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Construction of the MPI BMS Prototype Chamber

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Abstract

The first full scale prototype of an BMS ATLAS chamber was completed in May 1996 at MPI and was subsequently tested in the high-intensity H8 beam at CERN.

The chamber has dimensions of 2.2 m × 2.0 m and consists of two multilayers, fabricated from "modules" (units of 16×4 tubes), each having four layers of aluminum drift tubes. High-precision Al platforms were mounted on each of the modules for precision mounting of MPA sensors. The two multilayers are separated by a 25 cm wide support structure (two long beams, two cross plates, one central plate) which carries 4 independent RASNIK systems.

Several ATLAS notes have been prepared to cover all details of this project. In this note, we describe the techniques that were developed to produce the individual 2.2 m × 0.5 m modules, the attachment of the MPA platforms, and the procedure used to attach eight of these modules to the support structure; the note describes the modular chamber assembly technique. Initial learning experiences made with the gluing of anode wires and tubes into modules are reported on as well.

1 Introduction on Procedures for Modules

The initial phases of this R&D effort were discussed in a previous ATLAS Note [1], here we describe the subsequent developments in the construction of the prototype chamber. Several problems were uncovered after more extensive measurements were performed on the completed drift tubes and on the first module. These were associated with the original procedures employed in the gluing of anode wires into position at the endplugs of the drift tubes, and with gluing of drift tubes with Type A endplugs into modules.

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1.1 Corrective Measures Taken in Gluing Anode Wires

The positions of wires relative to their endplugs were found to be centered to within several μm along the Z direction [1]. (This corresponds to the direction of the stacking of neighboring drift tubes in the plane of the chamber.) However, when measurements were performed of the displacements of wires perpendicular to Z (along Y), it was found that there were large deviations, of order 100 μm, which were always in the same direction. This effect was traced to an oversight in the design of the procedure used for gluing wires at the plastic insulator part of the endplugs. In particular, the gluing of the wire was performed in two steps. Both involved the application of adhesives through an eyelet in the feedthrough. First, a fast-setting adhesive, which was cured immediately with ultra-violet light [2], was used to fix the wire in its intended location. (The tube was held in a horizontal position on V-blocks during this process.) This was followed by an application of epoxy [3] that was to form the long-term seal at the endplug, and provide additional bonding strength for the wire. The epoxy was applied over the wire (and over the photobond), and the excess spread within the small (2 mm) coaxial space between the wire and the wall of the plastic feedthrough in the endplug. (Here, the tube was held at an angle to limit the flow of the epoxy.) Unfortunately, on drying, both the adhesive and the epoxy shrunk by approximately 5–10%, thereby moving the wire down by about 100 μm out of the Y=0 plane (away from the eyelet). It was found that the effect from the shrinking of the photobond was quite reproducible, but the effect from the epoxy was less so, because it depended on the exact nature of its flow. Because of time-pressures of the production schedule for the chamber, this effect was corrected temporarily in the remaining endplugs as described below.

The half of the plastic feedthrough that had the eyelet was machined away, and a layer of epoxy was poured into the channel (on the other side), in order to reduce the space between the intended position of the wire and the side wall to about 100 μm. The wire was then glued to the hardened bed of epoxy using photobond [2], after which a small epoxy-fiberglass (G-10) platform was glued on so as to close off the feedthrough on the side where the eyelet was previously located. (Because of the unpredictable nature of the flow of the epoxy, the second epoxy bonding was therefore effectively eliminated.) This temporary correction was found to reduce the systematic excursions of the wire in Y to below 10 μm.

1.2 Corrective Measures Taken in Gluing Tubes into Modules

A similar problem was discovered in the gluing of the first module of tubes with Type A endplugs. It was mentioned in Ref [1], that the positions of both endplugs and tubes, prior to their being glued into a module, were very close to their desired locations. Also, the positions of the endplugs after gluing were found acceptable.

Nevertheless, the transverse (Z) positions of the tubes along their glued lengths (X coordinate) were subsequently found to be out of line. In fact, after gluing, the module developed a narrowed waste relative to the constrained height and width of their stacked endplugs. This narrowing was of the order of 250 μm in Z and about 50 μm in Y. The cause was attributed both to the fact that the spacers used between tubes were about 20 μm undersize, and that the $\sim$3 mm wide bands of epoxy [4] used in the gluing shrunk upon hardening, thereby pulling the stack together (as well as distorting the tubes). A different gluing procedure was therefore adopted to minimize such contraction. First, rather than depositing epoxy in 2–4mm wide layers across the narrow gaps between tubes, an epoxy dispenser was constructed for applying 1 mm wide stripes along the full length of each tube, at the azimuthal angles corresponding to where neighboring tubes were to touch when stacked together. Only a single layer of epoxy was administered per interface between tubes. Gaps of about 6 cm length in the stripes of epoxy were left where the tubes were to be supported on their special jigs [1], the latter being essential for assembling modules with tubes containing Type B endplugs.

2 Procedures for the Production of Modules

The first two modules using Type A tubes (Modules A1 and A2), and the first module using Type B tubes (Module B1) were assembled before our final procedures were established, and should be regarded as exploratory versions. The remaining modules (B2, B3, B4, A3 and A4) independent of the type of endplug, were assembled in the same manner, and represent our currently favored approach. (For a description of other similar stacking and gluing procedures, see Ref. [5].)

The final modifications in procedures involved using the special aligning jigs (designed primarily for constructing modules with Type B endplugs) to produce modules with both Type A and Type B endplugs. This decision was based partially on expedience, which necessitated simplification of overall procedures to speed up production, with the consequence that the "box" technique used to produce Modules A1 and A2 was abandoned for Modules A3 and A4 [1].

We summarize below some of the steps taken in the gluing of stacks of 64 tubes into modules.

- 1. Our precision granite table (1.0 m $\times$ 2.8 m), with imbedded steel runners on the sides, was cleaned thoroughly, and five 15 cm wide, 50 μm thick, foils were placed on the table in the approximate positions where the constraining jigs or "combs" [1] were to be located.

- 2. The comb-jigs were then placed on their 50 μm strips of foil. Exact aluminum spacers (546 mm) were placed at two extreme positions between the central comb and the next two outer combs, and another set of spacers (558 mm) were placed between those second and third sets of combs, with the latter positioned about 6 cm from the ends of the endplugs. A precision triangular granite block was positioned relative to the edge of the granite table, and the jigs aligned relative to the table and the triangular block (two 40 mm steel spacers separated the fifth jig from the triangular granite piece). A PVC stand, to be used for defining the end positions of the Type B endplugs (it could not be employed for Type A endplugs because of mechanical interference), was positioned near the end of the table where the signal sides of the tubes were to be placed for gluing. The combs were pressed to the long edge of the table (with 50 μm foils used as offsets) with precision bars mounted on the runners at the side, as well as with pressure bars from the top. (The pressure from the top was brought to bear at the bottom platform extension of the jig, which was about 10 cm wide.) After adjusting and tightening all screws, the jigs were found to be positioned to better than 10 μm relative to the side of the table. After the jigs were ready, the triangular granite slab was removed, and ten special precision aluminum spacers ("dog bones") were placed at the two ends of each of the combs. The configuration, prior to stacking and gluing of the tubes, is shown in Fig. 1.

- 3. The gluing commenced with each tube in the first layer receiving only one stripe of epoxy, except for the sixteenth tube in the plane, which did not require any. All the tubes were positioned in the stack at the same azimuthal angle, with their gas outlets pointing to the floor. The signal side was laid down first, and pressed against the PVC stand, and then the high-voltage (HV) side. The azimuthal angle of placement was checked to a precision of $<$10 mrad using a height gauge that located the position of the ground pin on the HV side of the endplug to an accuracy of $<$1 mm. After the first row of tubes was put down in the jigs, small pieces of 100 μm foil were placed between all the dog bones and the tubes, and between neighboring tubes, but only near the positions of the endplugs (just outside of the tooth locations of jigs 1 and 5, where there was no epoxy). In addition, 1.5 cm wide strips of 117 μm paper were placed across the stack at the five locations of the combs (near the teeth, where there was no epoxy), after which, the second row of tubes was added to the stack. This time, the epoxy was applied at three azimuthal locations on each tube, except for the two end tubes, which required only two stripes of epoxy to be glued to the stack. After the completion of the second layer, 100 μm foils placed in the same way as was done after the first plane of tubes. (The 117 μm paper strips required between planes were not added at this stage, but only after the first two layers were set, and the next layer was about to be epoxied on top.)

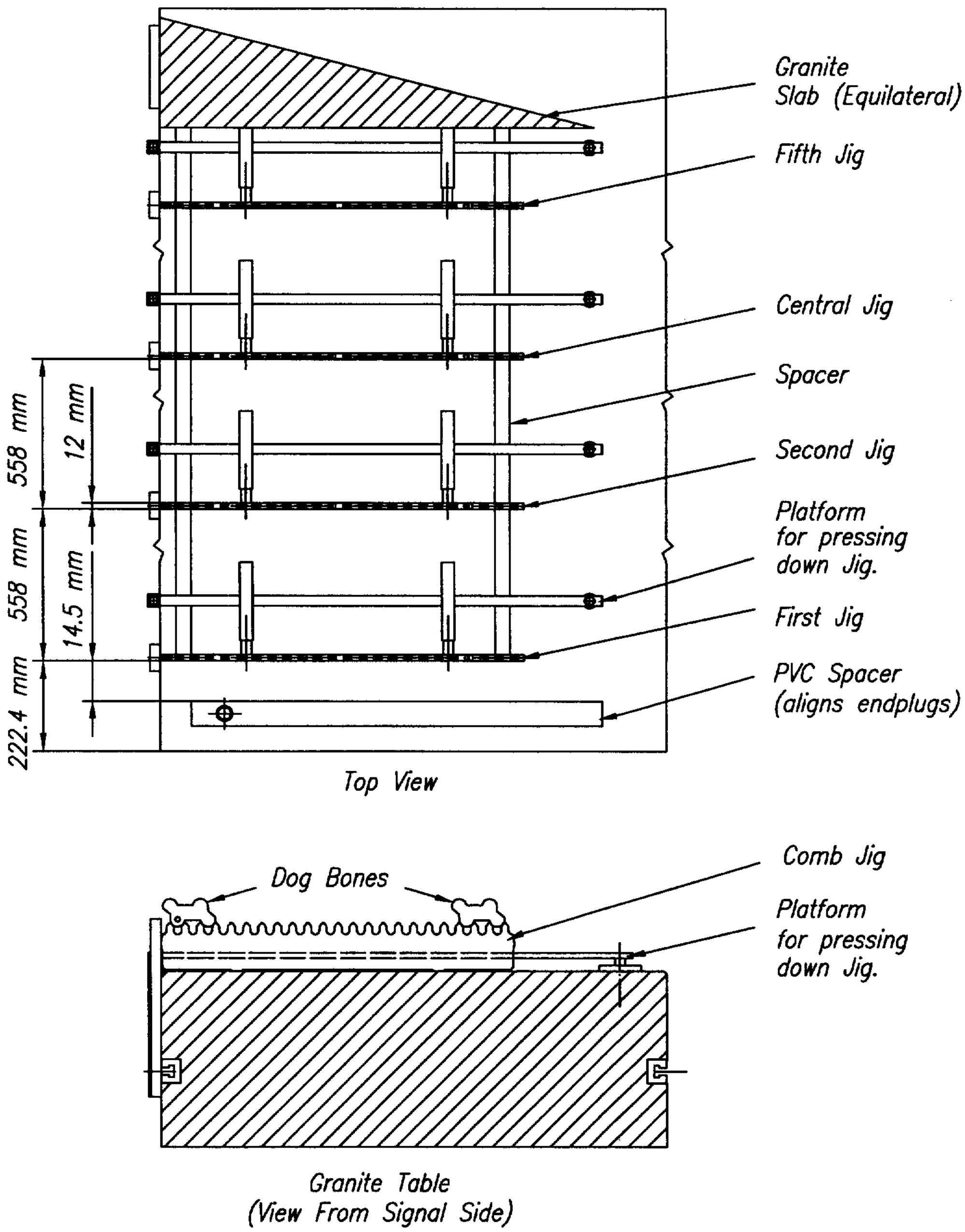

Figure 1: Sketch of the assembly of jigs and first set of "dog-bones" used for gluing 16 drift tubes into the first layer of a module. The granite triangular block used for aligning is an equilateral triangle, but distorted in the sketch. All the platforms and pressure plates are mounted directly to runners and locating holes in the precision table.

- 4. The gluing took, typically, about 1.5 hours per layer, and, upon completion of the first two layers, the epoxy was still quite maliable [4]. These layers were subsequently squeezed together using an upper set of combs in a vise-like manner, as shown in Fig. 2. Weights of 20 kg were bridged across the first two and the next two sets of combs, and a 14 kg weight was applied across the fifth comb (the weights were distributed quite uniformly at the locations of the teeth). The stack was left to dry for at least four additional hours before the next layers were added. Each of the following layers required a different dog bone, and consequently had to be glued and pressed and allowed to set individually.

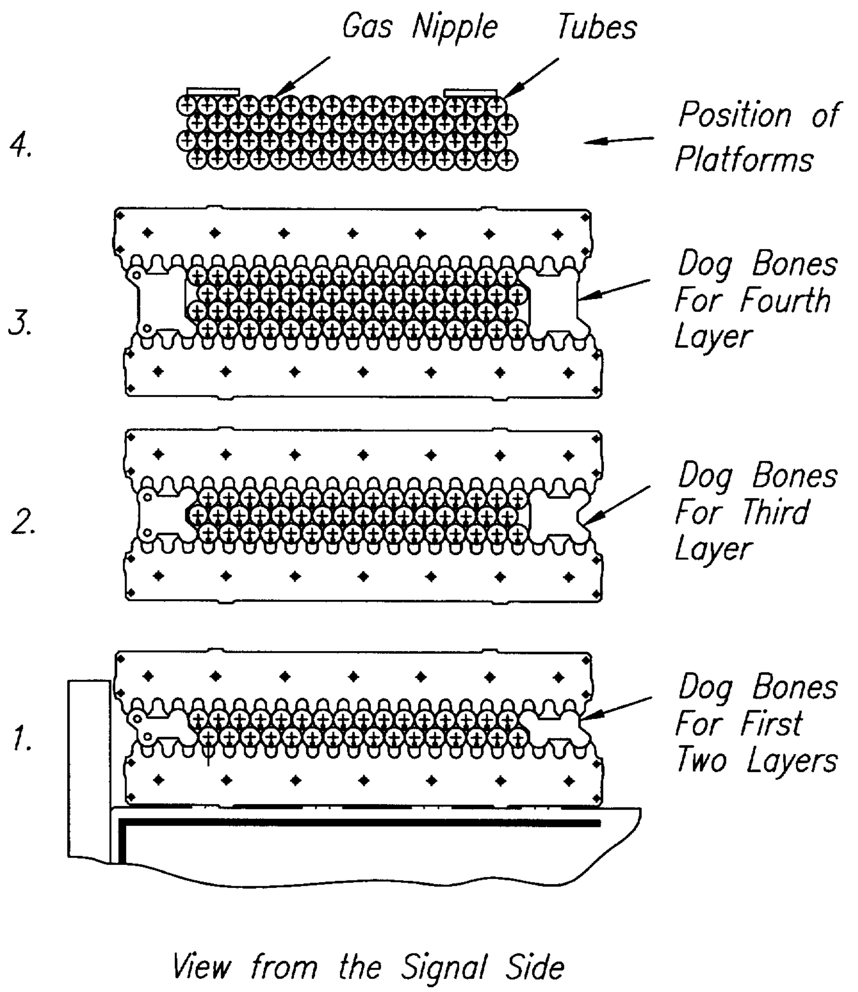

Figure 2: Sketch of the comb-jig (five used in stack), and the three sets of different "dog-bones", needed in the separate epoxying of a complete module. The fourth gluing involves the placement of ten platforms on the outer surface of the first epoxied layer of tubes (after module is turned over).

- 5. After all four rows of tubes were glued, the module was turned over in order to glue the 10 precision platforms to the outer layer [1]. This was done using five aluminum bridges referenced to the edge of the granite table, as shown in Fig. 3. The bridges were spaced precisely along the table, in a manner similar to that used for setting up the jigs. The first bridge was located 241.0 mm from the front of the table. The module was pressed against the edges of the bridges on one side (except for intervening 50 μm foils at the second and fourth layers of tubes), and was spaced on the other side by 3.480 mm steel shims that were placed at the third layer of only the first and fifth bridge). Two platforms, already in keyed and precise locations, were secured with screws to the top of each bridge, leaving a 100 μm gap between the platforms and tubes for administering epoxy. Once all the longitudinal spacers and bridges were in position, a single bridge was unclamped and removed, and a 1 mm stripe of epoxy was placed along 5 cm lengths of the three affected tubes. Each bridge was then repositioned and reclamped in its original location. To assure that the platforms sat precisely relative to the table during drying, the bridges were pressed in position to the edge of the granite table and weights (similar to those used in gluing of modules) were distributed on top of the bridges to squeeze the assembly together.

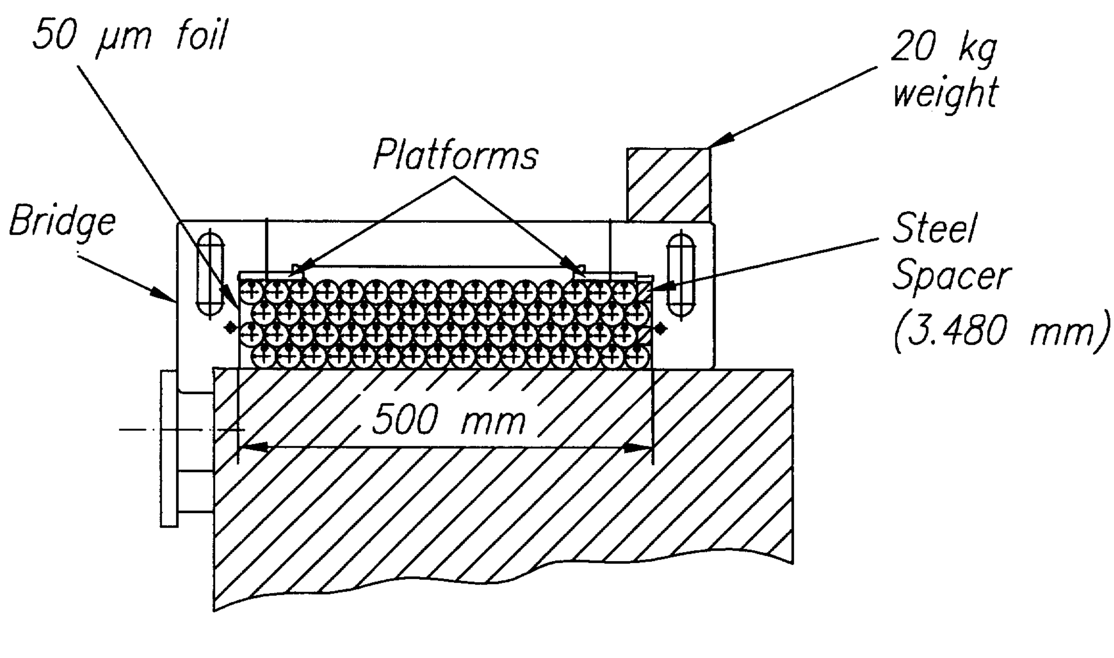

Figure 3: Sketch of the bridge (of which five are used in the procedure) for gluing the ten precision platforms to the outer layer of a module. The weights are added to keep the platforms in their precise locations during the setting of the epoxy.

3 Procedures for Attaching Modules to Frame

Because the granite table was only 1 m wide, the eight modules were epoxied to the cross plates of the frame in three stages [1]. First, the four central modules were attached, and then, separately, the two sets of outer modules. The frame served primarily as a joiner, with the precision coming purely from the placement of the modules relative to the granite table. Special aluminum spacers, with teeth separated at distances corresponding to the pitch of the glued tubes, were constructed for aligning modules to each other. Figure 4 shows the assembly after the gluing of the first four units. The procedure can be summarized as follows.

- 1. The bottom modules were positioned on ten precision 1 cm steel blocks that were captured within the platforms of the module. The toothed spacers were then placed on top of the modules, and the mirror-image planes on top of the spacers. The space between the modules left room for the frame and 200 μm gaps for applying epoxy at the top and bottom of the three cross plates. The 24.6 cm wide frame was supported by steel beams (with two 200 μm spacers for the epoxy) near the two longitudinal at the two ends of the table. When the alignment was judged to be good to 10 μm, the steel beams were used to lift the frame and the top module, in order to administer 2 mm wide and 5 cm long ropes of epoxy to all tubes at the positions of the three cross plates. The frame and top modules were then repositioned on the bottom modules, and the top modules removed. Again, 2 mm wide and 5 cm long ropes of epoxy were placed on all tubes at the positions of the three cross plates, and the modules replaced for drying.

- 2. In order to glue the next set of modules (A1 and A2) to the frame with Modules B1, B2, B3 and B4 already in position, required that the previously epoxied modules hang partially off the granite table. For the second gluing, modules B1 and B2 remained partially on the table, while Modules B3 and B4 rested on a granite extension that was attached to the main table. The side that was not to be glued was located relative to the right side of the extension, in a manner similar to that shown for the left side in Fig. 4. Adjustments were made in the shims so that the previously glued modules sat squarely on their 1 cm blocks on the table (only the ten left plaltforms of Module B2 were on the table). The central four toothed spacers were released from between Modules B1/B2 and B3/B4, and used to align A1 to A2, and A1/A2 to B1/B2. After alignment was finished, the lower (A2) module was removed, epoxy applied as in the previous gluing, and the module slid back on paper tracks into position (the rest of the assembly was lifted slightly during this operation). The paper tracks were then removed so that the module rested once more on the 1 cm steel blocks, as the frame was lowered on it. Finally, the top module (A1) was epoxied in a way similar to that used for B1 and B3.

- 3. The last two modules were attached with the frame cantilevered over the left edge of the table by about 1 meter. This required an additional support bar to prevent the assembly from toppling over. The procedures followed for the final gluing were similar to that used for the second gluing.

How it all worked is still a mystery! [T. Ferbel]

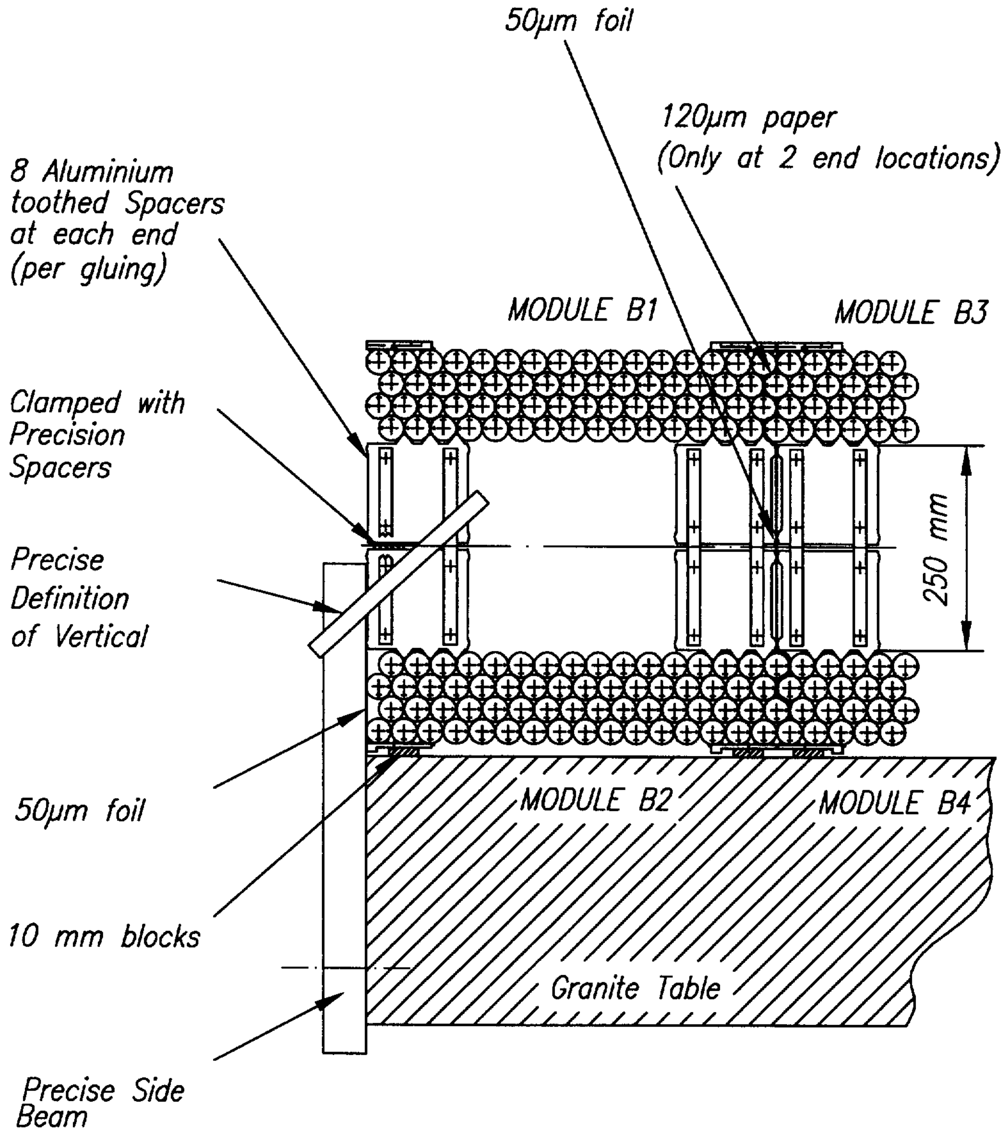

Figure 4: Sketch of arrangement used for attaching first four modules to the frame (which is not shown, but rests just within the sets of toothed spacers). The final assembly is given in Ref [1].

Acknowledgements

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