ATLAS Muon Note
January 25, 2002

X-ray Tomograph results from two BIS Module 0 Chambers and improvements of the construction procedure on the basis of the results

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Abstract

Two BIS Module 0 chambers have been scanned at the X-ray tomograph at CERN. In this note the analysis of the x-ray tomograph data is presented. On the basis of the results from the first chamber we implemented improvements in the chamber construction procedure which were verified with the second prototype. The X-ray tomograph results are compared with the QA/QC measurements during the assembly. The geometrical parameters of the chambers determined from the tomograph are in agreement with the design values.

1. Introduction

The two BIS module 0 chambers constructed at the University of Thessaloniki in June 1999 and March 2000 have been scanned at the stereo X-ray tomograph at CERN. The drift tubes for the BIS chambers were assembled at the University of Athens and tested at the National Technical University of Athens [1],[2]. The BIS chamber consists of two multilayers (ML), each composed of four layers of drift tubes. The drift tubes (including the endplugs) are 1685 mm long. There are 30 tubes per layer leading to a total width (z-direction) of the chamber of 916 mm The chamber design, the construction method as well as the strict Quality Assurance / Quality Control (QA/QC) procedures during the assembly have been described in [3].

The X-Ray tomograph scans provide a two dimensional map of the wire positions. The wire position accuracy was estimated to be better than 6 μm [4]. The wire positions are fitted using a grid with five parameters which correspond to the geometrical parameters of the BIS chamber and are defined by the assembly tooling.

Several scans have been made across the tube layers at the X-ray tomograph. During the scans the chamber was supported (or suspended) on the three kinematical points using an appropriate frame. Figure 1 shows the scans performed with the BIS chamber in the two orientations. Five scans were made across the tubes numbered from p1 to p5 with the support points on top (scans r0) and five scans numbered from p6 to p10 with the support points at the bottom (scans r1) chamber rotated by 180° around the chamber x-axis (tube direction).

The specifications for the MDT chambers for the Barrel region are 20 μm r.m.s. deviation from the nominal values for the wire location in the assembled chamber in y and z directions.

In section 2 the results from the X-Ray tomograph on the tube planarity are given and compared with the QA/QC measurements during assembly for both modules. In section 3 the observed deformation on the first module 0 (Artemis) is analysed and the improvements in the construction method applied to the second module is presented together with results on the second module proving the correction of the problem. In section 4 the results of the fit with a grid using the chamber construction parameters is presented. Finally in section 5 our conclusions are given.

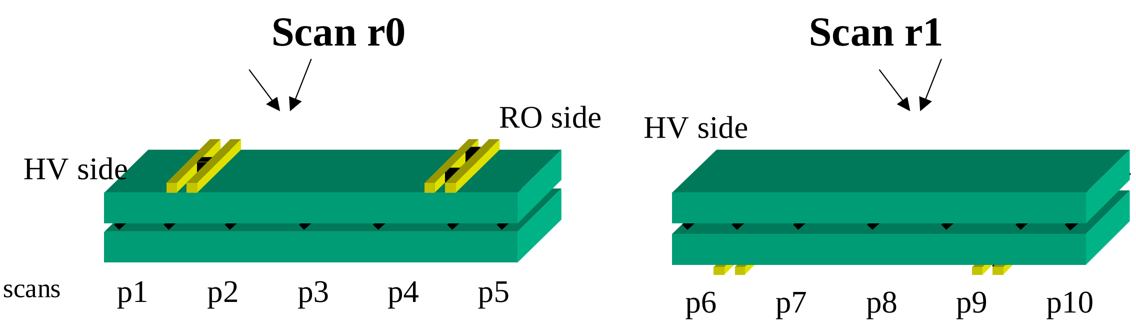

Figure 1: The various scans of the BIS chambers at two orientations.

2. Measurements of the tube layers' planarity

All the tube layers of the BIS chambers are glued on a set of jigs aligned on the granite table [3]. The shape (planarity) of each tube layer is determined by the jigs used in the assembly procedure. The X-tomograph data give the positions of the wires in the assembled chamber. The wire position within the tube is determined by the location of the two ends of the wire in the two endplugs of the tube. The tube position within the layer is determined by the jigs, particularly by the two outer jigs where the precision surface of the two endplugs sit.

As a result one expects the wire (tube) layer profile seen by the x-tomo to be influenced by both the procedures of tube assembly and chamber construction. The wire position inside the tube with respect to the centre of the end-plug was measured in the tube QA/QC [2] at NTUA. The tube layer planarity is controlled during the chamber assembly by measuring the endplug height while they are on the jigs [3].

Figure 2 shows the y residuals of the tube position fitted by a straight line for the BIS chamber Artemis at the HV side for the thirty tubes of each Layer. The data were averaged for the tubes of each Multilayer (ML1, fig 2 left and ML2, fig 2 right). The circle points correspond to the x-tomo measurements and the square points correspond to the endplug height measurements during the chamber assembly. The error is the standard deviation of the four measurements which correspond to the four layers of tubes.

From figure 2 it is evident that the wire positions seen by the x-tomo follow the same pattern as the tube height measurements which essentially comes from the jig shape. This can be explained from the fact that the wire location with respect to the center of the endplug varies in a range of 10 microns rms and is uncorrelated in z an y direction

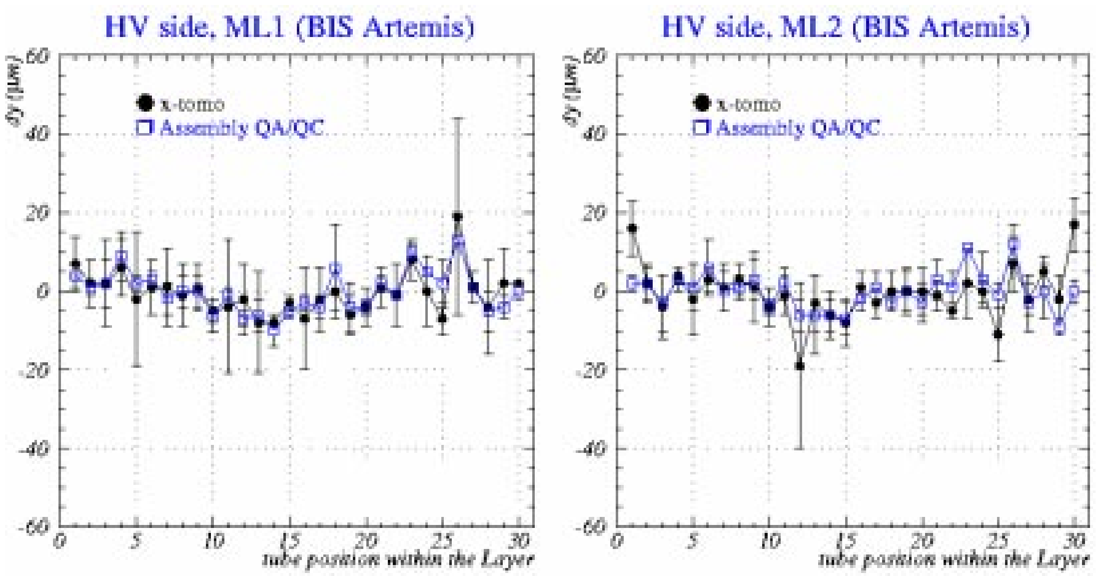

Figure 2: Average wire position in y for the ML1 (left) and ML2 (right) of BIS Artemis at HV side as measured by the X-ray tomograph (black circles). The open squares represent the average y tube position on jigs as measured during the chamber assembly QA/QC.

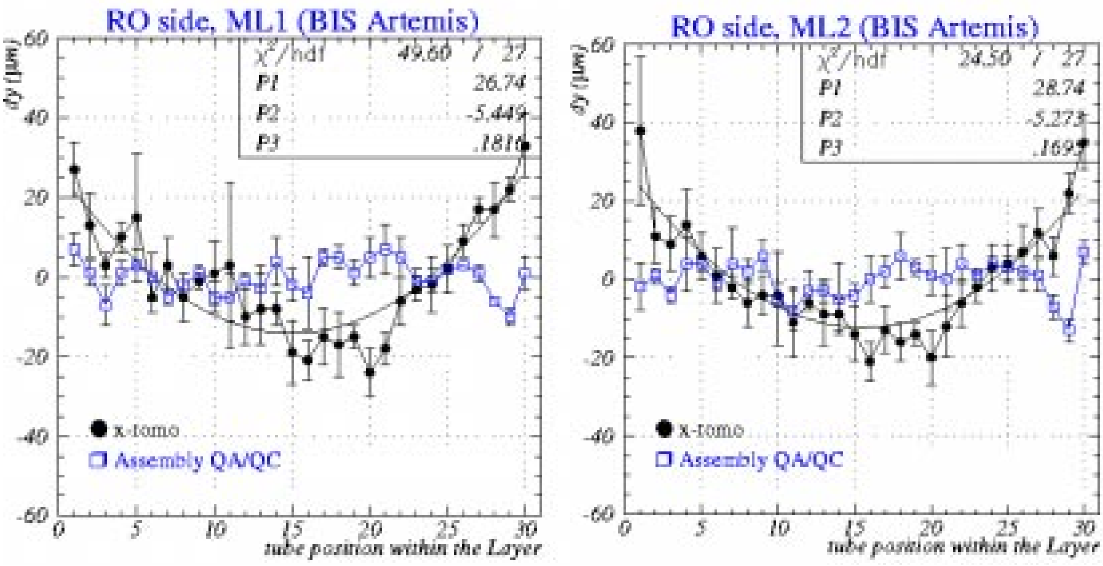

Figure 3: Average wire position in y for the ML1 and ML2 of BIS Artemis at RO side as measured by the X-ray tomograph (black circles). The open squares represent the average y tube position on jigs as measured during the chamber assembly QA/QC.

[2]. So, in the data averaged over the four tube layers contributes only in the error. The dominant factor for the resulted shape of the layer profile is the jig profile where the endplugs sit.

In figure 3 the results for the RO side are shown for the chamber suspended (r0 scans). The sag observed in the x-tomograph data is permanent as it was verified by the scans with the chamber supported (scans r1). This sag is originated by the gluing procedure followed for the support beams during the assembly of Artemis. The two support beams were glued together with the two U-pieces using a template. The most crucial point of the support beam assembly, which is shown in figure 4, is the planarity of the horizontal surfaces of the two U-pieces. These surfaces are the contact points of the chamber to the stiffback. If the two U pieces are not on the same horizontal plane,

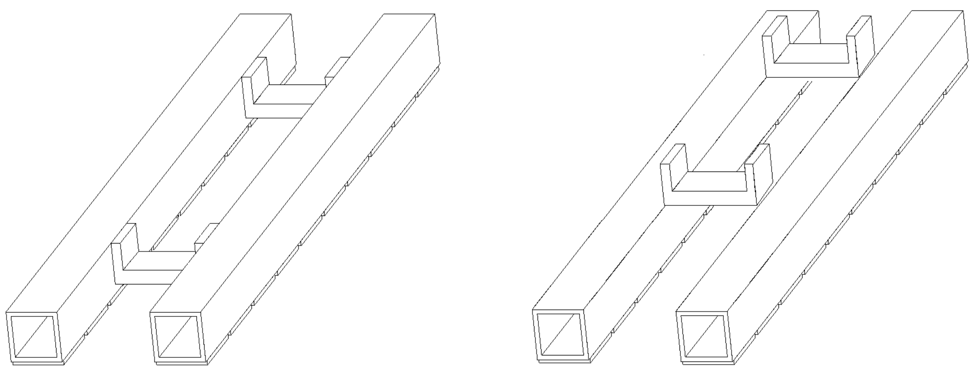

Figure 4: Assembly of the support beams with the U-pieces followed for the BIS chamber Artemis (left) and for the BIS Beatrice (right).

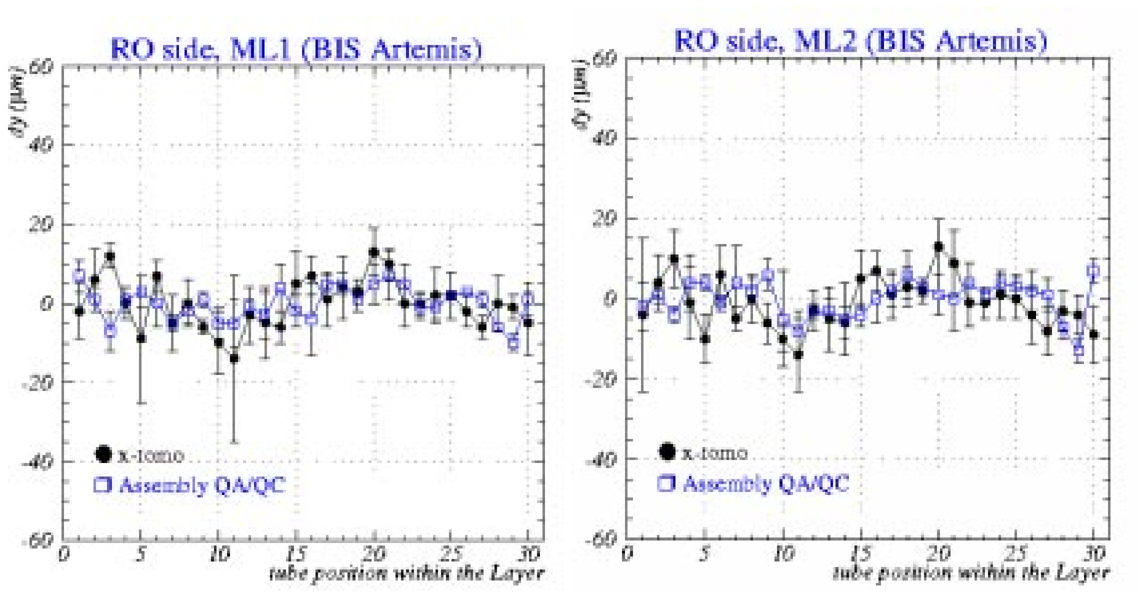

Figure 5: Average wire position in y for the ML1 and ML2 of BIS Artemis at RO side as measured by the X-tomograph (black circles), after the correction applied in order to exclude the permanent sag across the layers. The open squares represent the average y tube position on jigs as measured during the chamber assembly QA/QC

stress may develop from the fixing of the stiffback to the chamber while gluing the support beam assembly to the first tube layer. The stress is released after removing the stiffback from the chamber, thus resulting in a permanent deformation of the chamber as the one observed.

Removing this permanent deformation of the RO side by fitting the chamber sag with a second order polynomial and subtracting from the data, the x-tomo data follow the jig pattern as at HV side (Figure 5)

3. Controlling of the chamber permanent deformation

In order to avoid problems described in section 2 resulting to permanent chamber deformations without cost increase for the U-pieces fabrication controlled thickness and planarity to a few microns an alternative scheme was followed to glue the support beams on the chamber. The support beams are placed via two templates on the first tube layer. The U-pieces are first connected to the stiffback and then glued to the support beams (figure 4, right). The gluing of the U-pieces to the support beams and of the support beams to the first tube layer is done simultaneously once their position is verified by lowering the stiffback. That way the gluing of the support beam structure to the chamber is done free of stresses. Two Rasnik systems are used to monitor possible deformation of the support beams. The Rasniks are glued on the support beams before they are placed on the first tube layer while they are on the granite table controlled thickness and planarity to a few microns.

This method was followed in the second prototype. Data from the x-tomograph analysis of the second chamber Beatrice show that there is no deformation across the tubes. Figure 6 and 7 show the average y residuals of the wire positions for Multilayers 1 and 2 at HV and RO sides for the BIS chamber Beatrice. The x-tomograph data show a pattern similar to what was observed in chamber Artemis following the same originated from the jigs.

The BIS chamber Artemis was scanned in two orientations with a help of a frame. In the first case the chamber was suspended by the kinematical points and in the second one it was supported having the mounting blocks bellow the tubes (see figure 1). Figure 8 shows the chamber profile (y-residuals averaged for the eight layers) at RO and HV sides, for the two orientations (r0 and r1). Figure 9 shows the difference of the averaged y value of tubes in the two orientations r0 and r1, as a function of tube position within the layer for the HV and RO side respectively.

The difference between the two scans (r0-r1) on the RO side is less than ±10 μm. On the HV side the difference is also small, bellow 20 μm with the largest values at the two ends of the multilayers. This is related to the fact that there is a single point support on the HV side.

These results are in agreement with the studies made on a mechanical BIS prototype for deformations of the BIS chamber [4]. The studies had shown that the BIS chamber has the required stiffness.

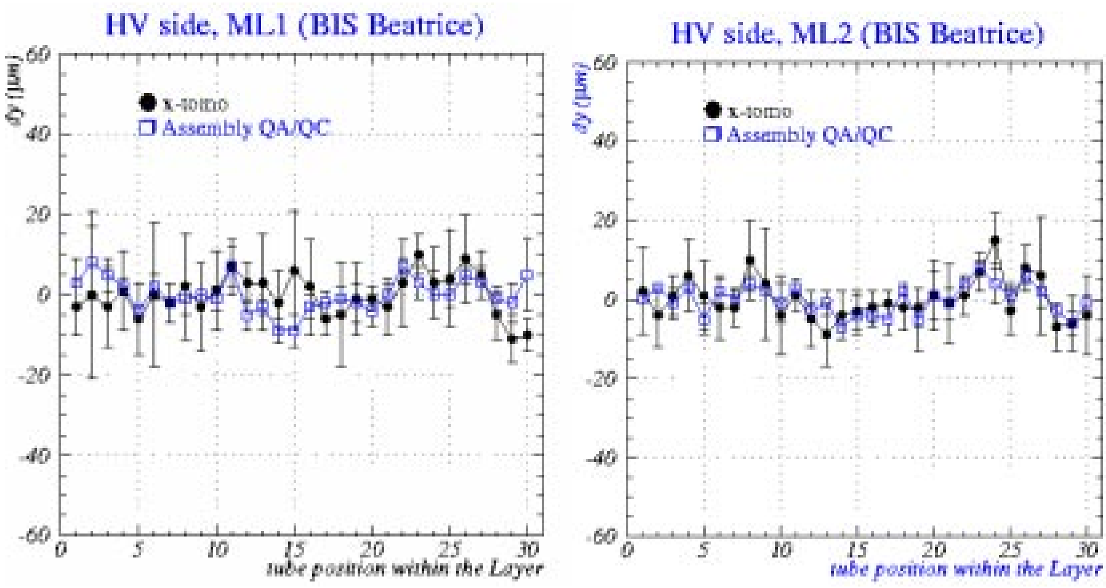

Figure 6: Average wire position in y for the ML1 and ML2 of BIS Beatrice at HV side as measured by the X-tomograph (black circles). The open squares represent the average y tube position on jigs as measured during the chamber assembly QA/QC.

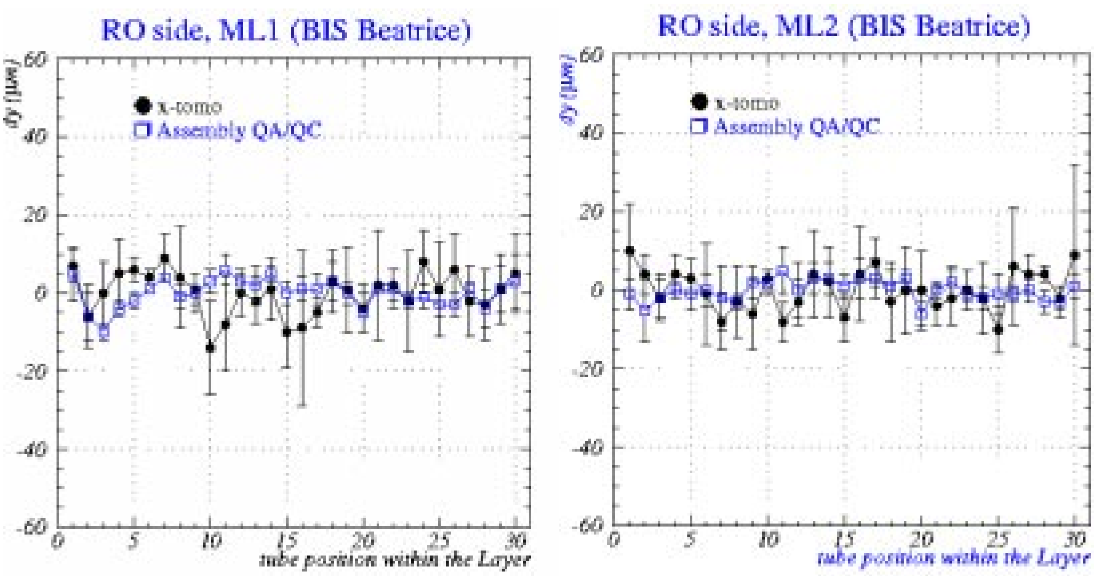

Figure 7: Average wire position in y for the ML1 and ML2 of BIS Beatrice at RO side as measured by the X-tomograph (black circles). The open squares represent the average y tube position on jigs as measured during the chamber assembly QA/QC.

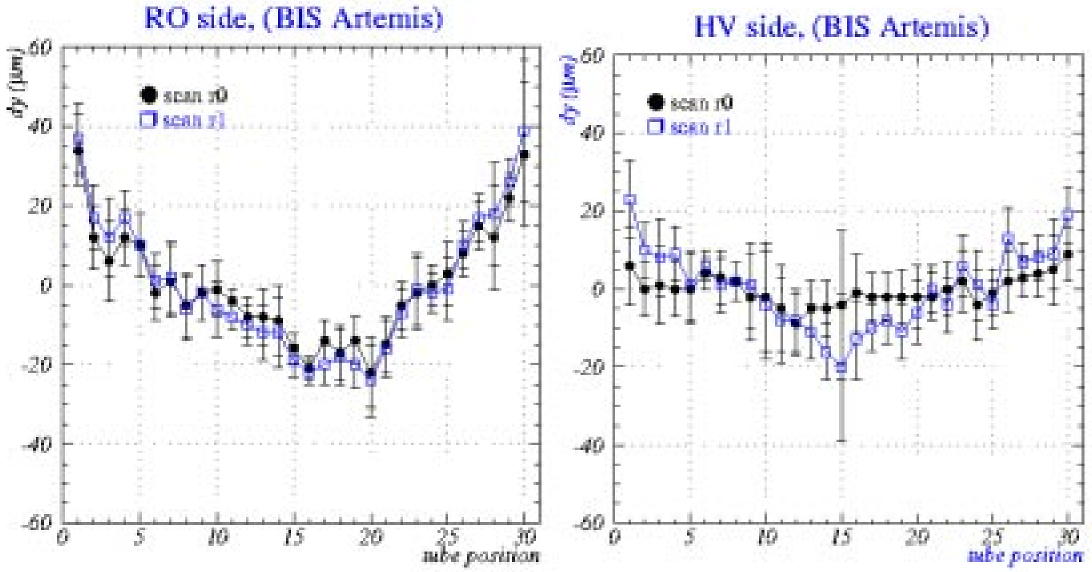

Figure 8 Average wire position in y for the RO and HV side of BIS Artemis as measured by the X-tomograph in the two orientations r0 (circles) and r1 (squares).

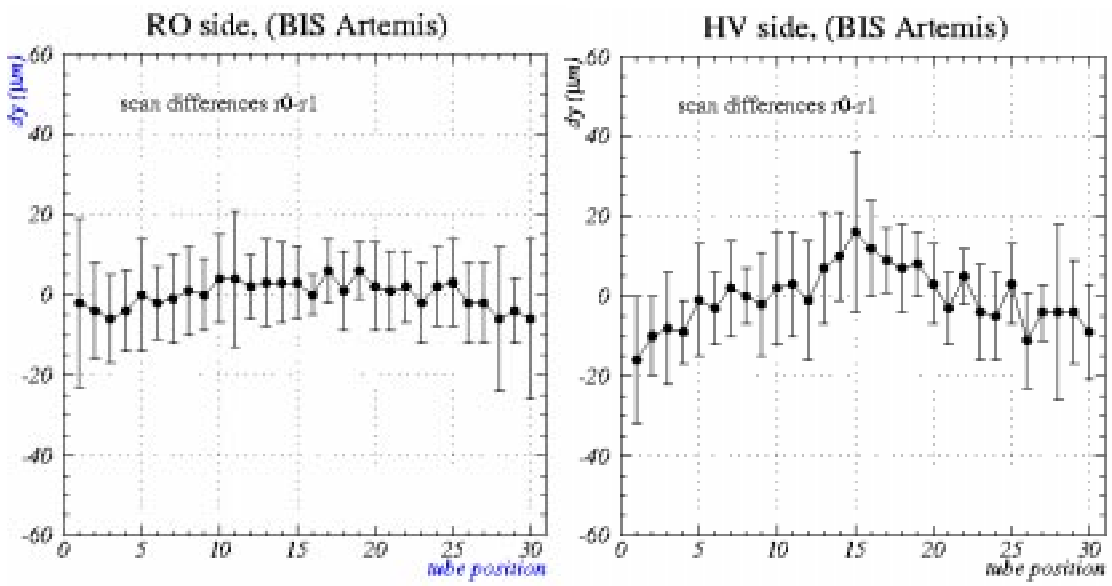

Figure 9: Difference of the two scans r0-r1of the average wire position in y for the RO and HV sides of the BIS Artemis.

4. Results with a Fitted Grid

The x-tomograph data were fitted with a five parameter grid. The grid parameters correspond to the geometrical properties of the chamber as defined by the measurements performed in Thessaloniki on the assembly tooling. These parameters are the wire pitch which is defined by the jigs (30.035±0.002 mm at 20°C), the distance between the tube layers (26.011±0.002 mm at 20°C) and the space between the two multilayers (38.545 mm) defined by the height blocks [2]. The other two parameters are the angle between the two multilayers and the horizontal shift between them.
The nominal values for the grid fit were

Table I	
BIS Nominal Parameters	
Wire pitch	30.035 mm
Layer Distance	26.011 mm
Multilayer Distance	38.545 mm
Relative Multilayer Shift	0 mm
Relative Multilayer Rotation	0 rad

The fitting of the data for BIS Artemis with the grid parameters fixed to the nominal values showed a horizontal shift of the top multilayer w.r.t the bottom one on the HV side of about 208 μm. On the RO side the relative shift of the two multilayers is in the opposite direction of 225 μm. This corresponds to relative rotation of the top multilayer with respect to the bottom multilayer. This effect is due to an accident happened during the chamber assembly as described in [3]. The shift and rotation are originated from the replacement of two broken base blocks during the assembly and has been measured by the Rasnik system during construction.

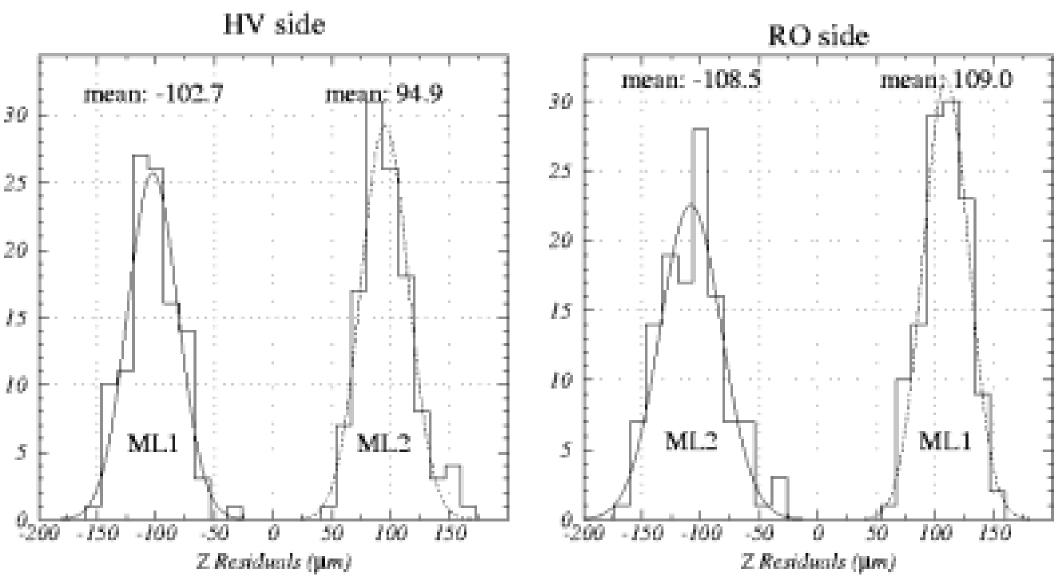

Figure 10: Distribution of the residuals in Z of the wire positions measured by the X-tomograph using a common grid fit with the five parameters fixed to the nominal values (BIS Artemis).

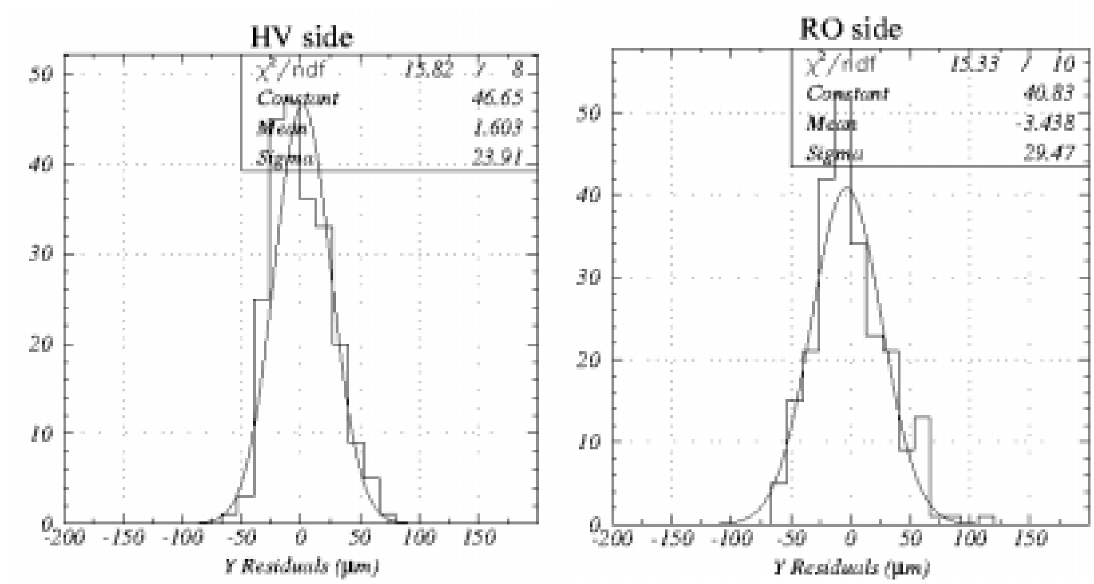

Figure 11: Distribution of the residuals in Y of the wire positions measured by the X-tomograph using a grid fit with the parameters fixed to the nominal values. (BIS Artemis)

Figure 10 shows the distribution of the residuals in Z of the wire positions measured by the X-tomograph with respect to the grid fit with the parameters fixed to the nominal values for the BIS Artemis for HV and RO sides. The two peaks correspond to the two multilayers and the distance between the peaks corresponds to the relative shift of the two multilayers. Figure 11 shows the distribution of the residuals of the wire positions in Y direction.

The data were also fitted with five parameters grid leaving the parameters free. The results of the grid parameters are shown in Mable M Figures 12 and 13 show the distribution of the residuals of the wire positions in Z and Y respectively, measured by the X-tomograph with respect to the grid fit with the parameters free.

The results show that besides the relative rotation and shift of the two multilayers, which were recorded by the QA/QC procedure, the quality of the BIS chamber Artemis fulfill the specifications and its parameters are in agreement with the designed parameters.

The results from the grid fit of the X-tomograph data for the BIS chamber Beatrice are shown in M ble M and figures 14 to 17.

Table II (Artemis)

				Pitch (Z) (μm)		Pitch (Y) mm		St dev
	dZ(μm)	dY(mm)	dA(μrad)	ML1	ML2	ML1	ML2	Mm
Nominal	*0*	*36.545*	*0*	*35*		*26.011*		
Scan								
P1 (HV)	-207	36.519	-2.1	36.6	37.2	26.018	26.009	**13.0**
P2	-83.5	36.515	-4.3	36.7	37.2	26.018	26.010	**11.7**
P3	-8.5	36.512	-0.5	36.6	37.3	26.017	26.011	**11.7**
P4	107.9	36.512	-11.6	36.8	37.5	26.018	26.011	**13.3**
P5 (RO)	224.8	36.504	0.6	36.8	37.5	26.018	26.012	**14.5**

Table III (Beatrice)

				Pitch (Z) (μm)		Pitch (Y) mm		St dev
	dZ(μm)	dY(mm)	dA(μrad)	ML1	ML2	ML1	ML2	μm
Nominal	*0*	*36.545*	*0*	*35*		*26.011*		
Scan								
P1 (HV)	30	36.525	-10.8	34.4	33.9	26.015	26.016	**10.9**
P2	13	36.513	-44.6	34.5	33.9	26.012	26.011	**9.4**
P3	2	36.504	-59.5	34.6	34.0	26.010	26.007	**9.4**
P4	-11	36.494	-86.6	34.6	34.1	26.007	26.003	**10.1**
P5 (RO)	-28	36.481	-115	34.6	34.0	26.004	25.997	**12.6**

5. Conclusions

The two BIS Module 0 chambers have been scanned at the X-ray tomograph at CERN. The complete data have been analyzed.

The fitted geometrical parameters for both chambers agree with the designed ones and the chamber specifications.

The permanent deformation observed in BIS Artemis was correctly attributed to the construction procedure. The modified construction procedure applied to the second module 0 Beatrice solved the problem as it was verified by the X-tomoograph measurements and results for Beatrice.

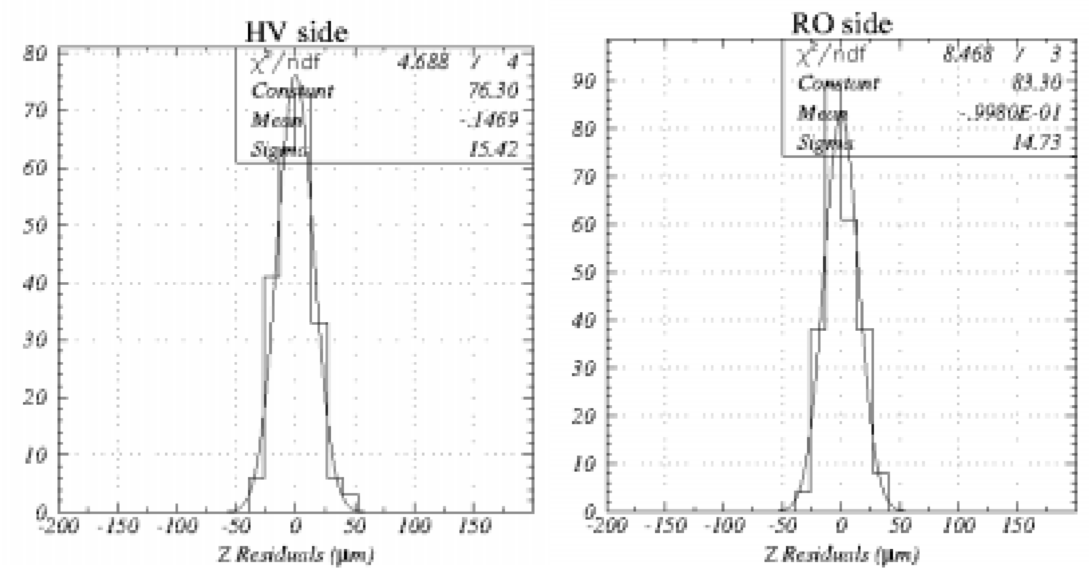

Figure 12: Distribution of the residuals in Z of the wire positions measured by the X-tomograph with respect to the grid fit with the parameters free (BIS Artemis).

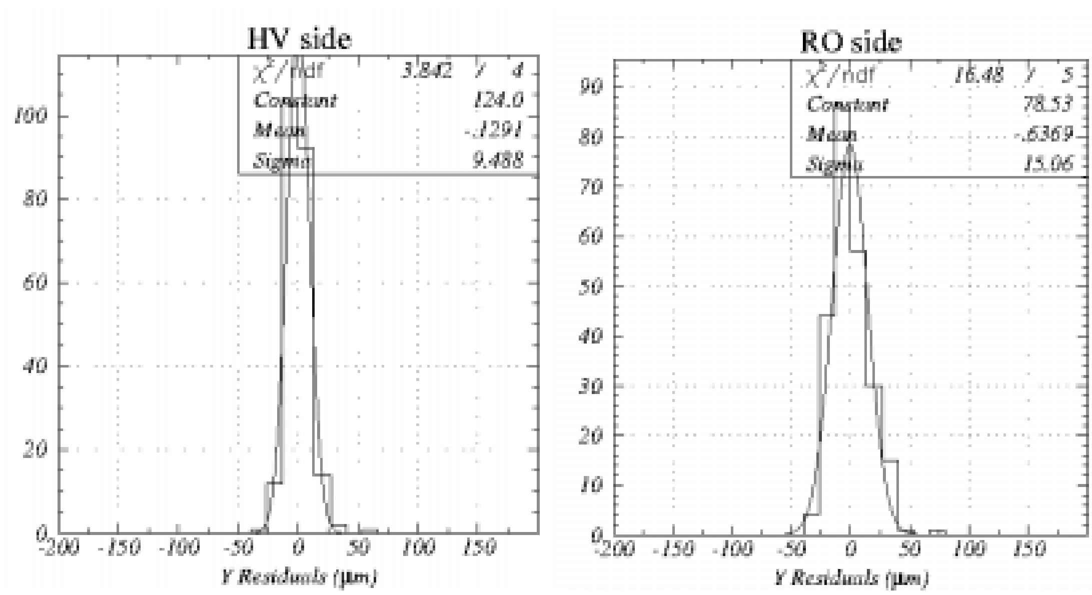

Figure 13: Distribution of the residuals in Y of the wire positions measured by the X-tomograph with respect to the grid fit with the parameters free (BIS Artemis).

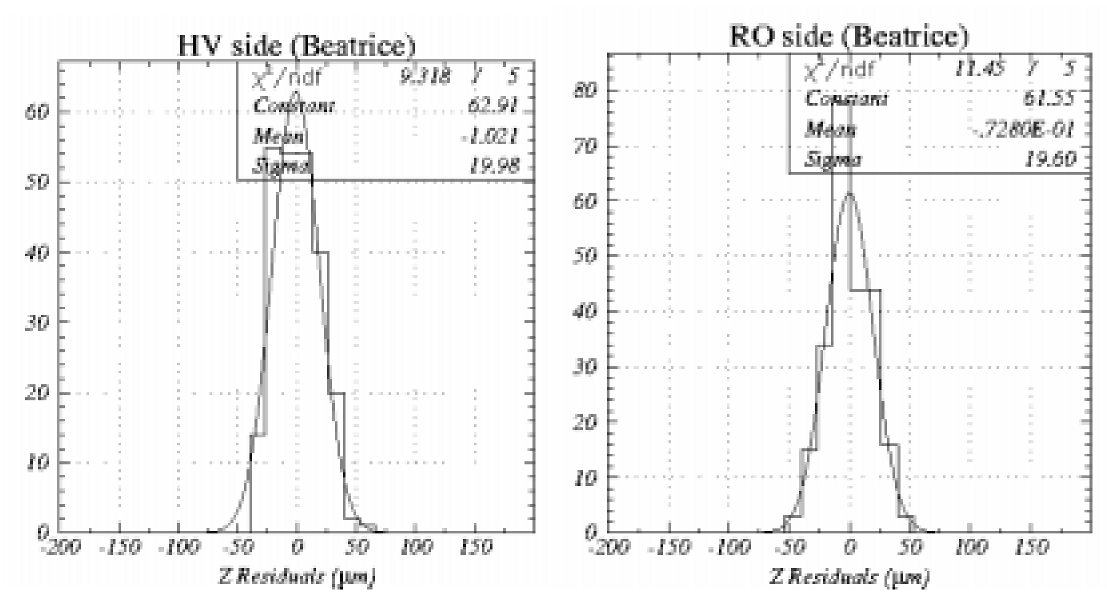

Figure 14: Distribution of the residuals in Z of the wire positions measured by the X-tomograph with respect to the grid fit with the parameters fixed to the nominal values. (BIS Beatrice)

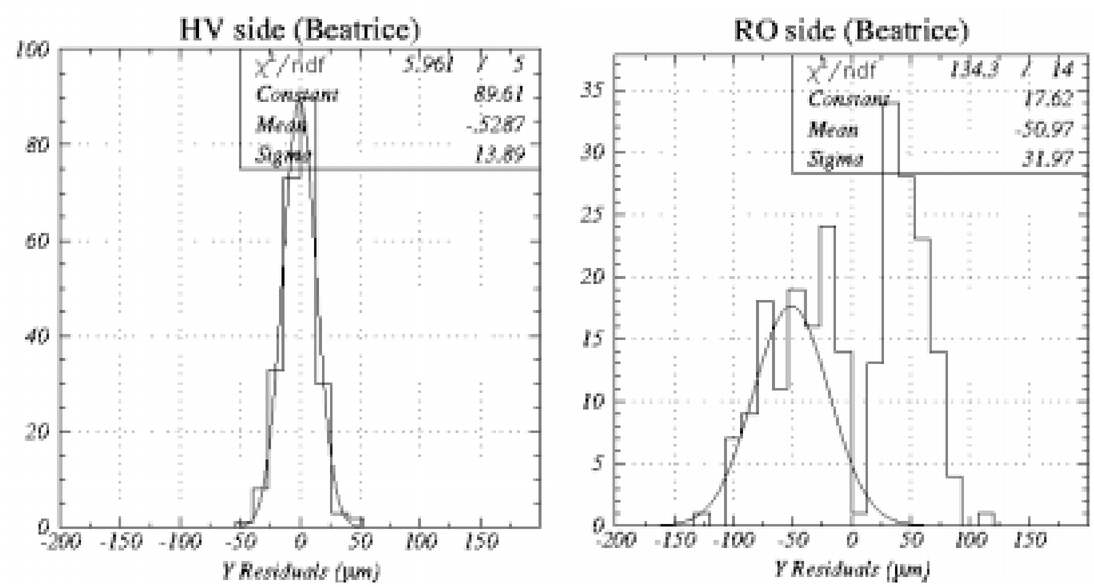

Figure 15: Distribution of the residuals in Y of the wire positions measured by the X-tomograph with respect to the grid fit with the parameters fixed to the nominal values. (BIS Beatrice)

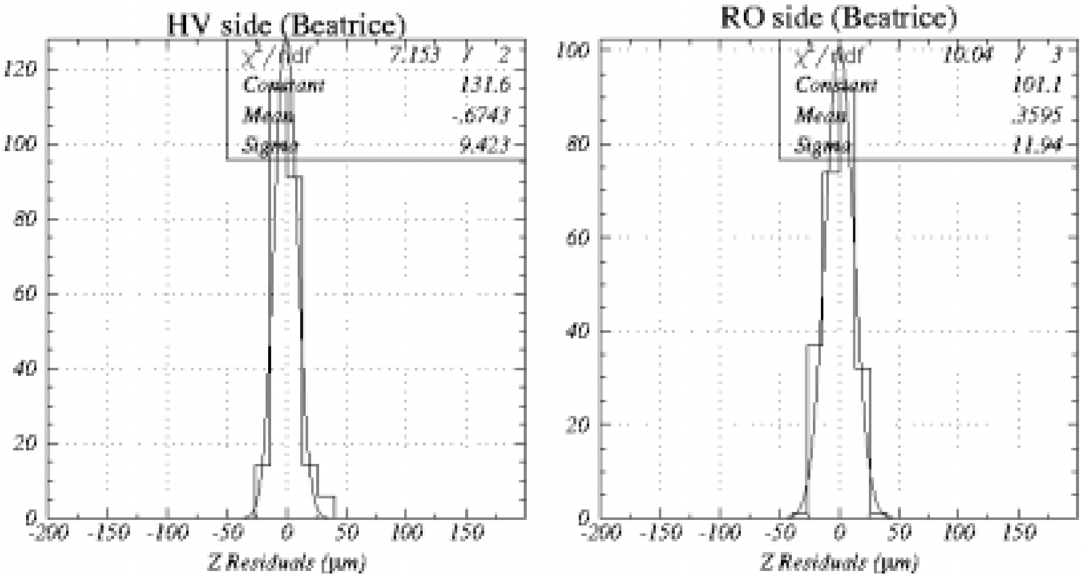

Figure 16: Distribution of the residuals in Z of the wire positions measured by the X-tomograph with respect to the grid fit with the parameters free (BIS Beatrice).

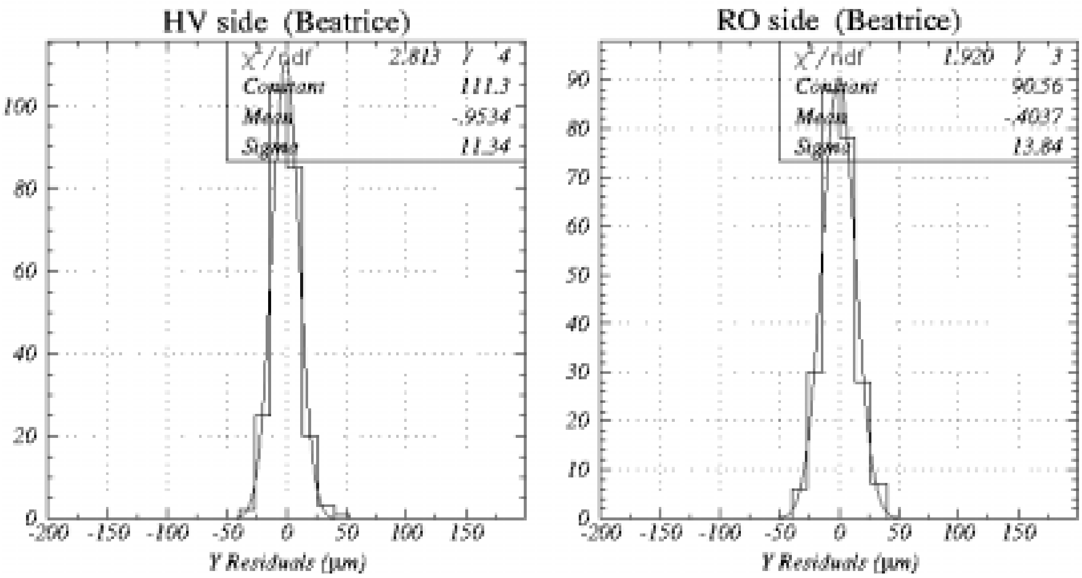

Figure 17: Distribution of the residuals in Y of the wire positions measured by the X-tomograph with respect to the grid fit with the parameters free (BIS Artemis).

Acknowledgments

We would like to thank Kostas Economou not only for his devotion to the project but mainly for his valuable suggestions for the modified construction procedure of the BIS chamber.

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