# LARP IR Cryogenics: Longitudinal He II Conduction in the Beam Pipe Analysis

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March 15, 2007

## Introduction

Previous calculations for LARP IR quadrupole cold mass cooling [1, 2] and IR triplet temperature profiles [3] assumed some effects to be negligible in order to make the equation-based models more manageable. One of these effects was longitudinal conduction through the He II in the 1 mm annulus surrounding the beam pipe. All heat deposited in the coils was assumed to be conducted via radial cooling channels in the collars and yoke to the yoke longitudinal cooling holes. This resulted in large temperature gradients along the Q1 beam pipe annulus. This paper examines the effect of this temperature gradient.

## Triplet Temperature Profiles

Figures 1 and 2 [3] present the calculated temperature profiles for two LHC upgraded inner triplets operating at a luminosity of $10^{35}$/cm$^2$-s. Figure 1 is for a triplet using a heat exchanger external to the cold mass, similar to the existing triplet. Figure 2 is for a triplet using a heat exchanger internal to the cold mass.

For both cases, significant temperature differences are generated only within the Q1 (this assumes all four quadrupoles are constructed with the same arrangement of cooling channels). These temperature gradients are used to estimate the longitudinal He II conduction in the beam pipe annulus.

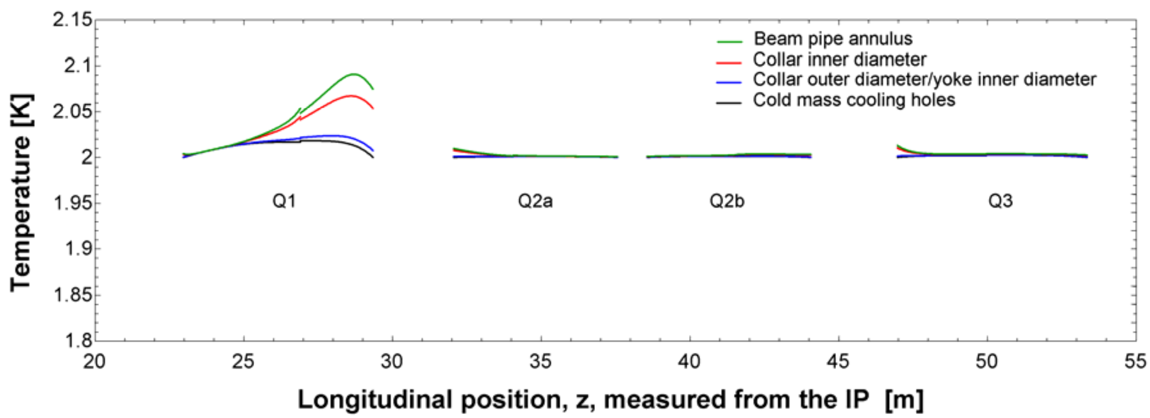


**Figure 1** Calculated inner triplet temperature profiles for an LHC upgraded inner triplet using an external heat exchanger at a luminosity of $10^{35}$/cm$^2$-s.

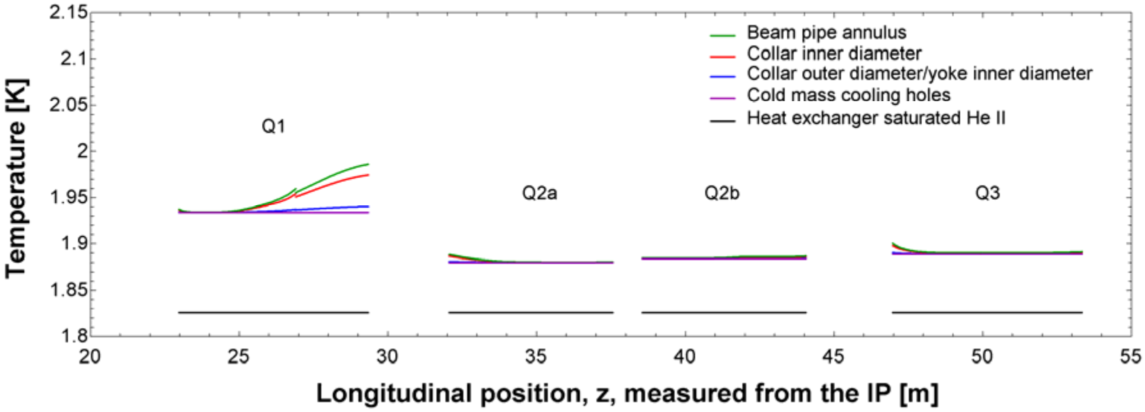


**Figure 2** Calculated inner triplet temperature profiles for an LHC upgraded inner triplet using an internal heat exchanger at a luminosity of $10^{35}$/cm$^2$-s.

**Analysis**

Figures 3 and 4 show the calculated longitudinal He II conduction in the Q1 beam pipe annulus for the case of external and internal heat exchangers, respectively. For both cases, the calculated longitudinal He II conduction in the beam pipe annulus is no greater than 2 W at any location within the Q1. The discontinuities are artifacts of the heat load distribution curve-fitting and resulting calculated temperature profile.

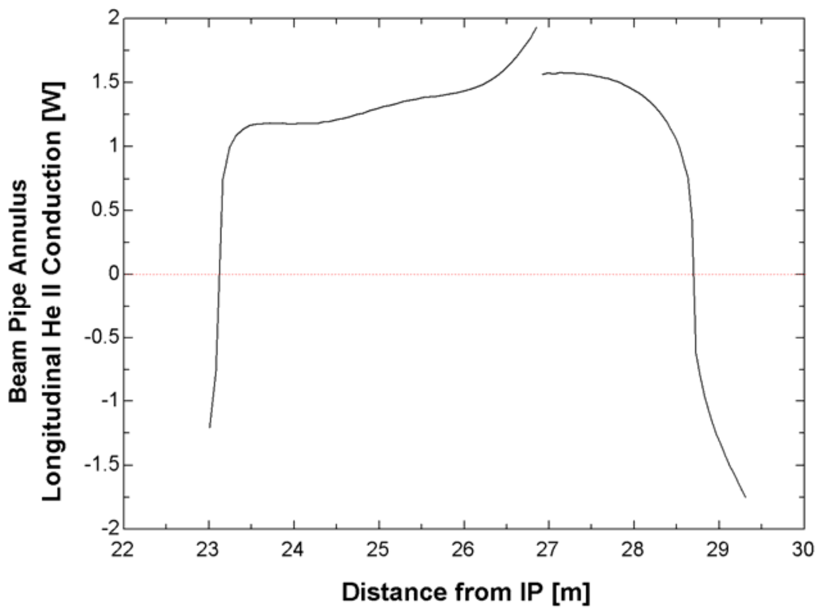


**Figure 3** Calculated Q1 beam pipe annulus longitudinal He II conduction using an external heat exchanger at a luminosity of $10^{35}$/cm$^2$-s.

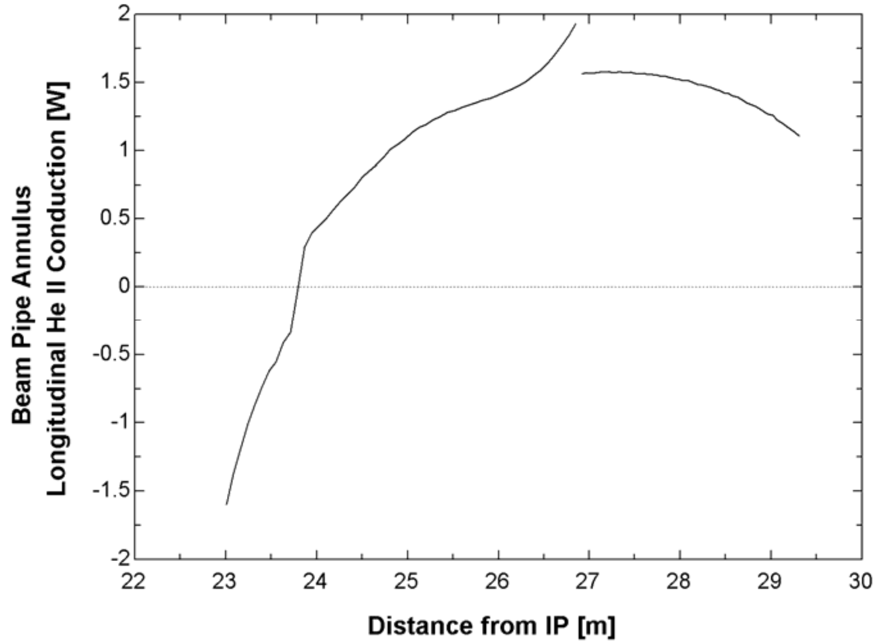


**Figure 4** Calculated Q1 beam pipe annulus longitudinal He II conduction using an internal heat exchanger at a luminosity of $10^{35}$/cm$^2$-s.

**Conclusions**

The beam pipe annulus allows a slight redistribution of the heat load, allowing it to find a path of least resistance through the cold mass cooling channels. This redistribution is typically a few W/m, based on the slopes of the curves in Figures 3 and 4. The result would be a slight smoothing of the calculated magnet temperature profiles. Neglecting this effect is therefore conservative in that a larger temperature range is calculated.

The assumption of negligible longitudinal He II conduction in the beam pipe annulus is therefore reasonable.

**References**

[1] R. Rabehl, "LARP IR Cryogenics: Parametric Studies of Heat Transfer in IR Quadrupole Magnets – Beam Pipe to External Heat Exchanger," LARP Document 279-v1, May 2006.
[2] R. Rabehl, "LARP IR Cryogenics: Parametric Studies of Heat Transfer in IR Quadrupole Magnets – Beam Pipe to Internal Heat Exchanger," LARP Document 341-v1, July 2006.
[3] R. Rabehl, "LARP IR Cryogenics: Inner Triplet Heat Transfer Studies," LARP Document 364-v1, September 2006.