

Progress in the LIPAc Validation and the roadmap towards SRF Linac Beam Commissioning

Keitaro Kondo (QST)
on behalf of IFMIF/EVEDA Integrated Project Team

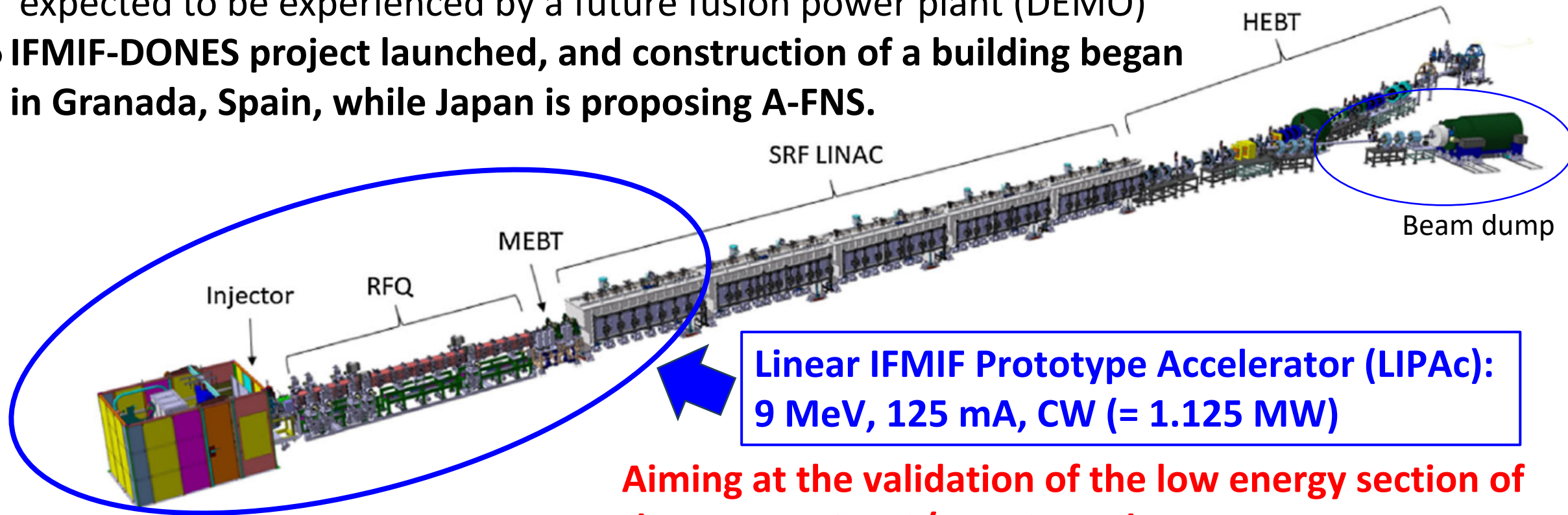
LINAC2026 - 33rd Linear Accelerator Conference

Daejeon, Korea – 20 Aug 2026



International Fusion Materials Irradiation Facility (IFMIF):

- Accelerator-based intense neutron source (D-Li, 40 MeV, 125 mA, CW = 5 MW/line)
- Subjecting candidate materials to a fusion-relevant high-energy neutron field expected to be experienced by a future fusion power plant (DEMO)
- IFMIF-DONES project launched, and construction of a building began in Granada, Spain, while Japan is proposing A-FNS.

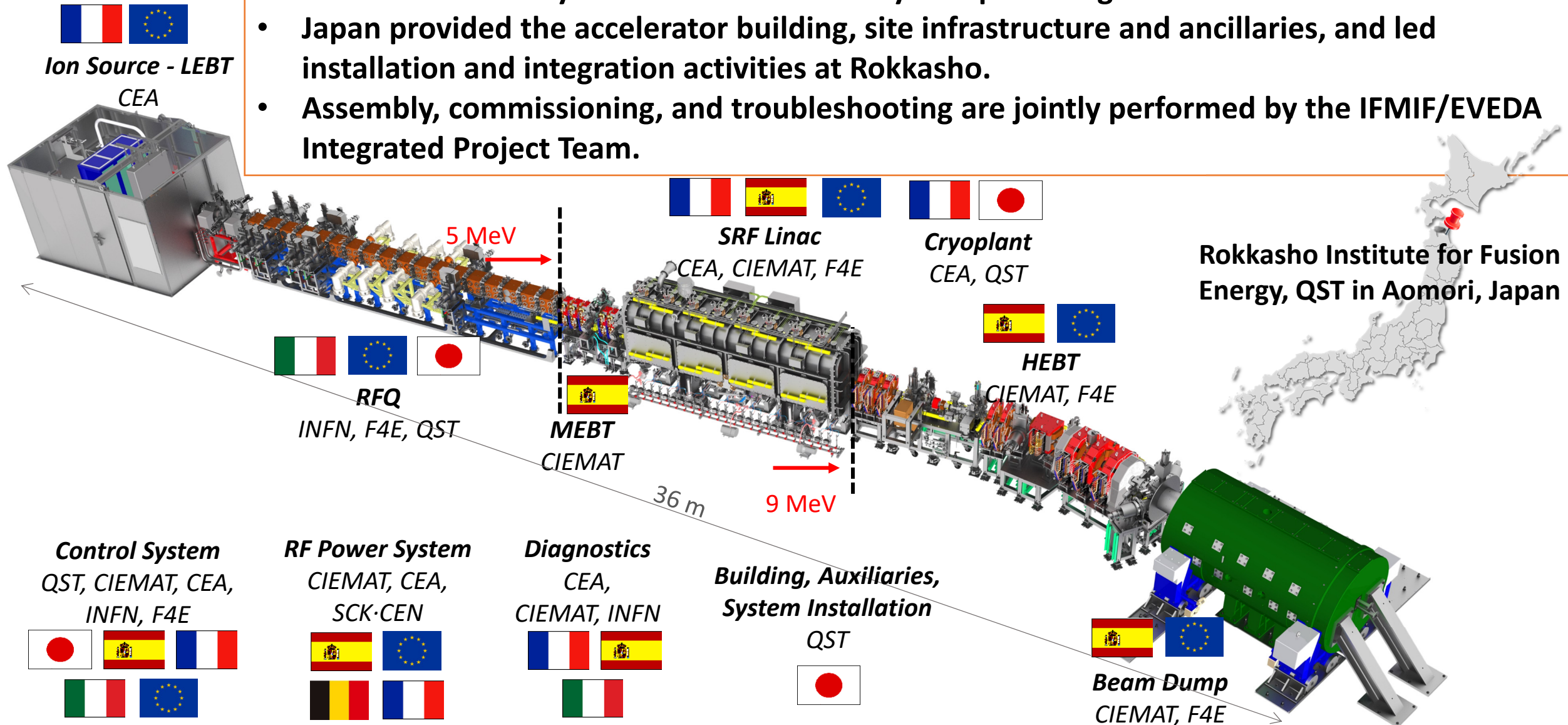


Aiming at the validation of the low energy section of the IFMIF-DONES/A-FNS accelerator.
Currently under commissioning at Rokkasho, Japan.



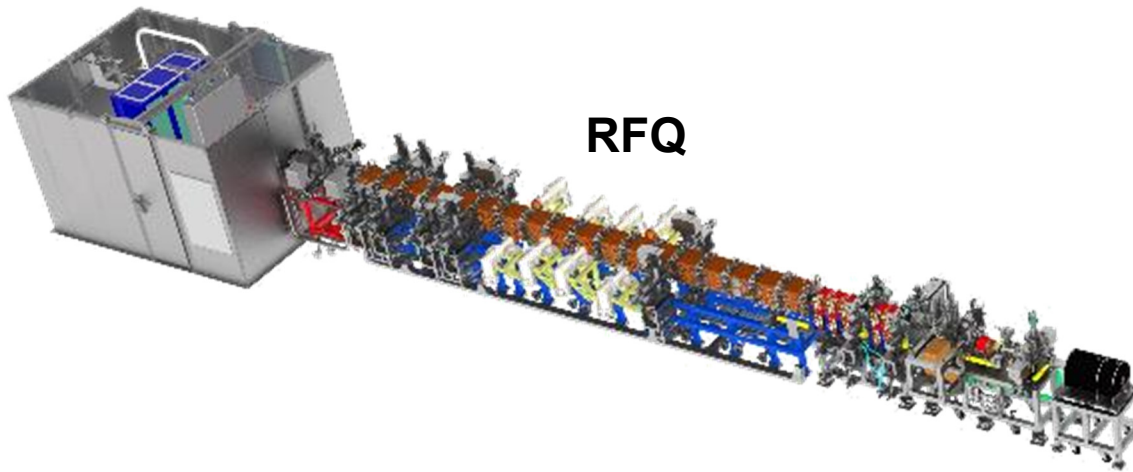
LIPAc: Linear IFMIF Prototype Accelerator

- Most accelerator systems were delivered by Europe through in-kind contributions.
- Japan provided the accelerator building, site infrastructure and ancillaries, and led installation and integration activities at Rokkasho.
- Assembly, commissioning, and troubleshooting are jointly performed by the IFMIF/EVEDA Integrated Project Team.





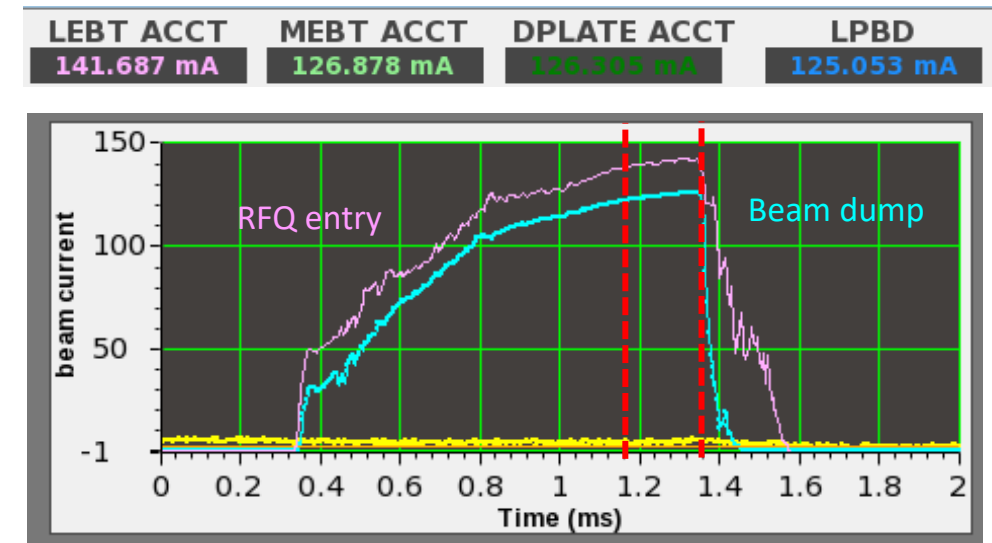
Phased approach to the final goal (9 MeV, 125 mA, CW)



• **Achieved 125mA deuteron pulse beam acceleration in July 2019.**

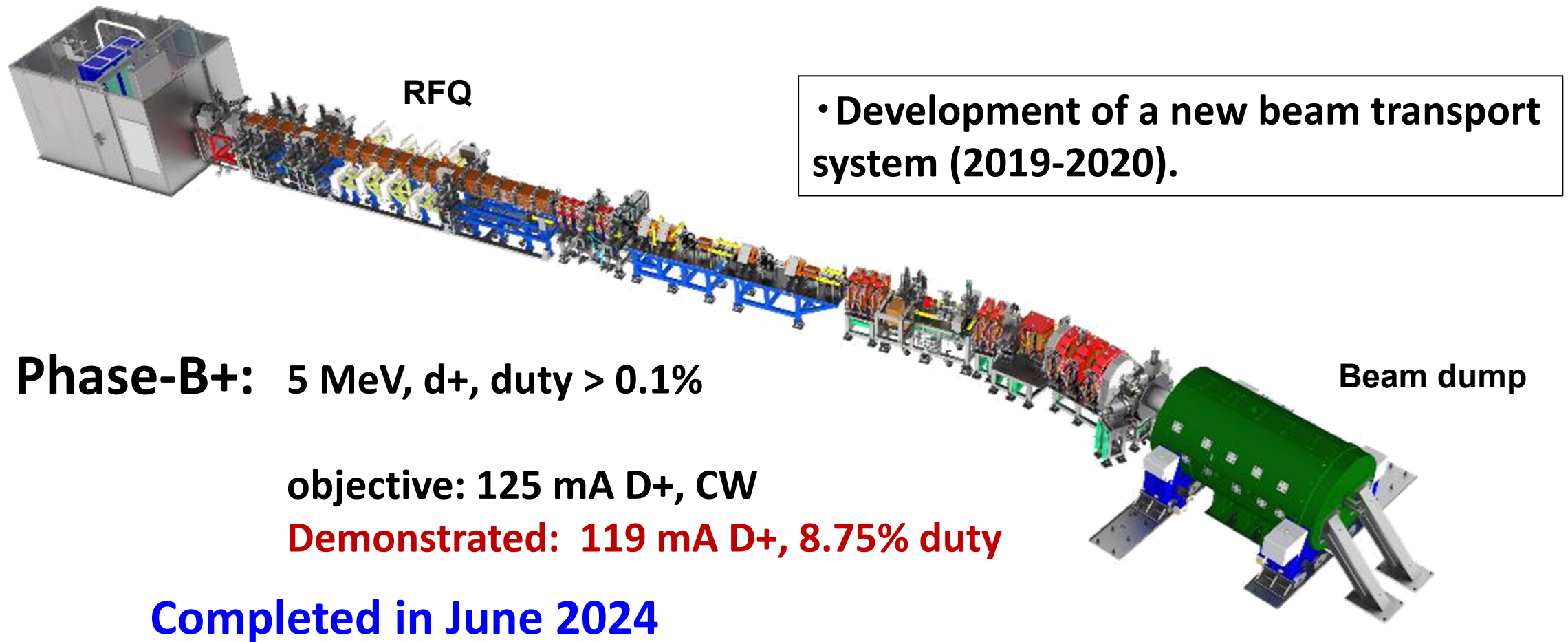
Phase-B: 5 MeV, d+, duty 0.1% (1 ms/1 Hz)

Completed in August 2019



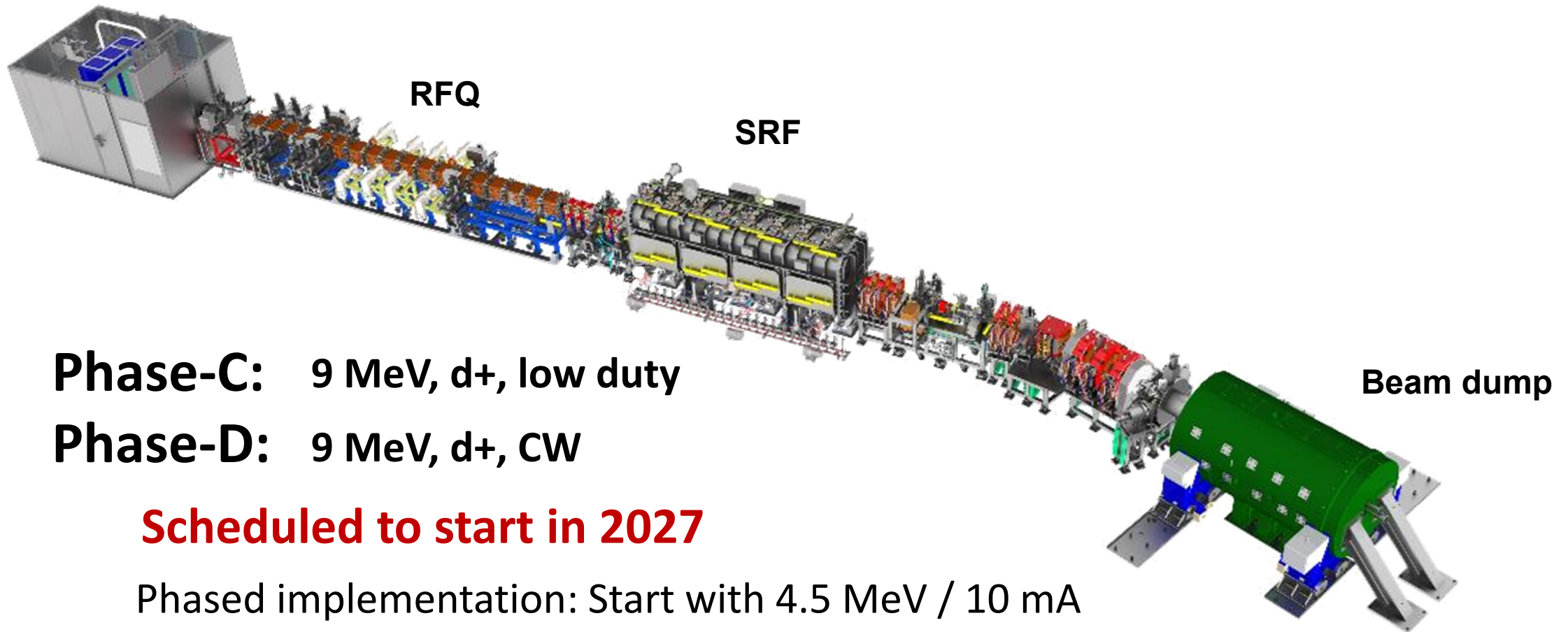


Phased approach to the final goal (9 MeV, 125 mA, CW)





Phased approach to the final goal (9 MeV, 125 mA, CW)



Phase-C: 9 MeV, d+, low duty

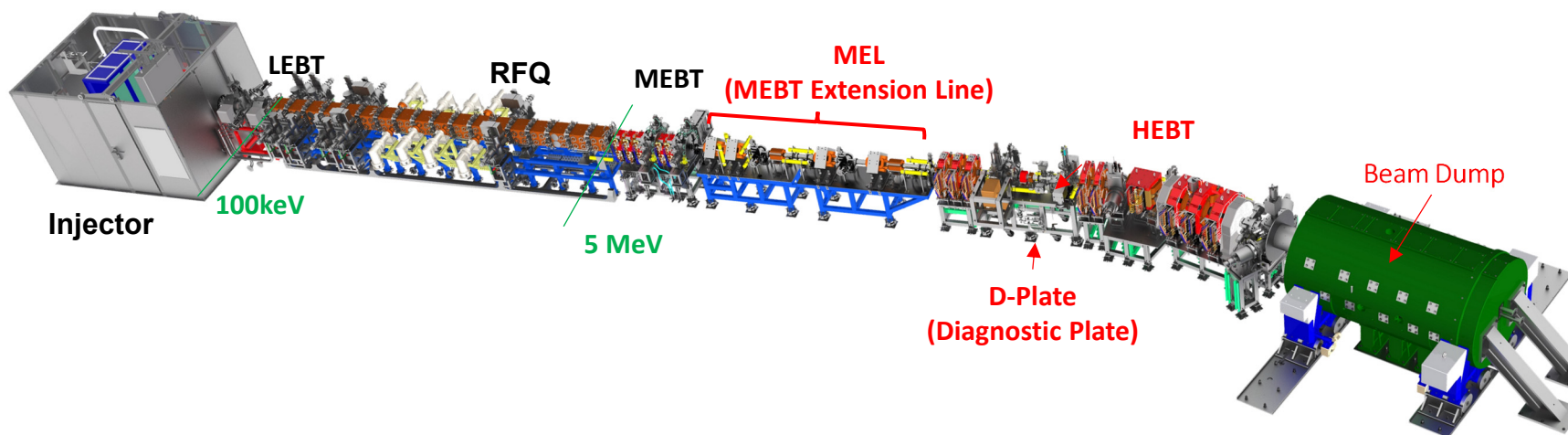
Phase-D: 9 MeV, d+, CW

Scheduled to start in 2027

Phased implementation: Start with 4.5 MeV / 10 mA
proton commissioning prior to high-current deuteron operation

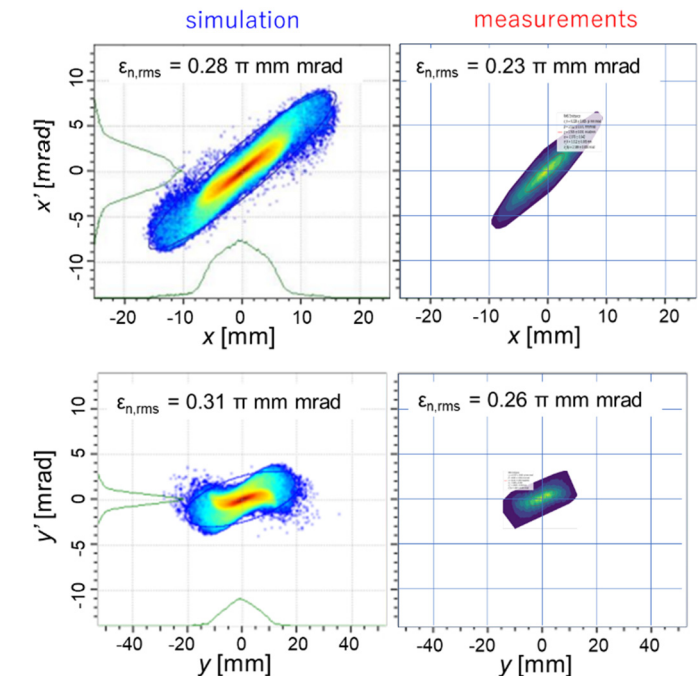
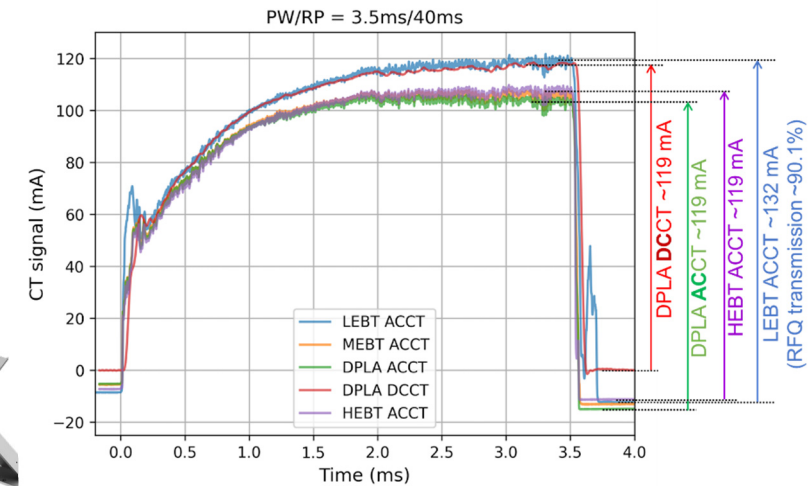


Key Outcomes of the last beam commissioning



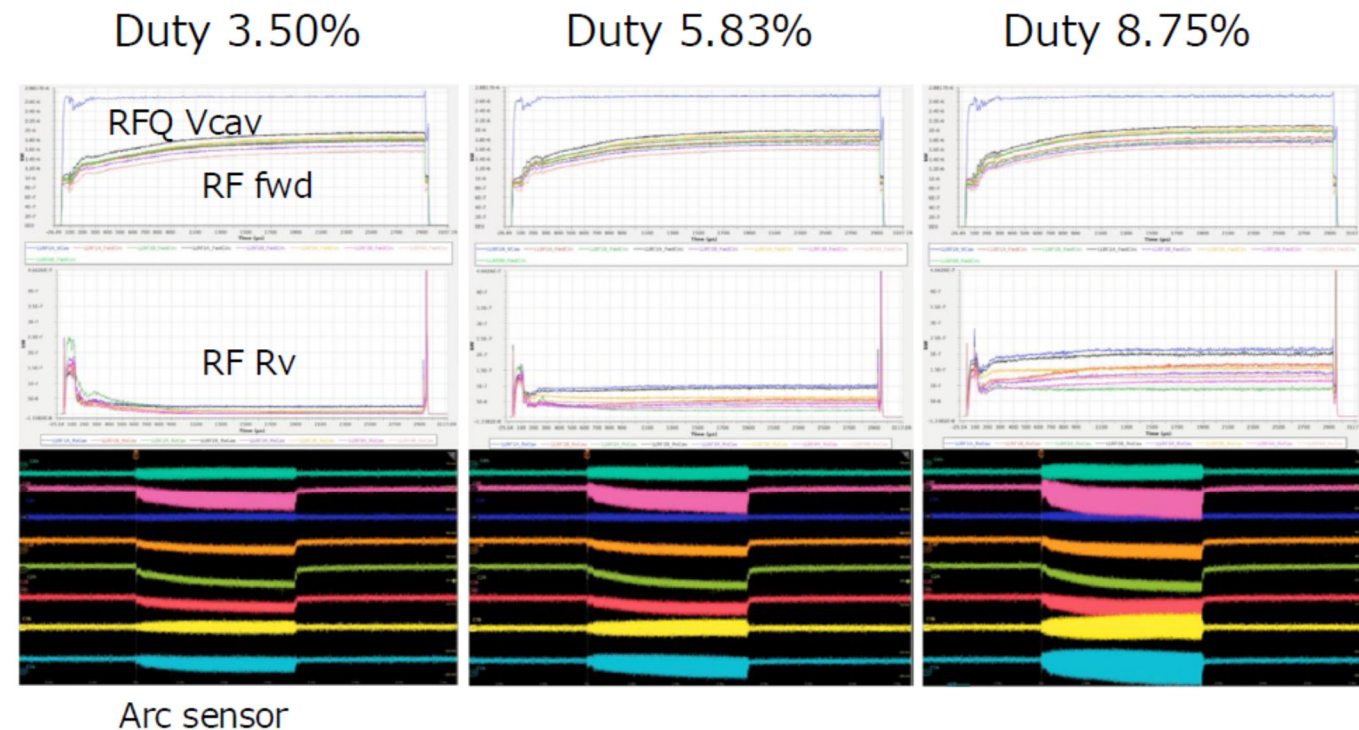
- Demonstrated RFQ acceleration of a **119 mA deuteron beam** at a **duty factor of 8.75% (3.5 ms/25 Hz)**.
- Validated beam transport, diagnostics, and beam characterization for the transition to the SRF Linac phase.
- Improved beam optics modeling, including fringe-field effects and optics re-tuning, resulting in excellent agreement between simulations and measurements.

(T. Akagi, et al., LINAC2024 THPB036,
J. Hyun, et al., IPAC'25 WEPM112)





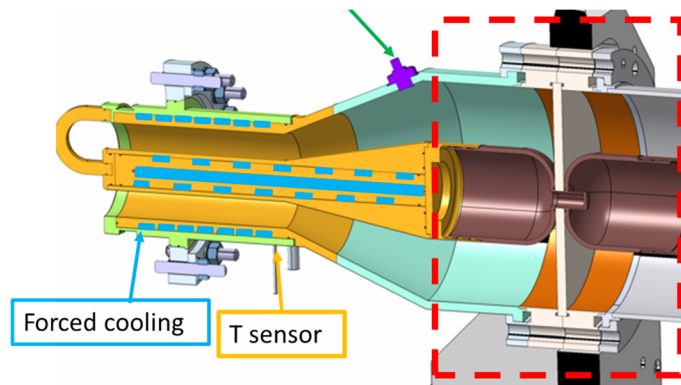
- Confirmed that operation beyond a 10% duty factor is difficult **with the current RF coupler design**.
- The LIPAc RFQ employs 8 RF couplers feeding a single cavity. Multipacting-induced variations among the couplers lead to RF-chain imbalance and trigger RF interlocks before steady-state conditions are established.
- The limitation is linked to the present inner-conductor design, highlighting the **need to validate a coupler suitable for future CW operation**.



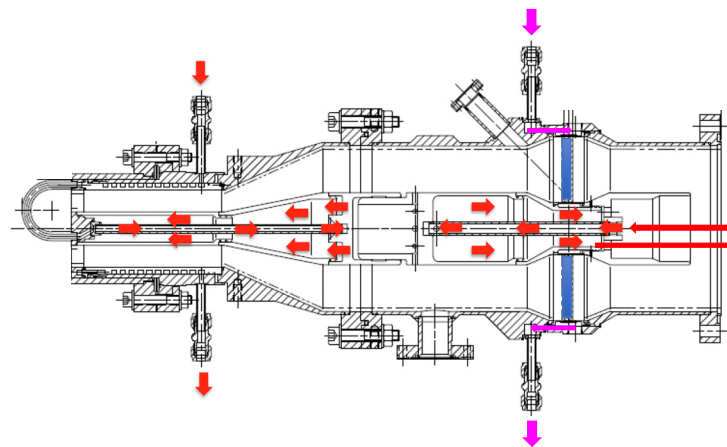


- A RFQ couplers with an inner-conductor design for CW and brazed window interface successfully demonstrated **190 kW/CW operation for 3-4 hours**.
- 6 couplers were tested in Rokkasho, but the test program was paused to prepare the SRF RF power system, as no dedicated coupler test bench is available on site.
- CERN, F4E, and QST have launched the production of ten further-improved couplers; the first two units are nearing completion.
- Also INFN is designing a new coupler as risk mitigation for ensuring capabilities of couplers production and performances in view of DONES.

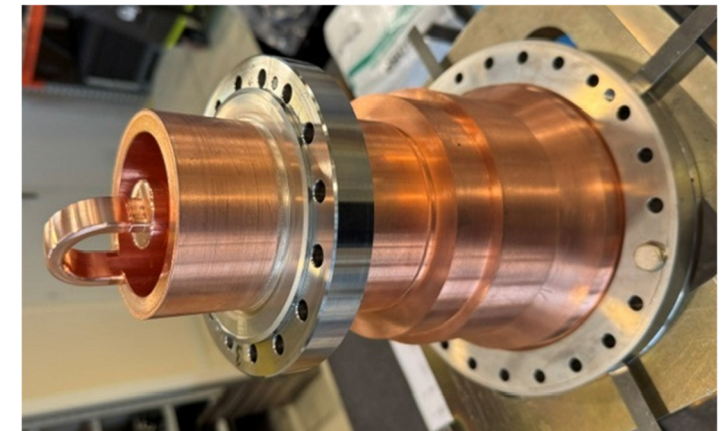
Previous coupler (using EPDM O-ring)



High-duty coupler (brazed)

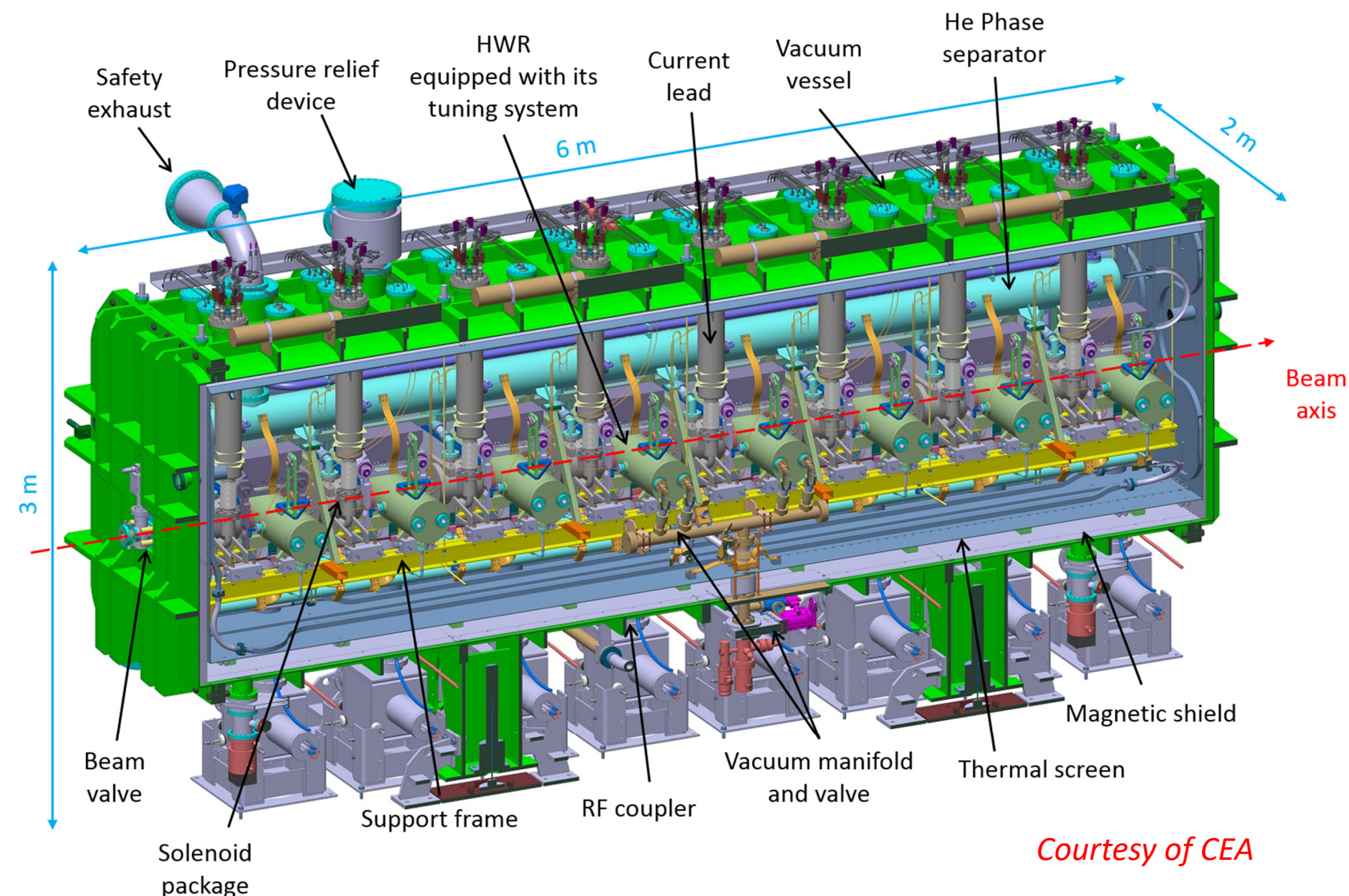


CERN coupler (brazed)





Overall cryomodule design led by CEA with major contributions from CIEMAT and F4E.



Courtesy of CEA

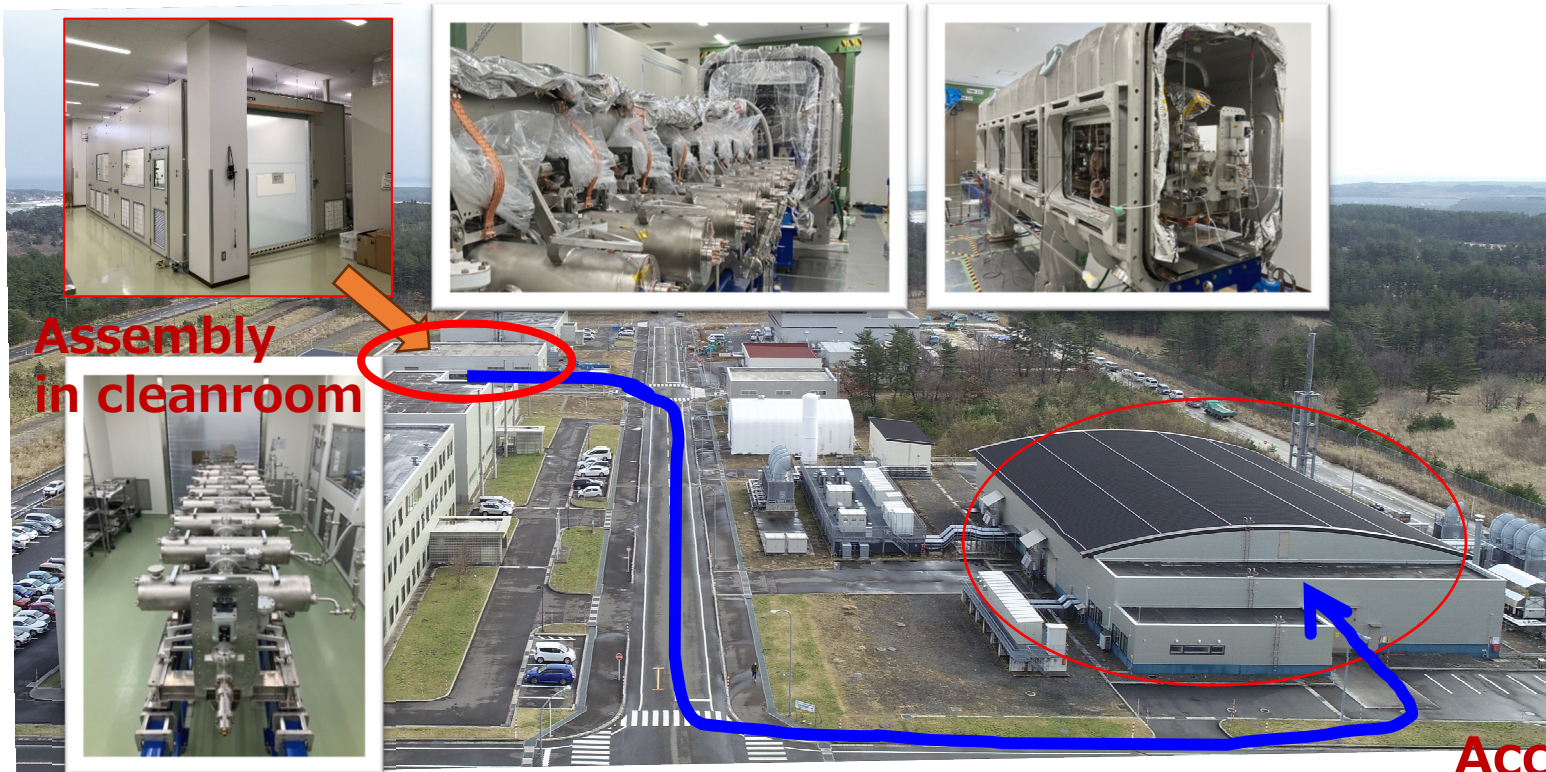
	Procurement responsible	Contractor
HWR cavity	CEA	Zanon
FPC	CEA	CPI
Solenoid	CIEMAT	Elytt energy
Current lead	CIEMAT	Elytt energy
Assembly	F4E	RI

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



SRF Cryomodule Assembly Progress

- To minimize transportation risks, SRF cryomodule was assembled at the Rokkasho site.
- Assembly activities, initiated in 2019 in a dedicated clean room, were suspended due to solenoid weld defects, vacuum leaks, and the COVID-19 pandemic, but resumed in March 2024 after completion of recovery actions.
- The cryomodule assembly was completed in March 2025 and transported to the vault.



(J. Chambrillon, et al., SRF2025 THP61,
T. Ebisawa, et al., SRF2025 THB07C01)



Accelerator building



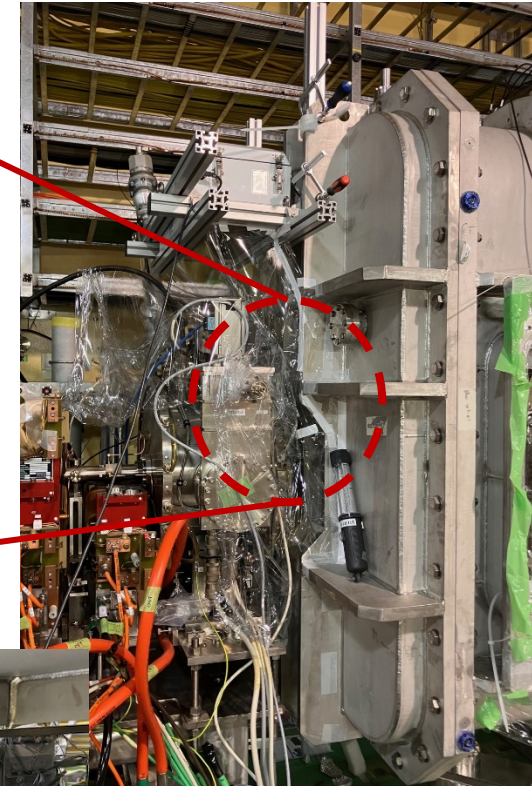
SRF Cryomodule installation work



Installation to the beam line



Final alignment of the cryostat



**↑ MEBT side
connection**

**← Pumping line
connection**



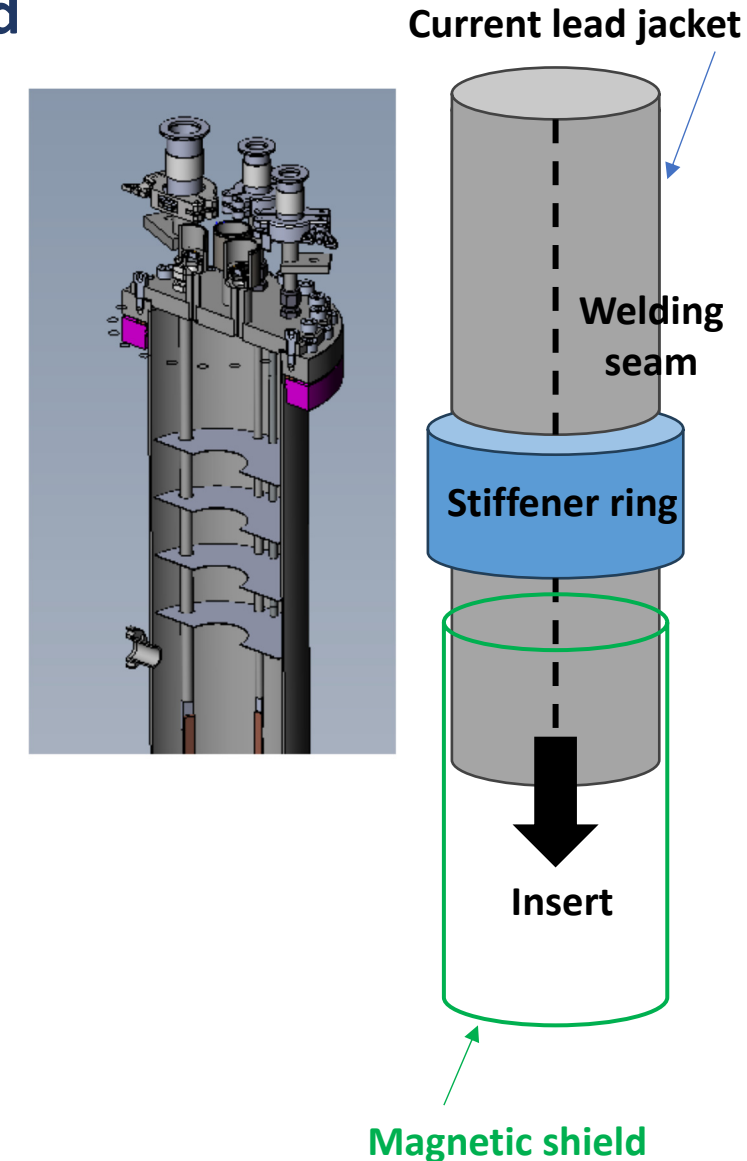
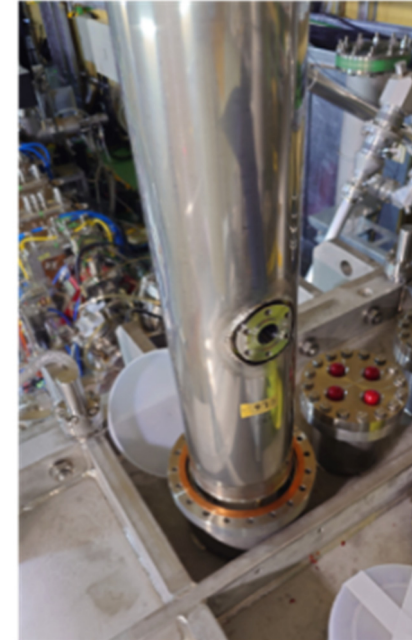
**↑ HEBT side
connection**





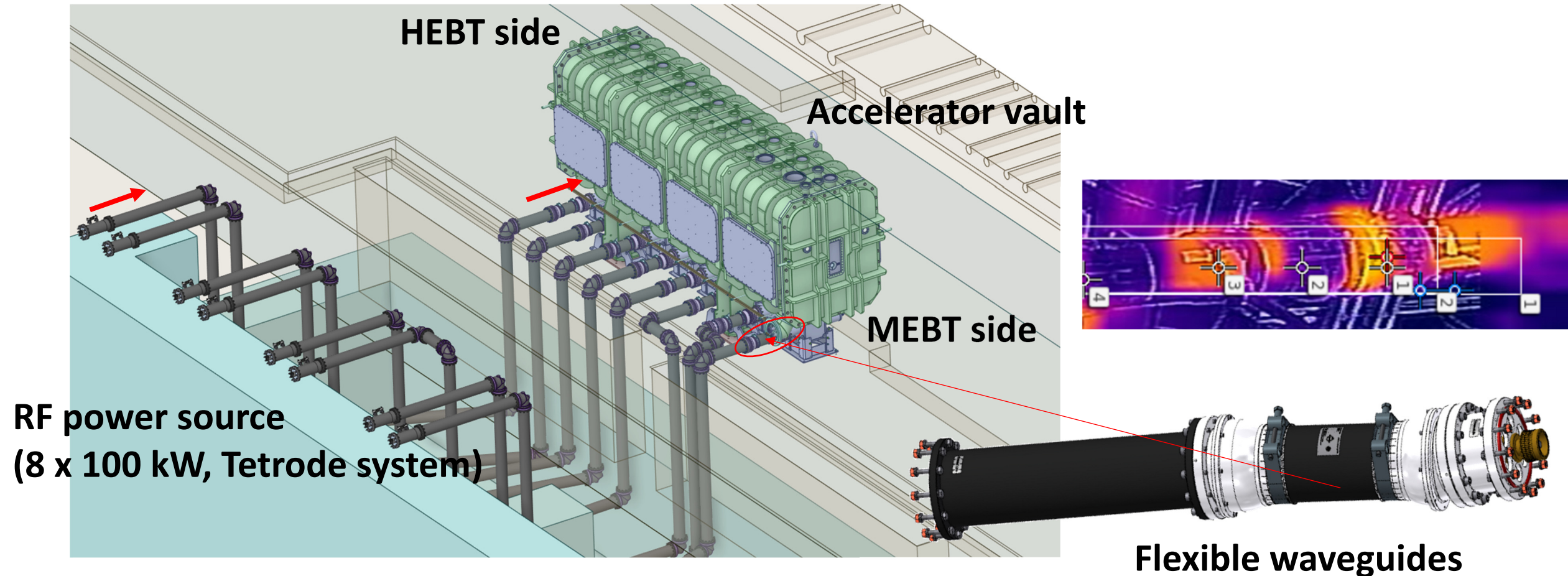
Overcoming Assembly Challenges

- Current lead installation started in April 2025 but was suspended due to **an interference issue with the magnetic shield**.
- A joint EU-Japan review led to the decision to **manufacture a new current-lead outer jacket in Japan**. By optimizing the welding procedure and assembly tooling to minimize distortion of the thin-wall structure, fabrication was successfully completed by the end of December 2025.





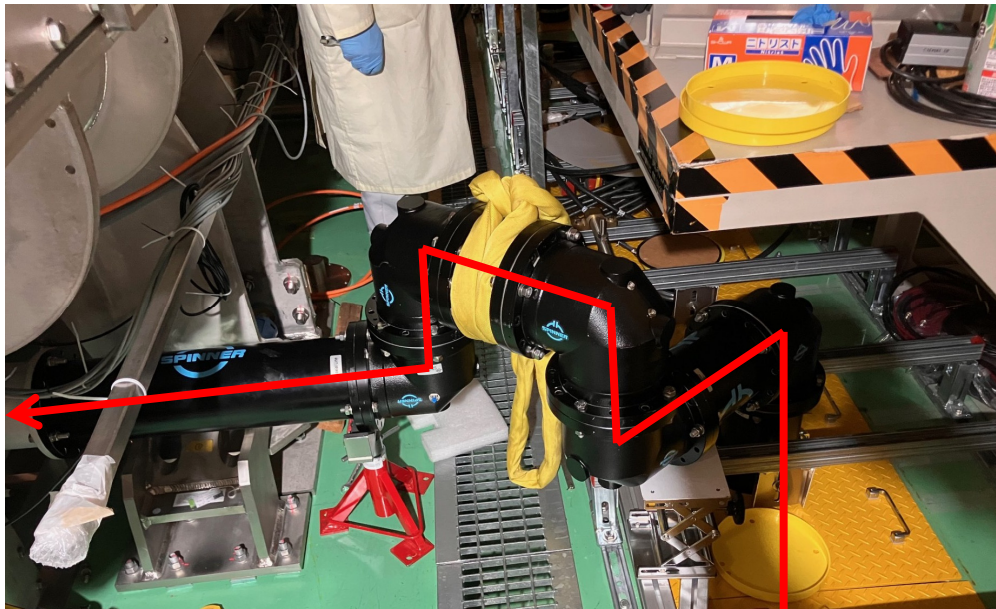
- The installation of the coaxial RF line for cavity RF power delivery was originally planned using a **commercial flexible RF line** (designed for 105 kW/CW). However, **unexpected overheating was identified** during testing, requiring a change of strategy.



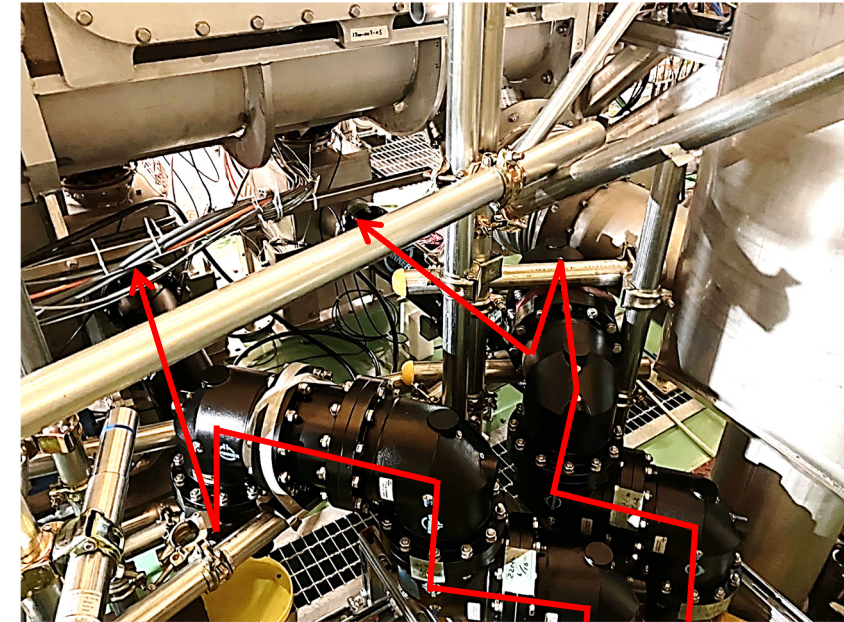


- The temporary RF connection was made using rigid RF lines for the warm conditioning. To accommodate alignment tolerances, a U-shaped RF line was introduced.
- All RF lines will be disconnected before the cooldown and will be restored after cryogenic commissioning and before beam operation.
- Although the overheating issue in the flexible RF lines remains under investigation, recent findings have provided some indications of the root cause.

RF coupler

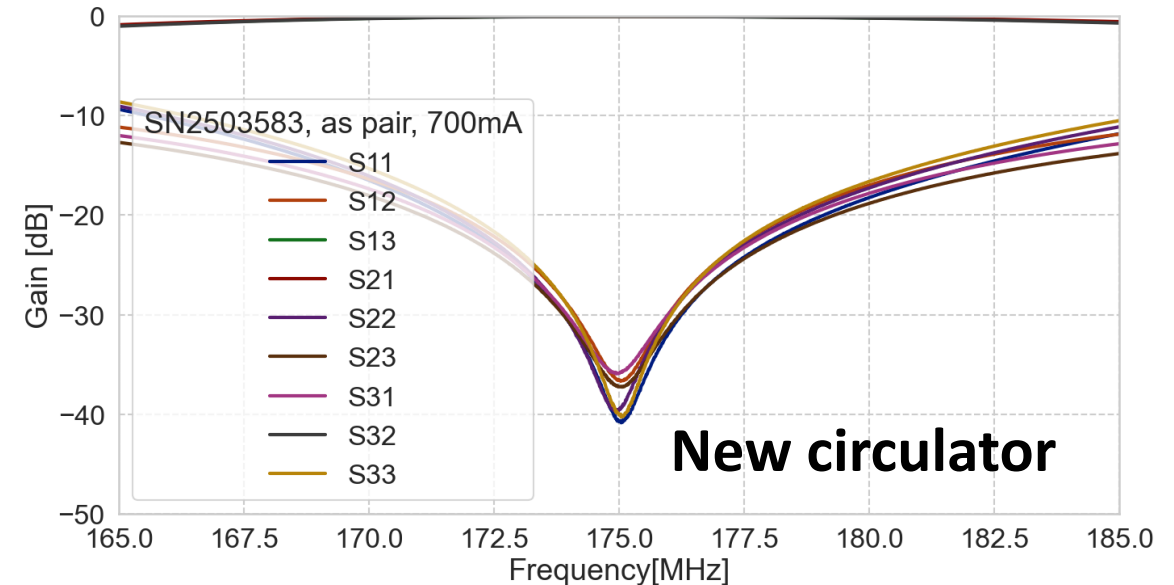
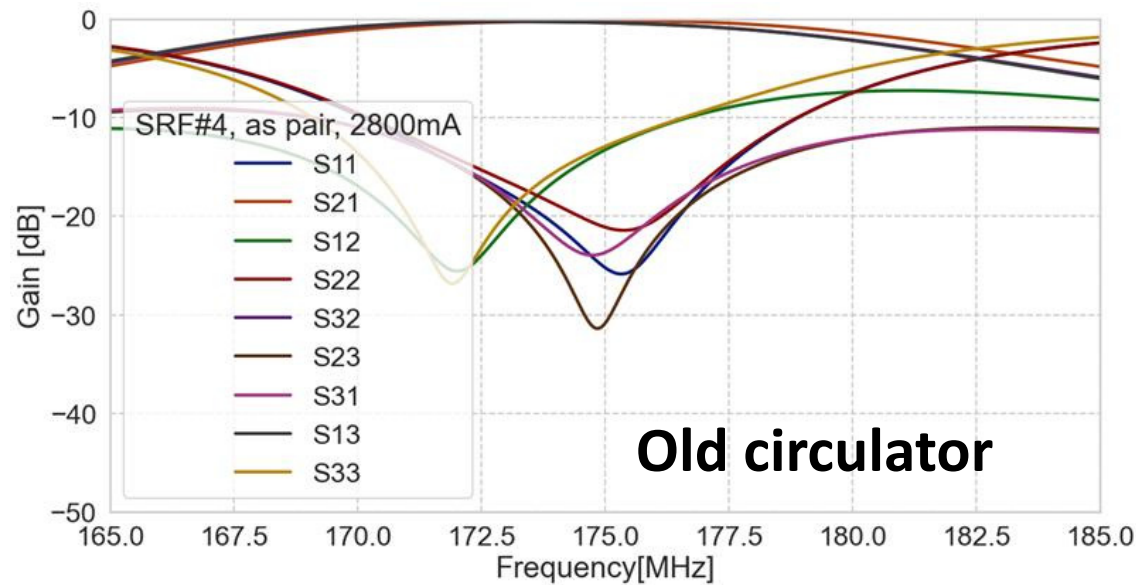


Underground pit





Limitations in the installed circulators directly impact both the warm-conditioning program and the strategy for SRF beam commissioning.

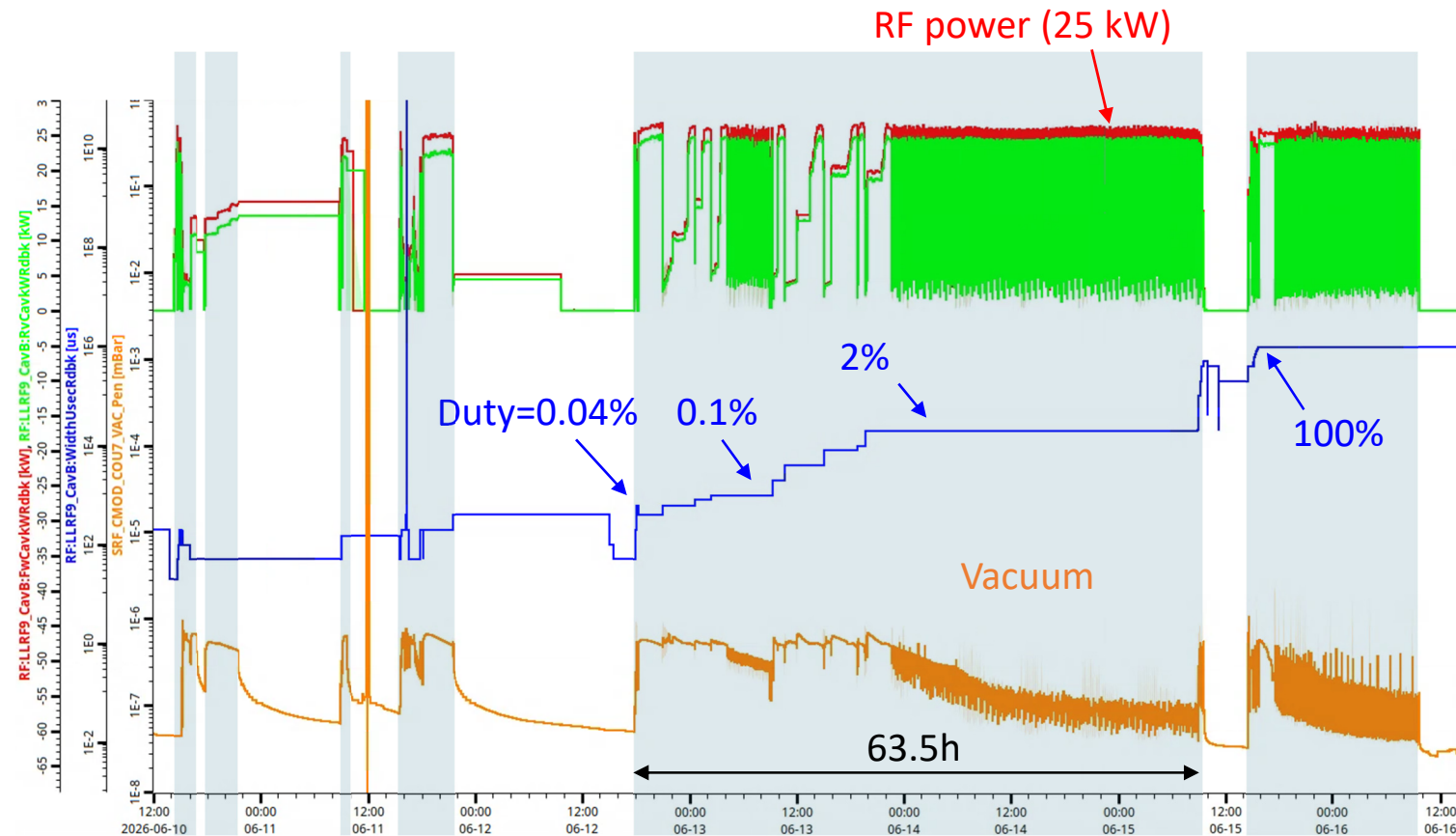


(K. Hirosawa, et al., SRF2025 TUP66)

- Only two of the eight 105 kW circulators satisfy the required RF specifications, **preventing operation at nominal deuteron commissioning power (~80 kW/cavity).**
- Warm conditioning is therefore **limited to 25 kW** and commissioning will start with **a proton probe beam**. New circulators are under production.



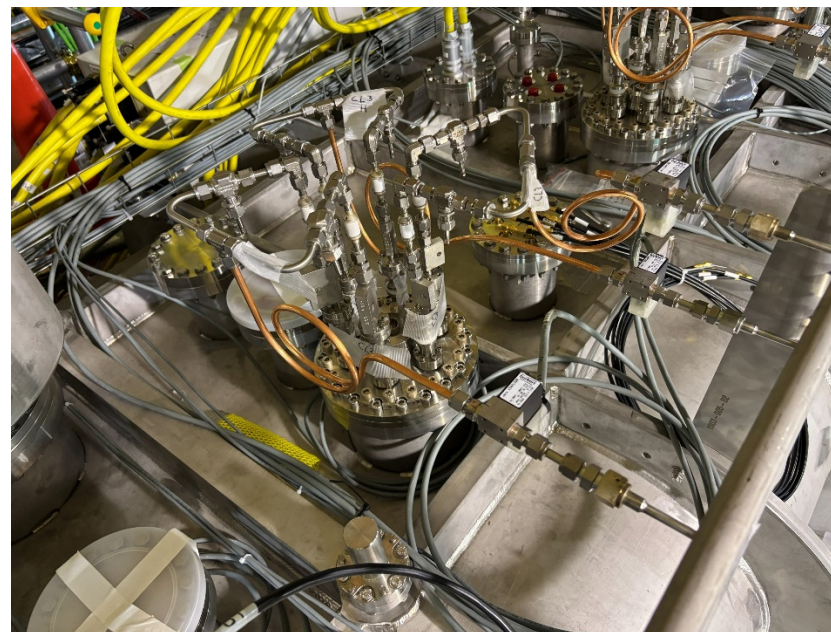
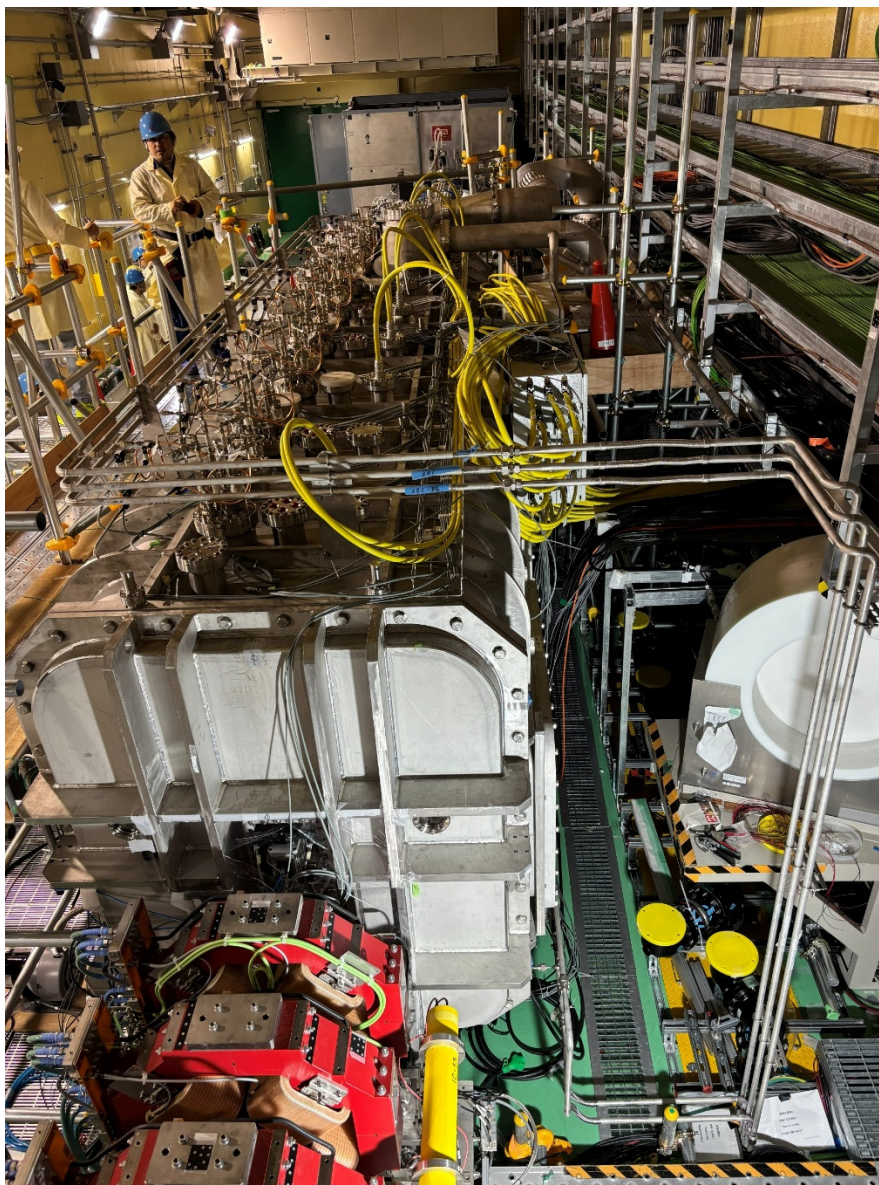
- **SRF Warm coupler conditioning was launched on June 10 with CEA experts.**
- Continuous 24/7 conditioning was maintained through the end of July by combining automated conditioning scripts with on-site shift coverage.
- Conditioning progress to date:
 - #2, #6, #7, #8: **CW achieved**
 - #4: reached 1% duty factor
 - #5: reached ~0.8% duty factor
 - #1: partially conditioned
 - #3: not connected



Warm conditioning history for SRF coupler #7



Cryogenic piping was just completed



Current lead connections



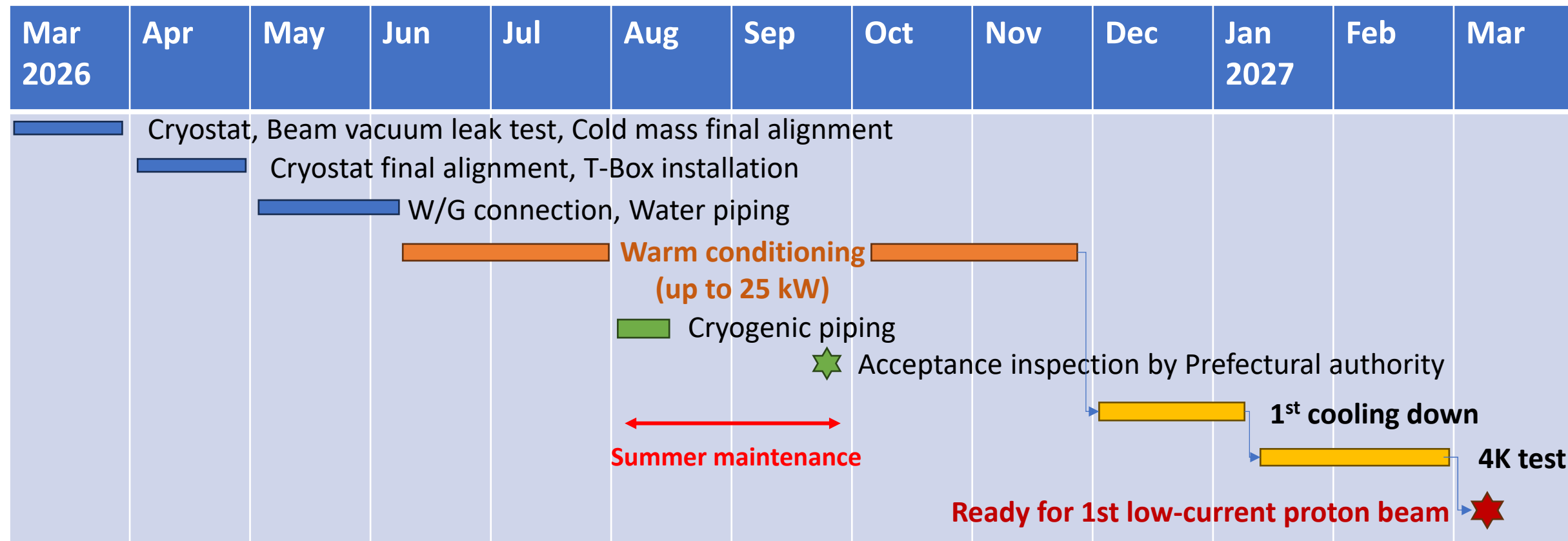
FPC connections



Safety outflow pipes



Machine integration is in its final phase. The project-approved accelerated schedule targets first cooldown in December 2026 and first proton beam in March 2027, subject to successful completion of the remaining readiness activities.



... Then Beam commissioning will start with a proton probe beam (4.5 MeV, 10 mA).



A phased commissioning approach has been adopted to validate the SRF linac with proton beams before progressing to full-current deuteron operation.

Leg 1 Mar/Jul 2027 (tbc)



<u>Stage 1</u>	10	mA	H+ pilot beam
<u>Stage 2</u>	62.5	mA	H+ nominal beam

Break (Warm-up, circulator replacement, and full-power coupler conditioning.)



Leg 2 In 2028 (indicative)

<u>Stage 3</u>	20	mA	D+ pilot beam
<u>Stage 4</u>	125	mA	D+ nominal beam

This strategy minimizes technical risk while maximizing early operational experience with the integrated SRF linac.



- **LIPAc RFQ successfully demonstrated 119 mA deuteron beam acceleration at 8.75% duty factor.**
- **The bottle neck to the RFQ CW operation was identified, and a robust coupler solution is under qualification.**
- **SRF cryomodule assembly is complete, and machine integration is in its final phase.**
- **LIPAc is entering the SRF commissioning era, with first cooldown expected this winter and proton beam commissioning planned for 2027.**



List of contributors

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And many not shown above have contributed and supported the LIPAc activities.