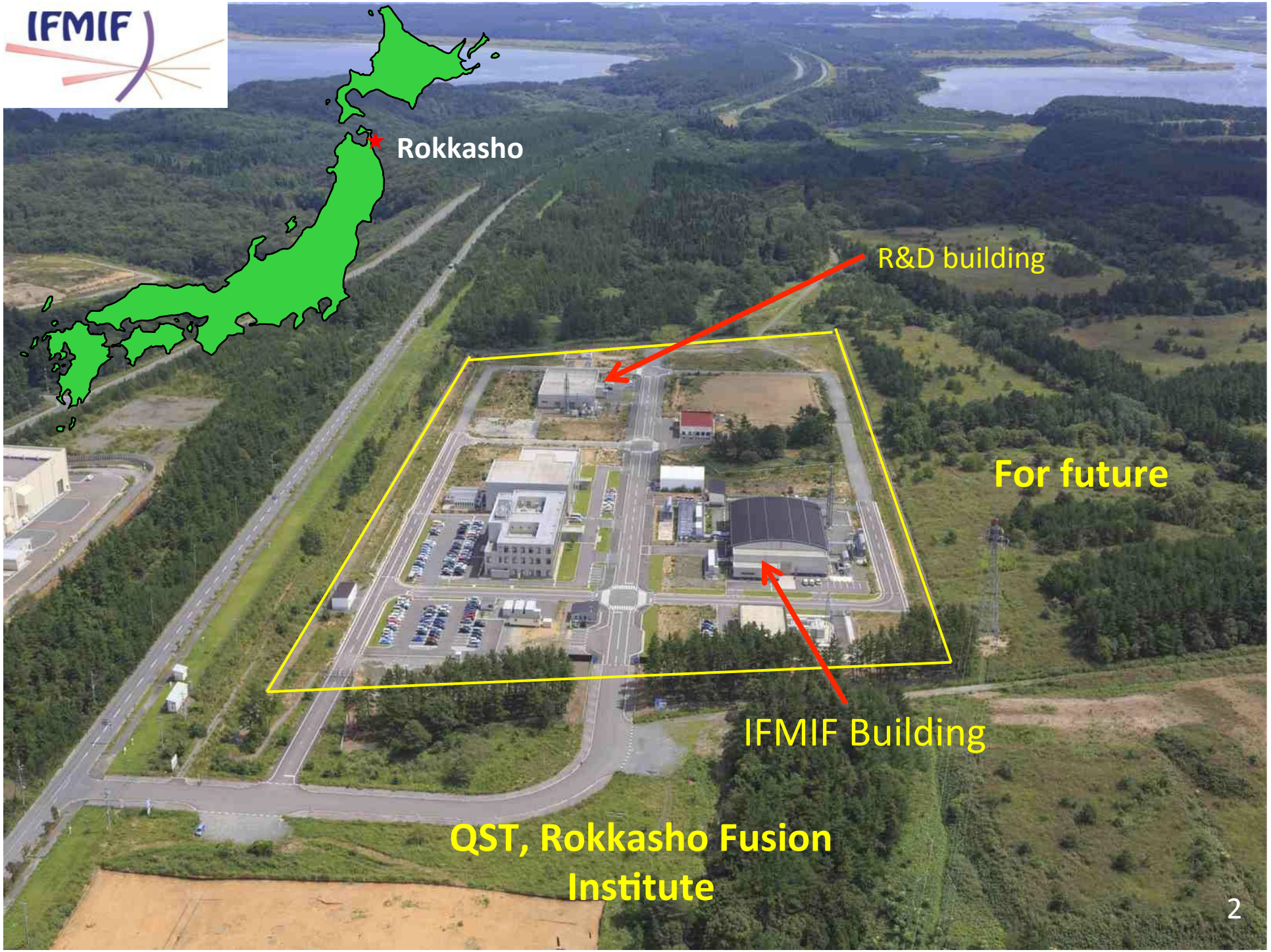
Progress of Linear IFMIF Prototype Accelerator (LIPAc) in collaboration with EU

K.Sakamoto[A)], R.Heidinger[C)], A. Kasugai[A)], P. Cara[C)], P. Abbon[D)], T. Akagi[A)], L. Antoniazzi[E)], N. Bazin[D)], L. Bellan[E)], P-Y. Beauvais[C)], B. Bolzon[D)], D. Bortolato[E)], N. Chauvin[D)], S. Chel[D)], M.Comunian[E)], H. Dzitko[C)],T. Ebisawa[A)], E. Fagotti[E)], D. Gex[C)], R. Gobin[D)], F. Grespan[E)], R.Heidinger[C)], Y. Hirata[A)],R. Ichimiya[A)], D. Jimenez-Rey[F)], A. Jokinen[C)], J. Knaster[B)], I. Kirpitchev[E)], K. Kondo[A)],S. Maebara[A)], A. Marqueta[B)], J. Marroncle[D)], P. Mendez[F)], B. J. Molla[F)], C. de la Morena[E)],M. Montis[E)], I. Moya[C)], A. Palmieri[E)], A. Pisent[E)], G. Phillips[C)], I. Podadera[F)], C. G. Pruneri[B)],D. Regidor[F)], B. Renard[D)], F. Scantamburlo[B)], T. Shinya[A)] M.Sugimoto[A)], and M. Weber[F)]

[A)] National Institutes for Quantum and Radiological Science and Technology (QST) , Rokkasho Fusion Institute, 2-166 Oaza-Obuchi-Aza-Omotedate, Kamikita-gun, Rokkasho-mura, Aomori 039-3212, Japan, IFMIF/EVEDA Project Team, Rokkasho, Aomori, Japan
[B)] IFMIF/EVEDA Project Team, Rokkasho, Aomori, Japan
[C)] F4E, Fusion for Energy, BFD Department, Garching, Germany
[D)] Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA/Saclay), France
[E)] Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro (INFN-LNL), Italy
[F)] Centro de Investigaciones Energéicas, Medioambientales y Tecnolóicas (CIEMAT), Spain

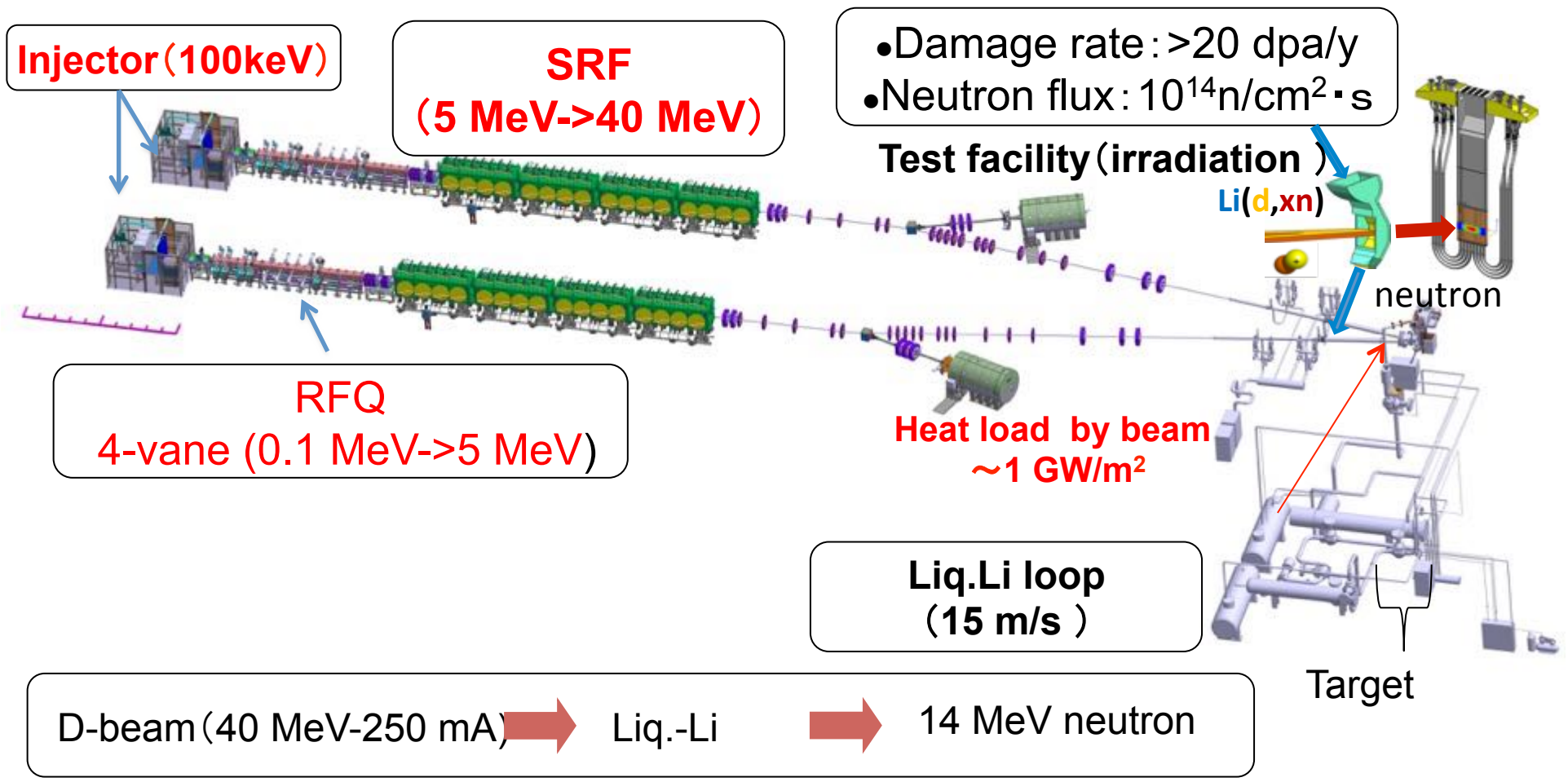

IFMIF
Rokkasho
R&D building
For future
IFMIF Building
QST, Rokkasho Fusion Institute

IFMIF Building

(26 Jan. 2018)

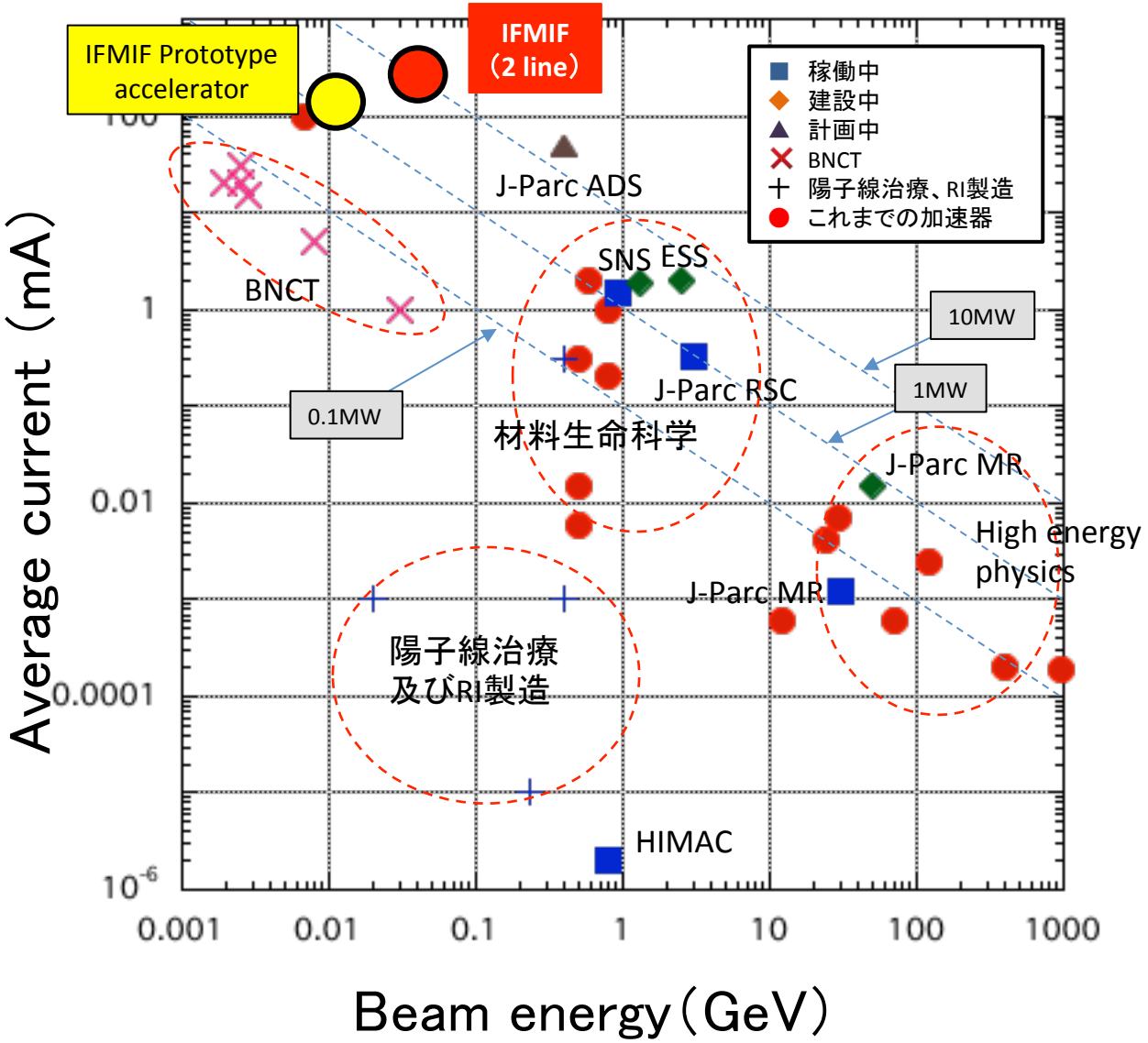
International Fusion Material Irradiation Facility（IFMIF）

Accelerator Based High Intensity Neutron Source for Fusion Material Irradiation



Accelerators (Beam energy vs. current)

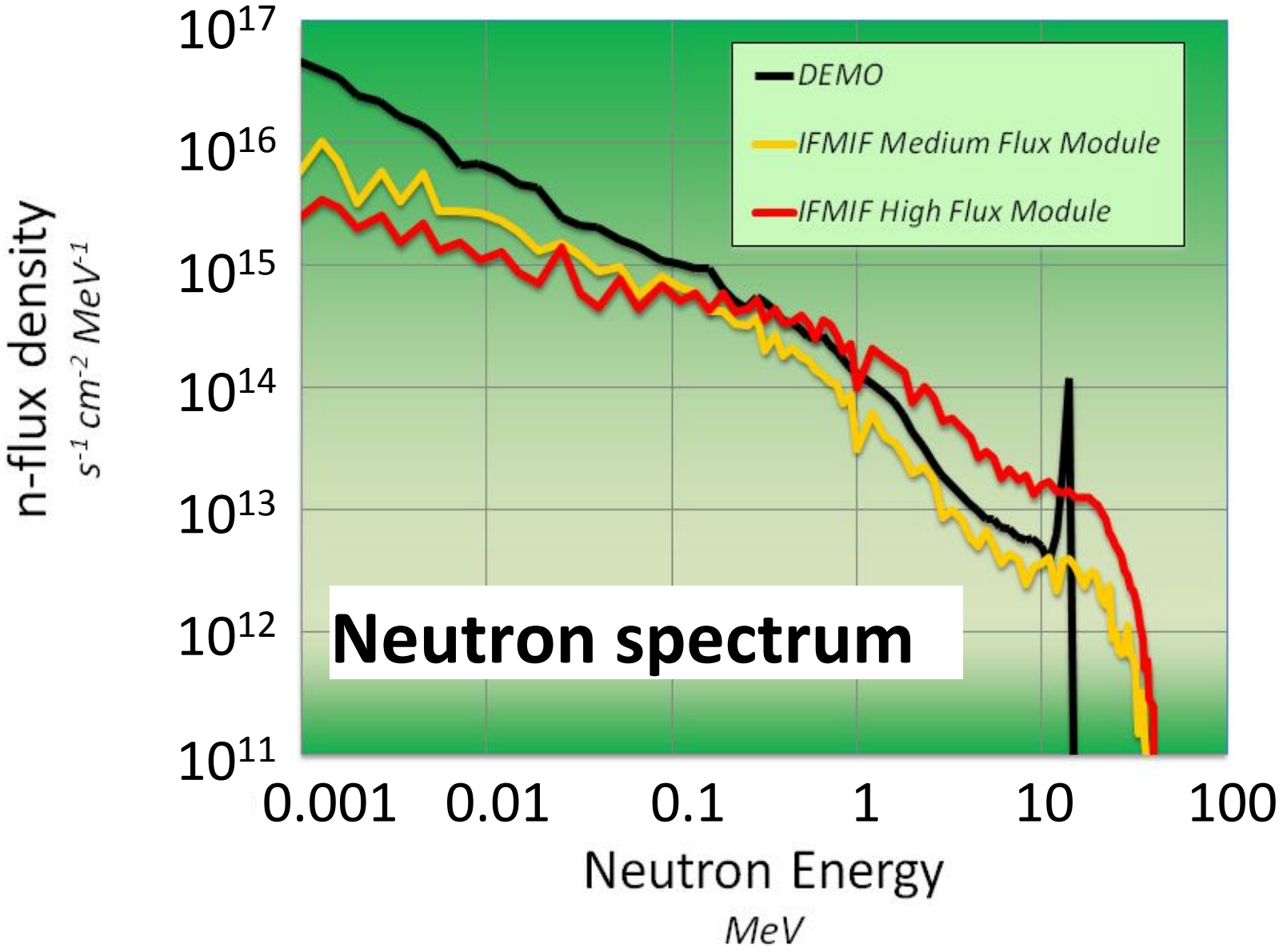
Neutron source

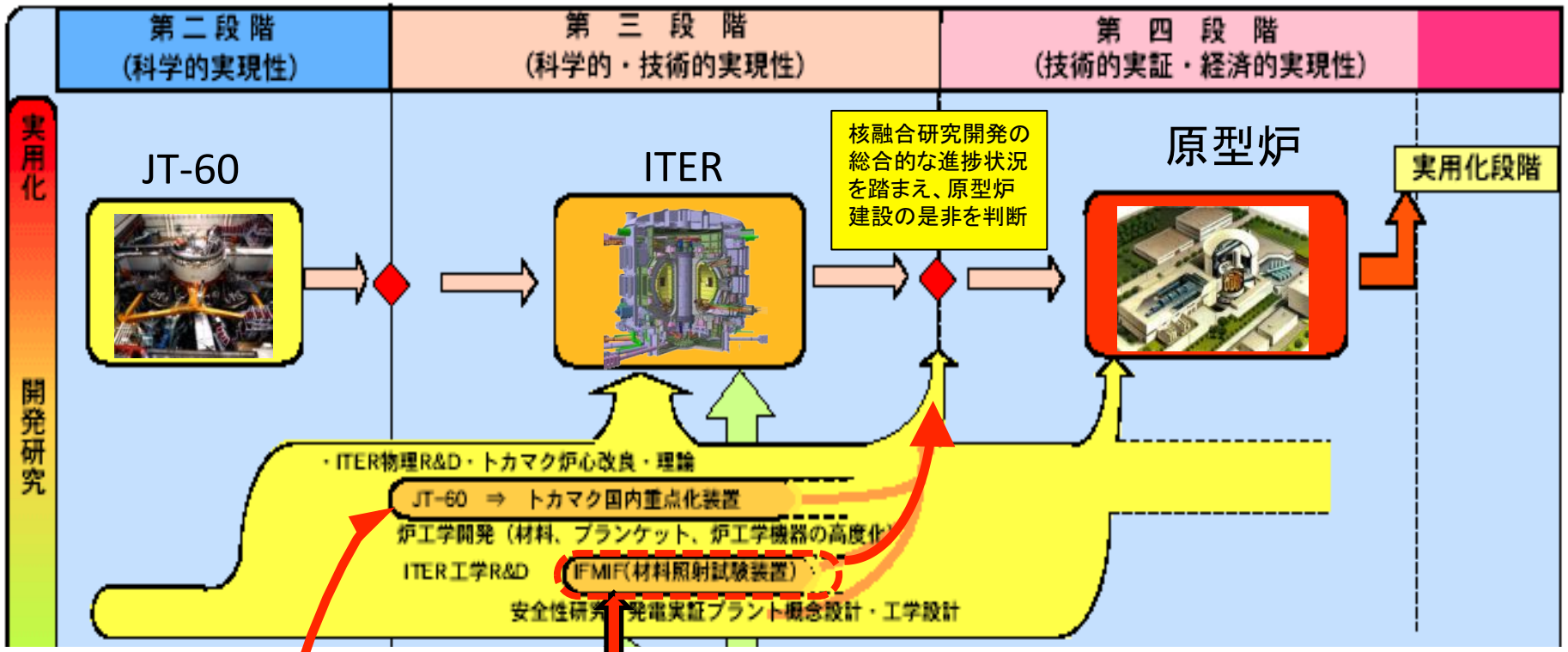


IFIMF prototype accelerator:

- High current,
- CW,
- D-beam

Neutron Spectrum at the test material

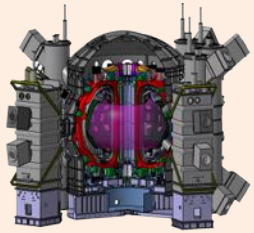




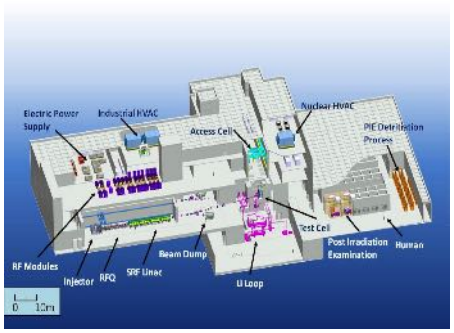
Development of fusion reactor

Satellite
Tokamak（JT-60SA）

Plasma research



IFMIF Irradiation Test by 14MeV fusion neutron facility

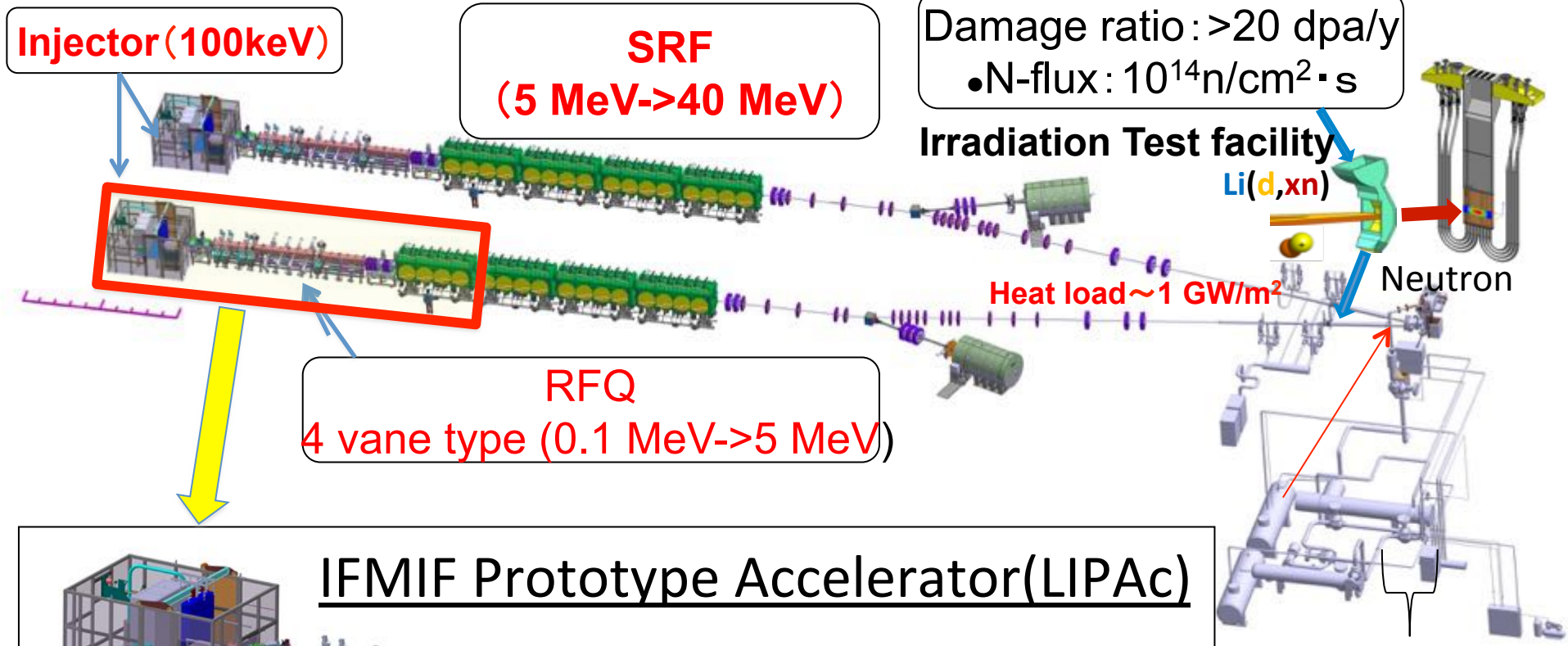


In order to evaluate the influence of neutron irradiation on material properties, it is necessary to investigate He generation by nuclear transformation and damage detection at the same time, so acquisition of material data under neutron environment is indispensable for material development similar to nuclear fusion reactor

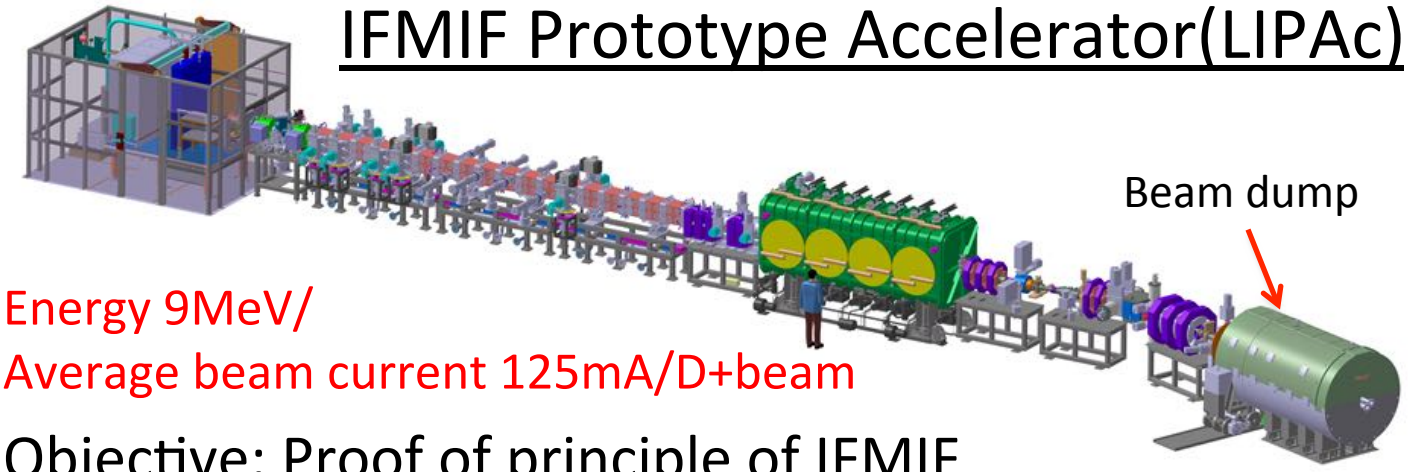
Progress of IFMIF Prototype Accelerator

International Fusion Material Irradiation Facility（IFMIF）

High Intensity neutron source for fusion material irradiation



IFMIF Prototype Accelerator(LIPAc)

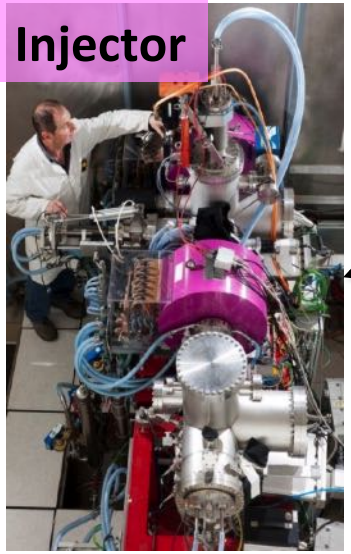


Energy 9MeV/
Average beam current 125mA/D+beam

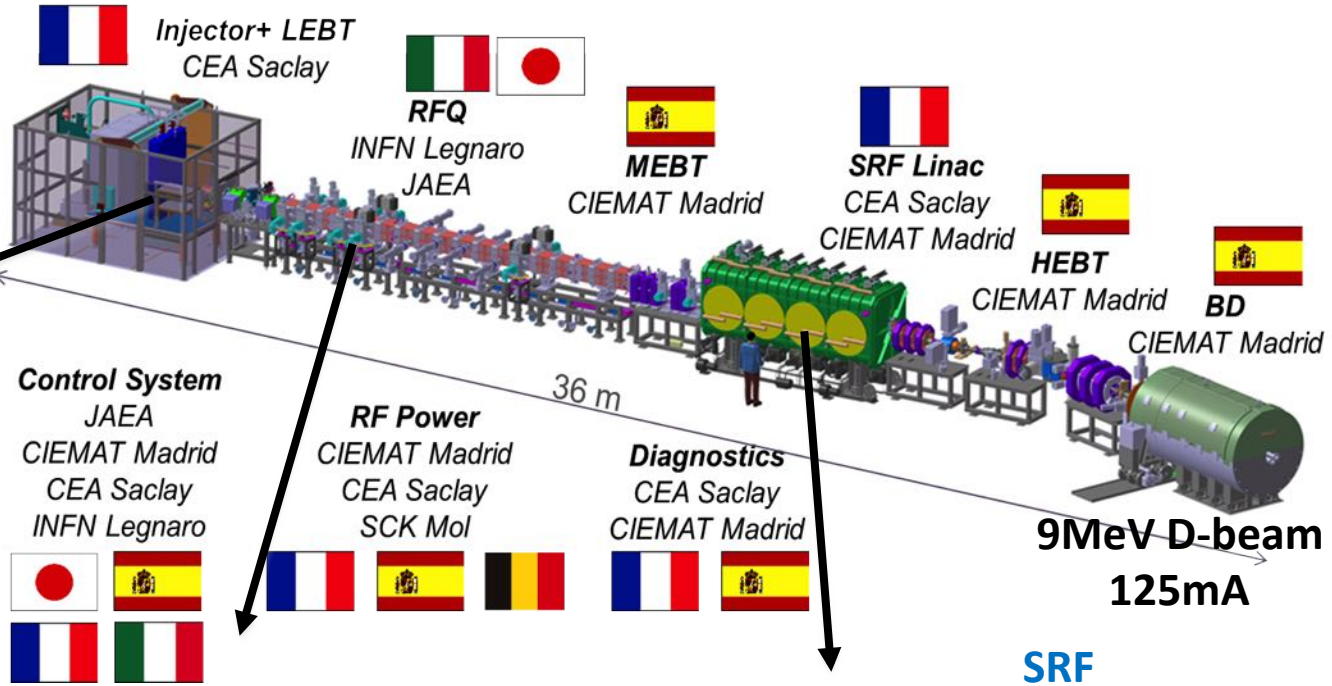
Objective: Proof of principle of IFMIF

IFMIF Prototype accelerator（LIPAc）

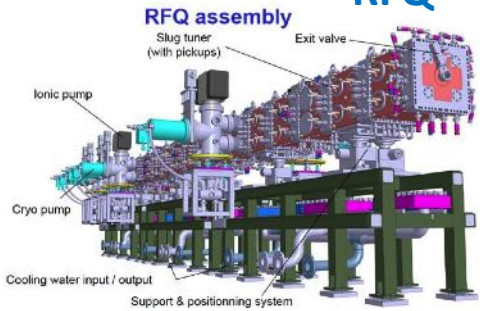
Injector

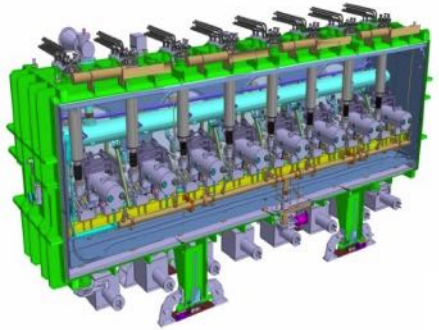


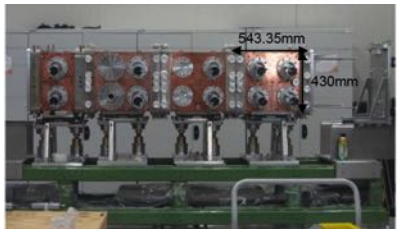
Injector



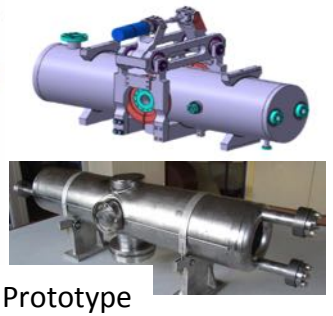
RFQ







SRF



Prototype

World Largest RFQ

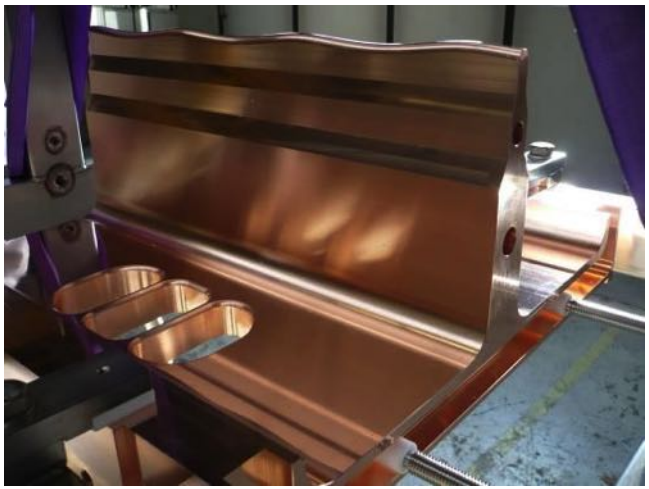
0.1MeV

Beam injection
（CW beam）

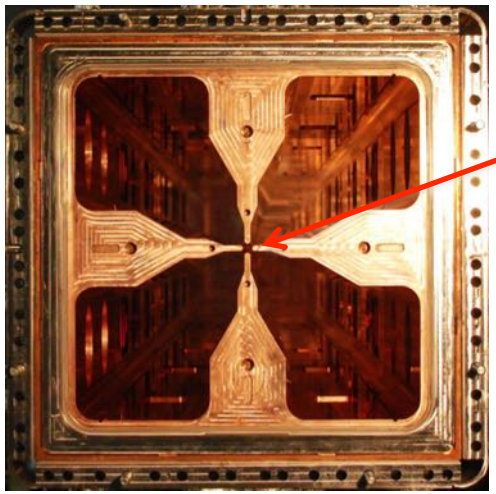
5MeV

Output
（bunching beam）

RFQ（Length 9.8m ：0.55mx18モジュール）



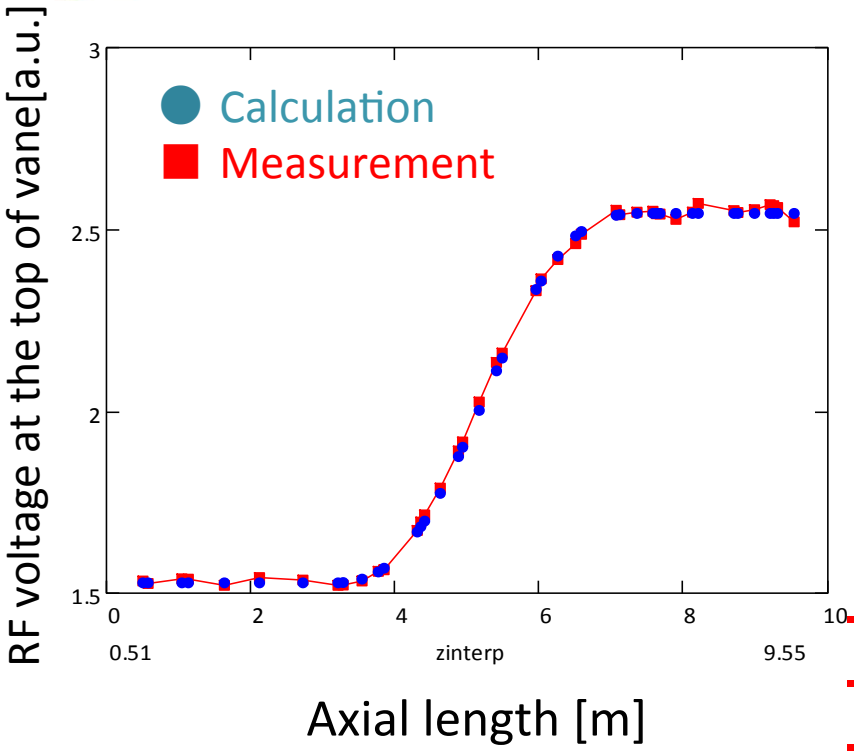
Vane before assembly



RFQ cross section
（430x430mm）

D+ beam
- acceleration
- focusing
- bunching

RFQ RF field adjustment at low power (2016)



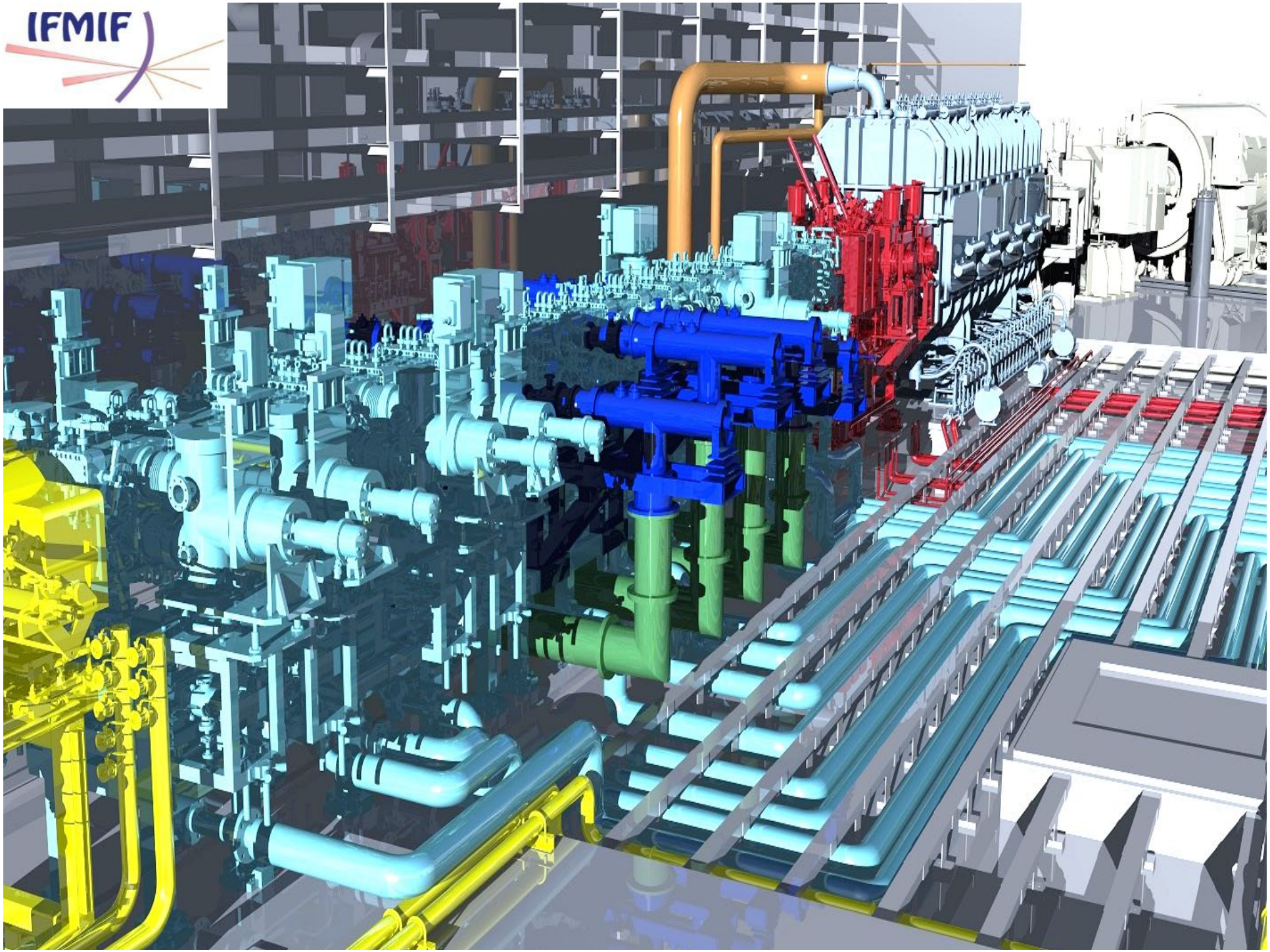
- Resonant frequency: 174.995 MHz
- Q = 11500 > 9000
- Error of RF voltage distribution ± 2%
- un-wanted mode ratio < 2%

98 tuners are adjusted.

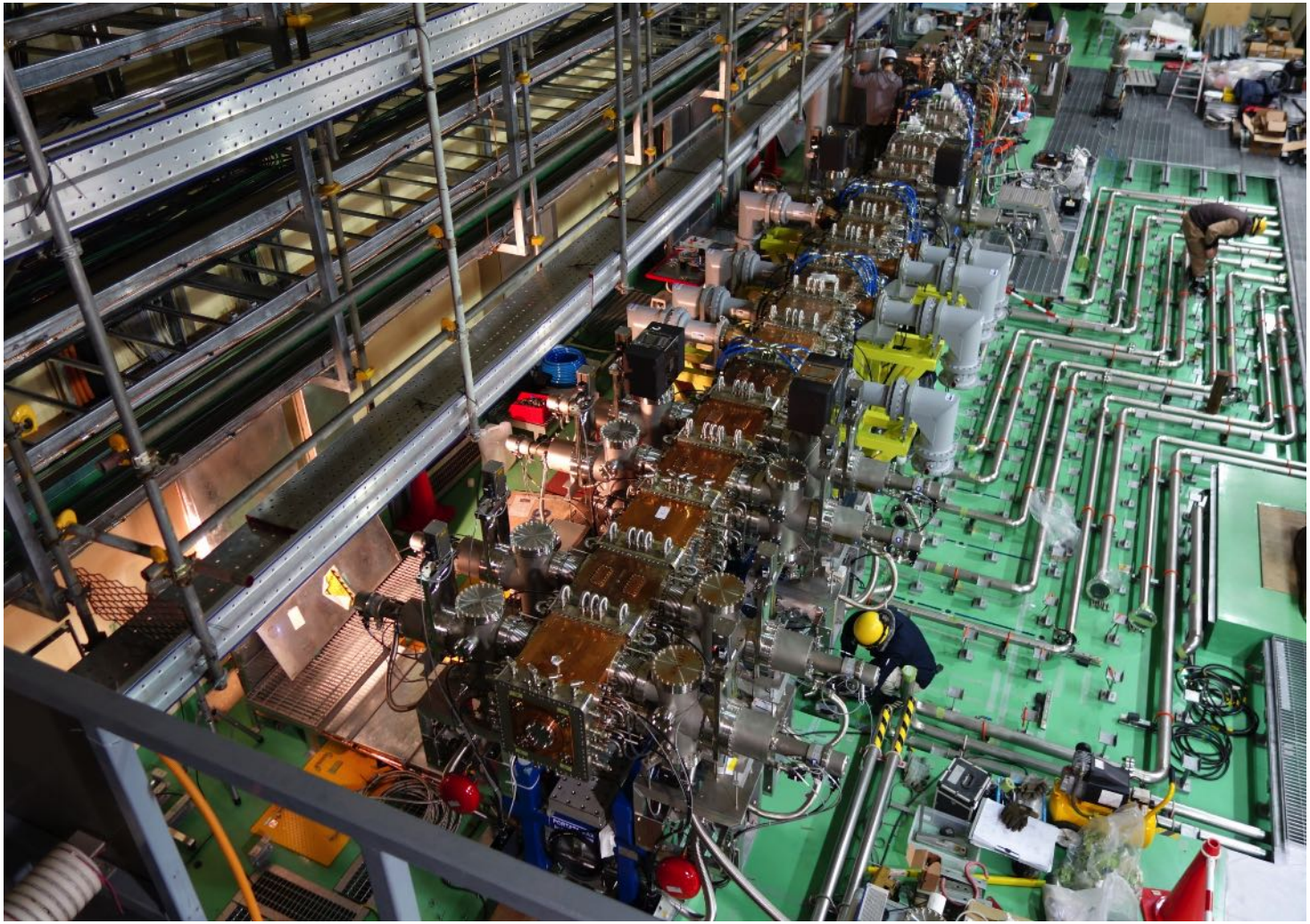
Required resonant frequency and electric field distribution as designed were obtained

RFQ and High Power RF System (2017)

Jul.2017: Waveguide was connected
From RF module to RFQ

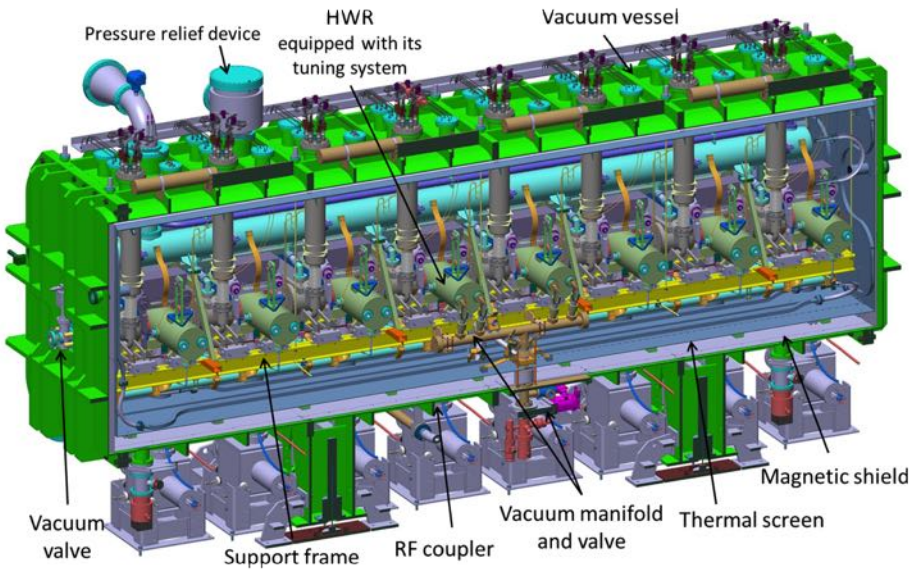

IFMIF

RFQ and Cooling Pipes

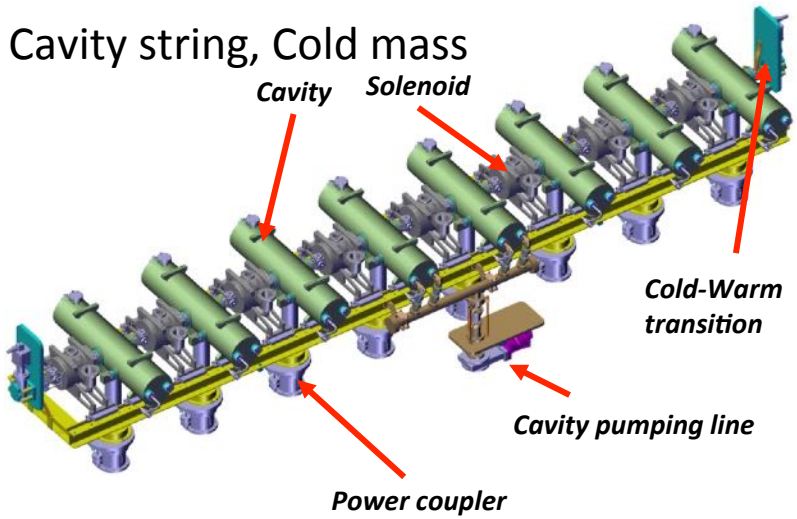


SRF Linac: Specifications

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

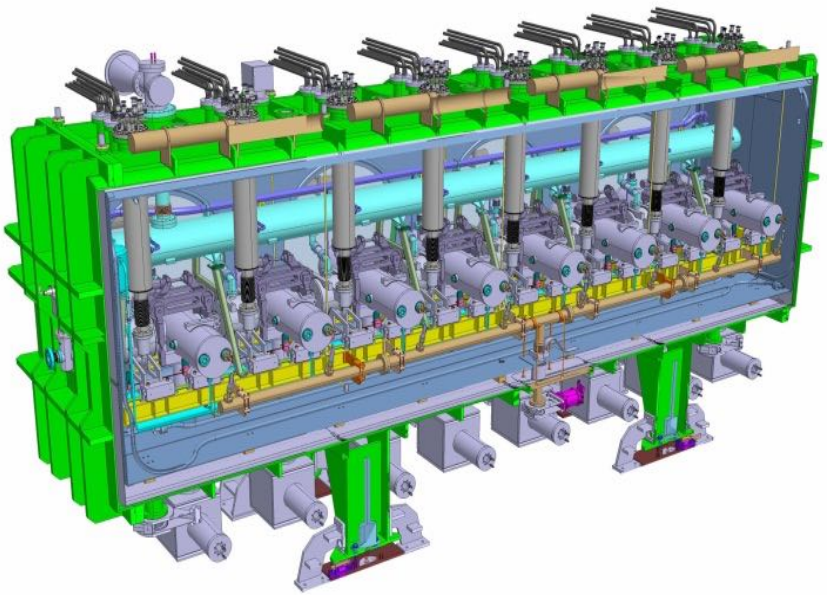


Cavity string, Cold mass



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

SRF Linac



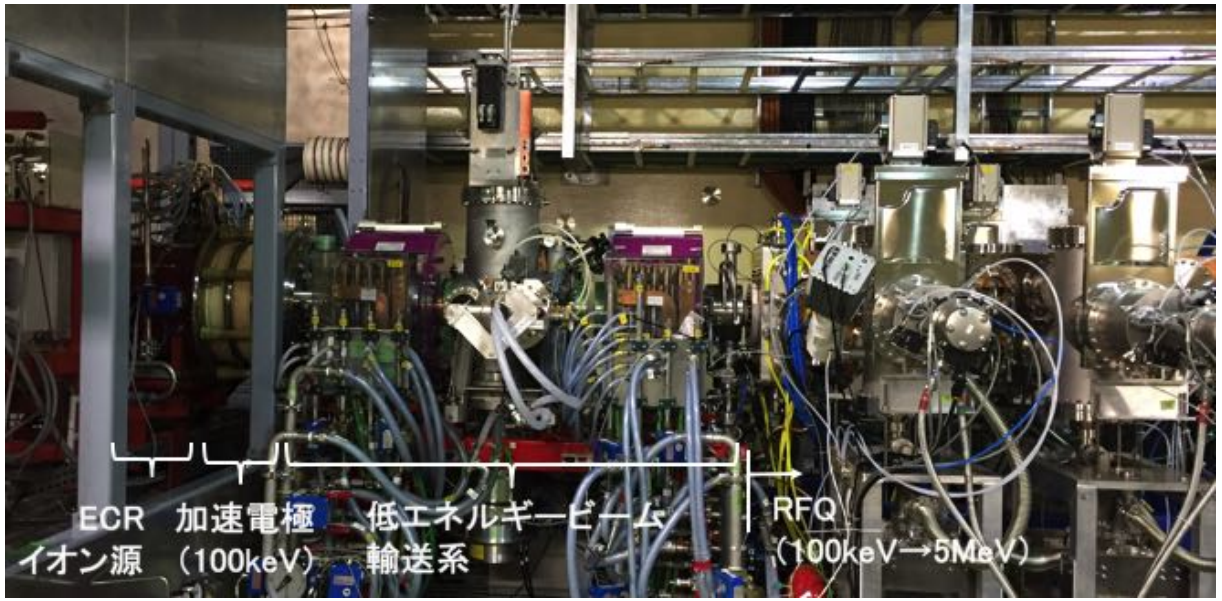
Inner structure of SRF
Super conducting cavity arrays
D+ beam/125 mA is accelerated
from 5MeV to 9MeV

Super conducting cavity
Prototype
（Nb, Ti）

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

Will be assembled at Rokkasho in 2018

Commissioning LIPAc components



Present status :

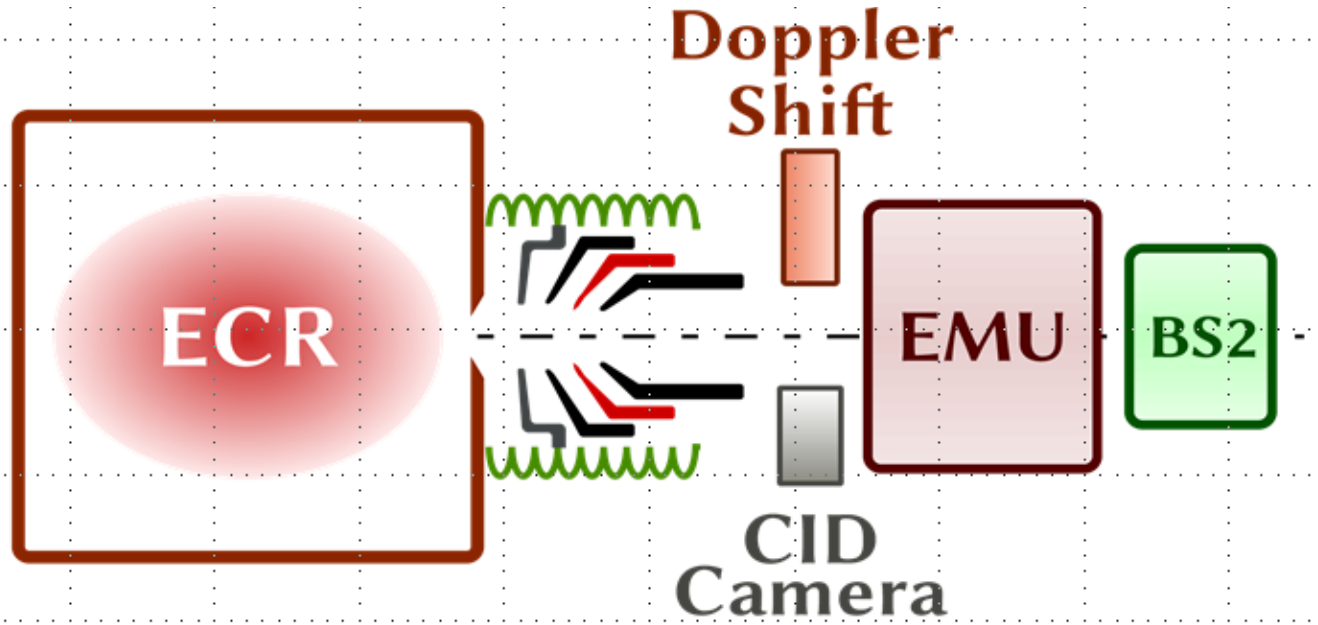
- Vacuum of Injector and RFQ is separated by gate valve
- H+, D+ beam is absorbed by the W-Faraday cup
- In parallel, RFQ conditioning is underway

Commissioning scene of LIPAc components

Parallel works of
- Injector
- RFQ conditioning
- MEBT commissioning
- D-Plate commissioning
- Part of control system

Toward first beam acceleration
By RFQ

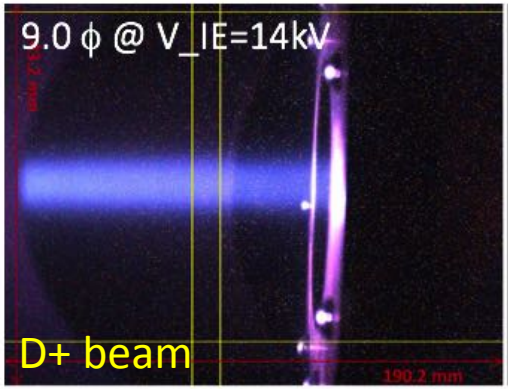
Configuration: conceptual set up

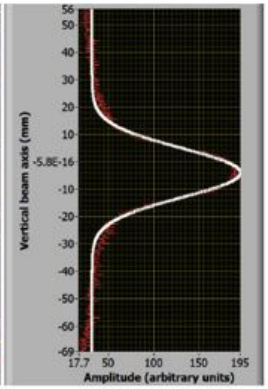


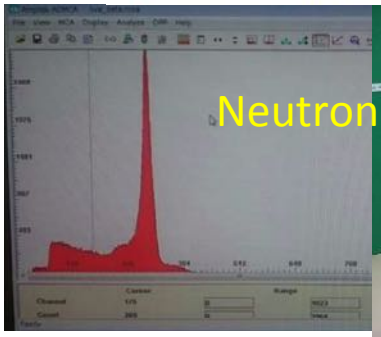
Available Diagnostics

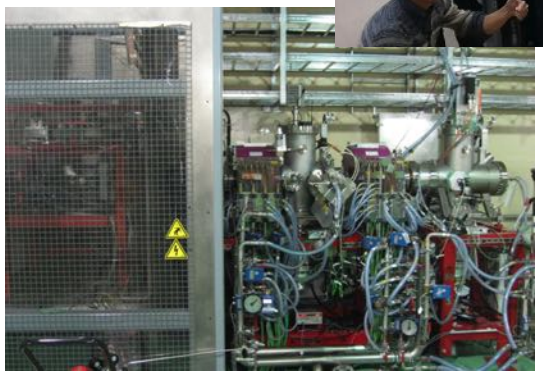
- Emittance Measurement Unit: Allison Scanner
- Doppler Shift Spectroscopy
- Profile Measurement: intensified CID camera
- Beam Stopper with electron repeller (permanent magnets upstream)

First Experiment of Injector (2015)

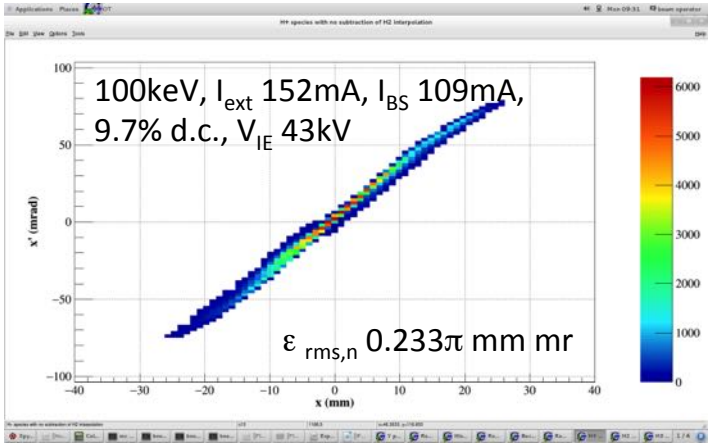








Emittance meter



Emittance@2015

（target: < 0.3π）

ε = 0.233π mm·mrad

@ beam current=109 mA

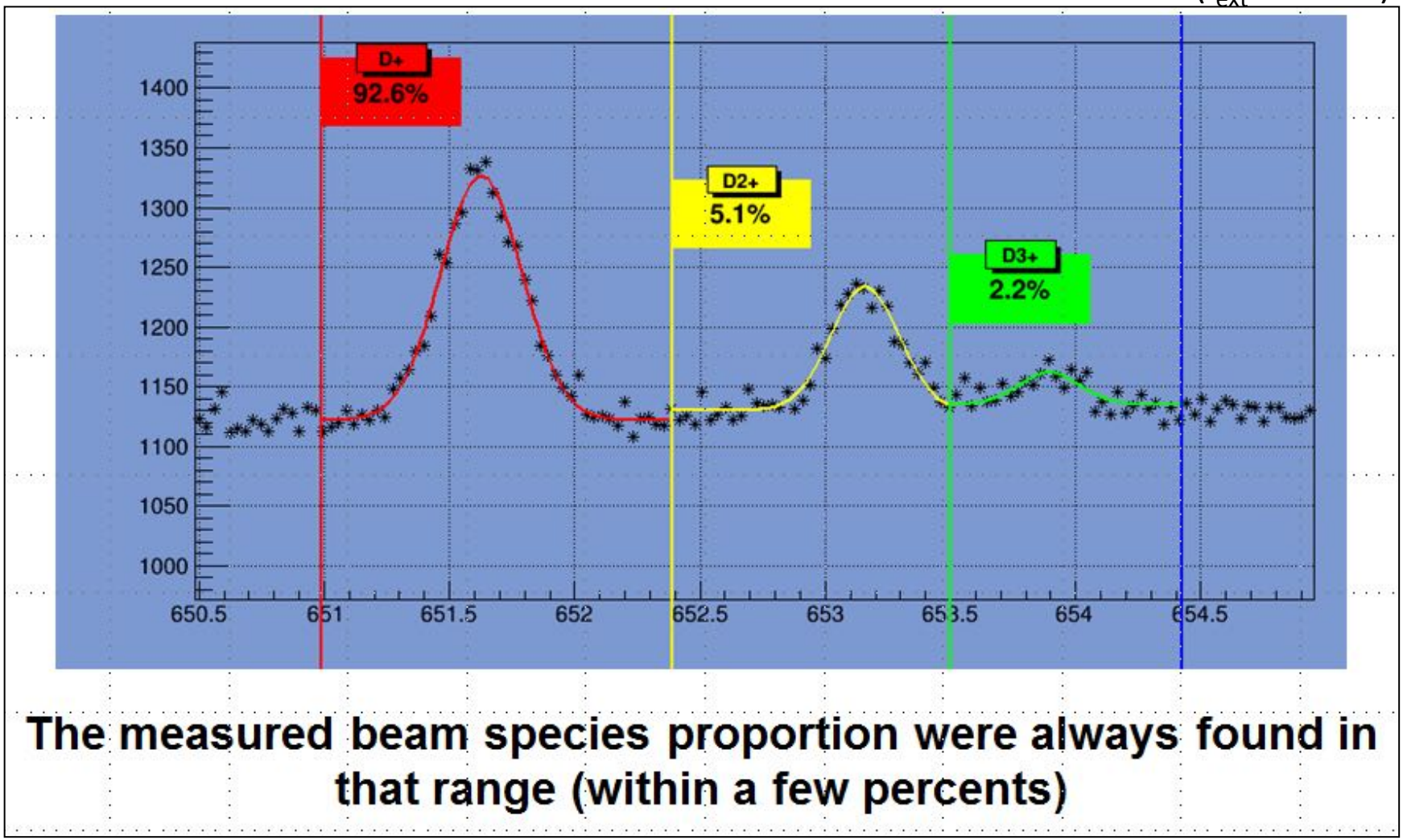
Beam voltage: 100 keV

10% duty

First D+ beam was obtained at

Beam species measurement (2017)

(I_{ext}=156mA)

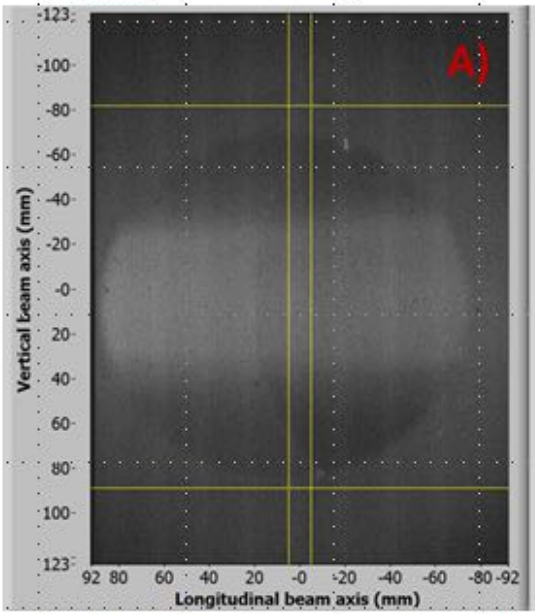


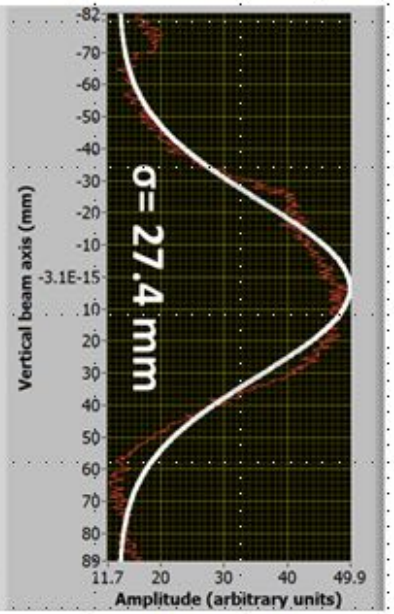
The measured beam species proportion were always found in that range (within a few percents)

Beam profile measurement (2017)

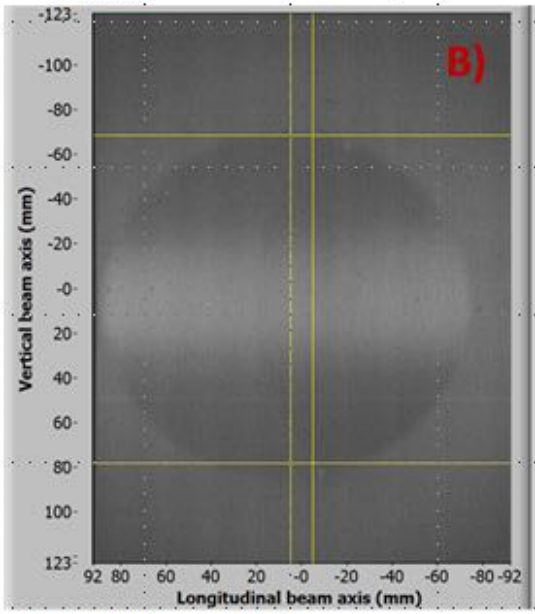
- Exposure time set to 30 s by performing average of images (no external trigger used)
- Gain of the MCP tuned to maximize the signal to noise ratio

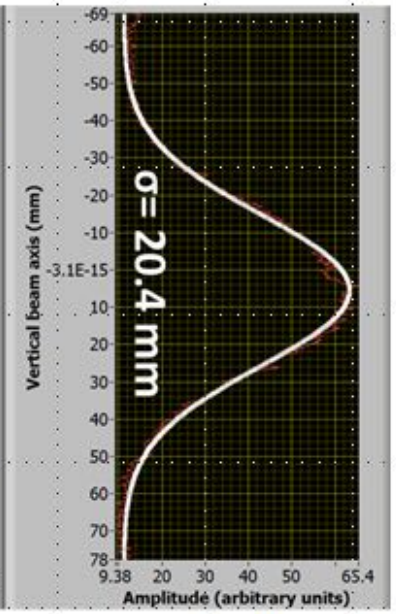
A) Iext= 156 mA; DC= 5.0% (VIE= 14 kV)





B) Iext= 116.5 mA; DC= 7.5% (VIE= 14 kV)





➢ Profile flattened (high space charge)

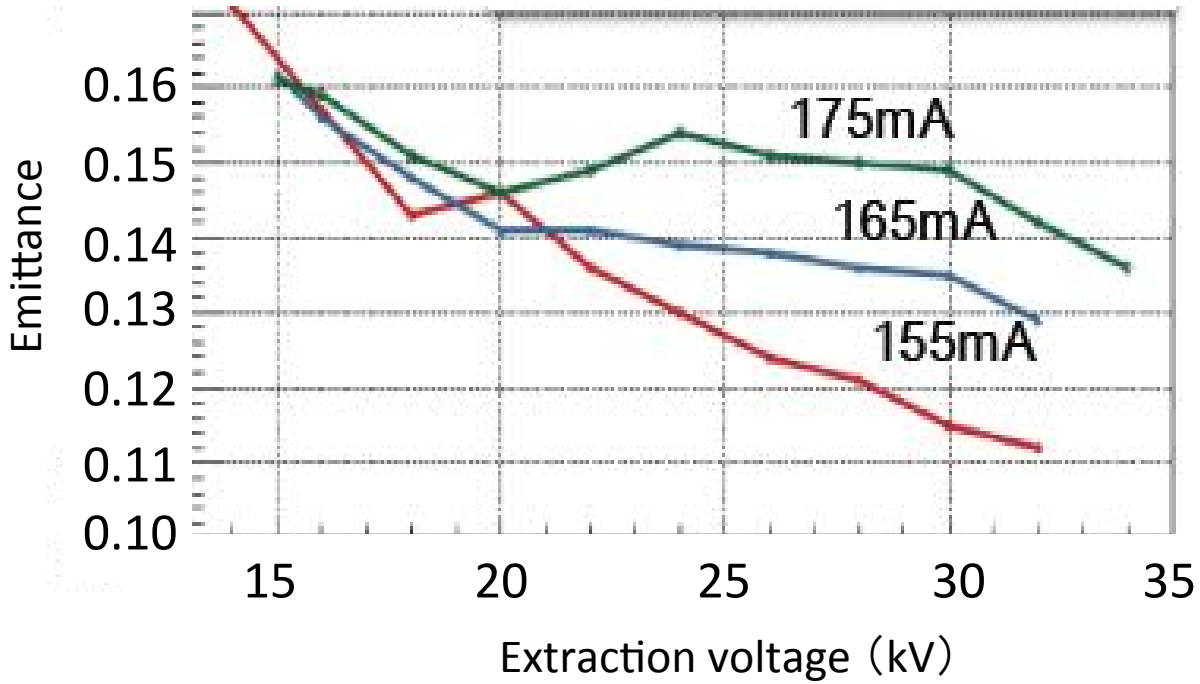
➢ Profile well Gaussian (lower space charge)

The intensified CID camera was tested successfully since the beam profile was measured with a sufficient signal to noise ratio at low duty cycle and for a beam of large size

Improvement to be done: Paint in black (baking) the vacuum chamber to avoid reflection

Beam Emittance measurement (2017)

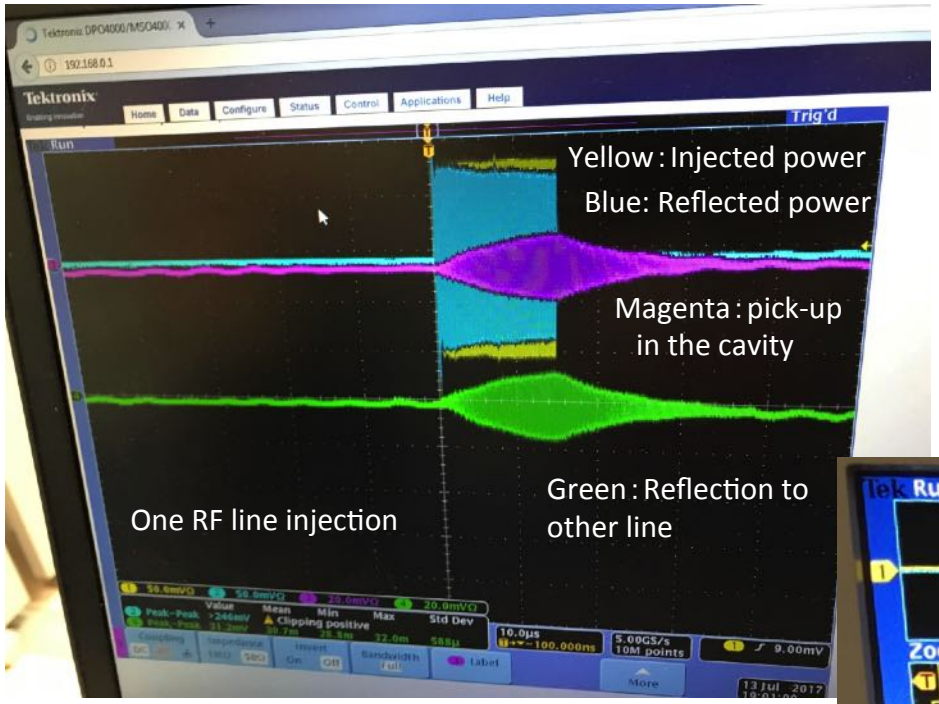
Injector Experiment (2017年10月ー)



D+ beam／100kV: Good Emittance of 0.15πmm•mrad was achieved.

(Initila target : <0.3πmm•mrad)

First RF injection to RFQ (July 2017)



(1) First step

Using 1 RF line

- low power（several kW）、short pulse 15μs、low duty（2Hz）
- ～10% power injection into the RFQ
- ～70% reflection from injected line、
- ～20% reflection to other lines (total)

(2) Second step

- Simultaneous injection from 8 RF lines（31 July 2017）
- White Rabbit

(3) Third Step

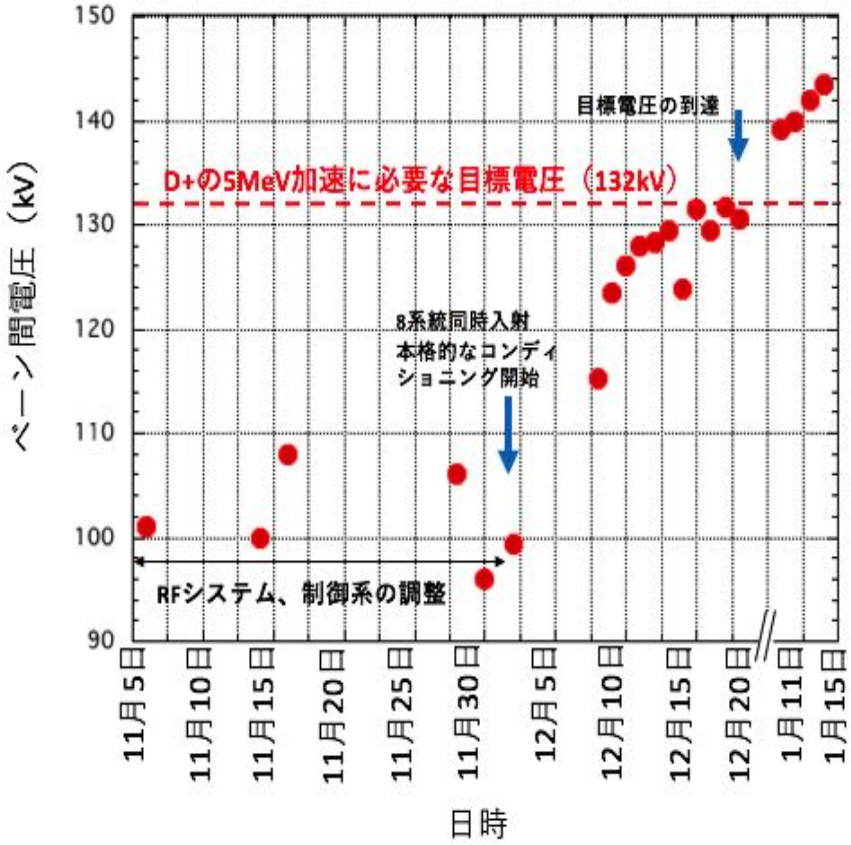
From October, RFQ conditioning has started.

RFQ RF conditioning with 8 RF modules

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

Our activities have entered into a new stage.

Status of RFQ Conditioning



<- Required Vane Voltage
for D+ beam acceleration

Short pulse (~20 microseconds)

RFQ Conditioning

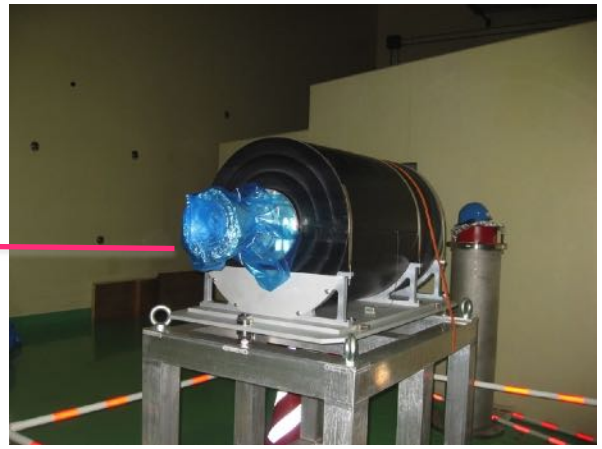
- Simultaneous Injection using 8 RF modules
- Voltage between the vanes : 143 kV (enough for D+ beam acceleration)

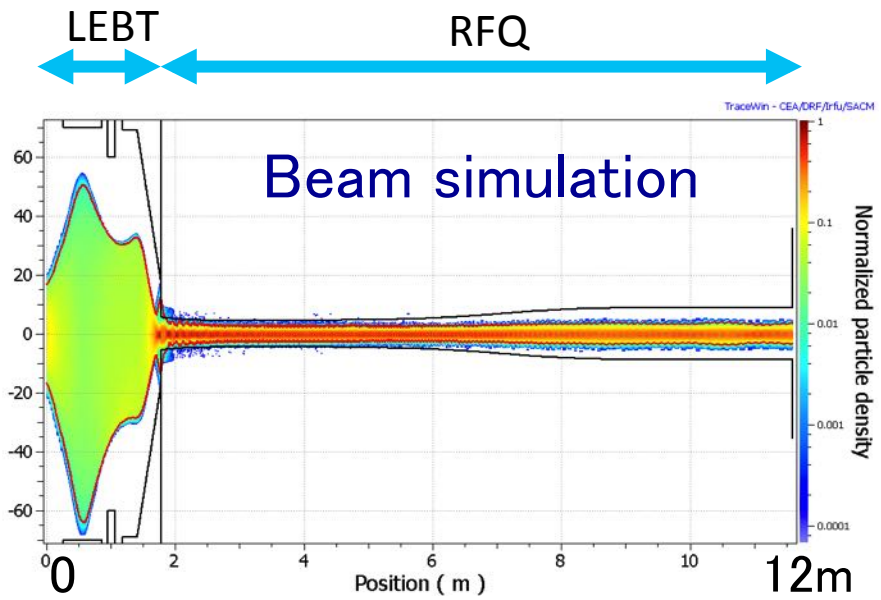
H+ beam acceleration commissioning

H+ beam acceleration commissioning will be started in February

Injector（100 keV/D^+140mA）

LPBD(Low power beam dump）





2.5MeV H+ beam acceleration
Duty 0.1%

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 D+ beam acceleration
  from 100keV to 5 MeV was achieved.

- H+ beam acceleration commissioning will be started soon.