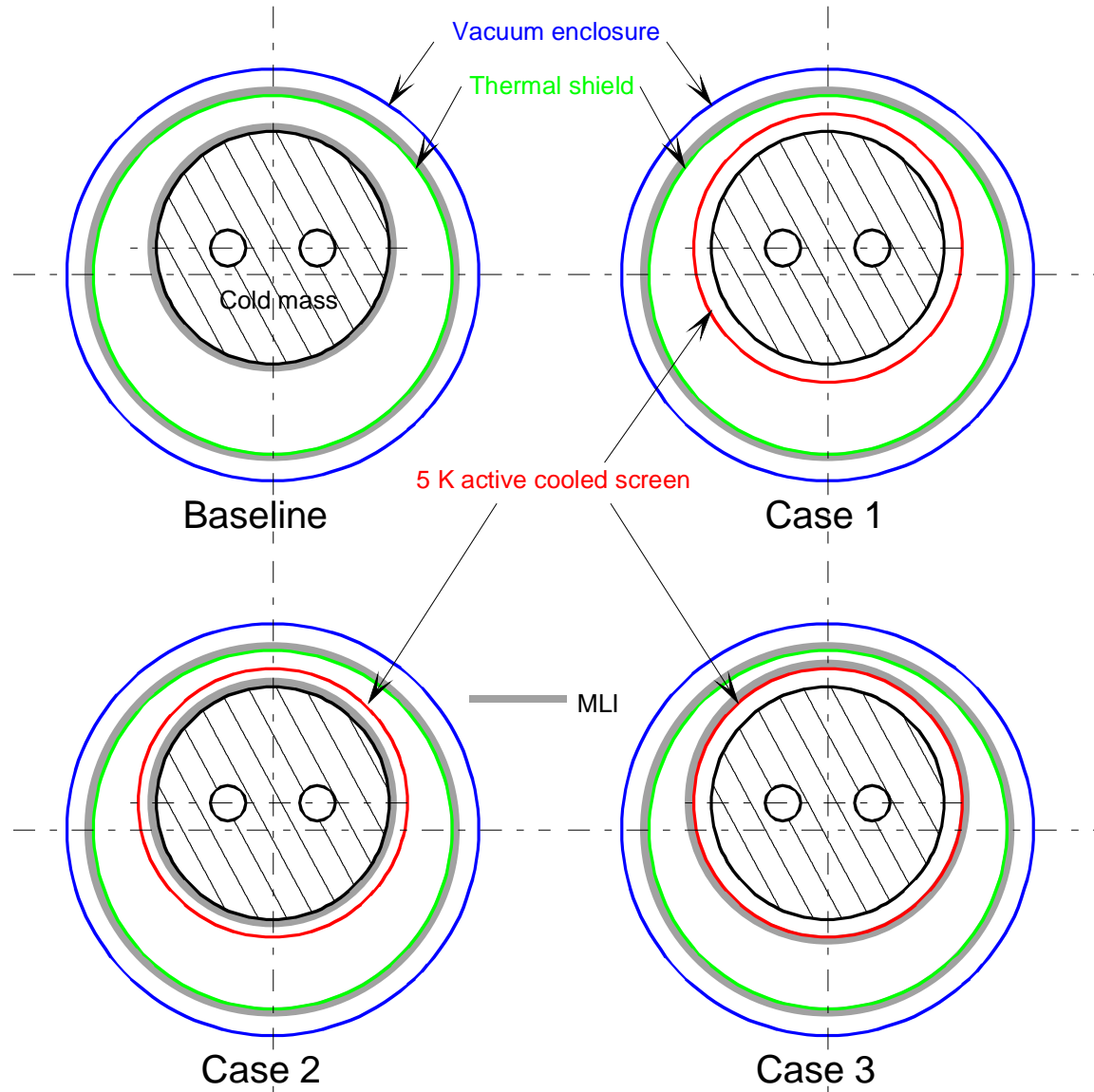


Study of a 5 K active cooled screen for LHC cryo-magnets: Cryogenic consideration

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5-K screen configurations



Baseline static heat loads per half-cell

Vacuum	4.5-20 K Circuit [W]	1.9 K Circuit [W]
Nominal (10^{-6} mbar)	6.7	14.4
Degraded (10^{-4} mbar)	6.7	23.5

Heat inleaks variation per half-cell w/r to baseline

Vacuum	Case	4.5-20 K Circuit [W]	1.9 K Circuit [W]
Nominal (10^{-6} mbar)	Case 1	+ 9.9	- 5.6
	Case 2	+ 9.9	- 5.6
	Case 3	+ 5.5	- 5.6
Degraded (10^{-4} mbar)	Case 1	+ 23.9	+ 9.7
	Case 2	+ 34.0	- 7.6
	Case 3	+ 4.5	- 4.6

Case 3 gives the best performances at nominal conditions and is the only one which gives acceptable performances in degraded operating conditions.

All data are calculated for a **maximum screen temperature of 10 K**

Installed capacity of local cooling loops

Calculation rules:

4.5-20 K circuit: $Q_{\text{installed}} = (1.25 Q_{\text{static}} + Q_{\text{dynamic_ultimate}})$

1.9 K circuit: $Q_{\text{installed}} = 1.5 \times (1.25 \times Q_{\text{static}} + Q_{\text{dynamic_nominal}})$

Circuit	Case	Q static [W]	Q dynamic [W]	Q installed [W]
4.5-20 K	Baseline	7	72.2	81
	Case 3	12.5	72.2	88 (+10%)
1.9 K	Baseline	14.4	8.8	40
	Case 3	8.8	8.8	30 (-25%)

Capital cost saving

- Overall reduction per sector of 540 W (54 half-cells per sector) over 2400 W installed ($\sim 20\%$) of the 1.8 K refrigeration unit capacity
- i.e. $\sim 14\%$ of the 1.8 K refrigeration unit cost
- i.e. ~ 240 CHF/m of magnet which could contribute to the active screen additional cost

Electrical power saving

- Coefficient Of Performance: COP (W/W)
 - 1 W @ 5 K costs 250 W @ 300 K
 - 1 W @ 1.9 K costs 930 W @ 300 K
- Operation saving over 10 years (5000 h/year) based on 70 CHF/MW.h
 - Saving @ 1.9 K : 5.6 W per half cell i.e. 0.1 W/m, i.e. 97 W/m @ 300 K, i.e. 340 CHF/m over 10 years
 - Extra cost @ 5 K: 5.5 W per half-cell i.e. 0.1 W/m, i.e. 26 W/m @ 300 K, i.e. 90 CHF/m over 10 years
- A total cost saving of 250 CHF/m of magnets which could also contribute to the active screen additional cost

Prototype-screen test

- Prototypes of actively cooled screens have been tested on a thermal model cryostat.
- Difficulty at this stage to take the decision to reduced the installed capacity (no capital cost saving (240 CHF/m) as it was time to order the cryo-plants)
- The potential saving on operation cost (250 CHF/m) was not high enough to continue the active screen implementation.
- MaRiC conclusion: In order to limit the investment, and for reasons of simplicity it was proposed to retain the Yellow Book reference design without an actively cooled 5 K shield.