



Automation for clean room work

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After the completion of the 103 E-XFEL modules assembly in July 2016, CEA is still involved in the construction of SRF linacs:

- IFMIF/LiPAC : one 8-HWR-cavity cryomodule (176 MHz)
- ESS : 30 medium and high beta cryomodules (704 MHz)
- SARAF : four 7-HWR-cavity cryomodules (176 MHz)

CEA is therefore naturally inclined to improve module assembly process w.r.t. quality, productivity and cost.

Some R&D programs are engaged to benefit from XFEL experience of large scale production



Number of vacuum operations for a complete cryomodule assembly

Procedure	n°1	n°2	n°3	n°4
# Angle valve to pipe connections	20	22	14	14
# Angle valve open/close cycles	29	21	13	13
# N2 flushing after an opening	17	17	9	9
# Leak checks	48	40	32	23

Two assembly ‘parameters’ could be correlated to module results :

- 1) The clean room operator invasiveness
- 2) The vacuum operation invasiveness (mostly but not only in the clean room)



From E-XFEL experience, the cost of module assembly for ILC 500 GeV is in the ballpark of 200 M€, almost entirely in labour cost.

→ Automation and Robotization

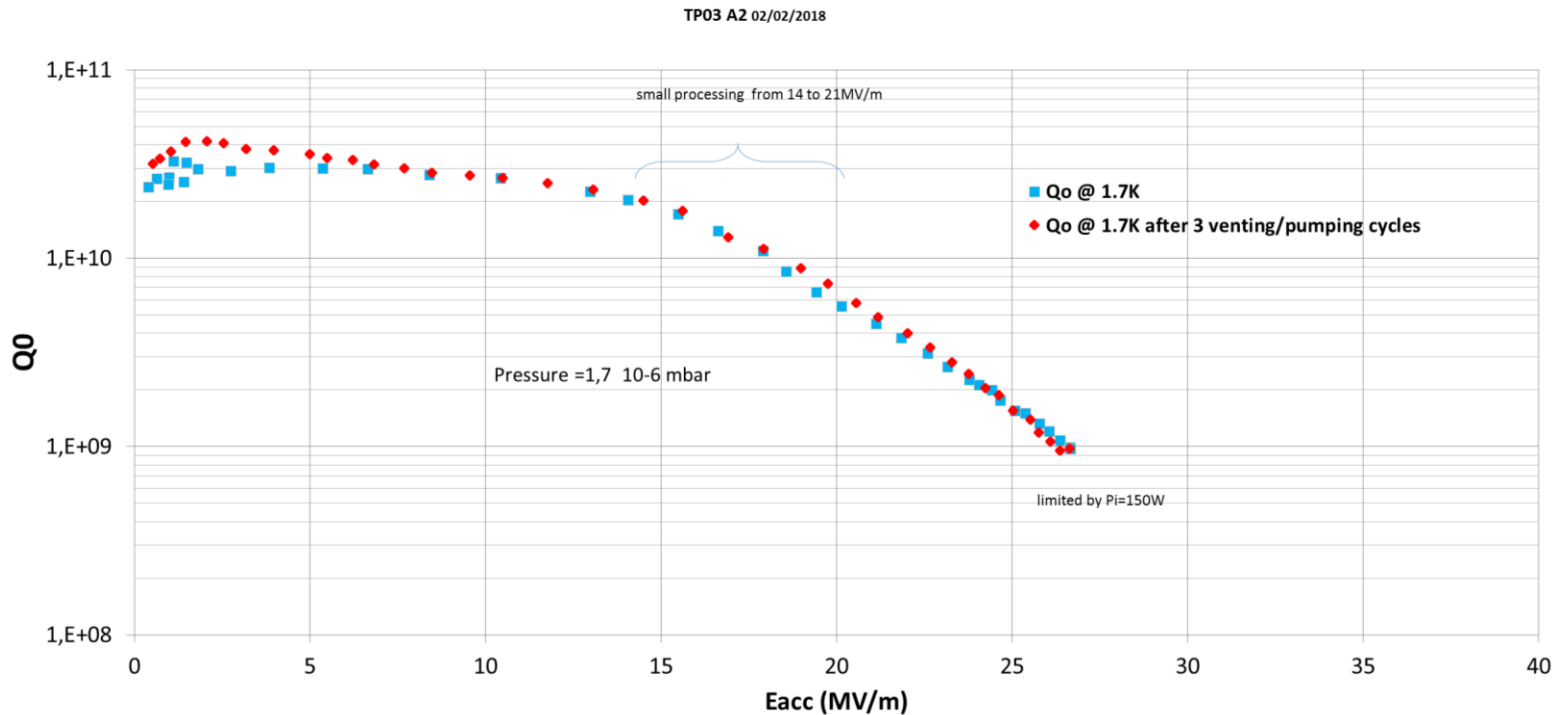
- Once the vacuum groups are connected to the cavities, vacuum operations (pumping, venting, flushing, leak checking) should be **fully automated**, to include slow pumping and venting, and valve opening.
- **Robotization** could be implemented e.g.
 - Ionized N₂ cleaning
 - Cold coupler assembly
 - String assembly
 - Warm coupler assembly

IRFU developed a fully automated pumping units reliable for beam vacuum operations (slow pumping, slow venting, flushing, leak check and residual gas analysis).

- A simple interface is adapted to non specialist technician
- High level of diagnostic for expert
- Remote supervision and control with access rights



Developed in the framework of ESS preparation, two prototype groups have been tested with R&D mono-cell cavities: comparison of performance after been back to the clean room and 3 venting/pumping cycles



These pumping units are now commercially available by a French company.

Robotization

Robotization will be beneficial with respect to :

- Reducing labour cost
- Reducing the assembly mistakes and non-conformities
- Uniformization of assembly procedures across the 3 or 4 regional assembly plants
- Introducing some 'plug-compatibility' in the module design



Cobotization of ionized N2 cleaning



Use of COBOT (COllaborative roBOT) from ISYBOT©

Cleaning of the holes of the flanges before opening the cavity

Usual ionized nitrogen cleaning



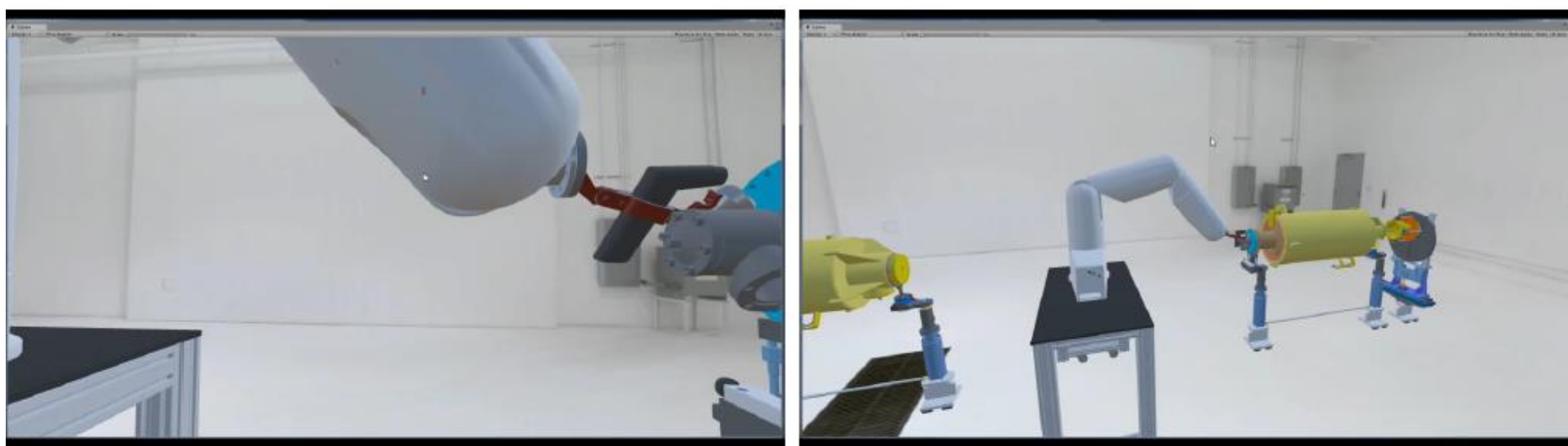
R&D supported by IRFU, the demonstrator will be tested on ESS cavities.

Cleaning station and procedure analysis



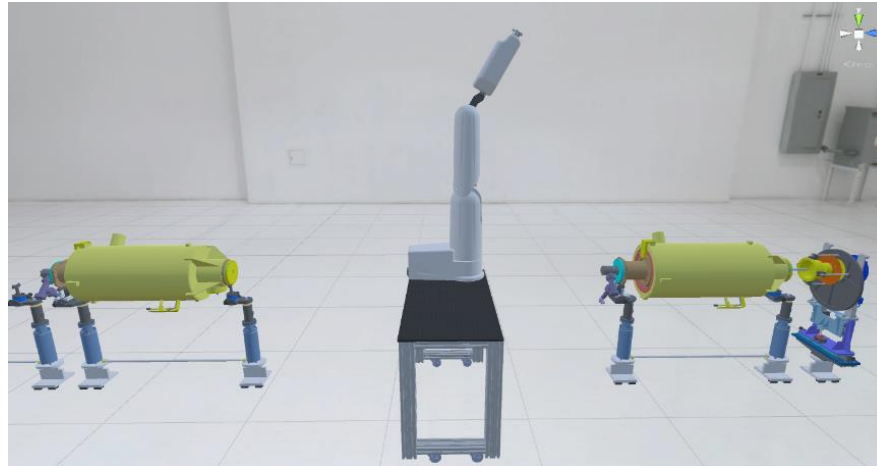
One location of the COBOT for the cleaning of the two flanges

Up to now the accessibility study lead to 7 holes not accessible over 48 holes (due to the right angle valve of the cavity) for two ESS flanges

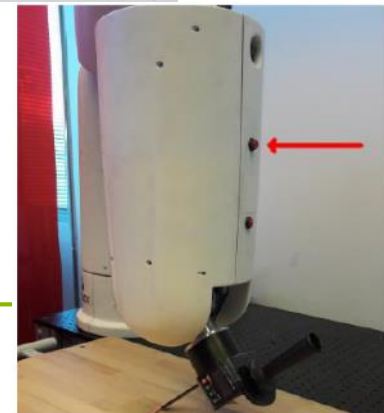


- Specific tool to hold the flange during the cleaning
- Mechanical interface between ionizer gun, isocinetic head of the counter and the robot has been built

- Development of the control interfaces:
 - Gun control by 24V relay (switch)
 - Particles counter communication to check particles every minute
- Automat implementation
 - Two configuration management (with and with out valve)



- learn the flanges position by 3 points contacts prior to the cleaning
- holes positions computation



The test will be performed on a real ESS elliptical cavity (704MHz) in ISO4 clean room soon.

Study of the coupler port flange has been performed but will not be demonstrate.



- Automation of the vacuum groups have been successfully performed by IRFU and transfer to industry
- The robotization of the cavity flanges cleaning by ionized N₂ is on the way with a collaborative robot
- Robotize the assembly is facing up to more challenges
 - Cold coupler assembly
 - String assembly
 - Warm coupler assembly
- with the automated HPR experience from MSU for FRIB, and vacuum units and cleaning cobot from CEA, an international effort can reduce cost for ILC