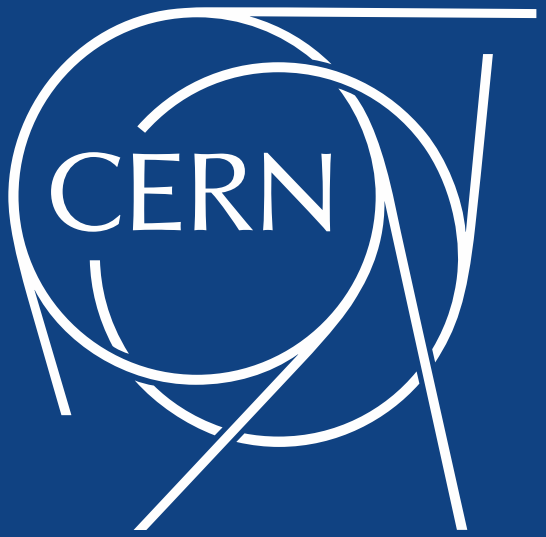
CERN

Evaluation of a potential explosive Front-End

AP.Bernardes[2], B.Crepieux[2], M.Czaspki[2], D.Gonnard[1], R.Guida[3], H.Encontre[2], LP.De Menezes[3], S.Marzari[2], N-T.Vuong[2]

Cern DGS[1], Cern EN-STI[2], Cern PH-DT[3]

Outline

- Target Failure Scenario
- Test Bench
- Results
- Summary

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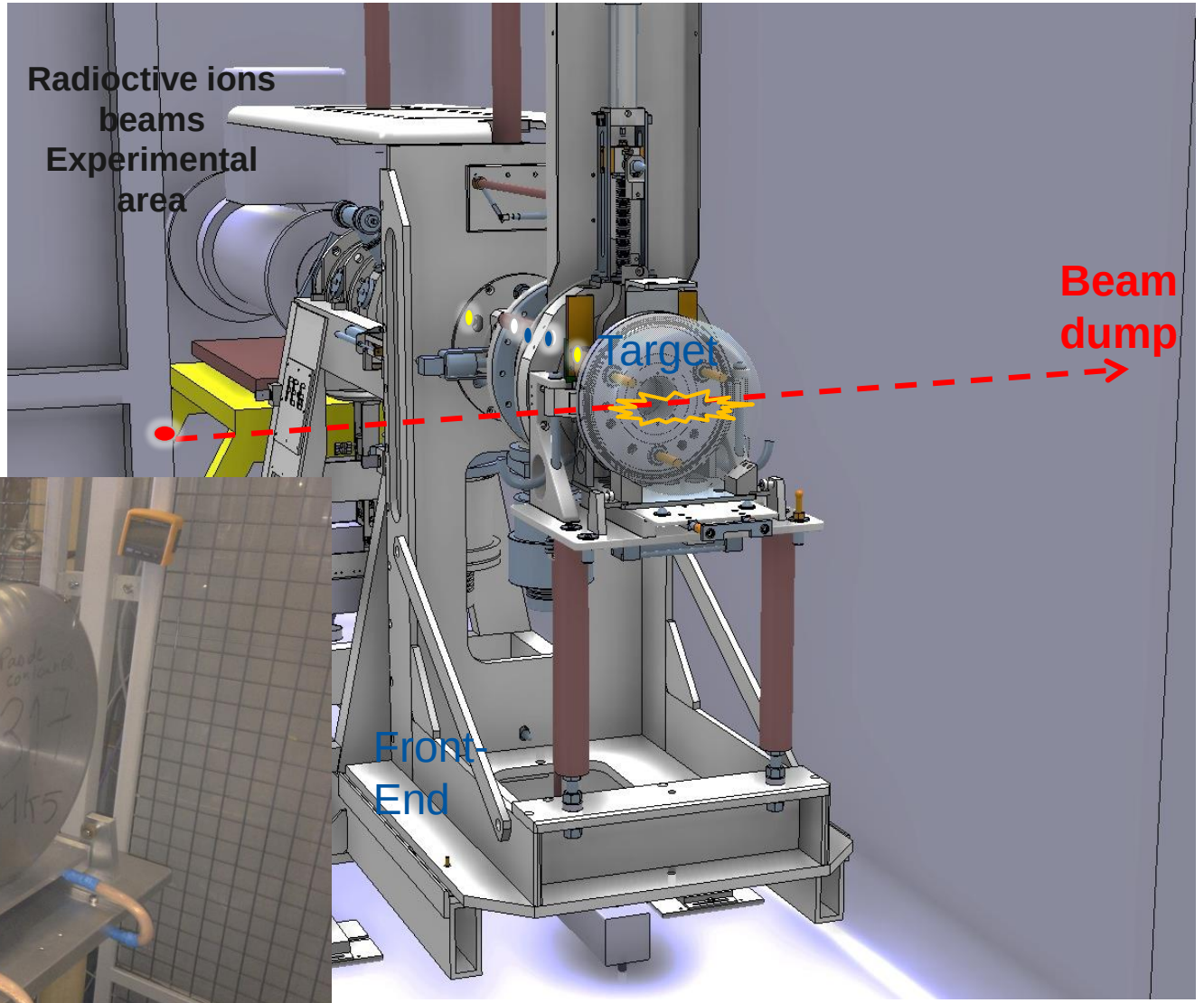
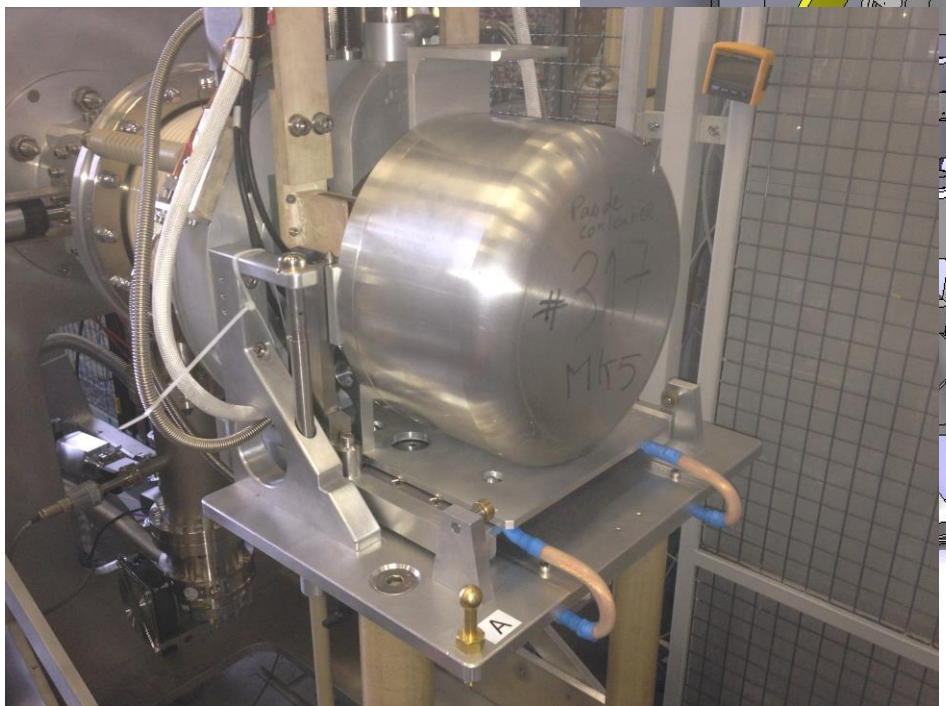
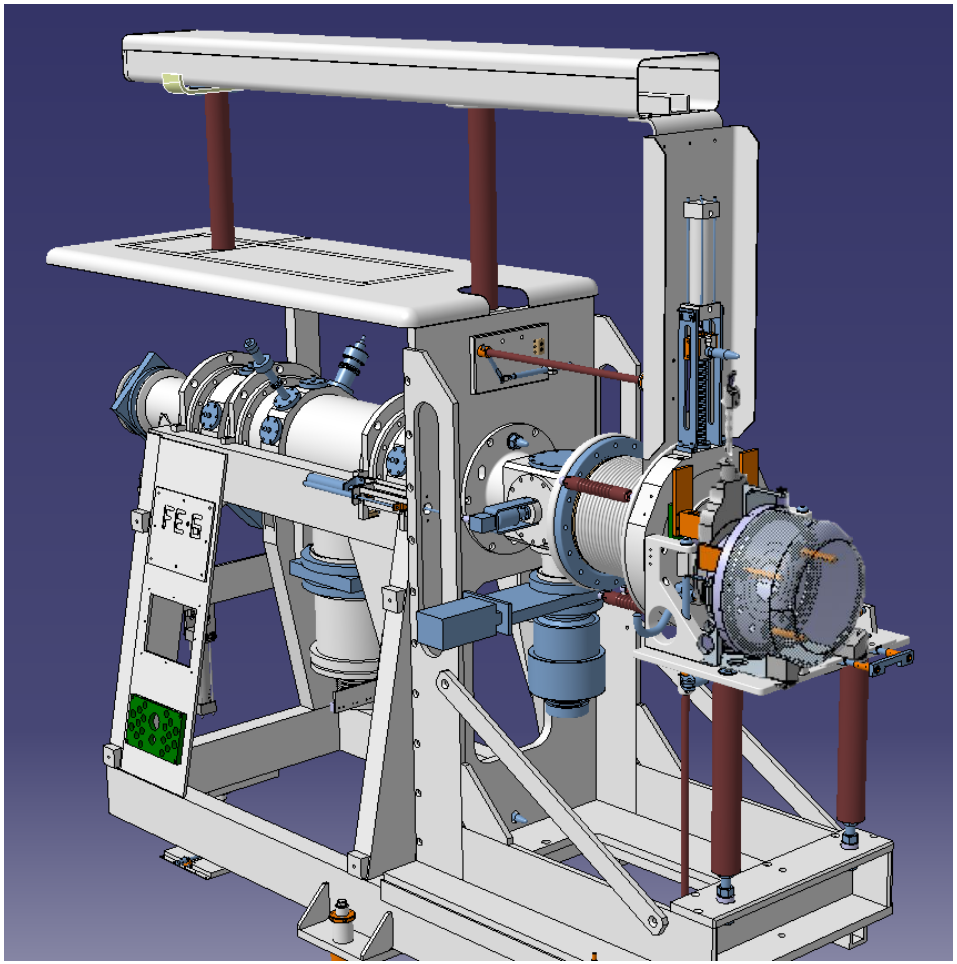
Target Failure Scenario

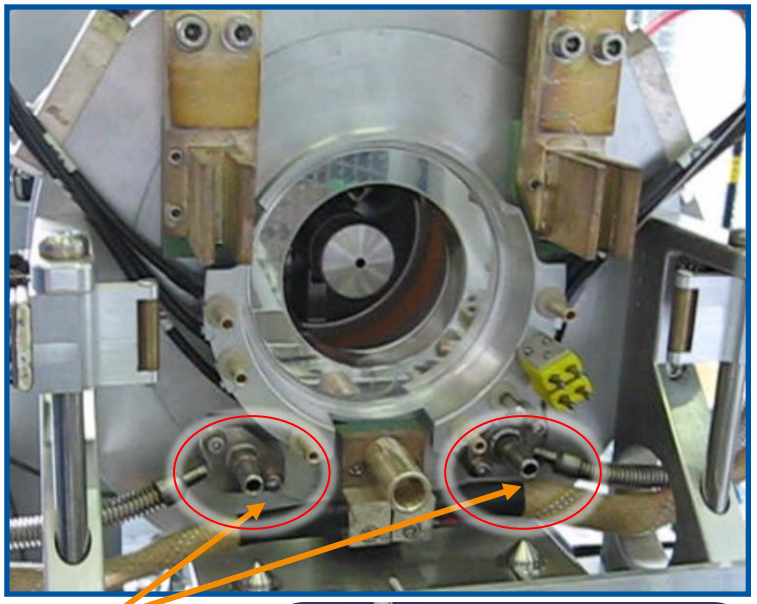
ISOLDE is an Isotope Separator On Line facility dedicated to the production of a large variety of radioactive ion beams



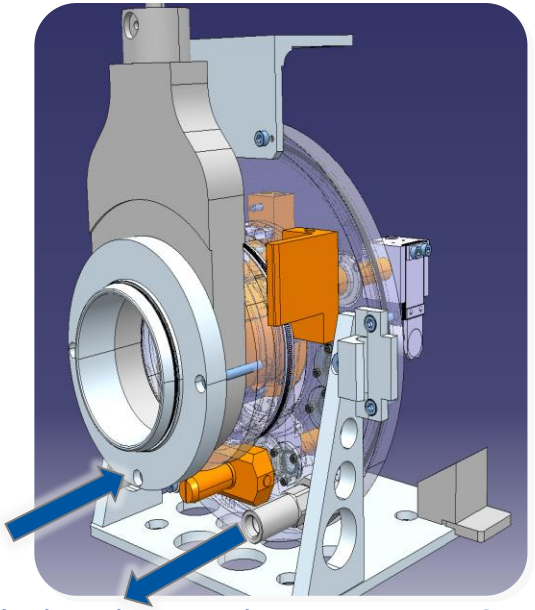


Target Failure Scenario





Cooling water



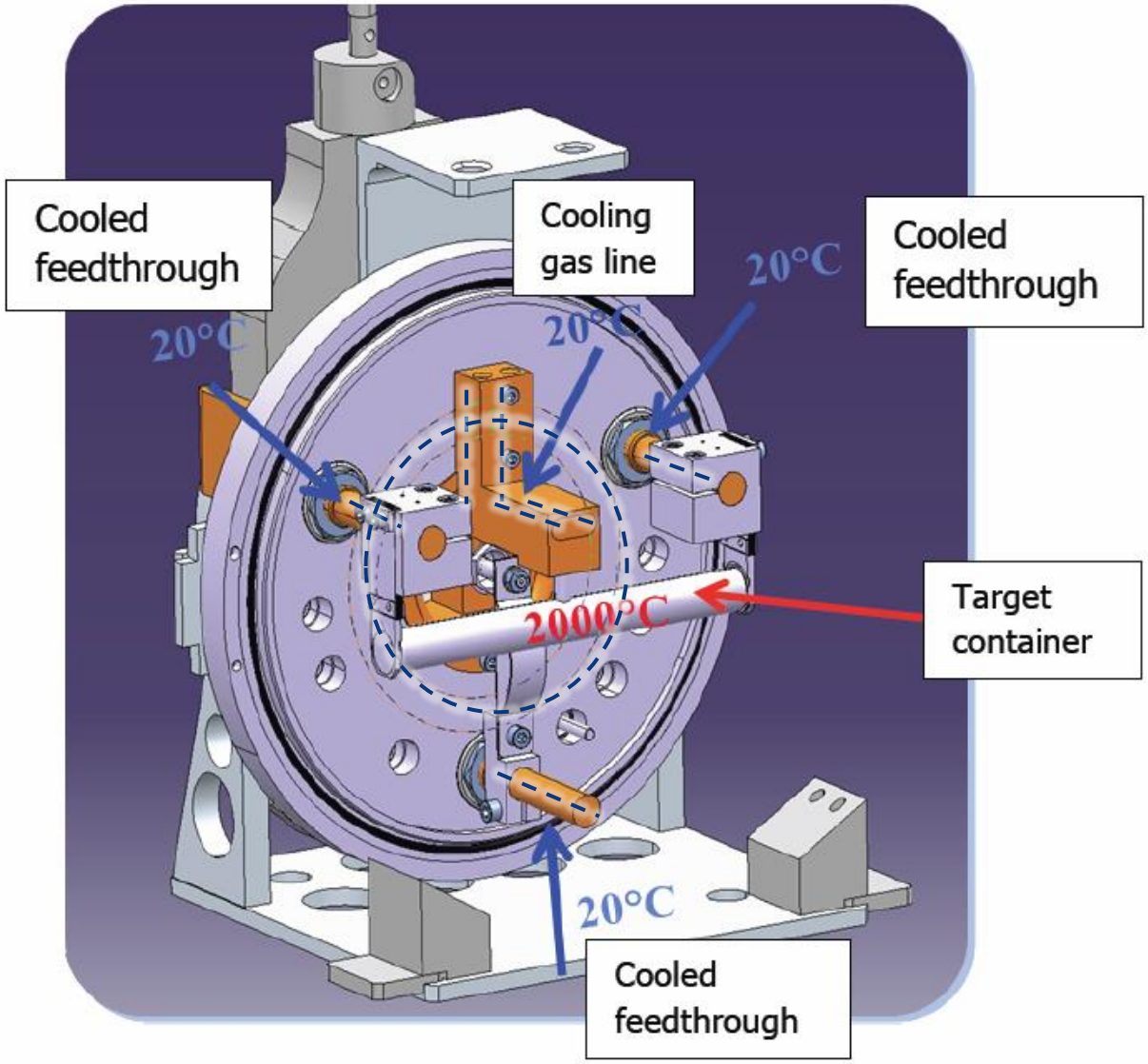
Target is pumped, heated and cooled via the FE connections

Target Failure Scenario

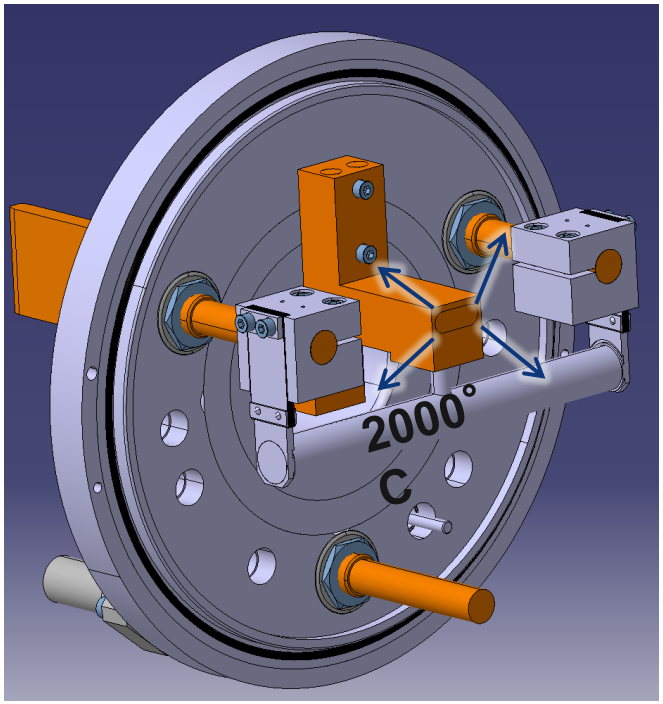
Water at 20° C is present:
-Inside feedthrough (O-rings on FE side)
-Inside target base
-Inside cold gas line (O-rings on target side)

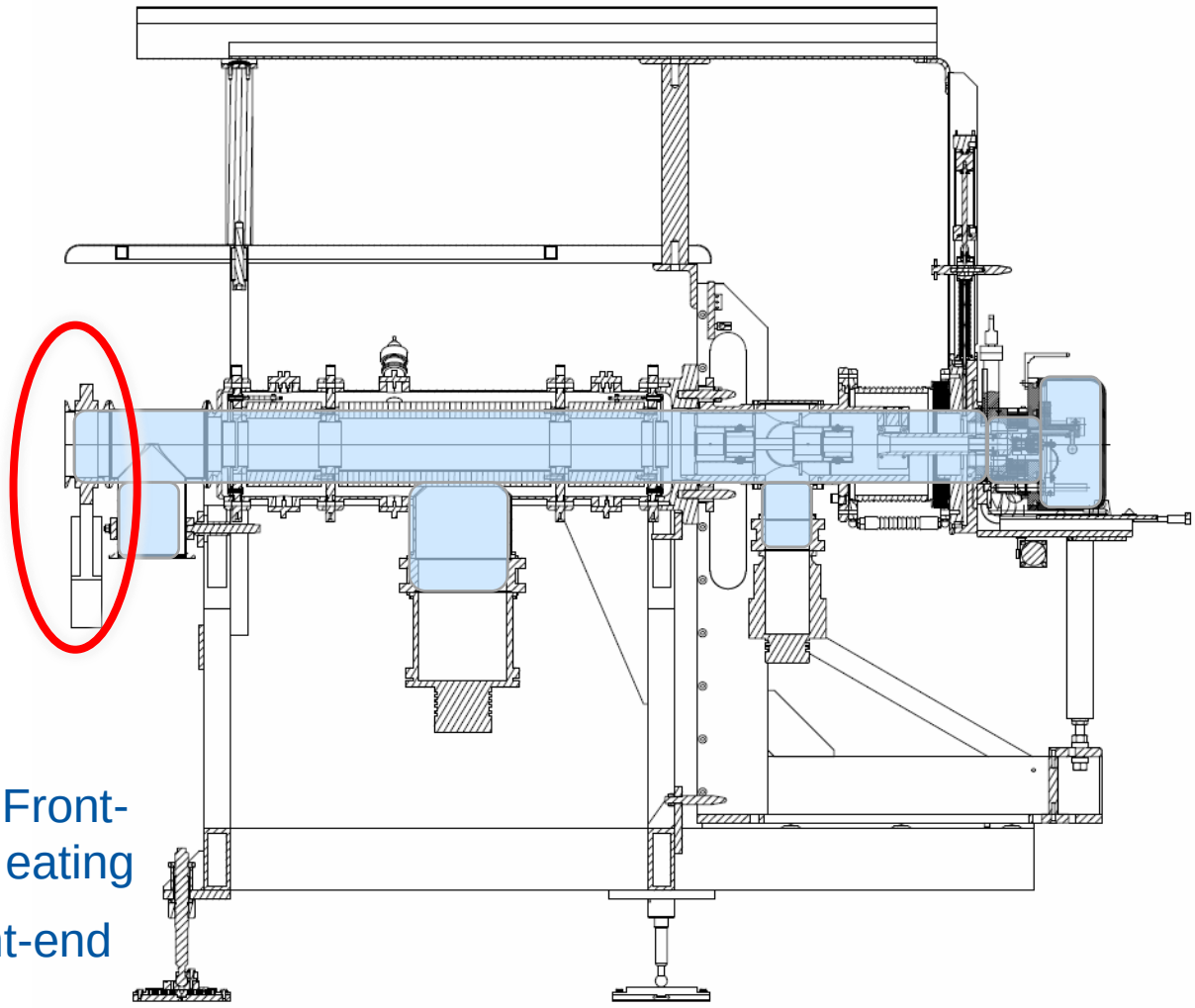
Cold gas line water leak is considered as the more critical → close and connected to container

2 events recorded in 20 years operation → **Only on cold target**



Target Failure Scenario



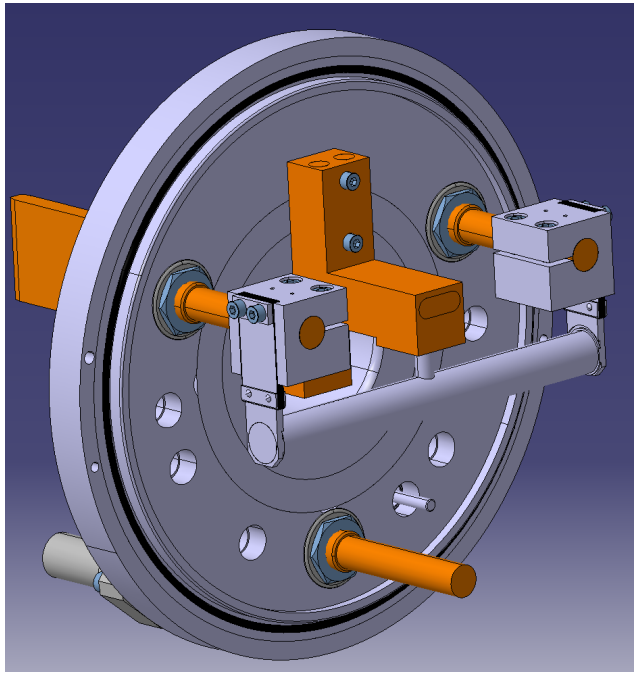


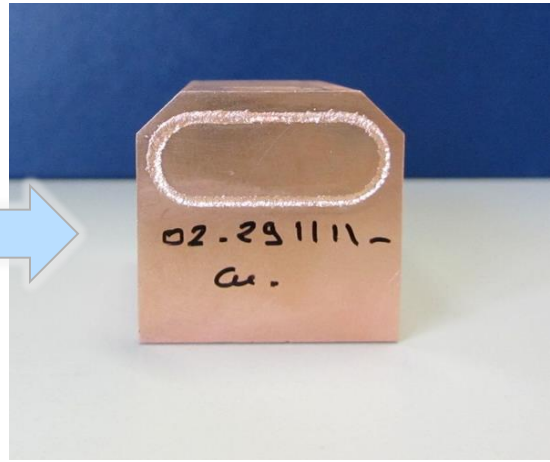
Water leak

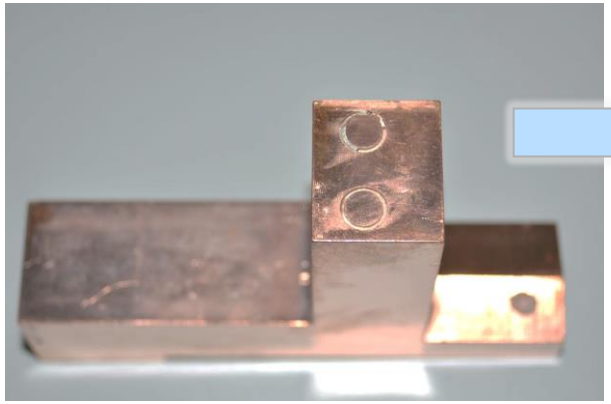
Vacuum interlock will close the Front-end shutter and stop the target eating

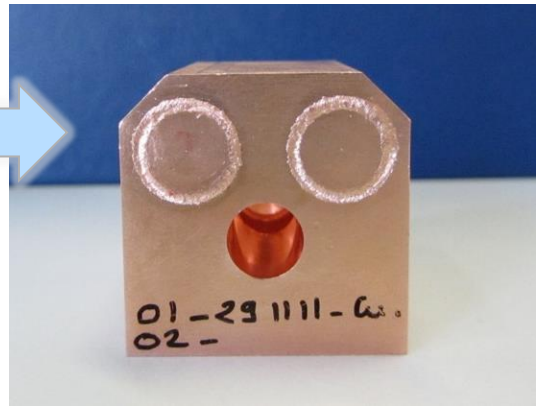
Water will flood target and Front-end

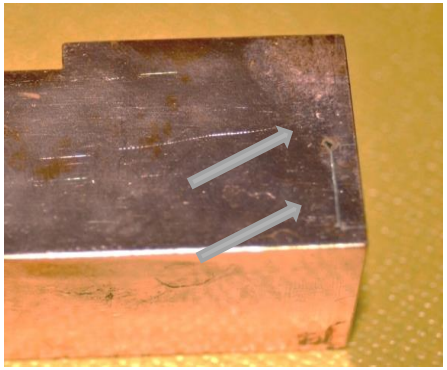
Target Failure Scenario







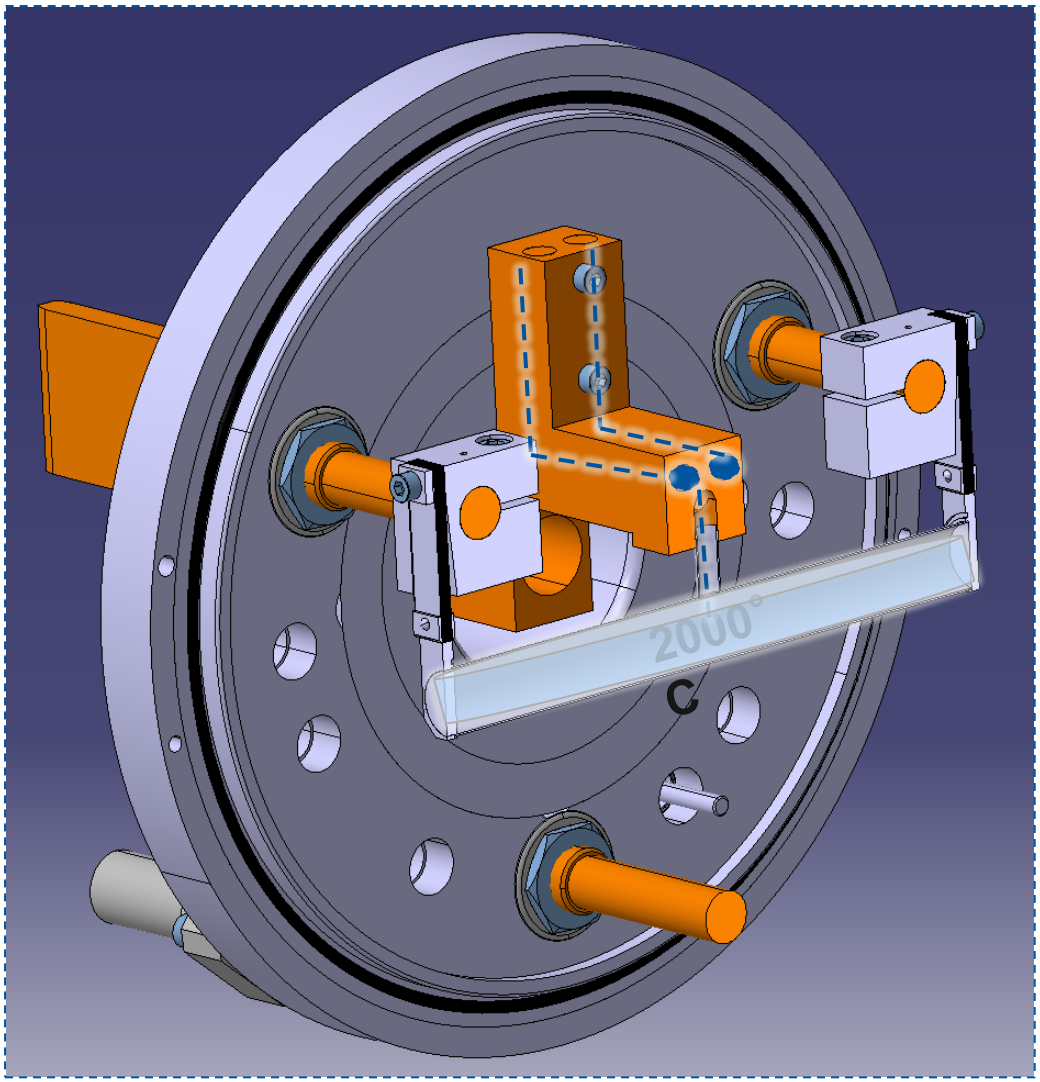




Leaking points

Electron beam welding technique used for new cold gas line + control quality → No water leak since 1990

Target Failure Scenario



Water leak between cold gas line and container → Worst case

Very conservative

Never happen in 20 years of operation

Worst case scenario selected for the test bench

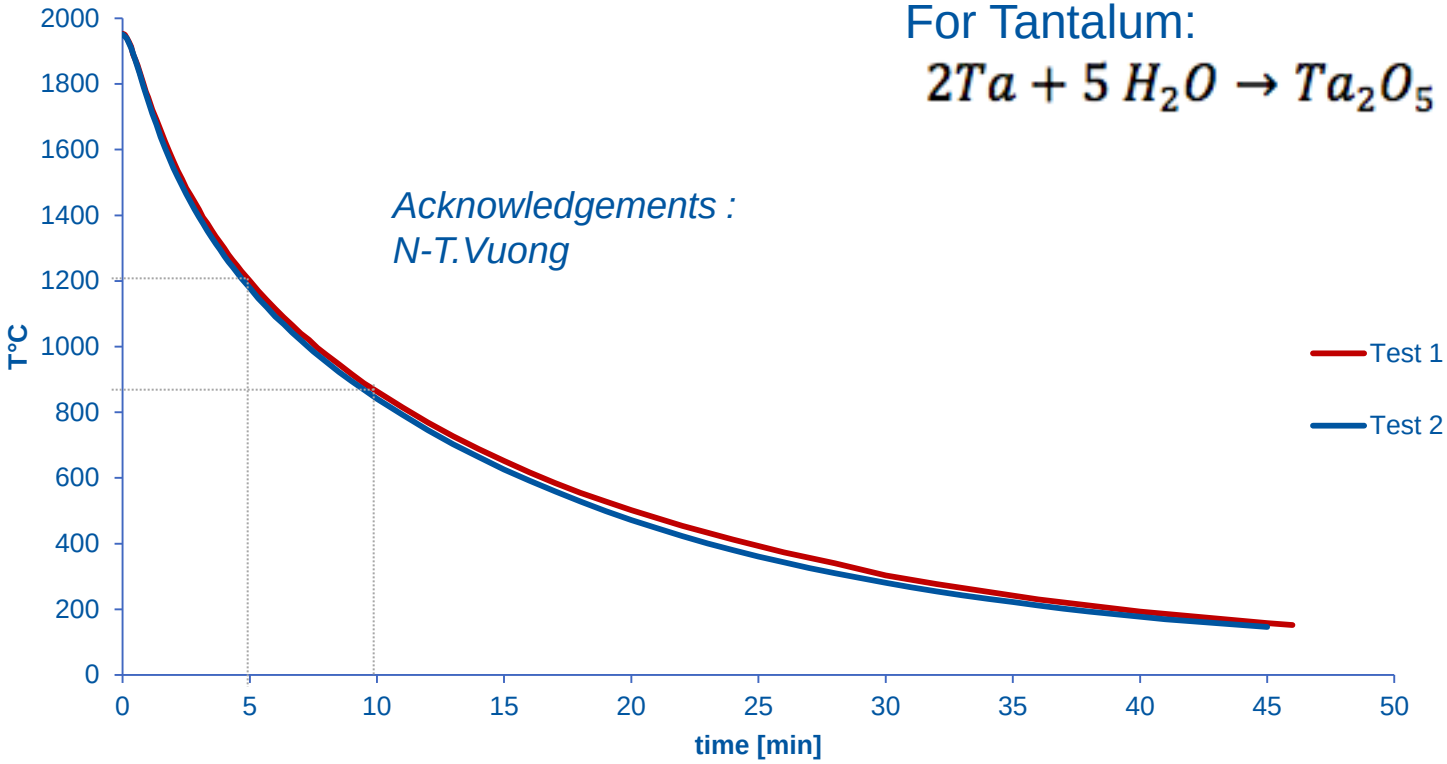
Target Failure Scenario

Thermic mass 50 g SiC > 100g UC_2
T_{init} = 1952° C

Hydrogen production → correlated to the material placed inside the container and water contact

For Tantalum:

$$2Ta + 5\,H_2O \rightarrow Ta_2O_5 + 5H_2$$



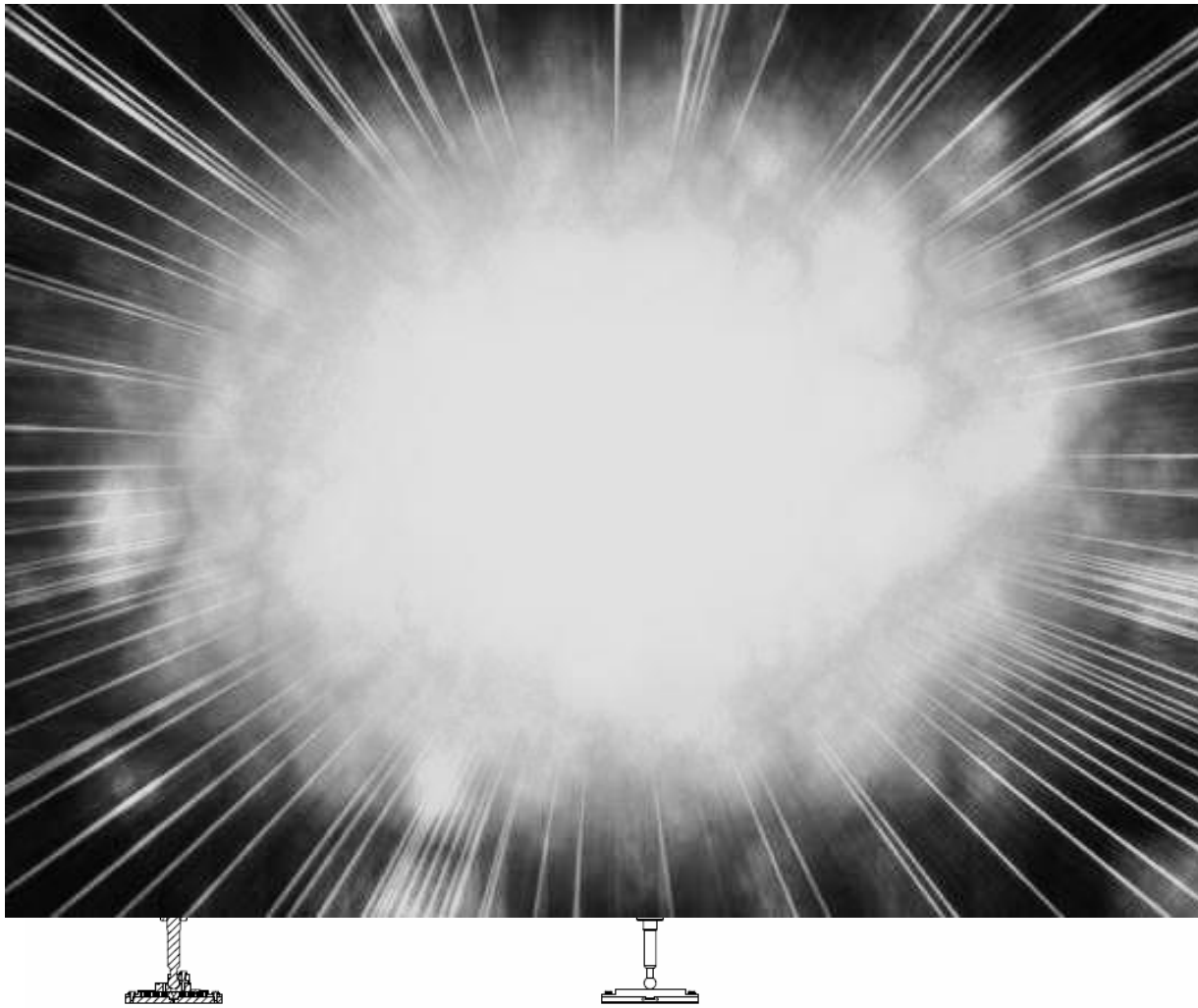
Acknowledgements :
N-T.Vuong

Target Failure Scenario

Small water leak through gas cold line

Water vaporization and Hydrogen production by oxidation of material → Build up of pressure inside FE

FE breakdown → Explosion by contact of the explosive mixture and air



Outline

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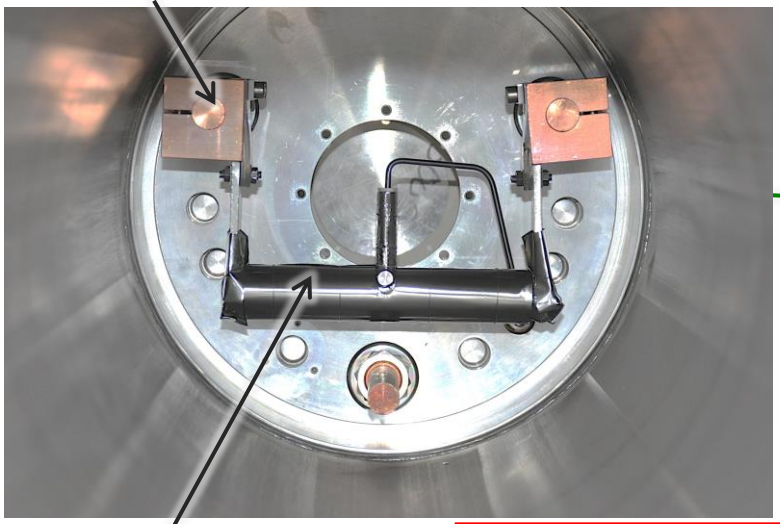
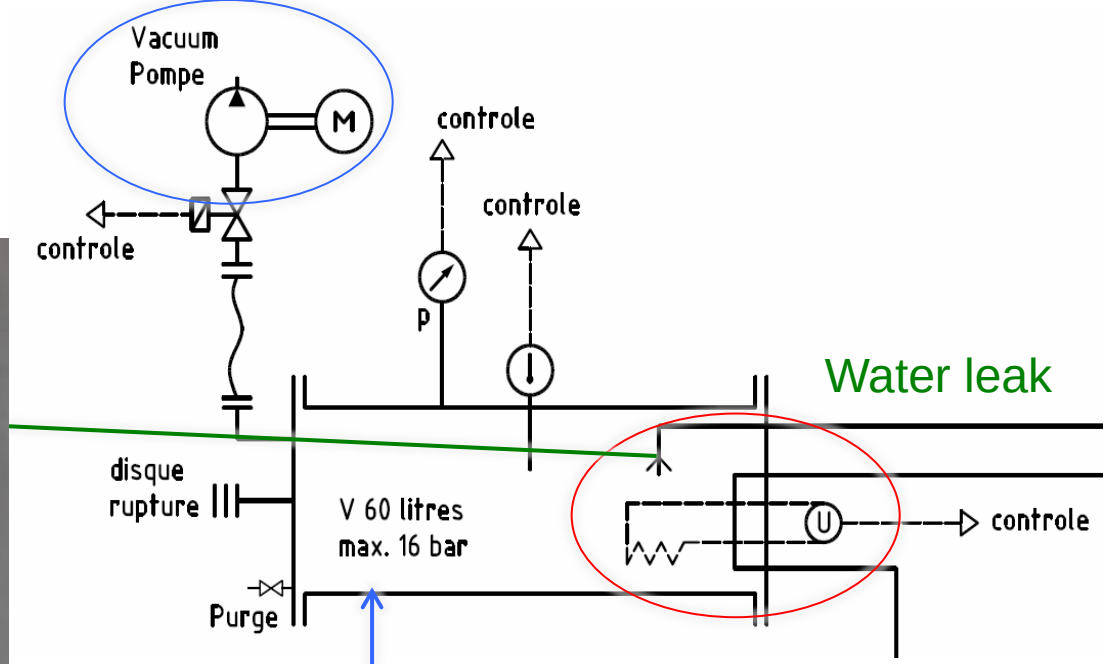
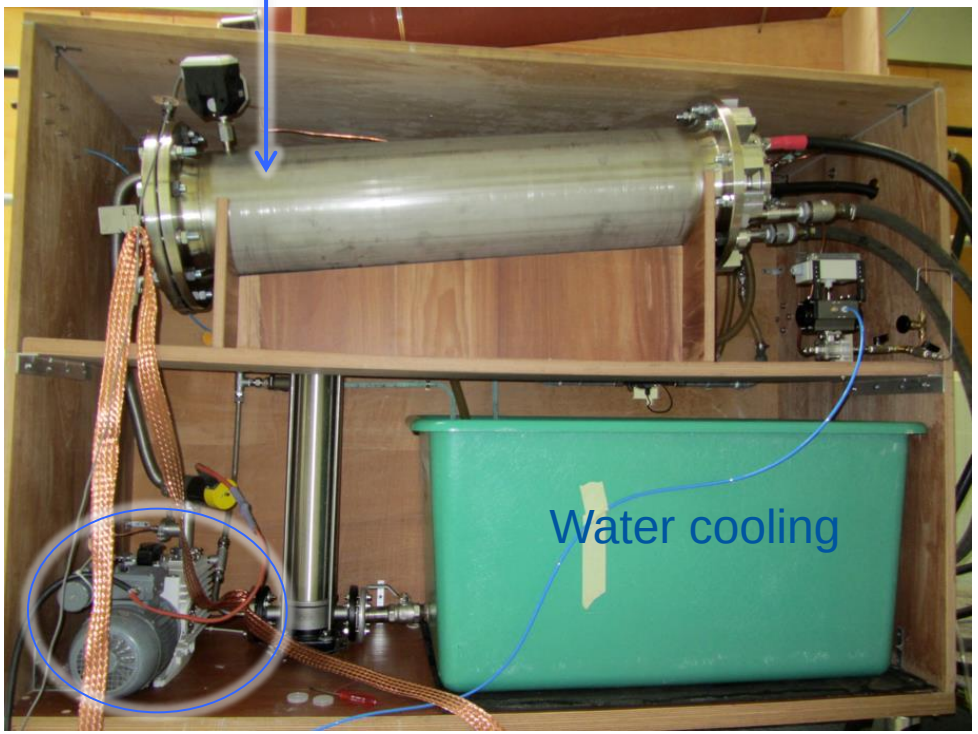
Test Bench

Container Heating system



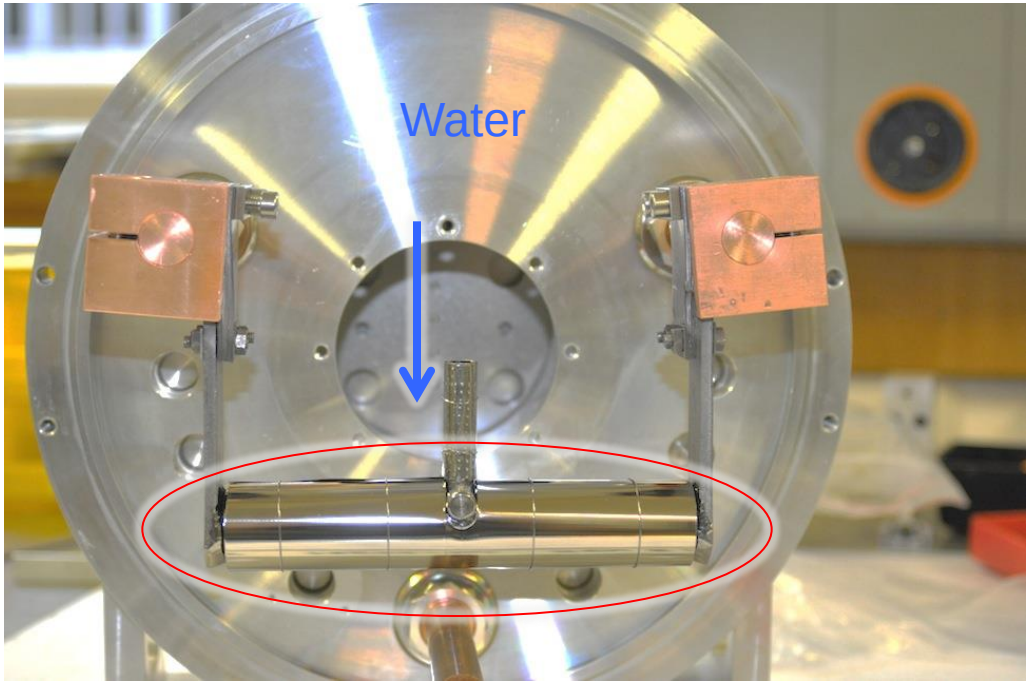
Container





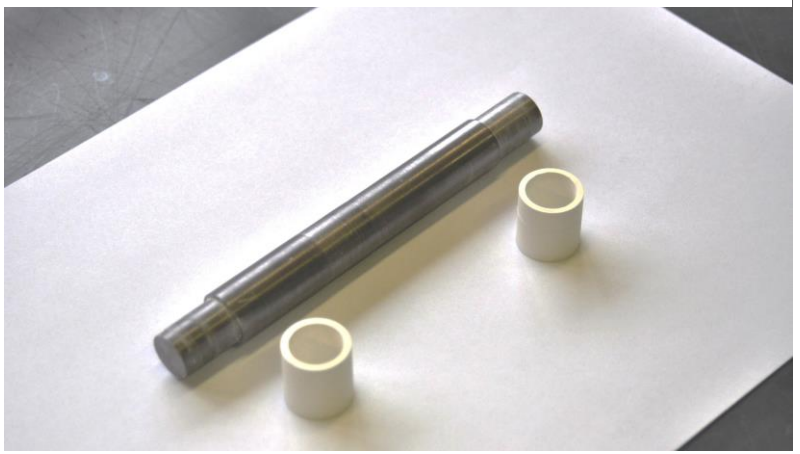
Test Bench
Acknowledgements :
B.Crepieux,
H.Encontre, S.Marzari

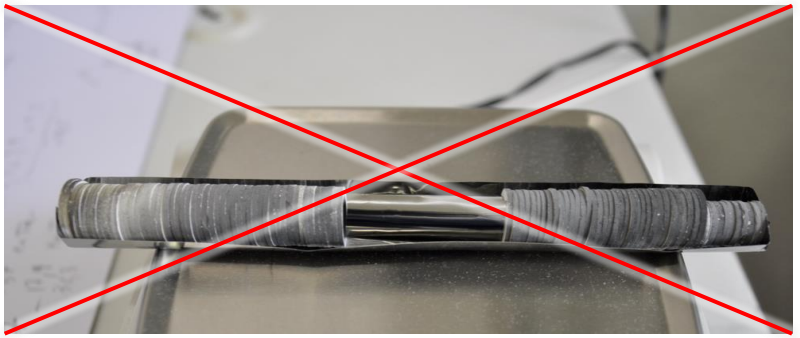
Test Bench



2 types of material were inserted inside container:

→ Tantalum bar (Reduced surface)
→ Tantalum rolls (Larger surface)
→ Pills or powder material were not tested

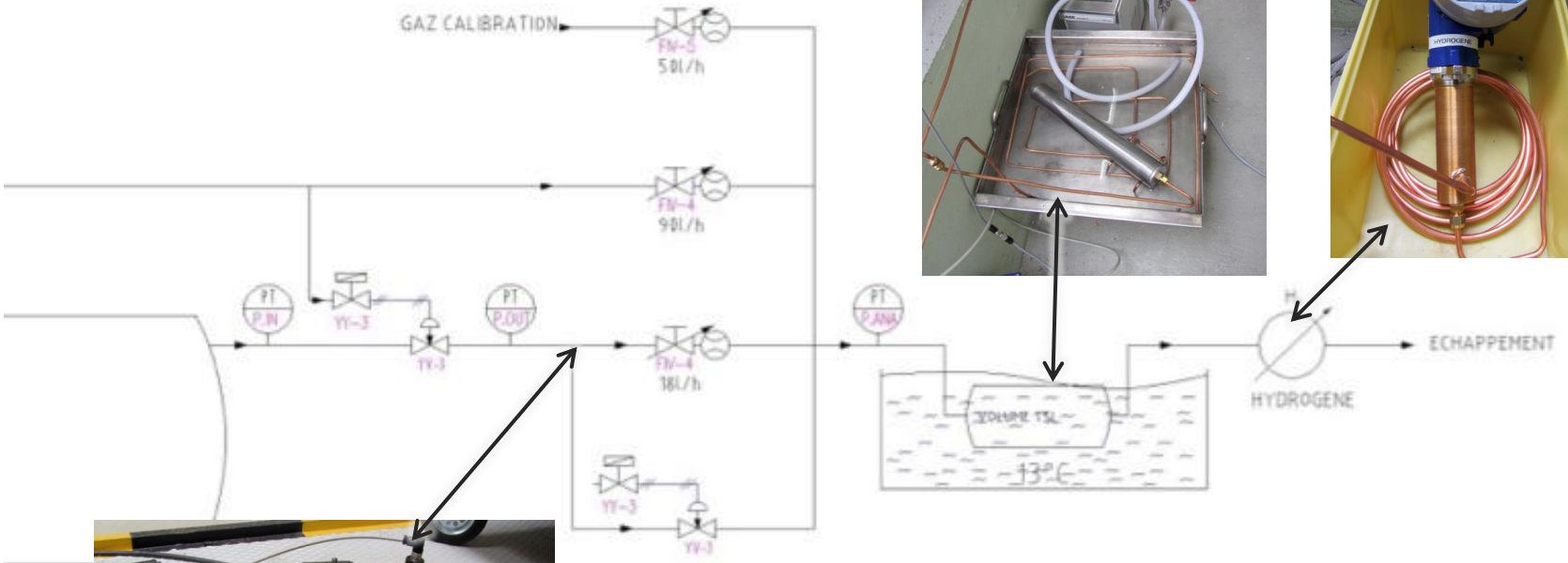




Test Bench

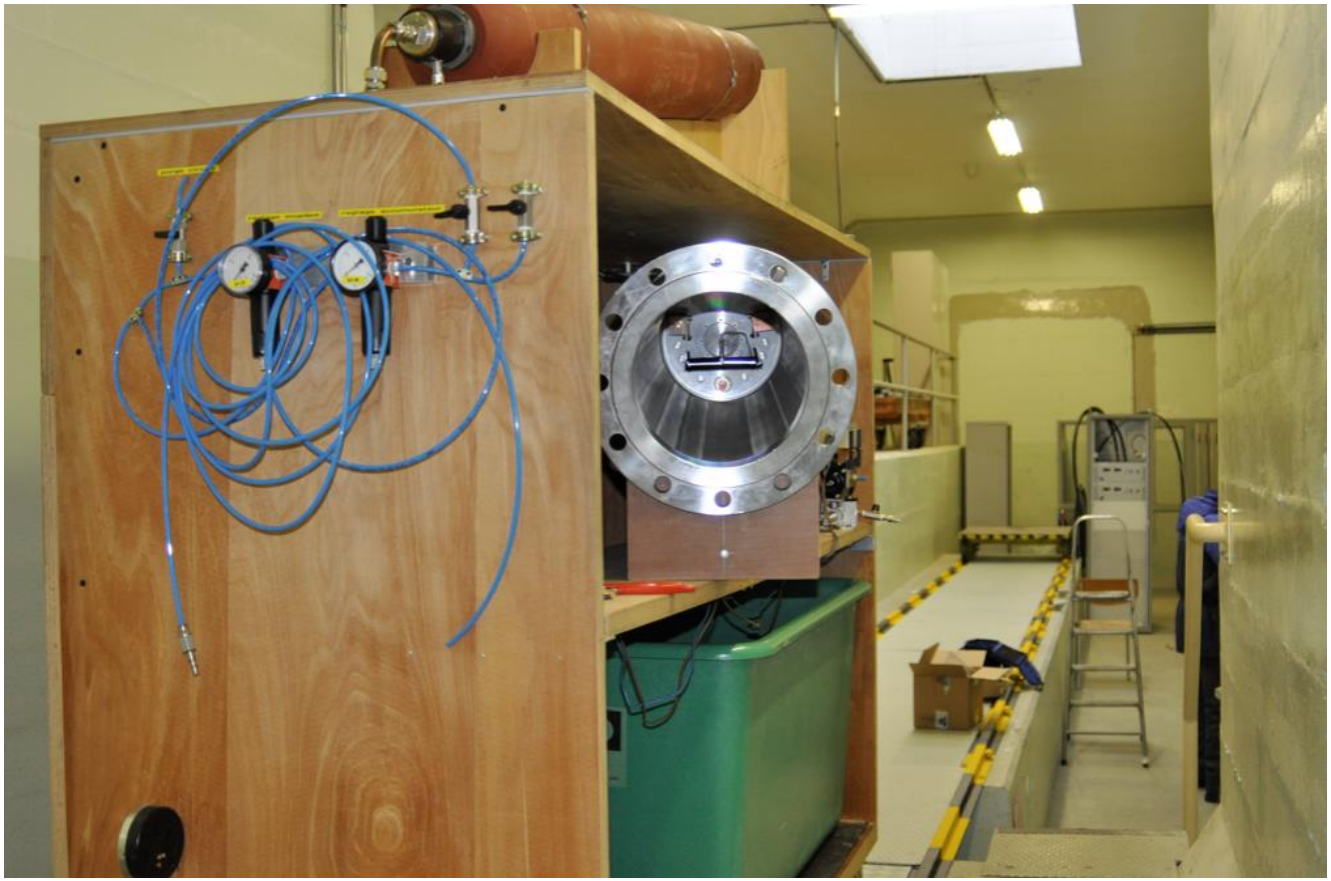
- Pressure and Hydrogen monitoring was done from outside the bunker
- Purge mode with Argon (3 flushings of the volume before access)

Hydrogen Monitoring
Acknowledgement : L.P De Menezes/PH



Test Bench

- Test was located in a bunker dedicated to pressure test
- During test – Access was forbidden
- Power, heating, water leak was started and stopped from outside



Test Bench
Acknowledgements :
B.Crepieux,
H.Encontre, S.Marzari

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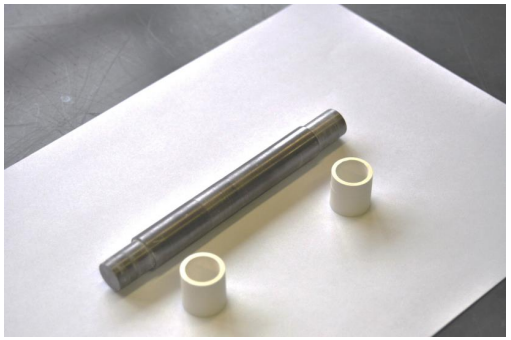
Results

Test 1:

Only **pressure was monitored** → Started with vacuum 10^{-5} - Expected pressure after water leak was 6 bars

Capteur : Digibar 0 -10 bars and local pressure gauge (recorded by video)

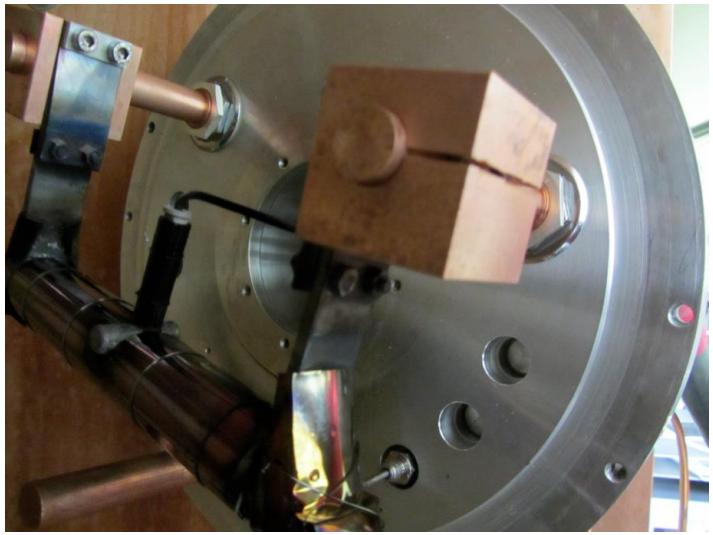


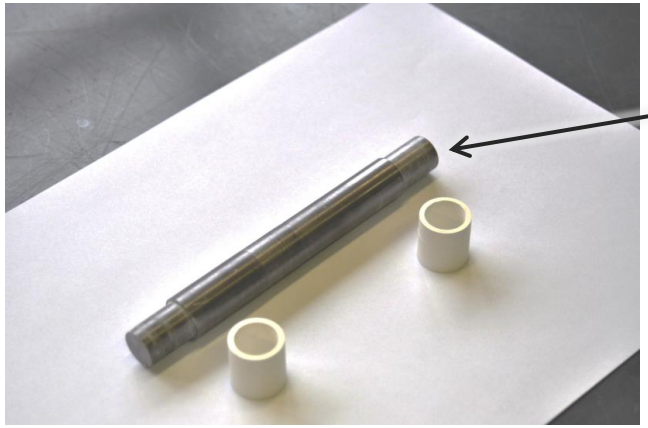
Tantalum bar	
Mass (g)	489.9
Specific surface area (m^{-1})	2.51
Energy (KJ)	136.4
Water leak (ml/s)	10
Time of leak (mn)	5

Acknowledgements : M.Czaspki
EDMS 1382648

Results

Pressure increase was negligible



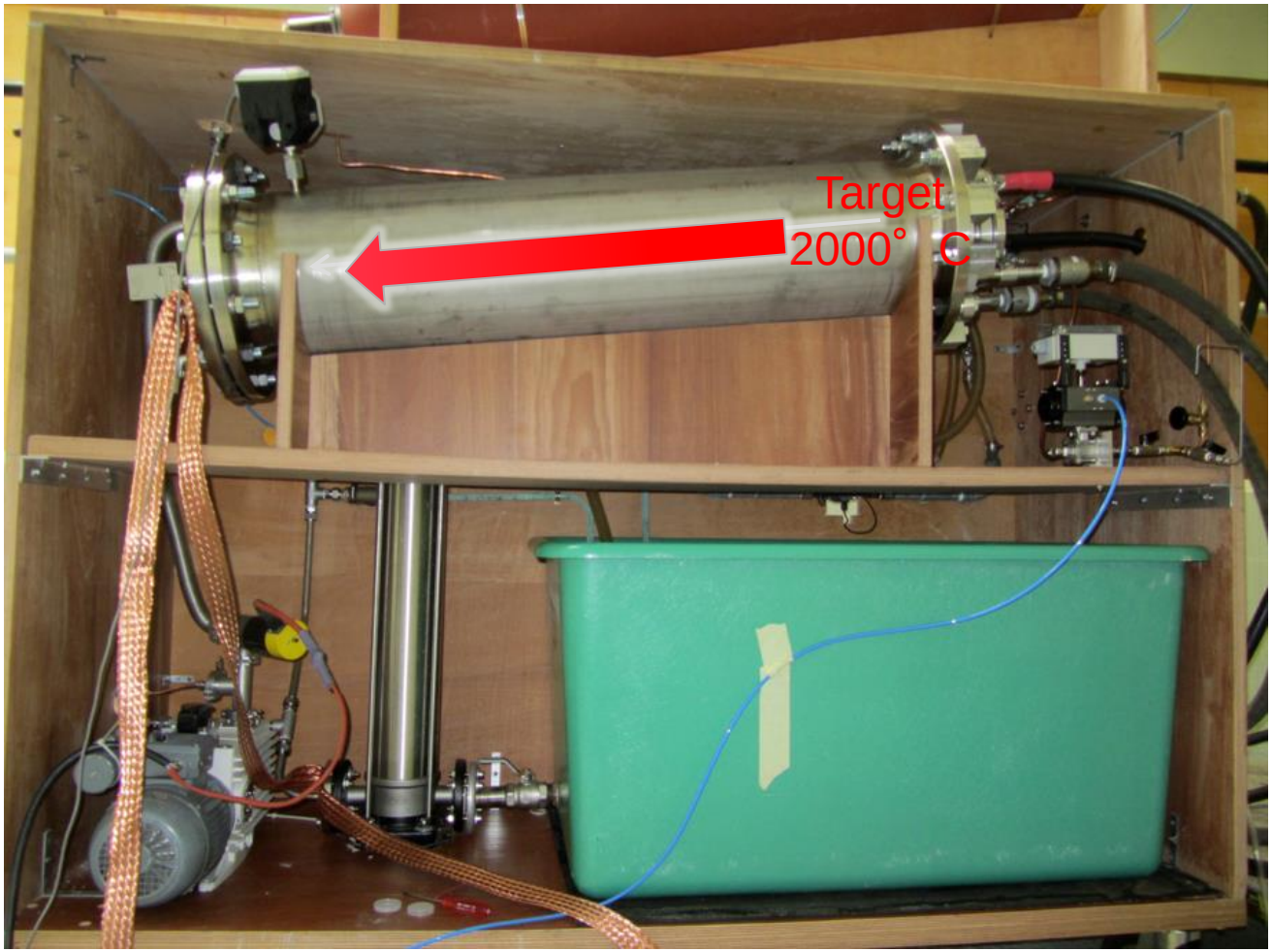


Results

No pressure increase was observed

Very large gradient of temperature

Water vaporization is followed by water condensation on cold surface

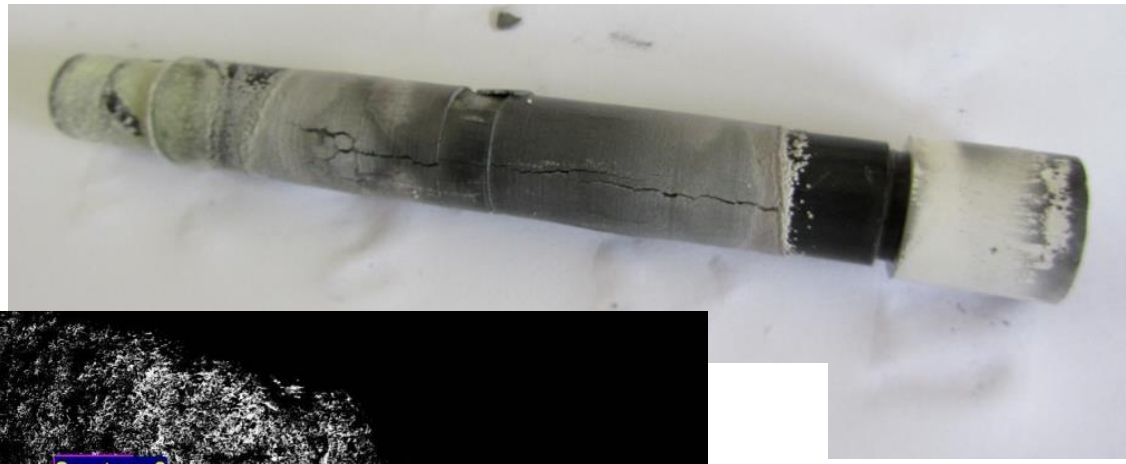


Results

Oxidation process occurred and Hydrogen was produced (under vacuum)

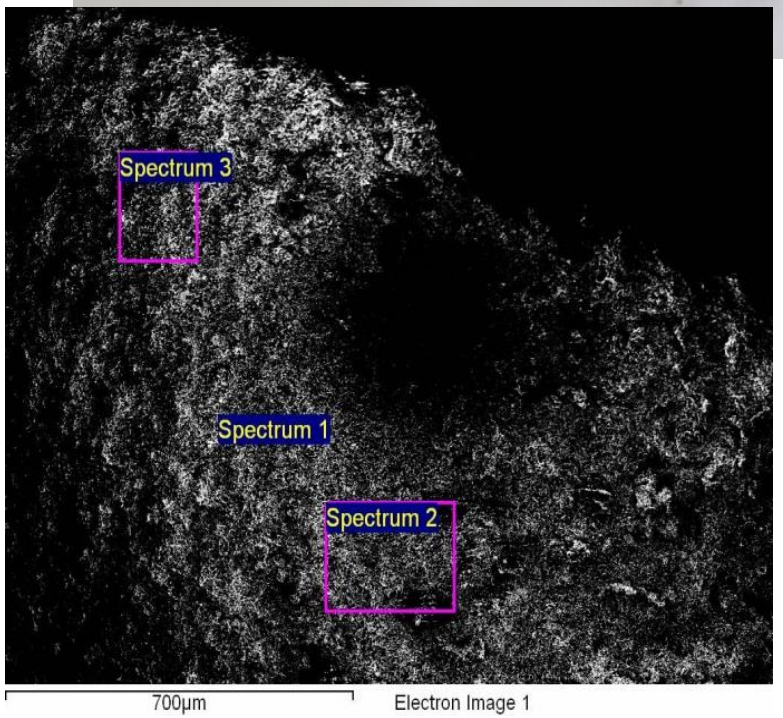
SEM and EDS analysis of the white deposite confirmed the production of tantalum oxyde

$$2Ta + 5\,H_2O \rightarrow Ta_2O_5 + 5H_2$$



Processing option : All elements analysed (Normalised)

Spectrum	In stats.	C	O	Ta	Total
Spectrum 1	Yes	2.53	22.44	75.02	100.00
Spectrum 2	Yes	3.35	21.20	75.45	100.00
Spectrum 3	Yes	4.82	21.06	74.12	100.00
Mean		3.57	21.57	74.86	100.00
Std. deviation		1.16	0.76	0.68	
Max.		4.82	22.44	75.45	
Min.		2.53	21.06	74.12	



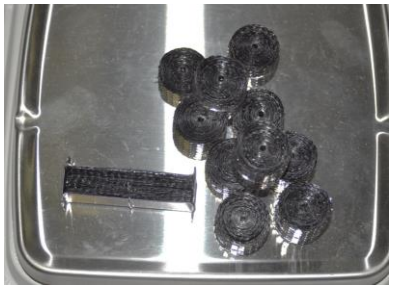
Mass calculation:

2 to 3 liters of H2 were produced

Acknowledgements : M.Czaspki
EDMS 1382648

Results

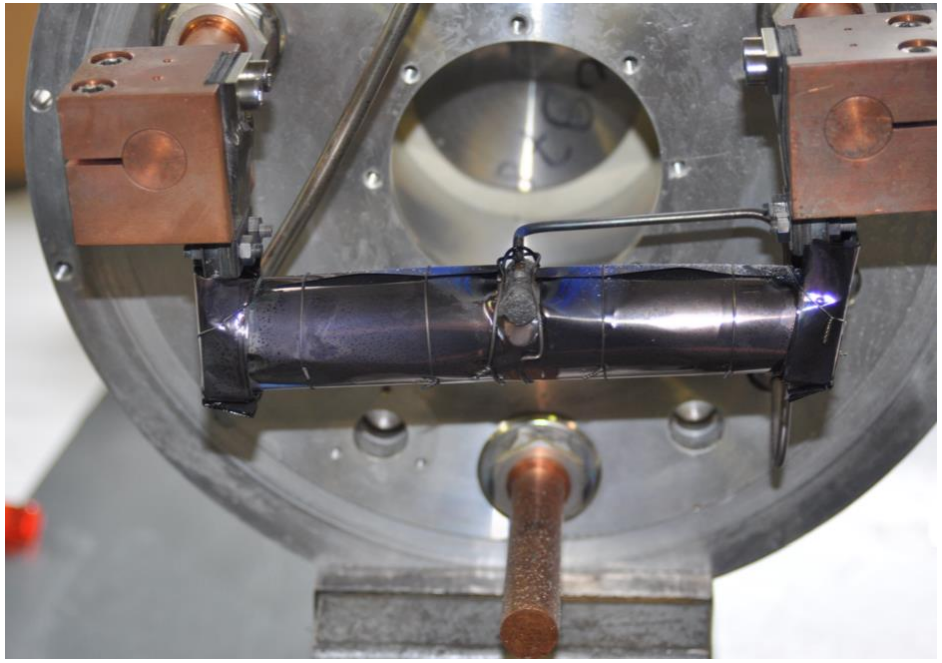
Test 2 and 3:
Focus on Hydrogen production and pressure monitoring
Pressure sensors were added on the purge setting (previous sensors not adapted)

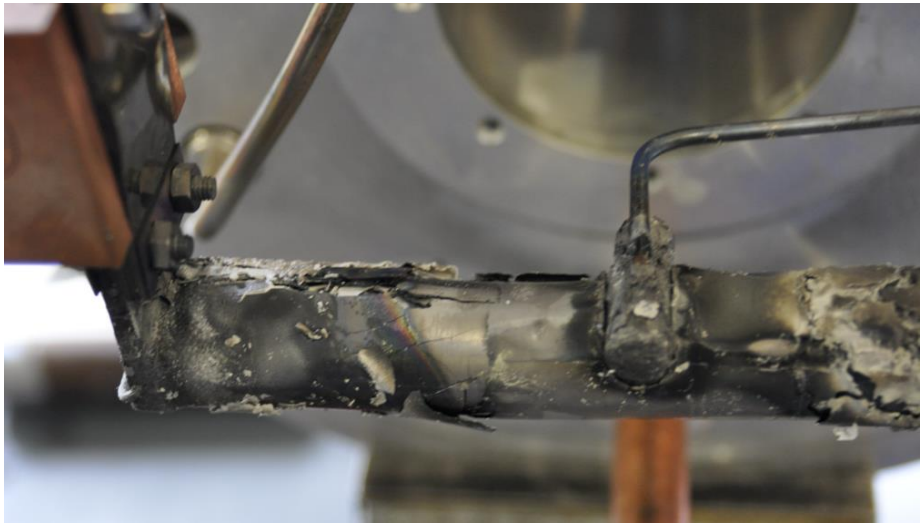


Tantalum rolls	2	8
Mass (g)	20.3	162.4
Specific surface area (m^{-1})	800	6400
Energy (KJ)	5.7	45.2
Water leak (ml/s)	10	2
Time of leak (mn)	1	2

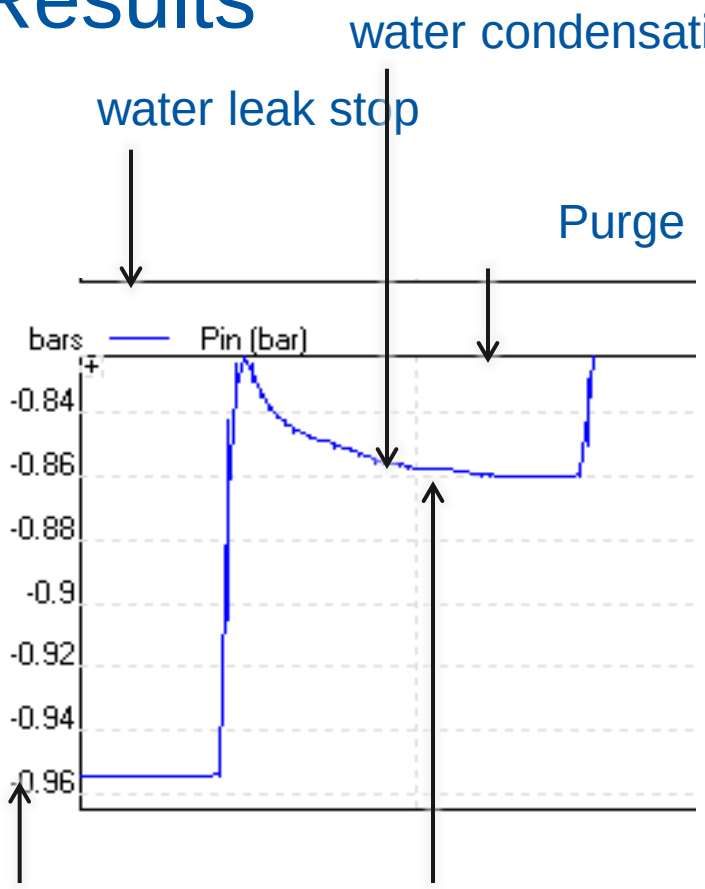
Acknowledgements : M.Czaspki
EDMS 1382648

Results





Results

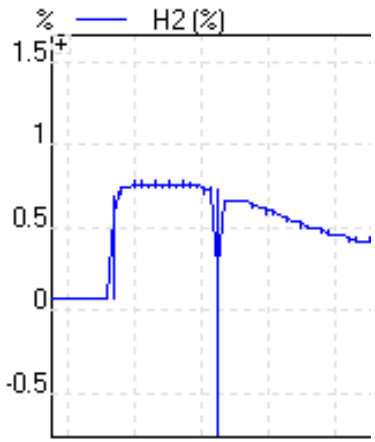


Pressure before water leak

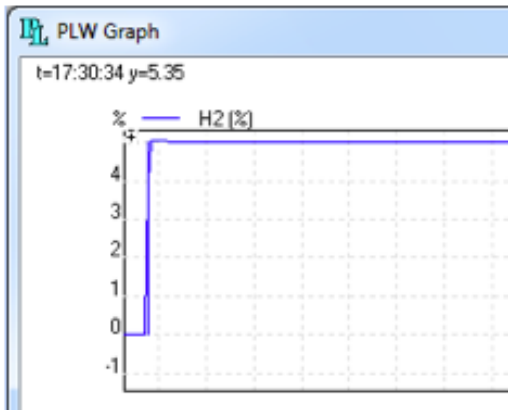
Pressure due to H2 production

Tantalum rolls	2	8
Initial pressure (mbars)	- 955	-955
Final pressure (mbars)	- 860	-585
Pressure variation	95	370
H2 (via pressure data) (l)	5	24
H2 (via H2 sensor data) (l)	4	-

Acknowledgements : LP.De Menezes and M.Czaspki



Dilution rate 90l/h



Sensor saturation

Outline

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Summary

- Pressure increase due to water is not critical (condensation)
- Pressure increase due to hydrogen production is correlated to chemical reaction efficiency
- **Significant production of hydrogen is confirmed**
- Production of hydrogen is highly dependent of the **target material** and the **“quality” of contact** between the water and the target material
- Water cooling is very efficient but it’s better to keep it outside the target if possible