PRELIMINARY

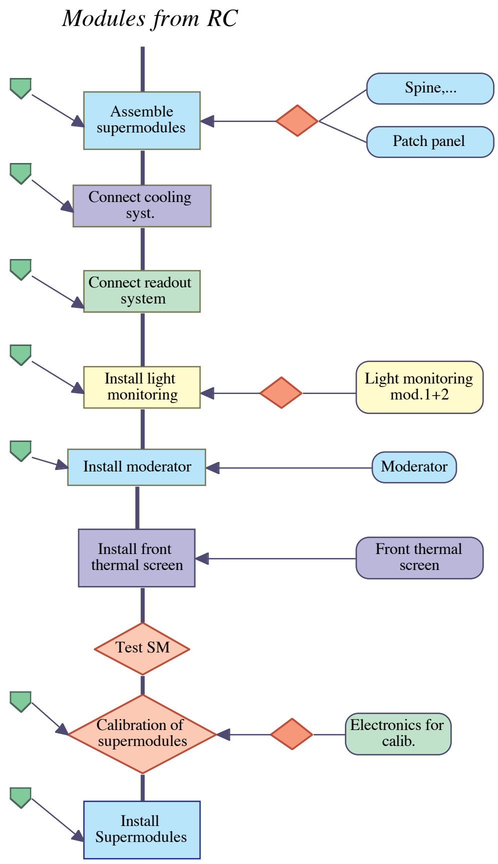

Fig. 3.33: Table 3.33. Flow chart of supermodule assembly.

3.2 Endcap design

Comment - some of the later subchapters may need to move to the chapter on assembly & integration (chap 8) but are included in their logical sequential order here for coherence.

3.2.1 Introduction

Overview

Preshower

The layout of the ECAL crystal endcaps is shown in Fig. xxx.The endcaps cover a rapidity range from 1.48 to 3.0. A silicon preshower detector is located on front of each crystal endcap detector, covering the rapidity range from 1.65 to 2.6.

The design of the crystal endcap detector has been driven by the need to provide a secure and precise mounting scheme for the lead tungstate crystals whilst maintaining physics performance and minimizing cost. The design provides a quasi projective geometry for the crystals in the endcap array.

3.2.2 Constraints (define)

space limitations

magnetic field

radiation environment (all materials, crystals, VPT's, electronics.

Environmental constraints

Mounting arrangements

Cooling

Hermeticity

Interface with other detectors

service requirements

installation/maintenance/operation

preshower

3.2.3 Geometry considerations

coverage, hermeticity, projective

physics case - gaps/cracks & acceptance

3.2.4 Endcap modularity

The modularity chosen for the ECAL endcap detectors seeks to exploit the advantages to be gained by using identical sub elements wherever possible.

To this end both endcap sections are identical and each endcap detector is constructed using symmetric Dee shaped sections (Fig. 1)

All of the ~20,000 crystals used in the endcap detectors are identical in shape and dimension.

The benefits gained from this approach are considerable in cost and also for all of the stages of fabricating and constructing the detectors.

To further exploit the use of identical sub elements the Dee shaped sections are built up using an array of sub detector units comprising 36 standard crystals arranged in a 6x6 formation as shown in Fig. 2. This sub detector element of 6x6 crystals forms the basic building block of the endcap array and is designated a 'Supercrystal' detector unit.

The arrangement of supercrystals used to build the Dee shaped sections of the endcap detectors is shown in Fig. 3. This rectilinear array of supercrystal units has quadrant symmetry and is simple to model in CAD to evaluate the gaps created in the overall array. This design arrangement provides a degree of pointing at manageable cost. The physics performance of the scheme has been extensively studied to ensure that a good balance between practical considerations and physics performance has been maintained.

The supercrystal sub detector units are supported in position by means of a cantilever support from a stiff back plate (Fig. 4). Each supercrystal unit has a special seating element interspersed between the rear plate of the supercrystal and the back support plate to enable each supercrystal unit to be positioned and pointed in the geometric direction required from its position in the support plate (Fig. 5).

The complex shapes required to complete the serrated inner and outer radii sections of the endcaps are formed by deconstructed standard 6×6 units (Fig. 6).

The construction of the two endcap detector sections will require a total of XXX standard supercrystal units and YYY deconstructed units.

The electronic readout modules for the endcap detectors are situated in the space provided between the support plate and the front of the HCAL endcap (HE).(Fig. 7). In order to provide a suitable radiation environment for the readout modules it will be necessary to install shielding to reduce the neutron flux produced on the experiment to acceptable levels for operation of the electronic modules during the expected 10 year operation of the CMS experiment. This radiation shielding requirement is implemented as shown in Fig. 7 by installing polyethylene shields to both the back support plate of the ECAL endcap detectors and to the front face of the HCAL endcap. A radial shield is also provided at inner radii.

All of the electronic readout modules will be located in this screened region to ensure safe operation over a 10 year period. All of the signals and services for the supercrystal detector units will be accessed through holes provided in the support plate (Fig. 8).

The cooling requirements for the electronic readout and crystals will be serviced by separate water cooling circuits thermally isolated from each other to accommodate the precision requirements of the thermal control of the crystal operating temperature.

To ensure that the ECAL endcap detectors are fully protected and operated in a controlled environment it is envisaged that an overall shield will be fitted over each endcap section (Fig. 9). The space enclosed by the shield will be controlled by streaming dry air through the region, to reduce the risk of He contamination in the vacuum photodetectors and any risk due to humidity. All services to the endcap preshower detectors will be routed over the outer surface of this shield.

The completed Dee sections are mounted in the CMS experiment by fixations to the front face of the HCAL endcap detector. This scheme is implemented by mechanical support sections fitted around the outer radius of the Dee section back plate which allow the back support plate to be bolted to mechanically secure positions provided on the front face of the HCAL endcap (Fig. 10).

The basic detector unit for the ECAL crystal endcap is a glass fibre alveolar container, see figure xxx, which houses a 6 by 6 array of identical crystals each of which is equipped with a vacuum phototriode (VPT) and ancilliary services. This unit is called a 'Supercrystal'.

268 identical supercrystals will be used to equip each endcap. Hermetic coverage with respect to the Barrel ECAL, will be achieved by using 56 partially deconstructed supercrystals around the external perimeter, as shown in Fig. xxx. Similarly, 8 partially deconstructed supercrystals will be used to fill in the interior perimeter at $\eta = 3$.

The supercrystals are mounted on the endcaps in an x-y grid, as shown in fig xxx.

The supercrystals will be mounted on quadrant or 'D' backplates before the assembly is installed in CMS. The structure of the alveolar unit has been designed so that the weight of the crystals (about 40 kg per supercrystal) can be safely transferred to a load plate on the back of each supercrystal without risk of damage to individual crystals. OLD text end.

3.2.5 Supercrystal Construction

The supercrystal sub detector units form the basic building elements used to construct the ECAL endcap detectors. Each supercrystal unit consists of 36 standard crystals formed in an array of 6×6 crystals as shown in Fig. 9.

The method chosen to support and provide security for the crystals is illustrated in Fig. 10. This strong, thin walled, lattice structure (alveolar) has been selected after considerable design study and provides a practical solution to the physics need to minimise both the space and material between crystals whilst maintaining a strong secure support housing for the crystals during all stages of fabrication, construction and installation of the ECAL endcap detectors.

The alveolar structure has been studied in detail using FEA techniques and the results obtained indicate that a lattice structure, formed using 0.4 mm thick inner wall GRP type material, will provide sufficient rigidity given that the rear end of the lattice structure is reinforced by strong inserts to maintain shape and form. The results from the FEA study are shown in Table 1.

The practical aspects of producing the required thin walled alveolar to the necessary dimensional tolerances and material specification have been investigated with commercial manufacturers and several initial prototypes have been produced for evaluation.

The 2x2 prototype unit shown in Fig.YY was produced by industry in Russia **name ?**. This prototype was manufactured using carbon fibre material and has 0.4 mm inner walls surrounded by a 0.2 mm outer wall. Dimensional tolerances have been measured and the results obtained are shown in Table 2. Further R&D work will be carried out in a staged programme to achieve a 6x6 alveolar unit for use in the test beam programme for 1998.

The 2×2 prototype has also been evaluated by means of load tests. For these tests the 2×2 unit was fitted with reinforcing inserts as shown in Fig. ZZ. The test performed was a simple cantilevered loading test to simulate the loading condition forseen in the endcap detectors. The results obtained from the load test are summarised in Table 3. The loading deflections of the structure correspond closely to the deflections predicted by simple FEA models.

To ensure that maximum light is collected from the crystal rear face, the internal surface of the alveolar will be finally coated with a reflective material. The techniques used to provide this reflective coating will be similar to those developed for the barrel section of the ECAL detector.

The design requirements for the rear end of the alveolar structure are made complicated by the need to resolve the design conflicts produced by the need to integrate services such as crystal cooling, EMC shielding, signal and electronic services and fibre optic monitoring into the basic structural elements for the supercrystal unit.

Each pocket of the alveolar houses a standard crystal fitted with a VPT glued to the rear face of the crystal. The VPT is operated with its photocathode at zero potential. The anode is operated with positive high voltage. It is preferable to operate the VPT in this mode in order to minimise problems which might arise due to any potential difference between the photocathode and the metallised reflective coating of the pocket which will be connected to zero potential and will form the primary EMC screen for each channel.

The structural design of the supercrystal is illustrated in Fig. QQ. Here, the strong insert elements which are glued into the rear end of each of the alveolar pockets provide the necessary structural constriant as well as fixing the crystal securely in position and providing a conduit path for cooling the crystals. The complex shapes of these inserts is a necessary requirement to take up tolerance variables in crystal length and to meet the geometry requiremnets of the rear end of the supercrystal where the complex 3D shapes produced at the crystal rear face must be transferred into a regular flat surface to allow the final support plate to be mounted in the correct position.

The design of this section of the supercrystal is extremely demanding since it is the relationship between the support plate and the outer profile of the alveolar which is used to ensure that each supercrystal unit is mounted on the Dee section support plate in the correct manner for the pointing geometry requirement.

The fibre optic monitoring equipment is housed in the service compartment created at the rear end of the supercrystal unit (Fig. SS). The fibre optic input cable is introduced via a connector mounted on the back support plate. The 37 way diffuser unit is mounted in the service compartment as shown in Fig. RR. The fibres used to monitor the crystals are routed through holes in the inserts as shown in Fig. TT. The spare fibre is connected to the control silicon photodiode for the monitoring system. The diode is also mounted in the service compartment.

High voltage supplies for the VPT units are connected via the backplate. The high voltage distribution system components are mounted on a service printed circuit board mounted in the service compartment (Fig. UU).

All of the 36 channel signals produced by the VPT's are routed through the supercrystal backplate and the Dee section support plate to the radiation screened enclosure for the electronic readout modules (Fig. VV).

The inserts also provide a physical contact to the crystal rear face and a conduit route to thermally connect the crystals to the water cooled sections provided on the Dee section support plate.

The 22 cm long (23.9 X_0) crystals have a square front face of 24.7 mm and a square back face of 25.9 mm with two tapered sides to provide an endcap with projective geometry, as shown in fig xxx.

The alveolar containers are made with 0.4 mm internal walls and 0.2 mm external walls. The crystals are packed to achieve crystal to crystal gaps of 0.5 mm within a supercrystal. Each of the crystal pockets within the alveolar unit will have a reflective lining to provide light collection to the VPT.

The reflective lining is currently part of the alveolar structure and comprises a 25 mm skin of aluminium previously coated by vacuum deposition with a 0.5 mm layer of silver and protected with 1 mm layer of polyester. Much of this technology has been developed by the CMS ECAL Barrel community which requires similar alveolar units.

3.2.6 Backplate support and pointing

Cooling

HCAL mounting

Design progress and FEA

3.2.7 Radiation shielding

To be updated with NEW radiation results (lower values!)

Good radiation shielding is of crucial importance for the electronic components in the crystal ECAL endcap detectors. Both the dose and neutron fluence increase exponentially with decreasing radius and rapidly surpass the levels to which electronic components are guaranteed by manufacturers. At the inner detector radius of 34 cm ($\eta = 3$) the dose is 1 MRad per year (10^5 pb^{-1}) at high luminosity immiediately behind the crystals (fig xxx.) The corresponding neutron fluence is 2. 10^{14} cm^{-2} per year.

The exposure to radiation has been significantly reduced by requiring that all the readout electronics be placed at a radius of greater than 50 cm ($\eta = 2.6$) and by housing all the readout electronics, including the preamplifier, within a cocoon of polyethylene behind the ECAL endcap support plate. The radial restriction limits the maximum level of dose to 0.4 MRad per year and the maximum neutron fluence to 10^{14} cm^{-2} per year. The polyethylene cocoon further reduces the neutron fluence (generated by both the endcap ECAL (EE) and endcap HCAL (HE)) to levels of about 2.10^{13} cm^{-2} per year.

Over the 10 years of LHC operation the maximum integrated dose seen by any readout electronics will be 2 MRad. The maximum integrated neutron fluence will be 10^{14} cm^{-2}. Many of the components of the ECAL electronics chain have already been shown to survive these levels of irradiation without performance impairment.

The radiation environment for the ECAL endcaps has been simulated with two separate programs, FLUKA and MARS. The programs give similar results for the relative variation of radiation as a function of position. They differ in their predictions of absolute rates, in particular the neutron fluence generated by MARS is a factor 1.5 - 2.0 higher than FLUKA. We have chosen to refer to the absolute rates from FLUKA in this section.

Much of the radiation background is generated by primary particle interactions within the crystal endcap calorimeter itself. The consequences of the irradiation for all non-crystal components are considered in this section. The consequences of the irradiation on crystal performance are discussed in Chapter 2.

The crystal ECAL endcaps have been designed to try to minimise the risk associated with the radiation field. FLUKA has been run with a number of different shielding configurations.

***********More text to come *****************

distribution of polyethylene

expected doses (neutrons and gammas)

3.2.8 Readout Electronics

Space

Fibre optic monitoring

R&D

3.2.9 Service requirements

3.2.10 Manufacture

Regional Centre

The design of the ECAL endcaps uses identical parts wherever possible. This simplifies the manufacture of the endcaps. The large numbers of identical parts will be manufactured commercially and the assembly into completed supercrystals will take place in the UK regional centre. The manufacture of supercrystals will require custom handling equipment. As each supercrystal is identical the equipment needed at the regional centre is kept to a minimum.

Crystals arrive at the regional centre having been tested at the manufacturer. An acceptance test will be performed on all crystals to check for obvious defects due to problems in transportation and handling. Some fraction of the crystals will be fully re-tested in a dedicated crystal laboratory. In the pre-production phase a large fraction of the crystals will be tested but in full production less than 1% would be tested in this way.

The alveolar containers will also be produced commercially. They will be subjected to a short acceptance test on arrival at the regional centre. The design of the supercrystals is such that the backs of the crystals do not form a smooth plane. The collars, which surround the VPTs, stiffen the alveolar structure and in addition are machined to provide a flat surface at the back of the supercrystal. This customising of parts takes place at the regional centre.

VPTs will also arrive at the regional centre having been tested at the manufacturers. They will be subjected to an acceptance test before being attached to a crystal, ready for insertion in the alveolar container.

In order to achieve the design resolution it is essential that quality control be maintained during the supercrystal construction. Tests will be performed during the manufacture of the supercrystals and in the final modules before they are shipped to CERN. The information from all the tests will be recorded in a database for use during beam tests and after the endcaps are installed in the experiment.

3.2.11 Construction

Build on surface at CERN

1. Preparation of the supercrystal for mounting.

Having exterior walls of only 0.2 mm thickness, the supercrystal is extremely vulnerable & should be supported & handled only by using special handling equipment. It may be stored resting it on one of its faces. Any movement or turning operation will require the use of the special handling equipment.

The compound tapered spacer which will provide the off pointing (fig???) will be fitted to the rear face of the supercrystal & precisely aligned with the datum faces of that item. Shims, if required, will be fitted to provide the precise compound angle at the mounting face. These operations will be carried out on an assembly bench equipped with handling equipment

2. Mounting the supercrystal to the backplate.

Because of its shape & susceptibility to deformation under load, the backplate must be supported at all times throughout the build process by a support frame. It must also always be kept in the vertical position; any deviation from the vertical will result in a change of loading causing serious deformation of the plate with catastrophic damage to the crystals.

Owing to this limitation it follows that the transfer of supercrystals from the assembly bench to the backplate must also be mechanised, & because of the need to support the supercrystal from below it also follows that mounting must commence at the top of the backplate. Subsequent supercrystals will be added below those already mounted to allow space for the loading gear (fig???).

While mounted in its frame the backplate assembly can be safely handled by using any of the normal lifting facilities provided by CERN.

3.2.12 Installation and Commisioning

The backplate assemblies (Dee's) will be completely assembled & tested above ground & lowered into the cavern only when required for assembly to the Hcal.

It is foreseen that the Dee's will be offered up to their mounting face on the Hcal from a rail system sitting approximately 2 metres below the beam height (fig ???). The rail will need adequate support from the floor, either by a custom built steel bridge or a wall of concrete blocks. A pair of trolleys running on the rail will carry the backplates, still in their supporting frames & having all services connected, from their open, maintenance position to their closed, working position. Hydraulically powered movements incorporated within the trolleys will allow precise positioning of the backplates onto the Hcal face & support while the fixing bolts are fitted. Only when fully bolted to the Hcal can the supporting frames be demounted.

For maintenance the above procedure is reversed. It follows that the mounting points for the support frames must not be buried by the services.

3.2.13 Maintenance planning

3.2.14 Survey ?

3.2.15 Timescale - MS Gant Chart