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The Hadronic Tile Calorimeter for the TESLA Detector, Design, Construction and Installation.

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1. Introduction

The TESLA detector uses calorimetric devices to measure together with the inner tracking system the energy of particles and jets in the full solid angle around the interaction region. The calorimeter system is a combination of electromagnetic (ECAL) and hadronic (HCAL) sandwich sampling calorimeters inside the magnet coil.

The HCAL is divided in 2 half barrel and 2 endcap calorimeter module assemblies separated by small non vertex pointing gaps between barrel and endcaps. Such a gap is needed for the readout connections of the calorimeters and inner tracking detectors. A planar cut through one half of the TESLA detector is presented in fig. 1, showing the calorimeter arrangement between beam pipe and magnet coil.

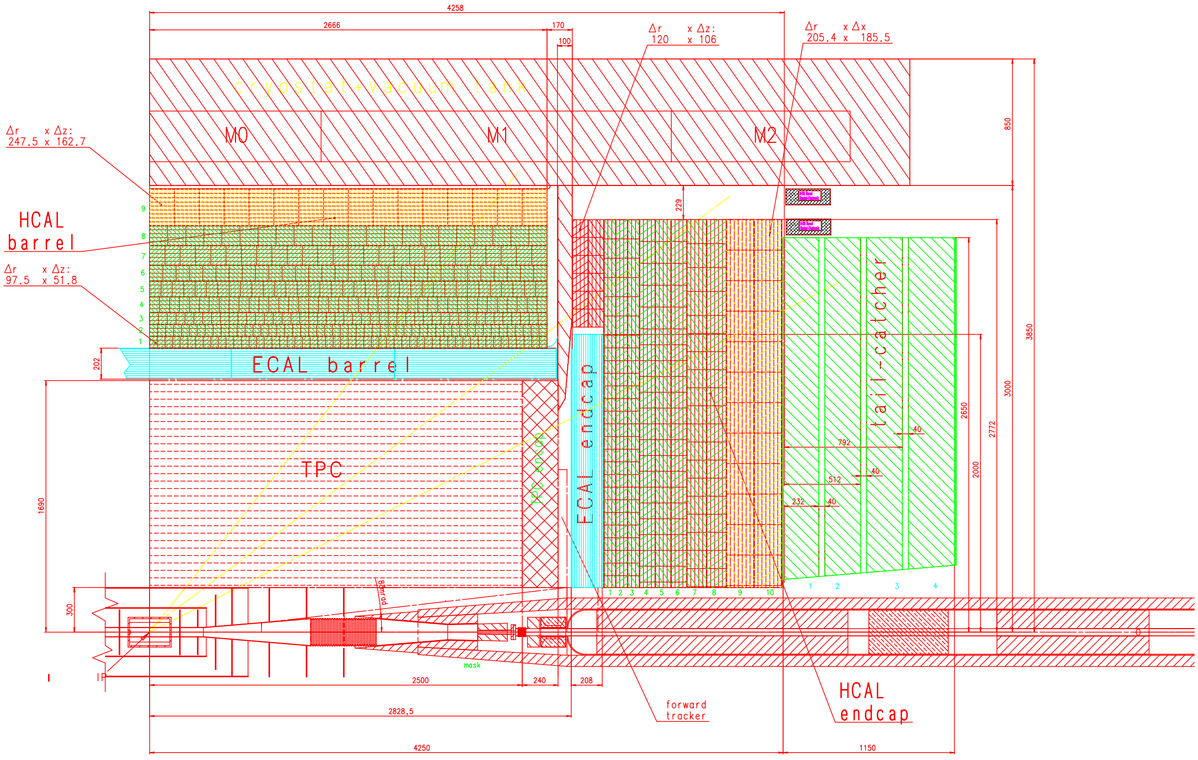


Fig. 1, Longitudinal cut through a TESLA detector quarter

Additional inner iron yoke cylinders ('pole tips') behind the HCAL endcaps are needed to reduce the field gradients inside the tracker volume. These yoke cylinders are added to the endcap yokes. They are cut in 4 slices which will be instrumented with detector layers to catch and measure the hadronic shower tails punching through the HCAL endcap. A description of the complete TESLA detector is given in ref. 1. More on the calorimeters can be found in ref. 2, 3.

2. The HCAL calorimeter sampling structure

The sampling structure of the calorimeter is optimised to get:

- good hadronic energy resolution,
- a sufficient number of sampling layers to identify and measure electromagnetic shower clusters inside the hadronic shower volume,
- good shower containment depth inside the magnetic coil and
- reasonable efficiency for MIP's within one sampling layer.

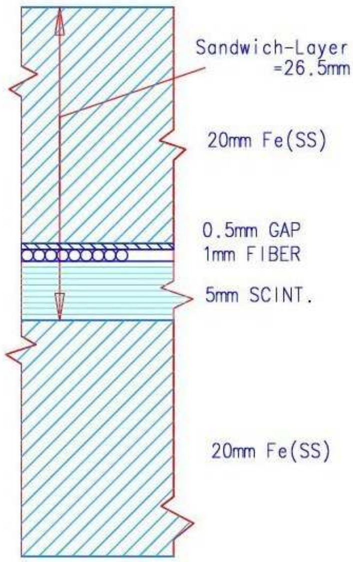


Fig. 2, Sandwich structure

With a sandwich structure of 20 mm absorber material - stainless steel or brass - 5 mm scintillator and 1.5 mm gap for fibre readout and tolerances up to 38 sandwich layers with a total absorption radial depth of $\geq 4.4\ \lambda$ fit into the HCAL barrel volume.

To be more detailed, the actual favoured sandwich structure has an absorber plate thickness of 19 mm with an additional stainless steel sheet of 1 mm to carry the scintillator tile plate. The gap for the insertion of the sheet/scintillator/fibre assembly measures 7.5 mm and houses:

- 1 mm stainless steel sheet as scintillator plate support,
- 5 mm plastic scintillator plate,
- 1 mm clear long readout fibres,
- 0.1 mm reflector sheets on top of scintillator and
- 0.4 mm gap for tolerances and to ease insertion of the assembled plate.

The tolerances for the flatness and thickness of the stainless steel plates are $\leq \pm 0.1$ mm each. The absorber plate material should be non magnetic[1)] with a magnetic permeability of ≤ 1.02 at a field of 4 T [2)].

The scintillator layers are cut in tiles of appropriate quadratic size and read out by inserted wavelength shifter (WLS) loops downstream connected to the long clear readout fibres. These fibres need together with the required tolerances for the tile plate insertion an additional gap of 1.5 mm. The sampling structure is demonstrated in fig 2. The sandwich sampling structure is identical for the barrel and end endcap HCAL modules. The clear fibres coated with some light insulation run in parallel along the tile plate, are guided in the gap between the barrel and endcap HCAL and finally correctly combined in front of the photodetectors in electronic boxes outside the calorimeter volume ref. 5.

A detailed description of the light readout of the HCAL is presented in ref. 3.

[1)] Austenitic stainless steel of type 316 has a permeability of 1.02, he may distort the magnetic field in the tracker volume in a not acceptable way. Thus the use of brass instead should be also considered. Induced currents during a quench of the magnetic field – maximally 200G/sec are expected - have also to be considered. Absorber material should have sufficient specific resistivity to keep such forces small enough. It will probably necessary to isolate the individual modules electrically to limit the induced currents.

[2)] F. Kircher et al, LC note LC-DET-2001-056

3. The mechanical design of the barrel HCAL

The HCAL is separated in two half barrels cylinders with 16 individual calorimeter modules each forming a tight, gap less cylinder of octagonal shape. The octants of such a cylinder - made from 2 combined modules of mirrored shape - carry the barrel ECAL modules (‘staves’). Details are given in the appendix.

A transverse cut through the barrel cylinder structure inside the coil is shown in fig. 3.

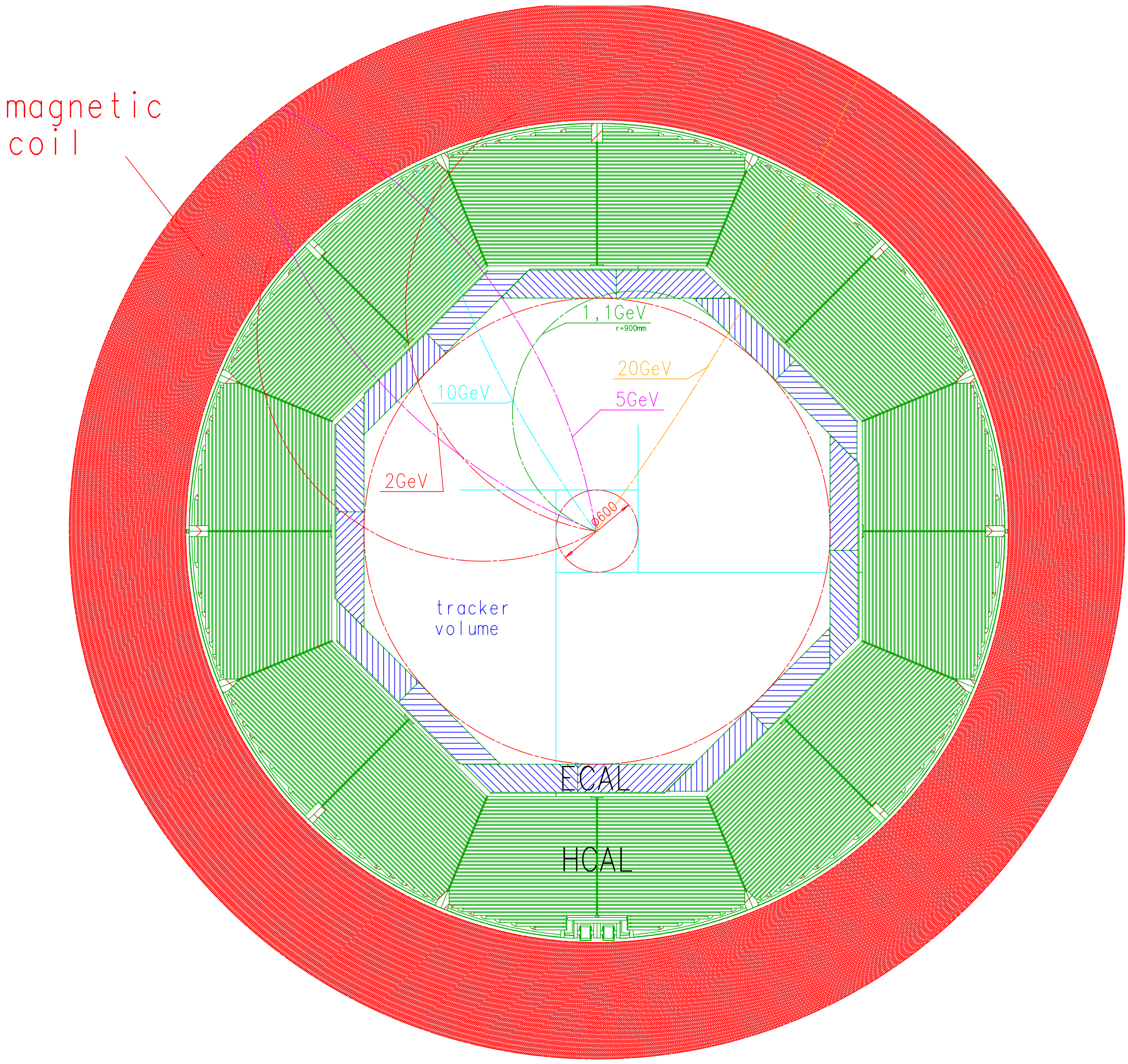


Fig. 3, Transverse cut through the TESLA detector with some charged particle tracks

The barrel HCAL stacks (Fig. 4) are 1.075 m deep filling the detector volume between 1.935 and 2.975 m radius. All absorber plates are 2.66 m long, with lateral sizes increasing in depth from 0.73 m (first plate of the stack) to 1.20 m (30. plate). The last 8 plates of the stack structure fill with decreasing lateral size the free space in front of the cryostat (fig 4) in order to minimise the azimuthal thickness variation of the calorimeter. The last (38.) plate has a width of 0.12 m only. In the gaps between the plates the scintillator tiles with actual lateral sizes - increasing with depth – are indicated.

All plates are supported and fixed in position by a wall of 3 mm thick large stainless steel sheets, closing the 2 longs and the inner front side of the module. The gaps of 6.5 mm between the absorber stack plates are stabilised by long columns of thin wall screws or e-beam welding connections , no further spacers are needed in the gaps. The assembled scintillator sandwich plates can be inserted in the gap as a whole. Such a design minimises cracks and insensitive regions within the detector layers.

A sketch of a complete barrel HCAL module is presented in fig.5, showing the stainless steel side walls with the arrangement of the fixation points. The large number of screws per unit is a consequence of the requirement to fix the plate positions and the backside 2 support rails (for module handling) by friction within the tolerances. Details on the screw design and position are given in the appendix. Details on the connection between the stack structure and the support rails are shown in fig. 4. The 3 mm stainless steel wall sheets are strong enough to stabilise the module during transport, mounting and installation within the required tolerances of $\leq \pm 0.1$ mm. All mechanical details for the barrel calorimeter stacks are listed in the appendix.

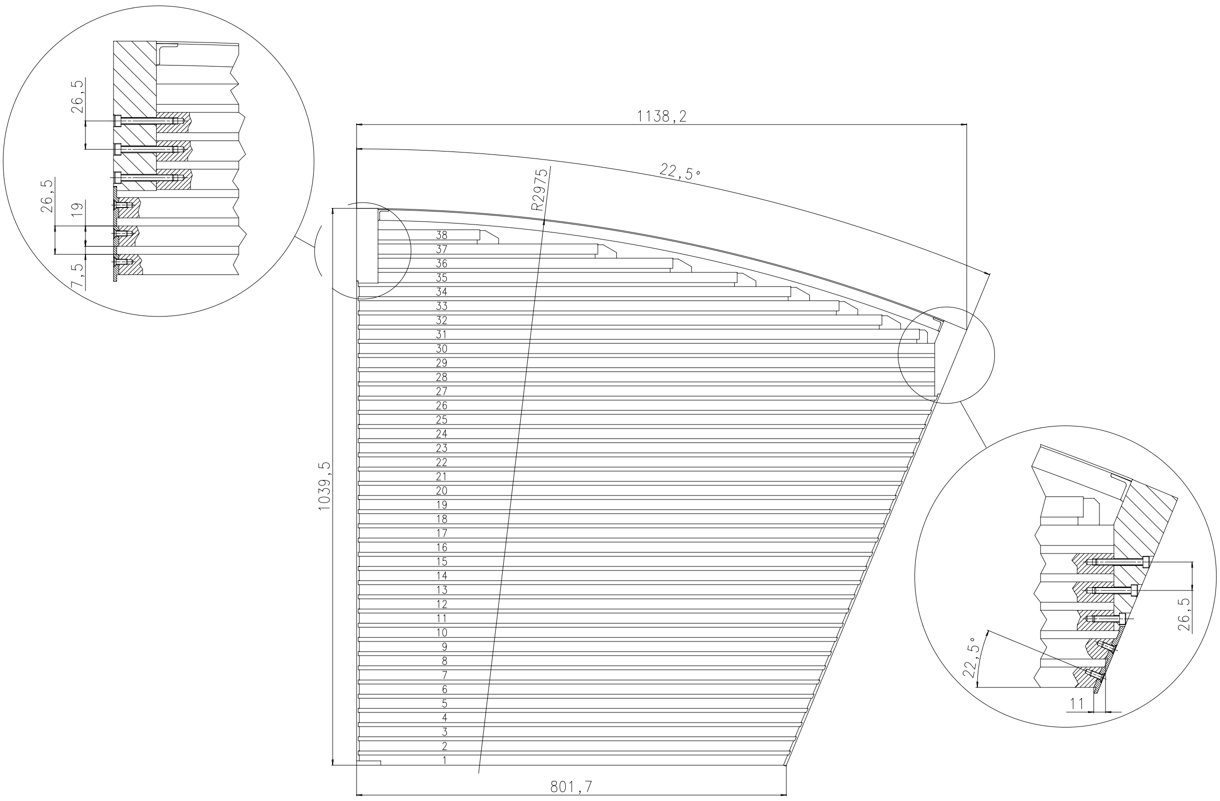


Fig. 4, Cut trough a barrel HCAL module with construction details in the outer corners

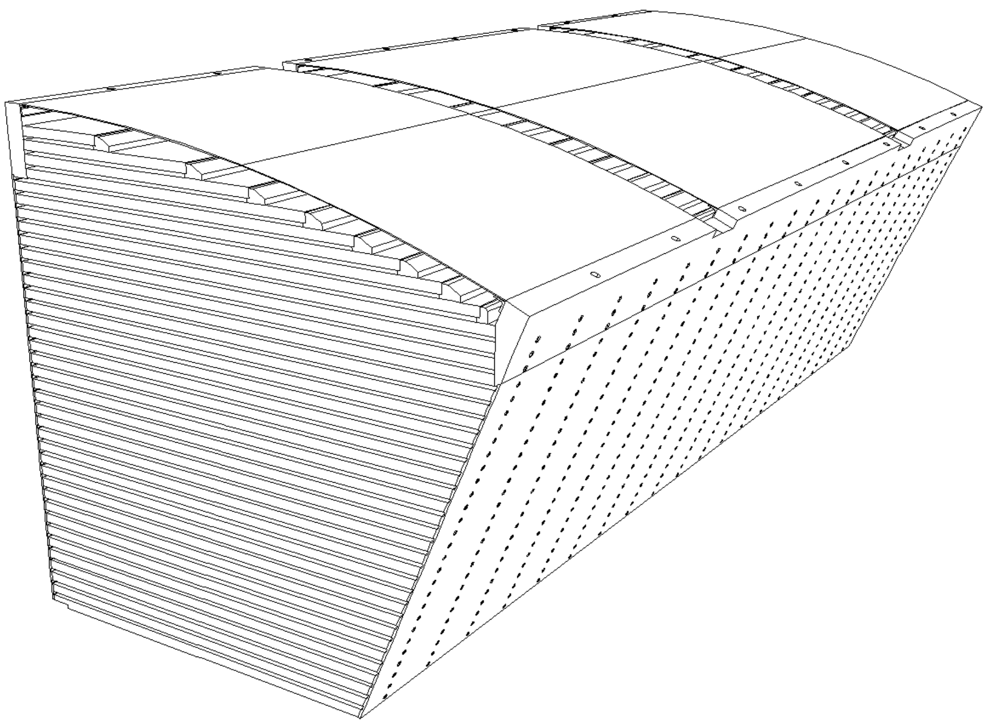


Fig. 5, View of a barrel calorimeter module

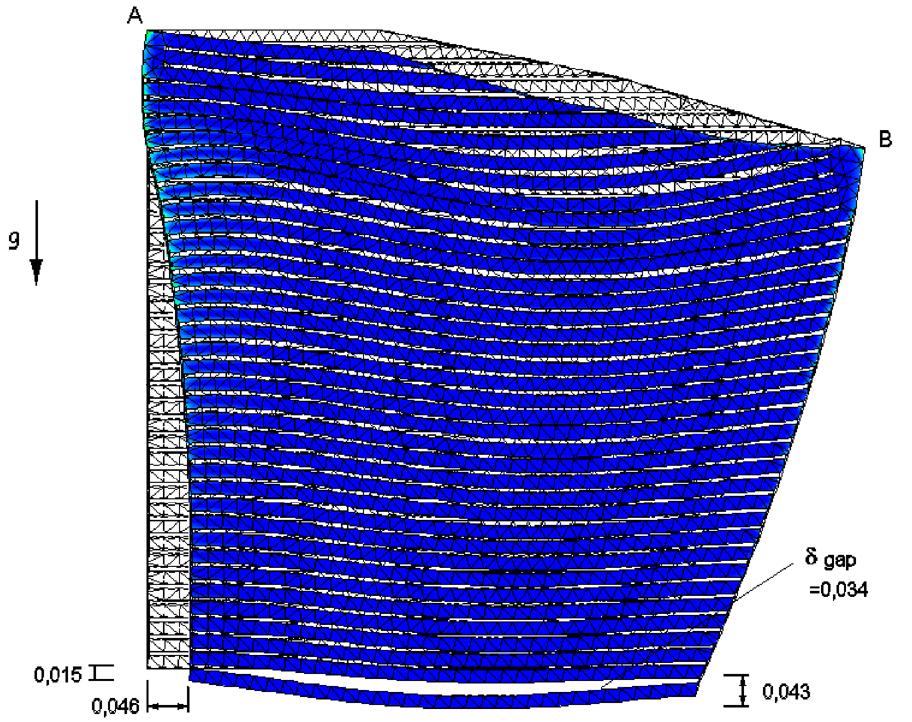


Fig. 6.1, HCAL barrel module with <u>horizontal suspension</u>, deformations exaggerated

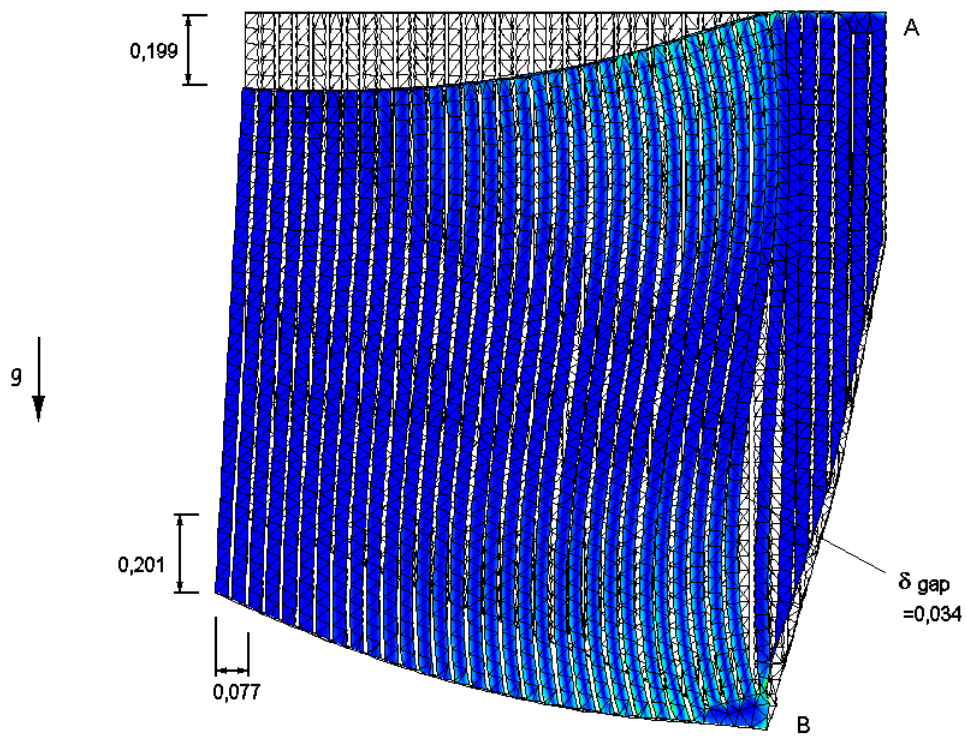


Fig. 6.2, HCAL barrel module with <u>vertical suspension,</u> deformations exaggerated

The result of a 'finite element analysis' for deformation and stress of the HCAL module structure suspended at the backside support rails is shown in fig. 6.1 for a horizontal and in fig. 6.2 for a vertical plate orientation. The deformations are oversized. In fig. 6.1, with horizontal suspension the displacement at the bottom along the gravity axis is only 0.015 mm, the displacement in the middle of the bottom plate is 0.043mm and the deformation perpendicular to that is 0.046 mm. The maximum displacement is 0.06mm. The maximum structure deviation of 0,01mm in a gap is also indicated.

In fig. 6.2, with vertical suspension, the maximum module deformation along the gravity axis is 0,200 mm and 0,077 mm perpendicular to that. The maximum gap deformation is 0,034 mm**.** The maximum shearing tensions for the stainless steel wall sheet are on the order of 10 N/mm^2, a map of the forces is shown and discussed in the appendix.

The deformations mentioned above are the result of simulation[3)] studies and rely on geometrically perfect contacts of sandwich plates and support walls. Inaccuracies during production, machining and assembling of plates and wall sheets can lead to an increase of the deformations. To get a measure of the real behaviour of a full size barrel module it is absolutely necessary to build a test module (probably shortened longitudinally) for studies under various support orientations and transport conditions.

4. The mechanical design of the HCAL endcaps

The endcap sandwich structure is the same as in the barrel HCAL. Each of both endcaps is assembled from 4 quadrants (fig. 7) where 2 of the quadrants are mounted and screwed together to half endcaps. The HCAL stack structure is enforced again with 3 mm stainless steel wall sheets on 3 quadrant sides. The left sides of the left (right sides of the right) quadrants are kept open for parallel exit of the horizontally passing RO fibres.

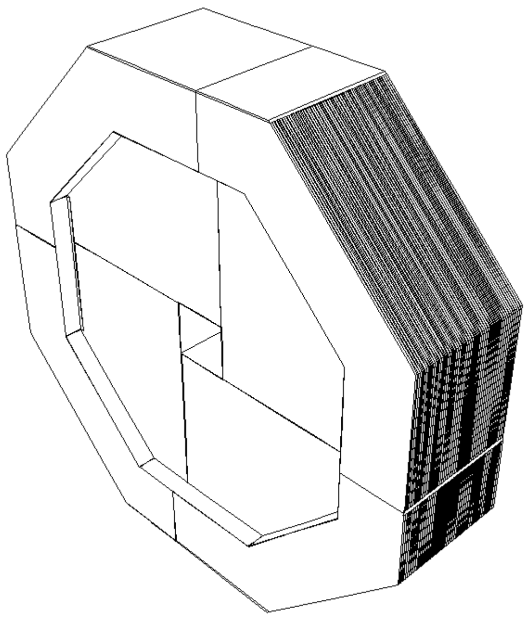


Fig. 7, The HCAL Endcap

Each HCAL endcap quadrants carries on his stainless steel front plate an ECAL quadrant which is smaller in radius (fig 1). To get also sufficient shower containment in this outside region, an octagonal shaped ring with HCAL sandwich structure is added around. Barrel and endcap ECAL

[3)] I-DEAS Master Series MS7, Finite Element Analysis together cover tightly the full angular acceptance. To avoid small vertex pointing gaps between the endcap quadrants where photons (in the ECAL) or neutrons (in the HCAL) could be pass through, a lateral asymmetric quadrant arrangement as indicated in fig. 7 is chosen.

The half endcaps close around the beam line, leaving an inner hole of 0.60 x 0.60 m^2 equivalent to an endcap acceptance hole of ≈5°, which is mostly covered by the tungsten mask calorimeter (see ref. 1). Inside the endcaps a tungsten shielded beam pipe support of 0,46 m outer diameter only is inserted. The empty space in between will be used for connections to the inner tracking detectors around the interaction vertex. When their space requirements are fixed, the endcap calorimeter inner hole dimensions can probably be reduced. It is also possible to keep the hole dimension as designed and fill the remaining volume with appropriate tagging scintillators. Such additional tagging scintillators could also be inserted in the two gaps between the barrel and the endcaps to measure crossing showers and improve the energy resolution. If needed the present gap width of 17 cm could be slightly increased by the order of 1 cm.

Together with the ECAL a longitudinal containment depth for the endcaps of 1.42 m or 6.3 λ is achieved. The containment along the 8 additional layers (0.22 m deep) of the octagonal ring outside the ECAL radius (fig. 1 and 7) is also 6.3 λ The number of HCAL longitudinal sandwiches is 45 inside and 53 outside. A small gap between the ECAL and the outer HCAL ring is needed for ECAL readout and cooling.

The complete octagonal shaped endcap disks fit to the barrel wheels within a radius of 2.975 m at the disk corners, but with the octagonal endcap frame rotated by 22.5°. The weight of a HCAL quadrant is 42 to, the ECAL quadrant in front weighs 5.2 to.

The inner iron yoke cylinders behind the endcaps topologically belong to the endcaps and increase the shower containment depth in this region with highest energies by 5.6 λ to 11.9 λ. The nose of the two pole tips weigh 65 to each.

5. Access to the calorimeter readout electronic

All readout fibres - all together e.g. about 4000/barrel module -are guided to photo detectors along long and narrow cable ways between endcap and the barrel and between endcaps and cryostat with 70 to 170 mm available gaps (Fig. 1). In these gaps the fibres will be protected and fixed by fibre stiffeners and fibre protection shielding and guided, collected and correctly assembled according to calorimeter cells at the front of photo detectors. Special ‘electronic boxes’ house and shield these photo detectors which are connected to preamplifiers and Flash Analogue to Digital Converters (FDAC’s) for signal conversion, amplification, signal analysis and subsequent digital readout. The electronic circuits are tightly packed using one box per HCAL module. All boxes - 32 for the barrel and 8 for the endcap modules - have to be cooled in order to reduce the electronic noise and improve the gain and stabilisation of the APD photo detectors. The boxes have be rather quickly accessible during short beam shut downs and will thus be mounted on the cryostat cylinder wall downstream the endcap disks as shown in fig. 1.

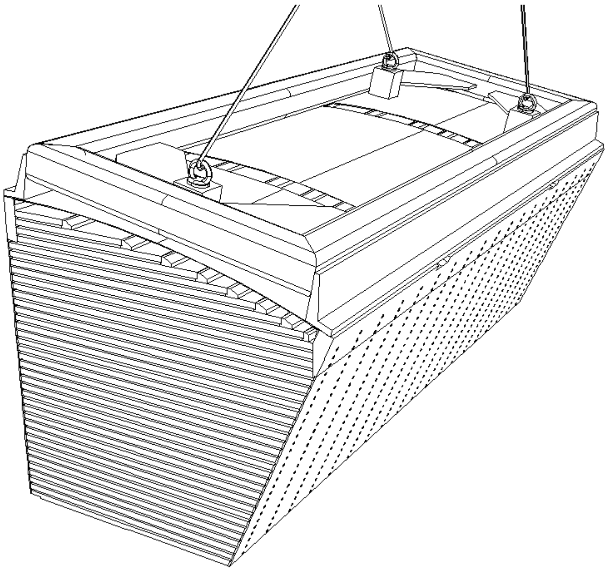
6. Construction and assembly of the calorimeter modules

All calorimeter modules are assembled as stacks of stainless steel plates with horizontal plate alignment and with temporary spacer bars inserted between the steel plates to keep the gap distances within the tolerances. Studies have to be started to find the most reliable method to fix the wall-stack structure within the required tolerances. After construction the stability of the gap width of all stacks has to be seriously tested within a stack handling and rotation program for acceptance. Such accepted modules will be stored in horizontal position for insertion of the completely assembled and tested scintillator tile plates connected with the long readout fibres. All tile plates have to be fixed in the gap and, to avoid gaps which deteriorate the shower energy measurements, have to be pushed by spacers inserts on the back side towards the front absorber plate. The best method has to found by investigations.

When all readout fibres are connected to photo detectors with appropriate readout electronic the individual modules will be tested and calibrated with cosmic muons.

7. Handling of calorimeter modules and installation

The individual 32 modules of the barrel HCAL weigh with scintillator tiles 15.3 to each and will be handled via special frames connected to their back support bars. Assembly of a half barrel is foreseen outside the coil volume using special handling devices (fig. 8.1, 8.2) to carry and rotate them into the correct azimutal angle position before they are stacked together in a ‘cradle’ scaffold as shown in fig. 9.



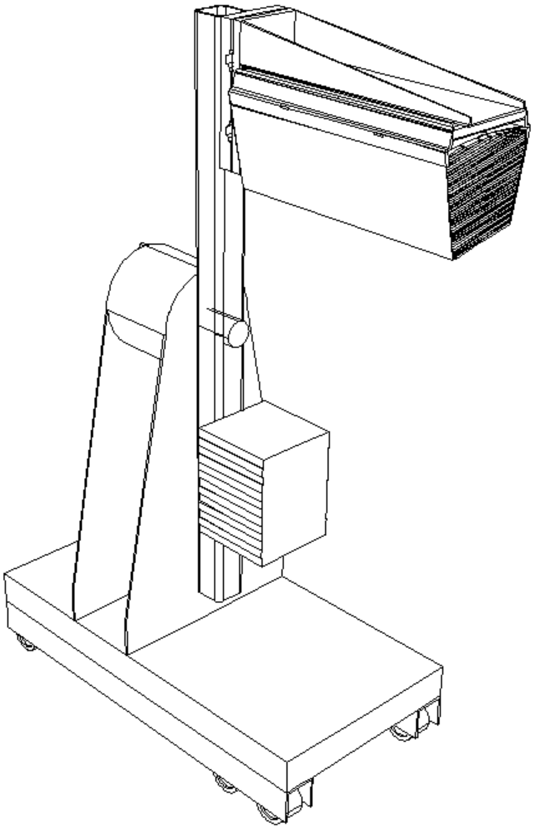


Fig. 8.2: Lifting device with rotation arm for insertion of barrel modules

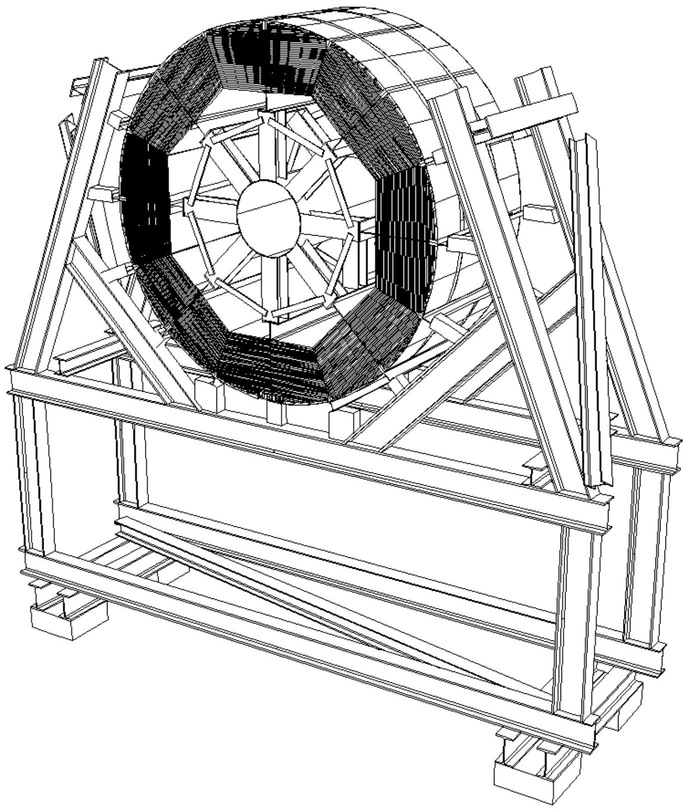


Fig. 9, Barrel cradle with inner assembly spider

Together 16 modules support each other to build a half barrel additionally fixed in position by small connection bars along the front plates. A whole half barrel cylinder will be adjusted in this ‘cradle’ with an inserted ‘spider’ construction for support to fit well - within a tolerance of less than 5mm - into the cryostat being slightly deformed by the coil weight.

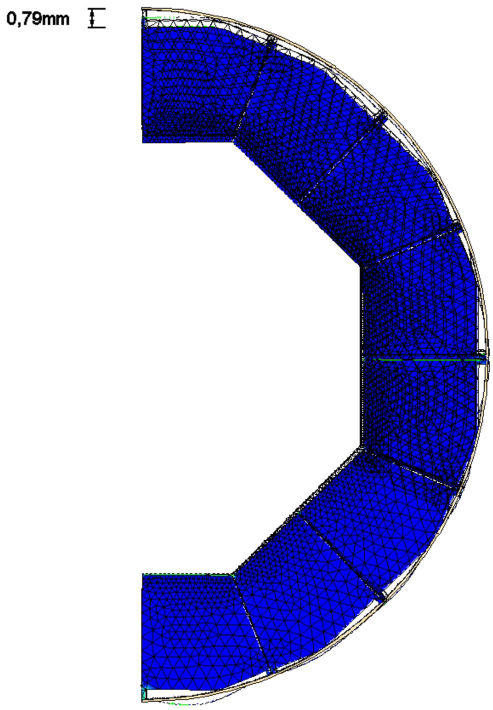


Fig. 10.1, FE-analysis of barrel <u>with</u> inner fixing (8 mm)

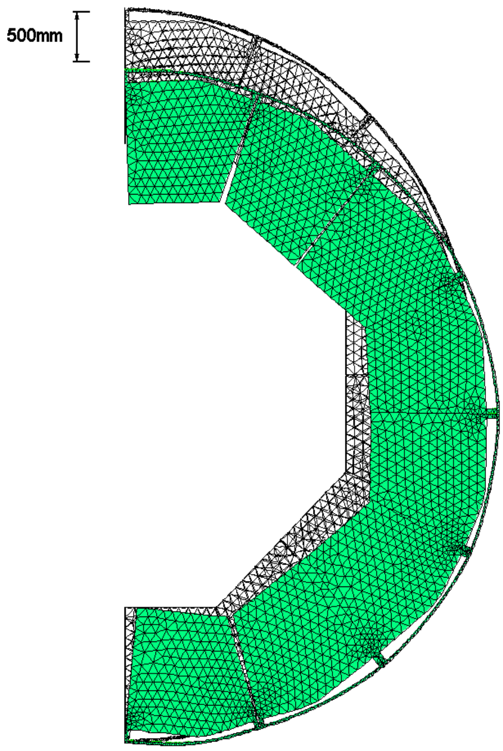


Fig. 10.2, FE-analysis of barrel <u>without</u> inner fixing

Fig. 10.1 and 10.2 shows the result of a ‘finite element analysis’ study for such a barrel cylinder during assembly. The maximum deviation on top is 0.79 mm, the deviation at half height of the barrel cylinder is in vertical direction 0.45 mm and in horizontal direction 0.28 mm (totally 0.53 mm). Without the inner connection bars the deviation would be more than 500mm.

Than the barrel cylinder will be fixed and enforced by 2 outer stainless steel belts with 100 x 20 mm cross section. The complete assembly with 245 to will than slide on rollers as shown in fig.11.1 - along bottom rails into the cryostat. Additional tools arranged along the side walls with special rolls (fig. 11.2) stabilise the assembly during insertion and keep the distance to the cryostat.

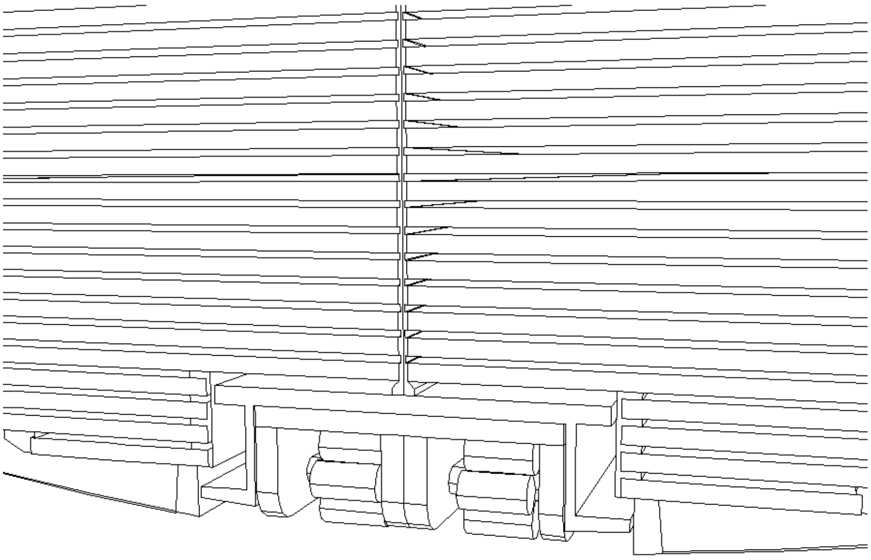


Fig. 11.1, Rollers for the insertion of the barrel calorimeter

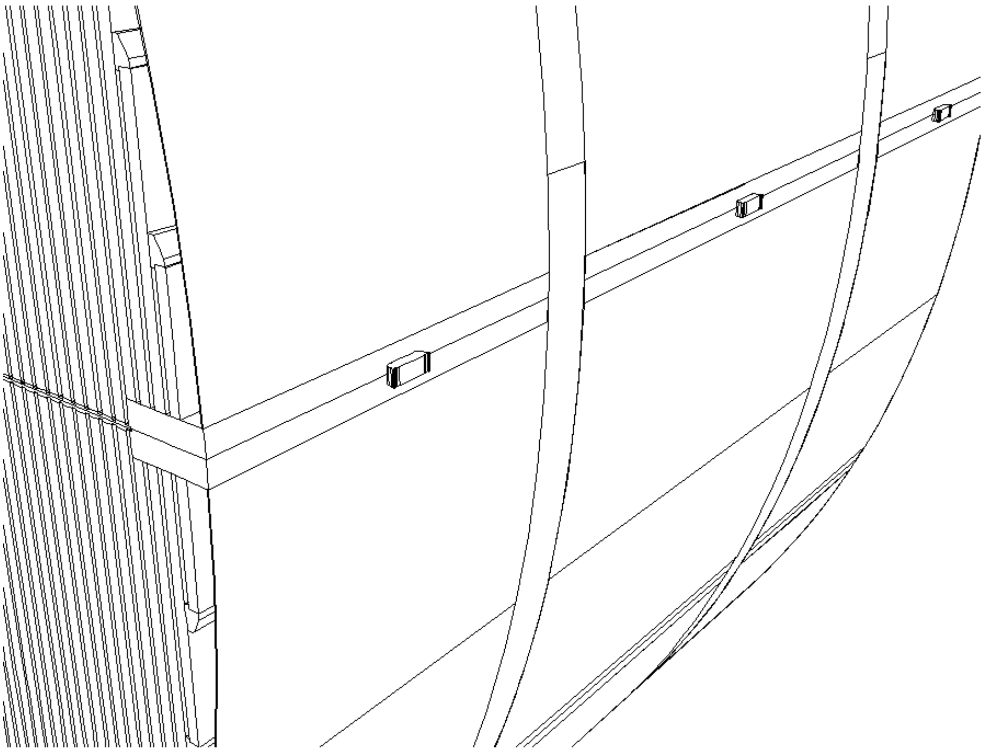


Fig. 11.2, Lateral stabilisation rolls

After insertion of the 2 half barrel cylinders the 40 ECAL 'staves' (with a total additional weight of 113 to) will be inserted and adjusted as described in the appendix. The complete barrel calorimeter with HCAL and ECAL modules installed is sketched in fig. 12. The weight of the complete barrel calorimeter part is 603 to.

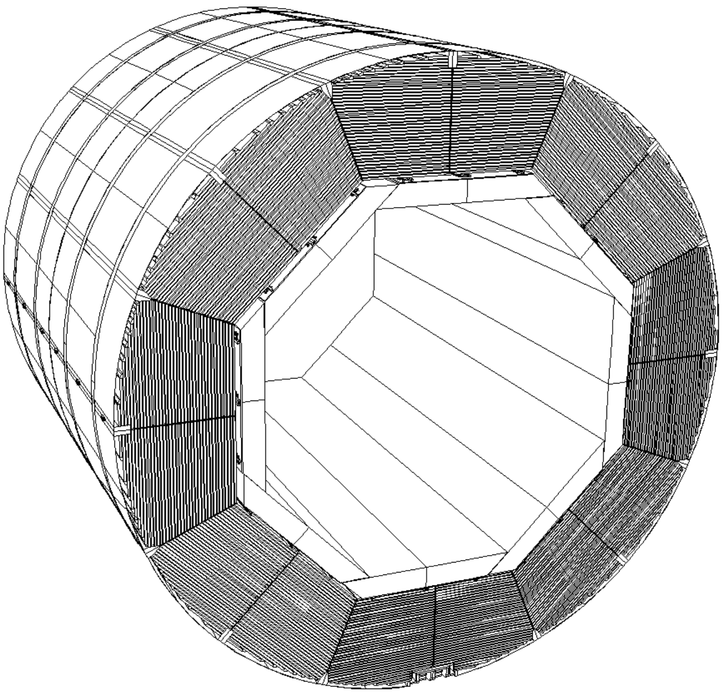


Fig. 12, The complete barrel calorimeter including HCAL and ECAL

The assembly, support and installation facility for the endcap calorimeter is shown in fig. 13.

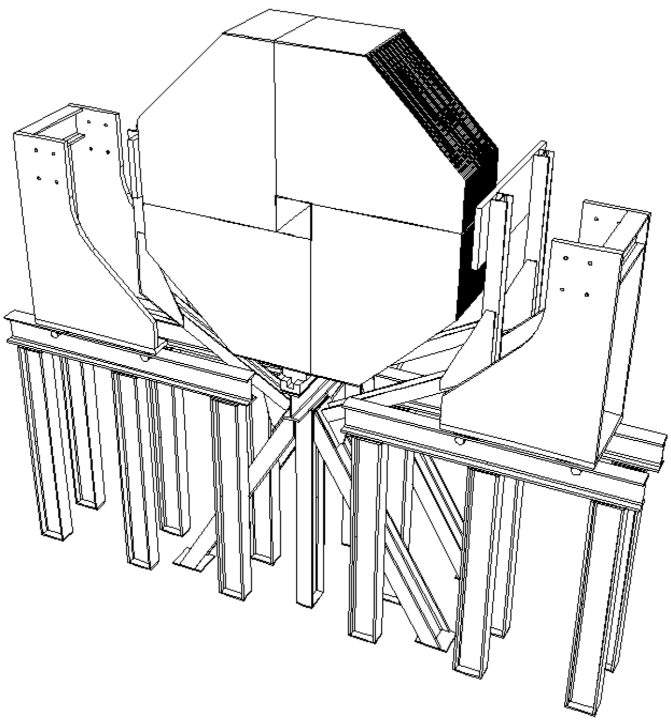


Fig. 13, Support facility for endcap calorimeter

After combining ECAL and HCAL quadrants 2 endcap quadrants are fixed to half endcaps which can close and open via rollers. Finally the closed to endcap calorimeter disks are shifted into their final detector position. The weight of a complete calorimeter endcap is 181 to.

Fig. 14 shows an artist view of the whole calorimeter assembly with closed endcaps. The total area of absorber and scintillator plates adds to about 5300 m^2 each. The number of individual scintillator tiles of sizes varying between 5 x 5 and 25 x 25 cm^2 is ≈800 000, the number of calorimeter cells to be read out is 202 000 with additional 2000 in the pole tips.

All together the TESLA calorimeter - including ECAL and ECAL in barrel and endcaps - represents a mass of 1037 to, with additional instrumentation in the pole tips of 130 to.

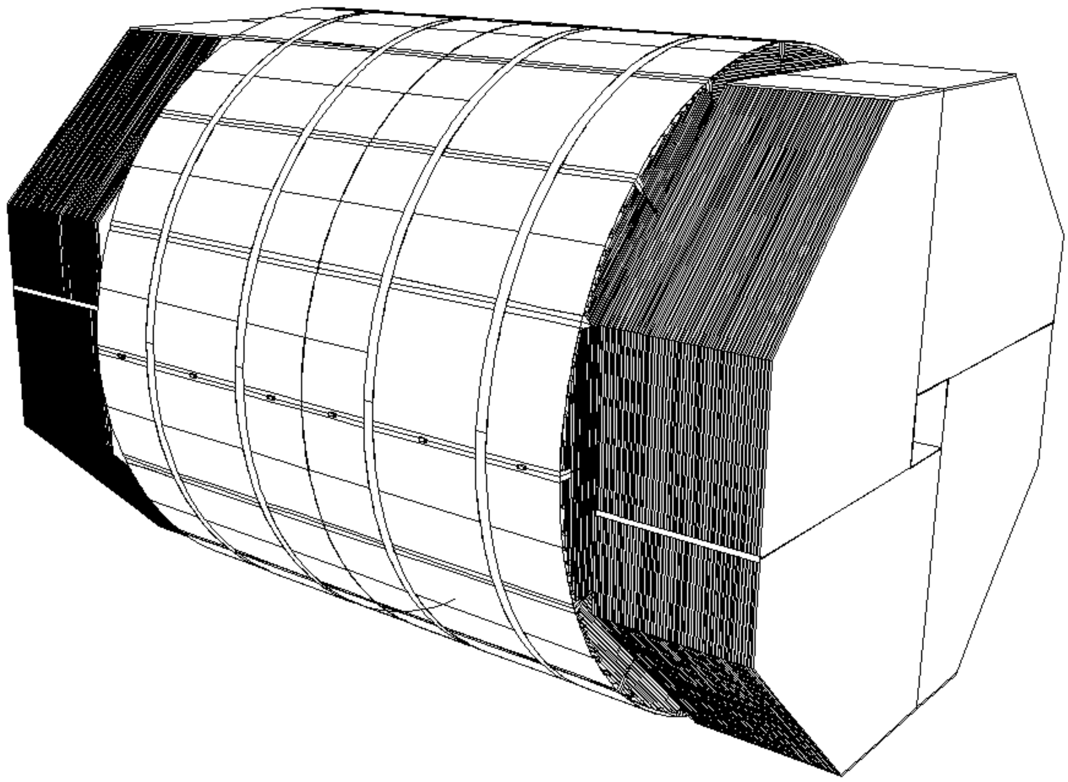


Fig. 14, The closed TESLA calorimeter barrel with stabilisation belts and endcaps

8. Outlook

Discussions on optimisation of design and construction for further improvement of the calorimeter structure go on and reduction of the gap tolerances is envisaged.

It is also necessary to build a HCAL barrel test stack of 1/3 to ½ of real length to investigate its mechanical behaviour and the minimum gap size available for tile plate insertion. Such a stack structure can be equipped with scintillator tiles and readout fibres for detailed single particle and jet energy and angle measurements.

9. Appendix

Technical Data for the HCAL

HCAL Barrel

mass of the complete HCAL barrel (with scintillators, absorbers and barrel-rings):	490 to
mass of the complete HCAL barrel (without scintillator-material and 1mm add. absorber):	2x225 to
length of one half HCAL barrel:	2666 mm
length of the complete barrel:	5332 mm
outer diameter of calorimeter:	5950 mm
inner diameter of calorimeter:	3871 mm
number of HCAL-modules in complete barrel:	32
mass with scintillators/fibre+1mm absorber:	15 315 kg
mass of one steel stack without scintillators:	14 025 kg
numbers of Fe-plates:	38

HCAL Endcap with outer HCAL ring

mass of the complete HCAL endcap (with scintillator and 1mm add. absorber):	196 to
mass of the complete HCAL endcap (without scintillator and add. absorber):	181 to
length of one HCAL Endcap:	1397 mm
numbers of HCAL quadrant in Endcap:	4
outer diameter:	5950 mm
dimensions of inner rectangular:	600x600 mm
number of Fe-plates:	53
mass of one quadrant without scintillators:	41 460 kg
mass with scintillator/fibre +1mm absorber plates:	45 210 kg
length without first layer:	1185 mm
number of Fe-plates:	45
mass of outer HCAL quadrant (without scintillator):	3 434 kg
mass with scintillators/fibre +1mm absorber plates:	3750 kg
length of outer HCAL ring:	204.5 mm
number of Fe-plates:	8

HCAL

mass of the complete HCAL:	882 to
length over all	8500 mm

Connection between ECAL and HCAL

HCAL and ECAL barrel

After rolling and fixing the HCAL barrel halves in the detector, the ECAL will be mounted (fig. 12). Each of the eight ECAL staves are fixed at 15 points on three rails at the inner plate one HCAL octant (fig 15). The HCAL have to carry the complete mass of the ECAL: 113 tons over all, 14.15 to for each HCAL octant. The ECAL staves are cut longitudinal, so each module of the half barrel gets an additional load of 3.5 to. The staves have to be carried by the first absorber plate. First calculations show a deformation of 0.4 mm for a plate of 19 mm thickness and 0.3 mm for 22 mm thickness. The detailed design is in preparation.

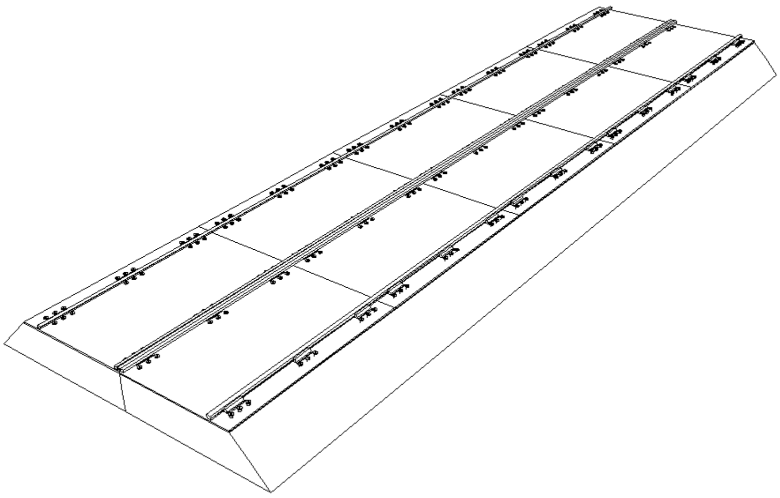


Fig. 15, ECAL stave with a mass of 14.15 to[4)]

HCAL and ECAL endcap

One HCAL endcap quadrant is shown in fig16. Before assembling the endcap quadrants, the ECAL endcaps will be bolted on the first plate of the HCAL endcap. The additional load of the quadrant is 5.18 to and acts on the first plate. The detailed design of the structure is in preparation.

After that two of the HCAL/ECAL quadrants will be assembled to one half HCAL/ECAL endcap and screwed together at the front and back-side with bars along the axis. Before rolling into the cryostate, the endcap halves will be closed and fixed to a disk (fig. 13, Scheme in fig. 17).

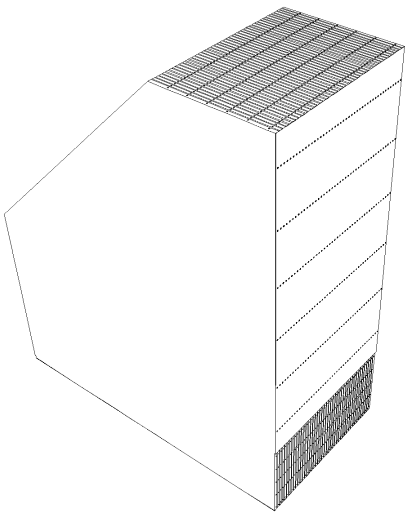


Fig. 16, HCAL quadrant without ECAL endcap

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4) H. Videau, private communication

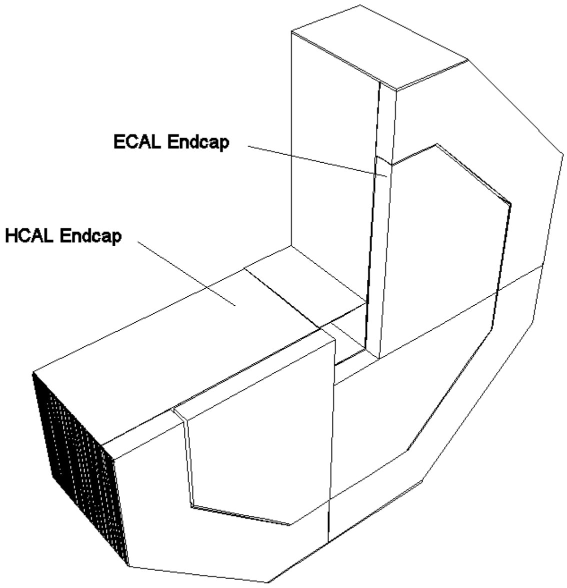

Fig. 17, Scheme of the combined HCAL and ECAL endcap with three quadrants

Table of dimensions and weights of the HCAL module

The table shows the dimensions and weights of the HCAL barrel plates (only plates, see fig. 4). All plates have a length of 2664 mm. The gaps between the steel plates are 7,5mm high.

No of plate	width bottom	width top	Width of gap	absorber surface	plate Volume	mass of plates
	mm	mm	mm	cm²	cm³	kg
1	791,30	799,17	803,37	151,09	40251,52	317,99
2	802,27	810,14	814,35	153,18	40807,11	322,38
3	813,25	821,12	825,33	155,27	41362,70	326,77
4	824,23	832,10	836,30	157,35	41918,30	331,15
5	835,20	843,07	847,28	159,44	42473,89	335,54
6	846,18	854,05	858,26	161,52	43029,49	339,93
7	857,16	865,03	869,23	163,61	43585,08	344,32
8	868,13	876,00	880,21	165,69	44140,68	348,71
9	879,11	886,98	891,19	167,78	44696,27	353,10
10	890,09	897,96	902,16	169,86	45251,87	357,49
11	901,06	908,93	913,14	171,95	45807,46	361,88
12	912,04	919,91	924,12	174,04	46363,06	366,27
13	923,02	930,89	935,09	176,12	46918,65	370,66
14	933,99	941,86	946,07	178,21	47474,25	375,05
15	944,97	952,84	957,05	180,29	48029,84	379,44
16	955,95	963,82	968,02	182,38	48585,43	383,82
17	966,92	974,79	979,00	184,46	49141,03	388,21
18	977,90	985,77	989,98	186,55	49696,62	392,60
19	988,88	996,75	1000,95	188,63	50252,22	396,99
20	999,85	1007,72	1011,93	190,72	50807,81	401,38
21	1010,83	1018,70	1022,91	192,81	51363,41	405,77
22	1021,81	1029,68	1033,88	194,89	51919,00	410,16
23	1032,78	1040,65	1044,86	196,98	52474,60	414,55
24	1043,76	1051,63	1055,84	199,06	53030,19	418,94
25	1054,74	1062,61	1066,81	201,15	53585,79	423,33
26	1065,71	1073,58	1077,79	203,23	54141,38	427,72
27	1073,50	1073,50	1075,50	203,97	54336,28	429,26
28	1073,50	1073,50	1075,50	203,97	54336,28	429,26
29	1073,50	1073,50	1075,50	203,97	54336,28	429,26
30	1073,50	1073,50	1042,00	203,97	54336,28	429,26
31	1045,00	1045,00	972,00	198,55	52893,72	417,86
32	975,00	975,00	892,00	185,25	49350,60	389,87
33	895,00	895,00	802,00	170,05	45301,32	357,88
34	805,00	805,00	702,00	152,95	40745,88	321,89
35	670,00	670,00	545,00	127,30	33912,72	267,91
36	550,00	550,00	405,00	104,50	27838,80	219,93
37	410,00	410,00	185,00	77,90	20752,56	163,95
38	190,00	190,00	190,00	36,10	9617,04	75,97

sum of plate cross-section surface:	0,647 m²
sum of plate volume:	1,725 m³
sum of plate mass:	13 626 kg
additional absorber volume:	89 dm³
additional absorber mass:	702 kg

Results of the Finite element analysis

Each HCAL module is assembled of 38 Fe absorber plates with a thickness of 19 mm (fig. 5). The Fe-plates are fixed on 3mm sheets at the left and right module side by screws. The thickness of the wall sheet is dimensioned to hold all plates without breaking or bending in all cases of handling and mounting.

Fig. 18.1 and 6.1 shows the FE-analysis of a module, hanging on point A and B with horizontal orientated plates. The maximum tensions at the enforcement rail (Fig. 18,1). In reality this tension is lower because the contacting area is a surface instead of a line. So the maximum tension to recognise is 8.9 N/mm² (8,9 MPa). For a yield-strength at 200 N/mm² this tension is no problem. A thinner structure shouldn't be chosen because of handling problems if the wall thickness is to low and because of a better shock resistance.

The maximum deformation in Fig. 18.1 is shown not in scale for a better visibility. In fact there's no contact between the calorimeter plates. The mass of the ECAL is not recognised in this calculation because it's not mounted in this situation. The 19 mm plates are fixed on the sheets by screws. The number of screws is calculated to hold the plates by friction and dimensioned that the contacted surfaces won't get a gap when loading forces. For a plate of 19 mm thickness, which is clamped on two sides the analytic calculation shows a deformation of 0.013 mm. A plate which has no angular restraints gives a calculated deformation of 0.06 mm. The deformation of the inner plate is between these values at 0.03 mm. The reason is the undefined deformation of the side sheets at this area. The plates in the stack above shows results from 0.01 mm to 0.06 mm.

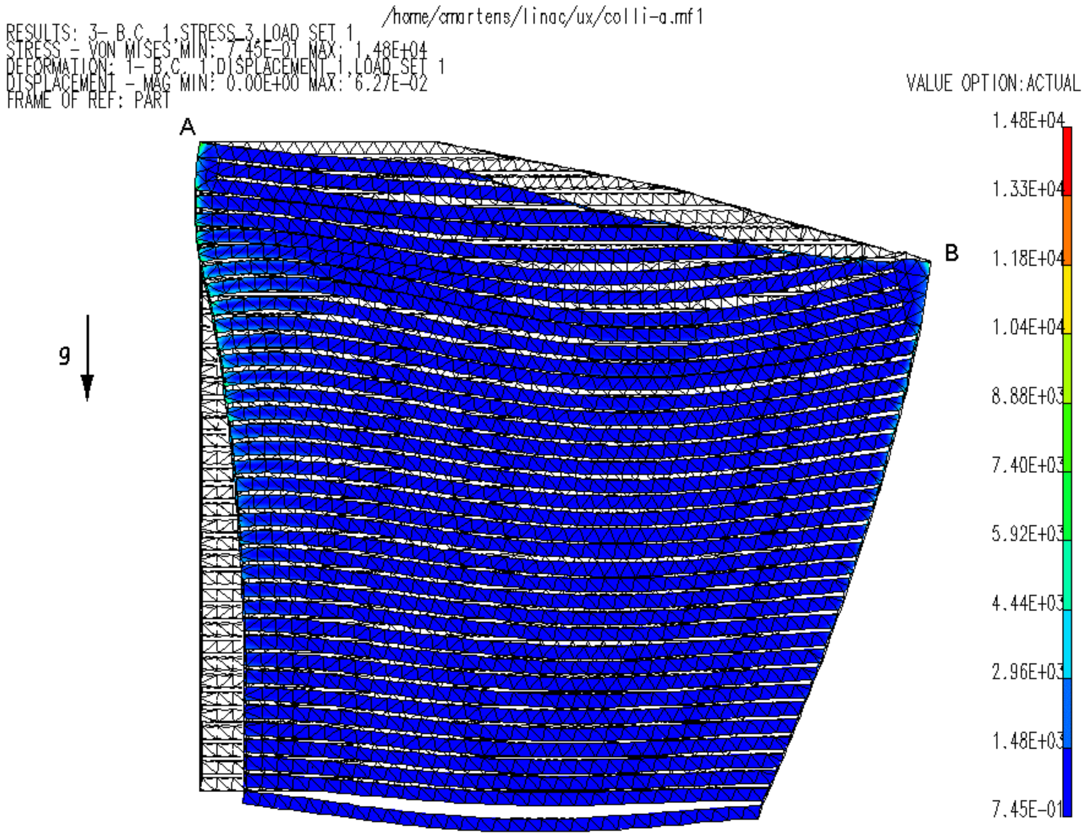

Fig. 18.1, Deformation and tension in HCAL module with horizontal orientated stack. The maximum deformation is 0.06 mm and oversized for a better visibility. The stress (von Mises) is dimensioned in mN/mm² (calculated with I-DEAS ms7)

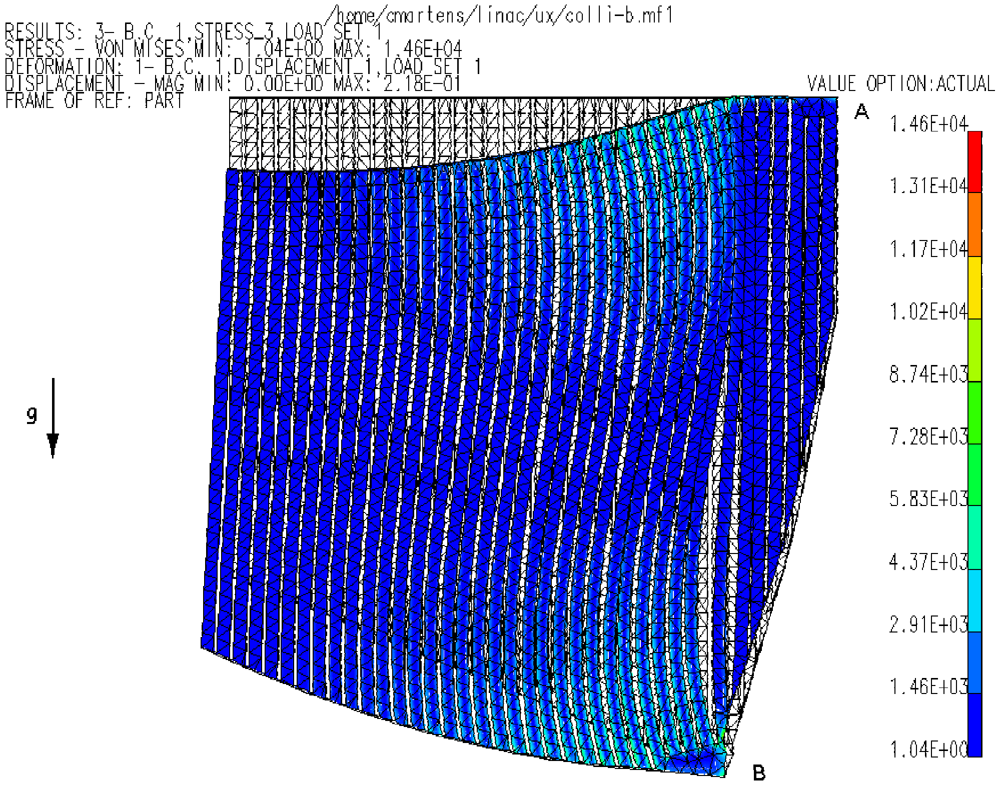

Fig. 18.2, Vertical orientated stack. The stress (von Mises) is dimensioned in mN/mm², the maximum deformation is 0.22 mm

In the case of vertical orientated plates, that means the gravity-vector is perpendicular to the plates, the deformation by shearing is dominant. The FE-Analysis shows this in Fig. 18.2, 18.3 and 6.2. The local tensions grows up to 14,6 N/mm² (von Mises) at the fixation area of the module (rail B in fig. 18.2). The tension in the side shells is 10 N/mm².

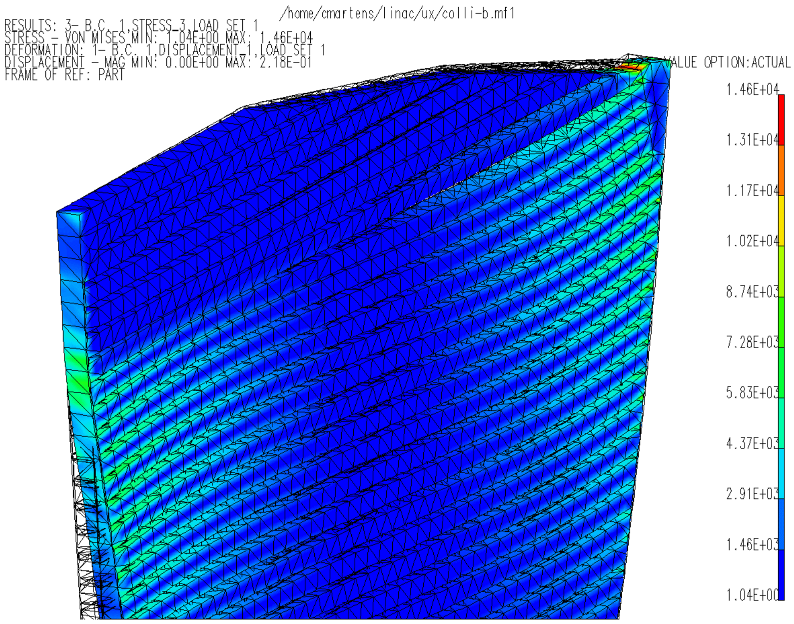

Fig. 18.3, Vertical orientated stack: The maximum tensions in the sheets by shearing is 10 N/mm²

10. Acknowledgement

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11. Literature

More about the TESLA detector and especially about the calorimeter design and expected performance can be found in:

1. The ECFA/DESY study group for TESLA, ‘Technical Design Report for a Detector at TESLA’, to be published in 2001 and WWW:

2. V. Korbel, The HCAL Detector at TESLA’, contribution to the Linear Collider Workshop, LCWS2000, FNAL, to be published and WWW:

3. V. Korbel, ‘The Optical Read Out of the HCAL Tile calorimeter’, LC-DET-2001-52, 2001.

4. V. Korbel, V. Morgunov, V. Saveliev and S. Shuvalov, ‘R&D for the TESLA Tile Calorimeter HCAL’, , LC-DET-2001-50, 2001.

5. V. Korbel, V. Morgunov, ‘Calibration and Monitoring of the HCAL Tile Calorimeter’, LC-DET-2001-51, 2001.

6. N. Meyners, K. Sinram et. al., ‘Mechanical Concept of the TESLA Detector’, LC-DET-2001-045

12. Figure captions

Fig. 1
Cut through the TESLA half detector between beam pipe and magnet coil. The inner iron yoke behind the HCAL endcap used as hadronic ‘tail catcher’ is also shown.

Fig. 2
The sandwich structure of the HCAL as used in barrel and endcaps.

Fig. 3
Transverse cross section of the TESLA detector with outside coil, HCAL, ECAL and the tracker area. Shown are also some curved tracks of charged particles with various marked momenta.

Fig. 4
Cut through a barrel module stack. In the gap between the absorber plates the scintillator tiles with actual sizes are indicated. Details of the connection to the support bars are also given. The backside of the stack is closed by a stainless steel protection sheet.

Fig. 5
View of a barrel calorimeter module.

Fig. 6
Results of a ‘finite element analysis’ of a barrel calorimeter stack module for horizontal (fig. 6.1) and vertical suspension (fig. 6.2). Size and position of maximum deviations are given. The deformations shown are not in scale.

Fig. 7
Design of the endcap HCAL with 4 quadrants and the additional outer front layers.

Fig. 8
A barrel module lifted by a crane (fig. 8.1) or carried by a special rotating device on a ‘forklift’ (fig. 8.2)

Fig. 9
Scaffold for the assembly of half barrel calorimeter cylinders. Individual HCAL modules are put together from down to top in a special designed ‘cradle’. For precise adjustment a inner ‘spider’ scaffold will be constructed.

Fig. 10
Result of a ‘finite element analysis’ study of the assembled barrel cylinder. The modules, fixed together by 6mm thick stainless steel connection plates and an outer shell of 2 mm form a stable cylinder with only 0.8 mm deformation at the top and 0,53mm at the left/right circumference (fig. 10.1). The results without inner fixing are shown in fig. 10.2.

Fig. 11
Tools for insertion of the barrel calorimeter cylinder. Fig. 11.1 shows the rollers inserted along the back end of the 2 bottom HCAL modules, fig. 11.2 shows a lateral stabilisation tool with rolls for insertion of the assembled HCAL calorimeter into the cryostat cylinder.

Fig. 12
The complete assembled barrel with two half cylinders and the ECAL modules inserted . Also shown is an octant array of 5 ECAL modules with mounted support rails to connect to the HCAL front plates and slide them into the HCAL cylinder.

Fig. 13
Shows the support structure foreseen for assembly and storage of the endcap disks. The ‘cradle’ offers rails for opening of the disks and their movement along the beam direction

Fig. 14
The closed TESLA calorimeter device with barrel stainless steel stabilisation belts as it houses inside the cryostat coil (not shown).

Fig. 15
ECAL stave with a mass of 14.15 to.

Fig. 16
Design of a HCAL endcap quadrant.

Fig. 17
Scheme of the combined endcap of HCAL and ECAL with 3 quadrants.

Fig. 18.1
Deformation and tension in HCAL module with horizontal orientated stack. The maximum deformation is 0.06 mm and oversized for a better visibility. The stress (von Mises) is dimensioned in mN/mm^2 (calculated with I-DEAS ms7).

Fig. 18.2
Vertical orientated stack. The stress (von Mises) is dimensioned in mN/mm^2. The maximum deformation is 0,22 mm.

Fig. 18.3
Maximum tensions in the sheets by shearing: 10 N/mm^2.