4. MECHANICAL DESIGN AND STRUCTURE (OUTER CALORIMETER HO)

4.1 OVERVIEW

The CMS hadron calorimeter (HCAL) consists of four parts. These are the inner barrel calorimeter (HB), located inside the magnet covering the central rapidity region of up to $|\eta| \leq 1.4$; endcap calorimeters (HE), for $1.4 < |\eta| < 3.0$, and forward calorimeters (HF) for $3.0 < |\eta| < 5.0$. In addition, since the space inside the solenoid is not sufficient to contain the hadronic showers completely, it is necessary to extend the barrel hadron calorimeter outside the solenoid. This part of the calorimeter which is located outside the coil is referred to as the outer calorimeter (HO-B).

The HO-B consists of two layers of scintillator tiles located on either side of the first layer of return yoke (YB1) which acts as the absorber (30 cm thick) for the outer calorimeter. The scintillation light from the tiles is collected using WLS fibres embedded in grooves in the tiles. These WLS fibres are spliced to clear fibres and the clear fibres transport the light to the photo detectors located at the outer boundaries of the barrel muon system.

In order to simplify the installation of the HO-B scintillator layers, several scintillator tiles will be packed into a single mechanical unit called the scintillator tray. For ease of installation, each tray will be one ϕ slice wide (5° in ϕ). However along the Z (η) direction, they will cover the entire span of a muon ring i.e. 2.53 m. The trays will be held by sheet metal C-channels welded onto the return yoke YB1 using “L” shaped brackets.

4.2 STATIC LOADS AND CONSTRAINTS

The weight of individual HO-B scintillator trays will be in the range of 25 to 30 kg only. Each tray will be supported by two sheet metal C-channels for the entire lengths of 2.53 m along the Z direction. Hence the weight per unit length on the tray support structure will be less than 15 kg/meter.

4.3 DYNAMIC LOADS AND CONSTRAINTS

Since the weight of the trays is less than 30 kg and they will be directly hanging from the return yoke, dynamic load will not be a serious issue for these trays.

4.4 MUON SYSTEMS REQUIREMENTS AND CONSTRAINTS

The outer calorimeter is geographically located inside the barrel muon system and hence is constrained by the geometry and construction of the muon system. Fig. 4.1 shows the position of the return yoke and the rings of muon stations in the overall CMS setup. The outer calorimeter layers are placed behind the muon station 1 and in front of the muon station 2 so that they occupy the space on either side of the iron yoke YB1. Radial position of the front faces of the two layers are 4.57 m and 4.89 m respectively (Fig. 4.2) and a radial thickness of 15 mm has been allocated for each of them.

The scintillator layers should map to the five rings of muon station and the optical fibres should be taken out through the space between the rings to the photo detectors placed at the outer end of the ring (at a radius of 7.43 m). The rings are 2.536 m long and are symmetrically positioned with respect to the centre point. The separation of ring 1 from the central ring 0 is

0.2 m and that between rings 1 and 2 is 0.12 m. The muon rings have 12-fold symmetry along ϕ and 75 mm thick stainless steel beams hold successive layers of iron for the return yoke.

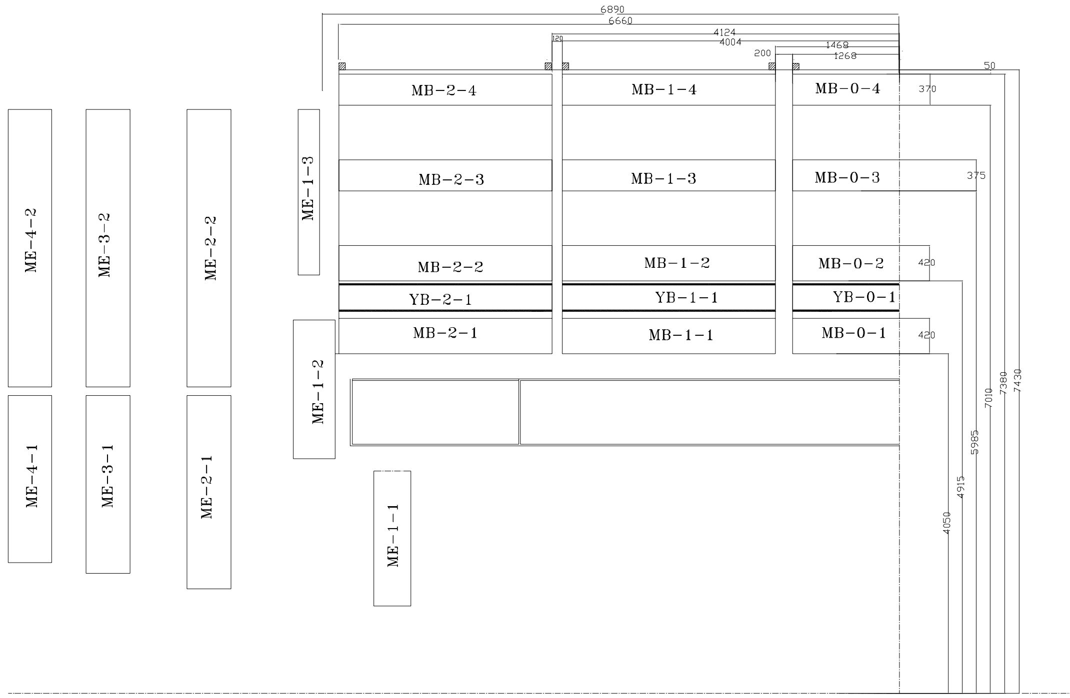

Fig. 4.1: Cross-sectional sketch of the magnet return yoke (YB1), muon detector (MB) and outer hadron calorimeter.

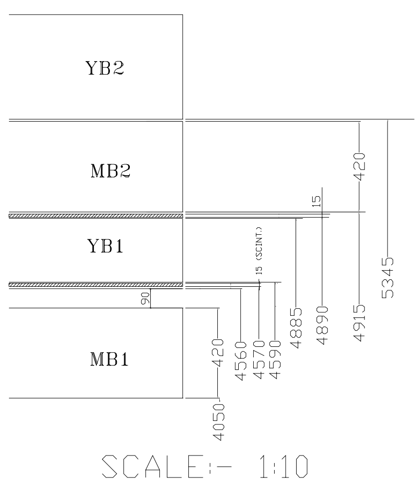

Fig. 4.2: Radial position of the two HO-B scintillator layers.

The sizes of the scintillator tiles are supposed to map to the inner layers of hadron calorimeter to make towers of granularity 0.087×0.087 in η and ϕ. The space between successive muon rings in the η direction and the space occupied by the stainless steel beams in the ϕ direction are not available for HO sampling and this will constrain the shape and sizes of some of the tiles for the outer calorimeter. In addition, the mechanical structures needed to position the scintillator trays will further reduce the sizes of the tiles as discussed in chapter 6.

4.5 OUTER CALORIMETER DESIGN

4.5.1 Frame layout

The scintillator trays are held to the magnet return yokes YB /-2,-1,0,1,2/ 1 by C-channels (0.5 mm thickness, 16.1 mm height, 10.5 mm breadth, and 2.536 m length) made out of sheet metal. The magnified view of two C-channels supporting a tray on one side is shown in Fig. 4.3. The C-channels point along the η direction and are spaced such that the scintillator trays can be inserted into them. The spacing between the centres of the C-channels holding a tray varies between a minimum of 0.267 m and a maximum of 0.571 m depending on the position of tray along φ. At one end of 30° sector in the outer layer it has been decided to combine a 123 mm wide scintillator tray belonging to the bend of the magnet with the previous 448 mm wide tray as a straight, extended portion in order to simplify the construction. In this arrangement the tray extends beyond the bend in the magnet iron. The support for this tray on the spoke side will be a specially shaped sheet metal channel since both the spoke and the iron yoke are inclined to the tray in an inconvenient angle.

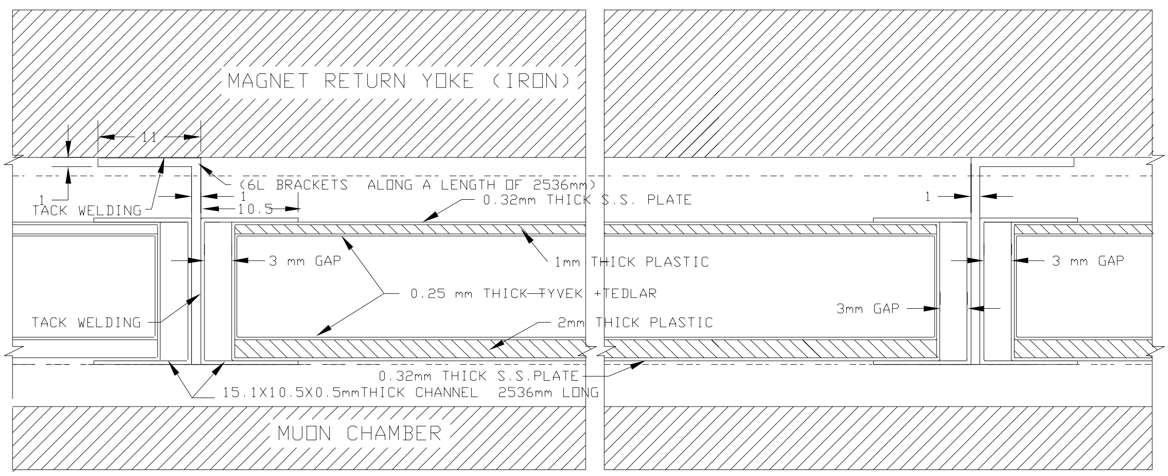

Fig. 4.3: Cross-sectional view of a HO-B scintillator tray and its support structure.

The channels are attached to the iron yoke by 1 mm thick, 2 cm broad "L" shaped brackets made of sheet metal of length 20 mm (with six brackets for a length of 2.536 m corresponding to a ring). The length of the bracket at a particular point depends upon the deviation of the magnet yoke surface from the standard. The shorter portion of this bracket is tack welded to the magnet yoke iron. The C-channels are tack welded to the longer arm of this bracket (brackets in the middle of a φ-section holding C-channels on both sides) after adjusting the C-channel in its proper position with a jig. This is necessary in order to keep the trays flat in a plane, to avoid bendings due to the slope variation in the surface of the magnet return yoke caused by the manufacturing process and to ensure that that the 5 mm "no-go" zone on the muon chamber side is not encroached. This jig will have markings or slots along its width to indicate the position of the L-bracket and C-channels. This jig will help in positioning the L-bracket of length 20 mm to make solid and flat contact with the magnet return yoke and make both the tray and the L-bracket stay clear off the "no-go" zone on the muon chamber side. We will have jigs of two different widths for two layers of the outer hadron calorimeter.

Other than these C-channels which are attached on both sides of the iron yoke through L-brackets, no other separate frame structure is necessary to hold the scintillator trays.

4.5.2 Bolt patterns

Since the L-brackets which hold the C-channels are tack welded there will not be any bolts in the supporting structure. However, the tray assembly itself is held by special brass bolts which are described in the tray assembly section. The L-brackets are welded to the magnet yoke with consecutive L-brackets along the length of 2.536 m having the welded side of the brackets facing opposite directions. By orienting alternate welded sides in opposite directions we will have a better balance.

4.5.3 Forces, stresses and deflections

The tray is supported along its whole length by rigid sheet metal C-channels anchored to the iron yoke of the magnet. Therefore there will not be any bending along the length of the tray weighing a maximum of 30 kg for the widest tray. Along the width (a maximum of 563 mm) of the tray, however there will be bending amounting to a maximum of 0.2 mm for the widest tray caused mainly by the 10 mm thick scintillator. Other trays will have less bending due to narrower width. The separate and independent buckling of the 0.3 mm stainless steel plate will be controlled by the brass screws and custom made nuts.

4.5.4 Assembly and installation

Specialised tooling is required for the installation of the hanging structure which consist of sheet metal C-channels onto the YB1 and also to insert the finished scintillator trays to their respective positions. In order to attach the C-channels to their correct positions, a jig will be made for each of the two layers. Before welding, the individual C-channels will be attached in pre-fabricated slots in the jig. The entire jig will then be positioned on either side of the return yoke (There will be two separate jigs for layer 1 and layer 2 as the positions of the C-channels are different for the two layers) by using two guiding slots on the support beams on either side of the 30° ϕ sector. The individual C-channels will then be spot welded onto the iron using "L" brackets. After the welding process is over, the C-channels will be detached from the jig and the jig will be removed keeping the C-channels hanging from the iron. The entire process will then be repeated for all the twelve ϕ sectors of a muon ring and for the five rings. A lifting fixture is needed for lifting and positioning the jig in the guiding slots before the welding of the C-channels onto the return yoke. Individual trays will be inserted in the slots of the C-channels at a later stage. A separate lifting fixture will be needed to lift and insert the trays.

4.5.5 Prototype sector

During 1997, we will construct two outer calorimeter layers to cover one HB wedge (20° in ϕ). The trays will be similar in size and design as per the HO-B specification. After fabrication and assembly the trays will be tested for their minimum ionising particle (mip) capabilities using cosmic ray muons at Bombay during early 1998 and finally will be taken to CERN during summer 1998 and will be attached behind the prototype barrel wedge for test beam studies.

4.5.6 HO-E overview, constraints, specifications and requirements

The outer calorimeter HO-E is geographically located inside the outer ring of the first endcap muon station and hence is constrained by the geometry and construction of the muon chambers making up the ME2 muon chamber ring. In fact the scintillator trays making up the HO-E system will be mounted within aluminium frames that will be attached directly to the ME2 support frames and will reside within the ME2 chamber space. There will be 36 trapezoidal trays captured within the muon chamber support frames, each subtending 10° of φ and the pseudorapidity range of $1.2<|\eta|<1.5$. Optical cables attached via optical connectors to the scintillator trays will route the scintillator response to the outer radius of the endcap muon absorbers. Decoder and electronic boxes will be located at this outer periphery of the muon absorber .

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