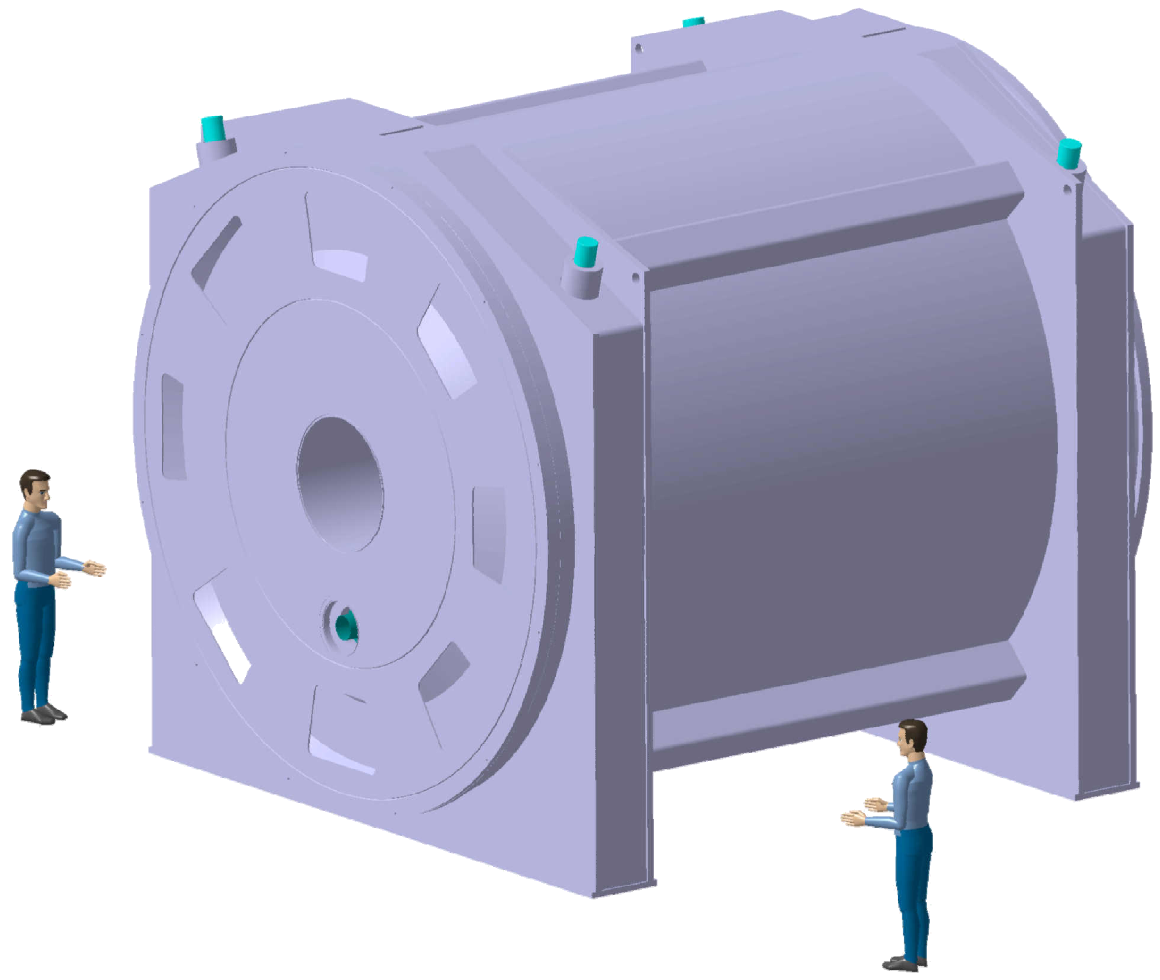
ISEULT CRYOGENICS

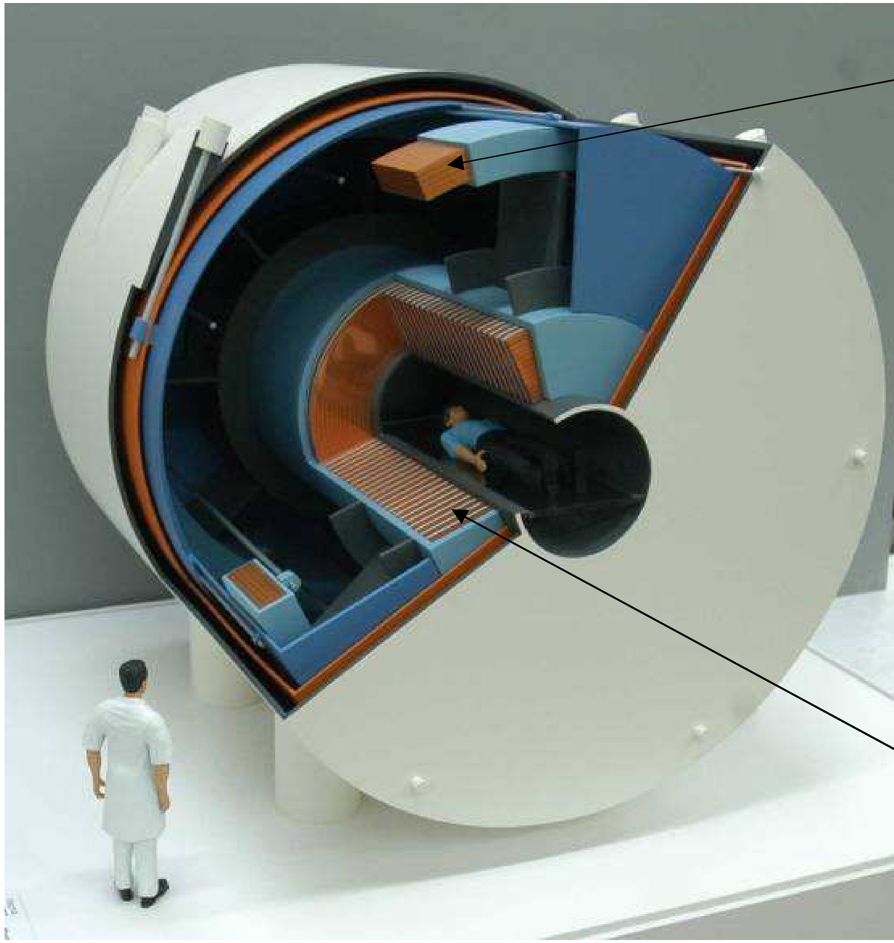
Preliminary design

irfu
cea
saclay



Iseult Magnet – Vacuum tank

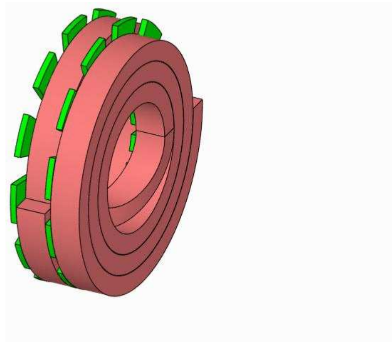
Magnet architecture



Active shiedling coils :
Impregnated coils

Pressurized HeII
1.8 K / 0.12 MPa

Central coil : Double pancake winding

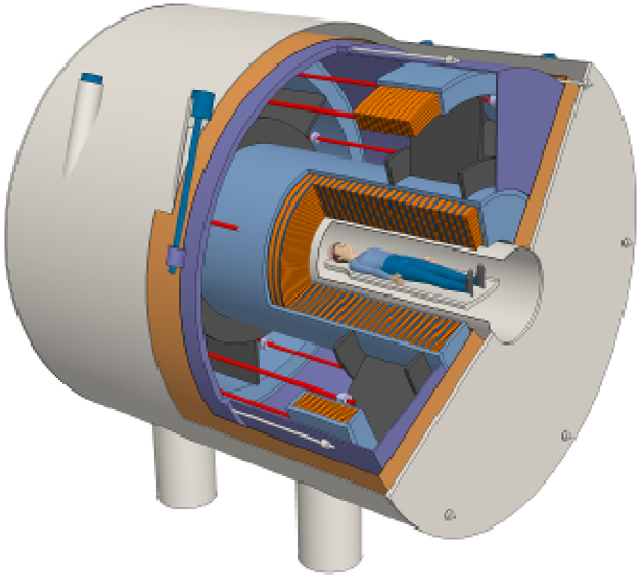


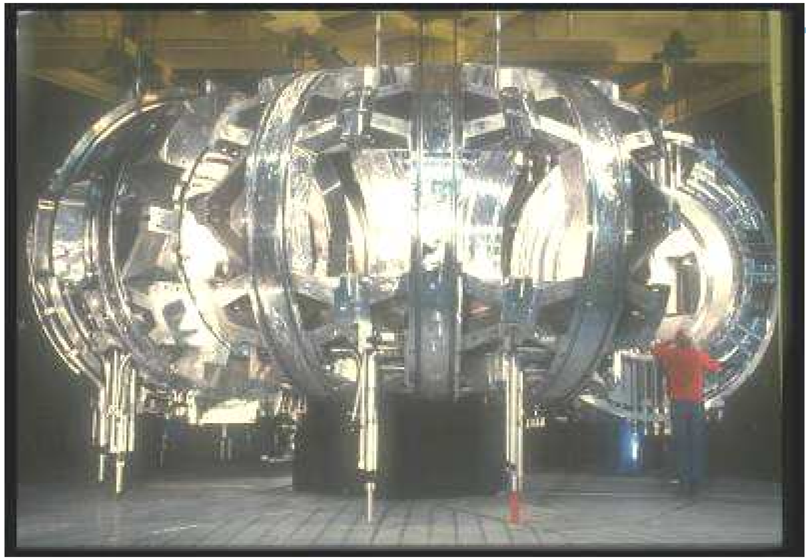
Iseult Magnet

General parameters

Item designation	Unit	Value
Central Field	tesla	11.75
Warm bore diameter	mm	900
Homogeneity in a 22cm diameter sphere	ppm (RMS)	< 0.05
	ppm (peak-to-peak)	<0.5
Field stability	ppm/h	<0.05
Axial 5 gauss line location	m	<9.6
Radial 5 gauss line location	m	<7.5

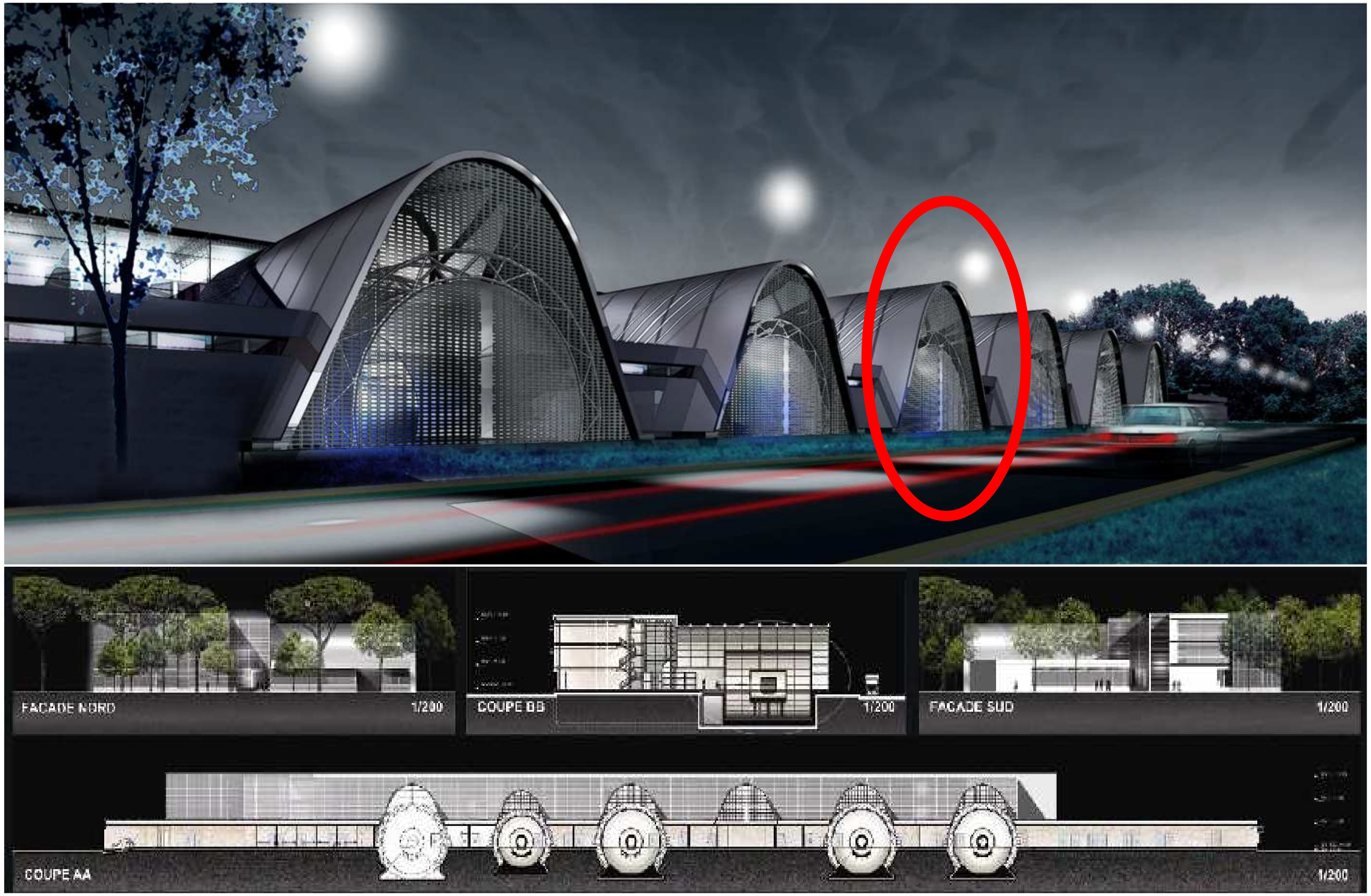
Comparison with Tore Supra (Fusion magnet)





	Iseult	ToreSupra
NbTi conductor cross section	4.6 mm x 9.2 mm	2.8 mm x 5.6 mm
Stored Energy	330 MJ	600 MJ
Total conductor length	187 km	300 km
Number of double pancake	170	468
Conductor total weight	60 t	45 t
Magnet total weight	120 t	160 t

Neurospin laboratory



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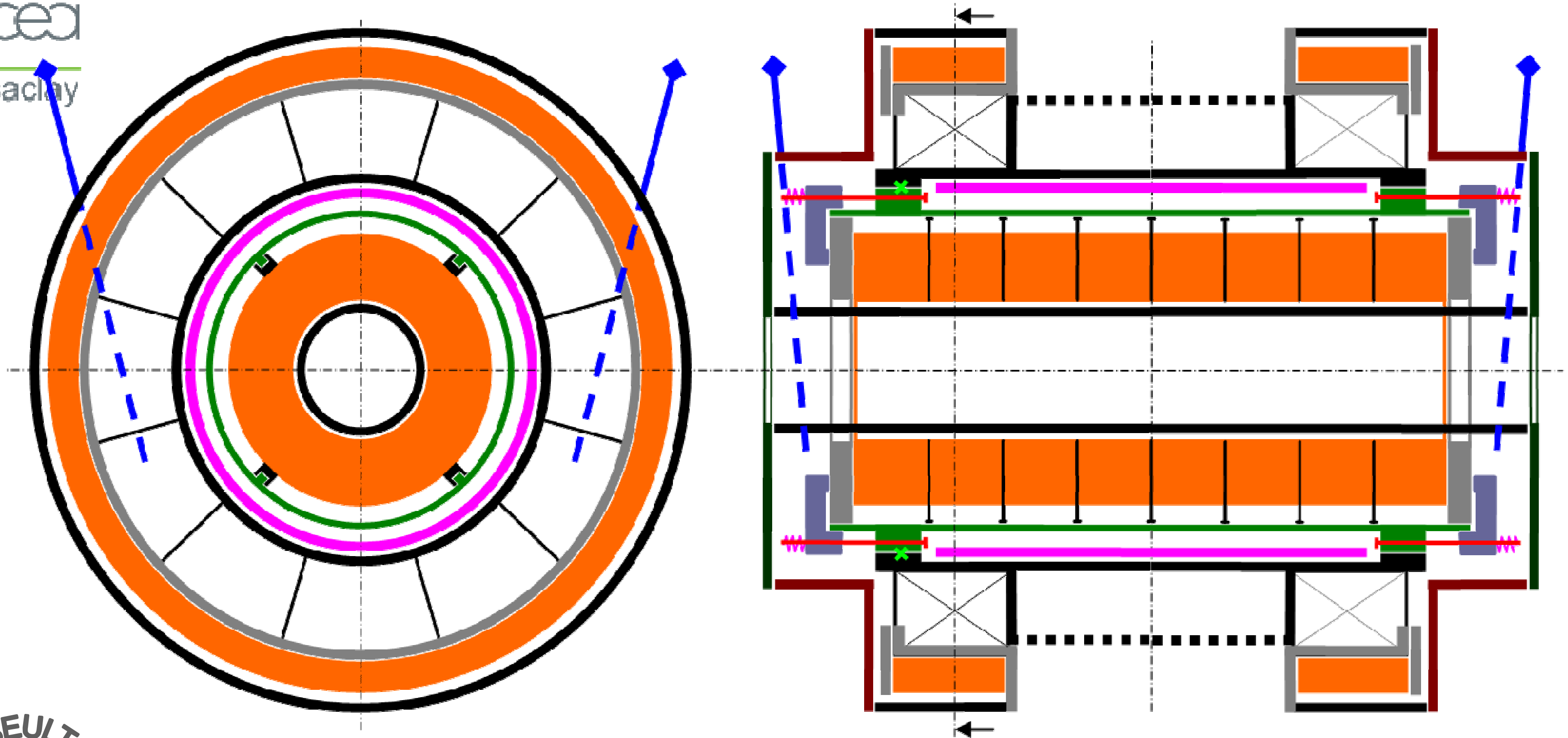
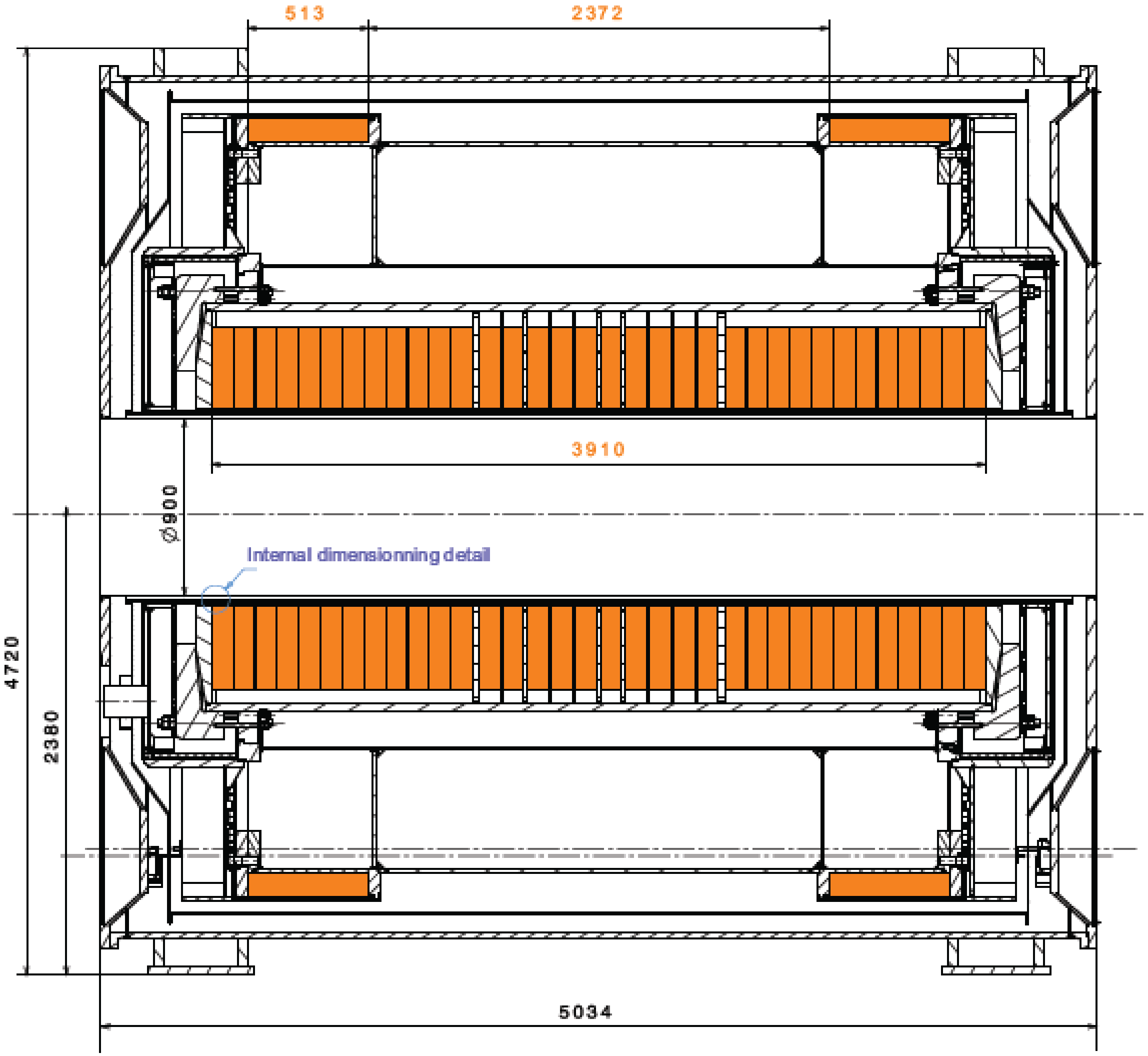
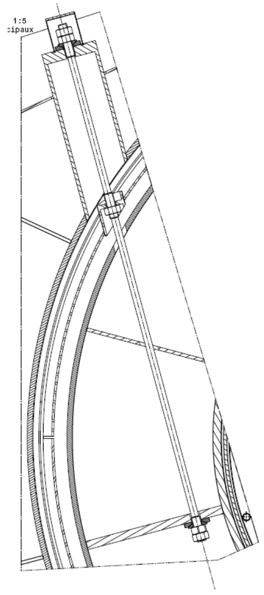
Cold mass design



Magnet architecture :

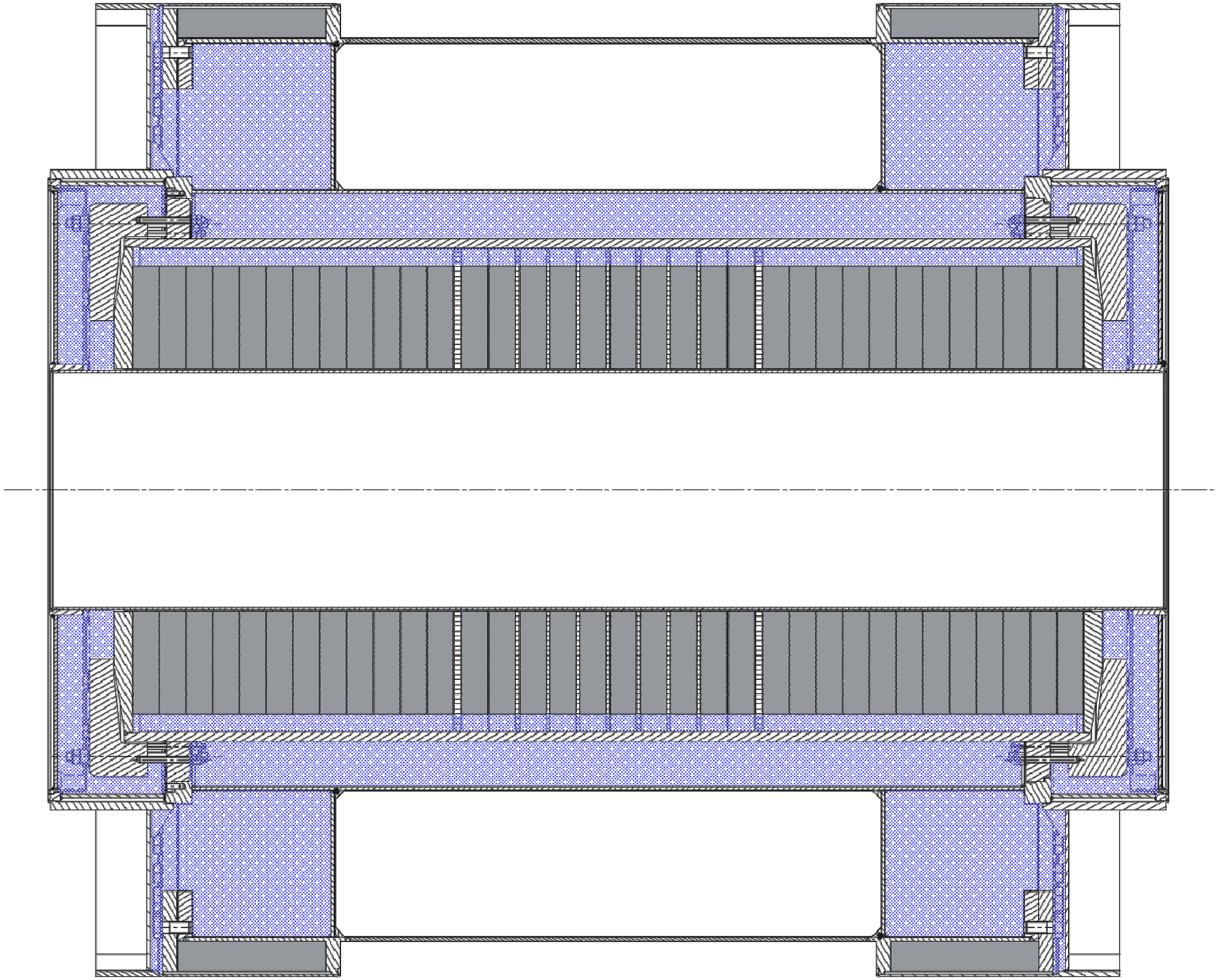




Suspension tie rod

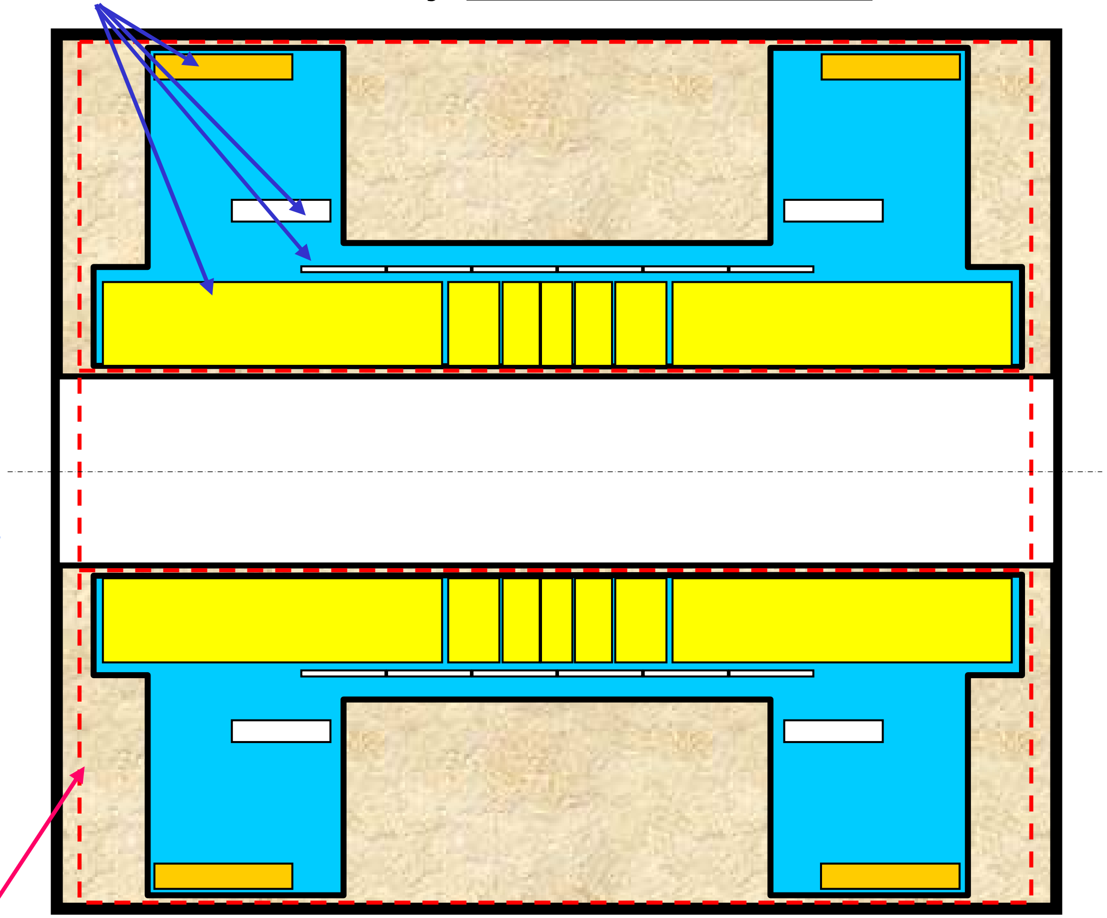
The cold mass (1,8 K) : helium tank and coils

➔ Detailed study : helium volume (to be reduced !)



General design of the cryostat

Several sc coils inside only **one common bath**: 1.25 bars @ 1.8K



Several m3 LHeII !

Cold mass > 100 tons

Only one thermal shield at 60 K (15 bars/60 K He cooled)

(66 K (6063 Al Alloy) or 72 K (3003 Al alloy) in the middle of the no-cooled central thermal shield)

- **a large cold mass to be cooled down to 5 K (weight > 100 t) in roughly one month**
- **Fill up and maintain the pressurized helium bath at 1.8 K & 1.25 bars inside a large volume (vol LHe > 5000 l)**
- **Cooling back after a fast discharge in a few days (tbp)**
- **Stand by at low temperature (< 100 K) on long duration without He refrigerator**
- **Warm-up**

Main goals of the ISEULT cryogenic plant

-Insure the transient cases :

- Absorb the additional losses during (de)energezing and slow discharge

- Make the fast discharge and quench safe

-Insure the abnormal cases

- Vacuum failure

- Few hours operation even in case of refrigerator stop

-Do not disturb the medical environment

First choices

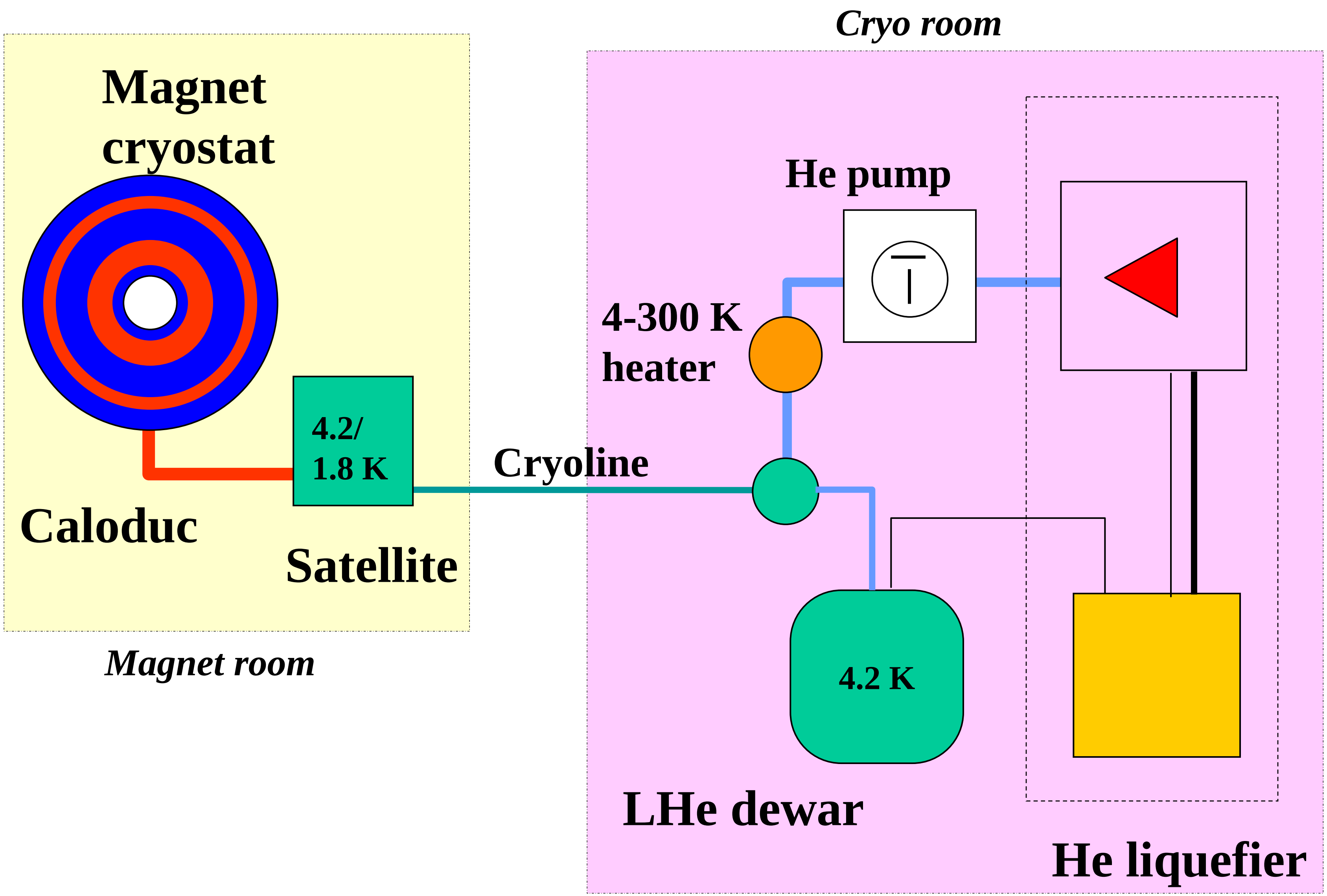
-To dissociate cryogenics and magnet "problems"

-To remove equipments from the magnet and from its medical environment

-And because superfluid helium is an excellent heat vector

- A cryogenic satellite will be located outside but near the magnet including cryogenic, electrical and safety elements.
- Hydraulic, vacuum and electrical links towards magnet cryostat are realised within a "caloduc" transfer line.
- A multiple transfer line (cryoline) will insure the cold fluid transport between magnet and technical rooms.
- He II tank of the magnet will be equipped with cold burst discs

Magnet room



Cryo room
Magnet
cryostat
He pump
4-300 K
heater
4.2/
1.8 K
Cryoline
Caloduc
Satellite
Magnet room
4.2 K
LHe dewar
He liquefier

Heat loads – main hypothesis

Thermal radiation

400 A ; 6 µm ; polyester spacer

Flux	W/m2		
between 300 and 60 K	3	MLI usual laying (n=30)	
between 60 and 4,5 K/1,8 K	0.15	MLI usual laying (n=10)	*Central tube*
between 60 and 1,8 K	0.050	MLI careful laying (n=10)	*Magnet cryostat*
between 4,5 and 1,8 K	0.001		

Conduction

Conduction integrals

range	Cu (RRR100)	Inox 316	G10	Al 3003	Ta6V
1,8-4,5 K	1340	0.472	0.14	15	0.885
4,5-60 K	88900	198	13.1	3800	106
60-300 K	104000	2870	154	32000	1310

Superfluid conduction

m	
3.4	
T	f(T)
K	$m/K.(W/m^2)^{3.4}$
1.8	4.80E+14
1.9	6.50E+14
2	4.70E+14

$$q = \left(f(T) \cdot \frac{dT}{dx} \right)^{1/m}$$

Vapor cooled current leads

2 x 0.075 g/s at 1500 A

2 x 0.045 g/s at 0 A

Residual gas conduction (insulation vacuum)

10^{-6} mbars

10^{-5} mbars around central tube

Heat loads (not definitive values)

05/02/2007	item	Radiation		Conduction		Convection (residual gas conduction)		Watts
60 K	*Magnet cryostat*	333	470	79	204	28	28	702
	Caloduc	12		15		-		
	Satellite	46		30		-		
	Valve Box and lines	79		80		-		
4.5 K	*Magnet cryostat*	-	1.2	-	24.2	-	0.4	25.8
	Caloduc	-		-		-		
	Satellite	0.7		8.2		0.4		
	Valve Box and lines	0.5		16		-		
1.8 K	*Magnet cryostat*	6.8	7.3	0.04	8.34	2	2	17.6
	Caloduc	0.3		3		-		
	Satellite	0.2		5.3		-		
	Valve Box and lines	-		-		-		

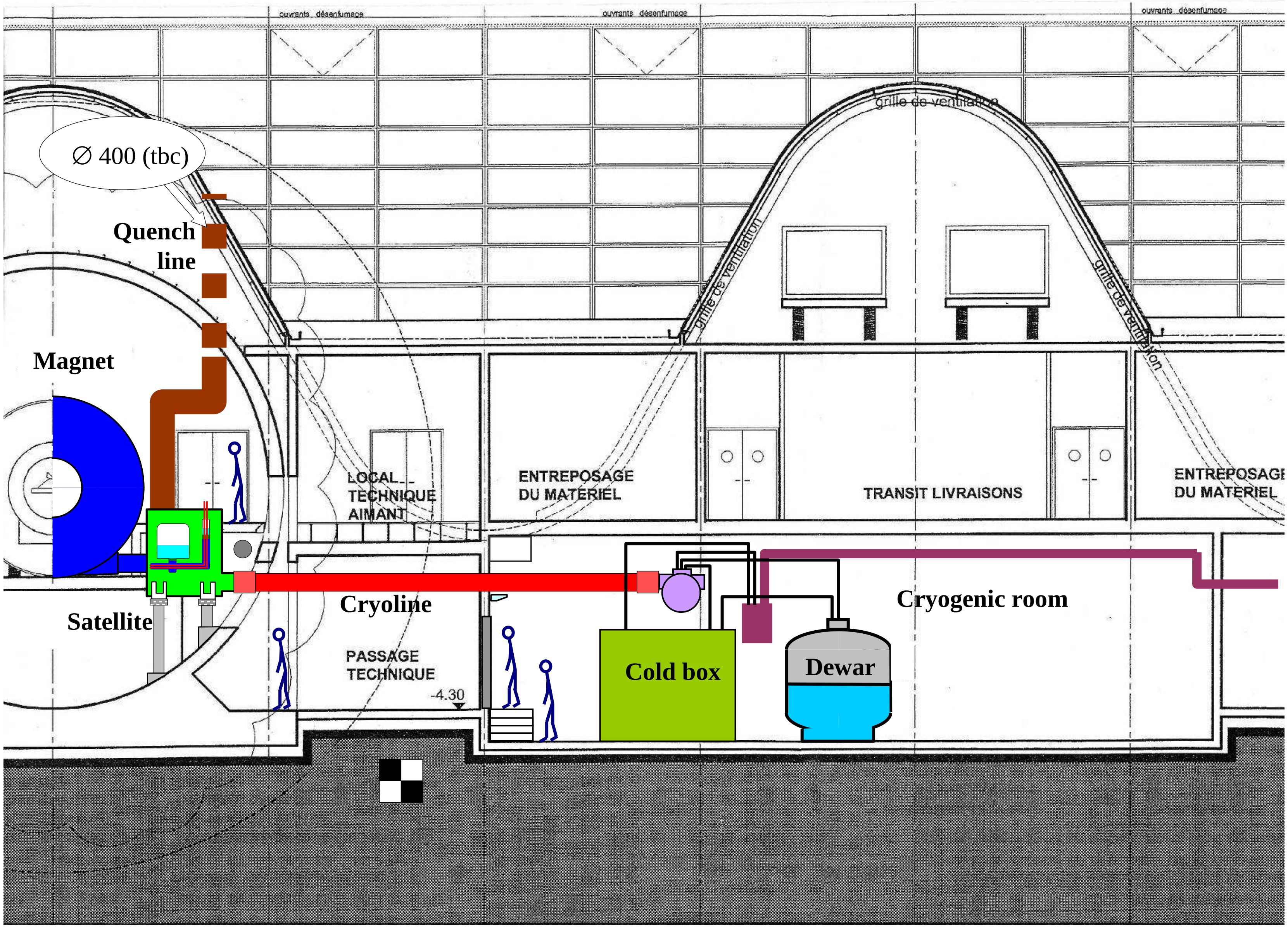
ratio [l/h @4.5 K] / [W @ 1.8 K]
2.5

margin
%
50

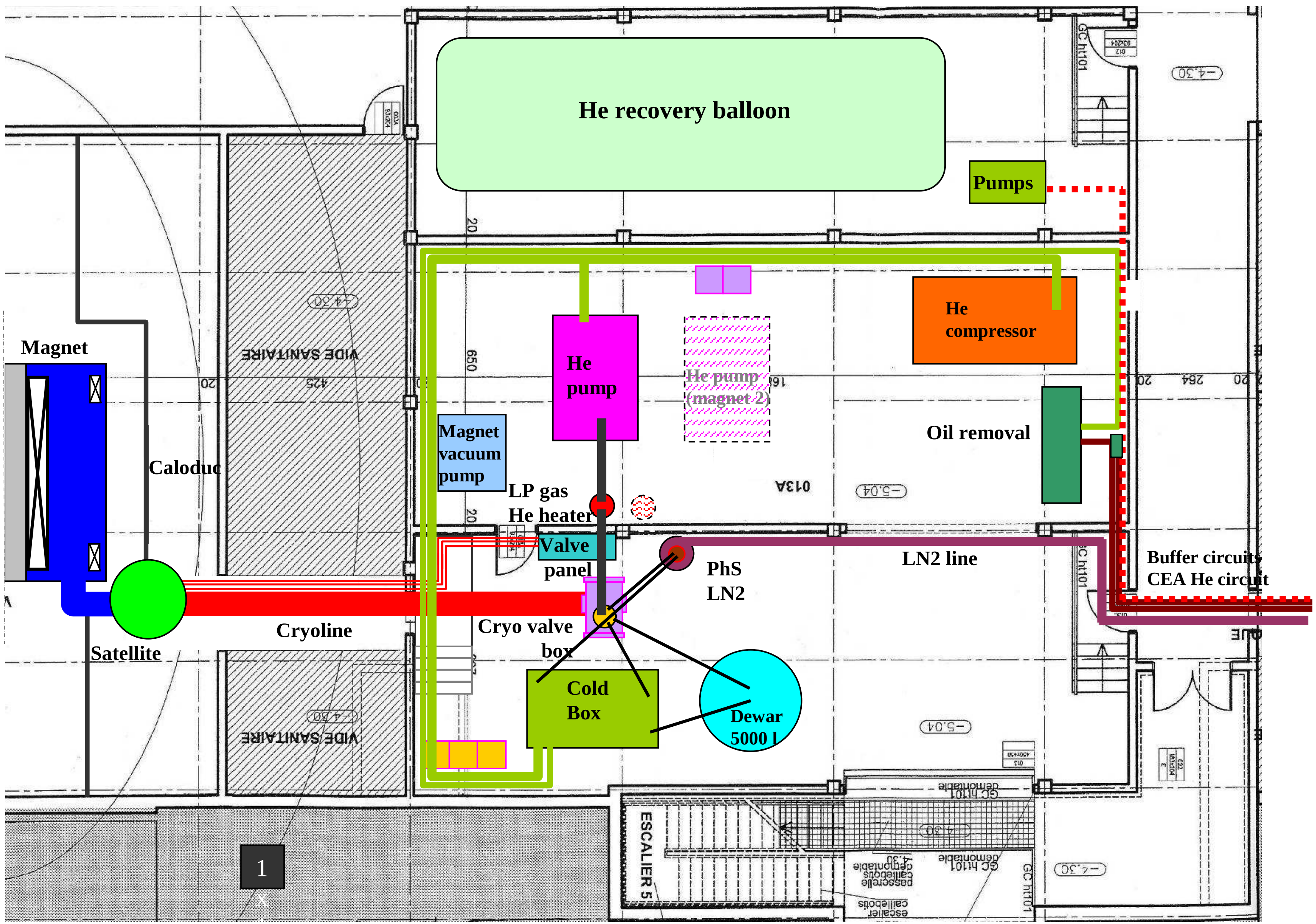
efficiency HX "4.2/1.8 K" + JT
0.95

Pure liquefier		
l/h 81		121
Mixed mode		
l/h 44	W @ 4.5 K 26	65.67 / 38.70

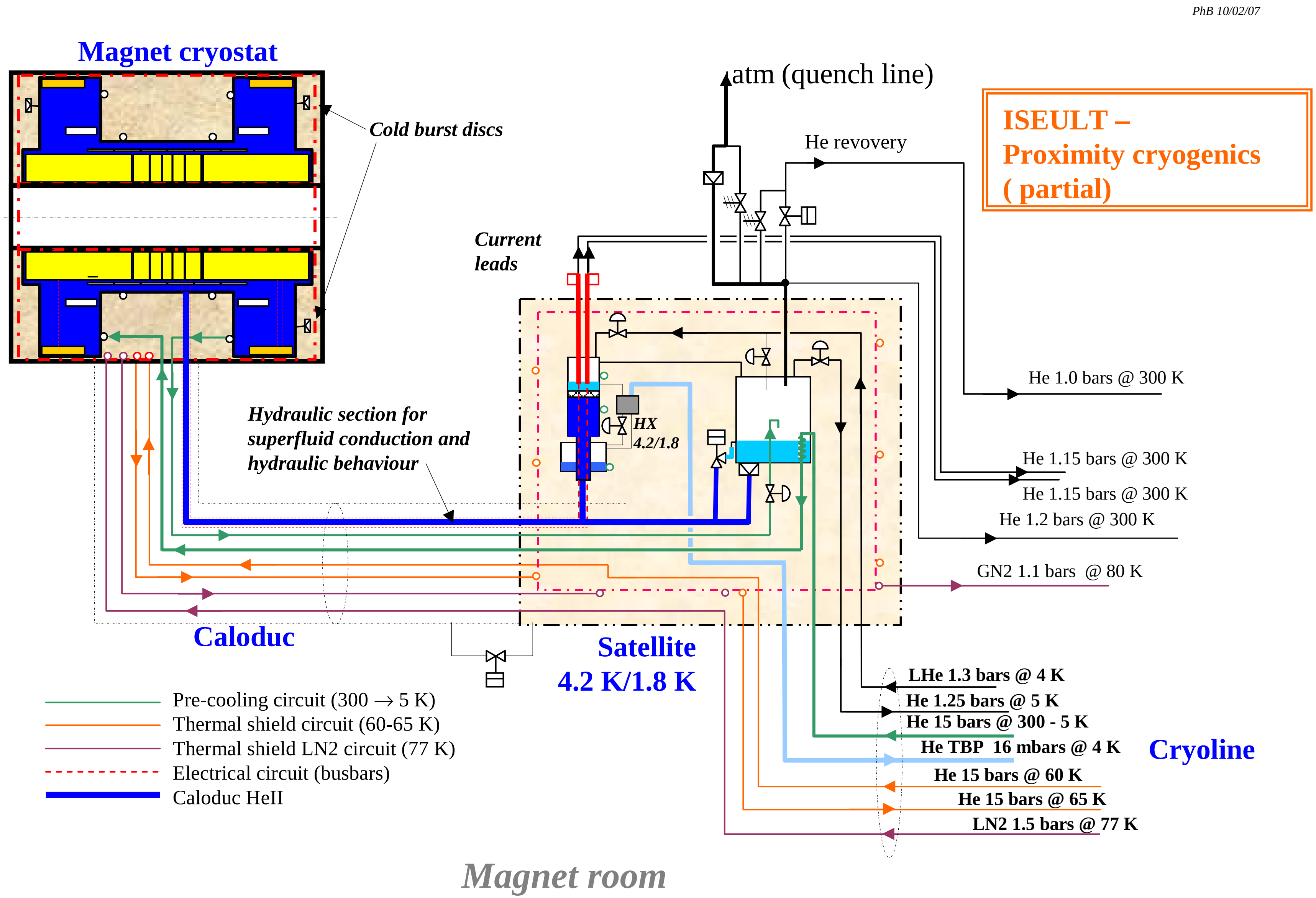
General layout



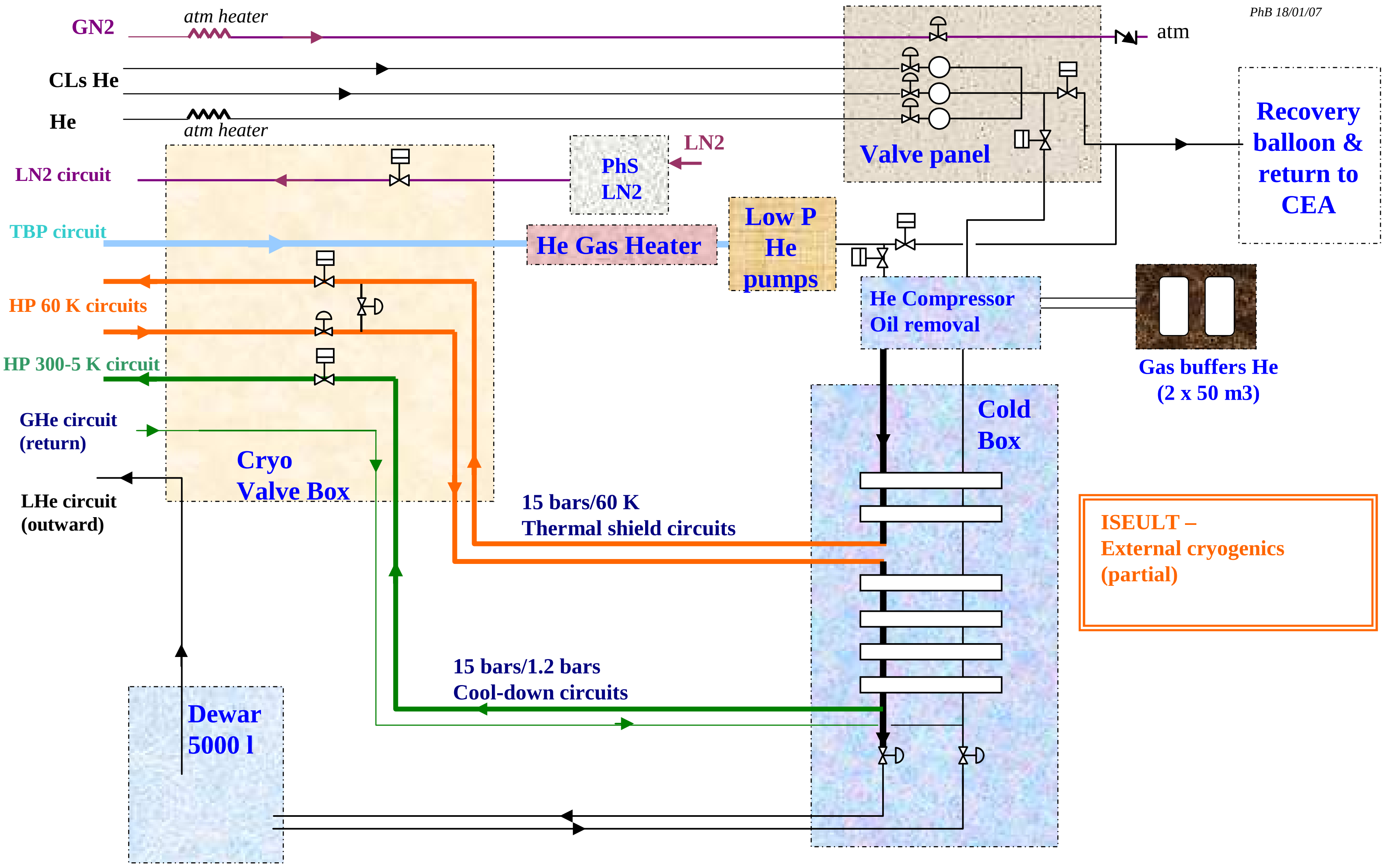
General layout



Proximity cryogenics (in the magnet room)



External cryogenics (underground room)



Cryogenic room (underground)

Main choices

- **A dedicated helium liquefier (in fact mixed mode refrigerator/liquefier) with a LHe large capacity dewar (5000 l)**
- **A room temperature pumping group for the 1.8 K bath (Roots+Rotary pumps)**
- **Use of nitrogen for pre-cooling (magnet cool-down, cold box operation, and low temperature stand-by)**
- **Thermal shields using 60 K high pressure gas flow from the cold box**
- **The extra heat loads due to transient cases (dI/dt) will be absorbed with a liquid level decreasing in the 5000 l dewar**

Main choices

-**In case of a failure on the helium liquefier , the 1.8 K refrigerator will go on by using the He pumps and by recovering helium, either with the He compressor or either with the CEA recovery loop, until a low level in the dewar.**

-**The He pumping group will have redundancy to avoid the stop of the pressurized bath and make the maintenance easier**

- **In case of EDF shutdown, a diesel group will insure the He pump operation at minimum and potentially also the He compressor (with an dedicated UPS for control process).**

Summary

18 W à 1.8 K
26 W à 4.5 K
702 W à 60 K

▪**Refrigerator cold box :**

-**81 l/h => 120 l/h** with margin **(option pure liquefier)**

-**44 l/h => 70 l/h + 40 W@4.5 K** with margin **(option mixed mode)**

-**4 days of lifetime in case of cold box failure BF**

-**Thermal shield circuit 15 bars@ 60-65 K** (mass flow > 35 g/s, ΔT < 5 K)

-**Cool-down circuit 15 bars @ 300-5 K**

-**Dewar LHe 5000 l (large autonomy in case of failure)**

-**Large gas buffers (2 x 50 m3) to keep pure gas and make easier the maintenance (pressure test)**

▪**Cooling-down with cold box**

Ancillaries

- ***He pumping group at 300 K***
  - **global tightness less than 10^{-6} mb.l.s^{-1}**
  - **doubling these equipments to avoid unexpected stop and to permit preventive maintenance (fore pumps and roots)**

- ***Options to keep purity of the loop He gas*** ***(without stopping the magnet)***
  - **purifying system at the outlet of He pumping group before compressor LP suction (switch system with charcoal LN2 cooled)**
  - **two charcoals pots inside the liquefier cold box with a periodic swing to regenerate one of them**
  - **preventive regenerative operation on the cold box and its only charcoal pot (2 days of shut-down for the He liquefier without LHe production and a magnet directly supplied by the 5000 l dewar)**

- **Possibility of external LHe supply** (via the 5000 l dewar)

Conclusions

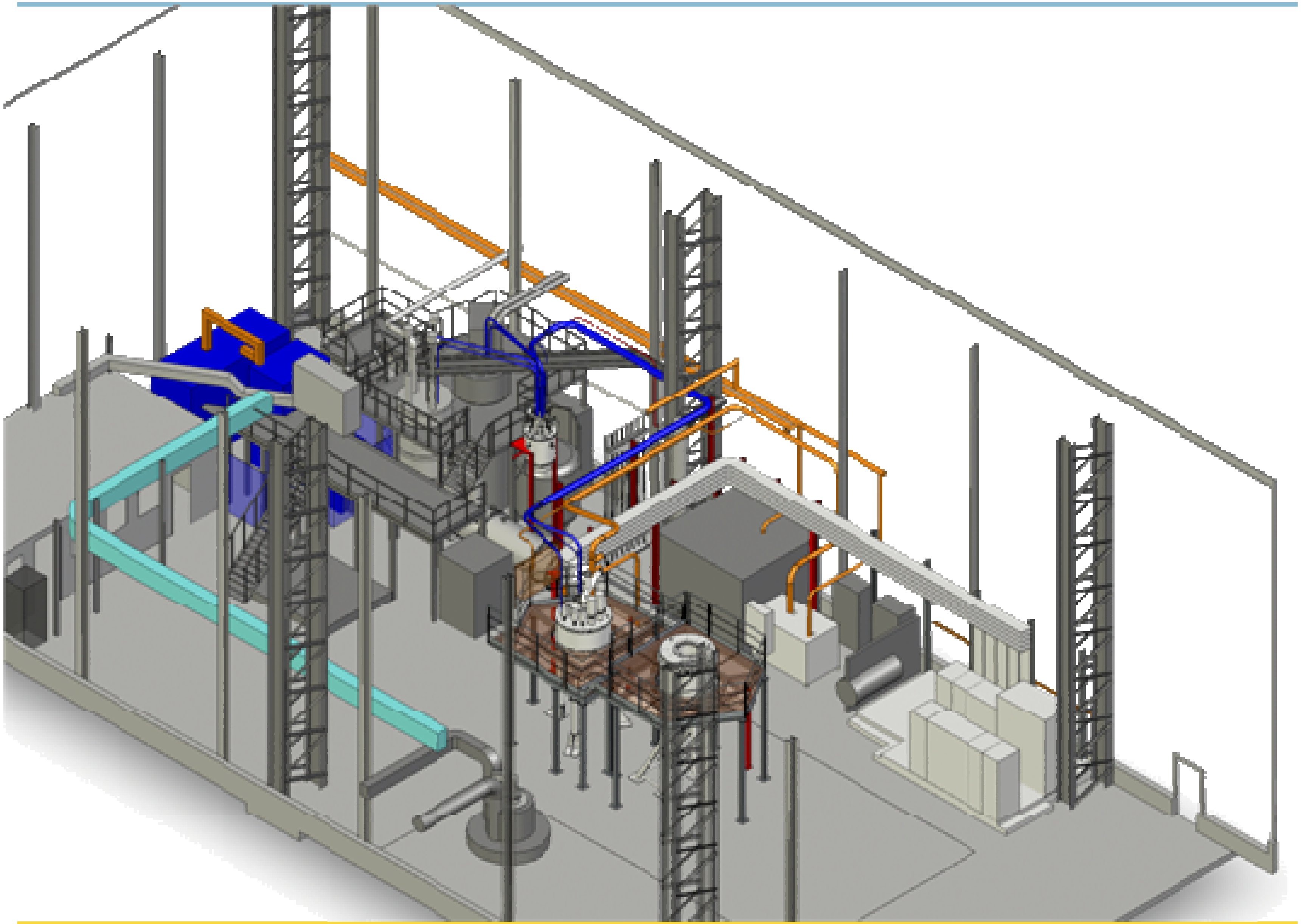
• ***The 1.8 K operation and heat loads request a dedicated He refrigerator***

• ***Design of the satellite must take into account the large volume of LHe inside the cryostat (safety in case of failure and possibility to transfer a part of the liquid back to the dewar).***

• ***"Fillers" have to be installed in the He II tank to reduce the effective liquid volume in the cryostat down to a reasonable "value" (5000 l)***

• ***Extra heat loads due to coupling gradient coils and magnet during imaging have still to be taken into account***

SEHT : Others developments on SACM test facilities



SEHT : Others developments on SACM test facilities

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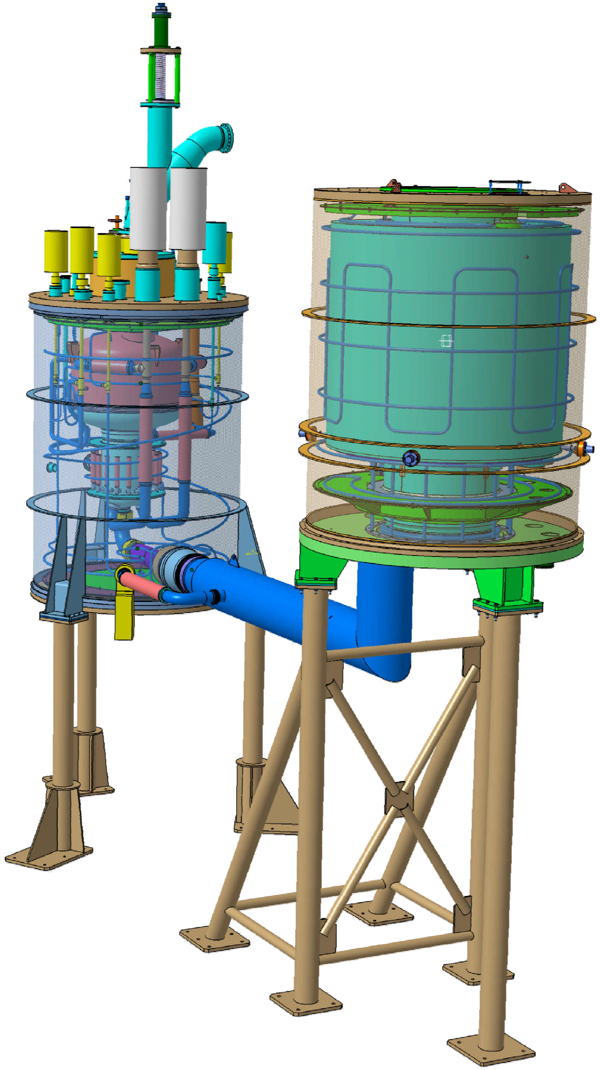
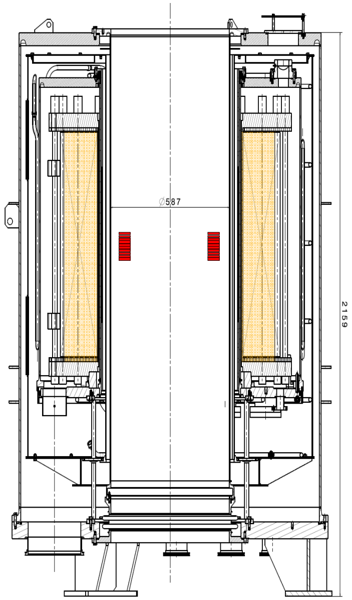
Cryogenic satellite



Magnet cryostat



SC pancake coil (ex LCMI 8T)

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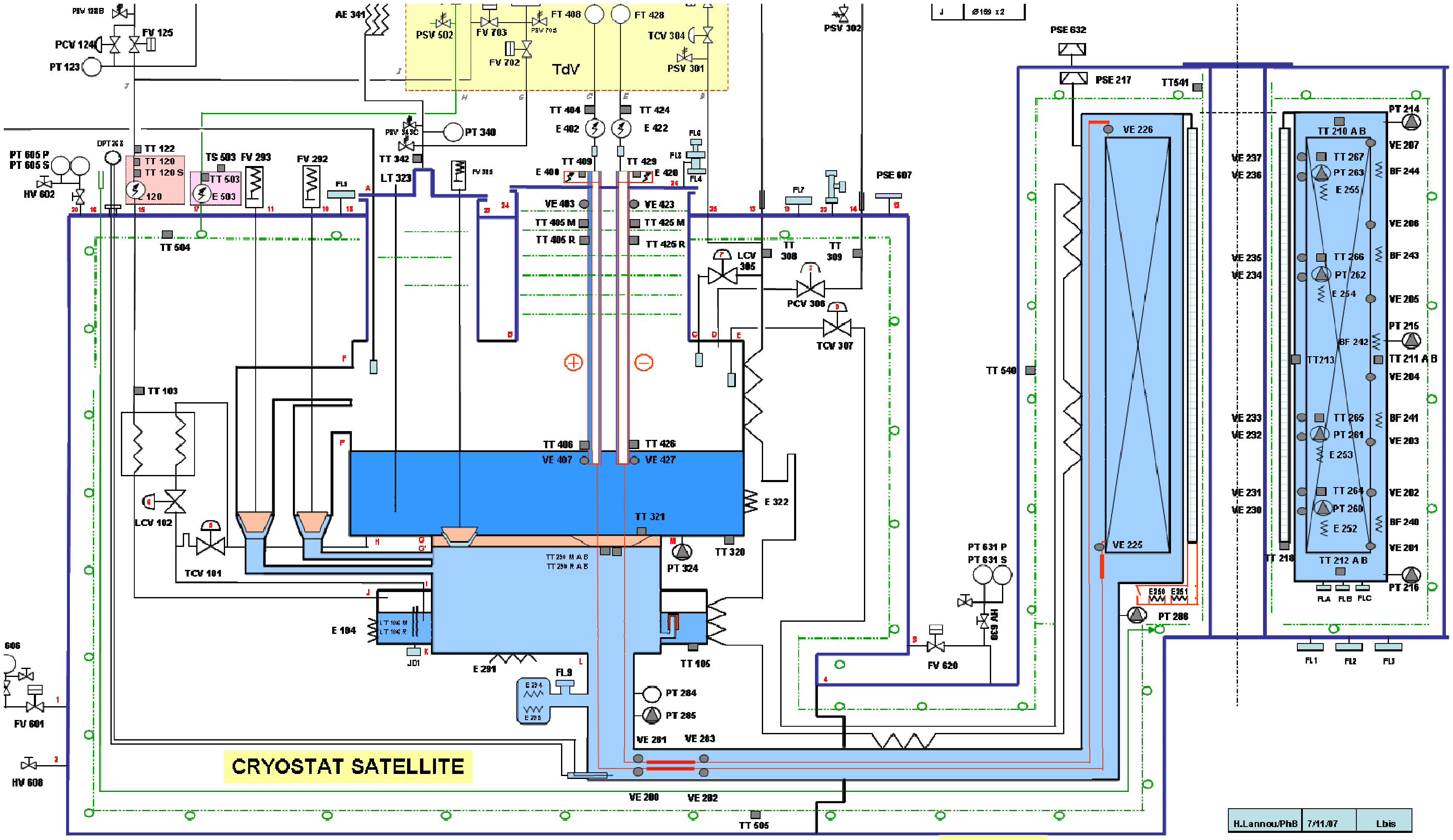
SEHT Test Station Objectives

- Cryogenics (design and equipment)
- Quench protection (MSS, equipment)
- Field Stability (power supply,
- Thermohydraulics (P (x,t), m)
- Local and global mechanics calculation
- Reduced Size Prototype (R0)
- Test of Iseult Full Scale Prototype (M0) and Iseult Modules

ISEULT 500

SEHT : PID



- **SEHT under assembly in technical building 198**