SUPERCONDUCTING TECHNOLOGIES

FOR THE NEXT GENERATION OF ACCELERATORS

WORKSHOP

Vittorio Parma
TE-MSC/CMI
On behalf of the
Cryostats & Machine Integration Section

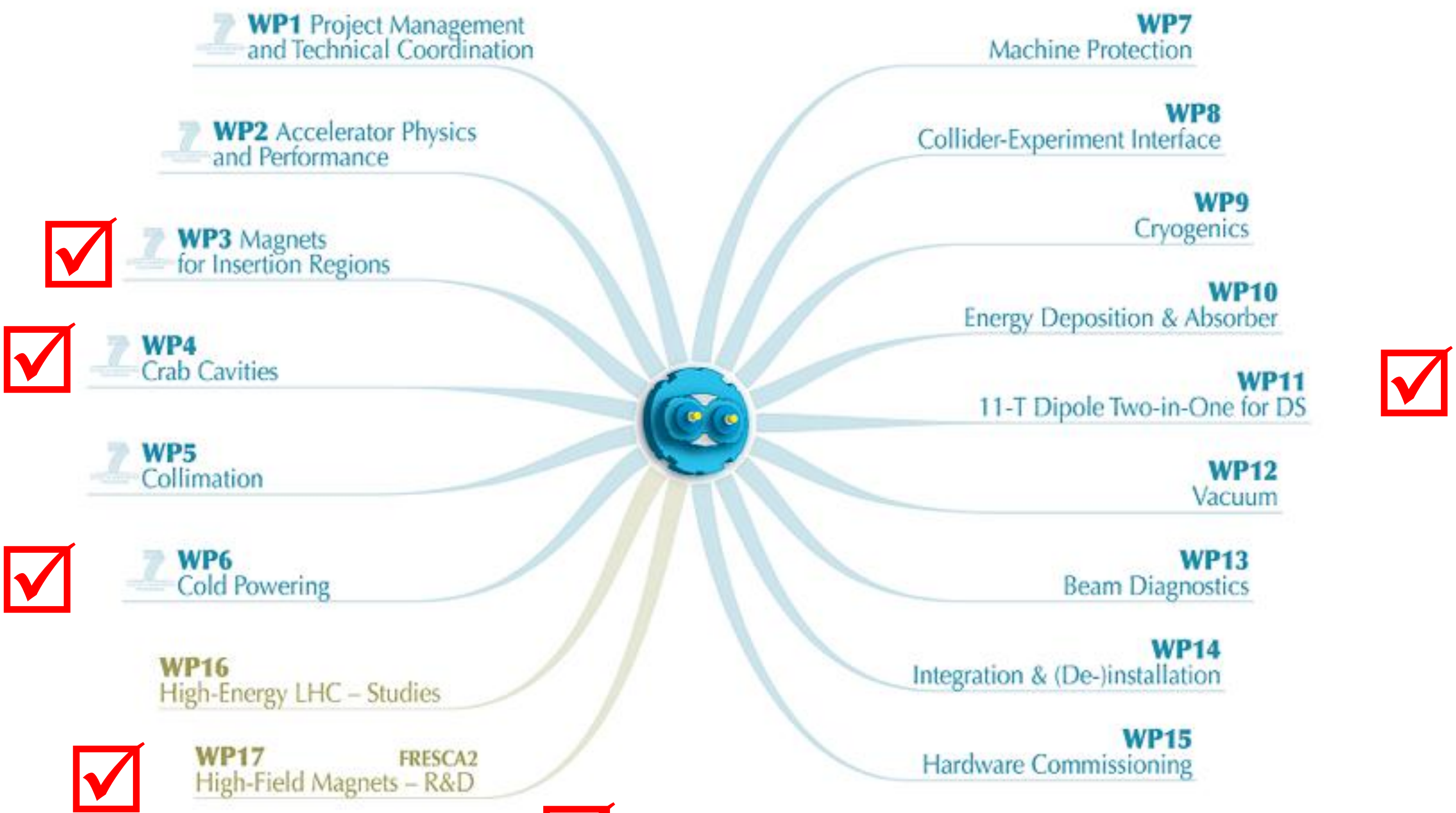
Cryostats for new applications

Topics

Upcoming projects and developments:

- Hi Lumi related:
  - The High Field Magnet (HFM) test station
  - New collimators in the LHC DS with 11T dipole magnets
  - New feedboxes (DFBs) for LHC upgrades
  - Dismantling/Upgrade of LHC Inner Triplets (new IT)
  - Cryomodule for Crab cavities (CCC)
- Other accelerators:
  - Cryomodules for the HIE-ISOLDE Upgrade
  - Cryomodule for SPL R&D

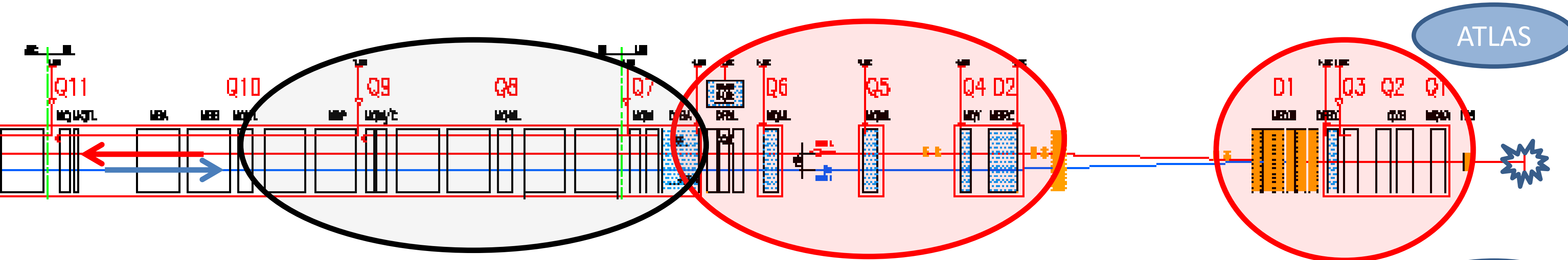
HL-LHC structure



☑ **= requires cryostat developments**

High Luminosity LHC

The LHC most affected zone (MAZ)



3. Special collimation locations where we need space by using a new 11 T dipole

2. New entrance to the matching section: Q4 magnets (other magnets ? collimators and SC RF Crab Cavities)

CMS

1. New Q1…Q3/D1 magnets in the IRs and interface to detectors; relocation of Power Supplies via the SC links

300 m x 4 +… : about 1.5 km long accelerator, pushed performance in a high radiation environment: 10…100 MGy

High Luminosity LHC

By courtesy of L. Rossi, L.Bottura

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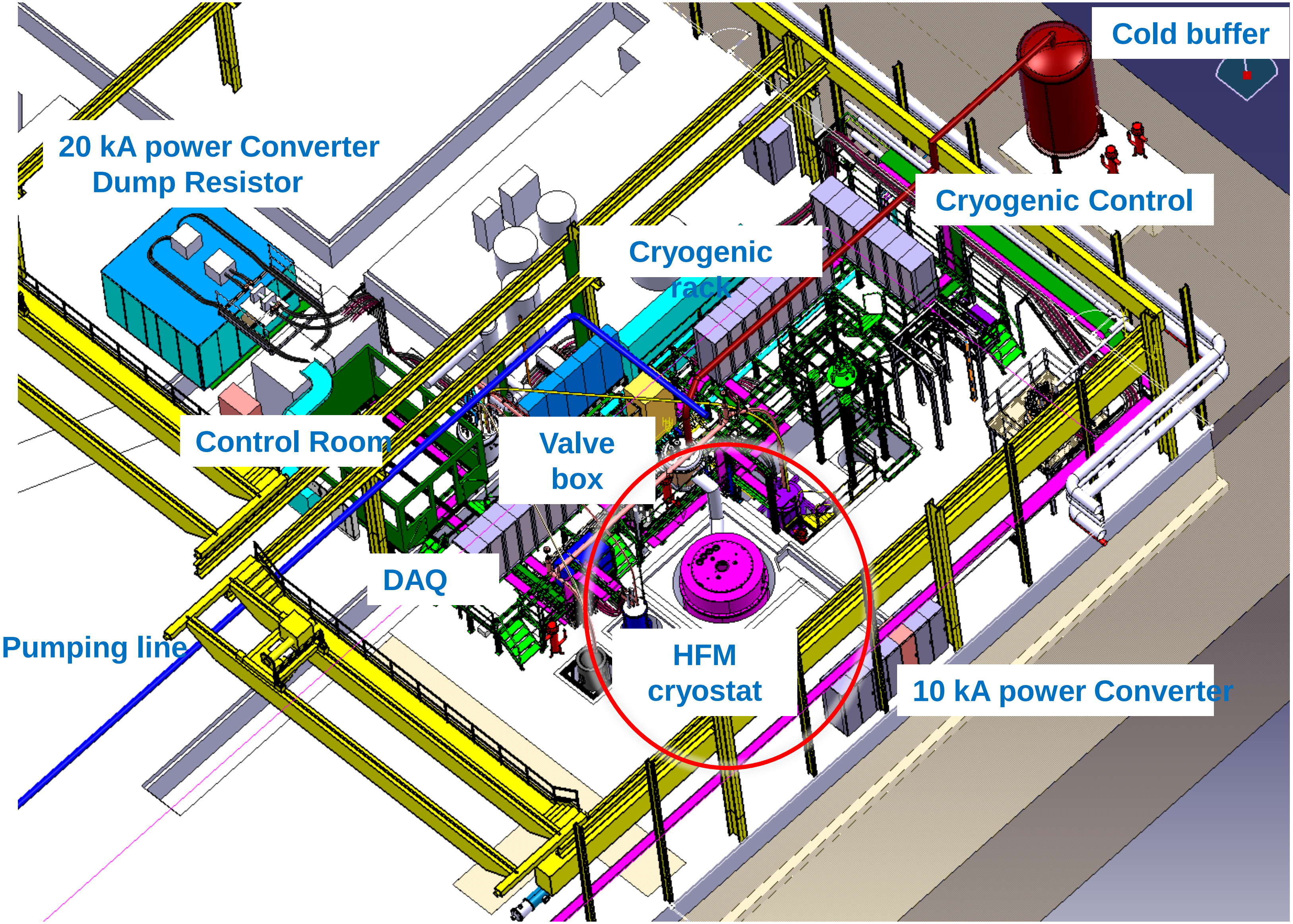
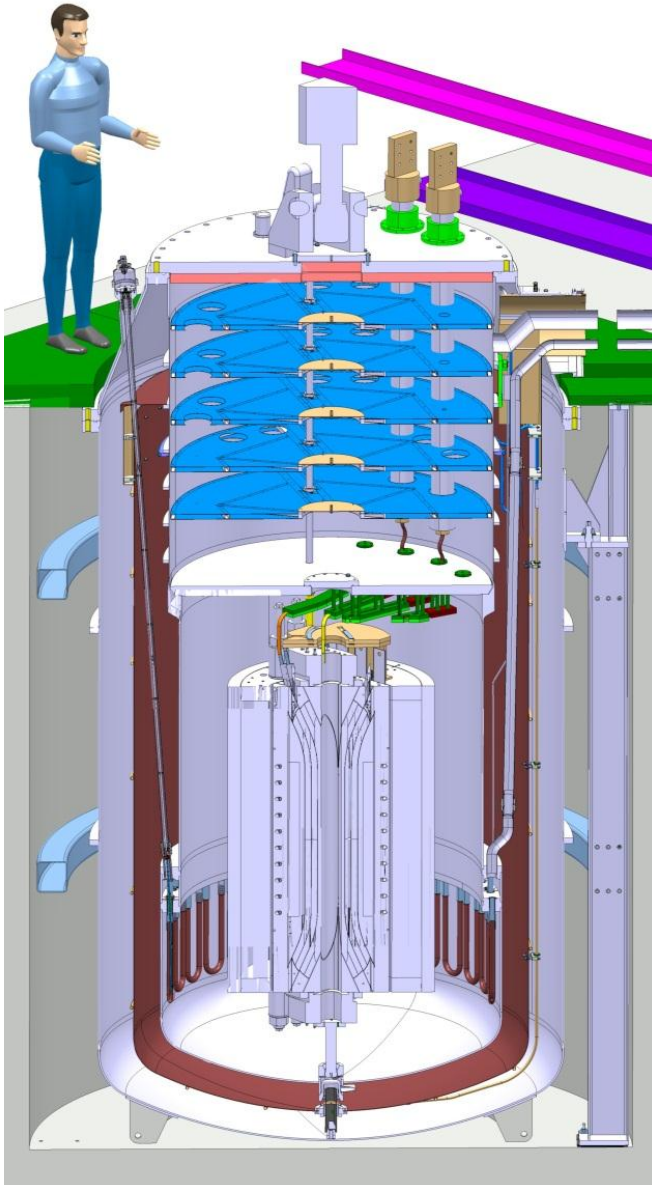
The High Field Magnet test station (CERN, SM18)

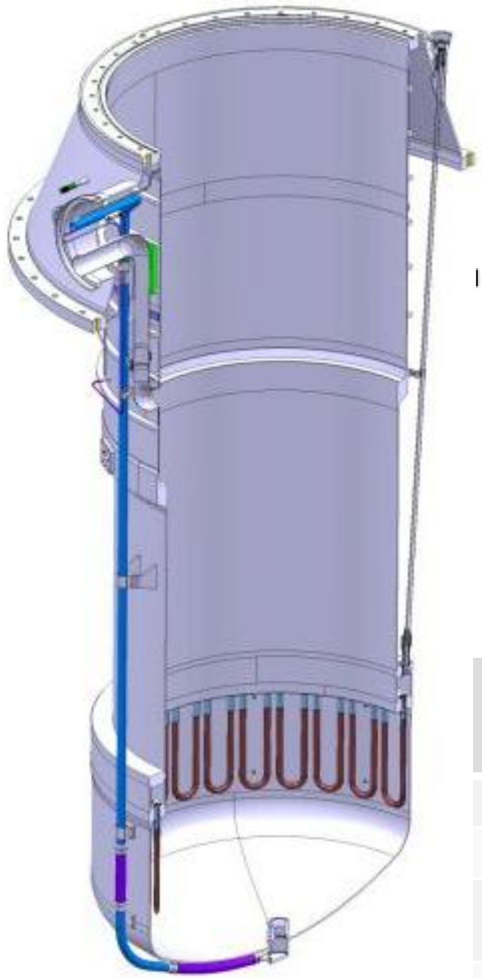


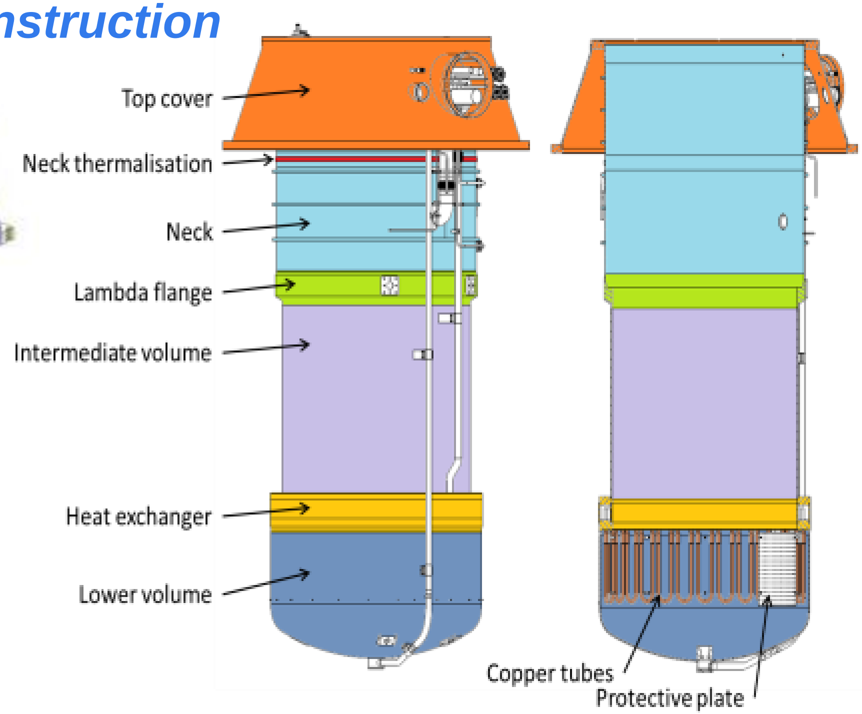
The HFM test cryostat



Helium vessel, main features

Ready to launch construction





Item	Material
Vessel and Pipes	AISI 304 L
Hoses and bellows	AISI 316L/316 LN
Heat exchanger	OFE Copper brazed to AISI 316 LN
Thermal shield	OF Copper

Item	Tolerances/leak rate
Lambda flange to top flange (ø1600 mm)	Parallelism within 1 mm
Centring pin to top flange	Position within 2 mm
Maximum welds leak rate	1.10^{-10} Pa.m^3/s

Item	Internal diameter [mm]	Length [mm]	Thickness [mm]
Top cover	1610/2300	770	10
Neck	1610	1650	3
Intermediate volume	1500	1655	8
Lower volume + Dished end	1700	890	8
Total length	4320 mm		
Total weight	3350 kg		

Property		Value
Magnet + Support weight		17 tons
Operation pressure	Internal	1 bar (max. 4 bar)
	External	0 bar
Design pressure	Internal	0 bar / 4.5 bar
	External	0 bar /1.5 bar
Nominal temperature	Neck	293 K – 4.2 K
	Helium vessel	1.9 K

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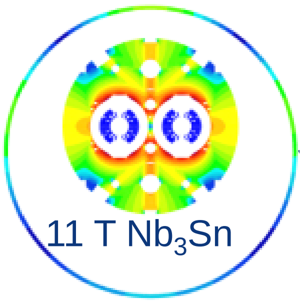
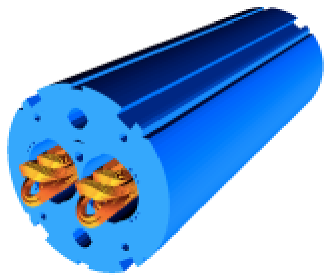
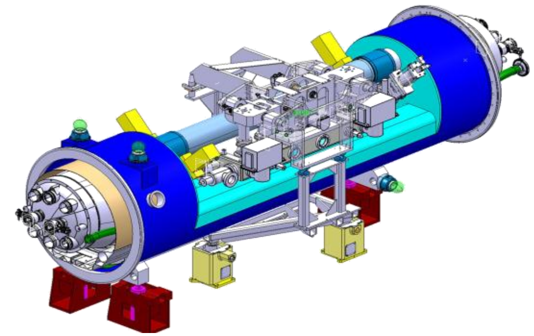
Cryostats for 11T dipoles + collimators

11 T dipole twin aperture magnet





Warm collimator unit
(present baseline solution, but not short enough)



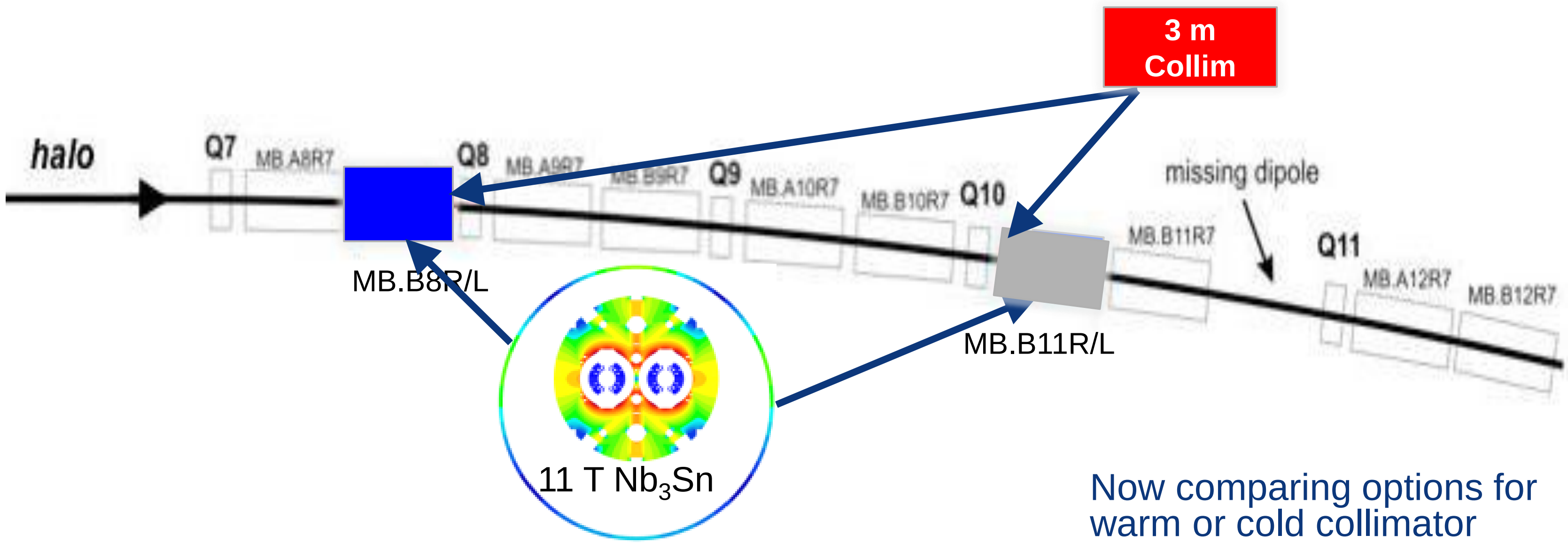
$\int BdL = 119.2$ Tm @ $I_{nom} = 11.85$ kA
in series with MB with 20 % margin

Two options for magnet arrangement

LS2 2017-18: IR-2 (demonstration)

LS3 2020: IR7/8, IR1/5 as part of HL-LHC (TBC)

Cryostats for collimators + 11T magnet



Now comparing options for warm or cold collimator

Warm collimator
(compact and "standard" technology)

Cold collimator
(more compact (?), "non-standard" technology)

Technology choice: beginning 2013. If collimation needs justify, a project will be launched

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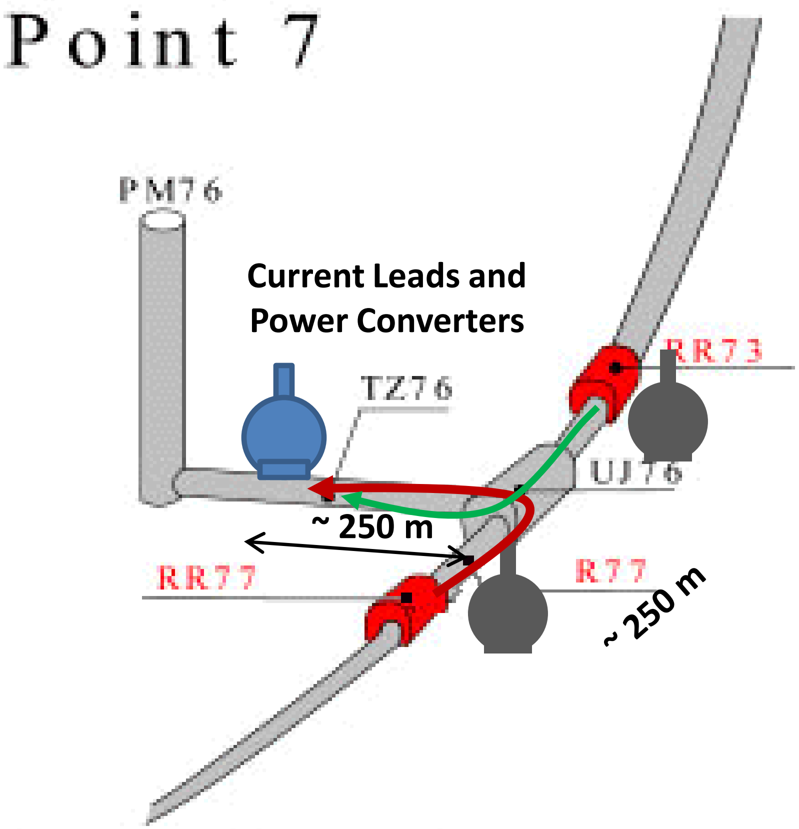
Cold powering upgrades

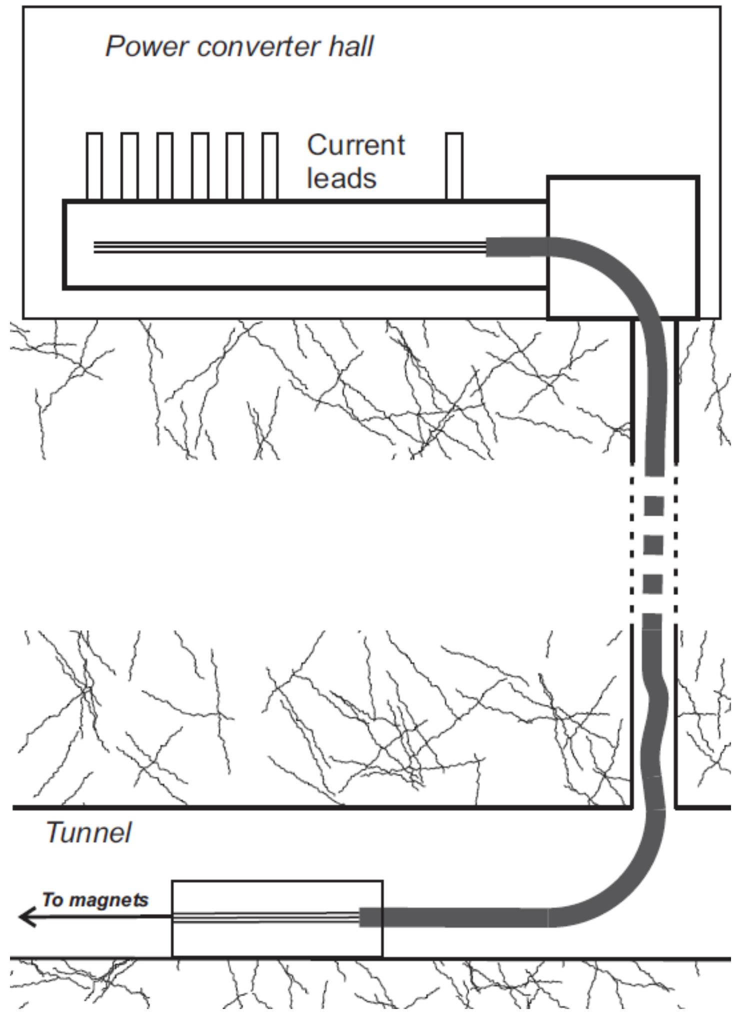


Underground installation

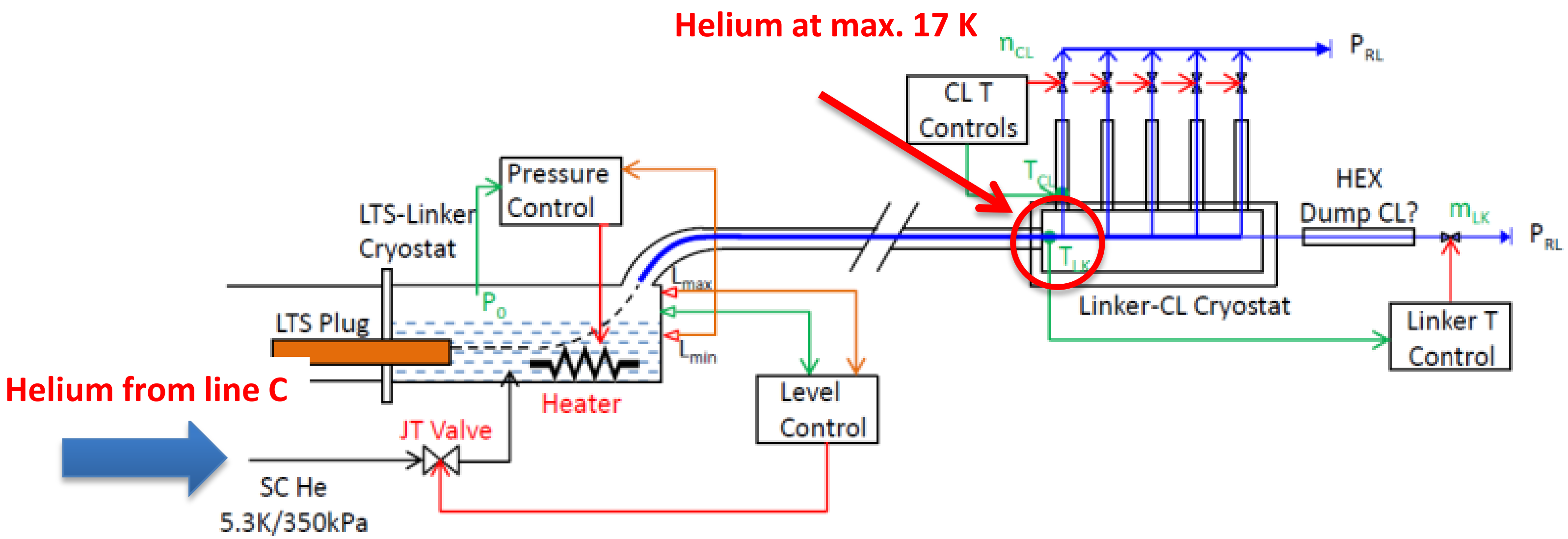
Two links each about 500 m long
48 cables rated at 600 A per link

See A. BALLARINO's talk

Points 1, 5,



Current cryogenics feeding concept (all sites)



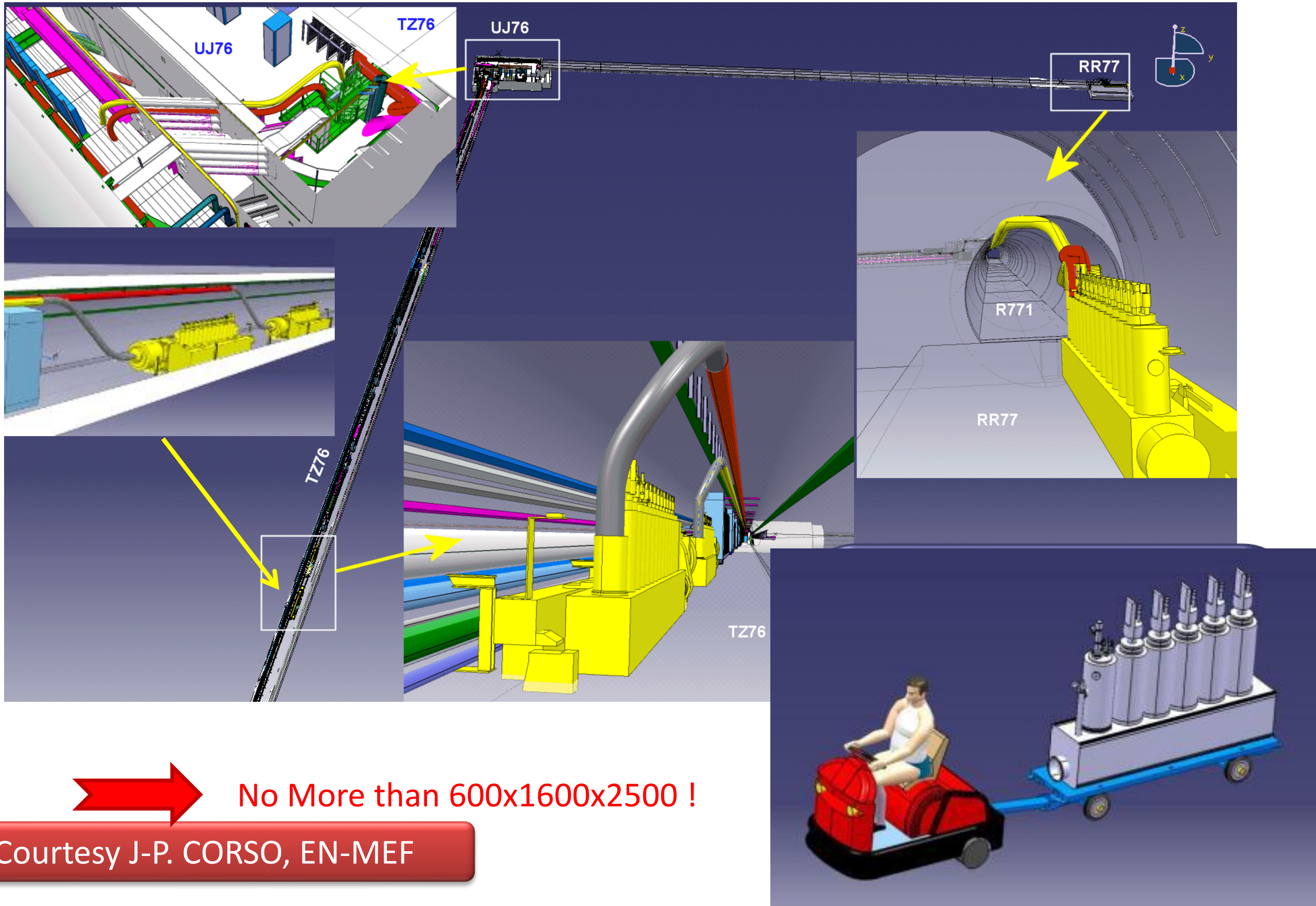
– The (assumed) 17 K limit for the MgB2 link allows only the 5 K, 3.5 bar helium from line C as coolant.

– The link will be cooled by helium gas created by evaporating the liquid helium in the spice box.

– Thermal shield solution not shown.

Courtesy of U.Wagner, Y.Yang, A.Ballarino

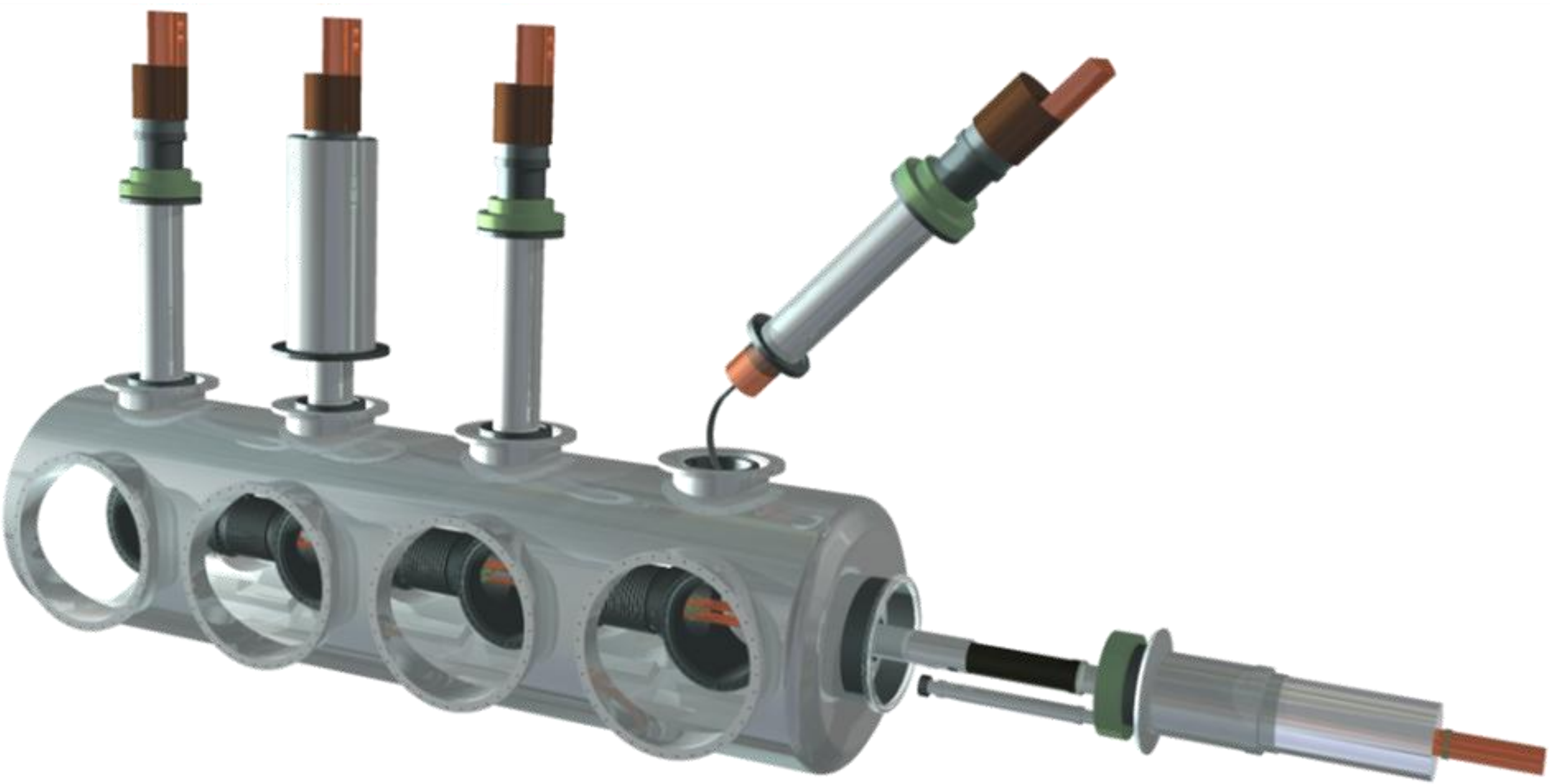
Underground Integration in Point 7



No More than 600x1600x2500 !

Courtesy J-P. CORSO, EN-MEF

Current Leads Module concept
(Y.Yang et al., Univ.of Southampton)



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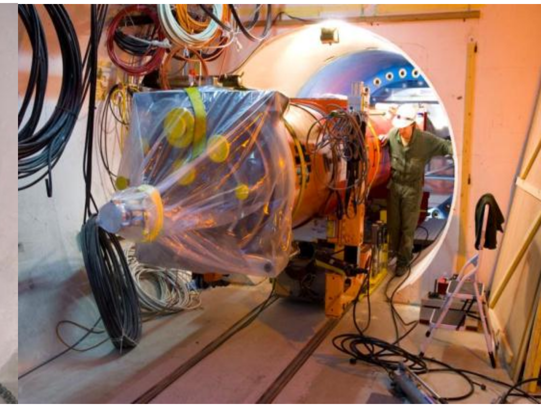
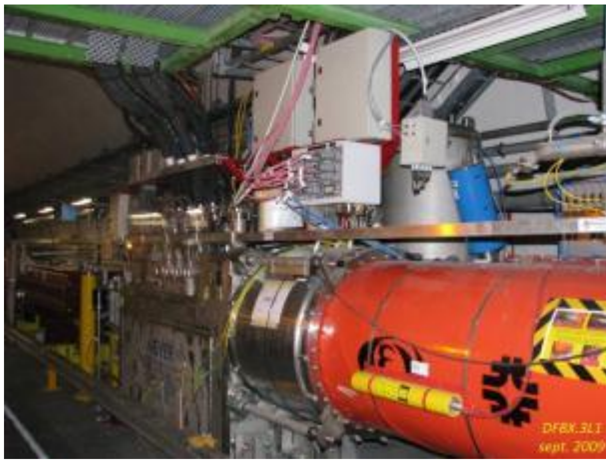
Dismantling/Upgrade of LHC Inner Triplets (new IT)

- Q1 in point 1 and 5 is encased in the detector outer shielding
- Installation and extraction cannot be done with standard procedures
- The initial installation of Q1 and Q2 was achieved through a 14 steps sequence with specific equipment and manpower intensive procedure
- Space is very tight, forcing manpower into close proximity with the triplets





Triplet Zone L1

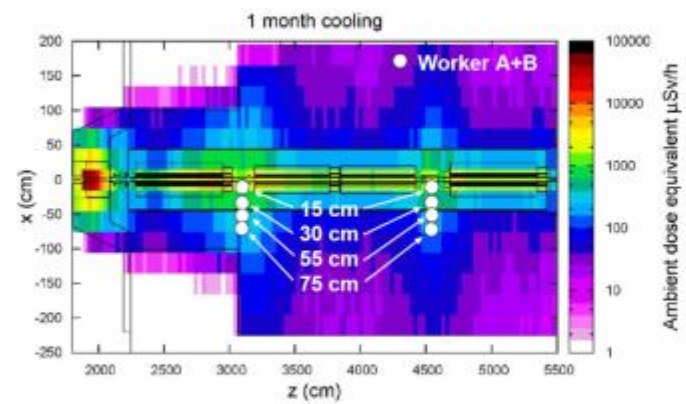
Disassembly/re-assembly in a radioactive environment

- The LHC-IR region is a tightly packed zone, with limited access, and will be activated by LS3
- Removal of magnets would result in relatively high dose, unless performed using remote handling tools
- New magnets will have to survive (10 times) harder radiation doses
- New triplets require larger aperture probably requiring larger cryostats, i.e. integration space even more tight than present
- New triplets and other associated SC equipment (D1, Q4,DFBX…) will have to be designed for easy installation/dismounting (**remote handling tooling**)

→ **Need for remote operation technologies:**

- Precision handling of heavy equipment
- Brazing/debrazing
- Cutting/welding robots
- vision systems

Fluka plots, and workers locations
(**manual dismantling** Q1-Q2, 1 month cool-down)



Associated exposure to radiation
of workers (with ALARA)

Distance to beam line cm	Working steps	Number of persons	Time h	Cooling time 1 month D mSv/person	Cooling time 4 month D mSv/person
75	Dismounting the tie - rods	2	1.0	0.12	0.05
	Dismounting the outside sleeve	2	3.0	0.35	0.16
	Removing the 2 MLI thermal shield blanket	2	0.2	0.02	0.01
	Dismounting the thermal shield	2	7.5	0.87	0.41
	Removing the 1 MLI radiative blanket	2	0.2	0.02	0.01
	Removing the supports: Spacer+ thermal shield	2	0.8	0.09	0.04
55	Cut to open FF	2	6.0	1.69	0.76
	Cut to open XBt	2	6.0	1.69	0.76
30	Cut to open XB	2	12.0	5.07	2.27
	Cut to open CY	2	6.0	2.53	1.14
	Cut to open M1, M2, M4	2	18.0	7.60	3.41
	De - braze bus bars (13 kA) M4	2	6.0	2.53	1.14
	Disconnect spools connections M4	2	3.0	1.27	0.57
	Remove QH, VT, thermometers, heaters, … from M2	2	6.0	2.53	1.14
	Cut to open V	2	6.0	2.53	1.14
	Remove 2 flexible CC'	2	4.0	1.69	0.76
15	Cut to open LD1	2	6.0	4.45	1.95
	Cut to open EE	2	6.0	4.45	1.95
		Individual dose		39	18
		Collective dose		79	35

- 1 month cool-down → 38 mSv/person
- 4 months cool down → 18 mSv/person

Note: CERN limit for an occupationally exposed worker is 6 mSv/year

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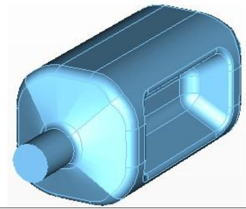
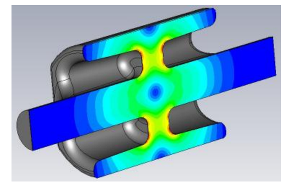
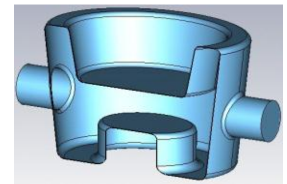
Crab Cavity candidates



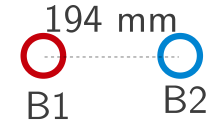




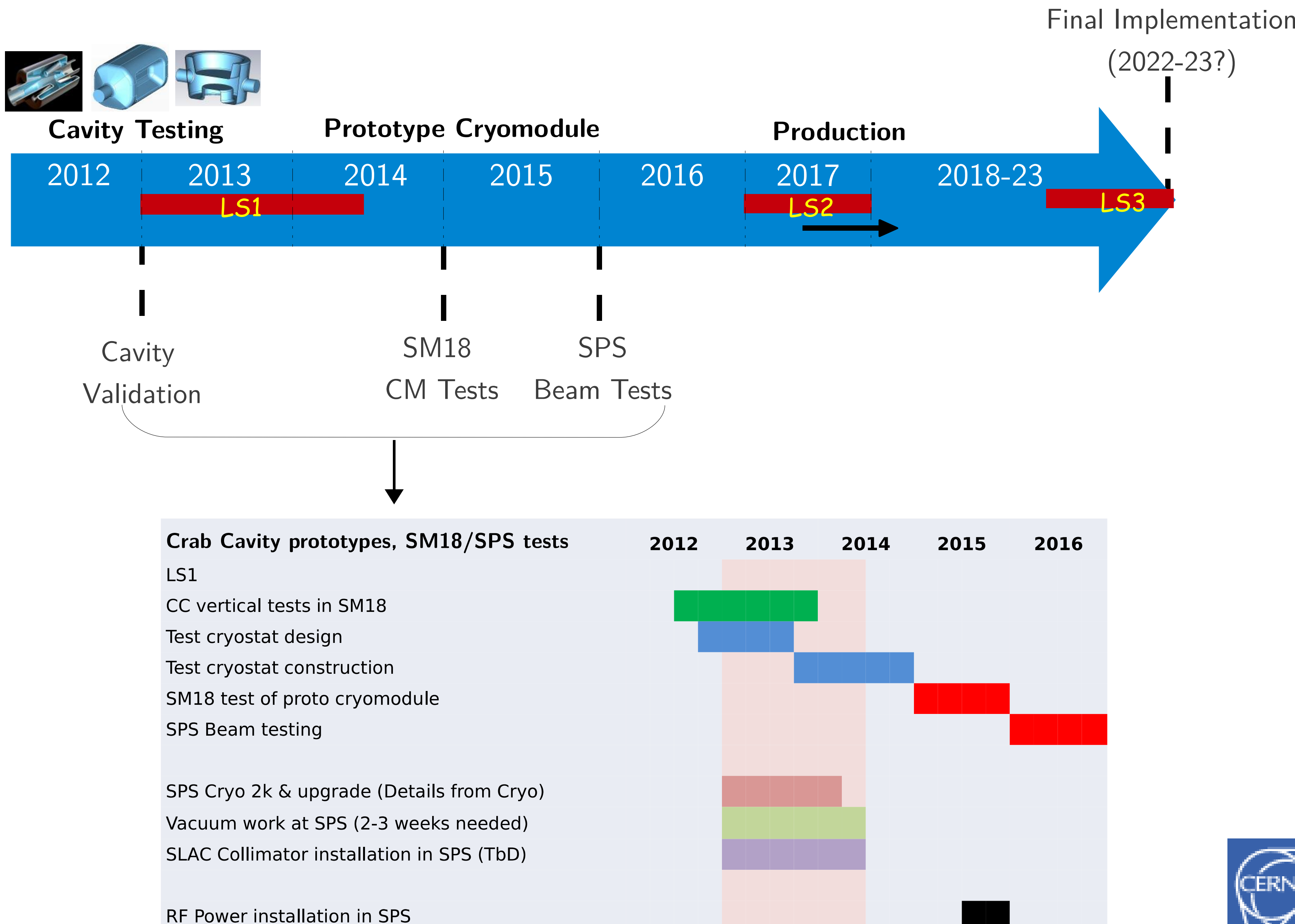
Geometrical

RF

	Double Ridge (ODU-SLAC)	4-Rod (UK)	¼ Wave (BNL)	
Cavity Radius [mm]	**147.5**	**143/118**	**142.5/122**	
Cavity length [mm]	597	500	330-405	
Beam Pipe [mm]	84	84	84	
Peak E-Field [MV/m]	33	32	43	< 50 MV/m
Peak B-Field [mT]	56	60.5	61	< 80 mT
R_T/Q [Ω]	287	915	345	
Nearest Mode [MHz]	584	371-378	657	

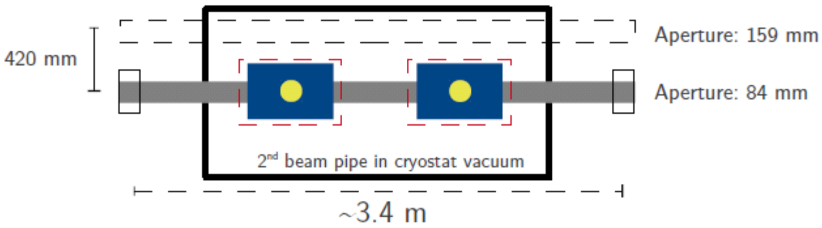


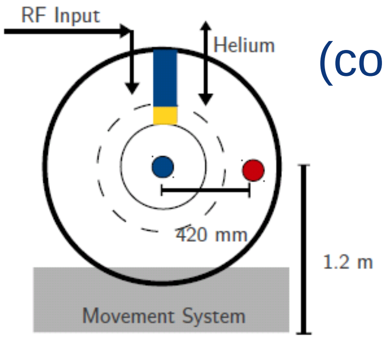
Timeline



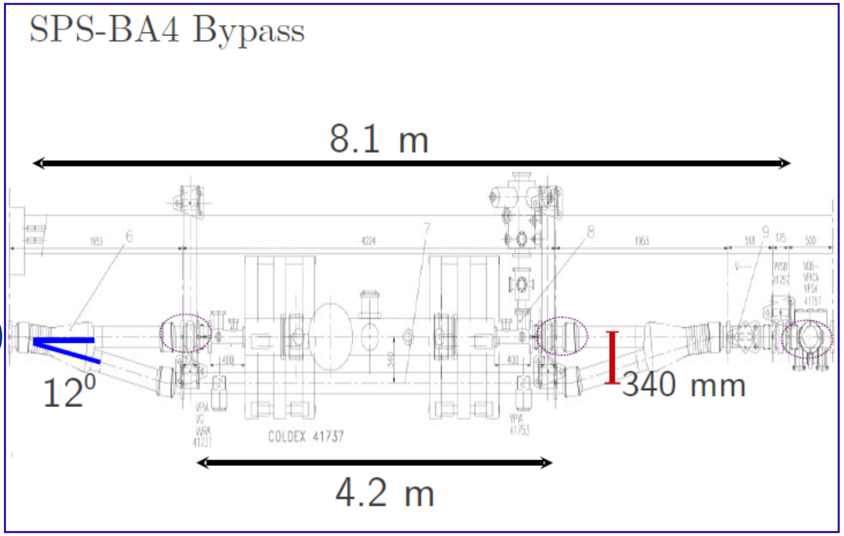
(courtesy A.Ratti, LBNL)

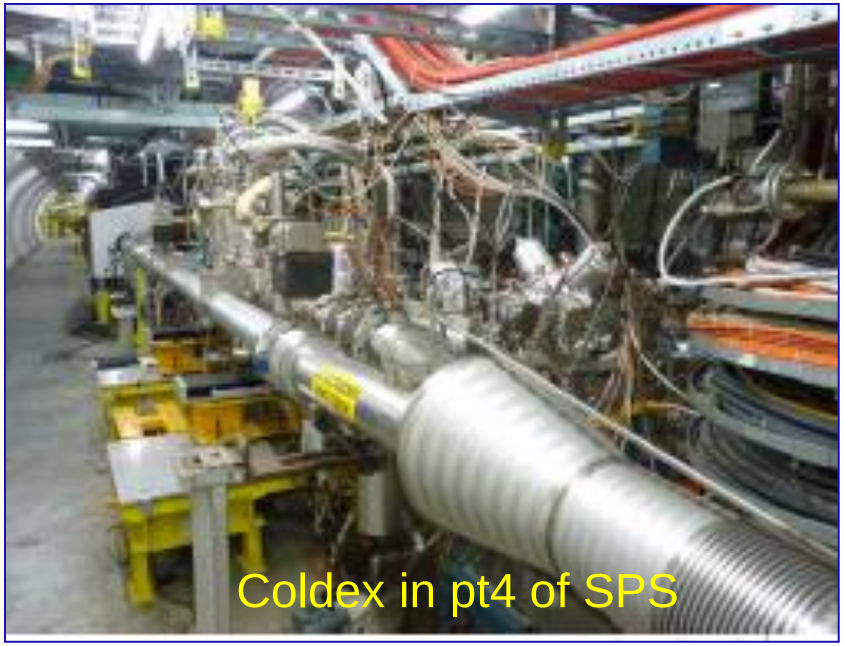
Test cryomodule for crab testing in the SPS





(courtesy: R.Calaga)




Coldex in pt4 of SPS

Needs:

- Test of 2 cavities with beam in SPS
- Possibility of testing in Pt.4 of LHC (i.e. beam tube spacing 420mm)
- Possibility of testing 3 candidate cavities (i.e. adaptable interfaces in CM)

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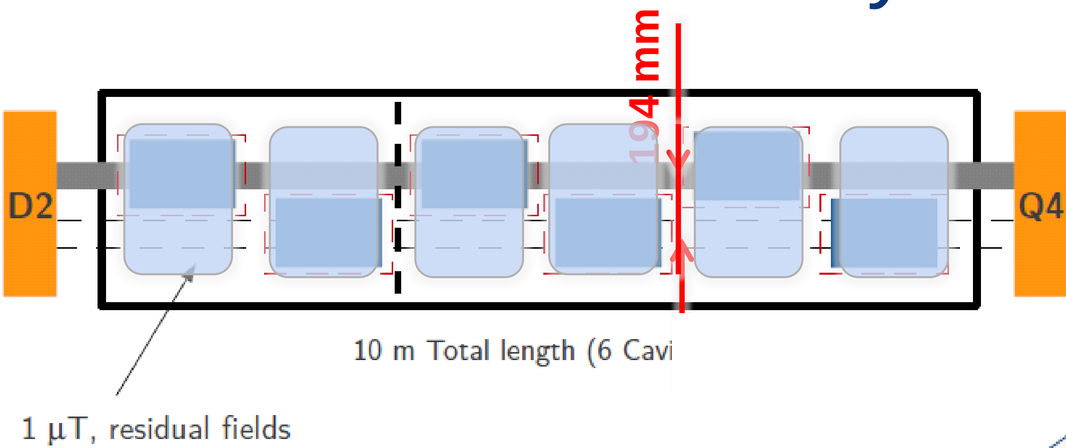
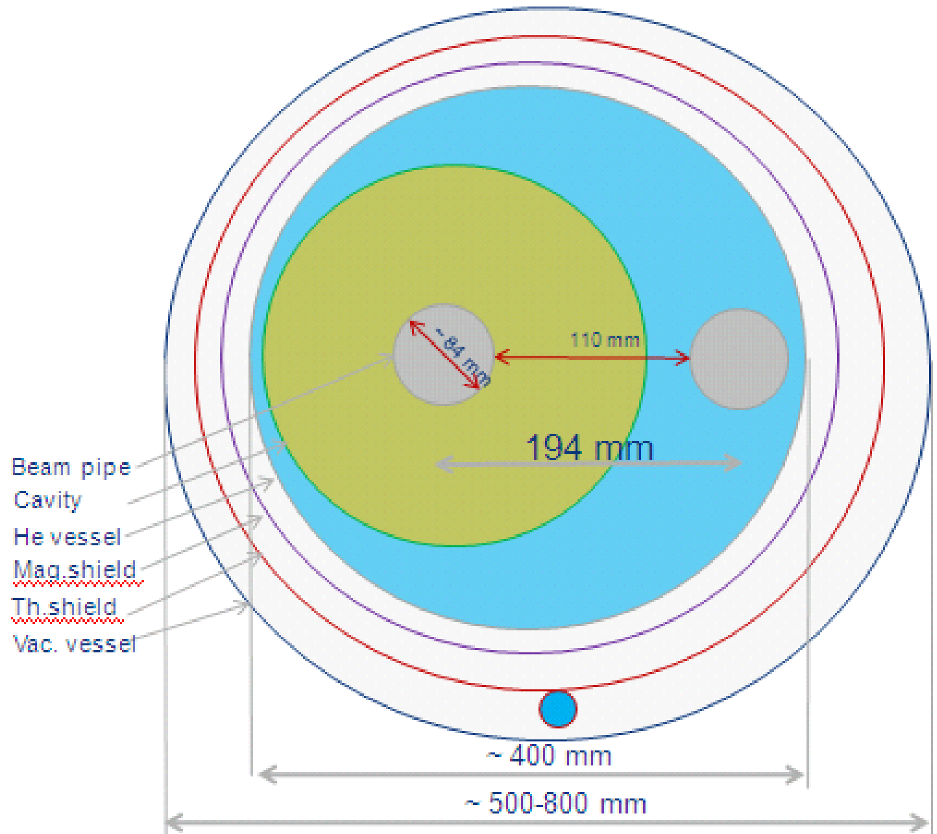
LHC Crab Cavities Cryomodule in Pts 1-5



Possible layout on either side of Pts.1 and 5

Possible cross section (outer envelopes):

- 194 mm spacing → 2nd beam tube cold in same He vessel
- Need for magnetic shielding



CERN WORKSHOP

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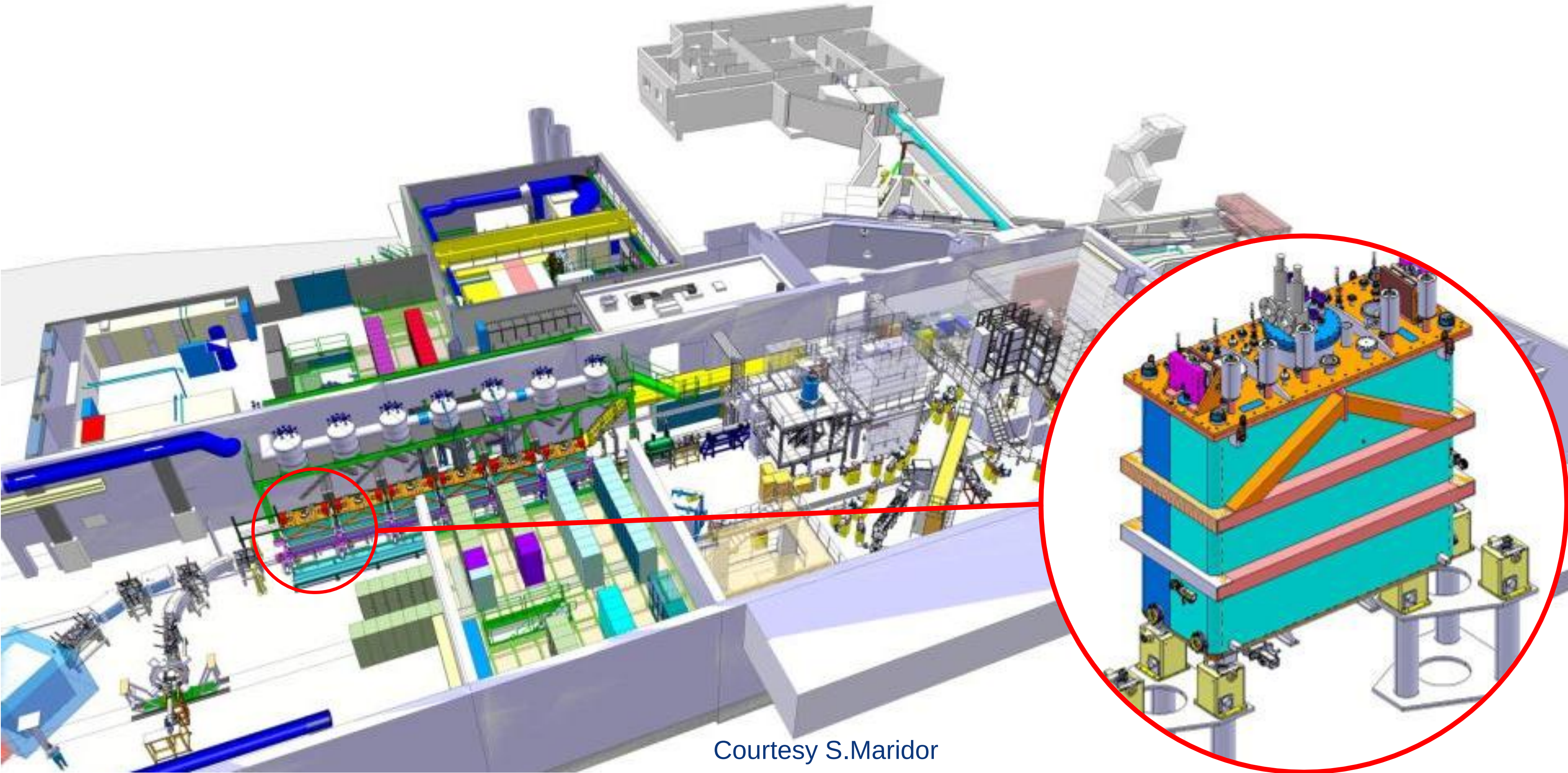
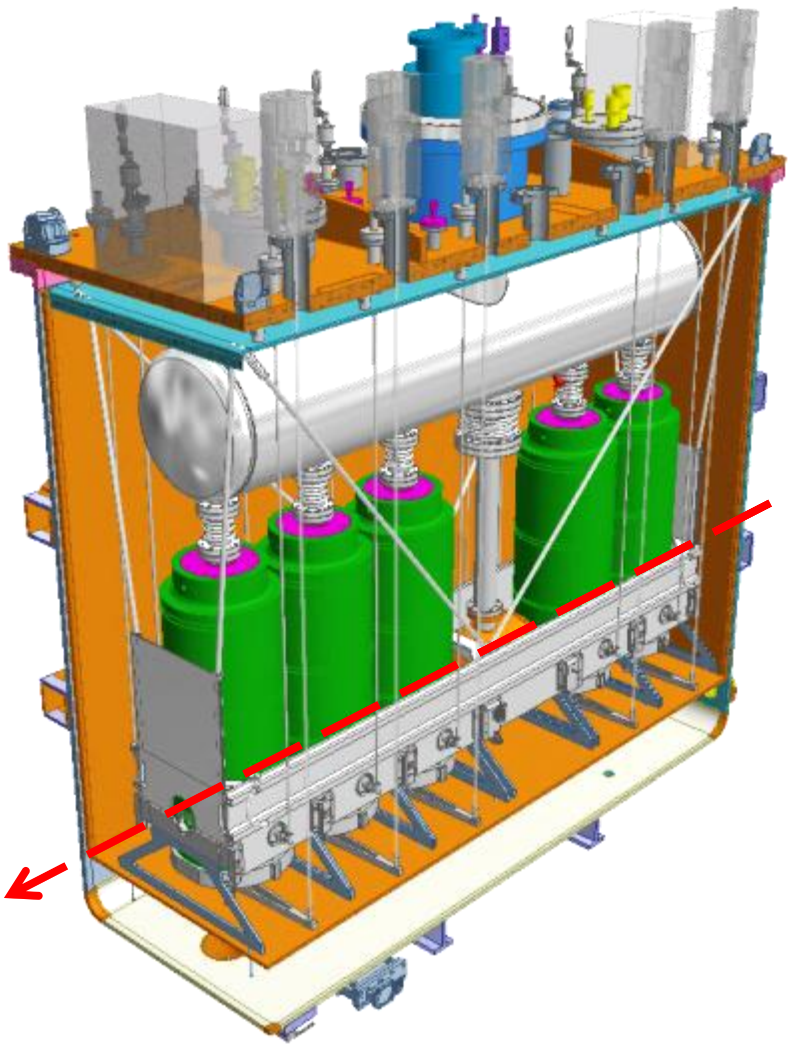
HIE-Isolde Cryomodule

- HIE-Isolde upgrade
- LINAC : 6 highB + 2 lowB cryomodules in series



Courtesy S.Maridor

HIE-Isolde Cryomodule



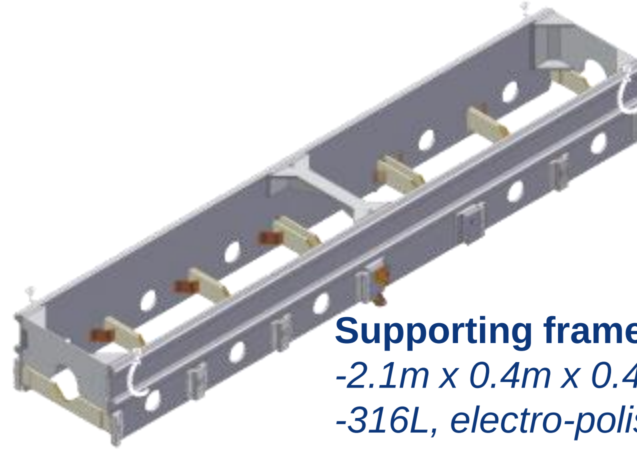
- 5 QWR RF cavities
- 1 solenoid – 200A
- 2 cryogenics circuits
    - 50-75K Gas Helium
    - 4.5K Liquid Helium
- Common vacuum
- Clean room assembly

Cryomodule Specifications

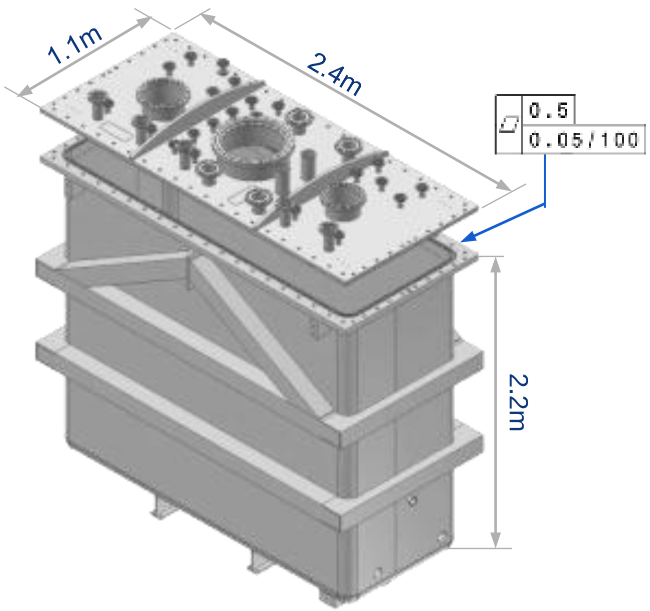
Vacuum level	1.10^{-8} *mbar*
Cleanliness level	*Clean room class100 (ISO5)*
Cavities and solenoid temperature	*4.5 K*
Cavities alignment specification	*Ø 0.6 mm coaxiality*
Solenoid alignment specification	*Ø 0.3 mm coaxiality*
Maintenance frequency	*1 per year*
Duration of operation	*20 years*

HIE-Isolde CM main components

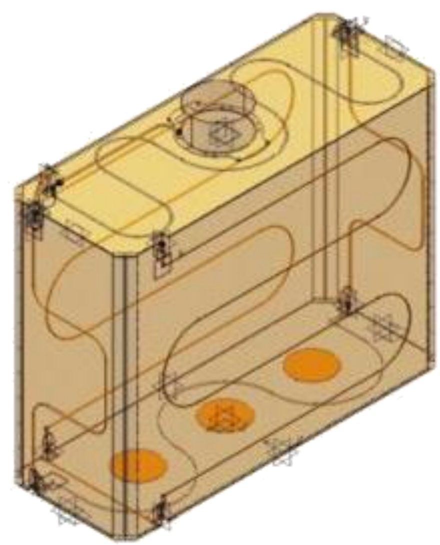
P-T table for main components	Pressure [bara]	Temperature [K]
Vacuum Vessel	1.10-11	300
Thermal Shield circuits	13	50-75
Reservoir	4.5	4.5
Frame circuits	4.5	4.5



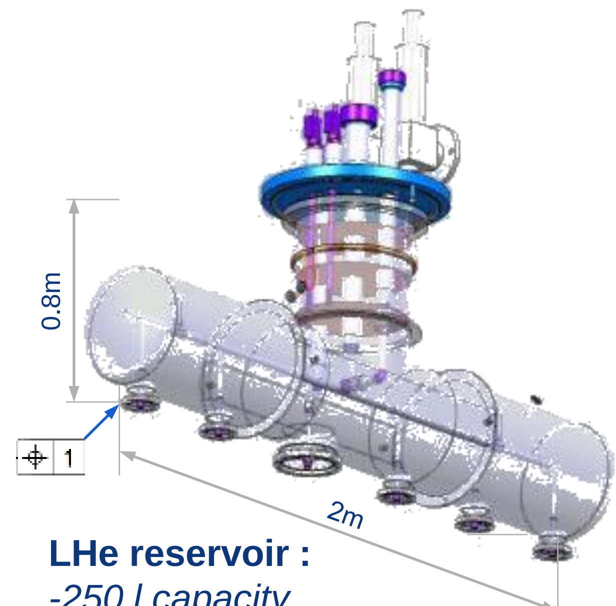
Supporting frame :
-2.1m x 0.4m x 0.4m
-316L, electro-polished
-130 kg welded assembly
-Piping : LHe 4.5K, 4.5 bara



Vacuum vessel (Lid) :
-15 mm (40mm) thick plates
-316L polished
-4.5 T welded assembly
-Double sealed (Viton)
-Interface planarity : 0.5 0.05/100



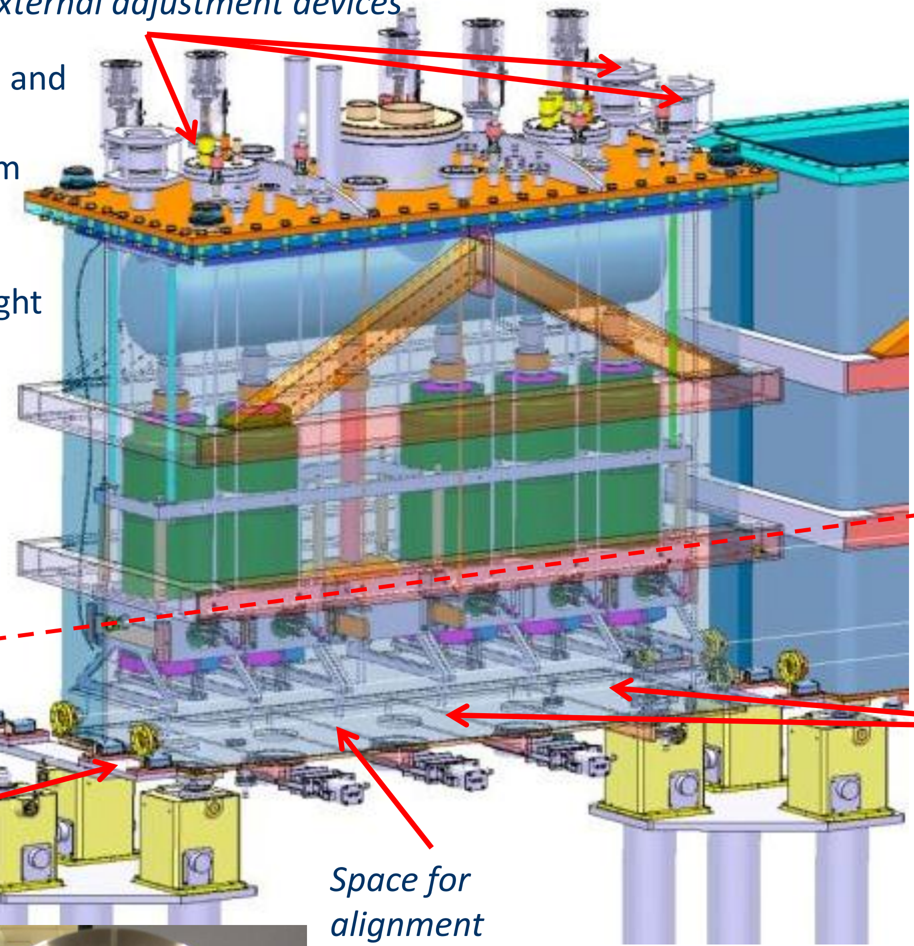
Thermal Shield :
-2.2m x 1.8m x 0.9m
-300 kg bolted assembly
-2 mm thick Cu Ni-plated
-Piping : GHe 70K, 13 bara
-No porosities after brazing

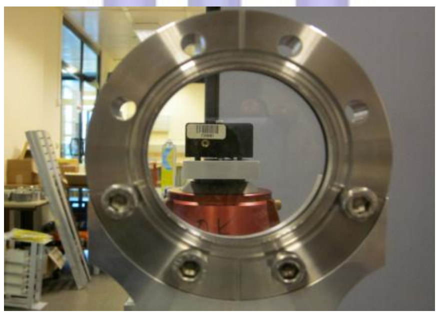


LHe reservoir :
-250 l capacity
-Ø 0.35m, t=4mm
-316L electro-polished
-Lower flanges location within 1 mm

Alignment of cavities and solenoid within the cryomodule

- Alignment and monitoring of the Cavities and Solenoids in the Cryomodules
- Alignment w.r.to a common nominal beam line (NBL) along the Linac
- Permanent system
- Precision demanded along radial and height axis at 1 sigma level :
  - 300 microns for the Cavities
  - 150 microns for the Solenoids



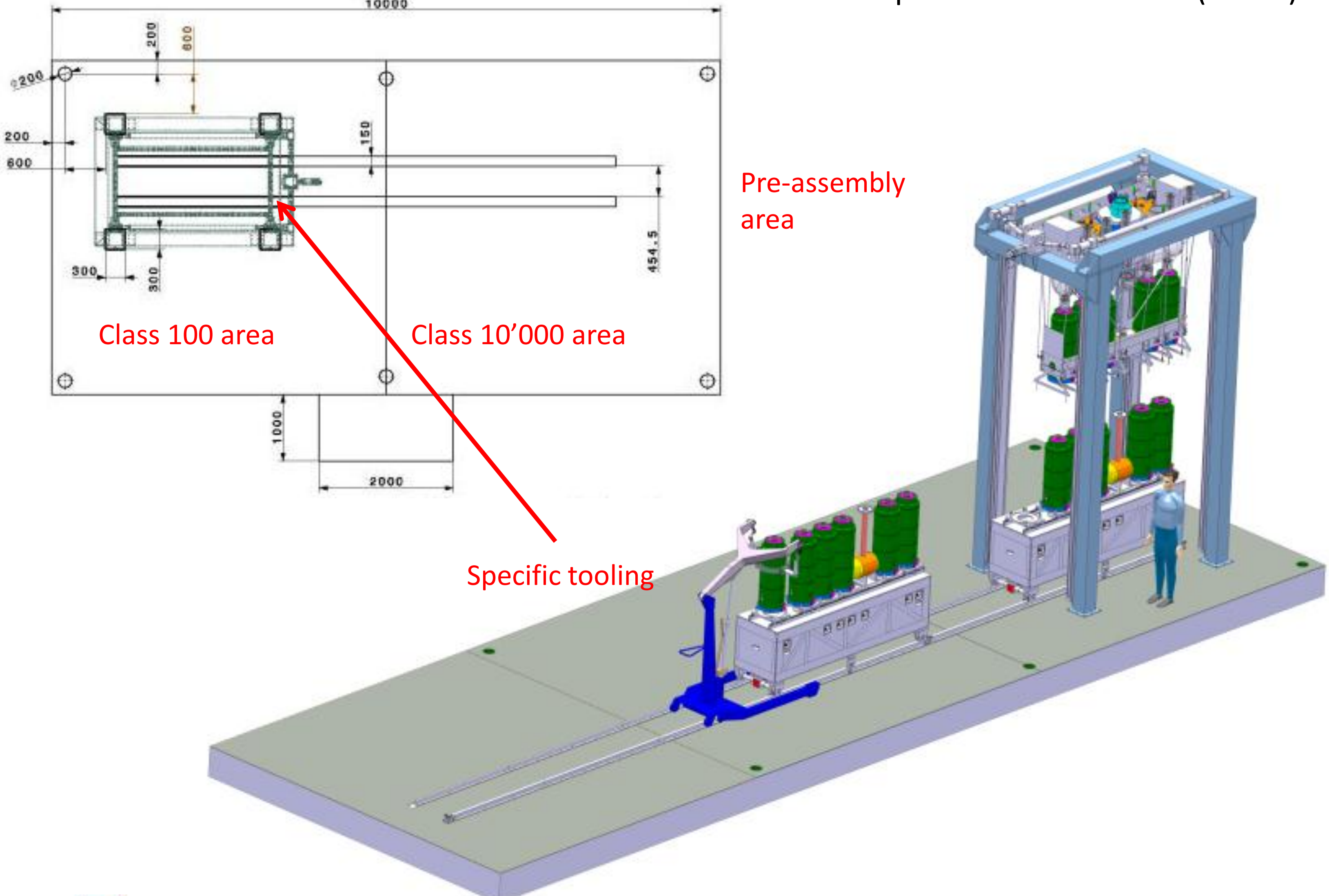


Optical quality viewports

BCAM

Clean-room (SM18)

Cleanroom procurement started (BE-RF)



Specific tooling: procurement to start, January 2013

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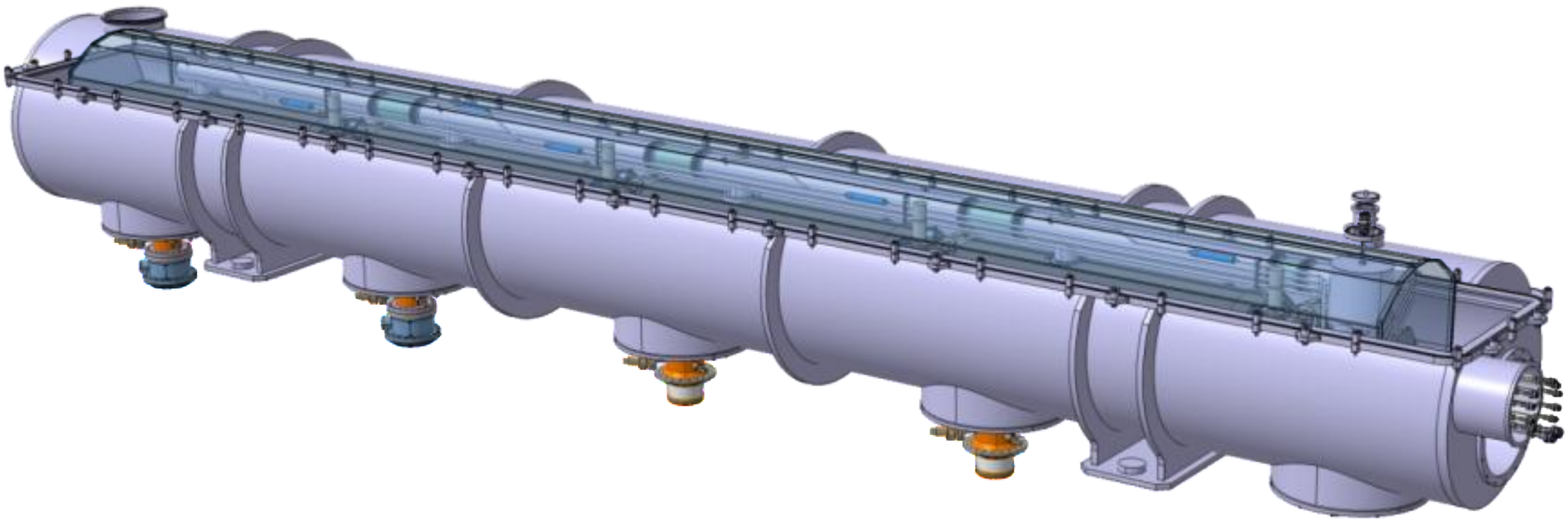
SPL cryomodule development effort

An R&D study:

- Development of SCRF for high intensity, multi-megawatt proton sources
- 704 MHz bulk Nb cavities operated @ 2 K
- Possible applications range from LHC injectors upgrades to neutrino factories and RIB experiments (Eurisol)
- Interest for spallation sources (ESS, see Ch.Darve's talk)
- Growing interest for future accelerators: LHeC, LEP3…

Assembly breakdown

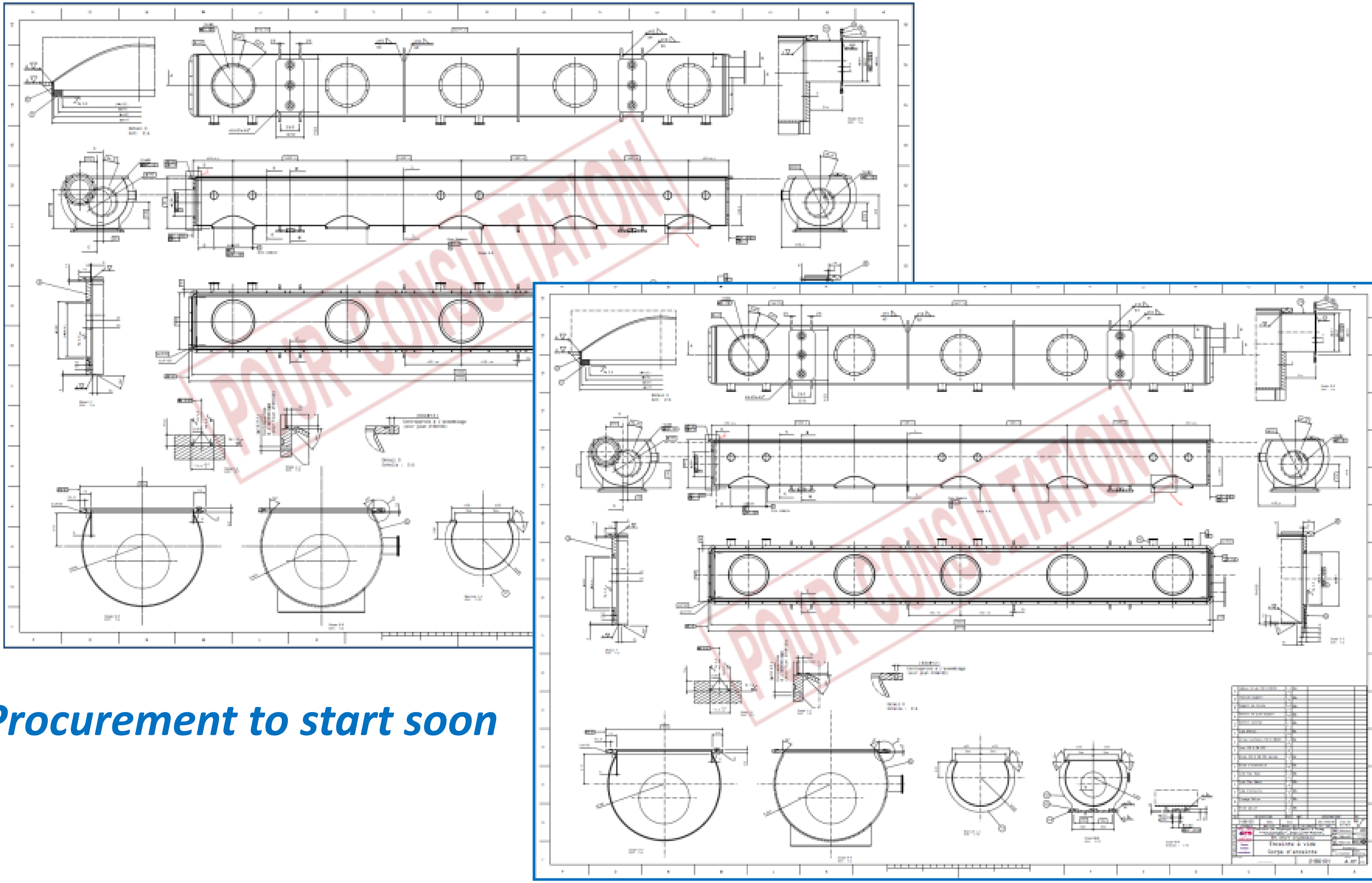
8- Closing the vacuum vessel



Degaussing of vessel may be needed

Design by CNRS-IPNO (S.Rousselot)

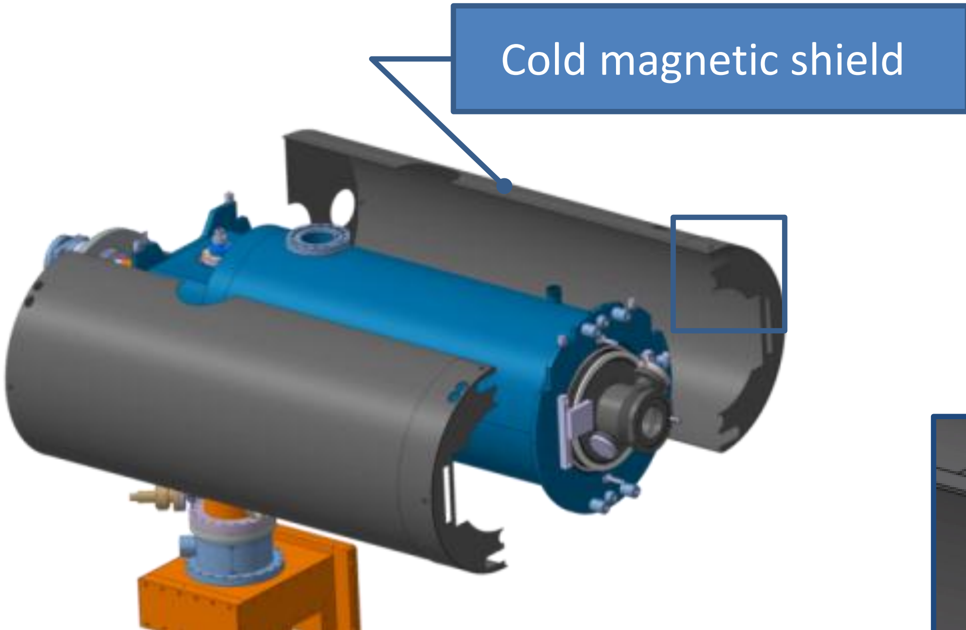
A 2-parts vacuum vessel, with tight machining for leak-tightness



Procurement to start soon

Procurement is managed through CNRS-IPNO, in the frame of the French in-kind contribution to CERN

Cold magnetic shield (cryoperm® or similar)



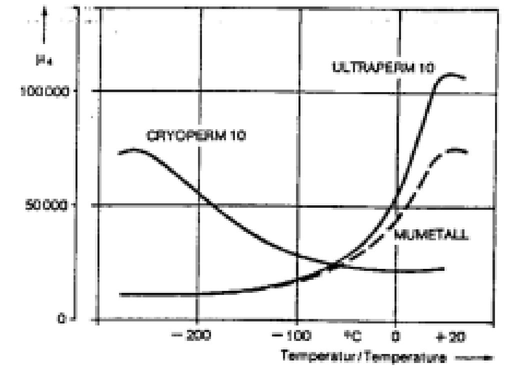
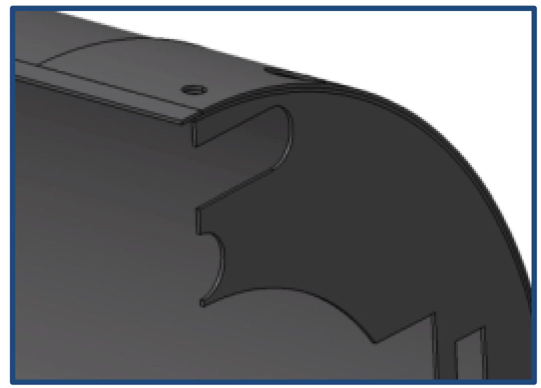
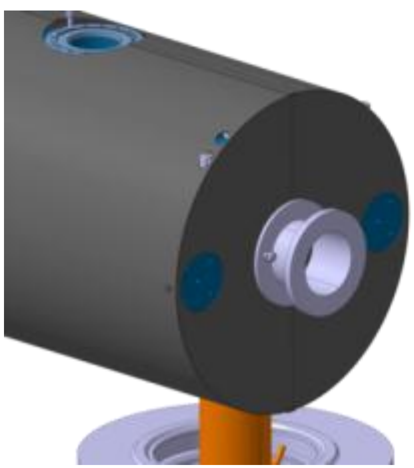
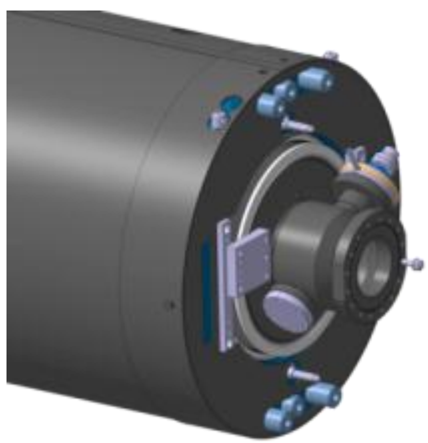


Figure 2 Permeability of some magnetic materials as a function of temperature (from VAC catalogue).





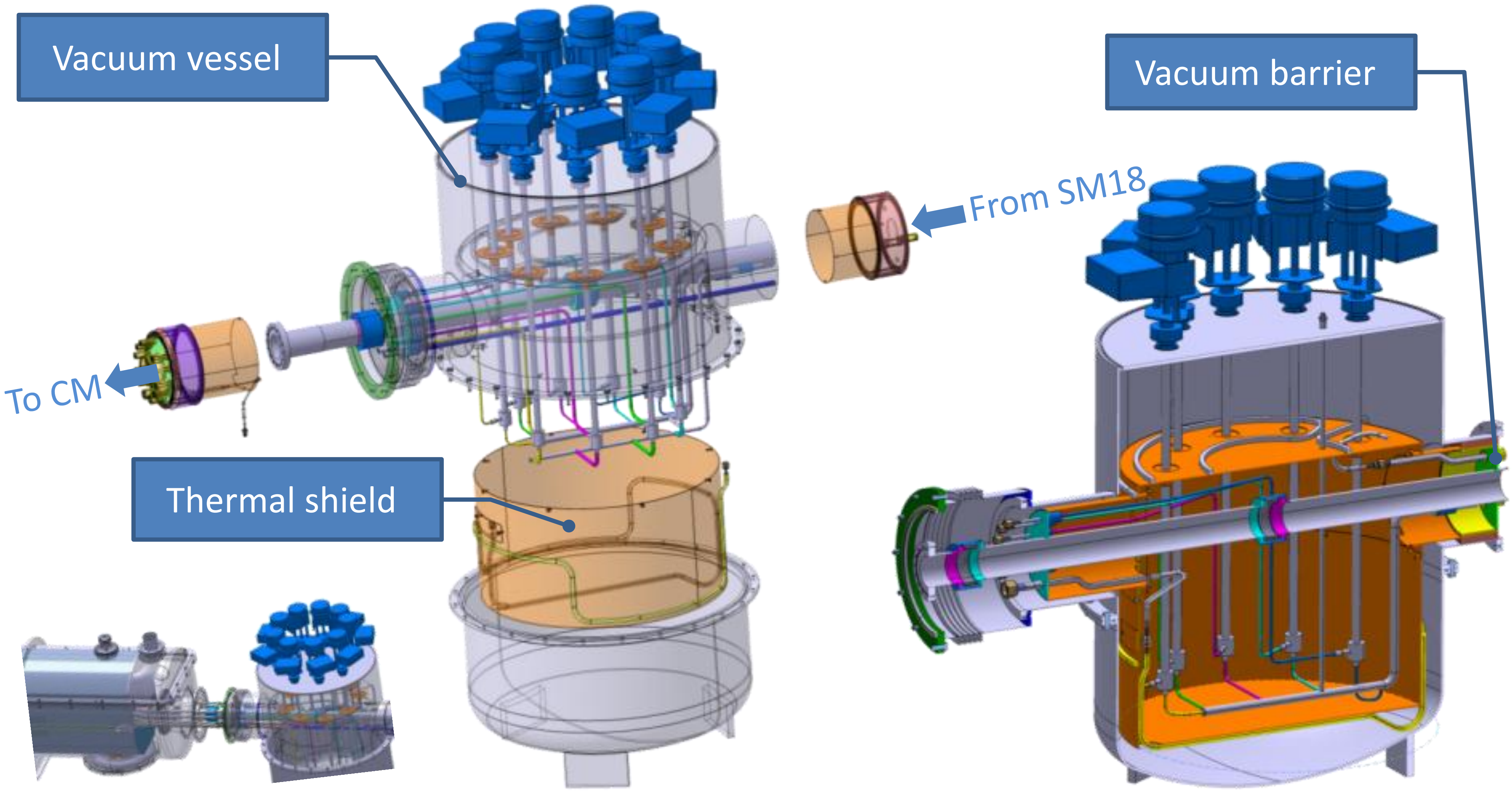


Coupler side

Tuner side

Design by CNRS-IPNO (S.Rousselot)

Valve box



Courtesy CNRS-IPNO (S.Rousselot, P.Duthil)

Potential competencies of interest from industry

Manufacturing capabilities and materials:

- Precise machining on sheet metal work constructions (sealing flanges)
- Stress relieving techniques for dimensional stability
- Stainless steels (304 & 316 series), construction steels, but also more “exotic” materials (cryoperm ®)
- Radiation hard materials (plastics, structural composites, MLI materials…)
- Hi quality welding techniques: TIG, MIG, EB welding, laser welding…
- Brazing techniques: vacuum brazing
- Remote operation tools
- …

But also…

Engineering capabilities:

- Design capabilities from conceptual or functional specifications
- Engineering capabilities on mechanical design, thermo-mechanics, cryogenics, supporting the proposed design solutions

Thank you for your attention