RadSynch 25

23-27 June 2025

Five years of operational radiation protection experience with the new EBS storage ring at the ESRF

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ESRF | The European Synchrotron

1 ESRF RADIATION PROTECTION POLICY

- ESRF radiation protection policy.
- EBS parameters for the shielding study: Lifetime and injection efficiency.
- Integration of two horizontal collimators in the storage ring, on C13 and C24.
- Comparison of the radiation maps made in the storage ring in 2018 before EBS and in may 2025.
- Report of the collimator radiation levels in C13 and C24 Experimental Hall side.
- Estimated annual exposure.

ESRF RADIATION PROTECTION POLICY

The basic radiation protection rule is the ALARA principle: As Low As Reasonably Achievable. At the ESRF we apply this principle by guaranteeing that everybody working at the ESRF (ESRF or CRG staff, users, external companies, …) should be considered as non-exposed workers.

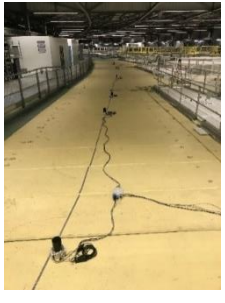
We therefore respect the annual effective dose limit for the non-exposed workers (which is the same as for the public) of 1 $mSv.y^{-1}$, corresponding to an average effective dose rate of 0.5 $\mu Sv.h^{-1}$, assuming 2000 working hours per year.

We have therefore adopted the following policy. We guarantee, in any area accessible during operation, the derived effective dose limit for non-exposed workers on a 4-hour basis: **2 μSv for period of 4 hours**.

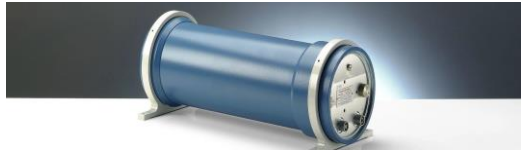
3 ESRF RADIATION PROTECTION POLICY

An ionisation chamber is installed outside each optics hutch and empty Beamport End. It is interlocked to the safety shutter of the corresponding front end and guarantees that the 2 μSv per 4 hours limit is respected around the beamline hutches. These radiation monitors are sufficiently fast to allow the closure of the front end during injection in the event of excessive dose levels.

128 neutron monitors, placed on the storage ring roof, are integrated into the accelerator personnel safety system. They guarantee that the operation of the storage ring will not create integrated doses higher than 2 μSv in 4 hours in all places accessible during operation, in particular in the Experimental Hall. If one of these monitors shows an integrated dose higher than 2 μSv, the injection in the storage ring is blocked until the end of the 4-hours period.

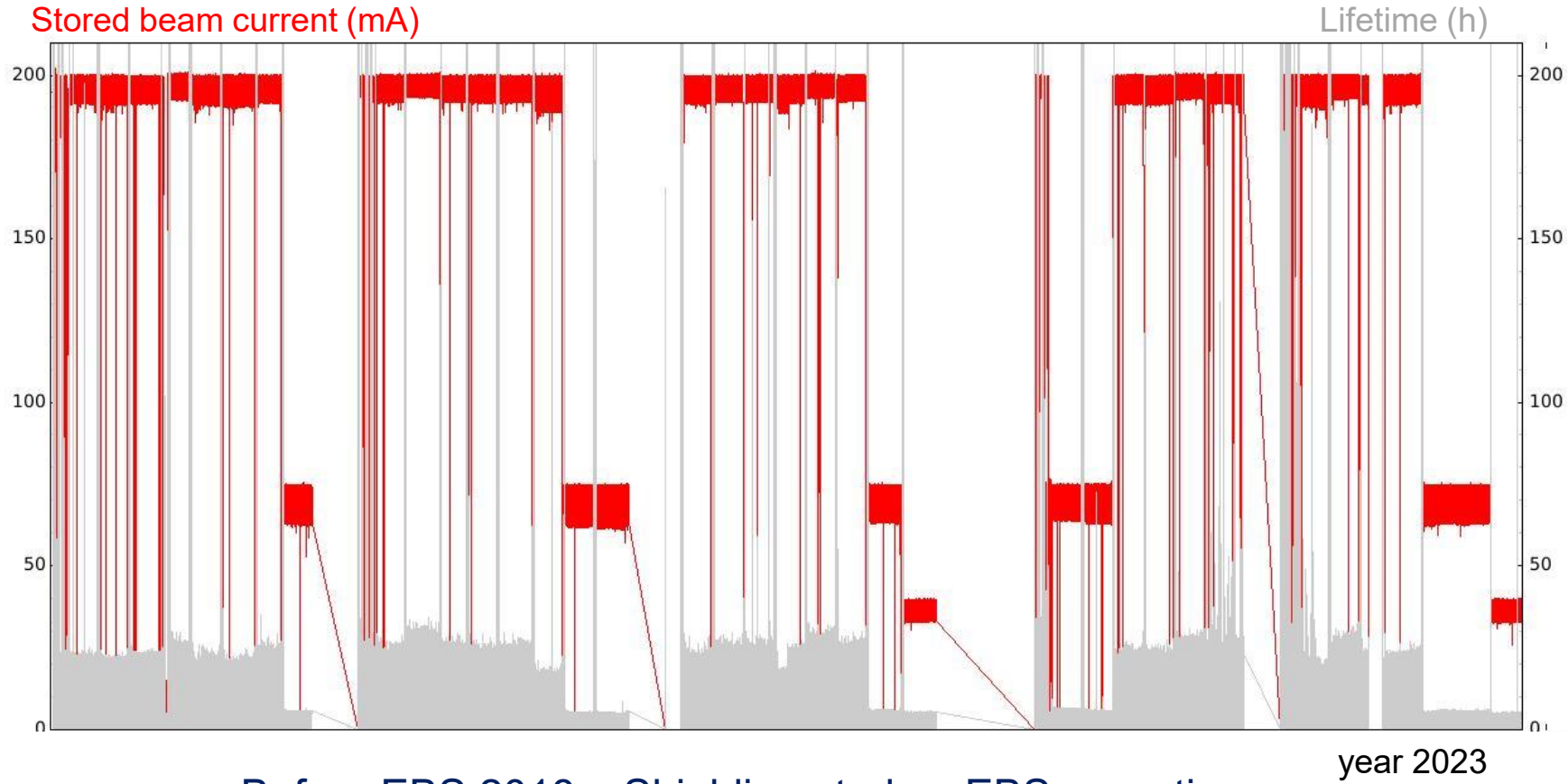


Neutron monitor on the Storage ring roof
Distributed by Radosys (Hungary)



Ionisation chamber around beamline OH
PTW (Germany)

BEAM LIFETIME



Before EBS 2018:
200 mA: 45 h
92 mA: 16 h

Shielding study:
200 mA: 19.3 h
92 mA: 1.8 h

EBS operation:
200 mA: 25 h
70 mA: 5.5 h

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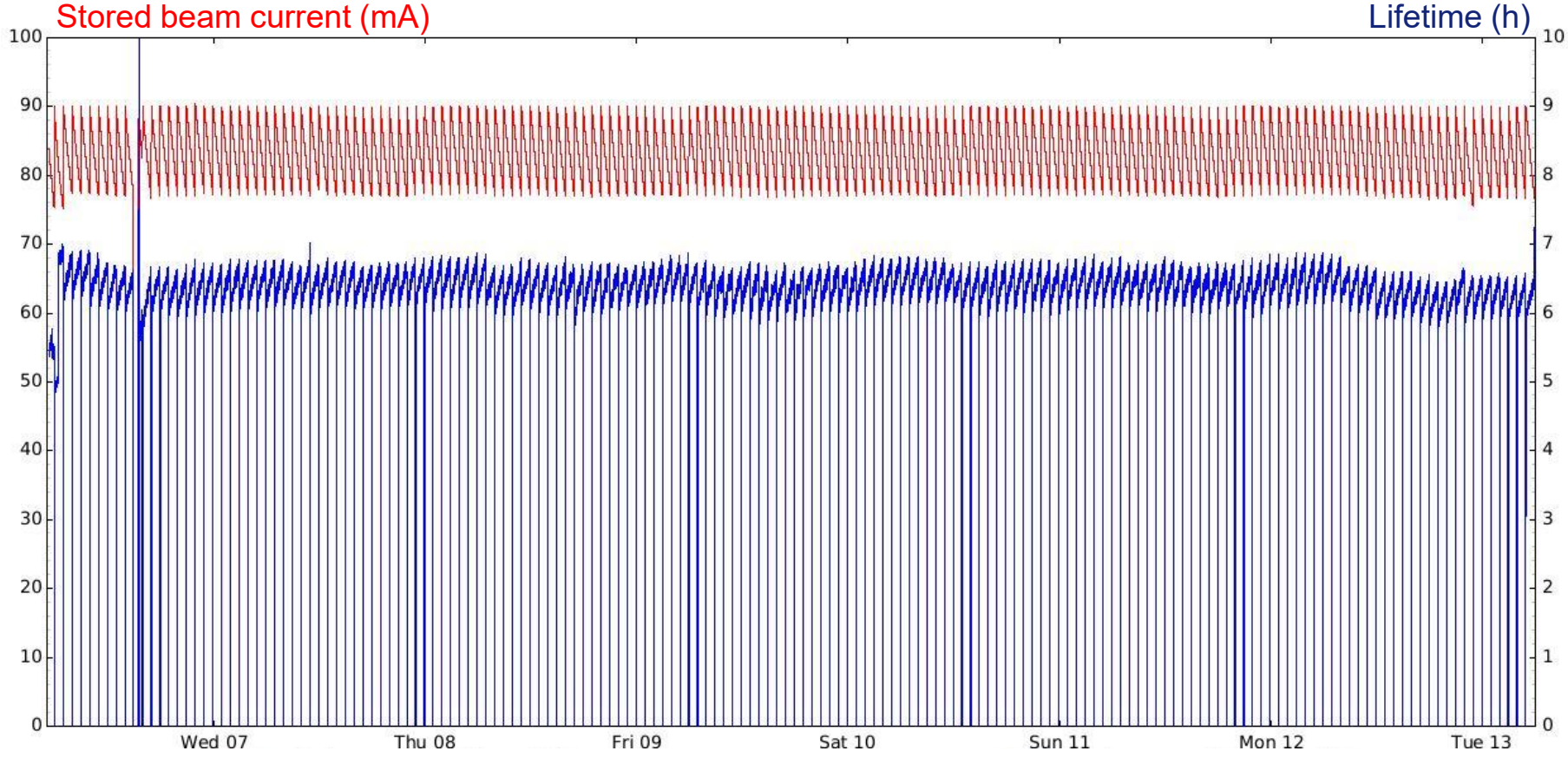
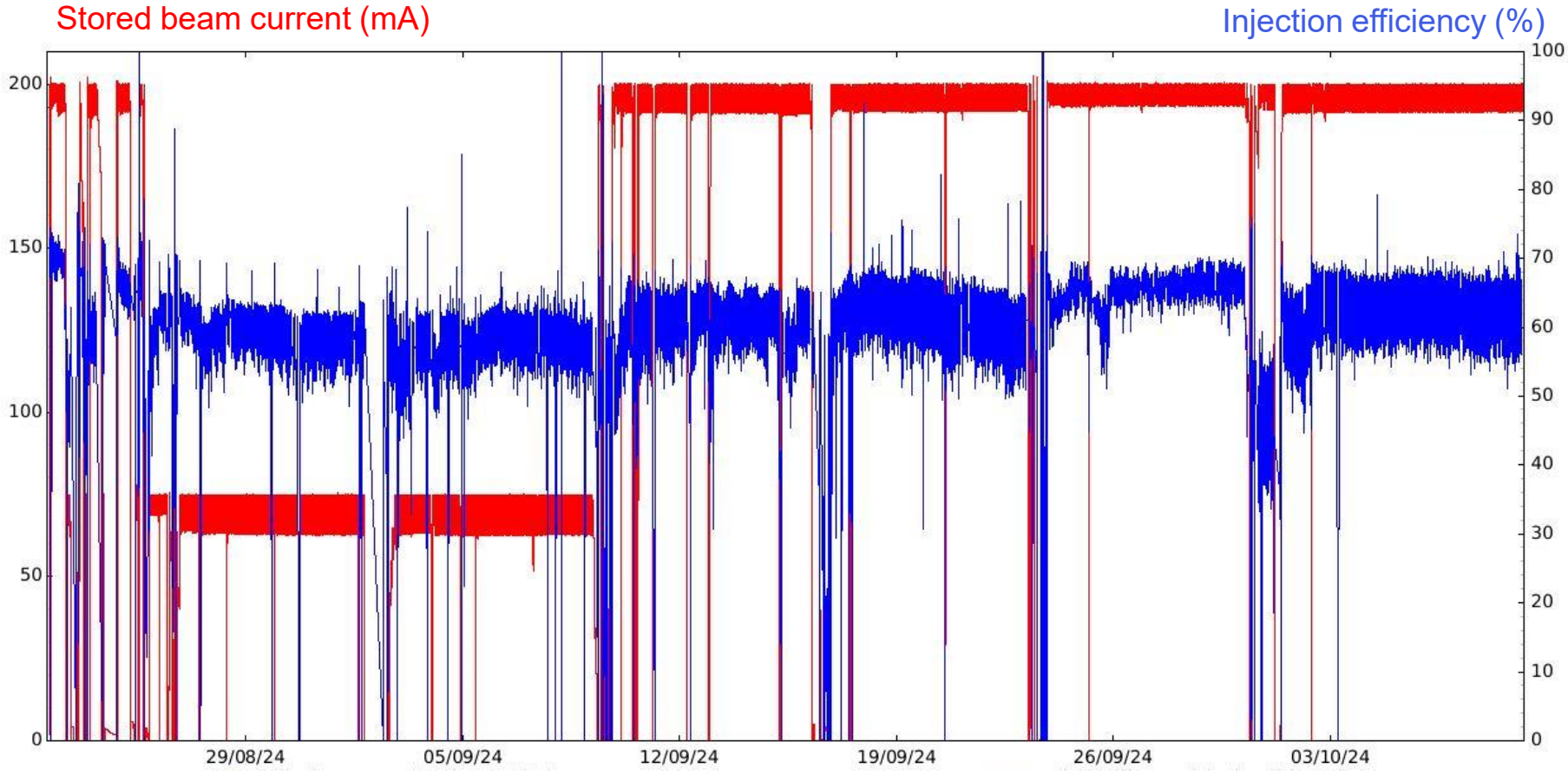
BEAM LIFETIME 16 BUNCH SINCE 2025



Shielding study:
200 mA: 19.3 h
92 mA: 1.8 h

16 bunch operation (since 2025):
90 mA: 6 h

INJECTION EFFICIENCY



Shielding study:

Conservative assumption: 50 %

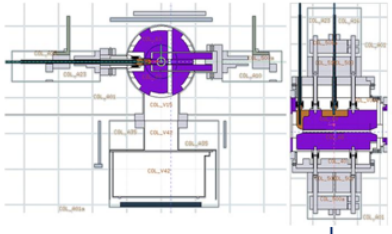
THE ESRF EBS STORAGE RING

$$\int_{4\ hours} \frac{dE}{dt} \cdot dt < 0.5\ \mu Sv/h \times 4\ h = 2\ \mu Sv$$

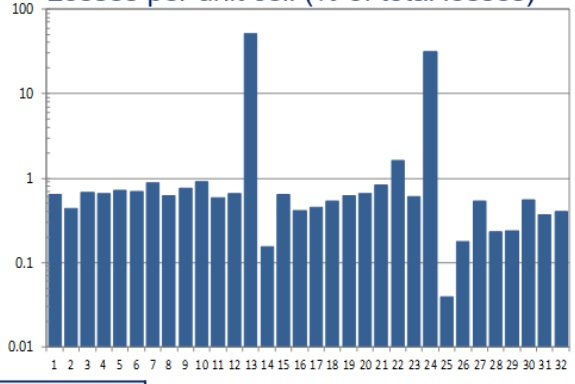
Main challenge:

e^- losses ×10 ⟺ use existing storage ring shielding

→ two dedicated beam loss collimators + local shielding



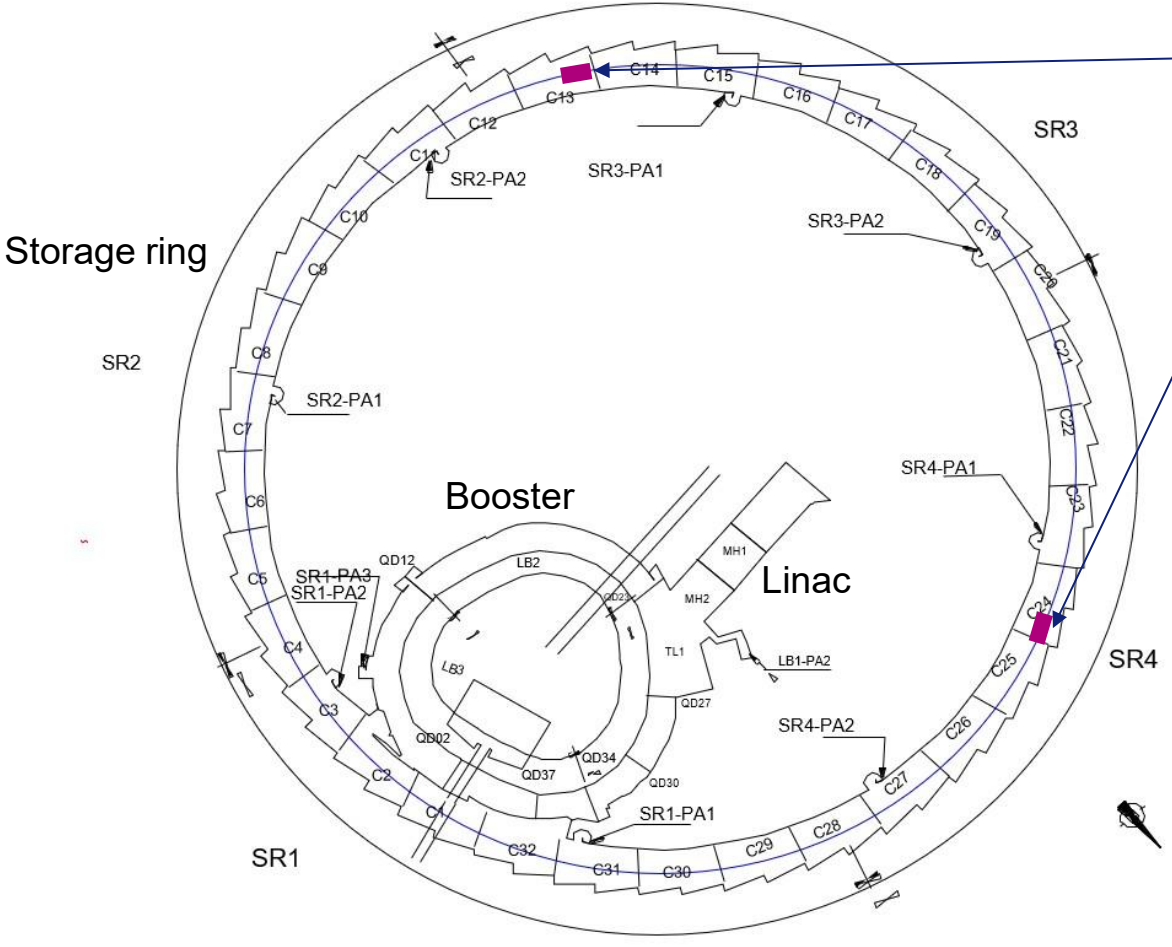
Losses per unit cell (% of total losses)



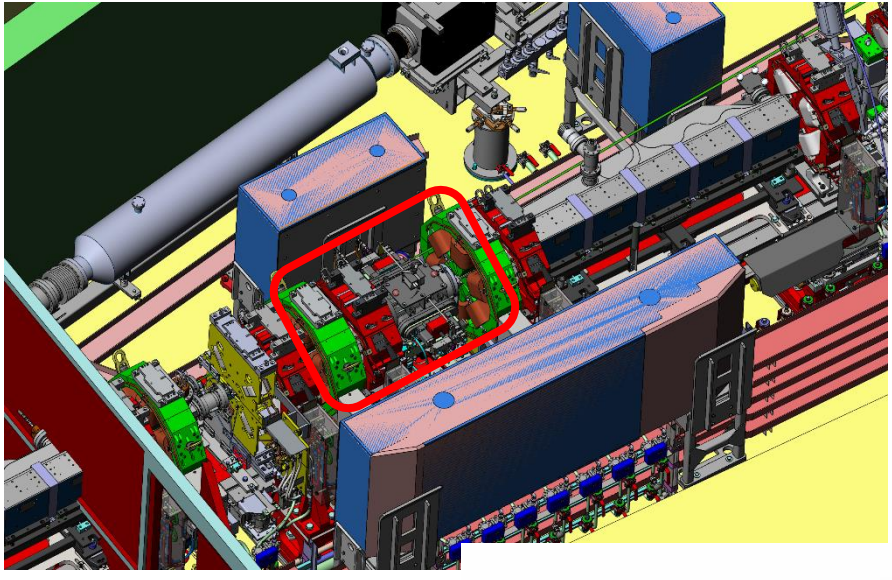
Distribution of beam losses along the storage ring lattice

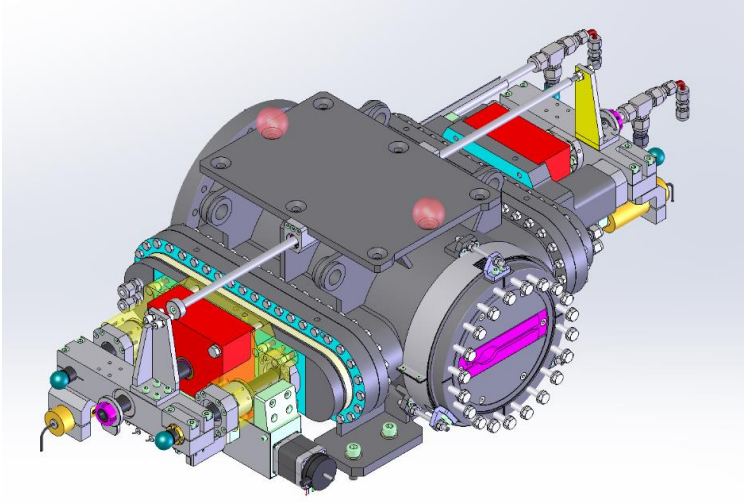
		Lifetime (h)		Beam losses (e/s)	
Mode	Stored beam (mA)	ESRF 1	EBS	ESRF 1	EBS
Multi-bunch	200	45	19.3	$2.2\ 10^7$	$5.1\ 10^7$
16 bunch	92	16	1.8	$2.8\ 10^7$	$2.5\ 10^8$
4 bunch	40	9	1.2	$2.2\ 10^7$	$1.6\ 10^8$

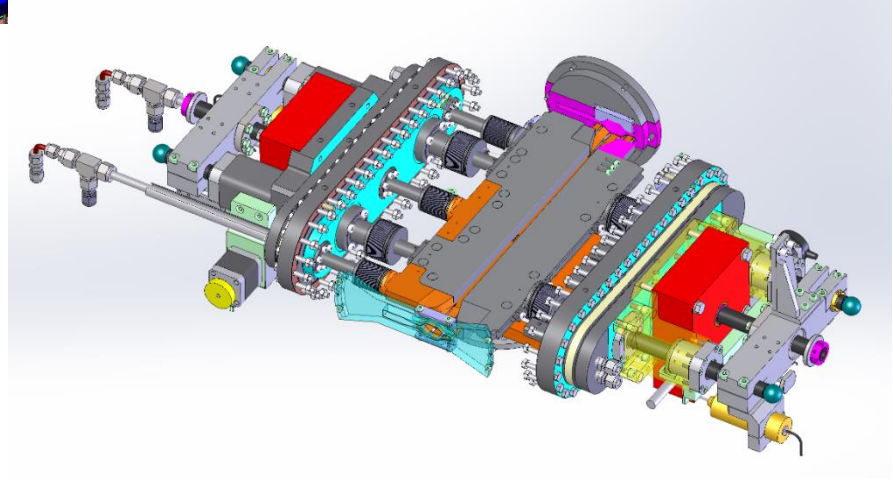
BEAM LOSS COLLIMATORS



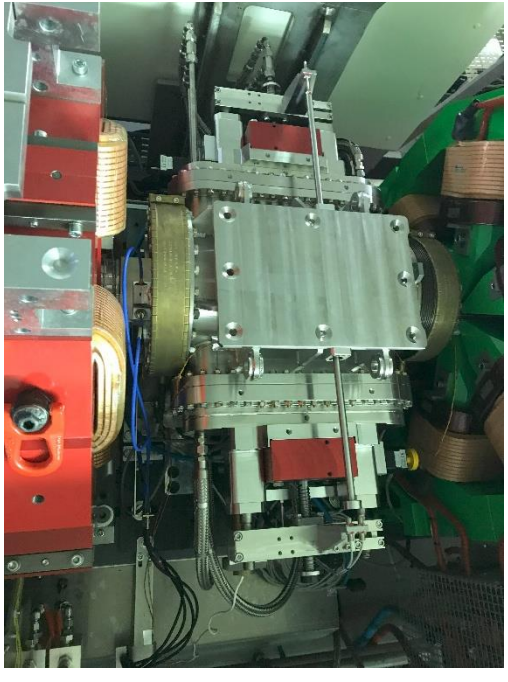
BEAM LOSS COLLIMATORS

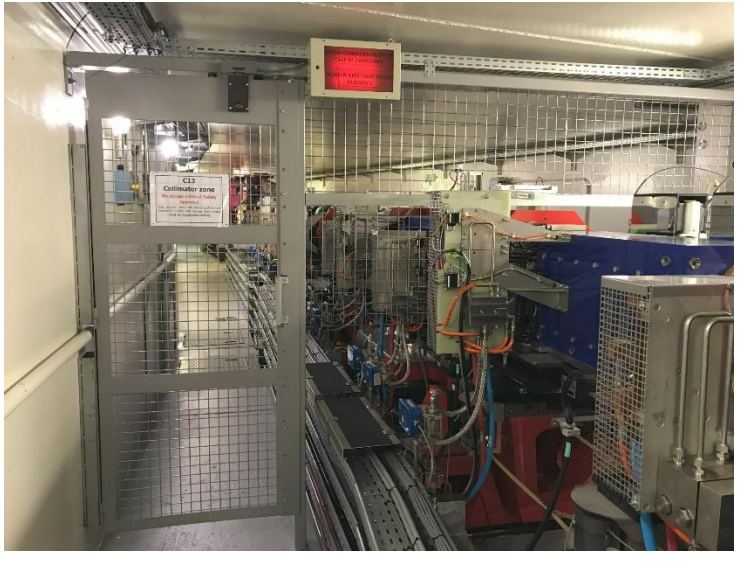






BEAM LOSS COLLIMATORS

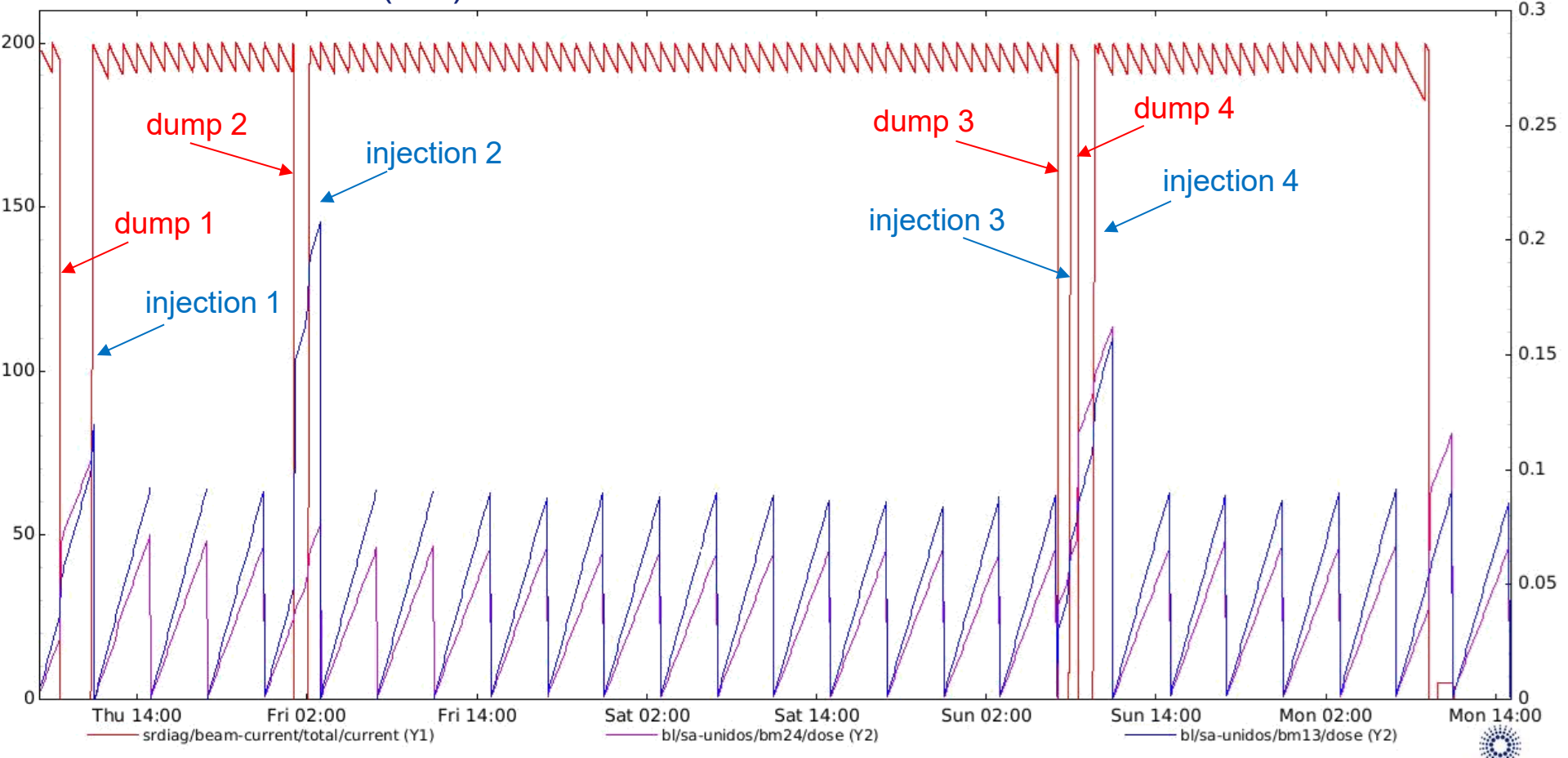




BEAM LOSS COLLIMATORS

Stored beam current (mA)

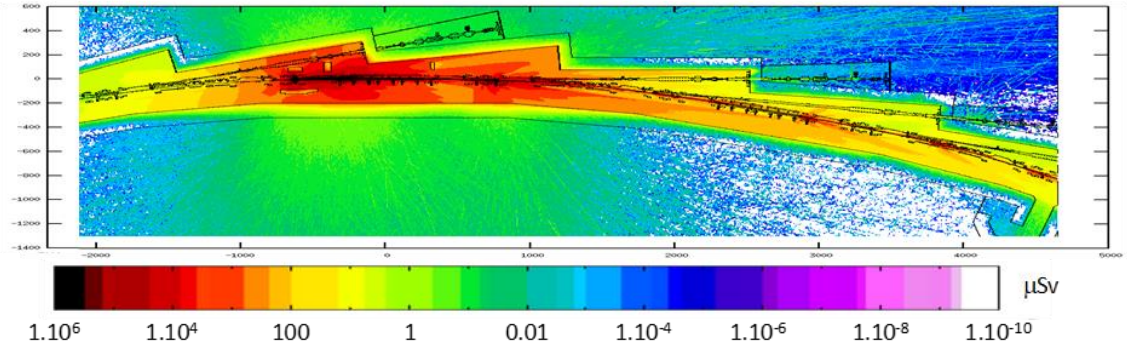
4-hours integrated photon dose (μSv)



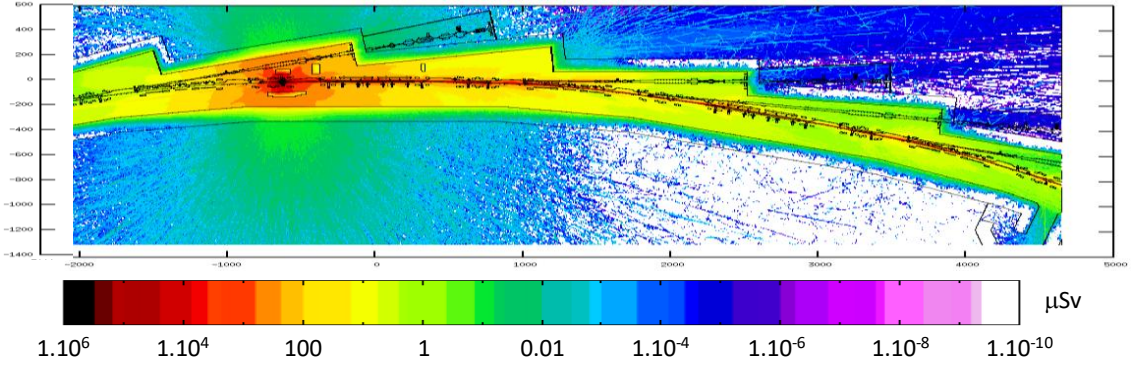
BEAM LOSS COLLIMATORS

	Integrated dose (nSv)			
	BM13	BM24	Sum	FLUKA
Dump 1	47	5	52	60
Dump 2	10	40	50	60
Dump 3	30	40	70	60
Dump 4	10	47	57	60
Injection 1	20	10	30	40*
Injection 2	20	10	30	40*
Injection 3	20	10	30	40*
Injection 4	28	10	38	40*

* 50 % injection efficiency

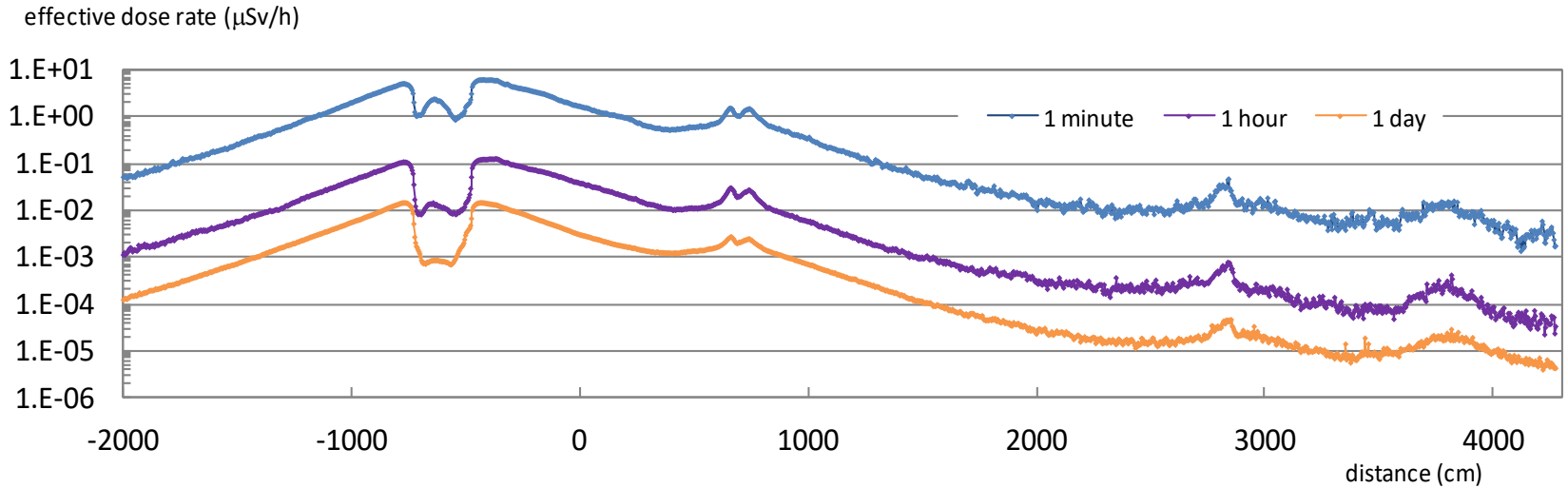


Effective dose distribution around the collimator in cell 13 following a 200 mA beam dump, with 50 % local beam loss.



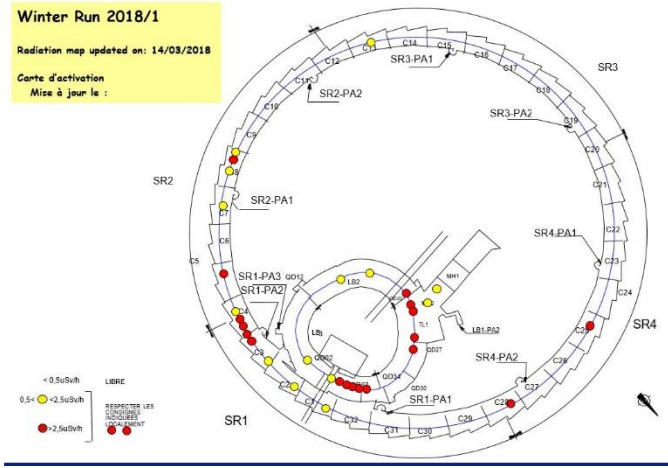
Integrated effective dose distribution around the collimator in cell 13 following a full 200 mA refill, with an overall injection efficiency of 50 %

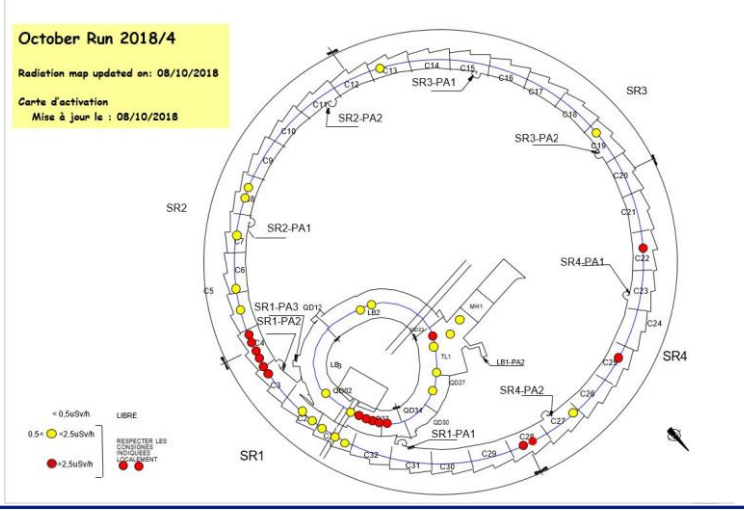
RADIATION LEVELS IN THE STORAGE RING - C13 COLLIMATOR

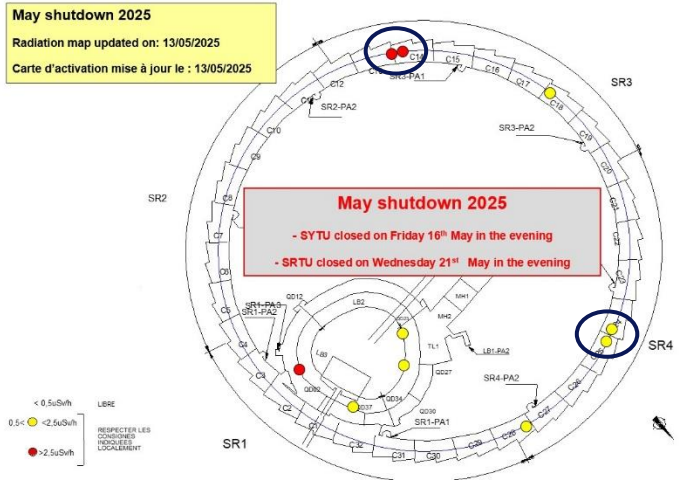


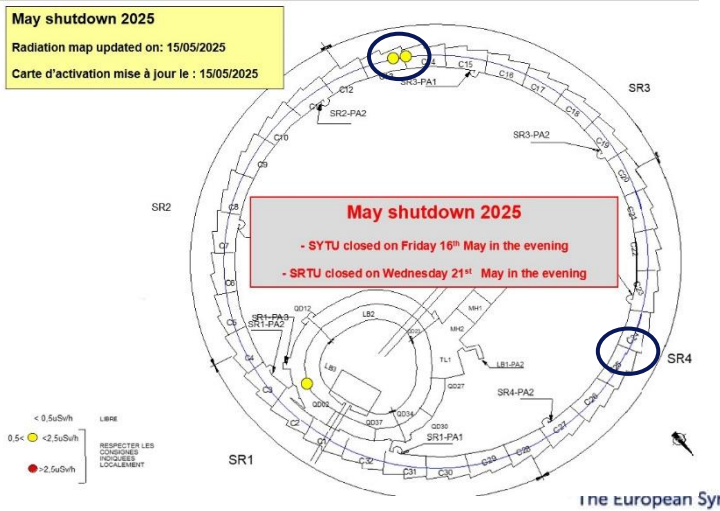
Effective dose rates in the freeway in the collimator cells after a 200 mA beam dump, after 1 minute, 1 hour and 1 day.

RADIATION LEVELS IN THE STORAGE RING – RADIATION MAPS

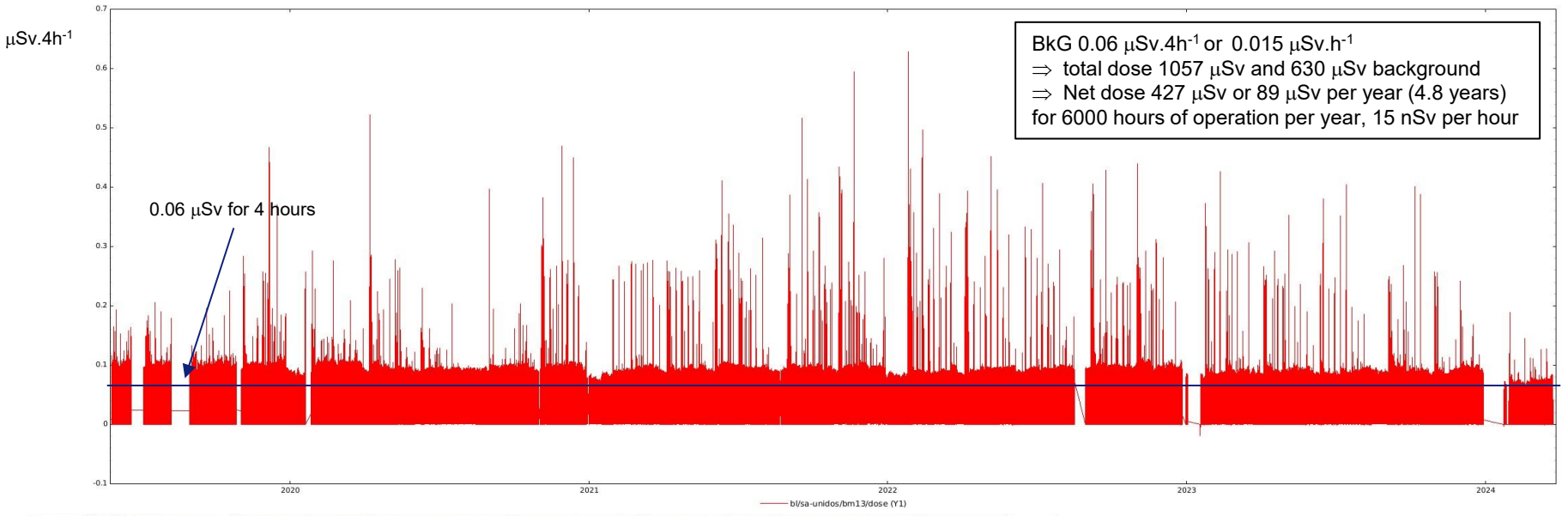


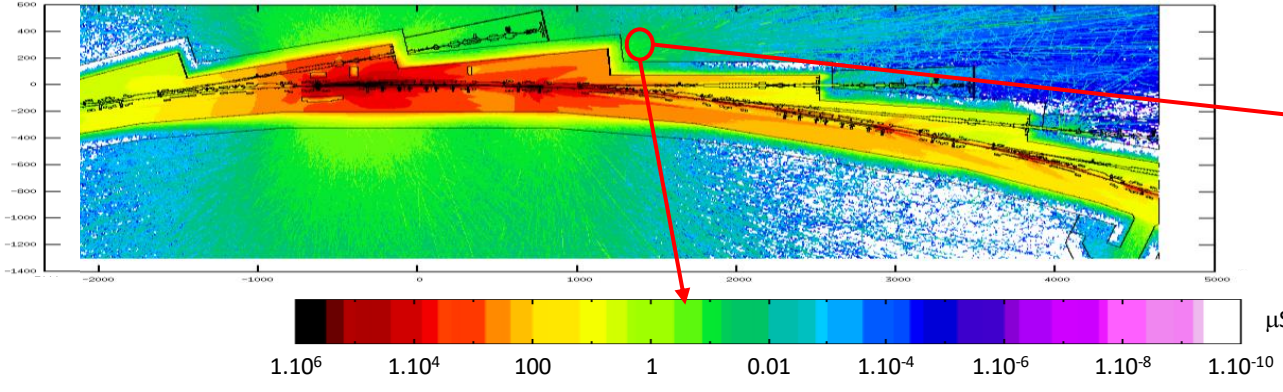






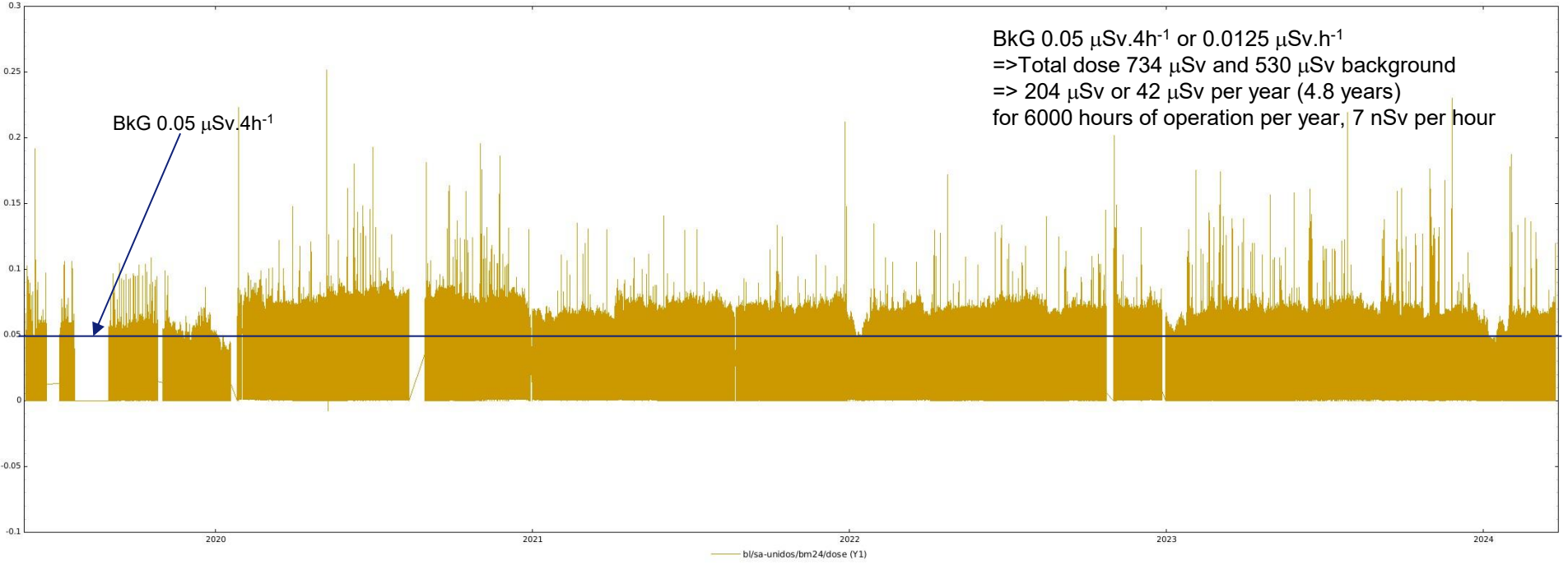
UNIDOS C13 BM13 (MAY 2020 – MARCH 2025) – EXPERIMENTAL HALL SIDE





FLUKA calculations for 200 mA beam dump

UNIDOS C24 BM24 (MAY 2020 – MARCH 2025) – EXPERIMENTAL HALL SIDE



ESTIMATED ANNUAL EXPOSURES

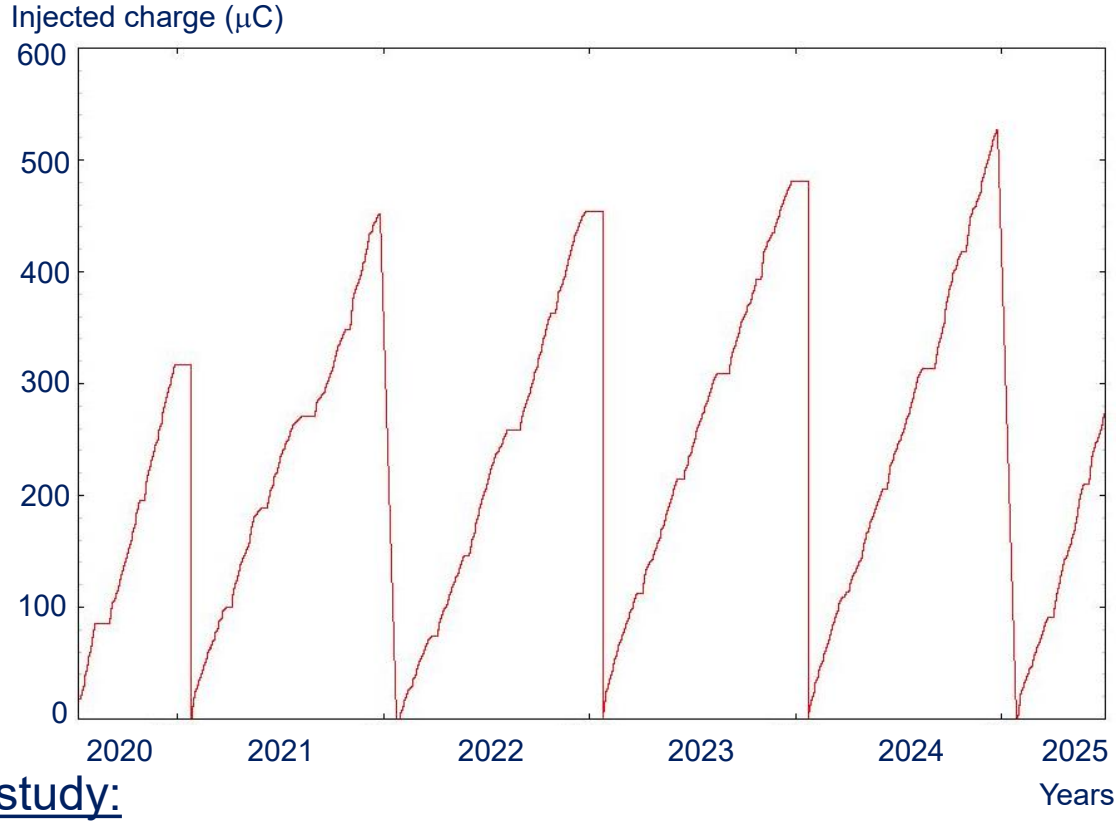
Operation limits:

Energy: 6.06 GeV

Stored beam: 205 mA

Injection efficiency: 50 %

Injected charge: 1200 μC /year



Since start of EBS:

Injected charge ≈ 500 μC /year

Shielding study:

200 mA: 19.3 h

92 mA: 1.8 h

ESTIMATED ANNUAL EXPOSURES

Assumption:
1200 μC /year
Injected charge
(operation limit)

Average: 16,25 μSv effective dose

Collective annual dose: 9,83 mSv for 605 staff.

In accordance with the measurements and ambient dosimetry

	Estimated annual exposure [effective dose, μSv]	Number of people concerned
ASD, RF & Linac group, Linac & Inj / Ext unit	59	5
ASD, RF & Lina groupc, other units	13	14
ASD, PSG group	13	12
ASD, other groups	9	44
ISDD, Accelerator Control Unit group	23	12
ISDD, Control Unit + Data Analysis Unit	14	41
ISDD, Mechanical Engineering group	24	46
ISDD, X-ray Optics group	15	14
ISDD, Electronics Unit	14	22
ISDD, Detector Unit	20	19
EXPD, personnel beamline BM05	40	4
EXPD, personnel beamline BM18	24	2
EXPD, personnel beamline BM23 / ID24	37	9
EXPD, personnel beamline ID12	27	4
EXPD, personnel beamline ID13	41	2
EXPD personnel beamline ID15	36	7
EXPD, personnel beamline ID17	40	5
EXPD, personnel beamline ID19	40	5
EXPD, personnel beamline ID21	36	4
EXPD, personnel beamline ID22	21	4
EXPD, personnel beamline ID23	27	3
EXPD, personnel other beamlines ID	20	103
EXPD, personnel other beamlines BM	27	5
TID, Survey and Alignment group	15	11
TID, Vacuum Group	15	17
TID, BIG, Electrical Engineering Unit	16	8
TID, BIG, HVAC, Fluids Engineering Unit	21	7
TID, BIG, Construction + Operation and Maintenance Units	11	14
TID, other groups	5	32
Safety Group	23	25
Others	4	105

CONCLUSION

The results shown are in line with Fluka calculations.

We have confirmed that the staff is still not exposed to ionizing radiation under French law.

Thanks to the installation of 2 collimators and since 2020 the action of the collimators in cell 13 and in cell 24, personnel doses and activation levels are lower than with the old machine.

More than 70% of the losses are concentrated on the C13 collimator and on the C24 collimator, as expected.

The calculations have been validated by ASNR (French Nuclear Authority).

Measurement results were also validated by ASNR during the December 2022 inspection and during the May 2025 inspection.

MANY THANKS FOR YOUR ATTENTION