Shielding Design for the Imaging and Medical Therapy Beamline at the Australian Synchrotron

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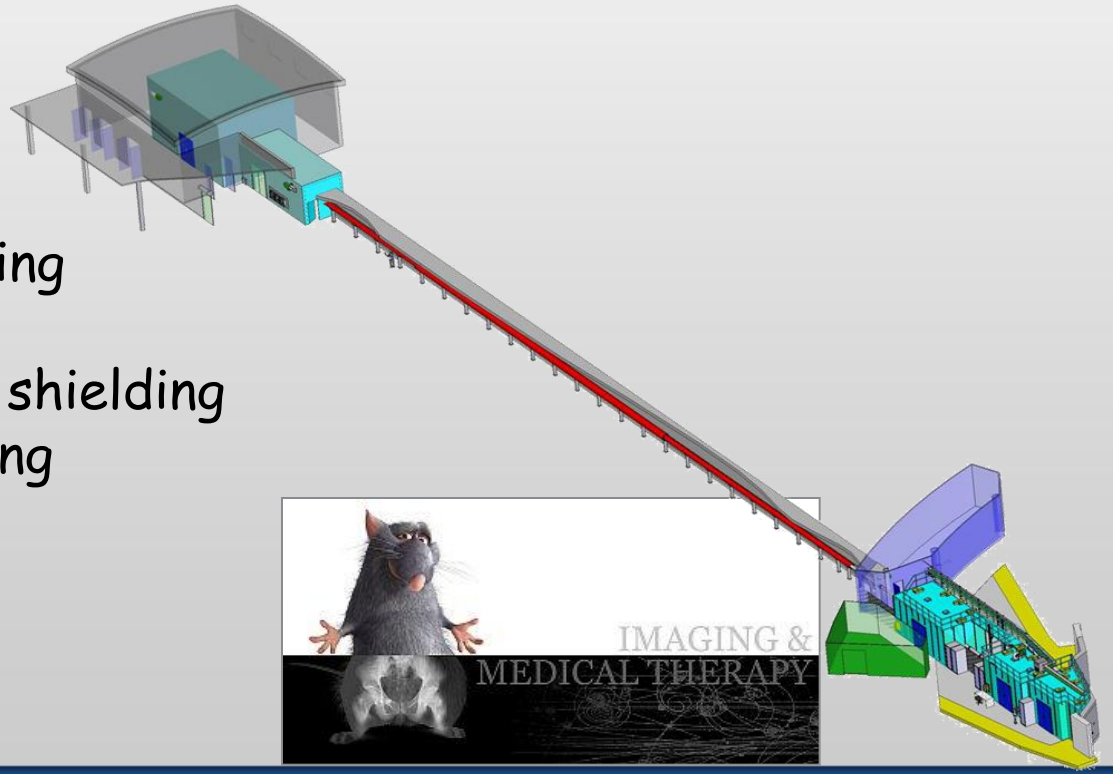
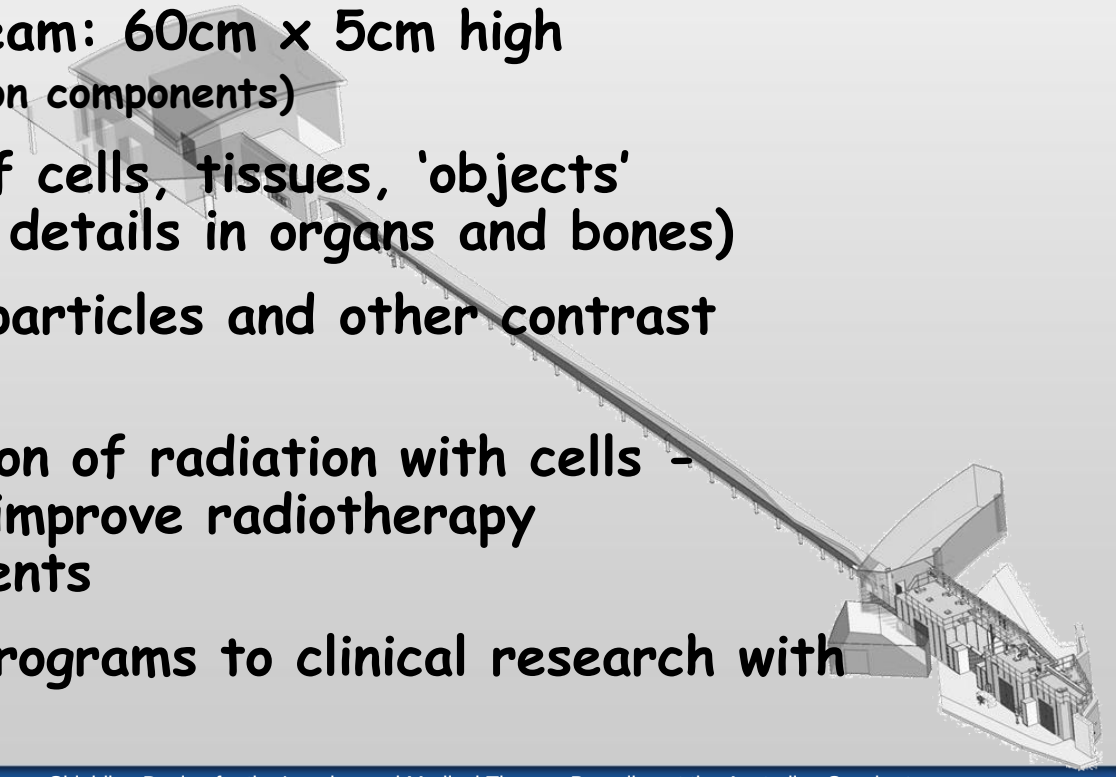
Contents



Science and Techniques – The Main Drivers

- 136m to sample
- World's biggest X-ray beam: 60cm x 5cm high
  (with maximum power > 20kW on components)
- High resolution imaging of cells, tissues, 'objects' (tumours, fine structural details in organs and bones)
- Cell tracking using nano-particles and other contrast markers
- Research in the interaction of radiation with cells – cancer and healthy - to improve radiotherapy prescriptions and treatments
- Extension of the above programs to clinical research with patients



Imaging and Medical Facility

Enclosure 1A – Optics & beam conditioning
Enclosure 1B – Fast white beam imaging and therapy
Enclosure 2A – Beam conditioning and shutters (*optics*)
Enclosure 2B – Medium and high resolution imaging, including mammography
Near beam surgery and preparation facility

Beam and animal transfer tunnel

MCSS, CSIRO, biomedical Imaging

Satellite building with:
- Bunker 3A – Optics and beam conditioning
- Bunker 3B – Very high resolution imaging, large objects (60 cm wide beam), patients
- Animal holding and preparation facility
- 2nd floor: Wet labs, clinical suite

Source characteristics

Shielding design assumptions

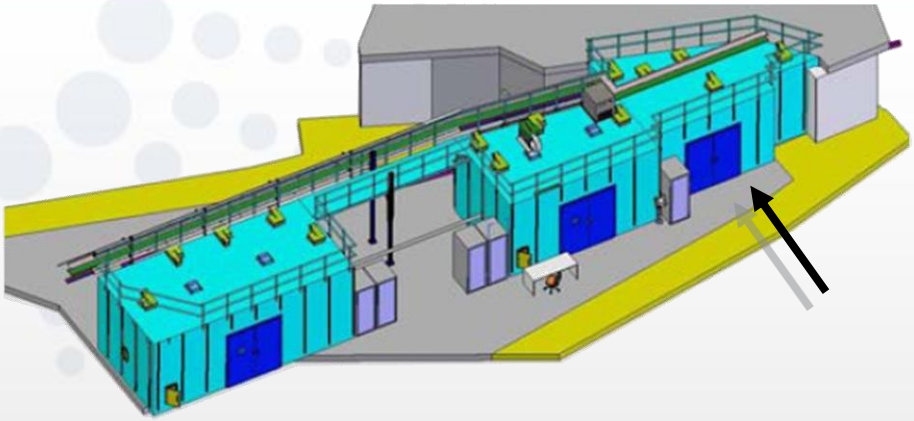
- Electron energy: 3 GeV
- Stored beam current: 400 mA
- Length straight section: 7.6 m
- Average pressure in the straight section: 2. × 10^{-9} mbar

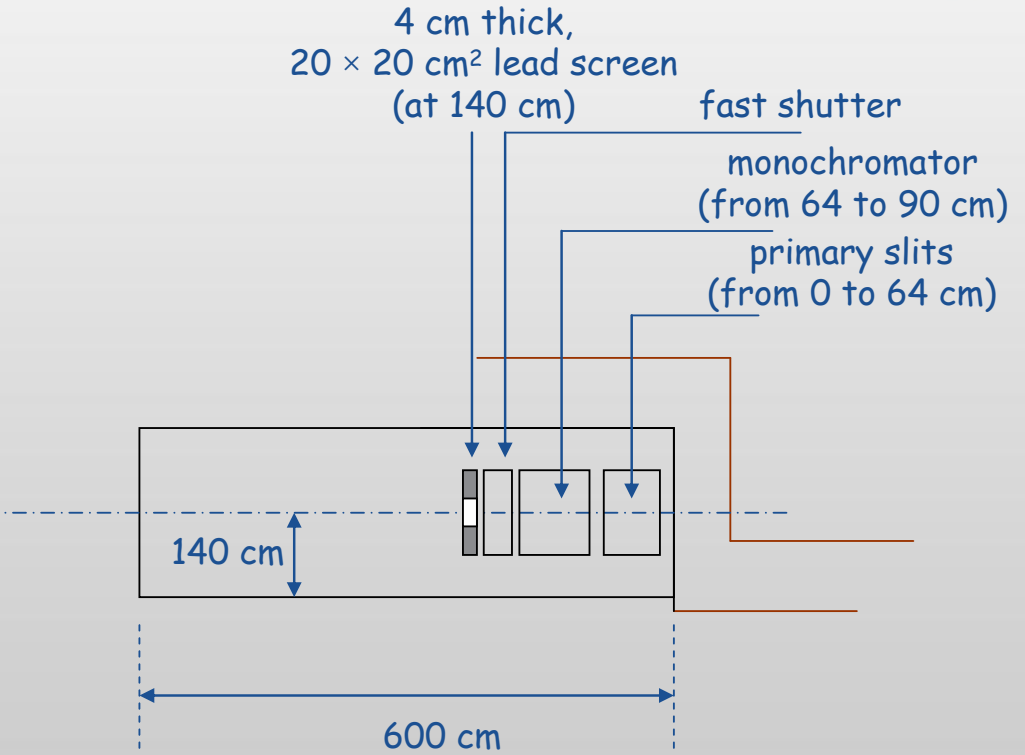
molecule	Relative pressure (%)	Partial pressure (mbar)
H_2	71	1.42×10^{-9}
CO	20	0.4×10^{-9}
CO_2	4	0.8×10^{-10}
CH_4	2	0.4×10^{-10}
H_2O	3	0.6×10^{-10}

Insertion device

- Present
  - 2.4 m, 85 mm
  - B_{max} = 1.4 T (E_c = 8.3 keV, K = 11.1)
  - P_{total} = 5.2 kW
- Future
  - 1.5 m, 38 mm
  - B_{max} = 4.17 T (E_c = 25 keV, K = 18.7)
  - P_{total} > 30 kW

Optics hutch 1A Bremsstrahlung



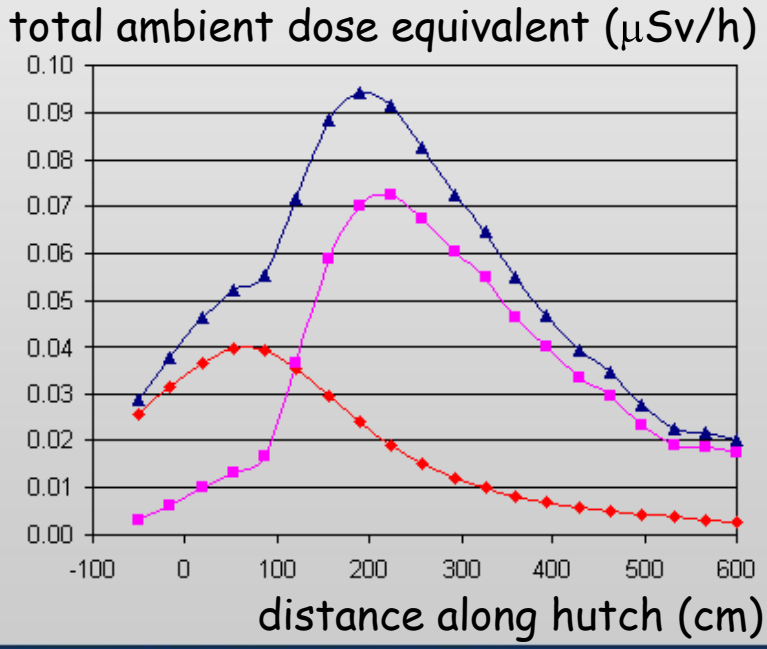


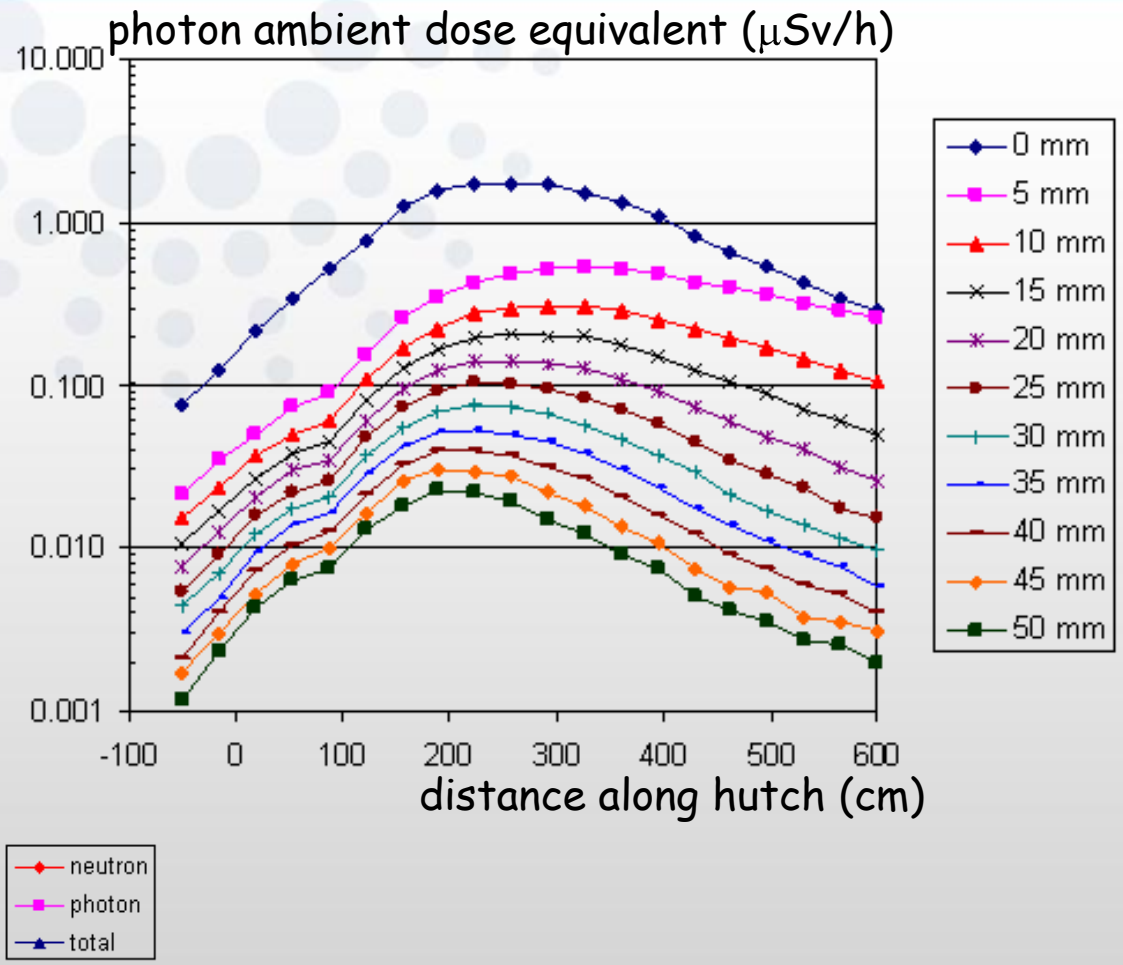
- Electron energy: 3 GeV
- Stored beam current: 400 mA
- Length straight section: 7.6 m
- Average pressure 2. × 10^{-9} mbar

- Design goal: < 0.1 μSv/h

Optics hutch 1A Bremsstrahlung

Sidewall

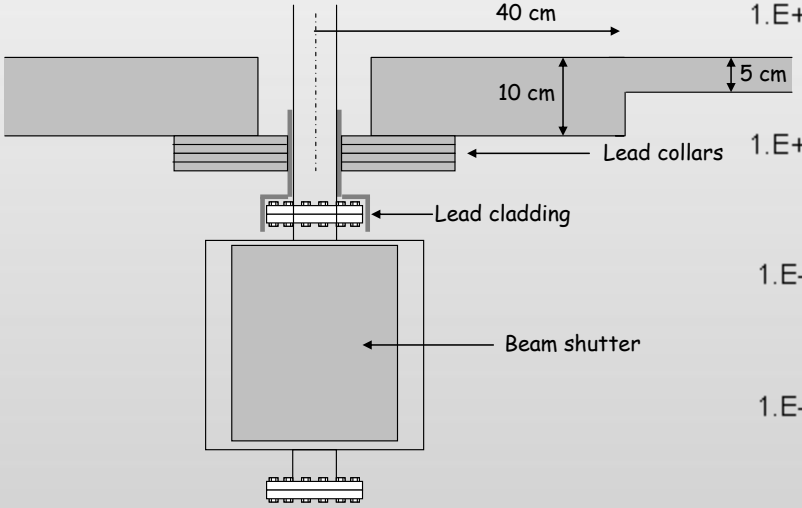


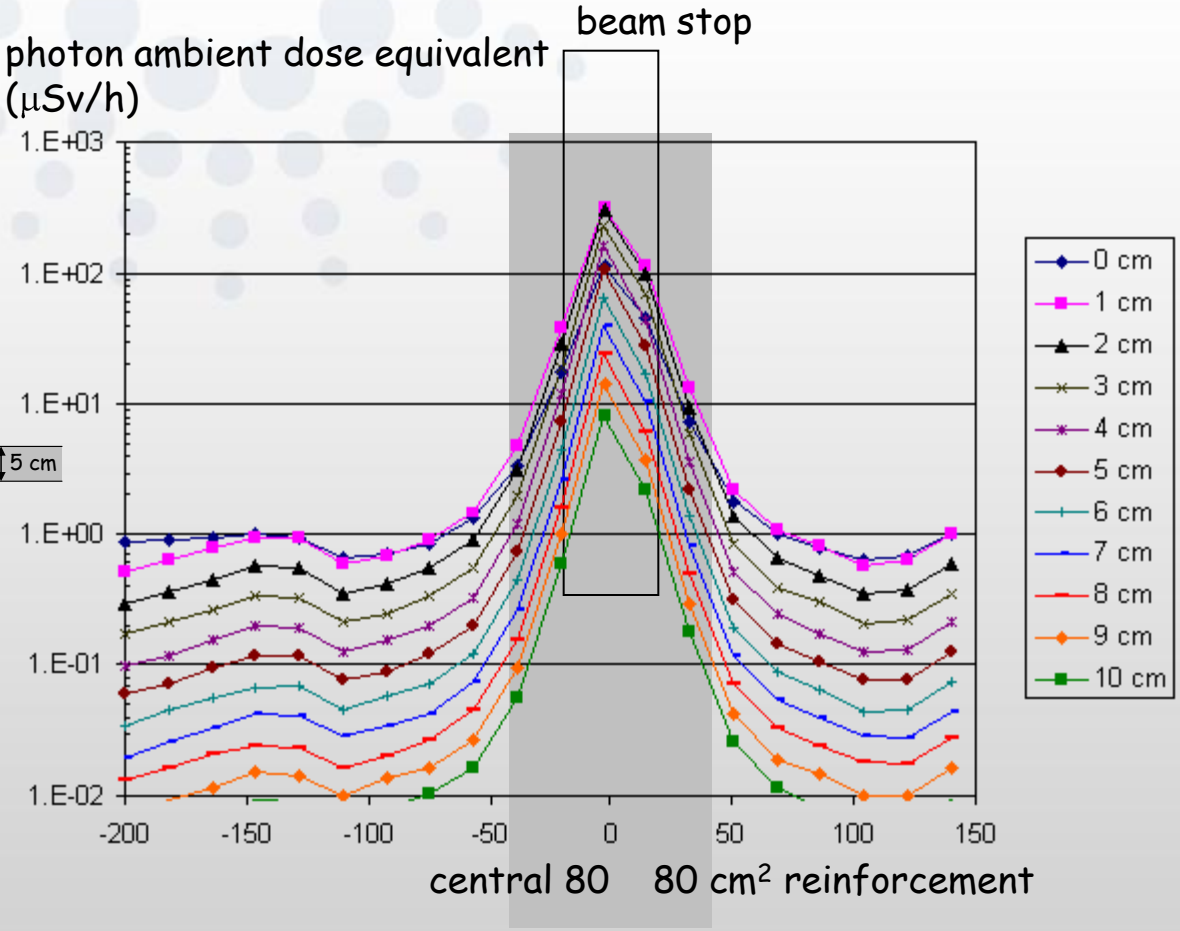


25 mm Pb sidewall

Optics hutch 1A Bremsstrahlung

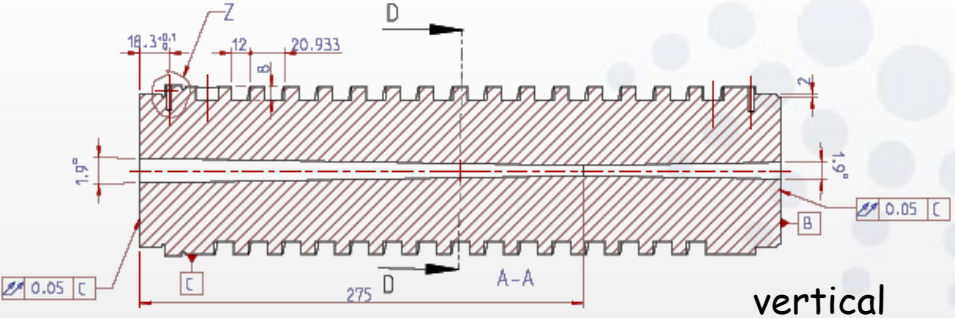
Backwall



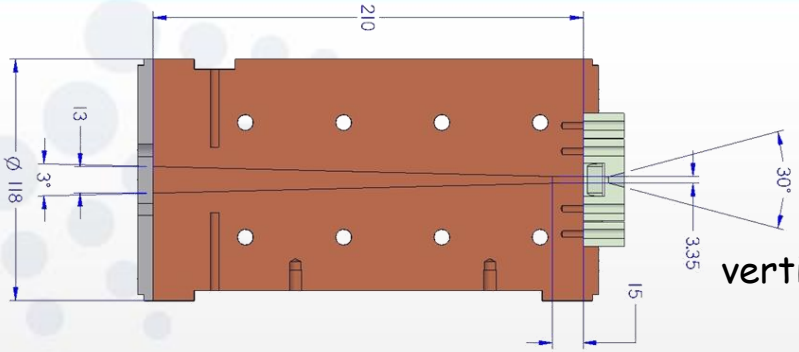


50 mm Pb backwall
+ 50 Pb reinforcement in central 80 × 80 cm²
+ local screens behind main scattering sources

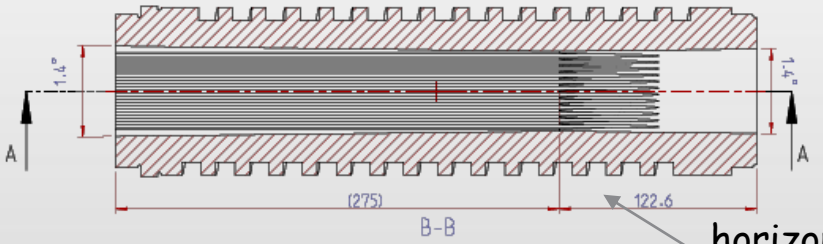
Front-end collimation



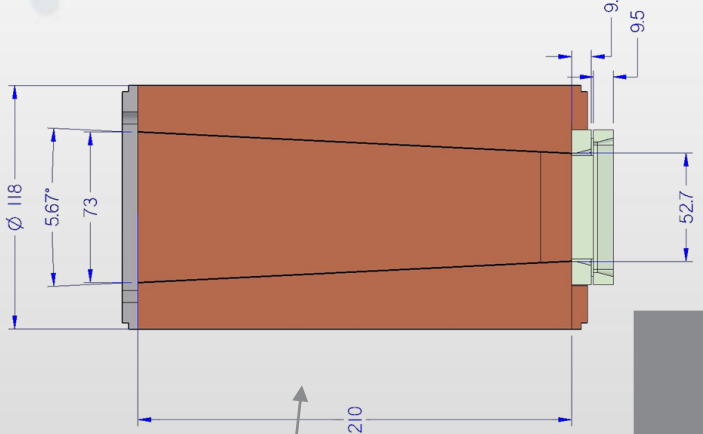
vertical



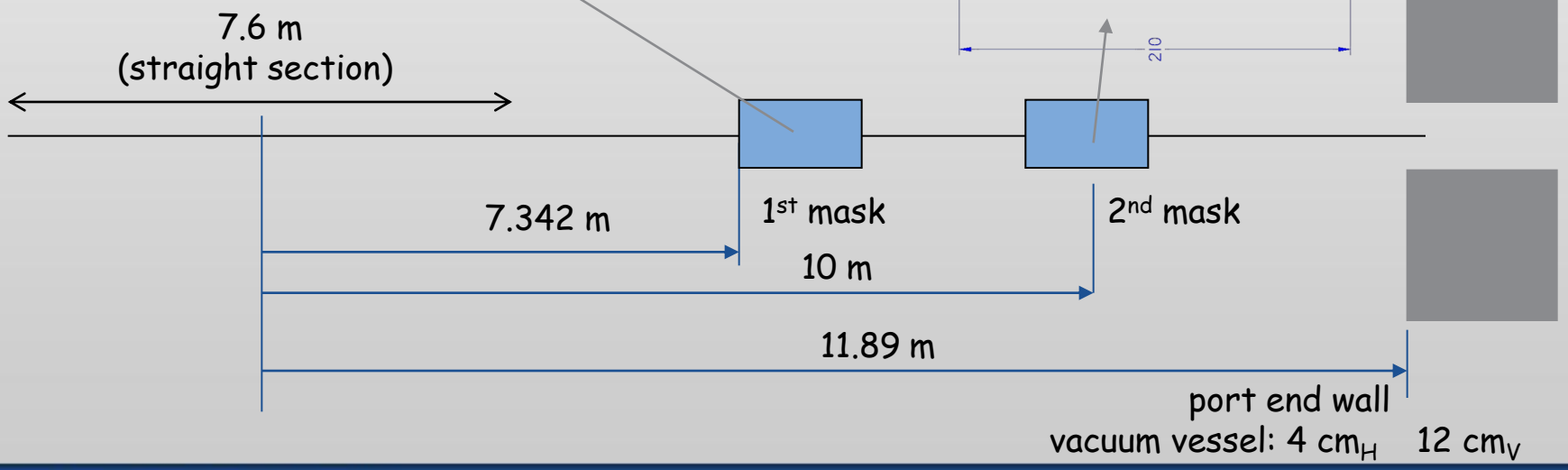
vertical



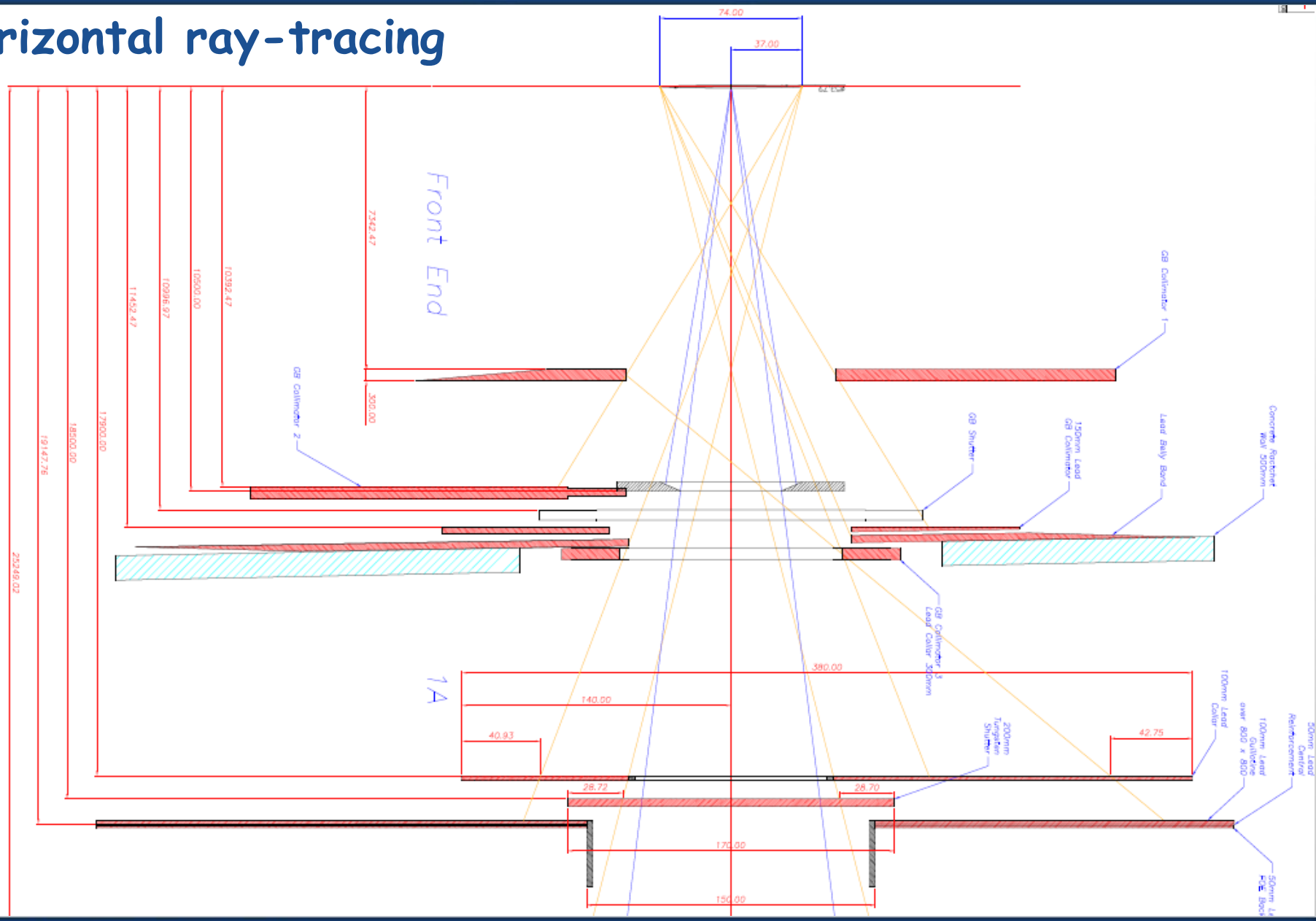
horizontal



horizontal

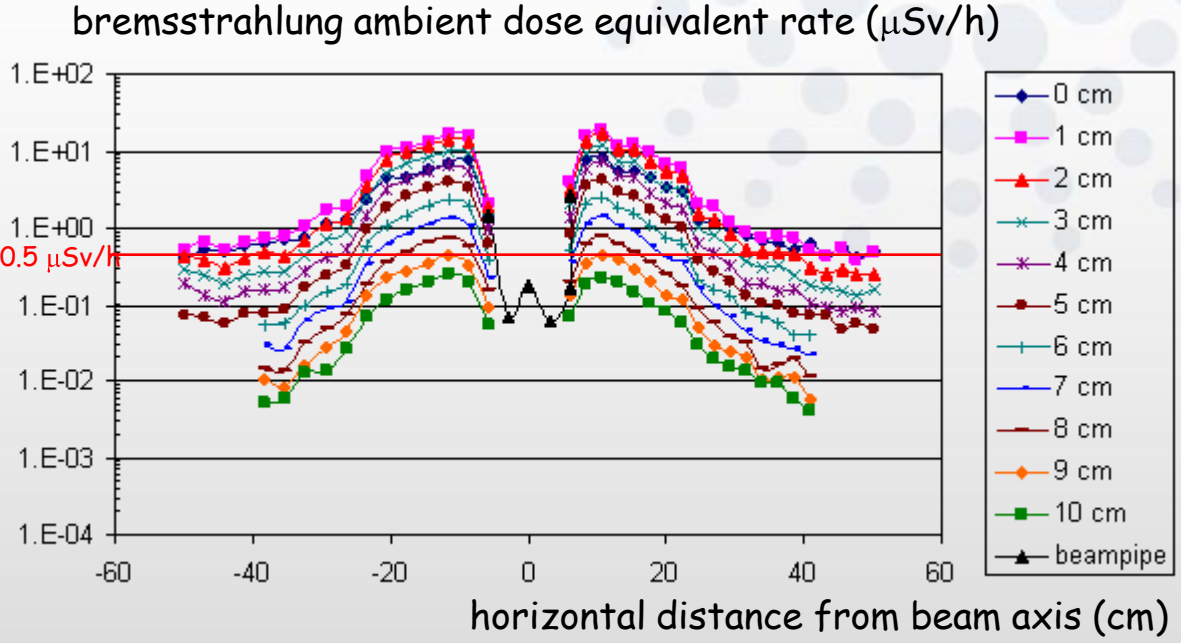


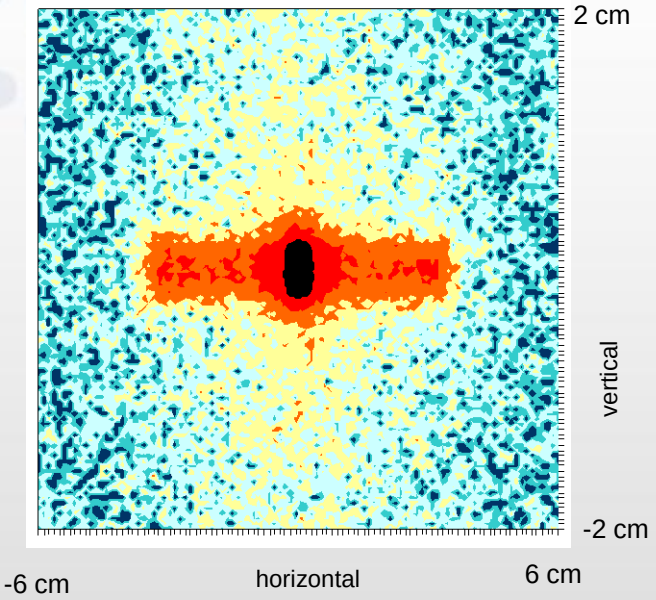
Horizontal ray-tracing

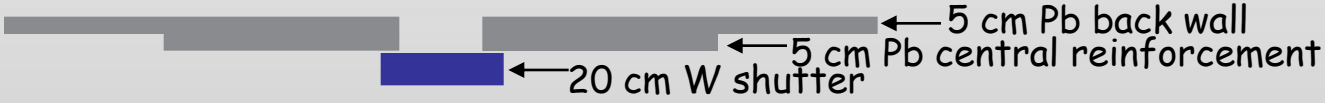


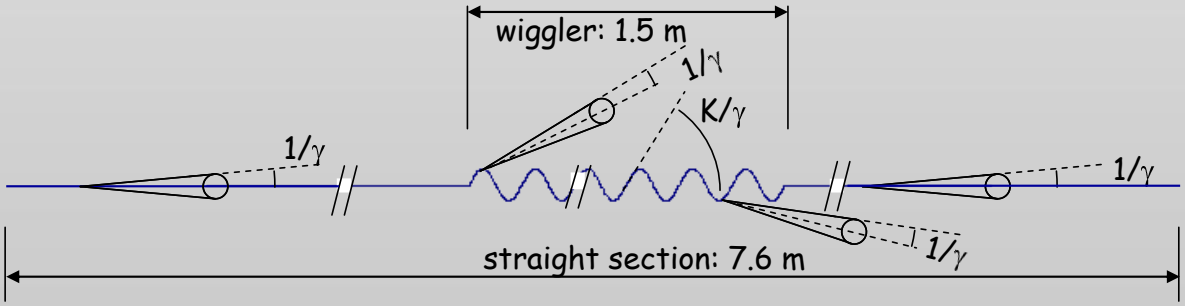
Central trajectory - with wiggler

bremsstrahlung ambient dose equivalent rate (μSv/h)

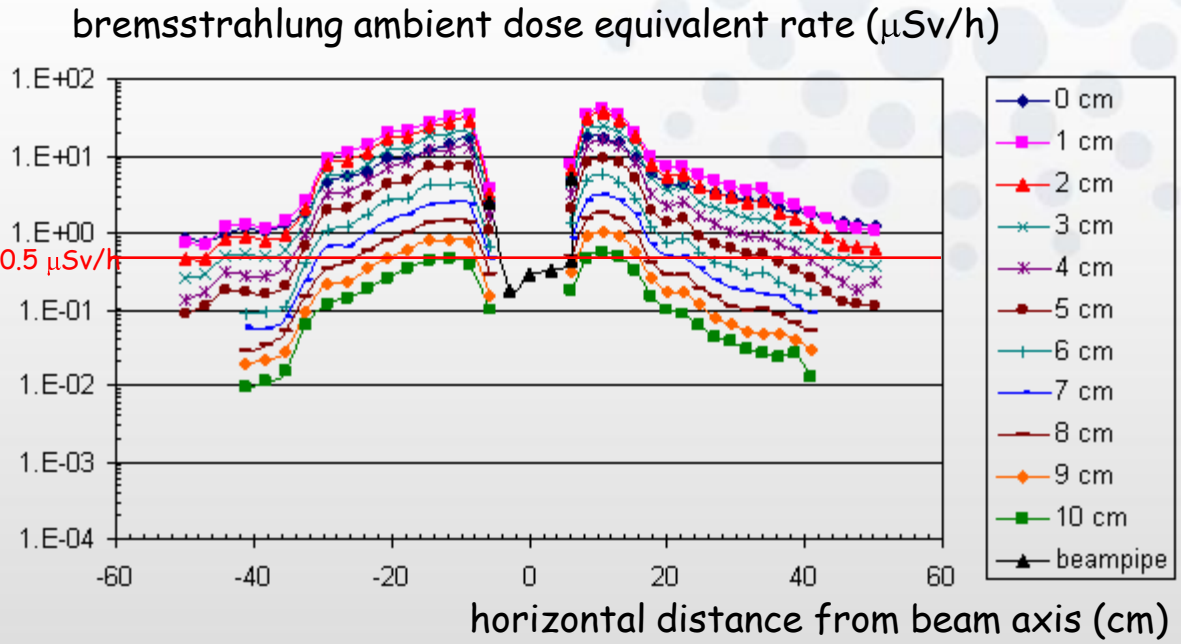


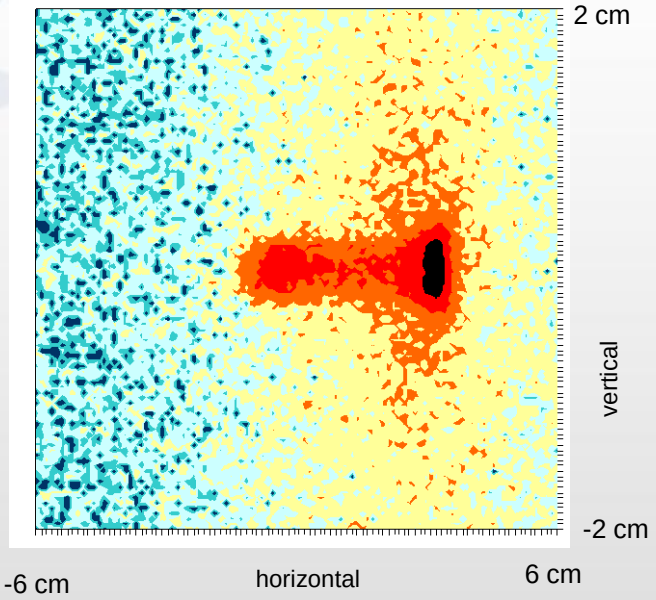


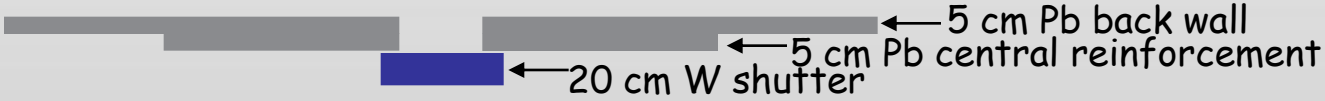


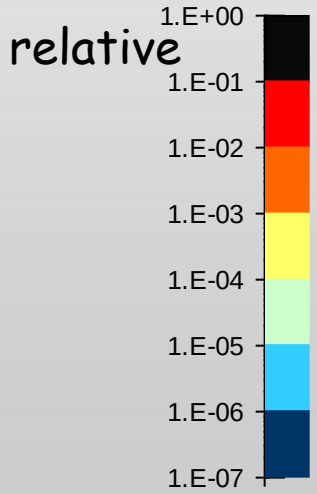


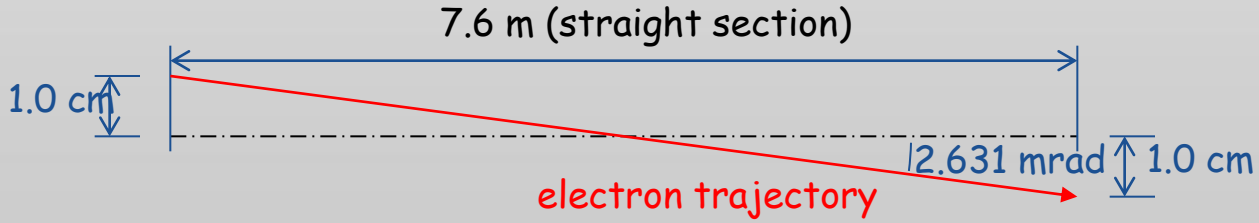
Horizontal offset ± 1 cm, 2.631 mrad - with wiggler



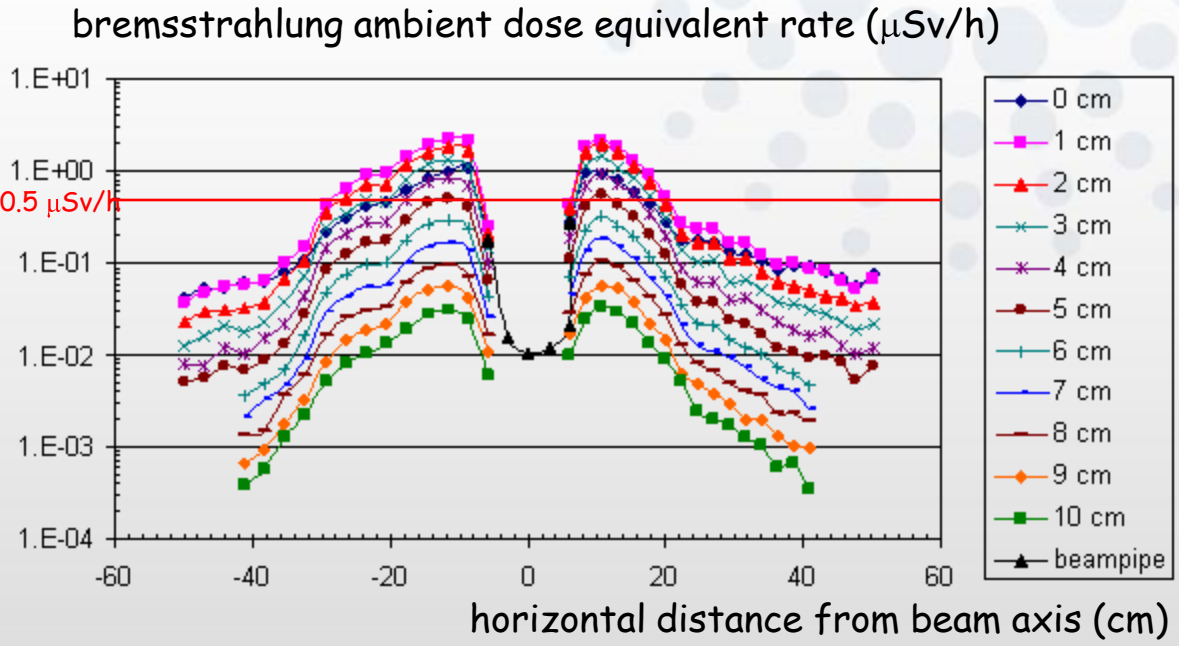


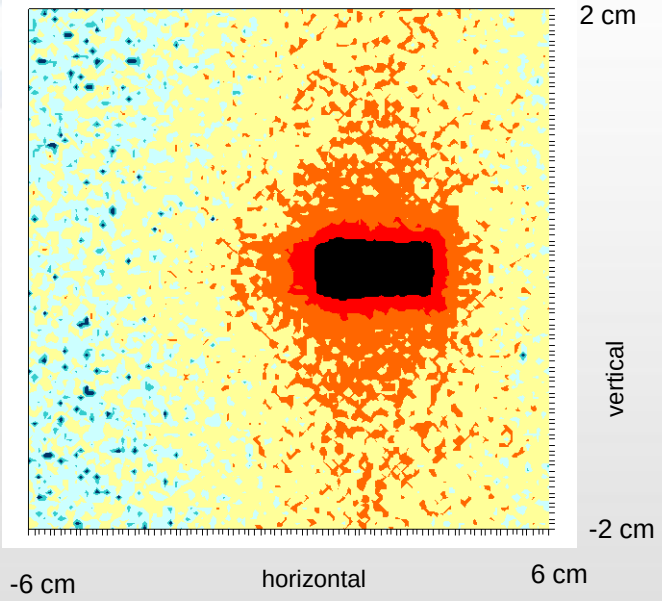


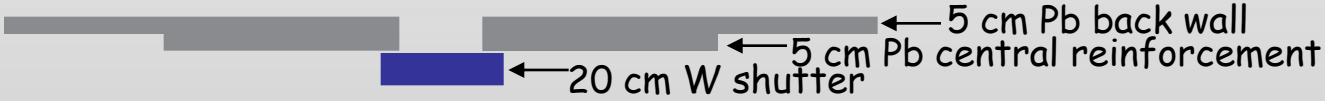


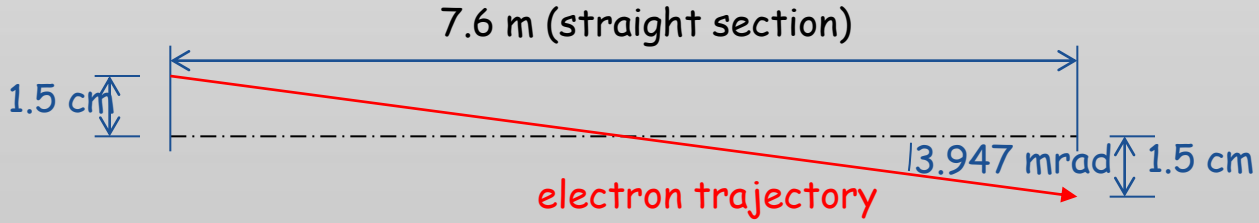


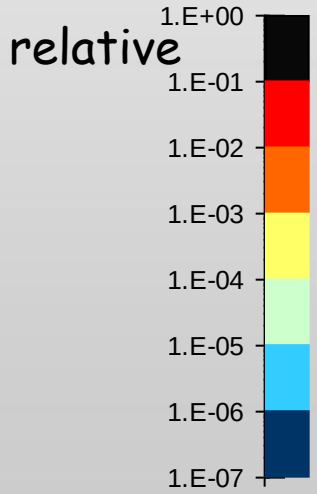
Horizontal offset ± 1.5 cm, 3.947 mrad - with wiggler



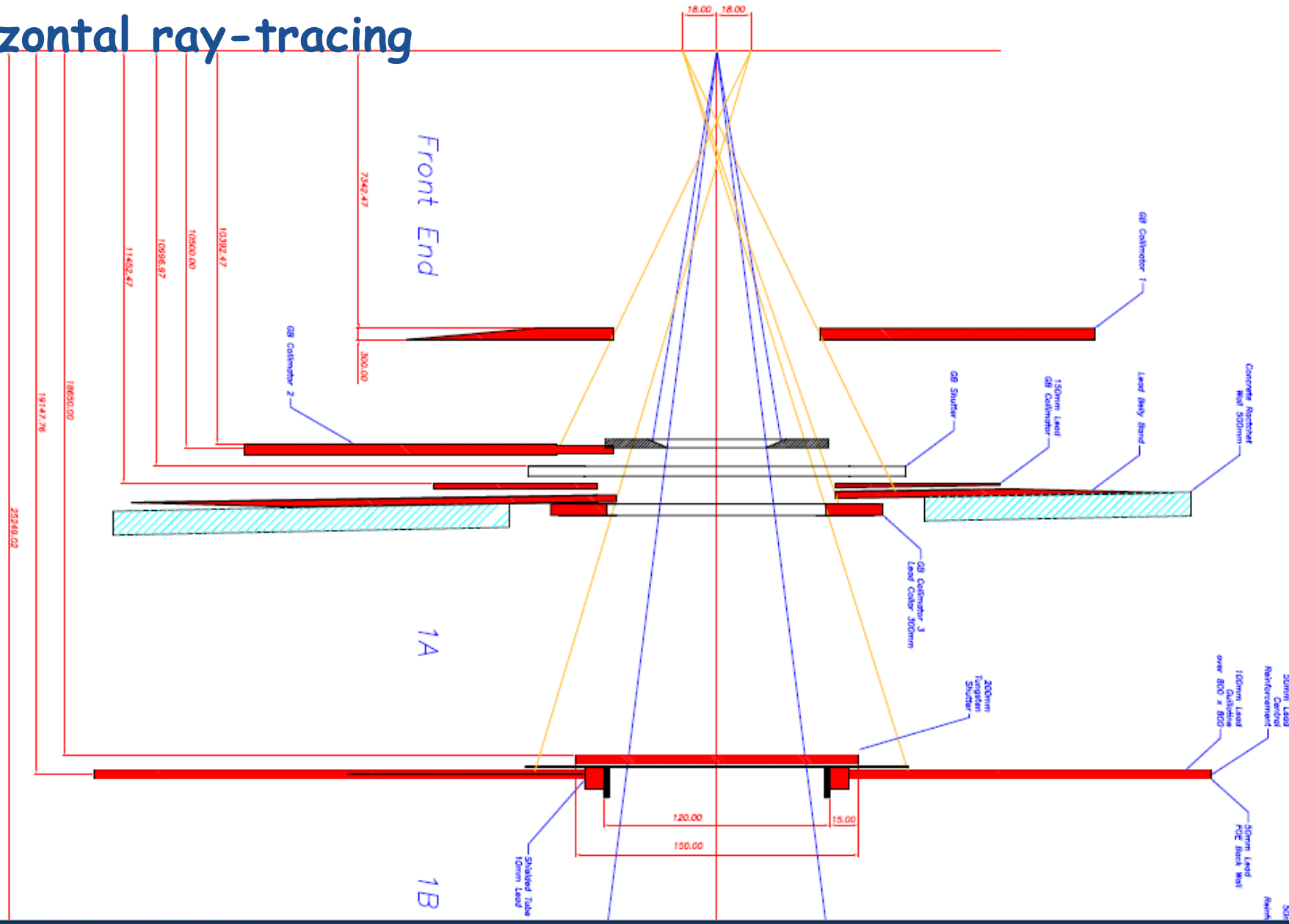




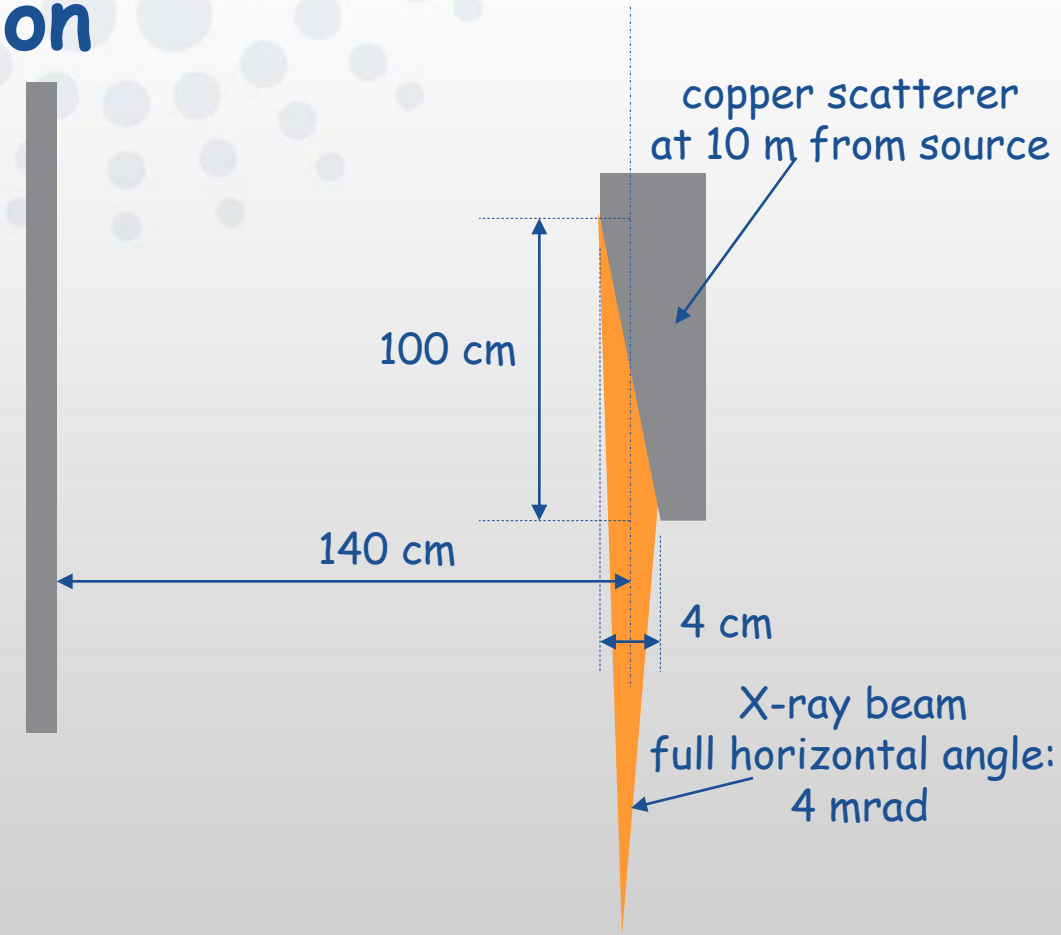




Horizontal ray-tracing



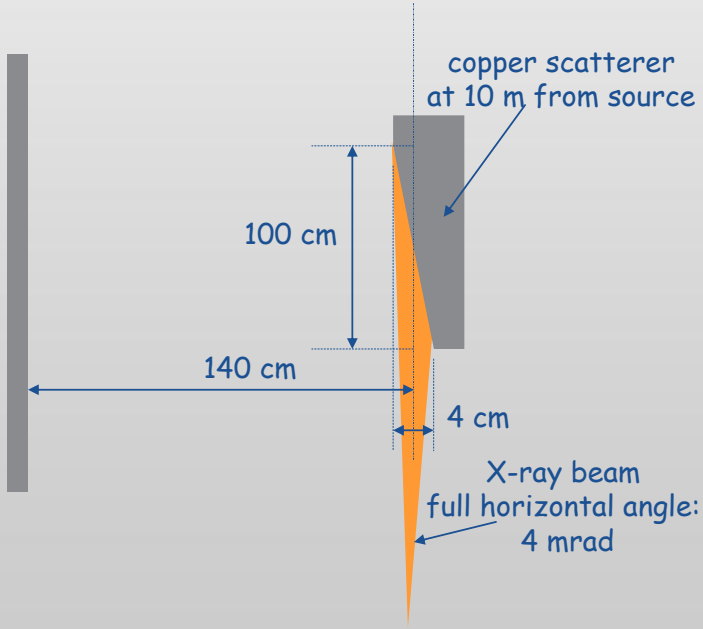
Optics hutch 1A
Synchrotron radiation

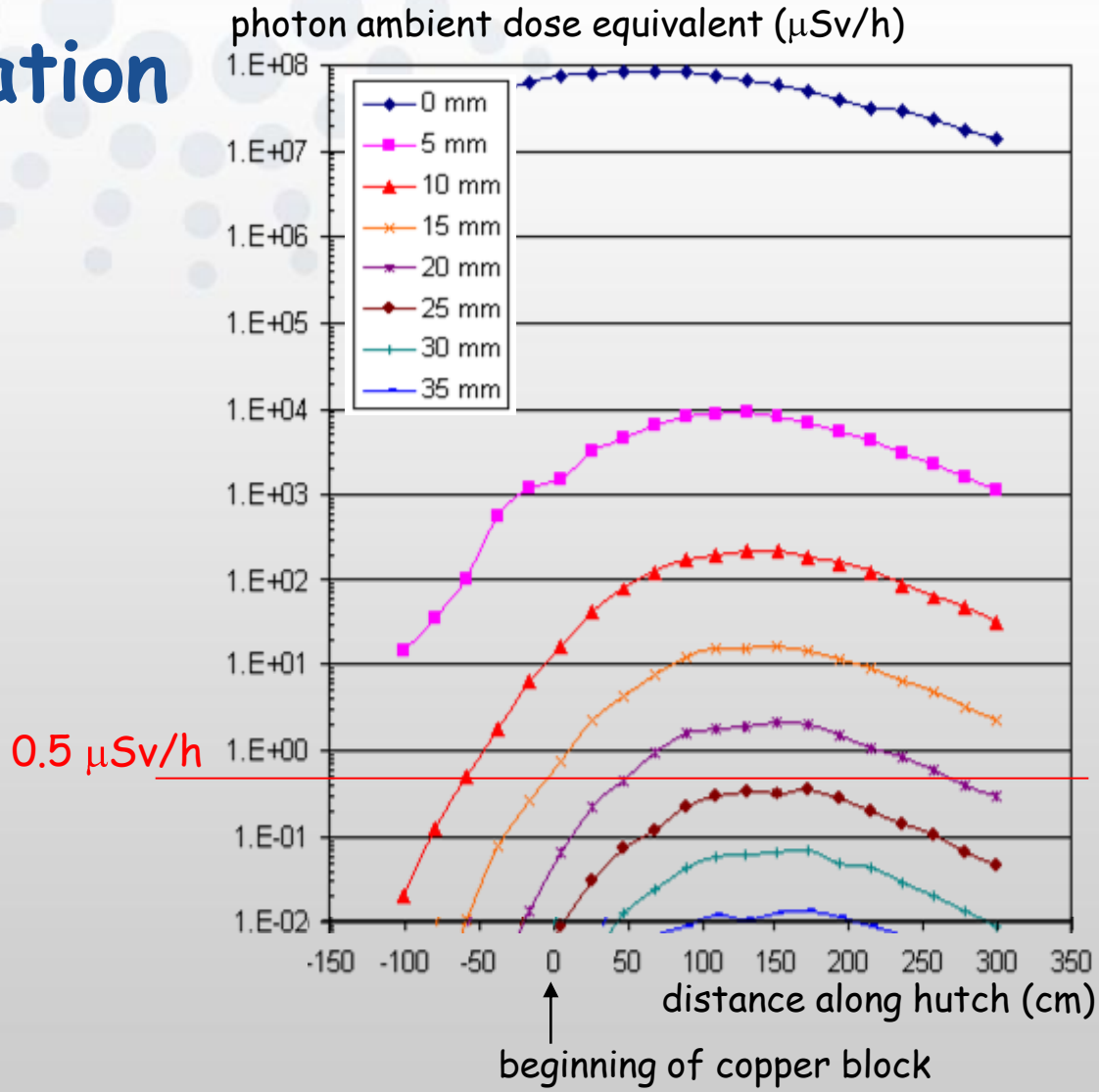


- Electron energy: 3 GeV
- Stored beam current: 400 mA
- Undulator:
  - Length: 1.5 m
  - Period: 48 mm
  - Maximum magnetic field: 4.17 T (E_c = 25 keV)
- Front end, full horizontal angle: 4 mrad

Optics hutch 1A
Synchrotron radiation

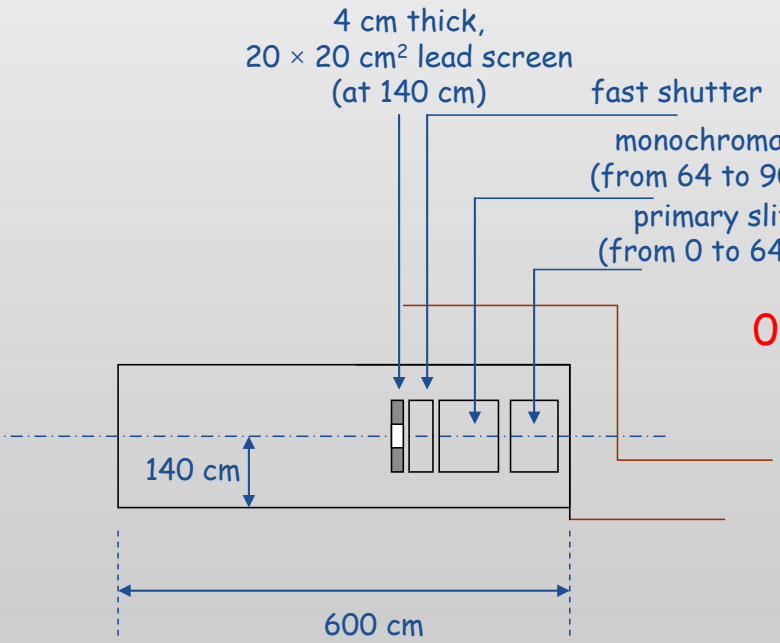
Sidewall

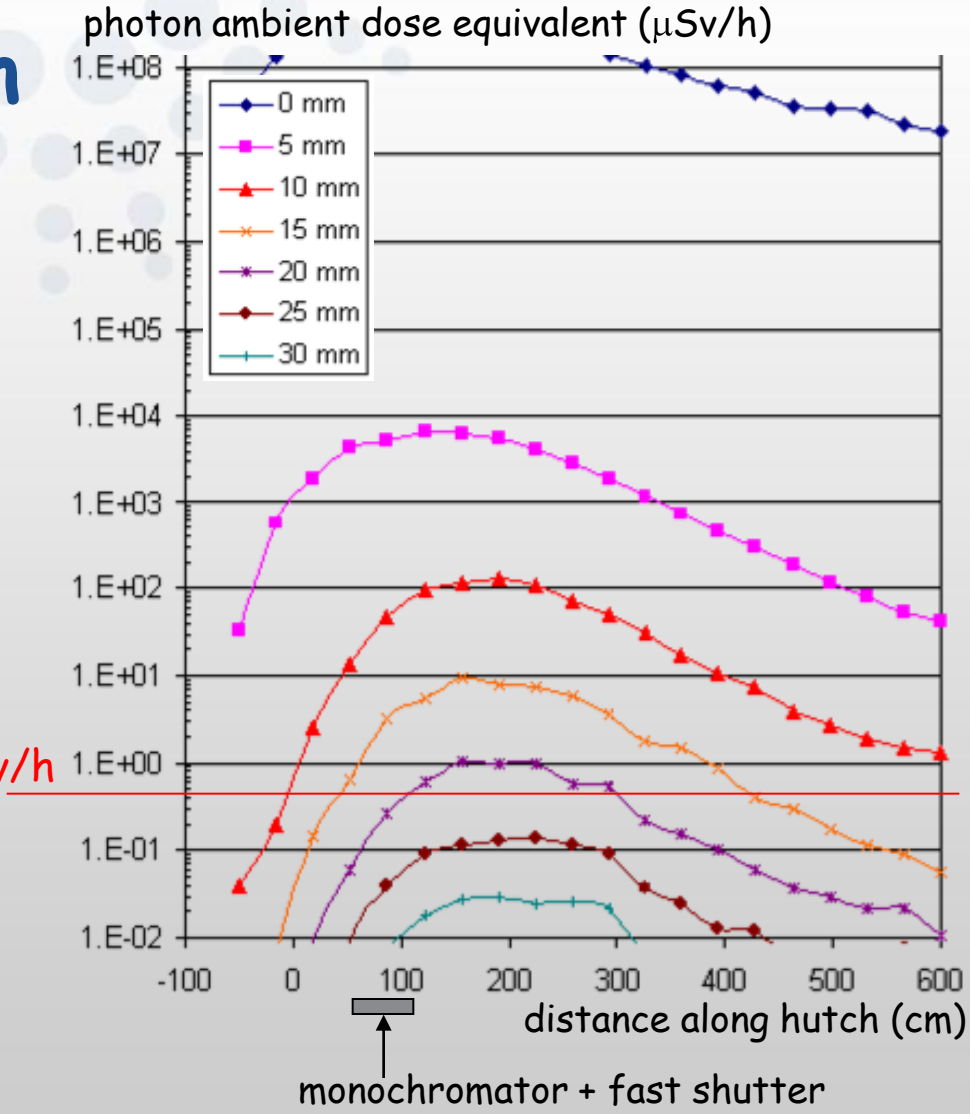




Optics hutch 1A
Synchrotron radiation

Sidewall





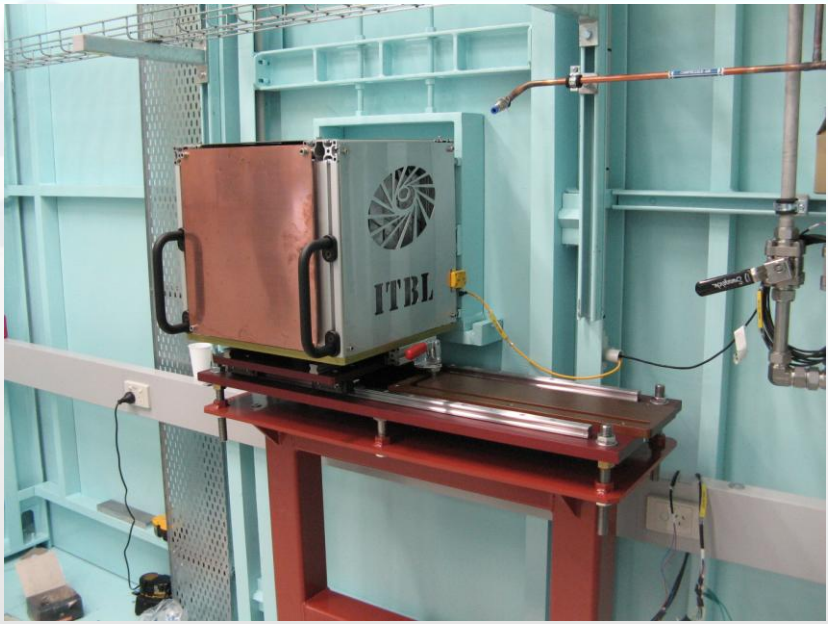

HYSTER

2B hutch

1A and 1B hutches

View from inboard side

December 2008



Personalised PSS panel

Manual Shutter 1B

Radiation Test 1A

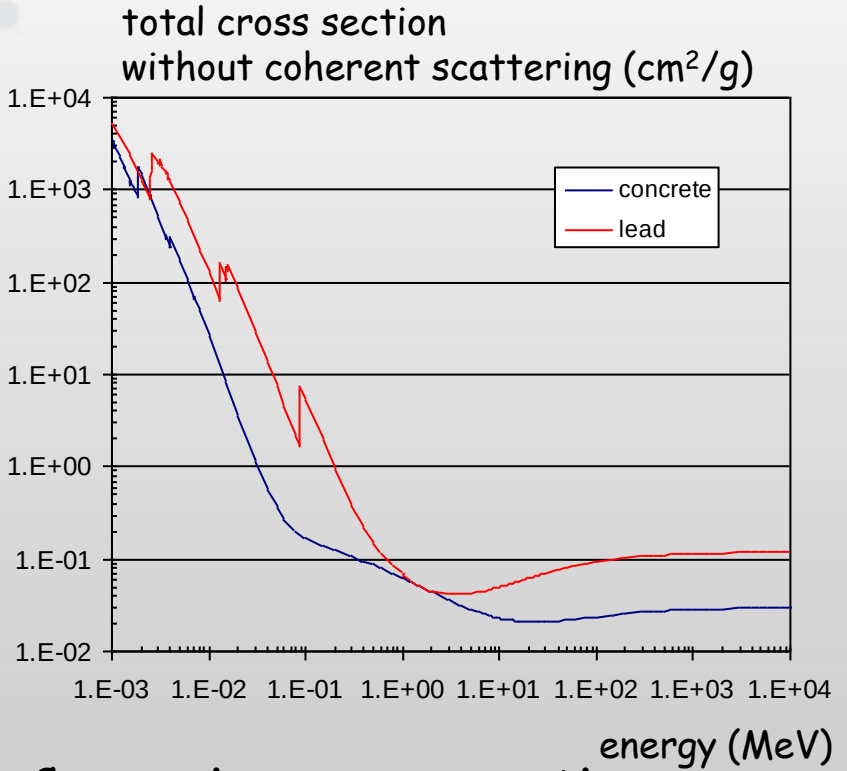
December 2008

Tunnel and satellite building Synchrotron radiation

Combination of lead, concrete and earth shielding
Concrete density: 2.4 g/cm^3
Earth density: 1.8 g/cm^3

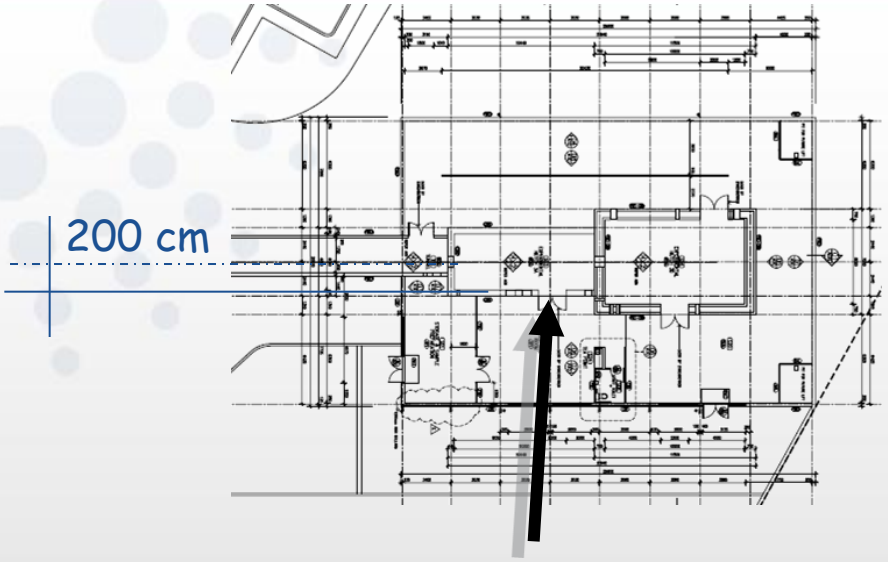
Element	Relative weight (percentage)
Oxygen	47.33
Sodium	2.84
Magnesium	2.11
Aluminum	8.24
Silicon	28.10
Potassium	2.64
Calcium	3.65
Iron	5.09

Elemental composition for soil

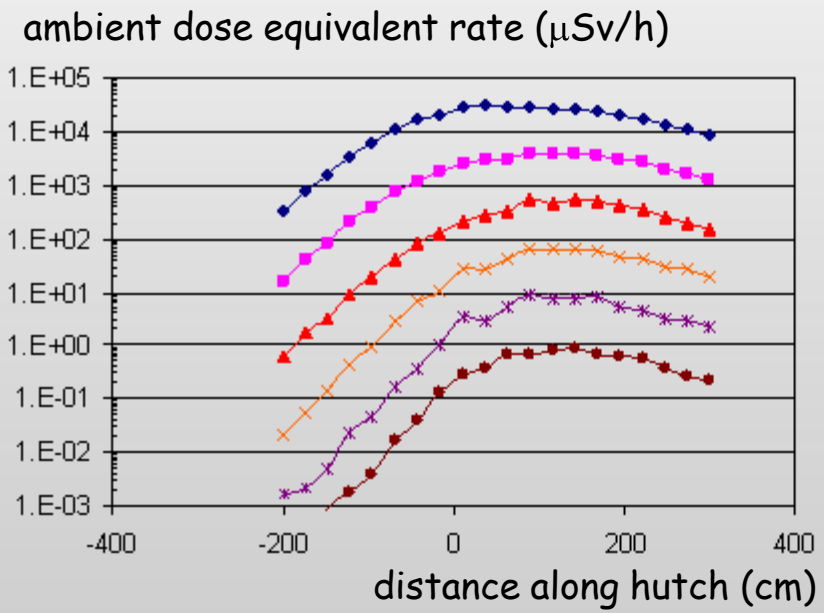


Comparison cross sections for lead and concrete

Optics hutch 3A
Synchrotron radiation



Sidewall



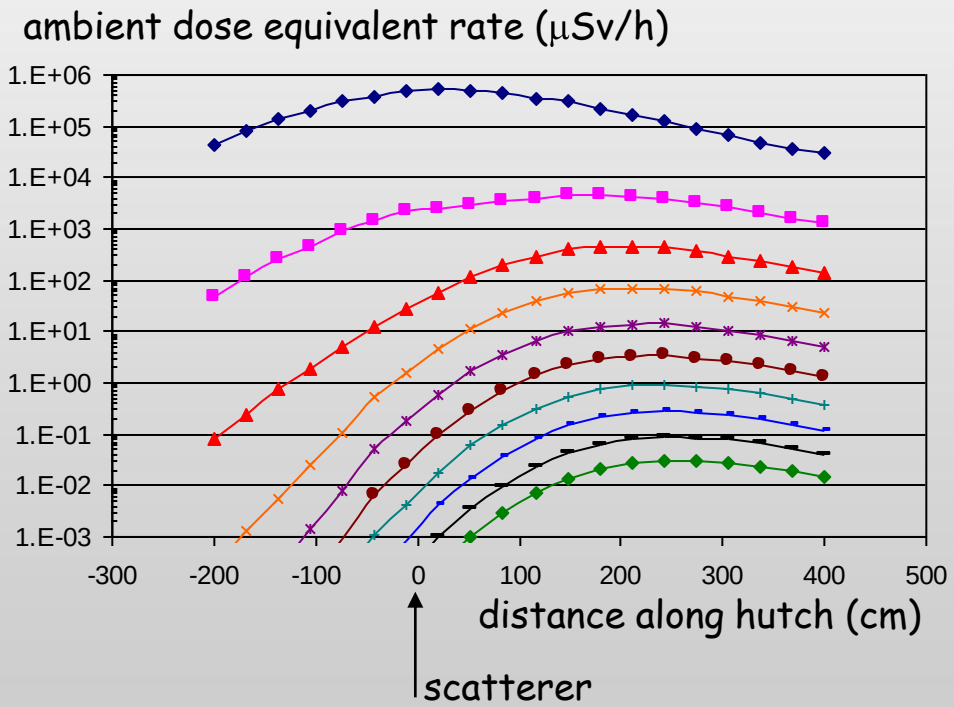
Distance beam axis to sidewall = 200 cm

Side wall:

44 cm concrete + 4 mm lead lining on inside

Optics hutch 3A
Synchrotron radiation

Door in side wall

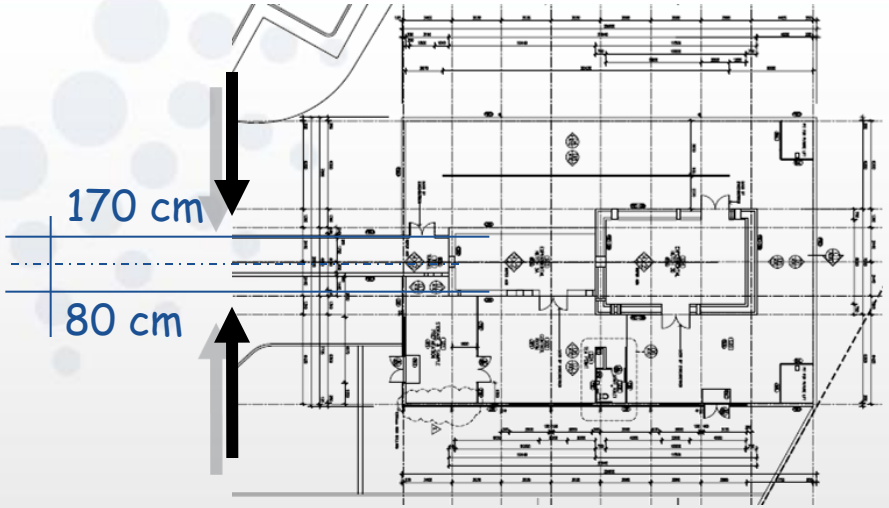


Distance beam axis to door = 244 cm

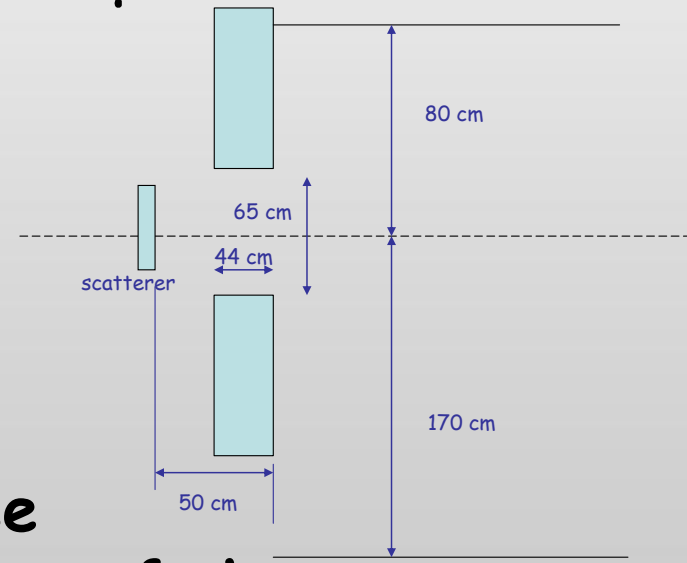
Door:

24 mm lead

Tunnel
Synchrotron radiation

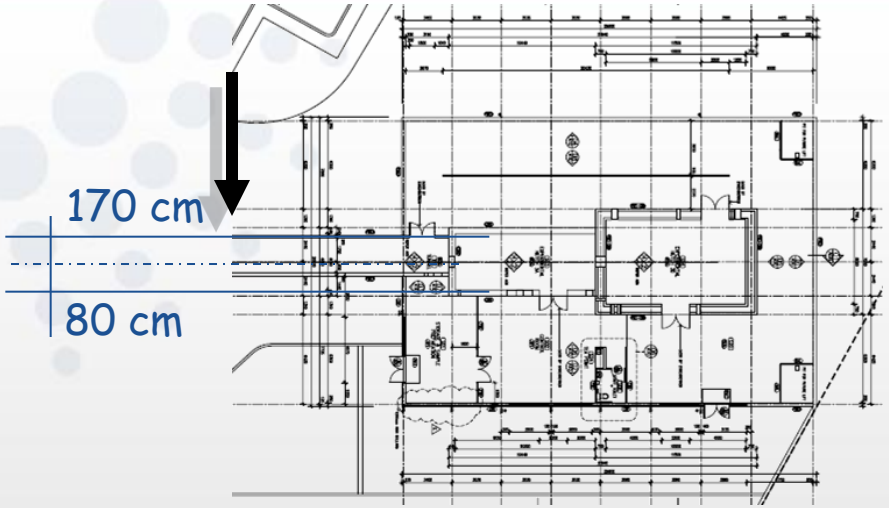


Shielding criteria:
Backscatter from 3A optics hutch: < 0.5 μSv/h

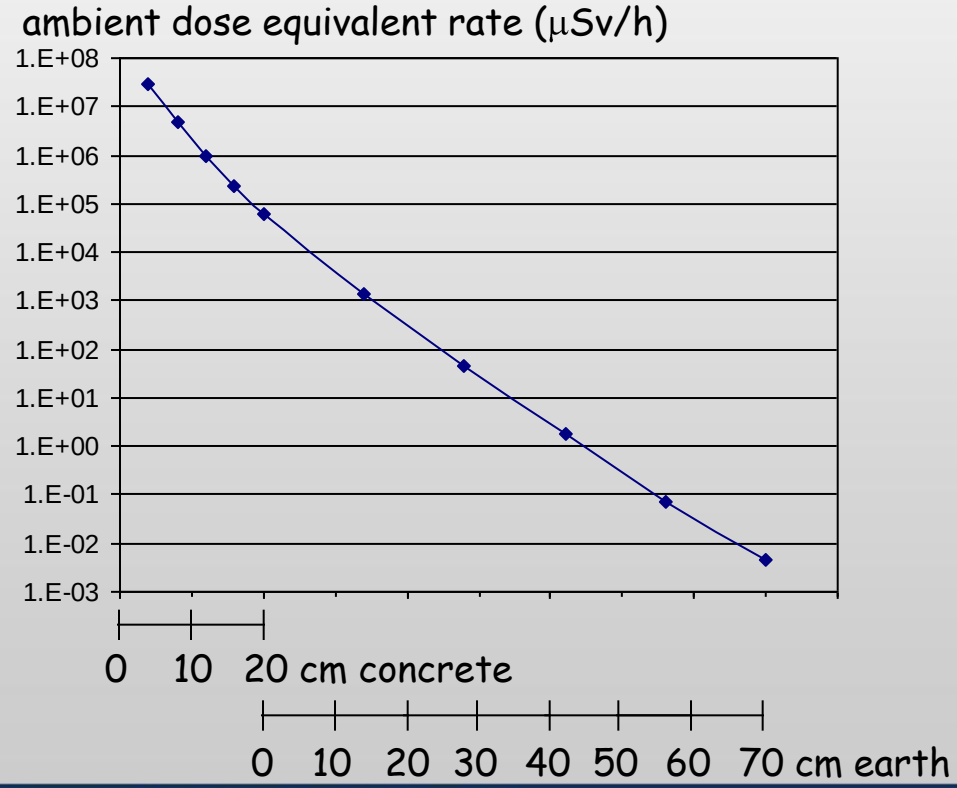


Air scatter: criteria on integrated dose
→ Personnel safety system, closure time of shutter

Tunnel
Synchrotron radiation



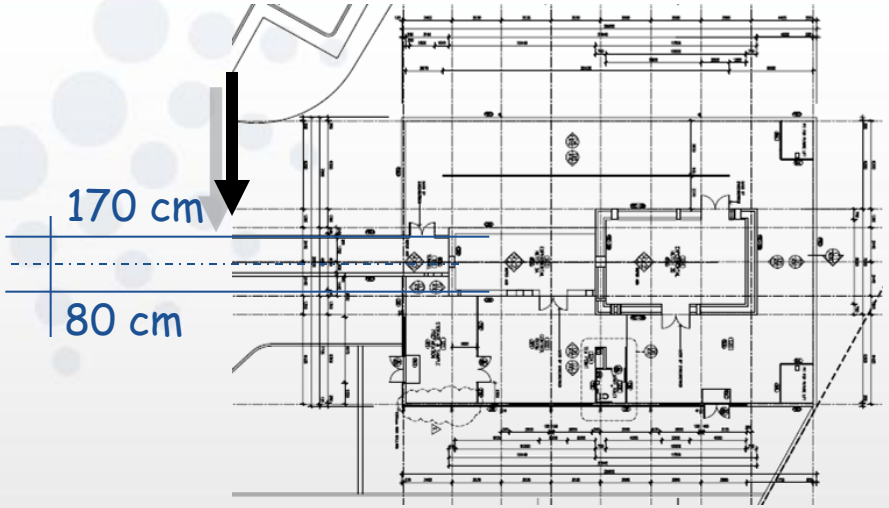
Air scatter
Outboard wall



Atmospheric pressure

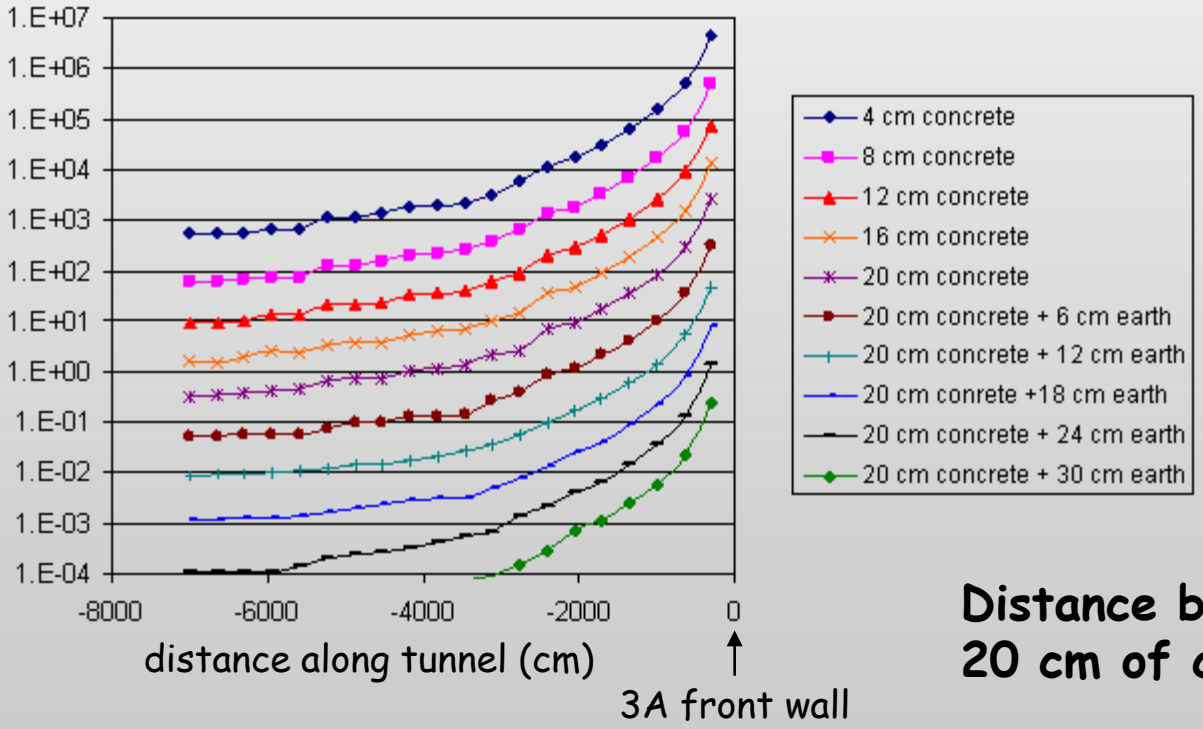
Distance beam axis to wall = 170 cm
20 cm of concrete + 70 cm of earth

Tunnel
Synchrotron radiation



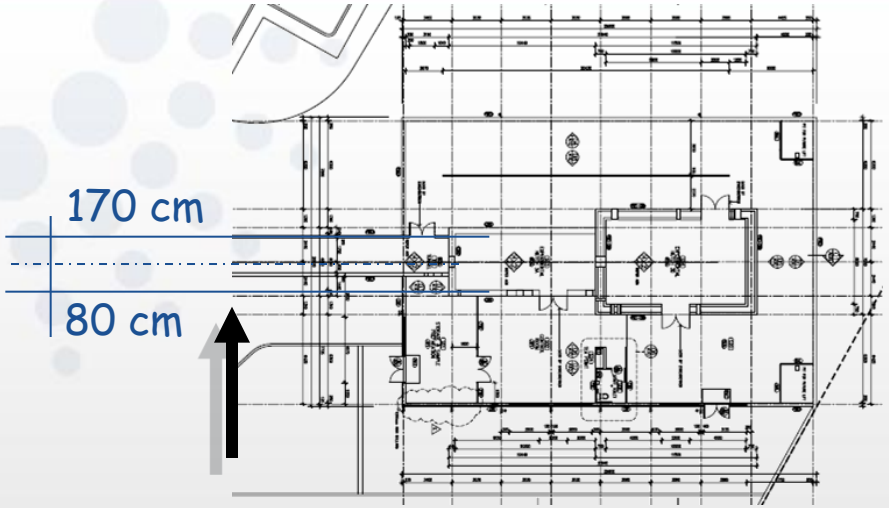
Back scatter
Outboard wall

ambient dose equivalent rate (μSv/h)



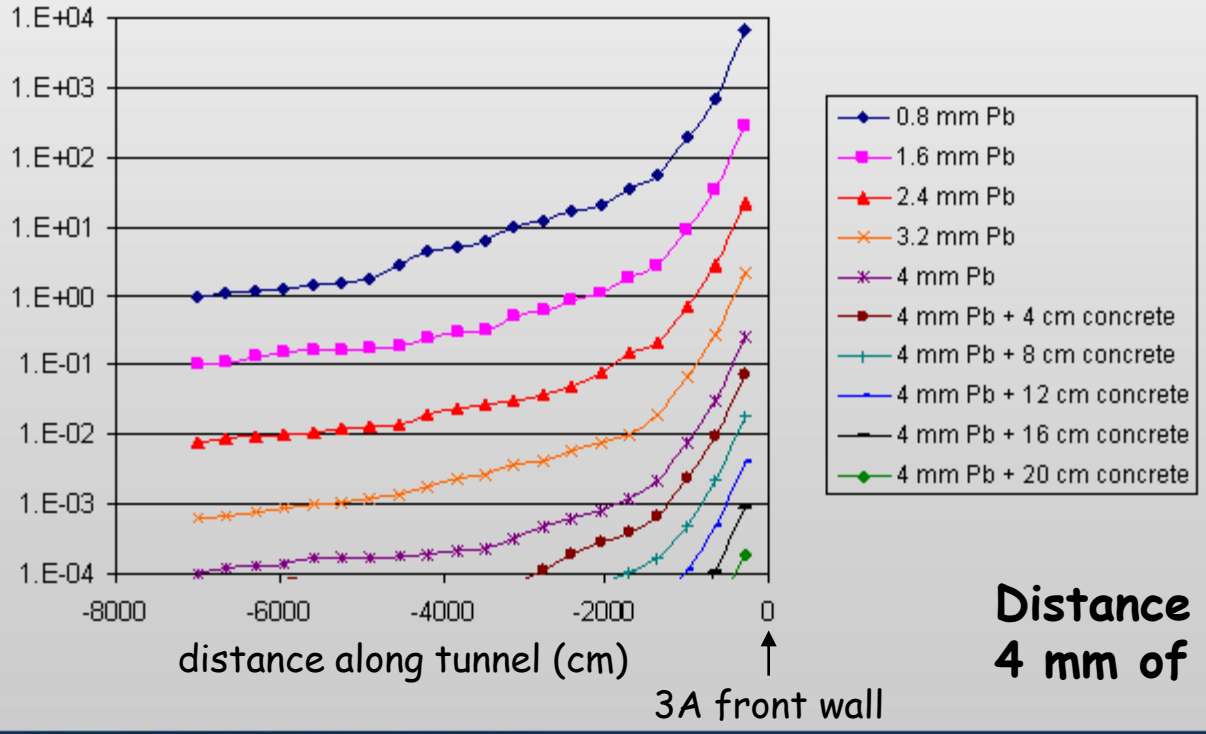
Distance beam axis to wall = 170 cm
20 cm of concrete + 70 cm of earth

Tunnel
Synchrotron radiation

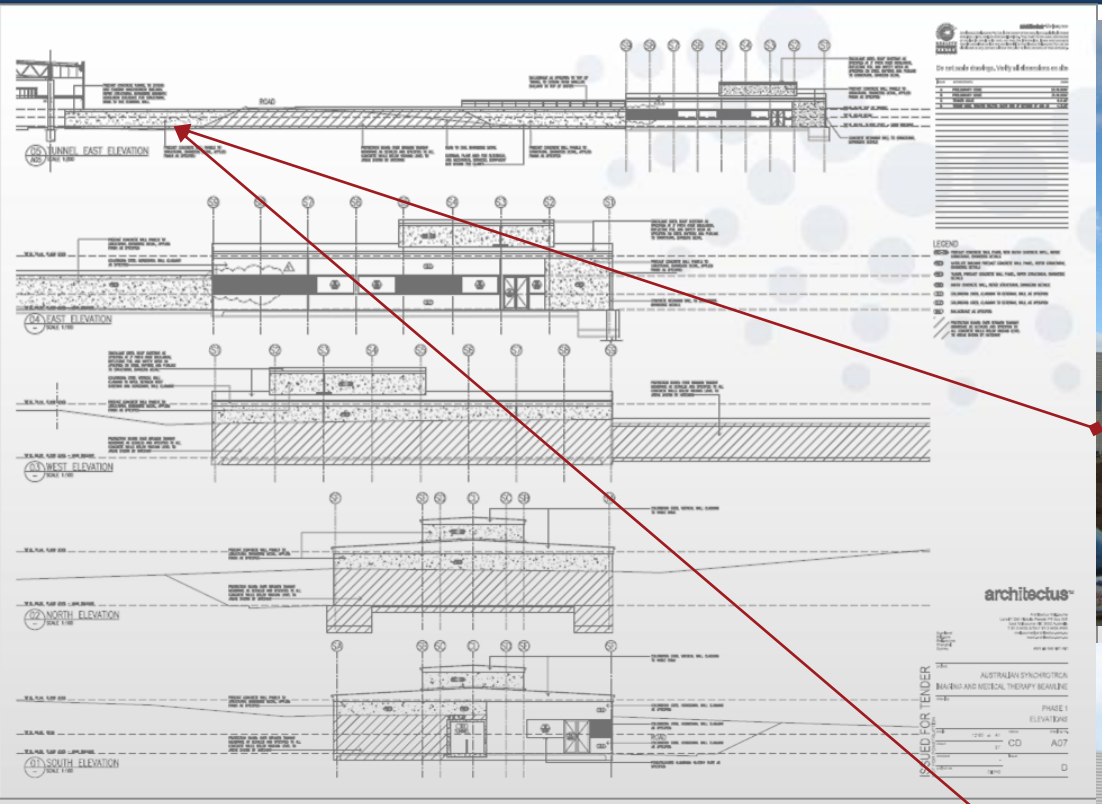


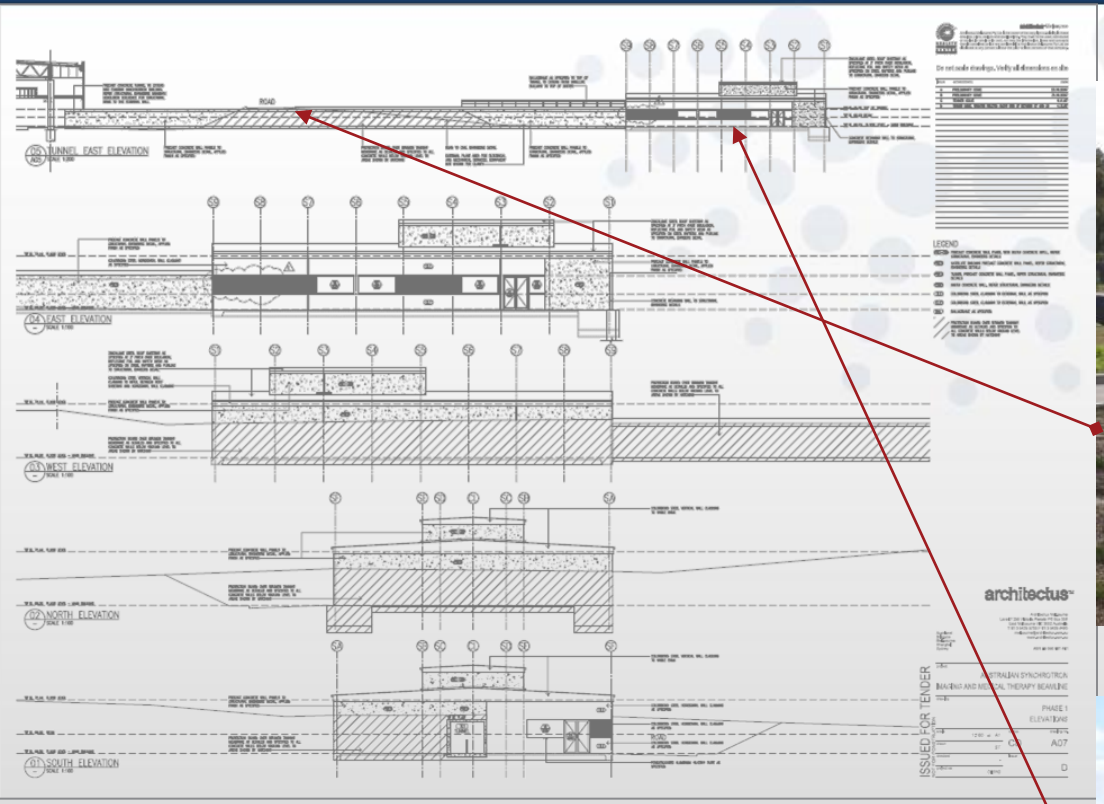
Back scatter
Inboard wall

ambient dose equivalent rate (μSv/h)



Distance beam axis to wall = 80 cm
4 mm of lead + 70 cm of concrete


EAST ELEVATION
WEST ELEVATION
NORTH ELEVATION
SOUTH ELEVATION
architectus
ISSUED FOR TENDER


01 TUNNEL EAST ELEVATION
02 EAST ELEVATION
03 WEST ELEVATION
04 NORTH ELEVATION
05 SOUTH ELEVATION
architectus
ISSUED FOR TENDER

Hutches 3A & 3B

Tunnel

Entrance 3B