

WP3 : Target Station and Pion Extraction

Eric Baussan (Coordinator) & Tamer Tolba (Co-coordinator)

***ESSnuSB+
4th Annual Meeting
Wik Castle (5-9/10/2026)***

WP3 : Target Station and Pion Extraction

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1. Overview of the Target Station Facility
2. Deliverables & Milestones
3. WP3 Activities
4. Answer to comments by the international advisory panel after 2nd Annual meeting

Work package number	3	Lead beneficiary:				1		
Work package title	Target Station and pion extraction							
Participant number	1	9	15	2	20			
Short name of participant	CNRS	UHH	CERN	UNISTRA	ESSB			
Person/months per participant:	46	52	14	12	7			
Start month:	1			End month:		48		

Task List

- 3.1: Coordination of the Target Station WP (CNRS)
- 3.2: Adapt the ESSvSB target station to the pion production requirements (CNRS, UHH, UNISTRA)
- 3.3: Investigate pion Extraction and Initial Focusing System (UHH, CNRS, CERN, UNISTRA)
- 3.4: Target Station Facility (CNRS, ESSB, UHH, UNISTRA)

Deliverables

- D3.1: Optimize the ESSvSB+ horn design and its pulse generator, month 18
- D3.2: Design of the pion Extraction and Initial Focusing Systems, month 24
- D3.3: Design of the Target Station, month 46.

Meetings:

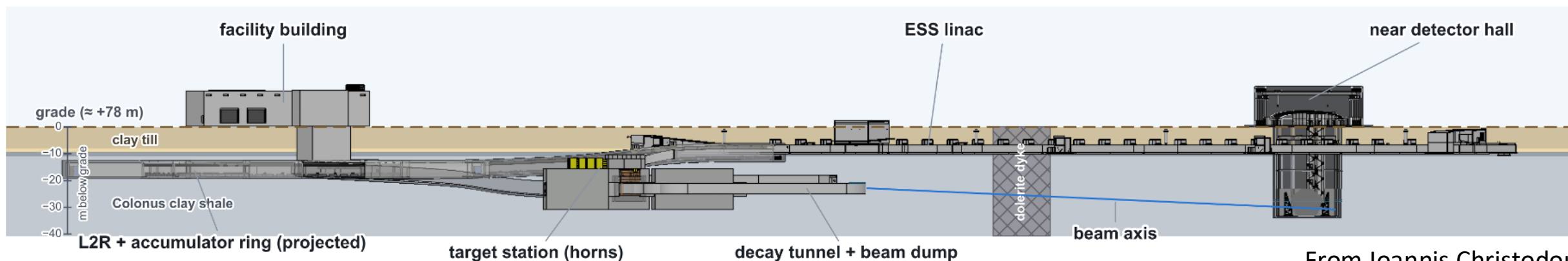
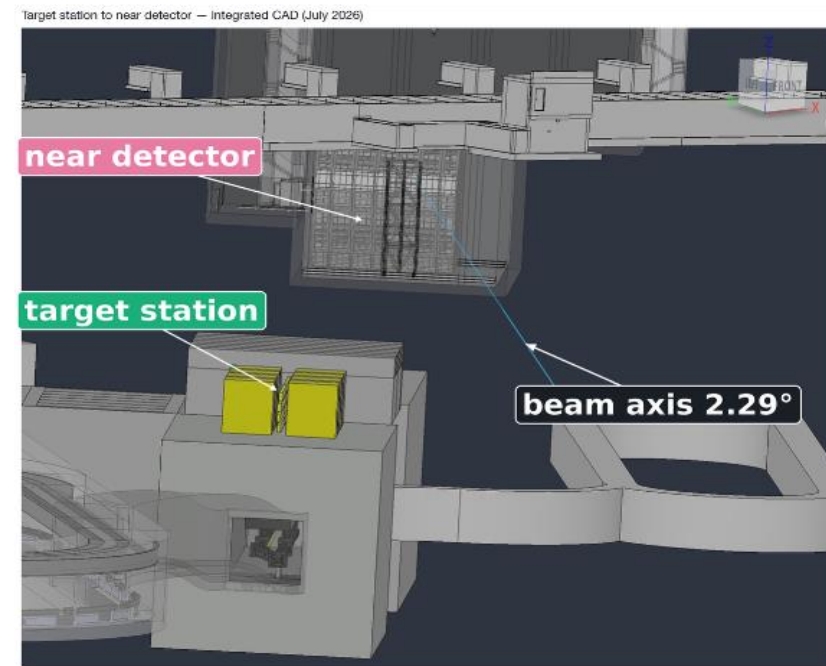
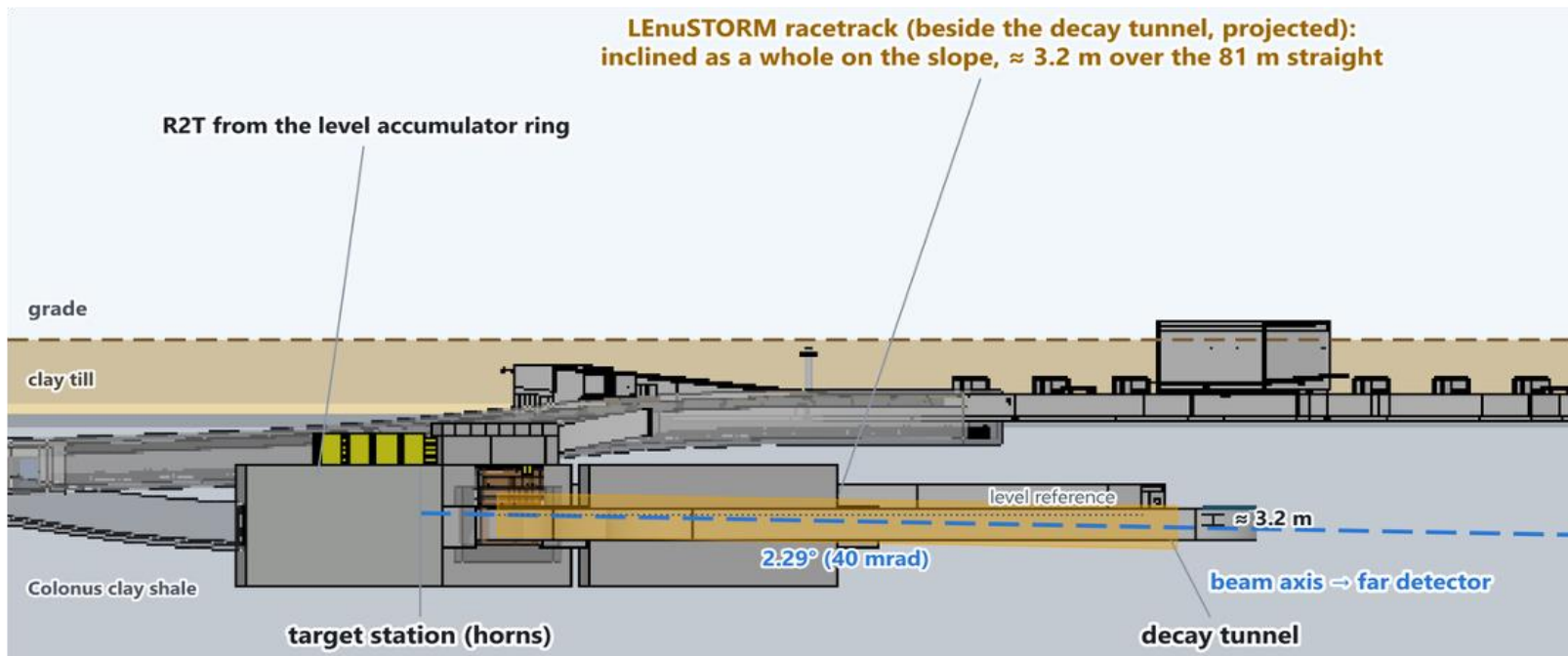
During the last annual year, 7 meetings were organized in total. After the 3rd Annual Meeting :

- 24th WP3+ Meeting 3rd February 2026
- 25th WP3+ Meeting 3rd March 2026
- 26th WP3+ Meeting 7th April 2026
- 27th WP3+ Meeting 5th May 2026
- 28th WP3+ Meeting 9th June 2026
- 29th WP3+ Meeting 7th July 2026
- 30th WP3+ Meeting 15th September 2026

Conferences:

- [IPAC 2026](#) : " **ESSNUSB+: Target Station Study** " – J. Hiegel- Poster - Deauville (France)
- [NUFACT2026](#): " **Carving a Neutrino Factory: A Multi-Disciplinary Conceptual Design Methodology for ESSnuSB** " – I. Christodoulou - Talk - Shanghai (China) - WP2/WP3

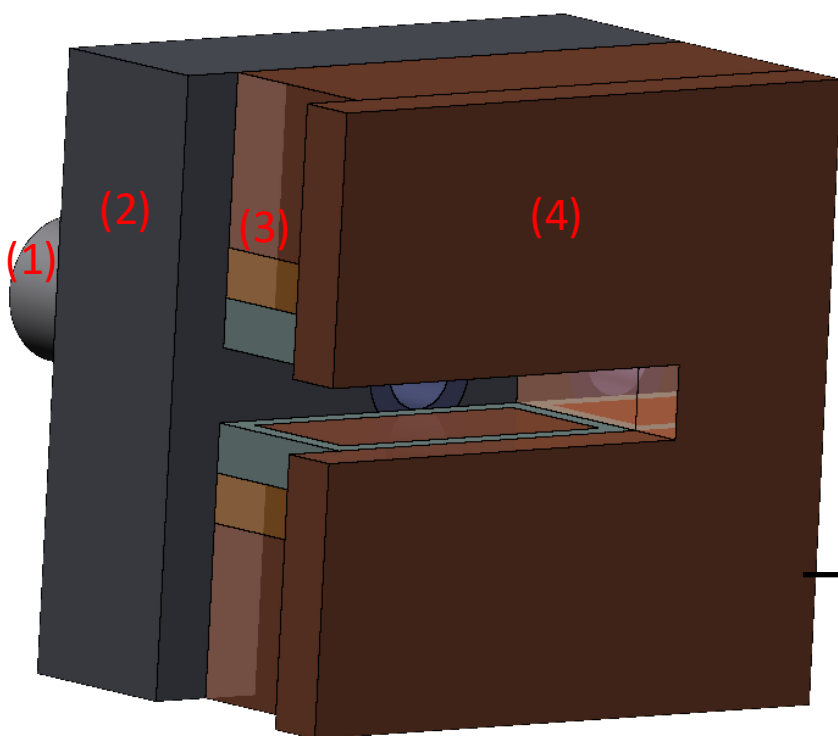
DELIVERABLES MILESTONES	DEADLINE	YEAR	DESCRIPTION OF THE TASK	PARTNER RESPONSABILITY	STATUS
D 3.1	M18	2024	Optimize the ESSnuSB+ horn design and its pulse generator.	CNRS	Delivered
D 3.2	M24	2024	Design of the pion extraction and focussing systems.	UHH	Delivered (M27)
D 3.3	M46	2026	Design of the Target Station.	CNRS	31/10/2026
MS 2	M12	2023	First design of the hadron collector.	CNRS	Delivered
MS 9	M24	2024	Preliminary design of the pion extraction and focusing system	CNRS	Delivered
MS 22	M36	2025	Final estimation of the pion beam	CNRS	Delivered
MS 24	M42	2026	Evaluation of the baseline design of the target station	CNRS	Delivered



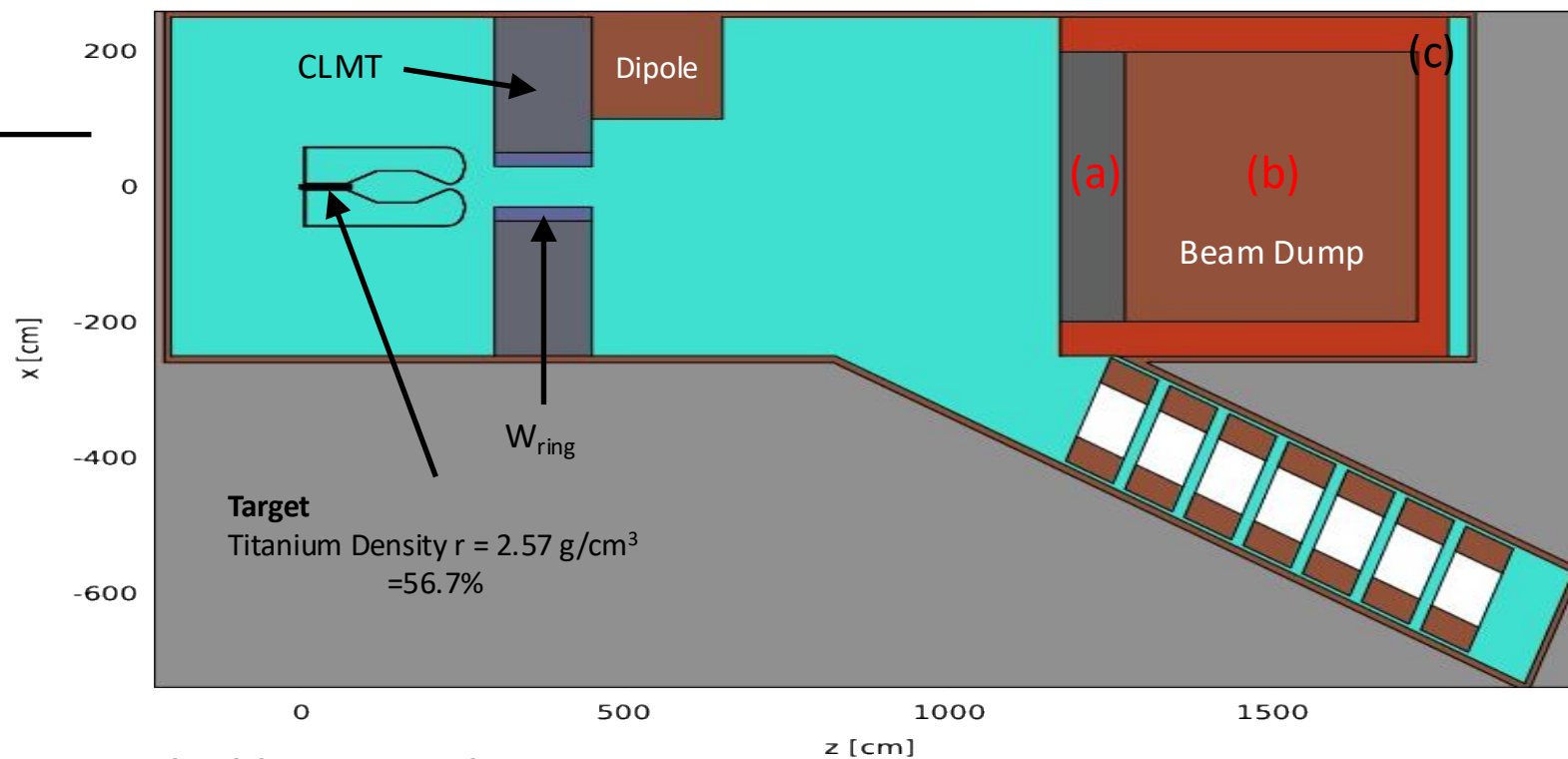
From Ioannis Christodoulou

Target Station – T2R

- Beam Dump Materials:
- Carbon (a), Iron (b) and CuCr1Zr (c)



Large Aperture Dipole

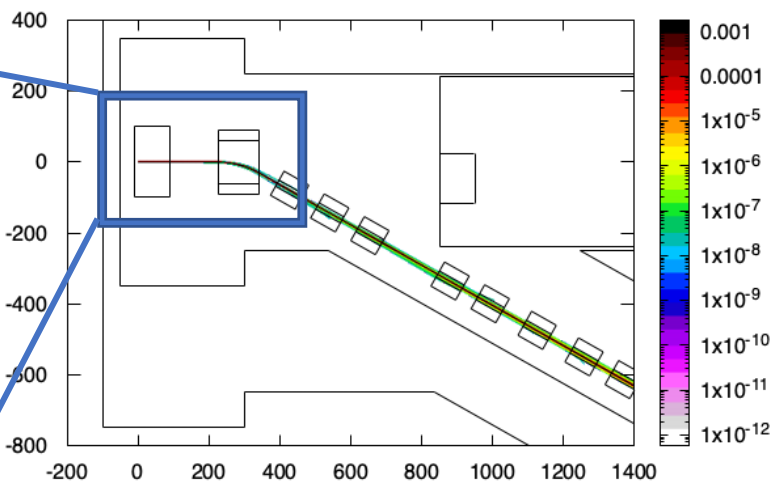
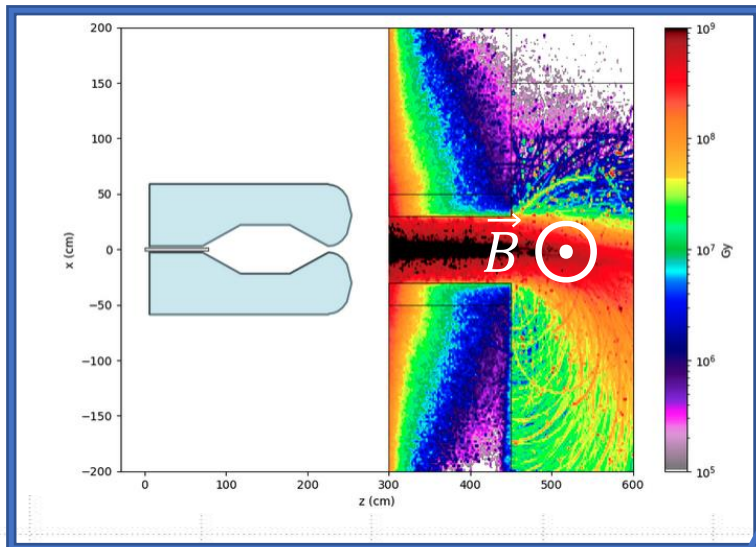


Shielding – Dipole system

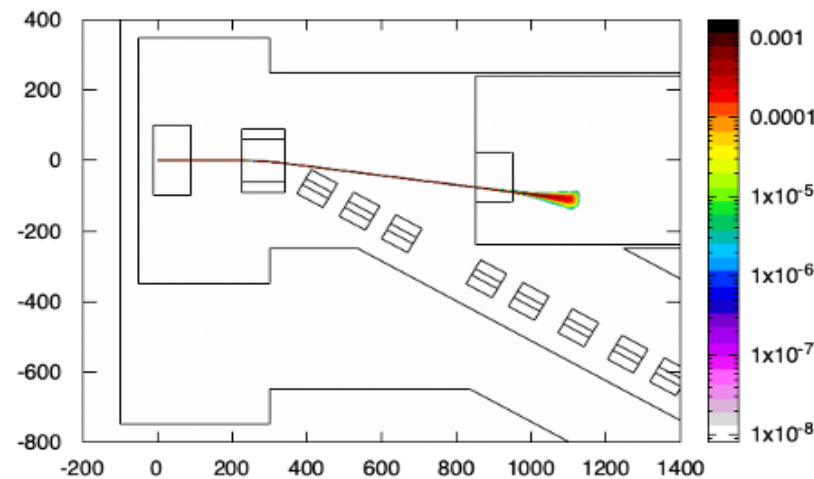
From left to right :

- (1) Horn
- (2) Shield (90% SS 316L + 10% H₂O) + W ring (85% W, 5% Ta, 10% H₂O)
- (3) Dipole: Yoke (Fe), W shield (W) and coils (Co)
- (4) Downstream shield (Fe)

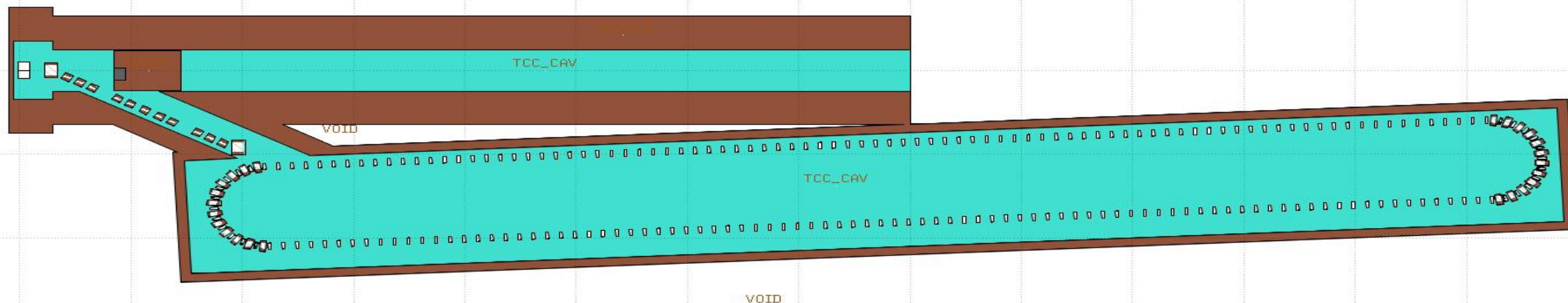
Race track ring (LENuSTORM)



Trajectory of the selected secondaries (pion) along the target to ring transfer line.



The trajectory of the non-interacted, primary proton beam.



Deliverable 3.3 : Design of the Target Station (M46)

1. Overview
2. Target Station
 1. Magnetic Horn
 2. Granular Target Concept
 3. Target-Horn Integration
 4. Power Supply Unit
3. Large Aperture Dipole Magnet
4. Target To Transfer Ring Line
5. Civil Engineering
6. Perspective for Improvement
7. Conclusion
8. References

Will be used as baseline for the CDR



Co-funded by
the European Union

Project Number:
101094628

Project Acronym:
ESSnuSBplus

Call Identifier:
HORIZON-INFRA-2022-DEV-01

Project Full Title:
Study of the use of the ESS facility to accurately measure the neutrino cross sections for ESSnuSB leptonic CP violation measurements and to perform sterile neutrino searches and astroparticle physics

Start date of project: 2023-01-01

Duration: 4 years

Milestone title: Final estimation of the pion beam (WP3+)

Due delivery date: 2025-12-31

Actual delivery date: 2025-12-??

Organisation name of lead contractor for this milestone: Centre National de la Recherche Scientifique (CNRS)

Project co-funded by the European Commission within Horizon Europe Framework Programme		
Dissemination level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	
EU-RES	Classified information: RESTREINT UE (Commission Decision 2005/444/EC)	
EU-CON	Classified information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)	
EU-SEC	Classified information: SECRET UE (Commission Decision 2005/444/EC)	

Milestone number	M22
Milestone name	Final estimation of the pion beam
Type of document	Report
Work Package	WP3: Target Station & Pion Extraction
Lead Contractor	CNRS, France
Lead Coordinators	UU Sweden, CERN Geneva

ESSnuSB+ GA10109462 - MS22: Final estimation of the pion beam

WP3 : Target Station and Pion Extraction

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Answers to comments by the international
advisory panel after 3rd Annual Meeting

Response: Steady temperature based on the cooling concept presented in ESSnuSB

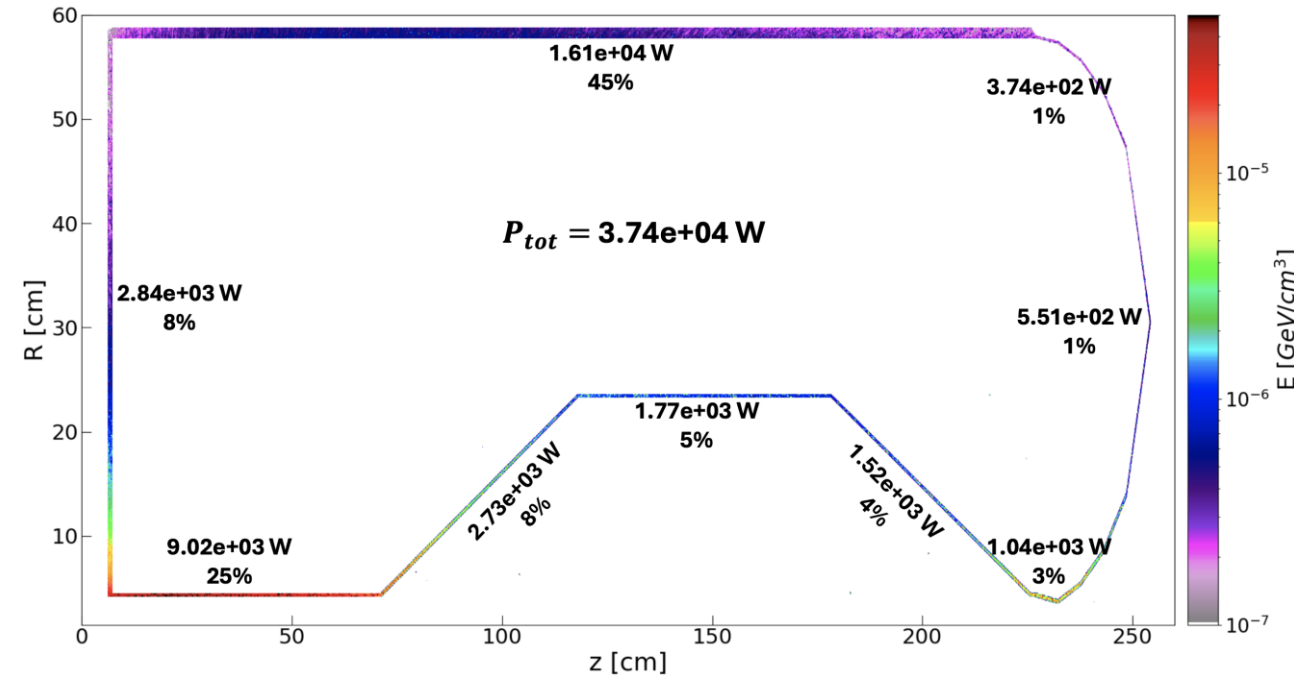
Proton Beam : 1.25 MW, 14 Hz

Horn Material : Aluminum Al T6061-T6

Total power deposition in one horn for:

- ESSnuSB : 50.81 kW (35.85 kW Nuclear and 15 kW Joule)
- ESSnuSB+: 55.82 kW (37.40 kW Nuclear and 18.42 kW Joule).

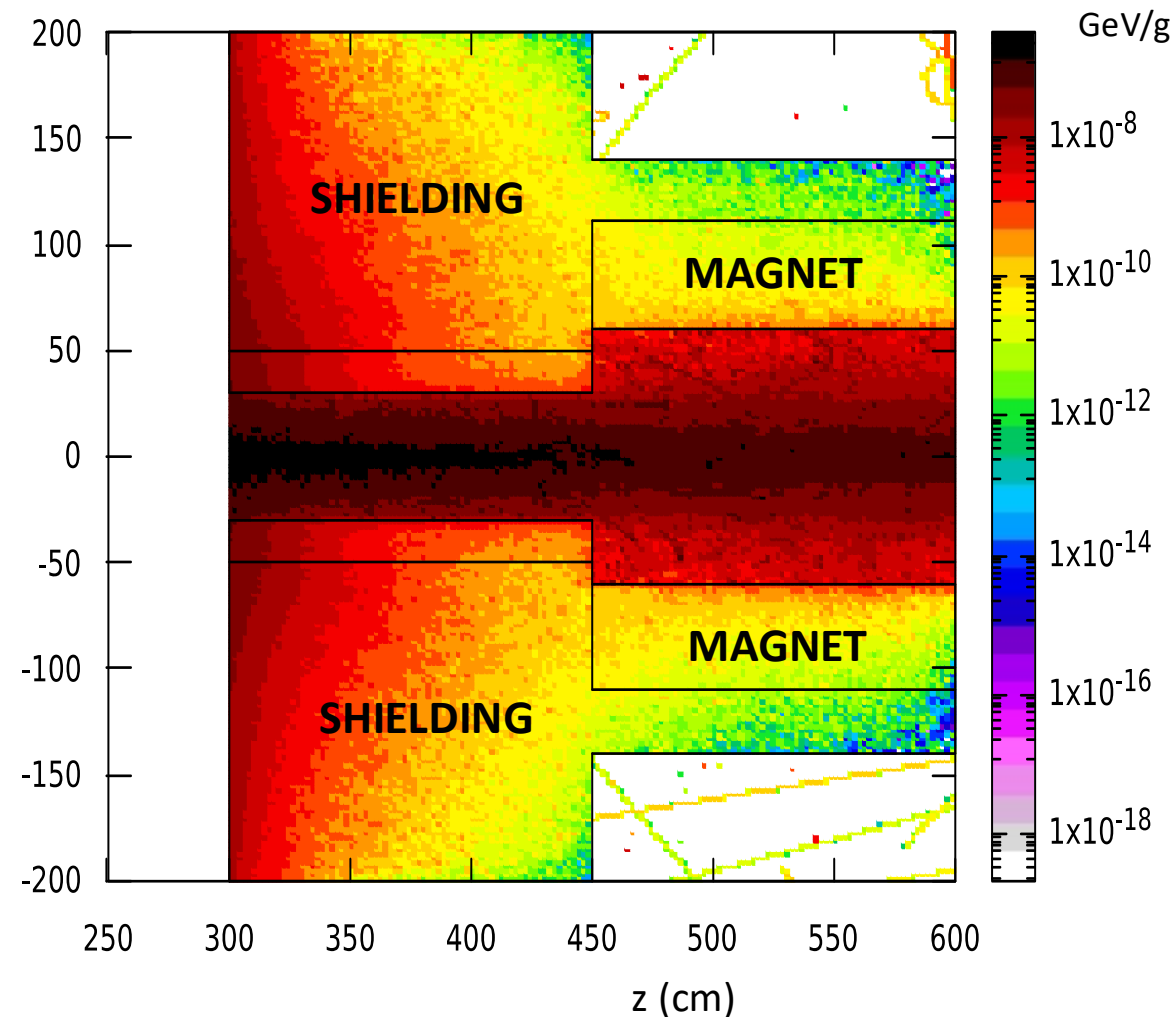
This 10% increase in the total power deposition should be absorbed by the cooling scheme by increasing the water mass flow rate in consequence. The cooling scheme will be adapted to the geometry of the ESSnuSB+ horn shape.



Power Deposition in the ESSnuSB+ Horn
1.25MW - 14 Hz

Response regarding recommendations about the “D3.2: Design of the pion extraction and focusing systems”:

- The coils of the dipole are assumed to be made of Copper. **Polyetheretherketone (PEEK) polymer material is the preliminary assumed magnetic insulation material of the dipole.** Studies (e.g., F. Lawrence, J. Nucl. Mat. 420 (2012) 338–341) have shown that PEEK retains its mechanical properties, such as hardness and tensile strength, even after exposure to irradiation doses up to 10 MGy.
- The dimension of the shielding, in front of the dipole entrance, has been calculated to lower the radiation dose to an acceptable level for the LADM elements and to maintain the transmitted pions as high as possible.



Response regarding recommendations about the “D3.2: Design of the pion extraction and focusing systems”:

- Updated FLUKA simulations have been performed **using revised material compositions and an updated geometry**, including modifications of the bending magnet design.
- The updated material cards include the proposed cooling-related compound materials, with stainless steel 316L and water considered for the collimator region and a tungsten-based compound for the shielding components.
- The collimator geometry remains unchanged **with an added tungsten ring** (element in gray color in Figure 2). The magnet has also been modified by incorporating a tungsten shielding component to provide additional protection for the coils.

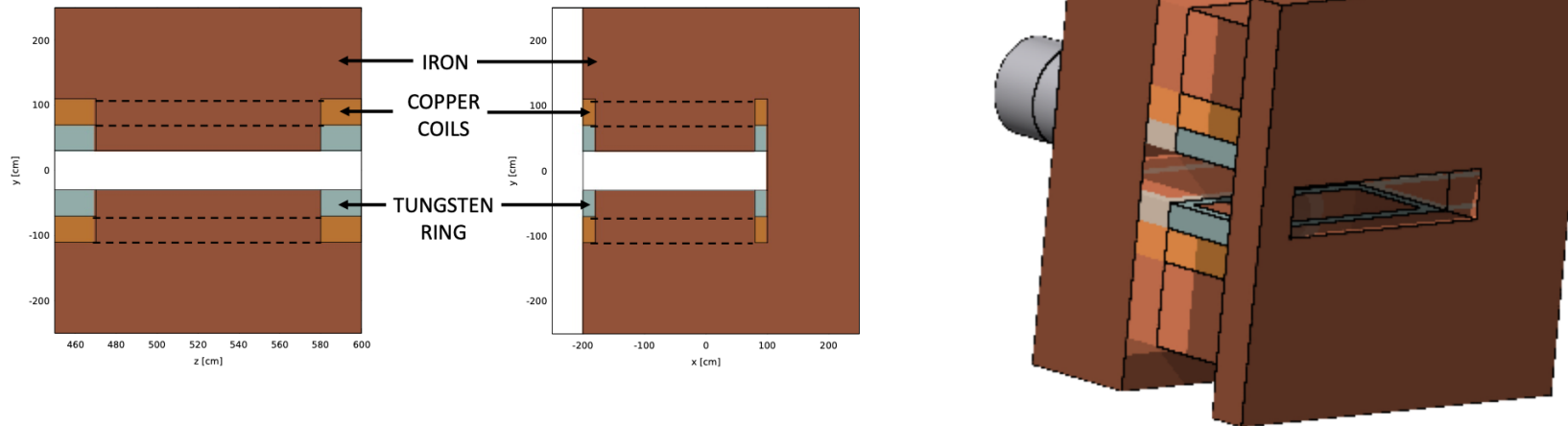
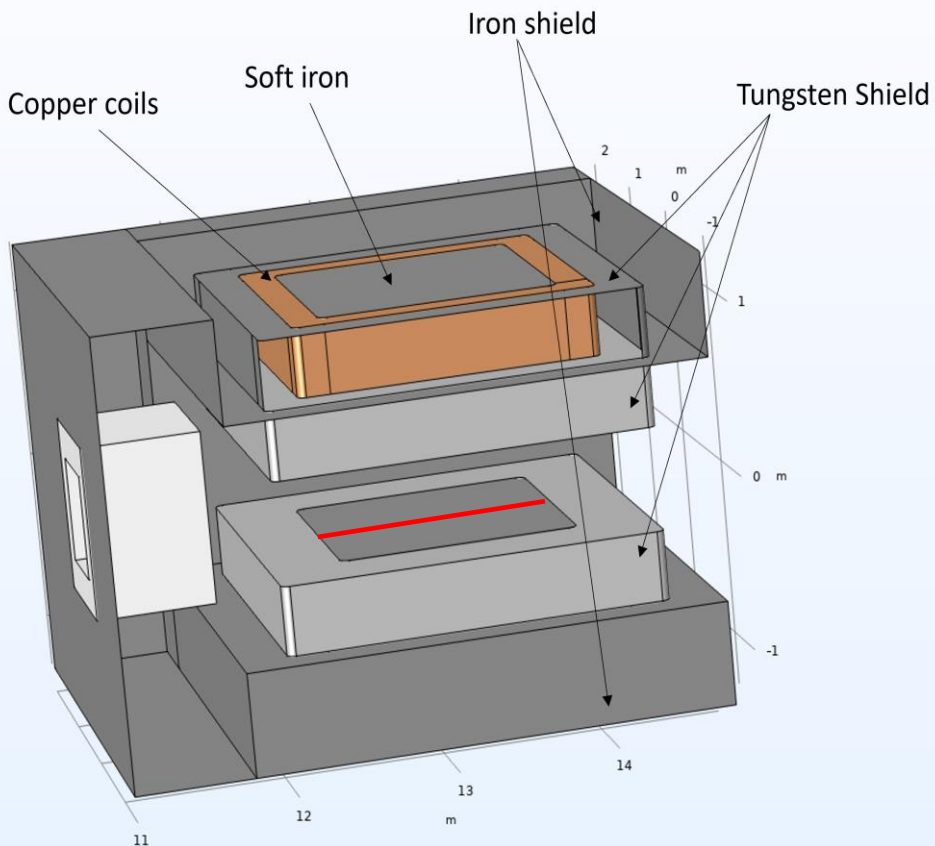
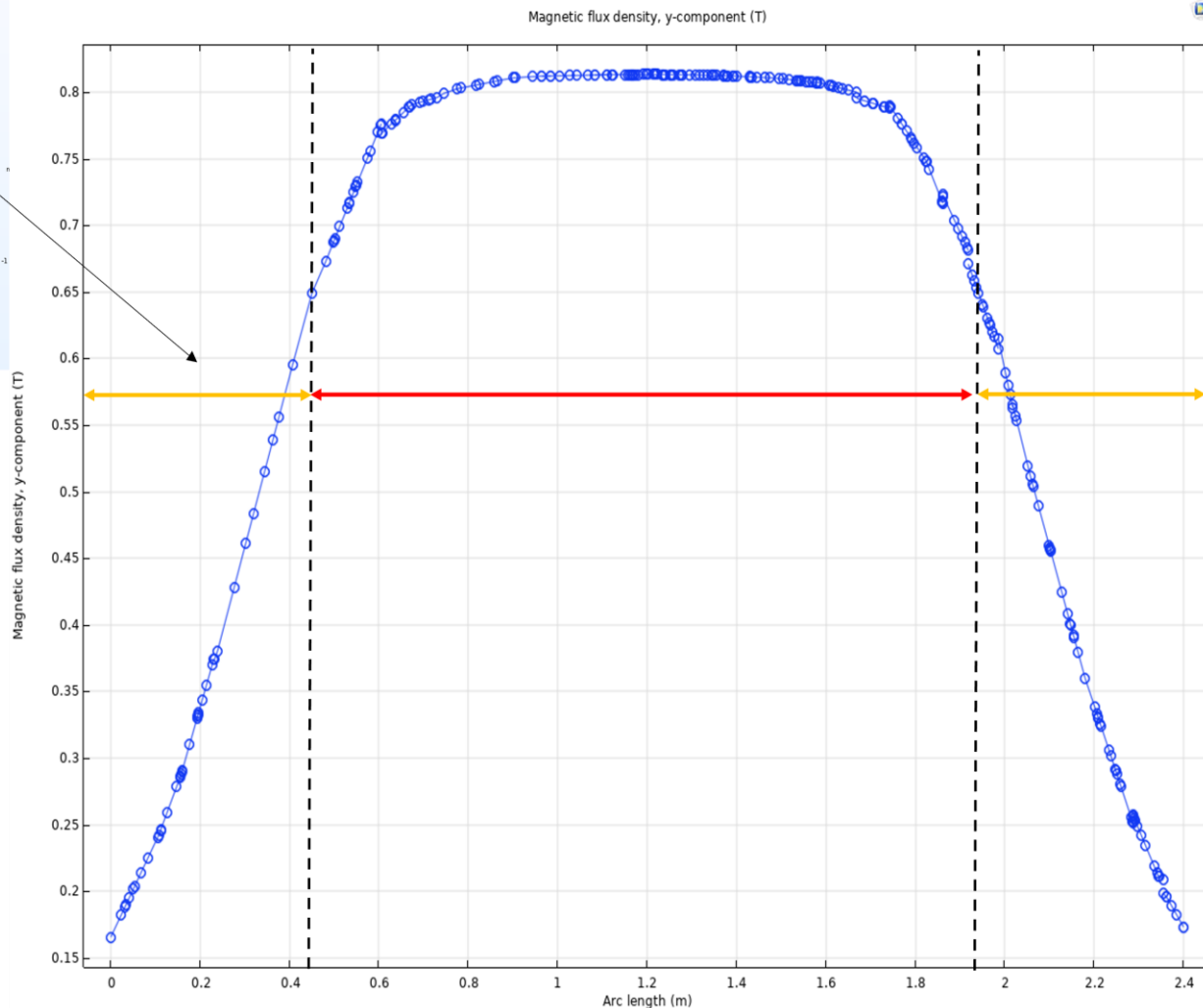


Figure 2 : 2D view of the Large Aperture Magnet Dipole (Left) Large Aperture Dipole Magnet 3D view (Right)

Response regarding recommendations about the “D3.2: Design of the pion extraction and focusing systems”:



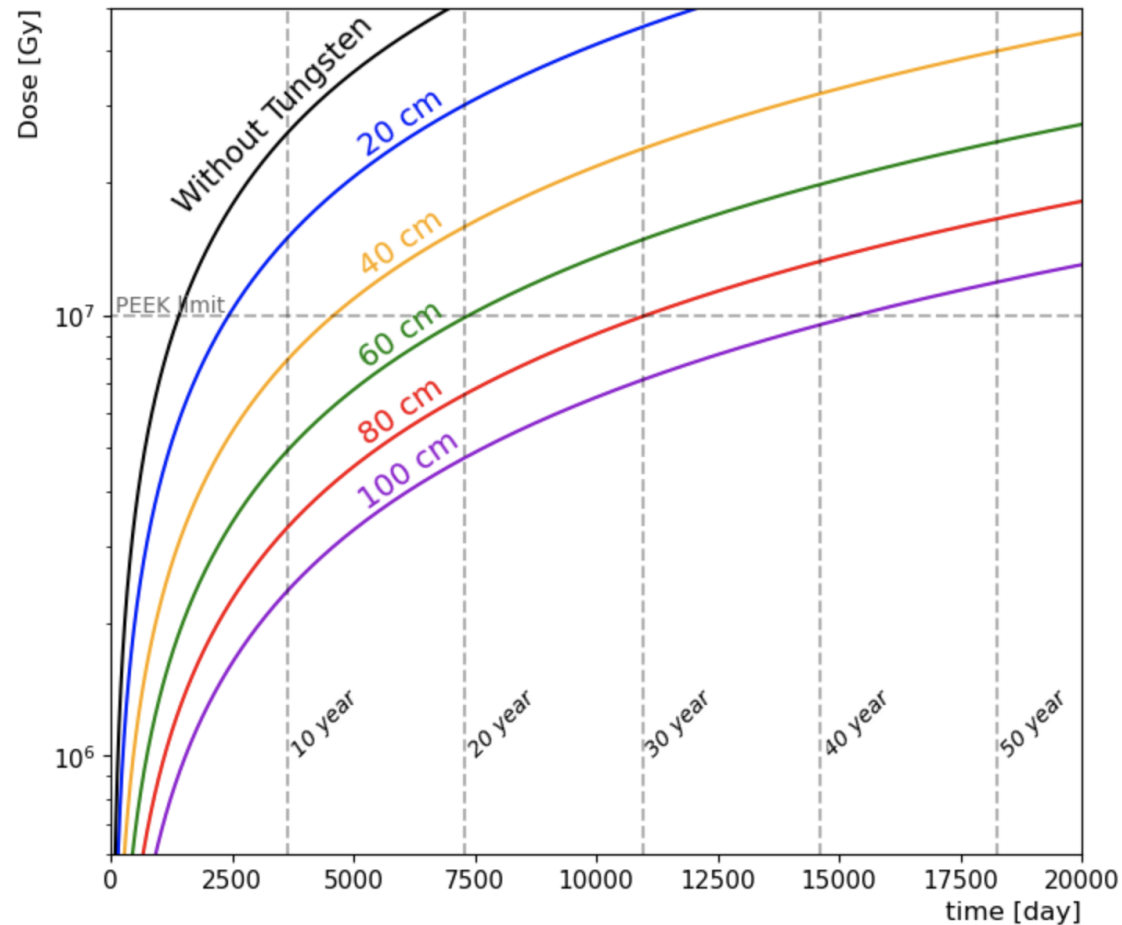
COMSOL Geometry



Response regarding recommendations about the “D3.2: Design of the pion extraction and focusing systems”:

Updated estimation of the radiation dose obtained for the components exposed to the highest radiation levels :

- Dose in the copper conductor : $2.53 \cdot 10^{-2}$ Gy/s corresponding to an accumulated dose of approximately $2.18 \cdot 10^3$ Gy/day.
- Considering the radiation tolerance limit of the PEEK electrical insulation material this dose level corresponds to an indicative operational lifetime of approximately 4000 days (see Figure).
- It should be noted, however, that the PEEK electrical insulation has not yet been explicitly implemented in the FLUKA geometry. Consequently, this lifetime estimate is based on the dose calculated in the copper conductor and should only be regarded as a first-order approximation.



=> A dedicated assessment of the dose deposited in the insulation material will be performed once the corresponding geometry is implemented.

Figure : Evolution of dose with time

Response regarding recommendations about the “D3.2: Design of the pion extraction and focusing systems”:

Power Deposition in the Facility

Component Deposited	Power [kW]	Standard Error [W]
Target	124	18.9
Horn	34.4	11.8
Collimator	294	87.0
Bending Magnet (coils)	0.15	0.7
Beam Dump (Graphite)	148	81.8
Beam Dump (Iron)	82	54.4
Beam Dump (Copper Alloy)	8.22	14.8

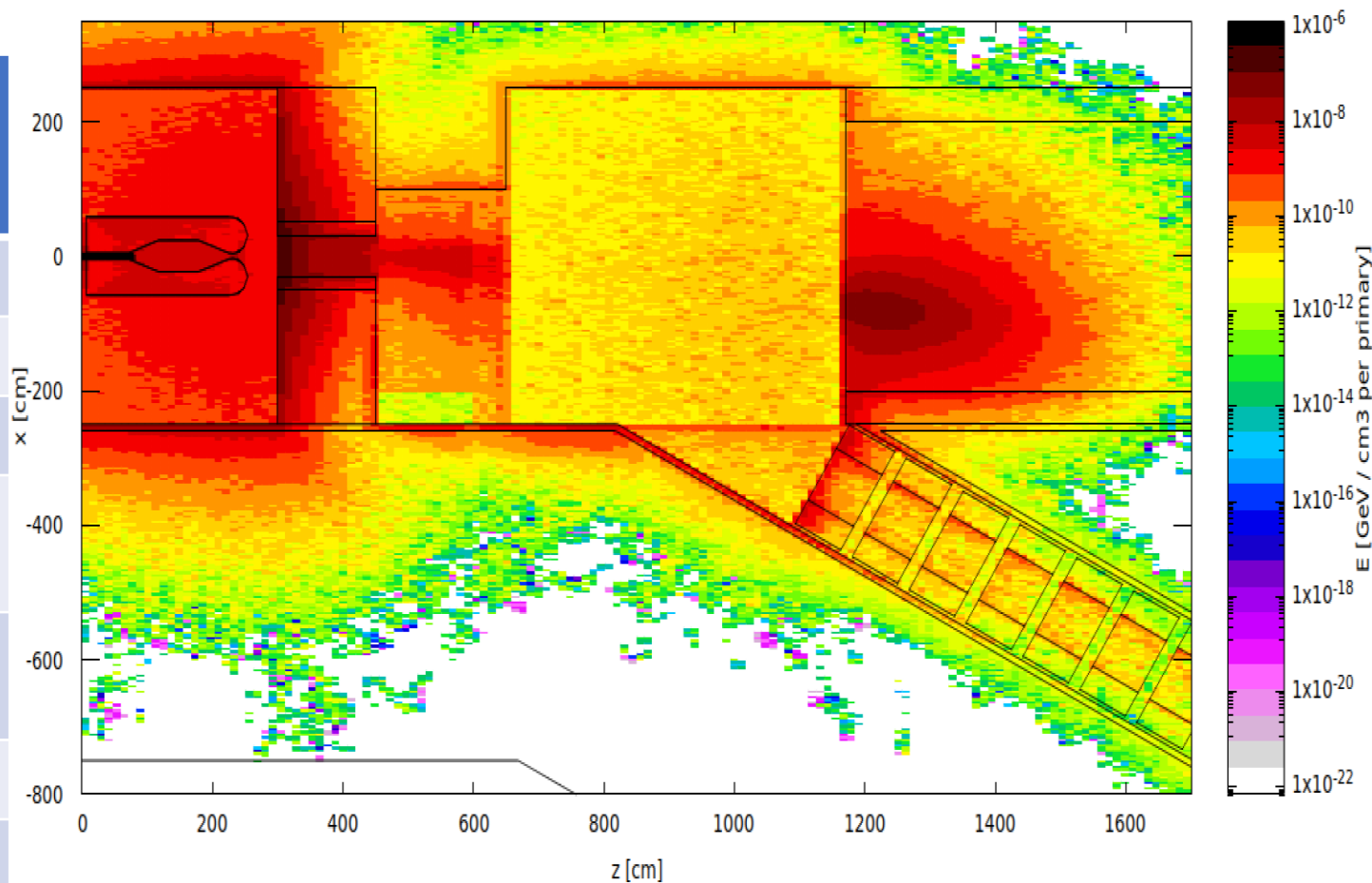


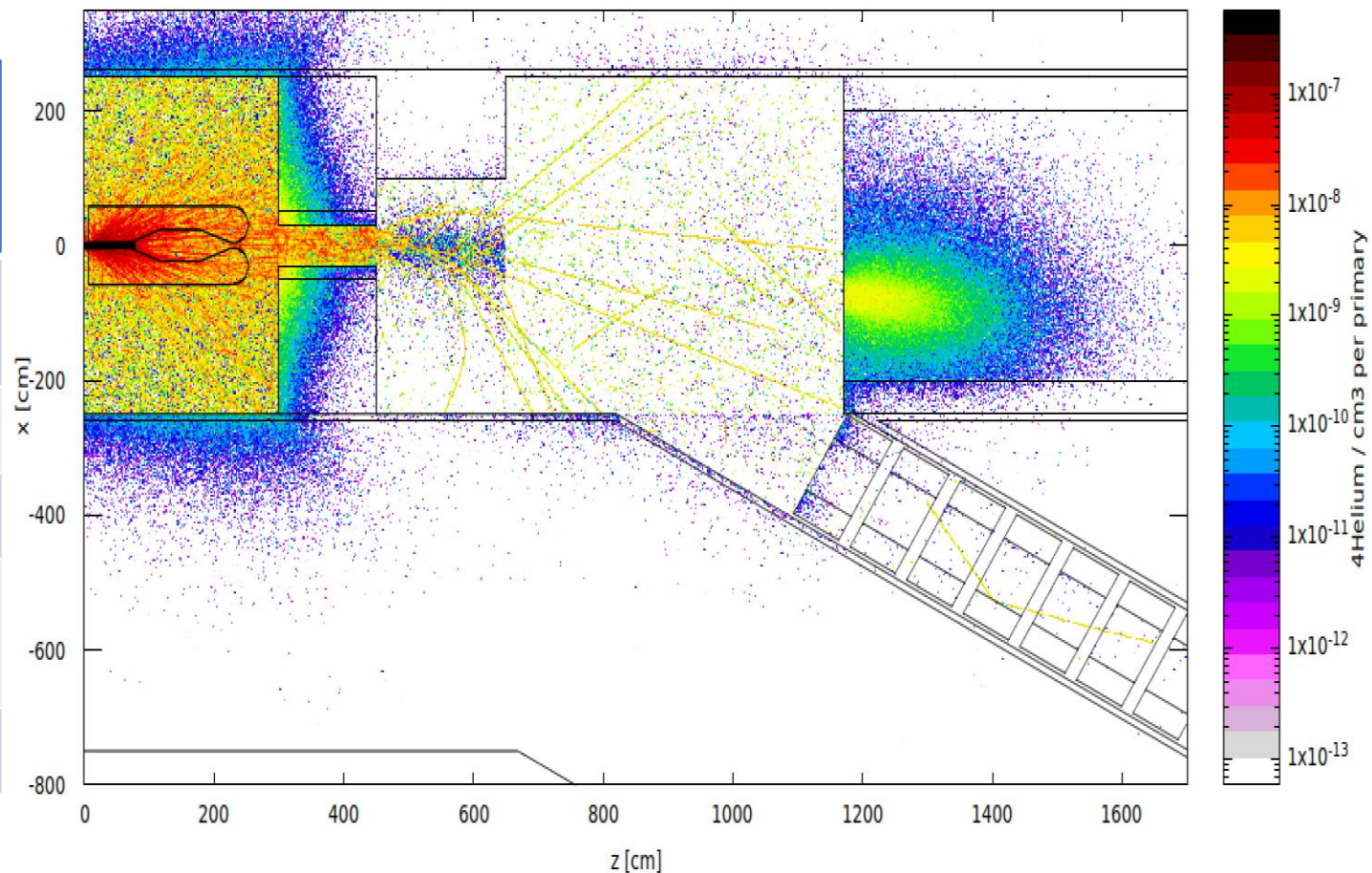
Figure : Energy deposition in the whole facility

Response regarding recommendations about the “D3.2: Design of the pion extraction and focusing systems”:

Displacement per atoms evaluation

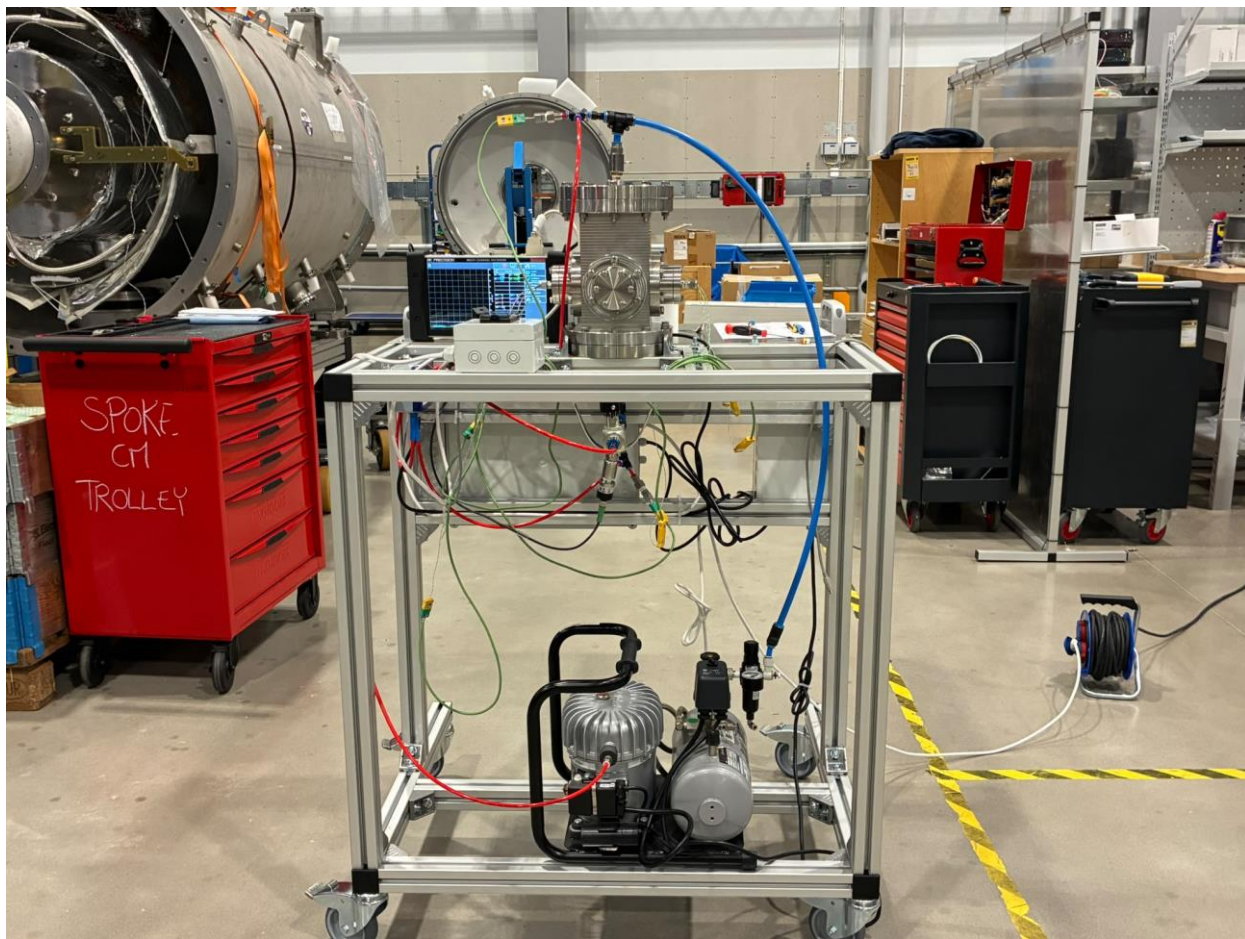
Target Station Component	DPA [s]	DPA [/day]
CLMT (stainless steel part)	1.58e-03	1.37e+02
CLMT (Tungsten part)	1.71e-04	1.48e+01
Magnet (Tungsten part)	2.93e-05	2.53e+00
MAGNET (Iron part)	8.00e-05	6.91e+00
MAGNET (Copper part)	3.02e-06	2.61e-01

Significant production of DPA and gas production like Helium which will impact lifetime of elements

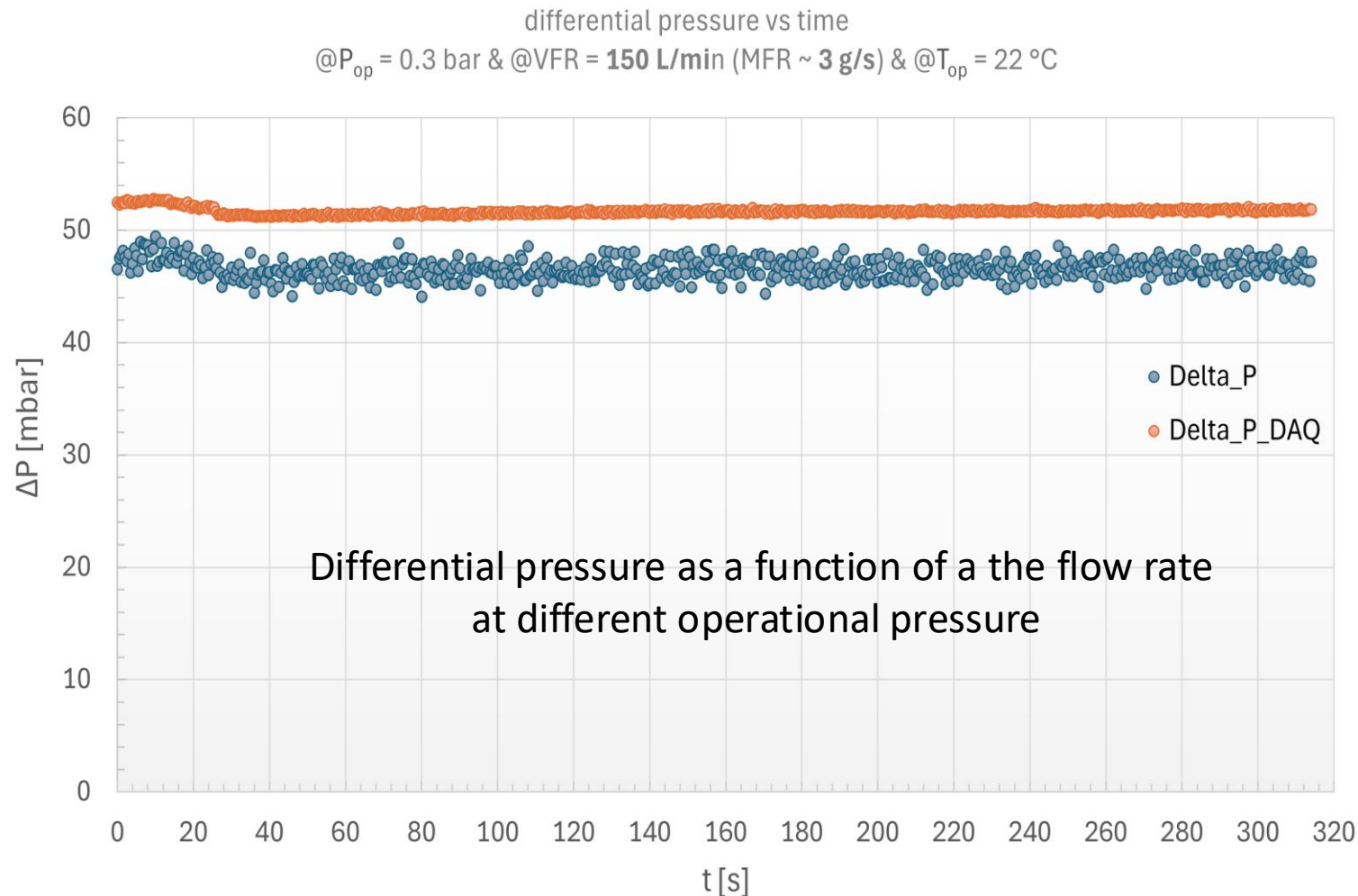


Helium production in the whole facility

Response regarding ETTF Experimental Setup : Data taking started with air

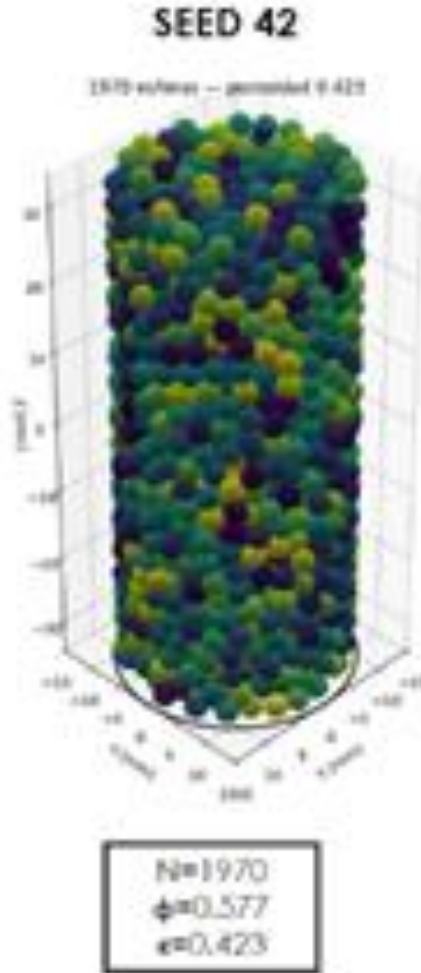


Response regarding ETTF Experimental Setup : Data taking started with air



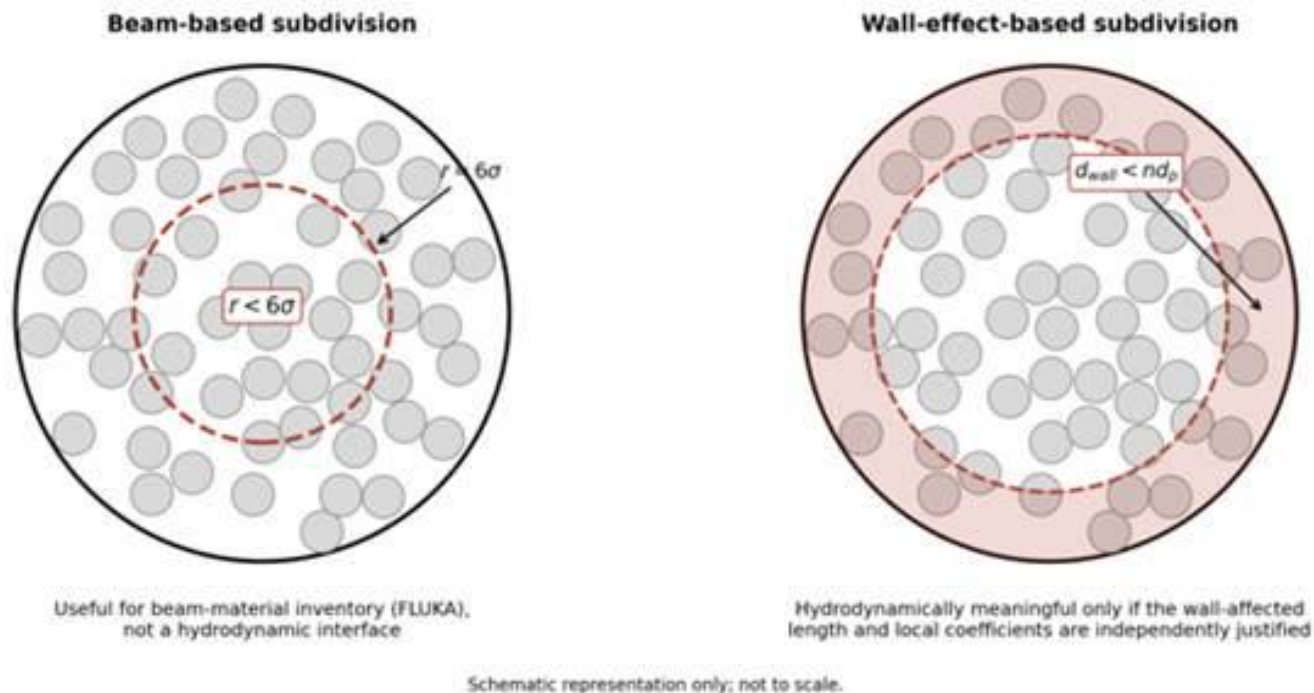
Response : Regarding the consistency between simulations

- A porosity study was carried out and it showed that previous theoretical value of 0.34 has been underestimated
- Porosity estimated with packing script is around 0.423 (1970 fitted in the considered volume).
- Porosity checked experimentally around 0.433 (1970 fitted in the considered volume) in a static and by vibrations



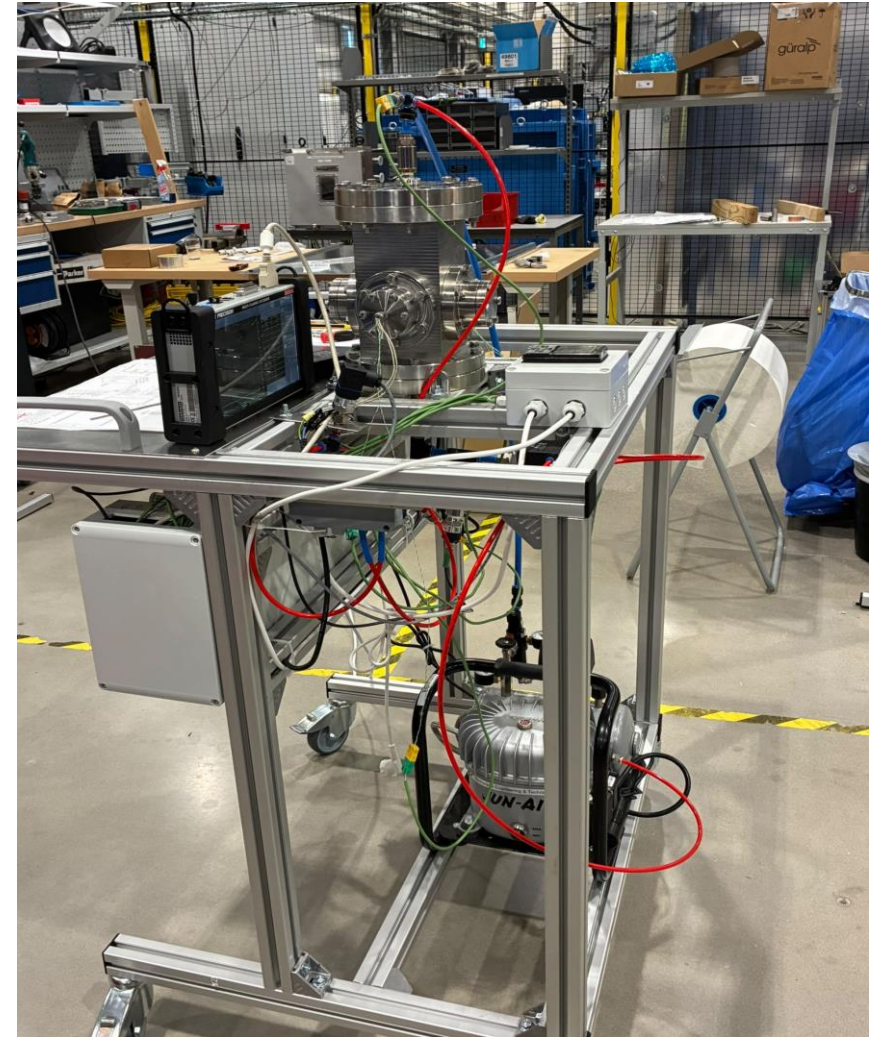
Response : Regarding the consistency between simulations

- Dividing the target into several layers of different density could influence the particle production but have a limited impact.
- This subdivision in 6s **does not represent a physical or hydrodynamic boundary**.
- The complex flow is modelled by means of the **Darcy-Forchheimer porous media approximation** which has some limitations related to **wall effects, entrance/exit losses, anisotropy, property constancy, and thermal coupling**.
- **Two CFD analyses** have been conducted in parallel to estimate the porosity:
 - one considering a **homogeneous porous media**
 - one solving **the helium flow through the interstitial voids space around modelled spheres** (the heterogeneous distribution is obtained by means of a Lubachevsky–Stillinger (LS) packing algorithm).



Response : Regarding the commercial helium compressor

- For the first ETTF phase, no additional compressor market survey is required, since **the air compressor is already provided** by ESS and the campaign will **operate at 0.30–0.35 bar(g), with a protected maximum pressure of 0.45 bar(g)**. The expected pressure drop during this air phase is only of the order of 1–10 mbar.
- This experimental campaign will be used to **validate the CFD predictions** and the **estimated pressure-drop behavior**. Based on these results, the **helium operating point will be refined**, and a **commercial helium compressor market survey will then be performed**.
- The final selection will be confirmed against the **required mass flow, suction pressure and pressure ratio**. Once the helium operating pressure is established, the **vessel and beam-window thicknesses will be verified through the corresponding structural analysis**



Summary

- All documents MS et Deliverables have been delivered
- Next step will be to finalise last deliverable D4.3
- Data Taking with ETTF started recently with air at limited pressure
- Work on the remaining aspects for civil engineering.

The WP3 members would like to thanks to the IAP members for their expertise and valuable comments.