The ITER Neutral Beam Test Facility

Design Overview

European Tasks ref.

TW3-THHN-IITF1 (2003-2004)
TW4-THHN-IITF2 (2004-2005)

Jean-Jacques Cordier
on behalf of EU Associations involved in the study

Outline

- Main objectives and context of the study
- Design of the Test Facility
- Description of the General Infrastructure
- Auxiliaries : Cryosystem and Cooling plant
- Summary

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NBTF : Context and Objectives

There is a general appreciation within the NB community, that an ITER-scale NB test facility will be required to demonstrate high voltage acceleration at ITER-relevant currents.

The facility would permit all elements of the ITER NB system to be tested at essentially full scale and at pulse lengths commensurate with those required for ITER (~ 1 hour).

The test facility would be constructed on the territory of the host Party.
The first injector would be transferred to ITER site (when qualification is achieved on the NBTF).
[EFDA]

Operation plan

- phase 1 : qualification of the ITER source, then accelerator, then Beam Line Components up to full 40 MW power (short pulses mainly).
- phase 2 : qualification of the ITER NB injector during long pulses (3,600 s) at full power (84 pulses in H mode, then 84 pulses in D mode)

The ITER Neutral Beam Test Facility - Schedule

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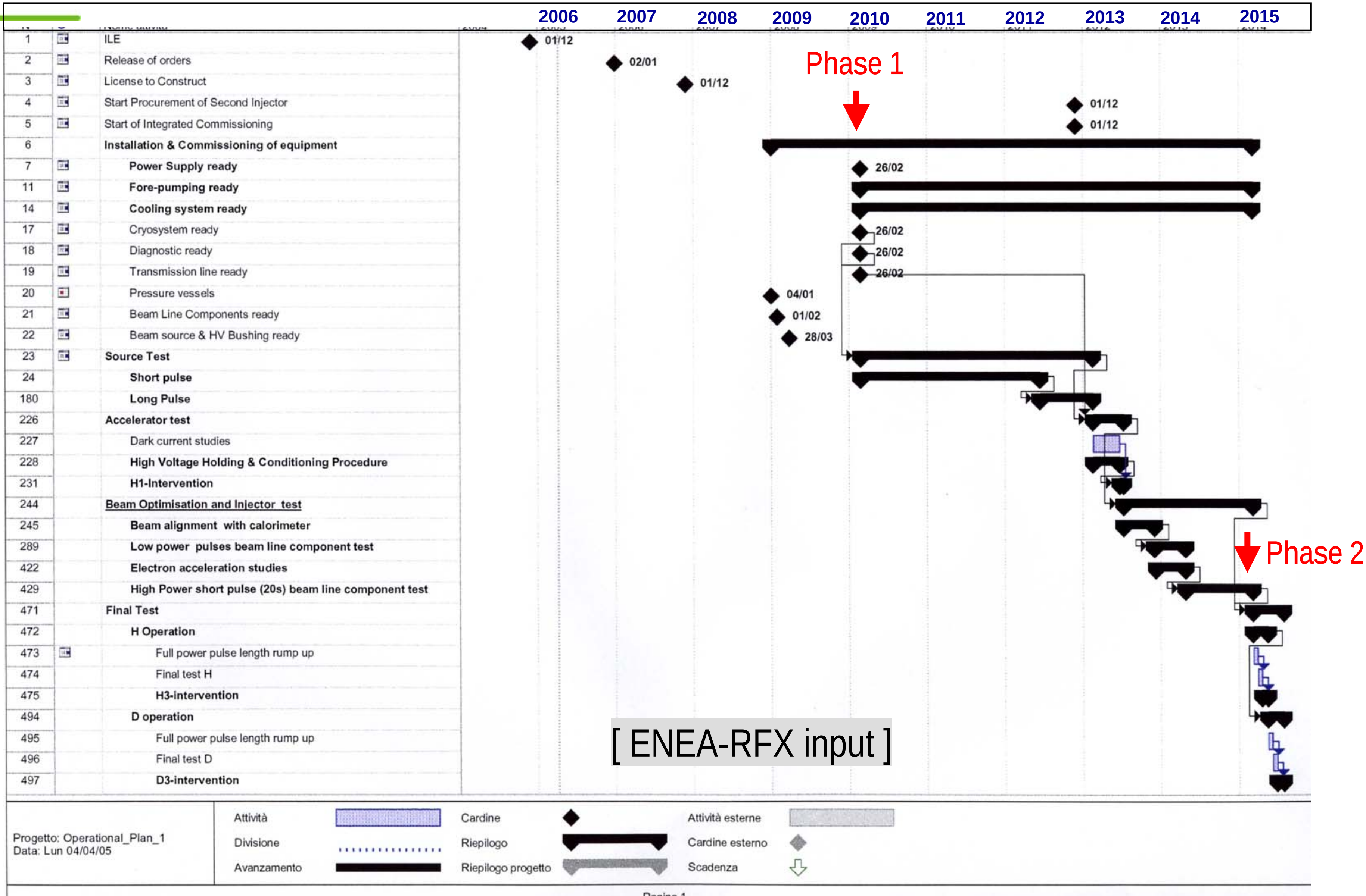
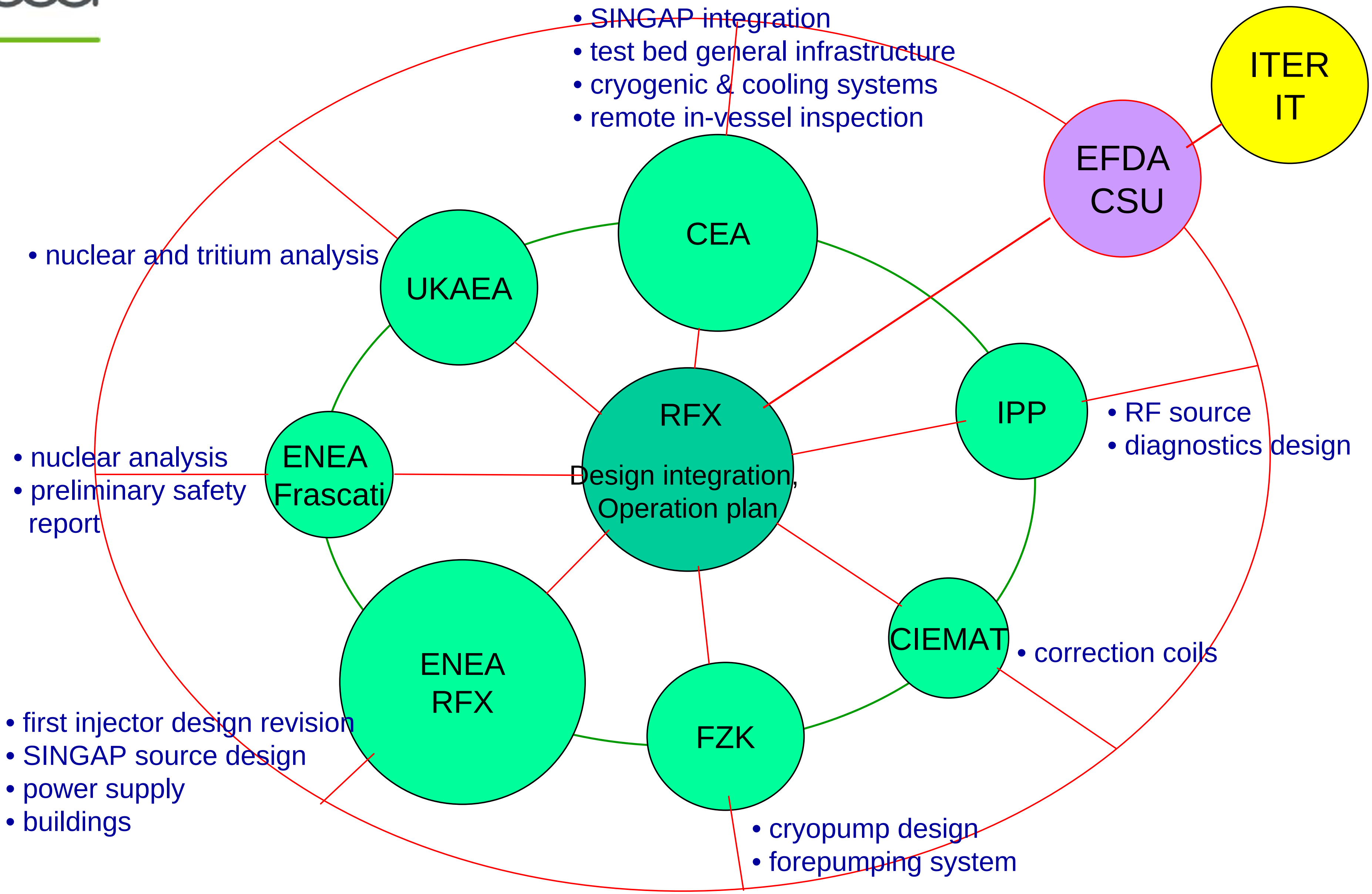
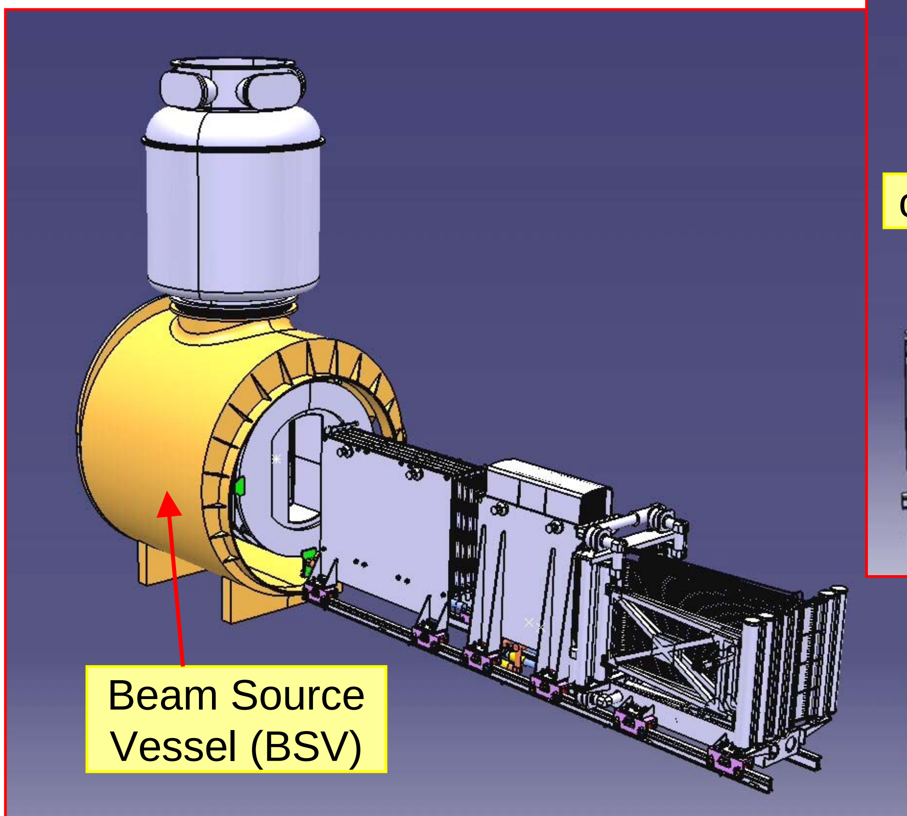


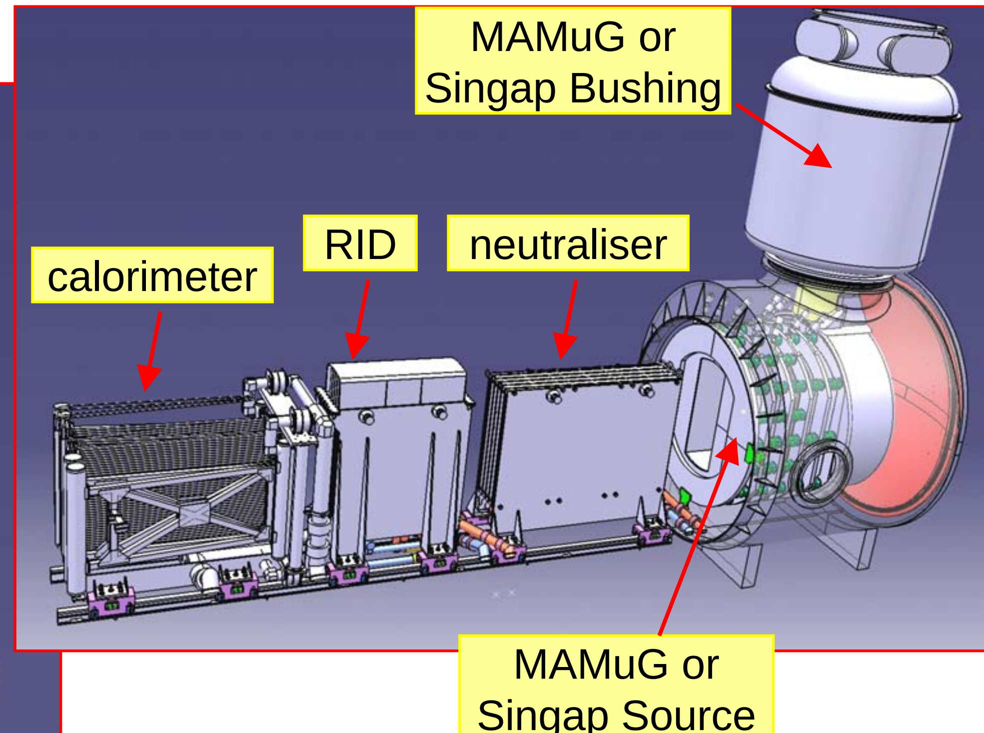
EU Task Organisation



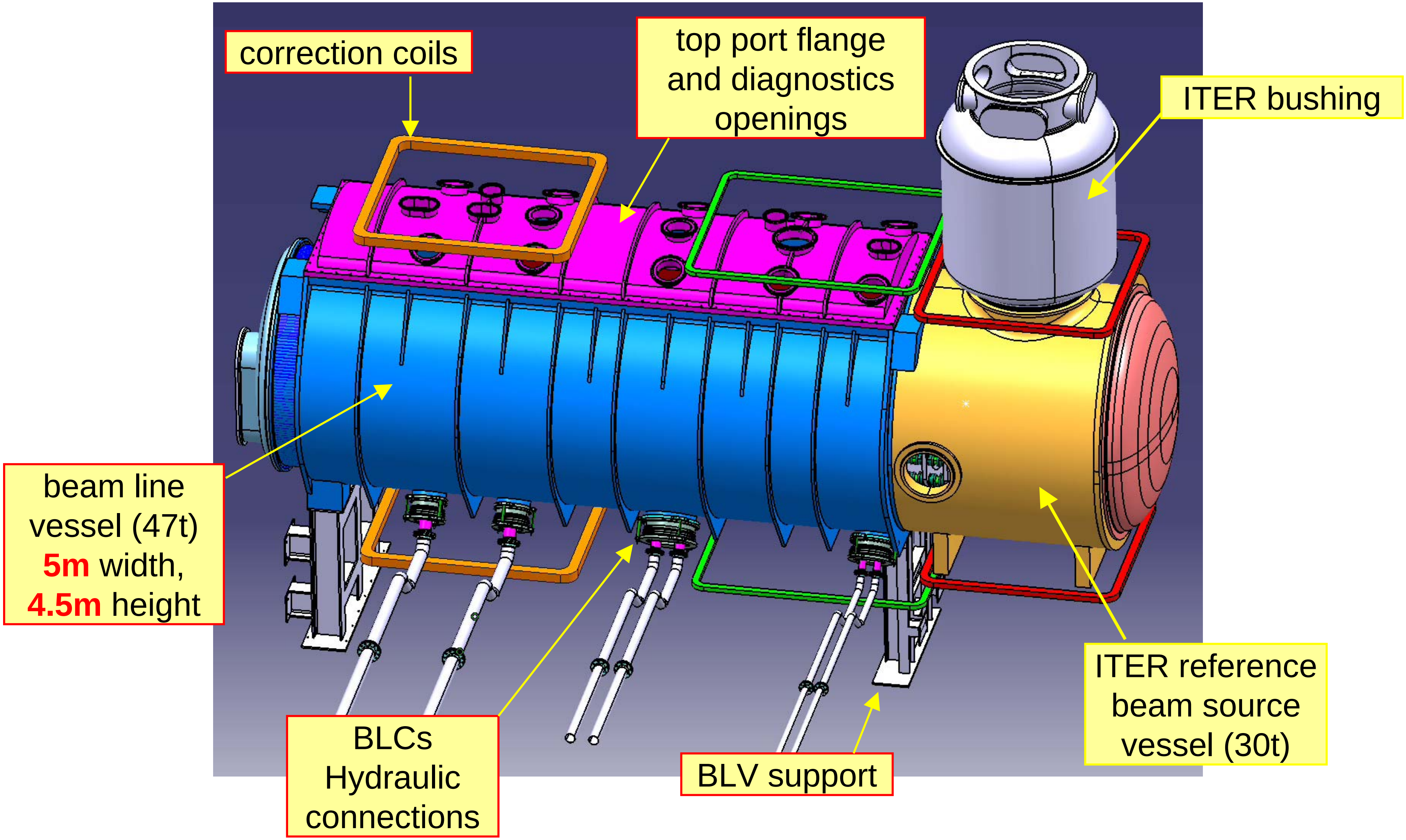
Design specifications :

The "ITER reference" beam source, BSV, HV bushing and beam line components…, have to be integrated in the Test Facility

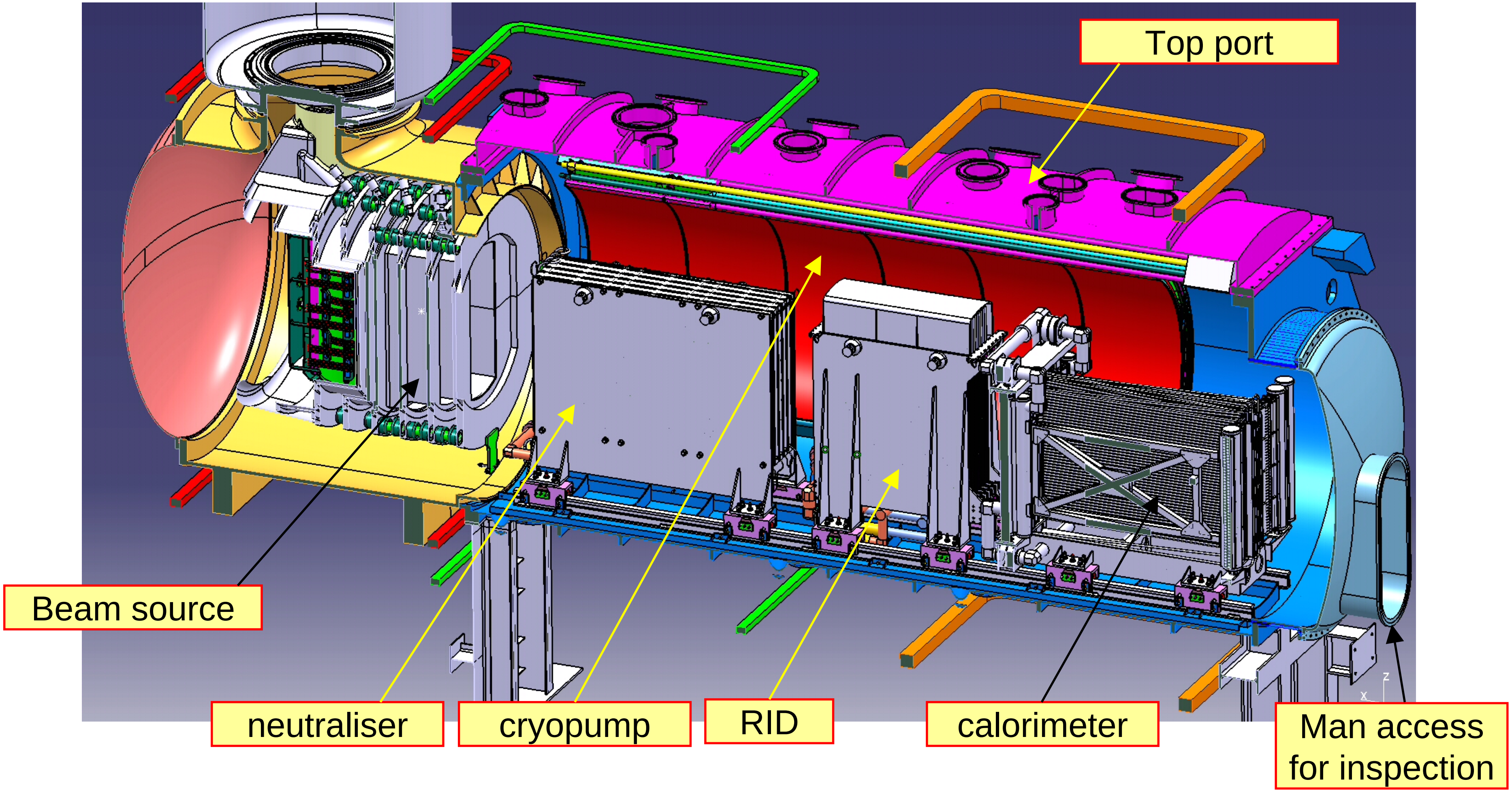




NBTF Global Design



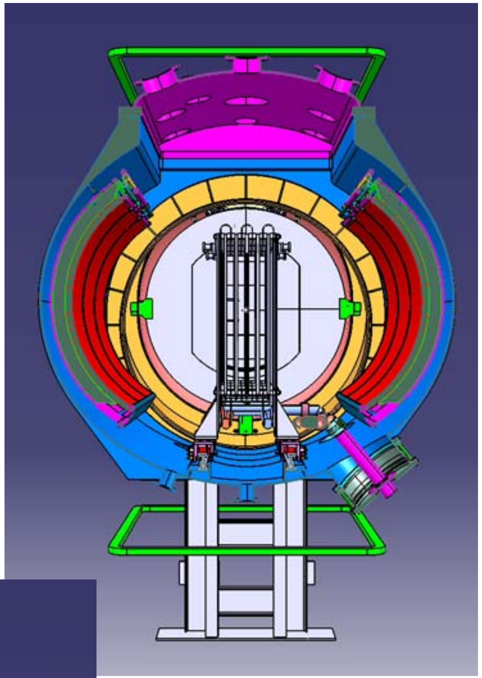
Test facility cross section

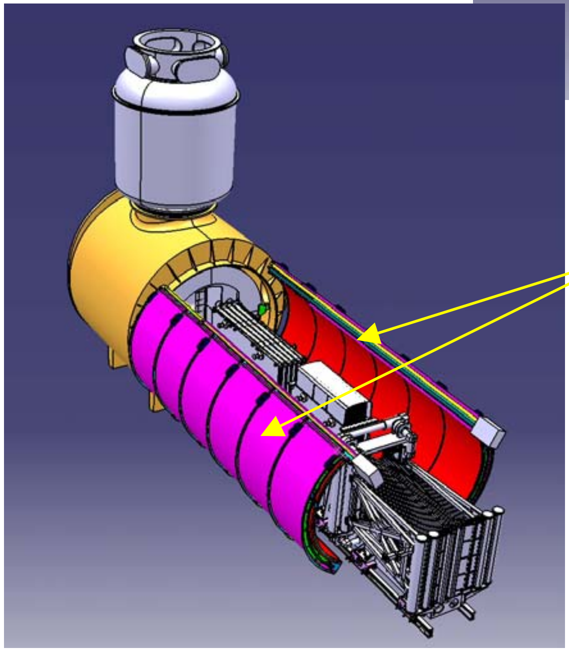


Test bed phase I et phase II configuration

Phase I (~ 3 years)

- set of diagnostics
- qualification at low then high power,
- H^- then D^- (limited at full power)
- low level activation

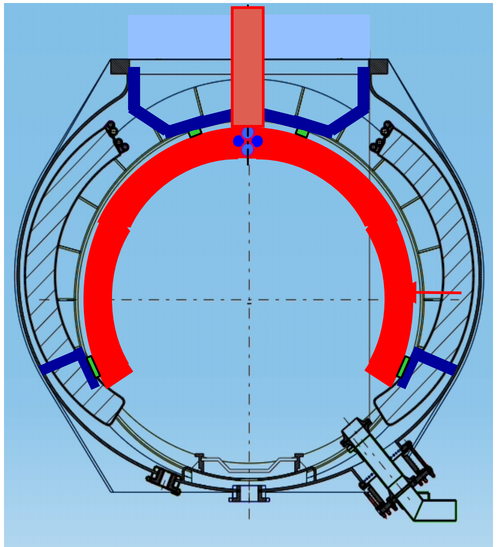


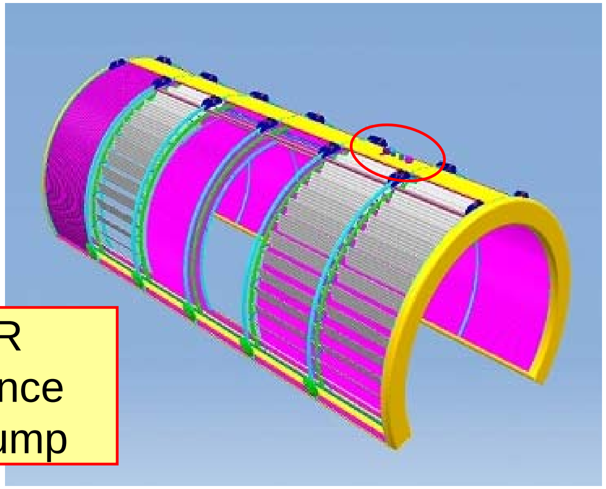


2 split halves cryopump

Phase II : ITER full configuration (6 months)

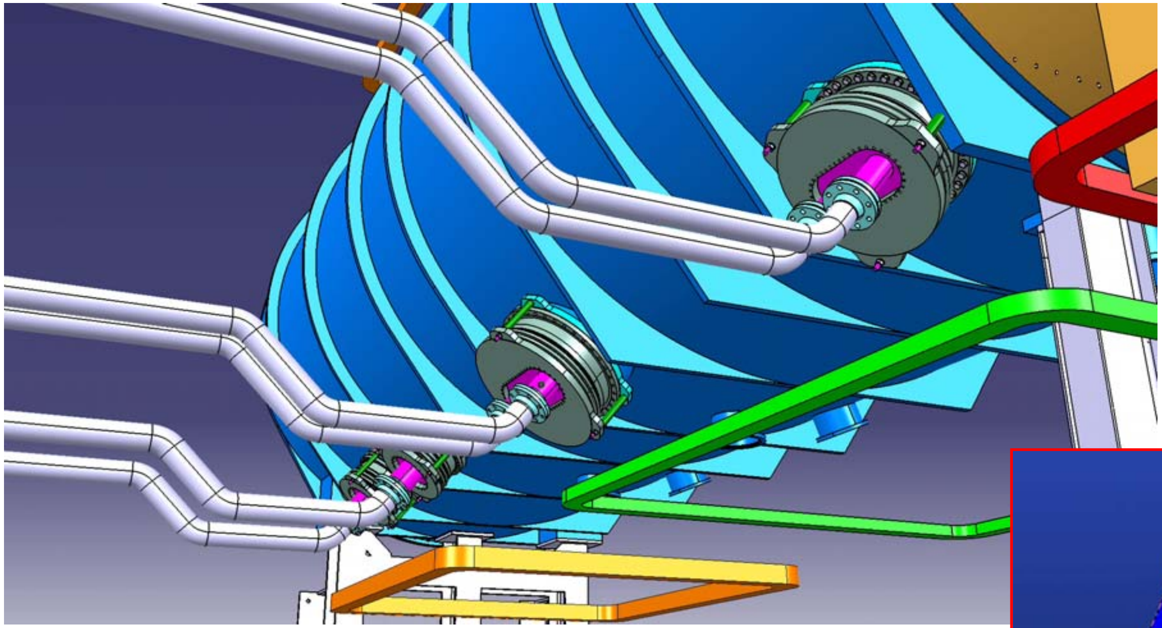
- long pulses (3600s),
- high power (40 MW)
- H^- then D^-



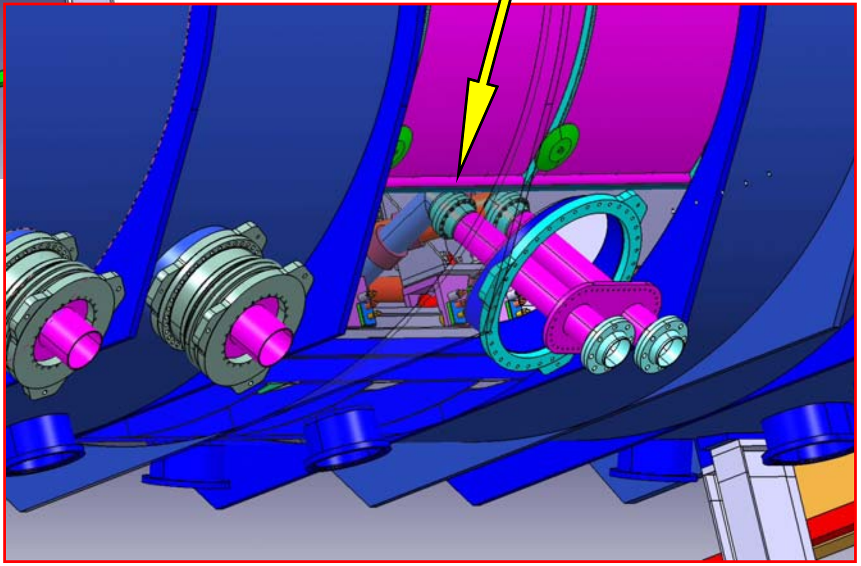


ITER reference cryopump

Hydraulic Connections of Beam Line Components



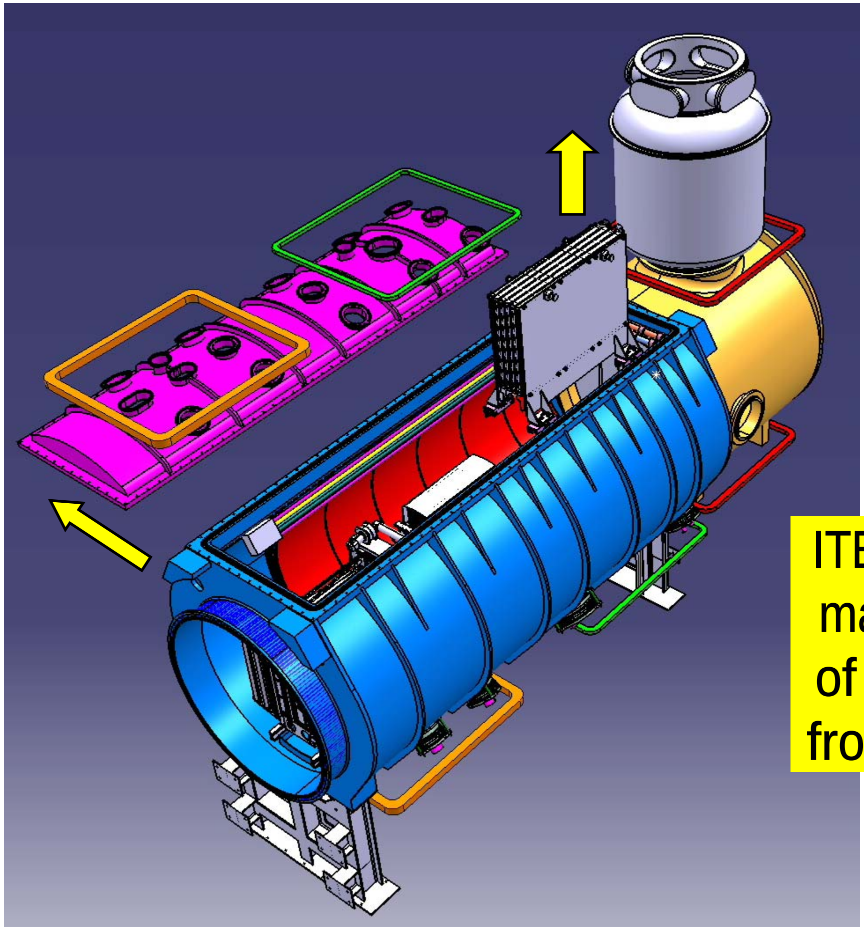
flanges bolting and tightness reliability, have to be demonstrated
(proof of principle, through representative mock-up)



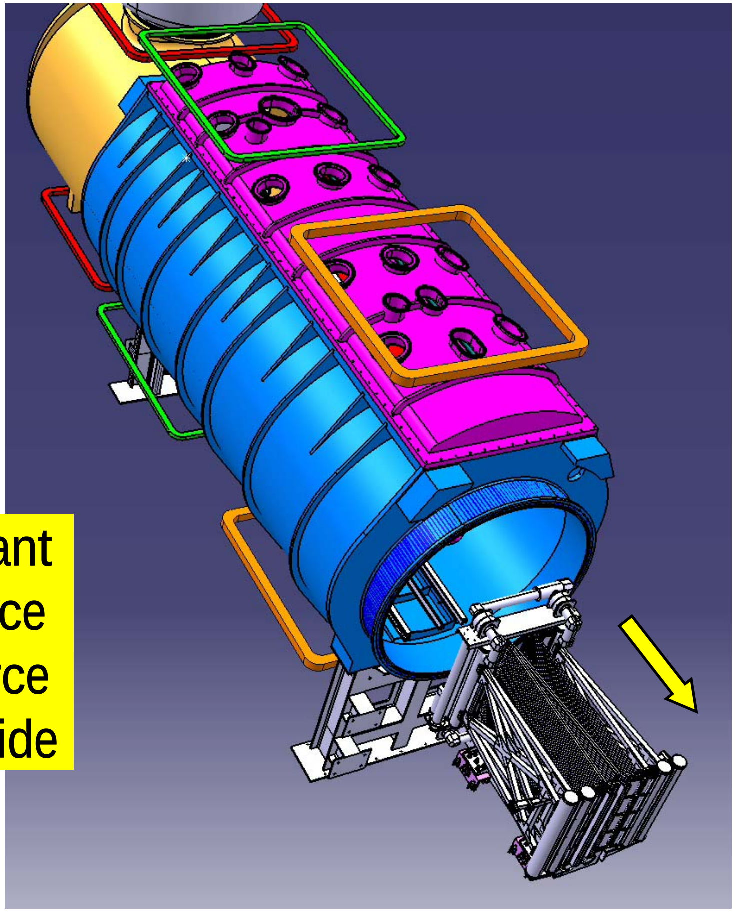
External bolted connection of BLCs :

- neither welding nor cutting [RFX input]
- metallic seal and single bolted flange (water tightness)
- easy maintenance, limited in-situ operations

Mixed Vertical Horizontal Access (MVH)



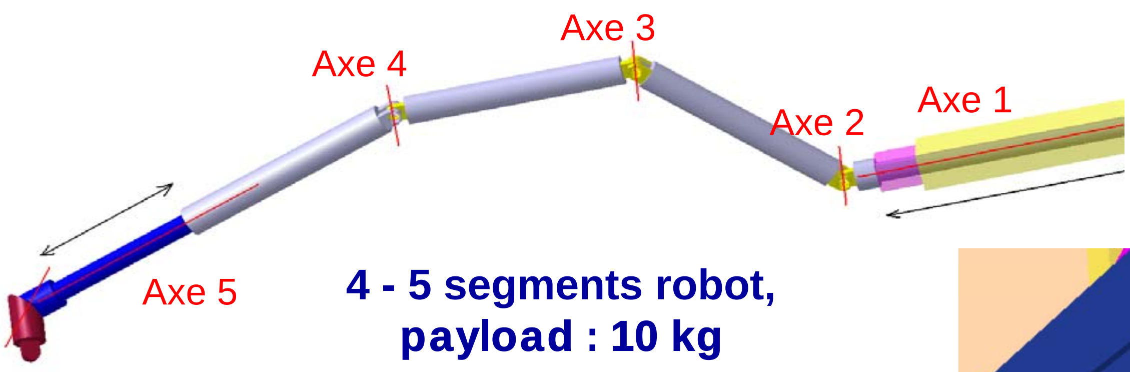
ITER relevant maintenance of the source from rear side



vertical maintenance during Phase I

horizontal maintenance during phase II

In-vessel viewing system : Articulated Inspection Arm

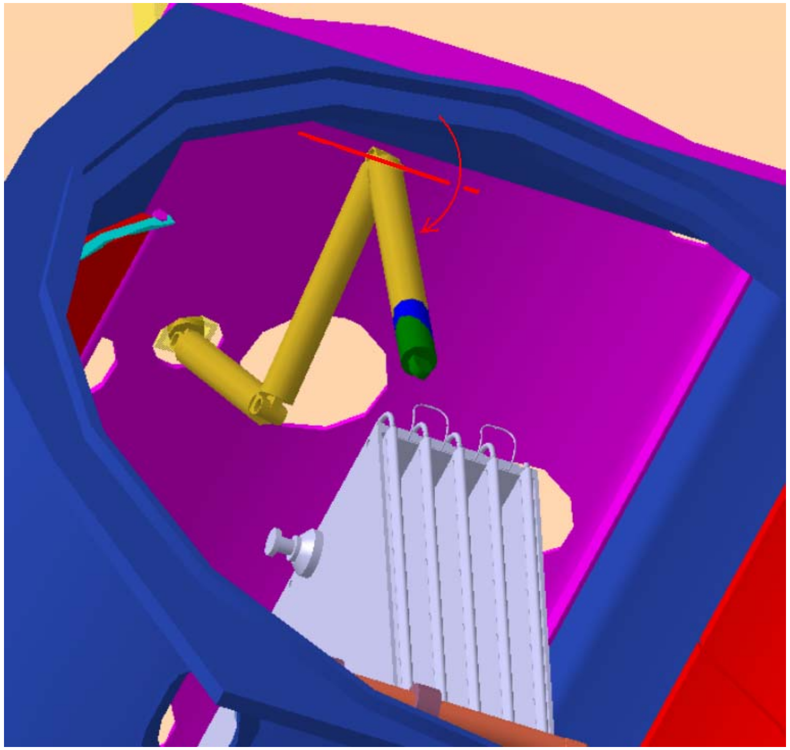


4 - 5 segments robot, payload : 10 kg

Inspection is performed under vacuum (BLCs at 350K and cryopump at 80K)

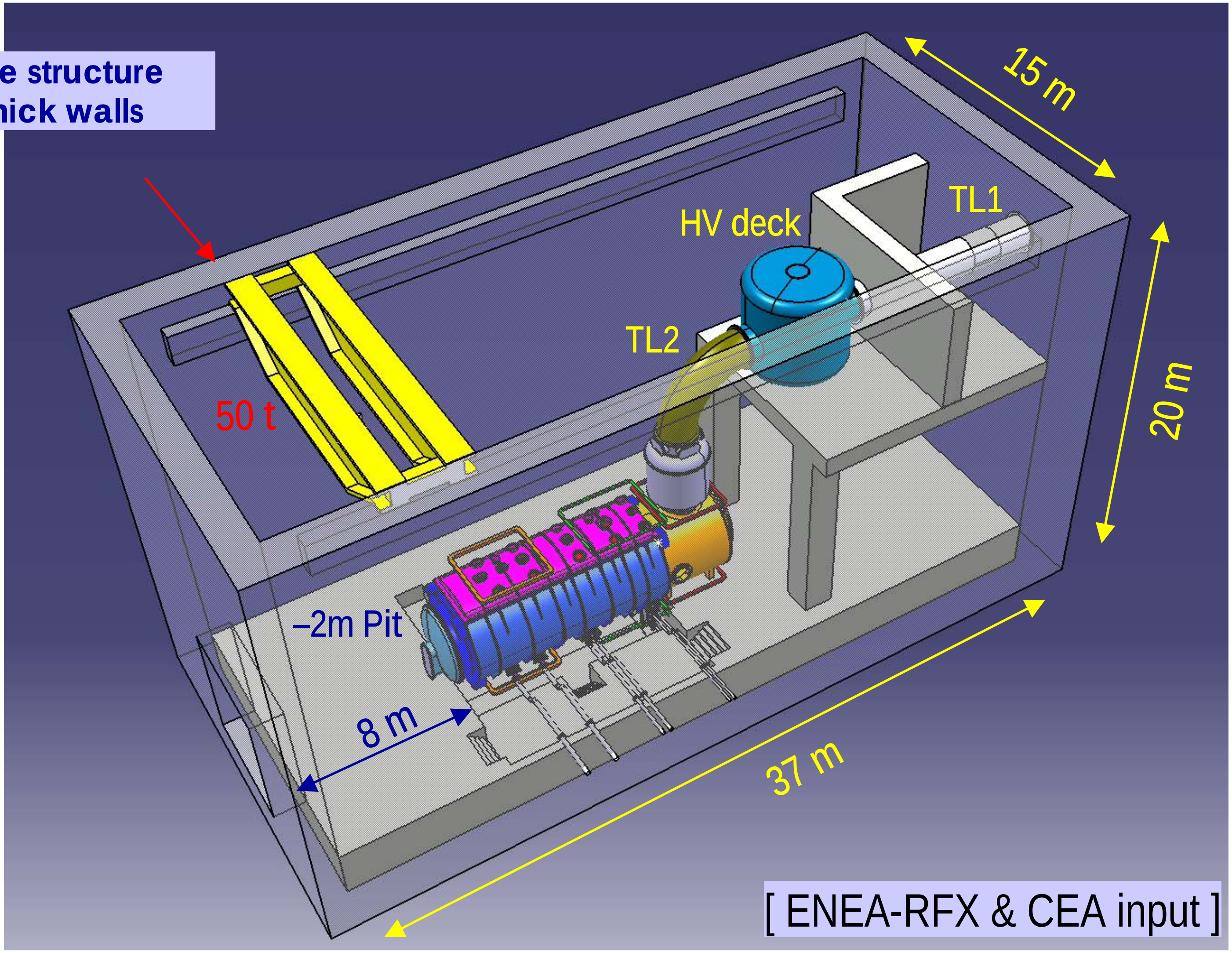
Source and Cryopump Conditioning is preserved

<u>Visual inspection</u> :
Ground Electrode, Neutraliser, RID Calorimeter (open configuration) and Cryopump

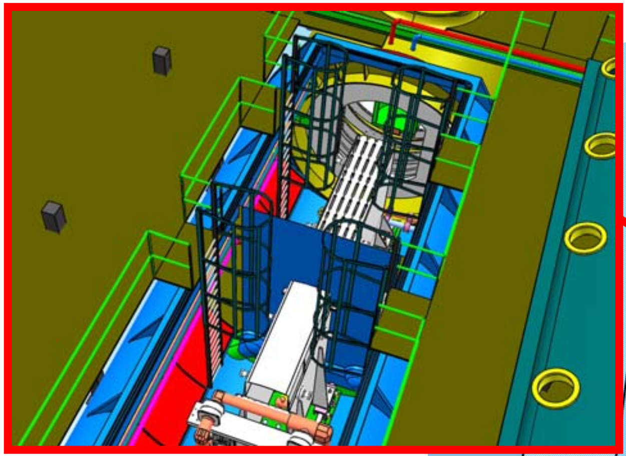


Experimental Hall

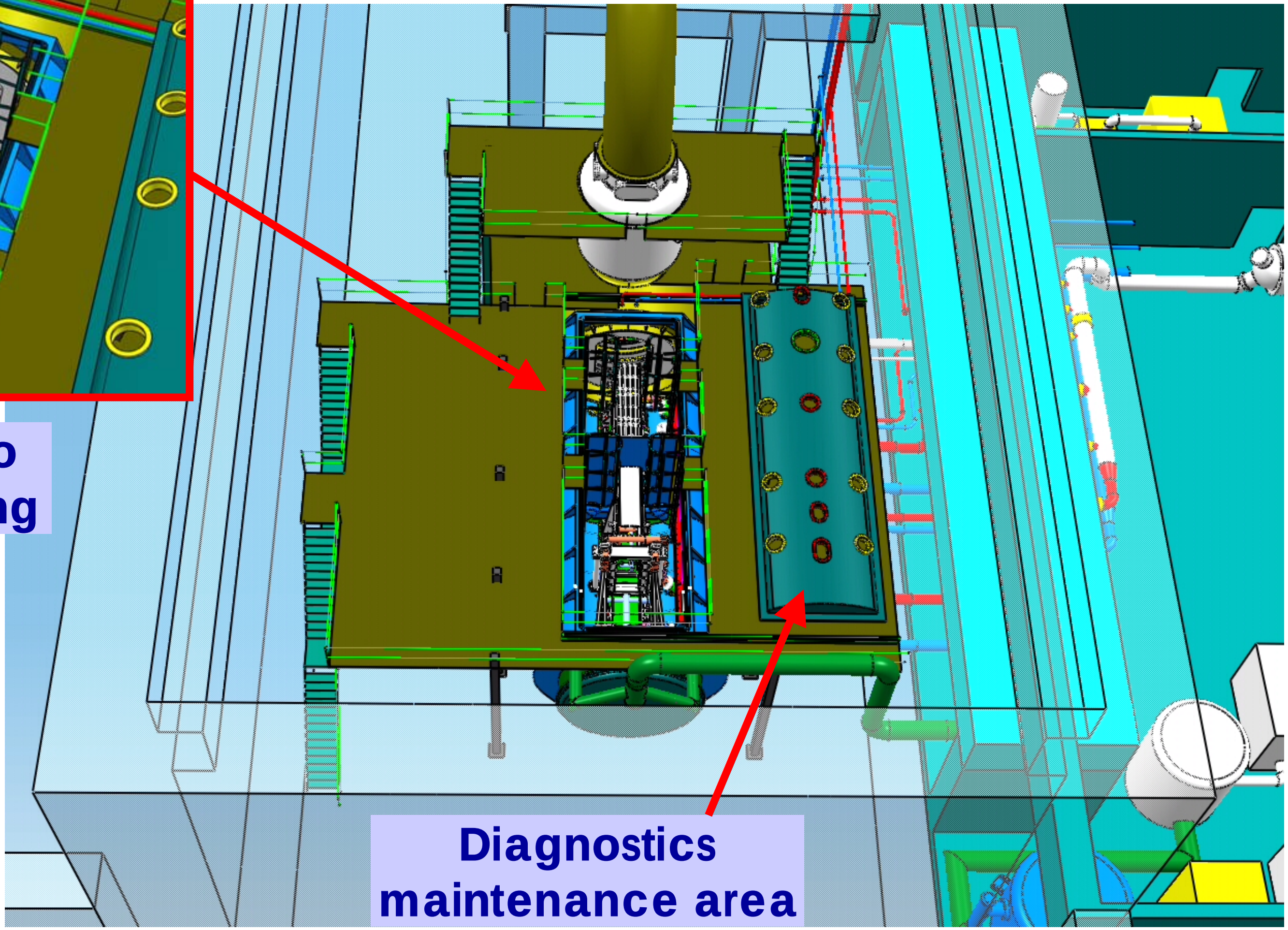
concrete structure
1.8m thick walls



Experimental Hall : man access platforms

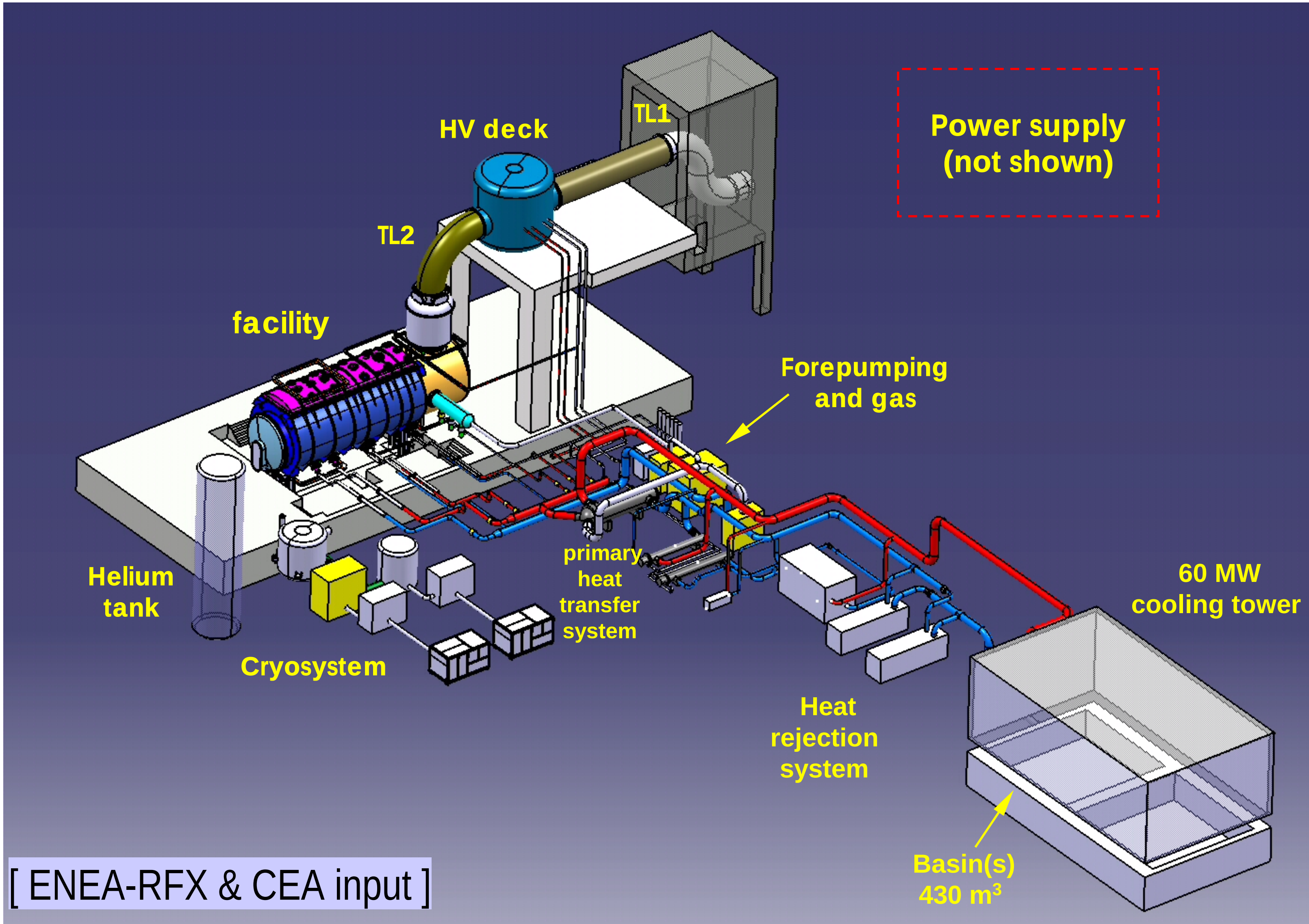


Upper access to BLV, BLCs, Bushing



Diagnostics maintenance area

ITER Neutral Beam Test Facility - Infrastructure



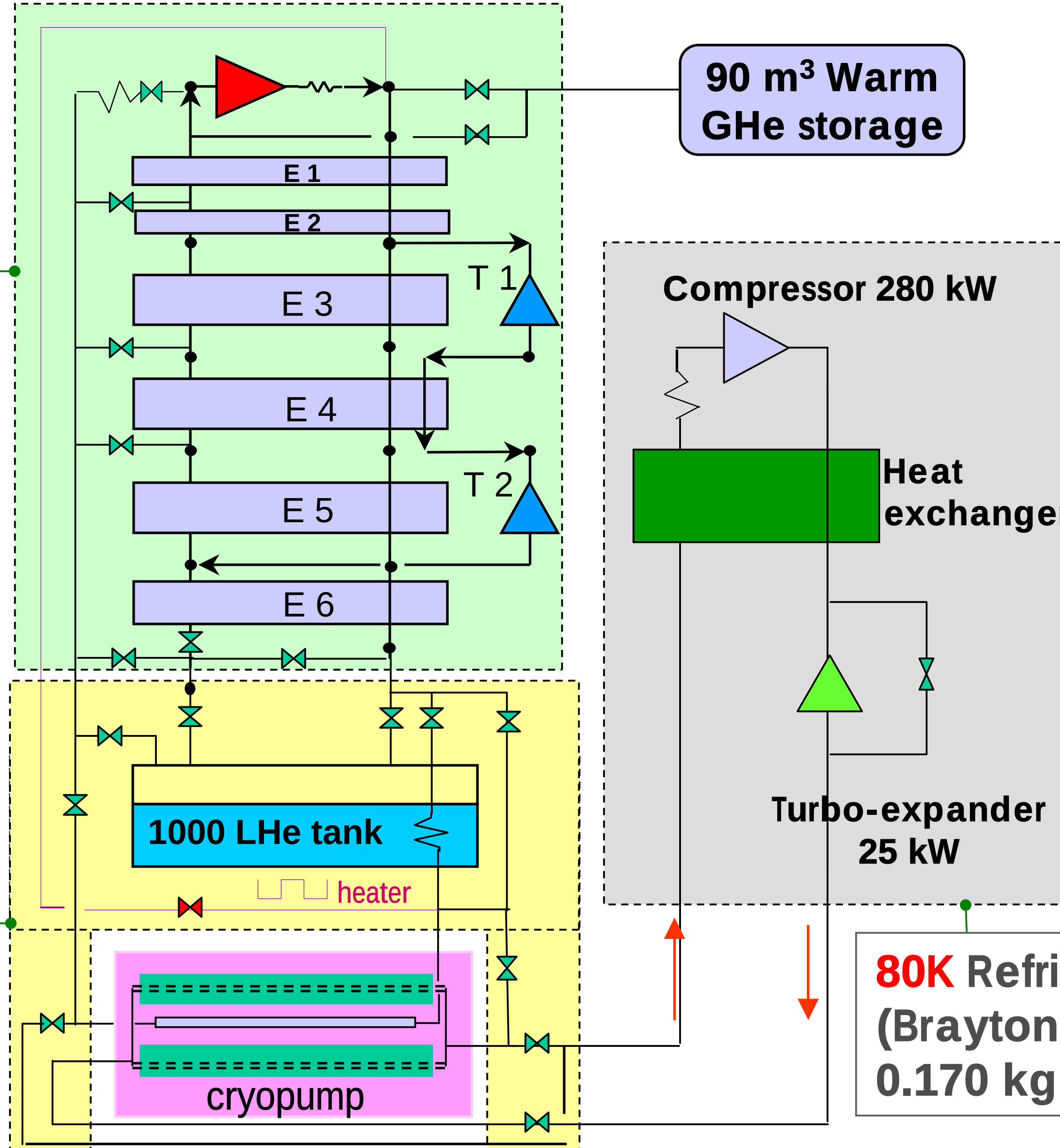
[ENEA-RFX & CEA input]

Cryopump Loading [FZK input]

Operating modes	Cryopanels	Shields and Baffles	Remarks
Stand By	T_{in} = 4.5 K T_{out} = 6.5 K Q_0 = 40 W	65 K< T_{in} < 80 K T_{out} = 90 K Q_0 = 18 kW	Beam Line Components T = 350 K
NBI operation Pulses	T_{in} = 4.5 K T_{out} = 6.5 K Q_1 = 160 W	65 K< T_{in} < 80 K T_{out} = 90 K Q_1 = 22 kW	short pulse (20 s) (100 pulses/shift) long pulse (3600 s) (2 pulses/shift) T = 350 K
Cryopanels Regeneration to 100 K	T_w = 100 K	T_w > 100 K Losses ~ 30 kW	Outgasing ($H_{2,\ D2)}$ Gas conduction Gap between walls 100 mm < d < 200 mm Forepumping capacity (roots)
Cryopanels Regeneration Up to 470 K	T_w = 470 K	($T_{w\ \sim}$ 470 K)	Cryopanels outlet are fed in series with Shields & Baffles inlet

Process Flow Diagram of the NBTF Cryoplant

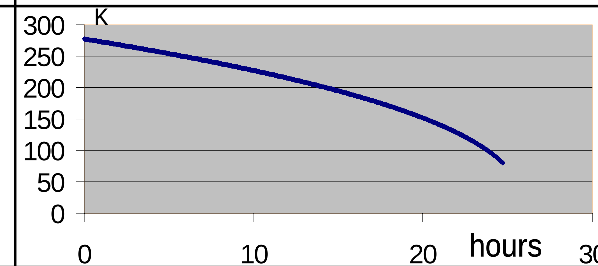
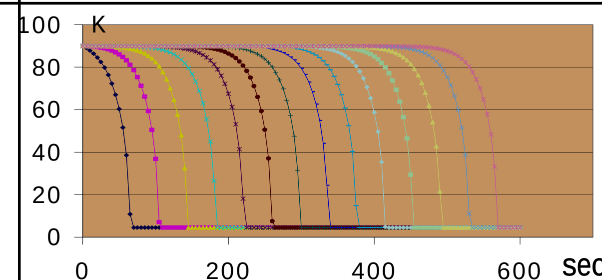
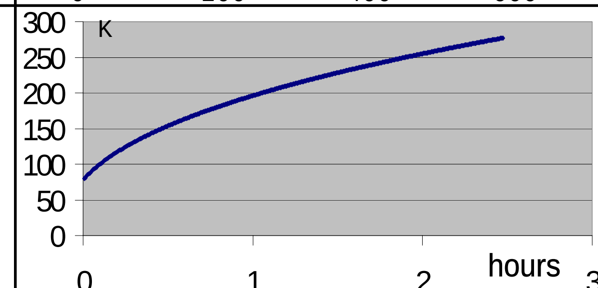
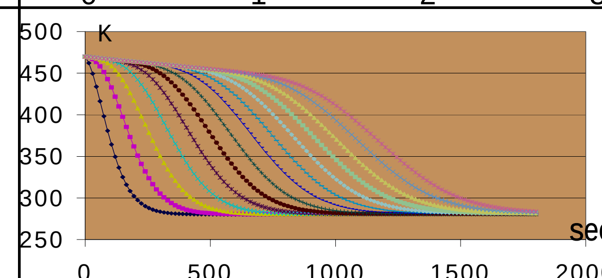
4.5K
Industrial Refrigerator
500 W
0.080 kg/s
0.4 MPa



Cold Valve Box

80K Refrigerator
(Brayton cycle)
0.170 kg/s, 1.8 MPa

Cryosystem - 4.5 K cryopanels behaviour

Operating modes	Refrigerator	Duration	Response
Cool down 300 K to 80 K 80 K to 4.5 K	Turbo-expander 1 kW 1 kW	**25 h** 1.3 h	
Cool down **after a 100 K regeneration** 100 K to 4.5 K	SCHe masse flow 0.035 kg/s @ 4.5 K	**550 s**	
Warm up 80 K to 300 K **Regeneration** 300 K to 470 K	Heating power 10 kW 40 kW	**2.5 h** ~ 1 h	
Cooling **after 470 K regeneration** 470 K to 300 K	GHe masse flow 0.080 kg/s @ 280 K	0.5 h	

NB Test Facility - Characteristics of the PHTS

Component	Inlet Temp. (°C)	Average Outlet Temp. (°C)	Max outlet Temp.(°C)	Saturation Pressure (MPa)	Inlet Pressure (MPa)	In Vessel Pressure drop (MPa)	Outlet Pressure (MPa)
Neutraliser leading edge	80	132	175	0.9	≤ 2.65	0.06	2.59
Neutraliser Panels	80	132	140	0.4	≤ 2.65	0.25	2.4
RID	80	132	205	1.8	≤ 2.65	0.07	2.58
Calorimeter	80	106	128	0.3	2.65	2	0.65
Ion Source, Filaments	20	43.5		0.1	≤ 2.65	0.9	1.75
Acceleration grid, Extractor, Plasma grid	55	93.3		0.1	≤ 2.65	0.9	1.75

NBTF: A global high pressure drop is preferred to a Calorimeter surpressor :
Inlet pressure 2.65 MPa (higher flexibility, adjustment of required flow rates)

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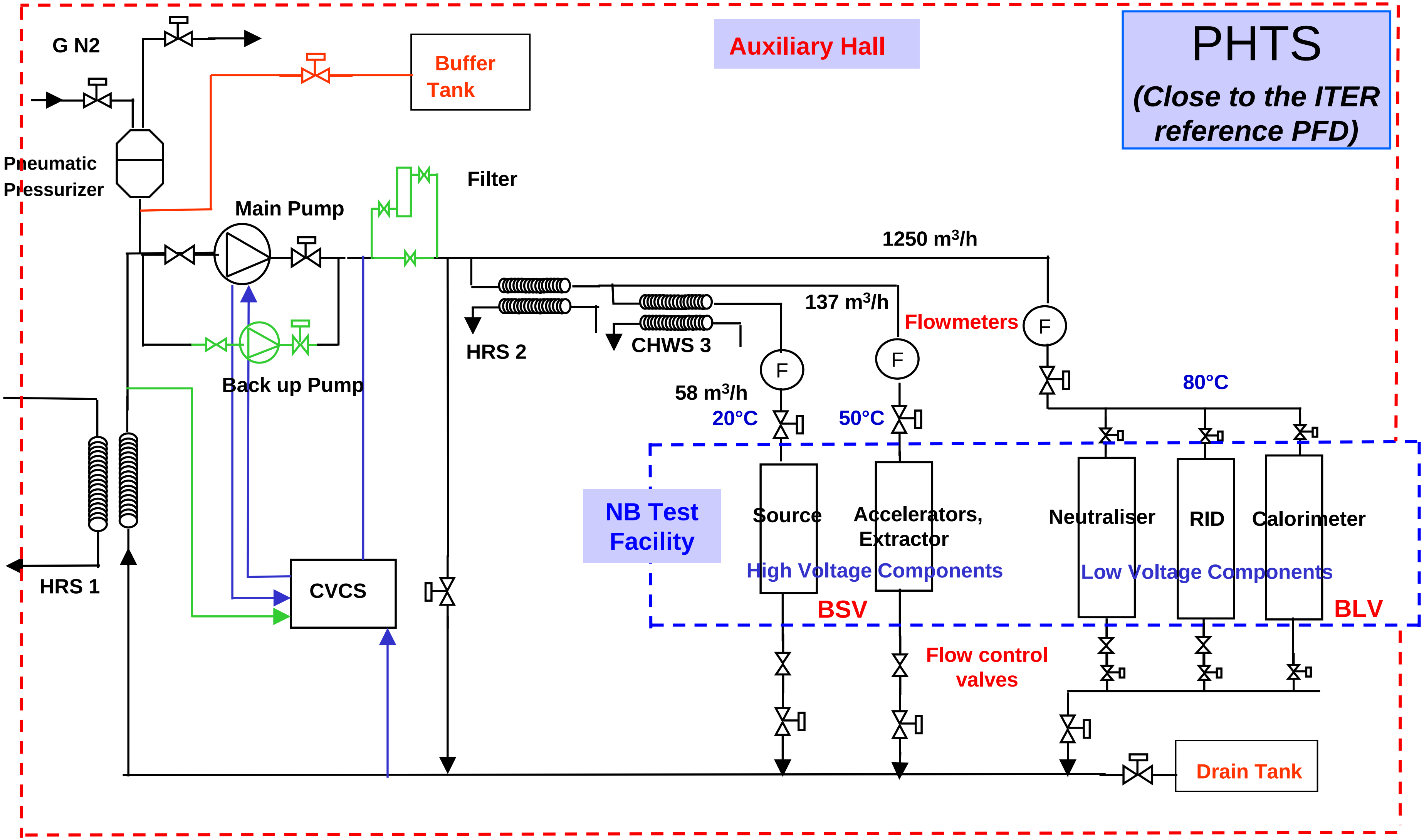
NB Test Facility - PHTS Flow diagram



HRS Characteristics – (NBTF secondary loop)

		P (kW)	Tinlet max (°C)	Toutlet max (°C)	Q (m^3/s)	Q (m^3/h)
Power Supplies		1 900	35	42	0.0636	229.1
	Acceleration Grid Power Supplies	200	35	42	0.0070	25.2
	Inverters	1 500	35	42	0.0500	180.0
	Ion Source Power Supply					
	rectifiers inside the HVD	70	35	42	0.0024	8.6
	Transformers inside the HVD	10	35	42	0.0003	1.2
	Devices located outside the HVD	100	35	42	0.0033	11.9
	Ground Related Power Supplies	18	35	42	0.0006	2.2
Cryo Compressors		280	15	30	0.0044	16.1
PHTS						
	HE1	50 000	35	70		1217.0
	HE2	4 000	35	50		228.3
CHWS	HE3	4 019	35	40		640.0
HRS Total		60 197	35	57		2330.5

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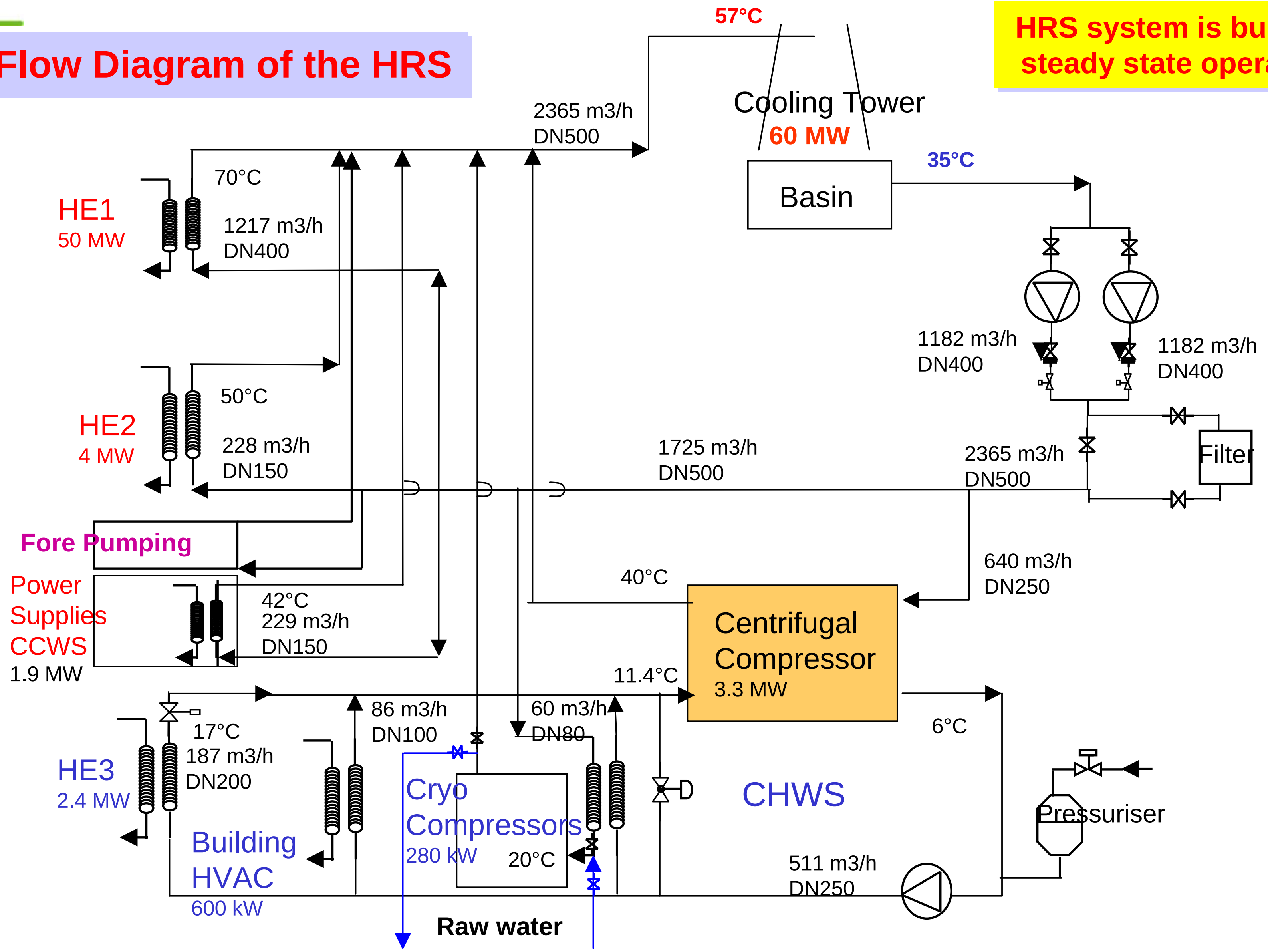
Flow Diagram of the HRS

HRS system is built for steady state operation



Summary

- A dedicated beam line vessel is designed for the NBTF, that allows easy man access, integration of diagnostics and in-vessel viewing inspection that would operate under vacuum

- Maintenance of NB injector components is optimised

- Conceptual design of the General Infrastructure is completed

- Designs of cryosystem and cryoplant fulfil the required NBTF specifications for both short (20s) and long (3600s) pulses at full 40 MW power