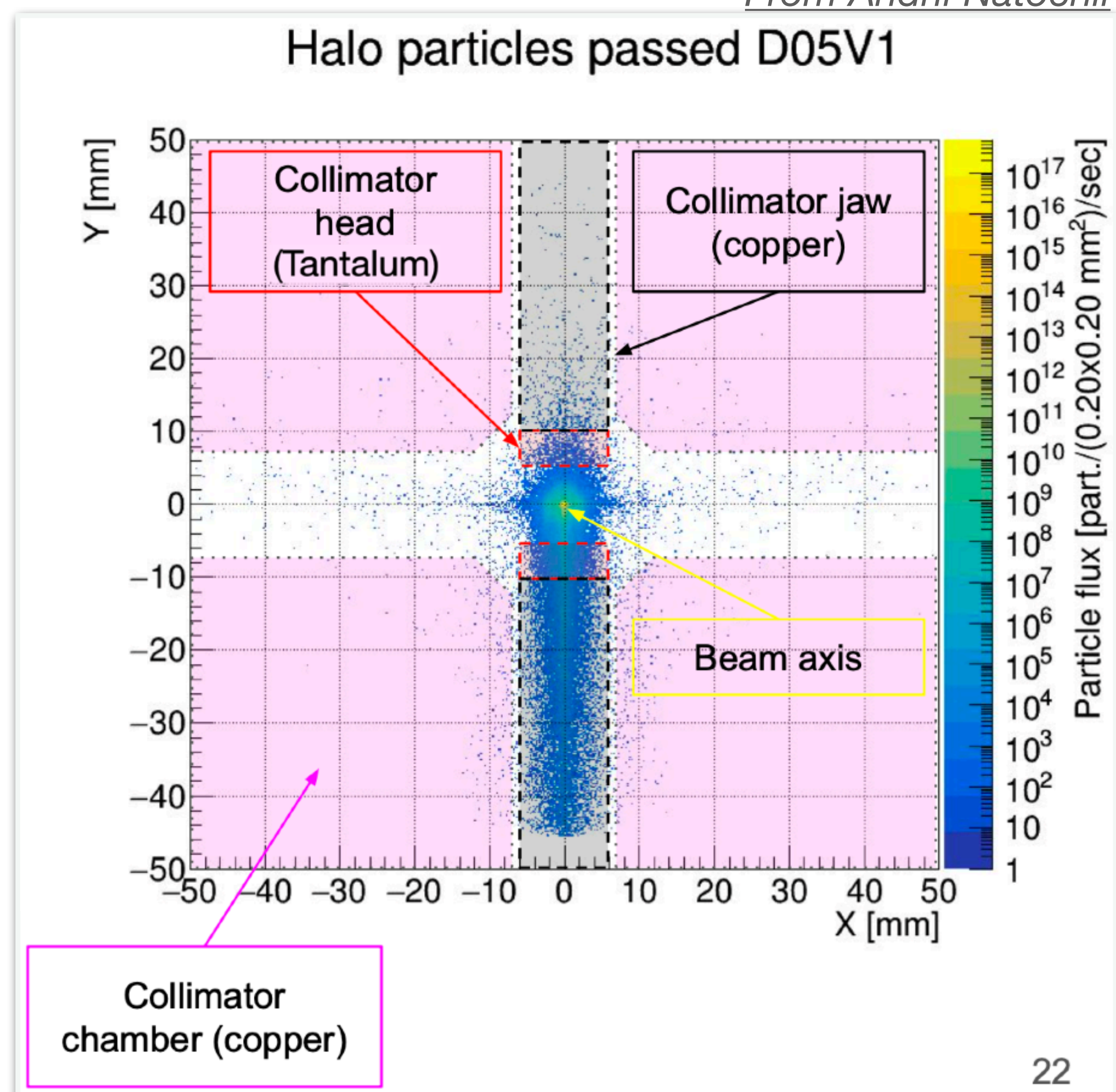
New collimator and Beam loss



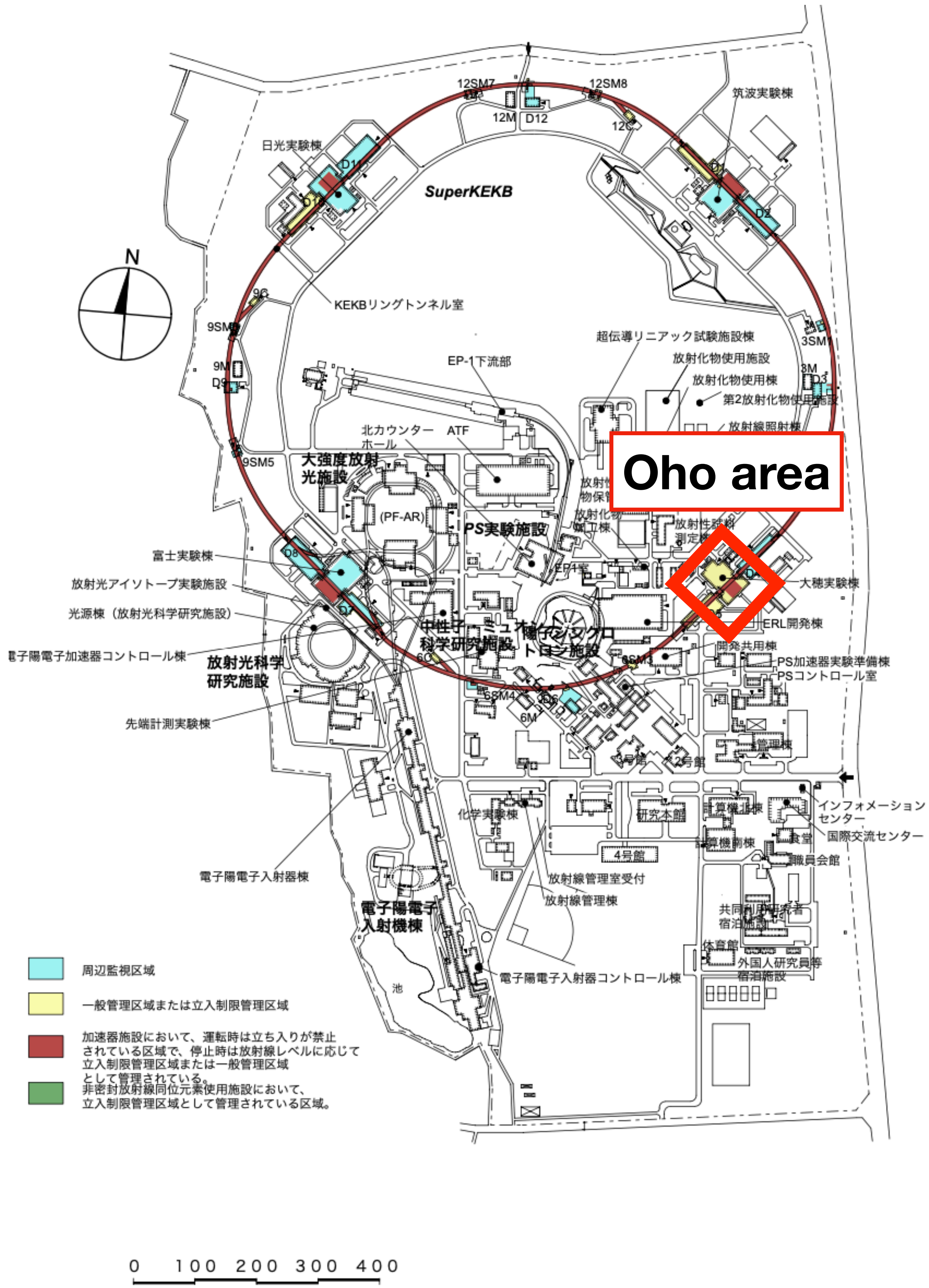


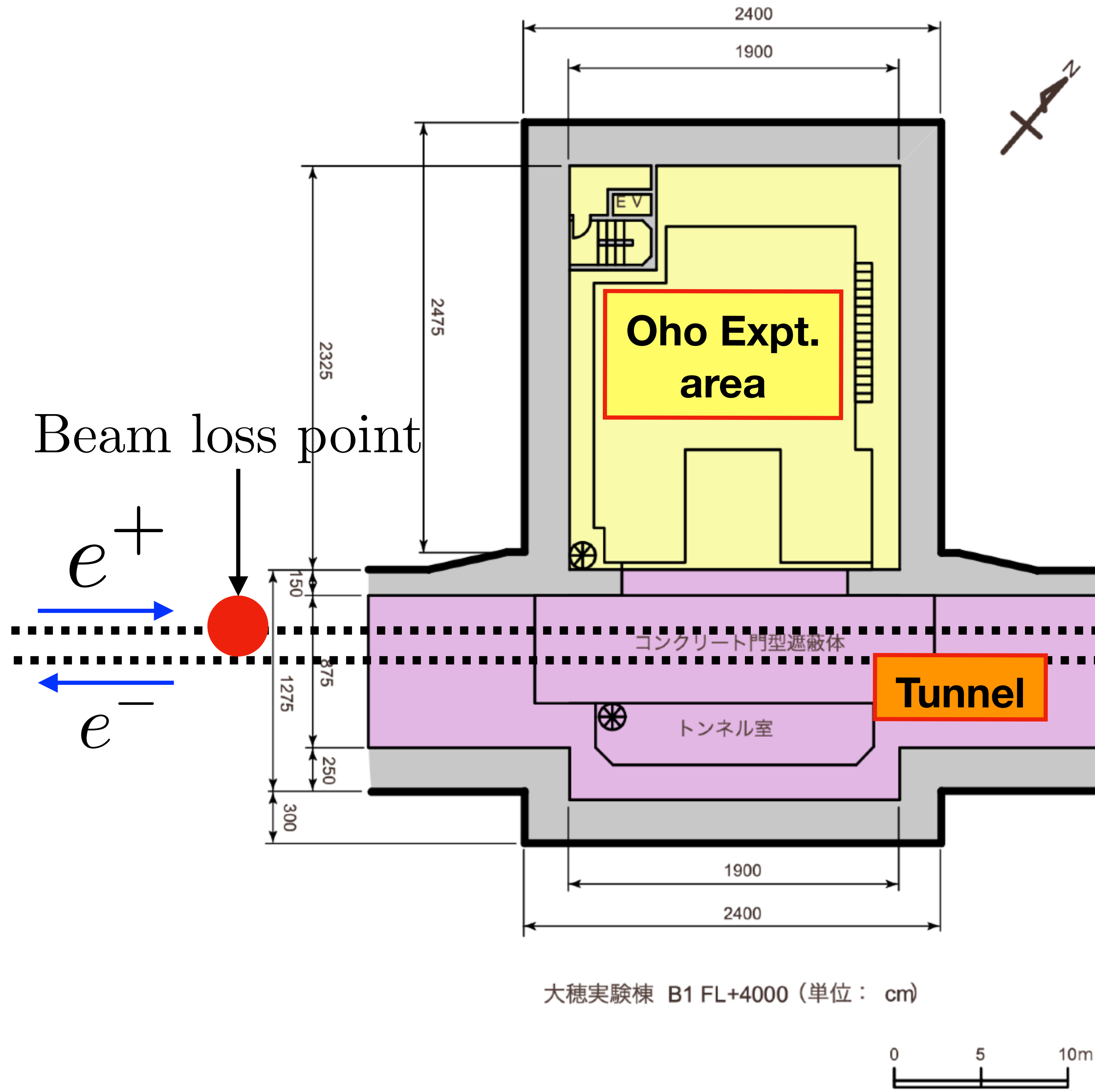
- Vertical collimator
- Collimatoe head: Tantalum (4mm)
- Hit rate = 8 x 10^9 Hz (~5W Beam loss)

From Andrii Natochii

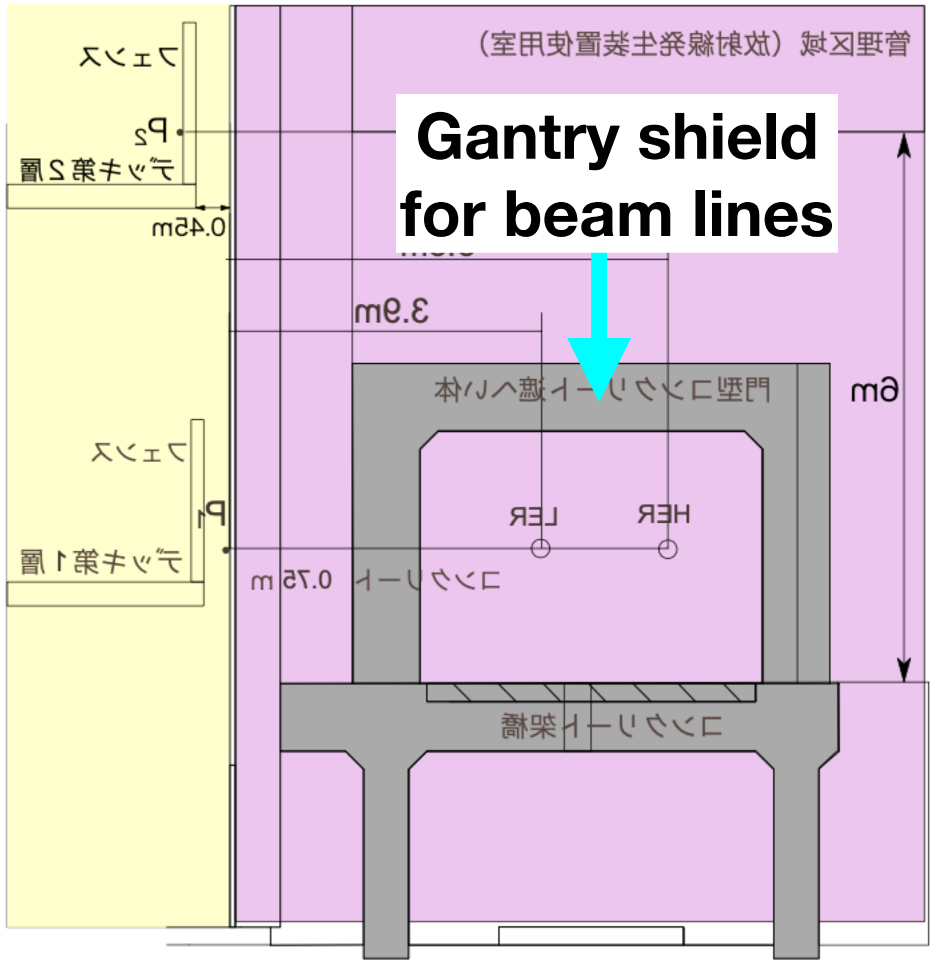


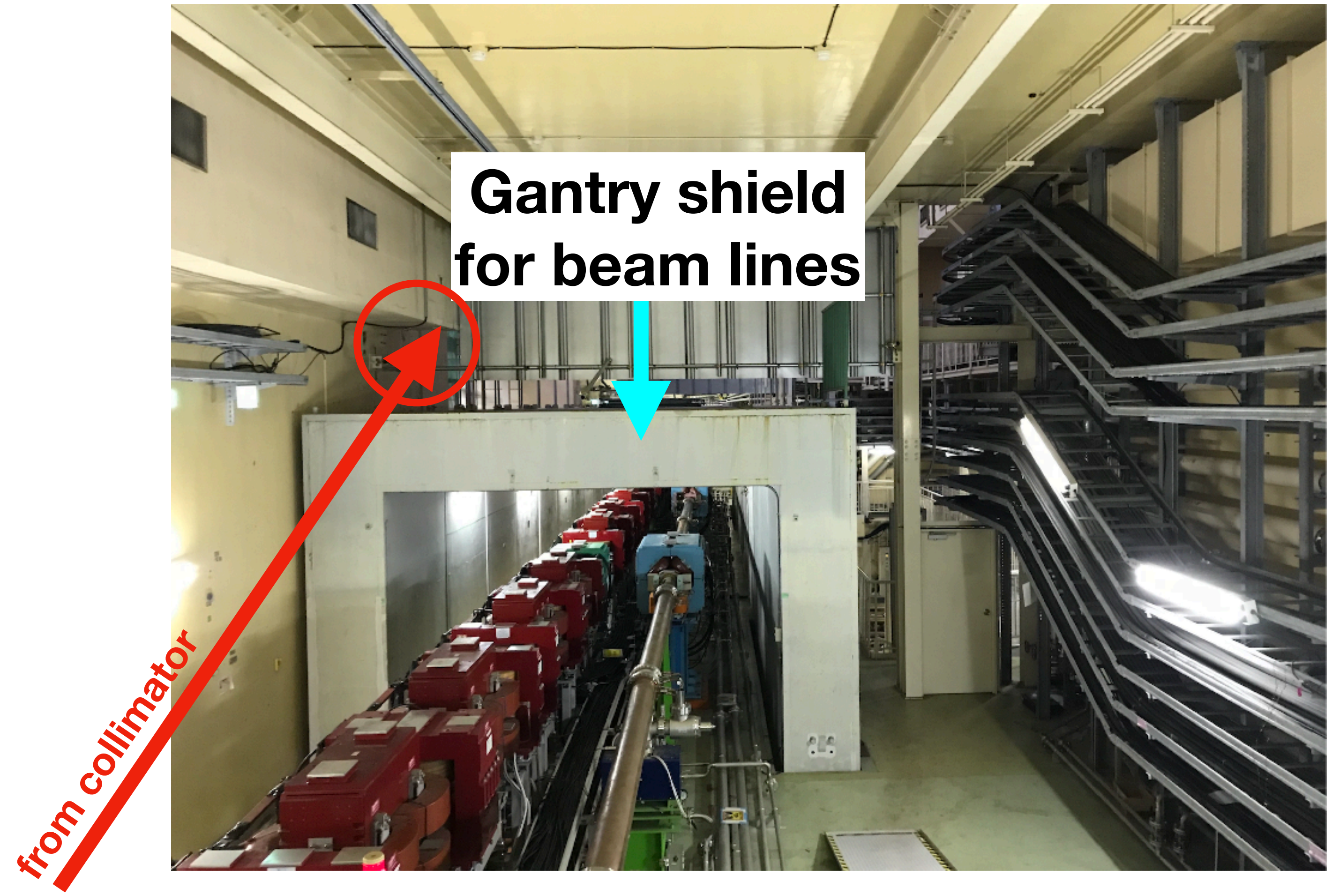
Beam loss point and proximity area (1 of 2)

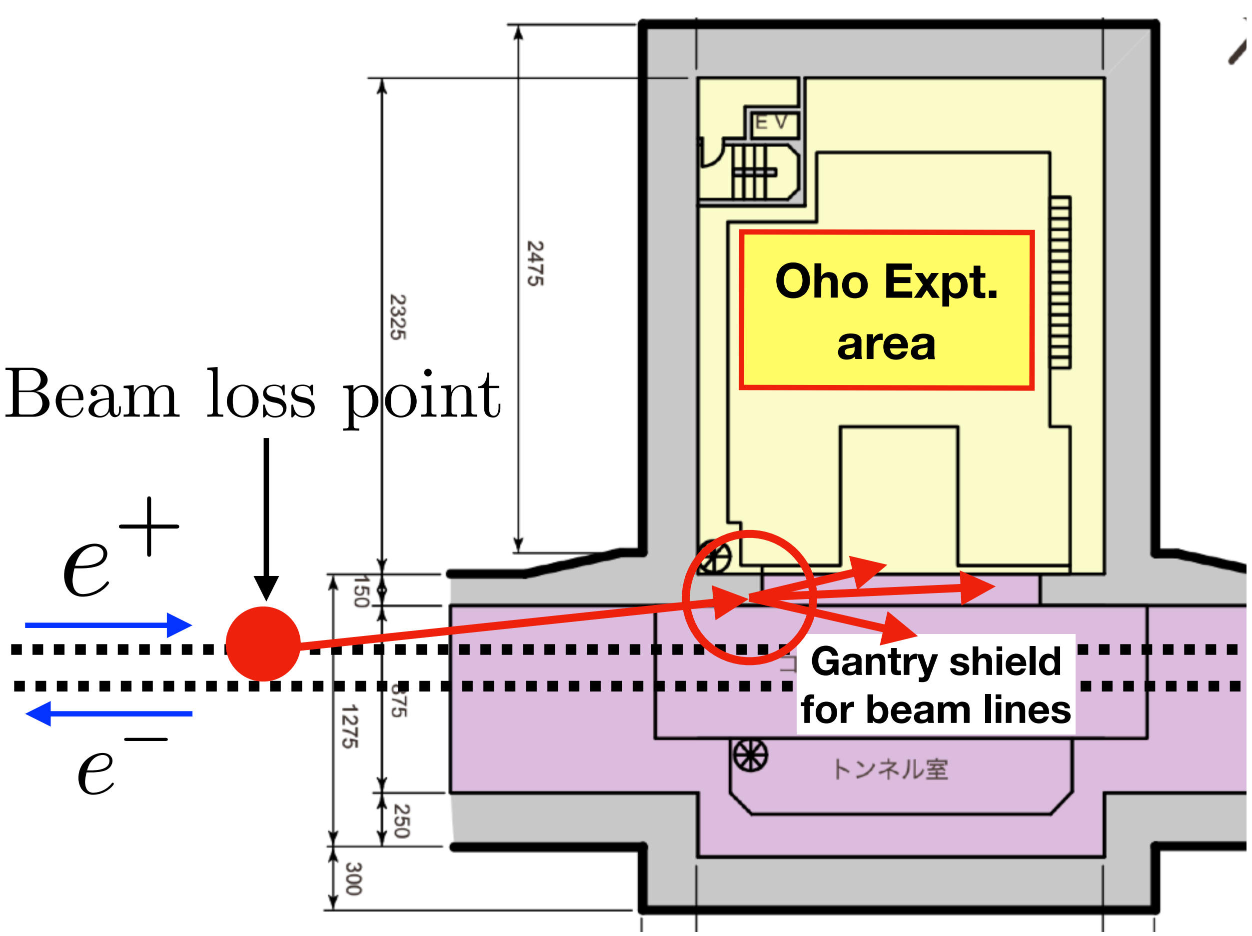


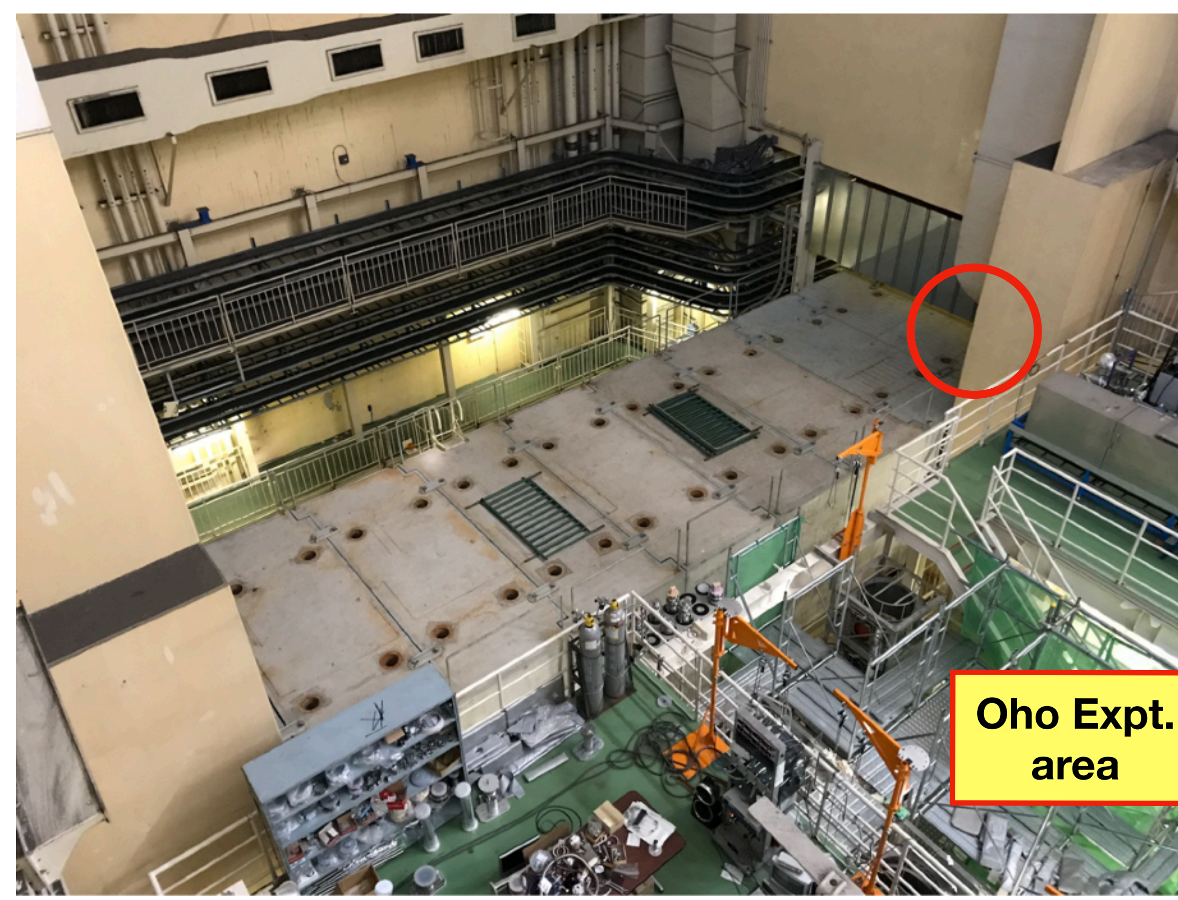


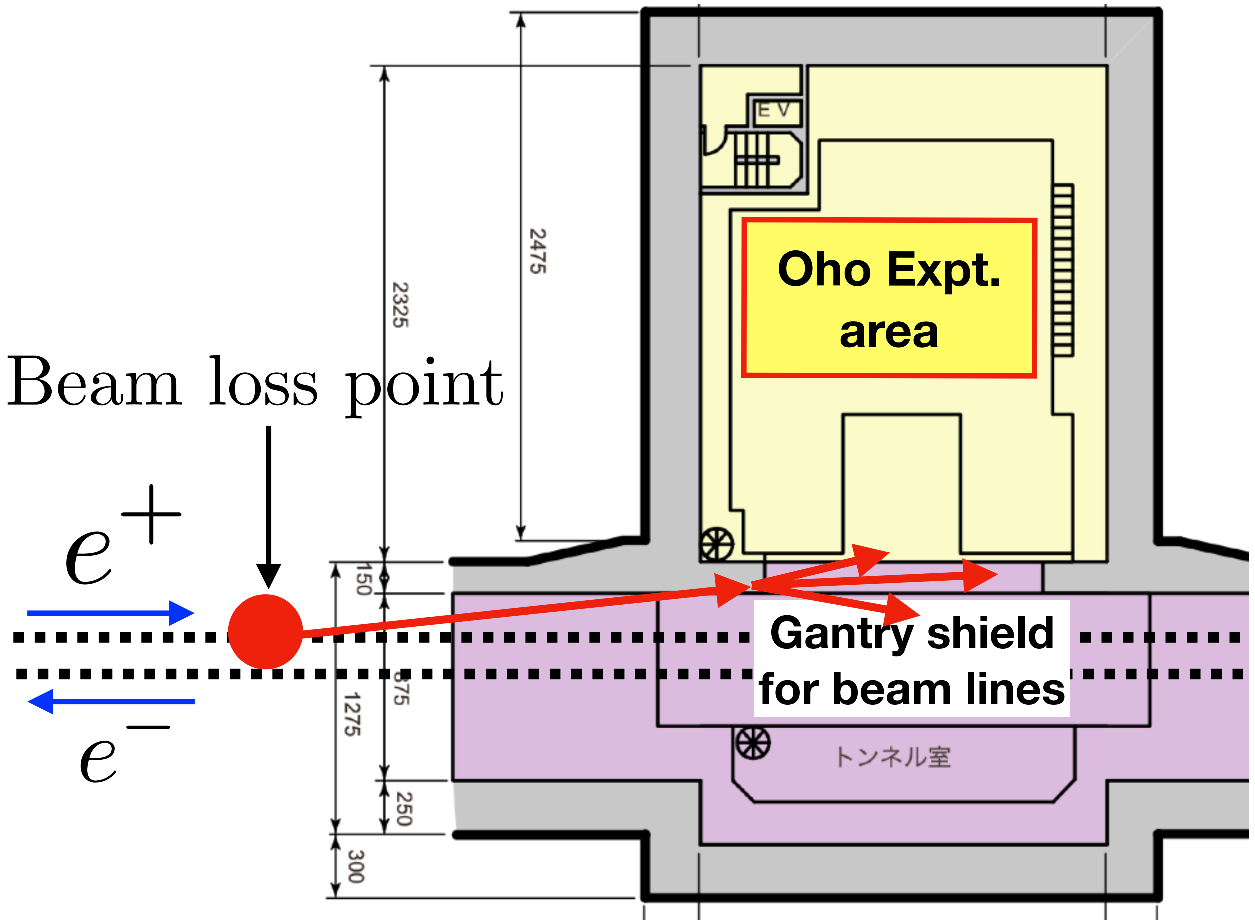
The dose-rate of Oho Expt area had been at BG level even during operation.


Gantry shield
for beam lines

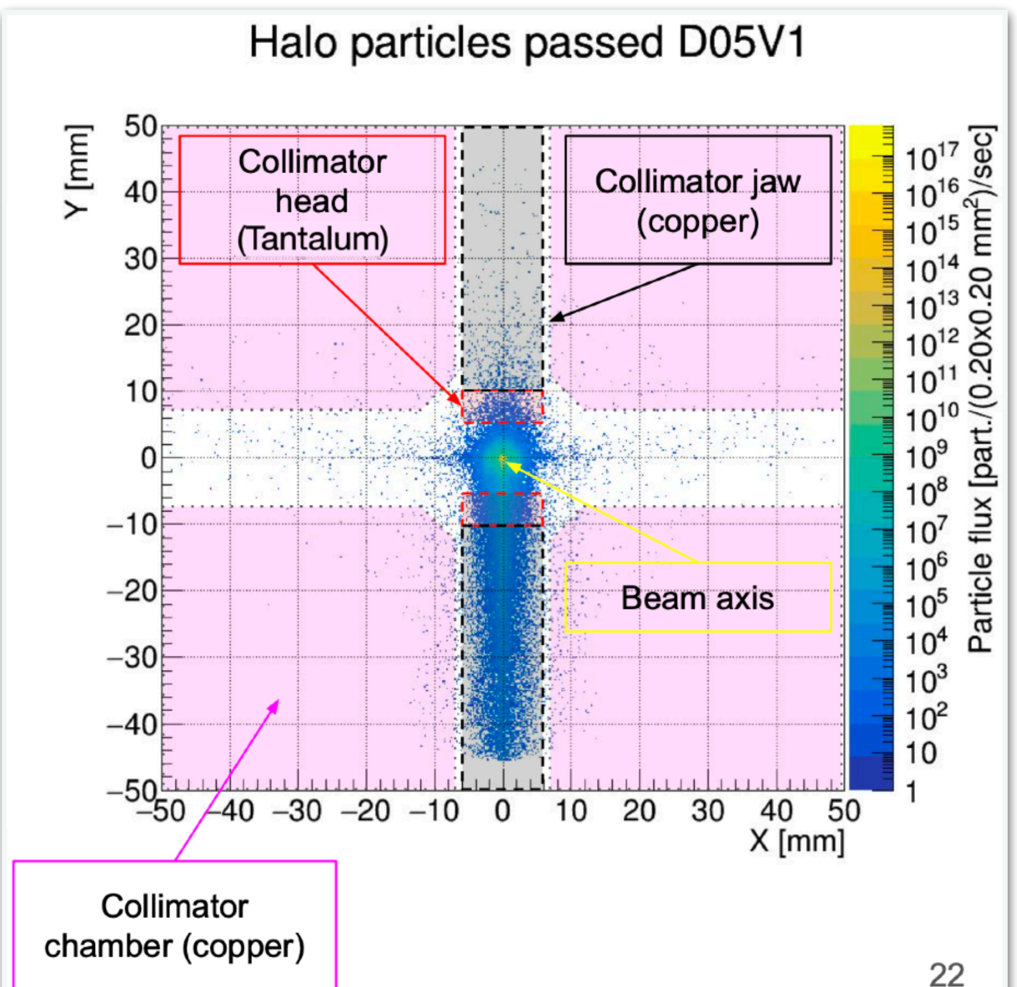

Gantry shield
for beam lines
from collimator


Beam loss point
e^+
e^-
Oho Expt.
area
Gantry shield
for beam lines
トンネル室
2475
2325
150
675
1275
250
300


Oho Expt.
area

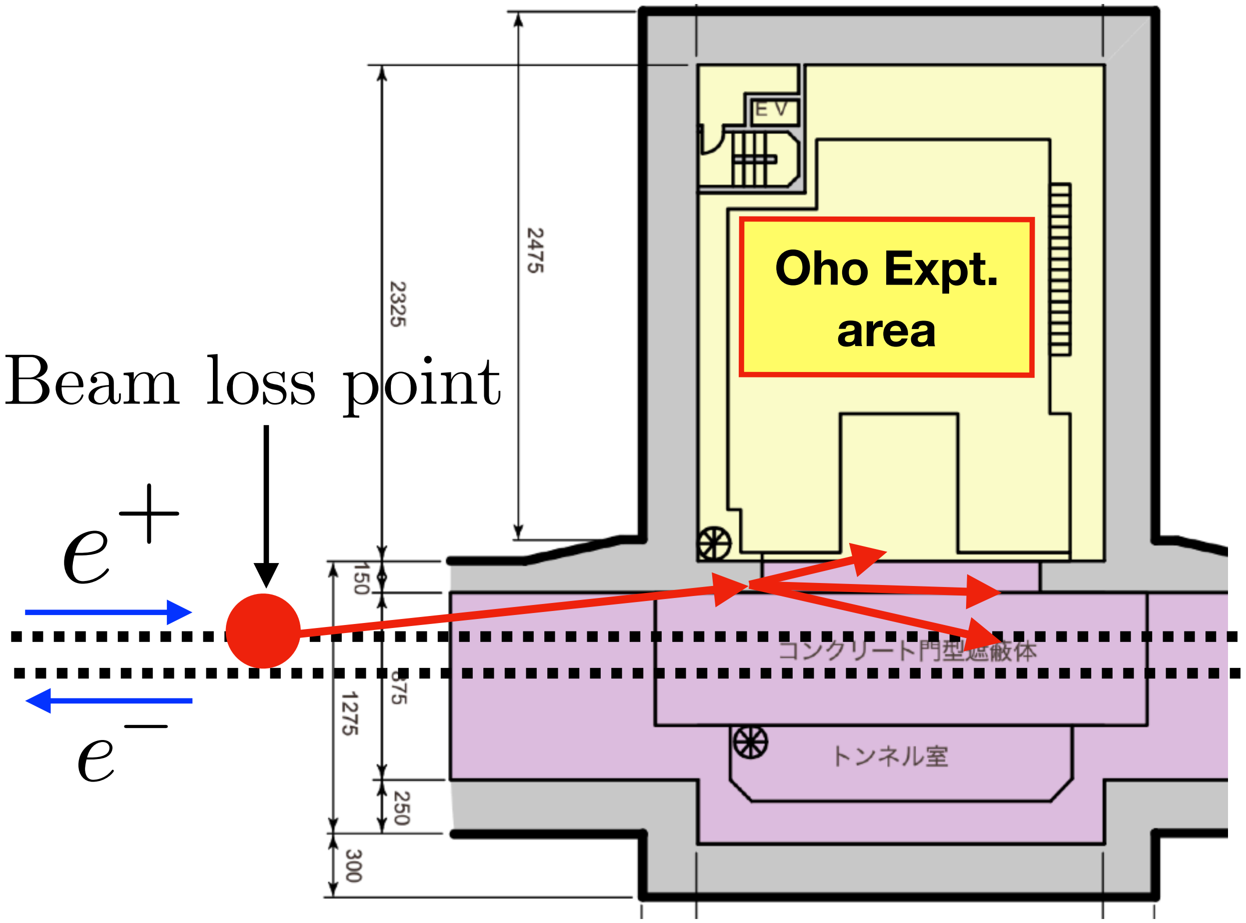


- Part of this area is used for small tests of the cavity.
- Radiaton-controled area
  - Level 1 (1.5 - 20 μSv/h):
    Registered radiation workers can basically access.
  - Level 2 (20 μSv/h - 100 mSv/h):
    Access restricted

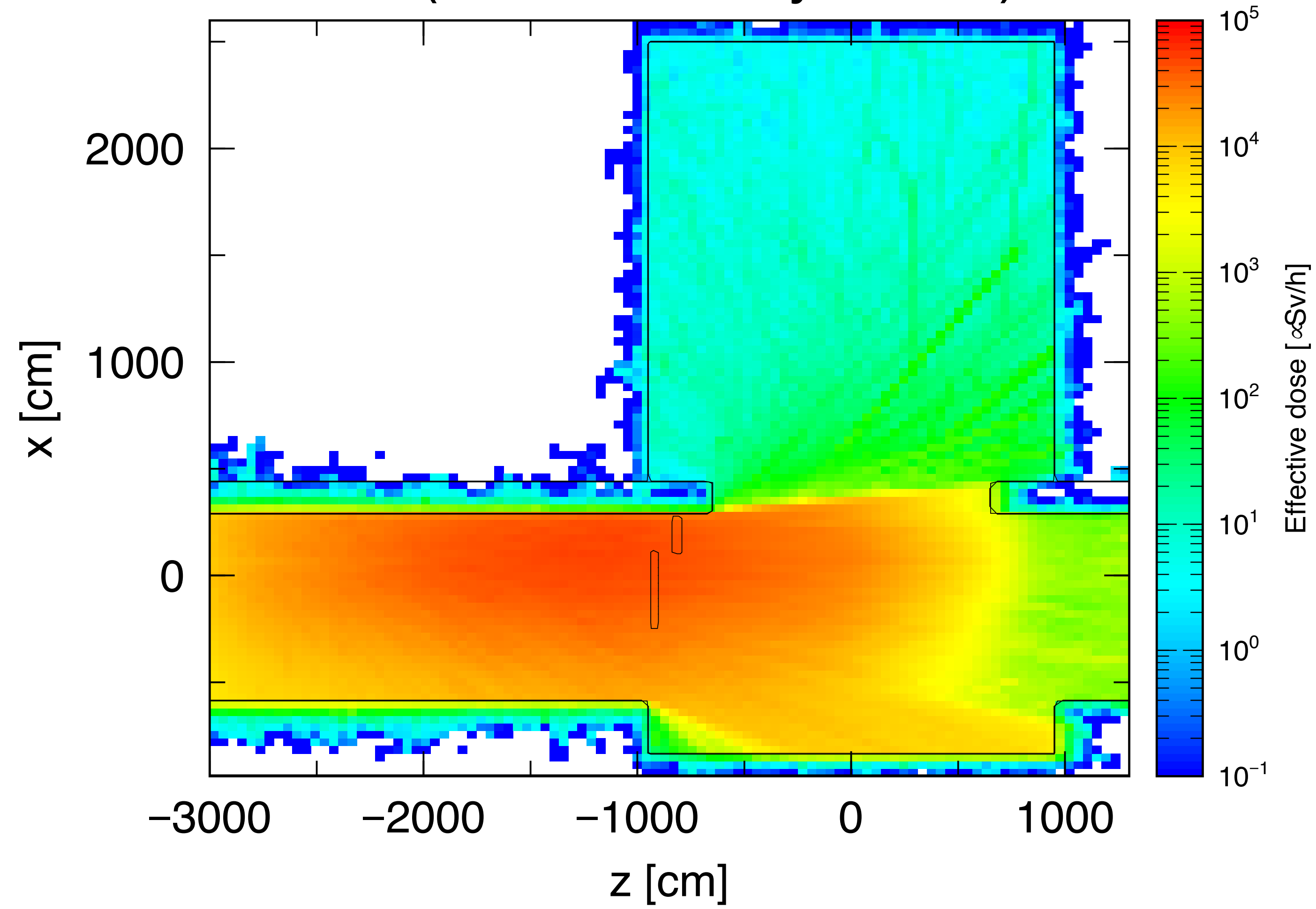


- Use Monte Carlo code, PHITS, for dose evaluation due to difficulty in semi-analytic equations.
  - ➡ Construct 3D geometry
  - ➡ Use phase space file for beam halo as source, which is calculated by a particle tracking simulation code, *SAD*.

(if no shield is placed)



y=5-6m
(Above Gantry shield)



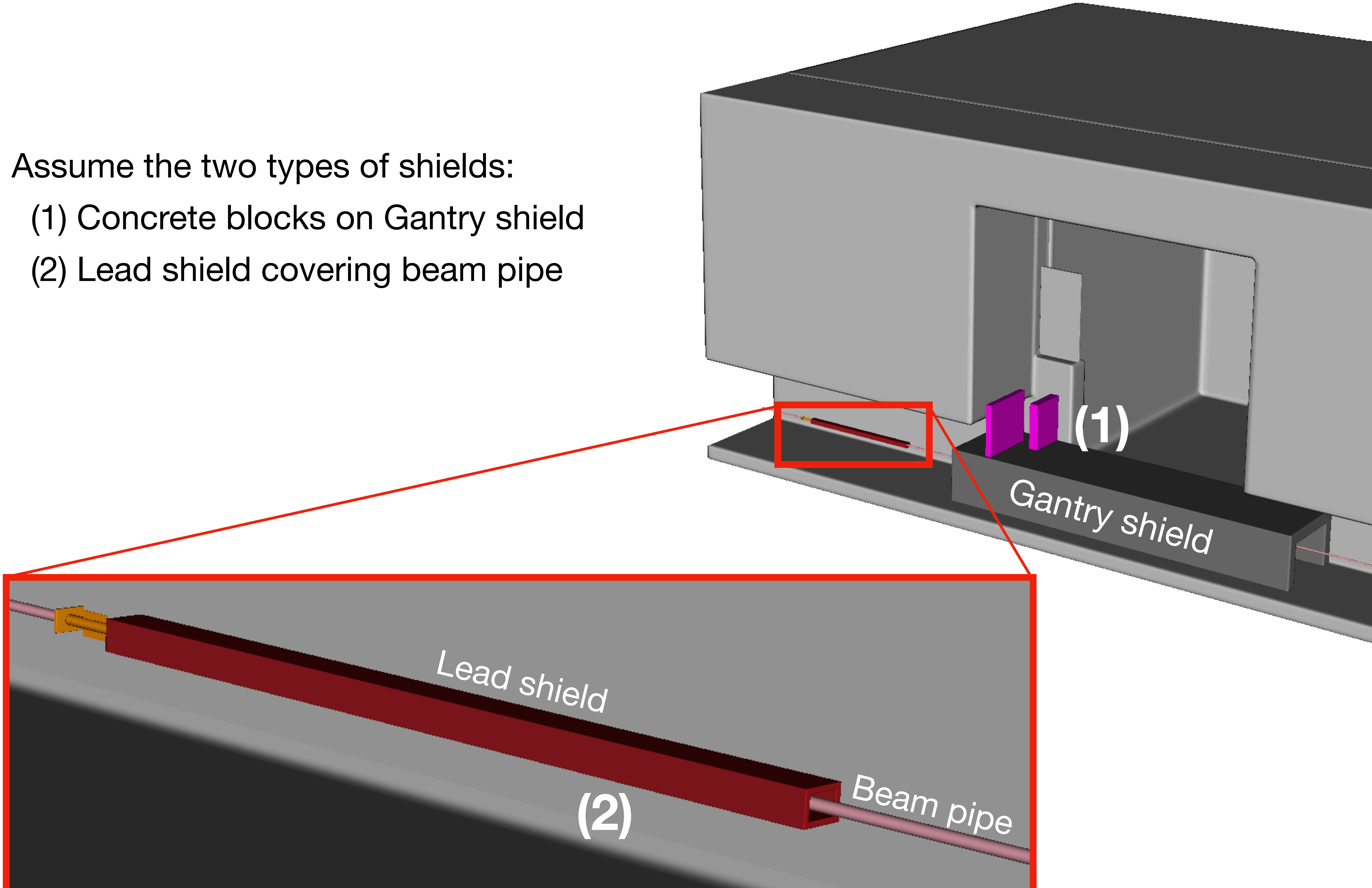
- Shower particles pass over the gantry shield
- The radiation dose is higher on the tunnel side of the experimental area (MAX~1mSv/h)

Early shield design

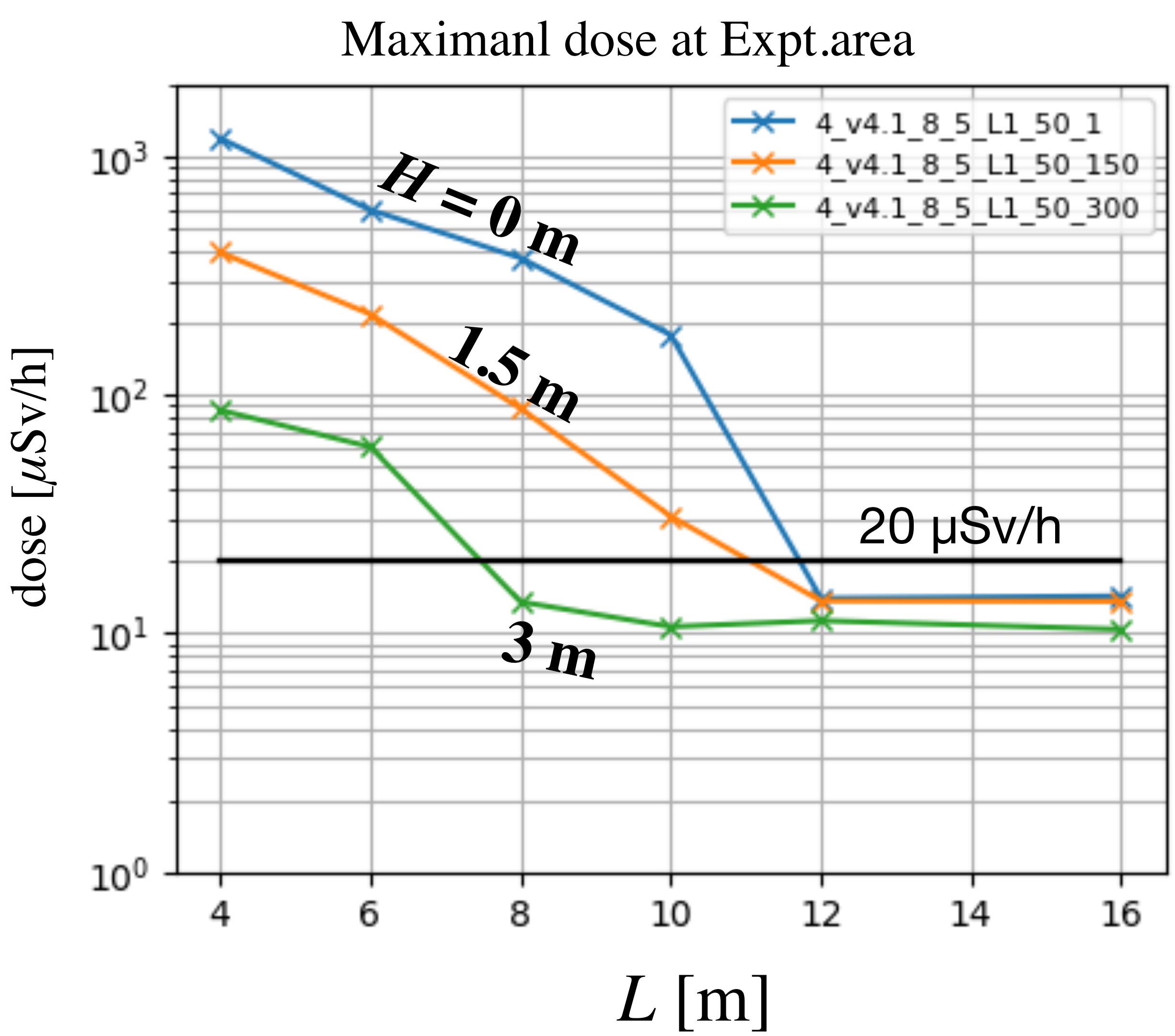
Assume the two types of shields:

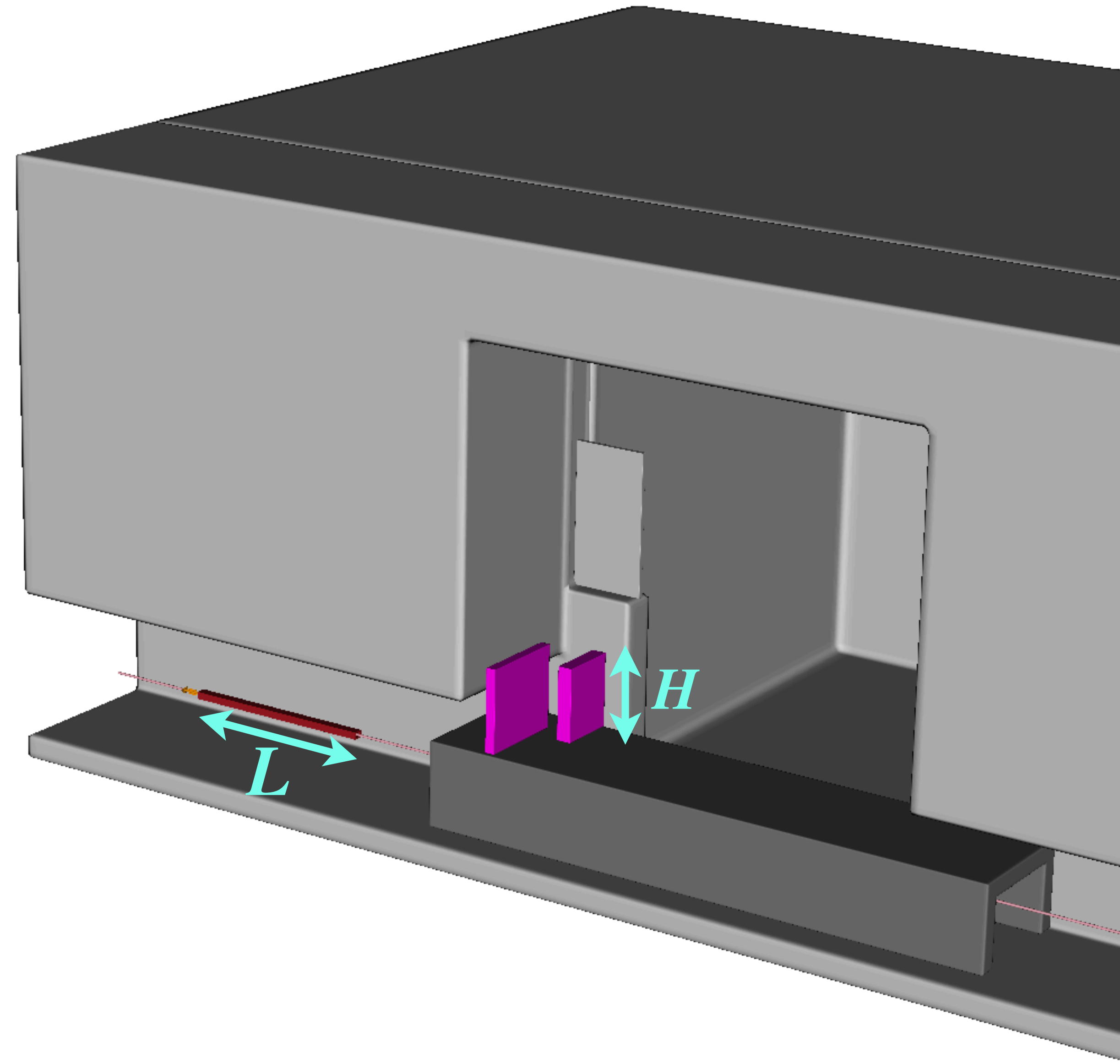
(1) Concrete blocks on Gantry shield

(2) Lead shield covering beam pipe



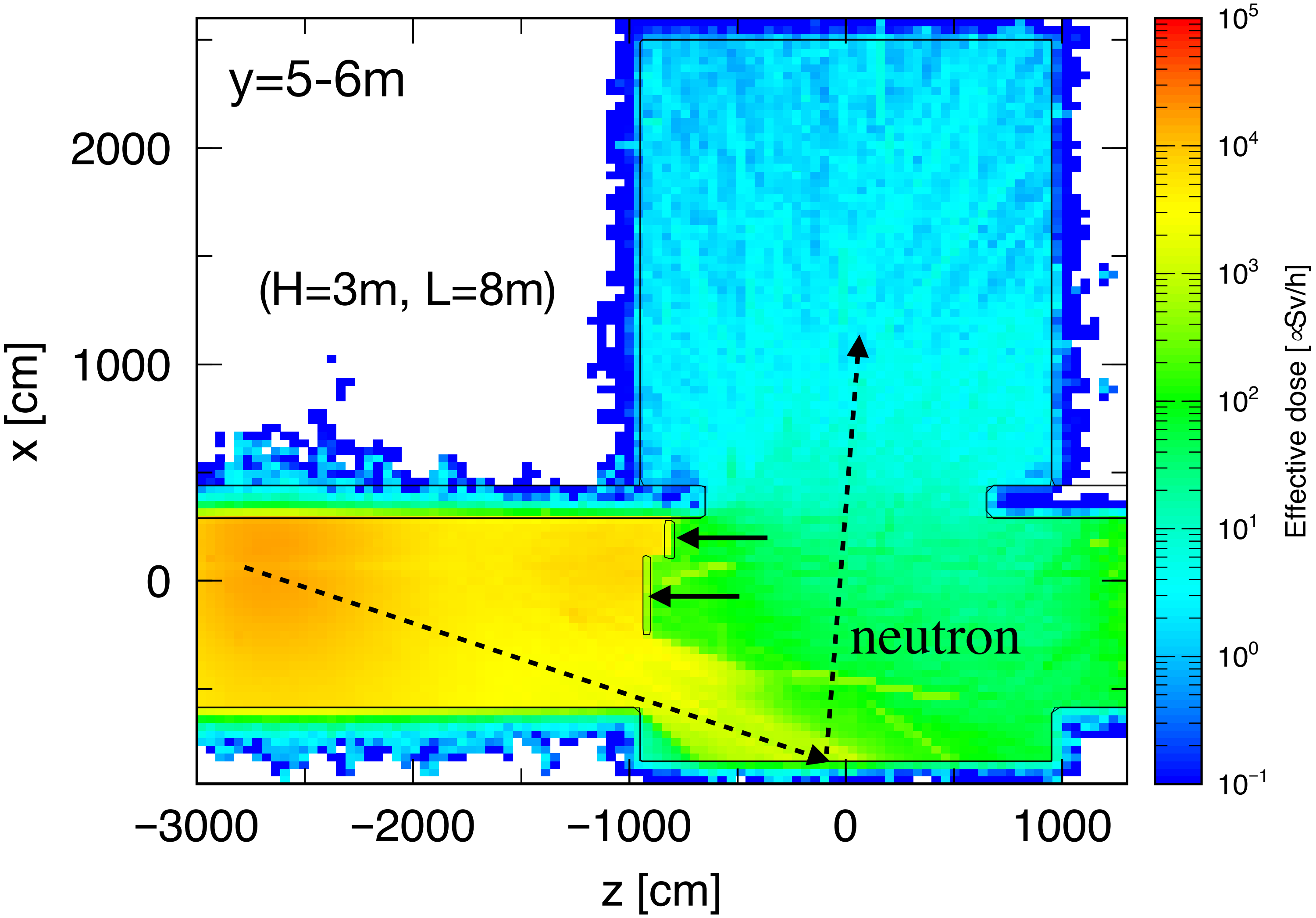
Assuming shield installation

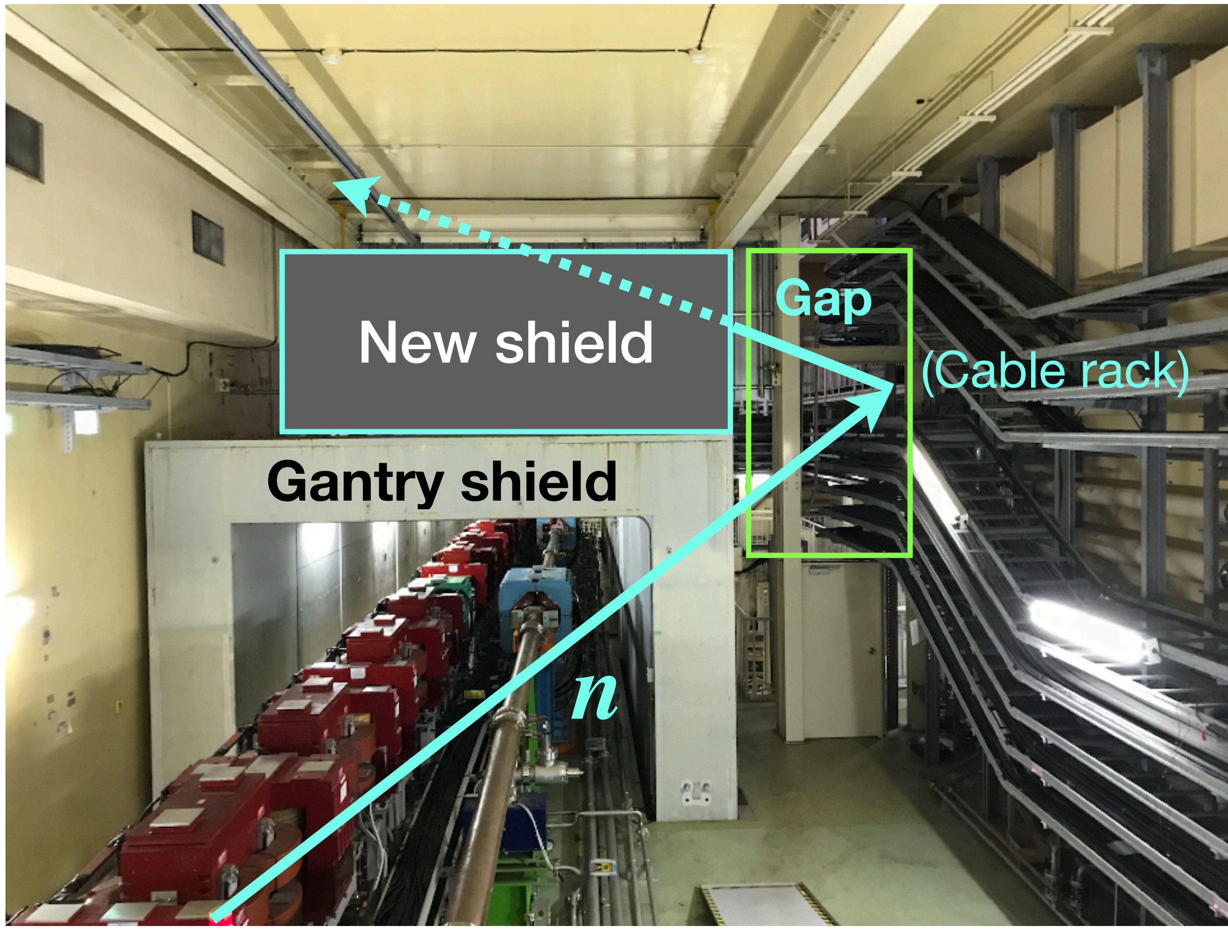




- By installing the sieldings, the maximum dose in the experimental area decreases by two orders of magnitude (~10μSv/h).
- Monitor dose increase during testing of the collimation system.
- Reinforcing shielding according to measurement results.
- Restrict access to the Oho area during operation, if necessary.

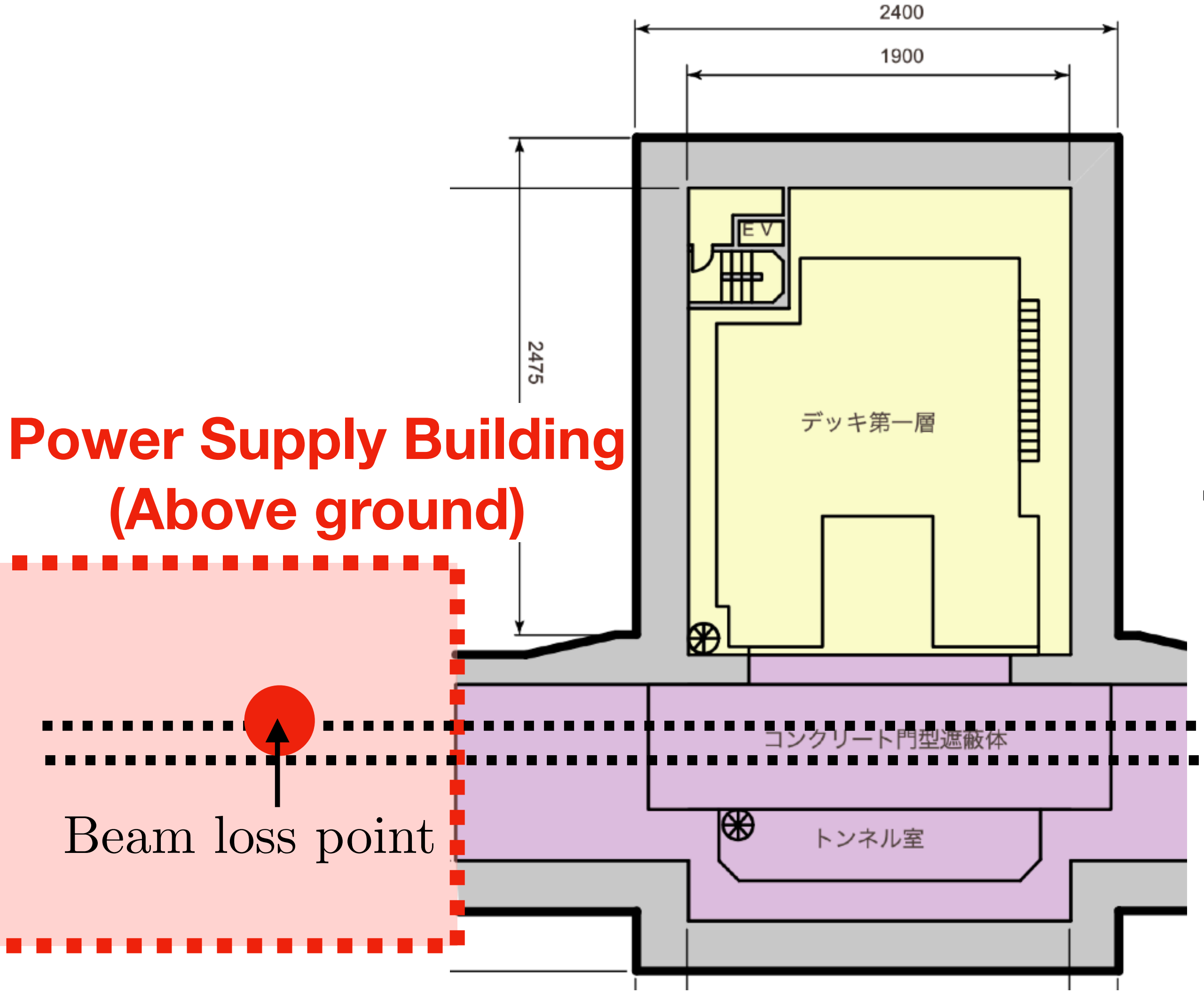
Future work

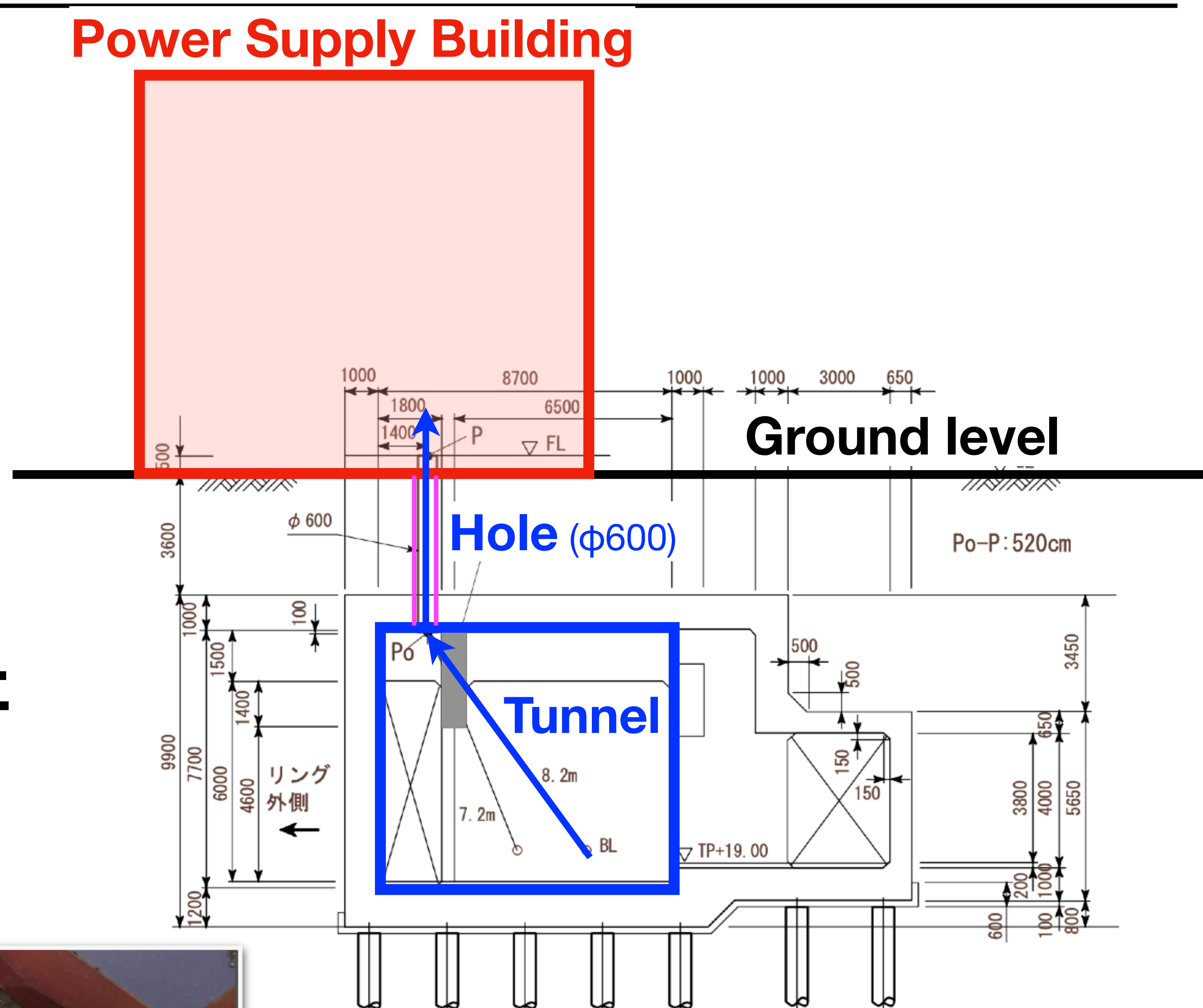




- Neutrons pass through a gap and are scattered in the Oho Expt area.
- Shield neutrons near the collimator.
- Consider shield design that does not interfere with beamline and collimator maintenance work.

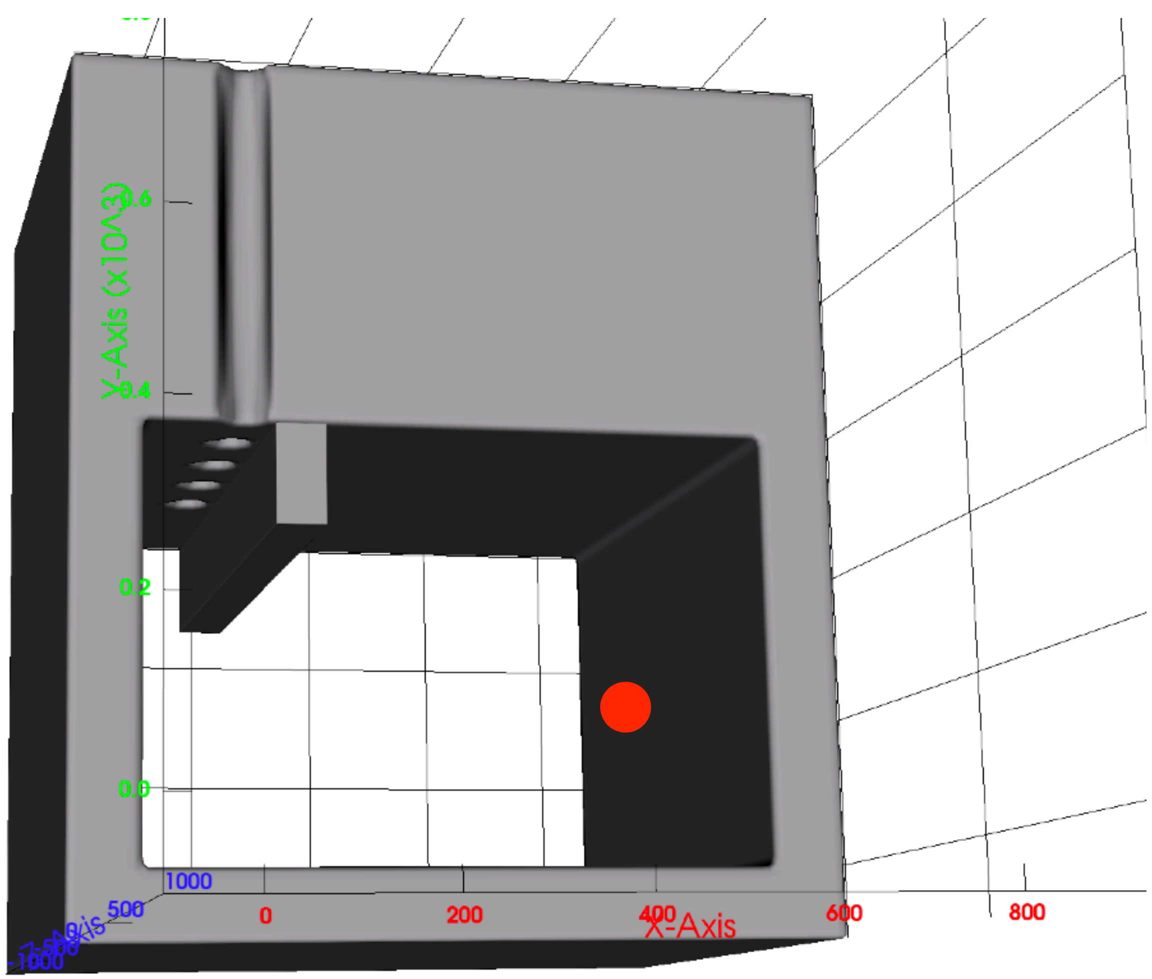
Beam loss point and proximity area (2 of 2)

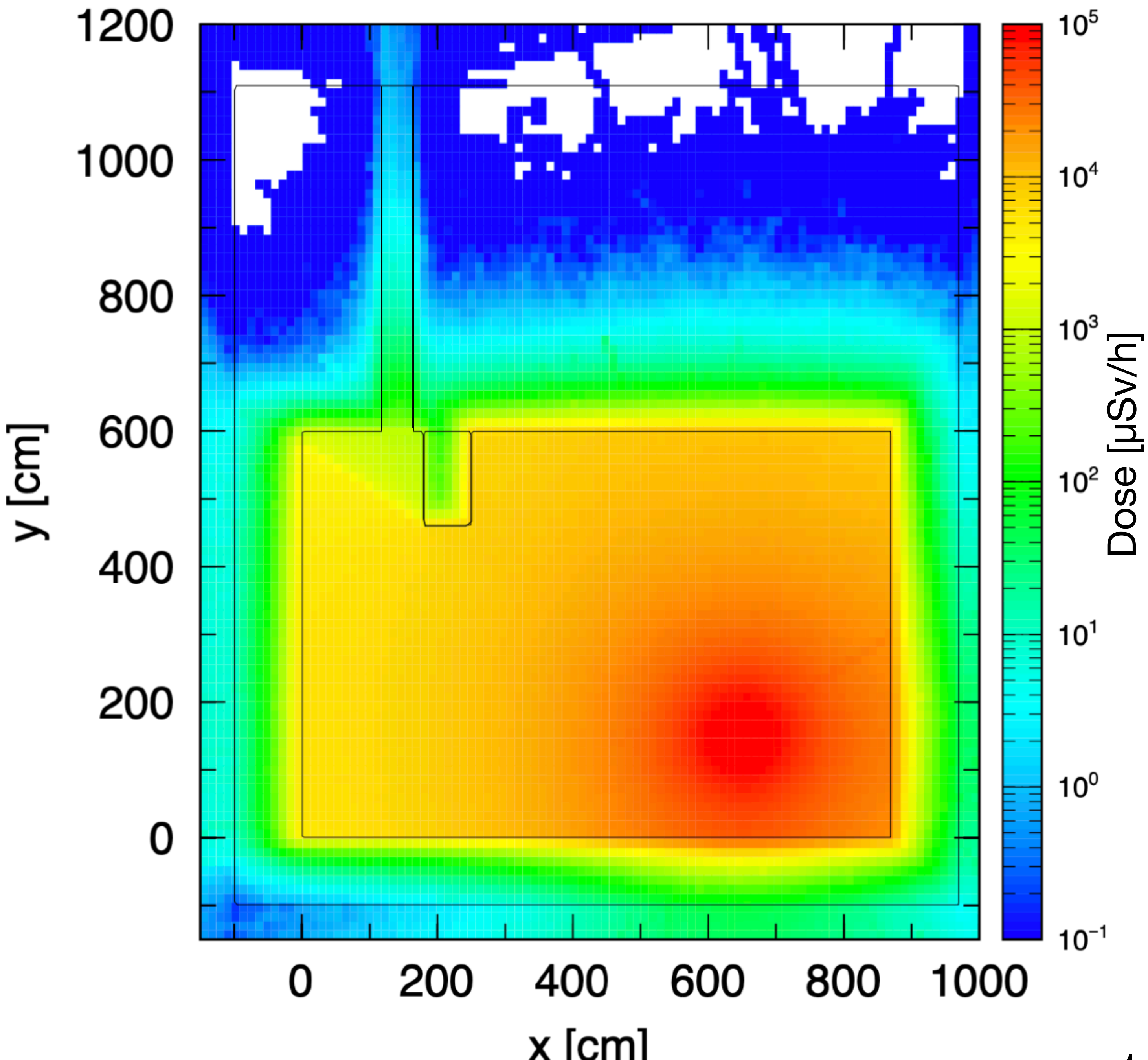




Power Supply Building

- 2 μSv/h (at the exit of the hole)
- Cover at the hole-exit with boron-containing polyethylene if necessary





Air activation in tunnel

- Evaluated by Swanson's formula

Nuclide	Limit (Bq/cm^3)	Saturation activity (Bq/cm^3)
^3H	8×10^{-1}	4.18×10^{-6}
^7Be	5×10^{-1}	8.36×10^{-7}
^{11}C	2×10^{-1}	8.36×10^{-6}
^{13}N	2×10^{-1}	4.35×10^{-4}
^{15}O	2×10^{-1}	4.69×10^{-5}
^{38}Cl	3×10^{-1}	1.84×10^{-7}
^{39}Cl	3×10^{-1}	1.25×10^{-6}
^{41}Ar	1×10^{-1}	1.02×10^{-4}
(Sum of ratios to limit values)		3.48×10^{-3}

- The sum of the ratios to the limits is sufficiently smaller than 1.
- No special action required

Related recent developments in PHITS

- Photonuclear reaction calculation for higher-Z targets is relatively slow.
- New features of PHITS can be used to speed up the calculation:

➡ Use of photonuclear data library (E_γ < ~200 MeV. Ver 3.27 or higher)

➡ PHITS-UDM ($E_{\rm data} < E_\gamma < 1$ TeV. Ver 3.30 or higher. https://github.com/sakaki-y/PHITS-UDM)

- Speed-up of the photonuclear reaction model itself is also in progress.

Summary

- SuperKEKB and Belle II are being upgraded.
- Non-linear collimation system is being installed in Oho area to reduce beam background for the collider Expt.
- 3D geometry was constructed by PHITS to evaluate the dose at the facilities close to the collimator.

  ➡ Shield is designed based on the evaluation.
- Monitor dose increase during testing of the collimation system.
- Reinforcing shielding according to measurement results.