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Design of a low dose rate calibration facility for environmental radiation protection dosimetry

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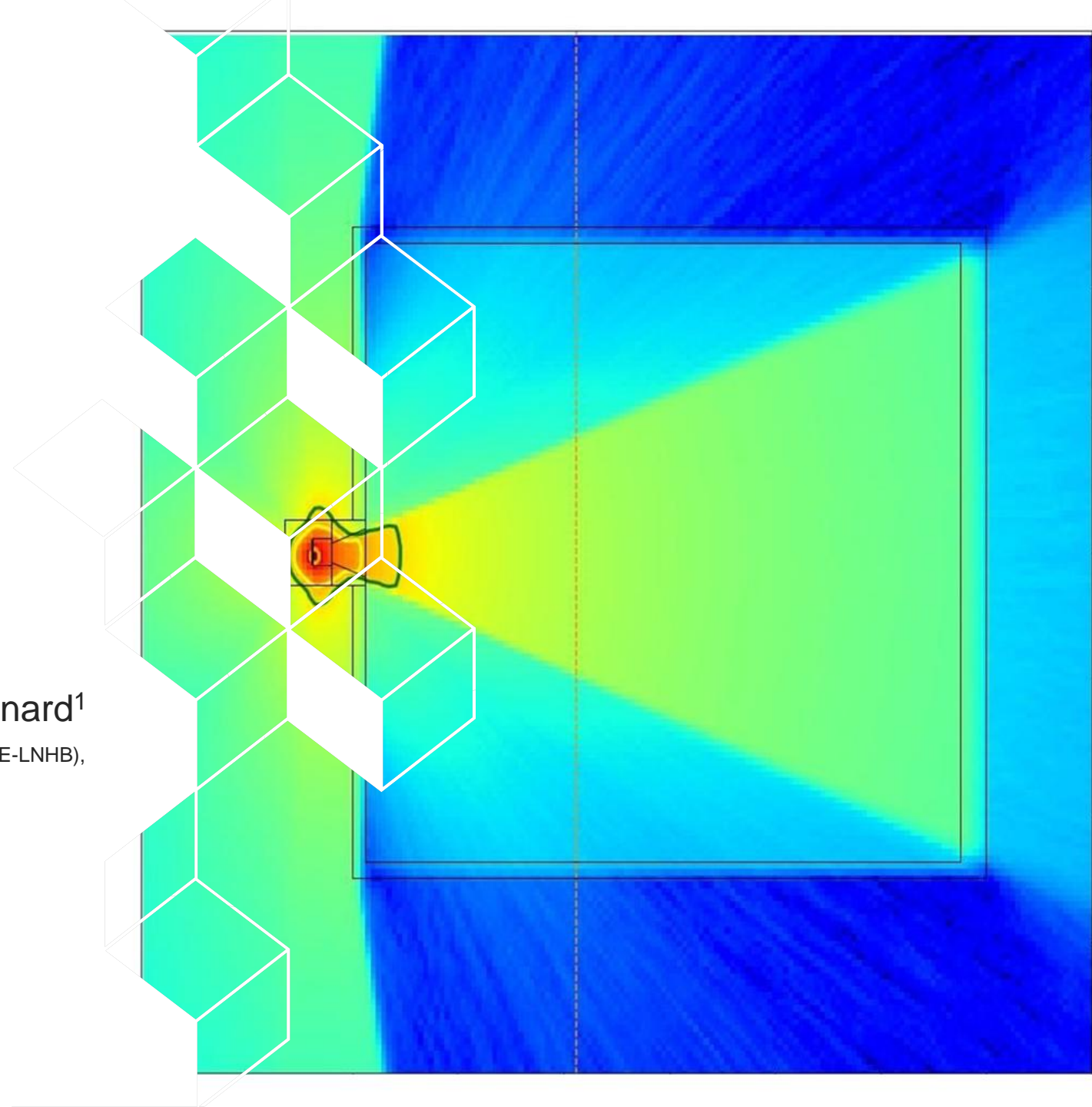


list

Design of a low dose rate calibration facility for environmental radiation protection dosimetry

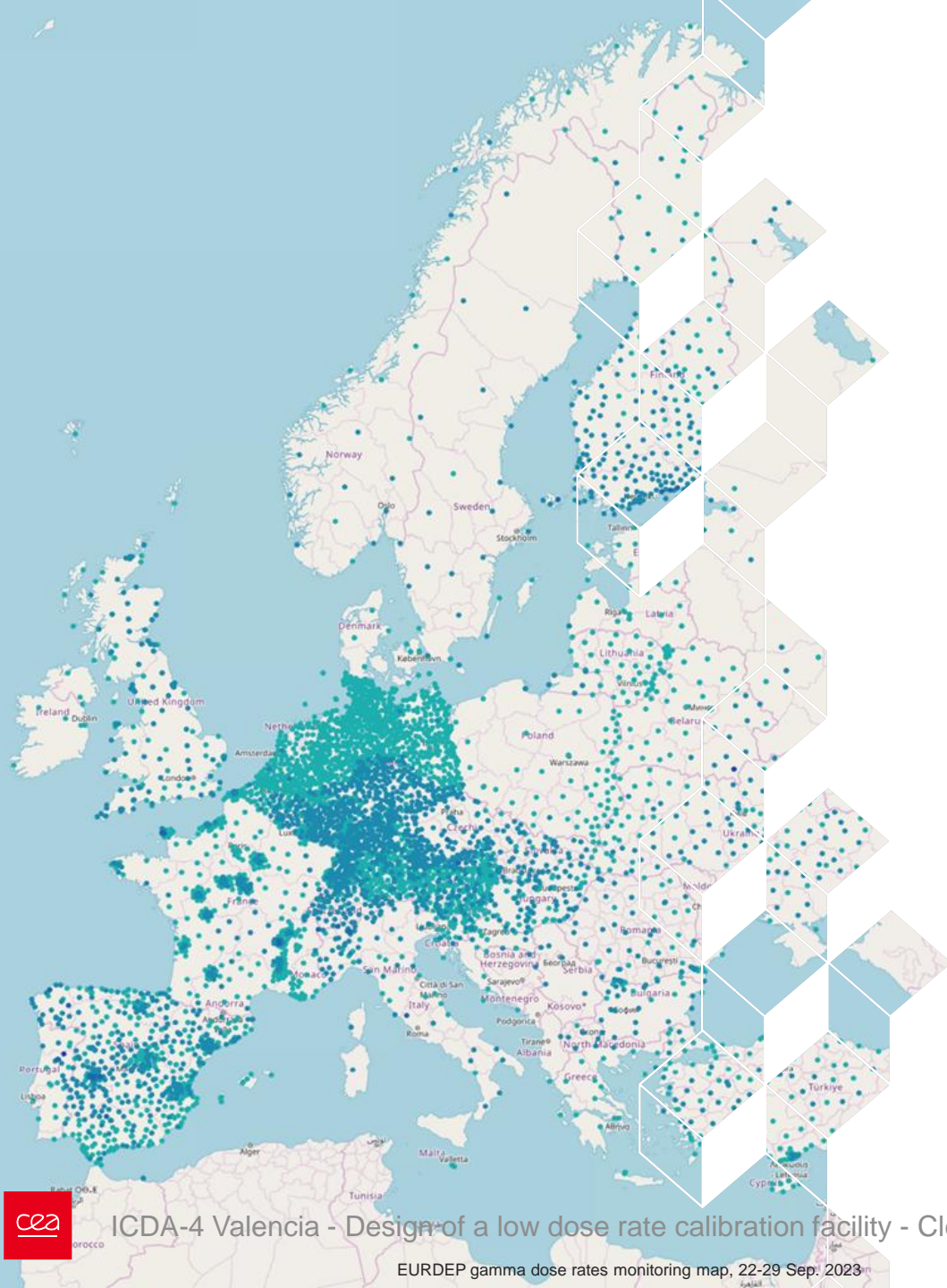
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Summary

1. Introduction
2. Numerical approach
3. Shielded enclosure design and optimization
4. Collimator design and optimization
5. Conclusion and outlook





Context of the LNE-LNHB

R&D activities at LNHB:

- LNHB-MD is the national metrology laboratory for ionizing radiation “dose” metrology.
- Fields: Medical and radiation protection for workers, the public, patients and the environment.
- Mission: Development, maintenance and transfer through calibration of national references for:
 - Radiotherapy,
 - Radiodiagnostic,
 - Radiation protection



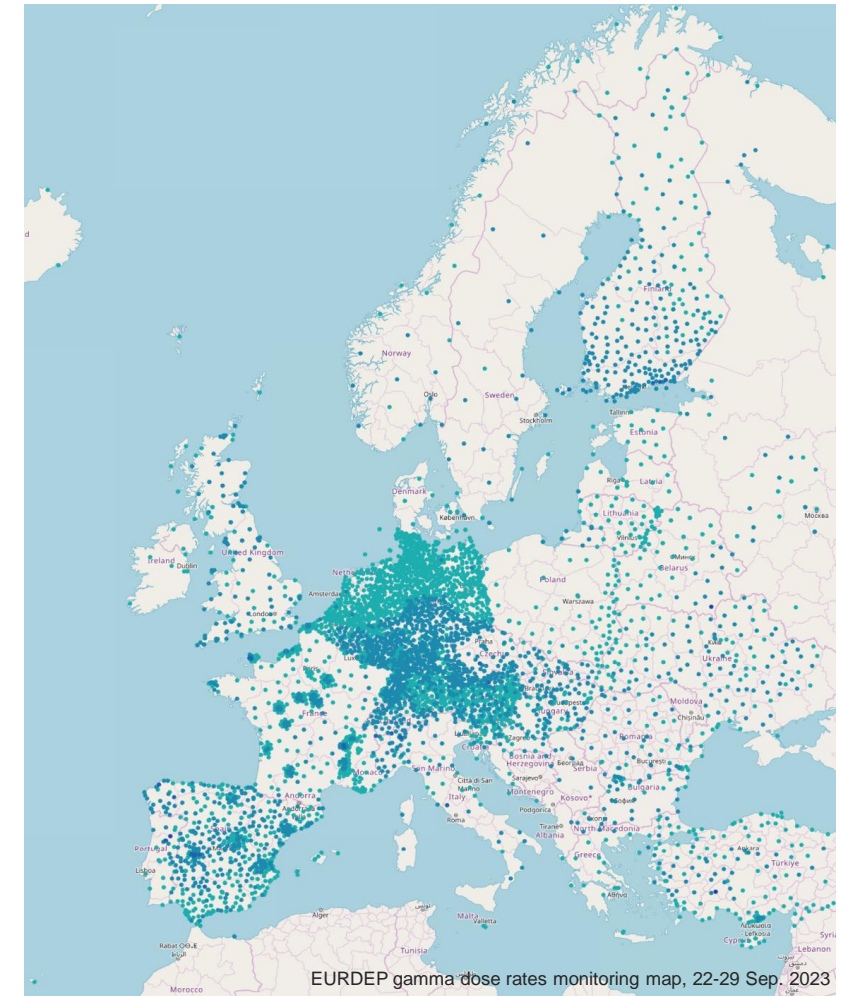
Introduction - Needs

National and international monitoring web such as the European Radiological Data Exchange Platform (EURDEP)

- Measures in the vicinity of facilities
- Emergency situations

Environment dosimetry for radiation protection

Dosemeters must be calibrated at low ambient dose equivalent rate $H^*(10)$ close to background radiation level (<100 nSv/h)



Introduction – Technical solutions

Dosemeters must be calibrated at low $H^*(10)$ close to background radiation level (<100 nSv/h)

- **Apply filters to a collimated beam**

- Already available
- High uncertainties



Multi-source setup
at DOSEO (CEA)

- **Underground facility (Germany, Romania)**

- Allows very low dose rate
- Expensive

Salt walls in the Unirea
mine (Romania)

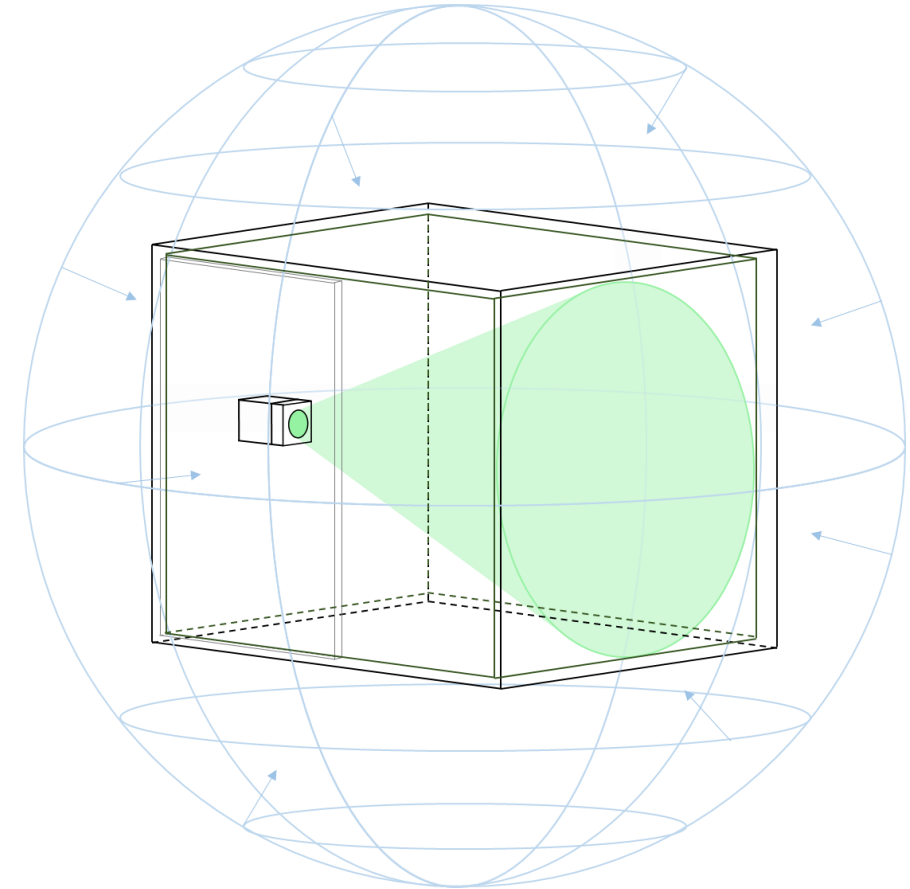


- **Lead shielding (Japan)**

- Decrease background level
- Easily accessible

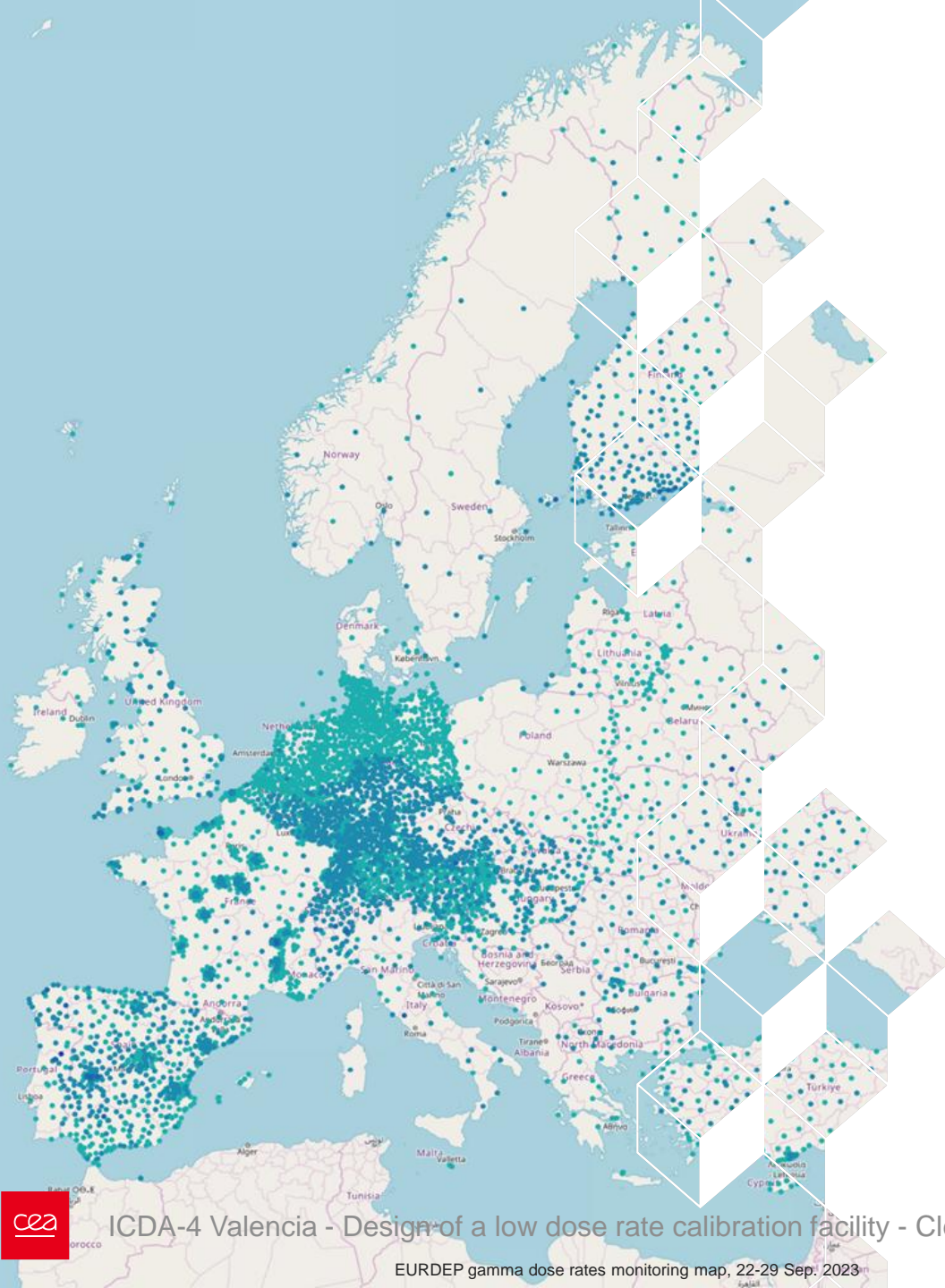


JISC, Tsukuba



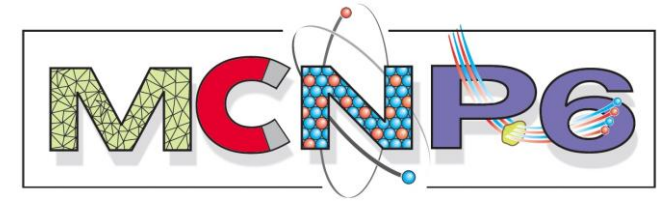
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Numerical approach

Simulations are carried out using the MCNP6.2 code



Global goal: optimize a low-background and dose rate facility through simulations

Step1: Optimization of the walls

Goal: divide by a factor of 10 the influence of the natural background irradiations inside the shielded enclosure

- Source term: based on the spectrometric measurement of the background radiation
- Simple geometry without opening nor collimator



Wall thickness and box size optimization

Step 2: Optimization of the collimator

Goal: flatten the beam profile, limit the inside scattering

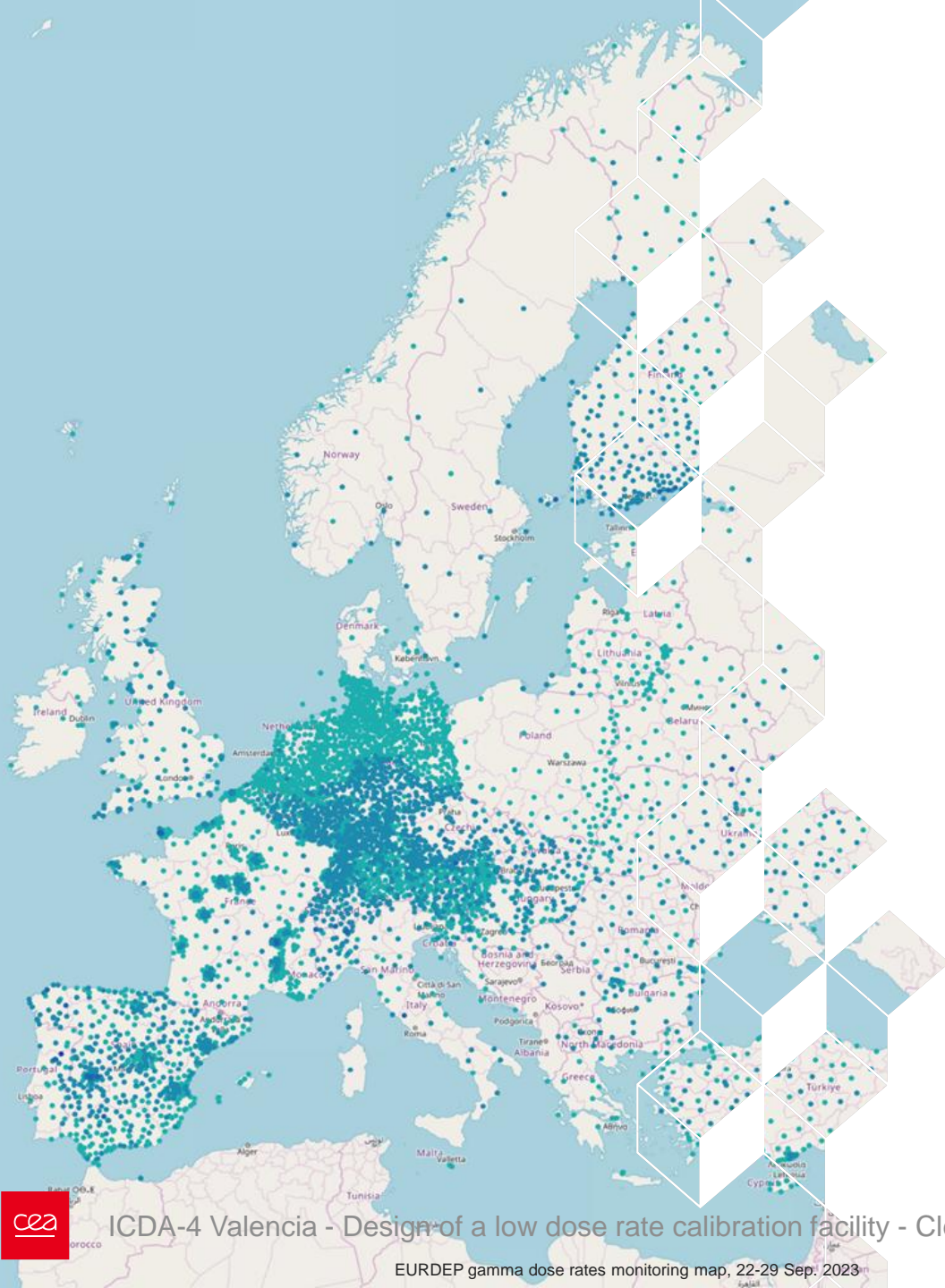
- Source term: Co-60 beam
- Enclosure optimized geometry with a first collimator to be optimized



Beam characteristics optimization

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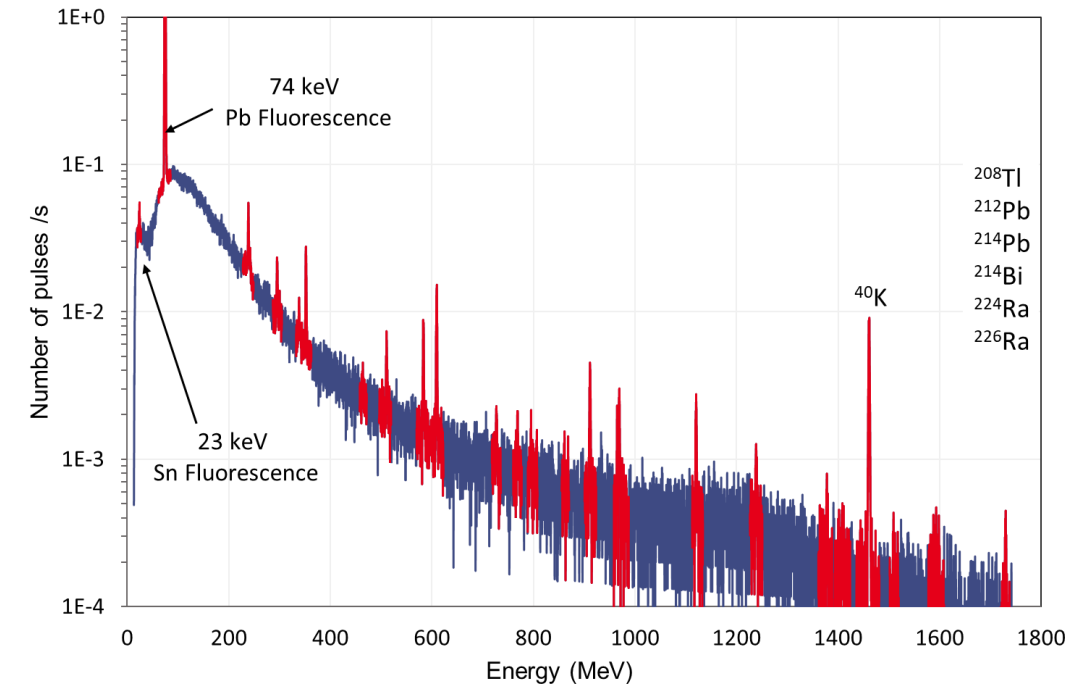
Shielded enclosure design and optimization

Natural radiative background

Measurement of the natural radiative background

- Using ORTEC GMX 35P4-70-PLUS-1 detector, cooled with liquid nitrogen
- Identification of the components: ^{208}Tl , ^{212}Pb , ^{214}Pb , ^{214}Bi , ^{224}Ra , ^{226}Ra , ^{40}K and the fluorescence rays of Pb and Sn.

These rays and their associated intensities are then used in the simulations as a large spherical source around the box to determine its optimum lead thickness



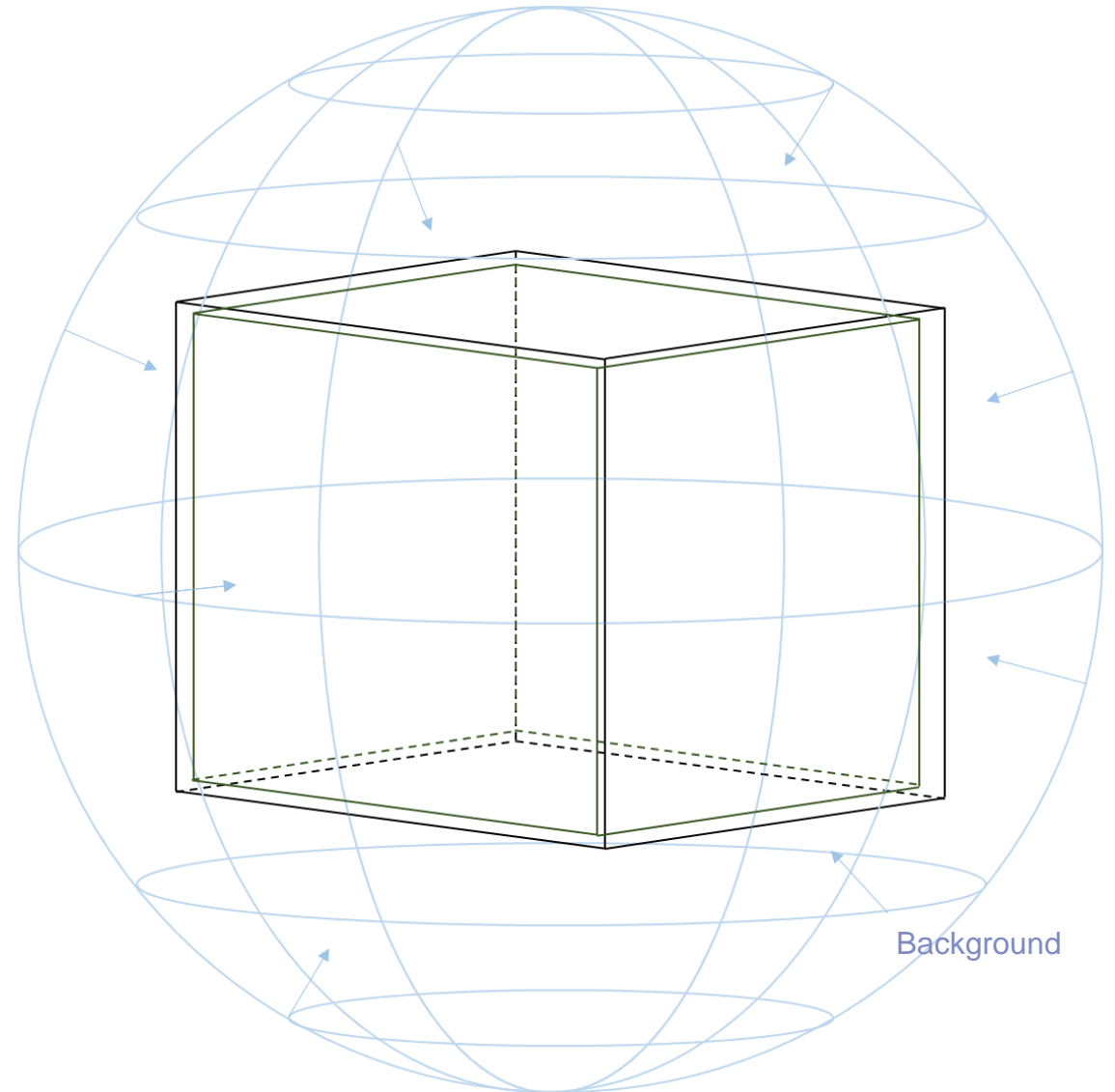
Shielded enclosure design and optimization

Simulation geometry

The shielded enclosure is simulated as a right parallelepiped with external dimensions of 100 x 100 x 150 cm.

The thickness of its walls varies from 1 to 36 mm.

The natural background is simulated as a spherical source with a radius of 100 cm



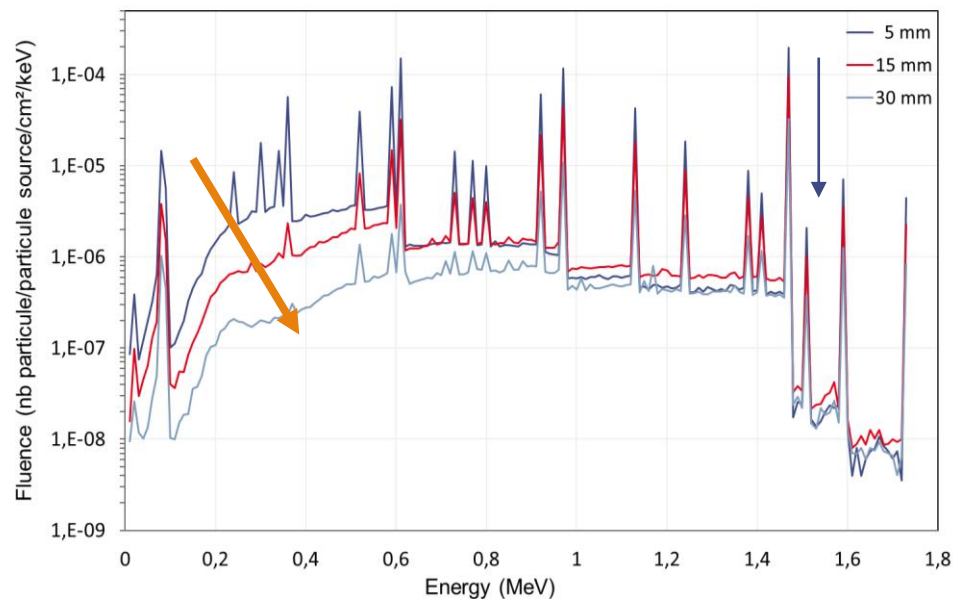
Shielded enclosure design and optimization

Thickness optimization from outside and inside radiations

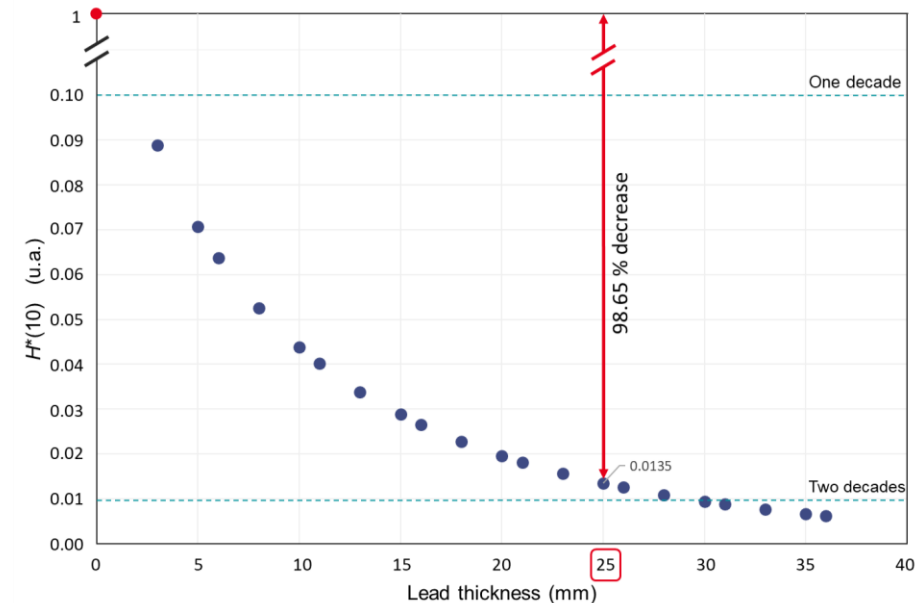
Variable: lead wall thickness

Simulation of a central tally 5 detector with a radius of 20cm

Spectra hardening (as expected)



$H^*(10)$ decrease inside the enclosure as a function of lead thickness.



✓ Goal achieved for 25 mm of Pb

Shielded enclosure design and optimization

Sizes optimization

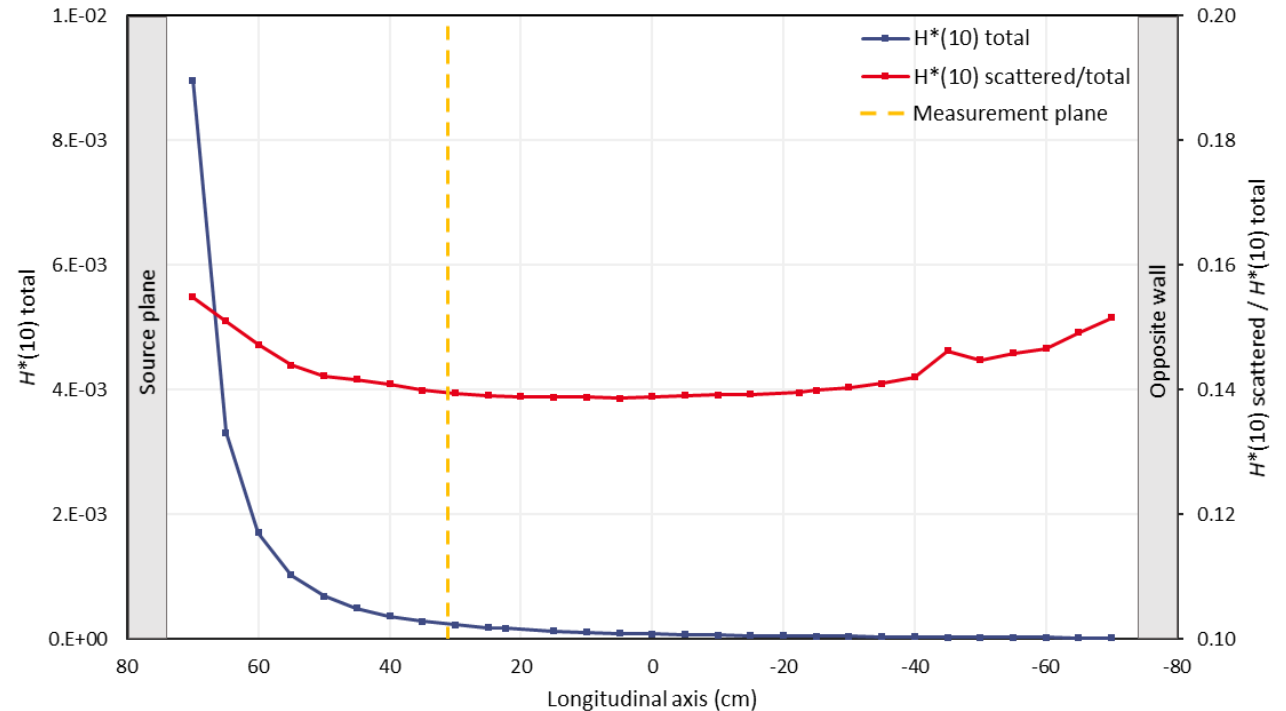
Variable: base enclosure length: 150 cm

Requirements:

- Lighter weight
- Hosts most of the detectors envisaged, up to 55 cm length
- Reference plane for calibration is at 50 to 40 cm of the source and with minimum scattering component

Final length: 120 cm is a good compromise to meet the criteria

✓ **Goals achieved with length of 120 cm**



Mirion



Saphymo



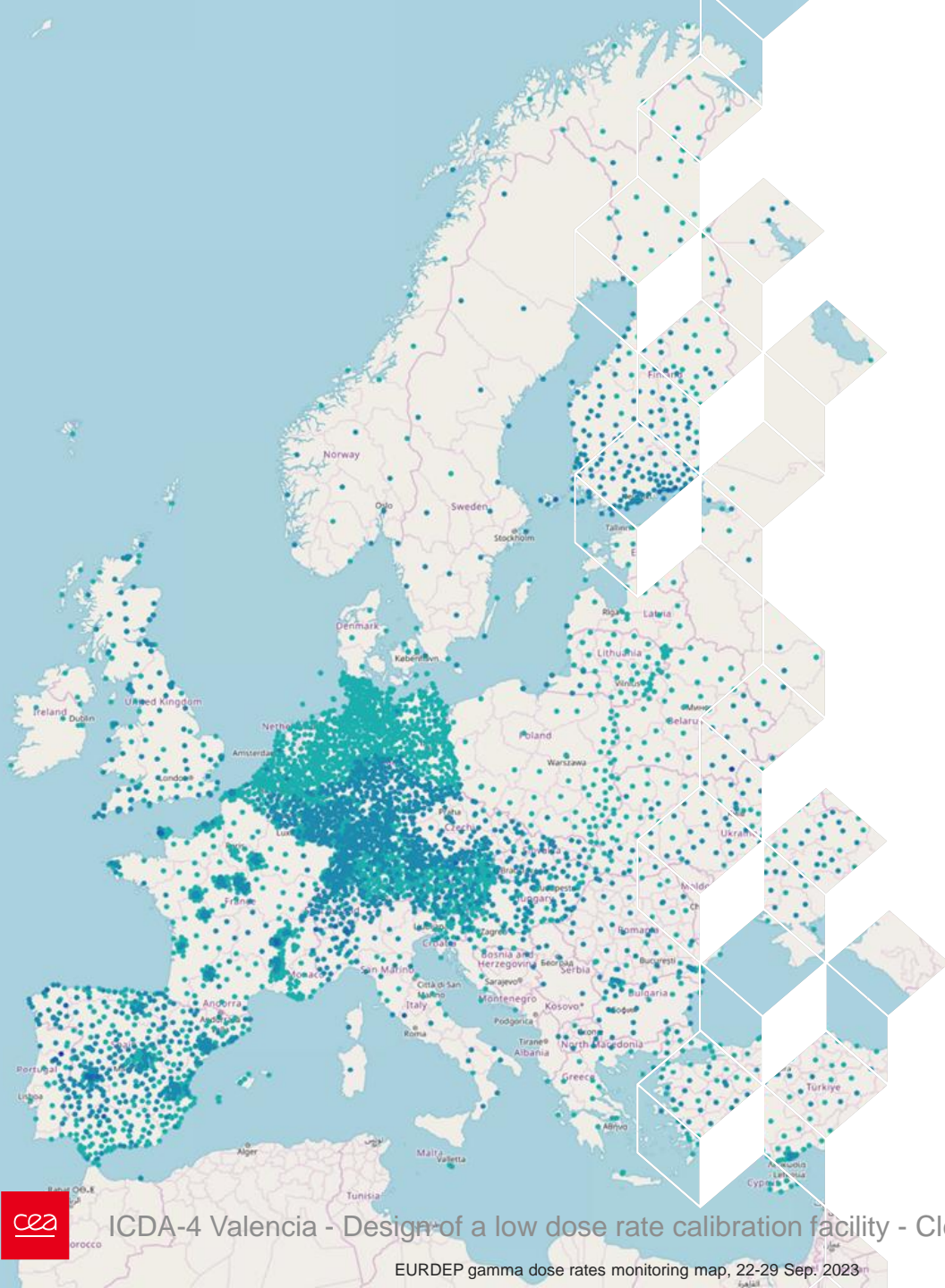
Bertin



Envinet

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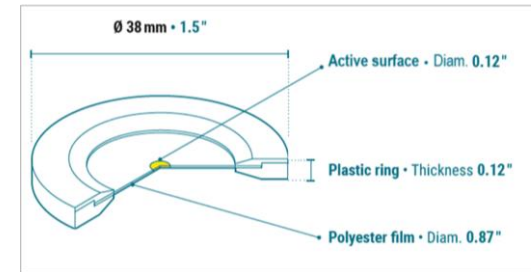
Collimator design and optimization

Simulation parameters

Source (LNHB manufacturing)

LNHB design: Cobalt-60, solid deposit on a plastic support:

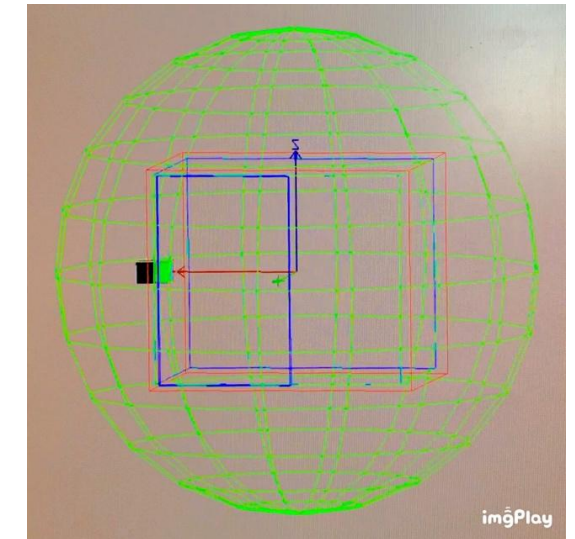
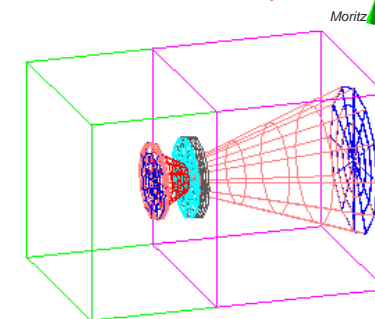
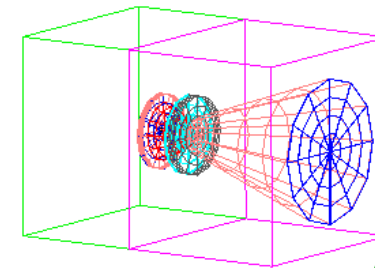
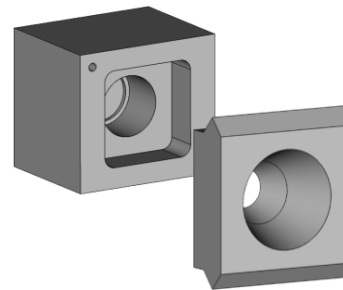
- Circle of 3 mm of diameter
- Photons emitter with ^{60}Co specific rays



Collimator geometry

List of the main features:

- 10x10x12 cm rectangular parallelepiped
- Holds the source in the axis
- Conical collimating cavity
- Electron absorption aluminum plate
- Cavities



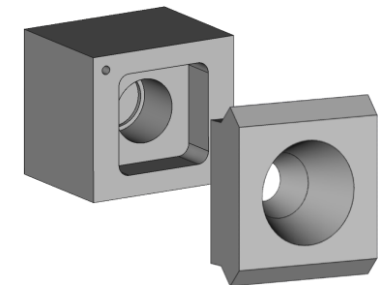
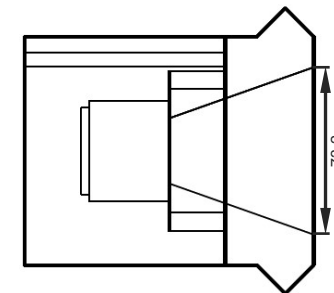
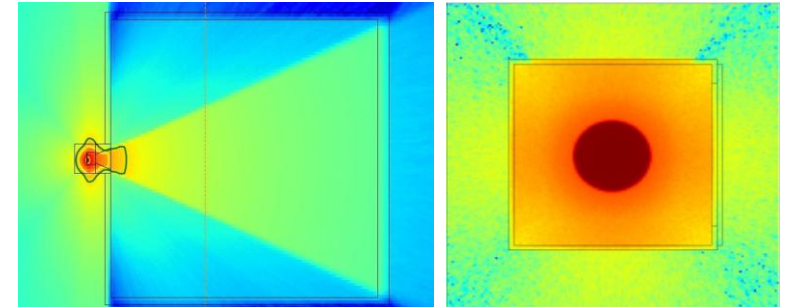
Collimator design and optimization

Collimator design goals

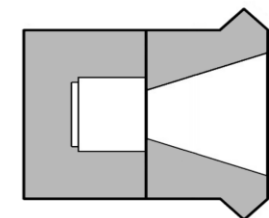
Goals:

- Enough enlightenment at the reference plane and the least possible lateral walls of the enclosure
 - Reduce the scattered component and therefore the correction coefficient for radial non-uniformity of the beam
- Removable source holder for switching with further sources (^{137}Cs)
- Sufficient thickness to protect the operator from radiation
 - Less than $23 \mu\text{Sv/h}$ contact dose rate

✓ **Goals achieved**



SHIELDING (mm)		
Betas and electrons (Total absorption)		
Glass	0.4	
Plastic	0.7	
Gamma and X rays (half and tenth value thickness)		
	1/2	1/10
Lead	16	46
Steel	36	93



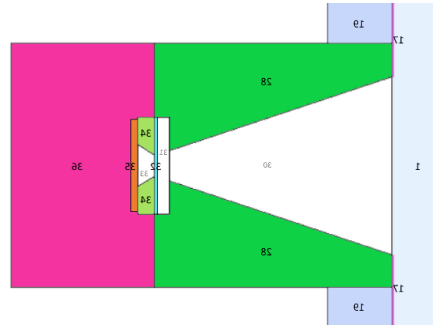
Collimator design and optimization

Beam profile optimization

Goal: Flatten the beam profile and lower the scatter component

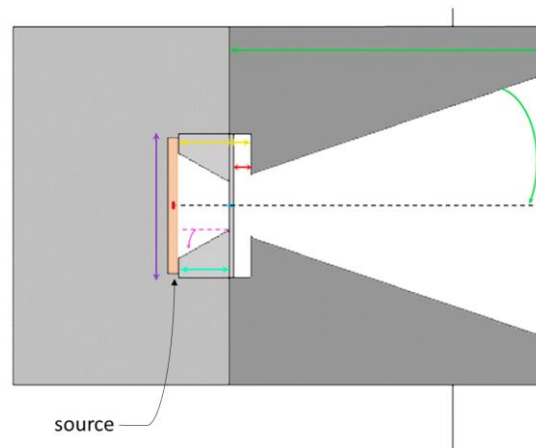
Use of the ICD card to:

- Distinguish the origin of the scattered photons
- Define the region to be modified



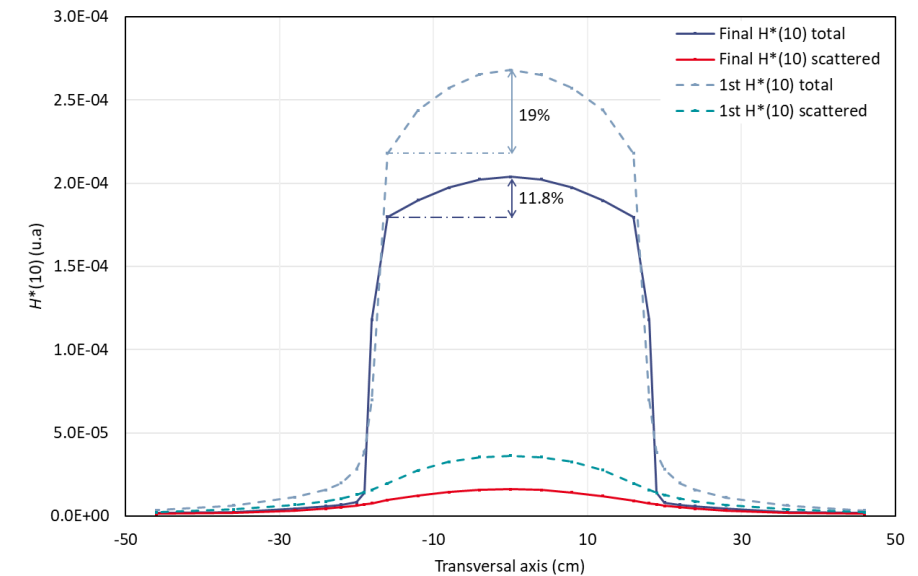
List of the main parameters studied:

- Collimator angle and length
- Cavity depth, width, volume
- Collimator position
- Angle of cavity
- Position of aluminum plate



The estimated final performance at the plane of reference is:

- 11.8% profile variation
- 7.4% maximum scatter



✓ **Goal achieved, flattened and less scatter**

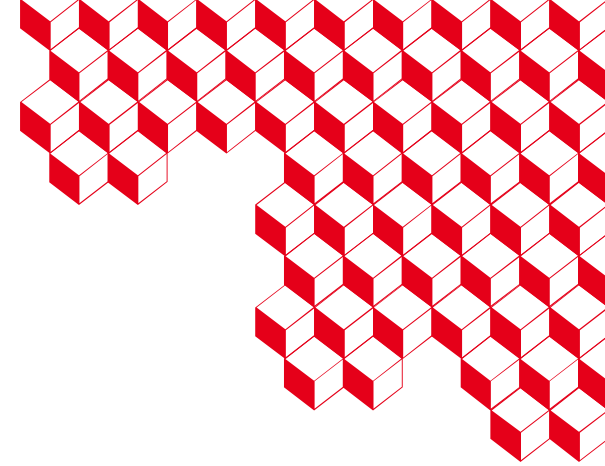
Conclusions and outlook

- ✓ ~99% radiative background decrease with 25 mm thickness
- ✓ Length 120 cm allowing a “lighter” weight (2.2 t) and inner size
- ✓ Good compromise between direct beam characteristics and wall scattering
- ✓ Removable source holder
- ✓ Worker radiation protection
- ✓ Flattened profile (11.8 %) and reduced the collimator’s scattering

Let’s build it !

See you soon in DOSEO at our low dose rate calibration facility.





Thank you for your attention

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