Commissioning Status of Linear IFMIF Prototype Accelerator (LIPAc)

Atsushi Kasugai (QST)
on behalf of IFMIF LIPAc Project

(Talk: Y. Shimosaki (QST/KEK) on behalf of him)

HB2018 (Daejeon, Korea), 21 June, 2018

Collaboration for IFMIF LIPac

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Outline:

1. Intoroduction
2. IFMIF LIPAc
3. Commissing Status of LIPAc
4. Schedule
5. Summary

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Fusion/Rokkasho

Introduction (1 / 3) Purpose of IFMIF

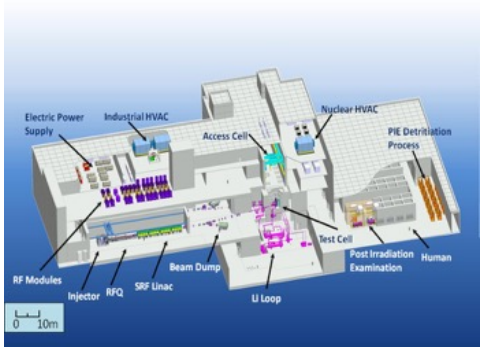
DEMO: Demonstration Power Reactor (propose)

ITER: experimental nuclear fusion reactor

DEMO: nuclear fusion power reactor
Production of power ~GW

For design, construction, and safe operation of DEMO, evaluation of material data under neutron environment is indispensable.

IFMIF: International Fusion Materials Irradiation Facility (plan)



An accelerator based neutron source using Li(d,n) reactions.

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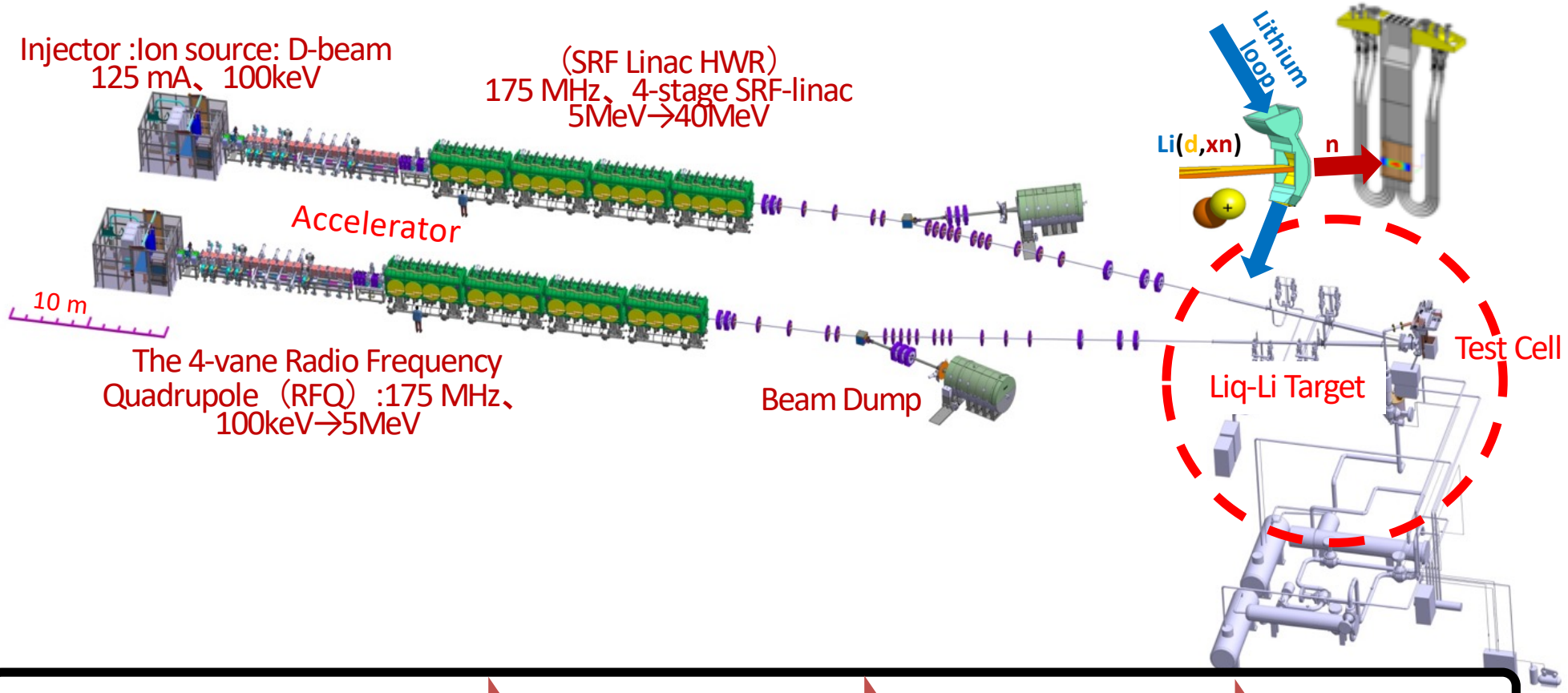
Introduction (2 / 3) Constitution of IFMIF

IFMIF: International Fusion Materials Irradiation Facility (plan)

IFMIF consists of two deuteron linear accelerators, free surface liquid lithium target, test cell, and the post irradiation examination facility.

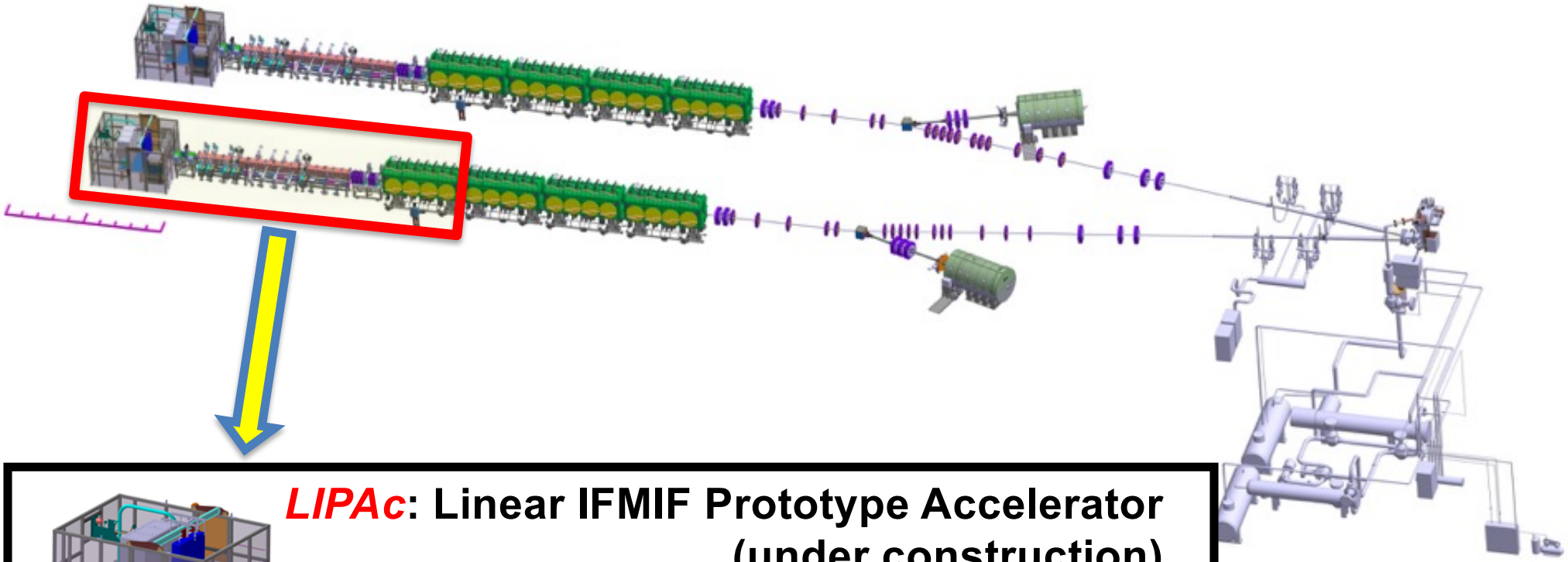


Deutron (40 MeV-250 mA) → Liquid Litium → Li-D → 14 MeV neutron → Test material

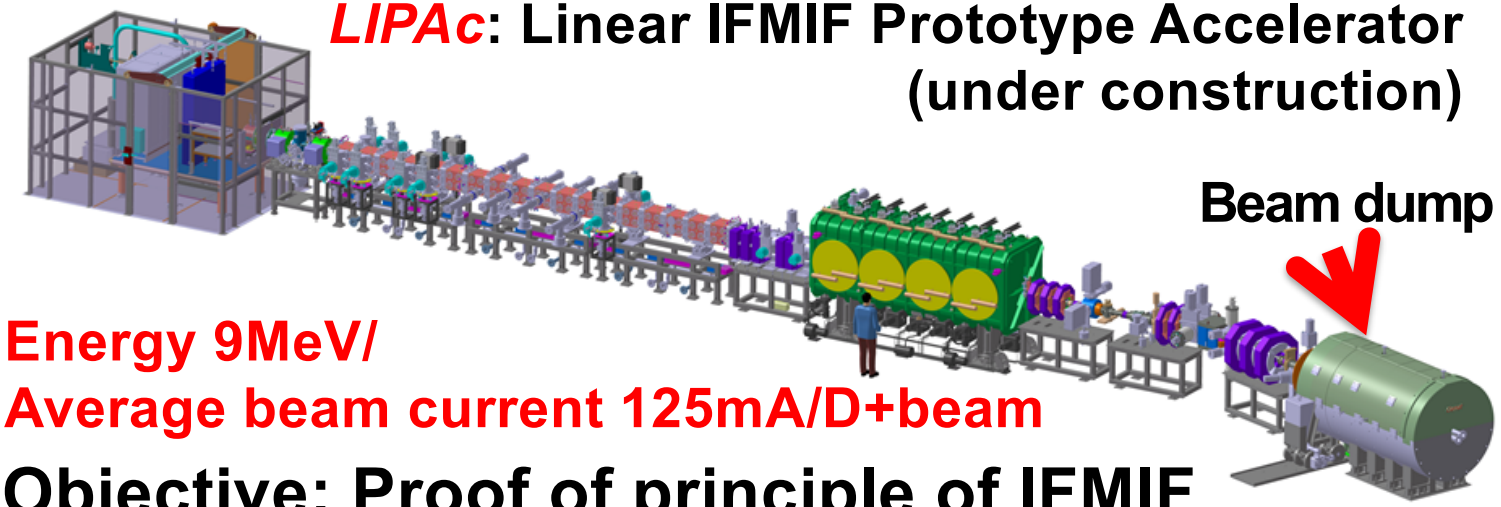
Neutron flux : 10^{14} n/cm^2・s

Introduction (3 / 3) What is IFMIF LIPAc

***IFMIF*: International Fusion Materials Irradiation Facility (plan)**



***LIPAc*: Linear IFMIF Prototype Accelerator (under construction)**



Energy 9MeV/
Average beam current 125mA/D+beam

Objective: Proof of principle of IFMIF

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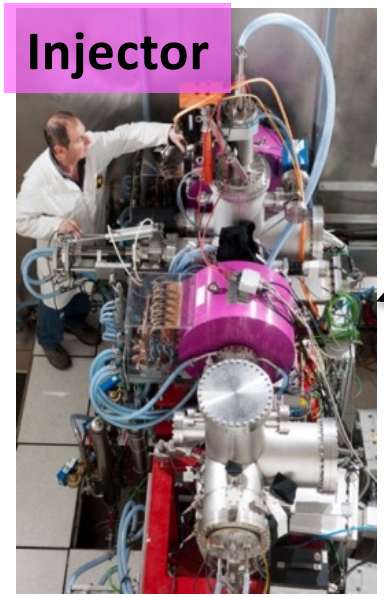
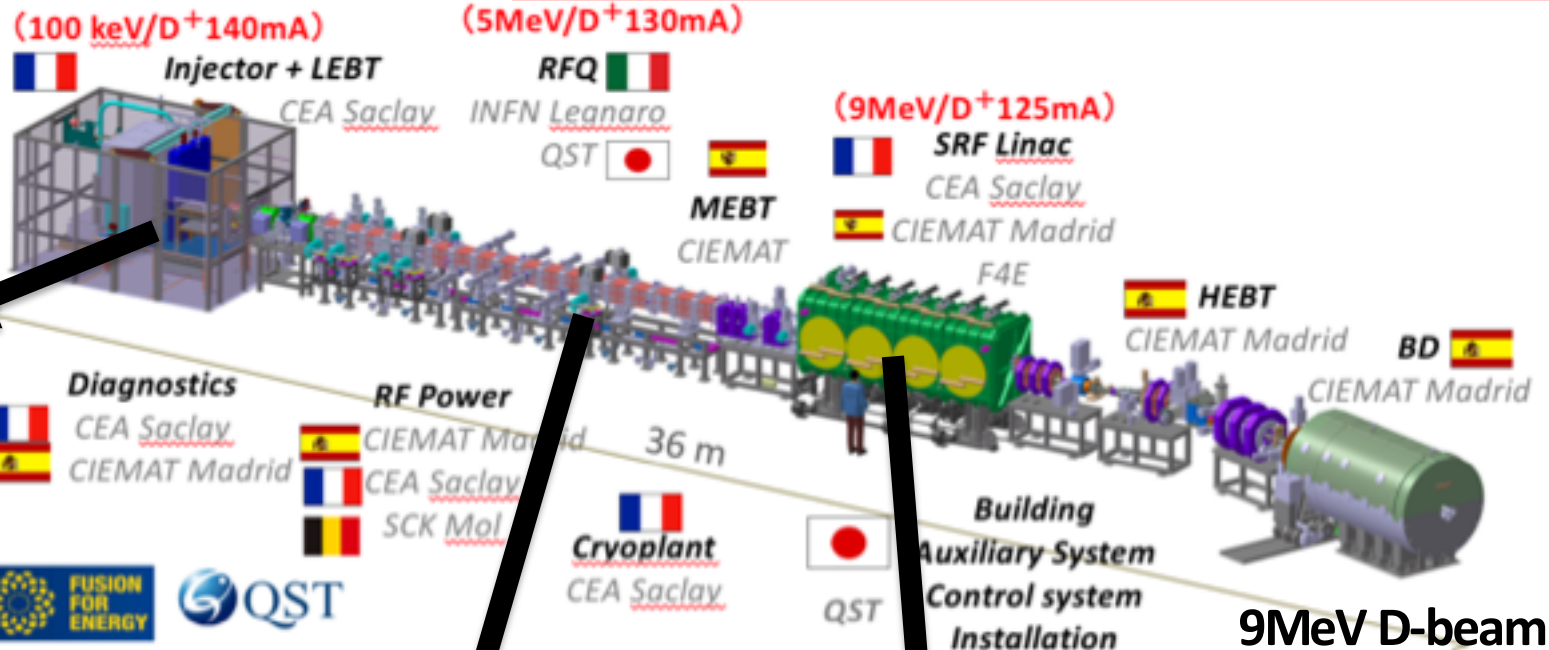
IFMIF Prototype accelerator（LIPAc）

Design, Manufacturing, Delivery: European Lab

Injector

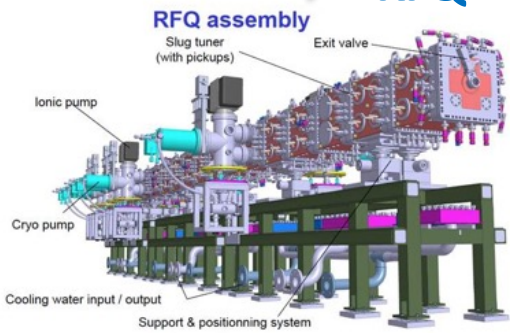


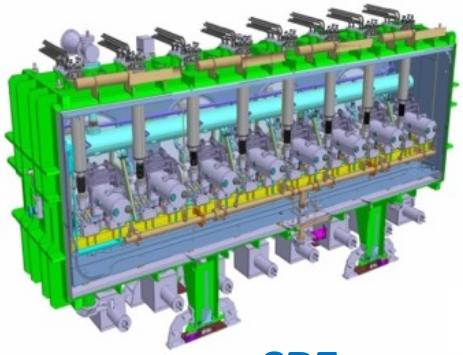


9MeV D-beam
125mA

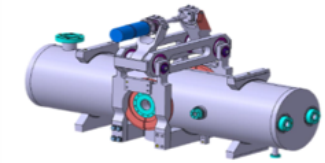
Injector

RFQ





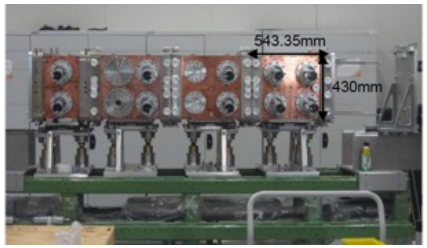
SRF

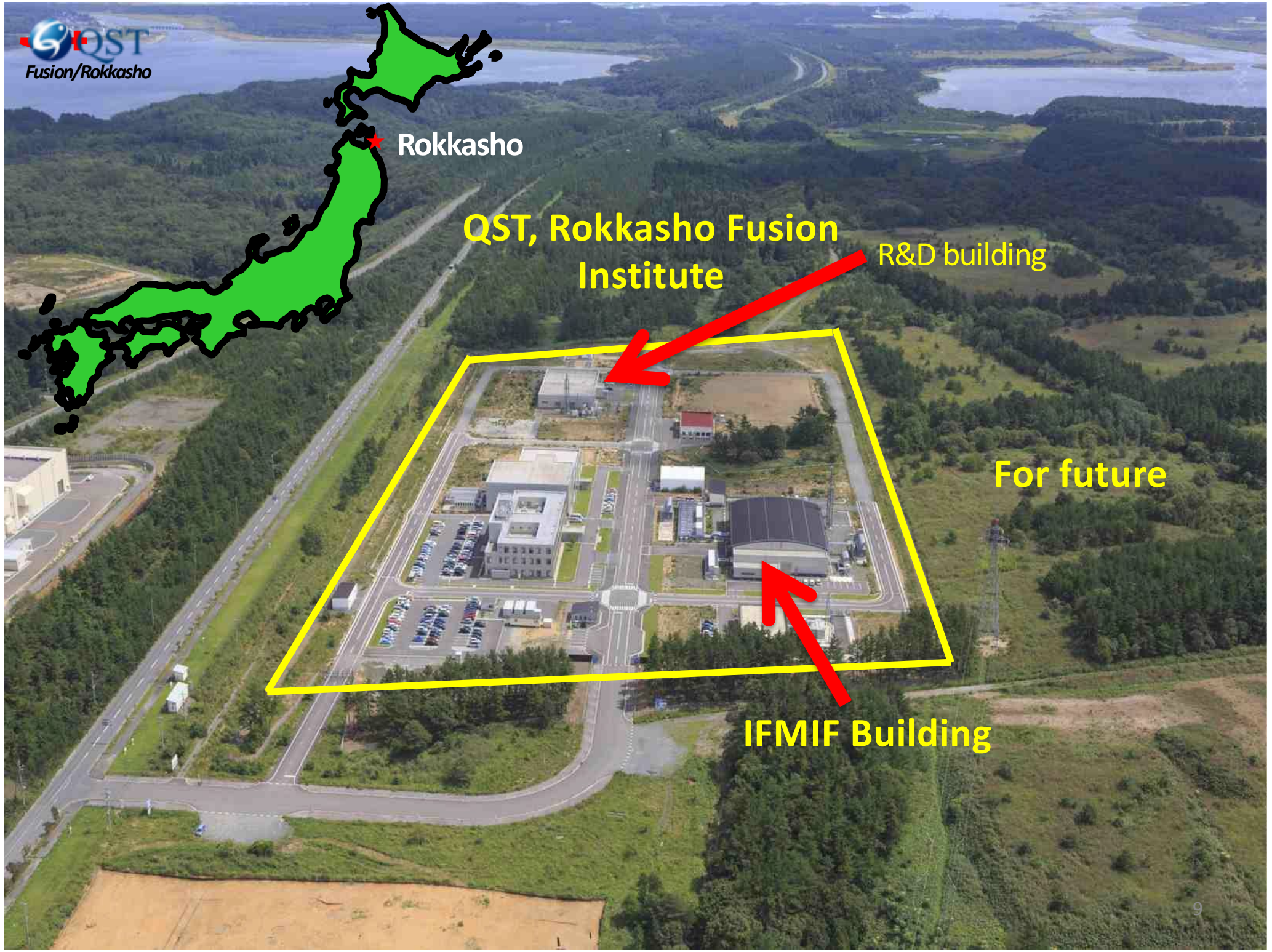


Prototype

Coordination of European activities

F4E
Project Team, Rokkasho

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Fusion/Rokkasho
Rokkasho
QST, Rokkasho Fusion Institute
R&D building
For future
IFMIF Building

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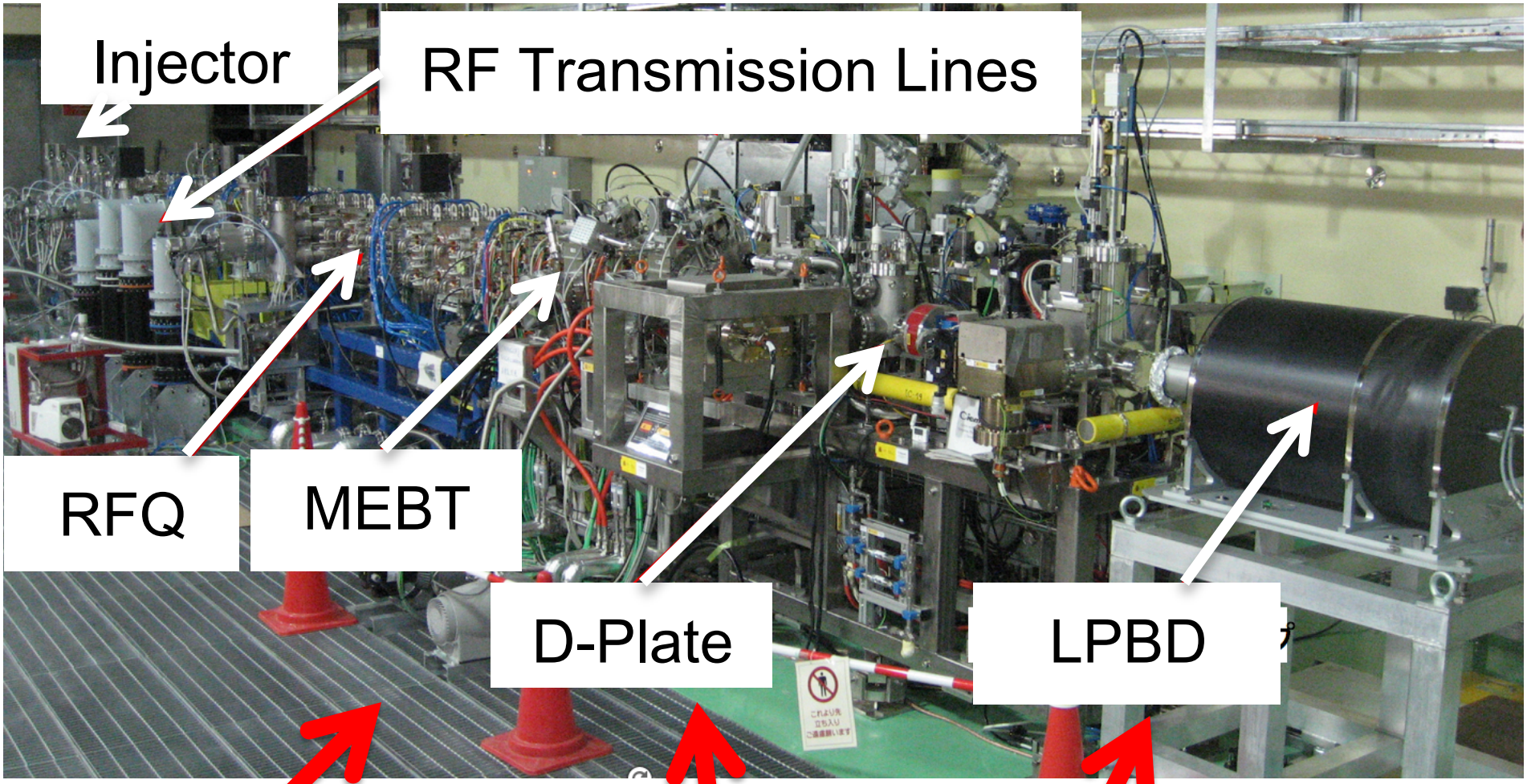
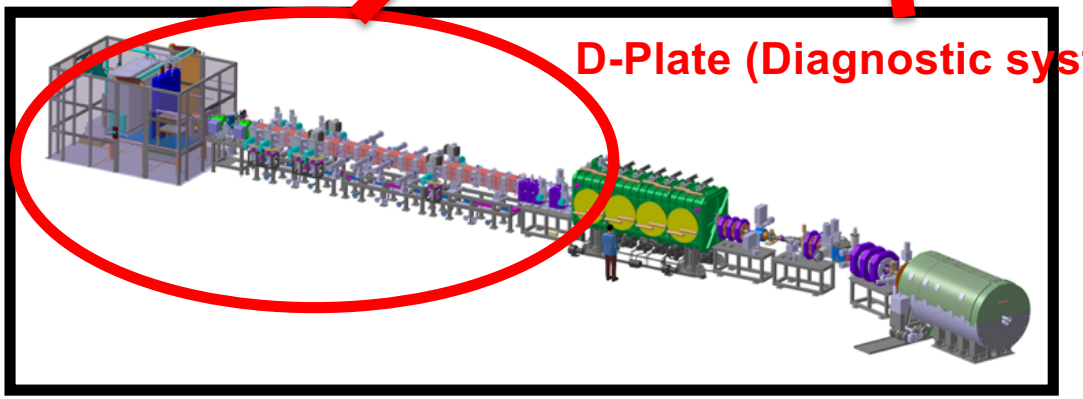
Present LIPAc





D-Plate (Diagnostic system) + LPBD (Low Power Beam Dump) (temporary)

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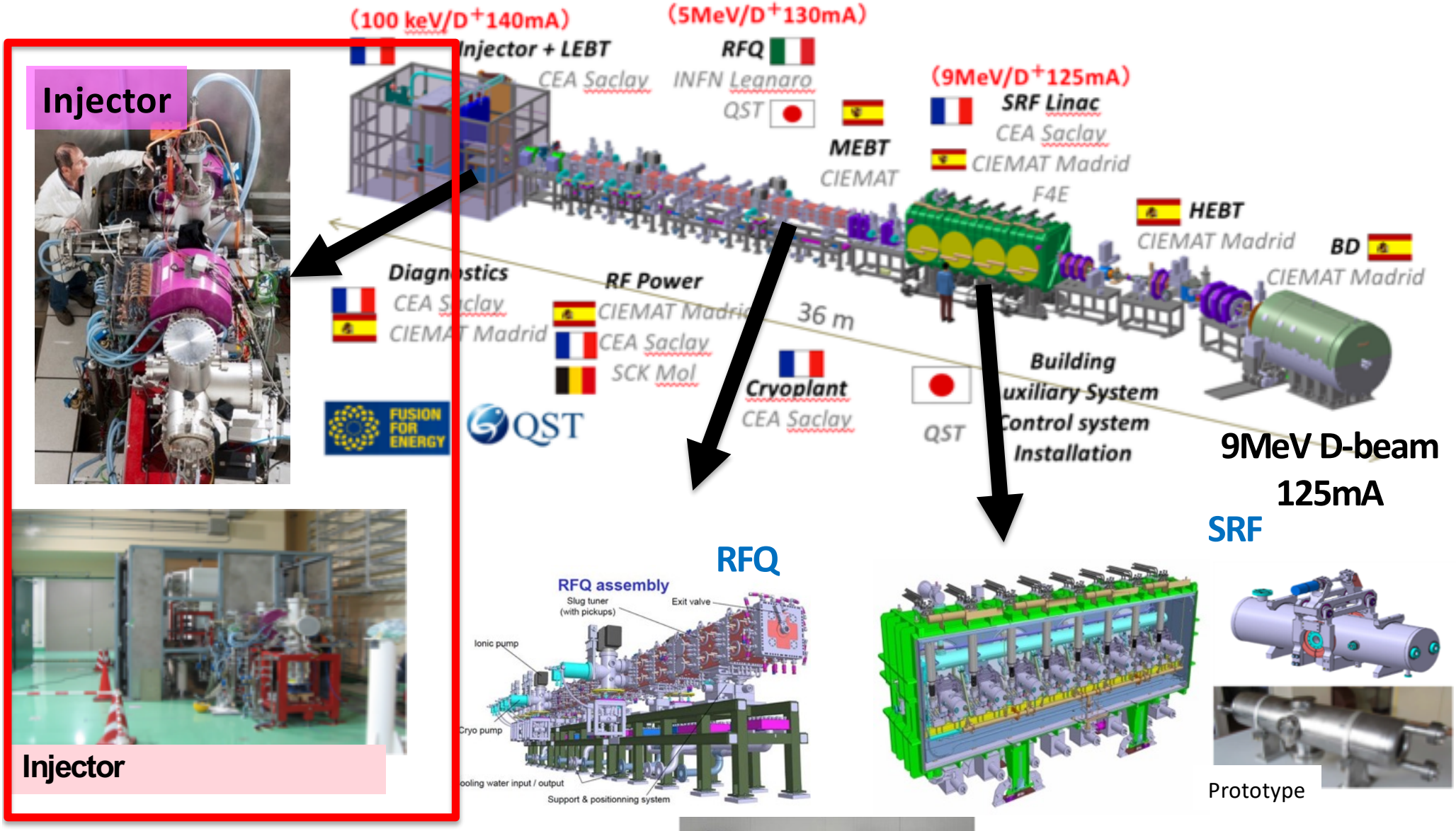
IFMIF Prototype accelerator（LIPAc）

QST Fusion/Rokkasho



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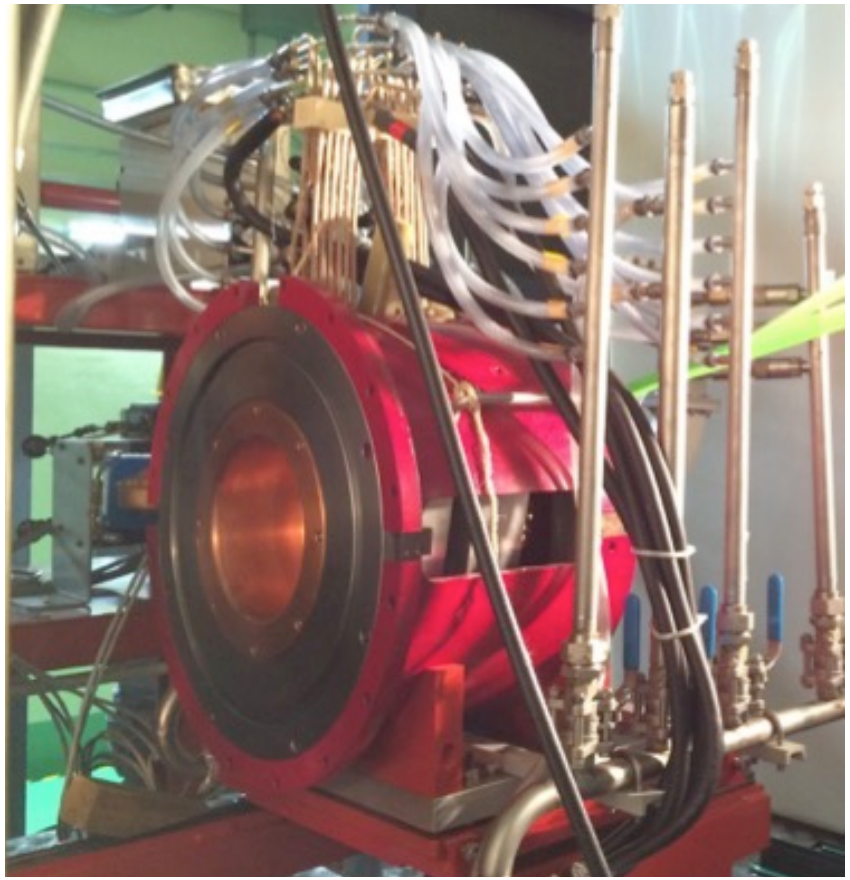
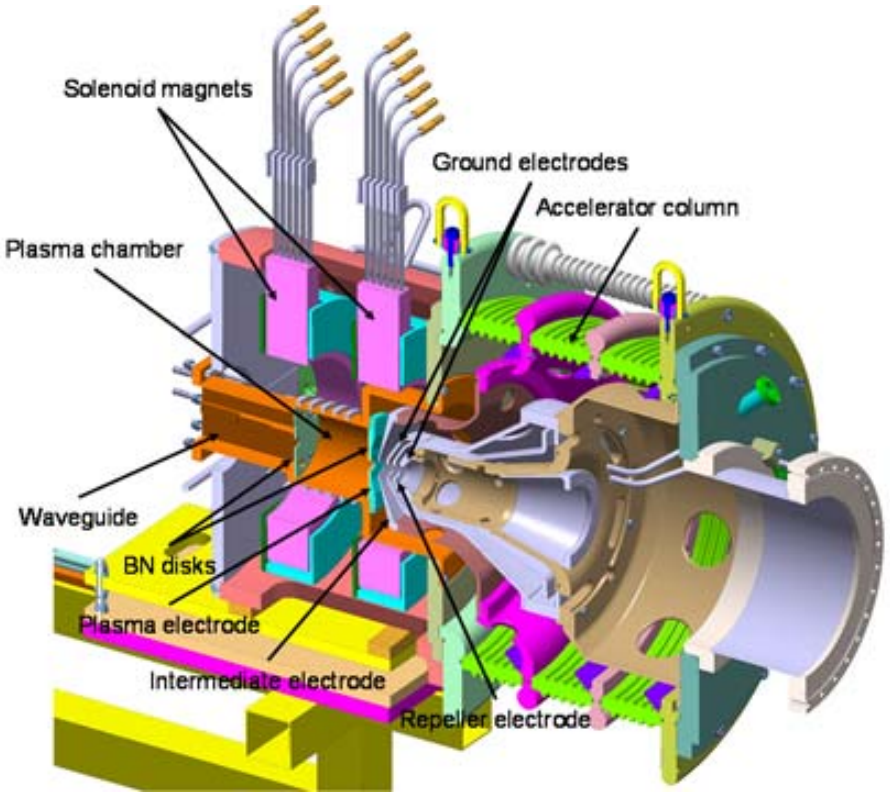
ECR Ion Source



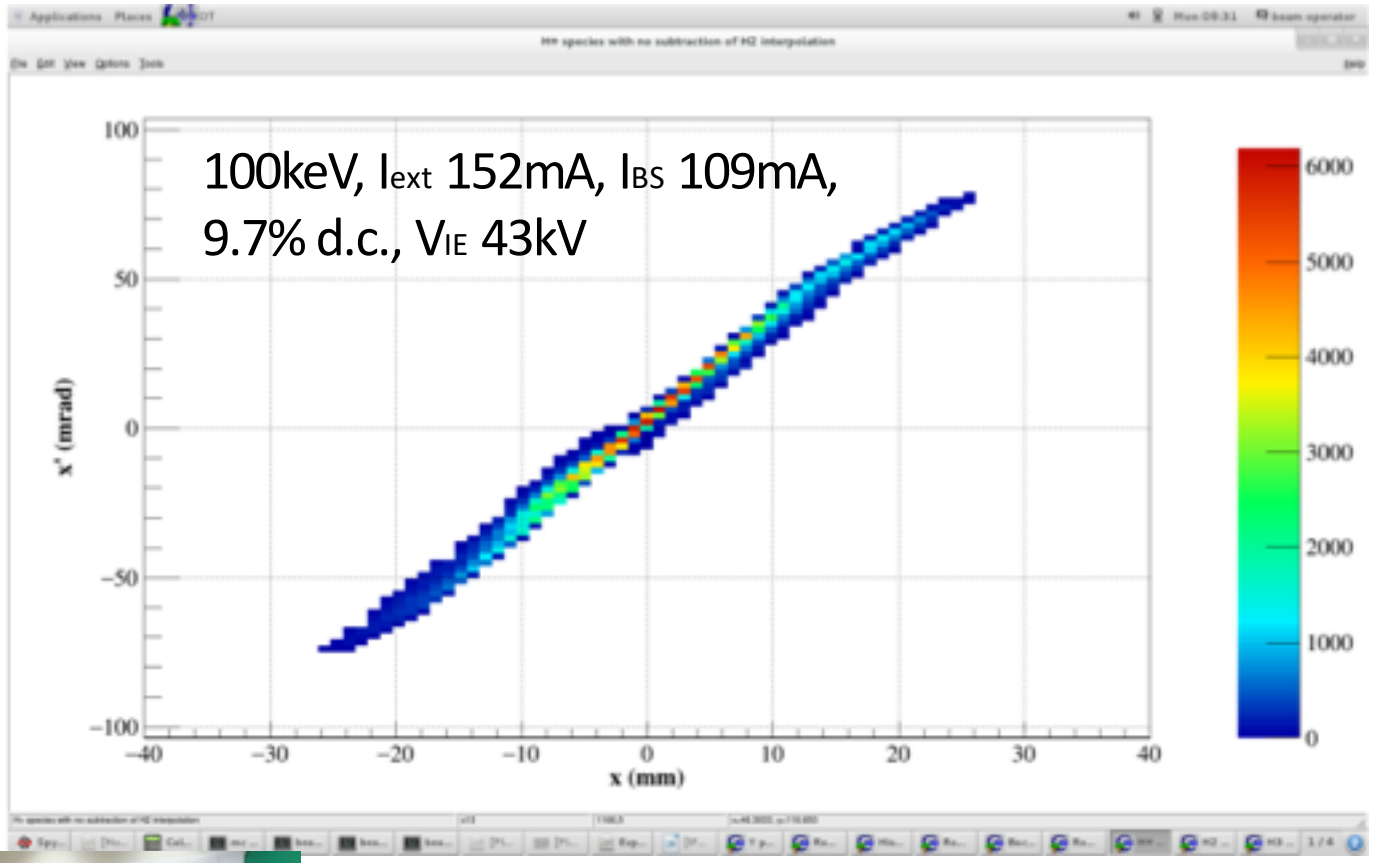


- **100 kV, >140 mA, <0.3π mm.mrad (initial target)**

- **5 electrodes system with secondary electrons repeller .**

(plasma electrode, intermediate electrode, 2 ground electrodes and repeller electrode)

First Experiment of Injector (2015)

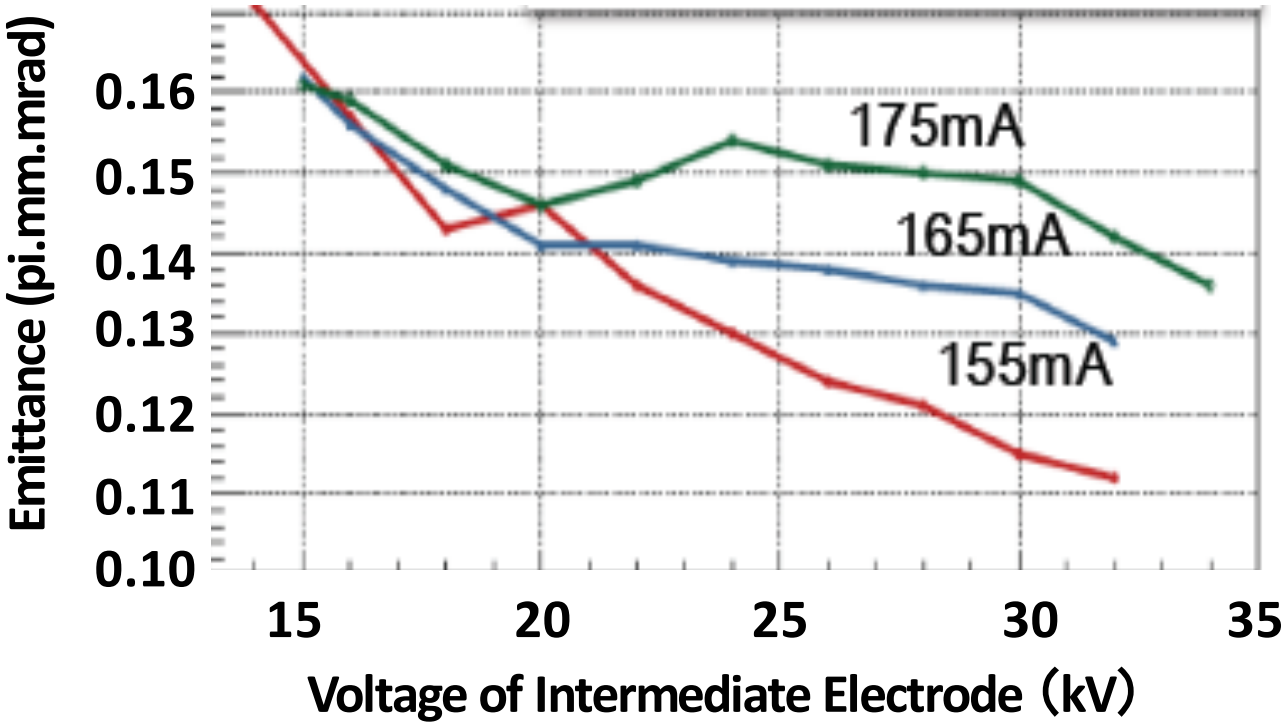


Emittance@2015
(target: < 0.3π)
ε = 0.233π mm·mrad
@ beam current=109 mA
Beam voltage: 100 keV
10% duty

Beam Emittance measurement (2017)

- Redesign of Electrodes
- 3D precise alignment for electrodes

Injector Experiment (Oct. 2017~)



D+ beam: 100keV, 2ms, duty cycle 5 %:

→ Good Emittance of 0.15πmm•mrad was achieved.

(ε = 0.233π mm·mrad @ first D+ extraction)

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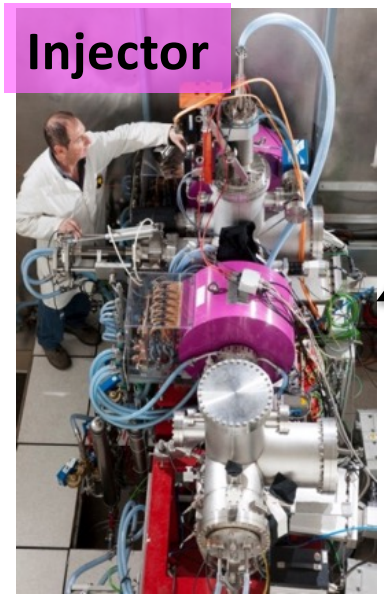
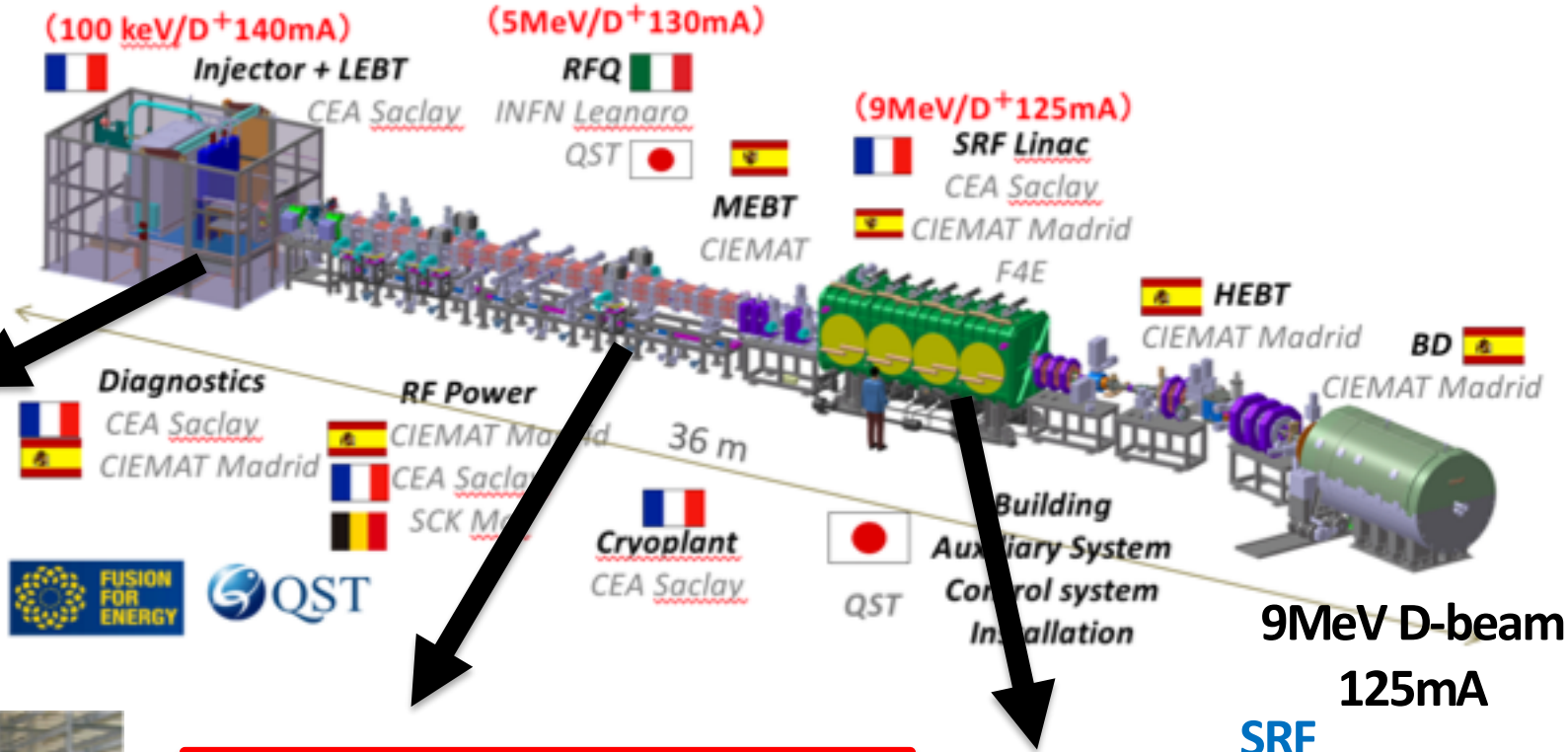
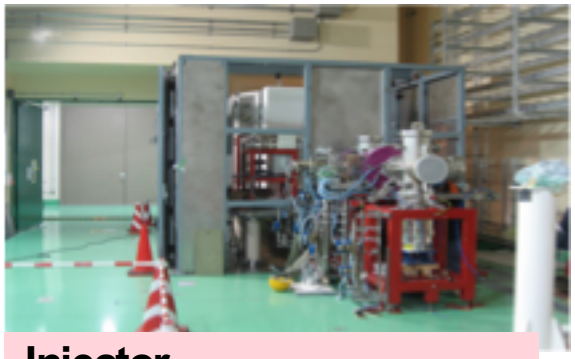
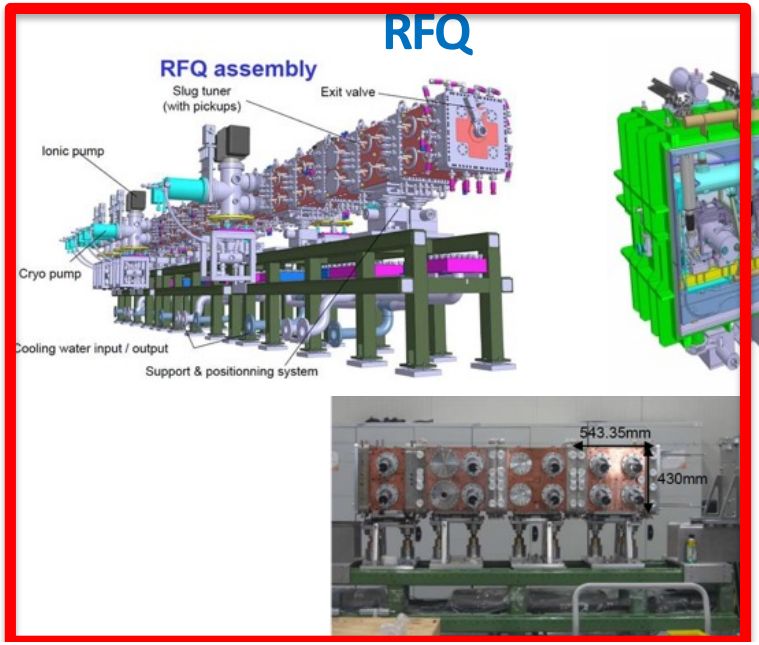
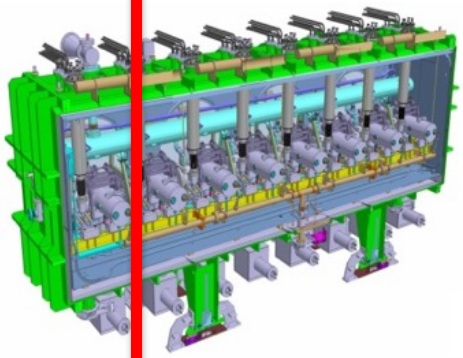
IFMIF Prototype accelerator（LIPAc）



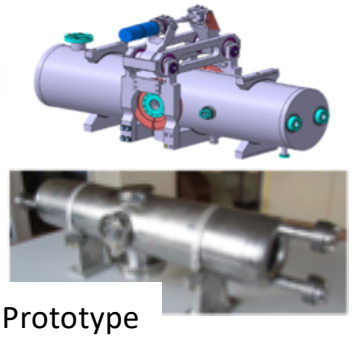








SRF



Prototype

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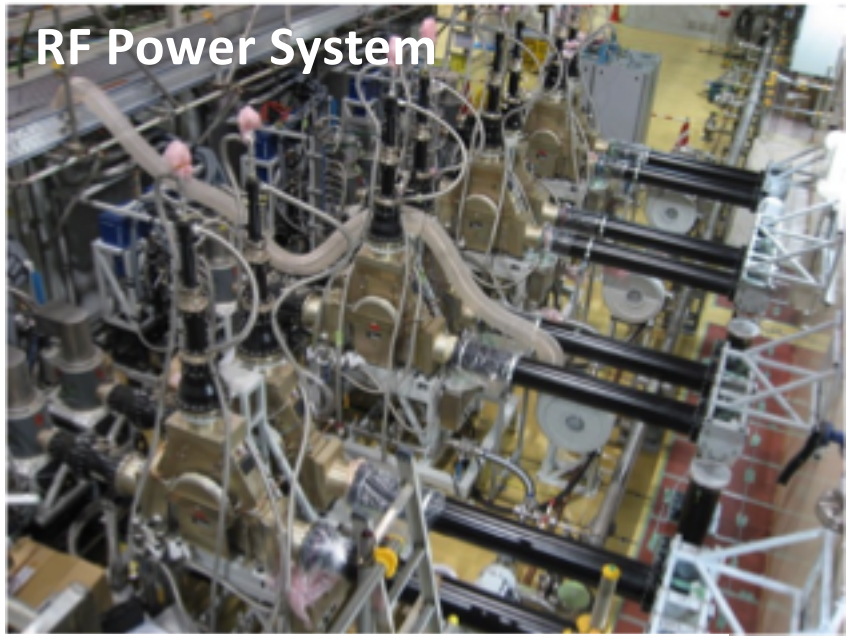
RFQ and High Power RF System (2017)

E. Fagotti, "Beam Commissioning of the IFMIF EVEDA Very High Power RFQ", in Proceedings of IPAC2018.



175MHz/200kW x 8 RF modules

- 9.8 m
- Resonant frequency: 174.995 MHz

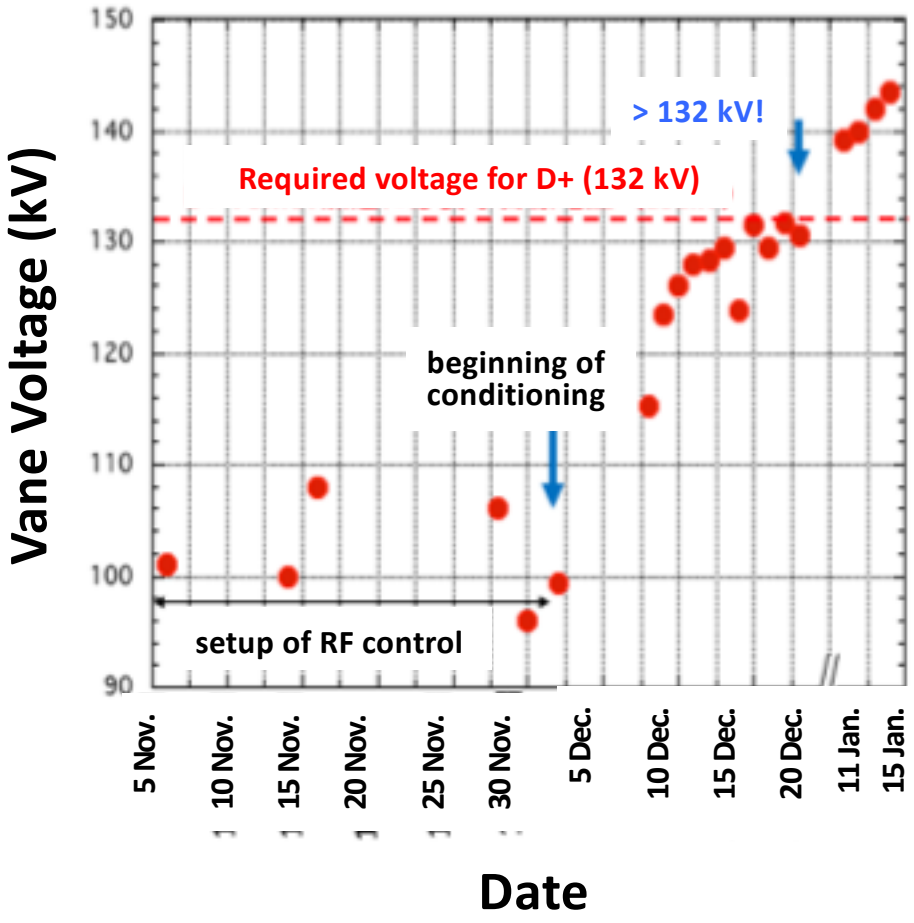
Jul. 2017: Vacuum pump, Cooling, Waveguide installed.

RFQ RF conditioning with 8 RF modules

1st RF injection to RFQ cavity with 8 RF chains synchronized was succeeded on 31 Jul 2017

RFQ Conditioning

RFQ Conditioning (Simultaneous Injection using 8 RF modules)



(Jan. 2018)

<- We achieved at 132kV,
short pulse (~20 us), 1Hz.

Troubles

(June 2018)

~77kV, pulse < 1ms, 1Hz

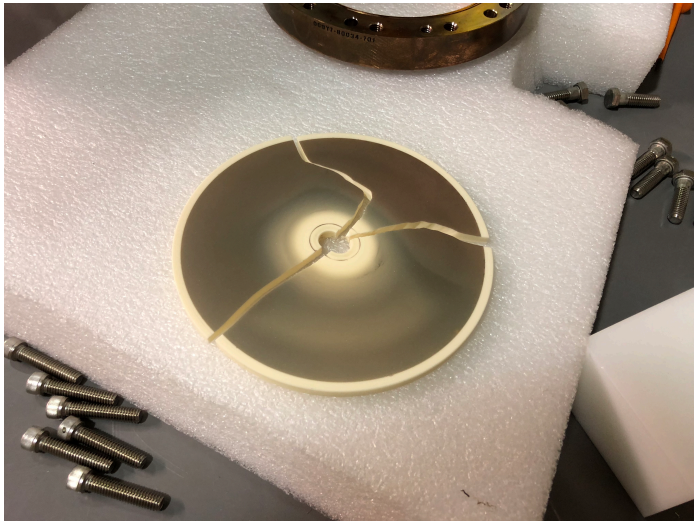
= Conditions for accelerating proton beam @ RFQ are satisfied.

Example of Conditioning Troubles

Damaged
dummy load to absorb reflection power from RFQ

→ Some dummy loads were replaced.

RF window at coupler was damaged
→ Vacuum leakage was occurred at RFQ.



E. Fagotti, "Beam Commissioning of the IFMIF EVEDA Very High Power RFQ", in Proceedings of IPAC2018.

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Commissioning scene of LIPAc components

For test of first acceleration by RFQ, H+, not D+, is chosen to avoid unnecessary activation.

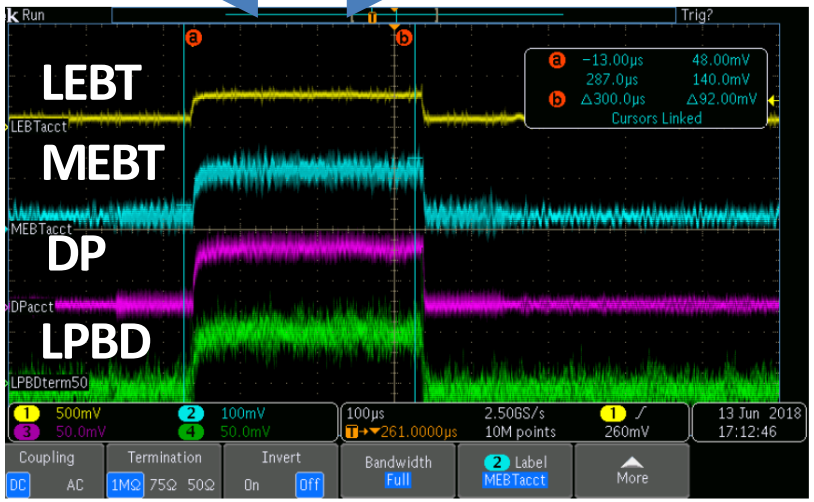
Toward first H+ acceleration by RFQ,

- **RFQ conditioning**
- **MEBT commissioning**
- **D-Plate commissioning**
- **Check of control system**

are simultaneously performed.

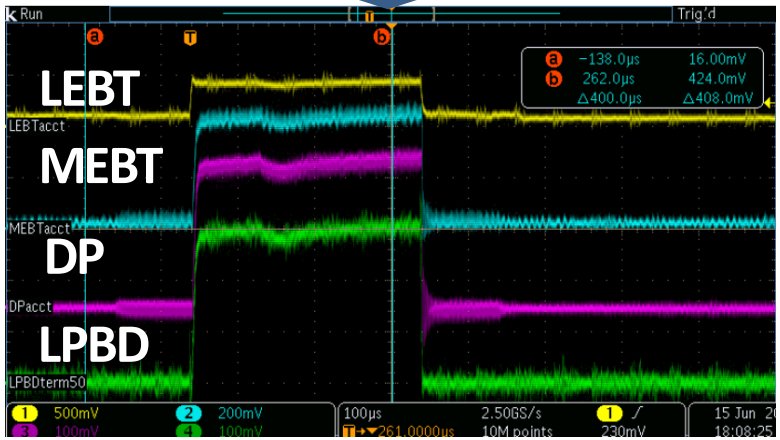
First proton beam injected into the RFQ on 13 June 2018

300 usec, 1Hz



7 mA @ LEBT and ~1.9 mA @ LPBD

→ about 30% of total transmission



After some optimization, more than 80% of transmission in the RFQ, on 15 June 2018.

http://www.ifmif.org/

M. Comunian et al., "Beam Dynamics Simulation and Measurements for the IFMIF/EVEDA Project", HB2018, WEP1WB02.

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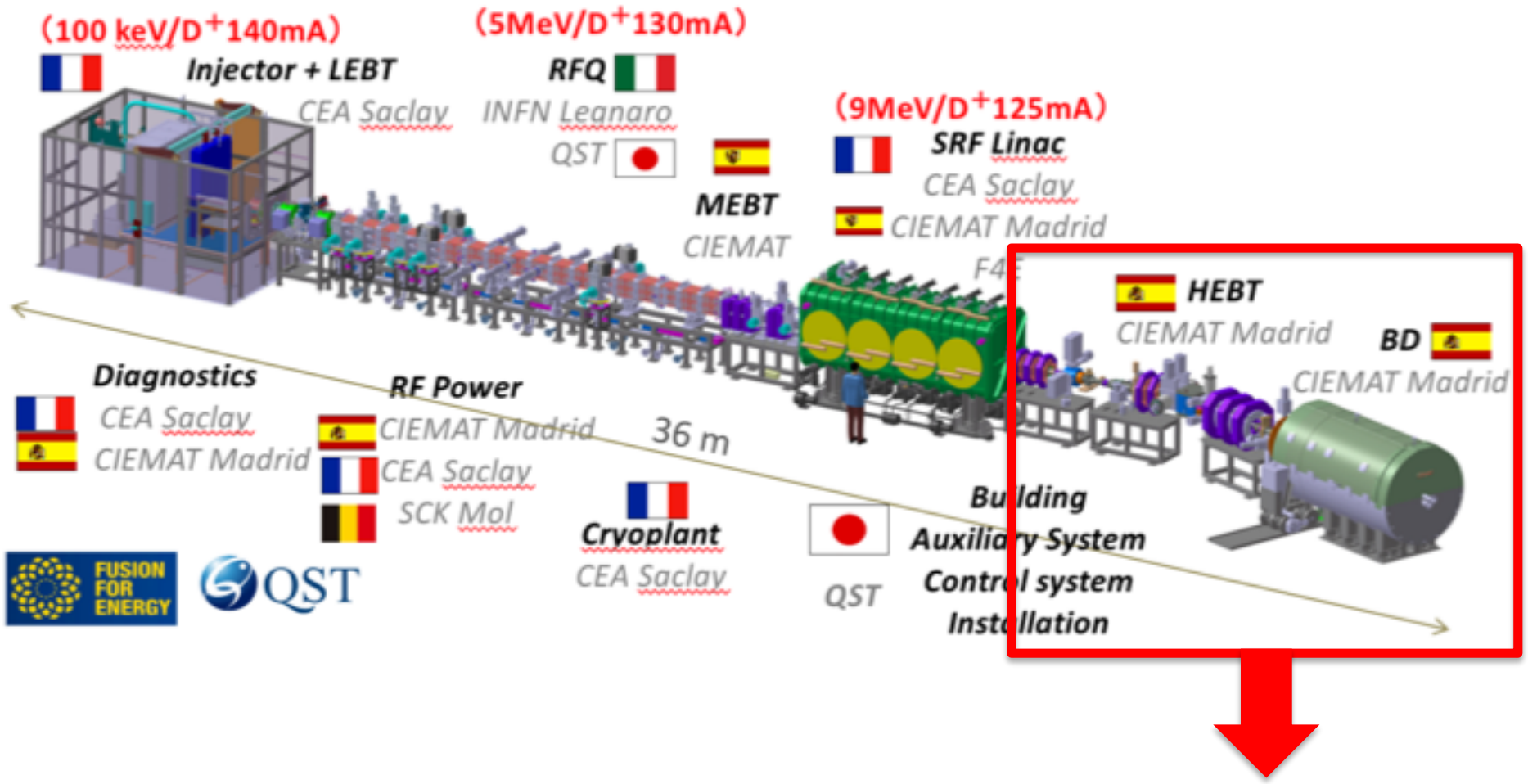

HEBT and BD will be installed in 2018

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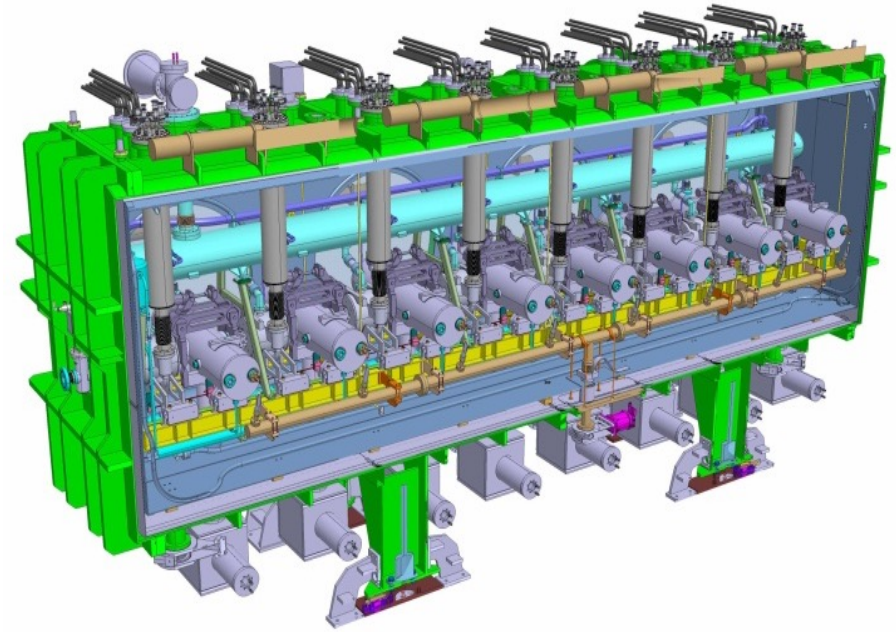
SRF Linac



Inner structure of SRF
Super conducting cavity arrays
D+ beam/125 mA is accelerated
from 5MeV to 9MeV

Super conducting cavity
Prototype（Nb, Ti）

RF test
Q~6E8@5.4MV/m
1.6E9 @low field

SRF will be assembled at Rokkasho in 2018.
conditioning from Aug. 2019.

Full beam commissioning will be performed from Jan. 2020.

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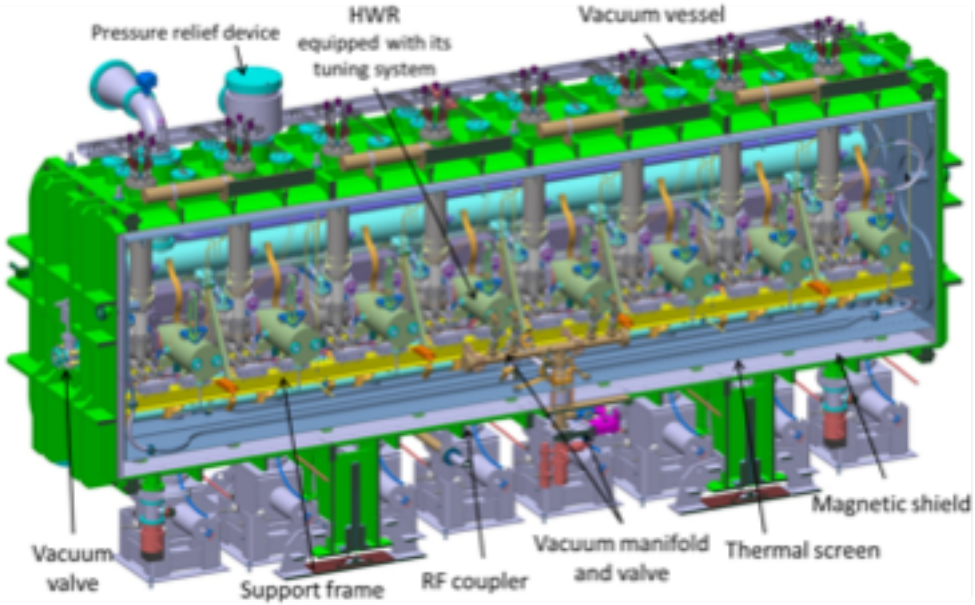
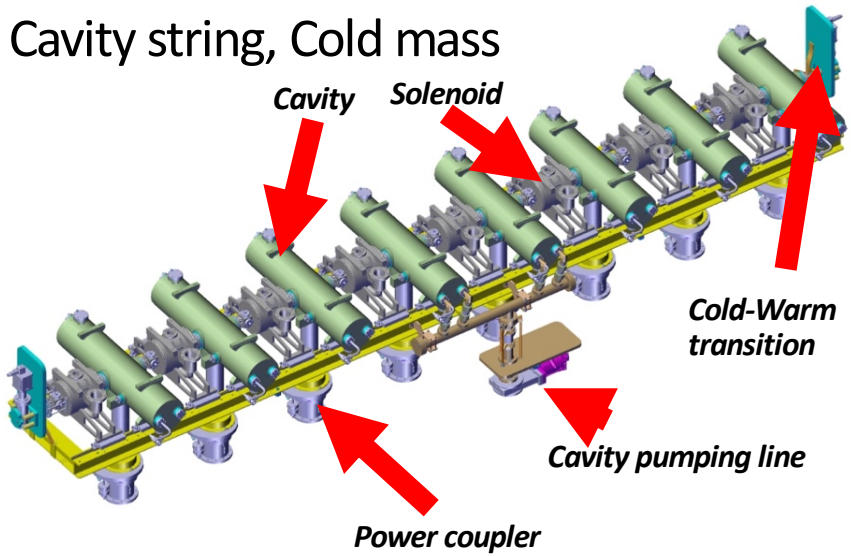
SRF Linac: Specifications

Objective: accelerate a 125 mA D^+ beam in CW operations from 5 to 9 MeV



Cavity string, Cold mass



Target Values of complete Cryomodule	
Frequency	175 MHz
β value of the HWR	0.094
Accelerating field E_a	4.5 MV/m
Unloaded Quality factor Q_0 for R_s=20 nΩ at nominal field	1.4×10^9
Beam aperture HWR/SP	40 / 50 mm
Freq. range of HWR tuning syst	60 kHz
Freq. Resolution of tuners	200 Hz
Max. transmitted RF power by coupler in CW (for LIPAc)	70 kW
Max. reflected RF power in CW	20 kW
External quality factor Q_{ex}	6.3×10^4
Magnetic field B_z on axis max.	6 T
∫ B.dl on axis	1 T.m
Field at cavity flange	≤ 20 mT
CBPM position meas. Accuracy	0.25 mm
CBPM phase meas. accuracy	2 deg
Total Static/Dynamic Heat losses	26 / 95 W

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Summary

- IFMIF Prototype accelerator is under construction
  with international collaboration between Japan and EU.

- In the Injector experiment, high quality D+ beam was demonstrated.
  175 mA extracted beam, Emittance= 0.15πmm•mrad @ 100keV.

- RF power commissioning is underway for RFQ (9.8m length).
  RF voltage (between the vanes) required for H+ beam acceleration
  was achieved.

- First H+ was injected into RFQ on 13 June 2018. After optimization,
  more than 80% of transmission in the RFQ was confirmed.

- Our activities have entered to a new stage.

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on behalf of IFMIF LIPAc Project

(Talk: Y. Shimosaki (QST/KEK) on behalf of him)

HB2018 (Daejeon, Korea), 21 June, 2018