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BIS-mech-prototype

Assembly and measurements of a mechanical prototype of the BIS MDT chamber

K. Ekonomou — *Physics Department, Aristotle University of Thessaloniki, Thessaloniki, Greece*
Ch. Petridou — *Physics Department, Aristotle University of Thessaloniki, Thessaloniki, Greece*
D. Sampsonidis — *Physics Department, Aristotle University of Thessaloniki, Thessaloniki, Greece*
J. Wotschack — *CERN and Physics Department, Aristotle University of Thessaloniki, Thessaloniki, Greece*

Abstract

A mechanical prototype of the BIS chamber has been assembled at the University of Thessaloniki. The prototype is described, experience in the assembly is reported, and results of deformation measurements under gravitational loads and for different chamber orientations are given.

1 Introduction

In order to gain experience with the assembly of the BIS MDT chambers for the ATLAS muon spectrometer a mechanical prototype has been assembled. The purpose of this prototype was not to reach the required precision in the construction of the chamber but to study the behaviour of the chamber under gravitational and thermal load in its different orientations in the detector.

Furthermore it is used to gain some experience with the auxiliary equipment of the chamber such as the chamber support, the Faraday cage, the protection covers, the in-plane alignment, temperature sensors, etc.

2 General description of the prototype

A sketch of the prototype BIS chamber is shown in Figure 1.The prototype resembles the final BIS chamber in most aspects, however, no effort was made to use any jigging for the assembly of the chamber. The chamber consists of two multilayers (ML) composed of four layers of 30 aluminium drift tubes each. The tubes had been recuperated from CERN, they were left-overs from the BOL and BML tube production at CERN. They have a diameter of 30 mm and a wall thickness of 0.4 mm. Within a ML the tubes are close-packed with a wire pitch of 30.0 mm. The MLs are separated from each other by about 8 mm. The arrangement of the tubes in the two MLs is mirror symmetric w.r.t. the mid-plane (x–y plane) of the chamber.

The chamber is supported via three kinematical mounting blocks connected to the top ML. The same support scheme as for module 0 has been realized, however, the distance of the rail centre from the upper ML is slightly larger than for module 0 and the support blocks are 230 mm from the tube ends instead of the 200 mm foreseen for module 0.

The outside of the two ML is covered by a layer of 30 mm thick insulating material and a 0.5 mm thick sheet of aluminium serving at the same time as thermal and shock protection.

The tubes (including the endplugs) are 1700 mm long; there are 30 tubes per layer leading to a total length (z-direction) of the chamber of 915 mm.

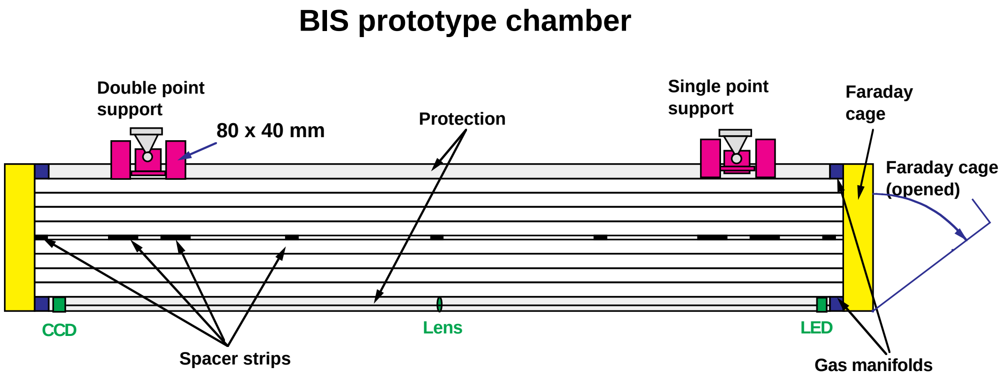

Figure 1: Sketch of a standard BIS chamber

The in-plane alignment system consists of a single ray RASNIK system and is mounted on the outside of the bottom ML. It is embedded in the thermal insulation and protected to the outside by the aluminium cover.

For the construction standard materials as found on the market were used; these materials and their dimensions are not always exactly identical to the ones foreseen for module 0.

A view of the almost completed chamber (missing are the Faraday cage side plates and the cover and the protection layer on the top of the chamber) on its support stand is shown in Figure 2.

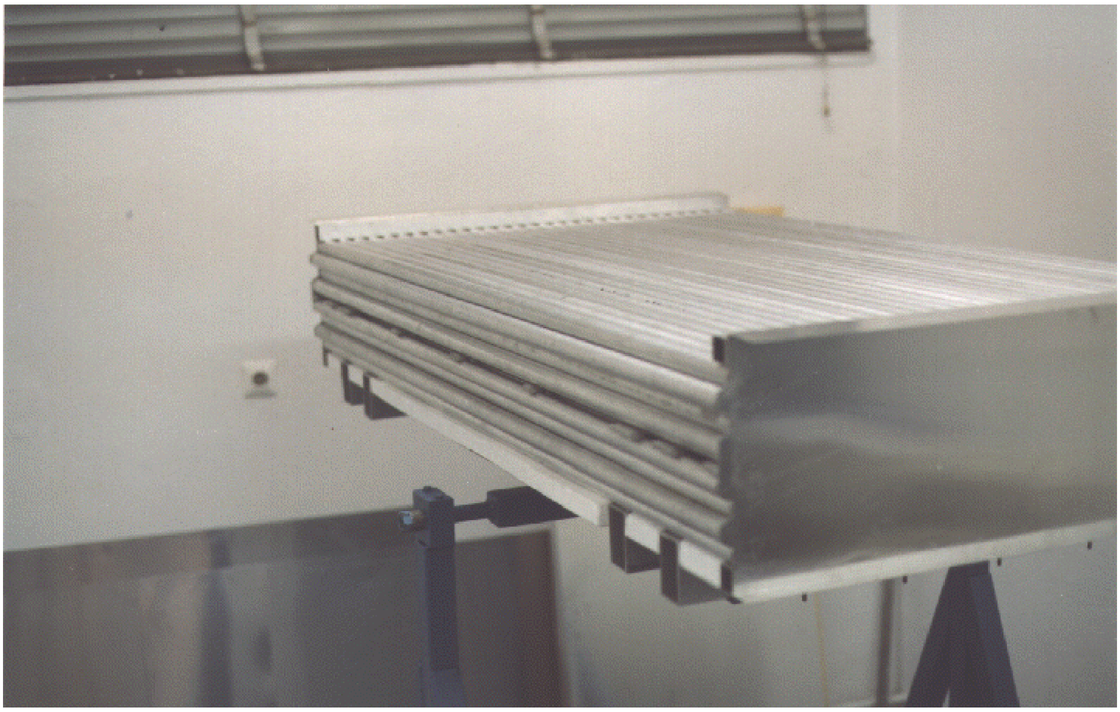

Figure 2: BIS chamber mechanical prototype almost completed. The chamber is supported on a support frame designed to allow for the rotation of the chamber into any orientation. Missing are here the top protection and the Faraday side and top covers.

3 Construction details

The mechanical prototype chamber differs from the module 0 chambers apart from the precision in the construction in several details; these differences are described below.

3.1 Multilayers

Bare tubes without wires but with dummy aluminium endplugs (53 g per endplug) were glued together on a granite plate with the tubes touching each other.

3.2 Spacer structure - cross strips

The cross strips are 8 mm thick instead of the 6 mm thick strips foreseen for module 0. There are a total of 9 (11) strips: two 60 mm and two 50 mm strips (the latter being made of two 25 mm strips) under the two support beams and five 25 mm wide strips. The latter are located at the tube ends, one in the middle, and two half way between the middle strip and the ones under the support beams. The spacer strips can be clearly seen in the photo of Figure 2.

3.3 Support

The support concept is the same as for module 0. Since no 55×55 mm square Al beams were readily available, these beams have been replaced by Al beams of 40×80 mm with a wall thickness of 3 mm (instead of the 5 mm as foreseen in module 0). The two U-shaped support plates of the double kinematic mount were made of 10 mm thick Al plates screwed and glued together. These plates are then glued between the two support beams. This can be seen in the photo of Figure 3.

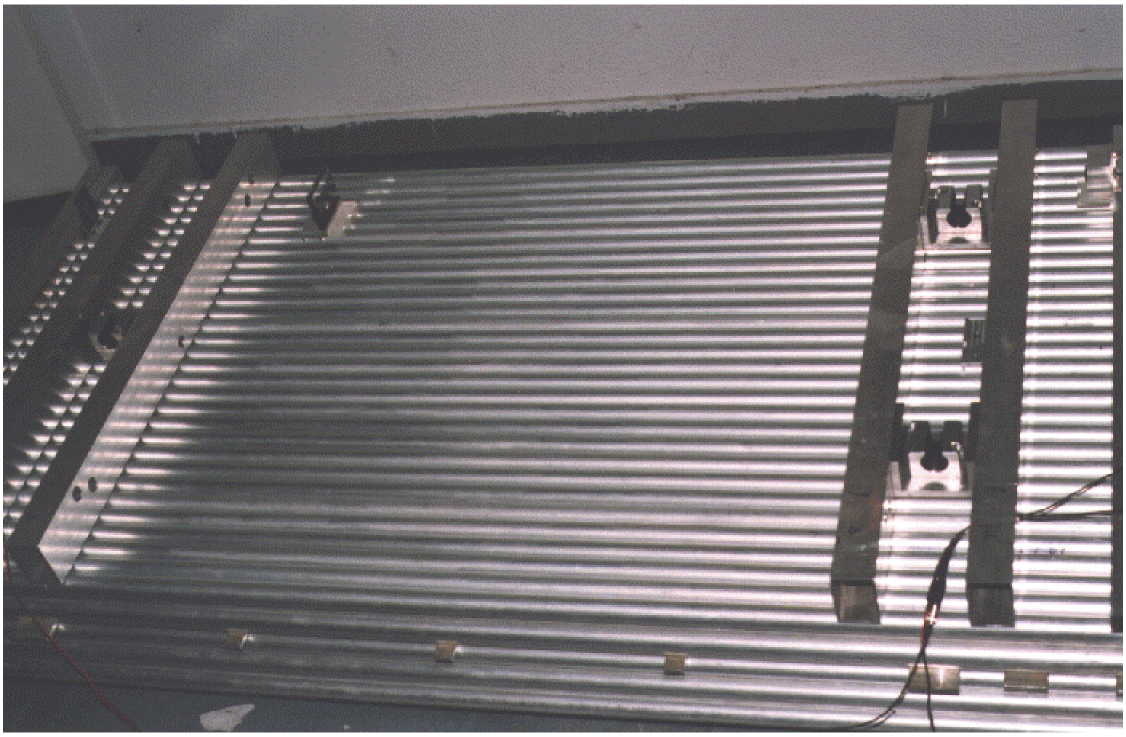

Figure 3: Double mount support on the right and the single mount support on the left. On the right the support beams and the kinematic mounts on their U-shaped support plates are clearly visible.

For the single point support a standard mounting block housing has been modified to allow for the sliding support on a steel rod. This is shown in a close-up view in Figure 4.

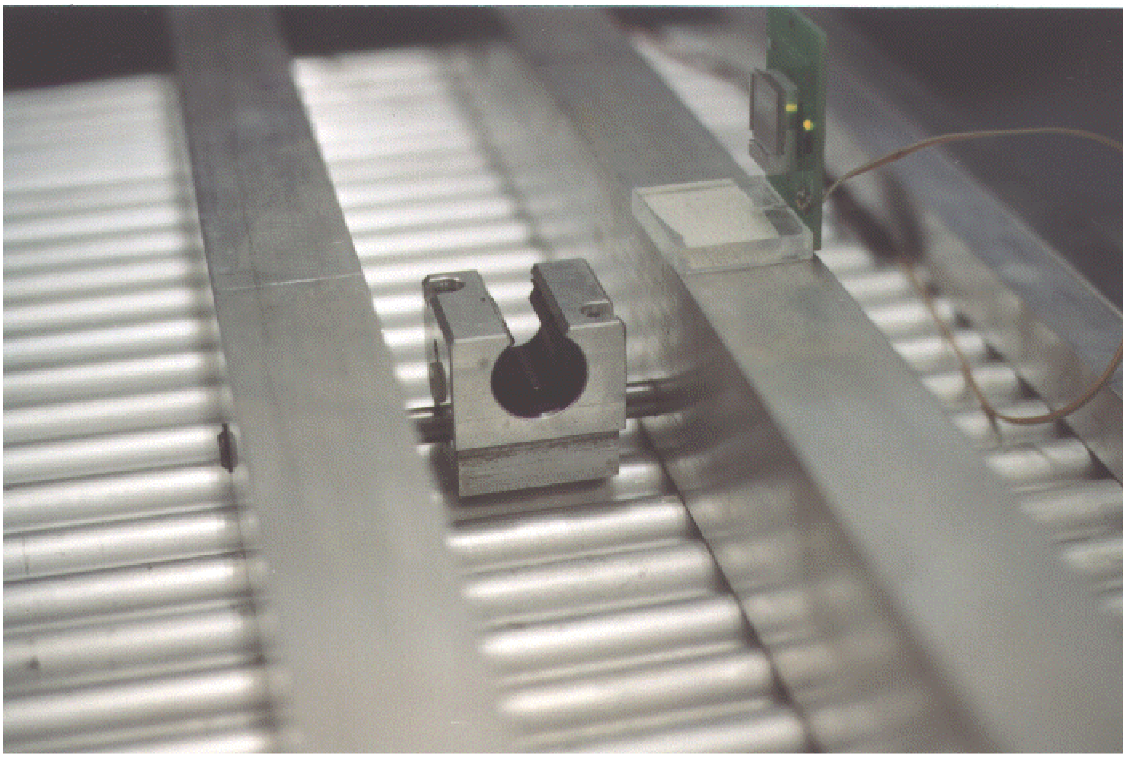

Figure 4: Detail of the single support kinematic mounting block on its transverse axis allowing for movements of the BIS support rails in the tube direction. On the right a temporarily installed LED/ mask of a RASNIK system is seen.

In the x-direction the mounting blocks are located at a distance of about 230 mm from the tube ends.

In the z direction the blocks of the double support are located at the Bessel points and the single support block is located on the middle line of the chamber w.r.t. its centre of gravity.

Because of implementation difficulties (which have to do with the support stand and are of no importance for the final chamber) the distance of the single support block w.r.t. the tubes is 5 mm bigger than the one of the double support system. This difference is compensated in the support stand by mounting the corresponding rails at the appropriate positions.

3.4 Electrical insulation

Not realized in the prototype.

3.5 Faraday cage

A single Faraday cage (FC) on each side covers both multilayers. It consists of a ground plate, two corrugated side pieces, and a cover which can be opened. It is made of 1 mm Al sheet material. Figure 5 shows the Faraday cage with its top cover being opened.

Figure 5: End face of the chamber showing the Faraday cage with its cover being opened. Note that in this position the chamber support is located below the chamber and the chamber is turned upside down compared to the sketch of Figure 1.

3.5.1 Ground plate

The ground plate (GP) is glued to the gas manifolds on the top and bottom and to (some of) the endplugs.

Along the top and bottom edges the GP has extensions folded by 90 degrees serving as connection pieces for the other parts of the FC.

3.5.2 Side plates

The side covers are shaped to follow the tube arrangement. The width of the piece is 58 mm. The pieces are glued to the extensions of the GP.

3.5.3 Cover

The FC is closed by an L-shaped cover. The long leg of the L is connected to the lower extension of the GP by two hinges such that it can be opened. When closed the short leg of the L overlaps with the upper folded part of the GP. Two turn-locks keep it in place.

3.6 In-plane alignment system

The in-plane alignment system consists of a single RASNIK system (LED+mask, lens, and CCD) mounted on the bottom multilayer. It is embedded into a 60 mm wide channel in the protection cover. The aluminium cover of the protection above the RASNIK elements is removable such that the RASNIK elements can be accessed for maintenance.

3.7 B-field and temperature sensors

The chamber can be equipped with up to 32 standard temperature sensors at varying locations.

3.8 Protection and thermal insulation

The chamber is covered on both outer faces by a protective layer which serves at the same time as thermal insulation. Styropor of 30 mm thickness is used as insulating material with a 0.5 mm thick sheet of aluminium glued to the outside of it. Figure 6 shows the top of the chamber covered with its protective cover.

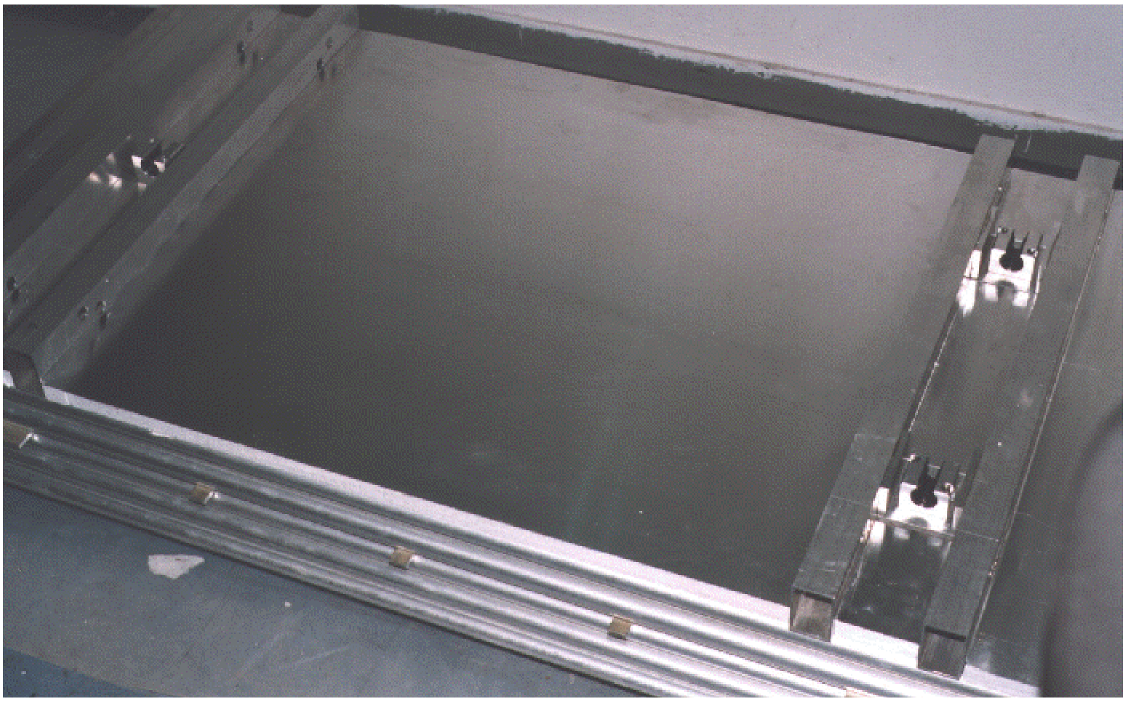

Figure 6: Top view of the chamber after the space between the gas manifolds and support beams has been covered with the protective/insulation cover.

4 Chamber assembly

The assembly of the prototype was made over a period of several weeks by a single person with occasional help of a second person. It proceeded along the following steps:

1. The tubes were glued together touching each other on flat table (non-precise granite plate) to make two individual multilayers (ML).
2. The support strips were glued to the bottom ML.
3. The top ML was glued to the strips.
4. The support beams (with the U-shaped suspension plates) were glued to the top ML.
5. The gas manifolds were glued to the top and bottom ML.
6. The Faraday cage ground plates were glued to the gas manifolds and the tube ends.

All these steps were done without aiming for high mechanical precision.

Standard Araldite two-component glue (type: 2011A/B) was used. The glue was applied by hand. Weights of several kilograms were placed on the parts to be glued together and the glue was left to cure over night after each glueing step.

5 Measurements of deformations under gravity

For the measurements of the chamber deformations a RASNIK system was used. Three different lenses were used. For the measurements along the tubes a lens with a focal length of 30 cm was used, the two others had shorter focal lengths.

All measurements presented here have been taken immediately after the completion of the chamber and are preliminary. In the next weeks these measurements will be repeated in a more complete and systematic way.

5.1 Deformation under load

The first series of measurements was done with the chamber in the horizontal position, placed on the floor. The chamber was supported on the two gas manifolds of the bottom ML. Weights were added on the top multilayer at three different locations as shown in Figure 7 and measurements were taken with the RASNIK in the three different positions as also indicated in Figure 7. For the measurements along lines A and B the weights were applied at the centre of the chamber. For the measurement along line C the weights were symmetrically distributed on the two sides as indicated in the figure. The results of the measurements are given in Figure 8. The sag shown is the sag in the middle of the chamber, extrapolated from the measured value under the assumption of a parabola shape of the chamber deformation.

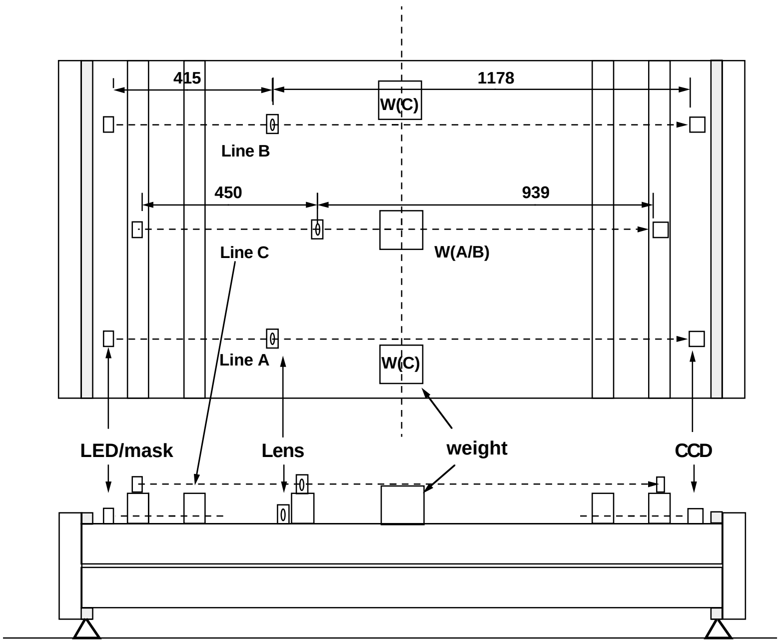

Figure 7: Setup of the chamber for the first series of measurements under gravitational loads with the chamber supported from its ends. Shown are the positions of the RASNIK elements and the place where the loads were applied to the chamber.

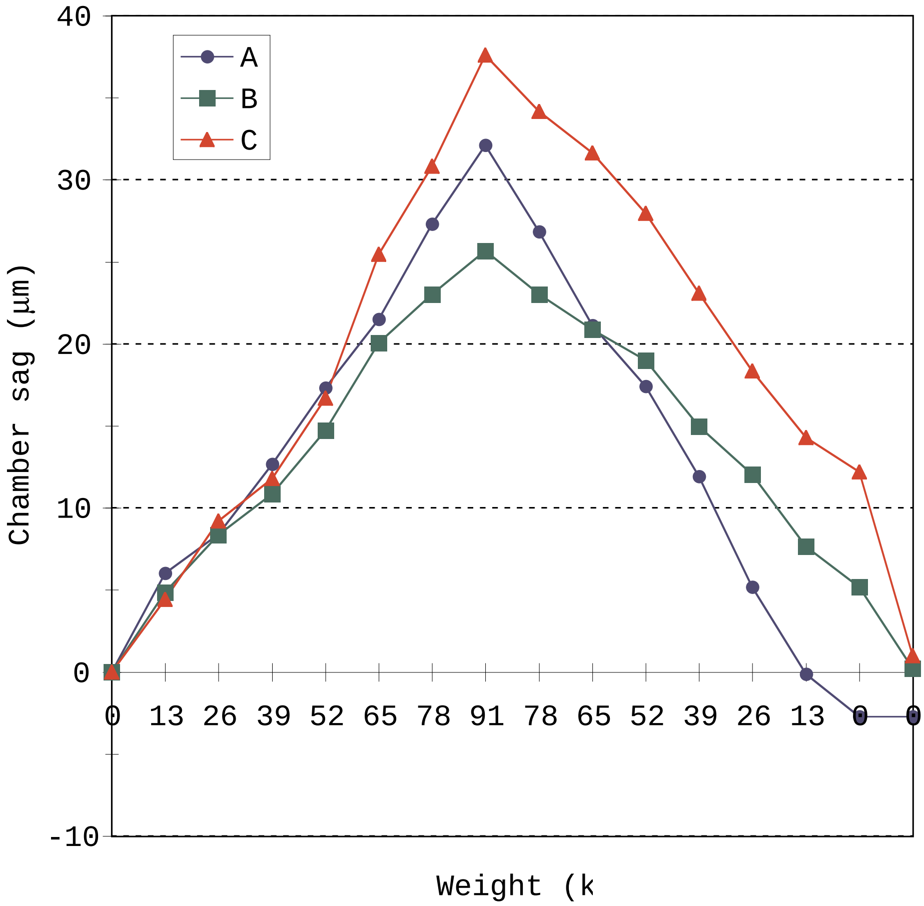

Figure 8: Results of the measurements with the chamber supported on the two gas manifolds, see Figure 7. Shown are deformations in µm as function of the added weights (kg). The last two points correspond to measurements with zero weight with 15 minutes difference in time.

The chamber sag is increasing about linearly up to about 35 µm for a load of about 90 kg and is then decreasing again. When all weights were removed the chamber came back to its original form within a few microns, however, only after some minutes of relaxation time. The differences in the deformations measured along the two sides of the chamber (lines A and B) and the sag measured along the centre line (C) at a level of up to 30% have not been analysed so far. Given that the deformations under load are very similar up to a load of about 50 kg the differences measured at bigger loads and on the descending slope may be the result of hysteresis effects. Successive measurements were taken within a few minutes; the effect of letting the chamber settle for about 15 minutes is visible in the difference between the two zero-load measurements at the end.

For a second series of measurements the chamber was supported on its proper kinematical supports on two 20 mm diameter rails, see Figure 9. With the chamber in the horizontal position the deformation of the chamber has been measured with the same weights added as in the first set of measurements. The results are shown in Figure 10. A similar qualitative behaviour as shown in Figure 8 is observed, however, with a maximum deformation which is about 20% smaller than in the case where the chamber was supported at the ends.

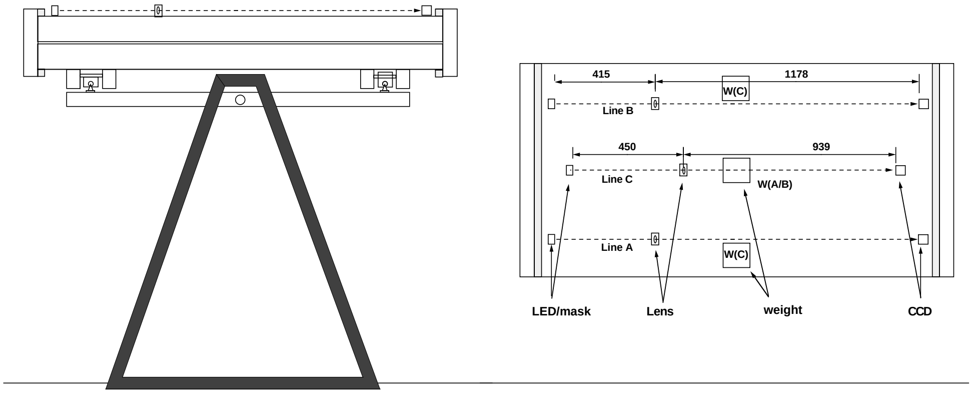

Figure 9: Setup of the chamber for the second series of measurements. The chamber is supported on its kinematical mounting blocks on two 20 mm diameter rails and placed in the horizontal position.

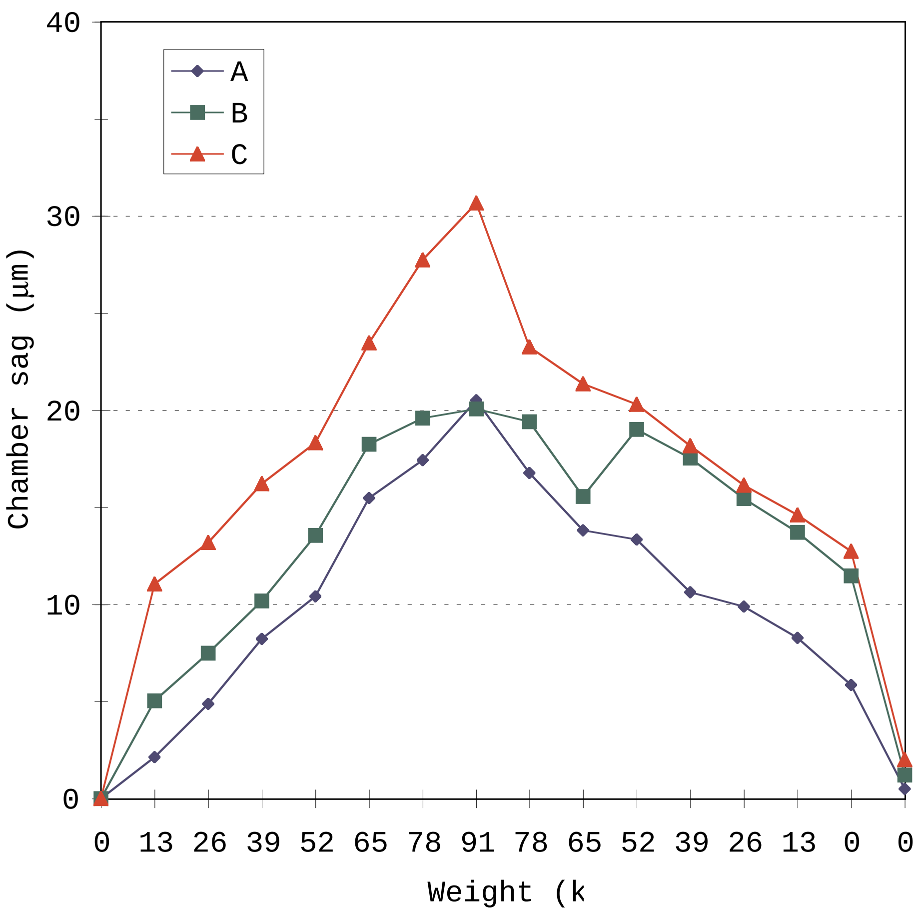

Figure 10: Results of the measurements with the chamber supported on its kinematical supports and in the horizontal position. Shown are deformations in µm as function of the added weights (kg). The last two points correspond to measurements with zero weight with 15 minutes difference in time.

5.2 Deformations as function of chamber orientation

In a third series of measurements the deformations of the chamber (without additional weights) have been measured with the chamber supported on its kinematical mounts in the eight different angular positions in which it will be installed in the ATLAS detector, see Figure 11.

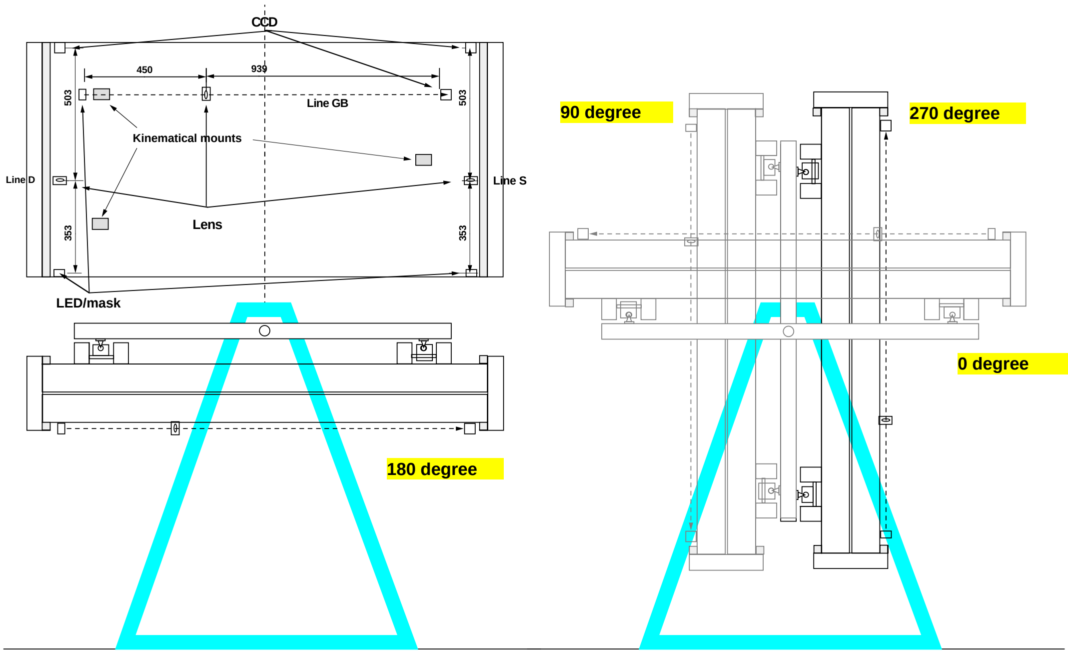

Figure 11: Setup of the chamber for the third series of measurements under gravitational loads with the chamber supported from its kinematical mounts. The chamber support frame can be rotated around the pivot point such that all eight positions of the chamber in the detector can be obtained. Shown are also the positions of the RASNIK elements for some of the measurements.

Deformations have been measured with the RASNIK elements in six different locations as shown in Figure 11 and Figure 13:

Line D: across the tubes close to the tube ends on the side of the double kinematical support;

Line S: across the tubes close to the tube ends on the side of the single kinematical support;

Line GB: along the tubes, with the RASNIK elements in the z position of a double support point and the mask and CCD on the support beams;

Lines LA and LB: along the sides of the chambers with the mask and CCD on the tube ends;

Line SM: over the support beams; with the mask at the tube end and the lens on the support beam.

The chamber positions in the detector are 22.5^o, 67.5^o, 112.5^o, etc. Note that the angle convention used here is not the same as used in the ATLAS detector. The 90^o position corresponds to sector 1 in the detector and 180^o corresponds to the upper sector (5) and/or the chamber in the horizontal position. For the convenience of the reader the sector numbers used in ATLAS corresponding to the respective rotation angles have been indicated in Figure 14.

5.2.1 Measurements across the tubes

Figure 12 shows the result for the measurements across the tubes near to the tube ends. While on the single support side all measurements are within a few microns identical the measurements on the double support side show a difference of the order of 15 µm between the chamber supports up and down. Since the zero line is arbitrary, and under the assumption that the deformation is the same (but with different sign) with the chamber up and down, this corresponds to a deformation of ±7.5 µm with respect to 'zero'.

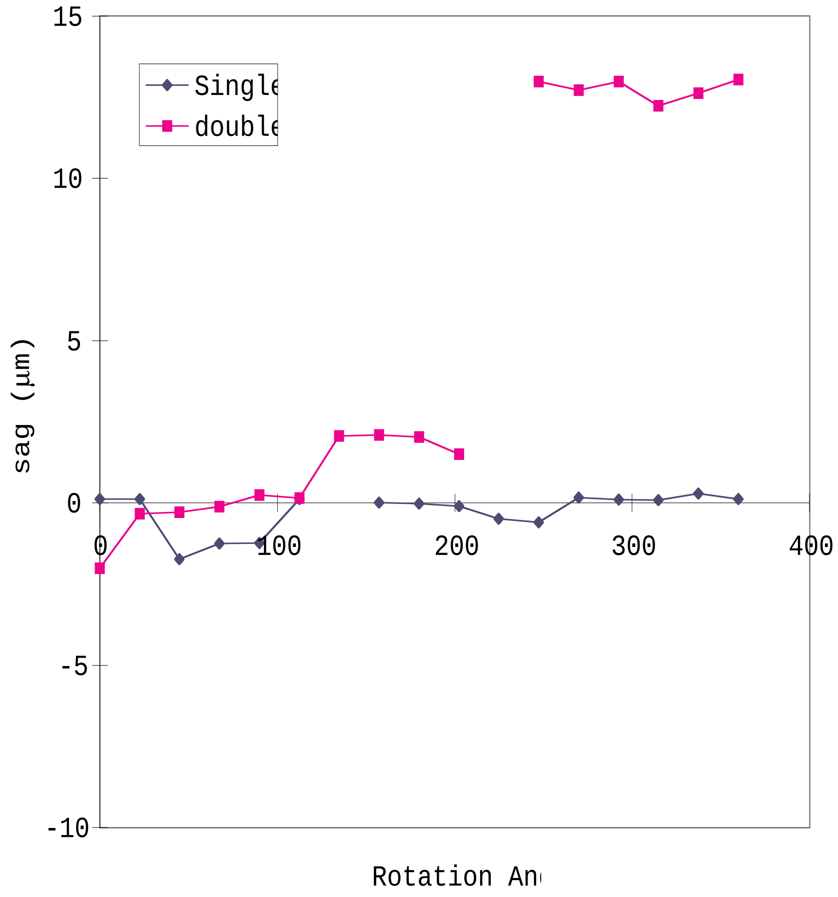

Figure 12: Deformation of the chamber as function of its angular orientation as measured across the tubes on the single and double support sides (Lines S and D).

5.2.2 Measurements along the tubes

Four sets of measurements were performed along the tube direction. The layout of the RASNIK system for the four sets of measurements is shown in Figure 13. Since the focal length of the lens is only 30 cm the lens could not be placed in the centre of the chamber where the biggest deformation is expected. The results have therefore been 'corrected' to a deformation in the centre of the chamber using the (not correct) assumption that the deformation has the form of a parabola. The results are given in Figure 14. For the GB measurement the parabola form is a fairly good approximation of the shape of the deformation. The LA and LB measurements measure the relative position of the tube ends w.r.t. the middle of the chamber, however, not taking into account the local deformation of the chamber because the support points are about 23 cm inwards of the tube ends. The SM measurement has been made to see these deformations.

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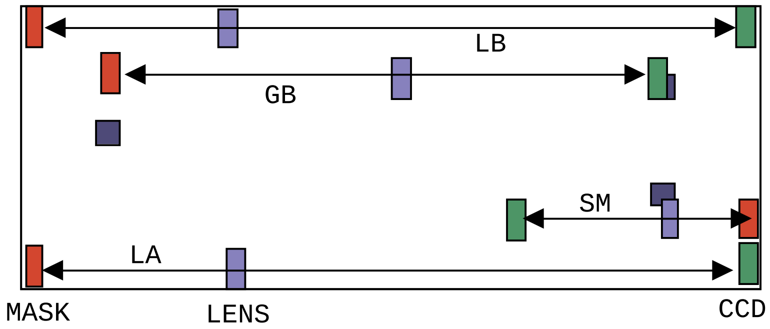

Figure 13: Layout of the RASNIK system for the measurements of the chamber deformation along the tubes as a function of rotation angle.

For two of the three sets of measurements along the tubes (LB and GB) the deformations are between ±10 µm. The LA measurements show a factor 2 larger deformations (but still OK); but these data should be taken with care because of potential problems with the RASNIK system at this line (will be verified in the next days). Note that the zero of the four measurements is arbitrary and that the measurements of each series should be taken as relative measurements within this series. The SM results show only very small deformations of the chamber across the support points.

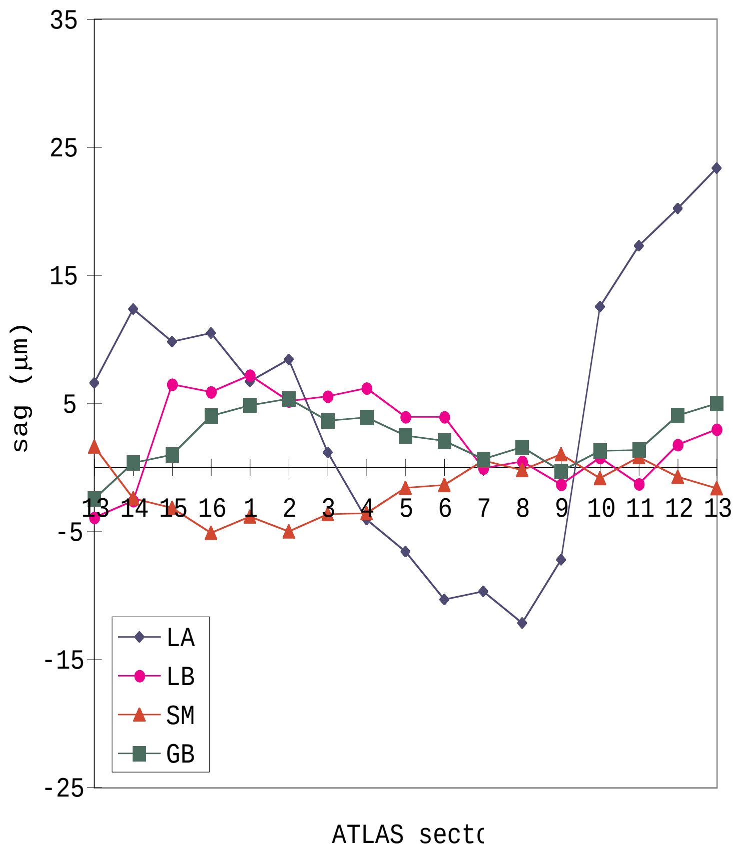

Figure 14: Chamber deformations as measured along the tubes as a function of chamber rotation angle for the four setup sketched in Figure 13.

In order to study the hysteresis effects the measurements along LB have been repeated, however, this time waiting each time 30 minutes after the chamber has been moved into a new position. The results are shown in Figure 15. The deformations are about a factor 1.5 larger than measured without waiting for the chamber to settle. The maximum deformation is less than ±15 µm.

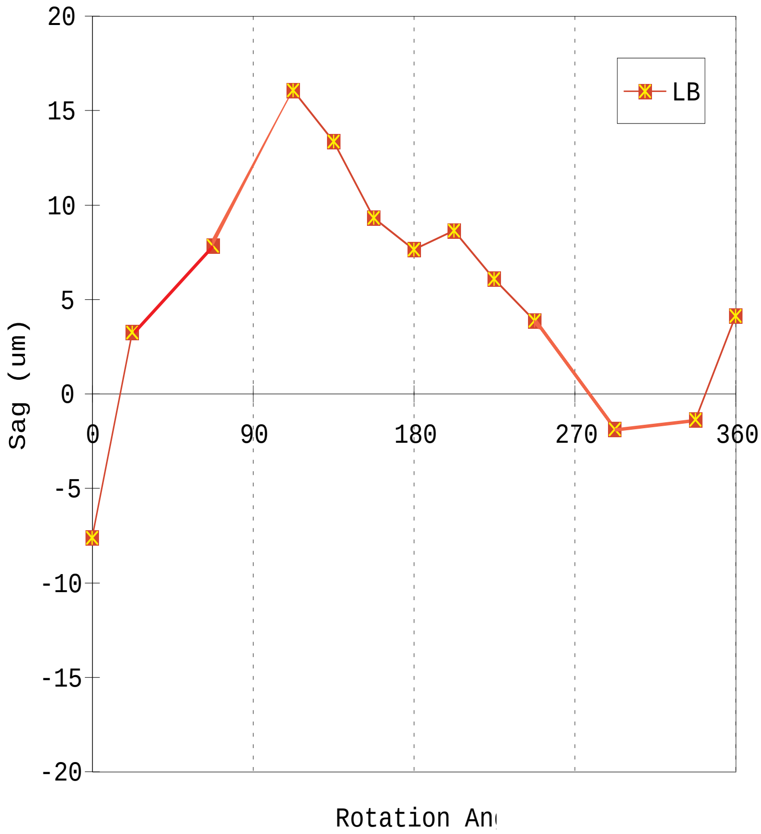

Figure 15: Same as Figure 14 for LB, however, waiting 30 minutes between turning the chamber into a new orientation and the measurements.

In order to understand the differences between the measurements shown in Figure 14 and Figure 15 the deformation of the chamber in the horizontal position (180^o) has been measured as a function of time over approximately one hour after it has been rotated by 180^o. The results of this measurement are given in Figure 16. They show clearly that the chamber deformation increases over about 30 minutes and then settles on a constant level which is about 10 µm larger than the initial deformation as shown in Figure 14 just after the chamber has been moved into its new orientation. The final deformation is consistent with the one shown in Figure 15.

6 Conclusions and outlook

The construction of the non precise mechanical prototype BIS chamber and its support scheme has been a very useful and helpful exercise.

The first measurements of the mechanical behaviour of the chamber are very encouraging and show that there are very small mechanical deformations of the chamber either under additional load or because of its support in different angular orientations. These results will be confronted

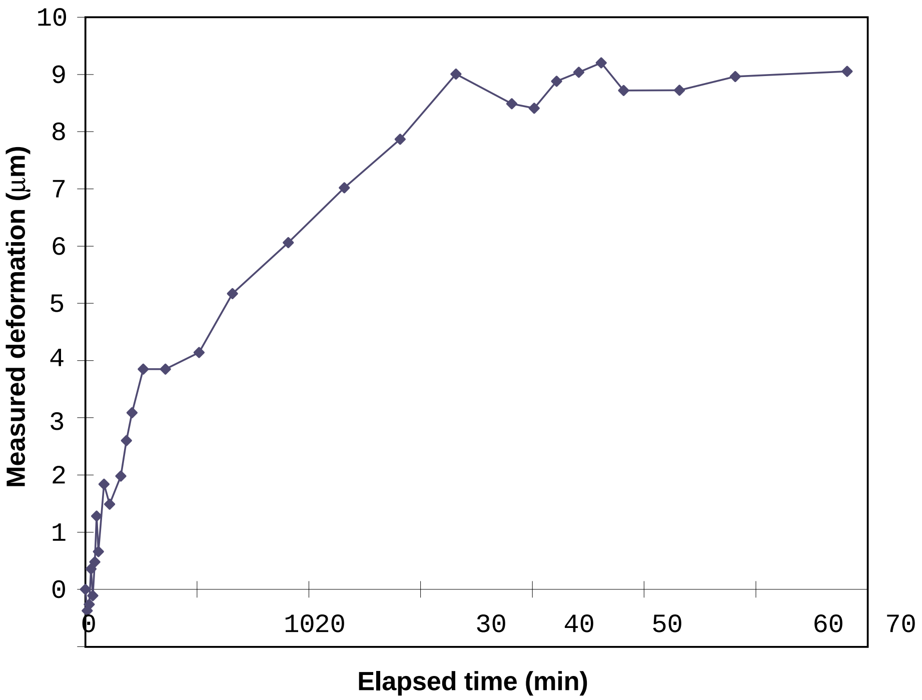

Figure 16: Measurement of the deformation along the LB line with the chamber in the horizontal orientation (180º) as function of the time of the measurement after the chamber had been put in position

with finite element calculations in the very near future. The comparison of the measurements with the calculations will be an important input for finalizing the drawings for the module 0 construction.

In a further series of measurements the thermal behaviour of the chamber will be studied. For this purpose the chamber will be equipped with 32 temperature sensors and the deformation of the chamber will be measured using again the RASNIK system.

The prototype will serve also to further study the implementation of auxiliary equipment and services on the chamber and will be of invaluable help to understand problems of chamber transport and storage.