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OPAL DETECTORS - EXPERIMENTAL EQUIPMENT FOR LEP

OPAL (Omni Purpose Apparatus for LEP) is one of the four very large experiments built for use on the new Large Electron-Positron collider (LEP) machine at CERN. It has been constructed by a collaboration of 24 research institutes from Europe, the Middle East, North America and Japan.

The OPAL experiment consists of 14 "independent" particle detection systems, of which the End Cap Muon Detectors and the End Cap Electromagnetic Detectors were designed and built at RAL in collaboration with University groups at Birmingham, Cambridge, Queen Mary and Westfield College. The vast scale of these detectors, combined with the stringent performance specifications imposed by the LEP environment, posed many difficult technical and logistical problems which required the development of new and innovative techniques at both the design and construction stages.

End Cap Electromagnetic Detector

This detector consists of 2264 individual lead glass counters.

The individual counters are assembled to form two 4 metre diameter detector arrays which are mounted on the magnet pole sections at each end of OPAL. Since the detector is required to operate in the main axial field of the magnet it is not possible to use normal photo multiplier devices to measure the light produced in the lead glass by the LEP events. A new single stage Vacuum Phototriode (VPT) device was therefore developed for this application. These devices operate well in high axial magnetic fields but produce very low gain. The electronic output signal must therefore be processed through a special low noise semiconductor amplifier mounted as close to the VPT as possible. Each End Cap detector assembly comprises 1132 individual counters mounted on a support backplate. The combined weight of the individual counters (∿20T) together with the need to route the services (Signal, HT and LV supplies, fibre optic calibration etc) through the back support plate makes the provision of a suitable support system extremely difficult. Final solutions using a composite back plate arrangement were obtained after considerable analysis (using FEA techniques) of the stress and deflection conditions produced in the backplate structure. The complicated front face shape of the detector array is defined by the need to fit the lead glass detector inside the ends of the inner tracking detector vessel. The arrangement adopted was chosen after careful 3D modelling of the array using CAD techniques and is built up using 33 different types of individual counter.

Individual counters are packaged in very thin (0.5mm) seam welded brass enclosures. These produce both the light and electrical screening environment required and a means of cantilevered support from the backplate. Overall tolerances achieved on the cross section of the counters was ∿0.2mm which was well matched to the maximum allowable clearance between counters of 0.5mm.

The 2264 individual counters were built at RAL and delivered to CERN for assembly and calibration of the 4 metre diameter arrays during 1988. Installation of the two End Cap Lead Glass detectors on OPAL was completed by March 1989 and the detector system was successfully operating at the start of the LEP programme in September 1989.

End Cap Muon Detector

The Muon detectors are situated outside the 1 metre thick iron yoke of the OPAL magnet (which is 10 metres long and 8 metres in diameter).

The large End Cap Detectors cover an area of 13m x 13m at each end of OPAL and measure both the position and direction of the outgoing Muon particles from a LEP event by detecting the Muons as they pass through the multi-layer sections of the detector system. The detectors are proportional counters working in the Limited Streamer mode and consist basically of an assembly of 6m long, 1 centimetre square cells made from extruded plastic with a 100 μmetre diameter wire held at ∿4.3kV at the centre of the cell. Ionisation produced by a Muon crossing a cell produces a microscopic spark (streamer) very near the wire. The streamer induces electrical signals on the position sensing electrode system of orthogonal aluminium strips outside the cell structure. The complete detector array comprises some 20,000 cells together with 40,000 readout strips each with its own channel of electronics.

To minimise fire hazards the cell elements and the large strip readout boards were manufactured using Halogen free polymers (Noryl). The cell structures were produced to an overall tolerance of ∿0.2mm using extrusion techniques and accurate positioning (∿0.15mm) of the readout strip patterns was obtained using a specially adapted commercial laminating machine.

The conductive coating applied to the cell walls to define the electrostatic field and yet permit the cell structure to be transparent to the electrical signals radiated from the streamer was developed in industry for this application. Uniform resistivity values of 10^6 ohms/square were achieved using a carbon loaded vinyl paint (V10) and long term testing has demonstrated the stability of the coating in the cell environment which contains hydrocarbon gases.

The final detector array was produced in modular sections at RAL. Each Module comprised 64 cell elements mounted side by side on a parallel strip readout board. These Modules ∿300 in total together with the orthogonal readout boards were transported from the UK to CERN where they were assembled to produce sub system arrays of Quadrant and Patch detector elements.

The End Cap Muon detectors were constructed and tested at CERN by July 1989 and the complete detector system was installed on OPAL and commissioned for the start of the LEP experimental programme in September 1989.

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