Maintenance considerations for the pre-conceptual design of the EU DEMO EC Mid Steering Antenna (MSA) equatorial launcher

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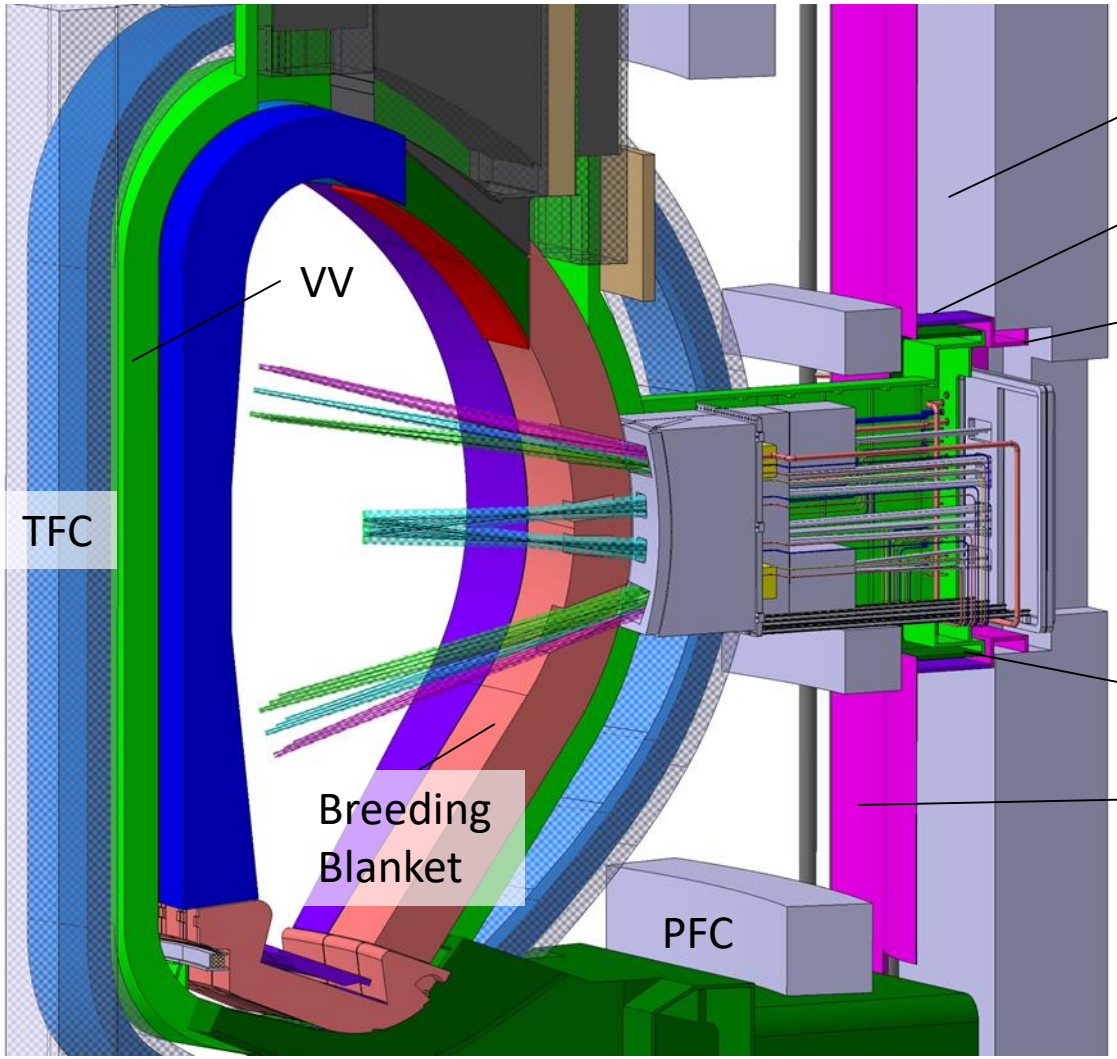
Outline

- Overview of the EU DEMO EC MSA equatorial launcher
- EC port plug design
- Neutronic shield design
- Port closure plates (First Confinement)
- Remote maintenance procedures
- Component maintenance concepts
- Tools
- Summary / Discussion

Overview EU DEMO with EC launcher

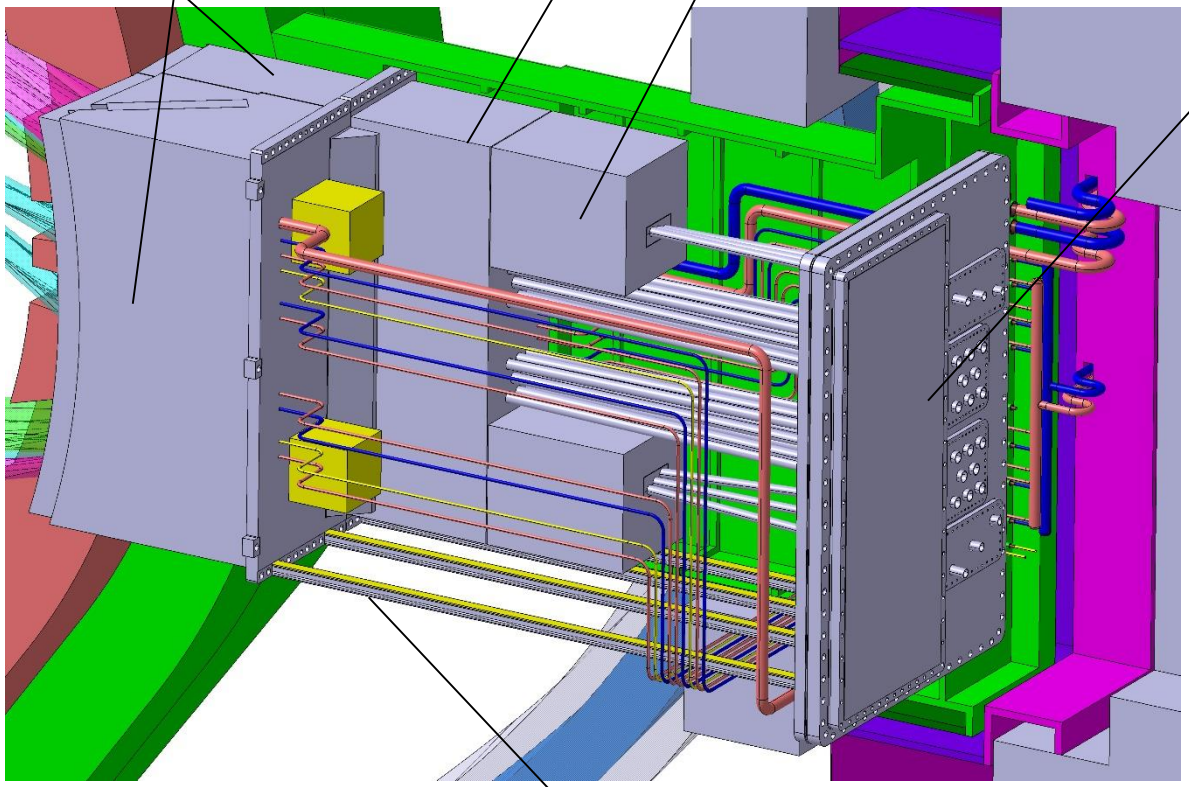


EU DEMO EC MSA equatorial launcher

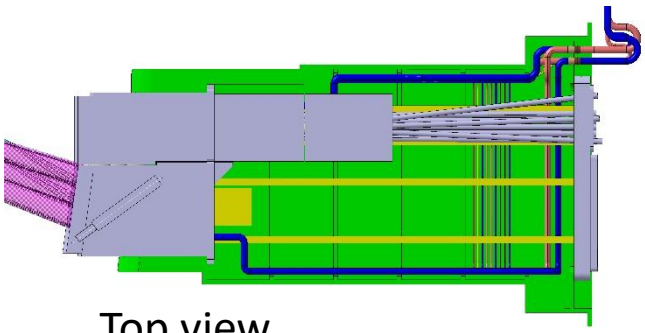
2 EC port plug modules

Auxiliary neutron shield A

Auxiliary neutron shields B1 & B2



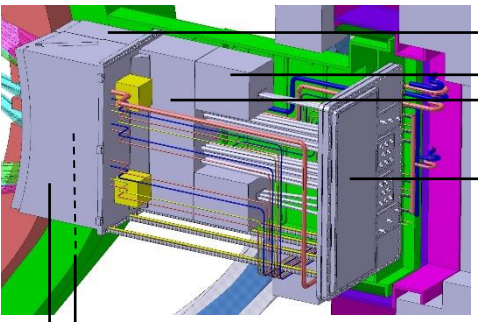
Port closure plate (with sub-plates)



Top view

Bottom rails with slides

EC MSA eq. launcher (exploded view)



PP module with fixed mirrors

Auxiliary shield A

Auxiliary shields B1/B2

Equatorial port

Vacuum closure plate + sub-plates

Set of mirrors, installed in port plugs

PP module with steering mirrors

In-vessel waveguides

Rails with slides

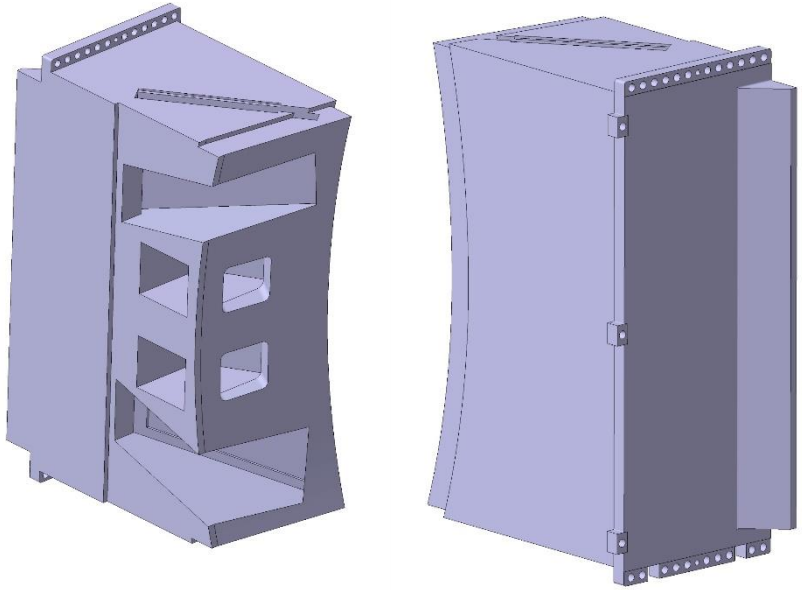
Steering mirror diagnostics (Dummies)

Port flange

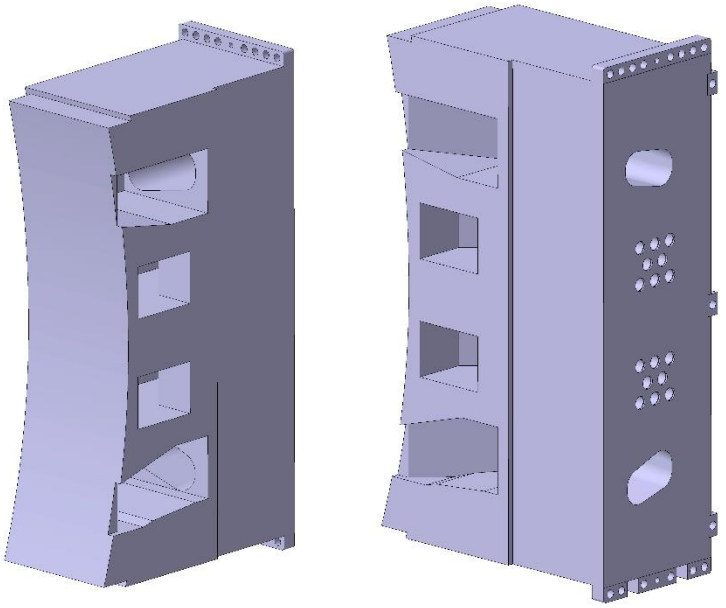
Supply pipes

EC MSA Port Plug modules

Two actively cooled port plug modules are installed into the DEMO equatorial port. Bolted fastening into the port is considered. The port plug modules have mirrors for quasi-optical beam propagation installed and provide dedicated passages for the beams.



- „Steering Mirror“ Equatorial Port Plug module (SM EPP)
- Material: EUROFER 97
- Typical dimension (h x w x l): 3,240 x 1,260 x 2,000 mm³
- Total mass for 20% cooling water: ca. 40,000 kg* (t.b.c)
- „RHC 2“ or „RHC 3“ (ITER classification, t.b.c)



- „Fixed Mirror“ Equatorial Port Plug module (FM EPP)
- Material: Stainless Steel (e.g. 316 LN, t.b.c)
- Typical dimension (h x w x l): 3,240 x 960 x 1,850 mm³ (l = 3,050 mm³ for auxiliary neutron shield A attached)
- Total mass for 20% cooling water: ca. 27,000 kg* (t.b.c)
- Total mass, incl. neutron shield A: ca. 47,000 kg*
- „RHC 3“ (ITER classification, t.b.c)

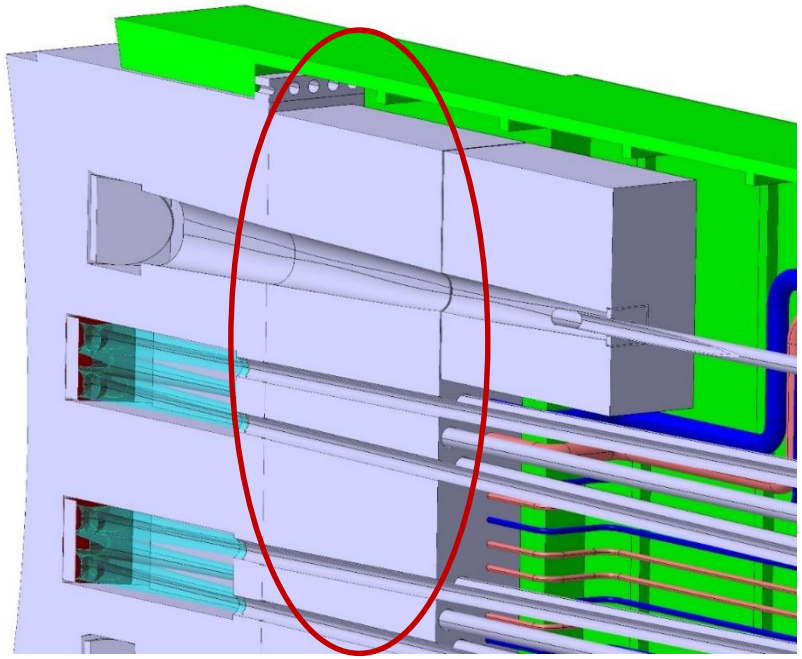
*without optical system components

Auxiliary neutron shield A

Auxiliary shield blocks are foreseen behind the FM port plug module in order to minimize neutron distribution in the port rear area, caused by neutron streaming through beam passages.

The auxiliary neutron shield A has typical dimensions of (h x w x l): 3,160 x 900 x 1,200 mm³ and a mass of ca. 20 tons. It can be integrated either as an individual component or being attached to the FM port plug module.

The auxiliary neutron shield A encloses the 2 x 8 waveguides for plasma heating and features beam passages for the quasi-optical beams for NTM control.



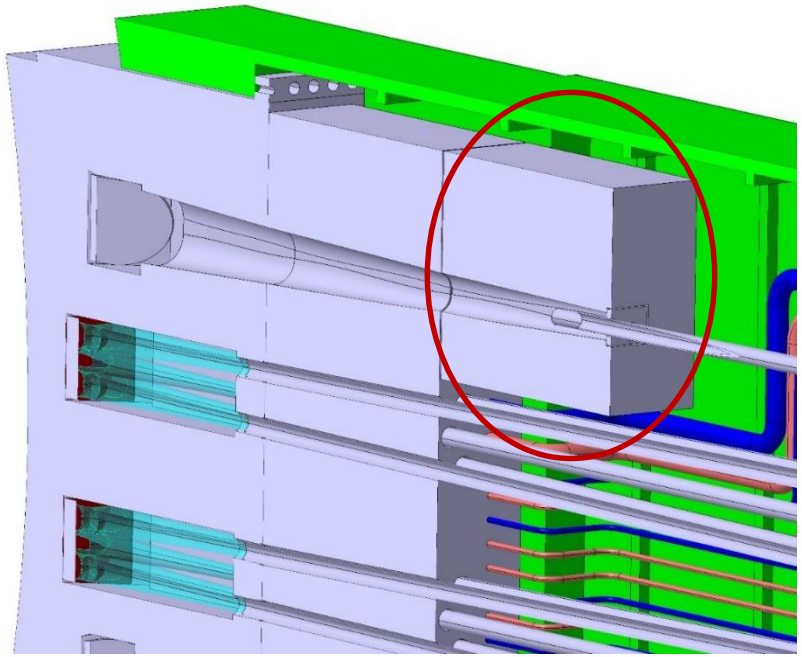
- If it will be an individual component, it has to be removed before any maintenance of the FM port plug module. The cooling water connections for the FM port plug module and neutron shield block A will be more complex for this design option
- If it will be part of the FM port plug module, this component becomes challenging in terms of mass of the port plug module (ca. 47,000 kg)

Auxiliary neutron shields B1 & B2

The two neutron shield blocks in the back have typical dimensions of (h x w x l): 950 x 900 x 1,170 mm³ and a mass of ca. 8 tons, each*. They are currently considered to be individual components, to be removed before maintenance of the FM port plug module/auxiliary neutron shield A.

The neutron shields B1 & B2 were introduced to bridge the gap between the auxiliary neutron shield A and the waveguide tips of the 2 x 3 NTM-control in-vessel waveguides. It is assumed that they will be either bolted towards the back side of the auxiliary neutron shield A or towards the side walls of the port.

The auxiliary neutron shields B1 and B2 feature beam passages for the quasi-optical beams for NTM control and provide mechanical support for the NTM control in-vessel waveguides at their rear sides.

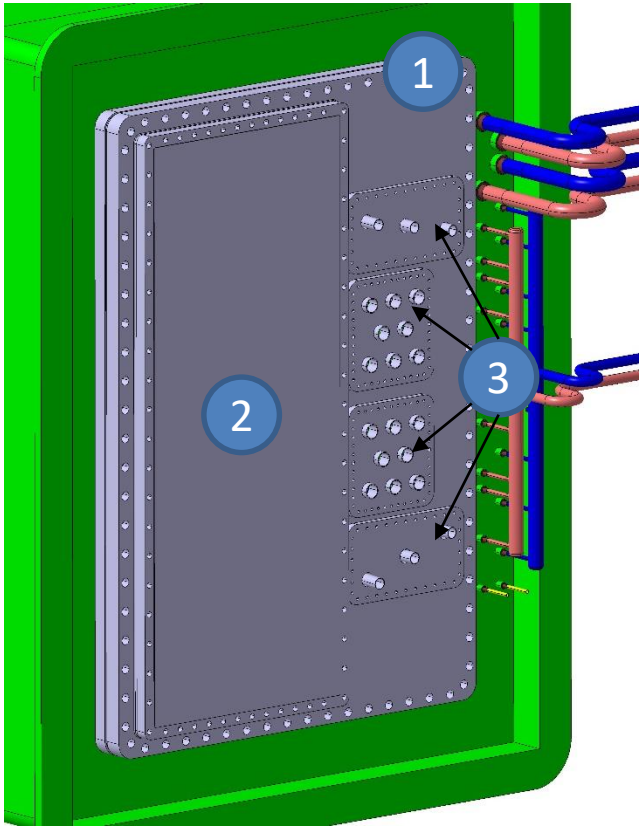


* If uncooled.

If water cooled with a steel/water ratio of 60/40 (volumetric), the mass will be in the range of 5.2 tons.

Closure plate / sub-plates

The closure plates form the removable parts of the First Confinement System at the back side of the port. They are arranged as a staggered and bolted assembly of a main closure plate (CP) and particular sub-closure plates in order to open the port to the required access accordingly.



- The main CP (1) carries the sub-plates and is attached to the port extension by bolts.
  Dimension is 3880 x 2730 mm²; mass is ca. 4,500 kg
- CP sub-plate (2) is integrated into the CP in order to allow individual removal of the SM EPP module without removing the waveguide assemblies.
  Dimension is 3640 x 1490 mm²; mass is ca. 3,500 kg
- Ex-Vessel waveguides and In-Vessel waveguides are connected by WG-feed-throughs, gathered on individual Sub-Closure plates (3) for each Waveguide section.
  Dimension of the Sub-Plates is 890 x 485 mm² for the NTM WG´s and 670 x 650 mm² for the heating WG`s;
  mass is ca. 125 – 130 kg for each.
- Sealings can be double metallic seals or lip welds

Remote maintenance procedures

- Scheduled removal and re-installation of EC port plug modules (ITER RH Class 2)
- Un-scheduled removal and re-installation of EC port plug modules (ITER RH Class 3)

- Sub-routines:
  - Opening / re-attachment of closure plate and sub-plates
  - Removal / re-installation of in-vessel waveguides
  - Cutting / re-welding of in-vessel pipes

- Optical system mirrors maintenance, currently considered to be performed in the maintenance area / Hot Cell (HC).

Closure Plate/sub-plates maintenance

Removal of the EC port plug modules for maintenance requires opening of the port, which means to remove the closure plate and/or sub-plates.

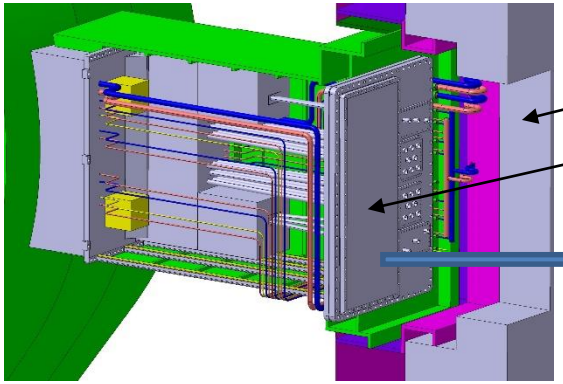
The maintenance concept of the EC launcher presents a simplified maintenance scheme for the SM EPP module. If design prove indicates a lifetime limit due to its direct exposition to the plasma and the sensitive steering mirrors, scheduled maintenance must be enabled. The FM EPP module is expected not to require scheduled maintenance but can be replaced in case of failure. This is why the closure plate is equipped with a sub-plate, whose removal allows access to the SM EPP module without opening the port completely. Thus the waveguides can be in place during maintenance.

The waveguides are bundled on additional sub-closure plates which serve as the fixed support in a statically determined fix-loose bearing system. The loose bearing is at the front side of the waveguides, which is why the bundles can be manipulated by gripping from the back side as a cantilevered system.

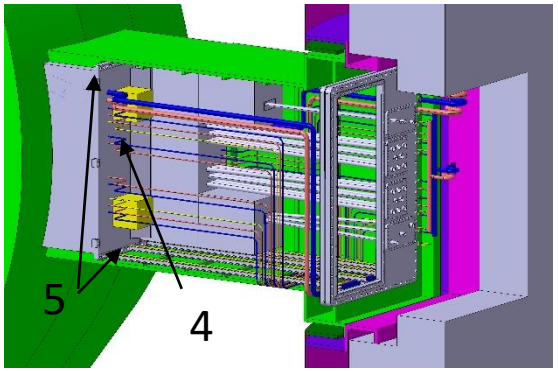
Grippers are not yet designed, but concepts with temporarily installed interface components are conceivable.

The seals of the closure plate and the sub-plates are assumed to be metal gasket seals or lip-welded seals.

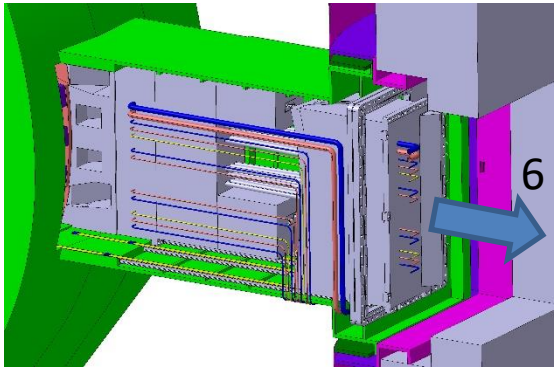
EC SM port plug module maintenance



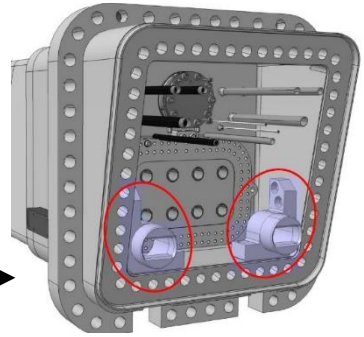
1) Clear port cell and bioshield plug
2) Approach Maintenance tool and unbolt / unseal closure plate subplate
3) Remove Closure plate subplate and store it inside the cask / the port cell / the HC (?)



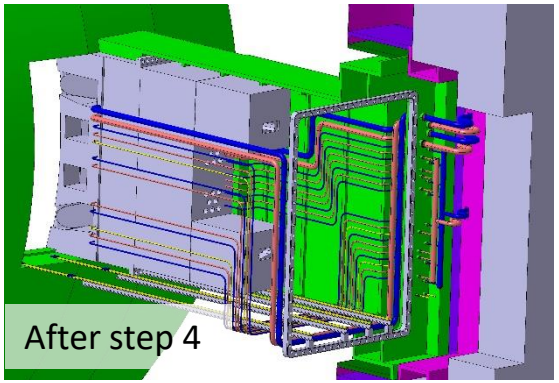
4) Approach cutting/re-welding tool and cut pipes at dedicated position
5) Approach bolting tool and unfasten the port plug
6) Approach tractor*, connect with port plug and remove towards the transport cask

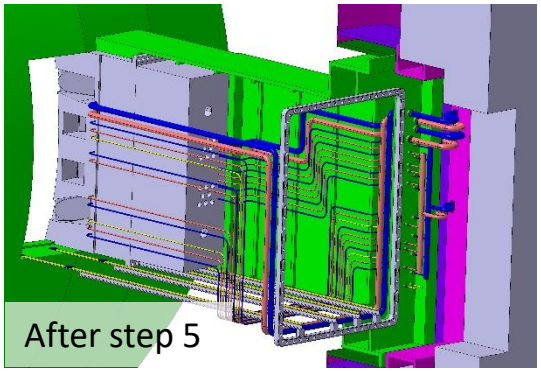


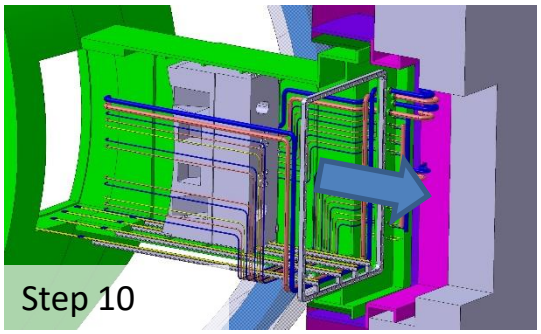
*Interfaces between tractor and port plug might be similar to standardized container twistlocks (temporarily installed, see example) →



EC FM port plug module maintenance



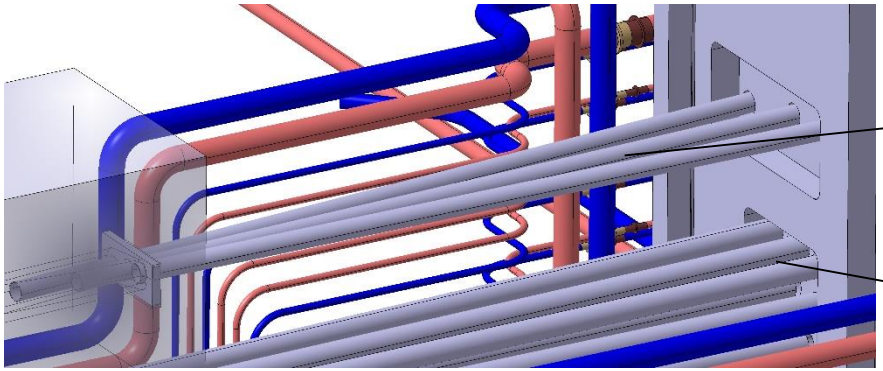




1) Clear port cell and bioshield plug
2) Remove EC SM Port Plug
3) Remove closure plate sub-plates with waveguide assemblies
4) Remove closure plate
5) Approach tractor / gripper and remove secondary auxiliary shield blocks
6) Approach cutting/re-welding tool and cut pipes at dedicated position
7) Approach bolting tool and unfasten the main auxiliary shield*
8) Approach tractor and remove auxiliary shield towards the transport cask*
9) Approach bolting tool and unfasten the port plug
10) Approach tractor and remove the port plug towards the transport cask

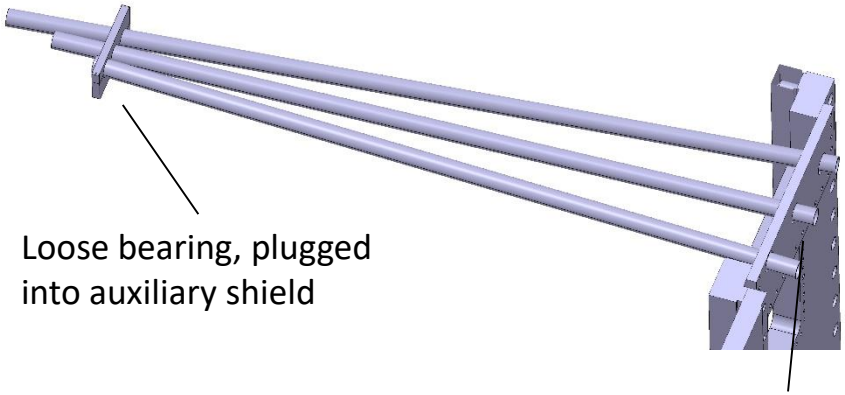
*these steps are neccessary only, if auxilary shield and port plug are separate components

Optical system maintenance (WG´s)



3 NTM control waveguides

8 plasma heating waveguides



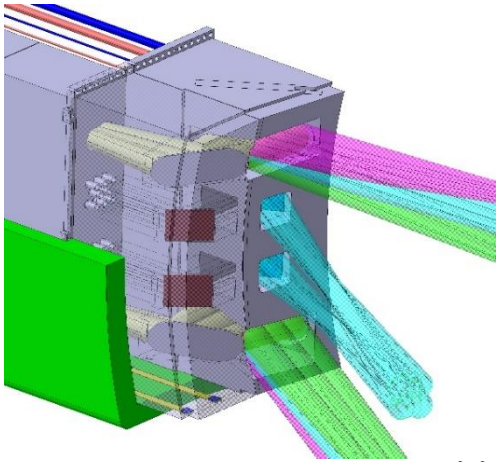
Loose bearing, plugged into auxiliary shield

Fixed bearing, bolted to closure plate

For maintenance unbolt, unseal and retract waveguide bundle together with closure plate sub-plate.

Waveguide bundles possibly to be repaired in maintenance area (HC)

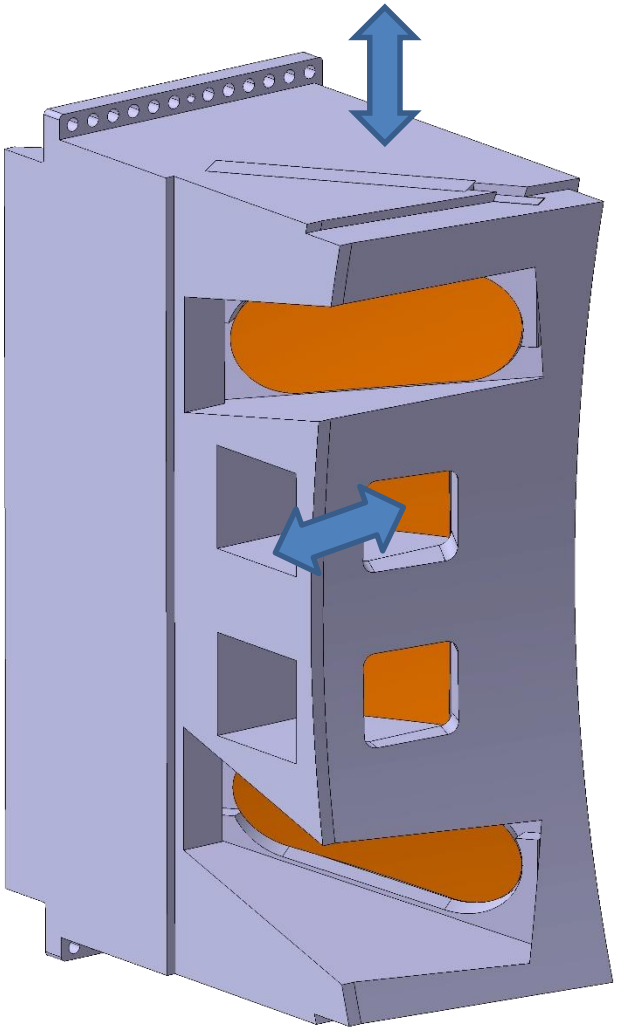
Optical system maintenance (Mirrors)



Mirrors are not maintainable in-situ*. Port plug modules must be de-installed and transferred into maintenance area (HC).

Current design concept assumes manipulation of optical components in both horizontal and vertical direction.

Cutting and re-welding of cooling connections to be investigated

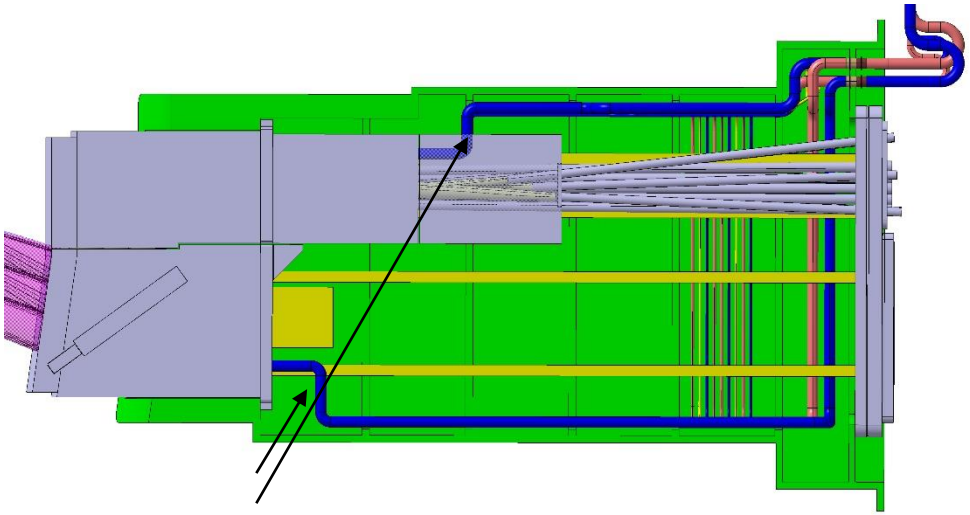


Steering mirror assembly to be maintained vertically through slot in SM EPP module

Fixed mirrors to be maintained horizontally through beam passage in SM EPP module

*the concept of in-situ repair of the mirrors of the FM PP module is under investigation in order to avoid de-installation of the in-vessel waveguides

Pipe cutting / re-connecting



Cutting / re-welding zones

The current design has the pipe forest integrated with clearance for un-blocked removal of the port plugs after cutting the pipe joints behind the plugs.

After cutting the pipes with an orbital tool the short stubs remain with the plugs while the pipe runnings along the port wall can remain in place.

Present diameter of the pipes is 88.9 mm for the main cooling lines (for structural components) and 25.4 mm for the individual cooling lines for the mirrors.

Tools possibly required (t.b.d.)

Transport tools:
- Gripper
- Tractor

Manipulation tools:
- Multi DoF manipulator

Operation tools for:
- Bolting and secure/Un-bolt
- Grinding
- Cutting
- Welding
- Grasp
- Clean

Test & Inspection tools:
- Cameras
- Physical measure
- Photogrammetry
- Pressure test device
- He Sniffer
- NDI

Summary / Discussion

- For the EU-DEMO EC MSA equatorial launcher a pre-conceptual design has been elaborated, taking into account remote maintenance for particular components.
- The remote maintenance procedures presented in this talk are pre-conceptual and require extensive analysis and detailed specification.
- Verification of the available tools is essential as well as adaptation of the components design with respect to RM. Proper design of the components can simplify RM procedures significantly, which is why RM aspects should be taken into account throughout the whole design process.
- PDFs (Plant Definition Forms) and TDFs (Task Definition Forms) are valuable management tools to describe RM procedures and to analyse the envisaged concepts and to prove their feasibility. Thus it is highly recommended to support the conceptual design process with such (or similar) tools.
- Close collaboration between design teams and remote maintenance team is required for future design progress.