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Thermal studies on a mechanical prototype of a BIS MDT chamber

D. Sampsonidis[a], A. Zisis[a], Ch. Petridou[a], J. Wotschack[a,b]

[a] Physics Department, Aristotle University of Thessaloniki
[b] EP Division, CERN, Geneva

Abstract

The deformations of a BIS MDT chamber owing to temperature gradients between the two multilayers and between the two Faraday cages were studied on a mechanical prototype. The influence of thermal insulation on the thermal behaviour of the chamber is also reported.

1. Introduction

In the ATLAS Muon spectrometer the temperature gradients across the muon chambers need to be limited for several reasons: the stability and uniformity of the drift velocity, the uniformity of the gas gain, and the allowed chamber deformations [1]. The position of the BIS chambers in the muon spectrometer, between the barrel toroid cryostat and the hadronic calorimeter, will cause temperature differences between the chamber surfaces. For this reason the BIS chambers will be thermally insulated with an insulator of 30 mm thickness instead of the standard 15 mm. Another temperature gradient is expected between the two Faraday cages owing to the different amount of heat generated by the electronics at the two ends of the chamber.

A mechanical prototype of the BIS chamber has been assembled at the University of Thessaloniki in order to study the deformations under gravitational and thermal load. The assembly of the BIS prototype has been reported in [2] as well as the gravitational deformations studies. In this note we present the studies of the thermal deformations of the BIS prototype.

We generated two different temperature gradients, between the two multilayers and between the two Faraday cages, and measured the chamber deformations. For these measurements the chamber was not covered with the insulation material. In addition we studied the temperature distribution on the chamber with and without its insulation in place.

2. Experimental Setup

The mechanical prototype consists of two multilayers, with four tube layers per multilayer, separated by 8 mm from each other. The multilayers are connected to each other via seven aluminium strips, each 25 or 50 mm wide. The chamber is placed on a support structure which allows for the rotation of the chamber into any of the positions of the BIS in the ATLAS muon spectrometer. The chamber was mounted on three kinematical points. We call the side of the chamber where the mounting blocks are M (Mounted), while the other side F (Free), as shown in Fig. 1.

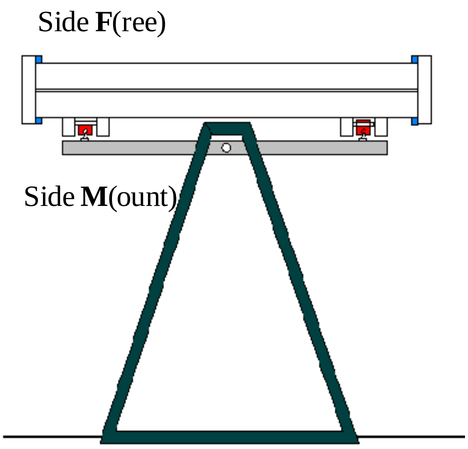

Figure 1: Setup of the chamber on its support structure.

The chamber deformations were measured by two RASNIK systems. The RASNIK components were fixed to aluminium plates which were glued onto the tubes. On the F side of the chamber the two RASNIK systems were placed as shown in Fig. 2 (left). The CCDs and the masks were located about 23 cm inwards from the tube ends, the lenses in the middle. Line A was 17 cm from the chamber edge and line B was 6 cm from the edge. On the M side the RASNIK rays were placed symmetrically 9.5 cm from the edge as shown in Fig. 2 (right). The CCDs and the masks were placed between the Al support beams.

The temperature measurements were done with thermal probes (LM-35) with typical accuracy of ±0.2 °C. The analog signal of the temperature sensors was read out and digitized by an ADC in a PC and monitored continuously. As heat source an electrical blanket was used, which could be operated on three power scales: 60, 30 and 15 Watts.

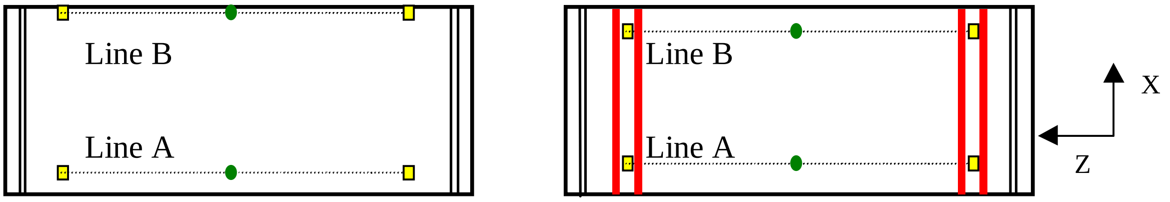

Figure 2: Setup of the RASNIK systems on the F side (left) and the M side (right).

The coordinate system used here follows the RASNIK coordinate system with the x axis along the support beams, y coordinate perpendicular to the chamber plane and z coordinate along the tubes.

The temperature sensors, when no insulation was used, were placed on the outer surfaces of the chamber and in the space between the multilayers as shown in Fig. 3 left. When the insulation was used the temperature sensors were placed in the middle of the chamber surface on five layers as shown in Fig. 3 right.

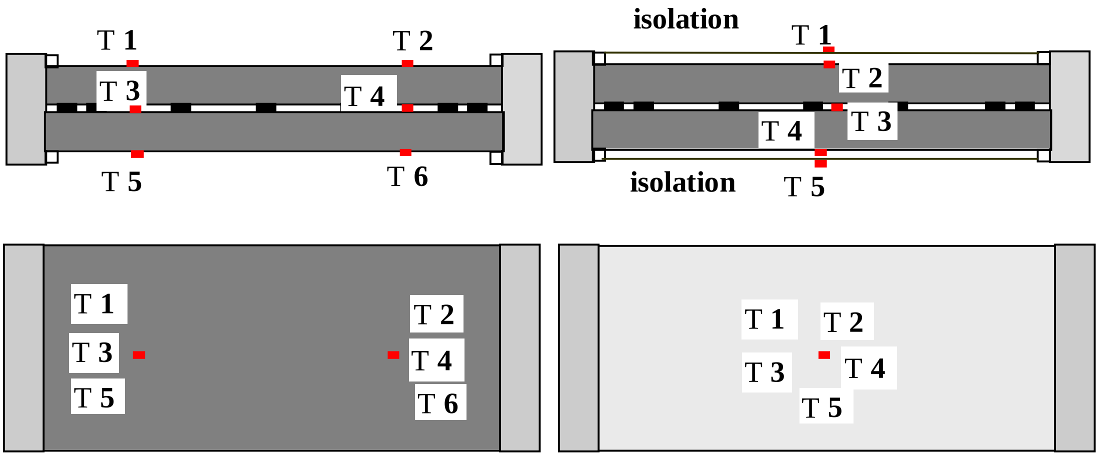

Figure 3: The positions of the temperature sensors when no insulation was used (left) and with the insulation covers in place (right), in cross section (up) and top view (down).

3. Measurements of deformations

The deformation measurements of the BIS chamber were done without the insulation covers because the physical dimensions of the RASNIK elements were such that the covers could not be placed at same time as the RASNIK. In a second set of measurements the thermal gradients across the chamber were studied with the chamber having the insulation in place but without the RASNIKs.

3.1 Thermal gradients across the multilayers

The chamber was heated by covering one side with the electrical blanket. The RASNIK elements were placed on the other side. The blanket was operated on the maximum power scale (60W). The temperature sensors were inserted between the tubes at the positions that are shown in Fig 3.

Figure 4 shows the temperatures on the outer surfaces of the chamber and in the middle space as a function of time when side M was heated.

Figure 5 shows the chamber sag in the y direction as a function of the temperature difference between the two outer surfaces of the multilayers. The temperature difference is defined as the difference of the average temperature measured by two sensors on each side. The arrows on the plot indicate the time sequence while the chamber was heated until the maximum temperature difference was reached and then while the chamber was cooled to the environment temperature.

The same when side F was heated is shown in Fig. 6.[1]

The two data sets correspond to the RASNIK systems along Line A and B (Fig.3).

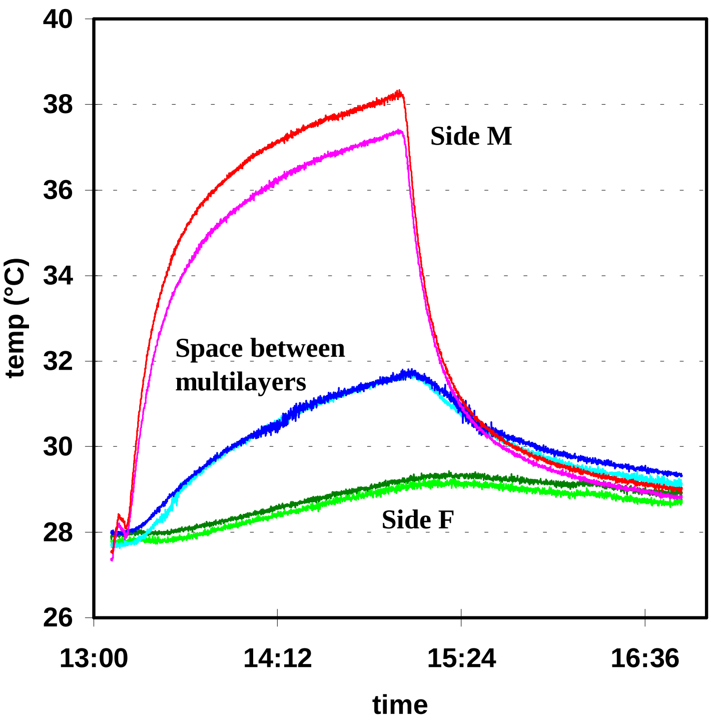

Figure 4: Temperatures recorded on the outer surfaces of the chamber and between the two multilayers when side M was heated. No insulation was used.

[1] In Figure 6 only the deformations during the heating procedure are shown because a technical problem interrupted the data taking during the cool-down.

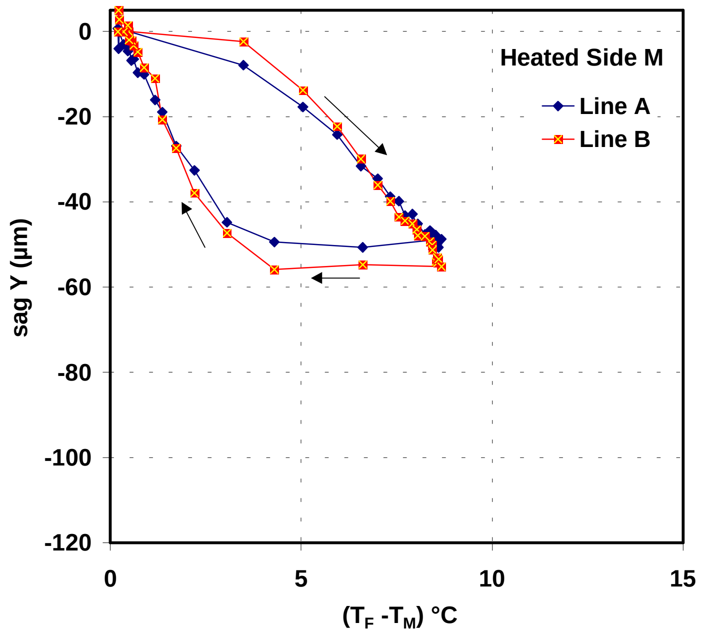

Figure 5: Chamber sag as function of temperature difference between the two multilayers.

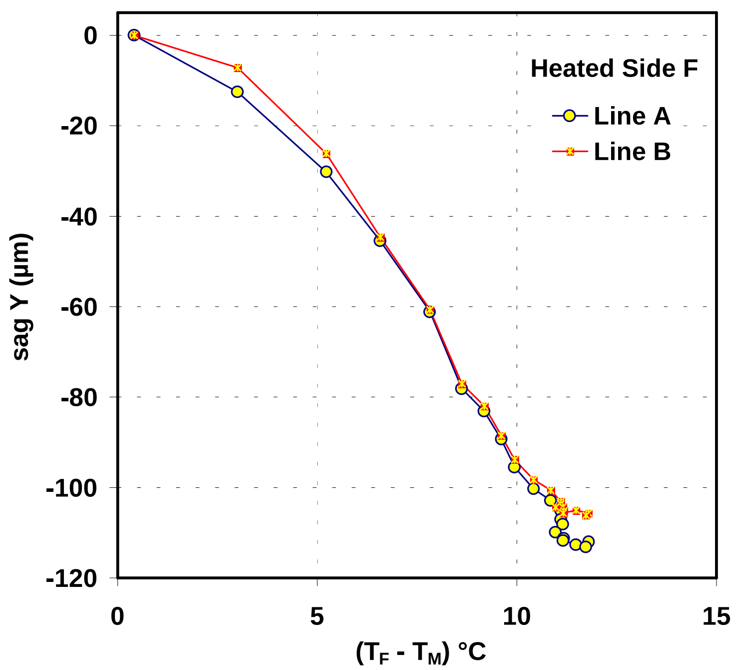

Figure 6: Chamber sag as function of temperature difference between the two multilayers.

The “hysteresis” behaviour of the curves in Fig. 5 is explained by the thermal inertia of the chamber. Only the data points at the two ends of the curves, corresponding to thermal equilibrium, can be used to deduce figures for the deformation of the chamber as a function of the temperature differences.

From Fig. 6 we conclude that the chamber sag in y direction is in average 10 μm/°C. The corresponding value from Fig. 5 is 6 μm/°C. This difference is explained by the way the chamber has been heated. When side F was heated the blanket covered almost the whole surface of the chamber. When side M was heated the blanket covered only the part of the chamber which was between the aluminium bars. This is equivalent to heating a chamber which is only 1200 mm long. Since the sag of the chamber is proportional to the square of the chamber length a larger deformation is expected for the case when side F (Fig. 6) is heated; the ratio of the sag values for the two cases is indeed very close to the ratio of the squares of chamber lengths.

In order to extrapolate these measurements to the conditions expected in the ATLAS detector the temperature map of the chamber with the insulation covers was measured. The chamber was heated, as before, from one side and the temperature was recorded at five points, outside the covers, between the insulation and the chamber surface and in the space between the two multilayers (Fig. 3). The blanket was heated with 15, 30 and 60 W. Figure 7 shows the recorded temperatures as a function of time when side F was heated. Table I gives the temperature differences between the two multilayers for three different temperature gradients outside the protection covers, corresponding to the equilibrium states for the three power scales.

From these measurements we can conclude that the use of the insulation protects the chamber from large temperature differences. With an external temperature gradient of 9 °C between the two faces of the chamber the temperature gradient between the two multilayers is only 1.5° C as measured on the outside of the multilayers[2]. Using the temperature gradient of 1.5 °C and the value of 10 μm/°C as extracted from Fig. 6 the deformation of the chamber in y stays well below 20 μm even for an external temperature gradient of 9 °C.

ΔT (outside the protection covers)	**ΔT (between the multilayers)**
2.62	0.68
3.38	0.96
8.99	1.52

Table I: Temperature differences outside the insulation covers and between the outer surfaces of the multilayers.

[2] To calculate the deformations of the chamber the difference of the average multilayer temperatures is probably the more relevant figure and this will be about the half of the above values, i.e. 0.75°C or less than 1/10 of the external temperature difference.

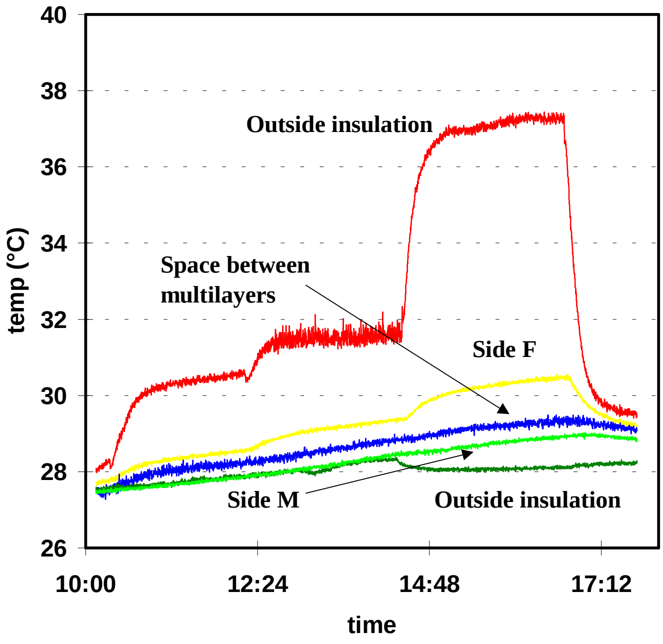

Figure 7: Temperatures recorded at five points when the insulation covers were used. The five points were on the outer surfaces of the covers, the outer surfaces of the multilayers and between the multilayers. Side F was heated and the blanket was operated on three scales of 15, 30 and 60 W.

3.2 Thermal gradients along the tubes

The heat produced by the front-end electronics of the MDTs causes temperature gradients along the tubes. In order to study such conditions we placed the heating blanket in the Faraday cage. This leads to a chamber expansion at the warmer side and a trapezoidal deformation which can be seen as y and x displacements by the RASNIK systems (Fig. 8). The RASNIK systems were placed on the F side of the chamber.

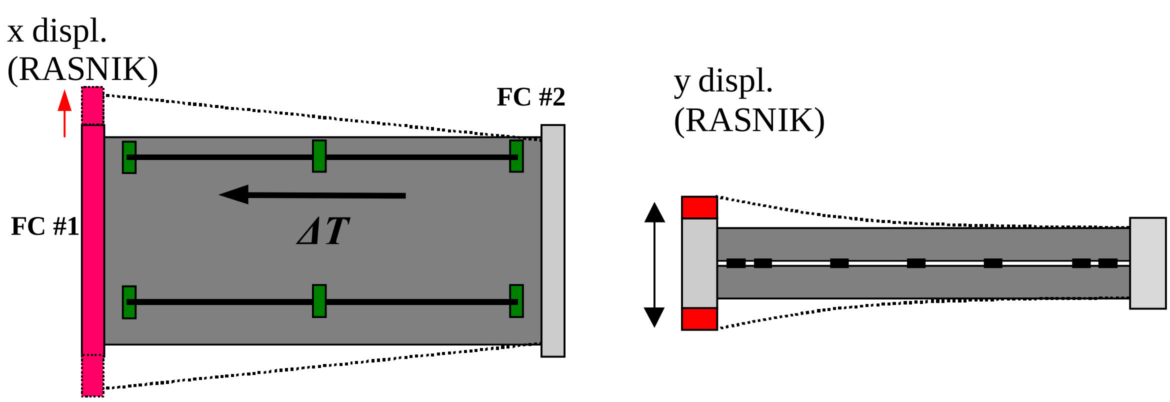

Figure 8: Expected deformations of the chamber owing to the heat dissipation in the Faraday cage (FC).

The chamber was in the horizontal position and the blanket was placed in the Faraday cage#1. The same measurements were performed with the blanket in Faraday cage #2 in order to check the symmetrical behaviour of the chamber. Figures 9 and 10 show the resulting chamber deformations in x and y direction as measured by the RASNIK. The x displacement for Line A is smaller because the RASNIK A was placed closer to the center (see Fig. 2). The y displacements are very small, of the order of few microns, and can be neglected.

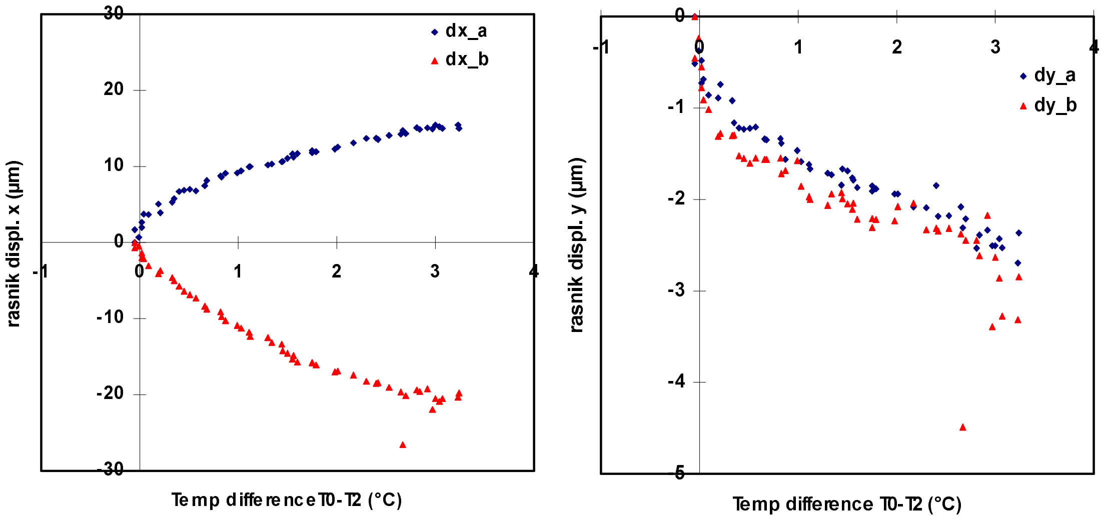

Figure 9: Chamber deformations in y and x direction as function of the temperature difference between the tube ends. The two curves correspond to RASNIK lines A and B. The chamber was in the horizontal position and the Faraday cage #1 was heated. No insulation was used.

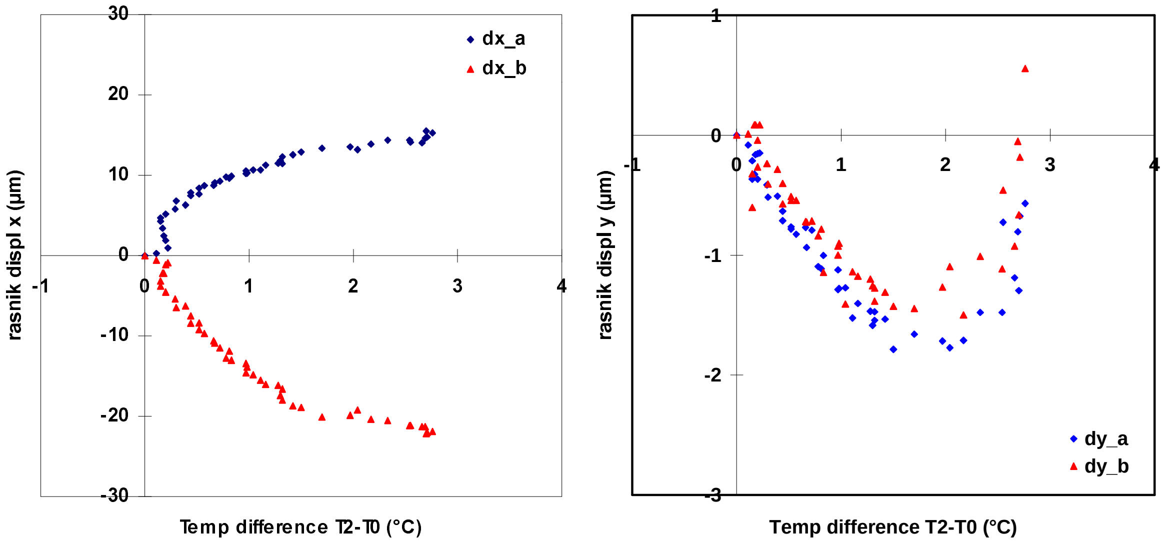

Figure 10: Chamber deformations in y and x direction as function of the temperature difference between the tube ends. The chamber was in the horizontal position and the Faraday cage #2 was heated. No insulation was used.

In a second series of measurements the chamber was oriented vertically. Figure 11 shows the x displacements; the warm Faraday cage was once at the top (left) and once at the bottom side (right). While the observed absolute deformations are about the same in both configurations the ΔT scales are shifted w.r.t each other because of the temperature gradient over 1.7 m height in the room.

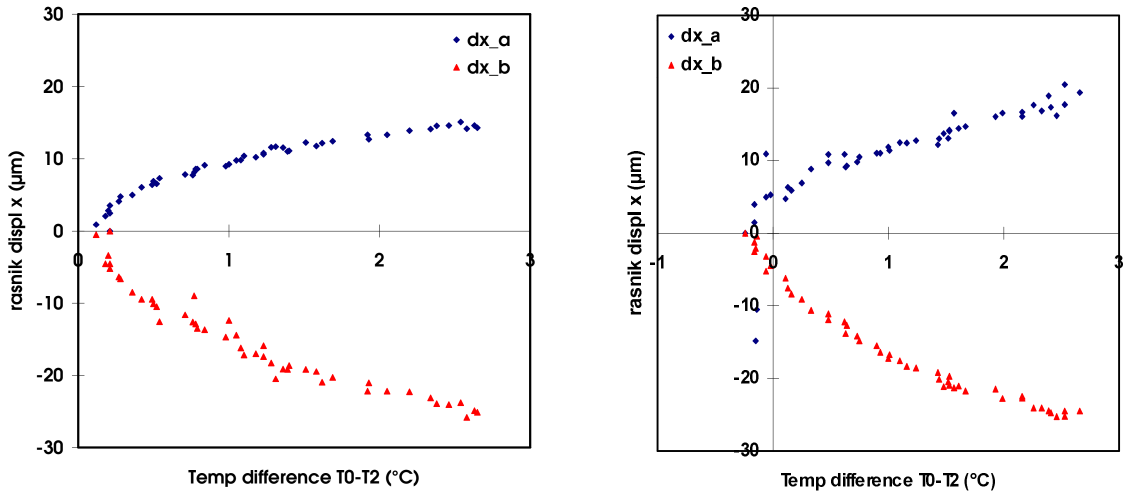

Figure 11: Chamber deformations in x direction as function of the temperature difference between the tube ends. The chamber was in vertical position and the Faraday cage #1 was heated. The warm Faraday cage was once at the top (left) and once at the bottom side (right). No insulation was used.

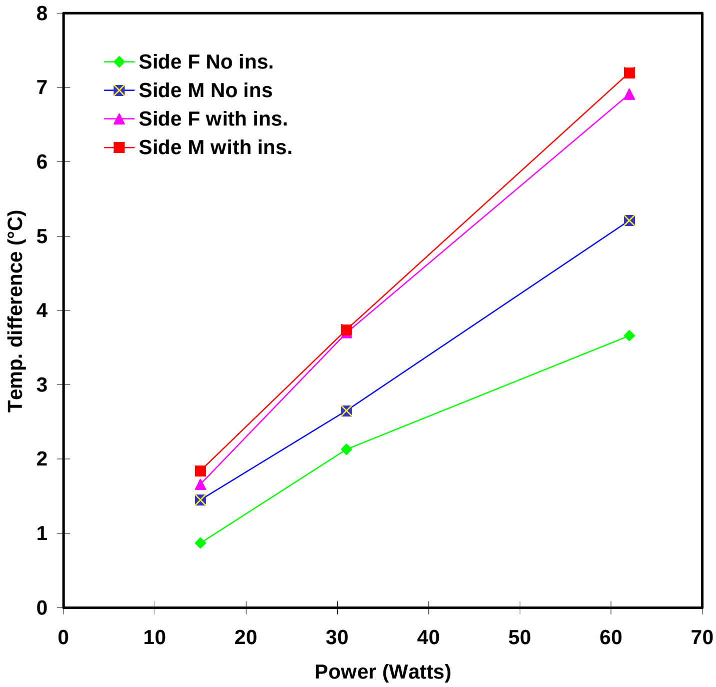

Figure 12: Temperature difference between the tube ends as a function of the dissipated heat in the Faraday cage

Then the temperature gradients along the tubes were measured on both sides of the chamber (F and M), with and without the insulation.The chamber was in horizontal position, and the F side at the top. When no insulation is used, the temperature difference on the F side is about 4 degrees for the 60 W heat source while on the M side the difference is about 5 degrees between the two ends. When the insulation is used the two sides of the chamber show the same temperature difference of about 7°C.

Figure 12 shows the temperature difference between the tube ends as a function of the dissipated heat in the Faraday cage, measured on the two surfaces (F and M) with and without the insulation. From the slopes of the linear fit we conclude that the temperature difference is about 0.11 °C/W when insulation covers are in place.

The heat dissipation by the front-end electronics is expected to be about 10 Watts for the BIS chambers and the temperature gradient between the tube ends is about 1°C; therefore the chamber deformations are of the order of 10 μm in the x direction.

4. Conclusions

The thermal behaviour of the BIS chamber stays well within the ATLAS recommendations. The use of insulating covers protects the chamber against temperature gradients across the multilayers. For a temperature difference of 9°C outside the protection covers the temperature difference between the two multilayers is about 1.5 °C which corresponds to a chamber deflection of less than 20 μm.

The temperature gradient along the tubes generated by the power consumption in one of the Faraday cages is 0.11°C/W. For 1 °C temperature difference between the tube ends the chamber deflection across the tubes and parallel to the multilayers is of the order of 10μm. The respective deflection across the tubes and perpendicular to the multilayers is of the order of 2 μm and negligible.

Acknowledgements

We acknowledge K. Filippousis and D. Damianoglou for their help in preparing the temperature probes.

References

[1] ATLAS Muon Spectrometer, Technical Design Report, CERN/LHCC/97-22 (1997)

[2] Assembly and measurements of a mechanical prototype of the BIS MDT chamber, K. Ekonomou et al., ATLAS Internal Note MUON-NO-243 (1998).