ESSnuSB+ First Annual Meeting

TARGET DIVISION

THERMAL AND MECHANICAL DEVELOPMENT OF A NEUTRINO TARGET

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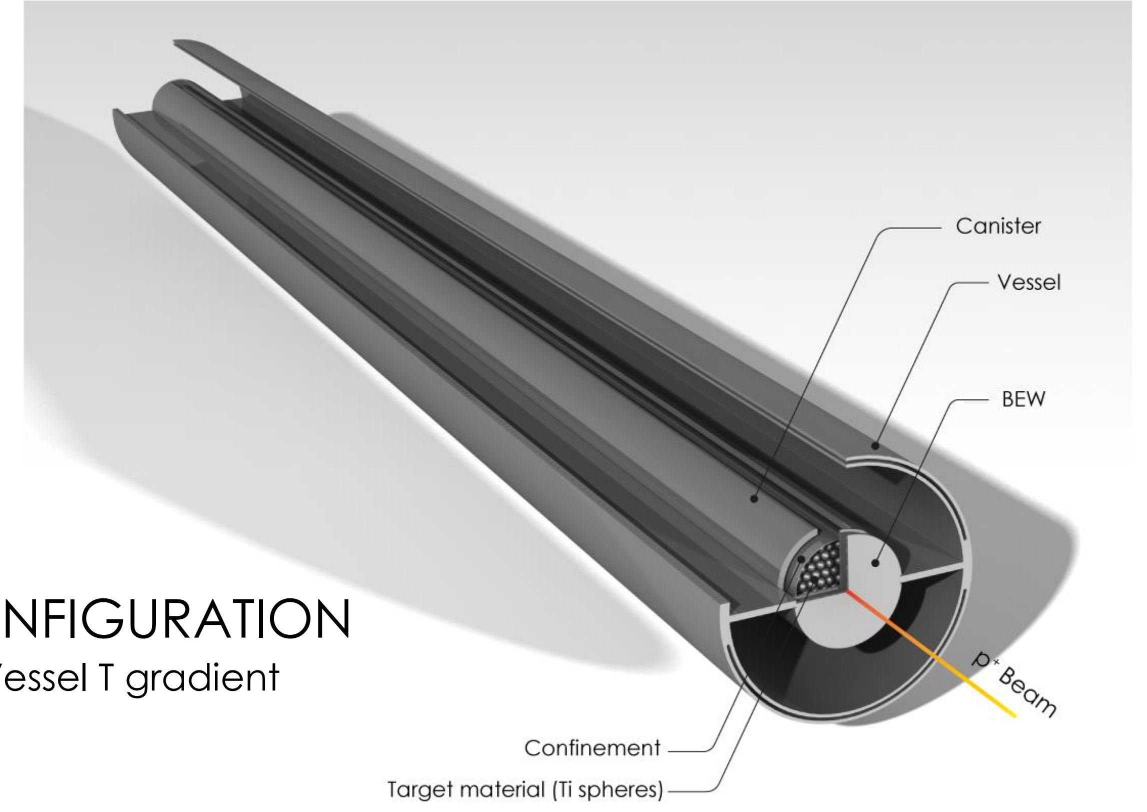


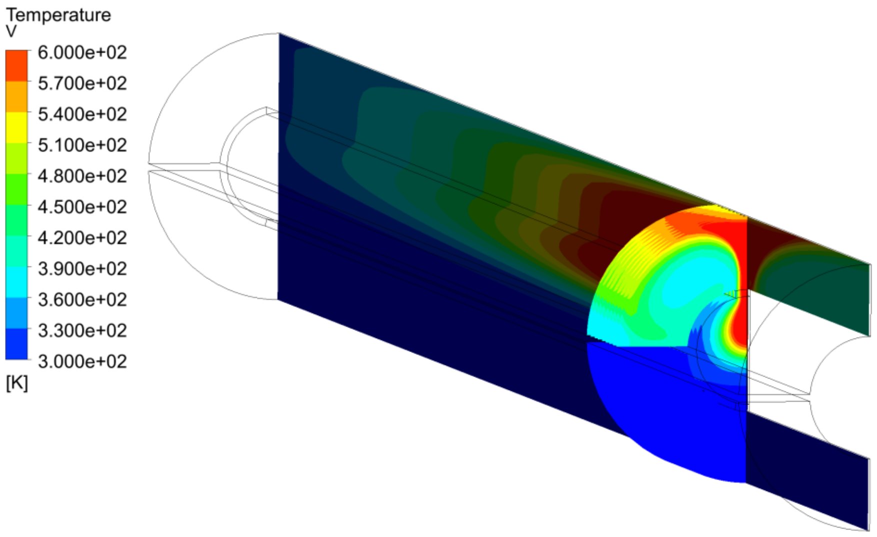
ESSnuSB+ TARGET STATION DESIGN ROADMAP

TARGET STATION CFD-THERMAL-MECH ANALYSIS / CONFIGURATION
- -STEADY STATE scenario (done 2023)→ BEW ok / high Vessel T gradient
- -TRANSIENT scenario (ongoing)

TARGET MATERIAL ANALYSIS
- -Explicit dynamics analysis (done 2024) → 3mm OK
- -BEW / plates analysis (pending late 2024)

PROTOTYPE DESIGN
- -Thermal/CFD analysis (done 2024)→ high heater power
- -Prototype canister /attachments design (ongoing)
- -ETHEL Rig simplification/replication (pending late 2024)
- -Validation (pending 2025)

ESSnuSB+ TARGET STATION CONFIGURATION



BEAM

E_{p+}	=2.5 Gev
BP	=4x1.25 MW
f_{beam}	=14 hz
T_{pulse}	=71 ms
t_{pulse}	=1.3 μs

TARGET (FLUKA heat gen)

Spallation material (<u>Ti</u>) 138kW

$T_{steady\ max}$ =670 °C ←2.38 kW/cm³

$T_{trans\ max}$ =670 °C + 50 °C

+

Beam Entrance Window (<u>Ti alloy</u>) 2.3 kW

$T_{steady\ max}$ =500 °C ←2.80 kW/cm³

$T_{trans\ max}$ =500 °C + 50°C

TARGET (MCNPX heat gen)

Spallation material (<u>Ti</u>) 164kW

$T_{steady\ max}$ =738 °C ←2.49 kW/cm³

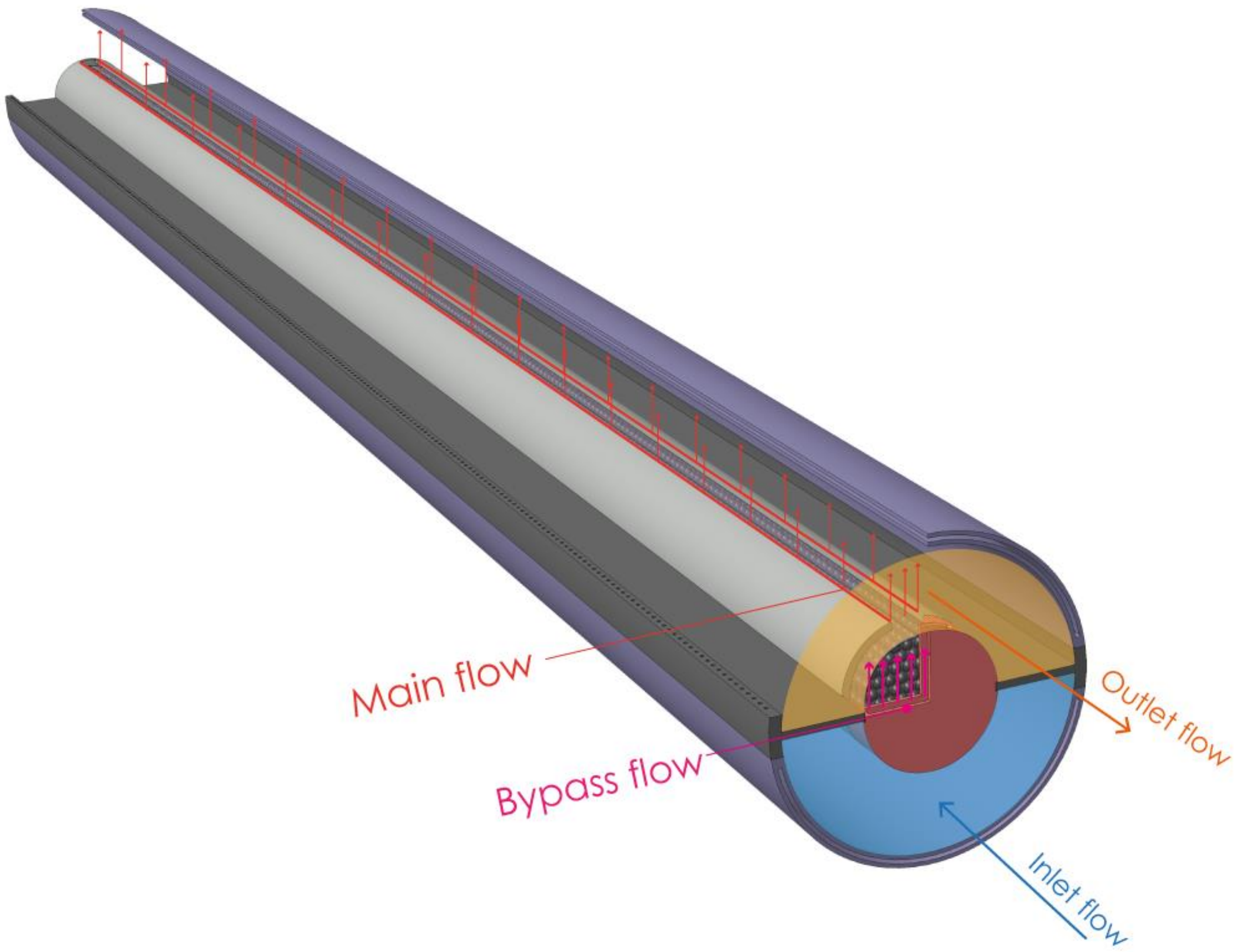
$T_{trans\ max}$ =738 °C + 50°C

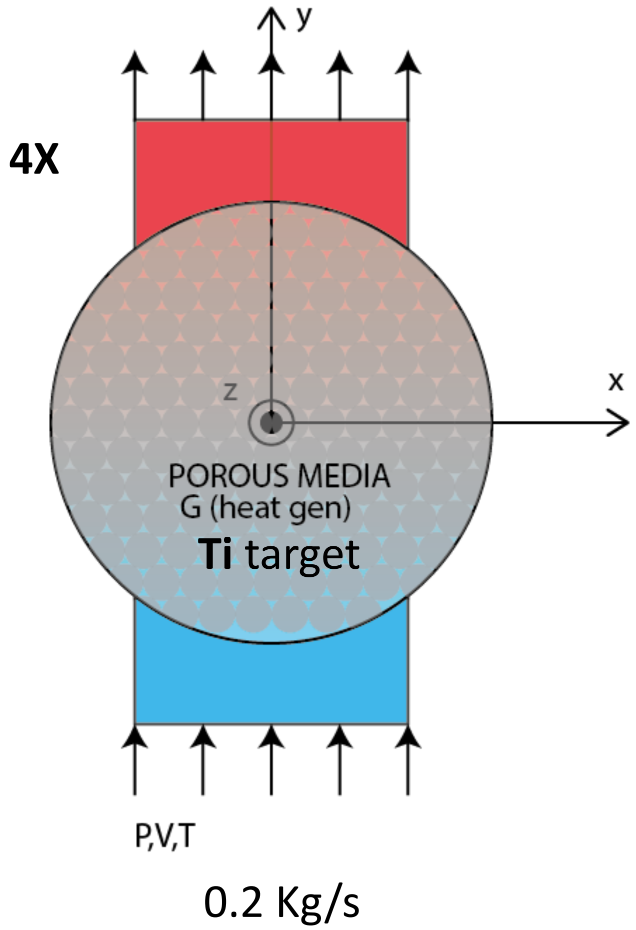
Beam Entrance Window (<u>Ti alloy</u>) 9 kW

$T_{steady\ max}$ =602 °C ←3.08 kW/cm³

$T_{trans\ max}$ =602 °C + 50°C

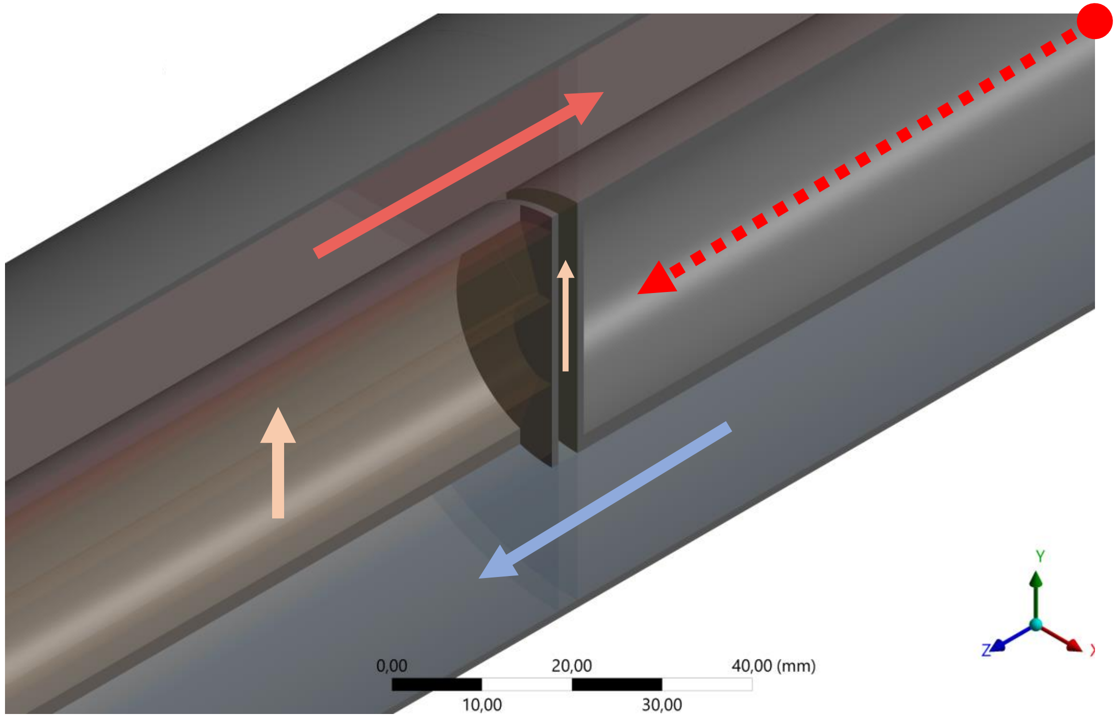
ESSnuSB+ TARGET STATION CONFIGURATION





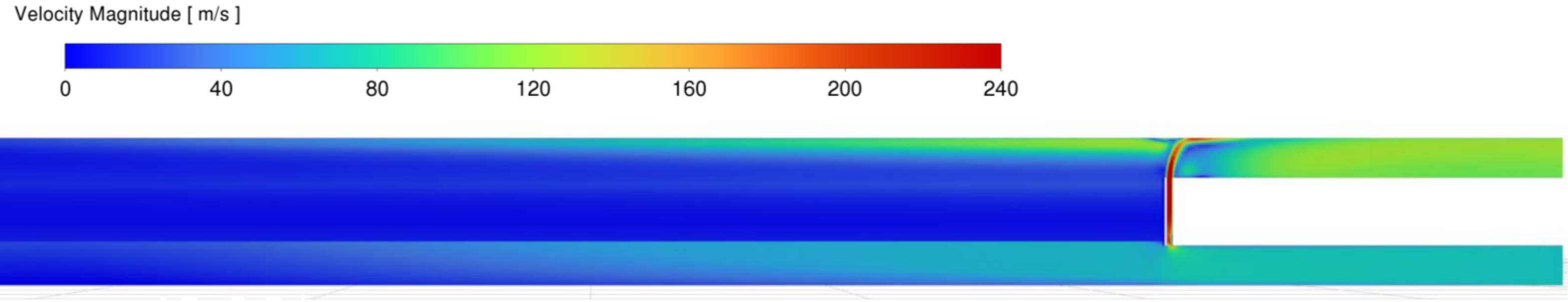
ESSnuSB+ TARGET STATION CONFIGURATION

Beam Entrace Window (BEW)



BEW with a 3mm grooved channel
creating a bypass flow

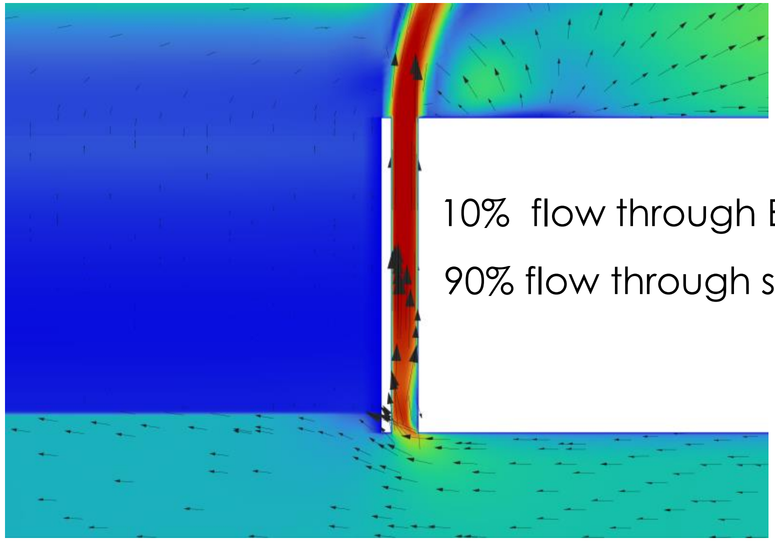
Beam Entrace Window (BEW)

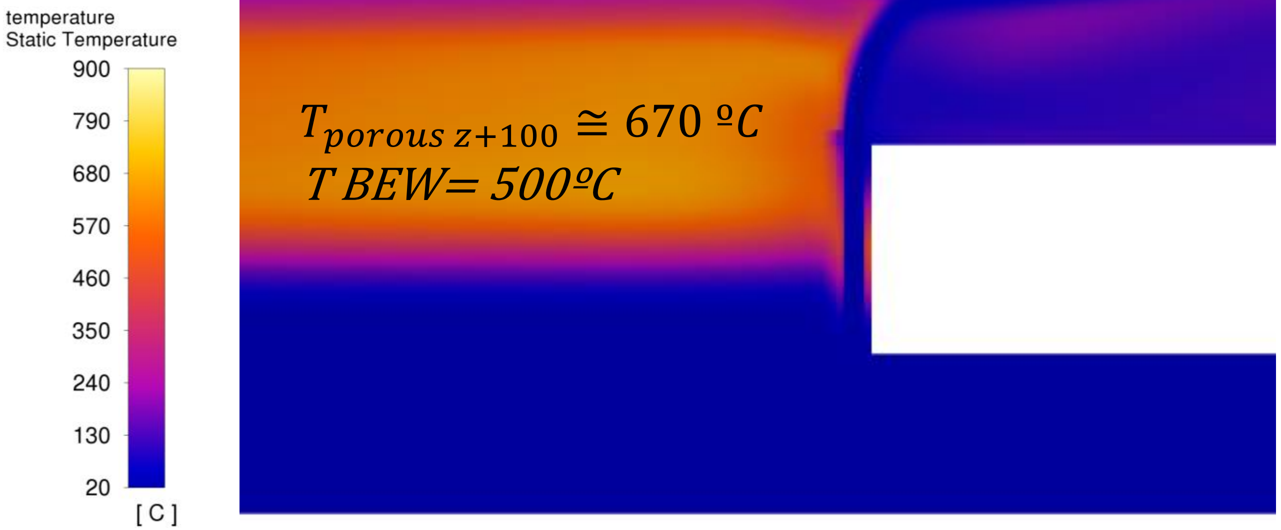


3 mm BEW

$\dot{m}_{Porous} = 0.18$ kg/s
$\dot{m}_{BEW} = 0.02$ kg/s
$v_{porous\ max} = 38$ m/s

An additional effect of creating a bypass Flow is that the velocity through the porous media lowers reducing the overall pressure drop.



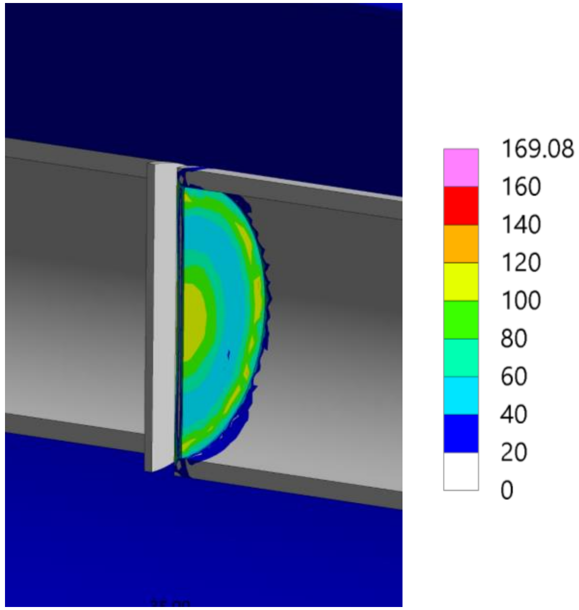


ESSnuSB+ Target Mech design

Primary loads (Pressure)

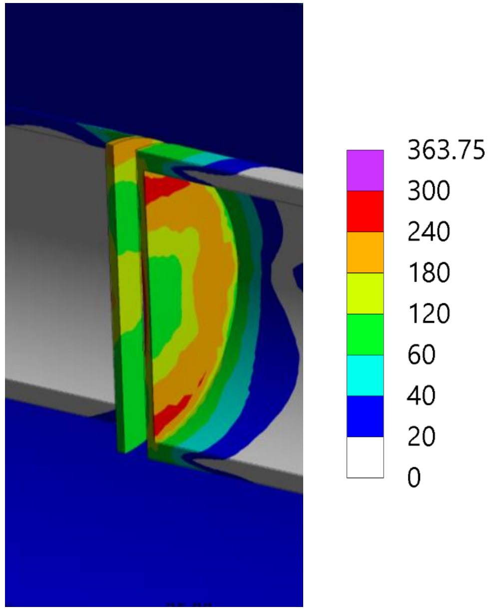
Target front (BEW)

Primary Loads

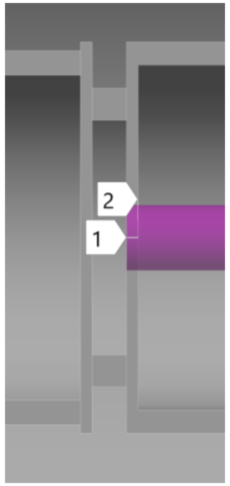


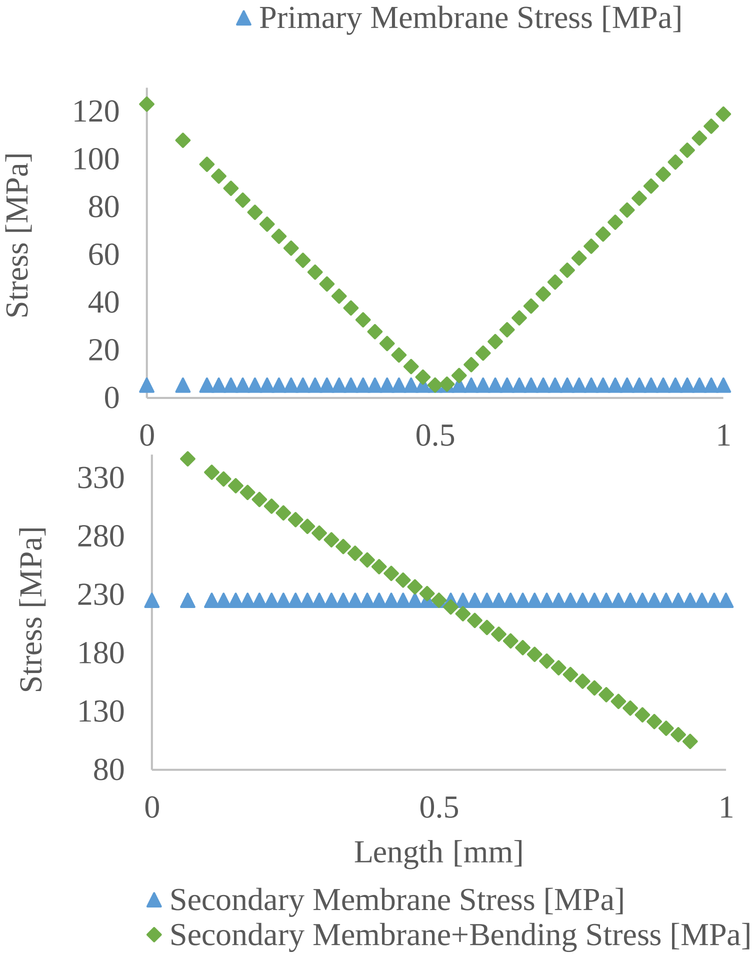
$\sigma_{BEW} = 125\ MPa$

Secondary Loads



$\sigma_{max \to BEW} = 364\ MPa$





Stresses are decomposed into membrane and bending stresses trough a segment that passes through a local maximum perpendicular to de wall to evaluate the material response.

ESSnuSB+ Target Mech design

	Model Results	RCC-MRx	Pure Titanium	Model Ti Alloy	Titanium Alloy
			CP1	Ti 6Al 2Sn 4Zr 2Mo	Ti 6Al 4V
Membrane stress					
$P_m\,[MPa]$	5.35	$P_m \leq S_m$	80	337	390
Membrane+Bending stress					
$P_b + P_m\,[MPa]$	123.03	$P_b + P_m \leq 1.5 \cdot S_m$	120	505	585
Membrane stress					
$P_m + Q_m\,[MPa]$	225.14	$P_m + Q_m \leq S_m$	80	337	390
Membrane+Bending stress					
$P_m + Q_m + P_b + Q_b\,[MPa]$	363.68	$P_m + Q_m + P_b + Q_b \leq 1.5 \cdot S_m$	120	505	585

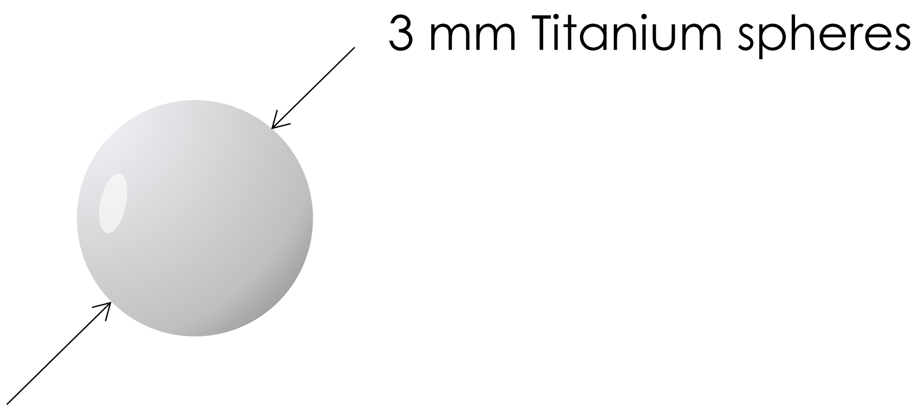
	Pure Titanium		Model Ti Alloy		Titanium Alloy	
	CP1		Ti 6Al 2Sn 4Zr 2Mo		Ti 6Al 4V	
		S_m		S_m		S_m
Yield stress	240	160	930	620	1100	733
Ultimate stress	240	80	1010	337	1170	390

Criteria	$S_m = 2/3 \cdot \sigma_{yield}\ [MPa]$
	$S_m = 1/3 \cdot \sigma_{ult}\ [MPa]$

Primary and secondary loads can be withstood by some of the classic Ti alloys.

Further mechanical analysis considering fatigue will impose additional limits.

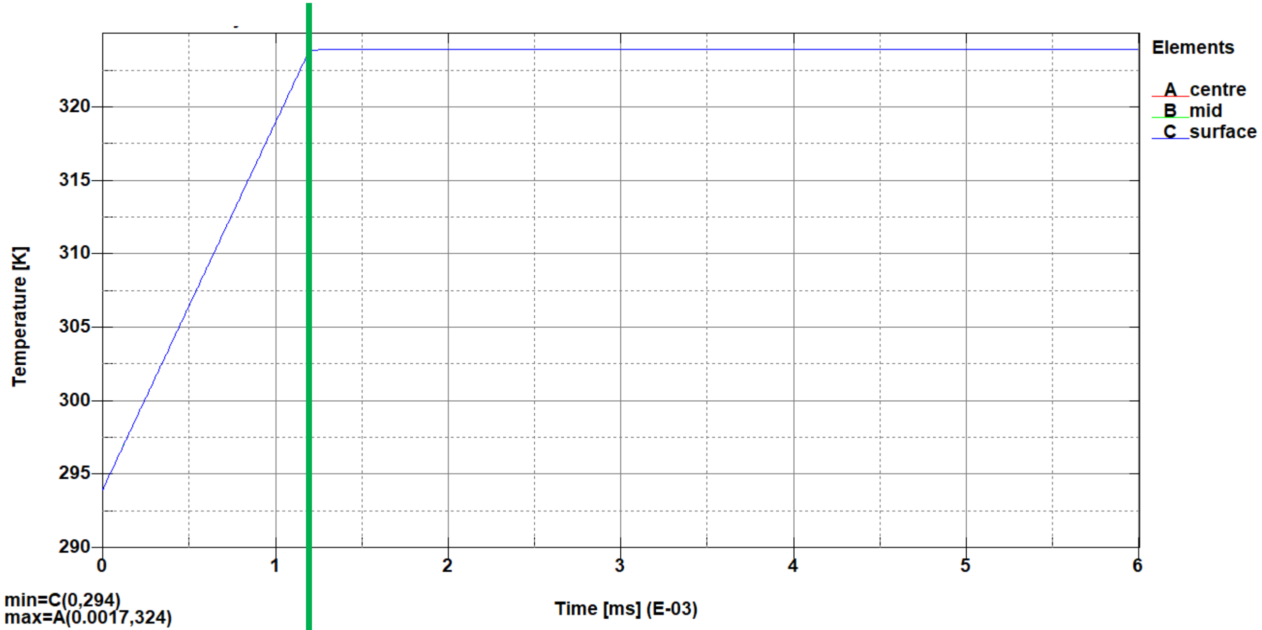
ESSnuSB+ Target Material

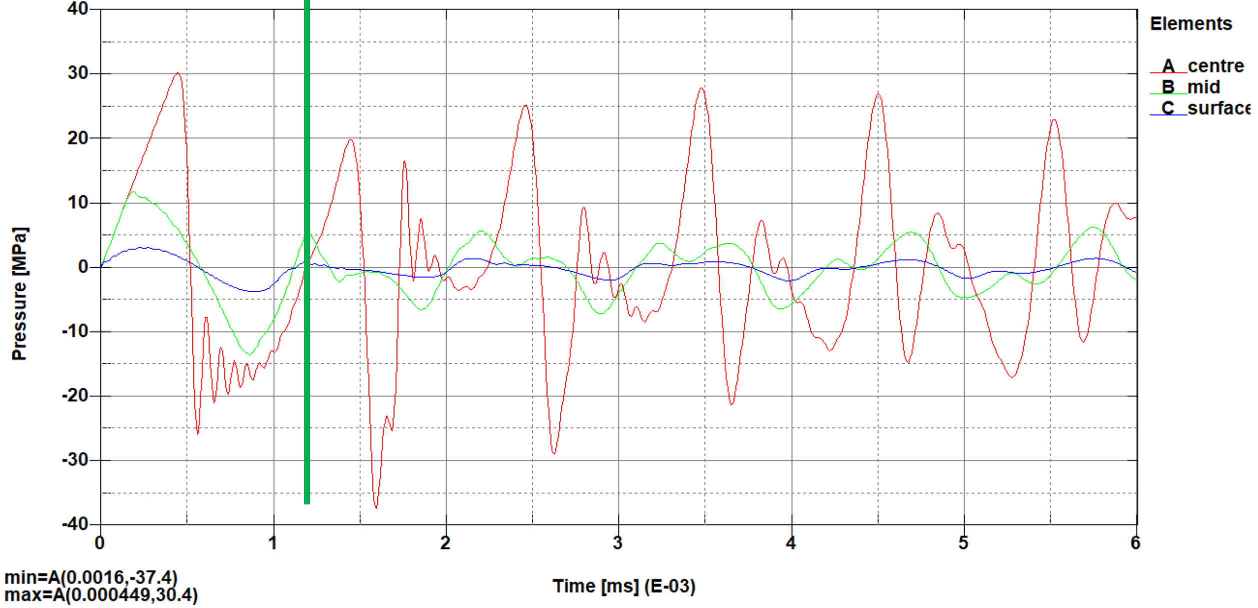


- Granular target allows less internal stress inside the material due to the much lower gradients inside the separated spheres.
- Titanium high specific heat reduces the temperature jump during the pulse.
- Diameter of the spheres has a relevant role in the inner stresses as well as the cooling capabilities of the target.
- No problems were observed in 3mm Ti spheres for this beam power and pulse-time when using a uniform heat distribution **for a single sphere**.

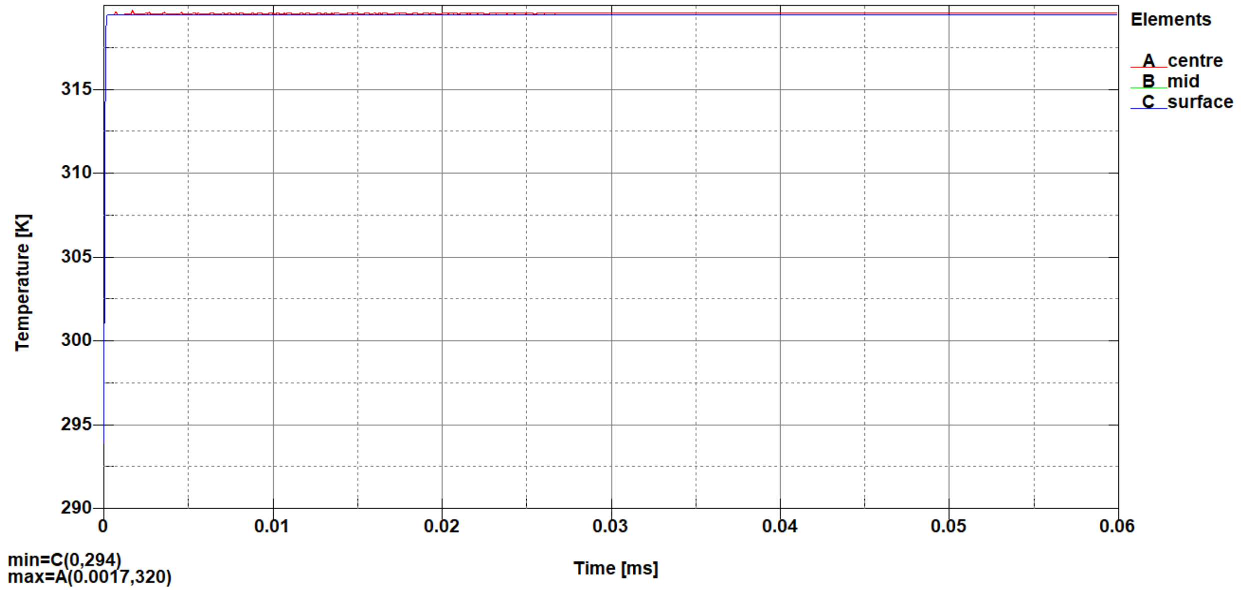
ESSnuSB+ Target Material

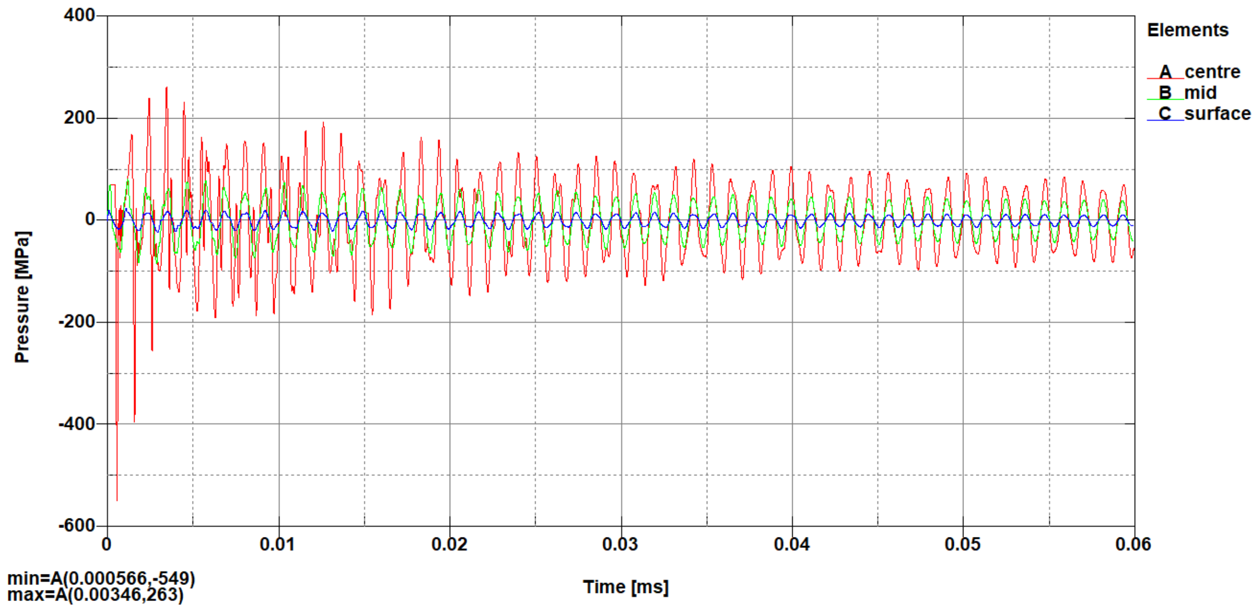
6mm sphere 1.3 microseconds



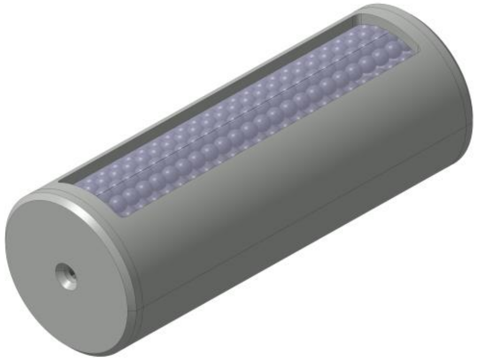


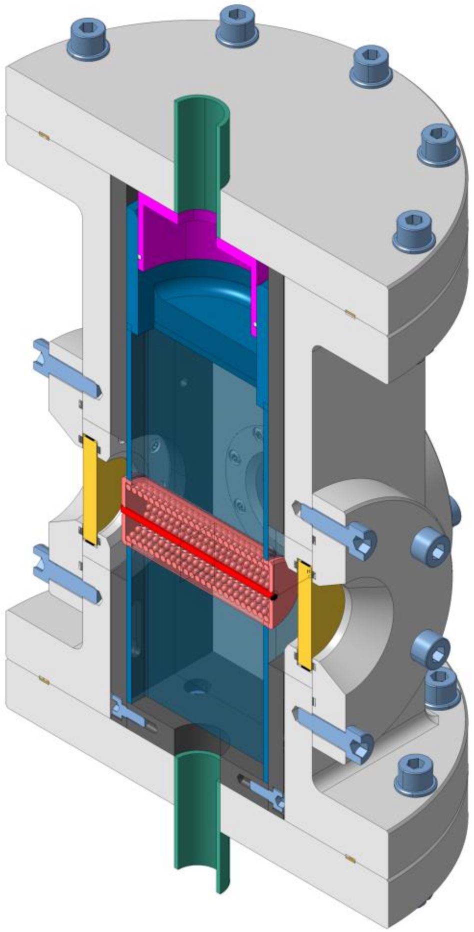
6mm sphere 0.13 microseconds pulse



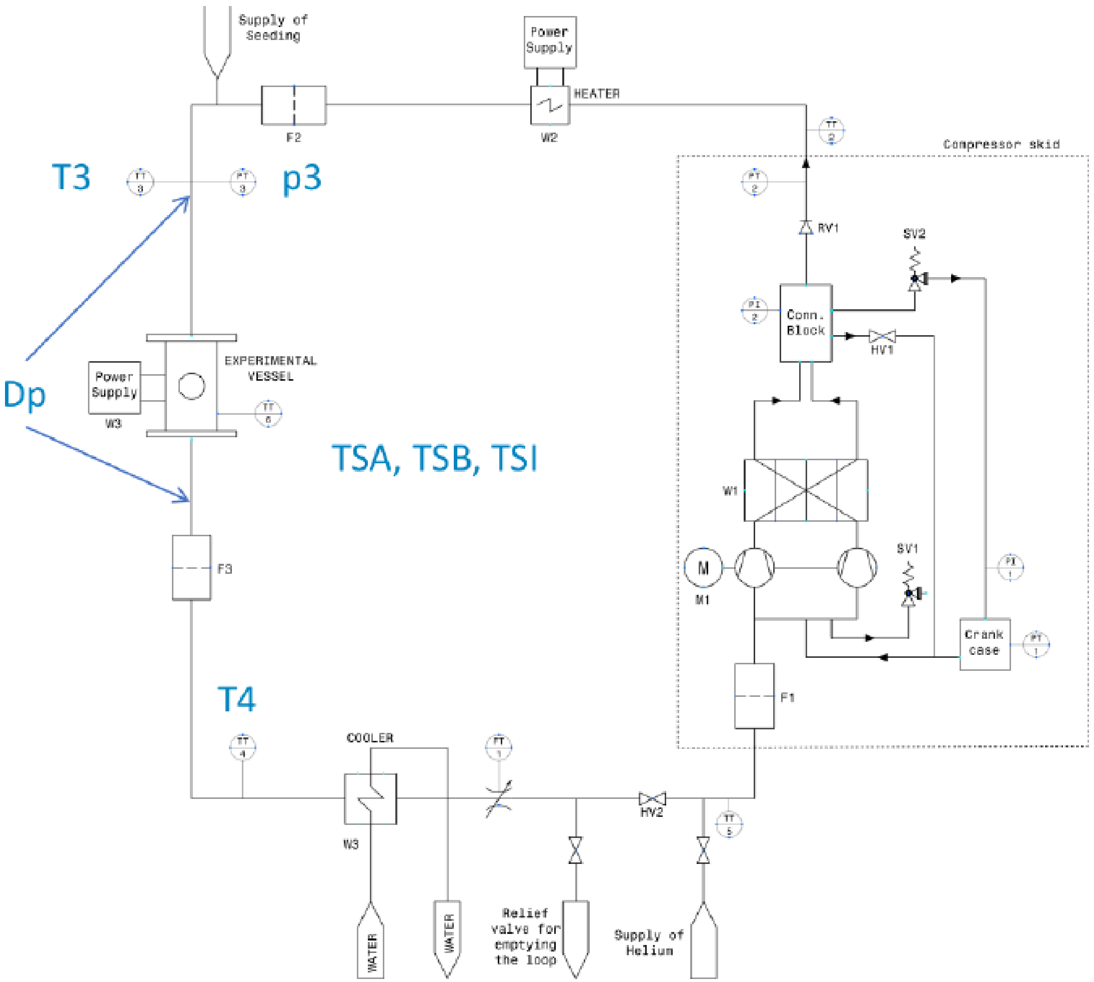


ESSnuSB+ Target PROTOTYPE DESIGN





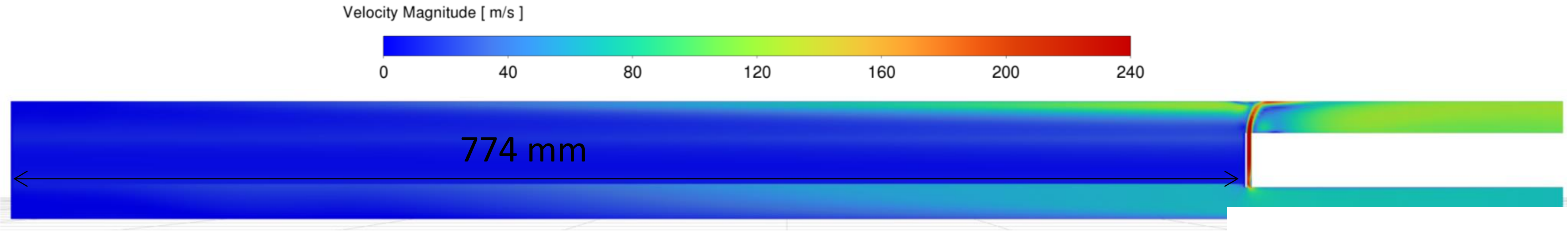
The ETHEL loop contains a booster compressor blowing about 3 g/s helium at between 6 and 10 bar(a) through a heater, a test vessel and a cooler, plus some filters, valves and a flow meter, see Figure 1. The test vessel is shown in Figure 2. For further detail, see [1].



ESSnuSB+ Target PROTOTYPE DESIGN

TARGET

$\dot{m}_{Porous} = 0.18$ kg/s
$\dot{m}_{BEW} = 0.02$ kg/s
$v_{porous\ max} = 38$ m/s
$\dot{Q} = 138\ kW$

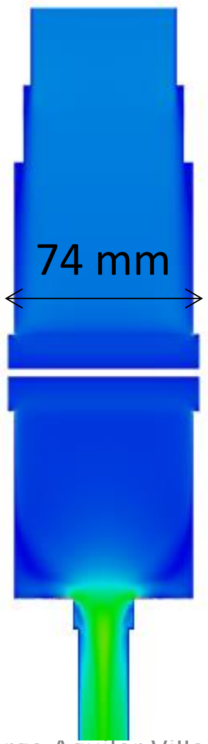


90% flow through spheres

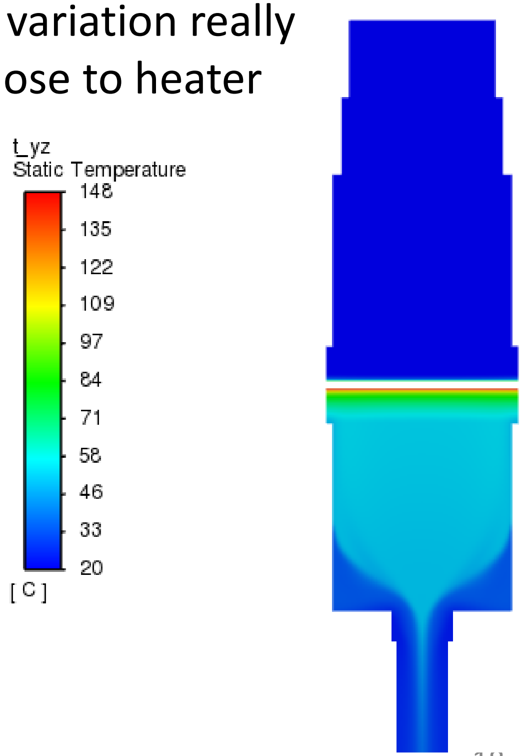
1/10 in length

PROTOTYPE

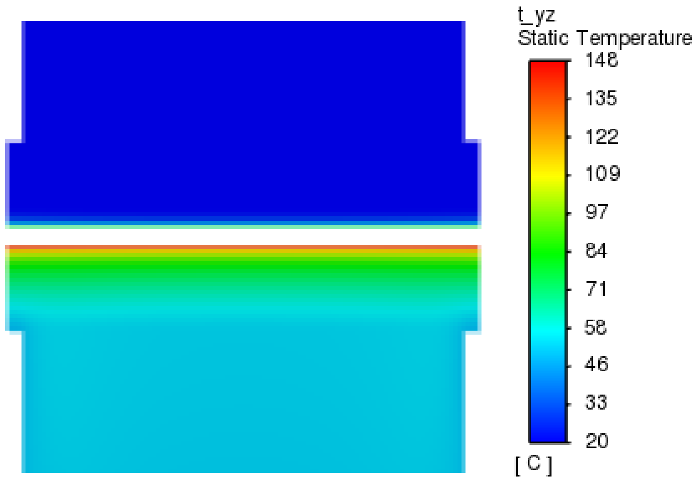
$\dot{m}_{max} = 3$ g/s
$v_{porous\ max} = 21$ m/s
$\dot{Q} = 0.5\ kW$ (not enough?)

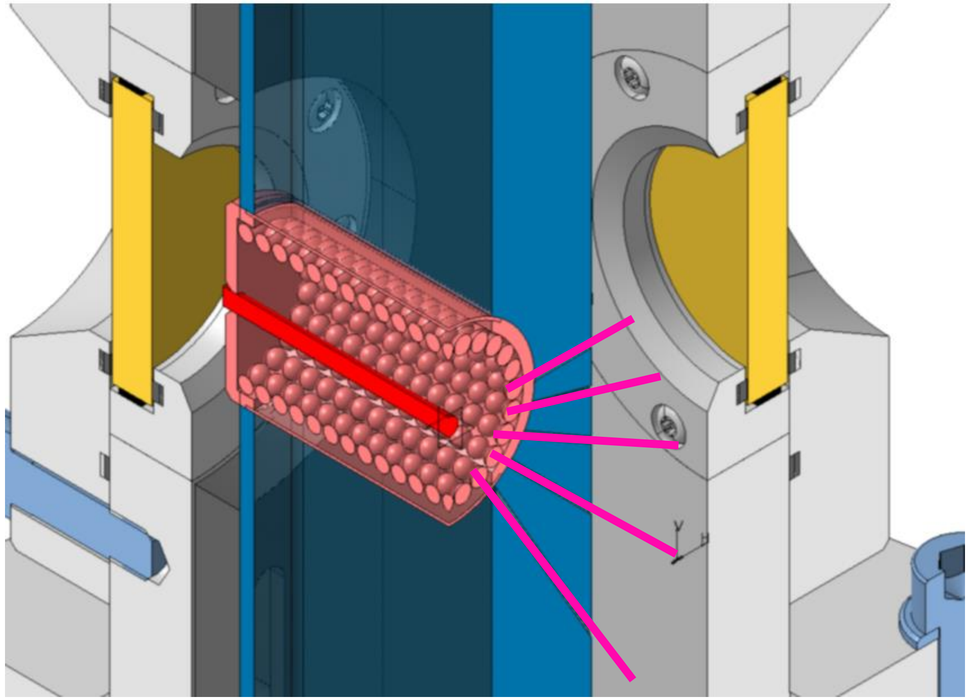


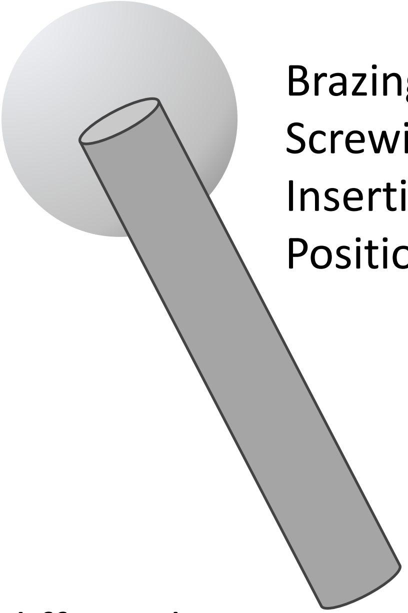
T variation really close to heater



ESSnuSB+ Target PROTOTYPE DESIGN







Brazing?
Screwing
Insertion?
Positioning?

¿How can we properly measure this gradient?

- Small region, difficult positioning and high gradient if we maintain similar velocities
- Measure T in sphere or between them?

Taking all of this in consideration maybe we should try to evaluate the experiment-CFD model differently. Heating until we reach a homogeneous temperature at small velocities and suddenly increasing it, this involves a transient CFD validation which is more expensive in terms of computational cost but maybe the experiment allows easier measuring.

ESSnuSB+ Target future scope

Design

→Supports and guiding system → Mech analysis

Explixit analysis (transient)

→Right now main concern→BEW (pressure waves)

→multiple spheres friction modelling.

Prototyping

ETHELnuSB+ definition and scope

- Experiment design
- Loop commissioning / reconstruction