RAL
DESIGN & DISCOVERY
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RUTHERFORD APPLETON LABORATORY
SCIENCE AND ENGINEERING RESEARCH COUNCIL

The ALEPH Electromagnetic Calorimeter

Understanding the forces of Nature

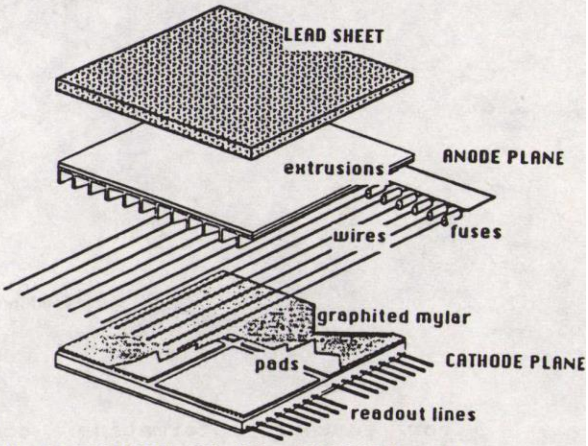
At the LEP accelerator at CERN in Geneva, electrons and their antiparticles positrons are made to collide head-on at four points around the large ring, 27 km in circumference. When the energy of each is close to 46 GeV, a new particle is created, about 100 times heavier than the proton. It is called the Z and is the carrier of the 'electroweak' force. It decays within 10^{-24} seconds, producing other particles which can be observed in detectors surrounding the collision. LEP is designed to produce millions of Z's per year, and will allow a thorough test of our understanding of the electroweak force.

Detecting electrons and photons

The electromagnetic calorimeter is one of the elements of the ALEPH detector. It distinguishes electrons, positrons and photons from other particles produced in Z decay. In dense media these particles lose their energy by producing a very compact shower of particles of lower energy. The energy and position of the original particles is inferred by measuring the ionisation produced by the shower in gaseous layers interleaved with thin sheets of lead.

Mechanical design and construction

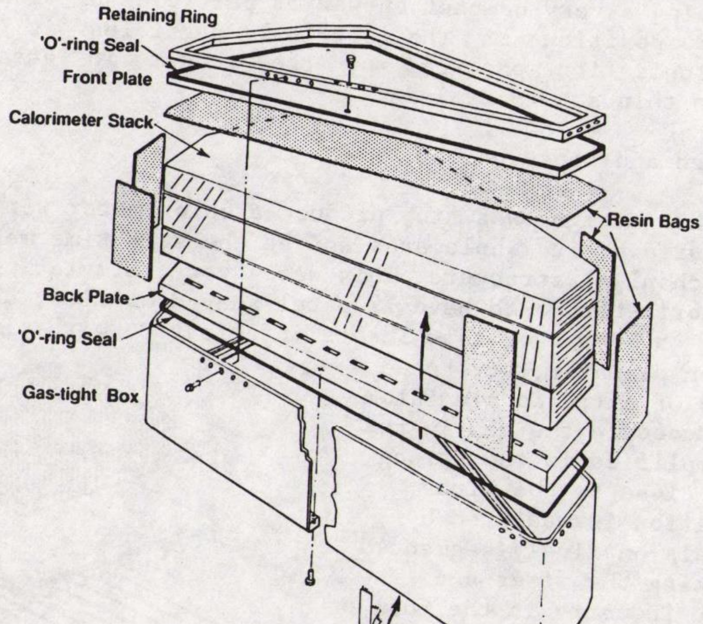
The aim of the design was to produce a calorimeter with accurately uniform behaviour over its whole area and at the same time make a sound and stable mechanical structure. This was a very stimulating challenge. The end-cap calorimeters each have 12 petal-shaped modules, each module a case containing 45 layers of lead sheets interleaved with planes of thin wires, 25 micron diameter, stretched inside channels of extruded aluminium. Ionisation produced in the gas in the extrusion is amplified in the strong electric field close to the wires. The shower position is measured by detecting signals on finely-segmented copper pads facing the wires and manufactured in industry in the form of large-area printed circuit boards. The detailed patterns for these boards were generated directly by computer. All these elements had to meet very strict tolerances on their thickness. When 45 layers were stacked the height remained uniform to 1 mm over 1 m. This required each component to be checked to be within 50 microns of its nominal thickness. It was necessary to



compress the stack to constrain the mechanical tightness. This was achieved by filling a thin PVC bag, between the stack and the front plate of the case, with epoxy resin at a pressure of 0.3 bar. When the resin is cured the front plate acts as a spring applying a uniform force to the stack. Careful checks on test assemblies ensured that any long term movement ('creep') of the lead over a number of years would be taken up by the tension in the spring.

The aluminium alloy cases were manufactured in industry to a very tight mechanical tolerance, so that a minimum of sensitive volume was lost and so that the modules could be mounted in the correct position. To fill the modules with the gas used (a mixture of xenon and carbon dioxide) they are first evacuated to remove all the air. Vacuum vessels are subject to stringent codes of safety, and all welds were X-rayed to check them. In addition, the vessels had to be leak-tight to avoid the introduction of small amounts of air which would cause a serious reduction in the signals measured. Finally, the distribution of the mechanical stress in the case under all conditions of evacuation, pressurisation and under the load of its own weight of 2.6 tonnes were computed using finite element analysis techniques. This ensured that the case was more than strong enough for the demands made on it.

The mechanical design was made at RAL and the construction at RAL and Glasgow University. The raw materials (extrusions, lead, printed circuit boards, etc) were supplied from industry and the 24 modules were assembled and tested over a three year period. The installation was completed at CERN in February 1989 and the calorimeter has performed excellently throughout the period of operation of LEP, which began in August 1989.



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