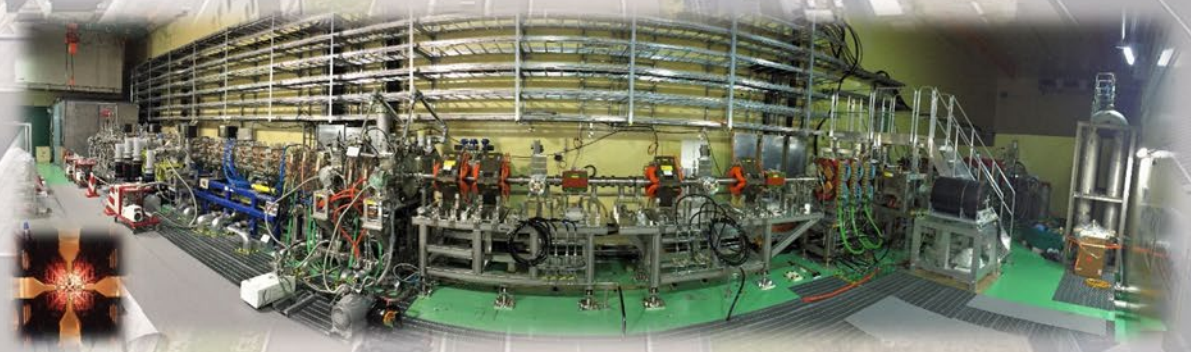
Cleanroom Assembly of the IFMIF SRF LINAc

Janic Chambrillon

Linear Collider Workshop 2024

Hongo Campus, University of Tokyo, Japan – 9th of July 2024

Target Facility



Accelerator Facility

Test Facility

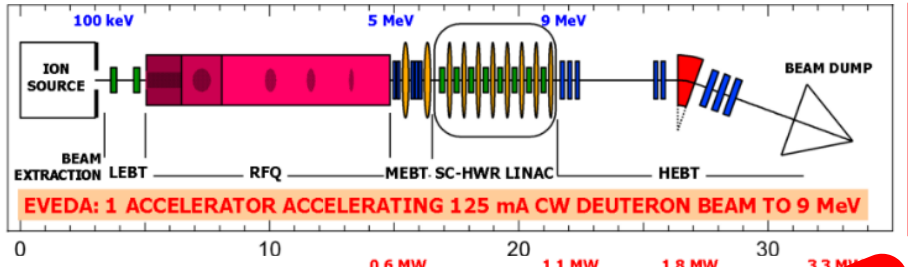
IFMIF/EVEDA Project

Outline

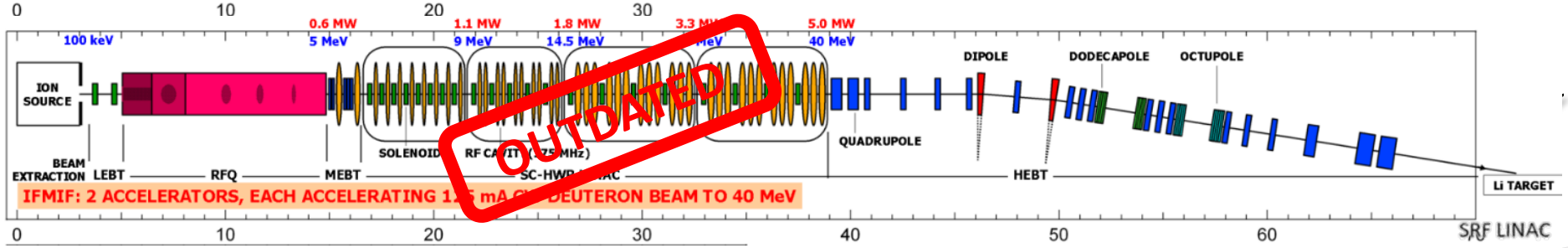
1. Introduction
2. Cleanroom assembly
3. Technical issues and NCs management
4. Conclusion

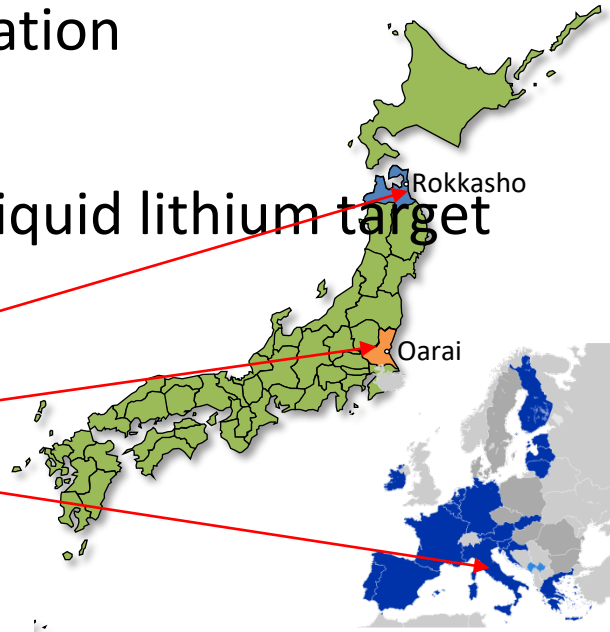
Introduction

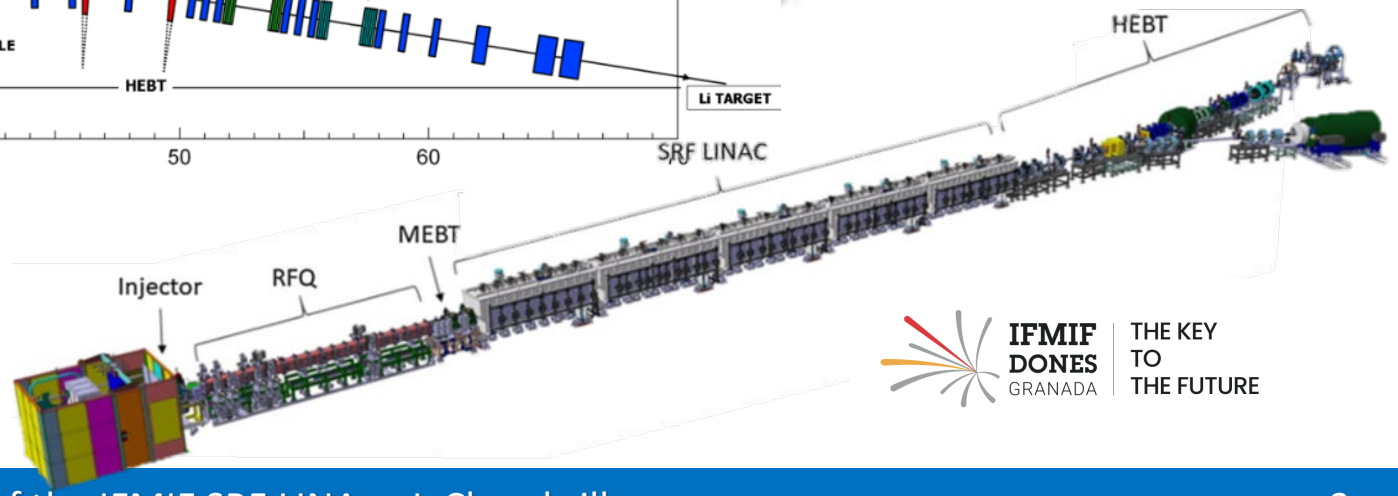
- LIPAc: Linear IFMIF Prototype Accelerator:
  - Under the Broader Approach Agreement, the EU-Japan collaboration
  - Technical demonstrator for Deuton production and acceleration
  - Used for neutron production by nuclear stripping reaction on a liquid lithium target



Validating the key technologies (high priority)
- The low energy part of accelerator
- The lithium target facility
- The high flux test modules







IFMIF DONES: EU project for the next accelerator

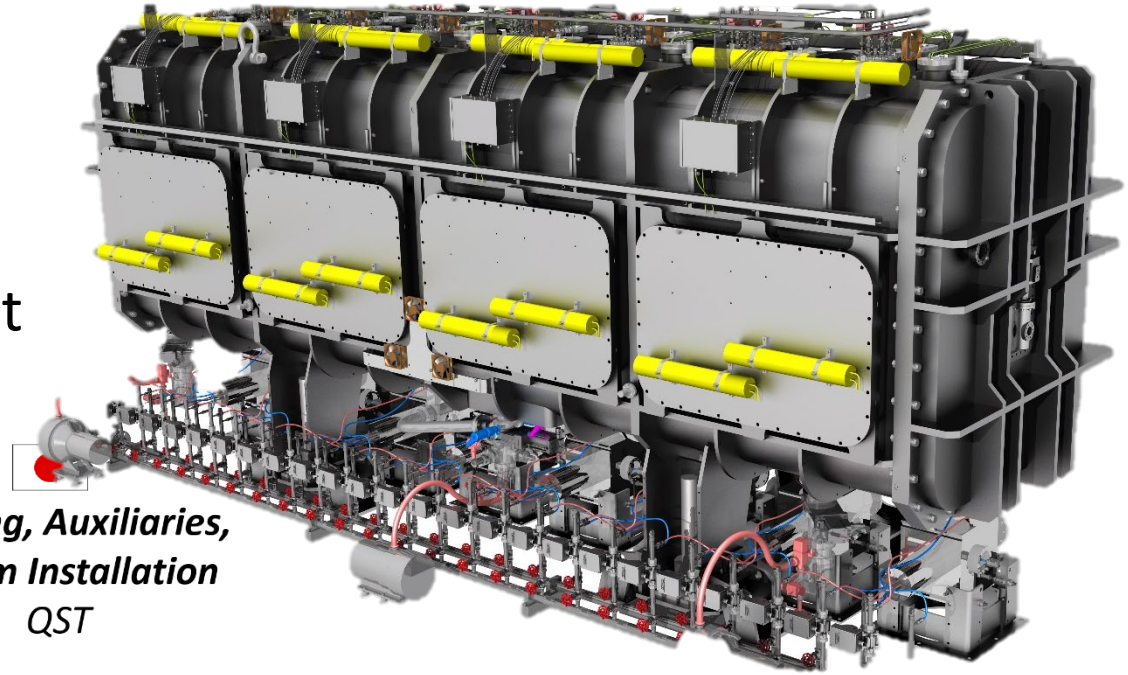
A-FNS: JP project for the next accelerator

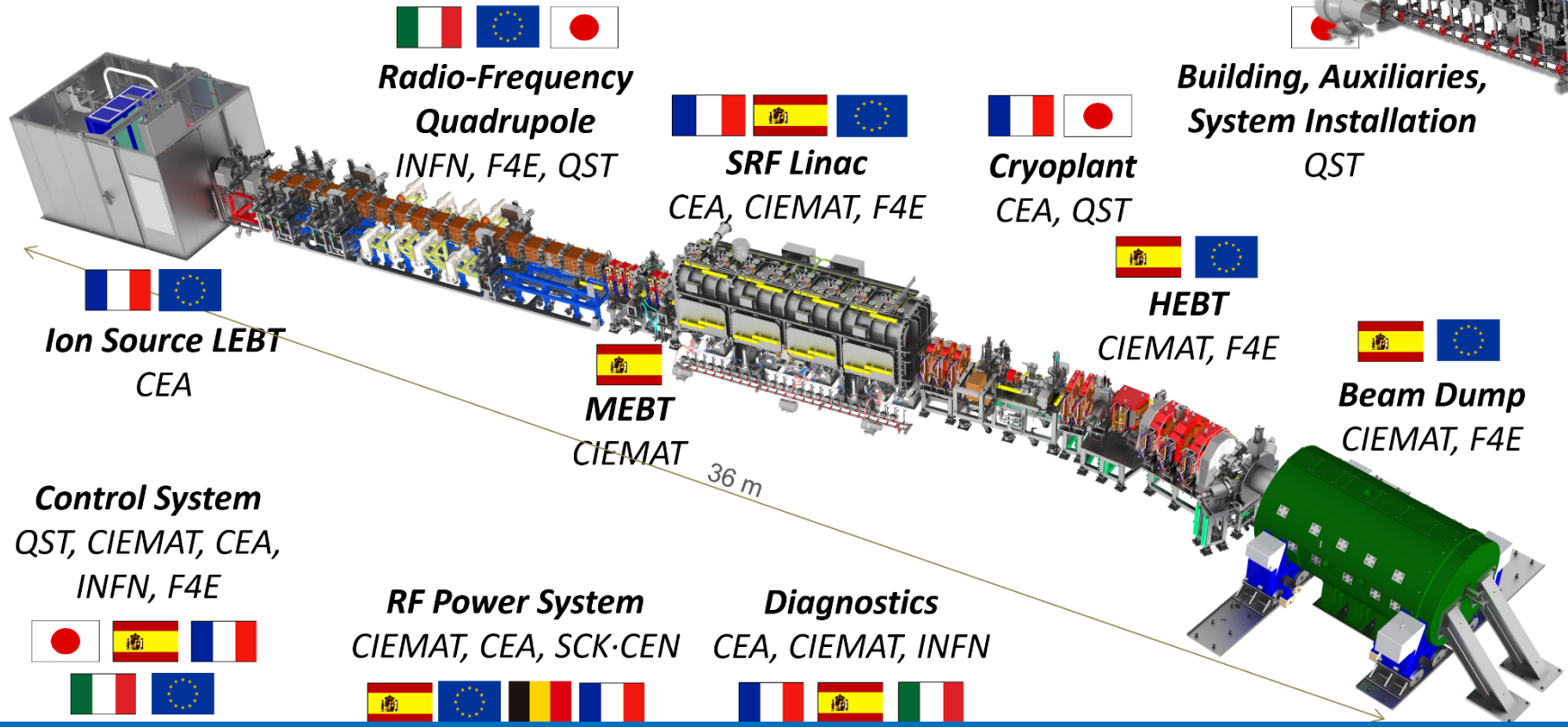
IFMIF DONES GRANADA | THE KEY TO THE FUTURE

*EVEDA (Engineering Validation an Engineering Design Activities)

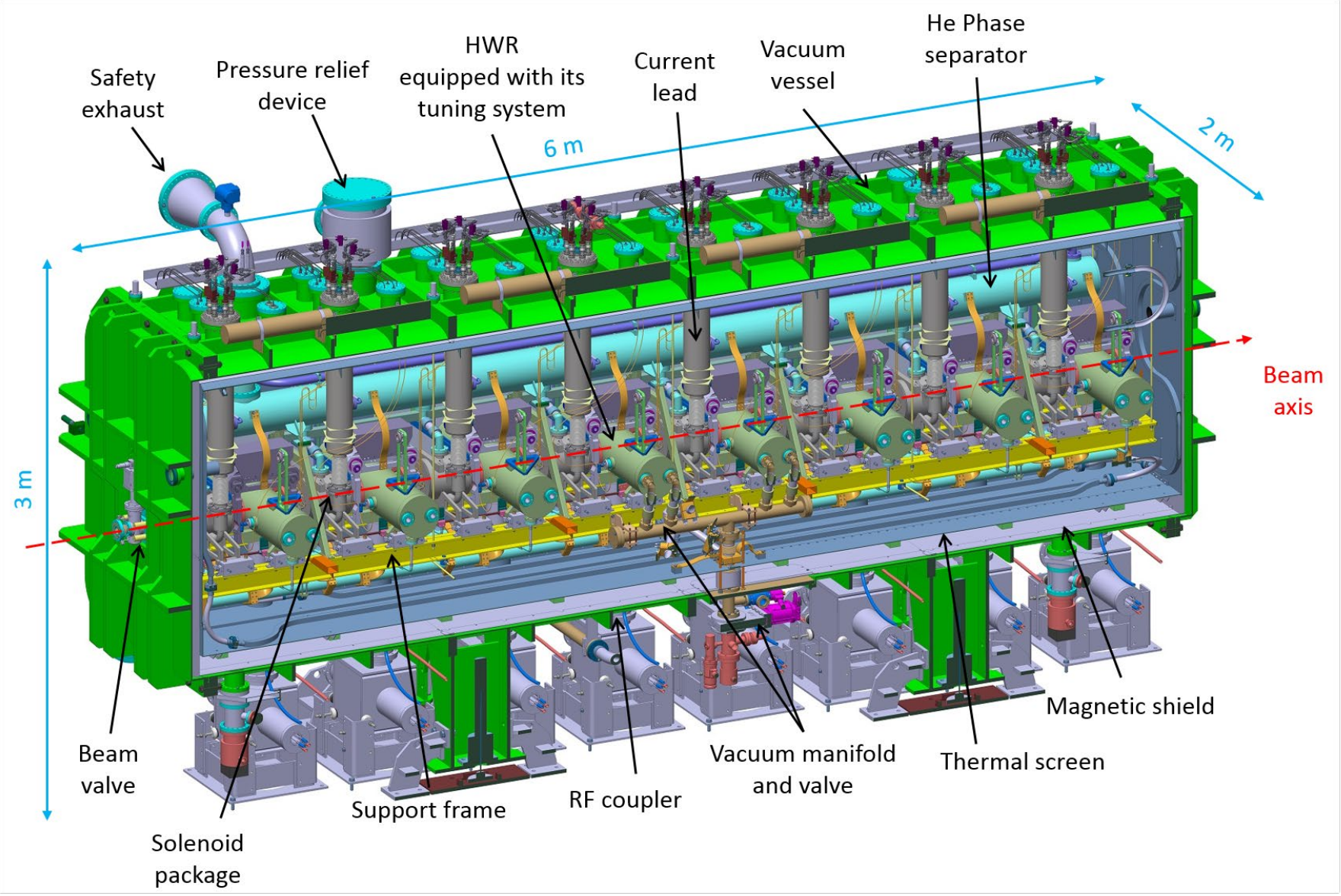
Introduction

- SRF LINAC was procured by CEA Saclay except for the solenoid package which was delivered by CIEMAT Madrid
- Assembly is done in Japan by Research Instrument GmbH





Introduction

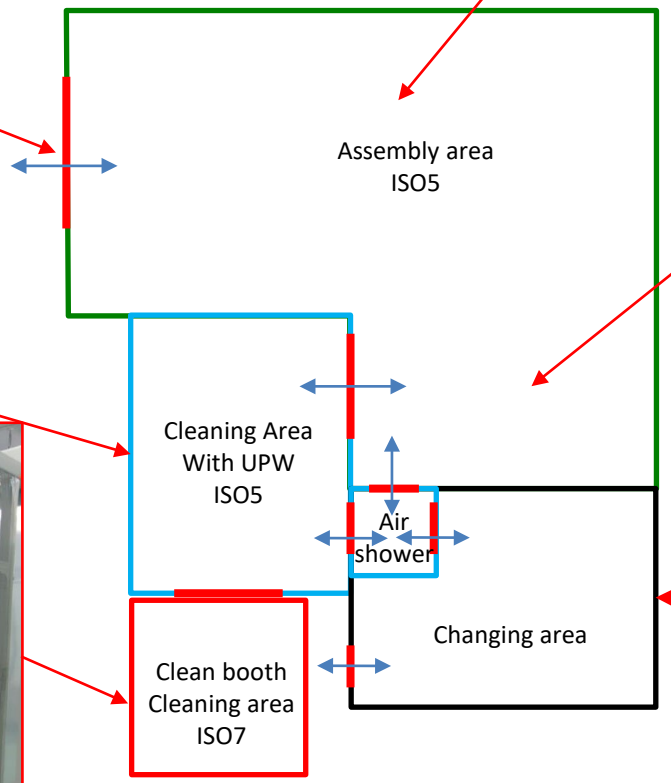


HWR	**175 Mhz**
β	0.094
E_a	4.5 MV/m
Q_0	1.4E9
Solenoid	**6 T**
$\int B.dl$ on axis	1 T.m
Field at Cavity flange	20 mT

Courtesy of CEA

Cleanroom Assembly

- Rokkasho cleanroom

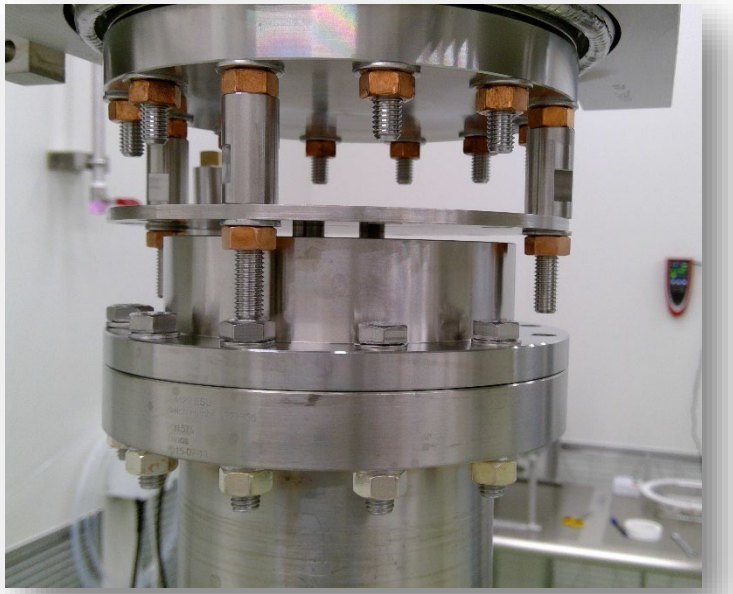


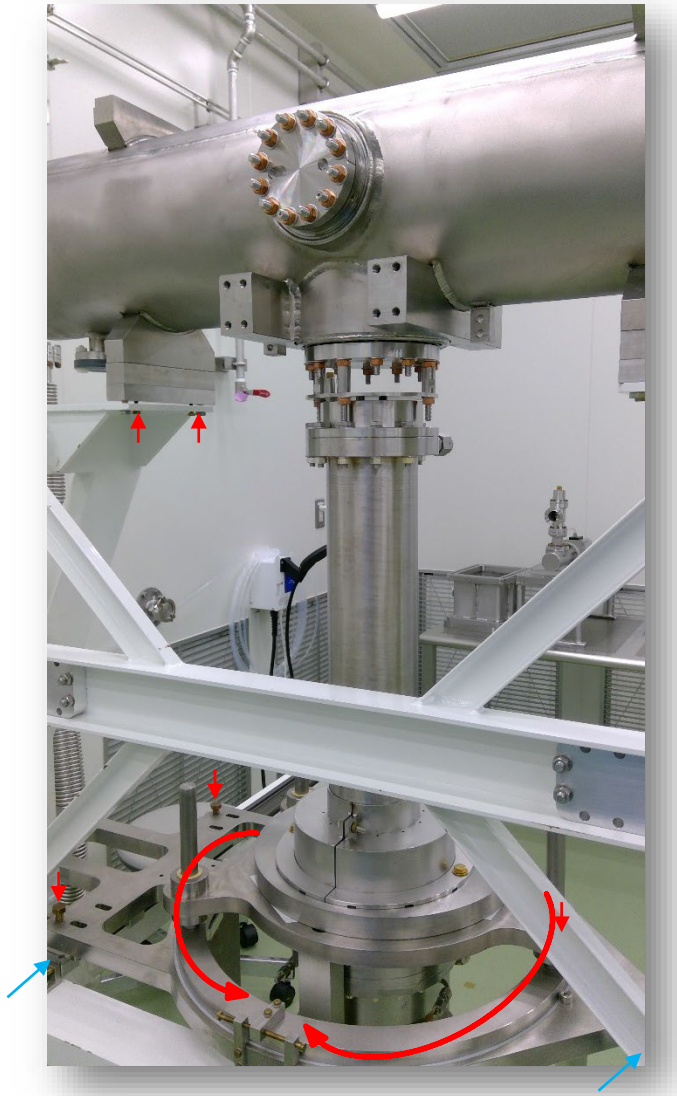
- Vertical laminar flow
- No recirculation

Cleanroom Assembly

- Incoming inspection (visual inspection and leak tests) of the SRF cavities, power couplers, solenoids and pumping line prior to any assembly.

- 1st Step: Cavity/coupler assembly:
  - Positioning and tilt adjustment of the cavities.
  - Positioning and adjustment (XY, tilt) of the power coupler.
  - Alignment flanges were used to check the adjustment.



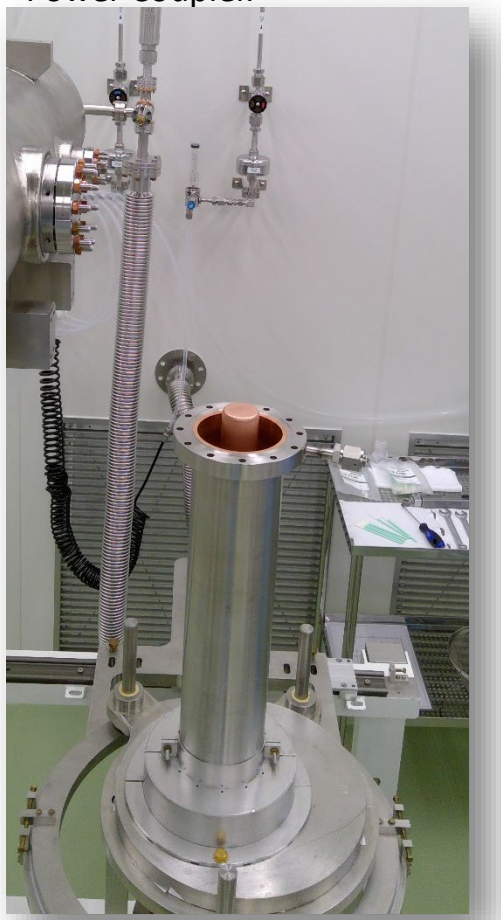


Cleanroom Assembly

- 1st Step: Cavity/coupler assembly:

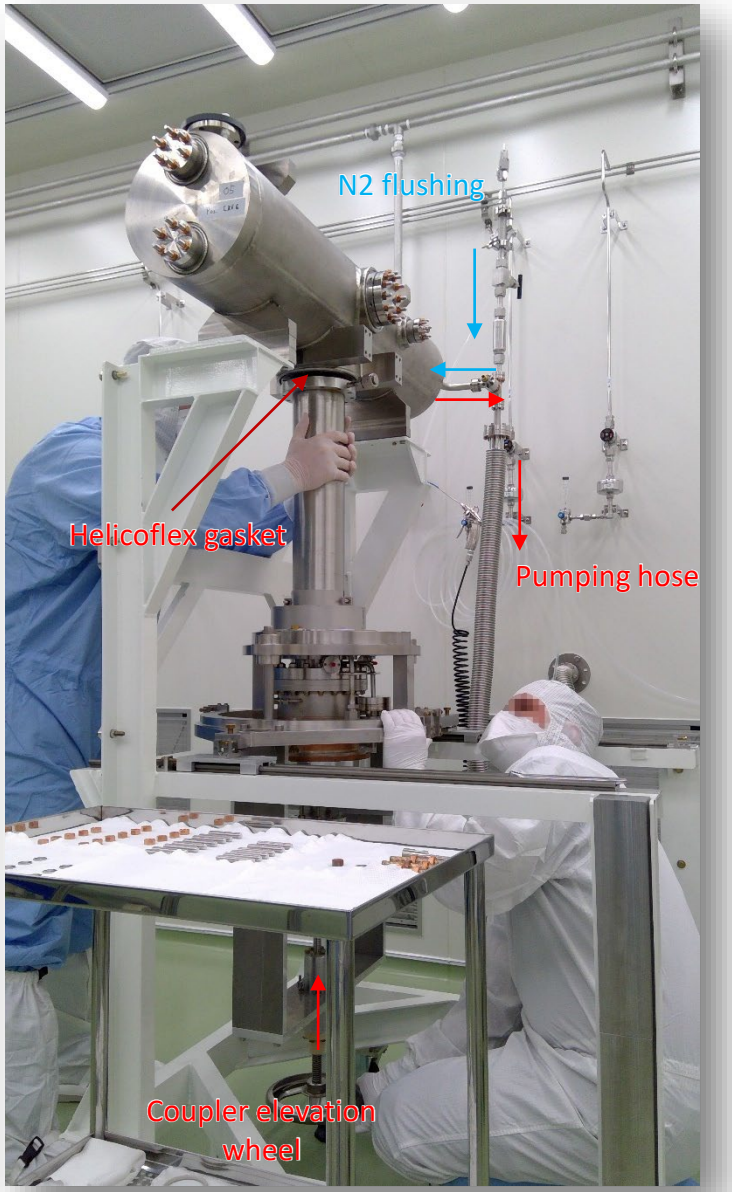
  →Each cavity has its own flush/pump unit

Opening and inspection of the sealing surface of the Power Coupler.



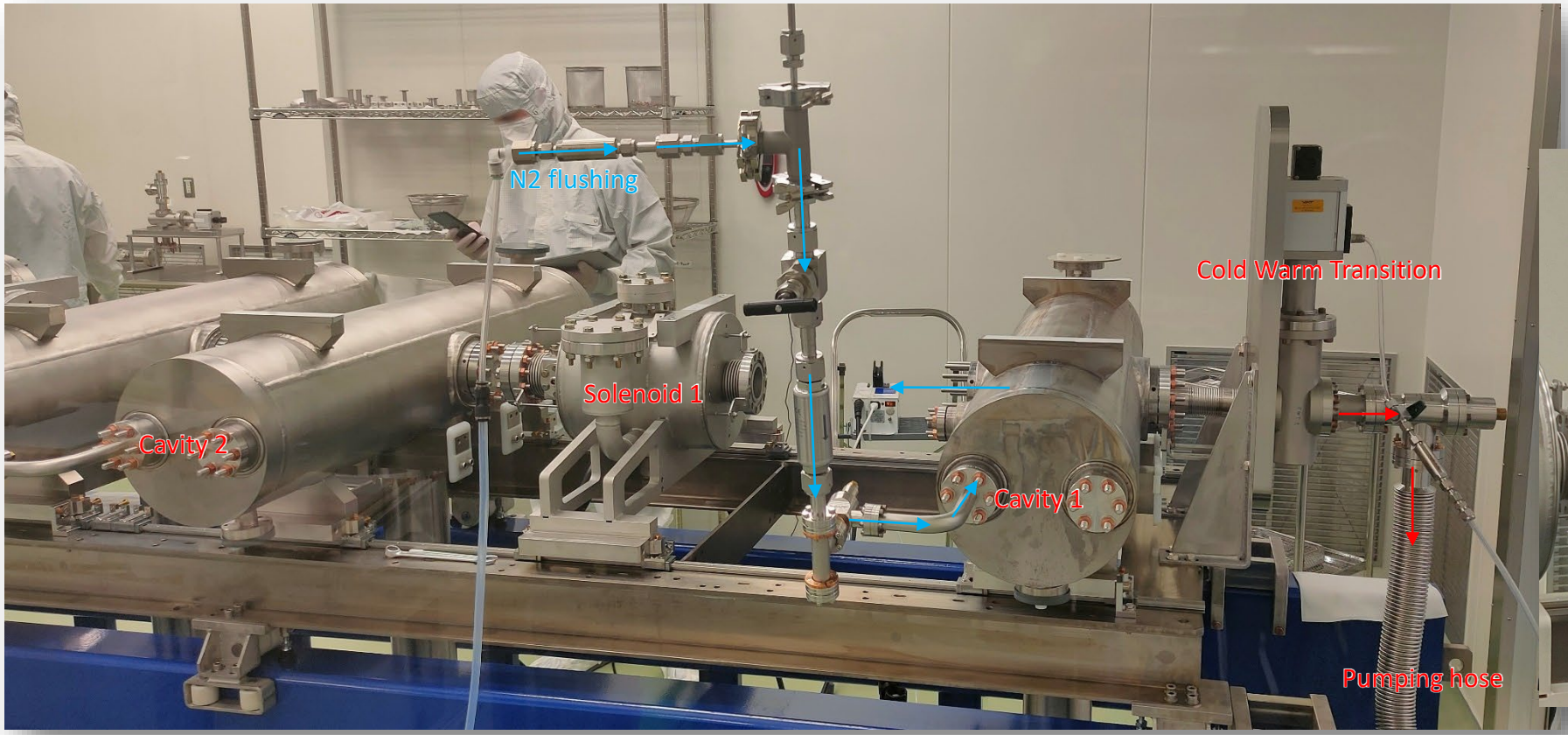
The gasket is installed, and PC is covered while the cavity flange is opened and inspected.

When ready, the cover is removed, and the PC is moved under the cavity.

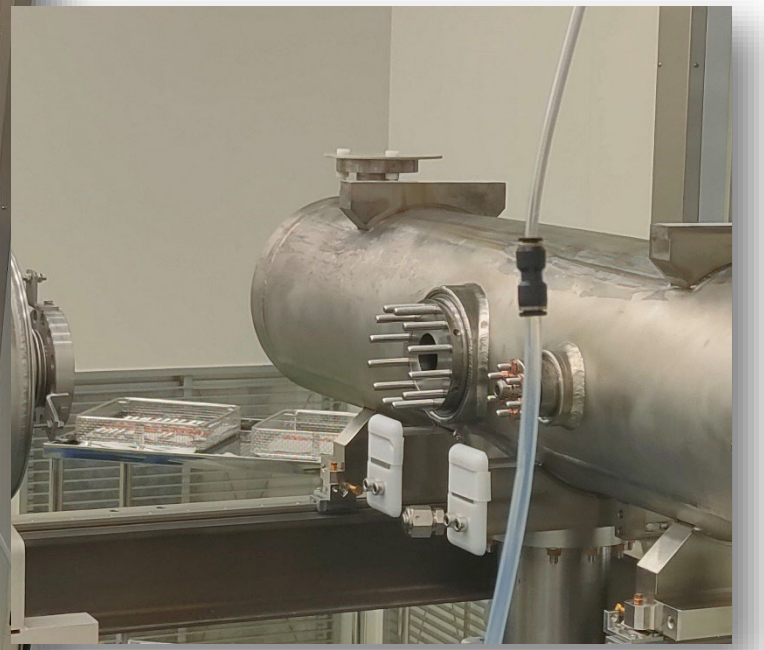


Cleanroom Assembly

- 2nd Step: beam line assembly
  - 3 sub-assemblies of beam line components + pumping line.
  - 1st sub-assembly: cold/warm transition + 3 SRF cavities + 3 solenoids.

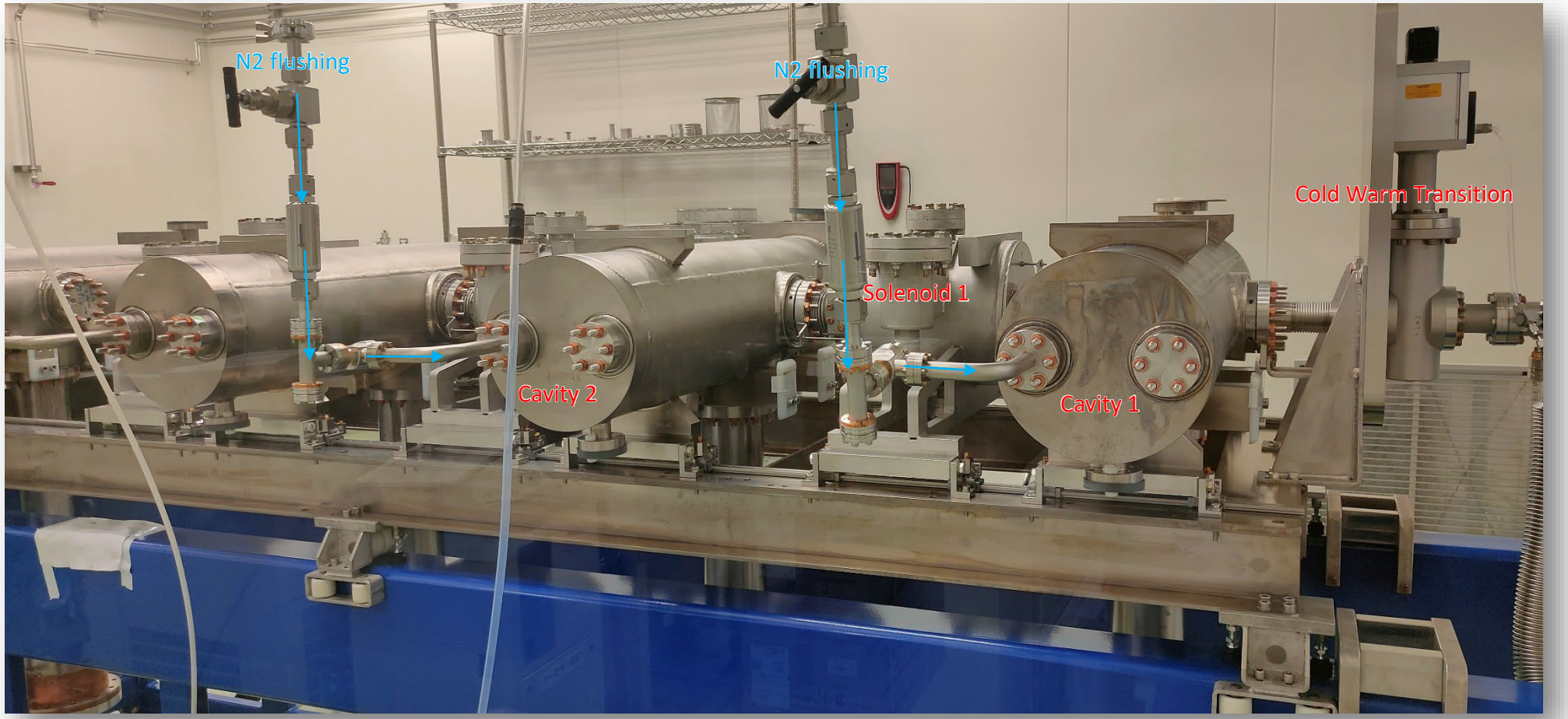


Studs were preinstalled. The solenoid flanges has slotted holes.



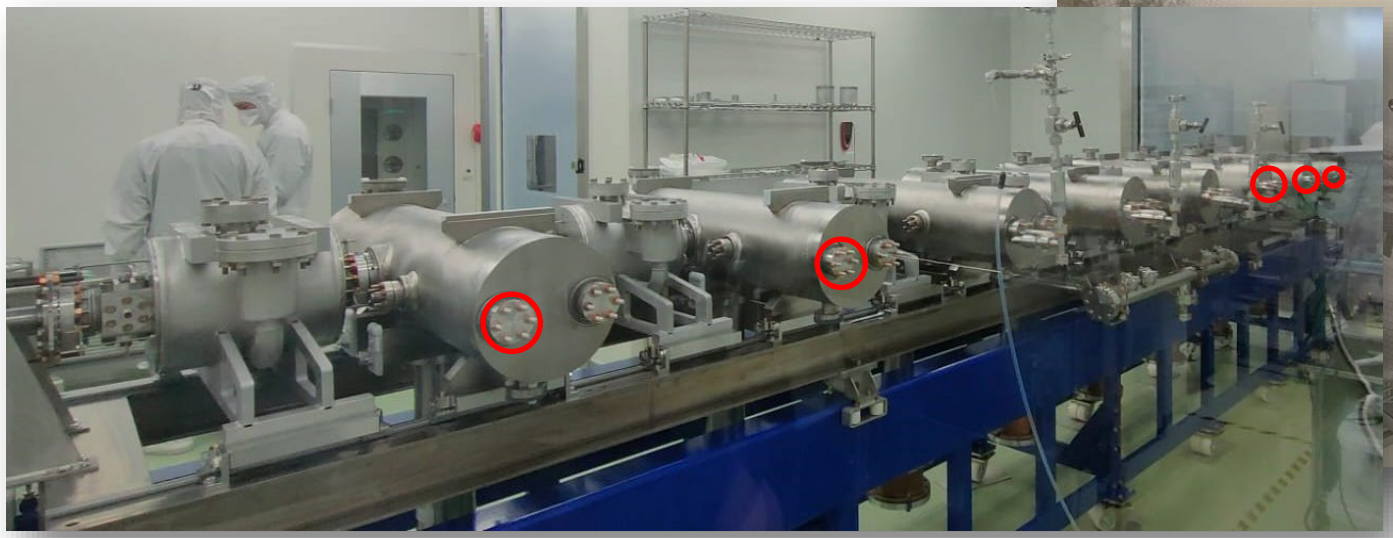
Cleanroom Assembly

- 2nd Step: beam line assembly
  - Double flushing when adding each new cavity to the assembly.



Cleanroom Assembly

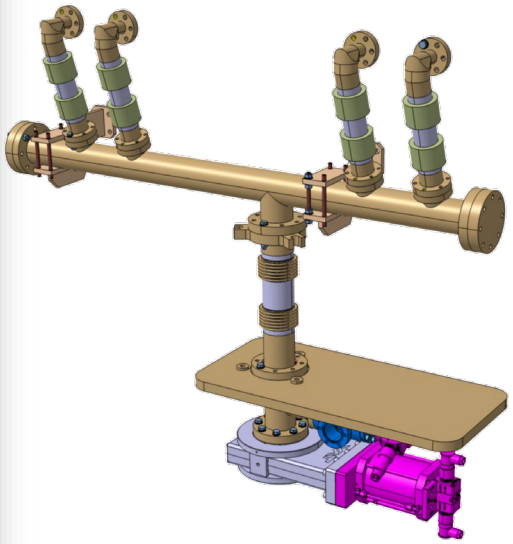
- 2nd Step: beam line assembly
  - Leak test 1, after the 1st sub-assembly leak tight.
  - 2nd sub-assembly: 2 cavities and 2 solenoids added to the 1st sub-assembly.
  - Leak test 2 leak tight.
  - 3rd sub-assembly: 3 cavities + 3 solenoid + cold/warm transition added to the assembly.
  - Leak test 3 leak tight.
  - Removal of 5 of the flushing units.
  - Leak test 4 leak tight.



Cleanroom Assembly

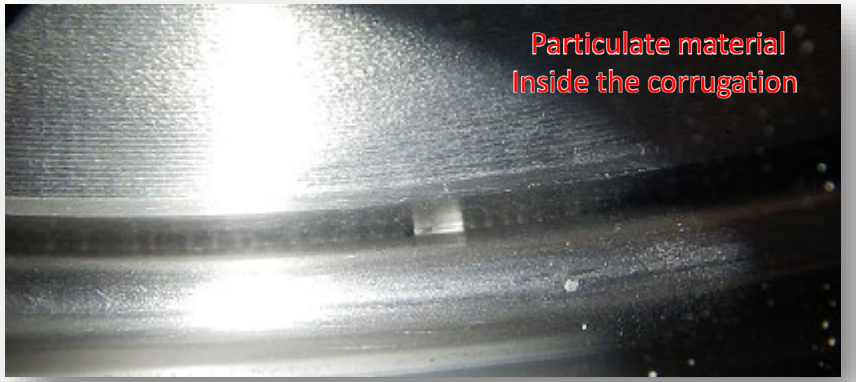
- 3rd Step: pumping line assembly
  - Pre-assembly and leak test of the pumping line prior to the connection to the beam line.
  - Leak test 5 leaking – cleanroom assembly paused.


Leak test of the pumping line assembly



Technical issues and NCs management

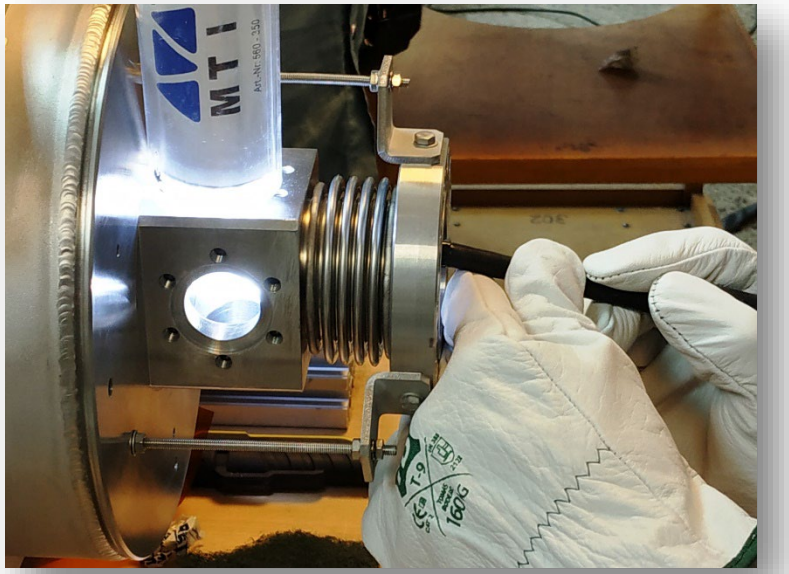
- **2019, March :** quality issue on the solenoid discovered during their HPR preparation in cleanroom at CEA.
  - Rust spots, weld quality issues inside the beam tube, particulate material trapped in the bellows, external surface finished.
  - Remedial actions: light grinding/polishing of the welds, pickling and passivation.
  - Black spots appeared on the newly passivated welds.
  - The process was repeated locally on the weld before a final passivation.



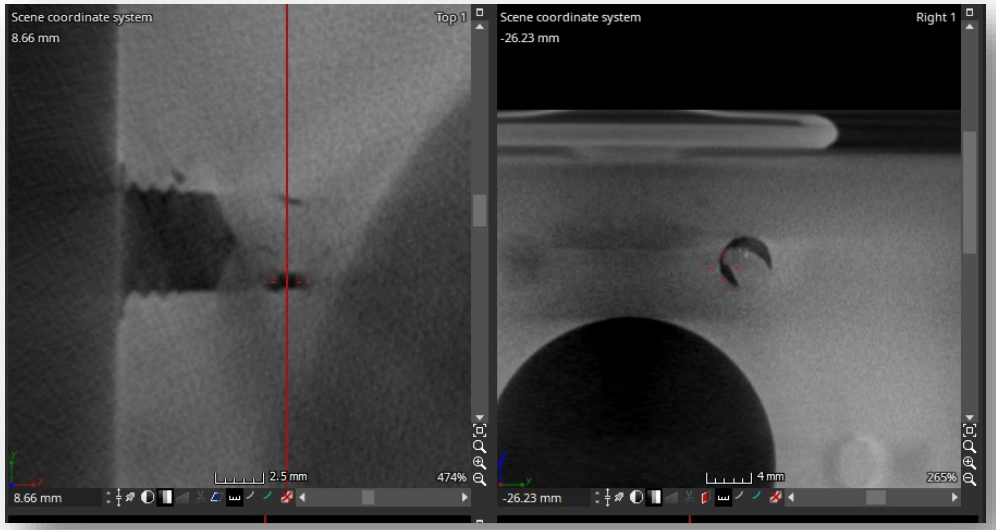
- **2019 September: completion of the remedial action.**

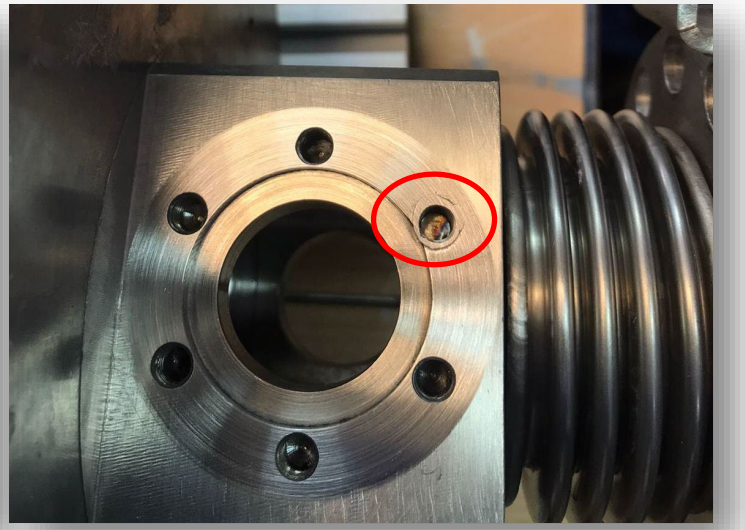
Technical issues and NCs management

- **<u>2019, October:</u>** a leak is detected on solenoid V06.
  - Located on the bellows on the BPM side.
  - A first attempt of repaired failed.
  - The bellows was changed by a new one.
  - After completion of the repair, a new leak was detected on a threaded hole of the BPM.
  - A previous repairs was actually discovered on that thread.
  - The hole was recharged with welding material but a gas volume was trapped.



- **Early 2020**
  - V06 was finally leak tight.





Technical issues and NCs management

- **2019, March:** strong helium background during the 3 first cavity/coupler assemblies.
  - Suspected: 1- permeation in the O-ring gaskets of the slow pumping system (SPS next to the cleanroom exhaust).
    2- issue with the Helicoflex gasket sealing surface.
  - Solution 1: A new slow pumping system with all metal gaskets.
  - Solution 2: mock-up of the C/C interface and test with Helicoflex gasket.
    - Aluminium Hexagonal gasket were used during the vertical test -> possible damage of the sealing surface?
    - All the assembly tests done were perfectly leak tight with thermal shock in liquid nitrogen.


Thermal shock of the C/C mock-up

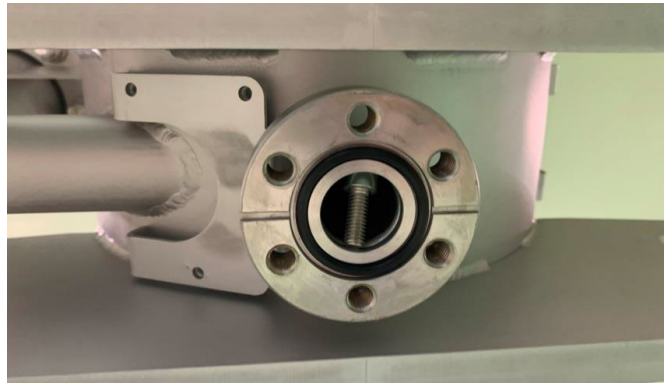
- **Assembly resumed in August 2022:**
  - Still strong helium background ~1E-9 mbar.l/s.
  - The valve isolating the calibrated leak was leaking.
  - Calibrated leak was removed.
  - All remaining assembling went smooth, 2 gaskets needed a second try.

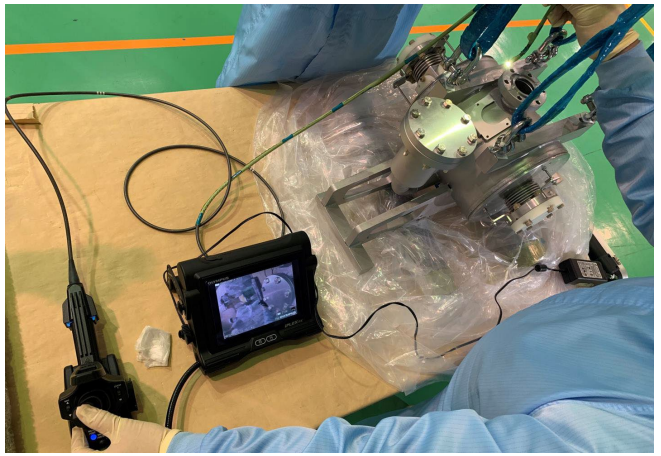
Technical issues and NCs management

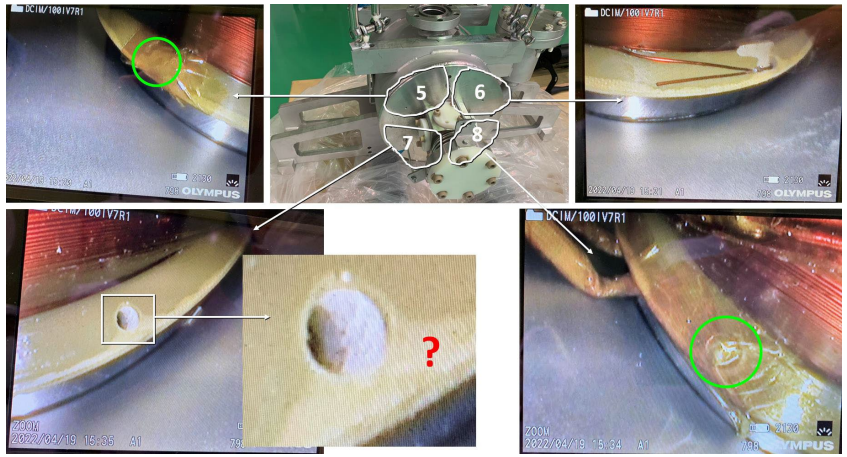
- **2022, June:** -rattling noise detected in 2 solenoids (V06 + V07) during the ultrasonic cleaning prior to HPR at MHI.

  -one BPM pick-up does not fit on solenoid V06 in cleanroom.

  – The two solenoid helium vessels were checked with an endoscope. One loose screw was found in the first one but nothing in the second.



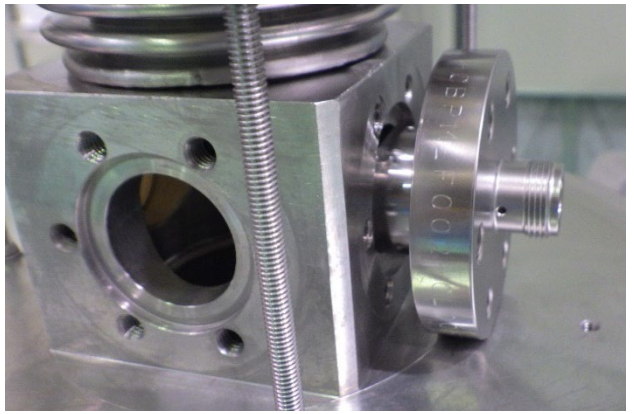


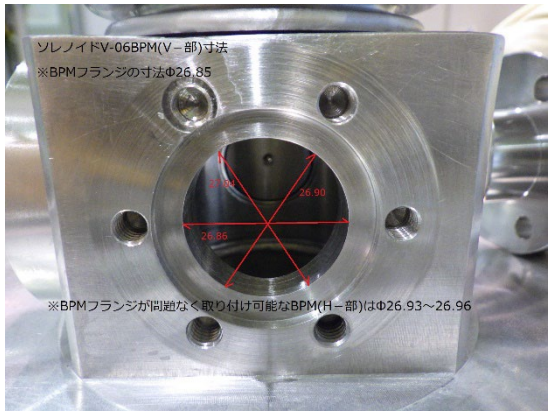


  – The screw found in V06 is used to keep the coil in place during the assembly and can be removed.

  – A CT scan of all the solenoids was decided.

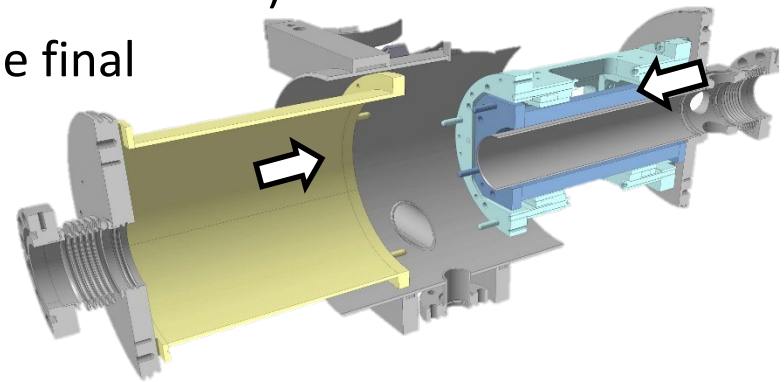
  – The BPM port on V06 was deformed. Same face that had one of its thread repaired. To be solved at QST during the cleanroom assembly.

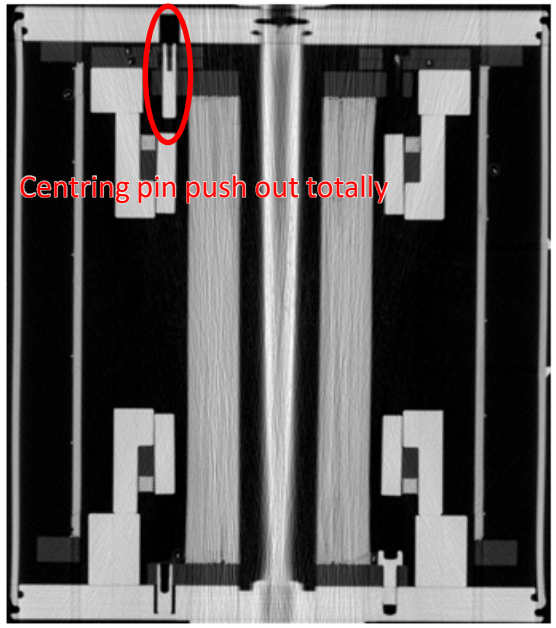


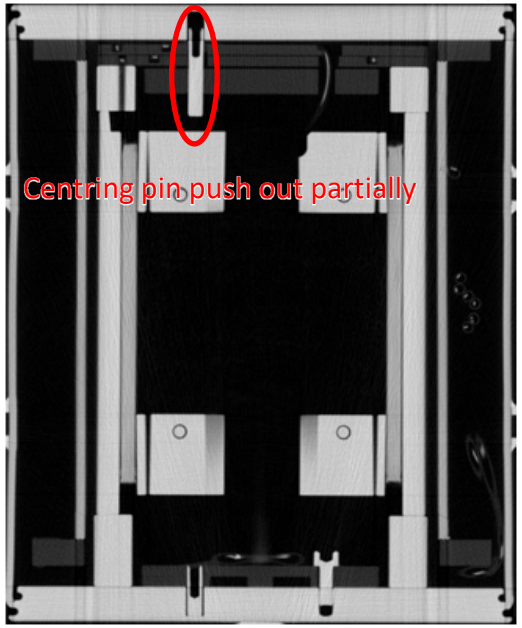


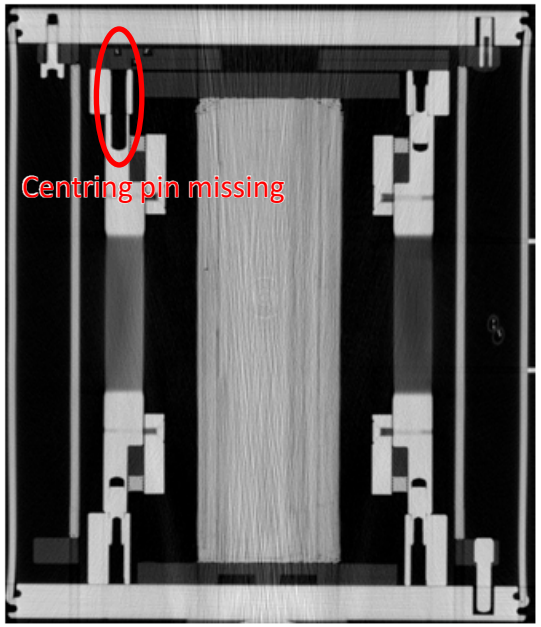
Technical issues and NCs management

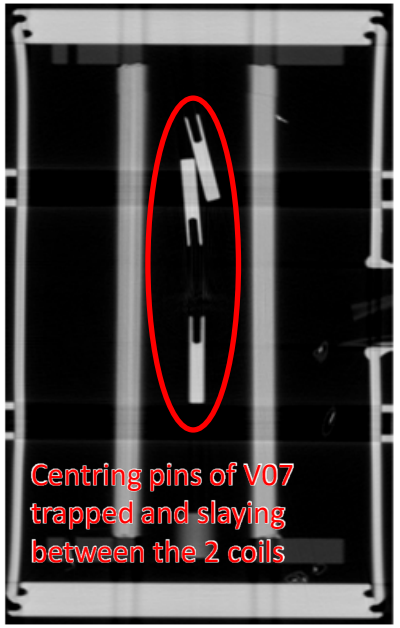
- **<u>2022, July:</u> CT scan of the solenoid at Hitachi**
  - New issues were detected by analysing the centring pins and screws used for the assembly of the coils (solenoids & steerers).
  - Some pins were pushed out during the final assembly.





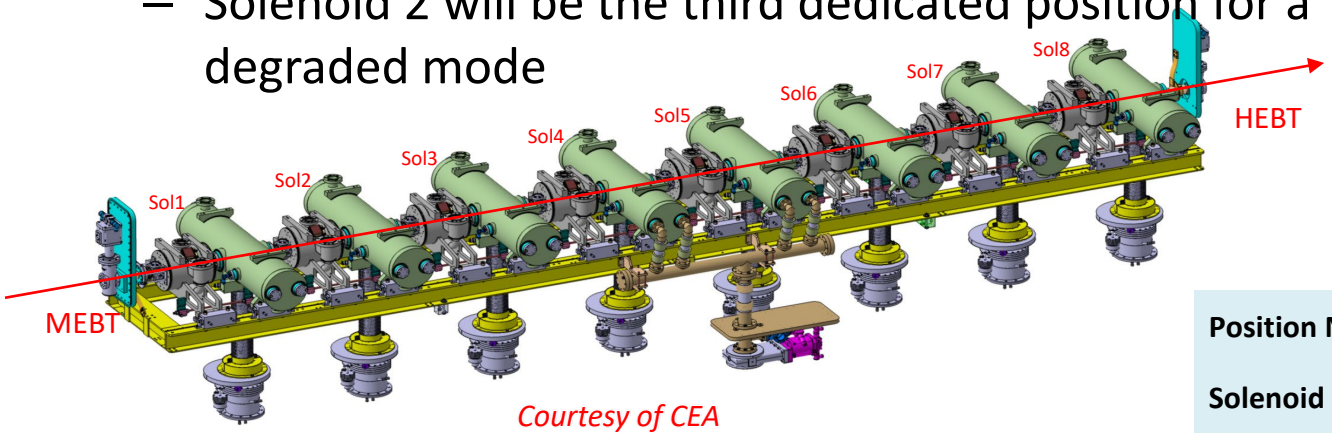






Technical issues and NCs management

- The solenoids were sorted by degree of severity.
- Beam simulations were done to determine the best arrangement on the beam line in case of a failure of one or more solenoid.
- Solenoids 1 and 8 are critical for the operation of the LINAC.
- Solenoids 4 and 7 can be turn off (Sol4 for a better beam physics)
- Solenoid 2 will be the third dedicated position for a degraded mode



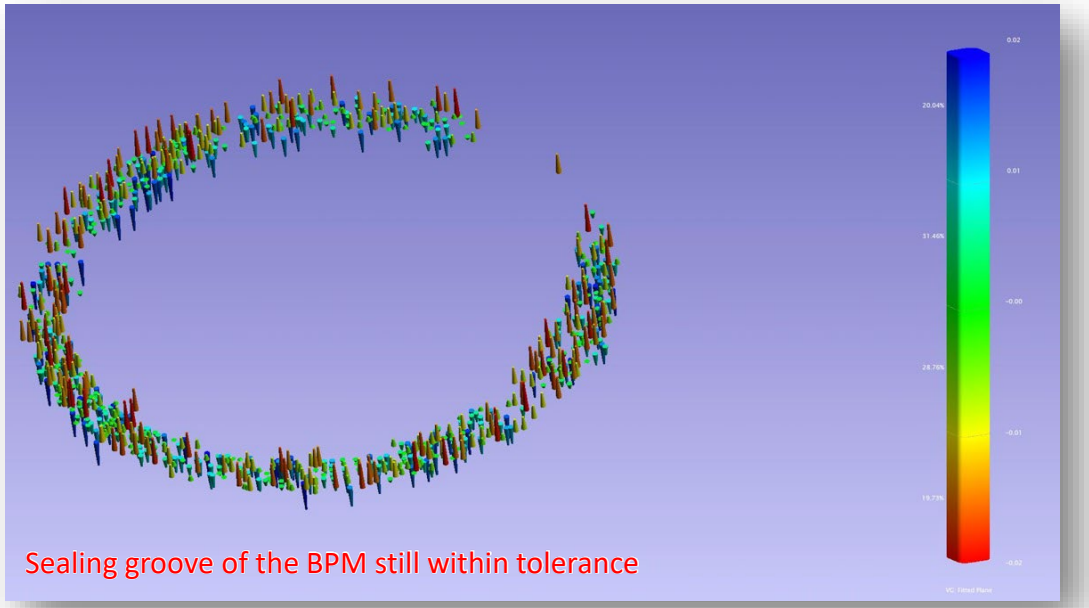
Courtesy of CEA

	Positioning with respect to the beam							
Position Number	Sol1	Sol2	Sol3	Sol4	Sol5	Sol6	Sol7	Sol8
Solenoid Number	V08	V03	V01	V07	V04	V05	V06	V02

Technical issues and NCs management

- **October 2022:** BPM pick-up issue on V06
  - The pick-up head was machined to removed 0.2 µm on the diameter.
  - The pick-up finally fitted but was tilted and leaking.
  - The face of the BPM was deformed probably as a consequence of the repair.
  - The sealing groove was still within tolerance, but a scratch was found.


Surface deformation of the BPM, out of tolerance

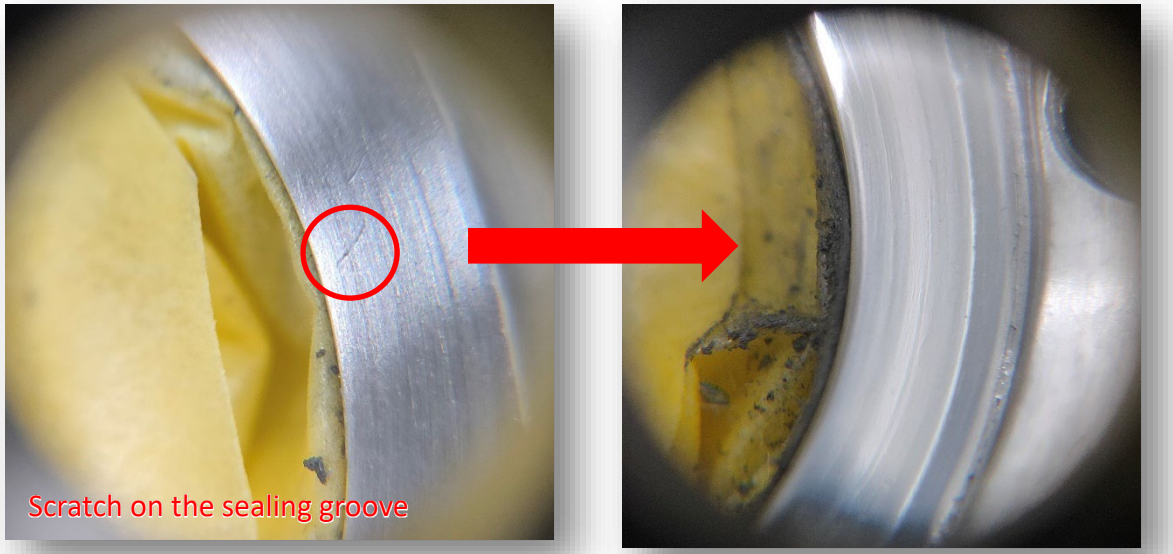

Sealing groove of the BPM still within tolerance

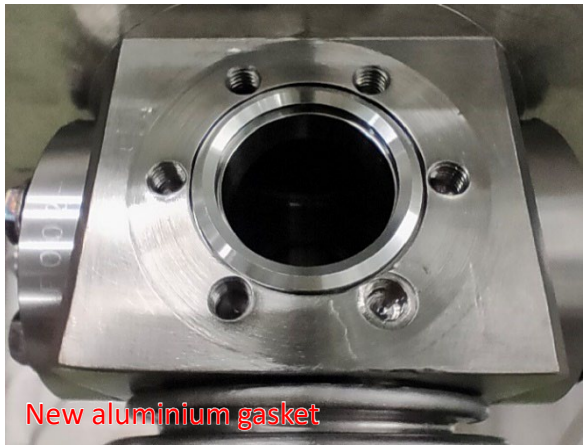
Technical issues and NCs management

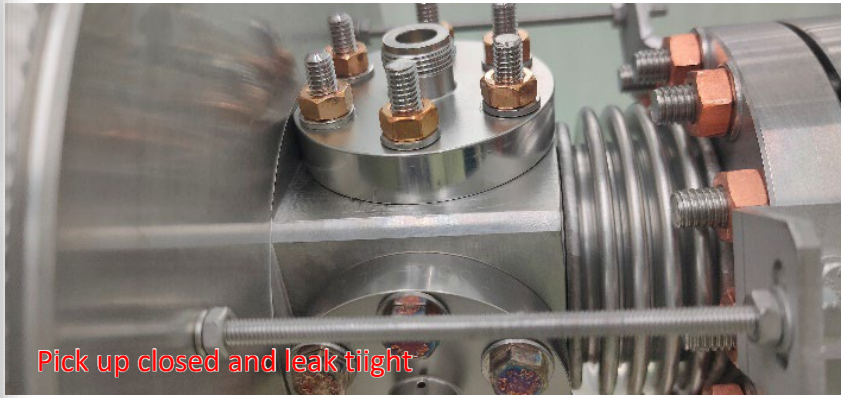
- After different attempts of preserving the HPR, a more invasive rework of the sealing surface was done. An aluminium gasket was also chosen in place of the Helicoflex to preserve the flatness of the pick-up.

- A new HPR was needed at MHI.

- During the incoming inspection at MHI, a new leak appeared on the bellows on the non-BPM side

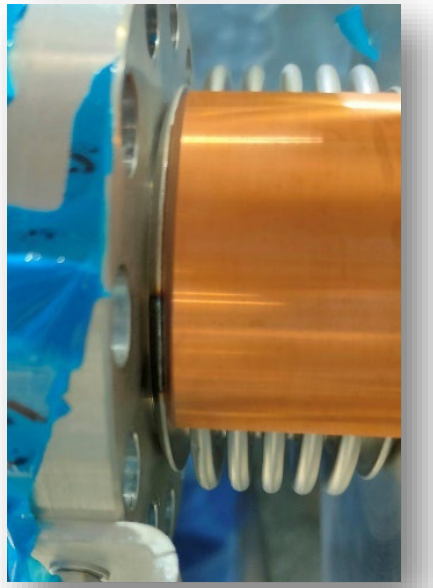


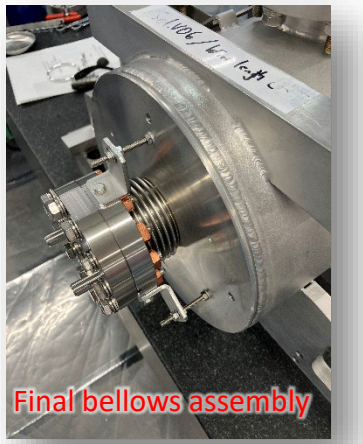


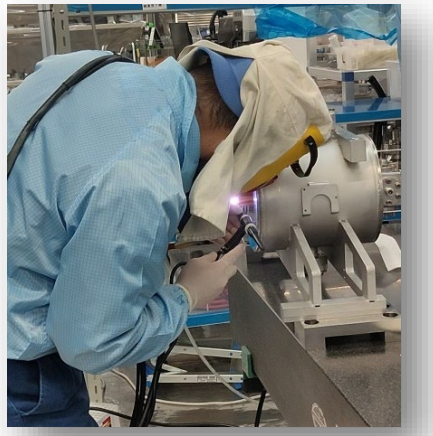


Technical issues and NCs management

- **September 2023:** V06 was shipped to MIRAPRO (bellows manufacturer) for a tentative of repair.
  - It was not possible to fix the leak after 6 attempts.
  - Decision was taken to change the bellows.
- **Early December 2023:** bellows was replaced and V06 was sent back to MHI for the HPR.
- **Late March 2024:** V06 was HPR and ready to come back to Rokkasho.

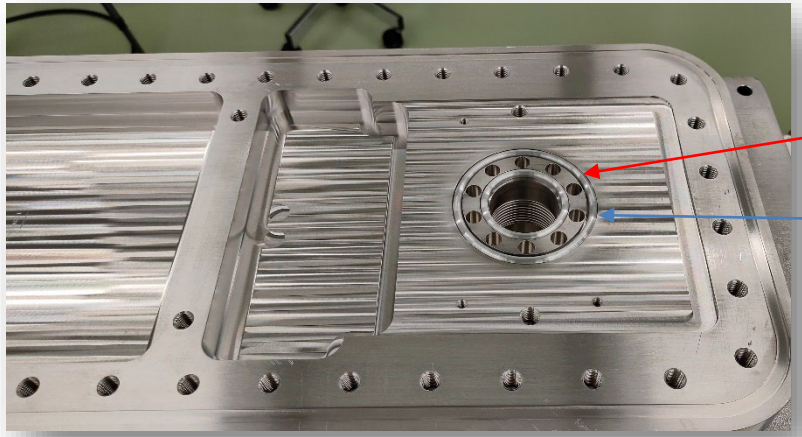


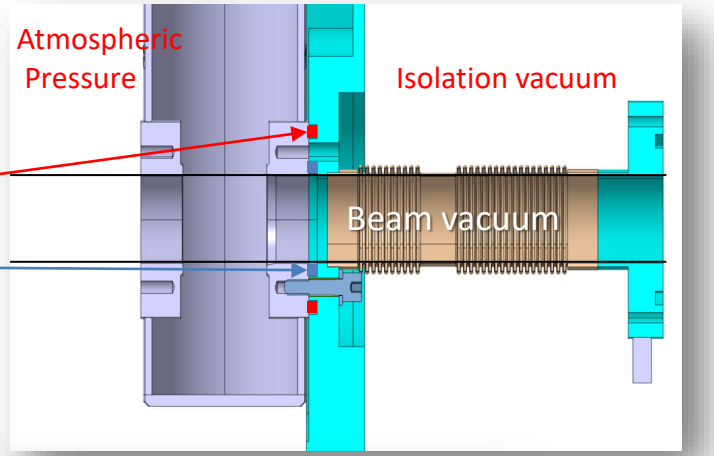


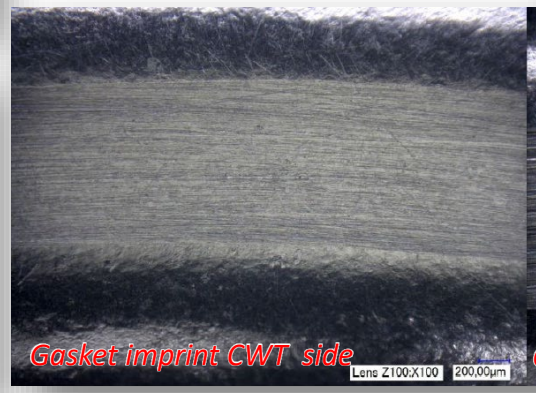


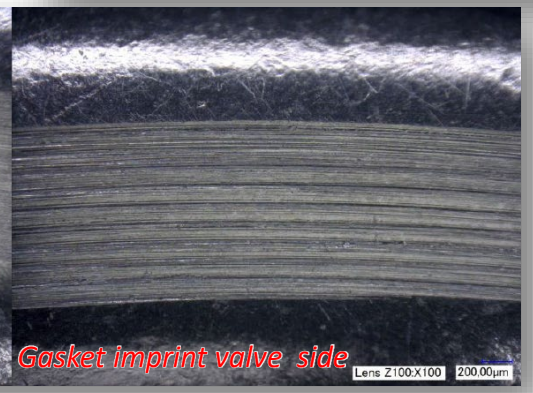
Technical issues and NCs management

- **October 2022:** the 2 cold warm transitions of the beam lines had NC on their sealing surfaces (Helicoflex gaskets)
  - Cold Warm Transition: allows transport of the beam to/from the SRF Linac.
  - Transition from 300 K to 4 K and from Atmospheric pressure to Vacuum.

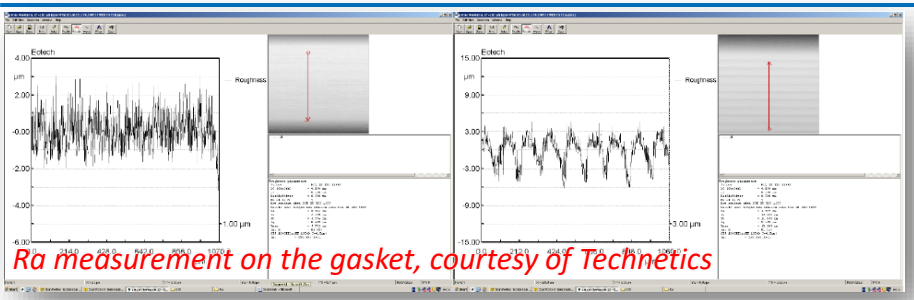








Technical issues and NCs management

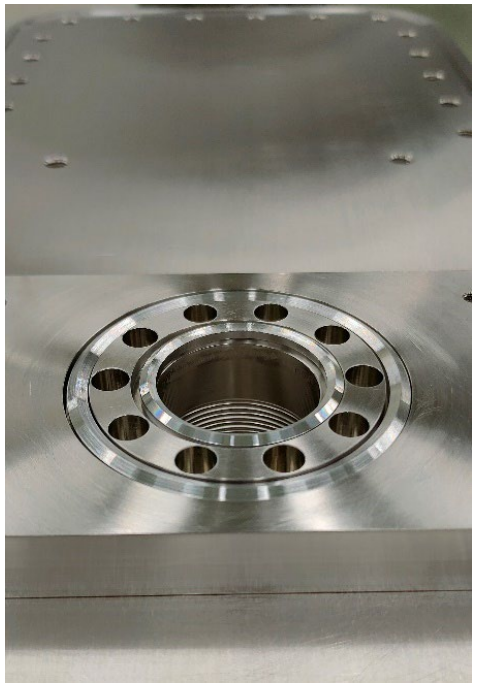


Ra measurement on the gasket, courtesy of Technetics

Seal	CWT1 Inner	CWT1 Outer	CWT2 Inner	CWT2 Outer
CWT side	0.8 µm	0.9 µm	0.7 µm	0.8 µm
Valve side	1.8 µm	1.8 µm	1.7 µm	1.9 µm

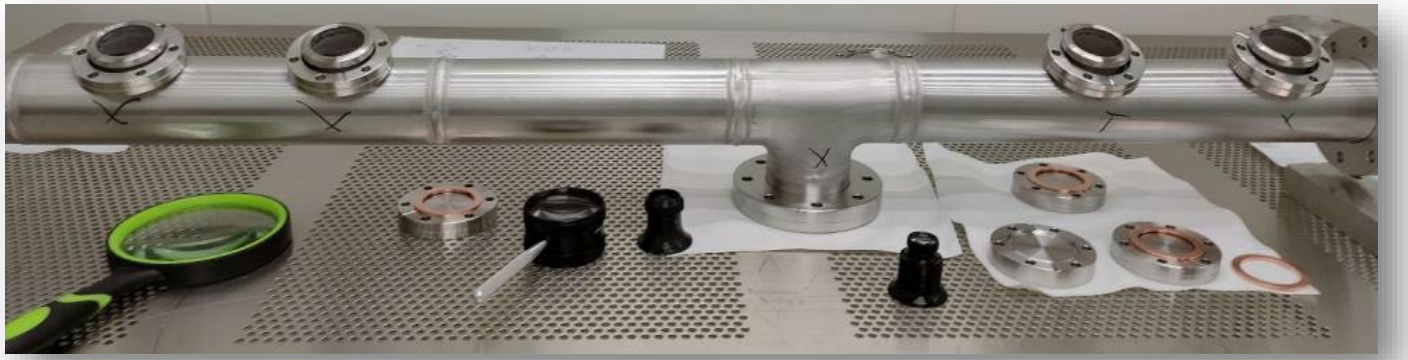
Final polishing for the aluminium gasket

- After two repair attempts it was not possible to get the two gaskets leak tight at the same time.
- New gaskets were ordered:
  - Helicoflex gaskets with tin plating.
  - Aluminium hexagonal gaskets.
- For the third attempt both new gaskets were leak tight.
- The Al hexagonal gaskets were chosen at the end (easier assembly and cleaner than Helicoflex for the inner gasket) solved in **September 2023**

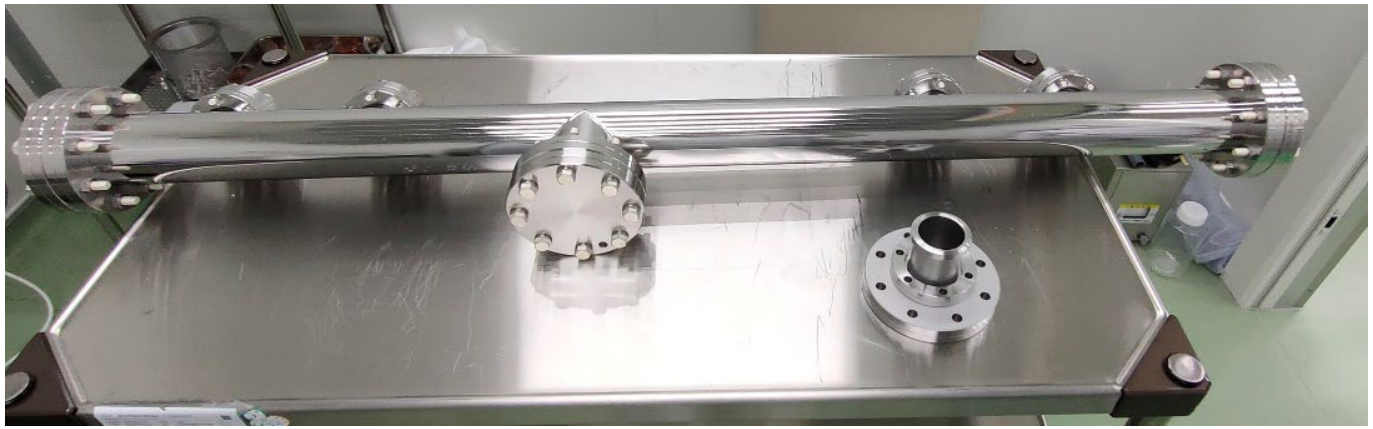


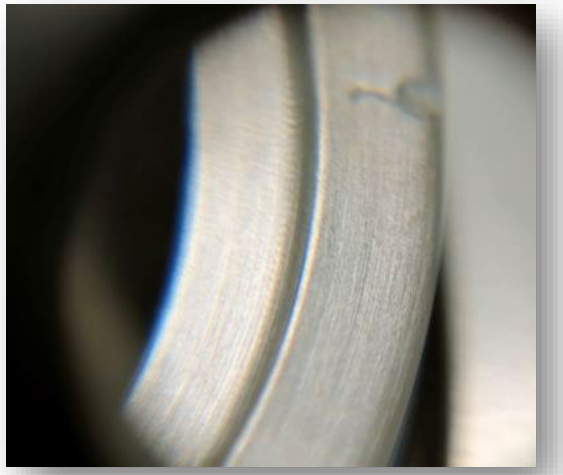
Technical issues and NCs management

- **October 2022:** multiple leaks on the pumping manifold
  - 4 of 7 CF flanges had dulled knives. Improper protection during passivation was suspected.



  - A new manifold was manufactured (easier than repairing) - **October 2023**





Technical issues and NCs management

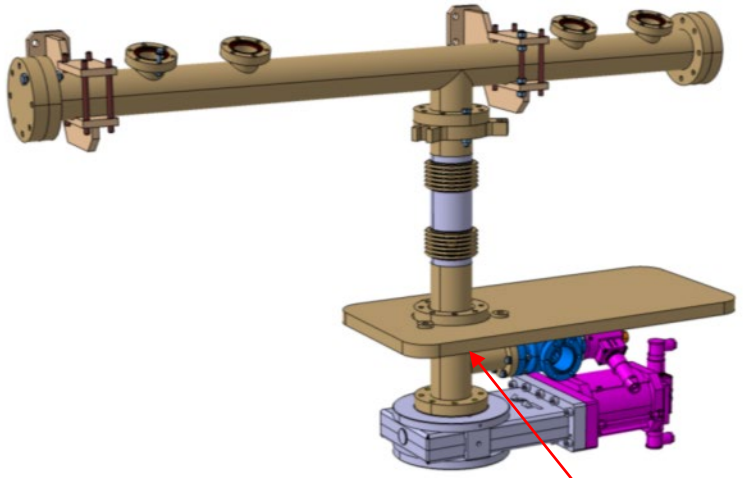
- **June 2024:** wrong assembly order on the 2 first solenoids
  - The 2 first solenoids were not the ones chosen by the beam physics group as a mitigation action.
  - Solved by disassembling and reassembling the correct solenoids.

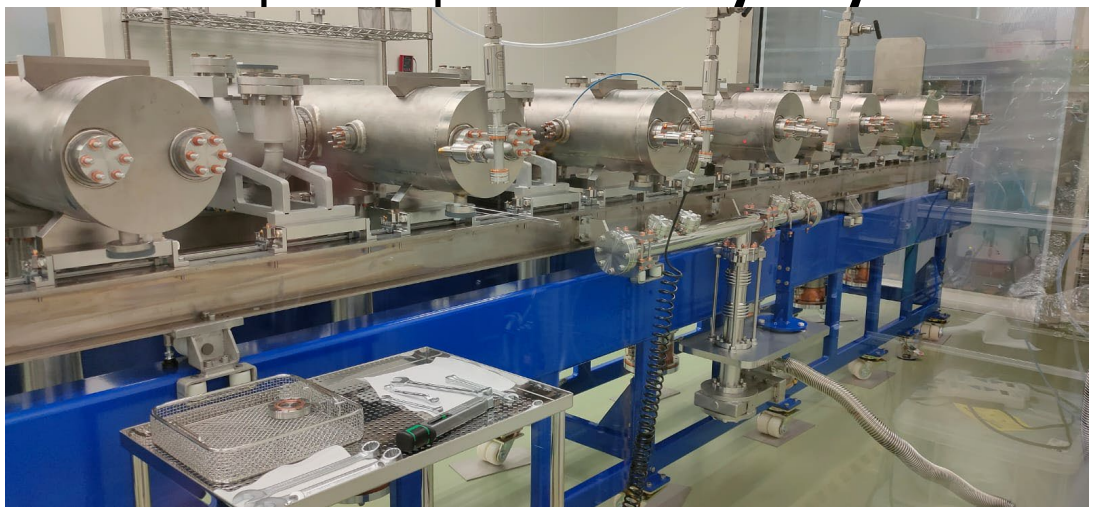
- **June 2024:** solenoid oversize
  - The bellows of the solenoids were not compress to right size (+7 mm longer)
  - 2 solenoids needed to be adjusted after their assembly.

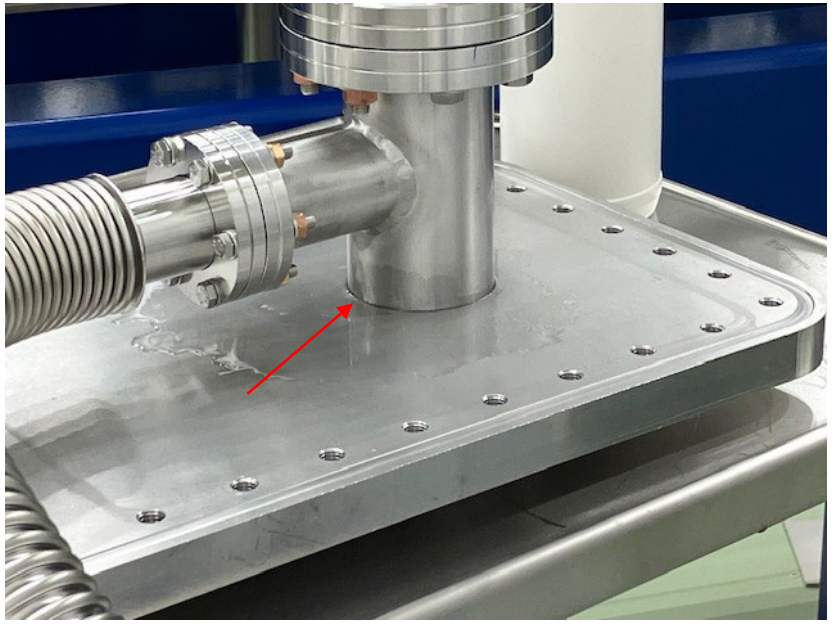
- **June 2024:** CF flange damage
  - Small dent found on a beam pumping line element.

Technical issues and NCs management

- **June 2024:** leak on the main pumping flange
  - A big leak was detected on the preassembly of the pumping line.
  - After investigation, a crack on a weld is suspected (bubble test).
  - A weak point of the weld cracked after assembly the main gate valve.
  - Repair expected **early July 2024**







Conclusion

- Good progress were made on the cleanroom assembly, but any technical issue is a challenge as we need most of the time to outsource the repair (no workshop in Rokkasho).

- Reinforcement of control at each step could have help to detect some issues in advance.

- Vacuum and cryogenic interfaces are weak points. Successful leak tests do not guaranty future leak tightness (mishandling at disassembly, dulled knives…)

- Cleanroom assembly is expected to resume by mid-July for its conclusion.

Acknowledgement

Thank you for your attention

T. Ebisawa , K. Kondo, Y. Carin, H. Dzitko, K. Hasegawa, N. Bazin, B. Renard,
D. Gex, F. Cismondi, D. Duglué, O. Piquet, L. Maurice, A. Gaget, R. Arnaud,
F. Scantamburlo, J.P. Adam, I. Moya, T. Yanagimachi, T. Izumori, H. Suzuki,
L. Gonsales, K. Kumagai, N. KaneKo, T. Narita, J.F. Campos, D. Jimenes, J. Alonso,
J. Molla, M. Trbolova, P. Ransic, H. Hurzlmeier, G. Phillips, V. Tomarchio, A.K. Preis,
M. Kimura, A. Kasugai,…

And many more