1 BI system layout and installation studies

The installation of new triple thin-gap RPC chmabers in the BI layer of the barrel muon spectrometer requires the replacement of the MDT chambers in the small BIS $r\phi$ sectors by sMDT chambers with half the drift tube diameter (15 instead of 30 mm) and hence almost half the chamber height because of the very tight space limitations while in the large BIL sectors new thin-gap RPCs of the same design as in the BIS sectors can be installed on the MDT rail system on top of the existing MDT chambers. The available space and the installation procedures for the sMDT and RPC chambers have been studied in detail by ATLAS Technical Coordination [?, ?]. It provided the envelopes for the design of the new BIS 1-8 sMDT and the BIS and BIL RPC chambers and their support structures. Details of the installation scenarios are discussed in Chapter **??**.

The design and construction of new BIS78 sMDT chambers with 2 x 4 tube layers and integrated thin-gap RPCs with three gas gaps for the replacement of the current BIS 7 and BIS 8 MDT chambers in the 2019-20 LHC shutdown is a pilot project for the complete replacement of the BIS MDT chambers by integrated sMDT and RPC chambers for HL-LHC. The drawings of a BIS 7/8 sMDT detector with integrated triple thin-gap RPC chamber of only 50 mm thickness are shown in **??**. The preliminary BI RPC design is shown in Figure **??**. The design of the remaining new BIS 1-6 sMDT and RPC chambers will be very similar to the BIS 7/8 design. Moreover, the design of the BIL RPC chambers is very similar to the BIS RPC design with differences only in area and in the rail supports to allow for installation on top of the existing BIL MDT chambers.

The common challenge for the mechanical design of the BIS sMDT and RPC chambers is the small available space and the control of gravitational deformations of the thin chambers with minimal space for support structure, both for sMDTs and RPCs. The BIS RPC chambers are mounted on their own support frames independently from the sMDTs (see Figure **??**) to prevent distortion of the sMDT chambers and will be installed on the existing BIS MDT rail system interleaved with the sMDT installation. A common transport, storage and installation frame for each pair of sMDT and RPC chambers has been designed.

In order to provide space for the RPC rail supports in between the sMDT chambers, a gap of 20 mm is required between adjacent sMDT chambers. This is achieved by removing one tube per layer of each BIS 1-6 chamber compared to the maximum possible. This does not affect the width in z of the Faraday cages on the readout and high-voltage ends of the chambers which contain an unchanged number of readout and HV distribution boards since the RPC supports have to pass between the sMDT chambers only in two locations along the tubes (see Figure **??**). The resulting tube layout of a sector of the new BIS sMDT layer for LHC phase 2, including the BIS 7/8 chambers, is shown in Figures **??**. Gaps between adjacent BIS RPC chambers are not required.

The new BIS and BIL RPC chambers will cover the solid angle range $|\eta| < 1.05$ with minimal acceptance gaps. Figures **??** and **??** show the RPC layout with the 8 small and 8 large $r\phi$ sectors following the same naming scheme as for the MDTs. The layout of the RPC chambers in the large BI sectors (see Figure **??** takes into account the necessary free space for the passage of the existing projective alignment rays to the BIL MDT chambers.

The trigger coverage including the new BI layer is being optimised using Monte carlo simulation. Figure **??** shows the result of an acceptance study for the first iteration of the RPC layout using MDT truth hits and applying a realistic BI RPC geometry, including the cutouts for alignment rays, services as well as inefficient regions at the chamber edges. The layout comprises 236 triple RPC chambers for phase 2 of which 96 are in the small sectors. They cover a total area of 470 m^2, corresponding a total detector area of 1410 m^2, one fifth of the present RPC system.

A total acceptance of the BI chambers of 91% is achieved, compared to 95% for the MDT chambers, which corresponds to a barrel trigger acceptance of already 95% in combination with the existing RPC layers. The figures shows that there is still room for further optimisation before the layout is finalised for chamber production. The total number of front-end electronics channels will be approximately 135000, scaling the strip pitch with the distance from the IP. The total number of trigger (PAD) boxes is 400, which will be very similar to the ones designed for the replacement of the trigger electronics in the present RPC system for phase 2.

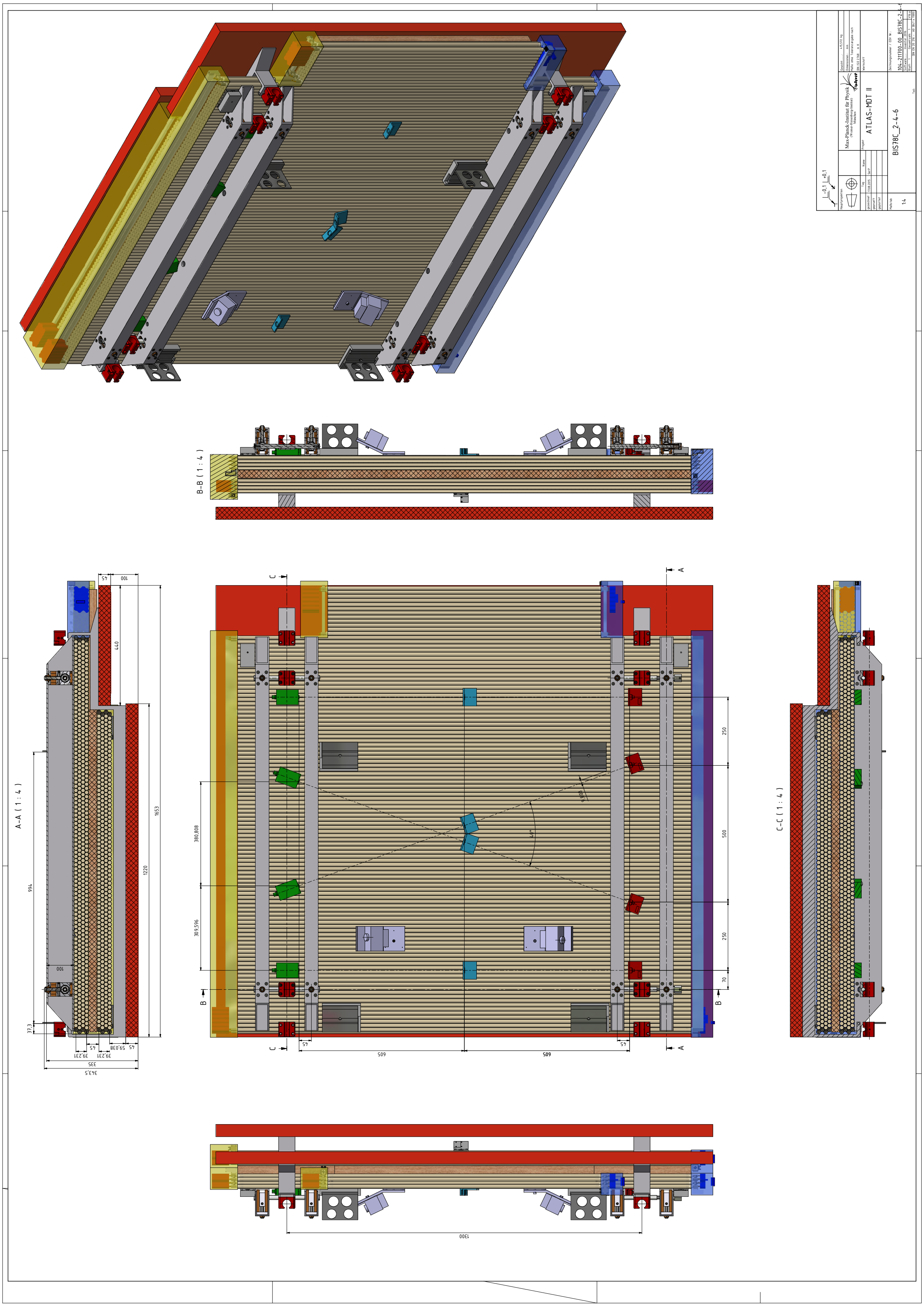

Figure 1: Mechanical drawings of a BIS 7/8 sMDT chamber with integrated triple thin-gap RPC. The RPC chamber is supported independently on the same rails in the BIS layer as the sMDT chamber. The same support scheme will be used also for the BIS 1-6 chambers.

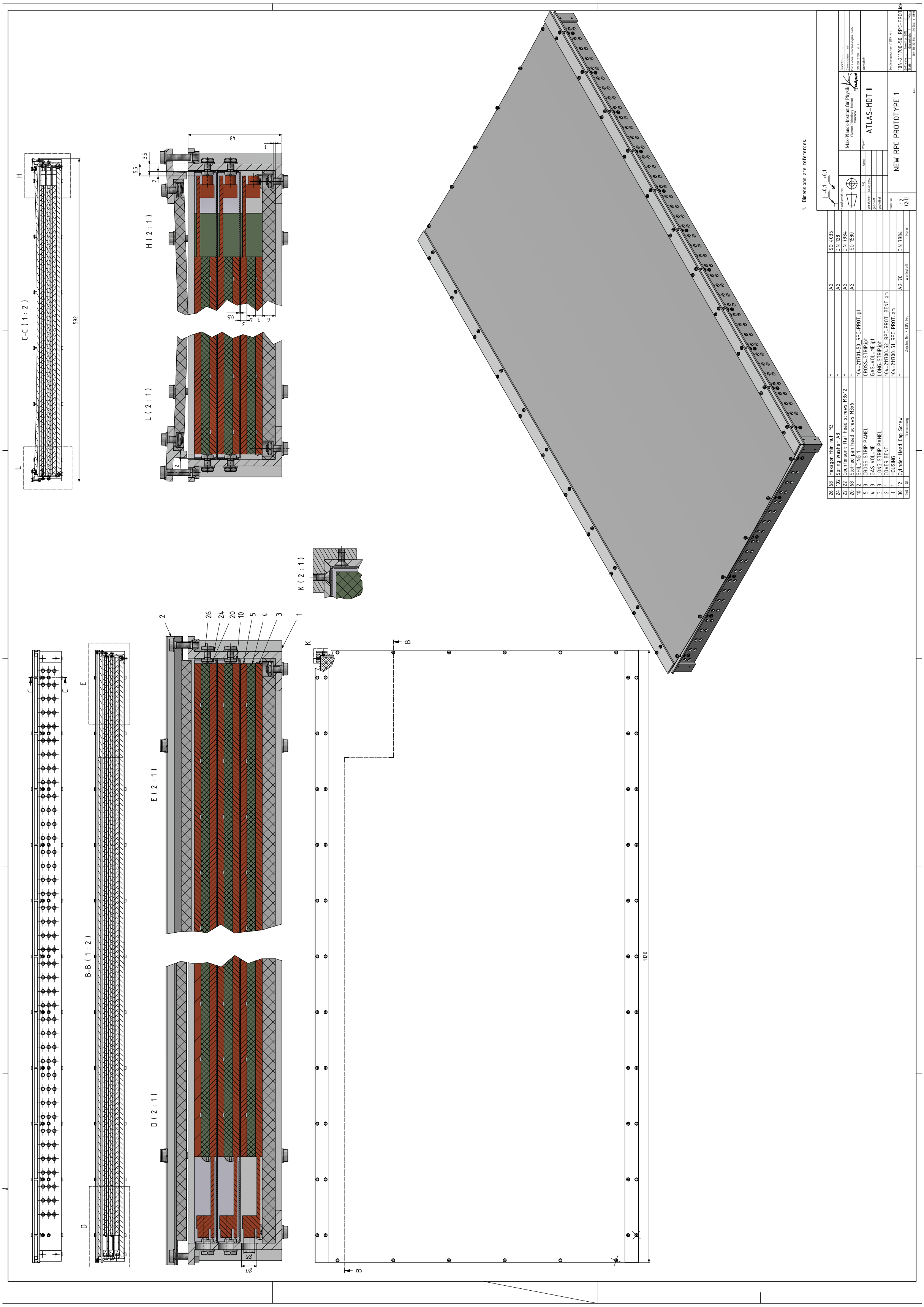

Figure 2: Mechanical drawing of a BIS triple thin-gap RPC chamber with only 50 mm thickness fitting into the BIS layer together with the BIS sMDTs.

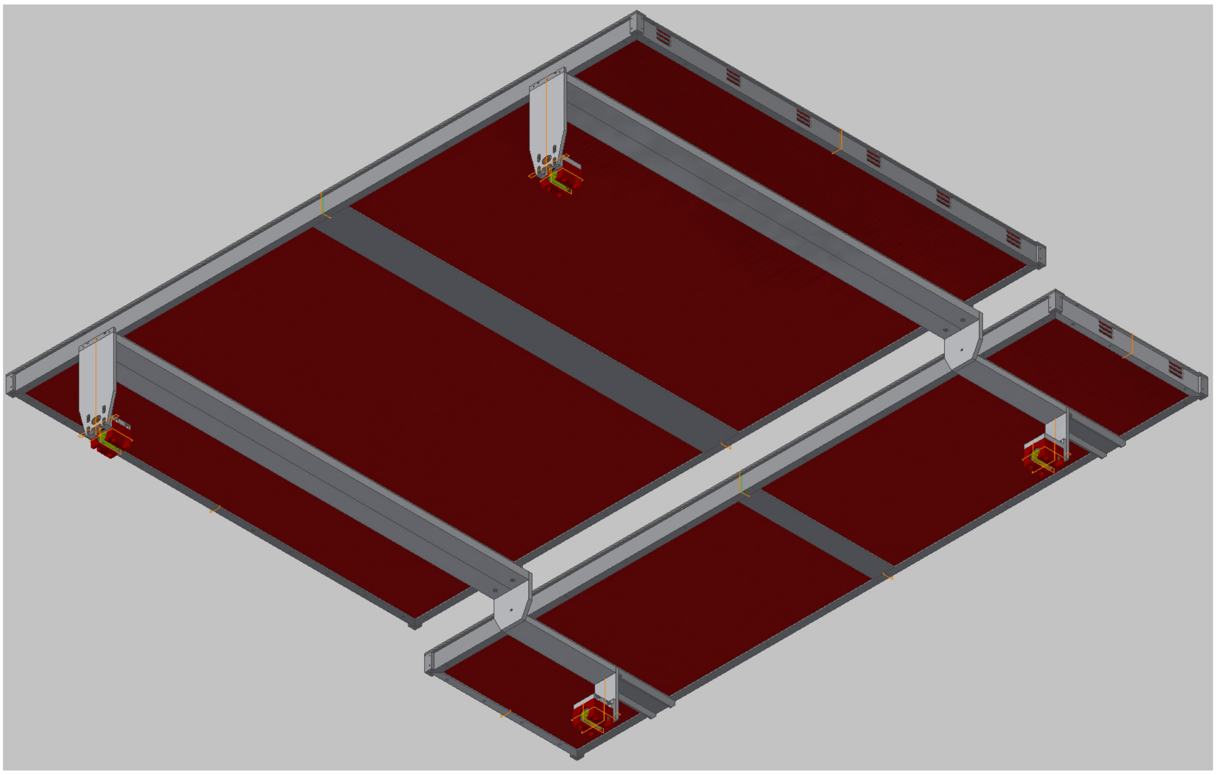

Figure 3: Mechanical drawings of a BIS 7/8 RPC chamber with rail supports.

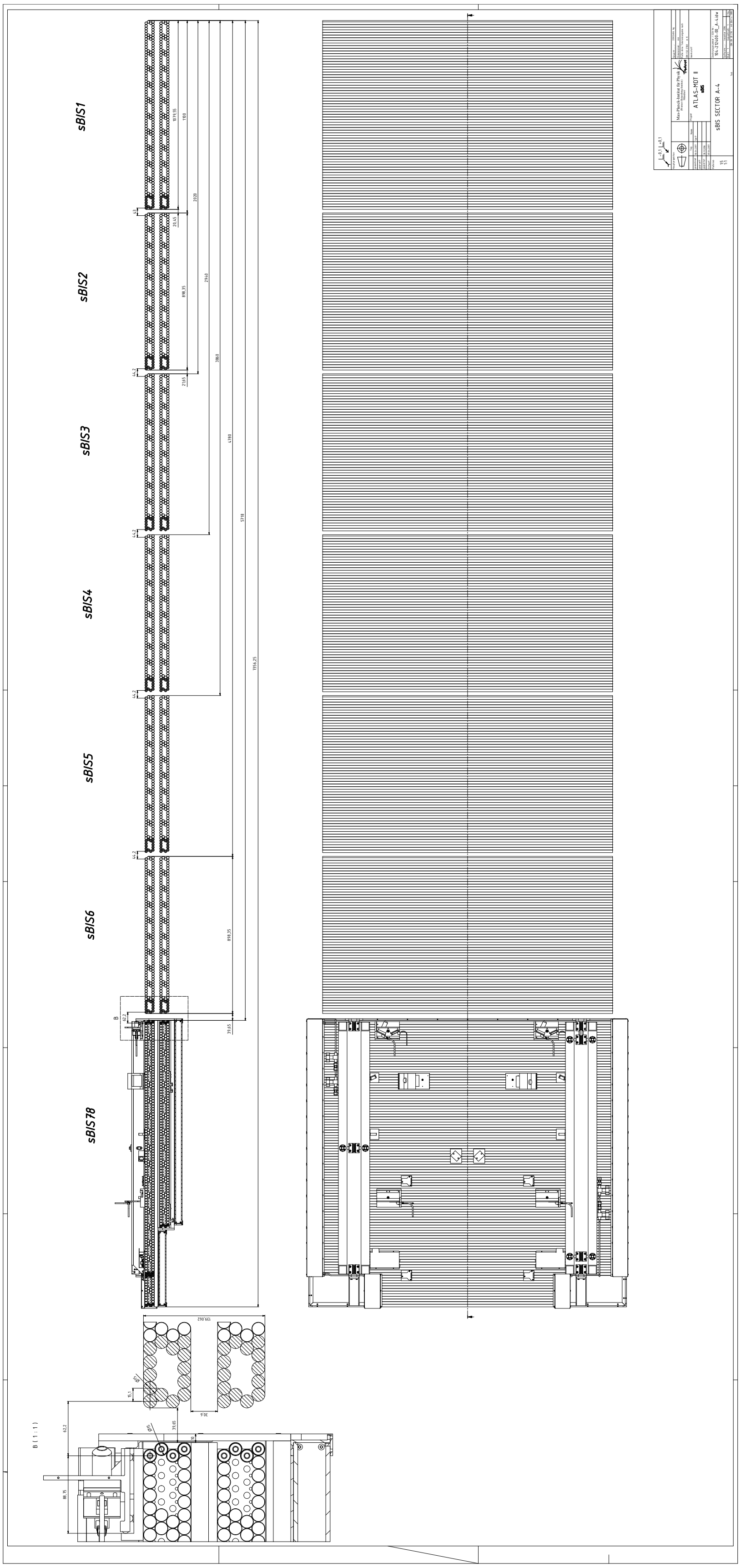

Figure 4: Layout of a complete BIS sMDT sector for phase 2 operation of the ATLAS muon spectrometer (left: view from the readout electronics side, right: view from the inside of the ATLAS detector towards the rail supports (shown only for the BIS 7/8 chamber).

Figure 5: Layout of the BI layer in the $r - \phi$ and $r - z$ projections with the new chamber positions indicated as red boxes.

Figure 6: Detailed layout of the odd and even sectors.

Figure 7: Layout drawing for BIL sector 1 side C.

Figure 8: Monte Carlo simulation of the BIL RPC chamber acceptance in sector 1 side C.