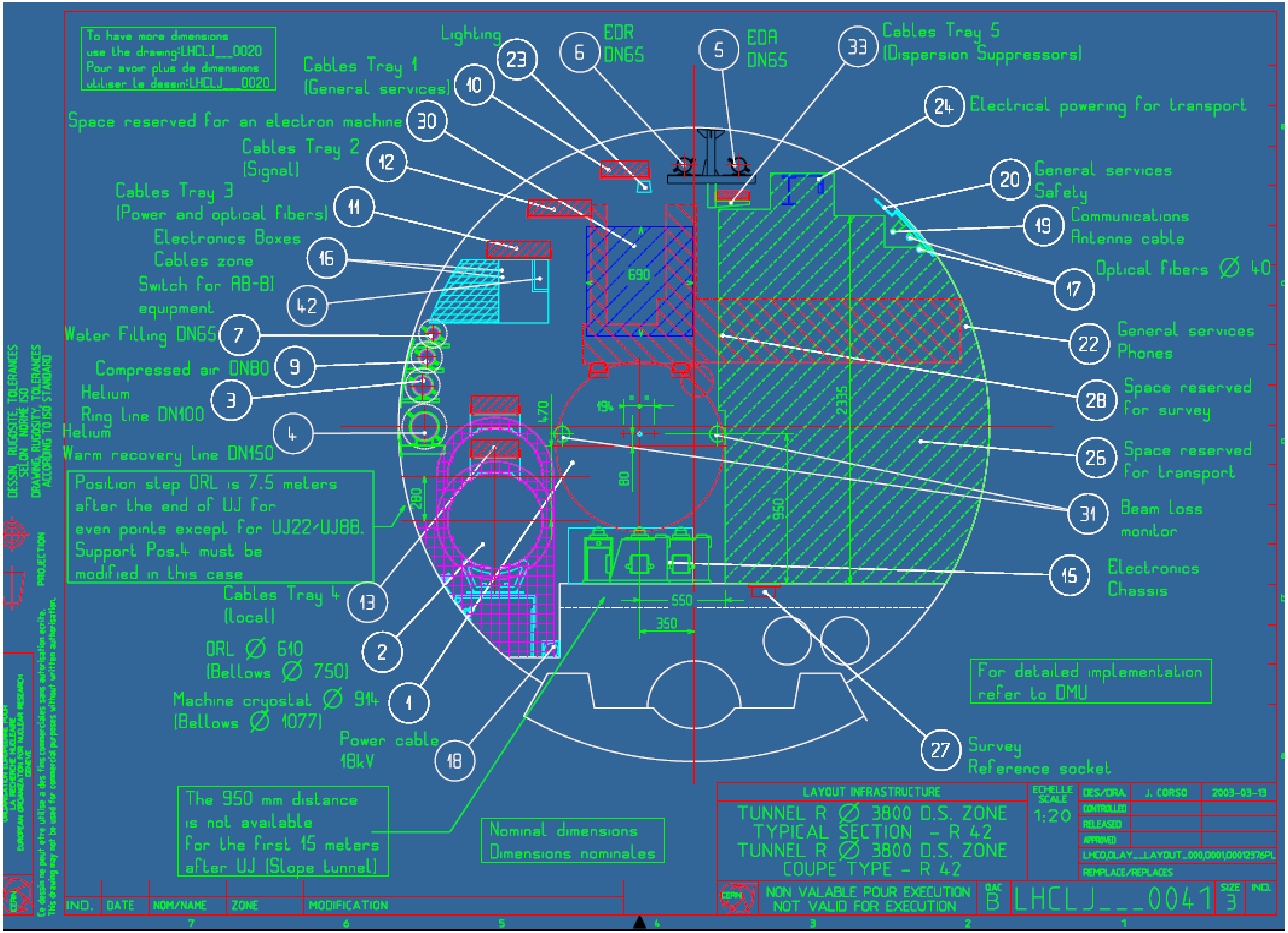
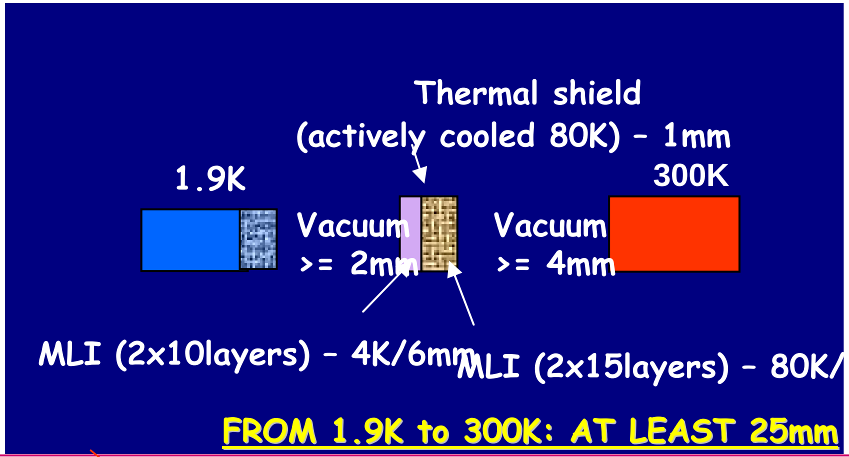
FP420 Integration Environment



Connection Cryostat



Thermal shield (actively cooled 80K) – 1mm

1.9K

300K

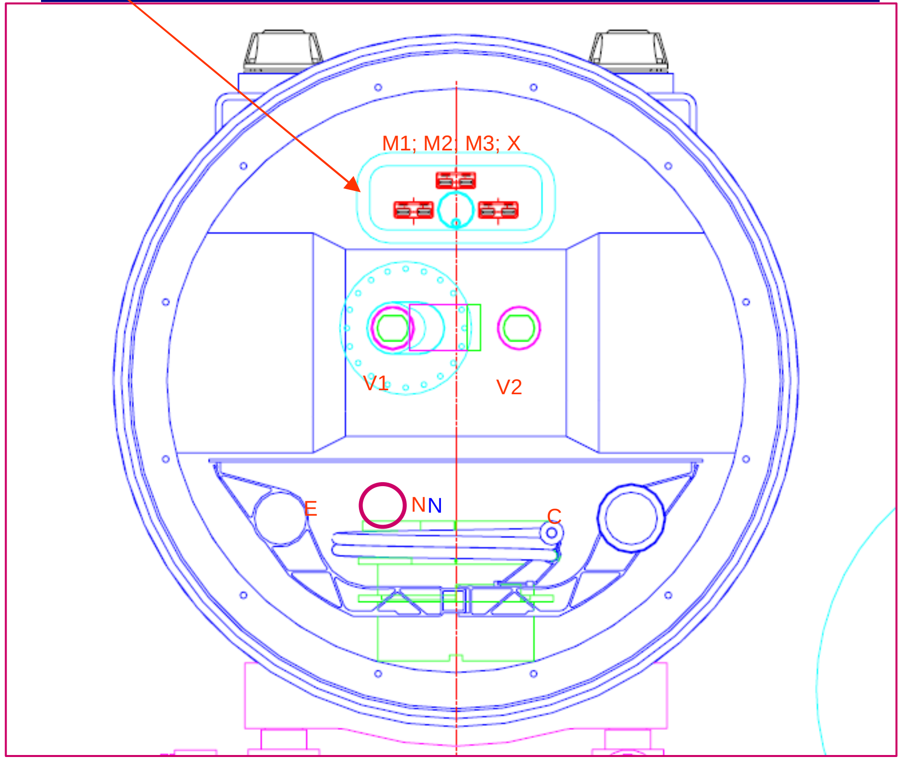
Vacuum >= 2mm

Vacuum >= 4mm

MLI (2x10layers) – 4K/6mm

MLI (2x15layers) – 80K/

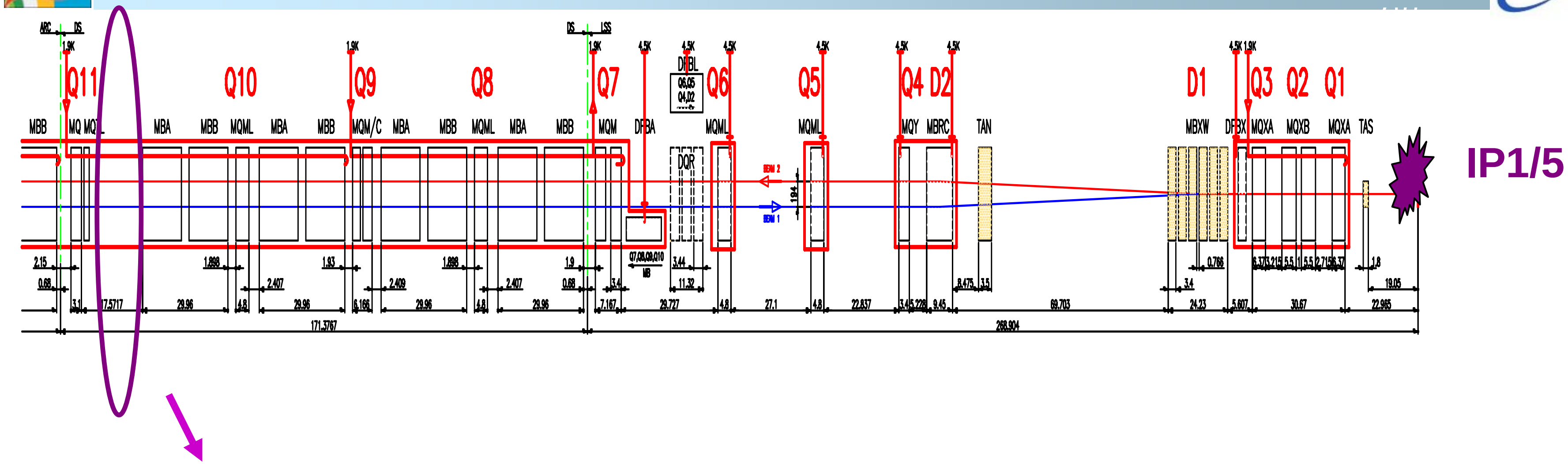
FROM 1.9K to 300K: AT LEAST 25mm

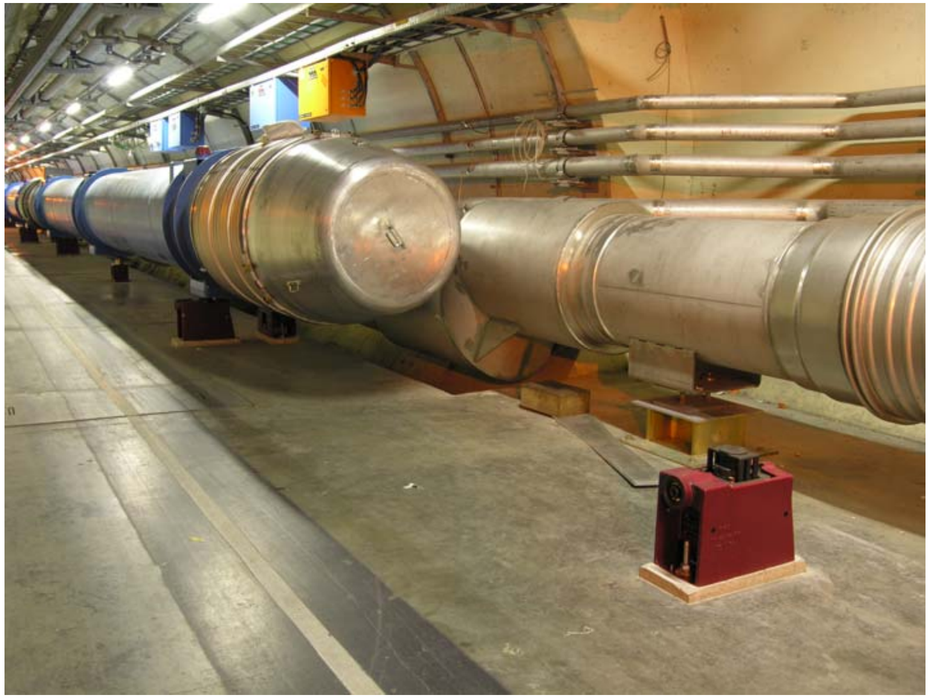


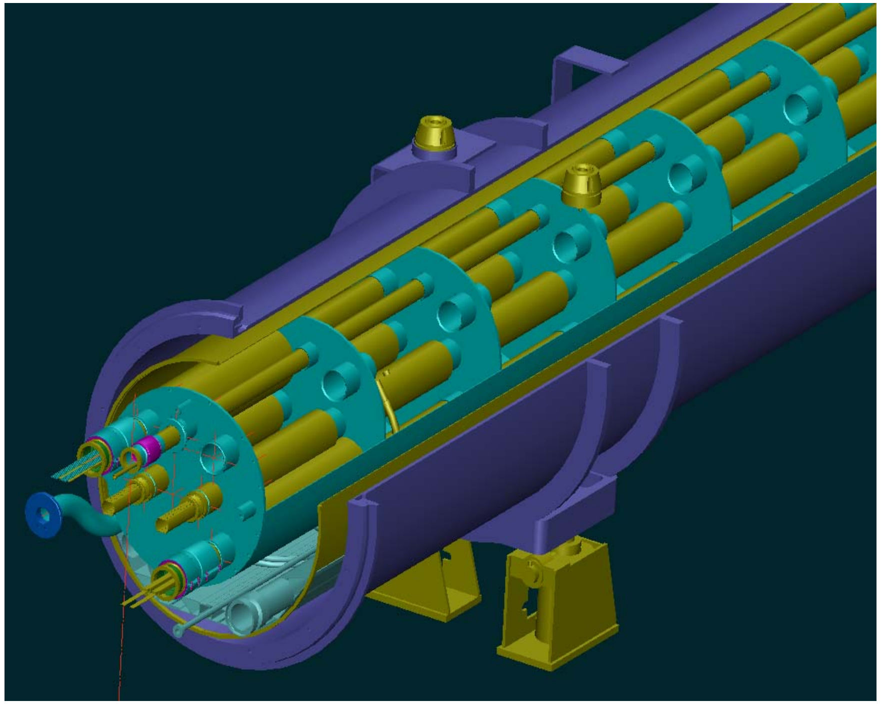
Connection Cryostat. Lines to be kept for continuity and insulation requirements

Line	T(K)	$Ø_i – Ø_e$(mm)
M1,M2,M3 Bus-bars	1.9	80-84
N Auxiliary bus-bars	1.9	50-53
X Heat exchanger	1.8	54-58
E Thermal shield	50-65	79-86
C' Supports posts and beam screens	4.6	15-17.2
V1,V2 He jackets	1.9	50-53 66-70

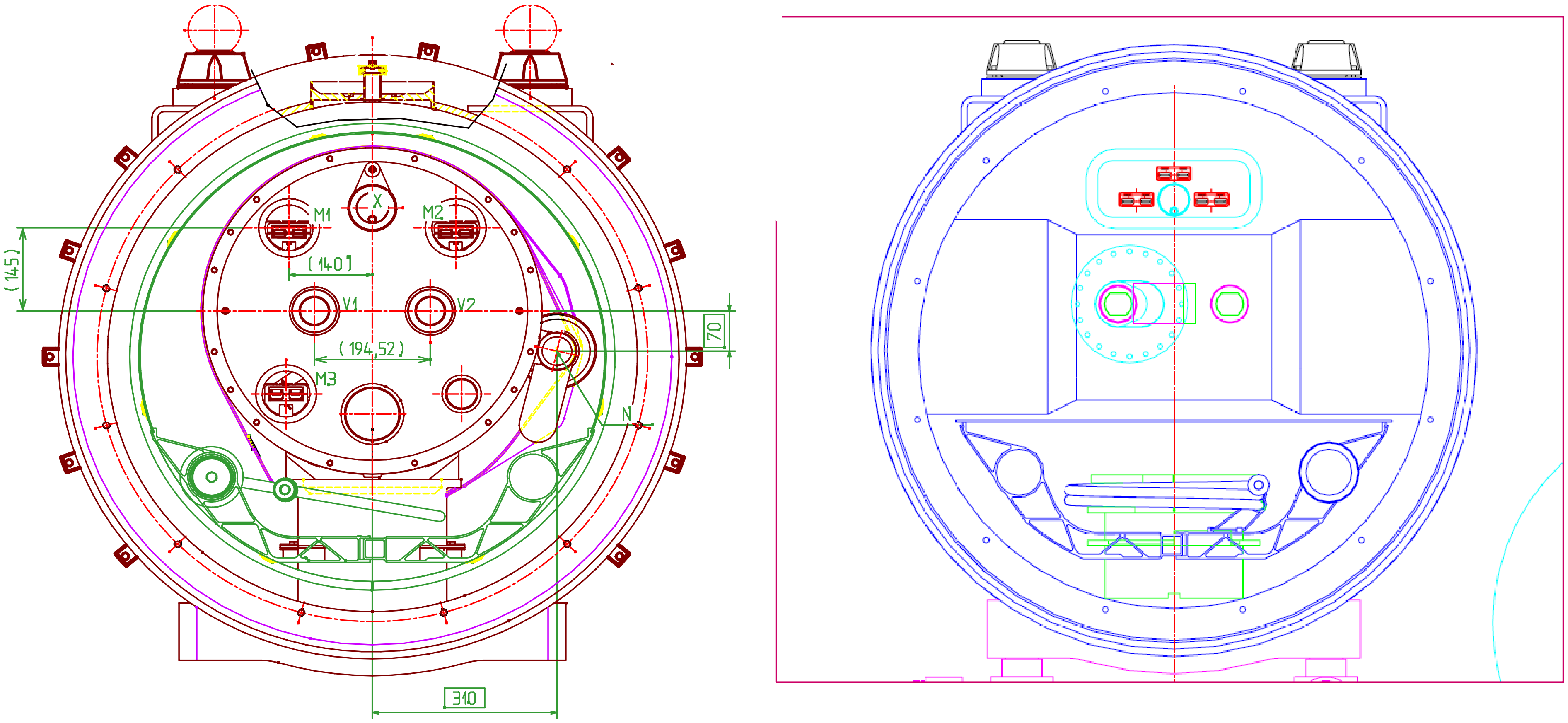
Layout on LHC

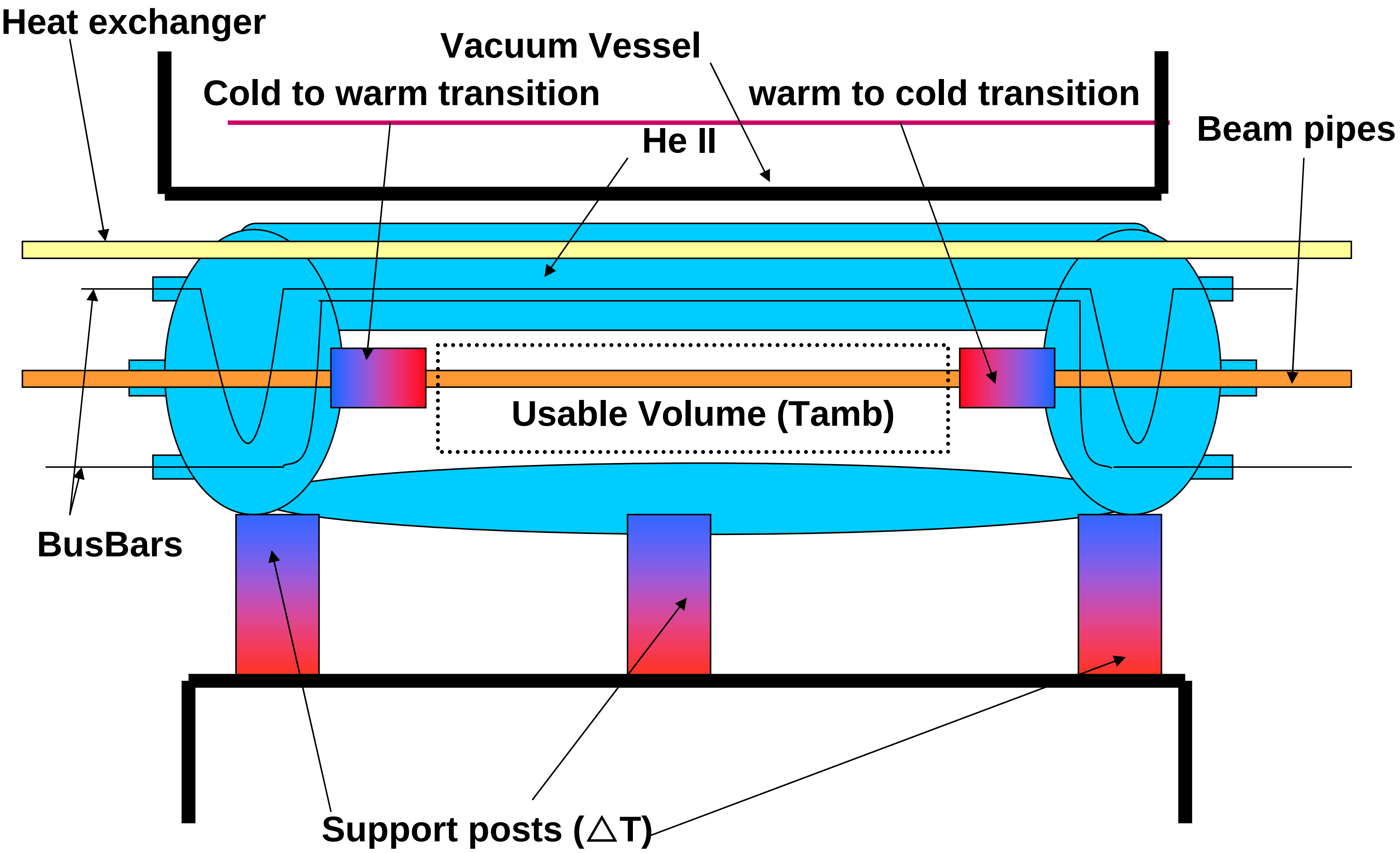






Integration of FP420. Proposal 1

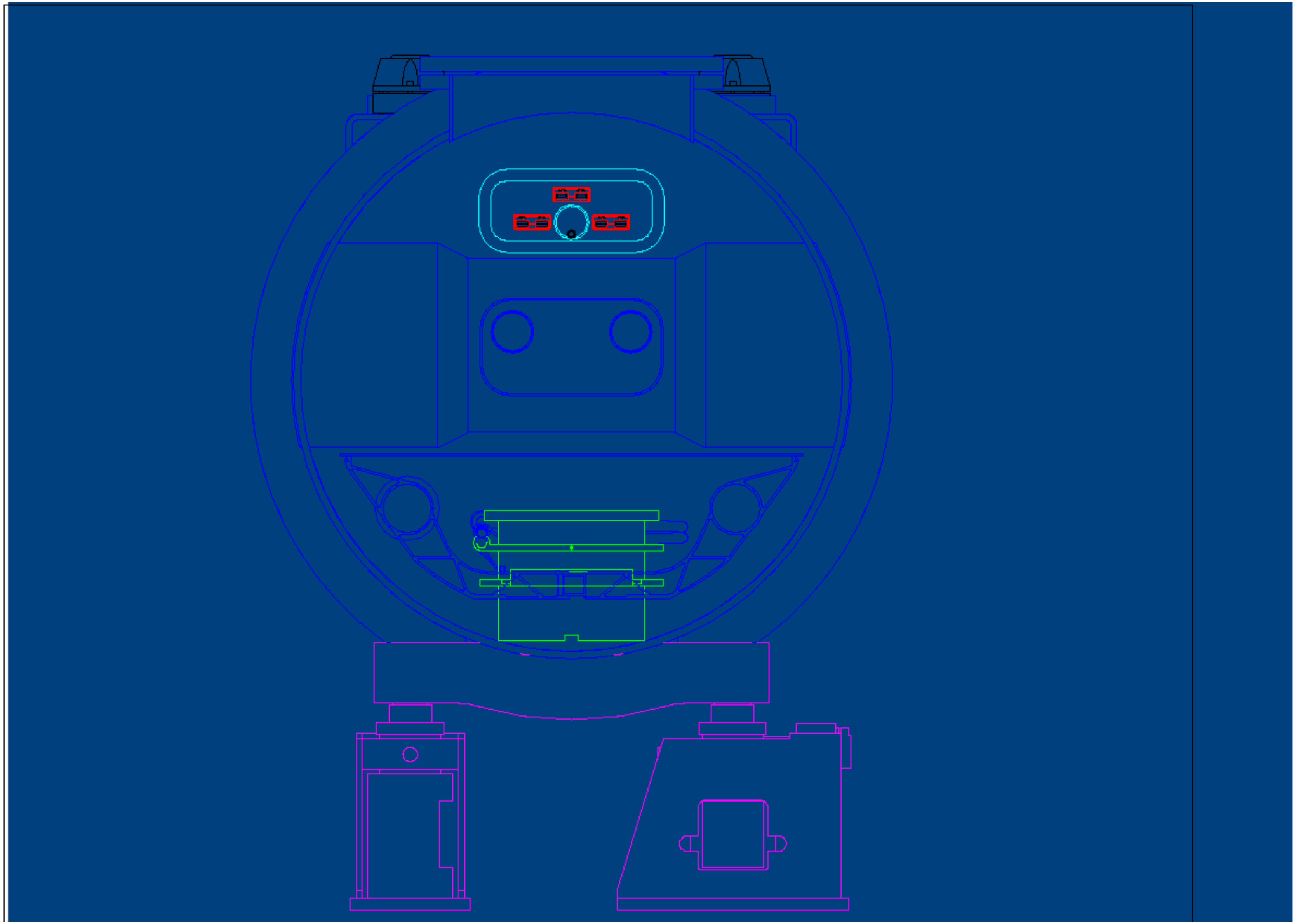




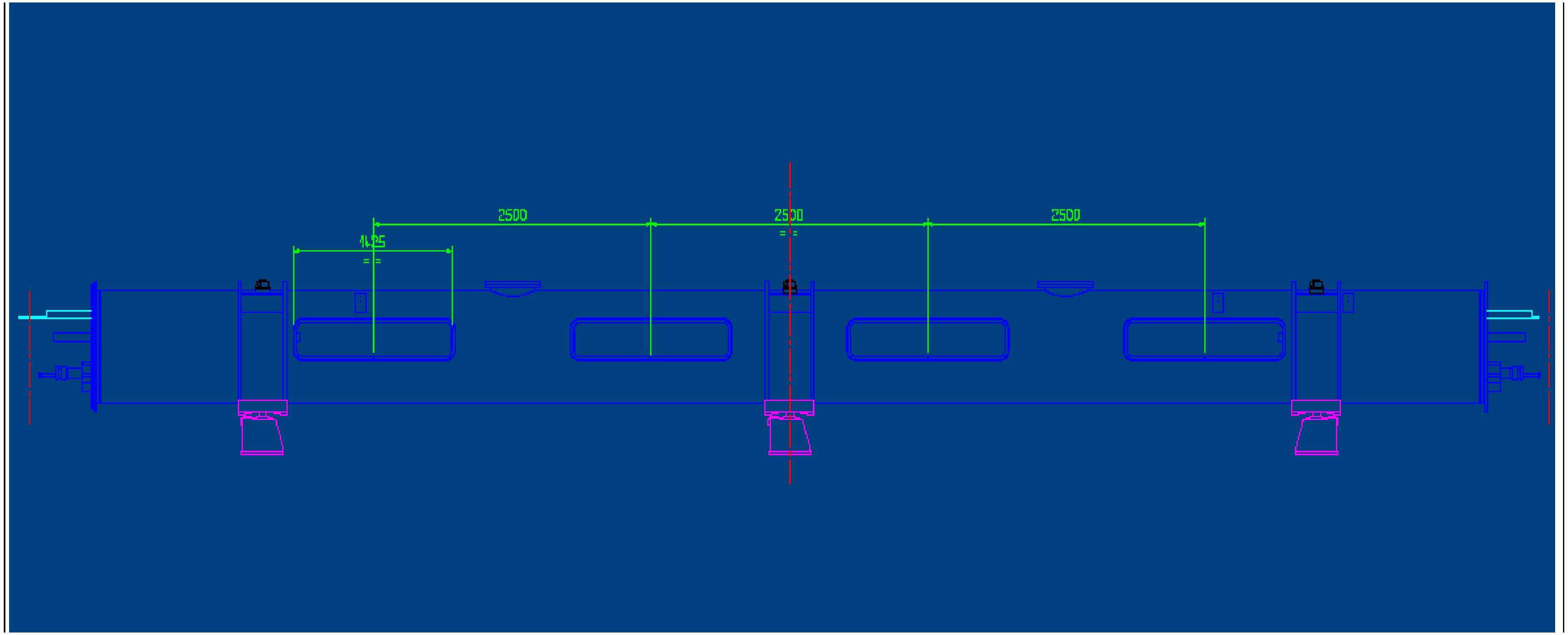
S. Marque / D. Dattola

FP420 - 09/11/2005

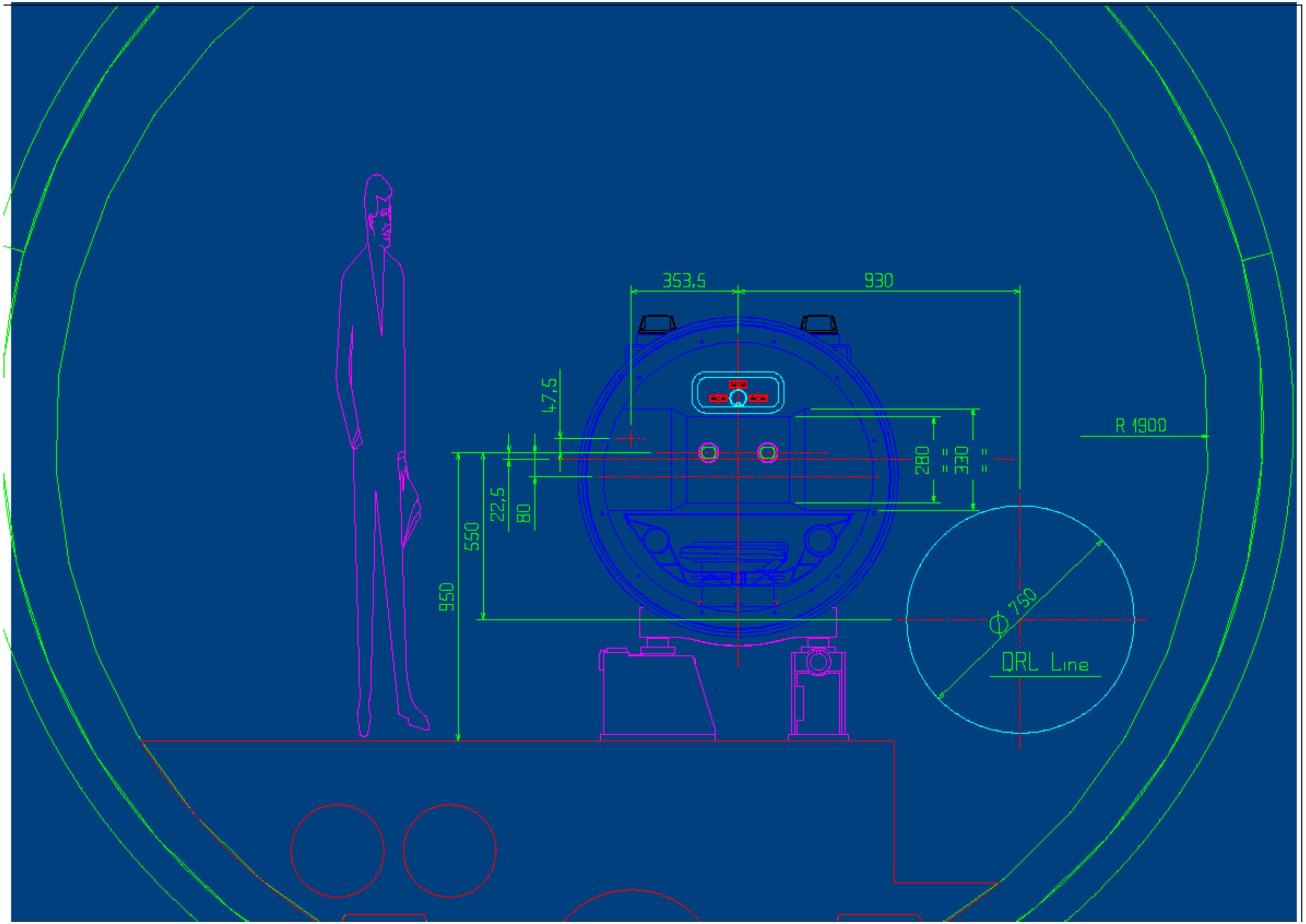
Slot on vacuum vessel Xsection



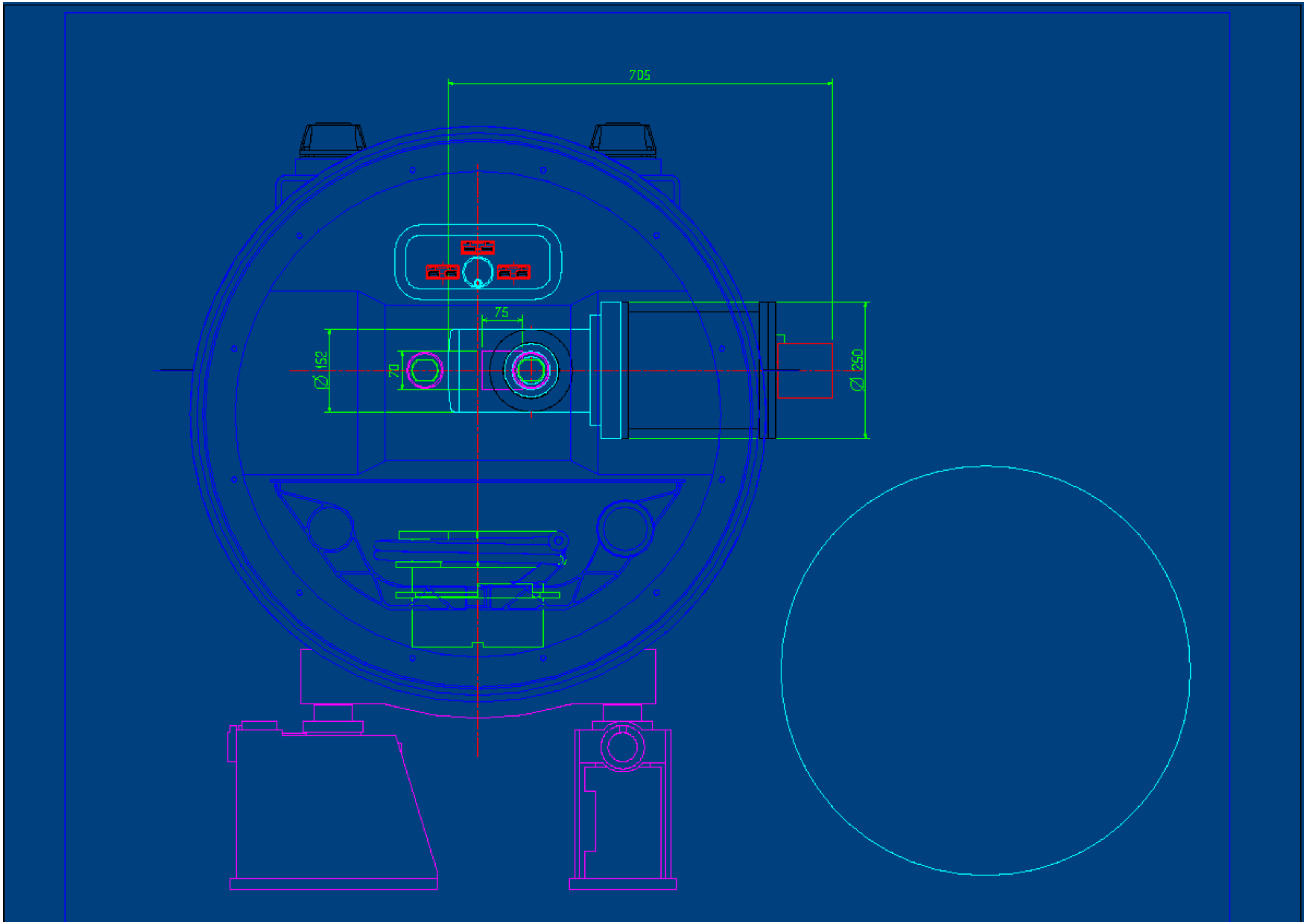
Slots on vacuum vessel



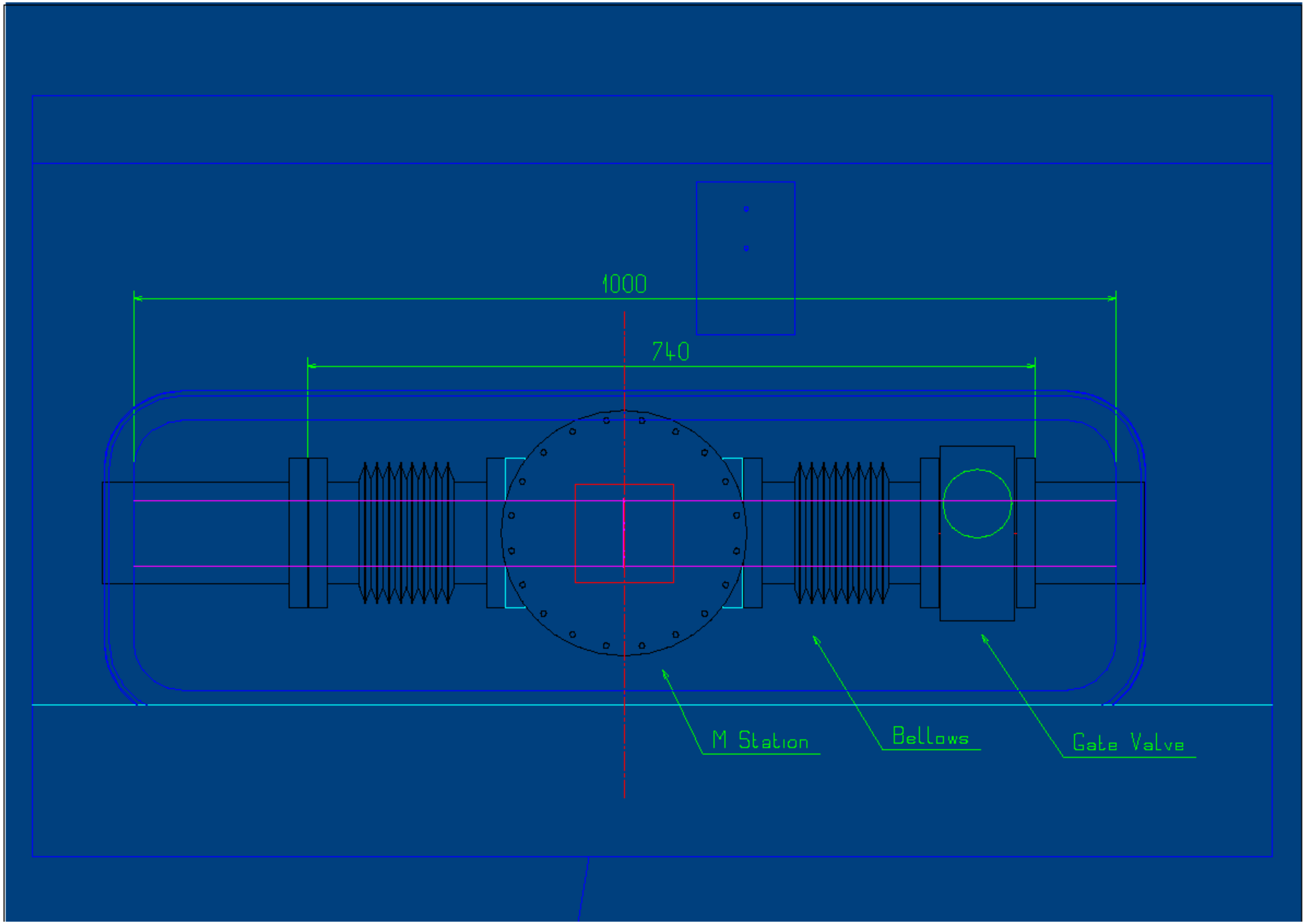
Dimension and positioning of slots



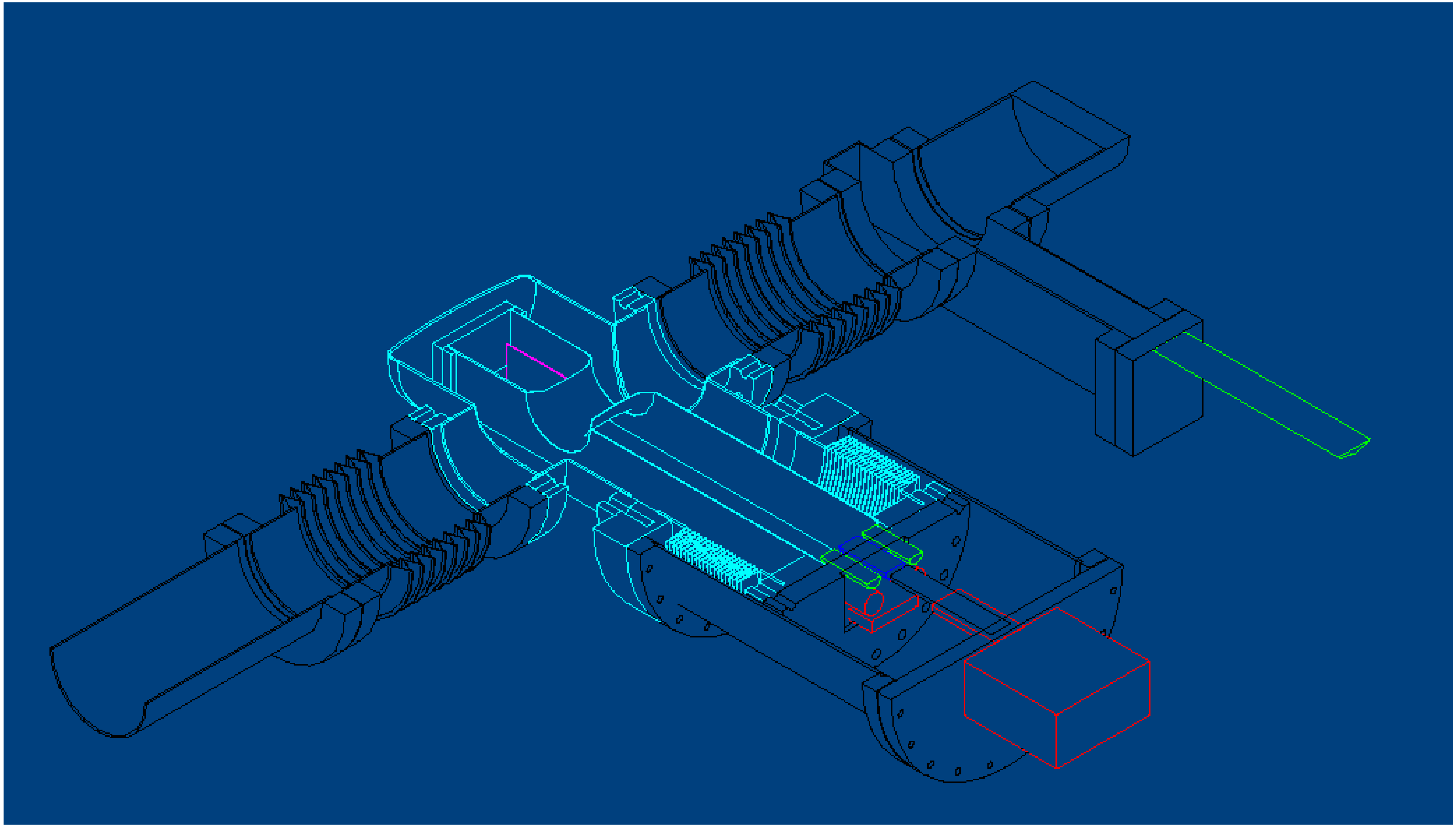
Micro Pot I



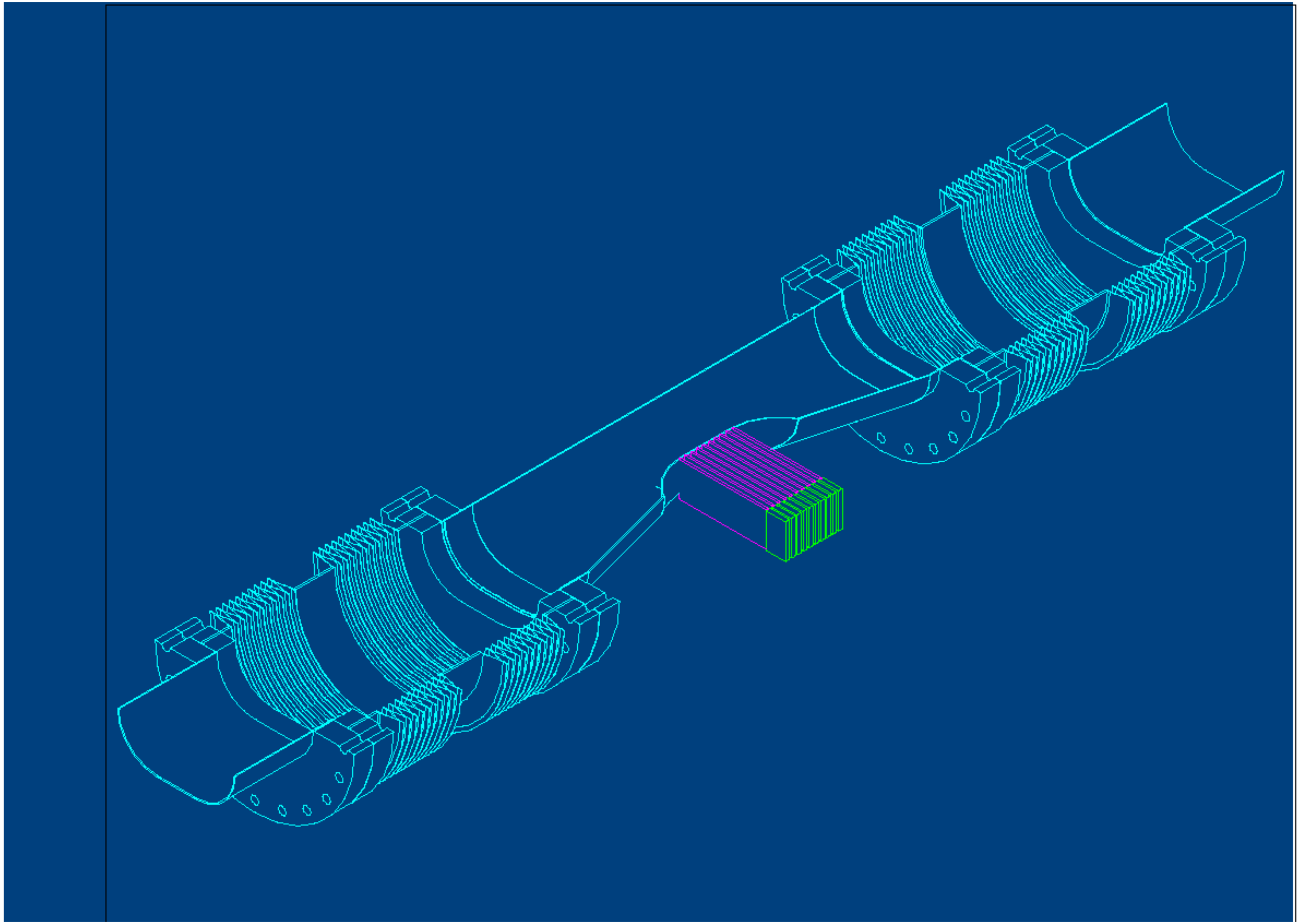
Micro Pot II



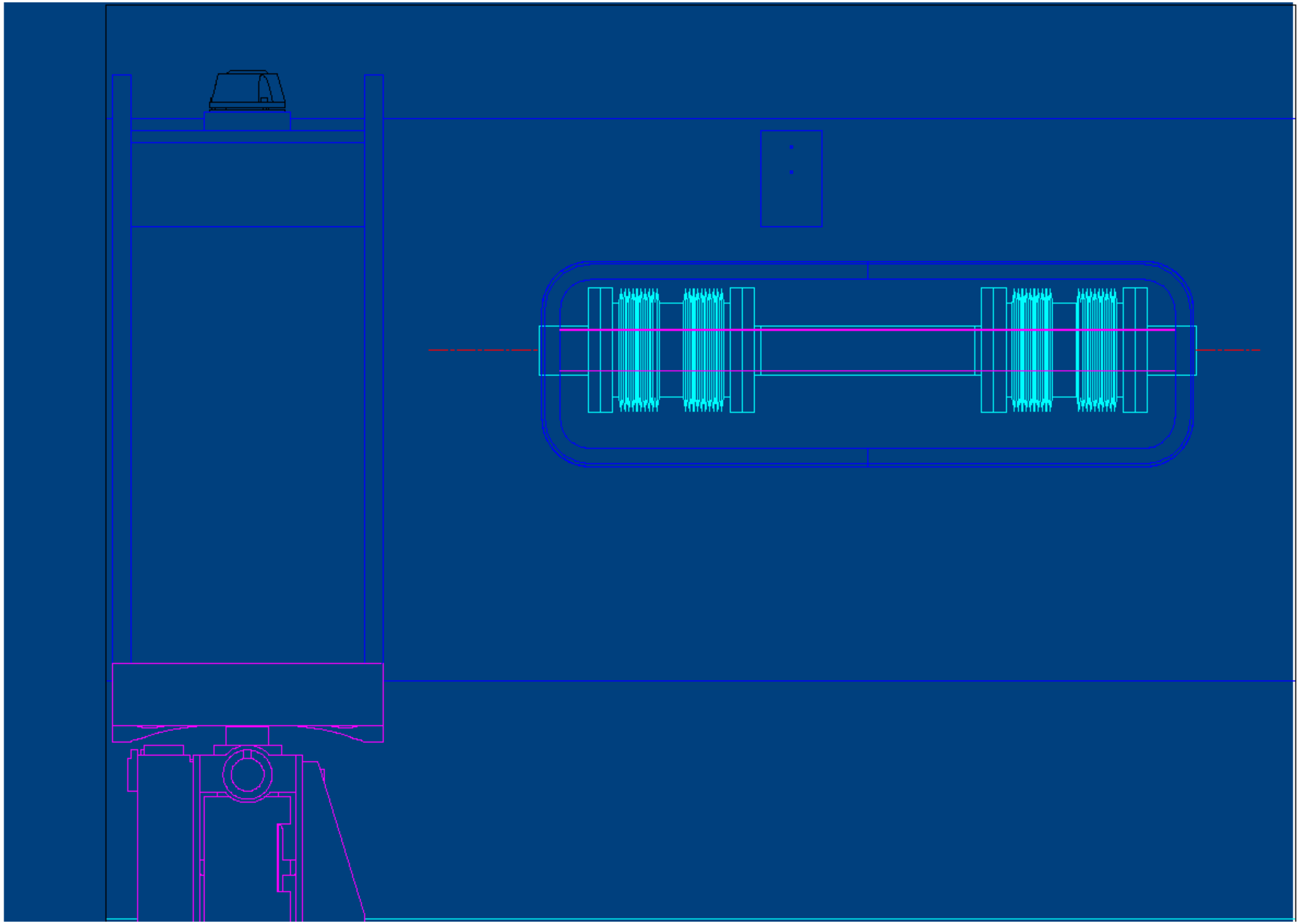
Micro Pot III



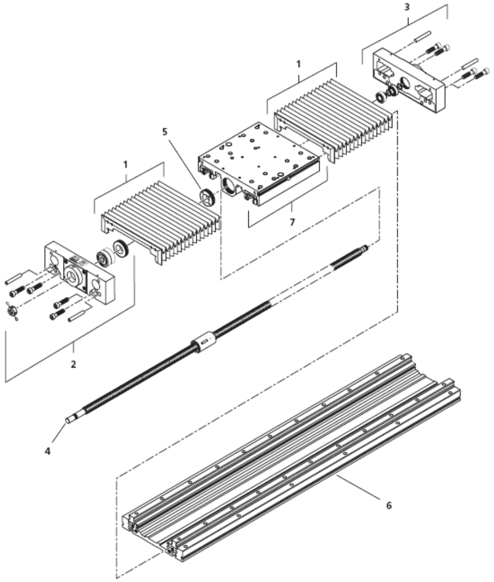
Moving Short Pipe I



Moving Short Pipe II



Positioningtable for MSP (Moving Short Pipe)

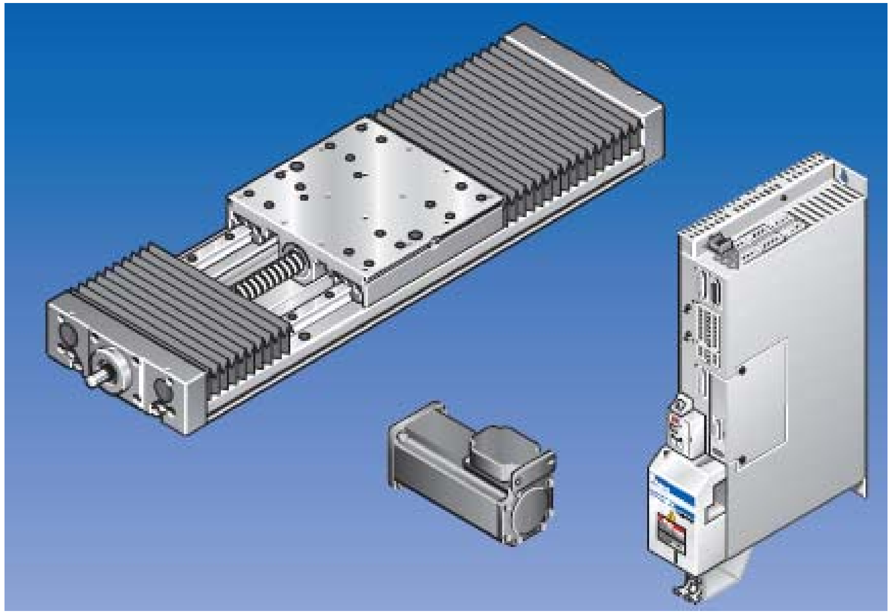


Structure:

Base plate and carriage made from precision machined aluminum extrusion or steel with reference edge
Guideway: Ball Rail® Systems with four long runner blocks per carriage
Precision Ball Screw Assembly to tolerance class 7 with clearance-free nut system
Fixed bearing end plates with two-row, preloaded angular contact ball bearing
Floating bearing end-plates with double floating bearing system

Accessories:

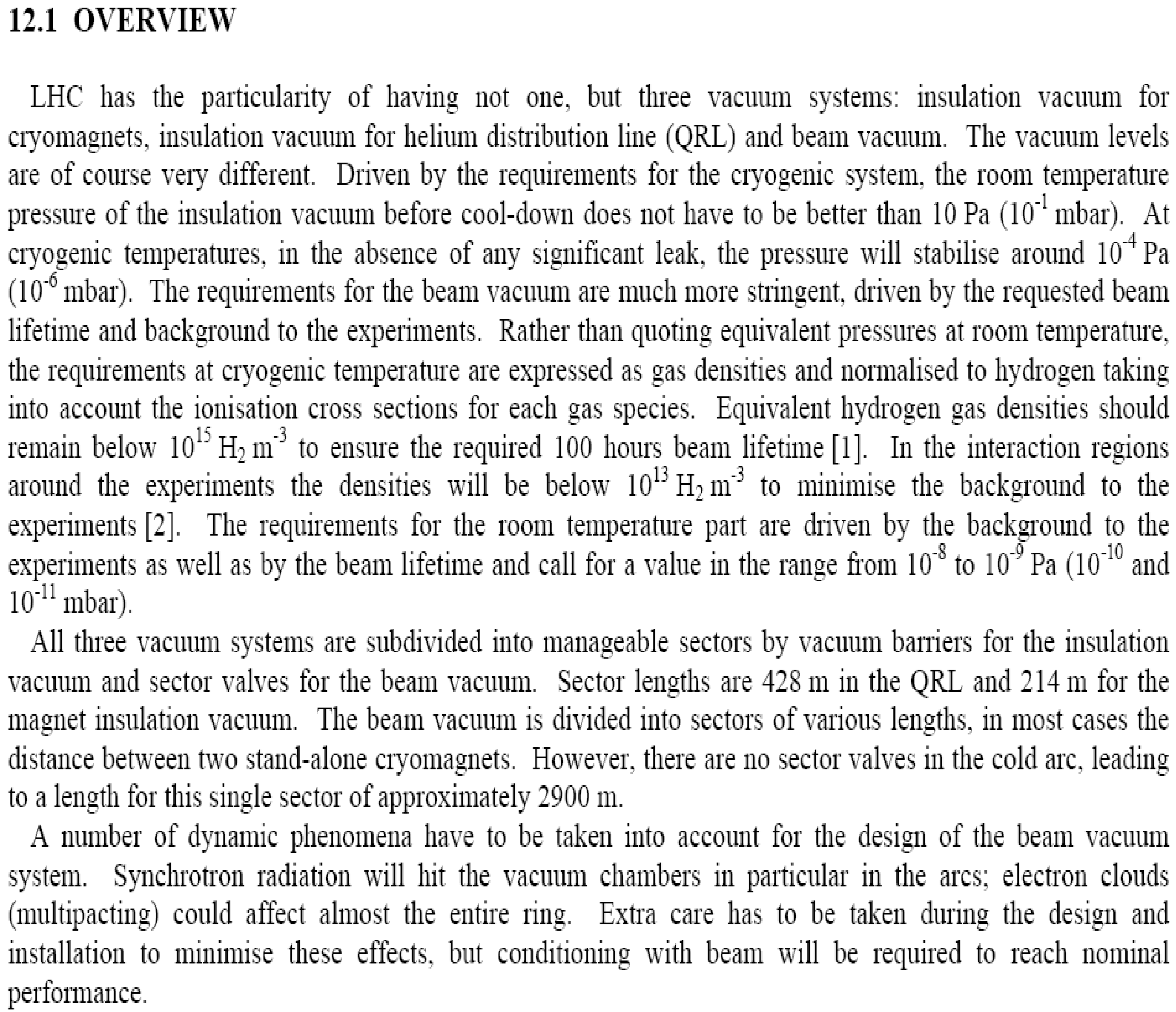
Bellows
Integral glass scale
Internal or external mechanical operated switch
Internal or external iduction-type proximity switch
Socket and mating plug for the switches
Aluminum frame cable duct
5-phase stepping motors
Maintainance-free digital AC servomotors



Shielding ?

Dose rate reduced from 1000->30 Gy/y
with 15mm thick lead shielding box
on beam tubes

LHC Vacuum System **(from LHC TDR)**



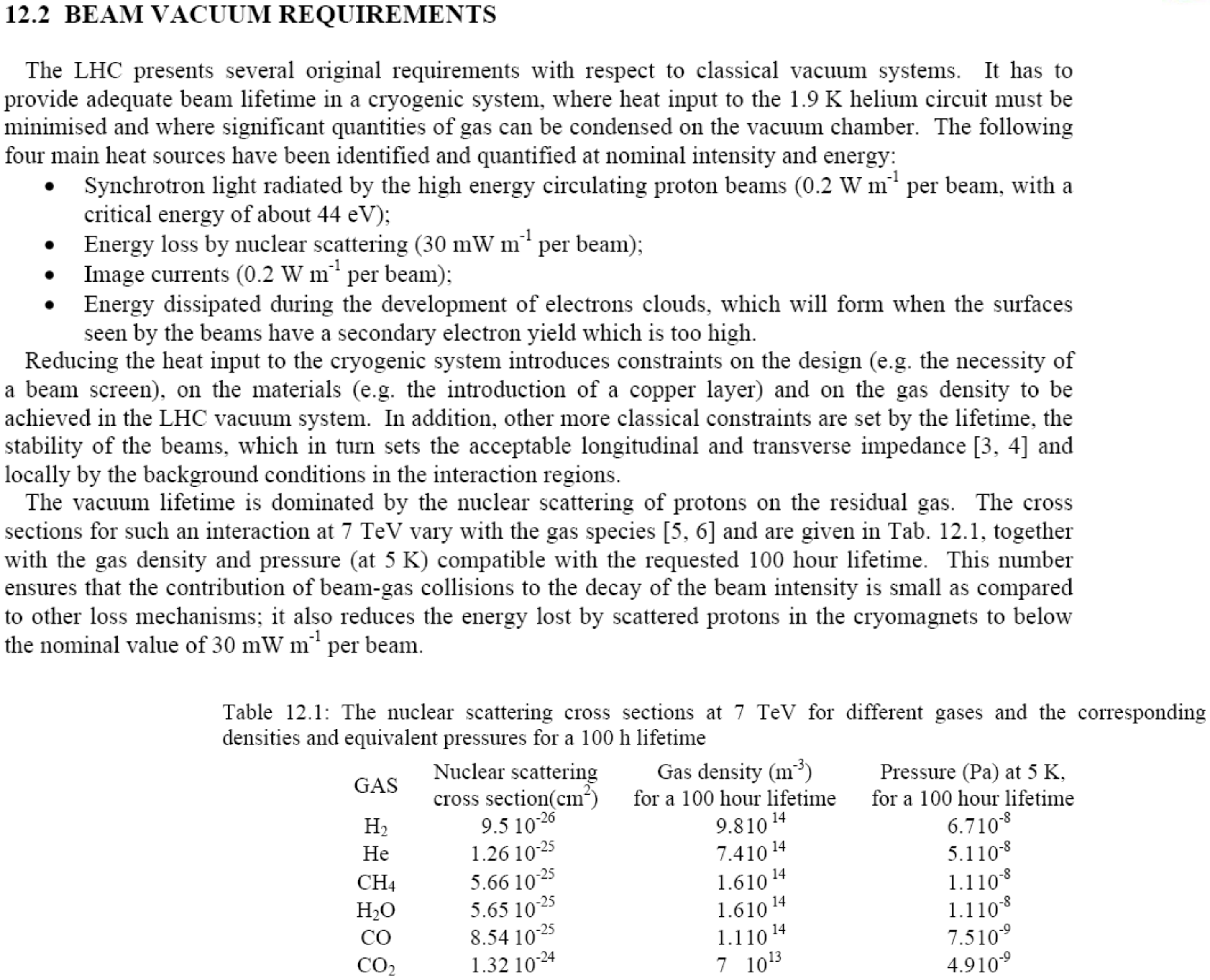
12.1 OVERVIEW

LHC has the particularity of having not one, but three vacuum systems: insulation vacuum for cryomagnets, insulation vacuum for helium distribution line (QRL) and beam vacuum. The vacuum levels are of course very different. Driven by the requirements for the cryogenic system, the room temperature pressure of the insulation vacuum before cool-down does not have to be better than 10 Pa (10^{-1} mbar). At cryogenic temperatures, in the absence of any significant leak, the pressure will stabilise around 10^{-4} Pa (10^{-6} mbar). The requirements for the beam vacuum are much more stringent, driven by the requested beam lifetime and background to the experiments. Rather than quoting equivalent pressures at room temperature, the requirements at cryogenic temperature are expressed as gas densities and normalised to hydrogen taking into account the ionisation cross sections for each gas species. Equivalent hydrogen gas densities should remain below 10^{15} $H_2\,m^{-3}$ to ensure the required 100 hours beam lifetime [1]. In the interaction regions around the experiments the densities will be below 10^{13} $H_2\,m^{-3}$ to minimise the background to the experiments [2]. The requirements for the room temperature part are driven by the background to the experiments as well as by the beam lifetime and call for a value in the range from 10^{-8} to 10^{-9} Pa (10^{-10} and 10^{-11} mbar).

All three vacuum systems are subdivided into manageable sectors by vacuum barriers for the insulation vacuum and sector valves for the beam vacuum. Sector lengths are 428 m in the QRL and 214 m for the magnet insulation vacuum. The beam vacuum is divided into sectors of various lengths, in most cases the distance between two stand-alone cryomagnets. However, there are no sector valves in the cold arc, leading to a length for this single sector of approximately 2900 m.

A number of dynamic phenomena have to be taken into account for the design of the beam vacuum system. Synchrotron radiation will hit the vacuum chambers in particular in the arcs; electron clouds (multipacting) could affect almost the entire ring. Extra care has to be taken during the design and installation to minimise these effects, but conditioning with beam will be required to reach nominal performance.

LHC Vacuum System **(from LHC TDR)**



12.2 BEAM VACUUM REQUIREMENTS

The LHC presents several original requirements with respect to classical vacuum systems. It has to provide adequate beam lifetime in a cryogenic system, where heat input to the 1.9 K helium circuit must be minimised and where significant quantities of gas can be condensed on the vacuum chamber. The following four main heat sources have been identified and quantified at nominal intensity and energy:

- Synchrotron light radiated by the high energy circulating proton beams (0.2 W m^{-1} per beam, with a critical energy of about 44 eV);
- Energy loss by nuclear scattering (30 mW m^{-1} per beam);
- Image currents (0.2 W m^{-1} per beam);
- Energy dissipated during the development of electrons clouds, which will form when the surfaces seen by the beams have a secondary electron yield which is too high.

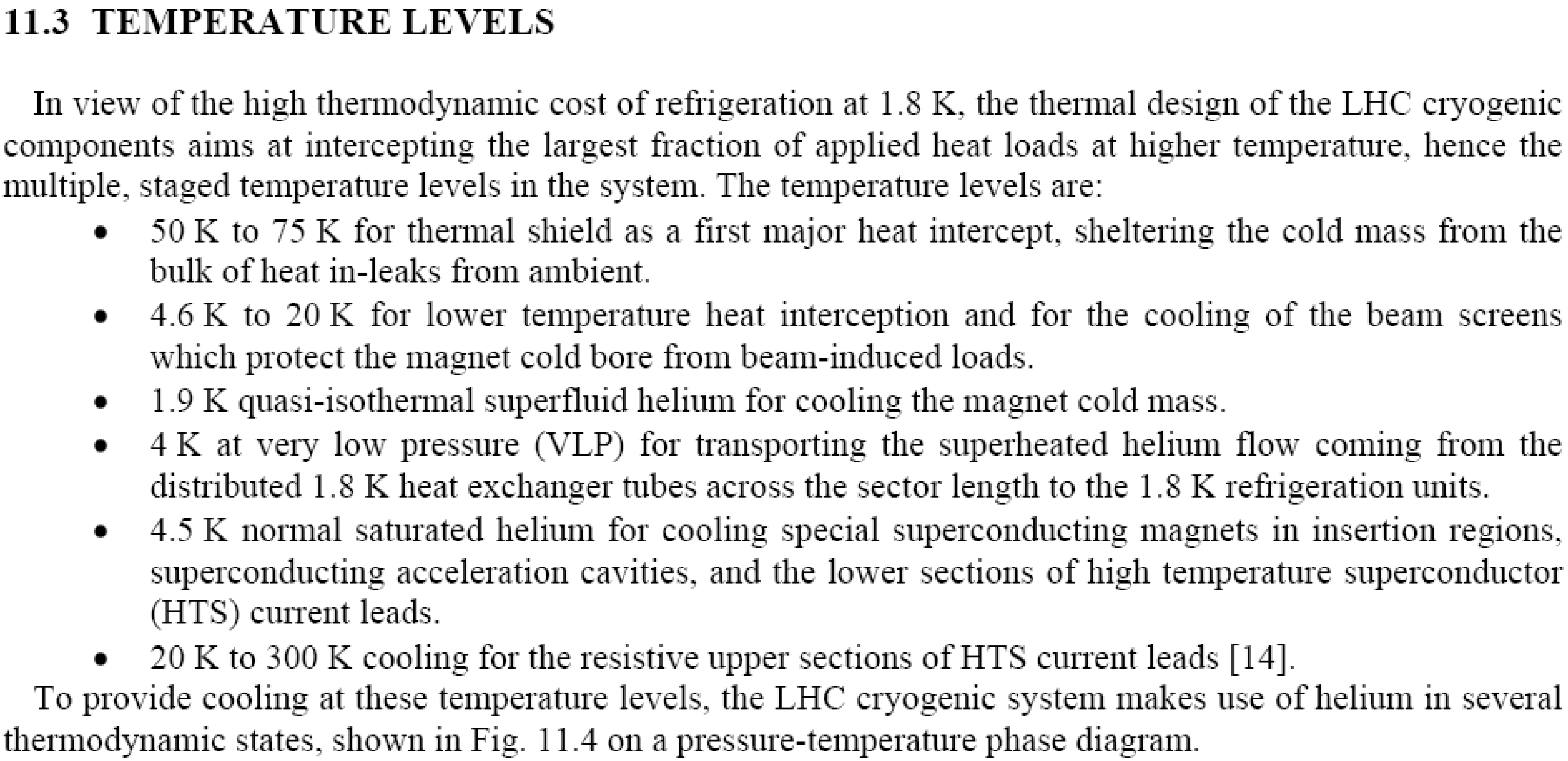
Reducing the heat input to the cryogenic system introduces constraints on the design (e.g. the necessity of a beam screen), on the materials (e.g. the introduction of a copper layer) and on the gas density to be achieved in the LHC vacuum system. In addition, other more classical constraints are set by the lifetime, the stability of the beams, which in turn sets the acceptable longitudinal and transverse impedance [3, 4] and locally by the background conditions in the interaction regions.

The vacuum lifetime is dominated by the nuclear scattering of protons on the residual gas. The cross sections for such an interaction at 7 TeV vary with the gas species [5, 6] and are given in Tab. 12.1, together with the gas density and pressure (at 5 K) compatible with the requested 100 hour lifetime. This number ensures that the contribution of beam-gas collisions to the decay of the beam intensity is small as compared to other loss mechanisms; it also reduces the energy lost by scattered protons in the cryomagnets to below the nominal value of 30 mW m^{-1} per beam.

Table 12.1: The nuclear scattering cross sections at 7 TeV for different gases and the corresponding densities and equivalent pressures for a 100 h lifetime

GAS	Nuclear scattering cross section(cm^2)	Gas density (m^{-3}) for a 100 hour lifetime	Pressure (Pa) at 5 K, for a 100 hour lifetime
H_2	$9.5\ 10^{-26}$	9.810^{14}	6.710^{-8}
He	$1.26\ 10^{-25}$	7.410^{14}	5.110^{-8}
CH_4	$5.66\ 10^{-25}$	1.610^{14}	1.110^{-8}
H_2O	$5.65\ 10^{-25}$	1.610^{14}	1.110^{-8}
CO	$8.54\ 10^{-25}$	1.110^{14}	7.510^{-9}
CO_2	$1.32\ 10^{-24}$	$7\ \ 10^{13}$	4.910^{-9}

Thermal design I (From LHC TDR)



11.3 TEMPERATURE LEVELS

In view of the high thermodynamic cost of refrigeration at 1.8 K, the thermal design of the LHC cryogenic components aims at intercepting the largest fraction of applied heat loads at higher temperature, hence the multiple, staged temperature levels in the system. The temperature levels are:

- 50 K to 75 K for thermal shield as a first major heat intercept, sheltering the cold mass from the bulk of heat in-leaks from ambient.
- 4.6 K to 20 K for lower temperature heat interception and for the cooling of the beam screens which protect the magnet cold bore from beam-induced loads.
- 1.9 K quasi-isothermal superfluid helium for cooling the magnet cold mass.
- 4 K at very low pressure (VLP) for transporting the superheated helium flow coming from the distributed 1.8 K heat exchanger tubes across the sector length to the 1.8 K refrigeration units.
- 4.5 K normal saturated helium for cooling special superconducting magnets in insertion regions, superconducting acceleration cavities, and the lower sections of high temperature superconductor (HTS) current leads.
- 20 K to 300 K cooling for the resistive upper sections of HTS current leads [14].

To provide cooling at these temperature levels, the LHC cryogenic system makes use of helium in several thermodynamic states, shown in Fig. 11.4 on a pressure-temperature phase diagram.

Thermal design II (From LHC TDR)

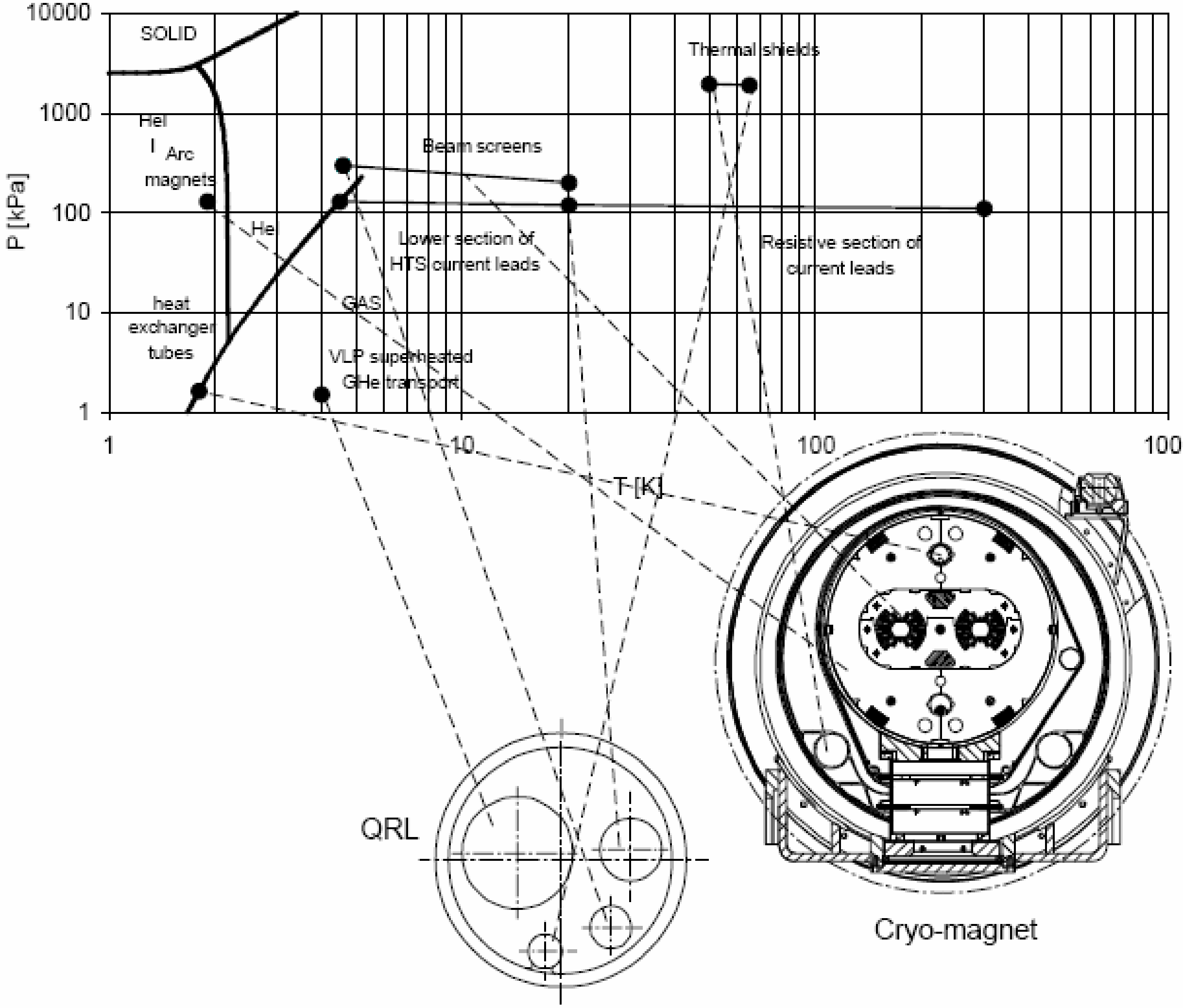


Figure 11.4 Thermodynamic states of helium in the LHC cryogenic system

Complete LHC TDR http://ab-div.web.cern.ch/ab-div/Publications/LHC-DesignReport.html