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ESS ELLIPTICAL CRYOMODULE: DESIGN PRINCIPLES AND ASSEMBLY

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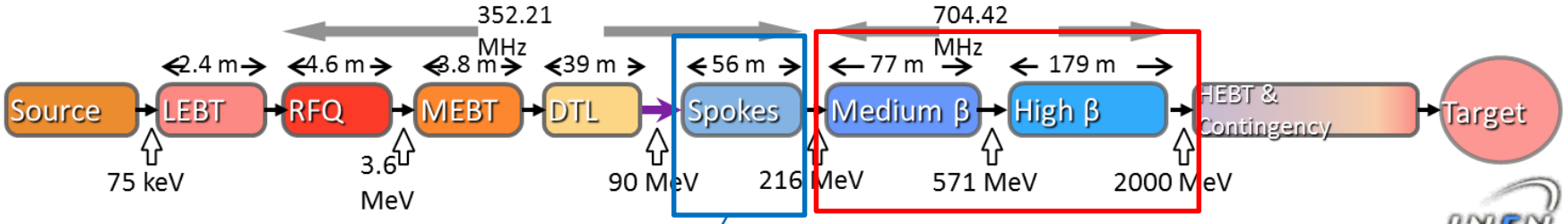
With material provided by the ESS ECCTD team

PIP-II Cryomodule Design Advisory Meeting

Fermilab – October 2018

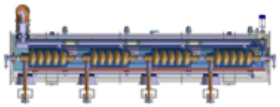
EUROPEAN SPALLATION SOURCE (ESS)

- European Spallation Source is under construction in the city of Lund, in southern Sweden
- ESS will offer neutron beams of unparalleled brightness for cold neutrons, delivering more neutrons than the world's most powerful reactor-based neutron sources today, and with higher peak intensity than any other spallation source
- ESS Cold Linac: a collaborative project



M-β

H-β



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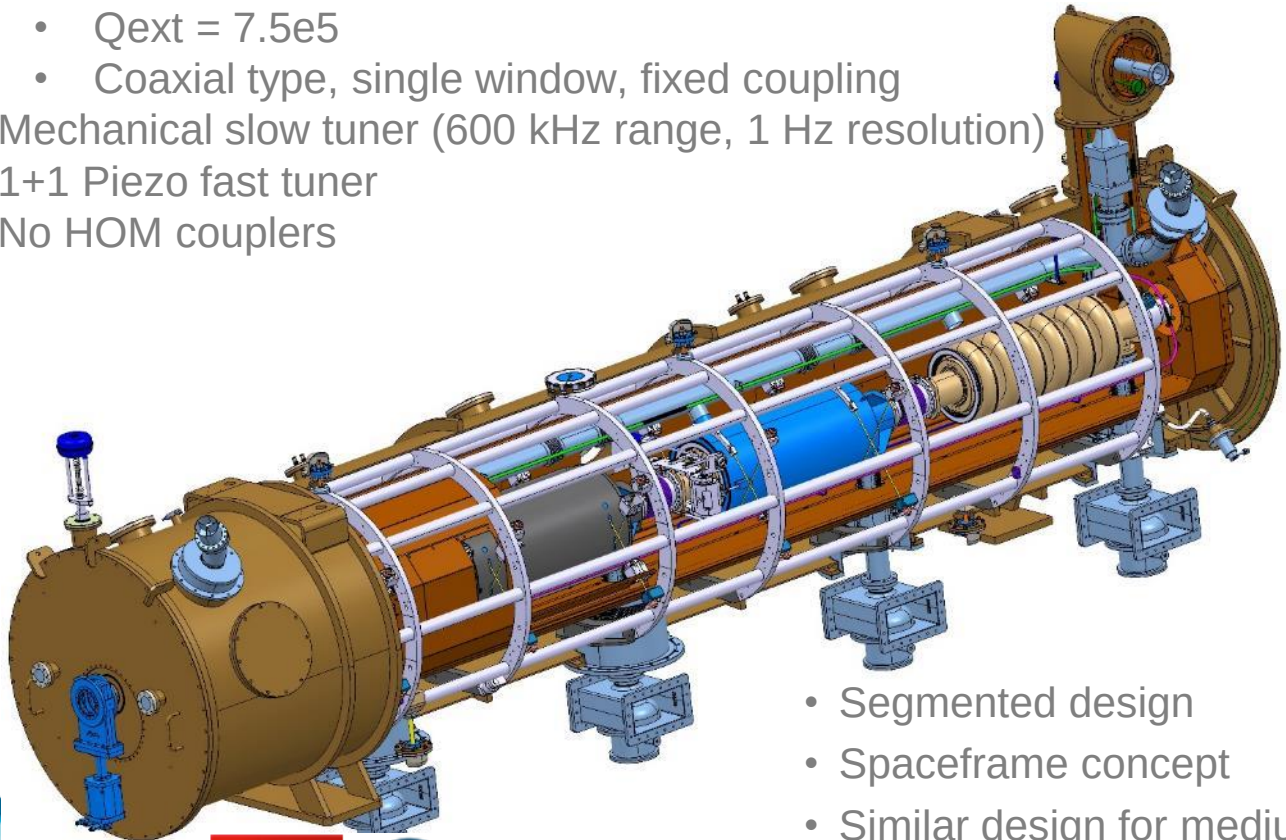
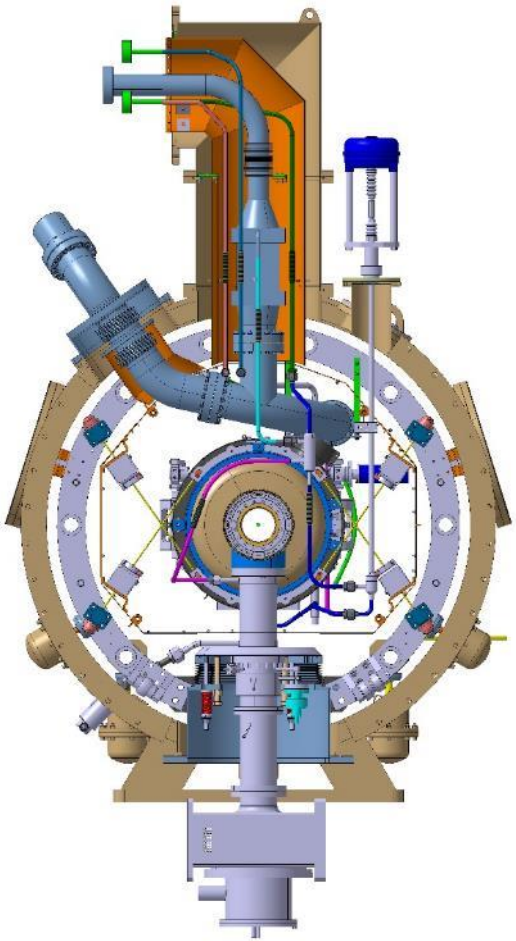
ELLIPTICAL CRYOMODULE MAIN FEATURES

- 704 MHz, 3.6 ms RF pulse at 14 Hz
- Eacc = 16.7 MV/m (MB) and 19.9 MV/m (HB) (Epeak = 40/44 MV/m)
- Q0 > 5e9 at 2 K
- Fundamental power coupler: 1.1 MW peak, 55 kW avg.
  - Qext = 7.5e5
  - Coaxial type, single window, fixed coupling
- Mechanical slow tuner (600 kHz range, 1 Hz resolution)
- 1+1 Piezo fast tuner
- No HOM couplers

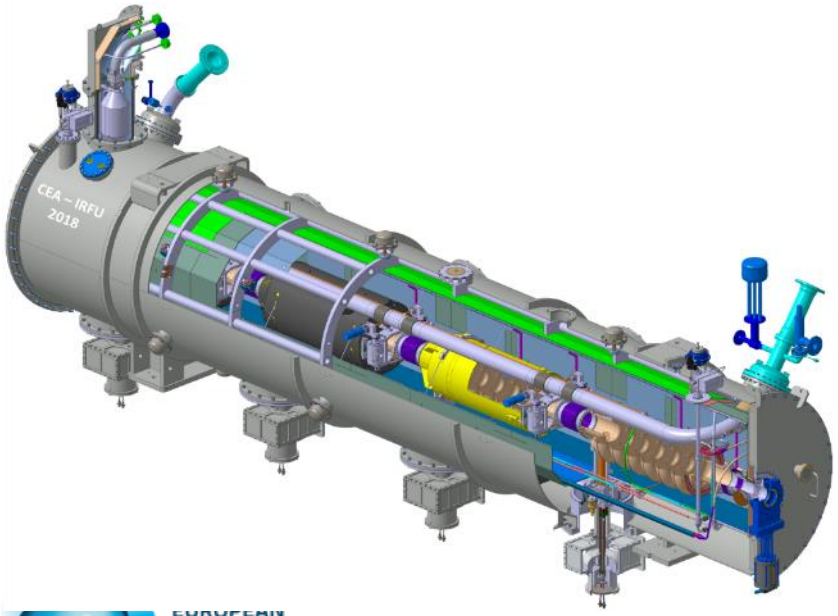


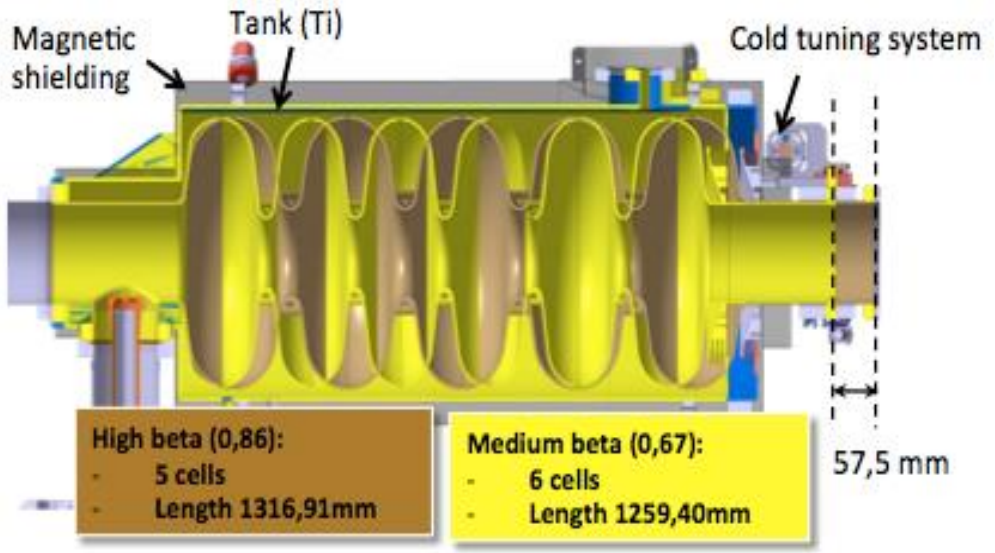


- Segmented design
- Spaceframe concept
- Similar design for medium and high beta cavities

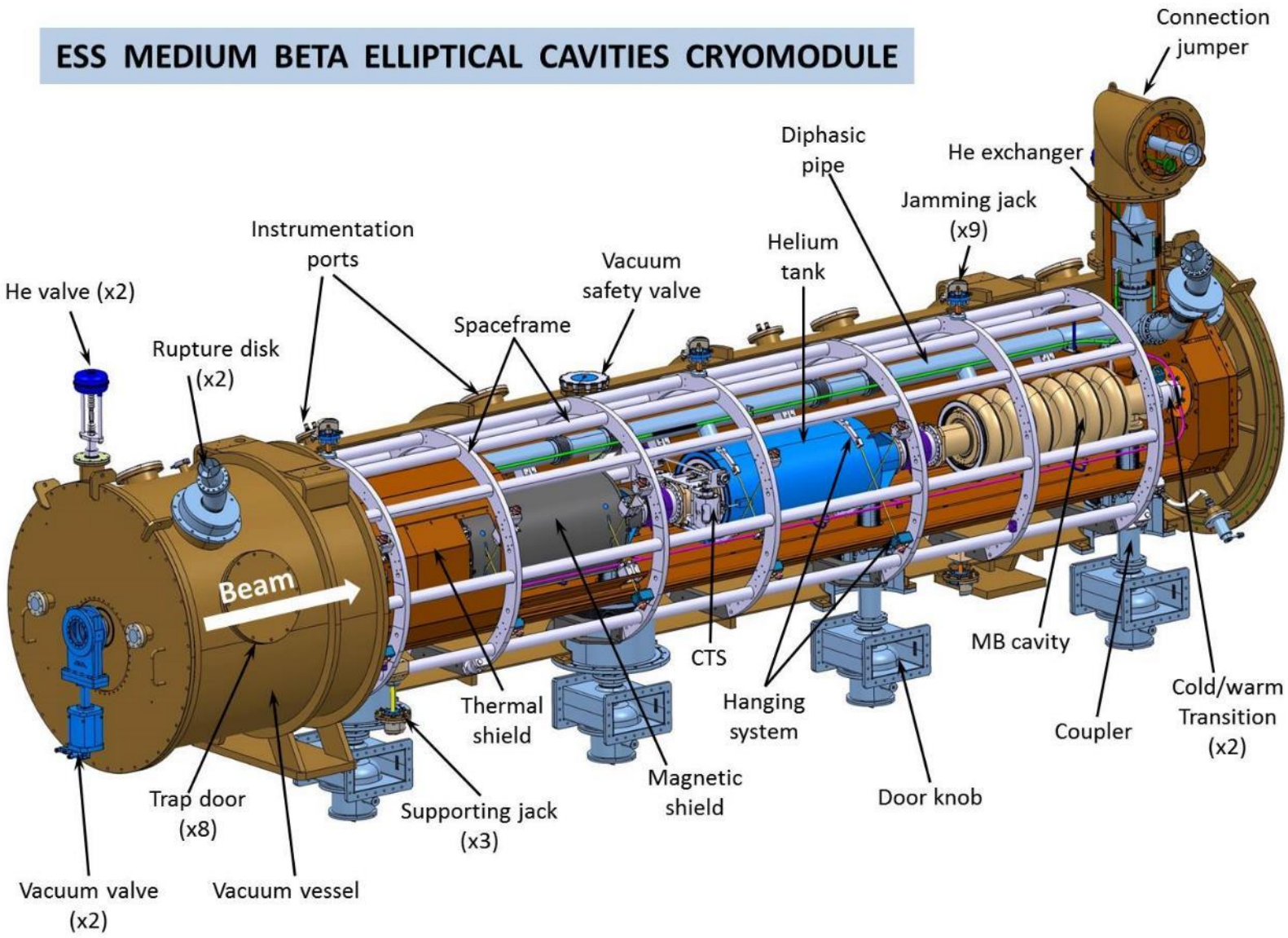
ELLIPTICAL CRYOMODULES

- Common design for medium and high beta cryomodules:
  - Made sensible thanks to the small length difference between 6-cell medium and 5-cell high beta cavities
  - Main components are identical: vacuum vessels, thermal shields, supports, spaceframes, alignment system …
  - Only few elements differ: details in cryo piping, beam pipe bellows
  - Same assembly tooling

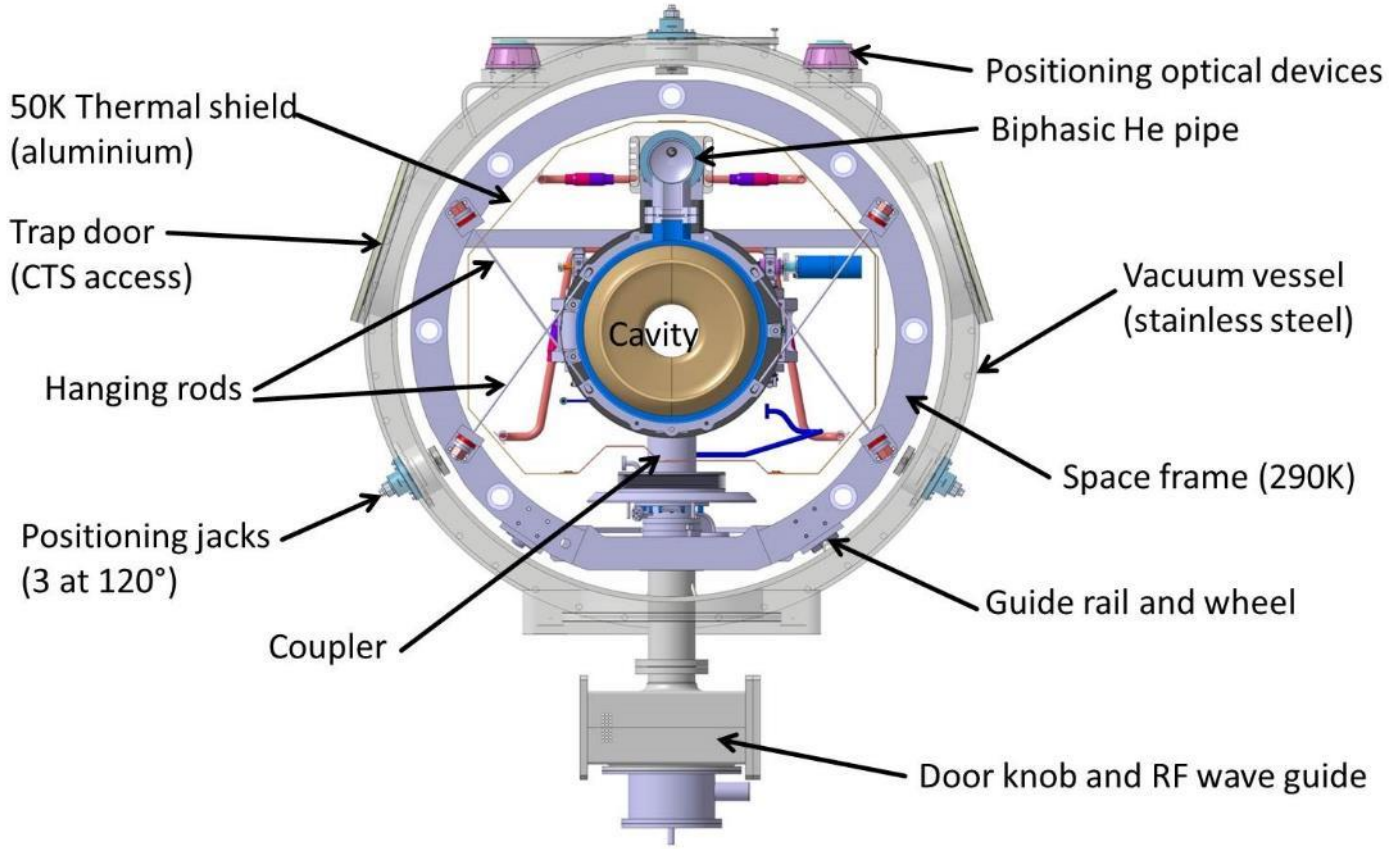


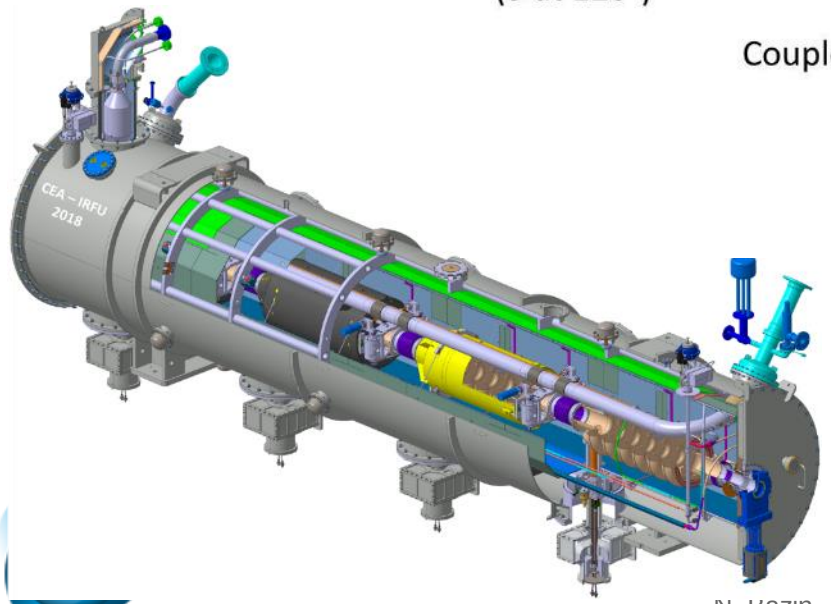


ELLIPTICAL CRYOMODULE

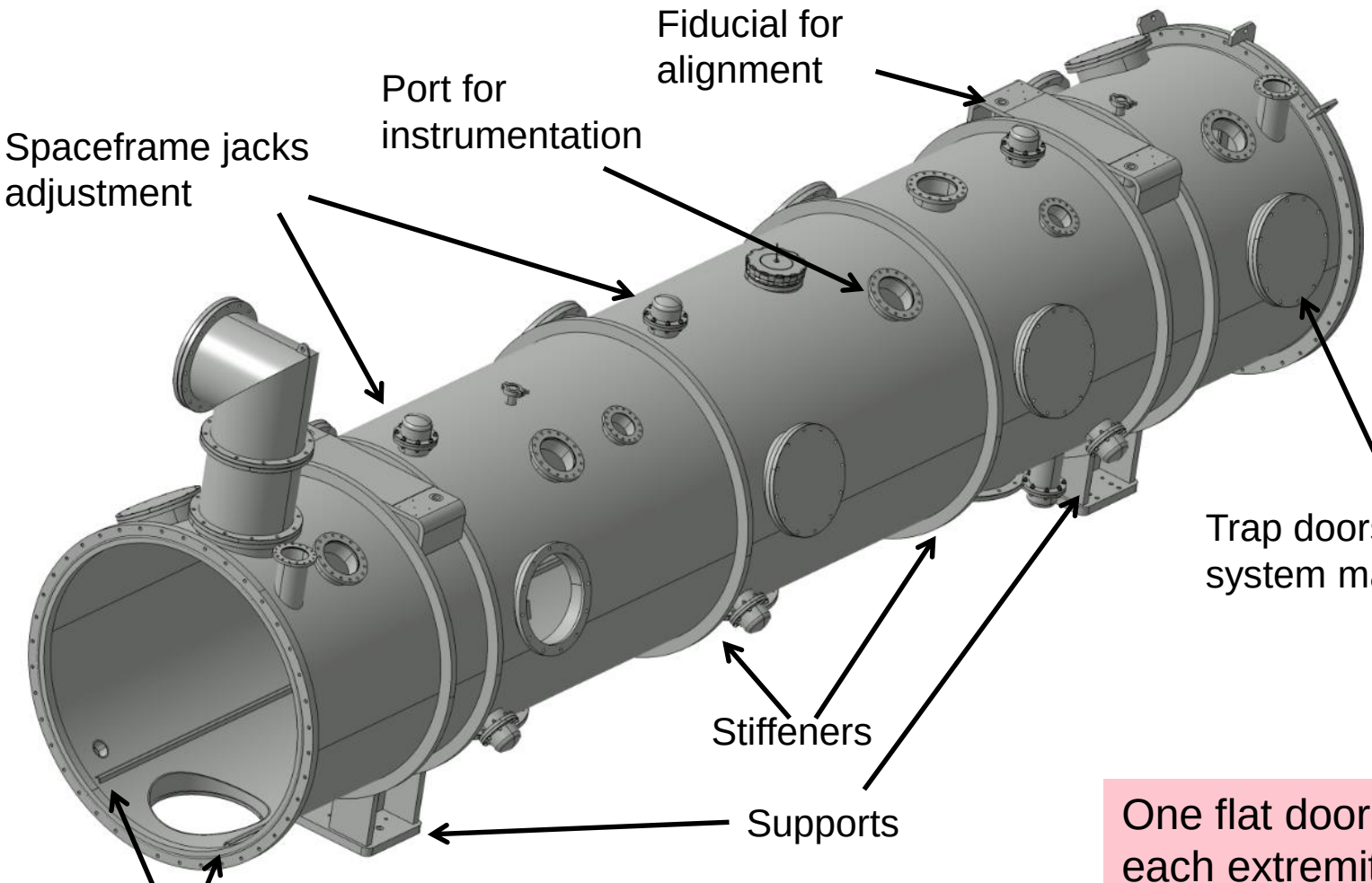


ELLIPTICAL CRYOMODULE



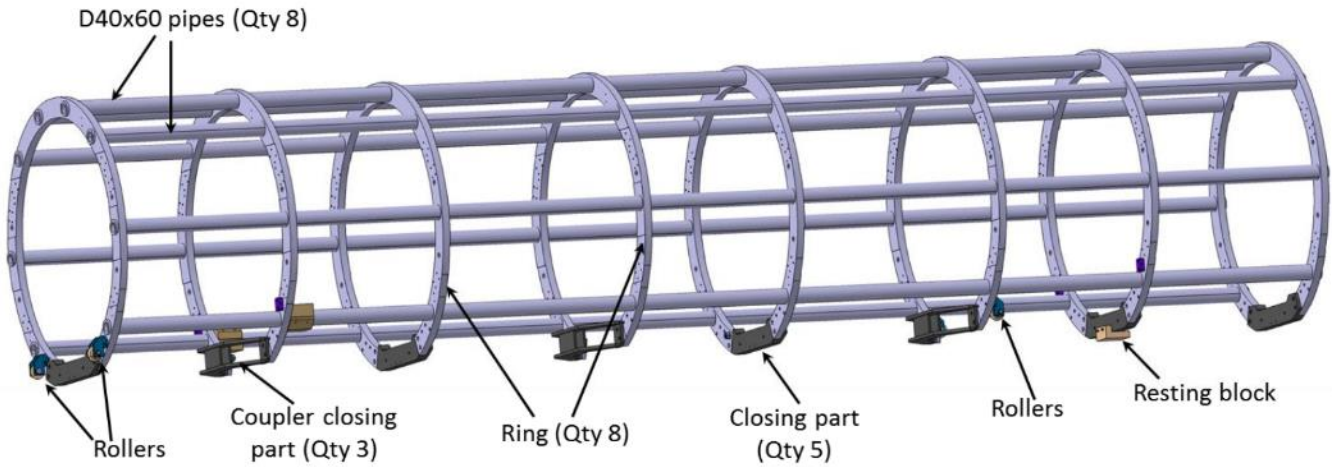


VACUUM VESSEL



One flat door at each extremity

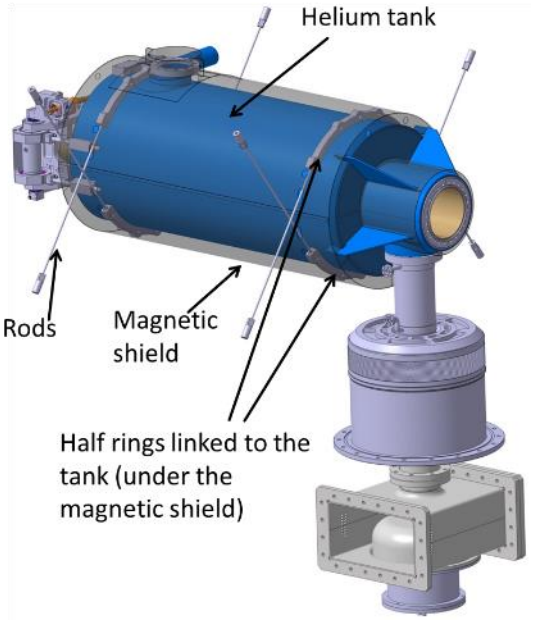
SPACEFRAME: PRESENTATION

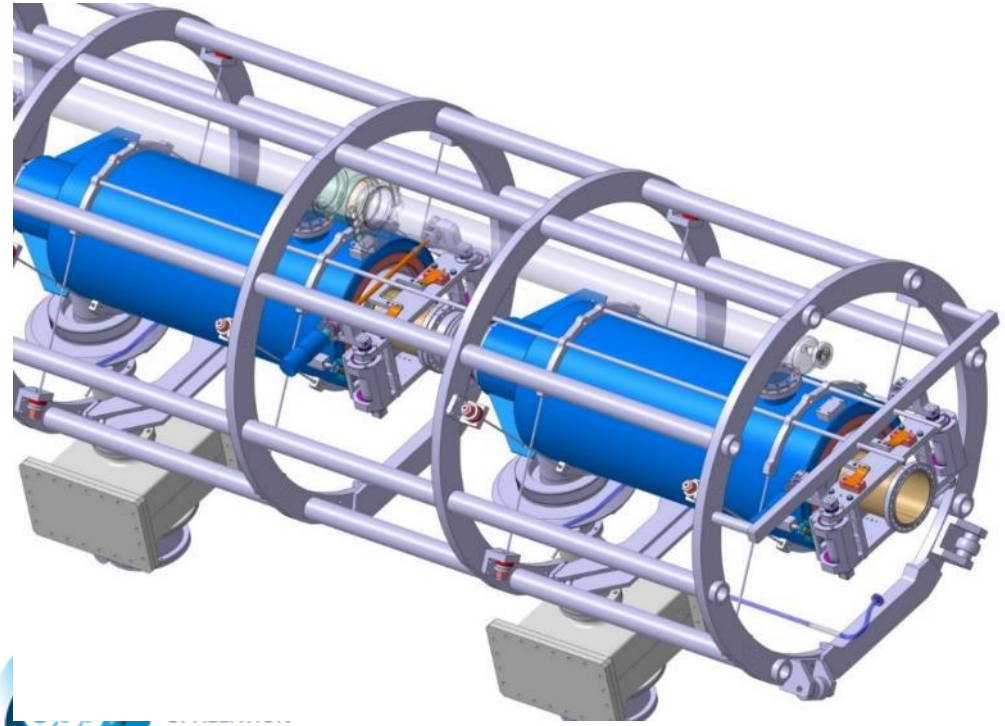


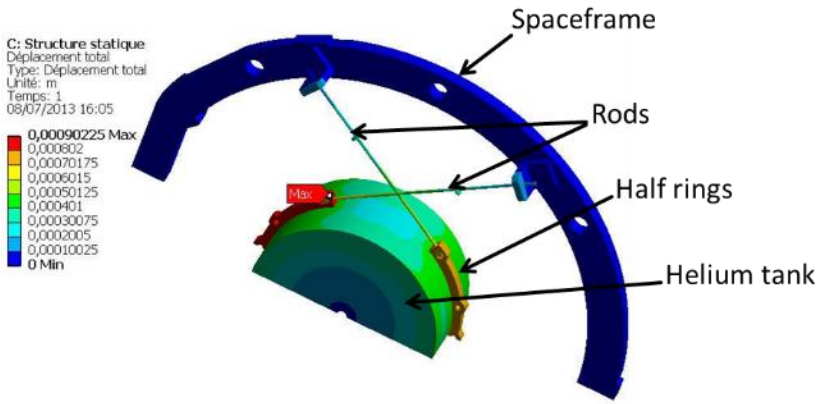
- Role of the spaceframe
  - Supports the cavity string
  - Key element for the alignment of the string → deformations along the assembly process shall be controlled
- Stays at room temperature → no deformation due to thermal shrinkage
- Made of aluminium

CAVITY: MOTIONS DURING COOL DOWN

- Each cavity are attached to the spaceframe thanks to eight rods
- Preloading in the rods → no motion of the cavity in transverse direction during cool down (more details in Gilles' presentation)

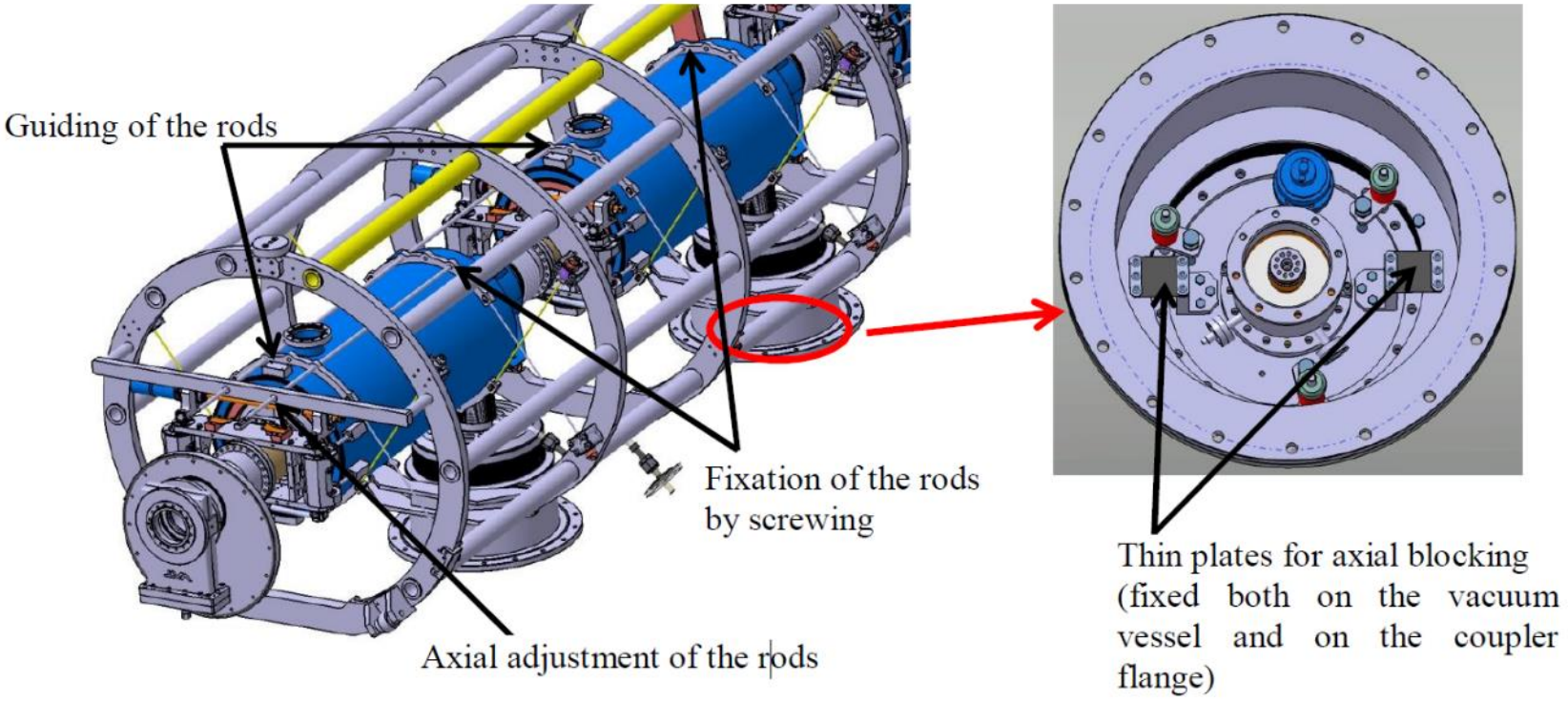






CAVITY: MOTIONS DURING COOL DOWN

- Axial position of each cavity is fixed during the assembly (use of temporary rods of temporary rods removed after the insertion of the cold mass inside the vacuum vessel)
- Plates fixed on the coupler flange and the vacuum vessel set the axial position but allow a vertical motion of the coupler (needed for the thermal contraction while cooling)



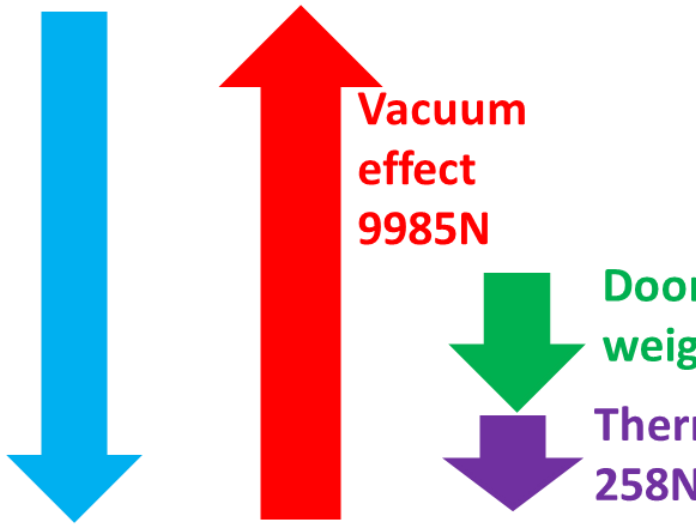
ATMOSPHERIC PRESSURE COMPENSATION

The aim of the device is to limit the load on the cavity flange while pumping and cooling (1 ton if nothing done)

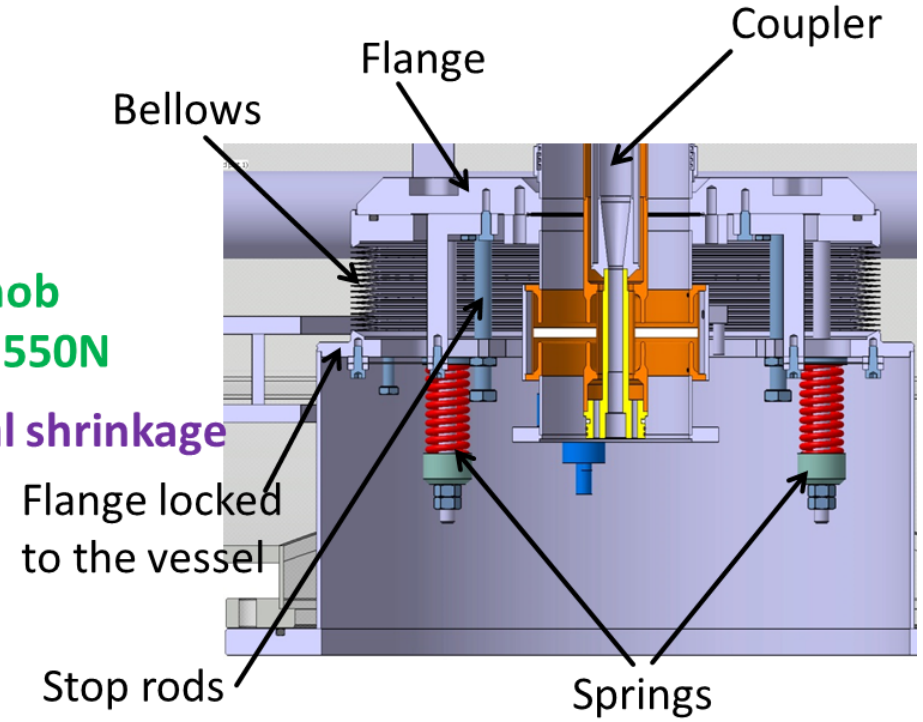
A pre-stress is performed by means of 3 heavy load springs (3 x 172N/mm). A stop rod device (x3) avoids any force on the coupler flange during this operation.

The vacuum pressure is applied to the bellows flange (Dext 360mm)

Due to the cooling, the thermal shrinkage of the coupler (0,5mm) induces both the lifting of the lower parts of the RF line (coaxial line and door-knob) and a compression of the springs



Effort on the flange (N)	0 (stop rod)	808 (Push)	0



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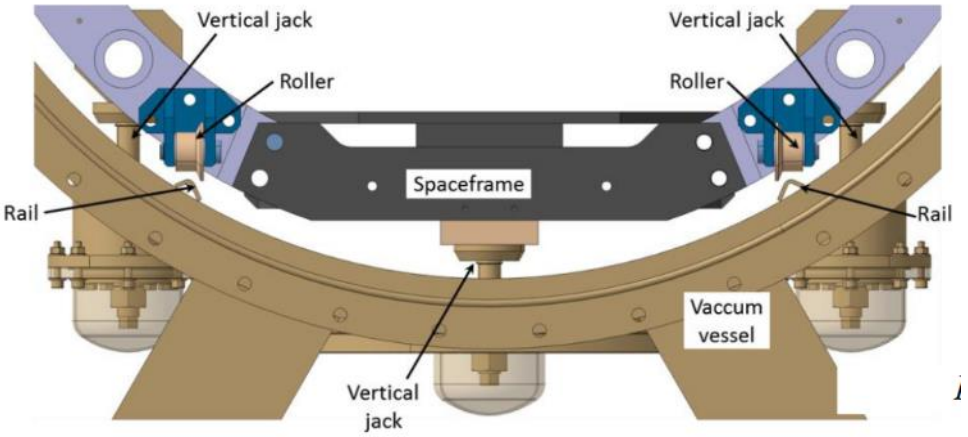
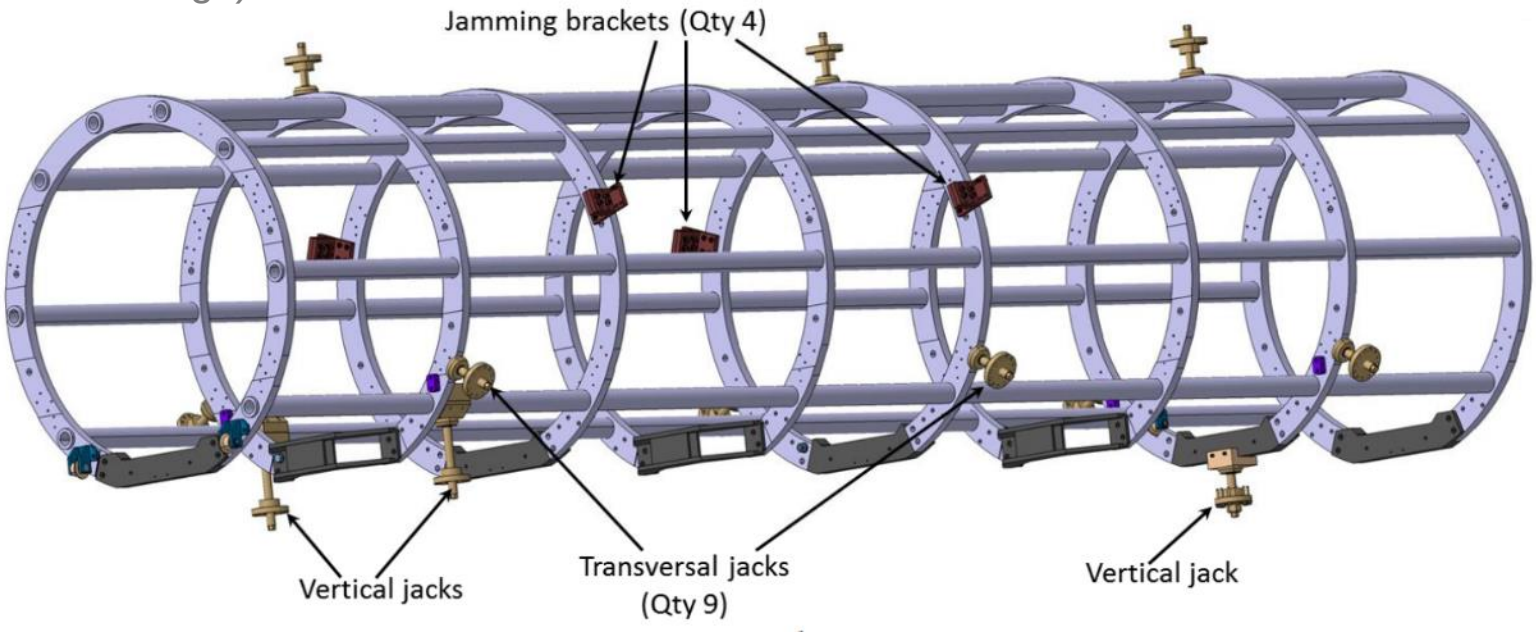
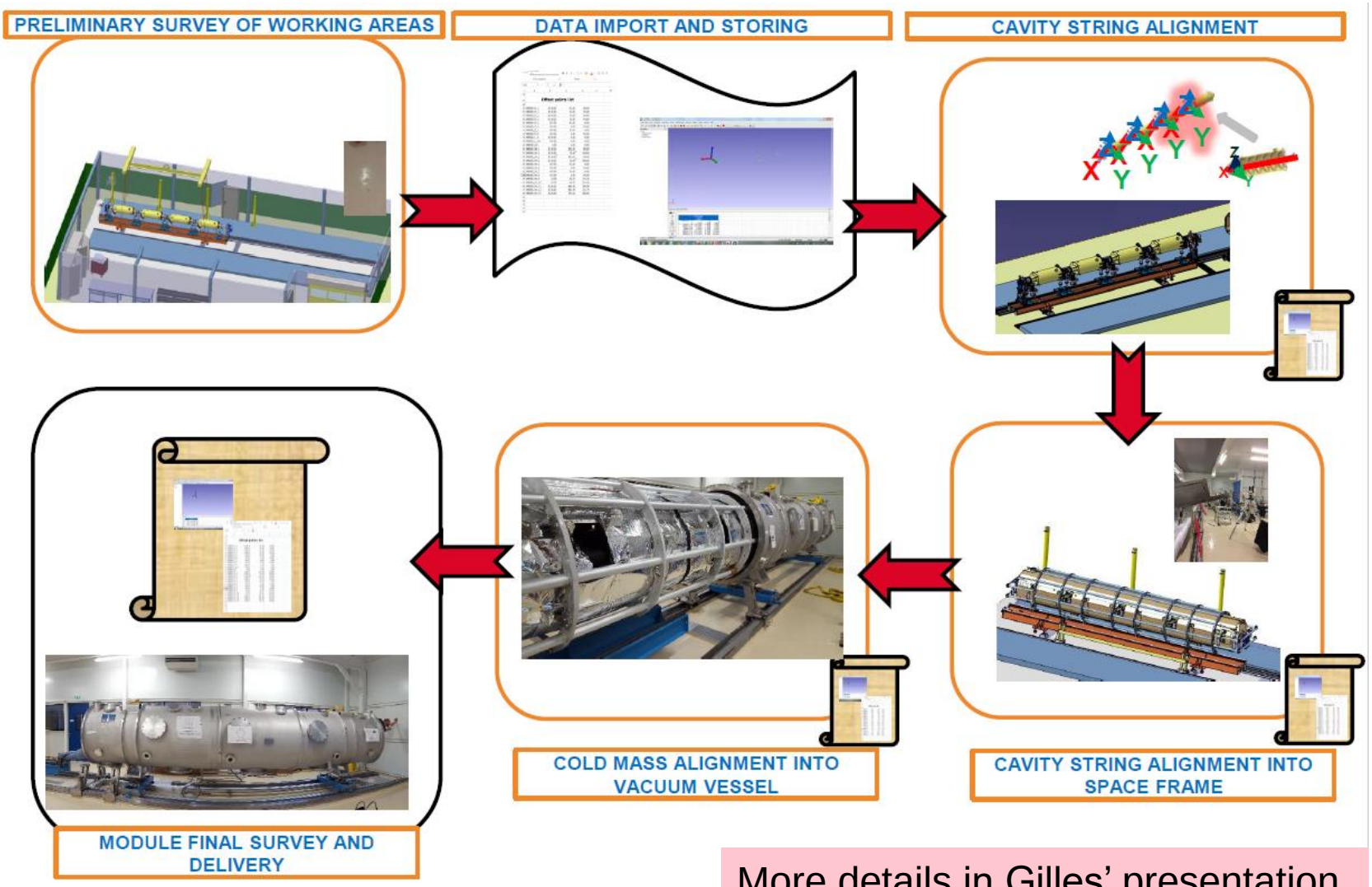
POSITIONING THE SPACEFRAME IN THE VACUUM VESSEL

- After insertion inside the vacuum vessel, the complete assembly is positioned by means of 3 mechanical jacks (2+1) located at the 2nd and 7th rings.
- After positioning of the whole assembly, the spaceframe is blocked by means of 9 transversal jacks (2nd, 5th and 7th rings) and fixed to the vacuum vessel using 4 brackets (3rd and 5th rings).



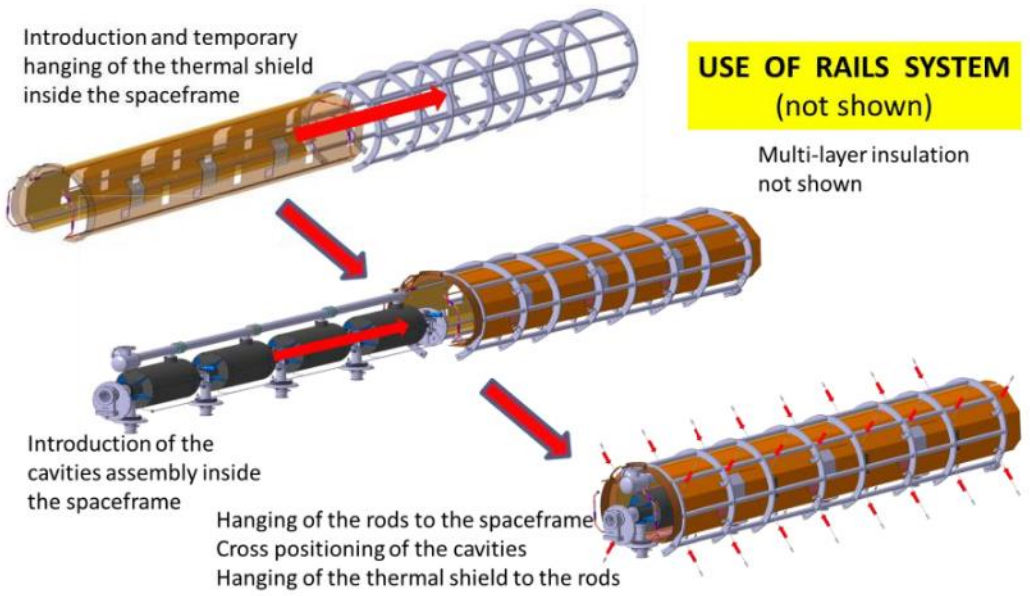


ALIGNMENT PHASES



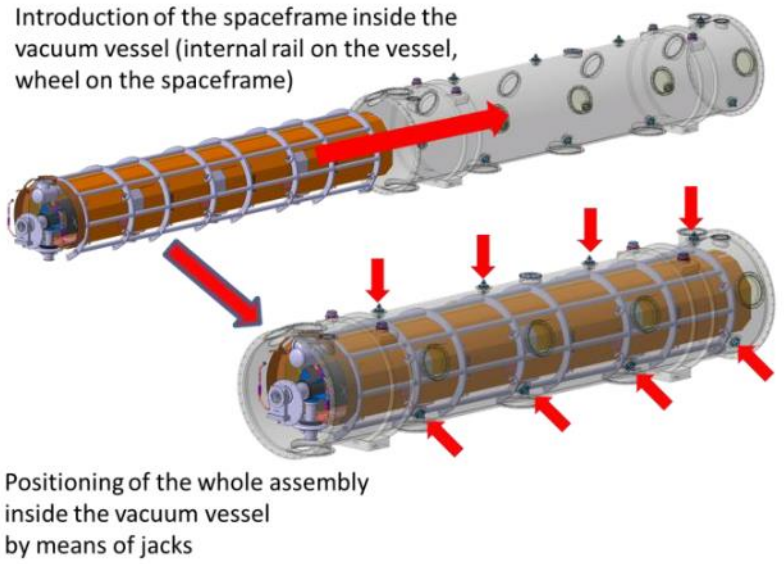
More details in Gilles' presentation

ASSEMBLY PROCESS



USE OF RAILS SYSTEM
(not shown)

Multi-layer insulation not shown



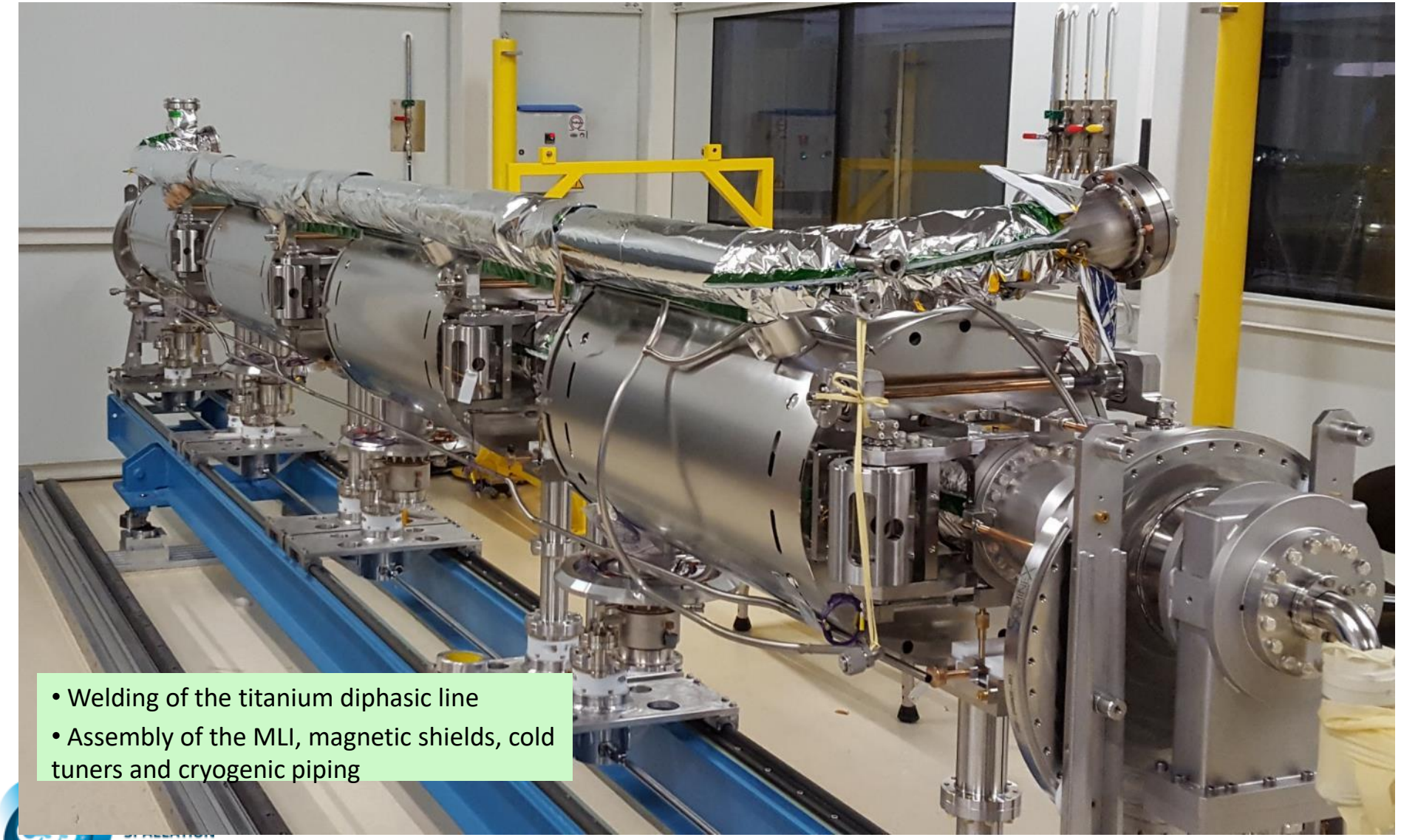
CRYOMODULE ASSEMBLY TRAINING USING A MOCK-UP CAVITY

- First validation of assembly toolings and assembly procedures
- Integration until the vacuum vessel

M-ECCTD CRYOMODULE CLEAN ROOM ASSEMBLY

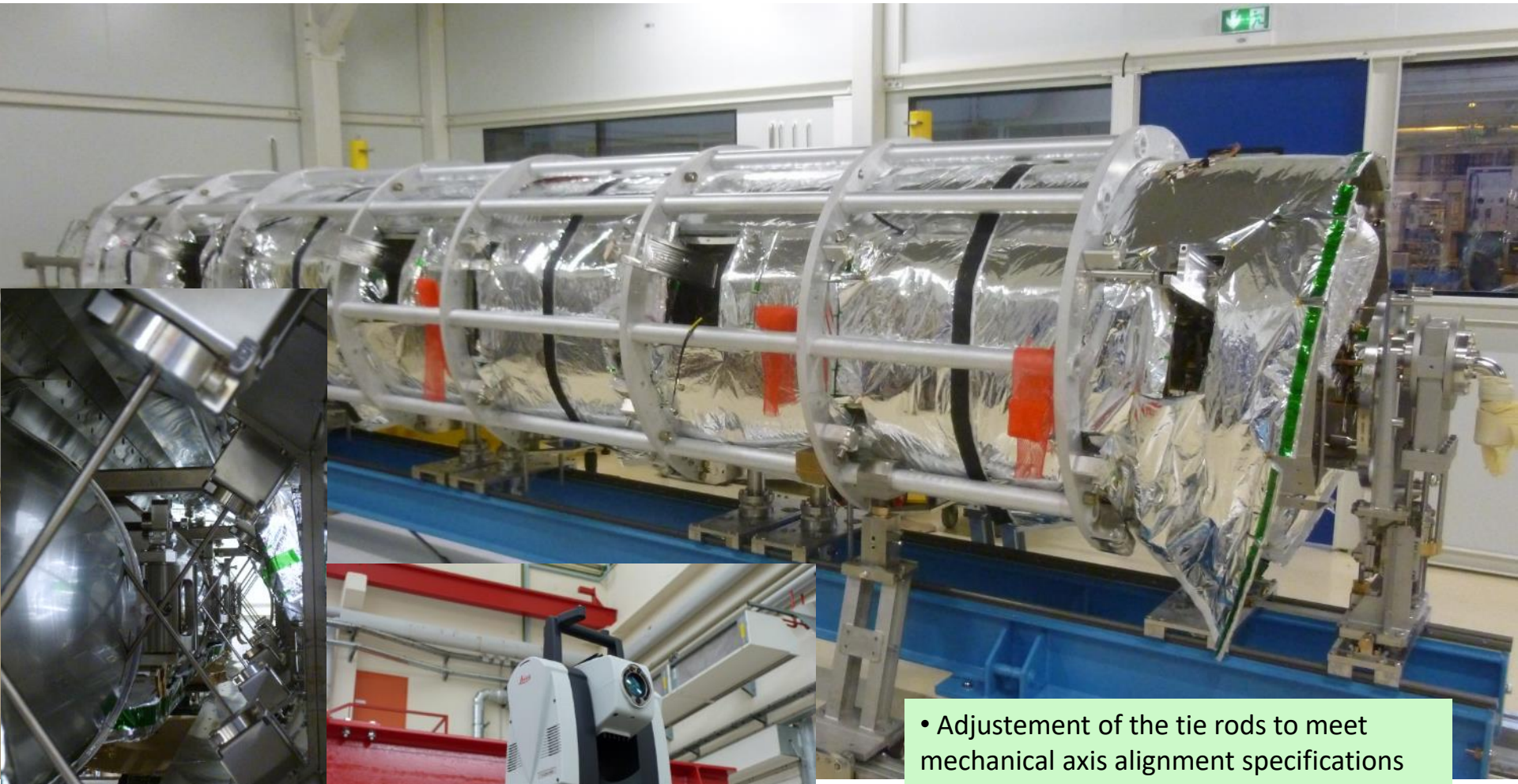
- Performed in the ISO4 Saclay clean room
- Nitrogen venting during assembly process
- XFEL type aluminium gaskets
- Cavities pre-aligned

CAVITY STRING DRESSING



- Welding of the titanium diphasic line
- Assembly of the MLI, magnetic shields, cold tuners and cryogenic piping

ALIGNMENT



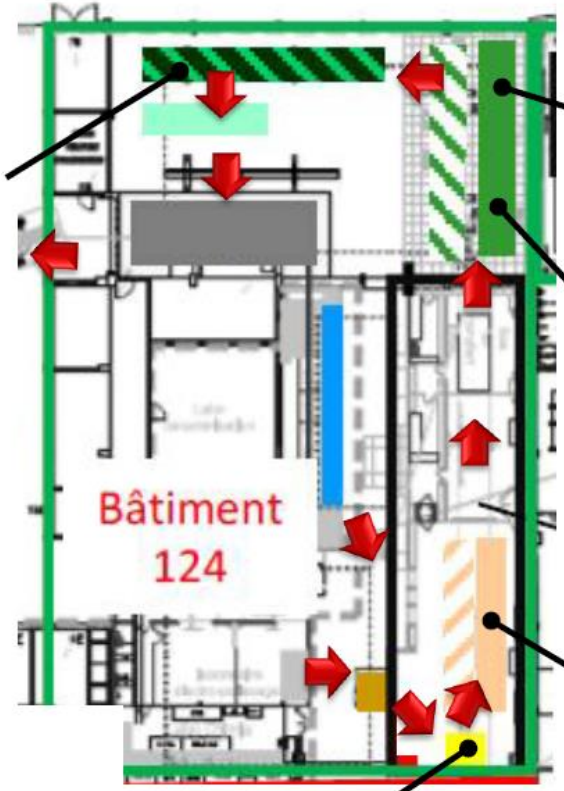
• Adjustement of the tie rods to meet mechanical axis alignment specifications

INSERTION OF THE COLD MASS INSIDE THE VACUUM VESSEL

INSERTION OF THE COLD MASS INSIDE THE VACUUM VESSEL

- Jumper connection assembly
- cryogenic connections at the cryomodule extremities
- Leak check of all the cryogenic circuits
- Closing the vacuum vessel

CRYOMODULE SERIES ASSEMBLY: WORKSTATION LAYOUT



- Ultra-sonic bath cleaning
- Industrial washer
- Cavity - coupler assembly
- Cavity string assembly
- Cavity string dressing / spaceframe insertion
- Spaceframe preparation / cryostating
- Coupler bell assembly
- Cryomodule loading

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CONCLUSION

- Experience has been acquired during the assembly of the medium cryomodule prototype by the ESS ECCTD team leading to some improvements of some parts and steps of the assembly process.
- More experience will be acquired with the assembly of the series cryomodules and the testing of several cryomodules.
- This experience will be very useful for the design of the PIP-II 650 MHz cryomodules if spaceframe is choosen.