Radiation protection issues for the Elettra 2.0 project: Monte Carlo simulation studies

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Elettra Sincrotrone Trieste

Outline

- The Elettra 2.0 project
- New and upgraded beamlines
- Radiation protection issues for the new SYRMEP_Life Science beamline
- Hutch requirements for the Nanospectroscopy beamline

The Elettra 2.0 upgrade project

Aims:

- Update Elettra lab bringing it at the forefront of synchrotron user facilities in a **broad photon energy window** ranging from IR and THz to the hard X-rays

Characteristics:

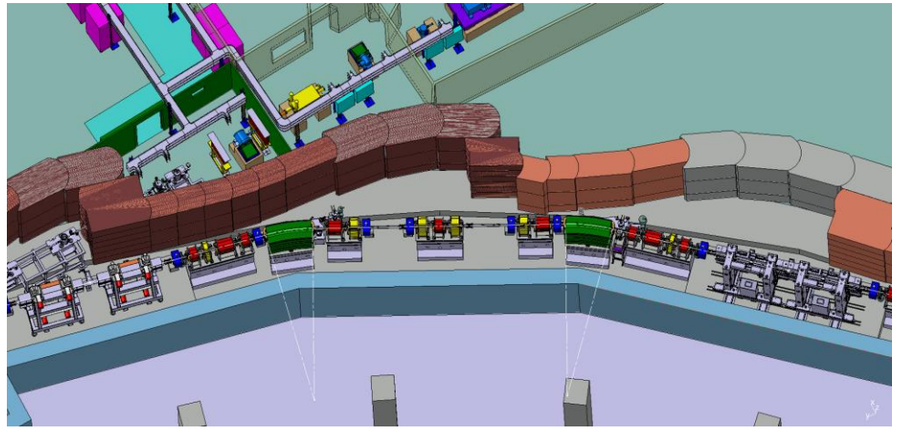
- New machine with lower **emittance** of the stored beam, (emittance levels capable of providing diffraction limited X-ray sources also in the horizontal plane).
- Availability of nano-beams (VUV to X-ray range)
- Increase the offers for X-ray imaging, X-ray Fluorescence, Diffraction and Small Angle Scattering.
- Beam energy: 2.4 GeV primarily, 2 GeV for 25% beamtime, average stored current: 400 mA

Constrains:

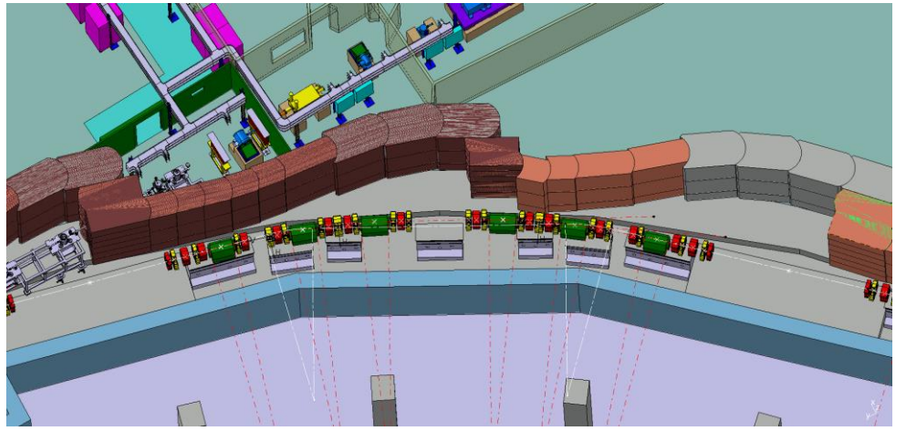
- Same machine circumference (259 m) and Experimental Hall
- Shielding blocks unaltered
- Same pre-injector and booster
- Keep the *dark* period as short as possible
- Maintain Experimental hall as *non classified* area (free access)

Elettra 2.0 Lattice

The existing double-bend achromat will be replaced by a special symmetric six-bend achromat (S6BA_E).
The lattice S6BA-E is made from 24 arcs, 12 long straights and 12 short straights and has a 12-fold symmetry i.e. 12 equal achromats.
Each section consists of 2 arcs separated in the middle by a short straight section of 1.26 m free space while the long straight sections are 5.224 m long.



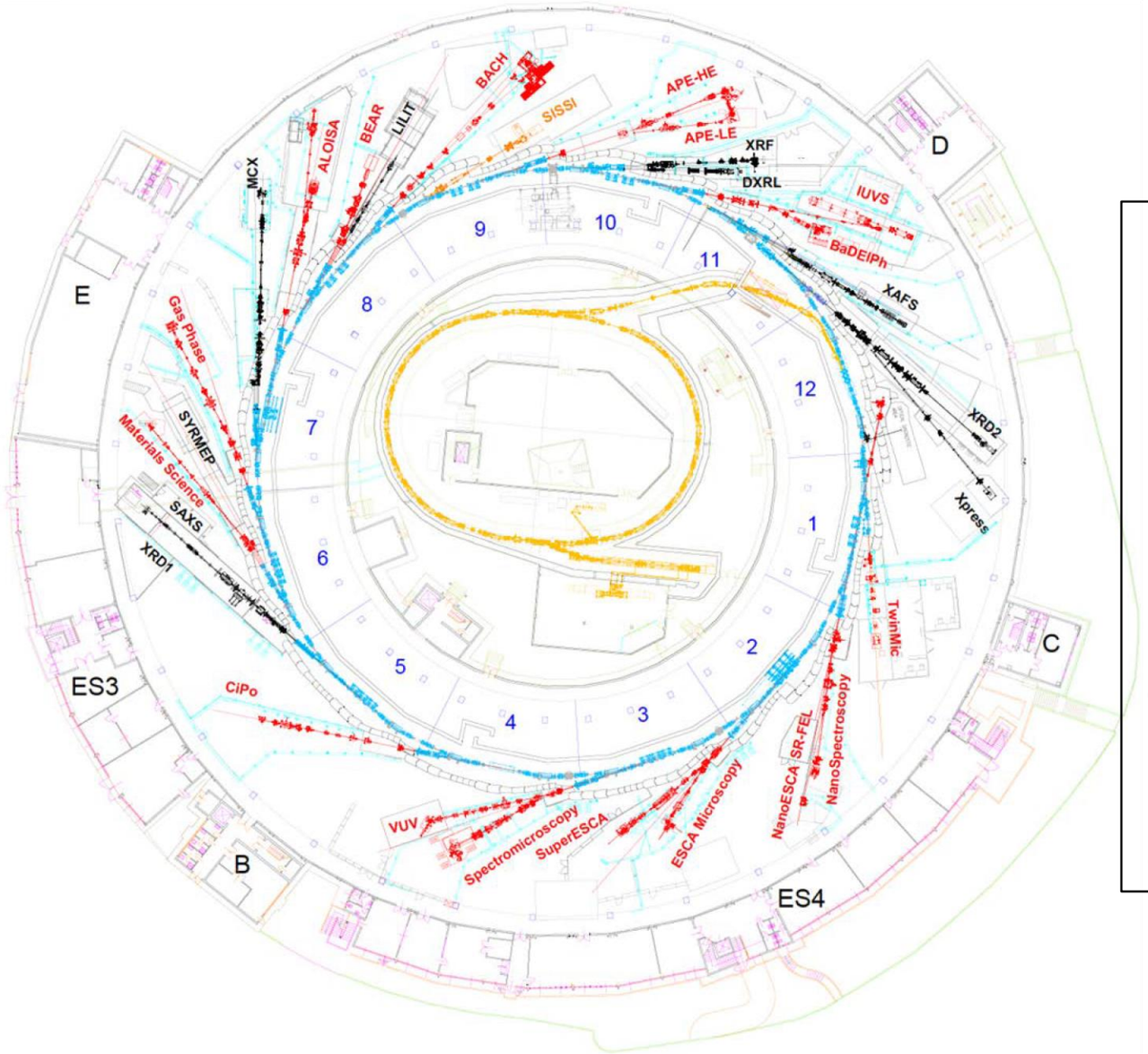
Elettra



Elettra 2.0

Parameter	units	Elettra	Elettra 2.0
Energy	GeV	**2** - 2.4	**2.4**-2.0
Current	mA	300 at 2 GeV, 140 at 2.4 GeV	400
Horizontal Emittance	pm-rad	7000 @ 2 GeV	212-147
Vertical Emittance (1% coupling)	pm-rad	70	2.12 - 1.5
Beam size @ ID (sx,sy)	mm	245 , 14 (1% coupling)	36 , 4

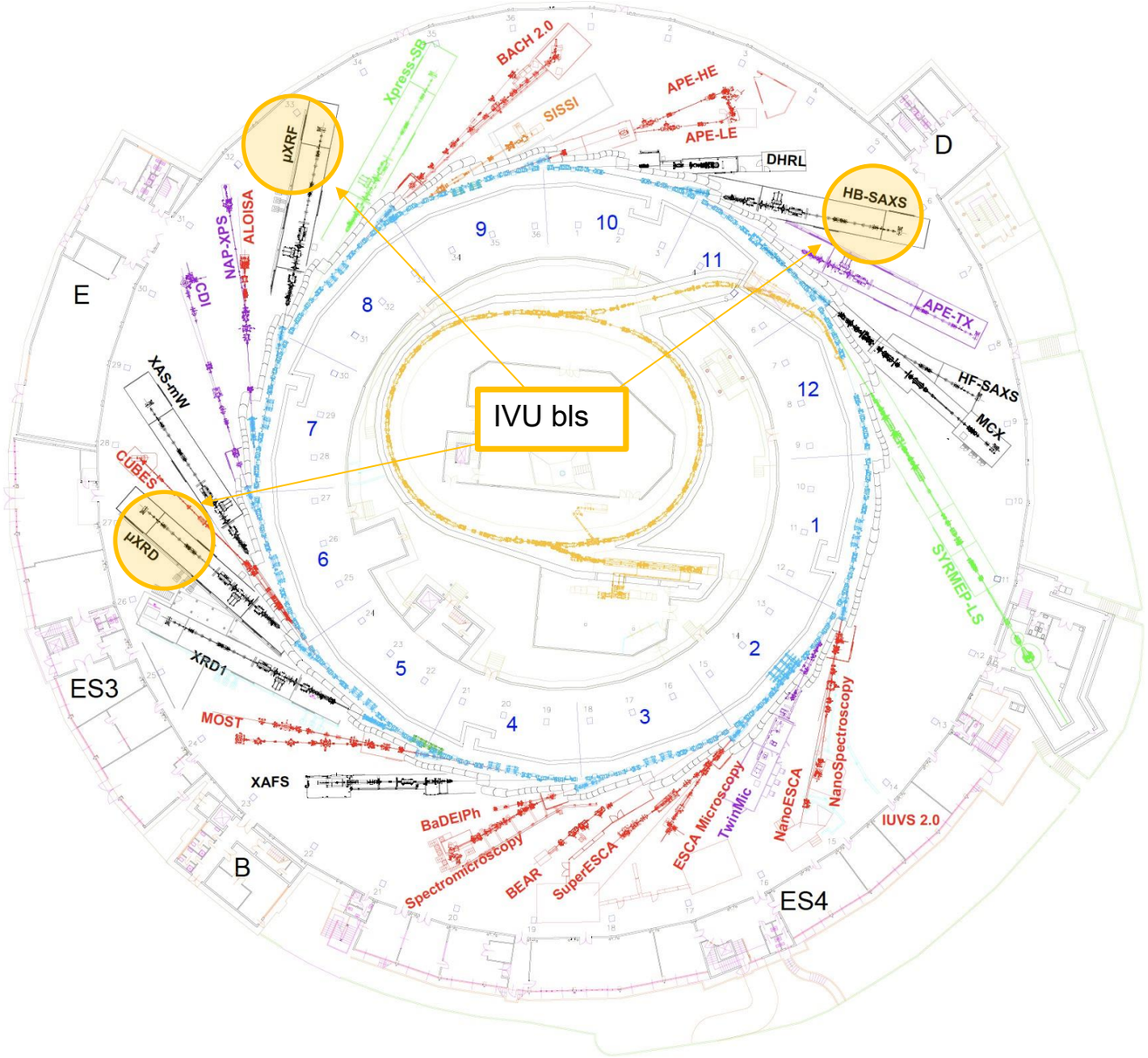
Elettra present configuration



28 beamlines

- 17 Bls VUV-Soft X-rays
  - 5 Elliptically polarized Undulator in Long Straight Sections (LSS)
  - 1 Electromagn Wiggler in LSS
  - 5 Linearly polarized Undulator in LSS
  - 2 Figure 8 Undulator in LSS
  - 1 Adjustable Phase Undulator (APU) in LSS
  - 1 APU in Short Straight Sections(SSS)
  - 2 BM
- 9 Bls hard X-rays
  - 2 on wiggler in LSS
  - 2 on Super Cond wiggler in LSS
  - 5 on BM
- 2 IR beamline on BM

Elettra 2.0 beamlines: an overview



Up to 32 beamlines

BIs hard X-rays

- ScBM (up to > 60 keV) ***2 NEW***
- IVU for micro-spot ***3 NEW***
- sW in SS ***NEW***
- SCW
- BM

BIs Soft-tender X

- APU in SS
- EPU in SS ***NEW***
- EPU in LS

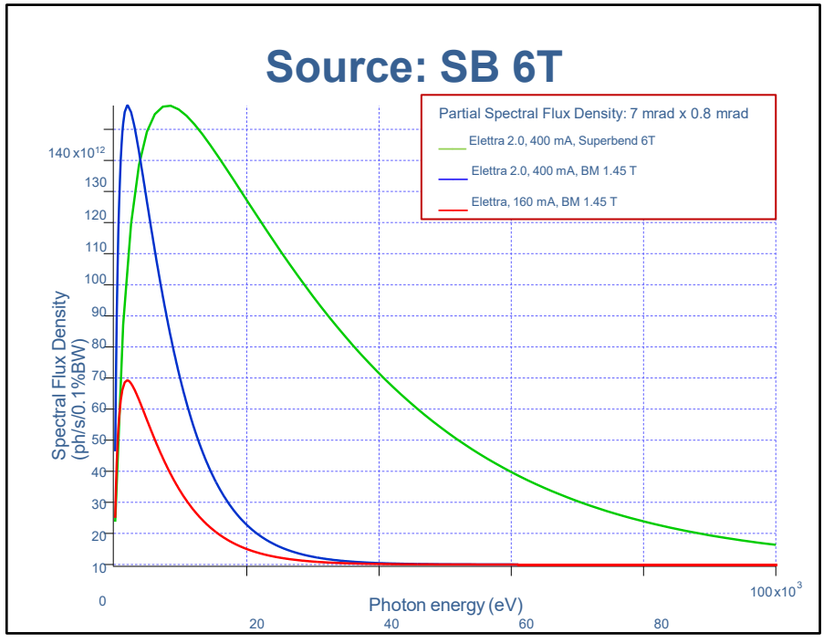
BIs VUV-SoftX

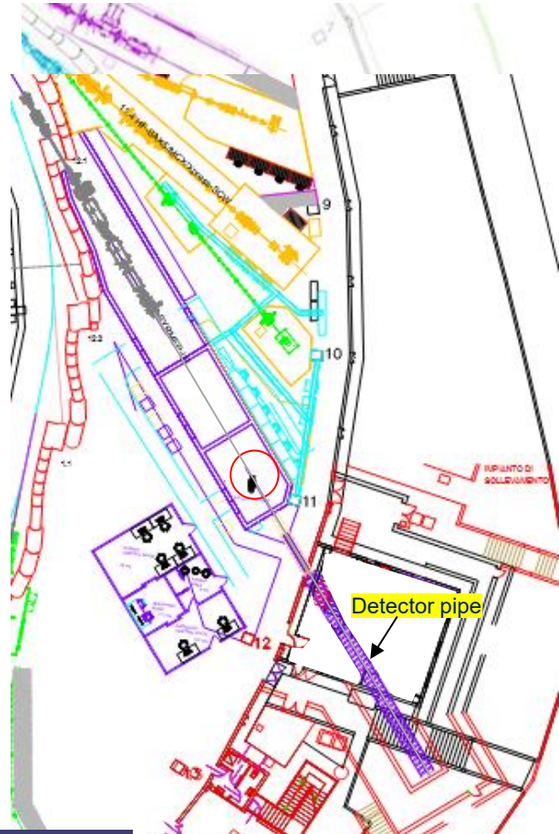
- EPU in LS
- LPU in LS
- F8 in LS
- APU (LP) in SS
- BM

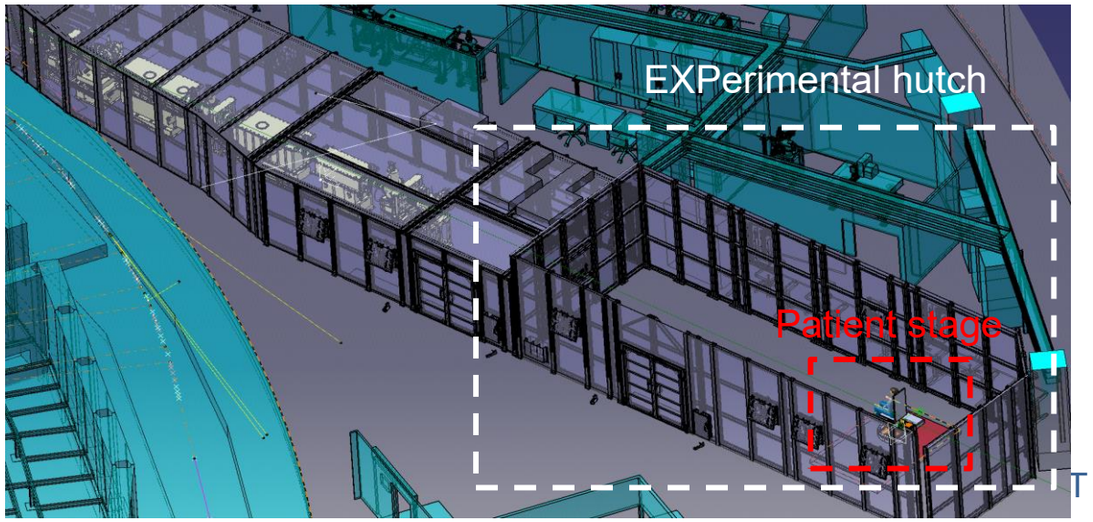
IR/THz beamline ***NEW***

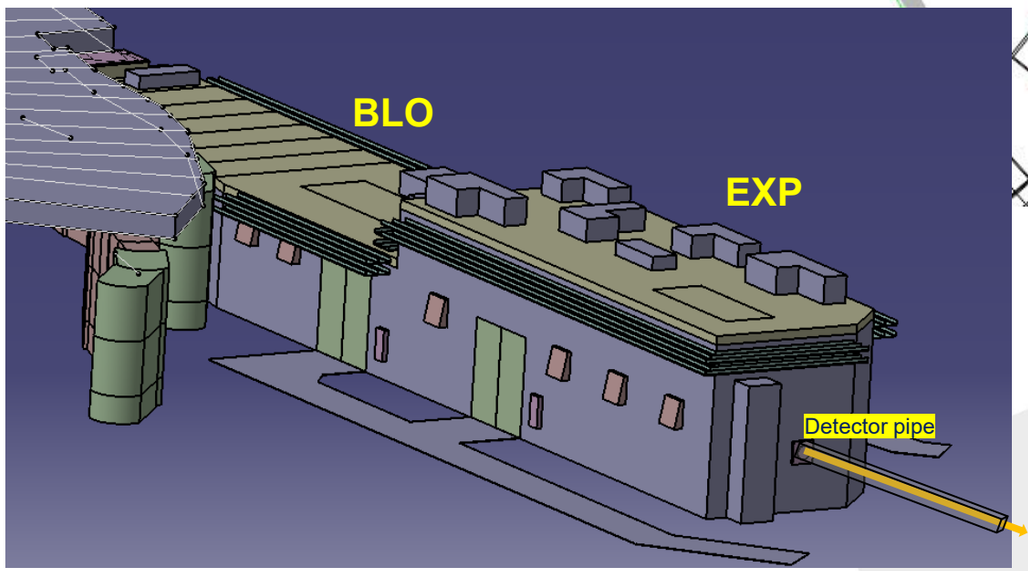
SYRMEP_LS beamline

- **Source**: 6T superconducting bending magnet
- **Usable energy range** (mono) : 10 - 130 keV
- **Acceptance** : 7 mrad x 0.8 mrad
- **BLO**: beamline optics (i.e. monochromators (Bragg, multilayer, Laue) and mirror)
- **EXP:** experimental hutch
- Medical facility foreseen for lung CT and breast CT
- Detector pipe □ 22 m long for the beam transport to detector

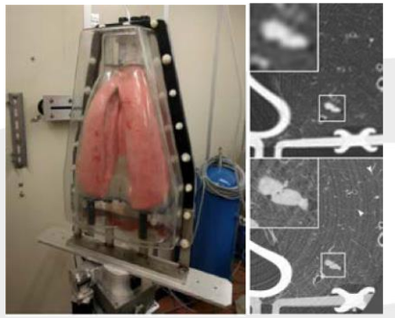








Lung CT



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SYRMEP_LS beamline

Considered radiation components

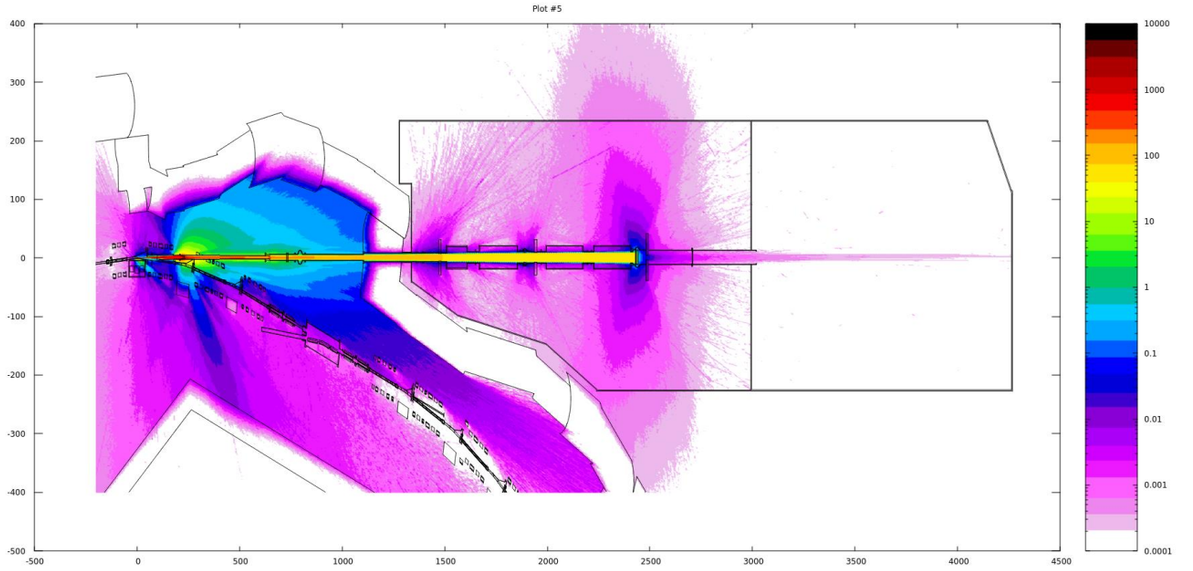
- Gas Bremsstrahlung
- Beam losses during injection
- Beamlosses due to the stored beam (Touschek)
- Accidental beam losses (Superbend quenching)
- Synchrotron radiation

- **Gas Bremsstrahlung (GB)**

Considered parameters: 400 mA stored beam, B = 1.46 T constant longitudinal profile

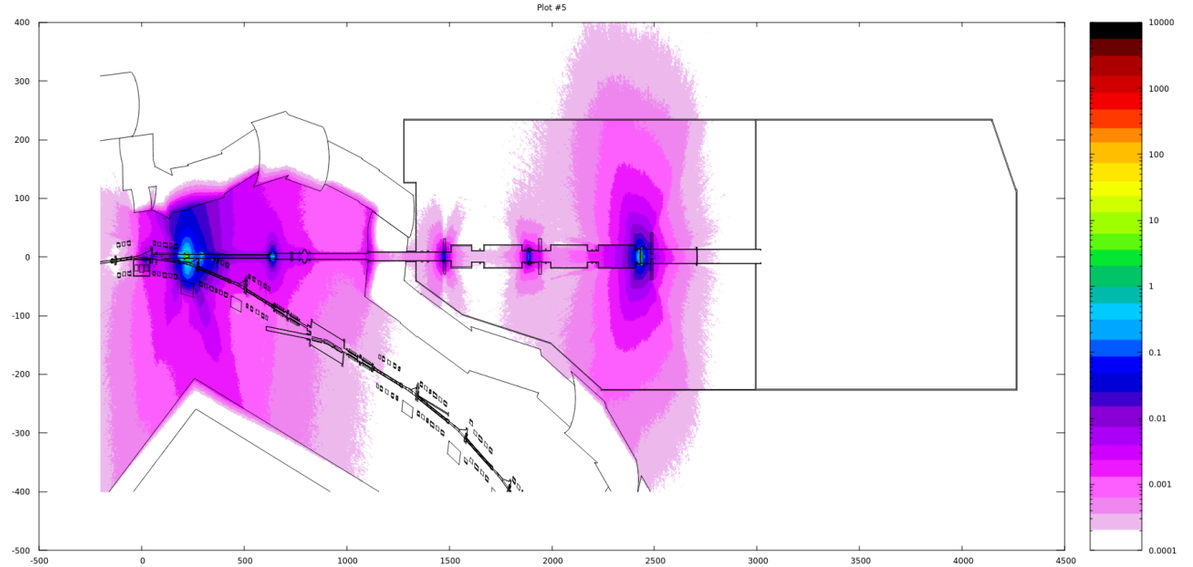
Effective dose distribution in a horizontal plane at beam height due to GB

$\mu Sv/h_{tot}$



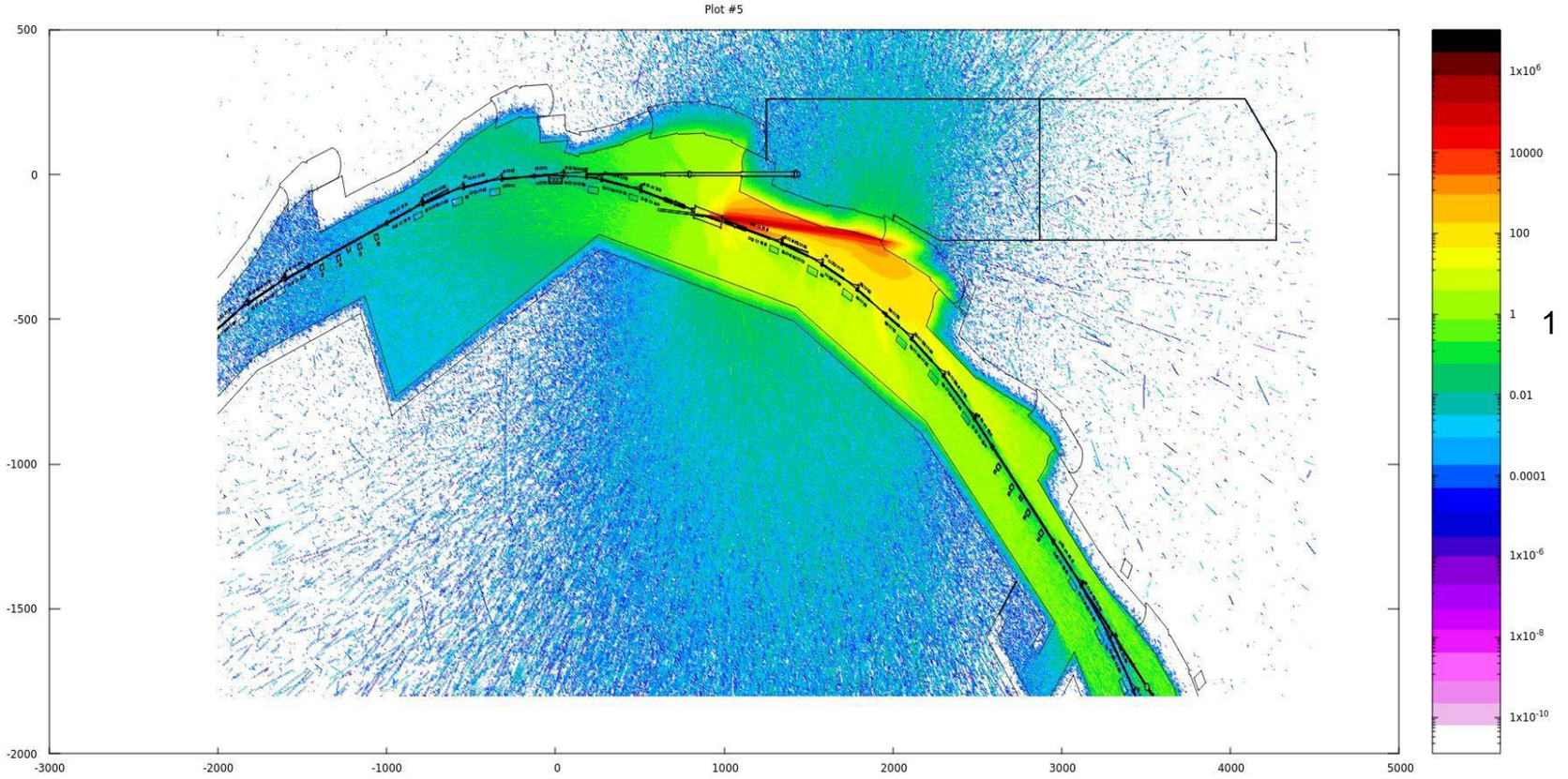
Total (gamma + neutrons)

$\mu Sv/h_n$



Neutrons

Injection losses – Integrated dose due to a 5 mA bunch from the booster lost on the injection septum (due to misfiring of the septum). Both SYRMEP shoppers closed (Front End and Optics Hutch).
Negligible scattered radiation (~ 1 μSv/h) is transported inside the optics hutch (that is not accessible during injection)



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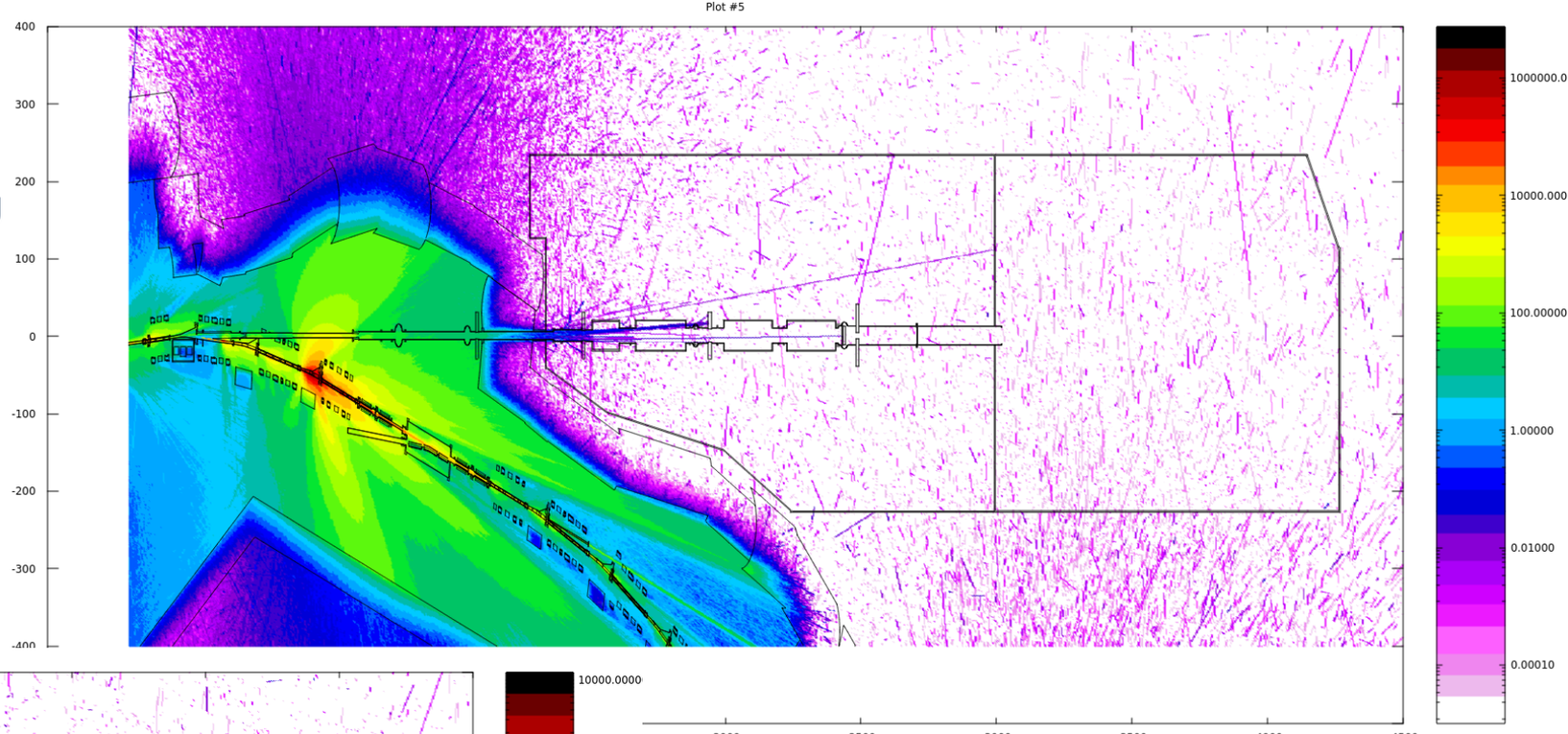
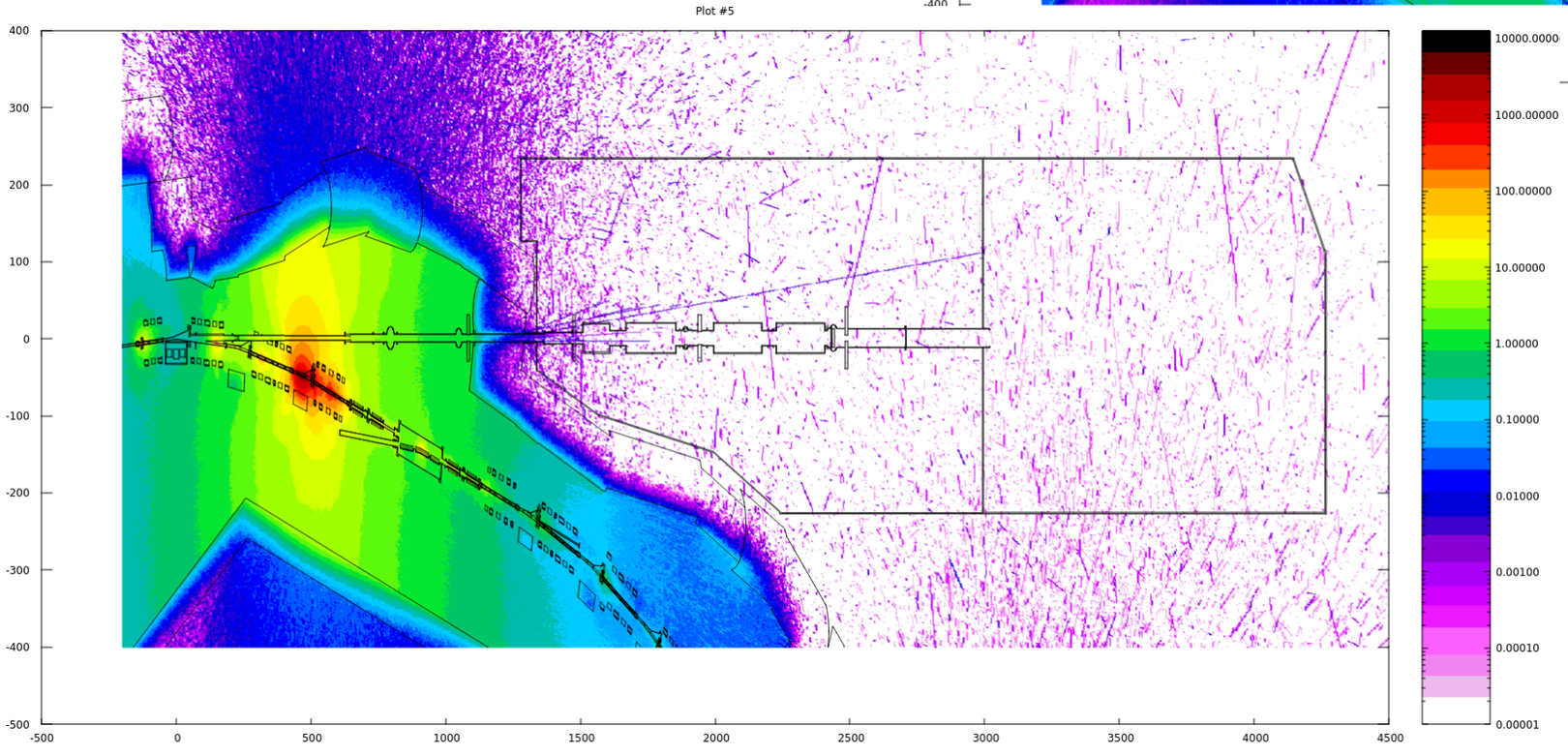
Stored beam losses due to Touschek scattering – Dose rates for a 400 mA stored beam with 9 h Touschek lifetime.
Both SYRMEP shoppers open

Total dose (μSv/h)





Neutron dose (μSv/h)
(different scale with respect to photons)

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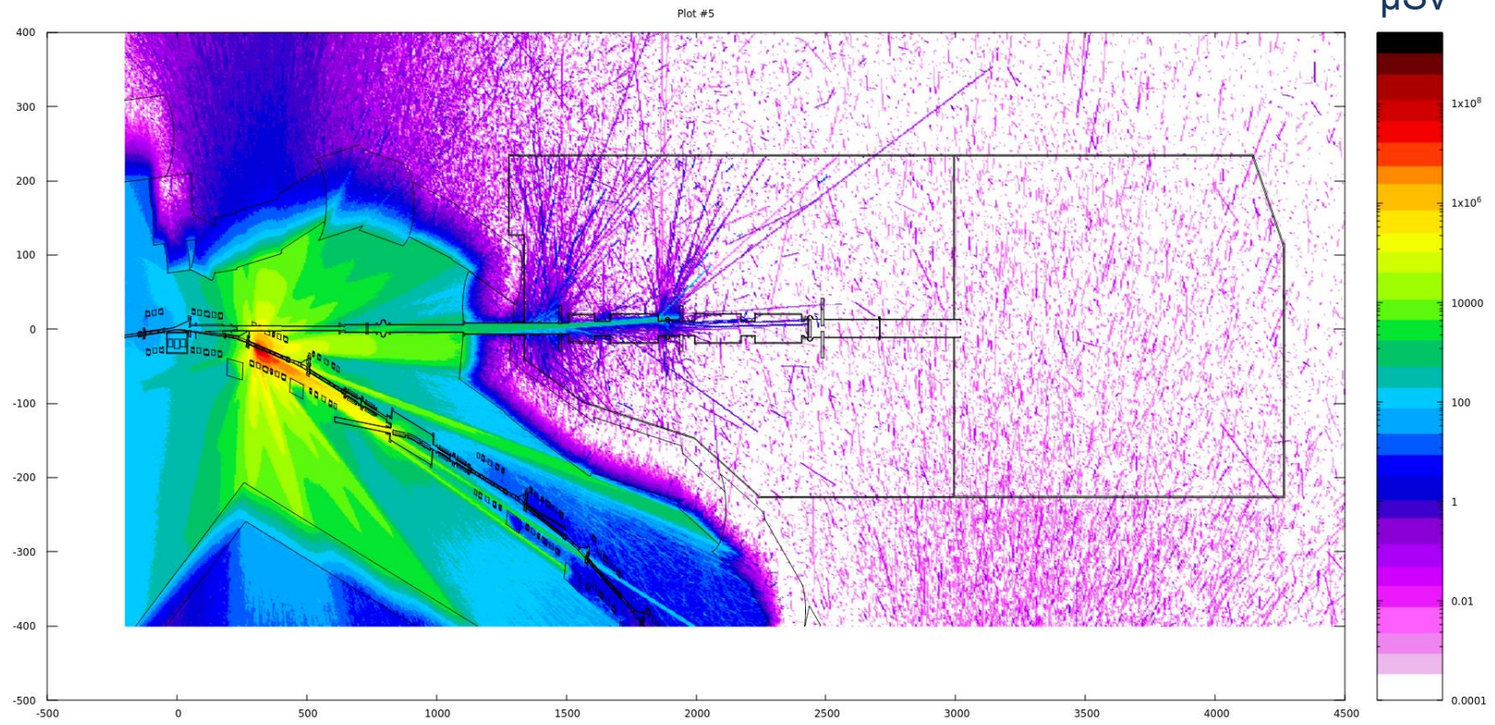
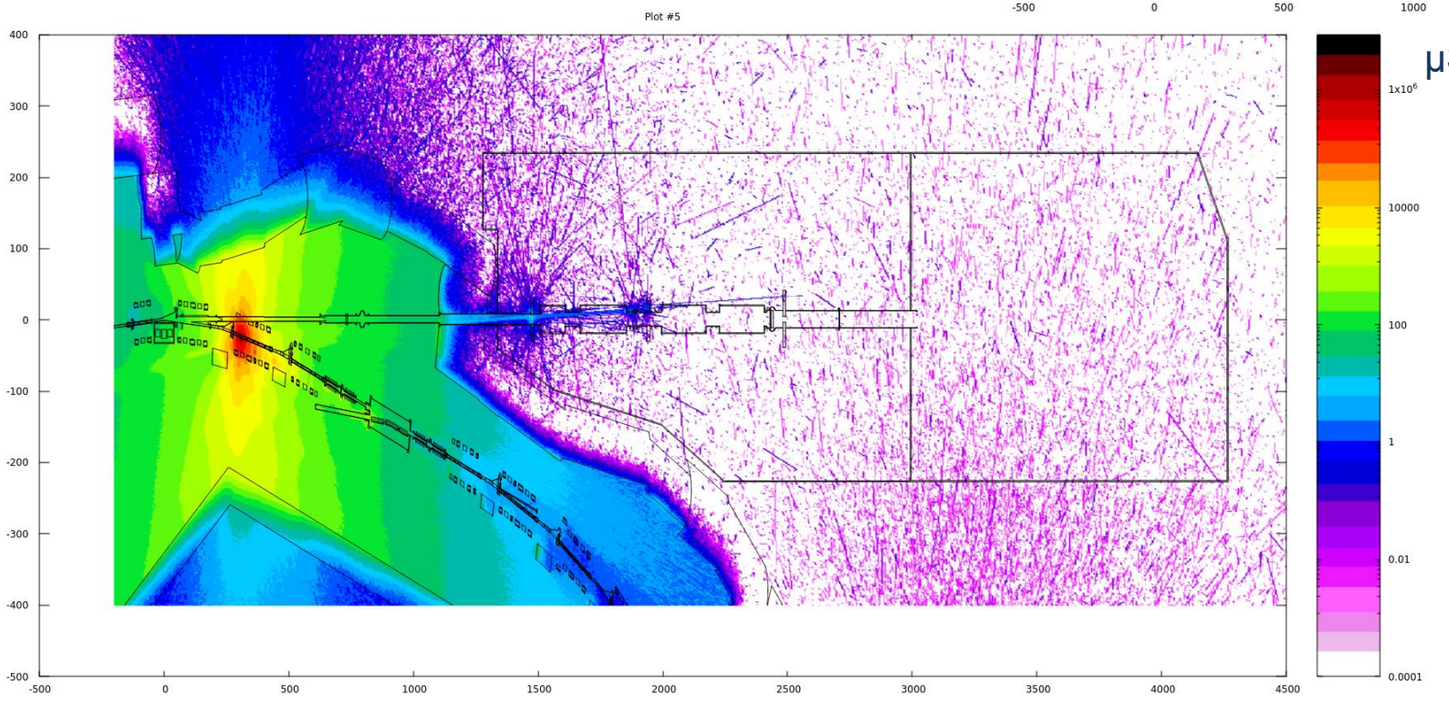
Stored beam loss – Integrated dose due to a 400 mA beam dump, caused by a superbend quenching.
Both SYRMEP shoppers open
This is realistic configuration, where the magnetic field in the superbend is slightly below its nominal value.
Outside the hutch the integrated dose is low (< 0.1 μSv per dump).

Total dose (μSv)



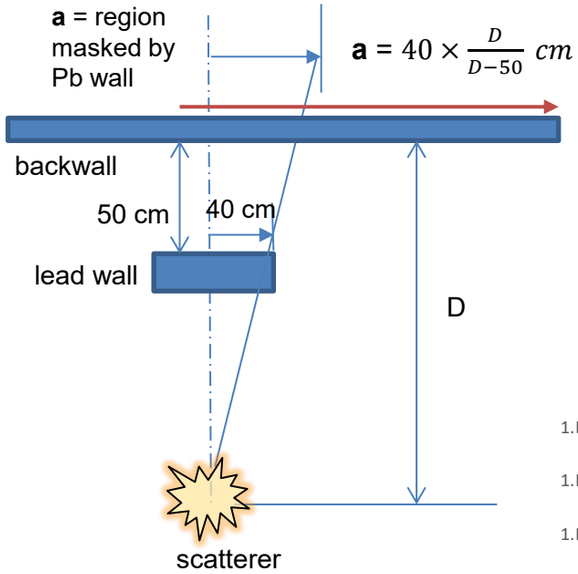


Neutron dose (μSv) (different scale with respect to photons)

SYRMEP_LS beamline

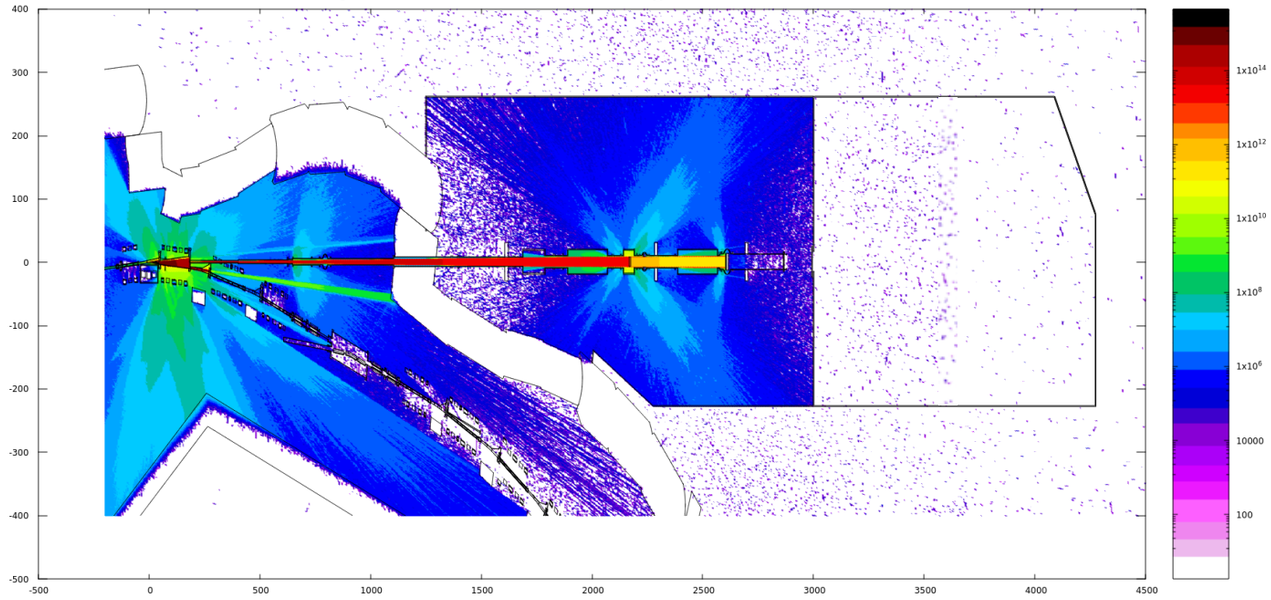
- **Synchrotron Radiation (SR)**

Considered parameters: 400 mA stored beam, B = 6 T constant longitudinal profile

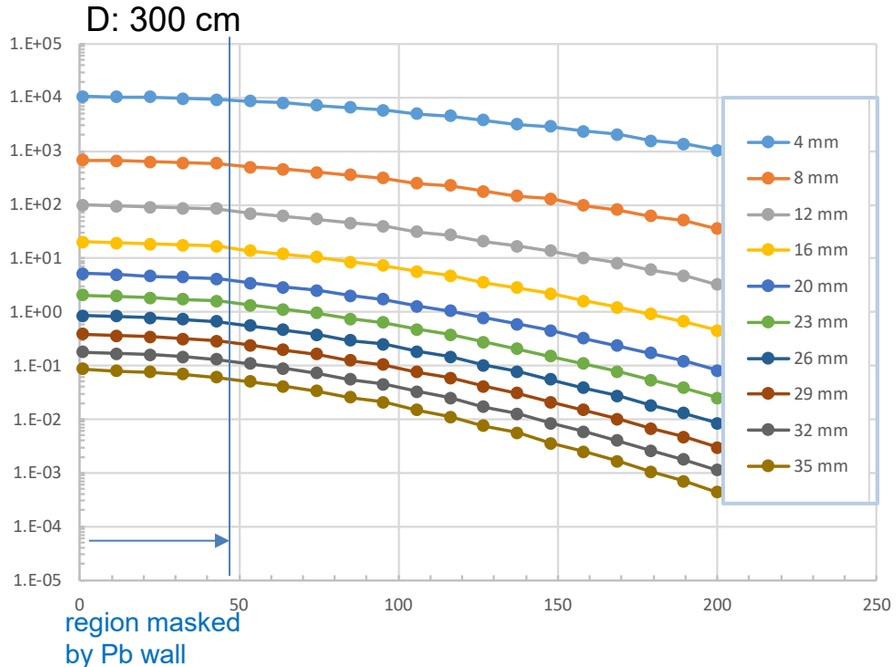


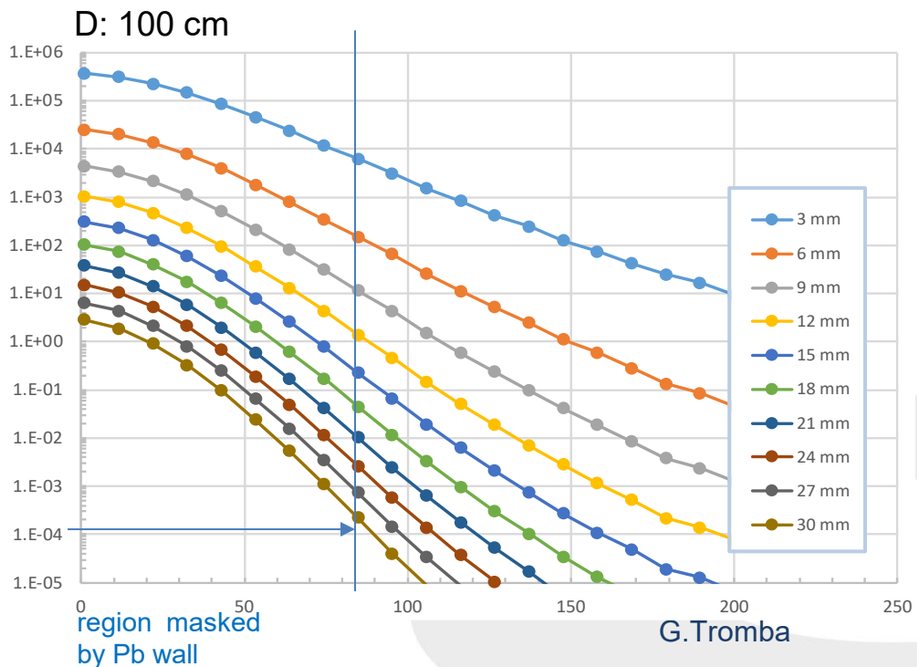
To overcome problems of biasing and lack of statistics, a dedicated Monte Carlo was developed to evaluate the backwall and lateral wall thicknesses

Effective dose distribution in a horizontal plane at beam height due to SR



backwall wall thicknesses





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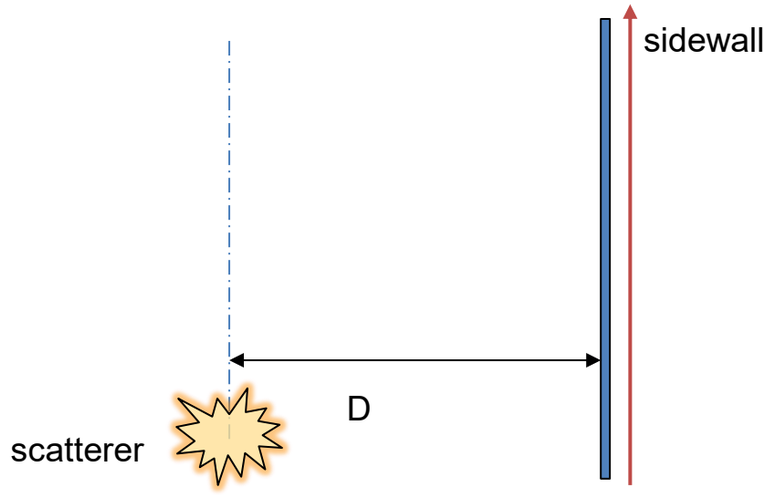
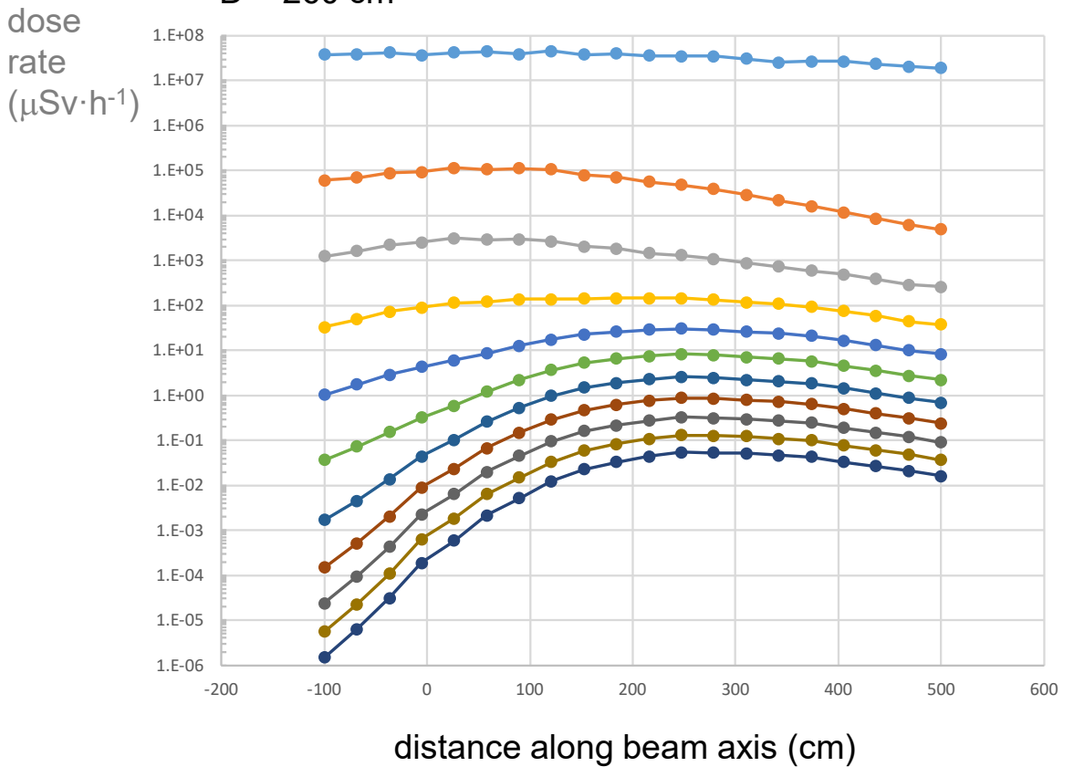
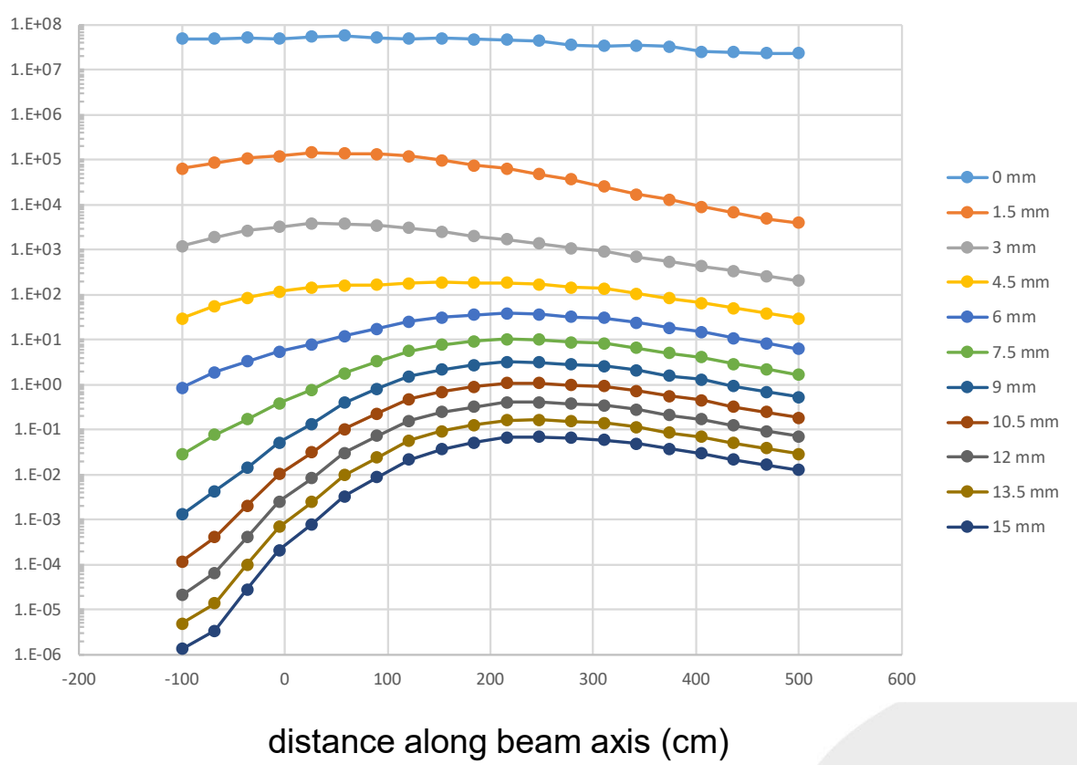
Lateral wall thickness



D = 260 cm



D = 230 cm



Detector pipe evaluations

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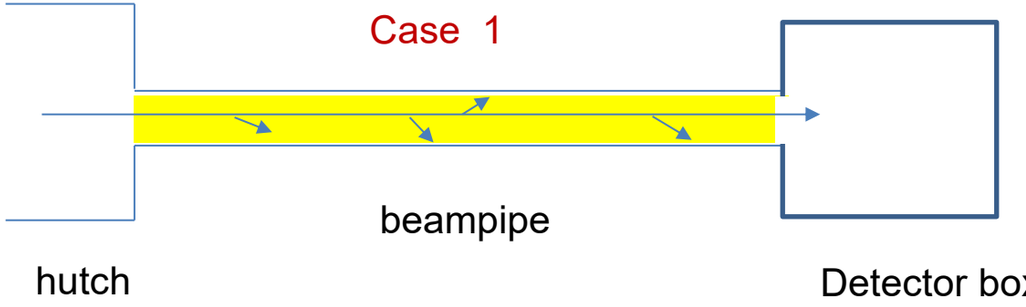
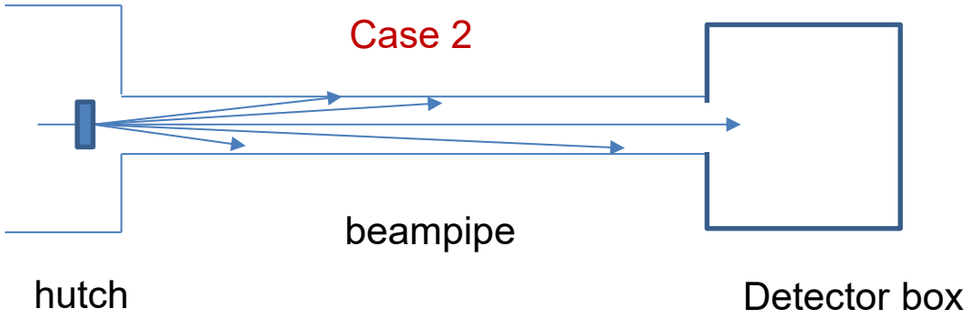
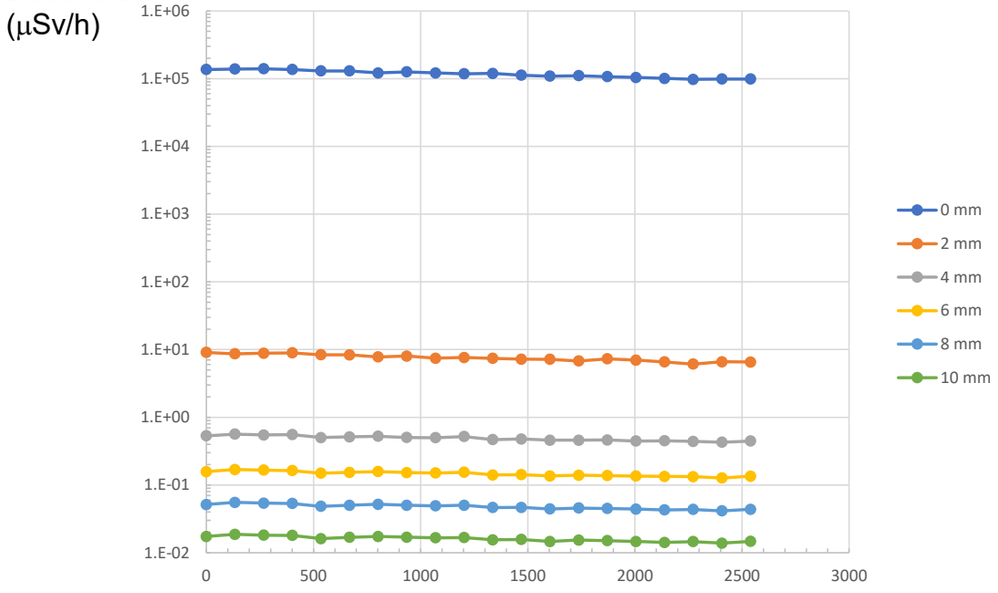


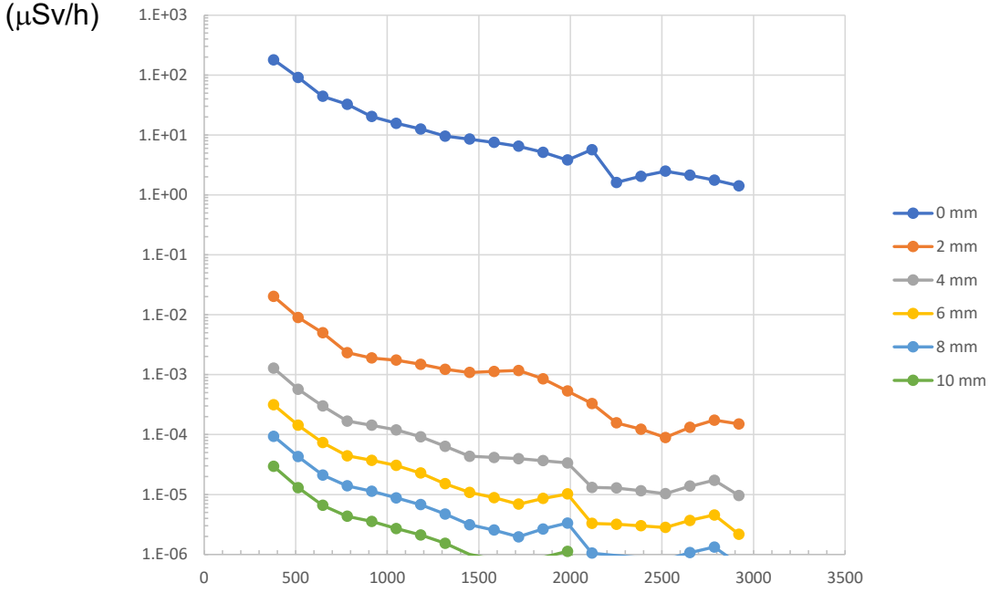


130 keV – air scattering in beam pipe



Distance along beam pipe (cm; 0 cm = beginning of pipe)

130 keV - patient scatter



Distance along beam pipe (cm; 0 cm = patient position)

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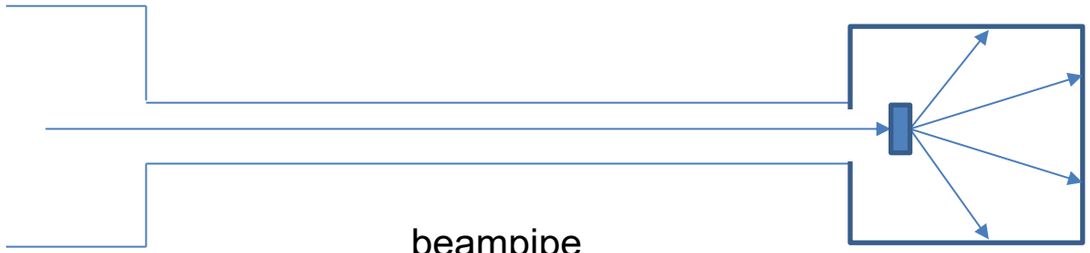
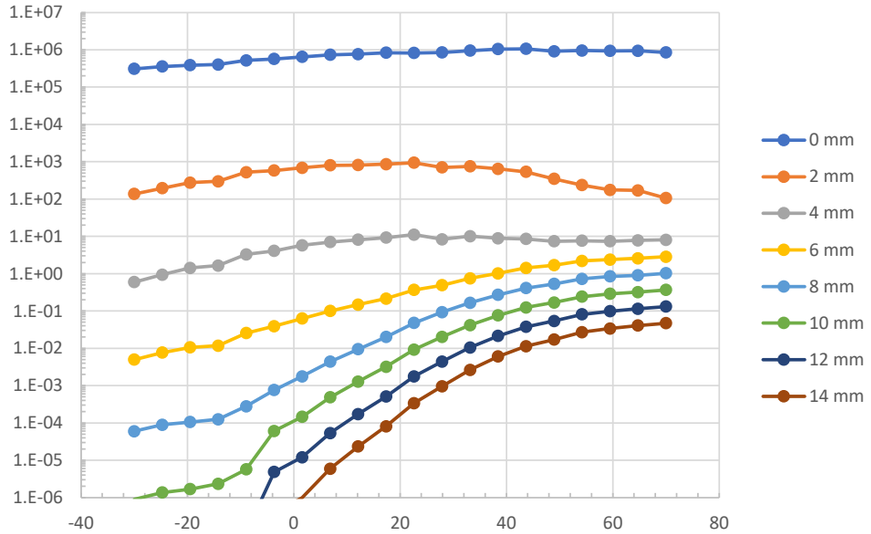
Case 3



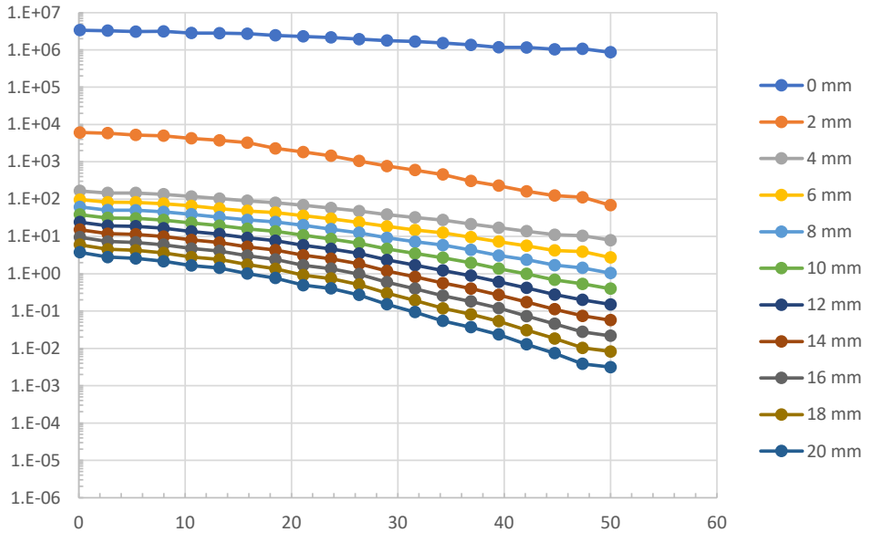
Detector box – side wall, roof – 130 keV



Distance along side wall box(cm)

Position detector

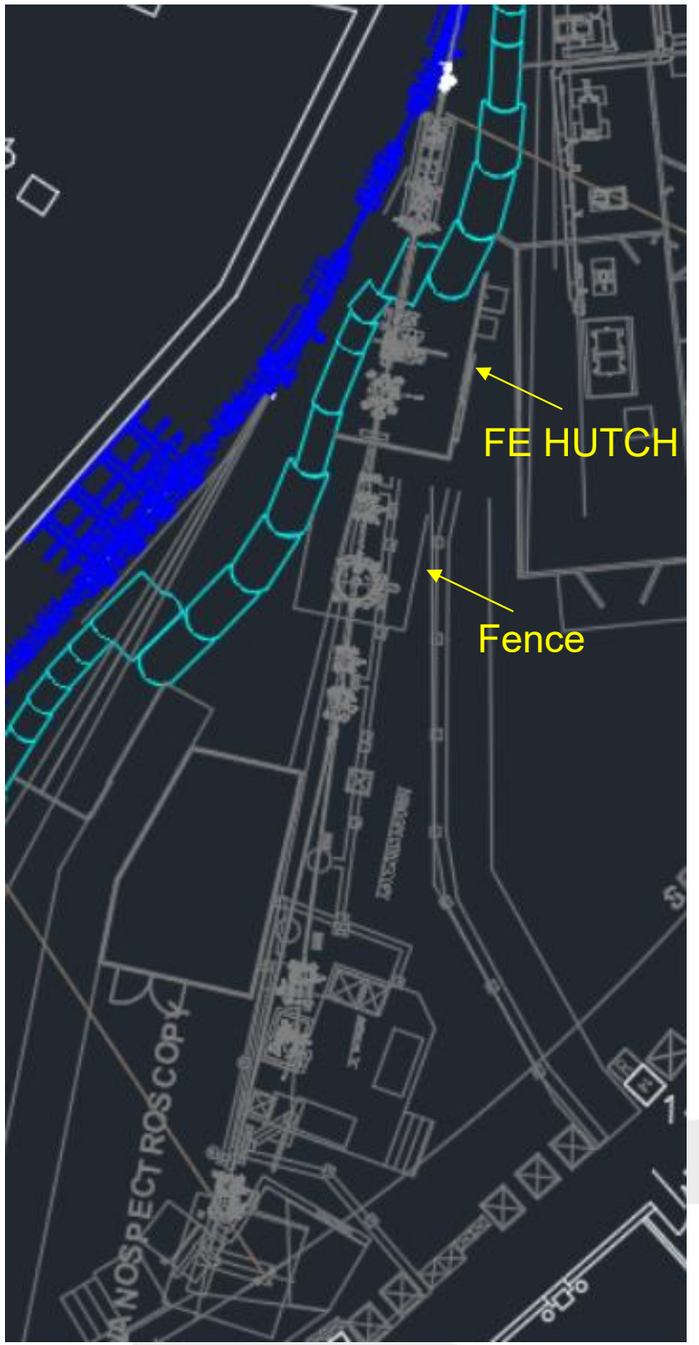
Detector box – back wall – 130 keV



Horizontal distance from beam axis (cm)

Exit 1.2 - Nanospectroscopy beamline

- **Source**: Elliptical polarized Undulator
- Existing beamline, not moved from the present position, it will become 1.4 exit
- **Usable energy range**: 27 - 1700 eV
- FE hutch (2 mm Pb) : it contains the first mirror and some local shielding
- Fence (accessible only with beamline closed): it includes a slit system and the first monochromator
- Local shielding walls positioned around some *hot* points



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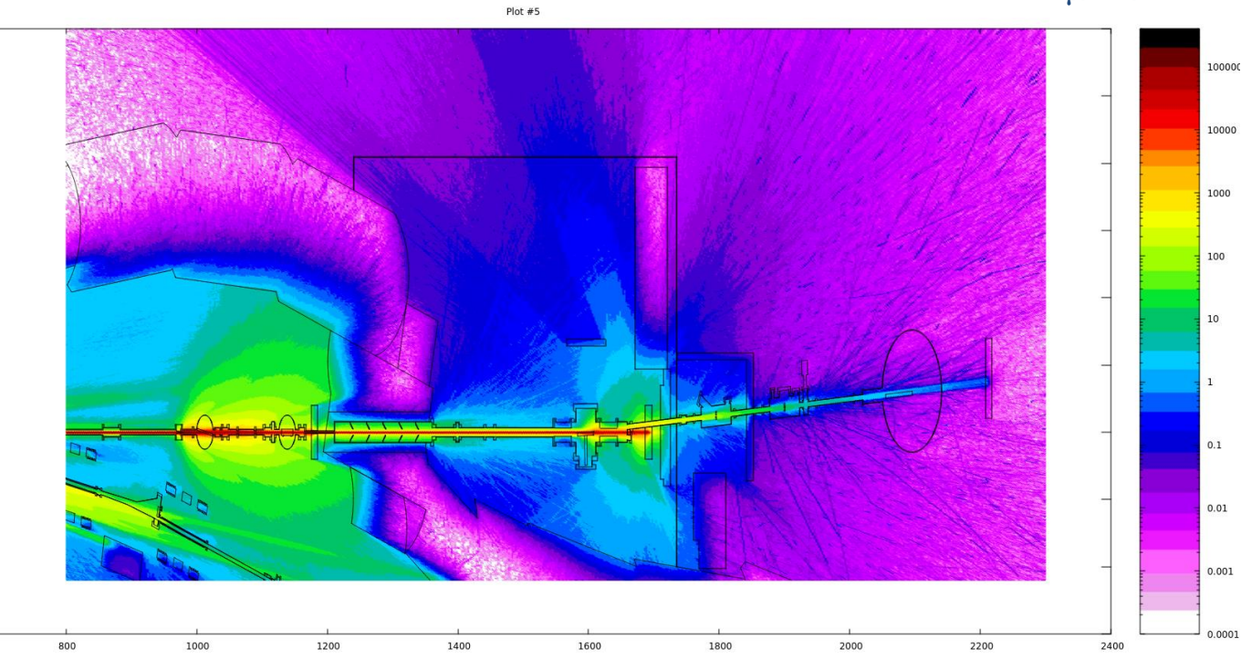
Considered radiation components (normal and malfunction conditions)

- Gas Bremsstrahlung (I = 400 mA , P = 1. 10^{-8} mbar)
- Touschek losses (I = 400 mA , 9 h touschek lifetime)
- Full stored beam (400 mA at 2.4 GeV) loss on input taper of ID vessel
- Incident scenario 1 : beam lost on input taper straight section during top-up
- Incident scenario 2 : dipole magnet downstream of straight section off during injection

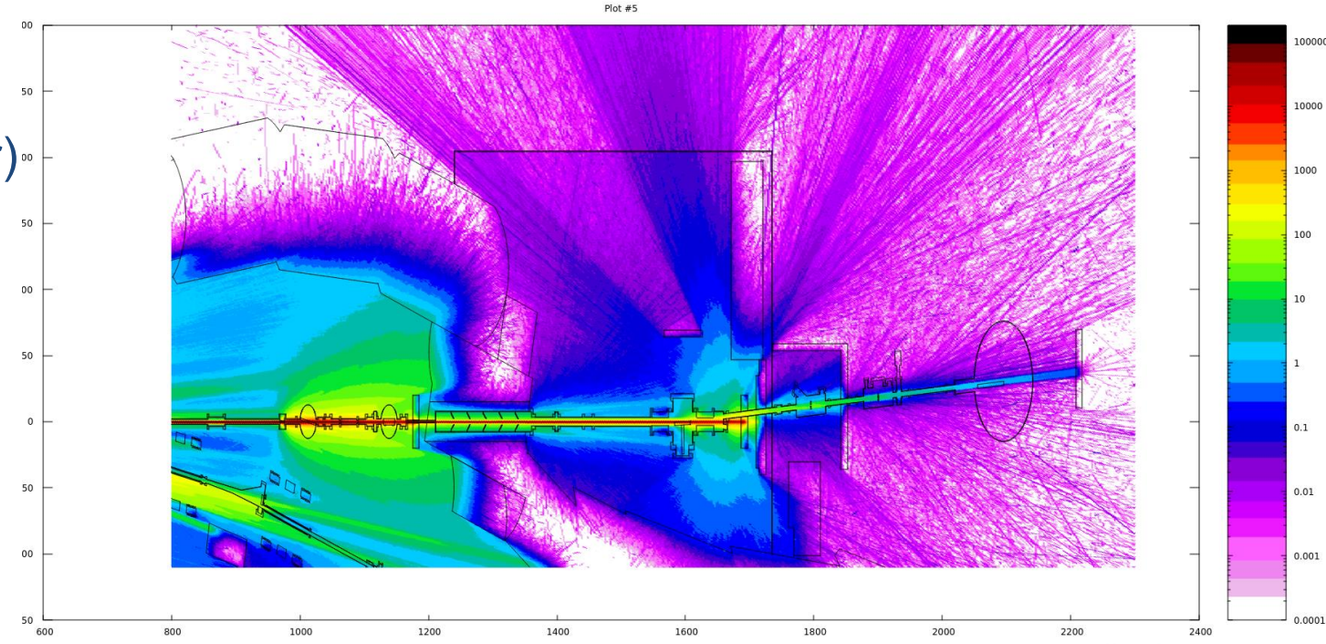
Gas Bremsstrahlung

Considered parameters: I = 400 mA , P = 1. 10^{-8} mbar)

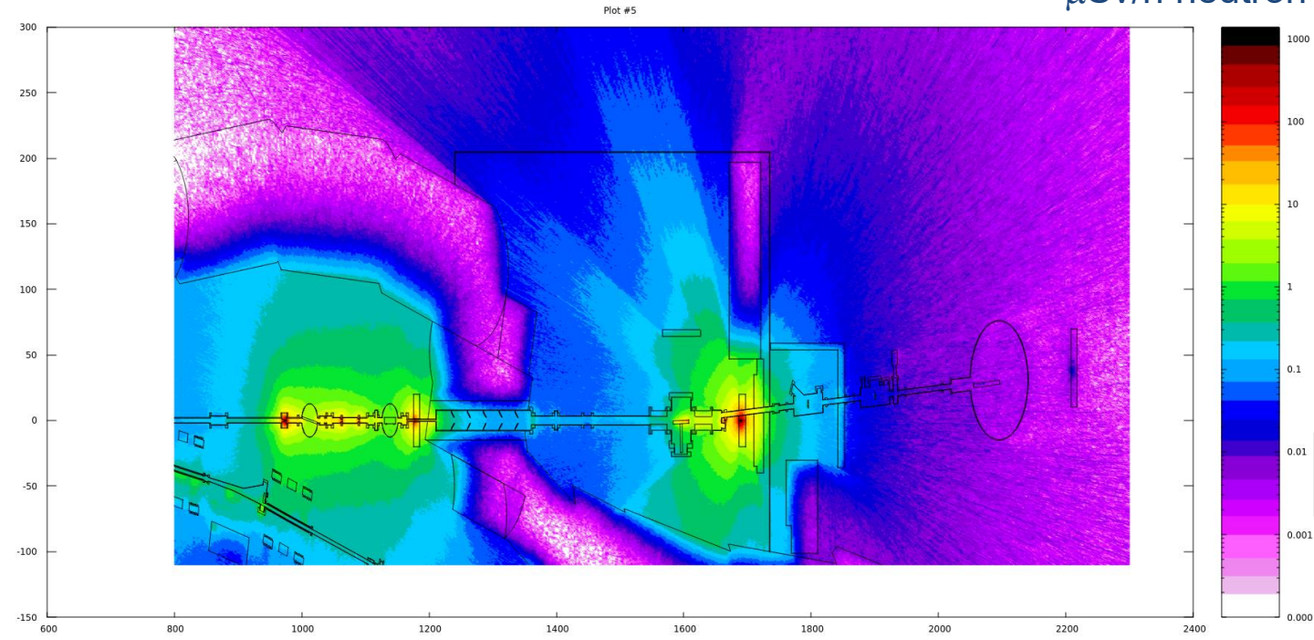
µSv/h total



µSv/h photon



µSv/h neutron



Dose rate distribution in horizontal plane at beam height

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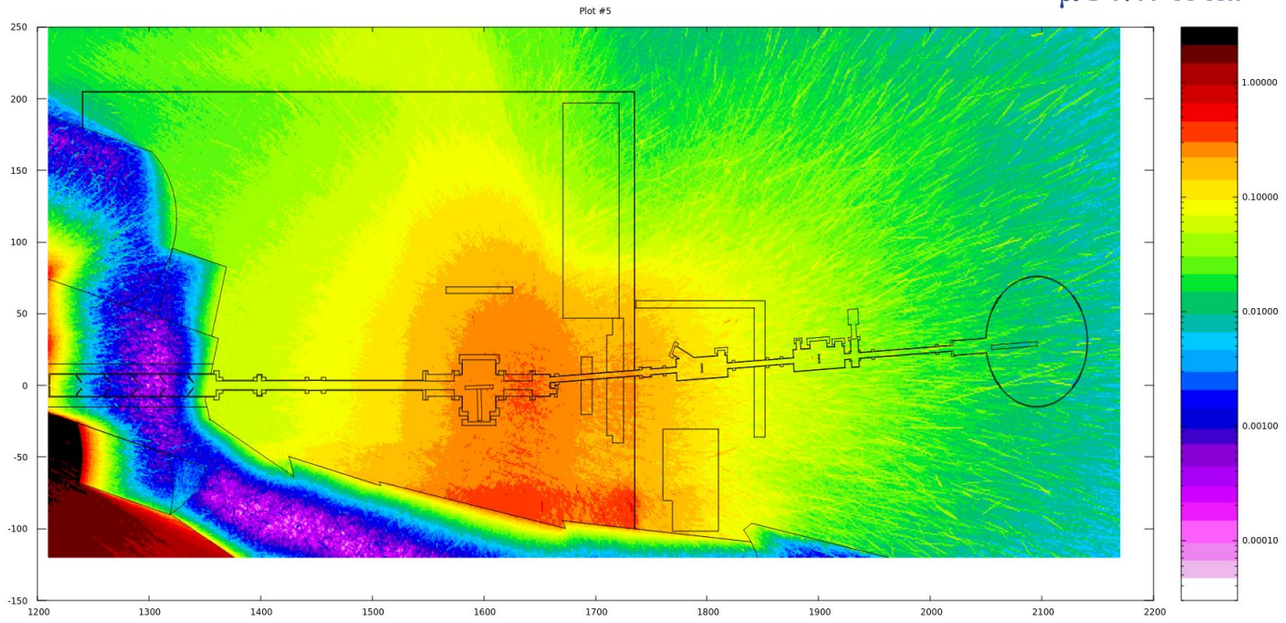
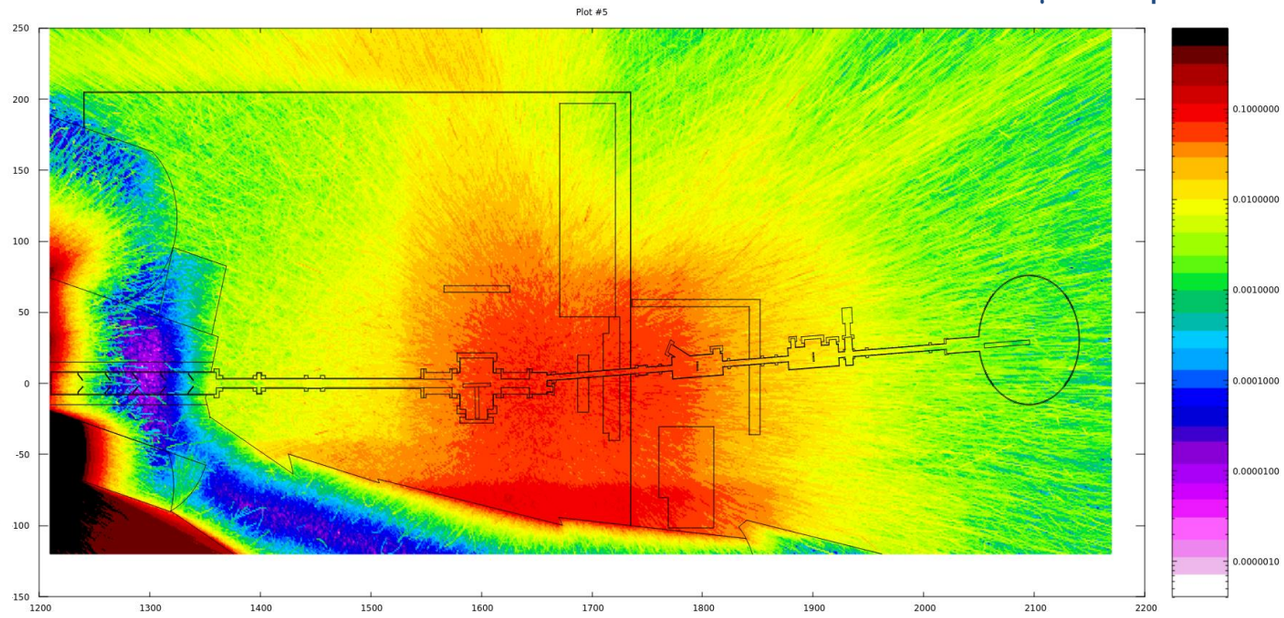
The hutch has no roof!!!!

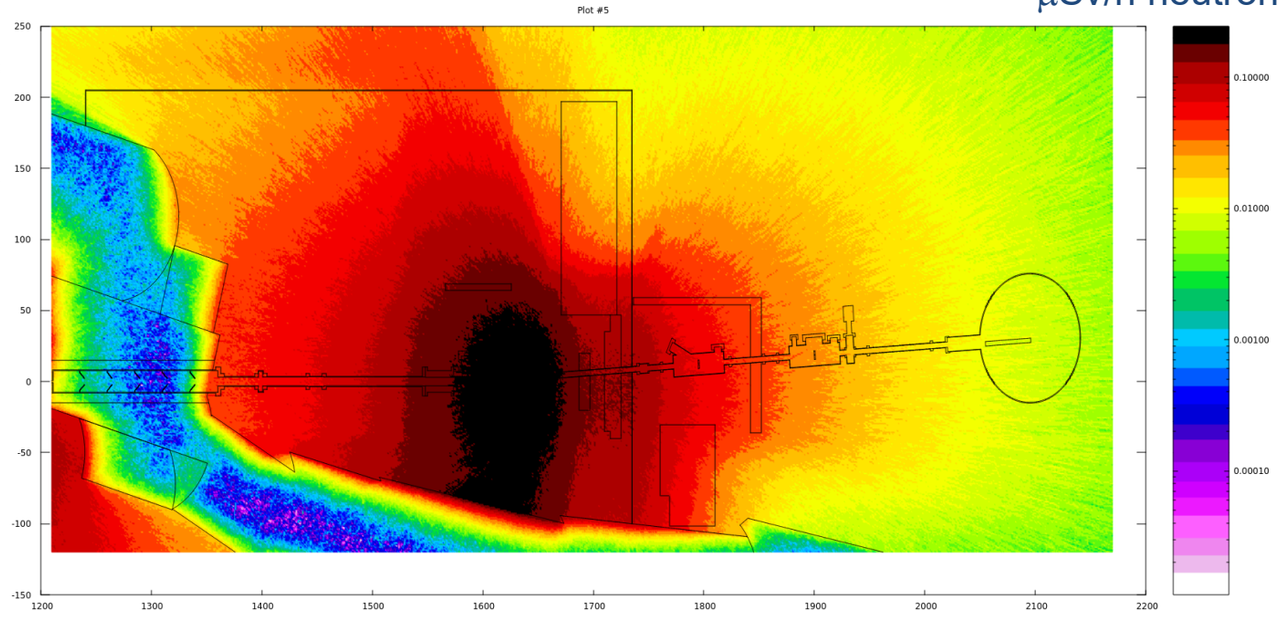
µSv/h total



µSv/h photon



µSv/h neutron



Effective dose rate distribution in horizontal plane above hutch

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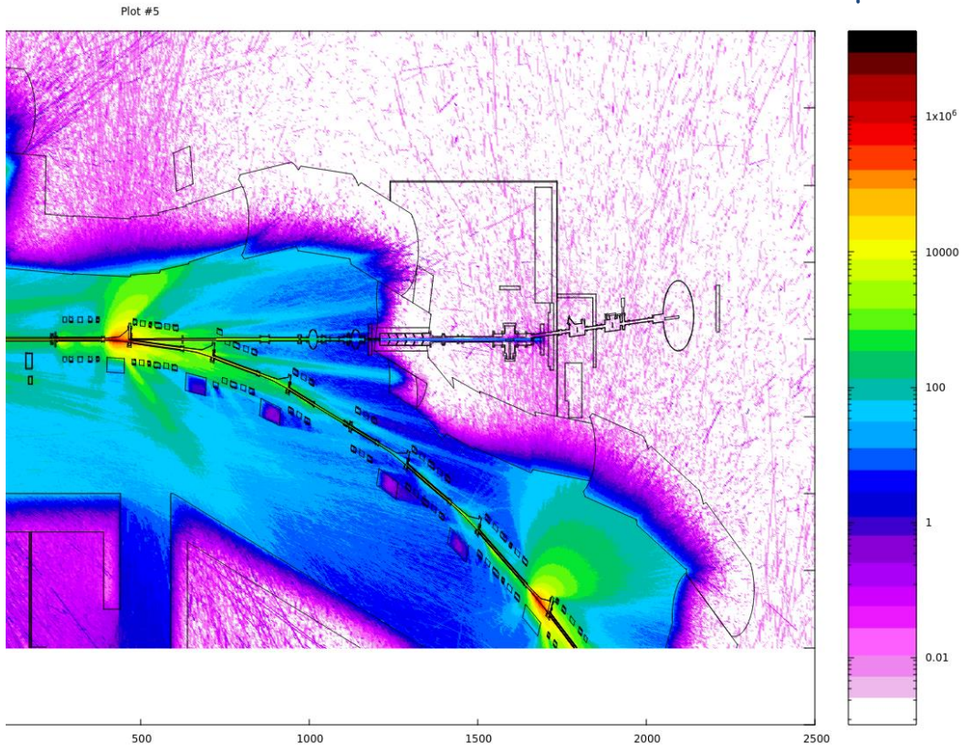
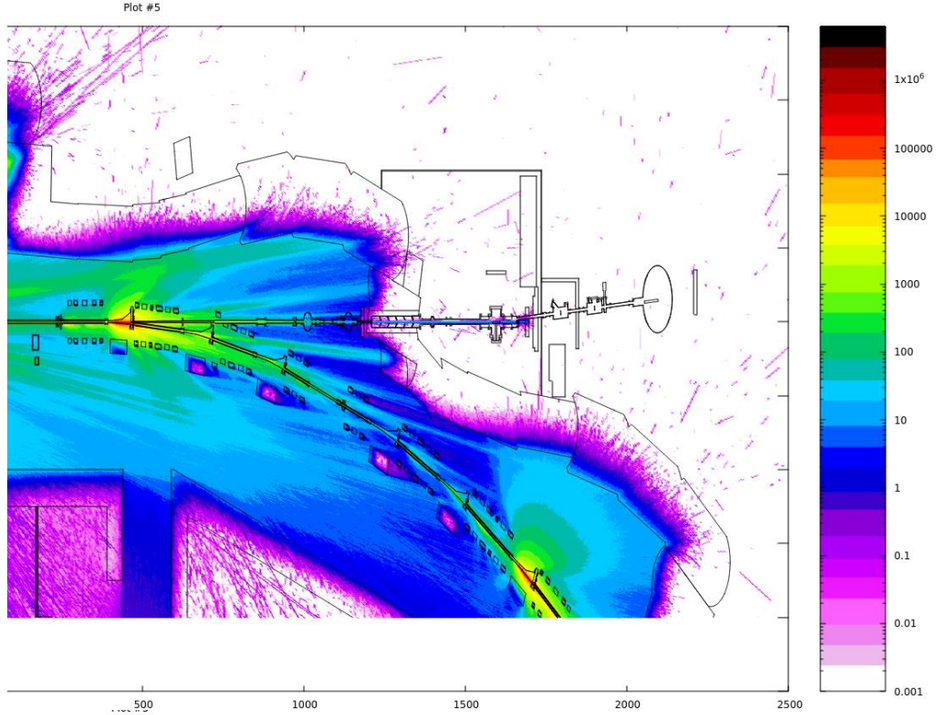
Touschek losses
400 mA – 9 h total touschek lifetime, Front end open

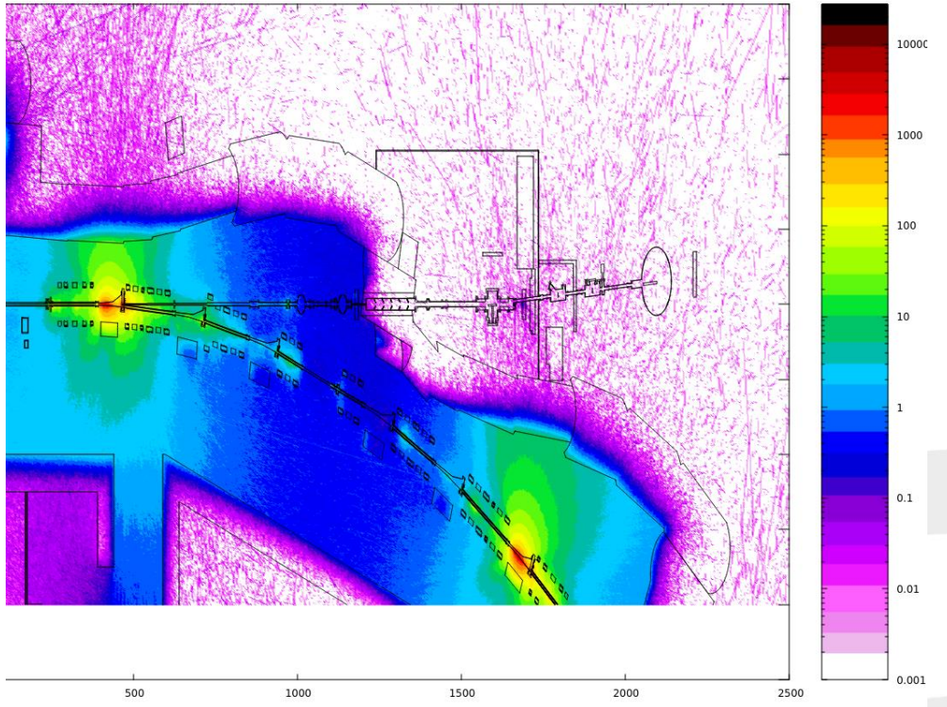
μSv/h total



μSv/h photon



μSv/h neutron



Dose rate distribution in horizontal plane at beam height

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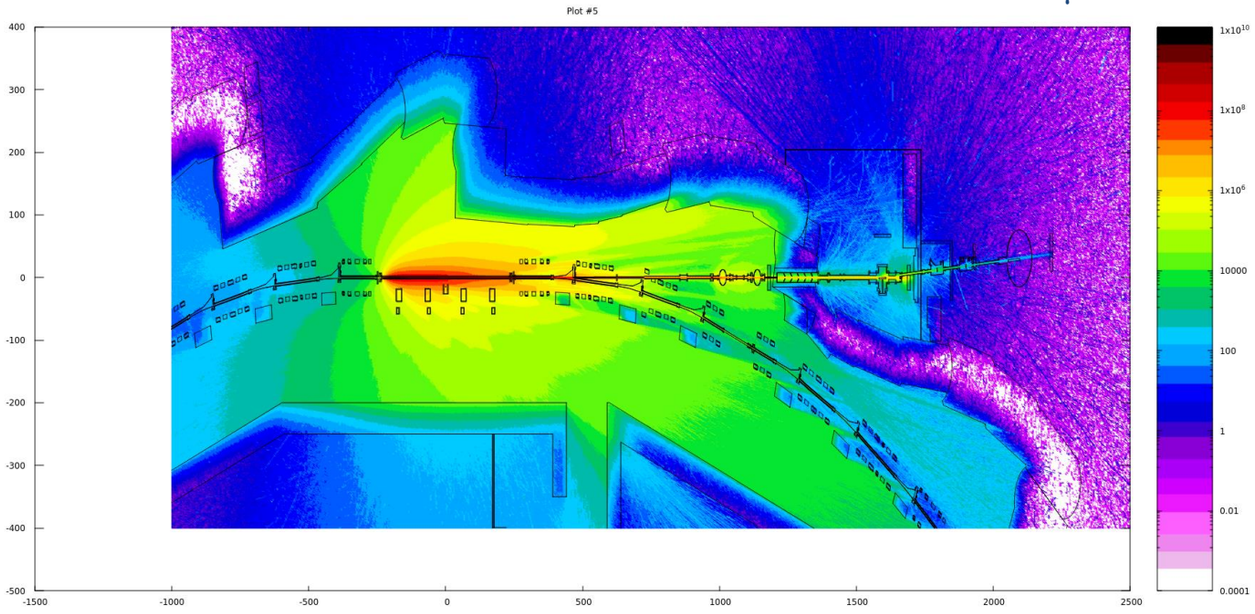
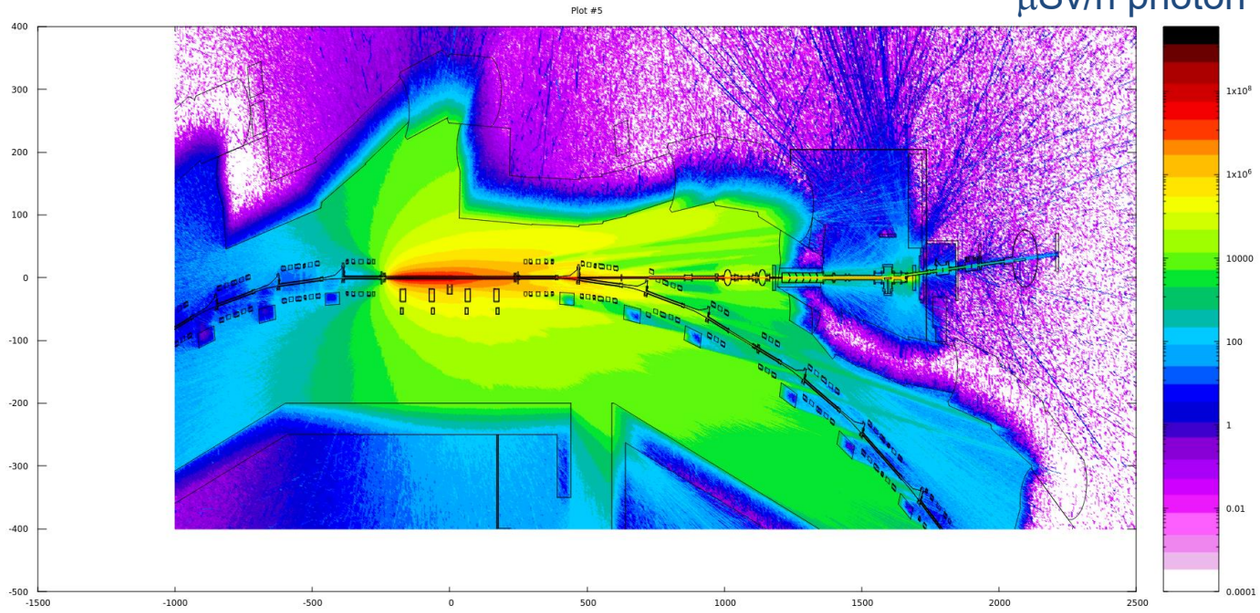
Incident scenario 1 :

beam lost on input taper straight section, Front end open (during top-up), instantaneous dose rates from 0.2 nC, 3.125 Hz beam injected from booster, completely lost on input taper

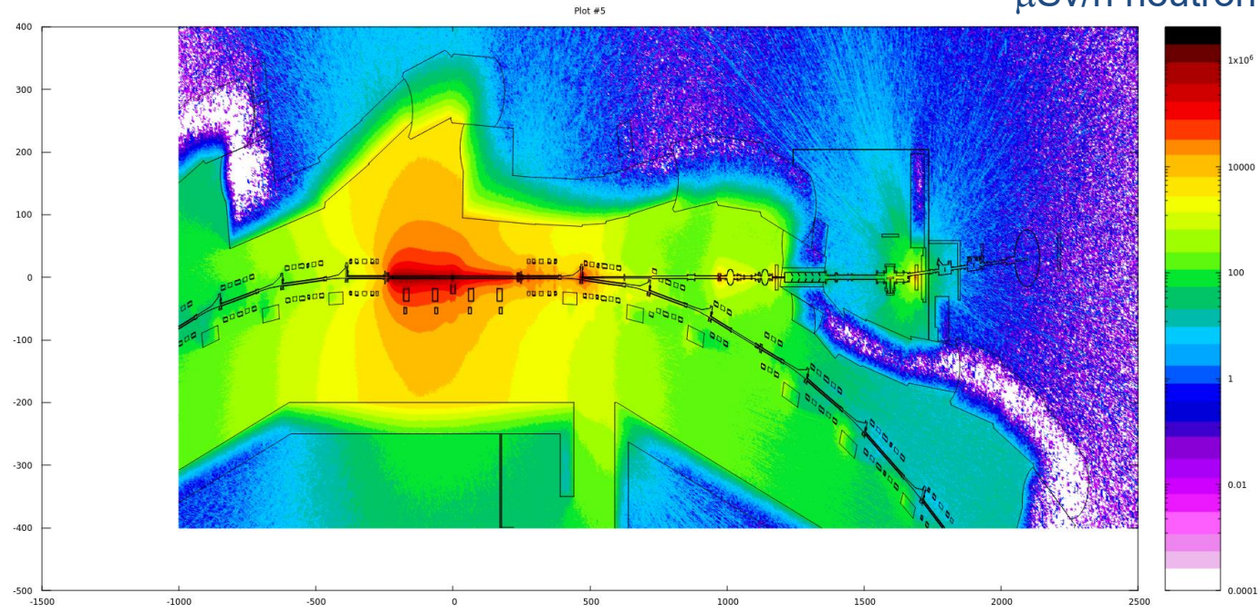
µSv/h total



µSv/h photon



µSv/h neutron



Dose rate distribution in horizontal plane at beam height

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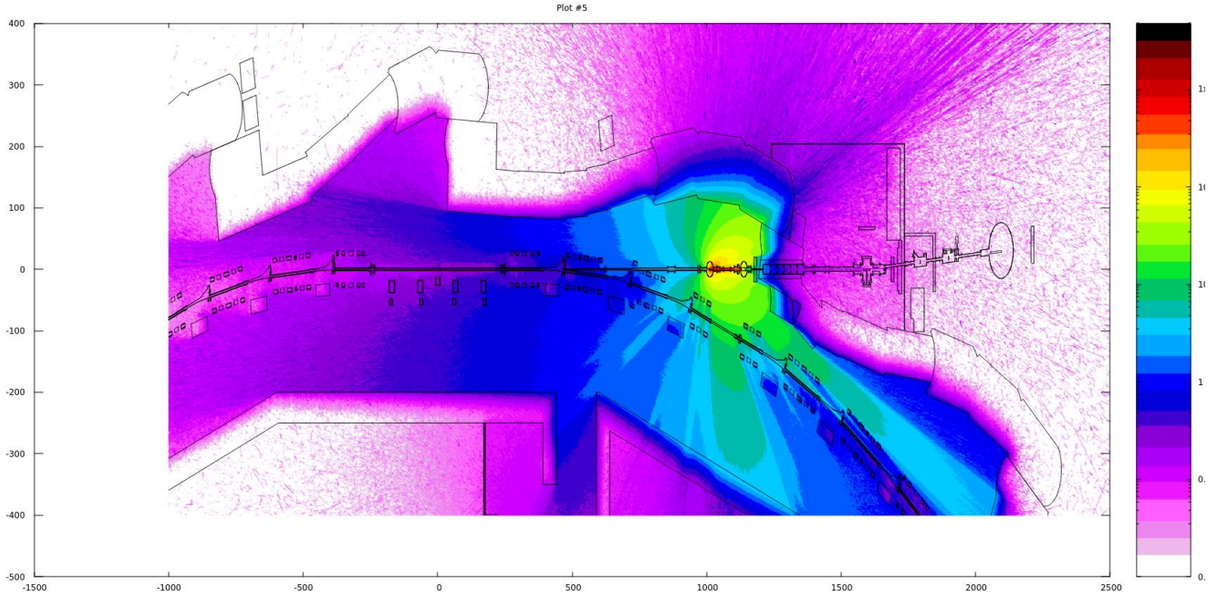
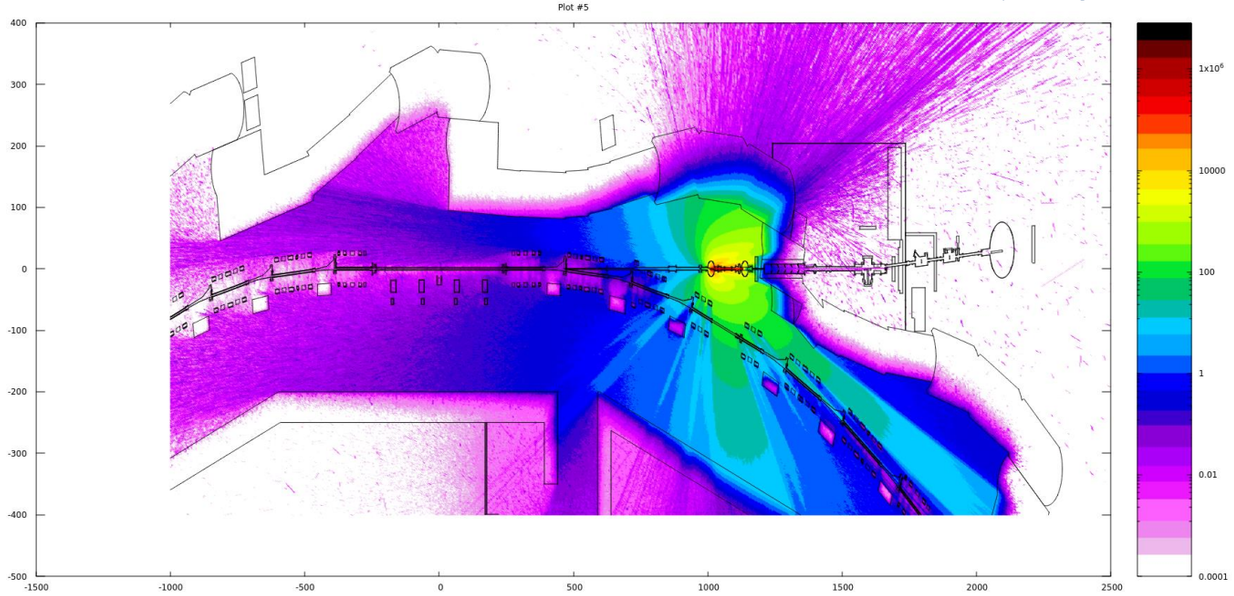
Incident scenario 2 : dipole magnet downstream of straight section off during injection, electrons into Front end with Front end closed, integrated dose from a single 2 nC pulse injected from booster

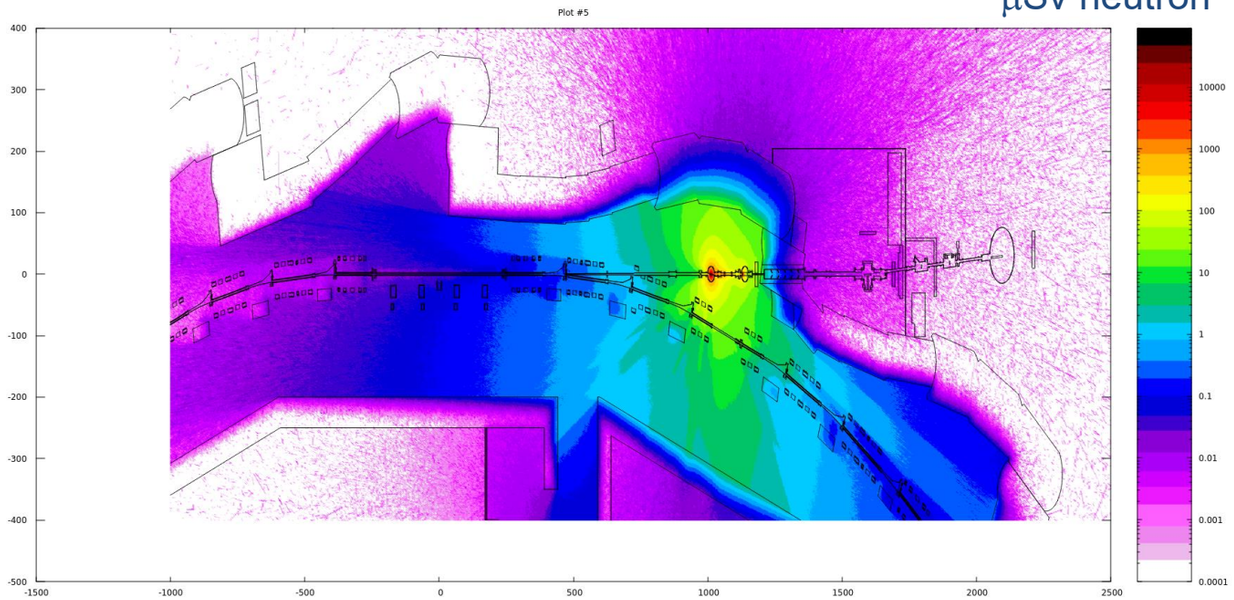
µSv total



µSv photon



µSv neutron



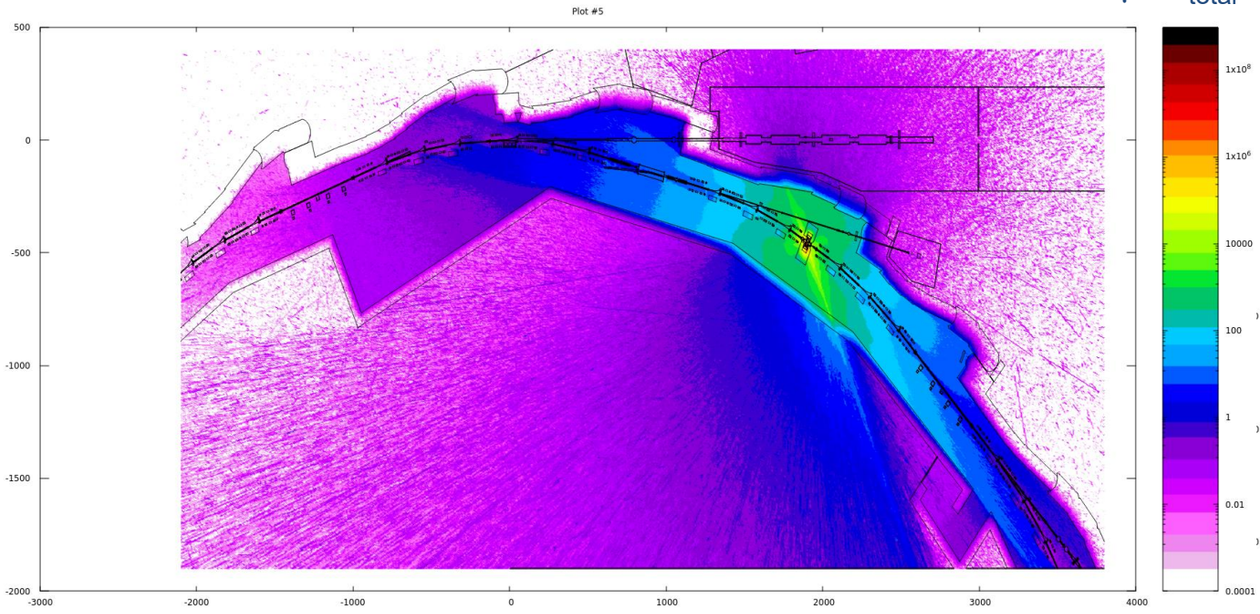
Dose rate distribution in horizontal plane at beam height

Beam losses in the storage ring - beamdump

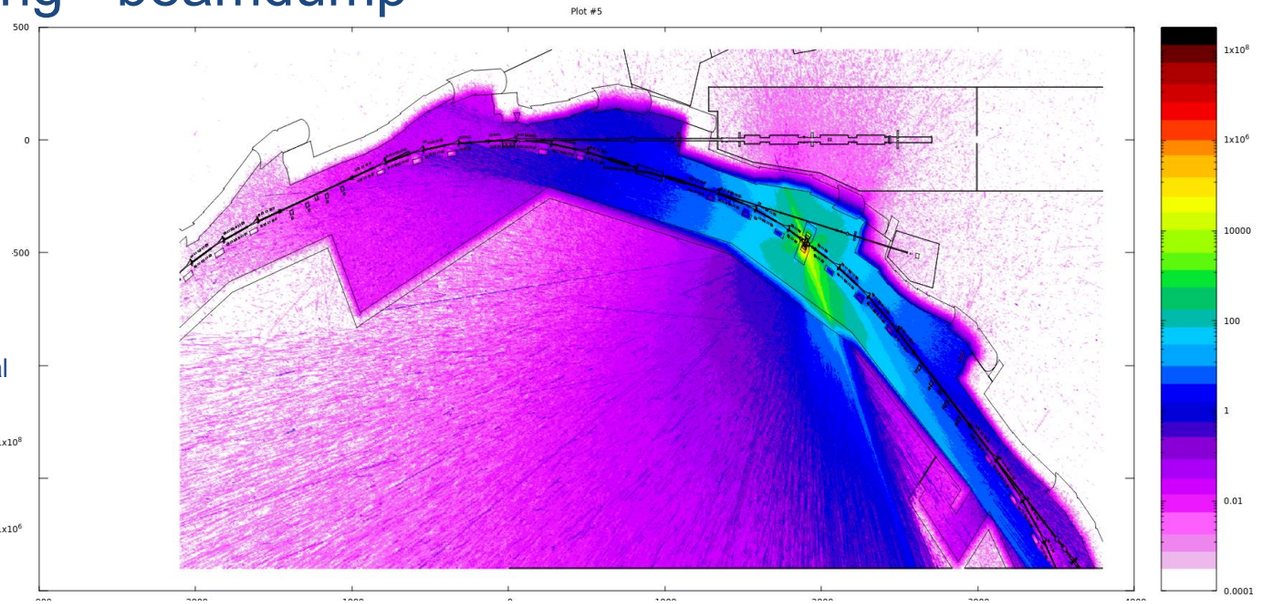
Integrated dose during 400 mA beam dump: total beam loss on the collimator

Dose distribution in horizontal plane at beam height

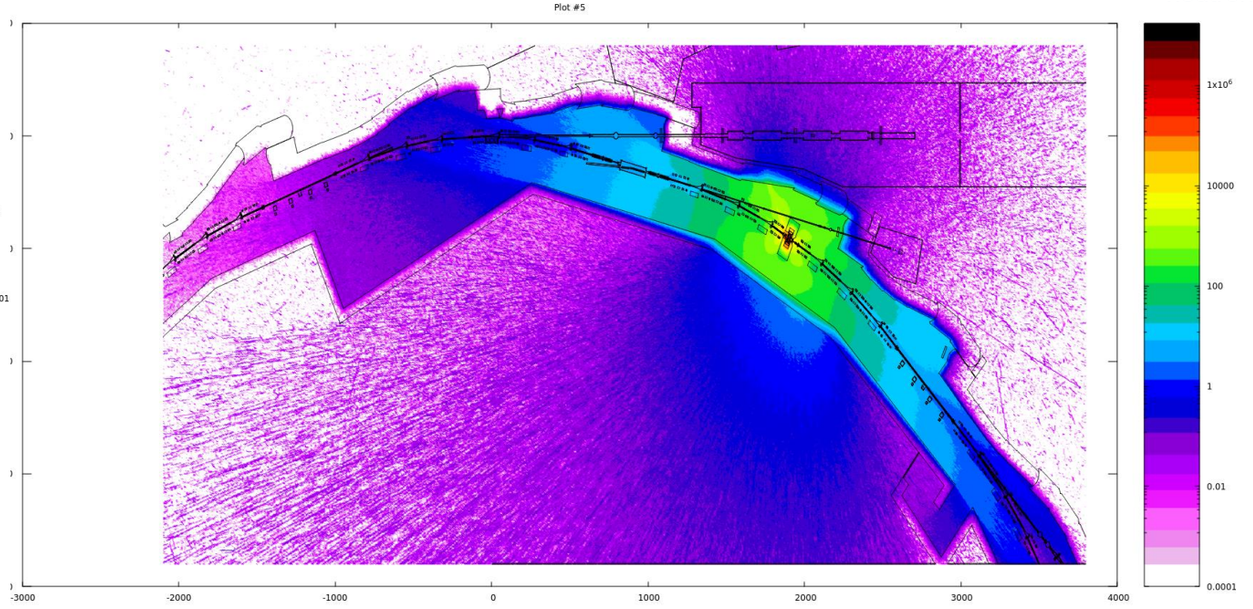
μSv_{total}



$\mu Sv_{photons}$



$\mu Sv_{neutrons}$



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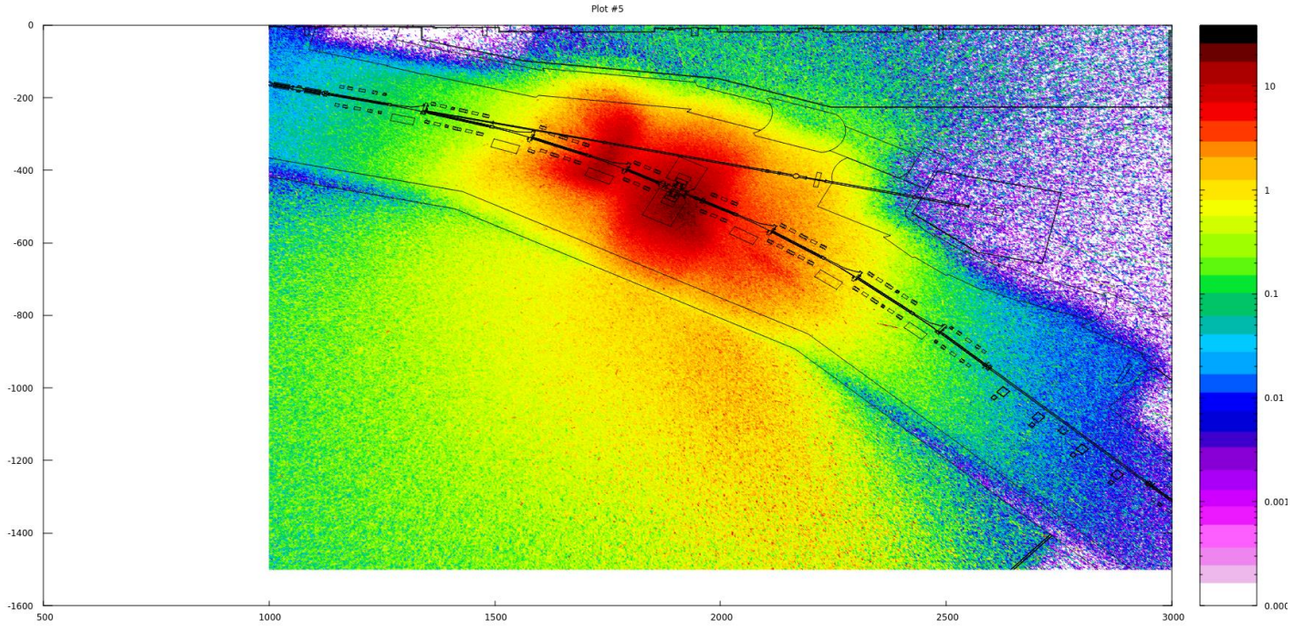
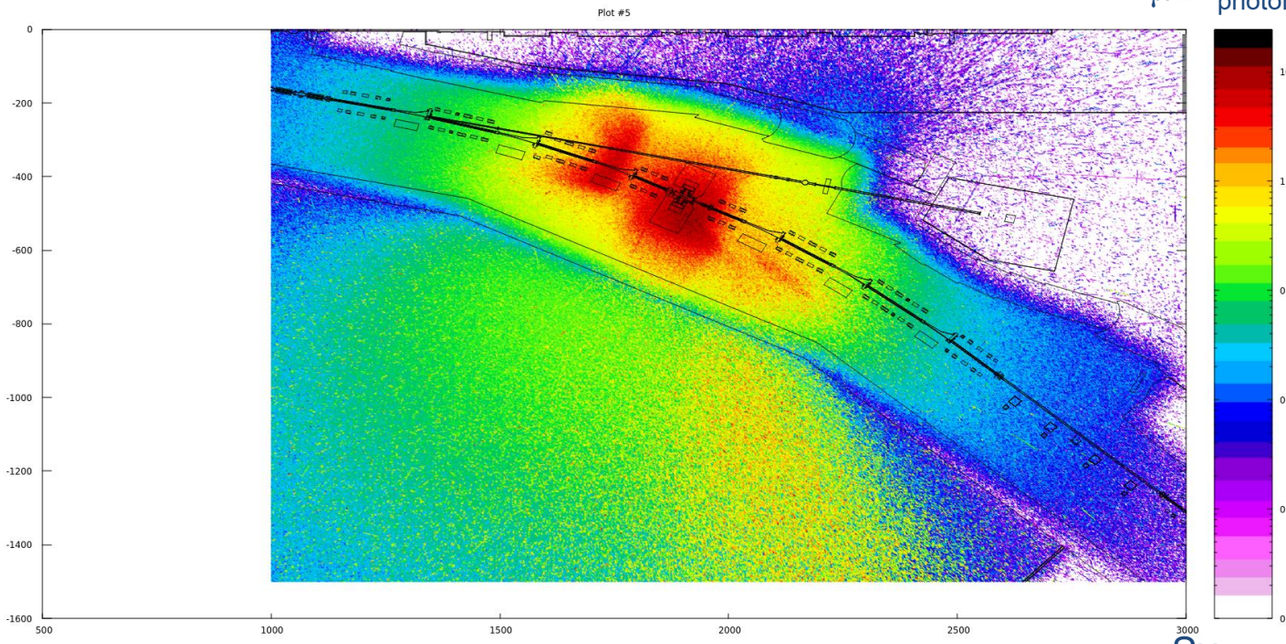
Integrated dose during 400 mA beam dump: total beam loss on the collimator

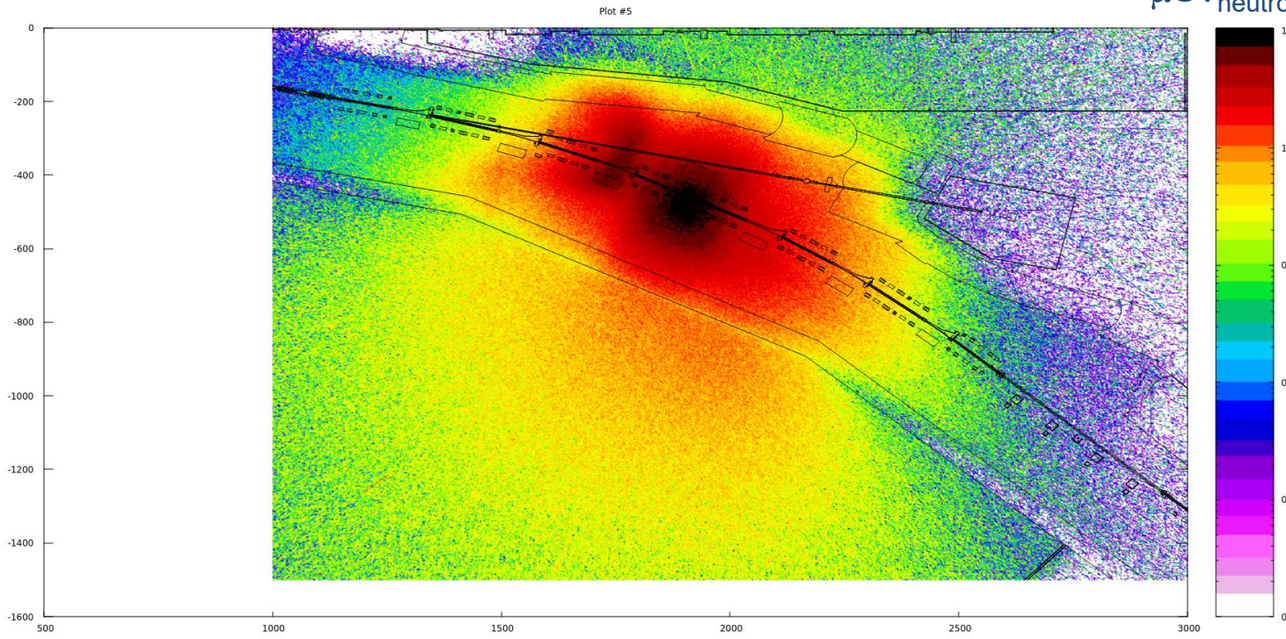
μSv_{total}



μSv_{photon}



$\mu Sv_{neutron}$



Dose distribution in horizontal plane above tunnel roof

Beam losses in the storage ring - injection

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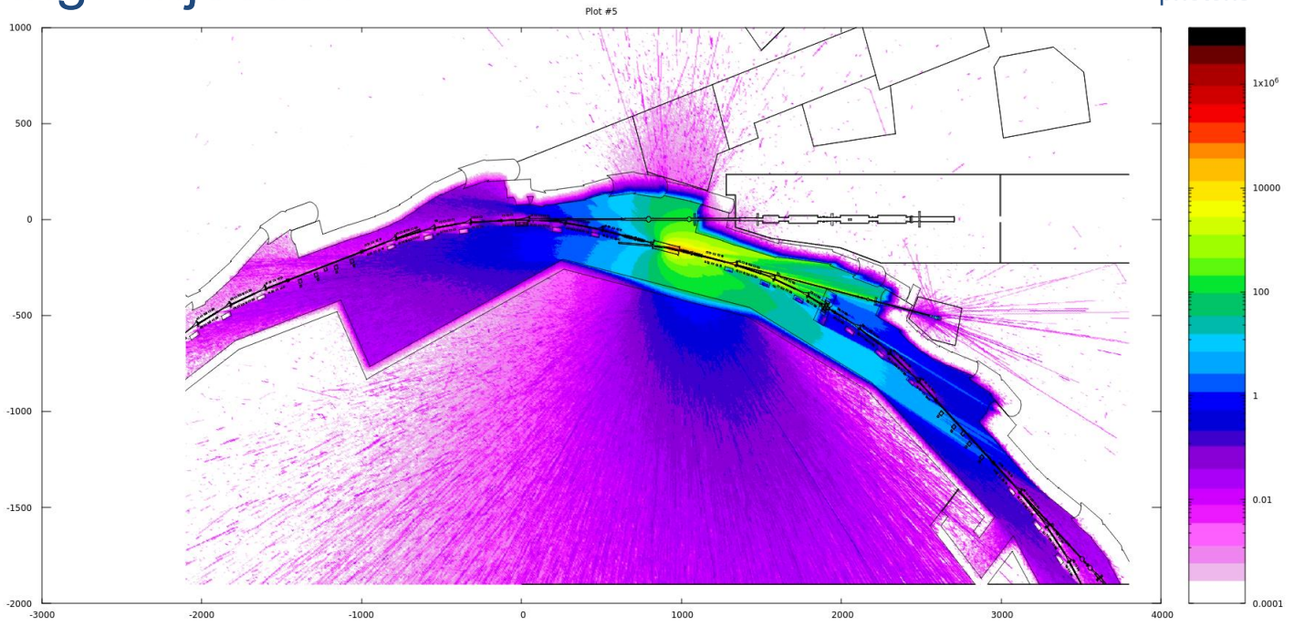
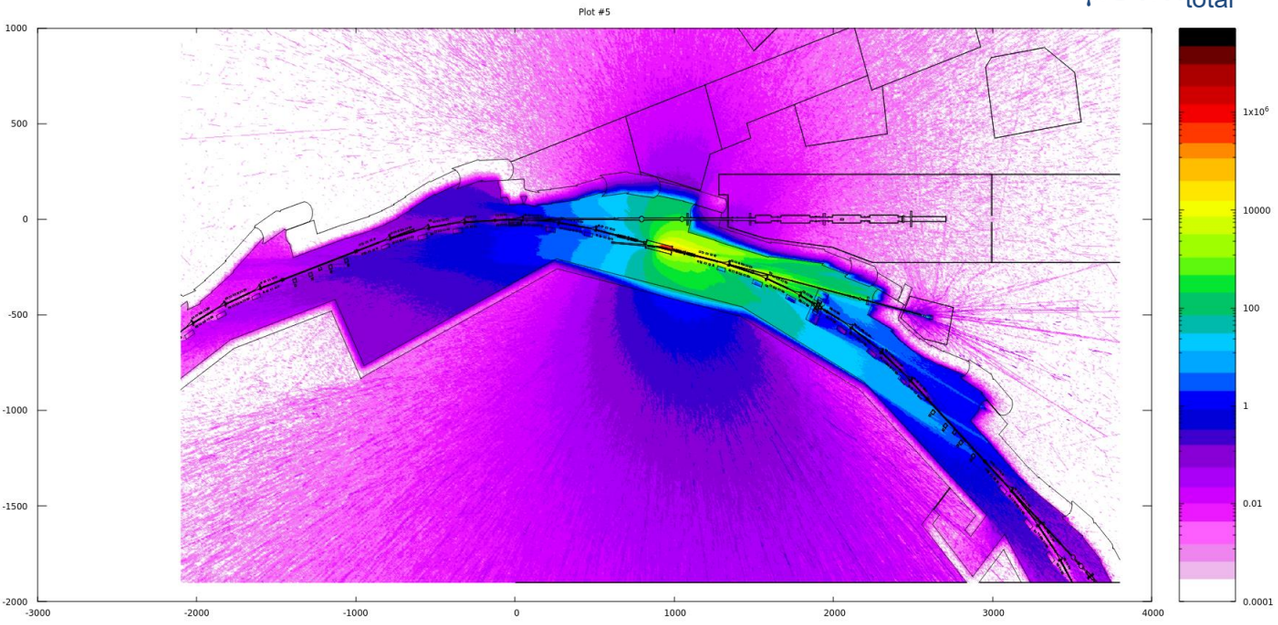
Dose rates due to injection losses
Assumptions: 400 mA, 9 h lifetime
Injection efficiency: 70 %, total injection losses on septum
Dose rates are dose rates averaged over 1 hour

Dose rate distribution in horizontal plane at beam height

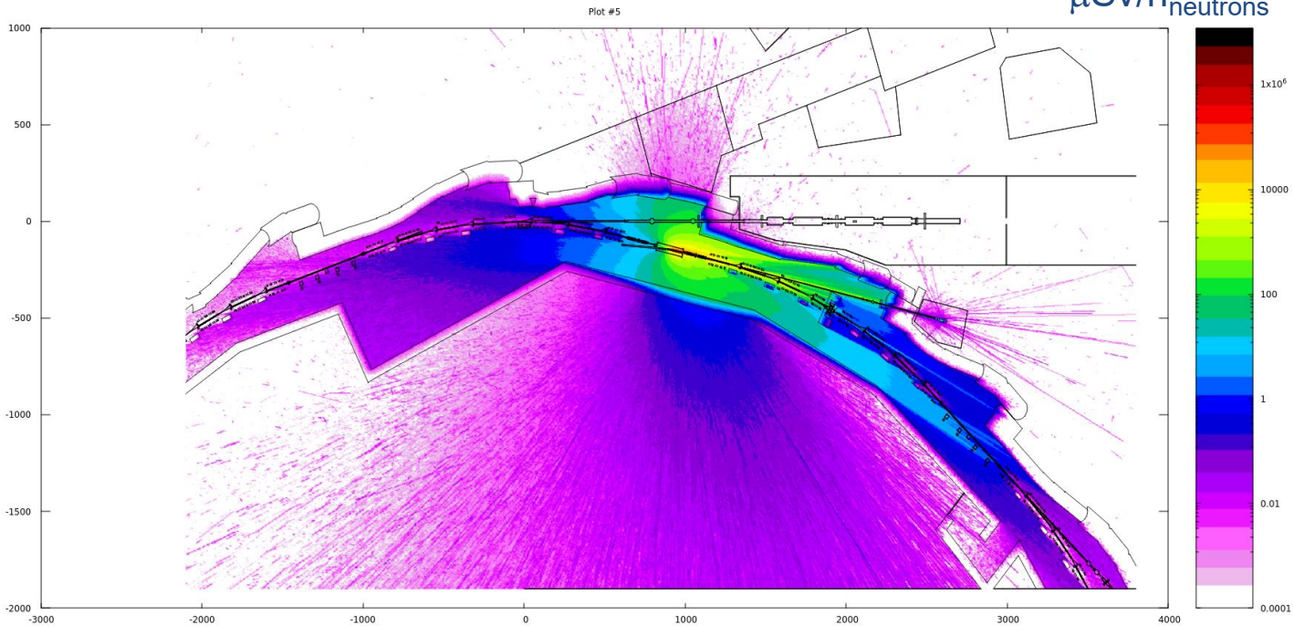
$\mu Sv/h_{photons}$



$\mu Sv/h_{total}$



$\mu Sv/h_{neutrons}$



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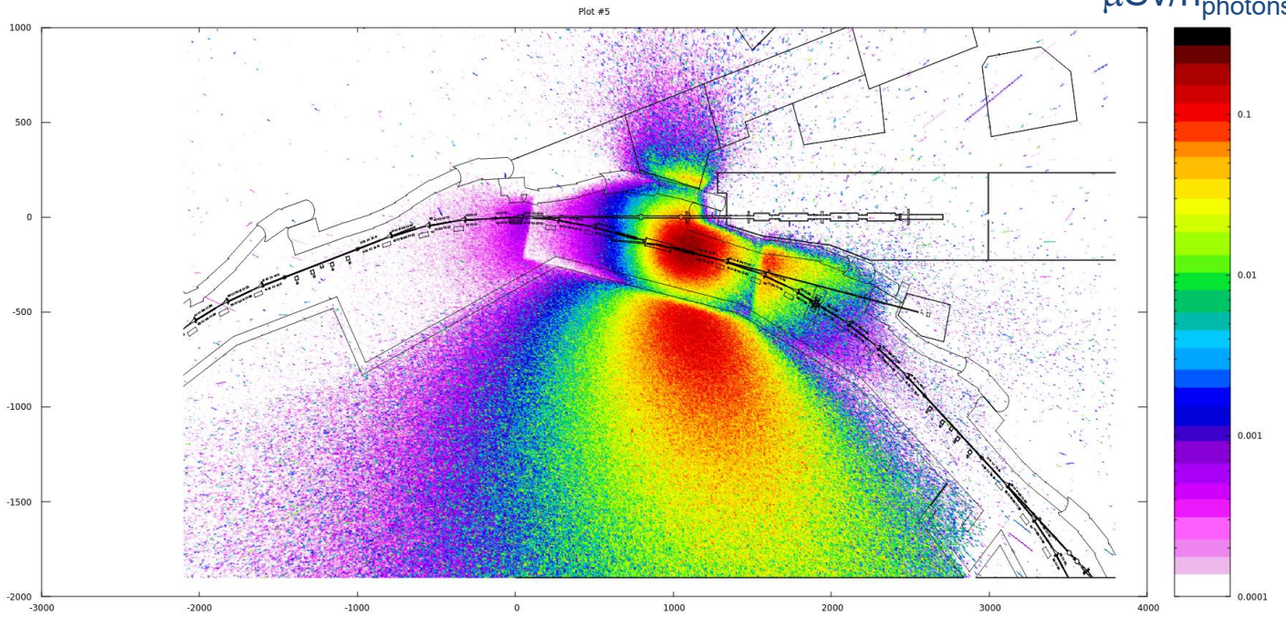
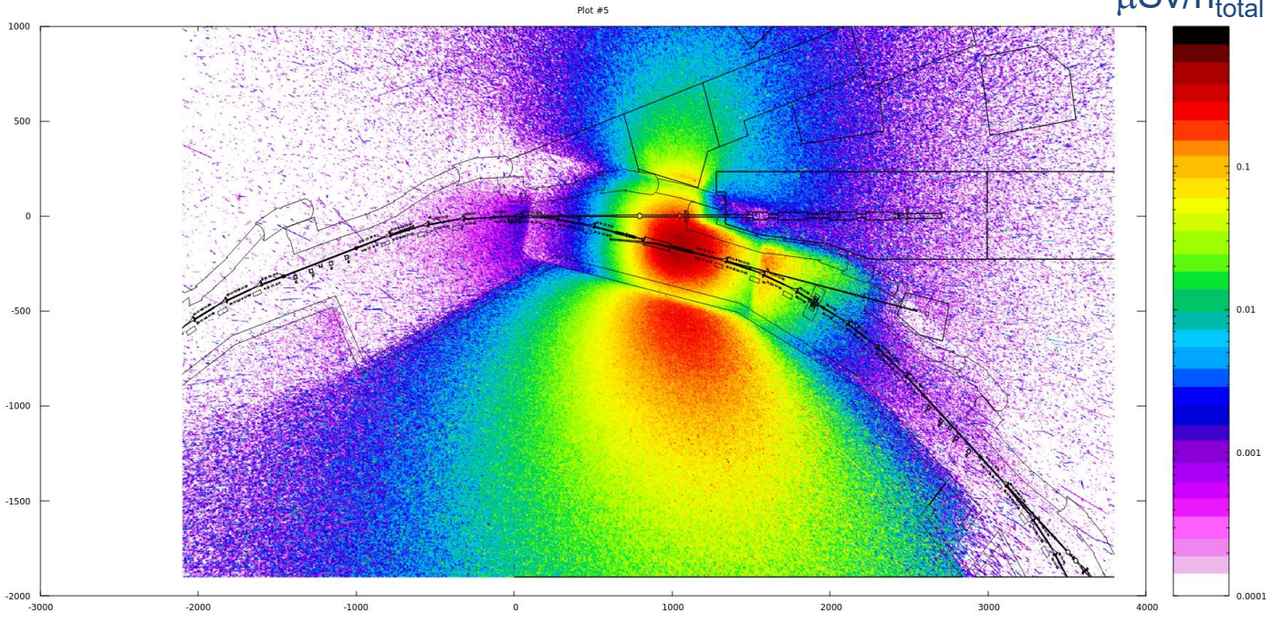
Dose rates due to injection losses
Assumptions: 400 mA, 9 h lifetime
Injection efficiency: 70 %, total injection losses on septum
Dose rates are dose rates averaged over 1 hour

Dose rate distribution in horizontal plane above tunnel roof

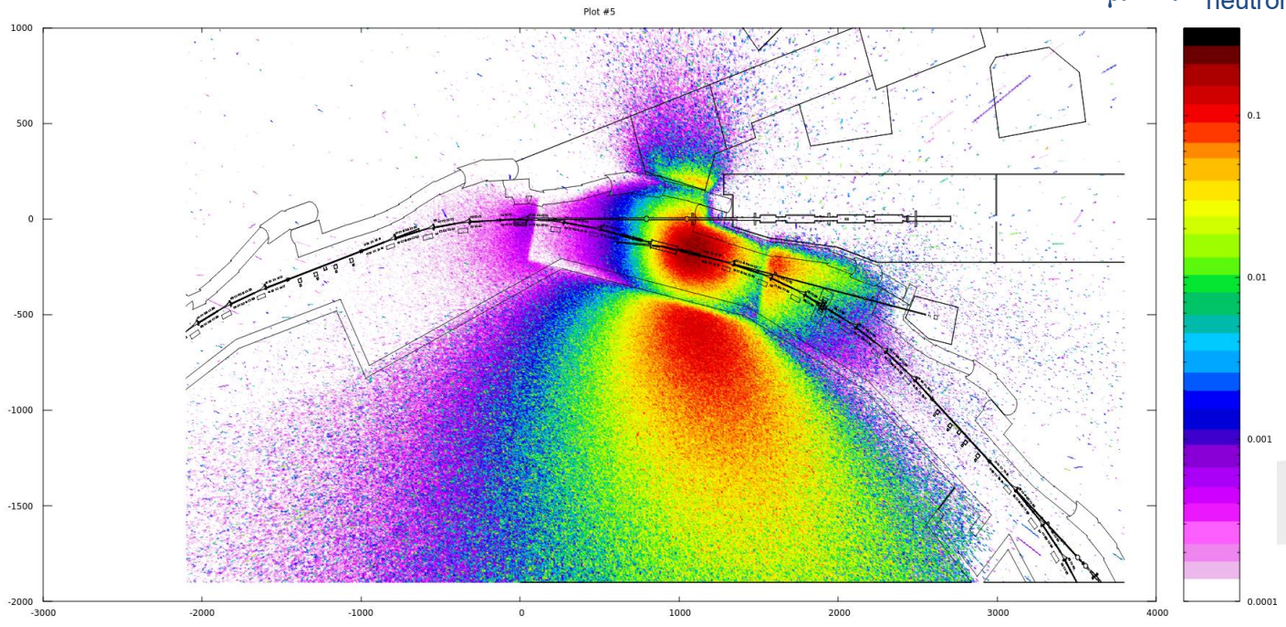
$\mu Sv/h_{photons}$



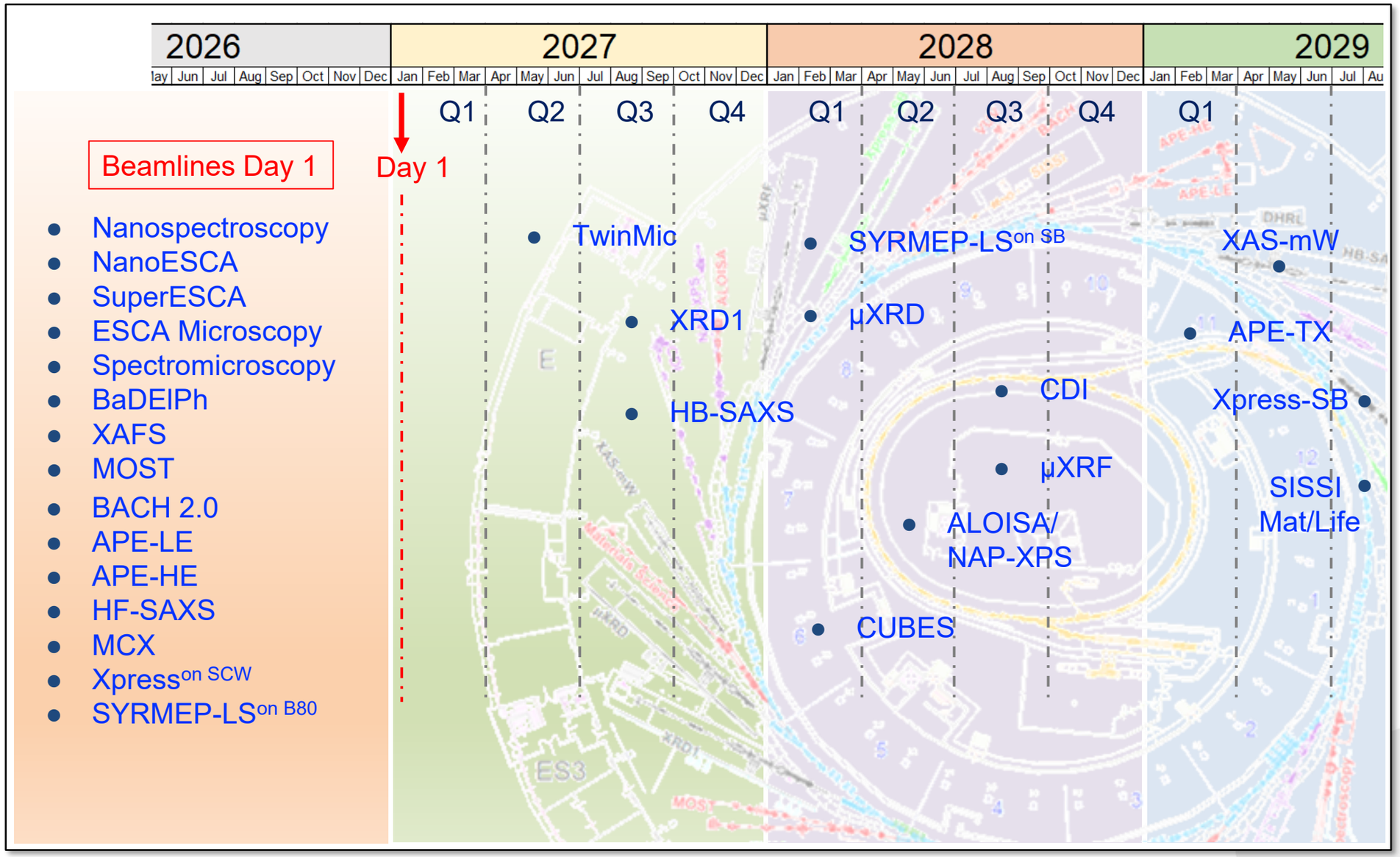
$\mu Sv/h_{total}$



$\mu Sv/h_{neutron}$



Expected beamlines commissioning on Elettra 2.0



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I am sorry not to be there with you…! 😔

Thanks for your attention!

giuliana.tromba@elettra.eu

www.elettra.eu

Elettra Sincrotrone Trieste

From Elettra to Elettra 2.0

		Elettra	Elettra 2.0
Operating for users		1994-2025	2027-
Beam energy	GeV	2.4 (25%) --- 2.0 (75%)	2.4 GeV (2.0 for some time)
Photon energies	keV	0.003-15	0.015 - 60
e – emittance - coupling	nm-rad	10 --- 7 - 1%	0.212 --- 0.150 – 3%
ID slots		11 Long + 1 short	11 Long + 5 short
Beam lines (IDs, Dipoles)	#	28 (19, 9)	32 (25 3 IVU, 7 3 SB)
e-beam size at IDs (σx,σy)	μm	286,16	36,6
Brilliance (ph/s/mm²/mrad²/0.1%bw)		$2X10^{19}$	10^{22}
Coherence ratio at 1 keV	%	0.5	30
e - intensity	mA	160 --- 310	400
Lattice -symmetry		2BA - 12 fold	S6BA-E(nhanced) -12fold
Fill patterns		multi-bunch, single or few bunch, hybrid	Whatever