Spallation material technical solution

Consorcio ESS-BILBAO & Instituto de Fusión Nuclear & ESS-ERIC

A. Aguilar, L. Mena, M. Mancisidor, I. Herranz,
R. Vivanco, M. Magán, G. Bakedano , T. Mora, J. Aguilar, P. Luna,
K. Sjogreen, U. Oden, F. Sordo, J.M. Perlado, J.L. Martínez

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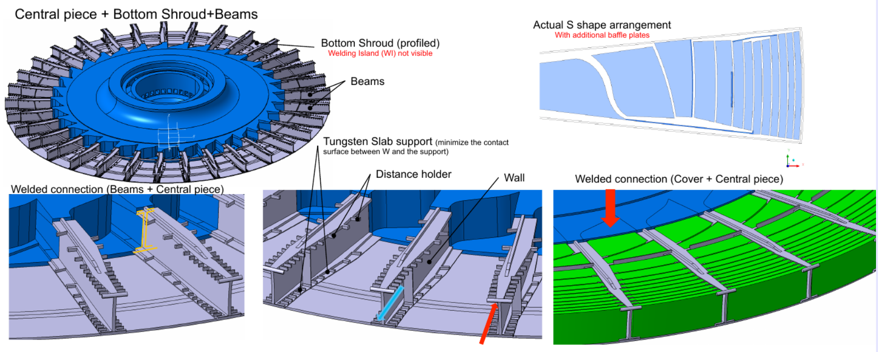
From TDR to Brick configuration

From TDR to Brick configuration

TDR proposal



ESS-Bilbao target proposal

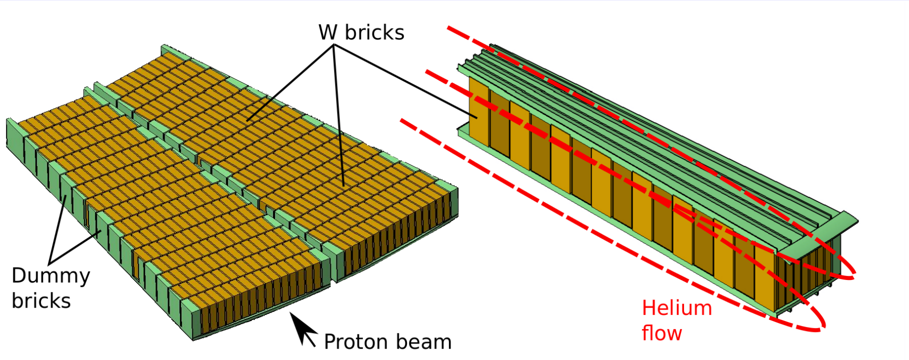
On January 2015, we propose a new configuration for the flow patron and the spallation material. It was accepted by ESS in the KO meeting.

From TDR to Brick configuration

Tungsten blocks placed in cross flow configuration

In order to reduce maximum stress in the slabs tungsten in the current model, we propose tungsten blocks (10 x 30 x 80 mm) in a “cross flow“ configuration where protons will not cross the target without interact with spallation.

Selection process



Comparison with the baseline

Advantages of the brick cross flow configuration

The brick configuration reduces around 80-90^{o}C the maximum temperature compared with the TDR and it completely fulfill the spallation material stress criteria on steady state conditions. Finally the pressure drop is even a little bit lower.

Considering Bertini & ESS-2014 mechanical properties. Steady state conditions [ESS-0036673]

	TDR	Bricks cross flow
Max. Velocity m s^{-1}	170	70
Max. Tem ^{o}C	402	314
Max. Stress Von Misses, MPa	132	58
Press Drop bar	0.4	0.25
Power MW	2.48	2,64

From TDR to Brick configuration

Manufacturing simplifications

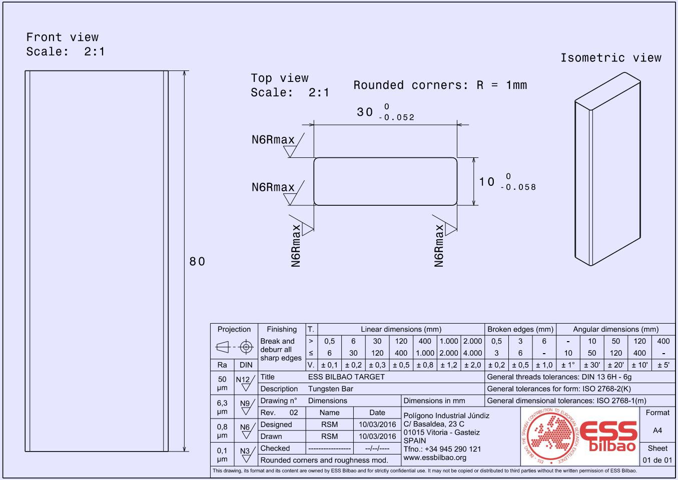
- The simplification in the spallation material shape allow to considerer most of the manufacturers all over the world.
- Hot rolled tungsten based on industrial standard quality.
- Low requirements on tolerances and surface quality

Simplifications on Target Vessel and internal structures

- Helium distribution based on plates and open volumes
- Even number of sectors (36)
- Decoupling nuclear quality vessel from internal structures.
- Only one component have to be produced by forge. Any component by casting

From TDR to Brick configuration

Tungsten brick



Load Scenarios

Loads scenarios

SF levels

- SF 1 and 2 are operating conditions associated with Normal operation, start and stop, and normal operational incidents.
- SF 3 Conditions are Operating Conditions which are rare and leads to shutdown and inspection, limit to 10 times in the lifetime.
- SF 4 Conditions are highly improbable but relevant for safety.

Load cases not considered for design proposes

- **Failure of rastering magnets:** " The impact of the beam produces an increase of temperature in the range of thousand degrees in any tungsten target"
- **Stationary wheel:** If the wheel stops without shutdown the beam, the temperature of the spallation material will increase $\sim 100^{o}C$ per pulse.

Geometry Proposal

Load scenarios

Requirement	Loads	Level	Prot.
Operating Conditions	Nominal Beam Operating pressure (10 bar) Operational cooling conditions (3 kg s^{-1}) Wheel rotation	SF1	A
Vertically displaced beam	Vertically displaced beam Operating pressure (10 bar) Operational cooling conditions (3 kg s^{-1}) Wheel rotation	SF2	A
Unsynchronized wheel	Horizontally displaced beam Operating pressure (10 bar) Operational cooling conditions (3 kg s^{-1}) Wheel rotation	SF2	A
Failure of rastering magnets	Non Raster beam Operating pressure (10 bar) Operational cooling conditions (3 kg s^{-1}) Wheel rotation	SF3	D

Geometry Proposal

Load scenarios

Requirement	Loads	Level	Prot.
Loss of coolant flow and pressure	Nominal beam Operating pressure ($<$ 10 bar) Operational cooling conditions ($<$ 3 kg s^{-1}) Wheel rotation	SF3	D
Stationary wheel	Nominal beam Operating pressure ($<$ 10 bar) Operational cooling conditions ($<$ 3 kg s^{-1}) Wheel stopped	SF3	D
Shut-down	No beam Operating pressure (10 bar) No coolant flow Wheel stopped	SF3	D

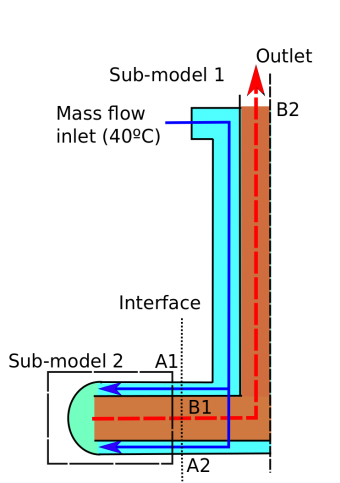
CFD analysis for complete Target

CFD analysis for complete Target

Boundary conditions

The analysis described on the CDR for the Spallation material & the internal structures is based on "Best estimate models". This means that boundary layers and detail definition of the channels are consider. Thus, it is not possible to analyze all the Target in a single CFD simulation. The following approach is considered:

- The model is split in the transition between central distributor to the cassette cooling channels
- Several simplifications are introduced in the cassette to produce a sweepable volume in between channels
- Heat flux is adjusted in an iterative process between the complete CFD model and the detail CFD model for the Spallation material analysis

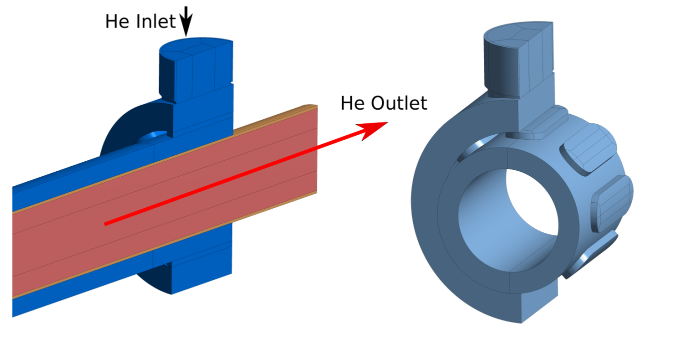


CFD analysis for complete Target

Sub model 1

The sub model 1 (rotating seal, shaft and distributor) has no symmetry planes however, most of the volume can be sweep following the helium flow lines. This consideration allows to resolve the flow including the boundary layer with acceptable Y^+.

CFD model for the distributor, rotating seal and shaft



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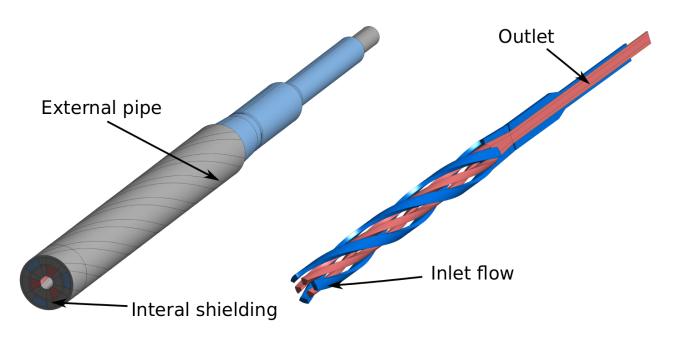

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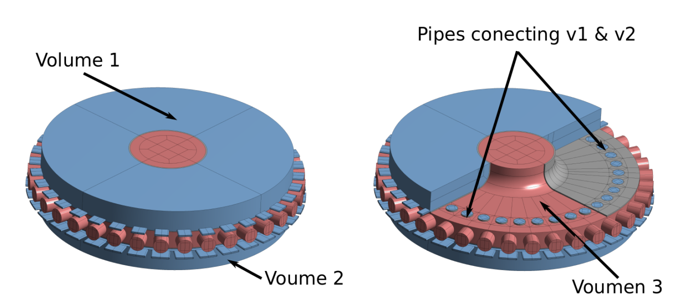
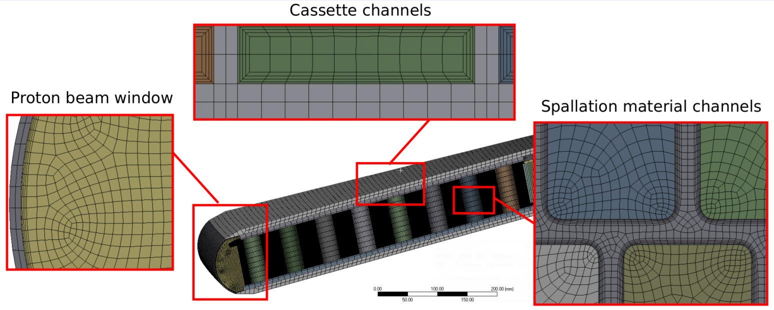


CFD analysis for complete Target

Sub model 2

The cassette geometry has been simplified removing the "Cassette grooves" and the expansion gab in vertical direction. This produce a sweepable fluid volume but it can not reproduce properly the heat flux in the cassette. To avoid this effect, we introduce thermal resistances in the top and bottom plates adjusted by means of an iterative process with the detail model of the Spallation material.

CFD model for the Spallation material and the cassette



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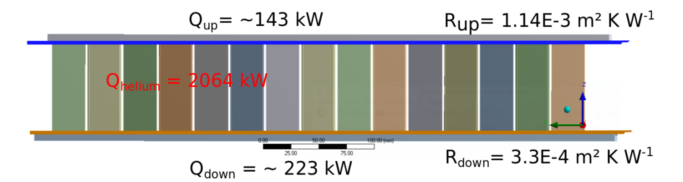


CFD analysis for complete Target

Mesh quality for sub-model 1 and sub-model 2

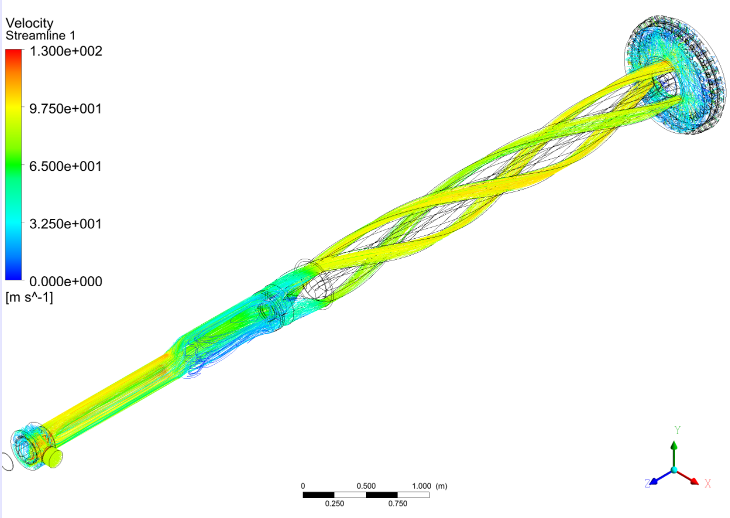
	Seal+Shaft+Distributor	Target
N^o Elements	3376444	1401759
(fluid)	3122560	1075890
(solid)	253884	325869
Orthogonal Quality	0.971	0.944
Skewness	0.100	0.171
Aspect Ratio	6.953	57.96

Remark

The model is solved by an iterative process in order to arrived to the convergence in the interfaces A1, A2 and B2 between both sub-models (Temperature and pressure).

CFD analysis for complete Target

CFD and FEM complete model from Rotating Seal to wheel distributor



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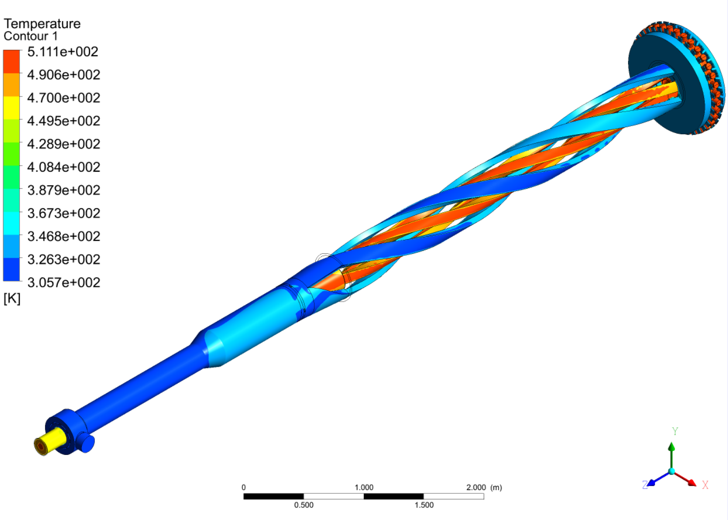

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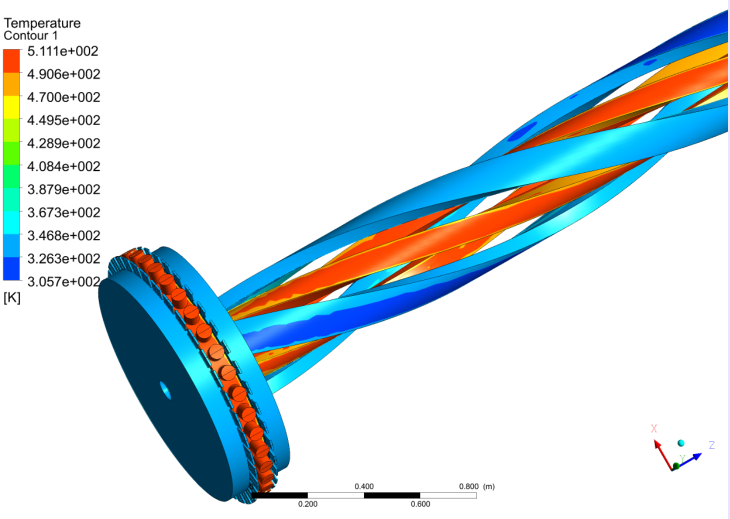

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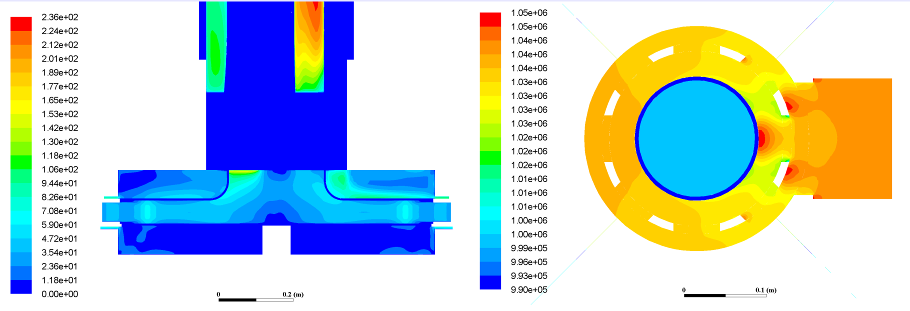

CFD analysis for complete Target

Boundary conditions for detail model

A1 ^oC	A2 ^oC	B1 ^oC	B2 ^oC	W_{max} ^oC	Cold bar	Target bar	Hot bar	Total bar
57	63	182	206	373	0.35	0.16	0.4	0.9

Helium Inlet helium conditions to detail model

The inlet temperature estimated by the complete model for the inlet to the spallation material is 95^oC. The analysis has been performed considering 115^oC in order to include 20^oC as safety margin. Pressure is set to 10 bar.

Conclusions

Conclusions

Summary and remarks

- A complete optimization process has been perform to simplify the TDR target proposal. The simplifications reduces significantly the technical risk of the project.
- Load scenarios that plays a role in the design process has been identified and considered in the analysis.
- Boundary conditions for helium flow has been established with significant safety margin based on the complete CFD analysis of the Target sub system.