Cryogenics for the IFMIF-DONES deuteron accelerator

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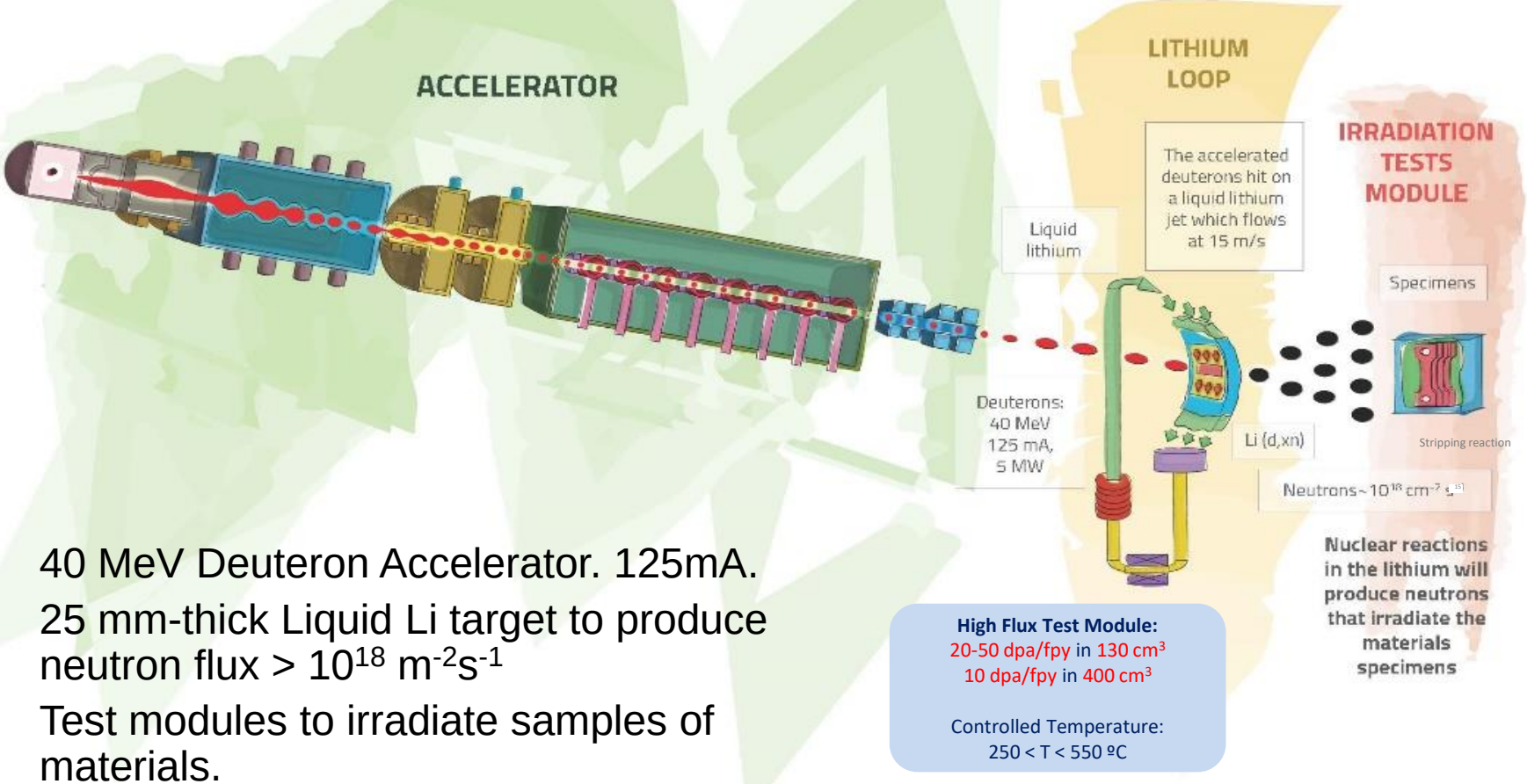
Introduction to the IFMIF-DONES Facility

Main Objective: material qualification for fusion reactors.

International Fusion Materials Irradiation Facility - DEMO Oriented Neutron Source

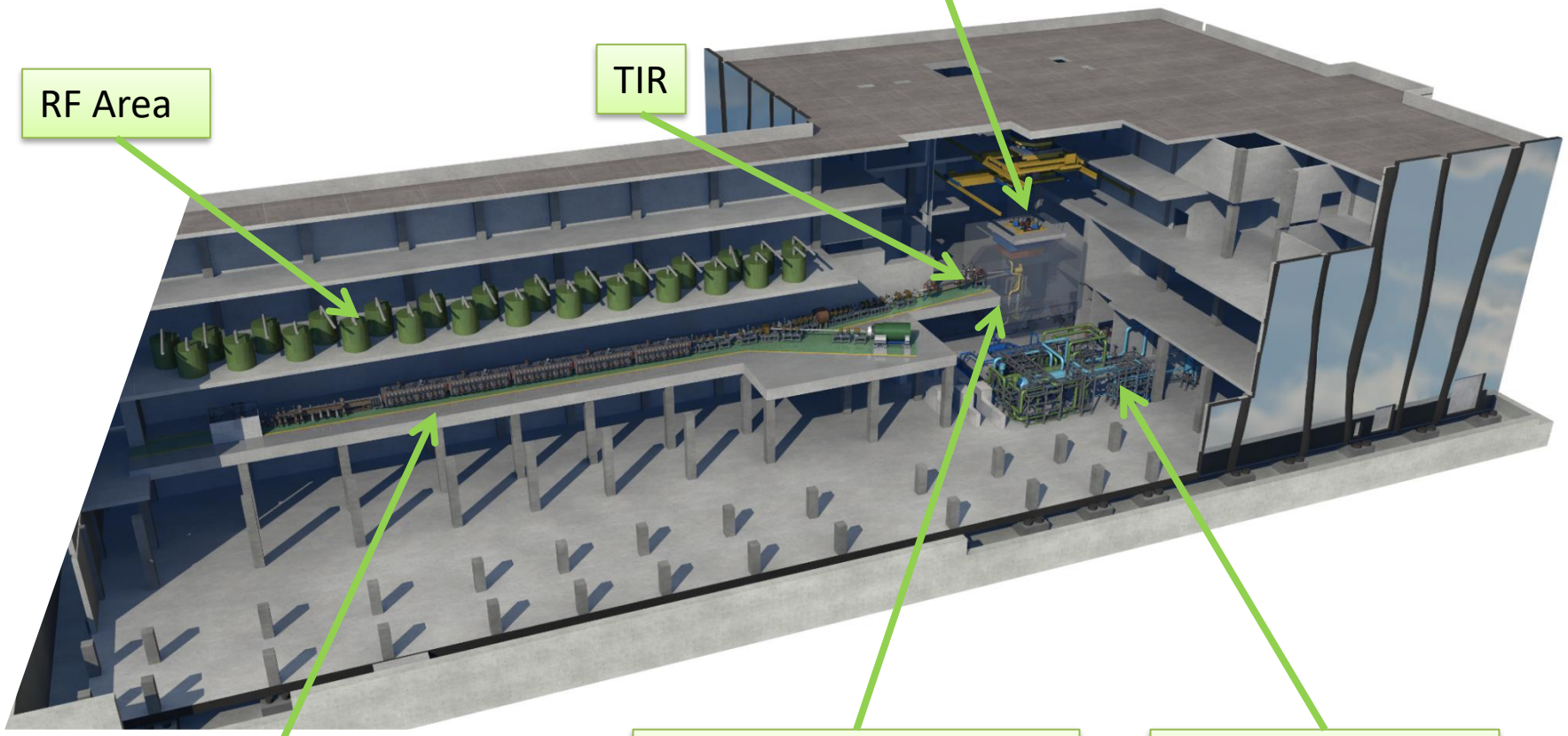


- 40 MeV Deuteron Accelerator. 125mA.
- 25 mm-thick Liquid Li target to produce neutron flux > 10^{18} $m^{-2}s^{-1}$
- Test modules to irradiate samples of materials.

Introduction to the IFMIF-DONES Facility

IFMIF DONES Facility

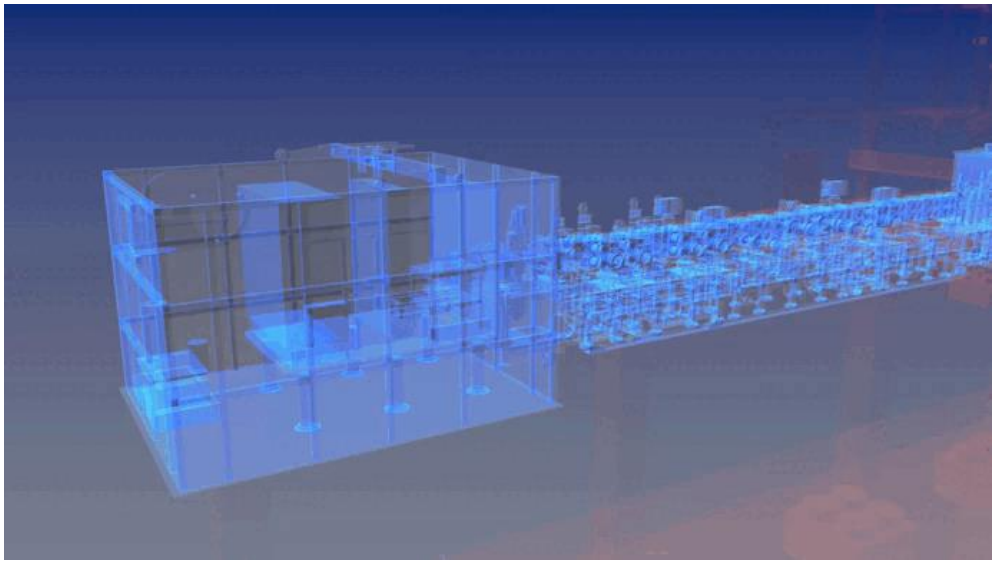
The site is located at Escúzar -18 km southwest from Granada city- Spain

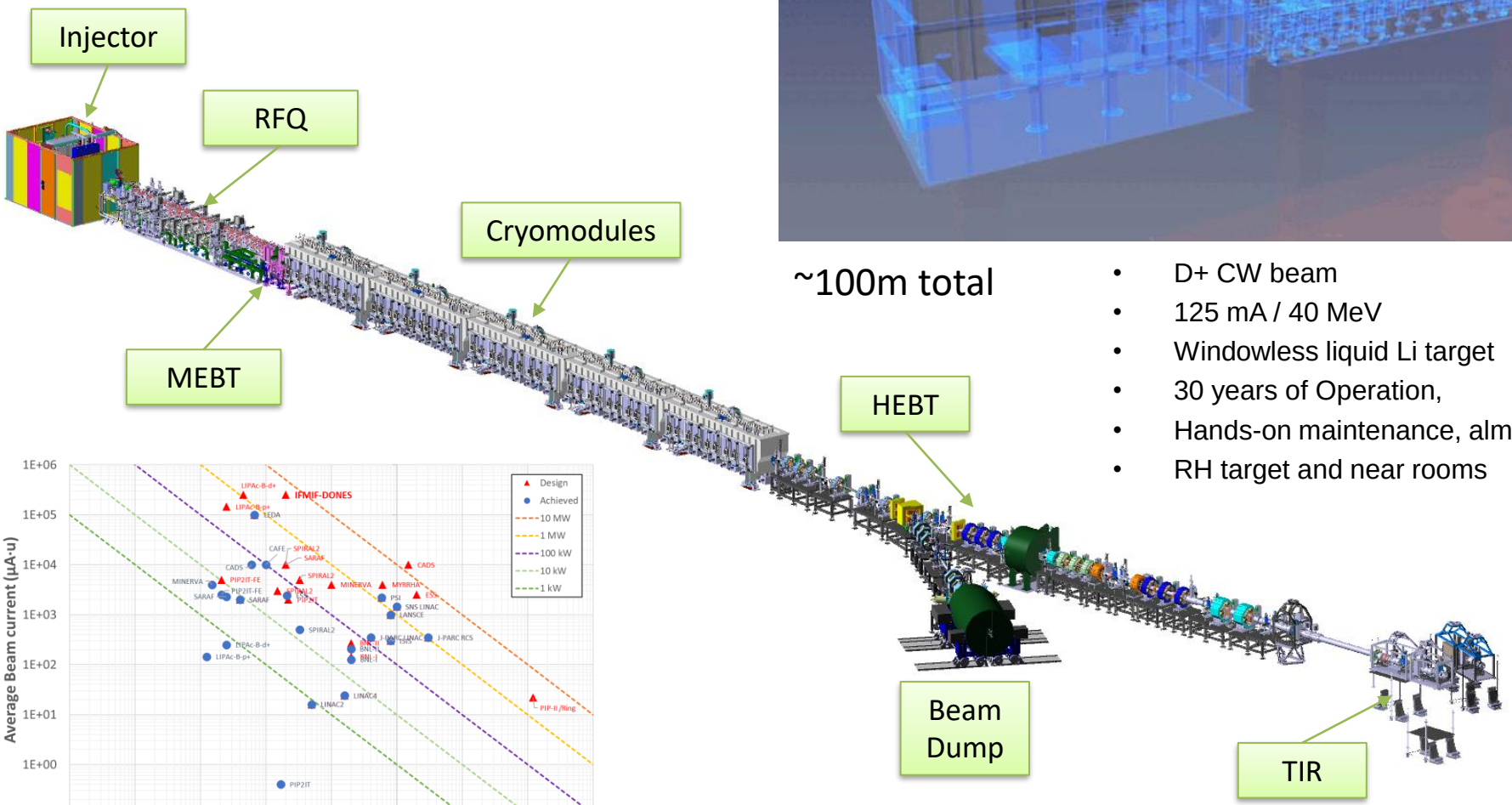


Introduction to the IFMIF-DONES Facility

Accelerator Systems

Operational at least 255 days/year
(70% Operational Availability).





~100m total

- D+ CW beam
- 125 mA / 40 MeV
- Windowless liquid Li target
- 30 years of Operation,
- Hands-on maintenance, almost all.
- RH target and near rooms

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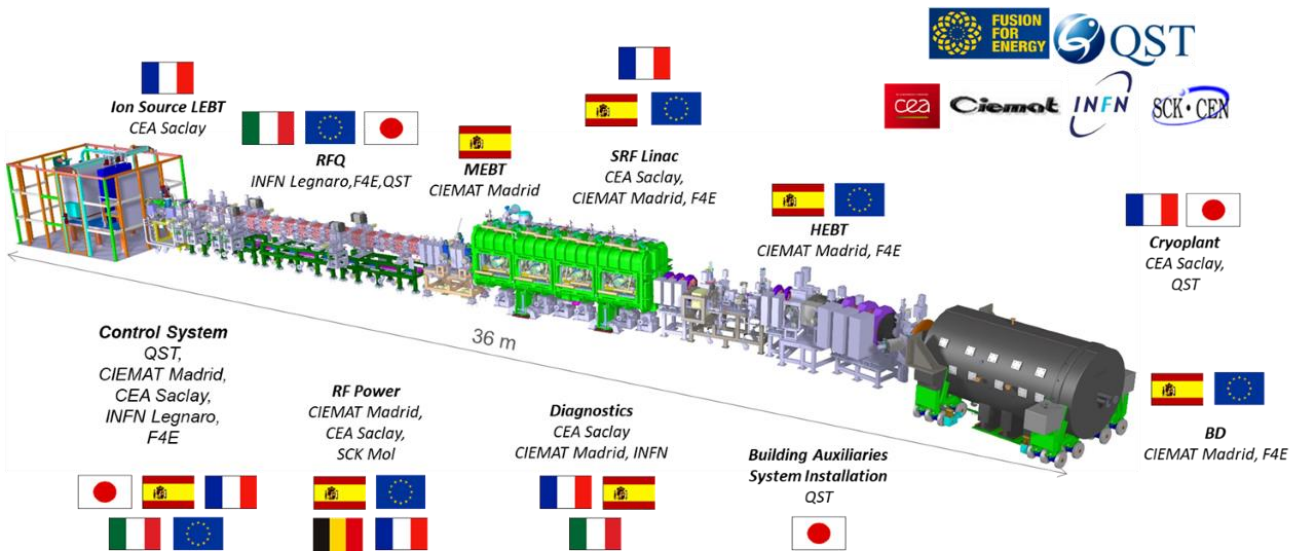
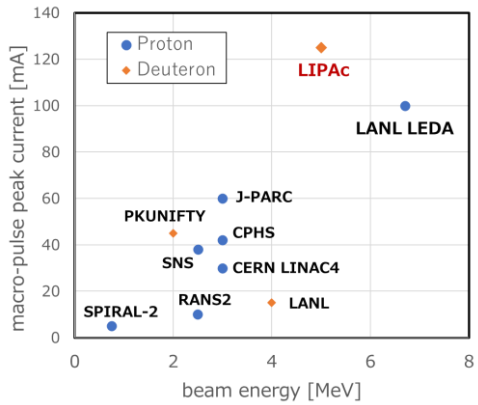
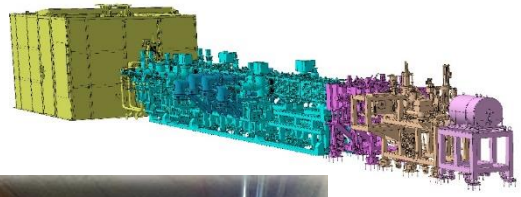
Accelerator Engineering Validation: LIPAc

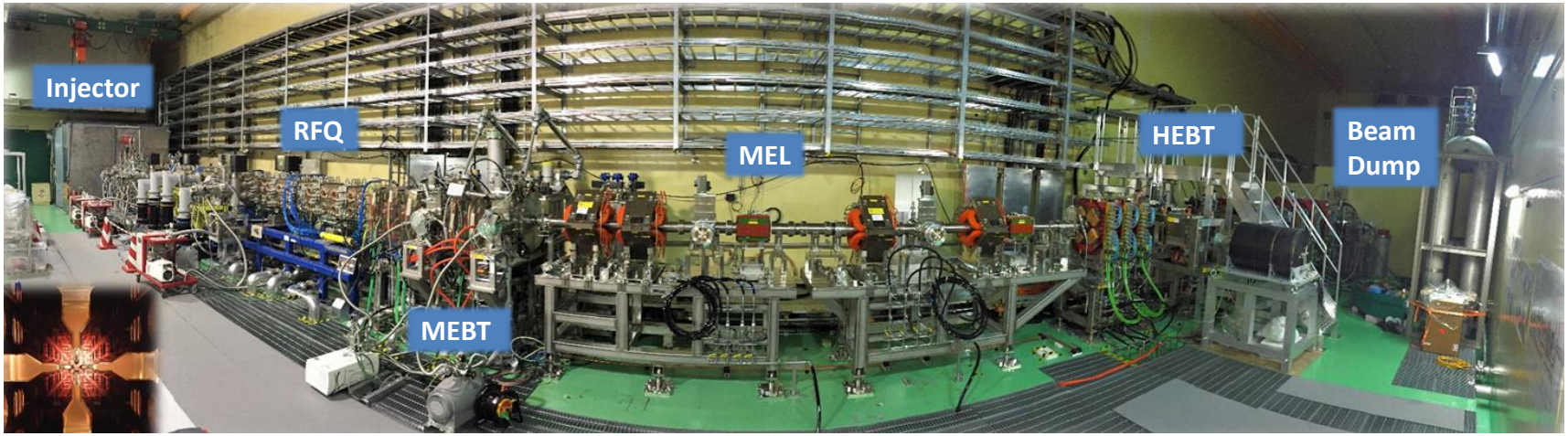
Liner IFMIF Prototype Accelerator (LIPAc) for the engineering validation. Currently on-going.
D+ CW beam 125 mA / 9 MeV





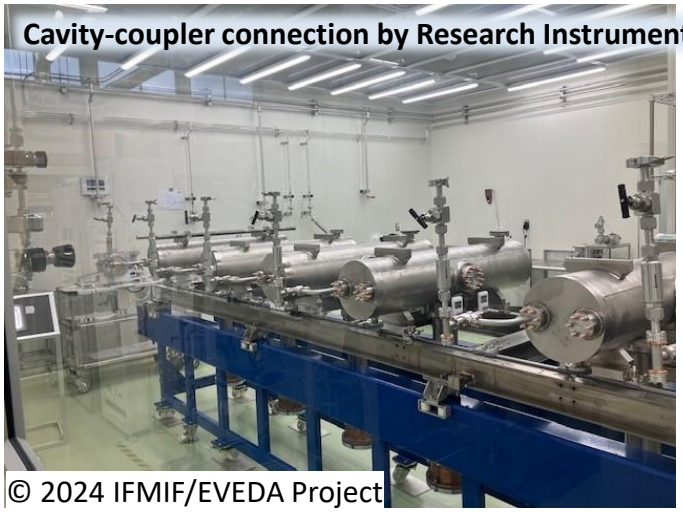
Already achieved **5 MeV - 125 mA**
625 kW, pulsed (up to 0.1 % duty)
in Phase B





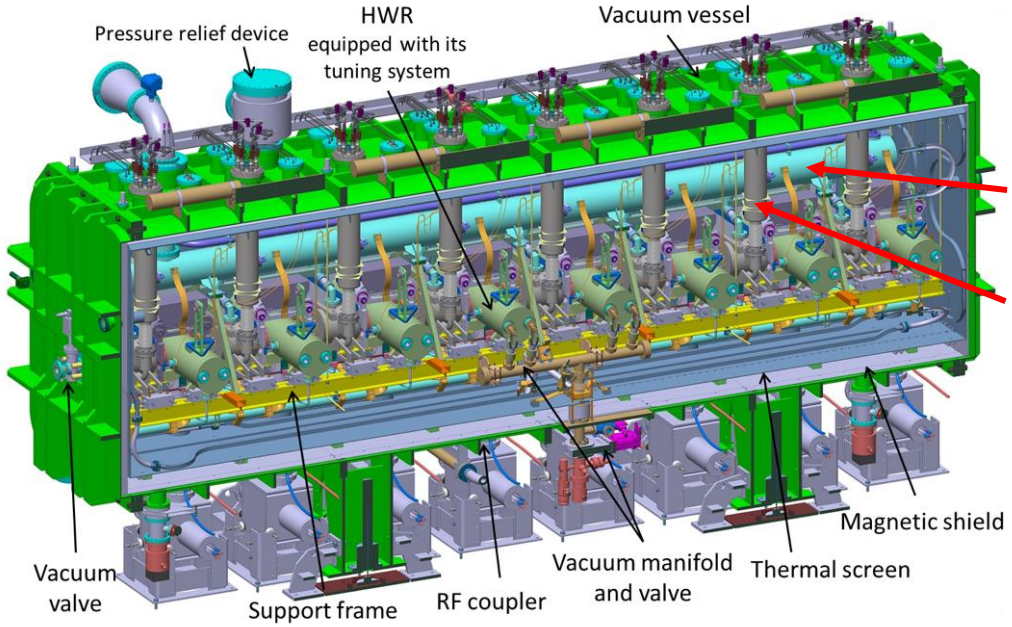
Accelerator Engineering Validation: LIPAc

In Phase C. The cryomodule will be assembled in the Vault.

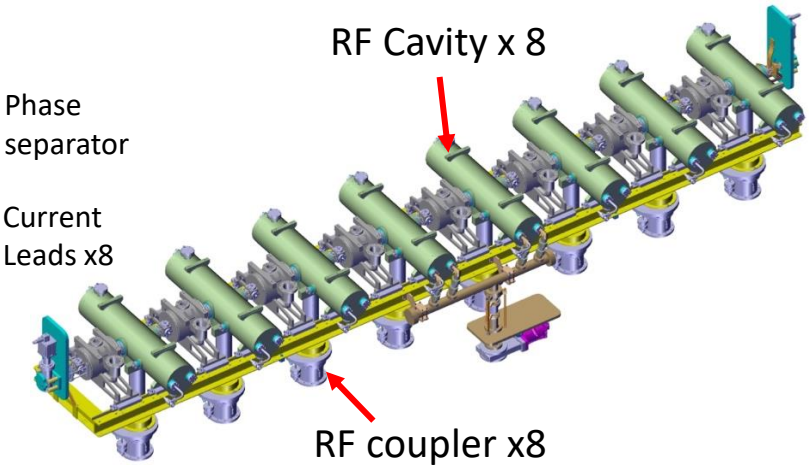


Cryogenics circuits

- LHe 4.5K He saturated conditions.
  - Each RF and solenoid cavity.
- GHe 4.5K He from phase separator.
  - RF couplers.
  - Current Leads cluster.
- GHe 50K He.
  - Thermal Shield



Side Loading of Cavity String



Cold Mass: 2000kg

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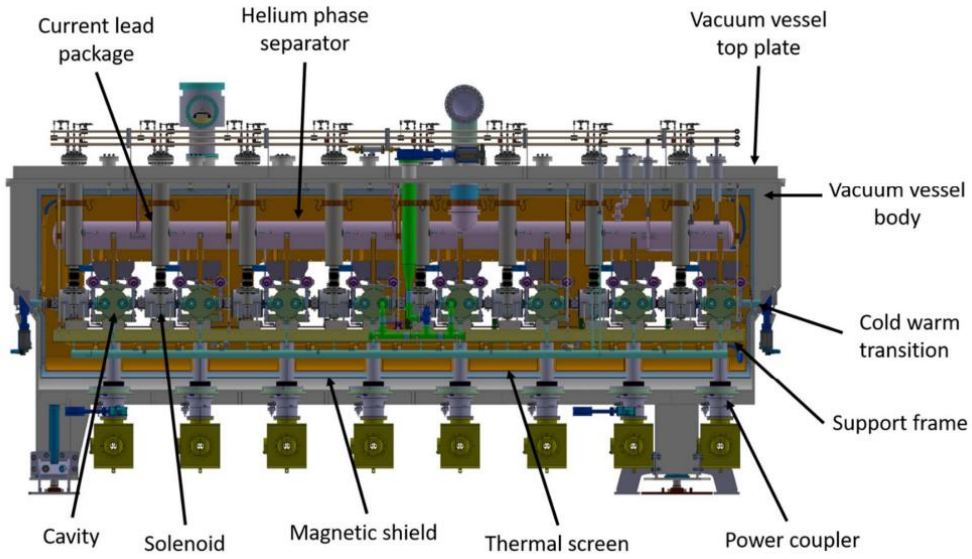
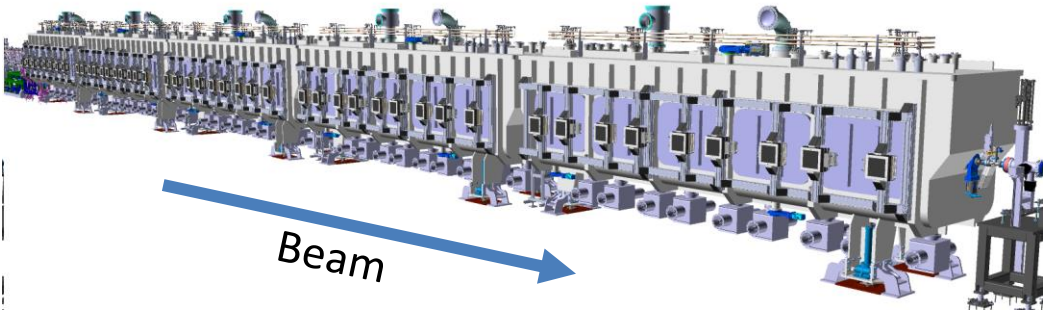
DONES Cryomodules

Five Cryomodules in DONES

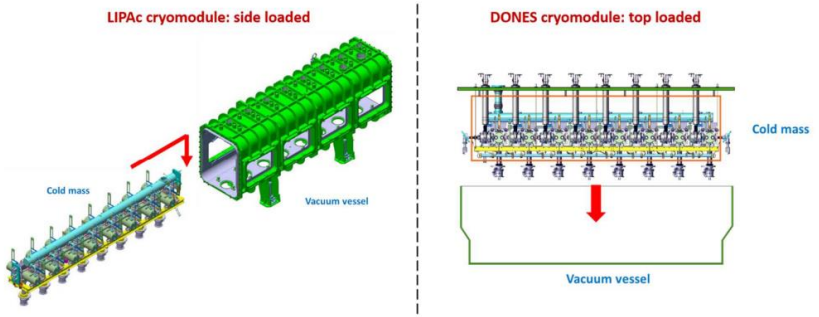




Design of the cryomodule very similar to LIPAc and to SARAF.

Cryomodule	CM1	CM2	CM3	CM4	CM5
HWR beta optimum	Low 0.116	Low 0.116	High 0.179	High 0.179	High 0.179
Elementary sequence	1 solenoid + 1 cavity	1 solenoid + 2 cavities	1 solenoid + 2 cavities	1 solenoid + 2 cavities	1 solenoid + 2 cavities
Number of elementary sequence	8	5	4	4	4
Inlet section	none	1 solenoid + 1 cavity	1 solenoid + 1 cavity	1 solenoid + 1 cavity	1 solenoid + 1 cavity
Output energy (MeV)	8.3	13.9	21.3	30.3	40

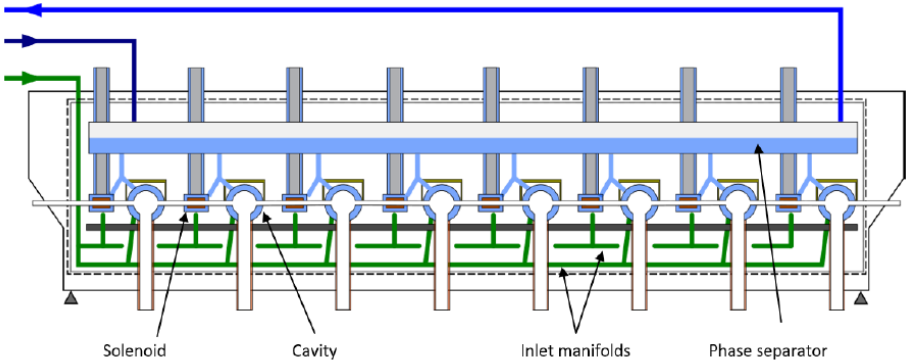
Differences with LIPAc

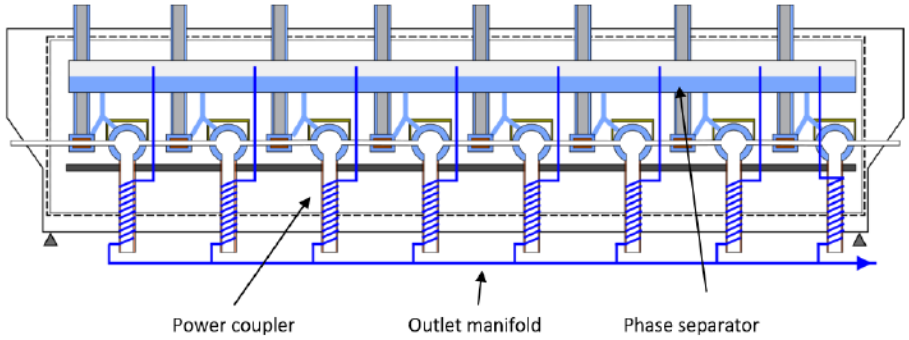


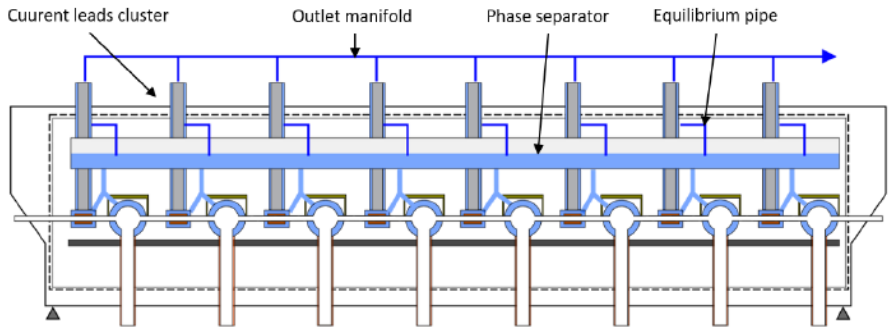
Design of Cryomodules is well advanced

DONES Cryomodules

Cryogenic Circuits







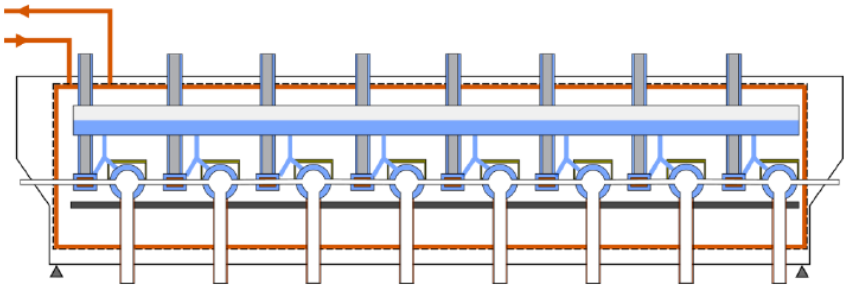
Same Cryogenics Circuits as in LIPAc:

- LHe 4.45K He saturated conditions.
  - Each RF and solenoid cavity.
- He 4.45K He from phase separator.
  - RF couplers.
  - Current Leads cluster.
- GHe 60K He.
  - Thermal Shield

Thermal Budget

Cryomodule: Heat Loads in 4K Circuit						
	CM1		CM2		CM3 - CM4 - CM5	
Static Heat Loads	32.7 W	9.63l/h	36.6 W	9.594 l/h	32.1 W	7.916 l/h
Dynamic Heat Loads	56 W	6.42 l/h	77 W	6.396 l/h	66.6 W	5.277 l/h
Total Heat Loads	88.7 W	16.05 l/h	113.6 W	15.99 l/h	98.7 W	13.19 l/h
Cryomodule: Heat Loads in 60K Circuit						
	CM1		CM2		CM3 - CM4 - CM5	
Static Heat Loads	173.7 W		178.6 W		177.7 W	

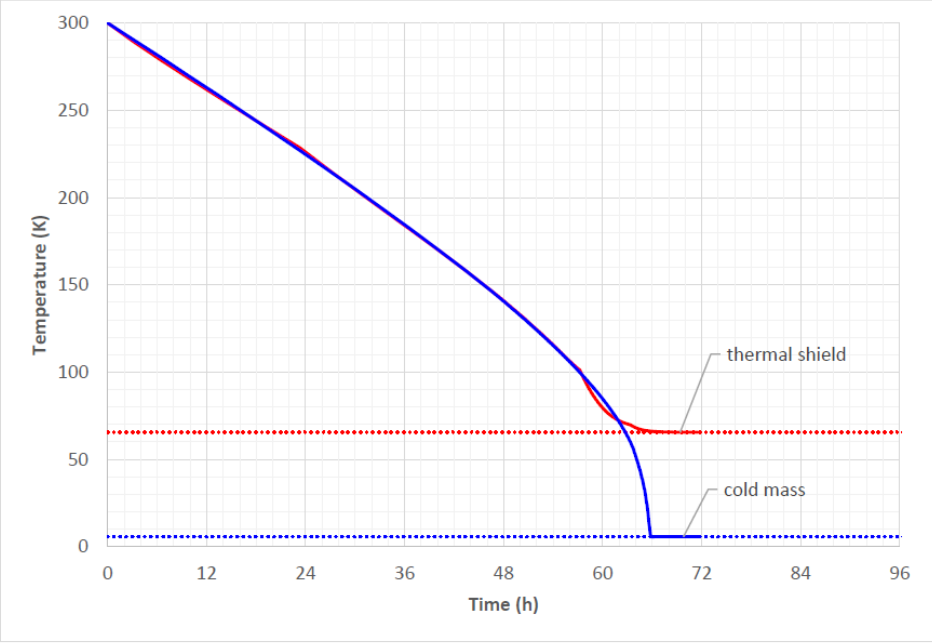
SRF Linac Requirement		Without margins	With margins
Total Heat Loads on 4K	Refrigeration Part	498 W	648 W
	Liquefaction Part	72 l/h	99 l/h
Total Heat Loads on 60K		885 W	1328 W



DONES Cryomodules: Studies

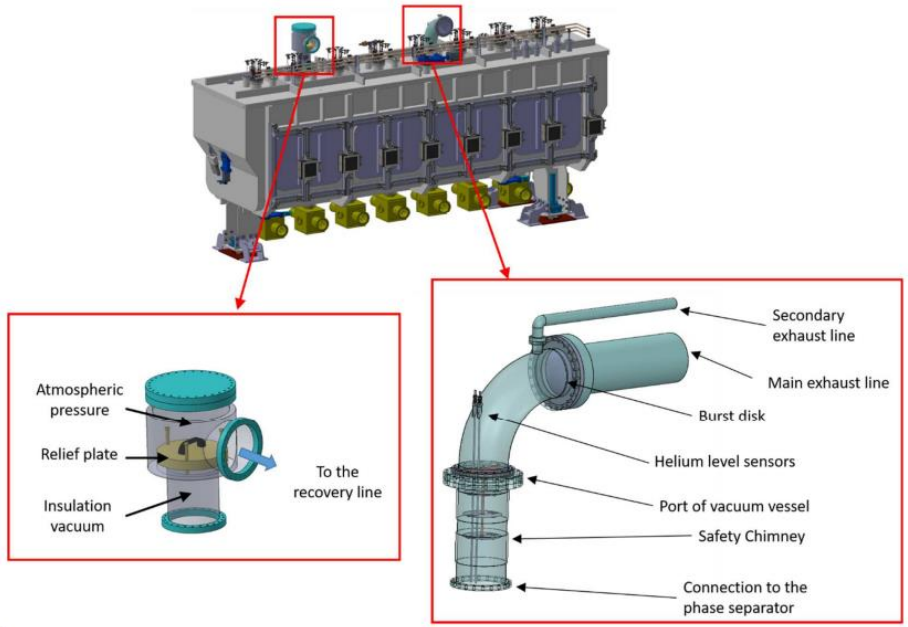
Cryogenic Studies: Cool-down time and Flow Rates

- Cool-down time calculation. 65 hours
- Flow Rates calculation.
- Valve Opening Studies



Cold mass temperature (K)			Helium flow rate (g/s) To the shield	Helium flow rate (g/s) To the cold mass	ΔT (K)
300	>	230	9.0	20.0	50
230	>	100	10.5	20.0	50
100	>	60	22.0	20.0	50
60	>	LHe	30.0	20.0	50

Safety Devices in the Cryomodules



Currently Simulations of accident scenarios of Helium release are being performed.

- MELCOR
- OpenFoam

Contents

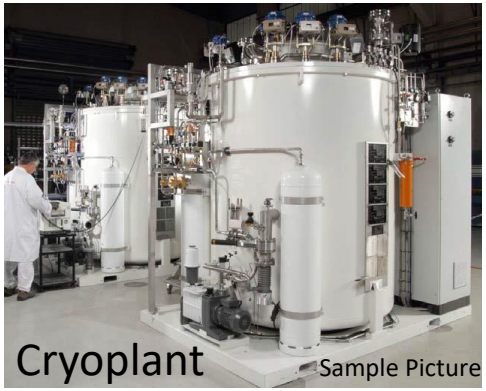
DONES Cryoplant and Cryodistribution

Cryoplant Preliminary Design

Still in preliminary design of the cryoplant and cryo-distribution.

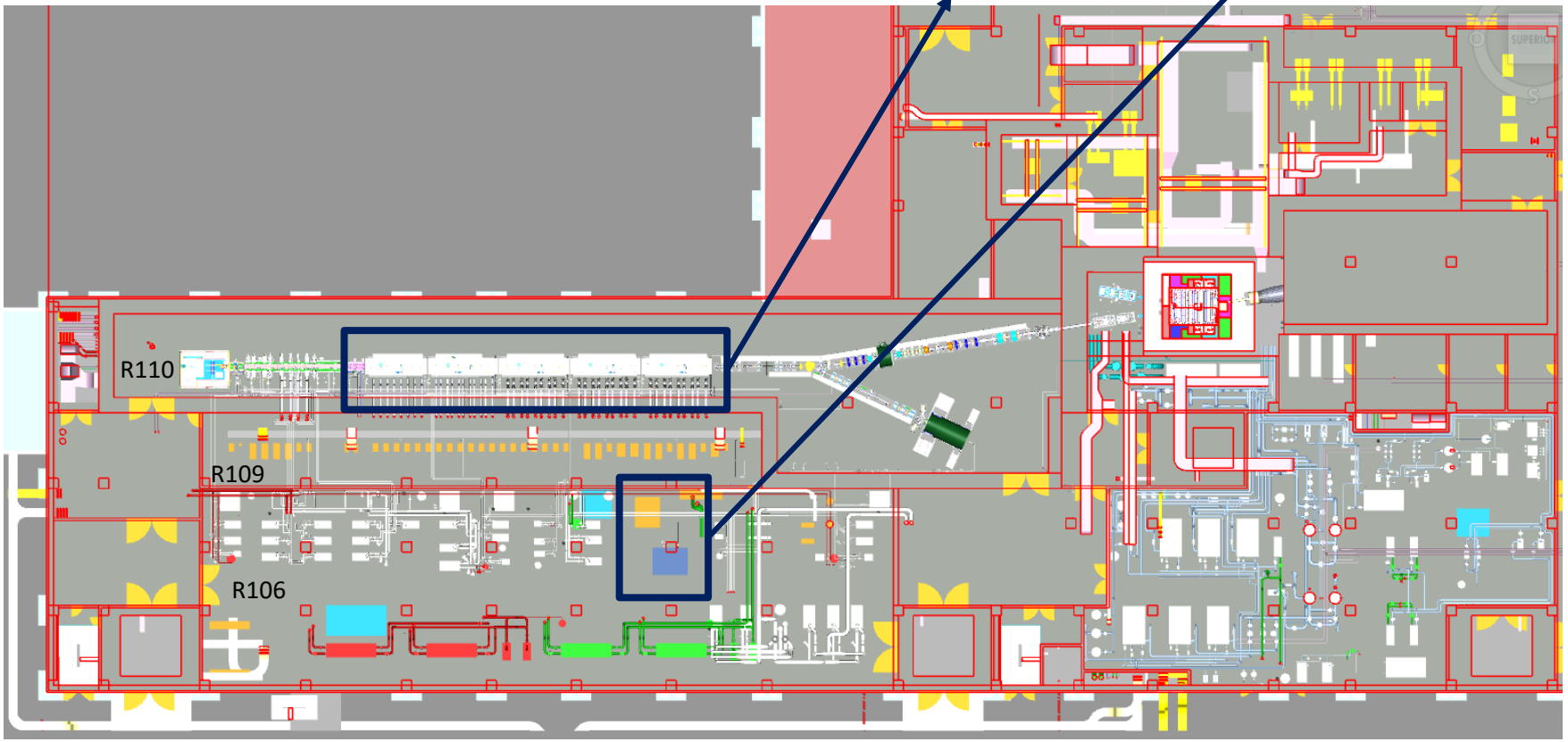
- Design will advance from conceptual to detailed design.
- Review of the design performed by experts of other facilities.

Cryomodules

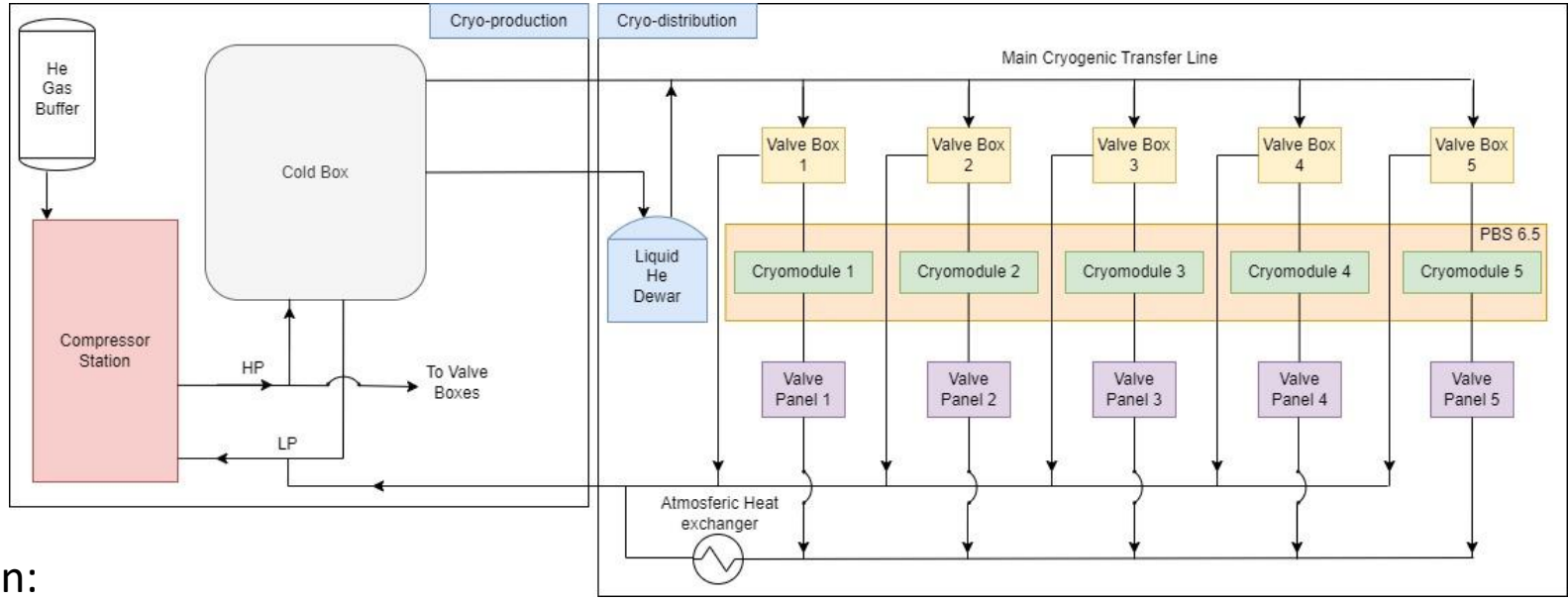


Cryoplant

Sample Picture



Cryoplant Preliminary Design



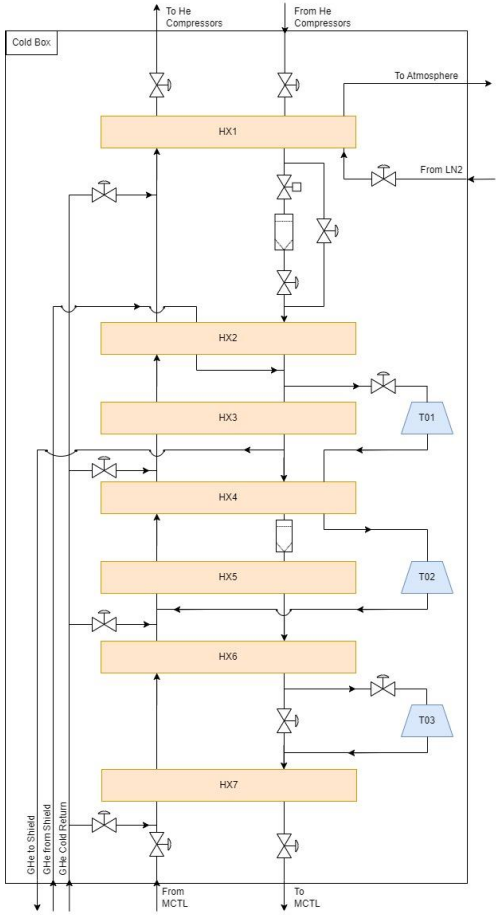
Cryo-production:

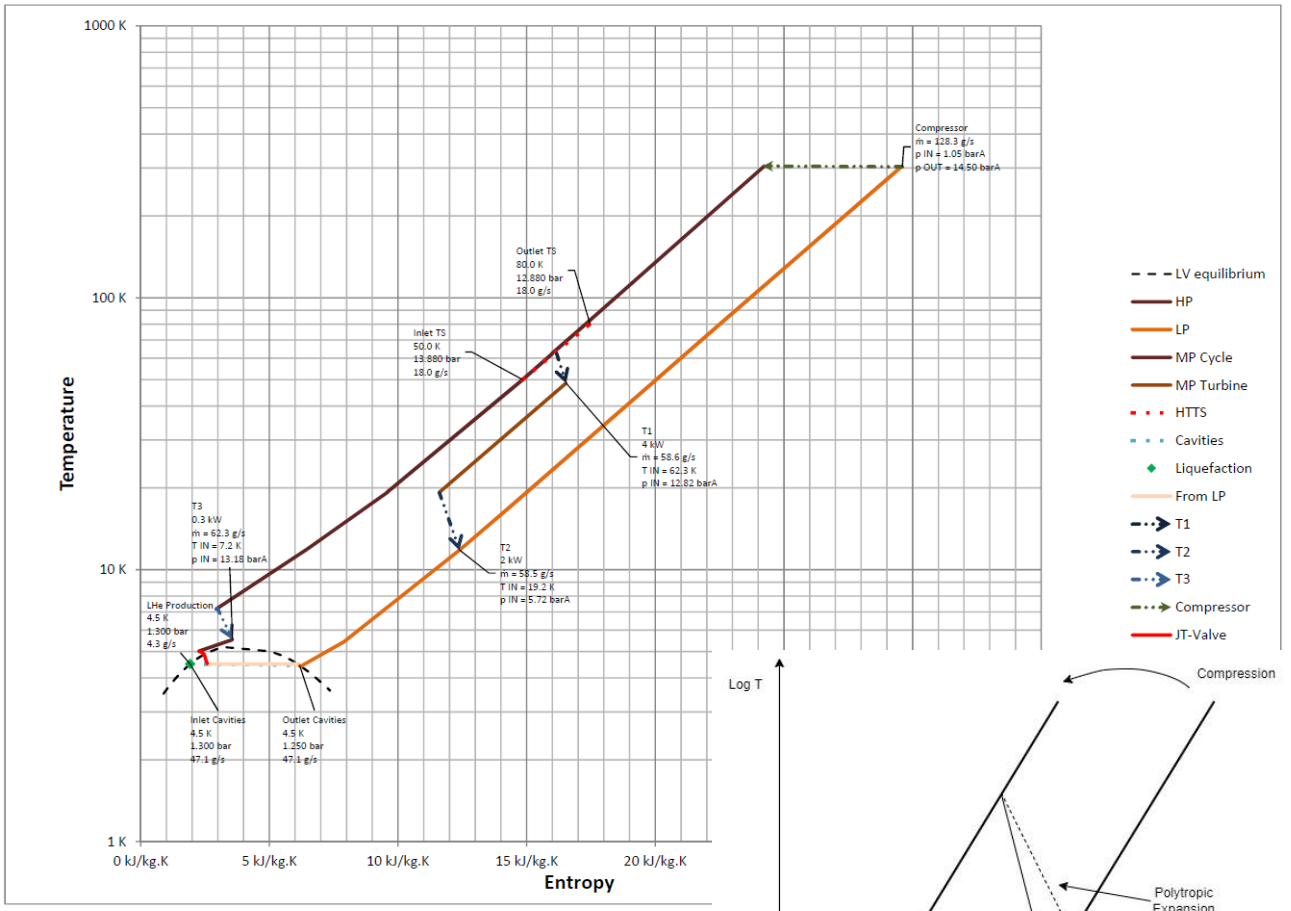
- Compressor Station. Two He compressors with oil removal system to supply the ColdBox with Helium.
- Cold Box: Where the liquefaction of Helium occurs. Claude Cycle.

Cryo-distribution:

- LHe Dewar. Storage of LHe in case of failure of Cold Box.
- Valve Boxes. Where the Joule Thomson Valves are located with the rest of the valves that connect to the cryomodules.
- Valve Panels: Used in the cool down process only, it allows a connection from the 60K GHe line.

Cryoplant Claude Cycle T-S diagram





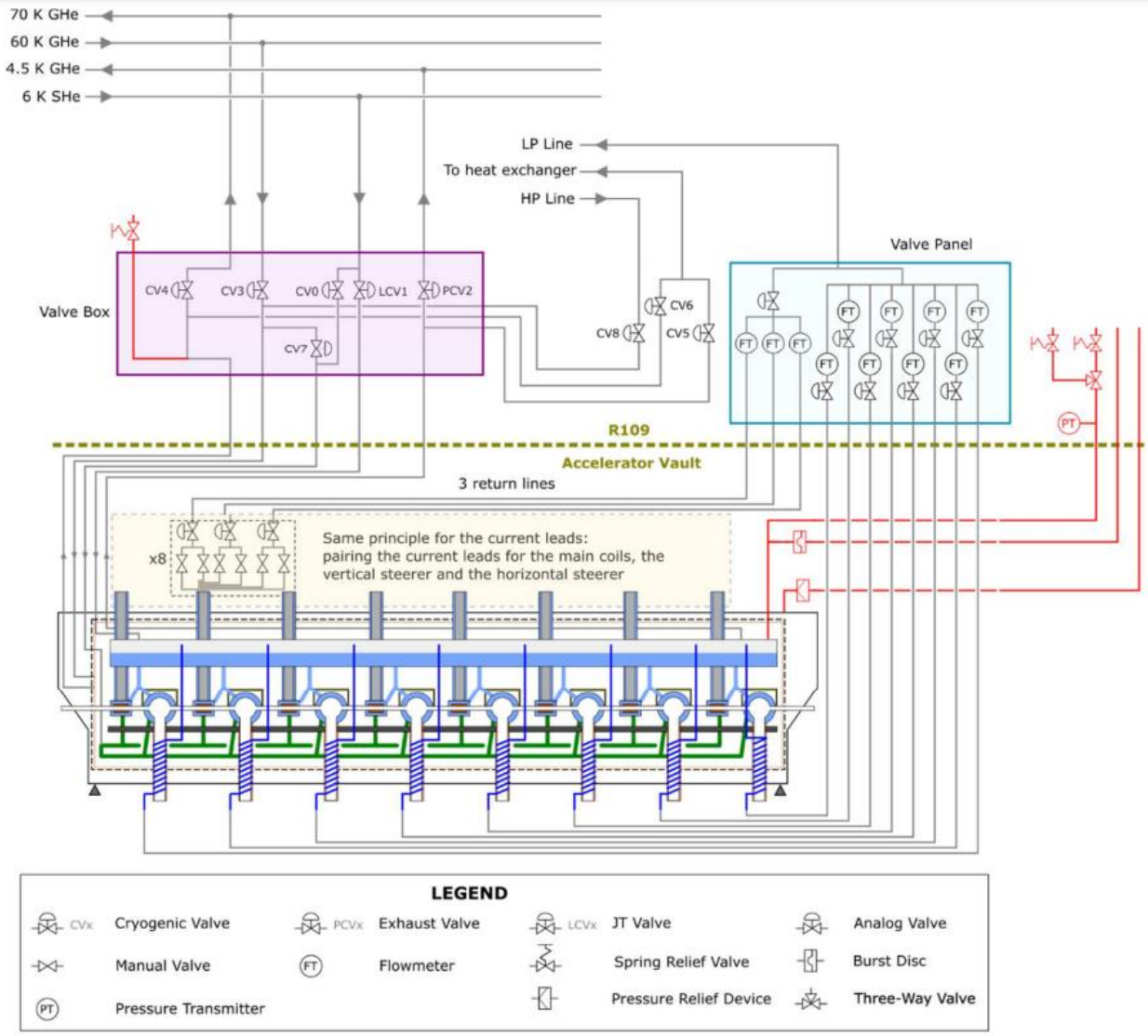
Typical Claude Cycle:

- 7 Heat Exchangers in series
- 2 turbines in series
- One last expansion super critical Helium
- Phase change done in the JT valve in valve box.

From preliminary Study. Still needs to be determined.

DONES Cryoplant and Cryodistribution

Cryodistribution of Cryomodule 1

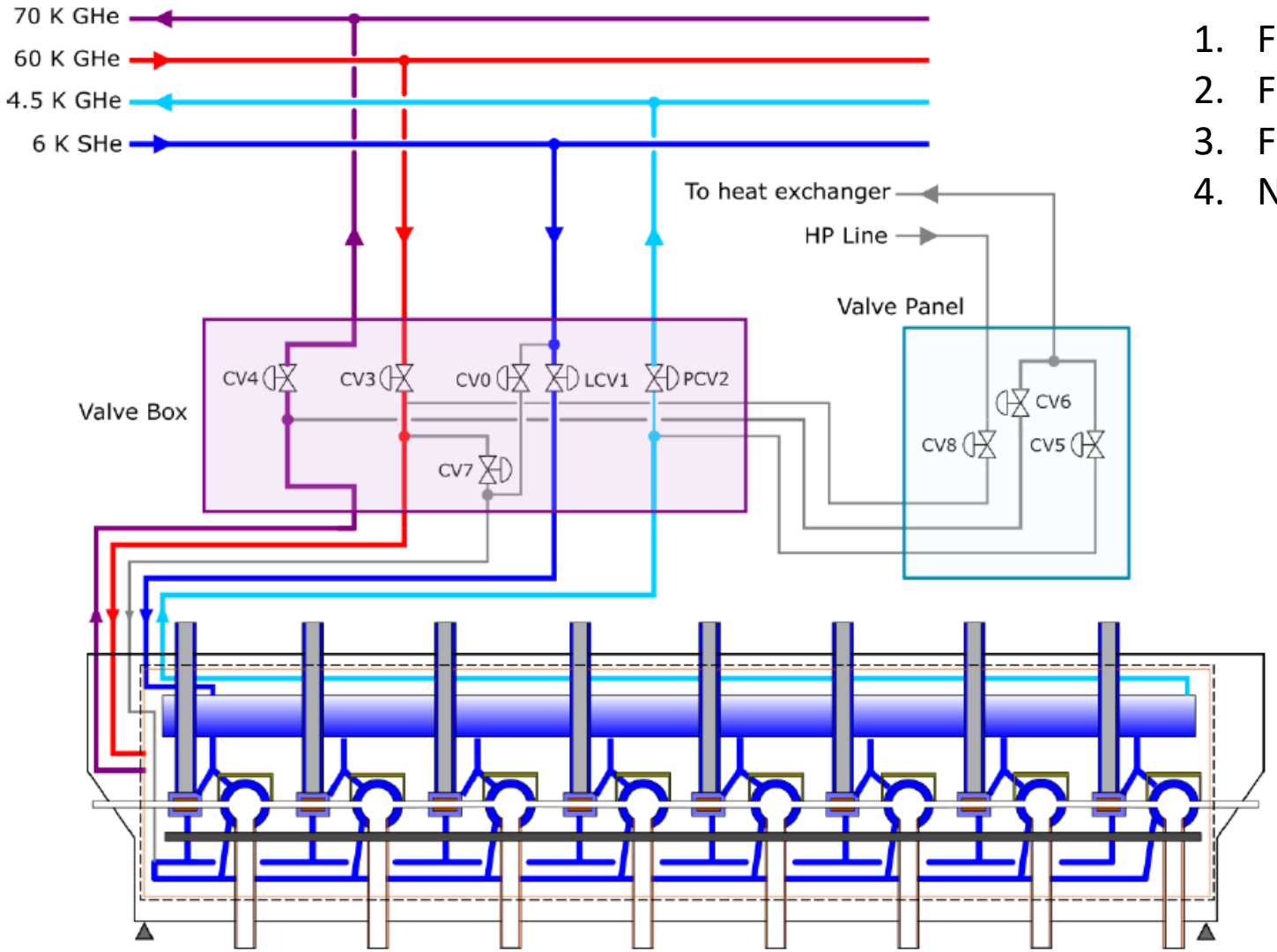


Valve Box in LIPAc

Cryo Transfer Line in LIPAc

DONES Cryoplant and Cryodistribution

Cooling Down Principle



1. From 300K to 110K
2. From 110K to 60K
3. From 60K to 5K
4. Nominal Operation

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Next steps and conclusions

- Cryomodule design is well advanced, including part of the cryo-distribution.
- Cryoplant still in preliminary design. Steps towards a detailed design must be taken.
  - 3D models
  - Detailed P&IDs
  - Thermal budget requirement including the cryo-distribution.
- Still awaiting final feedback from LIPAc, when the cryomodule is installed and the first cool down is performed. However, a lot of feedback has already been considered in the design.

Many Thanks for your attention!