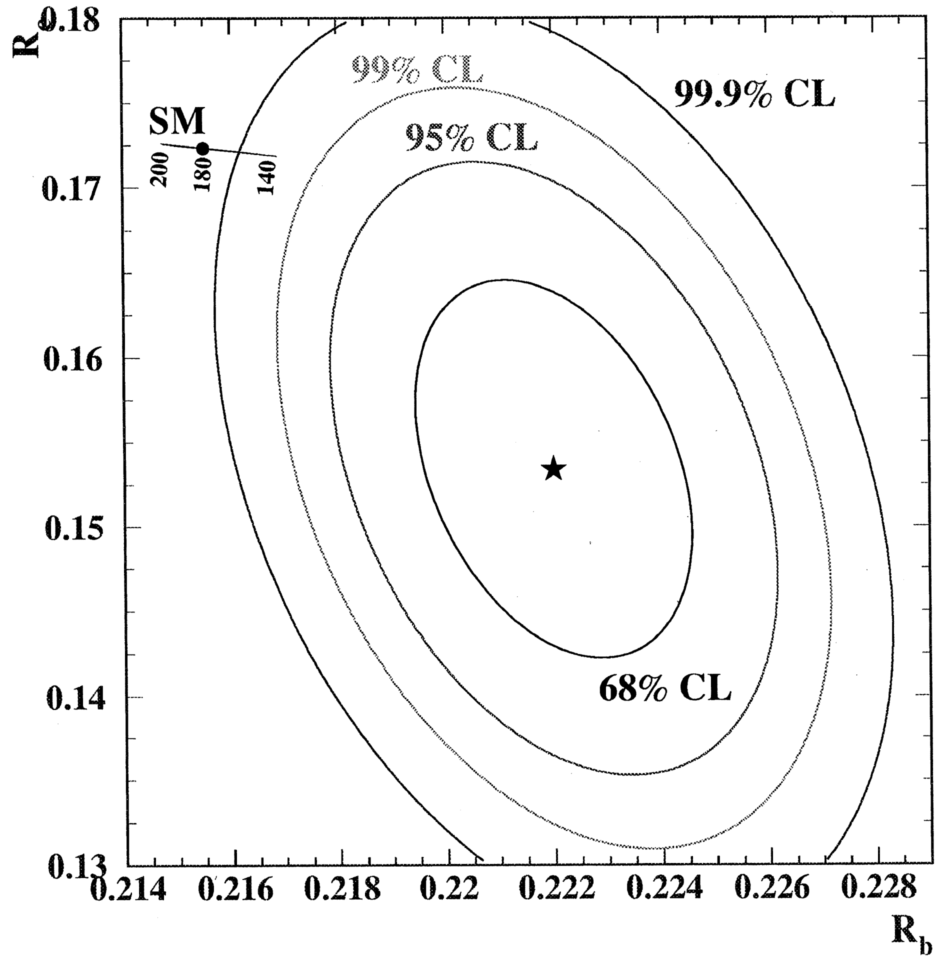
Physics monitor

A chink in the Standard Model? The fraction of Z particles seen decaying into particles containing the fifth ('b') quark (R_b - horizontal axis) and the fourth ('c', or charm) quark (R_c - vertical axis), showing successive statistical levels of confidence contours around the experimental result, compared with the prediction of the Standard Model (SM) for different values of the sixth ('top') quark mass.



SUMMER CONFERENCES
Heavy on flavour

A focus of attention at the major international high energy physics conferences this summer in Brussels and in Beijing was the latest batch of precision information from major experiments at electron-positron colliders - the four big detectors at CERN's LEP storage ring and the SLD experiment at the SLC linear collider at SLAC (Stanford). These experiments study the decay of the Z particle - the electrically neutral carrier of the weak nuclear force - produced when the colliding electron and positron beams are tuned to the Z resonance.

This precision data is a stringent test of the six-quark Standard Model, and as the weight of evidence builds up, physicists look hard for any cracks in the theoretical foundations.

In 1994, the LEP experiments almost doubled their accumulated score of Z particles (an integrated luminosity of 64.5 inverse picobarns in 1994 compared with 93.5 in the previous 4 years). In addition to the increased mass of data, improved precision came from better determinations of key parameters (beam energy, luminosity, electromagnetic coupling strength,....). SLD Z data has more than doubled over the past year. SLC also provides spin oriented (polarized) beams and the machine's polarization level has improved from 63 to 77%. The intercorrelation of the different parameters of the six-quark Standard Model was also boosted this year by the discovery of the sixth ('top') quark at Fermilab's Tevatron proton-antiproton collider (April/May, page 1).

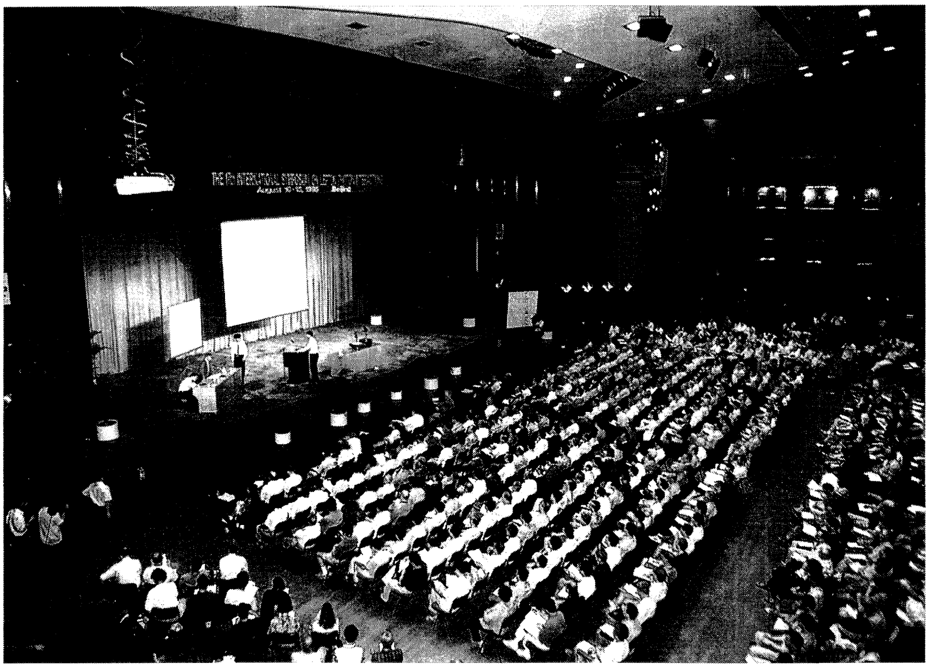
In the electron-positron sector, although the LEP experiments provide the mass of the data, the SLC's polarized beams mean that the delicate asymmetries seen in SLD provide the most precise single measurement of the vital electroweak mixing parameter.

Last year, it was difficult to reconcile these SLD asymmetry results from those from LEP, and some people were whispering about possible nonconformist physics effects, but with a year's additional data, the gap between the two sets of results has narrowed.

To correlate contributions from the different experiments, LEP Working Groups take results from all four - Aleph, Delphi, L3 and Opal - to furnish a useful pan-LEP result.

Precision information comes from analysing the different decay channels of the Z - giving various kinds of lepton pairs and different patterns of quark flavour. In particular the asymmetries of lepton pairs (electrons, muons or taus) or quark-antiquark pairs reflect the interference of different weak effects. In this precision work, the spin orientation (polarization) of the tau lepton provides a useful additional handle.

With the decays of the Z into heavy quarks providing especially useful information, a special working group pulls together results in this sector from the four LEP experiments and



Plenary sessions only - the floor at the International Symposium on Lepton-Photon Interactions, held at Beijing in August.

from SLD at the SLC. The Standard Model predicts exactly the Z decays into different quark-antiquark pairs.

Each of the four LEP experiments has so far seen about half a million examples of Zs decaying into B particles containing the fifth (b) quark. Combining these with results from SLD, the fraction of Z decays into B pairs, compared to decays into all quark flavours, is slightly too high for Standard Model comfort - 22.19% compared with an expected 21.56%. At the current level of LEP/SLC precision, this disagreement of about half a percent is practically a yawning gap. Already some physicists are talking about a possible breakdown of the Standard Model foundations, which have so far remained firm for more than a decade.

One important source of background for the b quark measurement is the fourth quark, charm (c). Particles containing c quarks can sometimes be misidentified, and this has to be taken into account. Overall, the fraction of Z decays into charm quarks is slightly on the low side, but if the Standard Model predicted value is used instead of the experimental result, the world-average b quark fraction comes down to 22.05%. The gap between theory and experiment is still uncomfortably large, but some people point to the inter-quark coupling strength lurking in the background and which could affect the interpretation of the data. At Beijing, Kaoru Hagiwara of the Japanese KEK Laboratory suggested how this could be done.

In his summary talk at Brussels, Don Perkins drew attention to this b quark disagreement, recalling a 1973 remark by Richard Feynman '....when everything is so neatly wrapped up....., with all experiments in exact agreement with each other and with the theory - .... one is learning absolutely nothing! On the other hand, when experiments are in hopeless conflict - or when the observations do not make sense according to conventional ideas, or when none of the new models seems to work, ... - ... one is really making progress and a breakthrough is just around the corner!'.

The top quark mass measurements from the CDF and D0 Tevatron experiments now provide important additional Standard Model constraints. After the long wait for its discovery, top quark physics is now underway in earnest. With precision results in several other sectors, the remaining room to maneuver is cramped, with implications for LEP2 - the push to increase the collision energy at LEP (September, page 6).

However the extension of the Standard Model to include supersymmetry is now almost discounted. Supersymmetry has twice the number of particles, with sleptons and squarks supplementing the standard fare of leptons and quarks (see next story). At Beijing, John Ellis looked forward to forthcoming Lepton-Photon Symposia becoming Slepton-Photino meetings!

Still missing completely from the experimental picture is any hint on the mass of the long awaited 'higgs' particle, the source of electroweak symmetry breaking and responsible for particle masses.

Although these effects have not yet been seen directly, they are nevertheless playing a role in the underlying quantum mechanisms, where they contribute transiently with 'borrowed' energy (April/May, page 10).

The implications of the accumulated Standard Model evidence (including electron-positron, proton-antiproton and neutrino data) for the higgs are still fuzzy. Nevertheless, the emerging picture suggests that higgs effects could easily set in below the scale of a few hundred GeV, with implications for LEP2.

Another natural focus of attention is

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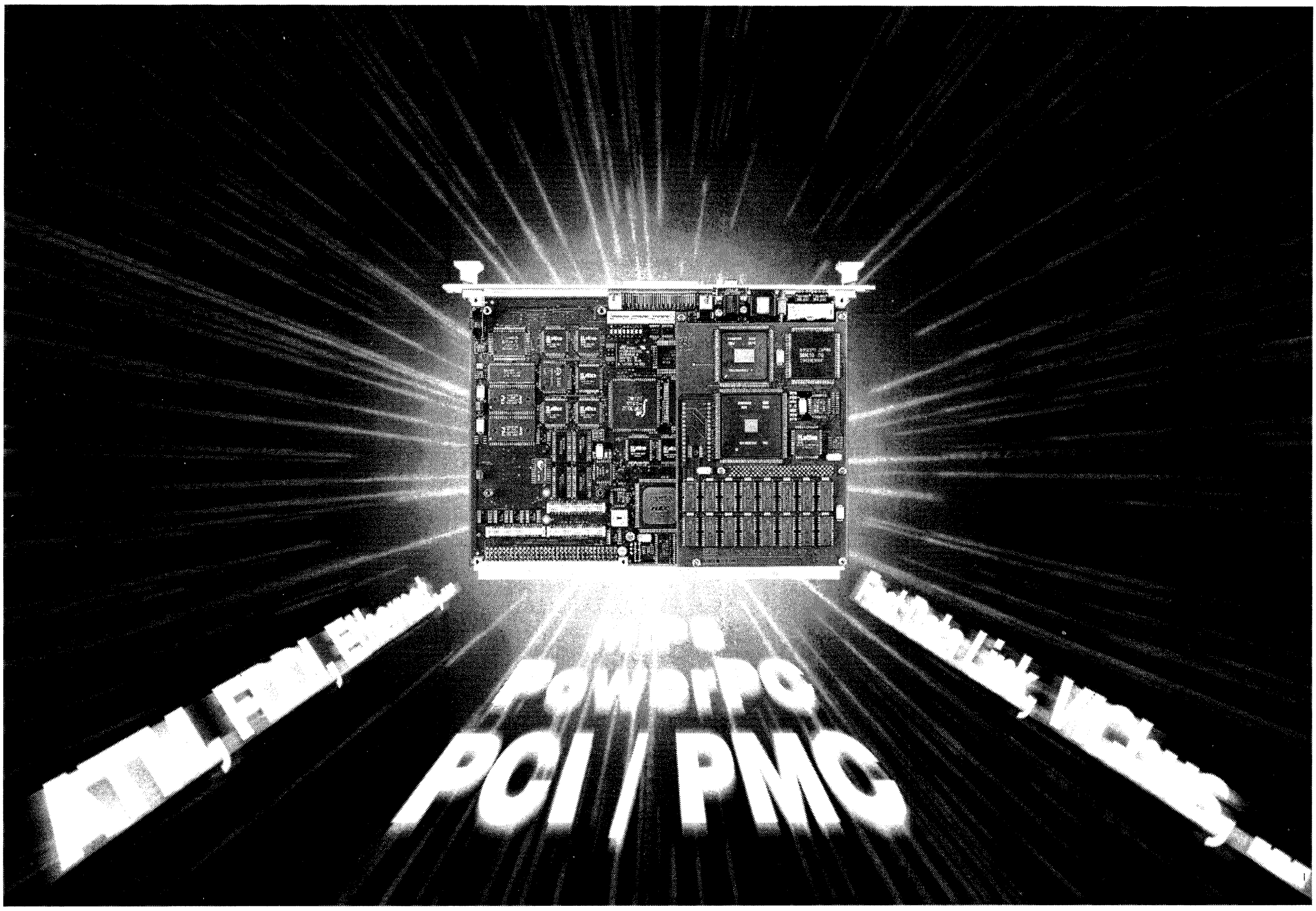

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CREATIVE ELEC

the results continuing to emerge from the HERA electron-proton collider at DESY, Hamburg, where the Zeus and H1 experiments look deep inside the proton, showing that its gluon content increases as the momentum fraction decreases. With a large kinematical range now covered, these results correlate well with data from fixed target experiments.

The two HERA experiments continue to see 'rapidity gaps', where events pile up in kinematical bands. Many people have understood this in terms of the incoming electron bouncing off a proton constituent in a 'colourless' way ('colour' is for the quark-gluon force what electric charge is for the electromagnetic force). Recently on the market is a new idea explaining rapidity gaps with a full-colour quark-gluon mechanism.

Also for proton structure, the enigmatic spin content of proton constituents is underlined in additional data from experiments at SLAC and at CERN (July 1994, page 19).

The neutrino sector is difficult to summarize, as invariably somewhere a result refuses to conform. The muon-neutrino content from cosmic ray interactions in the atmosphere is still significantly less than expected. This year has also seen much controversy in the continuing search for neutrino oscillations (June, page 13). Klaus Winter attempted to paint a tidy picture at Beijing and looked forward to new results.

Heavy quark effective theory, where heavy quarks are assumed to be infinitely heavier than the lighter ones, is now a useful calculation tool, getting answers right to within ten per cent.

Summarizing the physics scene at Beijing, Sam Ting enumerated the results coming in and compared them with the declared objectives of the world's major Laboratories. T.D. Lee drew attention to the need for future studies to understand CP violation - the delicate asymmetry between matter and antimatter.

Information from Klaus Mönig and Clara Matteuzzi

Spotlight on quantum black holes

Particle theorists are getting unusually excited these days as new ideas and different approaches converge in the search for a picture which describes all the underlying mechanisms of Nature.

Although the final picture has yet to emerge, the outline is becoming clearer. While the intellectual mountain range to be crossed was once intimidating, these new developments are beginning to point to a way over.

A series of recent topical workshops have highlighted these developments and leap-frogged ahead - including String 95 at the University of Southern California, Los Angeles, this spring and a conference on Mirror Symmetry and S-duality held in June at Trieste's International Centre for Theoretical Physics. Closing the Trieste meeting, prominent theorist Ed Witten said "this is one of the most exciting conferences in which I have ever participated".

With profound problems to be overcome, the new ideas now on the market at first look very unconventional. Classical electromagnetism exploits the parallels between electricity and magnetism but accepts the everyday wisdom that free magnetic charges (magnetic monopoles) do not exist. Particle theorists are not so sure, and for a long time magnetic monopoles have been tentatively included on the theoretical menu. The role of these monopoles has now become crucial.

Also playing a central role is the idea of supersymmetry. In a quantum theory, basic particles, like quarks and leptons (fermions), interact through force-carrying particles (bosons) like the photon of electromagnetism, the W and Z of the weak nuclear force and the gluon of the strong inter-quark force. In supersymmetry, each fermion has additional boson partners, and vice versa.

So far, no evidence for supersymmetry has been found, but the underlying ideas are so convincing that its existence is almost taken for granted among theorists. Supersymmetry would have governed the mechanics of the Big Bang, but as the temperature fell, supersymmetry 'froze' out and became almost invisible.

In the late 1970s, Klaus Montonen and David Olive pointed out that if magnetic monopoles are included in a supersymmetric quantum picture, the electric and magnetic sectors are in some respects mutually complementary. Magnetic charges provide additional calculational leverage, sidestepping the traditional problem of having to solve the equations of the theory through sometimes unsatisfactory approximations.

Subsequently, the ideas were enlarged to include 'dyons' - particles having both electric and magnetic charges, providing a much richer scenario.

Theories with sufficient numbers of supersymmetric particles can provide an appealing correspondence ('duality') between different sectors of the