Main Linac radiation shielding (Status of shielding wall review)

Radiation science center, Applied physics laboratory,
High energy accelerator research organization

T.Sanami

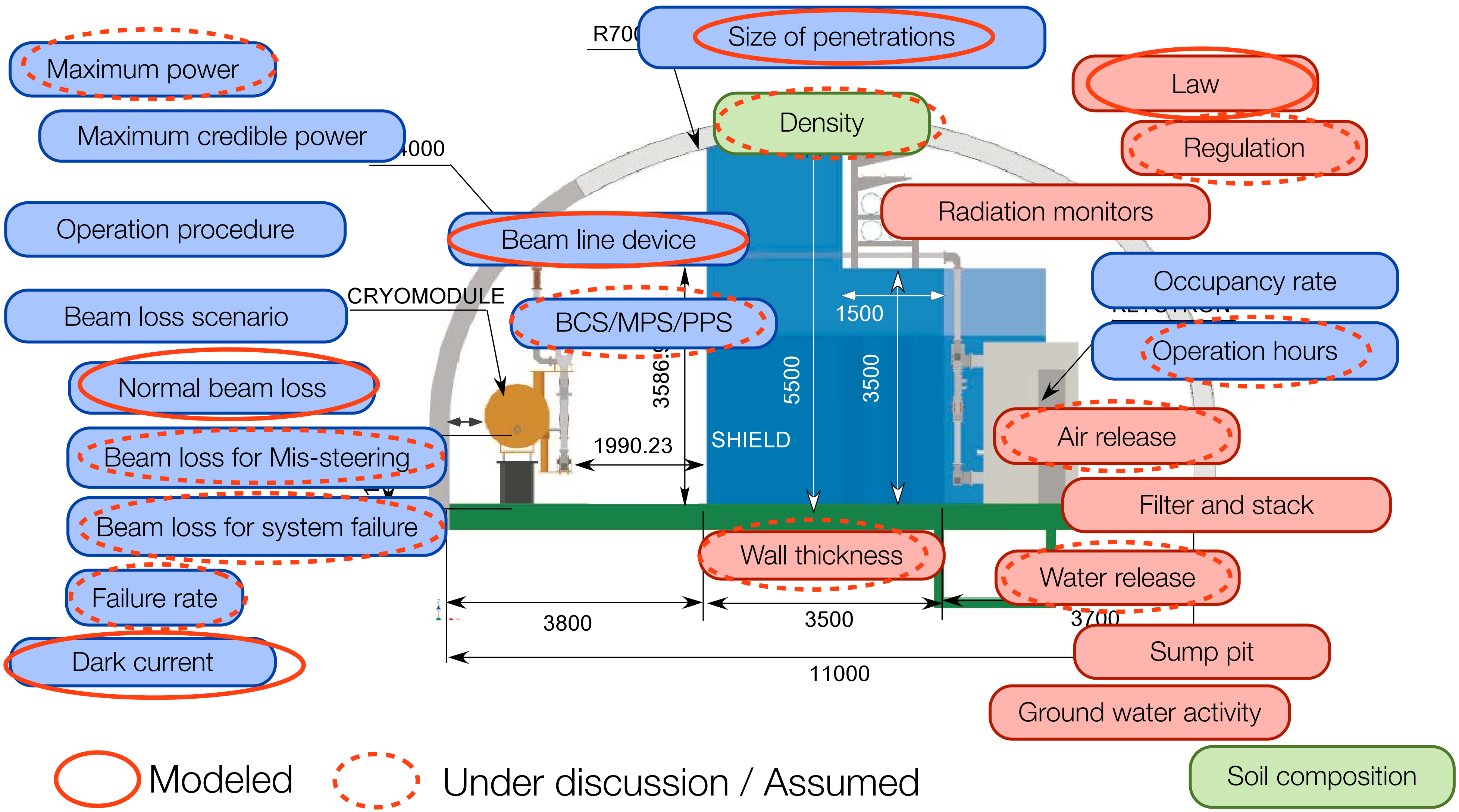
Progress in FY2014

- CFS-ADI at Tokyo and AWLC2014
  - Full beam loss on the worst target. Items should be evaluated
- 2nd ADI fuze meeting
  - Beam loss for normal operation
- In addition to these
  - Simulation models for Cryo-module, tunnel, for detail design
- Based on these information
  - Evaluation on main linac shielding with practical beam loss
  - Review of beam loss and shielding structure for whole accelerator sections
  - What should we do to obtain shielding strategy of whole ILC facility?

ML shielding - Scope

- Items to be evaluated:
  - Dose rate in service tunnel
    - Thickness of central wall thickness, effect of penetrations
    - Area classification
  - Tritium production in liquid helium
    - Area classification, placement of Helium refrigerator
  - Radioactivity in air and soil
    - Design of ventilation system of ML tunnel, estimate activities in ground water

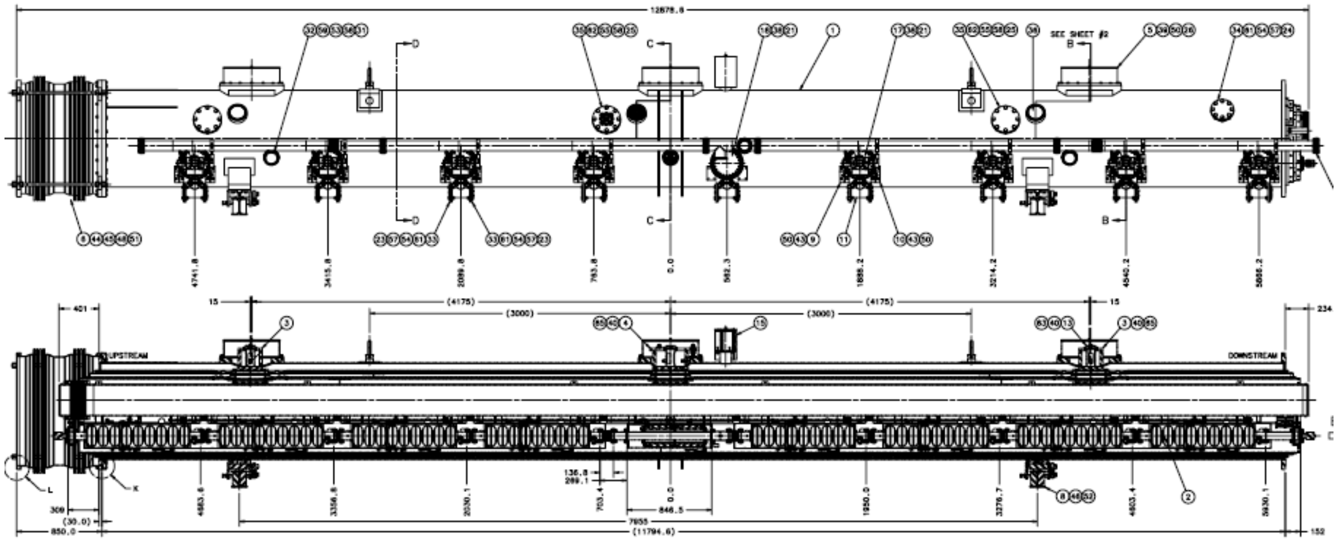
ML - parameters for shielding design

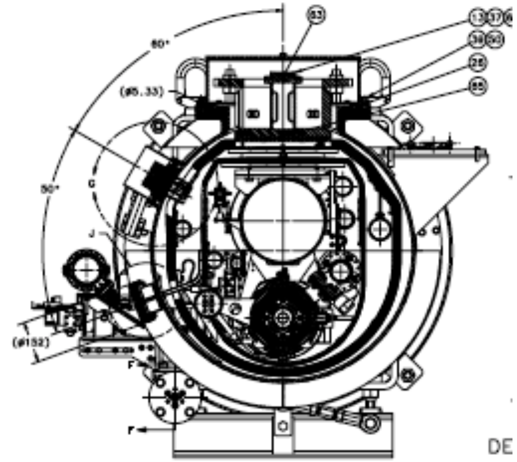


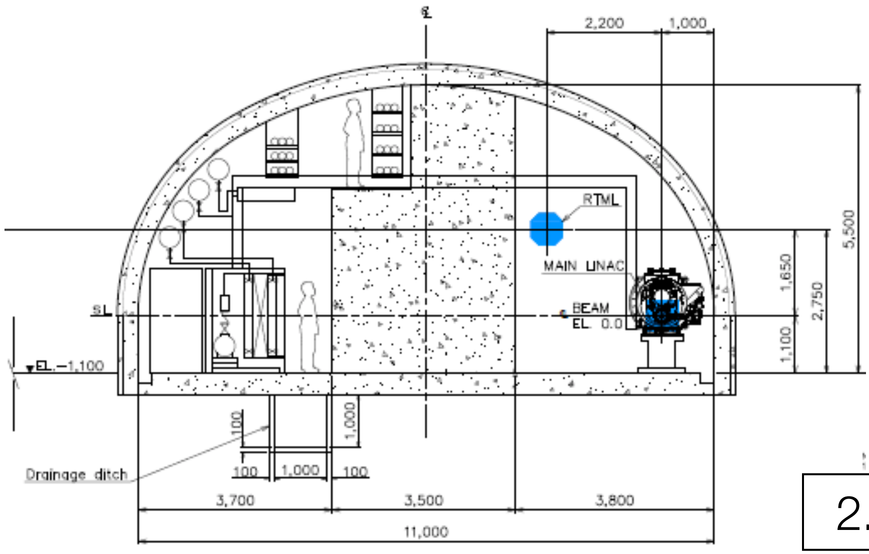
ML - Beam loss

- Beam loss: K.Kubo on 2nd ADI-meeing
  - Beam gas coulomb :
    - ML: 2.3e-7/E[GeV] W/m
    - RTML: 1.0e-6 W/m
  - Beam gas Brems. : 3e-9 E[GeV] W/m
  - Dark Current : 410 MeV, 88 I[nA] mW/quad (I nA for each cavity)
- Suppose 30MV/m、50 nA/Cavity, 38m btw Quad
  - Normal operation (under consideration) - 400MeV, 4.4W (6.875e10eps) at Q magnet
  - System failure (under consideration) - Entire bunch train at one point
  - Amount of normal loss is 10^6 times smaller than total beam power

ML -Engineering drawing





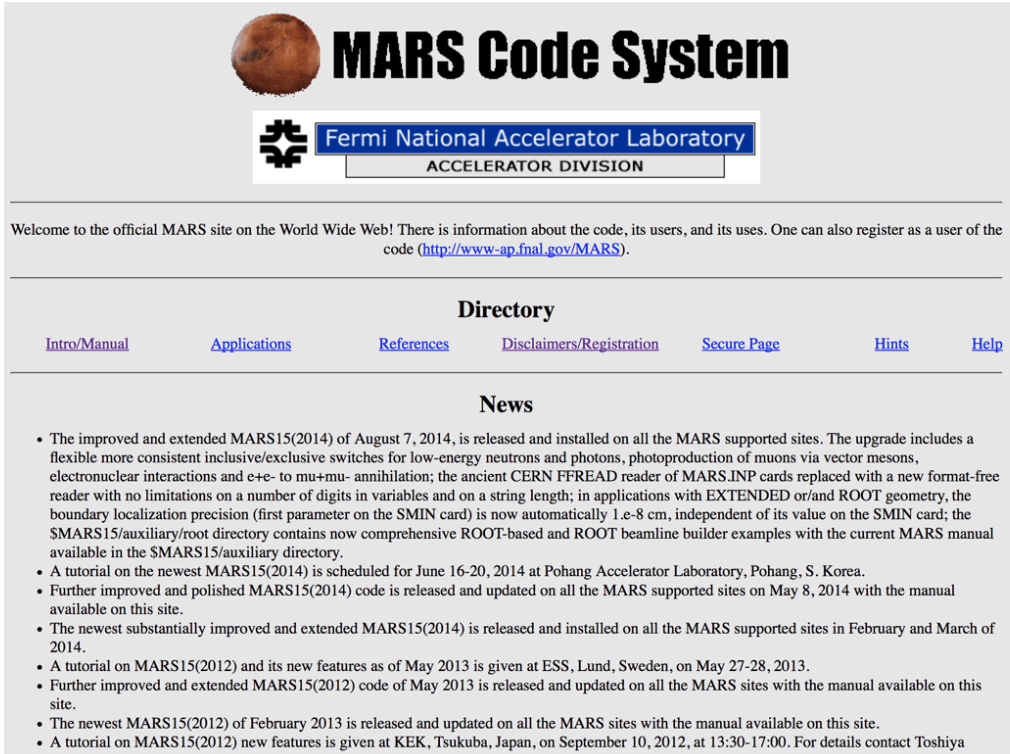


Section C-C

2.1.1.1 ILC Drawings-Civil_130730.pdf

Code for simulation

- MARS code
  - Physics from meV to TeV, three dimensional transport with models of electro-magnetic cascade, photo-nuclear reaction and low energy neutron reaction. Well-tested through experimental data.
  - Version 1512 (latest 1514)
  - MCNP mode with ENDF-B/VI
  - 1e-12 GeV for neutron
  - 0.2 MeV for others
  - LAQGSM model



MARS Code System

Fermi National Accelerator Laboratory

ACCELERATOR DIVISION

Welcome to the official MARS site on the World Wide Web! There is information about the code, its users, and its uses. One can also register as a user of the code (http://www-ap.fnal.gov/MARS).

Directory

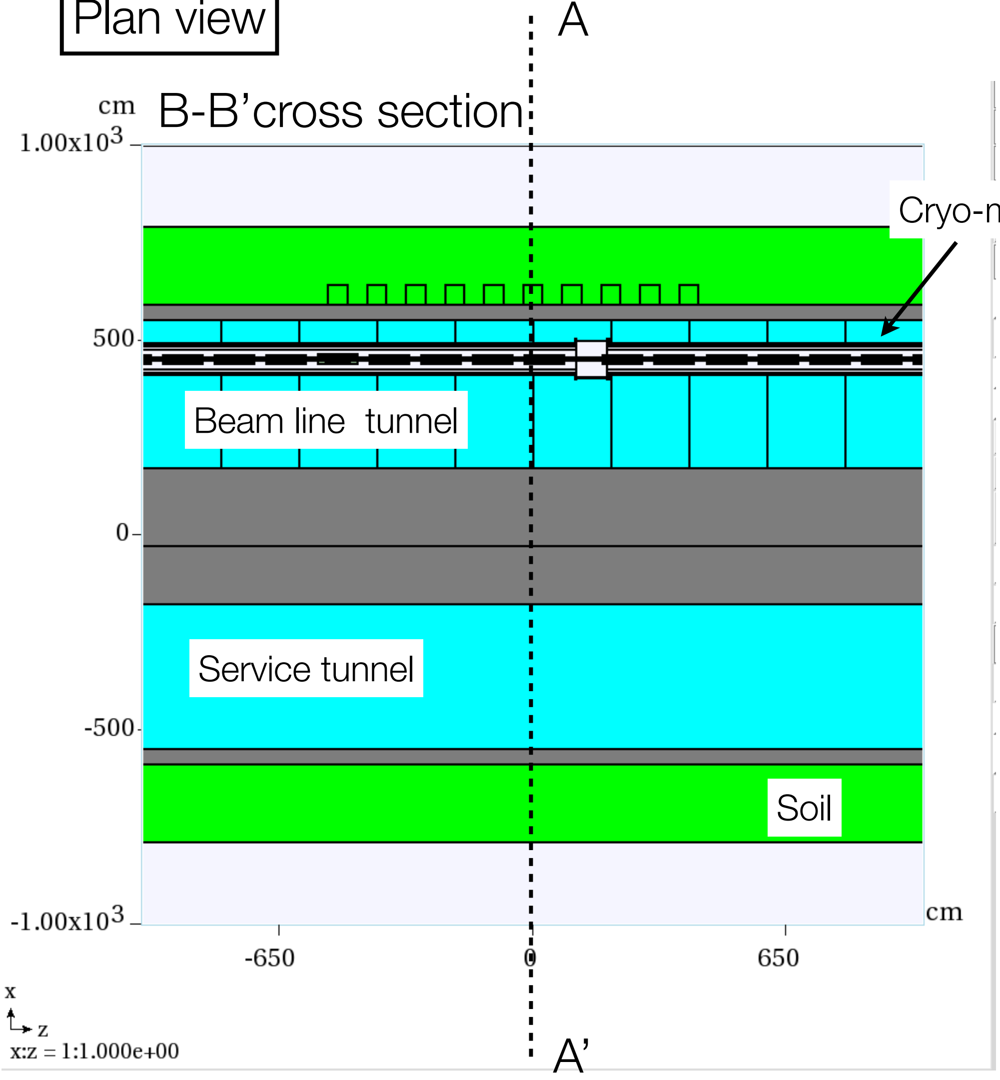
Intro/Manual | Applications | References | Disclaimers/Registration | Secure Page | Hints | Help

News

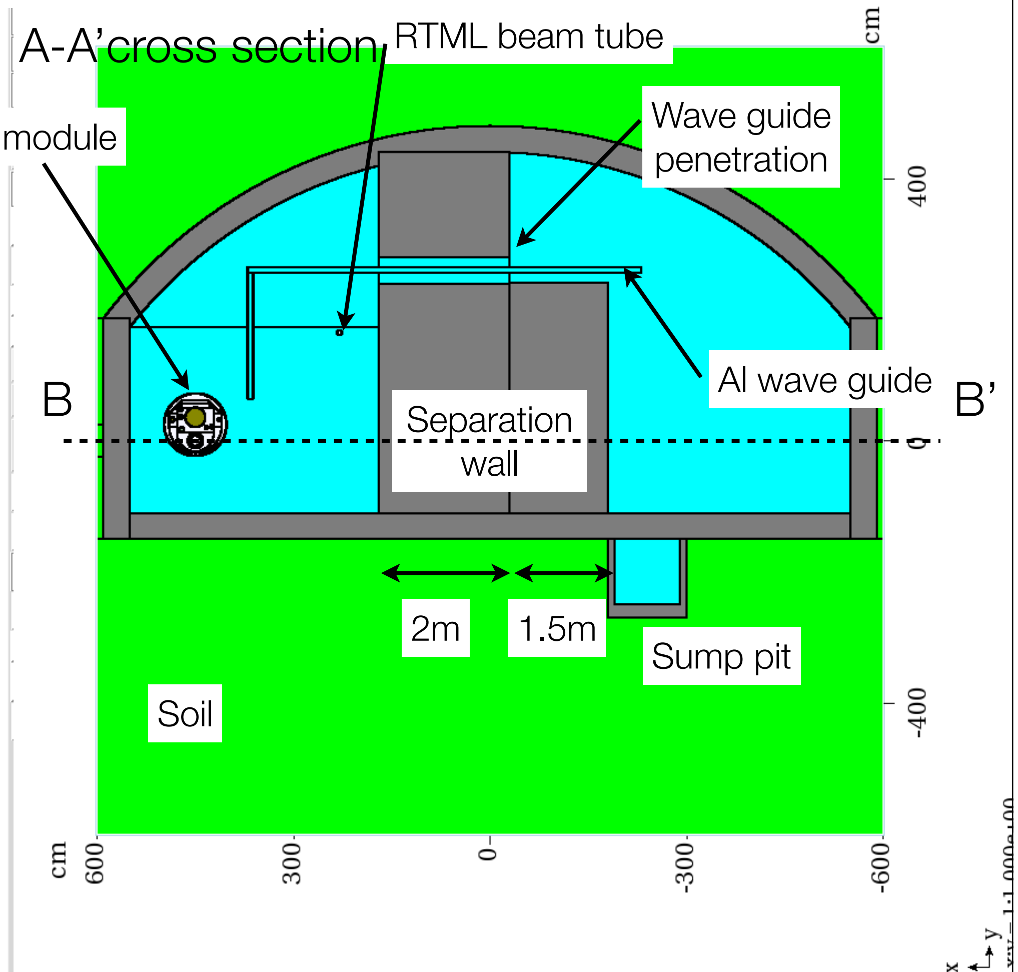
- The improved and extended MARS15(2014) of August 7, 2014, is released and installed on all the MARS supported sites. The upgrade includes a flexible more consistent inclusive/exclusive switches for low-energy neutrons and photons, photoproduction of muons via vector mesons, electronuclear interactions and e+e- to mu+mu- annihilation; the ancient CERN FFREAD reader of MARS.INP cards replaced with a new format-free reader with no limitations on a number of digits in variables and on a string length; in applications with EXTENDED or/and ROOT geometry, the boundary localization precision (first parameter on the SMIN card) is now automatically 1.e-8 cm, independent of its value on the SMIN card; the $MARS15/auxiliary/root directory contains now comprehensive ROOT-based and ROOT beamline builder examples with the current MARS manual available in the $MARS15/auxiliary directory.
- A tutorial on the newest MARS15(2014) is scheduled for June 16-20, 2014 at Pohang Accelerator Laboratory, Pohang, S. Korea.
- Further improved and polished MARS15(2014) code is released and updated on all the MARS supported sites on May 8, 2014 with the manual available on this site.
- The newest substantially improved and extended MARS15(2014) is released and installed on all the MARS supported sites in February and March of 2014.
- A tutorial on MARS15(2012) and its new features as of May 2013 is given at ESS, Lund, Sweden, on May 27-28, 2013.
- Further improved and extended MARS15(2012) code of May 2013 is released and updated on all the MARS sites with the manual available on this site.
- The newest MARS15(2012) of February 2013 is released and updated on all the MARS sites with the manual available on this site.
- A tutorial on MARS15(2012) new features is given at KEK, Tsukuba, Japan, on September 10, 2012, at 13:30-17:00. For details contact Toshiya

ML - Simulation model

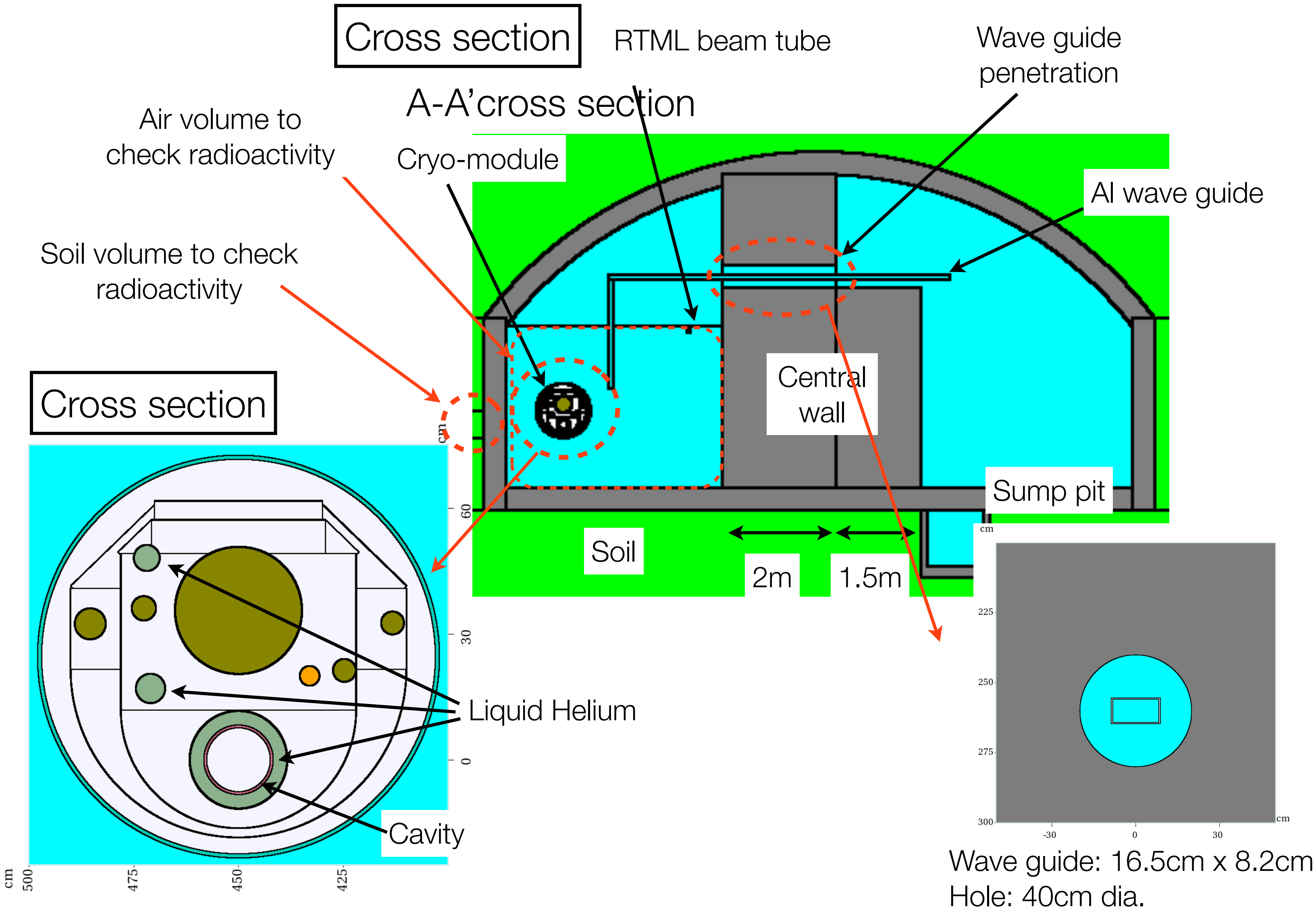
Plan view



Cross section

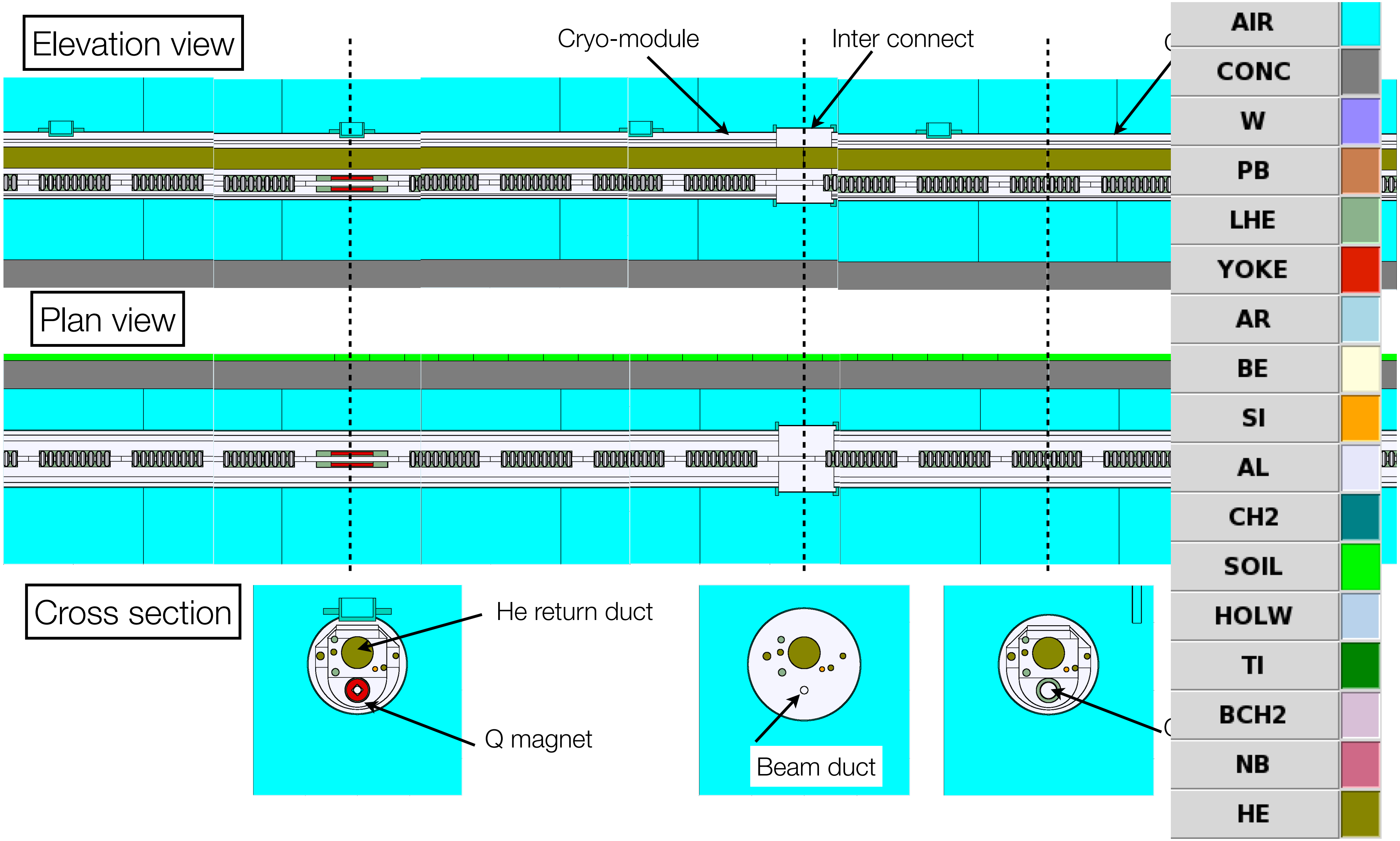


ML -Simulation model

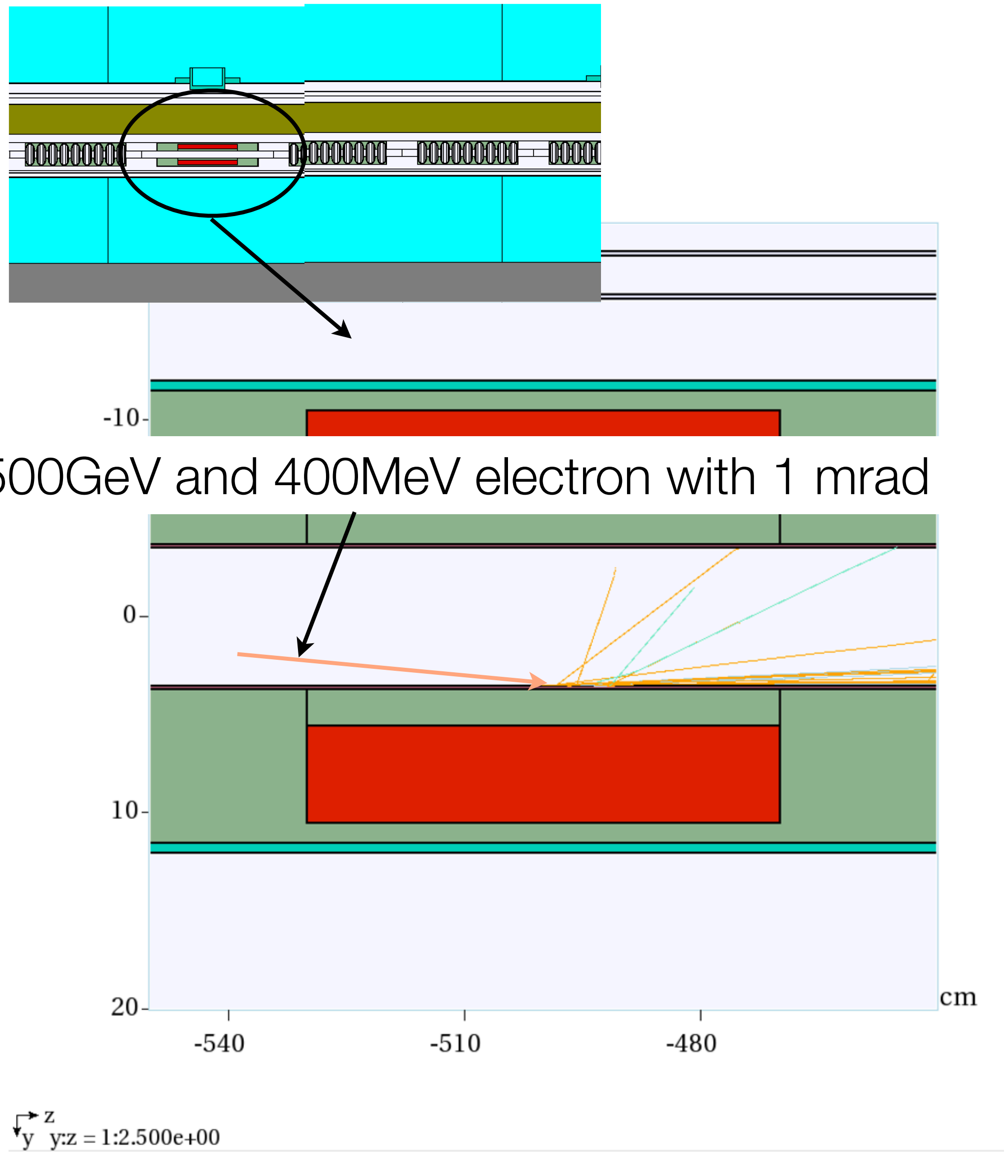


AIR
CONC
W
PB
LHE
YOKE
AR
BE
SI
AL
CH2
SOIL
HOLW
TI
BCH2
NB
HE

ML -Simulation model

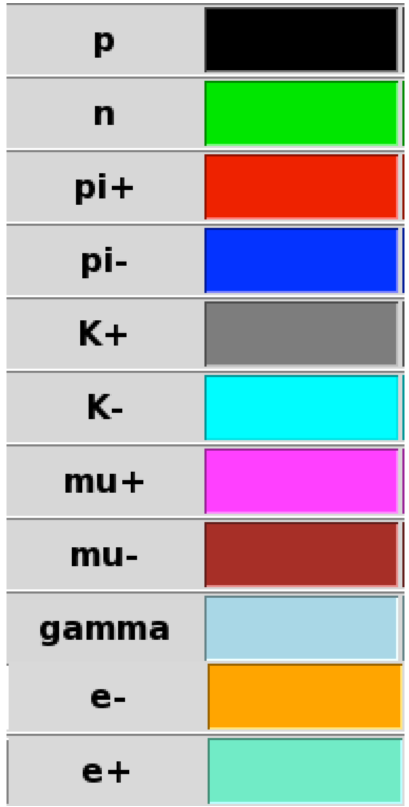


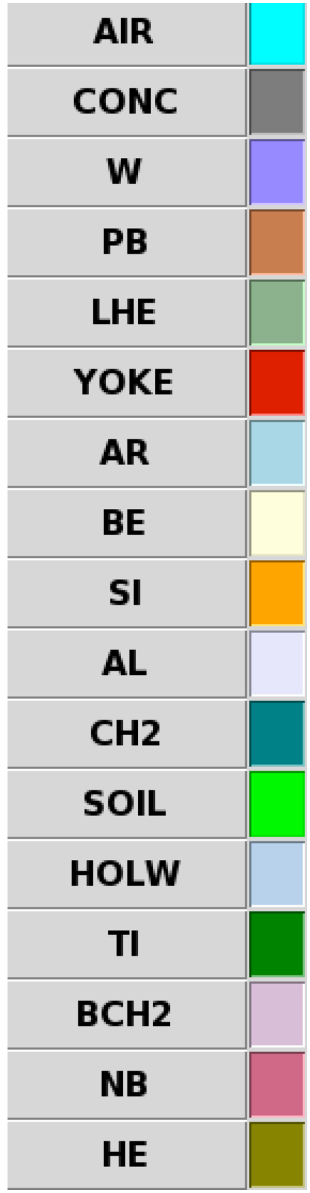
ML - Simulation beam loss



500GeV and 400MeV electron with 1 mrad

400MeV 1mrad on beam pipe of Q-magnet



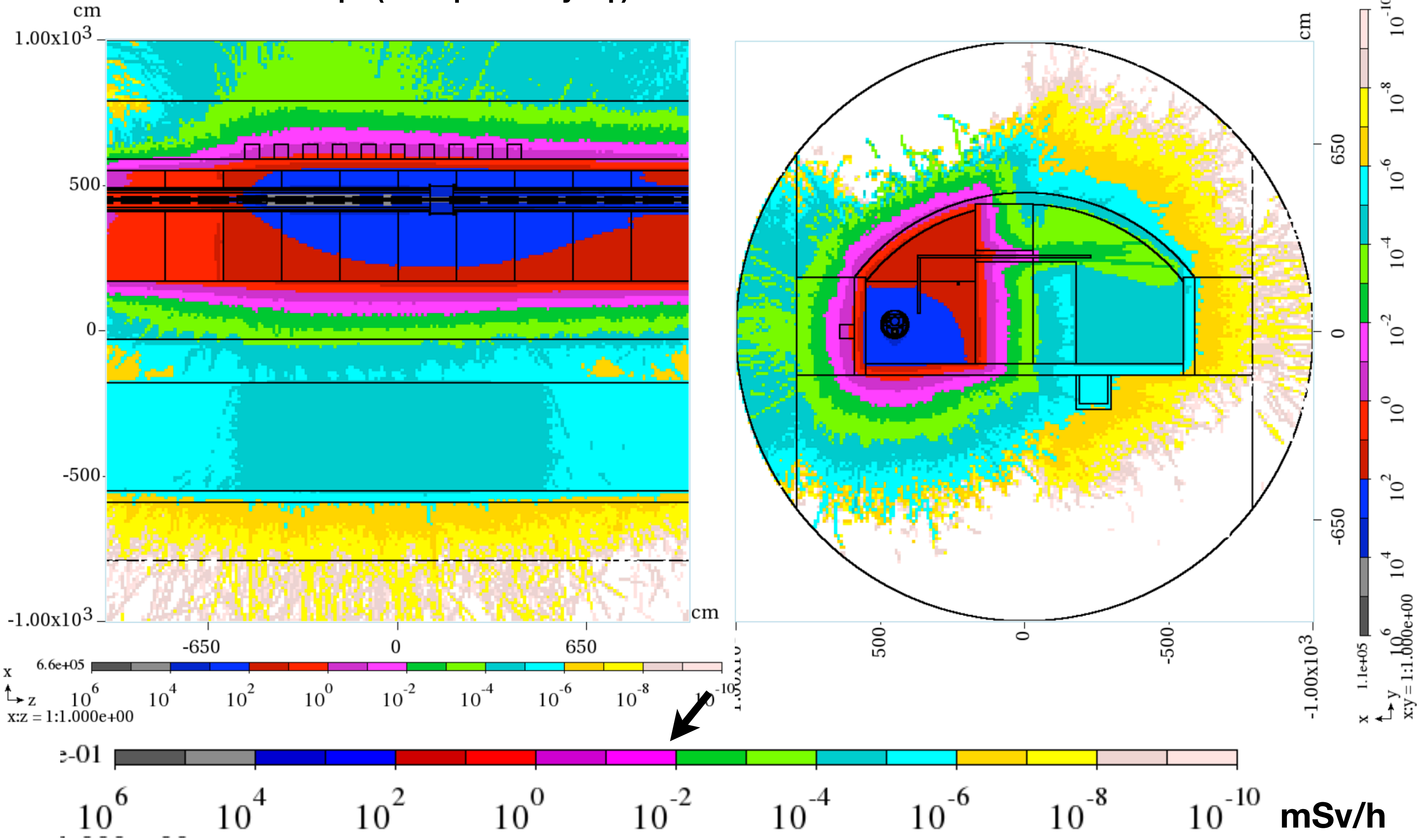


Japanese law

- Limit for personal
  - Radiation worker : 100 mSv / 5 years, 50 mSv / year 20 mSv/year
- Ambient dose limit
  - Radiation controlled area (accessible) : less than 1 mSv/week ∼25 μSv/h
  - Boundary at radiation controlled area : less than 1.3 mSv / 3 month ∼2.6 μSv/h
  - Site boundary : 250 μSv/ 3 month ∼0.1 μSv/h
    - Operation hours should be taken into account
- Activity in tunnel air, Activity in released air, Activity in drain water
  - Defined for each nuclide and chemical form

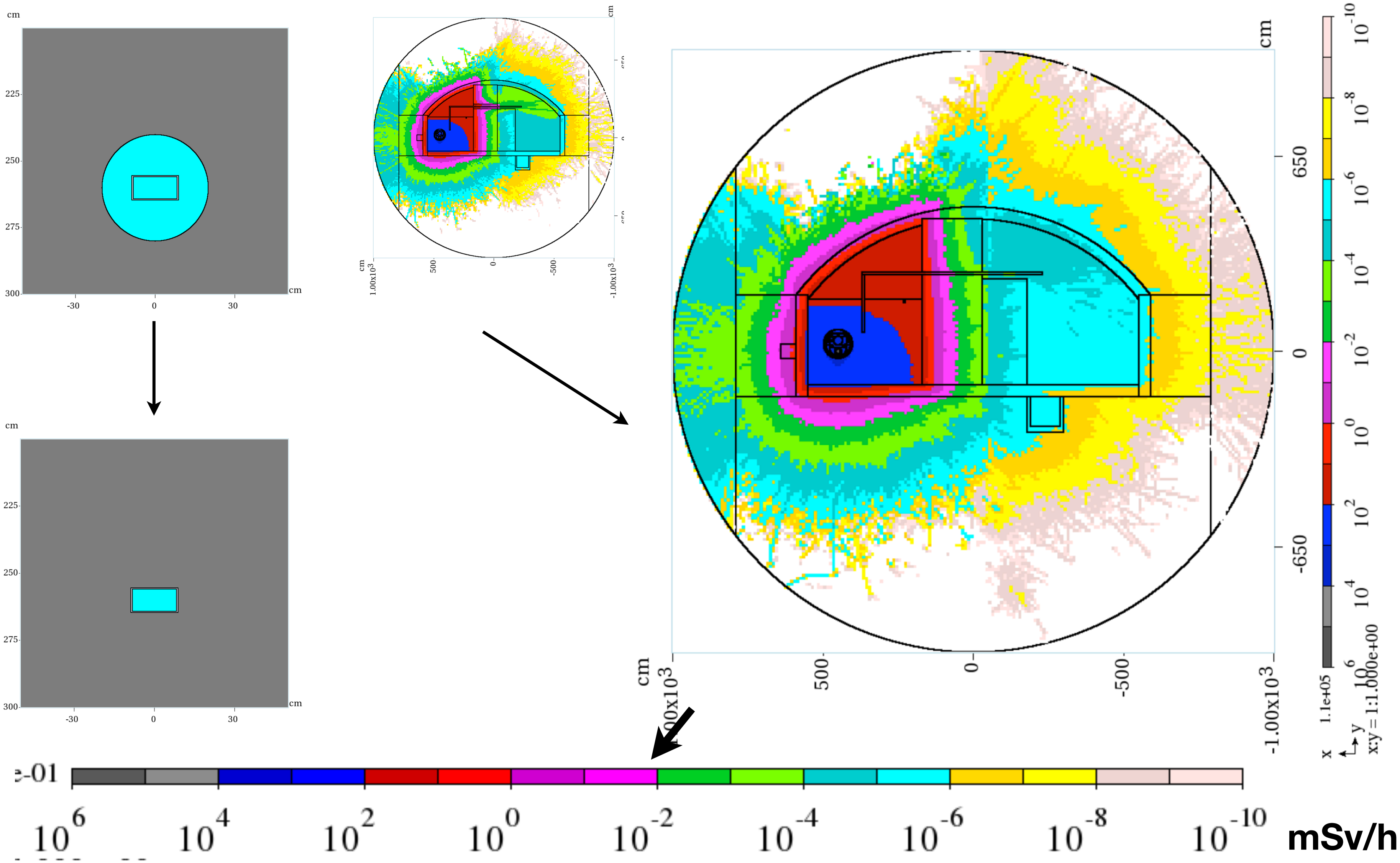
ML - Result

Normal loss : 6.875e10eps (50nA per cavity eq.) due to dark current



ML - Result (Close wave guide hole)

Normal loss : 6.875e10eps (50nA per cavity eq.) due to dark current



ML - Tritium in liquid helium

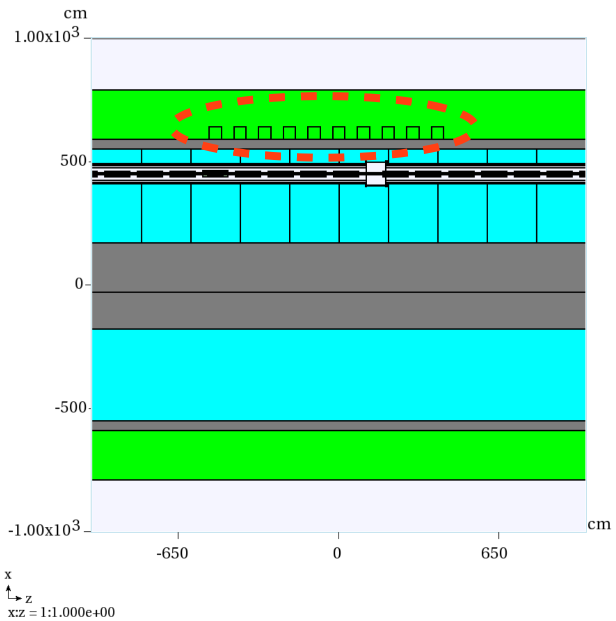
- **After 4000 hours full power operation**

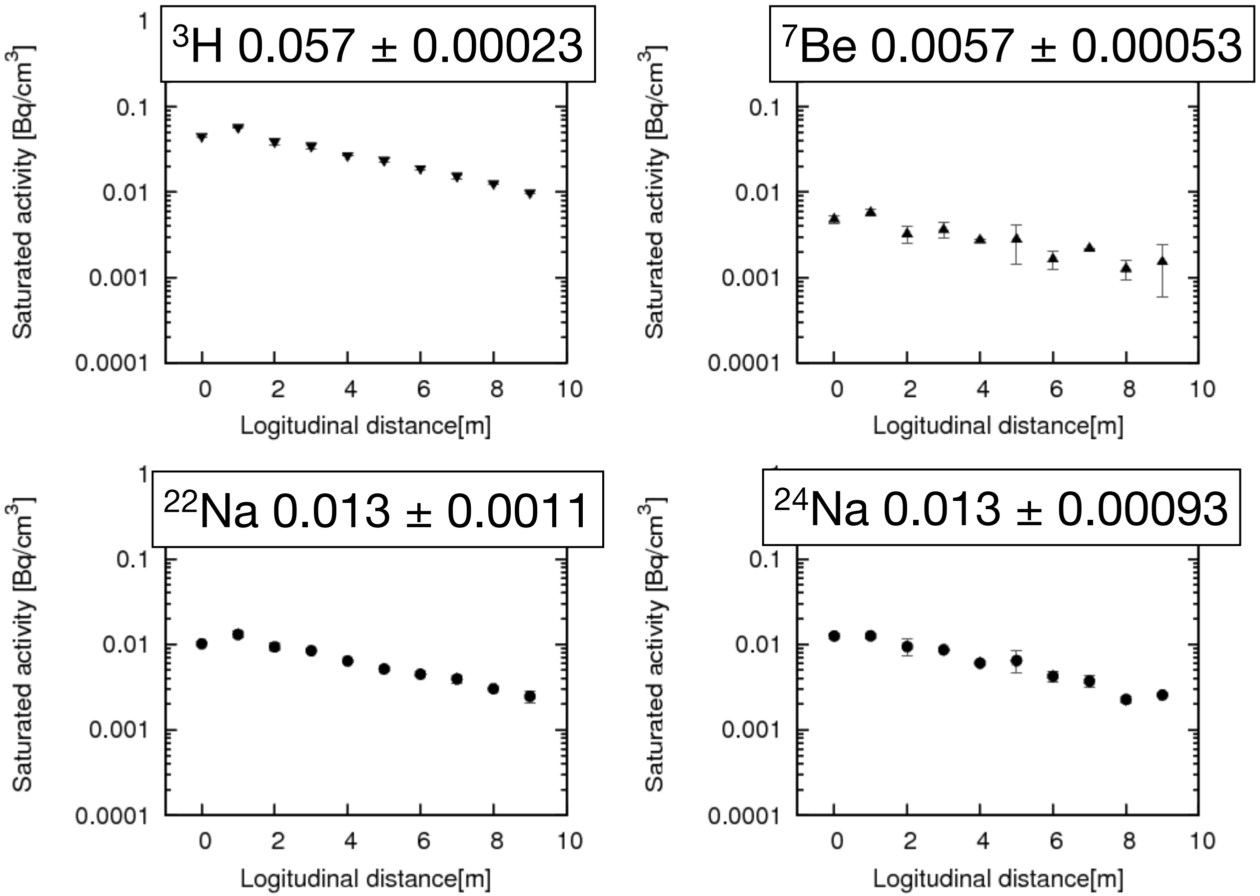
Nuclide	Saturated activity	Half life	Operation time	Activity after operation
^3H	Bq/cm^3	hours	hours	Bq/cm^3
MARS	1.93E+00	1.08E+05	4.00E+03	4.89E-02
Empirical eq.	9.65E+00	1.08E+05	4.00E+03	2.45E-01

- **Estimate concentration with assuming the amount of leakage to tunnel. It should be less than limit of air.**
- **Taking into account dilution if the tritium is released as air. It's concentration should be less than the limit.**
- **Taking into account dilution if the tritium is released as drainage. It's concentration should be less than the limit.**

^3H	Lower limit / content	Limit in air	Released air	Release water
HT gas	1×10^9 Bq 1×10^6 Bq/g	1×10^4 Bq/cm^3	7×10^1 Bq/cm^3	
HTO water		8×10^{-1} Bq/cm^3	5×10^{-3} Bq/cm^3	6×10^1 Bq/cm^3

ML, RTML - Activity in soil





MARS default soil
Density 1.9 gcc
Atomic fraction H 0.31, O 0.49, Al 0.04, Si 0.16

ML, RTML - Activity in soil

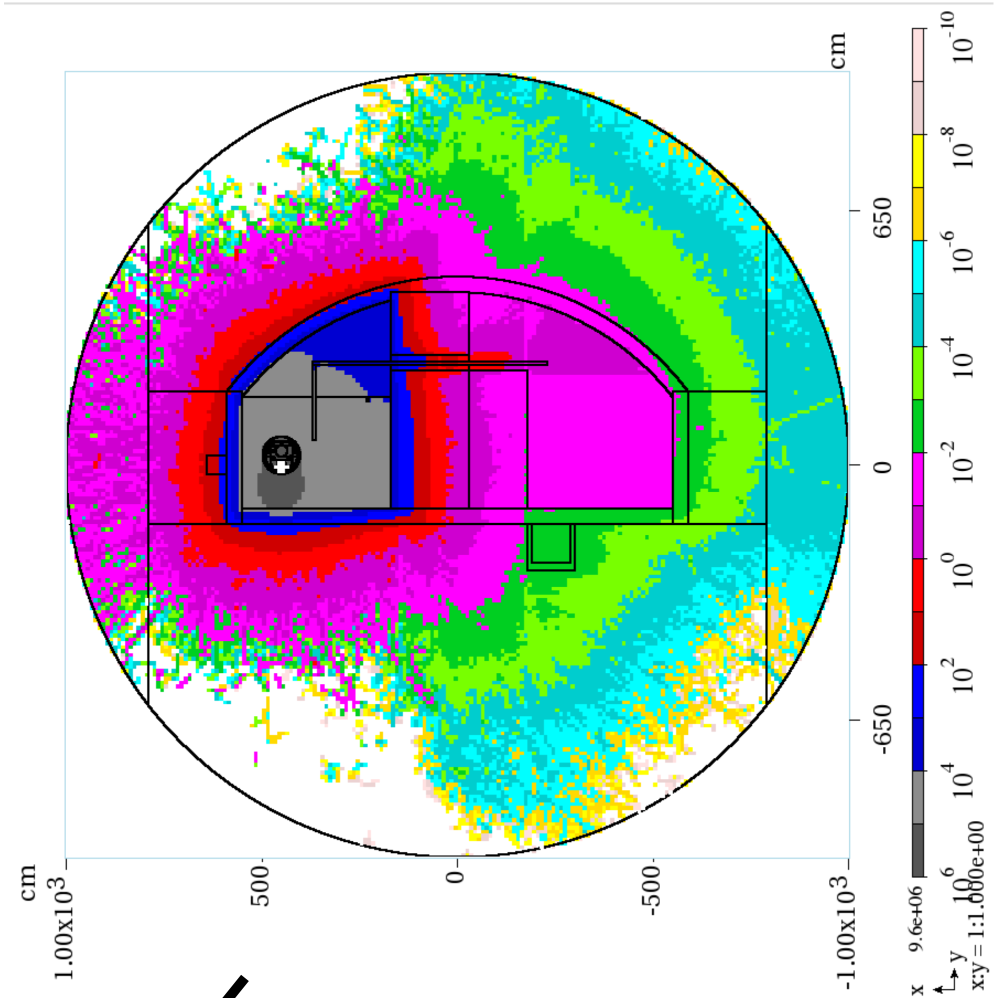
	Saturated activity	Half life	Operation time	Activity after operation
Nuclide	Bq/cm^3	hours	hours	Bq/g
^{3}H	5.70E-02	1.10E+05	4000	7.44E-04
^{7}Be	5.70E-03	1.28E+03	4000	2.66E-03
^{22}Na	1.30E-02	2.28E+04	4000	7.84E-04
^{24}Na	1.30E-02	1.50E+01	4000	6.84E-03

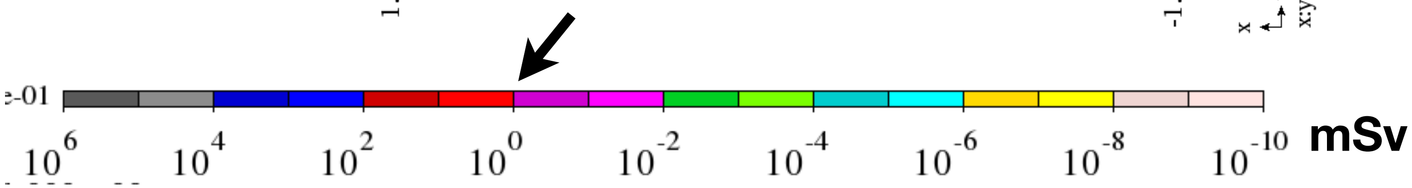
- **Soil activation →ground water activity**
- **For more precise estimation, we need real composition, density of the rock and ground water speed. Detailed inspection at the candidate site is preferable.**

	Lower limit of amount	Lower limit of concentration	Limit for drainage
^{3}H	$1x10^{9}$ Bq	$1x10^{6}$ Bq/g	$6x10^{1}$ Bq/cm^3
^{7}Be	$1x10^{7}$ Bq	$1x10^{3}$ Bq/g	$3x10^{1}$ Bq/cm^3
^{22}Na	$1x10^{6}$ Bq	$1x10^{1}$ Bq/g	$3x10^{-1}$ Bq/cm^3
^{24}Na	$1x10^{5}$ Bq	$1x10^{1}$ Bq/g	$2x10^{0}$ Bq/cm^3

ML - dose rate at system failure

- (assumption) entire 1 pulse train beam is lost at one point. Operation is stopped for a while. This kind of accident would be happened at the rate of less than one time per year.
- Integrated dose for single 500 GeV 4.26e13 electron loss
- Failure mode and it's effect are under consideration by ADI team

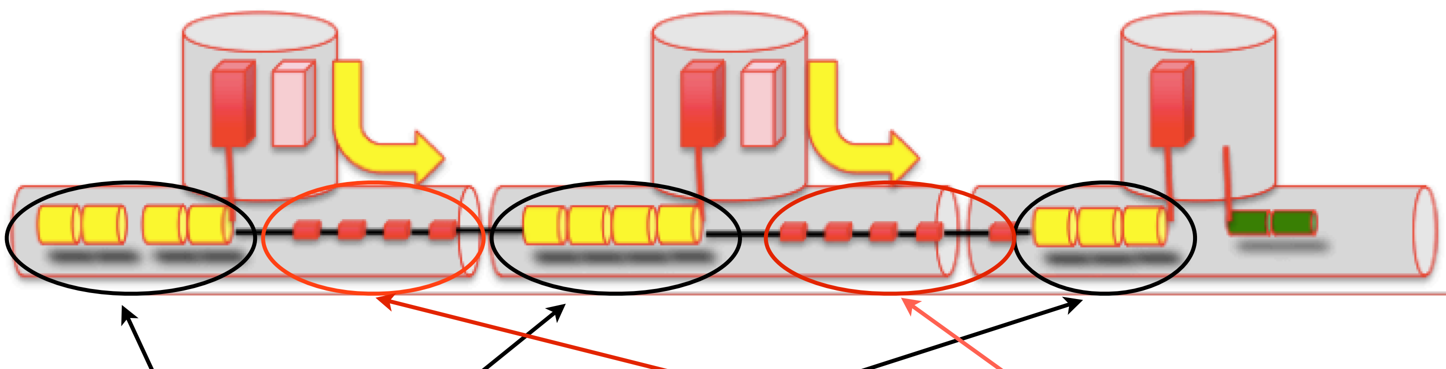




Remarks for ML Shielding design

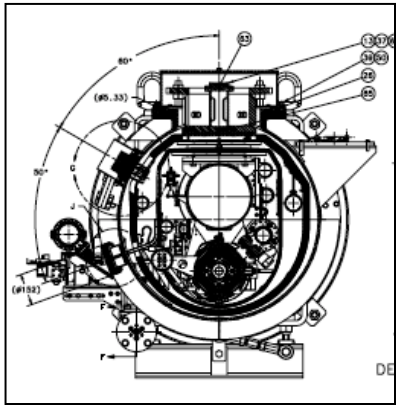
- Main Linac tunnel accommodate not only Main Linac
  - RTML with several collimators
  - Beam dumps for RTML tune up and for ML emergency pathway
- Air of downstream sections may flow into the Main Linac tunnel
  - BDS: 8 kW collimator, two full beam dump, 45 kW dump line loss
  - e+ TGT: 54.7 kW (350 GeV), 41.7 kW(500 GeV) on TGT, 9 dumps, 16 collimators
  - e- src: 1.6 kW collimator, 311 kW dump, 11.3 kW dump
- Beam loss at transition phase
  - Beam loss and failure scenario for tentative beam lines
  - 250 GeV, 350 GeV are 500 GeV configurations are tentative setup for 1TeV?

Energy upgrade scenario



Scenario C:
Fill from Shafts

- OK for beam dynamics
- No helium transfer line
- Spare cryo capacities



These sections are filled with well-known cryo-modules with fully equipped beam termination devices, failure scenario is under developing

?

These sections are filled with something. How long period dose it exist? Do we need to take into account beam loss and failure mode in these section for ML shielding design?

Status of each sections

	Beam loss	Beam line device	Tunnel structure	Dose rate	Induced activity
e- src	△	△	△	△	△
e+ src	○	△	△	×	△
DR	Failure mode?	△	×	×	Not necessary ?
RTML	△	×	△	△	Not necessary ?
ML	○	○	○	○	○
BDS	○	△	△	△	×
Detector hall	Normal loss?	○	○	△	Not necessary
Beam dump	○	○	△	△	△

×: No information, △: Modeled, ○: Evaluated, ◎:Finalized

Adapting to upgrade scenario

- According to staging scenario, ILC will start with low power
  - 250 GeV-2.6 MW, 350 GeV-3.7 MW, 500 GeV-5.3 MW, 500 GeV(LU)-10.5 MW, 1 TeV-13.6 MW (Tbl.8.2)
- Until now tunnel and shielding should be designed for 1 TeV
- Before operation, conservative assumptions are employed
- After operation, adequate assumptions becomes obvious
  - failure rate and scenario, credibility of devices (beam abort system, beam containment system, beam loss monitors, quench detection system, the other devices which consist of MPS and PPS), amount and distribution of actual beam loss, operation procedure(beam tuning and recovery time), unknown factors to introduce failure mode, actual operation time per year, occupancy time of service tunnel, for example.
- The information will helps a lot to improve not only reliability of devices but also accelerator operation itself. These facts would be reflected to radiation shielding strategy.

Summary

- Summary
  - Main Linac shielding design is in progress
  - Impact on dose and induced activities due to dark current and full beam loss
  - Normalization based on evaluated beam loss scenario is still required
  - Contribution form other sections, temporally devices should be taken into account
- In future
  - Develop radiation shielding strategy for whole ILC facility