4. INTERFACE WITH SUB-DETECTORS

4.1 INTRODUCTION

The design of the CMS detector has been driven by the requirements of modular assembly at the surface, and easy access for maintenance of the sub-detectors.

The central barrel ring is used to support the superconducting coil. The other four barrel rings and the two magnet end caps can slide on common rails along the beam direction. To keep the size of the underground area within reasonable limits, the complete magnet will be assembled inside the surface building. This also allows thorough testing of the magnet before transfer to the underground area.

While the magnet is at the surface, most of the muon chambers will be inserted in the iron yoke and each sub-detector will be prepared in large individual units, before being lowered into the underground cavern. Only final assembly, together with cabling and connection of services, will have to be carried out in the underground area.

The most difficult integration task concerns the central barrel detectors because space is at a premium within the magnetic field volume. The overall design of CMS takes this fact fully into account with the detector supporting systems using minimal radial space, nevertheless maintaining full accessibility and dismountability.

4.2 INTEGRATION OF SUB-DETECTORS

4.2.1 Magnet

Since the magnet is the main component of CMS in terms of size, weight and structural rigidity, it is used as the principal structural element to support all barrel detector components.

The central barrel ring, which is the only stationary part around the interaction point, is used to support the superconducting coil. The central section of the outer vacuum tank is attached to the inner part of the central barrel ring and the coil is symmetrically cantilevered from it. The other four barrel rings and end cap disks slide on common rails, running in the beam direction, to allow insertion and maintenance of the muon stations.

All the barrel sub-detectors, HB, EB and Tracker, are supported by the inner shell of the vacuum tank via a system of rails welded to it in the horizontal plane.

4.2.2 Muon System

Three layers of barrel muon chambers MB are interleaved inside the barrel yoke, and are thus protected when installed. The fourth layer of muon chambers, located on the outer surface of the magnet yoke, can also be installed before lowering the yoke into the cavern. Care will have to be taken to protect these chambers. The installation and testing of the completed barrel muon system will be made, as far as possible, at ground level to minimise the installation time in the cavern. This procedure allows the barrel muon system installation to remain outside the critical path of the general CMS installation planning.

Each end cap muon system consists of three vertical iron disks connected together. During installation and for maintenance of the system these iron disks can be disconnected and separated by displacing them along the rails. The end cap muon stations are mounted on the vertical disk faces and are normally inaccessible.

4.2.3 Hadron Calorimeter

The HB, which is composed of two elements, each weighing 500 tonnes, is supported only in the horizontal plane. This is achieved by rails fixed to the inner shell of the vacuum tank, and by a set of sliding pads sufficiently compliant to avoid local over-stressing of the vacuum tank wall. Maintenance access to the scintillator trays, which will be inserted during the pre-assembly at the surface, will still be possible from each end. The Tracker assembly is supported by two thin radial structures, attached directly to HB.

Each HE, which behaves as a single unit, is cantilevered from the first disk YE1 of the magnet end cap via the central shielding cone, which acts as a structural support. In addition, open straps provide added stability. This scheme leaves free space for the insertion and maintenance of the inner forward muon station ME/1/1. Maintenance access to the previously installed scintillator trays will still be possible in the radial direction.

4.2.4 Electromagnetic Calorimeter

The mechanical design of the electromagnetic calorimeter (EB) is optimised for the use of $PbWO_4$ crystals. Space used for the mechanical structure within the active volume of the calorimeter is reduced to a minimum, as the basket walls are designed to take only the reaction forces of the spring loaded crystals. Each super module is supported directly from the corresponding HB sector.

Each EE, which behaves as a single unit, is attached directly to the corresponding HE.

4.2.5 Tracker and Beam Pipe

At each end of the inner tracker, a 1 m long cylindrical section of beam pipe is provided for in-situ cutting and welding. The central section of the beam pipe remains an integral part of the tracker and is consequently removed with it.

The approach of installing (and removing) the central tracker as an integrated unit, containing detectors and the central section of the beam pipe, will permit independent assembly, testing and pre-alignment. In addition, this satisfies the essential requirement that the individual detectors be kept at the required temperature and gas condition during maintenance periods. Opening of the inner tracker will be carried out only in a dedicated cooled clean area situated at the surface.

4.2.6 Forward Calorimeter

To open the detector at one end, the corresponding HF must be removed. This must be done rapidly, with the HF fully cabled, to allow for optimum use of the shut-down period. For this reason, the HF is mounted on a stand supported by a structure composed of four parts, designed to support 400 tonnes. Mechanical jacks, sunk in the cavern floor, allow movement up or down in a three step operation.

A rotating shielding will provide, on both sides, the interface between the LHC machine and the CMS experiment at the level of the forward calorimeters

4.3. CABLING AND SERVICES

In contrast to the considerable amount of detector pre-assembly which can be completed at the surface, the installation of services for the various sub-detectors must be done underground. To minimise the installation time, a precise and well ordered cabling plan must be implemented.

As a general installation principle, hardware such as manifolds, pipes, ducts and semi-rigid gas lines will be installed first, followed by the more flexible elements, i.e. electrical and optical fibre cables. Cabling will be arranged to allow maximum access to detectors and front-end electronics with a minimum of uncabling, (see Fig. 4.1).

Considering the overall assembly procedure, the logical cabling sequence requires starting from the outer muon chambers and working progressively inwards towards the central detectors. Seen in cross-section along the beam line, cable runs from the inner detectors will follow the boundary between barrel and forward detectors. Returning over the coil end flanges, the cables will then be routed along the outer cryostat wall to exit radially over the front faces of the central barrel ring. Consideration has been given to muon chamber access by alternating the cable runs over their end faces. Likewise, end cap cables will exit over the front face of each end cap. From the magnet periphery, cables and services will be channelled on a support system around the detector to flexible cable trays (cable chains) located at each side of the magnet. At the exit of the cable chains, services and cables will be separated, gas and cooling pipes being directed to the 'service' cavern, cables to the 'counting-room' cavern.

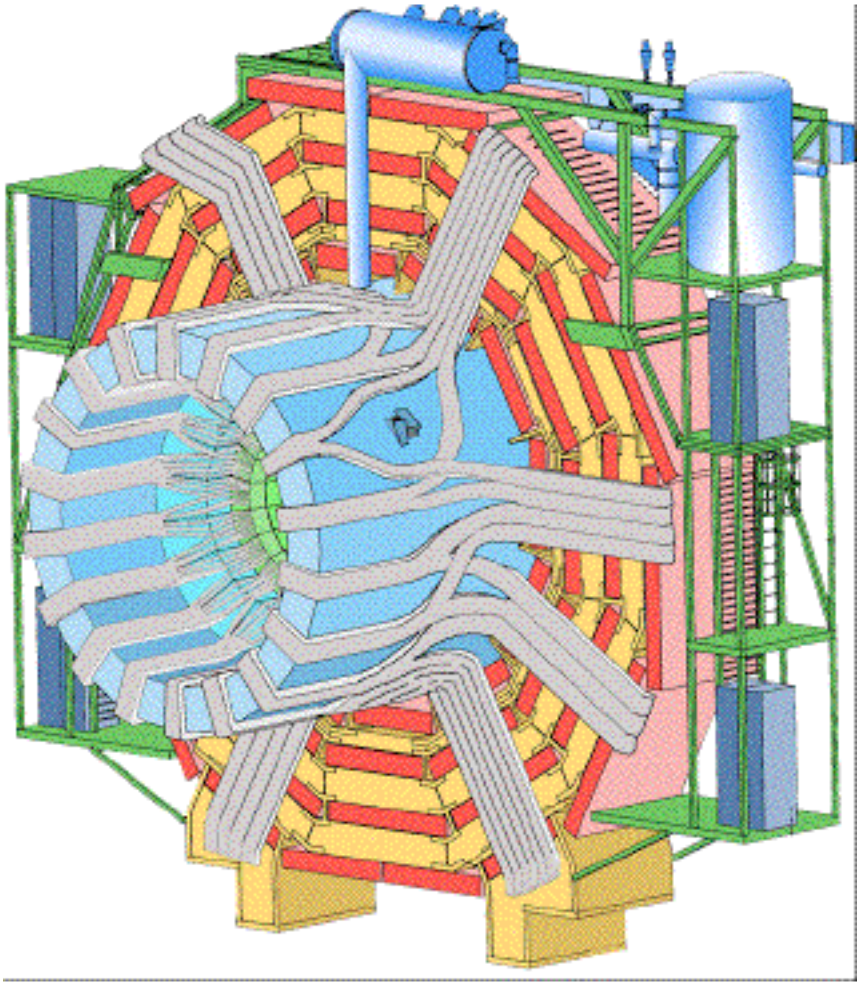

Fig. 4.1: The routing of cables and services from the inner barrel detectors over the vacuum tank, and along the barrel ring YB0

4.4 ACCESS AND MAINTENANCE OF SUB-DETECTORS

Particular attention has been given to:

- maintaining an easy access to the Tracker flanges, where most of the services for the barrel detectors are situated,
- facilitating the possibility of removing the complete Tracker to a dedicated surface laboratory during major shut-downs for maintenance or upgrade operations,
- allowing access to all sub-detectors for maintenance,
- maximising useful time during shut-downs.

Access is organised so that a minimum of uncabling (and thus recabling) of other sub-detectors is needed, and in particular to allow the electromagnetic end caps (EE) to stay fully cabled in order to maintain their calibration. Any opening of the detector at one end requires the removal of the forward calorimeter (HF) at that end. To fully use the shut down time, the HFs must be removed, and brought back to their final positions at short notice.

This also constraints the division of the experiment into end cap and barrel sections. The hadronic calorimeter end cap (HE), the electromagnetic calorimeter end cap (EE), are removed as an integral part of the corresponding magnet end cap.

The LEP experiments have been used as a model for defining safety requirements, and planning the access scenario. Thus, large scaffold arrays and hydraulic elevators for material and personnel are integrated with the gangways around the experimental hall and on the detector barrel.

Ease of access to all parts of the detector for upgrade, repair or normal maintenance has been an essential design criterion from the beginning. To obtain access from the fully closed position (see Fig. 4.2, p. XX) this will require the rotating shielding to be turned away by 90 degrees.

The forward calorimeter HF will be lowered to floor level, in three steps, by a special lifting mechanism. Each calorimeter will be stored in a shielded garage, situated at each end under the platform supporting the last machine elements, where maintenance may proceed in a radiation controlled area.

This will allow the magnet end caps to be fully retracted until the shielding cone of the magnet end cap covers the copper collimator. This gives the maximum floor space on both sides of the experiment for subsequent handling operations. In particular this position allows for the removal of the inner tracker on a special cradle.

In this position, the disks of the end cap yoke or the rings of the barrel yoke can be separated to give further access to all muon stations for maintenance (see Fig. 4.3, p. XX).