OVERVIEW OF ACHIEVEMENTS AND OUTLOOK OF THE IFMIF/EVEDA PROJECT

[1]K. HASEGAWA, [1]A. KASUGAI, [1]K. KONDO, [1,2]K. MASUDA, [1,2]S. SATO, [1,2]K. OCHIAI, [2,3]Y. CARIN, [3]H. DZITKO, [2,3]D. GEX, [3]F. CISMONDI, [4]S. CHEL, [5]A. PISENT, [6]D. JIMENEZ, [6]J. MOLLA, [7]G. MICCICHE, [8]D. RADLOFF, [9]D. TERENTYEV

[1]QST, Rokkasho, Japan, [2]IFMIF/EVEDA Project Team, Rokkasho, Japan, [3]F4E, Garching, Germany, [4]IRFU, CEA, Université Paris-Saclay, France, [5]INFN, Legnaro, Italy, [6]CIEMAT, Madrid, Spain, [7]ENEA, Brasimone, Italy, [8]KIT, Karlsruhe, Germany, [9]SCK-CEN, Mol, Belgium.

Email: hasegawa.kazuo@qst.go.jp

The IFMIF/EVEDA project faces numerous challenges, in terms of high duty cycle and high beam current in the prototype accelerator (LIPAc) and reliable operation of the lithium target. Despite these obstacles, significant progress has been made, and several key milestones have been achieved.

- The high duty cycle operation phase of the LIPAc 5 MeV RFQ was successfully completed in June 2024. The deuteron beam current and the duty cycle were 120 mA and 8.75%, respectively. This performance shows the highest intensity in the RFQs existing in the world.
- The assembly of the superconducting-Linac beam line components in the clean room was completed in September 2024. Preparation for the integration to the LIPAc is underway.
- A small lithium loop pilot plant in Japan has been fabricated to perform the impurity control within the lithium, while a full scale is under assembly in Europe.

1. INTRODUCTION

The Engineering Validation and Engineering Design Activities for the International Fusion Materials Irradiation Facility (IFMIF/EVEDA) project is underway as one of the three projects (IFMIF/EVEDA, IFERC and JT60SA) of the Broader Approach (BA) agreement between EURATOM and the Japanese government since 2007 [1]. The IFMIF is to provide accelerator-based D-Li neutrons at appropriate energy and sufficient intensity to test samples of candidate materials for fusion energy reactors such as DEMO. The mission of the IFMIF/EVEDA project is to produce detailed engineering design of the IFMIF and to validate on major systems: Accelerator Facility, Lithium Target Facility and Test Facility. In the current activities in the project, they are focused on the commissioning of the Linear IFMIF Prototype Accelerator (LIPAc) and enhancement of some sub-systems for fusion neutron source design (FNSD). This article overviews the achievements and outlook of the LIPAc commissioning and FNSD activities since the FEC2023 [2].

2. COMMISSIONING OF THE ACCELERATOR FACILITY: LIPAC

The Accelerator Facility validation activities aim with the LIPAc at demonstrating the acceleration of 125 mA deuteron (D^+) beam up to 9 MeV, which is an initial part of the 40 MeV IFMIF accelerator. The LIPAc presents several significant challenges: it features the world's highest current in Continuous Wave (CW), the world's longest and powerful Radio Frequency Quadruopole (RFQ), the highest hadron current through a Superconducting Radio Frequency (SRF)-Linac, and reaching 1.1 MW of beam power. Therefore, to mitigate risks, a phased approach has been and will continue to be implemented for the installation and beam commissioning. The LIPAc RFQ high duty factor operation Phase (B+) and final configuration Phases (namely C at low duty and D at high duty) are shown in Fig. 1. The 140 mA and 100 keV D^+ beam is generated in an ion source to be injected in a 5 MeV RFQ. The 5 MeV beam is transported through the Medium Energy Beam Transport (MEBT) line and injected to a 9 MeV SRF-Linac. The beam is then transported through the High Energy Beam Transport (HEBT) line, which includes a Diagnostics Plate (D-Plate) for beam characterization and a bending magnet toward the 1.125 MW High Power Beam Dump (BD). The main outcomes of the low duty cycle

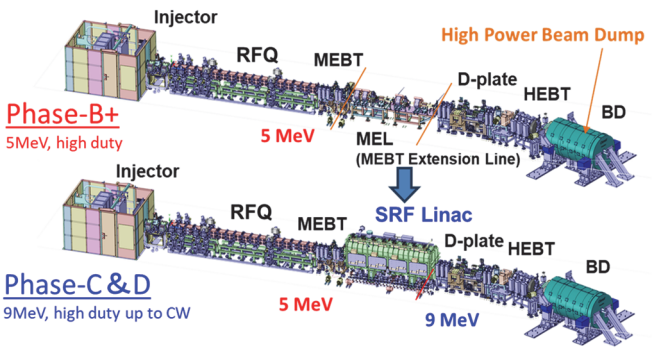

Fig. 1: Phased installation and commissioning of the LIPAc

(~0.01%) operation in the Phase B+ were reported at FEC2023 [3]. After the preparation of the high duty cycle operation for the RFQ, RF power supply system and beam diagnostics, the operation toward 10% started in March 2024. By the end of the Phase B+ in June, the maximum duty cycle of 8.75% was successfully achieved. As in Fig. 2, the beam current was about 119 mA at the HEBT, which was close to the nominal of 125 mA [4]. This performance shows the highest intensity in the RFQs in the world. It was identified, however, that more higher duty cycles are difficult to achieve with the current RF couplers for the RFQ.

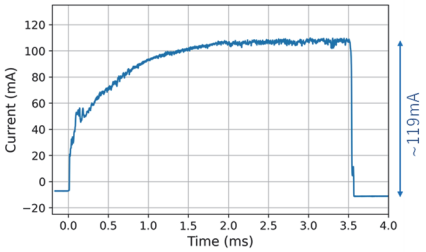

Fig. 2: Beam current waveform at the HEBT at 8.75 % duty cycle

In view of the phase C, the assembly of the SRF-Linac has been carried out in another building in parallel to the beam operation. The assembly of the beam line components in the clean room is shown in Fig. 3, and was completed in September 2024. This has achieved one of the project milestones and the cryomodule assembly is continuing outside of the clean room.

Fig. 3: Assembly work of the SRF beam line components in the clean room

3. FUSION NEUTRON SOURCE DESIGN ACTIVITIES

The activities in the BA are intended to prepare for the construction of the future Fusion Neutron Source facility. Common tasks have been identified in the frame of the FNSD activities and are being implemented in both Europe and Japan. One of the tasks involves a small lithium loop pilot plant (1:10 scale) designed to test a purification system of hydrogen and nitrogen, impurities that accelerates material corrosion and must be controlled for reliable operation. The construction of this pilot plant in Japan was completed in December 2024. The initial operation was carried out from January to February 2025. Other Engineering Design activities comprise tritium migration estimation, erosion/deposition modelling in the target system, use of LIPAc as testing facility, etc. Most of these FNSD activities are close to their conclusion in 2025, while the Li Loop pilot plants and using the LIPAc as testing facility tasks will continue.

4. OUTLOOK OF THE IFMIF/EVEDA

The project is shifting from phase B+ to C with the completion of the high duty RFQ beam operation and preparing the SRF Linac. The assembled cryomodule is expected to be transported to the LIPAc building in early 2025. Then it will be integrated into the LIPAc beam line, and the final configuration will be commissioned to demonstrate the targeted performance.

It has become clear that the current O-ring type RF couplers for the RFQ is a limitation to CW due to the multipacting. Some measures are being taken; another type couplers, brazed type, are under high power test, and new brazed couplers are to be designed and constructed as a backup option. The CW beam tests will be done in the SRF-Linac beam commissioning in Phase D.

In the meantime, the upgrades for several systems are on-going taking into account the lessons learned during commissioning and operation of the LIPAc [5]. The FNS facility in Europe, IFMIF/DONES, has been launched in Spain. The outcomes of the IFMIF/EVEDA project reflect the design, construction, commissioning and operation of the FNS facility through close collaborations between the two projects.

REFERENCES

[1] DZITKO, H. et al., Overview of Broader Approach activities, Fusion Engineering and Design Volume 201, April 2024, 114259

[2] CARIN, Y. et al., Overview of Achievements of the IFMIF/EVEDA Project, proceedings of FEC2023, IAEA-CN-316-1681 (2023).

[3] MASUDA, K. et al., Beam Commissioning of Linear IFMIF Prototype Accelerator (LIPAc) Toward High-Duty Operation at 5 MeV, 125 mA D+, proceedings of FEC2023, IAEA-CN-316-1741 (2023).

[4] AKAGI, T. et al., Completion of Phase B+ Beam Commissioning of Linear IFMIF Prototype Accelerator (LIPAc), proc. of the LINAC2024, (2024) 705-707

[5] CISMONDI F., et. al, Planned Future Upgrades of Linear IFMIF Prototype Accelerator (LIPAc), proc. of LINAC2024, (2024) 206-208