



## Ricerca di Sistema elettrico

# Rapporto di fabbricazione del prototipo del target assembly

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## RAPPORTO DI FABBRICAZIONE DEL PROTOTIPO DI TARGET ASSEMBLY

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## Sommario

La validazione delle procedure per le operazioni di ricondizionamento del target assembly di IFMIF è di primaria importanza in un impianto di questo tipo dove i componenti, a causa dell'intenso flusso neutronico cui sono soggetti, devono essere regolarmente mantenuti (manutenzione preventiva). Tutte le operazioni di manutenzione devono essere completate entro un tempo definito, che per IFMIF risulta essere di 20 giorni di cui 7 sono quelle entro cui il target deve essere ricondizionato o sostituito. A tal fine l'ottimizzazione delle procedure è di fondamentale importanza per riuscire ad eseguire tali operazioni di manutenzione. Per la validazione delle operazioni di manutenzione remota sono stati realizzati due prototipi: quello del target assembly e una sezione della test cell di IFMIF. Considerando lo scopo dell'attività di validazione il prototipo del target è stato realizzato in modo tale che le parti rilevanti ai fini dell'attività di manutenzione sono effettivamente realizzate considerando forme, dimensioni e accuratezza di lavorazione, mentre per le restanti parti, a parte le geometrie esterne e le dimensioni, non sono state richieste particolari accuratezze nella realizzazione. Ad esempio particolari geometrie, come l'ugello di adduzione del litio, molto complesse dal punto di vista della fabbricazione non sono state incluse e sono state considerate come black box.

La disponibilità di questi due prototipi permettono adesso la simulazione di tutte le operazioni di manutenzione previste per il target in un ambiente in cui le geometrie e gli spazi disponibili sono identici a quelle dell'ambiente reale. I prototipi sono adesso presso la DRP facility dell'ENEA del Brasimone.

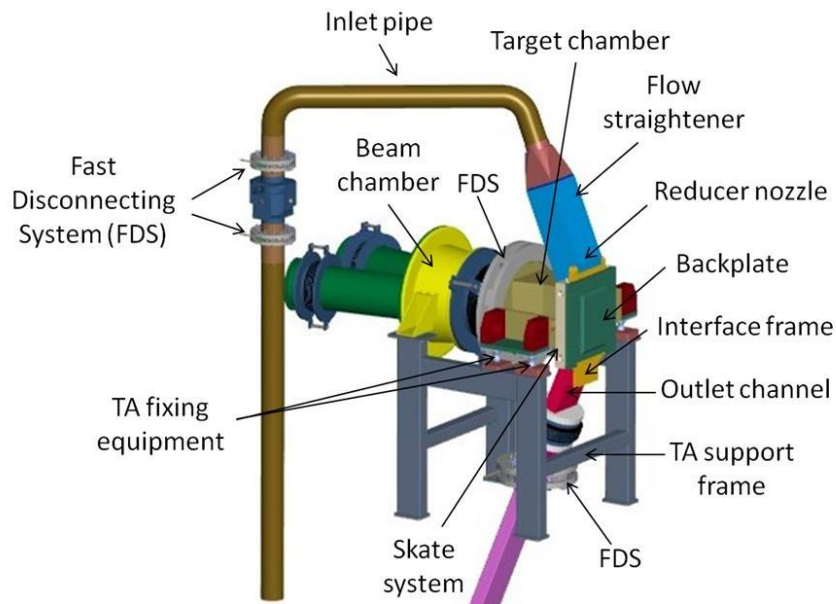
## 1 Introduction

The International Fusion Materials Irradiation Facility (IFMIF) is provided with a lithium Target Assembly (TA) to produce the required neutron flux for the irradiation of candidate fusion materials up to a damage rate of 100 dpa (cumulated damage in five years). Due to this severe operating condition the TA has to be refurbished at least one time per year. The remote handling maintenance of components of the IFMIF facility is one of the most challenging activities to be performed to guarantee the required high level of IFMIF plant availability. Among these components the maintenance of target assembly system appears to be critical because it is located in the most severe region of neutron irradiation. The present European target assembly design is based on the so called replaceable backplate bayonet concept. The remote handling maintenance activity of the target assembly comprises a number of in situ refurbishment tasks, like the: removal of the backplate, cleaning of surfaces from lithium solid deposition, inspection of the target body, installation of a new backplate and testing of the assembled system. However there is also the possibility to replace the entire target assembly and to perform these refurbishment tasks online in a dedicated hot cell.

To perform the validation of these refurbishment tasks the availability of the prototypes of at least of the target assembly and of the test cell is required. In fact the only way to assess the possibility of execution of all the refurbishment tasks for the target assembly within the expected time for maintenance, the annual preventive maintenance period for IFMIF has been fixed in 20 days, is to perform each maintenance tasks using a full scale prototype of the components. To this purpose a full scale prototype of the target assembly and of a section of the test cell mock up have been procured. An overview of the manufactured prototypes are given in this document.

## 2 The European Target Assembly concept

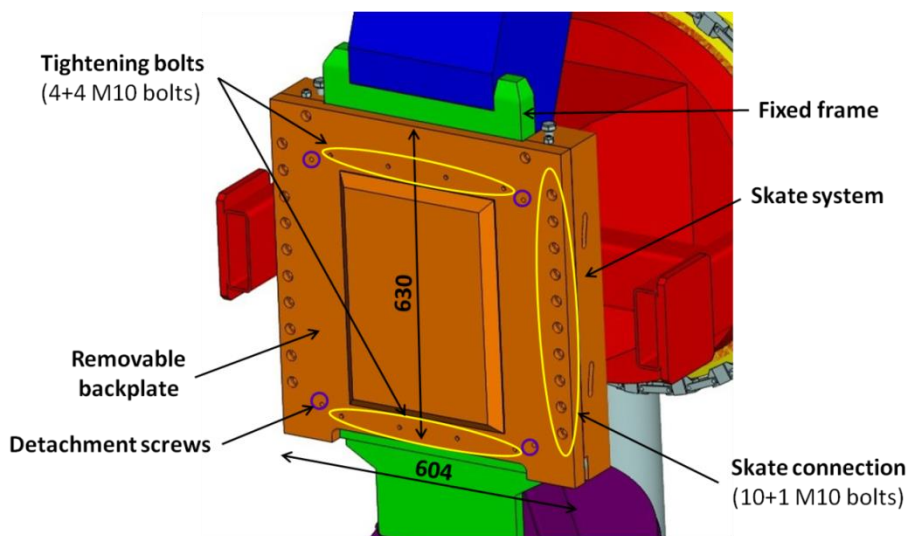
The European TA concept, known as bayonet concept, was conceived with the objectives to simplify the replacement and the refurbishment operations of this component to be performed during the preventive and corrective maintenance periods of IFMIF plant and to reduce the material for disposal as well[1,2] . A 3D model of the EU TA concept is shown in fig. 1. It consists of two main components: the body and the removable backplate. The body is attached to the lithium loop, in the inlet and in the outlet channels and in the beam side, by means of fast disconnecting systems (FDS). This latter system, used in place of standard bolted flanges, allows the TA replacement by maneuvering only few bolts, typically 2 or 3 bolts for each FDS connection, so that the intervention time for its substitution is reduced. A custom design of this connecting system was already validated in the past [3].



**Fig. 1 The EU Target system**

The target assembly is positioned above a support frame with iso-static references so to keep constant target position with respect to the TA support frame leaving at the same time the target body to accommodate/compensate thermal induced loads.

The removable backplate is a plate that once clamped to the fixed frame on the TA body forms the lithium flow channel. It is provided with a dedicated locking system[1,], suitable to remote handling, consisting of 8 bolts, 4 in the upper and 4 in the lower positions, and two skate systems located in the lateral sides, which provides the tightening force to seal the edge of the target chamber. The current bayonet concept foresees the extraction/introduction of the BP from the top of the fixed frame, by sliding it along the vertical direction. The removable backplate is shown in fig. 2



**Fig. 2 Removable backplate of the EU TA**

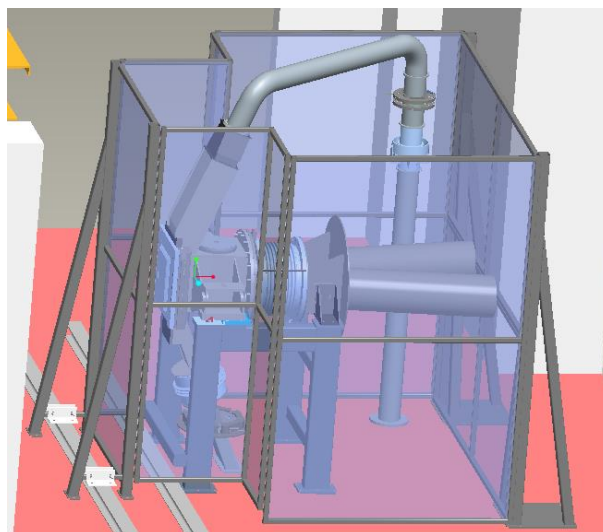
Sealing of the target assembly , at the inlet, outlet and the beam connection is ensured by means of metallic gasket ( Helicoflex HN290 soft iron/Nimonic 90/AISI 304). The sealing system of the backplate is instead provided with a Helicoflex HNV200 with the same configuration.

## 2.1 IFMIF Target prototype and test cell mock up

The prototypes manufactured for the validation activities of the remote handling maintenance of the target assembly are:

- 1) A full scale target mock up ;
- 2) A full scale of the support structure of the target assembly
- 3) A section of the test cell liner mock up.

All these components are illustrated in Fig. 3. Here is shown also the simulation of the integration of the prototype in the DRP facility at ENEA Brasimone.



**Fig. 3 Integration of the component in DRP**

### 2.1.1 Design of the Target prototype

The purpose of the construction of a prototype of the target assembly is to validate all the refurbishment maintenance operations to be performed for this component. Taking into account the scope of the work to be done the design of the target body mock-up was developed considering the following guidelines:

- the backplate is a full scale prototype. Machining of this component has to be within the required accuracy.
- the external shapes and dimensions of the target as the weight and COG match the conceptual design model;
- the target is structured over a central vacuum tight chamber that groups the beam and backplate, seals with the two side supports and the inlet and outlet duct are welded (see fig. 4).
- Leak test on inlet and outlet FDS is made in local vacuum tight chambers so to ease the localization of leaks;
- For all part of the target assembly not relevant for the remote handling purpose no particular machining accuracy is required. For these part only the external dimensions and shape have to be taken into account.
- Connection of the inlet and outlet channels is performed by means of Fast Disconnecting System (FDS)
- Connection between the beam duct and the target chamber is performed by means of standard bolted flange.

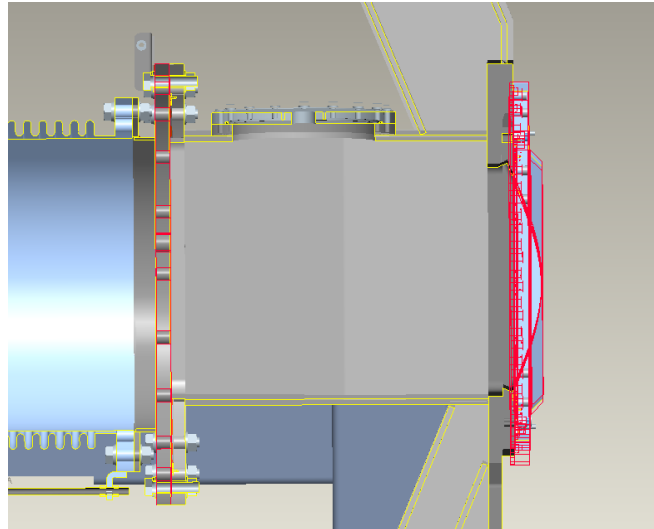


fig. 4 Target central section

In the following chapters a description of the main components, those relevant for the remote handling purpose, are given.

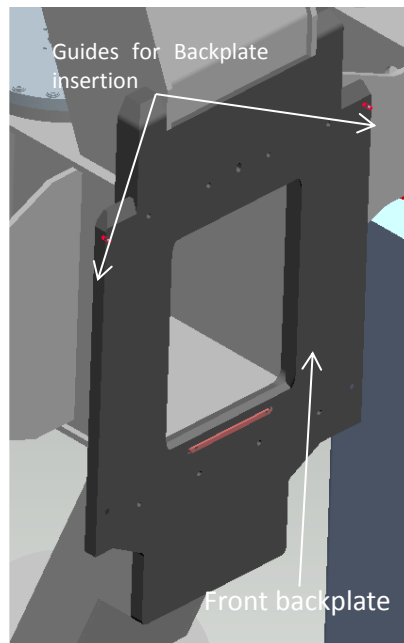
### 2.1.2 Backplate mock-up design

For the manufacturing of the backplate the following design choices were done:

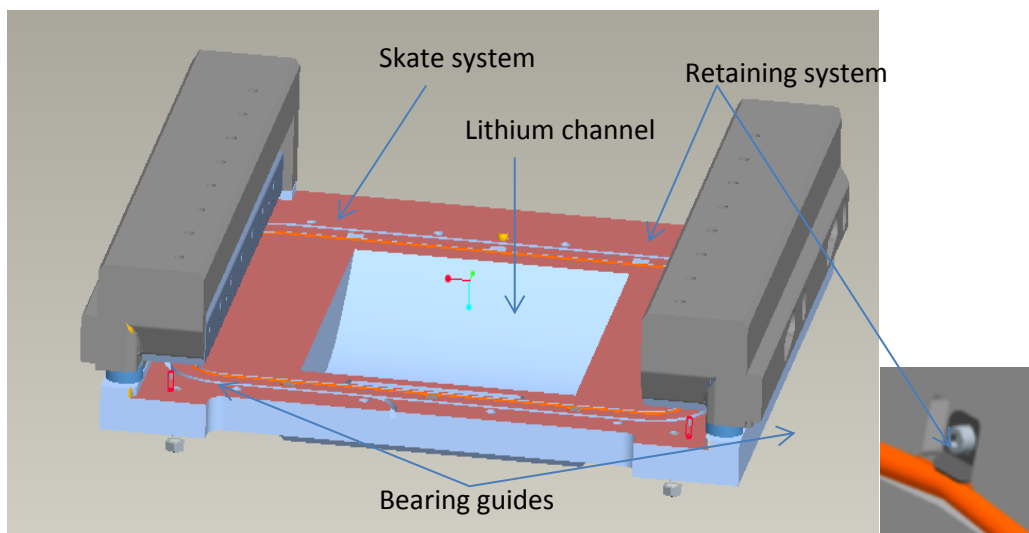
- Material AISI 304;
- Sealing is achieved with a Technetics HNV 230 gasket with outer Armco/soft iron layer and nominal sealing load of 220 N/mm.
- The vertical compression load on the seal is transmitted through a set of needle bearing pressed with linear cams. Each bearing set has a central INA NATV15 paired with two INA STO15. The load of the cam acts on the central bearing that push the two lateral bearing on the target frame.
- To guide safely the BP insertion on the TA frame two more side bearing are added. To guide the BP in the plane perpendicular to the beam and for the safe sliding of the BP, avoiding any metallic seal contact before BP locking, four pins are added. Each pin has a net height of 5 mm leaving 2 mm axial play between BP and frame.
- In consideration of the increased sealing load the number and material of the horizontal BP locking screws was reconsidered. The two sets of 4 AISI 316 M10 screws (A2-50) , foreseen by the previous design has been replaced by two sets of 5 high strength A2-70 M10 screws.
- The retaining system to keep the seal in its seat consists of three 0.6 mm thick L shaped evenly spaced are located on each side of the seal( see Fig. 6).
- Backplate leak detection channel was reduced using a D 5 mm 10 mm long ceramic support with two 1.8 mm axial holes to guide paired stainless steel wires. High temperature silicon rated for 350°C continuous operation is used to correct position the leak detection in its seat. The same leak detection is also integrated in the outlet FDS

The lift frame and the backplate are shown in Figs 5,6 .





**Fig. 5 target frame**



**Fig. 6 Backplate Beam side**

### 2.1.3 Outlet FDS design

The target assembly is attached with the inlet and outlet pipes of the lithium loop by means of Fast Disconnecting System (FDS). The FDS for the inlet pipes is described in the report RdS/2013/128 and then only the FDS for the outlet design is described.

The 320 ID FDS developed is based on the chain made from Technetics (France). This chain has two opposed actuating screws connected to the link with rotating nut so that all the links can orient freely to keep the best alignment with the central conical flanges.

The connection between the links are guided with 4 parallel slots that assure the correct and complete opening of the FDS. In case of jam of one or both the actuating screws 4 pins are removable to open the chain. For further safety two pin are locked to a bolt that moves on the slot, guiding the chain; two other pin are connected to a similar bush that slides on the slot with spring loaded ball. The 2D drawing of the FDS is shown in Fig. 7.

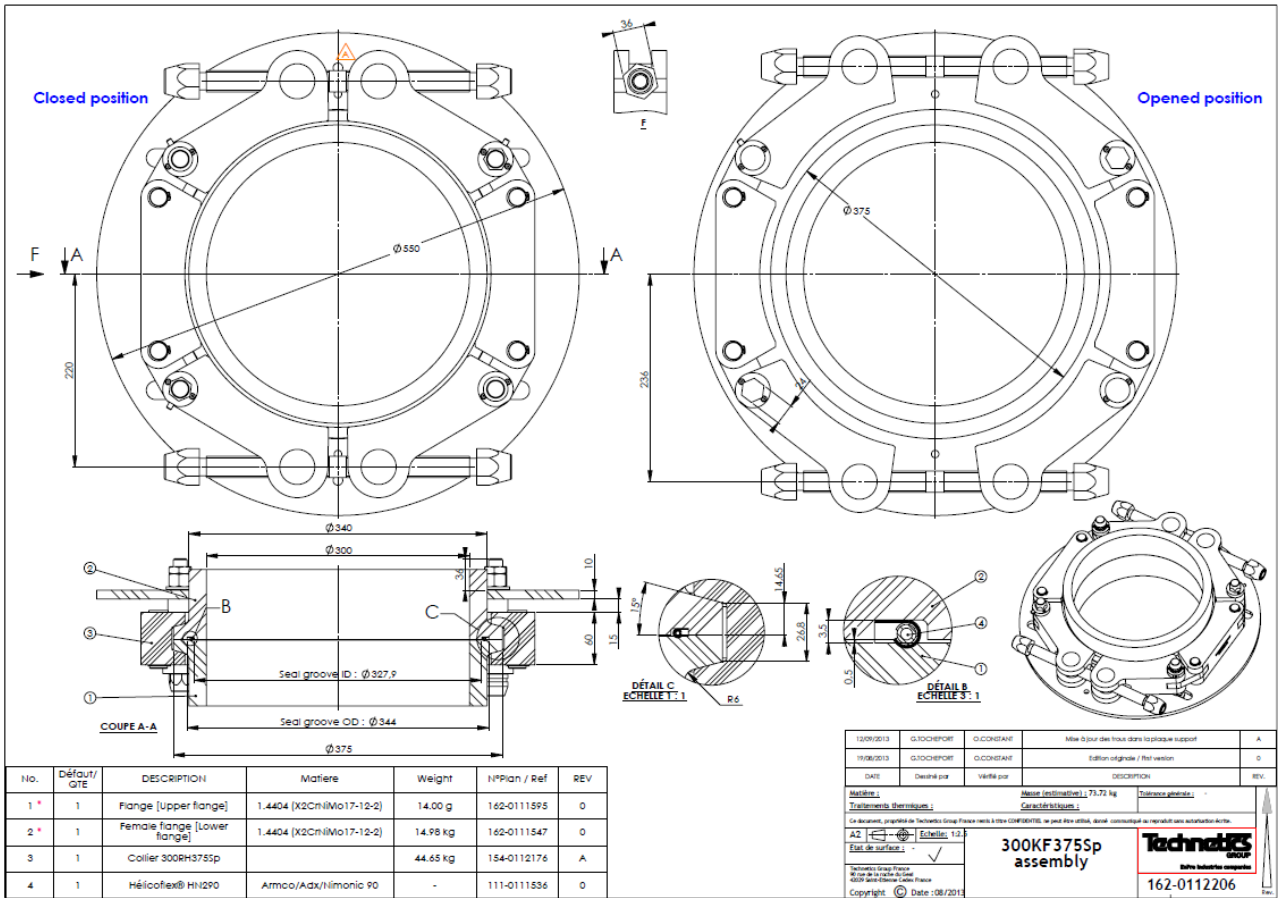


fig. 7 The FDS system for the outlet channel

The two conical flanges locked with the FDS host an HN290 metal gasket kept in position with its planar flange. A leak detection chain based on the same design above introduced is integrated in the lower flange while six M5 headless screws with hex key are integrated in the upper flange, being accessed with the chain open, and can detach the two flanges if glued by some lithium leakage. The following picture (Fig. 8) shows the two FDS flanges coupled with the chain and support plate completely hidden. The 6 holes of the M5 screws with conical guiding hole are visible as well as the pressure port used for He leak testing on the outlet FDS.

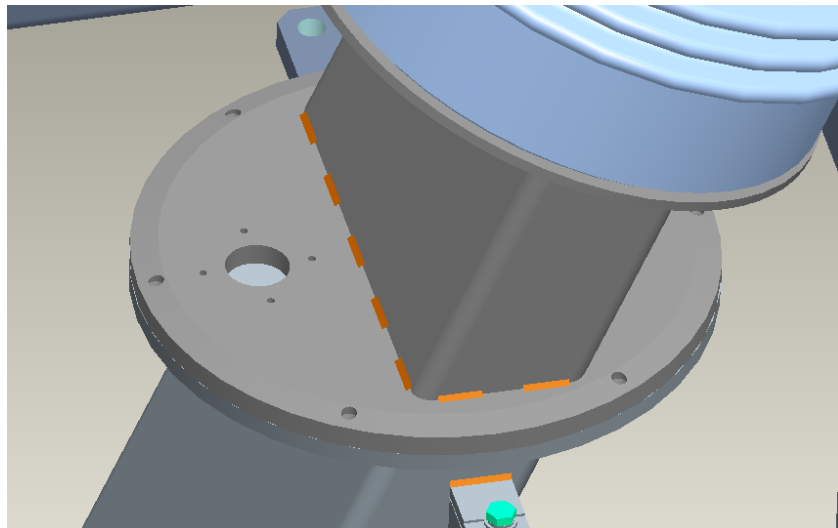


fig. 8 outlet duct FDS flanges

As required in the specification the FDS, once fully open, can be completely removed from the lower flange. A dedicated support frame, welded to the outer duct, support the FDS trough the FDS support plate kept in position with two reference pin and two M10 screws.

#### 2.1.4 Target support frame mock-up design

The scope of the target support frame is to keep the target in vertical position and to ensure that the 2 mm of constant gap between the backplate and the test modules, which hold the materials to be irradiated is permanently kept. To this purpose the target is firmly attached to the structure by means bolts and a suitable centring system has been developed.

The target support integrates the beam support, while the inlet riser pipe up to the FDS as well as the angled outlet duct, with its FDS, are positioned in the TC mock-up referenced to the target support frame( see Fig. 9).

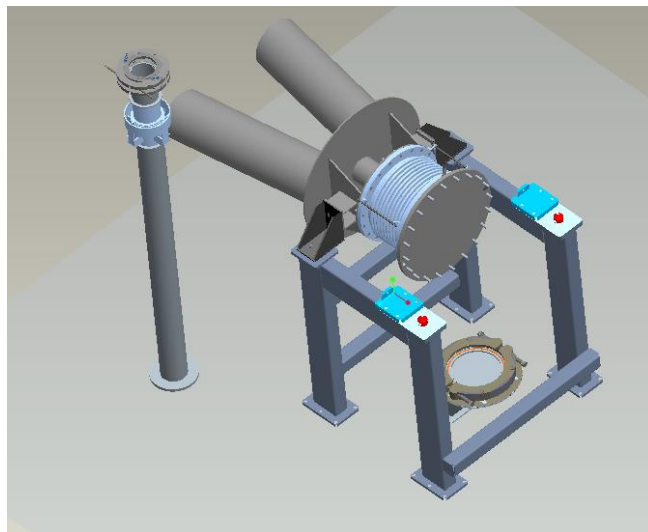


fig. 9 TA support frame

The target is positioned on the frame using as main reference two conical pin that match a conical seat on one side of the target body and a V shaped seat on the opposite side. Two planar surfaces complete the target positioning( see fig. 10).

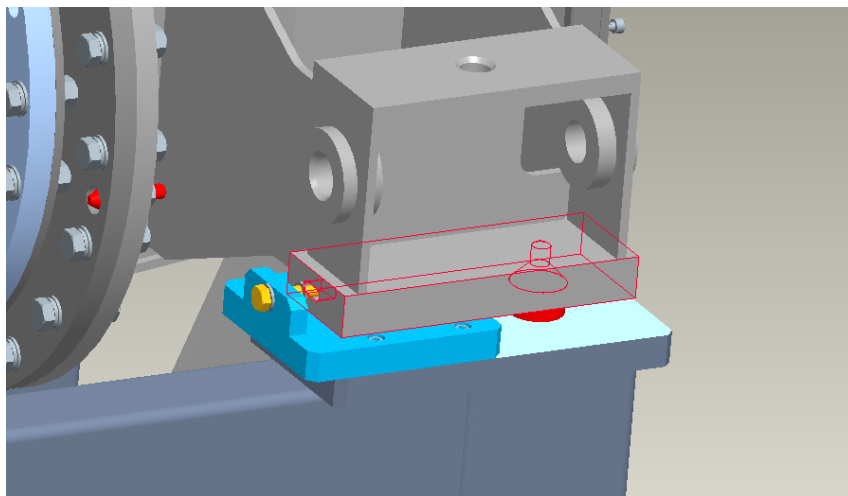


fig. 10 TA support references and locking screw

To secure the target on the frame once positioned one screw per side can be introduced in a corresponding slot in the target reference plates.

### 2.1.5 Test cell mock-up

To reproduce correctly the space surrounding the Target assembly and its support a TC liner mock-up has been also required.

A steel modular structure with 4 L shaped doors surround the target assembly so to leave the right gap for RH sequence simulations (see Fig. 12).

As anticipated and shown in fig. 11, in line with the BP removal Remote Handling strategy[4] only the Low flux Test Modules is considered as boundary in the TC mock-up.

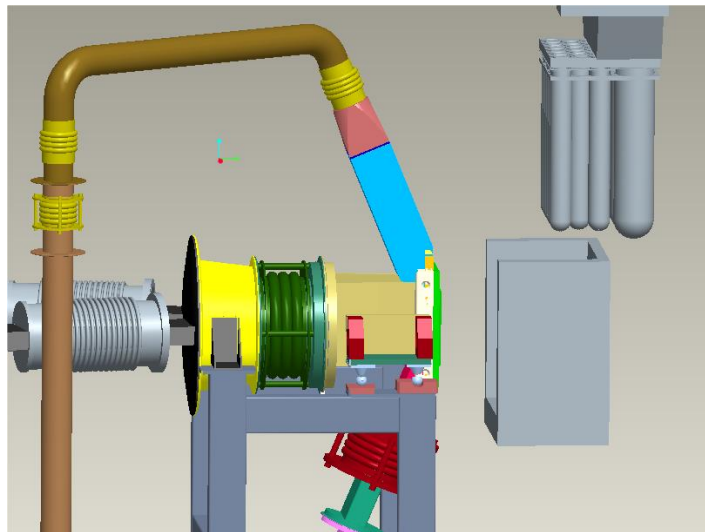


fig. 11 LFTM position in TC conceptual design

The liner frame is completed with aluminium/plastic three layers sandwich plates that merges a good plate stiffness with low weight.

The two lateral TC frames are bolted on the DRP facility floor and partially clamped on the DRP central rails with a dedicated clamps.

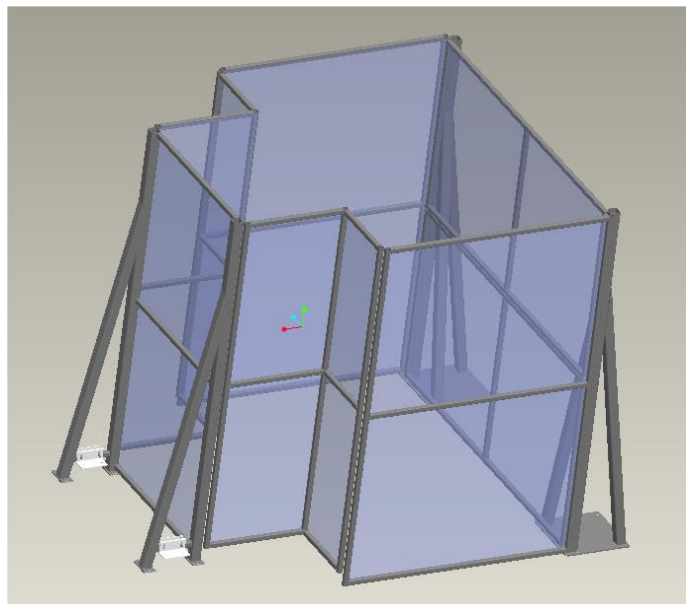
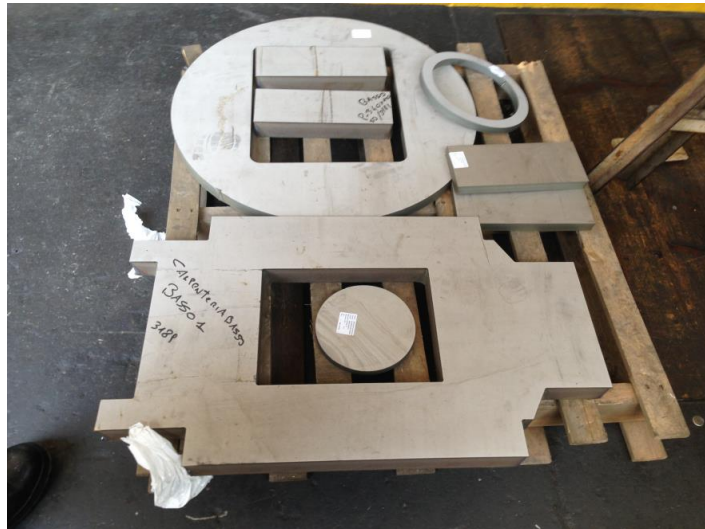


fig. 12 TC mock-up

## 2.2 Mock-up production

As anticipated almost all the components are only simulated ( dummy mock up) and then for these components only the external geometries and dimensions were considered relevant. Is the case of the target body: inlet and outlet channel and target chamber for instance. While the backplate , the interface frame and the inlet and outlet connections have been manufactured considering the construction accuracy required.

The following pictures shows some relevant phases of the TA mock-up production made in the Telerobot Ocem workshop in Valleggia (SV). In Fig. 13 the main components of the TA body are illustrated. Here the interface frame and the beam chamber flange are shown.



**fig. 13 TA body main components pre-machined before welding**

In figs. 14, 15 the integration of the TA is shown. Connection of the various TA's components have been carried out by welding or bolting. Bolting of components has been used only for those parts not requiring a leak test.

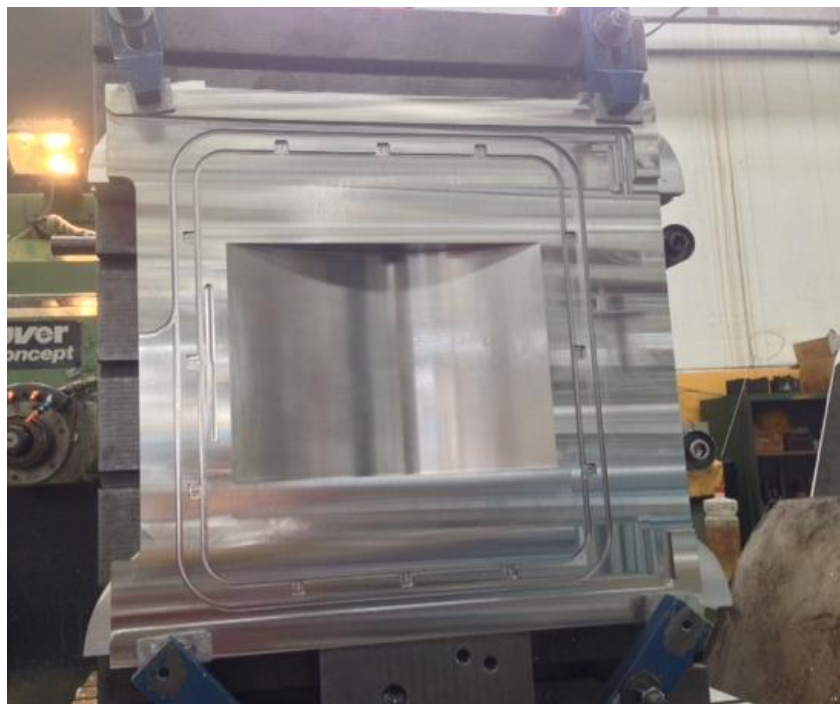


**fig. 14 TA body welding (inlet pipe positioning)**

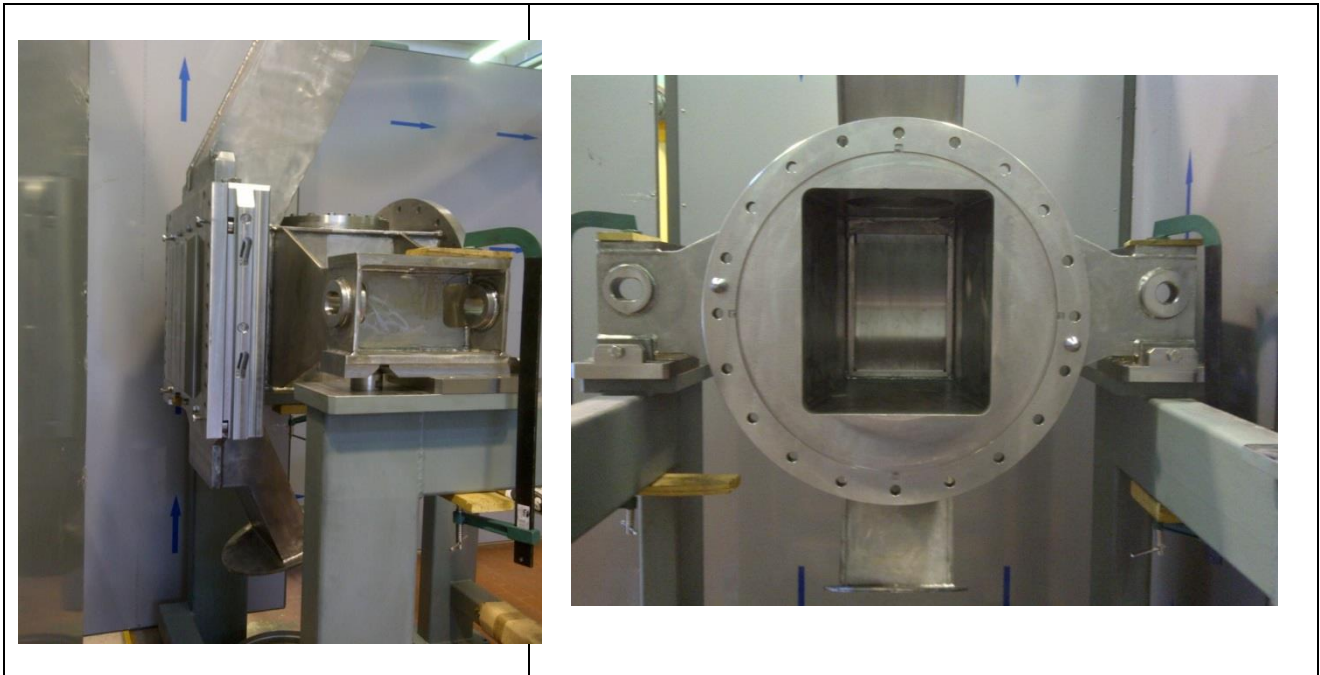


**Fig. 15 TA body machining**

In fig. 16 the backplate at the end of the machining process is illustrated. The accuracy achieved in the integration of this component onto the interface frame is within the expected one of  $< 0,1$  mm ( see Fig. 17 were the assembly of the backplate onto the target is shown. .



**fig. 16 BP machining**

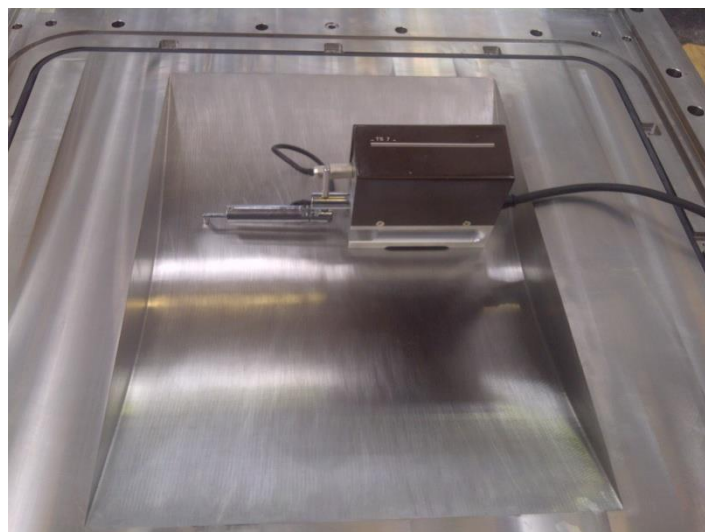


**Fig. 17 Assembly of the Backplate**

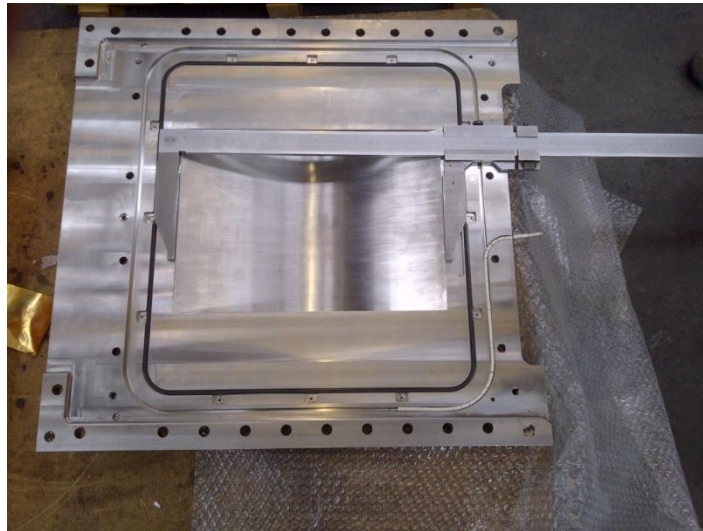
### **2.3 Testing of the prototype**

During and at the end of the fabrication several tests were performed, as follow:

- 1) Dimensional check of the prototype
- 2) Dimensional check of the backplate: main dimensions and roughness of the Li channel ( see figs. 18 and 19)
- 3) Check of the integration of the backplate
- 4) Test of the FDS.
- 5) Dimensional check of the target structure and of the TC liner mock up.
- 6) Compression test of the skate system before the manufacturing of the backplate( see next chapter).



**Fig. 18 Measurement of the roughness of the Li channel**



**Fig. 19 Dimensional check of the Backplate**

All the tests performed were successfully completed.

### *2.3.1 Backplate skate compression test on dedicated mock-up*

The Skate system of the backplate is the most important component of this component. In fact this device was introduced in the design to reduce the number of the bolting points so that the time for its replacement is reduced. However the effectiveness of this system in providing the required compression force to the gasket is of vital importance for the target assembly. Accordingly a dedicated mock-up of the skate system was made and tested. This mock up was also used for the optimization of the design. To check the effectiveness of compression of the cam some Belleville springs were used in place of the metallic seal. The following pictures 20 and 21 show the test mock-up that uses one of the two L support frames and actuating skate assembled on a BP mock up locking a target frame equivalent plate.



**fig. 20 Skate mock-up side view**





**fig. 20 frame mock-up with Belleville springs**

Using ten S4326 Belleville springs a compression load, similar to the seal needed force, can be achieved. The following table resumes the spring selection calculations.

**Tab. 1 Spring load calculation**

<b>Mock-up spring calculation</b>	
Number of spring	10
Spring deflection	0.71mm
Load per spring	9384N
Tot load	93840N

The reference design considers that with the seal fully compressed the bearing diameter match exactly the space above the cam upper profile. In this case an easy test of loading (even with no seal) showed that the wheel can easily pass over the cam with the consequent risk of cam locking and spring load release for overtravel (hence the introduced modification of skate end of stroke references).

A FEM simulation was done applying the sealing nominal load on the BP mock-up plate (red arrow in the picture that follows) and the corresponding reaction on the L support frame shows a quasi uniform deflection of 0.02:0.05 mm with a variation along the seal line well below the 0.1:0.15 tolerance required from the seal manufacturer.( see Fig. 21)

To leave some margin, the cam/roller position with the seal fully compressed, also to take in consideration L support/BP deflection over seal/cam load, a clearance reduction of 0.2 mm was first introduced. The resulting angle variation in the seal compression change slightly from the original design with the final cam angle at max seal compression of 3.4° instead of 3° as in the original configuration( see fig. 22).

Repeated compression test made on the mock-up shows little safety margin in the max compression load. With a torque of 20 Nm the minimum measured compression gap between the spring is about 0.1:0.15 mm with the cam near the end of stroke.

A further gap reduction of 0.2 mm (0.4 mm in total) was consequently introduced. The final torque to achieve the nominal load condition on the gasket increased up to 26 Nm ,but still with the expected value that was in the range of 20-30 Nm.

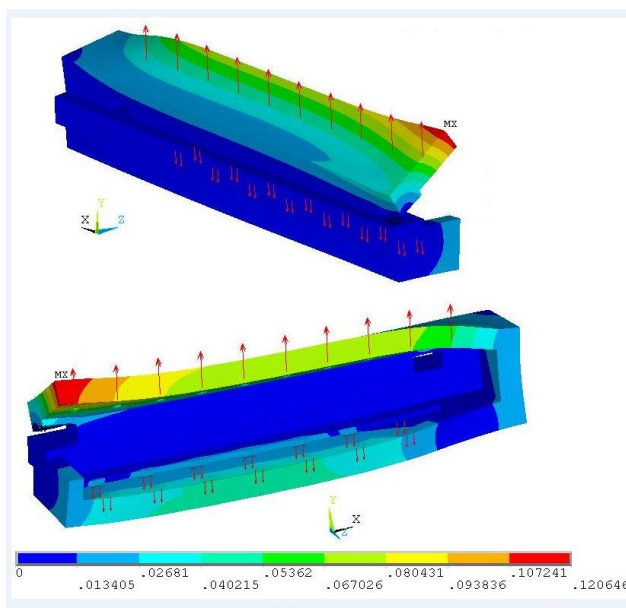


fig. 21 Skate L support FEM analysis

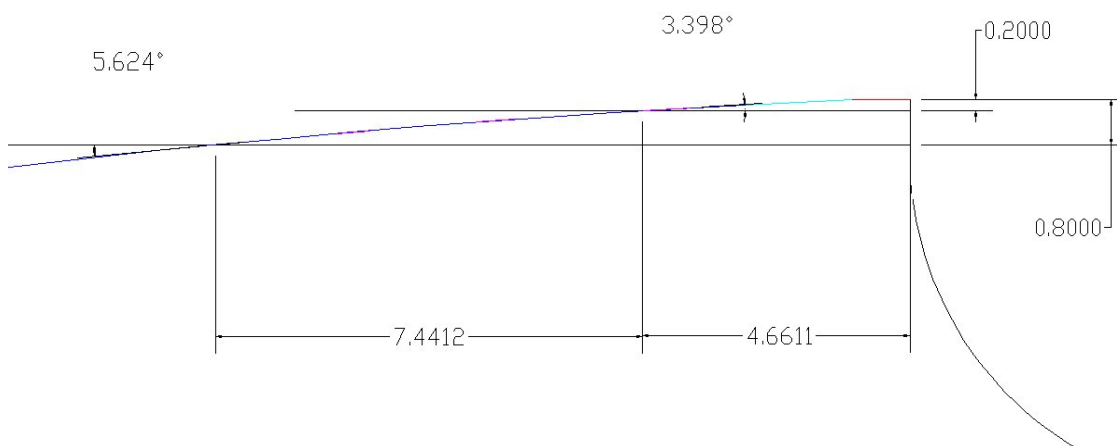


fig. 22cam off-set (1<sup>st</sup> iteration)

### 3 Conclusions

Prototypes of a full scale mock up of the target assembly and of the a section of the TC liner have been manufactured and now they are available in the DRP facility at ENEA Brasimone. A validation program for the refurbishment maintenance operations to be performed for the TA of IFMIF has been established, in agreement with the IFMIF Project Team in Rokkasho, and it will start in October 2013.

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