

# Radiation Shielding Design for Non-Standard Synchrotron Beamlines

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MINISTRY OF  
SCIENCE TECHNOLOGY  
AND INNOVATION



# Summary

- 1 Introduction & Motivation
- 2 IMBUIA – Mid-IR Beamline
- 3 SAPÊ – UV-C Beamline
- 4 CARCARÁ – Visible Light & 11 keV Beamline
- 5 Final Remarks

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# Radiation Sources

Inside the Concrete Shielding Wall (CSW)

Gas  
Bremsstrahlung

Electrons Losses

Neutrons

High Flux Scattered  
Photons

Outside the CSW

Synchrotron

# Dose Limits

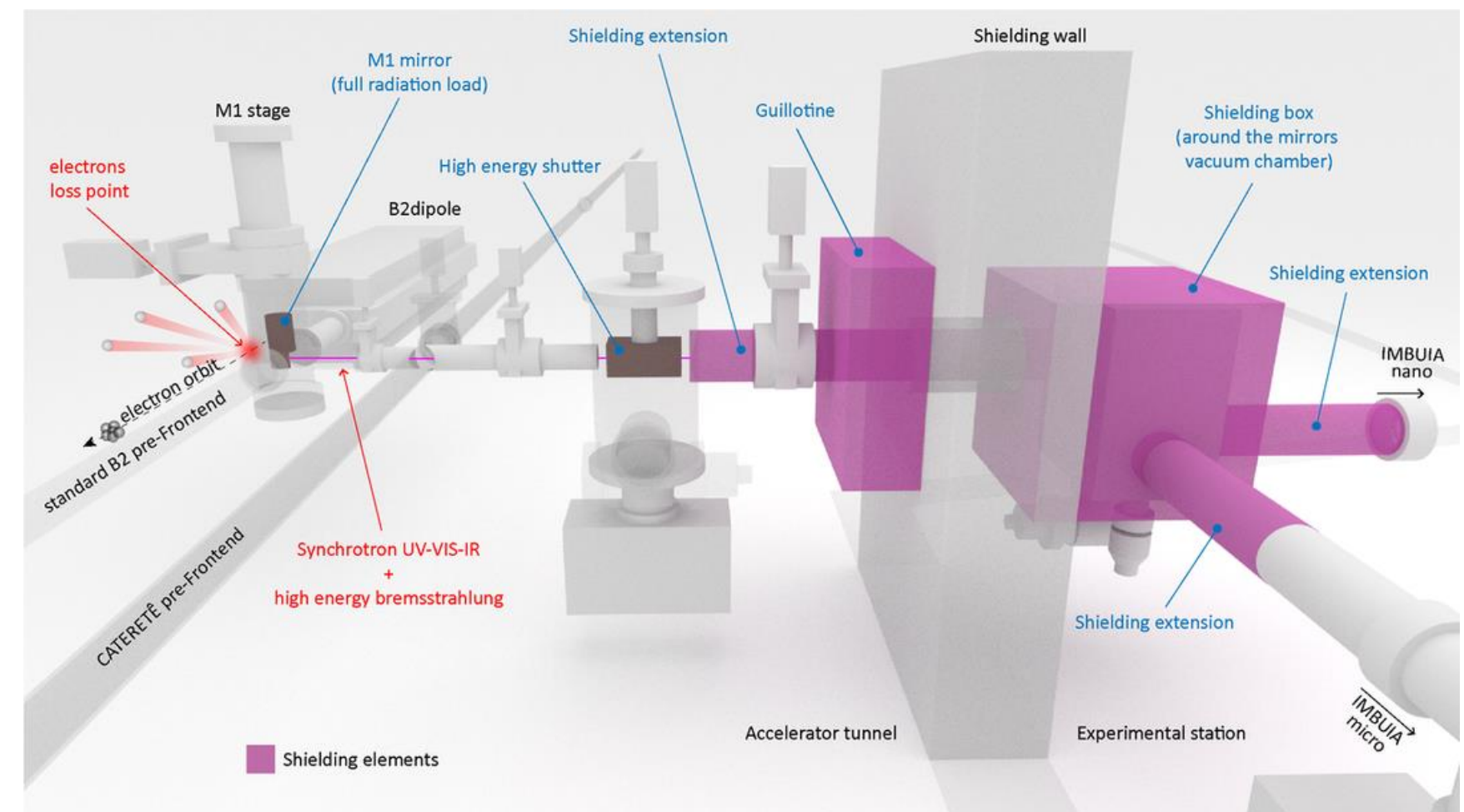
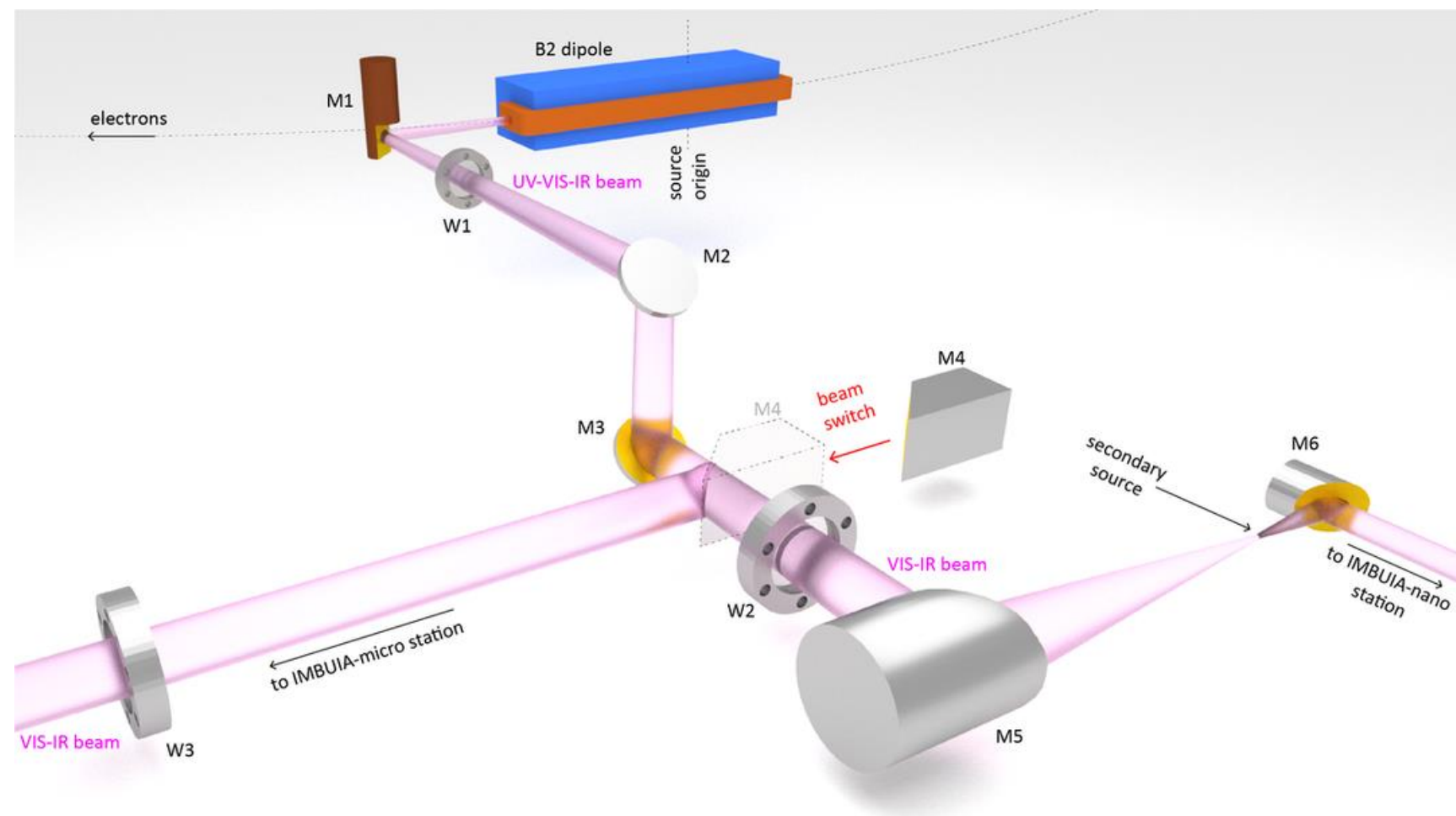
Annual Dose Limit (mSv)	1	
Annual Workload (h)	2000	
Limit Dose Rate ( $\mu\text{Sv/h}$ )	0,5	
	Factor	Limit ( $\mu\text{Sv/h}$ )
Frequently emission	5	0,1
Occasional emission	2	0,25

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# IMBUIA – Mid-IR Beamline

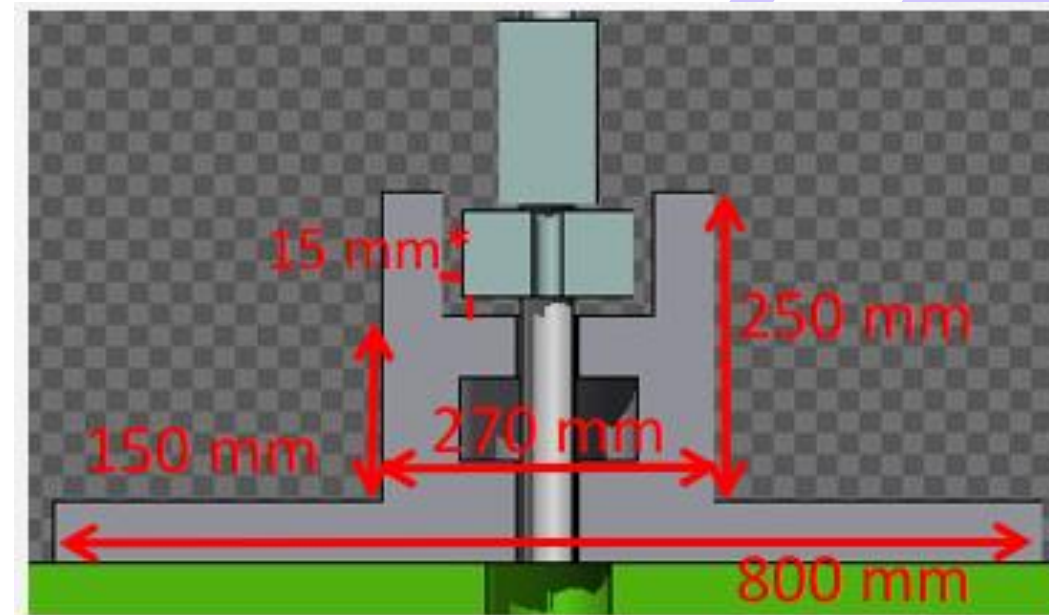
Infrared Micro- and nano-spectroscopy Beamline for Ultra-resolved Imaging Applications



# Front-end

## Tungsten Shutter:

- Restraining scattering radiation
- Diameter of the passage of the beam is 25 mm
- Possible to move in vertical direction

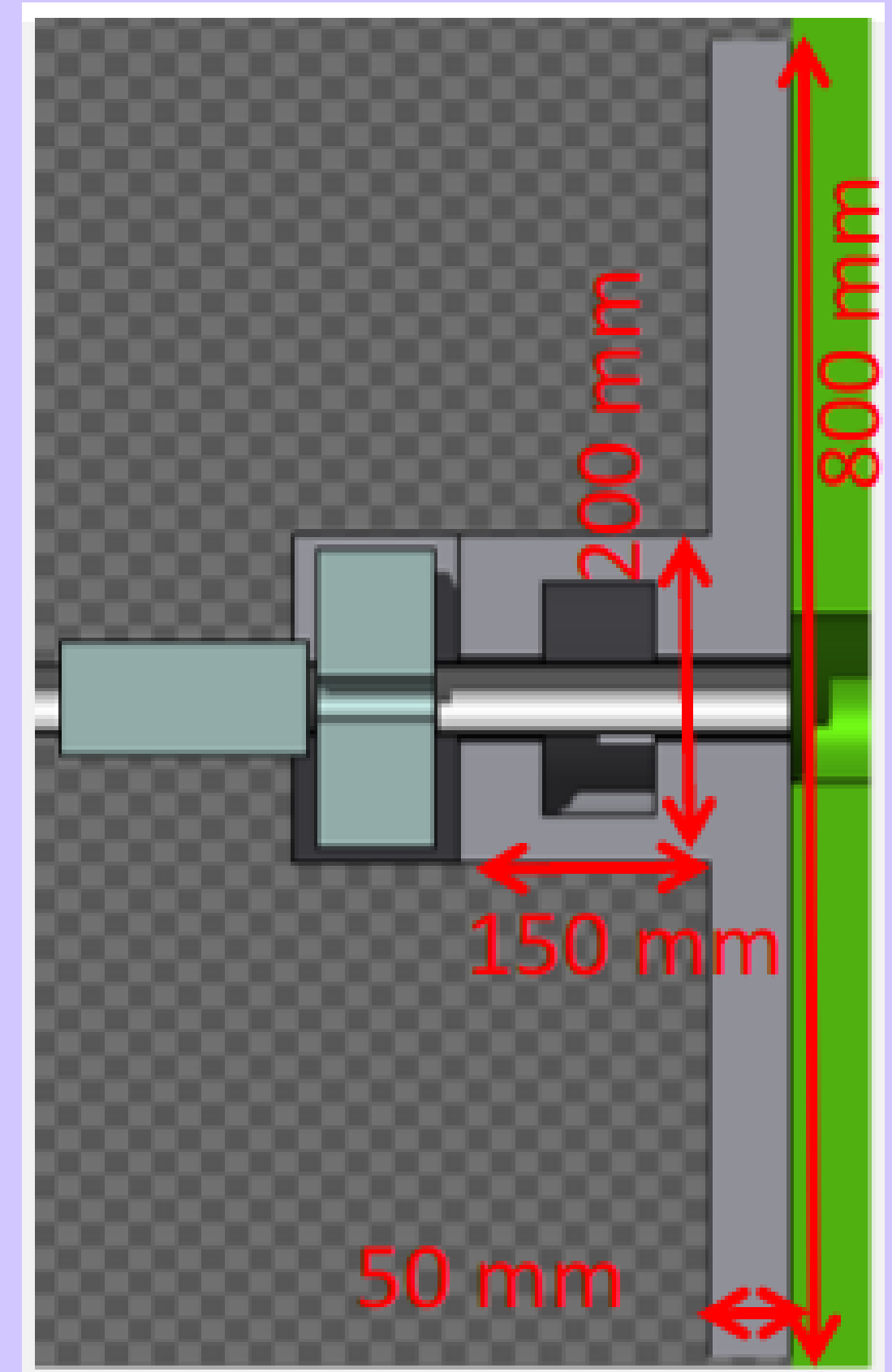
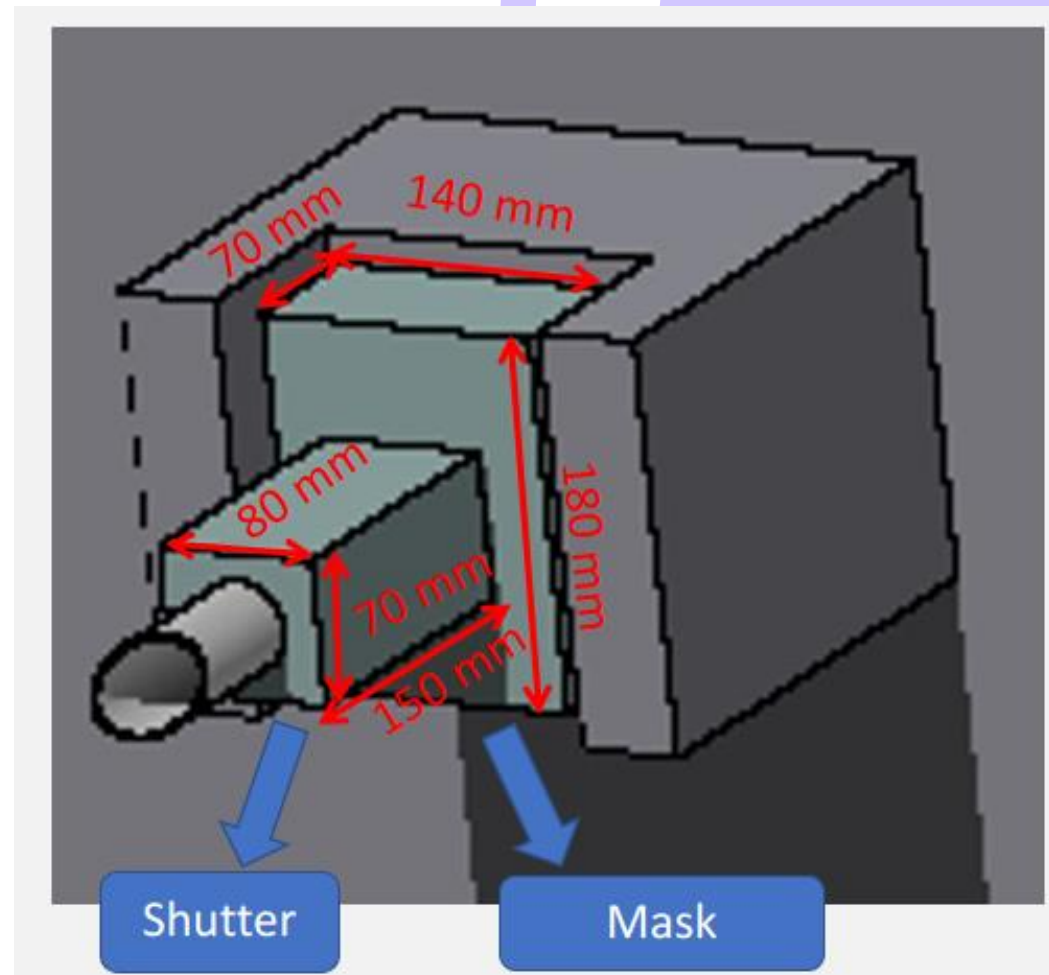


## Tungsten Mask:

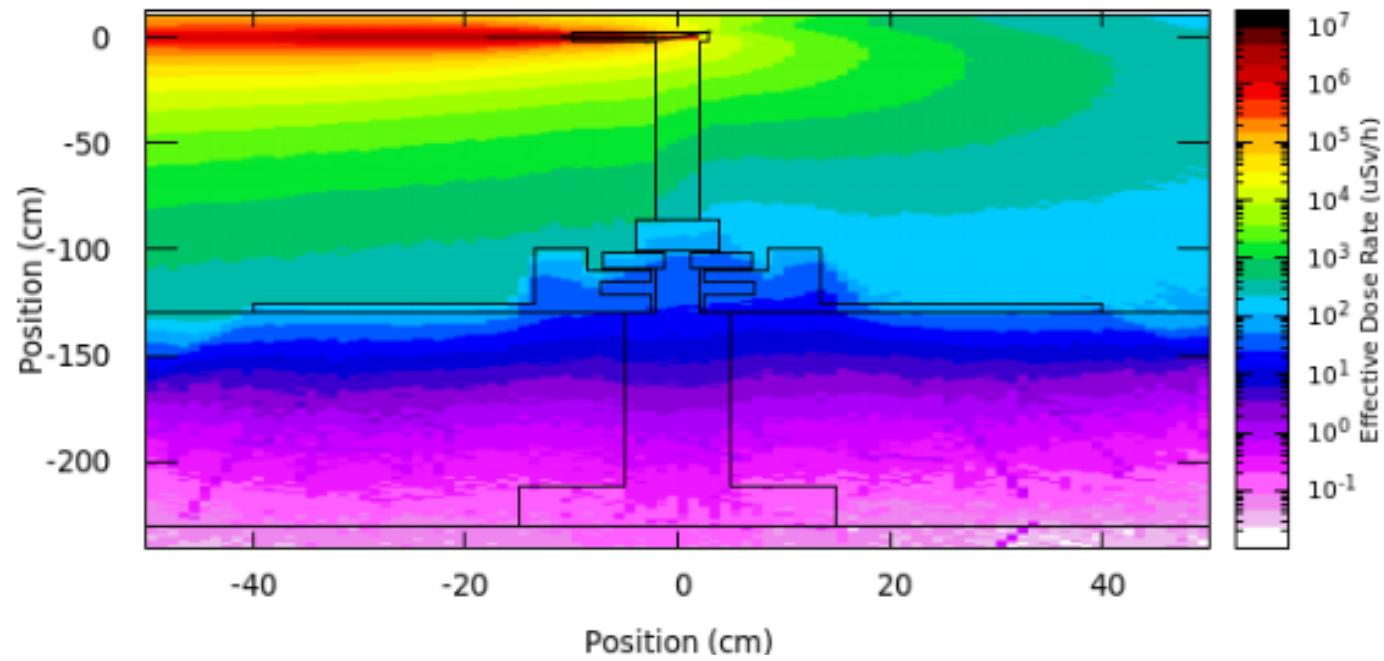
- Massive bloc
- Reduce the weight of the shutter

## Lead Reinforce:

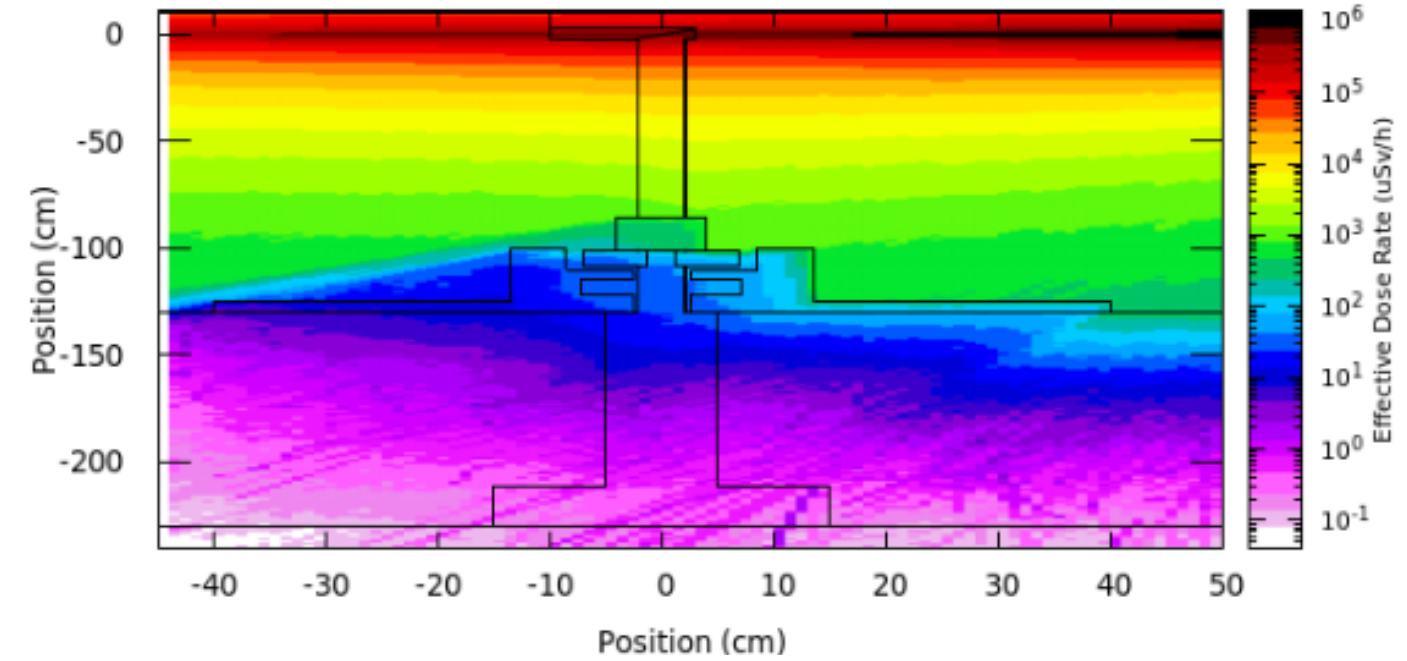
- Defined by simulations for electron loss and synchrotron scattering



# Frontend



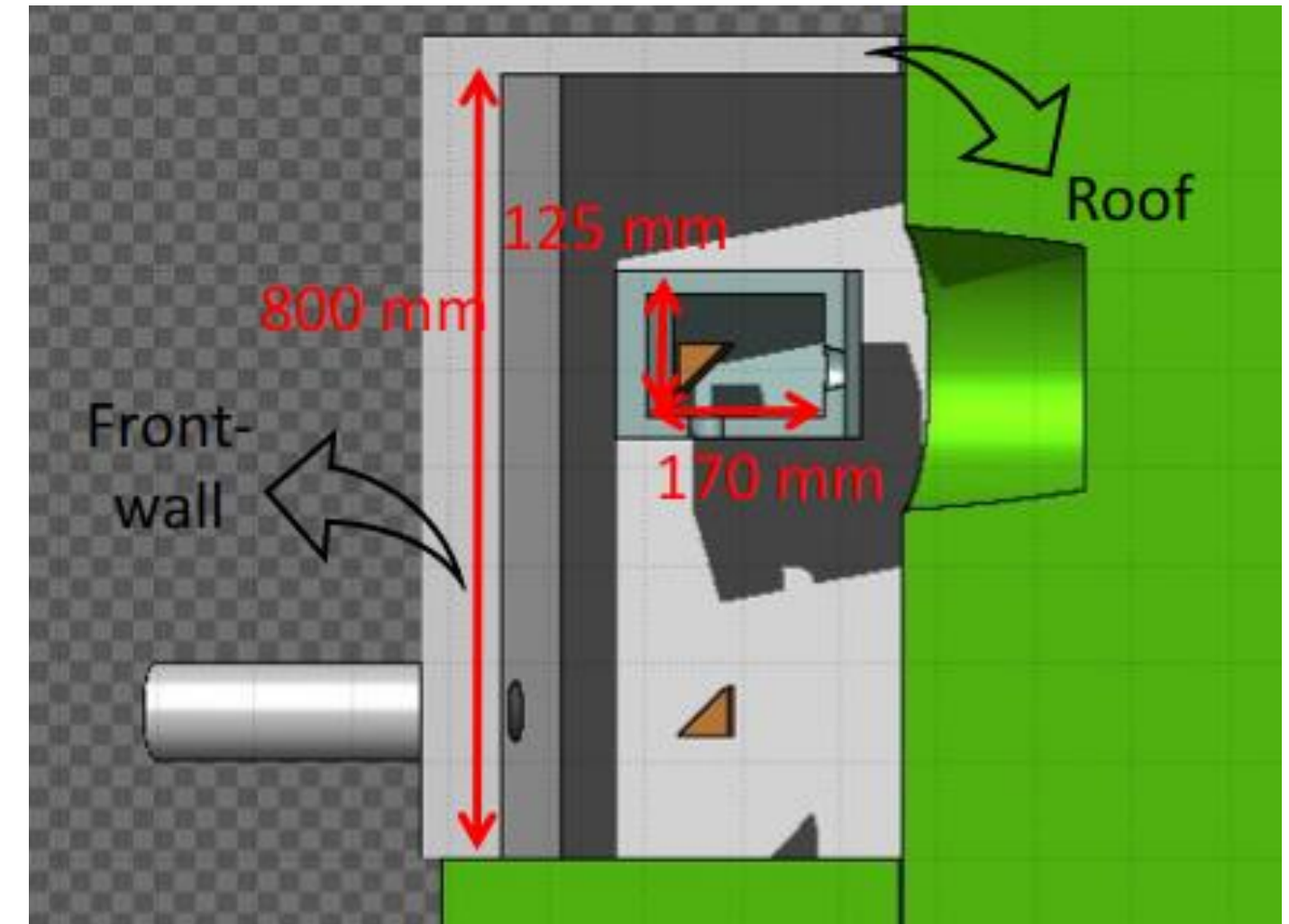
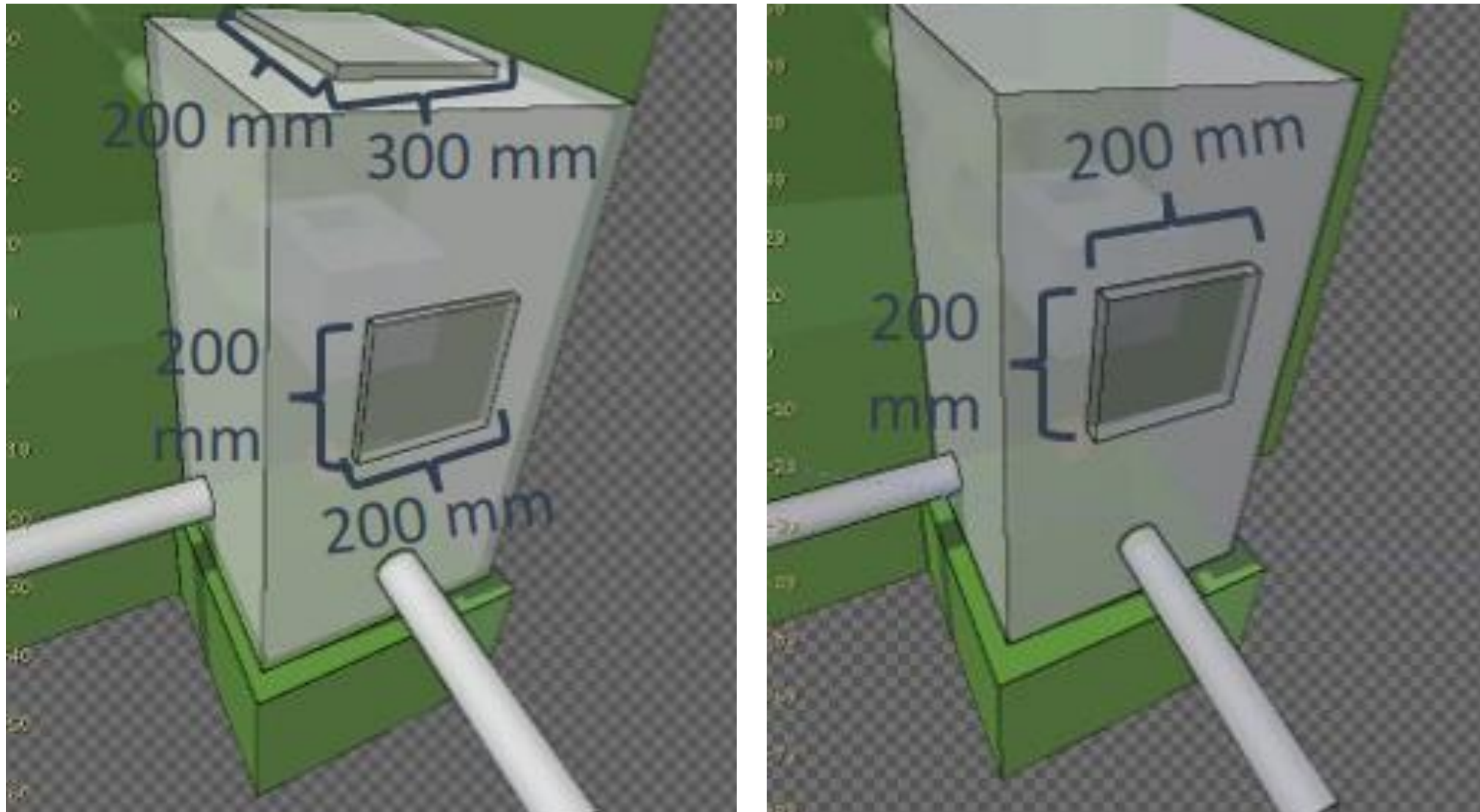
(a) Scatter aligned with Imbuia frontend exit



(b) Scatter 1 m before with Imbuia frontend exit

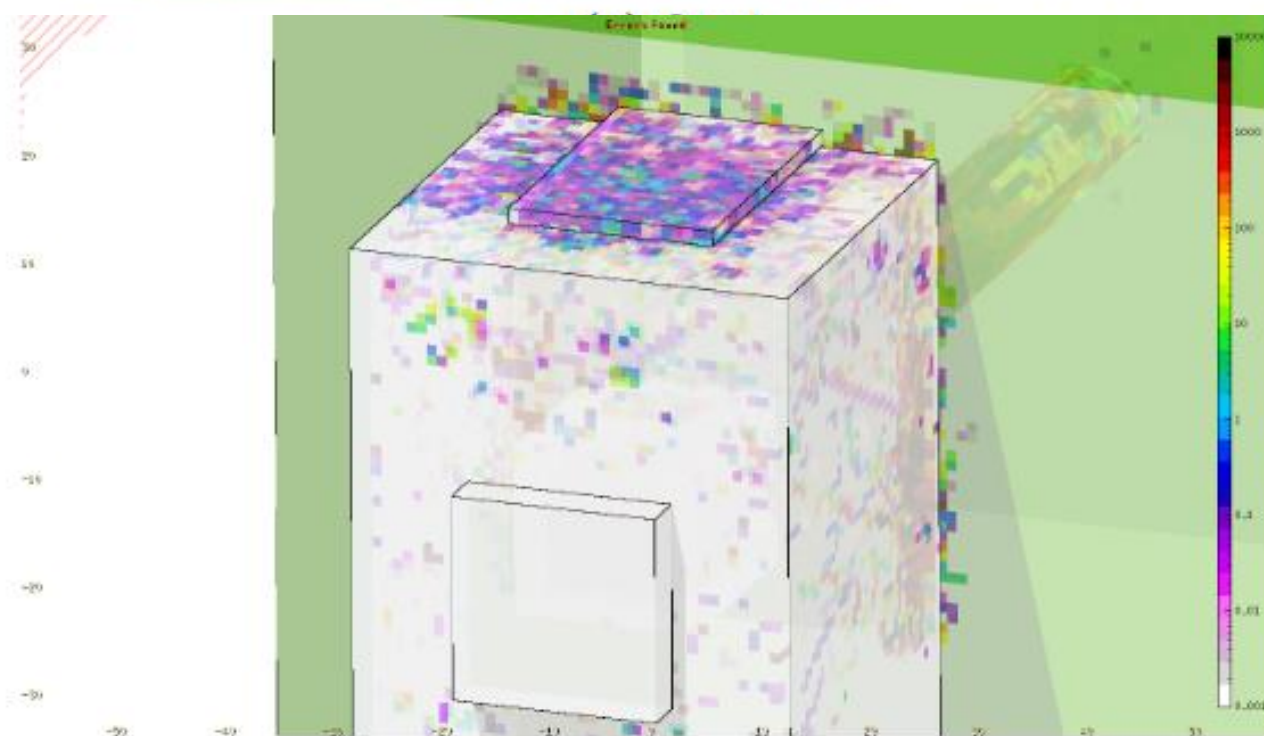
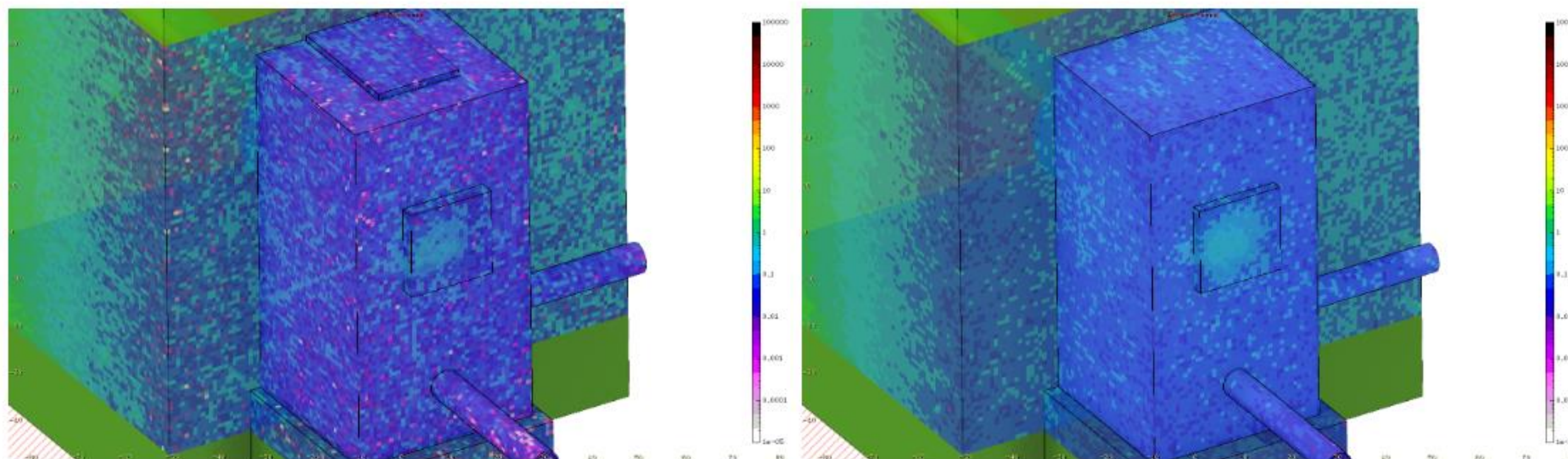
# Hutch

- Outside the concrete shielding wall, there is a hutch around the M2, M3 and M4.
- The pipe thickness and length were determined mainly by synchrotron BC scattering simulations.
- Specifications for two materials: steel and lead.

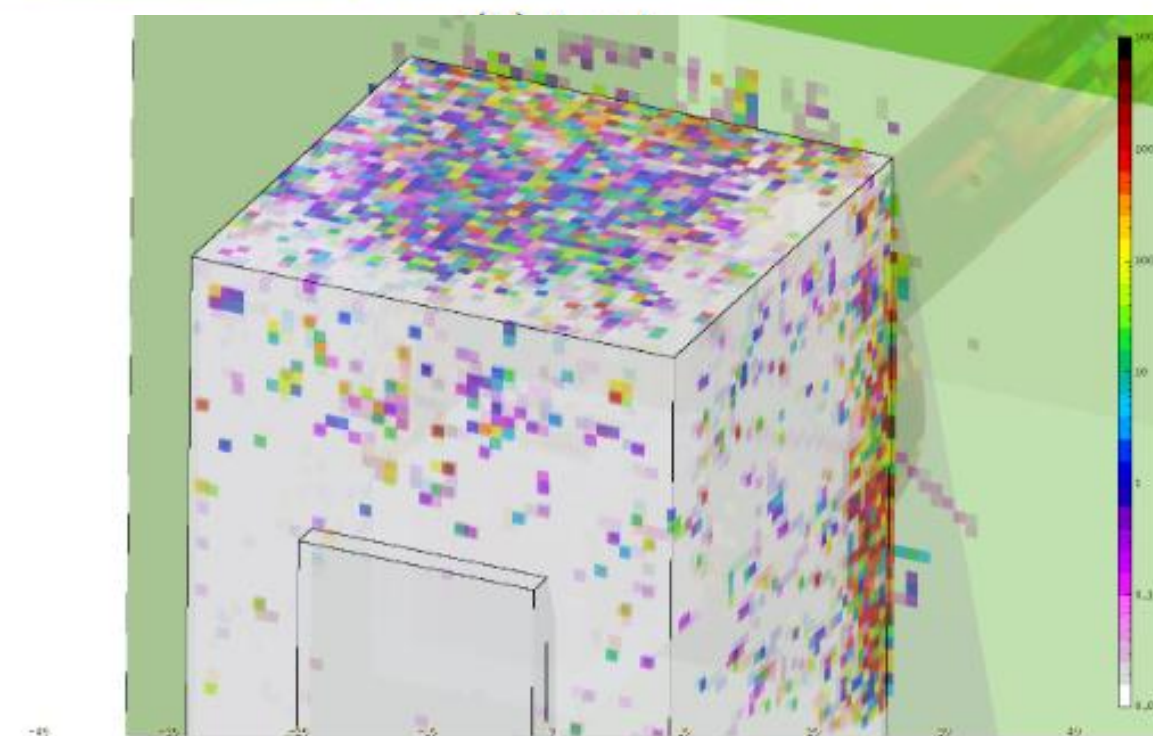


- Inside the Hutch, there are two mirrors, M2 and M3.
- The tungsten box that covers the M2 has a front-wall of 30 mm thickness and the other has 20 mm.

# Hutch

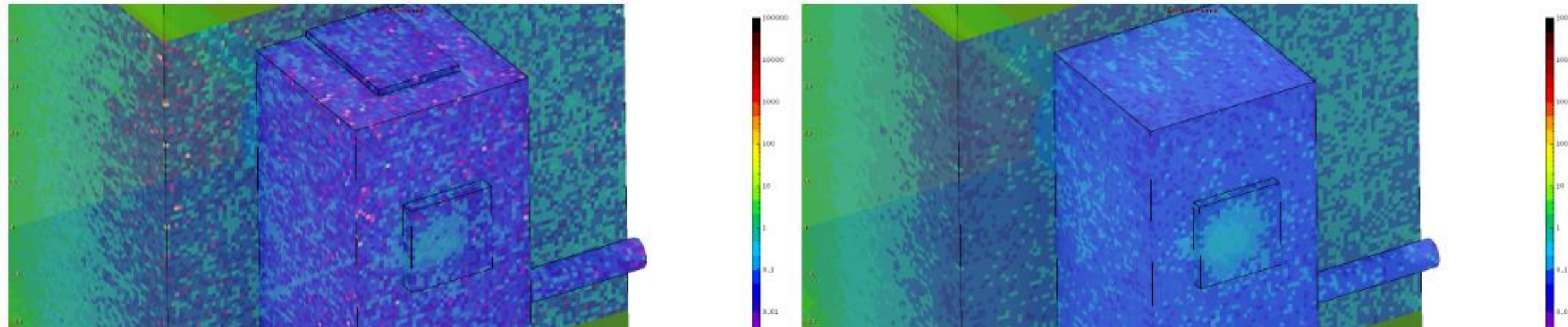


(a) Steel

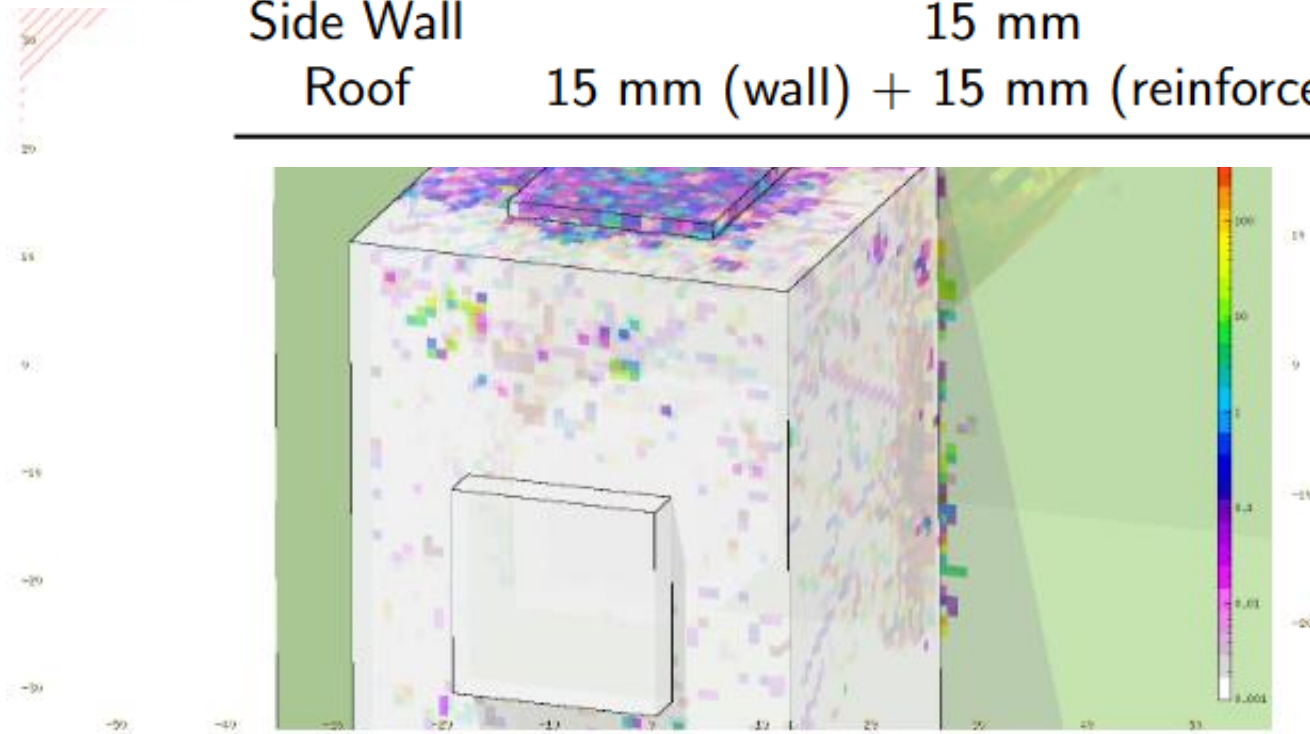


(b) Lead

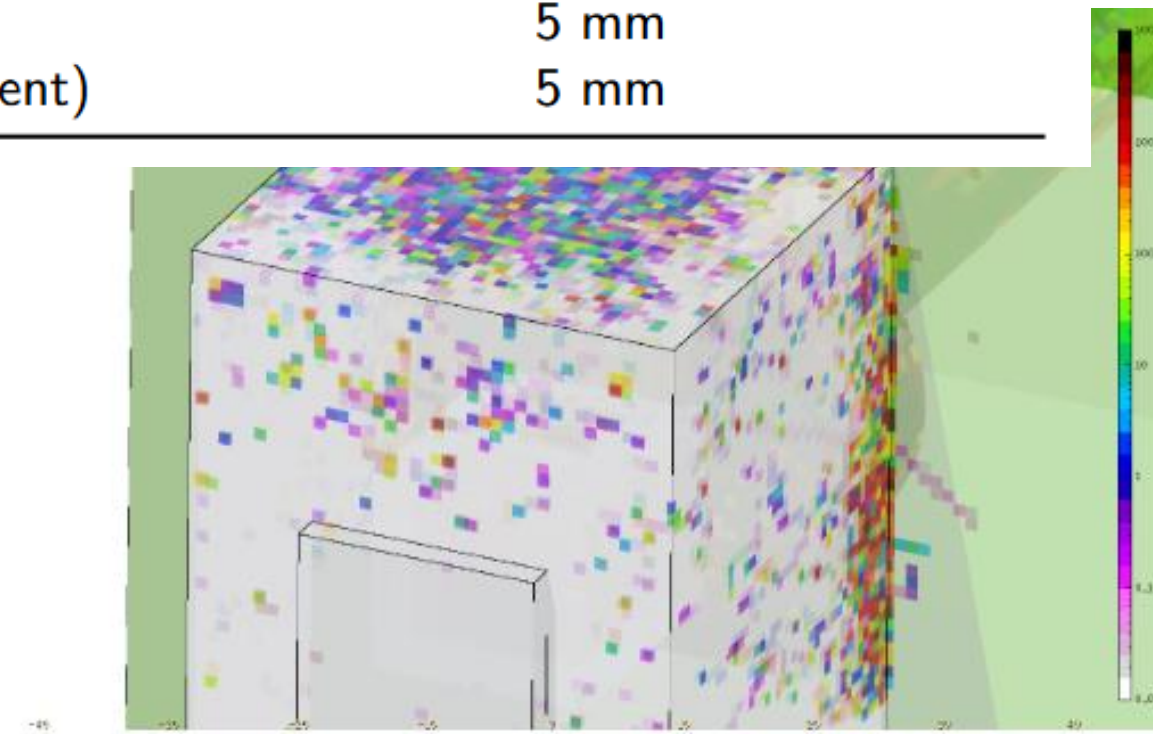
# Hutch



Wall	Steel	Lead
Front Wall	15 mm (wall) + 35 mm (reinforcement)	5 mm (wall) + 15 mm (reinforcement)
Side Wall	15 mm	5 mm
Roof	15 mm (wall) + 15 mm (reinforcement)	5 mm



(a) Steel

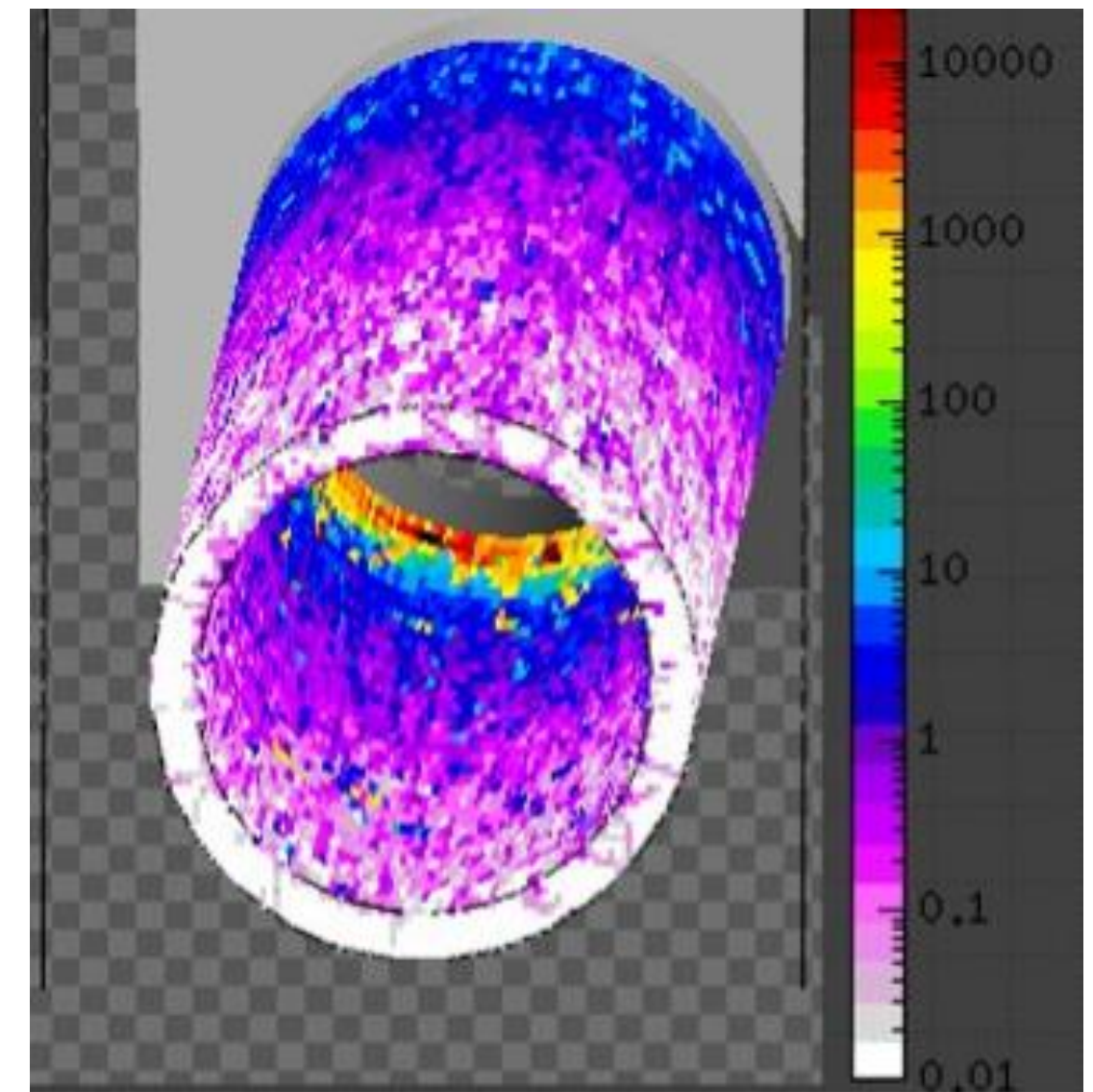
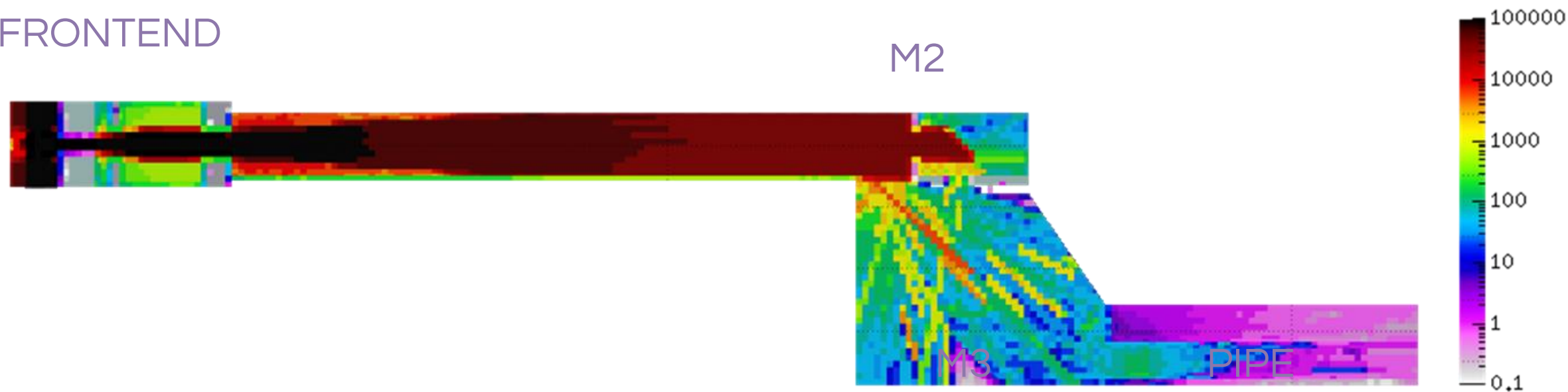


(b) Lead

# Pipe

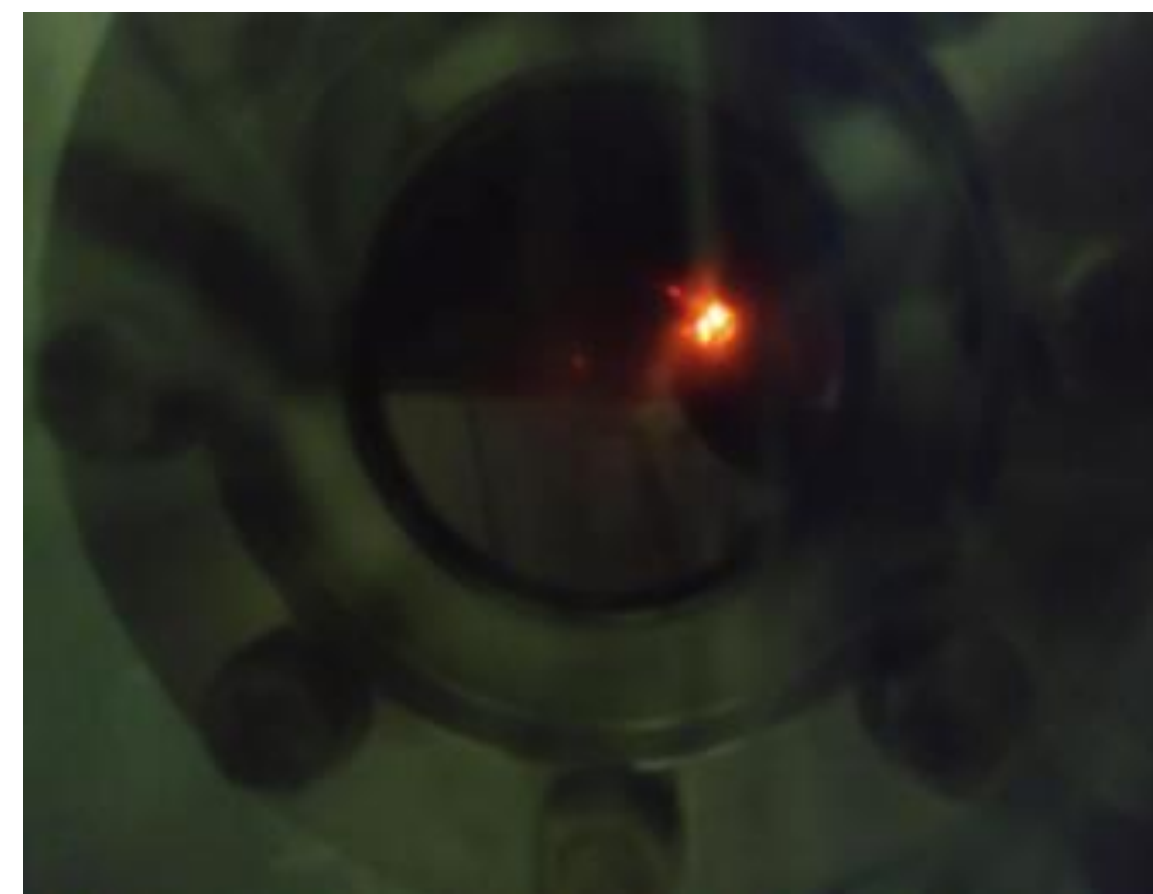
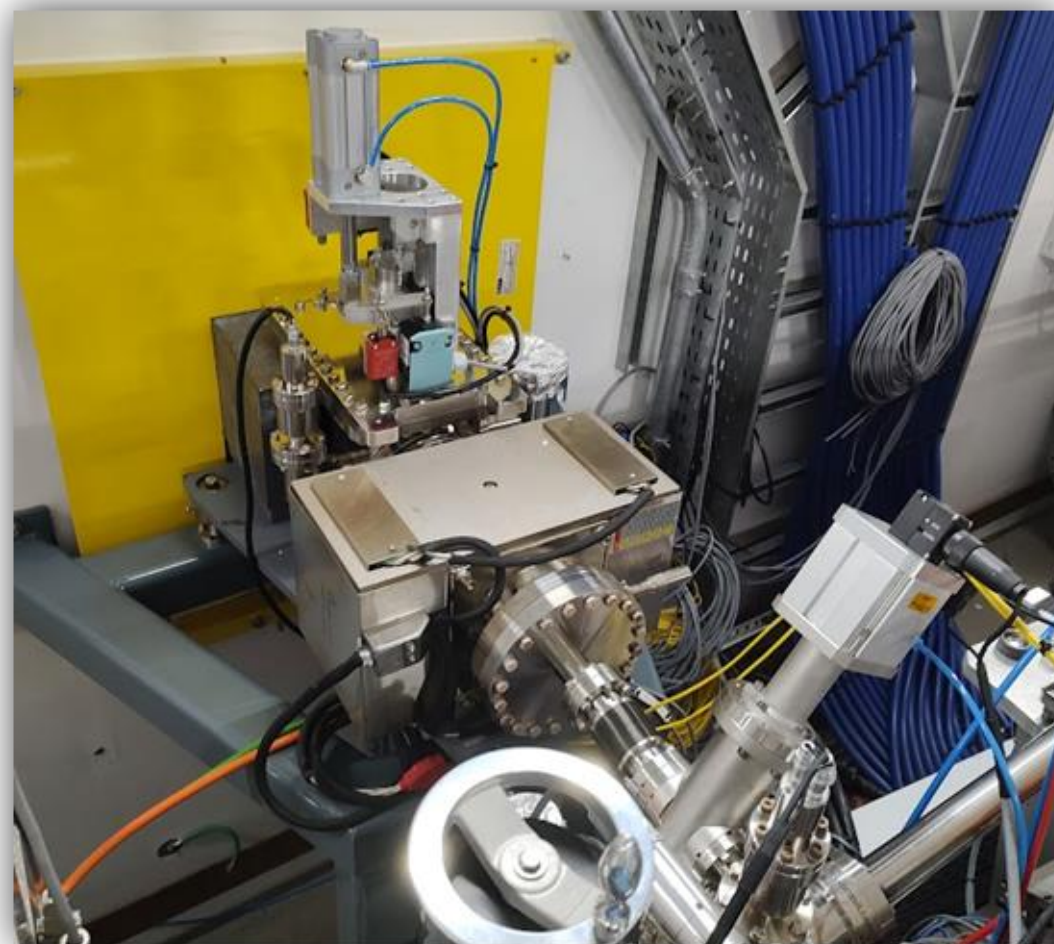
- Shielding at hutch exit designed for worst-case scattering scenario inside the front-end.
- Defined for operation with the shutter in the open position.
- Material: Steel
- Dimensions:
  - Length: 400 mm
  - Thickness: 6 mm
- Allows safe access around the hutch during beamline operation.

FRONTEND



# Beamline Construction and Operation

- Solution adopted: mix (steel for support)
- First beam at February 2021



No radiation dose measured above the background

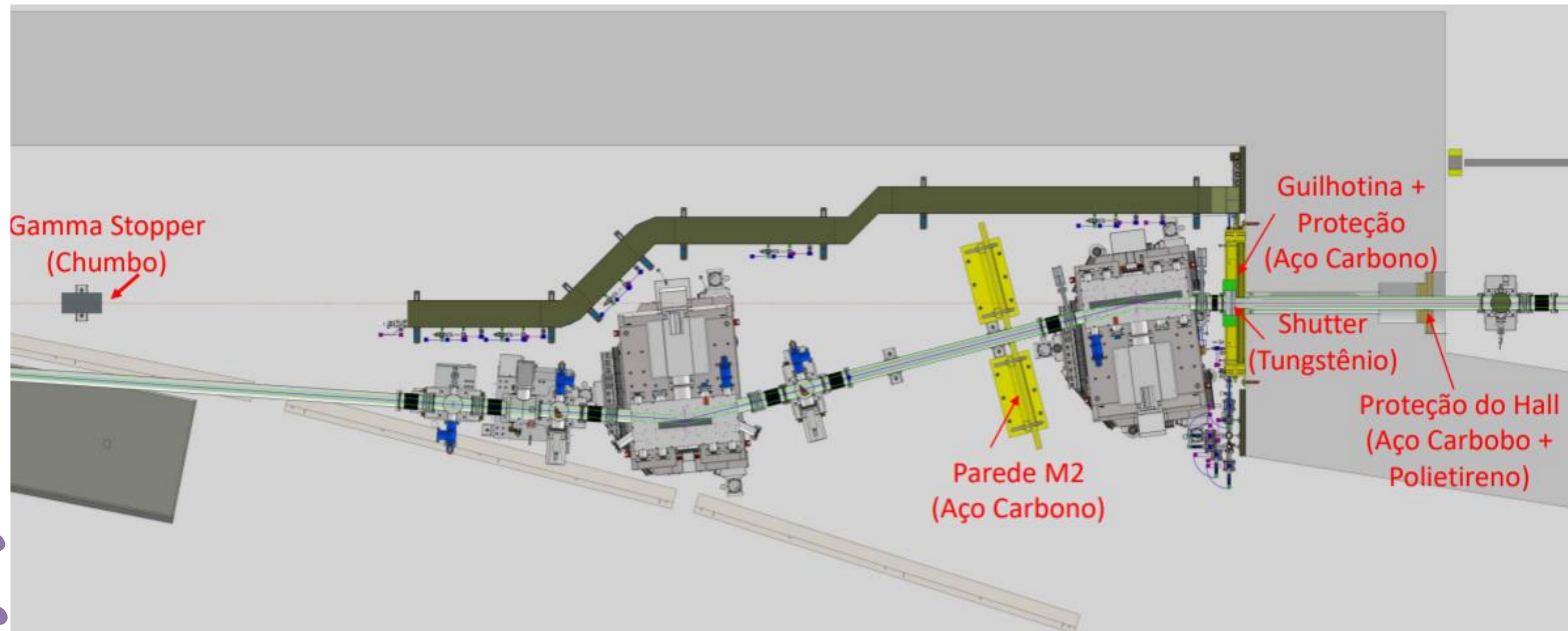


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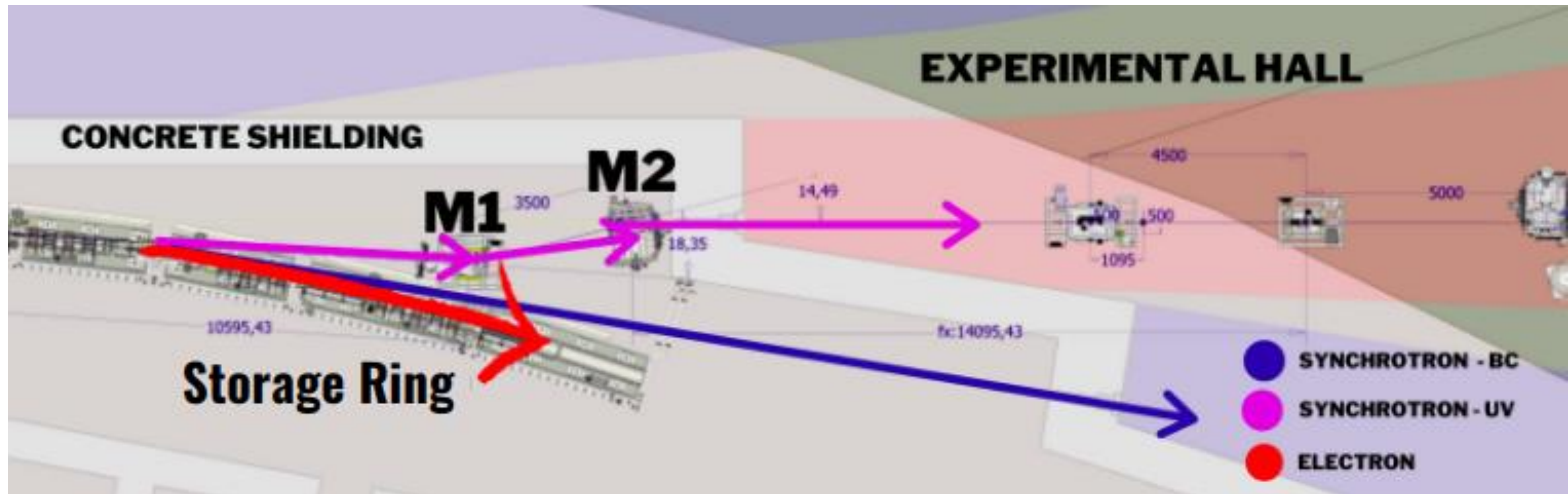
# SAPÊ – UV-C Beamline

Angle Resolved Photoemission Spectroscopy



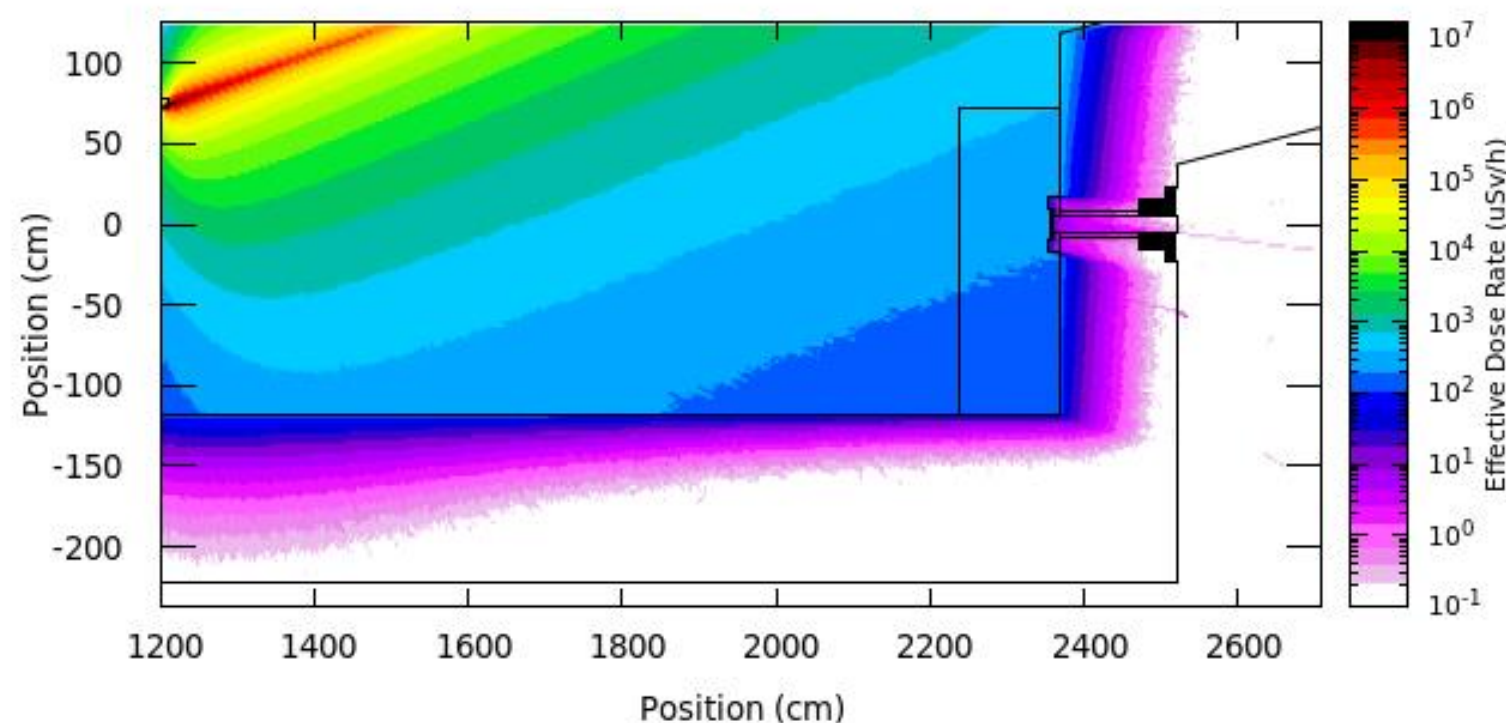
# Premises

- Concentrating as much shielding as possible inside the frontend.
- Ideally, being considered a radiation-free area outside the CSW.

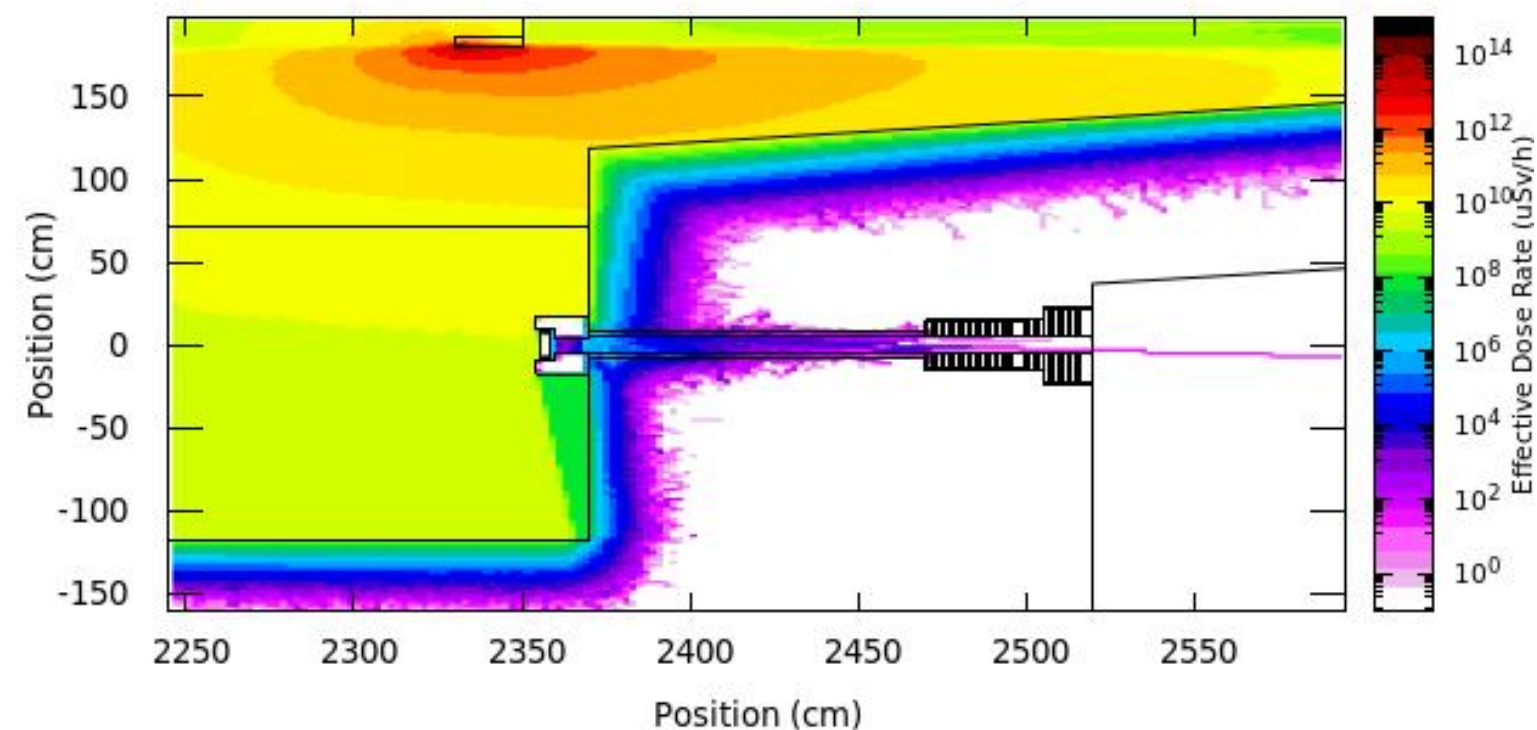


# Shutter - Close Position

## Electron Losses



## Photon scattering



Ideal scatterer:

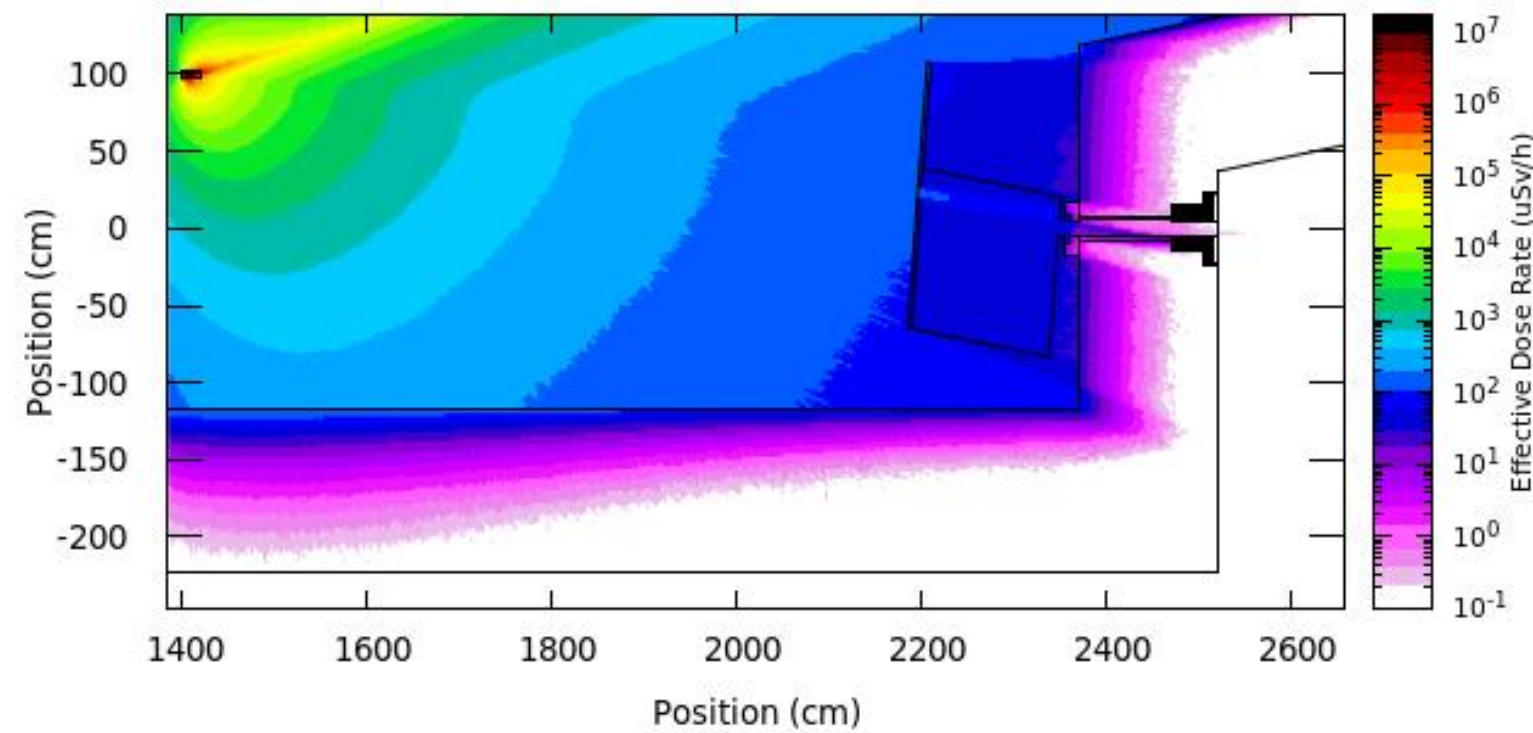
- Angulated cylinder;
- Any place in the Stored Ring or Booster.



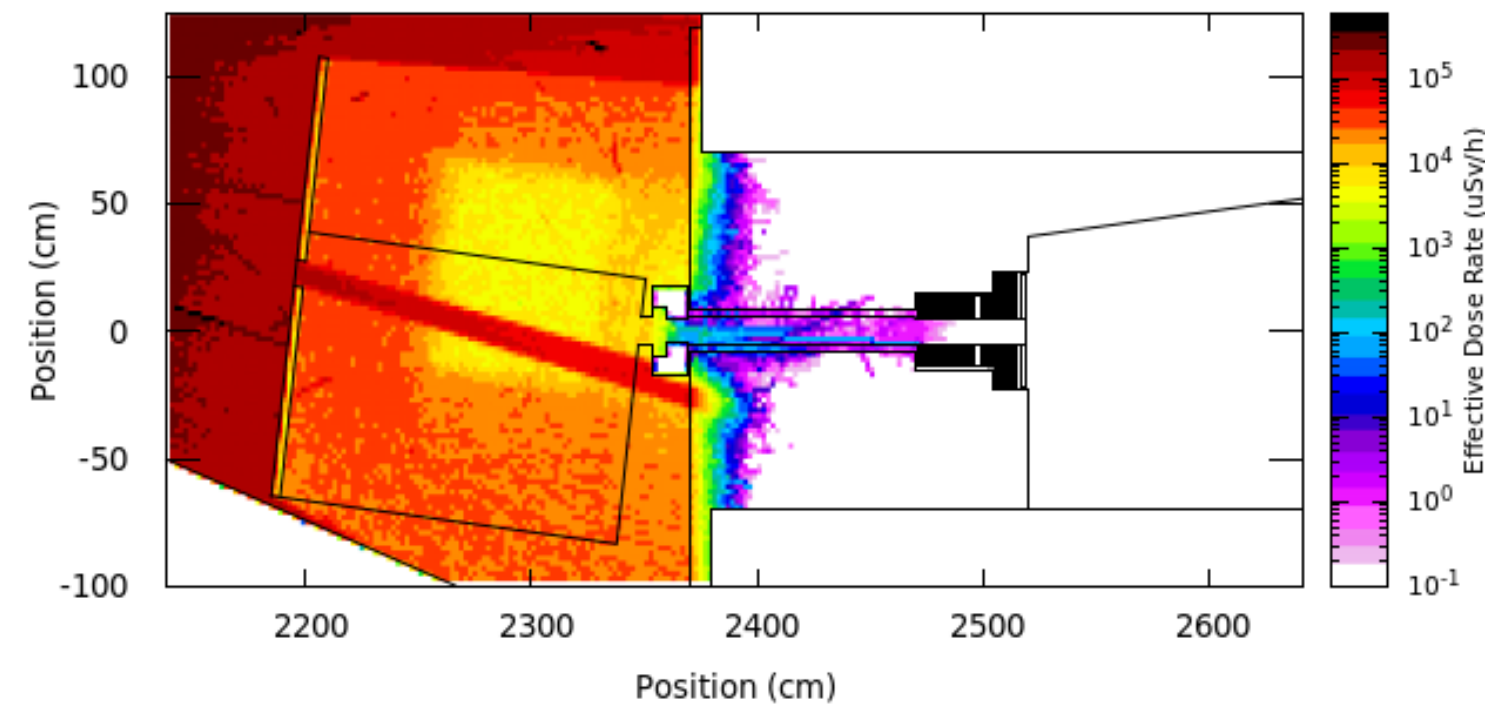
Copper Absorber placed after BC magnet before the Frontend's installation

# Shutter - Open Position

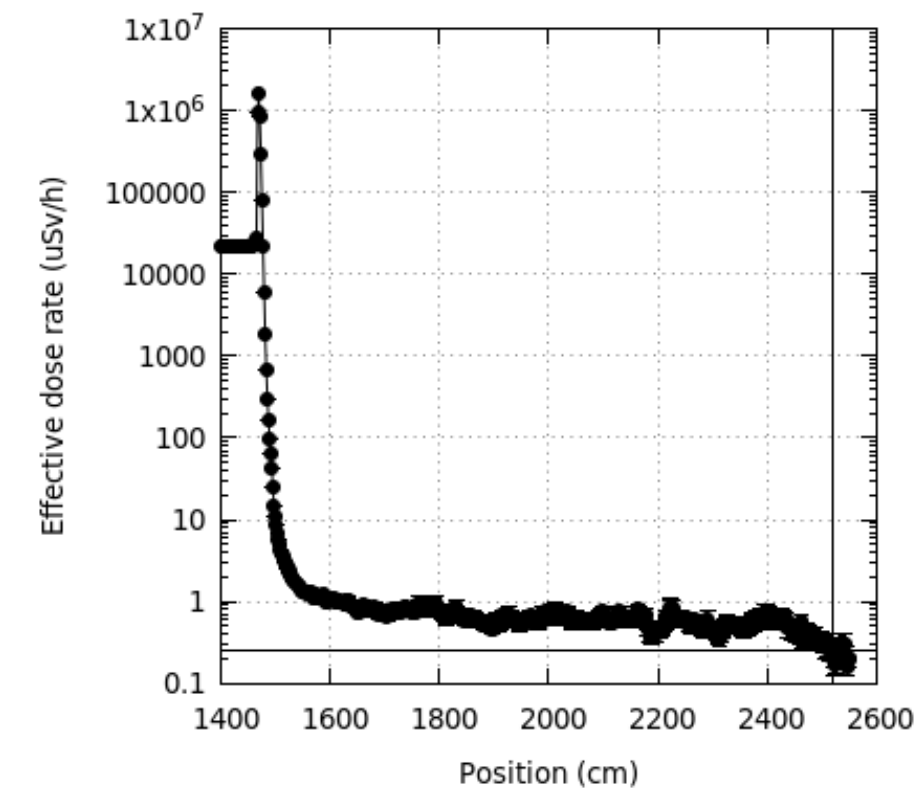
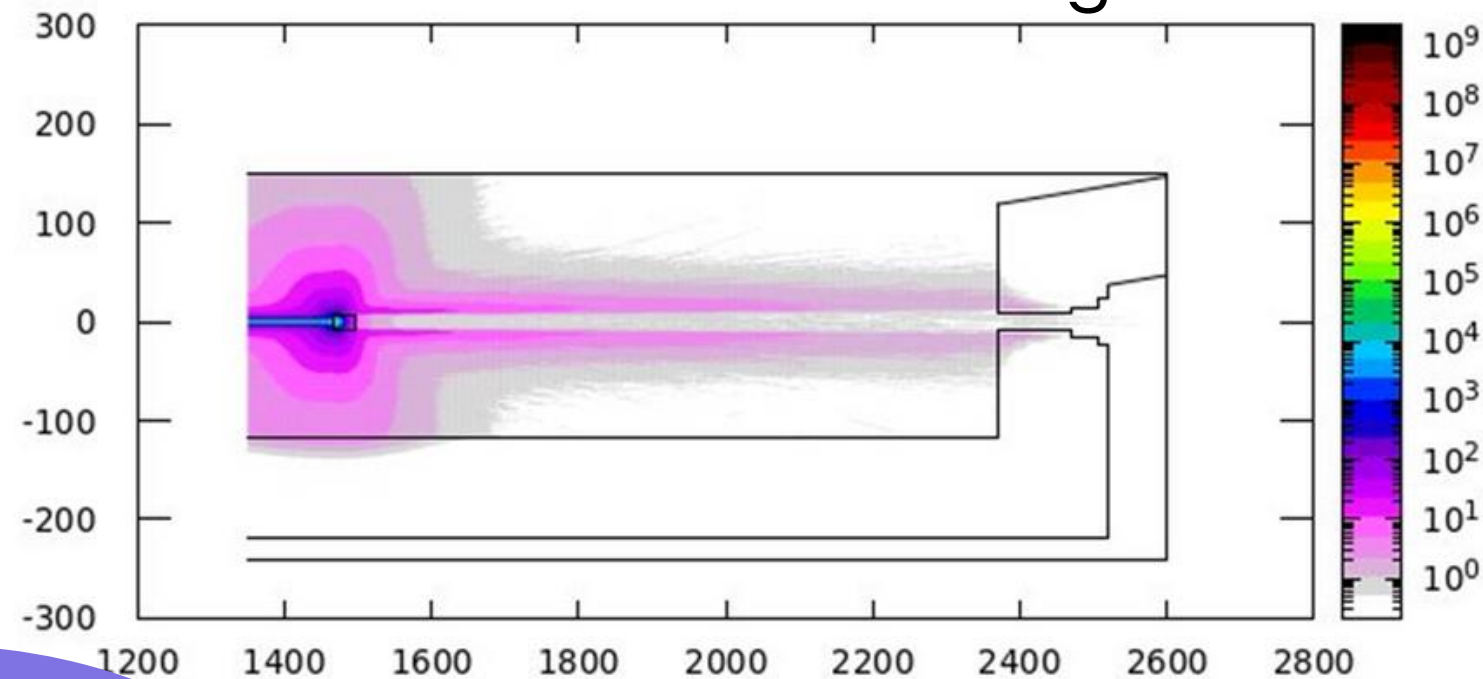
## Electron Losses



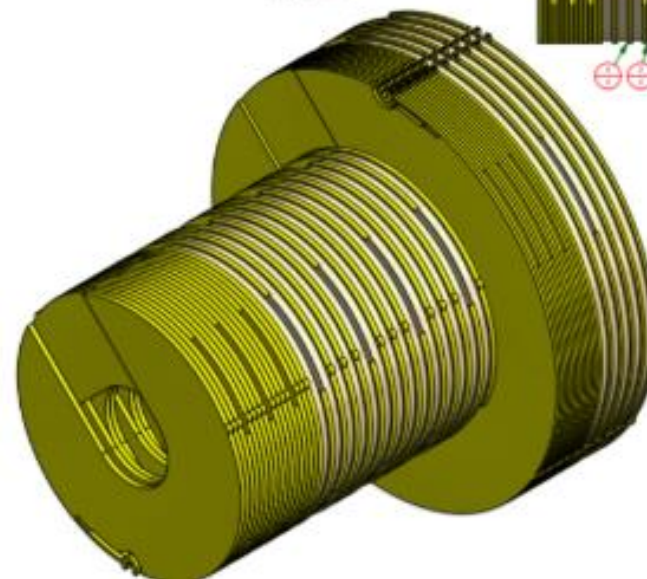
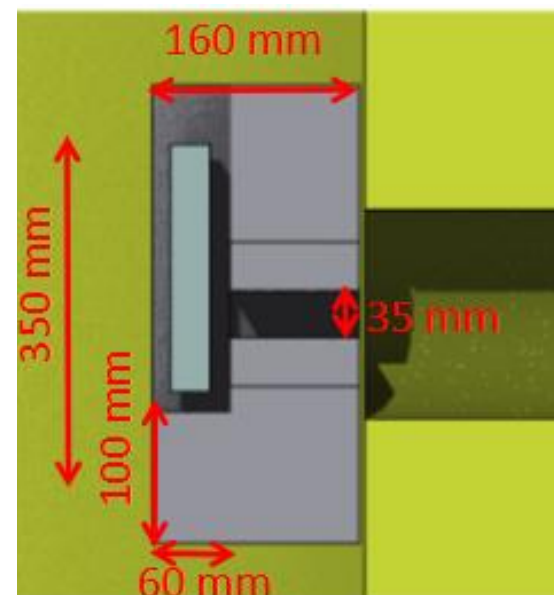
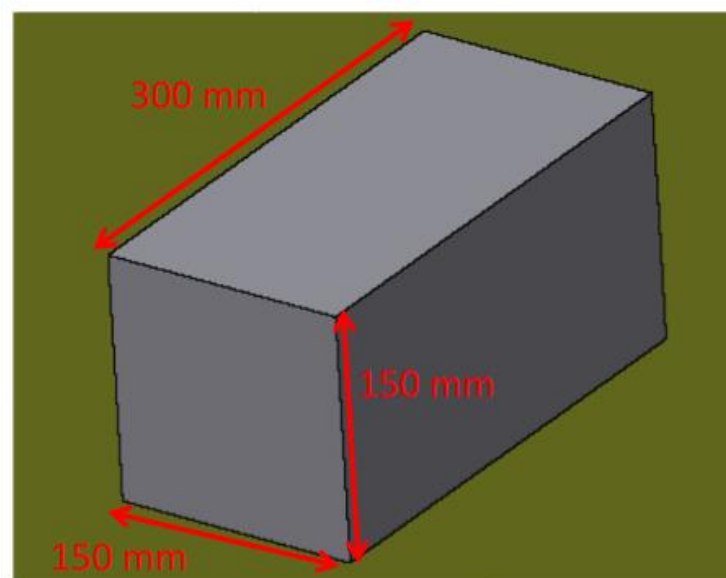
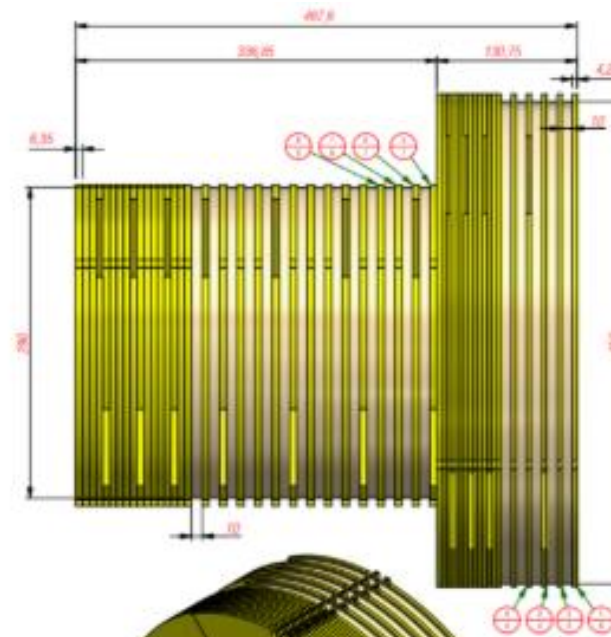
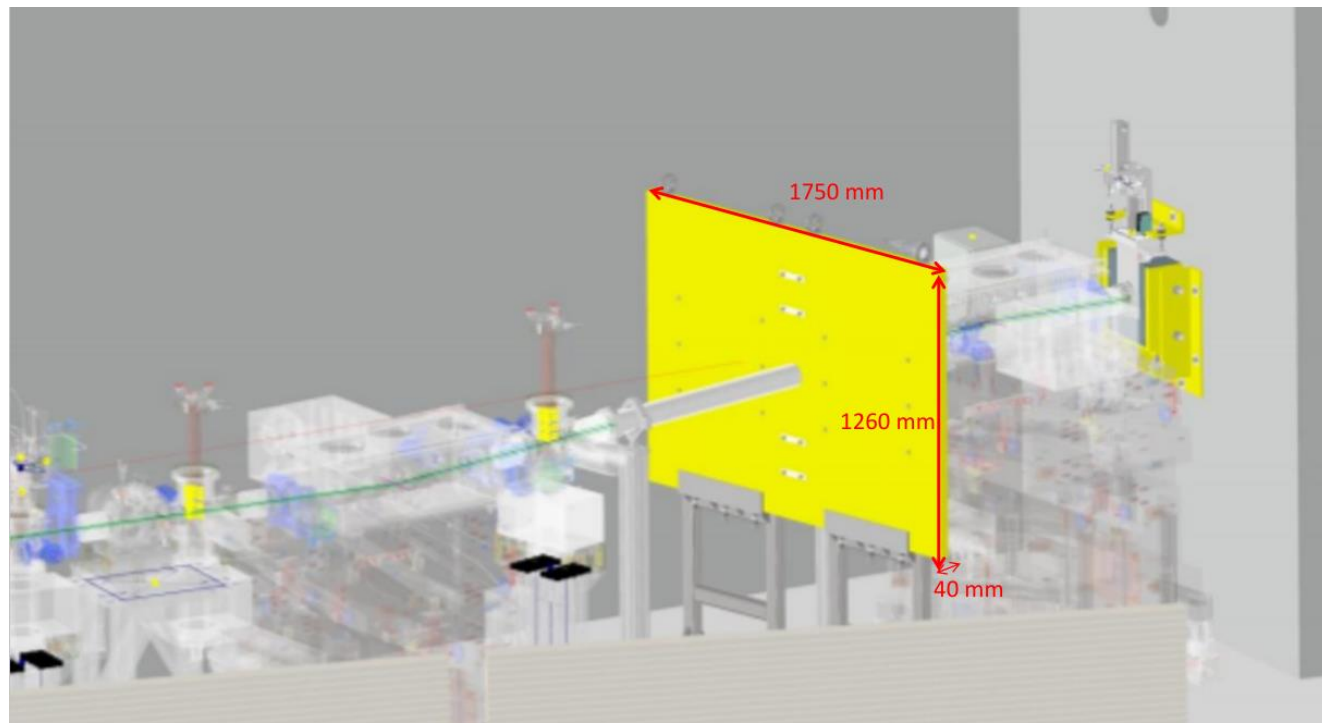
## Photon scattering



## Gas Bremsstrahlung



# Frontend elements



## Steel wall

- Scattering containment.
- Diameter of the passage of the beam is 102 mm.

## Lead Gamma Stop

- GB containment from the closest straight section.

## Tungsten Shutter

- Scattering containment.
- Massive bloc.
- Possible to move in vertical direction.

## Lead Reinforcement

- Scattering containment.
- 35 mm x 92 mm passage of the beam.

## Plates of steel and polyethylene

- Scattering containment.
- Diameter of the passage of the beam is 102 mm.

# Beamline Construction and Operation



No radiation dose measured above the background

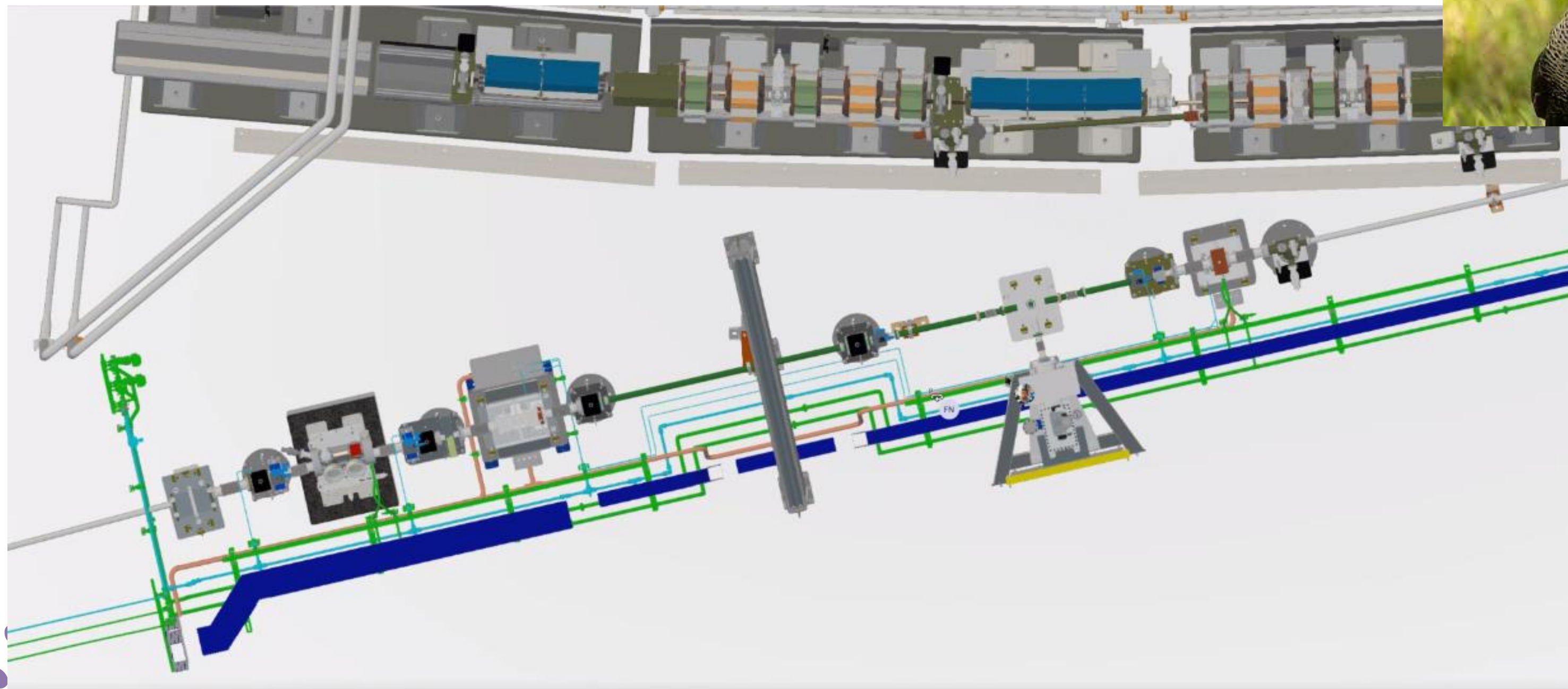


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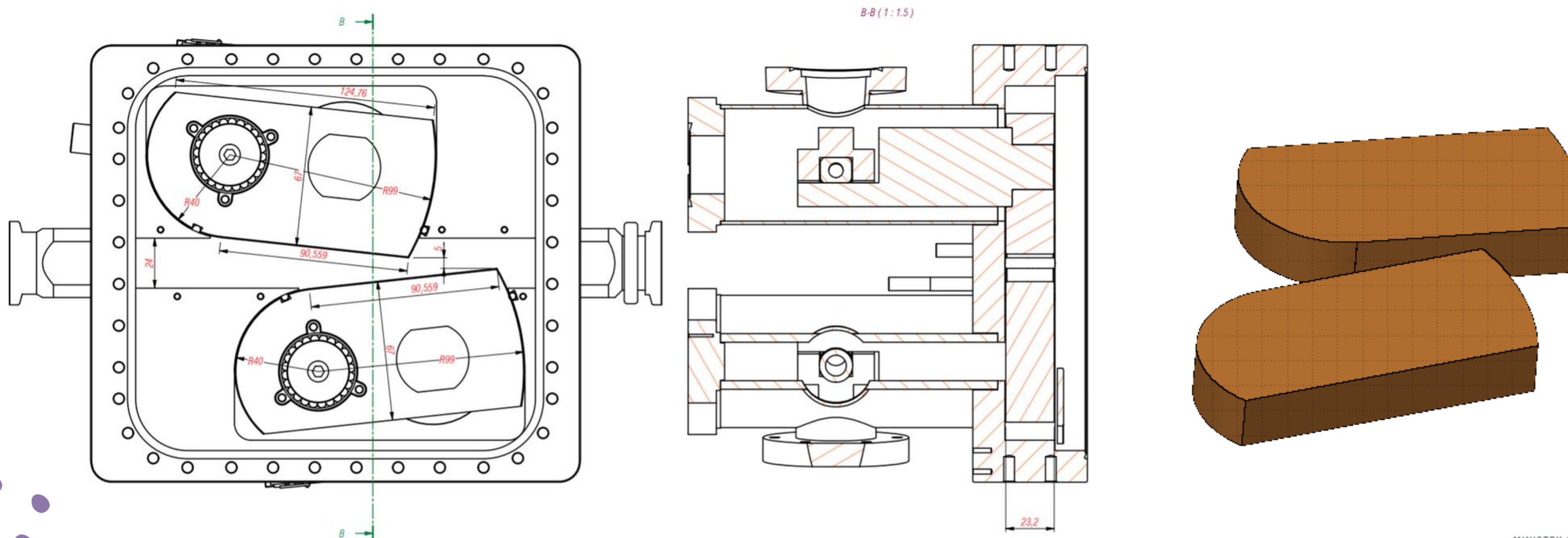
# CARCARÁ – Visible Light & 11 keV Beamline

Computation and Analysis of electron beam ChARacteristics

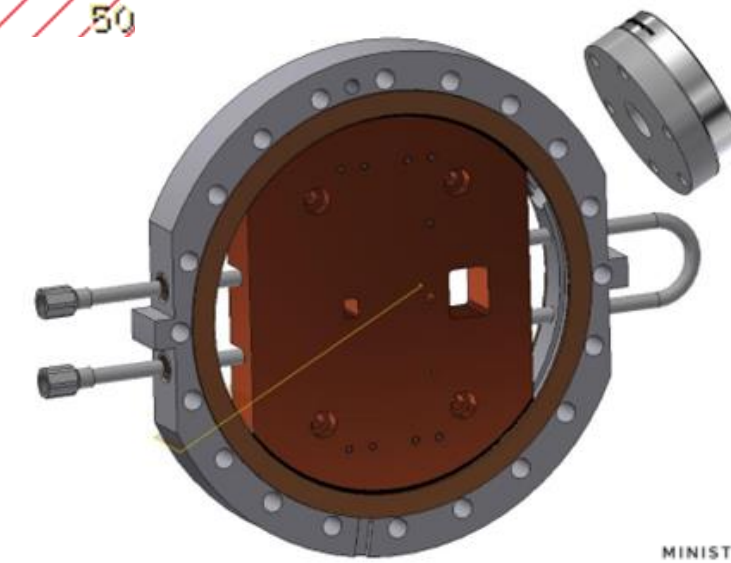
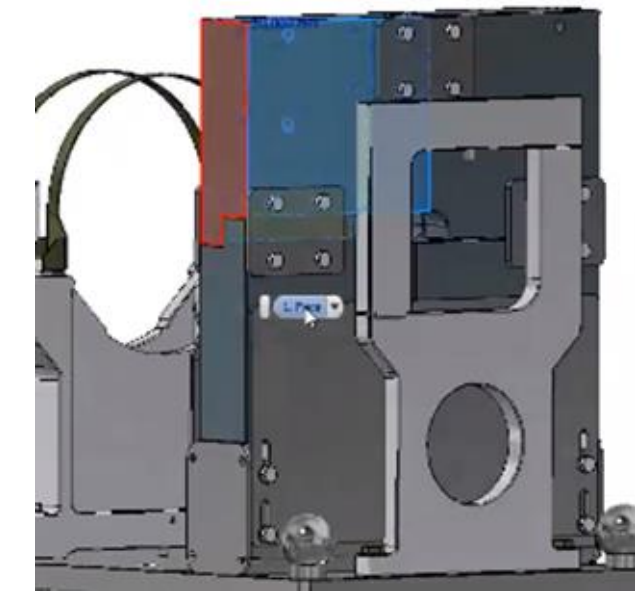
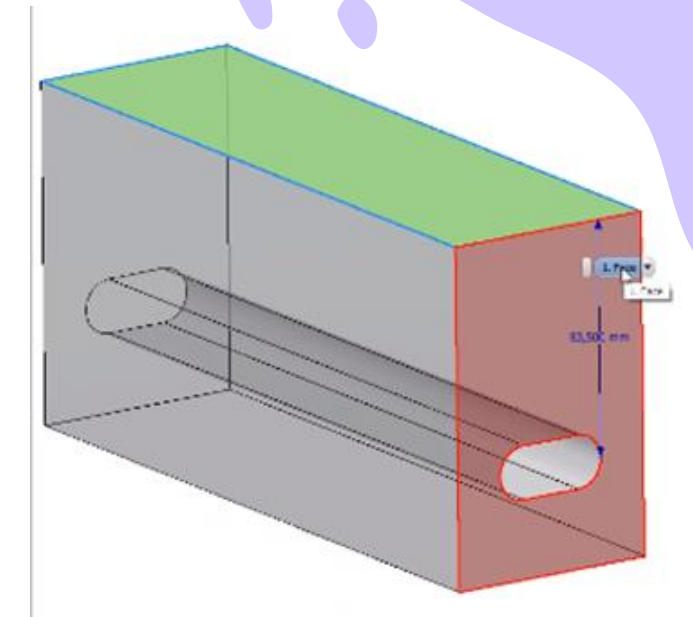
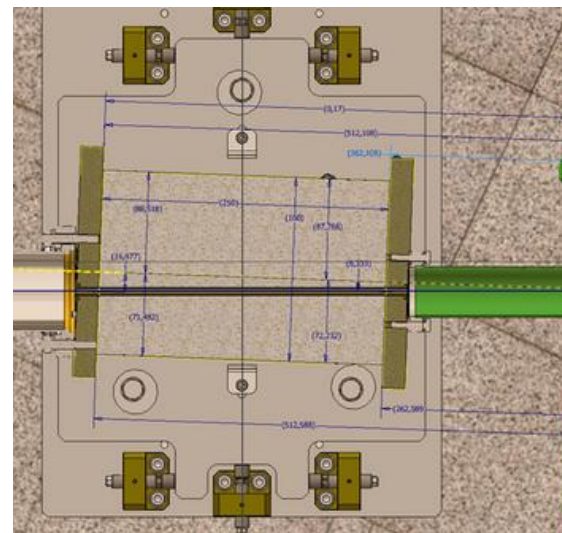
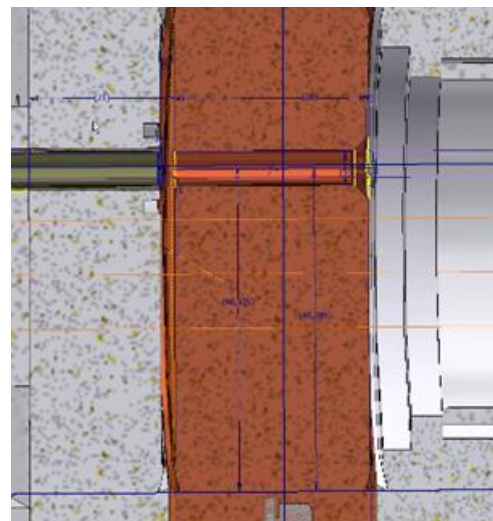
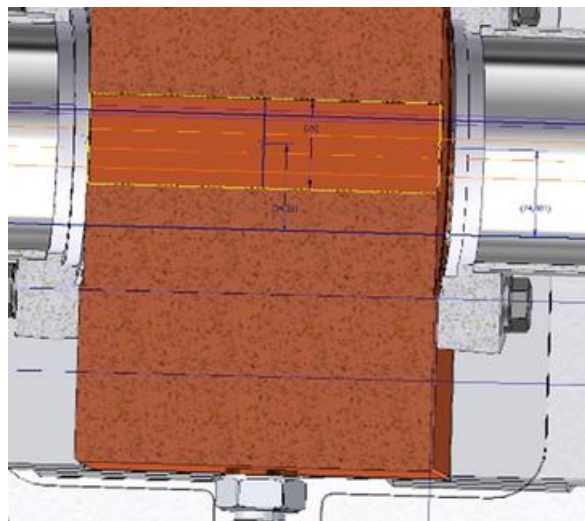
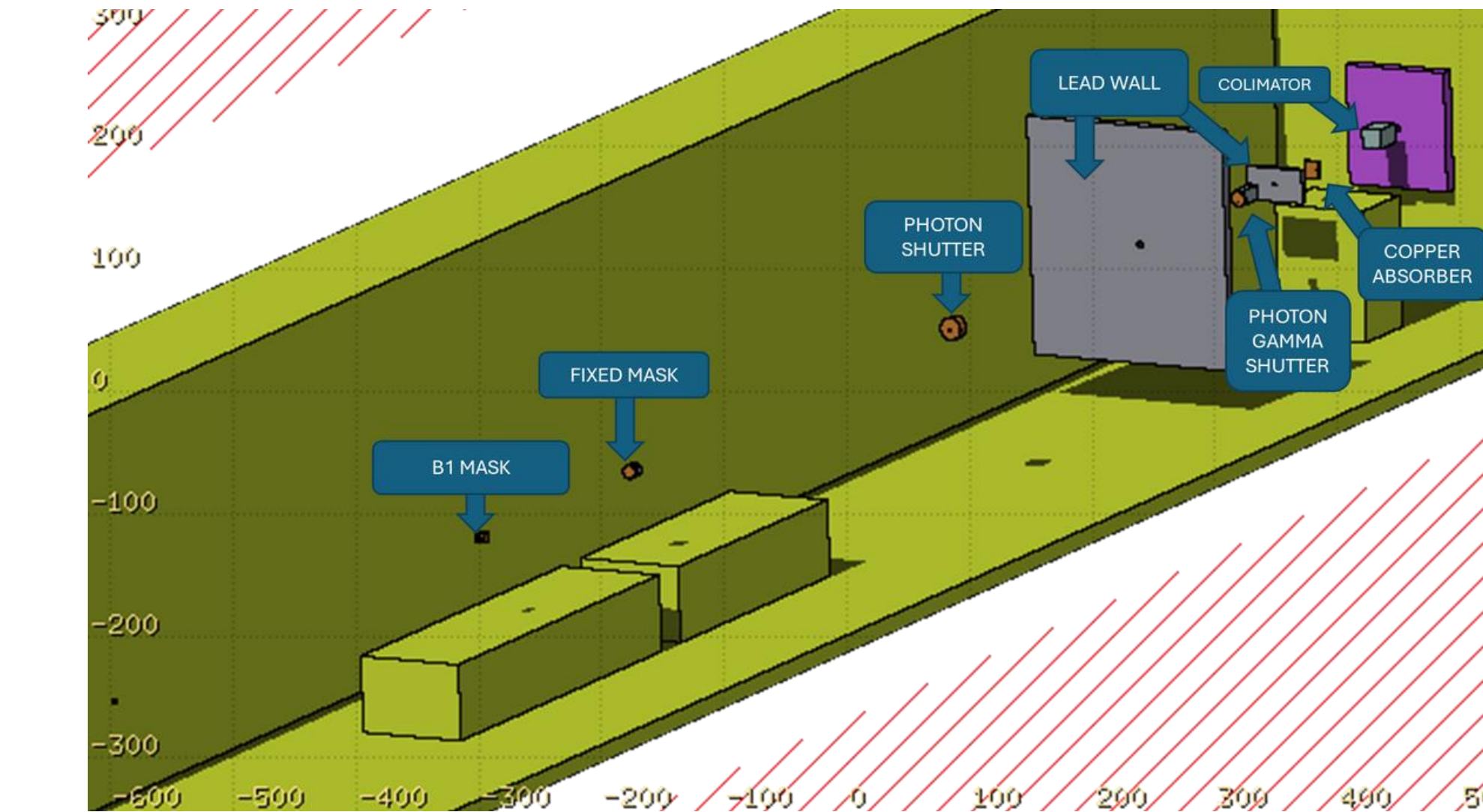
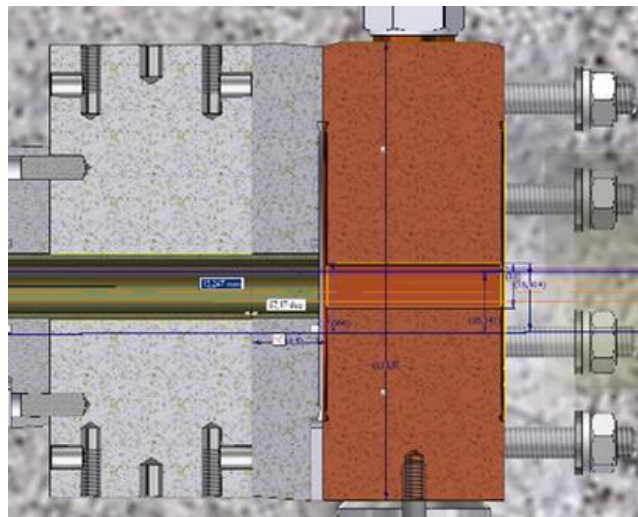
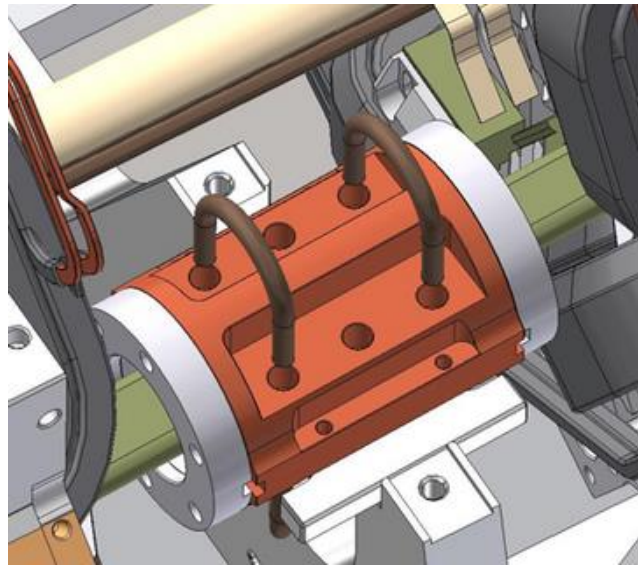


# About the Beamline

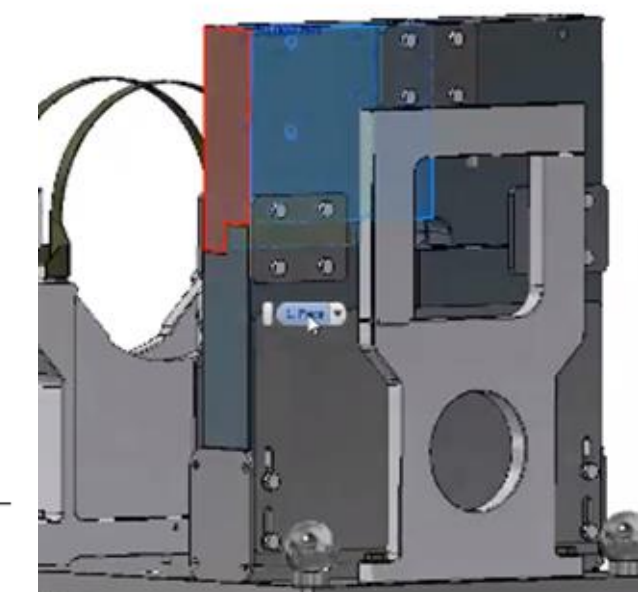
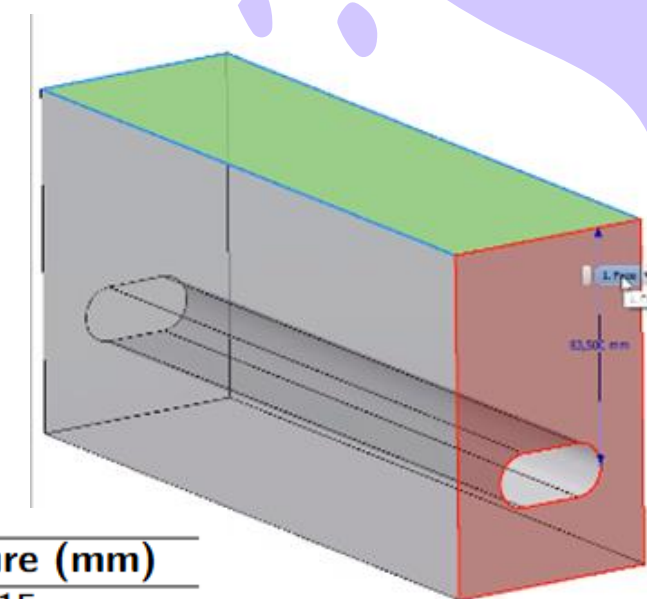
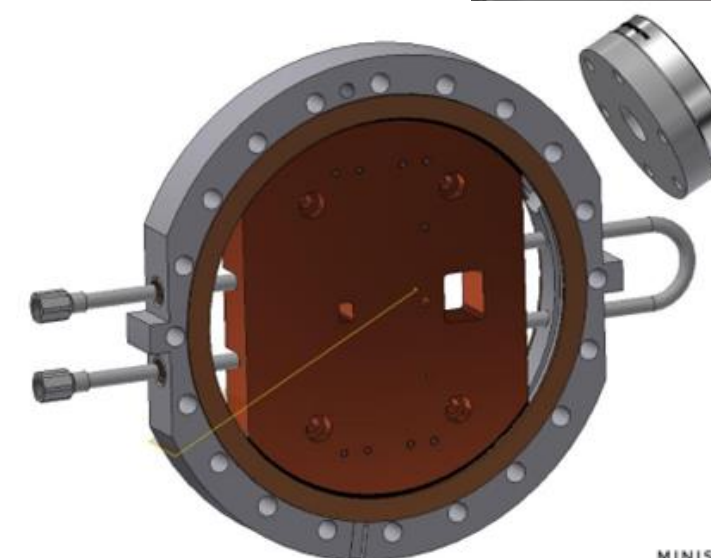
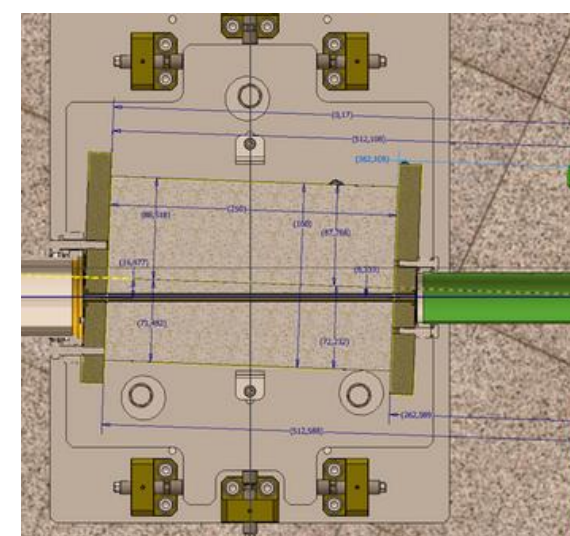
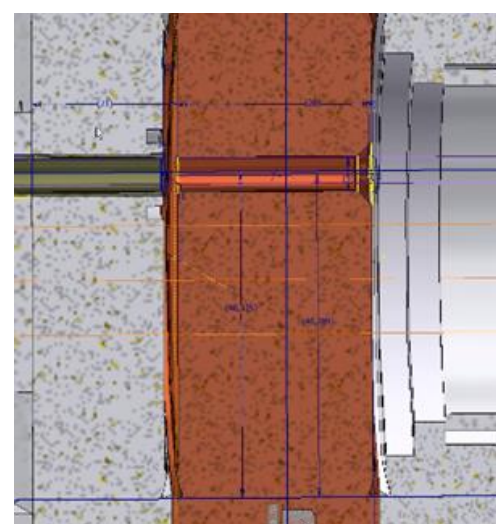
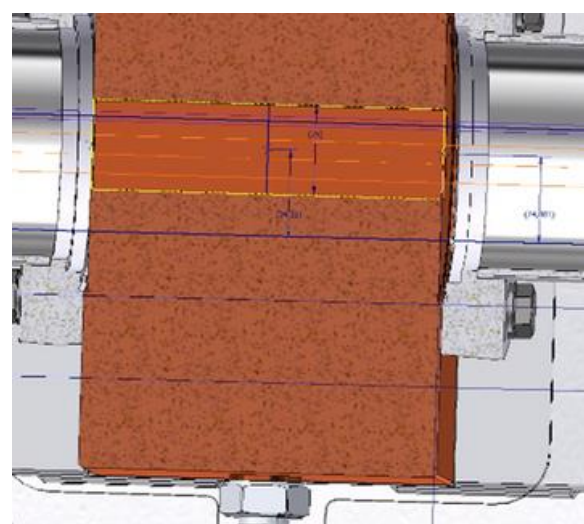
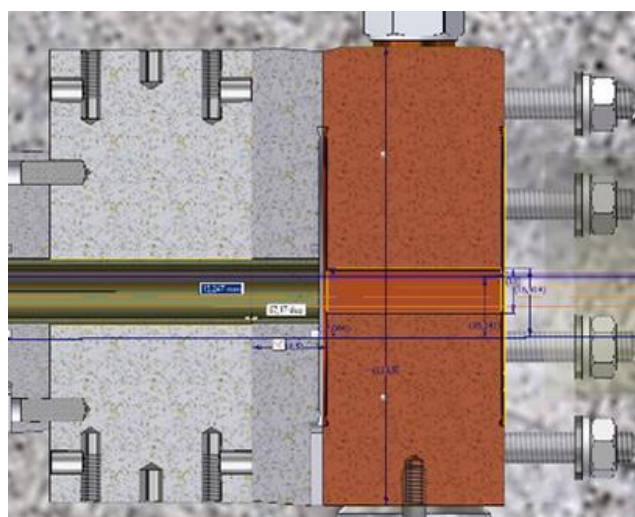
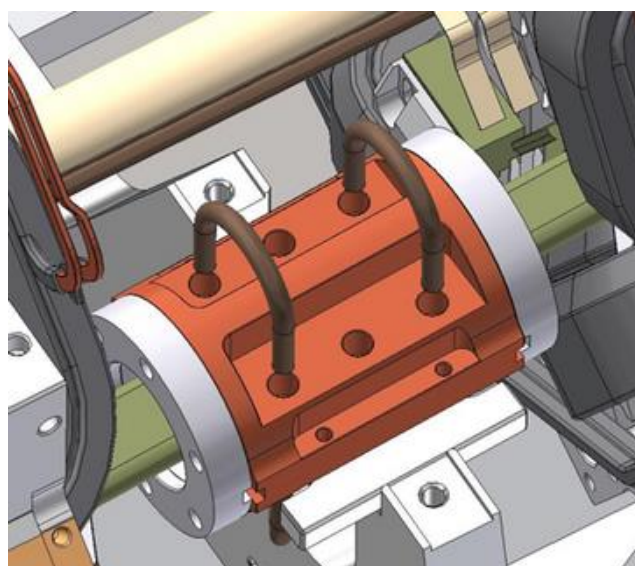
- Beamline dedicated to electron beam diagnostic. Therefore it is not a beamline for users.
- The beam is extracted from a B1 dipole and there are two branches:
  - CARCARA-X, was developed to measure the electron beam emittance using 11 keV x-ray.
  - CARCARA-V, will use part of visible light for characterization of the electron beam temporal parameters.
- The CARCARA frontend is in machine injection region, where there are elements for concentrate the electron losses in machine, called scrapers, and they are responsible of physical limitation of the beam.



# Radiation Protection Elements



# Radiation Protection Elements

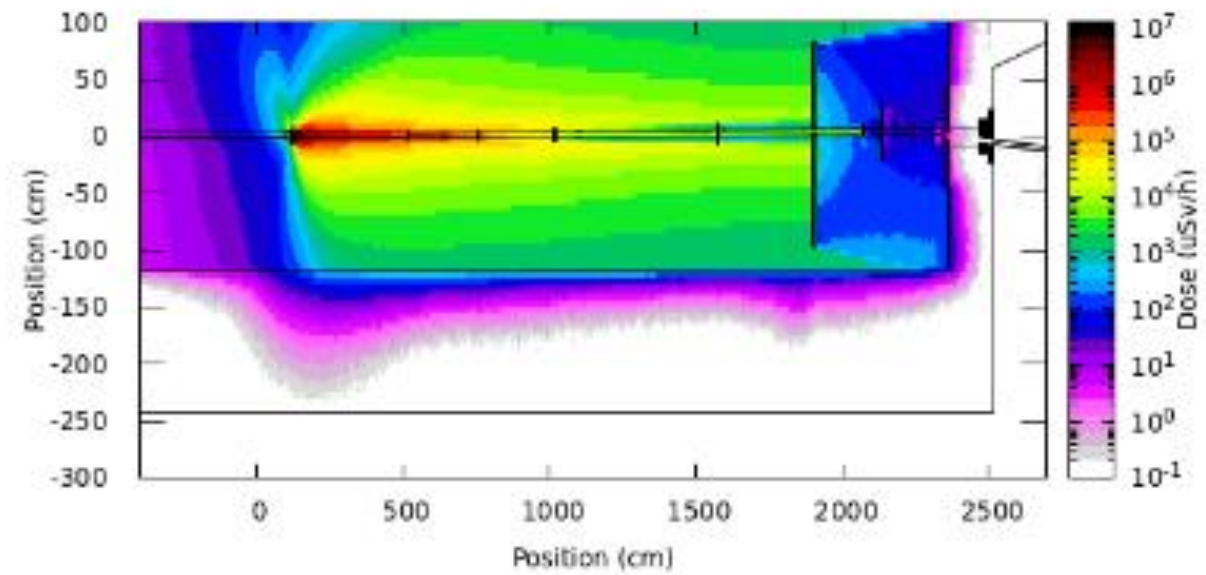


Element	Distance to CSW (mm)	Dimensions (mm)	Aperture (mm)
B1 mask (Copper)	26 115	70 x 70 x 87	15
Fixed Mask (Copper)	13 510	D: 114 / T: 43	11 (h) x 9 (v)
Fixed Mask (Tungsten)	13 491	D: 112 / T: 50	16.1 (h) x 19.1 (v)
Photon Shutter	7 947	D: 182 / T: 100	25 (h) x 17 (v)
Big Lead Wall	4 678	1800 x 2000 x 100	50
Copper Absorber	2 975	T: 28	5 (h) x 9 (v)
Photon Gamma Shutter	2 954	77 x 121 x 285	6 (h) x 10 (v)
Small Lead Wall	2 314	500 x 280 x 48	41 (h) x 15 (v)
Copper Sheet	1 715	120 x 148 x 20	6 (h) x 8 (v)
Tungsten Collimator	512	160 x 175 x 250	7.1 (h) x 9 (v)
Frontend Guillotine	0	1000 x 900 x 120	55
Frontend inside the Hutch			

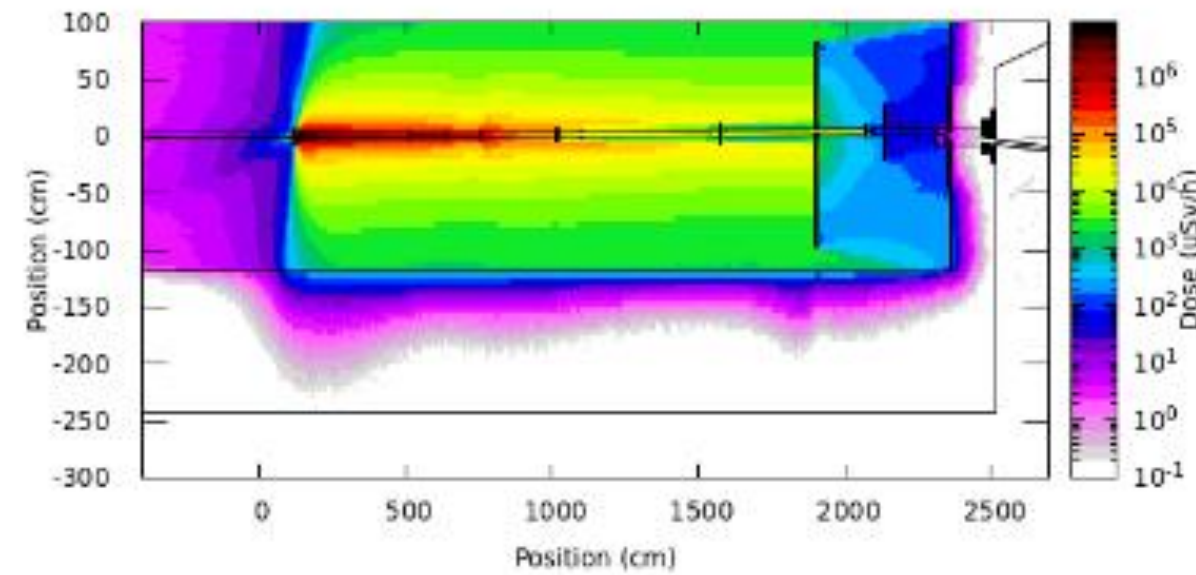
Notes: CSW: Concrete Shielding Wall / T: Thickness / D: Diameter

# Simulated scenarios

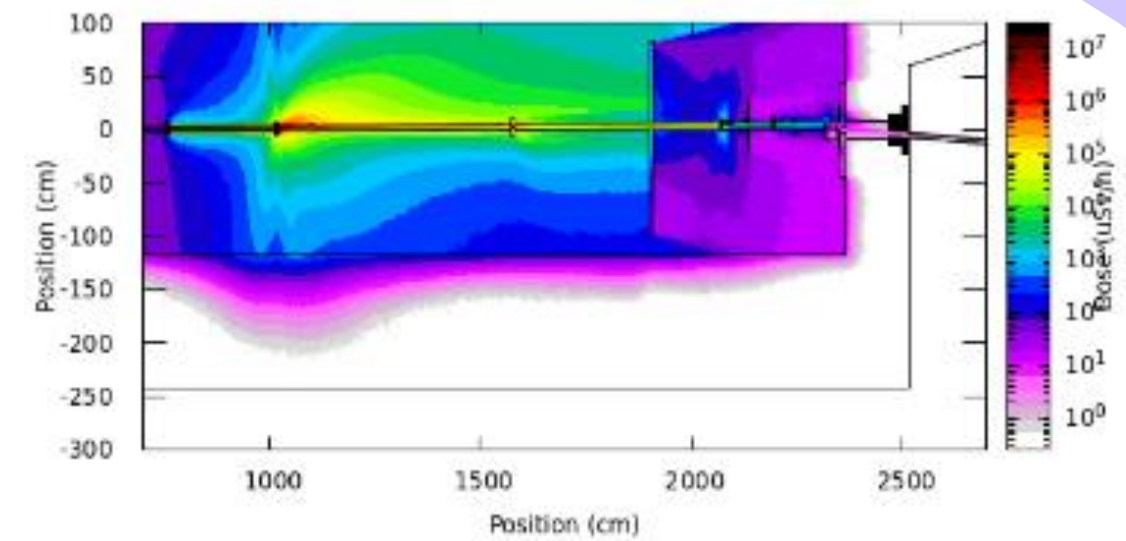
Electron Losses



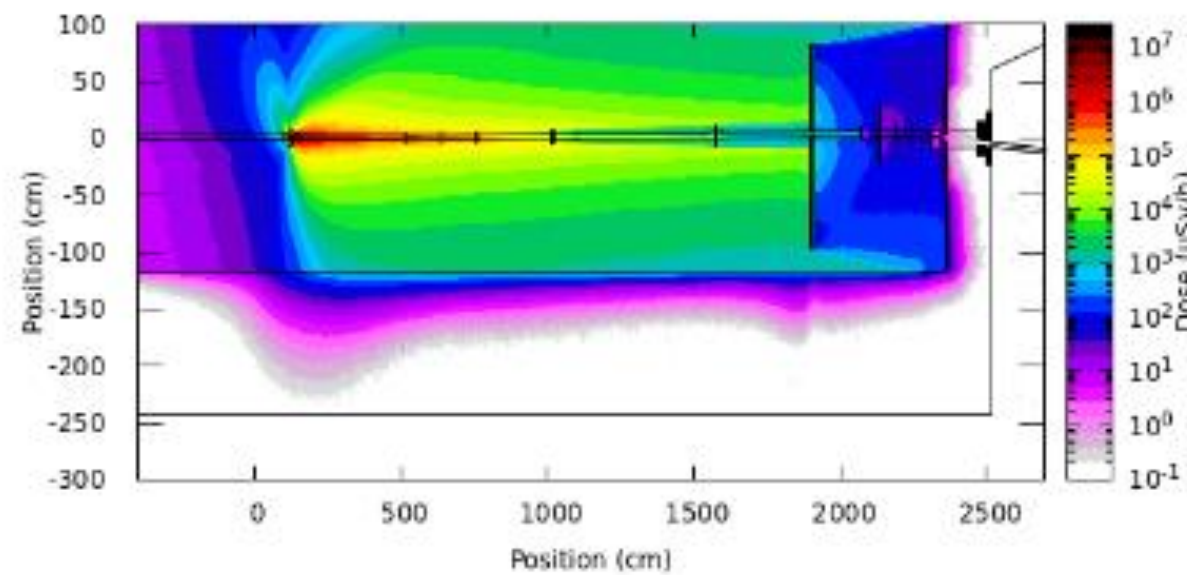
(a) Inboard Blade - Opened position



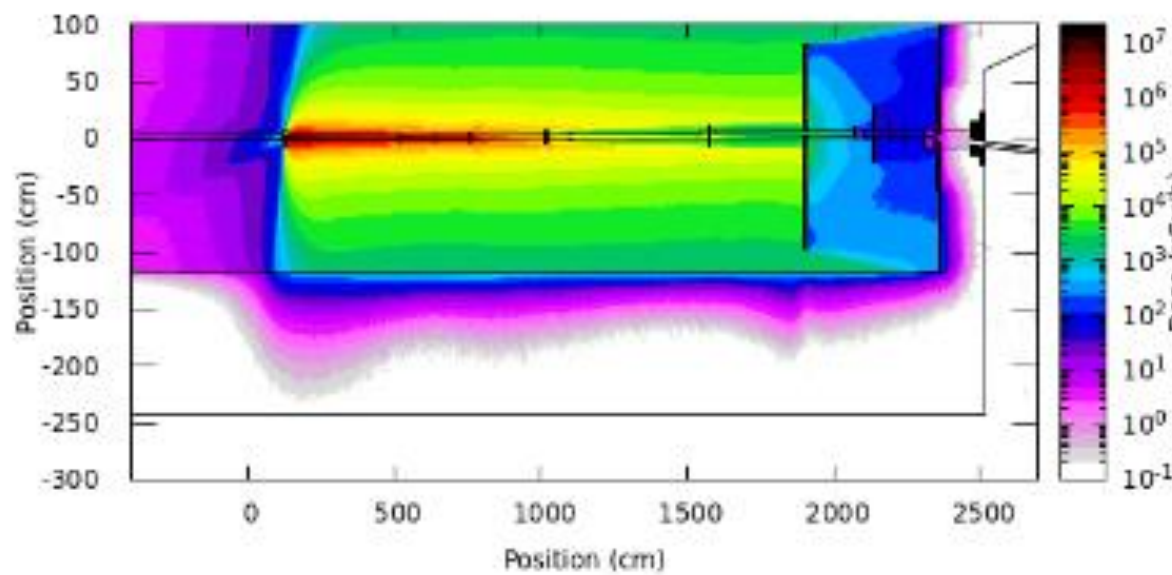
(b) Outboard Blade - Opened position



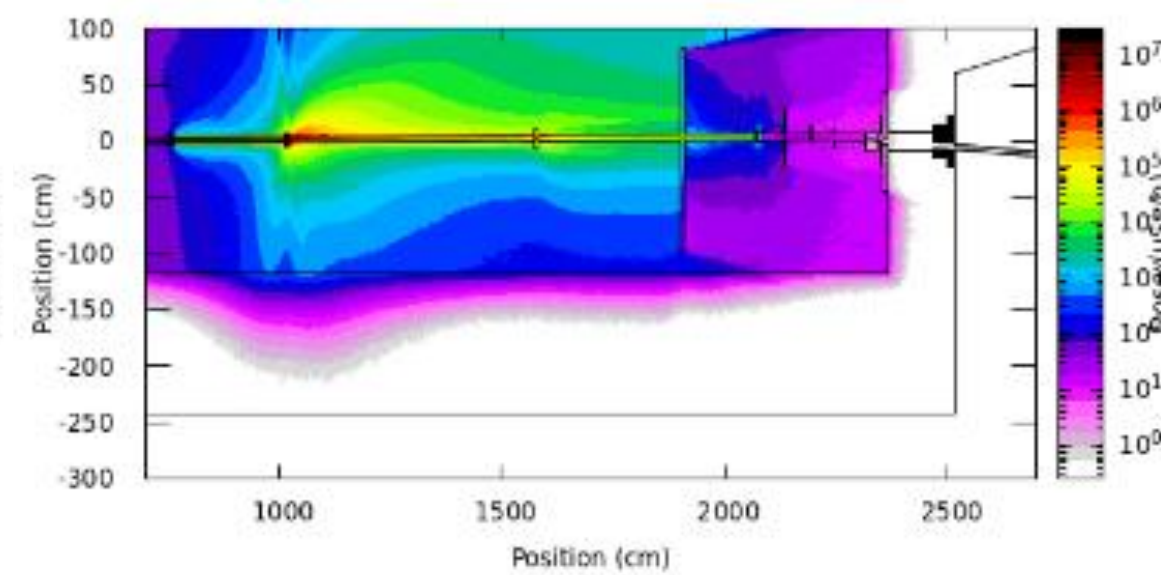
(a) Opened position



(c) Inboard Blade - Closed position

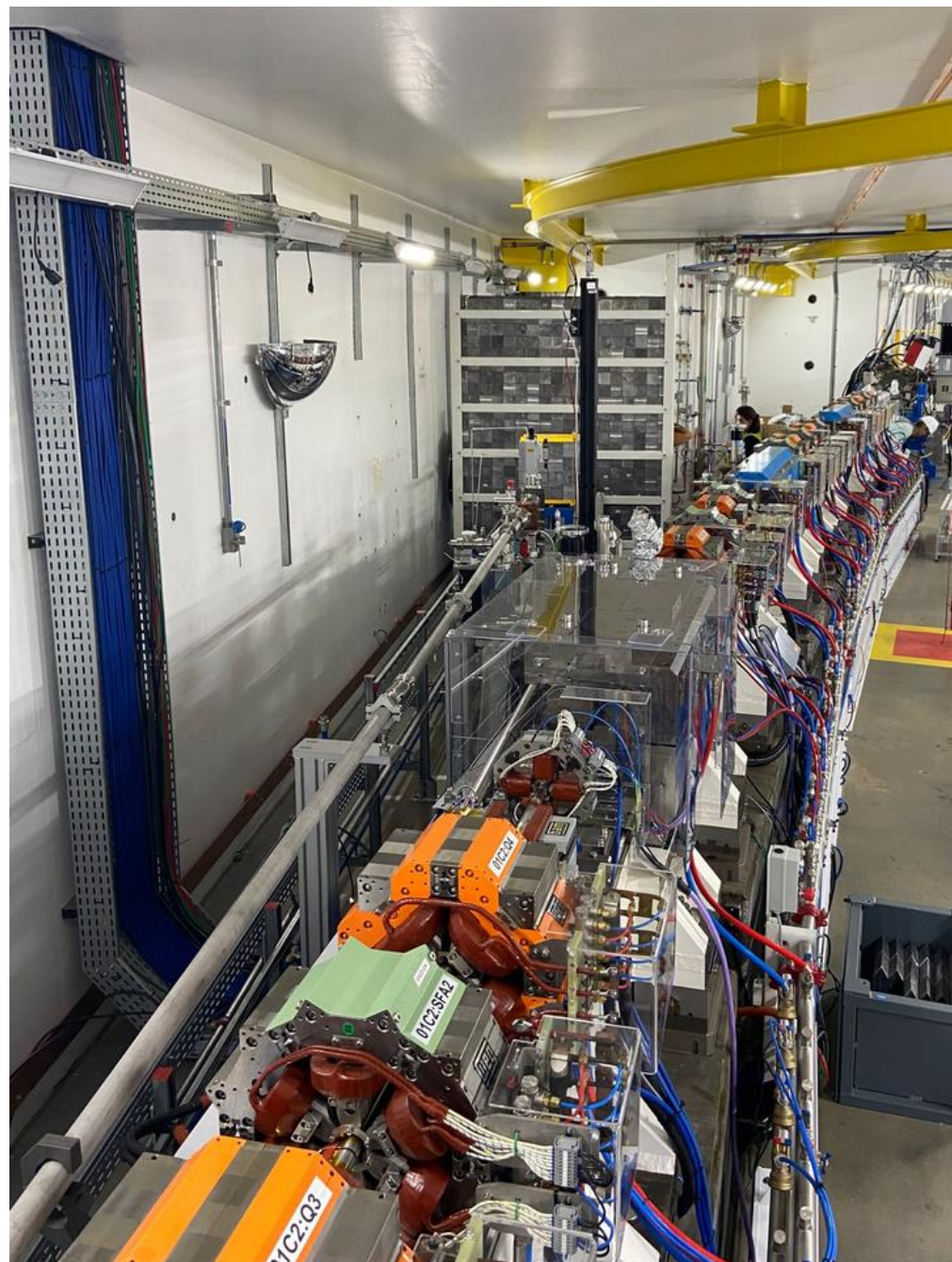


(d) Outboard Blade - Closed position



(b) Closed position

# Beamline Construction and Operation

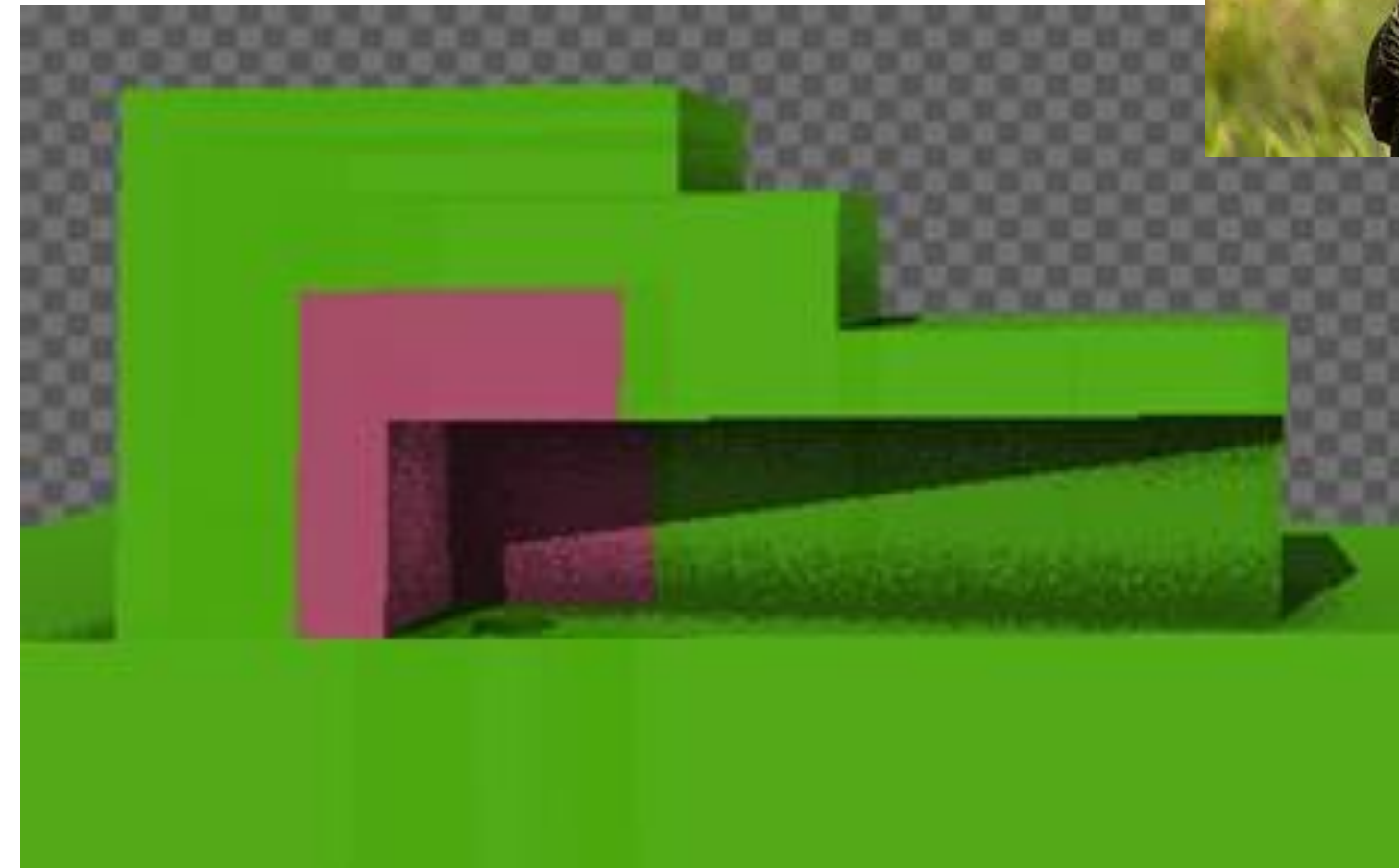
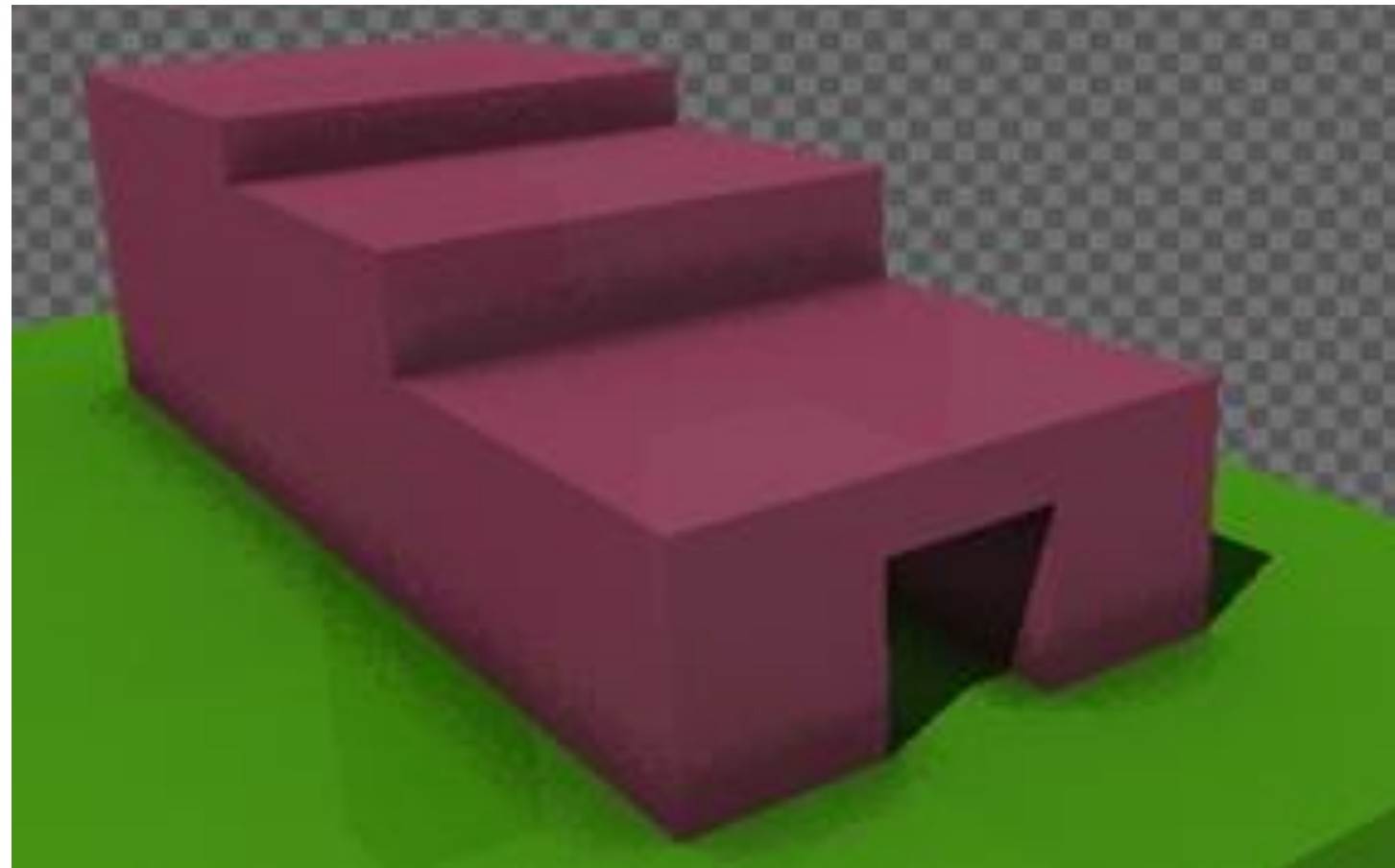


No radiation dose measured above the background



# CARCARÁ V – Visible Light

Computation and Analysis of electron beam Characteristics



But that's a conversation for another time...

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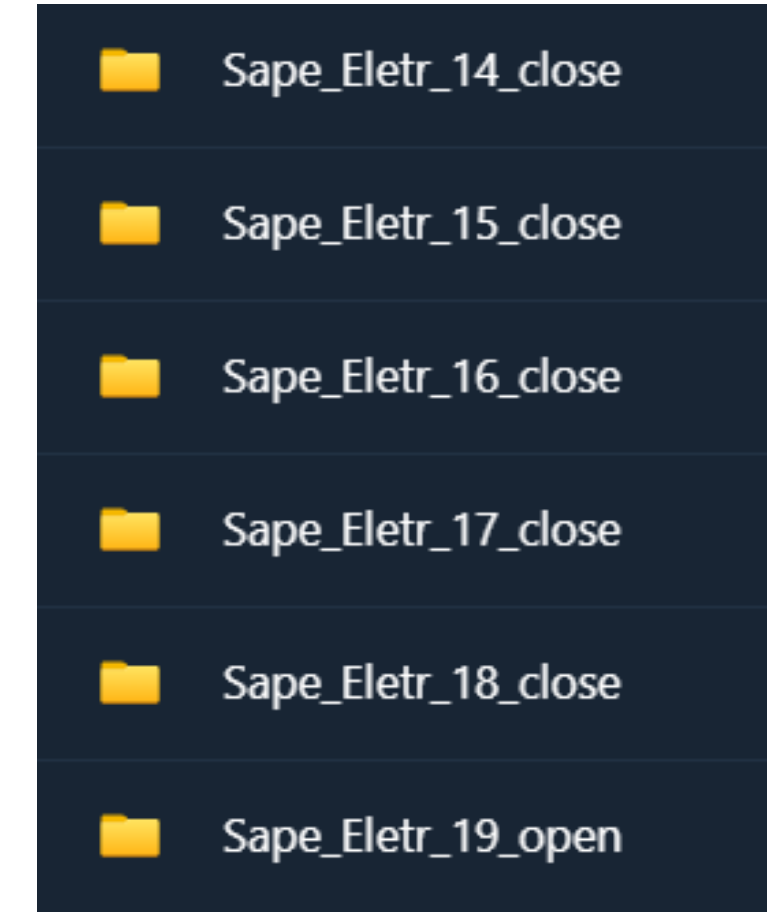
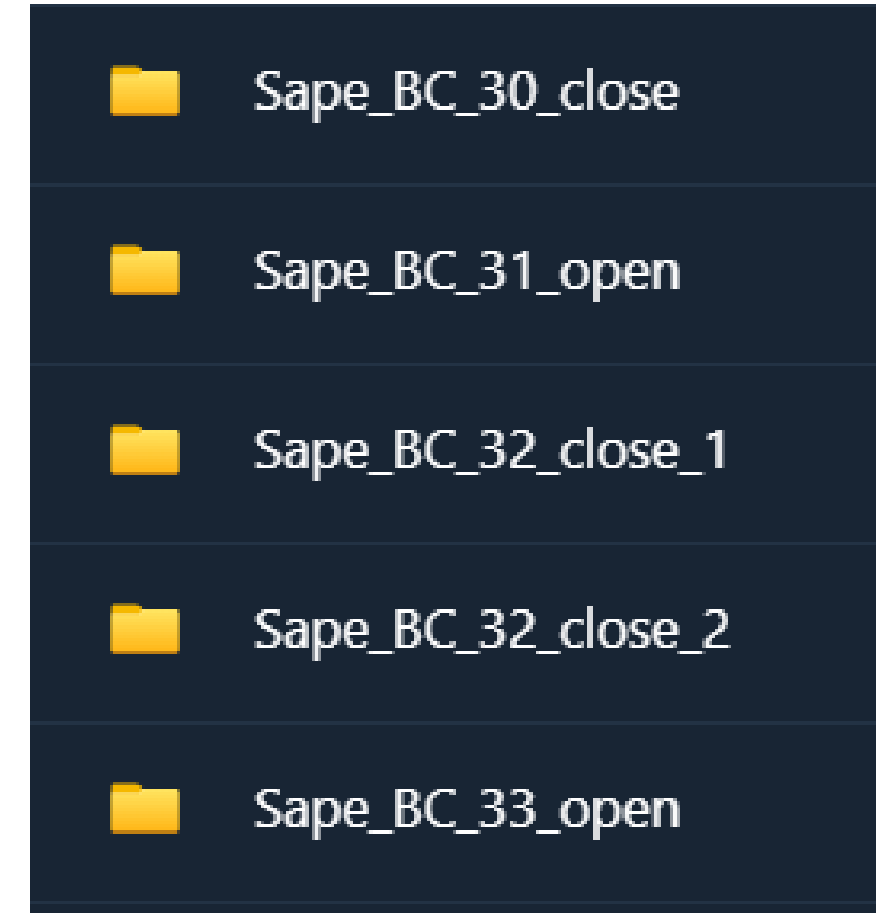
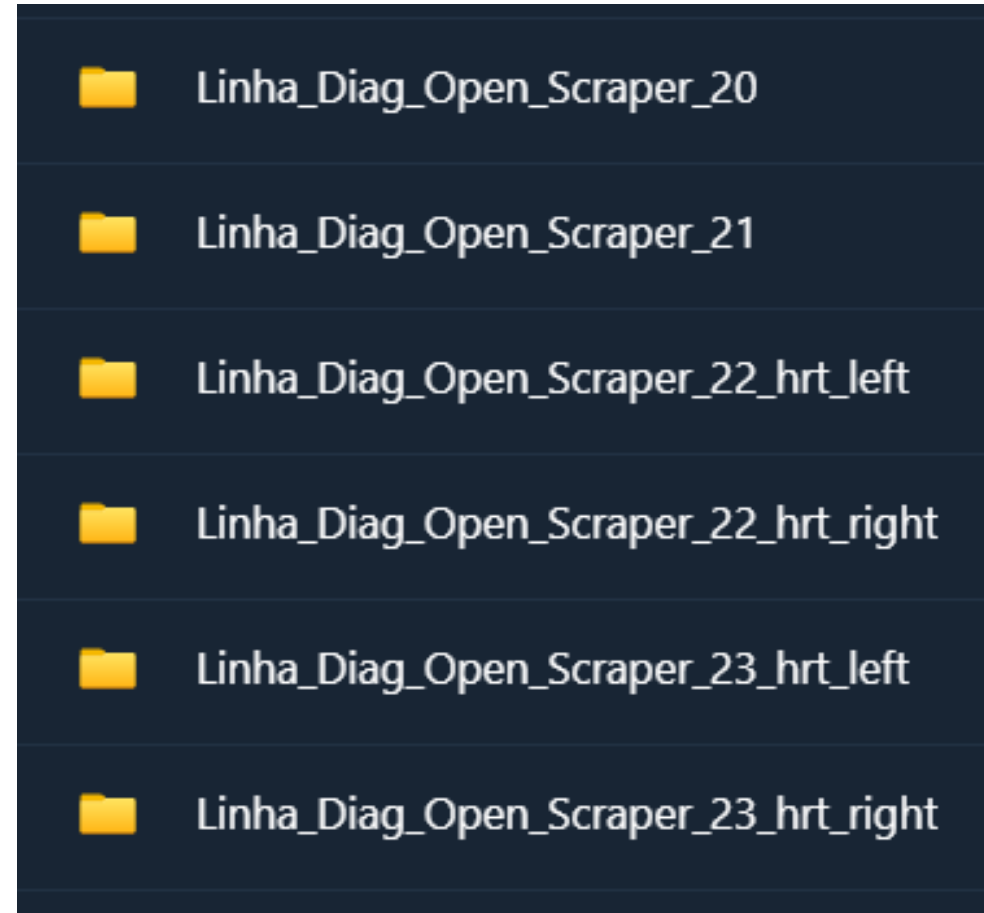
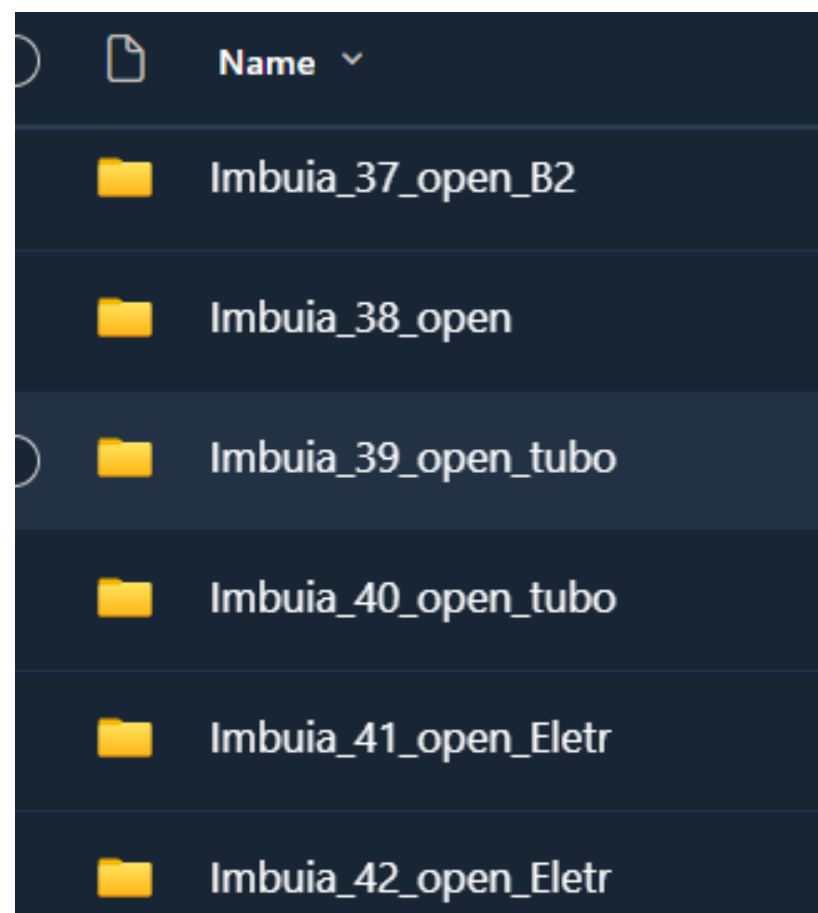
# Final Remarks

Monitor operational doses continuously, to confirm the effectiveness of the implemented shielding and to refine shielding models for future non-standard beamlines.

The methodology demonstrated here can be directly applied to future beamlines. CEDRO and TATU beamline are examples which adopted the IMBUIA's shielding solution. The design principles and optimization strategies remain adaptable.

This approach also enables greater flexibility in designing innovative beamlines, allowing the development of new types of light sources or extraction schemes without compromising on radiation safety or operational quality.

# ... and be careful with the creativity



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# Obrigada!

Authors: Isabela Moraes and Fernando  
Bacchim



MINISTRY OF  
SCIENCE TECHNOLOGY  
AND INNOVATION

