Overview and Current Status of the IFMIF-DONES Accelerator Systems

I. Podadera on behalf of the DONES Integrated Programme Team

LINAC2026
19/08/2026

Outline

1. IFMIF-DONES
2. The 5 MW deuteron LINAC
3. Accelerator status
4. Conclusions and Outlook

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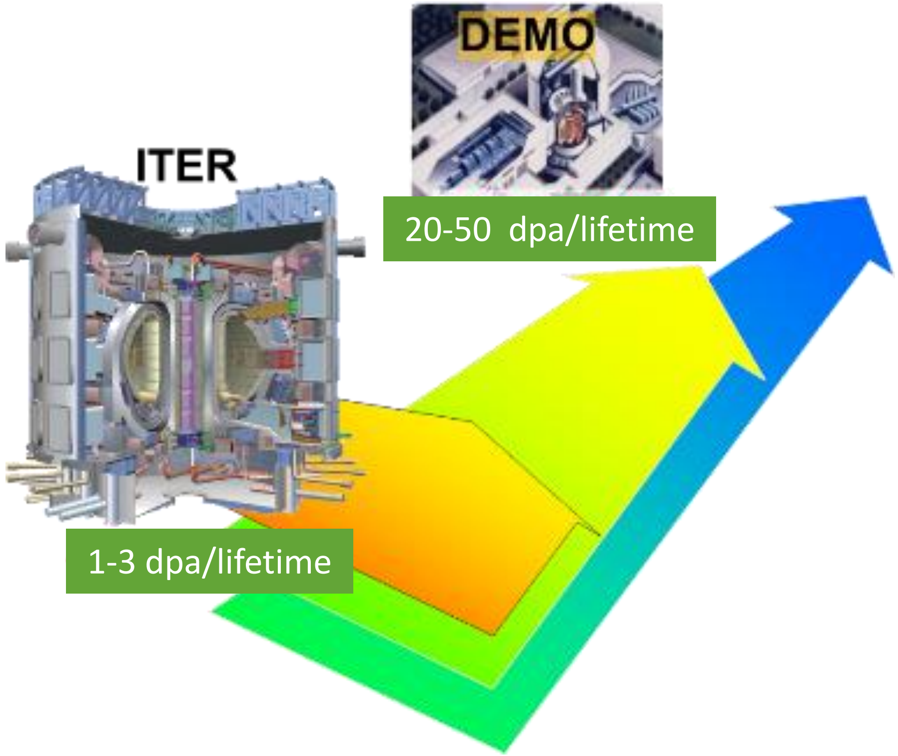
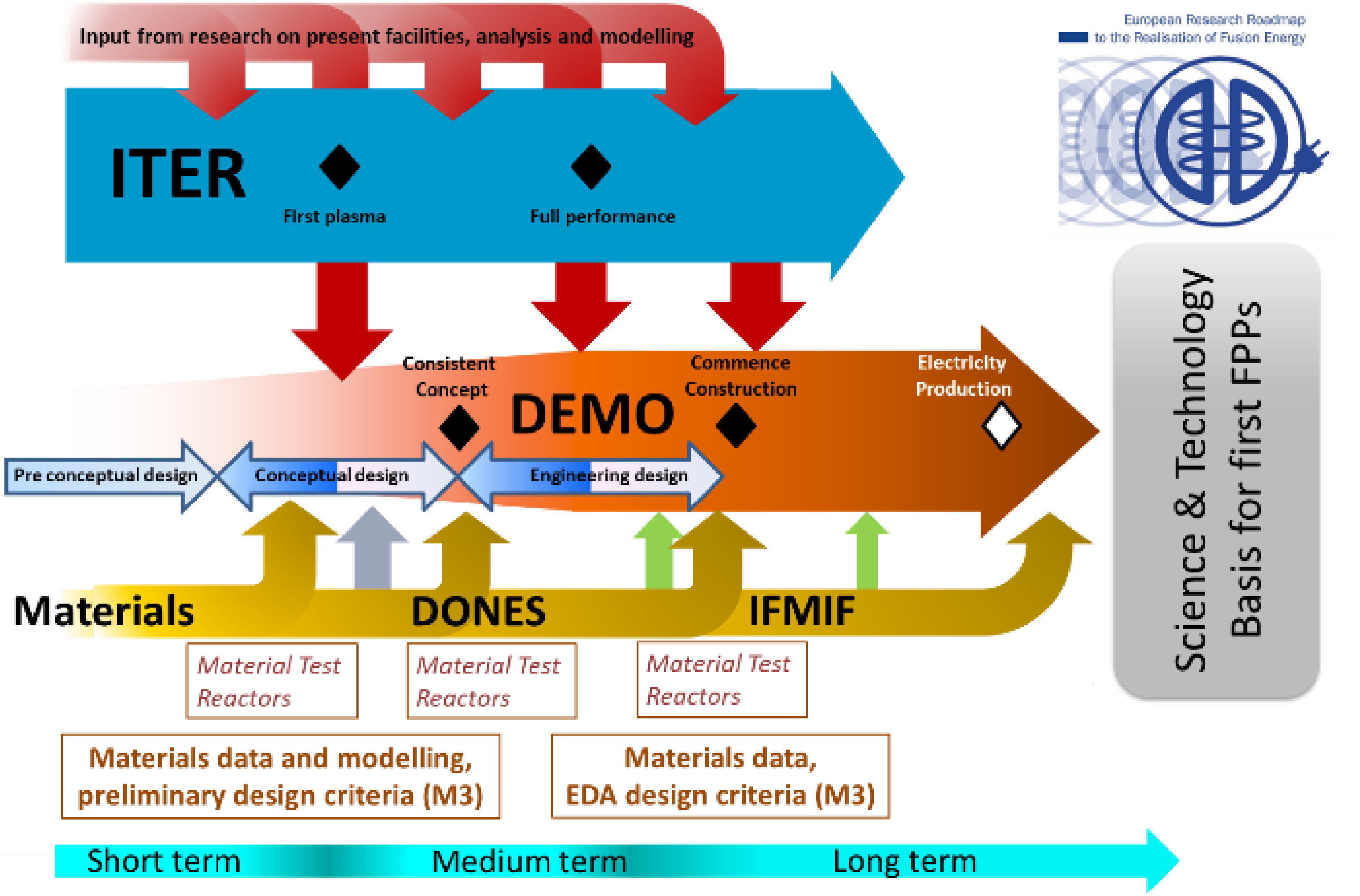
Why IFMIF-DONES ?

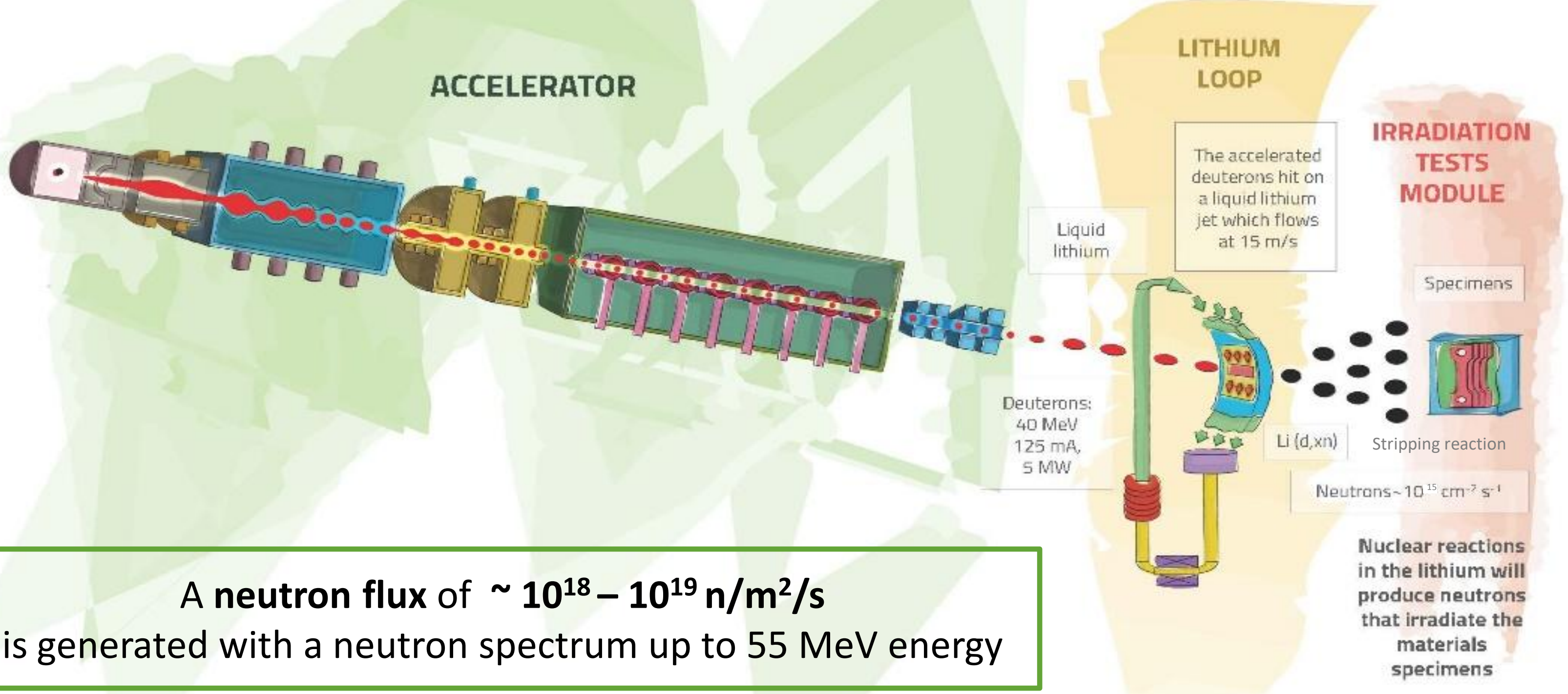
One of the main differences between **ITER** and **DEMO** is the radiation dose: at DEMO more than two orders of magnitude higher



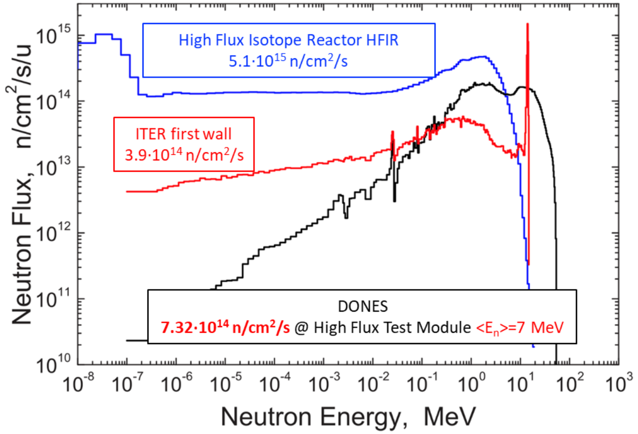


What is IFMIF-DONES?

An accelerator based **fusion-like neutron source** for the generation of data used for design, licensing and testing of materials to be used in the **DEMO and other fusion reactors**



A **neutron flux** of **~ 10^{18} – 10^{19} n/m²/s**
is generated with a neutron spectrum up to 55 MeV energy



High Flux Test Module requirements

Dpa	20 dpa_{NRT} (<2.5 years, 300 cm³) 50 dpa_{NRT} (<3 years,100 cm³)
Temperature	Controlled 250 – 550 C
Dpa gradient	<15% (gauge volume)
Temperature gradient	<3% (gauge volume)

Facility able to irradiation multiple irradiation modules simultaneously

IFMIF-DONES Facility

The site is located at Escúzar -18 km southwest from Granada city- Spain

ESFRI

European Strategic Facility RI Project

European Research Roadmap to the Realisation of Fusion Energy

High priority facility in the EU Fusion Roadmap

DAEJEON LINAC2026

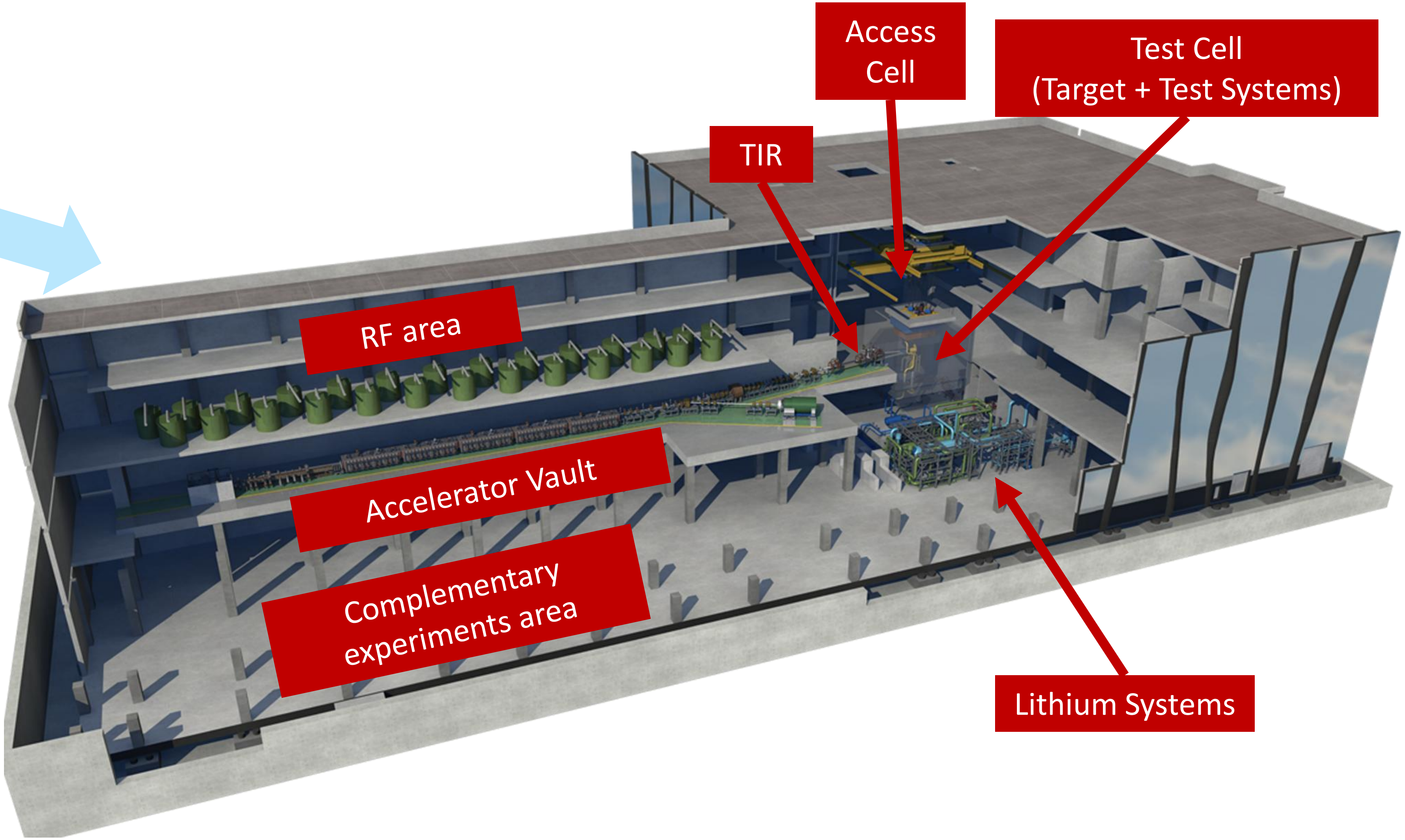
IFMIF-DONES Facility

70% Target Availability
30 years Operation

Site, Building & Plant Systems

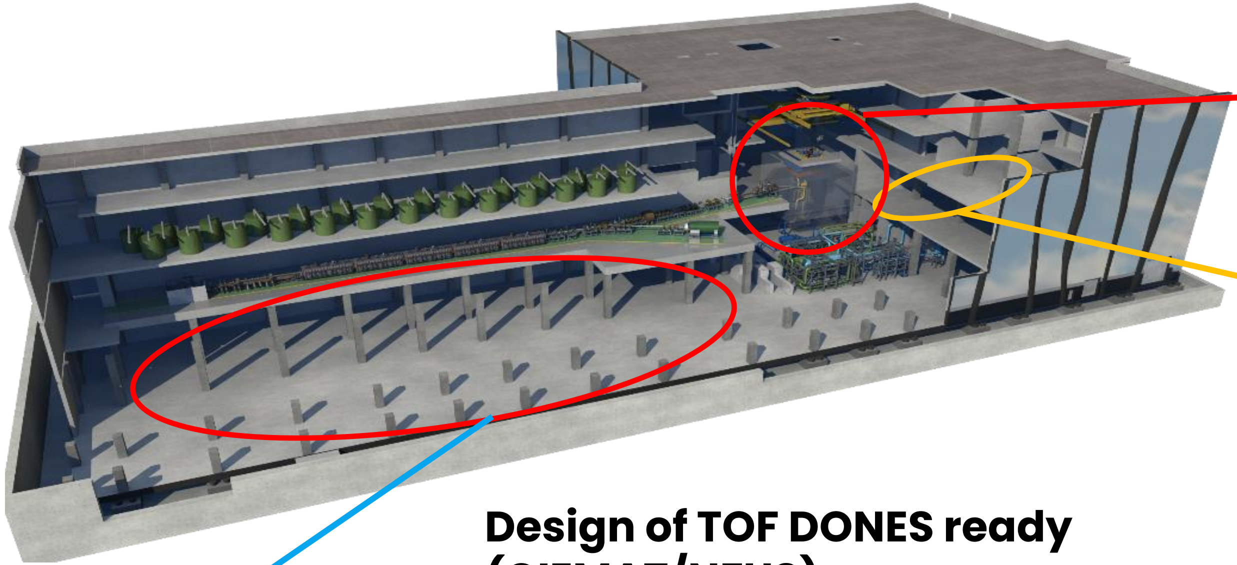
+

CICS

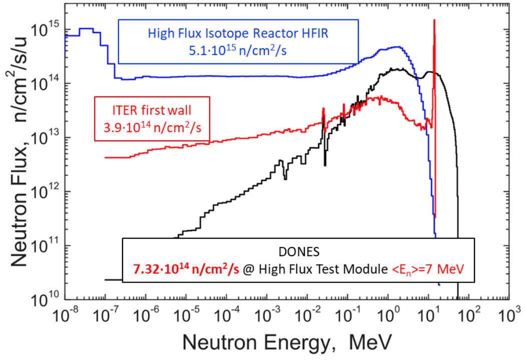


Facility & users

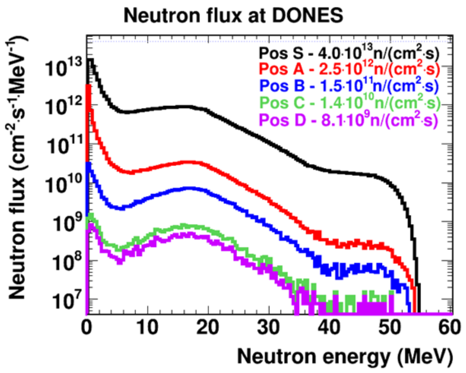
Three main experimental areas – First **Experimental Programme** to be presented this year



Test cell – Main neutron experimental area (fusion users)

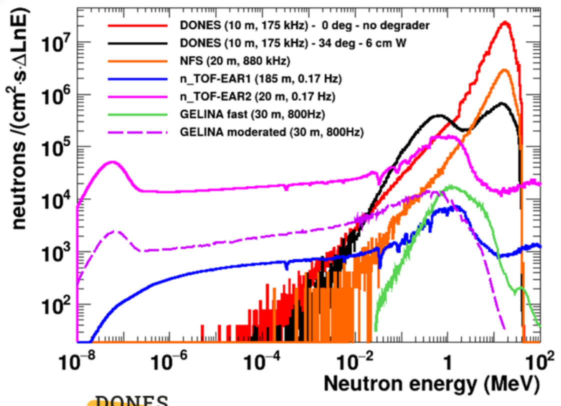


Area for complementary experiments with continuous neutron beam



Area for complementary experiments with deuteron beam

Design of TOF DONES ready (CIEMAT/NFUS)

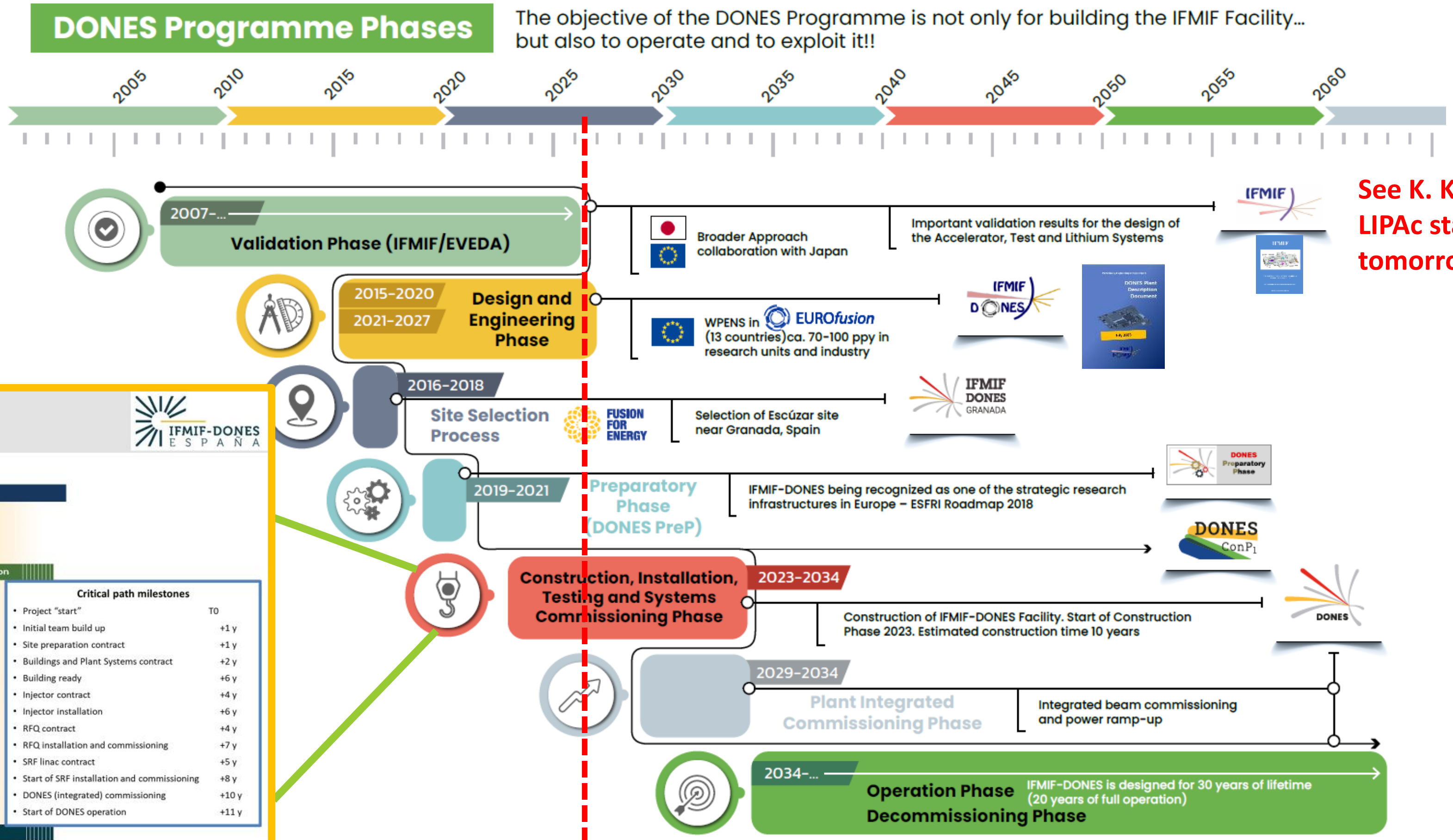


Next WS DONES Users – CIEMAT- Madrid – 13-15 October

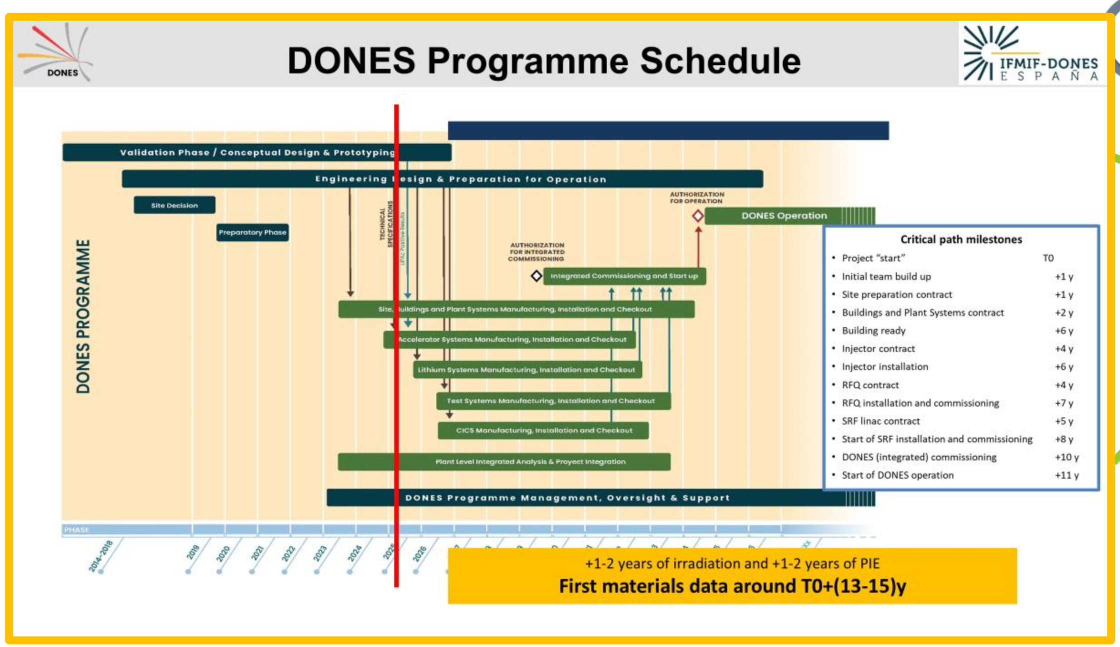
Fusion users (materials, breeding blankets,…)
Nuclear physics
Astrophysics
Medical applications
Industry, safety
Societal applications

https://indico.ifmif-dones.es/event/92/

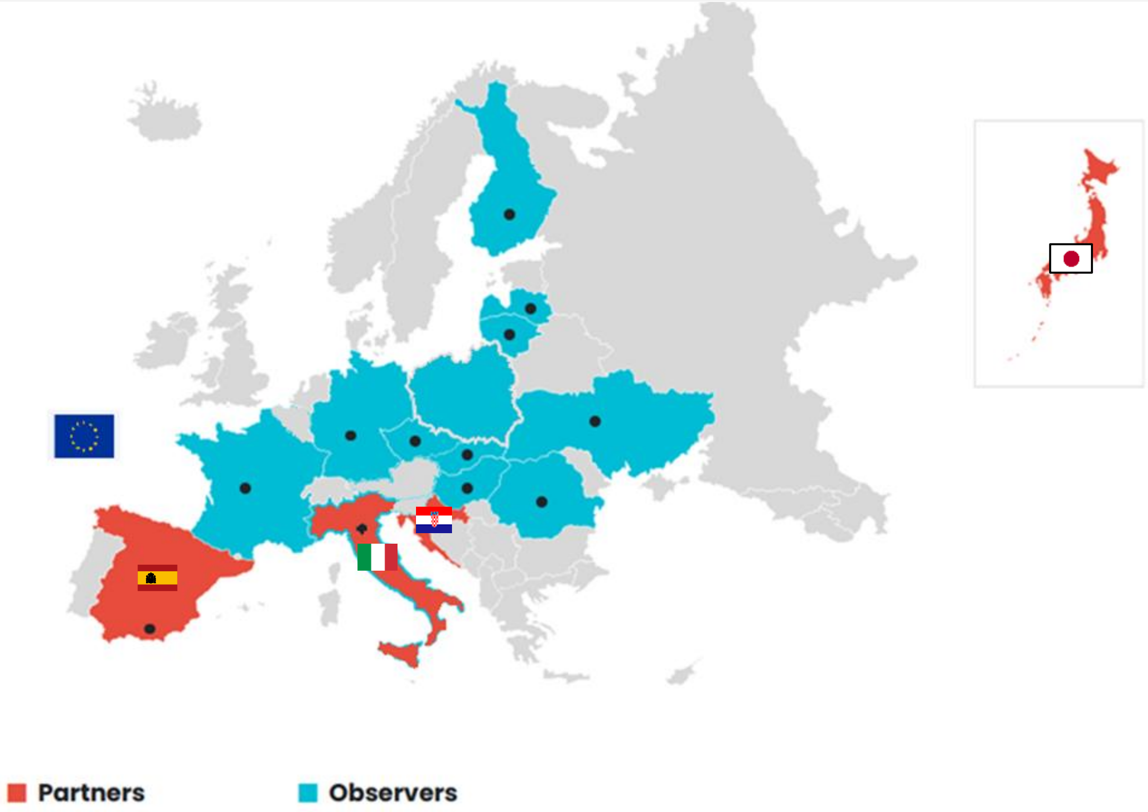
DONES Timeline



See K. Kondo-LIPAc status talk tomorrow



DONES Programme Governance



Current Parties

- *F4E (European Commission)*
- *IFMIF-DONES España (Spain, Host)*
- *INFN (Italy)*
- *QST (Japan)*
- *RBI (Croatia)*
- *ENEA (TBC)*

Observers:

- *Czech Republic*
- *Finland*
- *France*
- *Germany*
- *Hungary*
- *Latvia*
- *Lithuania*
- *Poland*
- *Romania*
- *Slovakia*
- *Ukraine*

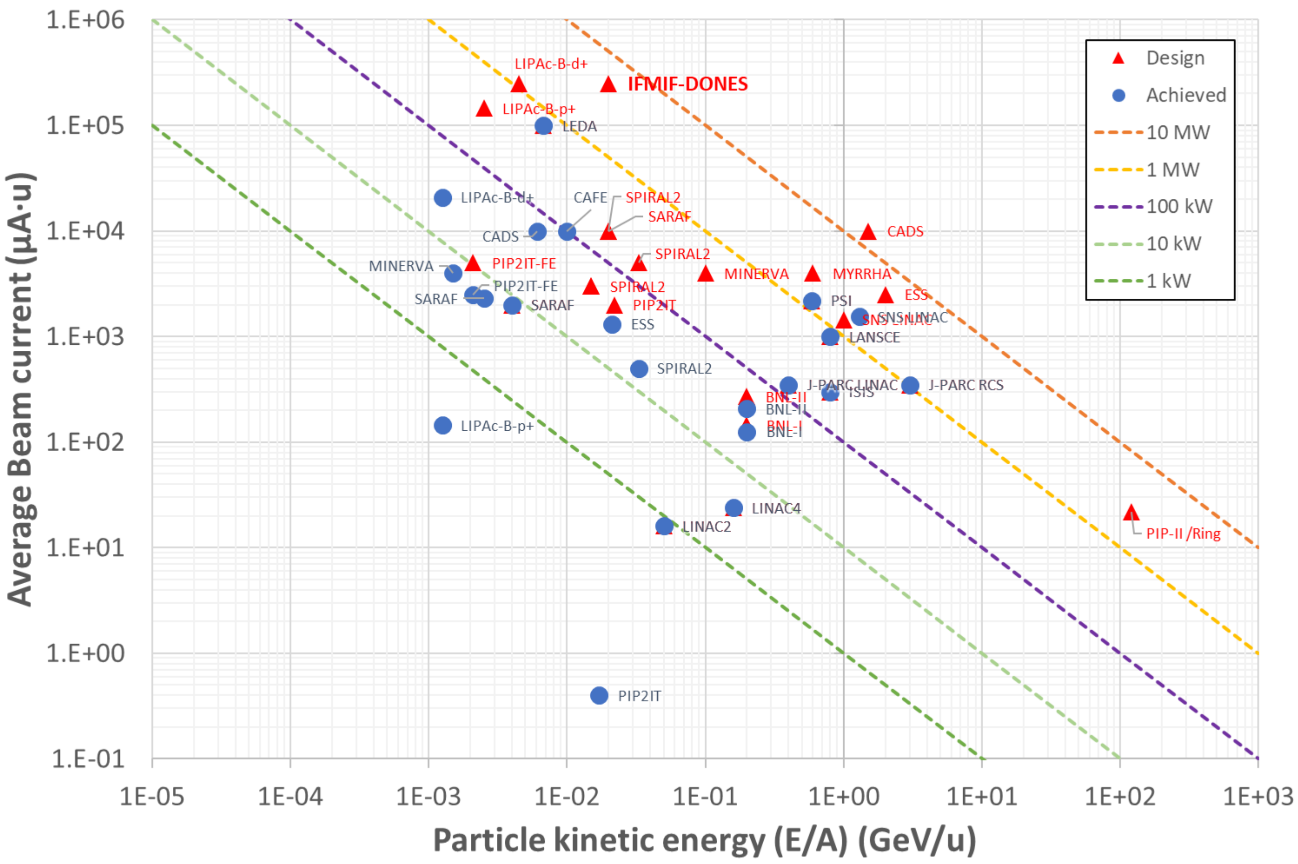
DONES Programme Governance

Signature of the
Multilateral International DONES Agreement
MIDA
21st November 2025

Outline

The 5 MW deuteron LINAC

40 MeV / 125 mA CW / 5 MW SC LINAC

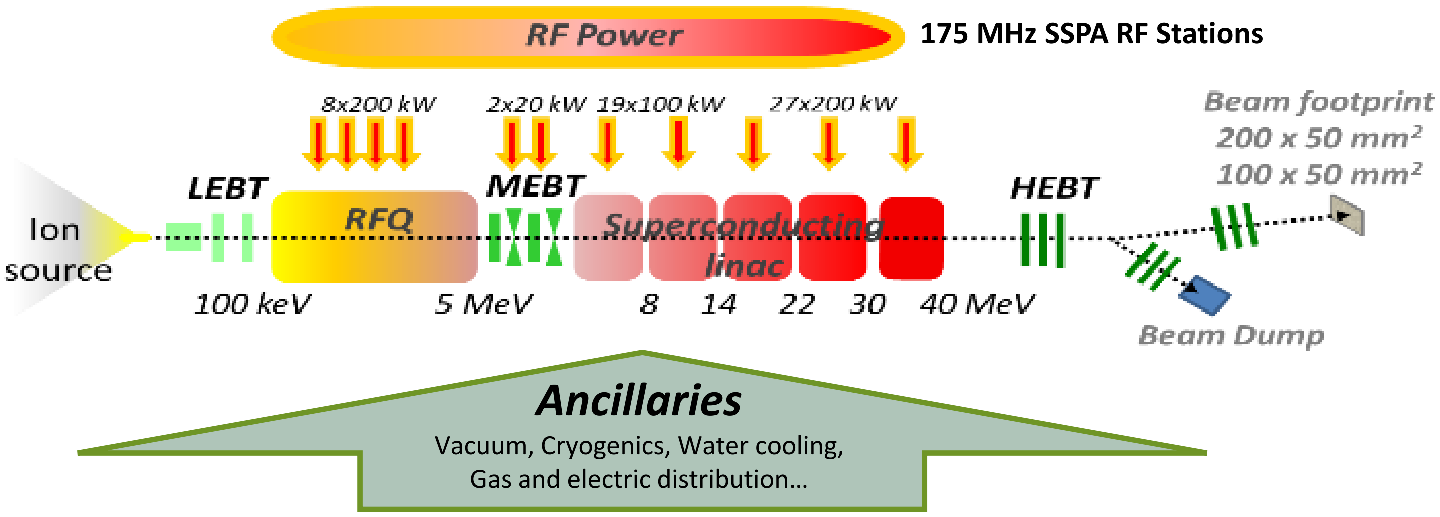


- Highest **D⁺ current** LINAC
- One of the highest **average beam power & perveance**
- Top **H⁺ & D⁺ Injector** performance
- Longest **RFQ**
- High **Beam loading** in resonant cavities
- Record of light hadrons current through **SC cavities**

Facility (Accelerator, target…) design considering feasibility upgrading to 10 MW!

DAEJEON LINAC2026

LINAC parameters



D+ CW 175 MHz SC LINAC

125 mA / 40 MeV → **5 MW**

Total length of ~**100 m**

Windowless liquid **Li target**

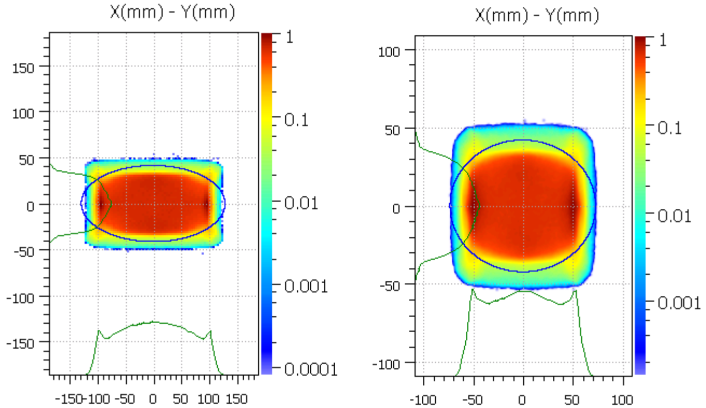
20 y, 87% **target availability**

Hands-on **maintenance (<1 W/m)**

Target-beam at 9° angle → **possibility to upgrade** with 2nd mirror accelerator (10 MW)

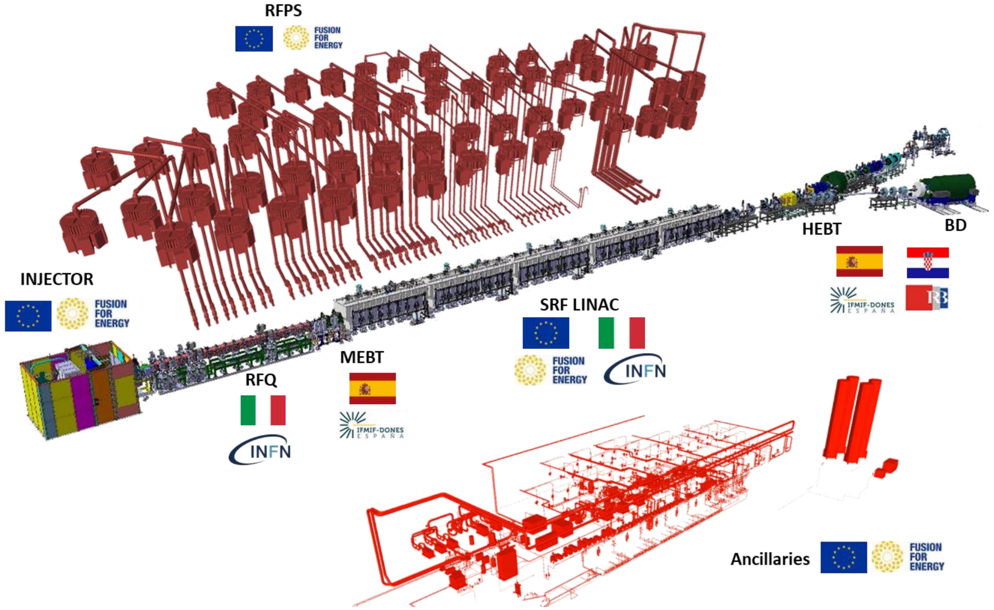
Independent **EMC mesh** embedded into the Building

Beam footprint @ target



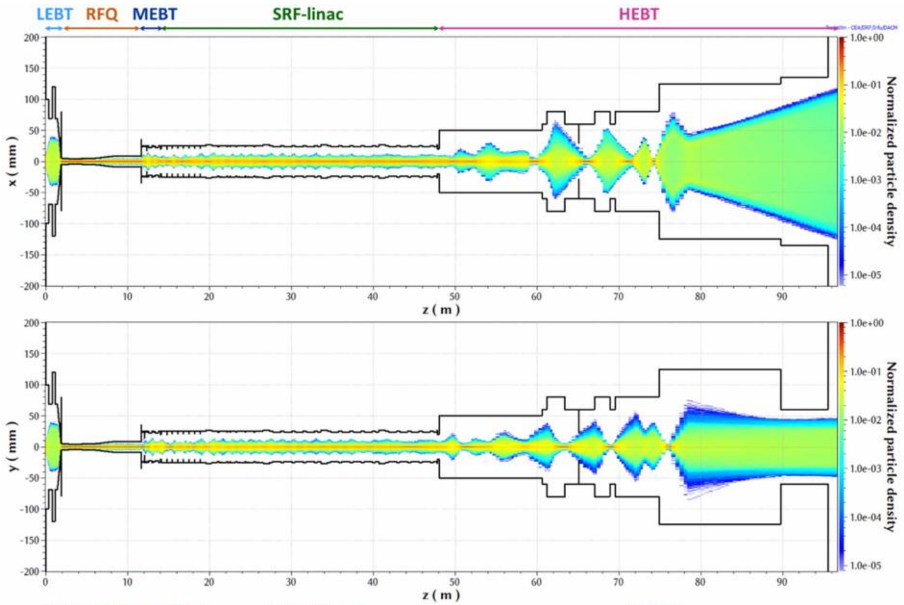
20x5 cm² footprint (reference)

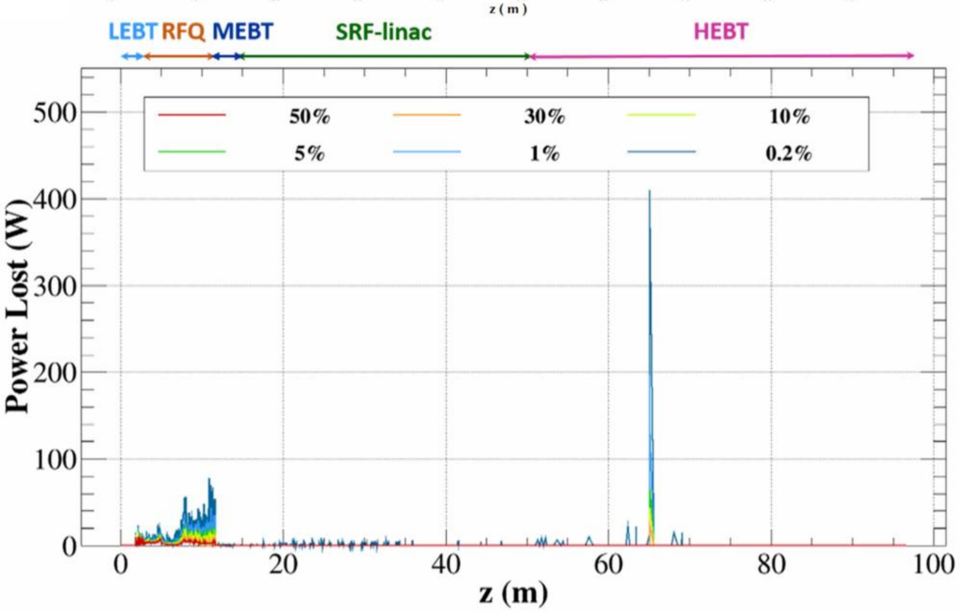
10x5 cm² footprint (optional)

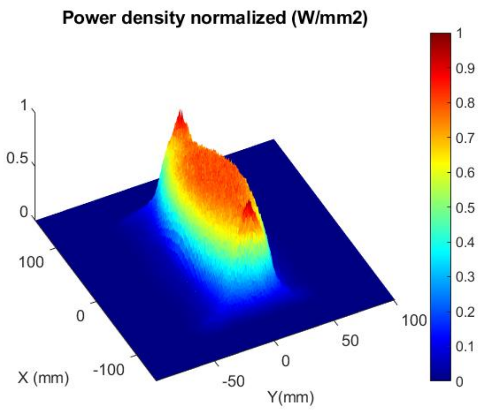


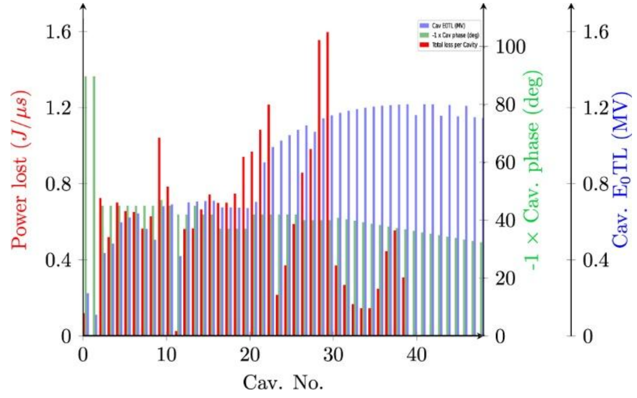
Beam dynamics design

- Reference **beam target footprint** 20 x 5 cm
- **Flexible beam footprint → Horizontal size** from 10 to 20 cm
- S2E simulations considering **static and dynamic errors**
- **Space charge compensation** → no relevant effect at 40 MeV but can be significant at 5 MeV
- **Accidental** simulations for magnets, cavities and solenoids
- Crosscheck with other codes ongoing (**pyORBIT**)
- **Uncertainty propagation** model of BDTL & LEBT+RFQ





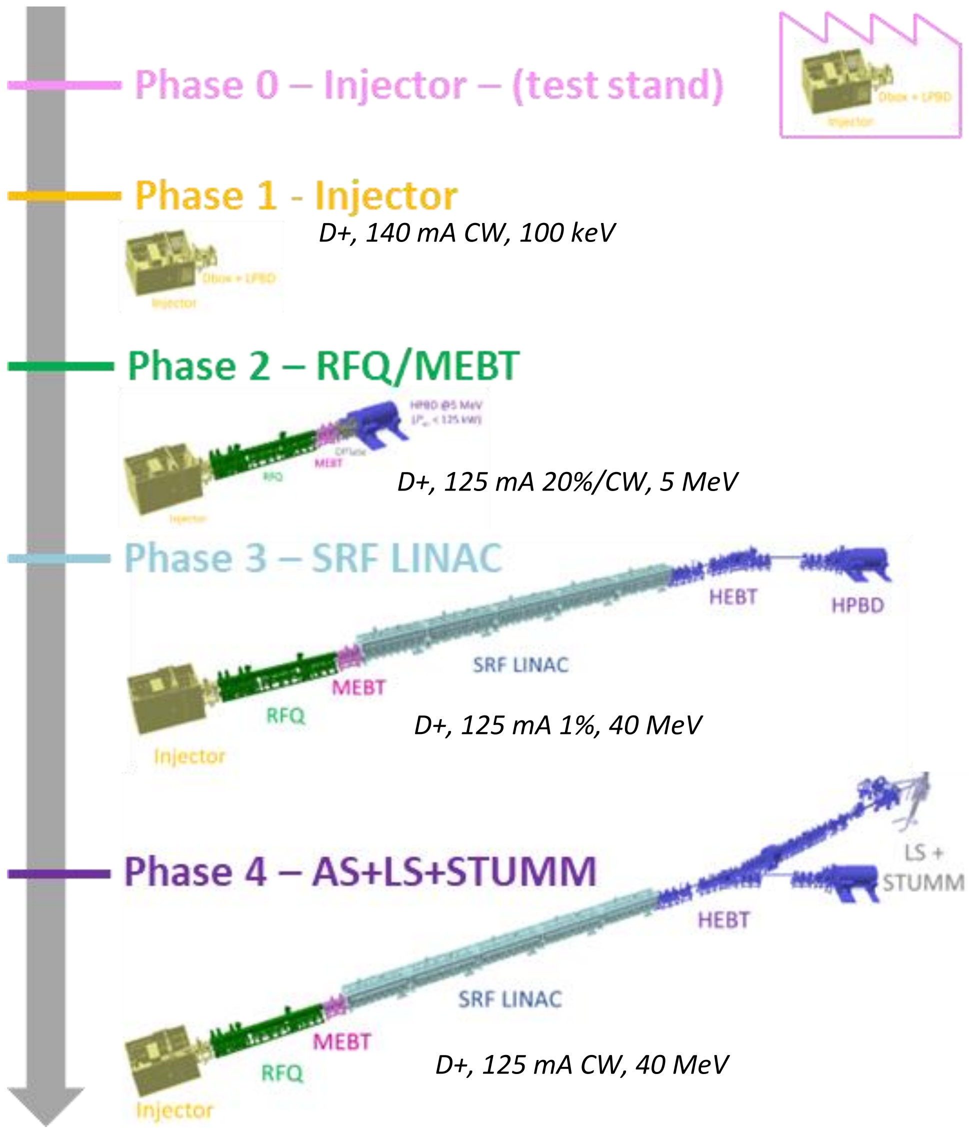




Commissioning & Operations Plan

- Main target → **Neutrons production with 40 MeV d(Li,xn)**
- **Staged Commissioning** similar to LIPAc and other facilities
- **Global Operation Modes** and **Control Logics** defined
- Lessons-learned from **LIPAc** and other facilities

Id.	Description	Beam destination
BE1	**Nominal operation**	**Lithium target**
BE2	Nom. Phase 1	DB2@Injector
BE3	Nom. Phase 2	HPBD@MEBT
BE4	Nom. Phase 3	HPBD@HEBT
BE5	Pulse p+ Phase 1	DB2@Injector
BE6	Pulse D+ Phase 1	DB2@Injector
BE7	Pilot p+ Phase 2	HPBD@MEBT
BE8	Pilot D+ Phase 2	HPBD@MEBT
BE9	Pilot p+ Phase 3	HPBD@HEBT
BE10	Pilot D+ Phase 3	HPBD@HEBT
BE11	Pilot D+ Phase 4	Lithium target
BE12	Experimental areas	Target@R026
BE13	Variable profile	Lithium target



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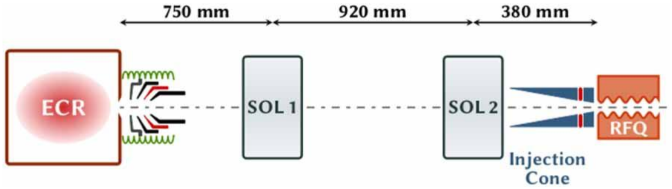
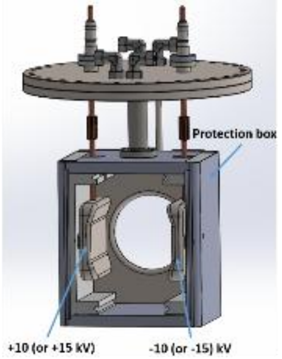
Injector (Ion Source + LEBT)

- **ECR** ion source – SILHI type
- **Validated** in LIPAc at nominal CW current → T. Akagi et al., J. Phys.: Conf. Ser. 3237 012037, 2026
- **Chopper** for high intensity pulsed D^+ beam
- Experimental campaigns ongoing with LIPAc to improve **dielectric disks** lifetime (Boron Nitride disks)- optimization of lifetime
- Injector enhancement based on **LIPAc operational feedback**



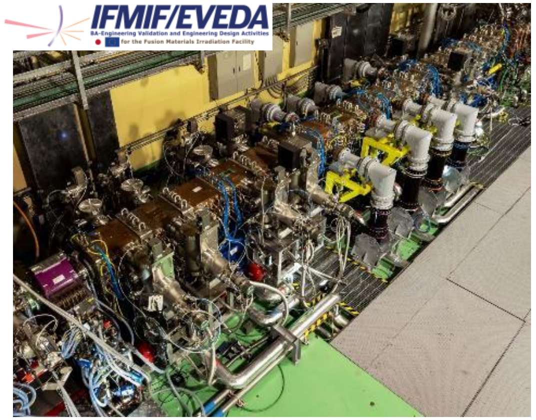


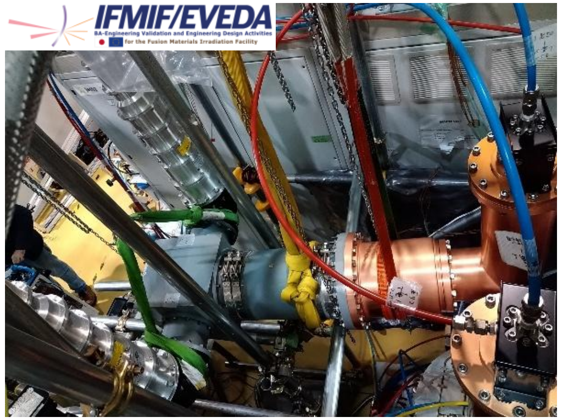
Component	Actuator type	Actuator time	MPS	SCS
Magnetron	FMSS (optical relay)	10 us	X	
Magnetron (PSU)	Relay (PSU interlock)	<1 ms		X
Gas injection valve	Relay	<1 s		X
Beam stopper	Pneumatic (w/ solenoid actuation)	<2 s		X

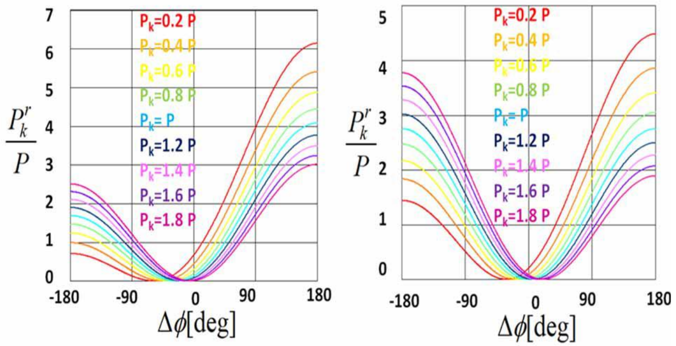
RFQ

- **Longest and highest power RFQ**
- Optimization from **LIPAc** feedback → **full beam current and transmission** achieved up to 8.75% DC (3.5 ms PW/40 ms RR). **RF conditioned** in CW up to 80% of field. New couplers to overcome these limitations → see K. Kondo talk
- 200 kW **Power couplers with brazed windows** redesigned to mitigate multipacting. Prototypes under construction.
- Optimization of mechanical structure manufacturing and installation → one single frame under study
- **Vanes erosion model** based on sputtering. Other phenomena under study (ion implantation, …) to assess the best mitigation strategy for longer RFQ lifetime

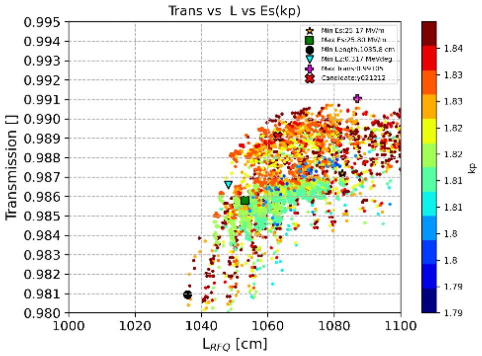
Length *L*	9.78 m (5.7 λ)
Resonance frequency f_0	175 MHz
Input beam current (D+)	130 mA
Voltage range (Vmin/Vmax)	79.29 / 132 kV
Input / Output energy (Ei / Eo)	0.1 / 5 MeV
Max electric field (Es,max)	25.2 MV/m (1.8 kp)



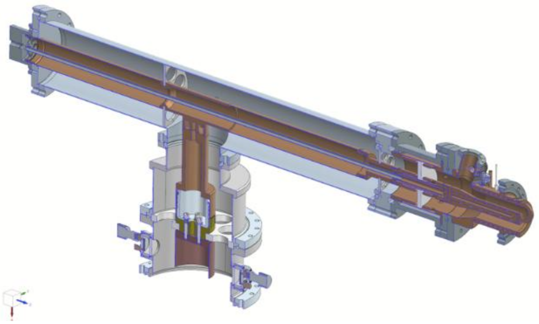




A. Palmieri, IPAC'23, MOPL128

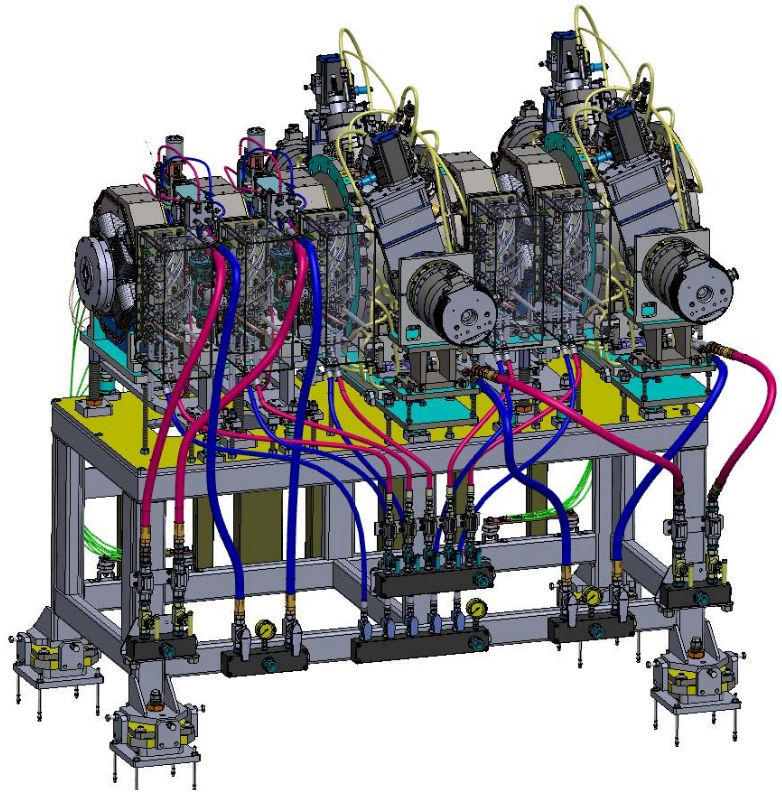


M. Comunian, SLHiPP'10



MEBT

- Optimization of the mechanical frame and overall integration to improve **accessibility**
- Improvement performance and maintenance of **combined quads-steerers**
- Radiation hard and low activation **materials**
- Enhancement of the **Beam Diagnostics** (DC measurement, loss measurement) and Vacuum package
- **Status:**
    - VATIAC validator under manufacturing
    - First pre-operational tests on-site in 2028



Mockup of the HEBT from VATIAC pre-operational prototype (work carried out within the DONES-VATIAC contract, a CDTI PPP initiative, funded by ERDF under the 2021–2027 Multi-Regional Operational Program for Spain)

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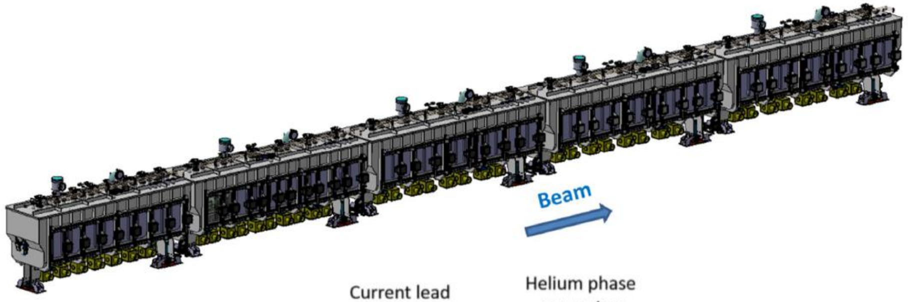
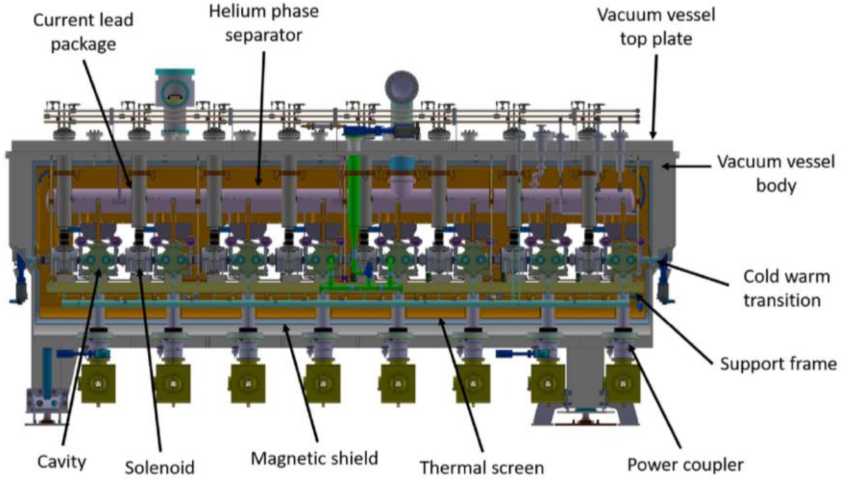
SRF LINAc

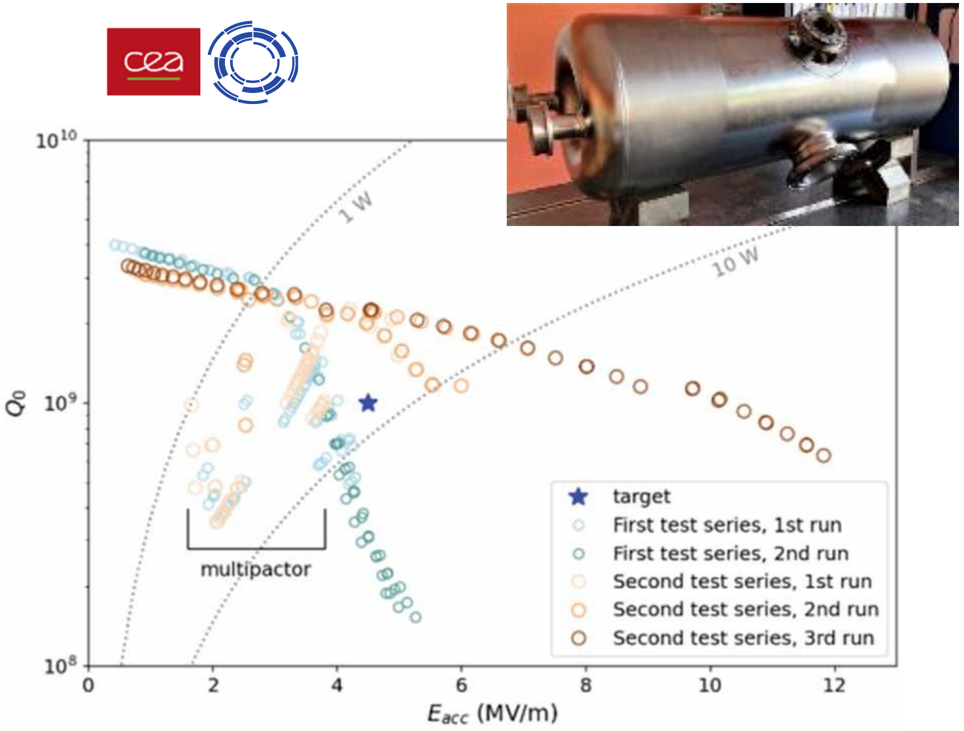
- **Five Cryomodules** top-loaded working @ 4.5 K
- Two types of scHWR's cavities: 19 x **low-β** and 27 x **high- β**
- <200 kW RF couplers. Biased T-box design
- 29 x **solenoids packages** (with steerers, BPM's & BLM's)
- 4 x **Short Warm Sections**
- **Valve boxes** in a parallel room to ease maintenance
- Complete study of **cryogenic hazards**
- **nBLM** (outside) and **scCVD Diamonds** (inside) as Beam Loss Monitors
- Assembly of the **LIPAc Cryomodyule** ongoing → first beam expected in 2027 → see K. Kondo tomorrow





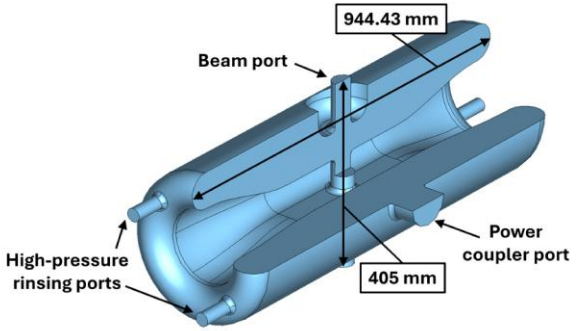
High-beta (β=0.175) cavities

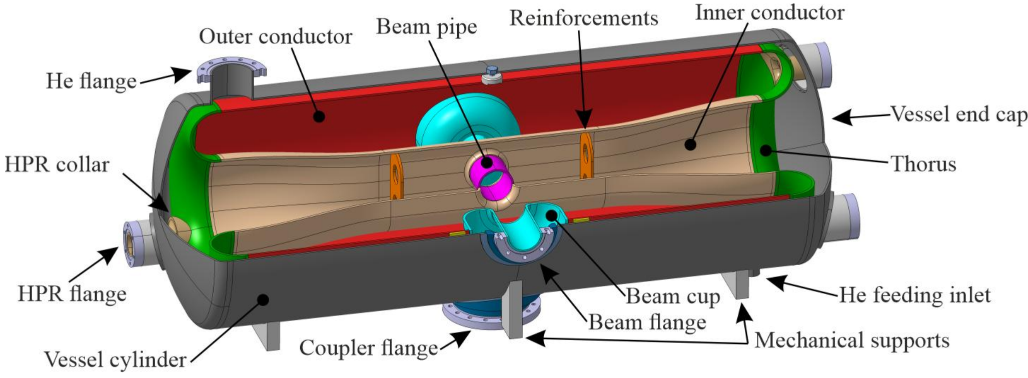
First prototype of a High Beta naked cavity already designed, manufactured and tested with margins related to the specification (CEA/EUROfusion)



J. Plouin, SRF2023, TUTB035
I. Podadera et al., Nucl. Fus. 65,12, 2026

Final design ongoing (INFN)

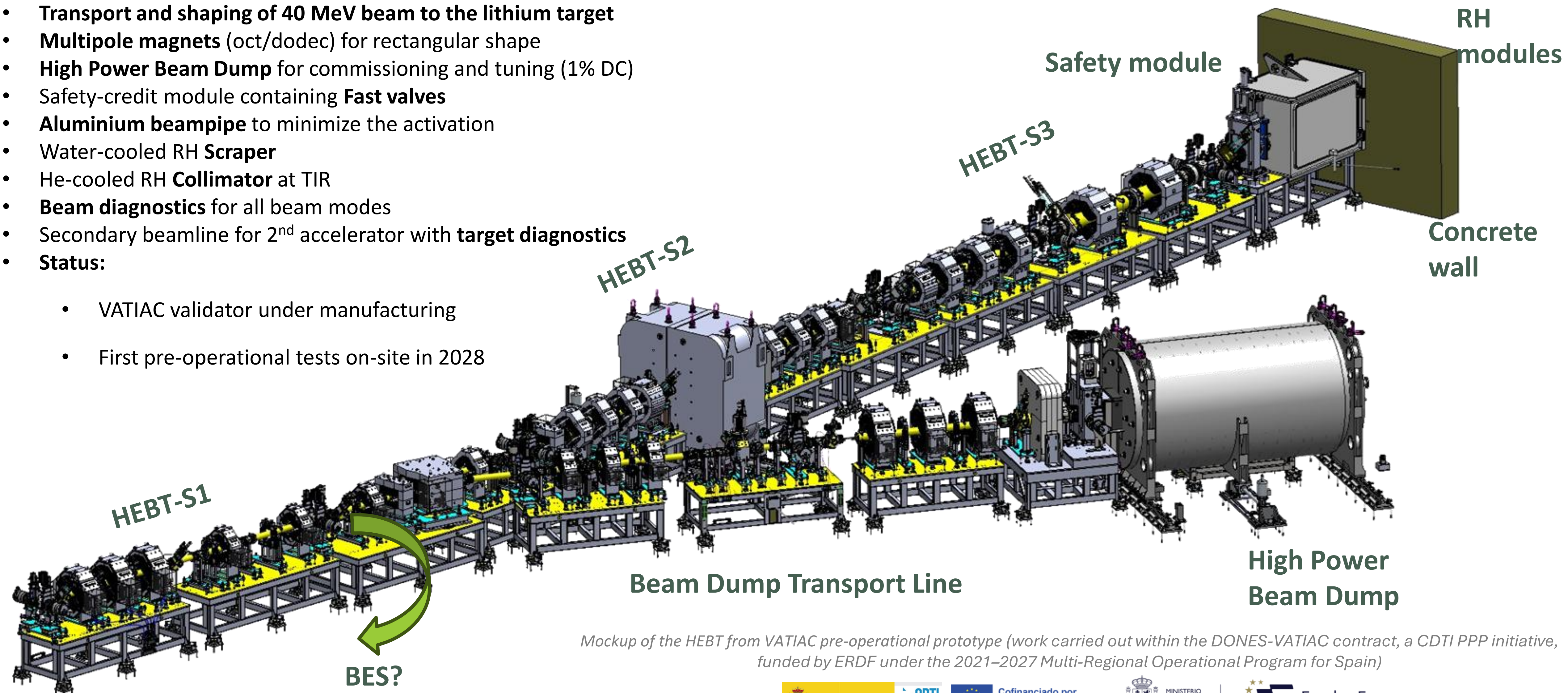




F. Grespan et al., IPAC'26, MOP7031

HEBT & BD

- **Transport and shaping of 40 MeV beam to the lithium target**
- **Multipole magnets** (oct/dodec) for rectangular shape
- **High Power Beam Dump** for commissioning and tuning (1% DC)
- Safety-credit module containing **Fast valves**
- **Aluminium beampipe** to minimize the activation
- Water-cooled RH **Scraper**
- He-cooled RH **Collimator** at TIR
- **Beam diagnostics** for all beam modes
- Secondary beamline for 2^{nd} accelerator with **target diagnostics**
- **Status:**
  - VATIAC validator under manufacturing
  - First pre-operational tests on-site in 2028



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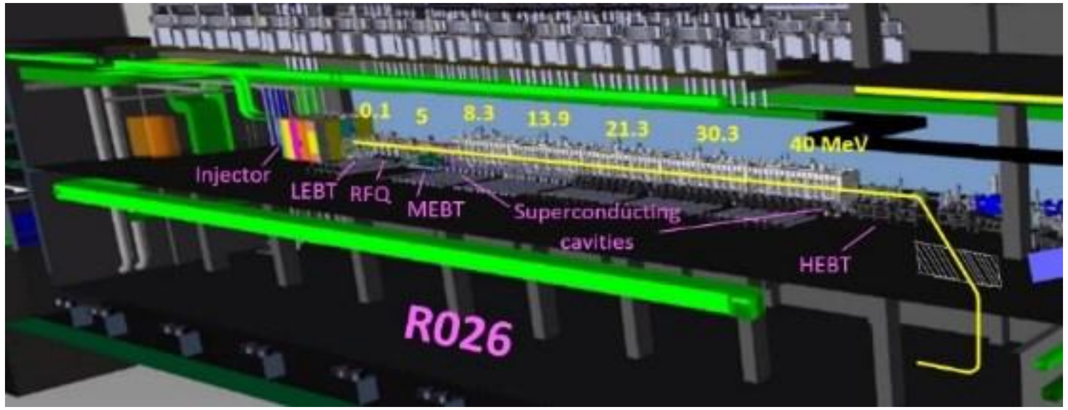
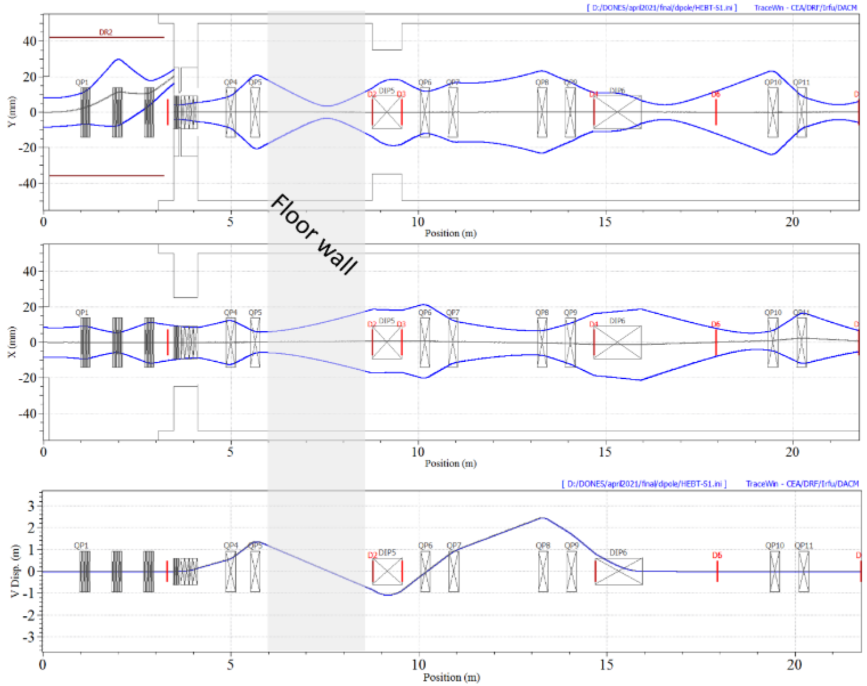
HEBT & BD

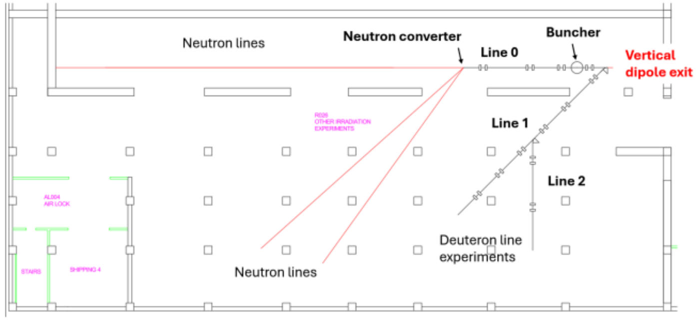
Beam Extraction System (BES) @ 40 MeV for complementary experiments under assessment

Reference layout: multi-meander line kickers (tens of kV) + electrostatic kicker + septum magnet

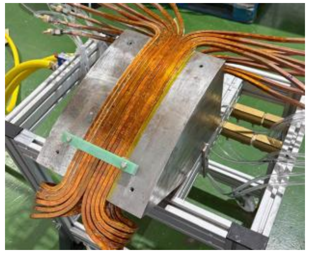
Prototypes design ongoing of kickers and septum magnets



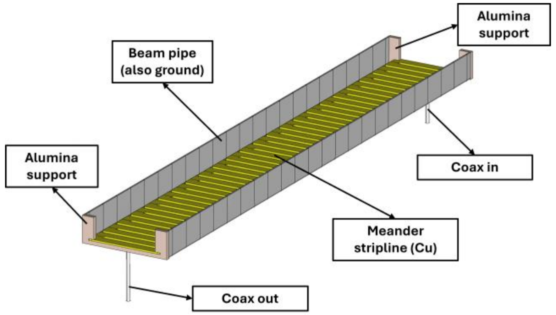




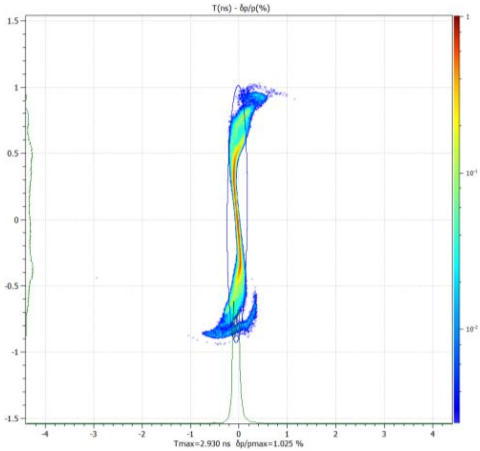
L. Bellan et al., IPAC'26, THP4116, 2026



SUPRASYS

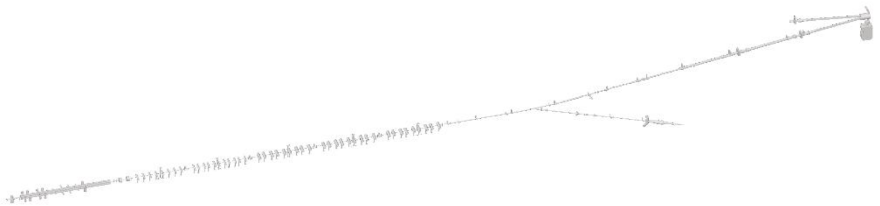


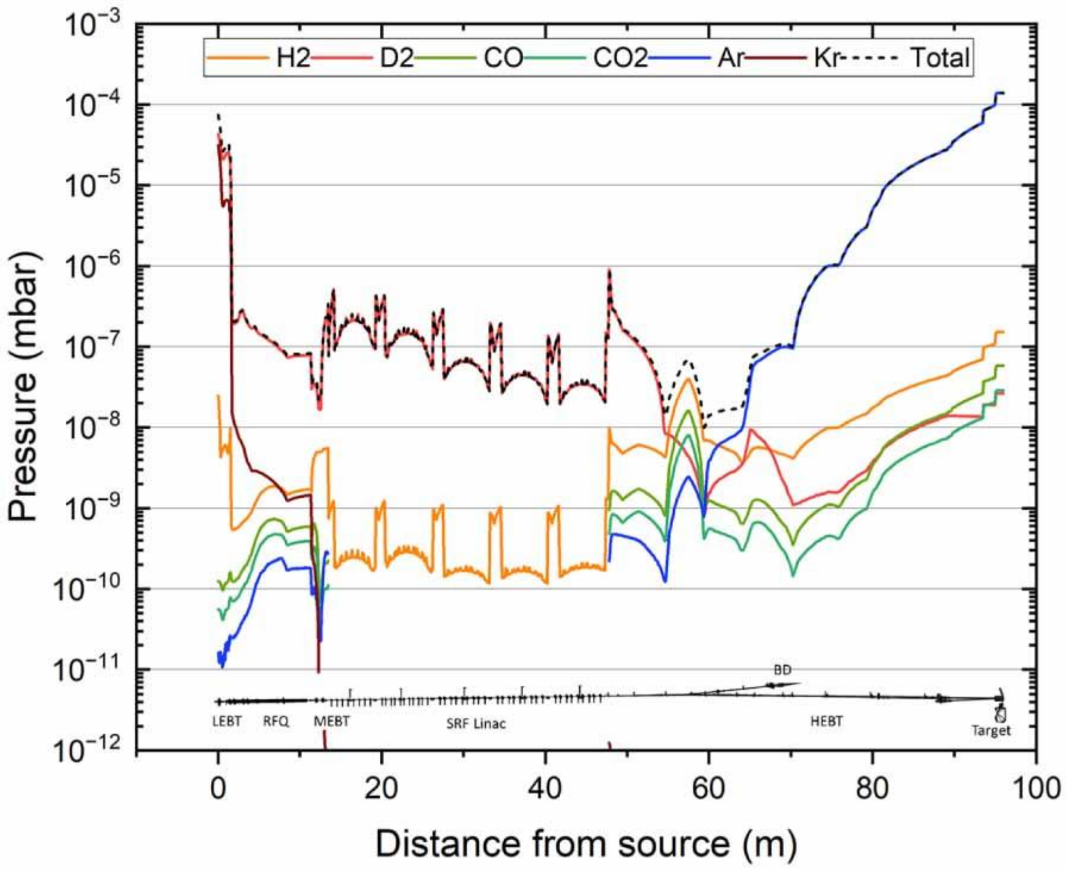
M. d'Andrea, LINAC2024, TUPB073



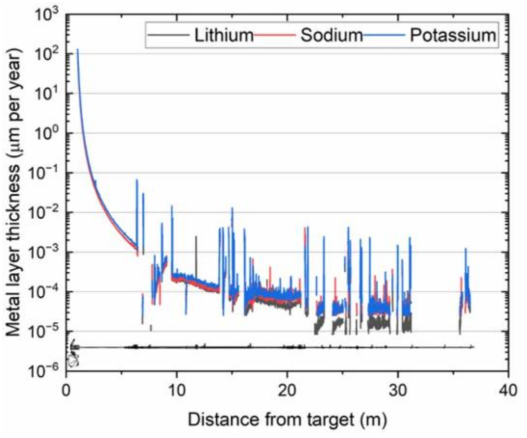
Vacuum

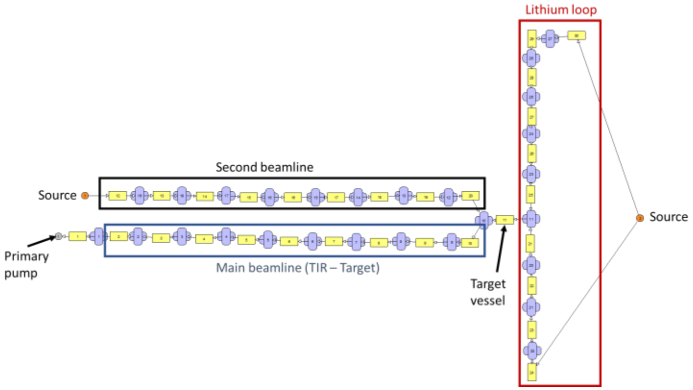
- **Differential vacuum profile** near the target with gas injection control (Ar), pressure between 10^{-4} to 10^{-5} hPa in the target and below $5 \cdot 10^{-8}$ hPa in the SRF LINAC (Molflow+)
- Use of **Slow Pumping Systems** in the SRF LINAC area
- Pumping in the SRF LINAC area to be optimized
- **Fast valves** for mitigation of accidental events and machine protection
- **Primary pumps** outside the vault
- **Equipment harmonization** to improve maintenance
- Quantification of the **lithium vapour deposition** along the line
- Simulations of the **lithium loop** (ITERVAC)
- **Vacuum Handbook**





C. Caballero et al., Vacuum 234 114091, 2025



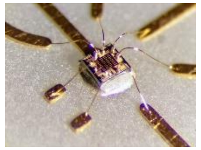


Beam Diagnostics

- Most beam diagnostics already validated @ **LIPAc** (Japan)
- Some **critical diagnostics** identified related with the high power beam and radiation background

HEBT@TIR:
- Characterization and monitoring of **beam profile @ footprint**
- Beam monitors under high radiation environment and Remote Handling maintenance

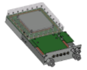
uBLM



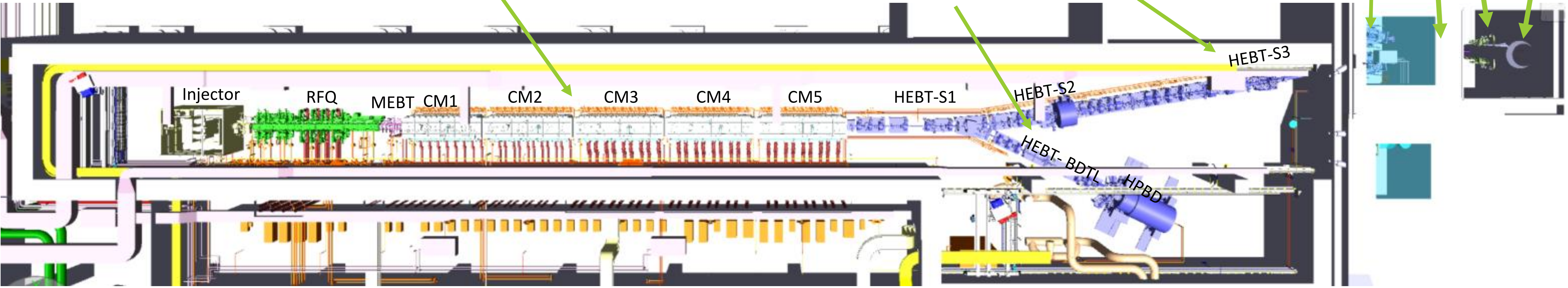
SRF LINAC:
- Measurement of **microlosses** (<1 W/m) @ cryogenic environment → CVD's
- Transverse profile @ Warm Sections

HEBT:
Non-interceptive profile monitors in multipoles section

Accelerator:
Monitors for lossless beam transport



HEBT/BDTL:
Monitors for longitudinal beam **characterization**



A. Ortega, IBIC'25, MOCC02, 2025

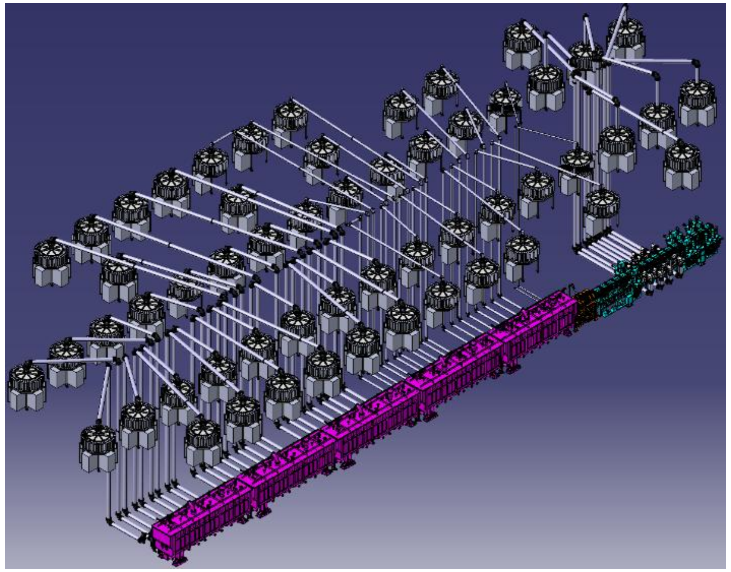
RF Power System

56 RF Stations to supply the RFQ (8), MEBT (2) & SRF (8/11/9/9/9) cavities

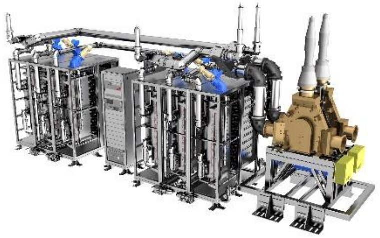
16 kW up to **200 kW**
CW 175 MHz RF Power System

12 MVA electric consumption

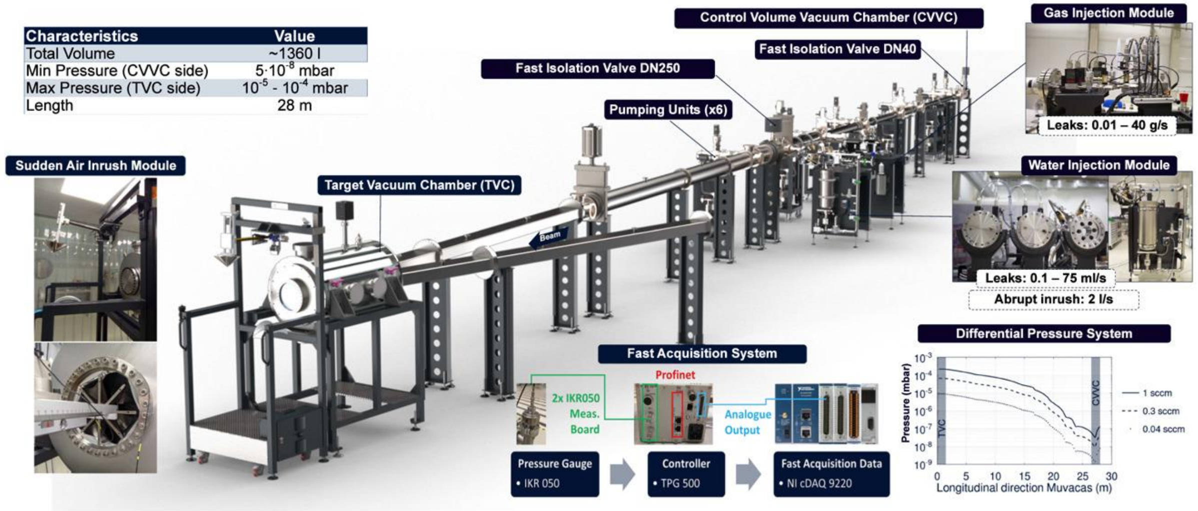
- Based on **SSPA** to improve the reliability and maintainability
- Several prototypes from CIEMAT/EF, INFN/EF and F4E validating 200 kW @ 175 MHz stations with several technologies and suppliers
- **Target efficiency AC/RF** (>60%) → achieved by prototypes
- Requirements for a powerful digital **LLRF** based on LIPAc experience
- Challenging design of the **coaxial lines (flexible line connection to cavities)**
- Assessment of **circulator** requirements and **transistors** technologies
- **Tendering of the full system (amplifiers+transmission lines) to be launched in few months by F4E**



C. de la Morena et al., Fus. Eng. Design, 189, 113475, 2023



Ongoing research prototypes



A. Sabogal et al., Fus. Eng. Design, 222, 115473, 2026

MuVACAS:

To validate protection of vacuum-related safety scenarios

EUROfusion

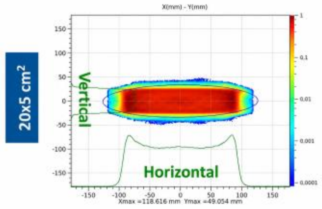
Quick Disconnecting System (QDS): To validate RH connection system at the target

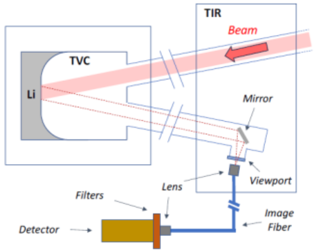
ENEA
ARQUIMEA
EUROfusion

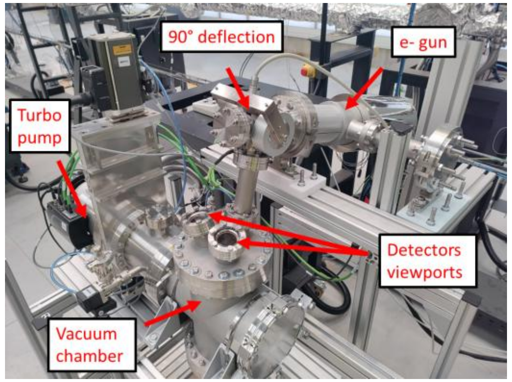
G. Benzoni et al., Fus. Eng. Design, 215, 2025
A. Rodríguez et al., Proc. ISFNT16, 2025

Lithium OTR Light Detector:

To validate the OTR light from liquid lithium







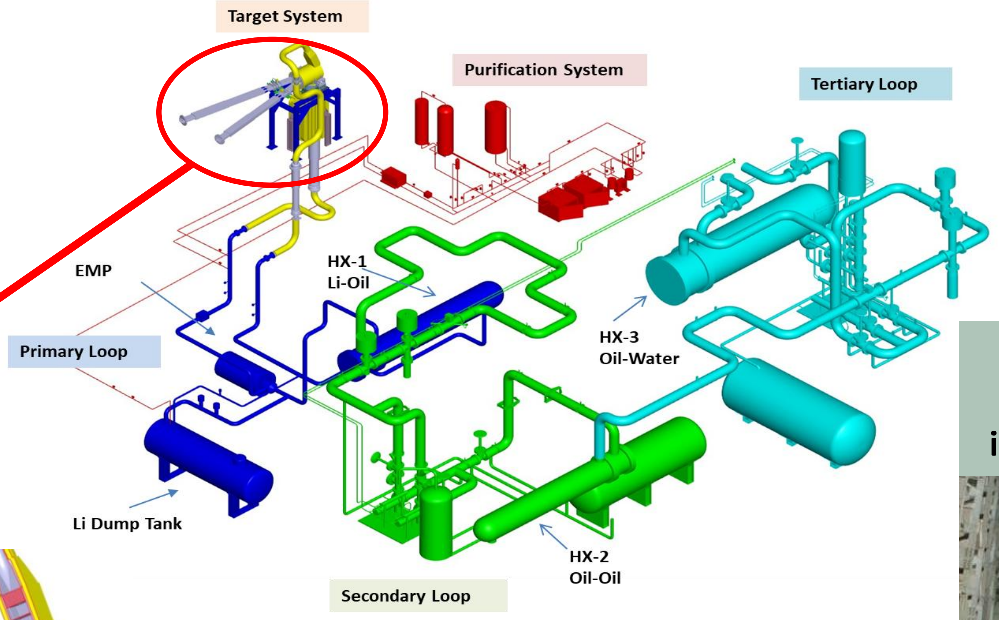
EUROfusion

J. Herranz et al., IPAC’26, WEP6074, 2026

Liquid Lithium Target

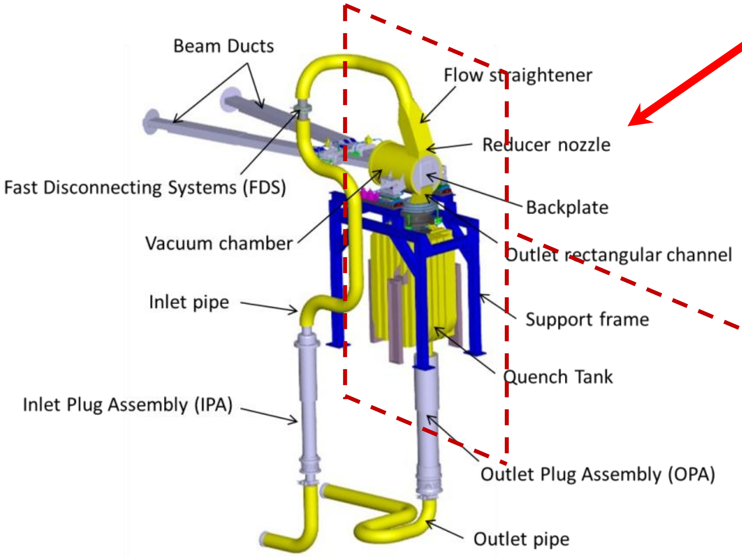
- **5 MW** power handling (ready for 10 MW)
- **Interaction beam-target** (vac chamber, transients, vaporization...)
- Three **heat rejection loops** (Li-Oil, Oil-Oil, Oil-Water)
- **Impurities** control and monitoring
  - Corrosion issues (affected by N content)
  - Radioactivity inventory (Be-7, Tritium, ACP…)

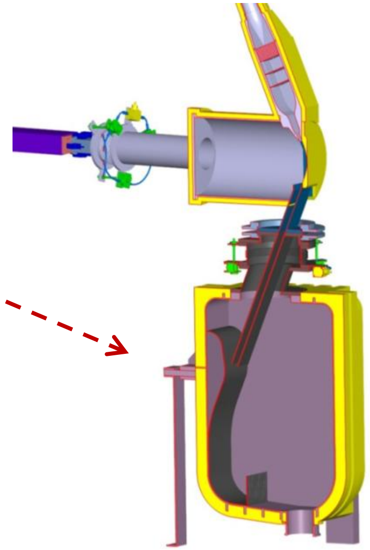
Lithium loops



Li volume ~14 m^3
Li flow rate: ~100 l/s

Target Assembly





Heat flux: 500 MW/m^2
Jet thickness: 25 ± 1 mm
Li inlet T: 300 °C
Li velocity: 15 m/s
Chamber pressure: 10^{-2} Pa

IFMIF/EVEDA ELTL validation results implemented in the design

H. Kondo, Fus. Eng. Design, 96-97, 117-122, 2015

Remote Handling

Cranes

Single-Failure Proof cranes handling high loads with precision
(+- 10 mm)

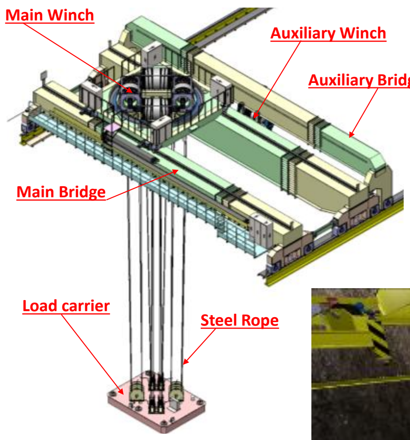
Manipulators

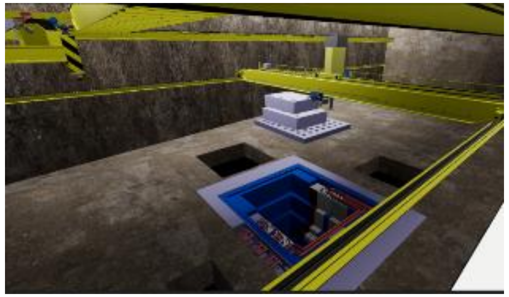
Serial manipulators for versatility

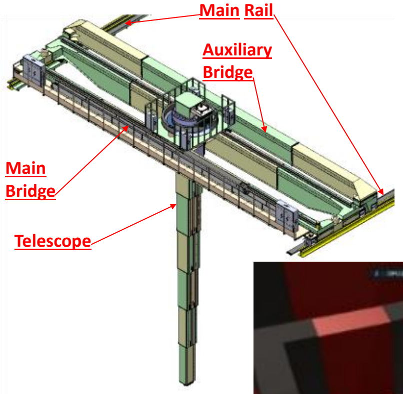
- Obstacle avoidance
- Path planning for tooling
- Wide workspace

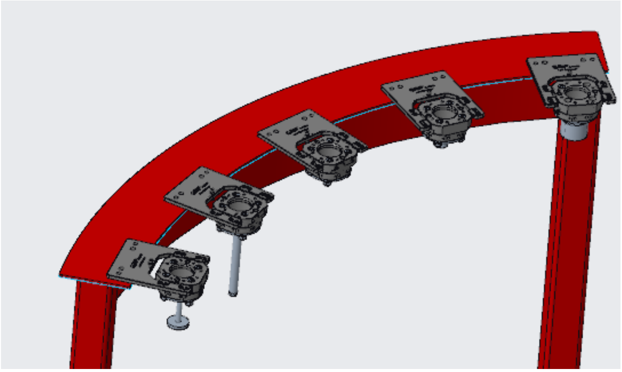
Parallel manipulator for precision

- High stiffness and stability
- High payload and precision



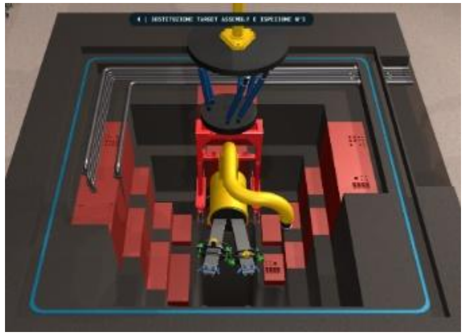






Serial kinematic manipulator Robotic Arm

Parallel kinematic manipulator: Stewart-Gough Platform



Control systems framework

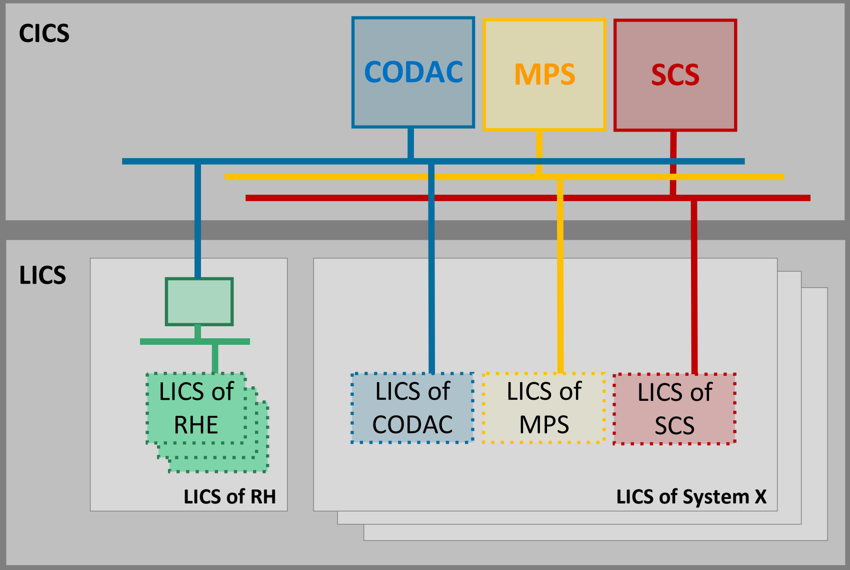
- Segregated **architecture** in three systems: routine control & communication (CODAC) , Machine Protection (MPS) and Safety (SCS)
- **Distributed control** based on EPICS framework (CODAC, MPS)
- Virtualization & containerization
- Configuration management
- Timing and synchronization based in White Rabbit standard

Safety Control System (SCS):
- It implements the safety functions regarding personnel or environment.
- Independent from CODAC & MPS.
- Complying with relevant standards for radiation safety.
- Subsystems:
  - Plant Safety Subsystem (PSS)
  - Occupational Safety Subsystem (OSS)
  - Personal Access Safety Subsystem (PASS)
  - Radiation Monitoring System for the Environment and Safety (RAMSES)
  - Individual Radiological Monitoring Subsystem (IRMS)

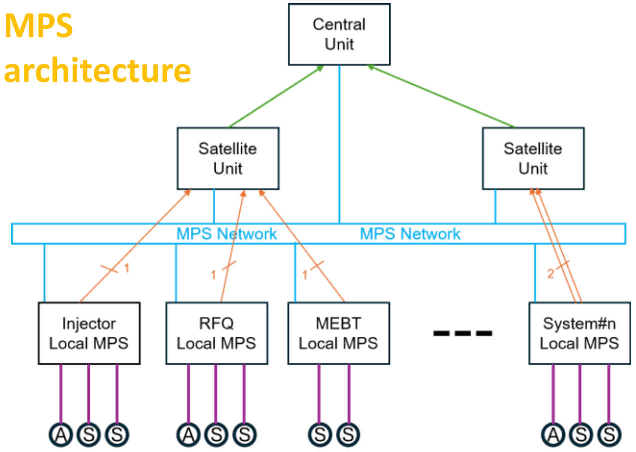
Control, Data Access and Communication (CODAC) System:
- It implements the orchestrated conventional control functions of all system of the facility.

Machine Protection System (MPS):
- It implements the machine protection functions against:
  - ✓ failures of the facilities system/component,
  - ✓ failures of CODAC system,
  - ✓ possible incorrect operation.

Central Instrumentation & Control Systems (CICS):
High-level supervision, coordination, and centralized data services for entire facility.



MPS architecture



See poster R. Lorenzo on Thursday (THPD025)

C. Carvajal et al., ICALEPCS2025, TUAG005, 2025

Construction status

Headquarters &
Aux. buildings ready

DJT Offices + Warehouse to host test stands

UGR DONES: Facility to test prototypes

Site construction
(including LINAC building)
starting in few weeks
(FWC already running)

Cofinanciado por
la Unión Europea

Ongoing activities

- The **team in Granada** is growing up (more than 80 pers. from esDONES & F4E).
- The **handover of engineering responsibility** to the Programme Team is finished
- **esDONES:** Calls for around 250 M€ already running (Accelerator & Test components, PLM, Engineering Support, Safety, Site & Buildings construction)
- **F4E:** Personnel assigned to Programme Team in Granada (+10), early procurement launched for accelerator components (couplers), and calls for tender under preparation (Injector, RF Power System…)
- Drafting and signature of **Procurement Arrangements** with Providing Parties – already four signed (Buildings, MEBT, HEBT, Test Cell)- four more expected before end of the year

Outline

DAEJEON LINAC2026

Conclusions & Outlook

The **IFMIF-DONES accelerator** is fully into the **Construction Phase**

Civil works for the main building housing the LINAC will start in few weeks

Procurement of the LINAC is ongoing with several systems under final design and manufacturing

The strategy implemented to find synergy with **similar facilities** (e.g. ESS, CERN, MYRRHA, SPIRAL2,…) in addition to **LIPAc** is an important asset to minimize/mitigate the risk and will be pursued

Strengthening the **collaboration** with the whole accelerator scientific and industrial community is key for the success of IFMIF-DONES and the next generation high current linear accelerators

Thank you for your attention…

www.ifmif-dones.es