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IFMIF-DONES OVERVIEW

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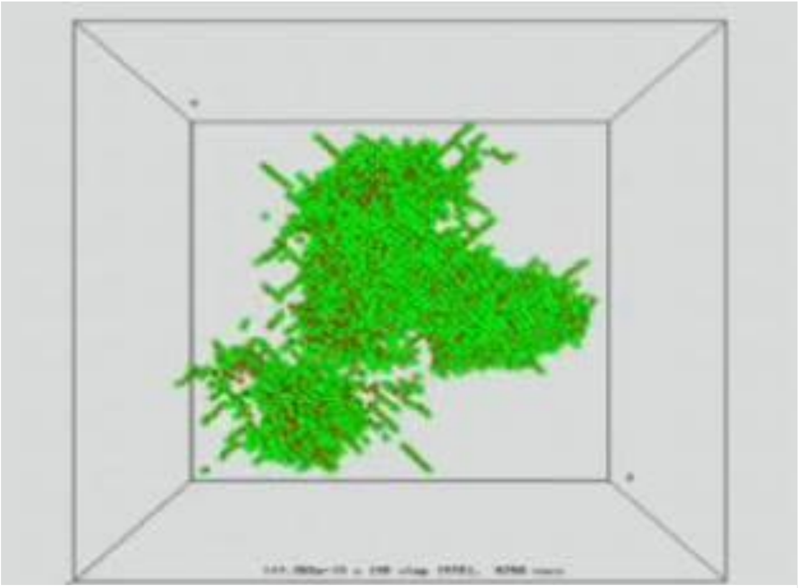
The problem of DEMO materials

Neutron damage to material:
- dpa, due to impact and cascades
- production of He and H, due to transmutation reactions, generates embrittlement and swelling

DEMO materials will need to be qualified at least at 20 dpa
Ideally we should use 14 MeV neutrons, but how to get them?

Testing requires high neutron flux: 10^{17} n/s



Molecular dynamics calculation of displacement damage due to neutron impact.

Today´s sources

Fission reactors: neutron energy too low, Ok for dpa but very few transmutation reactions (Eurofer case: Fe+n→Mn+H, Fe+n→Cr+He)
B-doping can help but not conclusive

Spallation sources: neutron energy too high: He,H/dpa too high, other damaging effects

How to get 14MeV neutrons at high rates?

Fusion DT reaction

- Driven Burning plasma (low Q): tritum availability (or Breeding blanket) , too long testing periods, technology, cost
- Accelerator driven DT source: low efficiency and neutron rate, technology

Lithium stripping reaction: D+^{6}Li →Be+n, D+^{7}Li →Be+2n

- Efficient, 5 MW D beam will generate the required 10^{17}n/s flux
- Produces a narrow cone of high energy neutrons
- n-spectrum can be tailored to the needs
- Technology challenging but main elements validated: IFMIF (DONES)

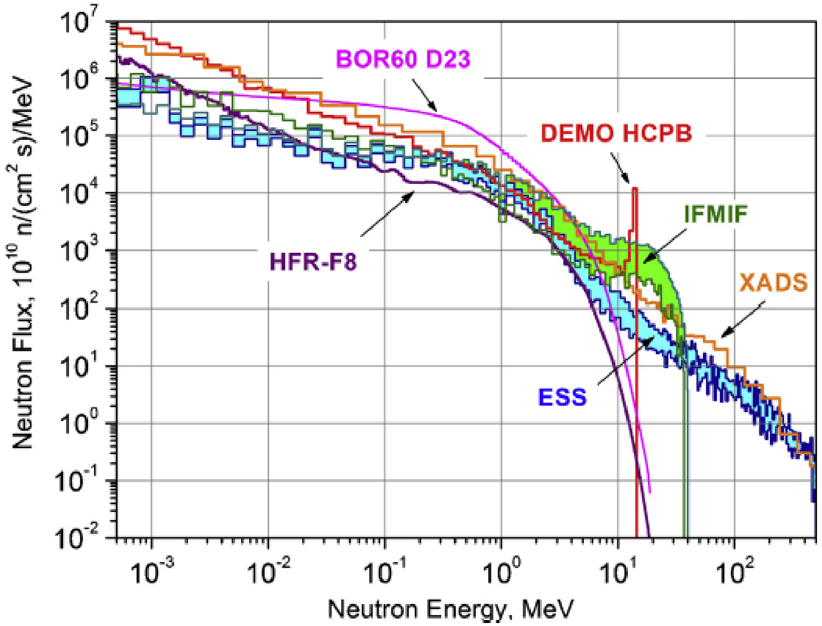
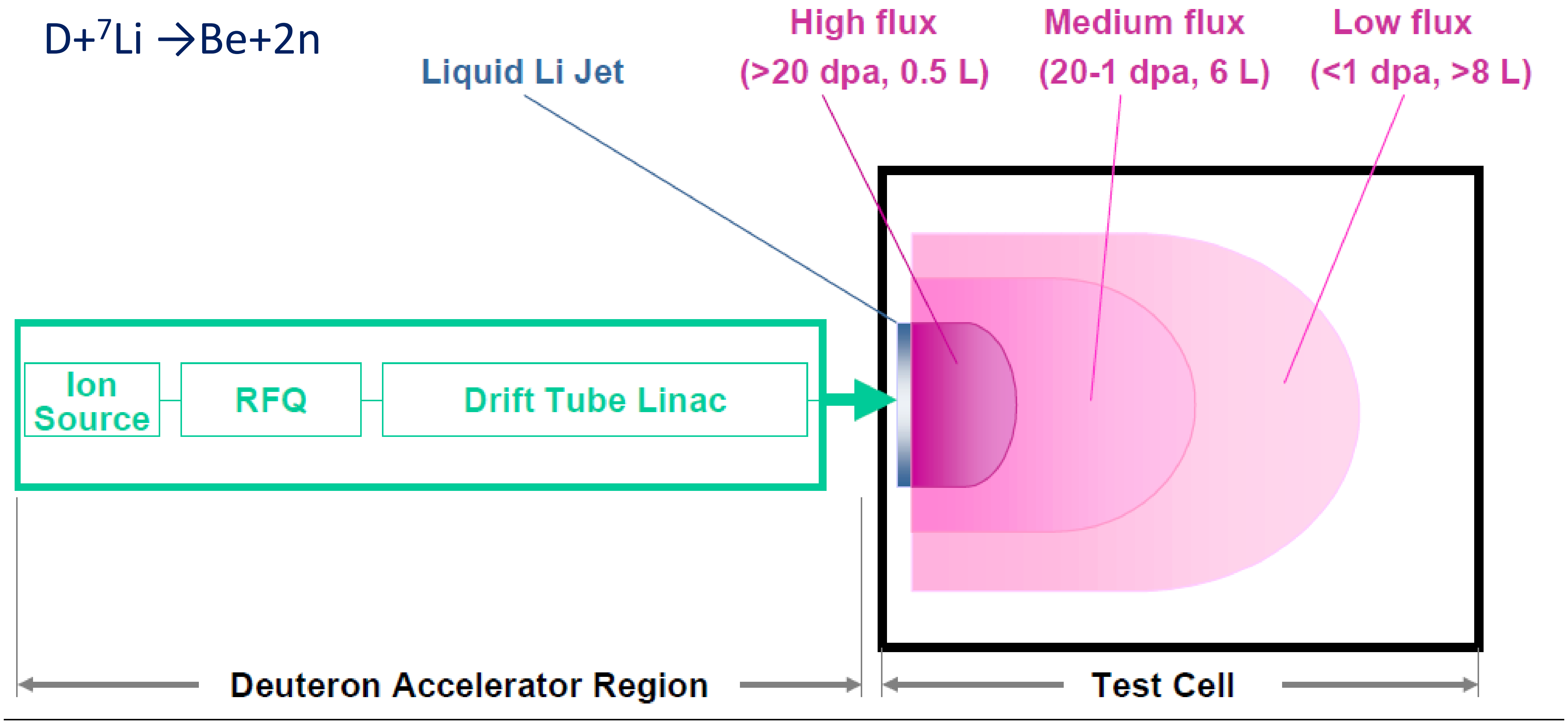


Fig. 5. Neutron spectra of the helium cooled pebble bed (HCPB) blanket of a fusionDEMO reactor, the IFMIF D–Li source high and medium flux test volumes, the spal-lation sources ESS and XADS as well as water-cooled mixed-spectrum (HFR) and Na-cooled fast-spectrum (BOR-60) fission reactors [42].

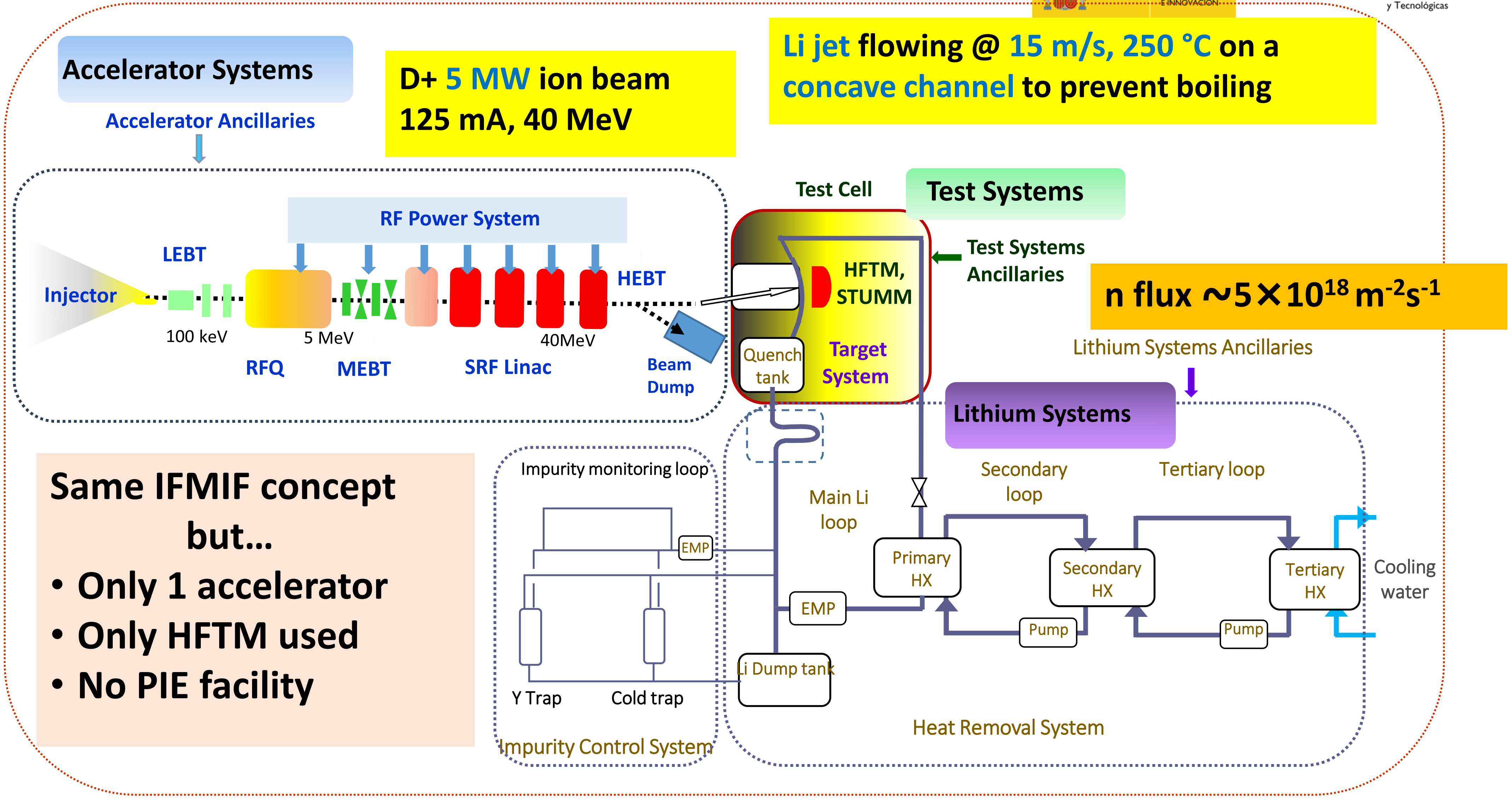
IFMIF: a Li stripping neutron source

$D + {}^{6}Li \rightarrow Be + n$

$D + {}^{7}Li \rightarrow Be + 2n$



IFMIF-DONES



Same IFMIF concept but…

- Only 1 accelerator
- Only HFTM used
- No PIE facility

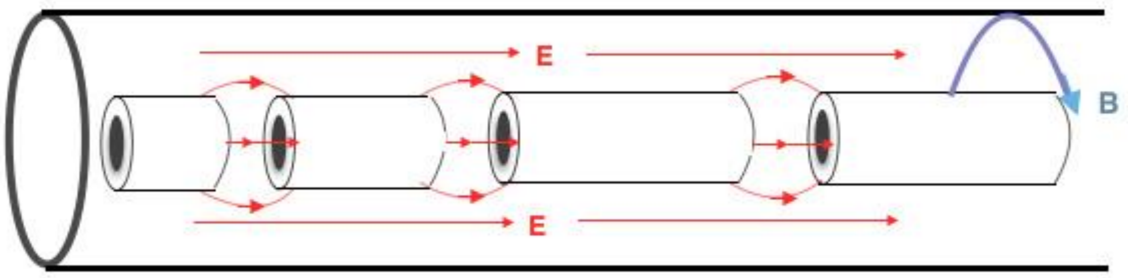
Site, Buildings & Plant Systems

- Layout & Site Infrastructures
- Buildings
- HVAC, Electrical Power Supply, HRS, etc.
- Remote Handling System

Central Instrumentation and Control Systems

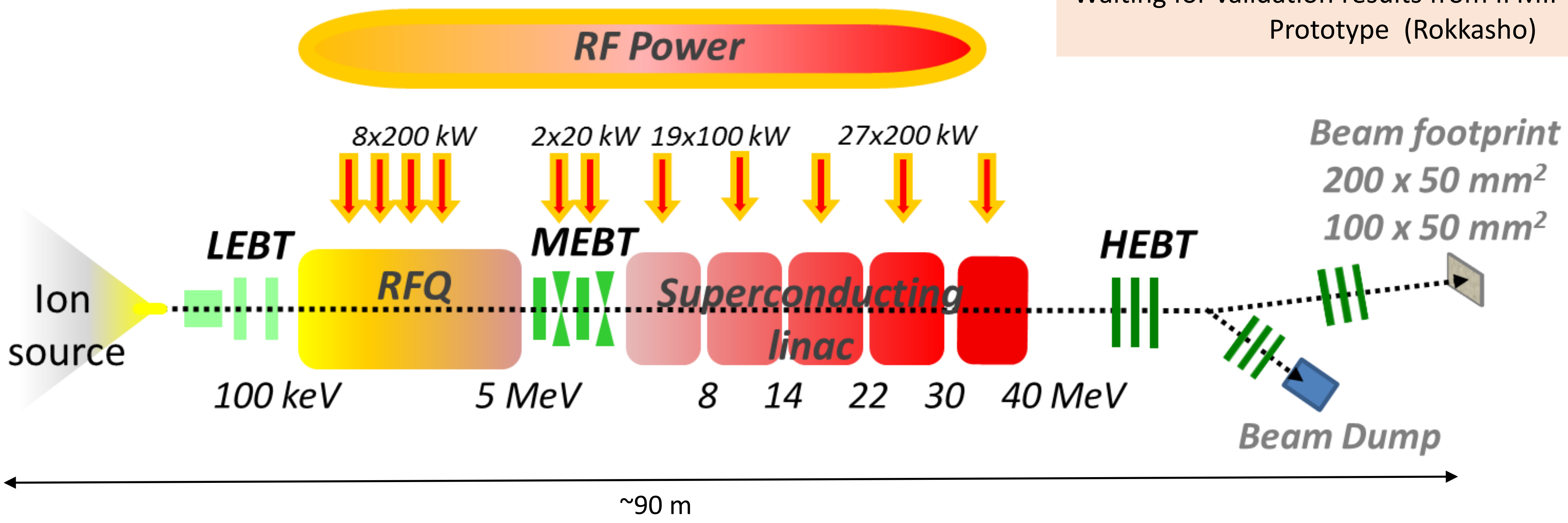
- CODAC System
- Machine Protection System
- Safety Control System

RF- driven linear ACCELERATOR



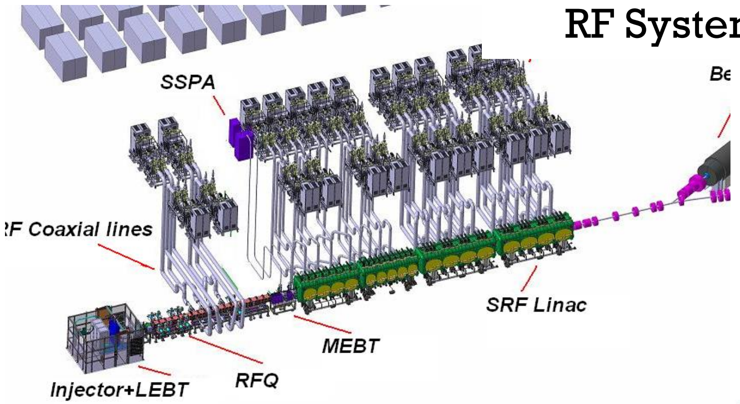
175 MHz, 5MW, 125 mA, CW, high availability: One of the more powerful accelerators in the world

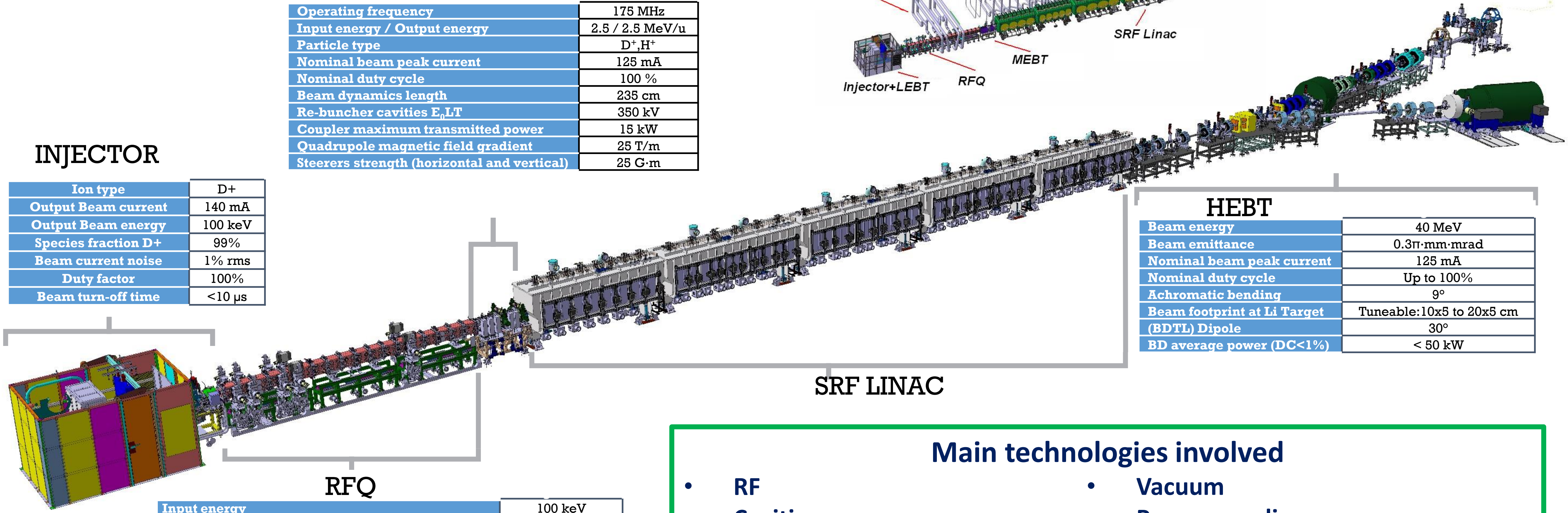
Waiting for validation results from IFMIF-EVEDA: LIPAc Prototype (Rokkasho)



ACCELERATOR layout

RF System: 6MW@175MHz





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_0LT	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 Li Target	Tuneable:10x5 to 20x5 cm
(BDTL) Dipole	30°
BD average power (DC<1%)	< 50 kW

SRF LINAC

RFQ

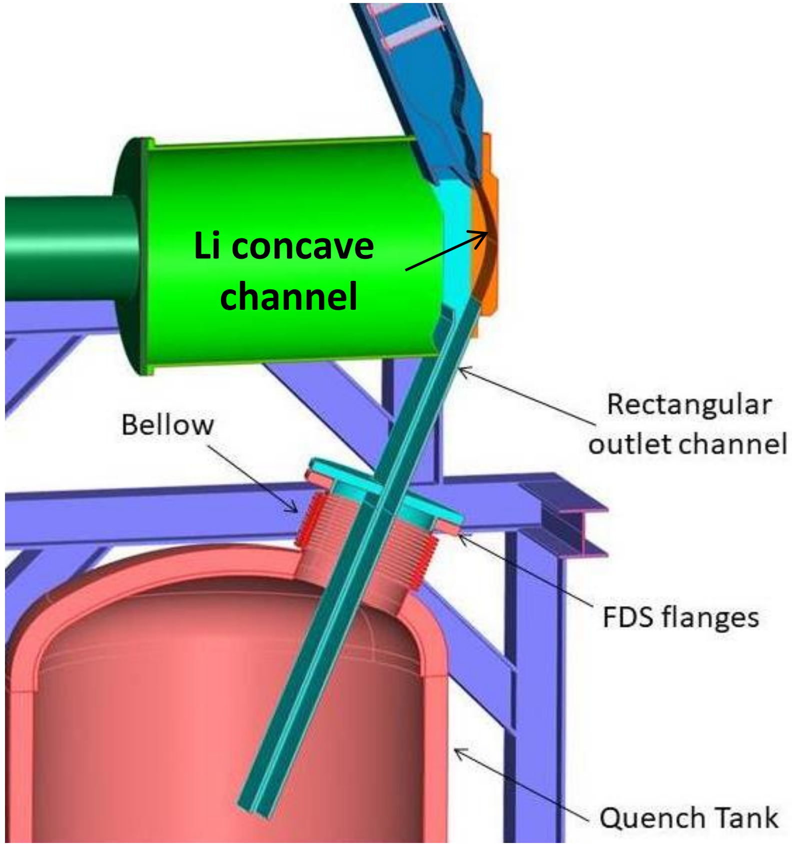
Input energy	100 keV
Output energy 5 MeV	5 MeV
Input D+ current	130 mA
Output D+ current	125 mA
RF Frequency	175 MHz
Max surface field	< 25.2 MV/m
Output rms emittance (norm.) transv.	< 0.30 π mm mrad
Output rms emittance longitudinal	<0.2 MeV deg
Duty factor	100%
Transverse zero current phase advance RFQ end	< 220 deg/m
Longitudinal zero current phase advance RFQ end	< 90 deg/m

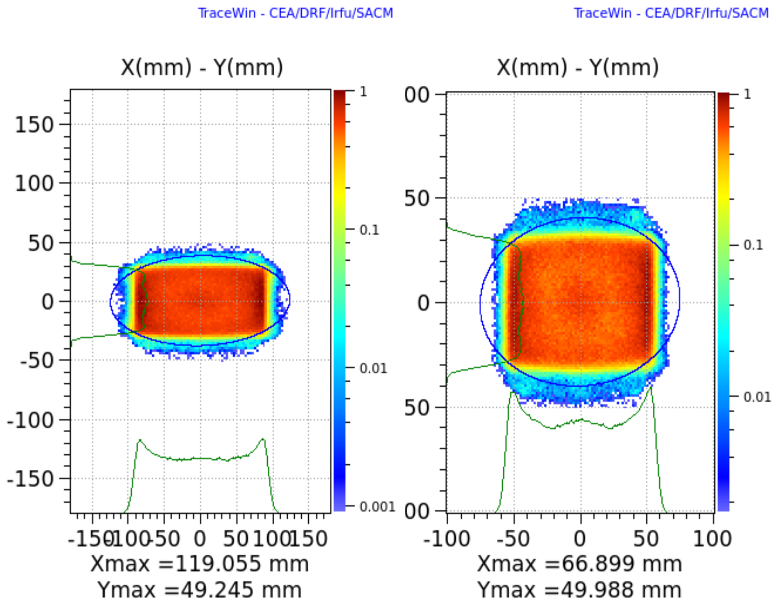
Main technologies involved

- RF
- Cavities
- Magnets
- Mecatronics (Cu, Nb, Al,…)
- Criogenics
- Vacuum
- Power supplies
- Cooling technologies
- Sensors and diagnostics
- Control (hardware and software)

Li Target

Li speed: 15 m/s





20x5 cm^2 footprint (reference)

10x5 cm^2 footprint

Issues:

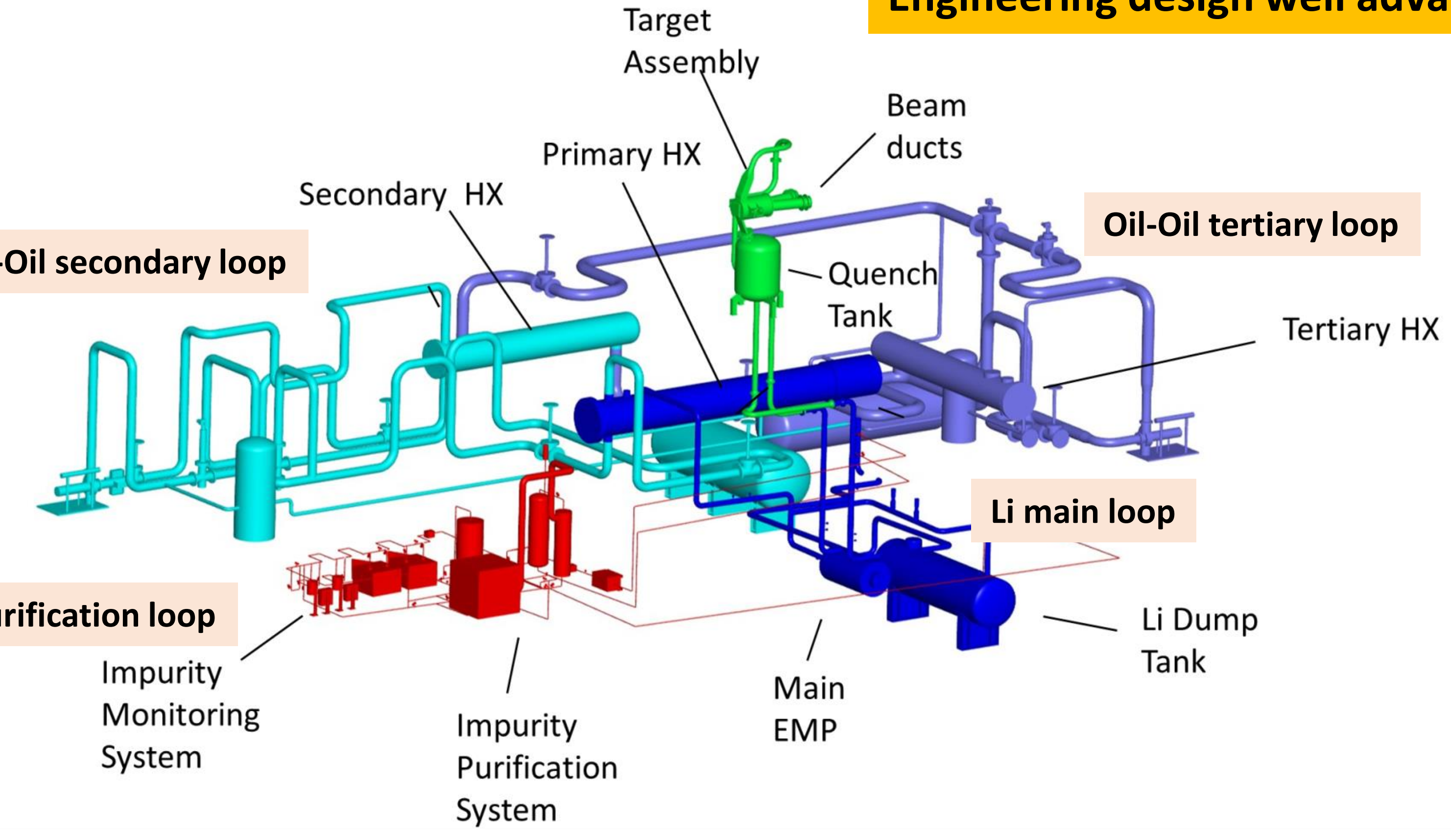
- 500 MW/m^2 Turbulence (thickness must remain 25±1 mm)
- Corrosion
- Purification

Prototype tested in Oarai, Japan

Li systems

Engineering design well advanced

Li volume ~12 m^3
Li flow rate ~100 l/s
Li temperature (cold side) ~300 °C



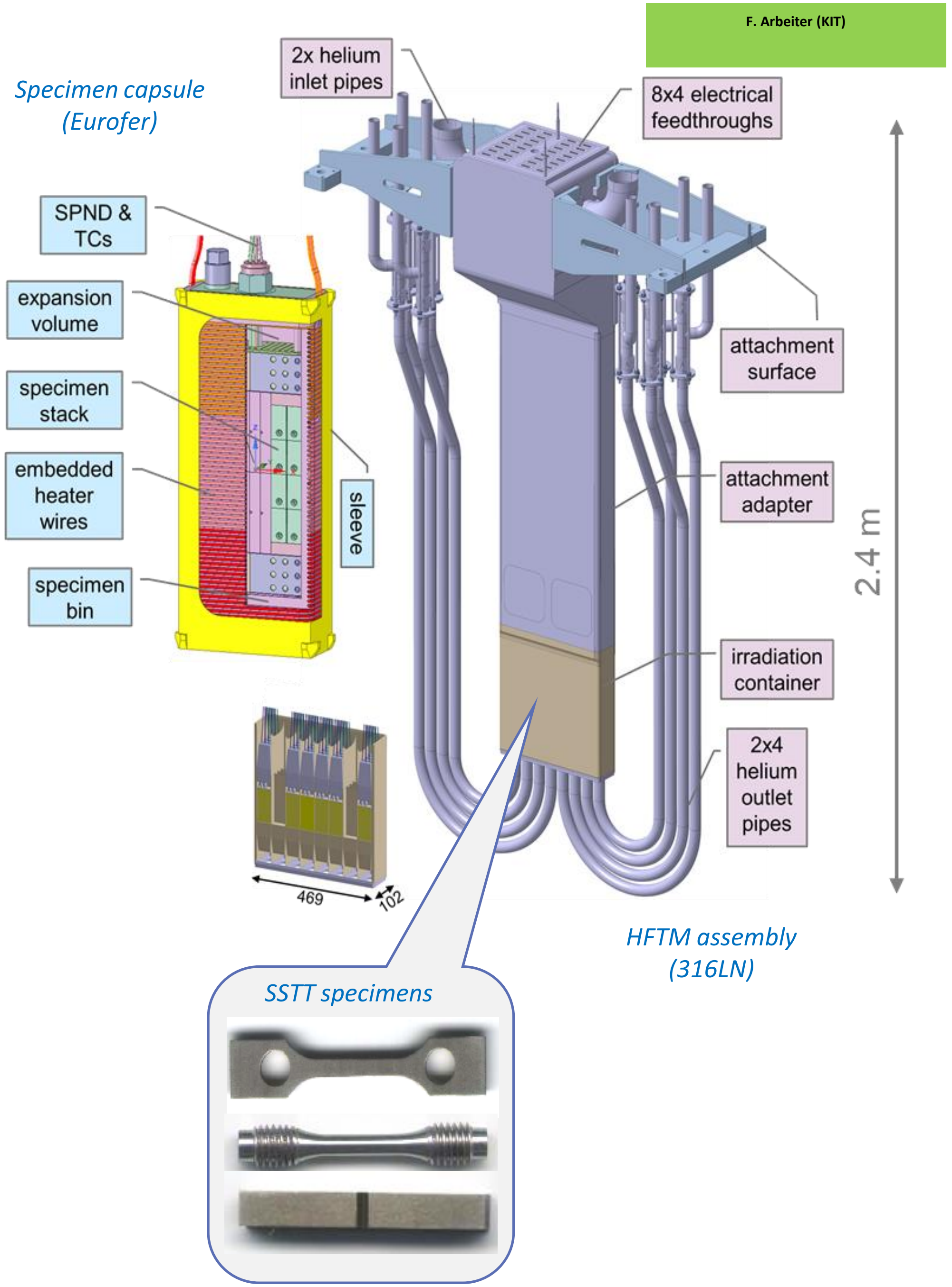
Design drivers:

Minimization of mobilizable T inventory (< 0.1 wppm) through:
- Li volume reduction
- H traps design and operation

Management of Li impurities control
- Off-line N trap integrated in the Li Dump Tank
- Cold trap: O, Be…

Main technologies involved
- **Liquid metals (fluids, monitoring and purification)**
- **Complex cooling loops**
- **Diagnostics**
- **Remote maintenance**
- **Control (hardware and software)**

High Flux Test Module



Heating: Nuclear **2.3 W/g peak**, 17 kW tot., 1.5 kWe per capsule

Cooled by **low pressure helium** gas (0.3MPa, 50°C), **Sodium** heat transfer filler

Lifetime: 1year / 2.5 years (**53 dpa**). Body made from **316LN** (acc. RCC-MRx)

Masses: Total 680 kg, 40 kg irradiation capsules with specimens

Specimens

Stainless steel

- 12–25 dpa/fpy in 306 cm^3 (~ 850 specimens)
- 13 appm He / dpa, 53 appm H / dpa.
- 250 – 550 °C, sodium immersed specimens

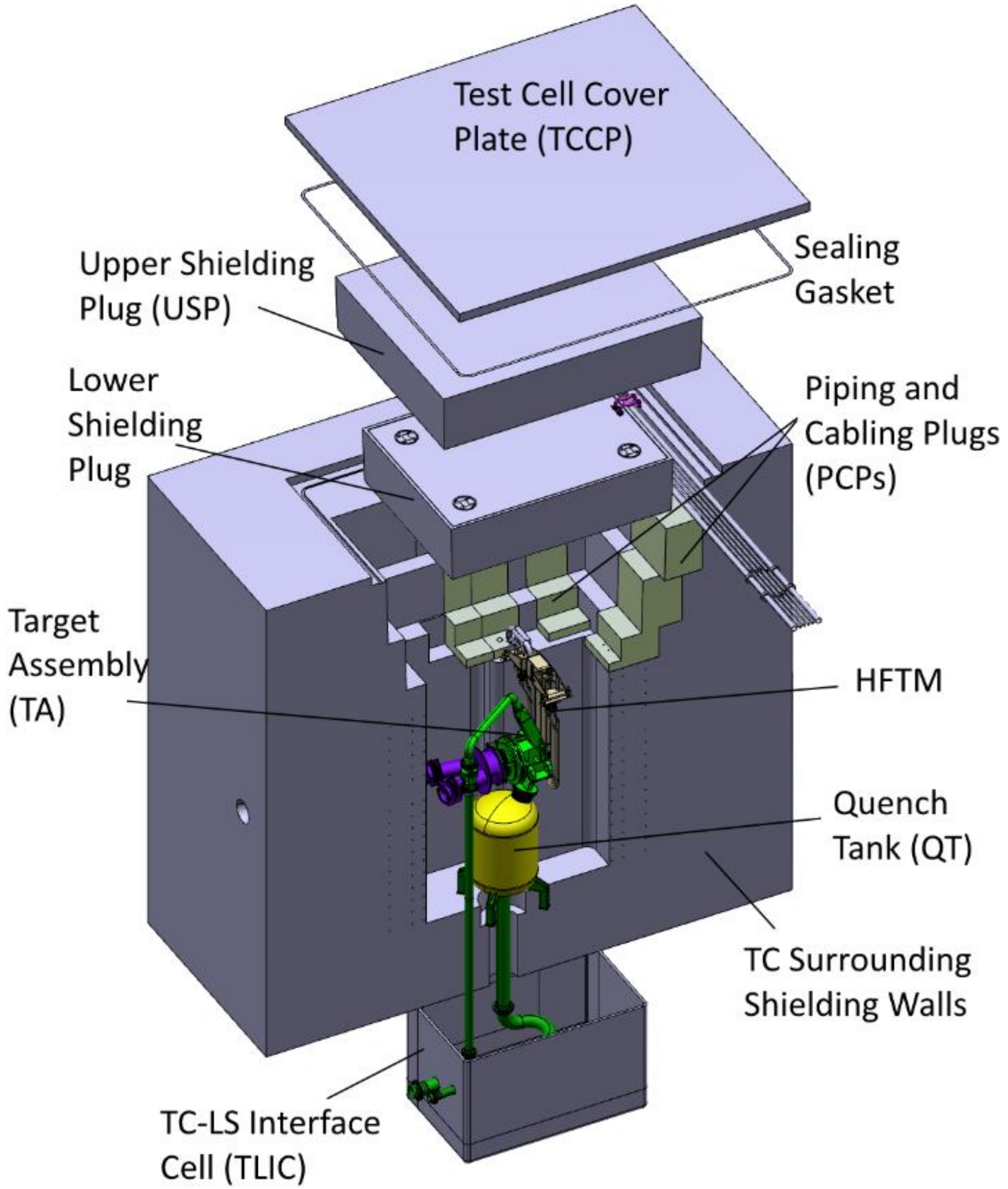
Copper

- 5–30 dpa/fpy
- 6–8 appm He/dpa is (~DEMO), 48–50 appm(H)/dpa (~1.4x DEMO)
- >100°C, helium immersed specimens

Tungsten

- 1–3 dpa/fpy in W
- 9–10 appm He / dpa, (2x of DEMO), 20–29 appm H / fpy, (3x of DEMO)
- Up to 800°C, assisted by self-heating , 8x20 cm^3 cylindrical HT capsules

Test cell



Main characteristics driven by the presence of neutrons and Li

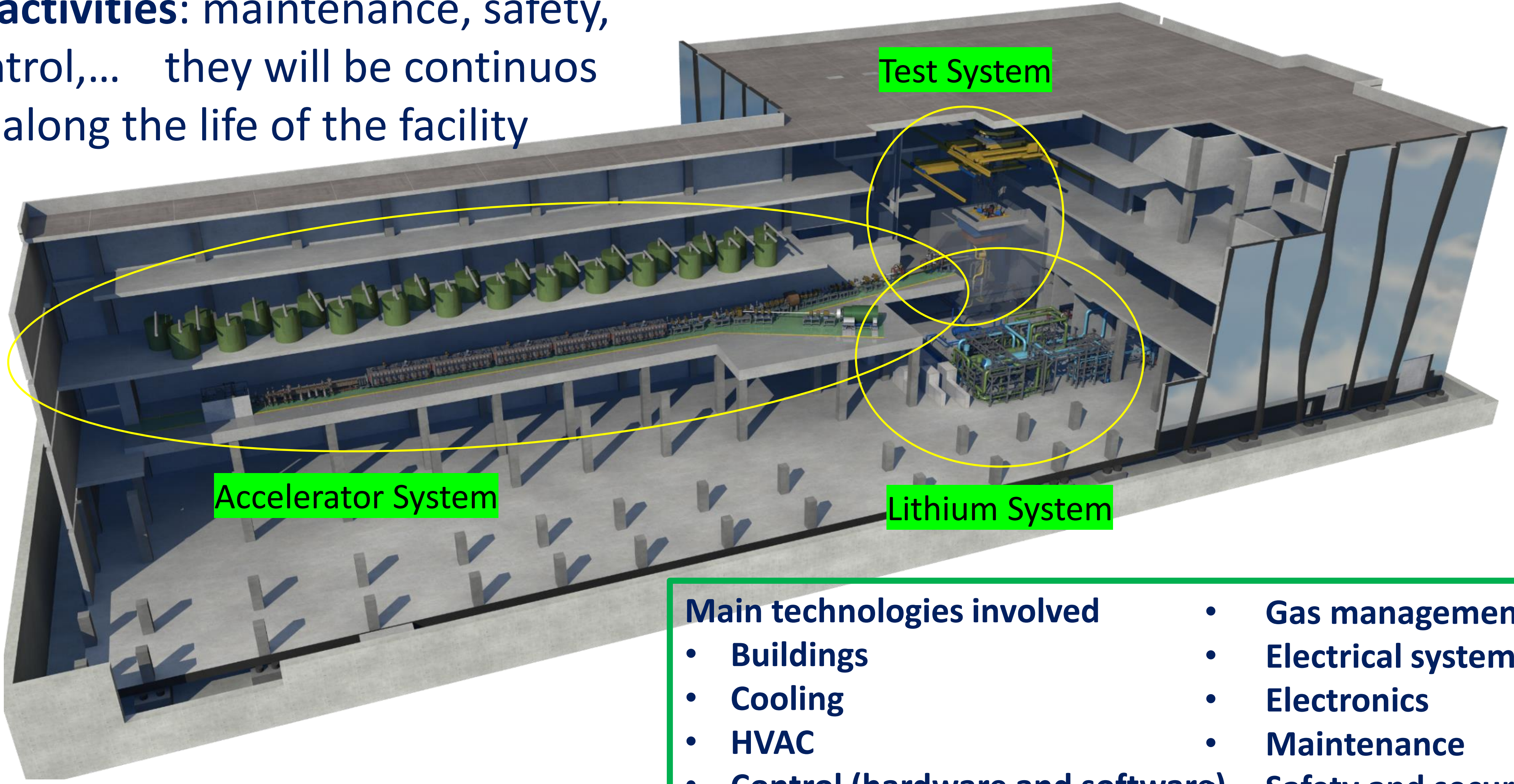
- **Internal components cooling by He**
- **Remote Maintenance required**

Main technologies involved

- **Mecatronics**
- **He and water cooling**
- **He, Ar and water systems**
- **Shielding materials and technologies**
- **Remote maintenance**
- **Vacuum**
- **Diagnostics**
- **Control (hardware and sofware)**

Conventional systems: half budget will go to buildings and conventional systems

Transversal activities: maintenance, safety, security, control,… they will be continuos activities all along the life of the facility



Main technologies involved

- **Buildings**
- **Cooling**
- **HVAC**
- **Control (hardware and software)**
- **Gas management**
- **Electrical systems**
- **Electronics**
- **Maintenance**
- **Safety and security…**

+ Waste management & decommissioning

Thanks for your attention