Progress Report on LIPAc

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LINAC2018

Beijing, China – 16-21 September 2018

Linear IFMIF Prototype Accelerator (LIPAc)

Rokkasho Fusion Institute (BA Site)

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And many people not shown above have contributed and supported the LIPAc activities.

Contents

1. 1 IFMIF Plant Design

Accelerator Facility

D+ 40 MeV/10 MW CW, 200 x 50 mm^2 footprint, high stability

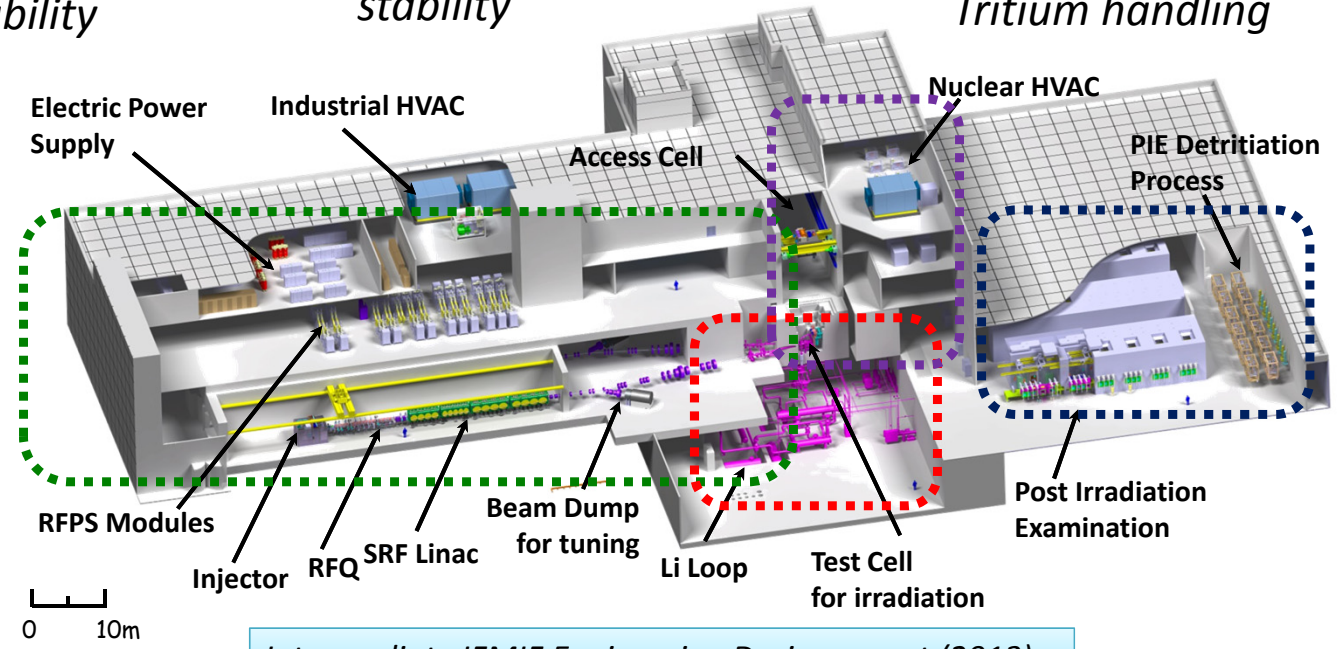
Lithium Target Facility

w260 mm x t25 mm, 15 m/s flow, impurity control, high stability

Test Facility

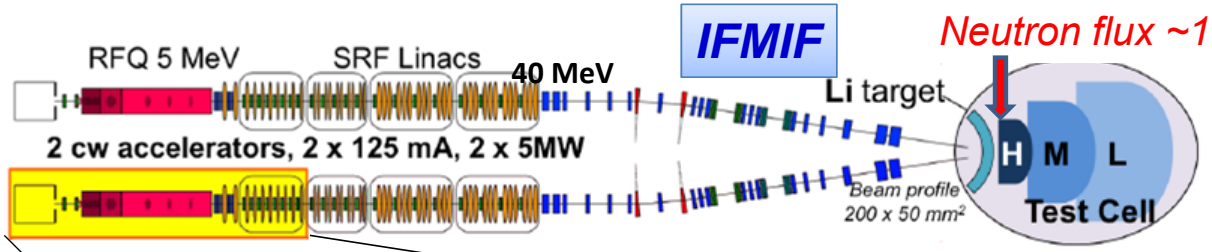
10^{17} n/s, T_{irrad} control, remote handling of activated materials, Tritium handling

PIE Facility



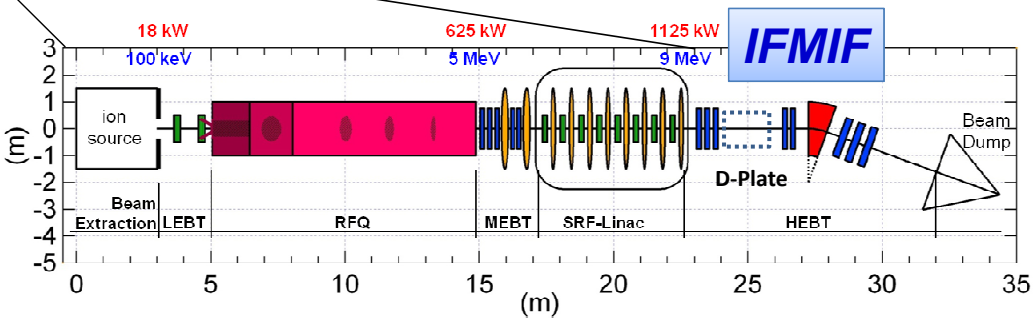
Intermediate IFMIF Engineering Design report (2013)

1.2 LIPAc – Staged Approach



Neutron flux ~10^{18} n/m^2·s

Volume of ***High flux area*** *>0.5 L for testing fusion reactor materials*



Validating low energy section up to 9 MeV (first SRF Linac)

As a backup plan, phase B-extended is discussed to validate high duty 5 MeV D+ beam acceleration by RFQ.

Beam commissioning with staged approach

Phase A → **Phase B** → **Phase C/D**

Injector		Diagnostic Box + Beamstop	*(Apr.2015 - Aug.2017)*
Injector	RFQ + MEBT	D-Plate + Low Power Beam Dump	*(Jun.2018 -)*
Injector	RFQ + MEBT	SRFL + HEBT/D-Plate	Final Beam Dump

1.3 LIPAc – Responsibility Sharing

JOINT WORK FOR INTEGRATION

System Installation, Checkout, Start-up, Commissioning
LIPAc Unit in Rokkasho
~50 people

- *Machine operation*
- *Beam Physics*
- *Injector & Diagnostics*
- *Control System*
- *Transport Line*
- *RF & Cavities*
- *Ancillaries and Maintenance*

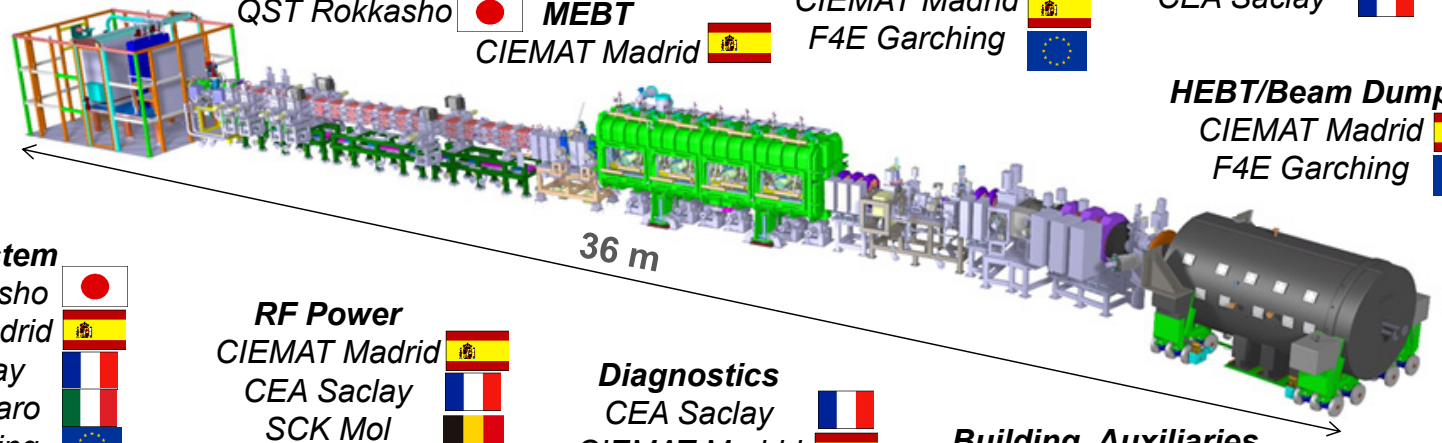
Injector
CEA/Saclay

RFQ
INFN Legnaro
F4E Garching
QST Rokkasho

MEBT
CIEMAT Madrid

SRF Linac
CEA Saclay
CIEMAT Madrid
F4E Garching

Cryoplant
CEA Saclay



HEBT/Beam Dump
CIEMAT Madrid
F4E Garching

Control System
QST Rokkasho
CIEMAT Madrid
CEA Saclay
INFN Legnaro
F4E Garching

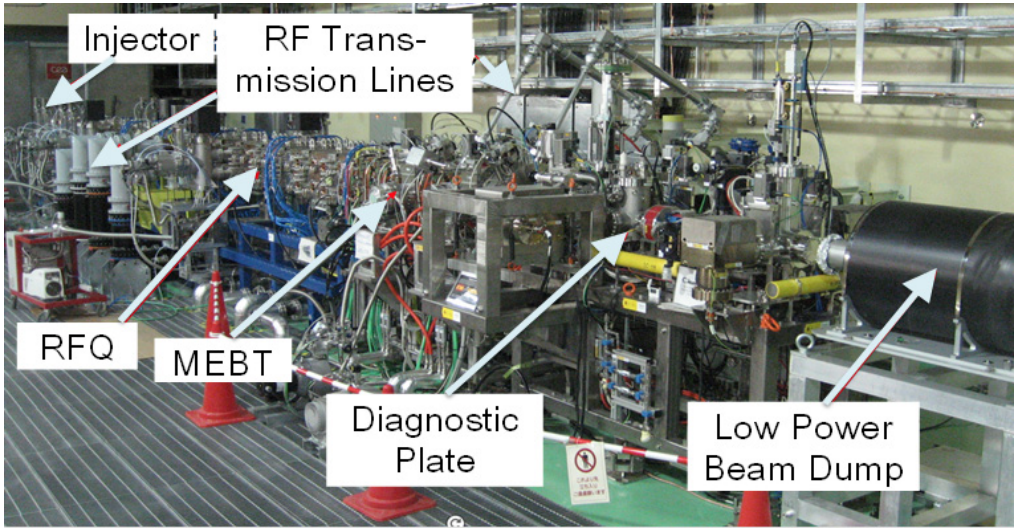
RF Power
CIEMAT Madrid
CEA Saclay
SCK Mol

Diagnostics
CEA Saclay
CIEMAT Madrid
INFN Legnaro

Building, Auxiliaries, Infrastructure
QST Rokkasho

1.4 LIPAc – RFQ Commissioning

Phase B installation was completed in October 2017.



Jul.'17: RFQ RF conditioning was started

Feb.'18: RFQ cavity voltage reached 132 kV (D+ acc. Level) @ short pulse 20 μm

Jun.'18: 50 keV H+ beam commissioning was started

Phase A → **Phase B** → **Phase C/D**

Injector — Diagnostic Box + Beamstop

Injector | RFQ + MEBT — D-Plate + Low Power Beam Dump *(Jun.2018 -)*

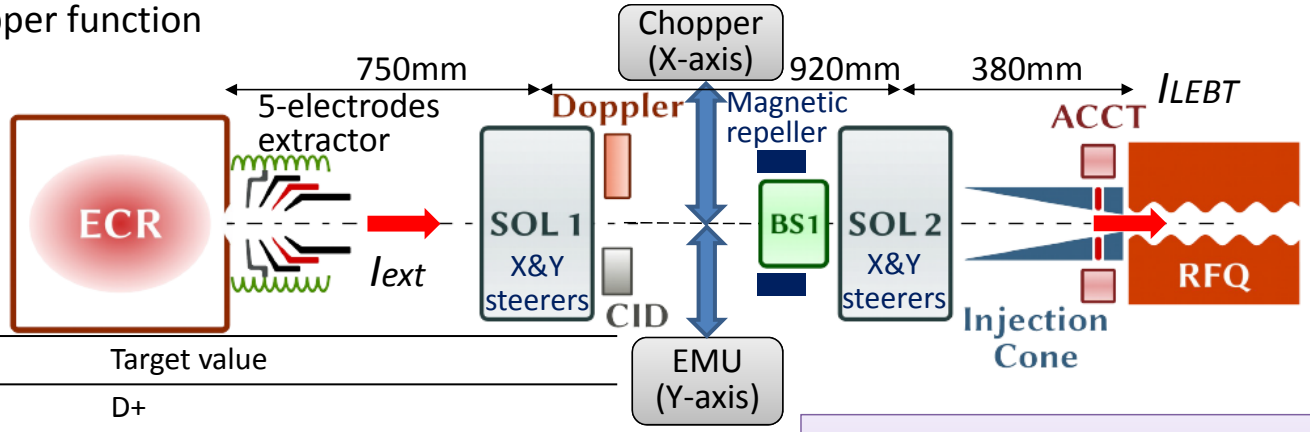
Injector | RFQ + MEBT | SRFL + HEBT/D-Plate — Final Beam Dump

Contents

2.1 Status of LIPAc – Injector

Before starting RFQ beam commissioning (phase B), working points for beam injection into RFQ were surveyed:

- D+ 100 keV/140 mA (plasma electrode (PE) with **12 mm** ϕ – *original design*)
- H+ 50 keV/70 mA or lower (PE with 9 or 6 mm ϕ – *newly fabricated*)
- Chopper function



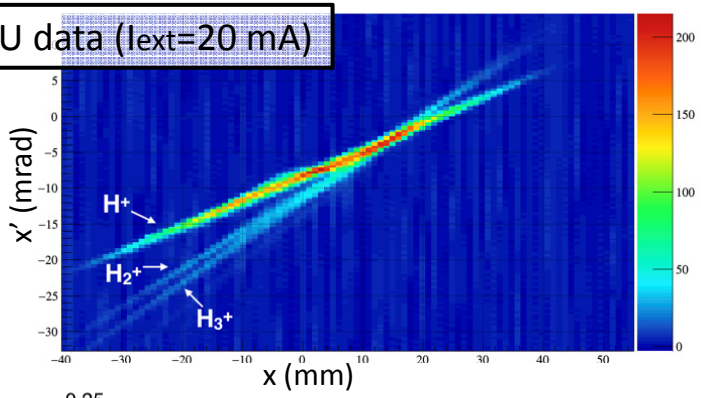
Requirements	Target value	
Particles	D+	
Output energy	100 keV	*(H+ 50 keV, 70 mA for system tuning)*
Output D+ current	140 mA	
D+ fraction	99%	*(at injection cone exit)*
Beam current noise	1% rms	
Emittance, norm. rms	0.25π mm mrad *(0.3π mm mrad for acceptance)*	
Duty factor	CW	

Diagnostics:

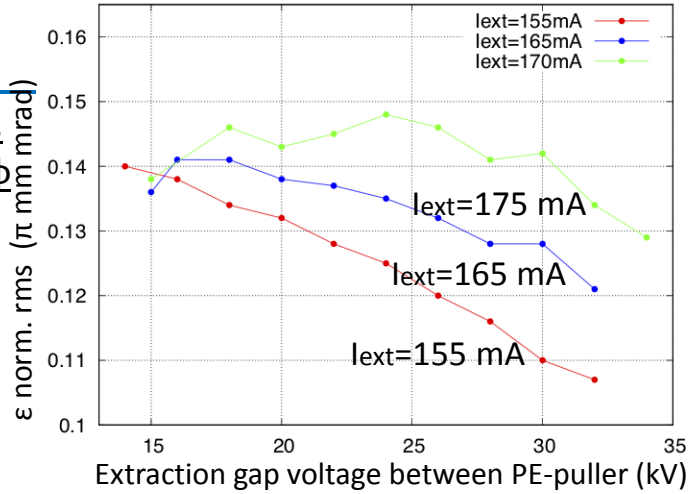
- Allison type emittance scanner (EMU)
- Doppler shift spectrometer – ion species
- Beam profiler using CID or CCD camera
- Beam stopper (BS1) - beam current

2.1 Status – Injector

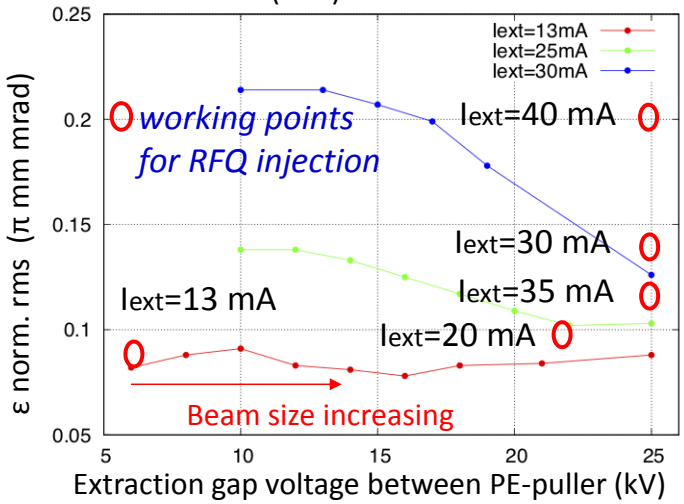
Typical EMU data (Iext=20 mA)



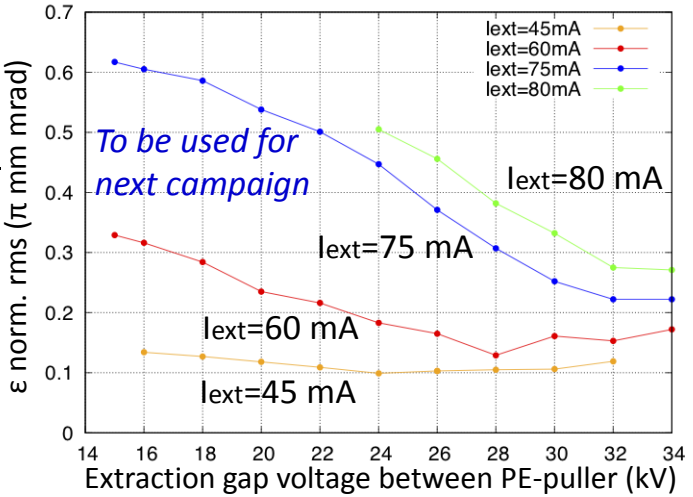
D+ 100 keV,
PE 12 mm ϕ



H+ 50 keV,
PE 6 mm ϕ



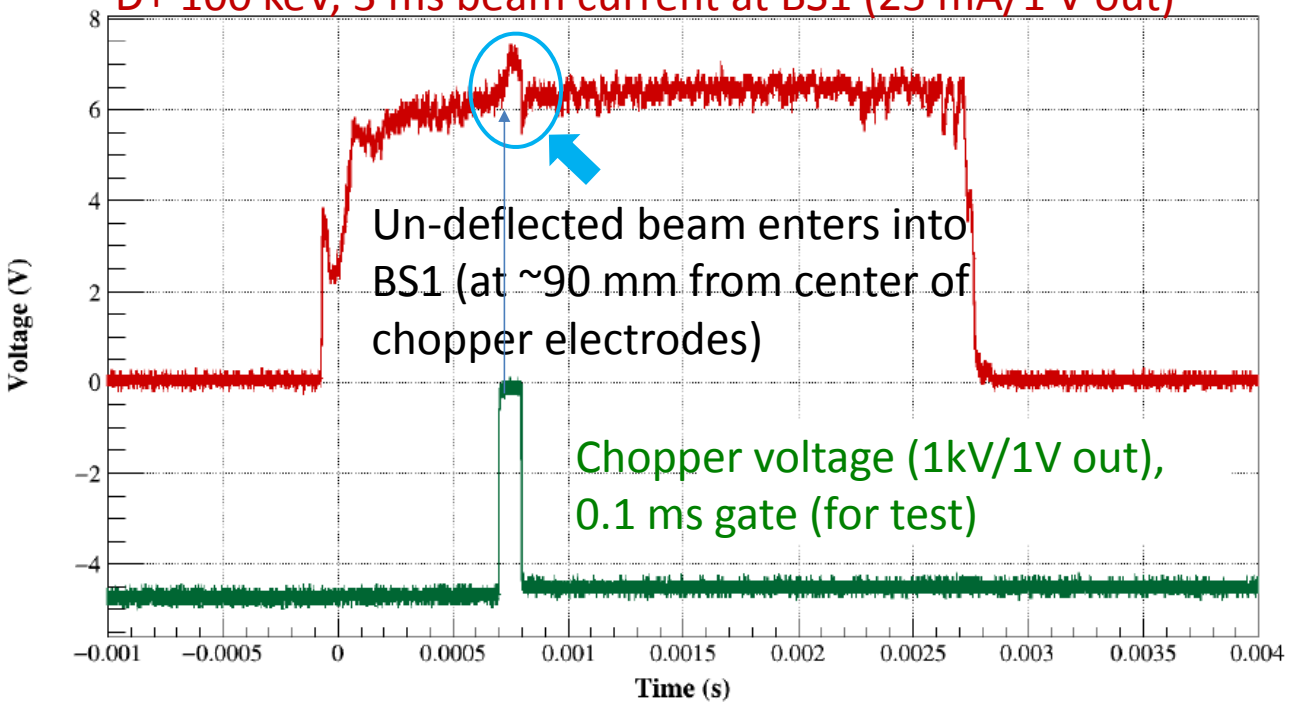
H+ 50 keV,
PE 9 mm ϕ



Detailed technical results will be presented in the other conferences, SOFR718 and FEC'18.

2.1 Status – Injector (chopper)

D+ 100 keV, 3 ms beam current at BS1 (25 mA/1 V out)



Chopper has entrance & exit holes (100 mm ϕ) to protect two deflection electrodes, HV (0 ~ -10 kV) and GND (size: W136 x L150, gap: 110 [in mm]).

For RFQ beam commissioning, HV=-5 ~ 7 kV, 0.3 ms gate width was used.

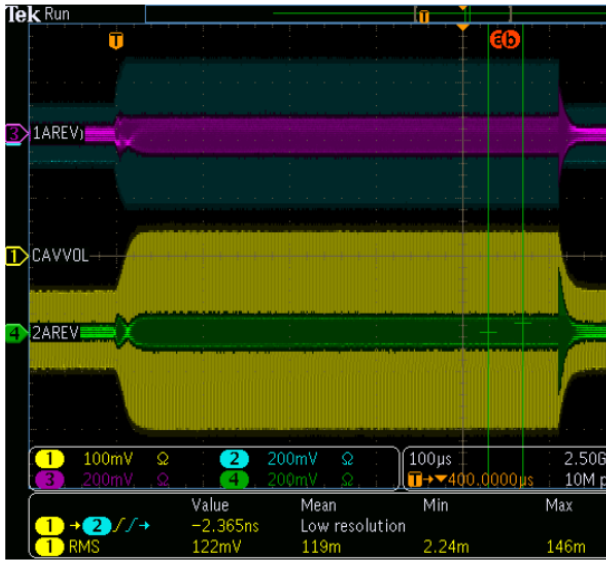
2.2 Status – RFQ, beam loading

Beam loading compensation with 7-RF chains operation

- Feedback system of master (#1A) +7 slave (#1B,#2A..#4B) RF chains using White Rabbit synchronization worked properly in beam operation:
  the forward power was increased to keep the power in RFQ cavity.

Base CW component is required for stable operation.

no beam (7 out of 8 chains running)



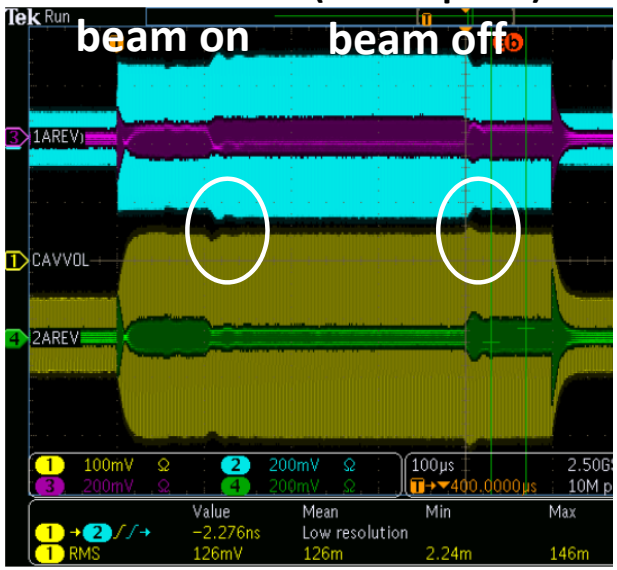
1A Ref

1A Fwd

2A Ref

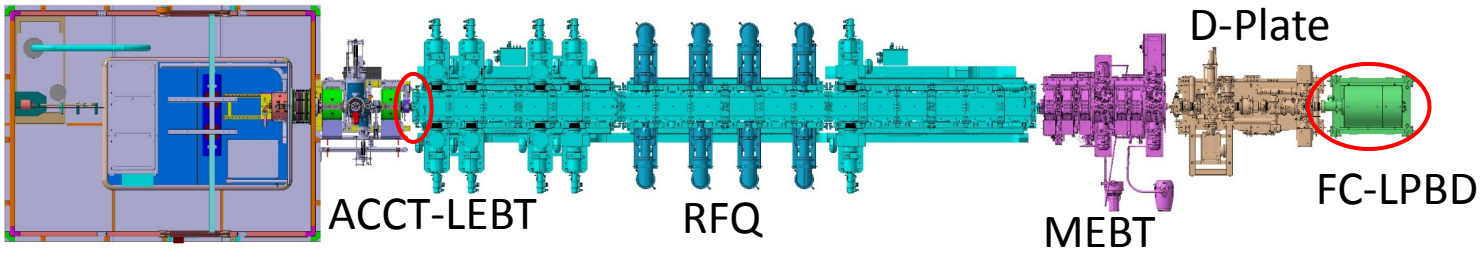
RFQ Cavity

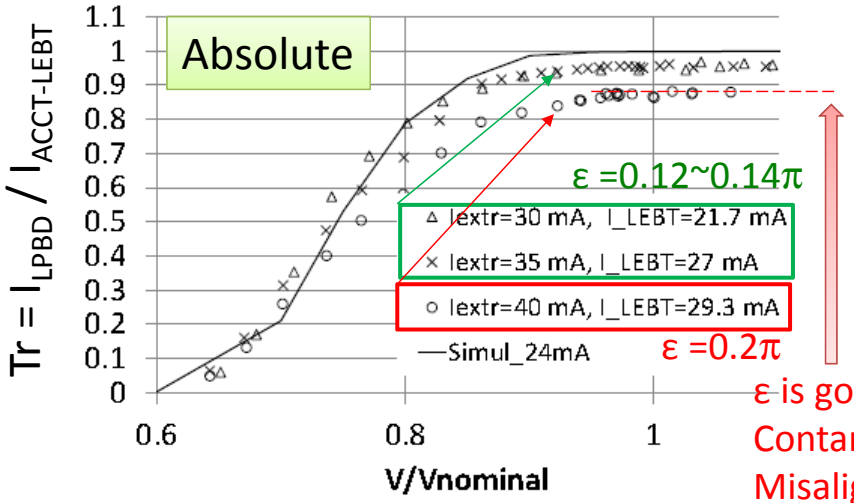
with beam (0.3 ms pulse)

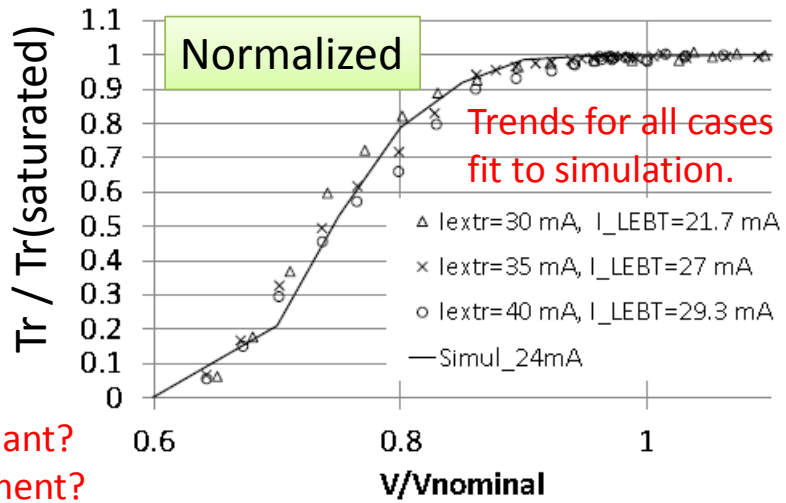


2.2 Status – RFQ, transmission

Transmission of beam from LEBT to LPBD vs. Cavity voltage



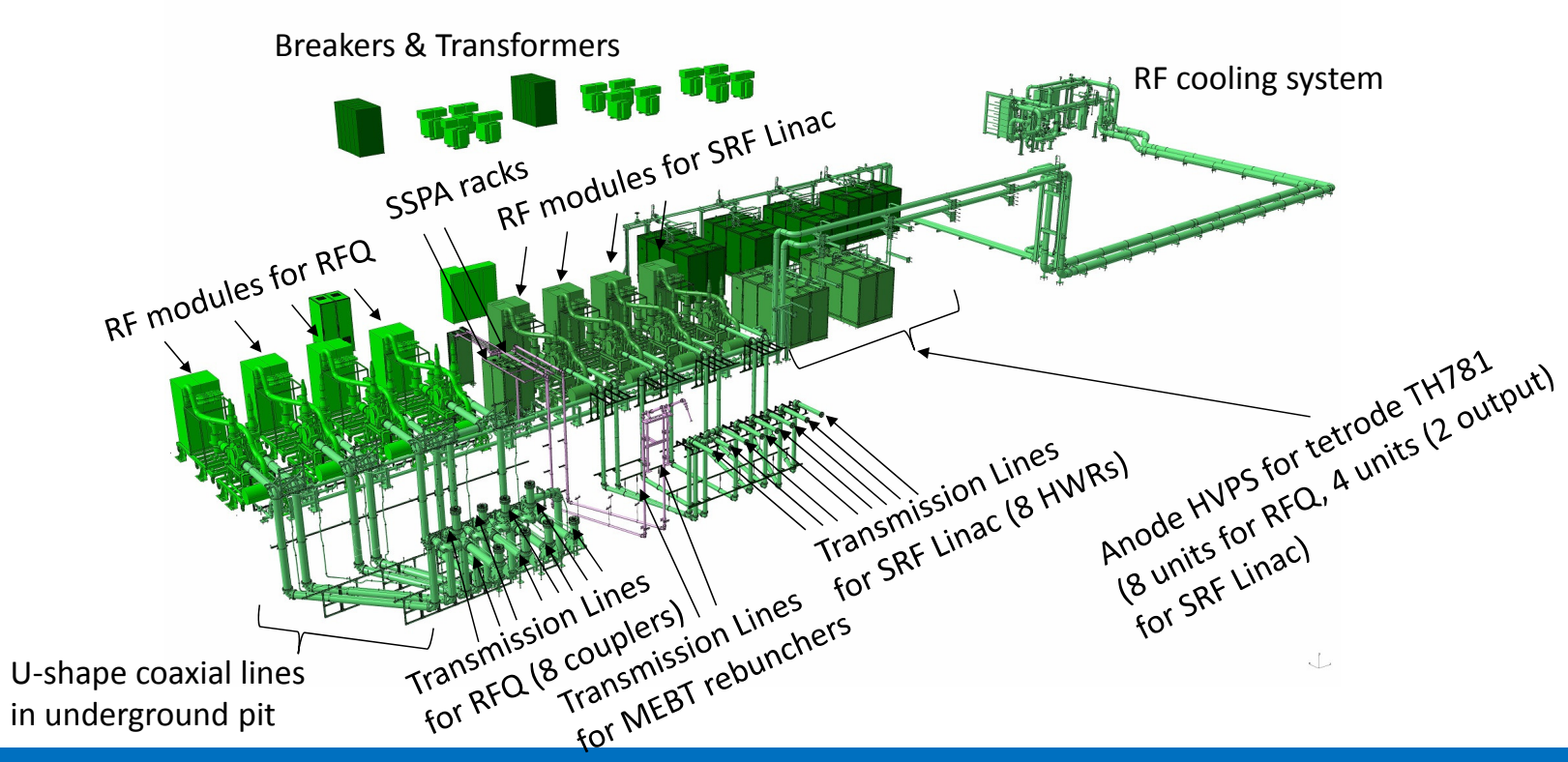




Please visit THPO062 "IFMIF/EVEDA RFQ Preliminary Beam Characterization" for more details.

2.3 Status – RF Power System

Components are mostly installed, and systems for RFQ and MEBT rebunchers are already running. Function test of systems for SRF Linac is started in 2018.

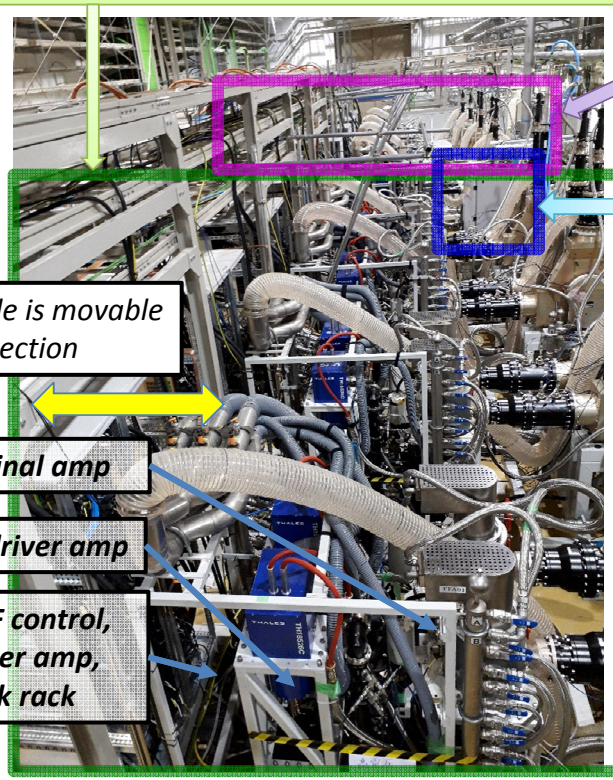


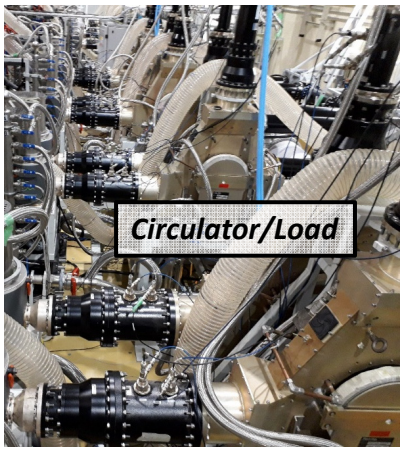
2.3 Status – RFPS, installation status

8 x 200 kW tetrode system for RFQ (2 chains per module)

8 x 105 kW tetrode system for SRF linac HWRs

2 x 16 kW SSPA system for MEBT rebunchers

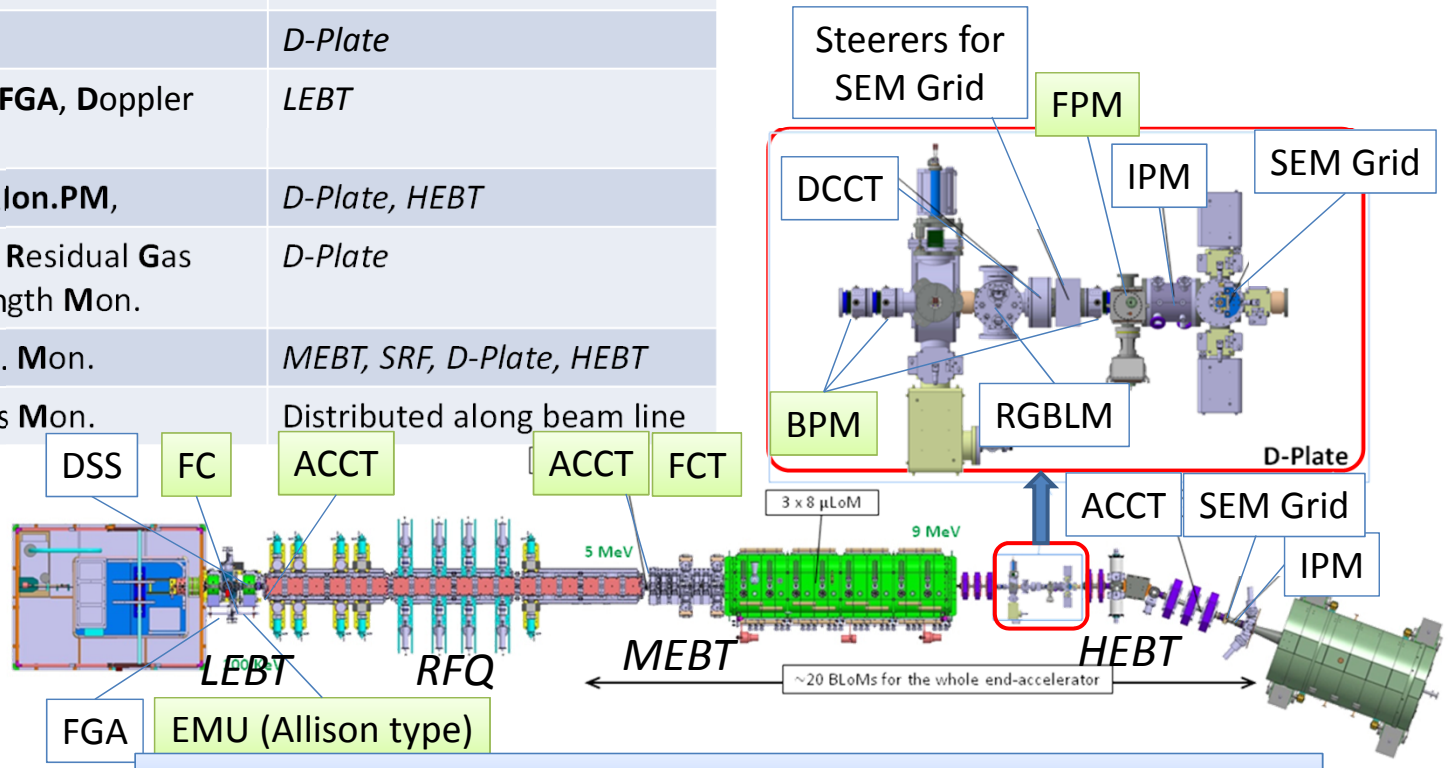




2.4 Status – Beam Diagnostics

Device	*Location(s)*
ACCT	*LEBT, MEBT, D-Plate, HEBT*
Fast **CT**	*MEBT*
DCCT	*D-Plate*
FC, **EMU**, **FGA**, **D**oppler **S**hift **Sp.**	*LEBT*
SEM Grid,**Ion.PM**,	*D-Plate, HEBT*
Fluor.PM, **R**esidual **G**as **B**unch **L**ength **M**on.	*D-Plate*
Beam **Pos. M**on.	*MEBT, SRF, D-Plate, HEBT*
Beam **Loss M**on.	Distributed along beam line

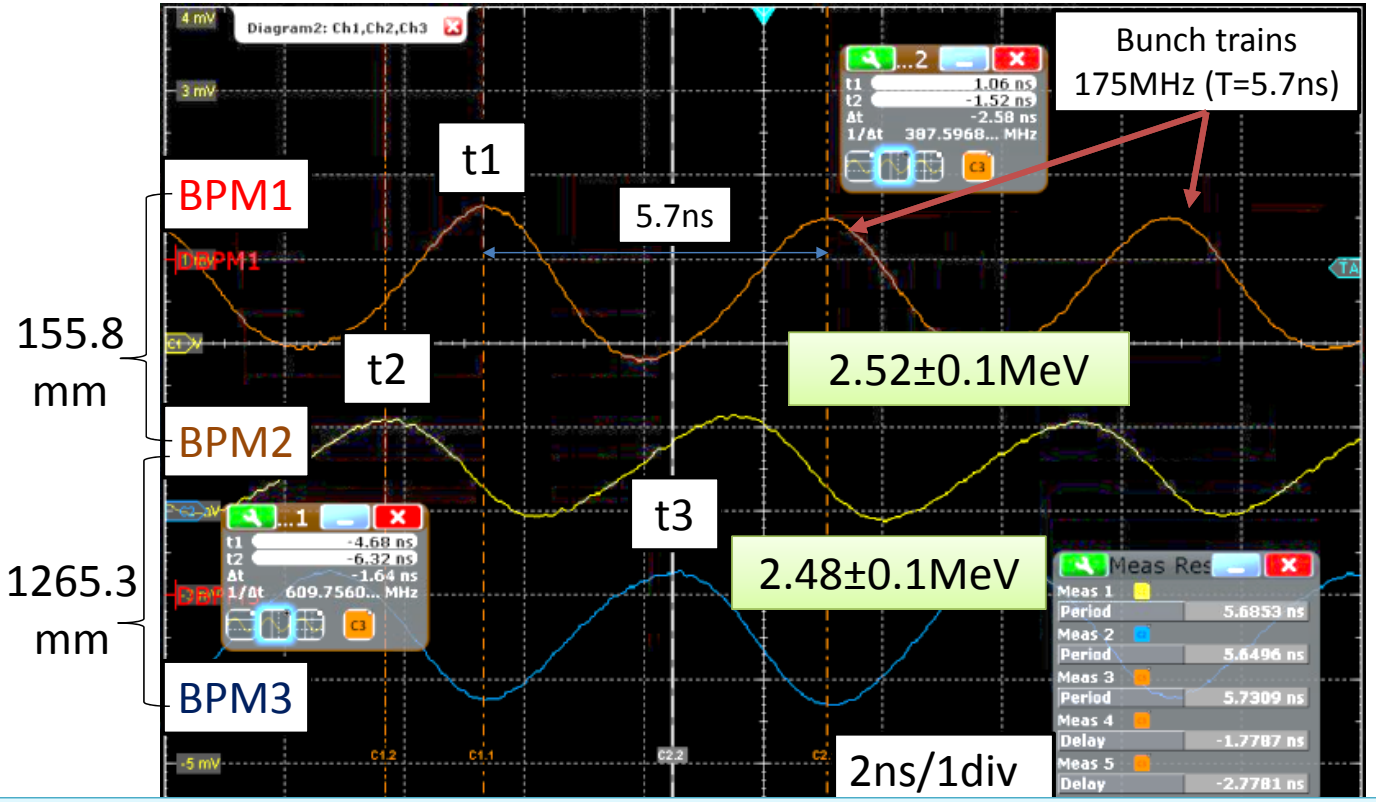
Beam diagnostics used in phase B1 commissioning (June – August 2018)



Other beam diagnostics will be used in the next campaign.

Beam Energy Measurement using TOF Method

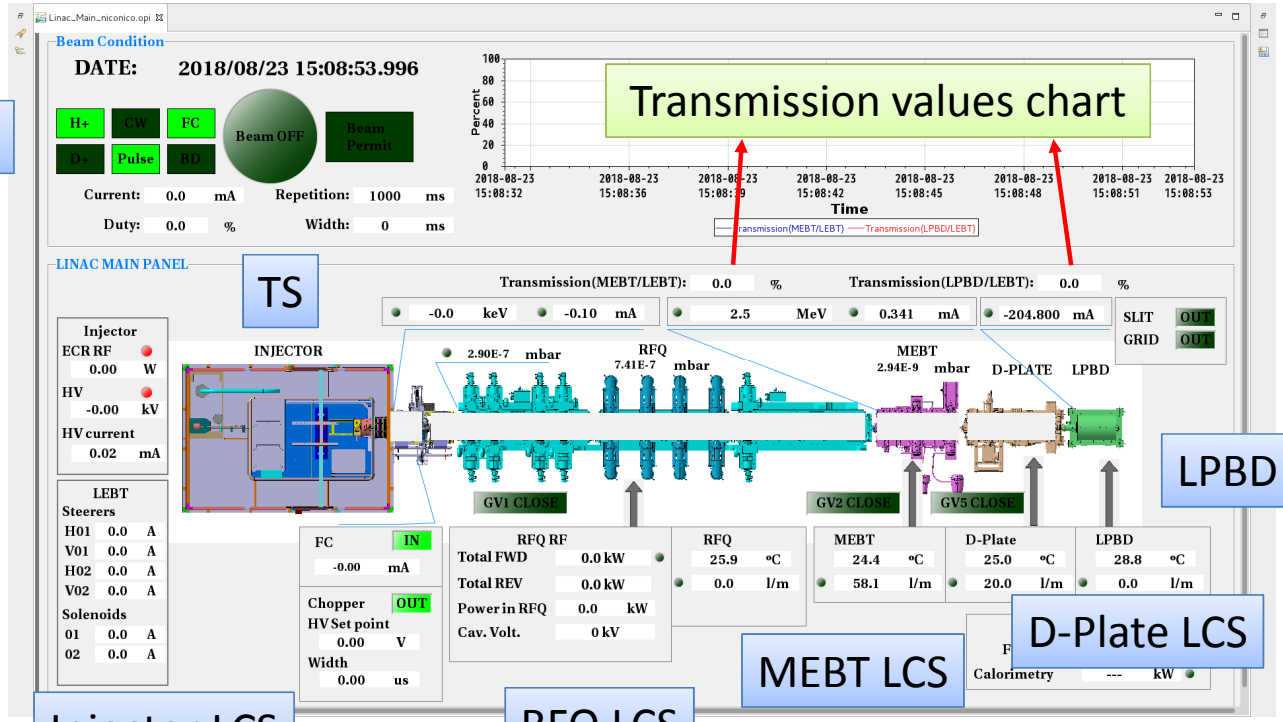
By measuring time differences among 3 BPM signals, TOF was estimated.



Please visit THPO062 "IFMIF/EVEDA RFQ Preliminary Beam Characterization" for more details.

2.5 Status – Control System

- Integration of local control systems to central control is progressed.
- Beam particle number counting at LEBT-ACCT is working for licensing need.

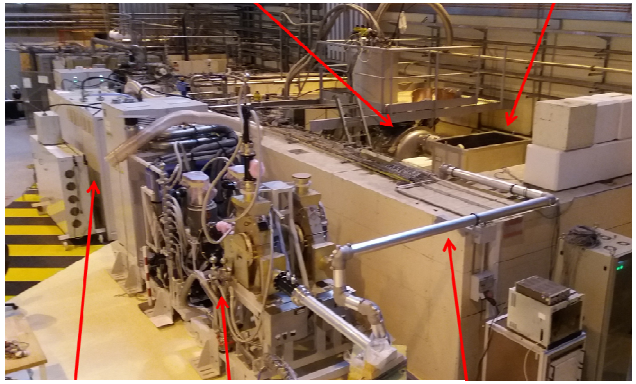


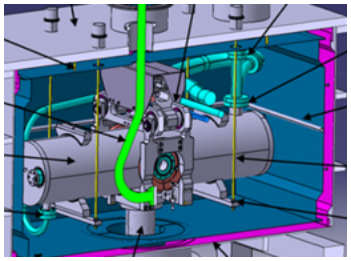
2.6 Status of LIPAc – SRF HWR

SaTHoRI Test stand at Saclay

CryoHoLab

SaTHoRI



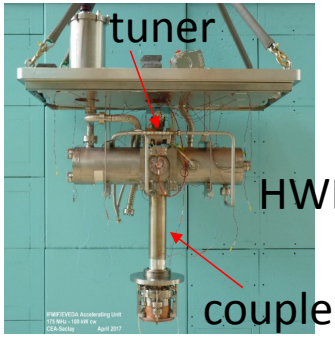


HVPS RF module (2x105 kW)

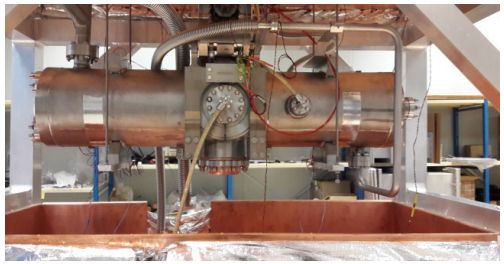
Coaxial line

High power and Tuner function test

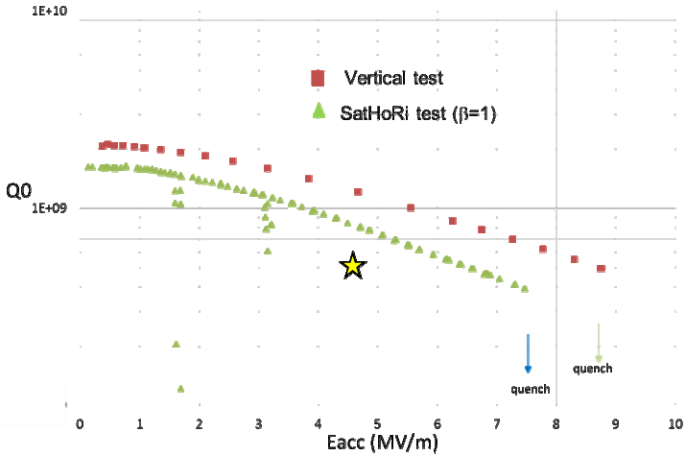
2 HWRs were tested, and confirmed the required performance (>4.5MV/m, δf >50kHz).



Critical coupling test



Q_0 @ E_{acc_nom}=4.5 MV/m: 8x10^8
> specification (5x10^8)

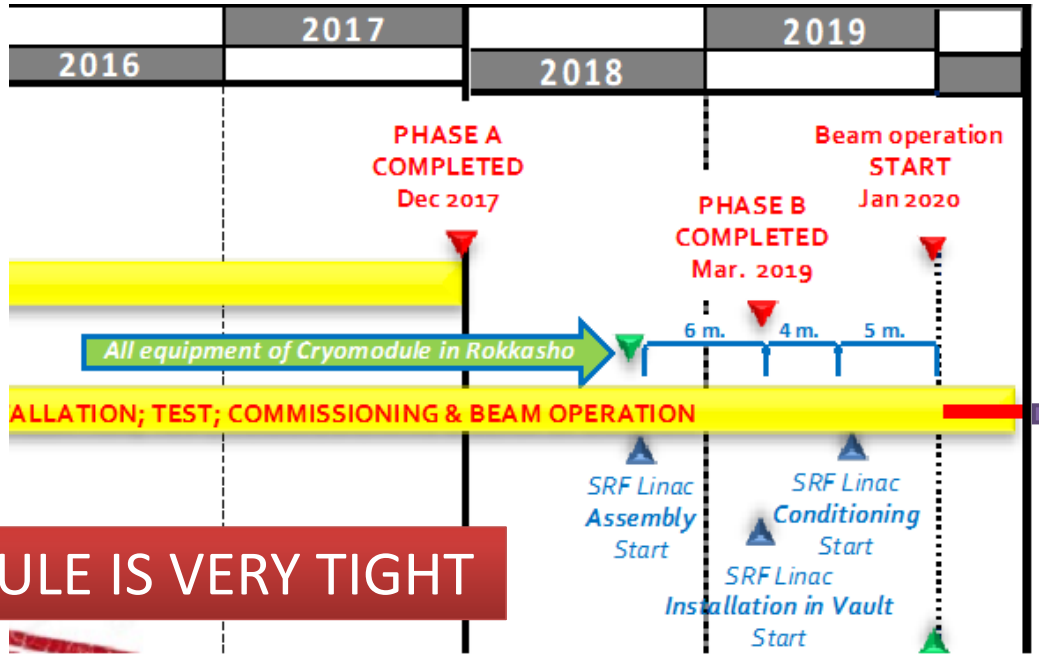


2.6 Status of LIPAc – SRF Assembling

- **Clean room**: built at Rokkasho in August 2018.
- **Coupler**: 3 pairs of manufactured 8 power couplers conditioned up to 100 kW. Conditioning of final pair is ongoing.
- **Superconducting solenoid**: under manufacturing. Ready by end of 2018 for the assembly.
- **Cryoplant**: plant was installed and commissioned in April 2017.
- **Assembly work of SRF linac**: waiting for the completion of delivery of the last components in Rokkasho.

3. Schedule

'07 – '17: System design; Fabrication; Test & Delivery in Rokkasho
'18 - : All equipment of Cryomodule in Rokkasho to start SRFL assembly
'14 – '20: Assembly; Installation; Test; Commissioning & Beam Operation
'19 – Jan. '20: SRF commissioning start; Final beam operation start



5 years extension of activity is under discussion.

SCHEDULE IS VERY TIGHT

4. Conclusions

- Kick-off of the RFQ beam commissioning achieved in June 2018.
- Initial data of RFQ beam transmission gave a good sign of RFQ design validity (@ H+, 50 keV, 35 mA, duty 0.3 ms / 1 Hz).
- Beam profile, emittance and bunch length were examined. It was uncompleted in the first campaign.
- H+ 50 keV/70 mA and D+ 100 keV/140mA beams satisfied required emittance. Ready for test in the next campaign.
- RFQ RF conditioning for high current D+ to be continued.
- Assembly work of SRF linac is waiting for completion of delivery of the last components in Rokkasho.

THANKS A LOT
FOR YOUR ATTENTION!

谢谢