Commissioning Plan of the IFMIF-DONES Accelerator

I.Podadera[1,2], J. Aguilar[3], F. Arranz[2], S. Becerril[3], L. Bellan[4], D. Bernardi[5], B. Bolzon[6], P. Cara[7], J. Castellanos[8], N. Chauvin[6], S. Chel[6], T. Dézsi[9,10], A. Ibarra[1,2], M. Ferreira[11], M. Garcia[2], J. Gutiérrez[12], V. Hauer[13], D. Jímenez-Rey[2], W. Królas[14], B. Kumar[15], T. Lehman[13], M. Luque[3], L. Macià[15], A. Madur[6], J. Maestre[3], C. Martins[11], G. Micchiché[5], J. Molla[2], C. de la Morena[2], F.S. Nitti[5], C. Oliver[2], A. Palmieri[4], A. Pisent[4], C. Prieto[12], Y. Qiu[13], D. Regidor[2], D. Sánchez[3], M. Sanmartí[15], C. Torregrosa[3], M. Weber[1,2], U. Wiacek[14]

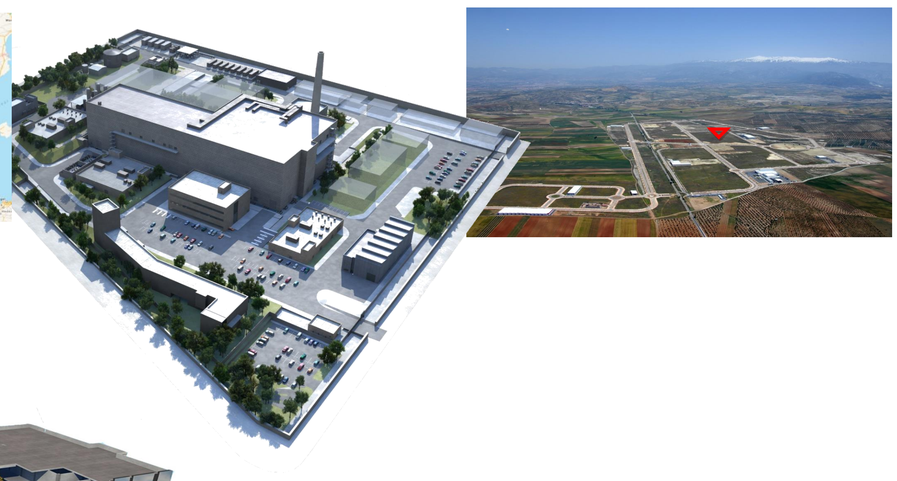
[1] *IFMIF-DONES España Consortium, Spain*
[2] *CIEMAT, Spain*
[3] *University of Granada, Spain*
[4] *INFN, Italy*
[5] *ENEA, Italy*
[6] *Université Paris-Saclay, CEA, France*
[7] *Fusion for Energy, Germany*
[8] *Universidad Castilla La Mancha, Spain*
[9] *CER, Hungary*
[10] *C3D Engineering Ltd., Hungary*
[11] *Lund University, Sweden*
[12] *EAI, Spain*
[13] *KIT, Kalrsruhe, Germany*
[14] *IFJ PAN Kraków, Poland*
[15] *IREC, Barcelona, Spain*

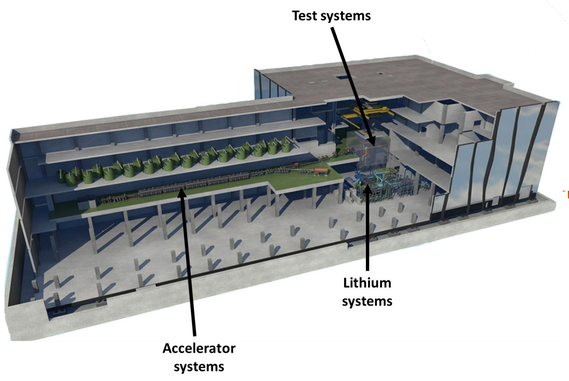
**E-mail address: ivan.podadera@ifmif-dones.es*

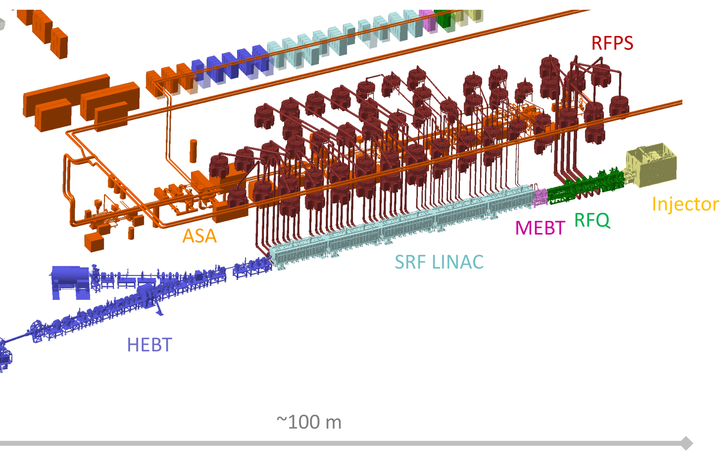
IFMIF-DONES Project

IFMIF-DONES is a facility to produce fusion relevant neutrons to test materials based on **Li(d,xn)** stripping reactions of **40 MeV D+**

Located at Escúzar
18 km southwest from
Granada city, Spain







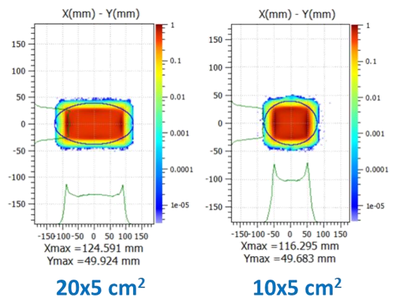
The 5 MW Deuteron Accelerator

100 m long, 175 MHz, D+ 5 MW CW scLINAC

The **Accelerator Systems**: Injector, RFQ, MEBT, SRF LINAC, HEBT, RFPS and AS Ancillaries (ASA)

Main AS Challenges:

- High availability (>87%) over lifespan,
- Remote Handling,
- Materials damage and activation,
- High CW beam control and monitoring,
- Control of the Rectangular beam shaping for dpa volume and gradient optimization
- Machine, safety protection and diagnose at extreme environmental and beam conditions

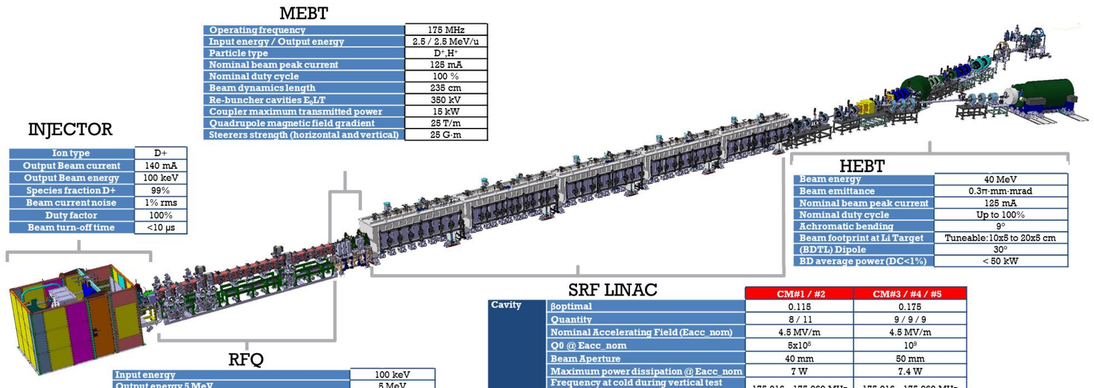


MEBT

Operating frequency	175 MHz
Input energy / Output energy	2.5 / 2.5 MeV/u
Particle type	D^+, H^+
Nominal beam peak current	125 mA
Nominal duty cycle	100 %
Beam dynamics length	235 cm
Re-buncher cavities E.F	350 kV
Coupler maximum transmitted power	15 kW
Quadrupole magnetic field gradient	25 T/m
Steerers strength (horizontal and vertical)	25 G·m

INJECTOR

Ion type	D+
Output Beam current	140 mA
Output Beam energy	100 keV
Species fraction D+	99%
Beam current noise	1% rms
Duty factor	100%
Beam turn-off time	<10 μs



HEBT

Beam energy	40 MeV
Beam emittance	0.3π·mm·mrad
Nominal beam peak current	125 mA
Nominal duty cycle	Up to 100%
Achromatic bending	9°
Beam footprint at I4 Target	Tuneable:10x5 to 20x8 cm
(BDTL) Dipole	30°
BD average power (DC<1%)	< 50 kW

RFQ

Input energy	100 keV
Output energy 5 MeV	5 MeV
Input D+ current	130 mA
Output D+ current	125 mA
RF Frequency	175 MHz
Max surface field	< 28.2 MV/m
Output rms emittance (norm.) transv.	< 0.30 π mm mrad
Output rms emittance longitudinal	<0.2 MeV deg
Duty factor	100%
Transverse zero current phase advance RFQ end	< 220 deg/m
Longitudinal zero current phase advance RFQ end	< 90 deg/m

SRF LINAC

		CM#1 / #2	CM#3 / #4 / #5
Cavity	βoptimal	0.118	0.175
	Quantity	8 / 11	9 / 9 / 9
	Nominal Accelerating Field (Eacc_nom)	4.5 MV/m	4.5 MV/m
	Q0 @ Eacc_nom	$5x10^9$	10^9
	Beam Aperture	40 mm	50 mm
	Maximum power dissipation @ Eacc_nom	7 W	7.4 W
	Frequency at cold during vertical test (cavity untuned, no power coupler)	175.016 - 175.060 MHz	175.016 - 175.060 MHz
	Tuning Range	- 50 kHz	- 50 kHz
	Loaded cavity bandwidth	2.7 kHz	-
	Working Temperature	4.45 K	4.45 K
Power Coupler	Transmitted Power	100 kW CW	200 kW CW
	Qext	6.3x104	-
Solenoid	Magnetic field Bz on axis	6 T	6 T
	Sterrers Field	3.5 mT.m	3.5 mT.m
	Quantity	8 / 6	5 / 5 / 5
	Working Temperature	4.45 K	4.45 K

Accelerator commissioning

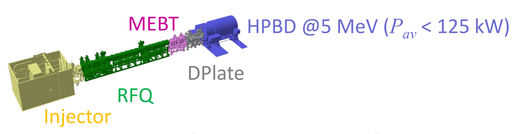
- **Tiered approach commissioning** alike other LINACs (LIPAc, SPIRAL2, ESS, SNS, LINAC4). To start four years later after **T0**- accelerator building construction (expected in 2024)
- **LIPAc commissioning** feedback (ongoing, see **TU2AA04** or **TUPORI029**) is a high value asset to optimize the IFMIF-DONES Commissioning
- **Hardware commissioning** (HWC) will be anticipated as much as possible to ensure readiness for beam:
  - Strategy to be followed for optimum commissioning of **RFQ** (RF conditioning), **SRF LINAC** (**cryoplant** and **RF cavities**) under analysis
  - **RFPS** and **Ancillaries** to be commissioned at earlier stage
- **Trade-off** between aggressive and conservative approach:
  - Validation of **integrated systems** right from first phase
  - Beam will be fully **characterized** at each phase to ensure smooth transition to the next phases
  - In each phase, **beam power** will be smoothly ramped up to minimize risks of machine damage or activation
  - **Proton** commissioning will be used only when strictly necessary
  - **RFQ** with a duty cycle high enough to emulate the nominal beam
  - Five cryomodules of the **SRF LINA**C commission in one-single stage

Beam commissioning stages

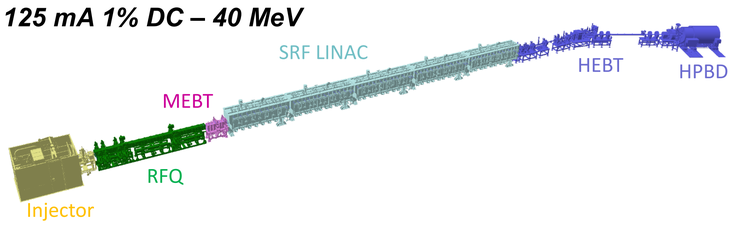
T0 — **Start of Accelerator building construction**

T0+4 — Phase 1- Injector
140 mA CW – 100 keV

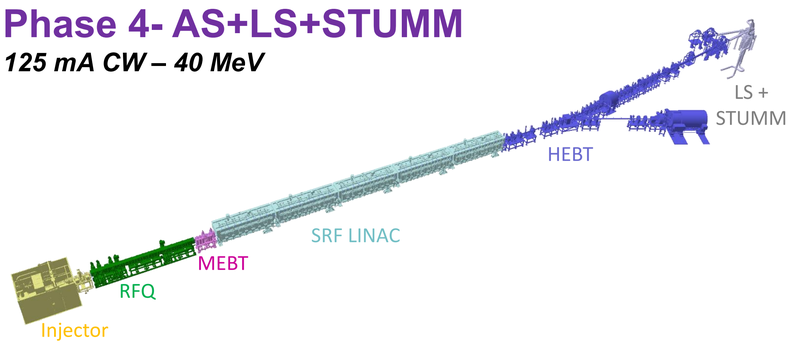
T0+5 — Phase 2- RFQ/MEBT
125 mA 20% DC – 5 MeV



T0+7 — Phase 3- SRF LINAC
125 mA 1% DC – 40 MeV



T0+9 — Phase 4- AS+LS+STUMM
125 mA CW – 40 MeV



T0+10 — IFMIF-DONES Operation

HWC objectives	BC objectives	Challenges
• HV and plasma conditioning • Integration with AS Ancillaries and Control Systems (including Machine and Safety protection)	• Check out all the injector, and ancillaries components • Full characterization of beam characteristics at RFQ interface point with protons and deuteron	• First beam operation in the facility • Co-living with parallel installation and HWC activities
• RFQ Field check • RFQ RF Conditioning • Re-bunchers RF Conditioning	• Check out all the RFQ, MEBT, diags and ancillaries • Tests all RFQ features • Beam characterization for SRF LINAC injection	• RFQ conditioning (integration RFPS and 8-chain RFQ up to CW) • Ramp up beam to test all the RFQ features for nominal beam operation w/o activating systems
• Cryomodules cool down • Cavities RF conditioning • Solenoids field	• Check out all the SRF LINAC • Optimize SRF LINAC transmission (including beam diagnostics tests) • Beam diagnostics @ different beam modes	• Lossless transmission along the cryomodules using beam diagnostics • Stability of the cryogenics systems and RF cavities during beam power ramped up • Feedback from LIPAc will mitigate the risks by developing specific procedures
• Remote Handling procedures • Target diagnostics • Integration with Lithium and Test Systems	• Provide nominal beam power to the lithium target for STUMM irradiation • Validate neutronics field with STUMM (Test Systems) • Test beam/lithium interaction • Optimize irradiation profile by tuning the accelerator • Validate the machine and safety protection systems	• Target beam diagnostics • Tests HEBT Remote Handling equipment • Integrated operation with lithium target • Irradiation optimization • Alignment of all the systems during power ramp up

IFMIF-DONES Programme is expected to start Construction Phase in short term!

LINAC2022 LIVERPOOL

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.