

ATLAS CAL-Note 60

Mechanical Design of the ATLAS Hadronic End-Cap Calorimeter

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Abstract

The mechanical engineering design of the hadronic end-cap is presented. The modular construction is described, and the techniques to stack, cable, and test the modules are discussed.

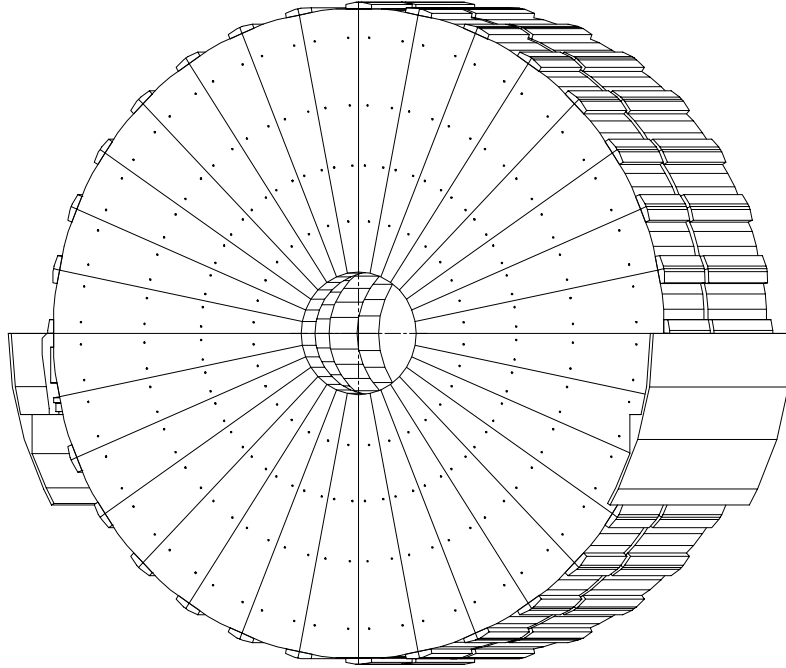


Figure 1: Isometric view of one hadronic end-cap, showing the front 24 plate, and rear 32 plate wheels, sitting on the cryostat rails.

1 Mechanical description

The two hadronic end-caps of the ATLAS detector occupy the region 4200 mm to 6118 mm measured axially from the interaction point and 1.5 to 3.2 in pseudorapidity. The physical volume, filled by the hadronic end-cap calorimeter, is approximated by a series of annular volumes with constant outside diameters and step-increasing internal diameters. Each end-cap consists of two separate ‘wheels’: each wheel being formed from 32 pie-shaped ‘modules’ (see figures 1 and 8). Figure 1 shows a 3-dimensional view of one end-cap, with portions of the cryostat, so that the rails which support the two wheels (66 Tonnes front wheel, and 85 Tonnes rear wheel) can be viewed. The modules are formed from 25 mm thick copper plates each separated by an electrode structure made up of a multi-layered sandwich of copper coated polyimide film / aramid fibre honeycomb (see figure 2). The latter sandwich contains the etched tile arrays which produces the required readout segmentation of $2\pi/64$ in ϕ and 0.1 in pseudorapidity. As can be seen in figure 3 the segmentation in pseudorapidity is stepped, because the electrode structure changes only every 8th layer, producing the desired semi-pointing geometry. The hadronic end-cap calorimeter thus contains seven groups of layers each comprised of eight identical plates and electrode structures. The modules of the front wheel consist of 24 layers, and the rear wheel of 32 layers in depth. This arrangement gives a total of about 10.0 interaction lengths. Each module is held together by seven tie rods (for locations see figure 4); the inter-plate spacing is maintained by stainless steel sleeves around the tie rods in the inter-plate gap. The relative size of these rods to the readout pads can be seen on figure 5

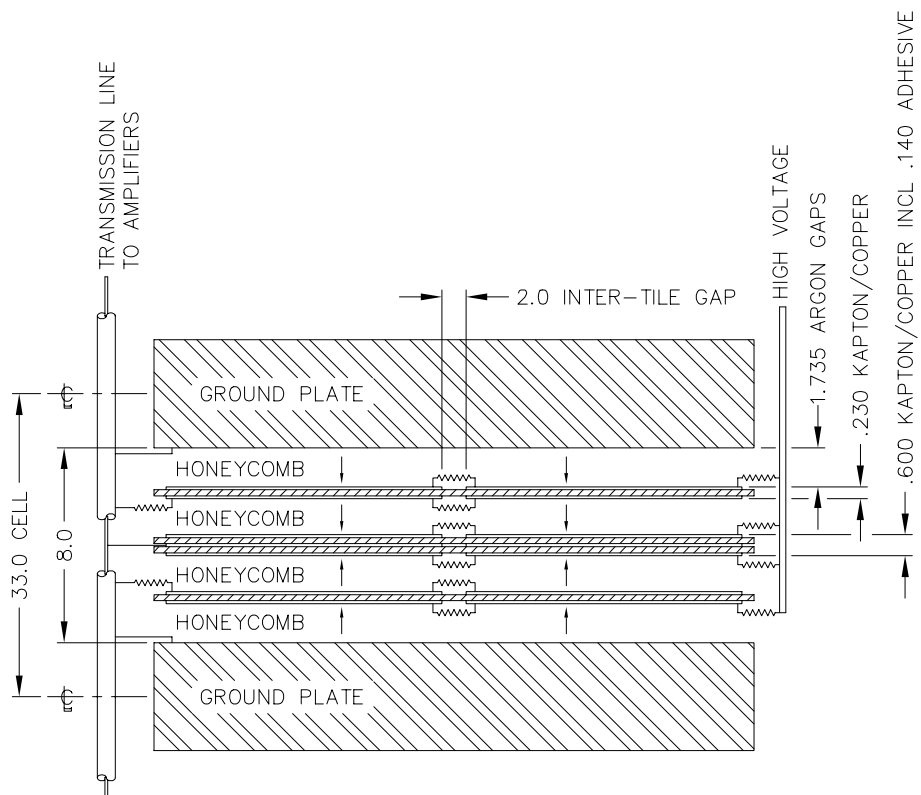


Figure 2: Schematic $\phi - z$ view of electrode structure.

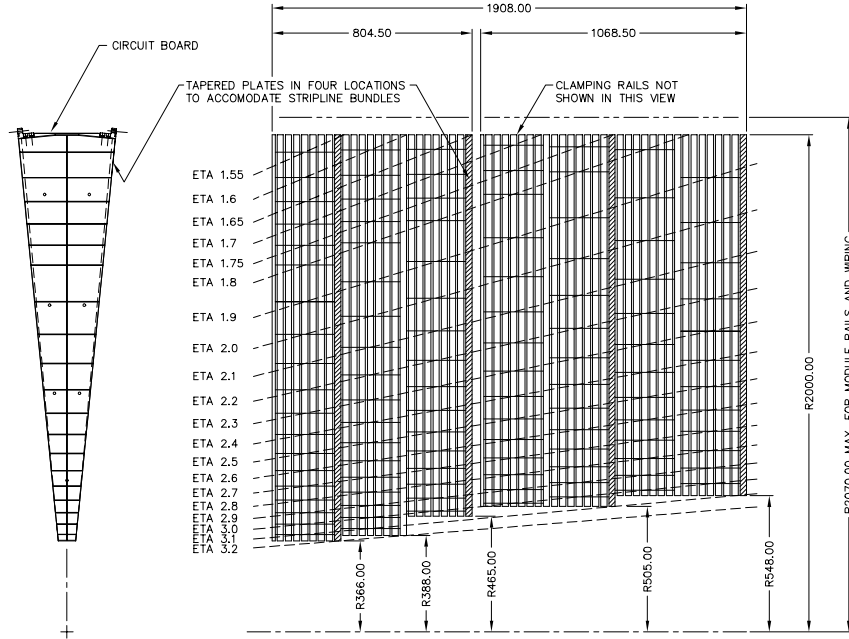


Figure 3: $r - \phi$ and $r - z$ view of hadronic end-cap.

for the inner small readout pads: the sleeves also locate the electrode structure in the gap. Once assembled, the 32 modules are arranged to form a wheel in the horizontal plane: stainless steel fixtures, previously bolted on the outer edges of each module, are now bolted together so as to clamp together the outer edges of adjacent modules (see figure 6). The inner edges of the modules are fitted with plastic spacer pads (see figure 7) which maintain the nominal 1 mm clearance between modules. Finite element analyses are being carried out to determine the stability of the structure during thermal cycling between liquid argon and ambient temperatures and to confirm the absence of unacceptable mechanical deformation when supported on rails in the cryostat. In order to provide optimum performance for electromagnetic showers extending into the front section of the hadronic calorimeter, the first copper plate is a thin plate (see figures 2 and 13). The exact thickness of this plate is under study.

2 Electrical description

The composition of the electrodes of the hadron end-cap calorimeter is shown in Figure 2. The spacing of the two copper-clad kapton electrostatic transformer (EST) planes and the copper/kap-ton/copper/kapton/copper signal plane is maintained by the honeycomb layers which are filled with liquid argon before operation. Signals from the etched tile arrays in the signal planes are transmitted by means of 50Ω striplines (coaxial cable bundles are also being considered) to the amplifiers (see figure 8). These signal lines are routed axially through shallow notches in the edges of the copper ground plates, and then

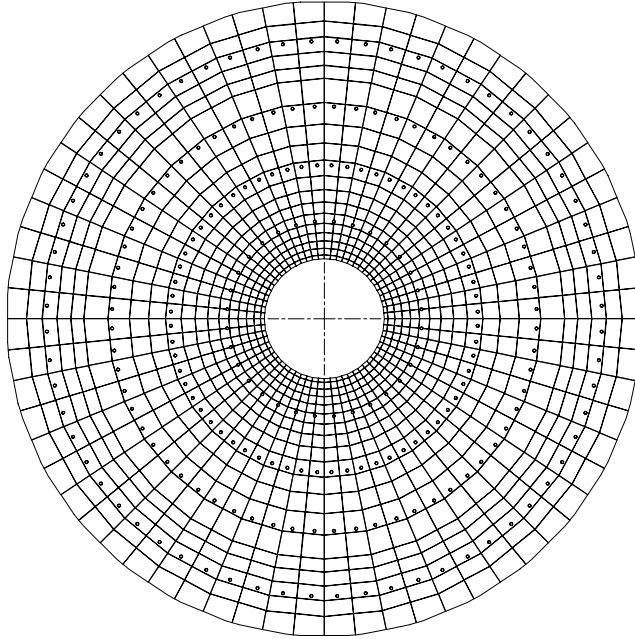


Figure 4: $r - \phi$ view of readout pad array, for layers 1 to 8 of wheel one. Location of all tie rods is shown.

radially in grooves in the copper plates to the preamplifiers (see figure 9 and 10). In order to provide depth readout of the calorimeter, the signals from a single ϕ, η segment are ganged into four separate regions after the preamplifier stage. As the preamplifiers and summing network are on a single chip, the signal line routing is chosen so as to preserve the order in the lines, and so that the signals to be ganged arrive at the preamplifier circuit board at approximately the same time. The front(rear) module is ganged in two readout regions comprised of: a front 8(16) layer region and a back 16(16) layer region. The axial routing passes through all the layers of a region of a readout depth before turning 90° and travelling radially to the amplifier (see figures 8, 9 and 10). The signal lines are connected to circuit boards mounted at the outer circumference of the wheels. A detail of the signal line routing near to the circuit boards is shown in figure 11. This routing has been chosen to limit time differences between the signals from individual layers in a ganged region to well below 2 ns. Low inductance signal ground is provided by making a ground connection of the 50Ω signal line to the 25 mm copper plates next to every signal connection. Several alternate methods of cabling are being considered using this same cable route, in particular replacing the striplines (with their rather narrow lines) with a bundle of co-axial cable.

The current reference calibration scheme requires that each readout amplifier be pulsed at its input. However the scheme where the calibration pulse is placed on each readout pad has been investigated from a mechanical standpoint. This scheme is considerably more expensive and complicated, but mechanically could be implemented.

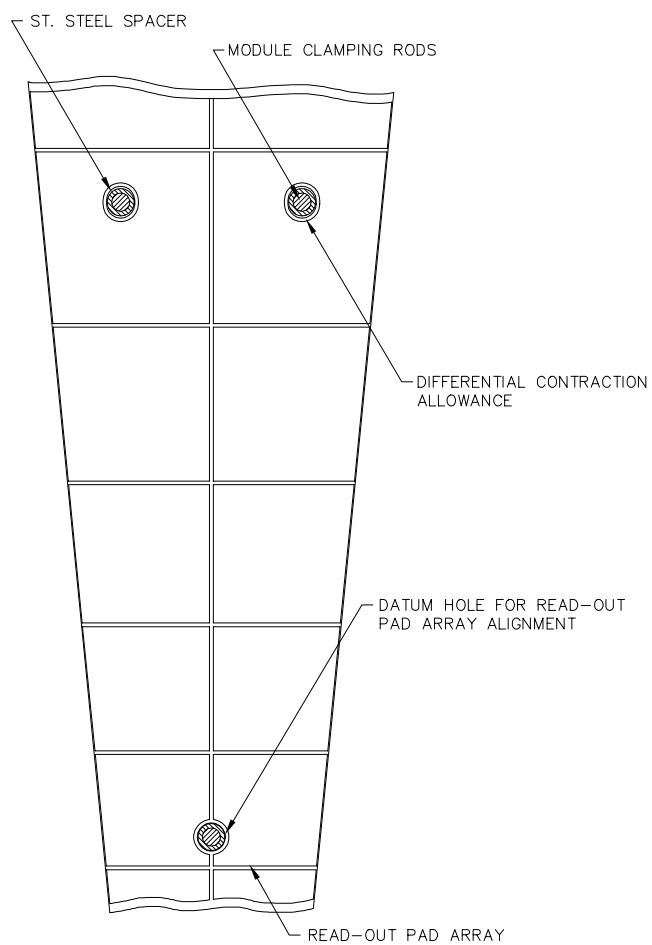


Figure 5: Partial $r - \phi$ view of readout pad array, showing 3 tie rods.

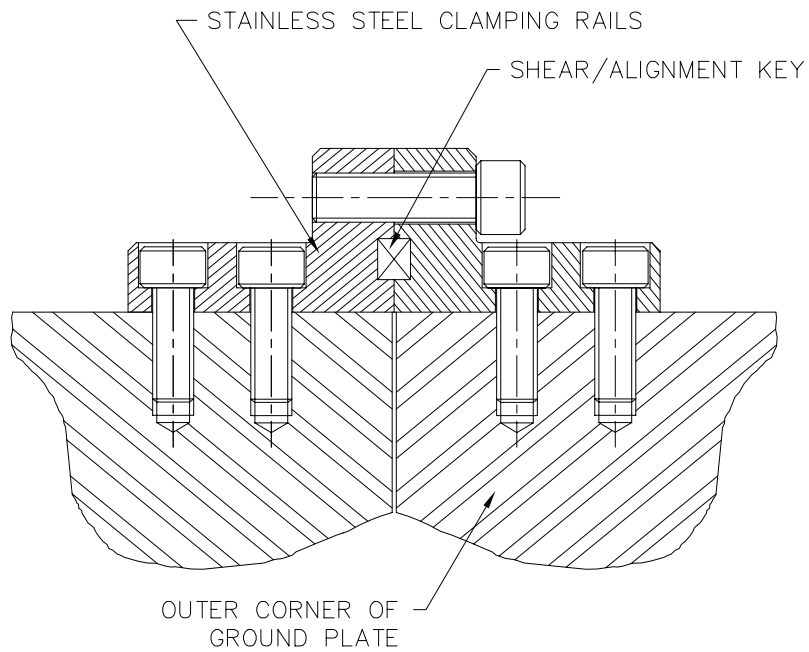


Figure 6: Detail of inter-module clamps ($r - \phi$ view).

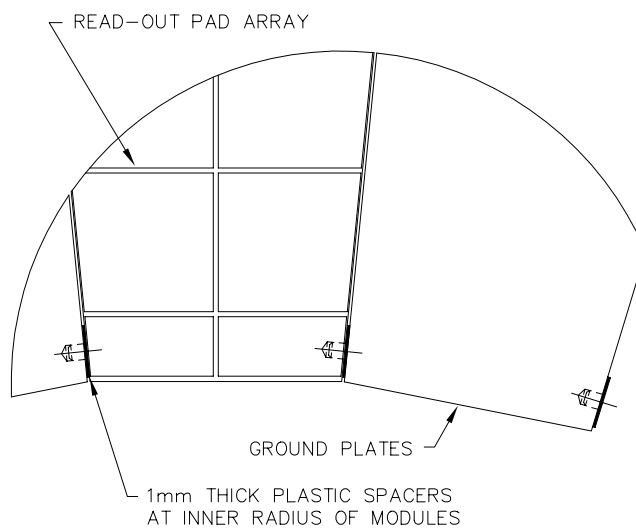


Figure 7: Detail of inter-module liquid crystal polymer plastic spacer ($r - \phi$ view).

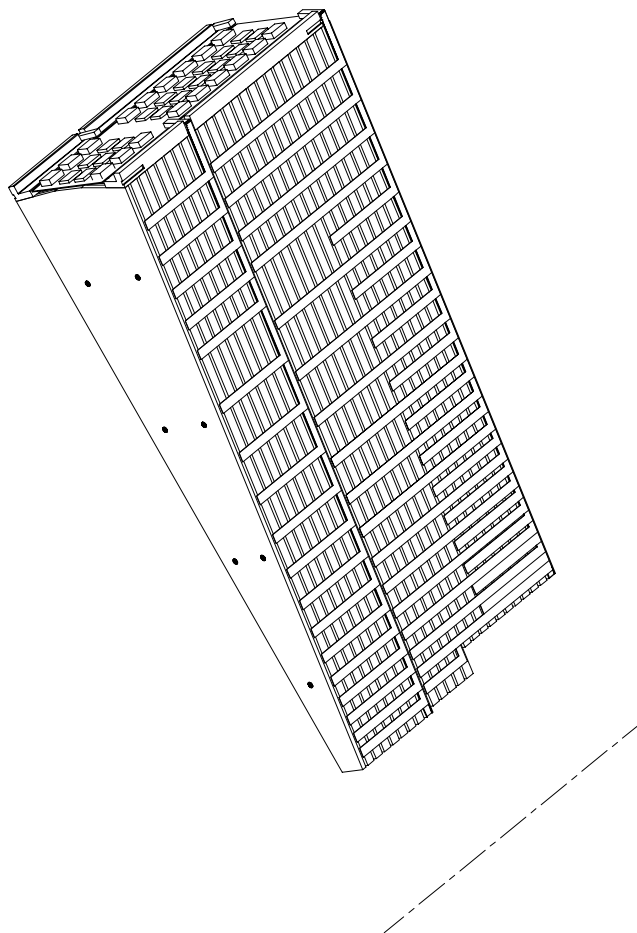


Figure 8: Schematic isometric view of one front wheel end-cap module, showing signal routing. The front 8 layers are routed together, as are the back 16 layers.

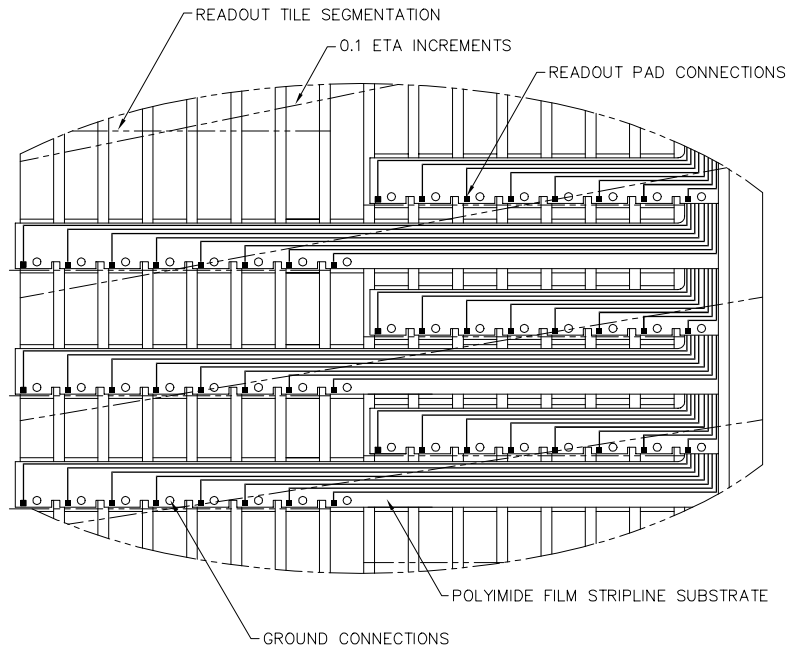


Figure 9: $r-z$ view of detail of wiring of signal lines on side of module. Ground connections are made to the 25 mm copper plates, with signal connections being made to the readout pads (not shown) in the 8 mm inter-plate gaps.

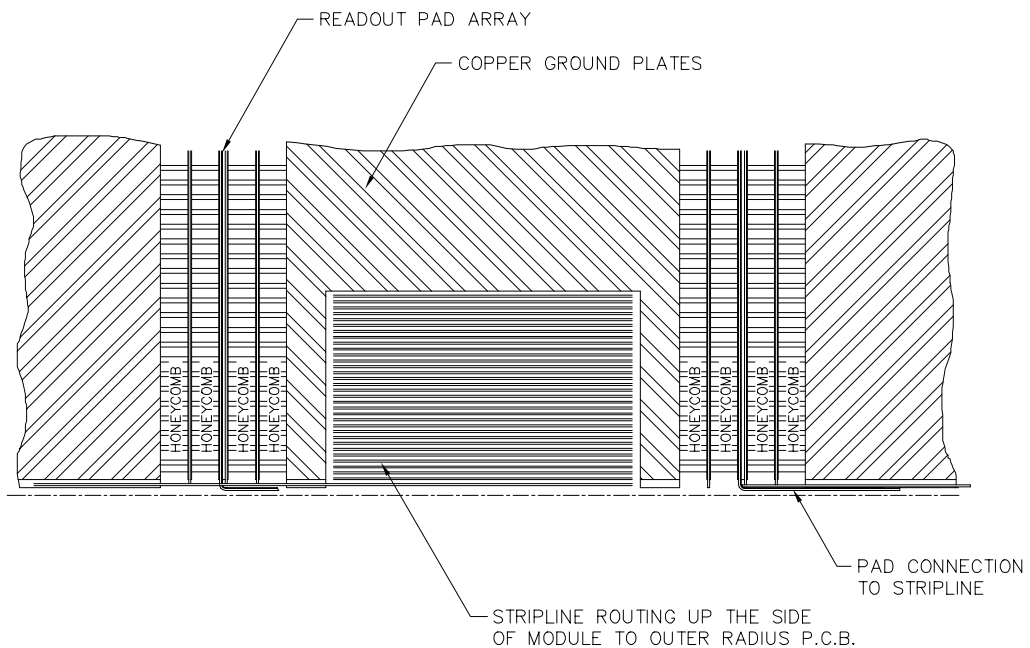


Figure 10: Schematic $\phi-z$ view of signal line routing as it travels radially out in a groove in the 25 mm copper plate.

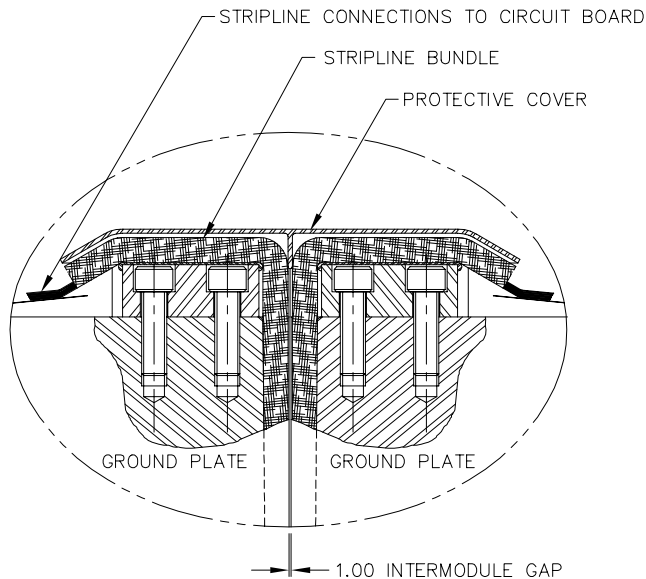


Figure 11: $r - \phi$ view of signal line exit at outer radius of module.

2.1 High Voltage Coupling and Distribution

The high voltage is distributed to the pads of the EST at different radii of the modules. The exact routing is under study. In each EST gap the high voltage is distributed either by a layer of high resistive coating or by resistors which connect the pads. The choice of the high voltage distribution has to take into account several competing factors (e.g. voltage drop due to the current draw from minimum bias events, protection of preamplifiers against sparking). A detailed evaluation is still in progress.

Each of the four EST layers in an 8 mm electrode cell (see figure 2) is supplied independently with HV: within a readout region the corresponding EST layers of each cell are supplied in parallel from a common HV source. In this way it is ensured, that in the event of a HV failure, only a single EST layer in a readout region is lost. In this eventuality the loss can be calibrated out. The maximum current draw of this system, due to minimum bias events, will be about $3 \mu\text{A}$ per EST layer. There are 16 independent HV lines per module.

3 Module assembly

The modules are assembled in the horizontal plane in a stacking jig, which ensures the accurate location of the components during the procedure (see figure 12). When stacking of a module is complete, the tie rods are tightened to a preset load (see figure 13), the stainless steel fixtures are bolted to the outer corners of the copper plates and a spacer is added to one edge of all the plates near the inner radius (see figures 6 & 7). 50Ω signal lines are connected to the readout pads, with the signal line grounds being connected to each copper plate it passes (see figure 9). Finished modules are inspected and electrically

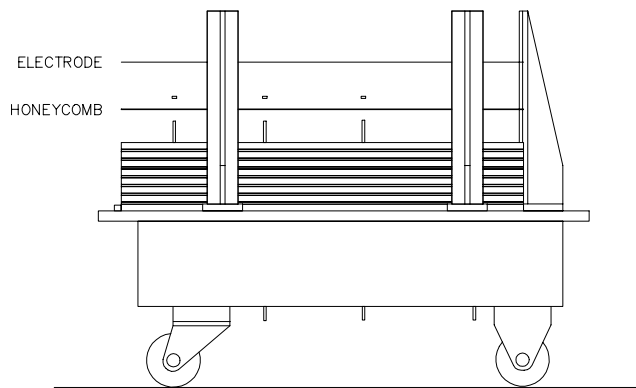
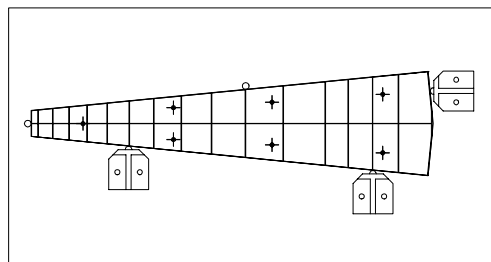


Figure 12: Stacking jig, showing honeycomb, electrode, and spacers being lowered onto the module during production.

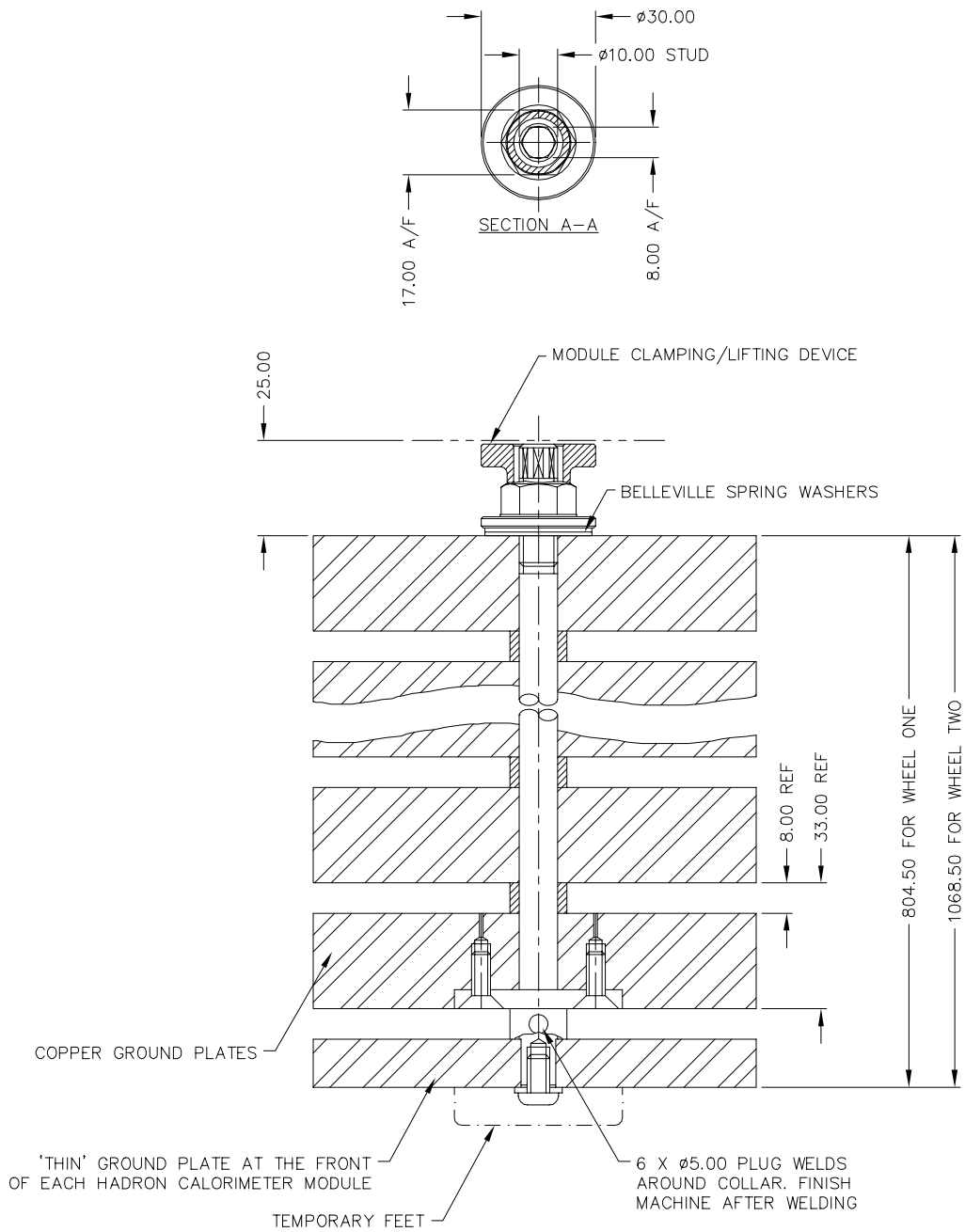


Figure 13: Detail of tie rods.

tested before wrapping and crating for transit to the CERN site. Following arrival at CERN, the first production batches of modules will be tested in liquid nitrogen. These tests will be conducted to determine whether the testing, previously performed at room temperature, will be a sufficient means of quality control.

4 Wheel assembly and insertion

Following arrival at CERN the modules will again be inspected and tested prior to assembling into ‘wheels’. Wheel assembly is carried out in the horizontal plane on a support platform. Modules are bolted together at the outer radius by a tangential ring of bolts through the stainless steel fixtures on the modules. Special fixtures are attached to the wheel, on the outer edge near the midplane, that will transfer the wheel load to the support rails. The completed wheel and platform is rotated to bring the wheel into the vertical plane, with the weight of the wheel slowly transferring onto the short rails built into the platform. These rails support the wheel in the same manner as the cryostat support rails. The wheel, on its support structure, is moved to the cryostat and the rails of the support structure are connected to the cryostat rails. Final inspection and electrical testing is performed before the wheel is slid into position in the cryostat. The second wheel of the end-cap and the wheels of the other end-cap are loaded in a similar manner. On both of the support rails the wheel location is fixed in the longitudinal direction but is able to move in the transverse direction to accommodate differential expansion and contraction. The transverse location of the wheel is maintained by a set of alignment pins at the top (and possibly the bottom) of each wheel assembly. This arrangement then allows relative thermal expansion and contraction of the wheels with respect to the cryostat walls, while keeping the centre hole of the wheel aligned with the forward calorimeter (mounted on the cryostat centre bore).