# Radiation safety evaluation for “KAMABOKO” Main Linac Tunnel

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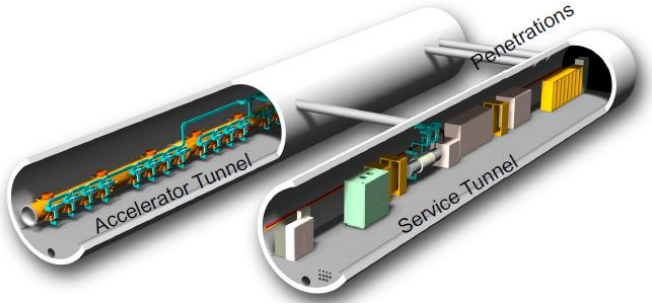
ILC Mechanical & Electrical Review and CFS Baseline Technical Review at CERN (21-23 March 2012)

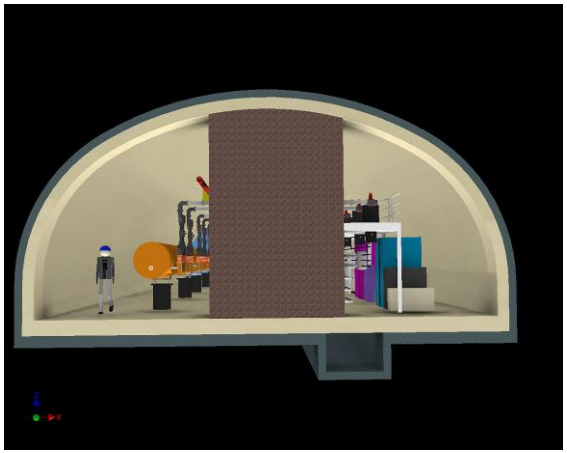
# Background

Cost optimization for RDR design




“KAMABOKO” single tunnel with
Separation wall

-Two tunnel area with affordable cost



Advantage:

- Service tunnel
- Higher ceiling
- Controllable shield thickness

# Radiation safety design

Radiation Safety design for ILC-ML tunnel

Direct radiations

Thickness of the wall

Design for special sections

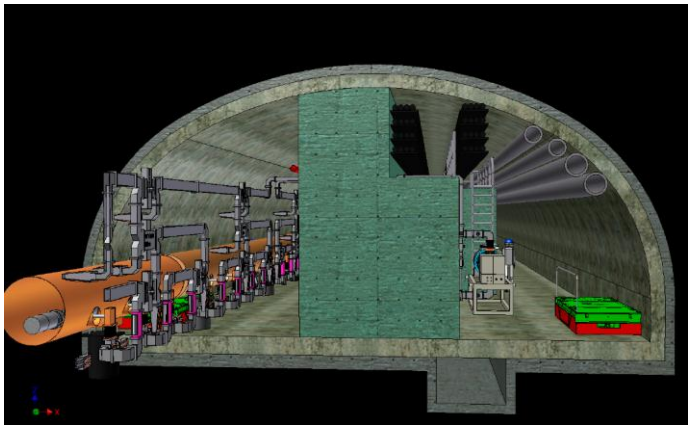
- Personal passage way, Waveguide hole, penetrations, tune-up dumps, collimators, etc

Induced activities

Activity in air, water

Damage for devices

Operation and decommissioning



# Methodology

Beam loss :

- 1 W/m for normal operation (Not authorized yet)
- 18 MW for system failure

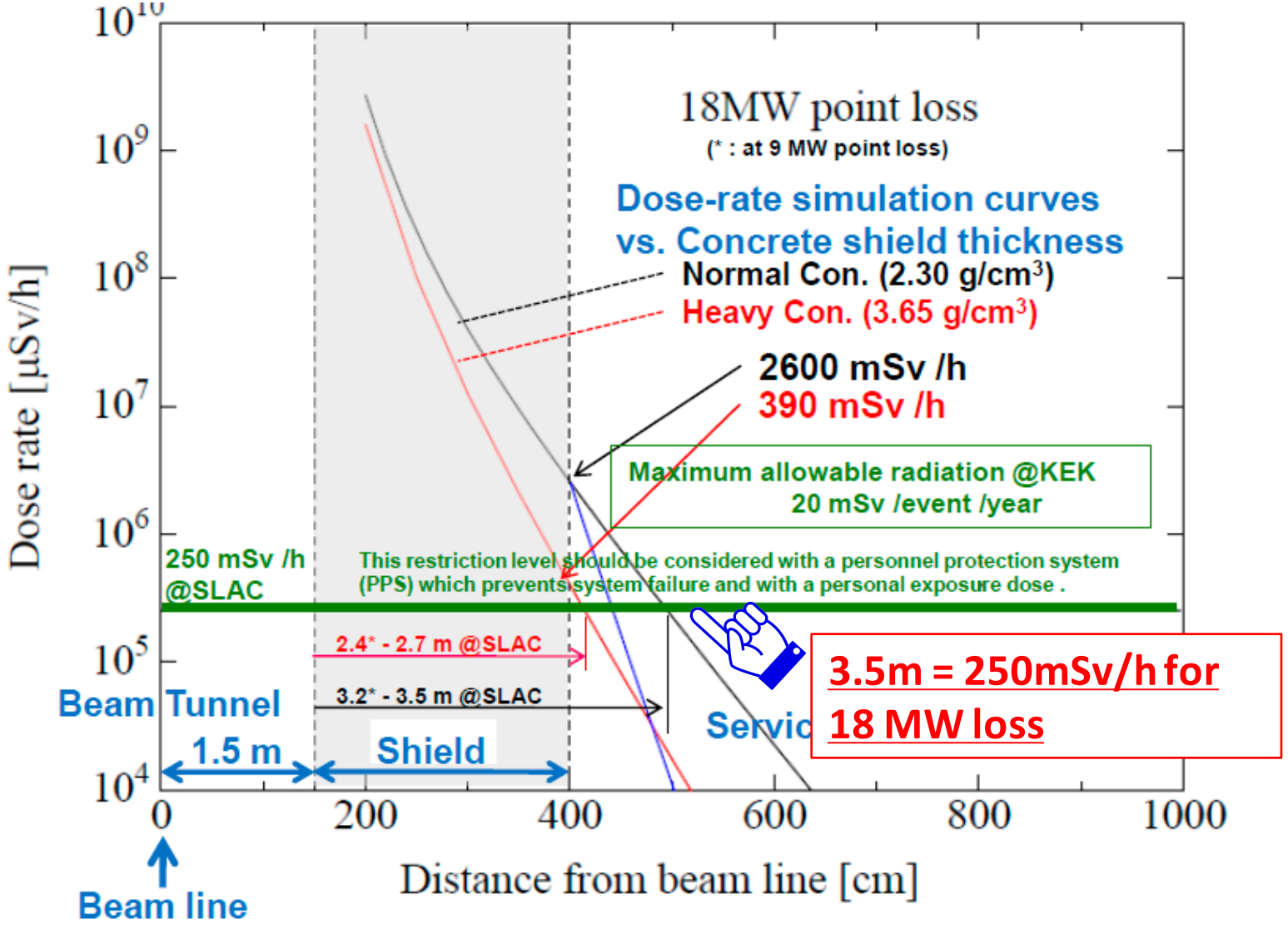
Limitation :

- 20 mSv/event/year (KEK) (How many events ?)
- 20 μSv/h for normal operation (KEK)

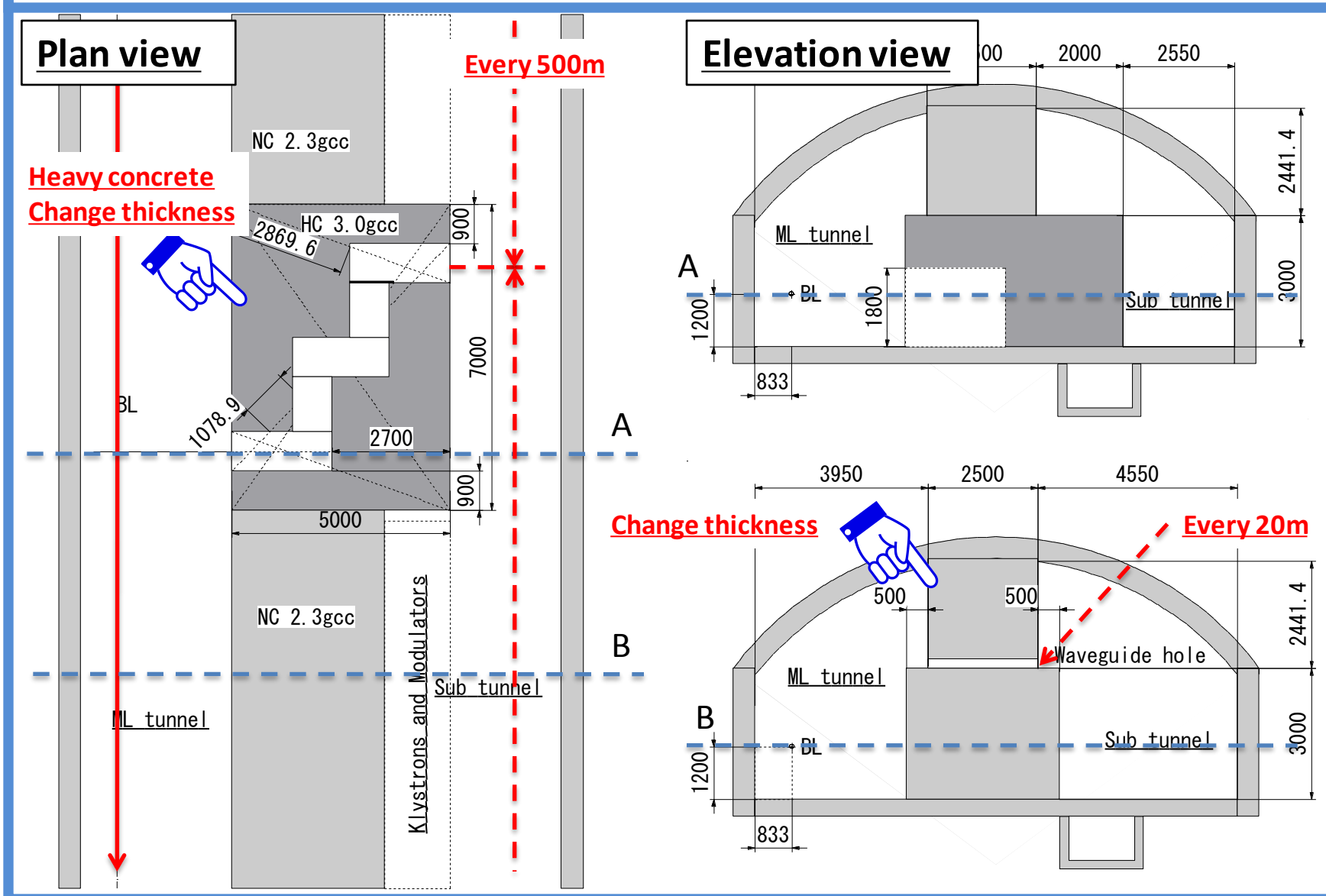
Tools :

- Bulk wall thickness : Jenkins empirical equation
- Maze and holes : MARS Monte-Carlo code
- Induced activity : IAEA technical rep. 188 (Swanson)

# Bulk wall thickness

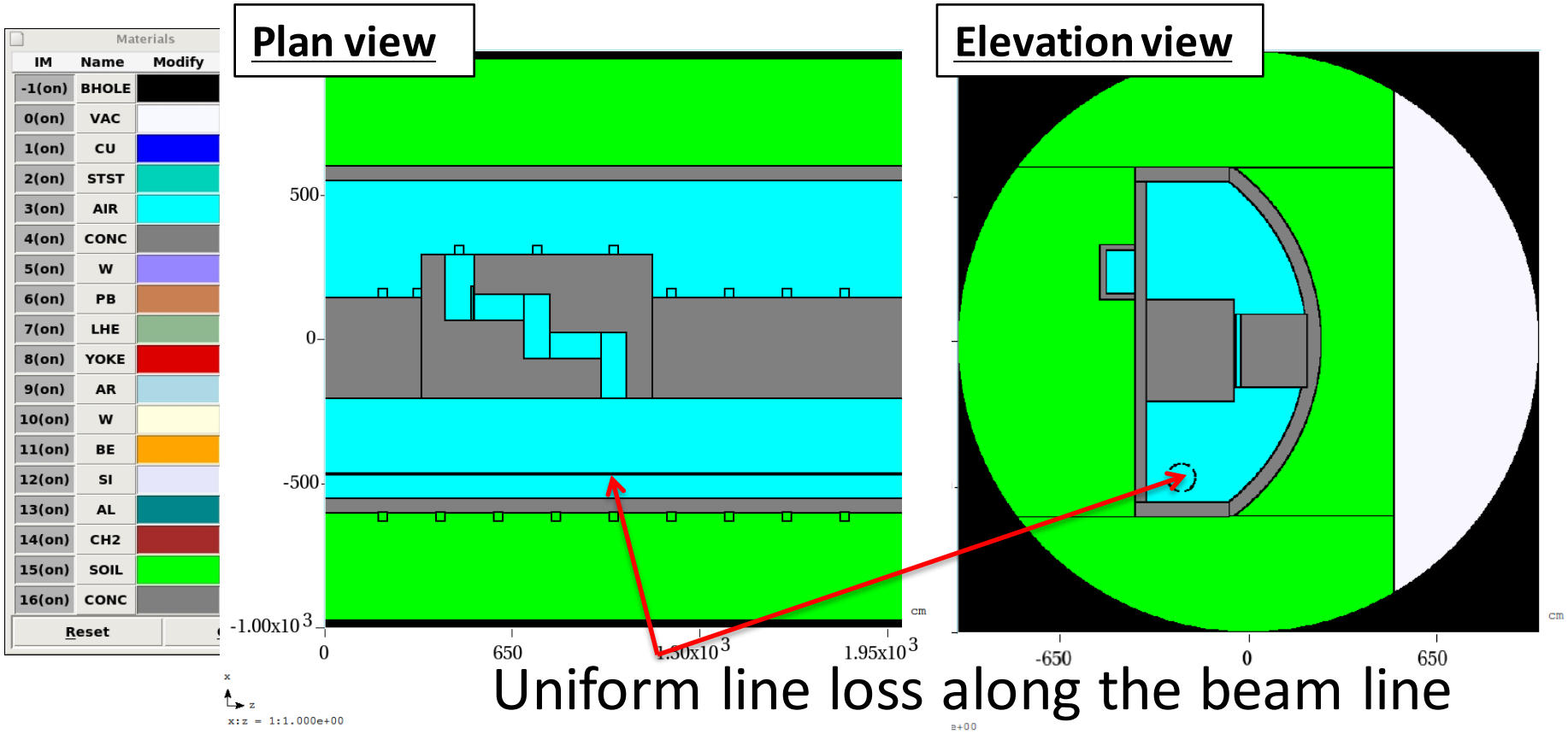


# Personal passage way+ Waveguide hole



# Model for Monte-Carlo calculation

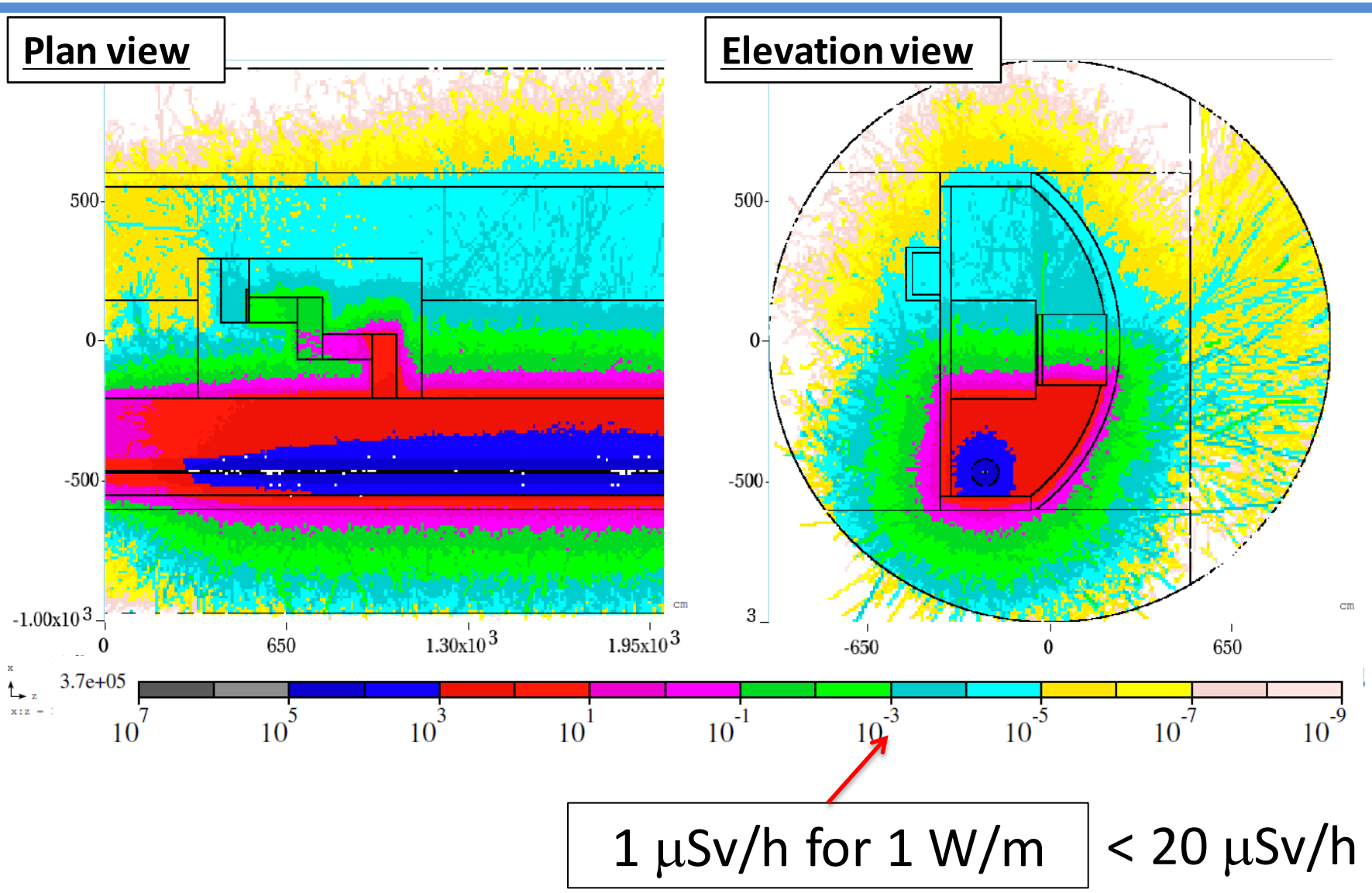
90 cm width crank with one 10cm thick iron slide door




Uniform line loss along the beam line

1 mrad grazing angle

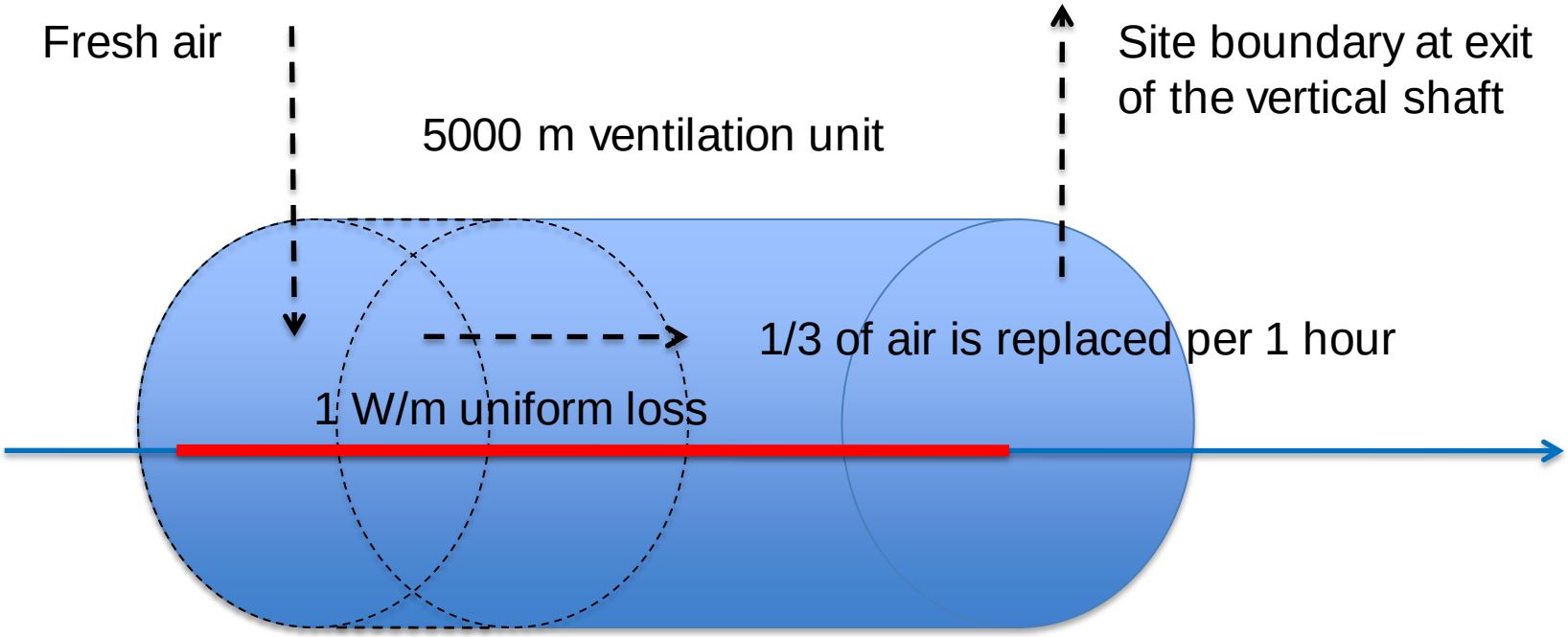
# Dose rate for 1 W/m uniform loss




1 μSv/h for 1 W/m < 20 μSv/h

# Radioactivity in air

| | **Beam loss rate** | **Length of ventilation unit** | **Total exhaust time** | Beam loss power | Fraction of energy deposit to air | L_path | Unit volume | Surface area | Thermal neutron production rate | Neutron production rate |
|---|---|---|---|---|---|---|---|---|---|---|
| | **W/m** | **m** | **h** | kW | | m | m3 | cm2 | n/s | n/s |
| ILCML air condition unit | **1** | **5000** | **3** | 5 | 0.01 | 2 | 89000 | 78250 | 4.8E+9 | 9.5E+12 |



# Radioactivity in air

| Nuclide | Saturation activity | Saturation activity concentration | Limit of activity in air | Limit of activity in exhaust | Ratio to air limit | Ratio to exhaust limit | Half life | Cooling time | Ratio to exhaust limit after cooling |
|---|---|---|---|---|---|---|---|---|---|
| | Bq/m/kW | Bq/cm3 | Bq/cm3 | Bq/cm3 | | | h | h | |
| 3-H | 5000000 | 5.61798E-06 | 0.8 | 0.005 | 7E-06 | 0.0011 | 106872 | | |
| 7-Be | 1000000 | 1.1236E-06 | 0.5 | 0.002 | 2E-06 | 0.0006 | 1286.4 | | |
| 11-C | 10000000 | 1.1236E-05 | 0.2 | 0.0007 | 6E-05 | 0.0161 | 0.34 | | |
| 13-N | 520000000 | 0.00058427 | 0.2 | 0.0007 | 0.0029 | 0.8347 | 0.166 | 0.1 | |
| 15-O | 56000000 | 6.29213E-05 | 0.2 | 0.0007 | 0.0003 | 0.0899 | 0.034 | | |
| 38-Cl | 220000 | 2.47191E-07 | 0.3 | 0.003 | 8E-07 | 8E-05 | 0.62 | | |
| 39-Cl | 1500000 | 1.68539E-06 | 0.3 | 0.003 | 6E-06 | 0.0006 | 0.9367 | | |
| 41-Ar | | 6.52484E-05 | 0.1 | 0.0005 | 0.0007 | 0.1305 | 1.83 | | |
| | | | | Total | 0.004 | 1.0734 | | | 0.5995 |

# Radioactivity in water

Cooling water inside the accelerator tunnel

Closed loop water pipes

1 W/m loss for 5000 m

5000 m long 2 “diam. X 2

| | Beam power | Beam loss fraction | Beam loss power | Amount of cooling water | Ratio to deposit power |
|---|---|---|---|---|---|
| | kW | | kW | cm^3 | |
| ILCML tunnel unit | 1.80E+04 | 0.0002778 | 5.000E+00 | 2.03E+07 | 0.0020 |

| Nuclide | Saturation activity factor | Saturation activity | Limit of radioactivity in **wastewater** | Ratio to limit | Half life | Cooling time | Ratio to limit after cooling time |
|---|---|---|---|---|---|---|---|
| | GBq/kW | Bq/cm^3 | Bq/cm^3 | | h | h | |
| 3-H | 7.40E+00 | 3.65 | 6.00E+01 | 0.061 | 106872.00 | | 0.06 |
| 7-Be | 1.48E+00 | 0.73 | 3.00E+01 | 0.024 | 1286.40 | | 0.02 |
| 11-C | 1.48E+01 | 7.30 | 3.00E+02 | 0.024 | 0.34 | 1 | 0.00 |
| 13-N | 3.70E+00 | 1.83 | 5.00E+00 | 0.365 | 0.17 | | 0.00 |
| 15-O | 3.30E+02 | 162.83 | 5.00E+00 | 32.566 | 0.03 | | 0.00 |
| | | | total | 33.04 | | | 0.09 |

# Conclusion

"KAMABOKO" tunnel design is evaluated
from radiation safety view point

- The basic concept has possibility to meet requirements of radiation safety criteria
- Beam loss powers and conditions are important for further evaluation

The outstanding merits of "KAMABOKO" tunnel,
Two tunnel area with affordable cost,
Shorter penetrations, Easier installation,
Additional space for utilities,
can accommodate with radiation safety design

# Spare slides

# RDR Tunnel design

Geological conditions

(7.5 m separation between two tunnels)

Penetration for waveguides

(48cm diam. with 7.5 m long )

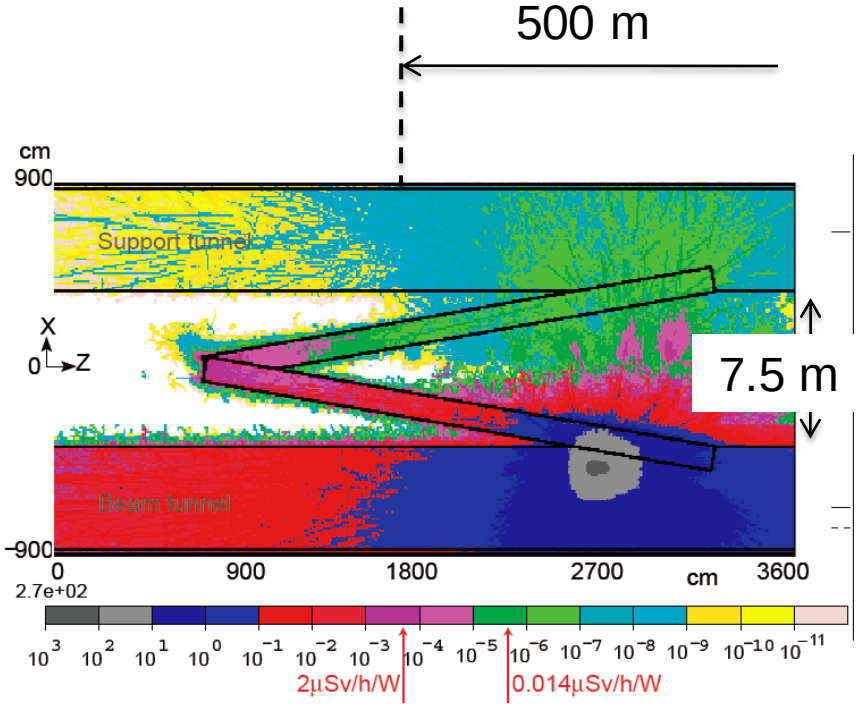
Personal passage way

(Every 500 m, 90 cm width

Dose rate for 18 MW

maximum credible beam loss

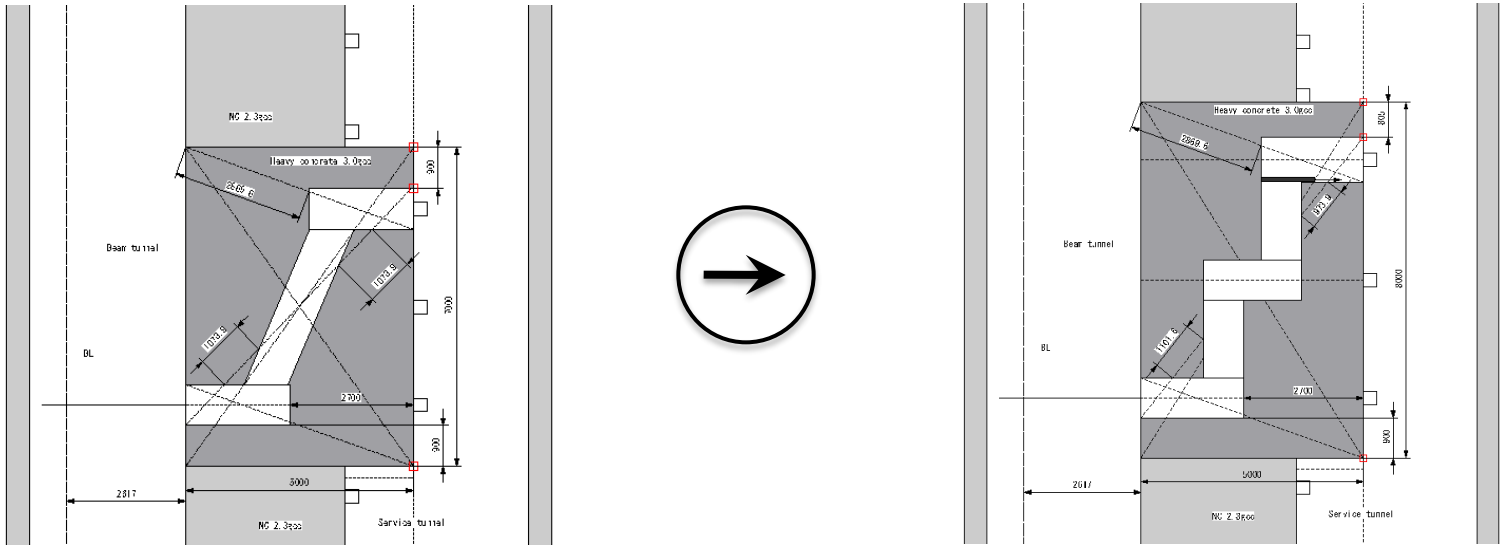
Tunnel separation design



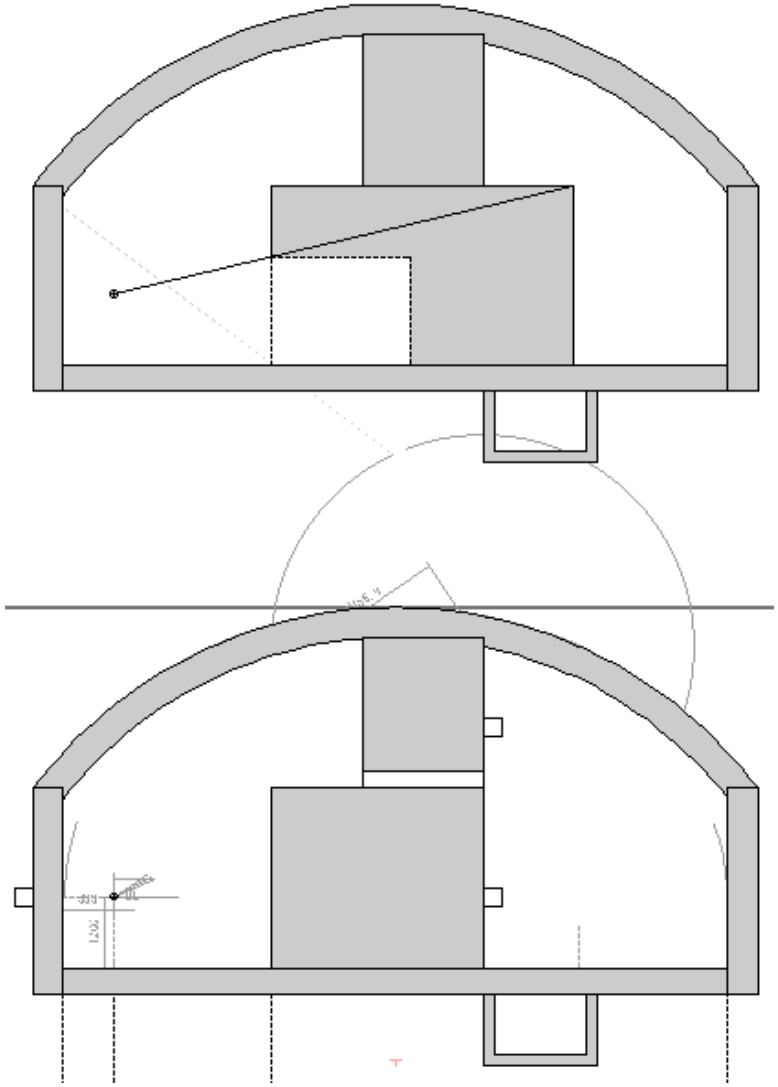
# Personal passageway

Ideas:

- Keep bulk wall thickness as 3.5 m
- 1.6 m additional thickness with 8 m long available
- Maze structure
- Partially use heavy concrete



# Elevation view



## Elevation view

Thinner wall above 3 m

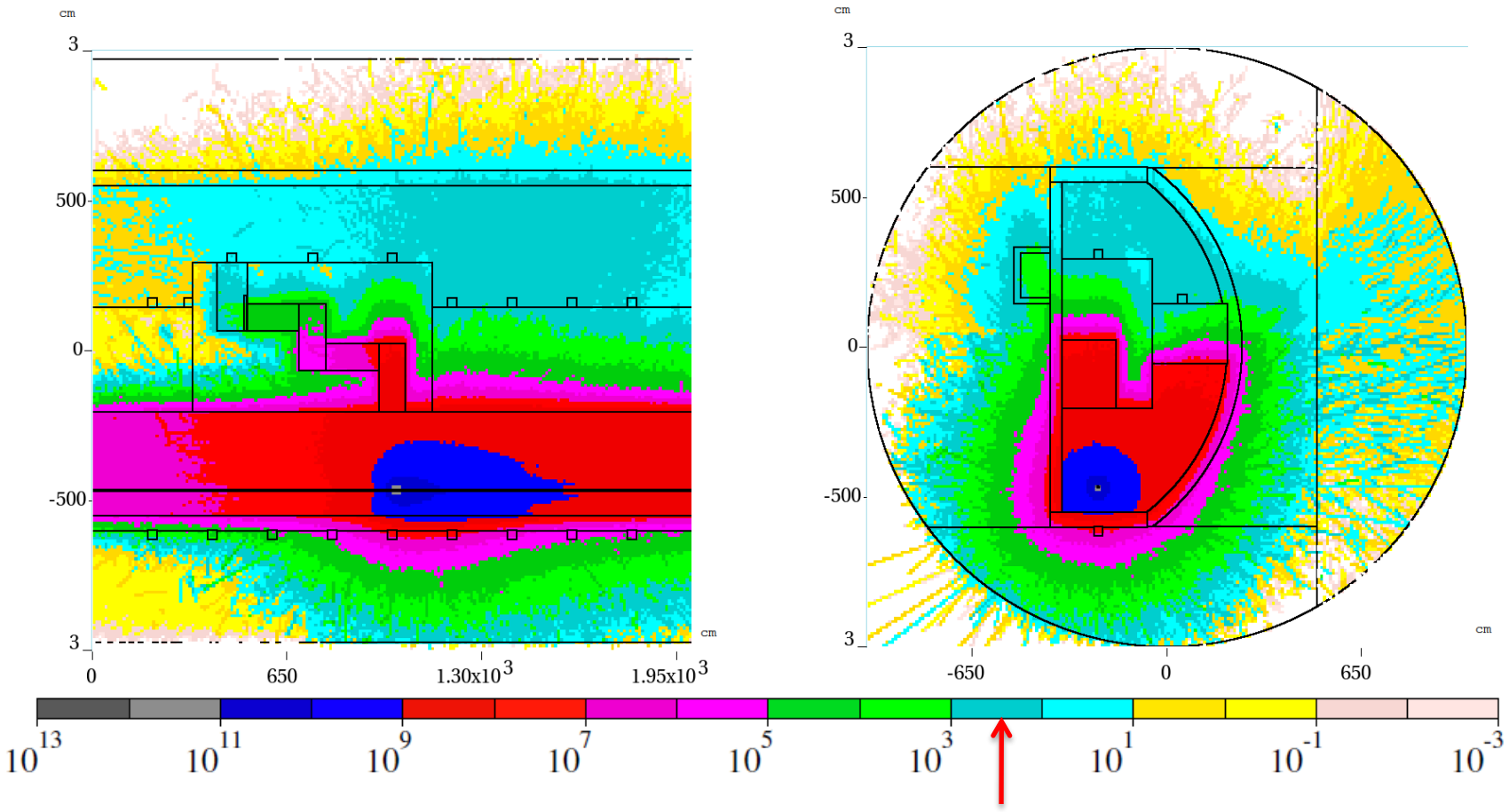
Shorten a waveguide hole

Smaller hole size

Easy installation

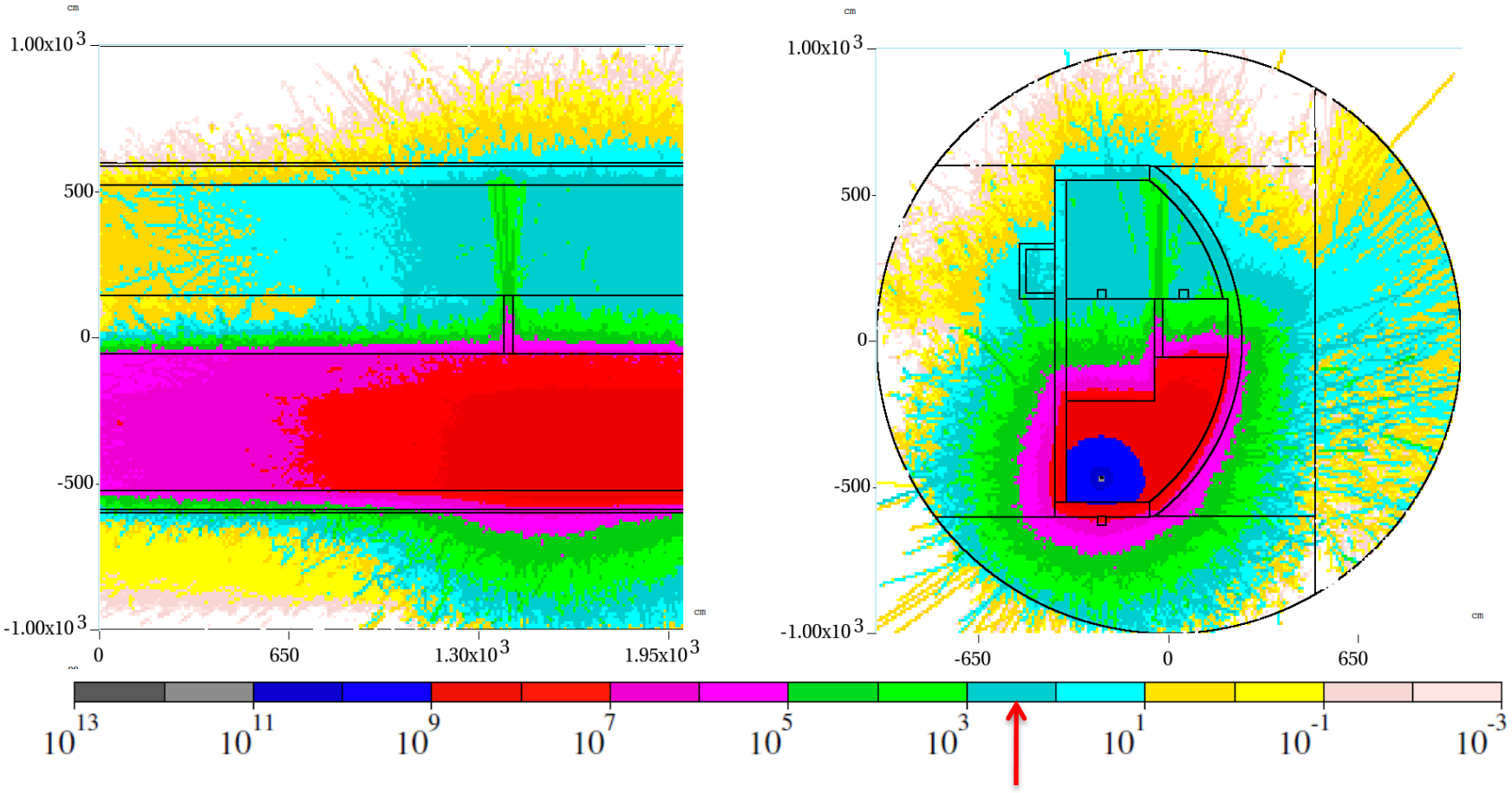
Additional space for utilities

# Dose rate for 18 MW point loss




250 mSv/h for 18MW

# Dose rate for 18 MW point loss

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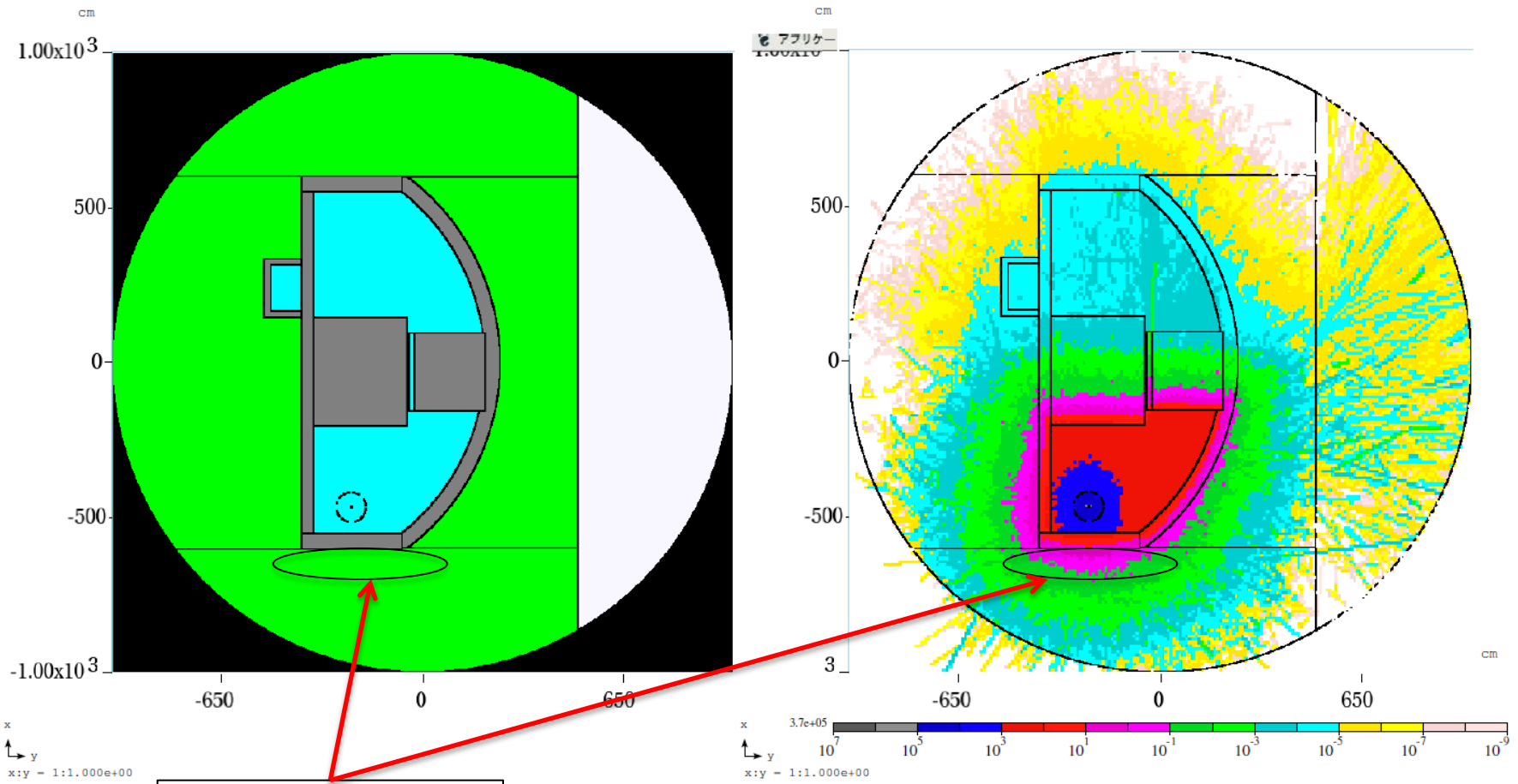
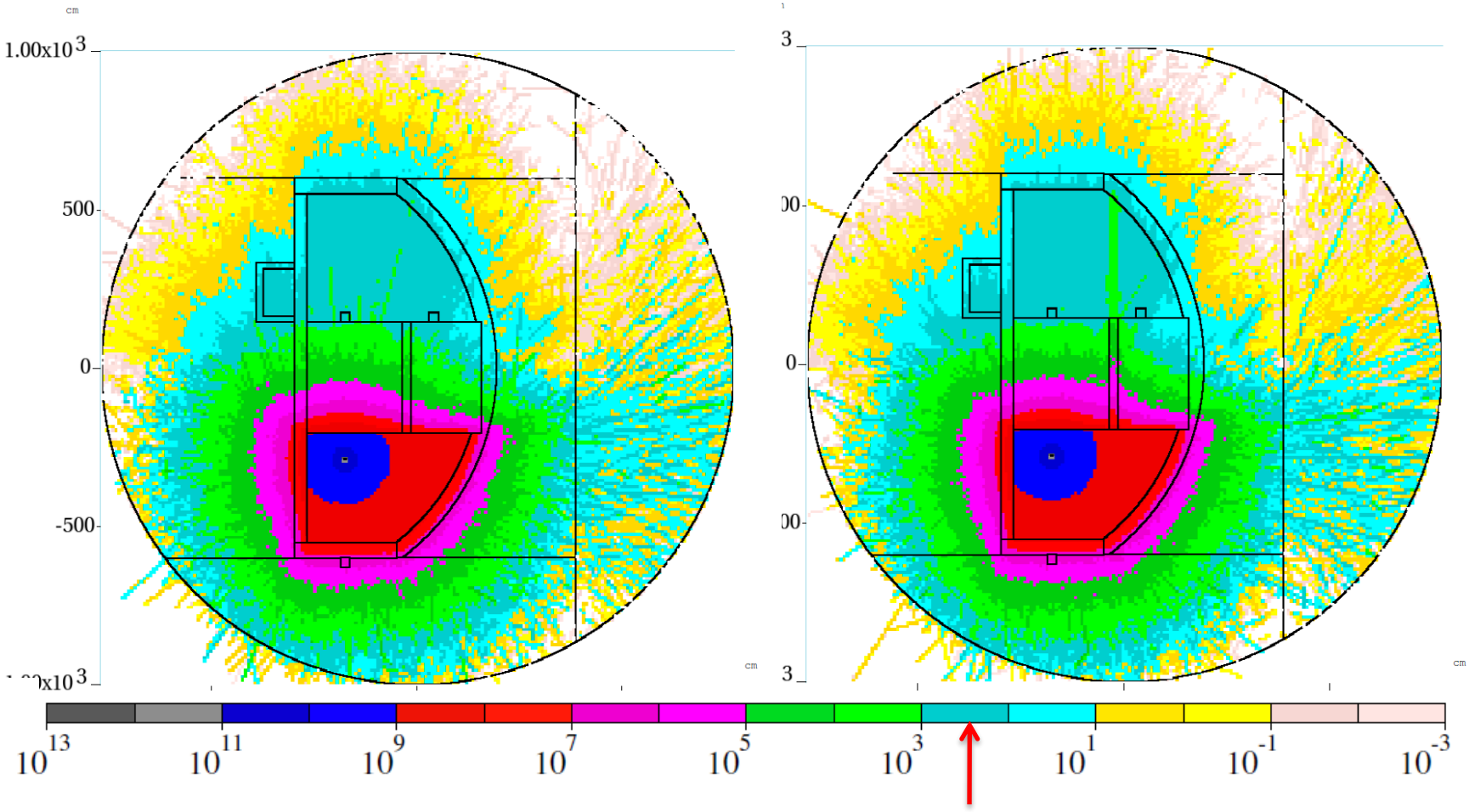
# Radioactivity in groundwater




~1 mSv/h ≃ 5 mSv/h (Depend on environment)

# WAVEGUIDE HOLE

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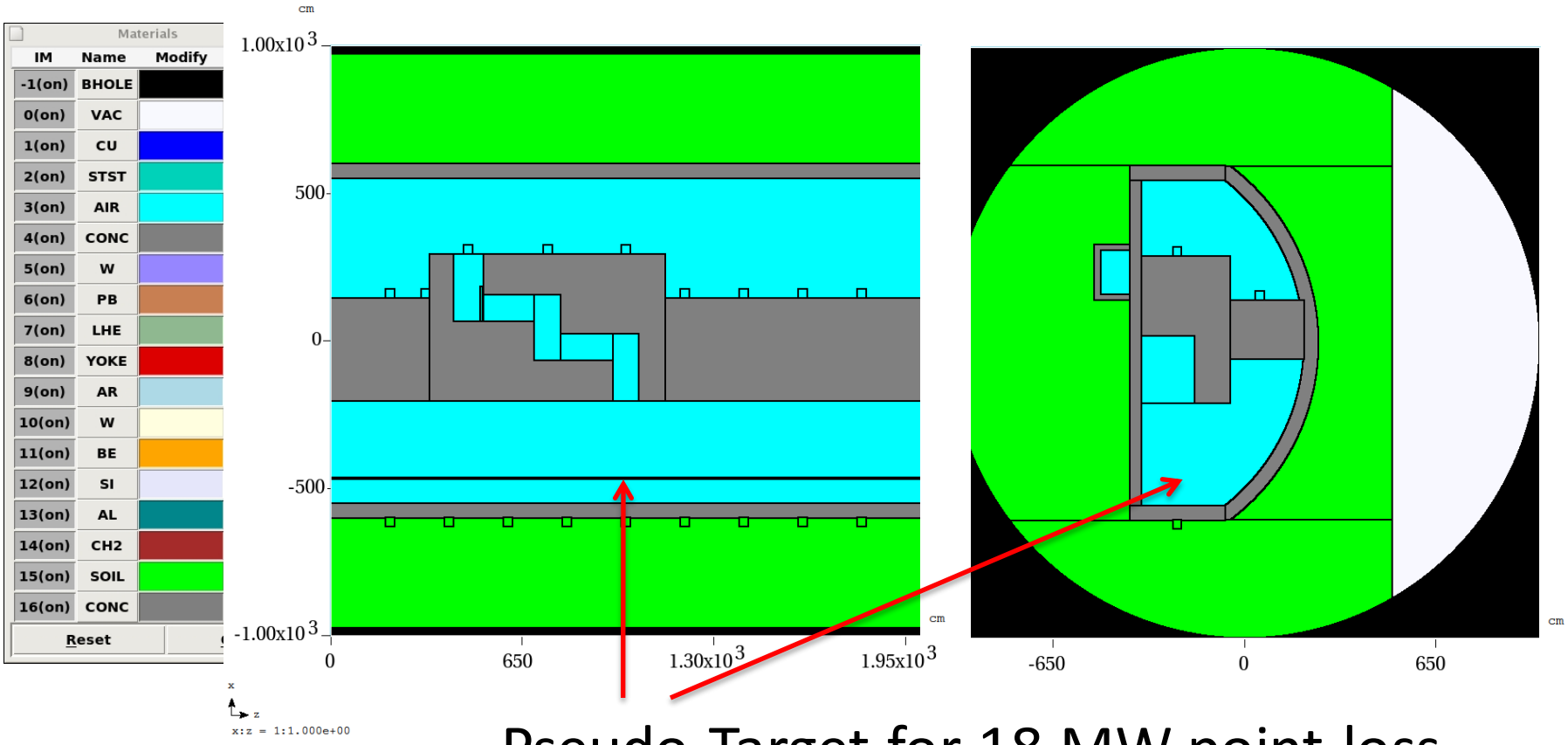
# CRANK WITH DOOR

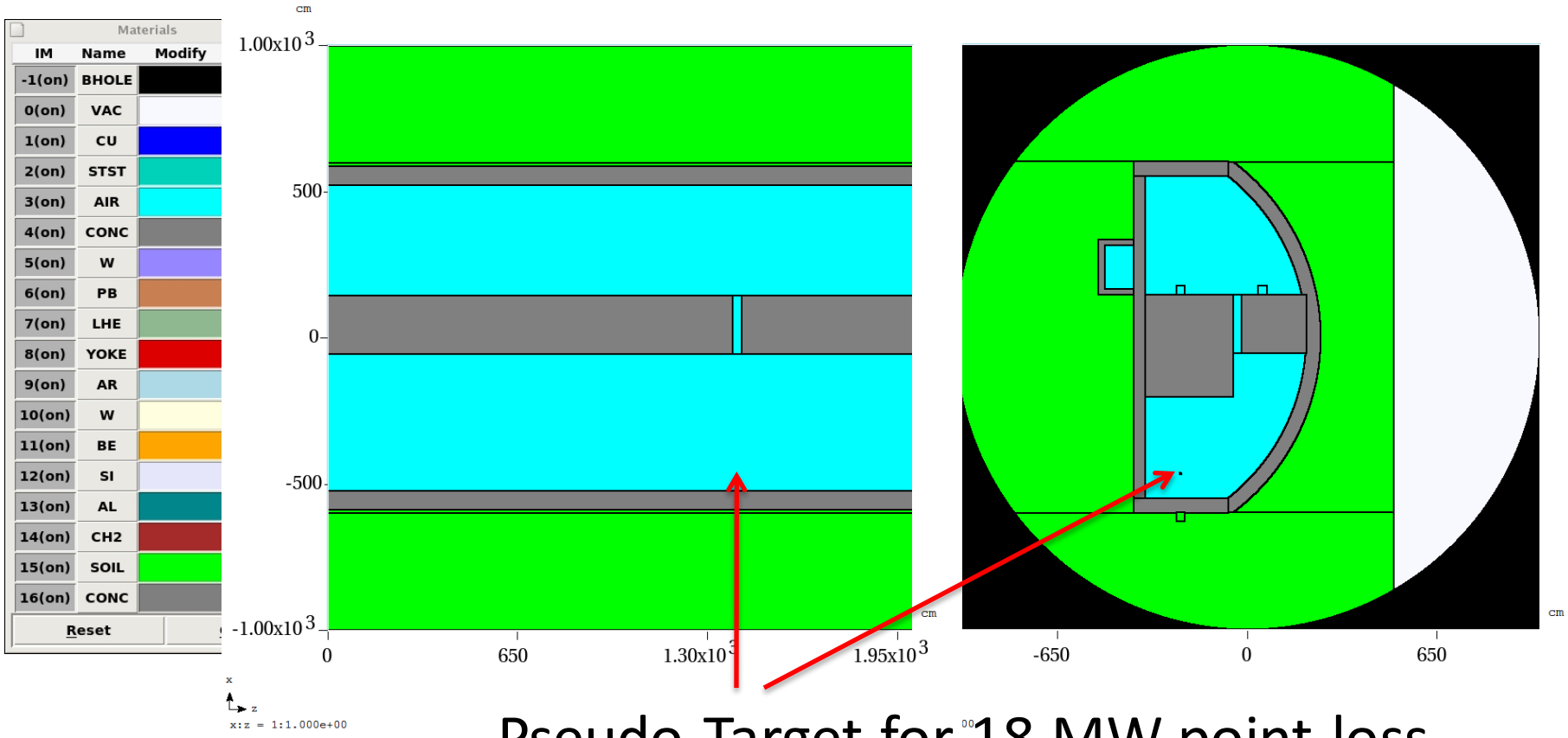
90 cm width crank with one 10cm thick iron slide door




Pseudo Target for 18 MW point loss

# WAVEGUIDE HOLE

30 cm diam., 2m long waveguide hole at 3m above FL




Pseudo Target for 18 MW point loss

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