Japan's Participation in IFMIF-EVEDA

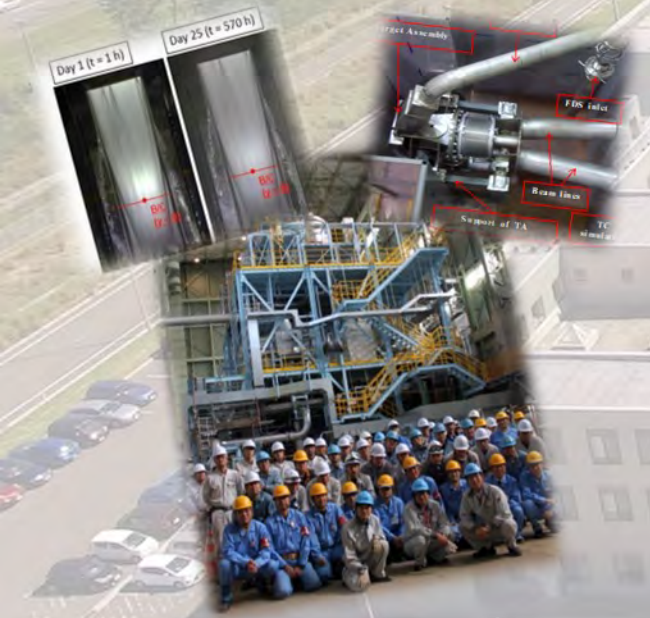
Kasugai, Atsushi

Rokkasho Fusion Institute

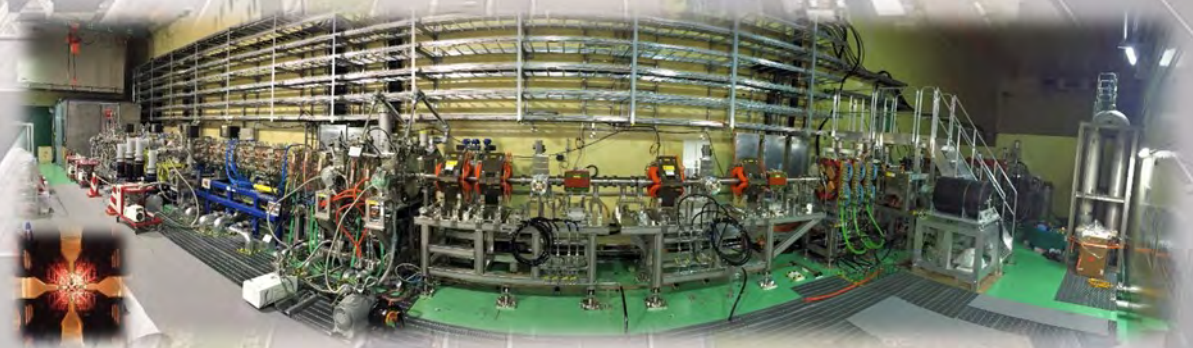
National Institutes for Quantum Science and Technology (QST)

DONES Business Info Day

Spanish Embassy, Tokyo, 4th December 2023



Target Facility



Accelerator Facility

Test Facility

IFMIF/EVEDA Project

Contents

Overview of Broader Approach (BA) activities

■JA and EU are jointly implementing three projects to support the early realization of fusion energy.
■Resources: Japan and Europe will each contribute the equivalent of 46 billion yen, contributing a total of 92 billion yen. (Phase I)
■Period: 10 years from the BA agreement effective date in June 2007 (automatic extension thereafter, Phase I)

Rokkasho, Aomori

IFERC

DEMO design, R&D

Joint Design for DEMO, R&D for Electric Power and fueling

ITER Remote Exp

Construction of REC Room

Computational Simulation

Plasma simulation, fusion material development, etc. by Super computer

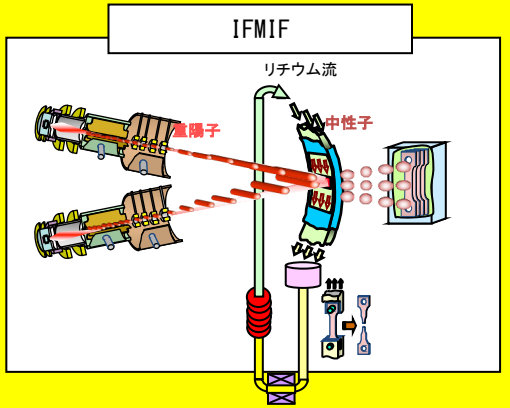
IFMIF/EVEDA

Eng. Validation of components

Engineering validation of prototype accelerator and Li target required for neutron irradiation facility for fusion materials

Eng. Design of IFMIF

Eng design based on validation



Naka, Ibaraki

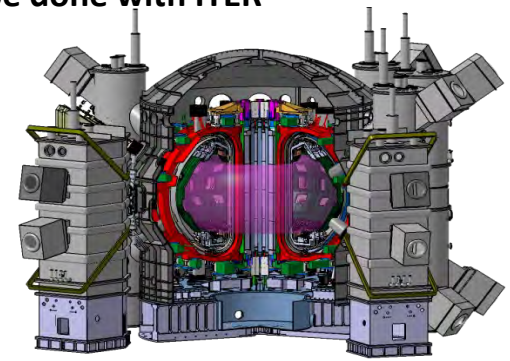
JT-60SA

Support research for ITER

Preparing plasma generation method prior to research at ITER
⇒Efficient research at ITER

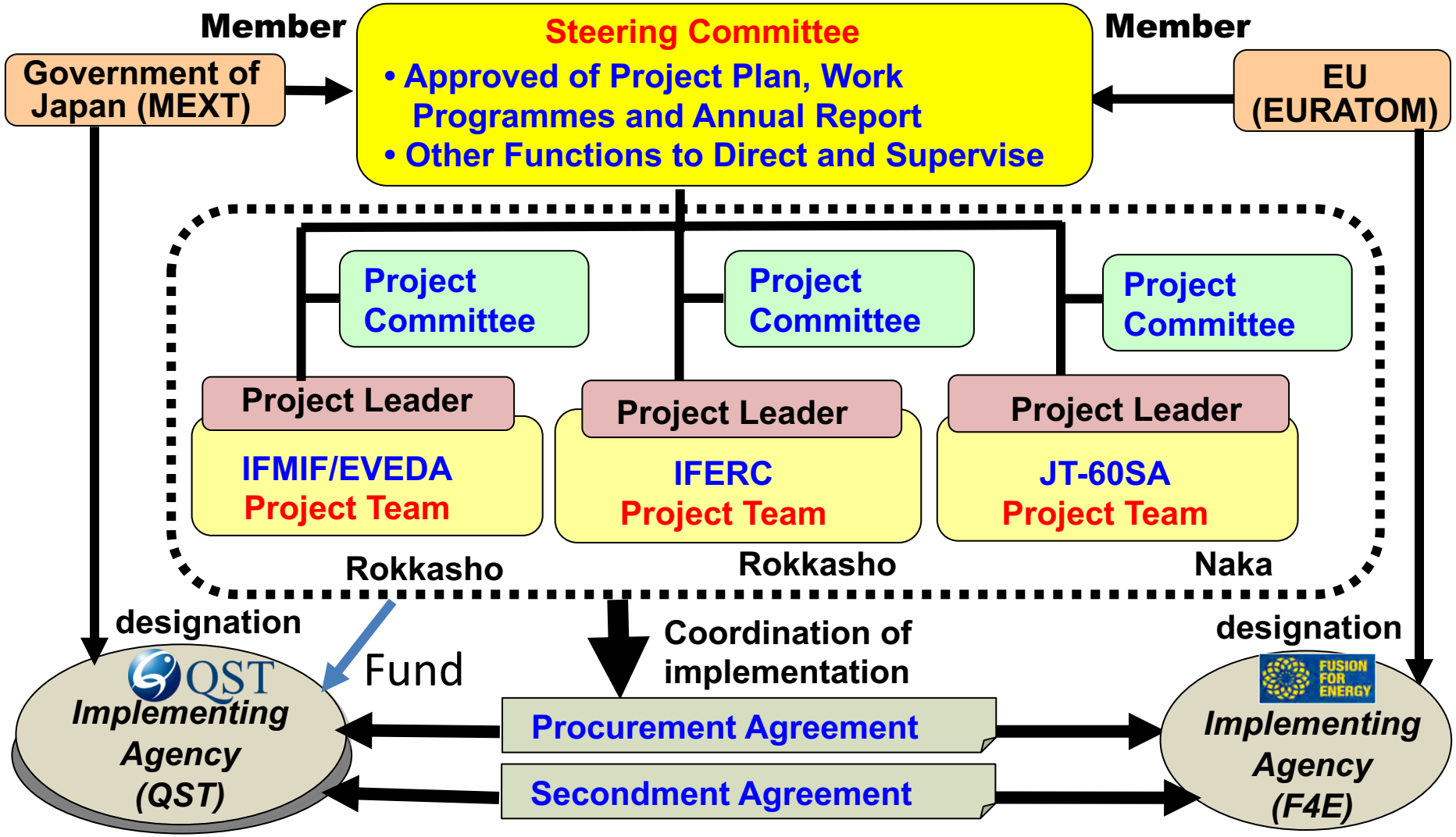
Challenging research for DEMO

Demonstration of safety, reliability, etc. of high-β operation that cannot be done with ITER



Framework of the BA Activities

- Three joint project are conducted between Japan and Europe for early realization of Fusion Energy
- Period: Ten years from 2007. (extend to March 2020)



F4E (The European Joint Undertaking for ITER and the Development of Fusion Energy)

Procurement Arrangement for IFMIF/EVEDA

Validation Activities	Accelerator Prototype	AF01	Transversal Activities of the Accelerator Prototype
		AF02	Injector
		AF03	RadioFrequency Quadrupole
		AF04	First Cryomodule of the SRF Linac
		AF05	Medium Energy Beam Transport
		AF06	RF Power System
		AF07	High Energy Beam Transport, Beam Dump
		AF08	Control System
		AF09	Diagnostics
		AF10	Installation, Checkout, Startup & Commissioning
		AF11	Accelerator Prototype Building
		AF12	Cryoplant
		AF13	Conventional Systems of the Accelerator Prototype
			Sub Total
	Lithium Target Facility	LF01	EVEDA Lithium Test Loop Construction & Operation
		LF02	Diagnostics
		LF03	Erosion/Corrosion
		LF04	Purification System
		LF05	Remote Handling
			Sub Total
	Test Facilities	TF01	Engineering Design and Validation of HFTM
		TF02	Irradiation Tests in BR2 Reactor
		TF03	Small Specimen Test Technique
		TF04	Engineering Design and Validation of other Modules
			Sub Total
IFMIF Design	IFMIF Engineering Design	ED01	Engineering Design of IFMIF Plant
		ED02	Engineering Design of Accelerator Facility
		ED03	Engineering Design of Lithium Target Facility
		ED04	Engineering Design of Test Facility
		ED05	Engineering Design of Post Irradiation Examination Facility
			Sub Total
Coordination	Project Team	Secondt	Professional Staff
		PT01	Support Staff
		Cash	Common expenses (missions, soft/hardware…)
		Cash	Common Fund (Accelerator Prototype experiments)
			Sub Total

Japanese Tasks (QST)

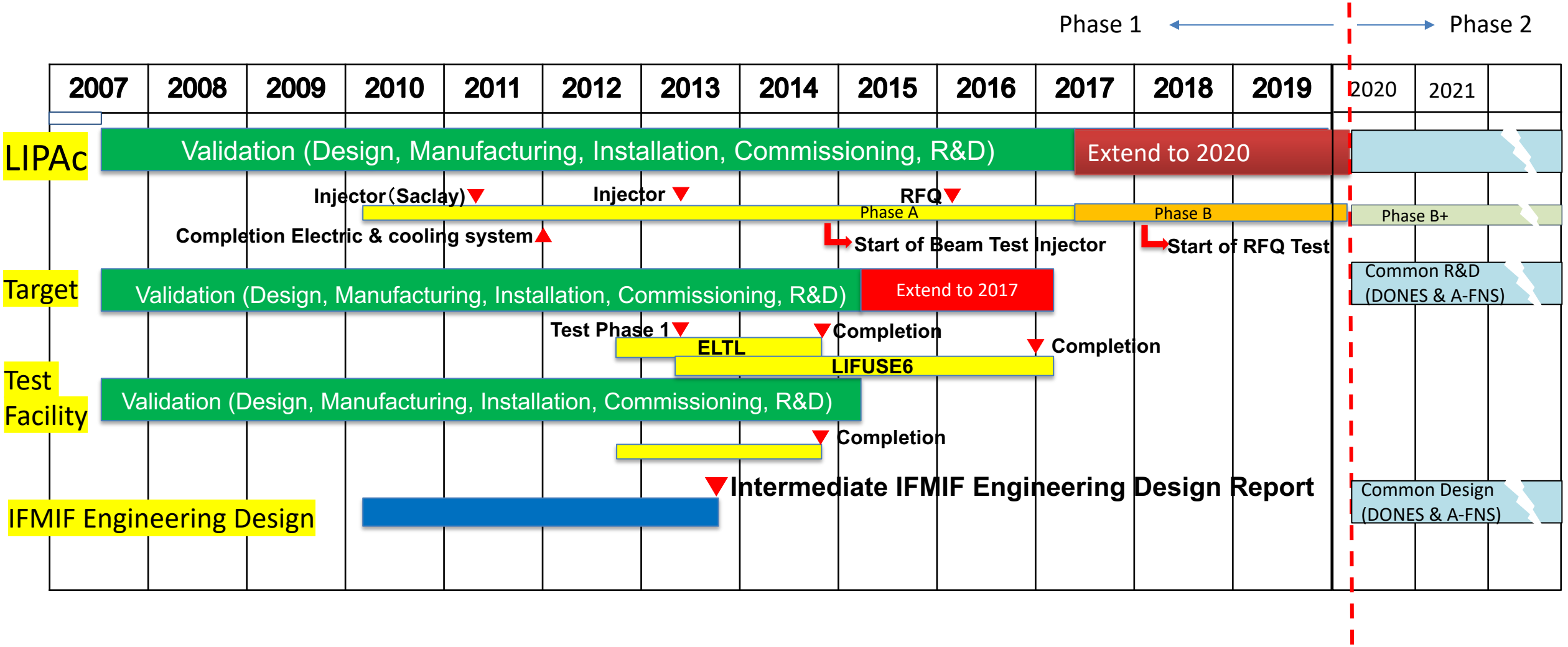
Joint Research

Universities

Contract

Companies

Schedule of IFMIF/EVEDA Project



Why a Fusion Neutron Source?

- 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 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

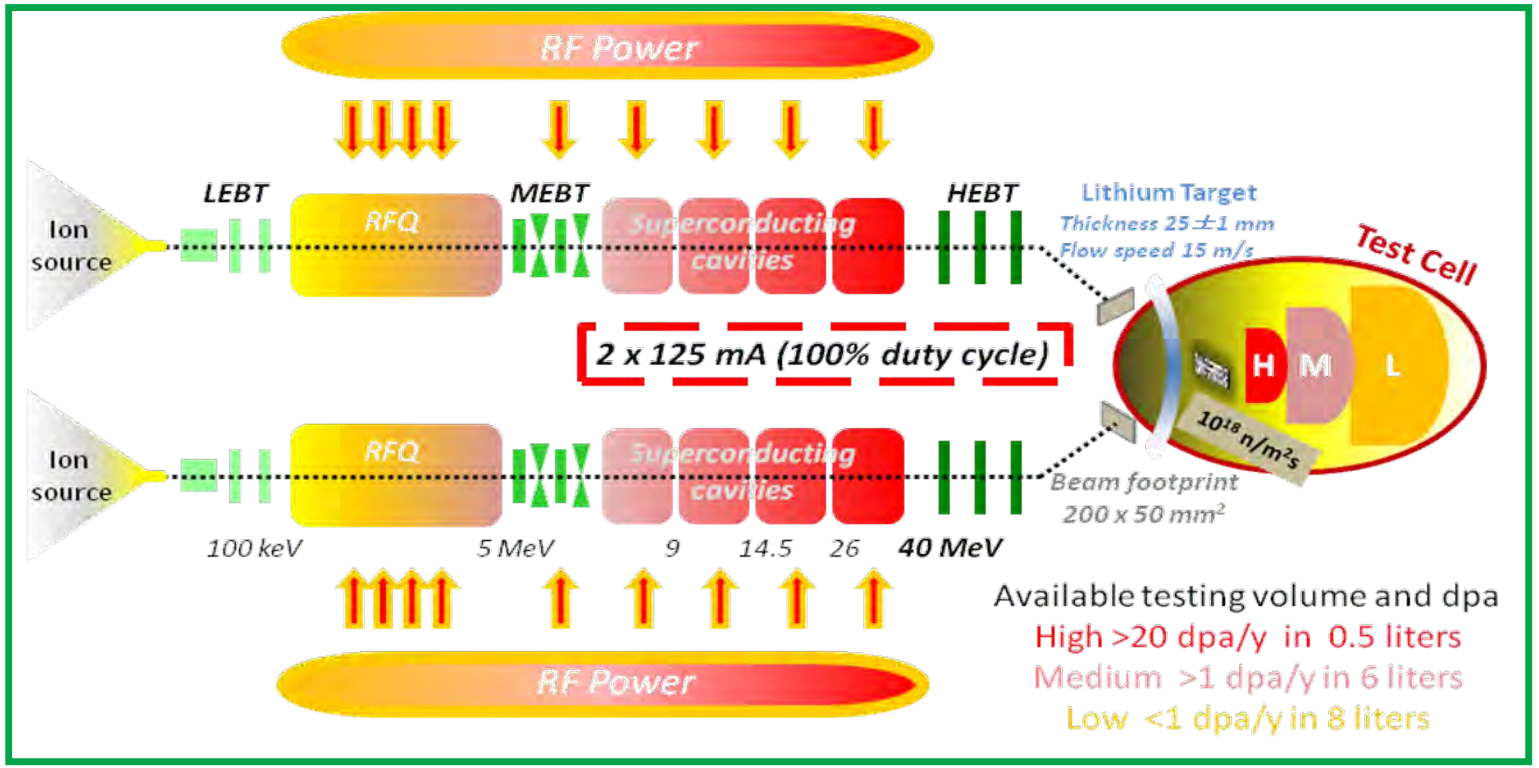
→ best fulfilled with a D-Li stripping source → IFMIF concept

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^2s 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%

EVEDA = EDA +EVA Phases

JGC

JGC was proactive contribution

Engineering Design Activities – EDA phase

Successfully delivered on schedule

Accelerator
CW, D+beam,
Beam Energy 40MeV
Current 125mA/line

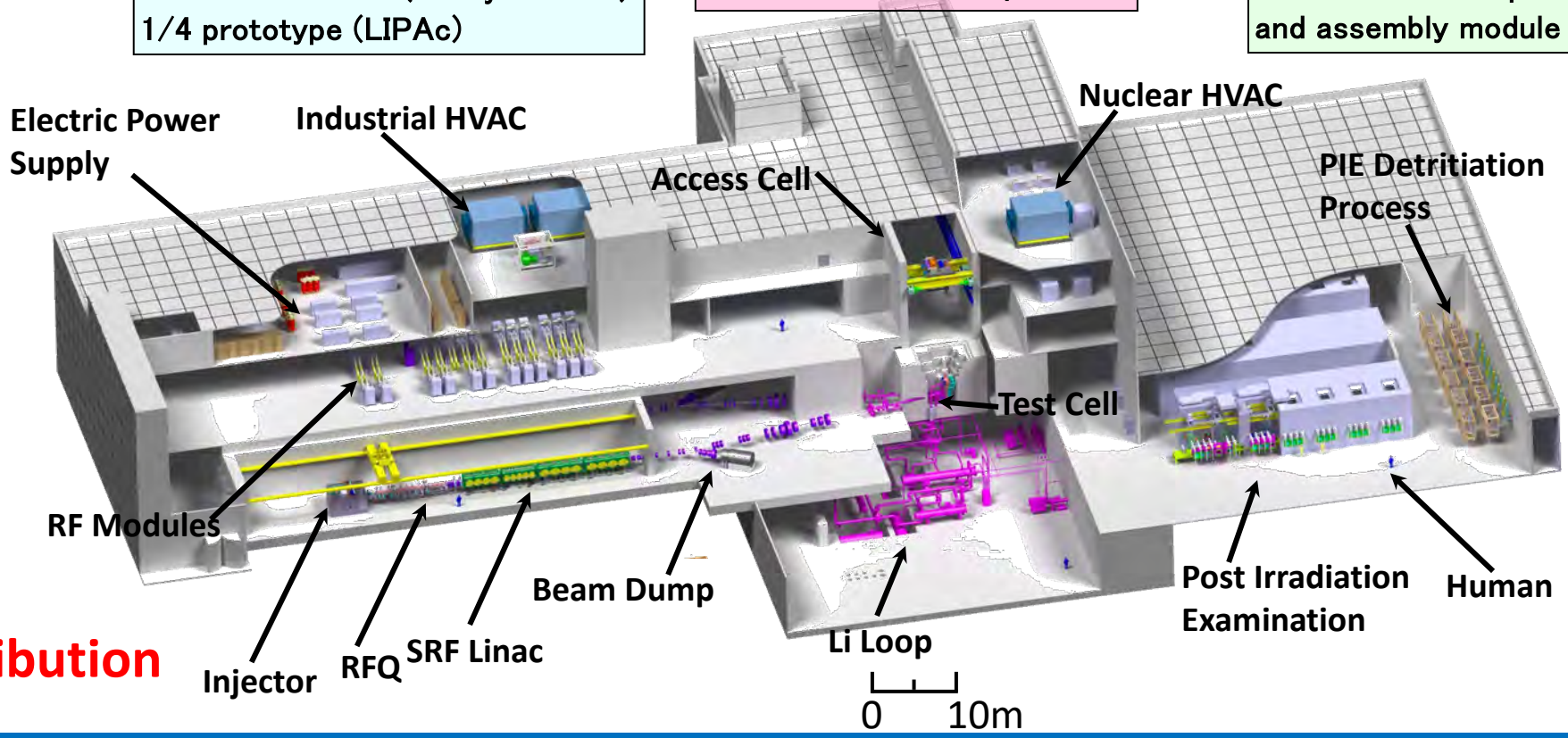
Validation : 9MeV (1−Cryomodule)
1/4 prototype (LIPAc)

Li Target
Power density 1GW/m^2
Neutron Energy 14MeV
Neutron Flux 10^{18} n/m2/s

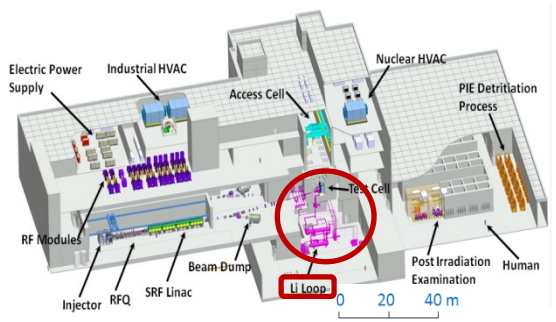
Validation: 1/3 Li loop (ELTL)

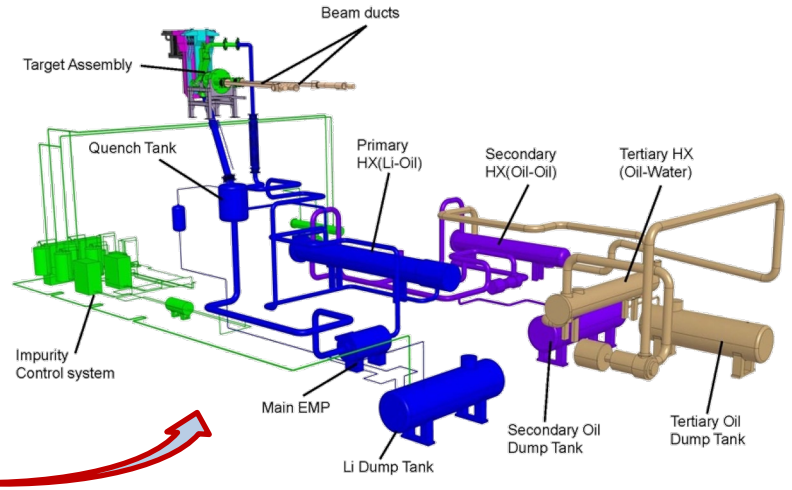
Test Facility
Material irradiation Data
Flexible modules for DEMO

Validation: mockup of rig and assembly module



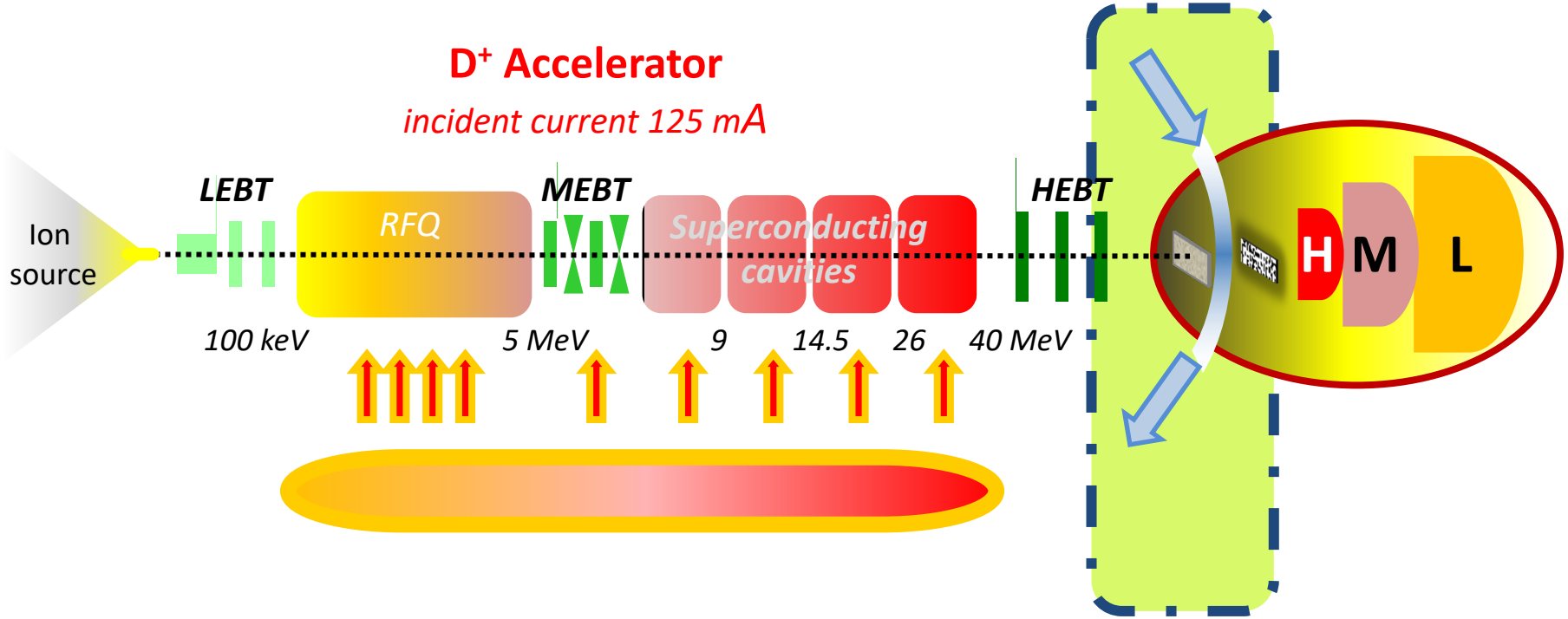
EVA Phase – Target Facility





D^+ Accelerator

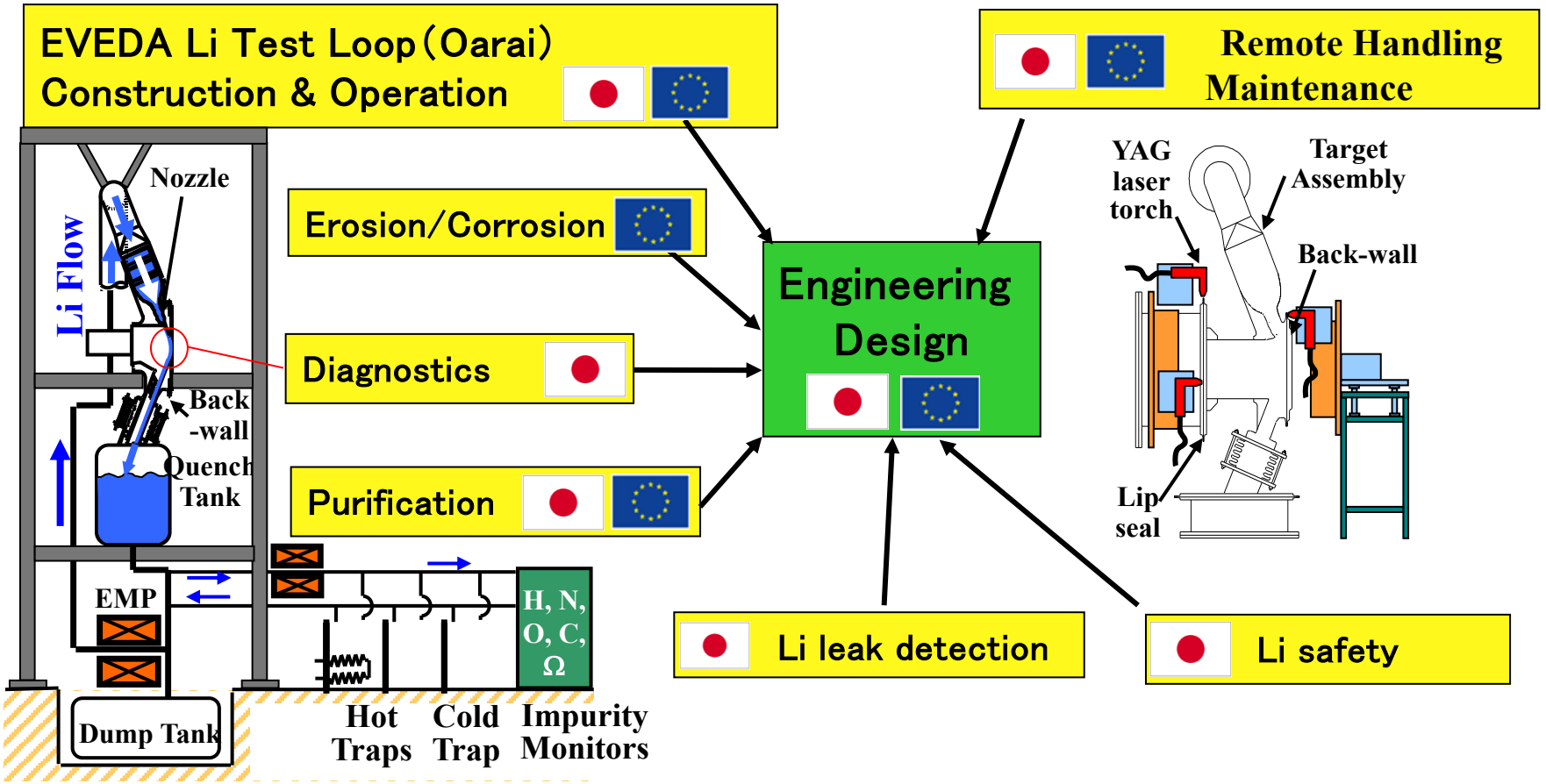
incident current 125 mA



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

Development of Target System in IFMIF/EVEDA

The target system engineering demonstration includes a lithium test loop, which aims to generate high-speed lithium flows of up to 20 m/s to demonstrate flow stability and long-term safe and sound operation of the entire loop, as well as lithium flow measurements. Japan will be primarily responsible for the design, development, and production of the lithium purification system. The lithium test loop was constructed at the JAEA Oarai Research and Development Center, and the development of the lithium flow measurement system, lithium purification system, and remote control system was carried out through joint research between the university and JAEA (at the time).



LF01 (Design, construction and operation of EVEDA Lithium Test Loop (ELTL))(MHI-MS)

LF02 (Lithium loop diagnostic measurement)
- Flow evaluation using Osaka University lithium loop
- Flow evaluation through water experiments (Nagoya University, Kyoto University)

LF04 (Demonstration of lithium purification system)
- Nitrogen hot trap (University of Tokyo)
- Hydrogen hot trap (Kyoto University)
- Hydrogen monitor (University of Tokyo, NIFS)

LF05 (Remote control technology)
- Laser subsystem (Osaka University)
- Welding characteristics evaluation (Hachinohe National College of Technology)

EVA Phase – Target Facility

ELTL in Oarai

Milestones on design, construction

Detail design started on 9 Apr. 2009

Construction started on 2 Nov. 2009

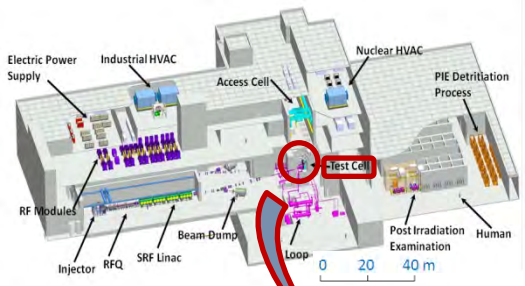
Construction completed on 19 Nov. 2010

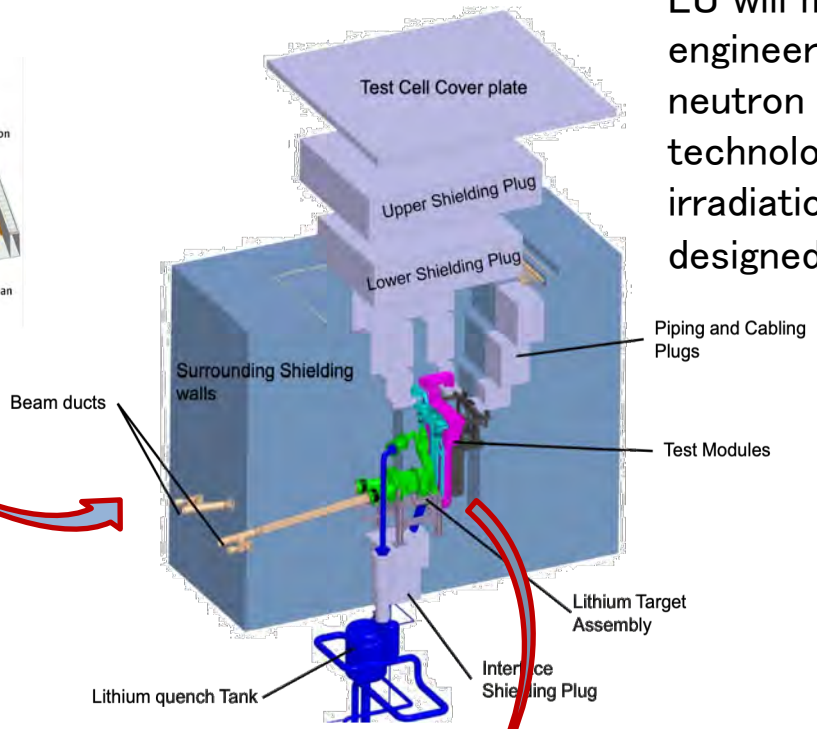
Test completed on 31 March 2015

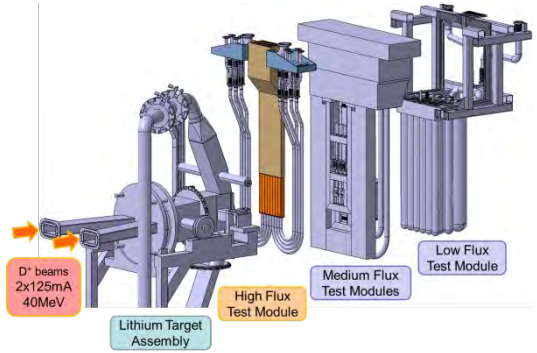
Dismantlement completed on Mar. 2017

Built by MITSUBISHI HEAVY INDUSTRIES MACHINERY SYSTEMS (MHI-MS) and operated by Ascend

EVA Phase – Test Facility







EU will mainly be responsible for engineering demonstration and engineering design of irradiation modules in the high, medium, and low neutron flux regions. In cooperation with universities, JA developed technology for high-neutron flux irradiation modules for high-temperature irradiation (~1000° C), developed micro-specimen testing technology, and designed post-irradiation testing facilities.

3 themes in charge of Japan

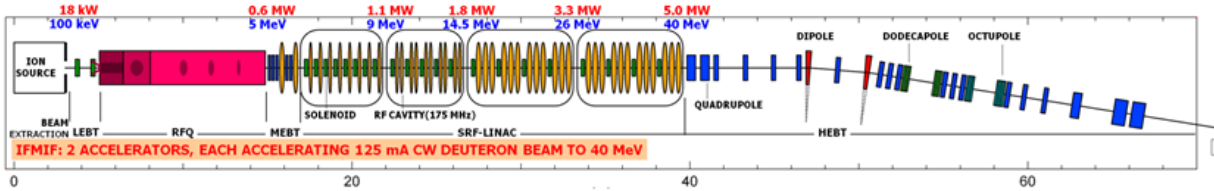
Post-irradiation test (PIE) facility design
- Basic conceptual design and detailed design of PIE facility equipment and related element confirmation study tests
- Creation of codes for handling radioactive materials, etc. related to PIE facilities

High Neutron Flux Region Test Module (HFTM)
- Design and element technology testing of high-performance irradiation module that can be used up to high temperatures

Micro specimen testing technology (SSTT)
- Testing of micro test pieces, testing methods and testing techniques for standardization such as ASTM, ISO, JIS, etc.

EVA Phase – Accelerator facility

IFMIF

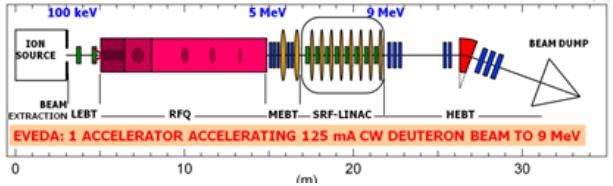


40 MeV

125 mA

5 MW

LIPAc

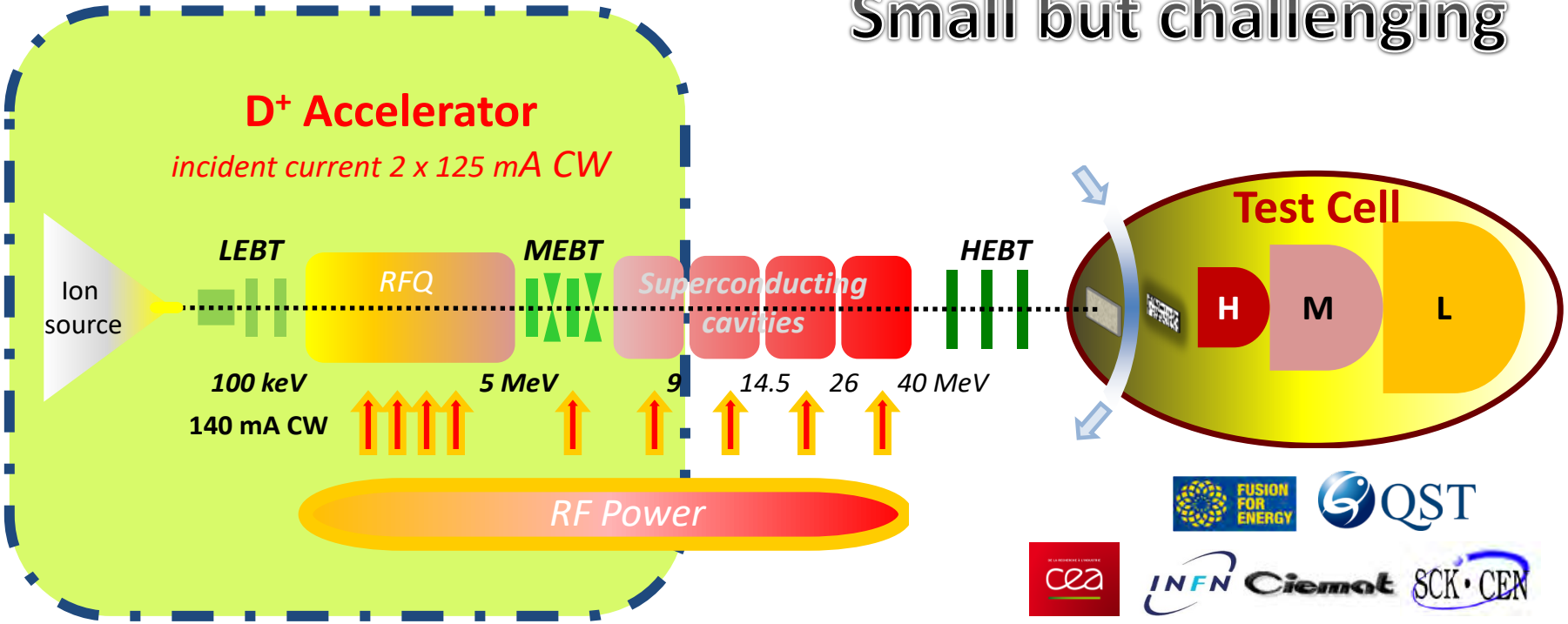


9 MeV

125 mA

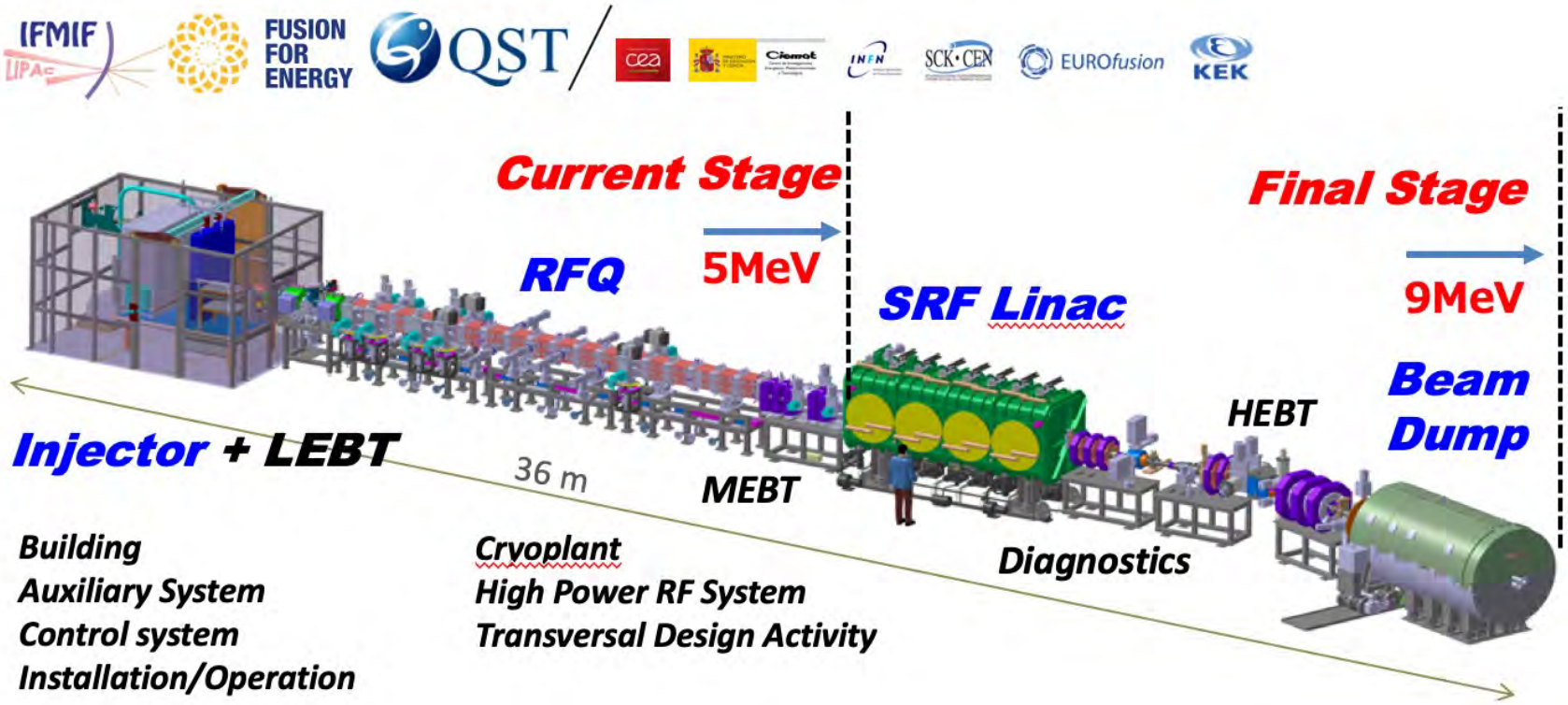
1.125 MW

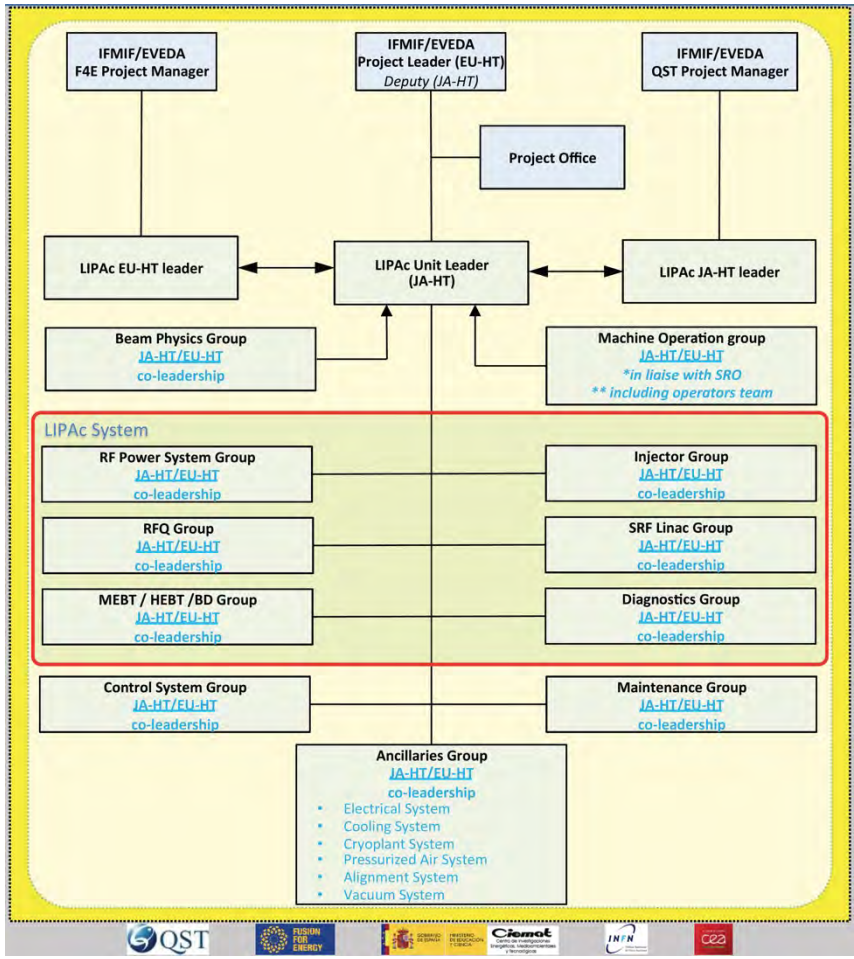
Small but challenging



LIPAc validation activity in Rokkasho

- Under the control of implementing agencies of EU (F4E) and Japan(QST) in BA activity, key components are mainly procured by EU research institutions, and the assembly and installation are mainly done by JA (QST) at Rokkasho.
- Test and operation are done to pursue the mission by **the EU-JA Joint team**.



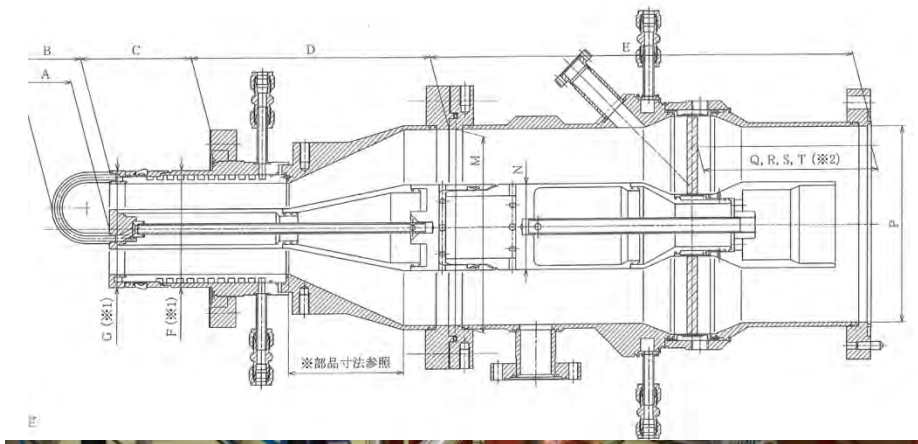


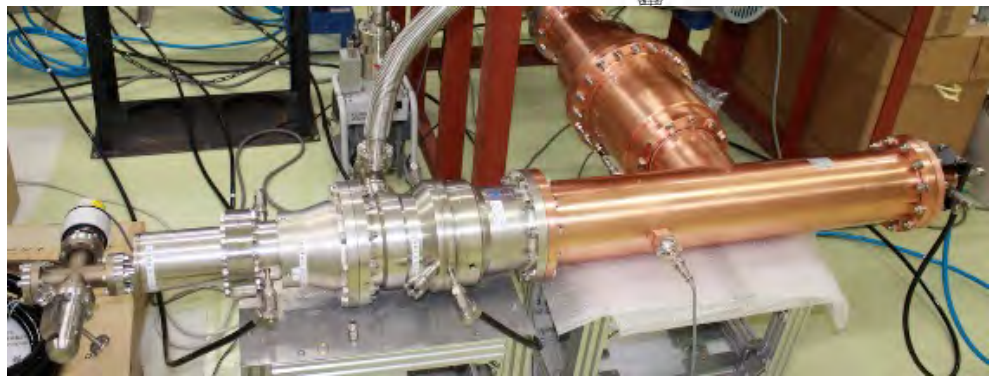
LIPAc Unit for Commissioning

LIPAc was Constructed at Rokkasho by JA-EU joint team

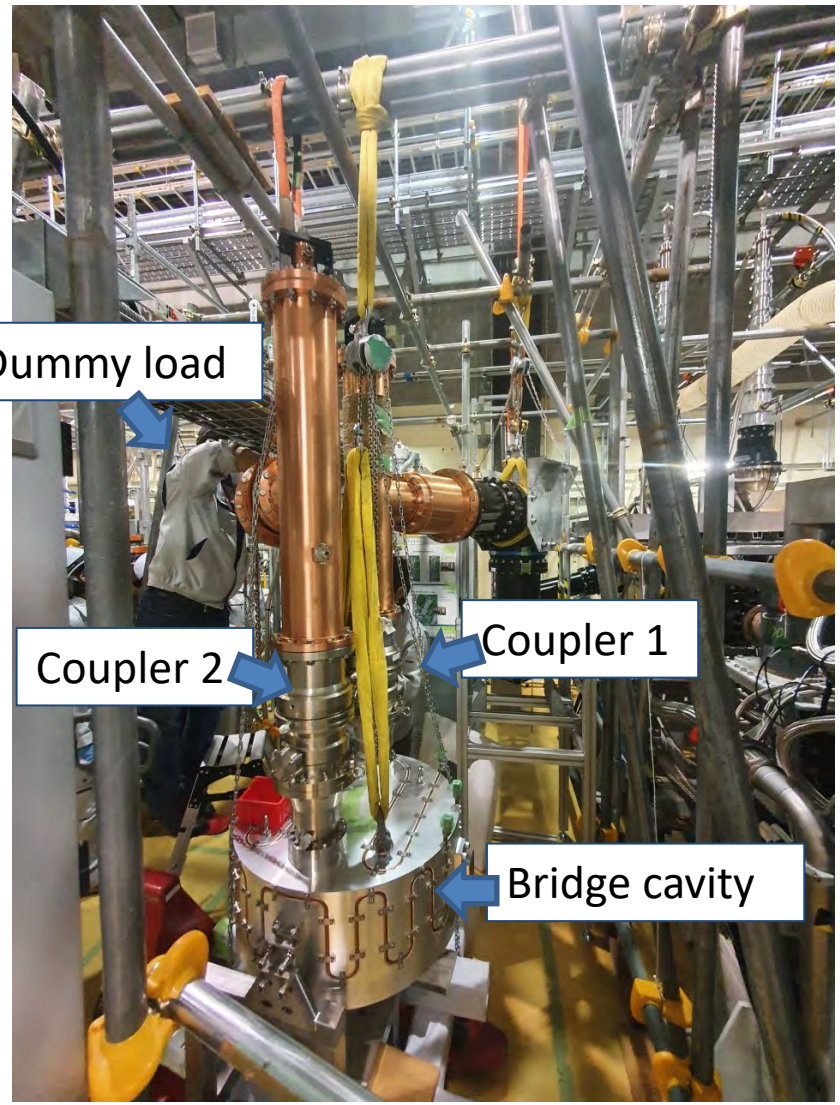
RFQ Coupler

Brazed couplers





- Brazed RFQ Couplers were manufactured by Hitachi Power Device.
- RF components by NIKOHA and Metal Technology



Control system

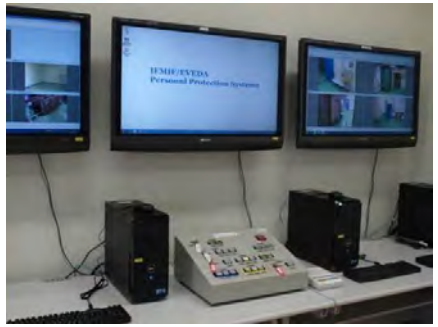
Manufacturing and installation of Personnel Protection System (PPS)

Ahead of future accelerator operations, PPS equipment is used to manage entrances and exit doors to restricted areas during accelerator operation, as equipment related to the management function of the accelerator building in the personnel protection system (PPS). Manufacturing and installation of similar products.

Development of Machine Protection System (MPS)

The MPS consists of three parts: the “remote monitoring and operation unit,” the “core unit,” and the “interface (I/F) unit.” The PLC of the remote monitoring and operation unit incorporates a unified PLC for the entire accelerator. We built a test bench and started development. Japan is in charge of central control.

PPS console



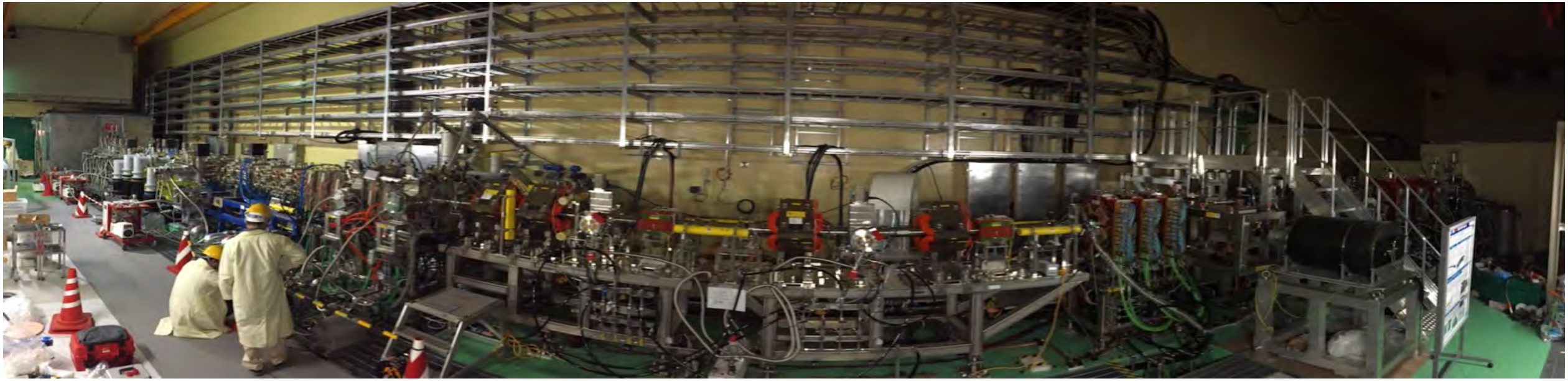
Personal keybox

MPS Development Strategy

- ✓ Build a reliable and robust system
- ✓ Beam stop time <10 µs
- ✓ Unify equipment and development environment for Japan-Europe joint project
- ✓ Flexible system construction as a prototype accelerator

Board production and maintenance was mainly performed by Mitsubishi Electric .
Software supported by GITEC, CosyLab

Installation, Commissioning



Involved Main Companies:

- NIHON Kensetsu Kogyo
- Kuriharant
- NAT
- NECO
- KANTO Giken
- MARUI Galvanizing
- JGC
- Ominato Seidensha
- Kami Gumi
- etc

Building and Conventional Facilities

AF11（Building）

AF13（conventional facilities）

Involved Main Companies:

Kumagai Gumi

Kandenko

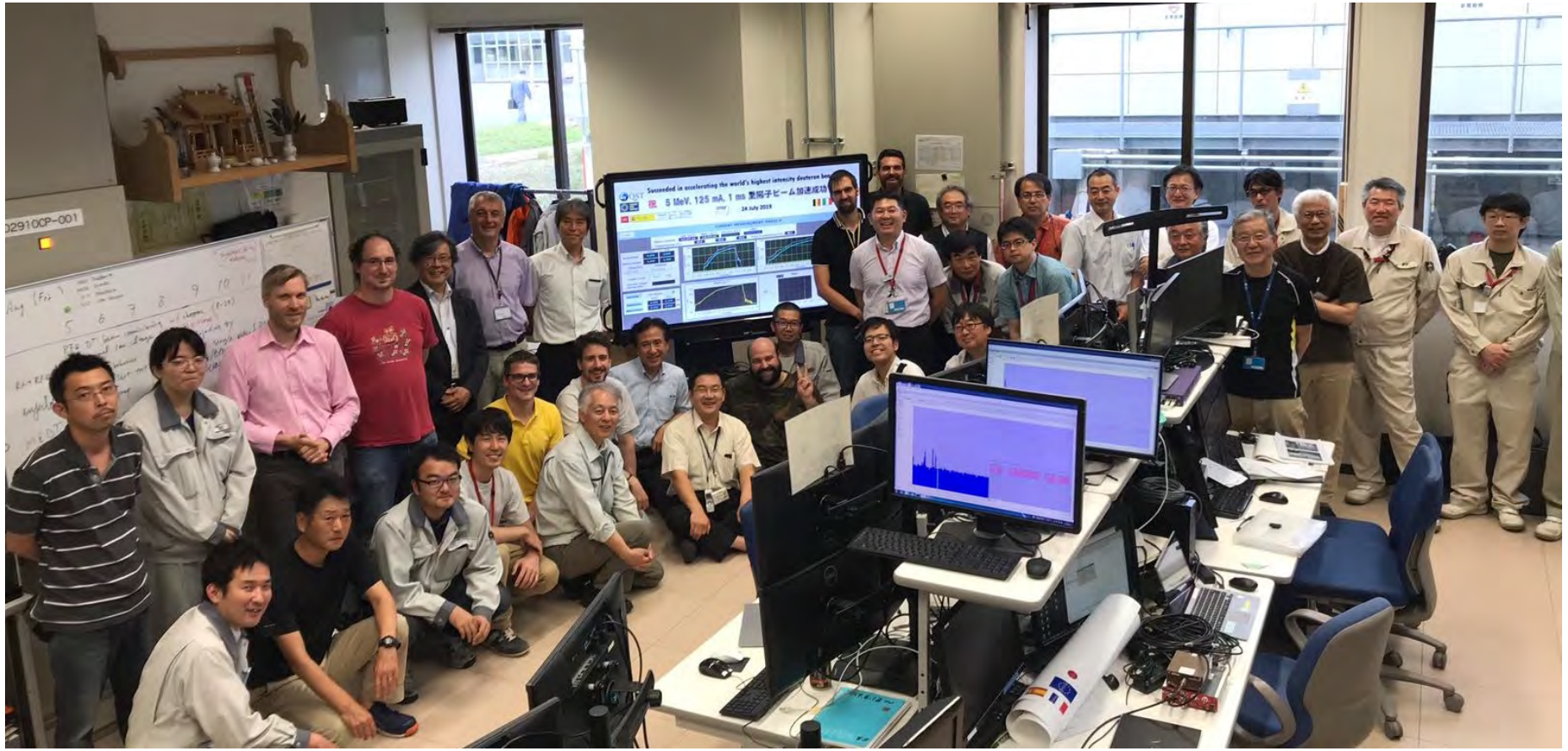
Takasago Thermal Eng.

TOMOE SHOKAI

Air Liquide Japan

Summary

Good Joint Work of JA and EU with many companies



世界最大強度で加速成功

六ケ所・核融合研
重水素ビーム実験

加速は困難とされ、45ミリアンペアがこれまでの世界最大だった。の実験成功に向け、最大限の努力をしたい」と語った。（藤林全晴）

Press Release
（August, 2019）

We look forward to continued cooperation from many Japanese companies in the future in the area for Fusion Neutron Source.

Contribution of Japanese Companies for IFMIF/EVEDA

	Task	Main Companies	Contents, main task
Engineering Design	ED	JGC	IFMIF facility design report
Lithium facility	LF	Mitsubishi Heavy Industries Machinery Systems（MHI-MS）	ELTL design, production, installation, and commissioning
		Ascend	Operation of ELTL
		Beam Seiko	Fabrication of nitrogen trap system
Test System	TS	No applicable manufacturer	
Accelerator facility	AF-03	Hitachi power device	RF coupler manufacturing
		NIKOHA	Fabrication of RF components
		Metal Technoligy	Fabrication of bonded cavity
	AF-08	Mitsubishi Electric	Production and maintenance of control boards, etc.
		GITEC	Control program support
		CozyLab	Part of control program
	AF-10	Nihon Kensetsu Kogo (NKK)	Installation of accelerator and power supply system
		Kurihalant	Installation of power supply and cooling water
		NAT	Installation, operation of LIPAc and various considerations related to commissionig
		Nuclear Engineering (NECO)	Cooling water related, equipment maintenance and operation of conventional facility
		Kanto Giken	Additonal shielding
		MARUI Galvanizing	Passivation cooling pipings
		JGC	Chiller installation
		Ominato Seidensha	Frames and equipment
		Kami-gumi	Import procedures, transportation, and delivery
	AF-11 AF-12	Kumagai-gumi	Construction of IFMIF/EVEDA building
		Sato General Design	Detailed design of IFMIF/EVEDA building
		Kandenko	Electrical equipment
		Takasago Thermal Engineering	HVAC, cooling water equipment
		Tomoe Shokai	Liquid nitrogen equipment
		Air liquide Japan	Helium gas buffer tank