Recent Developments and Future Projects at the ESRF

P. Berkvens

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BNL, May 8-10, 2013

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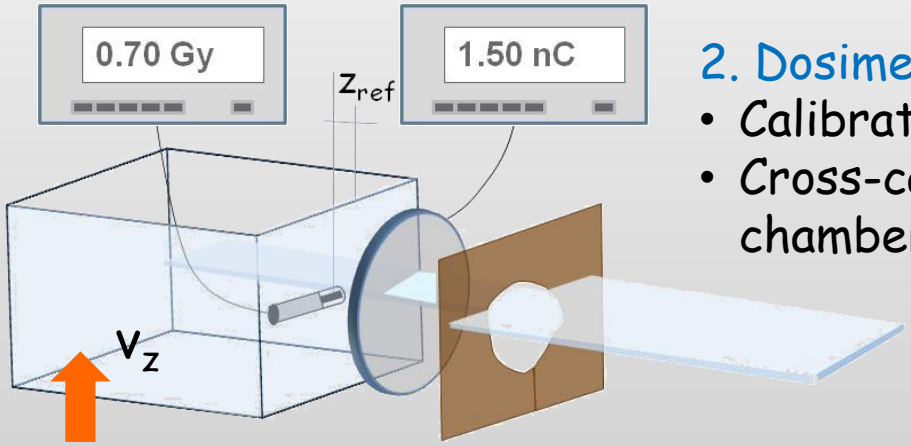
Clinical trials at the ESRF: SSRT

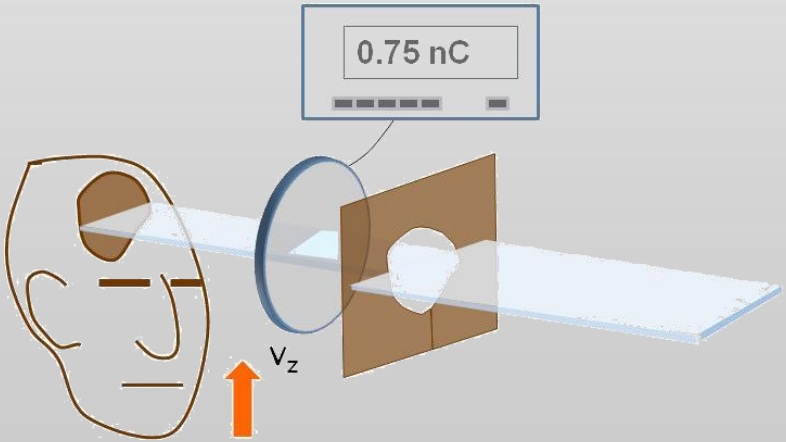
1. Treatment Planning System:

- Dose prescription D_1 in tumour for given orientation.
- Corresponding dose in water D_2 at reference depth.



2. Dosimetry calibration:

- Calibration of therapy facility in terms of dose D_2.
- Cross-calibration of transmission ionisation chamber.



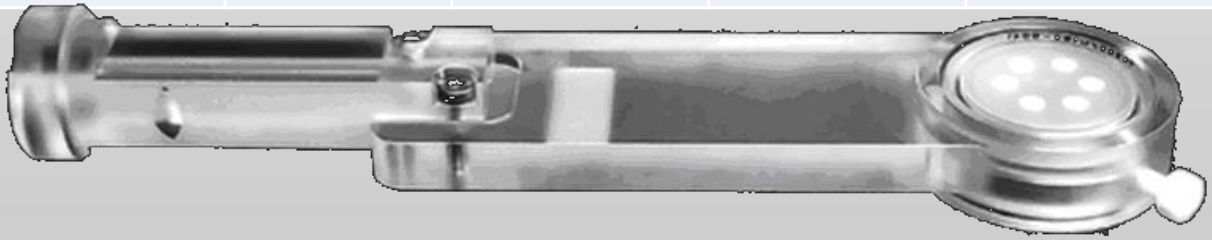
3. Patient treatment:

- Online measurement of delivered dose.
- Patient Safety System.

Clinical trials at the ESRF: SSRT

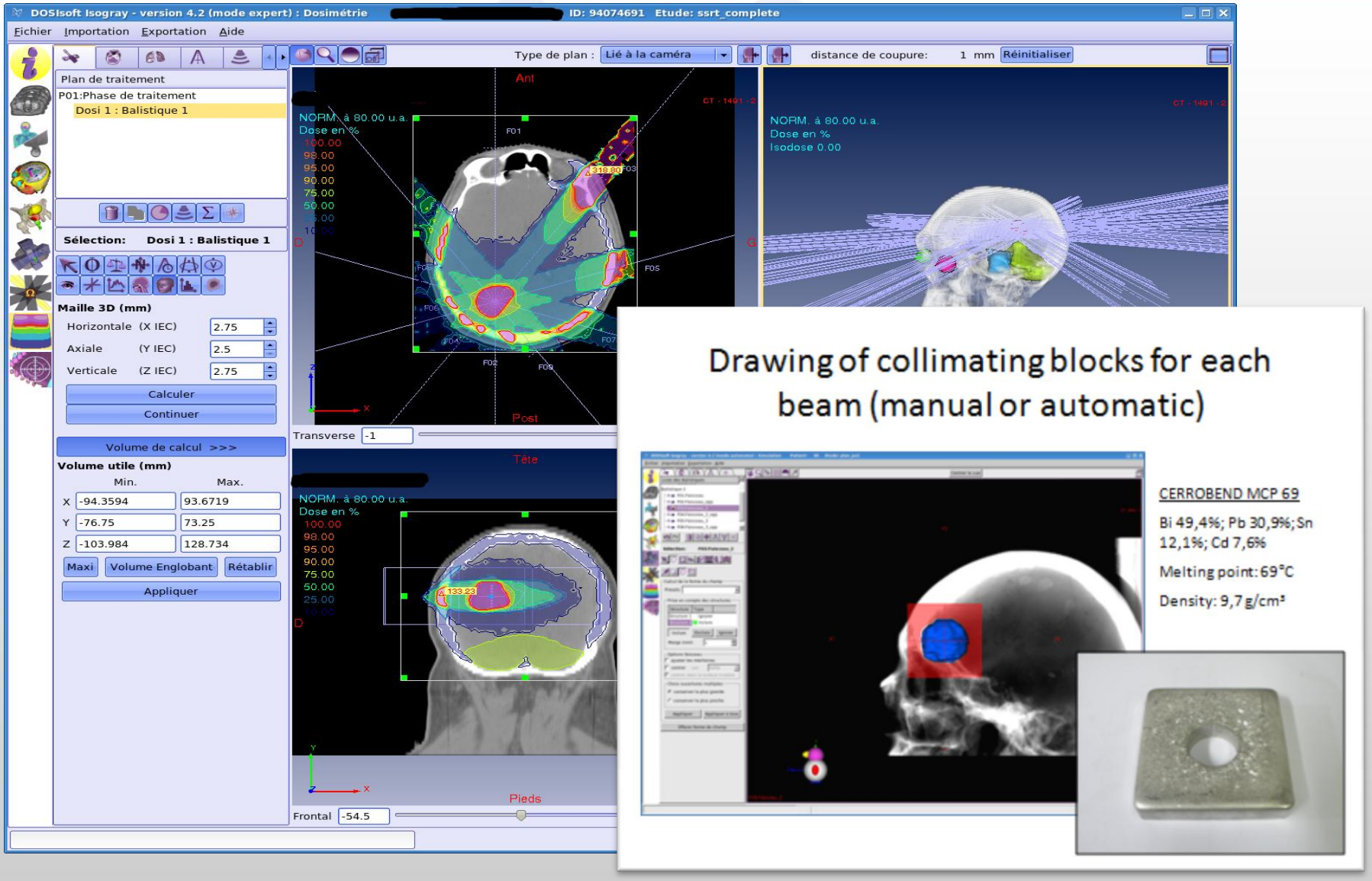
External control: TLD exposure, PTW Germany

Nom. Energy [keV]	Fieldsize [cm × cm]	Measuring depth [cm]	Dose ESRF [Gy]	Dose TLD [Gy]	Deviation [%]	Uncertainty k=1 [%]
80	5 × 5	10	0.970	0.980	-1.0	2.5
80	5 × 5	10	0.968	0.981	-1.3	2.5
80	5 × 5	3	1.028	1.024	0.4	2.5
80	5 × 5	5	0.976	0.972	0.4	2.5
80	5 × 5	3	1.038	1.038	0.0	2.5
80	5 × 5	5	0.974	0.972	0.2	2.5
80	5 × 5	5	0.978	0.982	-0.4	2.5
80	5 × 5	3	1.032	1.032	0.0	2.5



PTW TLD holder for external control

Clinical trials at the ESRF: SSRT



Monte-Carlo based Treatment Planning System

Clinical trials at the ESRF: SSRT

Cross calibration of transmission ionisation chamber for each individual beam, using the patient-specific collimators

Speed chair: 20 mm/s

Vertical scan height: 7 cm

Height beam: 2 mm

T = 22.7 °C

# of scans: 10

P = 995.7 mbar

# port	I [mA]	PTW semiflex [Gy]	PTW transmission 1 [nC]	PTW transmission 2 [nC]	PTW 1 [nC/Gy]	PTW 2 [nC/Gy]
1	152.30	1177	43.30	44.30	36.79	37.64
2	152.17	1178	44.65	45.65	37.90	38.75
3	152.05	1176	44.60	45.60	37.93	38.78
4	151.93	1178	45.40	46.45	38.54	39.43
5	151.81	1171	43.10	44.05	36.81	37.62
6	151.68	1175	44.60	45.65	37.96	38.85
7	151.57	1174	44.65	45.65	38.03	38.88
8	151.45	1175	45.45	46.45	38.68	39.53

Clinical trials at the ESRF: SSRT

Cross calibration of transmission ionisation chamber for each individual beam, using the patient-specific collimators

# port	I [mA]	Dose isocenter [Gy]	Dose ref. 2 cm [Gy]	Number of scans	Speed [mm/s]	Dose delivered [Gy]	Difference dose delivered / dose prescribed [%]
1	172.3	0.6056	2.831	30	25.59	2.824	-0.24
2	172.1	0.6056	1.0429	11	26.92	1.041	-0.16
3	171.9	0.6056	0.9653	10	26.65	0.963	-0.22
4	171.7	0.6056	0.8177	9	28.6	0.816	-0.16
5	171.6	0.6056	1.7575	18	25.14	1.754	-0.20
6	171.4	0.6056	2.2954	24	25.4	2.291	-0.20
7	171.2	0.6056	3.6814	39	25.29	3.673	-0.24
8	170.9	0.6056	4.066	43	25.18	4.057	-0.21

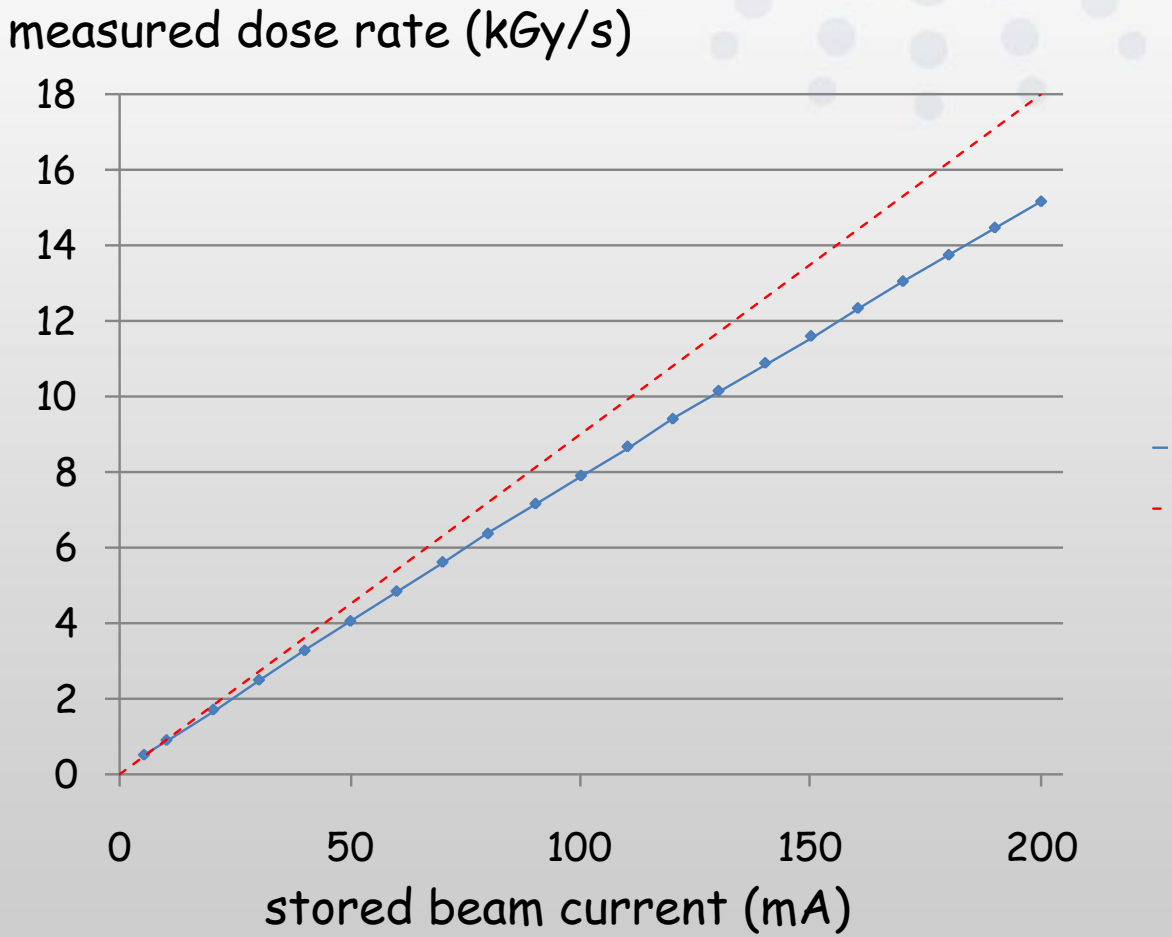
Clinical trials at the ESRF: SSRT

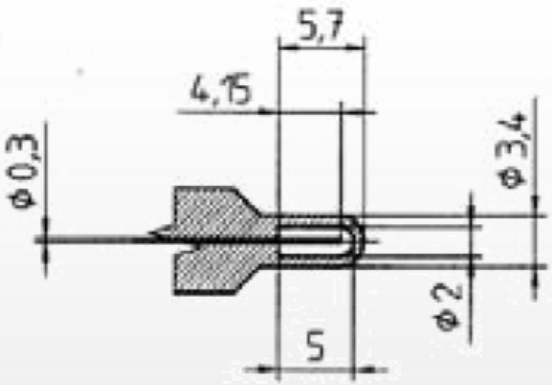
Clinical trials at the ESRF: SSRT

Ion recombination effect

MRT

PTW pinpoint 31014 (0.015 cm^3)





Ion collection time 20 μs

Dose rate	99.5%: 265 Gy/s
	99.0%: 580 Gy/s
Pulse dose	99.5 %: 3.5 mGy
	99.0 %: 7 mGy

2 × 2 cm^2 field

$$\dot{D}_{w,Q} = D_{w,scan} \times \frac{v_z}{z_{beam}}$$

Ion recombination effect

MRT

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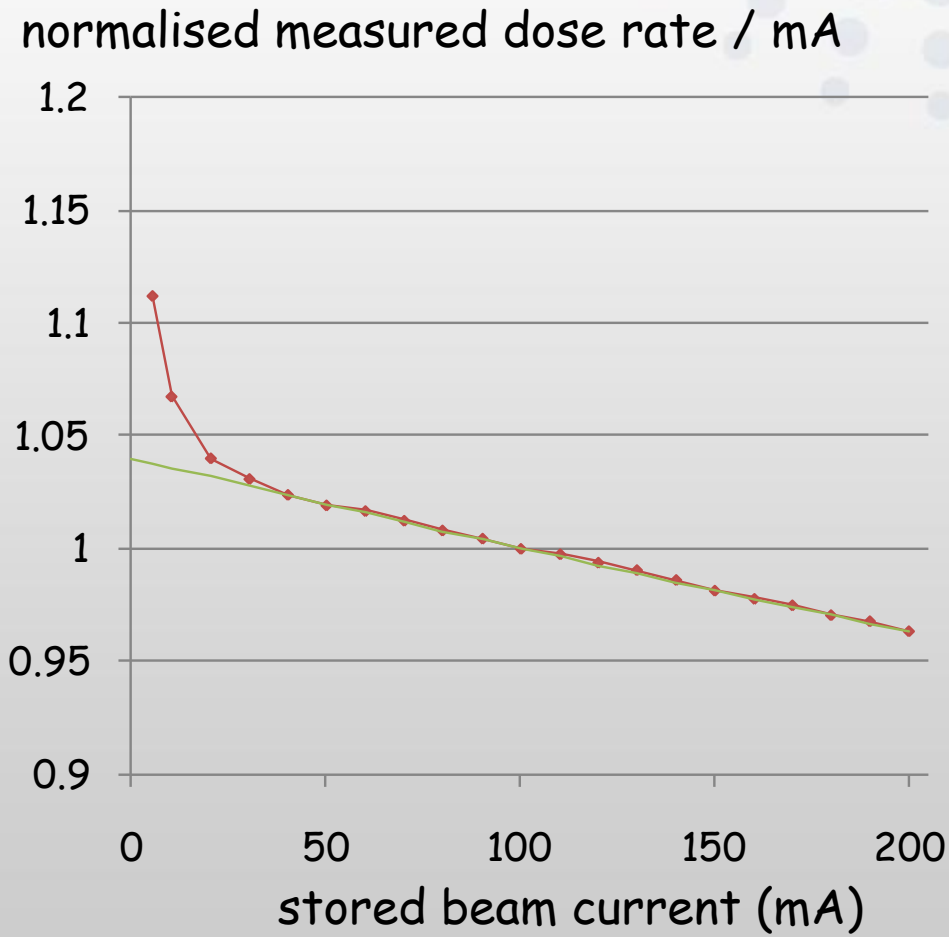

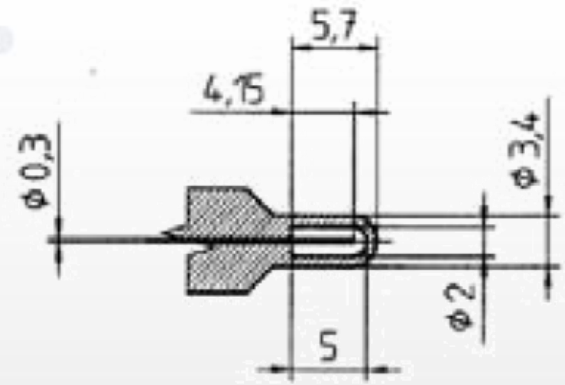

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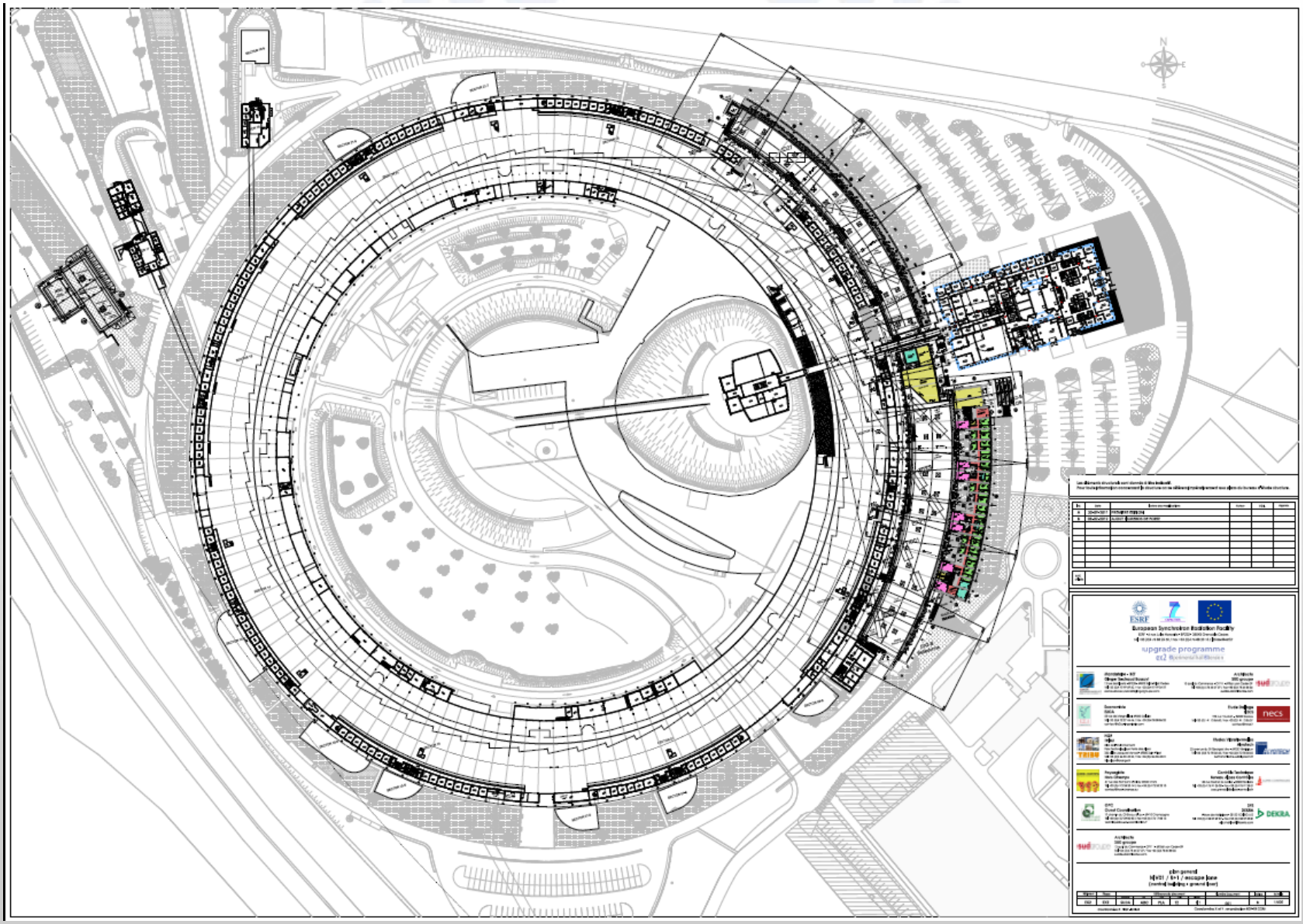
ESRF Phase I Upgrade Program



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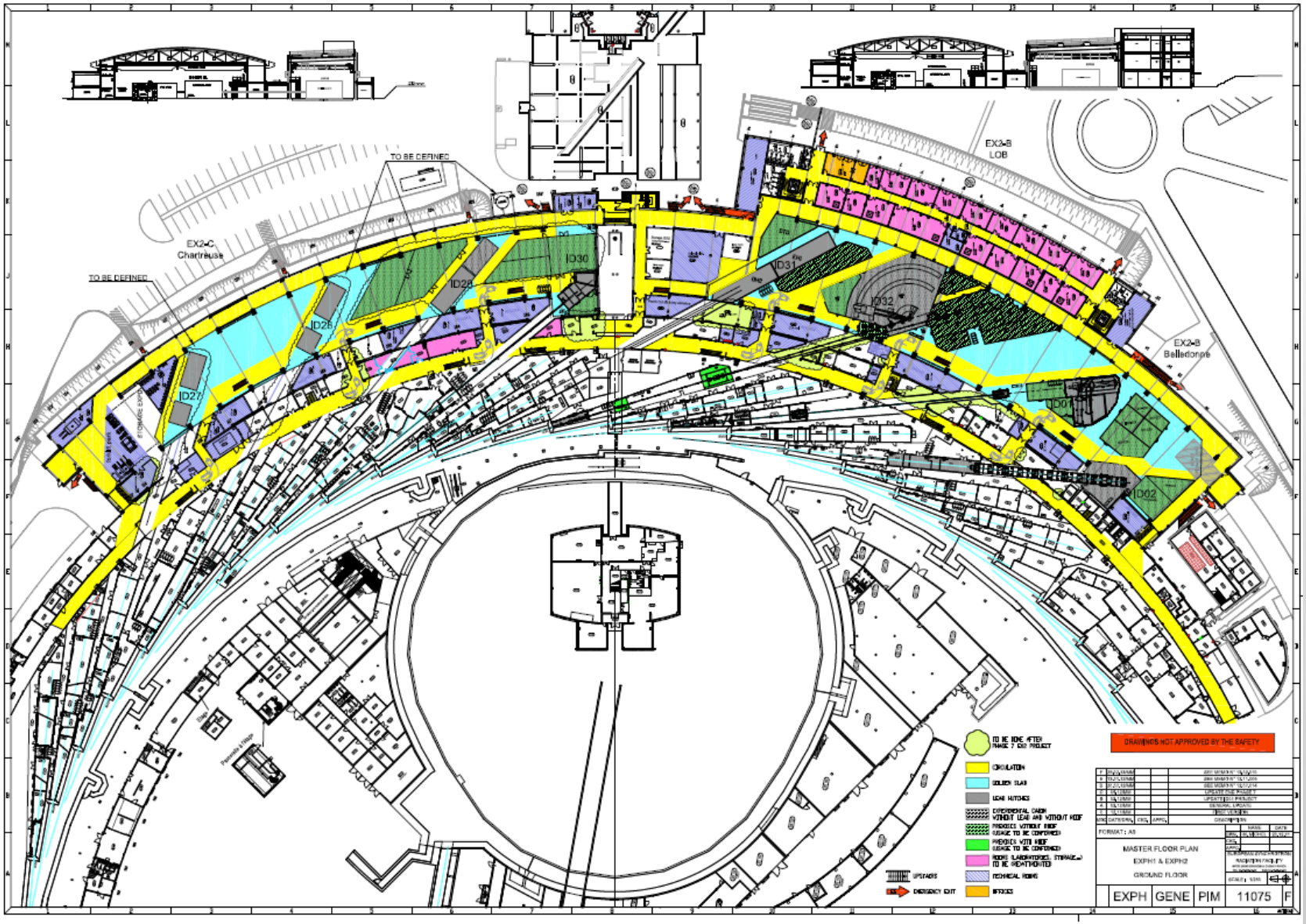
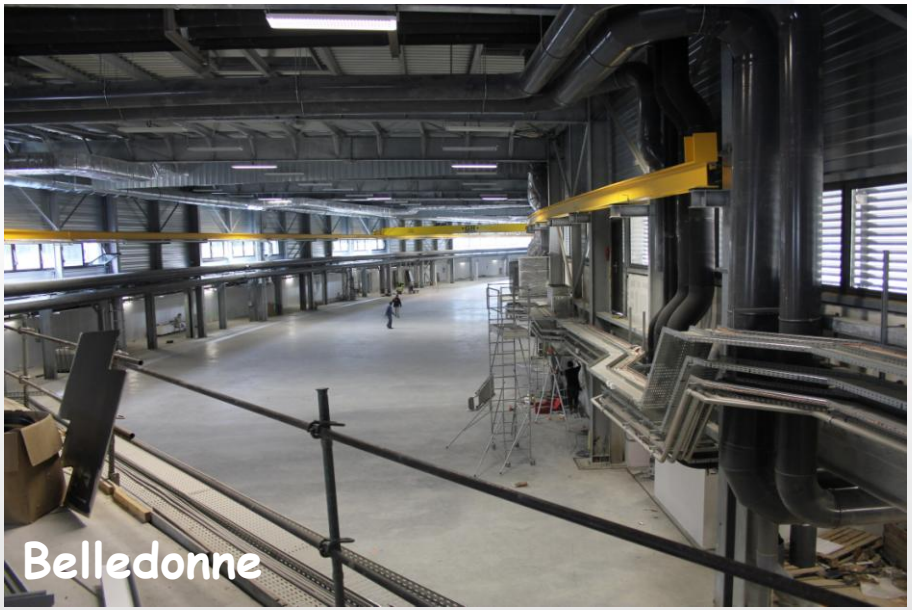
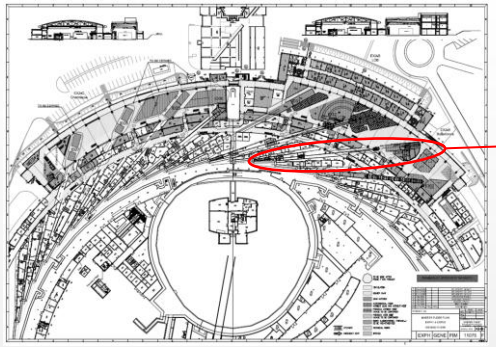
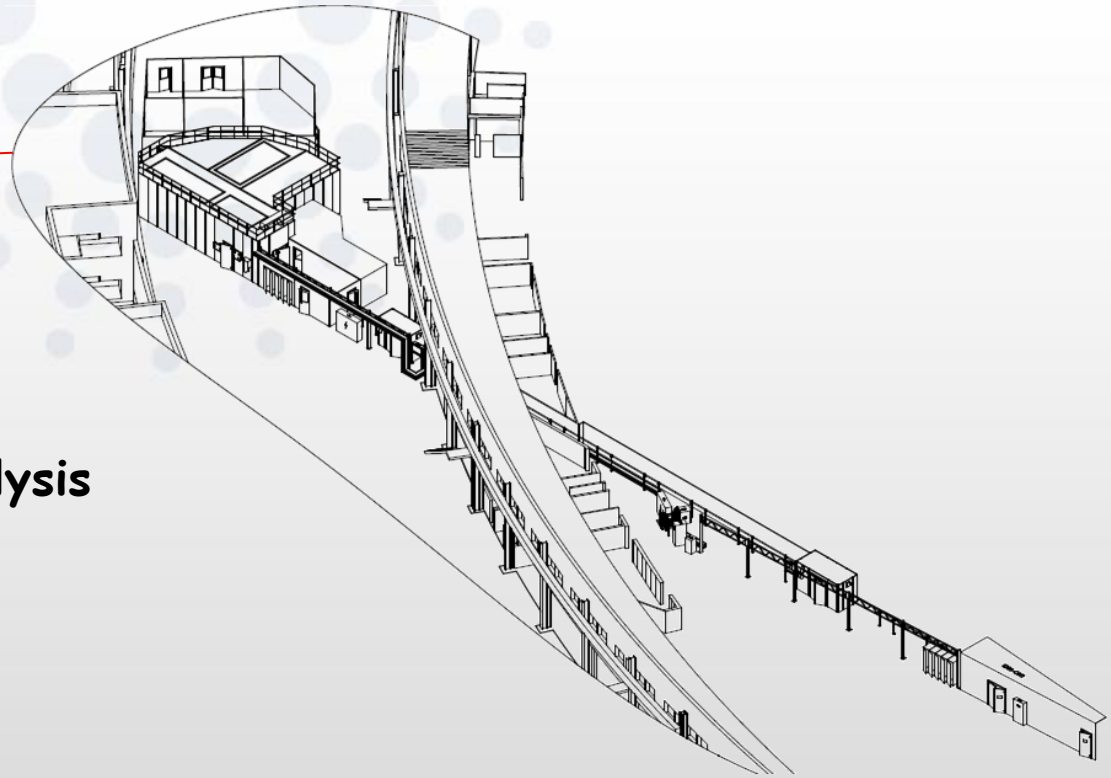


EX2 Chartreuse and Belledonne Experimental Halls

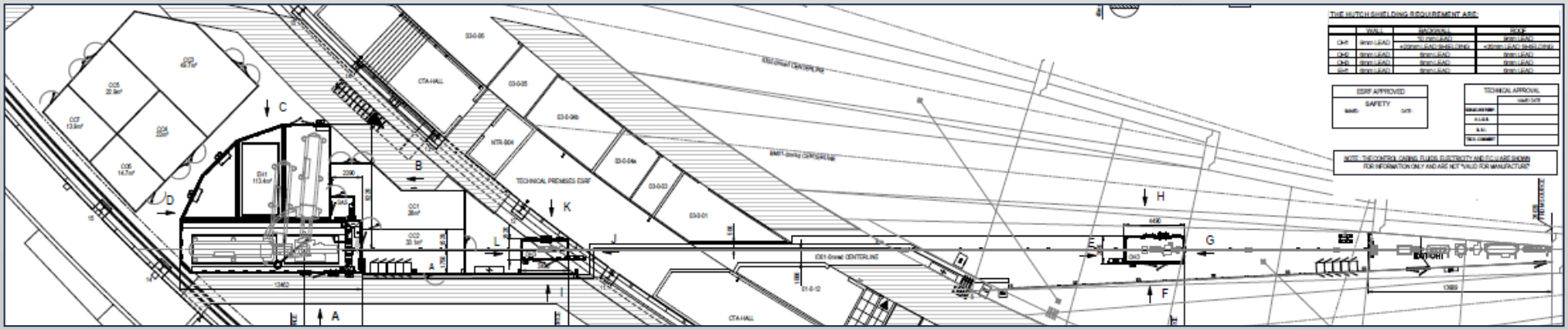


Phase I Upgrade Beamlines: UPBL01 – ID01

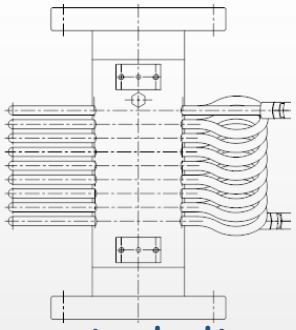




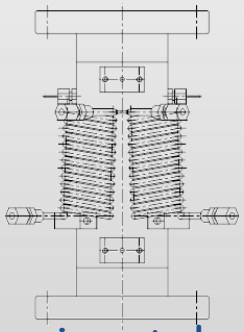
UPBL1:
Diffraction imaging for nano-analysis



Transmission through front end



vertical slit
4 mm
(± 0.089 mrad)



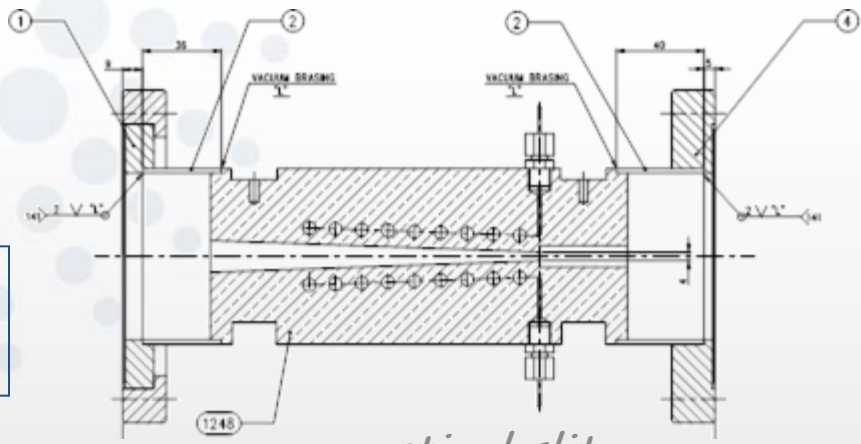
horizontal slit
2 mm
(± 0.074 mrad)

22.5 m

13.5 m

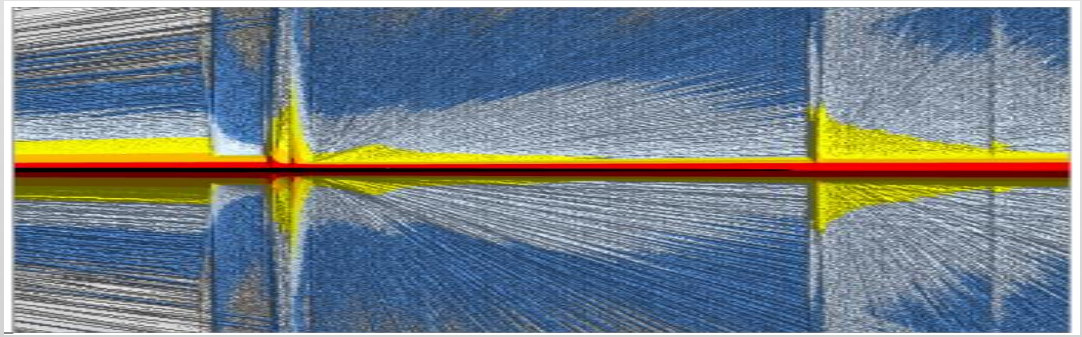
distance from middle of straight section

6 GeV:
$1/\gamma$ = 0.085 mrad



vertical slit

5 cm



-5 cm

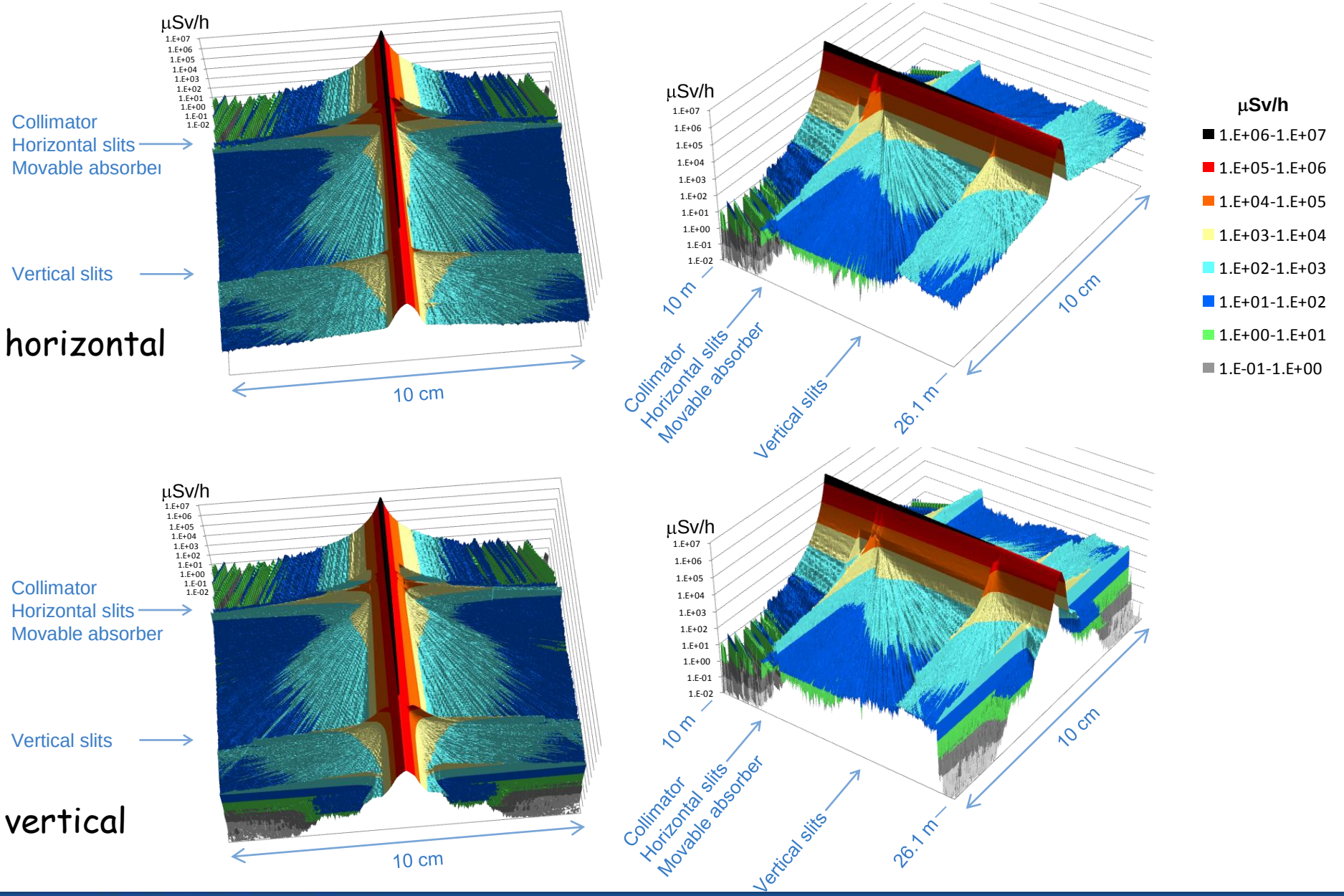
10 m

26.1 m

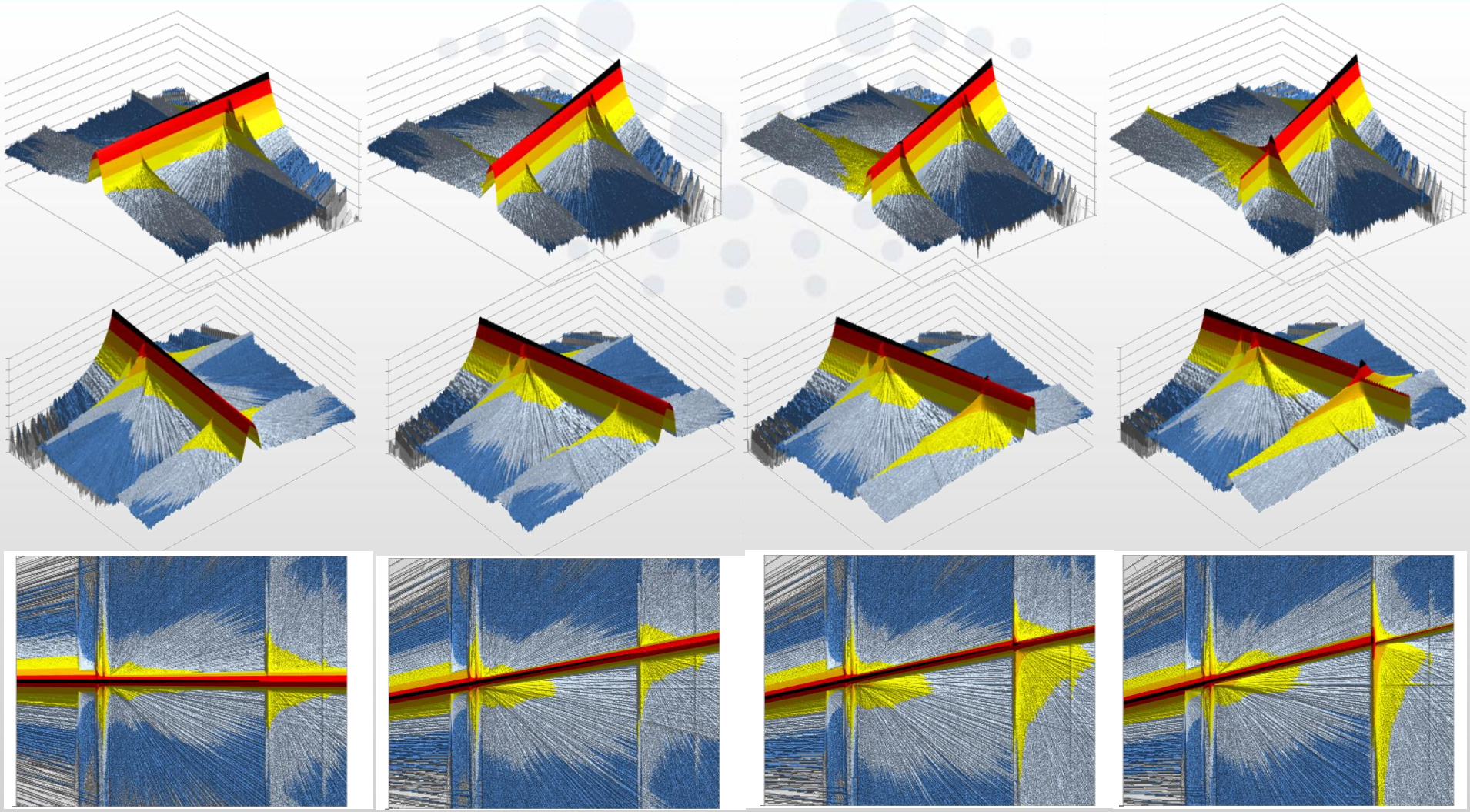
μSv/h

1.E+06-1.E+07	1.E+04-1.E+05	1.E+02-1.E+03	1.E+00-1.E+01
1.E+05-1.E+06	1.E+03-1.E+04	1.E+01-1.E+02	1.E-01-1.E+00

Gas-bremsstrahlung transmission in ESRF Front End



Gas-bremsstrahlung transmission in ESRF Front End

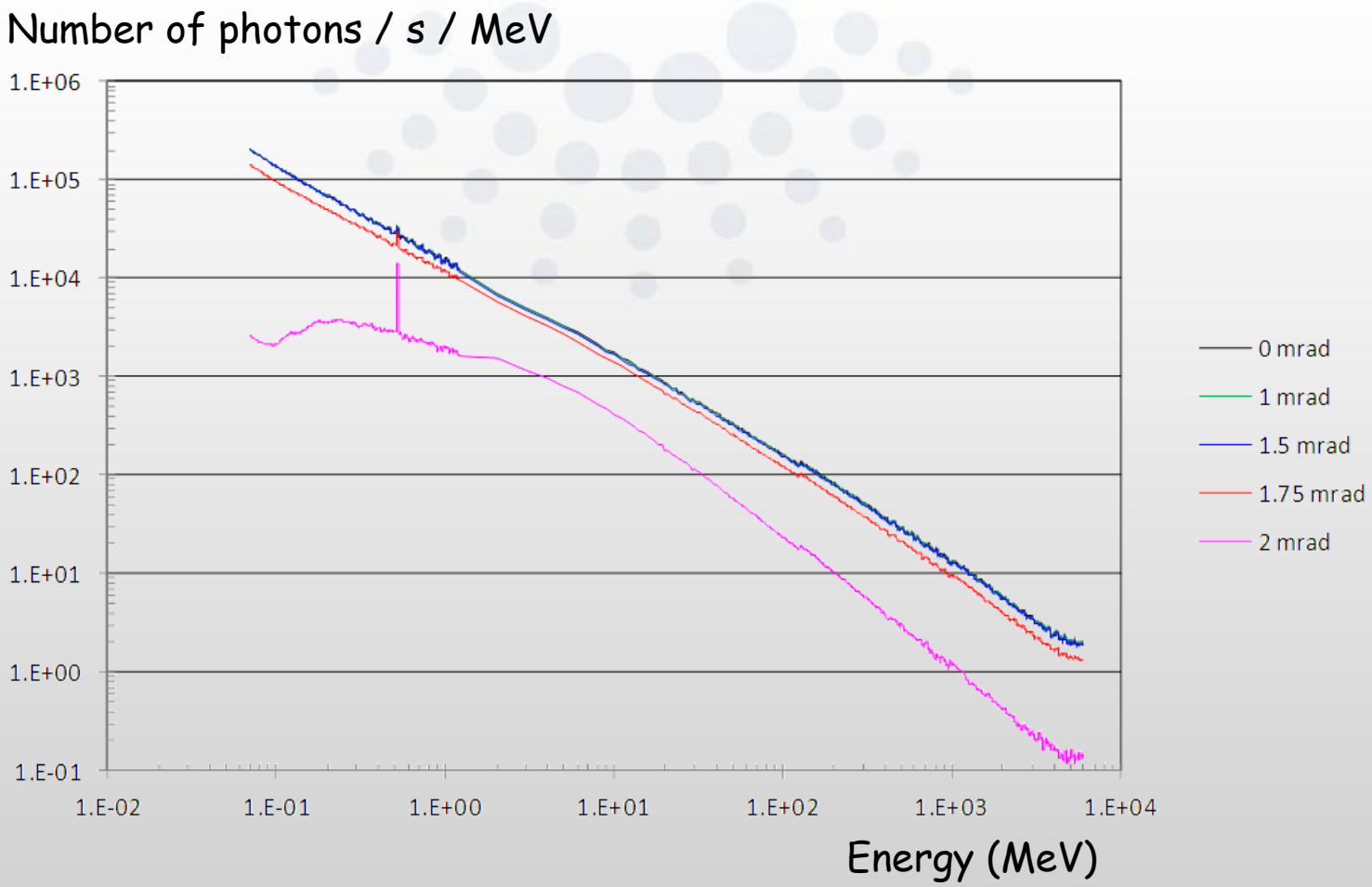


0 mrad | 1.5 mrad | 1.75 mrad | 2 mrad

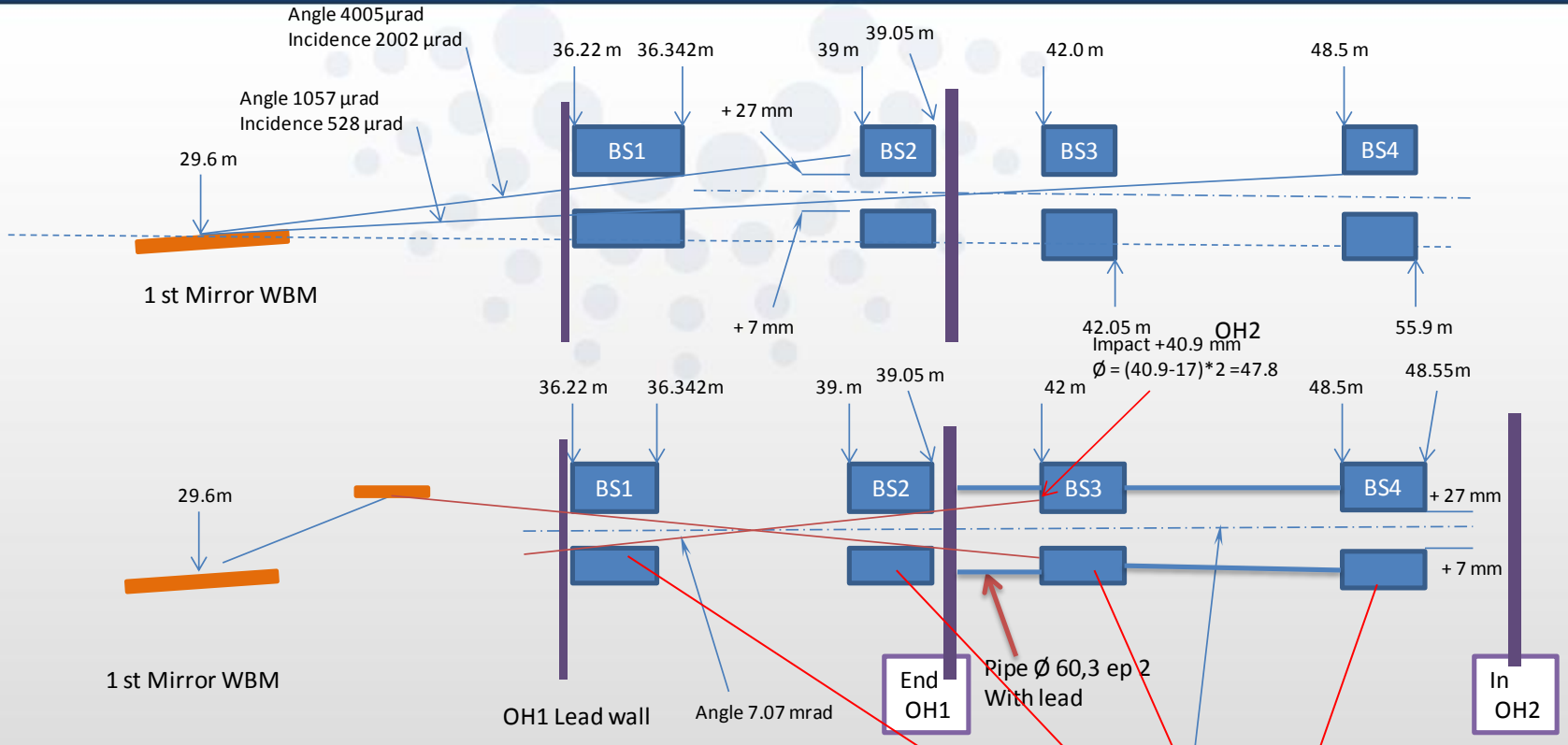
µSv/h

- 1.E+06-1.E+07
- 1.E+05-1.E+06
- 1.E+04-1.E+05
- 1.E+03-1.E+04
- 1.E+02-1.E+03
- 1.E+01-1.E+02
- 1.E+00-1.E+01
- 1.E-01-1.E+00

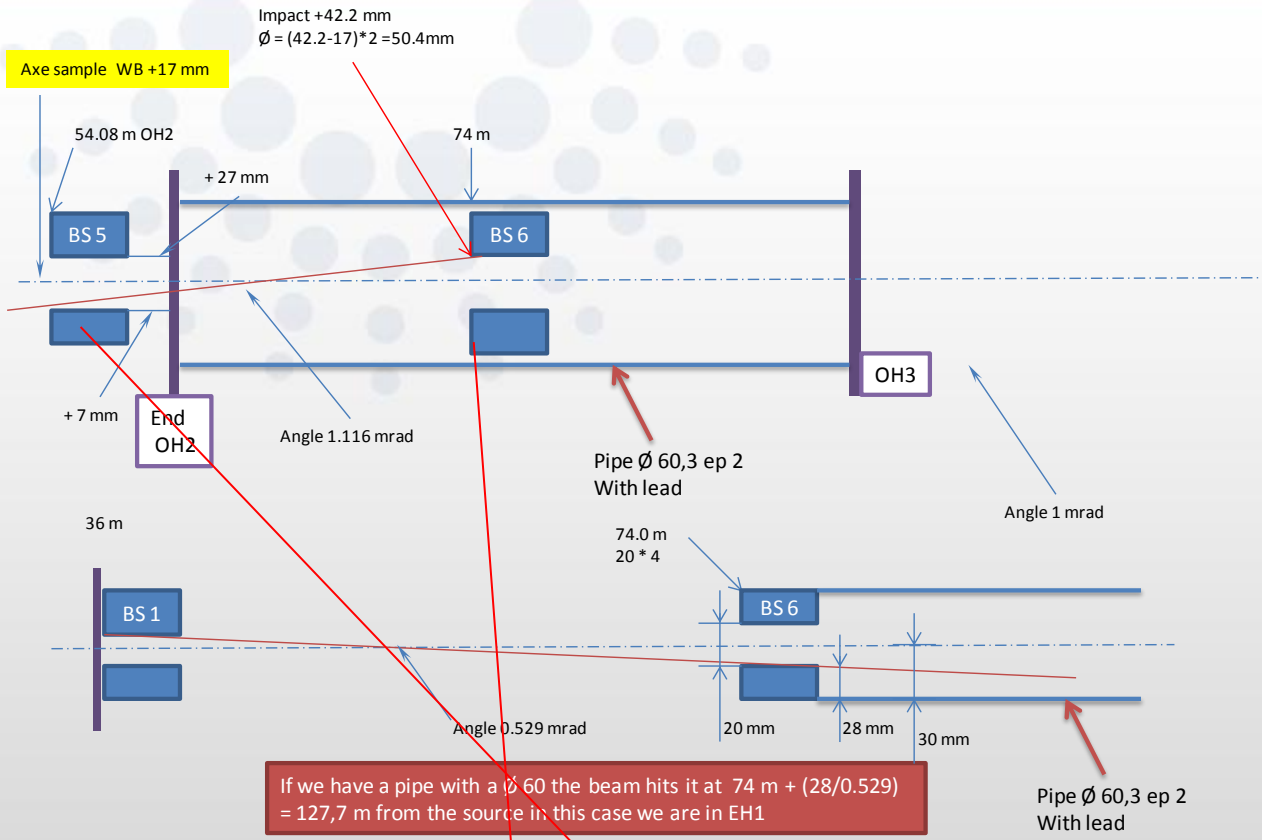
Gas-bremsstrahlung transmission in ESRF Front End

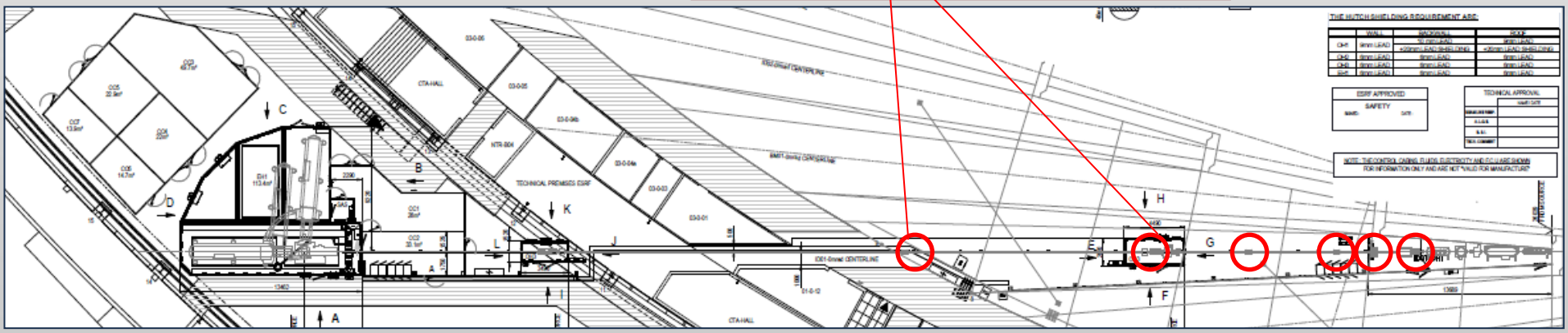


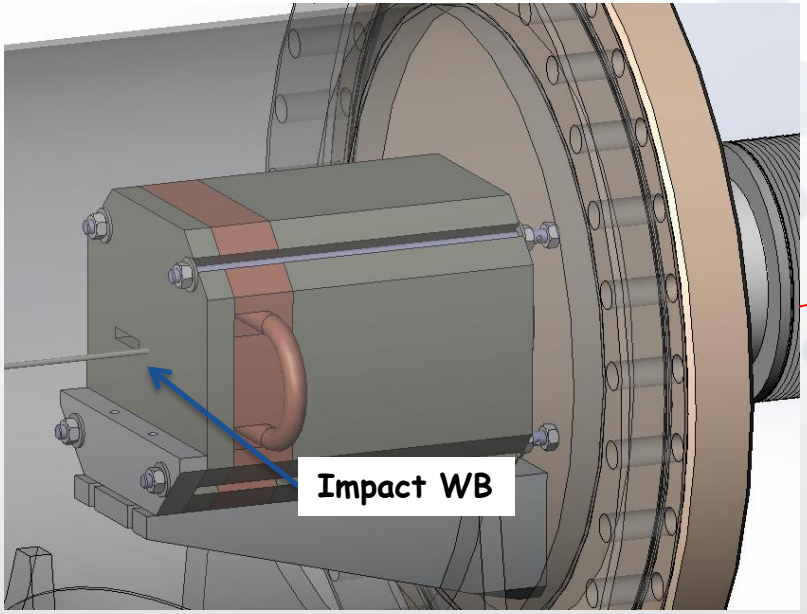
Phase I Upgrade Beamlines: UPBL01 – ID01

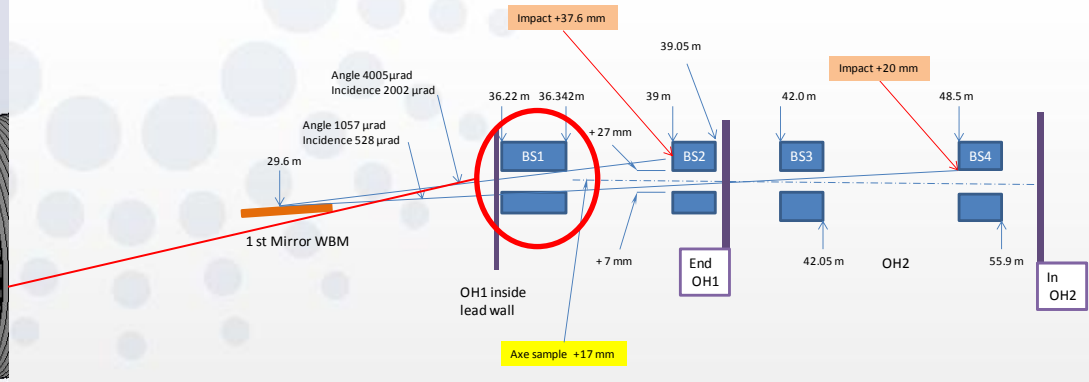


Phase I Upgrade Beamlines: UPBL01 – ID01



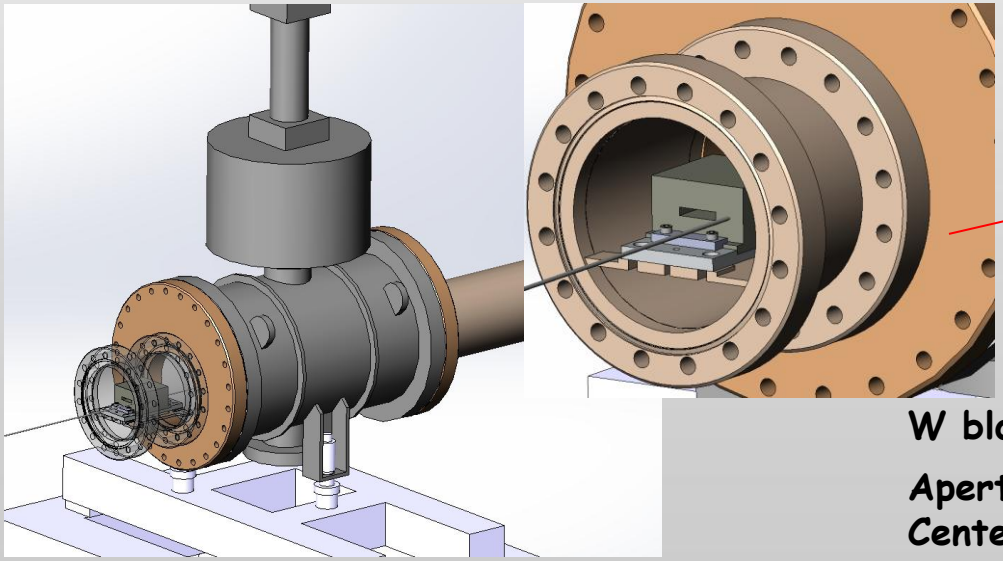


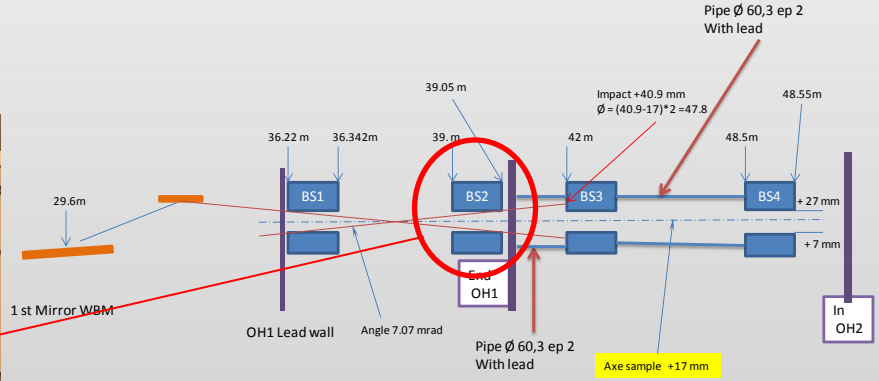




W block 100 x 100 x W10 + Cu22 + W90

Aperture 20mm x 4mm
Center at 17 mm from WB

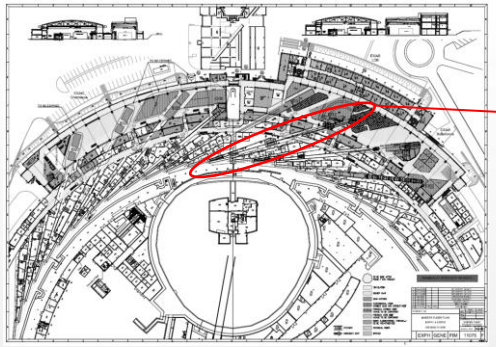


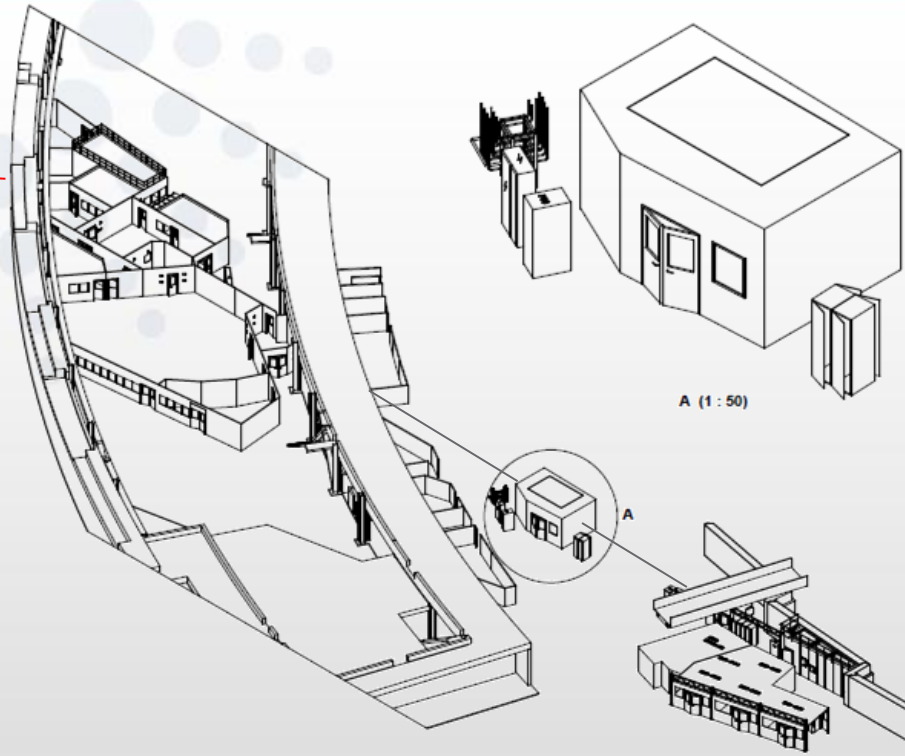


W block 50 x 30 x 50

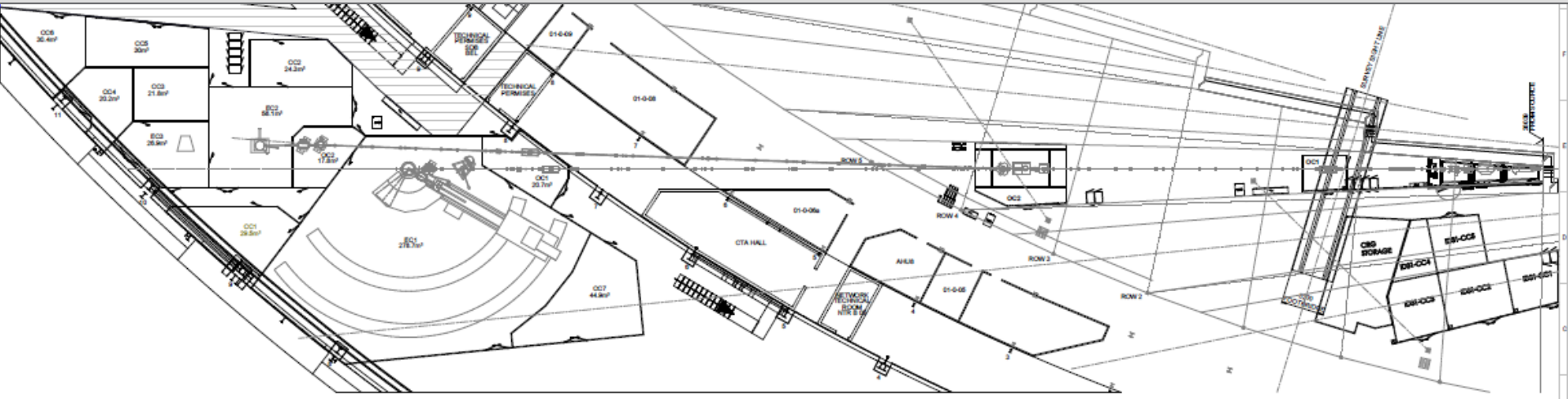
Aperture 20mm x 4mm
Center at 17 mm from WB

Phase I Upgrade Beamlines: UPBL7 – ID32

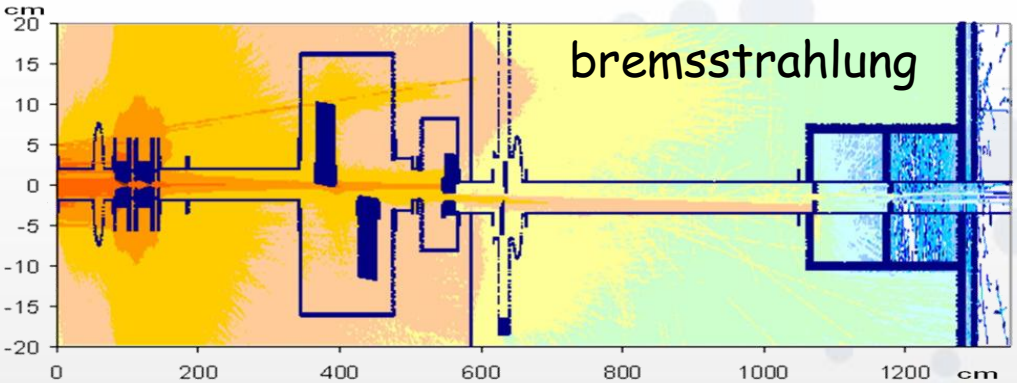


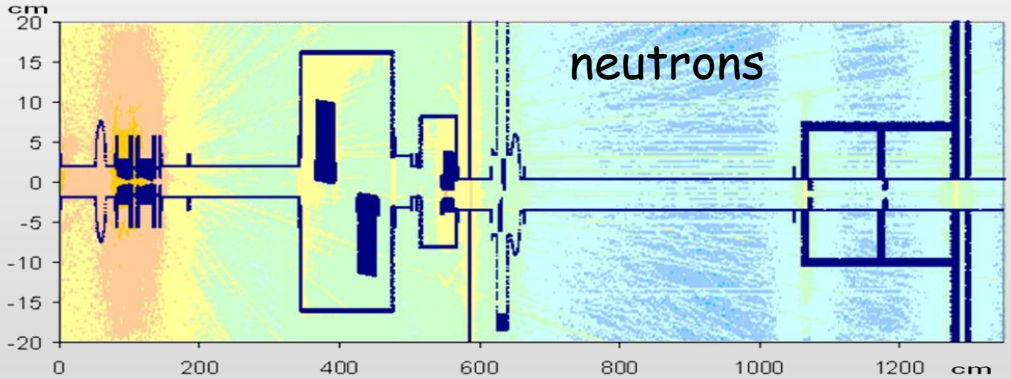


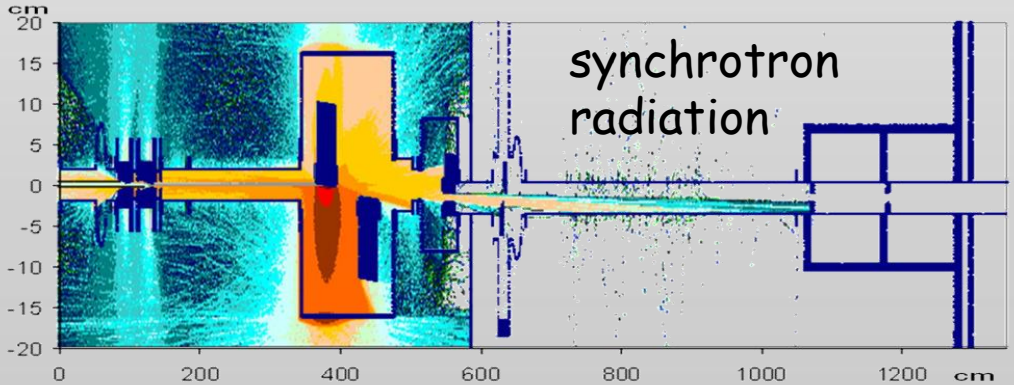
UPBL7:
Soft X-ray beamline for magnetic and electronic spectroscopy



Phase I Upgrade Beamlines: UPBL7 – ID32





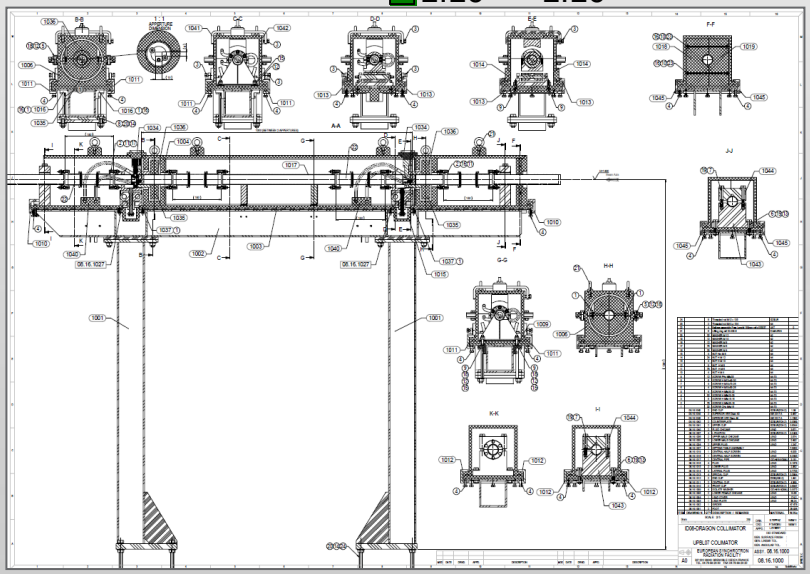


μSv/h γ,n

- $1.10^{3} – 1.10^{4}$
- $1.10^{2} – 1.10^{3}$
- $1.10^{1} – 1.10^{2}$
- $1.10^{0} – 1.10^{1}$
- $1.10^{-1} – 1.10^{0}$
- $1.10^{-2} – 1.10^{-1}$
- $1.10^{-3} – 1.10^{-2}$
- $1.10^{-4} – 1.10^{-3}$
- $1.10^{-5} – 1.10^{-4}$
- $1.10^{-6} – 1.10^{-5}$
- $1.10^{-7} – 1.10^{-6}$
- $1.10^{-8} – 1.10^{-7}$
- $1.10^{-9} – 1.10^{-8}$

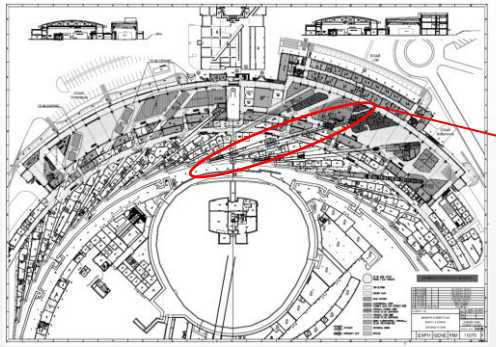
μSv/h X

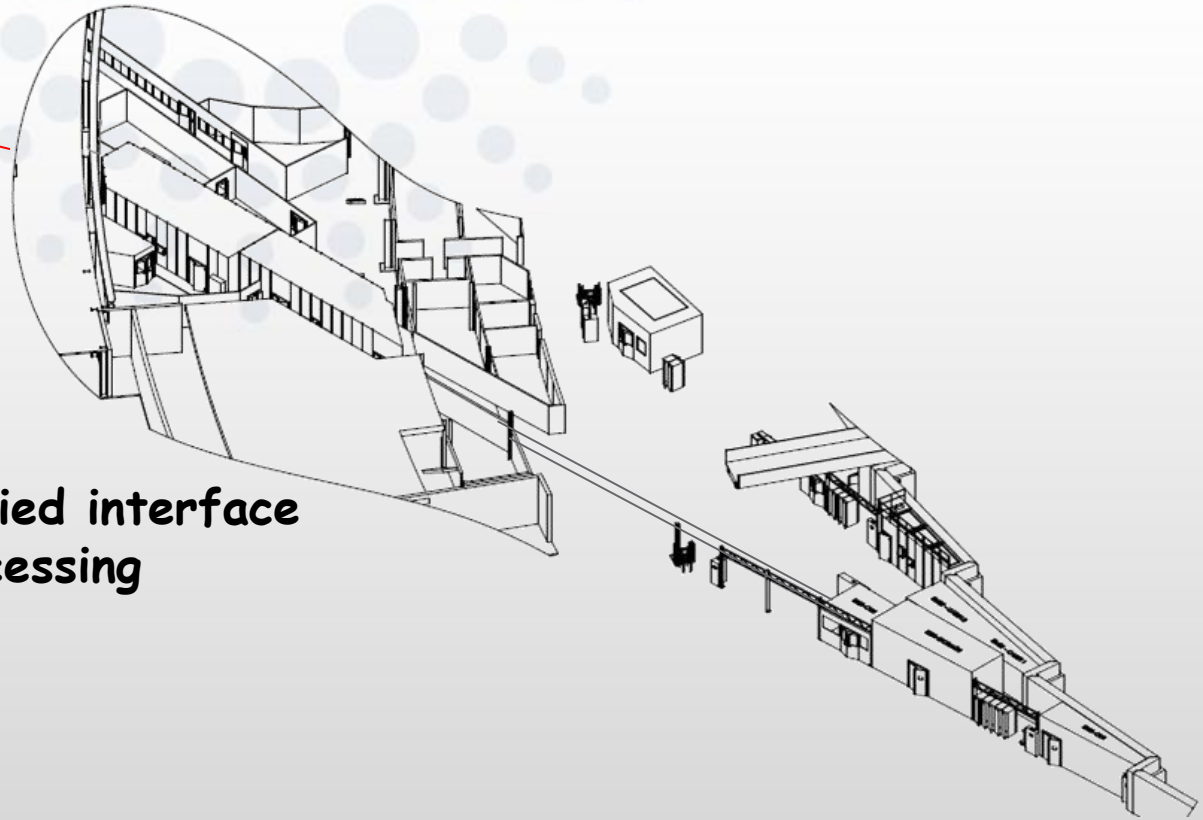
- $1.10^{12} – 1.10^{13}$
- $1.10^{11} – 1.10^{12}$
- $1.10^{10} – 1.10^{11}$
- $1.10^{9} – 1.10^{10}$
- $1.10^{8} – 1.10^{9}$
- $1.10^{7} – 1.10^{8}$
- $1.10^{6} – 1.10^{7}$
- $1.10^{5} – 1.10^{6}$
- $1.10^{4} – 1.10^{5}$
- $1.10^{3} – 1.10^{4}$
- $1.10^{2} – 1.10^{3}$
- $1.10^{1} – 1.10^{2}$
- $1.10^{0} – 1.10^{1}$
- $1.10^{-1} – 1.10^{0}$
- $1.10^{-2} – 1.10^{-1}$
- $1.10^{-3} – 1.10^{-2}$



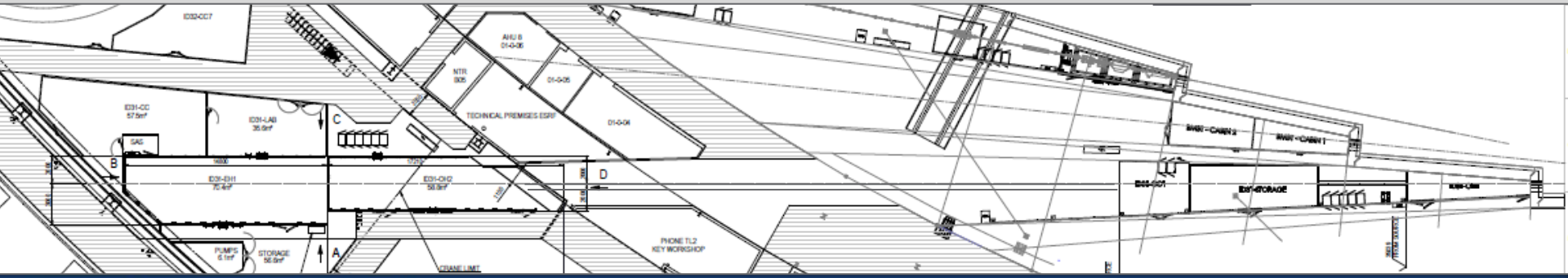
Phase I Upgrade Beamlines: UPBL7 – ID32

Phase I Upgrade Beamlines: UPBL2 – ID31

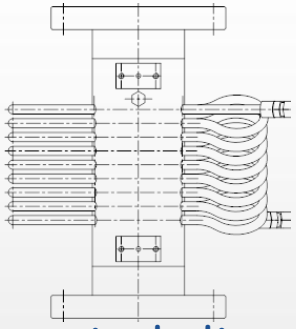




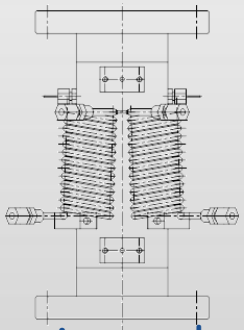
UPBL2:
High energy beamline for buried interface structures and materials processing



Transmission through ID31 front end



vertical slit
4 mm
(± 0.089 mrad)



horizontal slit
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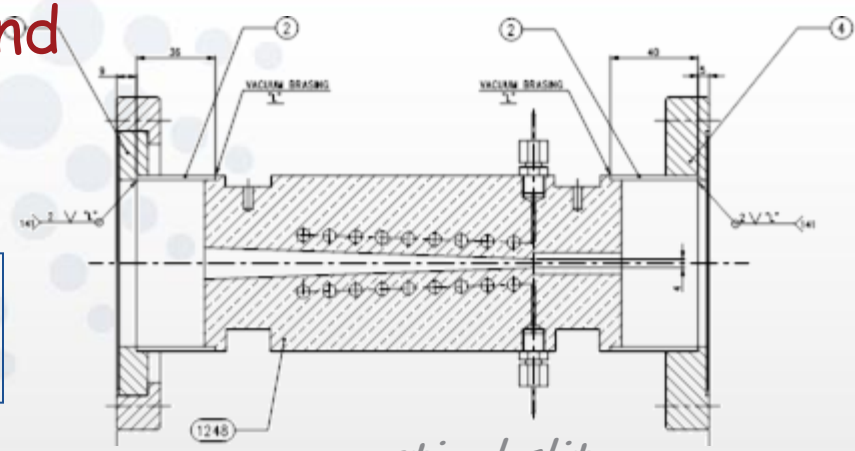
(± 0.074 mrad)

22.5 m

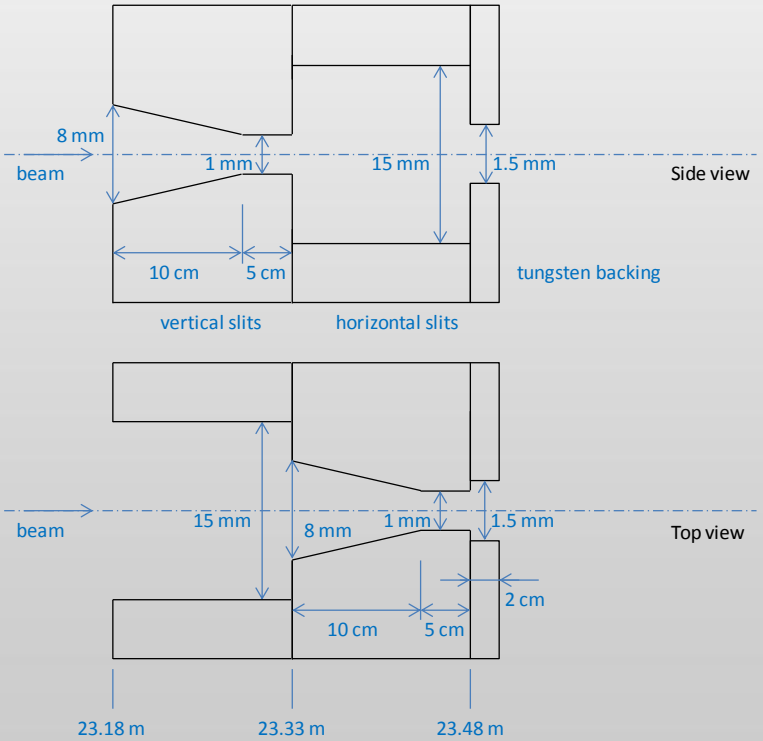
13.5 m

distance from middle of straight section

6 GeV:
$1/\gamma = 0.085$ mrad

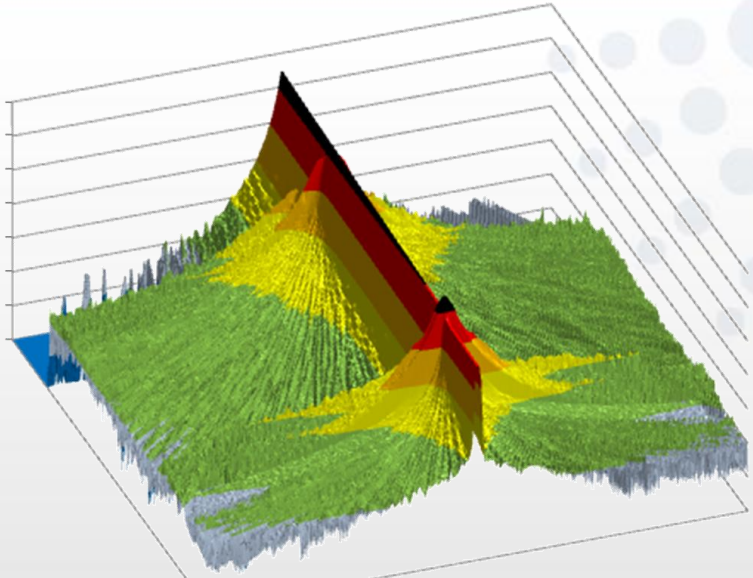


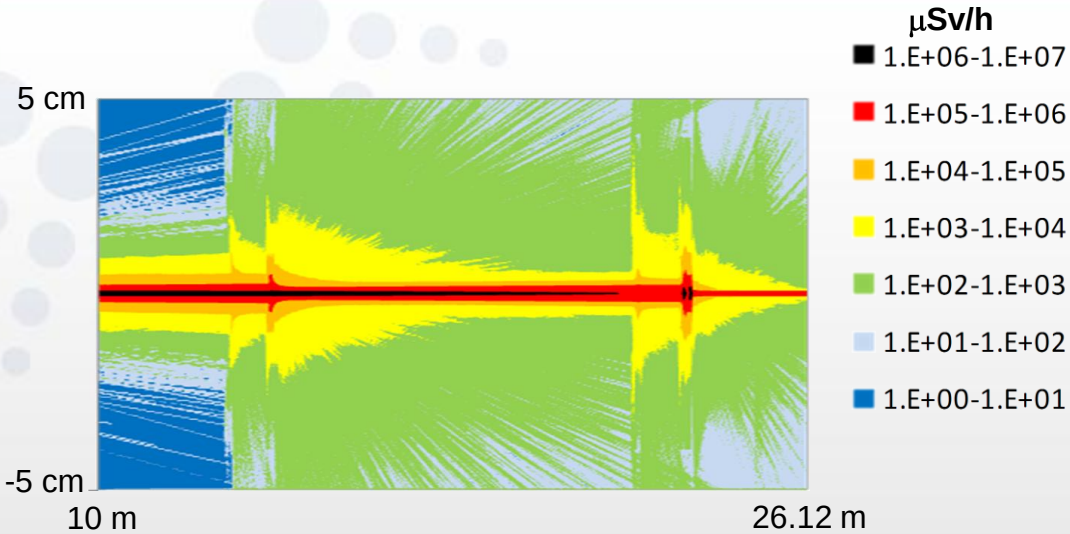
vertical slit



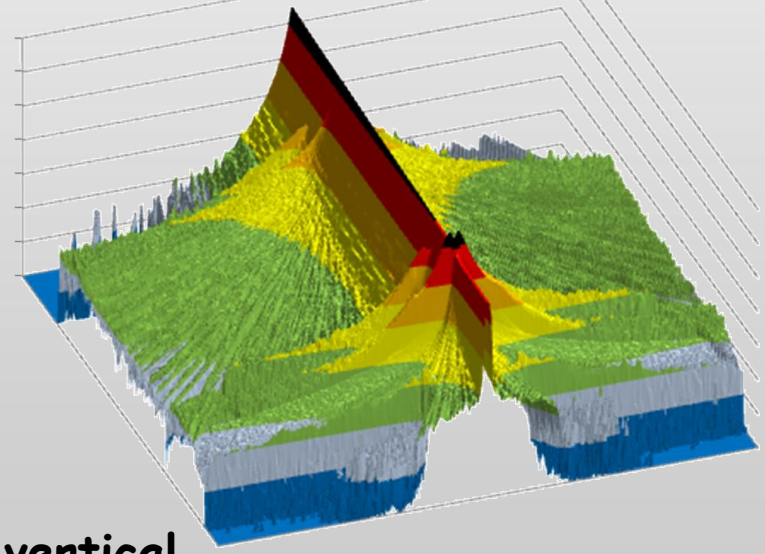
ID31 special horizontal / vertical collimator

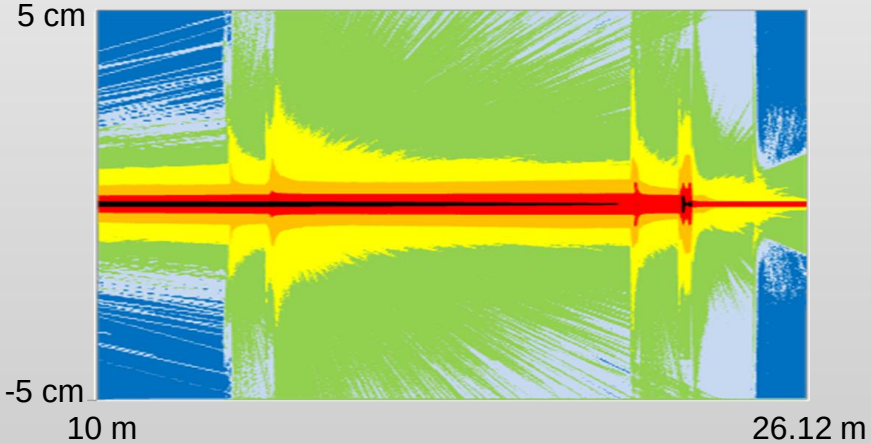
Gas-bremsstrahlung transmission in ID31 Front End





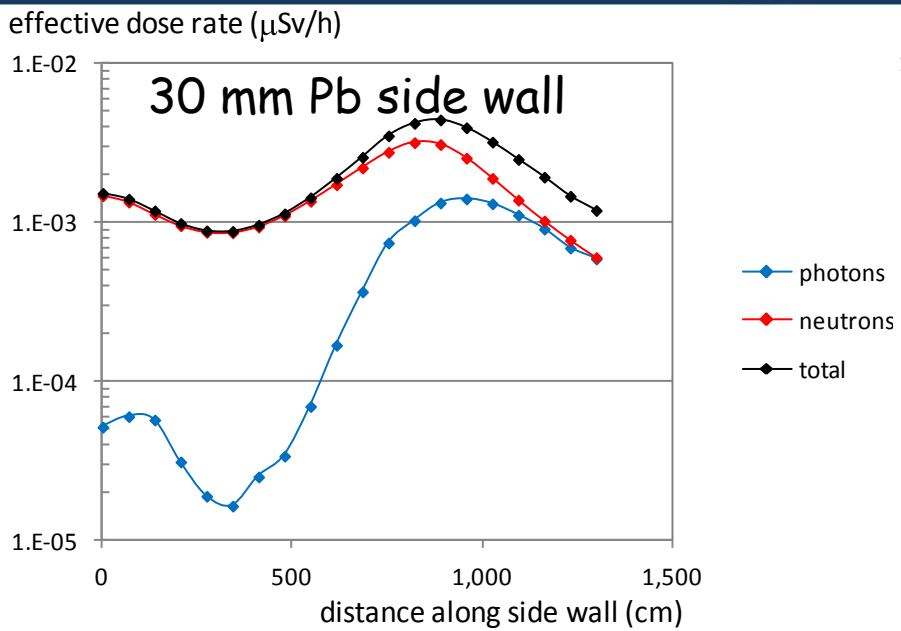
horizontal

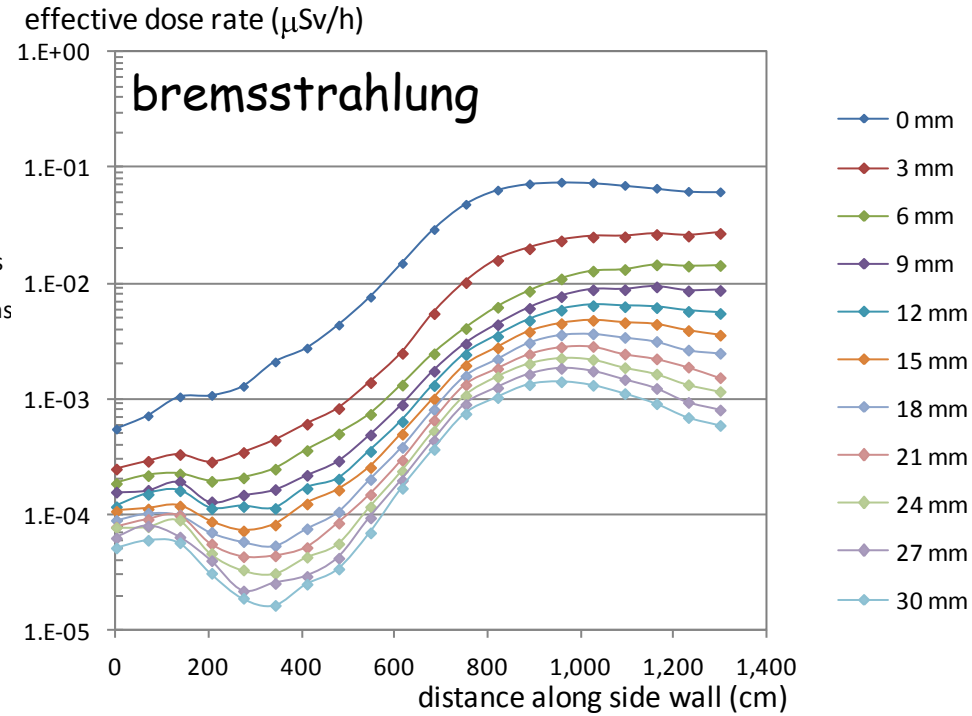


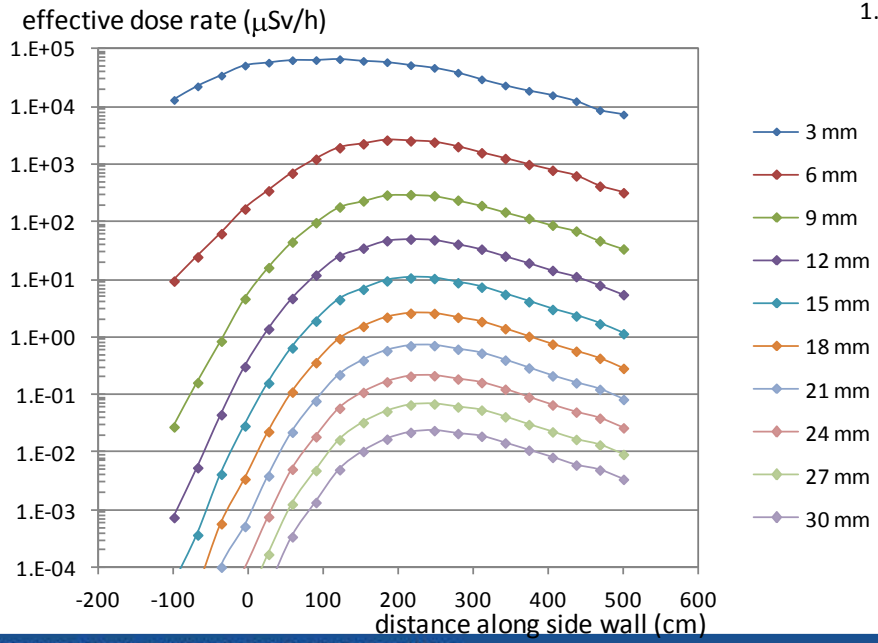


vertical

Phase I Upgrade Beamlines: UPBL2 – ID31







Synchrotron radiation

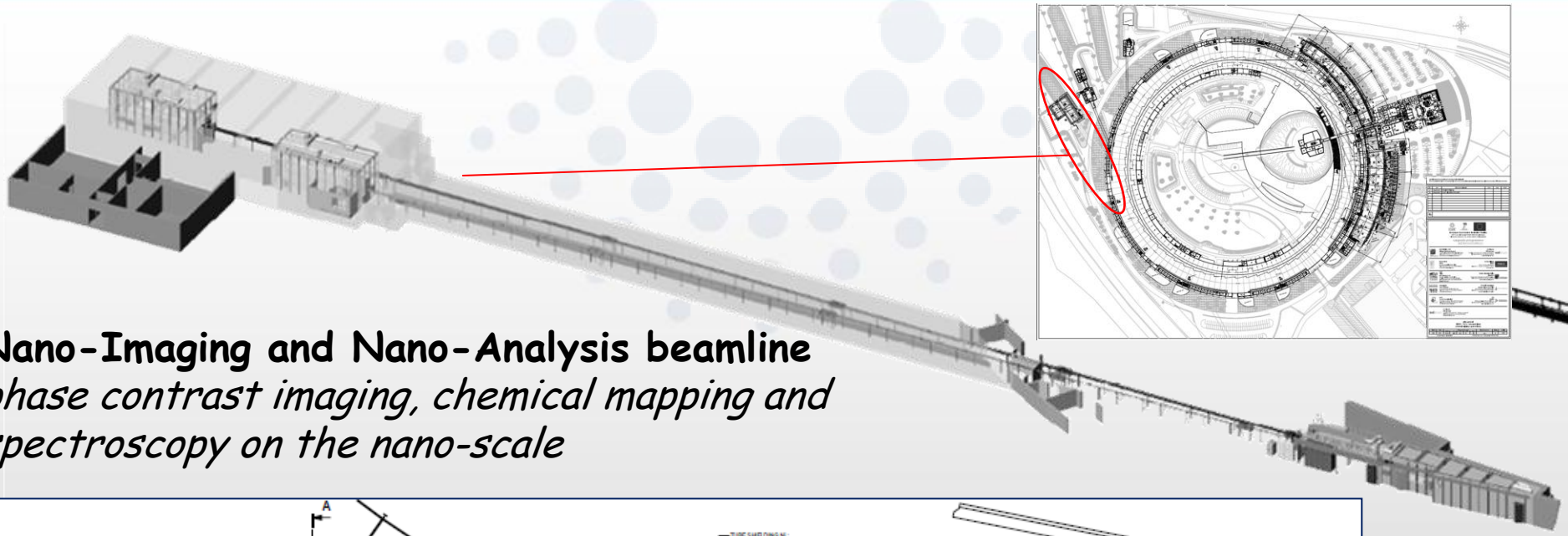
In-vacuum cryogenic undulator

Bmax = 1.2 T

Period: 14 mm

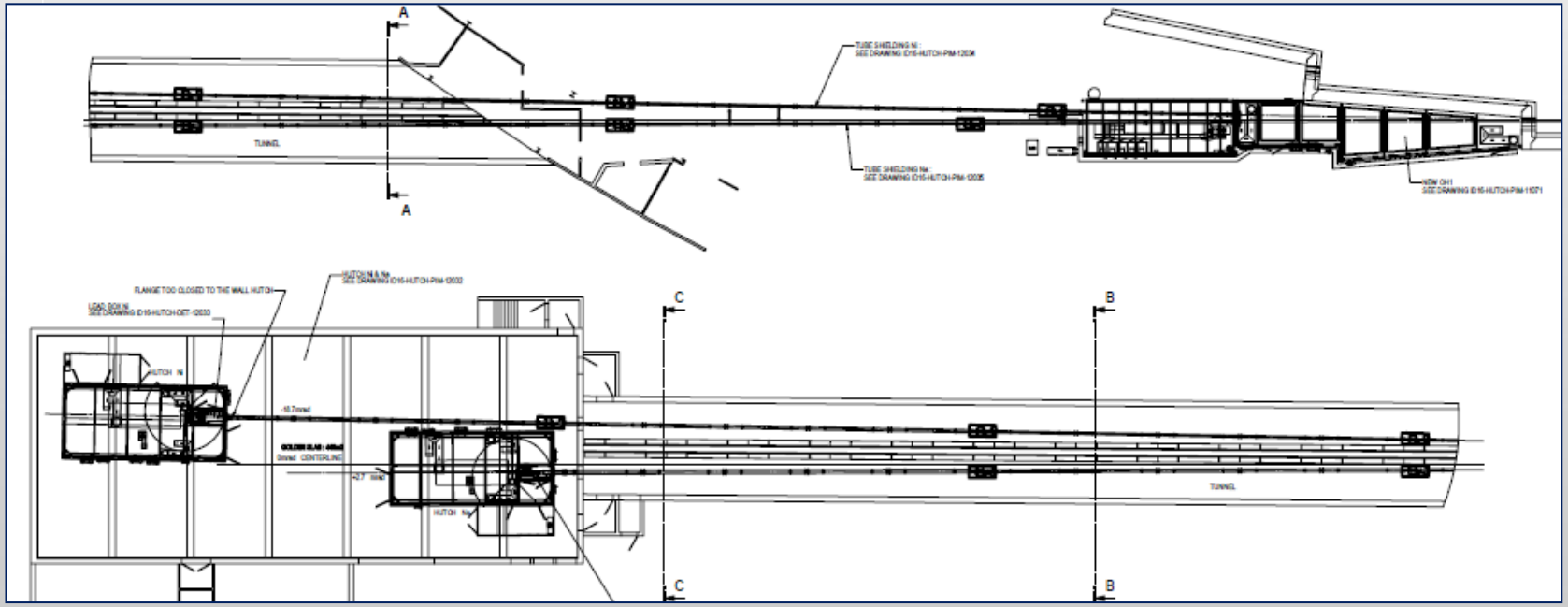
2 × 2 meters

Phase I Upgrade Beamlines: UPBL4 – ID16 (NiNa)

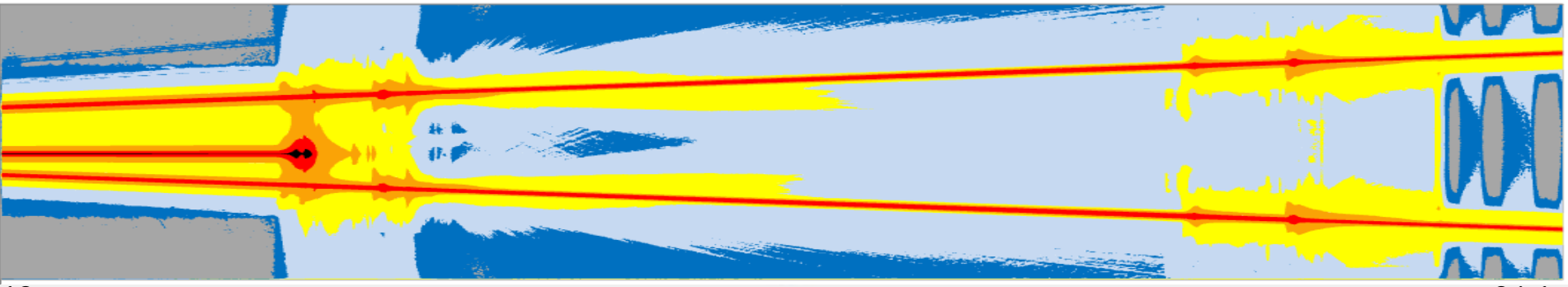


Nano-Imaging and Nano-Analysis beamline

phase contrast imaging, chemical mapping and spectroscopy on the nano-scale

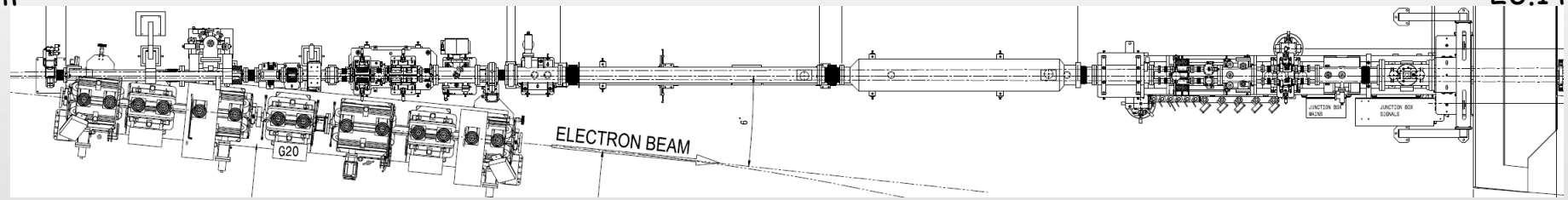


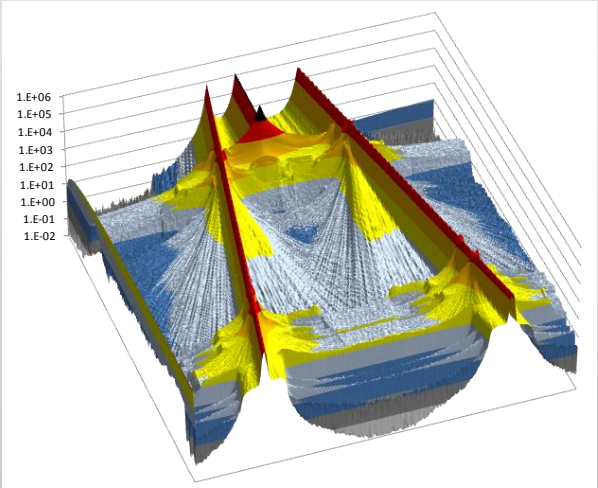
Phase I Upgrade Beamlines: UPBL4 – ID16 (NiNa)

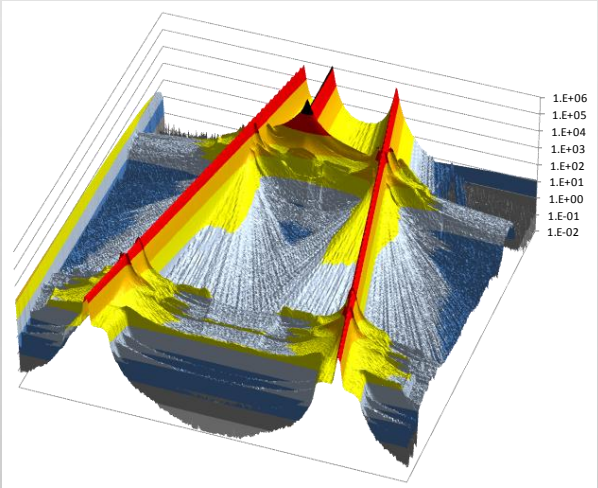


10 m

26.1 m







μSv/h

- 1.E+05-1.E+06
- 1.E+04-1.E+05
- 1.E+03-1.E+04
- 1.E+02-1.E+03
- 1.E+01-1.E+02
- 1.E+00-1.E+01
- 1.E-01-1.E+00

ID16
canted section
Front end
2.7 mrad canting

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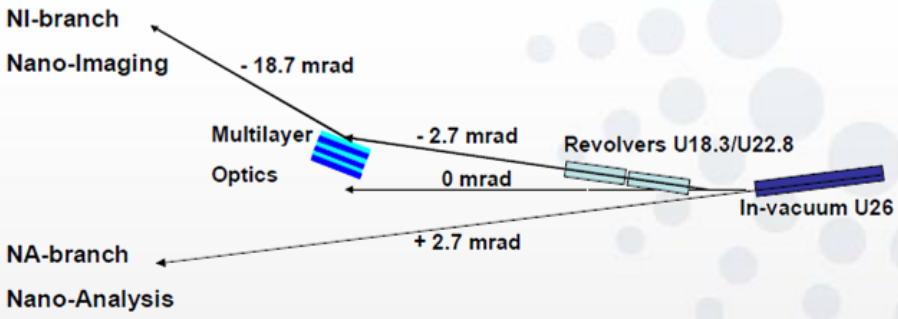
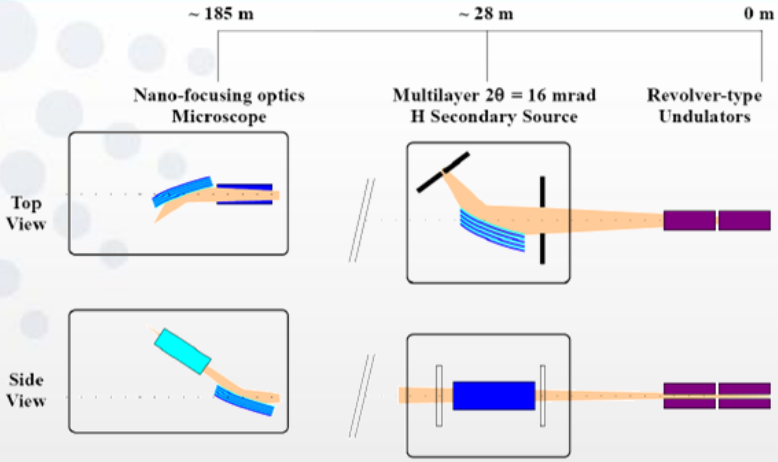
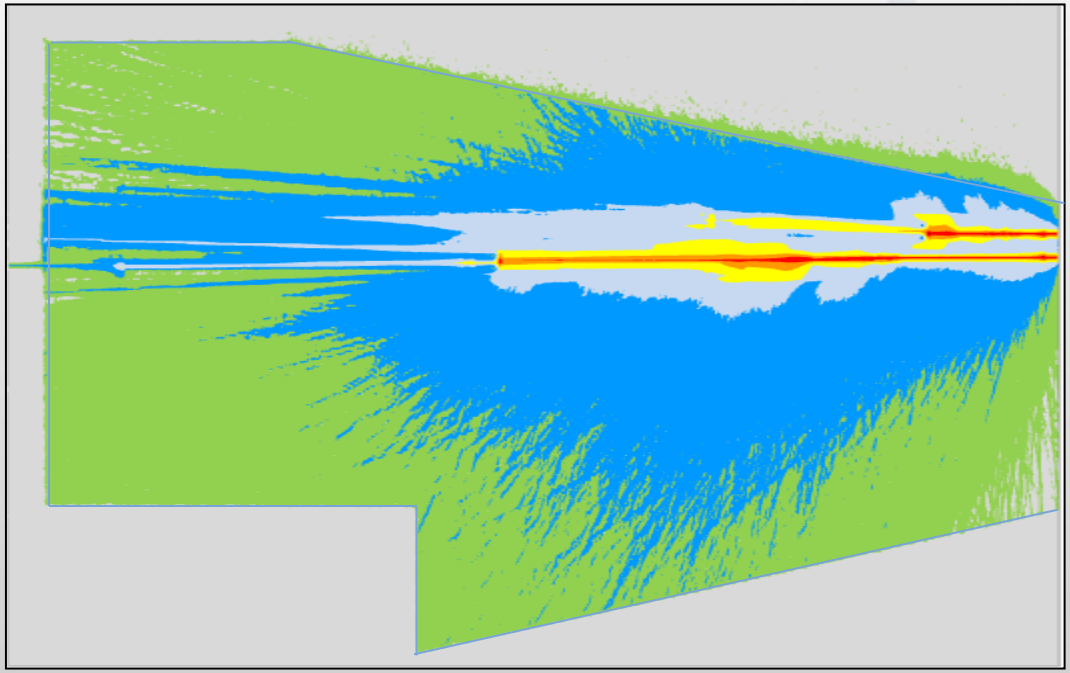
200 mA
1. 10^{-9} mbar

Phase I Upgrade Beamlines: UPBL4 – ID16 (NiNa)



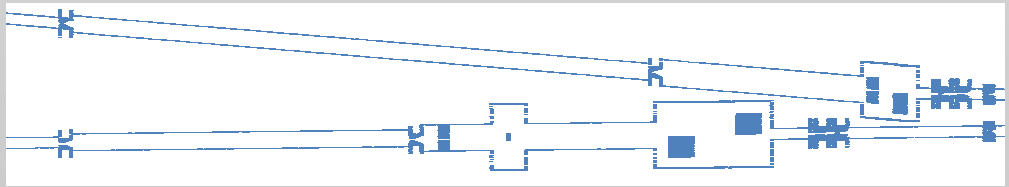


Ni-branch



Photon effective dose rate (μSv/h)

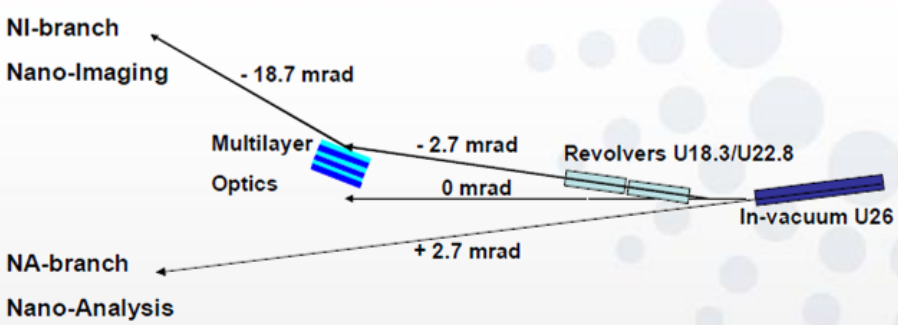
- 1.E+04-1.E+05
- 1.E+03-1.E+04
- 1.E+02-1.E+03
- 1.E+01-1.E+02
- 1.E+00-1.E+01
- 1.E-01-1.E+00
- 1.E-02-1.E-01
- 1.E-03-1.E-02

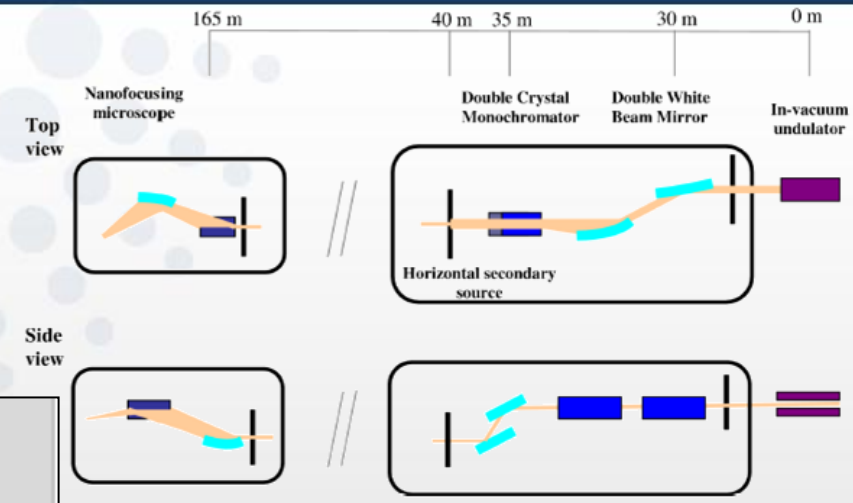


ID16
Optics hutch

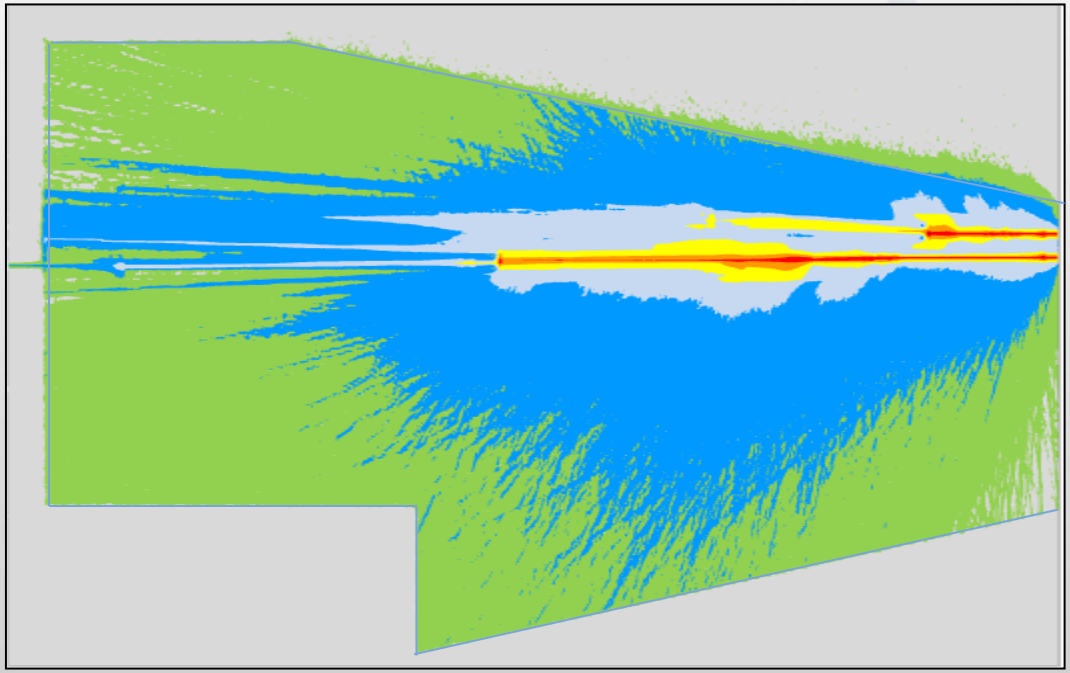
200 mA
1. 10^{-9} mbar

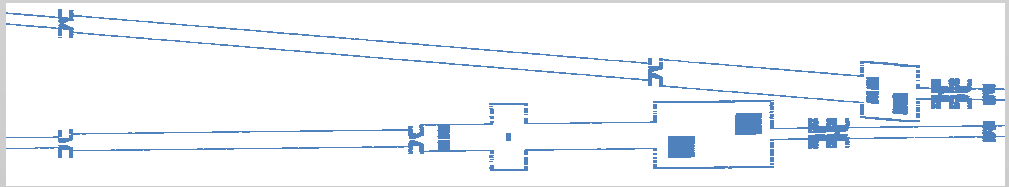
Phase I Upgrade Beamlines: UPBL4 – ID16 (NiNa)





Na-branch





Photon effective dose rate (μSv/h)

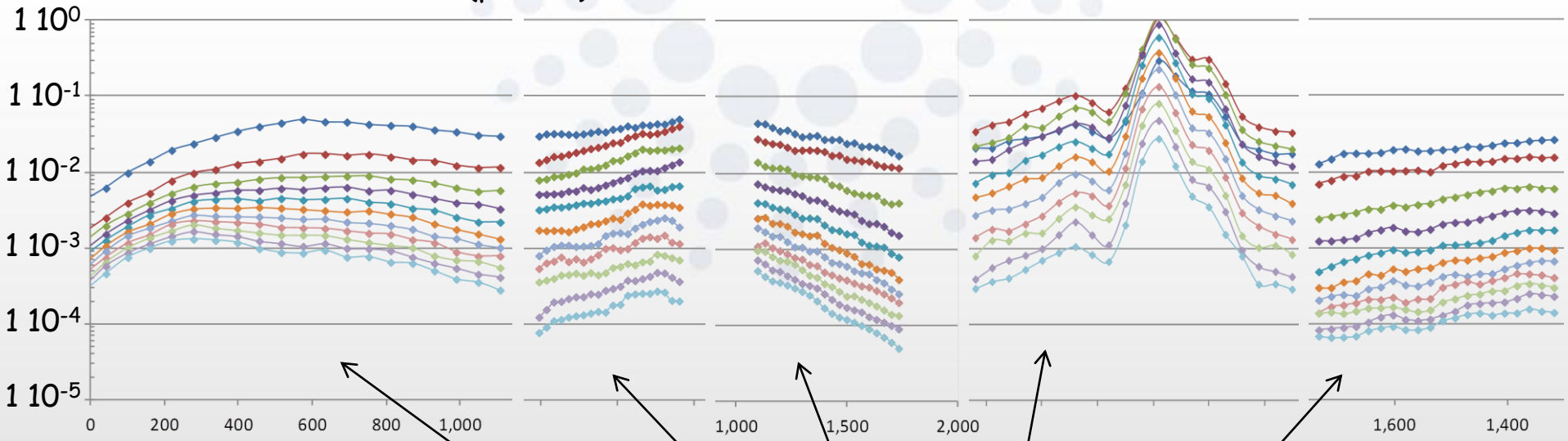
- 1.E+04-1.E+05
- 1.E+03-1.E+04
- 1.E+02-1.E+03
- 1.E+01-1.E+02
- 1.E+00-1.E+01
- 1.E-01-1.E+00
- 1.E-02-1.E-01
- 1.E-03-1.E-02

ID16
Optics hutch

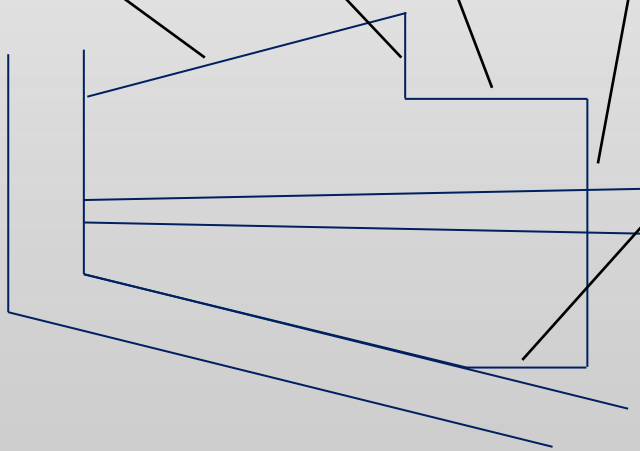
200 mA
1. 10^{-9} mbar

Phase I Upgrade Beamlines: UPBL4 – ID16 (NiNa)

Photon effective dose rate (μSv/h)



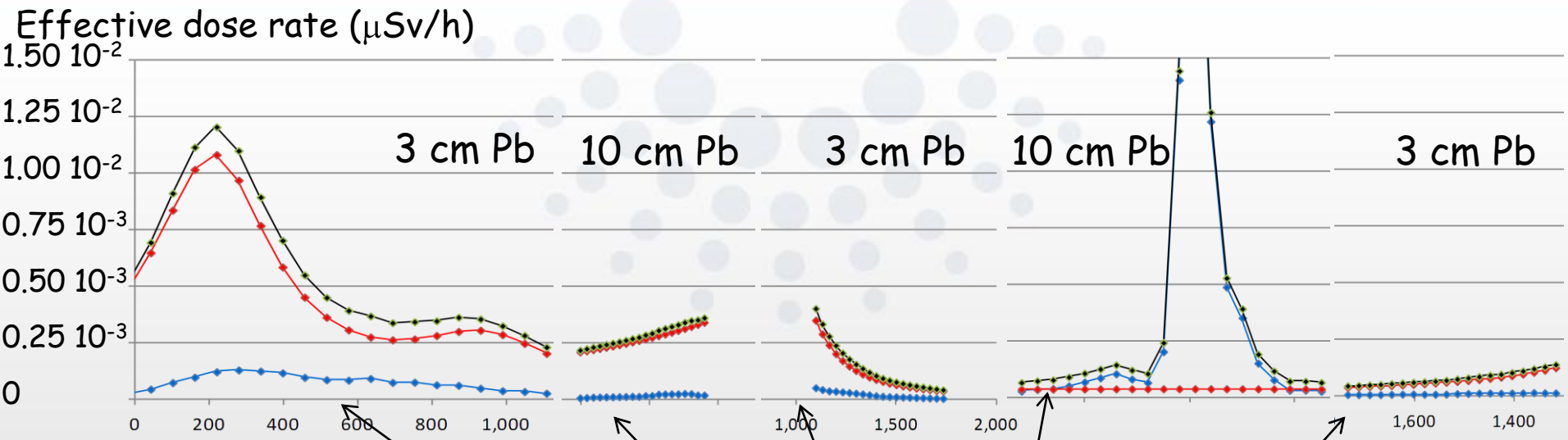
	Side walls	Back walls
	0 mm	0 cm
	3 mm	1 cm
	6 mm	2 cm
	9 mm	3 cm
	12 mm	4 cm
	15 mm	5 cm
	18 mm	6 cm
	21 mm	7 cm
	24 mm	8 cm
	27 mm	9 cm
	30 mm	10 cm

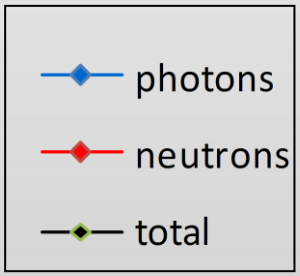


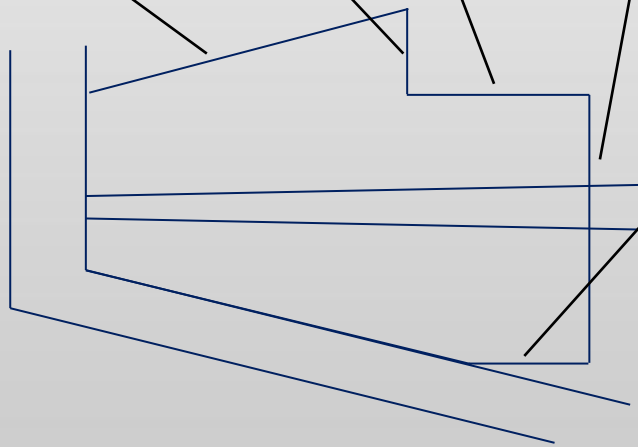
ID16
Optics hutch

200 mA
1. 10^{-9} mbar

Phase I Upgrade Beamlines: UPBL4 – ID16 (NiNa)





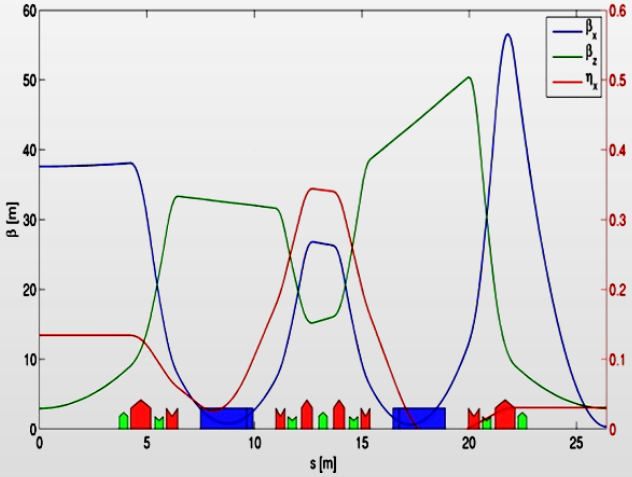


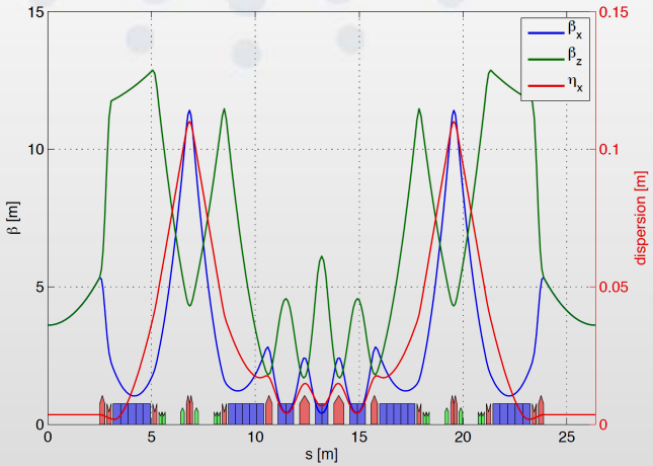
ID16
Optics hutch

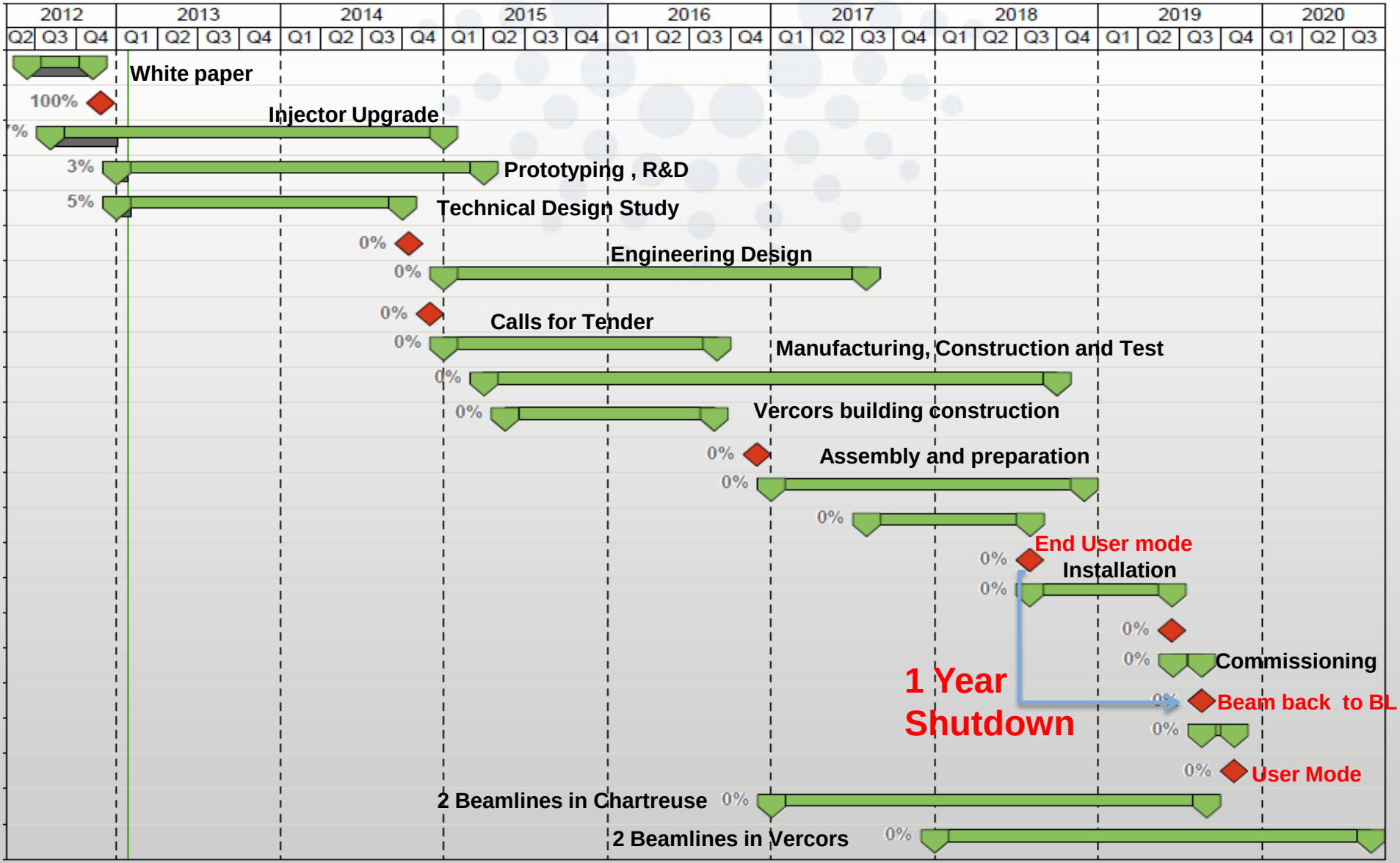
200 mA
1. 10^{-9} mbar

Phase I Upgrade Beamlines: UPBL4 – ID16 (NiNa)

Phase II Upgrade: Storage ring upgrade





Parameter	Existing Lattice	New Lattice
Energy, *E* [GeV]	6.04	6.04
Circumference, *C* [m]	844	844
RF frequency, *fRF* [MHz]	352	352
Beam current [mA]	200	200
Horizontal Emittance [pm ·rad]	4000	150
Vertical Emittance [pm ·rad]	4	3
Beta at ID center, βx , βy [m]	37.6 , 3.0 (high β) 0.35 , 3.0 (low β)	3.6 , 3.6
Beam size at ID center, σx , σy [μm]	413 , 3.9 (high β) 50 , 3.9 (low β)	24 , 3.3
Beam div. at ID center, $\sigma x'$, $\sigma y'$ [μrad]	10 , 1.3 (high β) 107, 1.3 (low β)	6.4 , 0.91

Phase II Upgrade: Storage ring upgrade