Radiation protection of Linac4

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Basic assumptions for the shielding design

- Classification of radiation areas (and workers)
- Beam loss pattern
- Routine operation and incidental conditions

Type of area	Max. annual effective dose	Max. ambient dose equivalent rate	RP requirements
Non-designated (non-permanent occupation)	1 mSv	0.5 µSv h^{-1}	None
Supervised	6 mSv	3 µSv h^{-1}	Personal dosimeter
Controlled	20 mSv	10 µSv h^{-1}	Personal dosimeter + individual dosimeter with alarm function

CERN classification of workers

- Occupationally exposed :
  - Class A > 6 mSv / 12 months
  - Class B < 6 mSv / 12 months

- Short term visitors: < 1 mSv / 12 months

(not classified as occupationally exposed)

- Non occupationally exposed:

  < 1 mSv / 12 months

Action levels, design constraints and reference levels

Action level

Any exposure exceeding 6 mSv during any consecutive 12-month period must be justified in a joint review by the department concerned and the RP group and authorized by the department head.

The Swiss authorities must be notified if an individual exceeds 2 mSv over one month.

Design constraint *(effective dose)*

Use of a design constraint in the design of new facilities, to ensure that the annual dose received by an individual at the time of the operation of the facility will not exceed a pre-defined value.

CERN reference levels

1) the annual individual doses should stay below 6 mSv
2) the effective dose due to internal exposure shall stay below 1 μSv per hour of stay

Basic assumptions on machine parameters

- Beam energy: 160 MeV
- As injector into the PSB:
  - 2 Hz, 32 µA average beam current, 2×10^{14} protons per second, 5.1 kW at 160 MeV, 0.08% of the SPL duty cycle
- "Routine" beam losses:
  - 10 W point losses every 10 m (past the shield equivalent to constant beam loss of 1 W/m)
- Accidental beam loss:
  - full loss of the entire beam in a given location for a limited amount of time
  - beam interlock required
- Radiation protection dimensioned for the operation of Linac4 as SPL Front-End

Radiation protection calculations

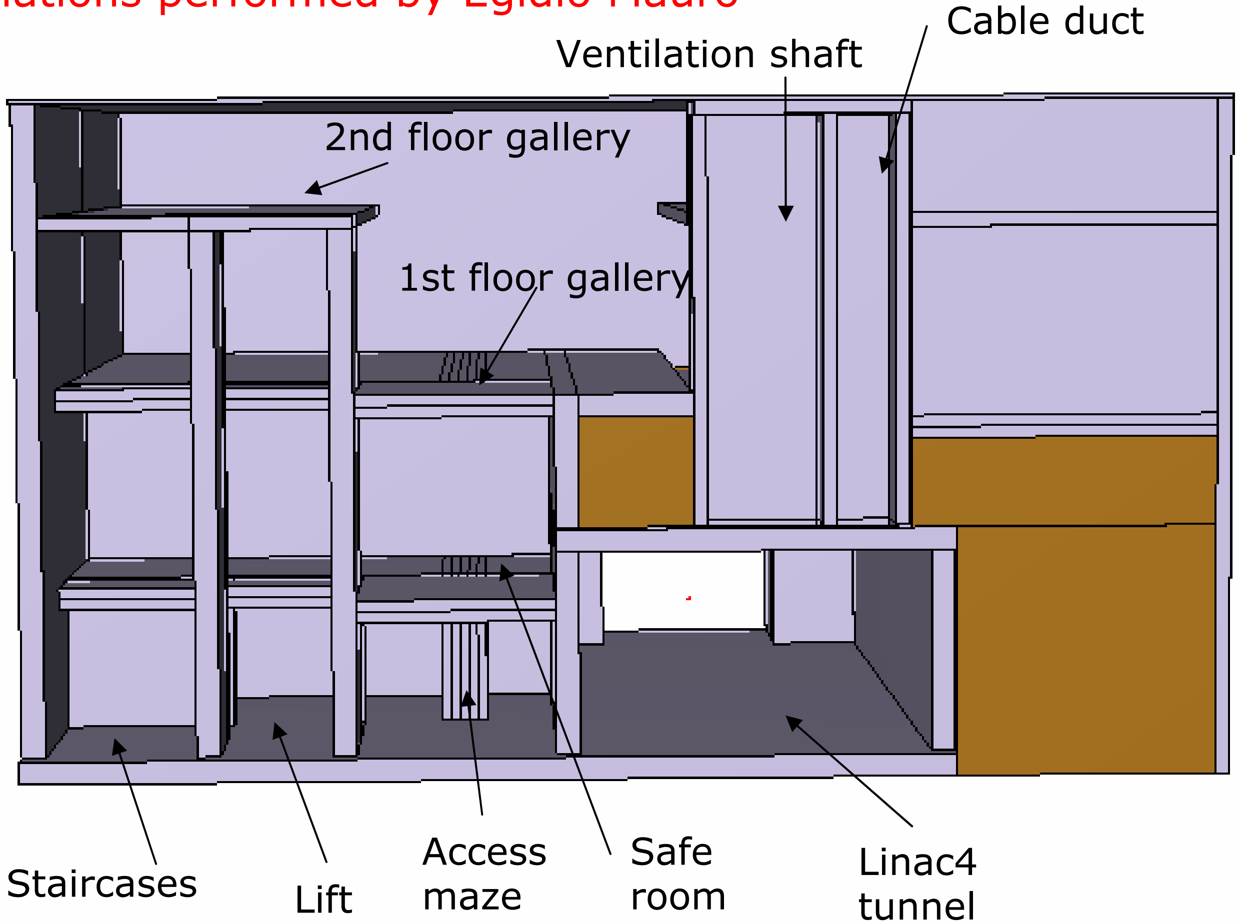
- Analytical model
  - point-source, line-of-sight for shielding
  - universal transmission curves for ducts and mazes
- Monte Carlo simulations (FLUKA)
  - to validate analytical calculations and to estimate induced radioactivity
- Layout
  - linac tunnel underground
  - klystron gallery on the surface on top of it, supervised area but 1 μSv/h taken as design value as building wall are thin and the area around is non-designated

Radiation protection calculations

- Direct stray radiation from the linac into the klystron building. Depth of linac tunnel finally dictated by the SPL downstream
- Neutron streaming through the standard waveguide ducts – Various configurations investigated
- Low-energy (3 MeV section) waveguides
- Access maze, lift shaft, ventilation and cable ducts, rooms on the upper floor at the low-energy end of the linac tunnel
- Ventilation and cable ducts at the high-energy end of the linac tunnel
- Additional shielding required in the existing Linac2 building around the Linac4 – PSB transfer line

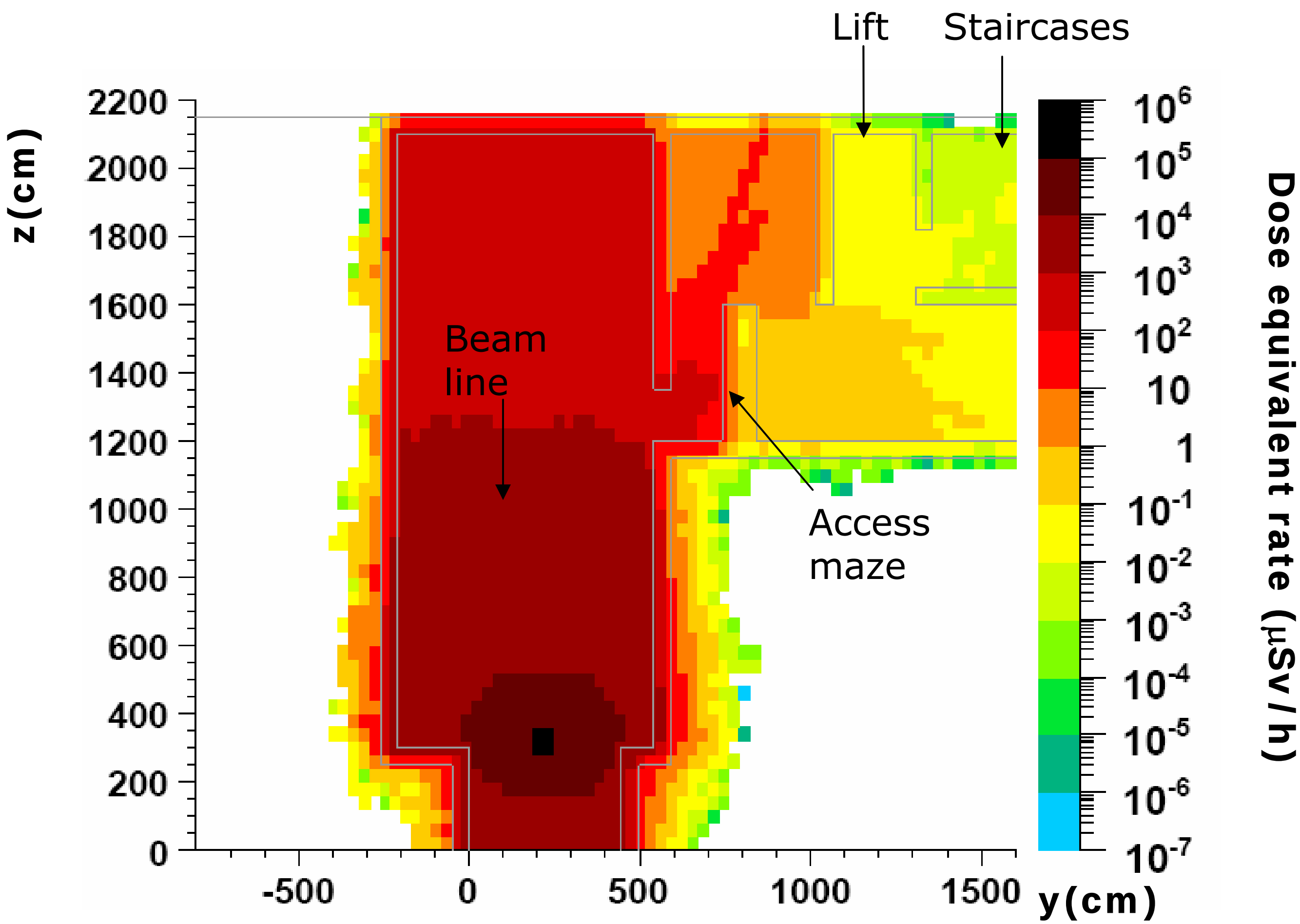
Low-energy section

All MC simulations performed by Egidio Mauro



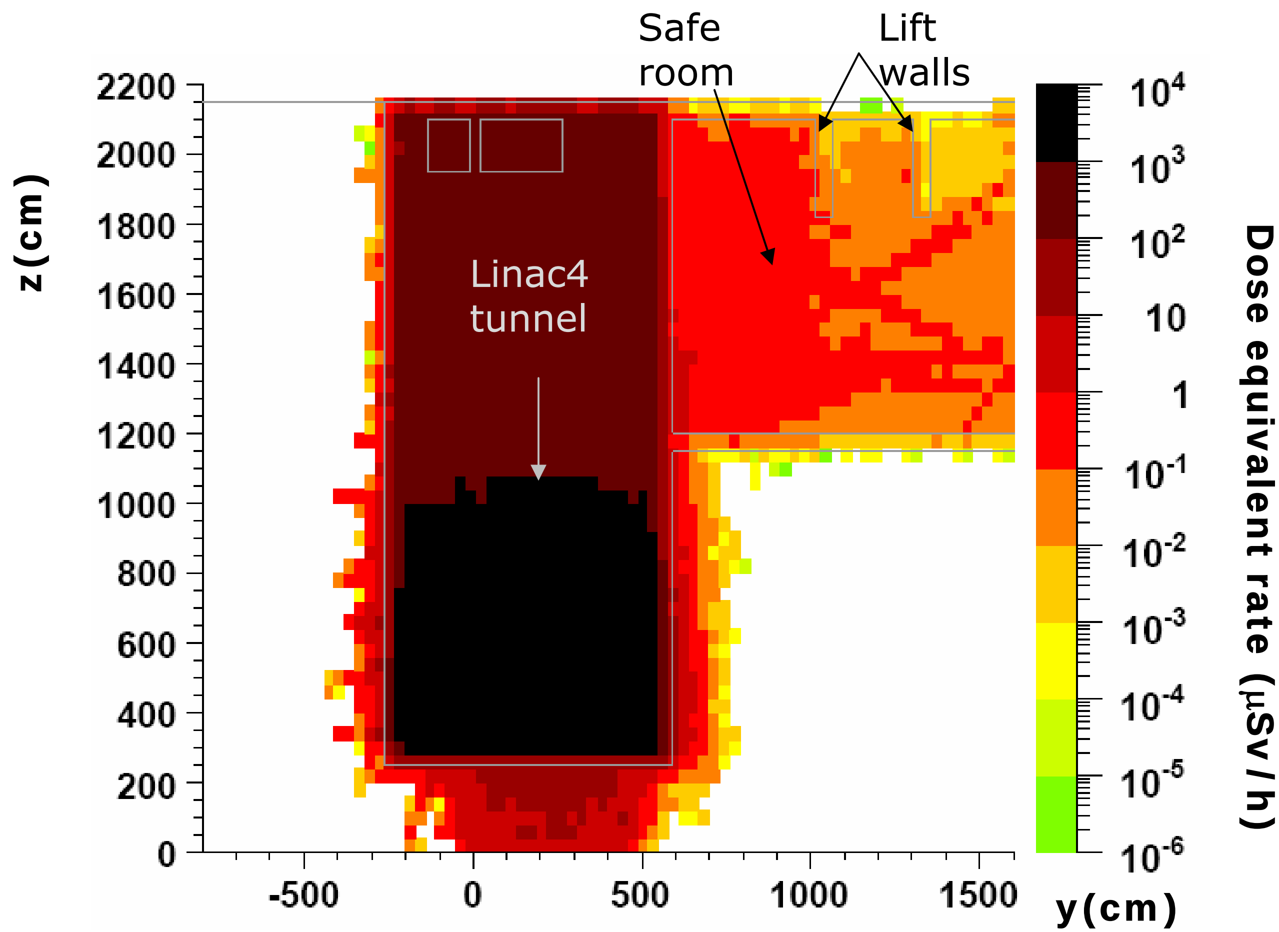
FLUKA geometry plot. Cross-sectional view of the low energy section of the Linac4. The view is looking downstream of the tunnel, towards the high-energy end of the accelerator.

Low-energy section: access maze



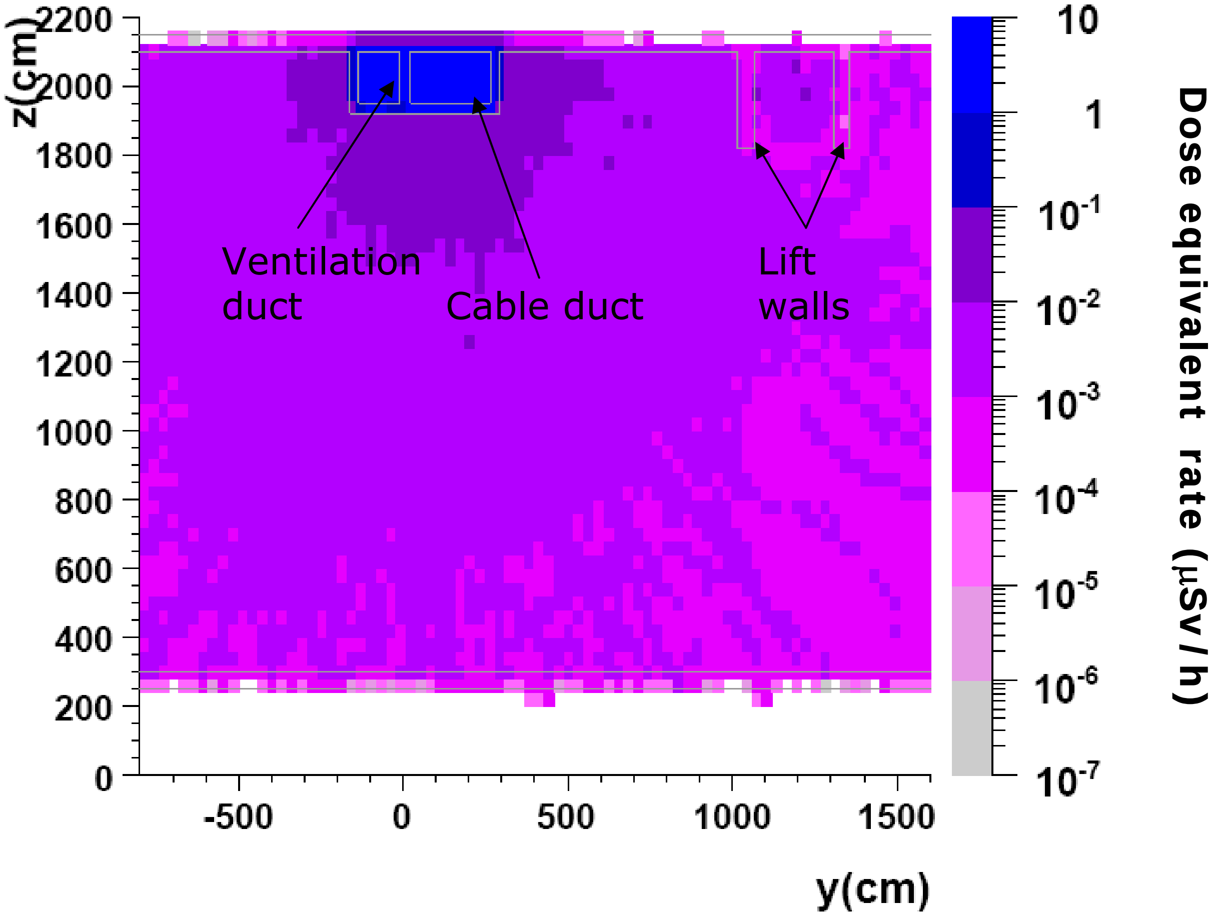
Beam loss in a 5 x 5 x 5 cm^3 copper target, 10 W, 11 MeV. Cross sectional view of the Linac4 tunnel and of the access area with the addition of the maze. H*(10) in μSv/h.

Low-energy section: “safe room”



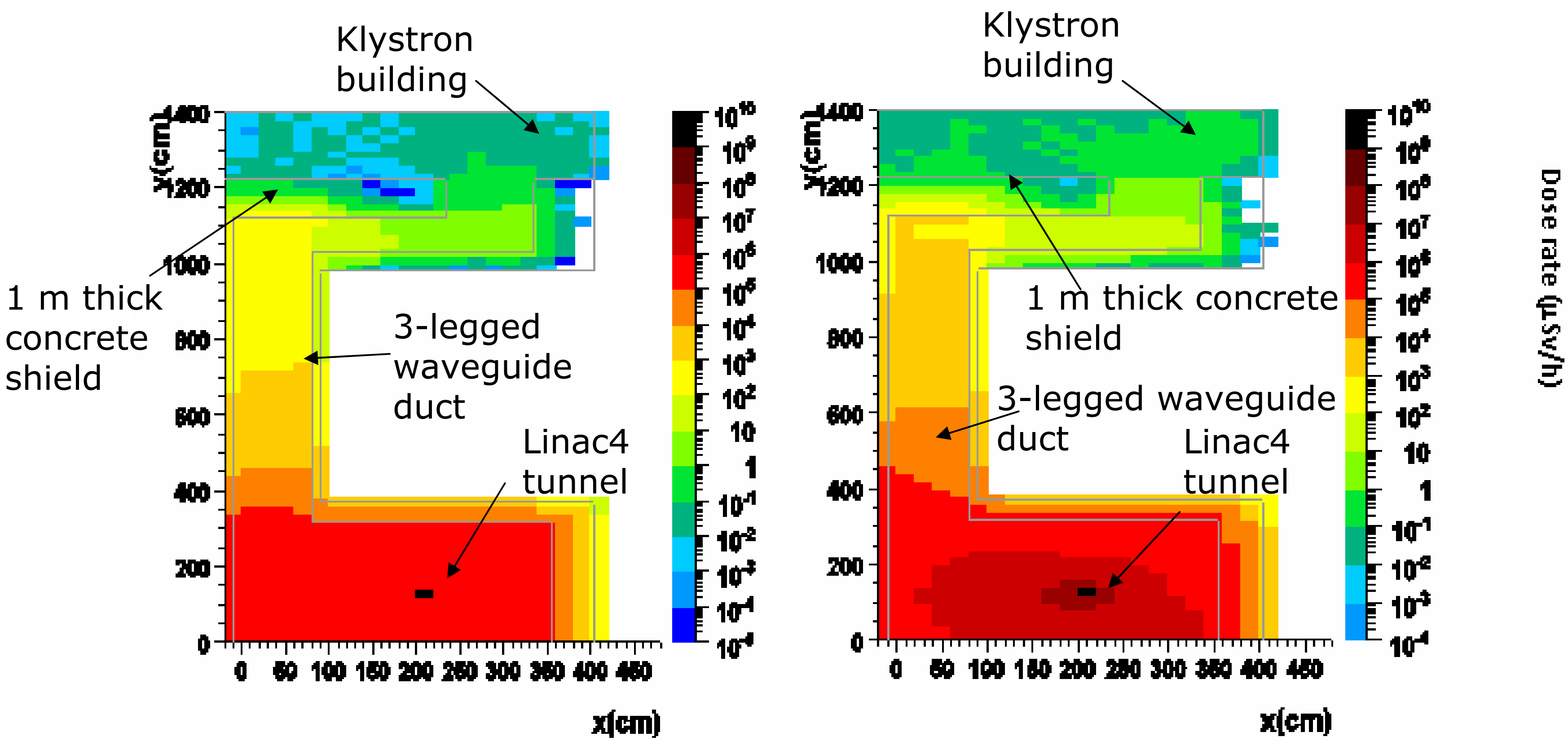
Beam loss in a 5 x 5 x 5 cm^3 copper target, 10 W, 11 MeV. Top-cross sectional view of the safe room at the height of 3.5 m with respect to the tunnel floor. H*(10) in µSv/h.

Low-energy section: gallery on first floor



Beam loss in a 5 x 5 x 5 cm^3 copper target, 10 W, 11 MeV. Top cross sectional view of the gallery on the first floor in the linac4 tunnel at an height of 7.6 m. H*(10) in μSv/h.

Waveguide duct



Beam loss in a 5 x 5 x 5 cm^3 copper target, 10 W, 160 MeV. Cross sectional view of the Linac4 tunnel, the 3-leg duct and the klystron building. Left: dose equivalent rate in the first duct. Right: dose equivalent rate in the second duct. H*(10) in μSv/h.

Conclusions

- Civil-engineering related RP studies essentially completed
- Upcoming studies:
  - dump at the end of the linac
  - induced radioactivity in materials, water, air