

MARS14 Collimation and Shielding Studies for the 3 GeV Ring of J-PARC Project

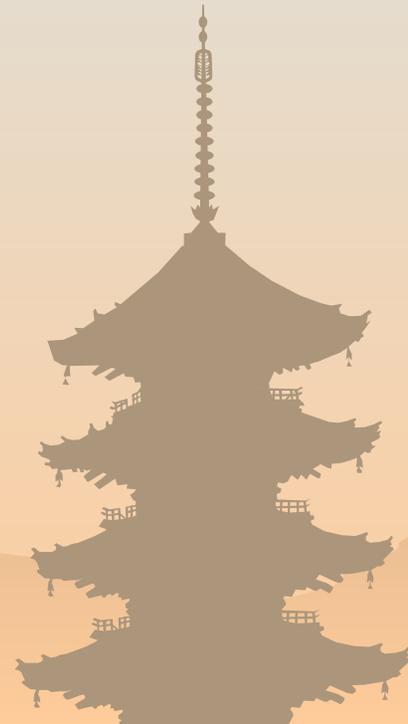
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Kazami Yamamoto (JAERI)

Yoshiro Irie (KEK)

Alexander Drozhdin (FNAL)



Background and Purpose

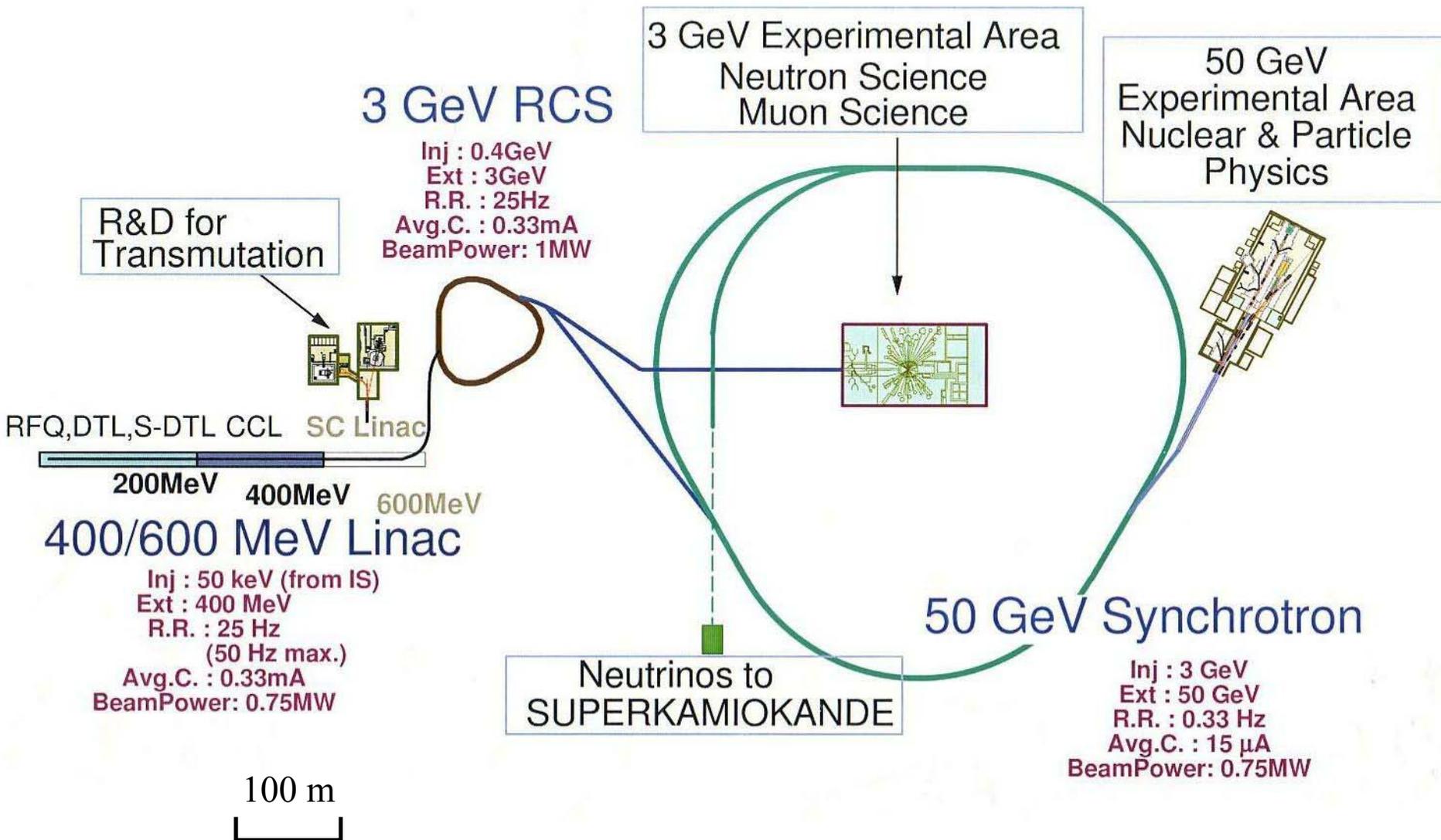
- ◆ J-PARC Project -- MW proton accelerator with **kW beam loss**
Serious problem for **neutron penetration, activation, damage**
Very thick shielding along beam line → High cost
↓
Effective shielding design for reducing construction cost
Residual activity estimation for beam line maintenance
- ◆ Empirical formula (Moyer model) is not appropriate for
 - **Distributed beam loss**
 - **Forward shield**
 - **Complicated target structure**→ Hadron cascade Monte Carlo simulation by MARS14 code
- ◆ Deep penetration problem in Monte Carlo simulation
statistical accuracy for 10 order attenuation through shield

Topics

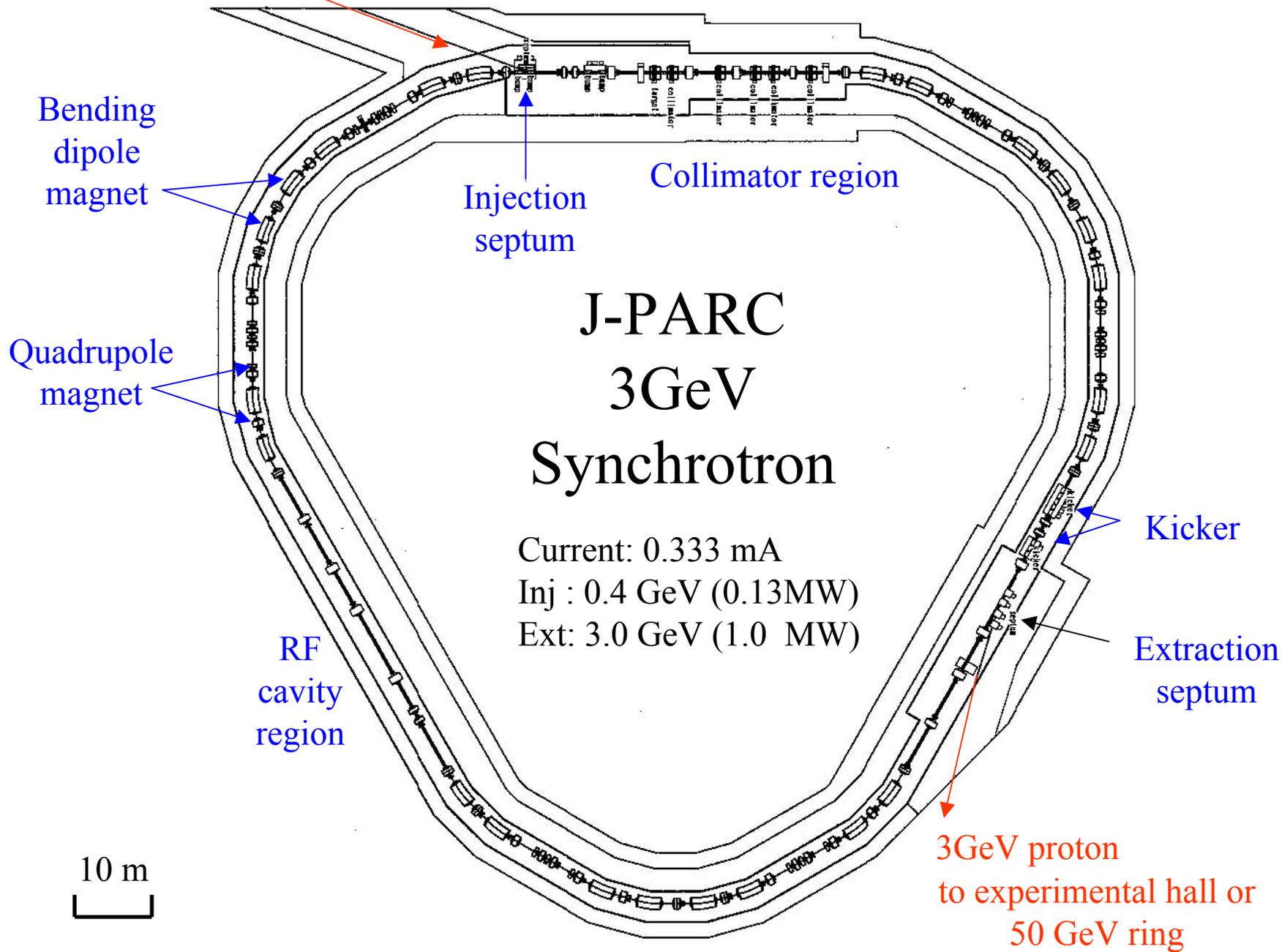
MARS14

- ◆ Shielding & Residual dose rate estimation
- ◆ Distributed beam loss
using **STRUCT-MARS connection**
- ◆ Whole ring and beam line module
using **MAD-MARS beam line builder**
- ◆ Deep penetration calculation
using **3-dimensional multi layer technique**

J-PARC Project



400MeV proton from linac



Beam Loss & Radiation Transport

Beam Loss Distribution at 3 GeV ring

- ▶ Injection
400 MeV–1kW at septum
- ▶ Extraction
3 GeV–1kW at septum
- ▶ Collimator region
STRUCT simulation
(Multi-turn tracking Monte Carlo code)
400 MeV–4kW distributed beam loss



MARS14 simulation

**Hadron cascade &
Radiation transport calculation**

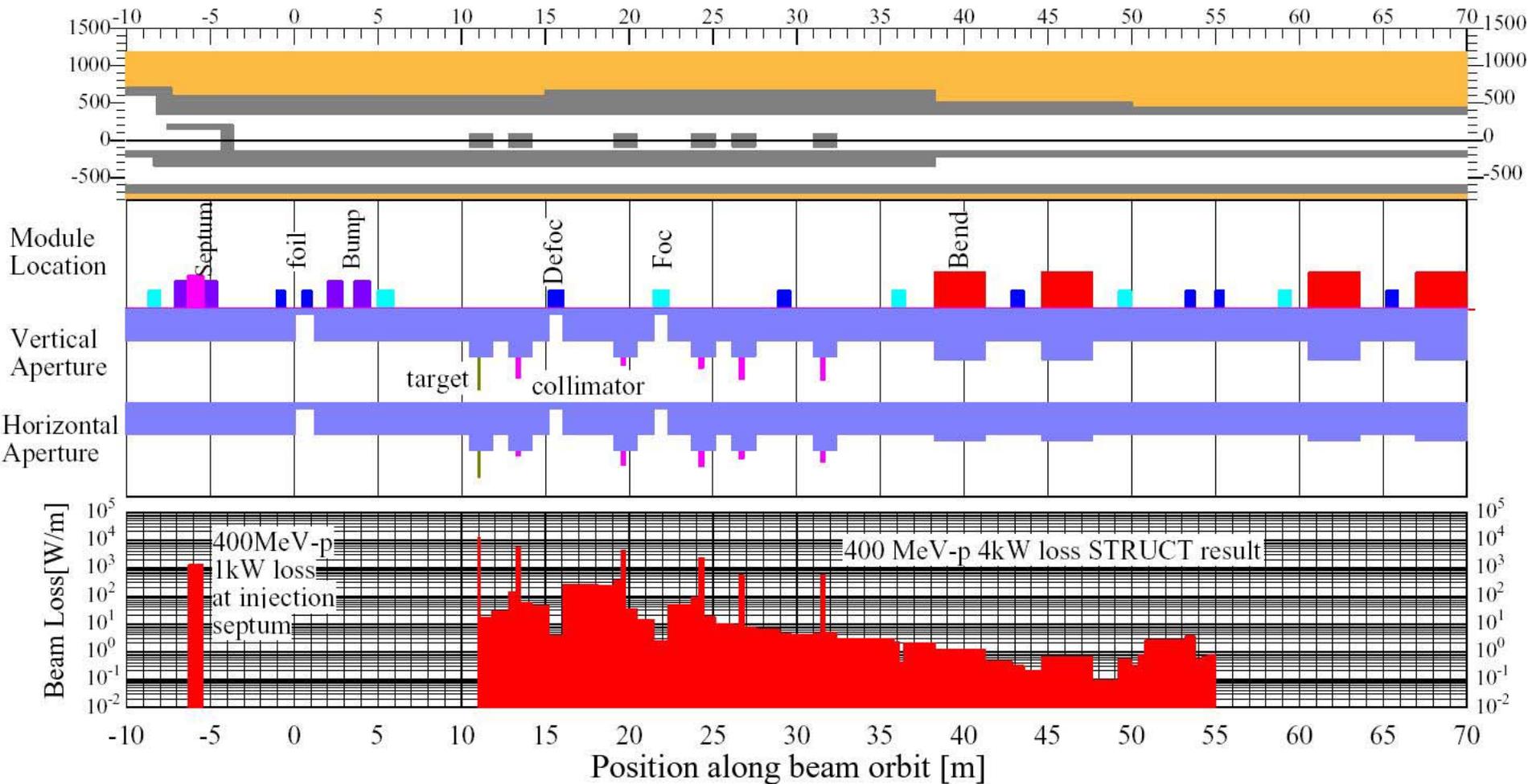
Shielding

Prompt Dose in operation

Residual Dose

Absorbed Dose

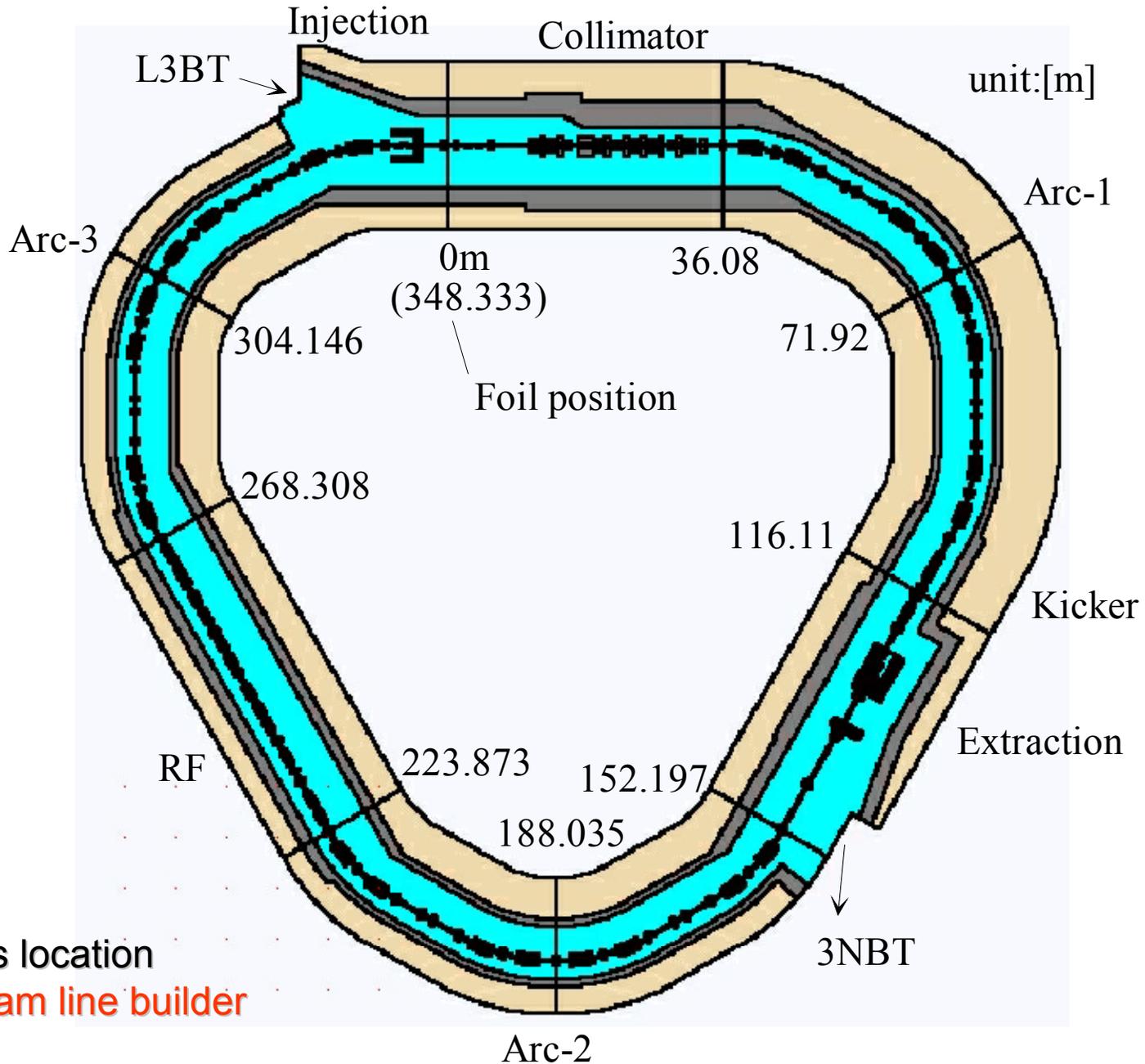
Beam line structure & Beam loss distribution (INJECTION)



MARS14 calculation

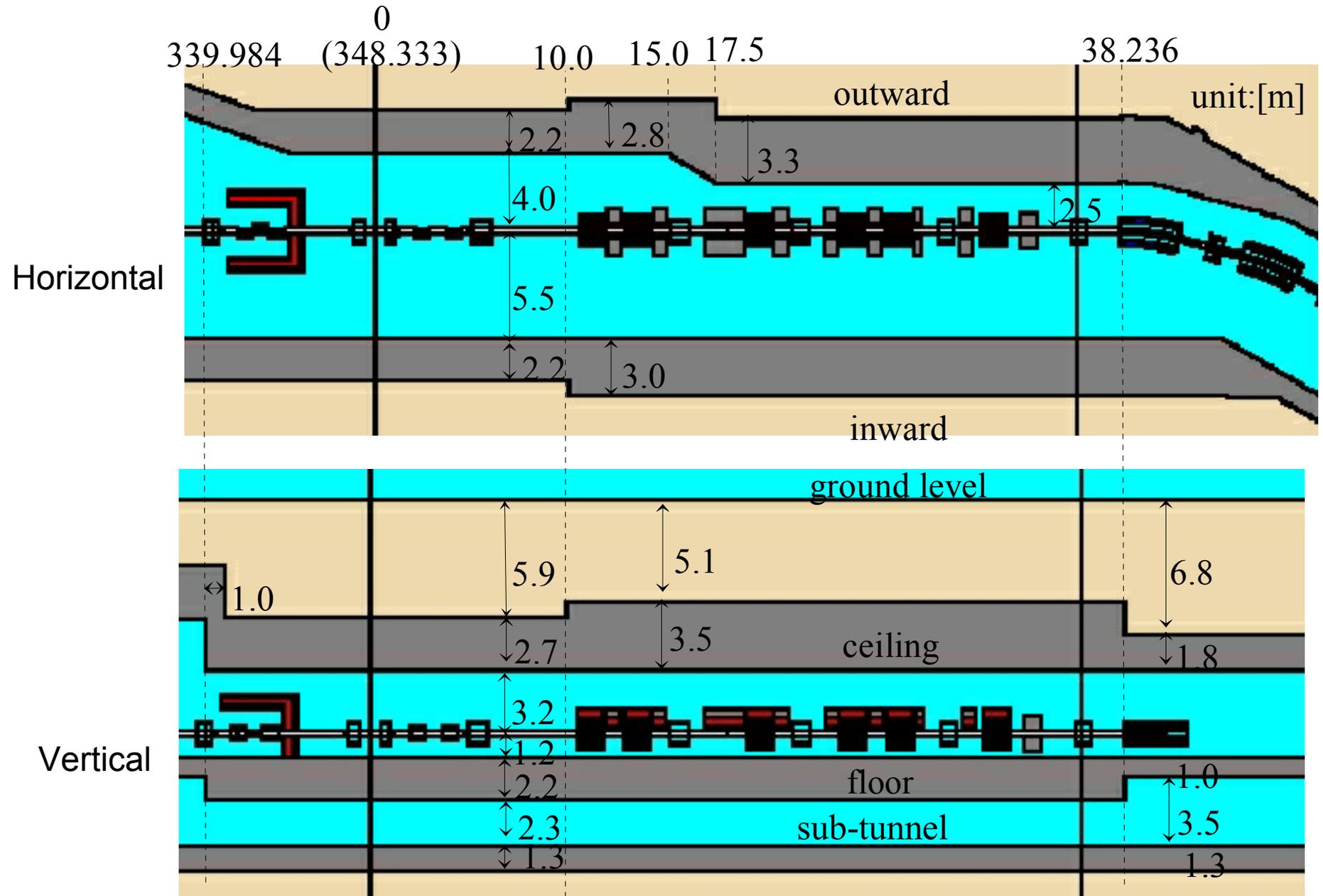
- Source → Proton beam loss distribution
- Geometry
 - Beam line modules (duct, magnet, collimator, etc.)
 - MAD-MARS beam line builder** → Describe module location
 - Shield – concrete (max 4.5m thickness),
soil (beam line; 11.8m below ground level)
- Magnetic field
- **3-dimensional multi-layer calculation** for deep penetration
- Estimation
 - Prompt dose rate in operation → Shield thickness
 - Residual dose rate → Exposure of worker
 - Absorbed dose → Radiation damage of material

MARS calculation geometry

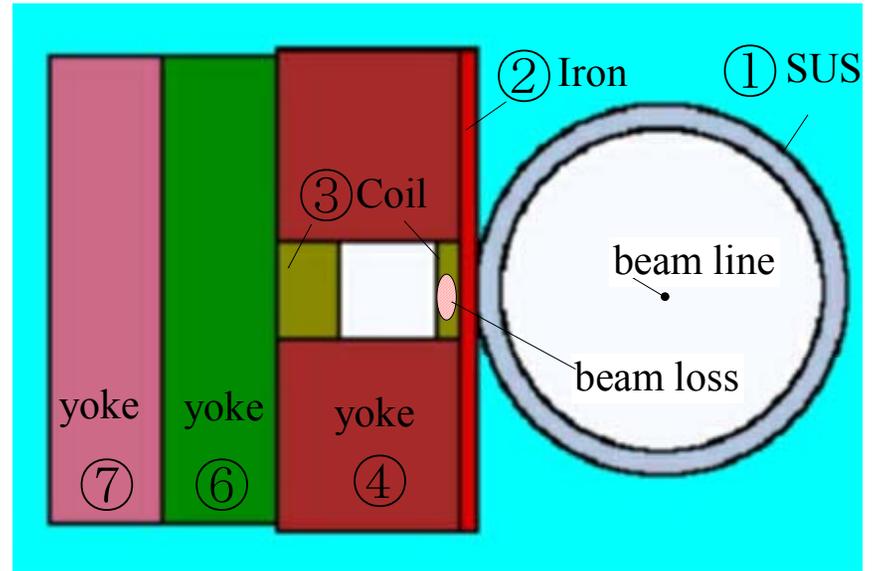
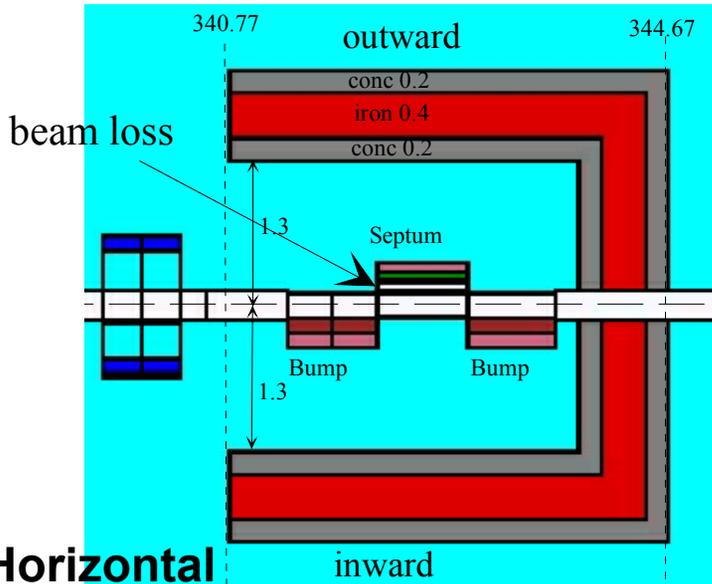


Beam line modules location
→ MAD-MARS beam line builder

Tunnel Cross Section at Injection and Collimator Region



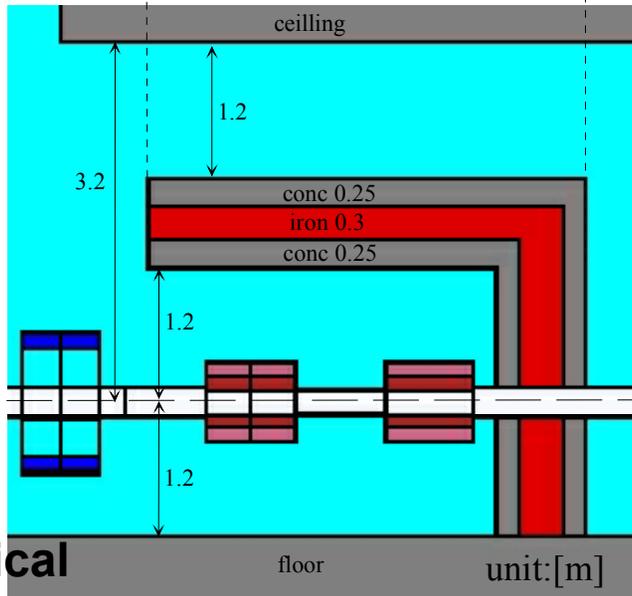
Beam loss at injection septum



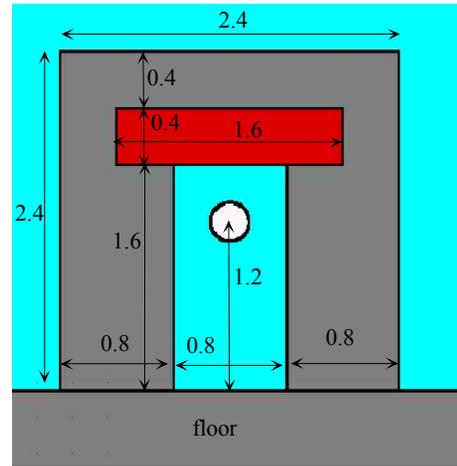
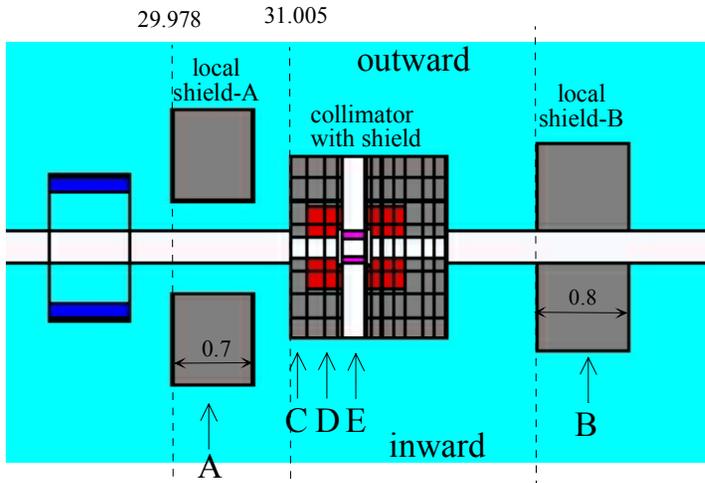
outward

inward

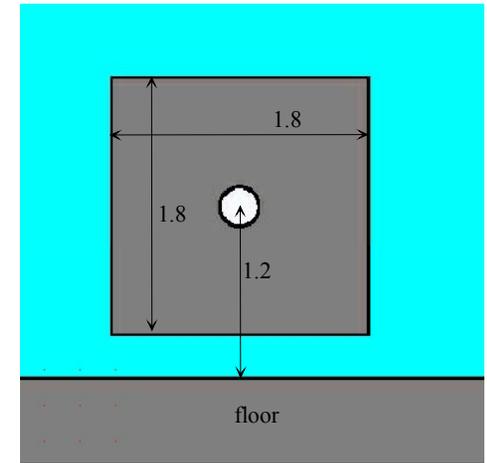
Injection septum



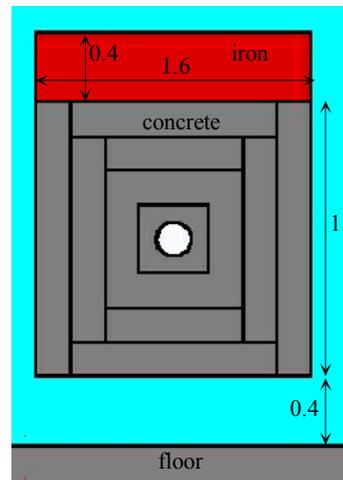
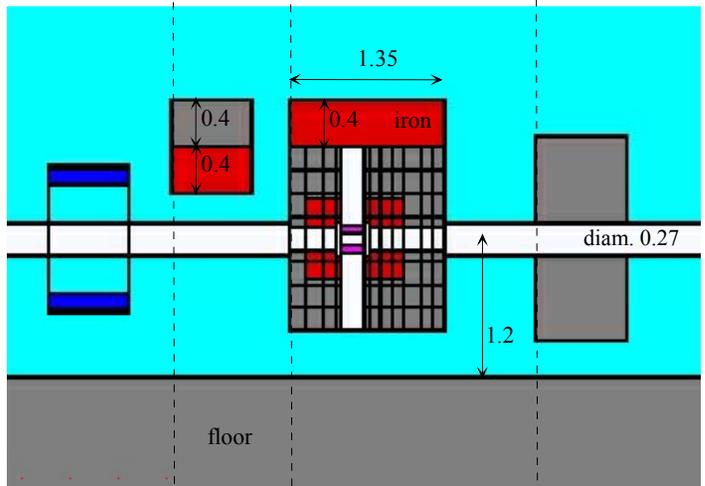
Local Shield at Collimator Region



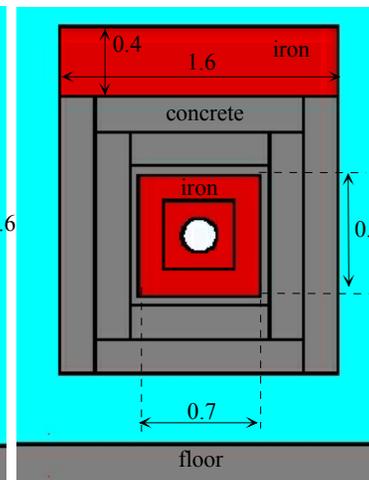
Local shield-A



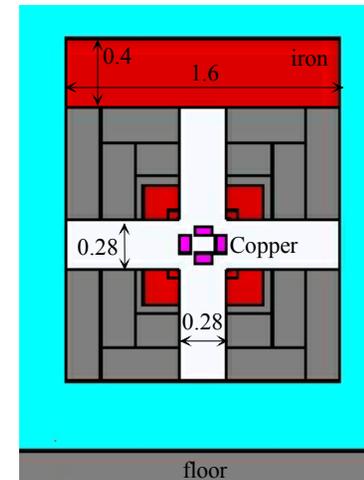
Local shield-B



C $z=0-0.15$
 $z=1.0-1.35$



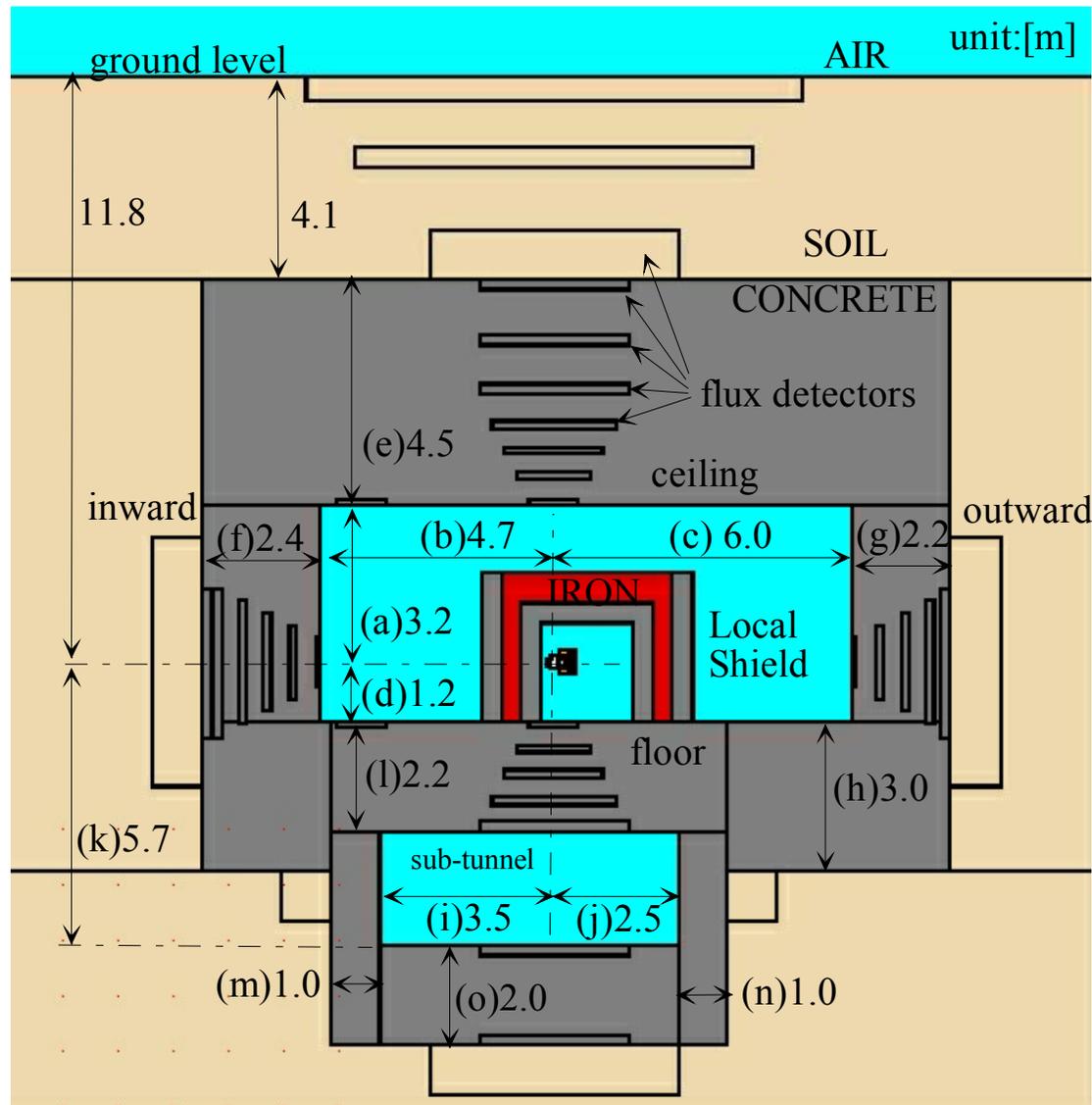
D $z=0.15-0.45$
 $z=0.65-1.00$



E $z=0.45-0.65$

collimator with shield

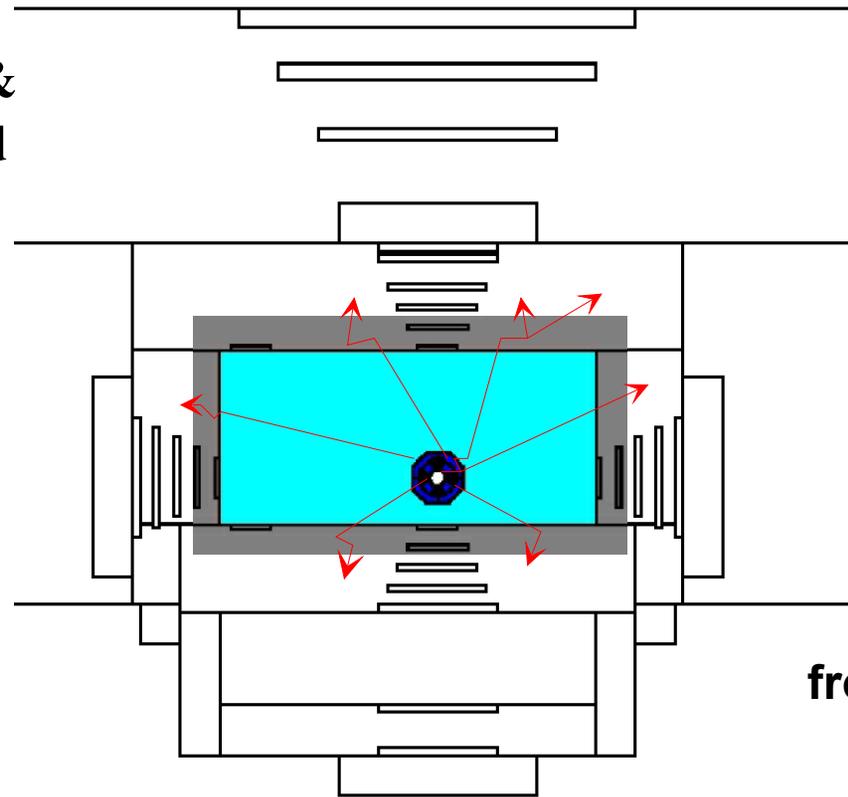
Flux estimation cells for MARS14 calculation



3 dimensional multi layer calculation for deep penetration

1st layer

**Beam line module &
Tunnel inside shield**



**Store information of
the particles leaked
from geometry boundary
(x,y,z,dx,dy,dz,E,W)**

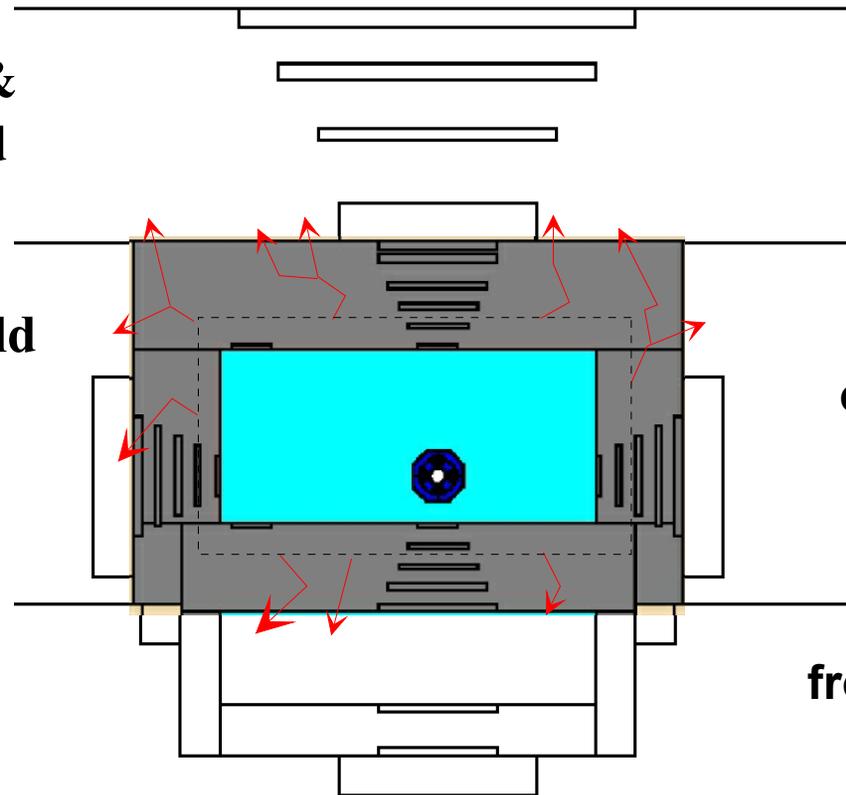
3 dimensional multi layer calculation for deep penetration

1st layer

Beam line module &
Tunnel inside shield

2nd layer

Tunnel outside shield



Leakage particles
of previous layer
are used as source
of 10 times multiplied
(splitting method)

Store information of
the particles leaked
from geometry boundary
(x,y,z,dx,dy,dz,E,W)

3 dimensional multi layer calculation for deep penetration

1st layer

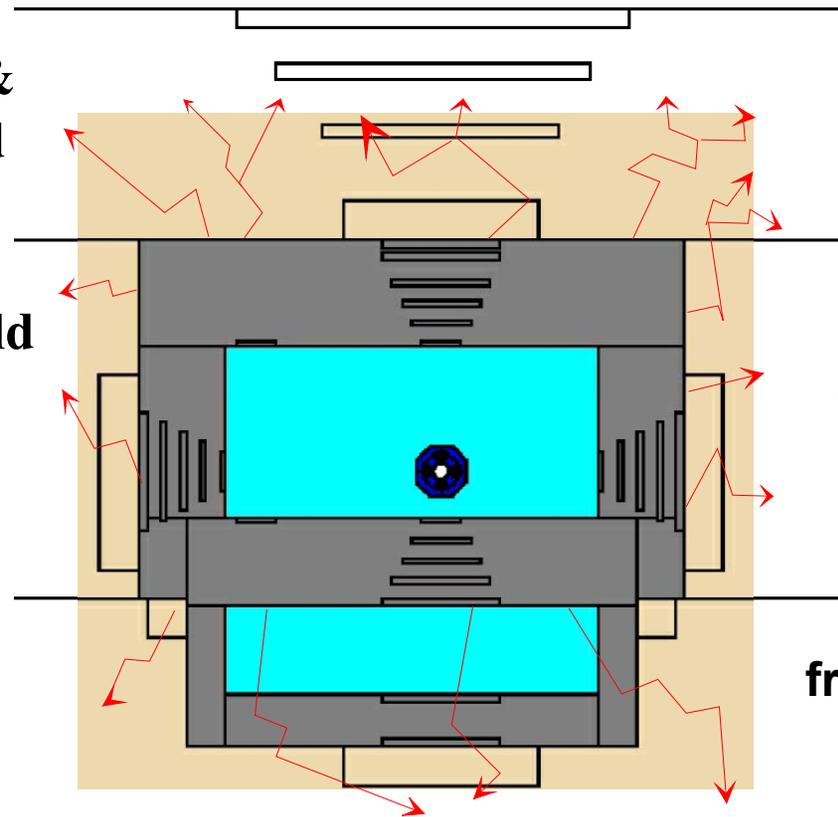
Beam line module &
Tunnel inside shield

2nd layer

Tunnel outside shield

3rd layer

Soil around tunnel



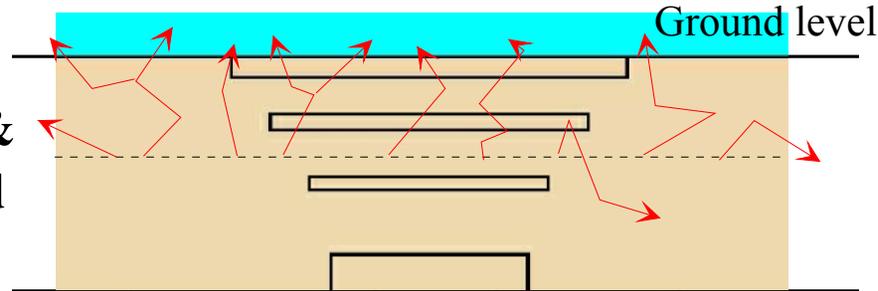
Leakage particles
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Store information of
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($x, y, z, dx, dy, dz, E, W$)

3 dimensional multi layer calculation for deep penetration

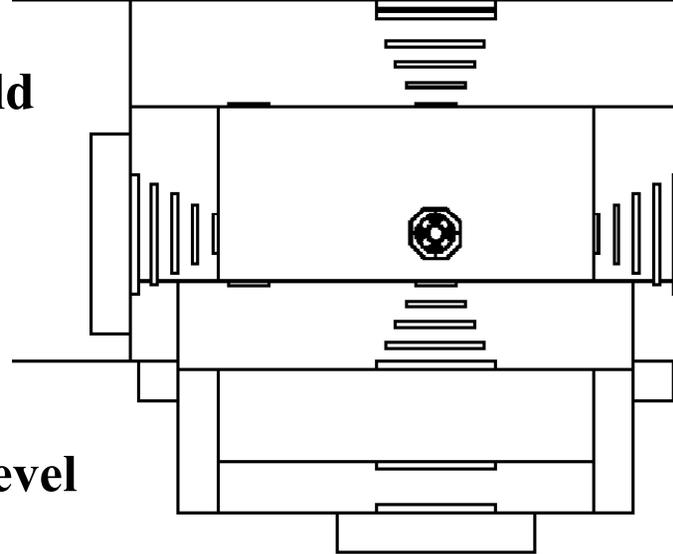
1st layer

**Beam line module &
Tunnel inside shield**



2nd layer

Tunnel outside shield



3rd layer

Soil around tunnel

Last layer

Soil below ground level

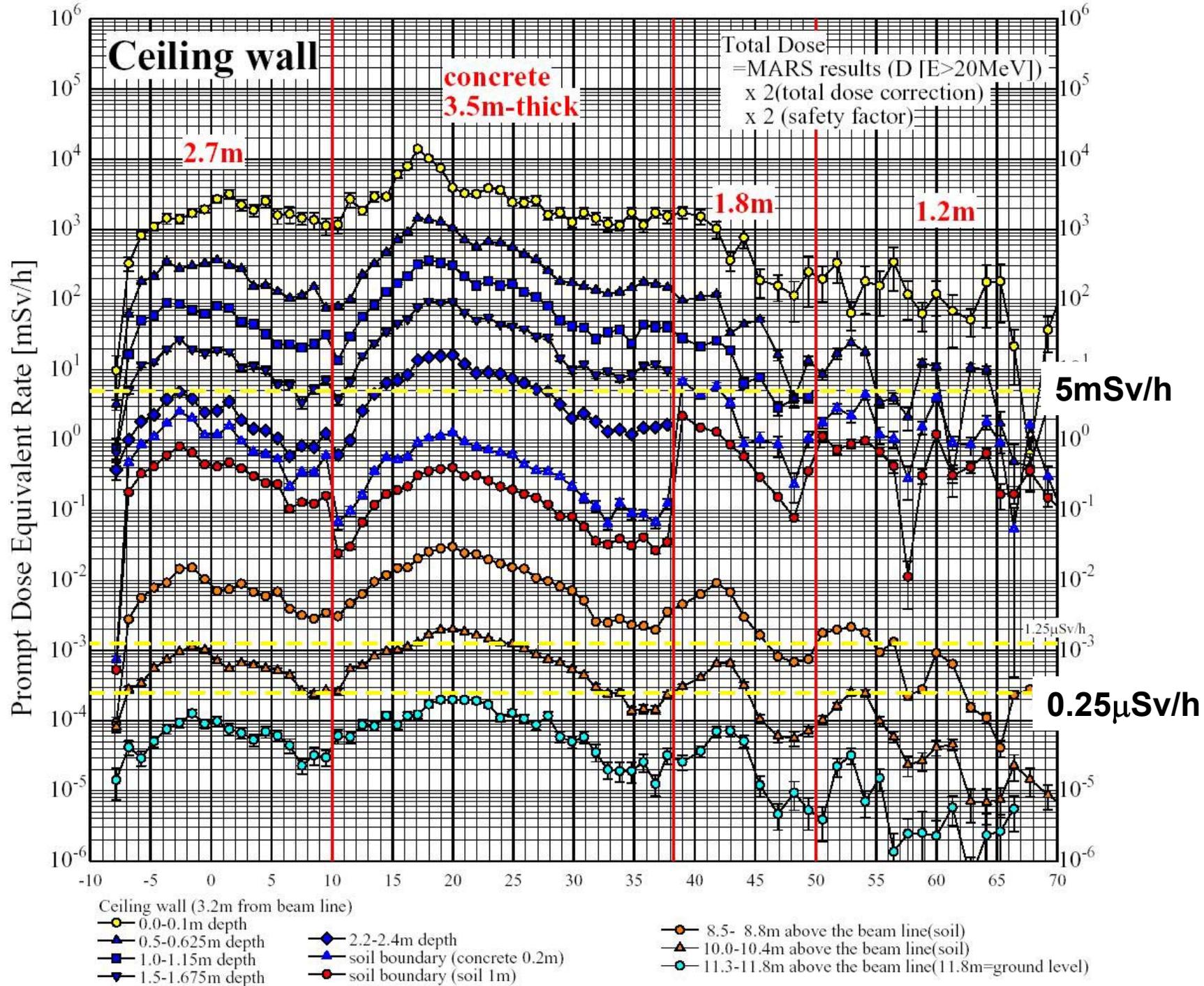
**Leakage particles
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**Store information of
the particles leaked
from geometry boundary
(x,y,z,dx,dy,dz,E,W)**

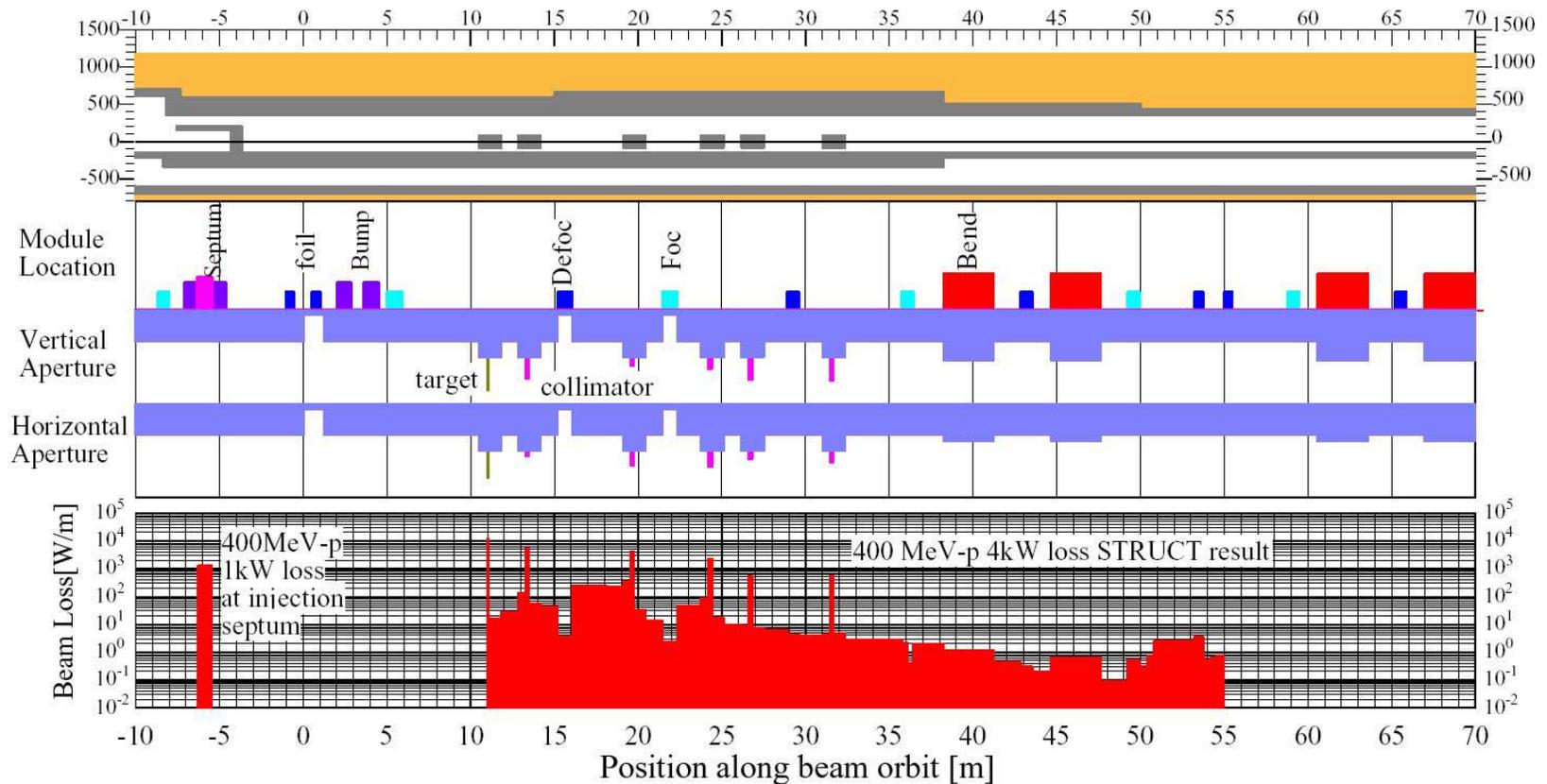
Design Standard of Dose Rate at J-PARC

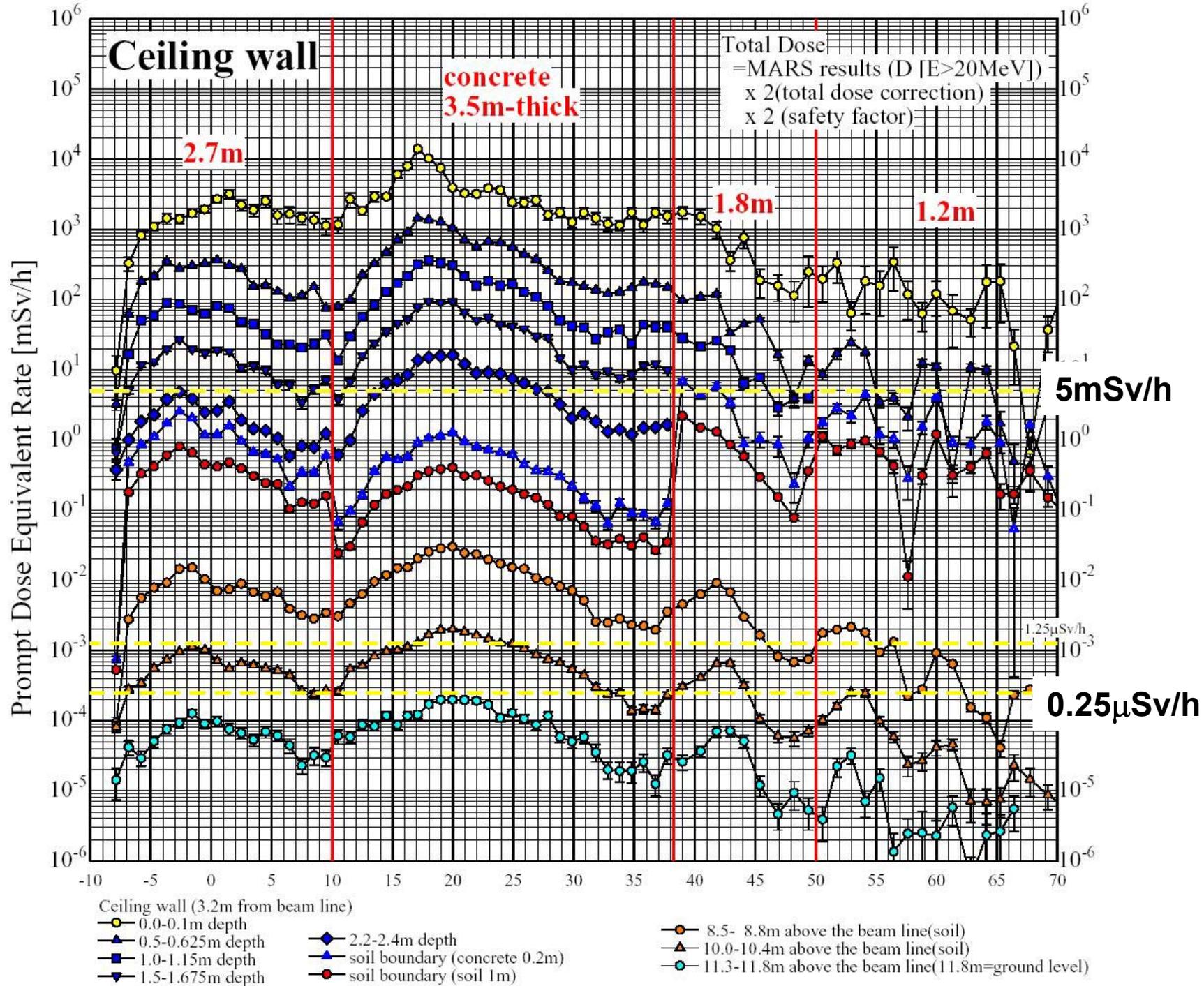
◆ Shield – Soil boundary $D \leq 5 \text{ mSv/h}$
(avoid ground water activation)

◆ Uncontrolled area $D \leq 0.25 \mu\text{Sv/h}$

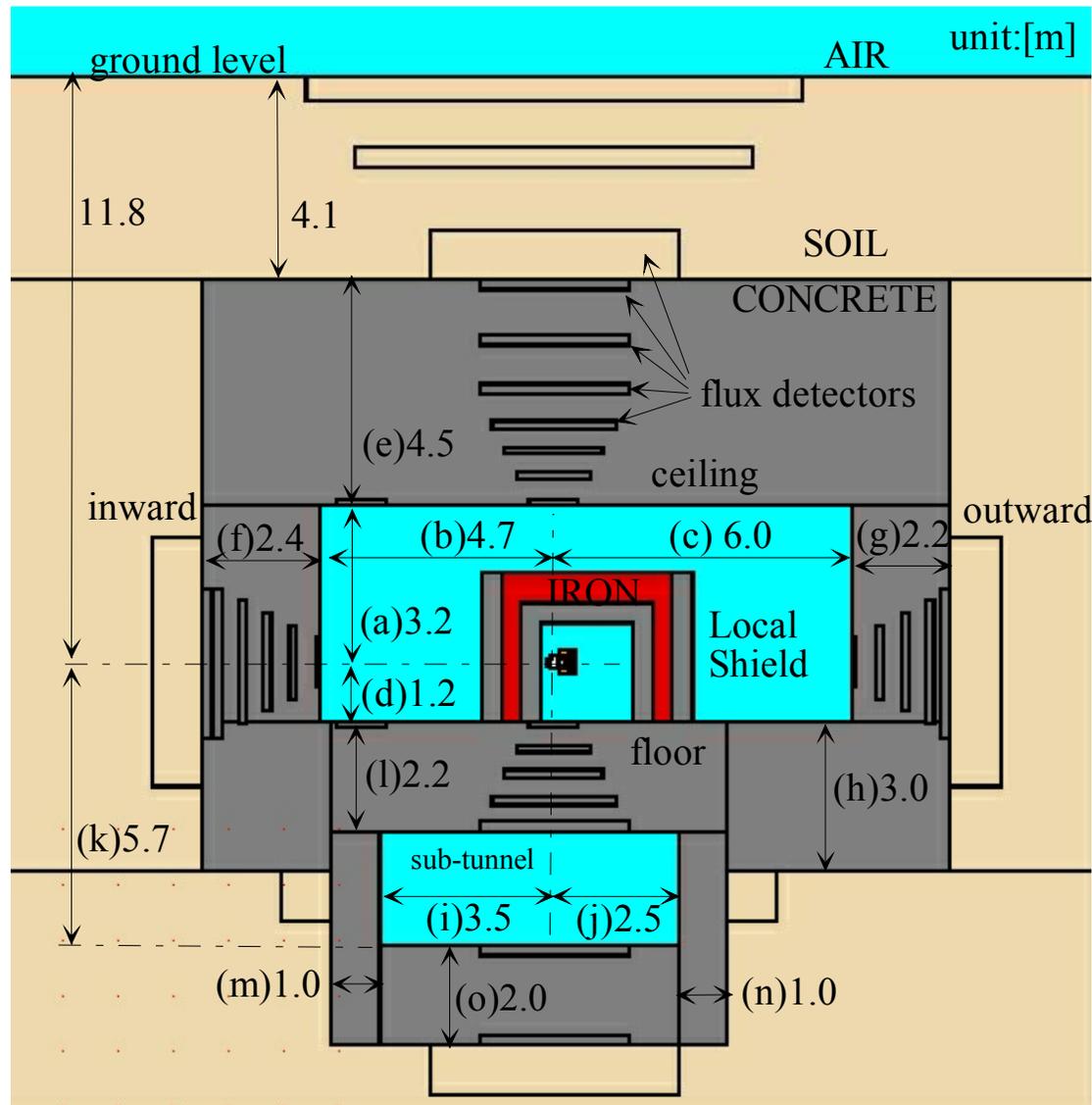


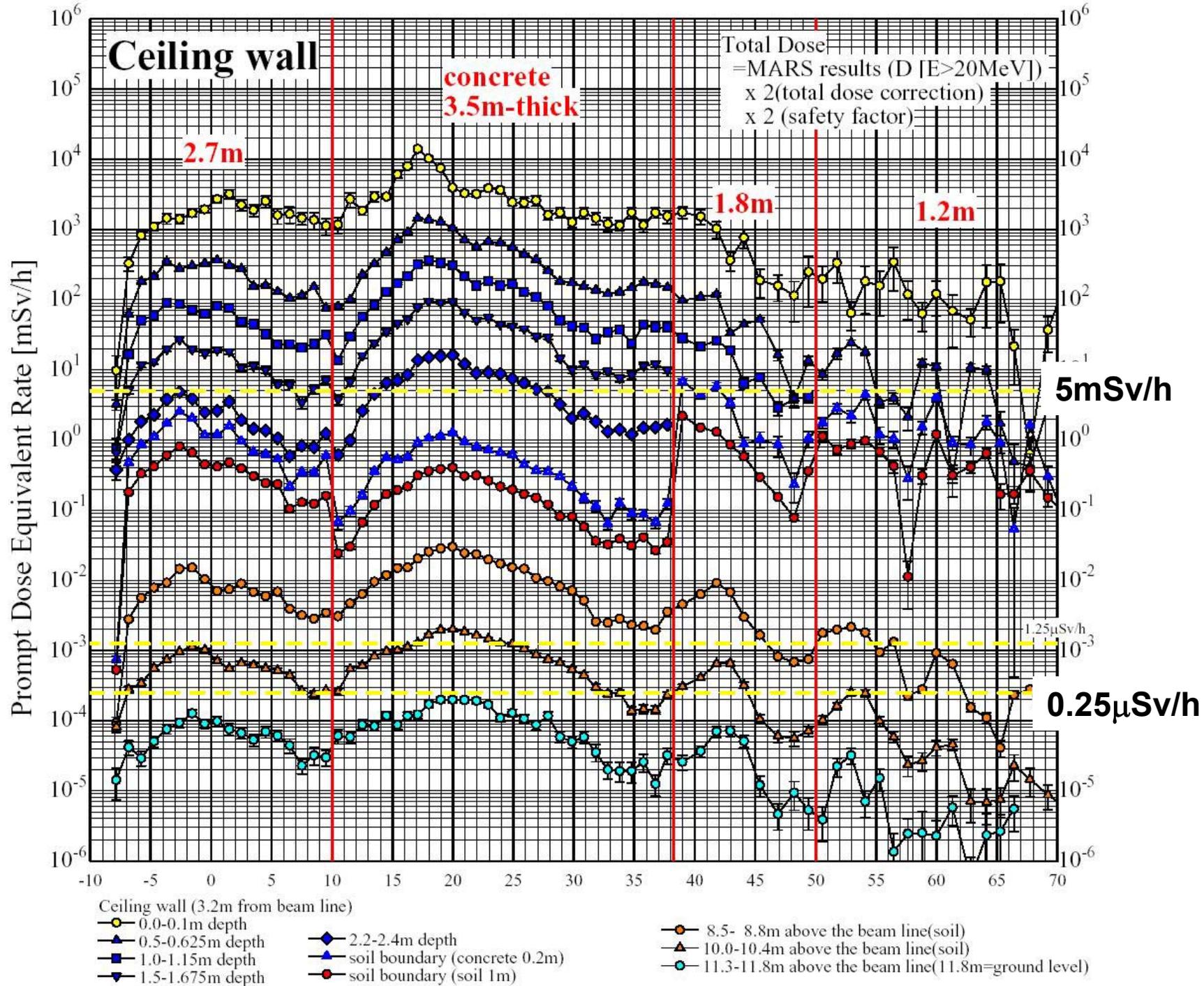
Beam line structure & Beam loss distribution (INJECTION)

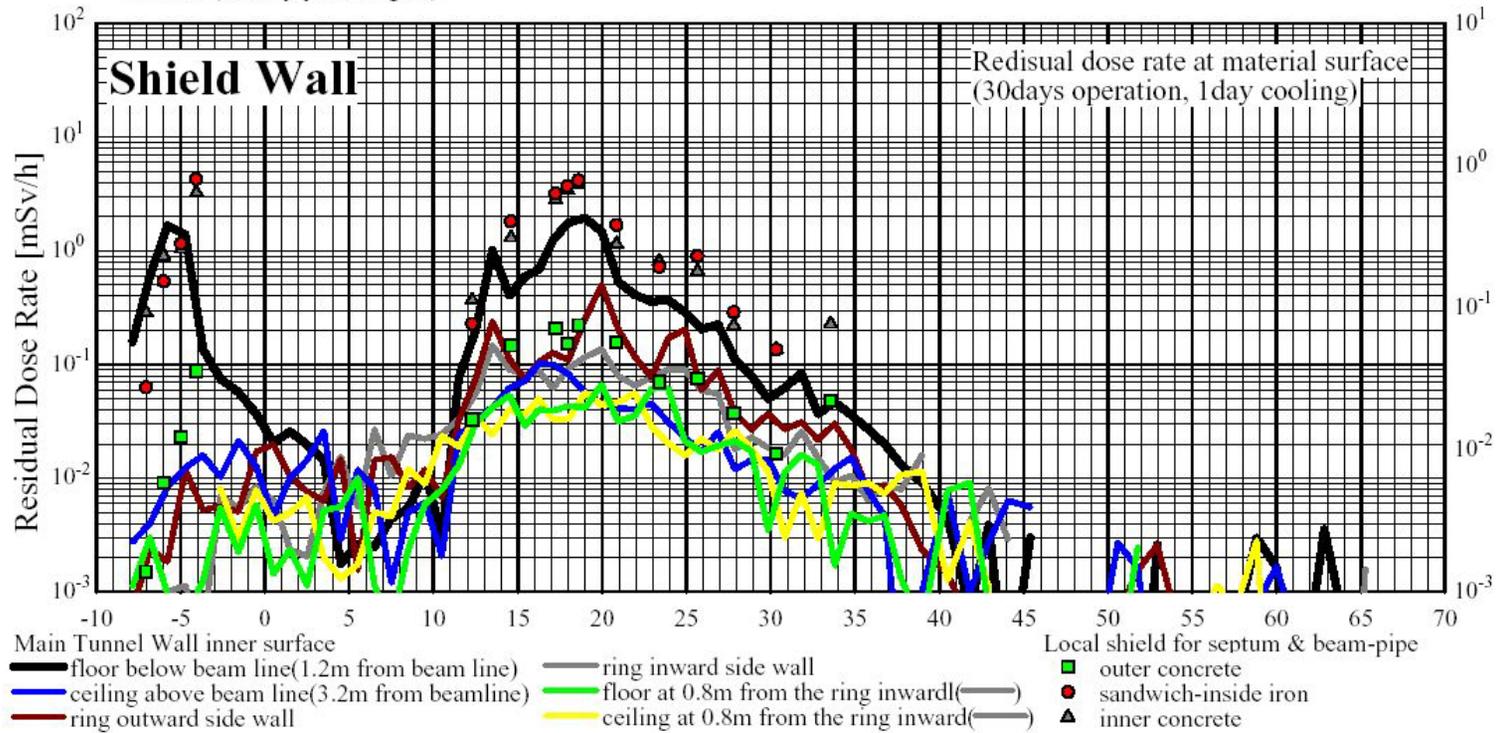
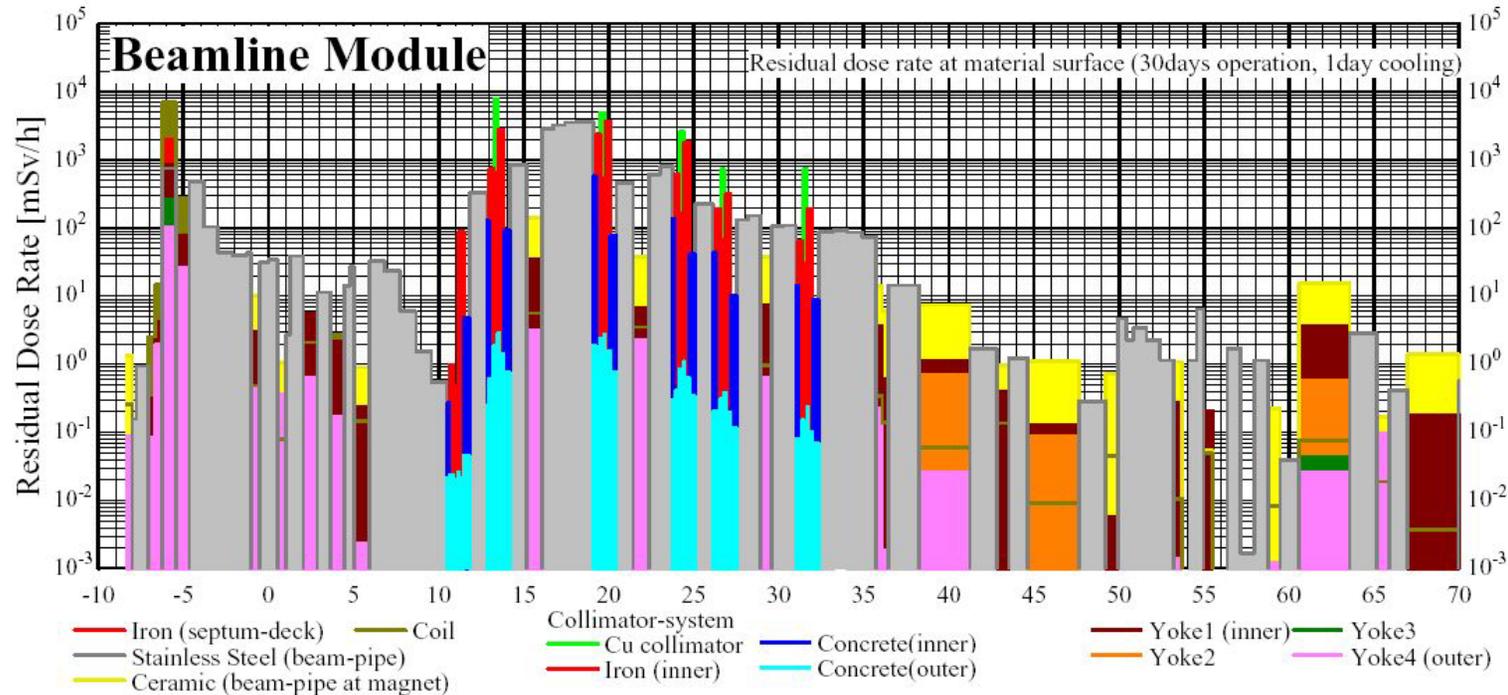




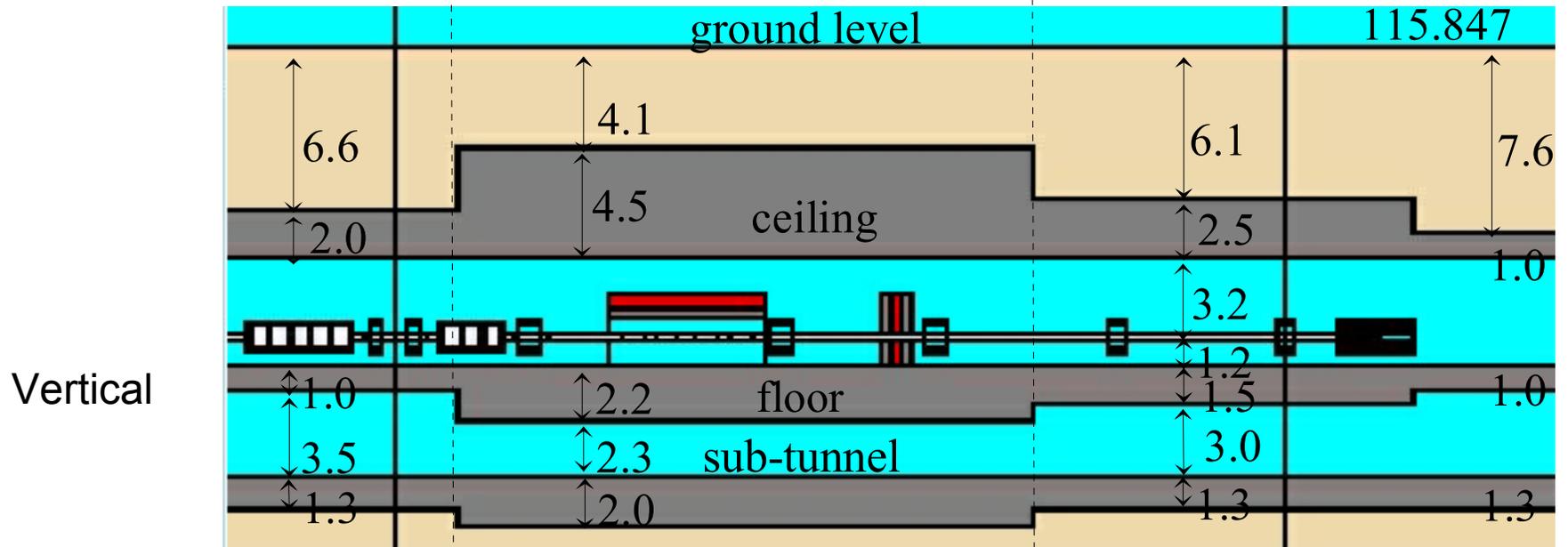
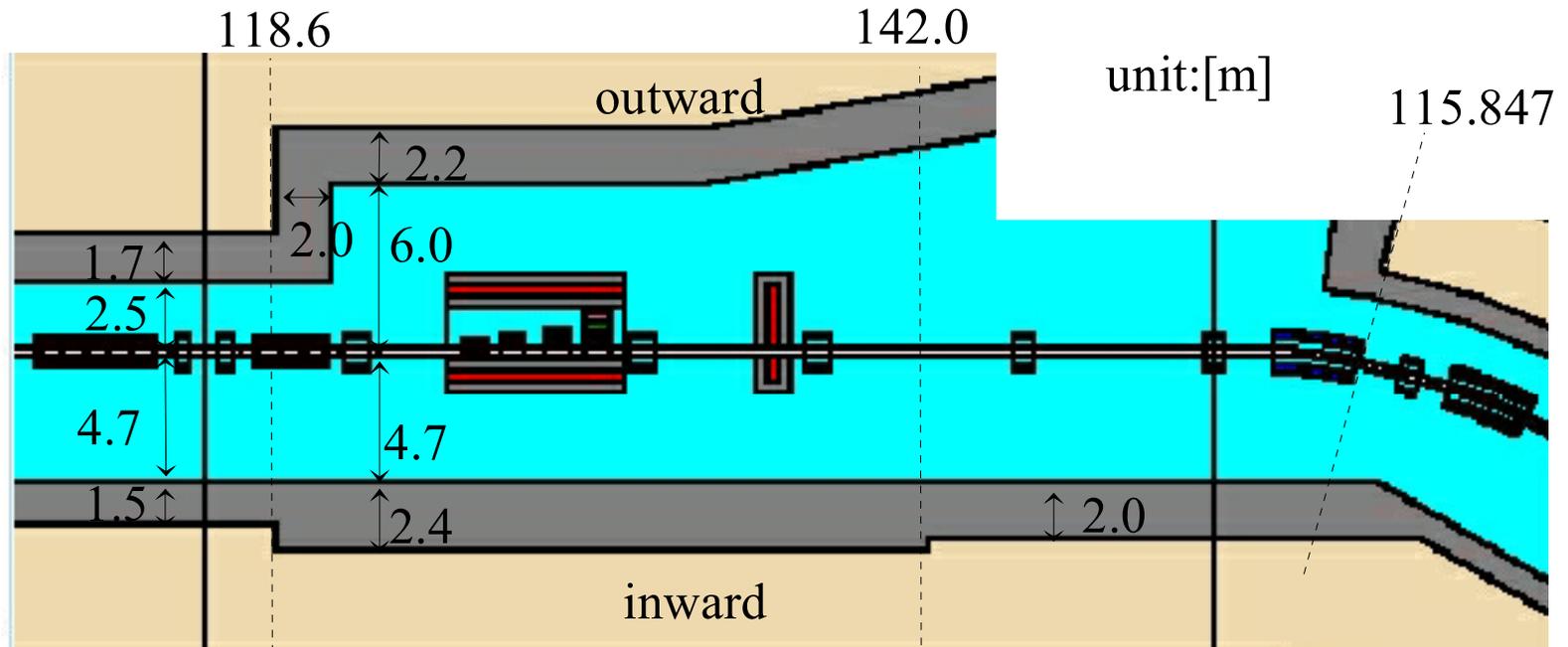
Flux estimation cells for MARS14 calculation



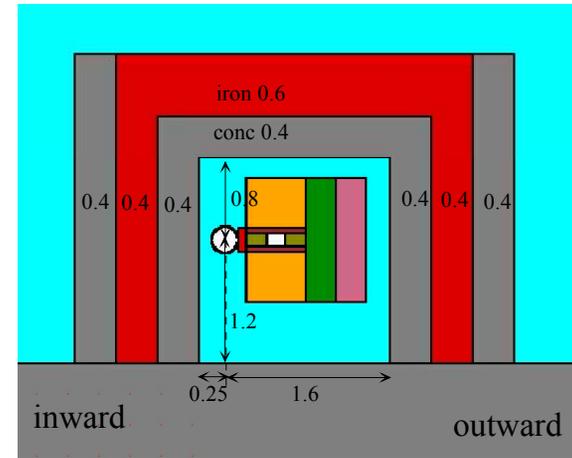
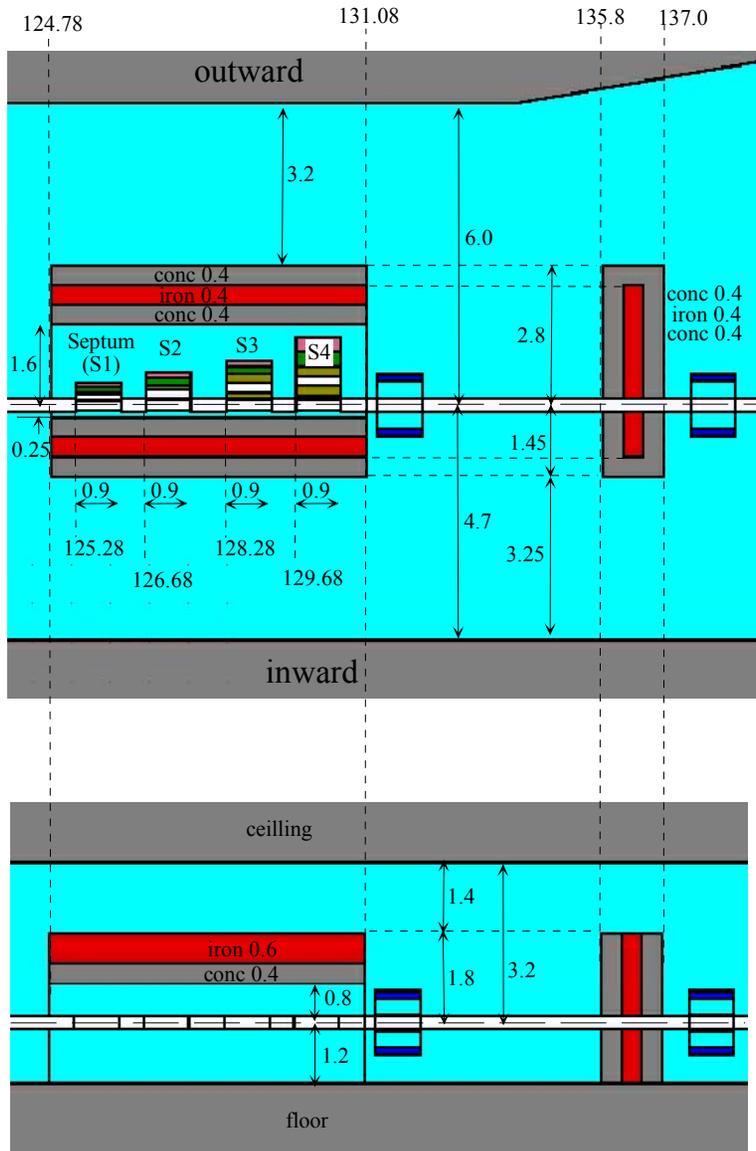




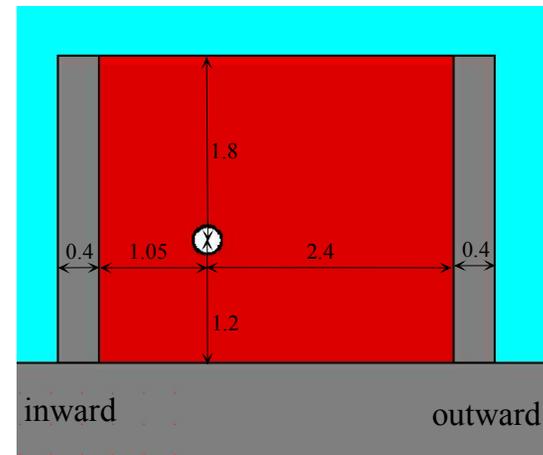
Tunnel Cross Section at Extraction Region



Local Shield for Extraction Septum



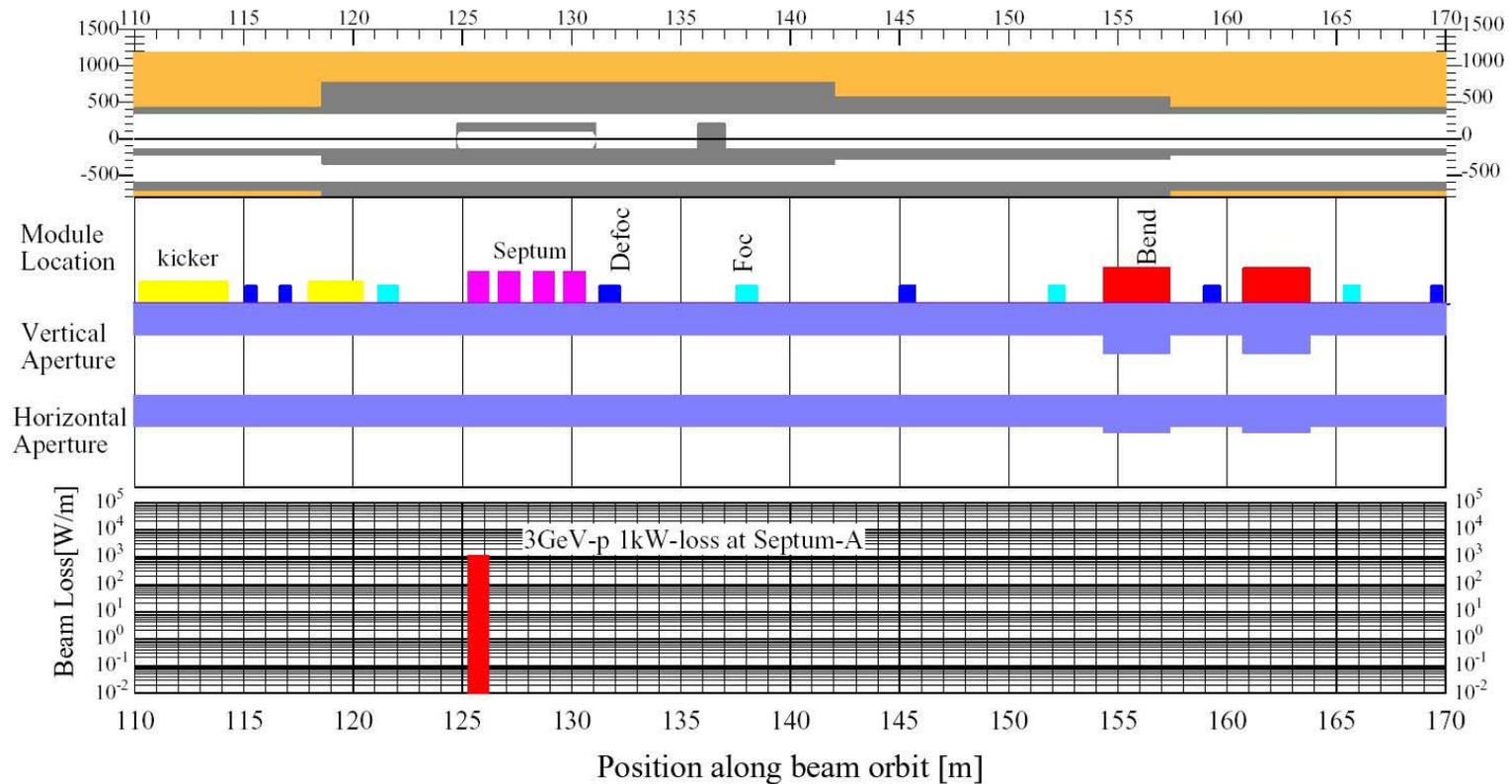
Extraction Septum(S4)
 $z=130.0\text{m}$

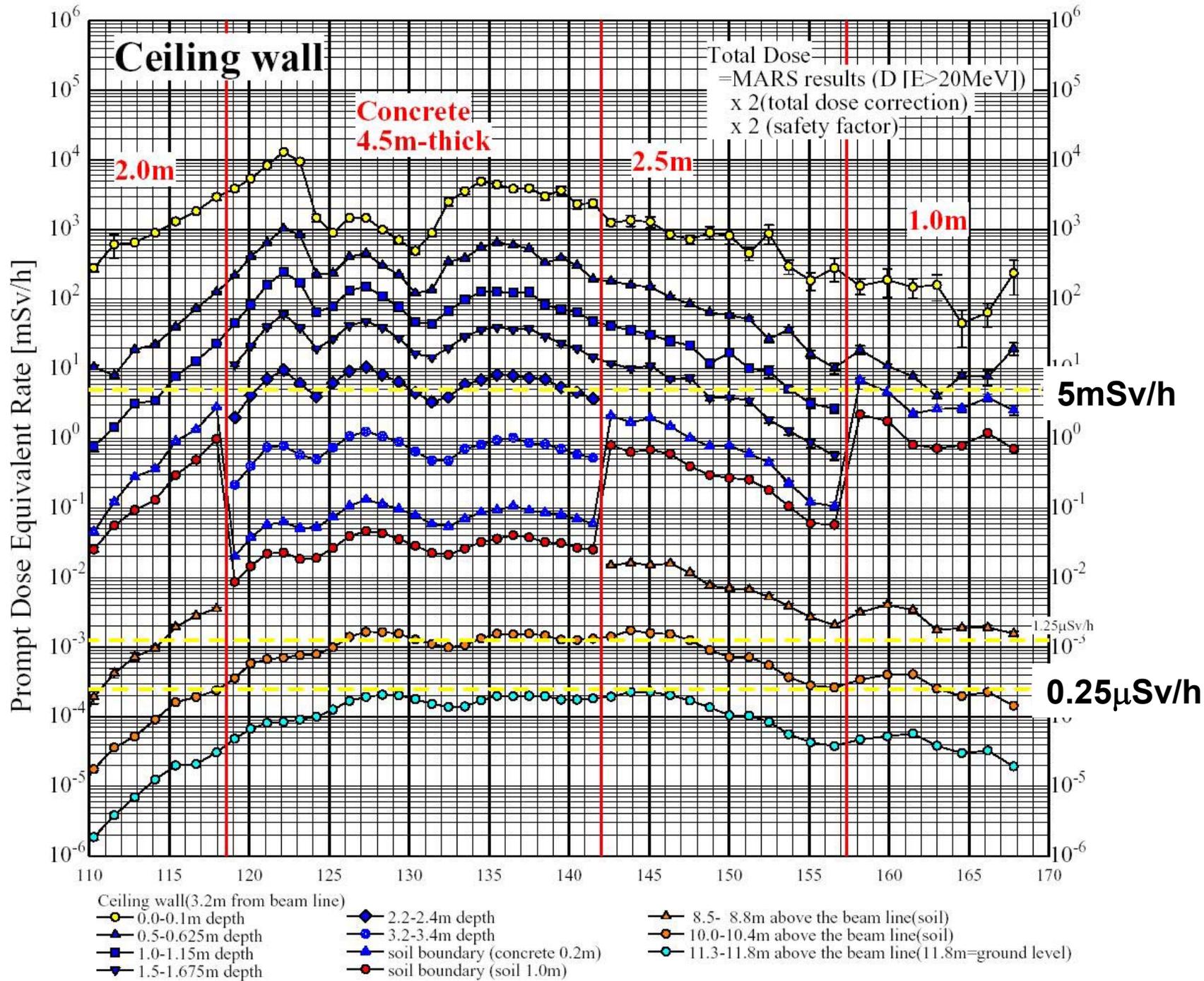


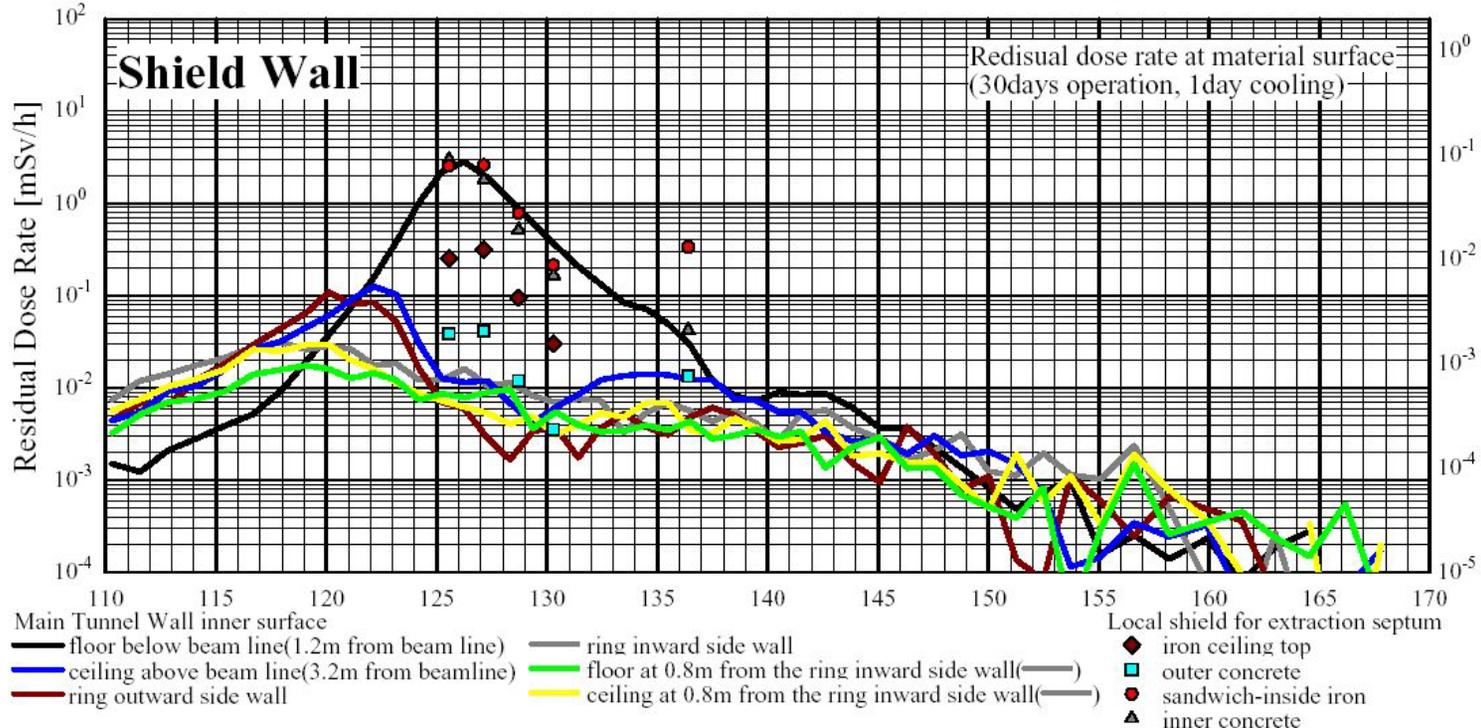
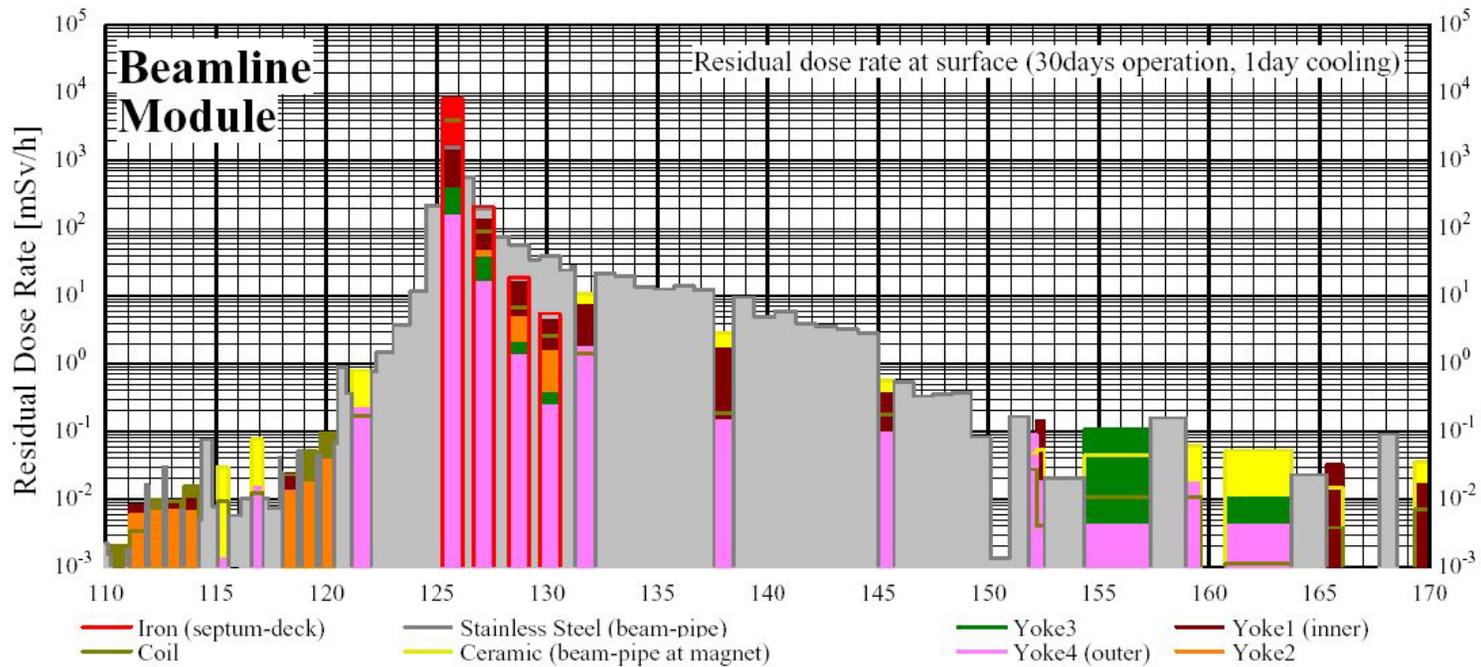
forward local shield
 $z=136.5\text{m}$

unit:[m]

Beam line structure & Beam loss distribution (EXTRACTION)







Summary

- ◆ Shielding & Residual dose rates estimation By MARS14 for J-PARC 3 GeV ring
- ◆ Shield thickness determination by estimation of prompt dose rate inside and outside thick shield along long tunnel regions
- ◆ Residual dose rate and maintenance
 - Collimator region (4kW loss)
 - ~10 Sv/h at surface, ~10 mSv/h at local shield
 - Active handling system will be introduced
 - Injection & Extraction septum (1kW loss each)
 - ~10 Sv/h at surface,
 - Too high for maintenance
 - low loss design in progress



**Thank you for your attention
to
MARS !**