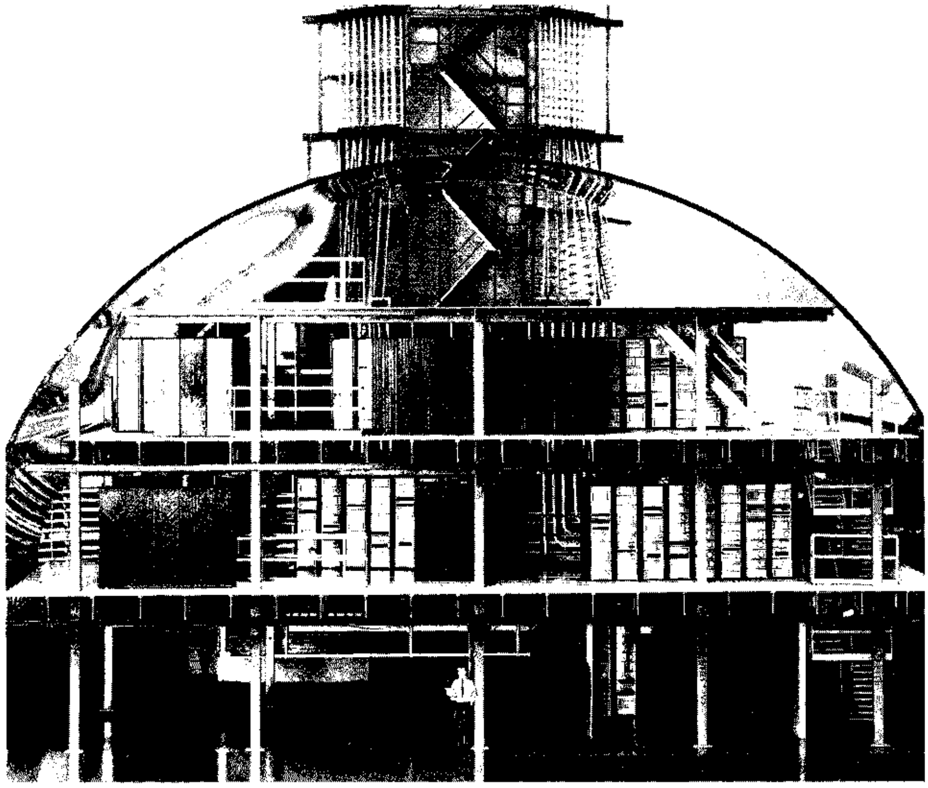
Innovative instrumentation

Model of part of an underground area for an experiment at CERN's new LEP machine. With LEP now under construction, the requirements for new detection techniques are as intense as ever.

(Photo CERN 174.10.83)



At this year's particle physics conference at Brighton (see October issue, pages 303-11), a parallel session was given over to instrumentation and detector development. While this work is vital to the health of research and its continued progress, its share of prime international conference time is limited.

At Brighton, Bernard Hyams of CERN was given the task of picking out themes and highlights from the mass of contributed material. In his one-hour talk, he addressed himself to theoreticians and phenomenologists, assuming that instrumentation specialists would already be aware of most of what he had to say.

Instrumentation can be innovative three times — first when a new idea is outlined, secondly when it is shown to be feasible, and finally when it becomes productive in a real experiment, amassing useful data rather than operational experience. Hyams'examples showed that it can take a long time for a new idea to filter through these successive stages, if it ever makes it at all!

Track measurement

For measuring the tracks of charged particles, the main activity on the floor these days is with drift chambers. These are now well understood, but new developments, such as the vertex detectors for the Mark II experiment at SLAC's PEP ring and the TASSO experiment at DESY's PETRA ring, concentrate on improving the track resolution in the continuing hunt for short-lived particles.

The particles (tau meson, heavy flavours) now being sought have short lifetimes which test experimenters' ingenuity to the full. Using drift chambers, the precision is at best 100 microns and close tracks can be clearly distinguished only if their separation exceeds a few millimetres. This is barely sufficient for rare particle hunting.

Once the workhorse of particle detection, bubble chambers have been declared dead repeatedly. 'However they continue to expand,' declared Hyams. The tiny track lengths being sought in experiments (such as measurements of the charm lifetime) test conventional technology, and holography is now an attractive proposition. Small holographic bubble chambers are working, and large-scale applications for neutrino physics look possible (see October issue, page 317). Both BEBC at CERN and a 1 m chamber at Fermilab have achieved 50 micron bubble images.

Another holographic possibility has been pointed out by a Munich / CERN group, which has probed 60 micron distances using holograms in a tiny streamer chamber. This may have a future since streamer chambers, unlike bubble chambers, have already been used in colliding beam experiments.

Silicon strips were first used twenty years ago, but only recently has a particle physics experiment used the method in practice (see March 1982 issue, page 47). Charm lifetime measurements are now benefitting from this technique. With a spatial precision of some 5 microns and a track resolution of 100 microns, they offer a tenfold improvement over drift chambers, and work at higher rates.

Charged coupled devices have been developed for television cameras and other optical imaging applications. Applications for particle physics are being actively investigated (see June 1982 issue, page 179). Beam tests have shown a spatial accuracy of 5 microns and a resolution of 40 microns.

Other innovative tracking techniques being currently investigated (though not yet in production systems) include silicon drift chambers, and scintillating optical fibres.

Velocity measurement

Velocity measurements are important for particle identification. While conventional ionization instruments seem to be reaching their optimal performance, Ring Imaging Cherenkov counters (RICH), first proposed 25 years ago, are now emerging as a serious alternative. Several such counters have been built (Experiment 603 at Fermilab and a Serpukhov instrument described in the November issue, page 384). Their ability to distinguish between high energy pions and kaons is impressive.

Various methods are used to image the detecting rings, including wire chambers and Time Projection Chambers. One interesting development in the Cherenkov area is the approach taken by the mammoth underground Irvine / Michigan / Brookhaven experiment searching for proton decay and other rare events. This detector picks up its Cherenkov rings from a few thousand photomultipliers dangling in some 7000 tons of water, thus also providing tracking information.

Calorimetry

With the increasing complexity of the events being studied at high energy, particularly in colliding beam machines, better resolution of energy deposition (calorimetry) is required to pick up the large numbers of photons released in the decay of neutral pions, themselves copiously produced.

With this in mind, a high density projection chamber is being studied for the DELPHI experiment at CERN's new LEP machine. It is essentially a large Time Projection Chamber containing many concentric lead cylinders with narrow intervening gas volumes. Recent tests of the model have been encouraging, giving good energy resolution while pinpointing shower impact points to a few millimetres and separating showers as close together as 10 mm.

Other teams are looking at the relative merits of barium fluoride and bismuth germanate (BGO) for electromagnetic calorimetry. Barium fluoride is comparatively cheap but has longer radiation length. It scintillates in the ultra violet and this can be measured with a simple proportional chamber. BGO is expensive, but has shorter radiation length and holds the promise of a total absorption calorimeter with wire chamber readout giving high spatial resolution.

Computation

The last topic described by Hyams was computation. While interaction rates in electron-positron colliders pose no particular problems, the high luminosities in hadron machines (both fixed target and colliders) mean that some kind of pre-selection has to be made. Existing techniques can only record a few events per second. Even then each event can produce a prodigious amount of information, requiring some ten seconds of processing time on a modern mainframe machine. Data processing thus quickly becomes a bottleneck.

One solution being increasingly advocated in sectors with limited computer resources is the development of special processors tailor-made for the particular application. One such project by a collaboration at Fermilab aims to handle some 10^5 events per second, each event having about twenty tracks.

CERN
First results from LEAR

When new physics conditions are opened up, new results are not far behind. Earlier this year the physics experiments at the LEAR Low Energy Antiproton Ring had their first taste of antimatter (see October issue, page 314). LEAR enables physicists to explore in depth the interactions of antiprotons under conditions which could only be briefly glimpsed before.

Using data from ten fifteen-minute spills of low energy antiprotons, giving a total of 3.5×10^8 antiprotons on target, a Saclay / Grenoble / Strasbourg / Tel Aviv collaboration has measured the scattering of 309.4 MeV/c momentum antiprotons off carbon nuclei.

This is the first step of a planned systematic study of antiproton-nucleus scattering, using a range of energies and target nuclei.

After scattering from the carbon target, the antiprotons were magnetically analysed by the SPES II spectrometer, allowing absolute elastic and inelastic reaction rates (cross-sections) to be determined. Data were taken at scattering angles from 10 to 55° in overlapping steps, and the apparatus was calibrated in initial runs with protons.

The elastic scattering angular distribution (where the antiproton appears to 'bounce' off the target nucleus) shows a diffraction-like pattern, in marked contrast to the elastic scattering of protons off carbon. Excitation spectra show the production rate of excited nuclear states, which also is different to that seen with protons.

These initial measurements put powerful constraints on the nature of the antiproton-nucleus interaction,