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DEFORMATION MEASUREMENTS IN A MODEL OF THE COIL SUSPENSIONS FOR THE ATLAS BARREL TOROID AND THE B0 MODEL

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Abstract

This paper presents the measurements of the deformations of the suspensions in a model of the tie rods for the ATLAS Barrel Toroid and for its scale model B0.

The test was made by using an aluminum bar suspended via a system of stainless steel tie rods to a stainless steel structure, the shrink of the bar, when cooled by a liquid nitrogen flux, generate stresses on the tie rods, recorded by a set of strain gages.

The aim of these measurements is to check the feasibility of the suspension system, the hardware and the software for the data acquisition, for the experimental activities foreseen (race-track coil, B0 magnet).

1. - INTRODUCTION

The CEA/DAPNIA/STCM and the L.A.S.A. (Laboratorio Acceleratori e Superconduttività Applicata) are involved in the ATLAS Collaboration for the design and construction of the model of a superconducting coil of the main magnet of the detector. The model, called B0, has several purposes like to verify the design choices, the construction capabilities, the operational behaviour of the large superconducting coil. In addition a small race-track test coil (2.7 m long, 0.7 m large) is being installed at CEA.

The main component of the Barrel Toroid and of the B0 are:

1. The cold mass, which is composed by :
   - the superconducting coil
   - the aluminum coil casing
2. The thermal shield around the cold mass
3. The vacuum shield, insulating the cold mass from the outer.

The cold mass is centered in the vacuum shield by a suspension system of titanium tie rods supporting the cold mass weight, the stresses caused by the thermal contractions of the cool-down and by the magnetic forces.

2. - EXPERIMENTAL SETUP

The CEA realized a 1/5 scale model of the cold mass in order to reproduce its displacements and the actions on the tie rods.

This model consisted of an aluminum 2.5 m long bar suspended via a system of 6 stainless steel tie rods to an E24 stainless steel structure. The cooling of the aluminum bar with a flux of liquid nitrogen, shrank the bar and generated the stresses on the tie rods.

The bar was enclosed in a polystyrene thermal shield and all the structure was enveloped in a mylar sheet in order to prevent the air condensation on the apparatus. Fig.1 shows the system during the measurements.

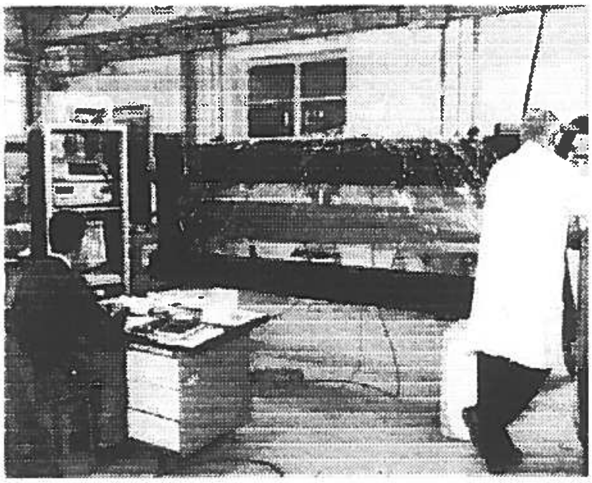

FIG 1 - View of the system during a measurement run.

In order to monitor the stresses and the temperature at which these stresses occurred, some sensors were placed on the apparatus. In Fig. 2 a sketch of the system together with the type and location of the sensors is shown.

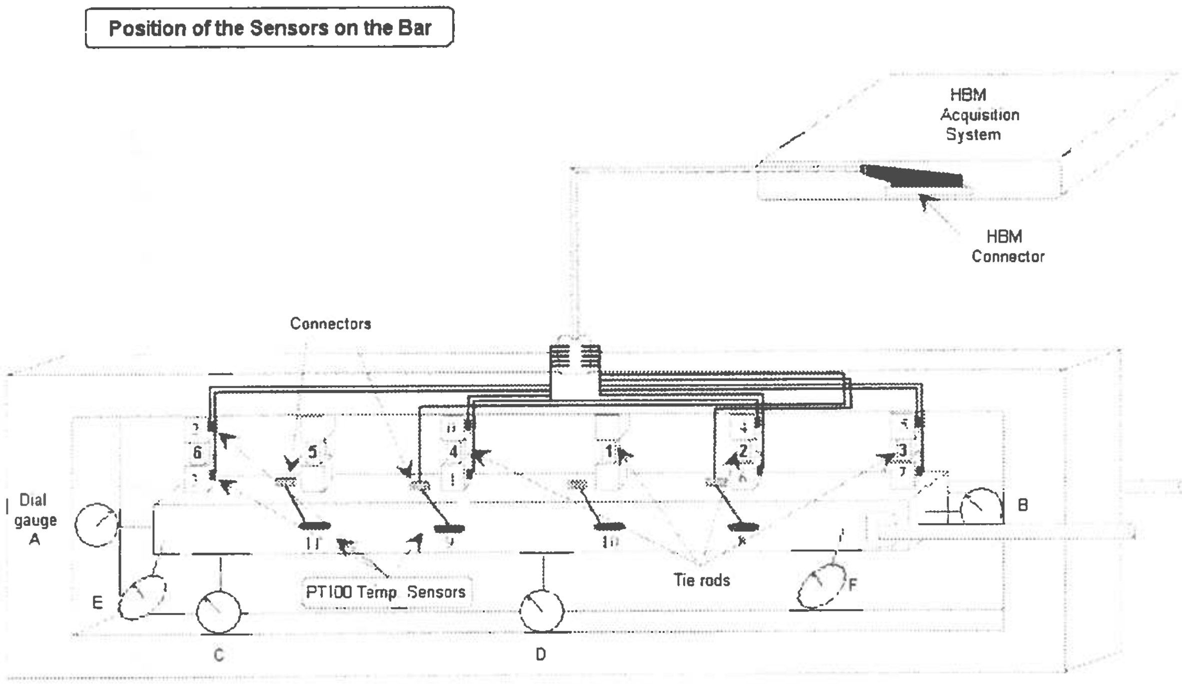

FIG 2 - Schematic view of the bar and location of the sensors. The number of the strain gage is in the middle of the tie rod, at the extremities of the tie rods there is the number of the temperature sensors.

The stresses were measured by a set of 7 strain gages of which 1 was used as compensation gage. The temperatures were monitored by 12 PT100 sensors. All the signal of the sensors were collected by two acquisition boards (one for the strain gages and the other for the PT100) of an HBM (Hottinger Baldwin Messtechnik) data acquisition system, controlled by the software Catman, running with Windows 95 on a Personal Computer.

Each acquisition board of the HBM system could accept only 10 channel, consequently the temperature could not be monitored at the same time by all its sensors, so we monitored the sensors PT0 to PT9 during the cool down, then we replaced the sensors PT8 and PT9 with PT10 and PT11 respectively and then monitored the temperature during the natural warm up of the system.

In addition six dial gauges (A, B, C, D, E and F in Fig.2) monitored the global movement of the bar. The dial gauges A and B red the horizontal shrink of the bar, C and D red the vertical movements, while E and F red the transversal displacement of the bar. The sensitivity of the dial gauges was 0.01 mm for A, B, E and F, 0.001 mm for C and D.

The technical drawing of the tie rods is shown in Fig. 3.

In order to "follow" the movements of the bar when cooled the tie rods were planned to form an angle with the vertical direction of 3.5 mrad (the tie rods n°1 and n°4), 17.4 mrad (n° 2 and n° 5) and 31.3 mrad (the n° 3 and n°6).

After the mounting the angles were 5.4 mrad for the tie rod n° 1, 19.1 mrad for the n° 2 , 32.3 mrad for the n° 3, 4.9 mrad for the tie rod n° 4, 18.1 mrad for the n° 5 and 32.4 mrad for the n° 6.

Fig. 4 shows the upper part of a tie rod with a temperature sensor.

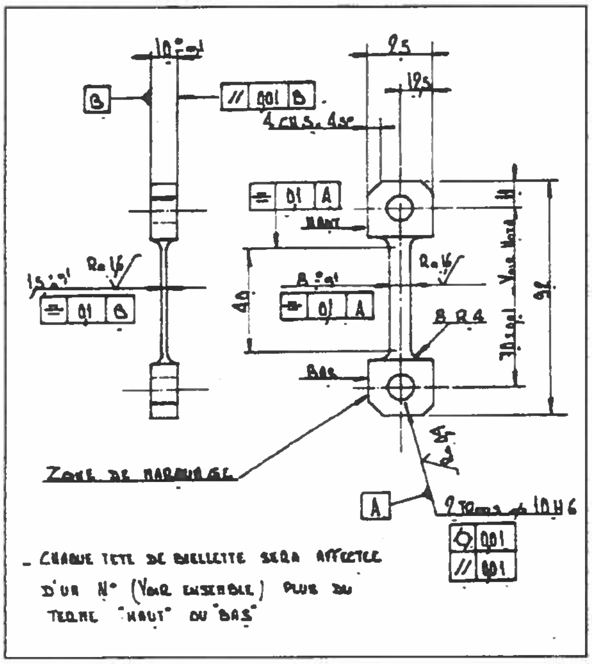

FIG 3 - Drawing of the tie rods.

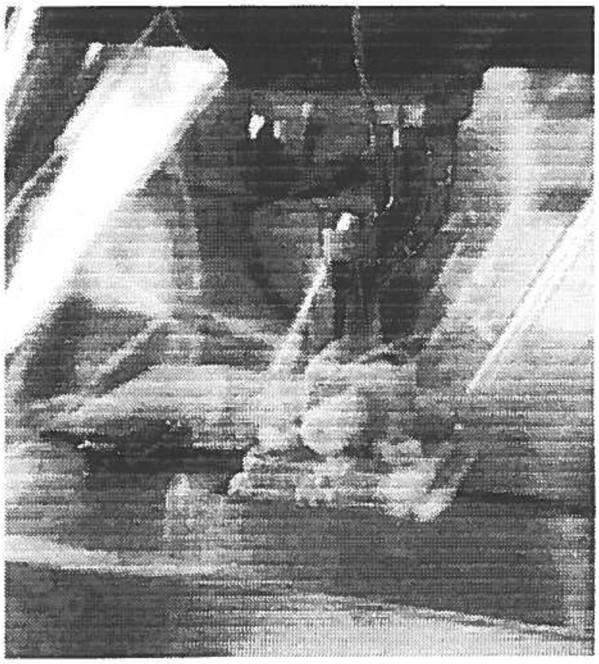

FIG 4 - Part of the tie rod at room temperature and the temperature sensor during the measurement.

3. - RESULTS

The data were collected in two different runs of the experiment i.e. two cool-down and warm-up. Two runs were necessary because of some lack of the data in the first run. From the data of the two runs we can say that there is a reproducible behaviour of the apparatus, but the absolute strain values can be slightly different between the two runs, as can be seen in the following figures.

In Fig. 5 the data of all the strains (corrected for the value of the compensation gage) during the first cool down is shown as a function of time. The temperature data of the sensors placed on the bar are reported too (dotted line, right scale). The sample rate during this experimental run was one acquisition every two minutes.

The temperature of the "hot" end of the tie rods is not reported in the figures because it was almost constant during all the measurement time and, in general, the temperature at the hot end of the tie rods (points 0,2,4,5, in Fig. 1) had a variation of maximum 3.5°, so the temperature of the suspension bar and of the upper part of the tie rods could be considered constant and equal to the room temperature.

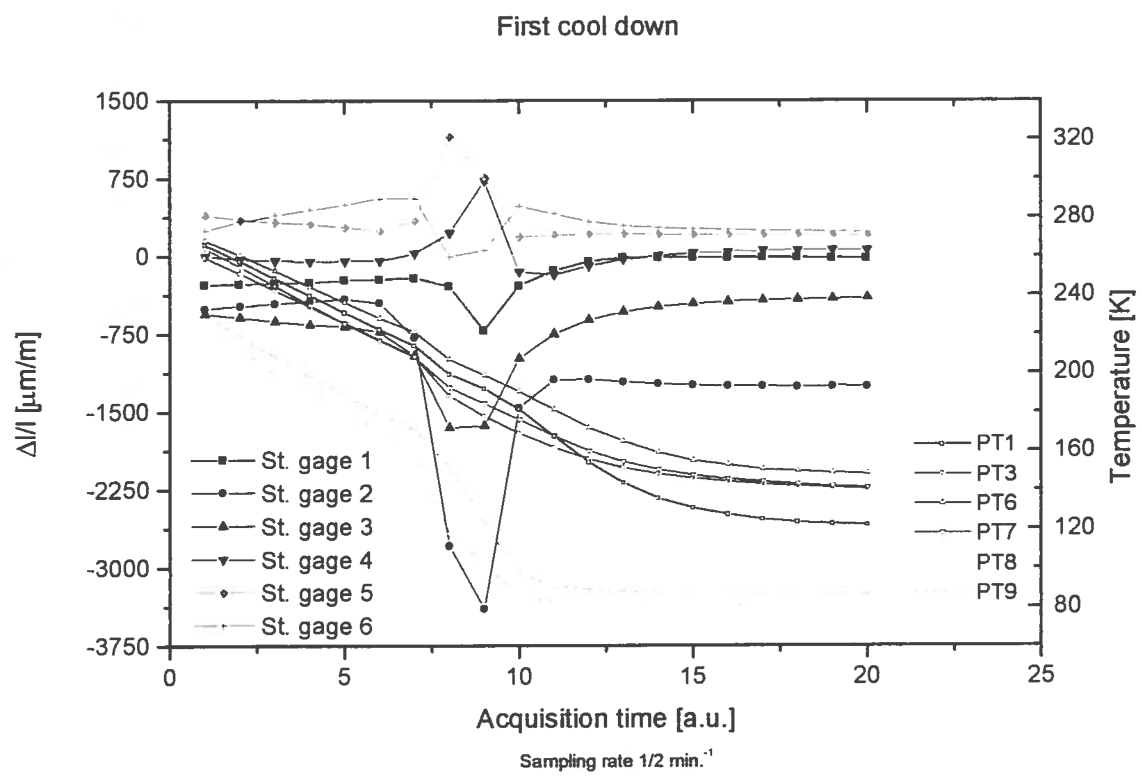

FIG 5 - First cool down.

Fig. 6 shows the data of the second run of measurement.

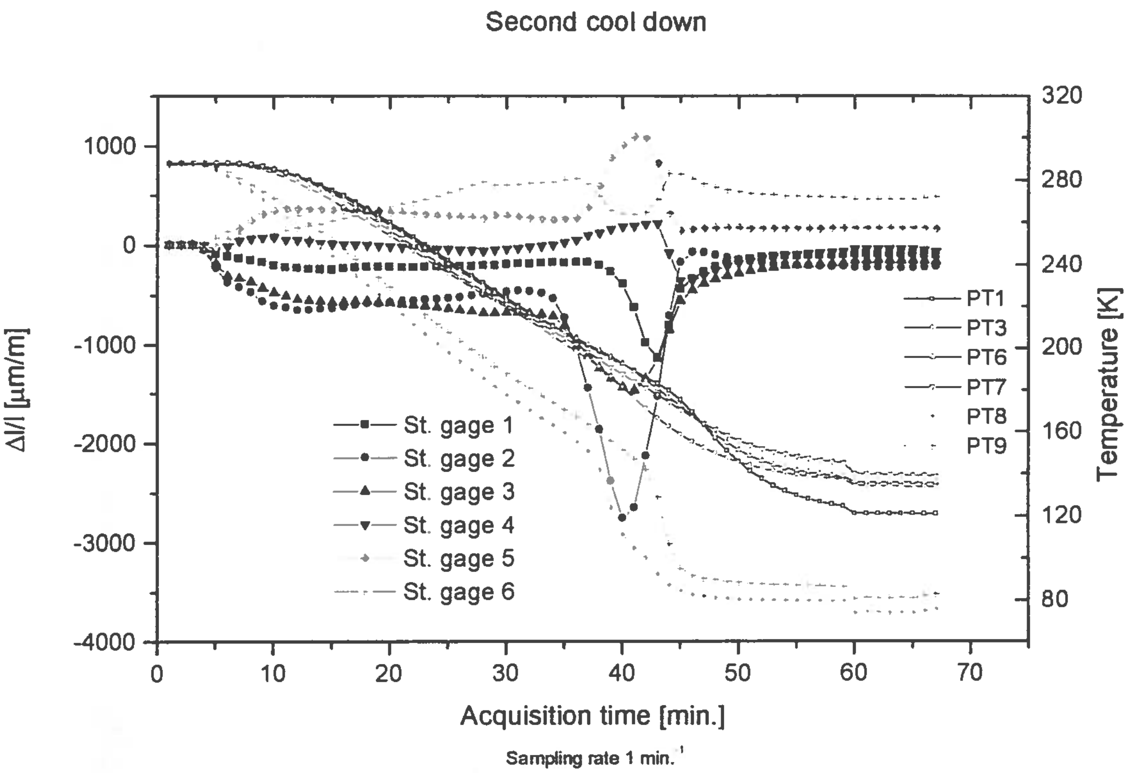

FIG 6 - Second cool down.

The sampling rate for this second experimental run was one acquisition every minute.

Being the data of the second cool down more complete, more frequently sampled and not so different from the first one, the analysis will be done on the data of the second cool down.

In Fig. 7 the data of the absolute length variation of the tie rods together with the data red on the horizontal dial gauges (upper part of the graph) are shown.

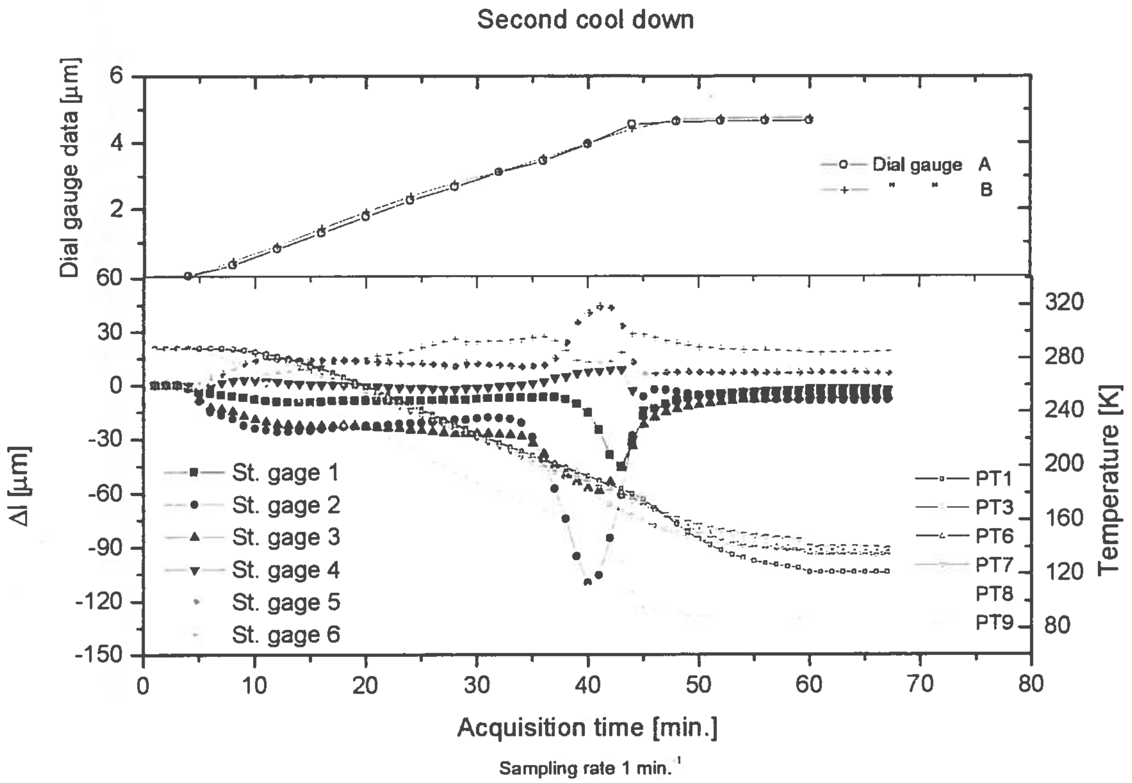

FIG 7 - Lower graph - Absolute deformation of the tie rods (left scale, solid symbols), temperature of the cold end of the tie rods and of the bar (right scale open symbol). Upper graph - Displacement of the ends of the bar as red on the dial gauges.

As can be seen from the figures the cool-down time was about one hour.

The rapid variation of the temperature of the bar around 120 K is due to the different cooling power between the gas and the liquid nitrogen, i.e. the nitrogen started to arrive in the liquid phase on the bar.

As from theoretical considerations(1) the maximum strain should be at about 200 K for all the tie rods, the shift to lower temperature is due to the higher values of the angles of mounting of the tie rods respect to the theoretical value, the relative shift of the maximum strain can be due to the same reason.

In Fig. 8 the data of all the dial gauges are shown.

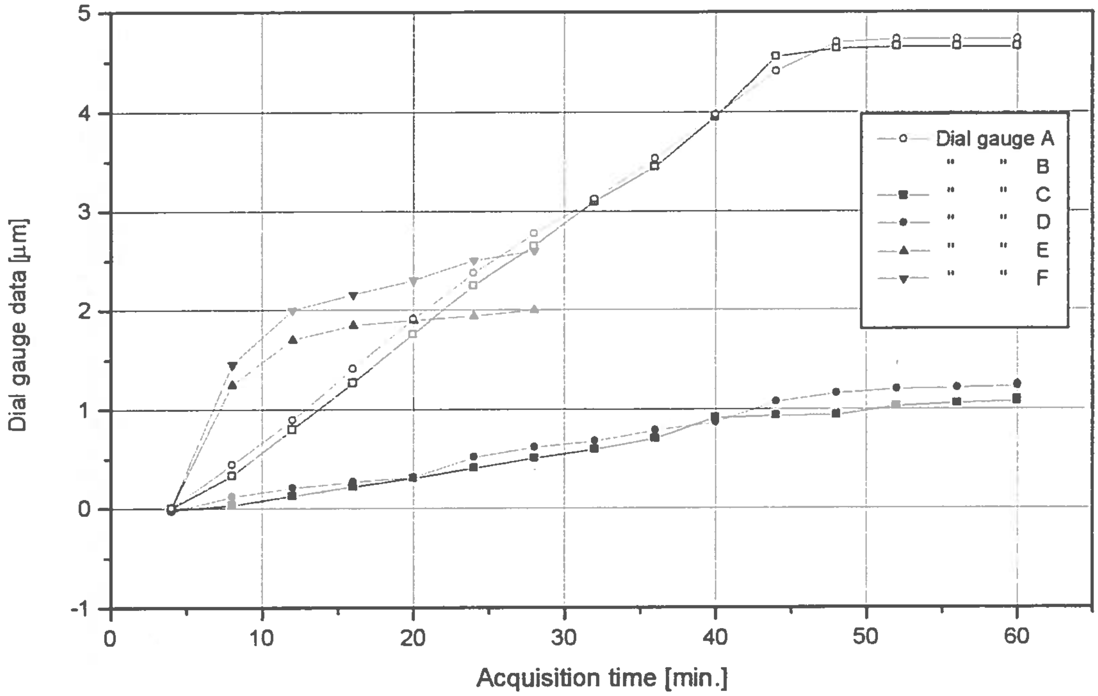

FIG 8 - Displacement of the bar as red on the dial gauges. A,B longitudinal movements (contraction); C,D vertical movements; E,F side movements.

As we can see the contraction of the bar is symmetrical on the two ends (dial gauge A and B), leading to a total longitudinal contraction of 9.37 mm, while the upward movement is of 1.096 mm and 1.242 mm as from the dial gauges C and D respectively.

The theoretical calculation of the thermal contraction of the tie rods, of the transverse dimension of the aluminum bar and of the small epoxy glass cylinders,used to make the mechanical contact between the dial gauges and the bar led to a value of 1.164 mm so the difference between this value and the mean value measured by the dial gauges (1.169 mm) is of 0.005 mm, showing a good agreement with the theoretical prediction and the measured values.

The evaluation of the longitudinal contraction led to a contraction of about 10.9 mm, while the measured value is about 14 % less as can be seen in figs. 7 and 8.

This discrepancy cannot be explained neither by the lateral movement, as from the data od the dial gauges E and F, nor by a misalignment of the bar during the contraction.

Probably the ice layer that formed on the bar during the cool-down could influence the global shrink of the bar and the stresses on the tie rods.

4. - CONCLUSIONS

This experience has demostrated the geometrical scale realization of the tie rods for the B0 test magnet and the Barrel Toroid for ATLAS. The precision of the measurements has been limited by the initial setting of the tie rods angle. The main result is the correct behaviour of the tie rods. In addition the data acquisition system and the related software that will be used for the magnets foreseen have been tested.

The test magnets (race-track, B0) and the ATLAS Barrel Toroid will operate in vacuum and with a suited thermal shield, so there will not be the indetermination and discrepancy in comparing the theoretical predictions and the experimental data.

5. - ACKNOWLEDGMENTS

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