Cryogenic upgrade of the low heat load liquid helium cryostat used to house the Cryogenic Current Comparator in the Antiproton Decelerator at CERN

Andrew Lees, Torsten Koettig, Miguel Fernandes, Jocelyn Tan
CERN, Accelerator Technology & Physics Departments, Geneva, Switzerland

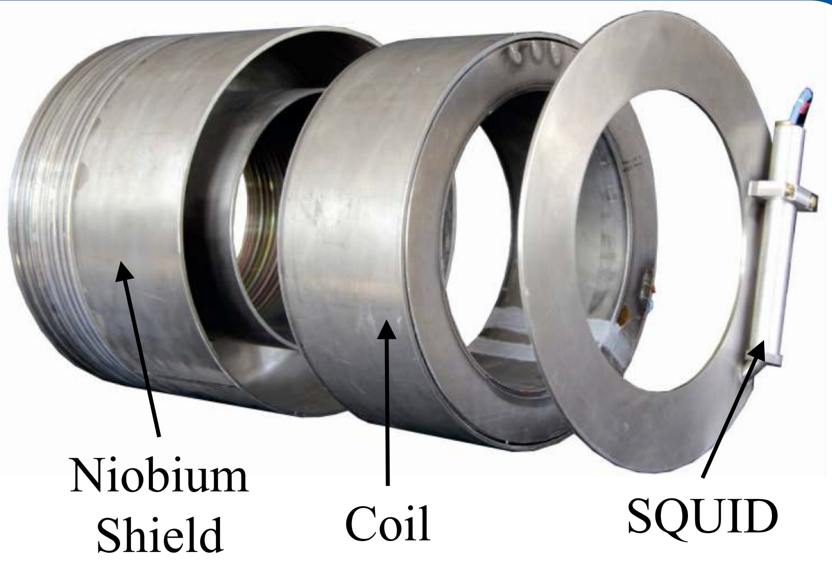
CEC/ICMC 2017
JULY 9-13
MONONA TERRACE
MADISON, WI

C2PoA-03

Introduction

Installed in the antiproton decelerator at CERN in 2015 to house cryogenic current comparator (CCC).

The CCC uses a superconducting quantum interference device (SQUID) to calculate the AD beam intensity by measuring the distribution of its magnetic field.



The SQUID is highly sensitive to mechanical vibrations, so the cryostat uses a titanium support system to reduce the transmission of vibration.

During first operation heat load of 1.04 W on the helium vessel, 0.47 W higher than design, caused a reducing LHe level. To improve the cryogenic performance the cryostat was upgraded during the shutdown of the AD in 2016.

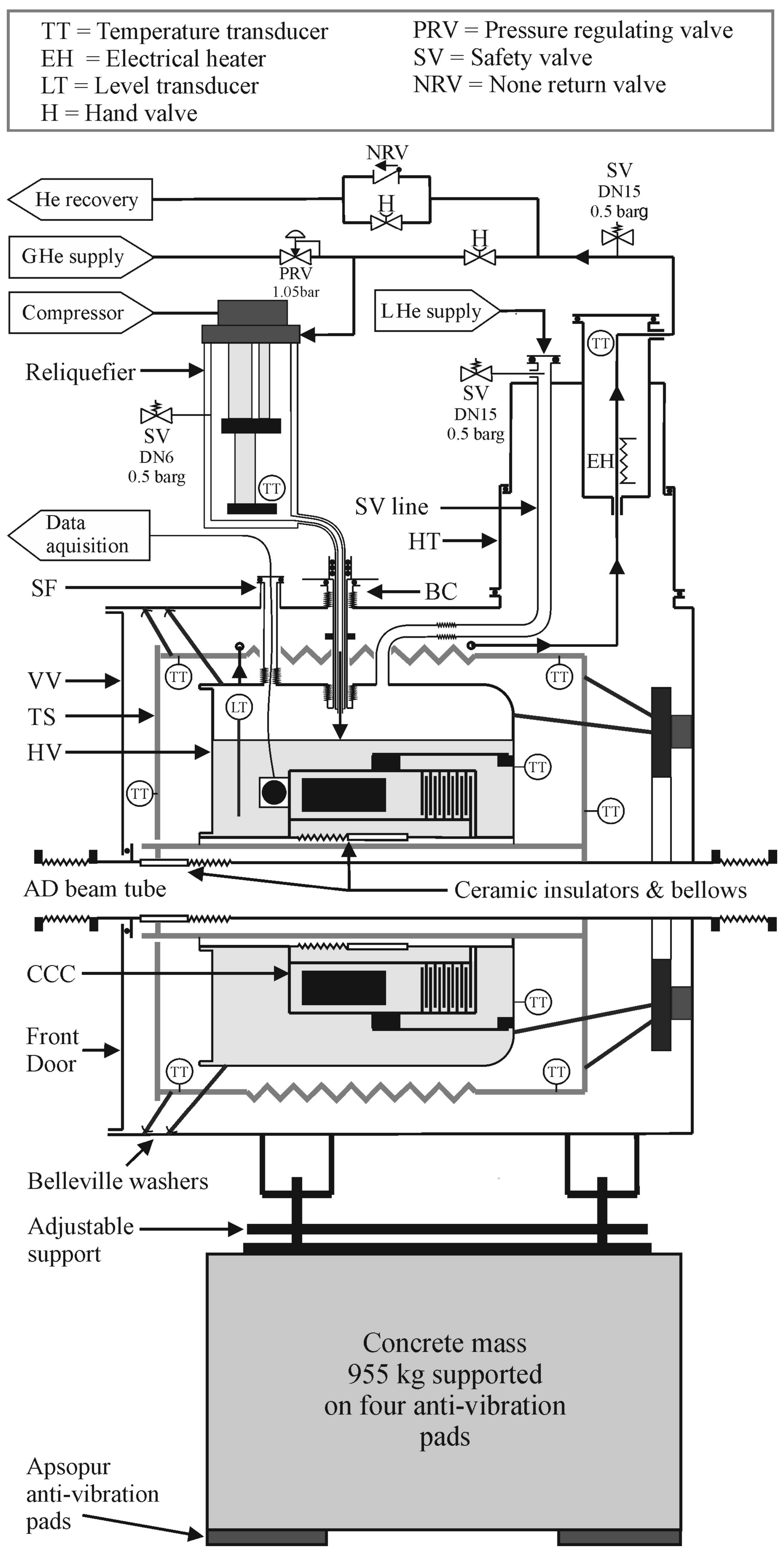
Cryostat design

Process

- Evaporated helium from the HV cools the thermal shield. It is then heated before being re-liquefied by a Cryomech PT415 liquefier.
- Warming of the HV increases evaporation and therefore cooling of the TS, tending towards a stable temperature, the reliquefier produces a cooling power 0.69 W.

Mechanical

- The VV is isolated from external vibrations using its mass and the inclusion of flexible elements.
- The HV and TS are supported using titanium support rods, optimised to limit resonance while limiting heat load due to conduction.
- Sources of harmonic vibration:
  - ⇨ Re-liquefier at 1-2 Hz and 50 Hz.
  - ⇨ Ground borne at 50 Hz.
  - ⇨ AD beam tube.
- Belleville washers account for thermal shrinkage. It is ensured that they are fully flattened when cold.



Modifications to support rods

Removal of strain gauge cables

Used to measure the support rod loads, none optimal installation and material caused high heat load on TS. So strain gauges and cables were removed.

Support rod section

Cross-section of the HV and TS support rods reduced from 20 mm³ to 16 mm² and 13 mm² respectively. Reducing the first modes of vibration of the HV and TS from 60.9 Hz to 59.8 Hz and 62.5 Hz to 60.1 Hz respectively.

Reduced calculated heat loads

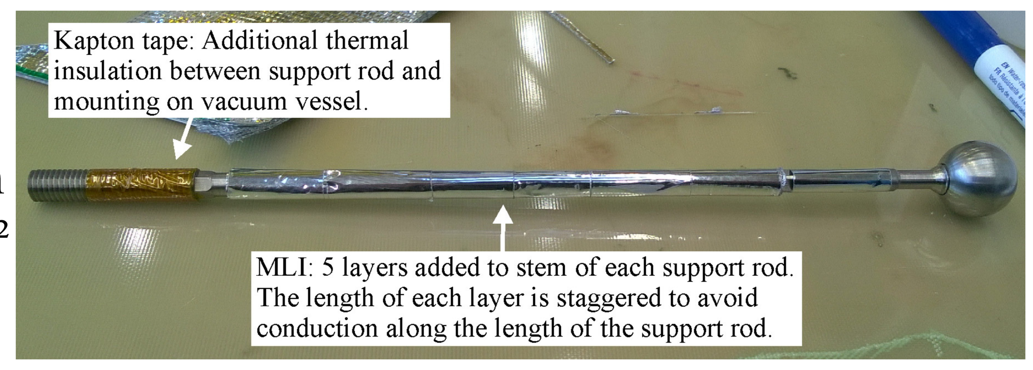
- Removal of strain gauge cables reduces heat load on TS by 6.07 W. This reduces the TS temperature by 15 K, reducing heat load on the HV.
- Reduced cross section of support rods reduces heat load on TS and HV by 1.04 W and 0.06 W respectively.
- The modifications to the MLI shown top right are neglected as it is difficult to calculate their effect accurately.

Thermal path	Heat Load (W)	
	TS	HV
Thermal Radiation	2.91	0.12
Support Rods	3.57	0.20
Bayonet Connection	0.49	0.05
SV line	0.56	0.02
SQUID Feedthrough	0.53	0.06
Instrumentation	0.06	0.04
Heater Line	0.09	0.01
Total	**8.22**	**0.52**

Modifications to MLI

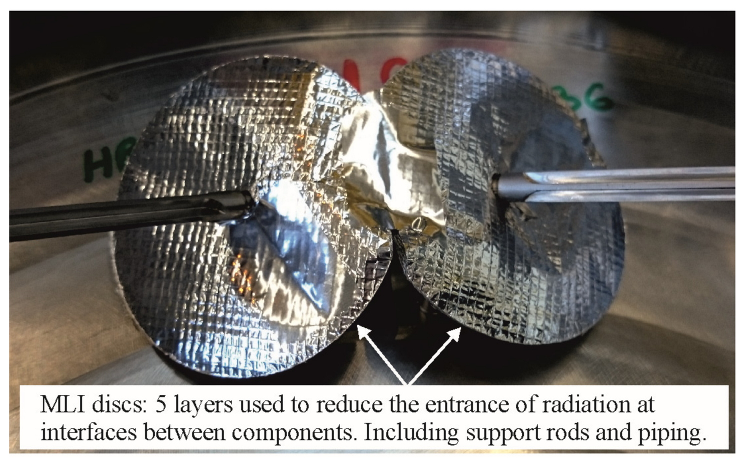
MLI added on support rods

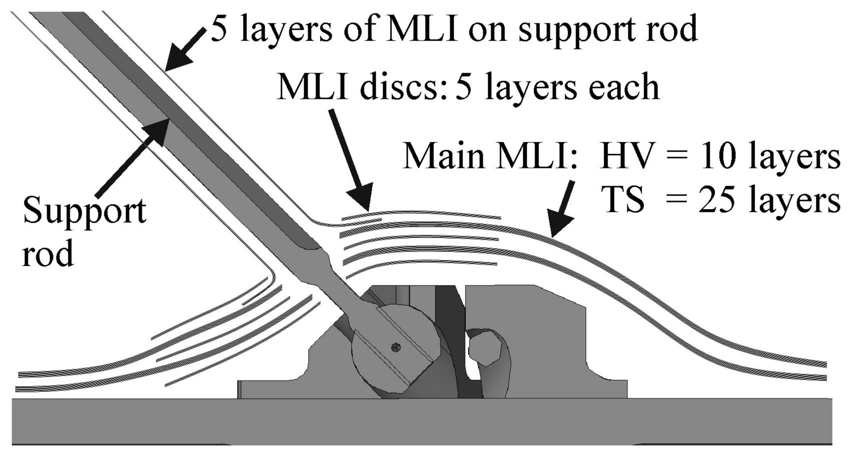
Thermal radiation on the support rods was originally not considered, however with a total surface area of 0.14 m² heat load may be ≈ 3.8 W.



MLI added on support rods

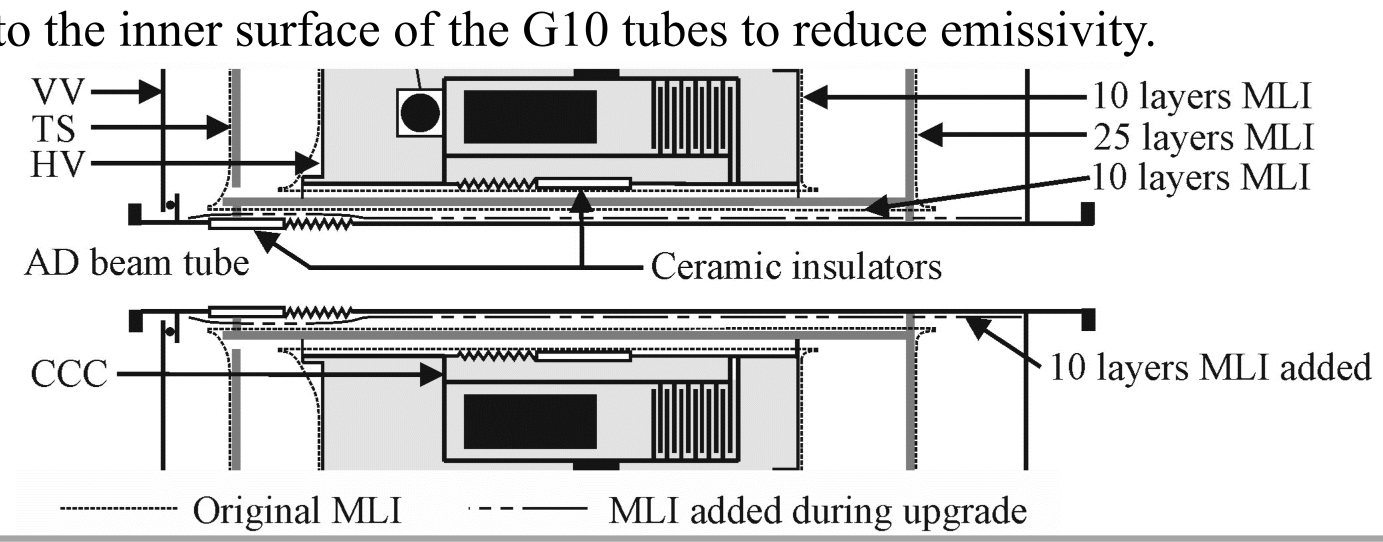
Due to the complexity of the cryostat the continuity of the MLI is broken in many locations. To reduce radiative heat load 3 discs of MLI, each including 5 layers, were installed around the component breaking the MLI. The discs were stacked sequentially with the MLI bundles of either the HV or TS.





MLI added on VV beam tube

Due to lack of space between the VV beam tube and CCC inner diameter, MLI is held in place with an expanding G10 tube, which compresses it. To reduce heat load, 10 layers of MLI were added on to the VV beam tube and 1 layer glued to the inner surface of the G10 tubes to reduce emissivity.



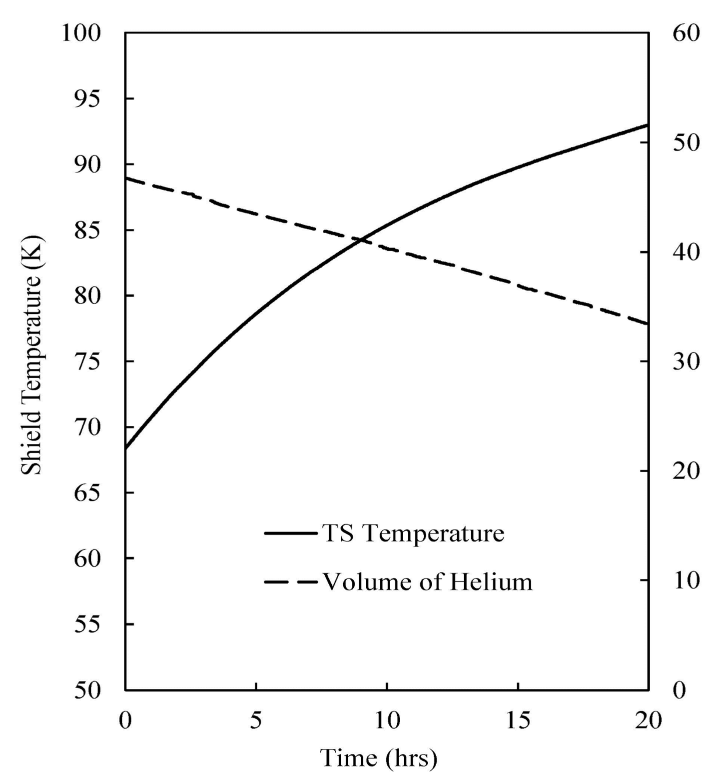
Diffusion through ceramic insulator

Once installed, a slow degradation of the insulation vacuum was noticed. It was found that helium had diffused through the ceramic insulators in the HV beam tube at the rate of $7 \cdot 10^{-4}$ mbar·l/s, 50 times the value expected by design.

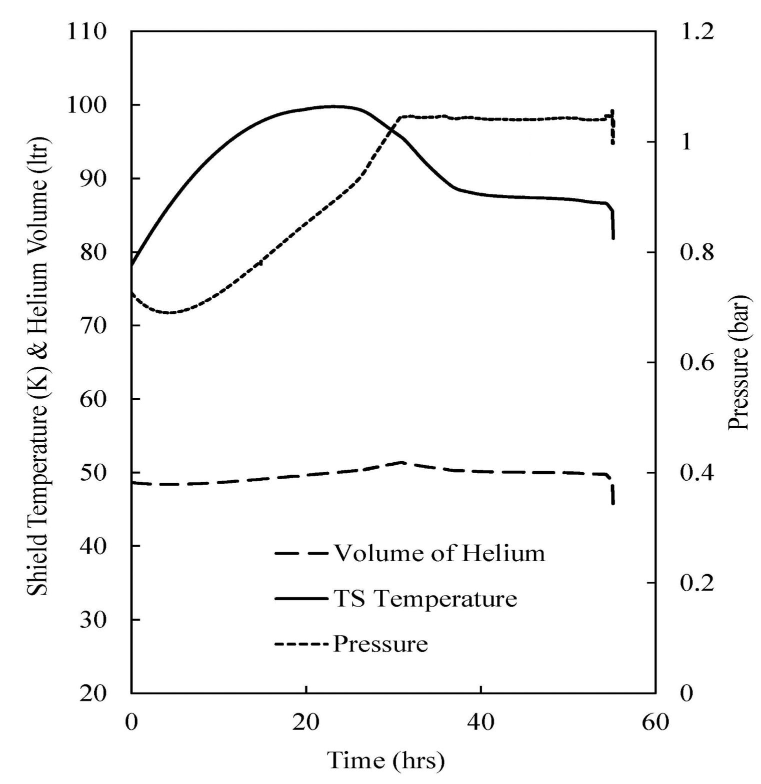
The cooldown procedure was modified to take advantage of the cryogenic effect on diffusion though the ceramic insulator when its temperature drops below 70 K.

Testing

- Without re-liquefier (20 hrs):
  - ⇨ Heat load on HV = 0.59 W
  - ⇨ Heat load on TS ≈ 4.20 W



- With re-liquefier:
  - ⇨ Stable operation after 30 hrs
  - ⇨ Stable LHe level



Conclusions

- Heat loads are now acceptable, allowing operation with a stable level of LHe.
- No indication of a reduction in mechanical performance.
- Diffusion of helium through the ceramic insulators discovered, procedure adapted to manage problem, incorporate monthly vacuum pumping.
- Study is required to eliminate the thermo-acoustic oscillations when filling.