

2 Design objectives and mechanical structure

2.1 General considerations

The TRD will identify electrons with high efficiency. At the same time it will provide a trigger signal for electrons with large transverse momentum p_t at Level 1. In order to fulfill both of these tasks a careful optimization of the thickness of the detector is required. A certain minimum thickness of the radiator is required for the efficient identification of electrons. While the total thickness in radiation length has to be kept as small as possible (for details refer to Chapter 10) to minimize small angle scattering, bremsstrahlung, and showering, it still needs to provide mechanical stiffness for the proper operation of the readout chamber. One of the major aims of the detector is the measurement of pairs of high p_t leptons. Therefore it is crucial to minimize dead areas between the individual detector units.

As outlined in Chapter 1 the detector will be comprised of 540 detector modules arranged in 18 supermodules. Each of the supermodules will contain six layers of detectors subdivided into 5 sections in z -direction. Each of the 18 supermodules will be a unit of installation and will be supplied as a whole with the services as described below.

The TRD is the detector with the largest number of readout channels in the ALICE setup. Given also the large number of individual detector units major design considerations need to focus on simplicity and cost effectiveness.

2.2 Mechanical structure

2.2.1 Space frame

The space frame is the main support structure for almost all detectors of the central arm of ALICE. The current version of the space frame is depicted in Fig. 2.1. Its location and installation within ALICE is described in Chapter 16. The TRD will be mounted inside the space frame just outside the inner opening. The inner opening accommodates the TPC and the ITS. Still inside the space frame structure, immediately following the TRD, TOF modules will be inserted and special provisions are made to support the HMPID and PHOS.

For this version of the space frame a detailed list of all the weights that need to be supported has been compiled [1]. The total mass that needs to be supported by the space frame amounts to 75 t. In this total the TRD is included with about 21 t. The weight for the TRD was based on the following estimate: the weight per m^2 of detector area is about 15 kg, where pad/-readout plane with its support, the radiator with its support, and electronics and services are contributing approximately 5 kg/m^2 each. The services for low voltage, high voltage, and cooling running inside the supermodule are included in this number. The weight of the supermodule support frame, the heat shield, and the rails contribute another 10 kg/m^2 (with a contingency of about 25% for the weight of the support). The revised weights of all detectors led to a redesign of the space frame using stainless steel profiles instead of aluminum with increased cross sections listed in Table 2.1 below [1].

Finite element calculations were performed using ANSYS[®] 5.6.2 [1]. Maximum relative displacements of the final positions of the detectors were calculated. Under the load of the detectors the space frame assumes a slightly elliptical shape. This leads to a maximum displacement of the TRD support points of 1.0 mm in horizontal and 2.0 mm in vertical direction.

One of the main conclusions drawn in [1] was that the supermodules need to be mounted with space for adjustment of the order of 3 mm. In that case none of the load due to deformation of the space frame

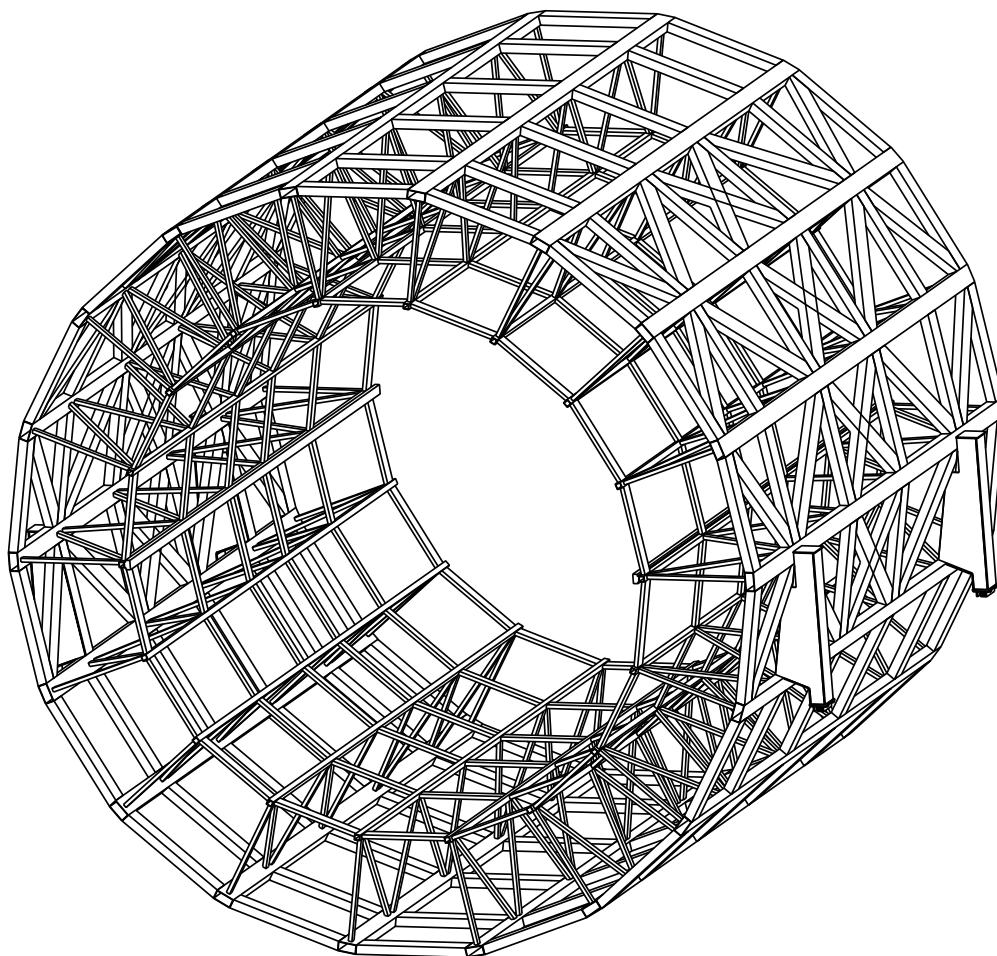


Figure 2.1: Axonometric view of the ALICE spaceframe.

Table 2.1: Dimensions of the space frame elements used in the simulations.

external frame beams	$100 \times 175 \times 3.5 \text{ mm}^3$
supporting rods	$200 \times 175 \times 4.0 \text{ mm}^3$
web rods	$60 \times 40 \times 4.0 \text{ mm}^3$
internal frame front/rear rings	$40 \times 135 \times 6.0 \text{ mm}^3$
inner rings	$40 \times 100 \times 6.0 \text{ mm}^3$
longitudinal beams	$60 \times 60 \times 3.0 \text{ mm}^3$
TPC beams with rails	$75 \times 100 \times 6.0 \text{ mm}^3$

would be transferred onto the supermodules themselves.

As the central detectors of ALICE evolve the design of the space frame may need to be reconsidered. The figures quoted here reflect the conditions implemented in the simulation framework AliRoot at the time when this document was prepared. As described in Chapter 16 the deformations have only recently been rechecked with the aforementioned total load on the space frame of 75 t.

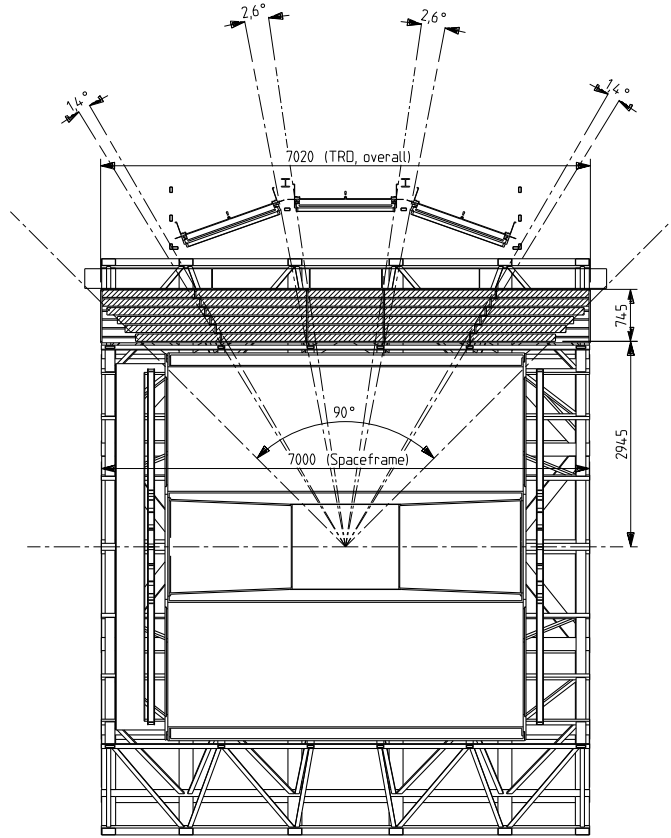


Figure 2.2: Cross-sectional view (cut through the xz -plane) of the space frame supporting the central detectors of ALICE. The angles on top of the figure indicate the shadows cast by the individual detector frames.

2.2.2 TRD in the space frame

In Fig. 2.2 a cut through the space frame with the TRD in xz plane is shown. Inside the supermodules the six layers of detectors are shown. In the layout chamber boundaries were aligned with the cross bars of

Table 2.2: Dimensions of the individual TRD modules. R_{Ra} : Radial distance from the interaction point at the front face of the radiator. L_2 : overall length of the center module. $L_{1,3}$: overall length of the modules left and right of the center module. $L_{0,4}$: overall length of the outer modules. L_{tot} : overall length of layer. L_F : total length of frames in z -direction (length of the active area of each module is $L_i - L_F/5$ ($i = 0..4$)). W_{tot} : overall width of a module in one layer. W_F : width of lateral profiles (width of active area of each module is $W_{tot} - W_F$). A_{tot} : total area covered by detectors. A_{act} : total active area.

plane	R_{Ra}	L_2	$L_{1,3}$	$L_{0,4}$	L_{tot}	L_F	W_{tot} [mm]	W_F [mm]	A_{tot} [m ²]	A_{act} [m ²]
1	2945	1100	1235	1235	6040	150	956	20	5.77	5.51
2	3071	1100	1310	1310	6340	150	1001	20	6.35	6.07
3	3197	1100	1385	1345	6560	150	1045	20	6.85	6.57
4	3323	1100	1460	1420	6860	150	1089	20	7.47	7.17
5	3449	1100	1530	1420	7000	150	1134	20	7.93	7.63
6	3575	1100	1605	1345	7000	150	1178	20	8.23	7.93
total									766.8	735.8

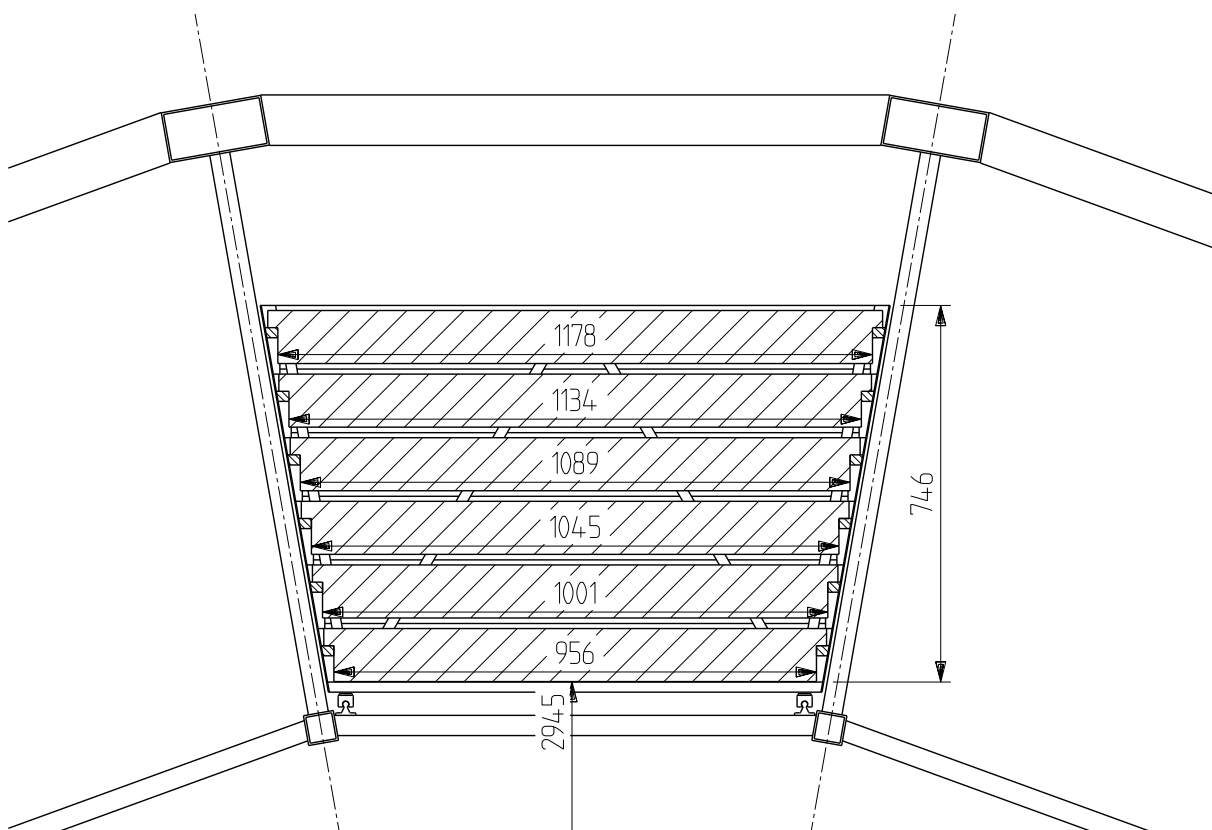


Figure 2.3: View of the TRD detectors cut in ϕ -direction

the space frame and detector boundaries of subsequent detectors (eg. HMPID). This was done in order to minimize shadowing and dead areas.

A front view of one sector of detector is shown in Fig. 2.3 including the supermodule casing and the rails that facilitate the installation of the supermodule as one piece.

2.2.3 TRD supermodule

Fig. 2.4 shows a drawing of the supermodule container for one sector. Every supermodule contains 6 layers of 5 detectors each. The layers are aligned with respect to one side of the supermodule. On this side the travelers that go on the rails inside the space frame are fixed with high precision. The travelers on the other side allow for adjustment to compensate the above mentioned deformations of the space frame under full load.

Dimensions of the individual chambers inside the supermodule are listed in Table 2.2.

Each supermodule is a unit of installation. It will be a closed volume with only connections for services to the outside. The side panels will be thin panels of aluminum supporting the low voltage bus bars and cooling pipes. The front face toward the inside of the detector will be a thin heat shield ensuring constant operating conditions for the TPC field cage on the inside, where a temperature stability of ± 0.1 K has to be achieved. The outside face of the supermodule will be covered by a foil to minimize heat dissipation into the magnet volume.

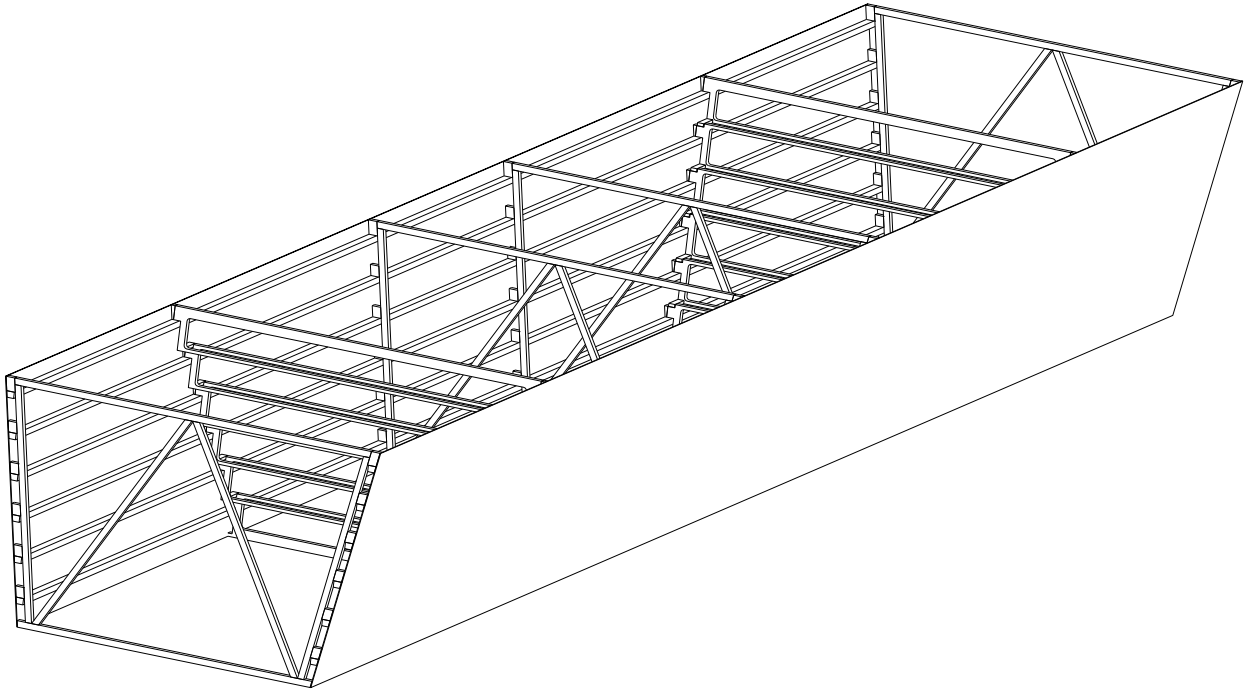


Figure 2.4: Axonometric view of the supermodule support structure with side panels.

2.2.4 TRD readout chamber

The individual TRD readout chambers are described in detail in Chapter 4 along with a description of the boundary conditions that led to the design depicted in Fig. 4.6. A TRD readout chamber consists of 48 mm of a composite radiator made of Rohacell[®] and polyethylene fibers (for a description see Chapter 3) followed by the drift electrode, a drift region of 30 mm filled with Xe,CO₂ (15%) and 2 wire planes in the 7 mm amplification region. All components are mounted on the side frames of the readout chamber. The readout chamber is closed on top with a printed circuit board that contains the cathode pads. The backing of this printed circuit board is made of carbon fiber reinforced Rohacell[®]. On top of this the readout board for the electronics is mounted with all layers for power, ground, and the lines for the digital readout. The cooling is directly attached to the readout boards.

2.3 Support for services

All services (low voltage, high voltage, cooling, gas, readout and control lines) for the TRD will be supported by the so-called "baby" space frame. Currently it is foreseen that this structure is very similar to the space frame itself, but detached from it. In this way the additional load due to the services will not contribute to the deformation of the space frame where position accuracy is needed. The "baby" space frame will be equipped with guiding rails on the side of the magnet door for installation of the supermodules. A somewhat simpler structure will be installed on the side where the magnet stays closed. The largest single contributor in terms of weight of the services of the TRD will be the low voltage cables. If all necessary supply voltages are provided from the outside without DC-to-DC converters, the weight of the bare copper conductor that runs inside the magnet will be approximately 7.2 t. For further details refer to Chapter 9.

2.4 Tolerances and alignment

Several aspects need to be considered for the definition of tolerances of the various components of the TRD

- tolerances affecting the performance of individual TRD readout chambers,
- mechanical alignment tolerances of the readout chambers within a supermodule affecting track matching within one sector,
- mechanical alignment tolerances of the supermodules within the space frame affecting the global track matching with other detectors in the central part of ALICE.

2.4.1 Tolerances for the TRD readout chambers

To ensure good alignment of the modules inside the supermodule all reference points for support of the readout chambers are designed to have a precision of better than 0.1 mm. This is at the same time also the relative position error of each pad with respect to the outer alignment face of the detector. For the pad plane this implies that the position of the alignment marks relative to the pads needs to have an accuracy of better than 0.05 mm. Before final assembly of the readout chamber the positions of these alignment marks will be measured with respect to the alignment surface, which will be the side of the chamber, where the traveler of the supermodule is fixed.

For gain uniformity it is necessary to prevent the pad plane from bending due to its own weight and the dynamical overpressure from the gas flow. For the nominal distance of 3.5 mm between anode wire plane and pad plane the maximum allowed deviation is 150 μm . Owing to the large number of wires crossing each pad, the wire placement in z -direction is not critical.

In order to ensure a uniform drift velocity across the whole readout chamber the flatness of the drift electrode needs to be better than 1 mm.

2.4.2 Alignment of readout chambers within a supermodule

One side of the supermodule, that where the traveler is fixed, will serve as reference surface for internal alignment of the readout chambers within the supermodule. During final assembly this side will be placed against an external reference surface from which measurements with respect to alignment marks on the top of the readout chambers will be made. The relative position of the reference marks themselves with respect to the individual pads will be precisely measured beforehand.

2.4.3 Alignment of supermodules within the space frame

Once the supermodules are installed in the space frame, they will be surveyed photogrammetrically from both sides of the space frame using external alignment marks on the supermodule. Its position will be measured precisely beforehand with respect to the reference surface and the fixed traveler.