Elettra Sincrotrone Trieste

Elettra 2.0 project: radiation protection issues for the new and upgraded beamlines

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11TH INTERNATIONAL WORKSHOP ON RADIATION SAFETY AT SYNCHROTRON RADIATION SOURCES (RADSYNCH23)

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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 – Exit 1.2 beamline
- Conclusions

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The Elettra 2.0 upgrade project

Aims:

- Maintaining the Elettra at the forefront of synchrotron user facilities in a **broad photon energy window** ranging from IR and THz to the hard X-rays;
- increasing the capacity of the laboratory to attract new user communities.

Concepts:

- The new machine will have substantial reduction of the **emittance** of the stored beam, (emittance levels capable of providing diffraction limited X-ray sources also in the horizontal plane). Intense nano-beams in the range of VUV to X-rays for the study of matter with very high spatial resolution will be produced.
- The project will also consider the demands of the X-ray users' community, increasing the offers for applications in the fields of X-ray imaging, X-ray Fluorescence, Diffraction and Small Angle Scattering.

Constrains:

- budget
- time constrains: keep the *dark* period as short as possible
- logistic constraints
  - same machine circumference (259 m) and experimental hall
  - Shielding blocks should maintain their position
  - Same pre-injector and booster

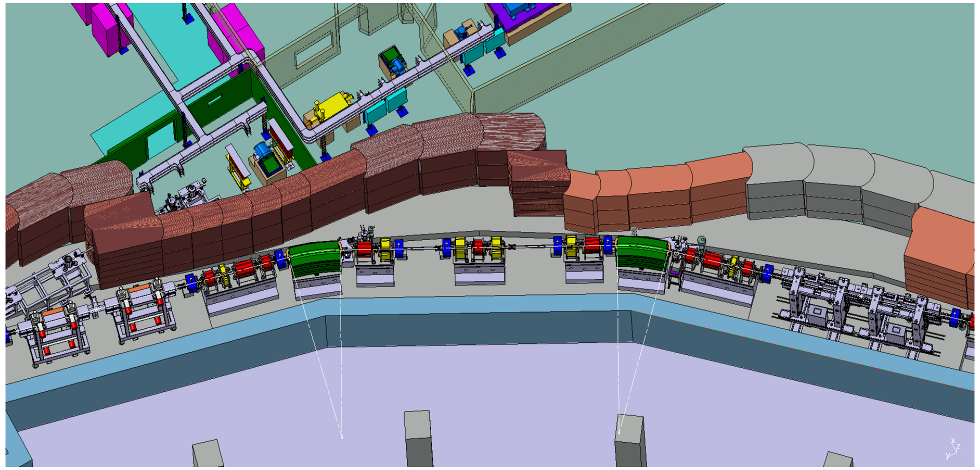
  } *minimize the number of beamlines to be moved from current position*
- upgrade plans for Partner Institutions' beamlines

Elettra 2.0 Lattice

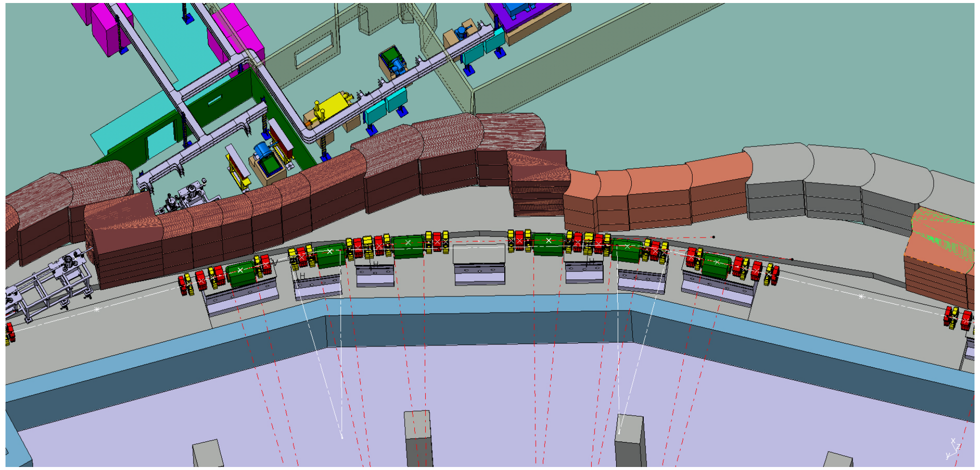
The existing double-bend achromat will be replaced by a special symmetric six-bend achromat (S6BA_E).

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.



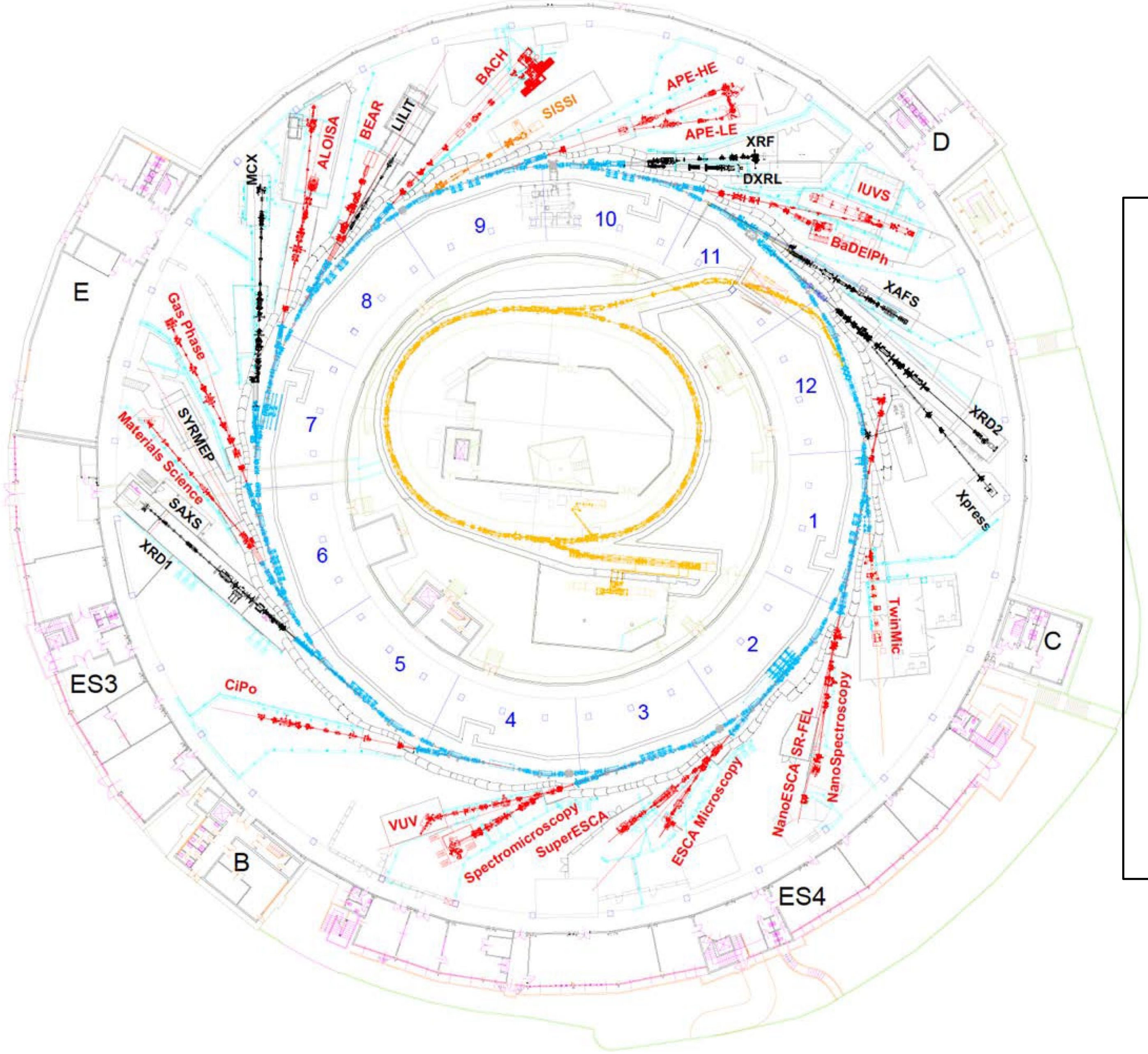
Elettra



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

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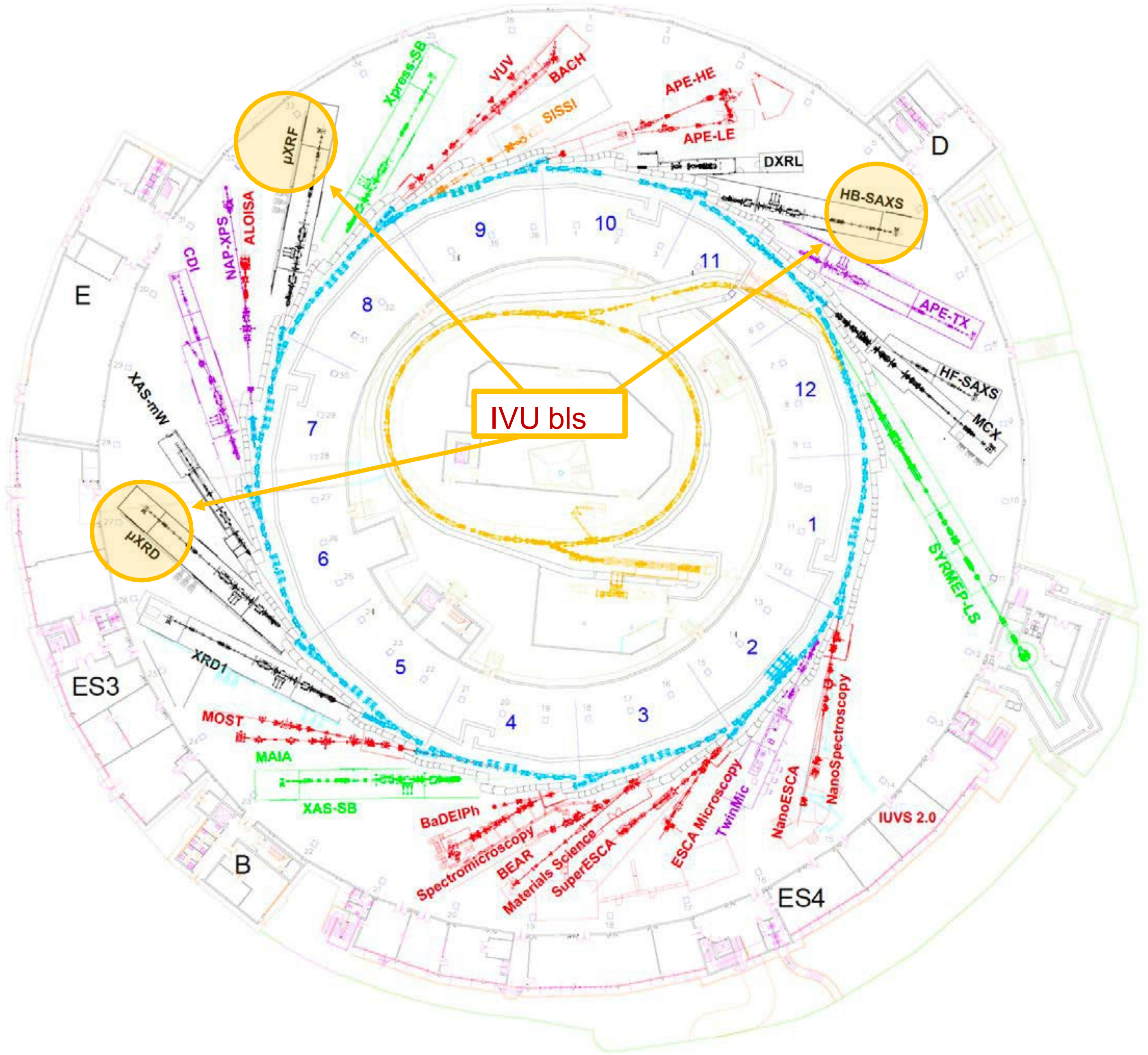
Elettra 2.0 layout



Elettra → Elettra 2.0

28 → **32 beamlines**

17 → **14** Bls VUV-SoftX

9 → **8** Bls hard X-rays

0 → **4** Bls on SB (up to > 60 keV)

0 → **4** Bls Soft-tender X-rays

2 → **2** IR beamline

+

1 UV laser lab (IUVS 2.0)

Courtesy of S.Lizzit

from Elettra to Elettra 2.0
Beamlines installation, movement, removal

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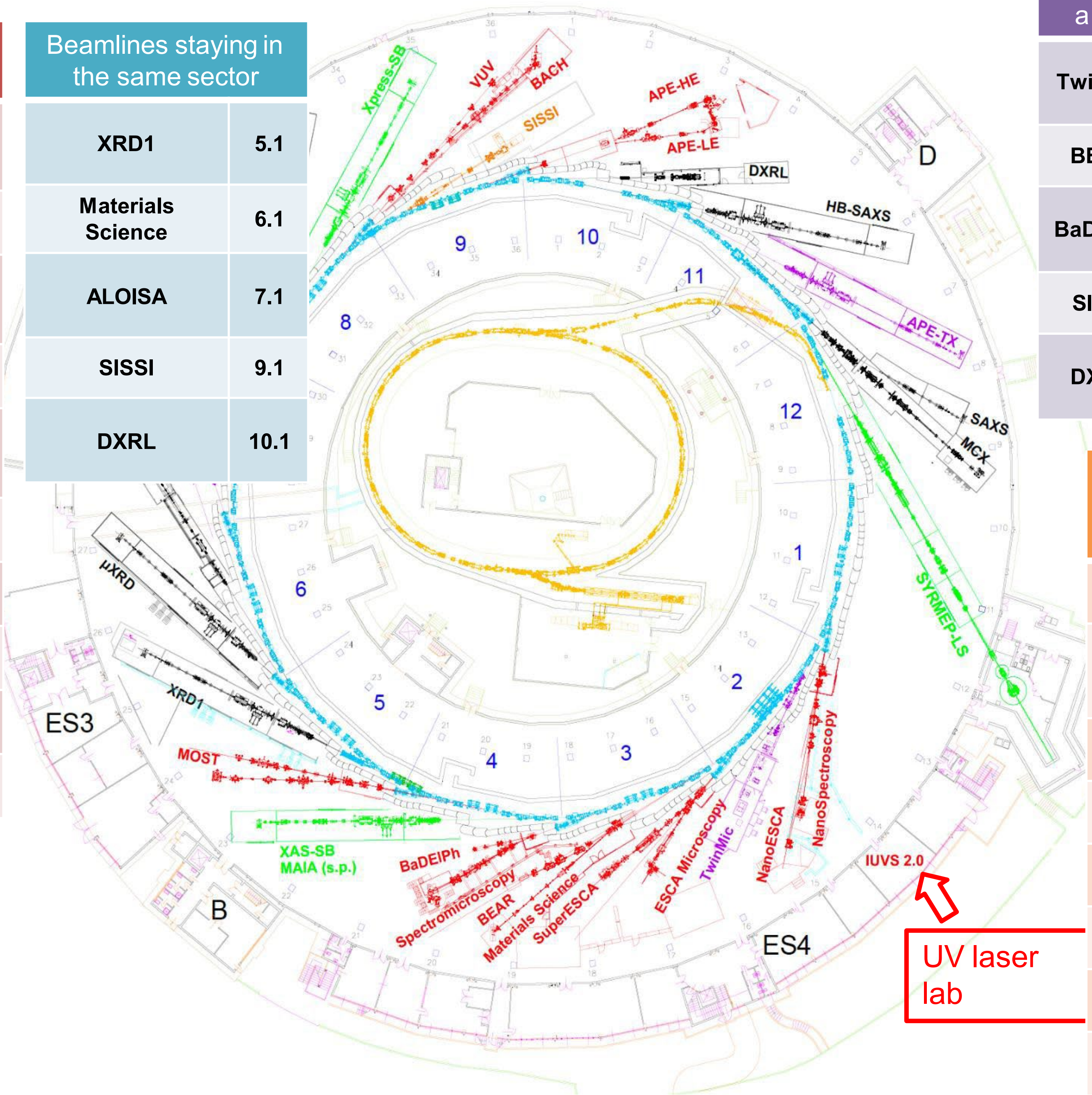
Beamlines keeping the same position	
Nanospectroscopy	1.2
NanoESCA	1.2
ESCA Microscopy	2.2
SuperESCA	2.2
Spectromicroscopy	3.2
MOST	4.2
BACH	8.2
APE-LE	9.2
APE-HE	9.2
(Xpress)	11.2

End stations moved to a new sector	
MCX	7.1 -> 11.2
VUV	3.2 -> 8.2

Beamlines staying in the same sector	
XRD1	5.1
Materials Science	6.1
ALOISA	7.1
SISSI	9.1
DXRL	10.1



Beamlines moved to a different sector	
TwinMic	1.1 -> 2.1
BEAR	8.1 -> 3.1
BaDEIPh	10.2 -> 3.2
SISSI	9.1
DXRL	10.1

Beamlines permanently removed	
SR FEL	1.1
VUV-beam transport	3.2
SYRMEP	6.1
MCX	7.1
LILIT	8.1
XRF	10.1
IUVS	10.2
XAFS	11.1

Courtesy of S.Lizzit

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SYRMEP_LS beamline

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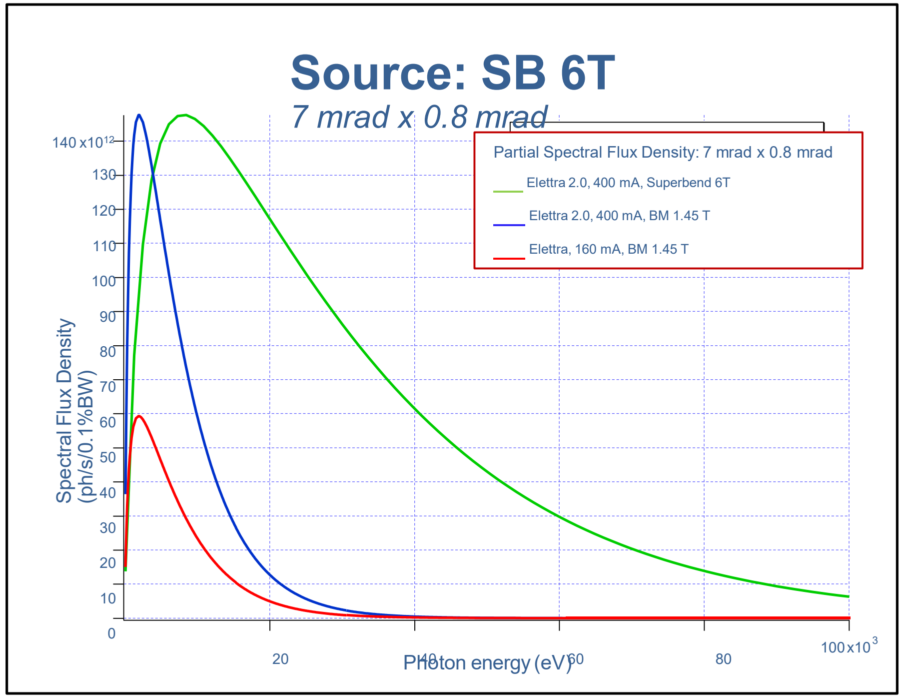
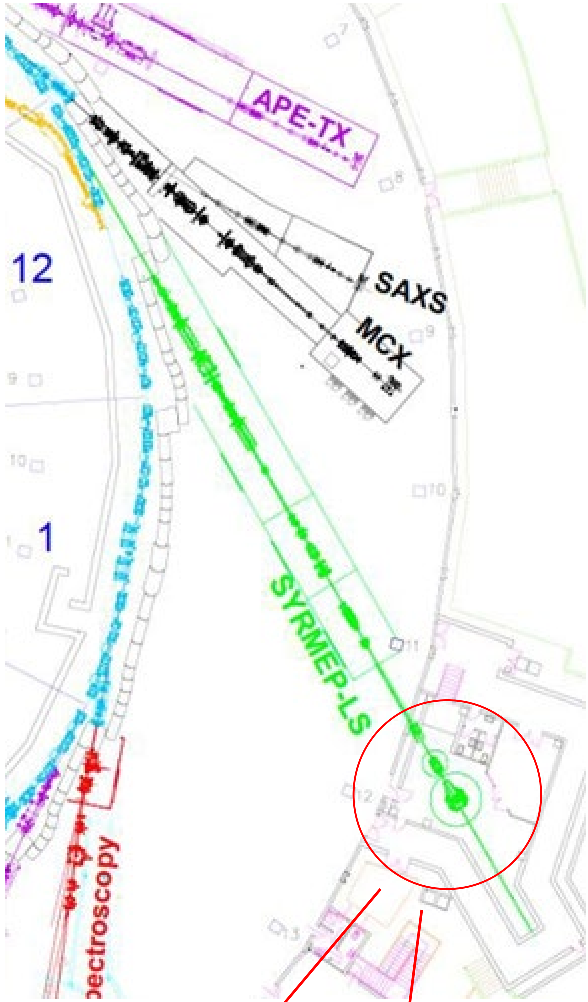
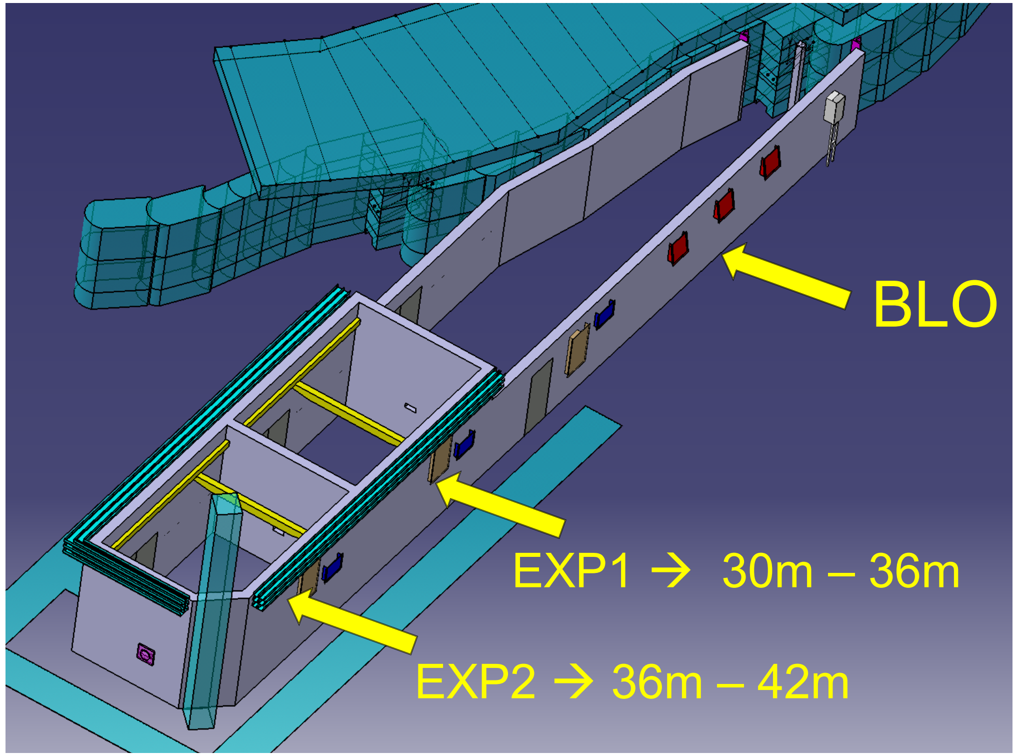
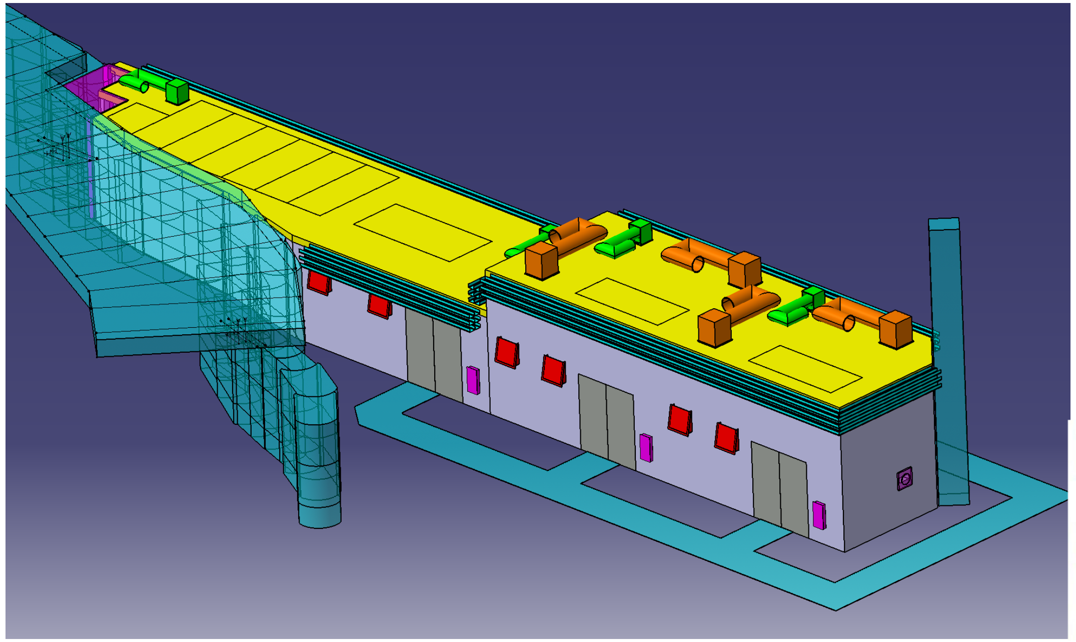
- **Source**: 6T superconducting bending magnet
- **Usable energy range** (mono) : 10 - 130 keV
- **BLO**: beamline optics (i.e. monochromators (Bragg, multilayer, Laue) and mirror)
- **EXP1, EXP2:** experimental hutches
- Transport of white/pink beam in EXP1 (eventually unified with EXP2)
- Medical facility foreseen lung CT and breast CT in a dedicated room outside the experimental hall

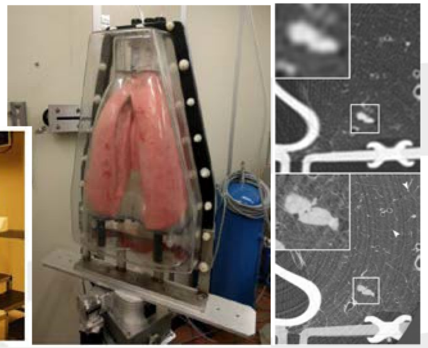








Lung CT



Breast CT

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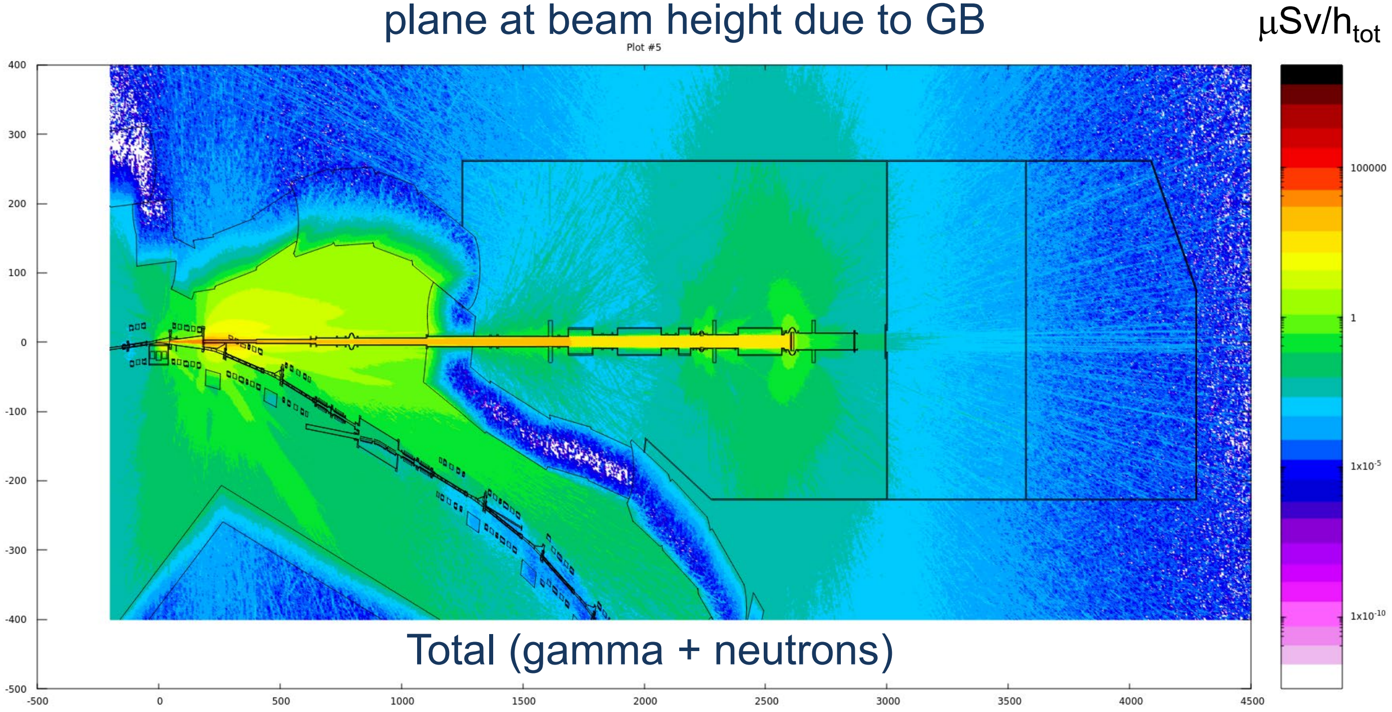
SYRMEP_LS beamline

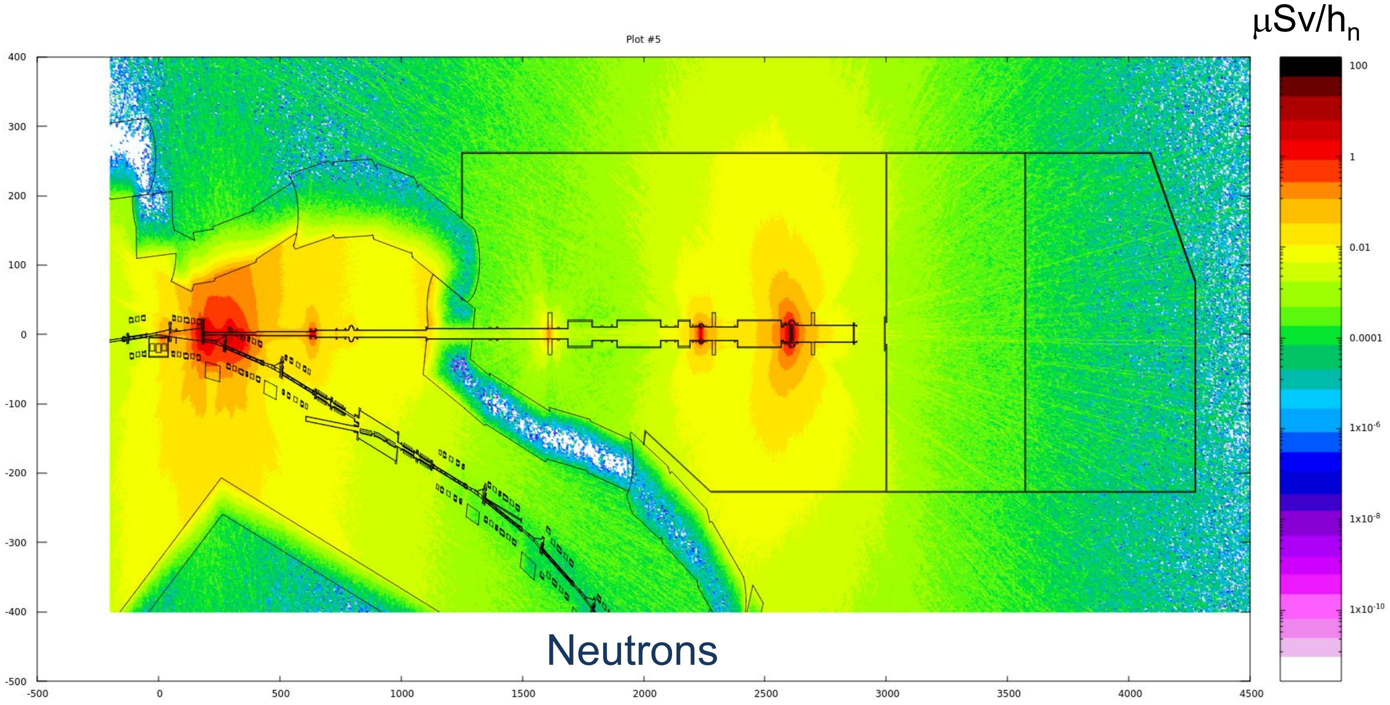
Considered radiation components
- Gas Bremsstrahlung
- Beam losses during injection
- Beamlosses due to the stored beam (Touschek)
- Accidental beam losses (Superbend quenching)
- Synchrotron radiation

- **Gas Bremsstrahlung (GB)**

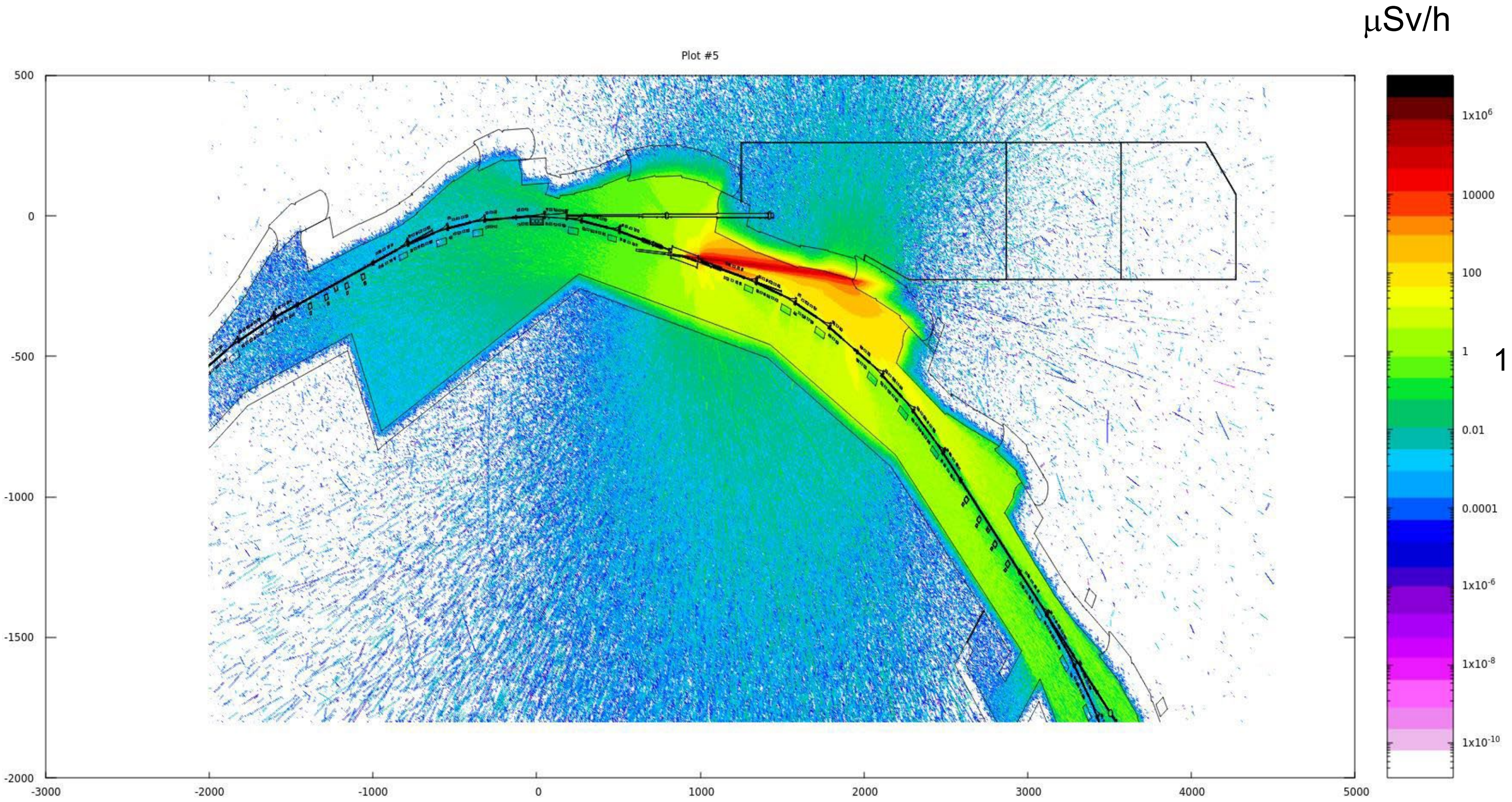
Considered parameters: 400 mA stored beam, B = 1.46 T constant longitudinal profile
A total doserate of **0.5 μSv·h^{-1}** inside the optics hutch is obtained for an average pressure in the straight section of **3.2 × 10^{-8}** mbar
A doserate of 0.05 μSv·h^{-1} inside the optics hutch is obtained for the nominal vacuum levels foreseen for 5 Ah conditioning (**3.2 × 10^{-9}** mbar!)

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





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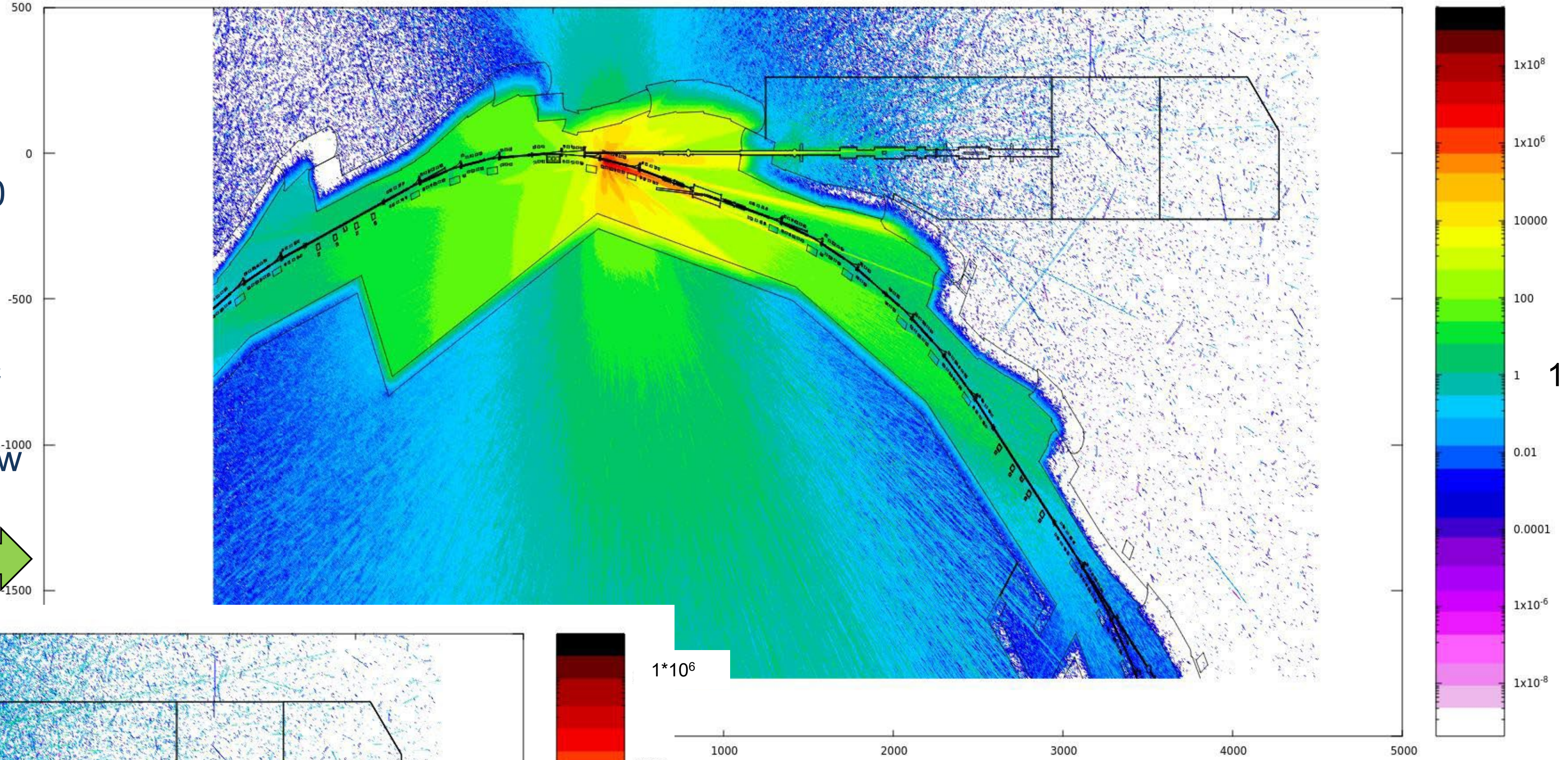
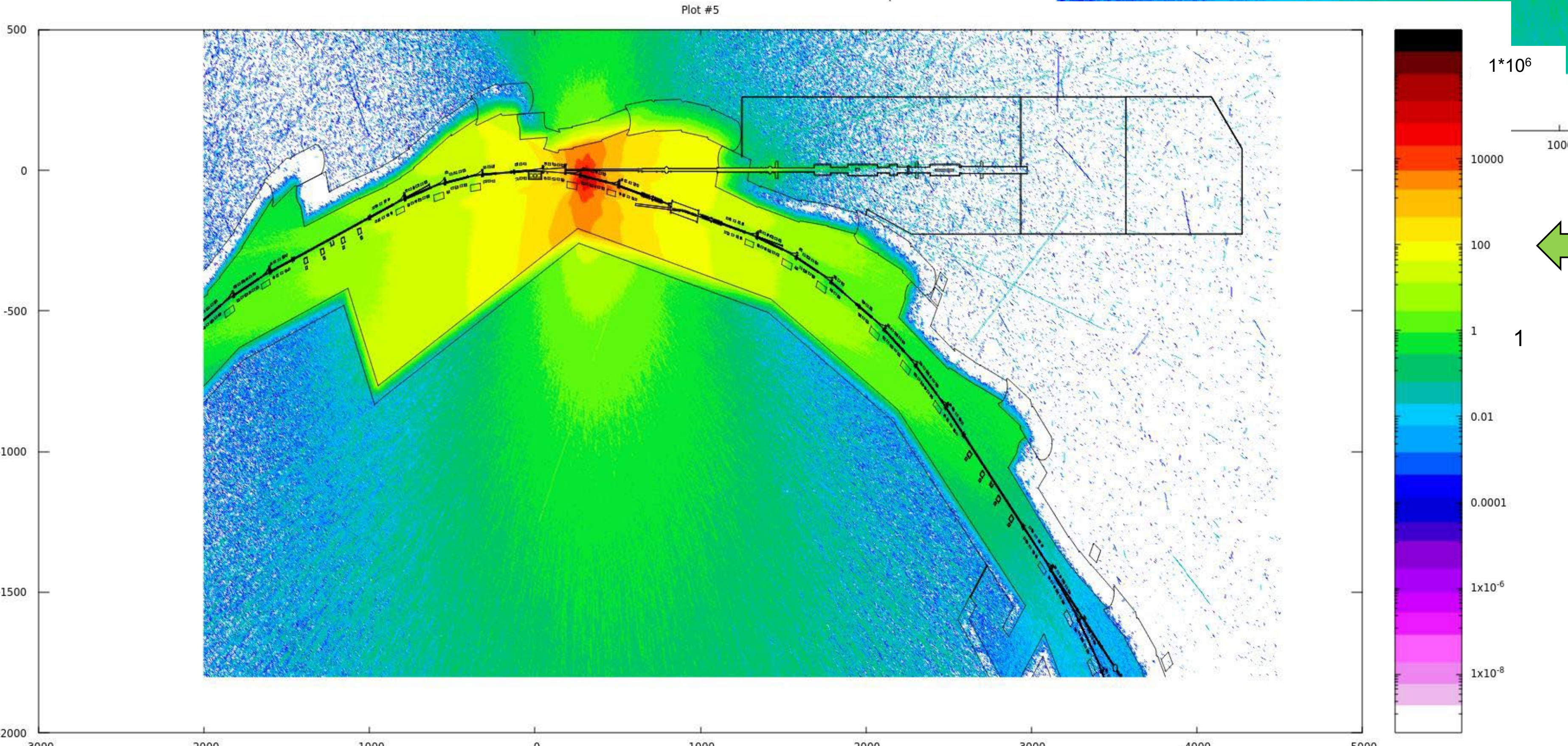
Stored beam loss – Integrated dose due to a 400 mA beam dump, caused by a problem with the superbend (e.g. quenching).
Both SYRMEP shoppers open
This is realistic configuration, where the magnetic field in the superbend is slightly below its nominal value. Outside the hutch the integrated dose is low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

Total dose (μSv)





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

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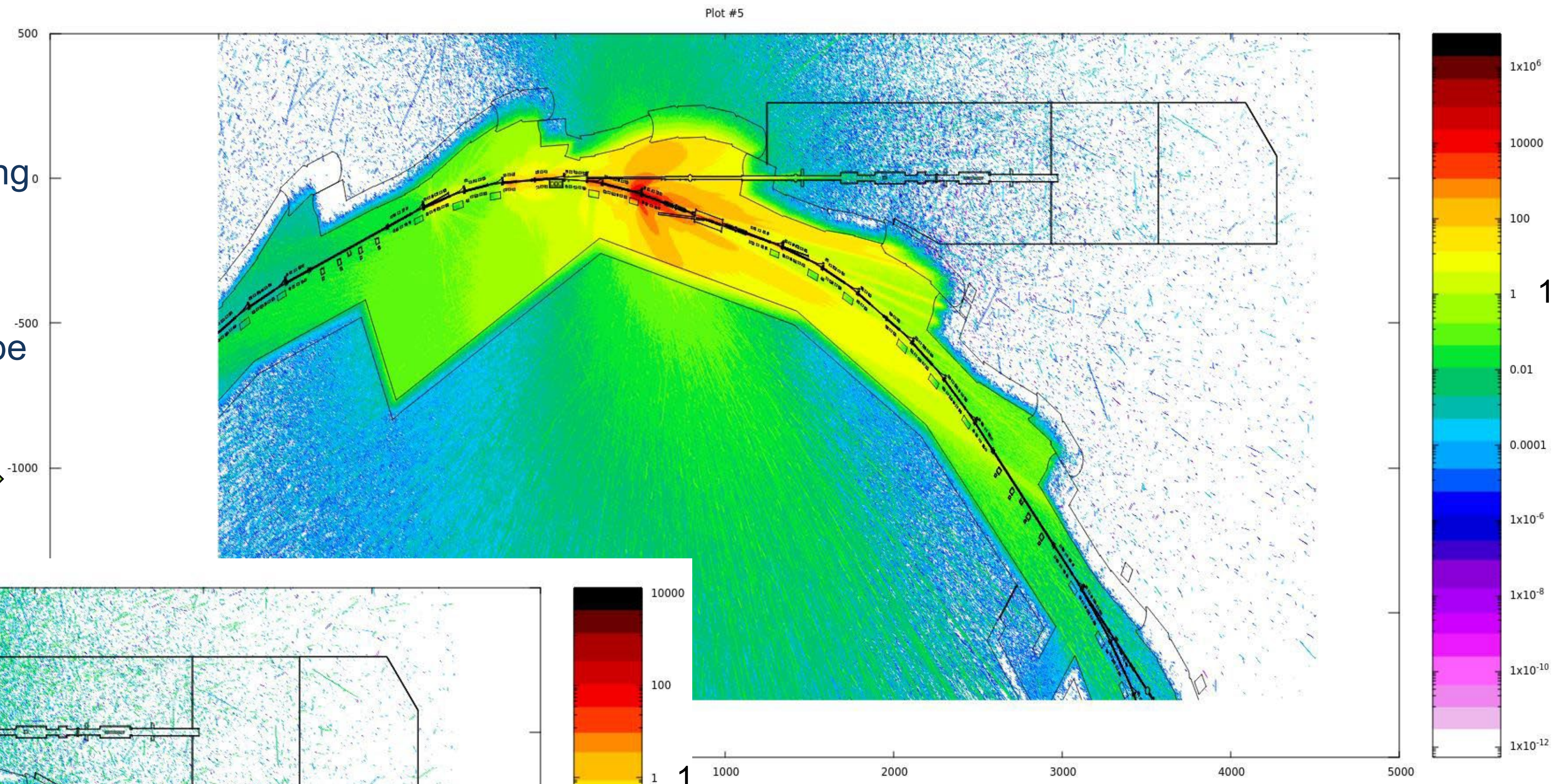
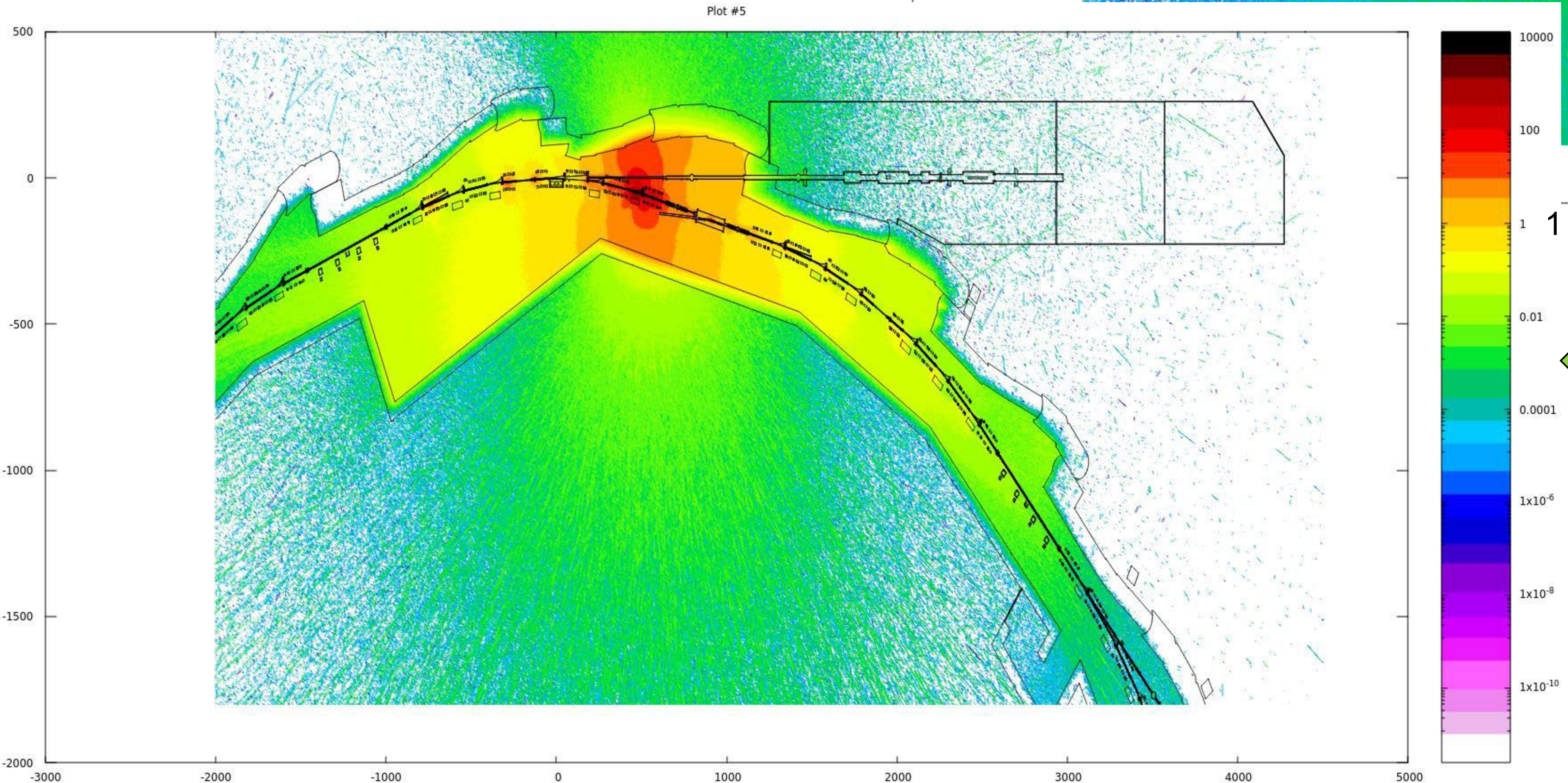
Stored beam losses due to Touschek scattering – Dose rates for a 400 mA stored beam with 9 h Touschek lifetime.
Both SYRMEP shoppers open
Dose rates inside the hutch around the beam pipe are of the order of 0.5 μSv/h

Total dose (μSv/h)





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

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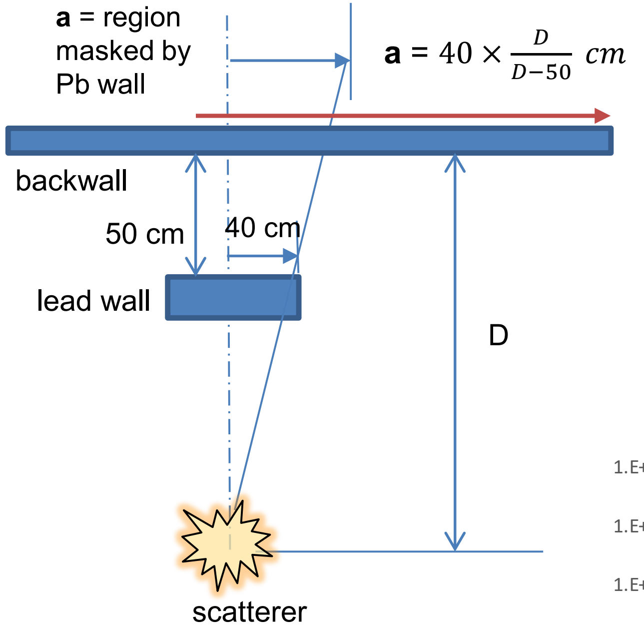
SYRMEP_LS beamline

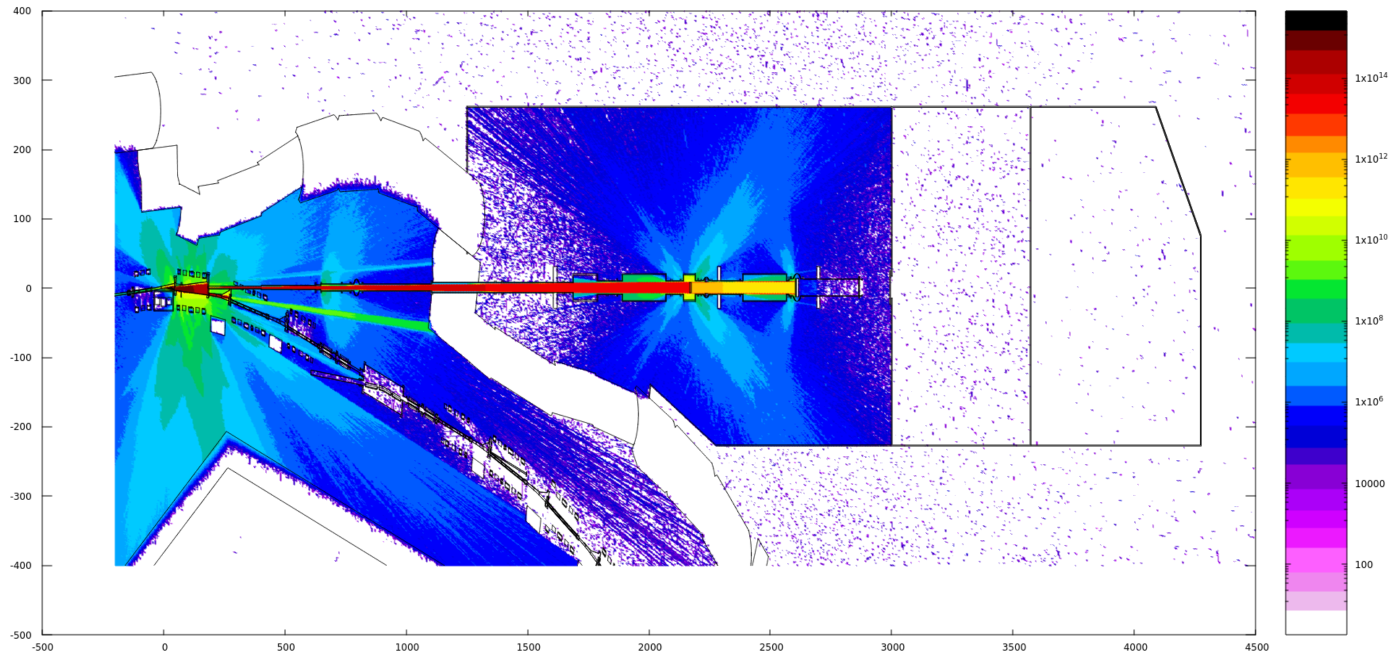
- Synchrotron Radiation (SR)

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



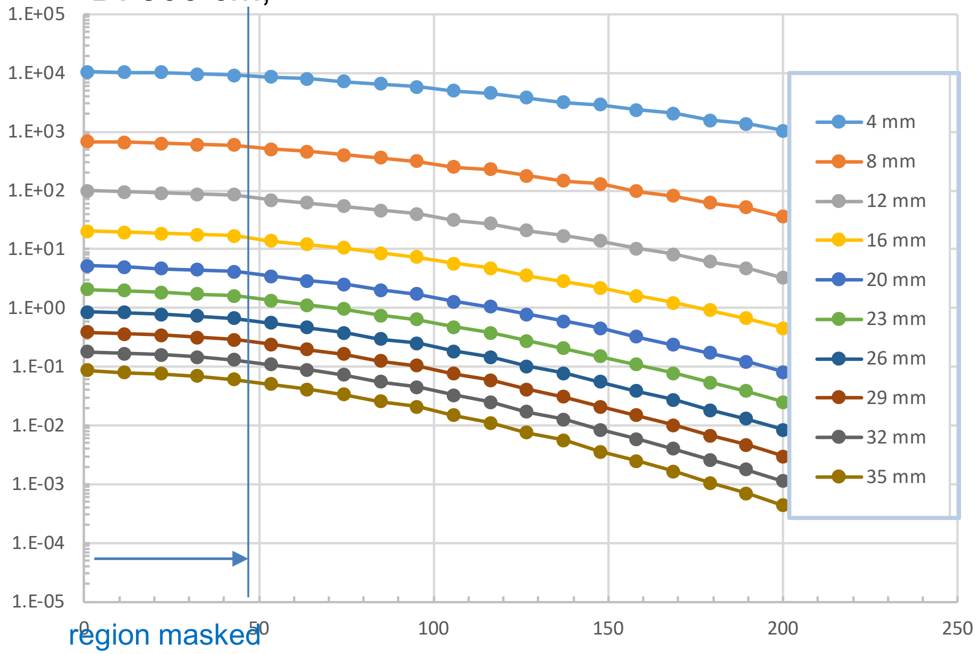
To overcome problems of biasing and lack of statistics, a dedicated Monte Carlo was developed by Paul Berkvens to evaluate the backwall and lateral wall thicknesses

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



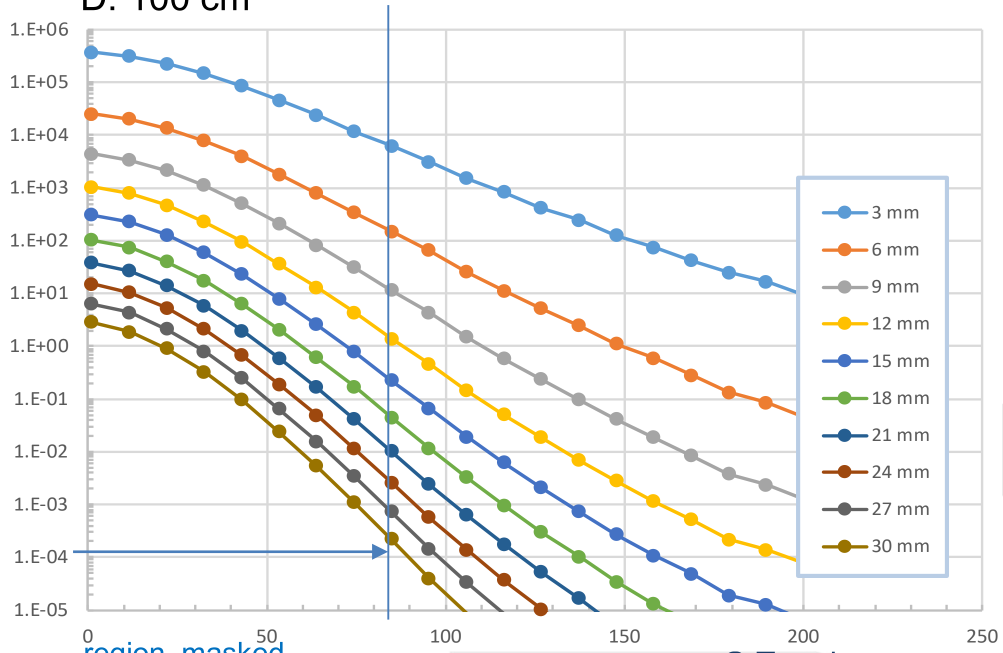
backwall wall thicknesses

D: 300 cm,



region masked by Pb wall

D: 100 cm



region masked by Pb wall

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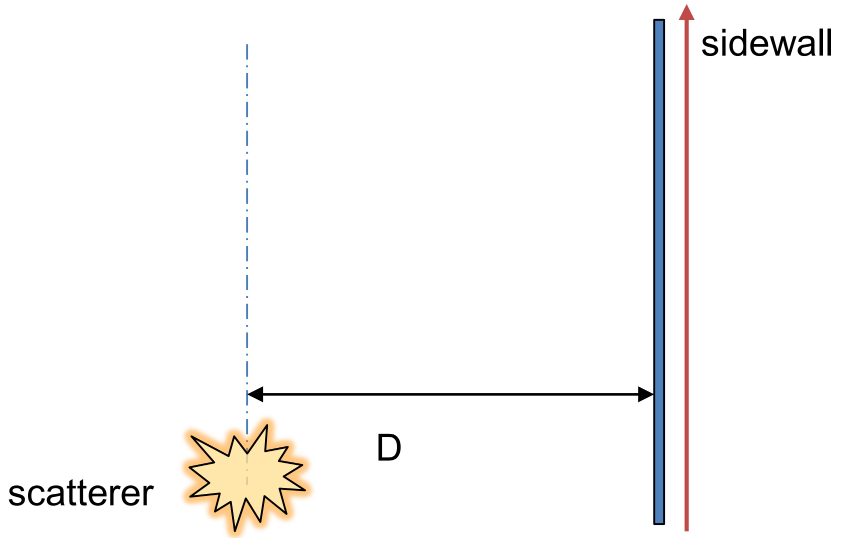
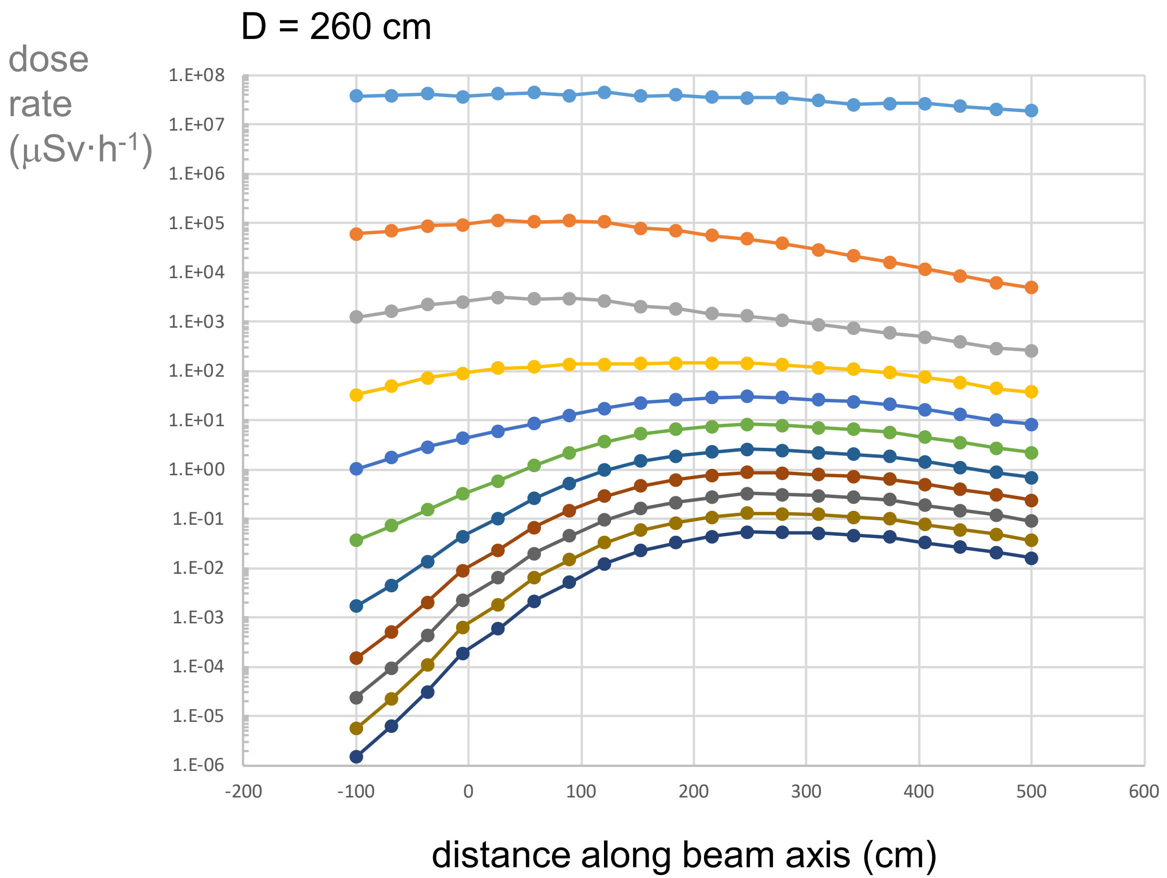
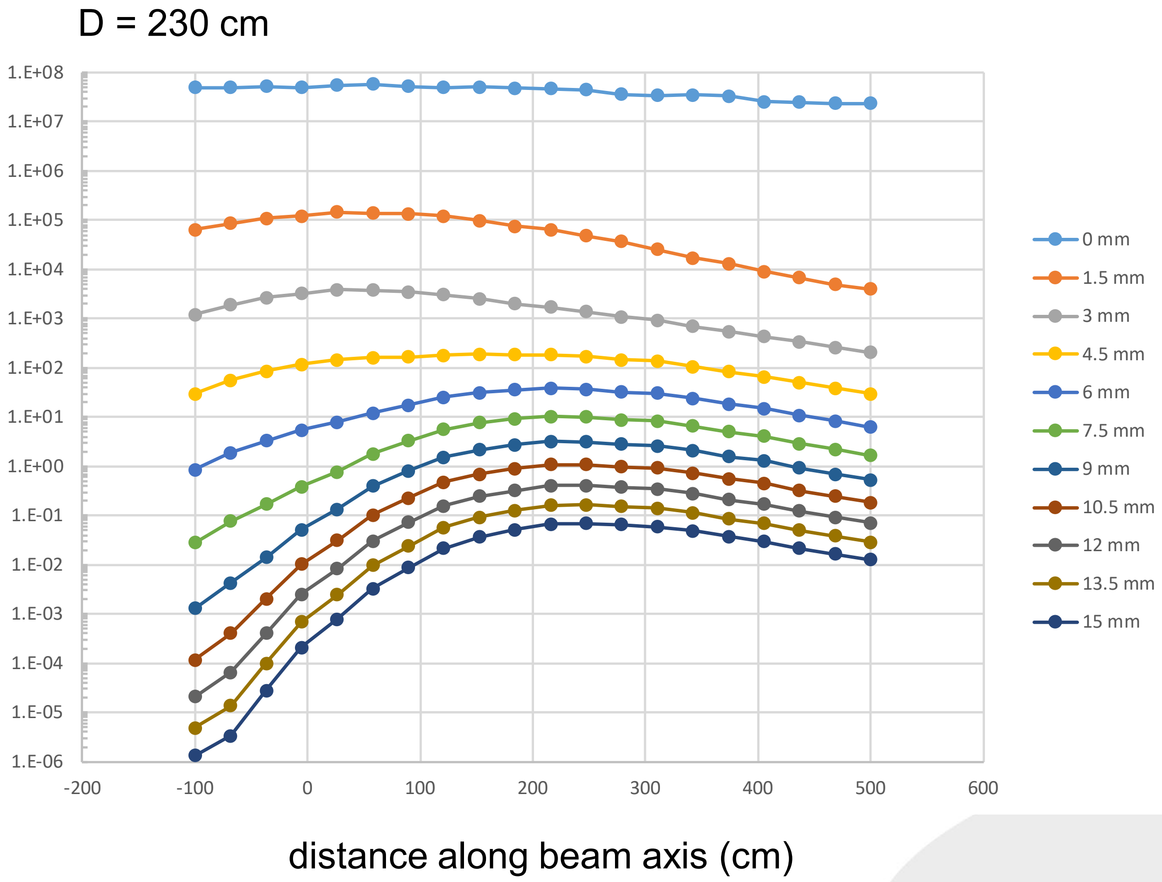
Lateral wall thickness







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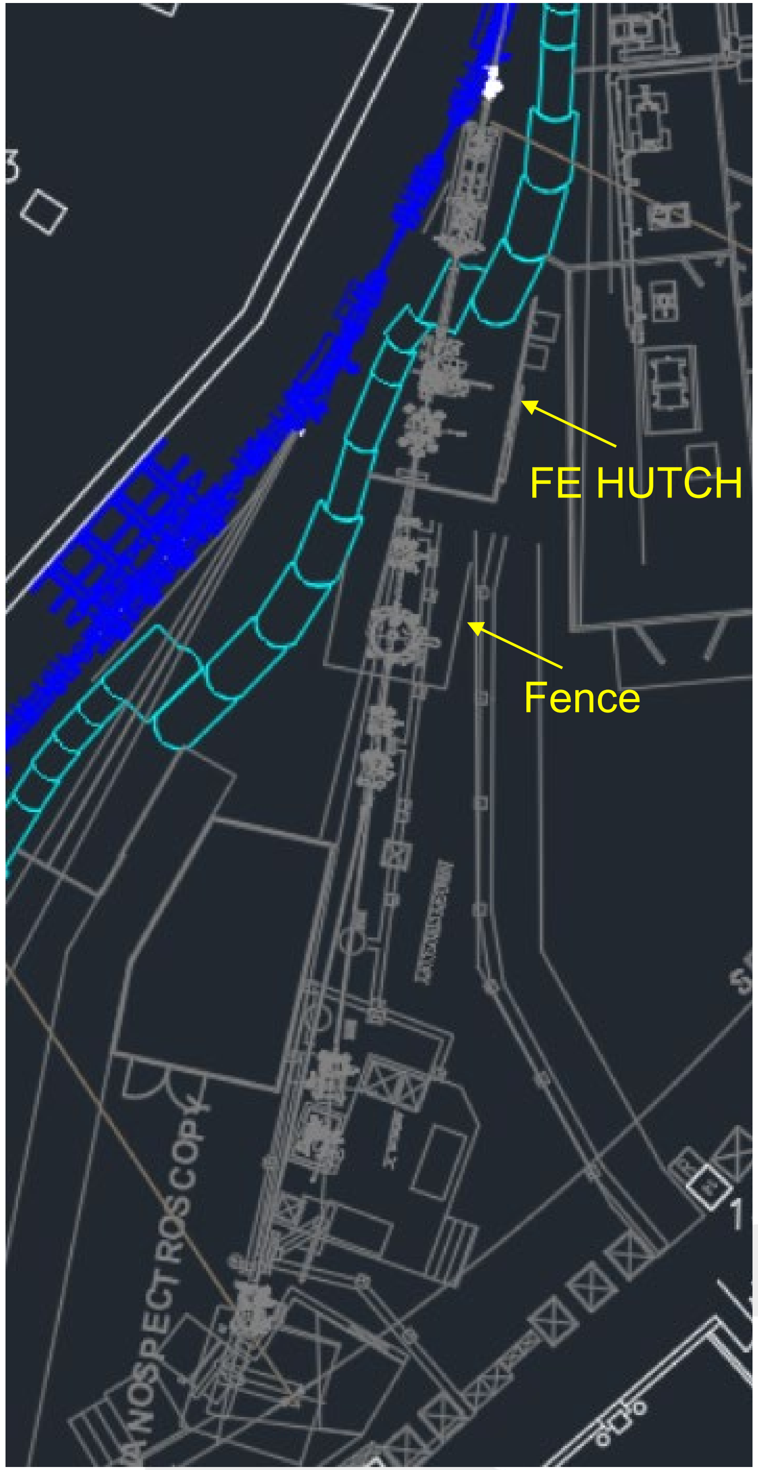
Exit 1.2 - Nanospectroscopy beamline (I)

- **Source**: Elliptical polarized Undulator
- **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

Considered radiation components

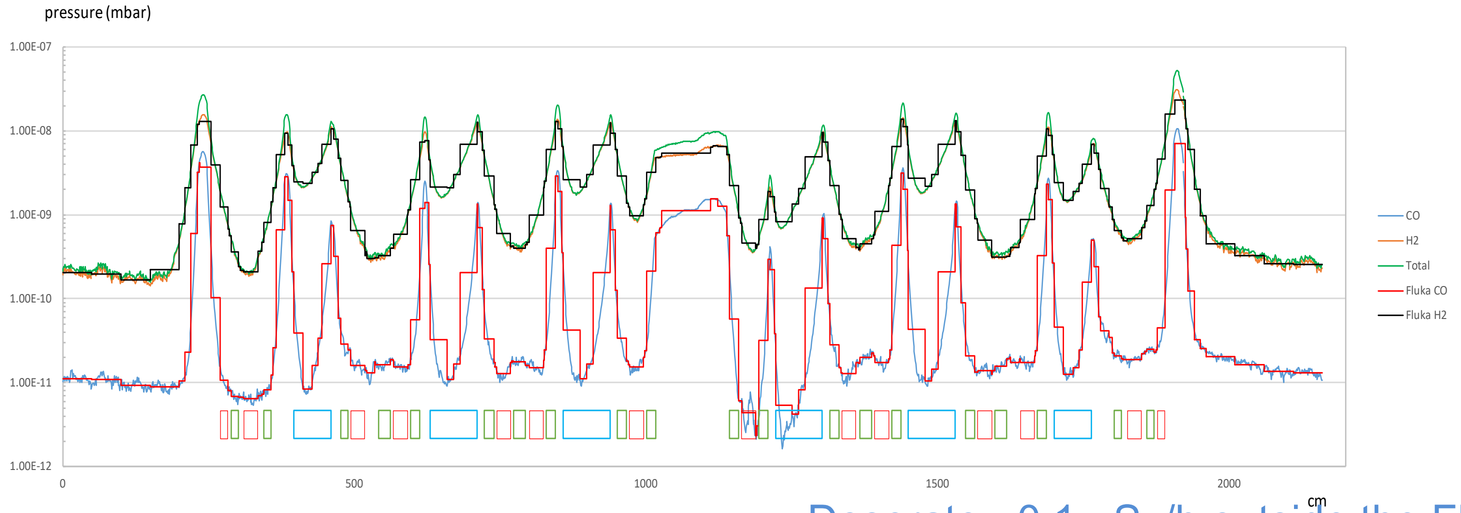
- Gas Bremsstrahlung (5 Ah vacuum conditioning and with more conservative vacuum conditions)
- Full stored beam (400 mA at 2.4 GeV) loss on input taper of ID vessel



Exit 1.2 - Nanospectroscopy beamline (II)

Gas Bremsstrahlung (5 Ah vacuum conditioning)

Pressure profiles along the unit cell, after 5 A·h conditioning, for a stored beam of 400 mA <at 2.4 GeV



Assumed compositions:

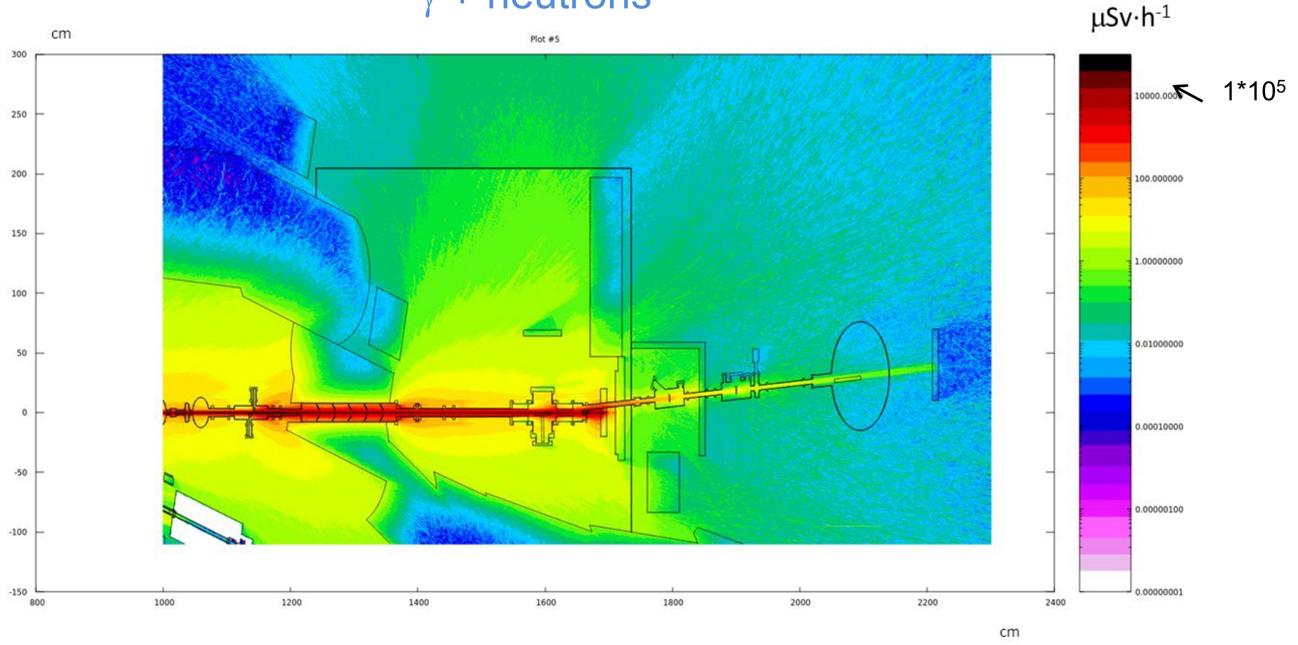
- CO and H_2 partial pressures (graph)
- partial pressures of CO_2 and CH_4, as 50 % of the CO partial pressure.

Corresponding average total pressure in the straight section: **$3.2\ 10^{-9}$ mbar.**

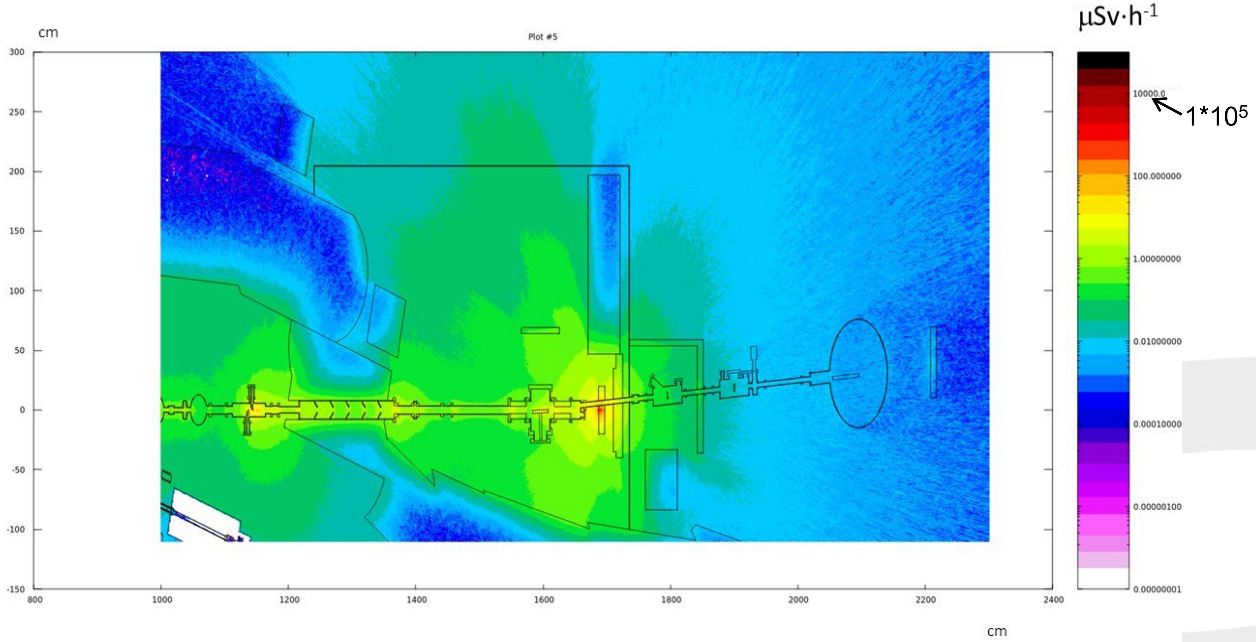
Too optimistic?

Doserate~ 0.1 μSv/h outside the FE hutch

γ + neutrons



Neutrons



Exit 1.2 - Nanospectroscopy beamline (III)

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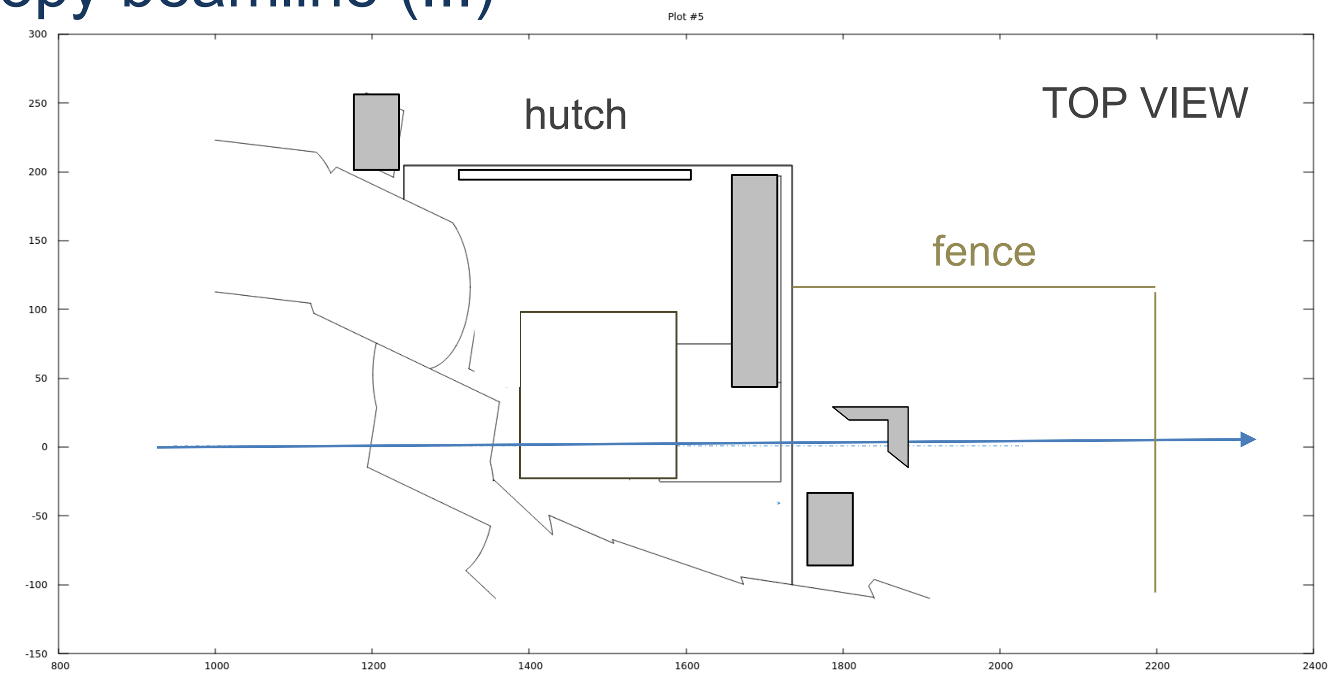
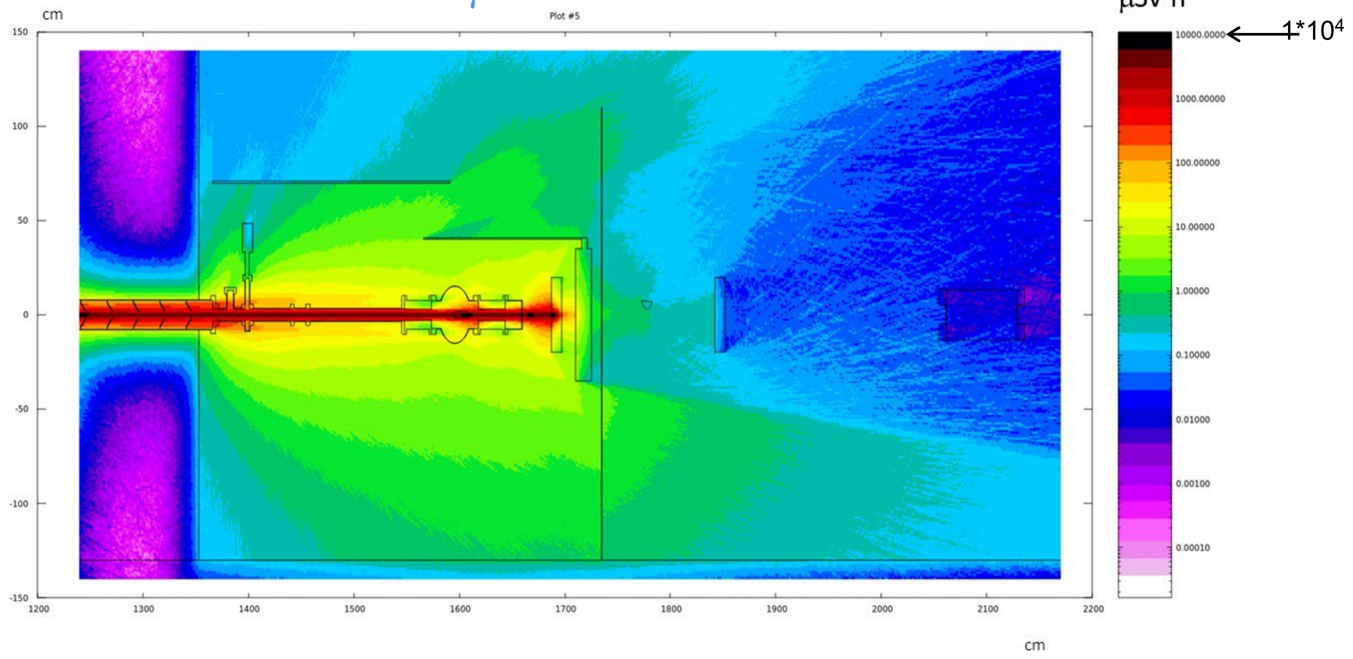
Gas Bremsstrahlung (more conservative assumptions)

- Worse vacuum conditions have to be assumed such as **$1\ 10^{-8}$** or **$5\ 10^{-8}$** (in case of leak or conditioning after a chamber ventilation….)
- To face this situation, **further local lead shielding have been positioned in the hutch and around the first element in the fence**
- In addition, two local lead roofs were placed inside the optics hutch

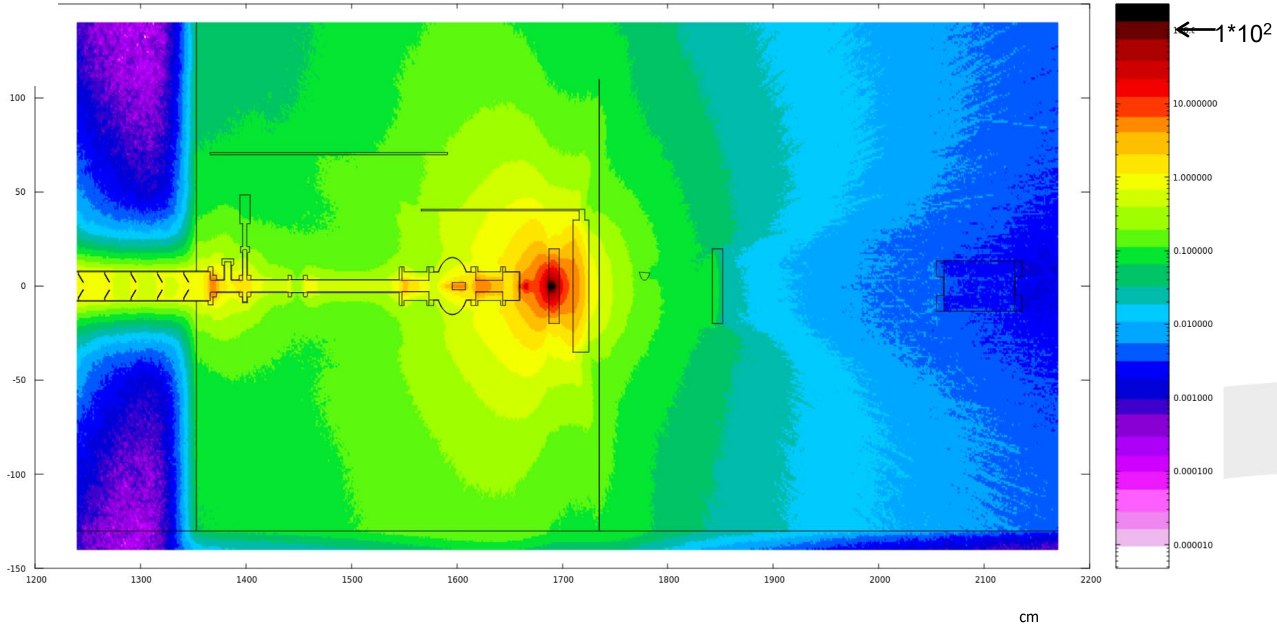


SIDE VIEW

γ + neutrons



Neutrons



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	average pressure straight section $5\cdot10^{-8}$ mbar		average pressure straight section $1\cdot10^{-8}$ mbar	
	2 mm Pb sidewall	2 mm Pb sidewall + 5 mm Pb reinforcement	2 mm Pb sidewall	2 mm Pb sidewall + 5 mm Pb reinforcement
sidewall total	2.35 μSv/h	1.41 μSv/h	0.47 μSv/h	0.28 μSv/h
sidewall neutrons	0.78 μSv/h	0.78 μSv/h	0.16 μSv/h	0.16 μSv/h
back wall optics hutch total	23.4 μSv/h		4.7 μSv/h	
back wall optics hutch neutrons	7.8 μSv/h		1.56 μSv/h	
back wall fenced area total	0.23 μSv/h		0.047 μSv/h	
back wall fenced area neutrons	0.05 μSv/h		0.0094 μSv/h	
roof total	6.25 μSv/h		1.25 μSv/h	
roof neutrons	2.5 μSv/h		0.5 μSv/h	

Maximum integrated dose rates behind the sidewall and backwalls (hutch and fence) and above the optics hutch, for a 400 mA stored beam with conservative average pressures in the straight section of. $5\cdot10^{-8}$ mbar and $1\cdot10^{-8}$ mbar.

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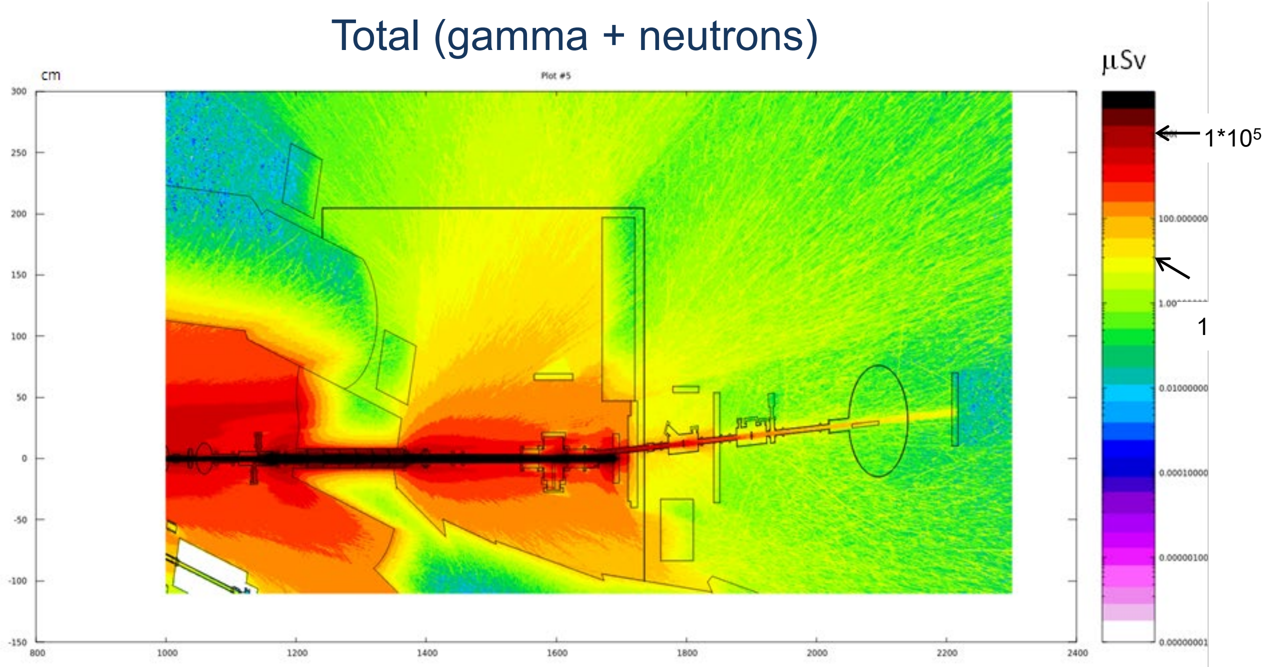
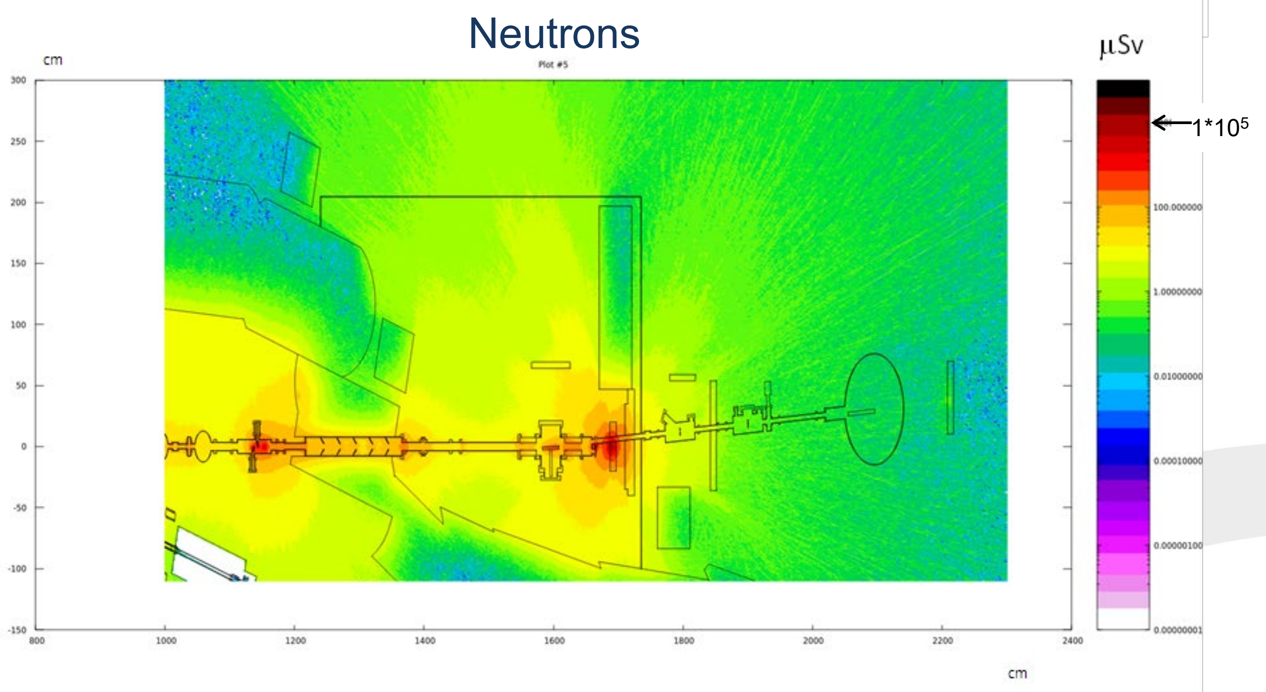
Exit 1.2 - Nanospectroscopy beamline (III)

Full stored beam (400 mA at 2.4 GeV) loss on input taper of ID vessel (very rare event)

Dose for one beam loss ~ 10 µ Sv





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Conclusions

- The Elettra 2.0 program foresees the implementation of a new machine with different characteristics and operation modalities
- New beamlines from super conducting bending magnets are requiring special attention from the RP point of view for their high powerful and high X-ray energy beams
- The shielding requirements for the beamlines that will remain unaltered and in the same position should be re-considered either for the increased component due to gas bremsstrahlung but also for the possible different beam loss scenarios.
- Simulations work is proceeding with the other beamlines….

Thanks for your attention!

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www.elettra.eu

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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/mm^2/mrad^2/0.1%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