IFMIF/EVEDA PROJECT:
Achievements and Outlooks beyond 2020

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Accelerator Facility

Target Facility

Test Facility

IFMIF/EVEDA Project

Outline

1. Introduction
2. IFMIF/EVEDA Status
3. LIPAc: Accelerator Facility
4. LIPAc: Commissioning Status
5. Outlook beyond 2020
6. Conclusions

Outline

1 Introduction

Broader Approach

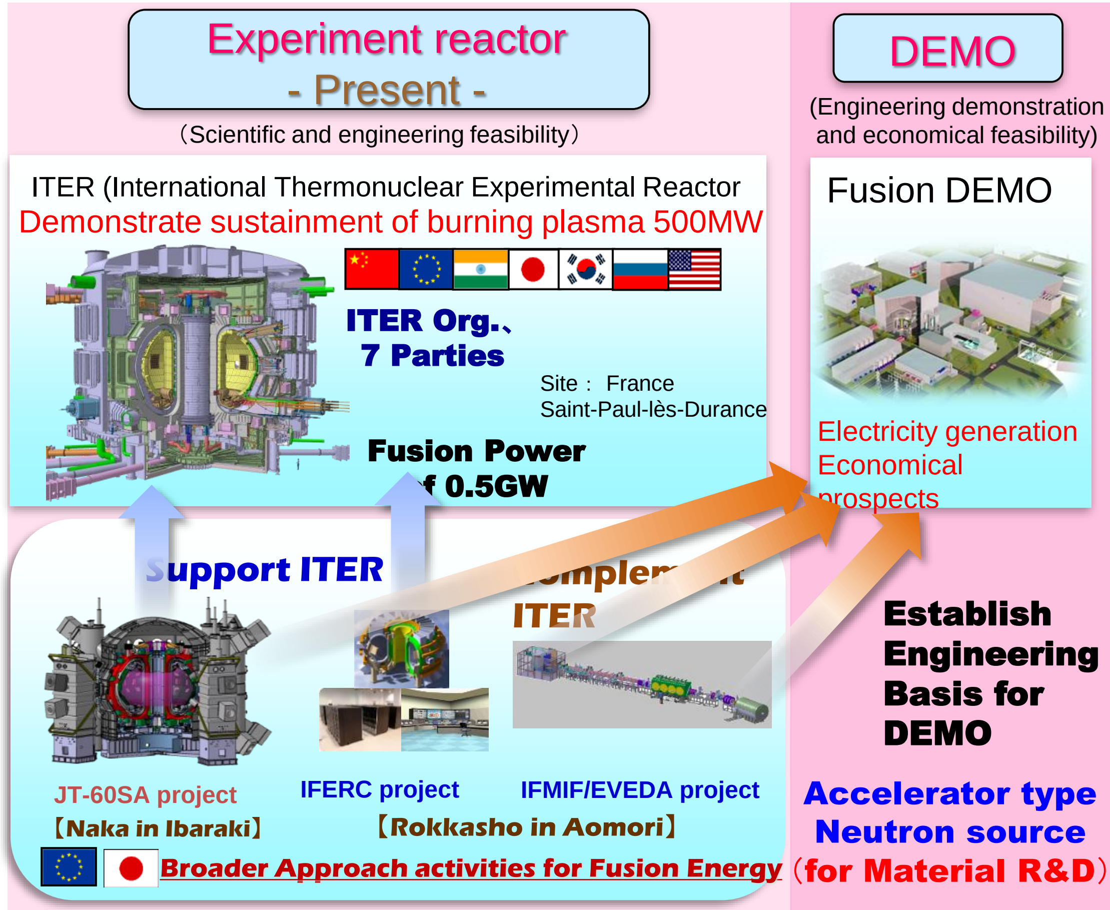
After signature ITER
November 2006

BA Signed in February 2007

Entered into force on June 2007

JA-EU Collaboration

In Japan



IFMIF

International Fusion Materials Irradiation Facility

EVEDA

Engineering Validation & Engineering Design Activities

Article 1.1 of Annex A of the **BA Agreement** mandates **IFMIF/EVEDA**

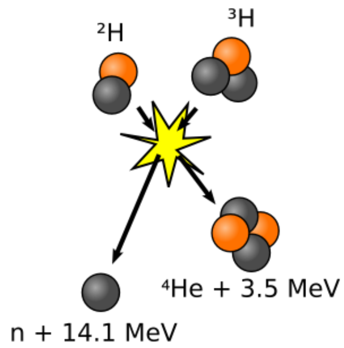
…to produce an integrated engineering design of IFMIF and the data necessary for future decisions on the construction, operation, exploitation and decommissioning of IFMIF, and to validate continuous and stable operation of each IFMIF subsystem

Why a Fusion Neutron Source?

The first wall of the fusion reactor vessel

will see 14.1 MeV neutrons

Due of DT reactions



ITER first wall will face

< 3 dpa at the end of its operation life

DEMO reactor is expected to see

>15 dpa per year of operation (20 years ~6 fpy)

It is also expected transmutation (He and H) reactions which will change the properties of the materials (structural and functional integrity)

- **Selection and qualification of candidate materials for fusion reactors**
- **Generation of engineering data for design, licensing and safe operation of DEMO up to end-of-life**
- **Completion, calibration and validation of material databases (mainly generated from fission reactors research)**
- **Material testing and simulation carried out simultaneously to correlated fundamental understanding of radiation response of materials**

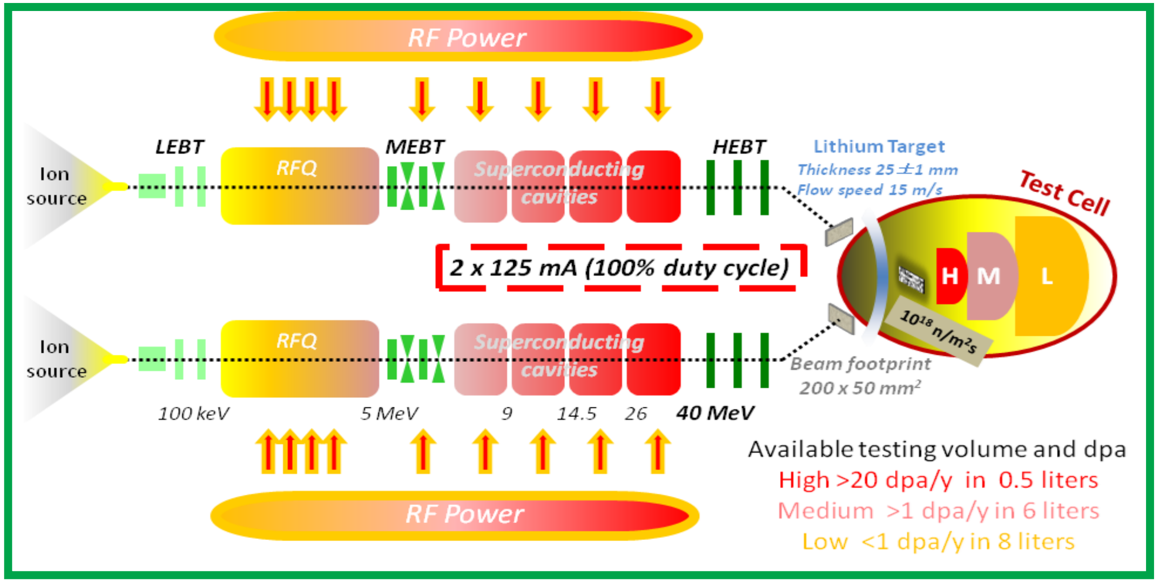
International Advisory Panels pointed out Fusion Neutron Source as essential need toward Fusion Power Plant → best fulfilled with a D-Li stripping source → IFMIF concept

IFMIF Concept

Two concurrent deuterons beam of 125 mA CW at 40 MeV

Impact on a liquid Li screen flowing at 15 m/s

Generating a footprint of 200 x 50 mm^2



A flux of neutrons of ~10^{18} n/m^{2}s is generated in the forward direction with a broad peak at 14 MeV and irradiate three regions:

- >20 dpa/fpy in 0.5 liters (H)
- >1 dpa/fpy in 6 liters (M)
- <1 dpa/fpy in 8 liters (L)

→ Availability of facility >70%

Outline

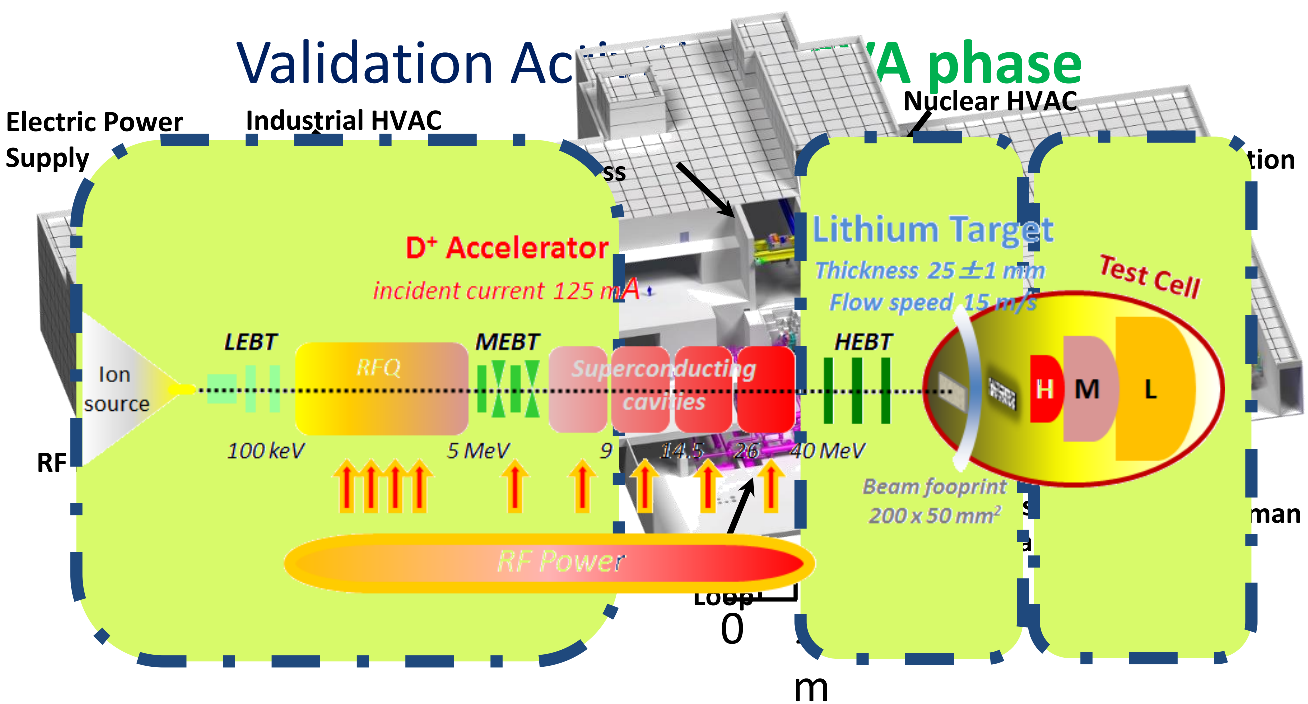
2 IFMIF/EVEDA Status

EVEDA = EDA +EVA Phases

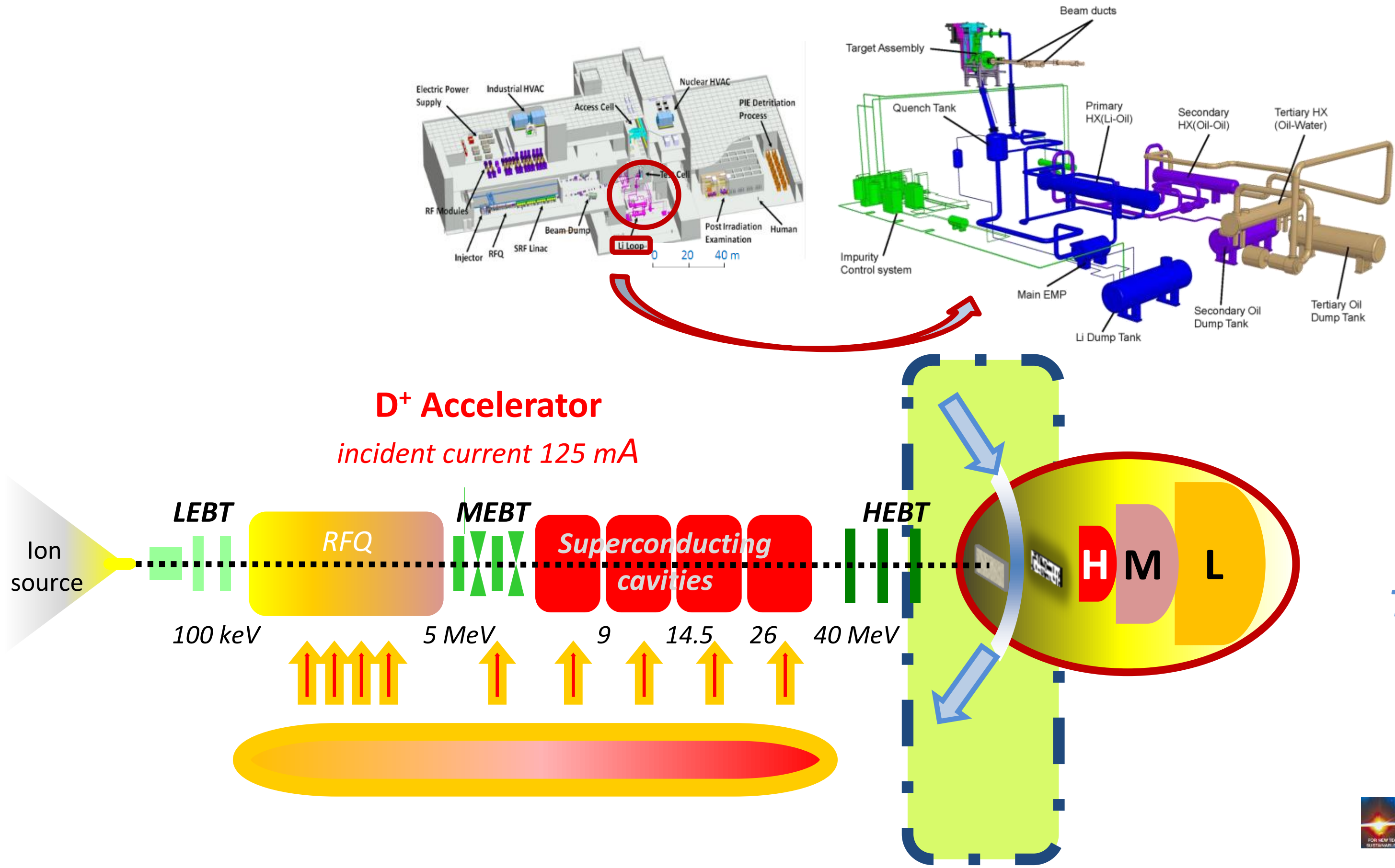
Engineering Design Activities – **EDA phase**

Successfully delivered on schedule

Validation Ac… A phase



EVA Phase – Target Facility



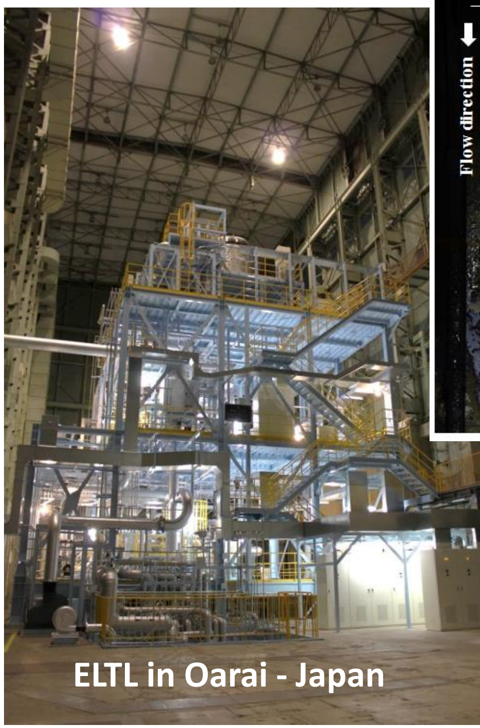
Lithium jet at 250 C
Flow speed 15 m/s
Thickness 25 ±1 mm

EVA Phase – Target Facility

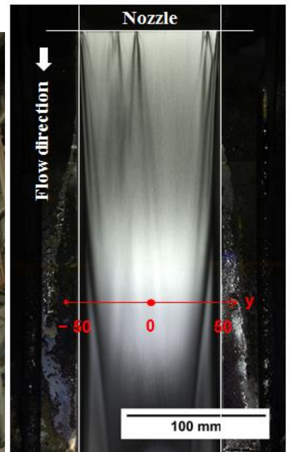
Milestones

Construction completed on 19 Nov. 2010

Test completed on 31 March 2015

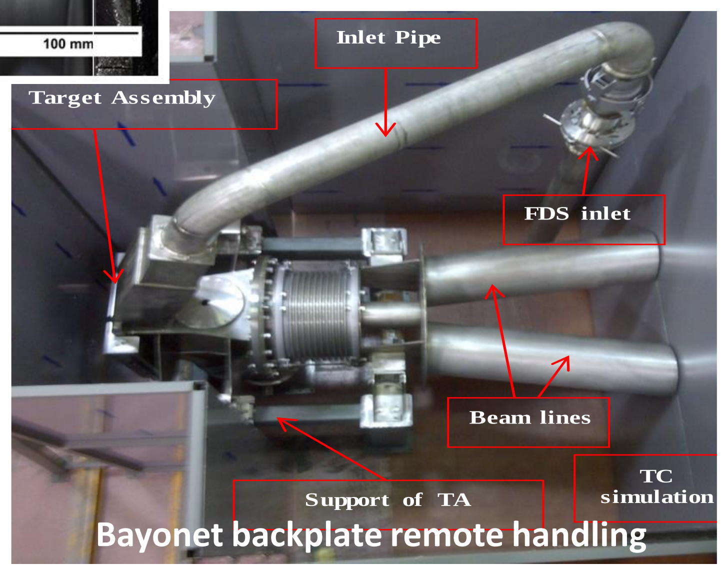


ELTL in Oarai - Japan

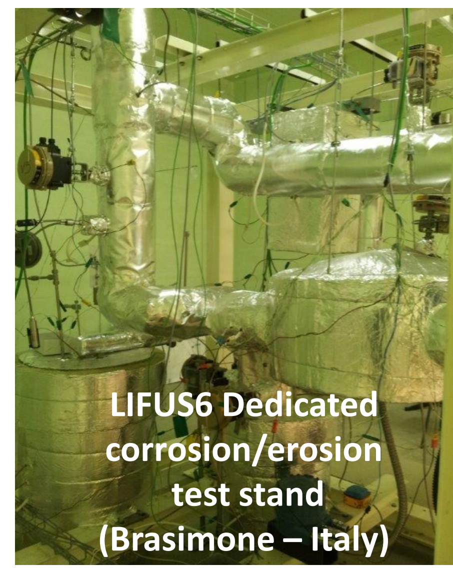


Results: No change in Li target thickness and stable Li target throughout the continuous operation for 571 h (~24 days).

System Integration was successfully demonstrated March 2015



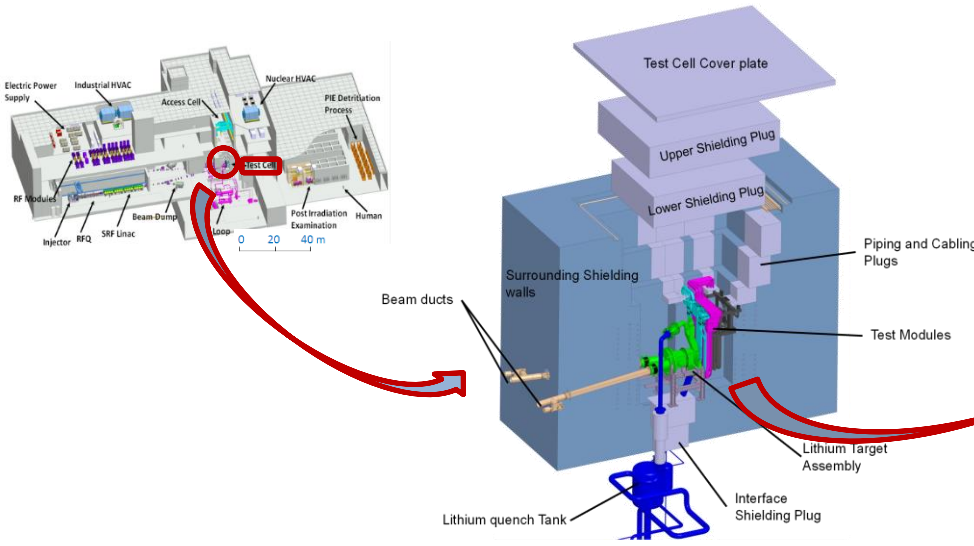
Bayonet backplate remote handling

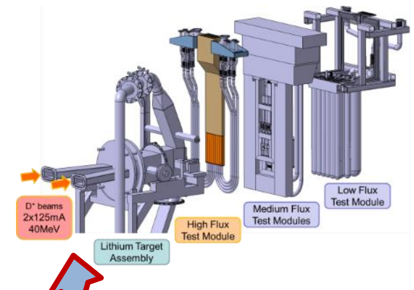


LIFUS6 Dedicated corrosion/erosion test stand (Brasimone – Italy)

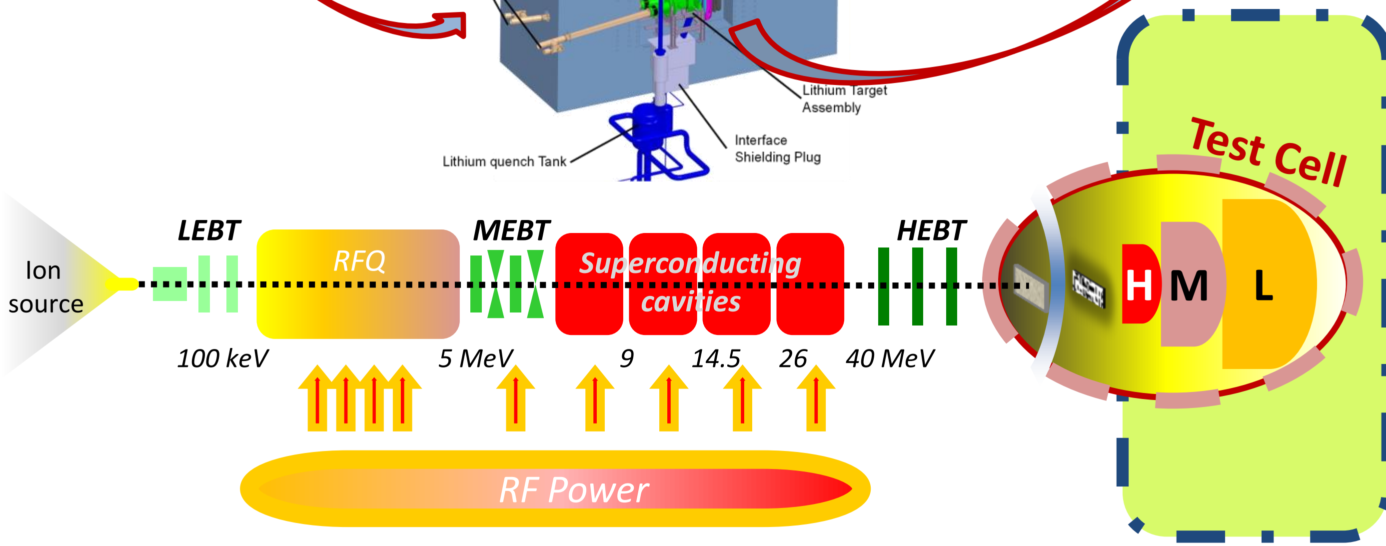
Engineering Validation Activities completed on Feb. 2017

EVA Phase – Test Facility





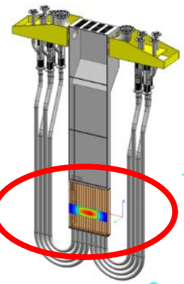
HFTM
20 dpa/fpy in 500 cm³
12 x 80 small specimens
independently cooled
within +/- 3% T

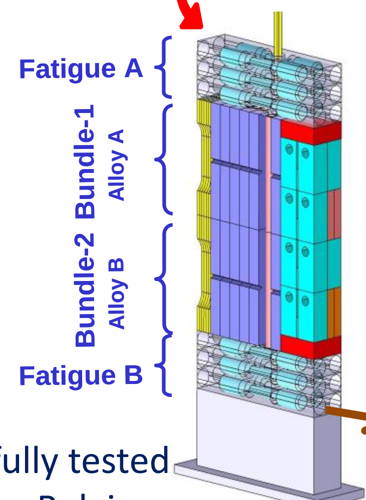


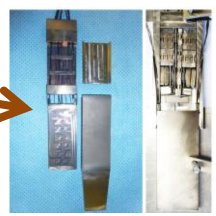
EVA Phase – Test Facility

6 reference specimens have been developed

Specimen type	Geometry
Tensile	
Fatigue	
Bend/Charpy DFT	
Creep	
Crack growth	
Fracture toughness	

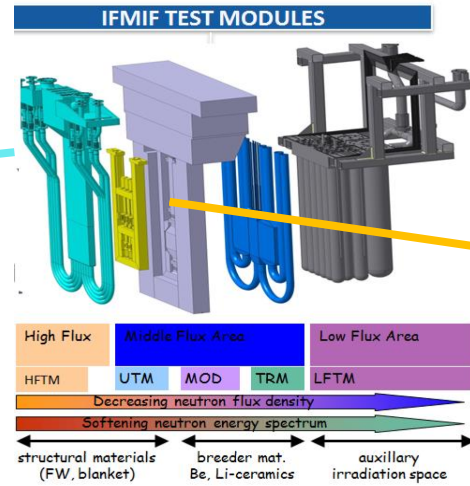


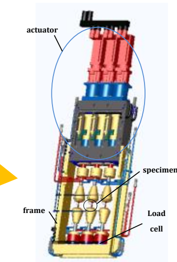


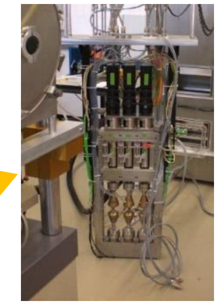


KIT
SCK•CEN

Successfully tested using the Belgian material test reactor BR2 in Mol

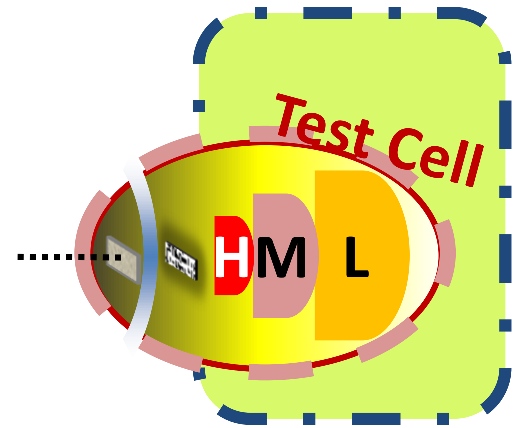






EPFL

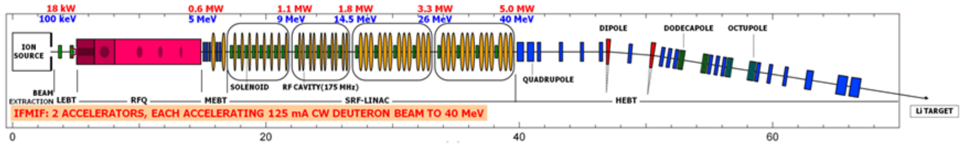
HFTM-DC in Karlsruhe



Validation Activities completed on Apr. 2015

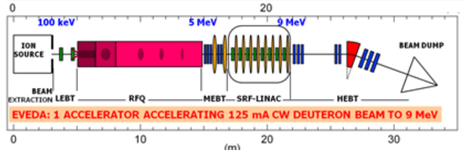
EVA Phase – Accelerator facility

IFMIF



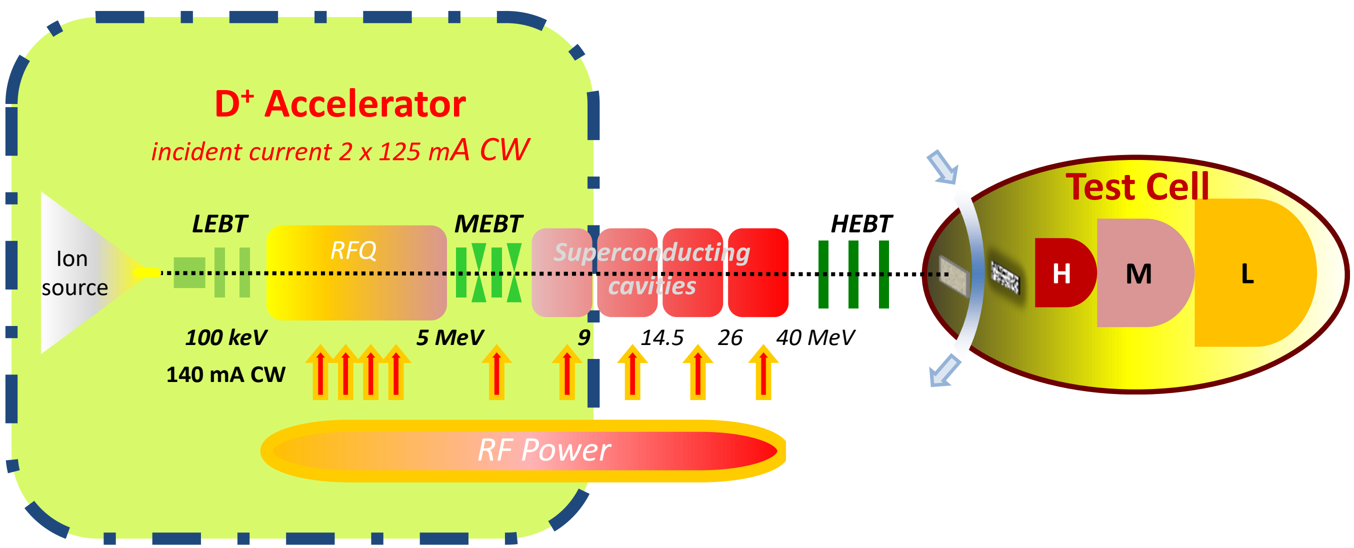
40 MeV
125 mA
5 MW

LIPAc



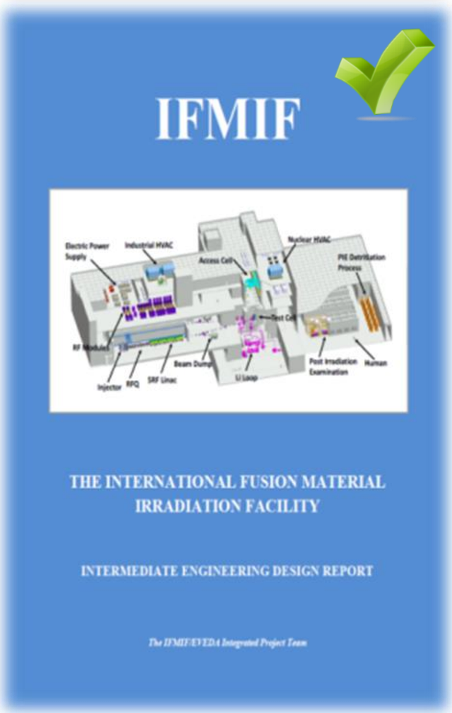
9 MeV
125 mA
1.125 MW

Small but challenging



IFMIF/EVEDA Phase I

EDA phase:

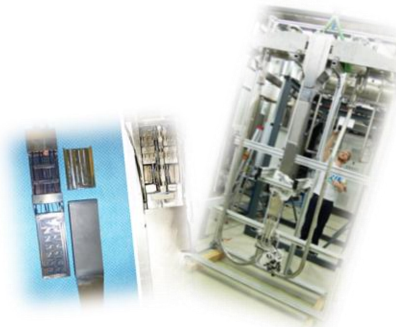

IFMIF

THE INTERNATIONAL FUSION MATERIAL IRRADIATION FACILITY

INTERMEDIATE ENGINEERING DESIGN REPORT

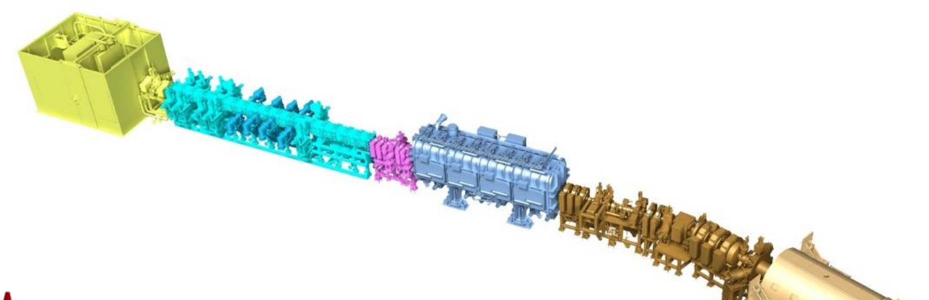
The IFMIF/EVEDA Integrated Project Team

EVA phase:



Test Facility

Target Facility



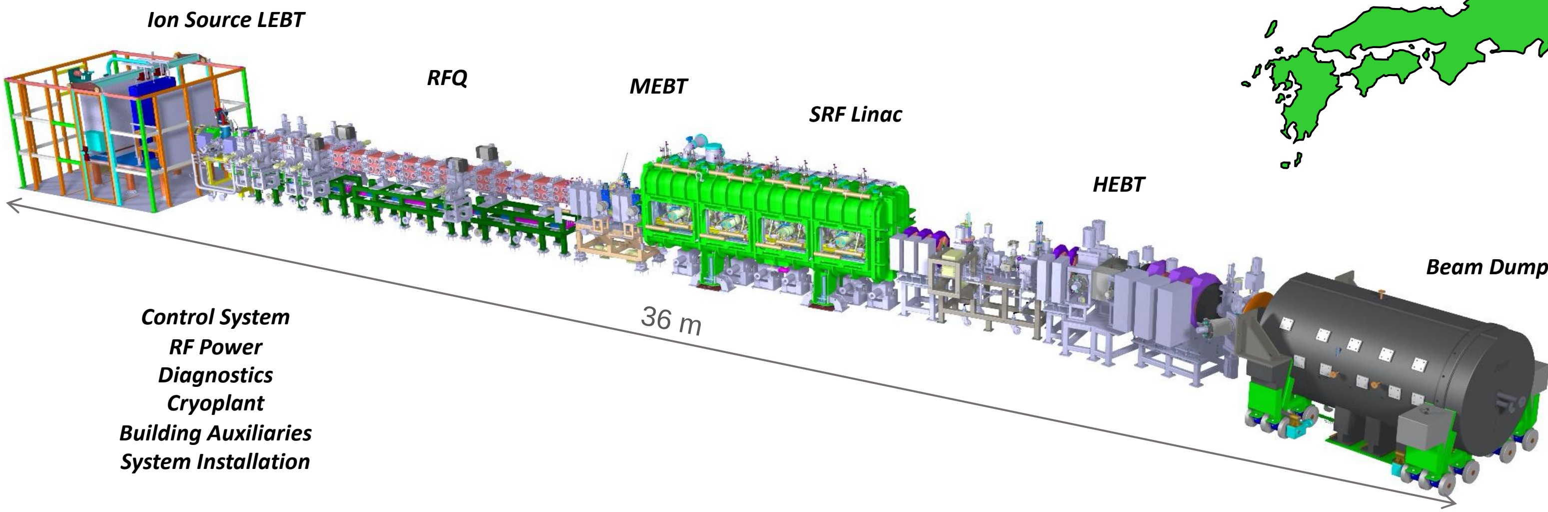
LIPAc (Linear IFMIF Prototype Accelerator) – Accelerator Facility
9MeV, 125mA CW, 1.125 MW

Outline

3 LIPAc: Accelerator Facility

Japan-Europe scientific collaboration

Japan-Europe scientific collaboration



Equipment designed and constructed in Europe, Installed and commissioned in Rokkasho

LIPAc a challenging accelerator

World's highest current linac in H^+ and D^+ in CW

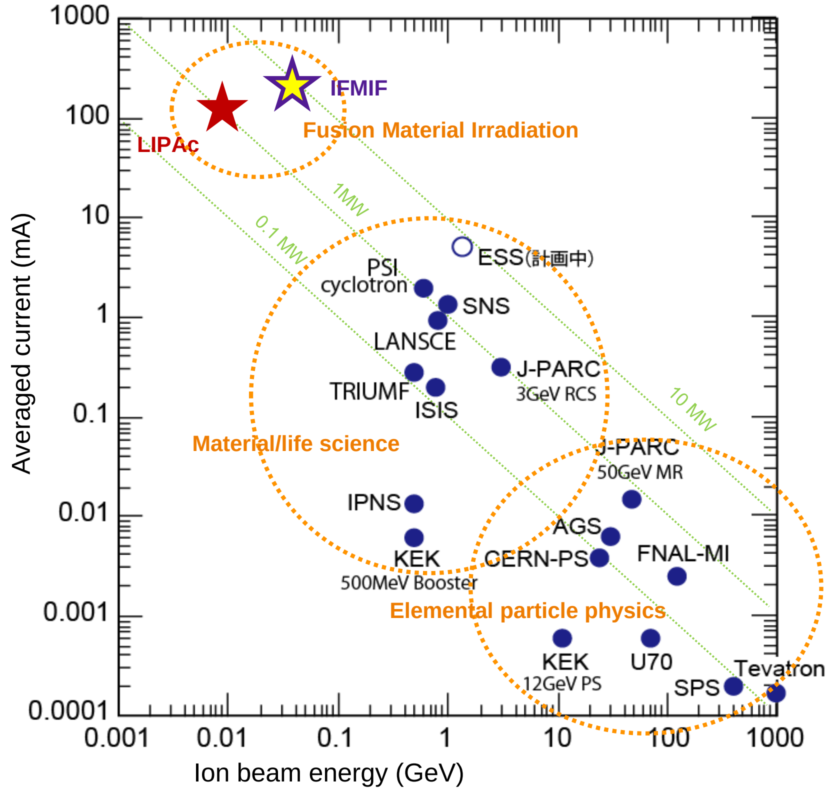
World's top H^+&D^+ injector performance

World's longest RFQ

World's record of light hadrons current through SC cavities

World's highest beam perveance

Accelerator Operational condition



Project Organization

Project Coordinated by IFMIF/EVEDA Project Leader

In liaise with 2 Home Teams

Organization evolved since 2007….

LIPAc Organization Since 2018:

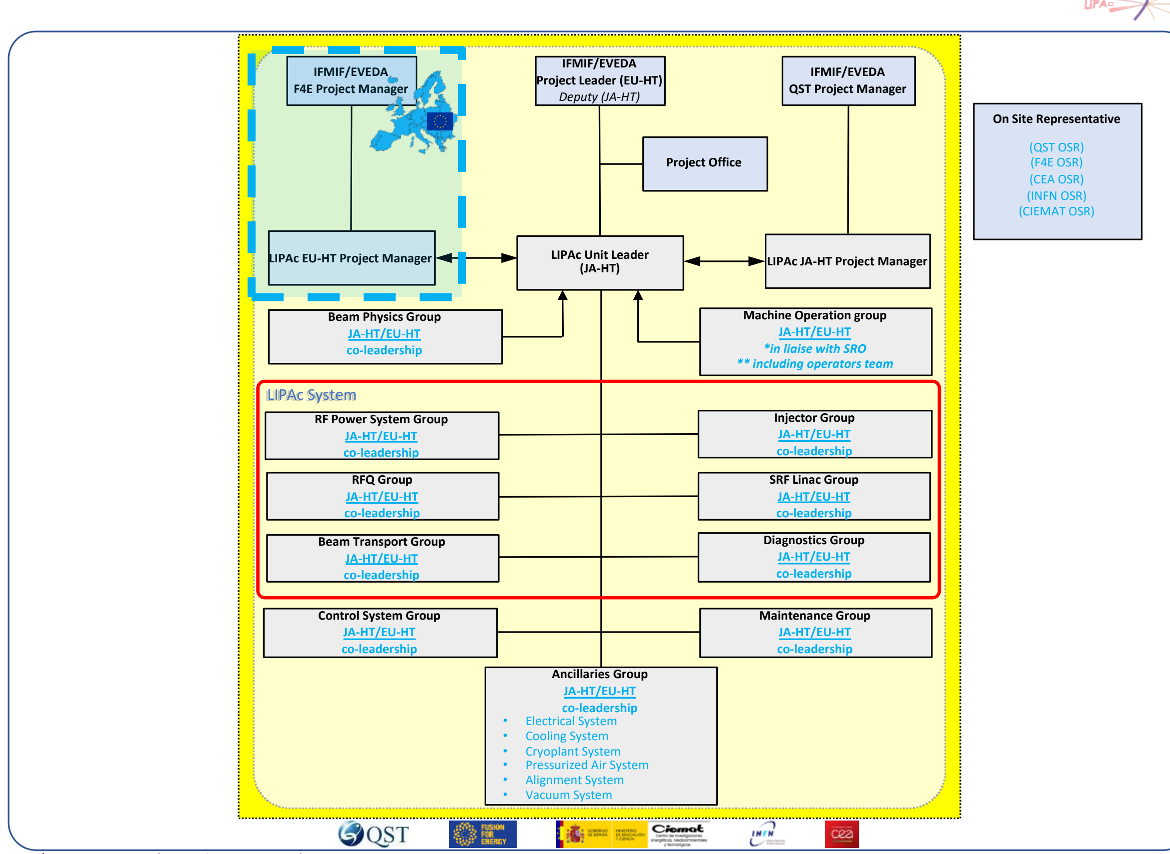
- Beam Operation,
- Maintenance,
- Installation & Commissioning...

System Installation, Checkout, Start-up, Commissioning

LIPAc Unit in Rokkasho

~50 people

LIPAc Operation Team



IFMIF/EVEDA CQMS-0920 (DMS Ref. BA_D_ 27MTRJ)

Outline

4 LIPAc: Commissioning Status

Commissioning with staged approach

4 configurations considered for 5 commissioning phases to validate the LIPAc performances

Commissioning with staged approach

1st configuration – Commissioning Phase A

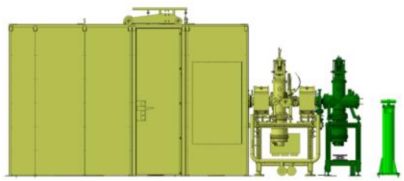
Phase A
100 keV - 125 mA
12.5 kW

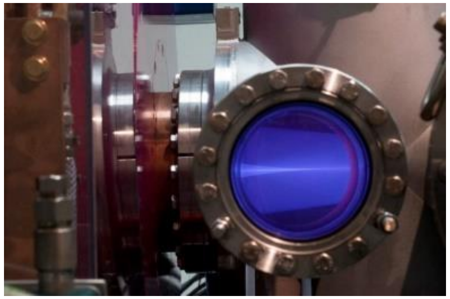
Injector | CW | Diagnostic Box + Beamstop

(Apr.2015 - Aug.2017)

COMPLETED

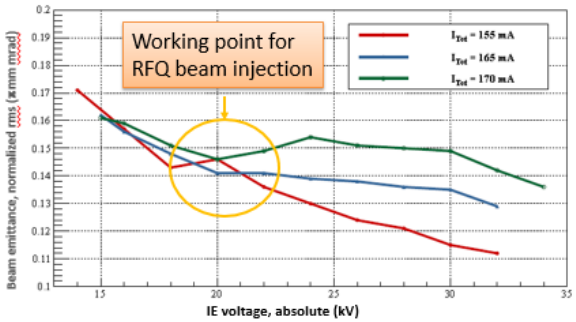
Phase A: Experimental campaign

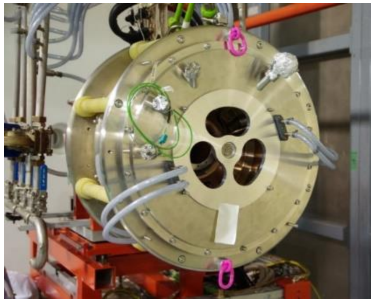


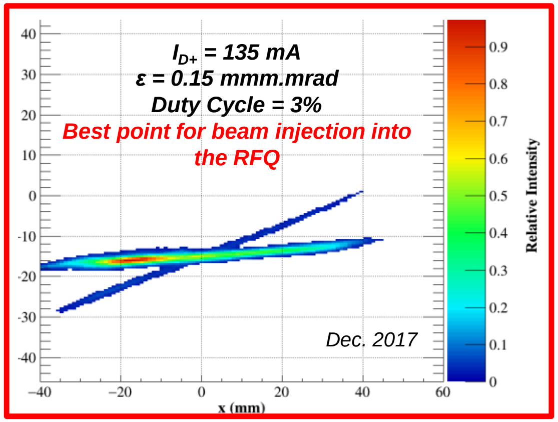


LIPAc injector requirements

- D^+ beam.
- Energy: **100 keV.**
- Intensity: **140 mA.**
- Final emittance: ⩽ **0.3 π mm.mrad (target value: ⩽ 0.25 π mm.mrad).**
- Twiss parameters at the RFQ entrance: less than 10% mismatch



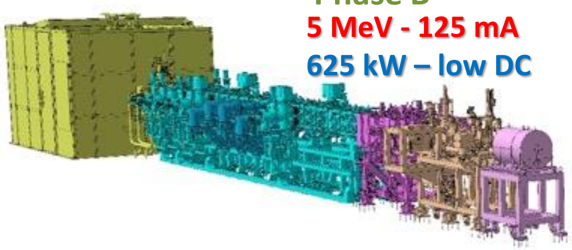




Commissioning with staged approach

2nd configuration – Commissioning Phase B

Phase B
5 MeV - 125 mA
625 kW – low DC



COMPLETED

Injector | CW | Diagnostic Box + Beamstop

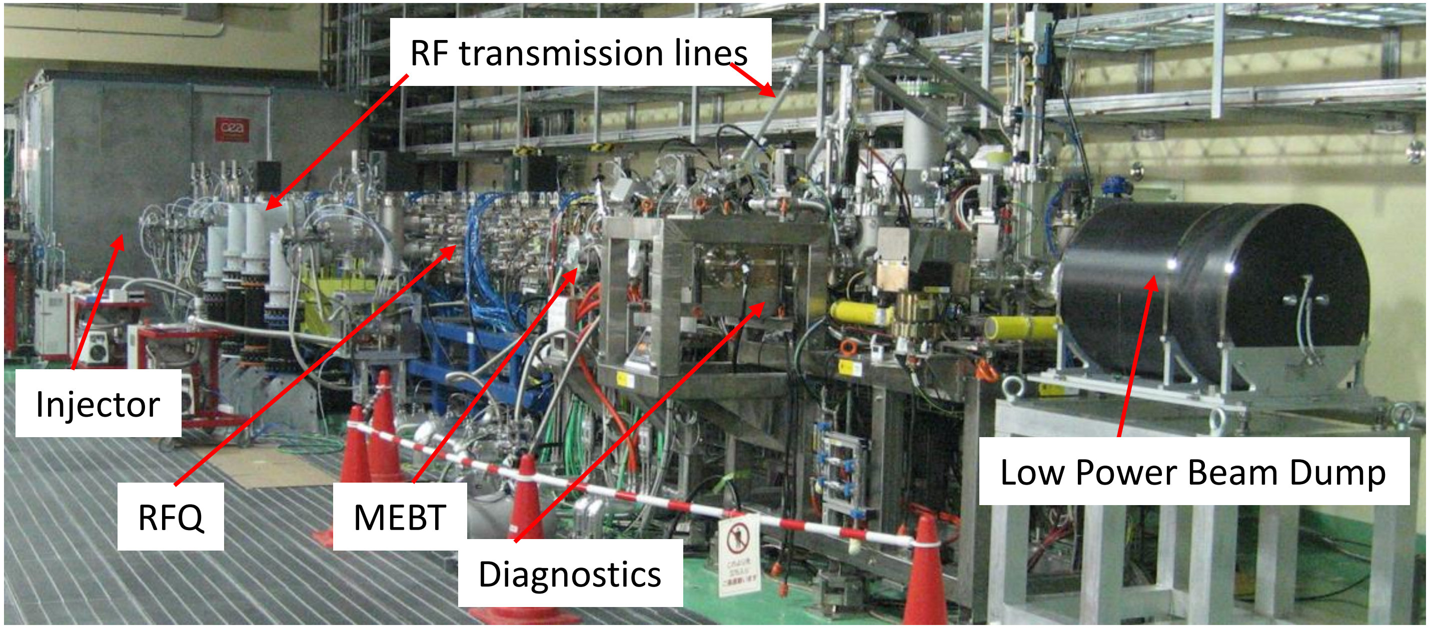
(Apr.2015 - Aug.2017)

Injector | RFQ + MEBT | D-Plate+BD | 0.1-1ms

(June 2018 – August 2019) Diag.-Plate + Low Power Beam Dump

Phase B: Experimental campaign

Phase B installation was completed in October 2017.



Operation Mode
2 shifts
Beam Operation
&
RFQ Conditioning

July 2017	February 2018	13 June 2018	March 2019	April 2019	9 August 2019
Start RFQ Conditioning	RFQ Cavity Voltage Nominal Value	1st H+ Beam	1st D+ Beam	End H+ Commissioning	End D+ Commissioning 125 mA, 0.1 d.c.

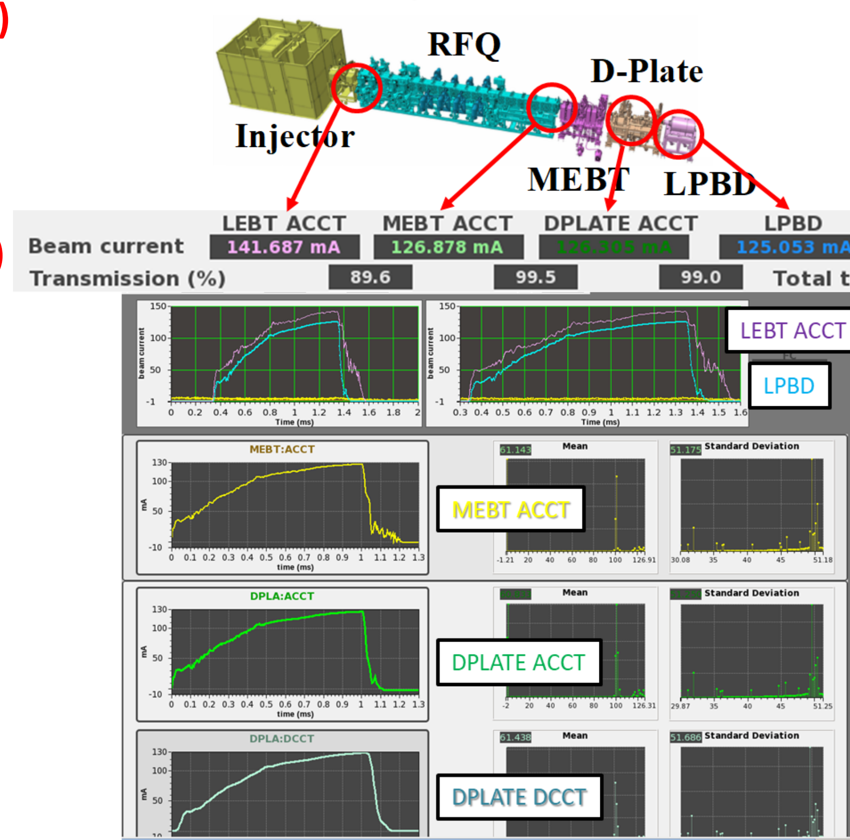
Phase B: Summary Experimental campaign

Achieved in LIPAc research activity

- RF operation at full RF level **(132 kV ~ 1 ms, 1 Hz)**
- Beam acceleration with nominal space charge with pulsed:
  - Proton beam **(2.5 MeV, 60mA)**
  - Deuteron beam acceleration **(5 MeV, 125 mA)**

Celebration of the end of 5 MeV, 125 mA, D+ beam acceleration on 9th Aug 2019

24 July 2019, 19:13



> 90% Beam transmission through the RFQ

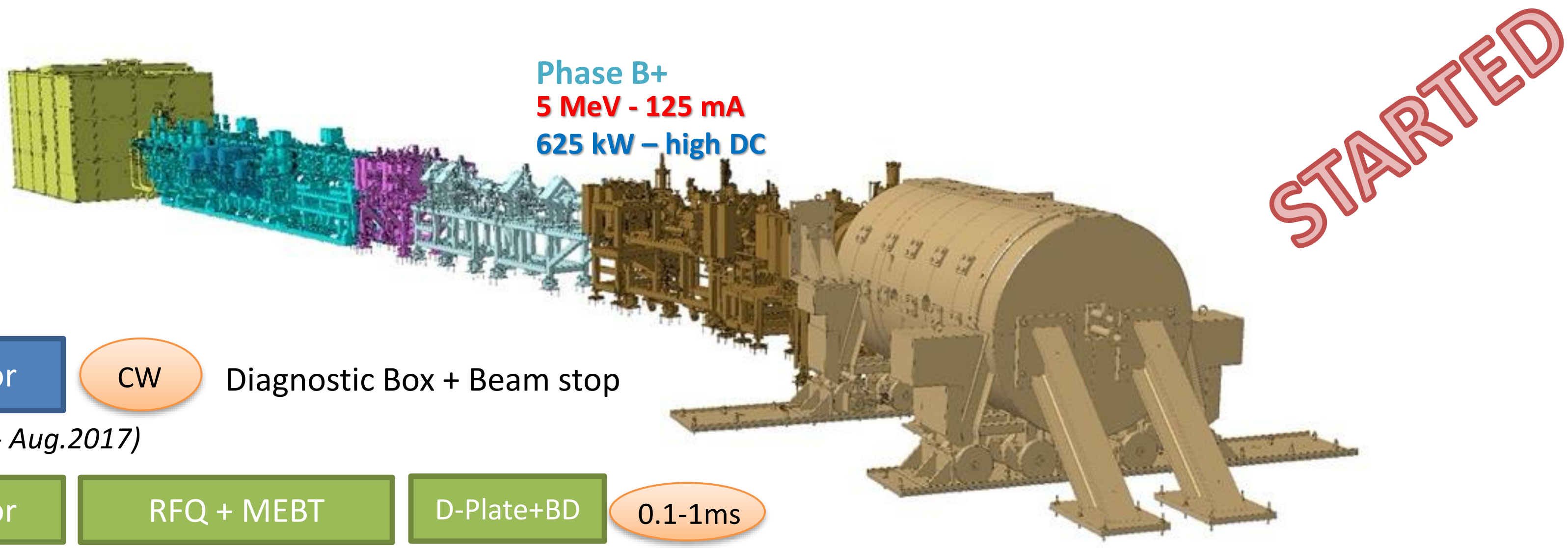
Significant project milestone reached

(125 mA, @ 5 MeV, 1 ms pulse)

We demonstrate that all the components needed to run the LIPAc accelerator in the phase B configuration work as expected.

Commissioning with staged approach

3rd configuration – Commissioning Phase B+



Injector | CW | Diagnostic Box + Beam stop

(Apr.2015 - Aug.2017)

Injector | RFQ + MEBT | D-Plate+BD | 0.1-1ms

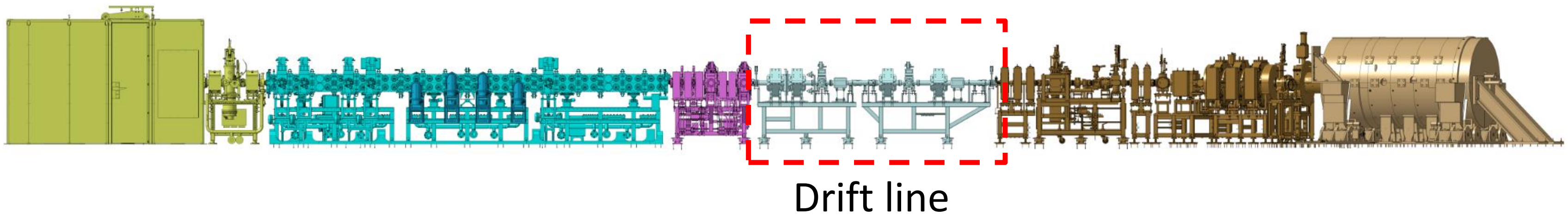
(June 2018 – August 2019) Diag.-Plate + Low Power Beam Dump

Injector | RFQ + MEBT | Drift line + HEBT/D-Plate | 1ms-CW | Final Beam Dump

Phases B+ and C in preparation

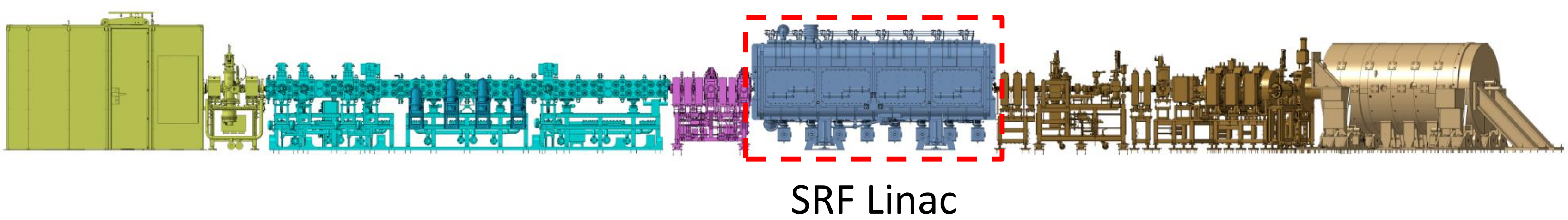
Phase B+: LIPAc in temporary configuration

5 MeV - 125 mA
625 kW – high DC

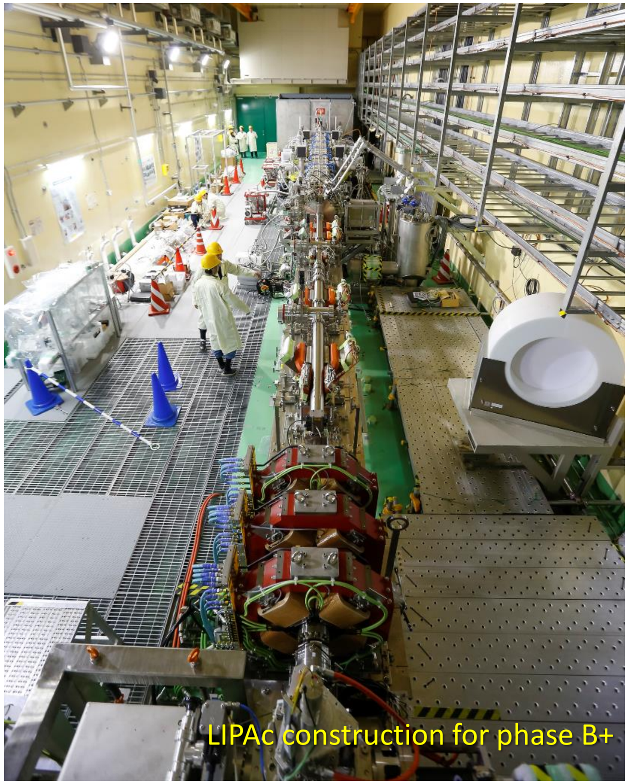


Phase C/D: LIPAc in its final configuration

9 MeV - 125 mA
1.125 MW – low and high DC



Phase B+: Status

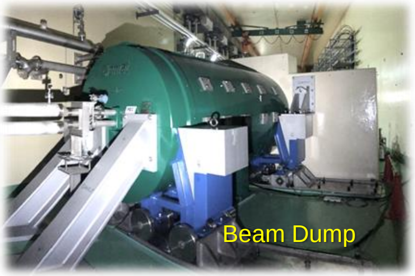


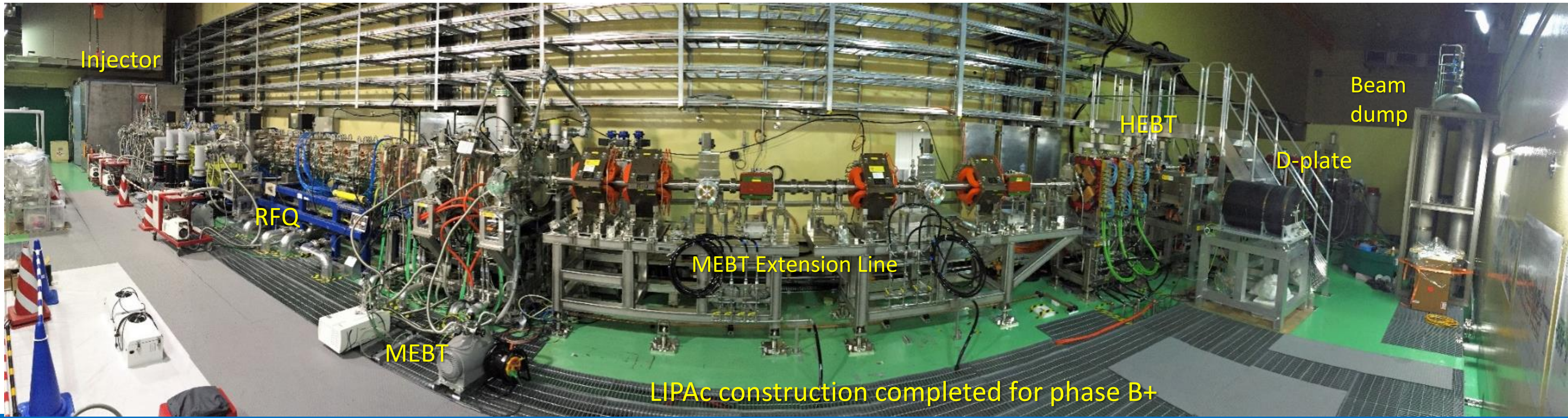
Check-out tests and individual commissioning of the HEBT/BD on going

(Performed remotely)

Injector and RF injection started

Start Beam Operation by the end of second trimester



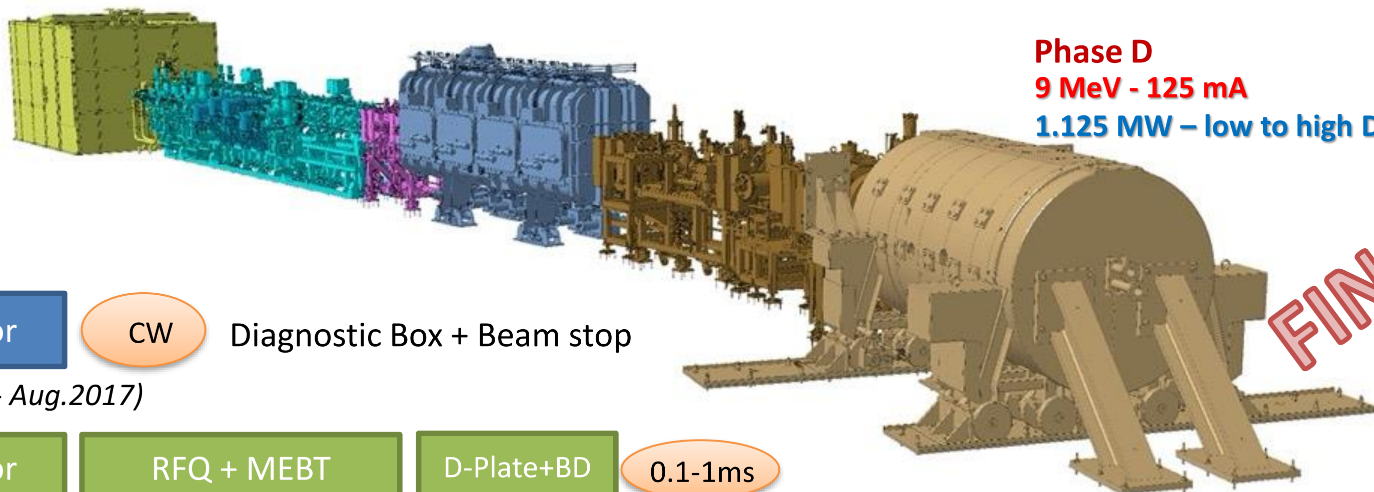


Commissioning with staged approach

4th configuration – Commissioning Phase C/D

Phase C (installation SRF Linac)
9 MeV - 125 mA
1.125 MW – low DC

Phase D
9 MeV - 125 mA
1.125 MW – low to high DC



FINAL STAGE

Injector | CW | Diagnostic Box + Beam stop

(Apr.2015 - Aug.2017)

Injector | RFQ + MEBT | D-Plate+BD | 0.1-1ms

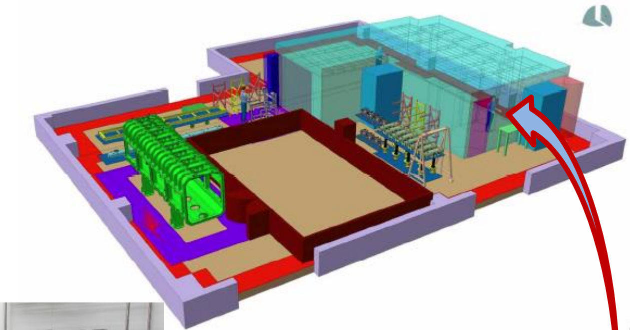
(June 2018 – August 2019) Diag.-Plate + Low Power Beam Dump

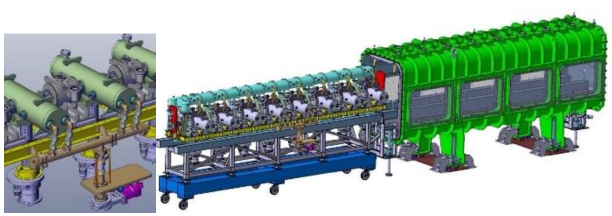
Injector | RFQ + MEBT | Drift line + HEBT/D-Plate | 1ms-CW | Final Beam Dump

Injector | RFQ + MEBT | SRFL + HEBT/D-Plate | 1 ms-CW | Final Beam Dump

Components under assembly in Rokkasho

- ☑ A clean room has been built in Rokkasho under the responsibility of QST in the DEMO Joint Research Building
- ☑ F4E is responsible of the assembly, CEA provide support
- ☐ Almost all components delivered on site, assembly to start last semester 2021





Outline

5 Outlook beyond 2020

Outlook beyond 2020

For IFMIF/EVEDA this fruitful collaboration is continuing in pursuing the mandate assigned to IFMIF/EVEDA Project by:

- ✓ Complementing the engineering design of the IFMIF-like Fusion Neutron Source and complementing the Lithium Target Facility engineering validation,
- ✓ Continuing the commissioning of the LIPAc (Phase B+, C and D), by enhancing systems already validated during the first phases.

LIPAc Outlook up to 2025

- **2020-2022:**
  Phase B+ commissioning (125 mA D+, 5 MeV – High DC)

- **2021-2022:**
  Assembly, integration and checkout tests of the cryomodule

- **2023-2024:**
  Phase C/D Commissioning (125 mA D+, 9 MeV – CW)

- **2021-2025:**
  LIPAc enhancement activities to improve both reliability and availability required for the fusion neutron source (e.g. A-FNS/DONES), but also to validate the operation requirements

Fusion Neutron Source Design up to 2025

The Fusion Neutron Source engineering design activities and the Lithium Target Facility engineering validation activities have restarted in 2020 aiming to provide an updated Fusion Neutron Source Engineering Design report.

The main activities will be dedicated to:

- **The enhancement of the design of the Lithium loop (e.g. tritium migration, erosion/deposition modelling, purification, accident analysis, optimization of the Li-Oil Heat Exchanger),**
- **The update of the Fusion Neutron Source Design focusing in the design activities for safety and accidental analyses.**

Lithium Engineering Validation tasks

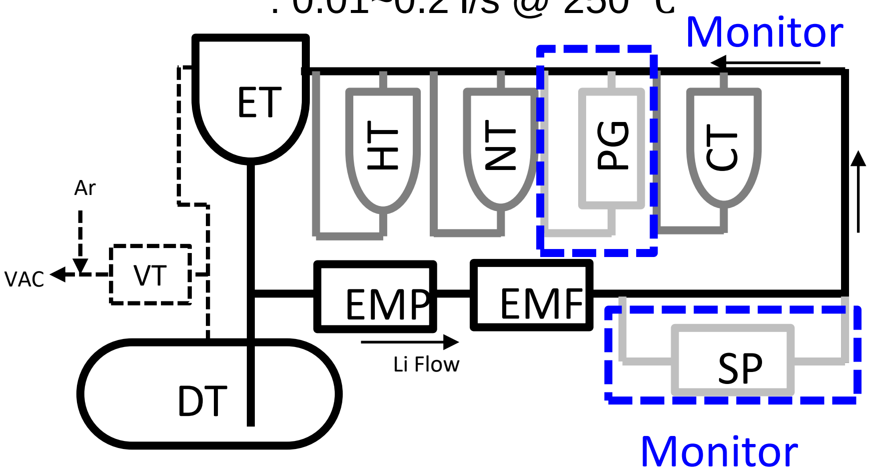
Li purification system validation activity

Concept of 1:10 pilot plant (JA)

Li inventory : 0.1 m^3

Li flow rate : 0.005~0.1 kg/s

: 0.01~0.2 l/s @ 250 ℃

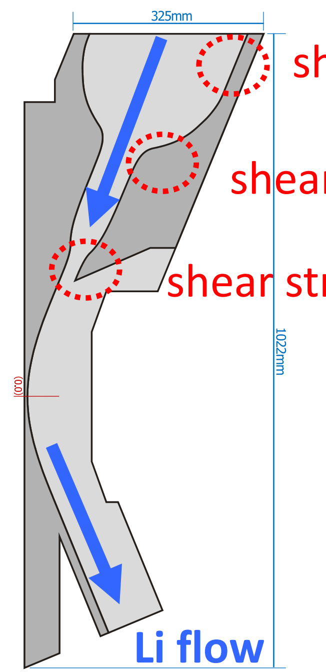


DT: Dump tank
ET: Expansion tank
VT: Vapor trap
CT: Cold trap
EMP: Electro-magnetic pump

EMF: Electro-magnetic flow meter
PG: Plugging gauge
NT: Nitrogen trap
HT: Hydrogen trap
SP: Li sampler

Erosion/corrosion analysis on ELTL materials (JA)

ELTL Target



Surface morphology analyses and tensile tests

Outline

6 Conclusions

IFMIF/EVEDA Summary

- Since the project started in 2007, this international collaboration has continued to grow and has achieved important milestones,
- We have managed to create an excellent team spirit with the ‘in-kind’ suppliers, F4E and QST,
- The recent progress and achievements reflect the importance of the fruitful collaboration between Japan and Europe for the development of the future fusion neutron source by:
  - ❑ Completing the design activities for the future neutron sources,
  - ❑ Enhancing the systems to demonstrate the full reliability,
  - ❑ Maintaining the competences and already developed know-how that are essential for the future.

Thank you for your attention!

Celebration of 5 MeV, 125 mA, D+ beam acceleration
9^{th} Aug 2019

JA-EU Collaboration