The neutron source system proposal for the ARGITU project

ECNS-2023

ESS-Bilbao Division Team

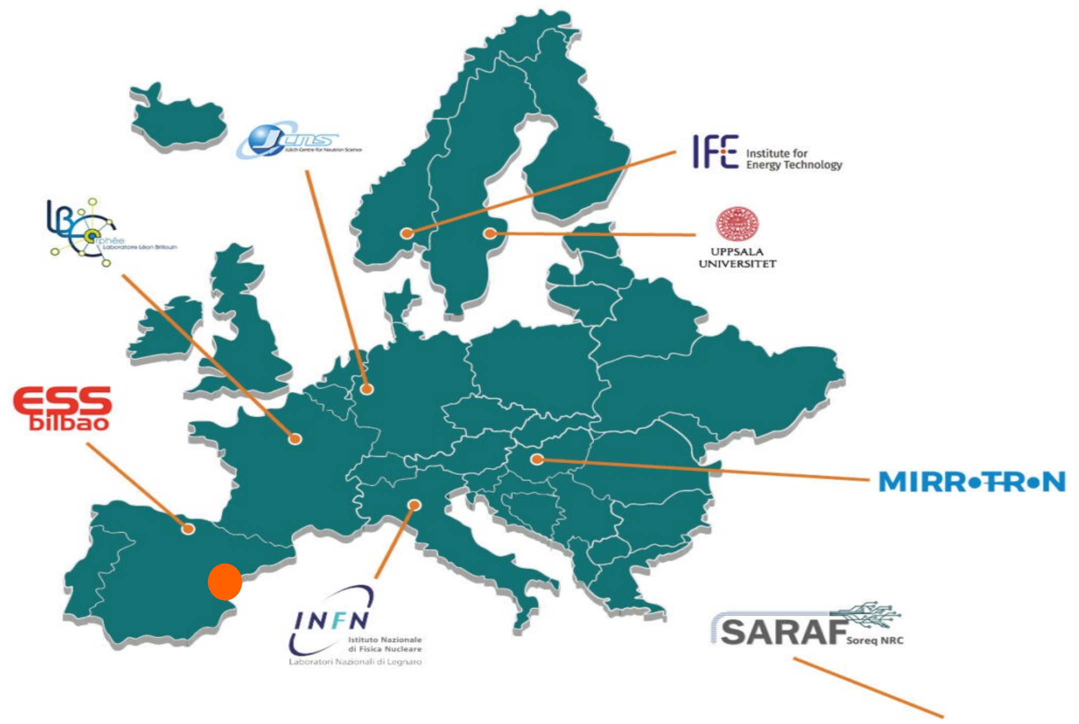
Mar 22, 2023

INTRODUCTION

ELENA

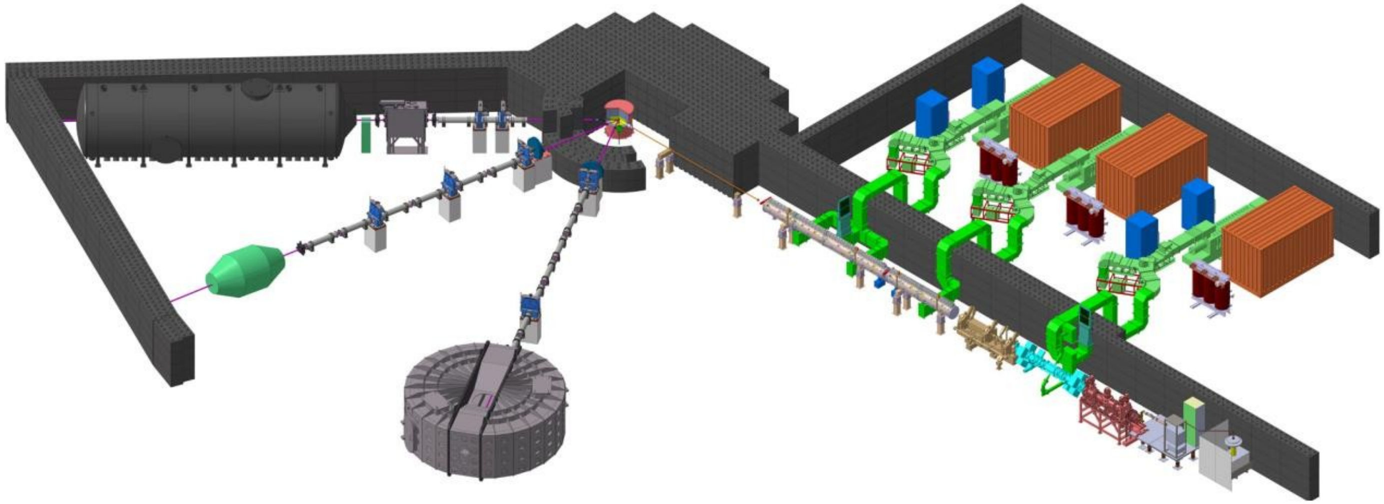
European Low Energy accelerator-based Neutron facilities Association

- ARGITU is part of European Low Energy accelerator-based Neutron (**ELENA***) Association.
- ARGITU Accelerator a multi-purpose machine that could provide 30 MeV proton beam.
- The proposed neutron source will have up to 4 instruments per target station, it could be possible to consider a dedicated moderator per instrument.



*** Association to promote cooperation within Europe in the field of neutron sources based on an accelerator and a low energy reaction to produce neutrons**

- ARGITU Conceptual design



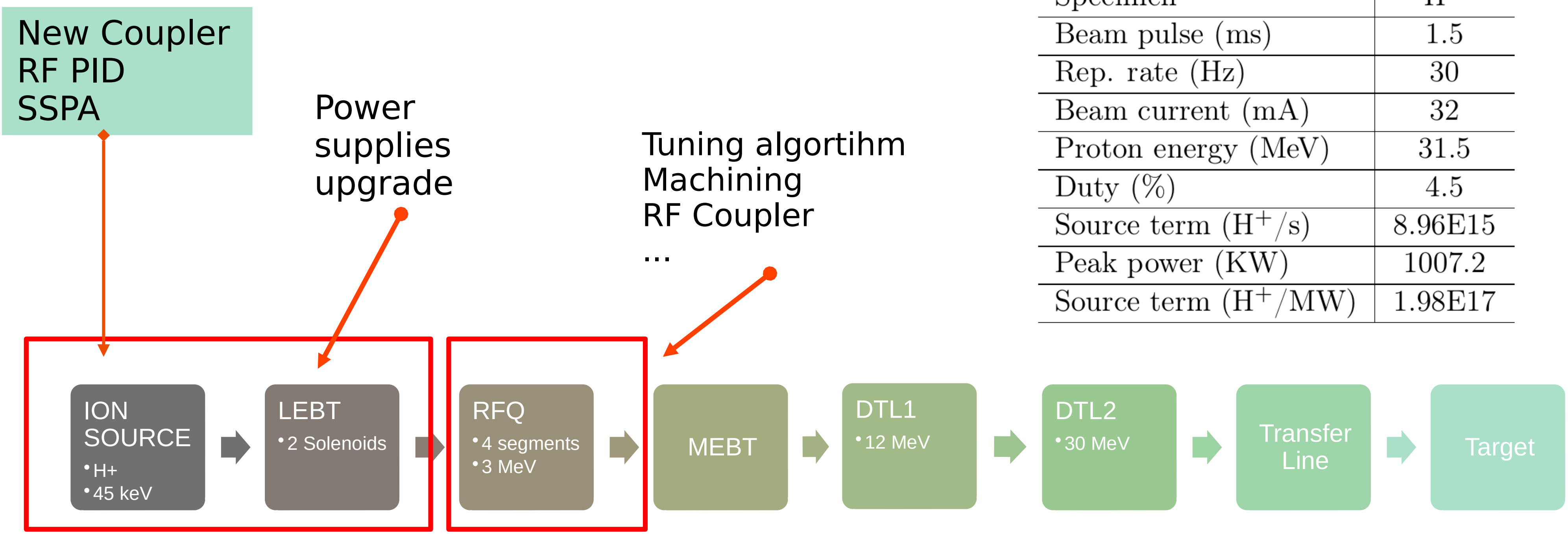
More info: M. Perez et al., "ARGITU compact accelerator neutron source: A unique infrastructure fostering R&D ecosystem in Euskadi", Neutron News, Vol. 31, issue 2-4, pp. 19-25, Dec. 2020, (https://doi.org/10.1080/10448632.2020.1819140)

THE ACELERATOR

Accelerator: General layout

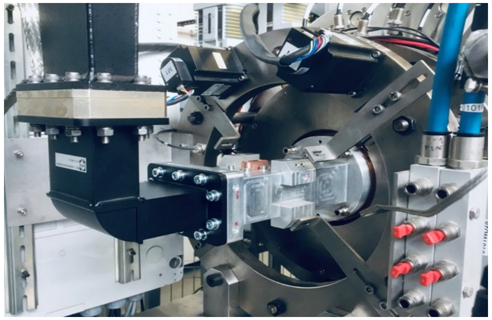
- ARGITU Accelerator a multi-purpose machine that could provide 32 MeV proton beam.
- The first part of the accelerator is on going. Ion Source, LEBT are in operation and RFQ is on manufacturing phase.

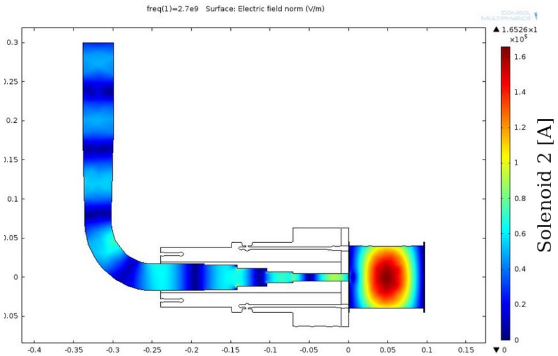
Parameter	Values
Specimen	H^+
Beam pulse (ms)	1.5
Rep. rate (Hz)	30
Beam current (mA)	32
Proton energy (MeV)	31.5
Duty (%)	4.5
Source term (H^+/s)	8.96E15
Peak power (KW)	1007.2
Source term (H^+/MW)	1.98E17

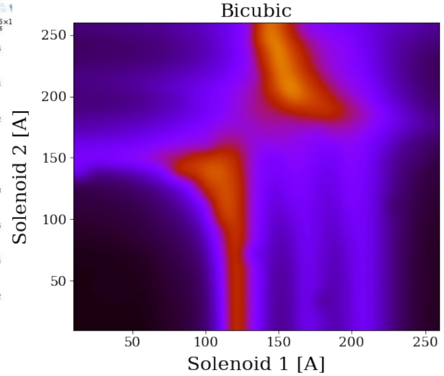


Accelerator updates: summary

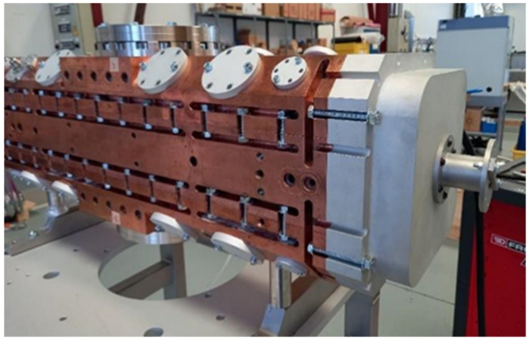
Injector / LEBT:
- New coupler installed
- SSPA 2.7 GHz
- ATU algorithm
- LEBT transmission studies

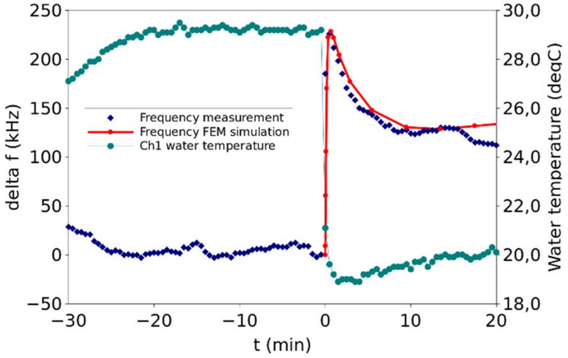


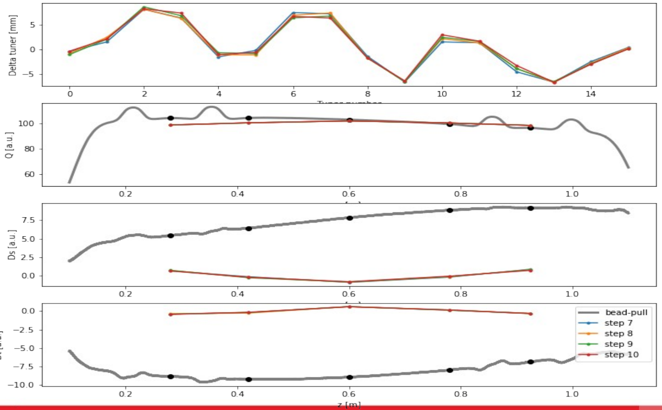


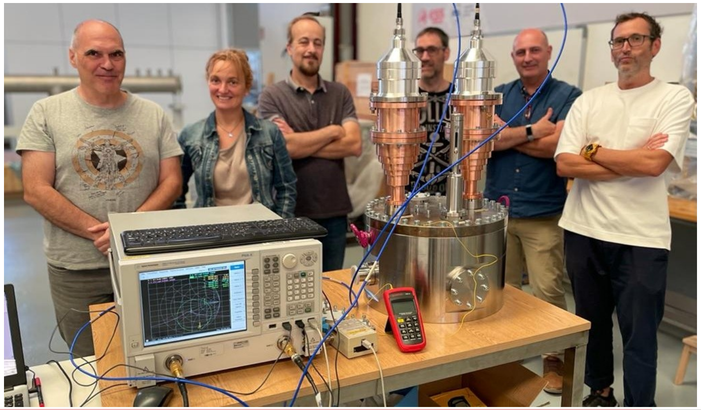


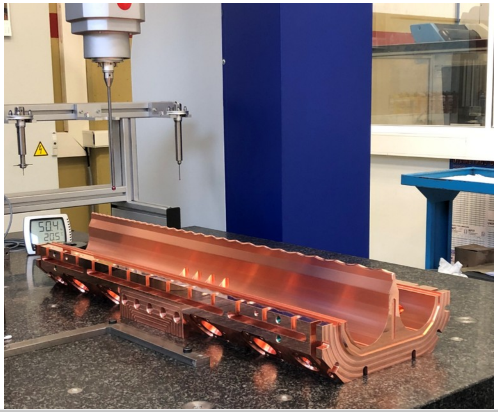
RFQ updates:
- RFQ-S1 characterization
- Dynamic cooling design
- Tuning algorithm tested (on Al cold model)
- Power coupler prototypes (x2)
- Progress in machining of S2-S4





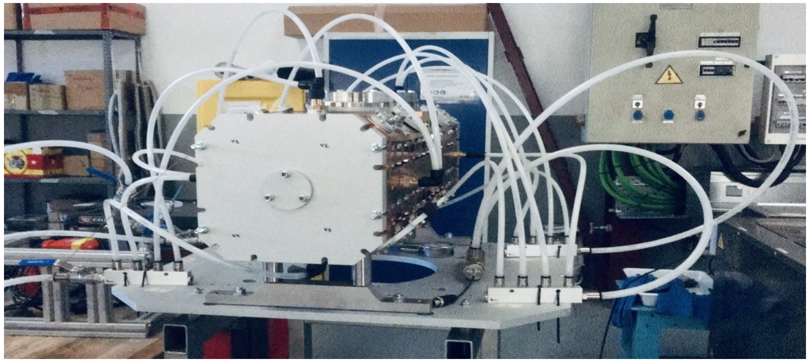


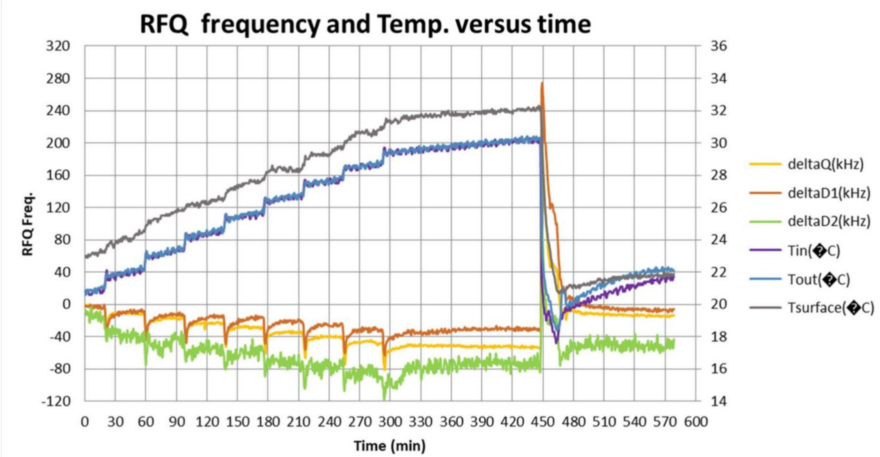


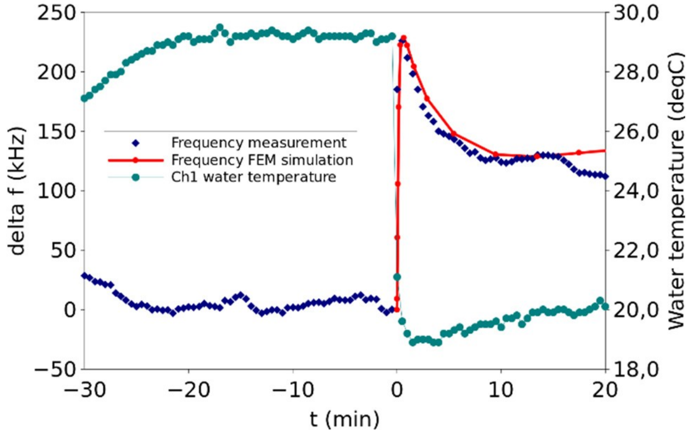


Accelerator updates: RFQ1- Characterization

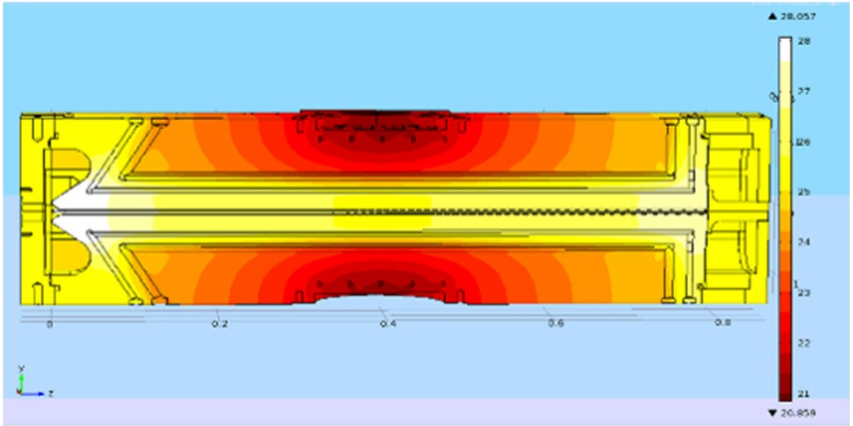
Water-cooling system based resonant frequency control during operation. Tests made to validate approach based on simulations. The aim was to obtain the frequency vs inlet water temperature in a step transient.







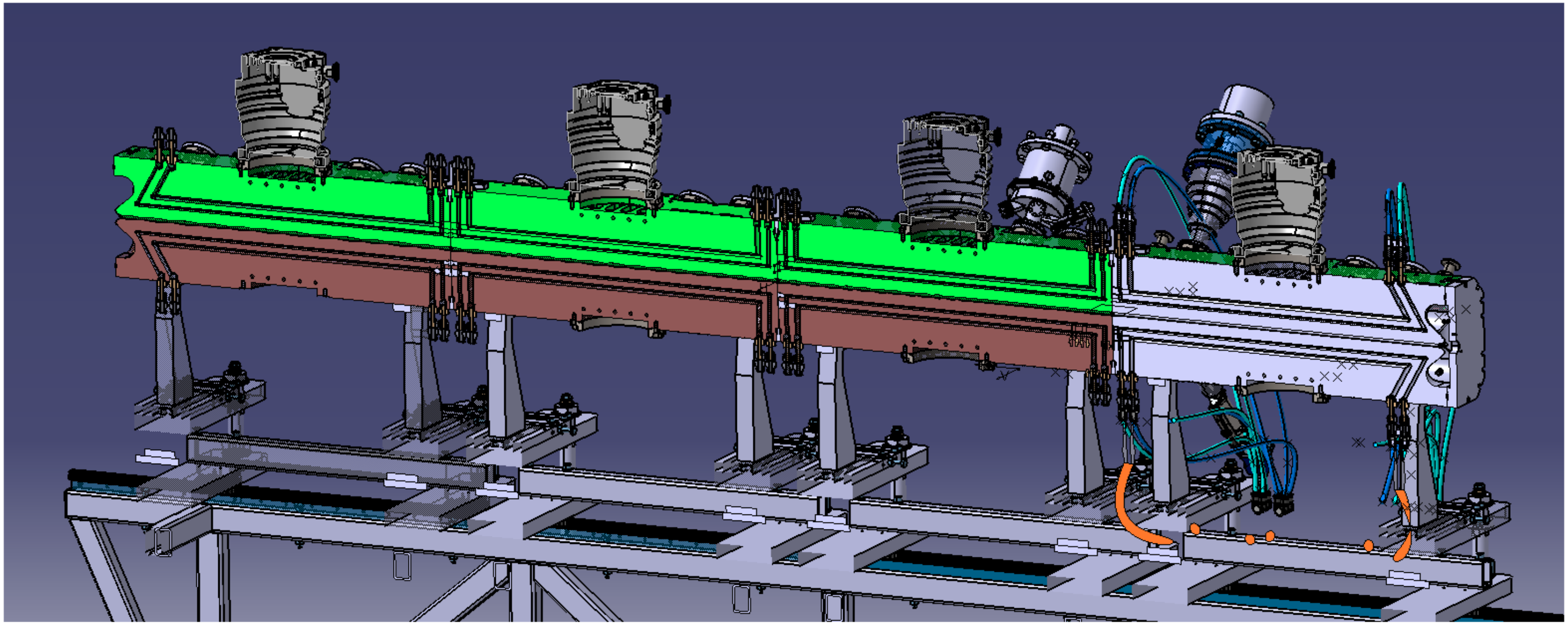
RF Frequency Water system tests



Water based effects on RF tuning simulations

“EXPERIMENTAL TESTS WITH THE FIRST SEGMENT OF ESS-BILBAO RFQ LINAC”. IPAC2021, Campinas, SP, Brazil (Virtual) MOPAB340

Accelerator updates: RFQ



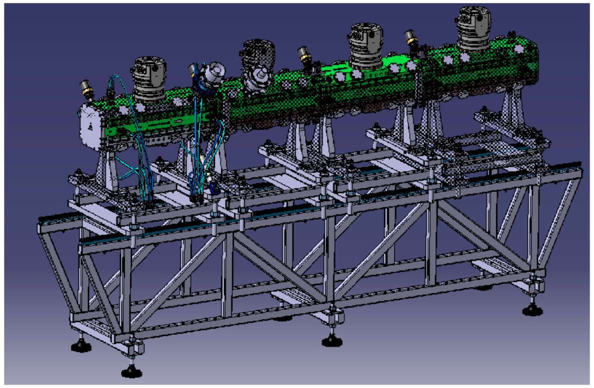


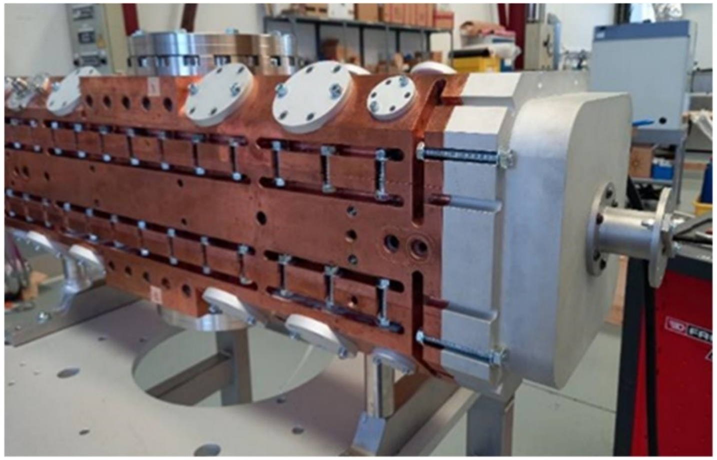
Table 1: ARGITU-RFQ Main Specifications

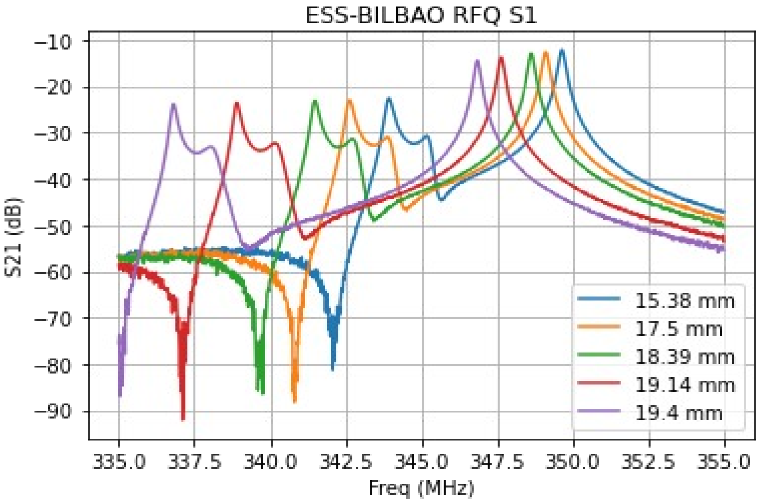
Parameter	Value
Specimen	H+
Beam current	32 mA
Beam energy	45 keV→3 MeV
RF Frequency	352.2 MHz
Pulse Operation	30 Hz; 1.5 ms; 4.5 %
Intervane Voltage	85 kV
Kilpatrick	1.85
Input emittance	0.25 π mm rad

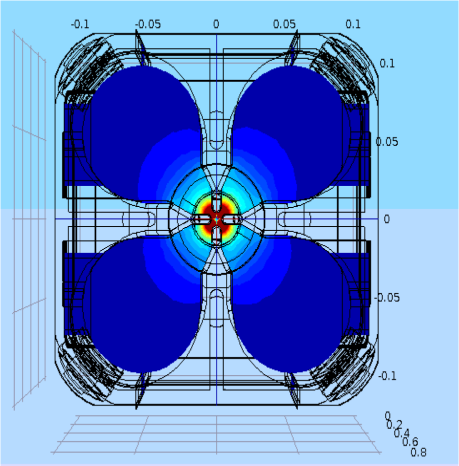
"Development of the radio frequency quadrupole proton linac for ESS-Bilbao", EPJ Web of Conferences 231, 02001 (2020), UCANS-8

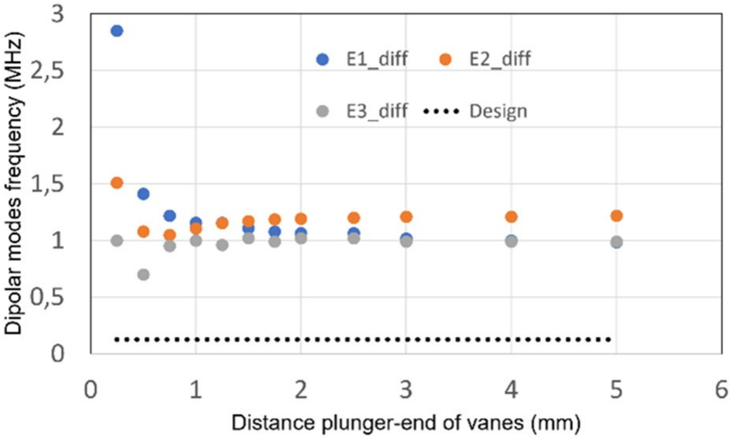
Accelerator updates: RFQ1- Characterization

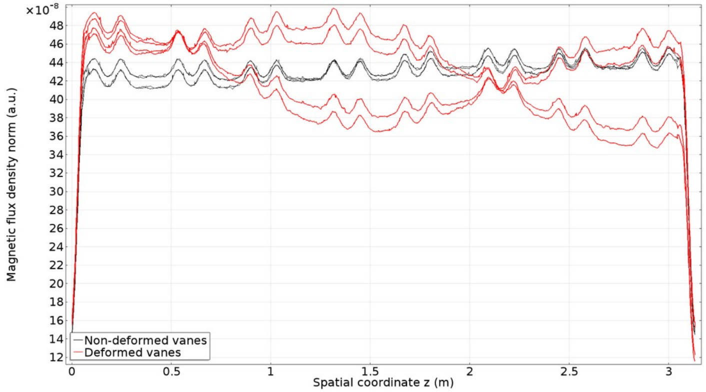
RFQ-S1 characterised in LPRF Measured dipolar modes are separated by about 1 MHz. Simulations and assembly metrology points out that realignment is needed





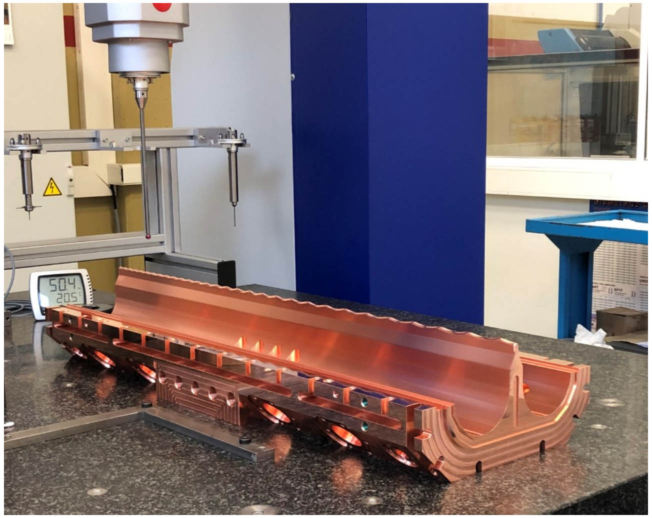


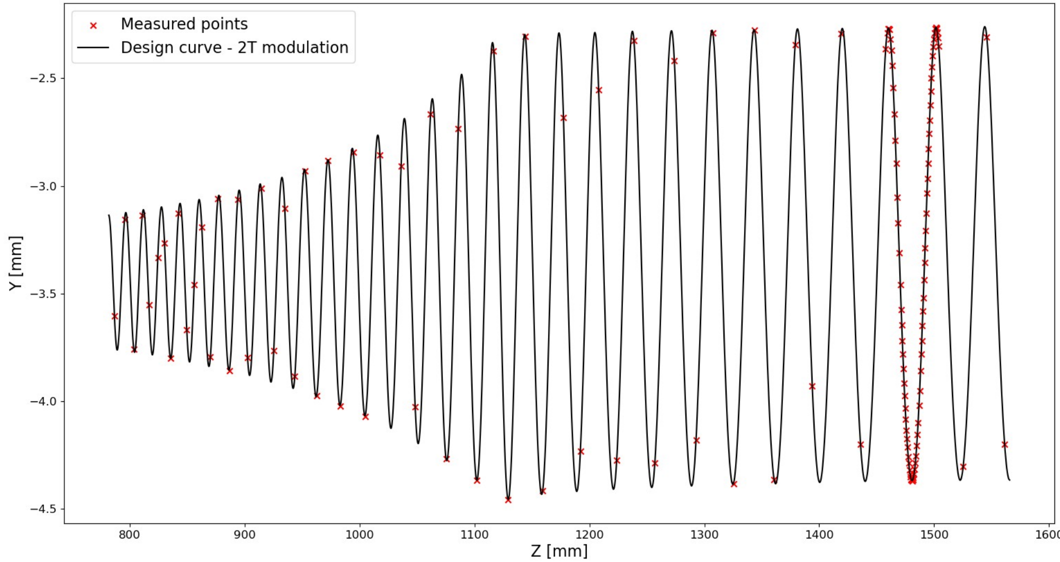




Accelerator updates: S2-4 MACHINING

New contract to machine rest of the segments in place.



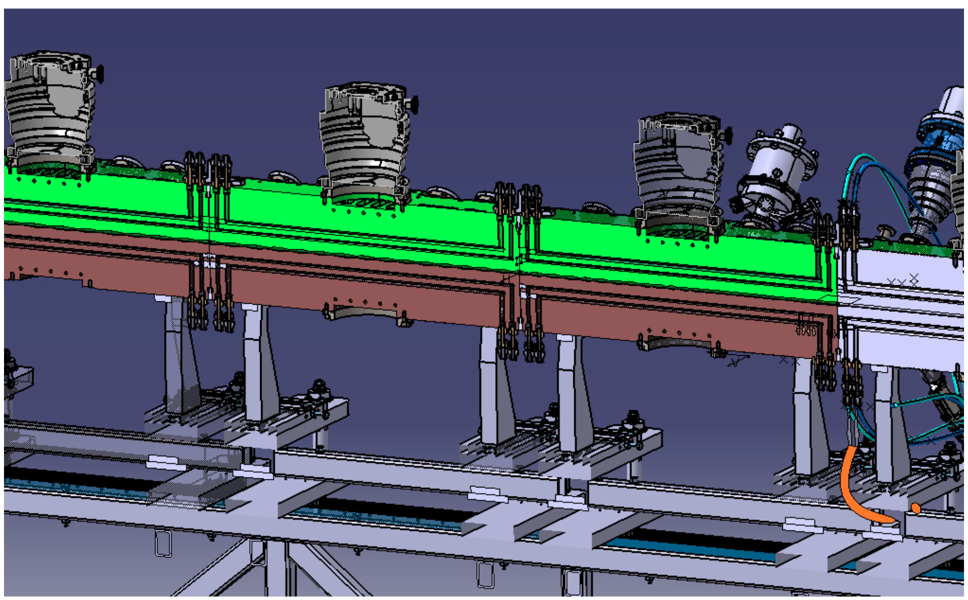


Metrology results for vane 2001 agree within 5 µm tolerance

REF	SIE	DES	TAE	DIS	SEM	EBW	ACA
RFQU-VN-2001							
RFQU-VN-2002							
RFQU-VN-2003							
RFQU-VN-2004							
RFQU-VN-3001							
RFQU-VN-3002							
RFQU-VN-3003							
RFQU-VN-3004							
RFQU-VN-4001							
RFQU-VN-4002							
RFQU-VN-4003							
RFQU-VN-4004							

	PROGRAMADO
	EN MÁQUINA
	REALIZADO

Accelerator updates: RFQ manufacturing & assembly



Accelerator updates: RFQ manufacturing & assembly

Segment 2 RF Validation tests in EGILE-DMP
Nov-2022
Mendaro- Spain

RFQ tests performed on segment 1.

Tuning algorithm and couplers ready. Low power **RF Testing done.**

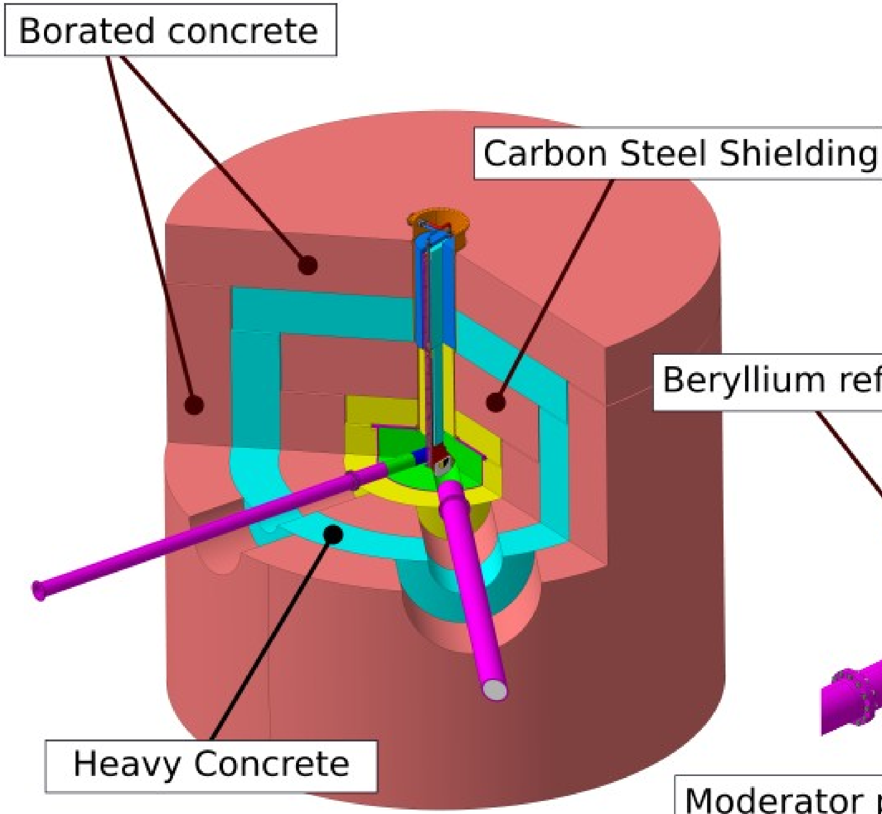
Segments 2 done!

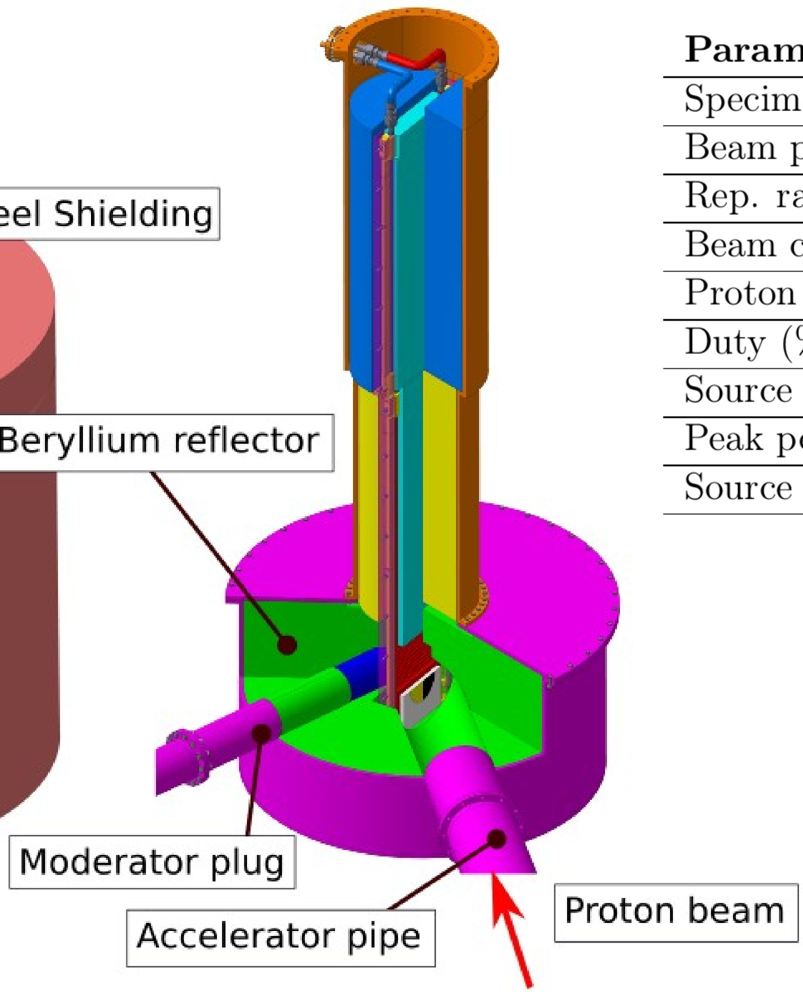
Segments 3 & 4 manufacturing on good progress!

THE TARGET STATION

The Target Station: General Layout

ARGITU Target Station will be based on a solid beryllium Target, with a total neutron yield in the range of 2~3 10^{14} n/s. In order to optimize the available space for instruments, the Target is prepared for vertical extraction.





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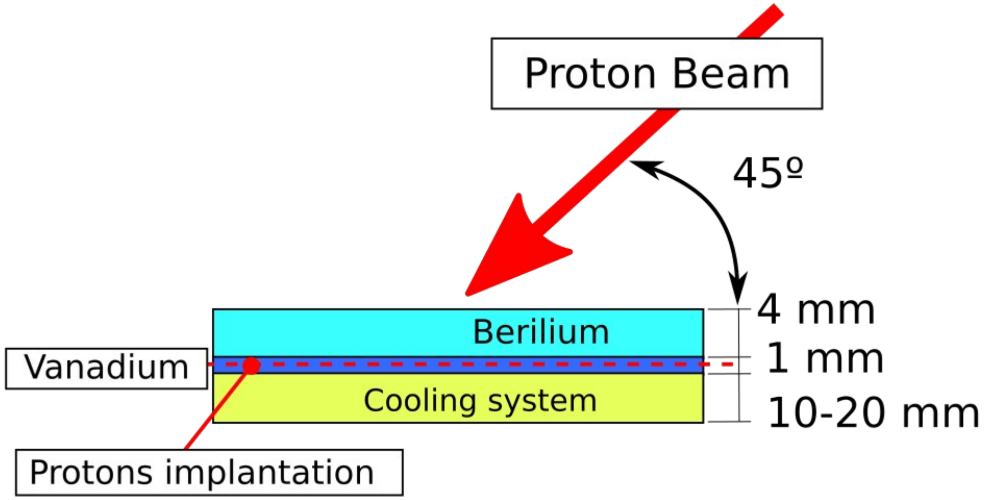
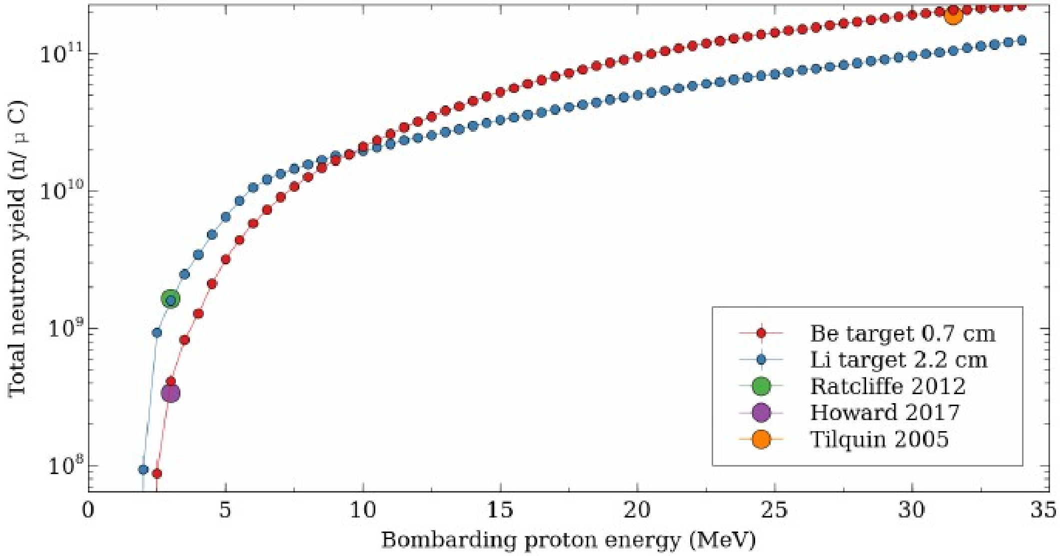
Source term (H^+/s)	8.96E15
Peak power (KW)	1007.2
Source term (H^+/MW)	1.98E17

The total expected deposition in the Target is **42.5 kW**

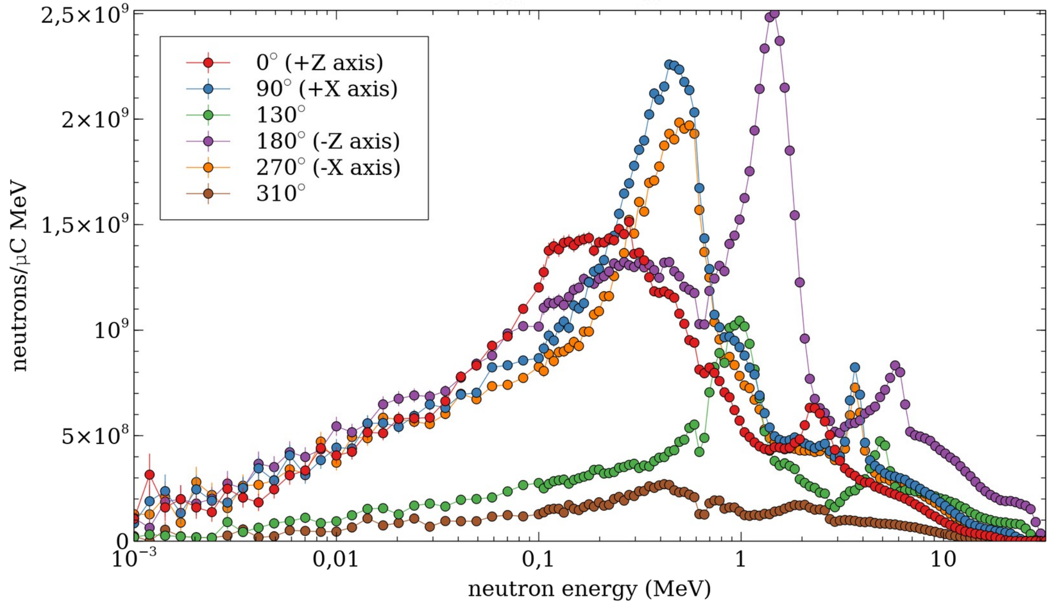
The Target Station: Target

Beryllium maximized the neutron yield for 32 MeV protons. If the Brag peak is inside the Beryllium we will have blistering failure in few hours of operation. 1 mm layer of vanadium is used to stop the protons



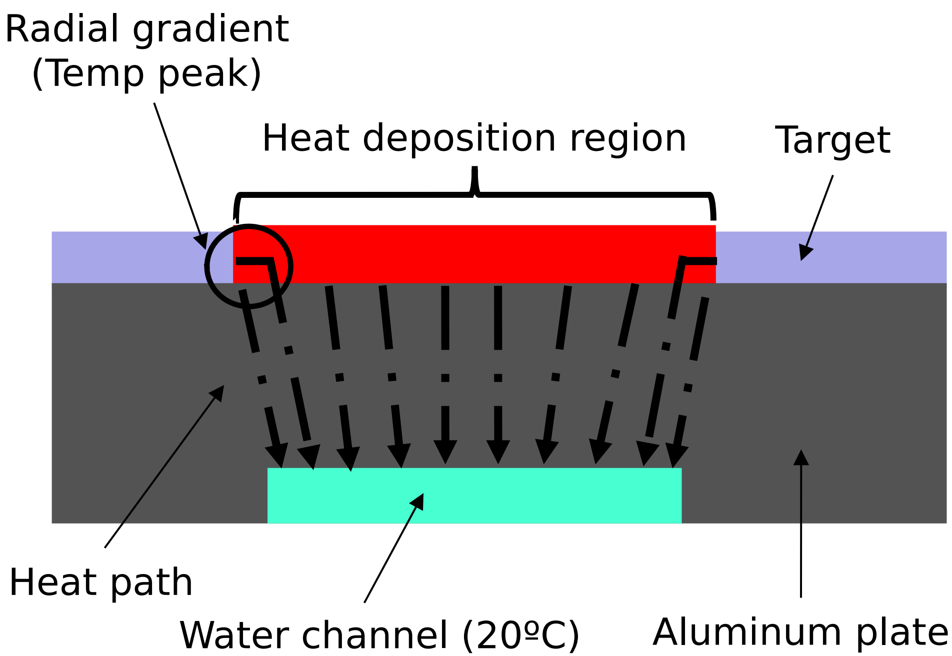


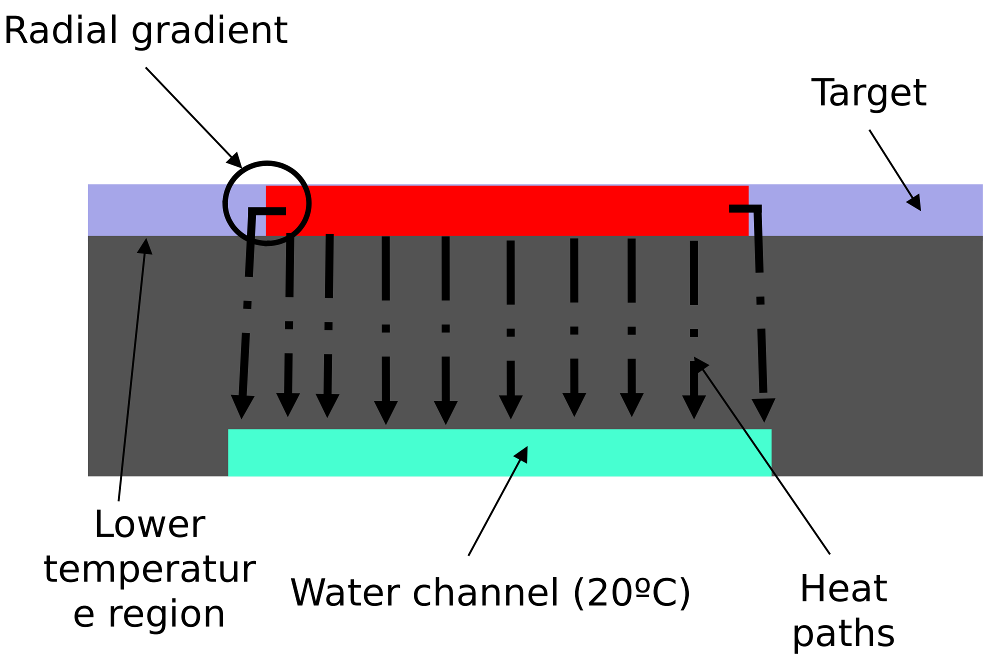
Introducing 45º between Target and beam the cooling area will be increased.



The Target Station: Target

The 45º beam produce an elliptical beam footprint. Combined with the lower thickness of the target and high conductivity materials creates challenging conditions to avoid large thermal gradients





If cooling area is smaller than footprint a temperature peak is produced.

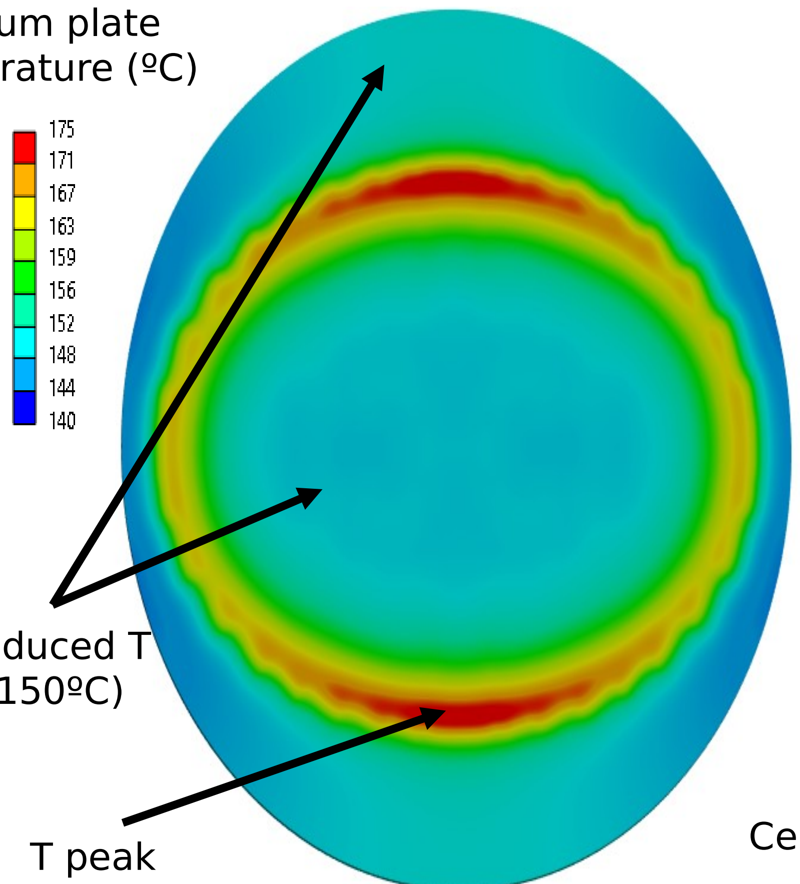
If cooling area is bigger than footprint the plate is cooler than the central part (thermal gradient at the edge)

The Target Station: Target

The best solution is to make the channel a little bit narrower than the footprint even though there is an internal temperature peak (30ºC).

260 mm x 180 mm cooling ellipse

Beryllium plate
Temperature (ºC)



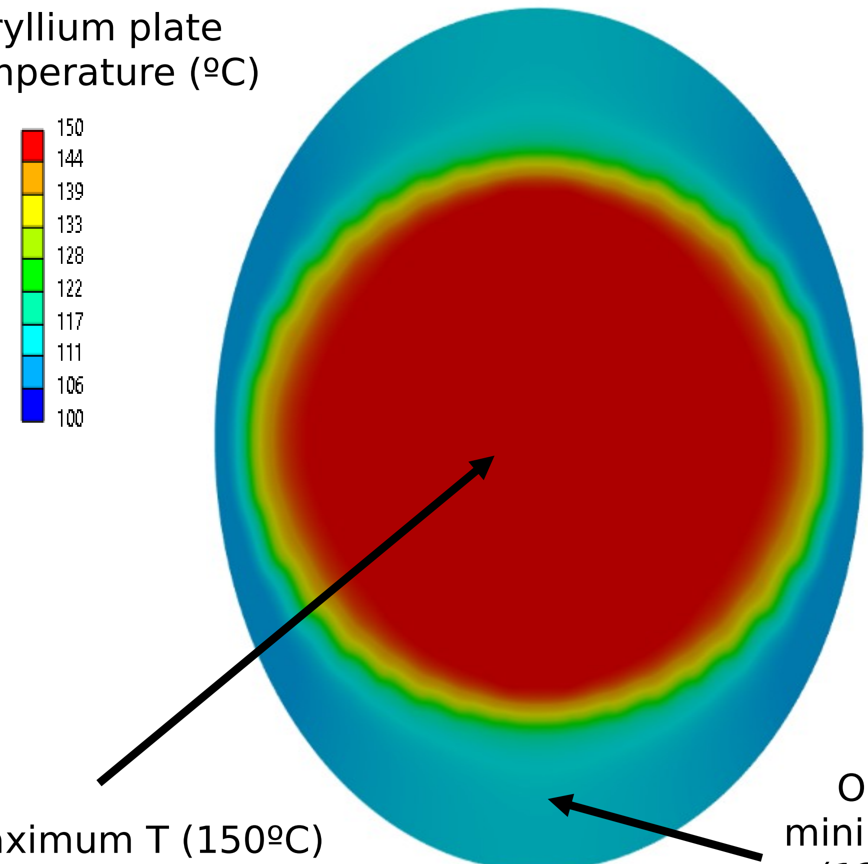
Reduced T
(150ºC)

T peak
(175 ºC)

Cooling channel is smaller than the footprint

270 cm x 190 mm cooling ellipse

Beryllium plate
Temperature (ºC)



Central maximum T (150ºC)

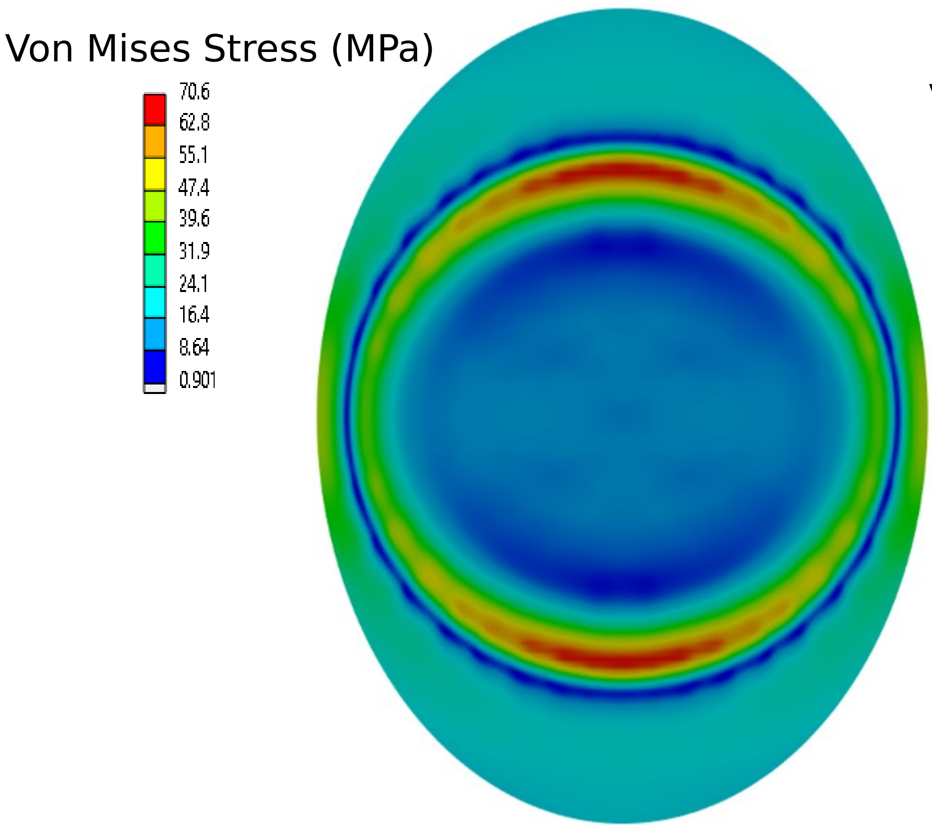
Outer
minimum T
(120ºC)

Cooling channel is larger than the footprint

The Target Station: Target

The best solution is to make the channel a little bit narrower than the footprint even though there is an internal temperature peak (30ºC).

260 mm x 180 mm cooling ellipse



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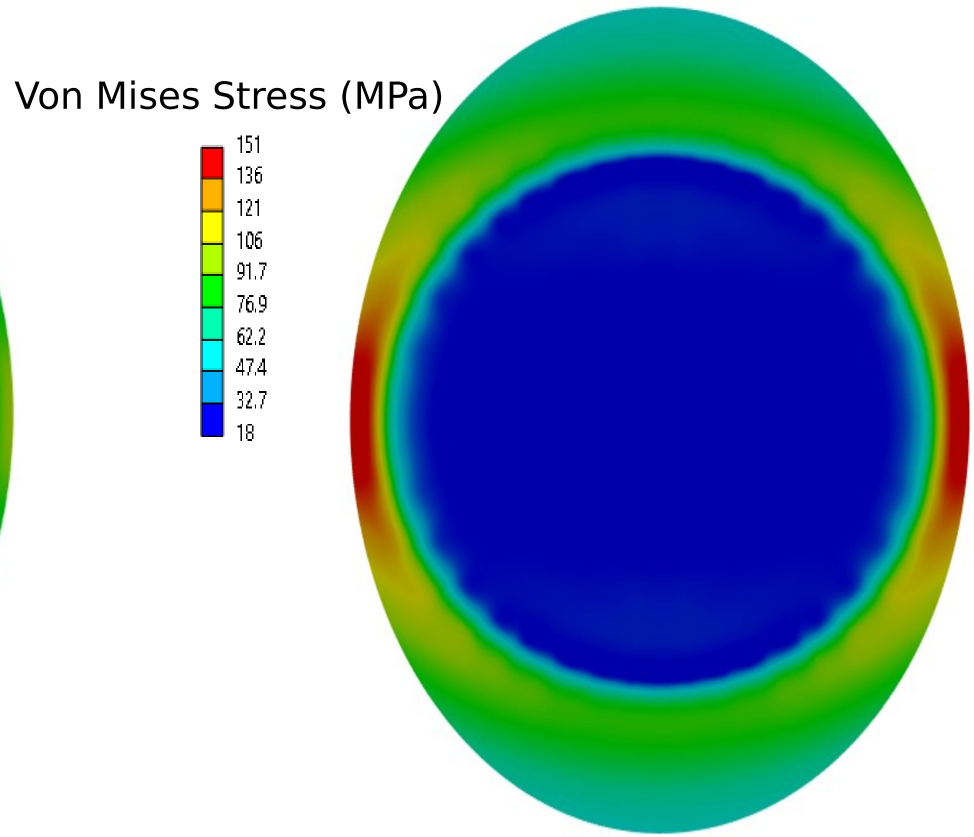
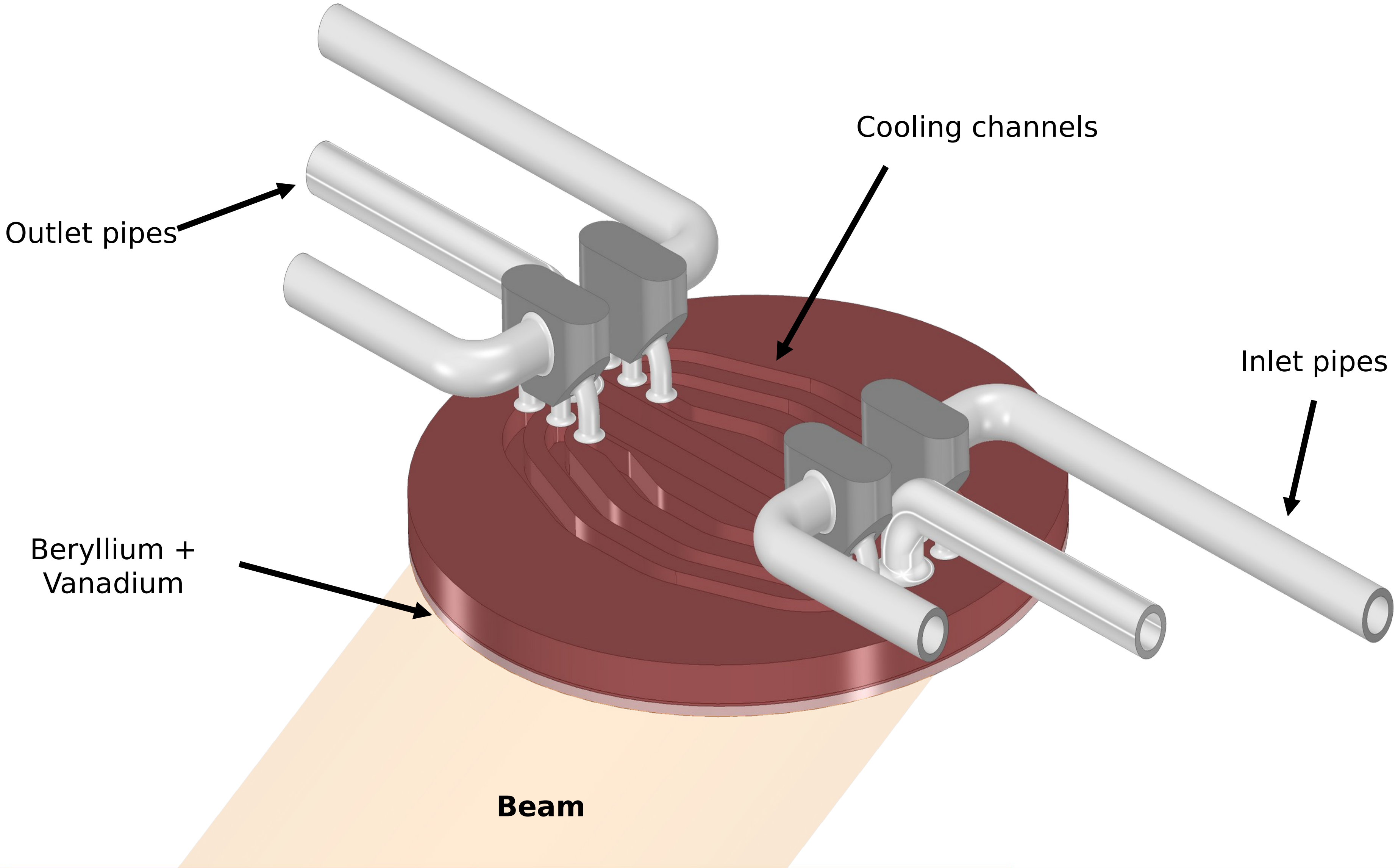


Cooling channel is larger than the footprint

The proposed shape of the target with the cooling channels after this first analysis is:

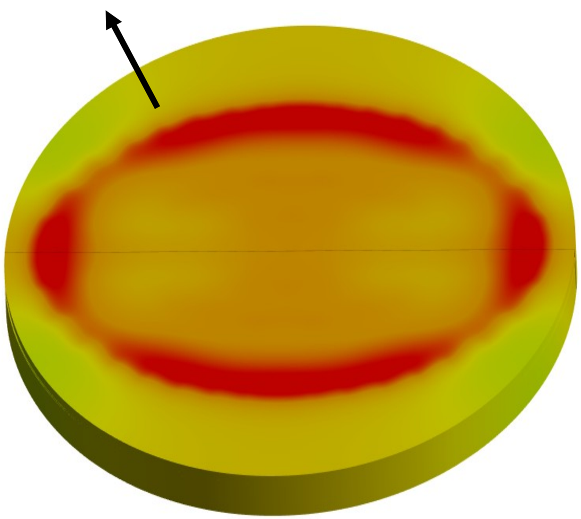


Conclusions

Estimated temperature map for the proposed geometry:

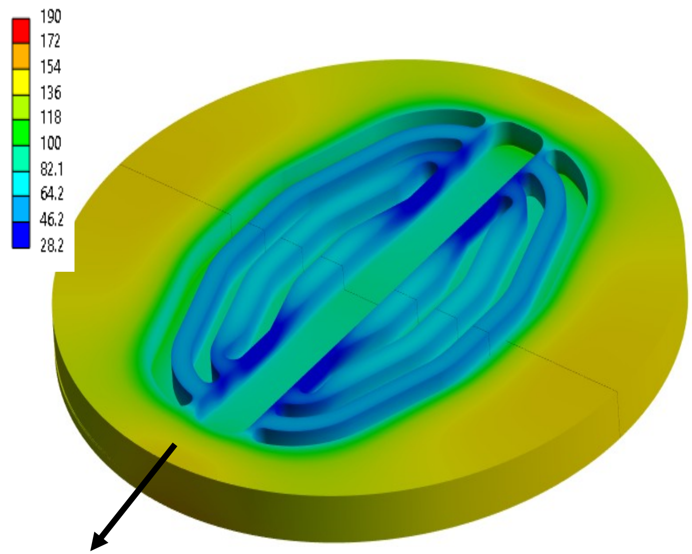
Front face

Beryllium + Vanadium



Cooling channels (back)

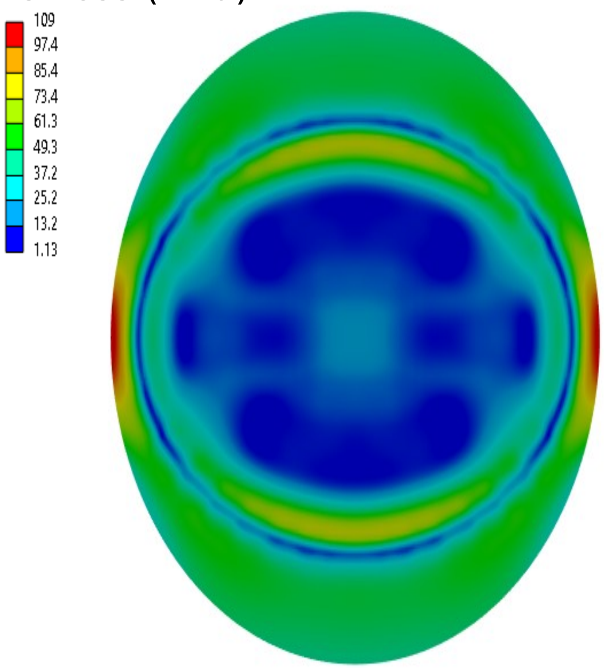
Temperature (ºC)



Aluminum cooling plate (<130ºC)

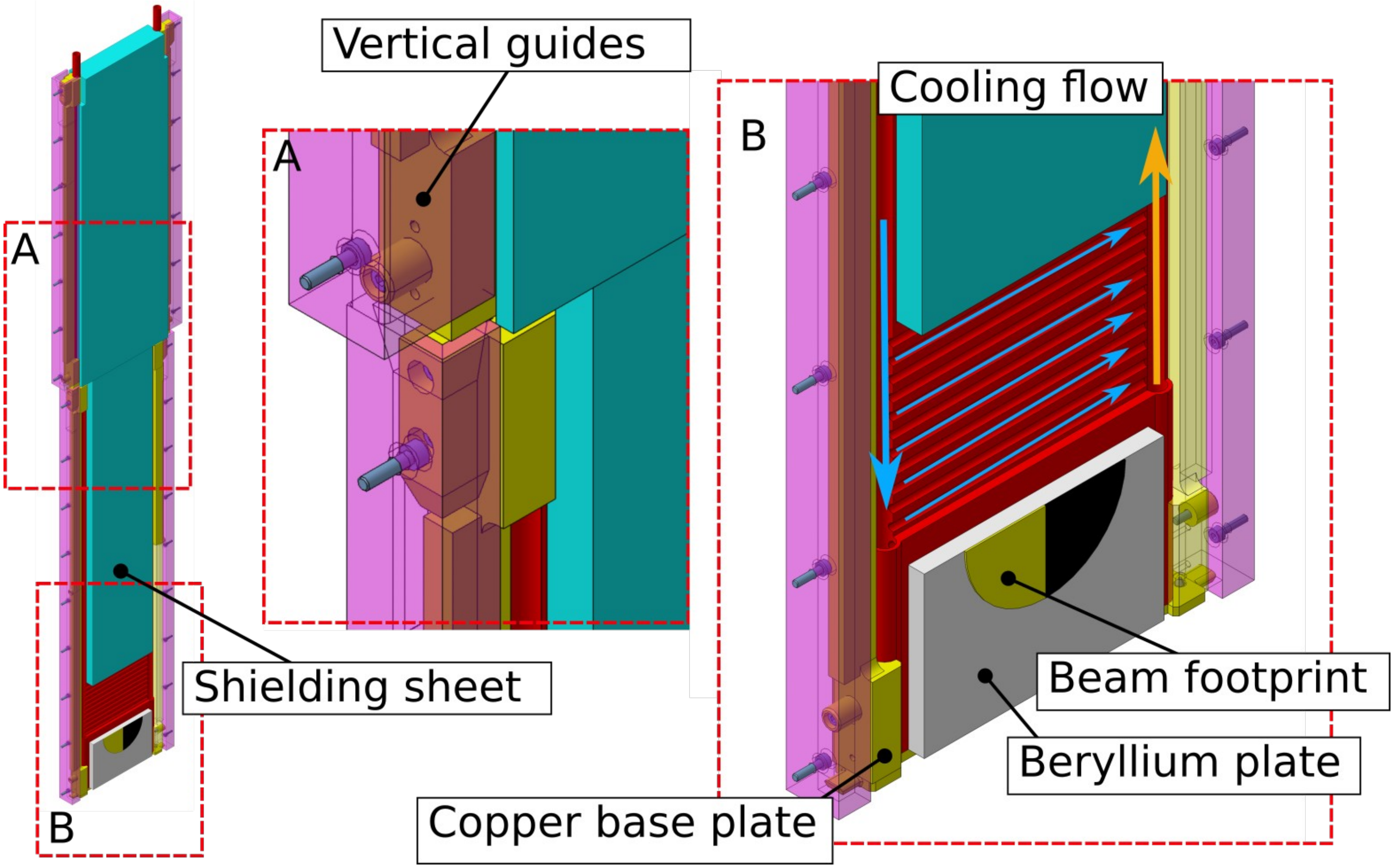
Front face

Von Mises Stress (MPa)



The Target Station: Target

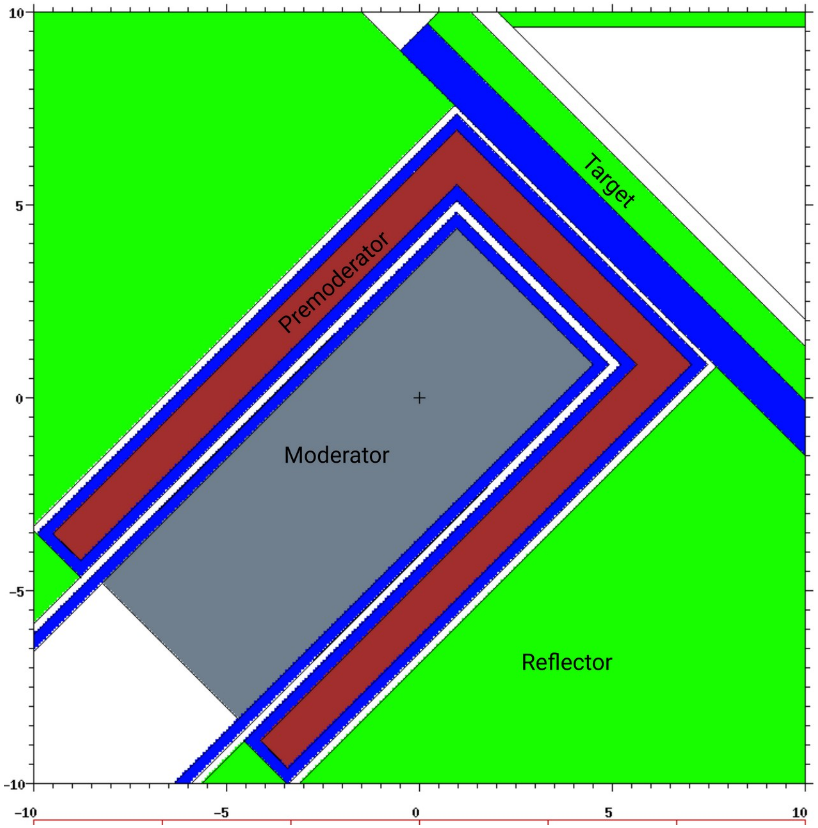
The Target plug will be prepared for vertical extraction to maximize the available space for moderators/instruments. The structure will be manufacture in Aluminum to minimize the radioactive inventory.

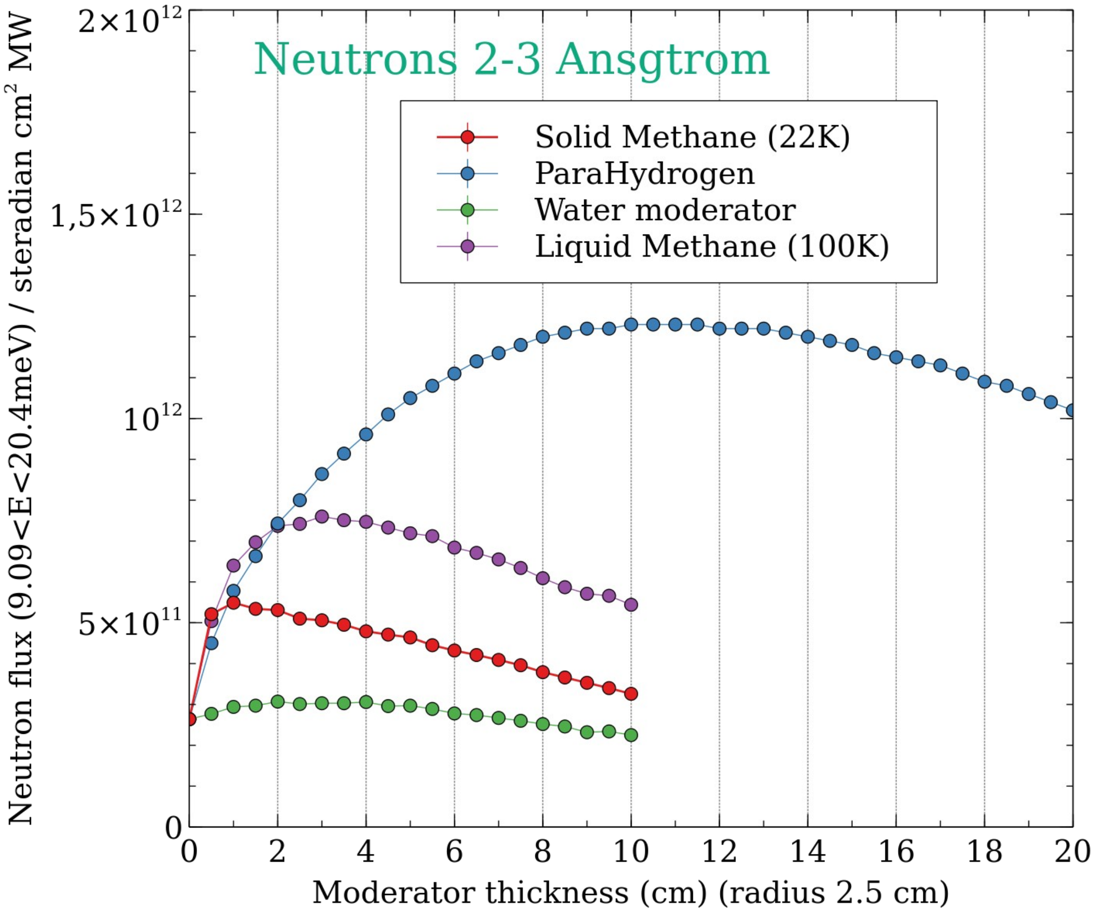


THE MODERATORS

The Target Station: Moderator

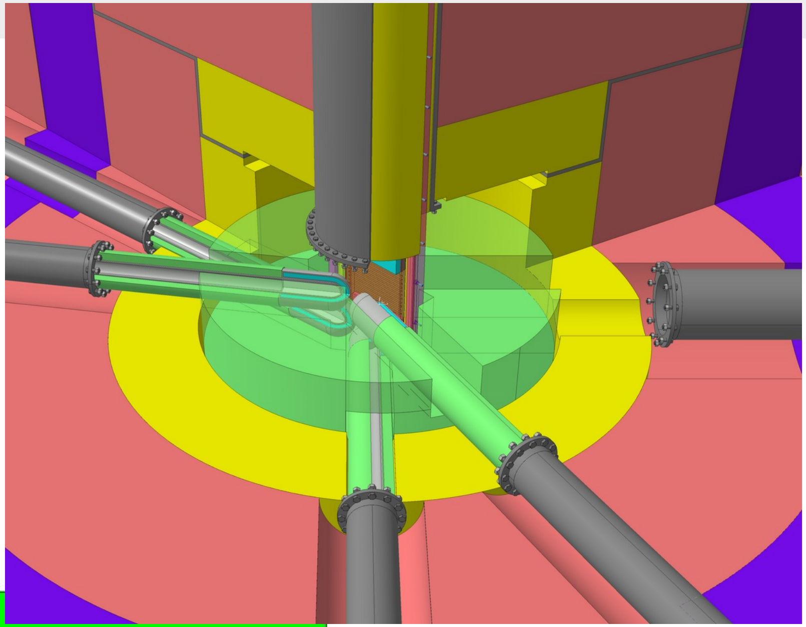
The “finger moderator” configuration will allow to define a dedicated moderator per instrument. The complete optimization process has been performed to propose modetators for 4 instrument lines **[See F. Fernandez presentation]**

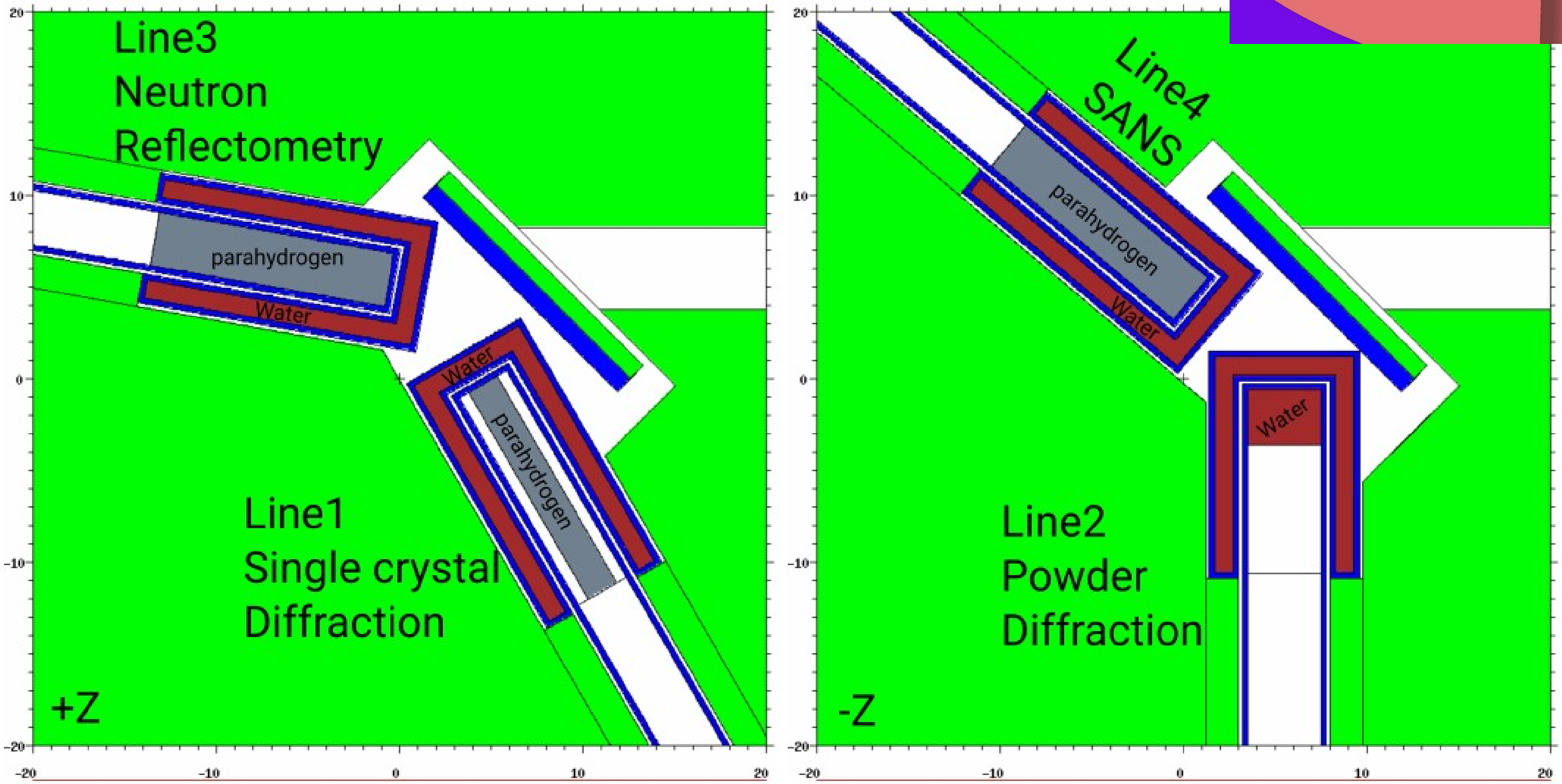




The Target Station: Moderator

The moderators will be place in two different planes symmetrically from the proton beam.





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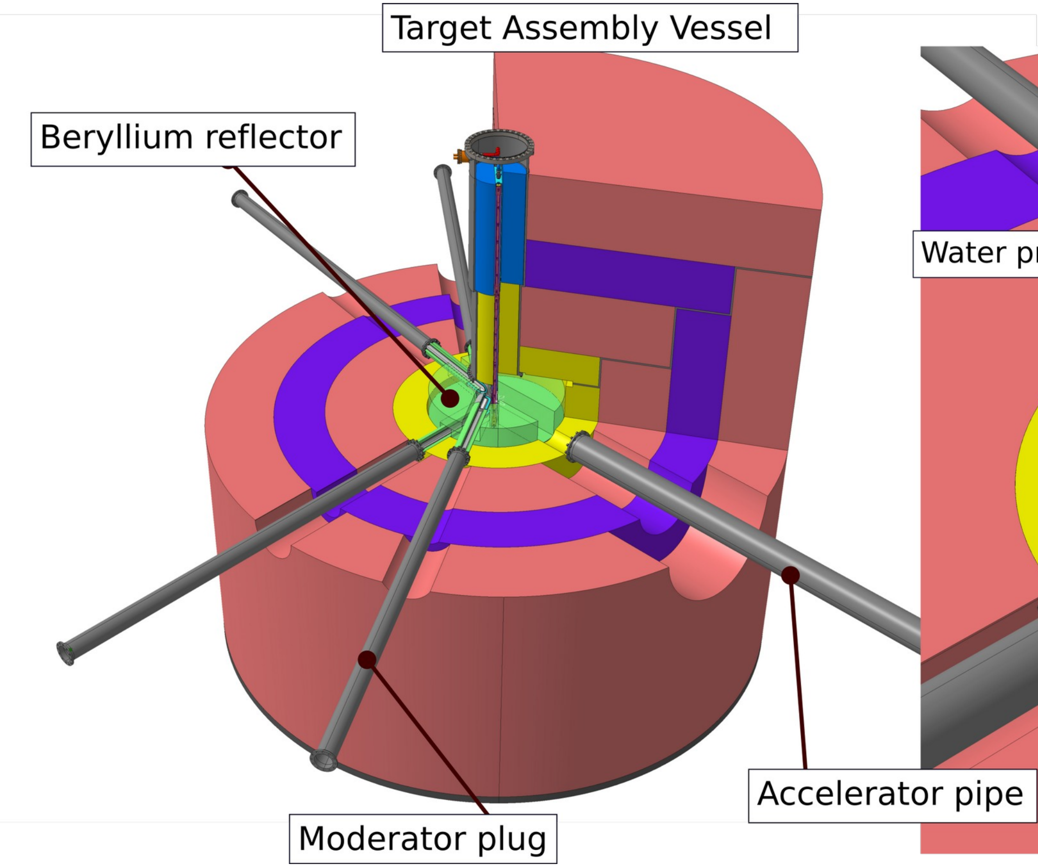

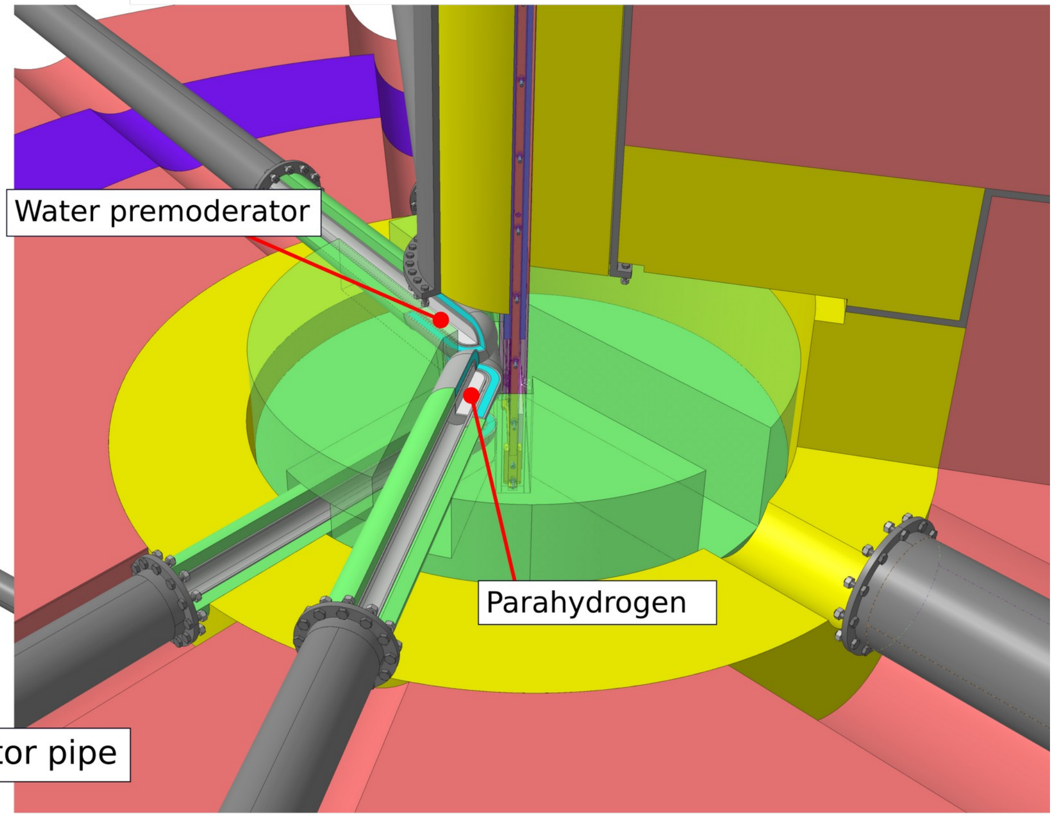

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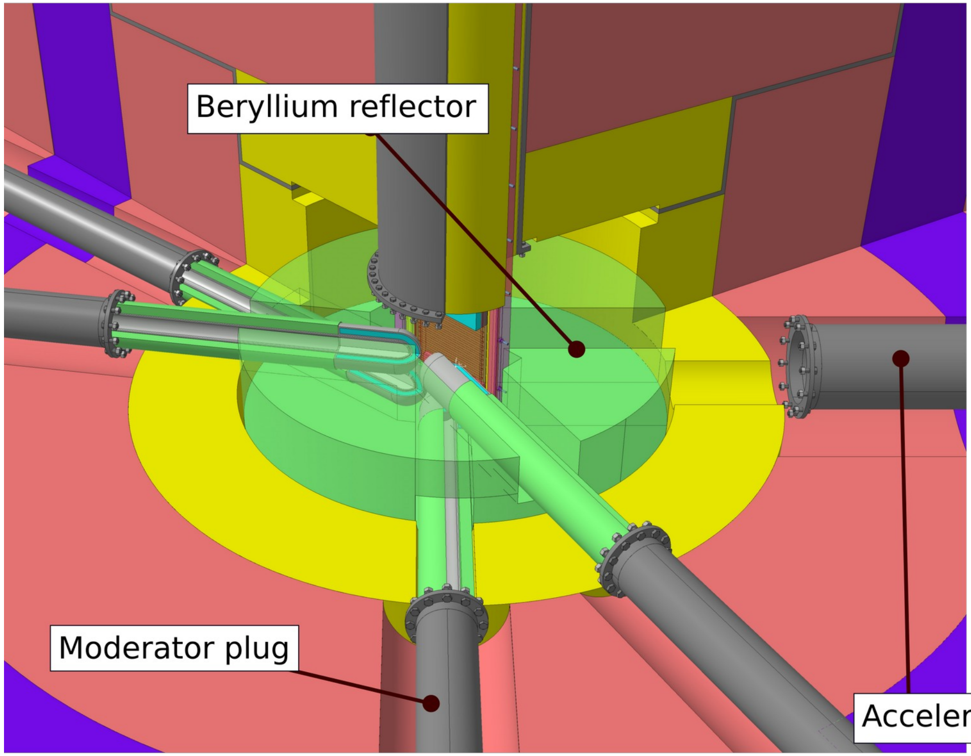
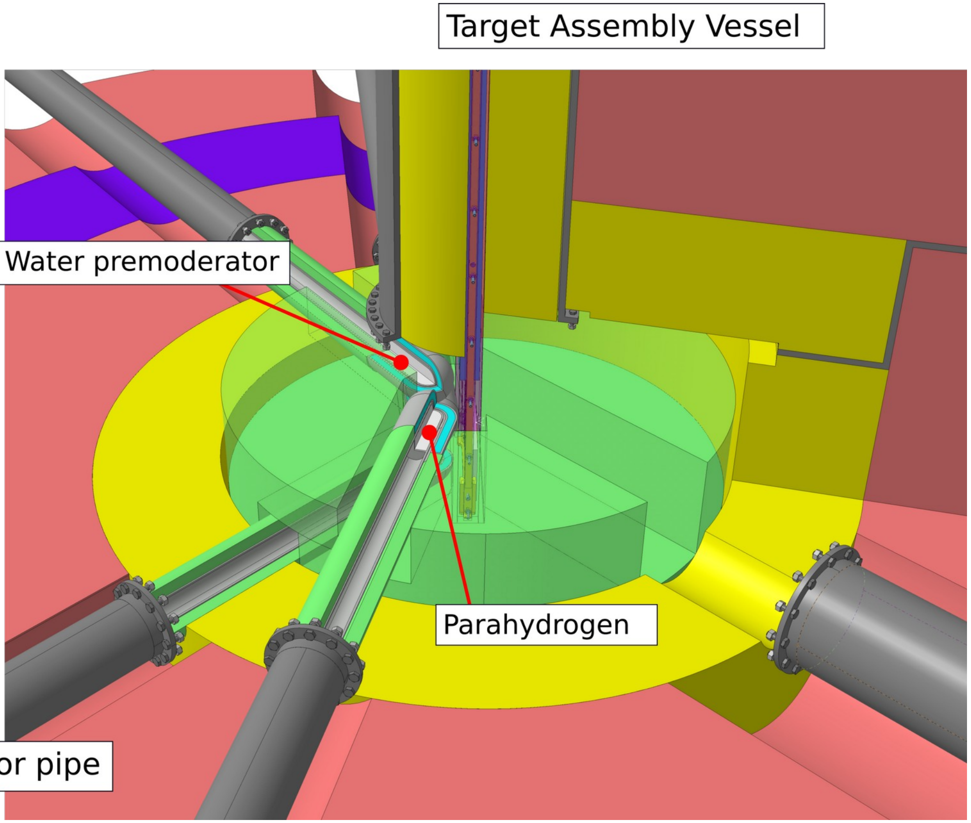
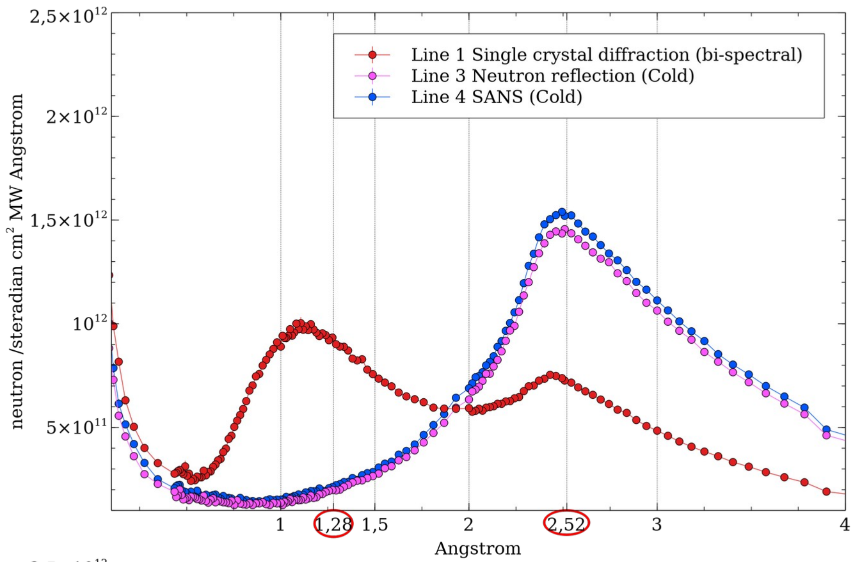
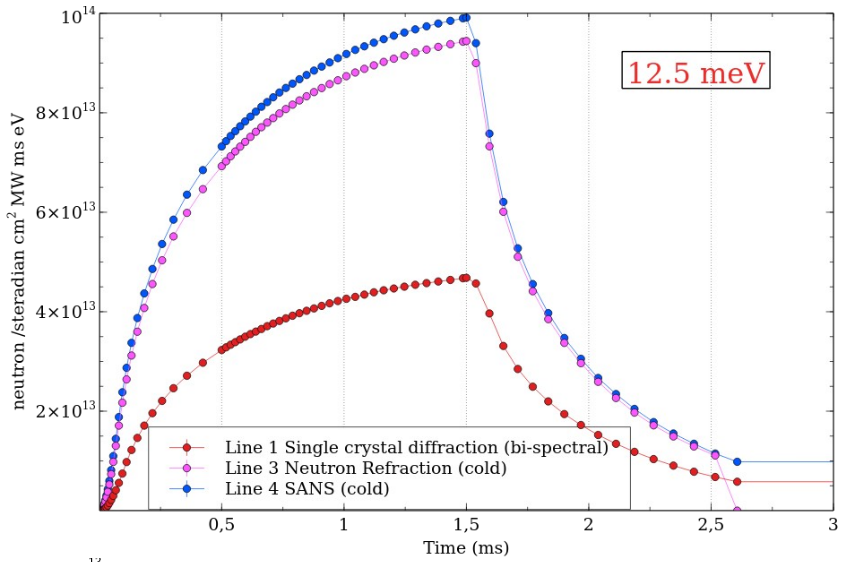


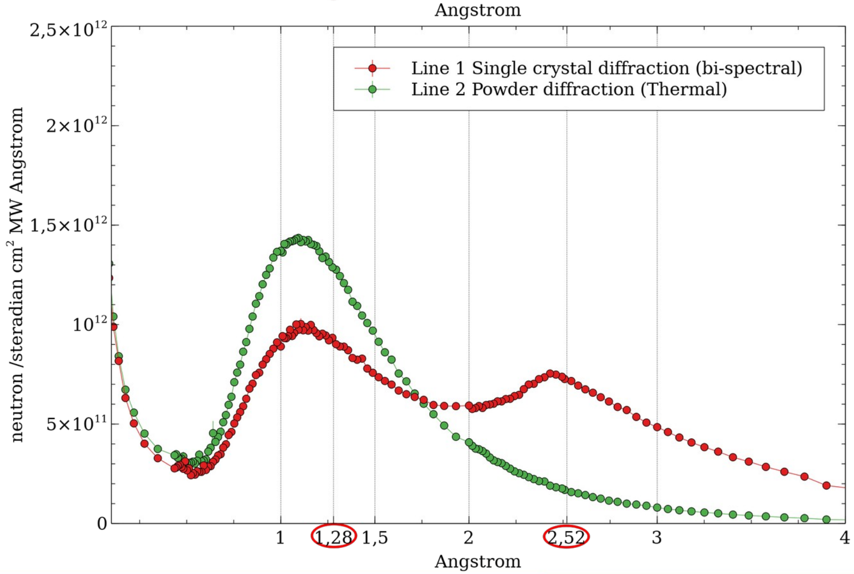


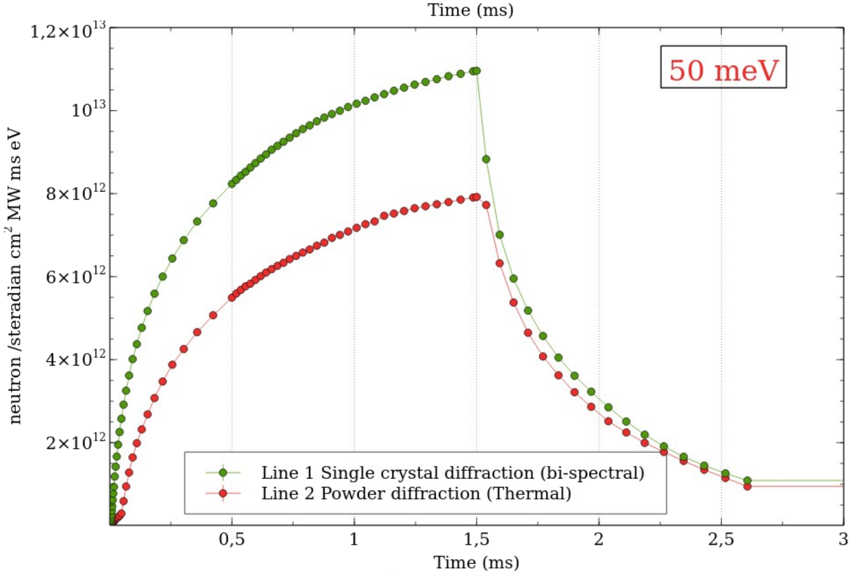
The Target Station: Moderator

The cold moderators will provide quite similar brightness (20% lower than single moderator configuration).









The Target Station: Moderator

Comparing the ARGUITU proposal with operational facilities, we can provide 50% of the time average flux in ISIS-TS2 H/CH4 moderator.

	Neutrons below 400 meV				
	Power [kW]	Rep. R. [Hz]	Surface [cm^2]	N. intensity [n/cm^2 s sr]	N. intensity [n/cm^2 ps sr]
JSNS C. Hydrogen	300	25	10w x 10h	1.3E+12	5.1E+10
	1000	25	10w x 10h	4.5E+12	1.8E+11
SNS C. Hydrogen	1000	60	12w x 10h	2.1E+12	3.5E+10
	1400	60	12w x 10h	3.0E+12	4.9E+10
ISIS-TS2 H/CH4, gro.	48	10	8,3w x 3,0h	5.0E+11	5.4E+10
ISIS-TS2 H/CH4, hyd.	48	10	12w x 11h	**3.0E+11**	3.0E+10
ARGITU 2022 1 Nline (cold)	50	30	Ø 5 cm	1.6E+11	5.1E+09
ARGITU 2022 4 Nlines (SANS)	50	30	Ø 3 cm	**1.5E+11**	4.9E+09

CONCLUSIONS

Conclusions

- ARGUITU accelerator is on manufacturing. RFQ manufacturing will be completed on 2023. Assembly and commissioning will be done along 2024.
- We are considering a Be+V steady state target cooling by water. The power level will be challenging but stiff acceptable for low pressure water cooling systems.
- The moderator system will allow specific optimization for each instrument with 4 experimental lines per target station.