MEDSI 2016 – Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation – BARCELONA

ESRF – The European Synchrotron

A NEW GENERATION OF X-RAY ABSORBERS FOR THE ESRF EBS STORAGE RING

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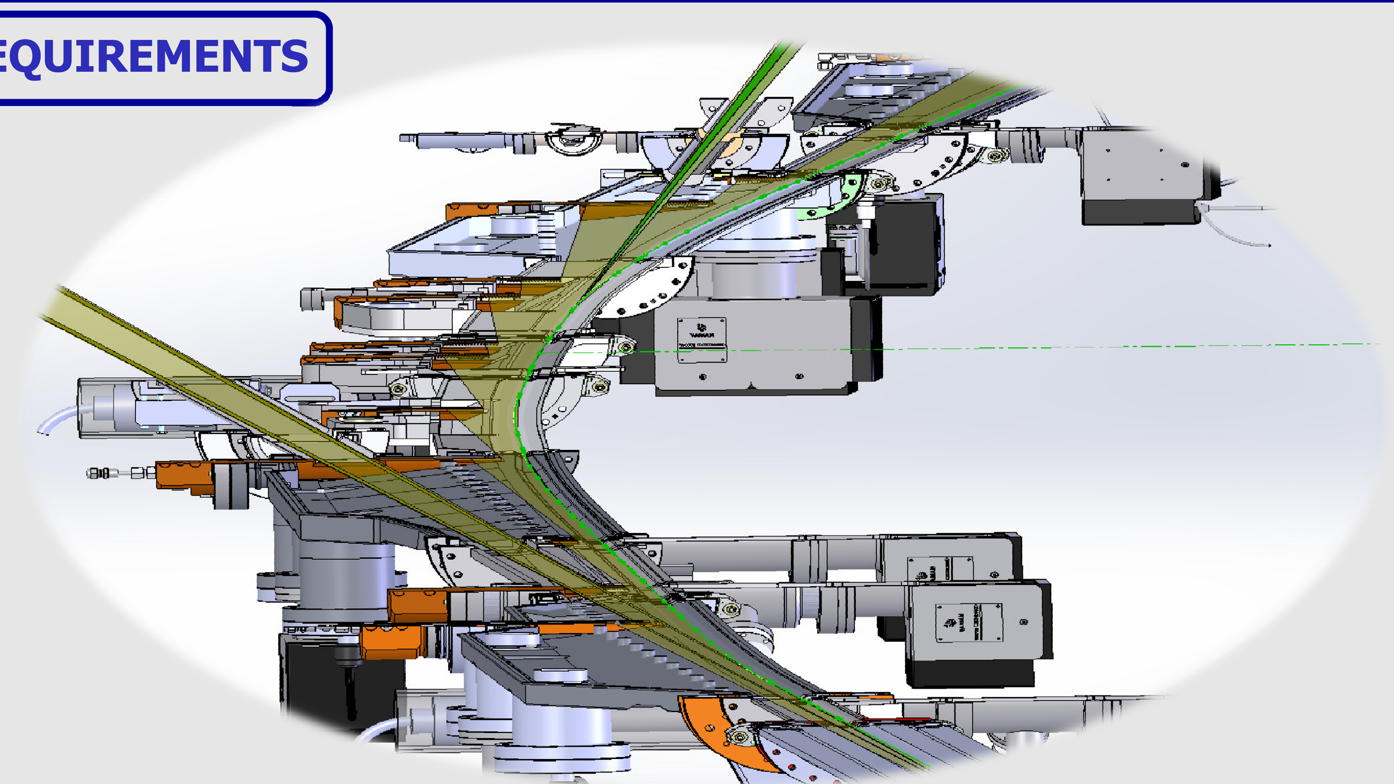
REQUIREMENTS

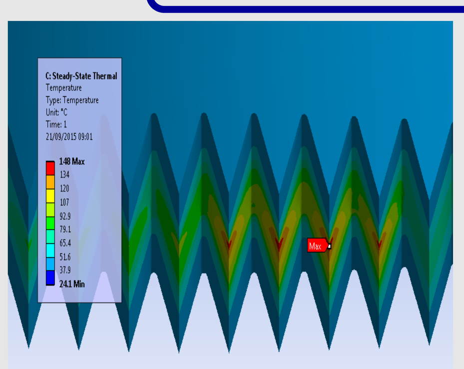


The X-ray absorbers are essential components of the storage ring vacuum system. Their function is to protect the vacuum chambers from the high power density produced by the dipole magnets synchrotron radiation. In the EBS storage ring, the 430 kW total heat-load will be stopped by 400 individual absorbers of twelve different types. The compact design of EBS, means small section vacuum chamber, important magnetic field area (25mm/x-ray beam) and close up magnetic poles, all of these constraints require us to design new absorbers.

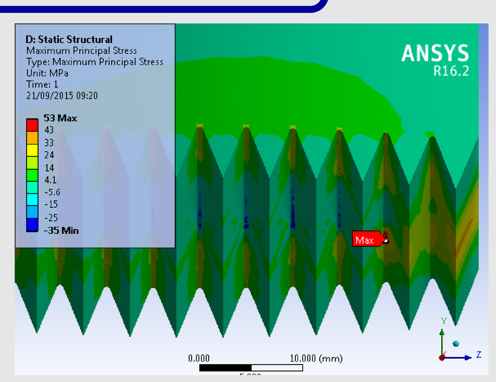
At MEDSI conference in October 2014, Sushil Sharma (*) presented novel design idea for high heat-load synchrotron radiation components: CuCr1Zr copper as an alternative to Glidcop®. We decided to use this material, associated with a novel design of integrating the vacuum sealing flange and avoiding any brazed or welded junctions. As CuCr1Zr cooper was never used at large scale for similar applications, we must fully investigate all properties before buying the 12 tonnes necessary for machining our absorbers.

(*) S. Sharma, "A Novel Design of High Power Masks and Slits", Proc. of MEDSI2014, Australia (2014)

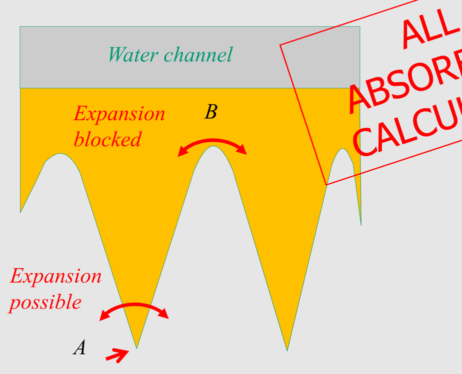
Optimized teeth geometry



Temperature contour plot on toothed absorber

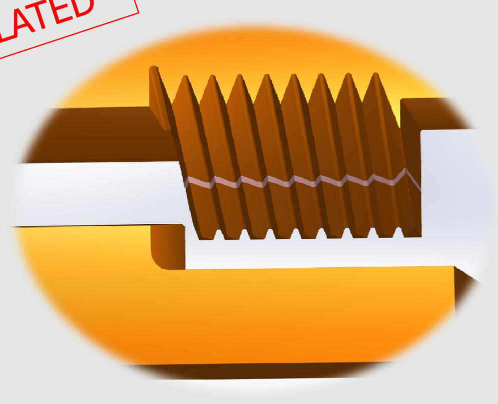


Maximum principal stress contour plot on toothed absorber



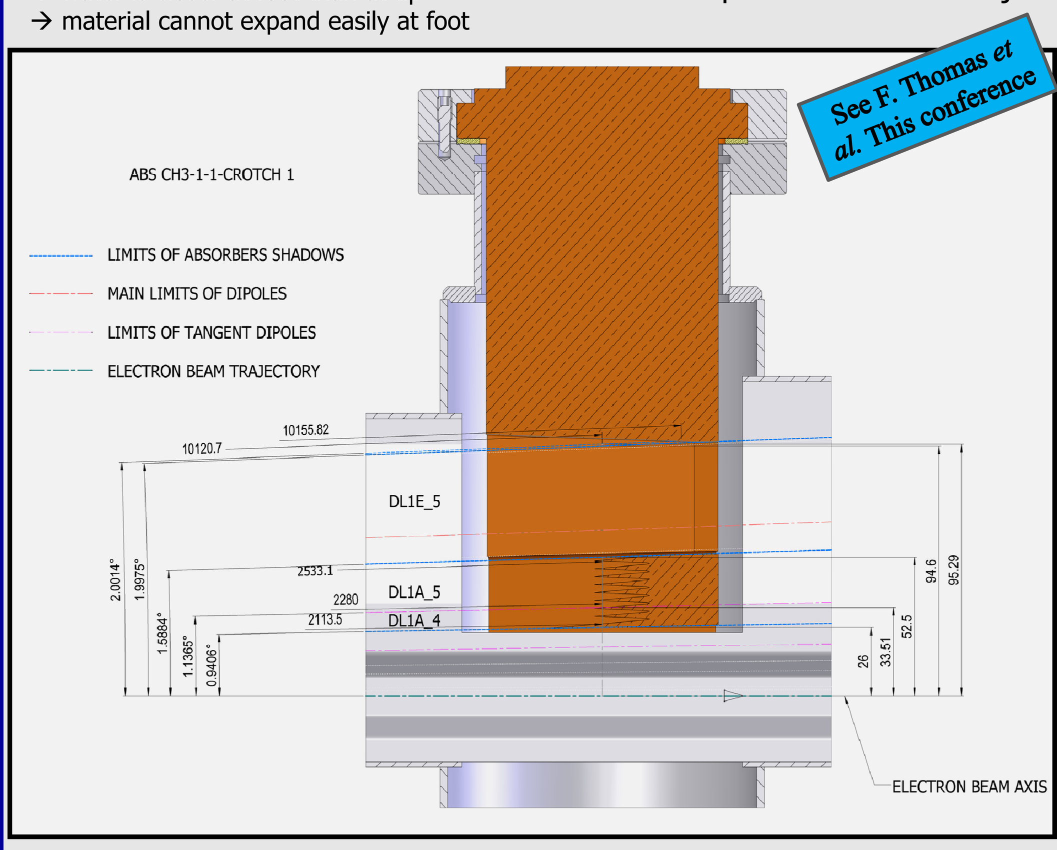
ALL ABSORBERS CALCULATED

A: Temperature is max Stress is min
→ water is farther away at tip than at foot
→ material can expand more easily at tip than at foot
B: Temperature is min Stress is max
→ water is closer at foot than at tip
→ material cannot expand easily at foot



Ray tracings
⇒ beam footprints on absorber's jaw

See F. Thomas et al. This conference

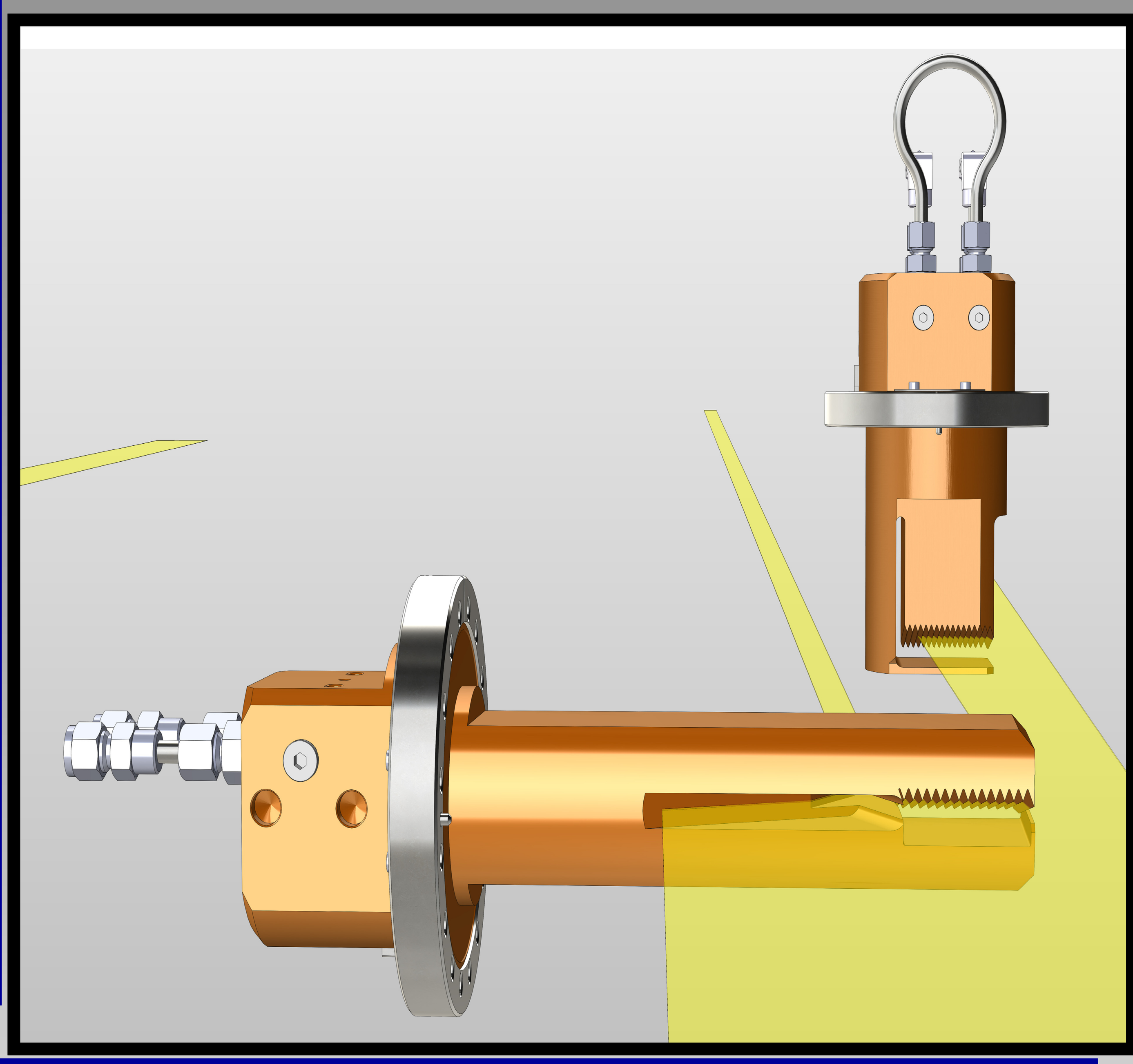


Ray tracing to defined the heat load on each absorber depending on upstream bending magnets illumination.

EDM(Wire cutting)
The main part of the absorbers has to be manufactured by EDM process, the challenge being to optimise the cutting parameters to obtain the surface roughness (Ra 1.6 µm) with minimum machining time. Thanks to the know-how of the company SAES RIAL, adequate parameters (wire diameter and material, cutting speed…) were identified and are in use for the pre-series manufacturing.

Conclusion

ESRF will use CuCr1Zr absorbers for its EBS storage ring:
- The material has been extensively studied on several samples: purity, inclusions, thermal and mechanical properties.
- A material specification (ESRF/ENG/15-09) has been issued to define the material, the EN standard CW106C being too permissive for or our application.
- A assembly manual was issued in collaboration with SERTO to specify hydraulic connection torques.
- Prototypes have been machined to validate CF knife in CuCr1Zr, UHV compatibility and the choice of SERTO water connections.
- A complete prototype absorber was installed and running in the present storage ring.
- Strong design choices were made regarding:
  - Efficiency in absorbing X-Ray beams and scattered beams: toothed absorbers, scattering blockers. No water cooling requested for the vacuum chamber itself.
  - Efficient and compact connection to cooling channels.
  - Assembly and positioning in the vacuum chamber easy and safe.
- The manufacturing contract is placed, the pre-series delivery is expected in December 2016.

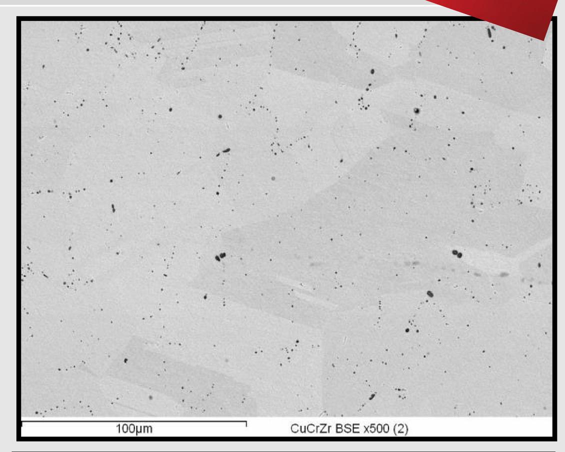


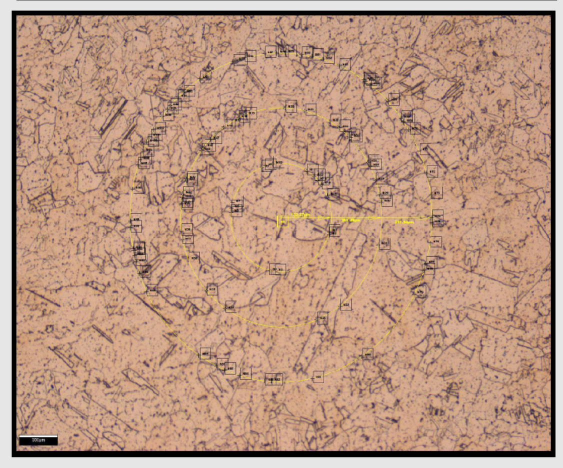
First step: Investigations on Cu Cr1 Zr

Characteristics	Needed for:
Chemical composition	UHV Compatibility Material outgassing
Inclusion	Leaks tightness
Hardness	CF knife and water fittings thread
Grain size	Risk of cracks, Leaks
Yield Strength	Heat load
Electrical conductivity	Heat load

la		Glidcop® Al-25	CuCr1Zr	Cu-OFE
MECHANICAL PROPERTIES	Young's modulus E (GPa)	130	128	115
	Yield Strength (MPa)	330	280	75
	Ultimate limit (MPa)	380	380	200
	Elongation at break (A%)	12	8	45
	Hardness (Brinell)	120	130	100
THERMAL PROPERTIES	Thermal expansion at 20°C (1/K)	16.6	17.5	16.8
	Conductivity at 20°C ($W.m^{-1}.K^{-1}$)	365	320	393
	Typical max. Heat load (W/mm^2)	70	50	20
DESIGN PROPERTIES	CF Knife edge possible	Yes	Yes	No
	Price (€/Kg) for rods > Ø100mm	46	14-34	

Mechanical properties





Inclusions and determination of grain size in accordance with ASTM E112

Hardness

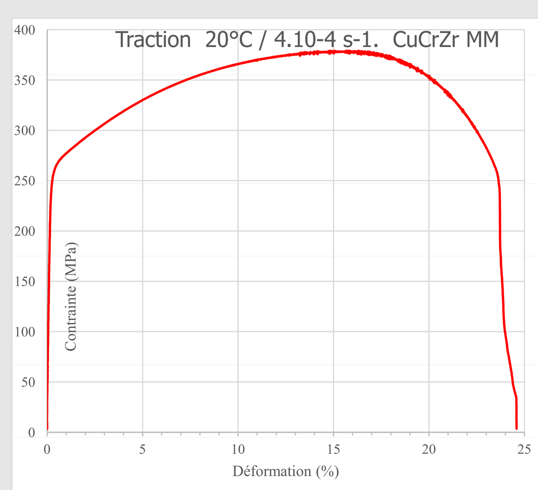
S(%)	Bi(%)	Cr(%)	Fe(%)	P(%)
<0.0010	<0.0010	0.59	0.0060	0.011

Pb(%)	Si(%)	Zn(%)	Zr(%)	Cd(%)
<0.0010	<0.0010	<0.0005	0.066	<0.0010

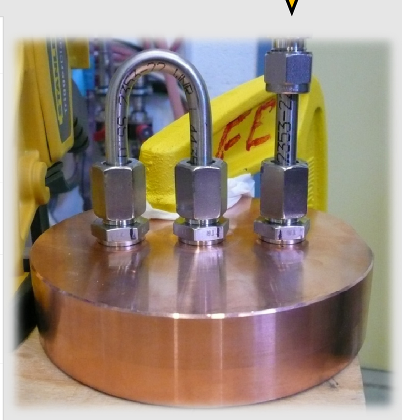
Chemical composition

Expertise from J.M Gentzbittel (CEA-LITEN – Grenoble)

Second step: Prototype Tests



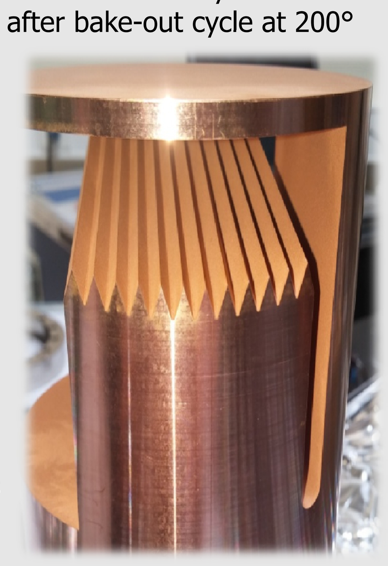
Rupture test



Pressure tests of SERTO water fitting
Static pressure test at 20 bars during 4 hours at 20°
Dynamic pressure test at 10 bars during 24 hours at 20°
New static and dynamic test after bake-out cycle at 200°

ESRF VACUUM GROUP APPROVED

Copper gasket test

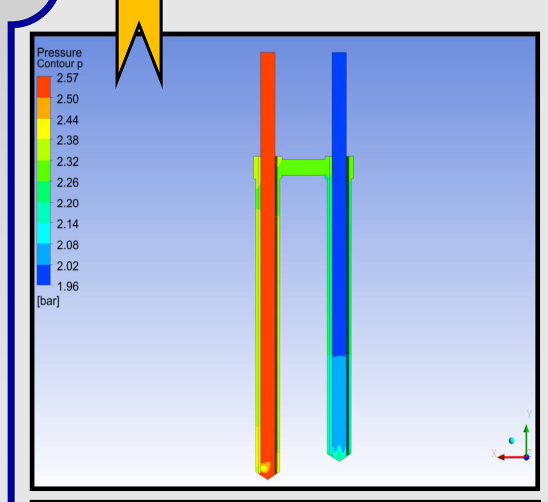


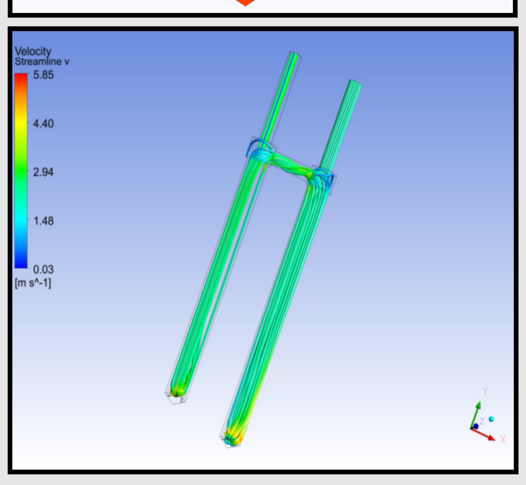
- ❑ Lab tests assembling/disassembling/baking CuCr1Zr flanges
- ❑ => 10 times reliability without failures.

Prototype installed in current machine in Oct 2015

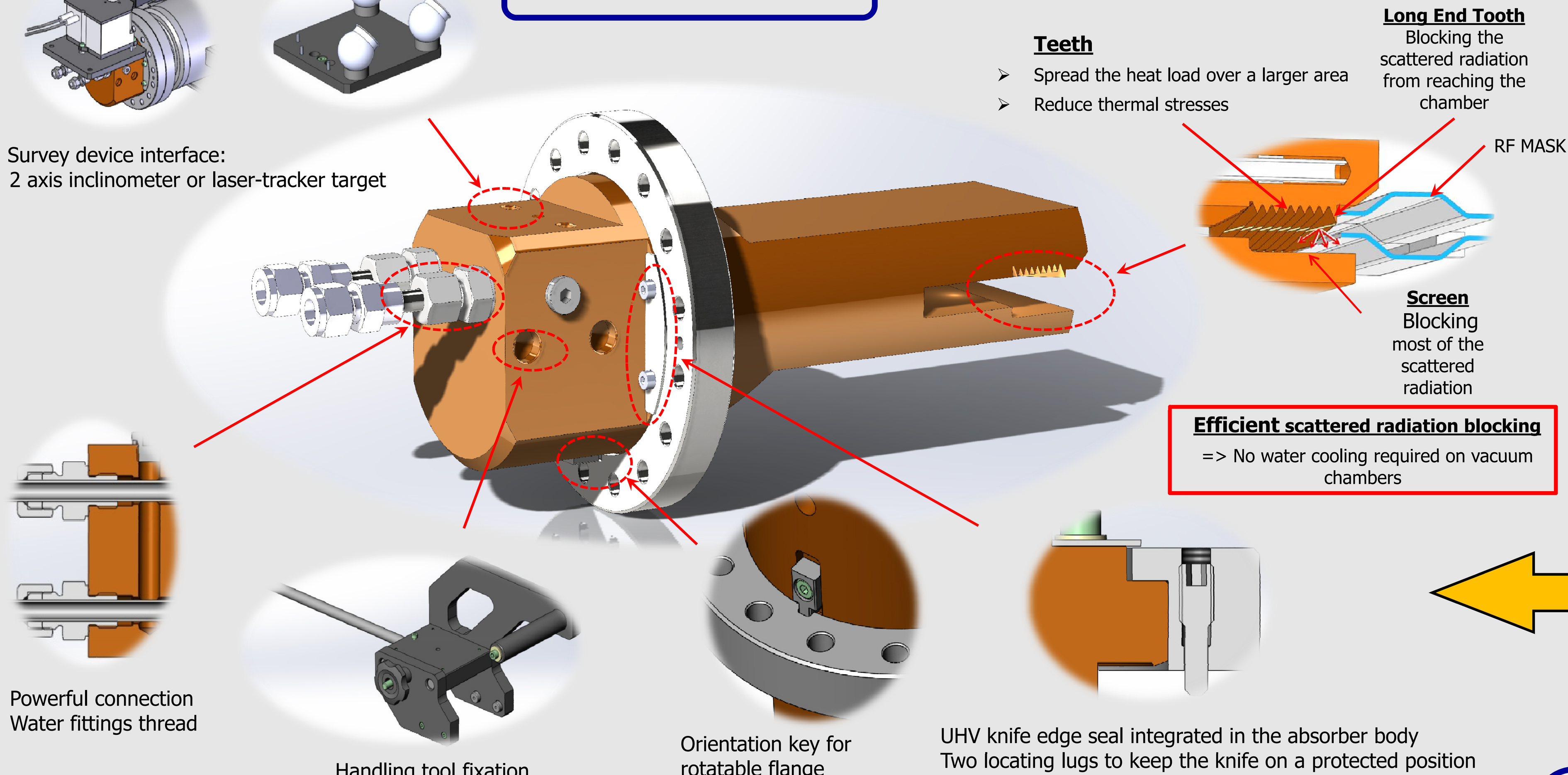
The CuCr1Zr alloy has shown the right properties to be used on the ESRF-EBS regarding the vacuum compatibility: the deformation of the knife after cycles of mounting and dismounting has a low value and assures the leak tightness, it can successfully follow a typical bakeout procedure and also resist to the cleaning procedure. In each test, the gasket used was a standard CF gasket(80HB) that will facilitate the supply and the logistic for the new machine.

Conceptual design





Water Box: Connecting mechanically 2 coolant channels



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