

WP3 : Target Station and Pion Extraction

“Summary Report”

Eric Baussan on behalf WP3+ Members

ESSnuSB+
4th Annual Meeting
Wik’s Castle (05-09/10/2026)

ESSnuSBplus 4th annual meeting

5-9 Oct 2026
Wik castle, Sweden
Europe/Stockholm timezone

 Enter your search term

Overview
Timetable
Zoom links
Venue
Travel information
Contribution List
My Conference
My Contributions
Participant List

Timetable

<	Mon 05/10	Tue 06/10	Wed 07/10	Thu 08/10	Fri 09/10	All days	>
12:00							
13:00							
14:00							
15:00							
16:00							
17:00							
18:00							
19:00							

Agenda of the WP3 session in common with WP4

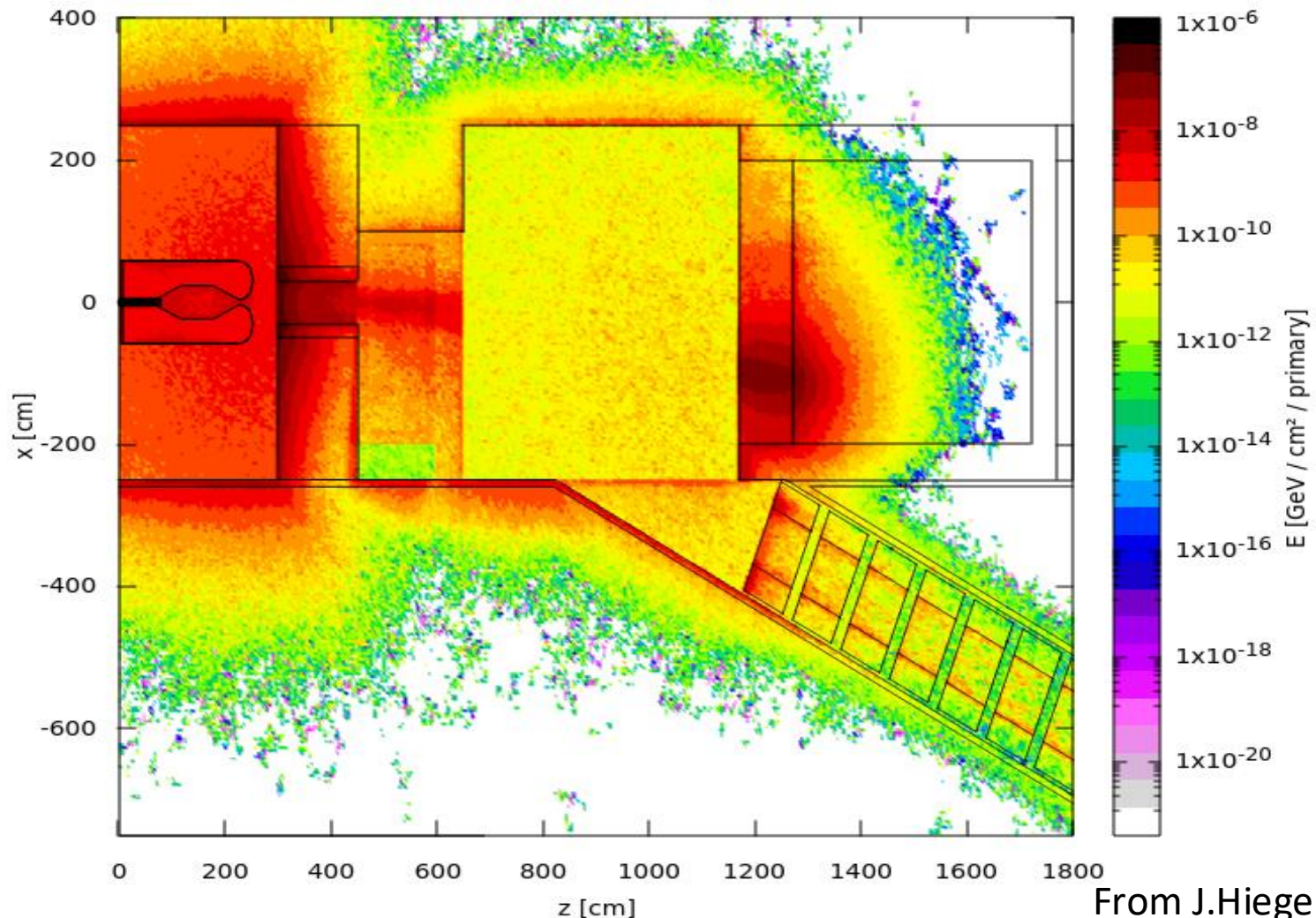
Print PDF Full screen Detailed view Filter

Parallel session B	Parallel session A
Breakfast Wik castle, Sweden 07:00 - 08:30 Implications of CRPA cross-section at FD Marco Vanderpoorten The Knights' Hall 08:30 - 09:00 Implications of 2p2h cross-section at FD Natalie Jachowicz The Knights' Hall 09:00 - 09:30 Coffee break Wik castle, Sweden 09:30 - 10:00 Solar neutrinos Alessio Giannetti The Knights' Hall 10:00 - 10:30 FD simulation and Gd doping Mahesh Jakkapu The Knights' Hall 10:30 - 11:00 Atmospheric neutrinos Sandhya Choubey The Knights' Hall 11:00 - 11:30 Implication of super-scaling cross-section model at FD Elena Abad Diaz The Knights' Hall 11:30 - 12:00 Discussion / Physics Nobel prize announcement The Knights' Hall 12:00 - 12:30	WP4 Introduction Maja Olvegård Anna's Room 08:30 - 08:40 Linac and transfer line upgrades Natalia Milas Anna's Room 08:40 - 09:00 RFQ and DTL Juan Luis Muñoz Anna's Room 09:00 - 09:20 Discussion Anna's Room 09:20 - 09:30 Liouvillean proton injection Elham Salehi Anna's Room 10:00 - 10:30 Laser stripping Anatoly Opanasenko Anna's Room 10:30 - 11:00 Accumulator ring Onur Gilanigullari Anna's Room 11:00 - 11:40 Ring to target transfer line Elian Bouquerel et al. Anna's Room 11:40 - 11:50 Discussion / Physics Nobel prize announcement Anna's Room 11:50 - 12:30

Lunch Wik castle, Sweden 12:30 - 13:30 Implications of GNN at END Peter Christiansen The Knights' Hall 13:30 - 14:00 T114 at J-PARC: Towards ESSnuSB Neutrino Cross-Section Measurement Bruno Kovač Bruno Kovač Recent update on cross-section results and emulsion technology Tsutomu Fukuda Coffee break Wik castle, Sweden 15:00 - 15:30 Discussion on CDR George Fanourakis et al.	WP3 Introduction Eric BAUSSAN Anna's Room 13:30 - 13:40 Granular Target Concept Jorge Aguilar Anna's Room 13:40 - 14:10 Hadronic Collector Julien Hiegel Anna's Room 14:10 - 14:40 Discussion Anna's Room 14:40 - 15:00 Pion transfer line and injection Ilias Efthymiopoulos Anna's Room 15:30 - 16:00 Racetrack ring design Mr Ting Wing Choi
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Target Station Facility Simulation

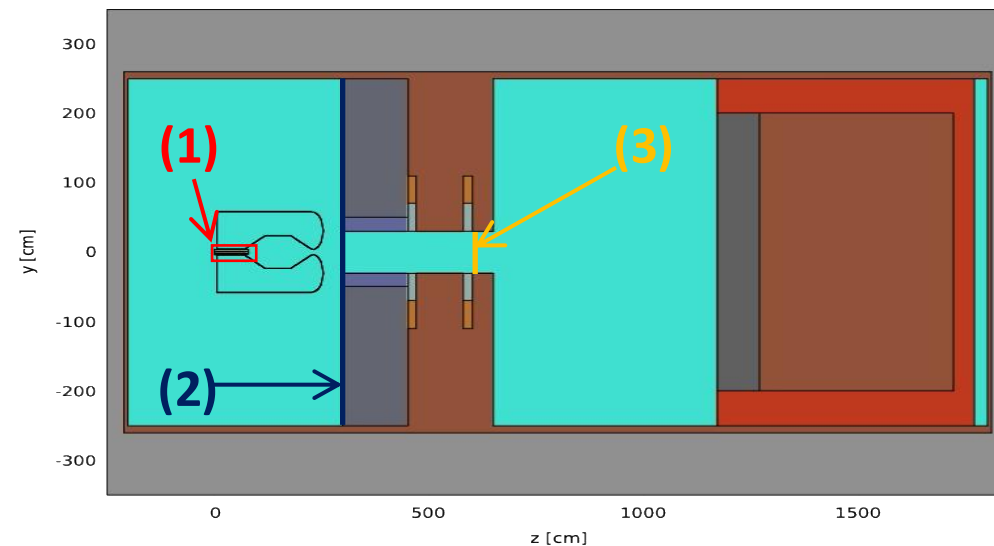
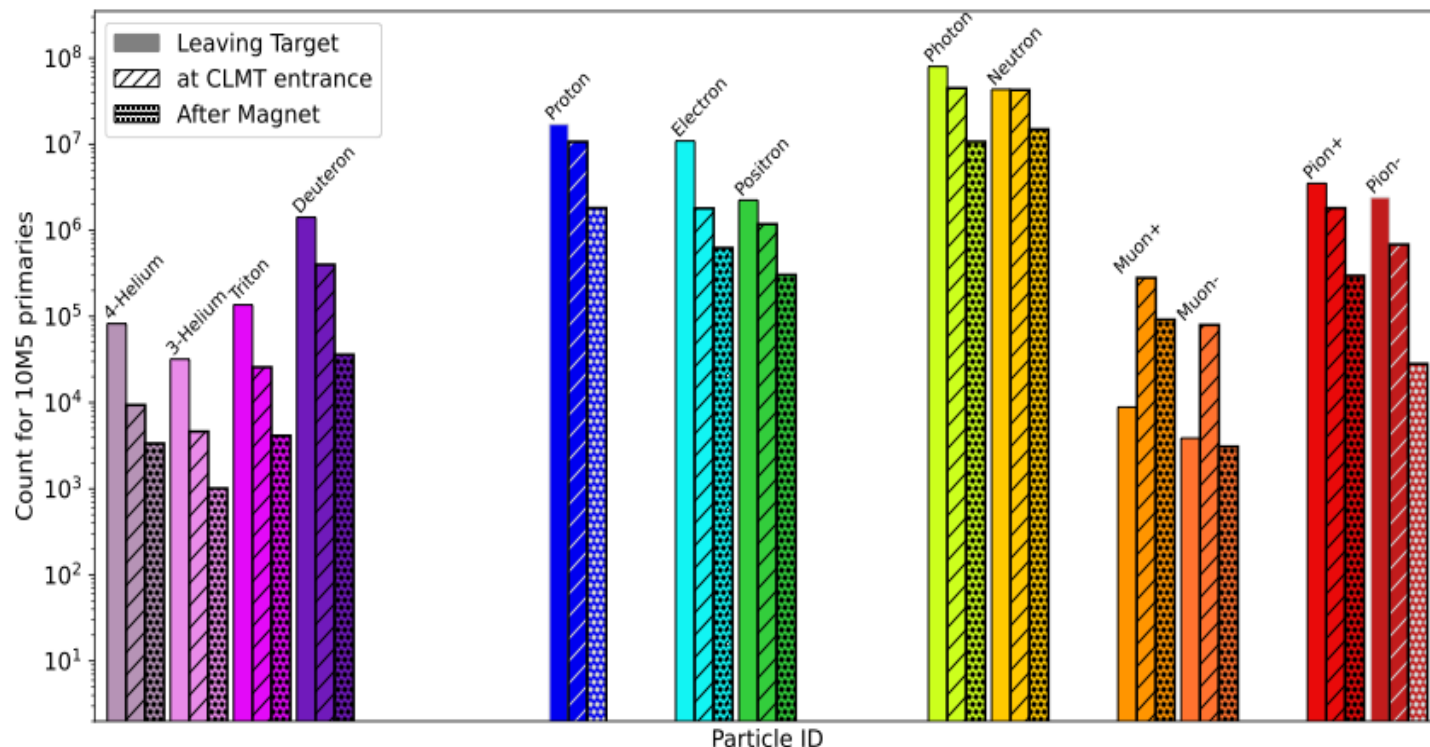
- Pion Distribution
- Power Deposition Study



All p-id distribution

Distributions are monitored at three locations:

- (1) **Leaving the target** : Particle production
- (2) **CLMT entrance** : Particles reaching the collimator, whether inside the aperture or not
- (3) **After the magnet** : Particles leaving the magnetic field of the dipole

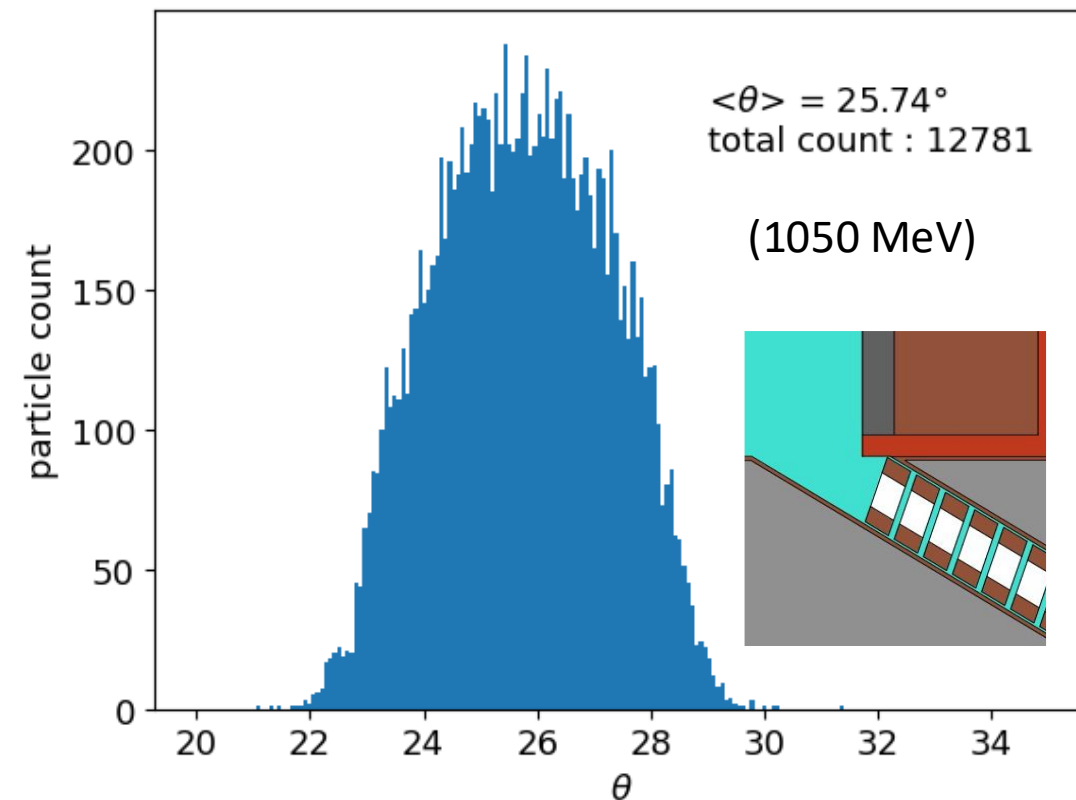
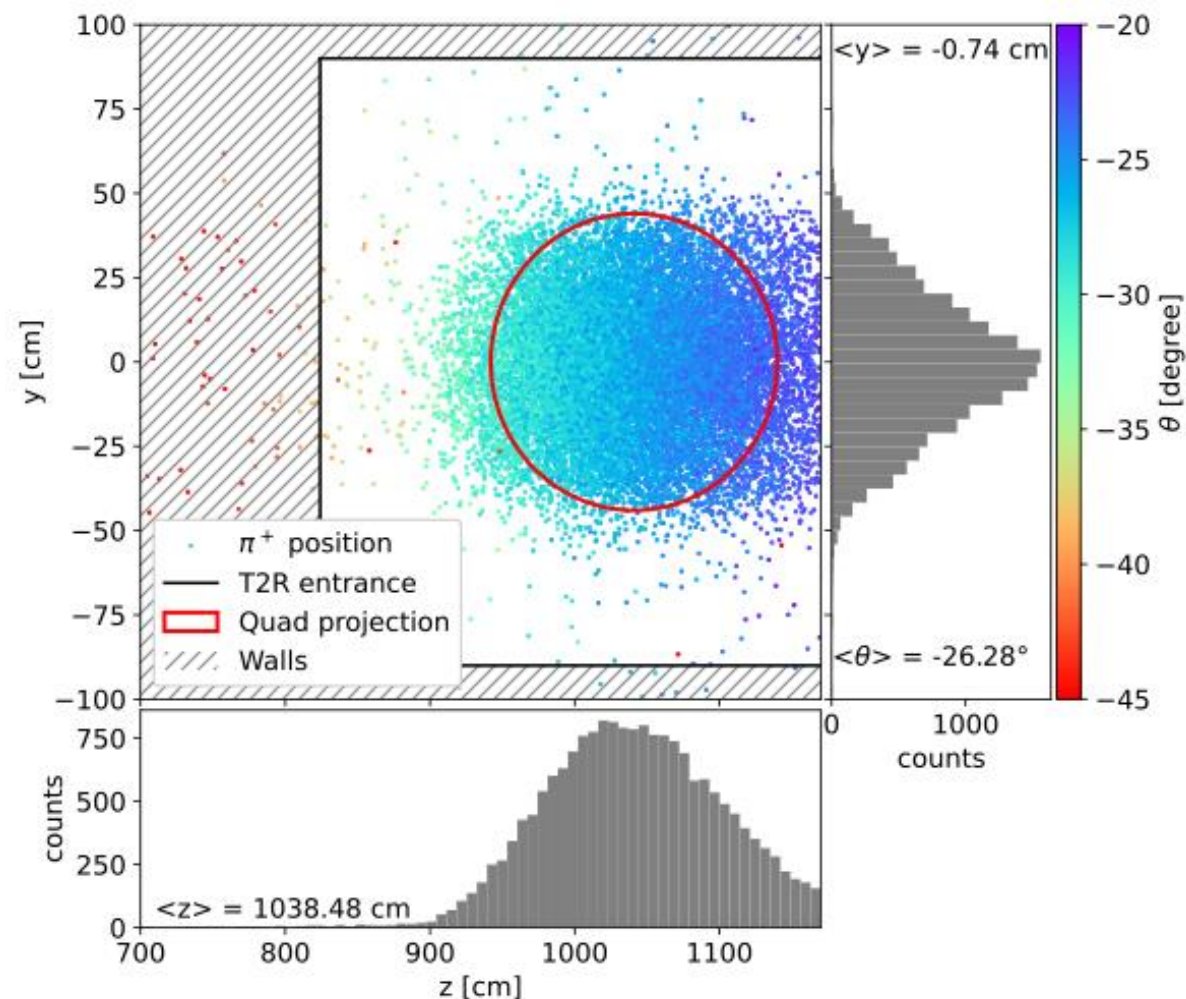


A total of 3,505,011 pions are produced, including 135,166 π^+ with energies in the $1050 \pm 10\%$ MeV range. This corresponds to 0.013 useful π^+ per POT.

A large number of particles, especially neutrons and photons, are also produced.

→ Significant radiation levels require shielding to protect critical components.

Pions distribution at the transfer line entrance

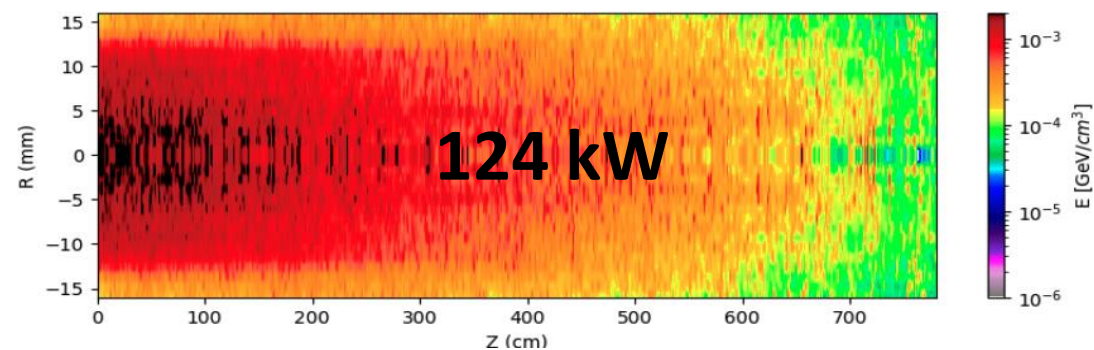
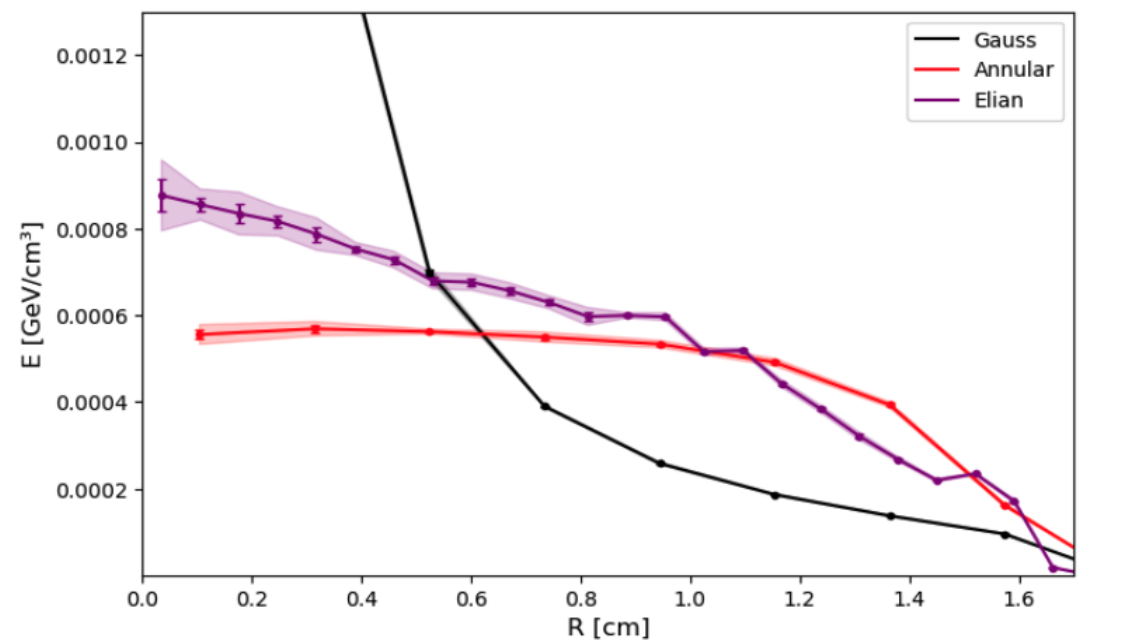
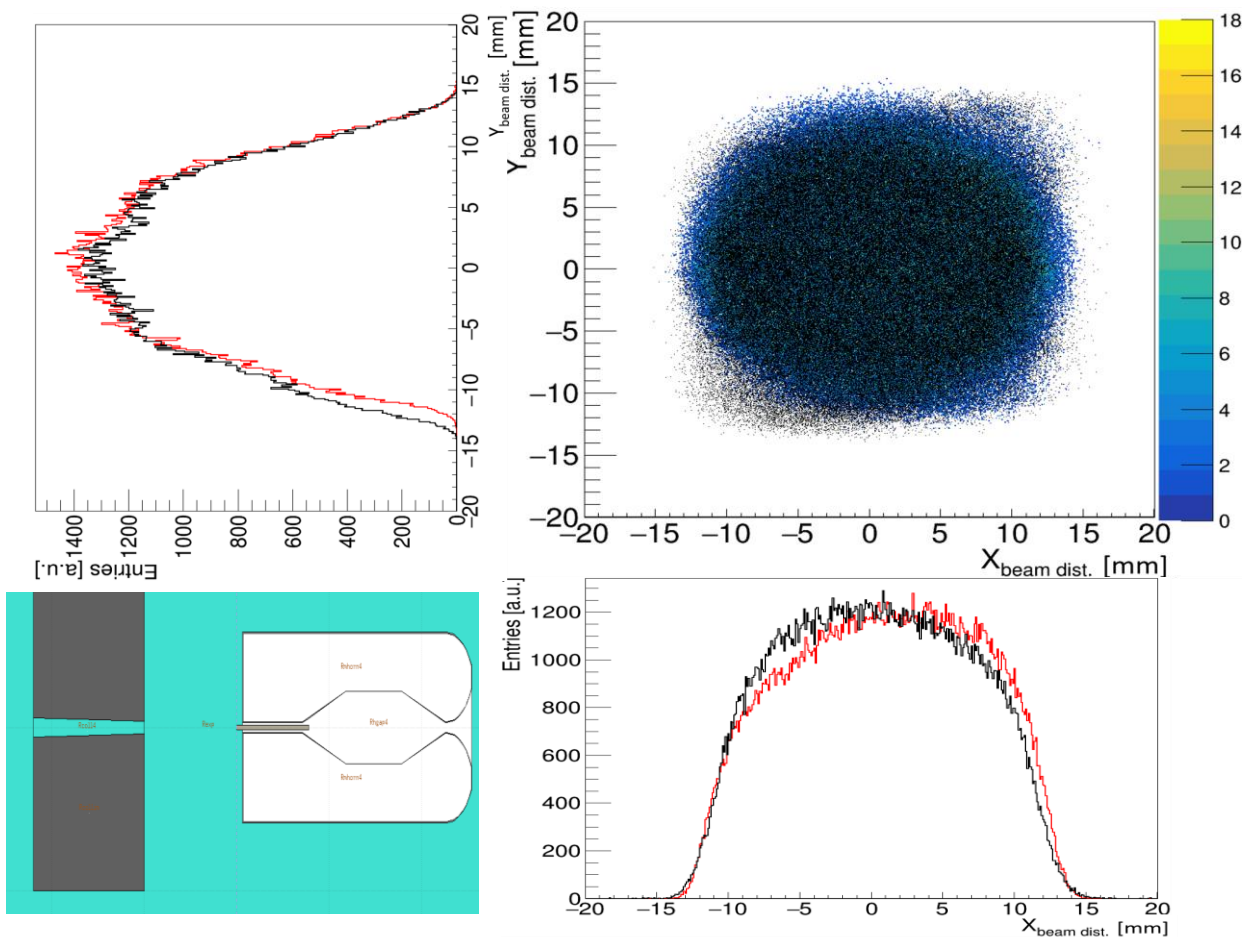


12,781 pions Corresponding to:

0.0012 pions/POT

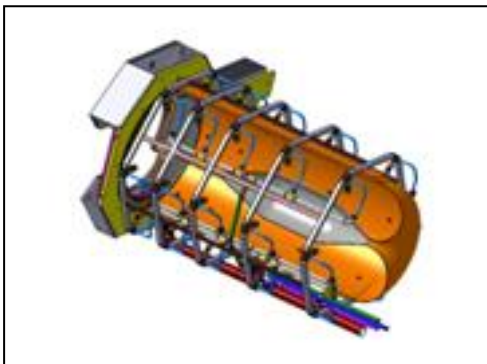
9.5% transmission (Target $\rightarrow$ 1st quadrupole)

Proton Beam: 2.5 GeV at 14 Hz with 1.25 MW



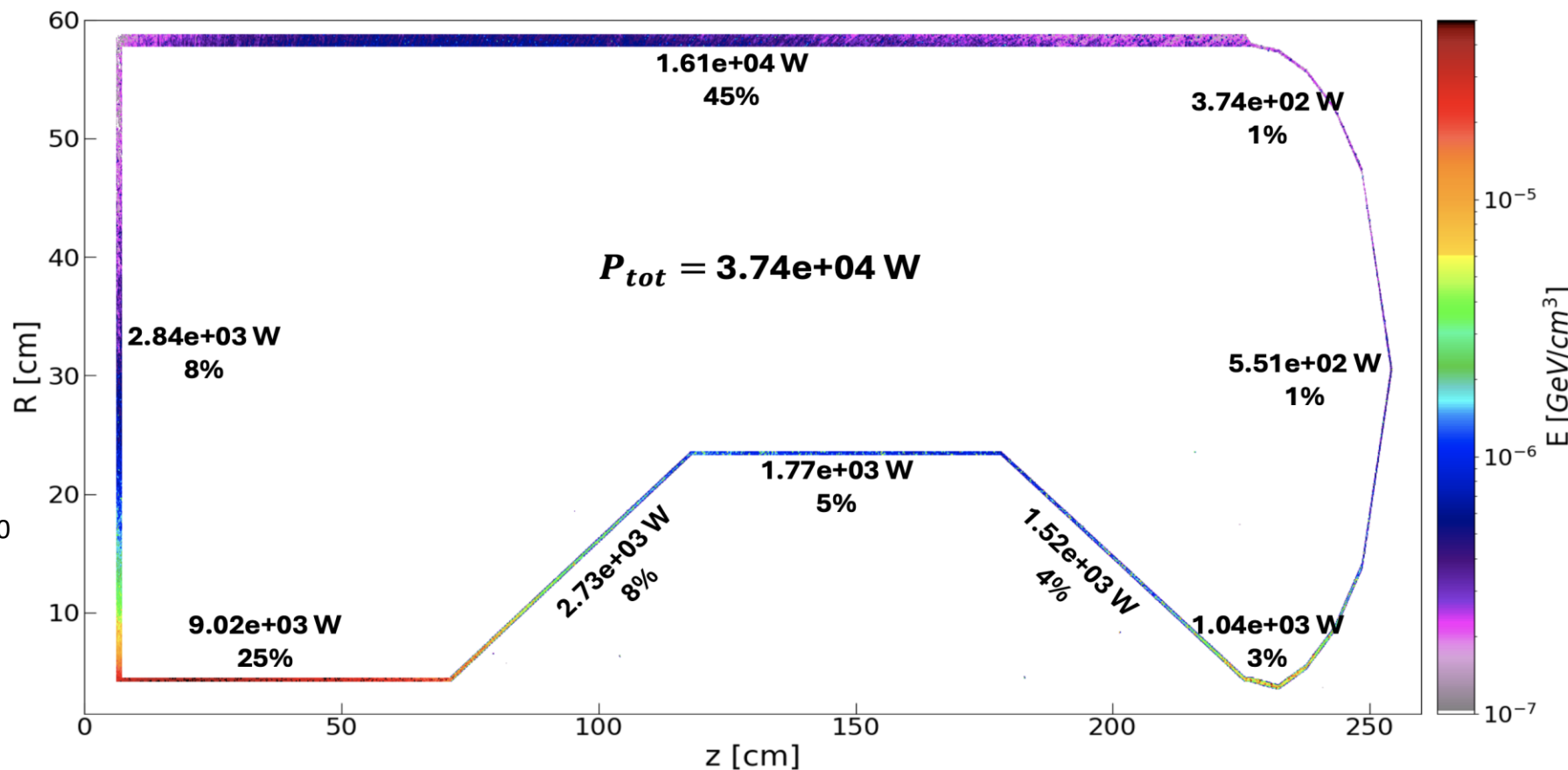
Target Material : Titanium

Power Deposition in the Horn



Cooling system (ESSnuSB):

- 30 jets, 5 systems of 6-jets longitudinally distributed every 60°
- Flow rate between 60-120l/min, h cooling coefficient 1-7 kW/(m²K)
- Longitudinal repartition of the jets follows the energy density deposition
- for $T_{Al-max} = 60^\circ C$ (assuming 1 MW per horn)

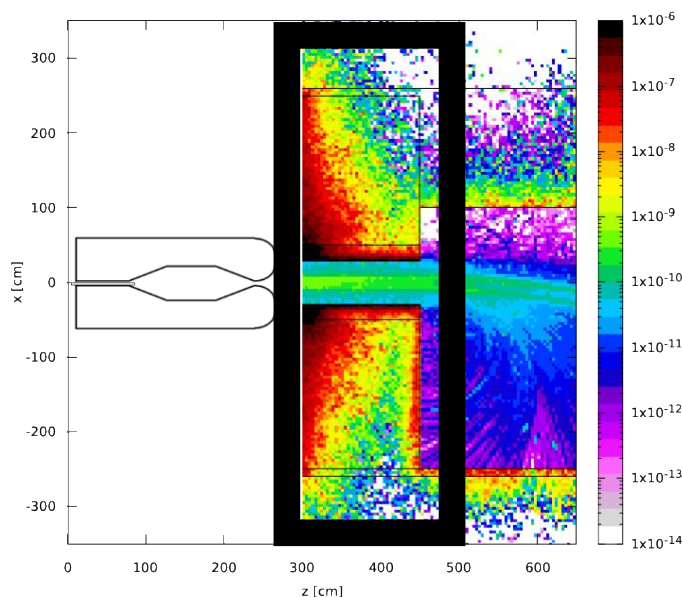


Total power deposition in one horn for:

- 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).

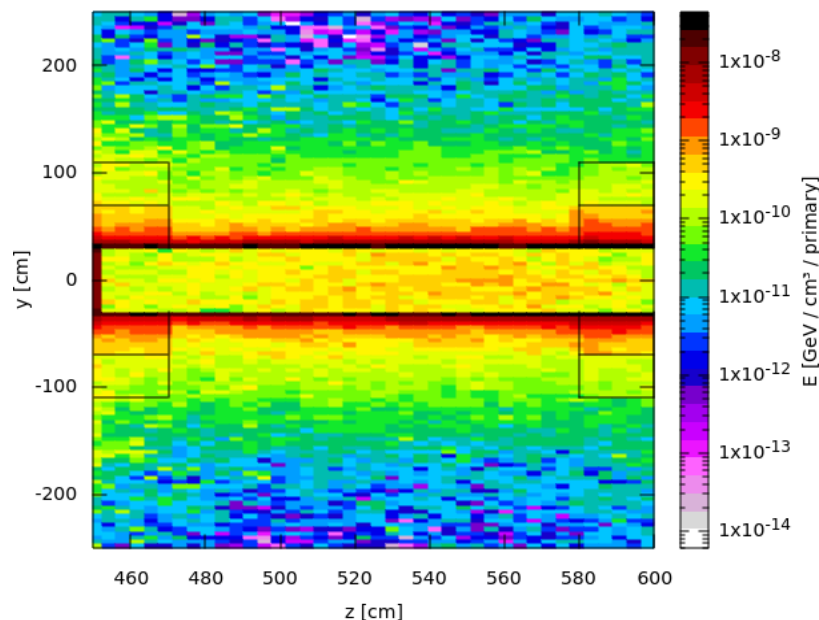
Power Deposition in the CLMT

- Region (Iron) : 294 kW
- Region W_{Ring} (W): 160 kW



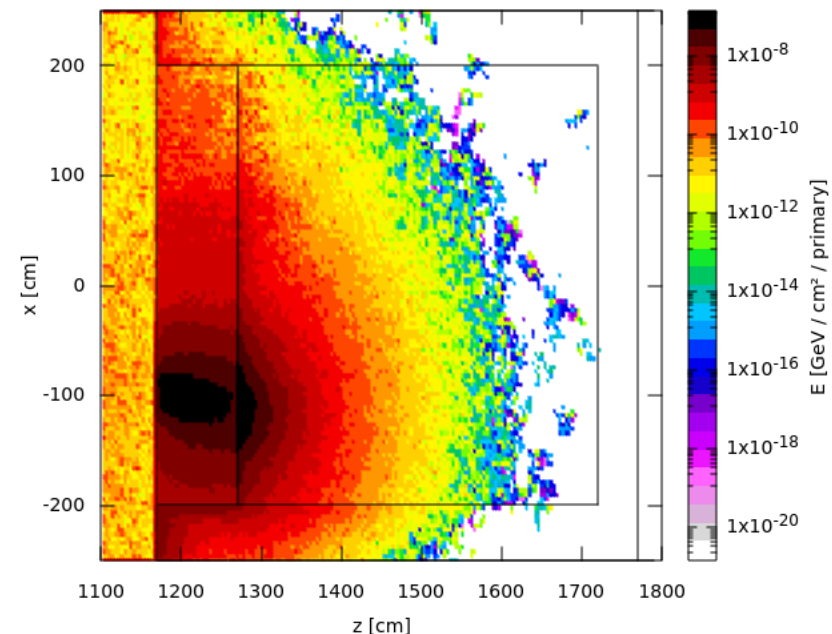
Power Deposition in the DIPOLE

- Region Dipole (Iron) : 9.05 kW
- Region W_{PLATES} (W) : 4.20 kW
- Region Coils (Copper) : 150 W



Power Deposition in the BEAM DUMP

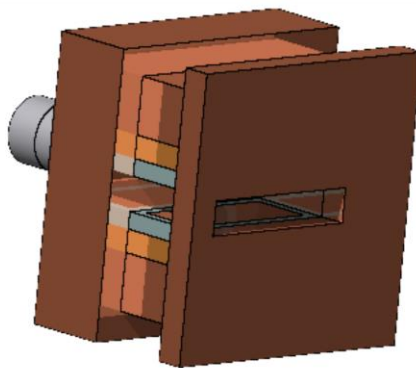
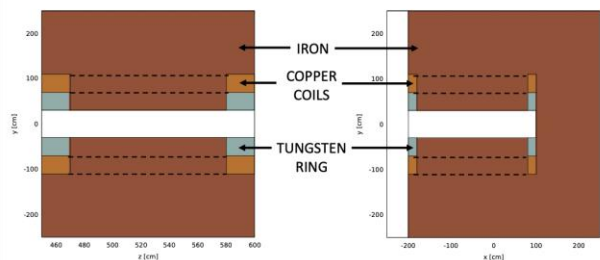
- Region B_{DUMP} (Graphite) : 148 kW
- Region B_{DUMP} (Iron) : 82.4 kW
- Region B_{DUMP} (Copper) : 8.22 kW



Dose evolution with time for different tungsten thicknesses

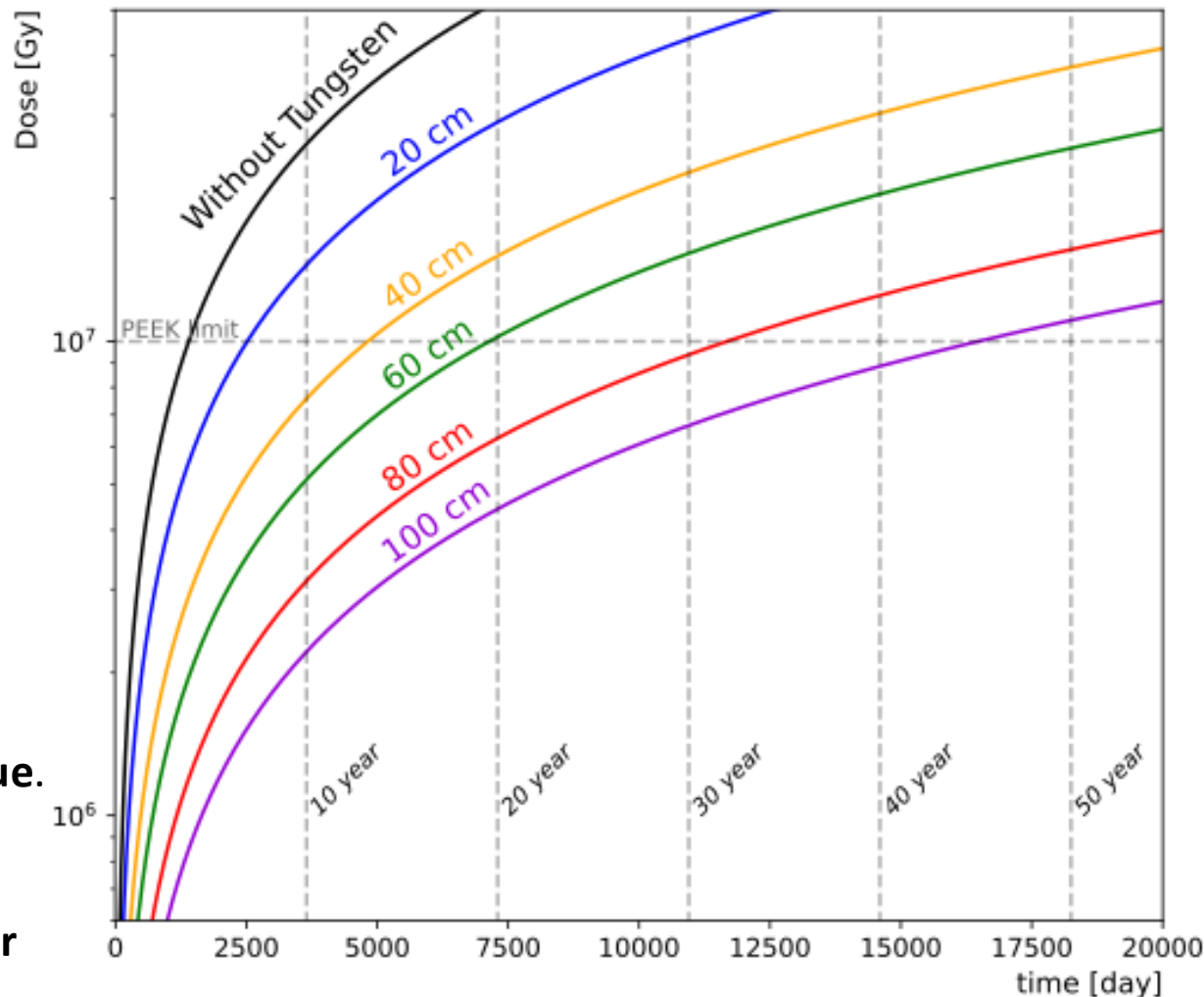
These values were obtained assuming **365 operational days per year**.

The dose study in the coils shows that the material may last **at least 10 years** with the current configuration (**40 cm tungsten**), when compared with the PEEK limit (*P. Beynel et al. (1982), H. Schönbacher (1982)*).

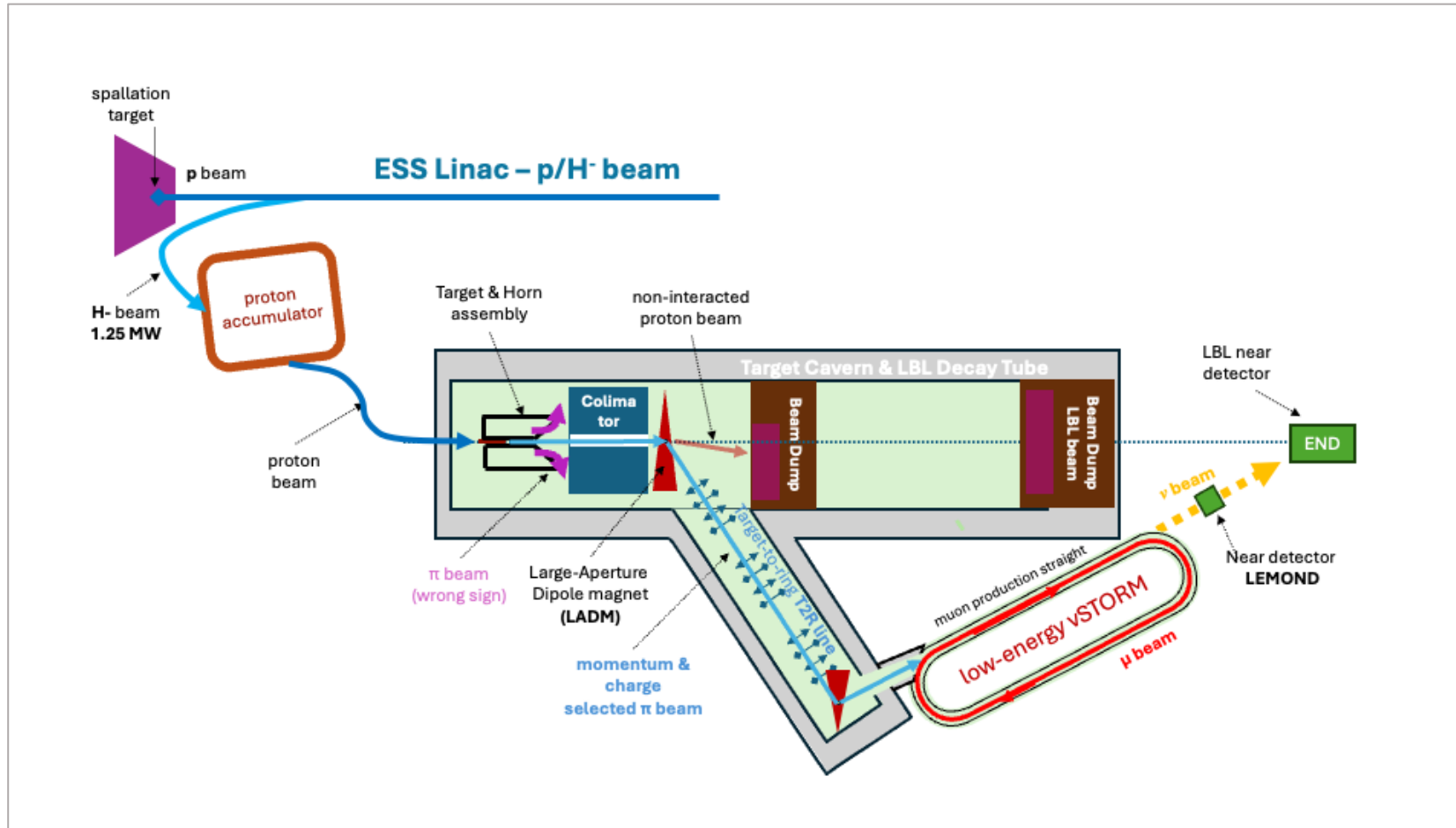


Note: The dose inside the region is, by definition, an **average value**. However, we can look at the voxel containing the **maximum dose** to estimate the local peak dose inside the coils:

5.67×10^7 Gy after 10 years*, assuming **365 operational days per year** and **40 cm tungsten**. **Above the PEEK limit !**

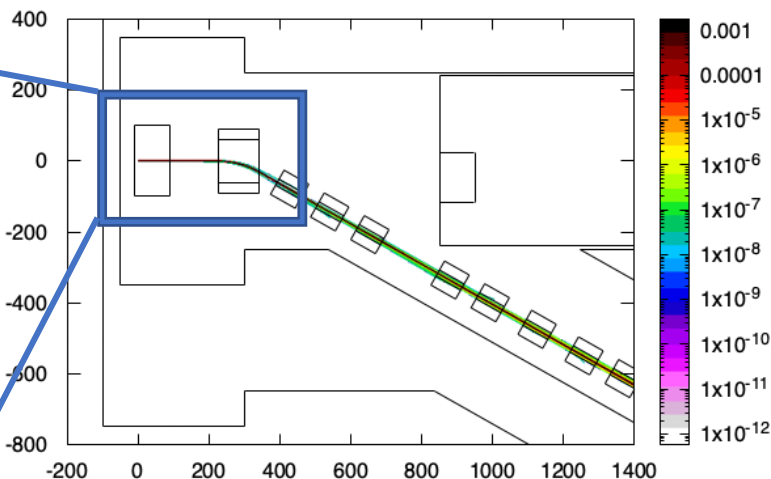
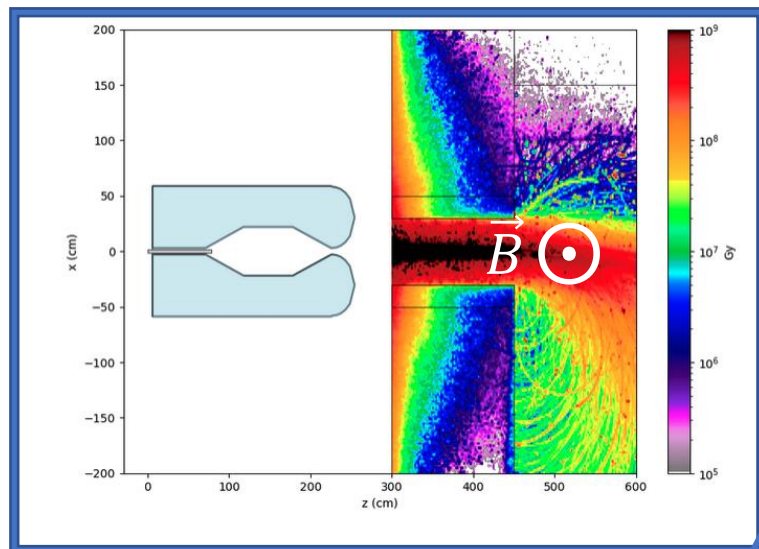


Target To Ring (T2R) Transfer lines

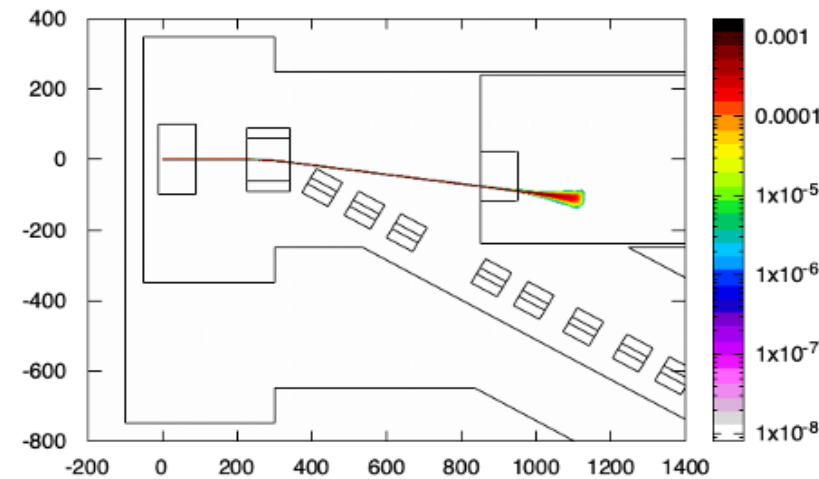


Ilias Efthymiopoulos
Max Topp-Mugglestone

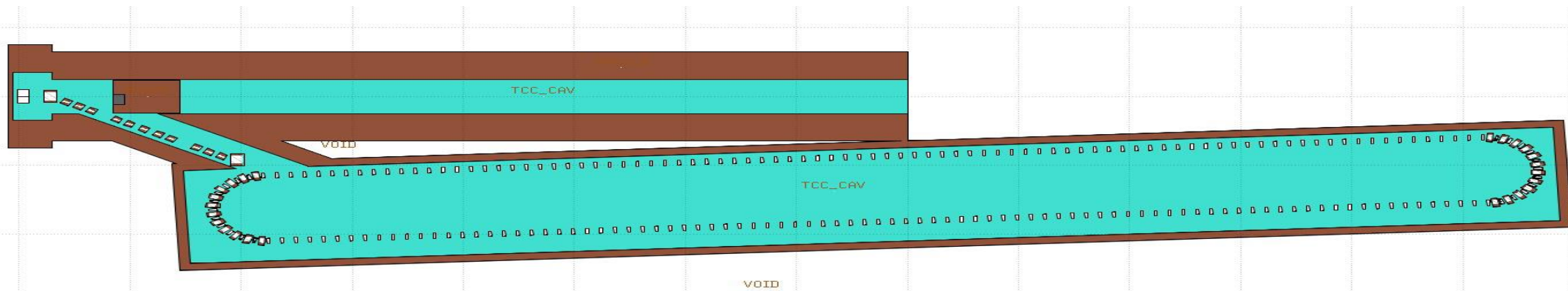
Race track ring (LENuSTORM)



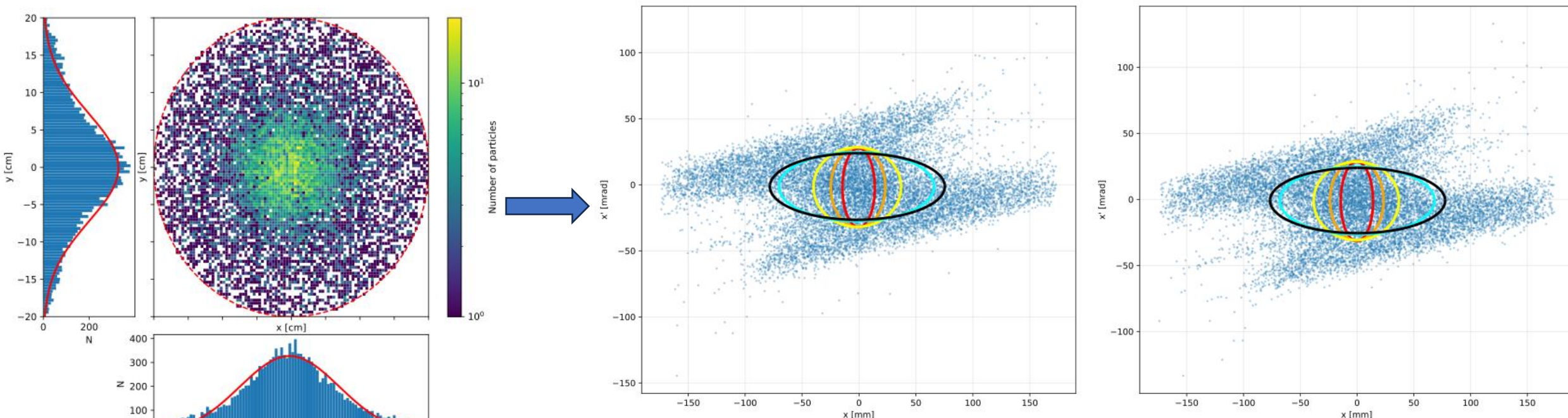
Trajectory of the selected secondaries (pion) along the target to ring transfer line.



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



- Initial **pion beam** parameters at the exit of the collimator (*Julien's FLUKA simulation*)

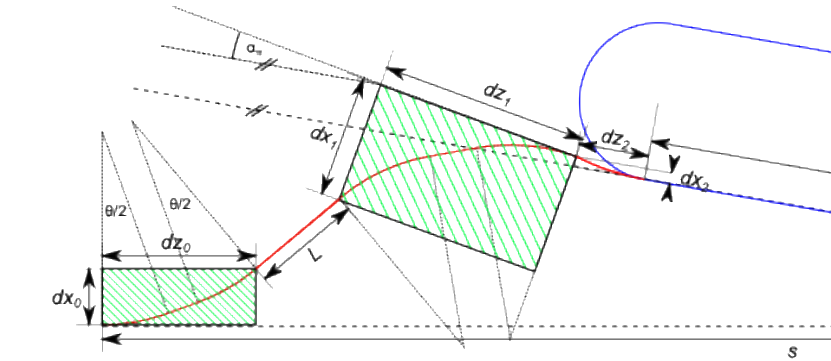


$1.46 \cdot 10^{-3} \pi/\text{pot}$ in the T2R momentum
range of $1.050 \text{ GeV} \pm 10\%$

used in optics and tracking studies

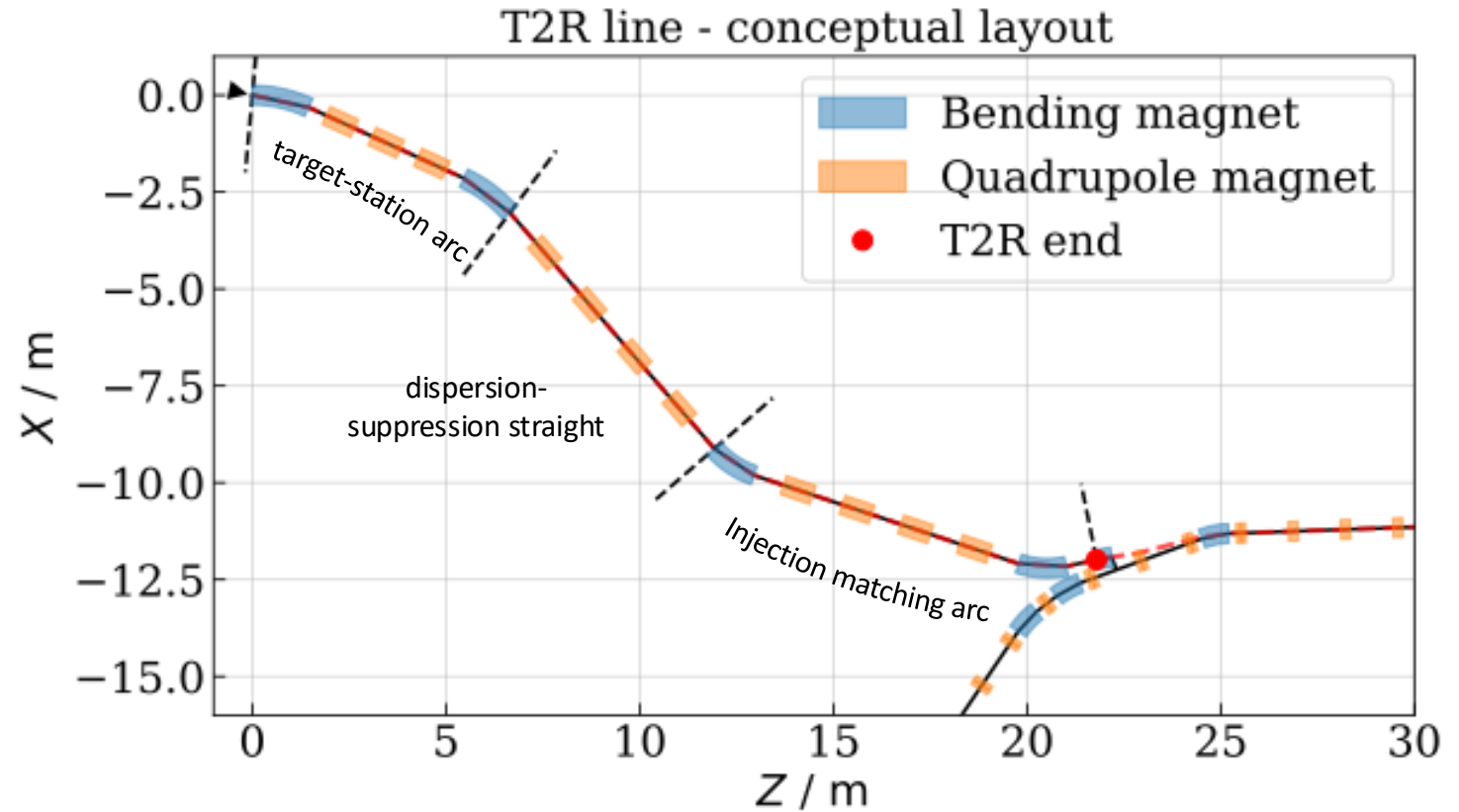
beam fraction	ϵ [m]	β [m]	α
10%	4.28×10^{-4}	0.47	-5.13×10^{-2}
25%	7.10×10^{-4}	0.79	-1.49×10^{-1}
50%	1.11×10^{-3}	1.26	-1.73×10^{-1}
90%	1.75×10^{-3}	2.66	-2.99×10^{-2}
100%	1.91×10^{-3}	3.11.10	-6.73×10^{-2}

- Three segment design



Collimator end plane

- Target-station arc: match to pion production from the horn/collimator
- Injection-matching arc: match to the parameters of the pion beam in nuSTORM injection point and have zero dispersion at the start of the production straight
- Dispersion-suppression straight: connect the optics between the two arcs

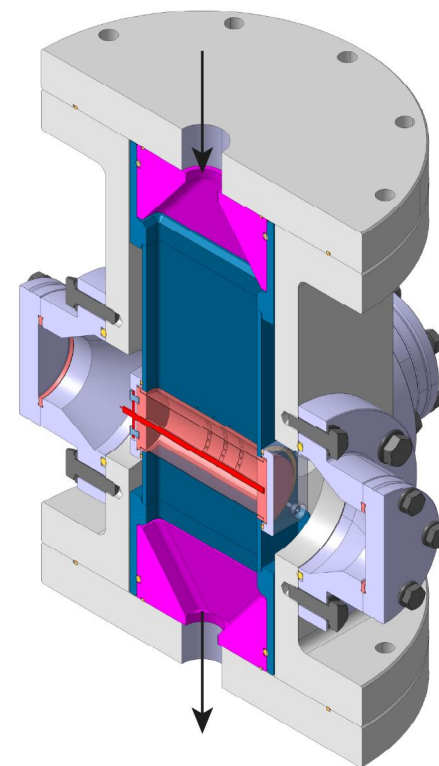
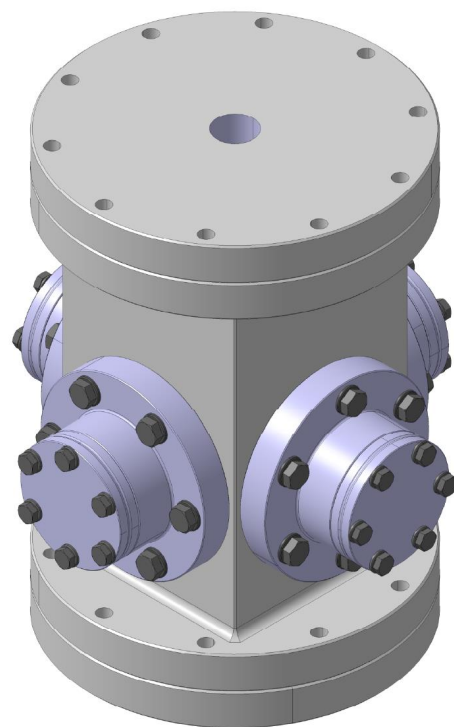


Expected pion flux at the **start of nuSTORM**:

$$1.46 \cdot 10^{-3} \times 50\% \times 16.4\% \times 60.6\% \rightarrow 7.2 \cdot 10^{-5} \pi/\text{pot}$$

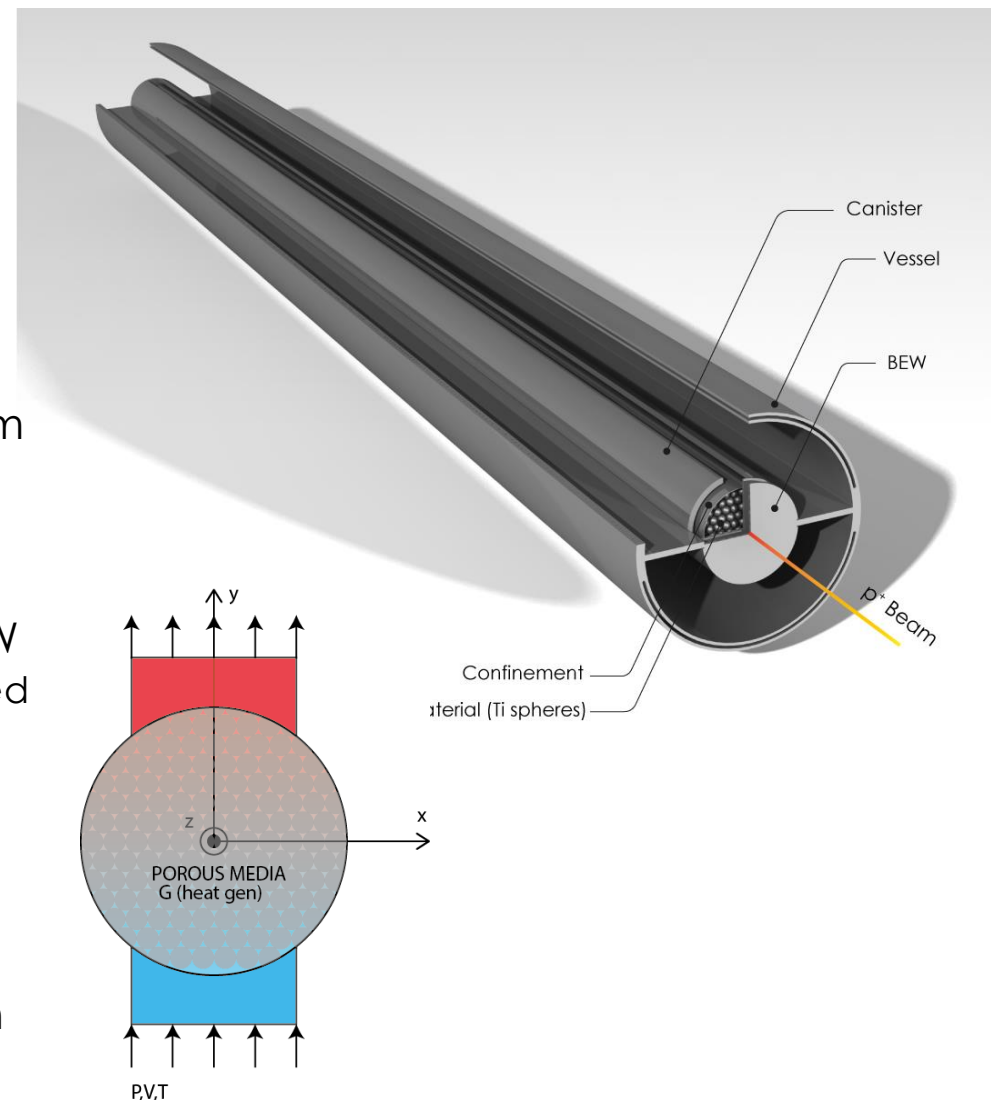
$$\times 3.22 \cdot 10^{22} \text{ pot/y (200d, 60\% eff)} \rightarrow 2.33 \cdot 10^{18} \pi/\text{year}$$

THERMOMECHANICAL DEVELOPMENT OF A GRANULAR TARGET



From Jorge Aguilar
ESS-Bilbao/ESS/UHH

Parameter	2023 design basis	Current status
Beam power per target		1.25 MW
Sphere diameter		3 mm
Helium cooling		10 bar, 200 g/s
Target dimensions	≈777 mm length; Ø56 mm outer tube; Ø34 mm inner canister;	
Geometric porosity	$\varepsilon = 0.34$	$\varepsilon \approx 0.45\text{--}0.46$
Flow distribution	200g/s	180 g/s bed, 20 g/s BEW 40 g/s shell bypass explored
Predicted pressure drop	≈(0.5 bar) 0.7 bar	≈0.5 bar, model dependent
Peak bed temperature	(530°C) ≈670 °C	≈500 °C updated baseline
Outer-wall temperature	≈356 °C	≈216 °C with mid-span bypass

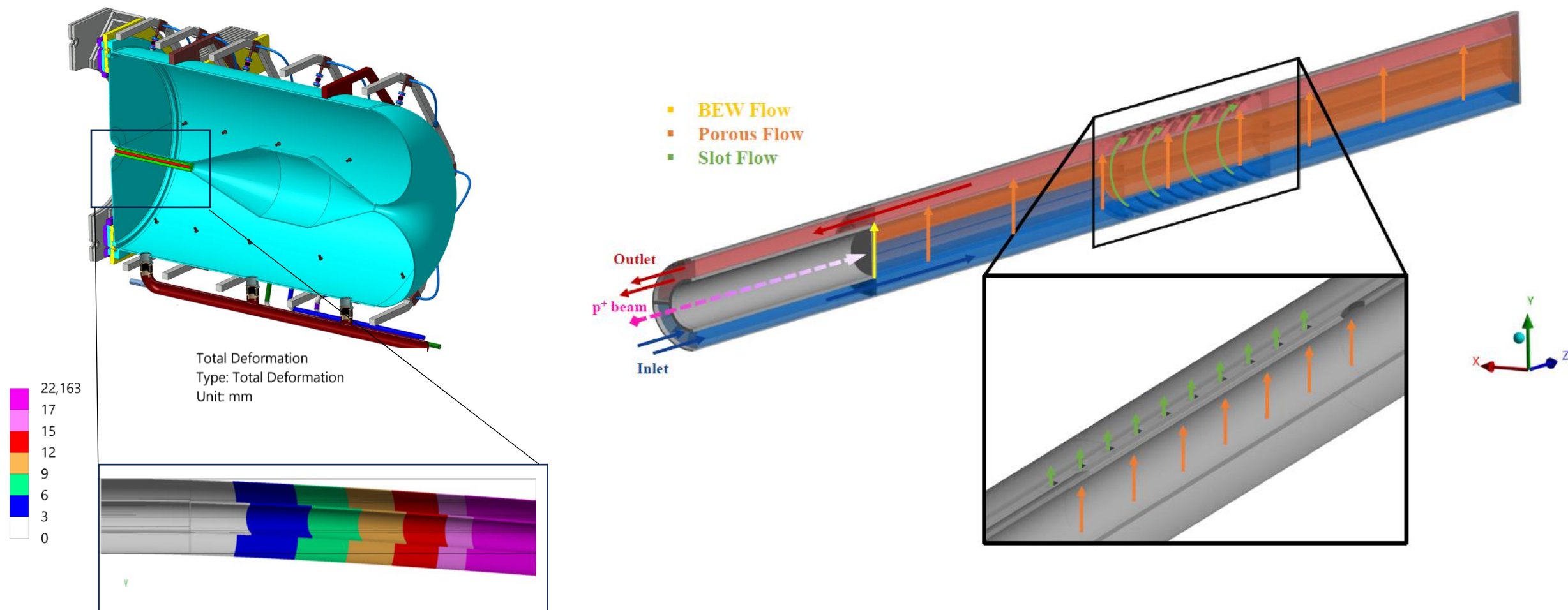


ESSnuSB+ Target Progress

The programme progressed from feasibility to experimentally anchored design decisions.

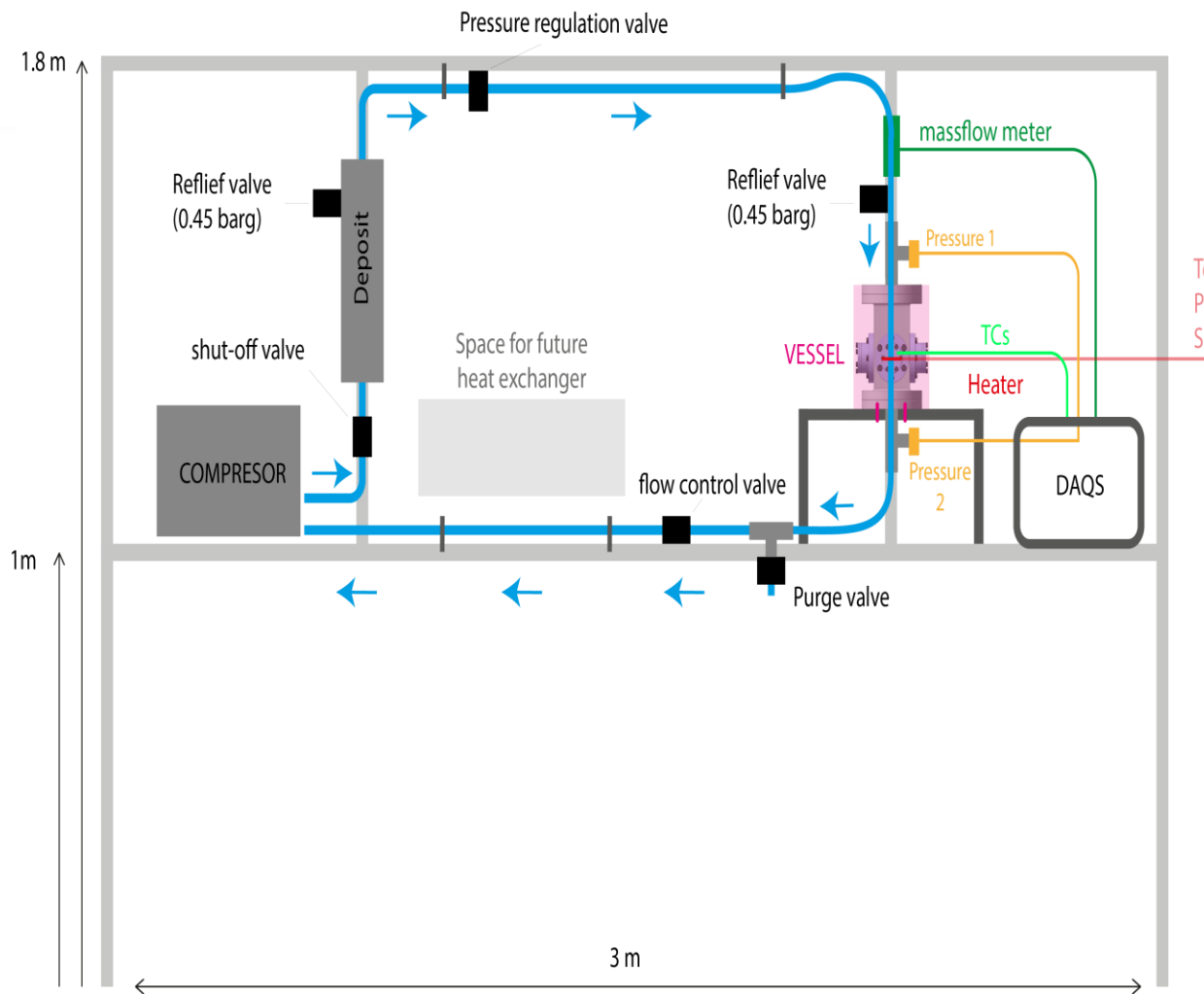
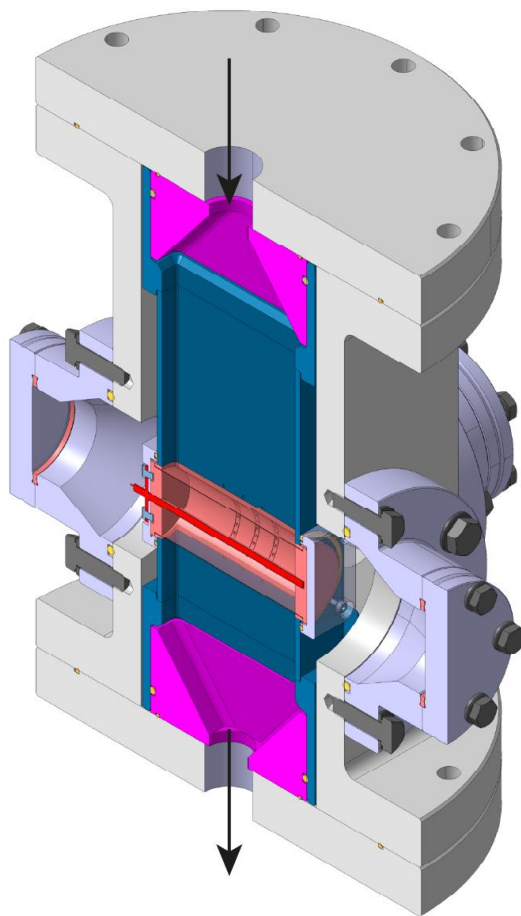
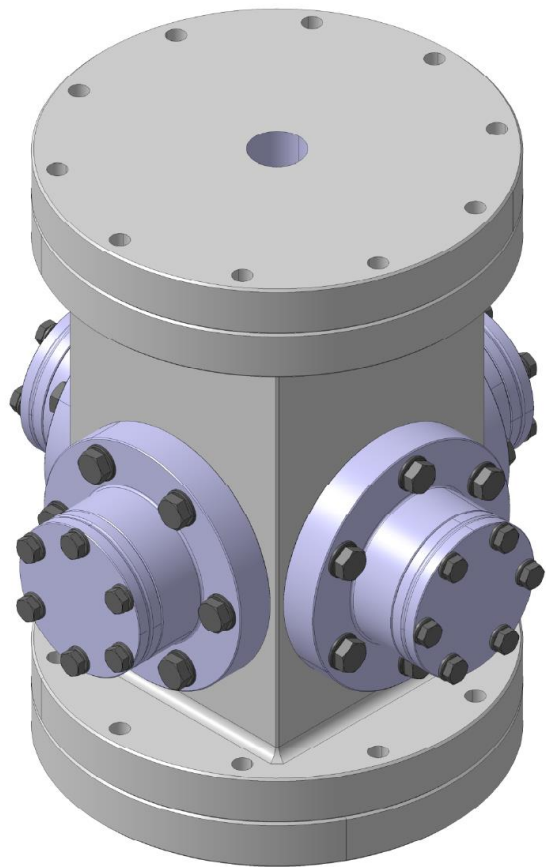


Exploratory screening of three axial slot locations to cool the outer shell and reduce the asymmetric thermal load that drives target bending.





ETTF Experimental Setup



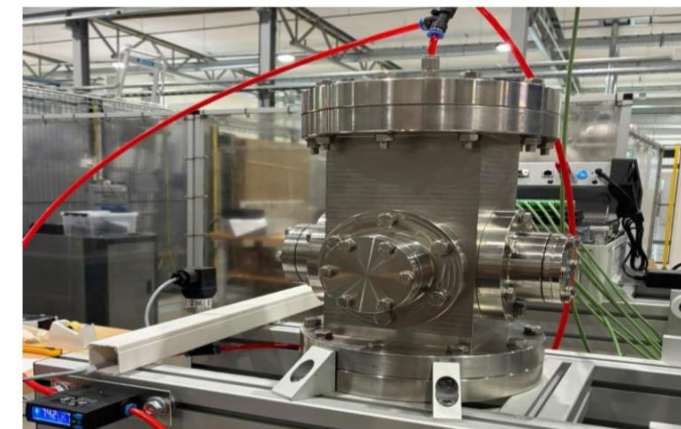
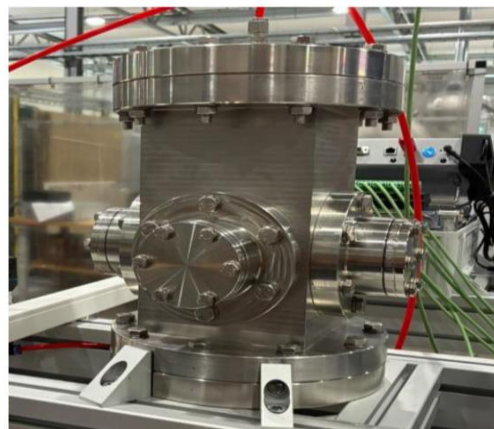
Test stand at the MML: loop, DAQ, campaign

Why: how the coolant flows through a packed bed should be measured, not only simulated

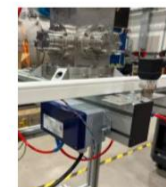
- **Hand-over pack** for the MML lab engineer (M. Snyder): envelope, loop sequence, tag list, checklist
- **Loop**: blower → shut-off → non-return → regulator → needle valve → vessel → vent; relief at 0.45 bar(g)
- **Instruments**: ΔP transmitter 0–50 mbar · supply pressure 0–1 bar · mass-flow meter · 6 type-K thermocouples · certified 24 V panel · 9-channel recorder at 2 Hz
- CATIA sections fixed minor issues with assembly
- **Commissioning**: first air-flow runs of loop and DAQ, 3 records (without the packed bed)
- **Test campaign** with ESS Bilbao and U. Hamburg at the MML: sampling plan at fixed pressures and mass flows

ROLES IN THE TEST CAMPAIGN

ESS commissions loop, DAQ and safety paperwork · ESS Bilbao brings the sampling plan and the target model

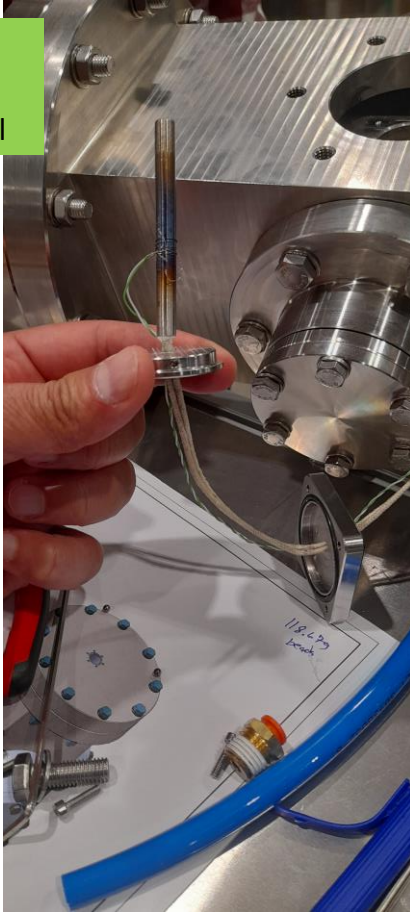


ETTF vessel on the air-test stand (ESS MML); the stand ready for the campaign.



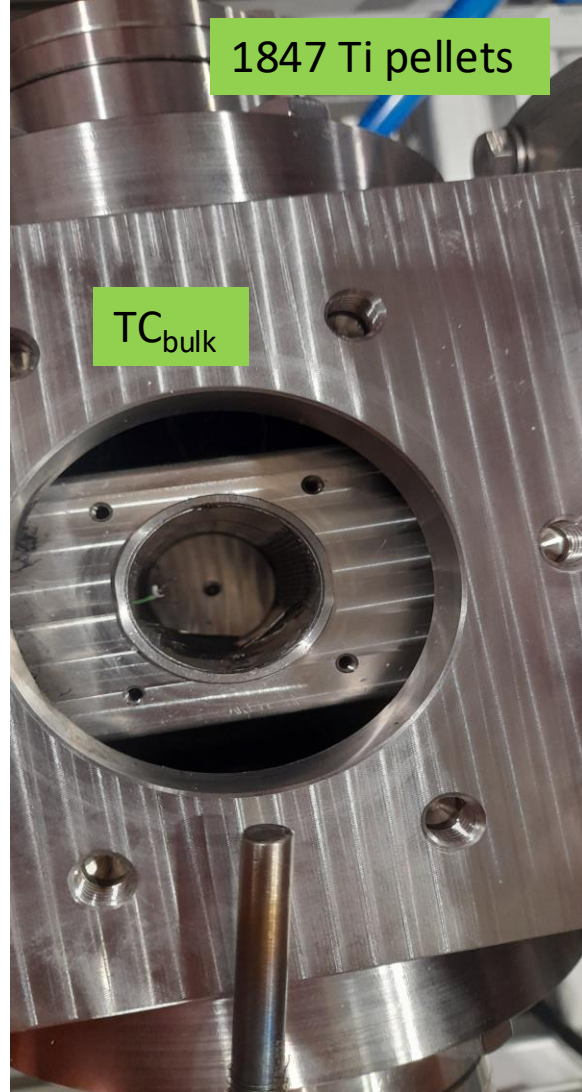
Data recorder · instrumentation panel · pressure transmitter and sensor · thermocouple and air inlet on the top flange.

TC_{Heater}
TC_{Heater control}

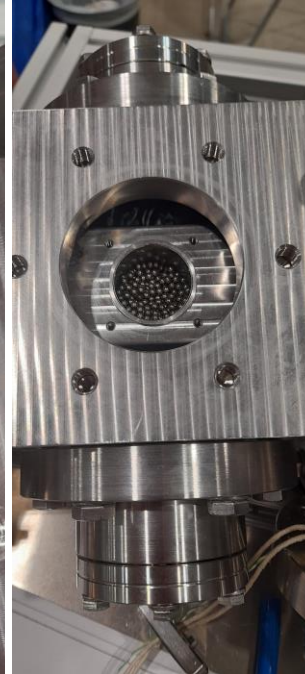


1847 Ti pellets

TC_{bulk}



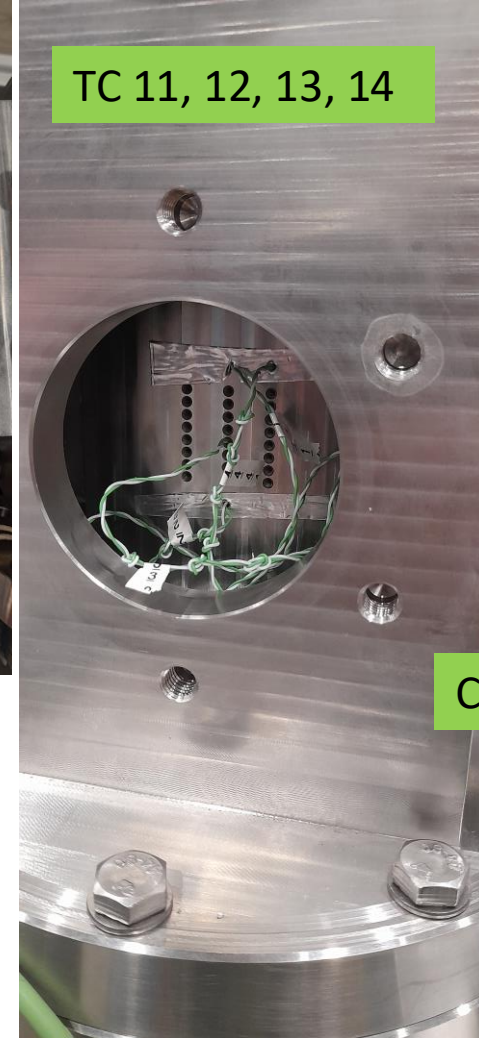
TC 11, 12, 13, 14



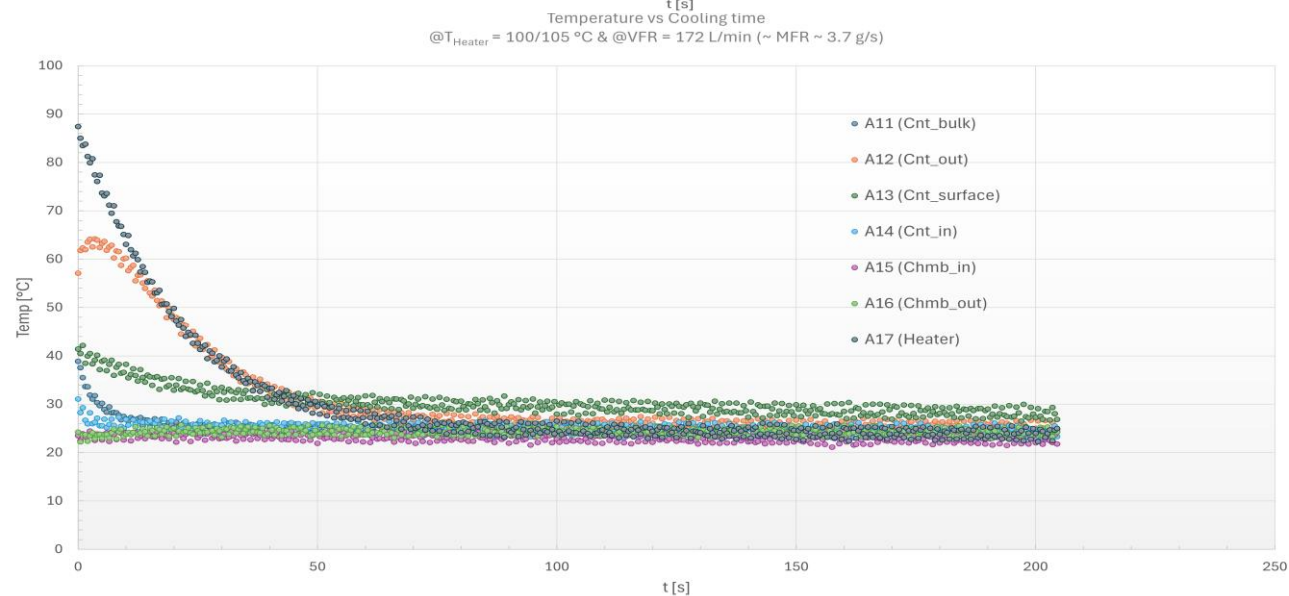
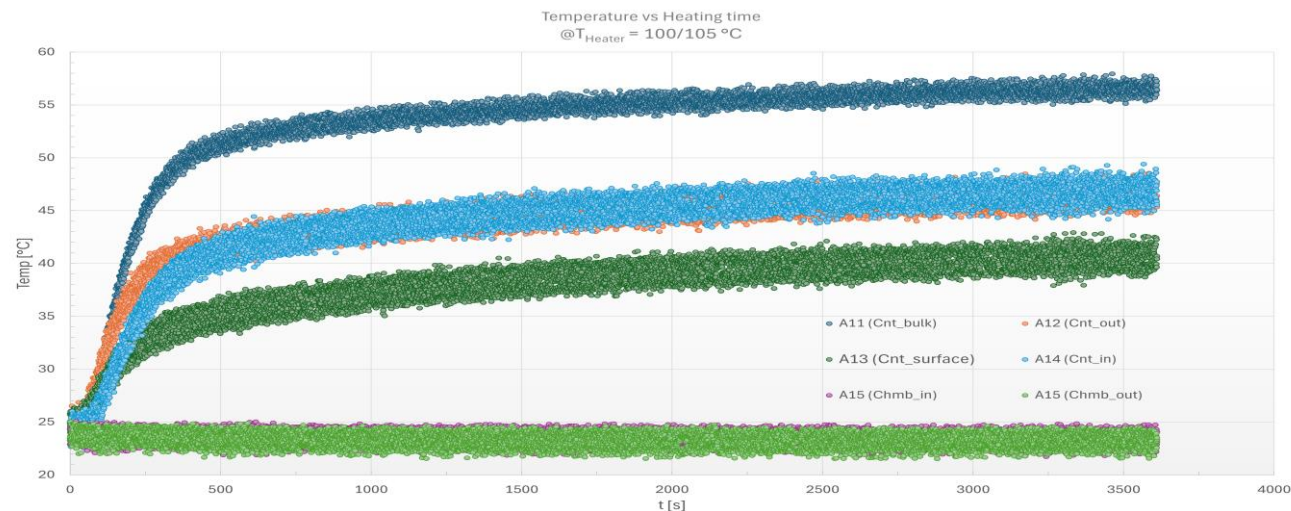
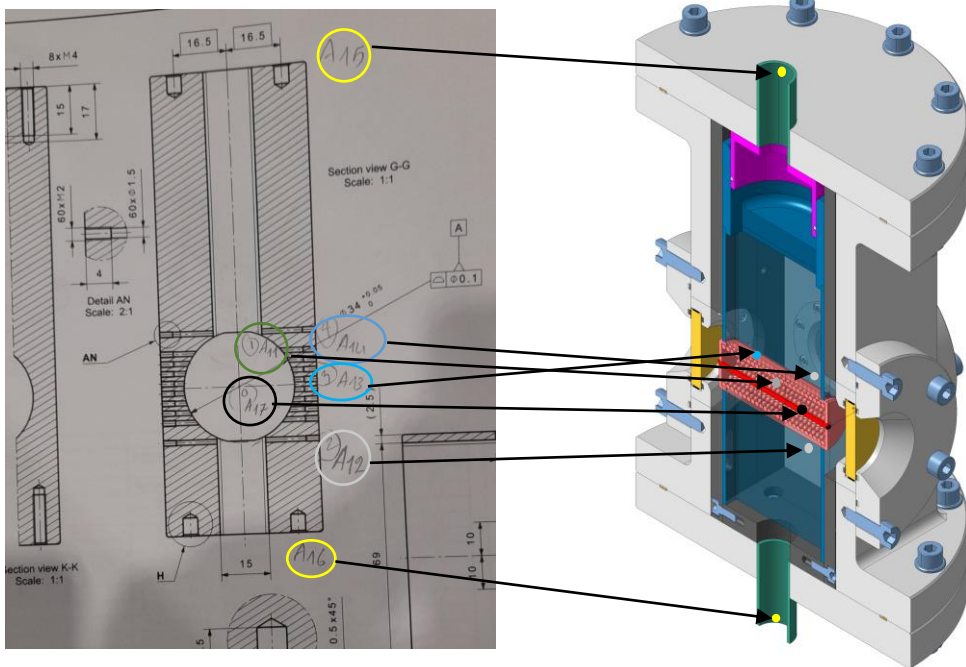
Ti pellets
80x 80

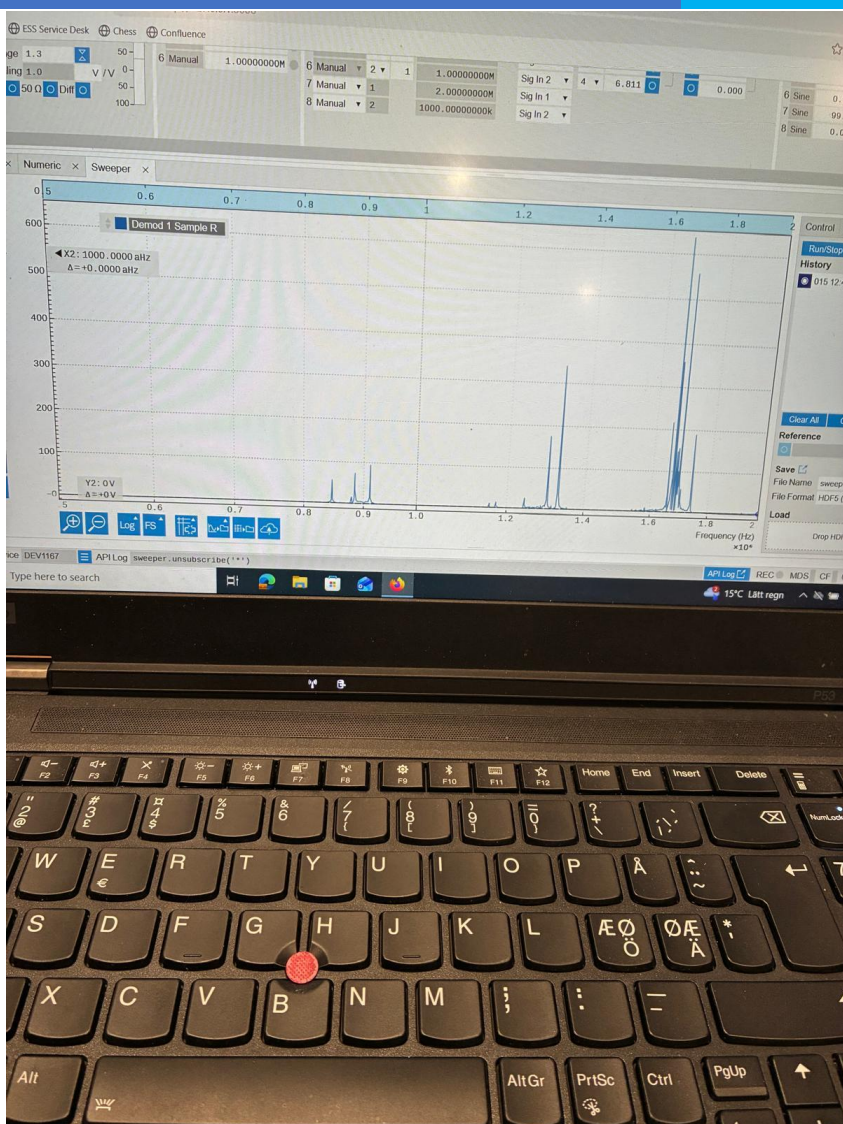


Canister cooling mesh

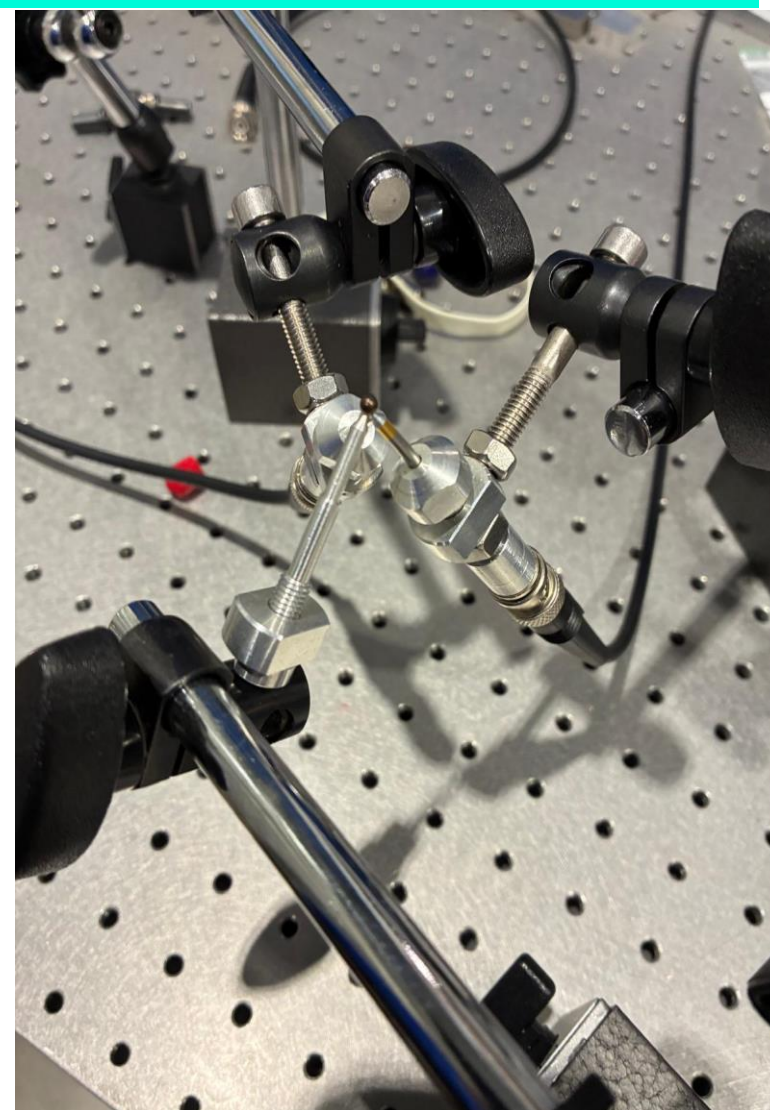


TCs positions





Measurement Young Modulus



Next Documents : Costing + D4.3 + CDR

PBS Name	Cost (Euros)
Target + Integration System	3 750 000
Hadronic Collector System	3 750 000
Horn Support Structure	2 000 000
Power Supply + Striplines	1 300 000
Proton beam window	1 300 000
Upstream shielding (ESSnuSB Beam Dump)	3 300 000
Target and Horn Replacement System	40.400 000
General Systems and Services	21 800 000
Facility Building Structure	20 724 000
Total	98 324 000

PBS Name	Cost (Euros)
Dipole Iron Yoke	4 280
Dipole Core soft iron	6 040
Dipole Copper Conductor	109 174
Dipole Electrical Insulation (PEEK)	607 878
Power Supply	tbd
Cooling system	tbd
Shielding Iron	4 915
Shielding Tungsten	1 913 856
Total	2 646 143

First estimation of the total cost of ESSnuSB+ (without T2R elements) looks compatible with ESSnuSB total costs

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 Summary

- All the elements of the Target Station Facility has been defined from the horn the entrance of the nuSTORM ring.
- Implement all the FLUKA frameworks to a complete simulation of the facility
- Technological solution are proposed regarding the granular target concept and preliminary measurements on the ETTF were performed in air phase.
- Finalise the last documents D4.3, Costing and prepare the CDR