Robotisation of Clean Room Assembly

Joint workshop of TYL/FJPPN and FKPPN 2026

A_RD_27:

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Clean Room Works




Small particle contamination

➡ Field emission

➡ Energy loss
Radiation
Quench

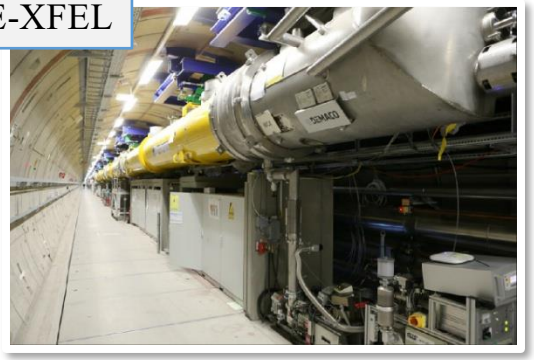
SRF cavity assembly requires:

- Ultrapure water cleaning
- ISO class 4 clean room
- Expert technicians
- Air blowing every after tightening any bolts
- More than an hour per one cavity
- Quality control in mass-production

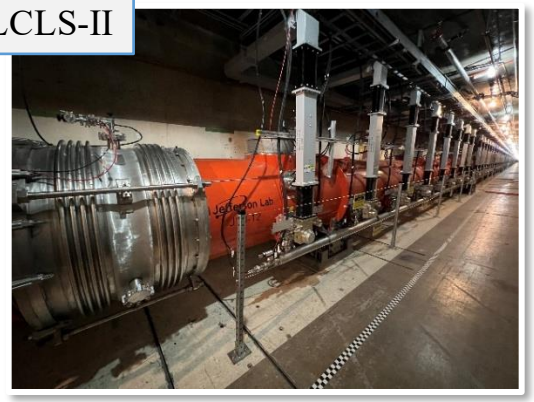
Motivation

SRF accelerators are required to have:
- More complicated structure
- Higher cavity performance
- Larger scale mass-production

E-XFEL



LCLS-II



Clean room work is becoming:
- More time-consuming and harder work for people
- More **sensitive** to smaller dust contaminations
- Requested to have higher **efficiency** and **reliability**

Robotic application was introduced

Robotic Application: Pioneer Labs

2016 MSU:

Design and Implementation of an **Automated HPR System** for FRIB SRF Cavity Processing

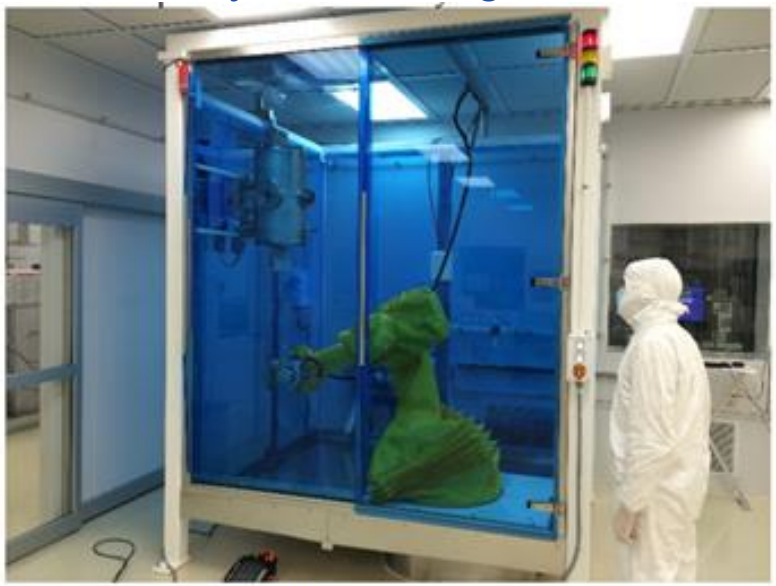


Figure 1: Robotic high-pressure rinse system, installed.

KUKA KR-16-2-CR
LINAC16 East Lansing,
I. Malloch *et al.*

2017 IMP:

Robotization of Clean Room **Processing and Assembly** at IMP

Robot assisting on HPR process

Robot assisting on cavity assembly

KUKA KR210
LCWS2021 remote
H. Guo *et al.*

2018 CEA:

The use of robotics in cavity **preparation and assembly procedures**

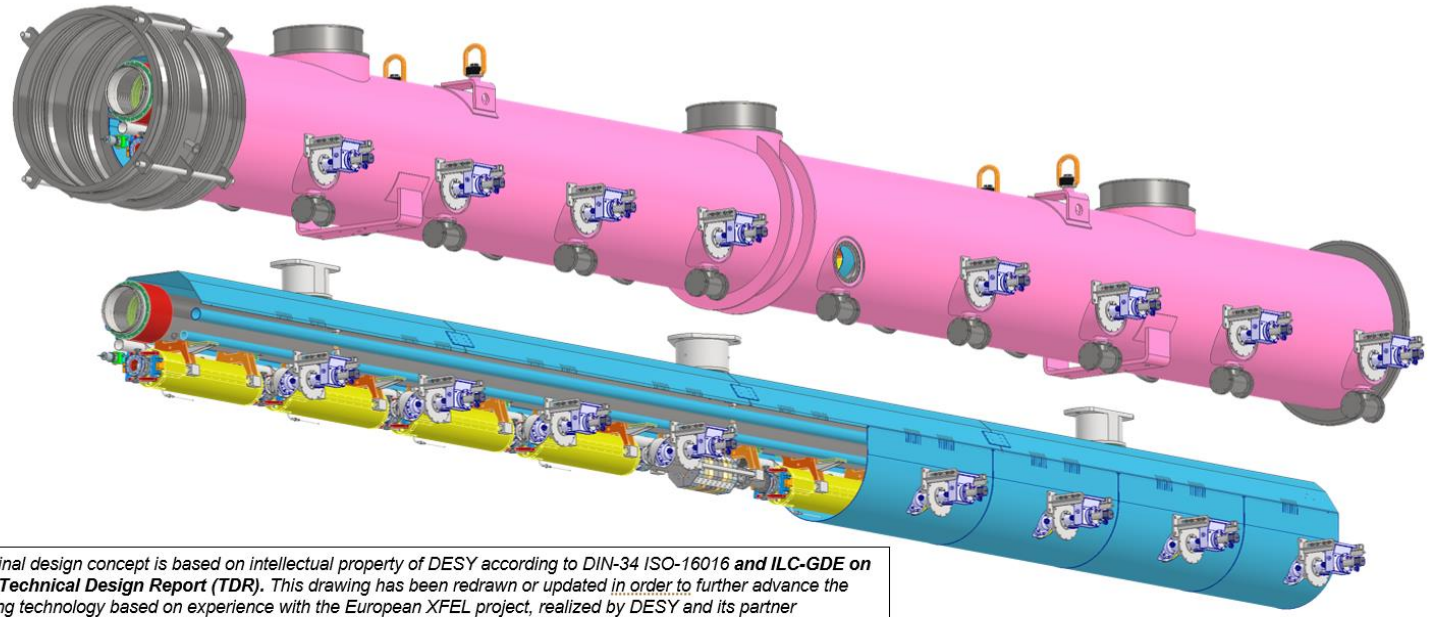
Part location teaching

Proto from ISYBOT
TTC2019 Vancouver
S. Berry et *al.*

Activities in KEK: Toward ITN Cryomodule

ILC Technology Network (ITN)

- KEK hosts the program to fabricate one ILC-prototype cryomodule.
- The cryomodule consists of 8 SRF cavities and one SCQ magnet.
- High power test will be performed without beam.

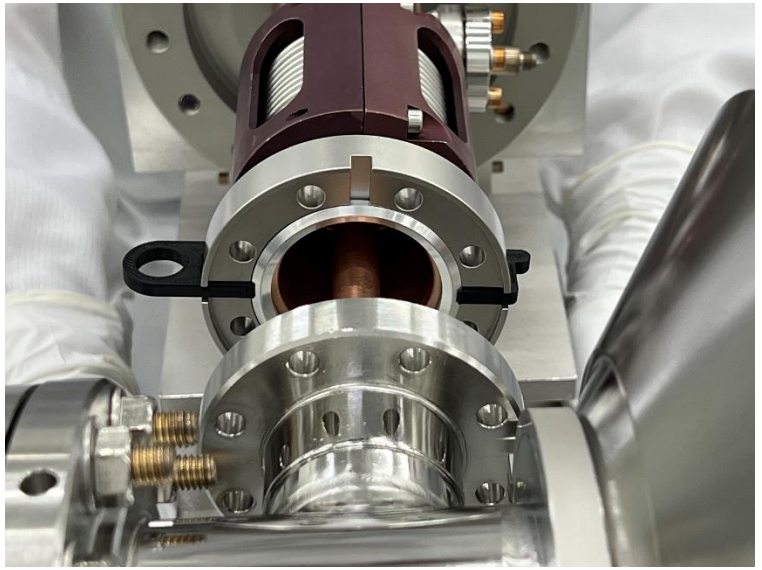


The original design concept is based on intellectual property of DESY according to DIN-34 ISO-16016 ***and ILC-GDE on the ILC Technical Design Report (TDR).*** *This drawing has been redrawn or updated in order to further advance the underlying technology based on experience with the European XFEL project, realized by DESY and its partner laboratories, and the LCLS-II project hosted at SLAC, in cooperation with Fermilab and JLab under supervision of the US/DOE. The design has been re-optimized by KEK, under the* ***agreement with*** *DESY, he SLAC/LCLS-II project office, and ILC-IDT Collaboration, exclusively for fabrication within the ILC Technology Network (ITN) program, hosted at KEK".*

Activities in KEK: Preparation of Cavity Strings

E-XFEL-type cavity support posts and coupler mounting jigs

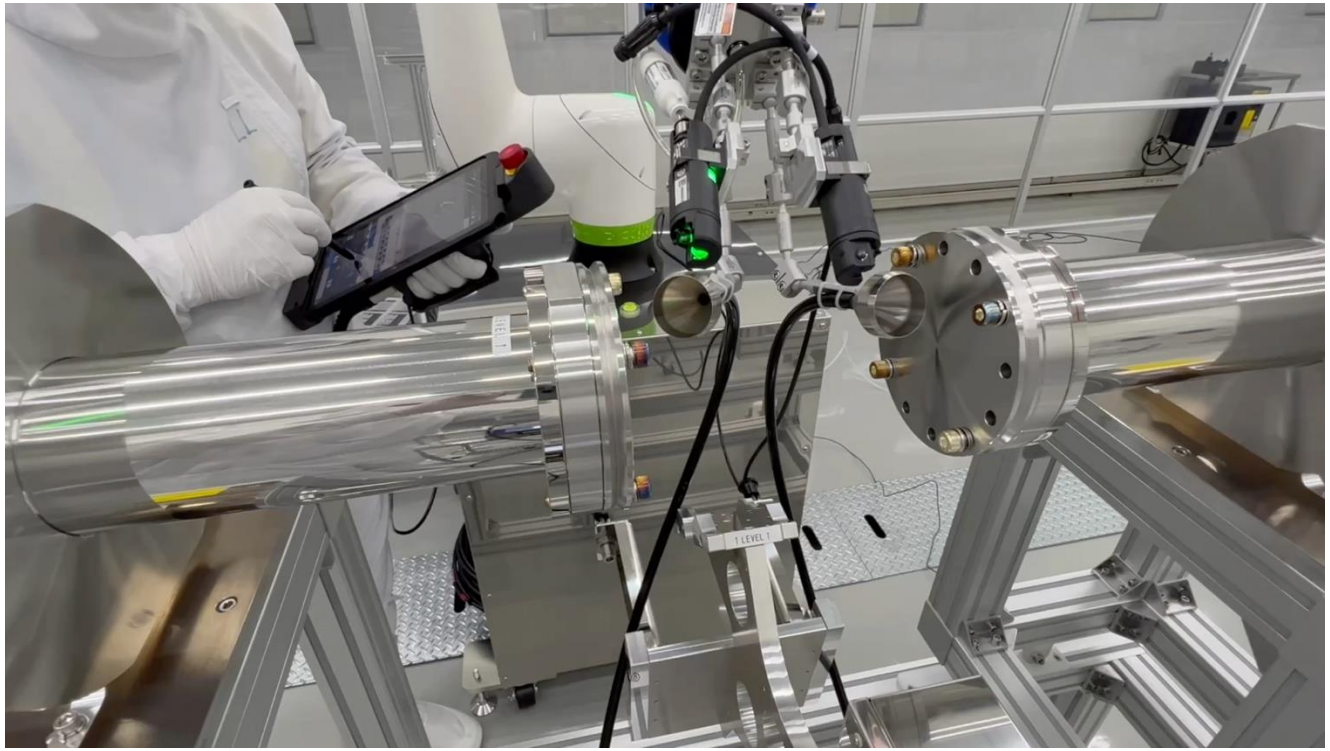
A demonstration of cold coupler installation using a mock-up cavity

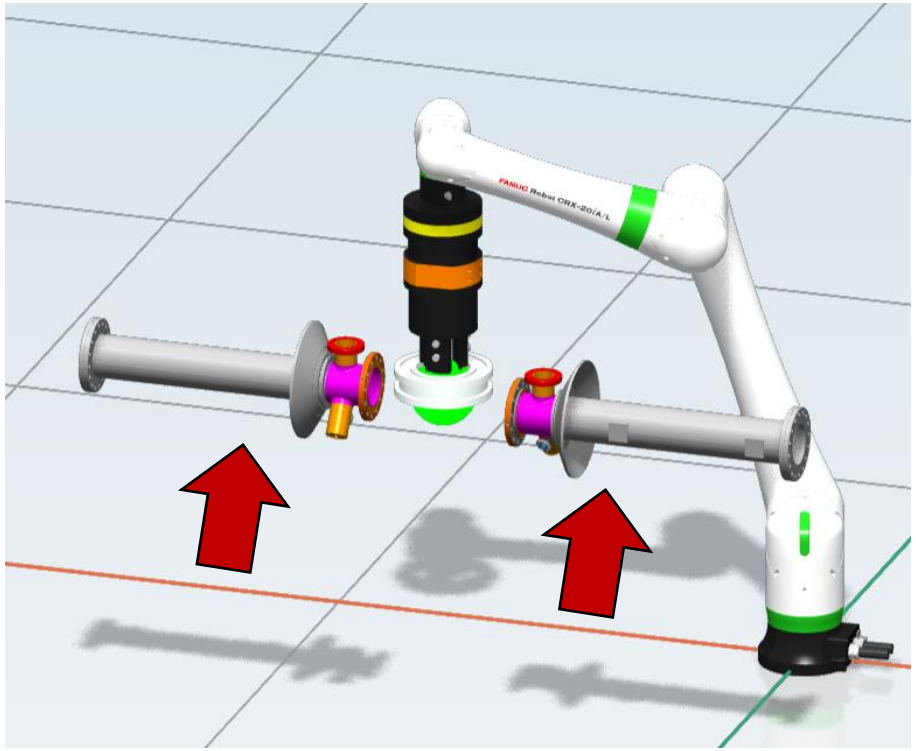


Air-Blow Cleaning

Fanuc CRX i20 A/L

- Cobot: Industrial robots which can work in the same space with human.
- Direct teach: A method of programming movements by moving the robot directly.

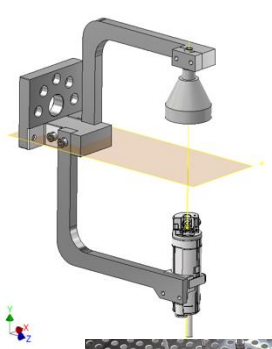


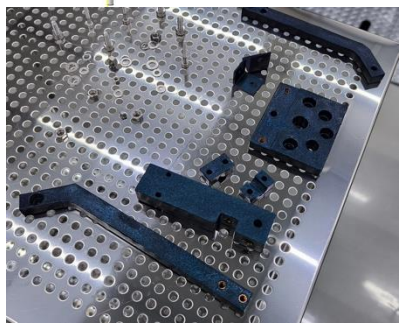


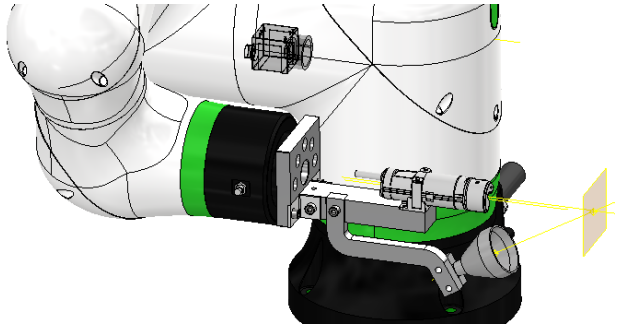
Hardware: End-Effector Development

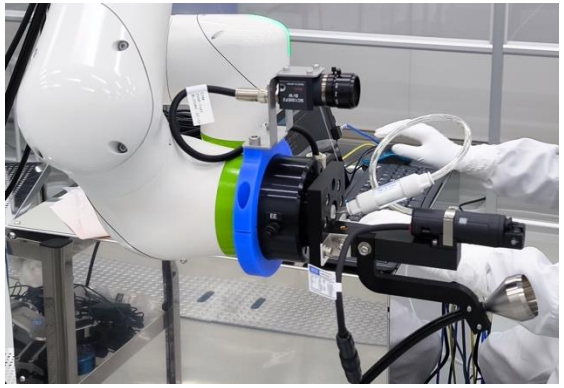
Two types of end-effectors for holding ion guns and dust monitor nozzles

Design and test of end-effector

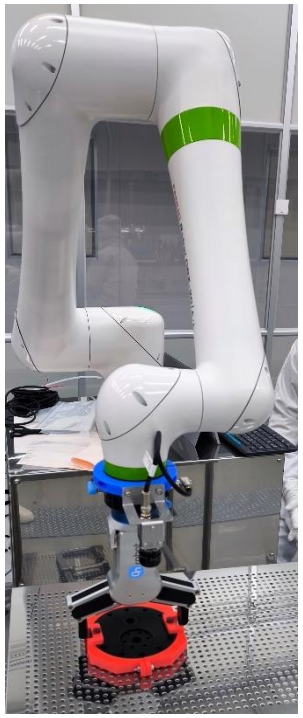


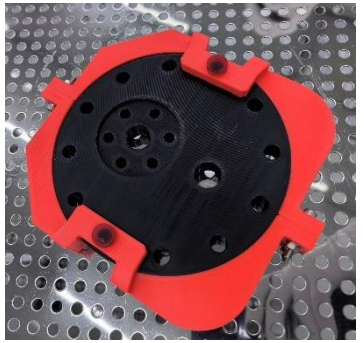




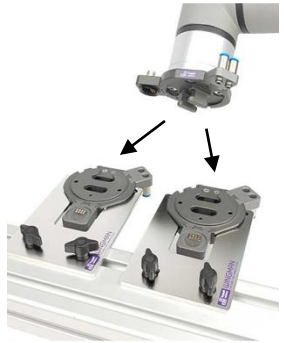


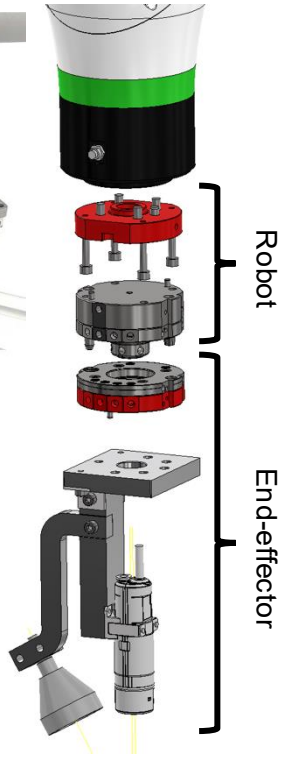
End-effector for holding a blank flange



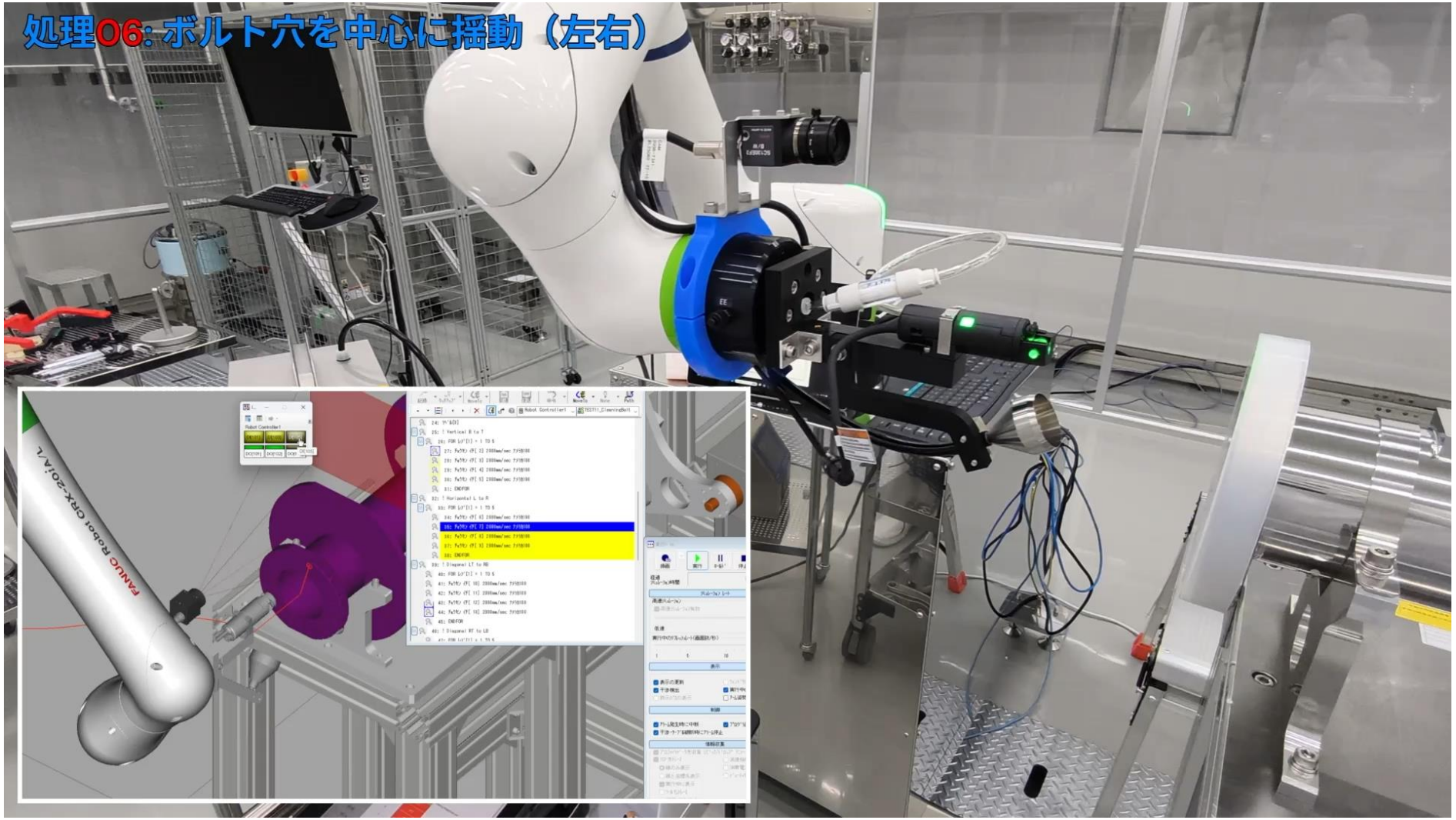


Tool changer



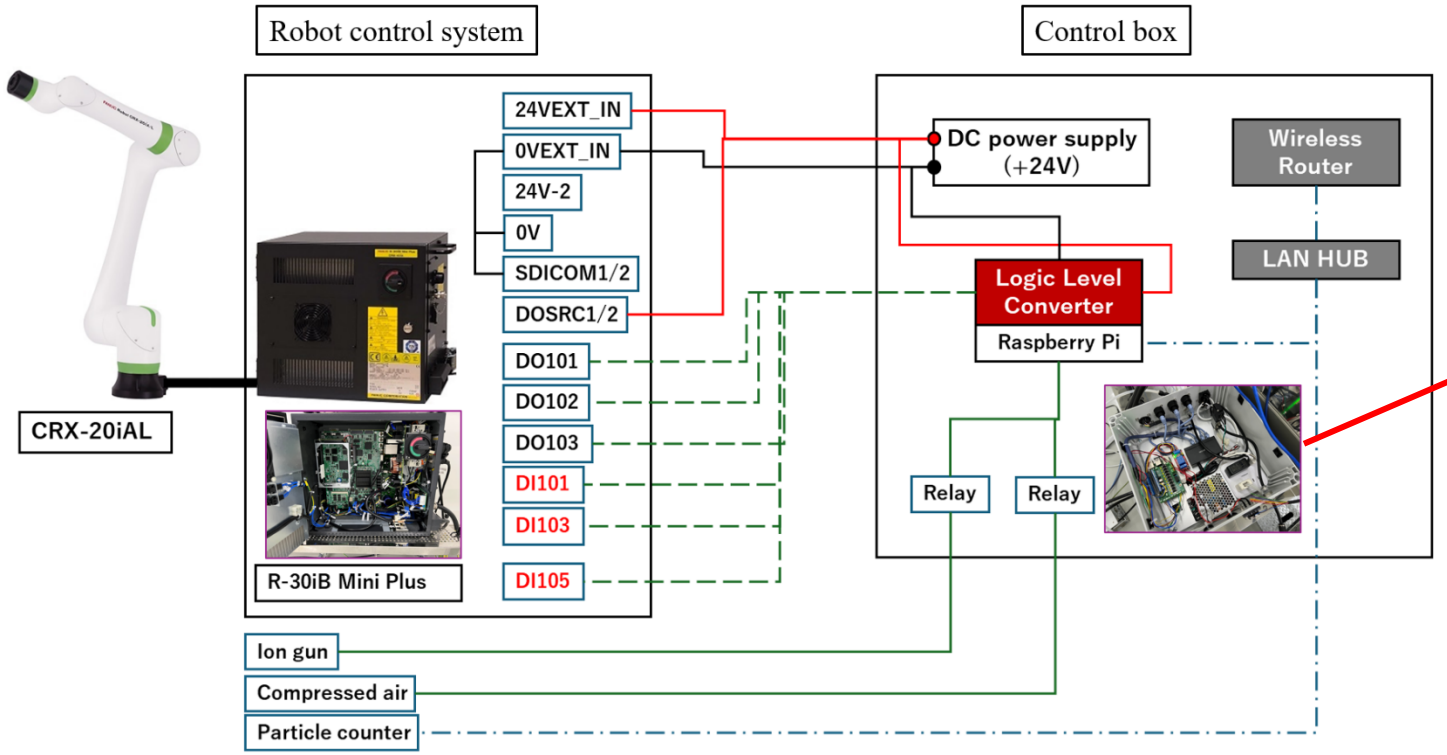


Software: Programming in Simulator

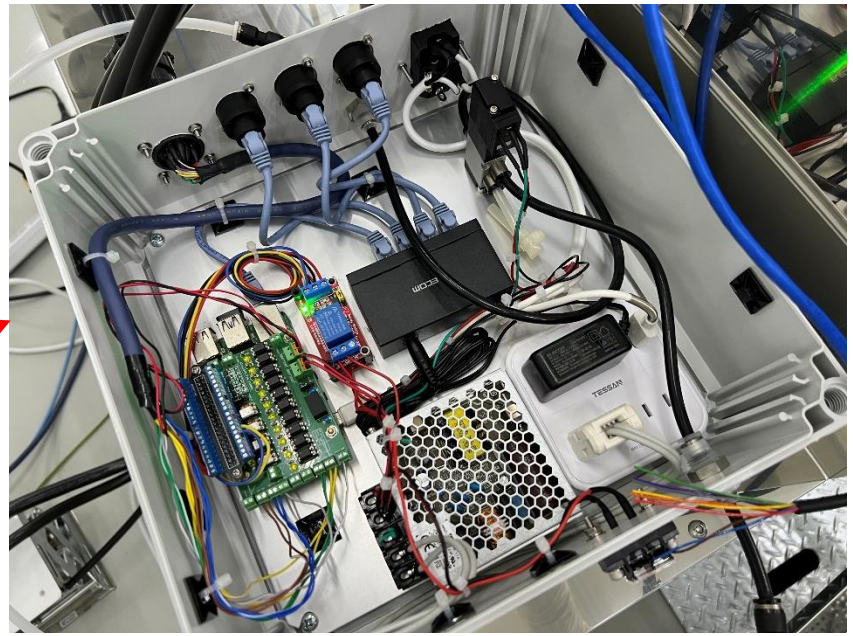


Development of Control System

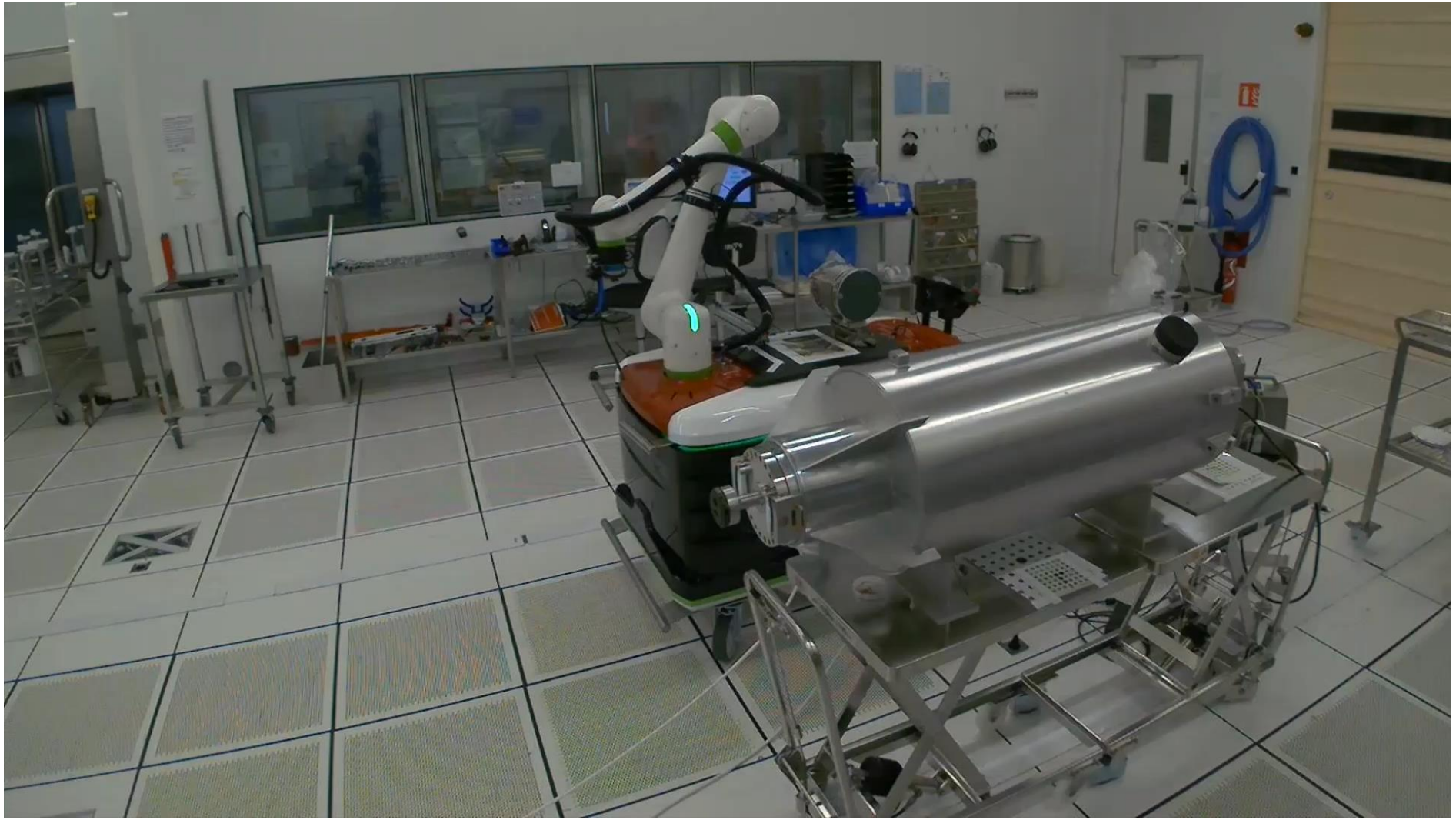
Wiring Diagram Between the Robot Control System and the Control Box



Equipment and wiring inside the control box



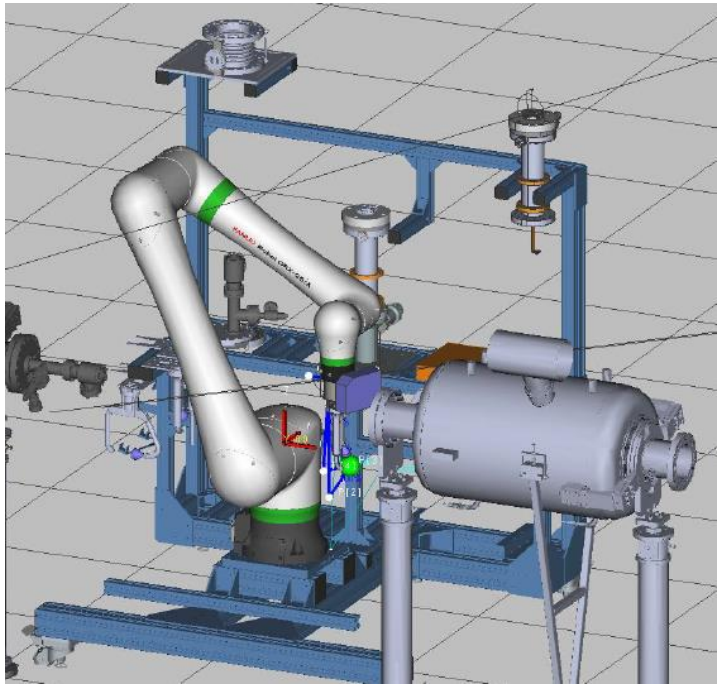
Recent progress in irfu/CEA



Future Works: Robot Station

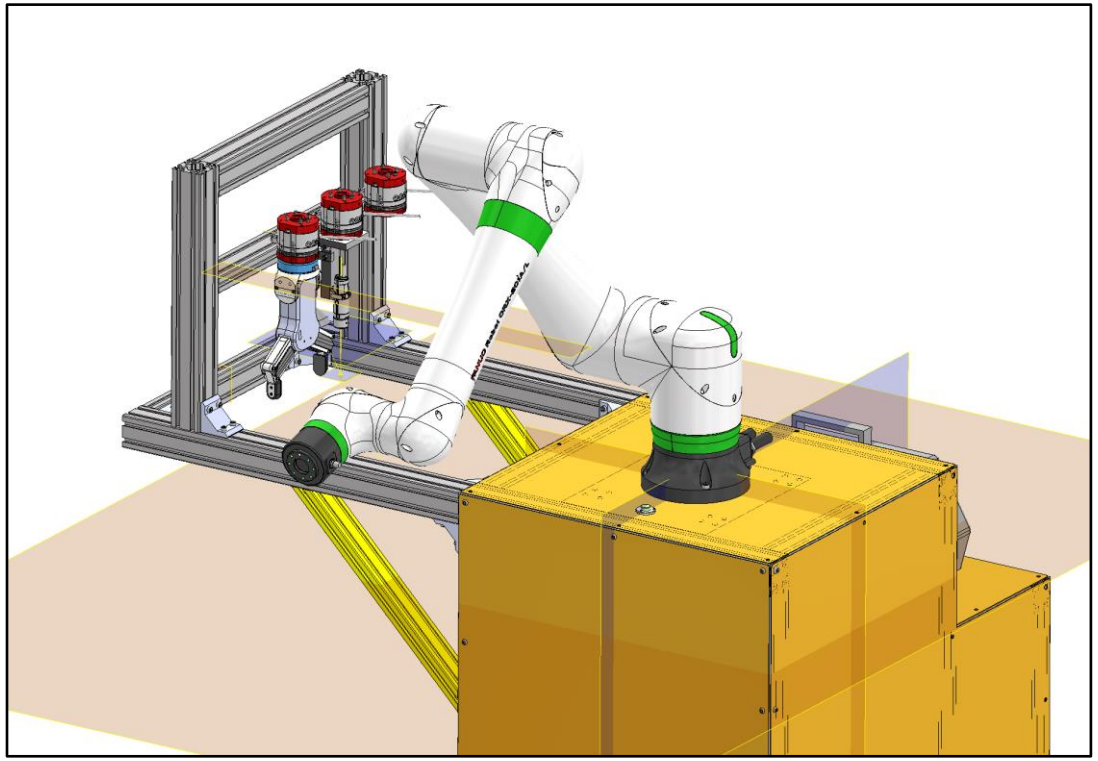
Robot station used at CEA

Equipped with all the parts and tools needed for assembly



Robot station at KEK

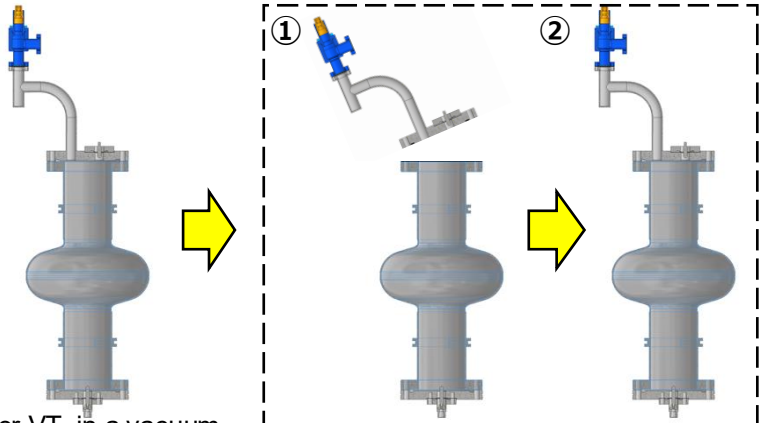
Under consideration



Future Works: Robot-Assembled Cavity Measurement

Innovation Center for Applied Superconducting Accelerators
応用超伝導加速器イノベーションセンター

Assembly Process Using Single-Cell Cavity



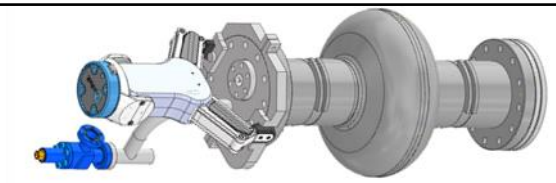
VT Again
Performance
Comparison

After VT, in a vacuum-sealed state.
Bring into the cleanroom.

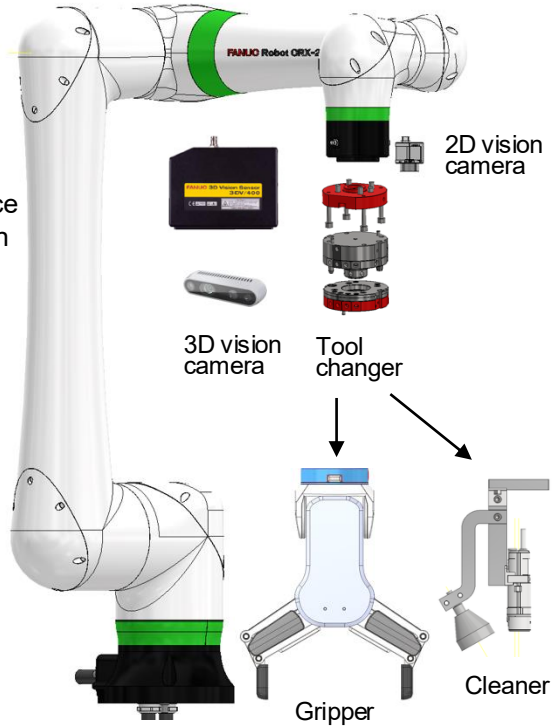
After returning to atmospheric pressure, the robot will perform the following:

1. Cleaning and removal of the blank flange
2. Installation of a different blank flange

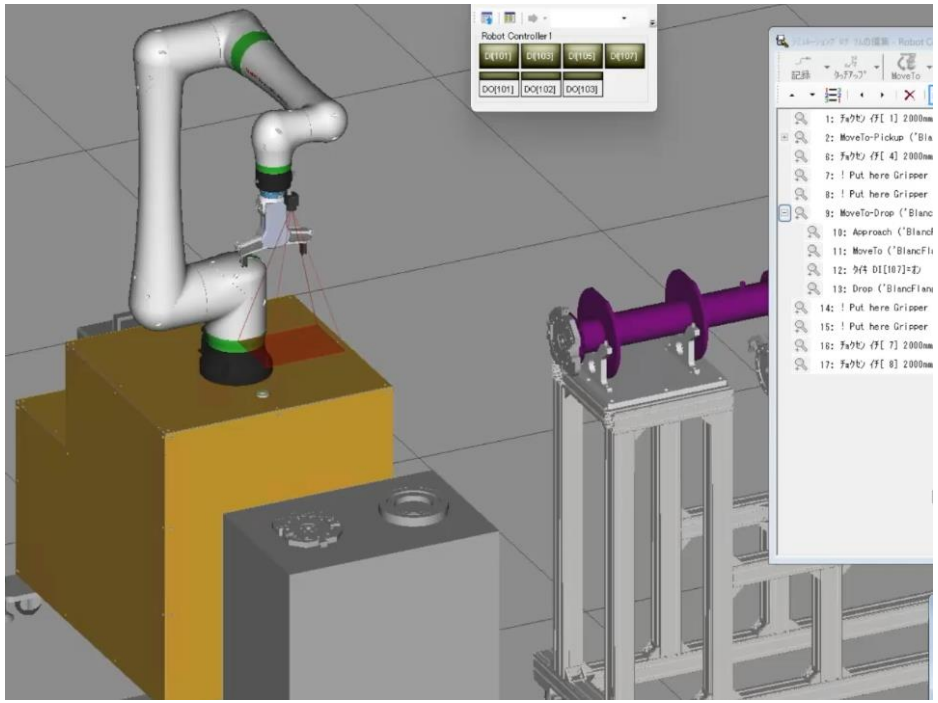
Fit check when gripping a blank flange with a gripper



Items to be installed on the robot

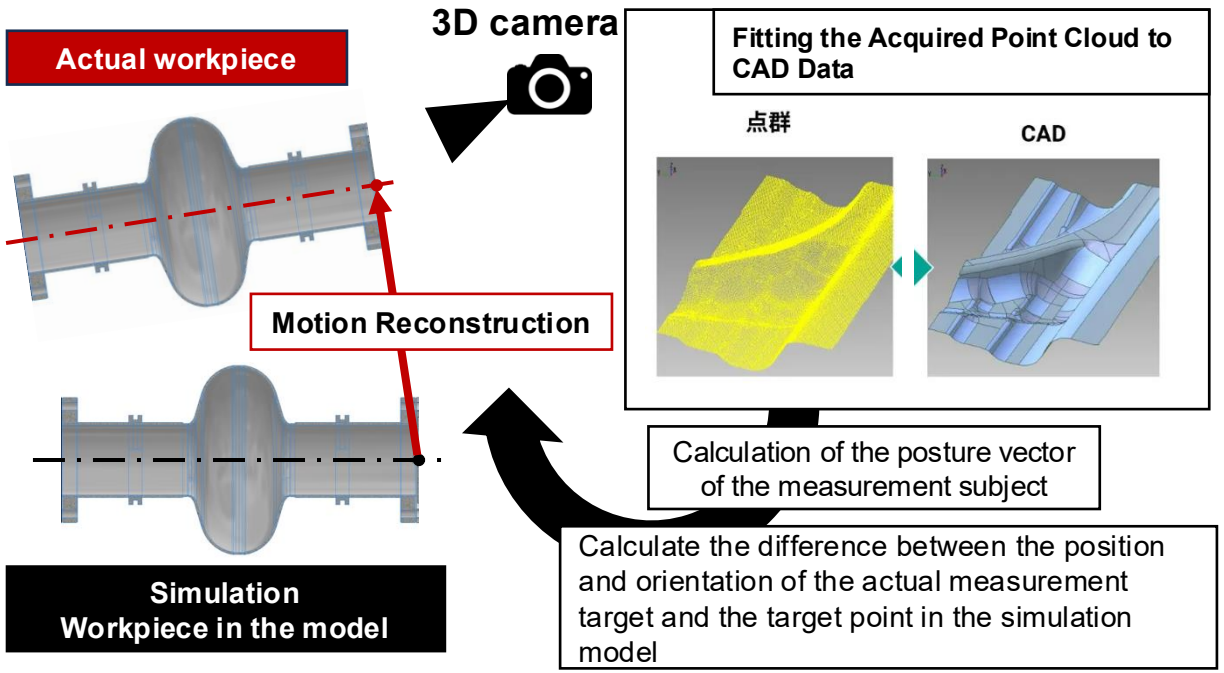


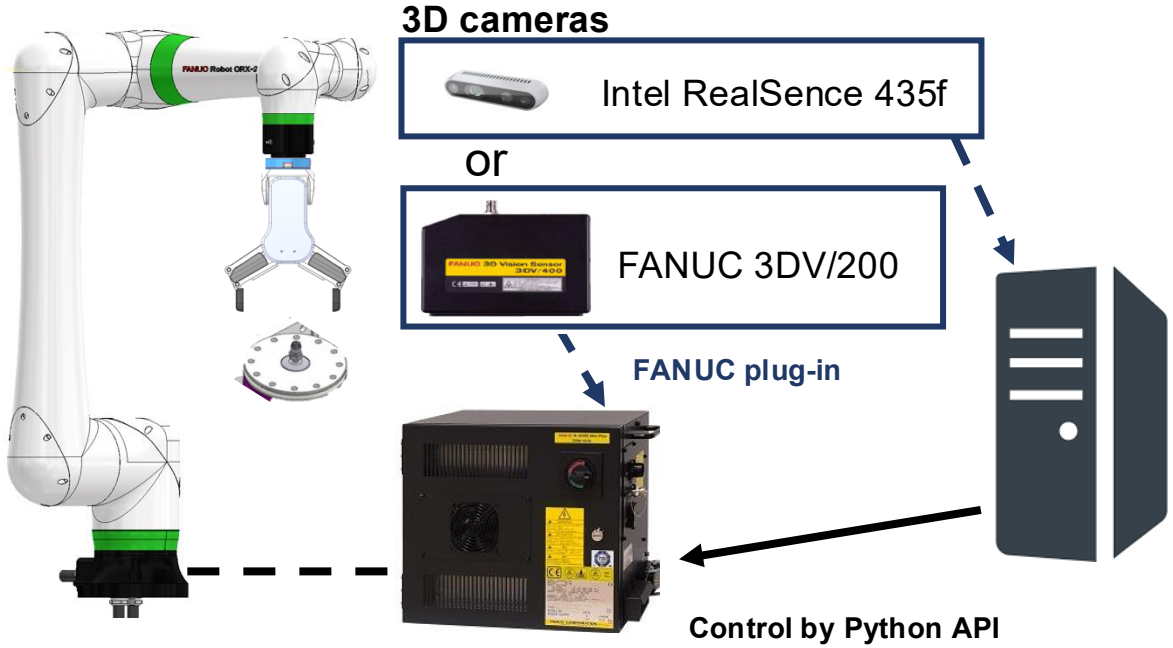
Operation program for gripping blank flanges



Future Works: 3D Vision

An example of correction using 3D vision

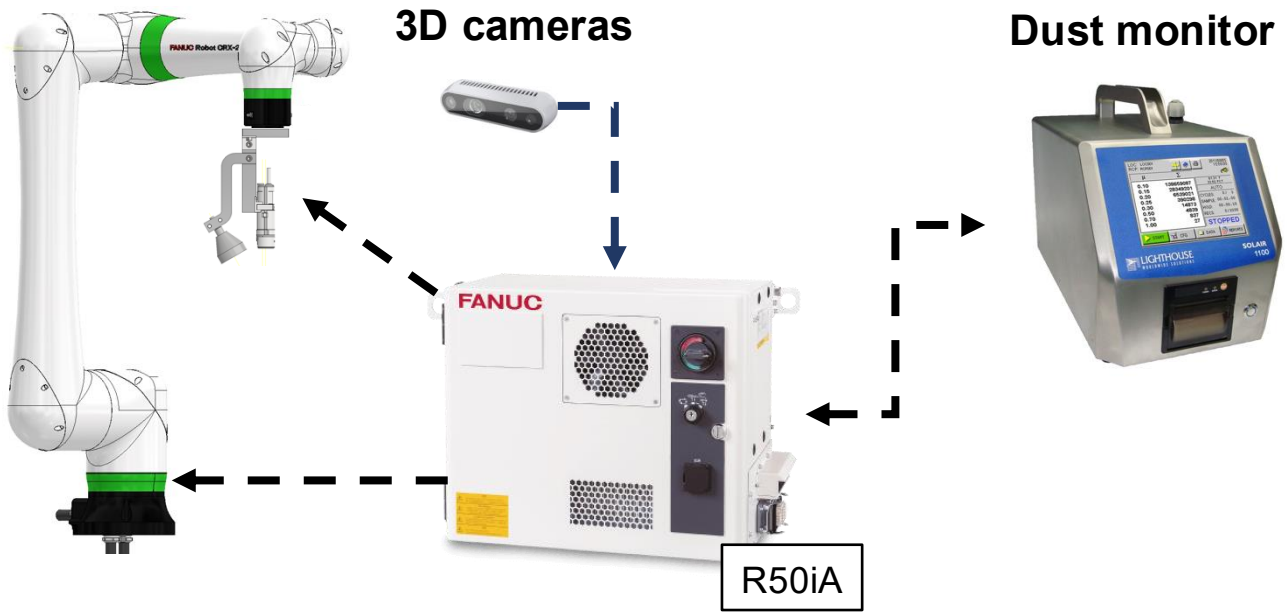




Future Works: Upgrading Robot Control System

ROS (Robot Operating System) /ROS2

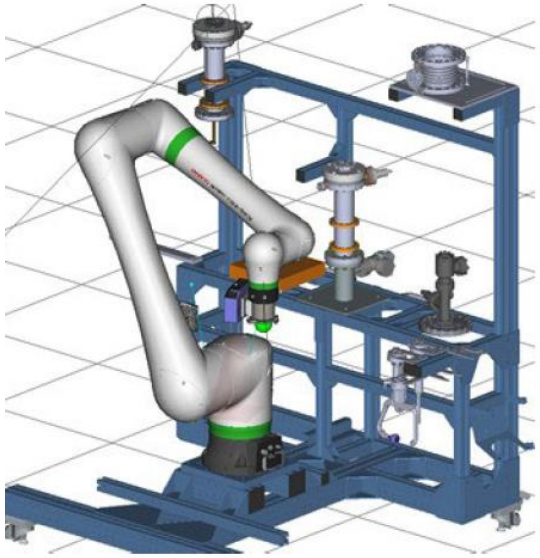
An operating system that includes the communication protocols, tools, features, and ecosystem necessary for robot development. Its core component is **communication middleware** for distributed computing. It is similar to EPICS in the field of high-performance computing.



Future Works: Development of Multi-Arm System

For cleaning

For assembly/disassembly



We also need to develop systems that prevent robots from interfering with one another!

CEA-KEK Collaboration

	DE LA RECHERCHE À L'INDUSTRIE cea PARIS-SACLAY	
Current situation	• Many experiences on clean assembly from E-XFEL, ESS, PIP-II • Robotic study started from 2018 • Many experiences on robotic study	• Robotic study started from 2023 • MEXT-ATD program on-going (cavity string assembly in FY2027) • Demonstration on auto-cleaning by robot done • 3D vision and ROS under preparation
Collaborative works	• VT assembly and performance check using real cavity (exchange visits) • Exchange and cross-check of test program for robot • Demonstration of cavity string using virtual clean room • ROS2/Python to be updated	

Summary

Robot application for SRF accelerators

- Robot technologies are necessary for higher efficiency and reliability.
- Several laboratories are working on robotics applications.

Achievements in KEK

- Robot study had been started using FANUC CRX cobot and cavity mockups.
- End-effectors have been produced for gripping parts and air-blowing.
- Robot programming on a simulator and remote-control system was established.
- CEA and KEK are sharing the knowledge through exchanging scientists and engineers.

Future works

- Cavity performance measurement is planned to directly evaluate the effect on field emission suppression by robot.
- Both hardware and software have upgrade plans for more advanced technologies.