POHANG ACCELERATOR LABORATORY
포항가속기연구소

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Bulk Shielding Calculation for 90° Bending Section of RISP accelerator

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Outline

- Introduction
- Beam loss scenario &

  Assumption for decision of tunnel thickness
- Bulk shielding calculation by Monte Carlo code, PHITS

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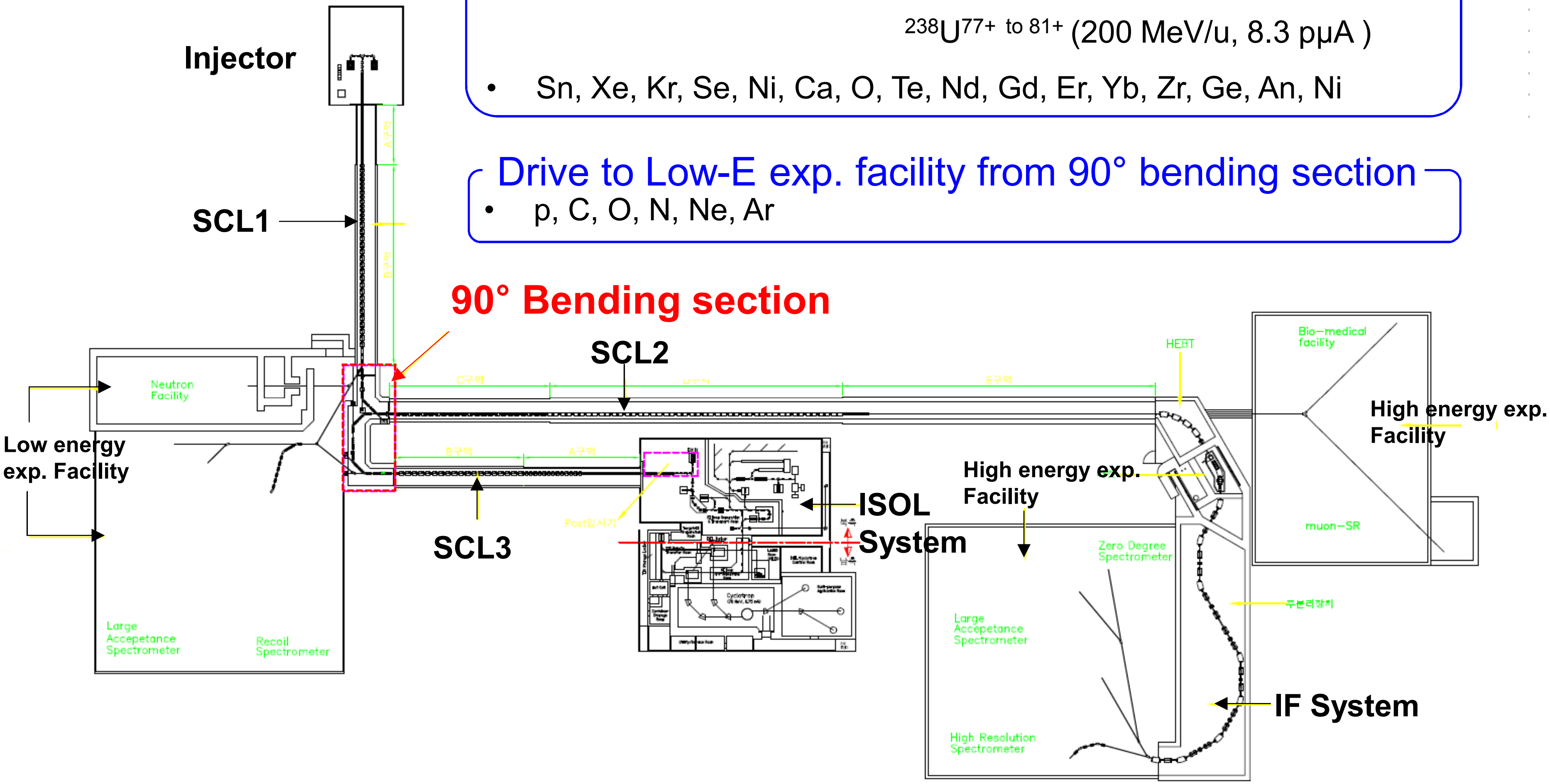
  2. Source term evaluation
  3. Distribution of neutron effective dose
  4. Neutron energy spectra inside the concrete shield
  5. Attenuation profiles of the effective dose through concrete shield
- Conclusion & further work

Introduction: Layout of RISP accelerator

Drive to SCL2 from 90° bending section
- $^{238}U^{33+,\ 34+}$ (17.5 MeV/u, 11.76 pμA) → $^{238}U^{77+\ \text{to}\ 81+}$ (200 MeV/u, 8.3 pμA)
- Sn, Xe, Kr, Se, Ni, Ca, O, Te, Nd, Gd, Er, Yb, Zr, Ge, An, Ni

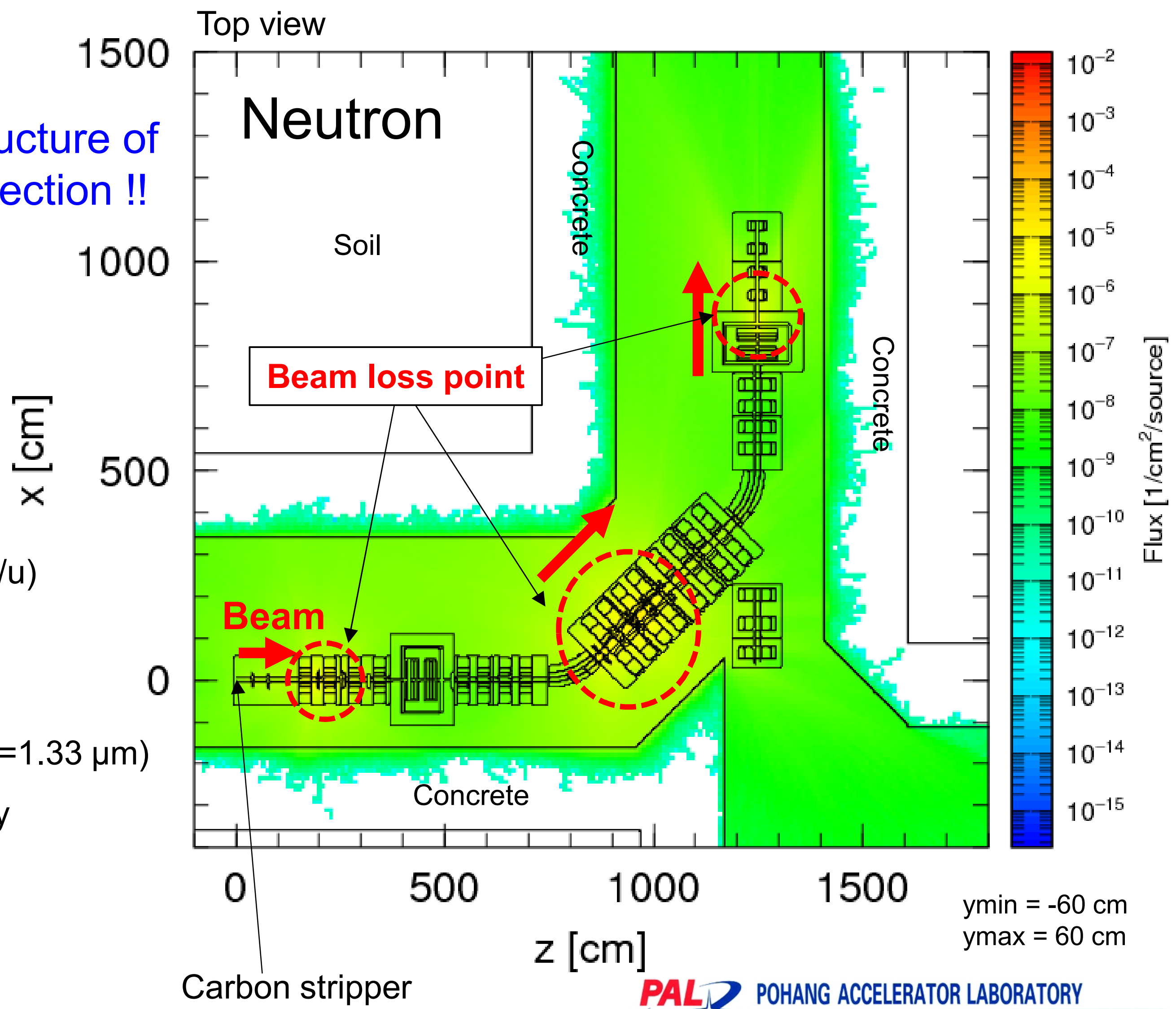
Drive to Low-E exp. facility from 90° bending section
- p, C, O, N, Ne, Ar



The structural drawing of RISP (2014. 09.26 version)

Introduction:
$^{238}U^{71+\ to\ 85+}$ transport at the magnetic field for $^{238}U^{79+}$

Old tunnel structure of 90° bending section !!



- Beam: $^{238}U^{71+\ to\ 85+}$ (18.5 MeV/u)
- Beam size: FWHM 0.4 cm
- Beam position:

  0.1 cm after carbon stripper (t=1.33 μm)
- PHITS 2.64 using [t-track] tally

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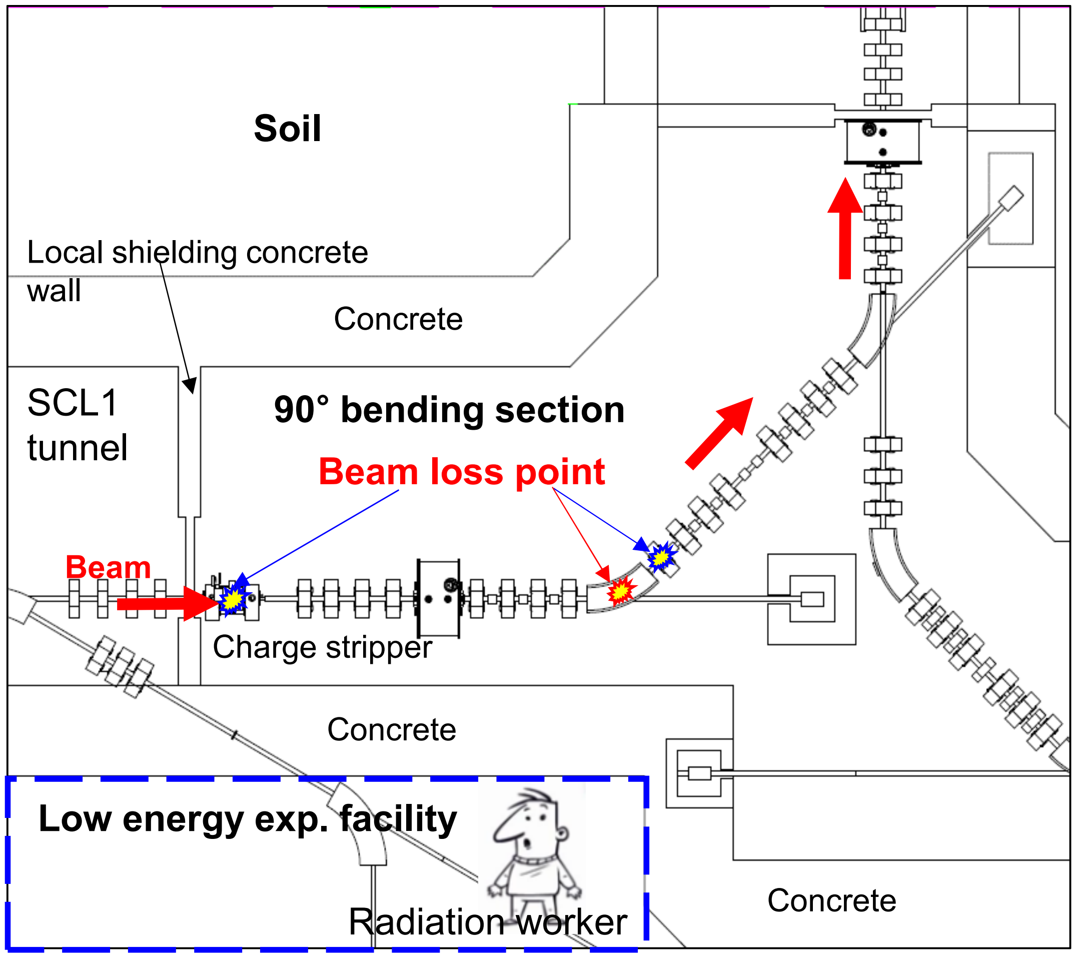
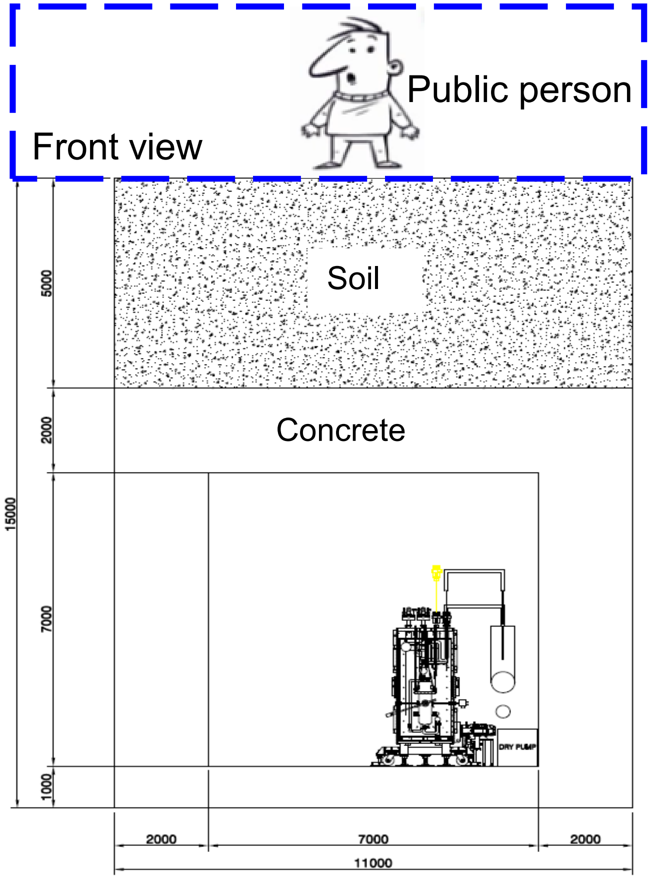
Introduction: Layout of 90° bending section

Top view



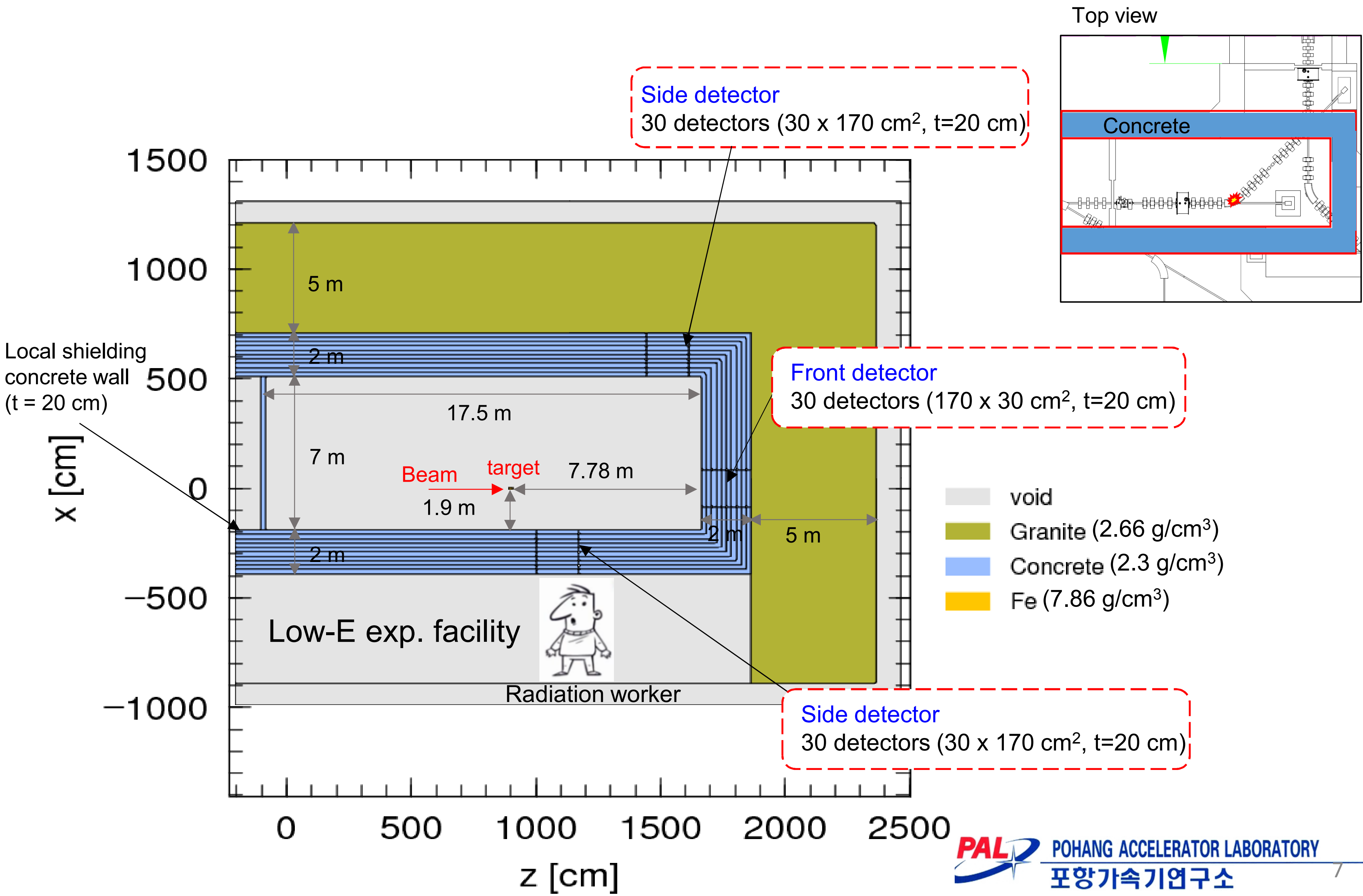


The structural drawing of RISP accelerator (2014. 09.26 version)

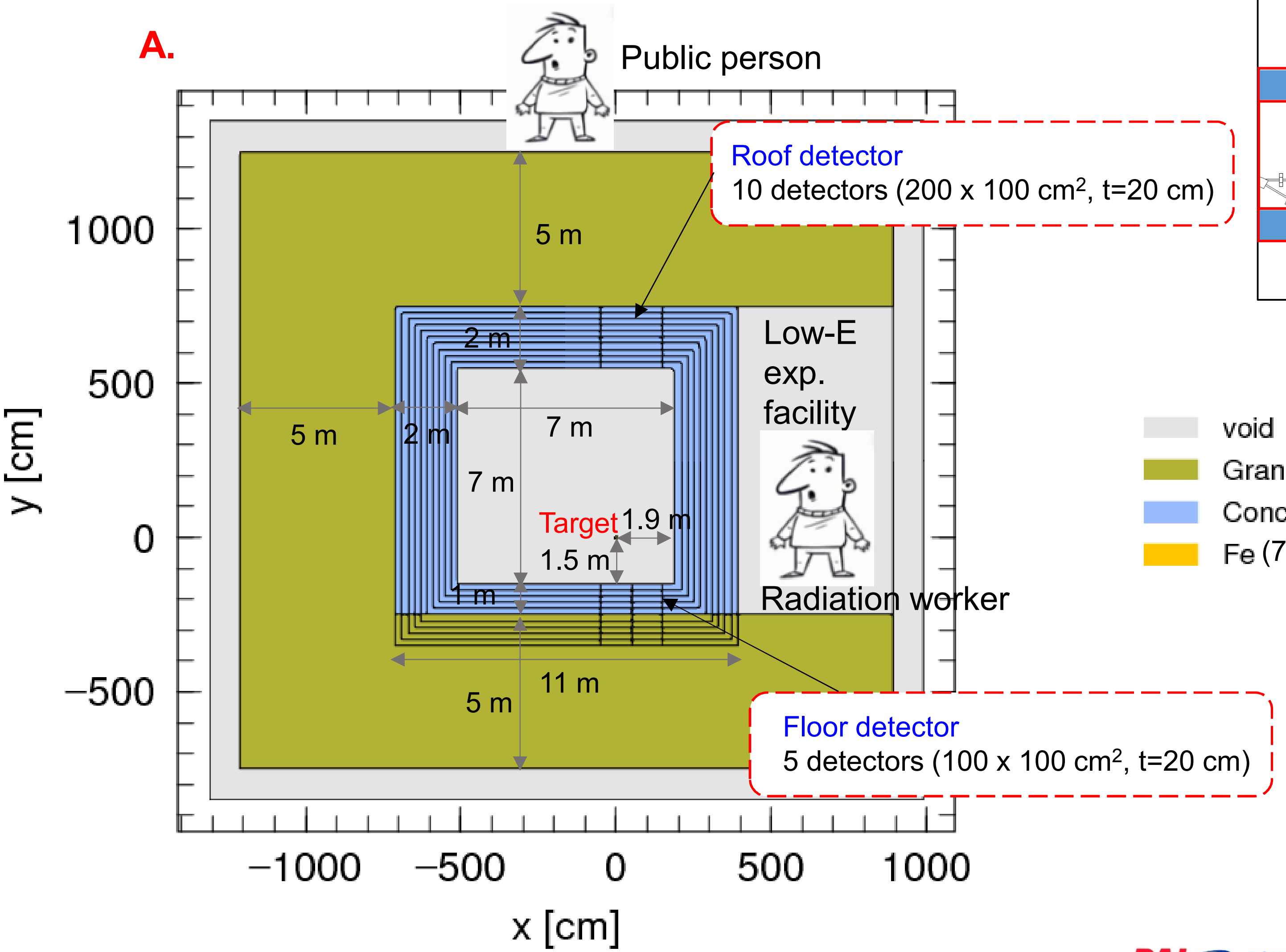
Beam loss scenario & Assumption for decision of tunnel thickness

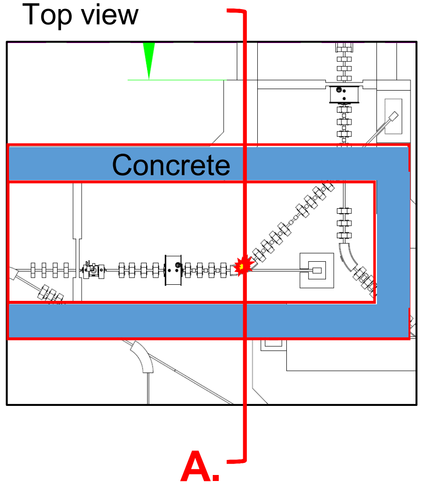
- Beam : **17.5 MeV/u $^{238}U^{92+}$** (11.76 pμA, 49.6 kW)
- Normal beam loss
  - Stripping reaction, ≤ 1% by LISE++ calculation
  - Beam selection for optimum charge state, 15% from RISP team
  - Beam transport, 68% by FLUKA calculation (32% beam transport efficiency)
- Accidental beam loss
  - Dipole failure, Beam mis-steering
  - Full power beam loss
- Dose rate limitation at the outer surface of shield
  - 5 μSv/h @ area for radiation workers
  - 0.25 μSv/h @ area for the publics
- Target assumption
  - Thin carbon (5x5x0.0005 cm^3) for stripping reaction
  - Thick Iron (Φ 10 cm, 20 cm-thickness) for beam selection and dipole failure

PHITS geometry of simplified tunnel : Top view



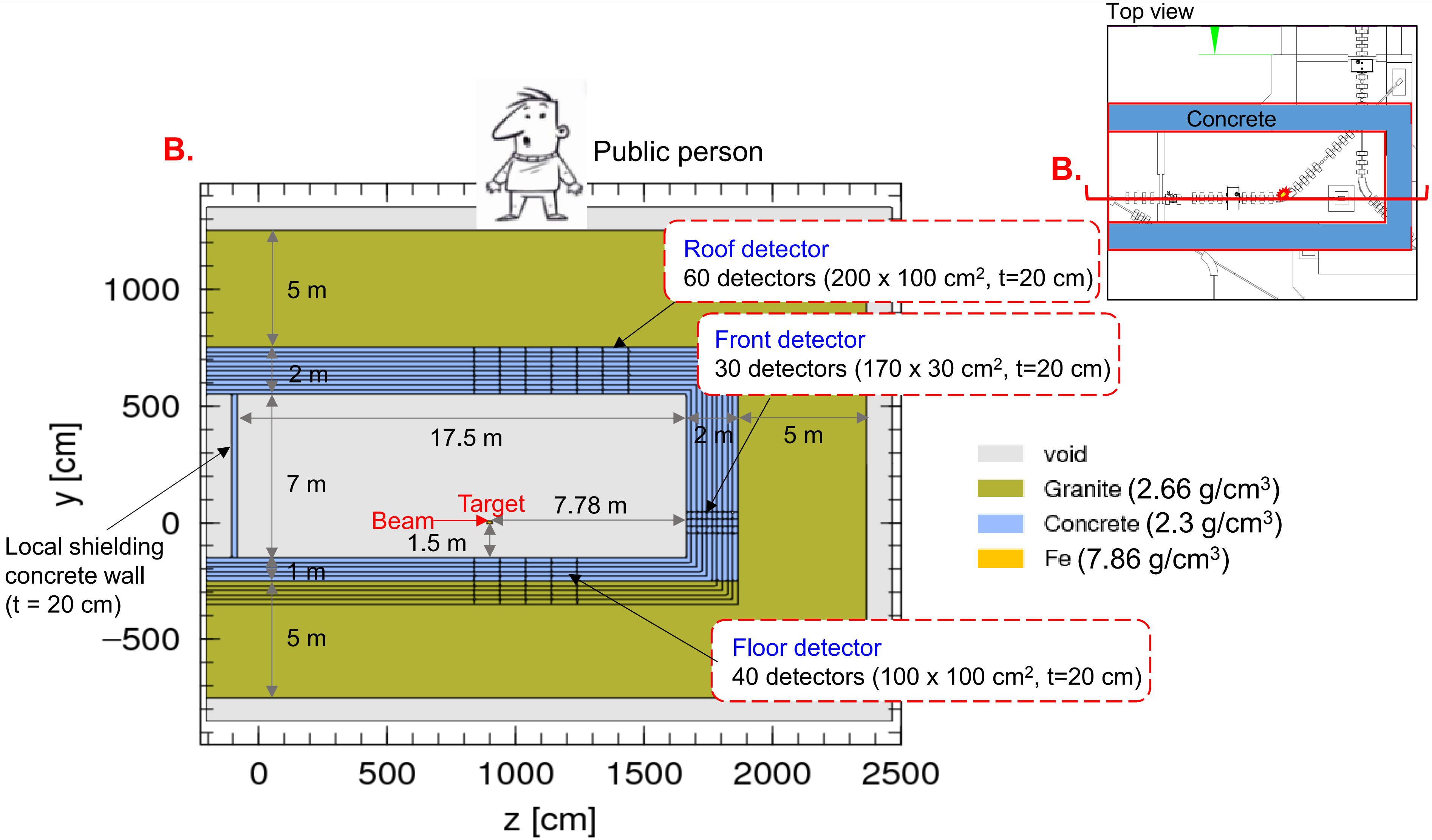
PHITS geometry of simplified tunnel : Front view



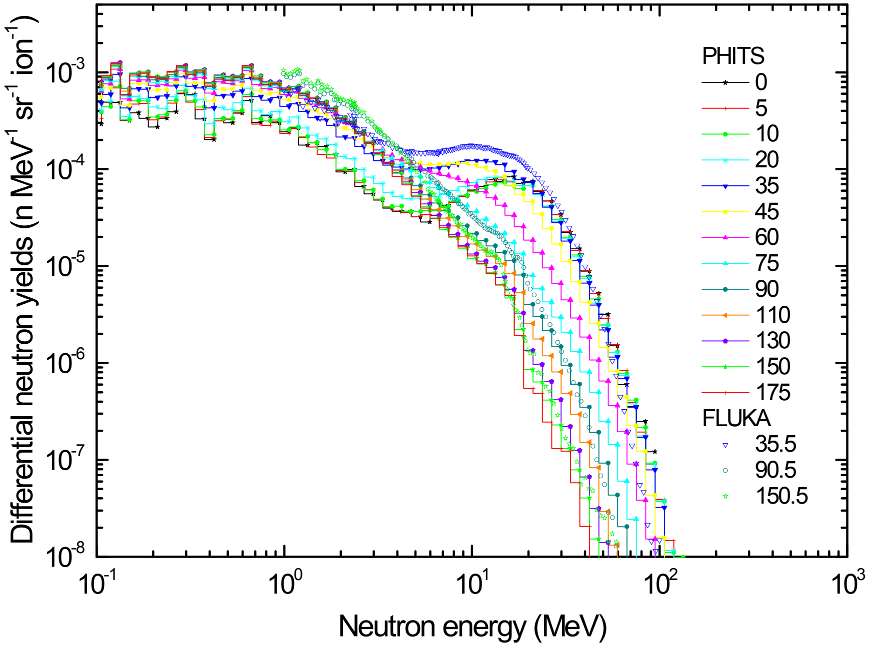


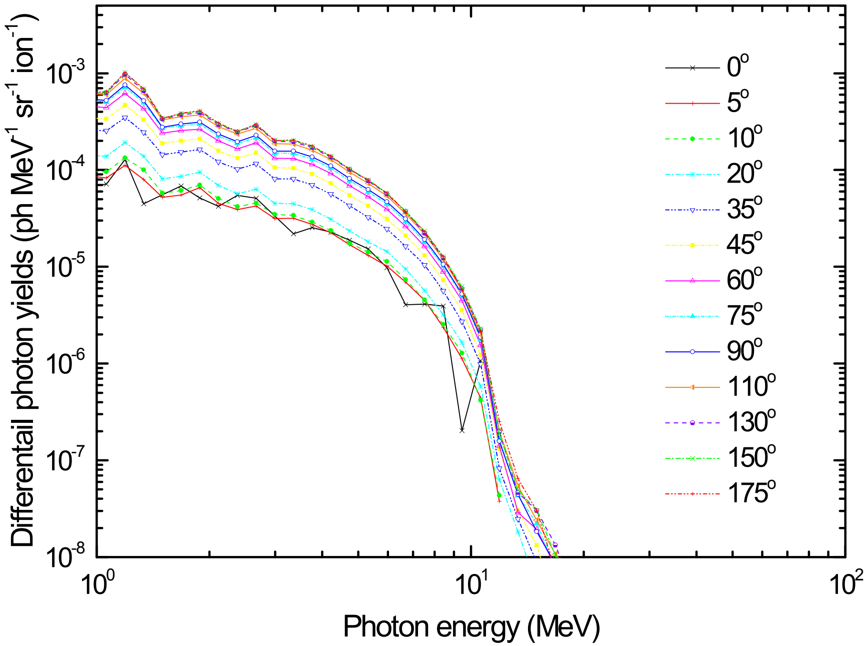
void
Granite (2.66 g/cm³)
Concrete (2.3 g/cm³)
Fe (7.86 g/cm³)

PHITS geometry of simplified tunnel : Side view



Source term evaluation for 17.5 MeV/u ^{238}U on thick Fe





- Beam particle : $^{238}U^{92+}$
- Beam energy : 17.5 MeV/u
- Beam shape : 2-D Gaussian (s-type = 3)
  x-FWHM: 0.1904 cm
  y-FWHM: 0.1360 cm
- Thick Fe target (Φ 10 cm, t = 20 cm, 7.86 g/cm^3)
- Ring type detectors
  : Every 5° from 0° to 180° with ±0.5° range
- Tally : Surface tally (t-cross)
- Physics model
  - Nucleus : SPAR (below 10 MeV/u)
    GEM + JQMD model (above 10 MeV/u)
  - Nucleon : JENDL-HE07 library (below 20 MeV)
    GEM+INCL4.6 model (above 20 MeV)
- PHITS 2.64

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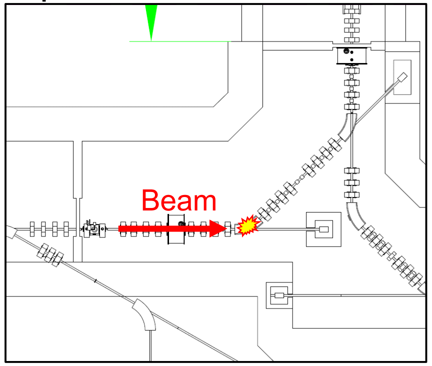
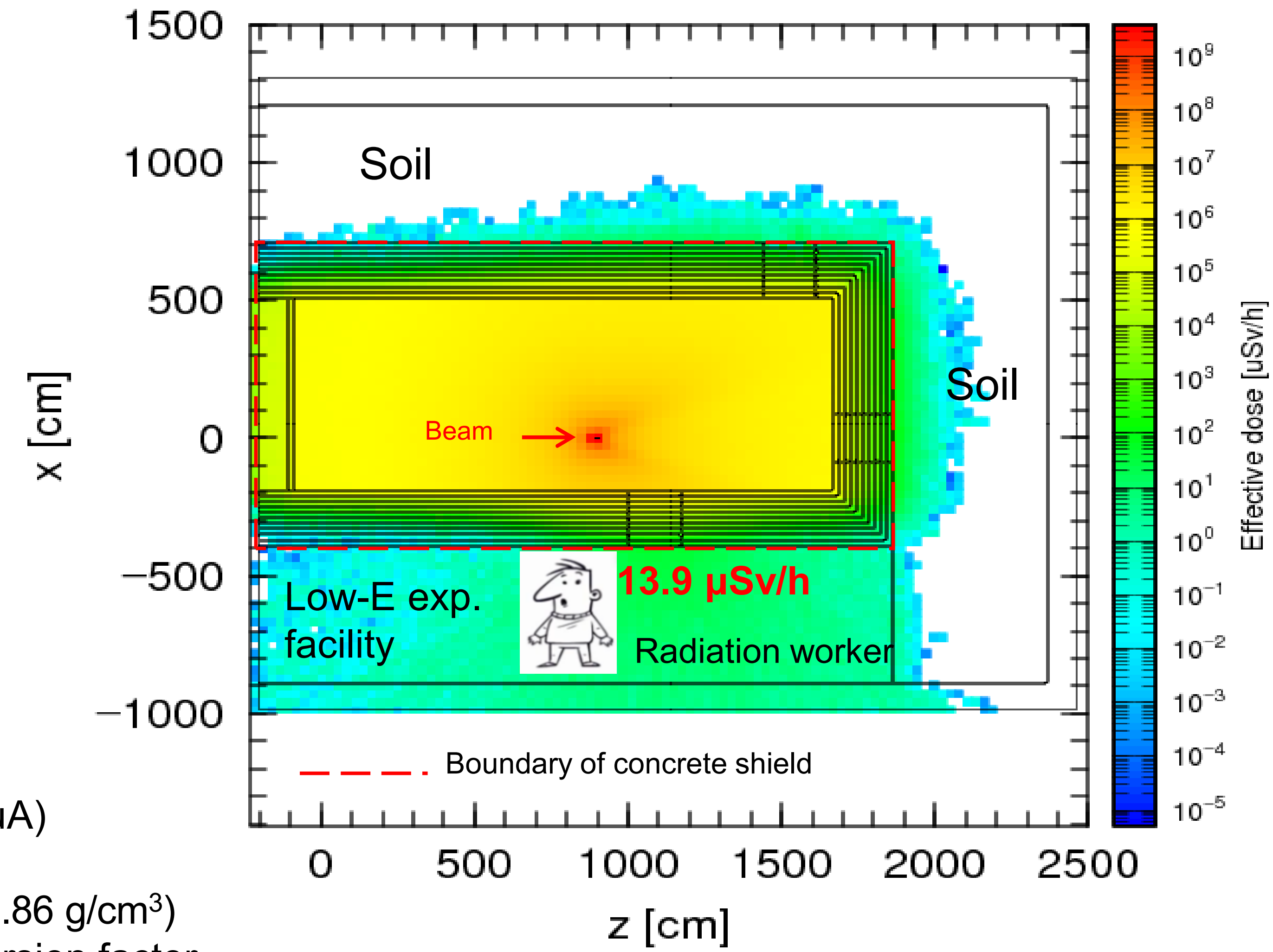
Distribution of neutron effective dose rate : Top view

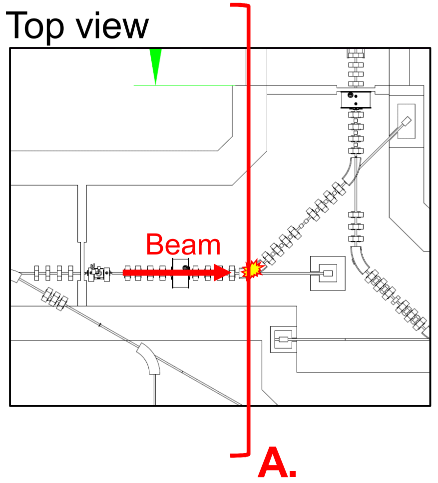
Top view

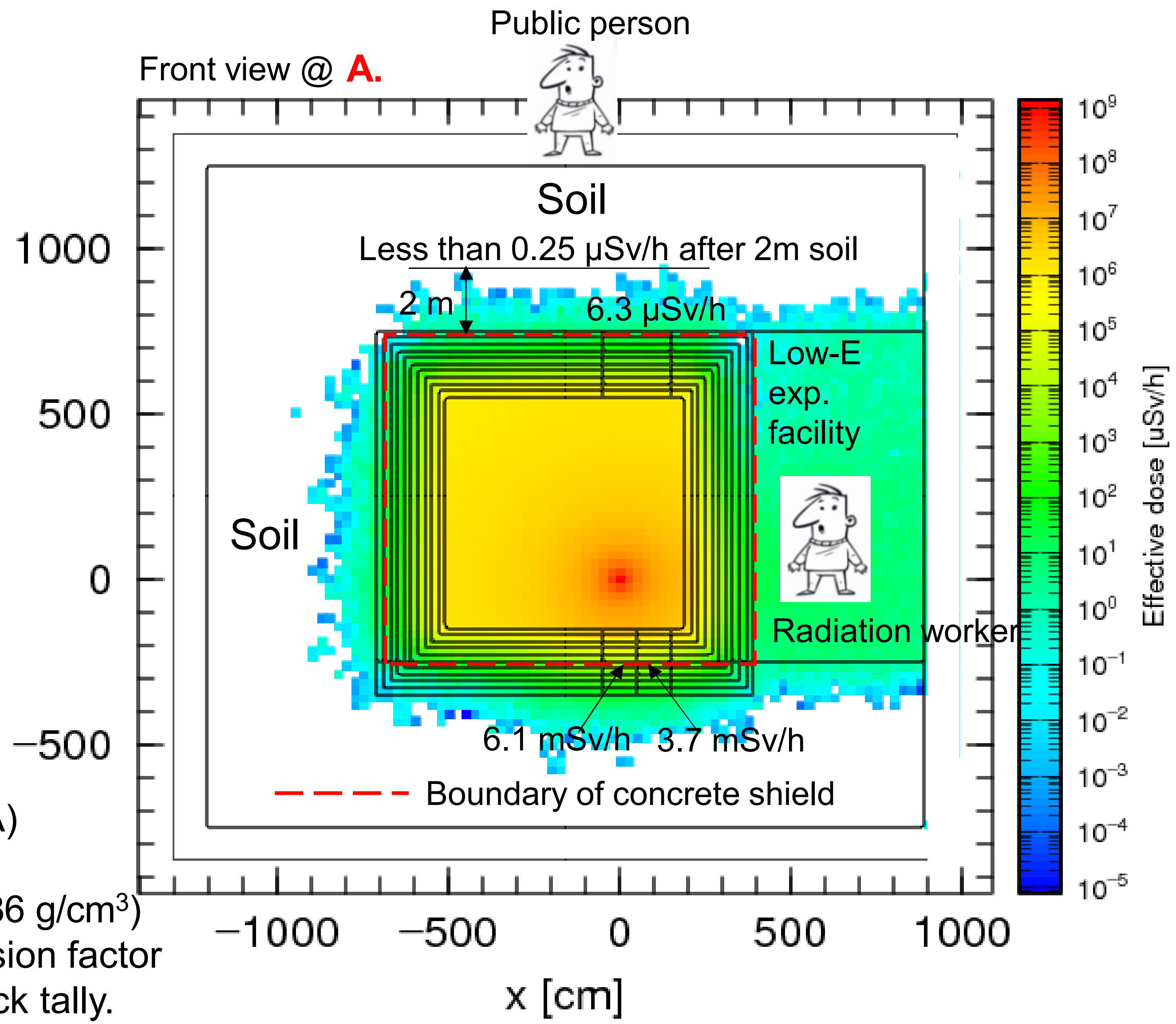




- Beam: ^{238}U (17.5 MeV/u, 11.76 pμA)
- Thick Iron target (Φ 10 cm, t = 20 cm, 7.86 g/cm^3)
- **ICRP-116** dose conversion factor
- PHITS 2.64 using T-track tally.

Distribution of neutron effective dose rate: Front view

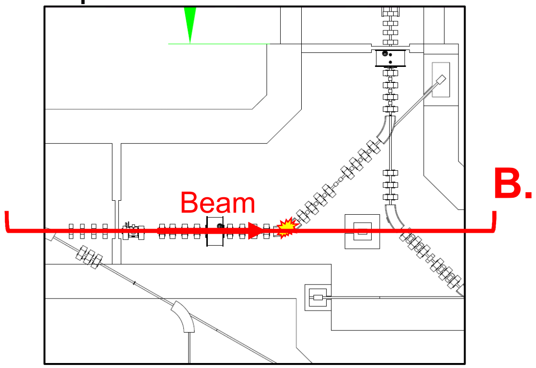




- Beam: ^{238}U (17.5 MeV/u, 11.76 pμA)
- Thick Iron target (Φ 10 cm, t = 20 cm, 7.86 g/cm^3)
- **ICRP-116** dose conversion factor
- PHITS 2.64 using T-track tally.

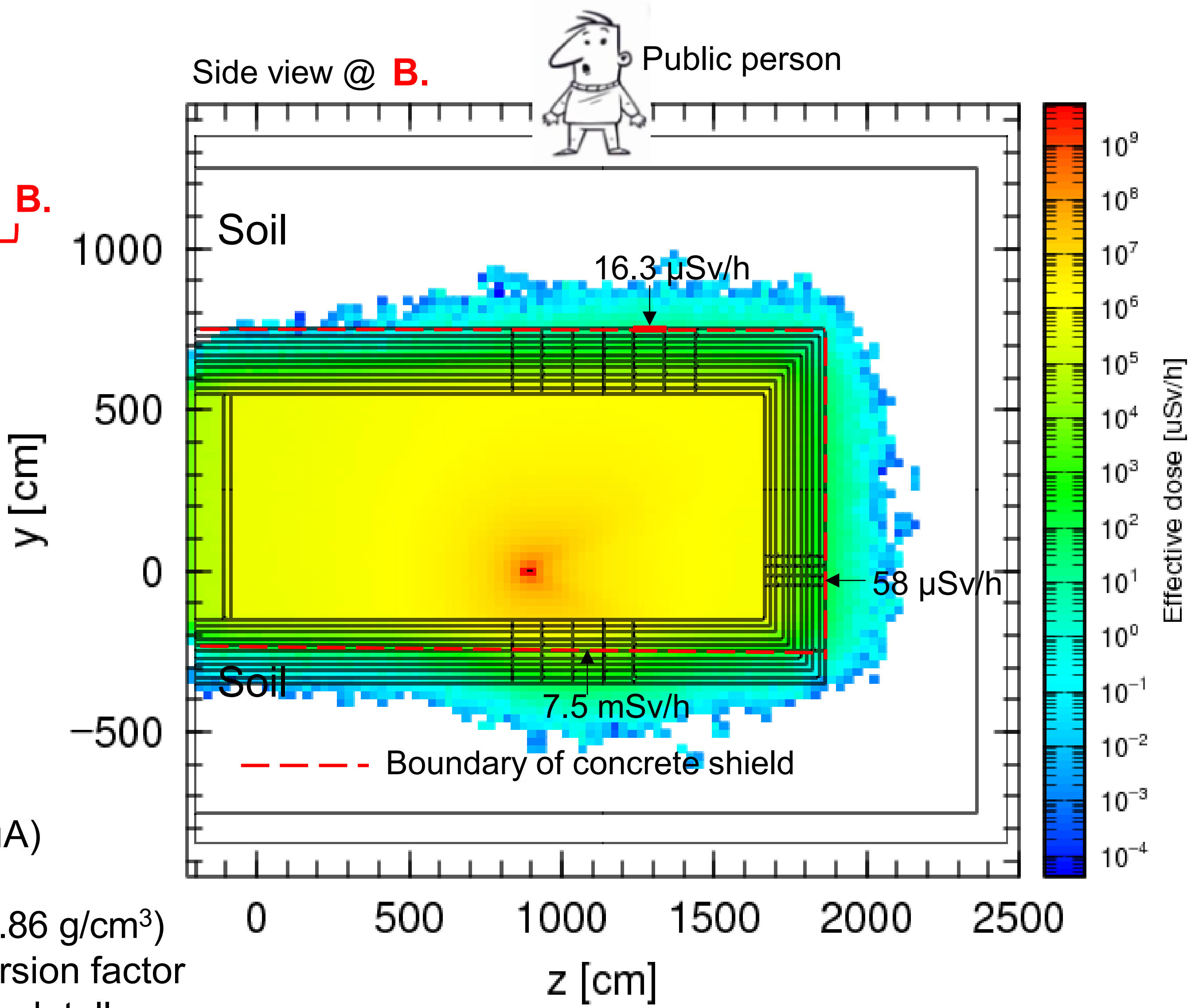
Distribution of neutron effective dose rate:
Side view

Top view



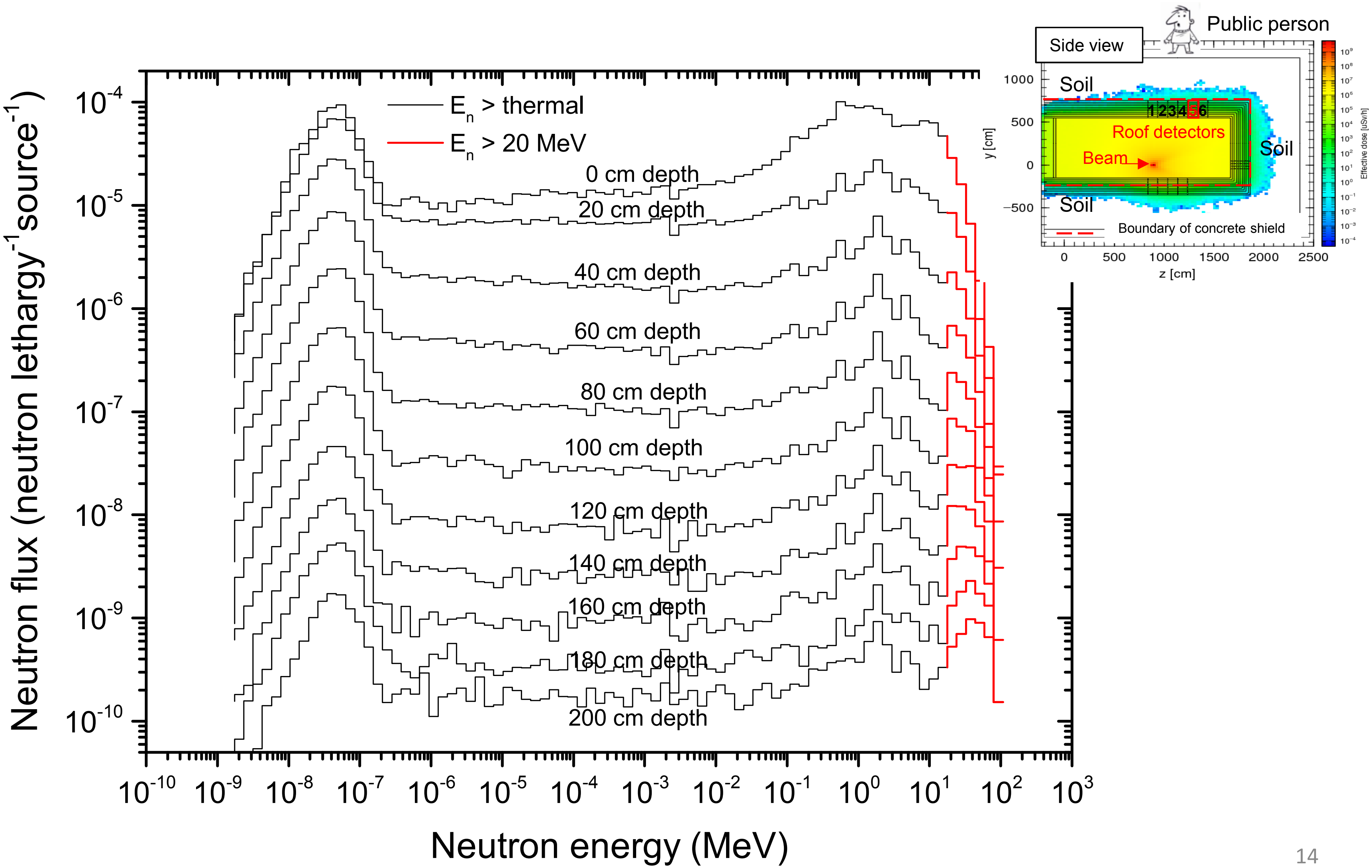
Side view @ **B.**

Public person

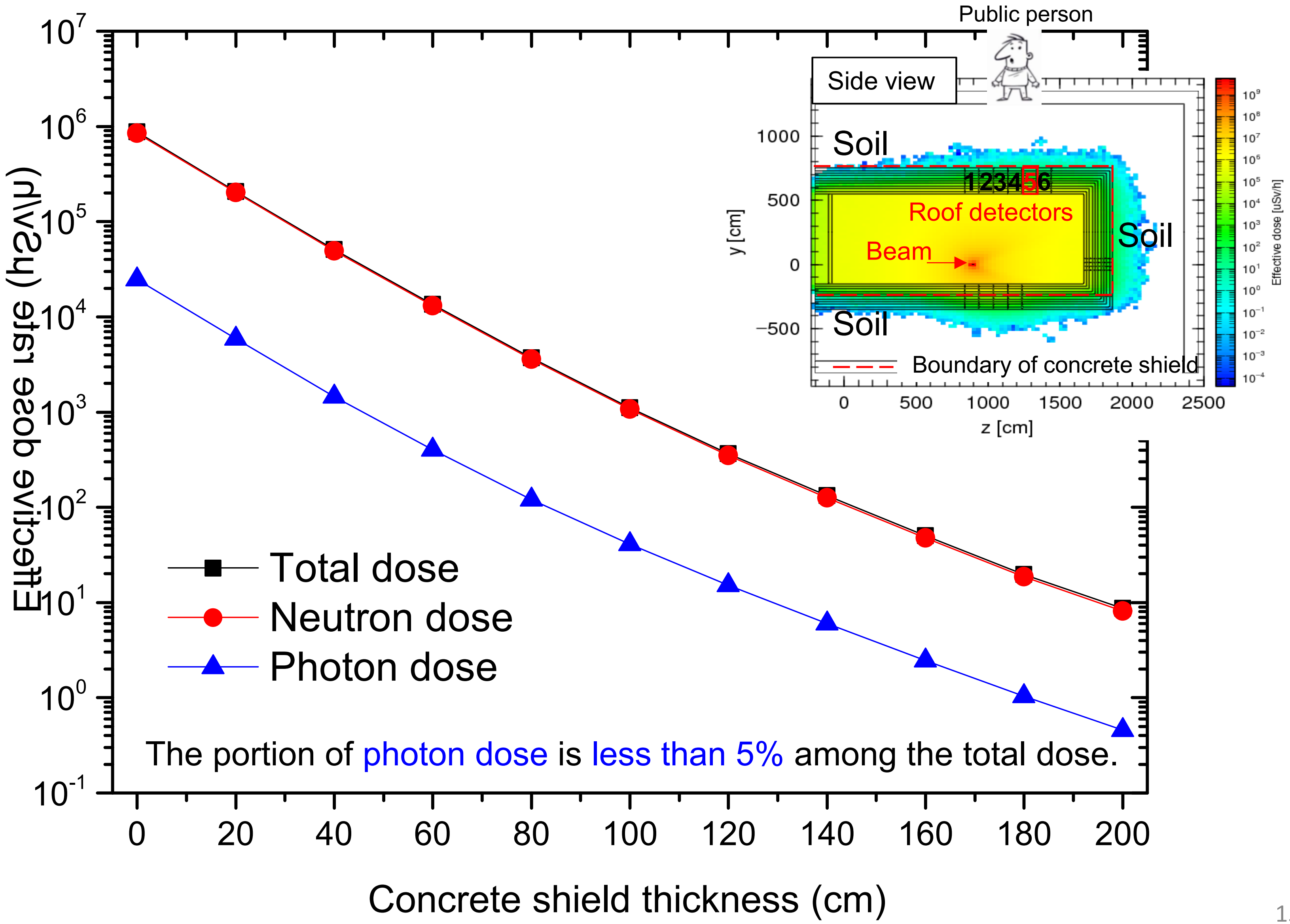


- Beam: ^{238}U (17.5 MeV/u, 11.76 pμA)
- Thick Iron target (Φ 10 cm, t = 20 cm, 7.86 g/cm^3)
- **ICRP-116** dose conversion factor
- PHITS 2.64 using T-track tally.

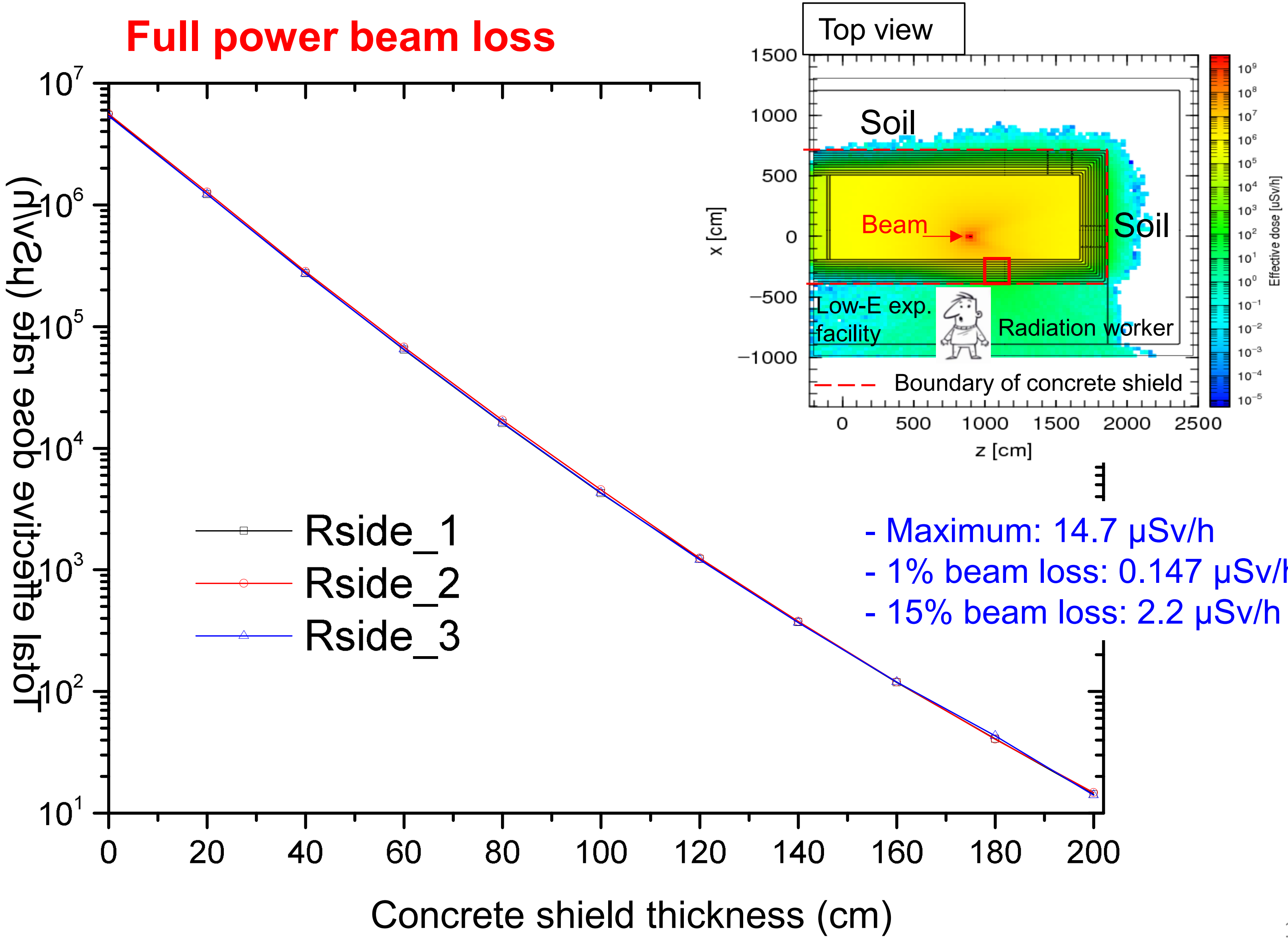
Neutron energy spectra down to thermal energy inside the concrete shield for 17.5 MeV/u ^{238}U on Fe target @ Roof detector_5



Comparison of attenuation profile of dose rate of total, neutron and photons for 17.5 MeV/u ^{238}U on Fe target @ Roof detector_5



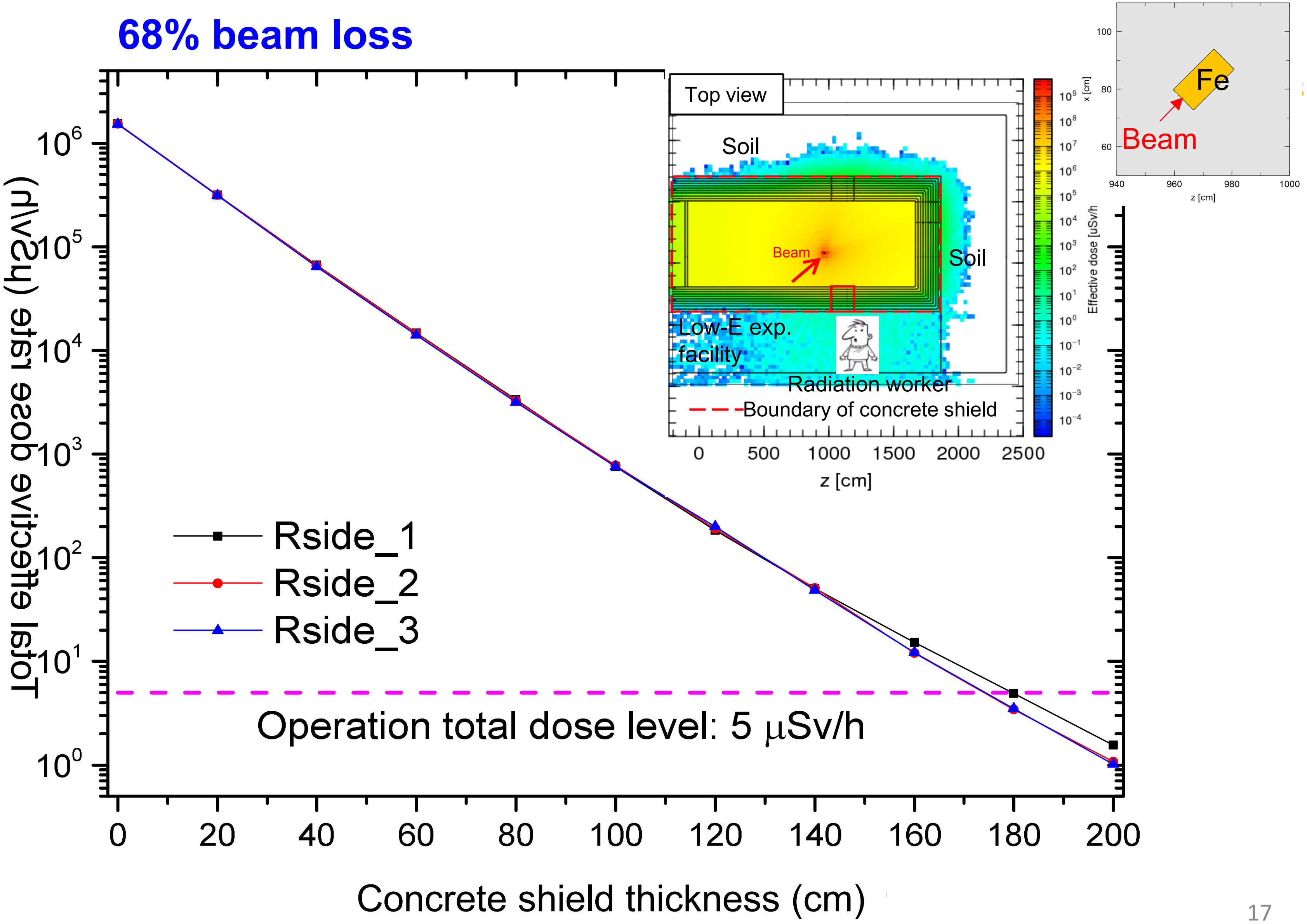
Attenuation profiles of the total dose rate through shield for 17.5 MeV/u ^{238}U on Fe @ Right side detectors



- Maximum: 14.7 μSv/h
- 1% beam loss: 0.147 μSv/h
- 15% beam loss: 2.2 μSv/h

Attenuation profiles of the total dose through shield for 17.5 MeV/u ^{238}U on Fe @ Right side detectors

68% beam loss



Conclusion & further work

Conclusion

- The calculation of the bulk shielding was performed using the simplified tunnel geometry.
- It is proved that the neutron above 20 MeV energy is important after the massive ordinary concrete.
- 2 m concrete shield thickness is sufficient at the area for radiation workers and the publics in case of the normal beam loss. And It is not thin even in the accidental beam loss case.

Further work

- The tunnel thickness adjacent to the soil will be reviewed again with the consideration of the soil and the groundwater activation.
- The amount of the normal beam loss has been analyzed using FLUKA code.

Thank you for your attention!!