MEDSI CHICAGO 2020

ESRF | The European Synchrotron

BM18, The New ESRF-EBS Beamline For Hierarchical Phase-Contrast Tomography

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July 26th 2021

SUMMARY

Brief general description

Overview of the beamline components

Nearly all the instruments are especially developed for this beamline

1.1 BM18: HIERARCHICAL PHASE-CONTRAST TOMOGRAPHY

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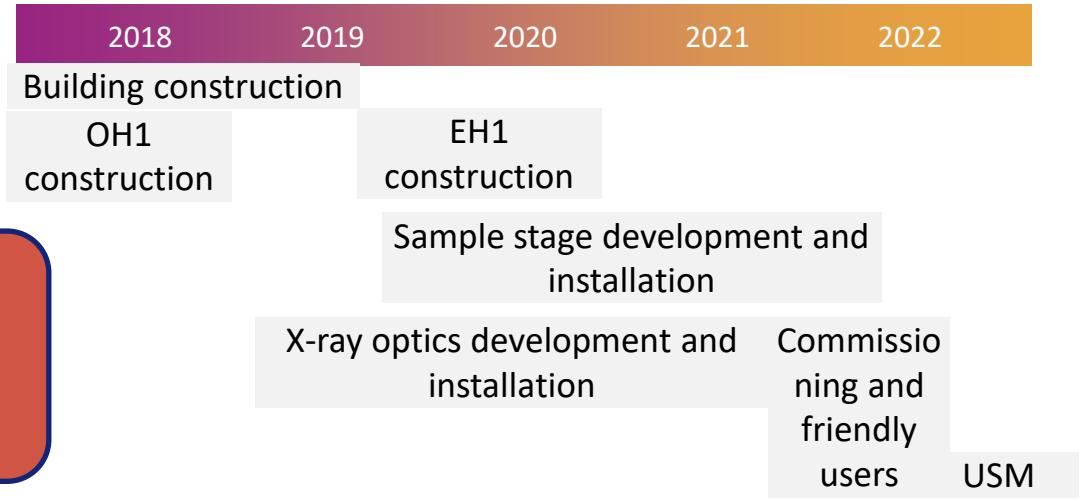
Main techniques:
- Hierarchical tomography
- Propagation phase-contrast imaging



EBS advantages:
- *Smallest possible X-ray source of the EBS*
- *Highest coherence worldwide for high-energy X-ray imaging.*

Main beamline characteristics:
- *Energy range:25-350 keV (polychromatic)*
- *220m long beamline, up to 38m for propagation phase-contrast*
- *Sample size up to 2.5m and 300 kg*
- *beam of 35cm*
- *High level of automation and high throughput*
- *Large resolution range (0.7 - 200 um)*

STREAMLINE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870313.

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Biomedical imaging

- A new scale in human body knowledge
- Understanding effects of diseases

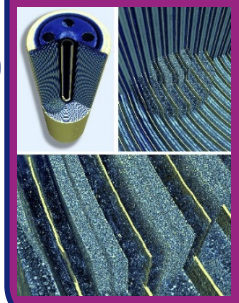
CHAN ZUCKERBERG INITIATIVE

Natural and cultural heritage

- understanding the evolution of life on earth
- Non-invasive structural study of archaeological specimens and art pieces

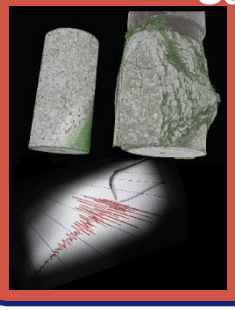
High sensitivity phase-contrast tomography in large and complex samples

Material sciences



- Non-destructive control of large devices (batteries, complex mechanical parts)
- Additive manufacturing (in-situ and ex-situ)

Geology



- origin of earthquackes
- Mecanisms of volcanoes
- Climate change

erc

Industrial applications

- Testing high-value objects
- Analysis of 3D structures of industrial products

Fraunhofer EZRT

STREAMLINE

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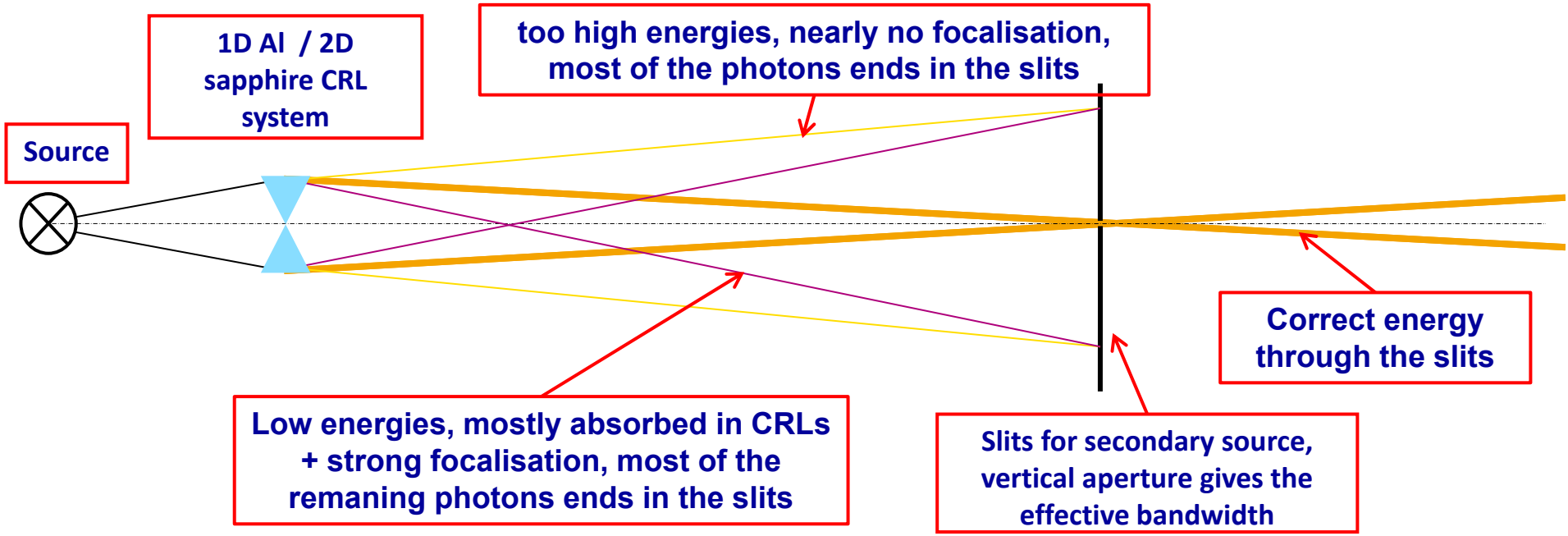

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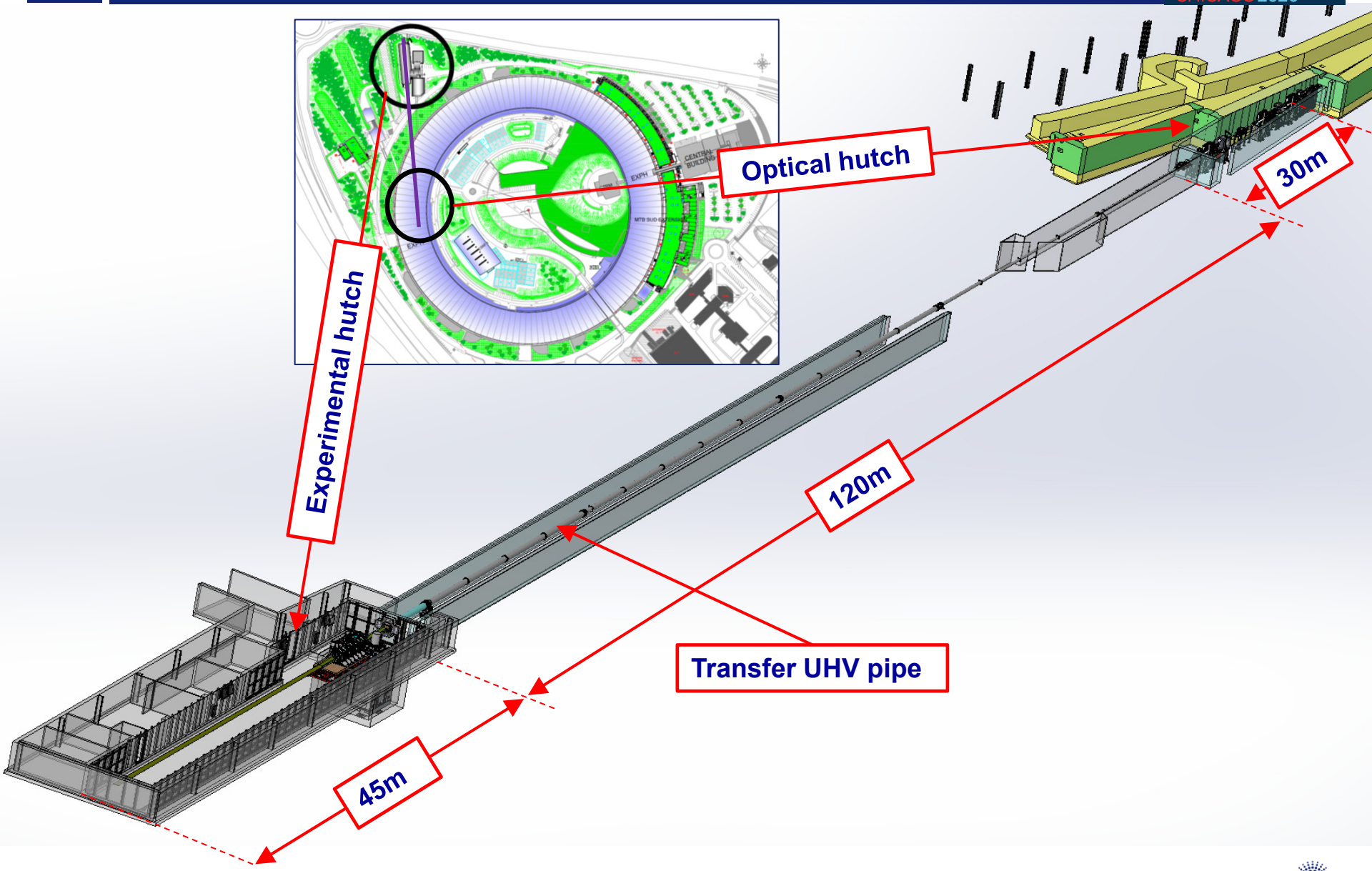
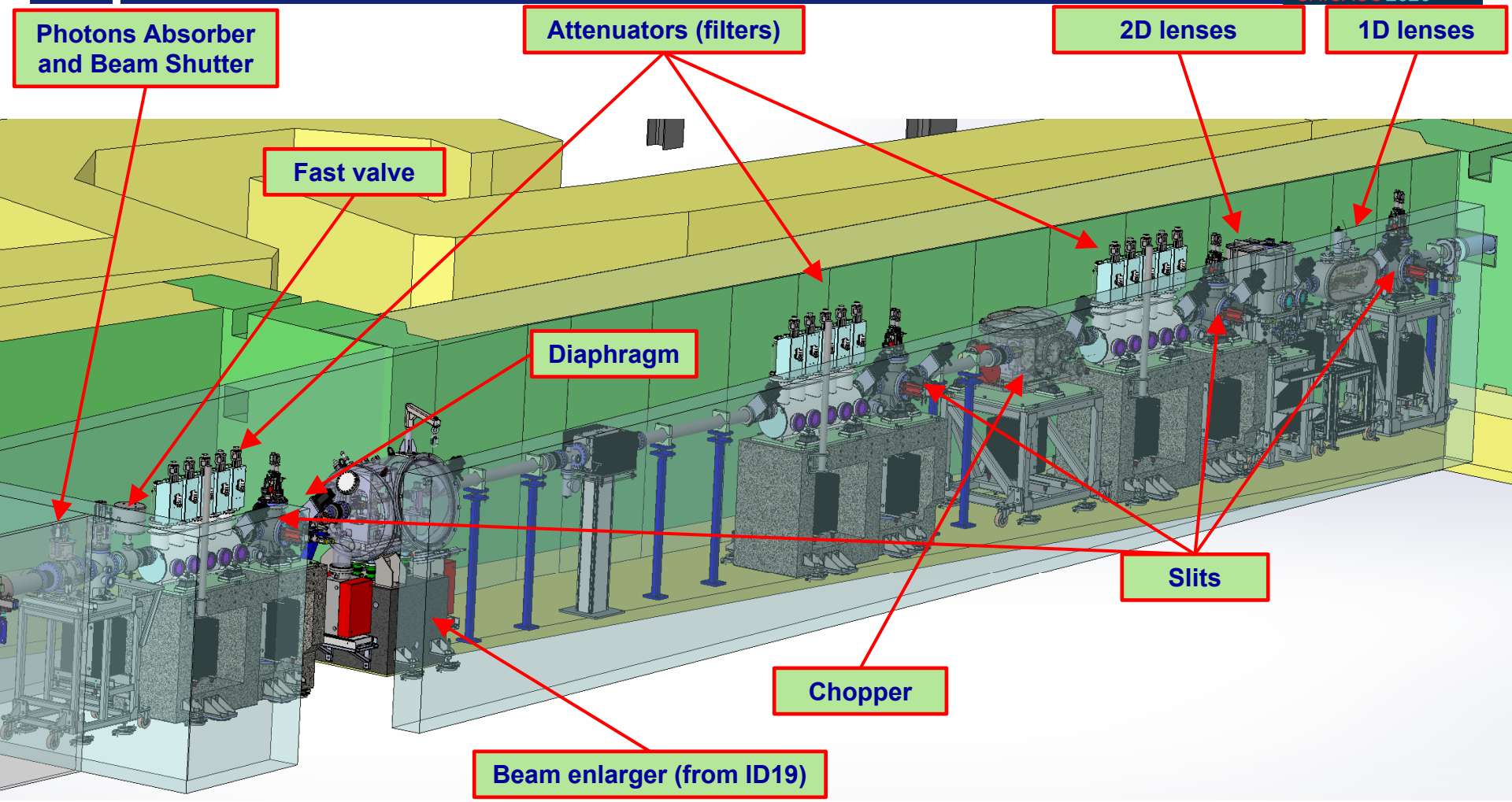
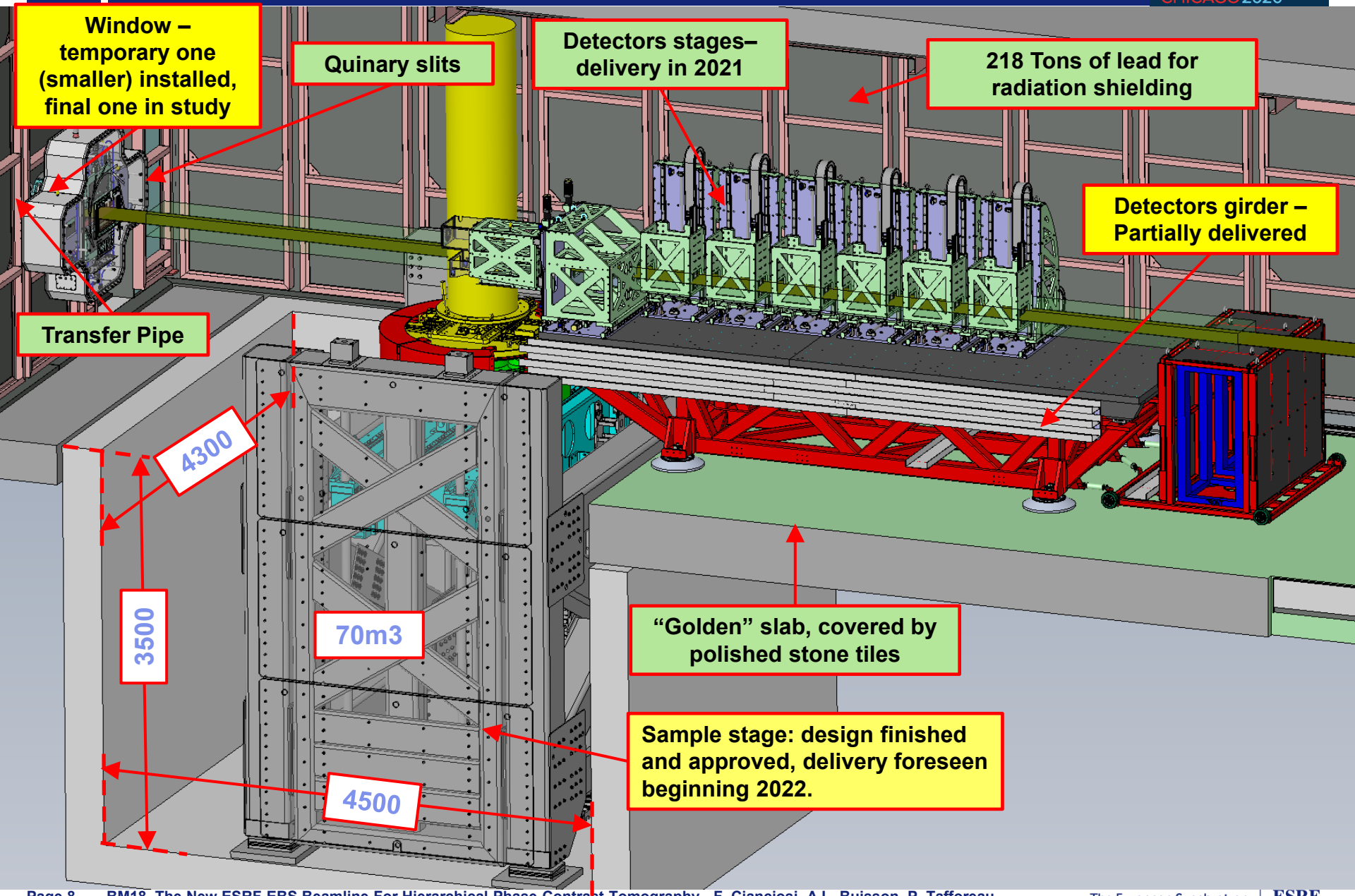


1.5 BEAMLINE LAYOUT – OPTICAL HUTCH



Nearly all components are ready, the few remaining are not critical for the start of the beamline. The radiation test is planned in September 2021

1.6 BEAMLINE LAYOUT – EXPERIMENTAL HUTCH



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Critical specification: Scan gap 10µm, → roll wobbling ~1µm - 10µrad

Linear actuators THKKR33 *in series*: the first one adjusts the position of both blades, the second one the aperture

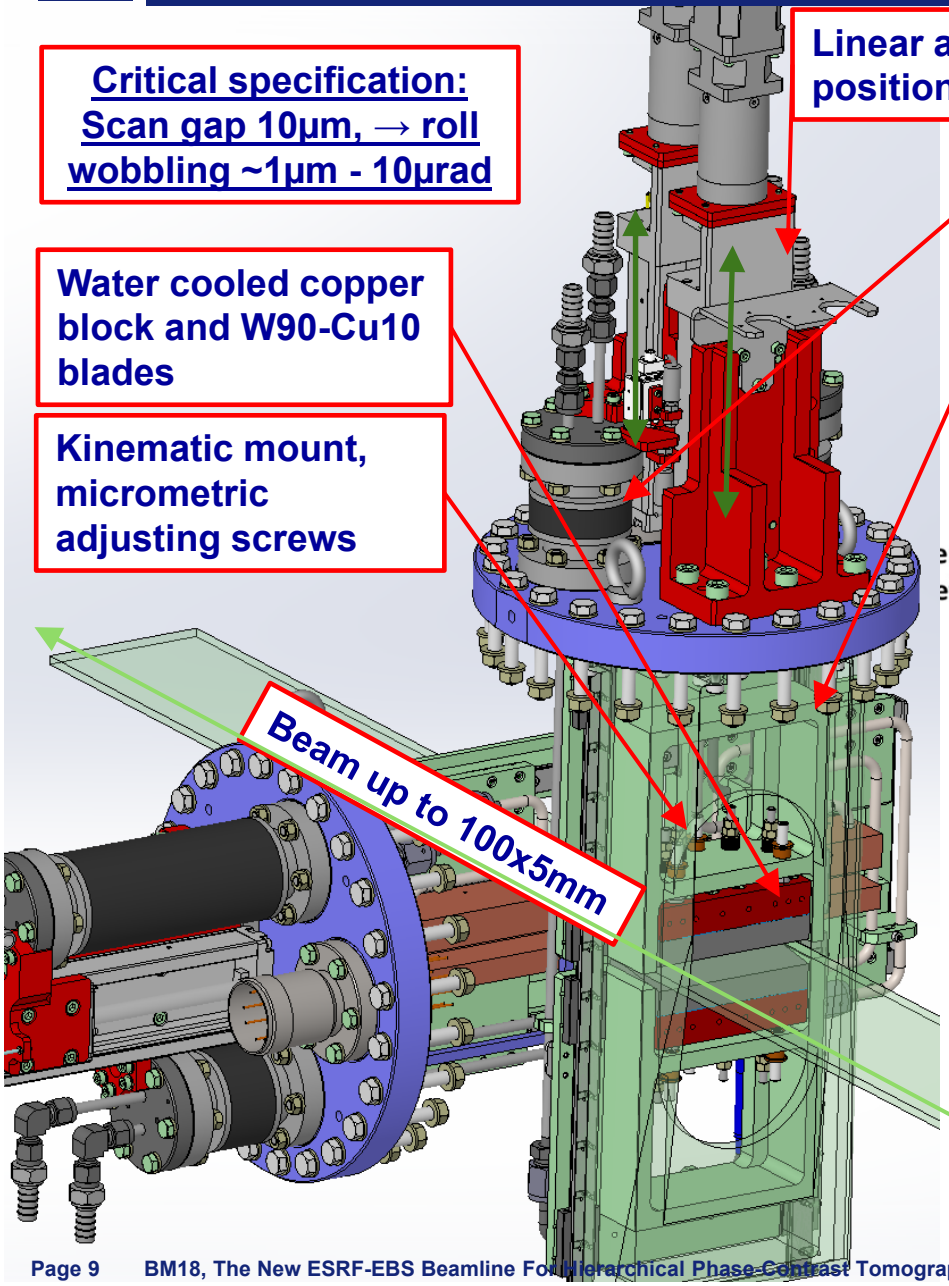
Invar connection, flexible radially

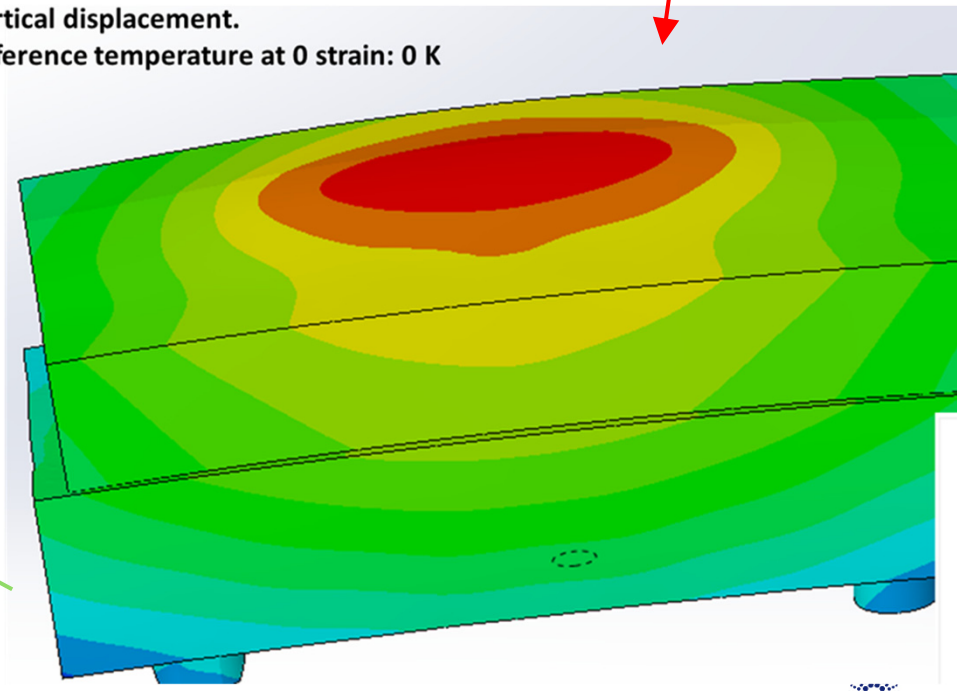
Water cooled copper block and W90-Cu10 blades

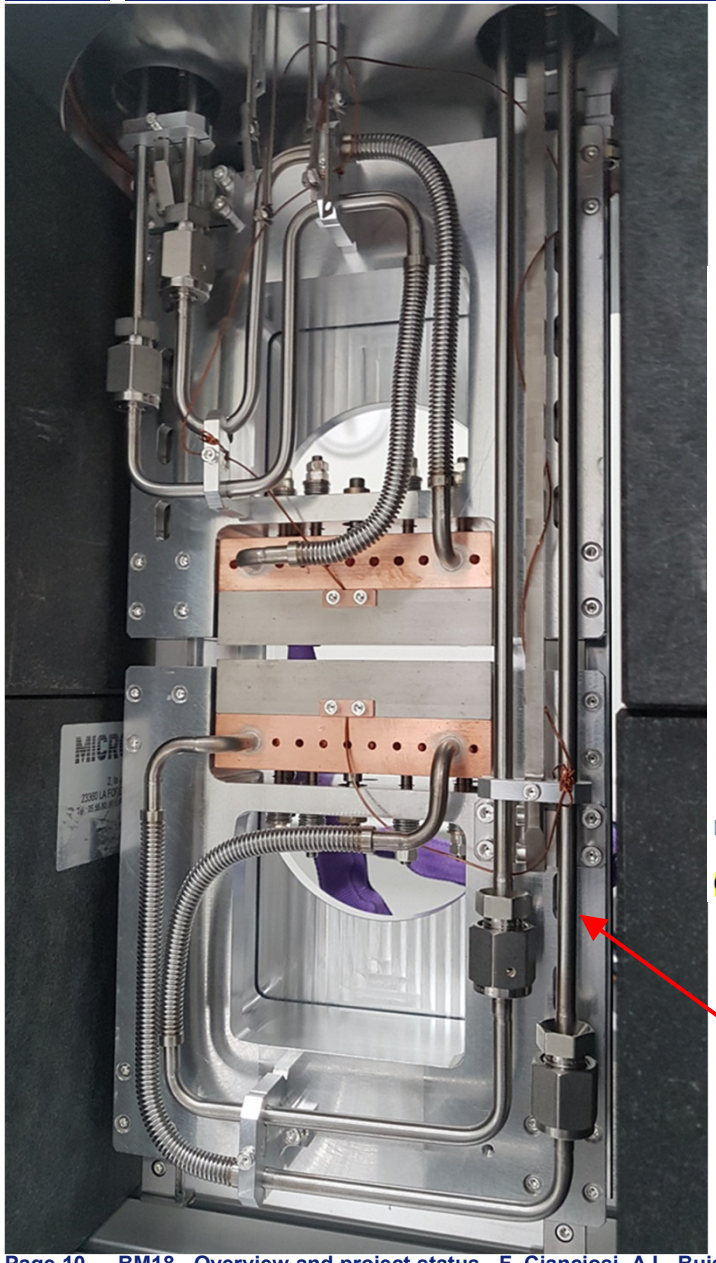
Rails Schneeberger MNNL14, specific for UHV, well spaced carriages

Kinematic mount, micrometric adjusting screws

FEM analysis to evaluate the displacement (<2µm) and deformation (<0.5µm)







Prototype received 2019 December
FAT results:
- **The resolution: 0.978 µm, standard deviation of 0.038 µm**
- **Bidirectional repeatability: 2µm**
- **Overall parasitic angle (wobbling): 2µm, very repeatable**

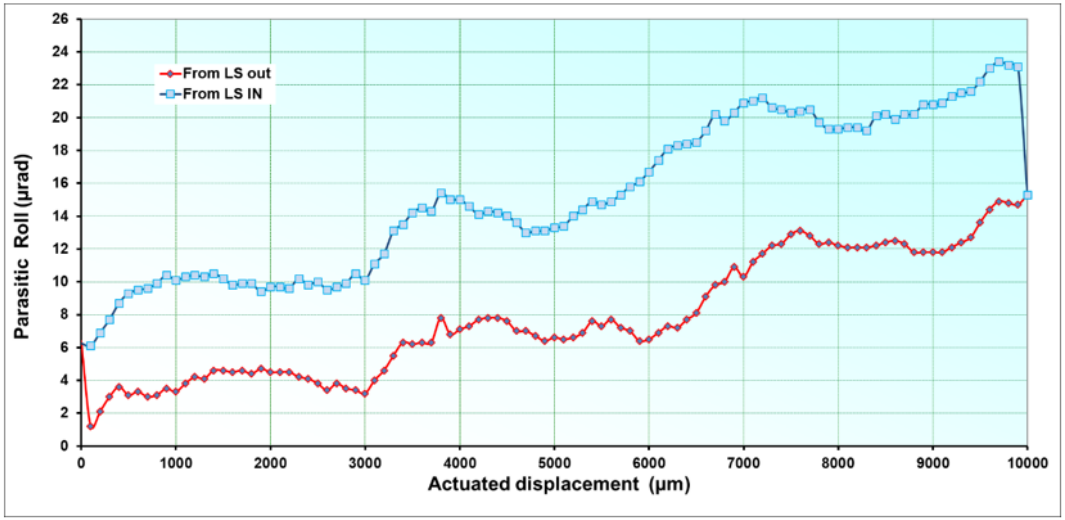


Fig. 16: Slit system parasitic roll in function of the displacement

OPA= 22.20 µrad

SAT results:
- **The measures made by the PAMU confirmed the FAT results, max wobbling about 2µm on the whole stroke.**

Used in BM5 and ID24 too

LENSES (1D + 2X1D)

5 axis translation stages

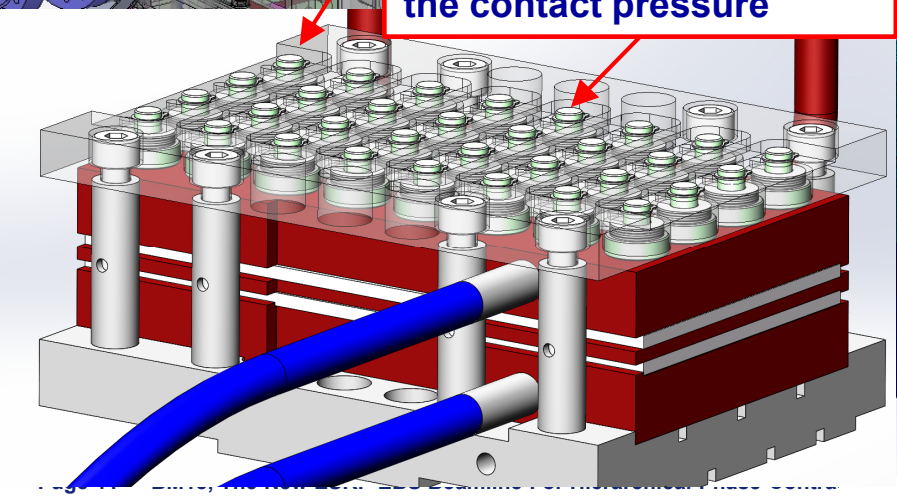
2D cross lenses - new design

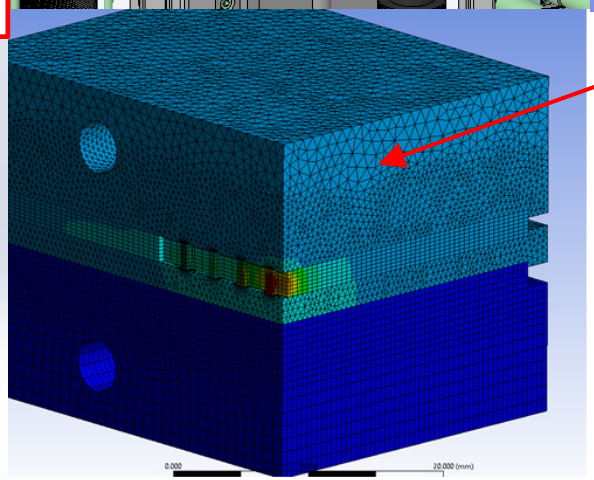
1D lenses from ID19

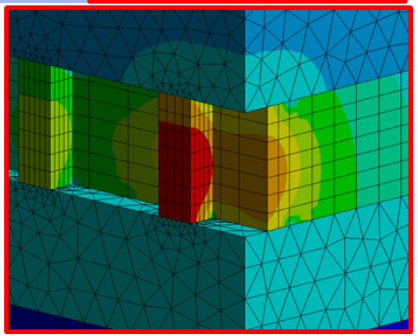
3 cooling loops for lenses and motors

Spring “bed” to optimize the contact pressure

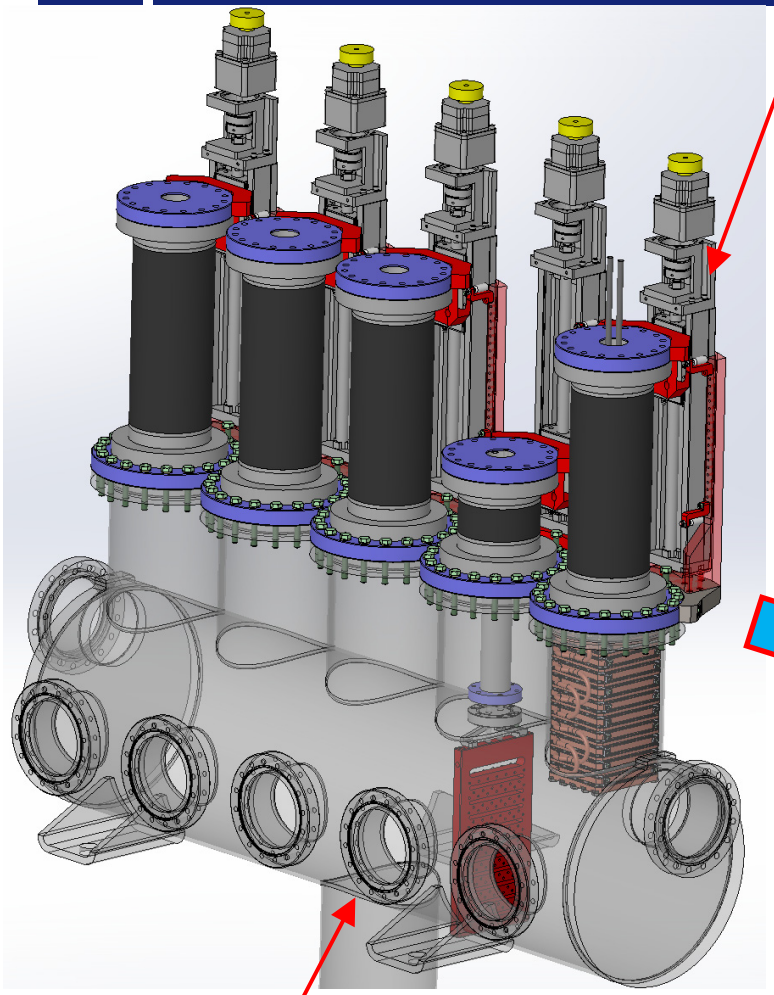
Thermal study with progressive power absorption in volume





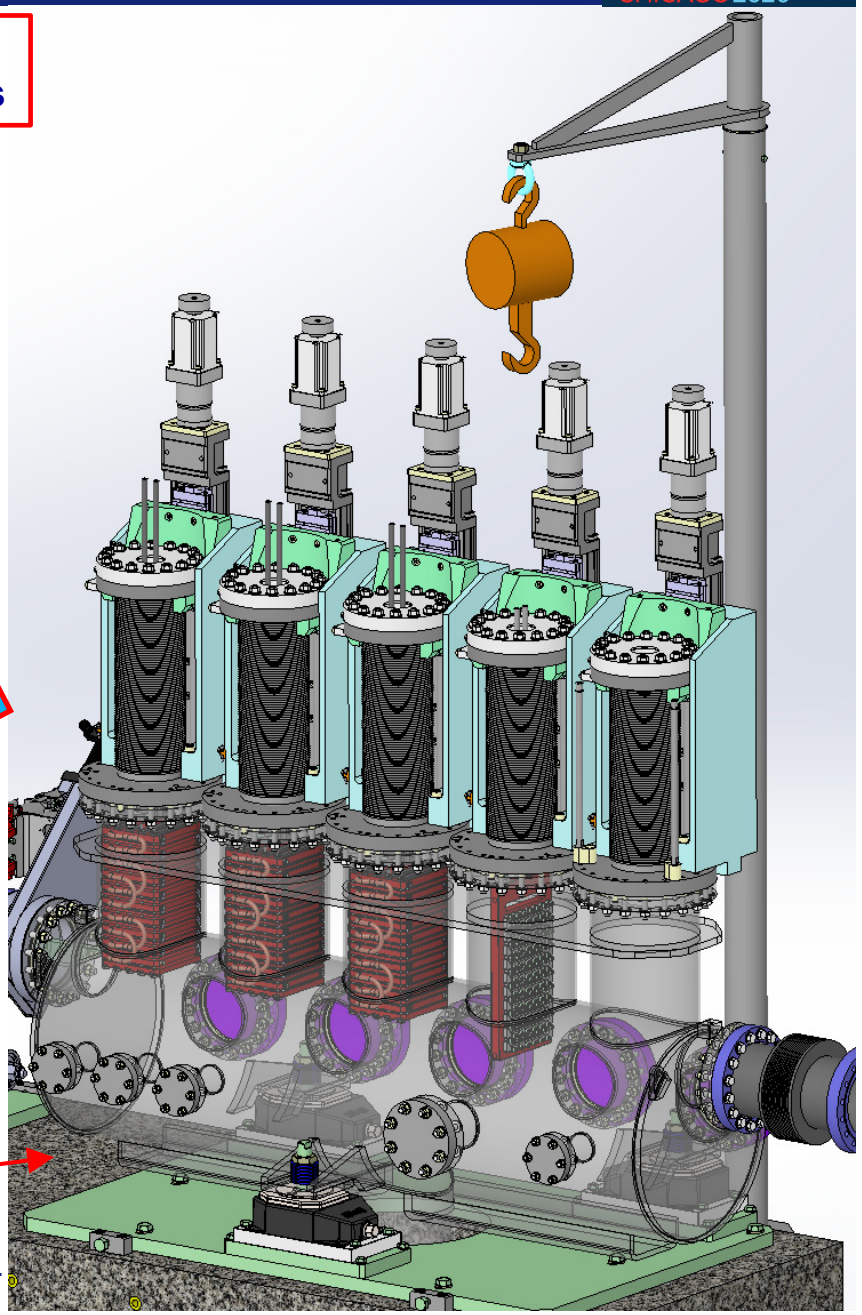


4.1 ATTENUATORS – CHAMBERS AND AXIS

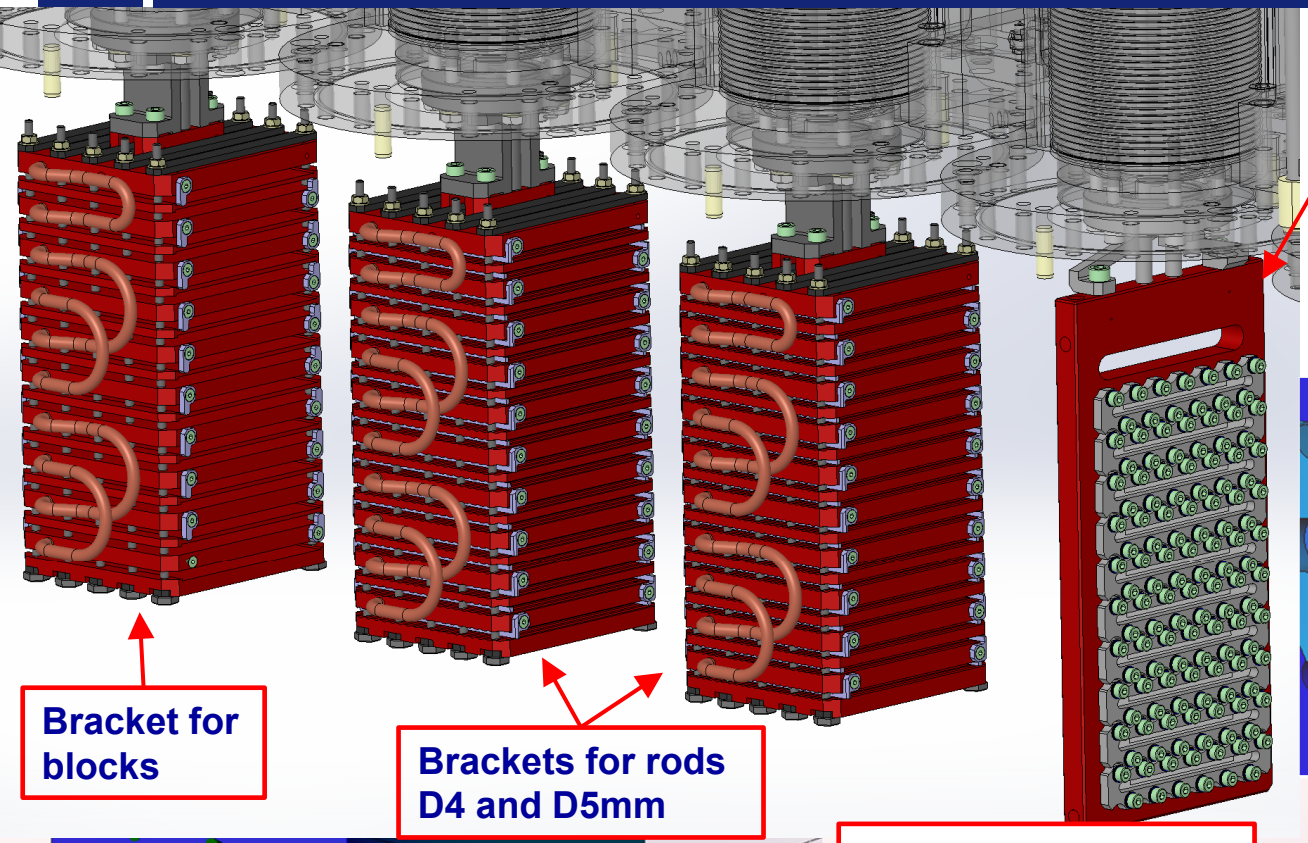


Commercial linear stages

ESRF conceptual design

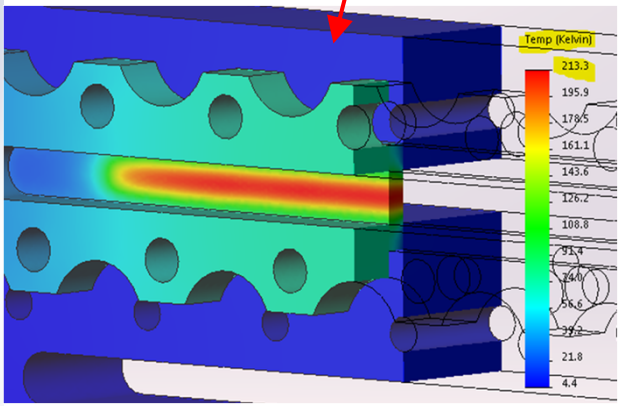


Final design developed by CINEL



Bracket for thin filters

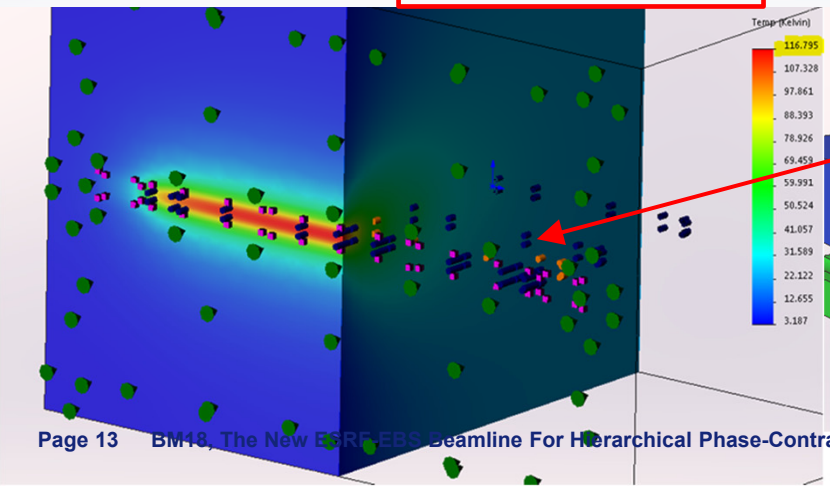
Examples of thermal calculations, repeated for all filters shapes and materials (C, SiO2, Al2O3, Al, Ti, Cu, Mo, Ag, W, Au)

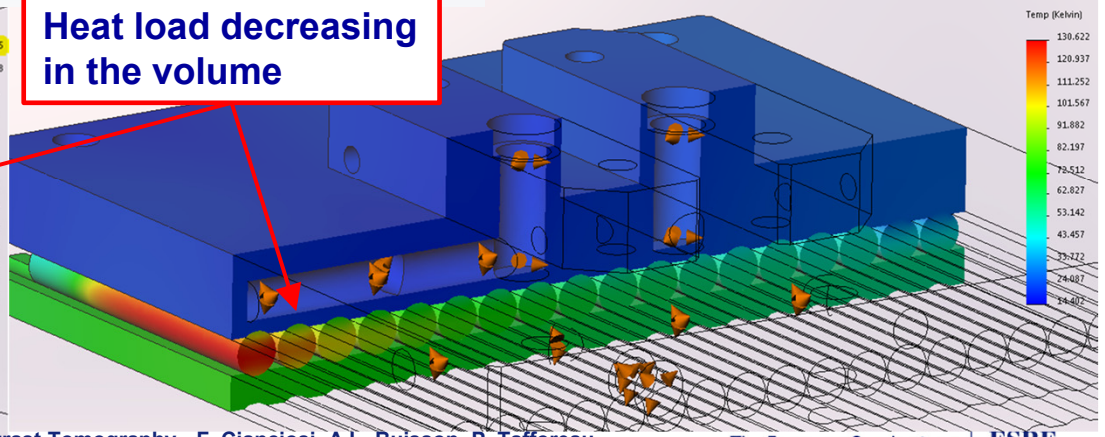


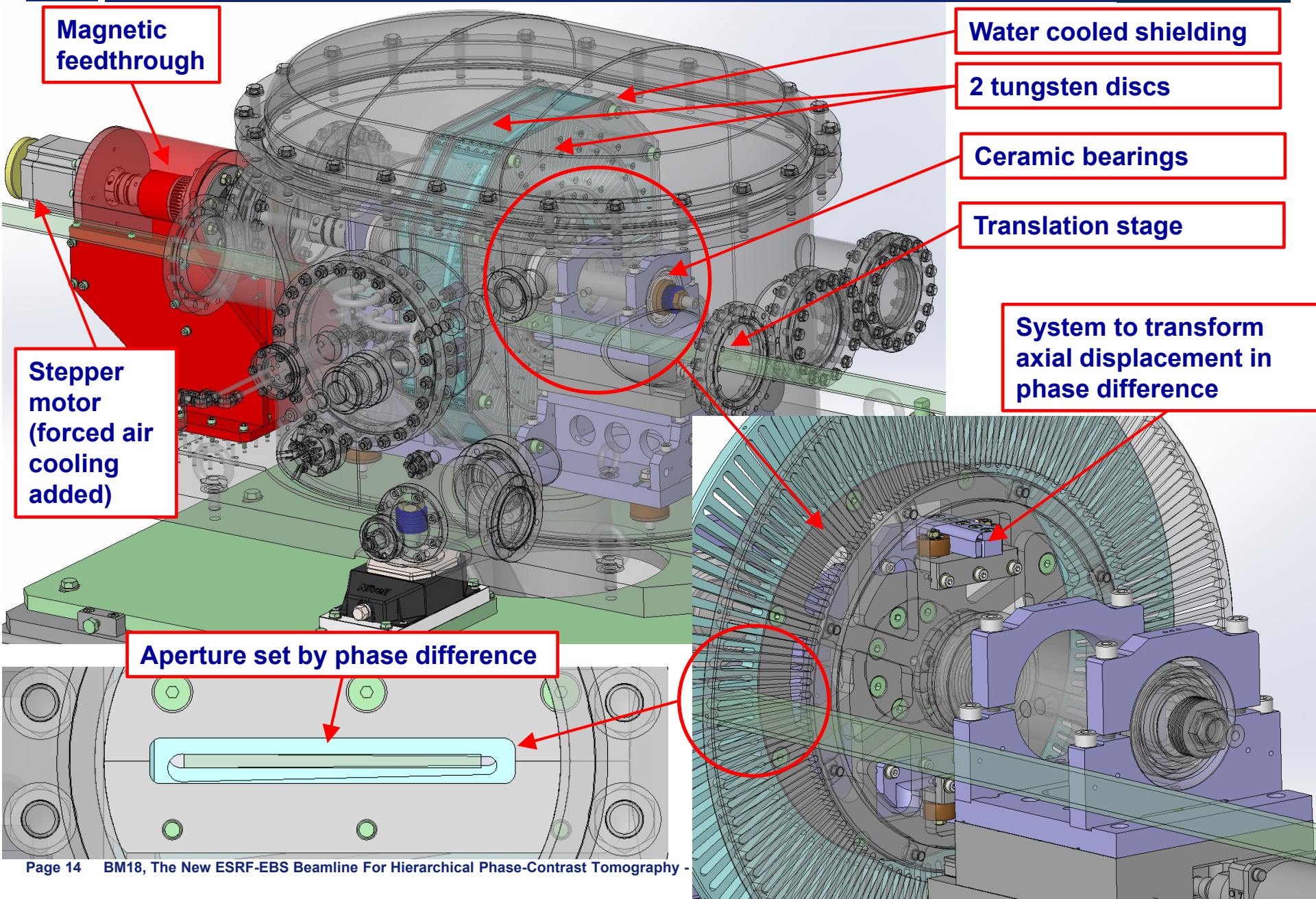
Bracket for blocks

Brackets for rods D4 and D5mm

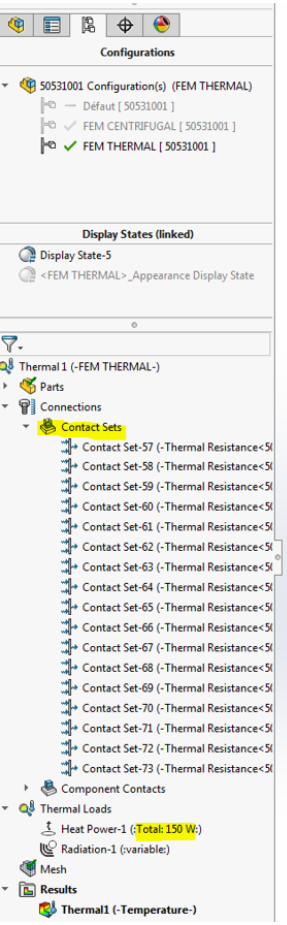
Heat load decreasing in the volume

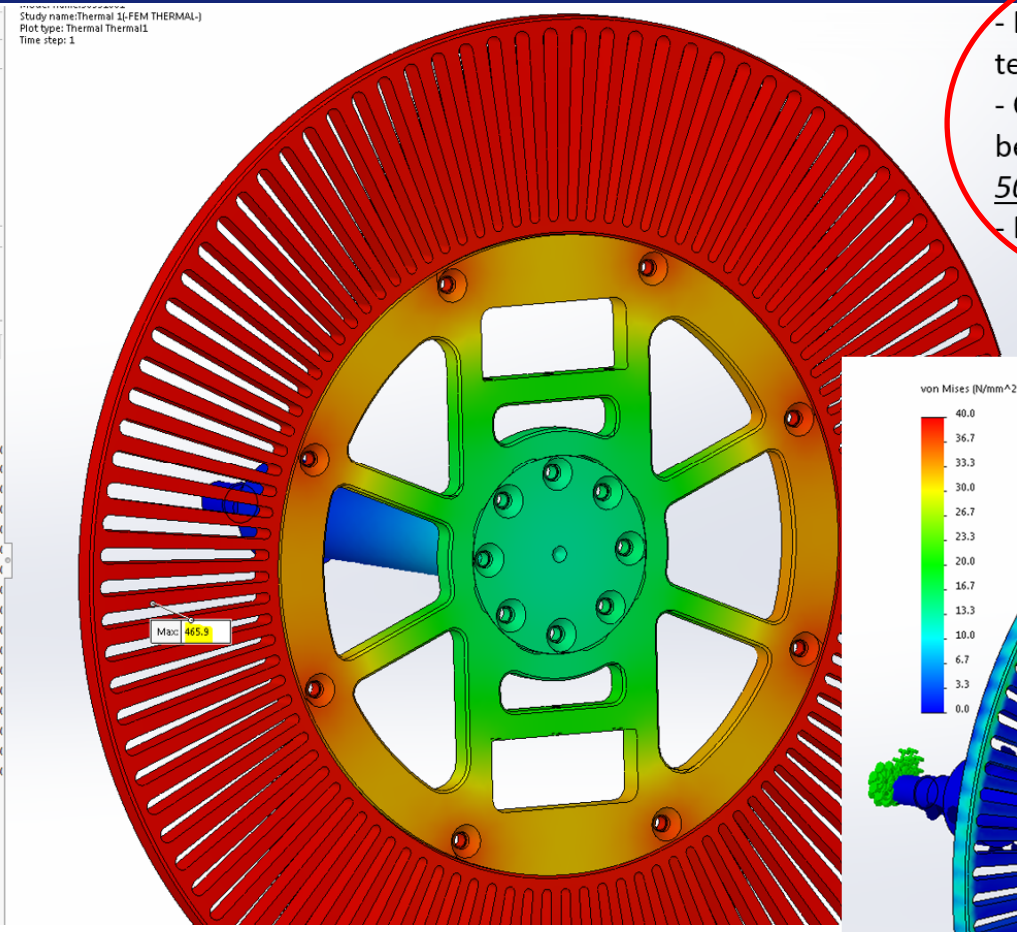





Magnetic feedthrough
Water cooled shielding
2 tungsten discs
Ceramic bearings
Translation stage
System to transform axial displacement in phase difference
Stepper motor (forced air cooling added)
Aperture set by phase difference

5.2 CHOPPER - CALCULATION

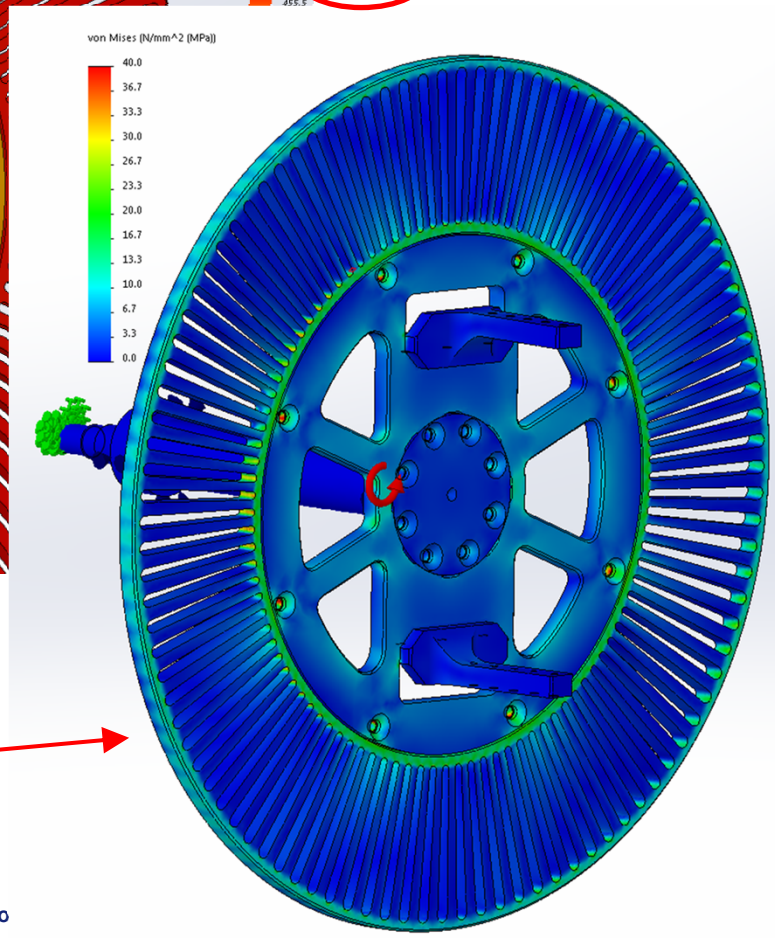




- Environment temperature 304.5K
- Conduction coeff. between all parts *5000* W/m2K
- Emittance coeff. 0.5

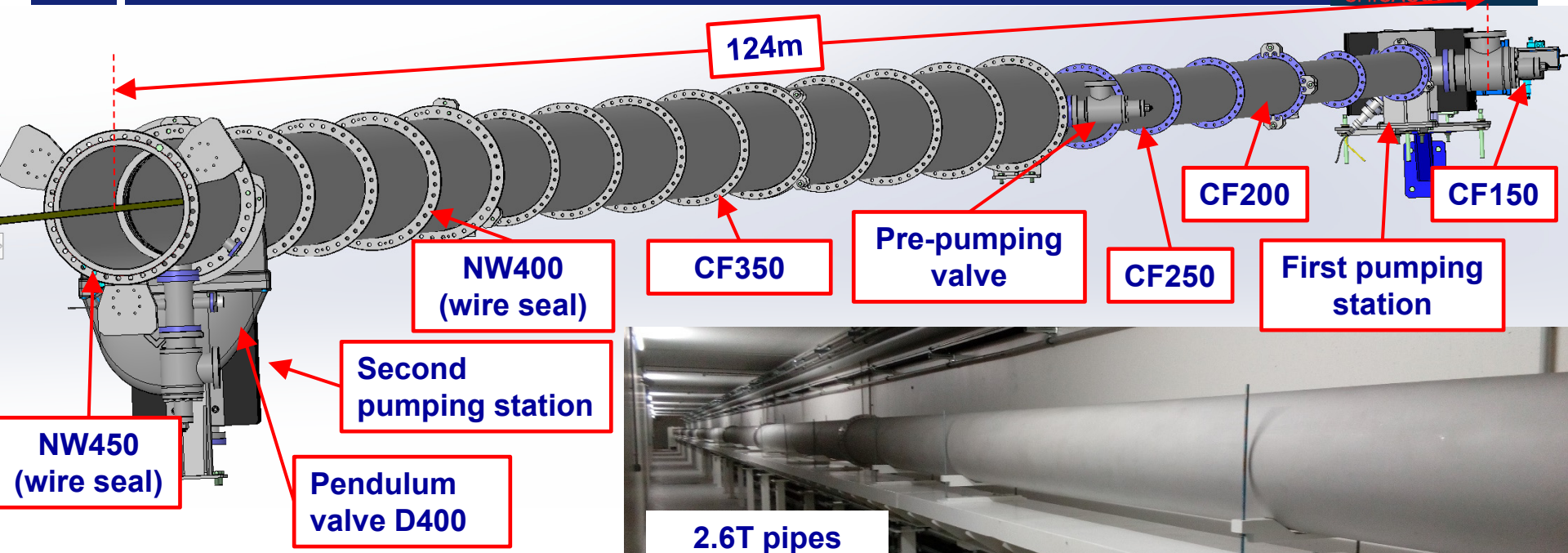
Radiation thermal transfer

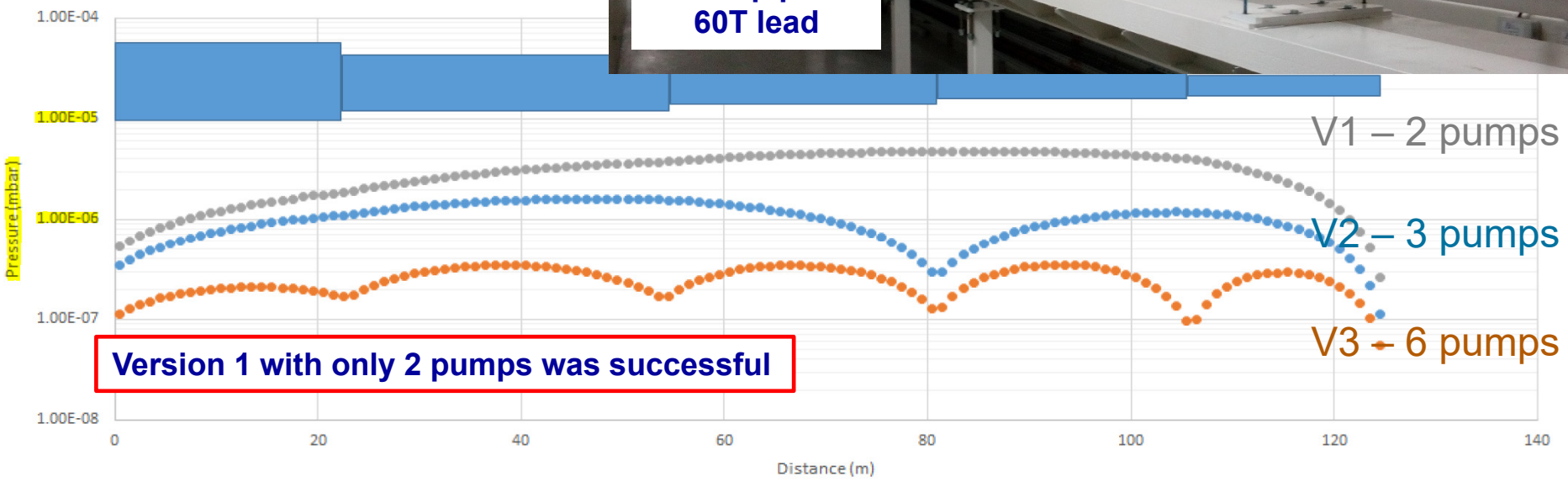
=193 C



Max stress less than 40MPa

TRANSFER PIPE





Version 1 with only 2 pumps was successful

7.2 WINDOW – SPECIFICATIONS AND TEMPORARY SOLUTION

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Specifications:

Beam dimensions up to360x200mm:
- **Enough strength to resist to vacuum (720kg)**

Material transparency:
- **Max thickness ~2mm (Z=13, aluminum) or 6mm (Z=6, carbon)**
- **Mirror surface polishing**
- **Microscopically and macroscopically homogeneous material**

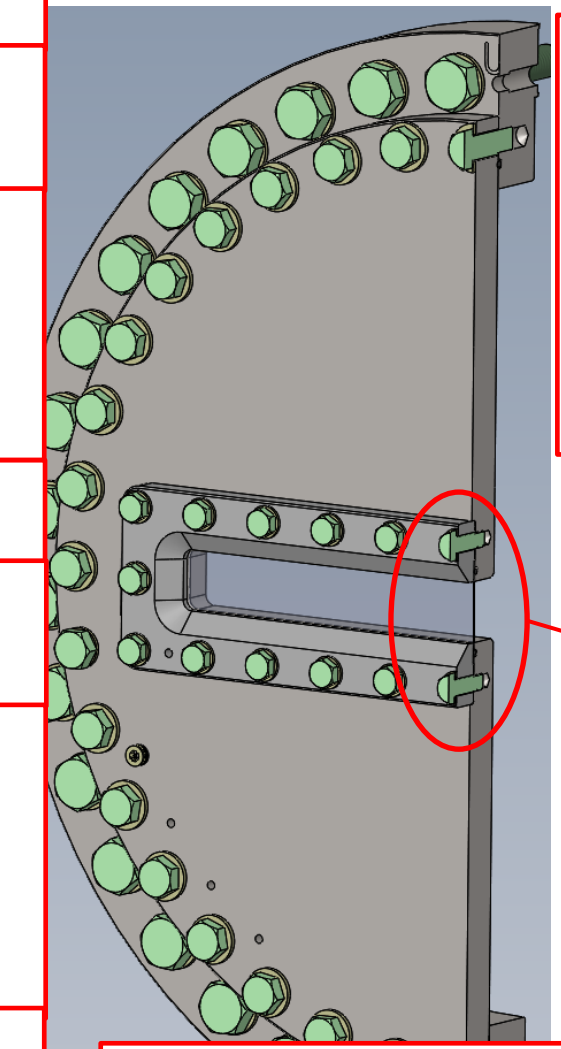
Resistance to radiations:
- **Many years of continuous X-ray beam**

Resistance to relatively high temperature:
- **Depending by the absorption rate and thermal conductivity**

Safety
- **Not unproven material and solution**
- **Good safety margin for stress**
- **Resistance to accidental impacts and scratches**
- **No danger for handling and in case of failure**

Durability
- **Resistance to air oxidation (even if under N2 pressure in use)**

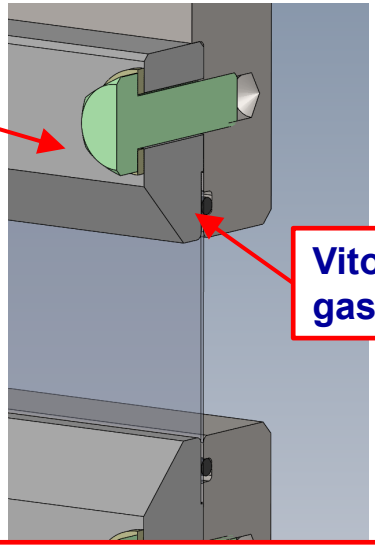
Reasonable price



Beryllium window made from Be plate 350x50x0.6mm, already own by ESRF.

Useful window 330x30mm

Calculation (P. Theveneau, analytical)
σ=125MPa
K safety respect yield: 1.76

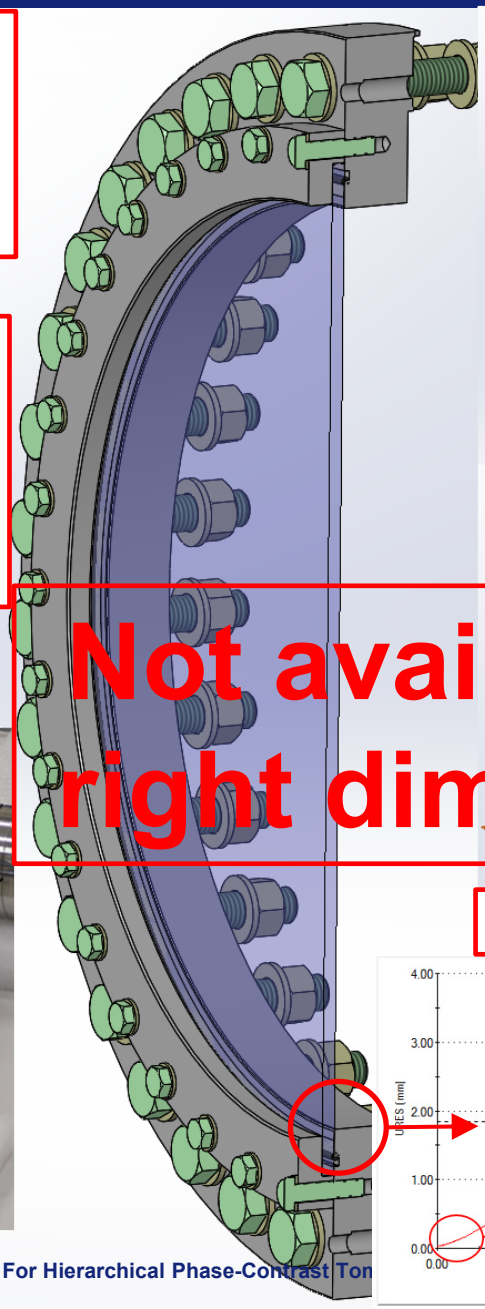


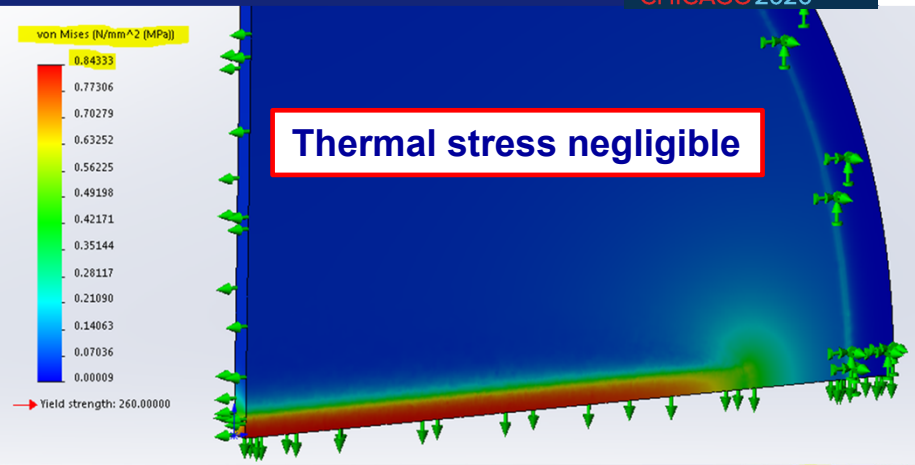
The obvious solution is a be window based on a plate 440x240x6mm, but the high price make us look if an alternative solution exists

Advantages:
- Relative big thickness allowed (6 mm)
- High tensile strength
- Heat resistance

Disadvantages:
- Fragile, possible failure in case of material defects or impact
- Uncertain mechanical properties

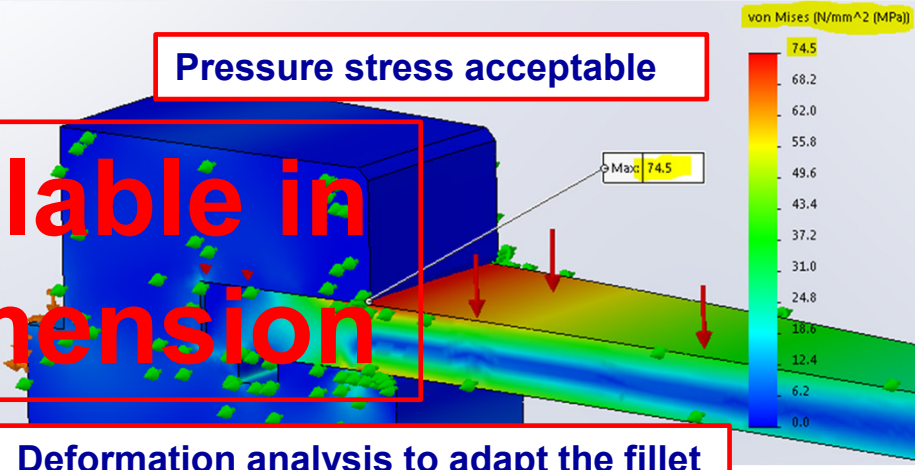
Reduced scale test





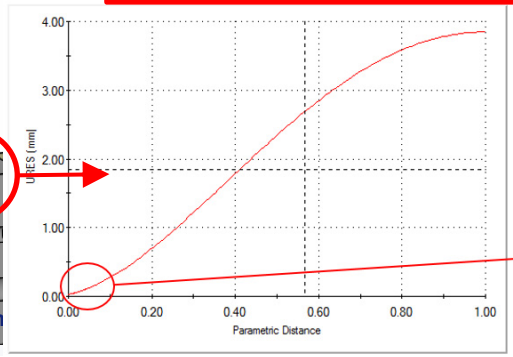
Thermal stress negligible

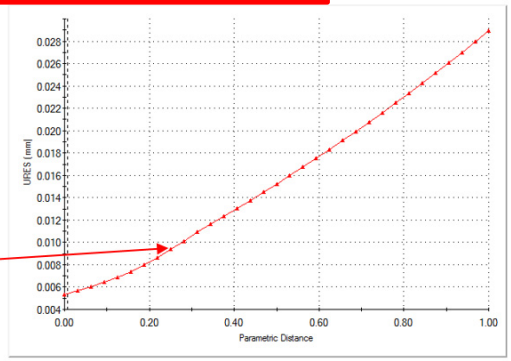
Pressure stress acceptable



Not available in right dimension

Deformation analysis to adapt the fillet



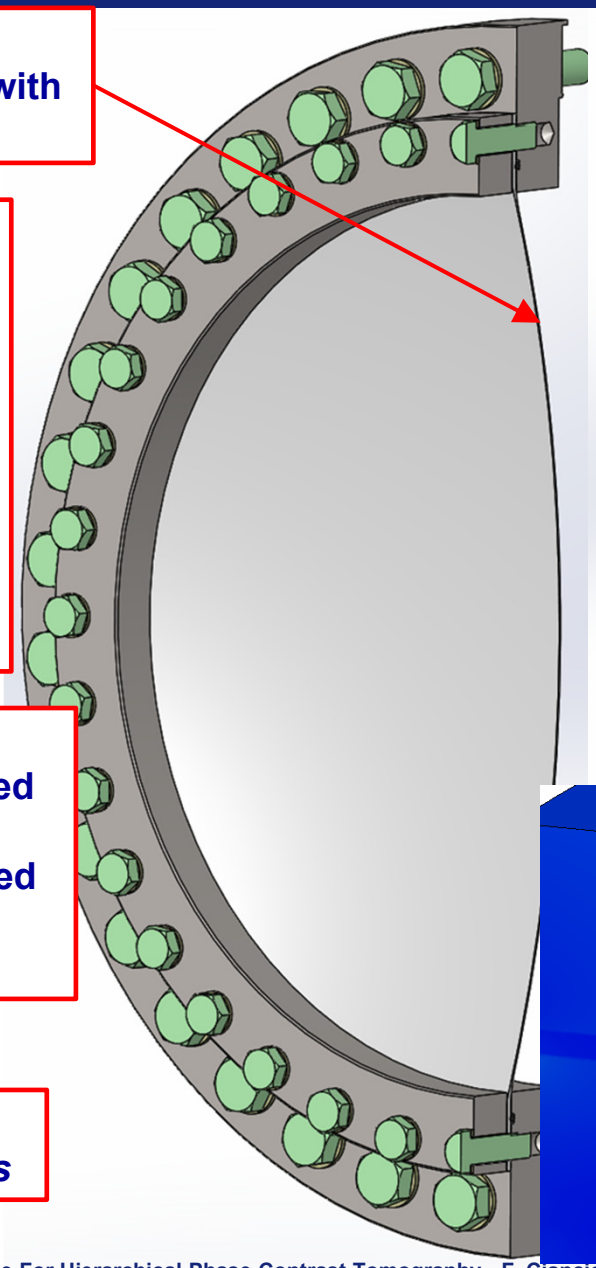


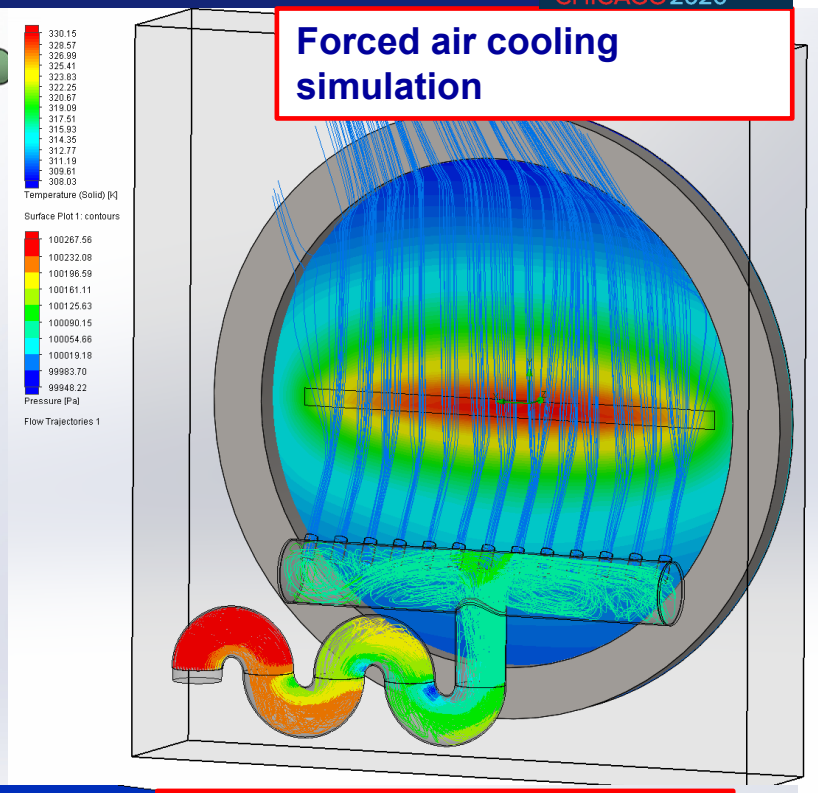
Dome in aluminum 1050 machined from the bulk, with variable thickness

Advantages:
- Ductile material
- Inexpensive
- Easy to procure
- Easy to polish
- Transparent as Be at high energy
- Mechanical characteristic well known.

Disadvantages:
- Small thickness allowed
- Sensibility to heating
- Only few alloy permitted Worst than Be at low energy

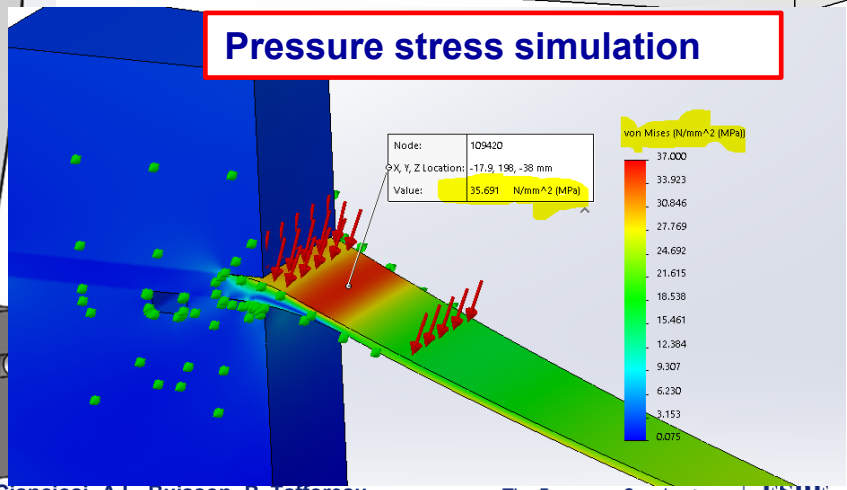
Thanks to Miguel Santos for the useful suggestions



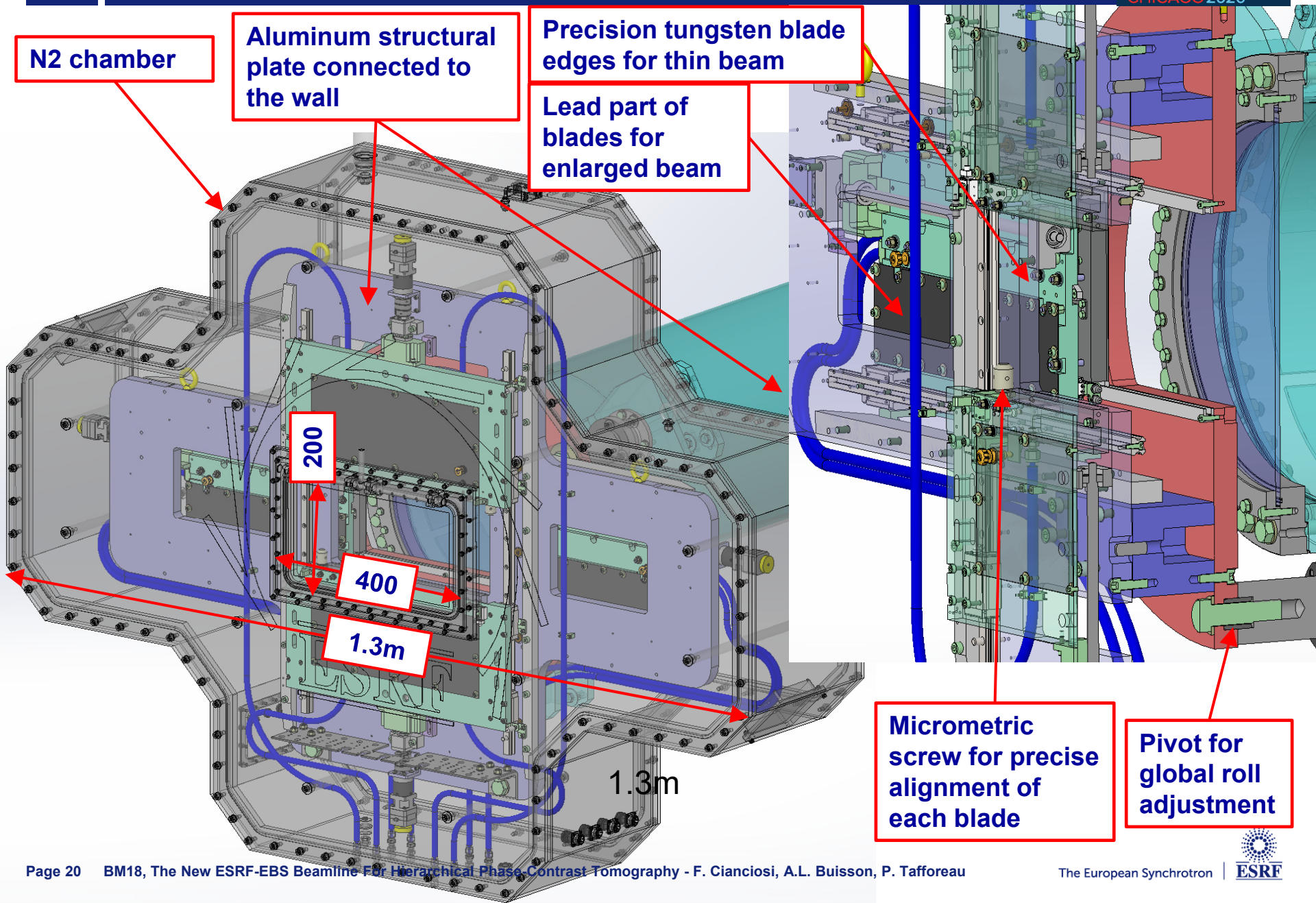


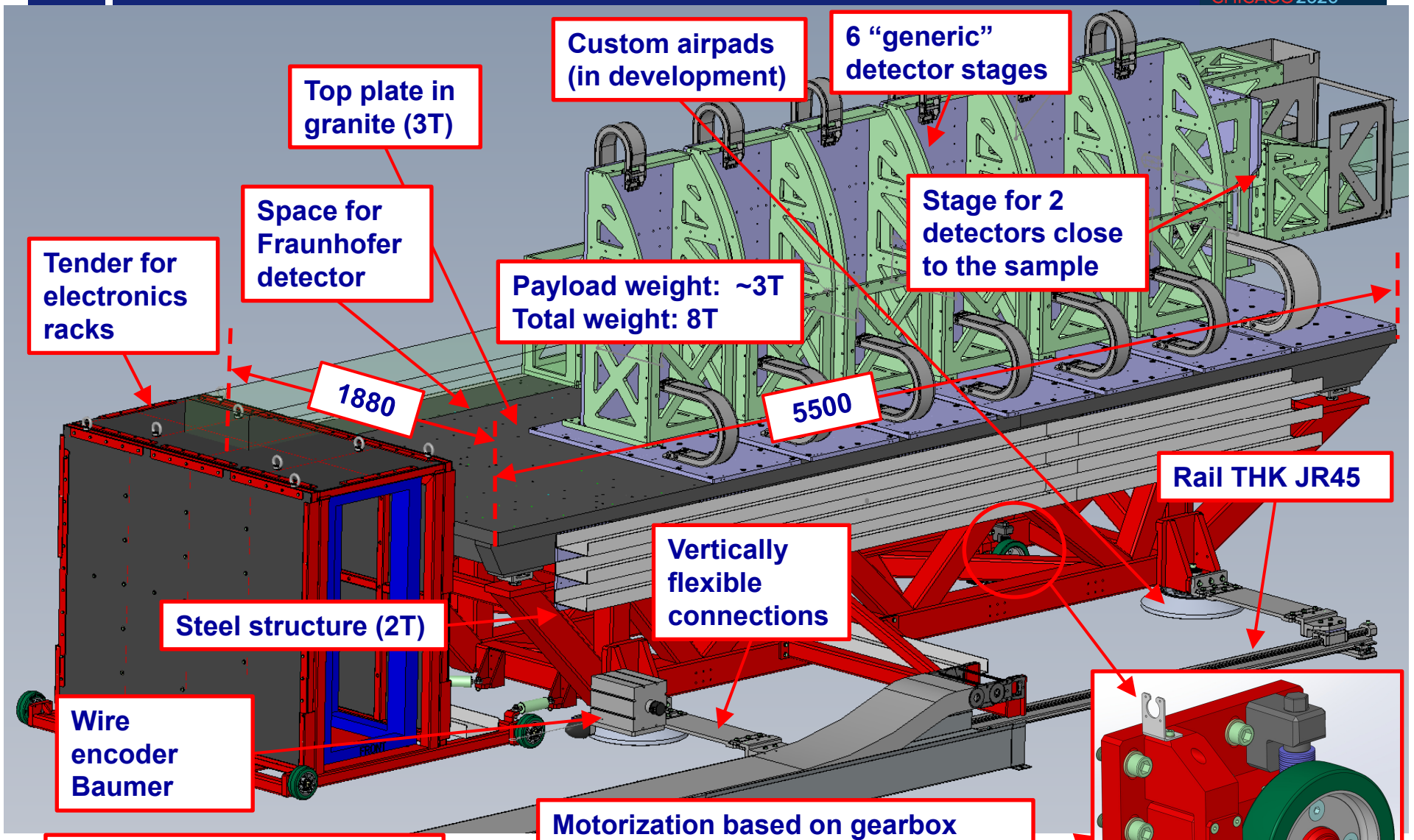
Forced air cooling simulation

Pressure stress simulation



EXPERIMENTAL HUTCH SLITS





Many thanks to T. Durand for the collaboration.

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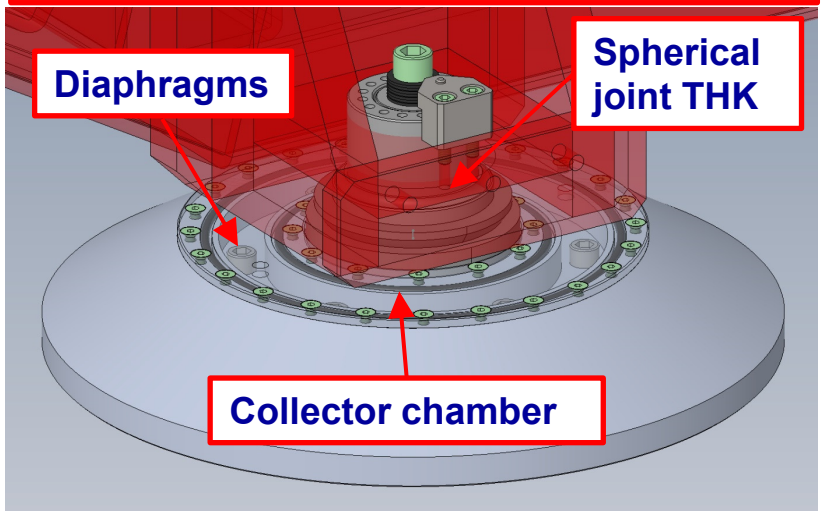
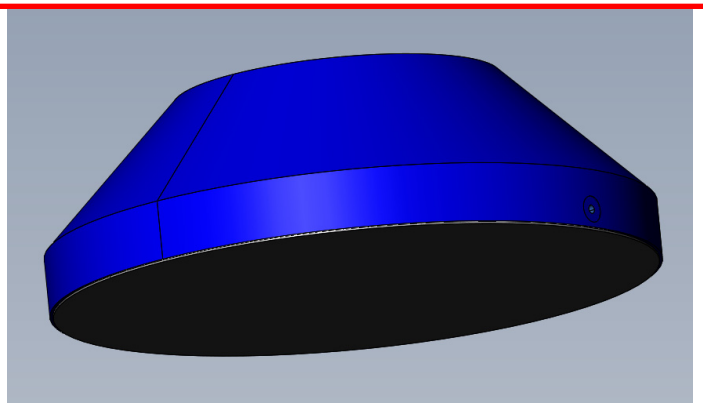
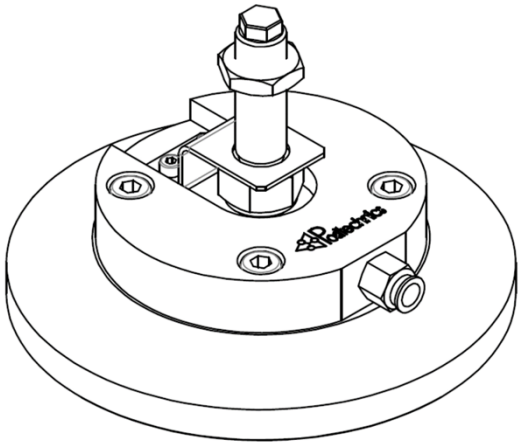
ESRF design D450mm (2T load, 4 pads)



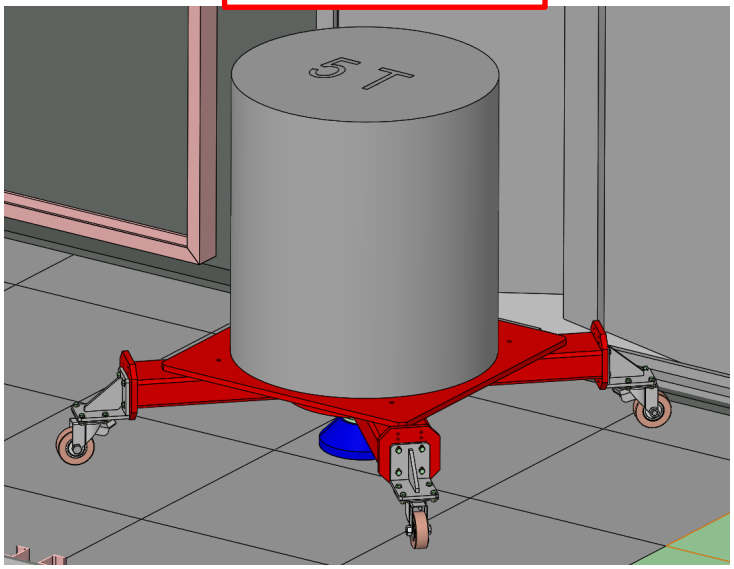
Commercial pad D300mm with porous graphite (1T → need to be coupled 2x4=8 pads)



Commercial pad D160mm (0.5T → need to be coupled in 2x2x4=16 pads)



Test on going…



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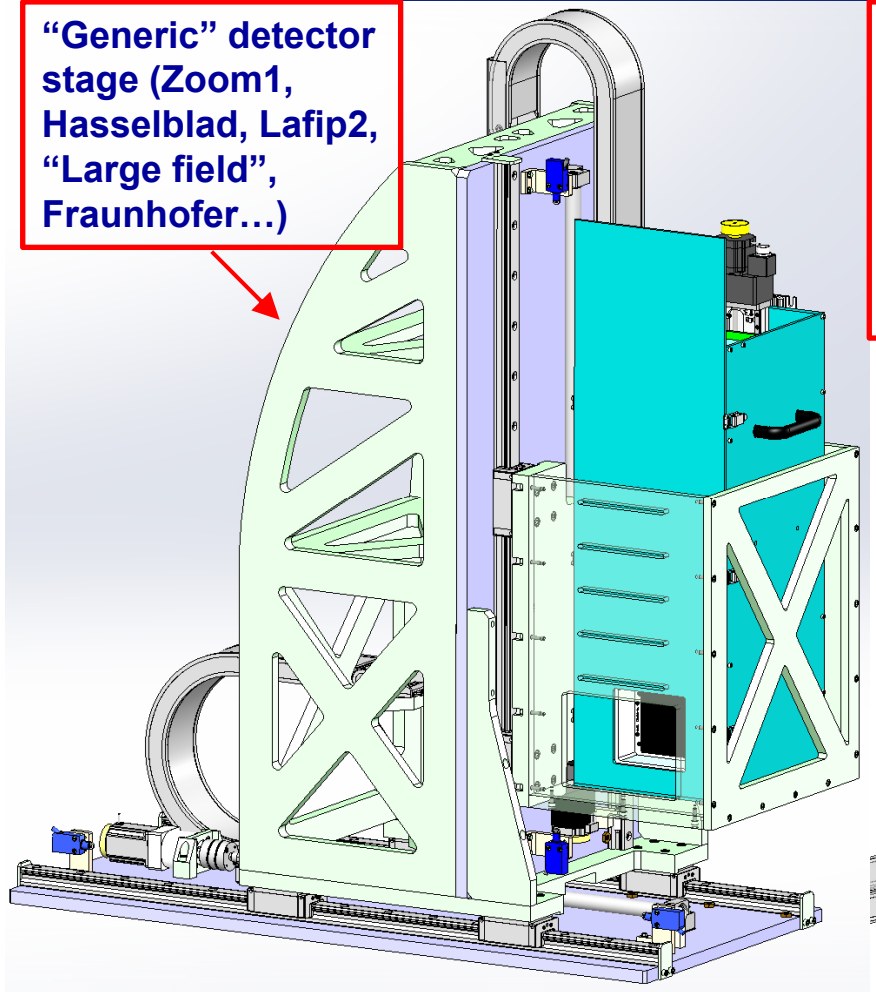
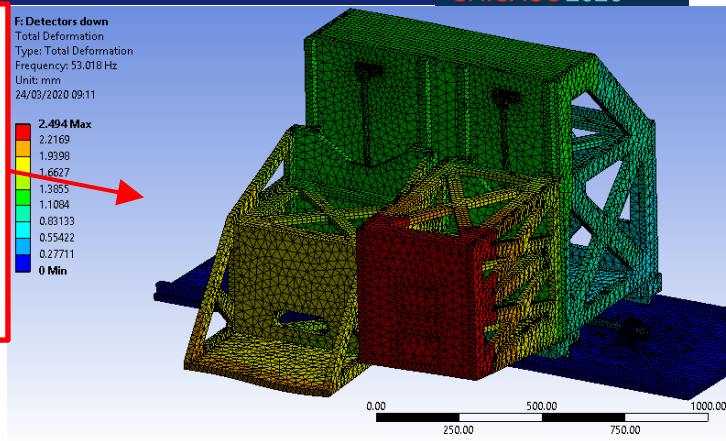
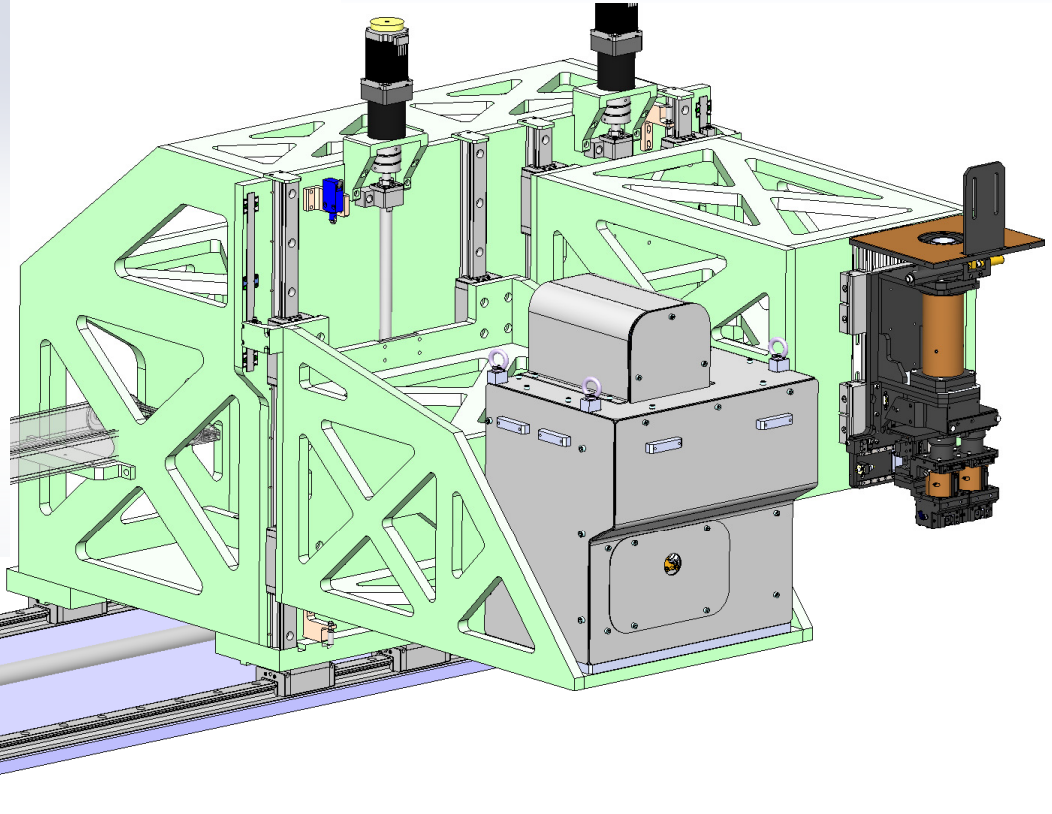
"Generic" detector stage (Zoom1, Hasselblad, Lafip2, "Large field", Fraunhofer…)



Careful analysis and precise optimization due to the cantilever shape and detectors weight.





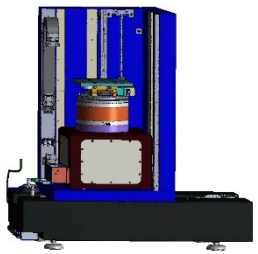
Detector stage for detectors close to the sample (Twinmic and Zoom2)

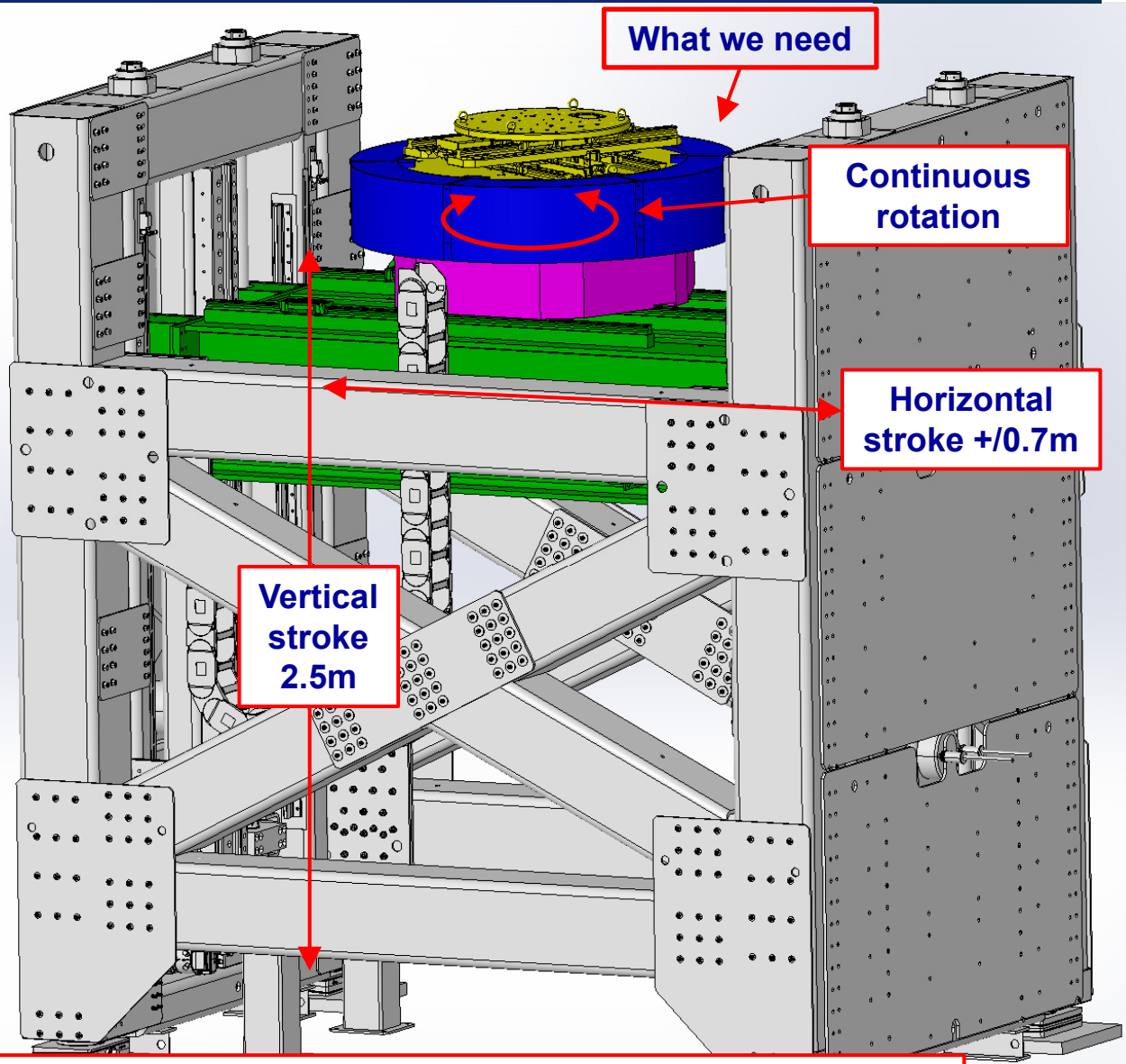
Main requirements:

- Sample: weight up to 300Kg, height 2.5m, diameter 0.6m (diam. up to 2.4m with limitation in vertical stroke)
- Positioning repeatability of tomography axis 1µm
- Spindle with sphere of confusion 0.5µm
- X-Y positioning stages for sample over the spindle

What we have to scan

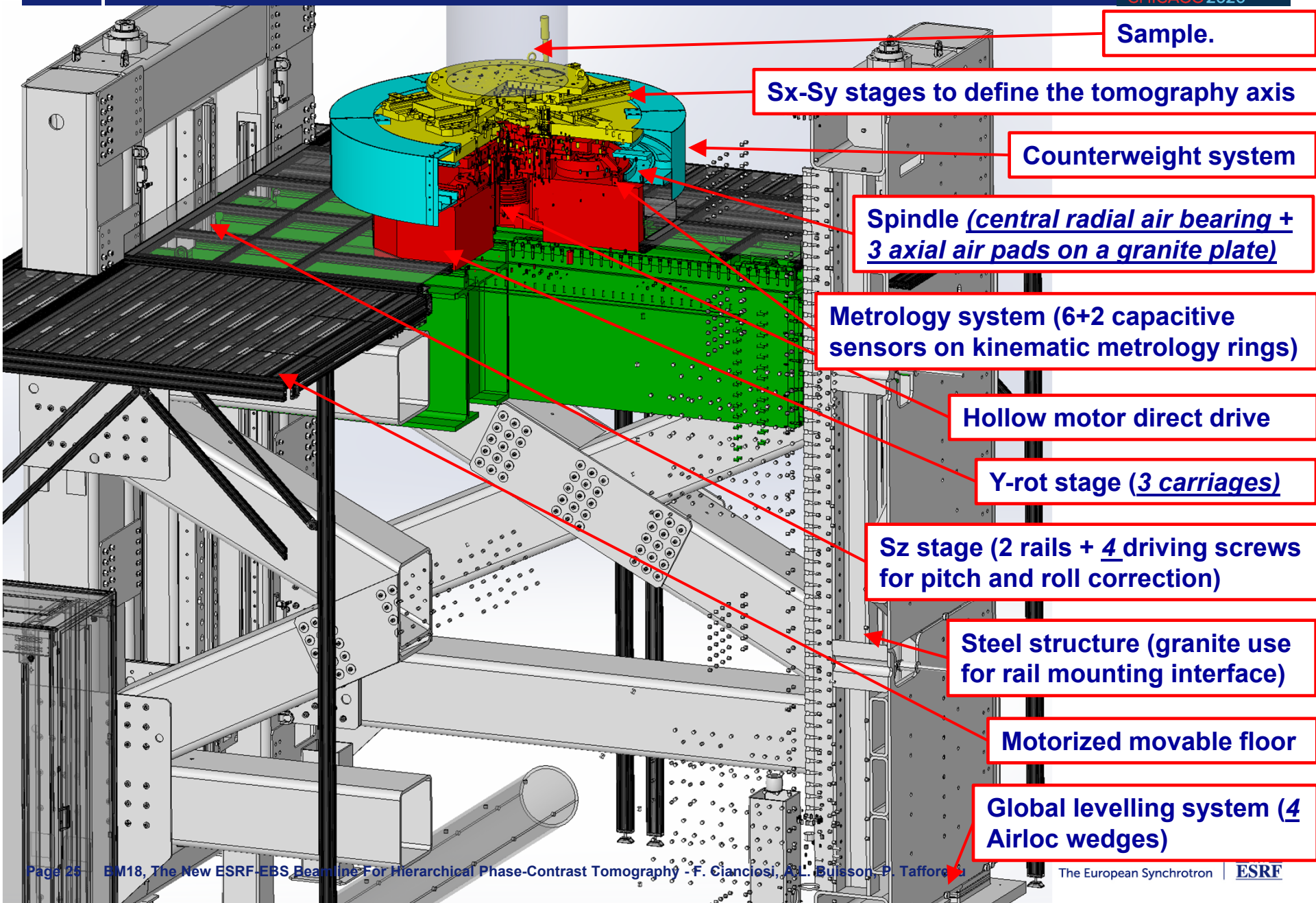
What we have



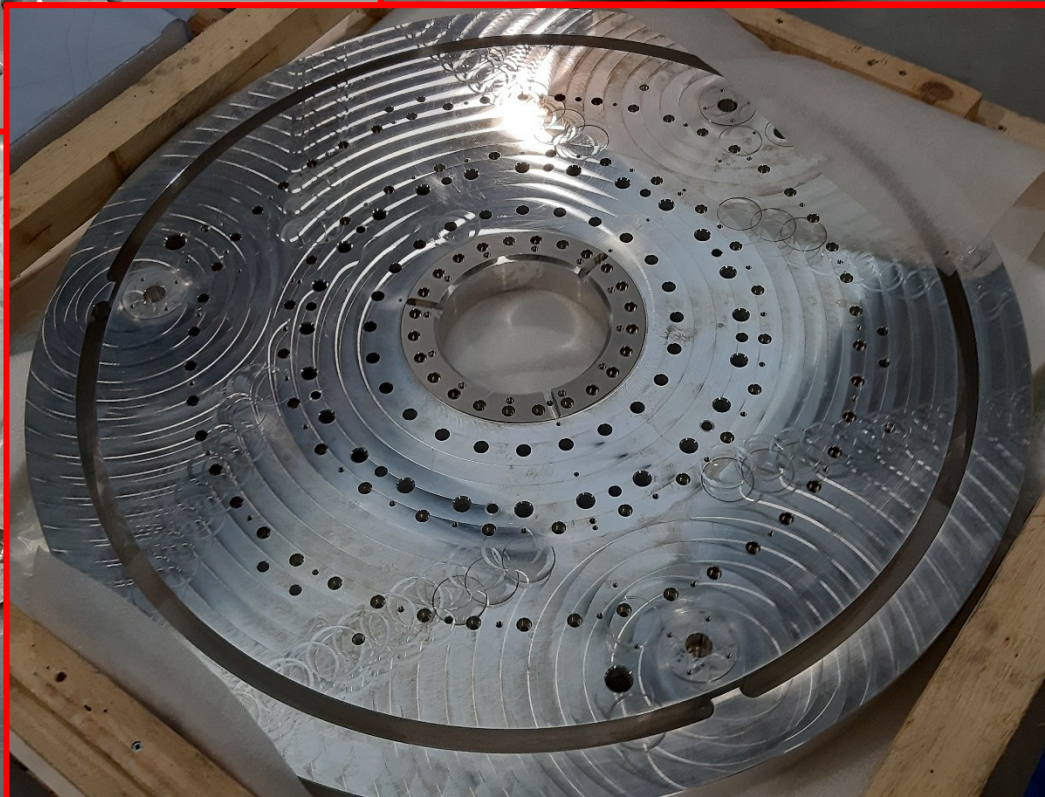


Contract for design and construction assigned to LAB Motion System (Belgium)
Design in close collaboration with ESRF

11.2 SAMPLE STAGE – PROPOSED DESIGN BY LAB MOTIONS SYSTEMS



11.3 SAMPLE STAGE – BEGINNING OF MACHINING



THE BM18 TEAM

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MANY THANKS !

Questions?

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