

of mass. The global cosmic ray detection effort produces no more than 300 events per year at this energy and no more than 2000 events per year at 10 TeV in the centre of mass. These numbers would increase tenfold if there was a 100 km² coverage with detection devices — certainly worthwhile until a 100 TeV accelerator becomes available, but no substitute for investment in new accelerators and their design.

Non-accelerator experiments, including searches for proton decay, searches for neutron oscillations, neutrino mass and oscillation experiments at reactors, and searches for neutrino-less double beta-decay, are likely to provide some of the most

eagerly awaited information on new mass scales. For example, each different type of proton decay mode would be associated with its own mass scale. While decays producing one lepton would require a mass of 10¹⁴ GeV, other decays can be proposed, producing additional leptons, and the masses involved become lighter by many orders of magnitude. All these decay modes could co-exist though some of them might be relatively rare. Thus proton decay experiments will have a long lifespan, with the vast information that they and they alone can provide. There is a good case for buying real estate under Mont-Blanc for long occupancy.

Notwithstanding Landau's famous admonition: 'Cosmologists are often wrong, but seldom in doubt' — cosmology, while also exploring other intermediate mass scales, provides our only window on masses beyond 10¹⁴ GeV.

But, even after painting this bleak picture for 'the experimental prospects of particle physics, I am continually and forever being amazed how relatively rapidly our experimental colleagues succeed in demolishing (or sometimes demonstrating) the seemingly inaccessible and often outrageous of our theoretical speculations. This continual interplay back and forth is the glory of all science, including our own.'

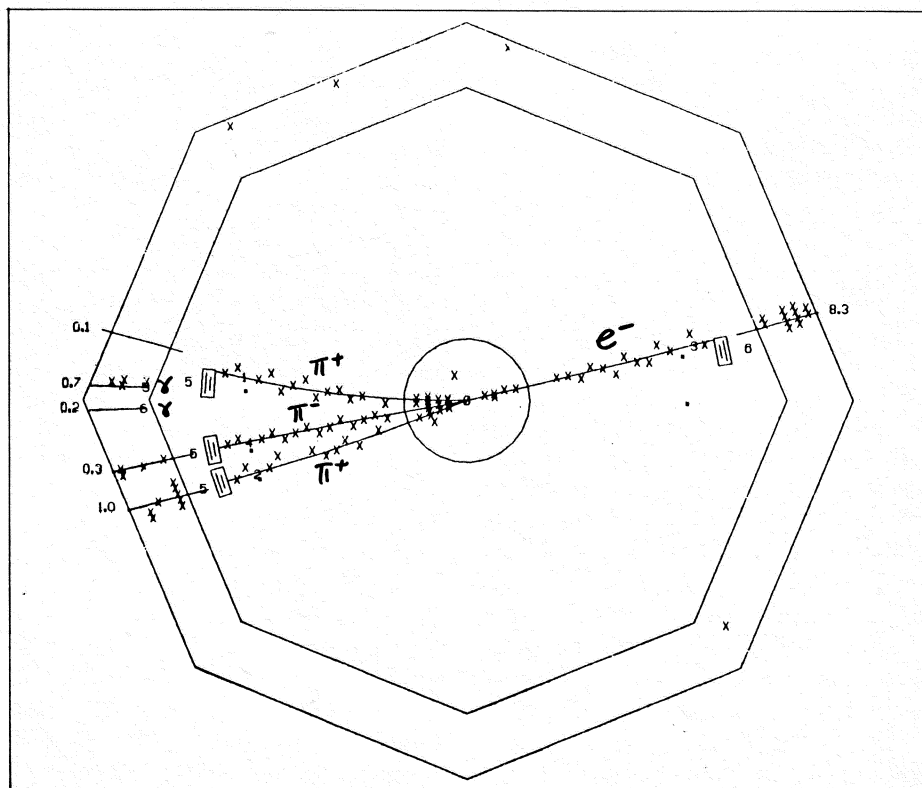
Physics monitor

More results from electrons and positrons

With the first crop of results now coming from the PEP electron-positron ring at SLAC and with a surge of new data from the PETRA ring at DESY, electron-positron physics is back in the limelight. This was especially noticeable at the recent Lepton/Photon Symposium in Bonn at the end of August.

At PETRA, the installation of new focusing quadrupoles ('mini beta' sections) to compress the stored beams has meant that the experi-

Annihilation of an electron and a positron into two tau leptons and their subsequent decay, as seen by the Mark II detector at PEP. One tau produces the electron on the right plus two invisible neutrinos, while the other gives the three charged pions on the left plus a neutral pion decaying in turn into the two gamma rays seen in the outer ring of shower counters.



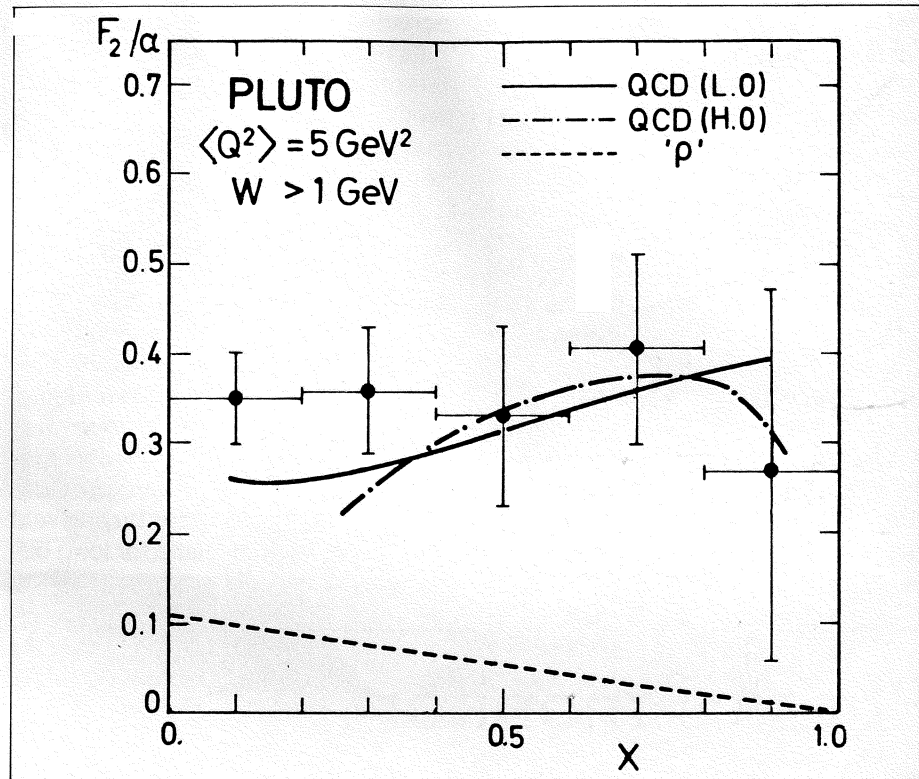
ments have been able to log data much faster than before (see July/August issue, page 237), and the physics dividends are now being reaped.

The PEP ring went into action last year, and first results are now emerging. In addition to confirming behaviour seen earlier at PETRA, PEP researchers have some new physics to report.

One goal of high energy electron-positron experiments is to look for the delicate interference effects between electromagnetic and weak interactions. Electrons and positrons can interact either electromagnetically through an intermediate photon, or through a weak boson. Although the electromagnetic process dominates, the standard theory says that the weak interaction increases with energy and in the PETRA/PEP energy range interference between the two processes should produce a small forward-backward asymmetry in the angular distribution of emergent muon pairs.

An average of the results from the JADE, Mark-J, PLUTO and TASSO experiments now gives the predicted asymmetry level (the errors are now down to about five per cent, except at PLUTO). At CELLO, the newcomer to the PETRA ring, the statistics do not yet permit any definite asymmetry to be seen. PEP measurements are also at the five per cent error level. The total asymmetry results amassed so far do not contradict the prediction of the standard model, and can now be usefully compared to the fixed target neutrino — electron data.

Another electron-positron specialty is photon-photon physics — the mutual interactions between photons accompanying the 'colliding' electrons and positrons. This provides a new window on the high energy behaviour of the photon, traditionally



The photon structure function as measured by the PLUTO detector at PETRA in those photon-photon interactions where a photon is probed deeply. The data points are incompatible with old ideas of vector meson dominance (dashed line). The two curves are the results of theoretical calculations. As these interactions involve free, rather than bound quarks, the theory is in good shape.

thought to be associated with virtual vector mesons (like the rho). Results from PLUTO show that the photon, when probed deeply, includes a distinct 'harder' component due to virtual unbound quark-antiquark pairs (not bound as mesons).

These photon-photon interactions are ideal for quantum chromodynamics (QCD) calculations because the contributing interactions involve free quarks and can be calculated by perturbative methods. This contrasts with the analysis of deep inelastic scattering on nucleons where the nucleon structure functions have to be taken from experiment and QCD effects can only be gauged from small correction terms.

A preliminary analysis of this PLUTO data was presented last year at the Madison Conference. Although the shape of the photon structure function has apparently changed, it is still incompatible with the old idea of

vector meson dominance.

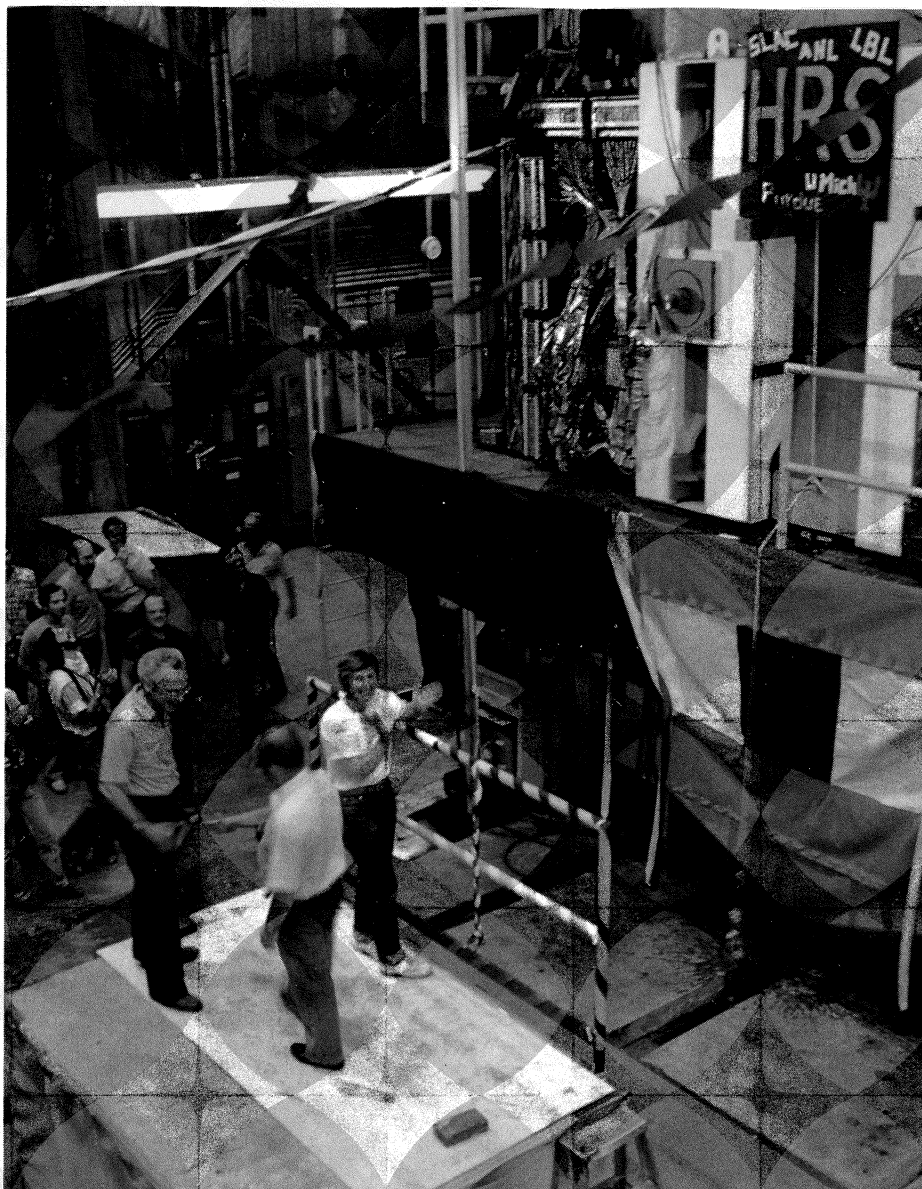
Also on the photon-photon front, TASSO has found eight examples of the production of proton-antiproton pairs. These eight events required two and a half years of data taking! Photon-photon studies also provide a new way of looking for resonances whose quantum numbers make them difficult to isolate otherwise.

Production of single gluons along with quark-antiquark pairs in electron-positron annihilation gives events with a three-jet structure. Comparison of the jet properties could reveal differences between the behaviour of quarks and gluons. CELLO finds the behaviour of neutral particles similar to that seen earlier for charged particles.

In contrast to some results from PETRA, the LENA detector at the lower energy DORIS ring at DESY finds no difference between the properties of quark and gluon jets. In

Celebrations as the High Resolution Spectrometer moves into intersection 6 of the PEP ring at SLAC. On the platform, Don Meyer of Michigan (left) is congratulated by Pief Panofsky while Adele Panofsky applauds enthusiastically.

(Photo Joe Faust)



what is probably a pointer to some future physics, LENA has also reported its first upsilron radiative decay. These decays could reveal more of the spectroscopy of hidden beauty particles.

Results from PEP are broadly in line with those of PETRA, but even at this early stage SLAC has some notable 'firsts'. The Mark II detector already had its first taste of tau leptons at the SPEAR ring, and together with the

MAC detector, has gone on to make further tau studies at PEP. In particular, some high resolution data from Mark II using comprehensive event selection and analysis to measure the tiny tau decay path (about a millimetre) gives a value for the lifetime of the tau as $4.9 \pm 1.8 \times 10^{-13}$ s, as compared with the theoretical estimate of 2.8×10^{-13} . Thanks to the high resolution provided by the drift chambers inside the Mark II magnet,

this is the first time that a definite value for the tau lifetime has been obtained.

Analysis of the hadron jets seen at PEP takes a different approach which uses quantities which are both directly measurable and calculable. The results agree with quantum chromodynamics predictions. Mark II finds that the behaviour of the lowest energy jet (which has the highest probability of being the gluon jet) is very similar to the low energy jets seen at SPEAR.

Because of the wide kinematic range covered, comparison of charged particle production seen in the Mark II detector earlier at SPEAR and now at PEP gives interesting results, and the scaling violations observed now begin to look like those seen in fixed target experiments.

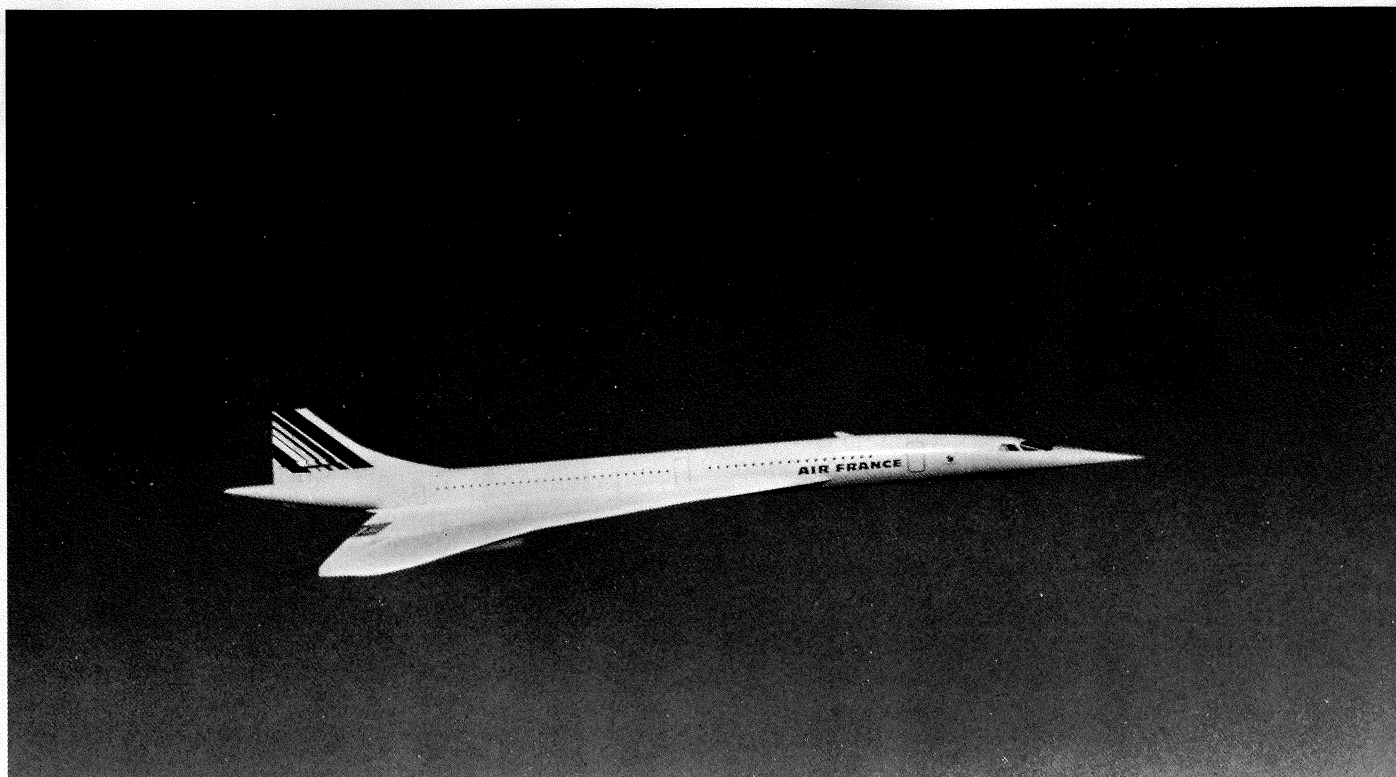
As at PETRA, experiments at PEP find unexpectedly high levels of baryon production. These effects invite explanation. It was initially suggested that the fragmentation of quarks into hadrons can pull not only quark-antiquark pairs but also a diquark-antidiquark system out of the vacuum. However the correlations between jet structure and baryon production seen at PEP suggest that even more exotic mechanisms might be required.

The Crystal Ball detector at the SPEAR ring continues to fill up the charmonium spectrum. After playing a prominent role in discovering the lightest spin zero charmonium particle, the eta-c (see March issue, page 68), Crystal Ball has now seen a heavier companion particle at about 3.6 GeV, and analysis of J/psi radiative decays gives evidence of new states, possibly 'glueballs'.

The prolific production of upsilons at DORIS and at the CESR ring at Cornell provides a good laboratory for studying the properties of gluons. Certainly a gluon of spin zero can

Concorde — adding to the repertoire of cosmic ray experiments.

(Photo Air France)



now be excluded. CESR has really capitalized on its ability to cover the full ϵ region, however DORIS is soon to be rebuilt as a single ring, reaching energies of up to 5.6 GeV per beam.

High flying physics

Cosmic ray physicists have always had to aim high. In the constant search for interactions produced as close as possible to the immensely high primary particles entering the earth's atmosphere from outer space, they have installed experiments on high mountain peaks and flown detectors aloft in balloons.

In these studies, there have been periodic sightings of remarkable configurations of secondary particles. These events, many of which bear exotic names like Centauro, Andromeda, Texas Lone Star, etc., frequently defy explanation in terms of

conventional physics ideas and give a glimpse of what may lie beyond the behaviour seen so far under laboratory conditions.

The 540 GeV collisions at the CERN proton-antiproton collider (equivalent to a 155 TeV proton beam hitting a stationary target) will for the first time provide man-made energies which approach the region where these exotic events might turn up. This search is perhaps second only on the experimental agenda to the quest for the intermediate weak interaction bosons.

But cosmic ray studies continue to produce interesting results. In 1978, the ECHOS experiment began by a France/Japan collaboration using emulsion chambers mounted in the baggage compartment of an Air France Concorde supersonic airliner. This has too produced its exotic event, tamely referred to as JF1af1.

Two emulsion chambers were

packed in the Concorde baggage hold, one being specifically designed for the detailed observation of high energy events. This 35 kg JF1a chamber contained three sections, an upper one with different types of nuclear emulsion plates to enable charge determinations to be made, a central target layer, and an emulsion calorimeter at the bottom. The second Concorde detector was more concerned with measuring particle fluxes.

The exposure was planned to cover 200 hours of level flight some 16 km above sea level, requiring a total of some two months in the aircraft. Because of the high altitude and relatively long exposure, a good crop of high energy interactions was obtained. In particular, the very first flight produced the JF1af1 event, estimated as containing about 150 gamma rays and a total radiated energy of 260 TeV. As well as its