BIS MDT assembly manual

Thessaloniki MDT group

Abstract

The assembly steps and quality assurance procedures for the construction of the BIS Monitored Drift Tube chambers are described.

1 Introduction

Monitored Drift Tube (MDT) chambers are used in ATLAS in order to measure the trajectories of particle tracks in the magnetic field of the muon spectrometer with a precision of the order of 50 µm. MDT chambers of different dimensions are arranged in the barrel region of the ATLAS detector in three measurement stations at about 5, 7.5, and 10 m radial distance from the beam axis. In the azimuthal direction the measurement stations are segmented into eight large and eight small sectors, alternating with each other. In each sector the stations are again segmented in the z direction (along the beam axis) into chambers of typical dimensions ranging between approximately 1 and 2 m.

The BIS[1] chambers whose assembly is described here are located in the small sectors of the inner station and have typical dimensions of 1 m in z direction and 1.7 m in azimuthal direction. Because of their location between the tile calorimeter and the barrel toroid coil cryostats and the restricted space in this area the design of the BIS chambers differs from the standard MDT chamber design, in particular by the missing spacer structure.

A sketch of the BIS chamber is shown in Figure 1-1. The chamber consists of two multilayers (ML) composed of four layers of drift tubes each. The drift tubes are made from aluminium; they have a diameter of about 30 mm and a wall thickness of 0.4 mm. Within a ML the tubes are close-packed with a wire pitch of 30.035 mm. The two MLs are separated from each other by 6 mm thick cross-strips. The arrangement of the tubes in the two MLs is mirror symmetric w.r.t. the mid-plane (x–y plane) of the chamber.

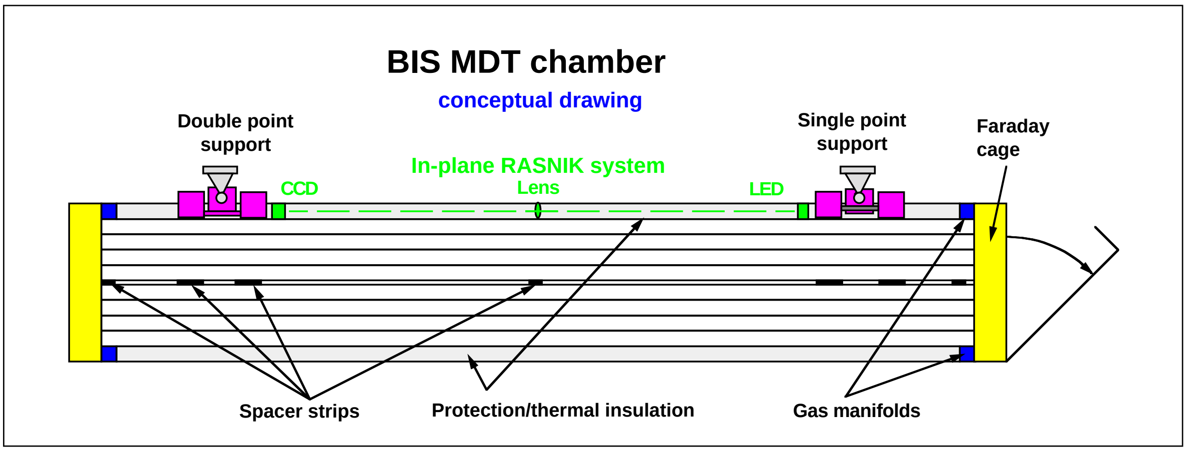

Figure 1-1 Sketch of a standard BIS chamber

The chamber is supported on three kinematical mounting blocks which are connected to the upper ML.

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 both of which serve at the same time as thermal and shock protection.

The drift tubes (including the endplugs) are 1685 mm long; there are 30 (36) tubes per layer leading to a total length (z-direction) of the chamber of 915 (1095) mm.

1. BIS stands for Barrel Inner Small

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

The BIS chambers differ in some important aspects from the standard barrel MDTs: tin particular in the support system, the missing spacer, and, related to the latter, the design of the Faraday cage, the location of the gas manifolds, and the thickness of the protection / isolation covers.

These differences necessitate a method of assembly different from the standard barrel MDT chamber assembly. Whenever standard procedures can be used they are used. Also every effort has been made to use standard assembly jigs and tools as well as to follow standard quality assurance procedures.

2 Assembly team

The ‘assembly team' is made of 3 people: two of them are responsible for the mechanical procedures; the third one is responsible for the computer controlled operations. They will be designated in the following as Operator 1 (O1), Operator 2 (O2), Operator 3 (O3). O3 is also responsible for the book-keeping of the operations accomplished.

They should operate inside the clean room using proper protections against dust, including gloves[1].

1. Types of gloves to be specified by / following general QA / QC procedures

3 BIS chambers and components

Two basic types of the BIS chambers are necessary for the spectrometer construction; they differ in the number of tubes per multilayer. In addition 16 special chambers with shorter tubes and a single multilayer only are required.

Because of the mirror symmetry w.r.t. eta=0 of the layout of the chambers in the spectrometer two versions of each chamber type have to be constructed, one for chambers on side A and one for side B of the spectrometer. They are called A and B and have their HV and readout sides inverted.

The list of chamber types is shown in Table 3-1.

Table 3-1 Different types of BIS chambers to be constructed

Chamber type	Length of assembled tubes (mm)	No. of tubes/layer	No. of chambers/type
BIS 1A	1671.5	30	40
BIS 1C	1671.5	30	40
BIS 2A	1671.5	36	16
BIS 2C	1671.5	36	16
BIS 3A	851.5	24	8
BIS 3C	851.5	24	8
Total			**128**

Each chamber is assembled from a set of individual components some of which are themselves assembled from smaller units. The assembly of the latter parts is not addressed here.

The individual components are stored in the temperature controlled room prior to use for at least one night.

3.1 Tubes

A total of 240 or 288 tubes are required for each of the two basic types of chambers. The tubes are made of aluminium, have a diameter of 29.97 mm, and are 1671.5 mm long, see Figure 3-1. Both tube ends are closed by endplugs with precision reference surfaces with a diameter of 30.010±0.010 mm. The tubes are assembled at the University of Athens, tested at the NTU Athens, and delivered in batches of about 100 tubes to Thessaloniki. Here the tubes are tested again for gas tightness, HV, and wire tension.

Figure 3-1 3-D view of a drift tube with its endplug

Each tube is identified by a bar code and has its electronical data sheet stored in the ACCESS database.

3.2 Support beams

The BIS support system consists of two pairs of rectangular aluminium profiles connected to the drift tubes as shown in Figure 1-1. Figure 3-2 shows a 3-D view of the two sets of the support beams. Two U-shaped support plates are glued between the two profiles of each support. On the two-point support side of the chamber these support plates will receive the kinematic mounting blocks after the assembly. During the assembly the stiffback is connected to these two plates. On the single support side the mounting block will be connected to the beams via two transverse rods; the two support plates are only used during the chamber assembly.

Figure 3-2 3-D view of the support beams

In order to electrically isolate the chamber from the support rails a series of glas-fibre plates are glued to the bottom of the aluminium profiles.

The support beams are assembled prior to the chamber assembly; their assembly is described elsewhere. The kinematic mounting blocks are not part of the assembly and are added to the chamber after it has been removed from the stiffback.

The support beams are marked as type ‘S’ (single support point) and ‘D’ (double support point).

During the chamber assembly the support beams are connected to the stiffback using the U-shaped support plates.

3.3 Gas manifolds

The gas manifolds distribute the incoming gas to all tubes of a multilayer and collect the outgoing gas. There are four manifolds per chamber, two input manifolds and two output manifolds. They are located at both tube ends on the outer sides the multilayers, see Figure 1-1, and extend (almost) over the full width of the outer tube layers.

A 3-D view of the manifold is shown in Figure 3-3. Because of the non symmetric arrangement of the gas in / outlets the gas manifolds come in two variants with mirror symmetric hole patterns. The manifolds will be marked with a colour code to make sure that the correct part is used at the correct place.

Figure 3-3 3-D view of a gas manifold

The manifold is produced in industry. The manifolds tubes are made of extruded aluminium profile. The main gas in / outlet is on the flat back side of the profile. The individual gas in / outlet holes will be drilled along the front side of the extrusion. The two tubes ends are closed with aluminium endcaps by welding.

The welds and fitting are tested for gas tightness in industry.

3.4 Cross-strips

The cross-strips separate the two multilayers from each other. They are made of aluminium and are 6 mm thick and 25 mm wide.

The cross-strips are glued at seven positions perpendicular to the tubes between the 4^{th} and 5^{th} tube layer. A 0.2 mm glue gap is foreseen between the cross-strips and the tubes on either side.

3.5 Faraday cage

The Faraday cage (FC) closes the chamber at both ends. Its purpose is to electro-magnetically isolate the front-end electronics and to mechanically protect the electronics and gas distribution at the two tube ends.

It consists of a ground plate (GP), a bottom and a top plate, two side plates, and a cover. Figure 3-4 shows an exploded view of the FC. The GP extends over the full height of the two multilayers and serves also as stiffening element against chamber deformations in the z-y plane.

Figure 3-4 Exploded 3-D view of the Faraday cage

The ground plate is glued and screwed (for electrical contact) to the endplugs when the last tube layer has been glued and the chamber is still on the jigs. All other parts of the FC are added when the chamber has been removed from the granite table. The parts are screwed to each other.

3.6 Protection and thermal cover

The chamber is protected on both sides by a 30 mm thick layer of aluminium clad foam. The clad foam is cut to the required size prior to the assembly. The protection material is glued to the tubes. Cutouts in the protective layer are foreseen for the RASNIK system, gas pipes, T- and B-field sensors, etc. and provisions are made that these elements can be accessed.

3.7 Auxiliary equipment

3.7.1 In-plane monitoring

To monitor the chamber deformations in the y direction (sag) a single RASNIK system is used. It consists of

1. light source (LED+diffusor plate) and a coded mask;
2. lense with focal length f=230 mm;
3. CCD.

The three RASNIK elements are mounted on the outside of the uppermost tube layer between the support beams, see Figure 1-1. The individual elements are fixed with screws to standard support plates which are themselves glued (with a fast curing glue) to the tubes. Figure 3-5 shows a 3-D view of the three RASNIK components.

Figure 3-5 3-D view of the RASNIK components

The RASNIK system is mounted immediately after the glue has been applied to the first tube layer and is used for monitoring the chamber deformation during the full assembly sequence.

3.7.2 Temperature sensors

Standard T-sensor base plates will be glued during the assembly to the tubes. Sensors will be mounted when available.

3.7.3 Magnetic field sensors

Standard B-field sensor base plates will be glued during the assembly to the tubes (if available, otherwise later). Sensors will be mounted when available.

3.7.4 Gas jumpers

Gas jumpers connect the individual tubes with the gas manifold. Figure 3-6 shows a 3-D view of the connection scheme.

Figure 3-6 3-D view of the gas connection scheme

A total of six different gas jumpers are needed. Two jumpers with straight tubes connect the two layers of tubes which are closest to the gas manifold to it; these jumper types can be used on both tube ends as well in the upper as in the lower ML. The jumpers which connect the tubes of layers 3–6 to the manifolds are bent and come in two variants with the end of the tubes bent in opposite directions. Figure 3-7 shows the six different gas jumper types.

Figure 3-7 Six different gas jumper tubes

The gas jumpers are connected to the gas manifold by a plastic clip. The clips come in two mirror symmetric variants in order to match the hole pattern in the gas manifolds, see Figure 3-8.

Figure 3-8 Gas jumper clips

The gas jumpers are mounted during Phase II of the assembly.

4 Infrastructure and assembly tools

The assembly of the chamber is done on a granite table of dimensions $2.7 \times 2.2 \times 0.4$ m^3 with a flatness of ±3 µm in a temperature controlled clean room following the general MDT specifications.

4.1 Clean room

The clean room is of class 'Dustfree'. It consists of two parts of 5×7 m^2 and 4×6 m^2. Temperature and humidity are controlled within ±0.5 °C and 45±5%. The room is equipped with six (?) temperature sensors placed in the locations shown in Figure 4-1 (exact locations to be defined).

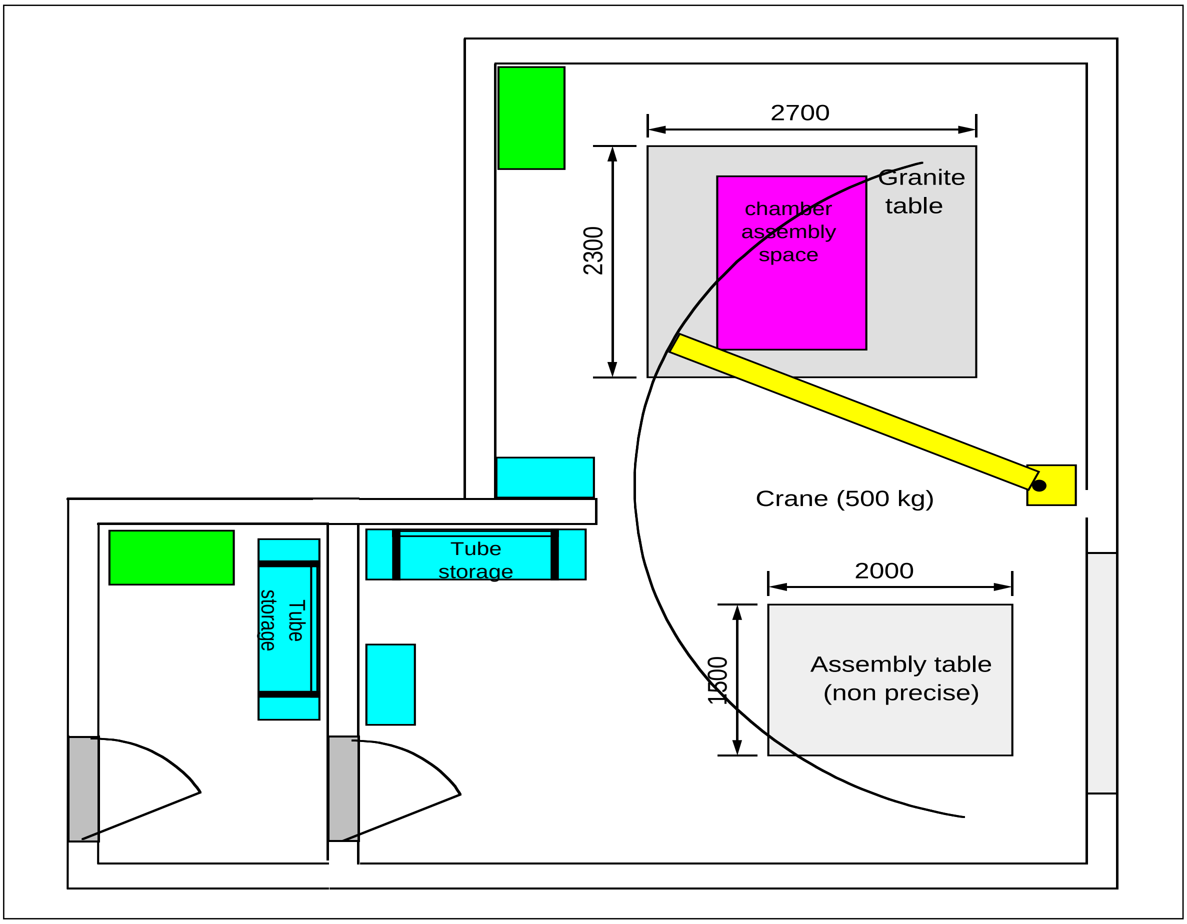

Figure 4-1 Layout of clean room showing the location of the assembly tables, crane, and temperature and humidity sensors

The granite table of dimensions $2.7 \times 2.2 \times 0.4$ m^3 has a flatness of ±3 µm. All of the chamber assembly requiring precision is performed on the granite table.

A non-precise table (1.5×2 m^2) is used for the mounting of chamber components which do not require large precision.

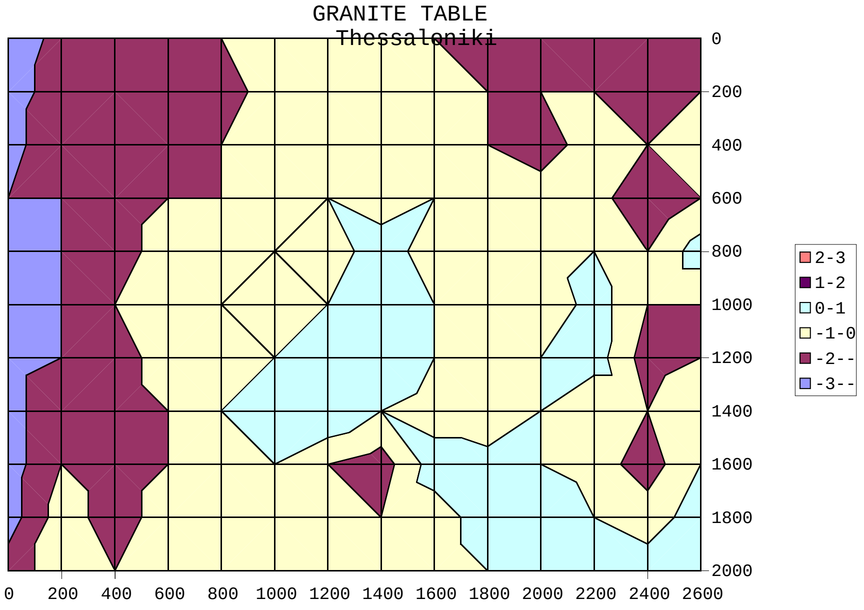

Figure 4-2 Granite table iso-lines showing the flatness of the table

The room is equipped with a 0.5 t crane with a pivoting arm. The tables are located such that a chamber can be moved by crane from one table to the other.t

The clean room also serves as intermediate storage room. Chamber parts (tubes, support beams, etc.) are stored here for at least one night before they are used in the assembly.

The clean room is equipped with 220 / 380 V mains, vacuum lines, compressed air, telephone, and ethernet connections.

4.2 Assembly tools

The main assembly tools are:

- six precision jigs for the placement of a tube layer with a vacuum suction system;
- four sets of stepping blocks;
- the stiffback;
- six RASNIK systems to control the position of the stiffback and its internal deformations;
- the on-chamber in-plane RASNIK system;
- a motorized glue dispenser;
- a template for the tube positioning on the jigs;
- templates for the positioning of the in-plane and praxial alignment sensor mounting plates;
- templates for the positioning of suspension beams and gas manifolds;
- bar code reader, connected to PC;

- mechanical feeler[1] with 3 µm measurement precision connected to PC.

These tools are described below in more detail.

The assembly sequence is controlled via a BridgeView[2] based computer program and all data are registered and stored in an ACCESS[3] database.

4.2.1 Jigs

During the assembly the tubes to be glued are positioned with an accuracy of better than 10 µm by a set of six jigs. The jigs[4] are made of 1100 mm wide aluminium bars, 35 mm thick and about 100 mm high, with 12 mm stainless steel rods glued to them, see Figure 4-3. The tube positions are defined by the positions of the stainless steel rods. The jigs themselves sit on two 30 mm diameter stainless steel rods and are fixed with clamps to the granite table.

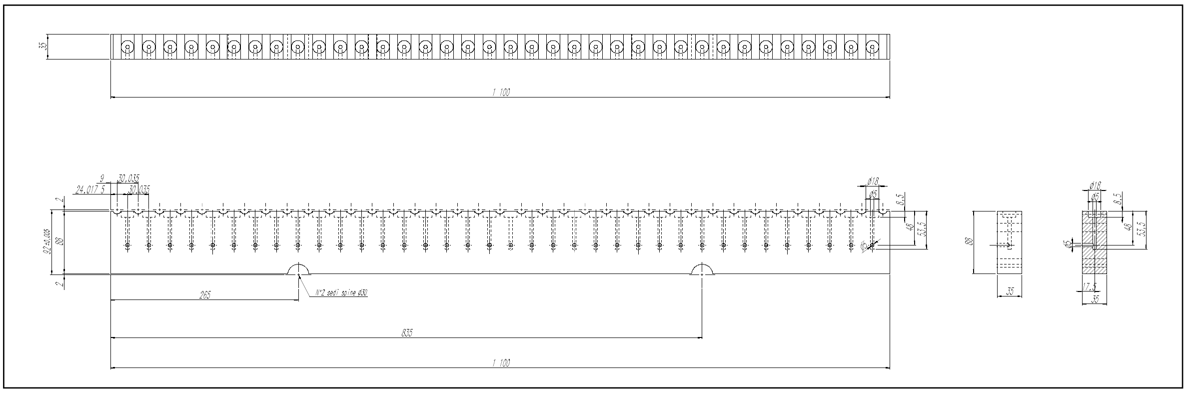

Figure 4-3 Single jig

The tube are held down in the jigs by means of a vacuum suction system. For this purpose the middle four jigs have vacuum suction heads between the 12 mm steel rods. Because of the tube endplug shape the same system can not be used for the two outer jigs. The two outer jigs have no suction system; instead a row of suction heads, without rods, is placed 35 mm inwards of each of the end-jigs (distance centre to centre of jigs).

The jigs are arranged on the granite table as shown in Figure 4-4.

4.2.2 Stepping blocks

The different height levels of the stiffback during the assembly sequence are achieved by adding layers of calibrated rods of diameter of 30.035 mm to the base of the sphere holders. This method guarantees the exact positioning of the stiffback in height (y) and in z position by using the same piling-up pattern as for the tubes. The third dimension (x, along the tubes) is controlled via a stop connected to the reference height block.

1. Mitutoyo, type....
2. BridgeView is a National Instruments trademark
3. ACCESS is a commercial database system by...
4. The design of these jigs follows the one used at Rome I.

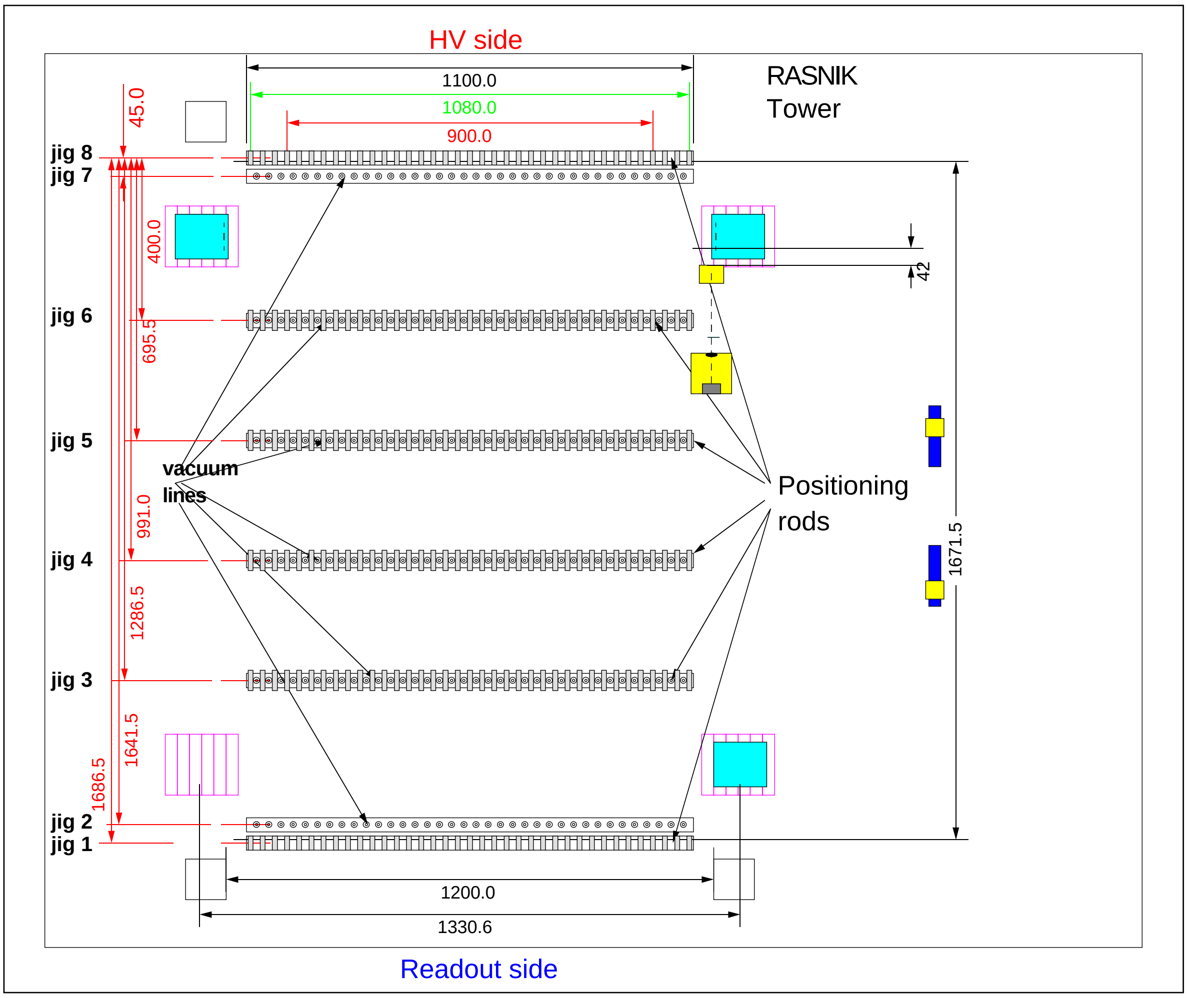

Figure 4-4 Arrangement of jigs on granite table.

The height blocks are numbered A–D, the four stepping blocks A_S1–A_S4, BS1–BS4, etc., the base block ABB, BBB, CBB, DBB, see Figure 4-5. In addition four offset blocks (AOB, BOB, COB,

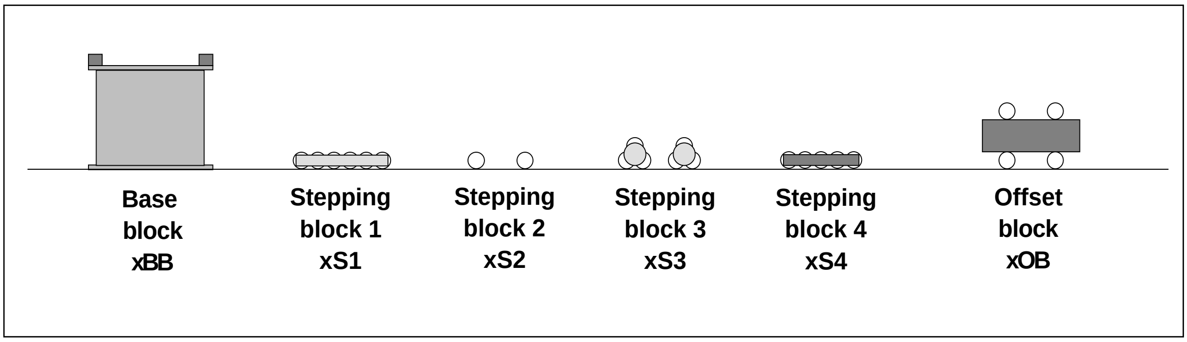

Figure 4-5 Different base and height stepping blocks used in the assembly

DOB) define the position of the fifth tube layer.

The four sets of piled up rods are shown in Figure 4-6 together with the additional offset block for the second multilayer.

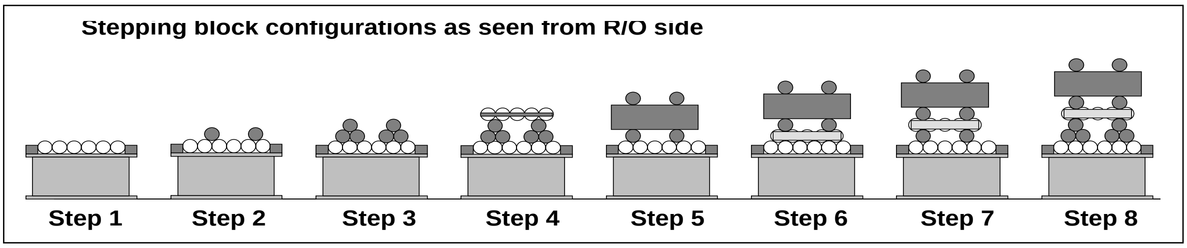

Figure 4-6 Combination of rods to achieve the required four height steps and offset block which is used as base for the assembly of the lower multilayer.

The base blocks together with the first set of stepping blocks (AS0, BS0, CS0, DS0) are once and forever adjusted and fixed to the granite table before the first chamber is assembled. They must not be removed. Only sets of blocks starting with the same letter must be used together.

4.2.3 Stiffback

The stiffback frame is connected to the BIS support beams throughout the full assembly sequence of each chamber. It is a rigid structure designed not to bend more than 10 microns under the full load of the chamber. It is supported at its four corners via a set of steel spheres on the sphere blocks. It is by raising these blocks that the different height levels are achieved.

A sketch of the stiffback is shown in Figure 4-7.

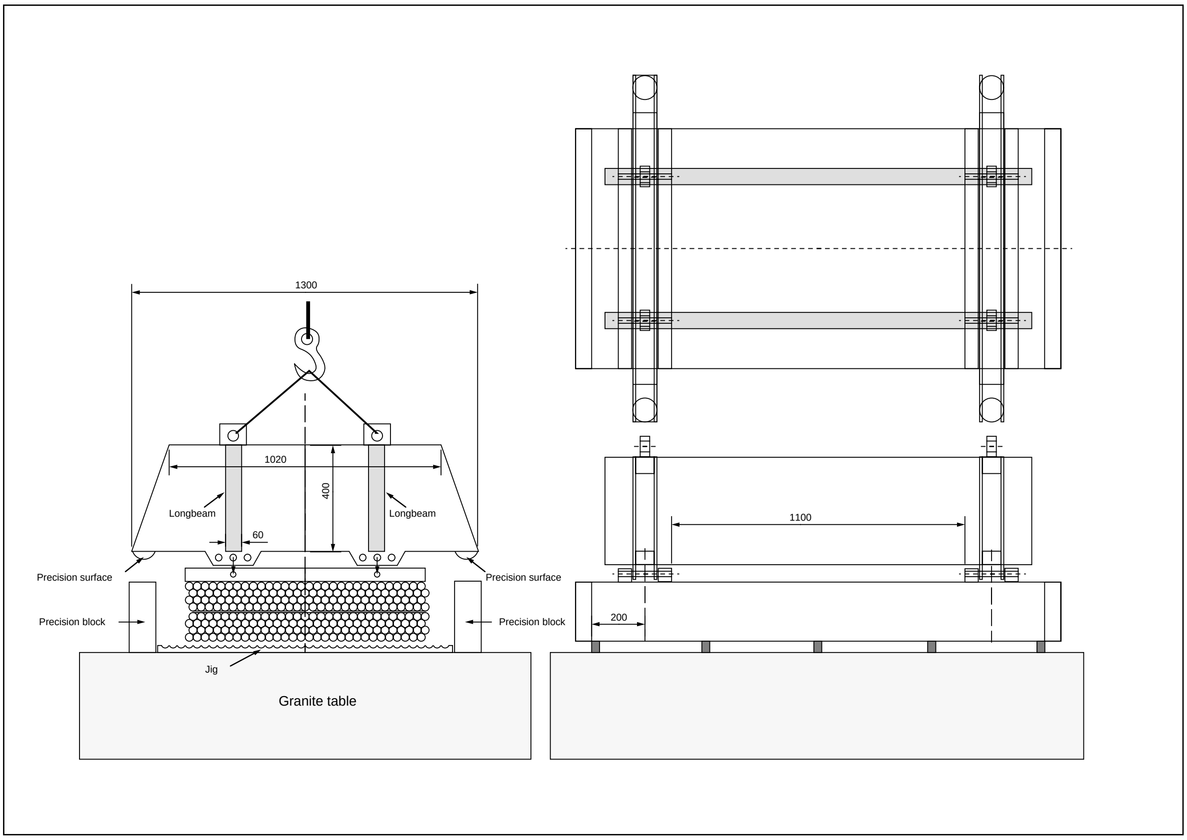

Figure 4-7 Sketch of stiffback structure

It consists of two cross-plates, 240 mm high and 1058 mm wide, connected to each other by two long-beams, 100×200 mm^2, and four arms with steel sphere as contact surface (sphere holders). The two cross-plates are separated by 1300 mm from each other. Two support blocks are glued to the bottom of each cross-plate. To these blocks the chamber support beams are bolted during the assembly.

The three brackets connected to each of the cross-plates allow for the positioning and fixation of the upper gas manifolds during the assembly. They stay connected to the gas manifolds as long as the stiffback is connected to the chamber.

4.2.4 RASNIK assembly monitoring systems

Position and deformation of the stiffback are monitored during the assembly process with the help of six RASNIK systems. Four RASNIK systems control the vertical and horizontal positioning of the stiffback at the level of the four spheres. The CCDs and lenses are mounted in aluminium towers and fixed to the granite table, the LED / masks are fixed to the sphere holders.

Two more systems are used to monitor the deformation of the cross-plates and are mounted on the cross-plates.

4.2.5 Templates

4.2.5.1 Tube positioning template

The tube positioning template consists of a layer of 36 short plastic tubes (35 mm) glued together on the jigs, see Figure 4-8. Each tube is 35 mm long, has an outer diameter of 30 mm, and a wall thickness of 5 mm. A 2.2 mm wide groove is machined into the inner wall in the bottom of each tube along the full length of the tube. On the bottom and the top stops are glued to the template at 25 mm from the reference side of the tubes. Provisions are made that the template can be clamped to jigs #1 and 8.

The template is placed on one of the end-jigs with the stop bar against the outer jig face. It serves at the same time to define the tube positioning in tube direction and to guarantee the right orientation of the tubes by requiring that the ground pin fits into the grooves in the template.

By inverting the template either orientation of the tubes (ground pin up or down) can be achieved.

The upper and lower stop bars on the template are colour coded (blue for up, yellow for down).

4.2.5.2 Suspension beam positioning template

To be added

4.2.5.3 Gas manifold positioning template

To be added

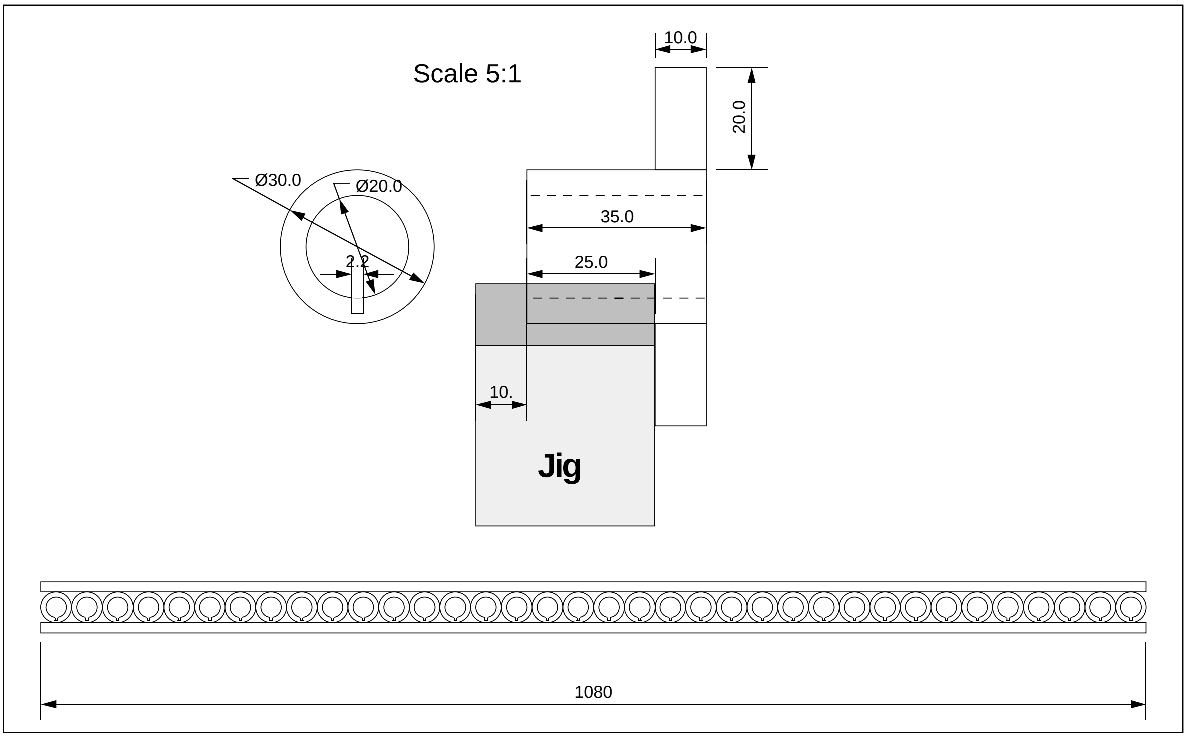

Figure 4-8 Tube positioning template

4.2.5.4 In-plane base positioning template

To be added

4.2.5.5 Praxial alignment platform positioning

To be added

4.2.5.6 Cross-strip positioning template

To be added

4.3 Database and electronic logbook

All relevant parameters will be recorded during the assembly and stored in an electronic assembly logbook.

These parameters are:

- environmental parameters (temperature, humidity, ...);
- the list of parts (tube numbers, glue batch, ...) and their location in the chamber;
- the data of the RASNIK systems which control the stiffback position and deformation;
- etc.

The data relevant for the chamber construction will be stored in the database in a format compatible with the global MDT database format.

During the assembly all relevant parameters will be available on-line on a display.

5 Assembly procedure

The assembly proceeds in two phases. Phase I comprises the precision glueing steps on the granite table. It takes eight working days. During Phase II the chamber assembly is completed on a non-precise table by adding the Faraday cages and by equipping the chamber with the auxiliary parts.

The steps of the assembly are described below. The steps of Phase I are shown graphically in Figure 5-1. Note that in the following, for convenience and in contrast to the general naming scheme, the tube layers are counted 1–8 from top to bottom.

Detailed operator instructions for each individual step are given in Chapter 6.

5.1 Phase I

During the full duration of Phase I the on-line assembly control program will be active. Data (environmental data, vacuum, RASNIK information) are logged in regular intervals (interval length to be determined) and stored in the local database.

5.1.1 Day 1

On Day 1 the first layer of tubes will be connected to the suspension beams. The steps to be followed are described in Table 5-1.

At the start of the chamber assembly the stiffback is suspended from the crane in a ‘parking’position.

5.1.2 Day 2

Layer 2 will be added. The steps to be followed are described in Table 5-2.

5.1.3 Day 3

Add the 3rd tube layer; same steps as on Day 2, but using the height blocks for step 3.

5.1.4 Day 4

Add the 4th tube layer; same steps as on Day 3, but using the height blocks for step 4.

This completes the upper multilayer of the chamber.

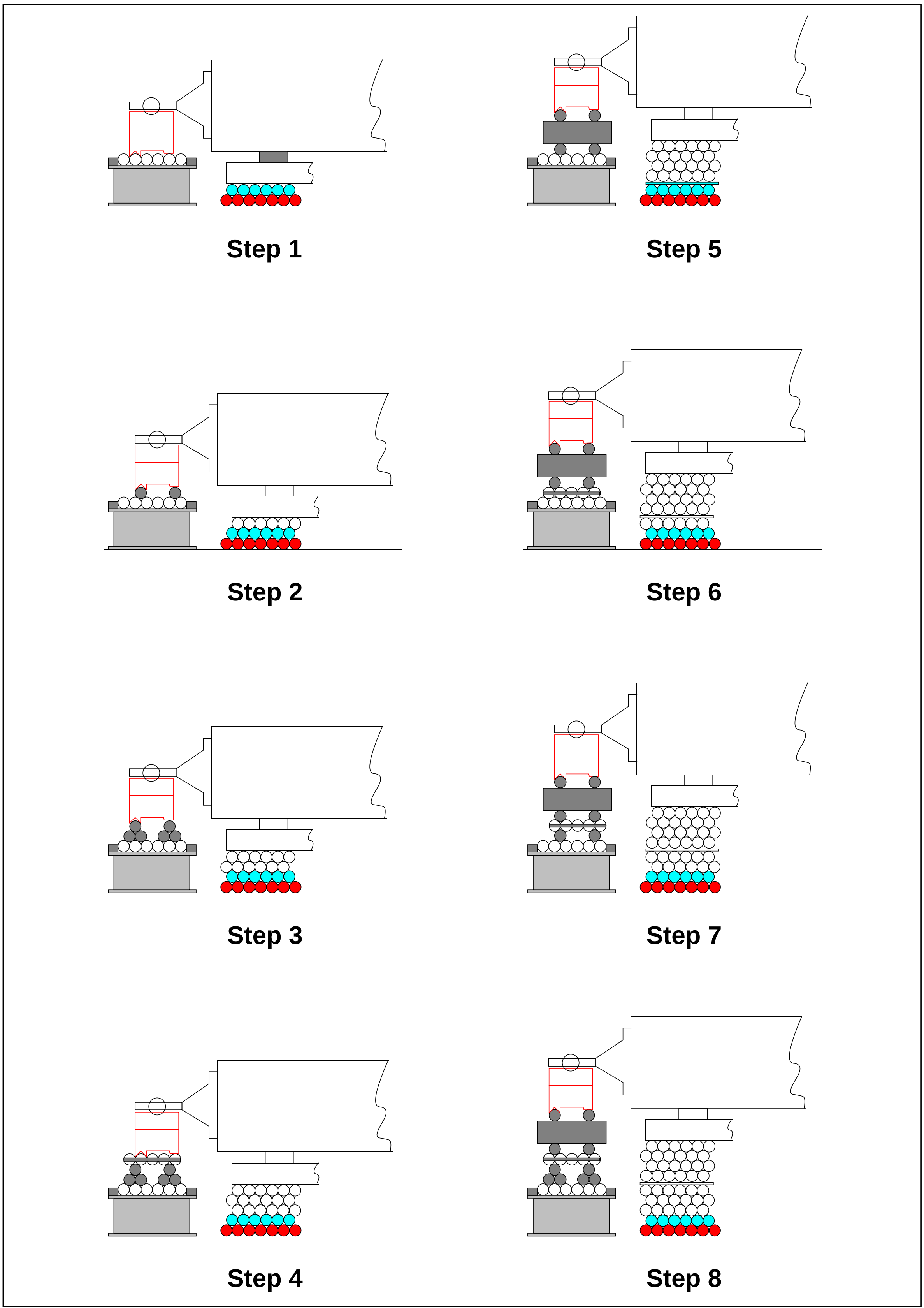

Figure 5-1 Schematic view of the chamber assembly showing the full chamber and the stiffback and the first glueing steps, see text

Table 5-1 Assembly steps on Day 1

Step	Description	Section ref.	DB entry
STEP 1	**Upper multilayer and support beams**		
1.	Start assembly control program and enter chamber identifier, etc.	6.1	yes
2.	Configure the four sphere blocks as indicated in Figure 5-1	6.10	
3.	Place support beams and gas manifolds via template on jigs	6.5	
4.	Place stiffback above height blocks and lower onto sphere blocks		
5.	Connect RASNIK cables to the patch panel		
6.	Connect support beams and gas manifolds to stiffback; record stiffback RASNIK data;	6.8	
7.	Lift stiffback	6.9	
8.	Place first layer of tubes on the jigs with ground pins mounted on endplugs in 6 o’clock orientation	6.2	
9.	Place the tube positioning template on jig#1 with yellow side up and put tubes into the right orientation and push them against the template; Place other tube orientation template on jig#8 (yellow side up) and verify ground pin orientation	6.2	
10.	Switch suction system on and store vacuum pressure in DB;		
11.	Read bar codes of all tubes in increasing V-groove order and store in DB		yes
12.	Verify correct tube placement; replace tubes if required; store end-plug heights in DB;	6.3	yes
13.	Lower stiffback; verify support beam and gas manifold glue gaps; mark positions of suspension beams and gas manifolds on tubes	6.5	
14.	Lift stiffback	6.9	
15.	Apply glue between the tubes	6.4	
16.	Place praxial alignment platform template on tube layer and fix (with fast curing glue) the praxial alignment platforms on the tube layer;	6.7	
17.	Apply glue for fixing of support beams and gas manifolds	6.5	
18.	Lower stiffback	6.8	
19.	Glue the support beams and upper gas manifolds to the tubes	6.5	
20.	Record stiffback positions		yes
21.	Fix the RASNIK in-plane monitor system base plates to the tube layer (using fast curing glue) and mount RASNIK elements; store RASNIK in-plane data in DB	6.6	yes
22.	Let glue cure over night		

Table 5-2 Assembly steps on Day 2

Step	Description	Section ref.	DB entry
STEP 2	**Layer 2 (same procedure for layers 3,4,)**		
1.	Switch vacuum off;		
2.	Lift stiffback;	6.8	
3.	Configure the four sphere blocks as indicated in Figure 5-1	6.10	
4.	Place the 2nd layer of tubes on the jigs with ground pins mounted on endplugs in 6 o'clock orientation	6.2	
5.	Switch vacuum on, and verify tube positioning, correct if required	6.3	yes
6.	Place a strip of adhesive tape (60 µm) across the tubes half way between the tube ends, cut tape between tubes		
7.	Apply glue between the tubes and at ±30 degrees from the vertical direction	6.4	
8.	Lower the stiffback onto the sphere blocks and add weights to the sphere holders	6.8	
9.	Check reading of all RASNIK systems; correct layer position if required;		yes
10.	Let glue cure over night		

5.1.5 Day 5

The lower multilayer will be added by continuing the stacking procedure described above, after having glued the cross-strips to the 5th layer of tubes. For layers 5–8 the ground pins in the end-plugs must be in the 12 o'clock position.The steps to be followed are described in Table 5-3.

5.1.6 Day 6

Add the 6th tube layer; same steps as on Day 2 but with ground pins in 12 o'clock position. The steps to be followed are described in Table 5-4.

5.1.6.1 Day 7

Add the 7th tube layer: same steps as on Day 6, see Table 5-4.

5.1.6.2 Day 8

Add the 8th tube layer: same steps as on Day 6. As an additional step the FC ground plates are glued to the two chamber ends, see Table 5-5.

Table 5-3 Assembly steps on Day 5

Step	Description	Section ref.	DB entry
STEP 2	**Layer 5**		
1.	Switch vacuum off		
2.	lift stiffback;	6.9	
3.	configure the four sphere blocks as indicated in Figure 5-1	6.10	
4.	place the 5th layer of tubes on the jigs with ground pins mounted on endplugs in 12 o'clock orientation	6.2	
5.	switch vacuum on; and verify tube positioning	6.3	yes
6.	apply glue between the tubes;	6.4	
7.	place the seven cross-strips using the template; mark their positions on the tubes; remove the cross-strips; apply glue (Araldit 2014)		yes
8.	place cross-strips on the tubes defining their position with the help of the template; apply a glue line on the top of the cross-strips parallel to the centre of the tubes		
9.	Remove cross-strip positioning template after 1 hour		
10.	lower the stiffback onto the sphere blocks and add weights to the sphere holders	6.8	
11.	check reading of all RASNIK systems; correct layer position if required		yes
12.	Remove cross-strip positioning template after 1 hour		
13.	let glue cure over night		

5.1.7 Day 9

All tube layers are now in place. The chamber is removed from the granite table. The steps are described in Table 5-6.

The granite table is free to be used for the assembly of the next chamber.

5.2 Phase II

The remaining steps of the assembly sequence are no longer influencing the mechanical precision of the chamber. They can be done off the granite table. The steps are listed in Table 5-7.

Table 5-4 Assembly steps on Day 6

Step	Description	Section ref.	DB entry
STEP 2	**Layer 6 (same procedure for layers 7 and 8**		
1.	Switch vacuum off;		
2.	Lift stiffback;	6.9	
3.	Configure the four sphere blocks as indicated in Figure 5-1	6.10	
4.	Place the 2nd layer of tubes on the jigs with ground pins mounted on endplugs in 12 o'clock orientation	6.2	
5.	Switch vacuum on, and verify tube positioning	6.3	
6.	Place a strip of adhesive tape (60 µm) across the tubes half way between the tube ends		
7.	Apply glue between the tubes and at ±30 degrees from the vertical direction	6.4	
8.	Lower the stiffback onto the sphere blocks and add weights to the sphere holders	6.8	
9.	Check reading of all RASNIK systems; correct layer position if required;		yes
10.	Let glue cure over night		

Table 5-5 Assembly steps on Day 8

Step	Description	Section ref.	DB entry
STEP 2	**Layer 8**		
1.	Same procedure as in Table 5-4;		
2.	Glue Faraday ground plates to the two chamber ends; fix with ground pins;		
3.	Let glue cure over night		

Table 5-6 Steps for removal of chamber from granite table

Step	Description	Section ref.	DB entry
Phase II	**Auxiliary equipment**		
1.	Take series of RASNIK measurements		yes
2.	Switch vacuum off; repeat RASNIK measurements		yes
3.	Disconnect RASNIK cables from patch panel		
4.	Lift chamber and move it from granite table to Table 2 (crane)	6.9	
5.	Place chamber on Table 2 on three 100 mm squared aluminium beams placed across the tubes in the x positions of the suspension points and in the middle		
6.	Disconnect stiffback from suspension beams		
7.	Lift stiffback and move to it ‘parking’ position		

Table 5-7 Phase II, assembly of auxiliary equipment

Step	Description	Section ref.	DB entry
Phase II	**Auxiliary equipment**		
1.	Glue the gas manifolds to the bottom ML using template		
2.	Completing the FC		
3.	Mount the gas connectors		
4.	Add the B- and T-sensors		
5.	Mount the electronics boards and cables;		
6.	Fix the protective layers		
7.	Add the mounting blocks		

6 Assembly steps - detailed description

In this section the steps of the assembly procedure as listed in Section 5 are described in detail.

6.1 Assembly control program, electronics logbook, and database

Before a new chamber assembly can start the database for the corresponding chamber needs to be opened on the PC. The chamber identifier, date of chamber assembly, and information about the technical personnel must be entered.

The operator is guided by the program through the different assembly steps.

The PC records the environmental data during all the time until this assembly step is declared to be completed. It is also ready to receive information from the bar code reader, from the RAS-NIK systems, as well as manually entered information.

6.1.1 Start the program

(Exact procedures to be established.)

1. Switch PC on (if off);
2. Enter: Login: BIS-assembly
3. Password: xxxxx
4. Select yyyyy from Files Menu
5. Klick on zzzzz

The Assembly -BIS program will start.

6. Follow the instructions as given by the program.

6.1.2 Stop the program

1. Select: Exit from the pop-up menu.

6.2 Placement of a tube layer

1. enter layer number into database / logbook;
2. clean jigs with compressed air;
3. Fix tube positioning template to jig #8;
4. screw ground pins into both endplugs of tubes to be placed;

5. place 30 tubes (or 36 for BIS chambers of type 2) on the jigs. If only 30 tubes are to be placed the first tube must be placed on the jigs in slot #4, the first and last three slots are left empty.

   The tubes must be oriented such that they fit into the tube positioning template on jig #8. Push tubes against template to define the tube positioning in the x-direction.

6. Fix tube-positioning template on jig #1;
7. control tube lengths; exchange tube if tube length differs by more than 0.5 mm;

   Read tube identifiers of rejected tubes and add reason for rejection in DB; store rejected tubes in clearly marked rack;

8. switch vacuum suction system on;
9. control tight suction contact (sound), adjust tubes if necessary; if tube needs to exchanged proceed as under point 7.
10. read the vacuum pressure and store in DB;
11. scan the bar code identifier of all tubes, starting at tube in slot #1 or 3.

6.3 Control of tube layer placement

1. Make sure all tubes are in good contact with the jig rods by tapping gently on the tubes;
   - if not OK: adjust tube position.
2. Check distance between adjacent endplugs with a 10 µm thick feeler; if the feeler does not pass the endplugs risk to touch each other; check situation on other sides of endplugs;
   - accept if the distances to the neighbouring plugs are OK;
   - if also the distance to the next adjacent plug is too small the offending tube must be replaced (and the database be updated, proceed as under Section 6.2, point 7).
3. Check distance between adjacent tubes along the tube length with the help of a feeler of 30 µm thickness which must be able to pass in between;

   if the distance between two adjacent tubes is too small:
   - this is accepted if the distances to the neighbouring tubes on the other sides are OK;
   - if also the distance to the next adjacent neighbouring tube is too small the offending tube must be replaced (and the database be updated, proceed as under Section 6.2, point 7).
4. Enter the result of the check into the electronic logbook.
5. Check the planarity of tube layer by placing a precision ruler across the endplugs and check visually for the endplugs touching the ruler everywhere;

   if single endplugs are visibly out of planarity reposition tube or replace if no change; proceed as under Section 6.2, point 7.

6. Check the planarity of tube layer by placing a precision ruler across the tubes at the positions of jigs #3–6; check visually the distance between tubes and ruler;

   if distances between ruler and tubes are larger than 100 µm reposition tube or replace if no change;

7. Measure the highest point of the endplug reference surface for all tubes at the two ends. For this measurement a mechanical feeler (Mitutoyo) with digital output connected to a PC is used. The measurement itself is a relative measurement with the following steps:

   a. measure the reference surface; the data are stored as reference;

   b. move the Mitutoyo slowly by hand with its base sliding on the granite table; the data are registered by the on-line program;

      if touching somewhere a new reference measurement has to be made and data measured after that are converted using the new reference.

   c. remeasure the reference surface at the end;

   d. the data are converted to an absolute measurement using the reference measurements;

   The results are analysed in the control program and displayed on the control screen.

   - If all values are within the expected tolerances the tubes are shown in green on the control window;
   - if a tube is shown in red the measurement is out of specs and the tube has to be repositioned or changed; proceed as under Section 6.2, point 7.

8. Store vacuum pressure in DB.

9. Mark layer as correctly placed in DB.

6.4 Application of glue to the tube layer

The glue is applied by means of a glue dispenser at the positions indicated in . Three different glueing heads are used:

- Head #1 has only a single outlet and dispenses glue in between two adjacent tubes.
- Head #2 has three outlets and dispenses glue in between two adjacent tubes and at ±30° from the vertical tube axis at the places where the next layer tubes will touch.
- Head #3 has a single outlet and dispenses glue on the outside of the tube at ±30° depending on the orientation of mounting it on its support.

The glue dispenser is motorized. The speed is to be adjusted to minimize the amount of glue but ensuring continuous glue lines.

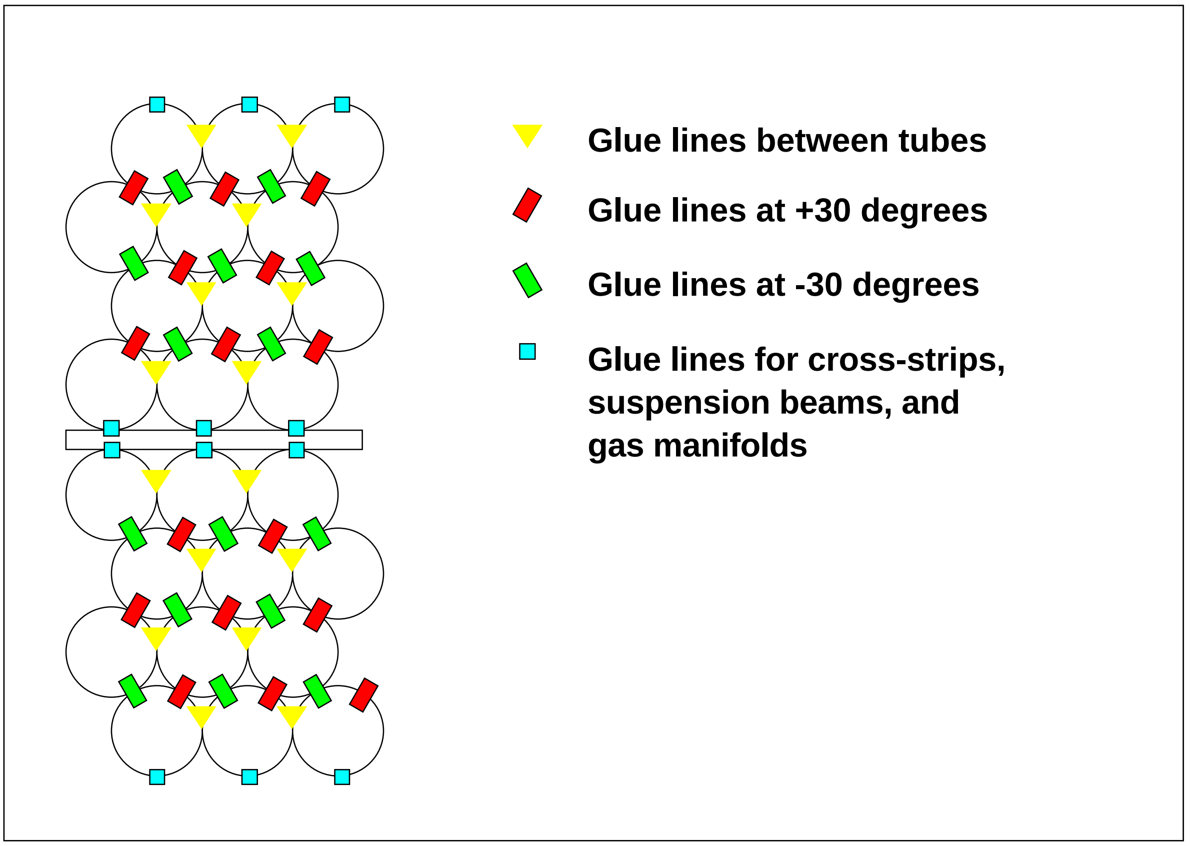

Figure 6-1 Schematic view of glue joints; only three tubes per layer are shown for simplicity; the sides are representative for the two chamber sides

6.4.1 Choice of glueing head

6.4.1.1 Main glue lines

- Layer 1 and 5: head #1;
- Other tube layers: head #2.

6.4.1.2 Extra lines

Because of the horizontal stepping extra glue lines must be applied on the outer tubes. Tube layers 2, 4, and 7 receive an extra glue line at +30 degree see from the readout side; layers 3, 5, and 8 receive an extra glue line at -30 degree. The following glueing heads are used:

- layers 2, 4, and 7: head #3 in position 1;
- layers 3, 6, and 8: head #3 in position 2.

6.4.2 Application of glue

1. fill one compartment of the reservoir with Araldite 2011A, the other with Araldite 2011B and place reservoir on support;
2. move glue dispenser bridge in position; place glueing head above chamber;
3. position the glueing head above the first group of two tubes; fix bridge position (pre-located positioning); lower the glueing head; start the glue application 2 mm from the crimp area and start the (motorized) advancement of the head until 2 mm from the crimp area at the other tube end;
4. displace the glue dispenser bridge to cover next group of two tubes; (apply glue symmetrically from centre to the outside of the tube layers switching between each application from one side to the other (???));
5. For layers 2–4 and 6–8 mount glueing head #3 to apply extra glue line on outside;
6. when finished remove glueing bridge to the side; remove glueing and mixing head and clean.

6.5 Glueing of support beams and upper gas manifold

1. Place suspension beam installation template on jigs 1, 3 and 6, 8.
2. place pre-assembled double-point support beam on template on the HV side and single-point support beam assembly on template on the readout side.
3. fix U-support plates to support blocks of stiffback with bolts;
4. lift the assembly and remove the templates;
5. lower stiffback onto precision sphere blocks, control distance between support beams and tubes by eye (sheet of paper must pass); read the four height positions and record; read the in plane RASNIK data and store;
6. mark area of glue application with felt pen on tubes (four support beams and two gas manifolds);
7. lift stiffback;
8. apply glue (Araldite 2014; with components A and B as 100:50) by hand (glue pistol) to the upper part of the tubes in the marked areas on the top of the tubes;
9. lower stiffback again onto sphere blocks and apply extra weight on sphere blocks;
10. read height and in-plane positions and store;
11. let glue cure for minimum 12 hours;

6.6 Positioning of chamber in-plane RASNIK elements

All steps must be done with vacuum on.

1. place in-plane location template;
2. apply fast curing glue (Araldite 2012) by hand to the bottom of the three support bases;
3. place support bases into template openings and clamp;
4. let glue cure for minimum 1/2 hour; remove template;
5. fix (with screws) LED/mask, lens, CCD units to their corresponding bases (marked); read bar code of RASNIK elements (if existing) and store in database;
6. connect RASNIK elements to assembly table RASMUX system;
7. read and store RASNIK data as in-plane zero value in database.

6.7 Positioning of praxial alignment platforms

The praxial platforms are placed on the first tube layer after the glue has been applied between the tubes but before the suspension beam (and stiffback) are glued to the layer.

The position procedure will be worked out with the praxial alignment team (CEA Saclay) during module 0 assembly.

6.8 Lowering of stiffback onto sphere blocks

The stiffback structure is connected to the crane via a steel support frame.

When lowering the stiffback care must be taken that the position of the reference sphere block is maintained.

When the sphere have engaged in the sphere blocks and the load is released additional weights are mounted onto the four sphere blocks to assure a tight set of the spheres in their receiving parts.

6.9 Lifting of stiffback

This step is repeated after each glueing step.

1. Read and store RASNIK data;
2. switch vacuum system off;
3. read and store RASNIK data;
4. remove weights from sphere blocks;
5. read and store RASNIK data;
6. lift stiffback;
7. record and store in-plane RASNIK data.

6.10 Placement of height blocks

Four height blocks define the positioning of the stiffback during the assembly. The vertical position of the height blocks is controlled by a set of precision stepping blocks; four different stepping blocks and one base block per height block are required, see Figure 4-6.

The base block is fixed to the table and stays always in position. The z-position of the stepping blocks is constrained in the reference tower by mechanical means to guarantee that the reference block is always in the same position during the full assembly procedure. The other blocks are free to move; there is no particular precision required in their placement.

The positions of the stepping blocks and the configurations of the height block for the different steps are graphically shown in Figure 5-1.