LIEBE: project review – October 2015

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EDMS 1554616

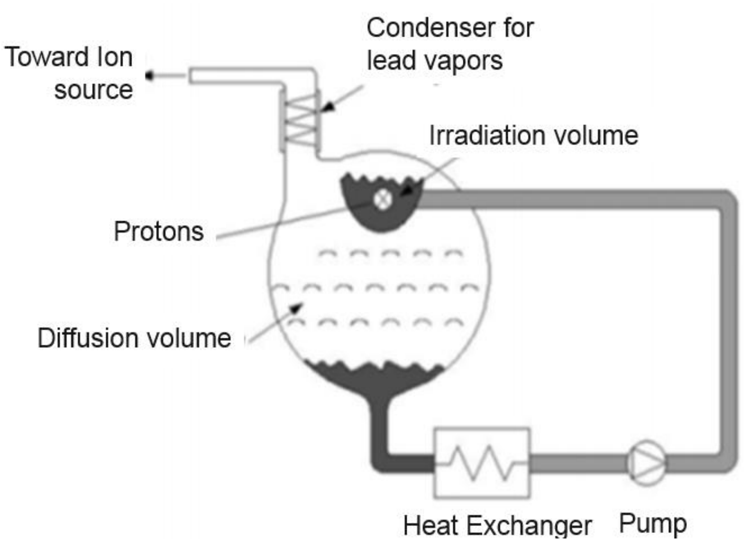
Review - objectives

- Validation of the technical choices
- Feedback from experts on several problematics
- Preparation for upcoming required modifications (front end area)
- Please, don't hesitate to interrupt me if you have any question!

Context

Context (1)

- Development of a **high power** target that allow a higher release of **short-lived species** (targeted isotopes: ^{177}Hg (130 ms half life)) by creating a shower of LBE



Schematic layout propose during the EURISOL Design Study phase

Short-lived species → Irradiation volume, Diffusion volume

→ • Droplets as small as possible are required
  • Minimum velocity: **1,8 m/s**

High Power → Heat Exchanger, Pump

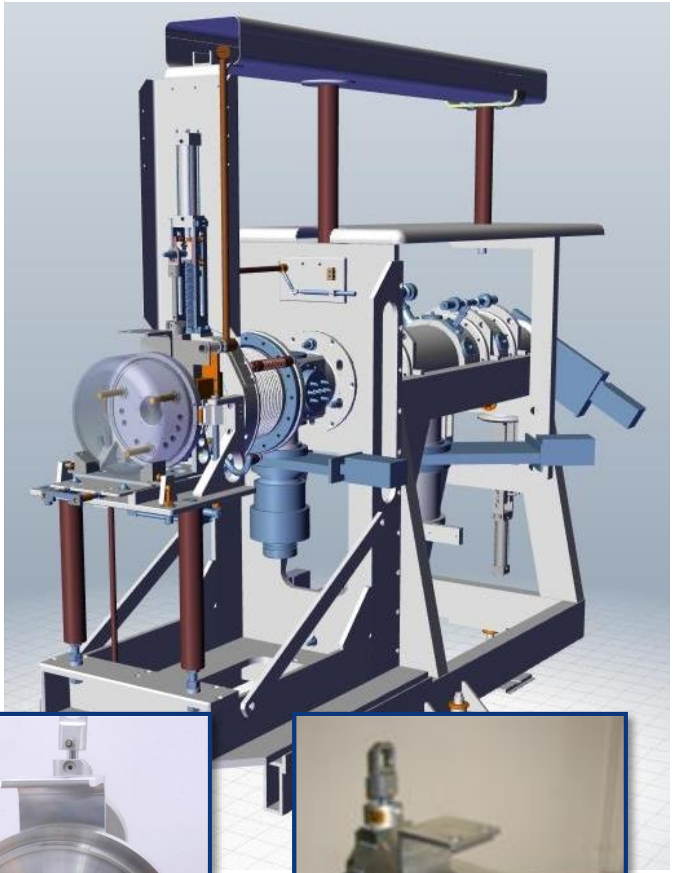
Standard liquid ISOLDE targets → Ion source, Condenser

*Liquid loop target using Lead Bismuth Eutectic (LBE) operated between **200** and **600** ˚C*

Context (2)

- Operating a target @ ISOLDE
  - Target must be compatible with the ISOLDE robot
  - Target must be compatible with the ISOLDE front end
  - Target must have a double enclosure to ensure no possible contamination of the front end
  - Target must be remotely controlled and monitored

ISOLDE front end



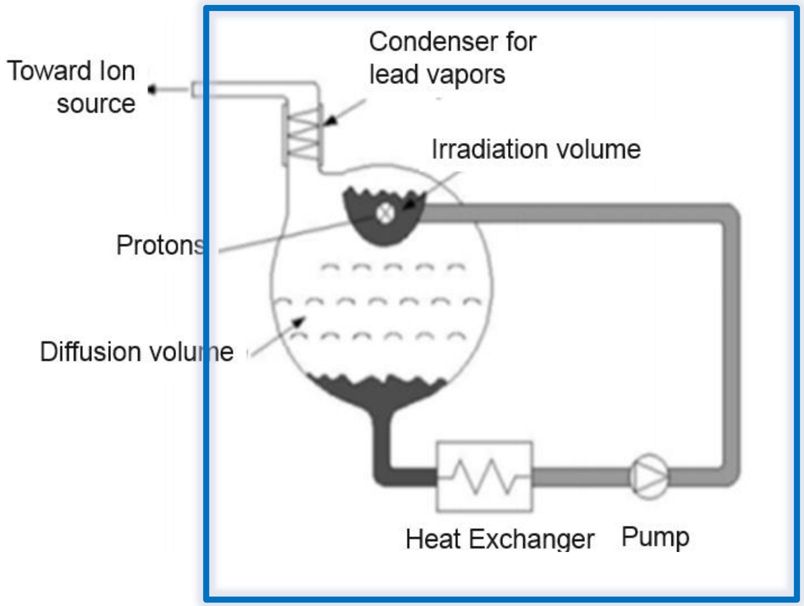
Max. weight: 65 kg

ISOLDE robot

*Standard ISOLDE target unit – **without** double enclosure*

*Standard ISOLDE target unit – **with** double enclosure*

Operating conditions



Double enclosure

- Temperature of LBE: between 200 and 600 ˚C
- LBE loop under vacuum through condenser and extraction line
- Safety measure for possible breakup of the double enclosure: gas system

Monitoring of P_{mid}

P_{mid} < 200 mbar -> leak of internal loop

P_{mid} > 800 mbar -> leak of double enclosure

Pressure sensor

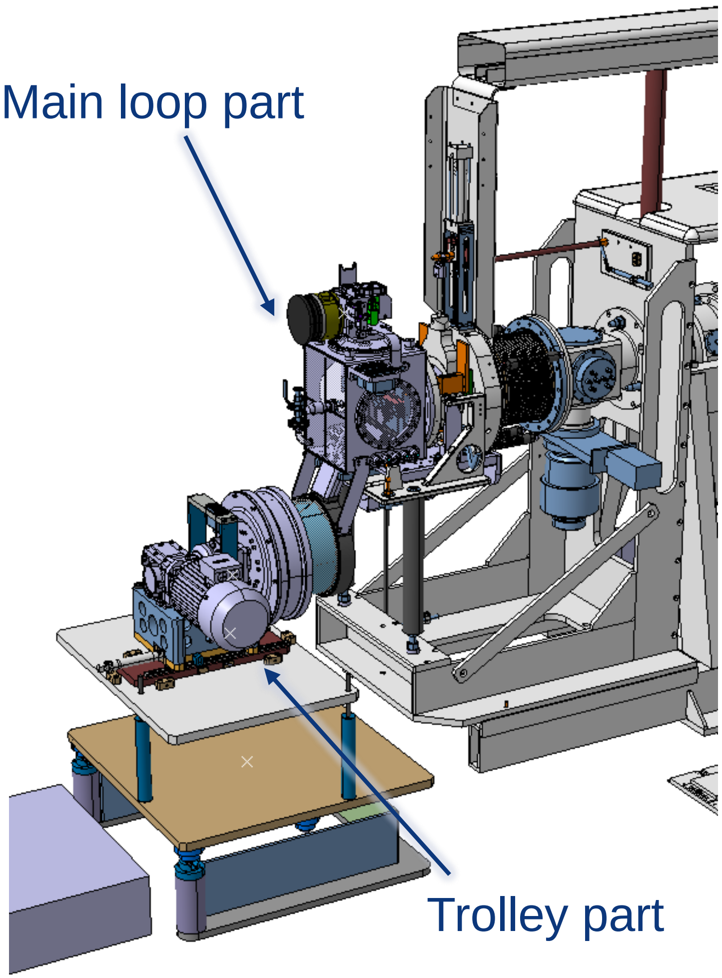
P_{int}= Vacuum (10^{-6} mbar)

P_{mid} = Low pressure (200 to 800 mbar)

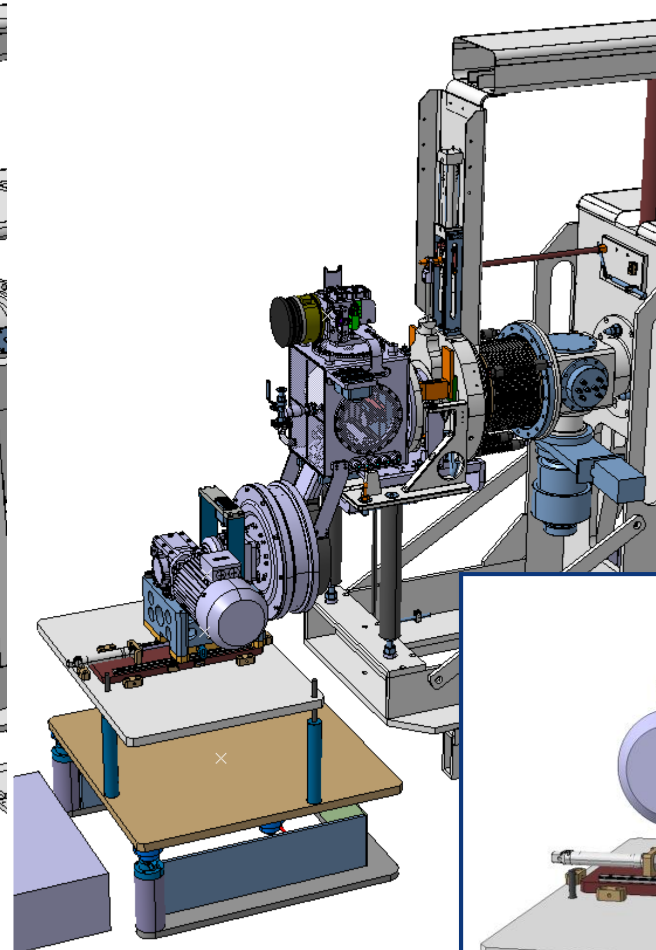
P_{out} = Normal atmosphere (1 bar)

Proposed design – general overview

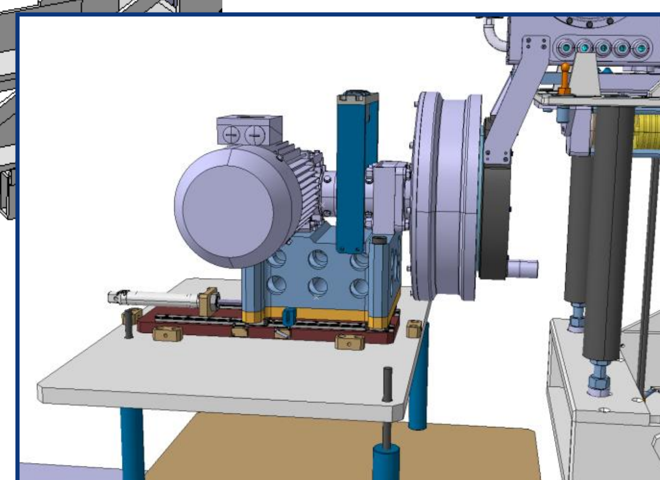
Proposed design (1) - general



Uncoupled position



Coupled position

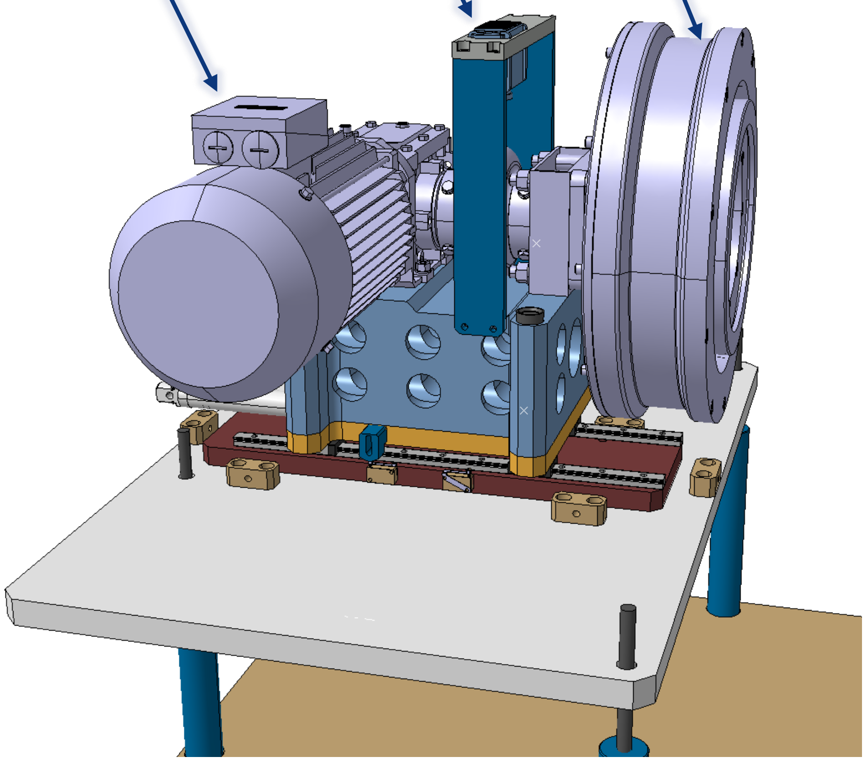


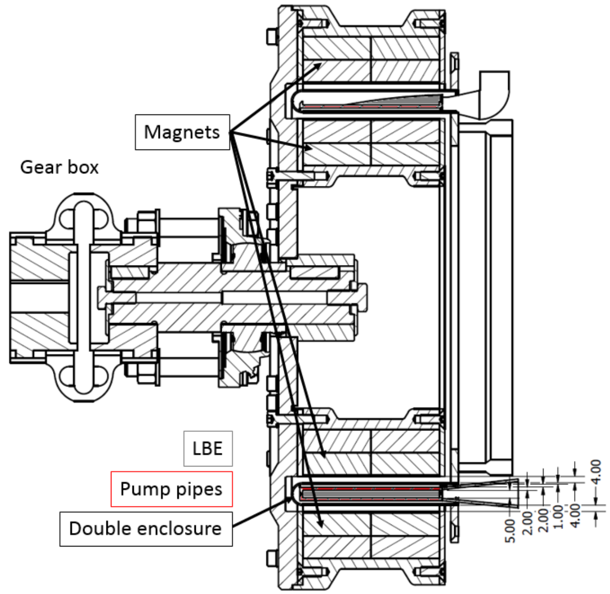
A two parts target is proposed:

- Main loop target with LBE circulation

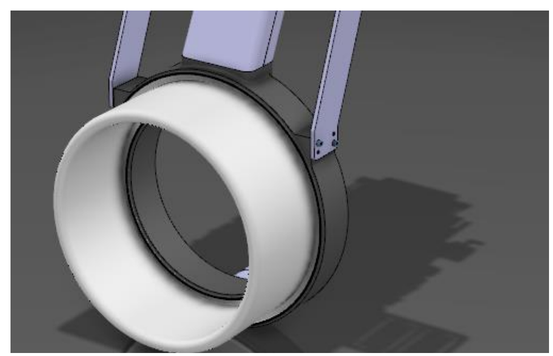
- Trolley part with magnets and engine of pump

Proposed design (2) – pump design





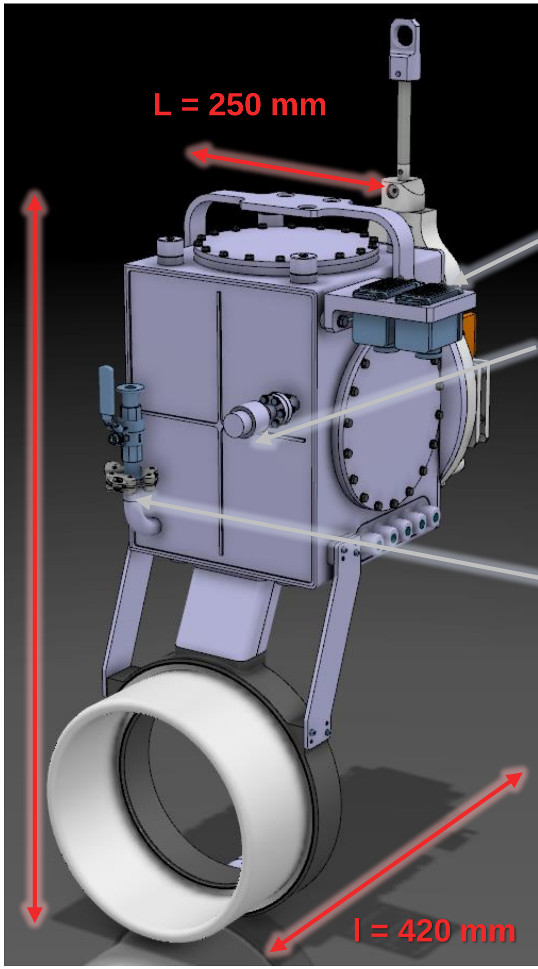
*Gaps between double enclosure and **internal** magnets: 4 mm*
*Gaps between double enclosure and **external** magnets: 5 mm*



Double enclosure around pump pipes

Proposed design (3) – main loop part

h = 770 mm



Patch panel

Pressure sensor

Valve for vacuum and gas filling

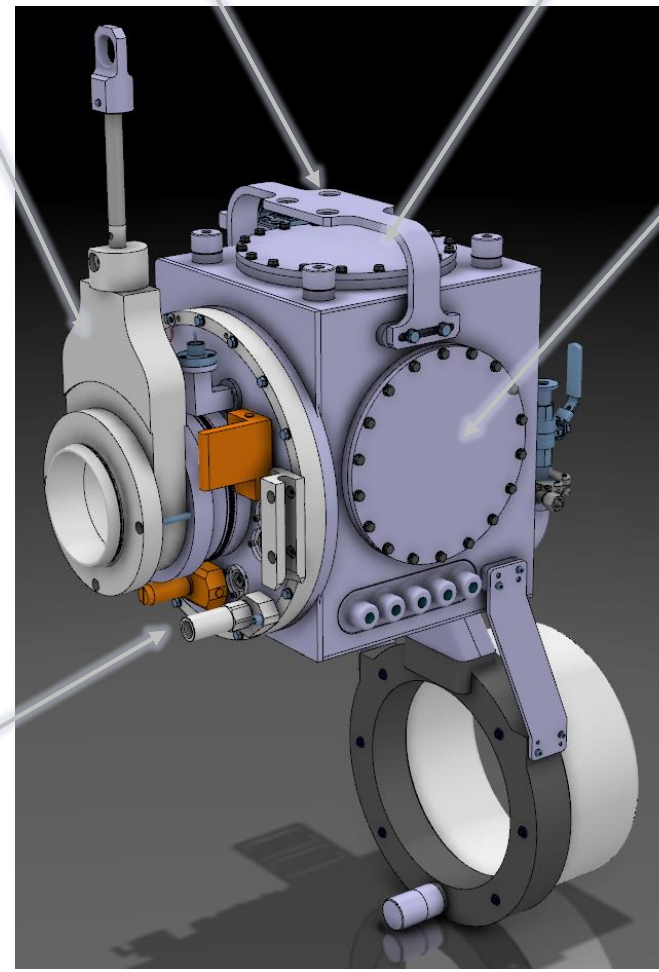
Standard ISOLDE base

Standard ISOLDE interface

Lifting hook

Opening for filling tank

Opening windows

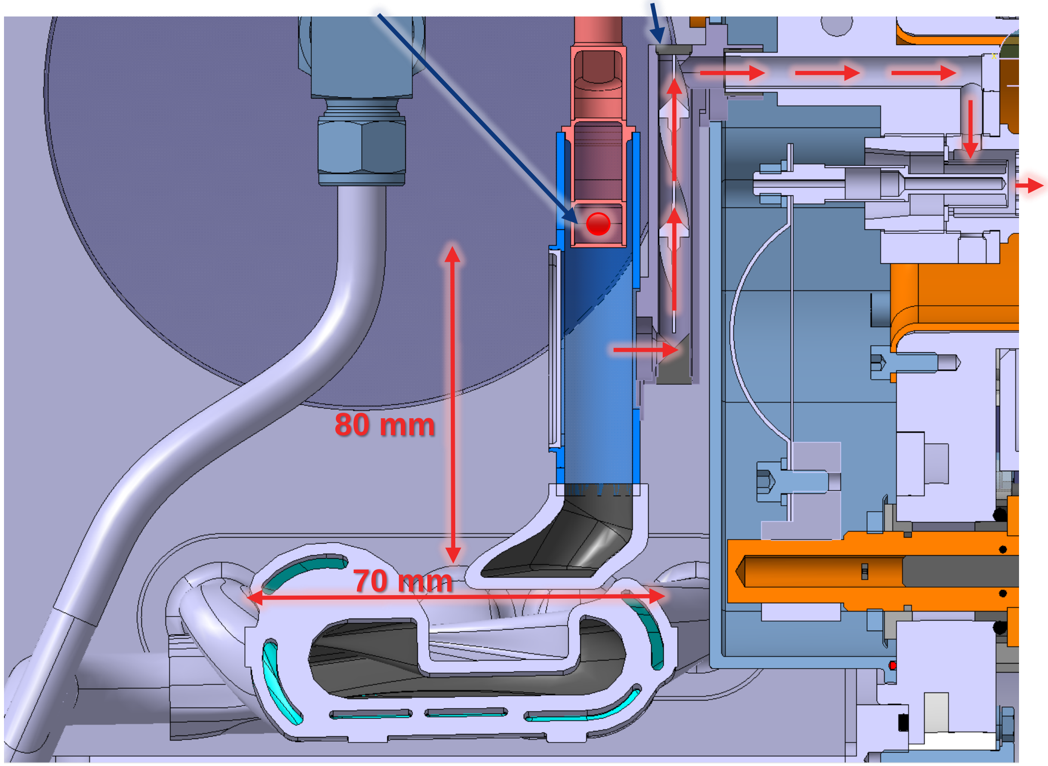


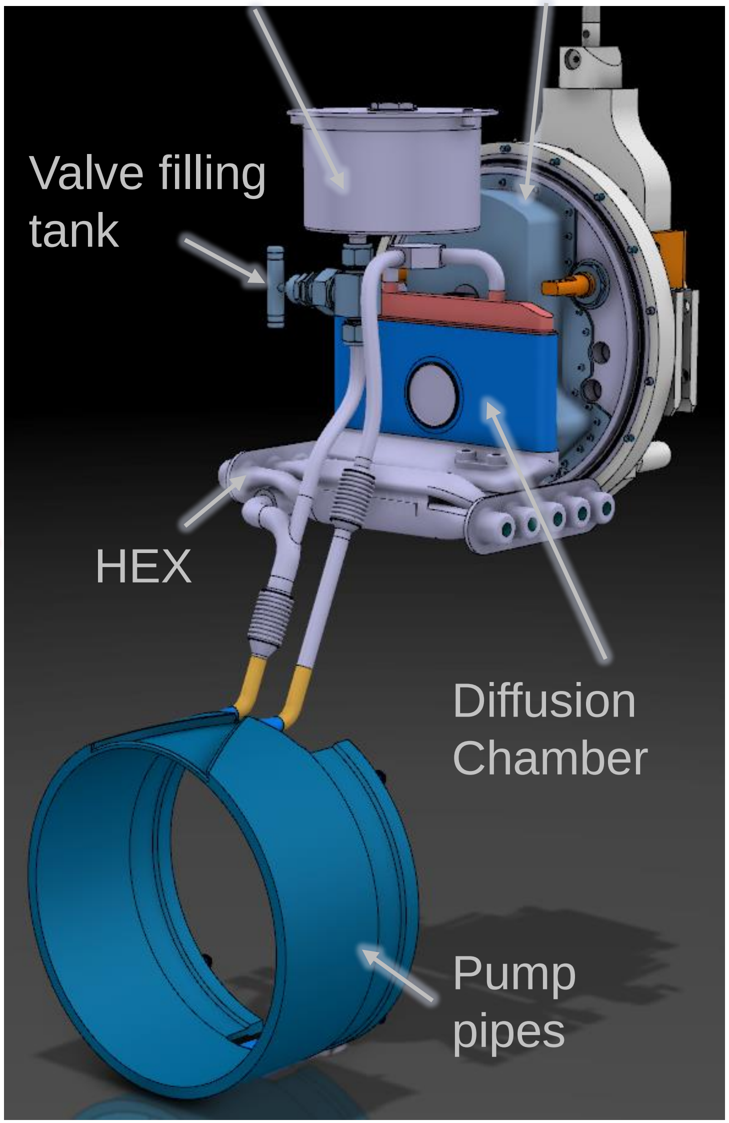
All parts are in Stainless Steel 316L or 304L

Total weight: **67kg** with water pipes and valves!

Proposed design (4)

- Inside view





Proton Beam impact *Isotopes path – under vacuum (10^{-6} mbar)*

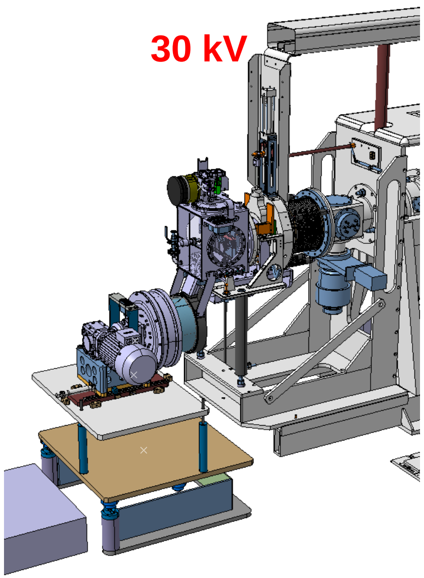
All parts are in Stainless Steel 316L or 304L

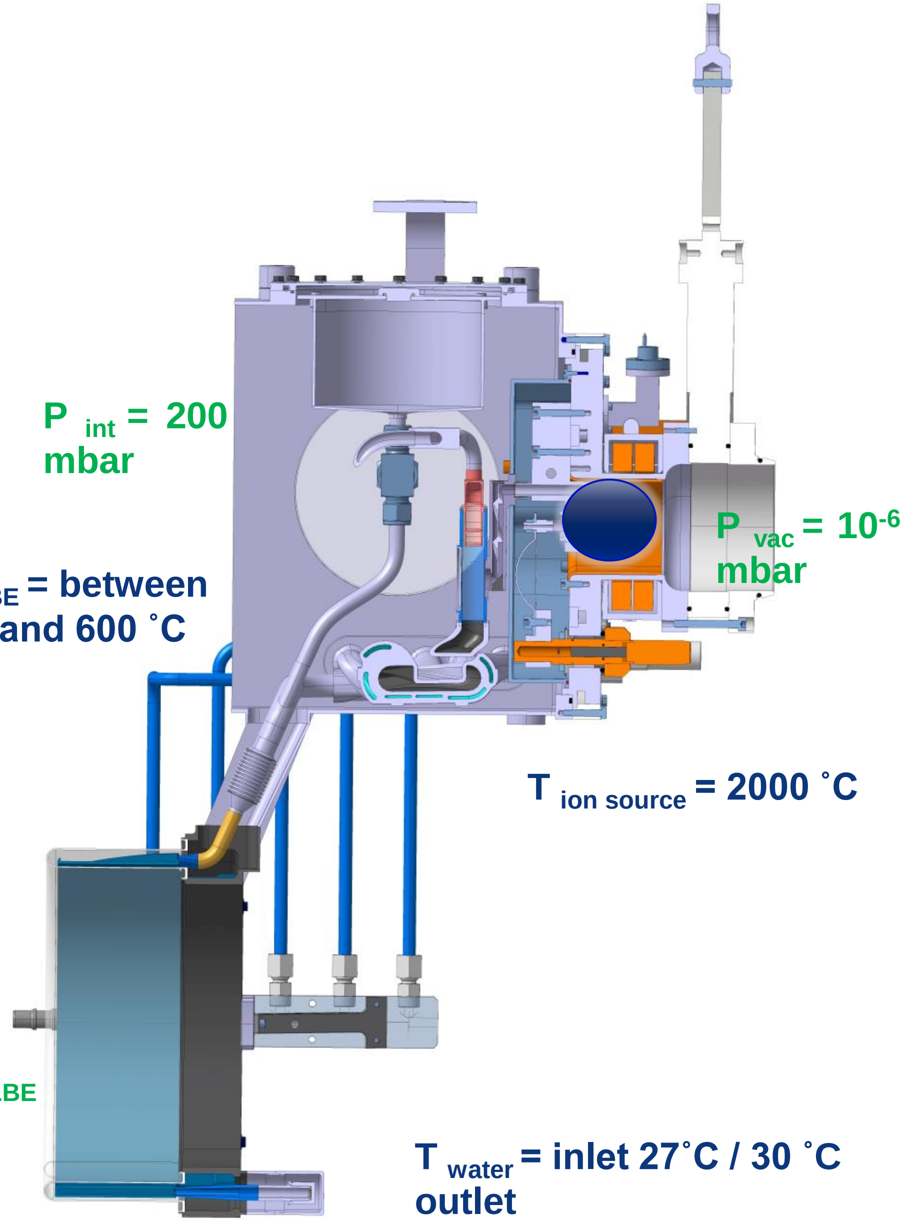
Special constraints

Front end area: under 30 kV

In the target:

- *Different temperatures*
- *Different pressures*

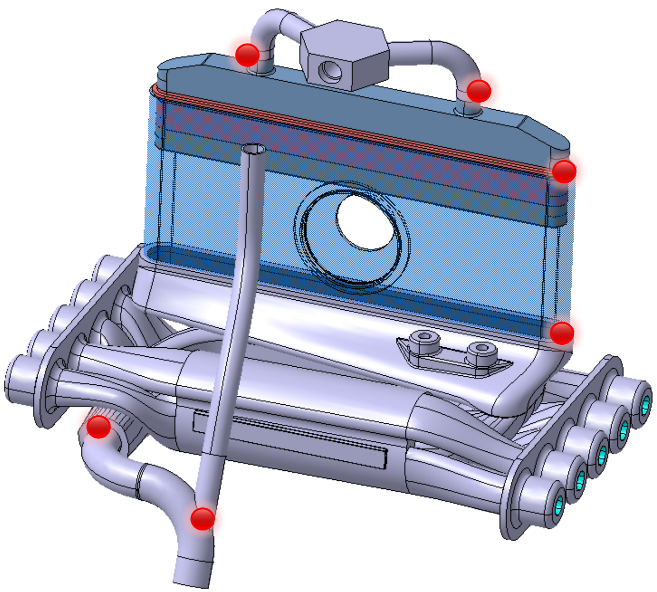




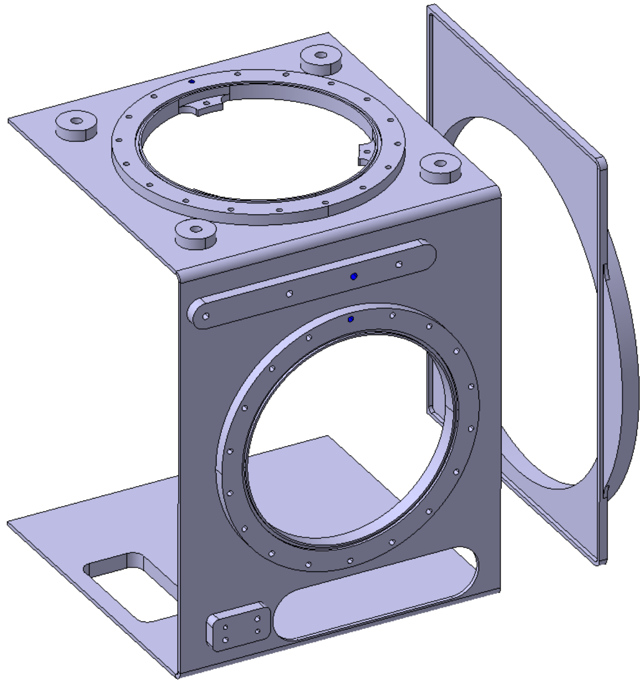
Assembly procedure

Assembly procedure (1)

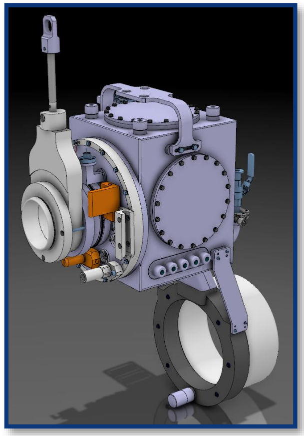
- *Welding*

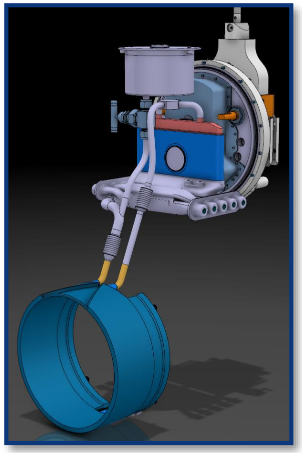


1. Assembly of the HEX with the diffusion chamber, shower part and inlet pipe from the filling tank
+ heating elements installation



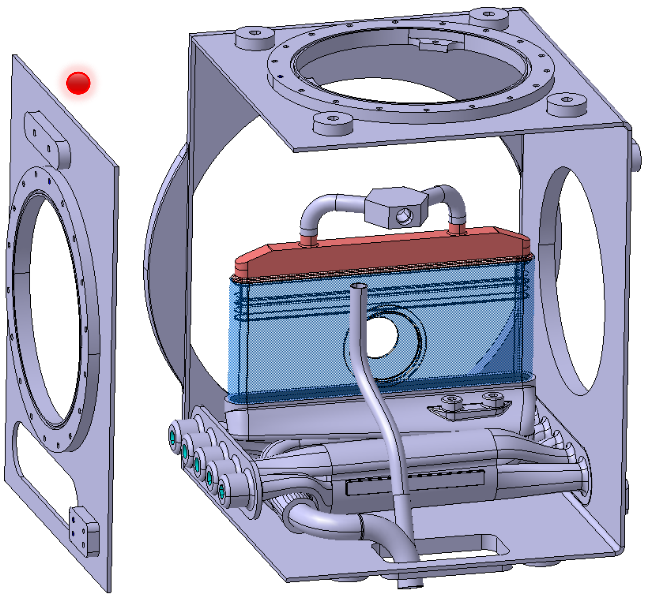
2. Folding of a flat plate machined for a U shape – welding to back plate after plate stabilization





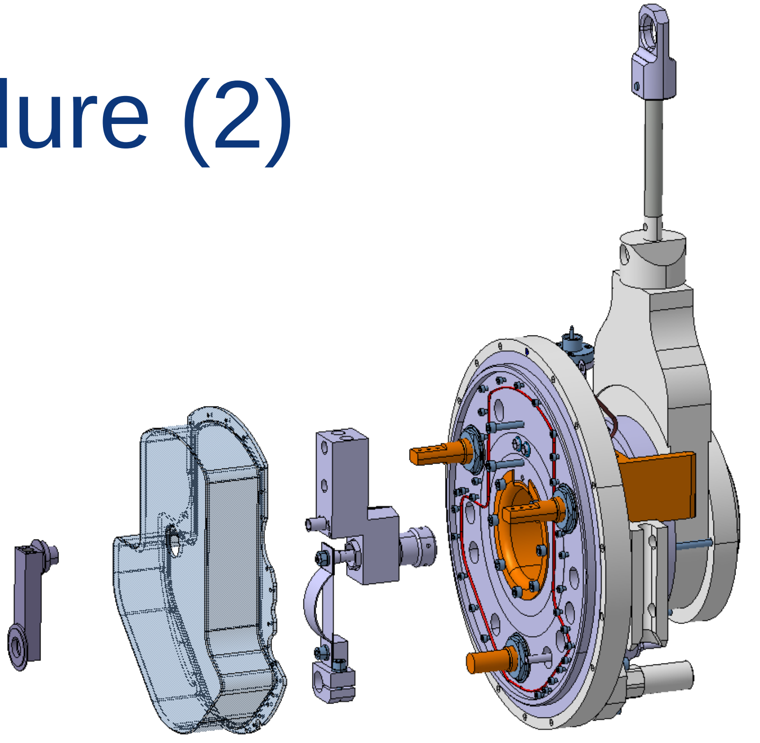
Assembly procedure (2)

- *Welding*

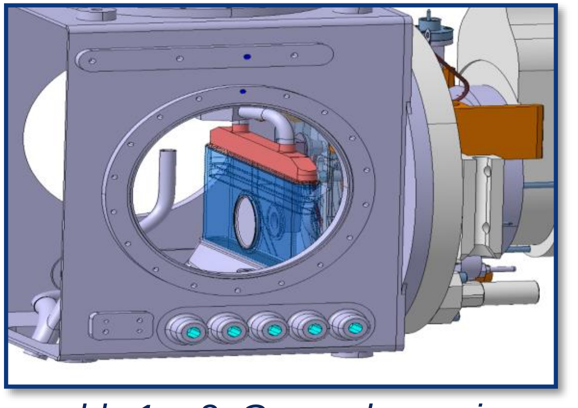


3. Welding of the side plate to close the tank

Sub-assembly 1 done



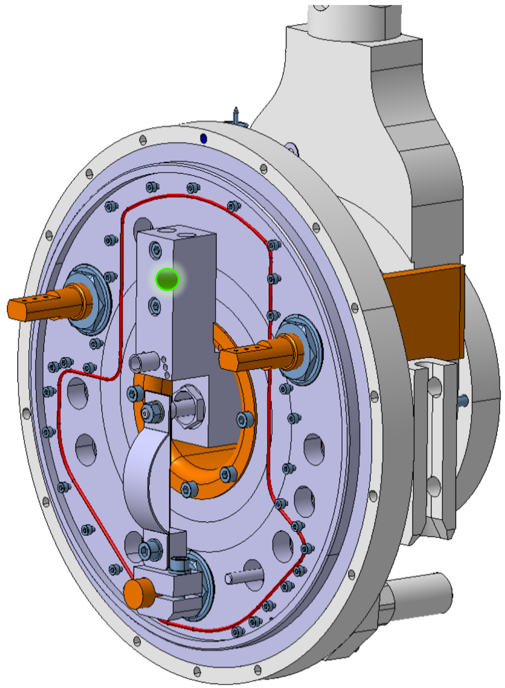
General view of sub-assembly 2



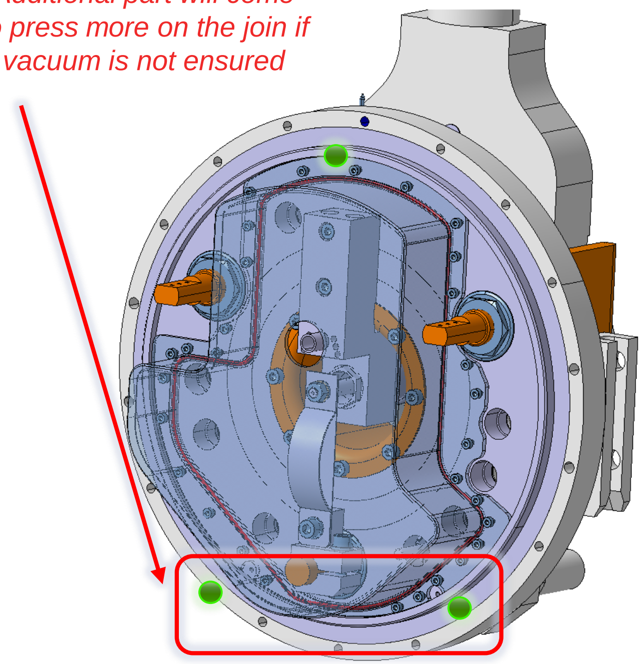
Sub-assembly 1 + 2, General overview

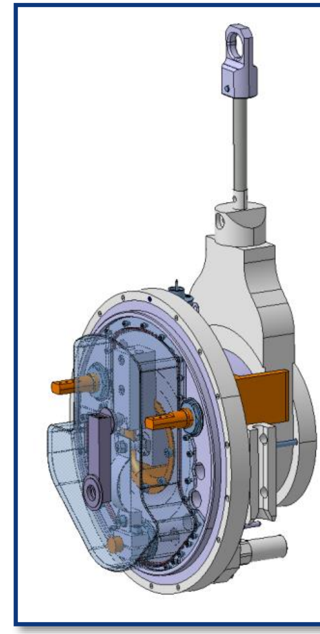
Assembly procedure (3)

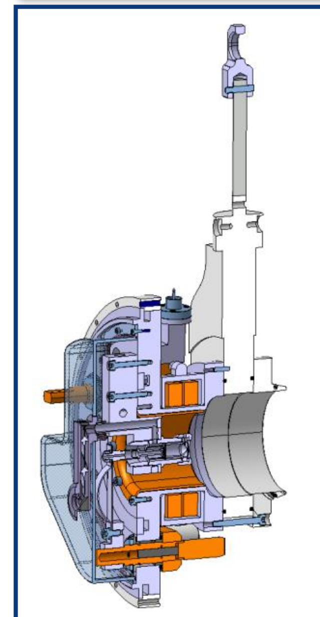
- Screws



Additional part will come to press more on the join if vacuum is not ensured





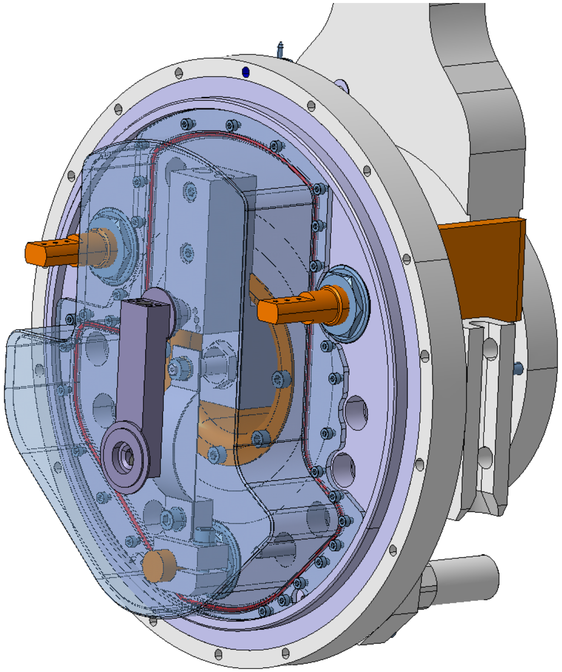


4. Assembly of the ion source part with the base flange – maintain in position with screw

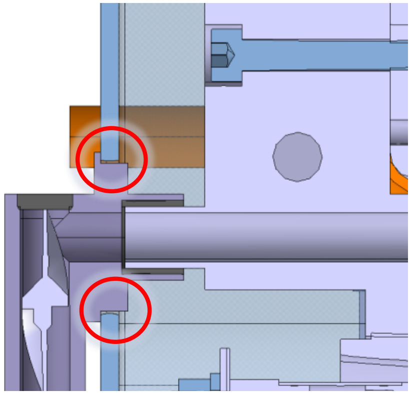
5. Positioning of the internal vacuum vessel – maintain with screws

Assembly procedure (4)

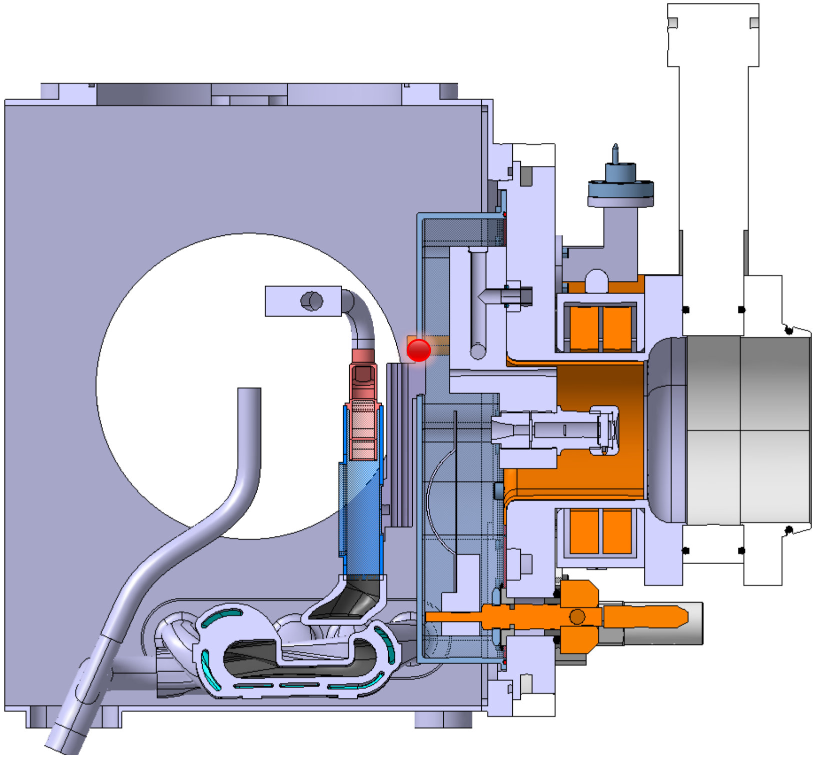
- *Welding*



6.1. Positioning of the chimney…



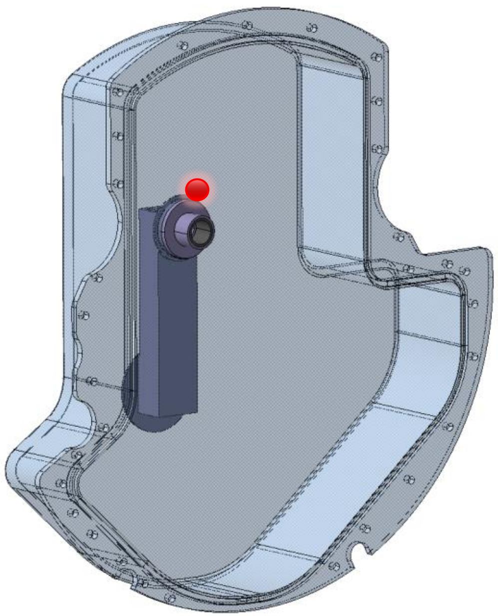
Gap on each side: 0,5 mm



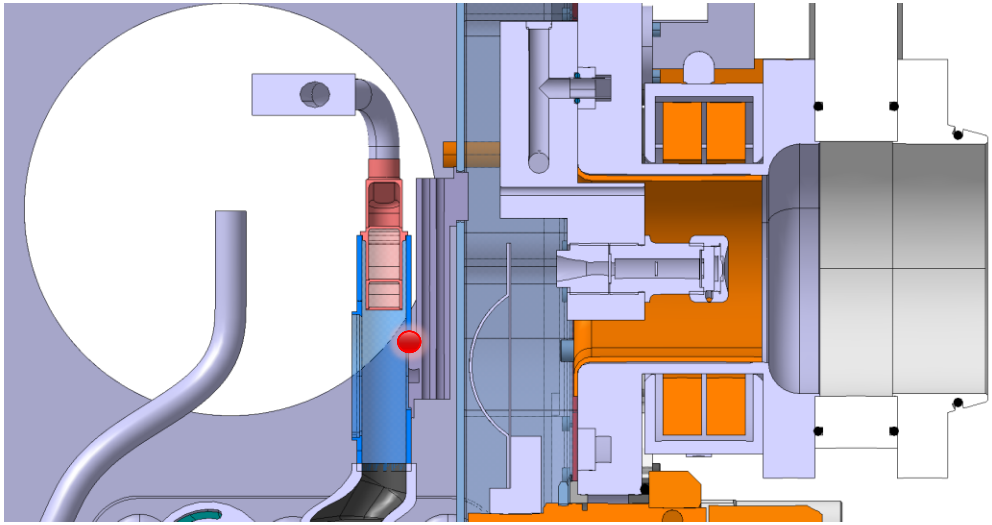
6.2 … with the diffusion chamber and small welding point to mark the proper position of the chimney

Assembly procedure (5)

- *Welding*



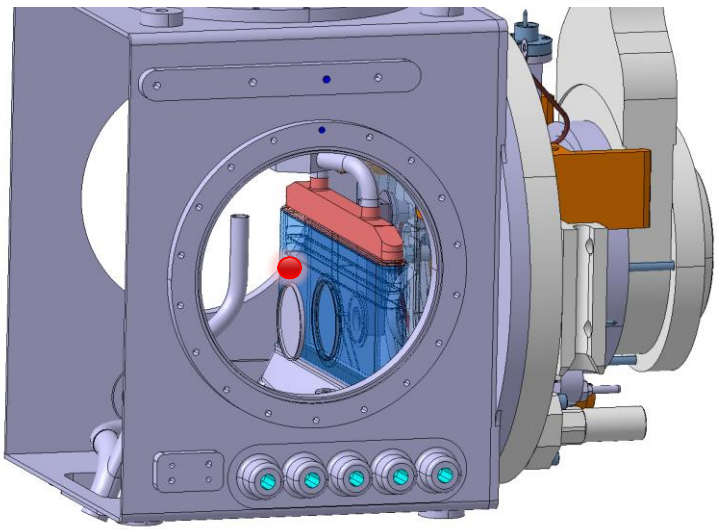
7. Welding the chimney to the interval vacuum vessel from the inside



8. Welding the chimney to the diffusion chamber from the inside of the diffusion chamber (access from the frontal opening)

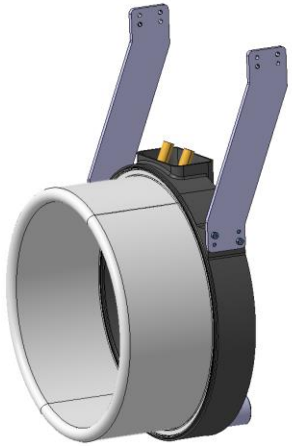
Assembly procedure (6)

- *Welding*

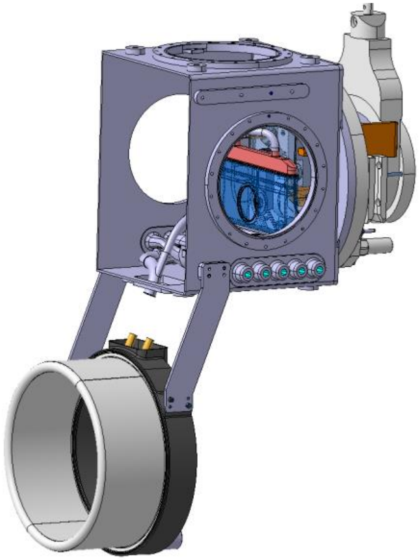


9. Welding of the frontal plate to the opening

Sub-assembly 1+2 done



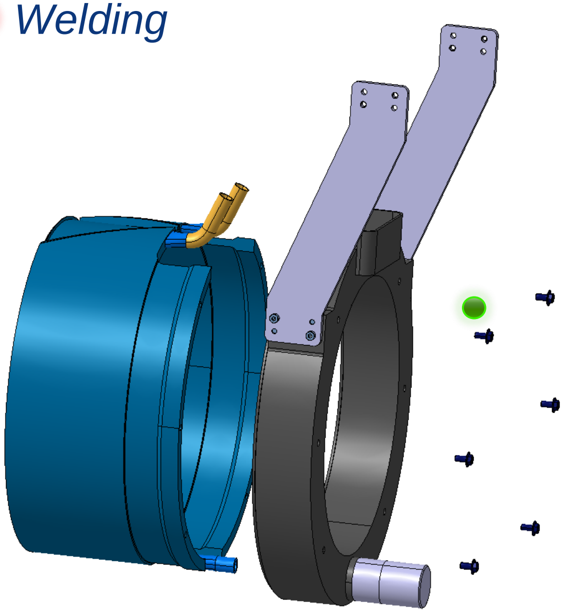
General view of sub-assembly 3



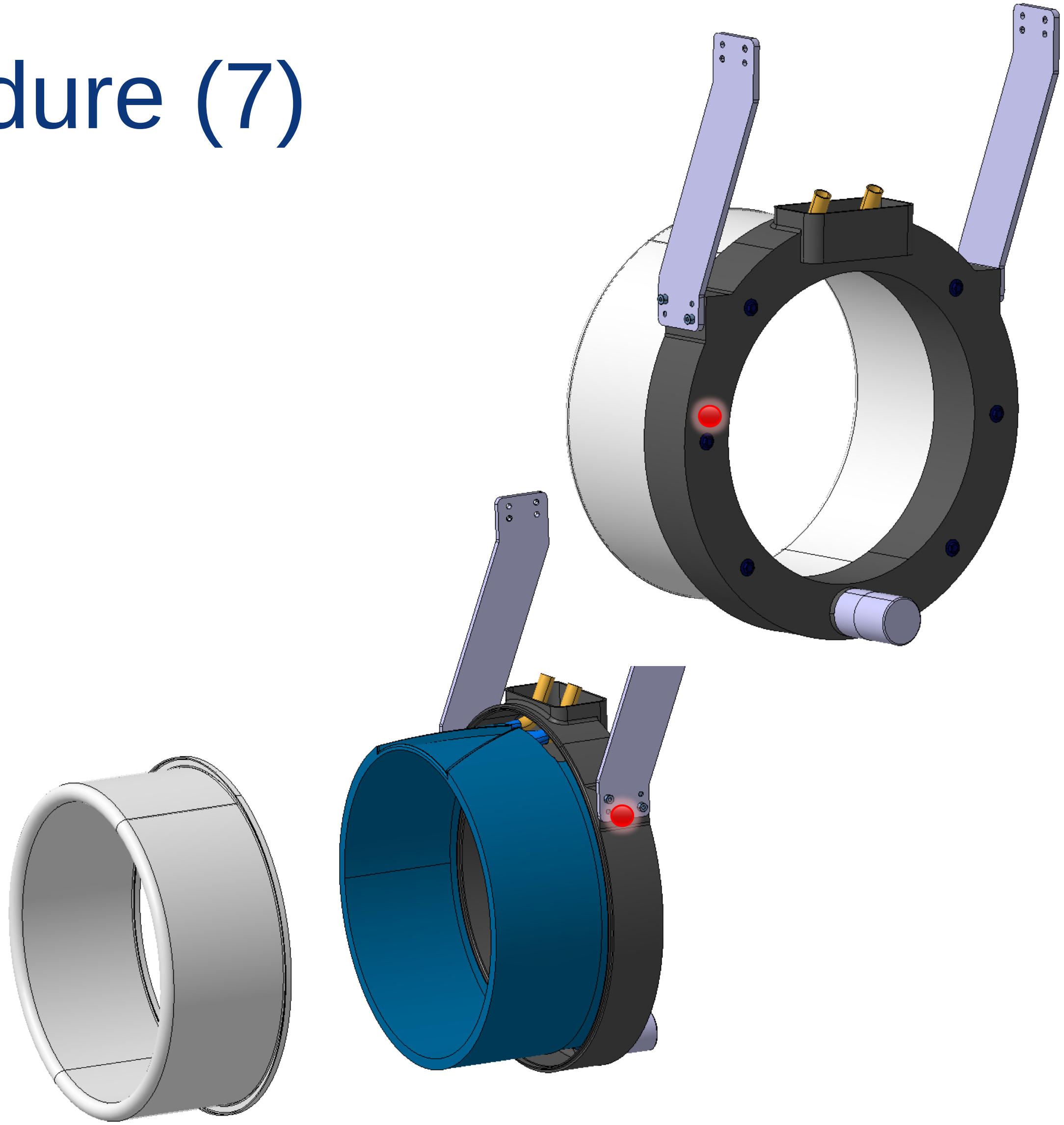
Sub-assembly 1 + 2 + 3, General overview

Assembly procedure (7)

- *Screws* (green dot)
- *Welding* (red dot)



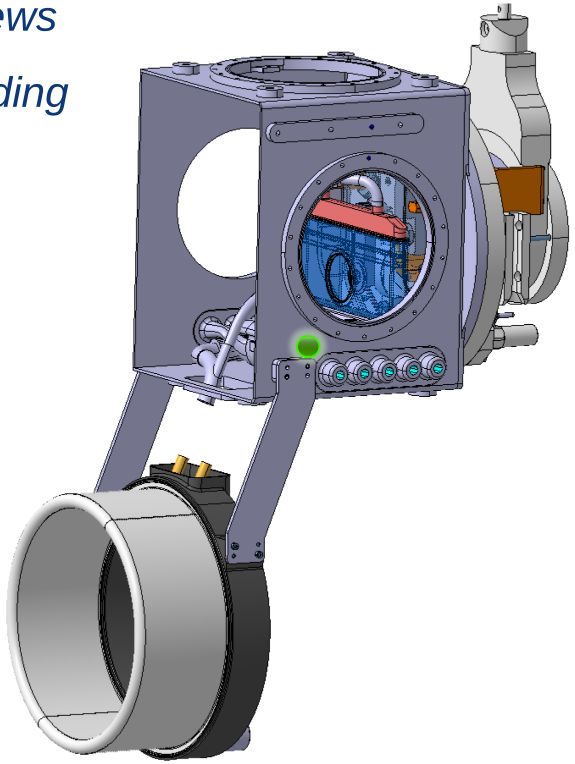
10. Positioning the pipe of the pump and screwing them to the frame
+ heating elements installation



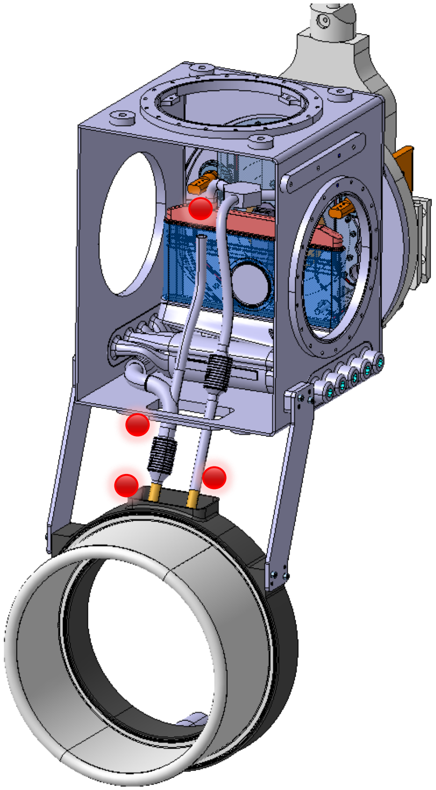
11. Welding the double enclosure around the pump pipes and the screws that maintain it

Assembly procedure (8)

- *Screws*
- *Welding*



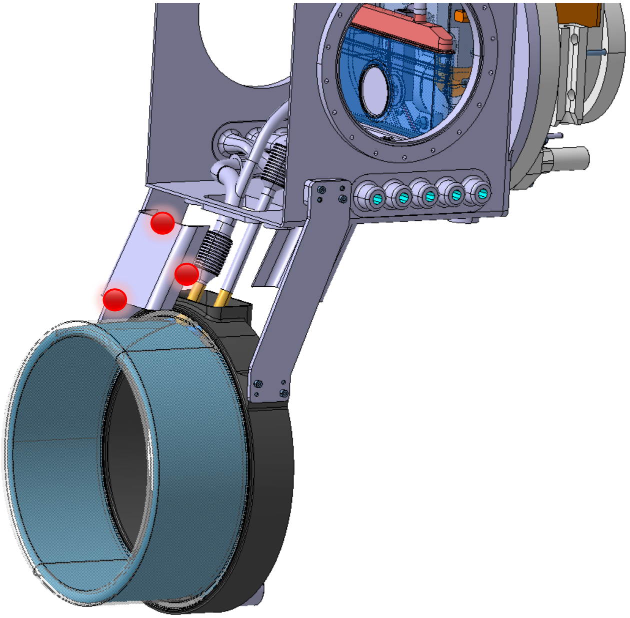
12. Screwing the bottom part to the upper one

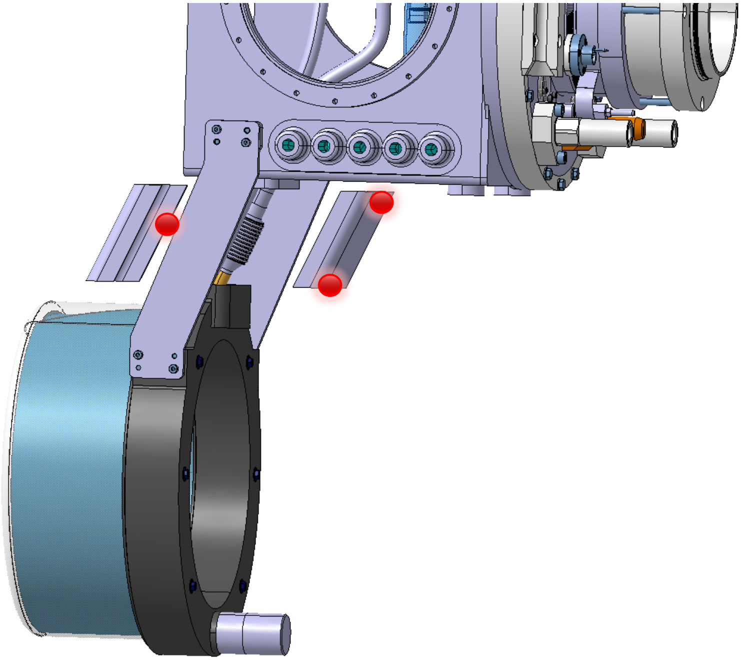


13. Welding the loop pipe
+ heating elements installation

Assembly procedure (9)

- *Welding*



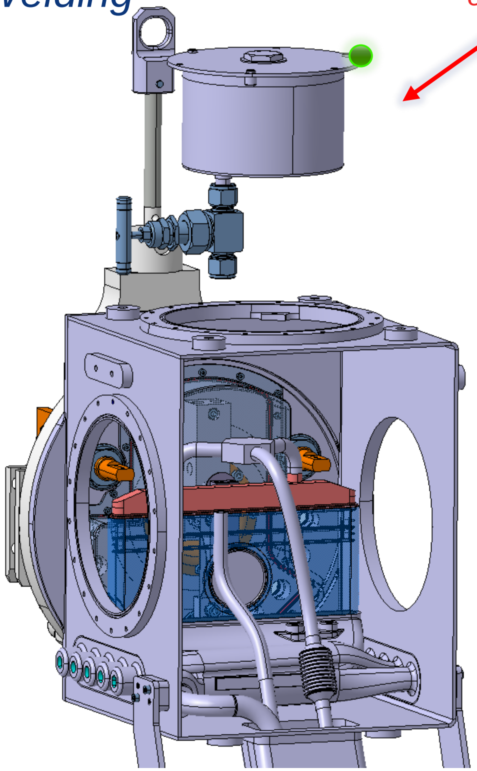


14. Positioning and welding of the middle part

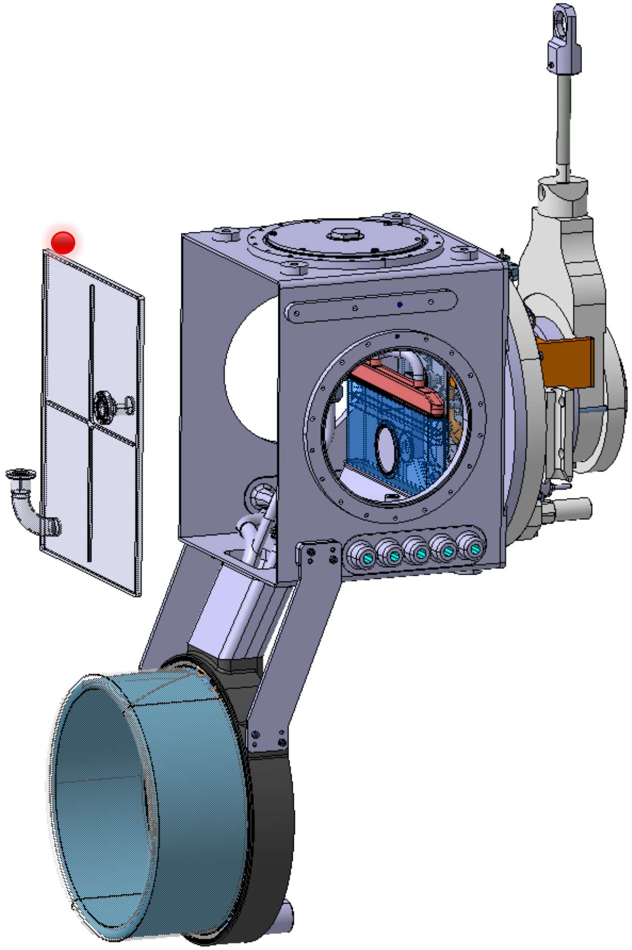
Assembly procedure (10)

- *Screws*
- *Welding*

Filling tank full of solid LBE – filling under glove box with controlled atmosphere – transported with additional tool screwed on the thread available



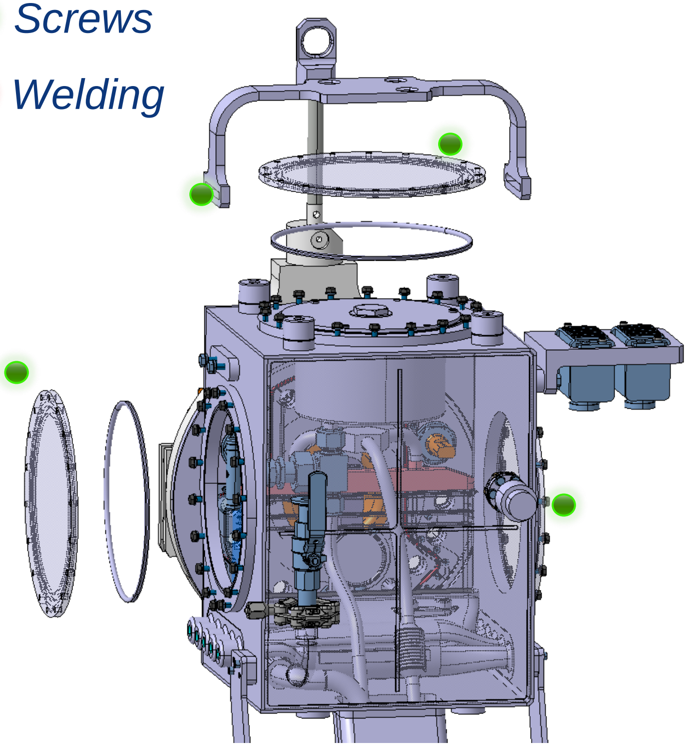
15. Positioning and screwing of the filling tank Swagelok connection for valve



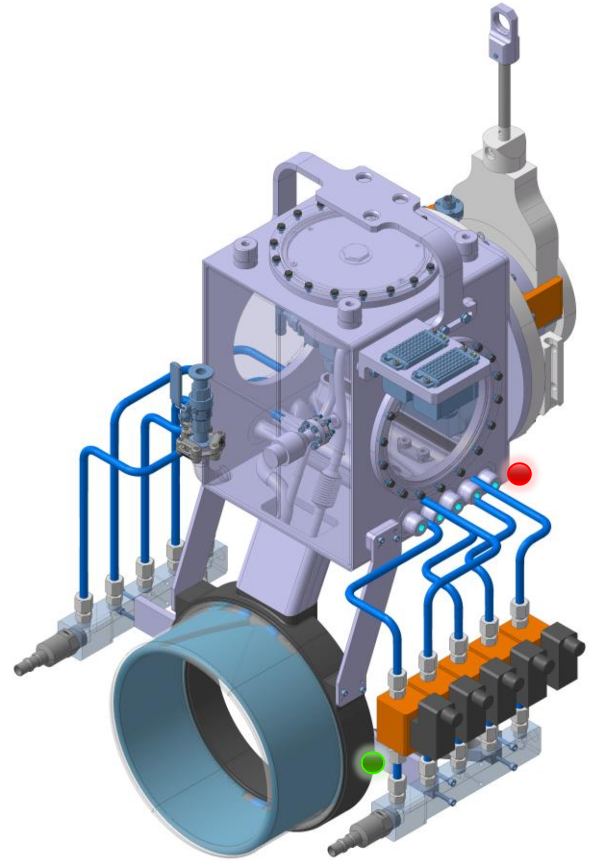
16. Welding of the front wall prepared with "piquage" for valve and pressure sensor

Assembly procedure (11)

- *Screws*
- *Welding*



17. Screwing of flanges for the three windows (with joints – see special later) and of lifting part
+ cabling of heating elements and instrumentation



18. Welding of the water pipes and screwing of the support for valves

Assembly procedure – general info

- Vacuum test done at each stop of the assembly process

- Welding solution chosen in order to minimize the deformations

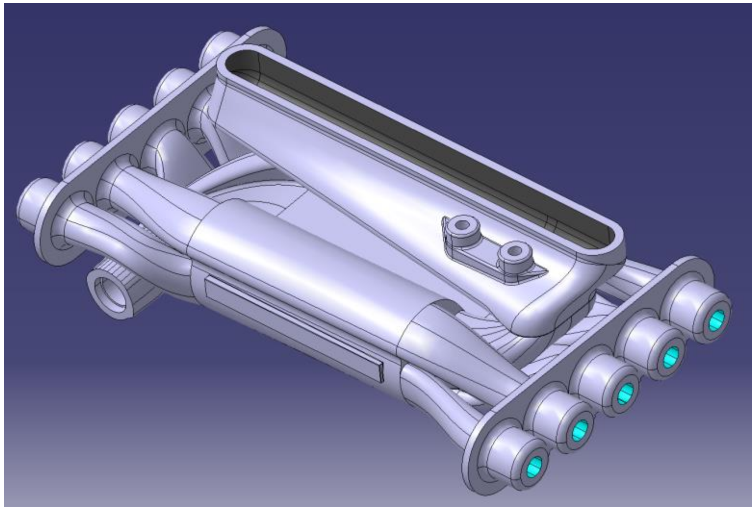
- Assembly process does not present the mounting of the heating elements that will be installed all along the fabrication

Design specificities

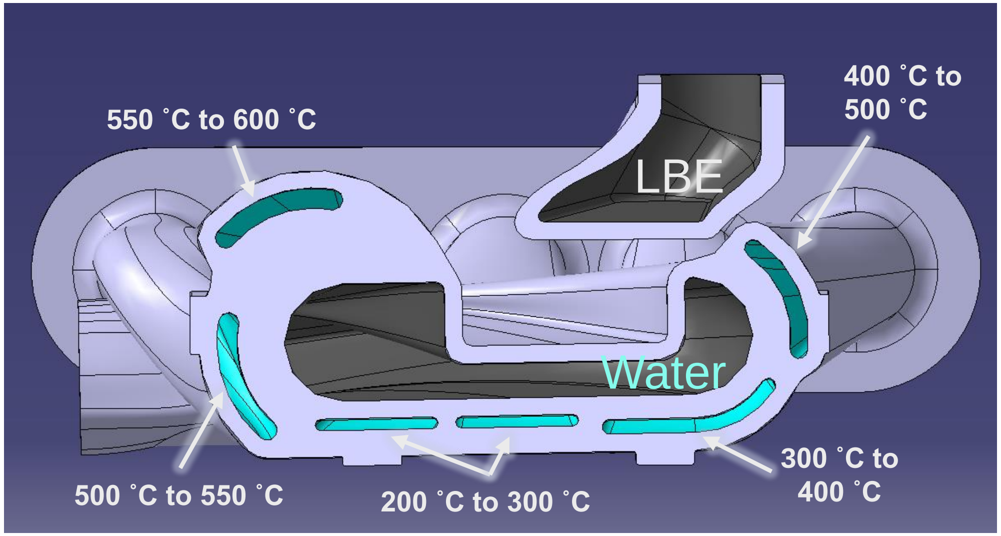
Design specificities (1)

Part in 316L produced with additive manufacturing

Previous design – produced for tests



- 6 water channels,
- 5 channels alimented separately and independently (one per 50˚C or 100 ˚C)
- 2 channels together (from 200 ˚C to 300 ˚C)



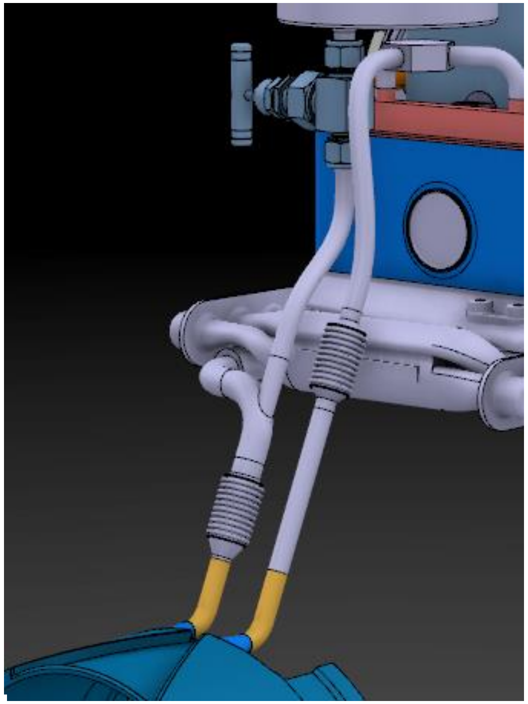
Isolde parameters	Water	LBE
Flow rate (l/s)	0.22	0.23
T_{inlet} (ºC)	27	Variable
T_{outlet} (ºC)	< 90	Variable

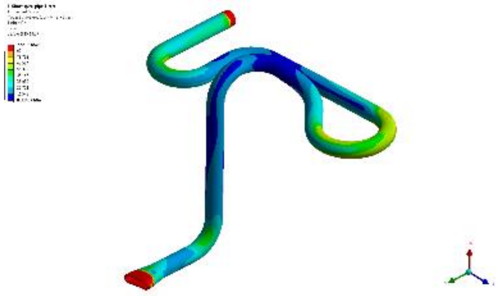
Design specificities (2)

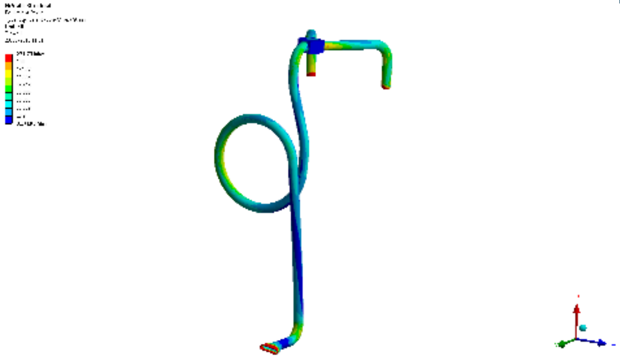
- Requirements:
  - Thermal expansion to compensate: **3 mm** max,
  - Pressures losses before pump inlet: **under 0,001 bars**,

- Retained solution:
  - 2 * 0,2 mm thick hydro formed **bellow**:
    - **-60 µm** corrosion into the SS pipes in 24 days

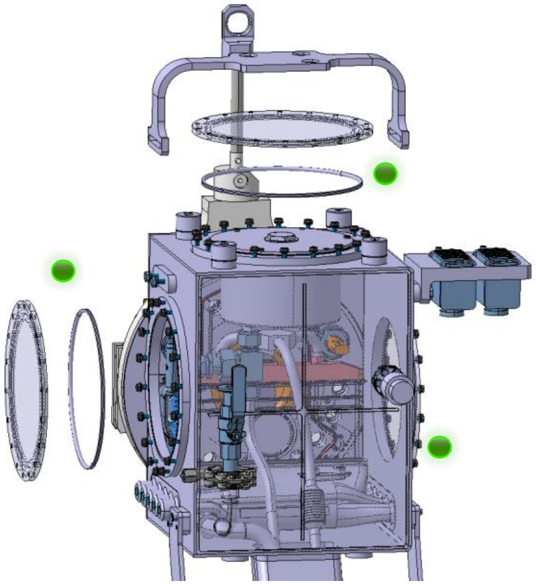
- Studied solutions:
  - 10 Different pipes shapes and diameter: pressure losses **too high**





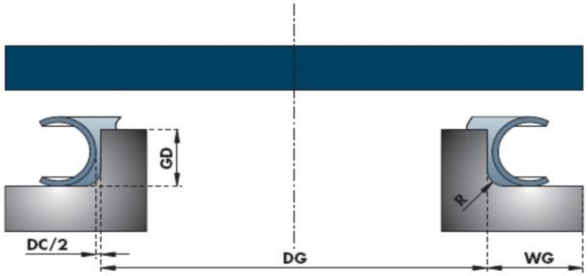


Design specificities (3)

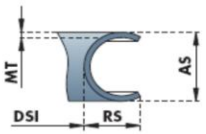


- Joints requirements (**170 mm Ø**):
  - Temperature of use: **300 ˚C**
  - Leak rate maxi: **1.10^{-5} mbar.l/s**
  - Force maxi on joint: **70 kN** (18 screws - 6 Nm/screws - M5 – Titanium)

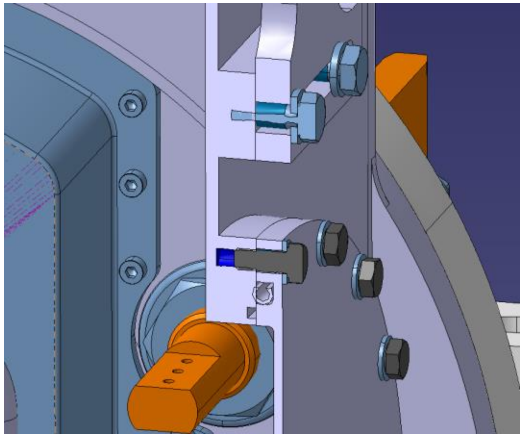
- Retained solution (to be tested!):
  - CE seal, Inconel with Silver coating, from HTMS



Inconel joints with copper coating

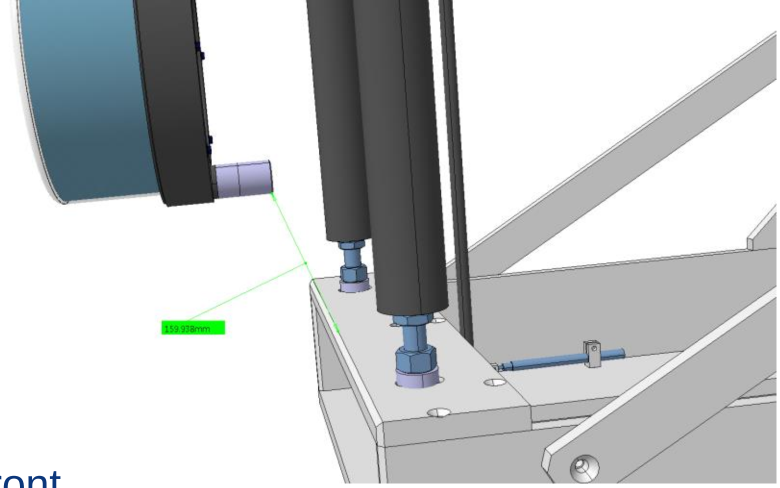


Joint from HTMS



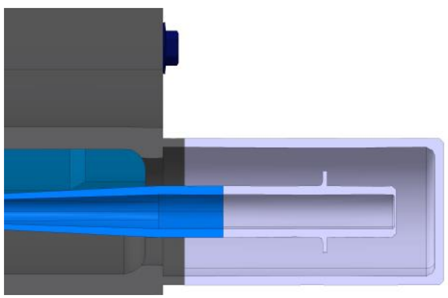
- Studied solutions:
  - Papyex joints: leak rate of 2.10^{-3} mbar.l/s
  - Annealed standard copper joint with knifes flange: 8.10^{-3} mbar.l/s

Design specificities (4)

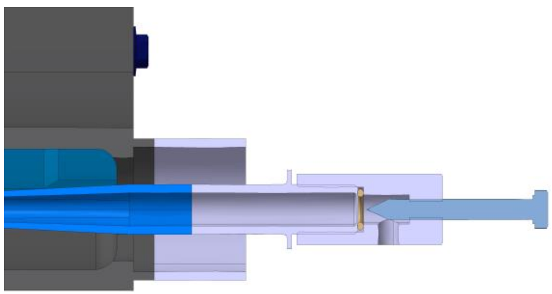


- Emptying system requirements:
  - To be used when LBE at 200 ˚C
  - Openable with target on front end
  - Inside double enclosure
  - Distance between double enclosure and front end minimum of 150 mm to avoid electrical arc

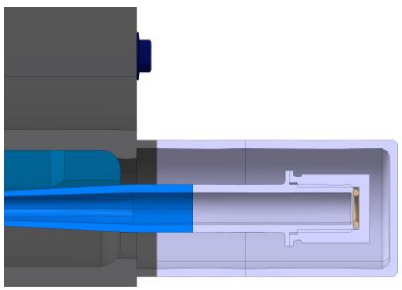
- Retained solution:



1. Welded cover – ended pipe with thin end

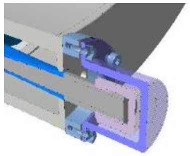


2. Cutting cover with "coupe tube"
3. Screwing special screw
4. Breaking thin end wall with needle
5. Removing needle -> flow



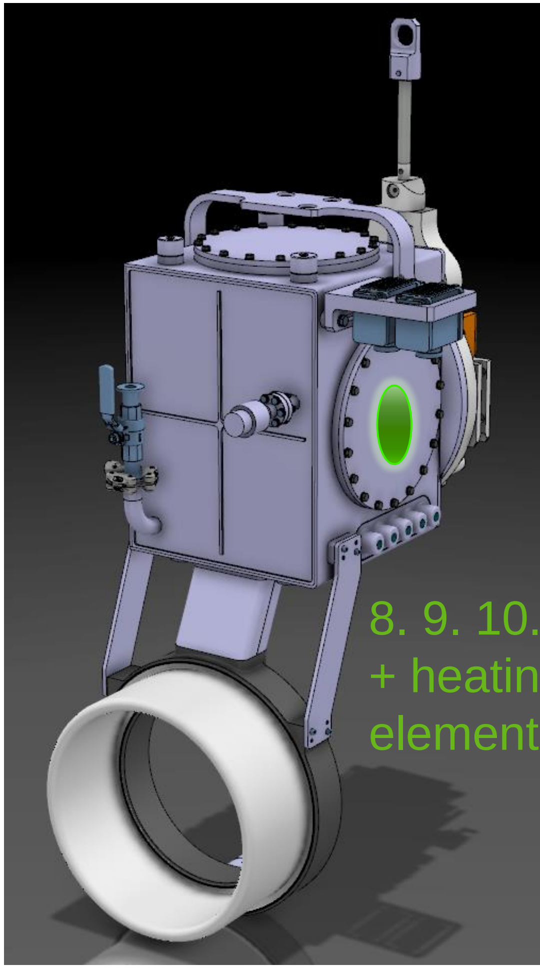
6. Removing special screw
7. Screwing new screw with cylinder head gasket
8. Placing new cover and welding

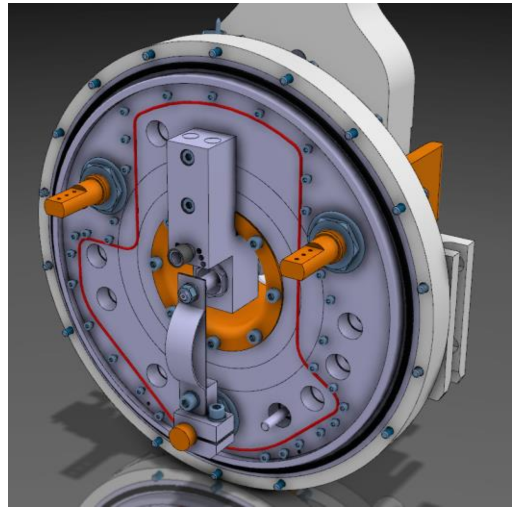
- Studied solutions:
  - Simple screw and joint: dangerous and difficult to find proper joint



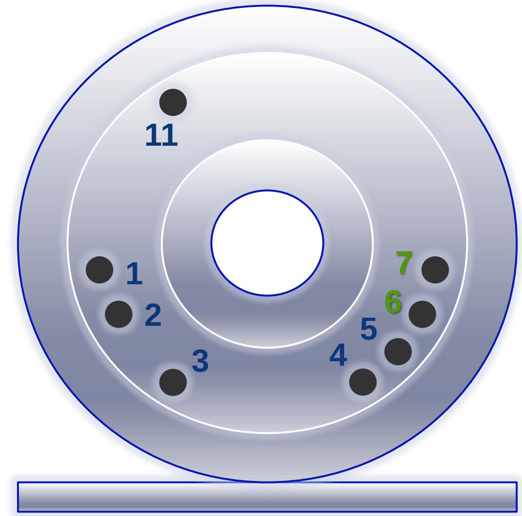
Heating & monitoring

Monitoring



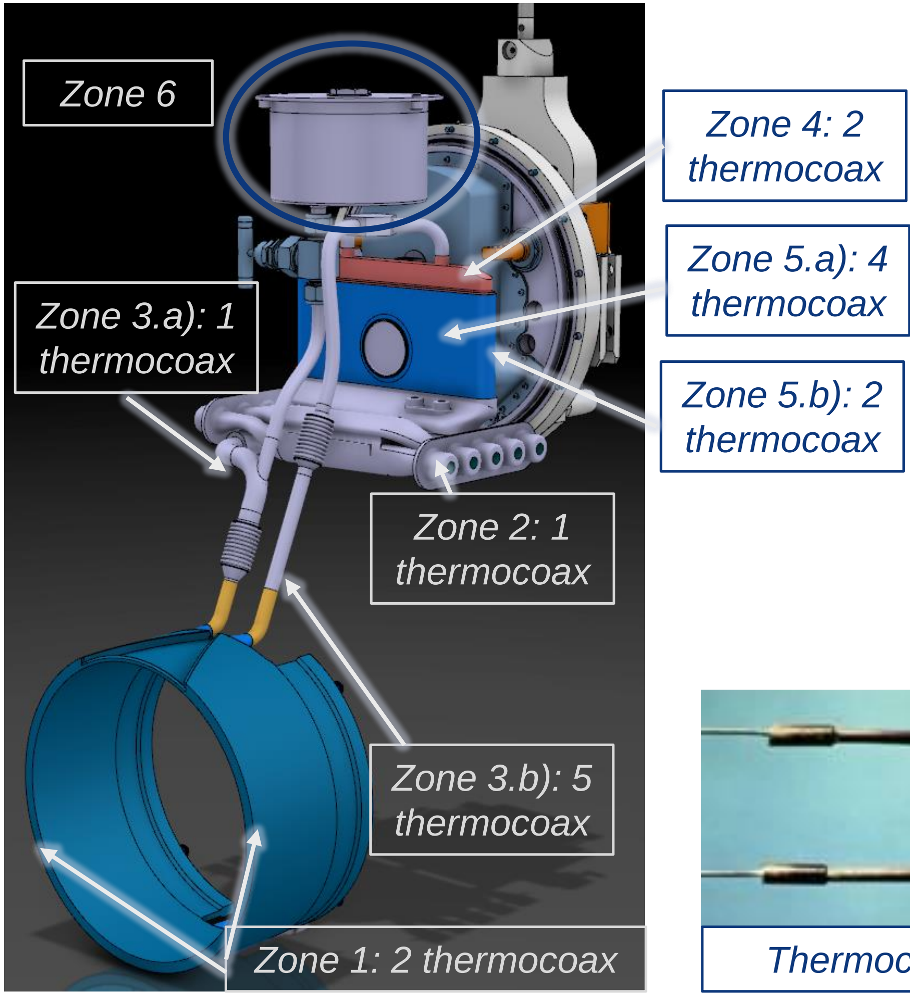


- All heating elements feedthrough on window + connected to the patch panel
- All thermocouples for heating elements go the same path
- **Accelerometer** possibly installed on target and pump

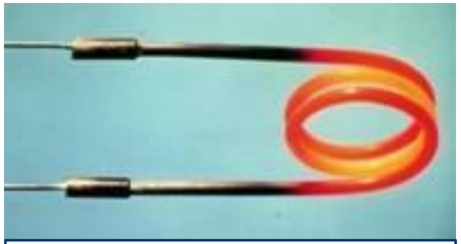


1. Ion source (Anode)
2. Transfer line heating
3. Backup connector
4. Ion source (Magnet)
5. Gas line
6. Multipin Thermocouples (9 cables)
7. Chimney heating
8. Thermocouples (Multipin 25 cables)
9. Pressure sensor
10. Level meters (Multipin)
11. Thermocouples transfer line(multipin 9 cables)

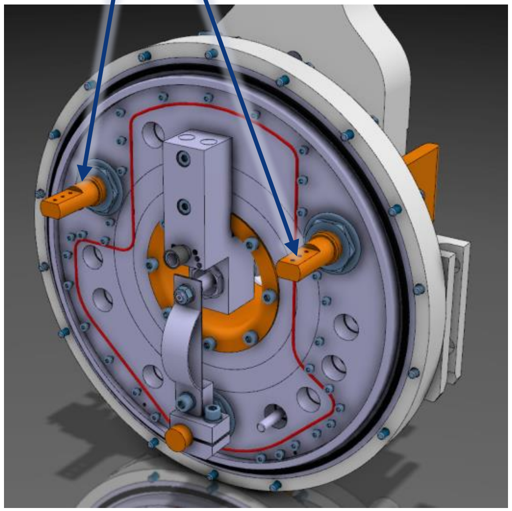
Heating



- 6 different zones heated and controlled separately,
- Zone 6 heated through actual current from ISOLDE



Thermocoax heater

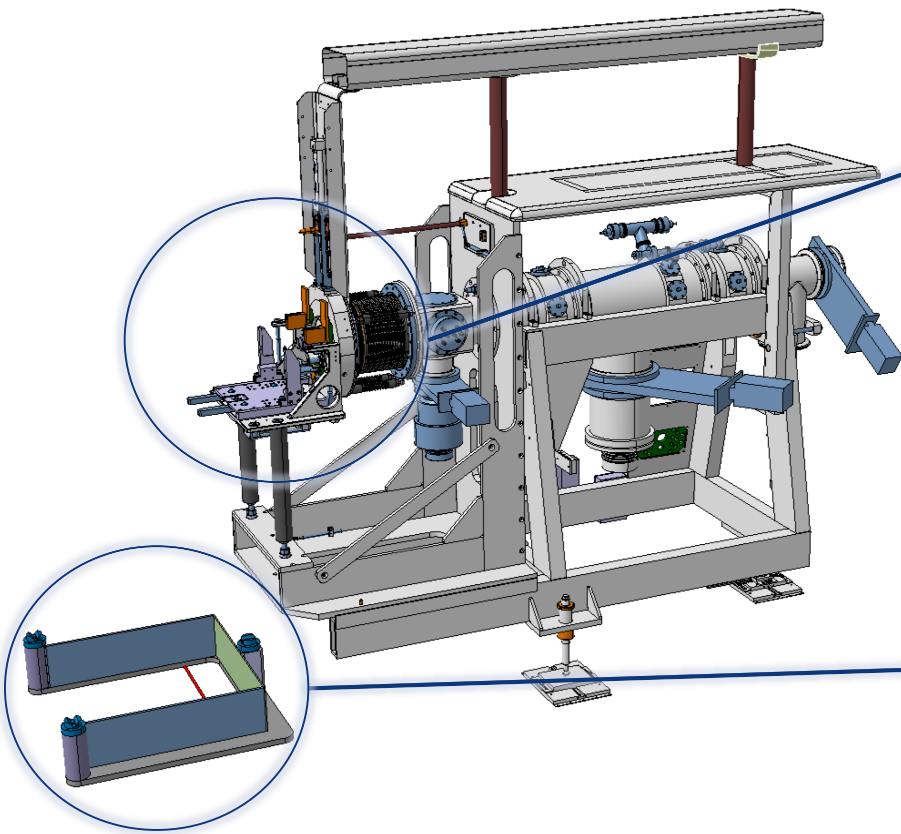


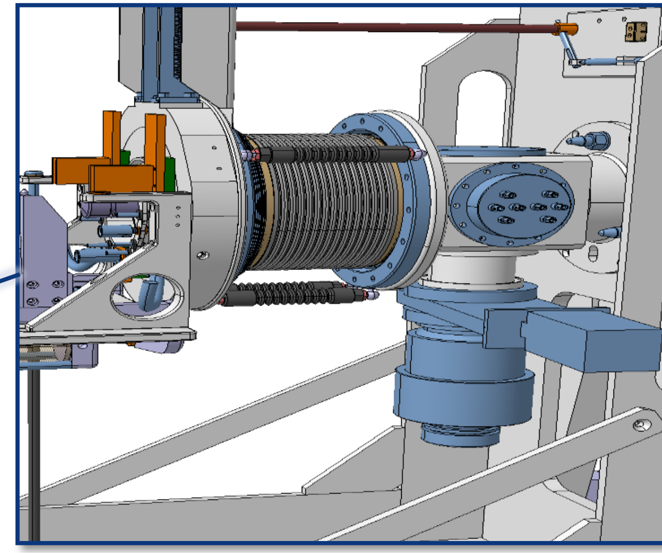
Open points for heating and monitoring

- Type of feedthrough to be used:
  - 17 heaters 8,5 A per heater,
  - 17 thermocouples,
  - Space?
- How to attach the heating elements:
  - Adding pins on system,
  - Using wires (0,1 mm Ø) for pipes,
  - Other ideas?
- Use of accelerometer? Which one? Where to positioned it?
- Interlock to be put? On what?

Installation

Installation (1)





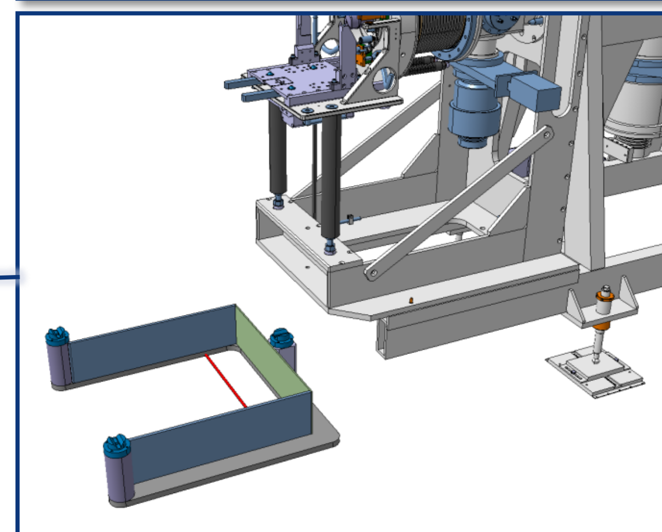
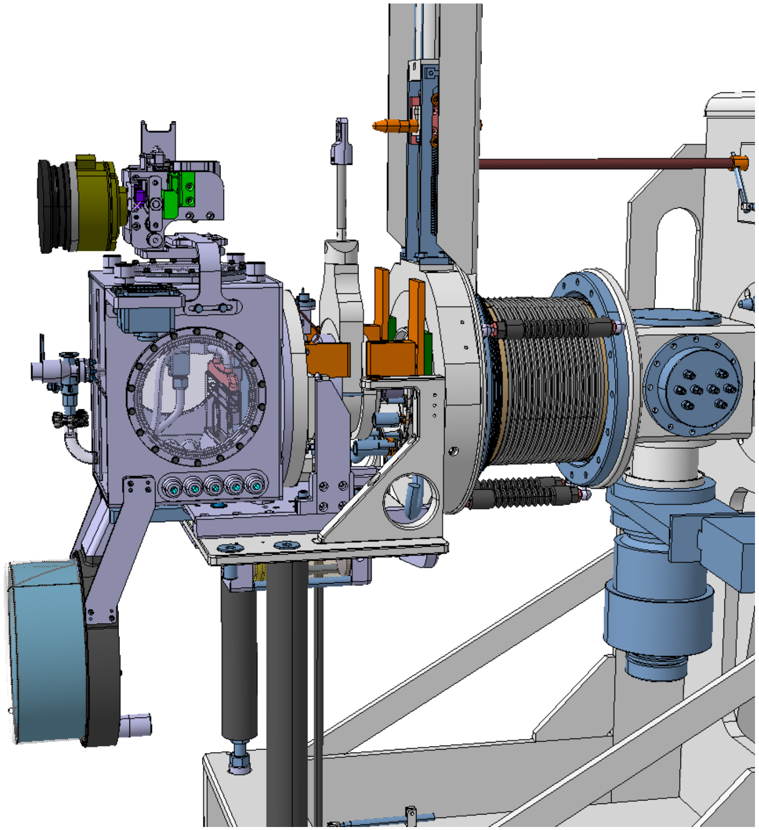
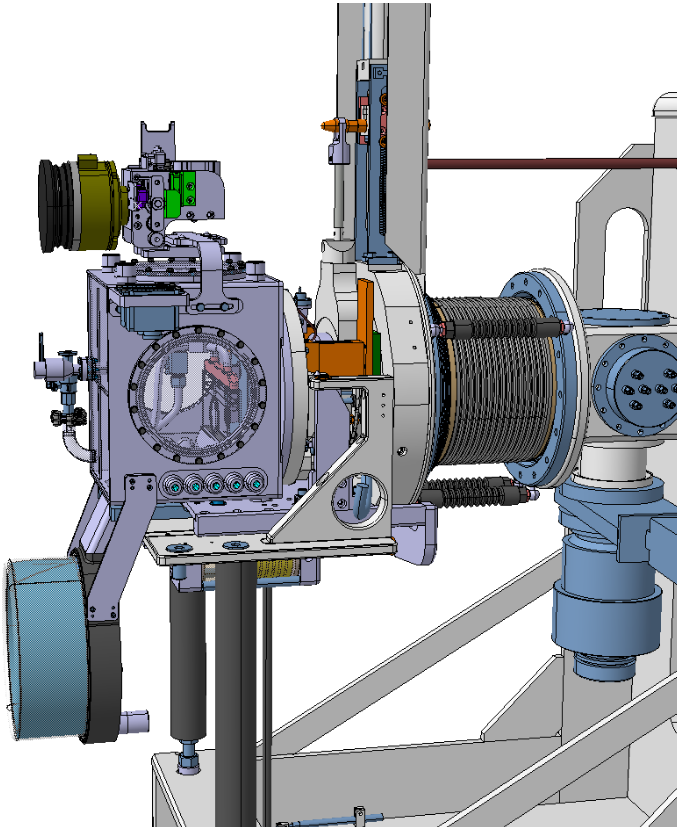


Plate can be used at 0 and 90 degrees to be compatible with the off-line and on-line front end!

Installation (2)

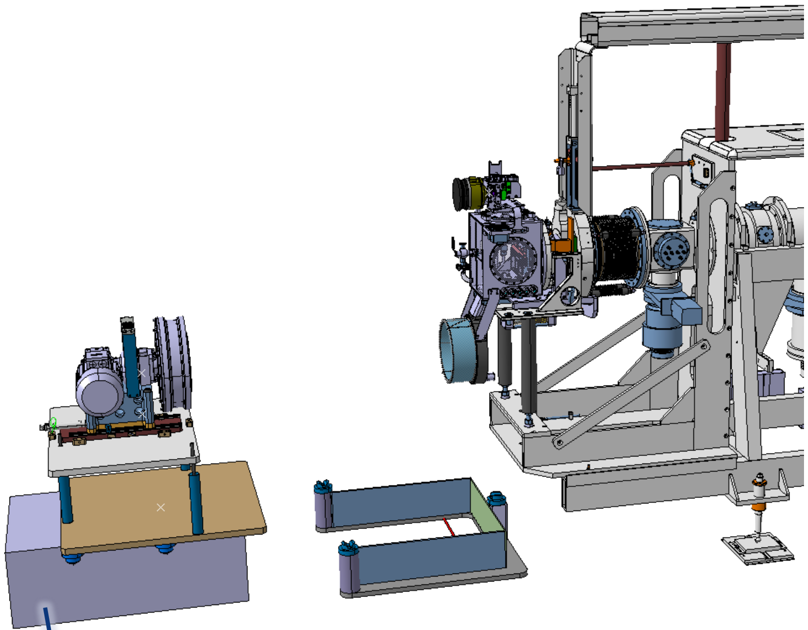


1. Main loop part of the target brought by robot

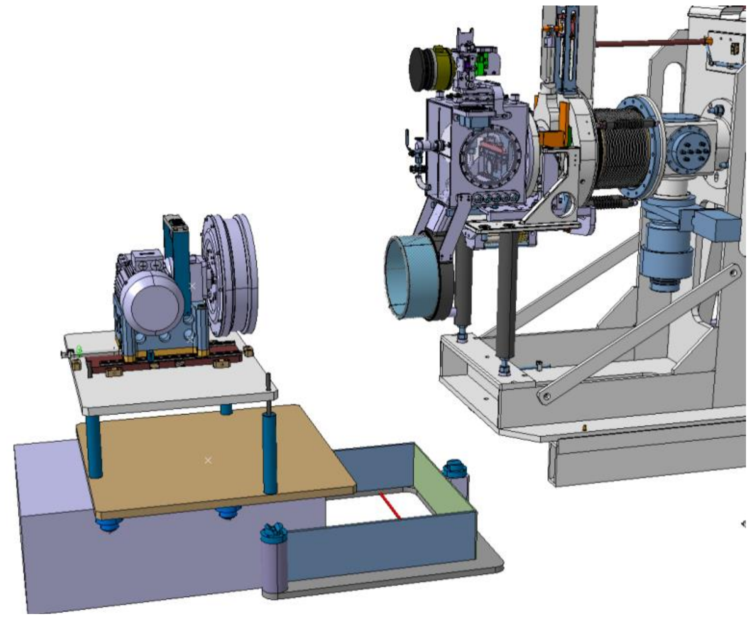


2. Coupling of the target to the front end

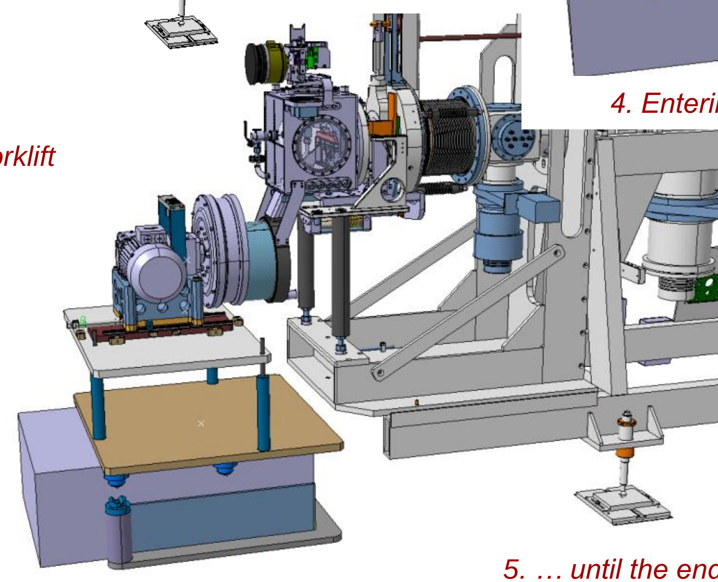
Installation (3)



3. *Arrival of the trolley part on the forklift*



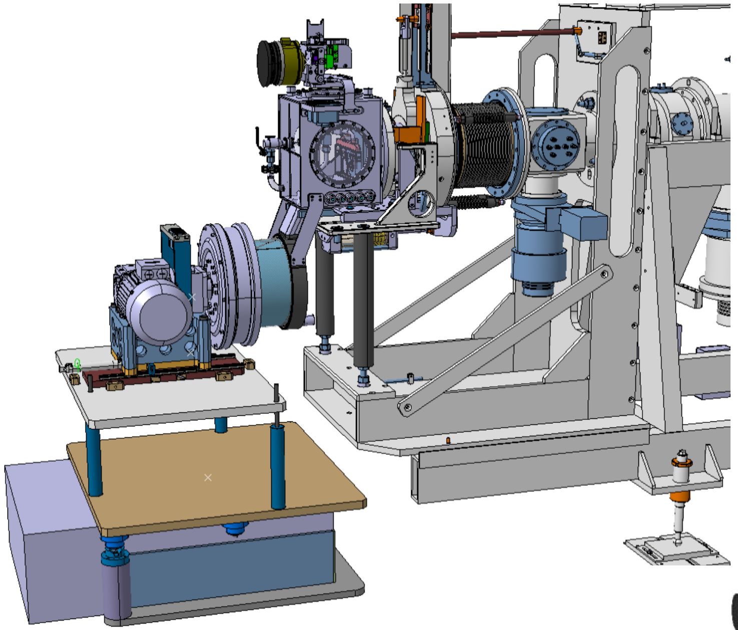
4. *Entering inside the positioning plate…*



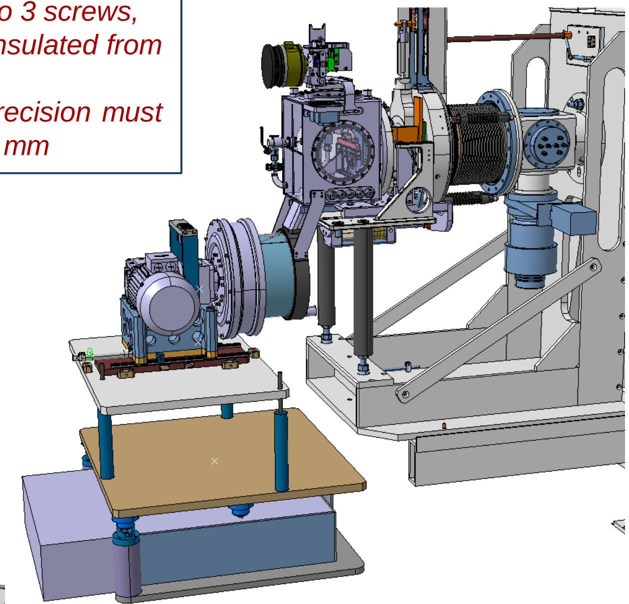
5. *… until the end of the plate*

Installation (4)

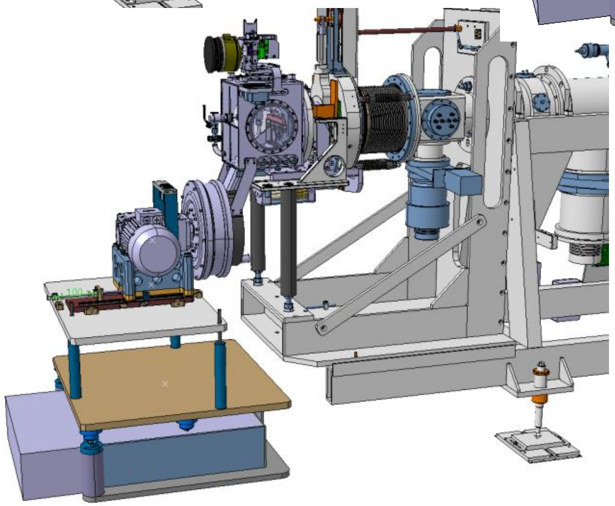
- *Regulation of trolley upper plate thanks to 3 screws,*
- *Upper plate insulated from lower part,*
- *Positioning precision must be bellow 0,5 mm*



6. Lifting down the trolley part…



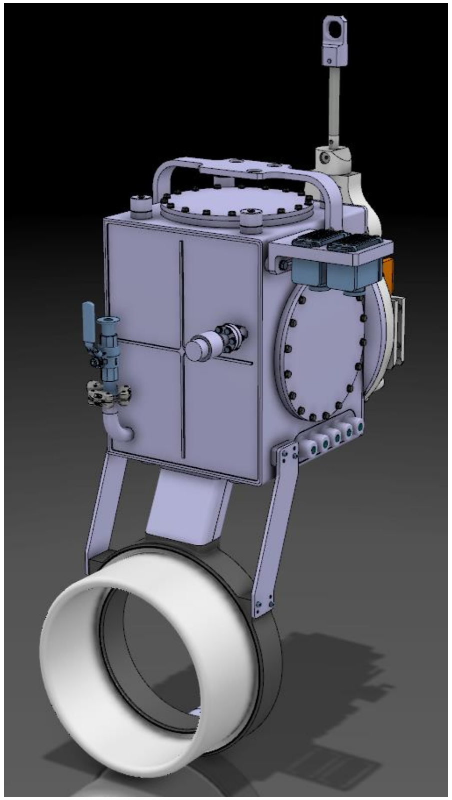
7. … and lifting down the forklift



8. Finally translating the magnets around the main loop part

Trolley part under study!!

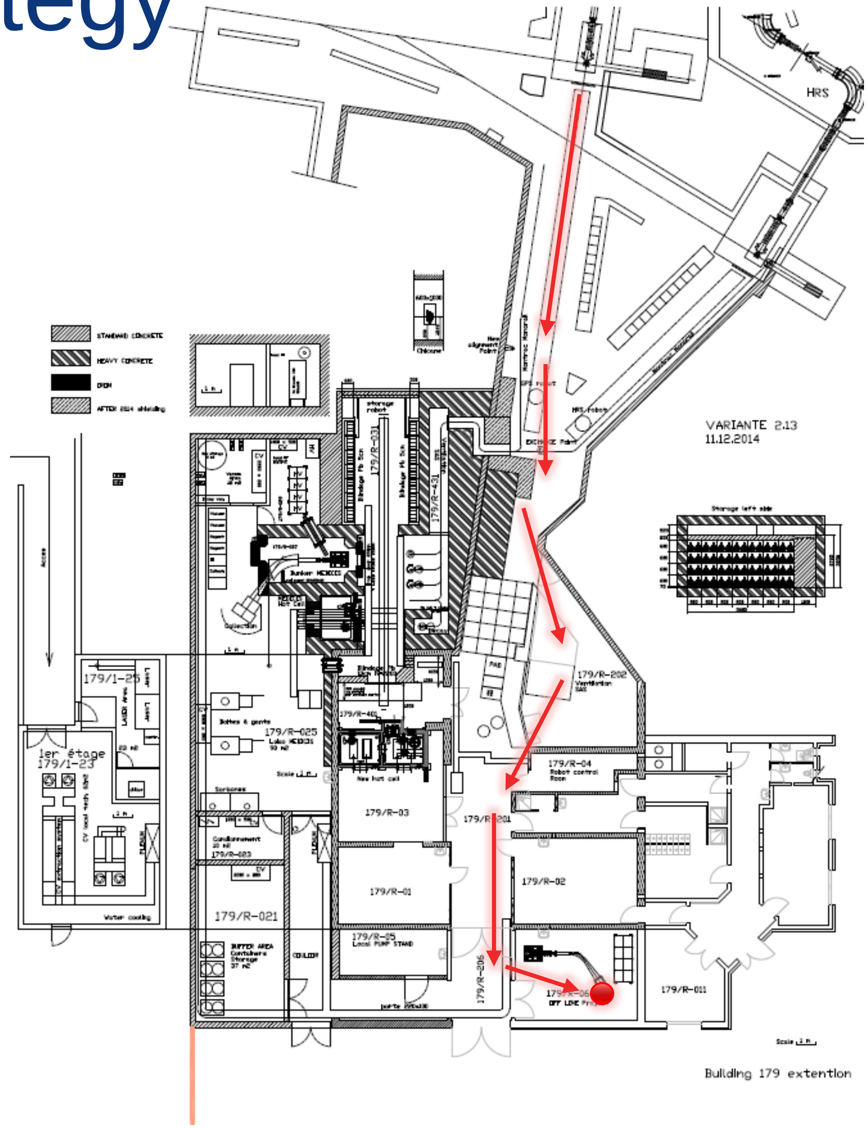
Installation (5)



- Then:
  - Coupling of the water pipe (manual operation),
  - Coupling of the pump and target patch panels (manual operation),
  - Coupling of the pressurized gas for actuator operation (magnet movement) (manual operation)
- Alignment strategy (to be better defined):
  - Pre-alignment thanks to the offline test,
  - Installation of the target, information on target positioning by measures,
  - Re-alignment of the trolley accordingly,
  - Possible re-alignent inside Faraday Cage when trolley is brought

After irradiation - strategy

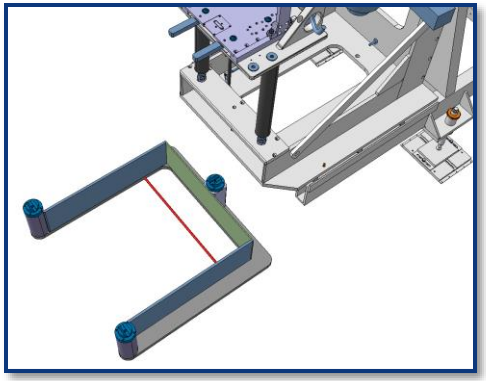
- Unplugging of all connections to be done remotely (Kuka robot or Telemax)
- Trolley to be removed remotely
- Target removed with the K7uka robot and put in a storage box, on wheels, shielded for storage

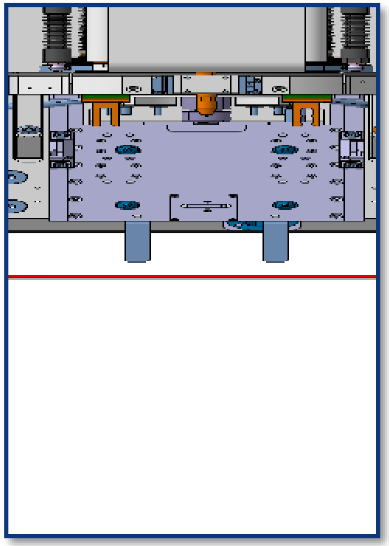


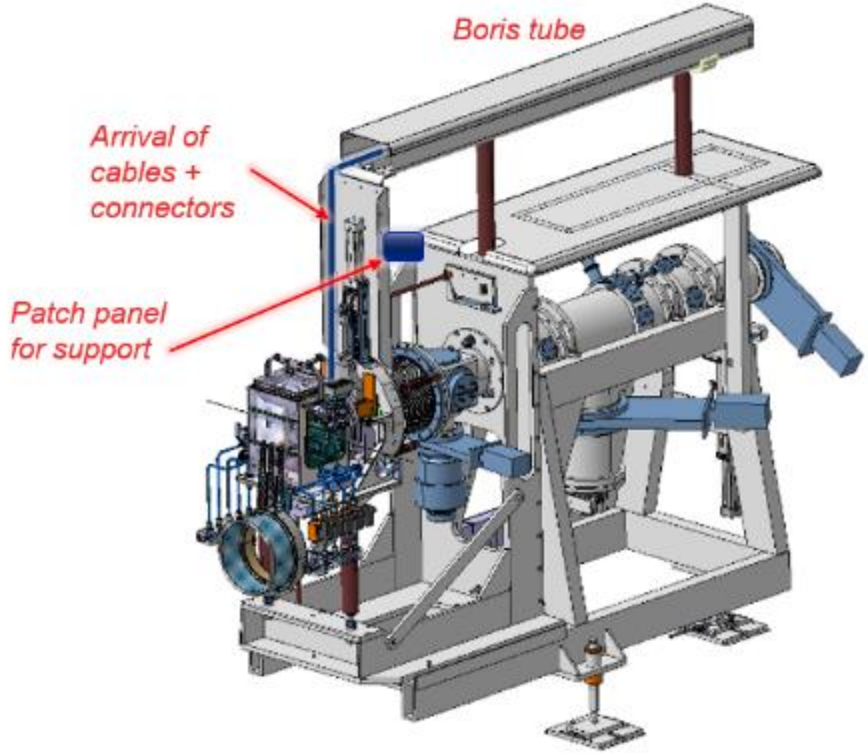
Front end modifications

Front end modifications (1)

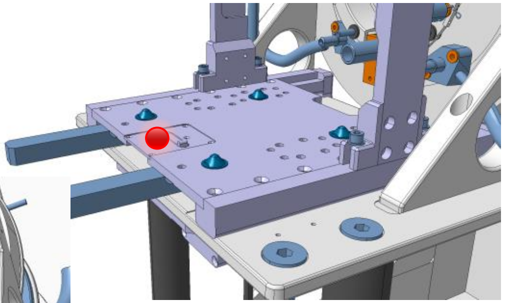
- Modifications:
  - Pulling cables for heating and thermocouples Inside the Boris tube (52 cables for a total surface area of 190 mm² – fit inside a 16 mm Ø tube)
  - Installing a patch panel on front end for support (on existing holes)
  - Fixing the trolley positioning plate
    - Taking reference,
    - Drilling holes,
    - Installing plate

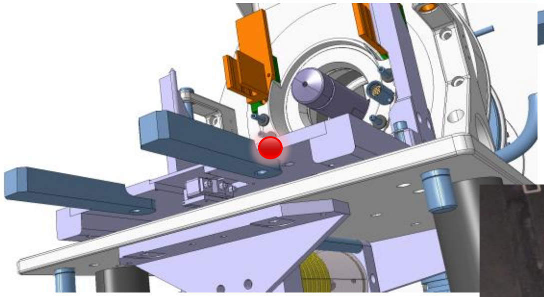




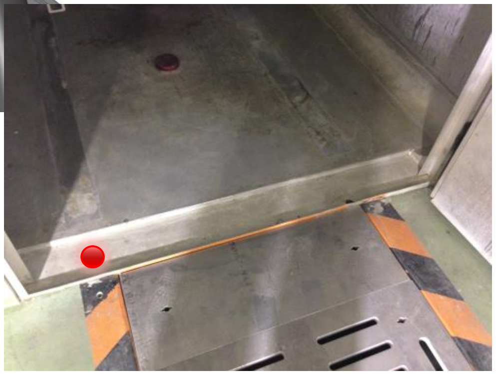


Front end modifications (2)

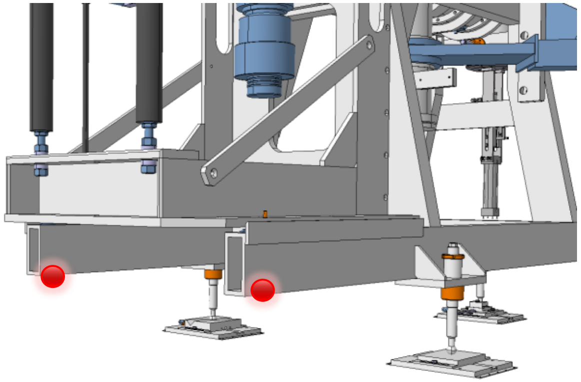




- Modifications:
  - Installation of target plate support
    - *Need to screw from under (2 screws)*



  - Installation of plate on the floor (existing plate)
  - Removing of electrical cables and plugging elsewhere (to be defined!)
  - Front legs to be added on front end



Timeline

Timeline (according to planning EDMS 1531196_v0,7)

Manufacturing

Action	Start date	End date	Progression	Responsible
3D & 2D drawings	-	27/10/2015	90%	EN/MME
Trolley design	-	23/10/2015	60%	EN/STI
Trolley 2D drawings	26/10/2015	13/11/2015	0%	EN/STI or MME?
Trolley manufacturing	04/01/2016	29/01/2016	0%	EN/STI?
Front end 3D and 2D modifications	16/11/2015	08/01/2016	10%	EN/STI
Target procurement	-	05/11/2015	60%	EN/MME
Pipe Pump reception	30/09/2015	09/12/2015	0%	
Target parts production	20/10/2015	08/01/2016	0%	EN/MME
Target Assembly	27/11/2015	15/03/2016	0%	EN/MME
Control system development	-	13/11/2015	90%	EN/STI
Control system test	16/11/2015	18/12/2016	0%	EN/STI
Trolley test	01/02/2016	26/02/2015	0%	EN/STI
Target Offline test	16/03/2016	25/03/2016	0%	EN/STI
Front end modifications	01/02/2016	29/02/2016	0%	EN/STI
Target Online test	28/03/2016	08/04/2016	0%	EN/STI
Targeted installation date	*01/04/2015*			

Tests & modif.

Next steps & conclusion

- Remaining 3D modifications (water pipes integration) but design principle known
- Joints, bellow, HEX and emptying system are critical points: tests are required
- Remaining 2D drawings to be done
- Front end modifications need to be anticipated
- Many tests are planed
- Open points remaining:
  - Weight ok?
  - Installation of heating elements?
  - Feedthrough for heating elements & thermocouples?

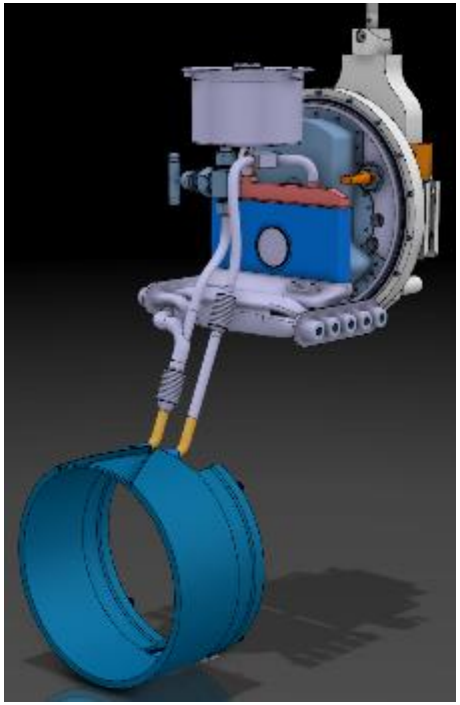
Feedback - comments

Thank you for your attention!

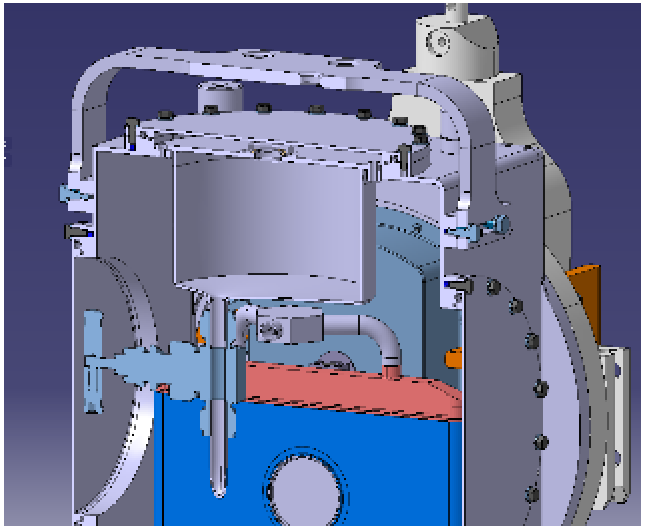
Thanks to all the contributors…

- V. Barozier
- R. Betemps
- T. Coiffet
- G. Favre
- R. Folch
- D. Patrzalek
- A. P. Perez
- L. Prever-Loiri
- A. Ravni
- … (and many others…)

Starting procedure (1)



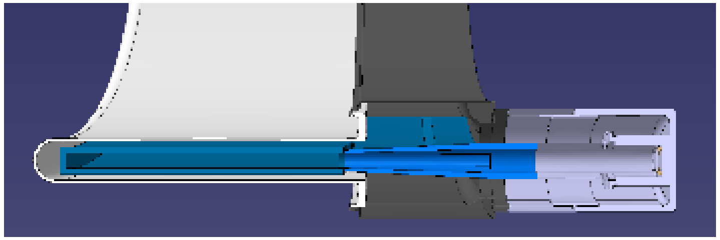
- Preparing 2 filling tank,
- Filling of the filling tank: in a glove box, under controlled atmosphere, the 2 Swagelok connection closed,
- Leaving LBE solidifying,
- Changing Swagelok connection with Swagelok valve
- Installing/screwing the filling tank on vessel,
- Locking the Swagelok connection,
- Putting main loop under vacuum,
- Opening the valve,
- Closing the side opening of vessel



Starting procedure (2)

- Putting the vessel at low pressurize atmosphere (first vacuum) -> vessel will keep the pressure?
- Coupling of pump part/ water/ control panels
- Heating the full loop, when T ok, heating the filling tank,
  - 5 heating areas for loop + 1 heating filling tank
  - Ion source/transfer line/chimney heating (numbers 1/2/4/7)
- Level validated with level meters,
- Magnets in position, pump on, operation of the loop

Stopping procedure



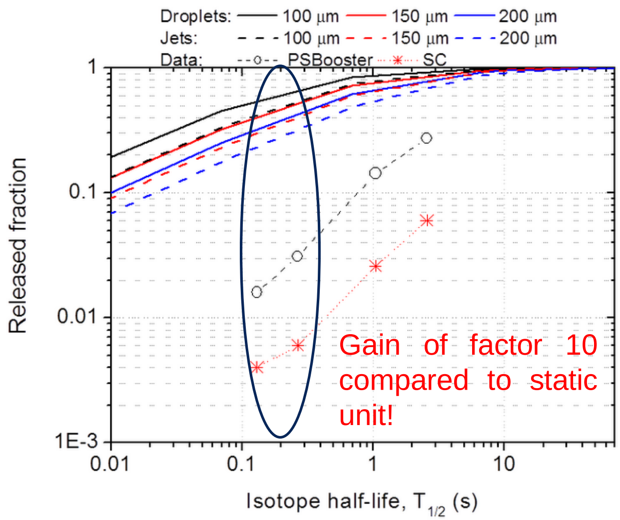
- Stopping pump, magnets off, uncoupling of pump part,
- Loop kept at 200 deg C, opening the vacuum valve of vessel,
- Opening the vessel,
- Pressurizing the loop with >1bar P noble gas,
- Cutting the double enclosure (coupe tube),
- Screwing part with needle, advancing needle to break the thin wall, emptying,

IMAGES

- Venting the loop and cutting heating,
- When loop at T amb, closing the screw
- Welding the new double enclosure cap,
- Placing a new filling tank.

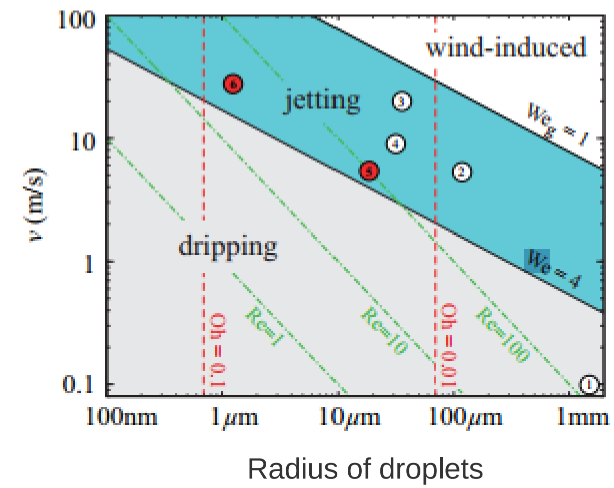
Context (2)

- Short-lived species release improvement



Diffusion: model from Fujioka et al. (NIM 186 (1981) 409)
Data: Lettry et al. (NIM B 126 (1997) 170)

Droplets shape inside diffusion chamber
-> As small as possible



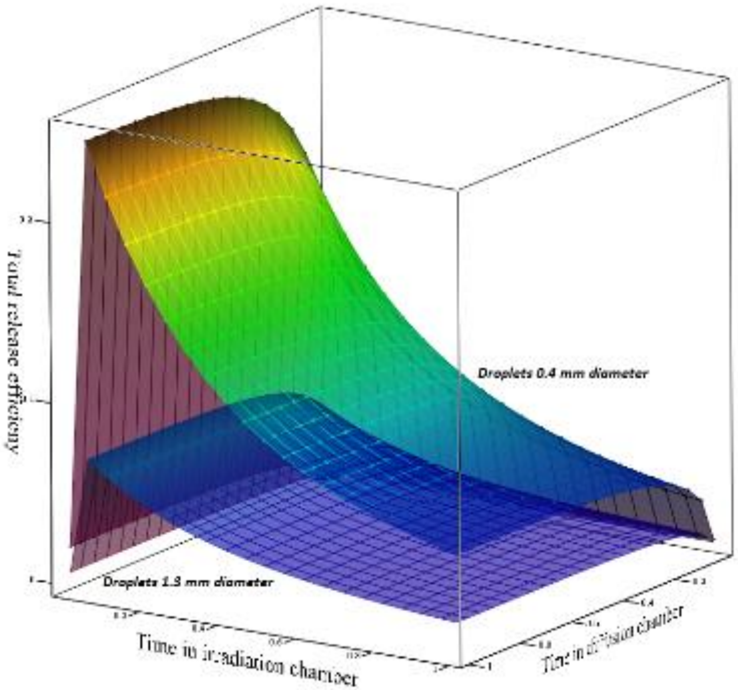
Droplets: *regimes formations*

Smallest holes diameter achievable on a 1 mm-thickness SS plate: 0,1 mm

	Dripping	Jetting
Ø $_{droplets}$ (mm)	1,3	0,4

- **Jetting** regime preferred!
- Minimum velocity: **1,8 m/s**

Context (3)



Diffusion release efficiency in function of time in diffusion chamber & irradiation chamber

Higher release efficiency for:

- Smaller droplets
- Smaller time in diffusion chamber $\mathbf{t_{irra}}$
- Higher time in diffusion chamber $\mathbf{t_{diff}}$

$$v_{out} = \frac{V_{irra}}{S_{holes} * t_{irra}} \quad and \quad h_{diff.cham} = \frac{1}{2} * g * {t_{diff}}^2 + v_{out} * t_{diff}$$

		Design parameters	
		v_{out}	S_{holes}
t_{irra}	↘	↗	↗
t_{diff}	↗	↘	↗

With: $v_{out} > 1{,}8\ m/s$ and $v_{out} = \frac{Q_{loop}}{S_{tot\ holes}}$

- The surface of holes should be **maximized**
- The loop flow rate is a **key parameter**

Context (3)

- High Power target:
  - Beam impact bring extra power in the order of kW -> need to extract this additional power by using an **Heat Exchanger** (HEX)
  - Need of circulation of liquid by using an electromagnetic **pump**

Heat sources	Heat sinks
Beam: up to 1 220 W	-
-	Radiation: depend on LBE temperature
Pump: about 1 400 W	Pump: depend on LBE temperature
-	Heat Exchanger: depend on LBE temperature

HEX dimensioning – power equilibrium

Power (W)		200		300		400		500		600	
		min	max	min	max	min	max	min	max	min	max
+	beam	0	1 220	0	1 220	0	1 220	0	1 220	0	1 220
+	pump	900	1 400	900	1 400	900	1 400	900	1 400	900	1 400
-	radiation	13		17		20		22		23	
-	pump	134	153	303	345	571	671	977	1 140	1 524	1 786
-	HEX	753	2 454	580	2 258	309	1 929	-	1 458	-	807

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