The Linear IFMIF Prototype Accelerator (LIPAc)

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Introduction

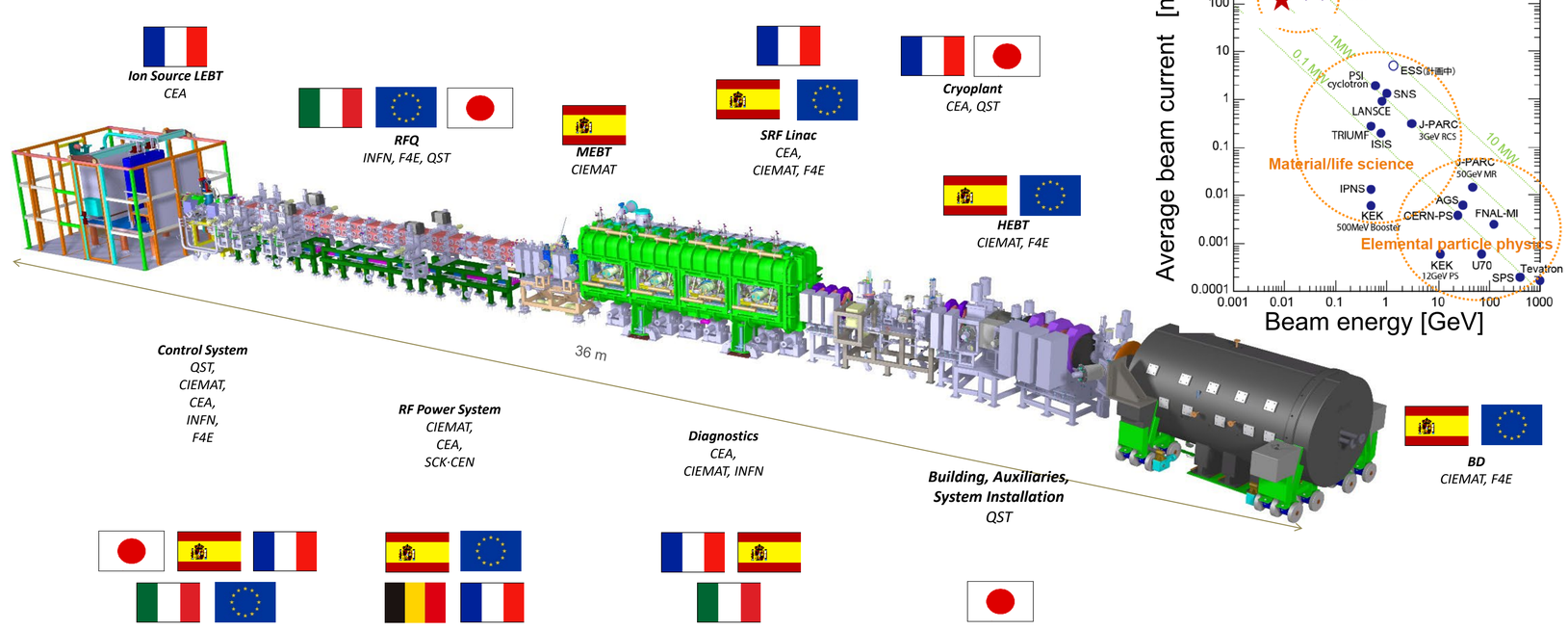
The goal of the International Fusion Materials Irradiation Facility (IFMIF) is to provide an accelerator-based, D-Li neutron source to produce high energy neutrons at sufficient intensity and irradiation volume for DEMO materials qualification. DEMO will follow the ITER project and will be the first of a kind fusion Power Plant with net electricity input in the grid. The IFMIF/EVEDA project is part of the Broader Approach (BA) agreement between Japan and Europe, with important contribution from Italy. In addition to the evolution of the engineering design, the key technological challenges are to be validated by prototyping projects. One of them is the construction, commissioning and validation of the Linear IFMIF Prototype Accelerator (LIPAc) that will operate at 125 mA Continuous Wave (CW) deuteron current up to 9 MeV.

LIPAc current status

The LIPAc in its current configuration operates with D+ and consists of a 100 keV injector, a 5 MeV Radio Frequency Quadrupole (RFQ) accelerator, a medium and high energy beam transport lines and a beam dump. In its final configuration it will include a Half-Wave Resonator-Superconductive RF (HWR-SRF) linac and will target to commission a D+ beam of 125 mA CW at 9 MeV. A temporary transport line is currently replacing the SRF linac.
In 2019 the beam commissioning campaigns achieved to accelerate a 125 mA D+ beam through the RFQ at low duty cycle of ~0.1 %. In 2021 and 2022 extensive experimental campaigns have been carried out on the injector and RFQ targeting CW operation. The injector campaign aims at identifying the best configuration for operating at CW and nominal beam current. The RFQ operation aims at reaching RFQ conditioning at CW at nominal voltage of 132kV.

Accelerator requirements of LIPAc in comparison with IFMIF:

Primary Parameters	LIPAc	IFMIF	Units
Number of Linacs	1	2	
Duty factor	CW	CW	
Ion type	D^+	D^+	
Beam intensity on target	125	2 x 125	mA
Beam kinetic energy on target	9	40	MeV
Beam Power on target	1.125	2 x 5	MW
RF Frequency	175	175	MHz
Target material	Cu	Li	
Total length	34.00	84.69	m
Injector length	5.05	5.05	m
RFQ length	9.81	9.81	m
MEBT length	2.35	2.35	m
SRF Linac length	4.64	22.42	m
Number of cryomodules	1	2 x 4	
HEBT total length	9.65	45.06	m



Installation and Commissioning: LIPAc Phases

Phase A – (Ion source):
Target deuteron beam production: **140 mA-100 keV**
Deuteron beam performance to date:
@100keV, V_{IE}:43kV,
I_{BS}:109 mA (I_{ACCT}: 114 mA, I_{ext}:152mA)
9.7% d.c., $e_{rms,n}$:0.233 π mm.mrad).

Phase B (Ion source + RFQ + MEBT + Dplate + RF Power System):
Installation started: March 2016
Commissioning up to 5 MeV completed July 2019
Highest ion beam current with a linac in the World

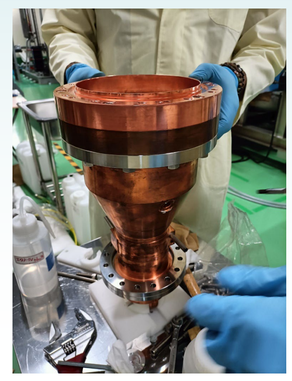
Phase B+ (Ion source + RFQ + MEBT + MEL transport line + HEBT/BD + RF Power System):
Commissioning up to 5 MeV target to complete by end of 2023

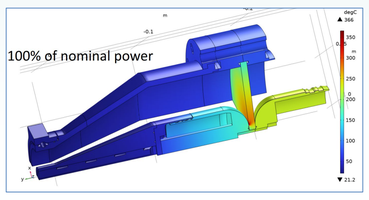
Phase C + D (Ion source + RFQ + MEBT + SRF Linac + HEBT/BD + RF Power System):
Integrated commissioning of the LIPAc up to 9 MeV:
- in pulsed mode(Phase C),
- continuous wave operation (Phase D)

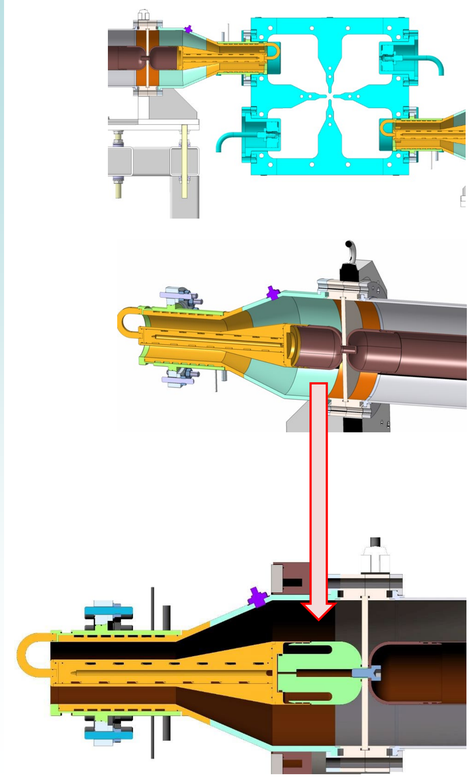
Recent upgrades

Redesign of RFQ coupler anchor by INFN

- ✓Driven by observed temperature-dependent vacuum leak (o-ring damage)
- ✓Solution supported by extensive analysis
- ✓Thermal dissipation improved by secondary path through layer of thermal paste
- ✓Prototype procured and tested in Japan
- ✓Anchors substituted in all RFQ couplers

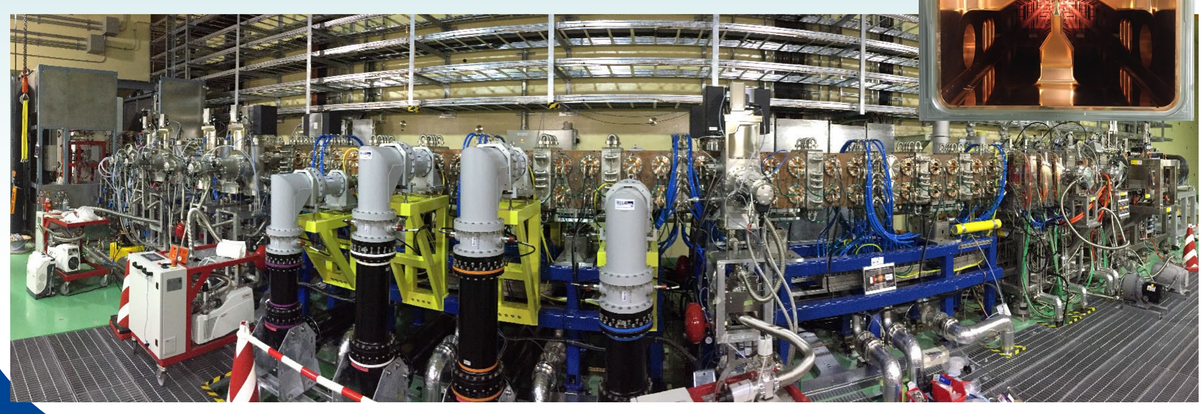






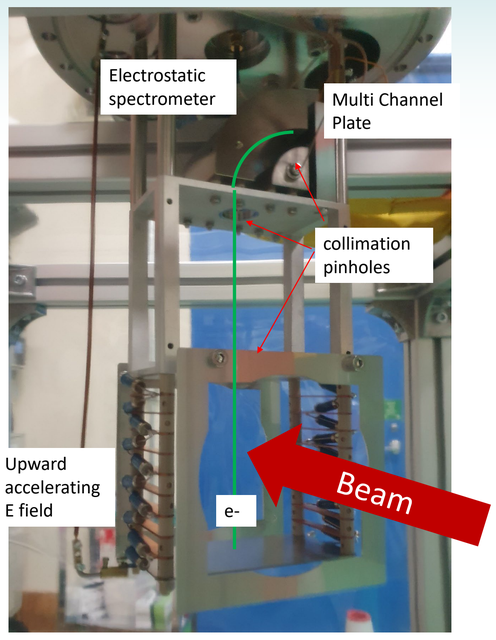
INFN contributions: RFQ and RGBLM

Main target: resonant RF cavity to transport, bunch and accelerate the DC beam from 0.1 to 5 MeV.
- Nominal frequency of 175MHz @132kV vane voltage fixed using static tuners
- Cooling system used for fine RF tuning (driven by the temperature difference between electrodes and the external body of the cavity).
- Vacuum system based on cryogenic pumps
- Overall length 9.81 m (the longest ever built)

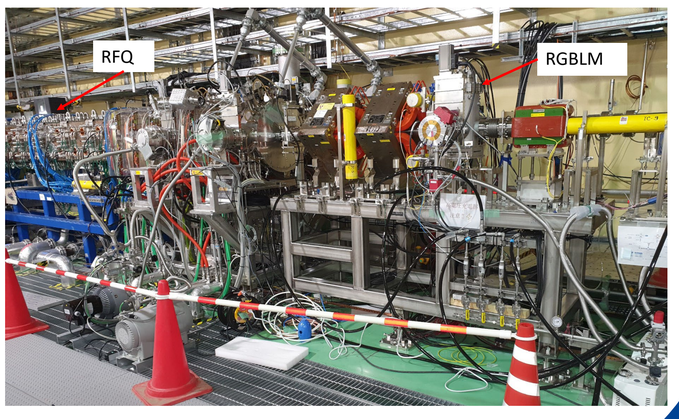


Accelerator fisheye view with RFQ at the centre; (top) internal view of RFQ

Residual Gas Bunch Length Monitor: measures the arrival time of secondary electrons from beam induction ionization of rest gas (~10^{-8}mBar) Vs. the RFQ accelerating RF signal phase



- rms accuracy ± 20ps
- validated at INFN-LNL ALPI beam line
- under commissioning in Rokkasho



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