# Cryogenic Margin and Operation Issues

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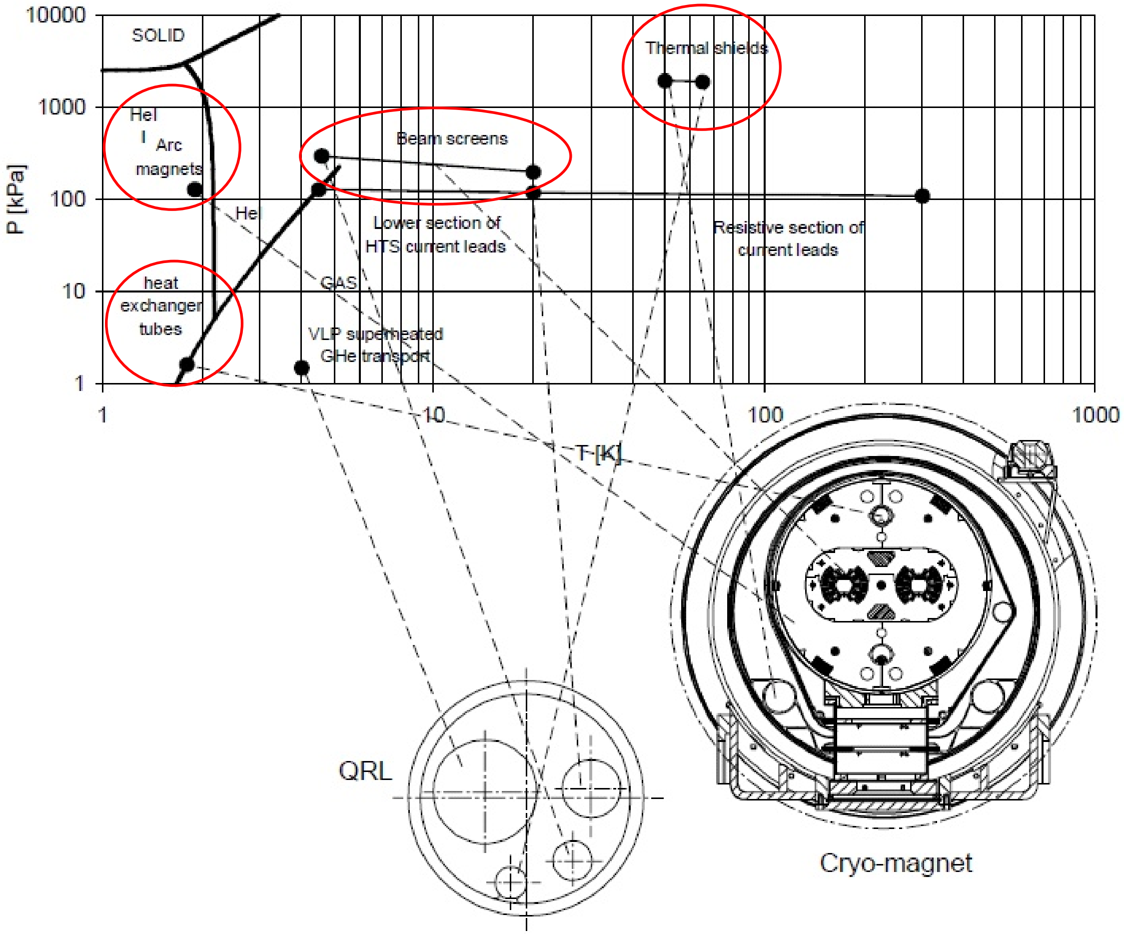
# Introduction

Starting points / assumptions for 11 T magnet and cryo-collimator / bypass assembly:

- classic MB longitudinal hydraulic and conduction requirements

- classic MB heat loads requirements + collimation load estimates

# Cold Mass and Cryostat Requirements for new 11 T Magnet & Collimator




The 11 T Nb3Sn dipole cold mass and its cryostat must provide identical cryogenic piping and hydraulic conditions as the standard MB dipoles; from which specifically:

<u>Cold mass</u>

1) continuity of the copper pipe which serves as 2-phase superfluid helium heat exchanger.

2) minimum 15 and up to 26 liters/meter maximum pressurized superfluid helium content

3) longitudinal hydraulic impedance less than the equivalent of a 50 mm smooth pipe for cool-down / warm-up and quench discharge

4) free helium section of > 60 cm$^2$ for heat conduction

5) radial free helium connections to evacuate the heat from the coil to the 2-phase heat exchanger pipe (essentially beam pipe spacing, open collar nose and collar and yoke spacings identical to the MB standard dipole, 98 % filling factor, should suffice)

<u>Cryostat</u>

- 5 - 20 K beam screen cooling in the beam-pipe
- 5 K support post cooling
- 55 - 65 K support post and thermal shield cooling
- continuity of Line N

**Design Validation by Thermal Model** →

# Cryogenic Margin: typical DS

## Typical DS Heat Loads

| | | Temperature levels | | |
|---|---|---|---|---|
| | | 50-75 K | 4.6-20 K | 1.9 K LHe |
| **LHC Nominal** | Heat inleaks [W] | 794 | 28.4 | 34.1 |
| | Resistive Heating, Feedthrough and Instrumentation [W] | 7.44 | 1.66 | 18.1 |
| | Beam losses [W] | - | 354 | 44.4 |
| | Total [W] | 801 | 384 | 96.6 |
| | Average distributed load [W/m] | 4.7 | 2.2 | 0.56 |
| **LHC Ultimate** | Heat inleaks [W] | 794 | 28.4 | 34.1 |
| | Resistive Heating, Feedthrough and Instrumentation [W] | 26.6 | 4.4 | 18.6 |
| | Beam losses [W] | - | 1037 | 70.2 |
| | Total [W] | 820 | 1069 | 123 |
| | Average distributed load [W/m] | 4.8 | 6.3 | 0.72 |

The DS cooling sections considered for inserting 11 T Magnets & (Cold-) Collimators are about 25 % shorter than the regular ARC cooling sections

Generally we will have about 25 % margin on the heat loads for the 1.9 K (cold-mass) and 5 - 20 K (beam-screen) circuits:

8-11 W @ 1.9 K
30-90 W @ 5 - 20 K

# Cryogenic margin: collimation loads

( V. Boccone )

Expected Collimator heat loads to the Jaw and additional load to magnet

Collimator Jaw: 50 - 150 W

Magnets: < 5 W

Magnet: 5 W at 1.9 K (~ 0.5x15 m long magnet equivalent) OK!

Collimator Jaw: 50 - 150 W

- 150 W at 1.9 K (~ 14x15 m long magnet equivalent, too cold for Vacuum) Not OK

- 150 W at 5 - 20 K (~ 1.6x15 m long magnet equivalent)

Marginal, Takes away any margin on Electron Cloud, Instabilities? -> Not OK

- 150 W at 80 - 140 K (~ 2x15 m long magnet equivalent)

coolant to be taken from 55 - 65 K supply, heater to be installed --> OK!

# Conclusions

- Cold mass construction needs to start to take into account the heat extraction requirements, prefereably this should be verified by a thermal model later on in the design phase

- Cold mass cooling at 1.9 K can easily accommodate the extra (~5 W) heat load

- Collimator Jaw cooling to be envisaged at > 80 K, both for heat load as well as vacuum requirements

- Active heating to 80 K of the helium bleed from the 55 - 65 K thermal screen cooling needed

- No apparent specific operation issues except for unknown electron cloud behaviour with Jaw at > 80 K.