Update of the BM18 ESRF Beamline Development: Presentation of Selected Equipment and their Commissioning

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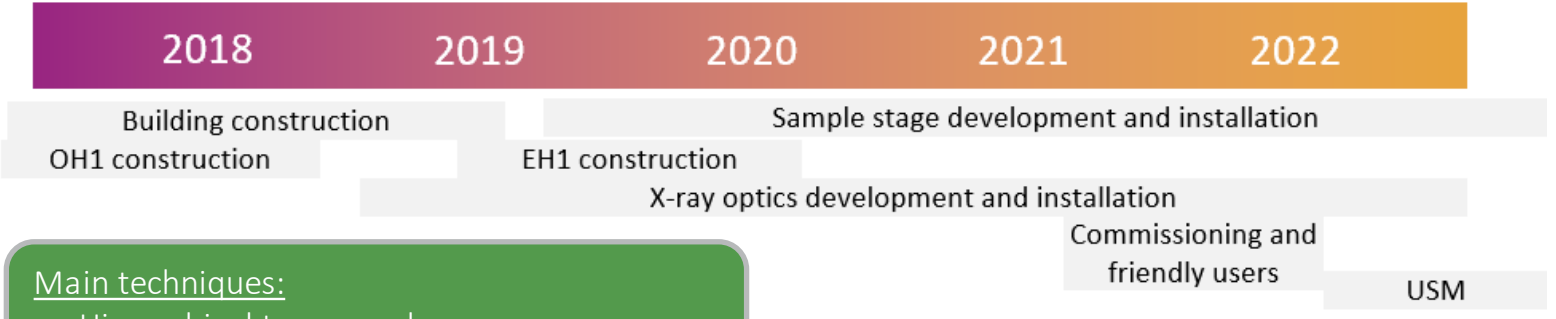
OUTLOOK

1. BM18 beamline
2. In-vacuum Fast Shutter
3. Wide Aluminium Window
4. Quinary Slits
5. Detector Girder & Detector Stages
6. The XXL Sample Stage
7. Conclusions

BM18: HIERARCHICAL PHASE-CONTRAST TOMOGRAPHY



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

EBS and refurbishment improvements:
- *Smallest possible X-ray source of the EBS*
- *Beam of 35cm with highest coherence worldwide for high-energy X-ray imaging.*
- *Large resolution range (0.7 - 120 m)*

Main beamline specifications:
- *Energy range: 50-270 keV (polychromatic)*
- *220m long beamline, up to 36m for propagation phase-contrast*
- *Current sample size 0.5m and 30 kg*
- *Future sample slice up to 2.5m and 300 kg*
- *High automation level for high throughput*

45m long experimental hutch with large polychromatic beam at high energy

BM18: HIERARCHICAL PHASE-CONTRAST TOMOGRAPHY

CHAN ZUCKERBERG INITIATIVE

Biomedical imaging (~30 %)

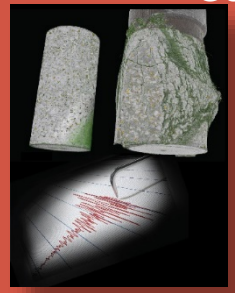
- A new scale in human body knowledge
- Understanding effects of diseases

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

Geology



- Origin of earthquackes
- Mecanisms of volcanoes
- Climate change

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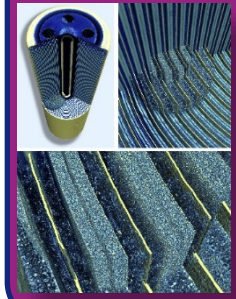
Material sciences (~25 %)



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

Industrial applications (< 25%)

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

Fraunhofer EZRT

BM18: HIERARCHICAL PHASE-CONTRAST TOMOGRAPHY

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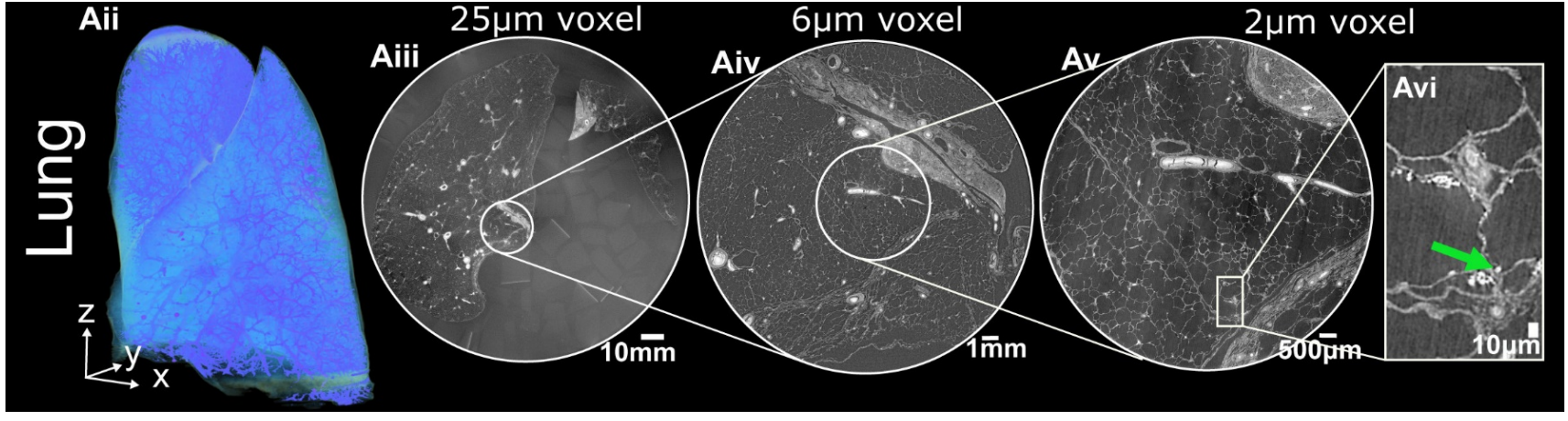
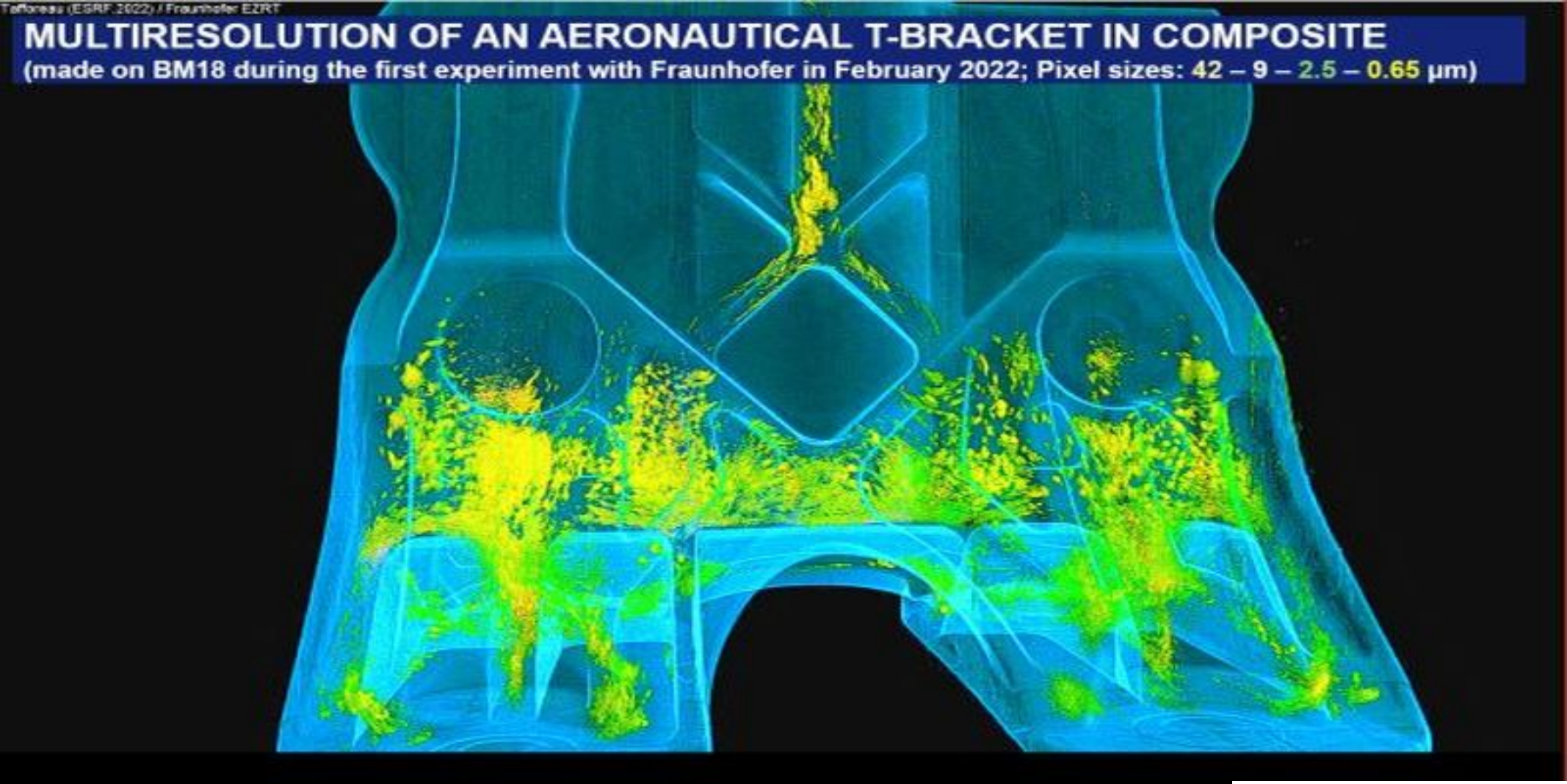


Tafforeau (ESRF 2022) / Fraunhofer EZRT

MULTIRESOLUTION OF AN AERONAUTICAL T-BRACKET IN COMPOSITE

(made on BM18 during the first experiment with Fraunhofer in February 2022; Pixel sizes: 42 – 9 – 2.5 – 0.65 µm)



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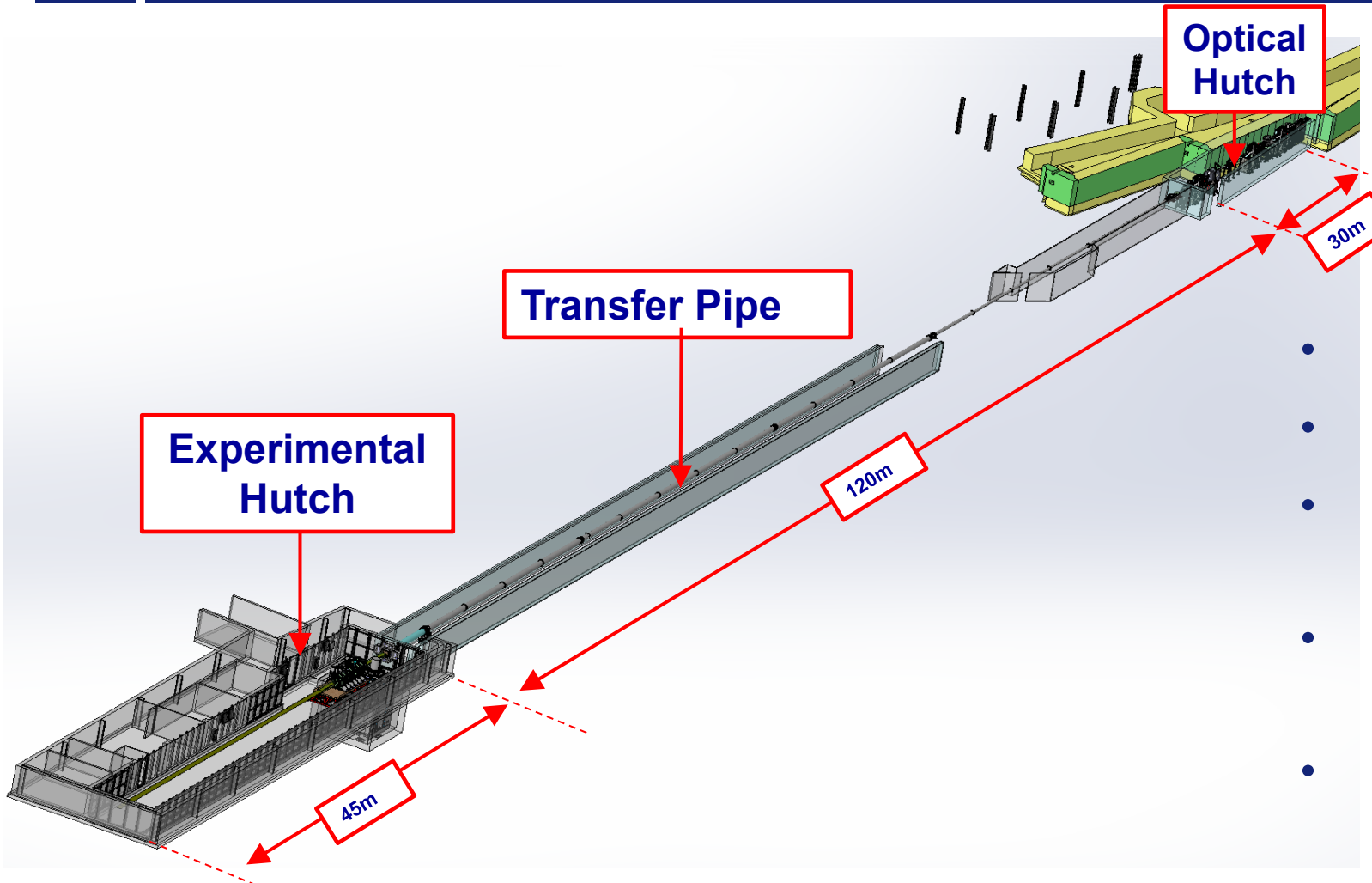
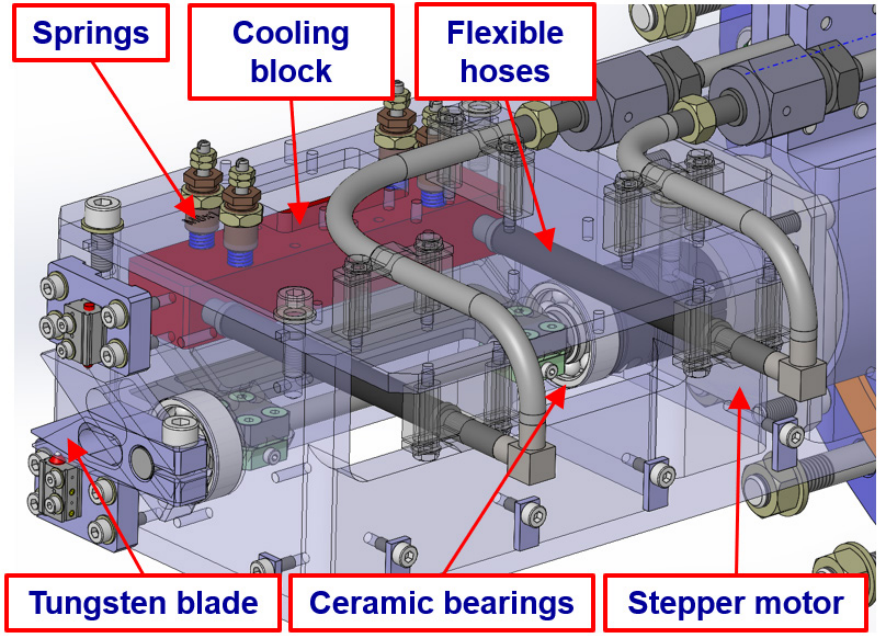
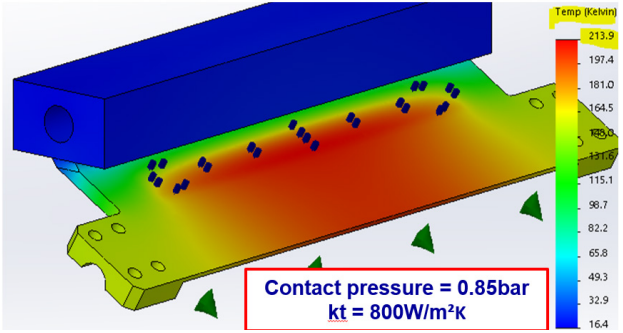


- Polychromatic
- 50-270 keV
- Resolution range = 120-0.65 µm
- Propagation distance up to 38 m
- Sept.22: 1st user

2. IN-VACUUM FAST SHUTTER



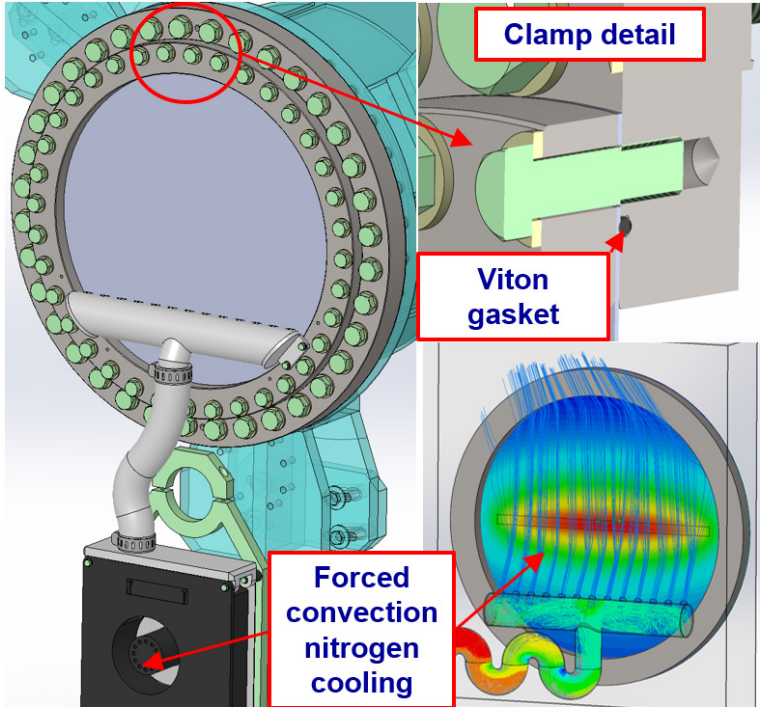


- **To replace the use of the *Photon Shutter* for obturation**
  - ✓ Quick shutting off (opening/closing: 0.1s)
  - ✓ Continuous operation
  - ✓ Life time of several millions of cycles
  - ✓ UHV components

- **P_i~300W; Beam size 100x5 mm**
- **$T_{Max\ blade}$ = 214 ºC**
- **Phase 1= Quick rotation to intercept the beam**
- **Phase 2= Slower movement to ensure contact with cooling block**

=> First tests at the beginning of 2024

3. WIDE ALUMINIUM WINDOW (FROM UHV TO AIR)



- **For beam size 400(h)x200(v) mm**
- **Need a material:**
  - ✓ Vacuum tight
  - ✓ Homogeneous
  - ✓ As transparent as possible
  - ✓ Easy to polish up to Ra<0.1
  - ✓ Financially affordable
- **Selected material=AL00-FL-000300 from *Goodfellow* (purity ~99%)**

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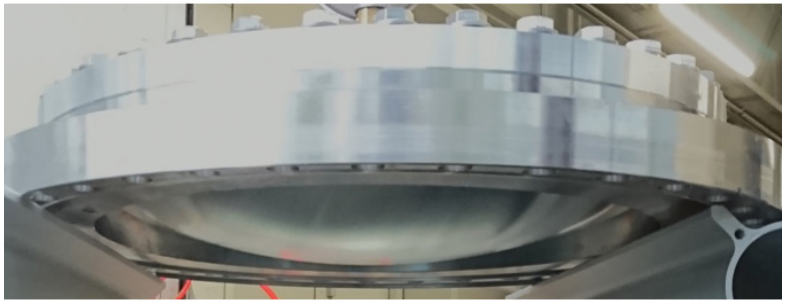

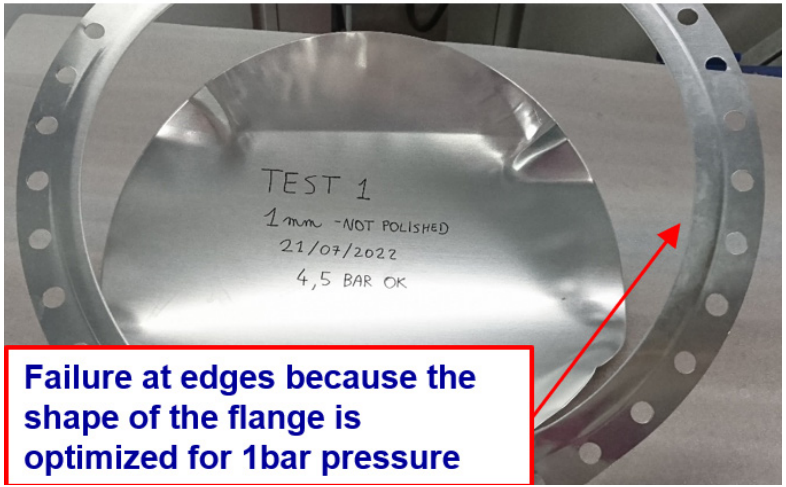

Failure at edges because the shape of the flange is optimized for 1bar pressure

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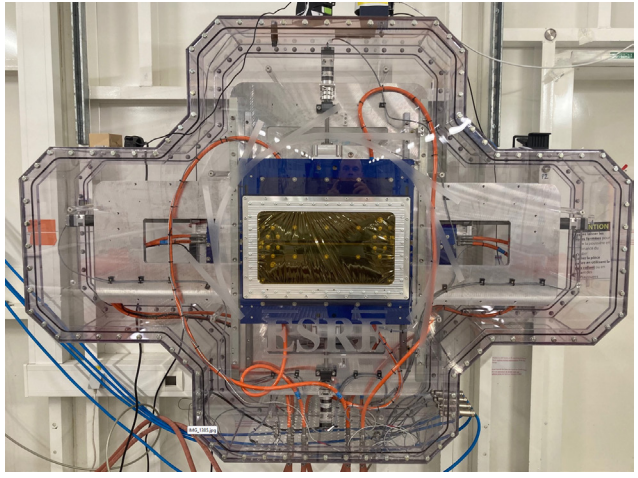
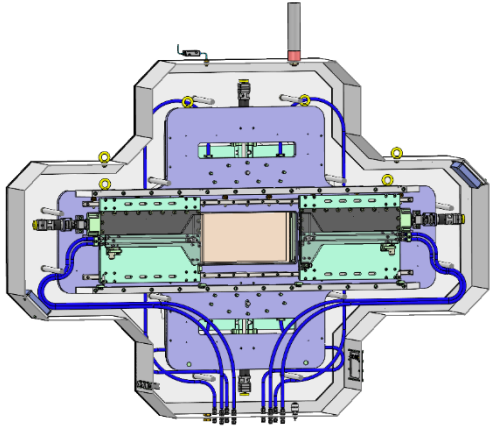
- **Water test of 1, 1.2, 2 mm thk**

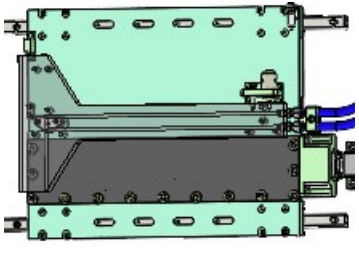
  => Safety factor > 3 (even for the 1mm thk)
- **Manufactured with 1mm-thk Al**

=> In use since January 2023

4. QUINARY SLITS



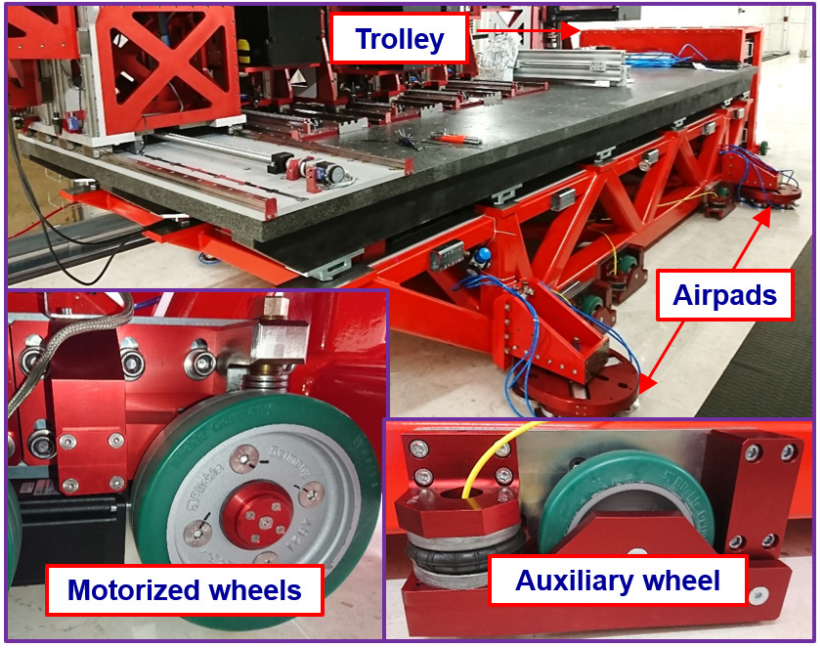




- **For a white beam of 400x20 mm (or enlarged beam of 350x200 mm):**
  - ✓ 4 motorized cooled W blades of 400(h)x200(v) mm (20mm thk)
  - ✓ A PETG chamber flushed with N2
  - ✓ 25 µm thk Kapton window
- **Achievements:**
  - ✓ Sustain the 300 W
  - ✓ Min vertical gap = 20 µm
  - ✓ // error = 5 µrad
  - ✓ MIM = 1 µm
  - ✓ Repeatability = 1.5 µm
  - ✓ Stable over more than a week

=> In use since March 2023

5. DETECTOR GIRDER



=> In use since January 2022

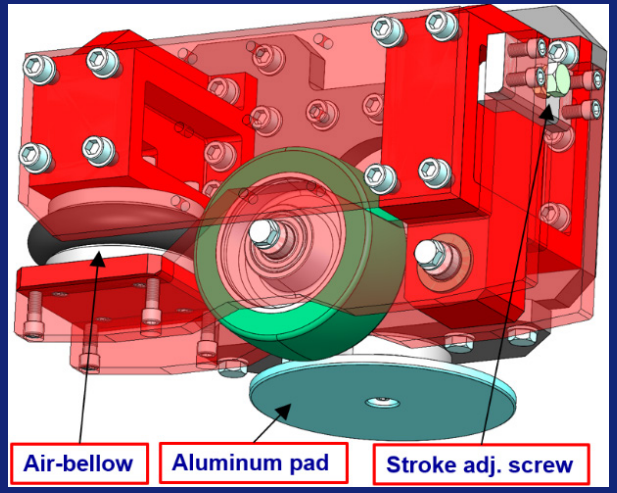
[1] F. Cianciosi *et al.*, "BM18, the new ESRF-EBS beamline for hierarchical phase-contrast tomography", in *Proc. MEDSI conf.*, Chicago, USA, Jul. 2021, pp. 1-5. DOI : 10.18429/JACoW-MEDSI2020-MOIO02

- **Goals were to get a stiff structure to:**
  - ✓ Support the detectors assy (payload of 3 T)
  - ✓ Move over 30 m (along beam path) => use of friction Motorized Wheel + 4 groups of 6 *Positechnics D160 mm* airpads) [1]
- **Prerequisite planarity, for the 140 m² marble floor, was to be within :**
  - ❑ 60 µm over a 1m diameter circle
  - ❑ 150 µm over the whole area

  => Never reached this prerequisite (despite many campains)…
- **Design update with:**
  - ✓ 7 Auxiliary pneumatic wheels located over the periphery of the frame => to relieve the load (they have no stroke limit)
  - ✓ 4 Main pneumatic wheels located at the 4 corners => to replace the 4 groups of airpads (their stroke is limited to 1 mm)
  - ✓ 4 Motorized wheels (instead of 1) to overcome the additional frictions

5. DETECTOR GIRDER

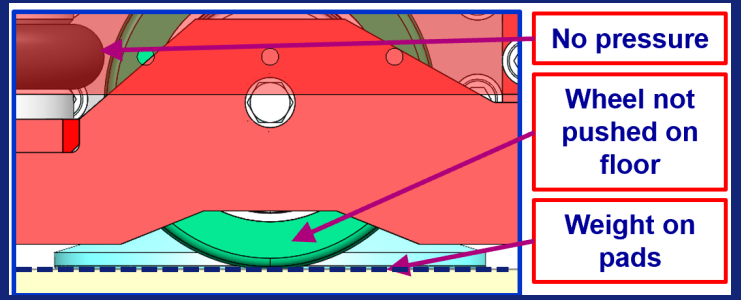
Main wheels design:
(to replace the airpads groups)



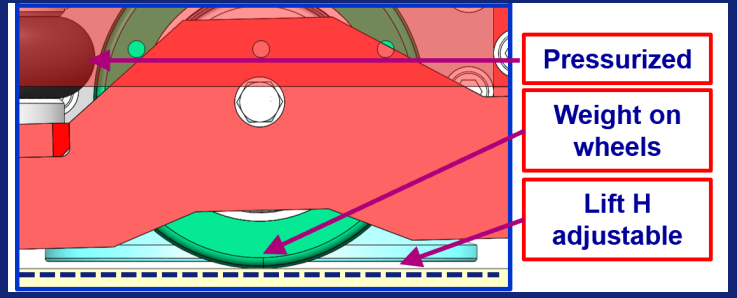
During image acquisition:

- ✓ Suppress the air in the bellow
- ✓ Rest on Aluminium pad

Wheel in retracted position
(Al pad in contact with the floor)

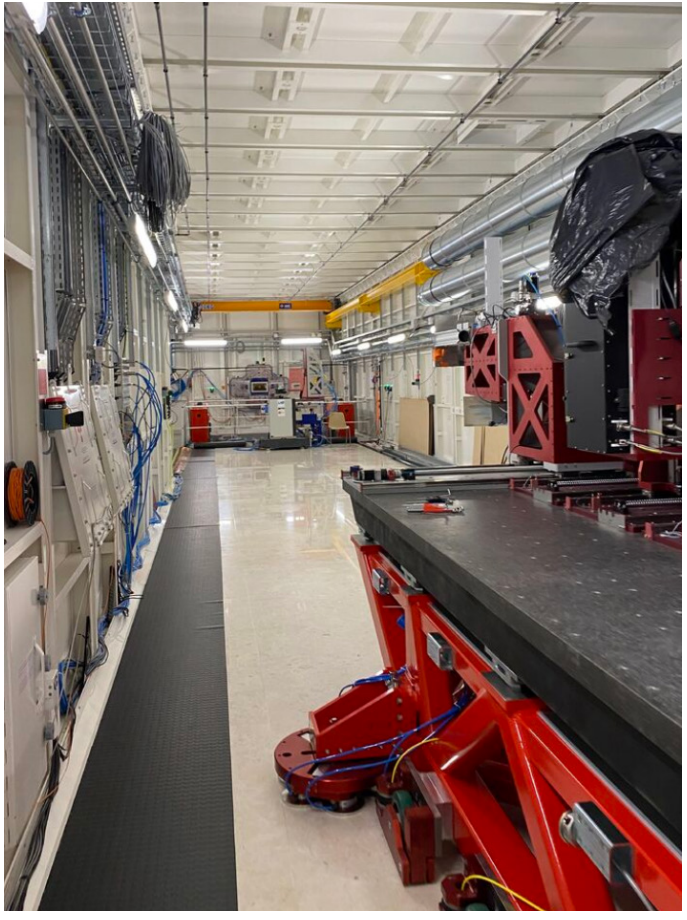


Wheel in contact with the floor



=> First tests at the beginning of 2024

6. DETECTOR STAGES



- **The Detector Girder is equipped with 9 combined stages**
- **Now: 8 detectors installed (pixel size range: 0.65 to 120 µm)**
- **Characteristics of the combined stages:**
  - ✓ Max weight of detector = 200 kg
  - ✓ Max size of detector = 900x700x500 mm
  - ✓ Stroke = 600 mm
  - ✓ MIM = 1 µm
  - ✓ Stability on 1 pixel (6 µm) over 6 days

=> In use since May 2022

6. THE XXL SAMPLE STAGE

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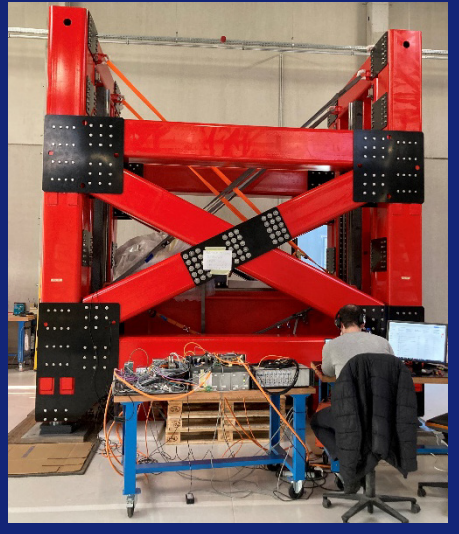
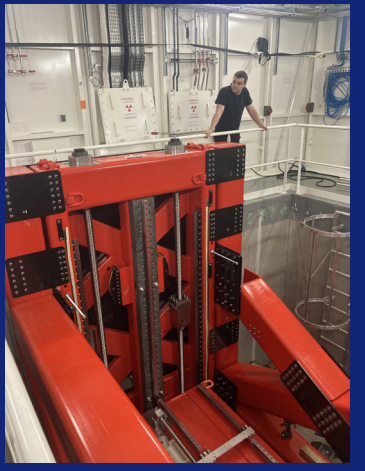


06-08/12/22
@ LAB Motion Systems



12/07/23 & 26/10/23 *@ ESRF*

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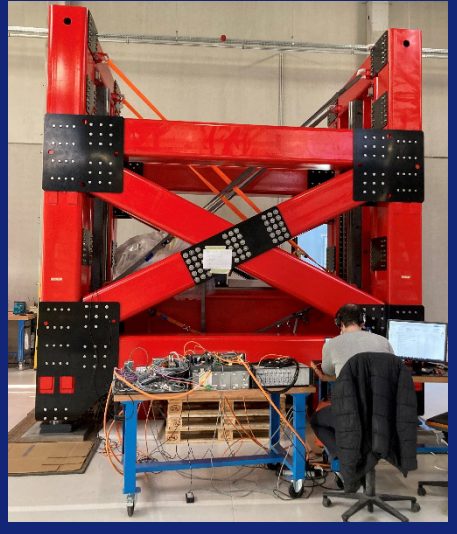

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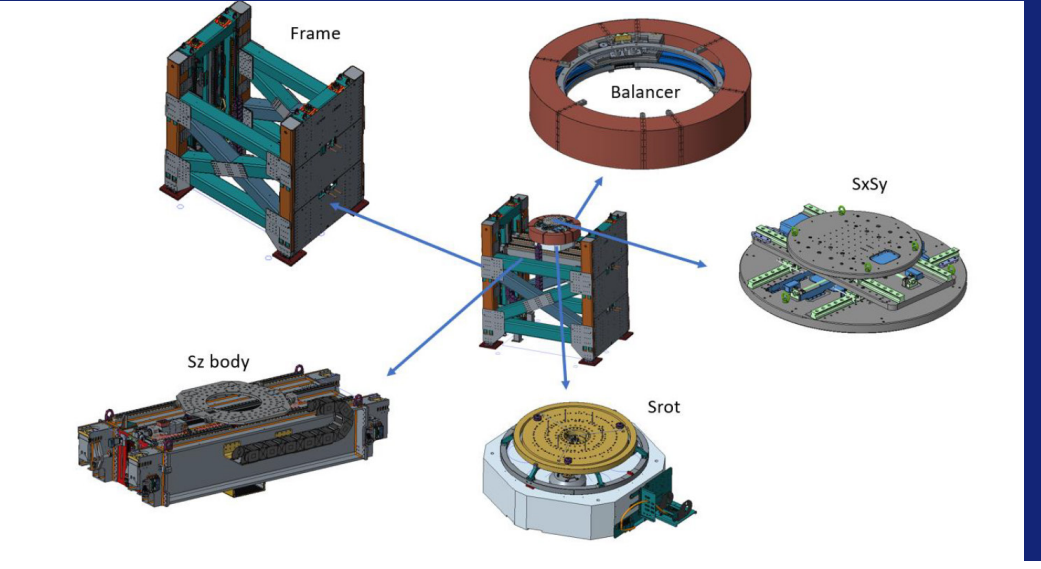
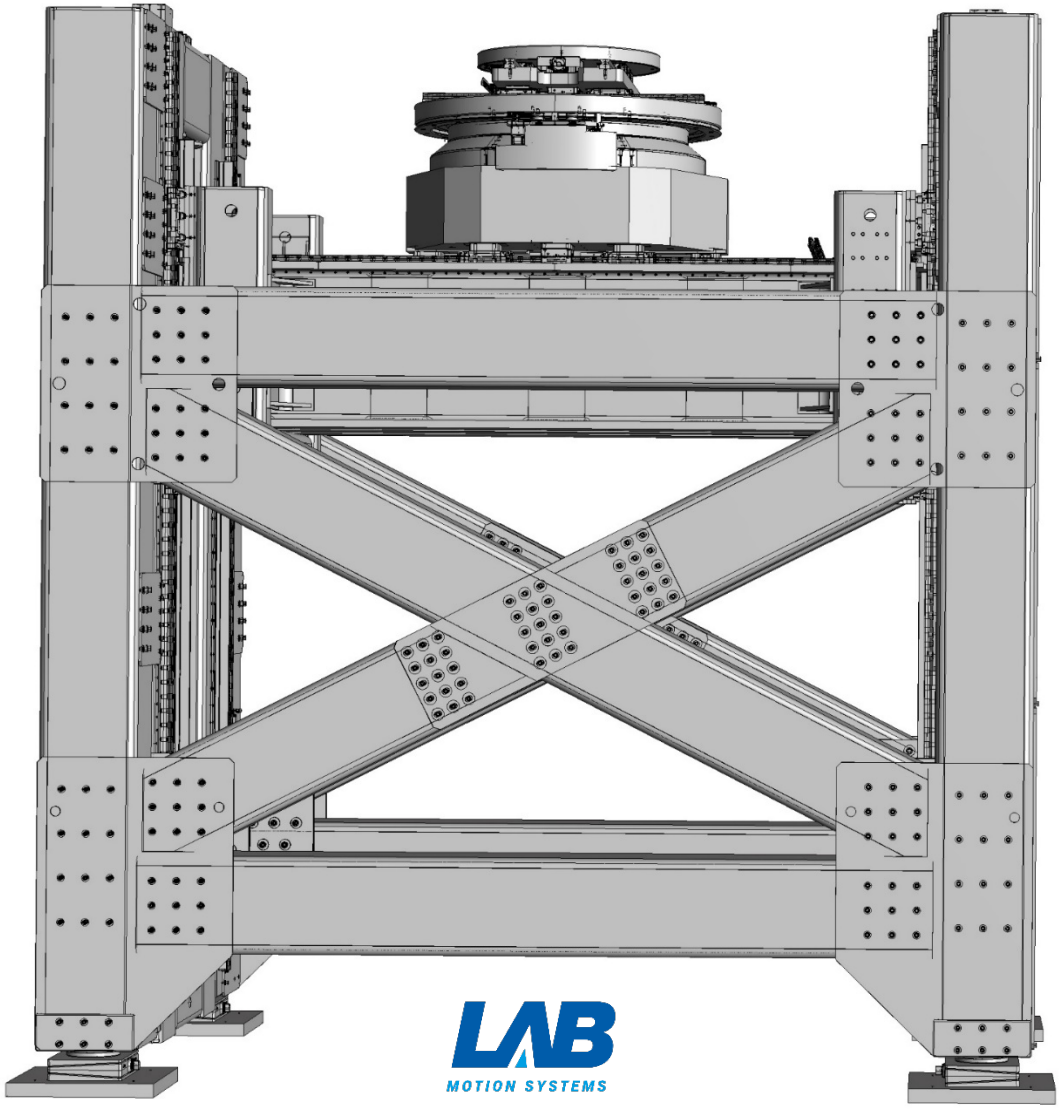
Motion
Systems



Future giant sample stage of BM18

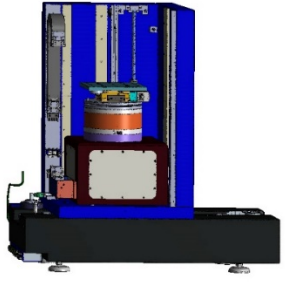


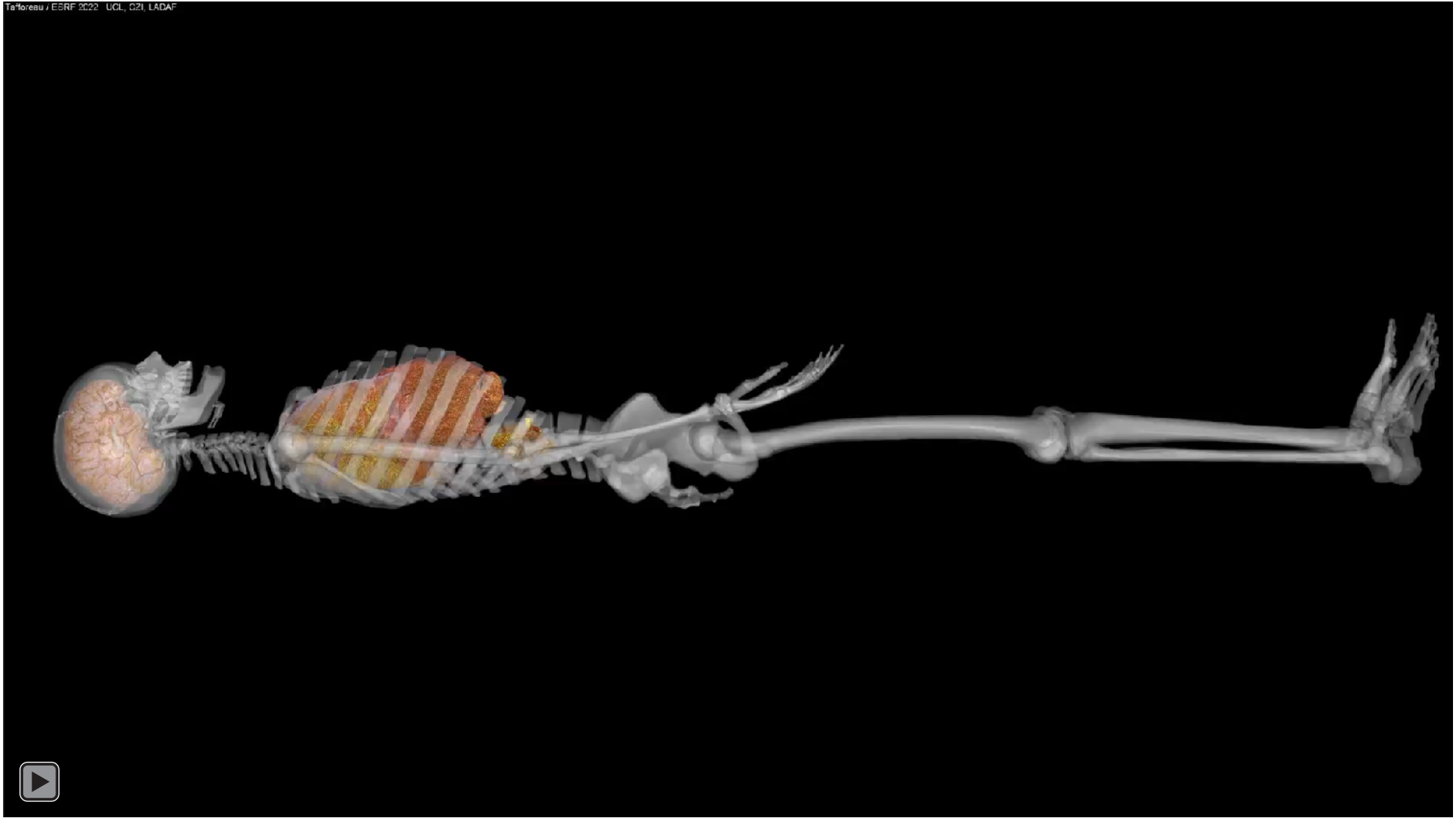
LAB MOTION SYSTEMS

The next step:
Making the multiresolution range go from 50 cm/30 kg to 250 cm/300 kg.

Biomedical project : going from the human organ atlas to the full human body atlas (https://human-organ-atlas.esrf.eu/)

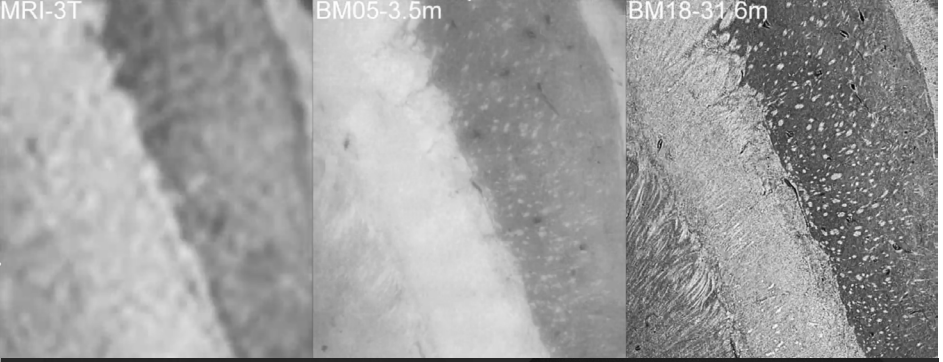
Present tomograph on BM05 and BM18

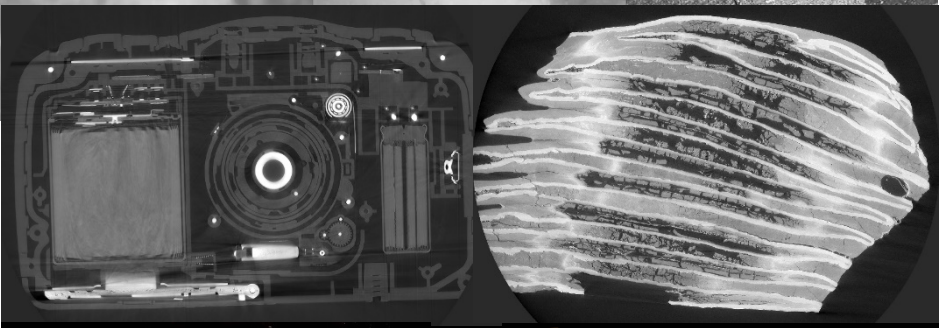



Tafforeau / ESRF 2022 UCL, G2I, LADAF

7. CONCLUSIONS

- After more than a year of commissioning and experiments, BM18 has largely fulfilled most of its goals and is highly subscribed
- It is expected that the beamline will be fully equipped by the end of 2024
- The commissioning of the XXL Sample Stage will begin in early 2024 and will be available mid-2024 (based on present state of the installation) => unique equipment (sample size and resolution)
- The Human Atlas program remains one of the main priorities.
- Most of installed equipment are prototypes=> still room for improvement and further characterization.





Thank for your attention !

Many thanks to all the people, at the ESRF and in many other places, that worked (and are still working) a lot to make BM18 a reality !

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