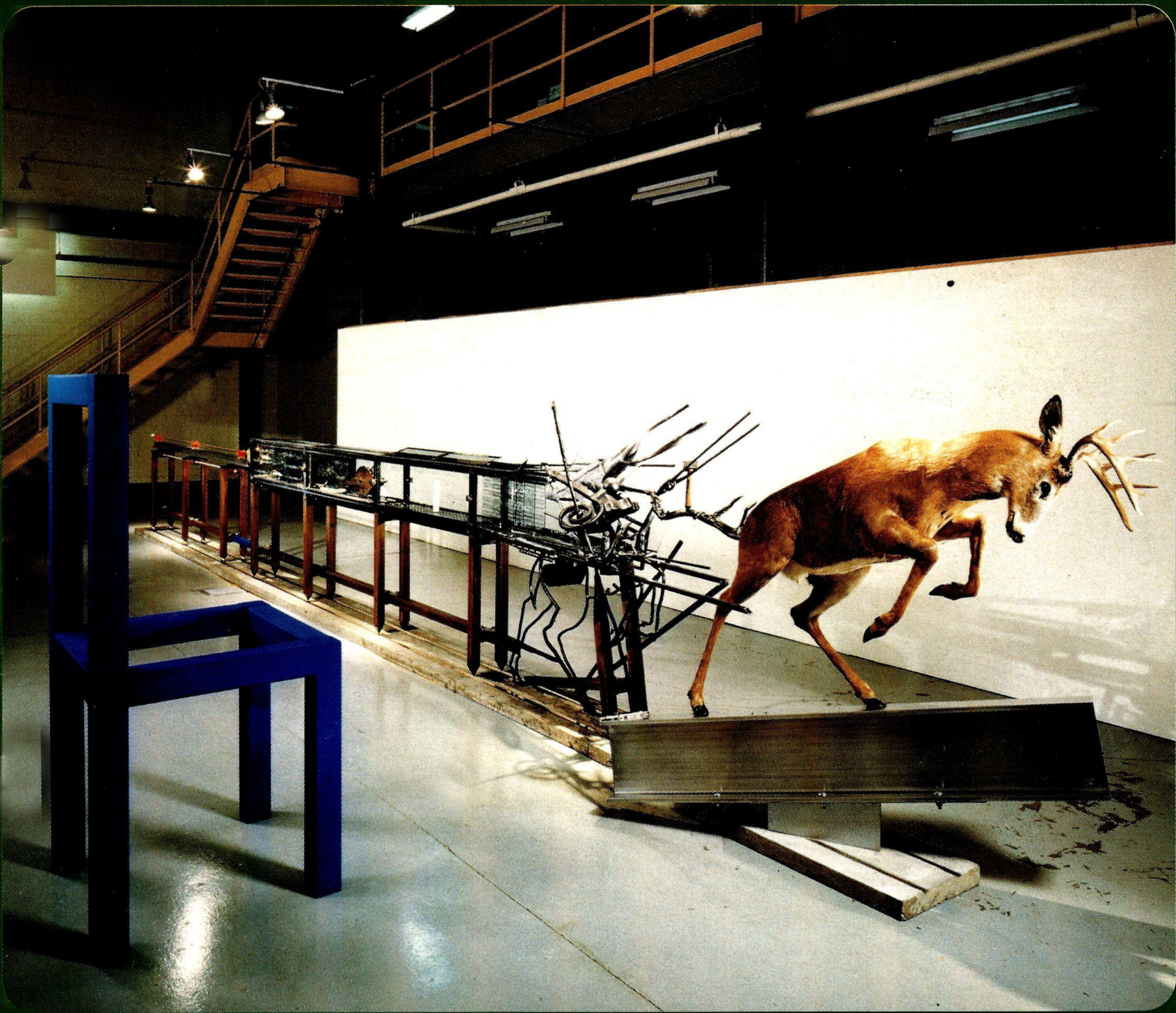
CERN COURIER

International Journal of High Energy Physics



VOLUME 29 9 NOVEMBER 1989

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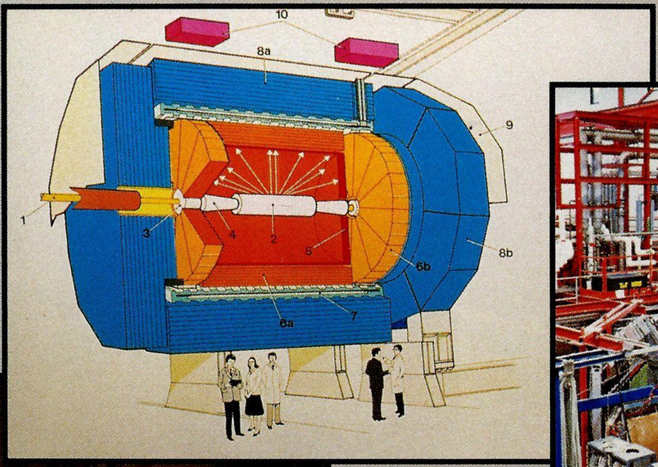

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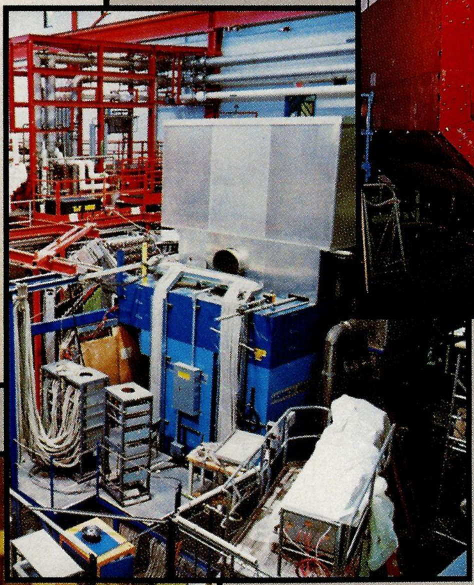

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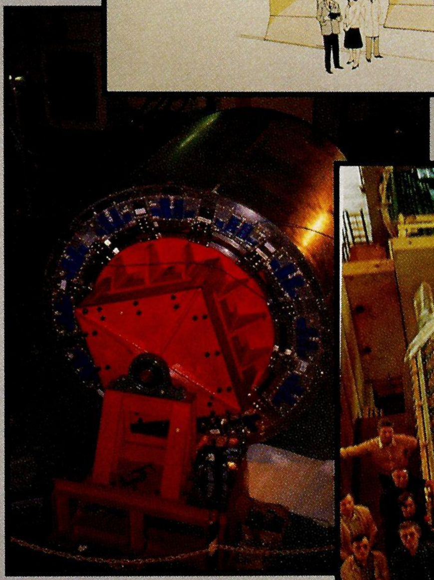

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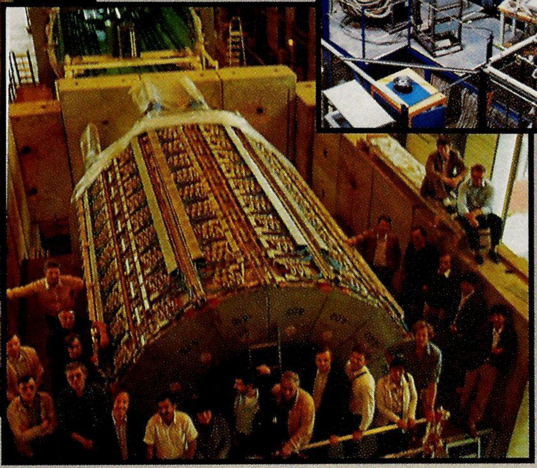

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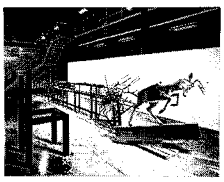
Around the Laboratories

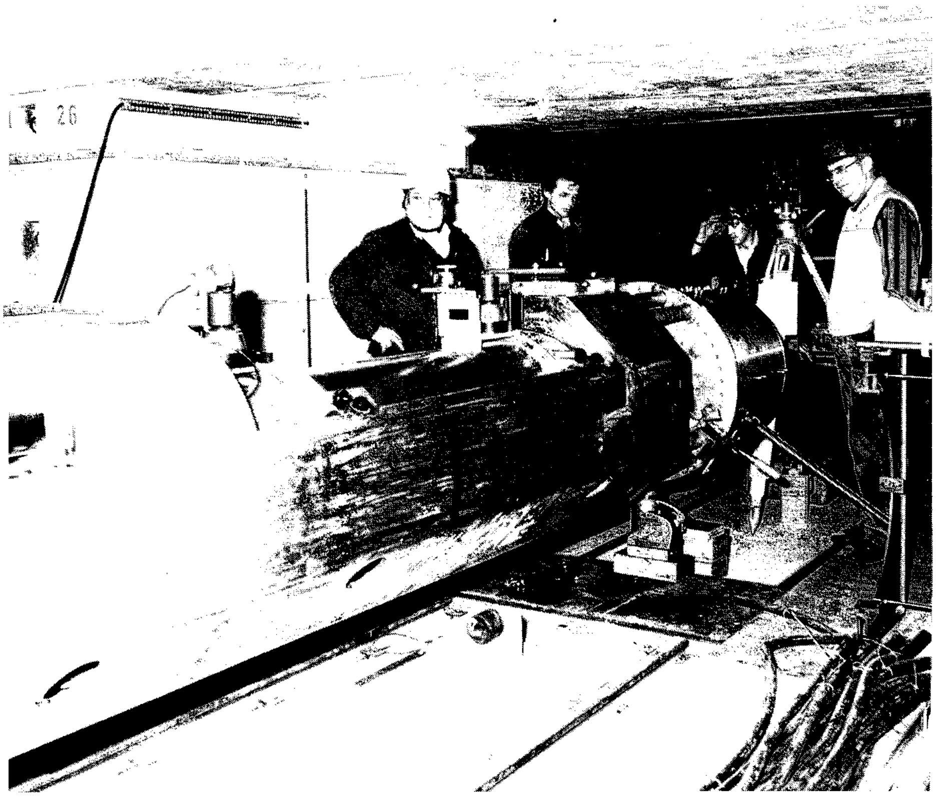


Cover photograph:
The Standard Model (Abandoned) by US artist Stephen Rueckert was recently on show at Brookhaven. The sculpture, inspired by linear accelerators, depicts some of the basic ideas of physics and explores the process of creation in particle collisions. The chair on the left denotes the observer (Photo Sheldan Collins).

Around the Laboratories

One of the superconducting ('low-beta') quadrupole magnets used to compress LEP's beams and boost the collision rate.

(Photo CERN 393.3.89)



CERN
EP progress

After the valuable pilot physics run in August (September, page 1) the four big experiments – L3, Aleph, Opal and Delphi – at CERN's new LEP machine got back to work with 45.5 GeV colliding electron and positron beams towards the end of September.

Machine commissioning work earlier in the month had seen good performances, with single beam intensities reaching 1.95 mA. A period of colliding beams for physics followed, and after a few false starts, a good performance came around the weekend of 23-24 September, with 40 hours of stable 45.5 GeV beams and healthy collision rates.

During the subsequent machine development session good results came from a radiofrequency longitudinal feedback system, designed to eliminate unexplained coupled bunch instabilities, with a record 3.8 milliamps of total stored current (2.2 mA of positrons with feedback, 1.6 mA of electrons without). The experiments then took over again for sweeps across the Z energy range. With healthy beams and good running conditions, the four detectors saw more than ten thousand Z particles, the electrically neutral carriers of the weak nuclear force.*

The superconducting low-beta quadrupoles to squeeze the beams and boost collision rates in the experimental areas came into action for the first time.

The strong horizontal-vertical coupling which had been dogging LEP since switch-on in July was compensated by running the machine with non-standard horizontal-vertical tuning ('tune split'), and by using skew quadrupoles originally installed to help compensate for the effect of the experiments' solenoids.

During a scheduled shutdown in October, the LEP team embarked on a crash programme to install an additional 16 skew quadrupoles, two in each of the machine's eight arcs, however this is seen as a temporary solution, as a more evenly distributed compensation system would be better suited to the LEP goal of handling polarized (spin-oriented) beams.

The coupling is attributed partly to a thin layer of nickel used in the fabrication of the vacuum chambers to bond layers of lead and aluminium. Asymmetries due to the earth's magnetic field and to current distributions could also play a role.

Initial physics results from LEP, including the Z mass and limits on the number of neutrino types, were announced on 13 October. More news next month.

STANFORD
Z update

With another hundred examples of the Z particle, the electrically neutral carrier of the weak nuclear force, logged through the end of August, the Mark II collaboration studying electron-positron collisions at the SLC Stanford Linear Collider could update their Z results (September, page 12 and October, page 1) for the European Physical Society meeting, held from 6-13 September in Madrid. The enlarged data sample gave a fresh limit on the possible kinds of light neutrinos (September, page 6).

The Stanford Linear Accelerator Center emerged largely unscathed from the earthquake of 24 October. More news next month.

Realignment of the masks inside the Mark II detector during early August led to lower backgrounds and higher luminosity (a measure of the collision rate) for the SLC. Late that month a peak luminosity of 2 x 10^{28} per sq cm per s was achieved, corresponding to about 2 Zs per hour. Running under these improved conditions at a total energy of 91.4 GeV, the Mark II physicists raised their total Z score to nearly 350 by month's end.

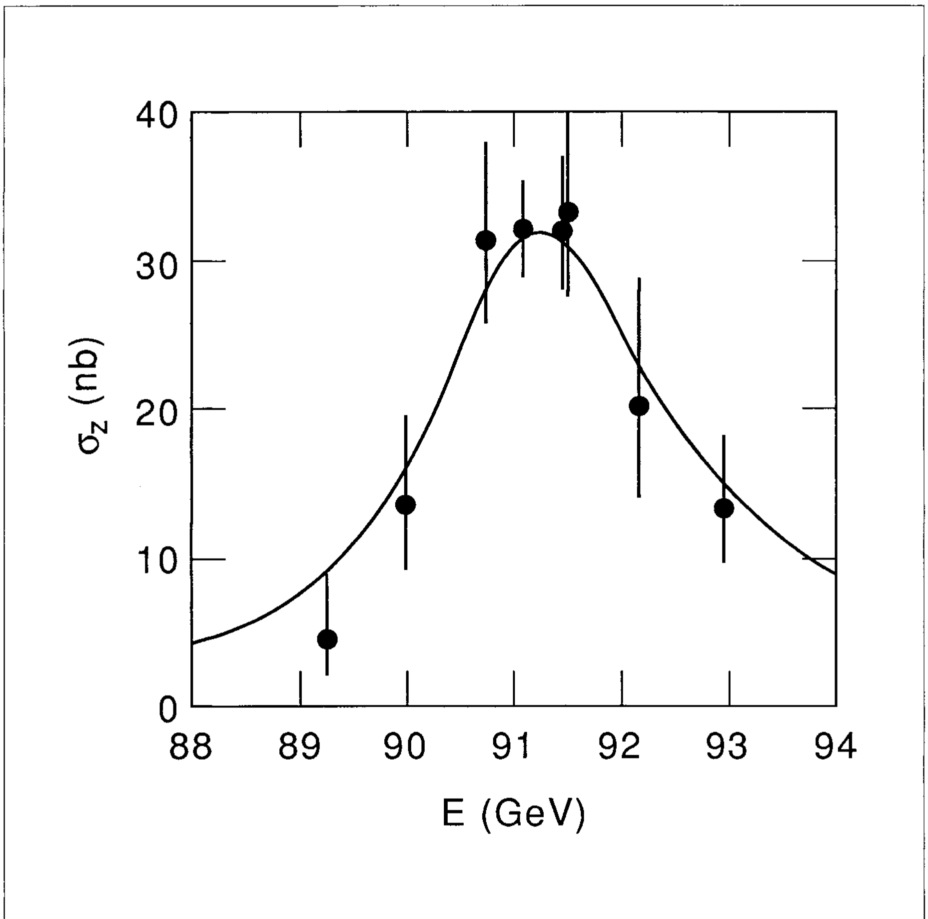
Based on a subset of 332 events presented at Madrid, the Mark II team put the Z mass at 91.17 ± 0.17 GeV, tightening up slightly on what was presented a month earlier at the Stanford Lepton-Photon Symposium (October, page 1). The width of the Z peak came in about the same as before, 1.9 +0.4 −0.3 GeV, consistent with but a little below the expected 2.5 GeV for three 'generations' of quarks and leptons.

The real news came under the heading of light neutrinos – the wraith particles which usually pass right through a detector, leaving no trace. Additional kinds of neutrinos give the Z extra ways to break up (into a neutrino and its antiparticle) that cannot be picked up by a detector. Assuming conventional theory (the Standard Model) to be correct, additional light neutrinos beyond the three kinds already known (electron-, muon-, and tau-types) should therefore decrease the **visible** Z production rate (cross-section), which is what physicists actually determine in electron-positron collisions.

By accurately measuring the **height** of the Z peak, rather than its width, the Mark II physicists were able to place the most stringent limits yet announced on the possible number of light neutrino species. The cross-section at the top of the peak came in at 32-33 nanobarns, corresponding to 2.7 ± 0.7 different kinds of neutrinos. This means that the likelihood of a fourth light neutrino and a fourth generation of quarks and leptons is now less than five per cent.

On other fronts, the hadronic decays of the Z were behaving very much in accordance with the dictates of quantum chromodynamics (QCD – the candidate theory of inter-quark forces). Event behaviour (sphericity, aplanarity, multiplicity and thrust) fits extremely well with simulation calculations. And an apparent excess of Z decays into tau leptons – noted a month earlier at the Stanford conference – had begun to evaporate under the hot August sun.

Finally, the collaboration searched for signs of as-yet-unseen particles like the elusive sixth ('top') quark, a fourth generation b' quark, or a neutral heavy lepton. If they had masses less than half that of the Z, such particles would be easily detectable through their unusual decay topologies. With nothing of the kind turning up, the Mark II physicists were able to rule them out below 40 GeV. Particularly cogent were the limits on a b' quark, excluded up to a mass of 45 GeV.



The production rate (cross-section) of Z particles in electron-positron collisions as seen by the Mark II team working at the SLC Stanford Linear Collider. The curve drawn through the data points corresponds to the Standard Model with three light neutrinos.

DESY
HERA Progress

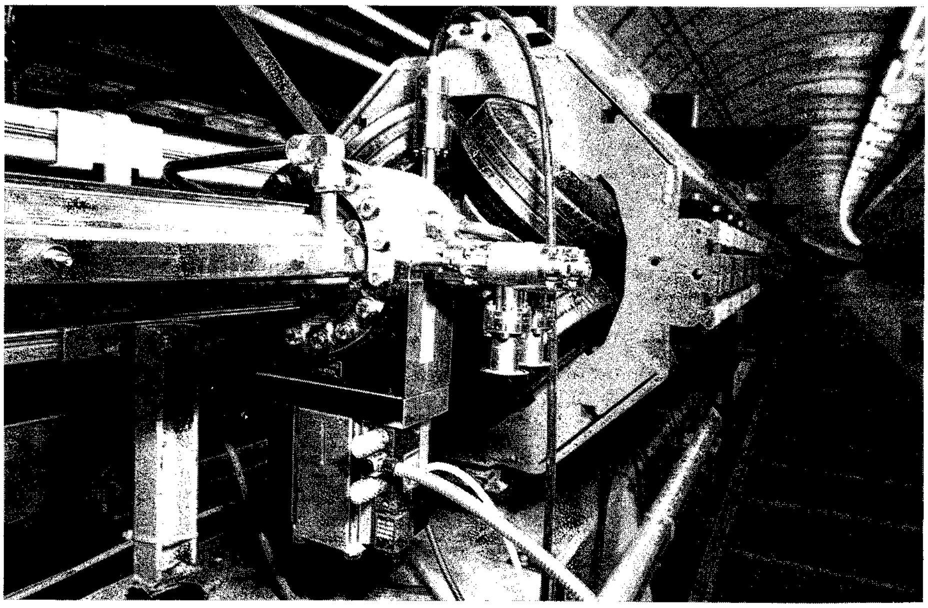
September was a milestone month for the team testing the electron storage ring for the HERA electron-proton collider at the German DESY Laboratory in Hamburg. As flashed in the October issue (page 21), electrons were accelerated up to the highest energy allowed by the complete system of normal conducting radiofrequency accelerating cavities presently installed (6 transmitters with a total power of 8 MW).

After reaching 26.4 GeV on 17 September, the beam energy was inched up to 27.5 GeV a few days later, very close to the 'zero-current limit', without any particle losses or other problems. Surely a good omen.

Single bunch currents were up to 2.49 mA, corresponding to 3.1 10^{11} particles – nine times the design value. 20 bunches gave a total stored current of 2.5 mA. Some vertical instabilities did not limit the average stored current. Mean beam lifetime was about five hours and orbit corrections fixed the beam position to within less than 2.5 mm.

7 GeV electrons, provided by the DESY II synchrotron fed by the 200 MeV linear accelerator LINAC I, were accelerated in 20 bunches to 13 GeV in the PETRA ring. These 20 bunches could be sent to HERA in a string or accumulated in one bucket to form a single bunch.

The radiofrequency system of the HERA electron ring was completed for the test run, as were the beam position monitor system, the orbit correction programmes and the controls for all magnet power supplies.

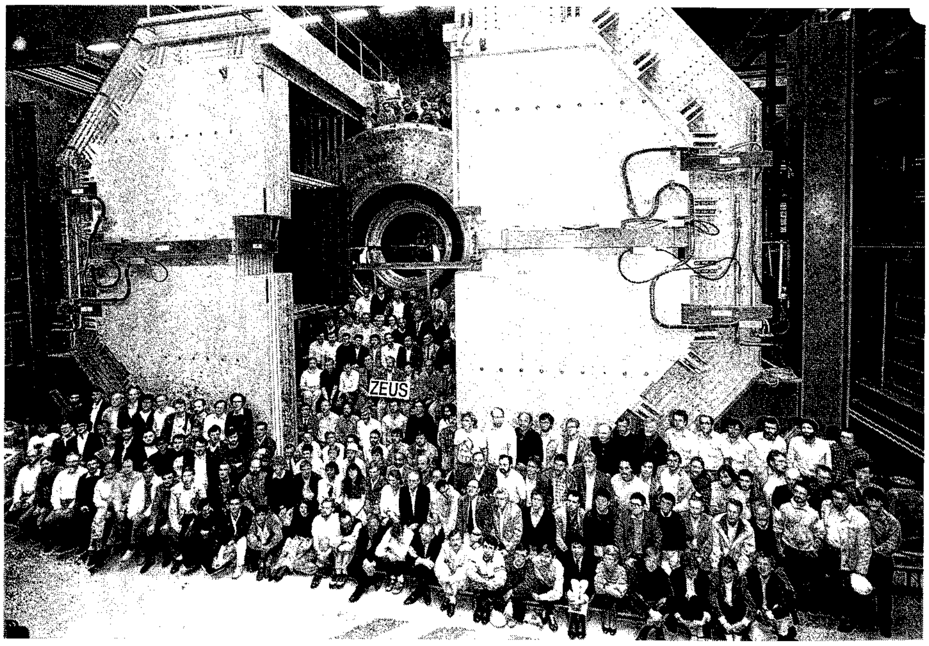


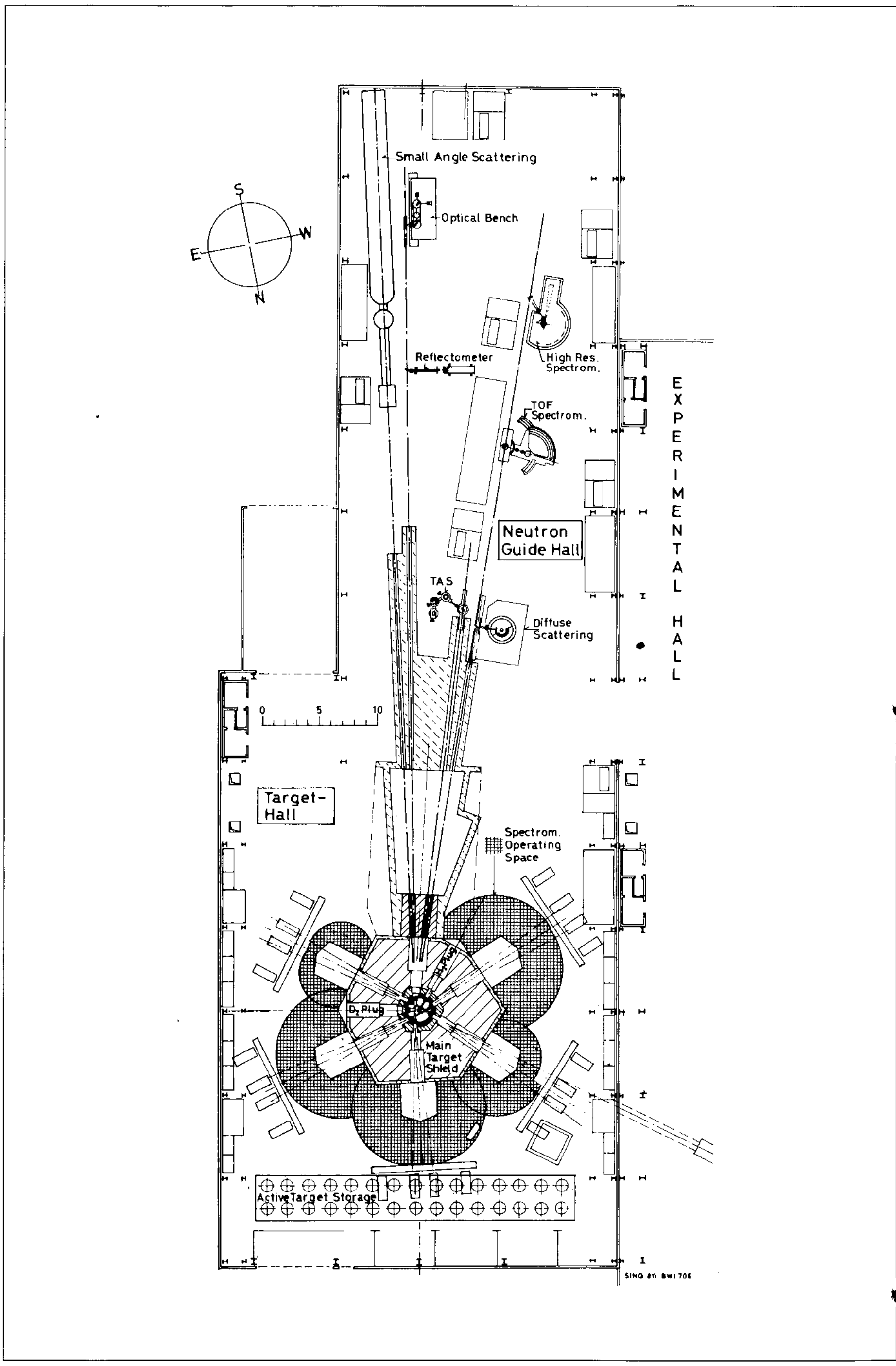
A multibunch programme to reach the design current of 58 mA with 210 bunches requires a yet-to-be-implemented broad-band transverse and longitudinal feedback system, and several improvements in the electron injector chain.

Superconducting radiofrequency cavities and their cryostats are now arriving for assembly and testing.

▲ *The electron ring of the HERA electron-proton collider being prepared at the German DESY Laboratory in Hamburg – up to 27.5 GeV.*

▼ *The two HERA experiments – H1 and Zeus – continue to make steady progress. Here the Zeus team pose in front of their detector. Late in September, the thin superconducting coil, 1.7 m in diameter, to surround the inner tracking chambers reached its design field of 1.8 Tesla.*





Proposed layout of the SINQ spallation neutron source now under construction at the Swiss Paul Scherrer Institute, showing the range of initial instrumentation.

The eight cryostats, each with eight cells, should be ready for installation next March 1990 for HERA electrons to be accelerated and stored up to 33 GeV, ready for tests on beam polarization.

However no further electron ring operation is scheduled for the next twelve months, all efforts now concentrating on installation of HERA's superconducting proton ring. All quadrupole magnets have arrived, and the rate of dipole supply indicates that the final magnet should be in the tunnel next November.

Meanwhile preparations for the two HERA experiments push ahead. The 6 m-diameter superconducting coil for H1 made at the UK Rutherford Appleton Laboratory has been installed in its iron yoke and successfully cooled down. It reached its design current of 5500 A and the 1.2 Tesla field was carefully measured by a UK group. The smaller coil for Zeus has reached its design field of 1.8 Tesla with 5000 A.

PSI
Spallation neutron source

The cyclotron complex at the Swiss Paul Scherrer Institute (PSI – formerly known as SIN), delivering 200 – 250 microamp proton beams at 590 MeV for a range of physics research, is being upgraded to supply currents eventually above a milliamp (May, page 19).

Following this upgrade, residual proton current will be used for a spallation neutron source, SINQ, for which construction got underway last year. As well as providing Swiss scientists with a new medium-flux neutron source for fundamental and applied research from 1994, it will enable the technology of spallation sources to explore new possibilities en route to the next generation of intense neutron sources.

With the PSI cyclotron delivering a quasi-continuous proton beam, SINQ will be a continuous neutron source, using a liquid lead-bismuth production target bombarded with protons vertically from below, and a large heavy water moderator.

While the resultant high energy particle flux means that the moderator has to be surrounded with several metres of iron and concrete shielding, the low gamma radiation level enables cold neutron sources to be placed in the optimum position inside the moderator.

SINQ is planned exclusively for neutron scattering use, with the emphasis on cold neutrons supplied through four guide-tubes to an experimental hall, with an additional ten beam tubes in the target hall, together serving a comprehensive range of initial instrumentation.

This year's Prizes for Achievement in Accelerator Physics and Technology were awarded to Karl Brown of SLAC and Daniel Birx of Science Research Laboratory during the US Particle Accelerator School held at Brookhaven. From left, USPAS Director Mel Month; Brown; James Leiss, who presented the awards to the winners; Birx; and Brookhaven Deputy Director Marty Blume.

US PARTICLE ACCELERATOR SCHOOL
Summer schools

Continuing it's educational efforts, the US Particle Accelerator School (USPAS) held two summer schools this year. The USPAS has two basic purposes – education in accelerator physics and technology, in particular to train apprentices and update experts; and to encourage US universities and Laboratories to offer programmes in accelerator physics by developing textbooks, training faculty, and organizing schools.

The first of this year's summer schools was a two-week university-style course held at the University of California at Berkeley. These university-style schools aim to present courses in greater depth, to promote student-teacher interaction, and to encourage the attendance of younger students, as university credit can be earned.

Emphasizing the importance of university education in particle accelerators, Mel Month, Director and Founder of the USPAS said, 'As graduate students, physicists are taught at the university how to build detectors or portions of large detectors – but their only real opportunity to learn how to build an accelerator or any of its parts has been at accelerator Laboratories after they graduate. This just won't do. In the future, we must find new ways for students to study particle accelerators in the university.'

The Berkeley course in June was the most successful university-style school to date. Over half of the 140 registered students will receive up to 3 university credit hours. Courses included: theory and design of particle beams, introduction to accelerator physics, introduction to free electron lasers, principles of acceleration, and introduction to beam instabilities.

The second of this year's summer schools was held from July 24 – August 4 at Brookhaven. Symposium-style, concentrating on lectures, it covered a wide range of subjects, including particle beam fundamentals, intense beams, accelerator technology, instabilities, nonlinear dynamics, high luminosity colliders, and linear colliders, with an afternoon devoted to the new US Superconducting Supercollider (SSC) project.

In addition, this year's Prizes for Achievement in Accelerator Physics and Technology went to Daniel Birx of Science Research Laboratory of California, and Karl Brown, of Stanford Linear Accelerator Center (SLAC), at a ceremony at Brookhaven. These awards were initiated in 1985 and are an annual feature of the US Particle Accelerator School.

Daniel L. Birx was cited 'for developments in high power magnetic switching technology with applications such as high repetition rate induction linacs, free electron lasers and laser isotope separation'. His important work has impacted a number of prominent US national projects – high power free electron lasers (FEL) for defence applications, FELs for heating fusion plasmas (the MTX experiment at Livermore), high average power gas lasers, and the development of high power 'relativistic klystrons' in a collaborative effort involving SLAC, Berkeley and Livermore. These microwave source developments may be an important step towards future high gradient linear colliders for physics.

Karl L. Brown was honoured 'for insights into particle beam transport and for introducing formalisms in use throughout the world.' He has pioneered both the development and application of concepts of charged particle optics. His contributions have helped make possible new sophisticated designs in the latest generation of electron-positron colliders.

This year's Accelerator School Prize Committee consisted of J.E. Leiss, W.K.H. Panofsky, R.H. Siemann, and S. van der Meer and the awards were supported by Universities Research Association, the Continuous Electron Beam Accelerator Facility, SURA, Intermagnetics General Corporation, Varian Vacuum Products, and the Westinghouse Electric Company.

The US Particle Accelerator School is sponsored by the US Department of Energy and National Science Foundation, and by major Laboratories.

RADIOFREQUENCY SUPER-CONDUCTIVITY Workshop

Superconducting radiofrequency is already playing an important role in he beam acceleration system for the TRISTAN electron-positron collider at the Japanese KEK Laboratory and new such systems are being prepared for other major machines. Thus the fourth Workshop on Radiofrequency (r.f) Superconductivity, organized by KEK under the chairmanship of local specialist Yuzo Kojima and held just before the International Conference on High Energy Accelerators (see page 10), had much progress to review and even more to look forward to.

As well as TRISTAN, where 16 five-cell 500 MHz superconducting cavities have operated for more than 5000 hours (see photograph on page 13) and where 16 additional cavities are already installed to take beam energies towards 33 GeV, the new LEP electron-positron collider in operation at CERN and the HERA electron-proton collider being built at the German DESY Laboratory in Hamburg are both scheduled to benefit from superconducting r.f.

For HERA, sixteen four-cell cavities have been ordered following successful beam tests of a prototype module (January/February 1988, page 15), while at CERN, following excellent long-term performance (more than 8000 hours) of a LEP-type cavity at the SPS ring (November 1988, page 15), four superconducting cavities are being prepared for LEP and orders for 20 more niobium cavities have been placed.

Plans for the large fully superconducting CEBAF recirculating linac to be built at Newport News, US, are well advanced. The number of recirculations has been increased from 4 to 5 and 360 five-cell 1500 MHz cavities are being ordered.

The recirculating Darmstadt linac (September 1987, page 34) is steadily being upgraded. It is routinely used for nuclear physics studies, and plans for the addition of a free electron laser are advancing. The venerable Stanford (HEPL) superconducting recirculating linac is now mainly used for free electron laser physics. Plans for superconducting linacs are being worked out also at Saclay (France) and Frascati (Italy).

Although niobium sheets are still the preferred cavity material, great progress has been made in recent years, especially at CERN, in niobium-coated copper cavities. Their high quality factors at 4.2K (more than 10^{10}) and their insensitivity to thermal breakdowns make them promising candidates for future applications. At CERN, construction of an initial set of eight such cavities is advancing well.

In the field of superconducting heavy ion accelerators, more than ten projects are operational or near completion, and an impressive accumulation of operating experience has proved the reliability and flexibility of the technique. Developments and improvements include new types of cavity for use with bright proton and deuteron beams at higher velocities, while for slower particles, Argonne has shown that heavy ions leaving a high-voltage platform can be directly accelerated by a superconducting cavity.

Higher accelerating fields are needed for future linear colliders and would also be useful for high intensity particle 'factories'. Ongoing work looks at the limitations posed by field emission loading. Using high quality niobium and special surface treatments (such as high temperature annealing and helium processing) accelerating fields of the order of 25 MV/m have been reached almost routinely in monocell 1.5 and 3 GHz cavities at Cornell and Wuppertal. As well as improved performance, cost reduction is another major goal en route to increased applicability.

Superconducting r.f. specialists are also helping to develop the new high temperature superconducting materials. Many new or improved deposition methods for thin layers have been applied, such as electrophoretic depositions, epitaxial growth, plasma spraying and magnetron sputtering, sometimes using strong magnetic fields.

Progress towards lower r.f. losses and the quest for higher magnetic fields open the way for small passive r.f. devices such as filters or antennae.

R.f. probes have proved to be a diagnostic boon, enabling 'bulk' properties of thin layers to be measured, avoiding the percolative nature of d.c. measurements.

With an ever-increasing number of superconducting cavities, more investigation of large cryogenic systems at 4.2 and 2K and of non-bath cooling methods are required.

The meeting displayed the dynamism of the r.f. superconducting community. Despite impressive progress since the previous such workshop, a large range of performance parameters and materials remains to be explored. (See also following story.)

From Herbert Lengeler

RADIOFREQUENCY SUPER-CONDUCTIVITY At Cornell

Superconducting niobium accelerator structures are now operating in electron storage rings at 5 – 10 MeV/m accelerating gradients (November 1988, page 39). However with the theoretical capability of niobium as high as 50 MeV/m, set by the critical magnetic field for superconducting breakdown, there is much room for improvement.

Research on radiofrequency superconductivity continues at Cornell to understand the limitations, and to push niobium cavity performance higher. Successes will open the door to new accelerators for B-factories and for big superconducting linear colliders, as well as boosting projects currently in the pipeline (such as CEBAF).

One major obstacle to higher gradients is heavy field emission from spots on the niobium surface when surface electric fields exceed 20 MV/m, corresponding to 10 MeV/m accelerating field. Ensuing electron currents heat up the cavity wall.

Improved surface treatments have been developed, including heating in an ultra-high vacuum furnace between 1200 and 1350 C. Over a dozen tests on several single-cell 1.5 GHz cavities averaged 40 MV/m, double the figure for similar test cavities prepared by conventional techniques. The best result was 53 MV/m. Heat treatment reduced both the number and strength of emission sites.

With the highest-ever surface field in a niobium cavity being 70 MV/m, physicists were eager to know whether surface electric fields of 100 MV/m, approaching the theoretical magnetic field limit, could be tolerated.

To explore this, a non-accelerating cavity has been developed with a very high electric field in a small area (0.5 sq cm), and low fields elsewhere. This cavity attained 145 MV/m, encouraging further efforts to push higher.

Japan Accelerator Conference

At the international level, the high energy accelerator scene evolves rapidly and the International Conference on High Energy Accelerators is where its strong pulse can best be felt.

This year, the Conference was held for the first time in Japan, with the 14th meeting in the series having been hosted in August by the Japanese KEK National Laboratory for High Energy Physics, Tsukuba. The venue was a recognition of the premier accelerator physics and technology status achieved by this diligent nation.

The KEK Laboratory entered the field comparatively late with the construction of the 12 GeV proton synchrotron starting in 1971. KEK's booster synchrotron for the 12 GeV machine feeds also a pulsed spallation neutron source, a meson Laboratory, and a medical science centre. Pride of place is taken by the 30 GeV per beam TRISTAN electron-positron collider which became operational three years ago as the then world's highest energy machine of its type. Its electron-positron source, a 2.5 GeV linac, also feeds the 'Photon Factory', a synchrotron radiation centre used by over 1500 scientists.

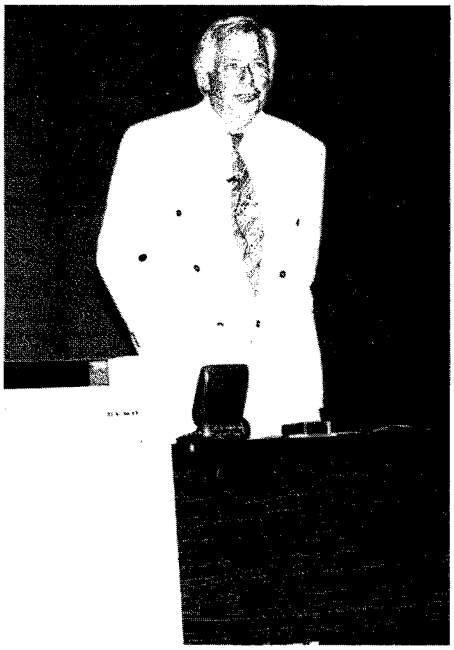
Future plans include the Japanese Hadron Project (July/August 1987, page 5), to include a 1 GeV proton linac, a compressor/stretcher ring and a heavy-ion linac, together supplying a wide range of beams (muons, pions, spallation neutrons and exotic nuclei). Replacing the present 500 MeV booster by the 1 GeV proton linac will improve substantially beam intensity and quality from the 12 GeV proton synchrotron.

KEK is famed for the excellence of its engineering, and in some sectors spearheads world accelerator technology. It is the world's largest-scale user of superconducting radiofrequency cavities, in the TRISTAN beam acceleration system, and is presently a front runner, in terms of a developed design and related research, among the Laboratories working on the new generation of electron-positron linear colliders.

To these accomplishments was added an impressive demonstration of organizing a big multinational meeting, all in an atmosphere of courteous yet warm hospitality.

The International Conference on High Energy Accelerators this year was held in Japan for the first time. Hosted by the KEK Laboratory, not yet twenty years old, the meeting reflected the great advances made by Japanese accelerator physics and technology.

Gunther Plass – progress report on the commissioning of CERN's new LEP electron-positron collider.



Electron and positron machines

News of the commissioning of CERN's new LEP electron-positron collider came in the opening talk by Gunther Plass. This was a poignant moment for the Japanese hosts because it signalled that the TRISTAN machine was no longer the world's highest energy electron-positron storage ring (Stanford's SLC collider also goes to higher energies but is not a conventional storage ring). In an opening address, former KEK director Tetsui Nishikawa paid tribute to CERN's impressive performance in building and commissioning such a large and complicated machine so quickly.

The initial major problem in LEP was a strong horizontal-vertical coupling, and initial efforts concentrated on changing the horizontal tune of the machine to minimize the effect (see page 1).

While LEP's immediate aim is to move towards its designed operating parameters, longer term goals include using the 'pretzel' scheme developed at Cornell to boost the collision rate. The progressive introduction of superconducting accelerating cavities will push the energy eventually above 90 GeV per beam. (The development at CERN of superconducting cavities using a micron layer of niobium sputtered onto copper, rather than the conventional solid niobium, is looking promising in this respect, although long-term performance needs to be examined.) Polarization (spin alignment) of LEP's particles will extend the physics possibilities.

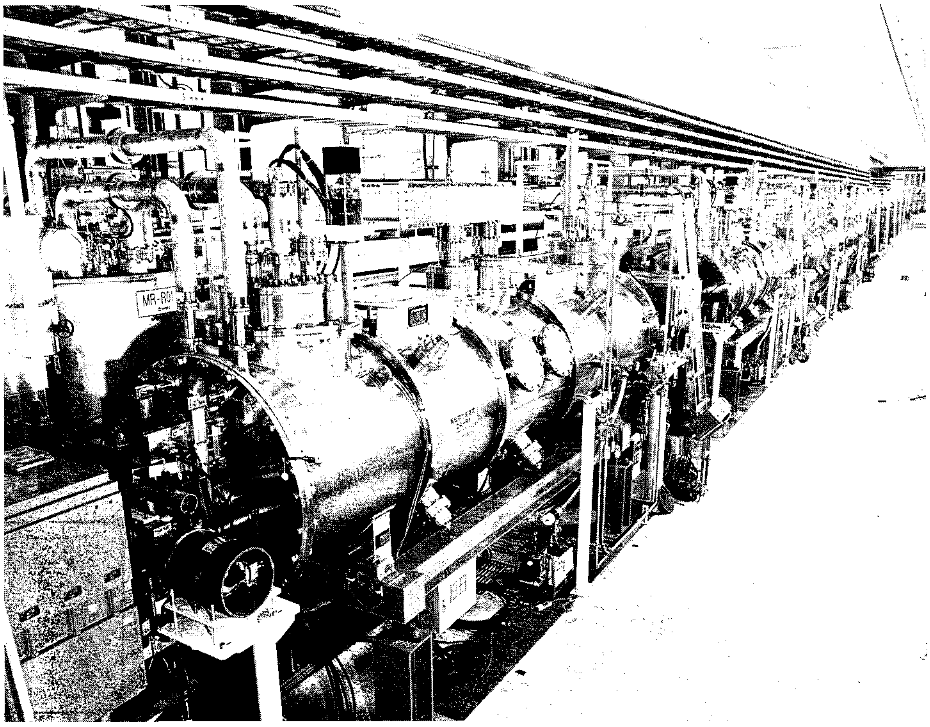
Stanford's SLC linear collider had just pipped LEP to the Z post. Burt Richter iterated initial results from the Mark II experiment on the width of the Z peak (September, page 12 and October, page 1).

Although SLC now has to compete with LEP, it has been very successful in achieving its initially declared aims of mastering important new accelerator physics problems, blazing a trail for energies beyond LEP. The Stanford Linear Accelerator Centre (SLAC) has pushed the performance of low emittance sources (which no longer seem to be a problem), has largely cured the problem of wakefield effects (using a combination of good beam steering and the BNS damping scheme, developed at the Soviet Novosibirsk Laboratory by V. Balakin, A. Novokhatsky and V. Smirnov – December 1988, page 13), has developed final focus schemes, and has demonstrated that micron-size beams can be handled.

There are immediate plans to improve SLC's collision rate by doubling the machine's repetition rate to 120 Hz and by upgrading the positron production target. Soon Mark II will make way for the big SLD detector and polarized beams will be available, opening the door to new physics studies. Longer term, the SLC rep rate will be taken to 180 Hz, and the damping rings and the final focus redesigned.

Building on SLC experience, linear collider studies are continuing at SLAC, and in collaboration with the Soviet Novosibirsk Laboratory and KEK. Ongoing work covers

The TRISTAN electron-positron ring at the KEK Laboratory is the world's largest single application of superconducting radiofrequency accelerating cavities.



several types of power source, where the Laboratory has convincing expertise – the klystrons developed for SLC exceeded their design aims in both peak power and lifetime. One example is the induction linac (in collaboration with Berkeley and Livermore) which has yielded 170 MW peak power. Others are pulse-compressed conventional klystrons, cluster klystrons for a 1 GW, 12 GHz source (with Brookhaven) and crossed-field amplifiers (with industry).

The TRISTAN machine at KEK was covered by K. Takata. Following the introduction last year of sixteen superconducting radiofrequency cavities (December 1988, page 13), the energy of the electron and positron beams has been taken to 30.7 GeV and the luminosity has attained 1.4 x 10^{31}. The cavities have now been in operation for some 5000 hours (3100 for physics) developing 100 MW. Field gradients vary from 3.5 to 6 MV/m with an average of 4.4. No serious deterioration in performance has been seen.

A further sixteen cavities will take the peak energy per beam to 32.5 GeV. Mini-beta insertions to squeeze the beams should more than double the collision rate next year.

S. Takeda described KEK's advanced plans for electron-positron linear colliders. Several steps are foreseen en route to a Japan Linear Collider, JLC, and a 70-strong team is working (part-time) on the project.

A Test Accelerator Facility is already under construction and will eventually house all key elements of the machine in prototype form – 1.5 GeV S-band injection linac, damping ring, 1 GeV X-band linac, and final focus. The first stage of real machine construction could get underway around 1995, to achieve 200 GeV colliding beams by the turn of the century – the Japan Intermediate energy Linear Collider (JILC). An energy increase to 300 GeV would follow an upgrade of the power sources, followed by a further increase to 500 GeV with a luminosity target of 10^{33}.

The other contenders in the linear collider stakes are VLEPP at Novosibirsk and CLIC at CERN, reviewed by A.N. Skrinsky and Simon van der Meer respectively. The former aims for 1 TeV (1000 GeV) per beam eventually, starting at half that figure, and is authorized for construction by a branch of the Novosibirsk Institute at the Serpukhov site near Moscow, where the UNK proton ring is taking shape.

CERN's CLIC aims for 1 TeV beams and lower energies have not been looked at, even though they would ease problems. 'We have plenty of time to think,' commented van der Meer. Wolfgang Schnell's two-beam scheme for CLIC, using a high current superconducting drive linac operating at 350 MHz (the LEP superconducting cavity frequency), has been pushed a little further. It has the advantage of automatic phasing between the two linacs under highly relativistic conditions. A 2.5 km drive linac with an accelerating field of 6 MV/m and 4 x 10^{11} particles in millimetre bunches (a non-trivial problem) transforms to 80 MV/m on 5 x 10^{9} particles per bunch in the main linac, achieving a luminosity of over 10^{33}. Detailed design remains in a 'primitive' stage.

Significantly, all the present linear collider schemes use conventional technologies, albeit pushed beyond conventional limits. Development of exotic ideas, such as plasma beat-waves and wakefields, which stirred up excitement a few years ago, has not yet matured.

Some of this ongoing work was reviewed by Tom Katsouleas. In the past year, homogeneous plasmas and field gradients equivalent to 300 MV/m over half a centimetre have been achieved in beat-wave mode at the UK Rutherford Appleton Laboratory. New technology for short pulse lasers has emerged at Livermore and Osaka, opening up prospects of 20 to 80 MV/m gradients.

Jim Simpson reported the Argonne project (June 1988, page 16) for a 1 GeV device using wakefield acceleration in a dielectric waveguide (sometimes called a Cherenkov wave tube). Such devices have no transverse forces to disrupt the beam, removing the alignment problems which dog structural and plasma wakefield systems, and look like one of the most interesting avenues to explore.

It was gratifying to see a resurgence of activity at the Yerevan Institute. A. Amatuni reported on investigations of new acceleration techniques.

A few rungs lower on the electron beam energy ladder, initial operation of the Beijing BEPC electron-positron collider was reported by the Institute's Director Fang Shouxian. An initial sample of J/psi particles heralds the start of the physics programme.

The hadron route

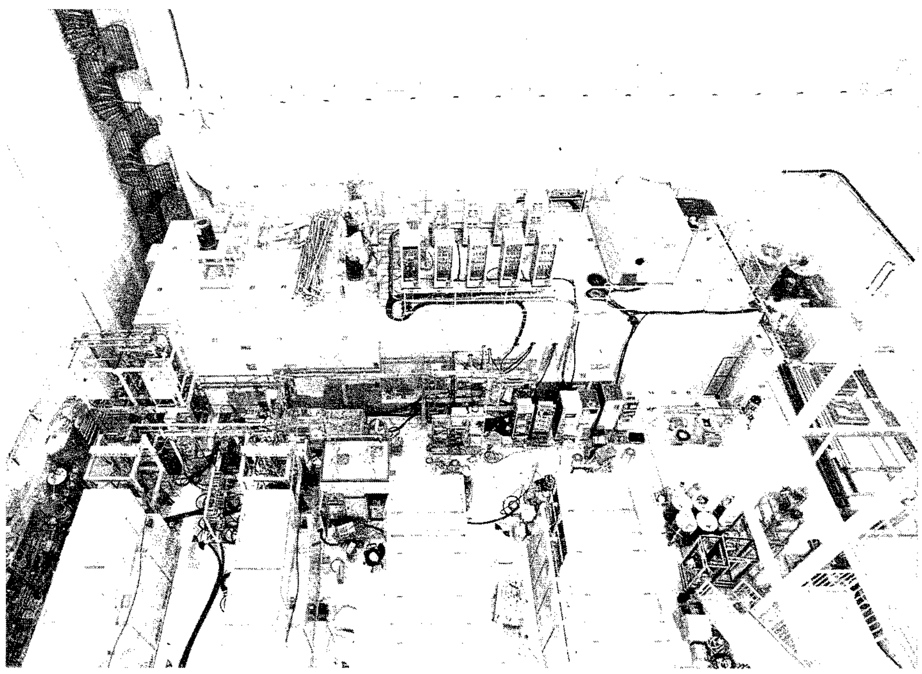
Studying the high energy behaviour of the quark constituents of protons is the goal of the 87-kilometre US Superconducting Supercollider (SSC) ring, to be constructed in Texas, and CERN's plans for the LHC Large Hadron Collider in the LEP tunnel.

Helen Edwards gave the latest SSC news, where work is concentrating on a 'site-specific' design now that the new Laboratory has found its definitive home in Ellis County, Texas. Design aspects under investigation include a possible increase of the magnet aperture from 4 centimetres to a more conservative 5 (requiring more superconductor and thus having an impact on cost), a reduction in half-cell length to 90 cm, increased energy (2000 GeV) for the booster feeding the main proton rings (easing problems related to persistent currents in the superconducting magnets), and a diamond-shape bypass configuration at the interaction regions (avoiding a 'garage' solution for multi-detector installation). Some of these design options could be cross-cancelling, for example increasing the injection energy to 2 TeV may resolve the magnet aperture worries. There is not yet any push to modify the design and aim for higher collision rates.

Development and testing of superconducting magnets – the lion's share of the project – will be boosted by a new magnet facility in Texas, supplementing the programme now underway at Berkeley, Brookhaven and Fermilab. Attaining the 6.6 tesla design field is no problem, but field quality, reproducibility and minimizing construction costs need more work. Industrial production will start soon, in line with a plan for a thousand preproduction magnets by the end of 1992. Full production would then be launched in 1994 so that the SSC can produce its first 20 TeV proton beam collisions in 1998.

Initial construction funding has been approved by both US Houses, and at the time of the Conference the wording of the two authorizations still needed slight reconciliation. For example the Senate wanted to add a further $25 million in the next fiscal year 'to initiate the first tunnel sector contract'.

There were also slight divergencies on the technological outcome of the mammoth project. While Congress was concerned about 'the absence of substantial commitments from foreign countries',


The Test Accelerator Facility at KEK. This will eventually house prototype elements for the proposed Japan Linear Collider (JLC).

K. Takata covered KEK's TRISTAN electron-positron collider. Until the arrival of LEP at CERN, TRISTAN was the world's highest energy electron storage ring.

the Senate stressed that the SSC should go ahead regardless, and was more worried about the transfer of US-developed high technology. The Senate authorization included a provision that SSC money should not be used to establish collaborations with foreign countries without prior assurance that it would be in the best interests of the USA.

These concerns need to be mollified in the coming months if the outstanding tradition of international collaboration, long a hallmark of accelerator physics and technology to the mutual benefit of all parties involved, will prevail for the SSC.

Giorgio Brianti described plans for CERN's LHC Large Hadron Collider, aiming for around 8 TeV proton beams in a ring of 10 T 'two-in-one' superconducting magnets installed above LEP in CERN's 27-kilometre tunnel. The design reaches for a high luminosity, above 10^{34}, to challenge the higher energies of SSC. Progress on the necessary high field magnets is promising (September, page 5), and was highlighted in a review of the technology by Romeo Perin. European industry has been involved in this venture from the outset.

Compatibility between normal LEP operation and LHC installation has been checked. Studies of detector configurations – one to handle high collision rates, one general-purpose and one for electron-proton (LEP-LHC) collisions – have started. LHC could be completed within six years and Brianti hoped 'to report at the next International Accelerator Conference (scheduled for Hamburg in July 1992), that construction has started'.

Confidence in these future superconducting colliders stems from the success of the Fermilab Tevatron. Gerry Dugan reported its recent successful run (September, page 13), where collision luminosity reached twice the design goal of 10^{30}, and with plans for new low beta insertions to further squeeze the beams, electrostatic beam separators and a linac upgrade to 400 MeV, could go to 5×10^{30}. Longer term plans include replacing the present large ring of conventional magnets by a superconducting version.

The next step up in proton energies will come from the UNK machine being built at Serpukhov. V. Yarba described the construction schedule, with completion of the 400 GeV conventional injector ring foreseen for 1992, followed two years later by a 3 TeV superconducting magnet ring.

There are also discussions about a timely transfer to Serpukhov of CERN's antiproton source, which first came on-line in 1980, for proton-antiproton collisions at 3 TeV per beam. Prototype UNK superconducting magnets are continuing to perform well (December 1988, page 2), and a hundred magnets are to be built next year prior to full production getting underway in 1991. Next year should also see completion of the 21 kilometre UNK tunnel.

The Laboratory that moved large-scale production of superconducting magnets out into industry was DESY in Hamburg, where manufacture of magnets for the 820 GeV HERA proton ring is an international affair. The 30 GeV electron ring gave its first beam last year (see page 4). M. Leenen reported on construction progress, where a first proton ring octant cooldown is scheduled by the end of the year, with cooldown of the full ring less than one year away. Potential problems of persistent currents in the superconductor have been well enough studied and people are confident that correction coils will make the necessary compensations.

Factory workers

Complementing the high energy frontier now is the high intensity frontier, aiming to re-examine with greater precision areas of physics already scanned. In particular, charge-parity (CP) violating decays are just as much a mystery now as when they were discovered twenty-five years ago.

The candidate machines to explore this high intensity horizon are called particle 'factories', with kaon and B meson (containing the fifth

Helen Edwards (here flanked by Satoshi Ozaki, right, and 'Pief' Panofsky, left) reported latest developments around the US Superconducting Supercollider (SSC), now with funding approved.

'beauty' quark) versions lining up to investigate CP violation.

Kaon factories are hadron machines with intensities a hundred times more than current synchrotrons, while B factories are electron-positron colliders spanning the 10 GeV mass region to produce B mesons.

Mike Craddock was able to tune his habitual kaon factory act to take account of recent developments around the five-ring KAON project at the Canadian TRIUMF Laboratory (October, page 9), and a five million rouble cash injection for the Moscow project, which could get underway in 1993. Other projects at Los Alamos, in Japan and in Europe are still alive but not kicking vigorously (though the European scheme has been offered a home at Legarno near Padua).

The design of B factories was perhaps the only topic in the whole Conference to stir a ripple of contention. The need is for luminosities of 10^{33} or more to produce B mesons in sufficient quantities for interesting physics to show up. Hadron colliders are disfavoured as the detector technology to sift out the interesting rare decays is not yet in place. For the electron-positron option, the big question is the choice of storage ring or linear collider route. The former is most favoured, as linear collider technology is not yet as well mastered.

Contention number two is whether to use equal energy (symmetric) or different energy (asymmetric) operation. As suggested by P. Oddone at Berkeley, colliding unequal energy beams gives a moving centre-of-mass, facilitating the separation of the B decays. It also pays dividends in machine terms, with magnetic separation of the beams possible. However there is as yet little experience of beam behaviour under these asymmetric conditions and no guarantee of high luminosity can be given.

Ongoing B factory proposals include Cornell's 'CESR Plus' scheme (October, page 14), Novosibirsk (with a VEPP-5 14 GeV scheme or a 7 on 4 GeV option), and PSI in Switzerland (symmetric and asymmetric options – July/August, page 27) among the storage ring contenders. Workshops (October, page 25) help clarify the picture, with a major meeting planned for Berkeley in February.

Applications

In contrast to the 'local' European and US Accelerator Conferences, where the increase of accelerator technology applications is stressed, the International Conference clung close to its high energy theme. However even here the intense electromagnetic beams provided by synchrotron radiation sources and free electron lasers were well aired in talks by Claudio Pellegrini, K. Huke and Alan Jackson.

FELs potentially have much higher peak power than other radiation sources and their basic physics is now well understood. Many are now in operation. Some are linked to linacs, like the Berkeley/Livermore work initiated by Andy Sessler (achieving 1 GW at 30 GHz, 9 mm wavelength with 45% efficiency), and the Stanford (University) and Los Alamos schemes. Others use storage rings (Orsay, Novosibirsk). New developments include a gas-loaded FEL at Stanford (to reduce the beam energy needed to produce a given wavelength radiation).

It is in the field of synchrotron radiation sources where accelerator physics and technology has contributed most, leading to a host of practical applications. Such sources can also do much useful work even when built on a scale modest by high energy accelerator standards, enabling developing countries (China, Korea, Taiwan, India, Latin America, ...) to enter the field.

The new generation of synchrotron radiation sources use wigglers and undulators in straight sections to produce more intense beams (earlier schemes exploited the radiation released when the electron beams were bent). New projects include the Advanced Light Source (ALS) at Berkeley and the European Synchrotron Radiation Facility (ESRF) at Grenoble. Given design and construction 'with care', the

problems of creating and maintaining the necessary low emittance beams now seem to be mastered.

Conclusion

The meeting concluded with a review of the work of the International Committee for Future Accelerators (ICFA) by its chairman, Yoshio Yamaguchi, and by succinct reviews by former KEK Director Tetsui Nishikawa and former SLAC Director 'Pief' Panofsky.

Nishikawa estimated that simply to sustain all operating and proposed accelerator projects requires about ten times more accelerator physicists than are currently available!

Panofsky saw the approach of a new watershed in the exponential growth of particle collision energies over the past fifty years. The next generation of machines, such as the SSC and the new linear colliders, have 'exhausted the capacity of our present knowledge', and he called for an increased proportion of resources to investigate new ideas to keep the exponential growth on its traditional steady upward track.

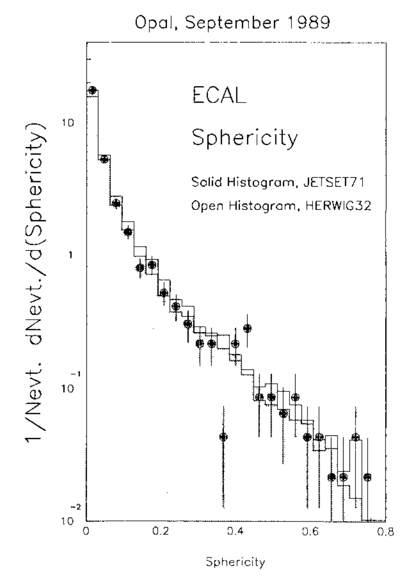
Madrid Physics Conference

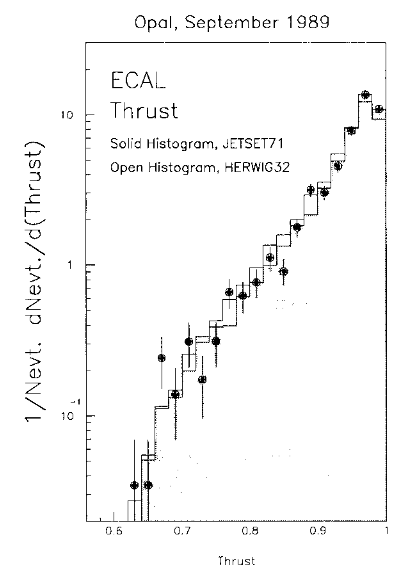
Hard on the heels of the Lepton-Photon Symposium at Stanford in August (October issue, page 1) came the International Europhysics Conference on High Energy Physics in Madrid from 6-13 September. With the two meetings held so close together, there was much overlap in the physics reported, although some teams were able to use the extra month to present new results. A notable example was the Mark II team working at Stanford's SLC linear collider, who presented new limits on the number of allowed neutrinos (see page 1).

The Madrid meeting attracted about 600 participants from all over the world. An initial three days of parallel sessions followed by four days of plenary talks could cover the field in depth and in breadth.

The Local Organizing Committee included physicists from the two Madrid Universities, Autónoma and Complutense, as well as from the Spanish Research Council (CSIC). The Conference opened with short addresses by C. Lopez, Rector of the Universidad Autónoma de Madrid and Chairman of the Local Organizing Committee, and P. Pascual, scientific advisor to the Minister of Education in Spain, who both expressed their satisfaction on seeing this major meeting organized in Spain so soon after the country has rejoined CERN as a Member State and at a scientifically historic time, with CERN's new LEP collider coming into operation.

Thus the parallel sessions began with a special two-hour survey of three of the four LEP experiments and their results from the LEP pilot run. J. May (Aleph), U. Amaldi (Delphi) and A. Michelini (Opal) surveyed the status of the experi-





The Madrid 'Europhysics' conference on high energy physics in September gave a foretaste of things to come at LEP, with multihadron production in Z decays, as seen by the Opal detector. The histograms are simulations of quark 'fragmentation' into hadrons.

ments, their plans for the near future and the results obtained so far. Opal was able to present multihadron production rates by the Z, the electrically neutral carrier of the weak nuclear force, as well as some jet shape distributions, in good agreement with models of quark 'fragmentation' into hadrons.

A wealth of new experimental results and theoretical investigations emerging from the 15 parallel sessions was summarized in the plenaries. These sessions began with short addresses by R.A. Ricci, President of the European Physical Society, and W. Bartel (DESY), Chairman of the EPS High Energy Physics Division.

A new EPS prize for outstanding work in high energy physics was awarded for the first time, going to Georges Charpak (CERN), who received his medal from R. Salmeron (Ecole Polytechnique), former Chairman of the HEP Division of the EPS. Replying, Charpak emphasized the importance of detector developments and pointed out the consequent spinoff ties between particle physics and other fields of science, particularly medicine and biology.

LEP Project Leader Emilio Picasso reviewed the history of the new machine, and its physics debut on 13 August with the first Z reported by the Opal collaboration only minutes after the start of the pilot physics run.

A. Hutton (Stanford) described the history of Stanford's SLC Linear Collider and looked at the problems encountered with this new type of machine. However things are now well under control, and early next year a polarized electron source will be installed to boost SLC's physics potential.

J. Dorfan (Stanford) came with new results from the Mark II collaboration at SLC. Based on a 332-event scan of the Z, they are able to place new limits on the allowed number of light neutrino types (see page 1). It was impressive to witness how well Standard Model calculations tuned at a total energy of 29 GeV could describe hadronic Z decays when extrapolated to 90 GeV.

K. Fujii (KEK) summarized electron-positron collider physics below the Z mass. The experiments at PEP (Stanford) and PETRA (DESY, Hamburg) gave high precision tests of the Standard Model while TRISTAN (KEK, Japan) covered the energy regime up to 60 GeV.

L. Nodulman (Argonne) reviewed the results of the CDF team working at Fermilab's Tevatron proton-antiproton collider. With lots of data from a year of running at a collision energy of 1800 GeV, they have been able to measure the masses of the Z, getting a value centred on 90.9 GeV, compatible with that from SLC, and the companion charged W particle, centred at 80 GeV. No new particles were reported and the threshold for production of the sixth ('top') quark was pushed up to 77 GeV.

J.-M. Gaillard (Orsay), covering the UA experiments at CERN's proton-antiproton collider, came to very similar conclusions. With an impressive list of quark field theory (quantum chromodynamics – QCD) calculations, he confirmed that the Standard Model is in good shape.

The spectroscopy and decay of heavy flavour particles has experimental input from fixed target experiments as well as from storage rings. A review by R. Morrison (Santa Barbara) included a long list of identified charmed and beauty particles. The detailed knowledge accumulated so far can account for 95% of all decays of the D neutral, charmed meson.

There was progress in the physics of the B mesons, containing the fifth (b) quark, where the mixing of electrically neutral Bs is now well established. The Argus (DESY) and Cleo (Cornell) experimental teams have first indications of charmless B decay, with component b quarks decaying directly into u quarks. The evidence comes from the shape of the lepton spectrum in semileptonic decays.

These measurements provide new input for calculating the elements of the (KM) matrix interrelating six kinds of quarks, reviewed by I. Bigi (Notre Dame). According to his evaluation, the violation of charge/parity (CP) symmetry is again open for discussion, with the new result by the E731 experiment at Fermilab based on only a fraction of their data (October issue, page 4). The result from the full statistics is eagerly awaited.

Looking at the electroweak sector of the Standard Model, R. Barbieri (Pisa) pointed out the potential importance of weak radiative corrections (see following story).

The hadronic (strongly-interacting) sector of the Standard Model was reviewed by J. Stirling (Durham), G. Martinelli (Rome) and A. Mueller (Columbia). Stirling looked at evidence in favour of QCD. Helpful in this respect is a resolution of some long-standing disagreement between two series (EMC and BCDMS) of measurements of nuclear quark structure using muon beams, following a reanalysis at Stanford of electron beam data. Mueller, still QCD-ing, tried to resolve the apparent paradox of quarks carrying little or none of the proton spin (June 1988, page 9). Another approach to QCD came from Martinelli, who presented impressive results from lattice calculations which avoid the problems besetting a traditional perturbation approach. An example was a calculation of the electric dipole moment of the neutron. L. Alvarez-Gaume (CERN) looked beyond the Standard Model, particularly in the direction of string theories.

The widespread application of Standard Model predictions was emphasized by M. Rees (Cambridge) who explored links between cosmology and particle physics, and H. Meyer (Wuppertal) reviewing non-accelerator experiments. The relative abundance of different helium isotopes in the universe appears to limit the allowed number of neutrino types to three.

Summarizing, L. Maiani (Rome) emphasized that with everything fitting so well into the Standard Model, there is a need to explore higher energies to understand where the Standard Model comes from. For this, new accelerator techniques are needed to attain these energies, complemented by new detector technologies to withstand high rates and high radiation doses. These aspects were covered by W. Schnell (CERN) and R. Wigmans (LAA Project) respectively.

Non-physics attractions included a memorable concert by Victoria de los Angeles, who delighted the audience with a recital of Spanish songs from the Renaissance to contemporary composers.

From Fernando Barreiro and Wulfrim Bartel

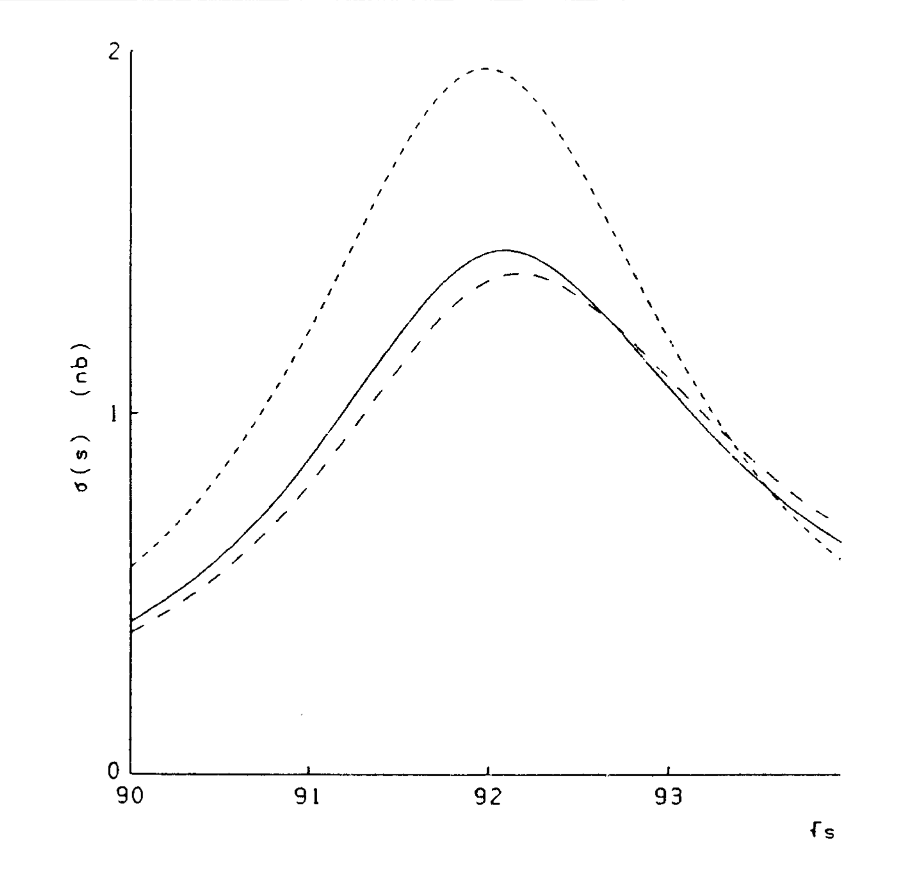
Making corrections correctly

The standard 'electroweak' picture, synthesizing electromagnetism with the weak nuclear force (via the gauge symmetry group SU(2) x U(1)) agrees so far with all experimental results. Despite these impressive successes, it is only a crude overall check of the model since only the results of first-order approximations (perturbations) have been verified.

Refined calculations in modern field theory use successively finer approximations (perturbations) from a series expansion of possible interaction mechanisms, including multiple exchanges of the field particles transmitting the forces.

For a model to be elevated to the status of a theory such as quantum electrodynamics (QED), such higher order effects – called radiative corrections – have to be carefully checked by precision experiments.

Although the Z particle – the electrically neutral carrier of the weak force – was discovered at CERN's proton-antiproton collider back in 1983, precision studies of the Z become possible only with the advent of experiments at the new



The importance of radiative corrections in high energy electron-positron physics. For a hypothetical 92 GeV resonance for the Z particle – the electrically-neutral carrier of the weak nuclear force – in a spectrum of pairs of charged muons are shown non-photonic corrections (fine dashed line), the result (dashed line) of adding first order quantum electrodynamics corrections, and the result (solid line) of second order corrections applied to the first curve.

high energy electron-positron colliders – Stanford's SLC linear collider and CERN's 27-kilometre LEP ring. Thus electroweak physics is about to enter a fascinating phase, paralleling the era forty years ago when QED, then a fledgling theory, met the challenges of the measurement of the Lamb shift and the anomalous magnetic moment of the electron.

Calculation of electroweak radiative corrections (EWRC) first needs a prescription for dealing with the otherwise troublesome infinities of higher order terms in a consistent way. This is known as a renormalization scheme. Furthermore, while the QED radiative corrections at low energies are typically less than one per cent, under SLC and LEP conditions corrections become substantial. Thus an essential part of LEP and SLC physics is to ensure that these corrections are calculated to high precision and incorporated systematically in the analysis of the experimental data.

To push this effort, a NATO Advanced Research Workshop 'Radiative Corrections: Results and Perspectives' was held at the University of Sussex, UK, from 9-14 July. The Organizing Committee included F. Boudjema and N. Dombey (Sussex), F. Dydak (CERN), F. Berends (Leiden) and C. Verzegnassi (Trieste), and the Workshop was sponsored by CERN, the UK Science and Engineering Research Council, the University of Sussex and NATO's Scientific Affairs Division.

Two major themes for working groups were the choice of renormalization scheme and the implementation of radiative corrections in electron-positron experiments.

The first group was led by M. Böhm (Wurzburg) while B.F.L. Ward (Tennessee State) gave a review of the present situation. Until recently, EWRC calculations adopted a number of different approaches but now theorists generally agree on a scheme where the perturbation parameter is the fine structure constant (1/137) and the other parameters are the masses of the field particles, including the Z and its electrically charged partner, the W. While the fine structure constant is known and the Z mass will soon be measured to great accuracy, a precise fix on the W mass will not be available for some time, suggesting that the weak interaction (Fermi) constant from muon decay should be used instead.

In the minimal standard model (one Higgs particle) the vital electroweak mixing is fixed by the ratio of the W and Z masses. However M. Veltman (Michigan) in his opening talk and A. Sirlin (NYU) in his summary both emphasized that data should be analysed in a general way which did not assume this relationship, the mixing parameter being measured independently by, for example, the forward-backward asymmetry of Z decays into pairs of muons or tau leptons. G. Altarelli (CERN) described how this work is being influenced by the increasing belief that the expected but so-far unseen sixth ('top') quark is heavier than initially suspected.

The second working group was led by R. Kleiss (CERN), with P. Rankin (Colorado) giving the review. With an objective of attaining a tenth of a per cent precision at the Z peak, high order QED corrections came under special scrutiny. As these corrections may be extremely sensitive to kinematic restrictions ('cuts') of the experimental data, 'Monte Carlo' electron-positron event simulators are required. J. Campagne (Saclay), G. Bonvicini (SLAC), and S. Jadach (Cracow) were among those presenting their latest results and there is now no serious disagreement between the different groups. Kleiss emphasized that experimentalists should agree on their cut procedures so that different experiments can be compared. If not, a second-best option was to publish both corrected and uncorrected data.

A third working group, led by W.J. Stirling (Durham), looked at the interplay of the radiative corrections from the electroweak picture and from the QCD (quantum chromodynamics) description of interquark forces.

Z. Kunszt (Zurich) and J.H. Kühn (MPI, Munich) reviewed the role of QCD in electron-positron physics while W. Hollik (Hamburg) analysed EWRC in the context of the electron-proton collisions scheduled from the HERA machine now under construction at the German DESY Laboratory in Hamburg. The need for precision knowledge of the QCD perturbation parameter was stressed. G. West (Los Alamos) showed the dangers of using perturbation theory when unexpected large coefficients can limit the predictive power of a series expansion approach, and called for a practical algorithm to estimate the coefficients of the perturbation series, particularly in QCD.

In his closing talk, A. Sirlin admired the radiative correction progress made over the past few years, especially by the contributions of many young physicists to a subject unfashionable until only recently.

From Fawzi Boudjema and Norman Dombey

Transputers in the Black Forest

Students at this year's CERN School of Computing had hands-on experience of transputers.

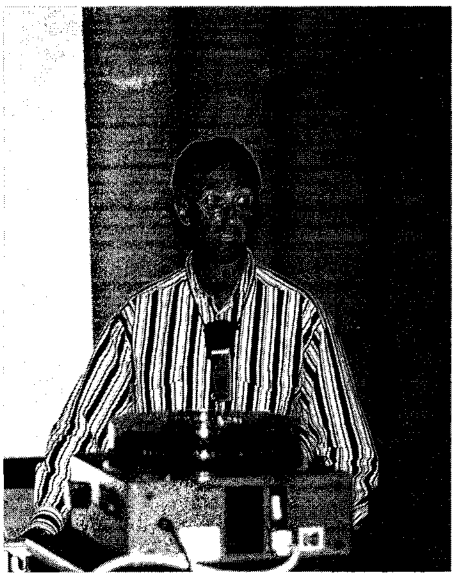
Although the CERN School of Computing this year covered its traditional wide range of computing applications for high energy physics, particular emphasis was placed on new techniques for next generation experiments. High speed networks, parallel and vector processing, neural networks and expert systems are all shaping up to play an important role in the future.

High-speed long-haul networks give high-performance remote access for physicists working on CERN experiments from their home institutes (see article on HEPnet, page 28).

Parallel and vector computing can dramatically increase both the power and cost effectiveness of computing on-line and off-line.

Neural networks and expert systems offer the interesting possibility of 'training' computers to deal with the ever-growing complexity of high energy physics data acquisition and control tasks.

Held in Bad Herrenalb deep in the German Black Forest, and with local arrangements handled by Heidelberg's High Energy Physics Institute, the school attracted 72 students from Europe and North America. Underlining the school's forward-looking objective, the programme began with a report by CERN Director Emilio Picasso of the initial operation of CERN's new LEP electron-positron collider (September, page 1). CERN Computing Division (DD) Leader David Williams looked ahead to Computing in the 90s, while long-time DD Leader Paolo Zanella looked back over the eventful thirty-year history of computing at CERN.



Bob Dobinson of CERN explains ideas for future physics data acquisition links.

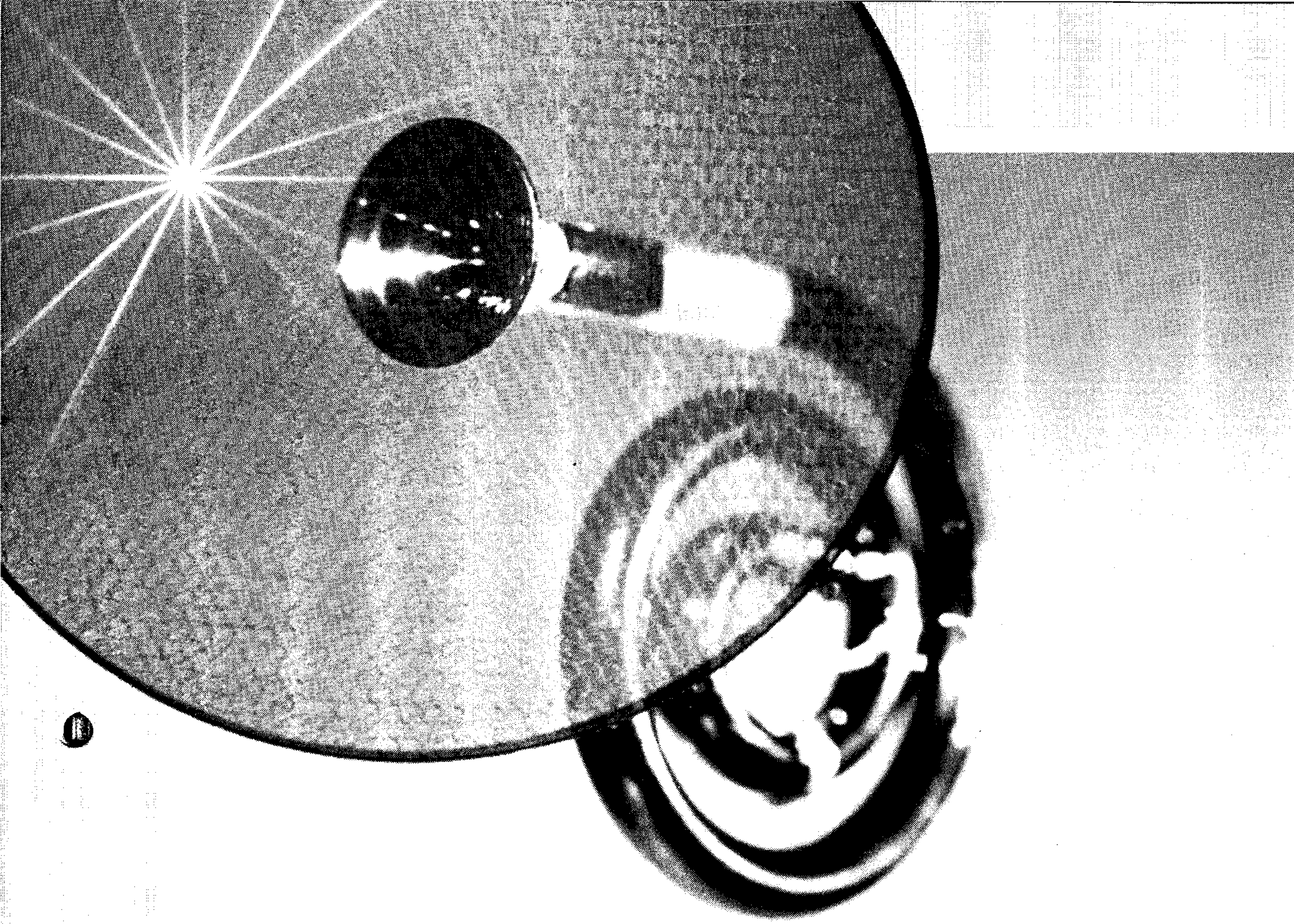
Long-time lecturer at CERN Schools Bob Churchhouse (University of Wales, Cardiff) gave fascinating insights into ciphering algorithms (an important safeguard against hacking as long as the encryption stays one step ahead!) and the 'in' concept of fractals.

Students this year learnt about parallel processing using INMOS' transputer – an innovative British microcomputer on a chip designed from the outset to be used in multiprocessor arrays. Instead of a single processor working on an application, multiple processors can work collectively on a problem 'in parallel'. The transputer comes with a powerful language – Occam – designed specifically for programming multiprocessor systems.

Supplementing the formal lectures on Occam was hands-on experience of parallel computing in a specially set-up transputer lab. Each of 12 Personal Computers (provided by IBM) was equipped with four transputers courtesy of Transtech Ltd and the UK national (SERC/DTI) transputer initiative at the Rutherford Appleton Laboratory, with INMOS providing the software. Enthusiastic students progressed from a simple 'hello world' program running on a single transputer to applications involving multiple processors working together.

The practical course was organized by Bob Dobinson and David Jeffery of CERN, assisted by Andy Hamilton from INMOS, Andy Jackson from the Transputer Support Centre at the University of Southampton and Weizhao Lu from Hefei University of Science and Technology in China.

Meiko, a UK firm specializing in high-performance transputer-based systems provided a demonstration machine during the second week of the school. Powerful graphics can obviate the need to learn special



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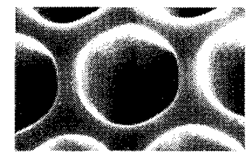

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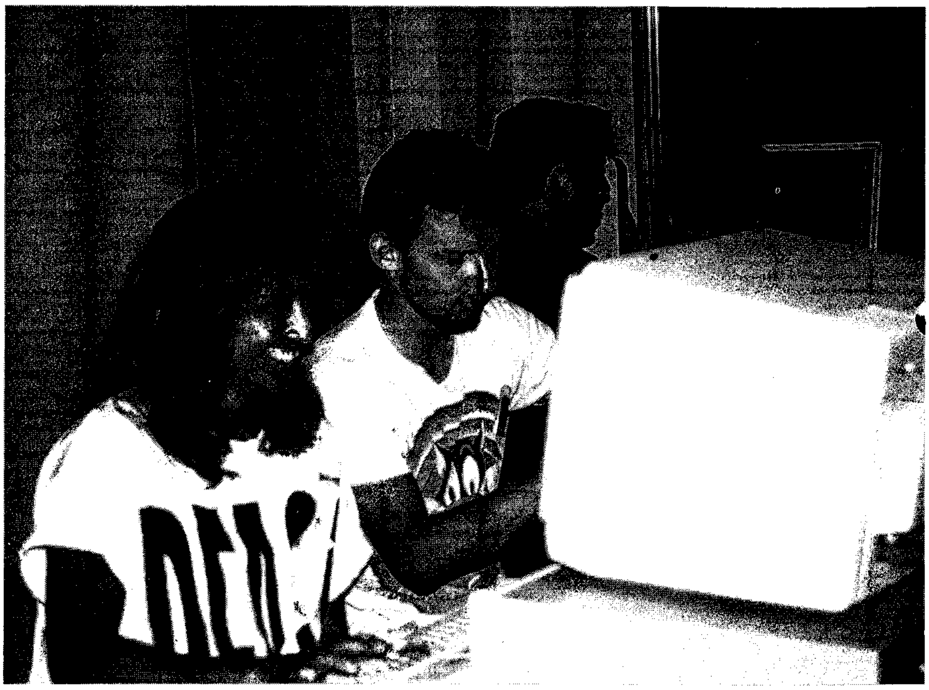
new languages, such as Occam, for parallel processing. Meiko and CERN are collaborating to produce next generation transputer software.

Students were able to keep in touch with their home base via electronic mail using a microVax loaned by Digital Equipment Corporation.

The traditional vital role played by computing in high energy physics is becoming even more pivotal as demands become more intricate and exacting. At the end of the course, students felt better equipped to face the challenges of the future.

From Bob Dobinson



Andy Hamilton from INMOS explains how it's done.

Casting HEPnet

HEPnet is the name used to describe the various computer networking facilities dedicated to high energy physics. HEPnet interconnects some 3000 computers in Europe and some 10000 throughout the world.

Some European countries already have a well-developed national computer network for the academic community (e.g. JANET in the United Kingdom, or more recently DFN in Germany). Where no such network exists, there are active plans to develop one. Furthermore, there are two major international computer networks used by the academic community – EARN and EUNET – as well as plans for centrally-funded links between the national networks within the Eureka COSINE project.

However high energy physics (HEP) has special additional requirements. Experimental facilities are large, expensive, unique, and centralized, while the scientists who use them are spread over at least 200 institutes in Europe, and many more in other continents. There is also a very high level of international collaboration.

The main Laboratories act as large centralized data sources. However many of the smaller institutes generate a lot of data through simulation work. The total data flow is therefore both large and manifold, bringing in its wake a demand for network connectivity between collaborating research centres.

In the near future, it is expected that data analysis will be dominated by the use of powerful graphics workstations working with mainframe computers or supercomputers. Such distributed processing over geographical distances clearly requires powerful networks.

The national networks, where they exist, are largely incompatible with one another. HEP, as an international community, requires international compatibility. The current and future international networks are either rather restricted in their functionality (EARN and EUNET), or in their choice of protocols (COSINE) and their performance is limited when judged by the needs of HEP. However in many cases existing infrastructures can be linked at marginal cost to form a wider network capable of meeting evolving needs.

For these reasons and more, the HEP community evolved its own computer network infrastructure to supplement general-purpose national and international networks.

Over the past five years, coordinated work by the HEP community has led to notable achievements – establishment of an infrastructure of international HEP leased lines; an international private X.25 network with a common addressing scheme; a worldwide DECnet (10,000 nodes); international CBS services; an emerging SNA/RSCS network; an emerging TCP/IP network; and a rich set of gateways and converters.

Leased lines

Today, a total of 20 international leased lines partially or totally dedicated to HEP are in operation over 3 continents (11 lines at 64 Kbps; 9 in the range 9.6/19.2 Kbps) with connection points for France, Germany, Italy, Netherlands, Spain, Sweden (giving also access to Denmark, Finland, Iceland, and Norway), Switzerland and the United Kingdom; the USA and Canada; and Japan.

In France, Italy, Spain, the USA and Japan, the international links connect to a national infrastructure of leased lines dedicated to HEP. In the UK and Scandinavia, they connect to general-purpose leased-line networks (JANET and NORDUNET respectively).

The HEP leased lines form one of the biggest specialized intercontinental communications infrastructures and is complemented in most countries by the PTO (Post Office) public X.25 networks, and by general-purpose research networks such as EARN/BITNET and EUNET/USENET.

Plans are well advanced for additional European and intercontinental links, and for the upgrade of several of them to the range 1.5/2 Mbps.

X.25

The private HEP X.25 network runs on top of the leased line infrastructure, covering France, Italy, CERN/Switzerland and the USA, and has nodes in Germany, the Netherlands and Spain. It is connected to the JANET and NORDUNET general-purpose X.25 services.

It uses the HEP X.25 addressing scheme based on the CCITT X.121 standard. Where the scheme is fully implemented, the connected hosts (DTEs) are fully connected, and any DTE can be called using the same address from anywhere in the network.

DECnet

DECnet is currently the biggest HEP network, with more than 10,000 nodes spread over Austria, Denmark, Finland, France, Germany, Italy, Norway, Portugal, Spain, Sweden and Switzerland in Europe, and in the USA, Canada and Japan.

Except for Austria and Portugal, which are linked via the public X.25 networks, the HEP DECnet runs over HEP leased lines, mostly on top of the HEP X.25 service. The HEP DECnet is coordinated with the Space Physics Analysis Network (SPAN) run by NASA in the USA and ESA in Europe. Additional connections are planned with Belgium and the Netherlands.

SNA/RSCS

International SNA services are now emerging in Europe. Links are currently available between Saclay and Lyon in France and Zürich, Geneva and CERN in Switzerland. In addition RSCS/BSC services are available between Rutherford Appleton in the UK, DESY in Germany, and CERN. However the bulk of the RSCS services between HEP sites is currently provided by the EARN network.

The HEP SNA/RSCS services run currently directly on leased lines (or subchannels via bandsplitters), and not (yet) on top of lower layer facilities such as X.25. Additional SNA connections are being considered between CERN and centres in Italy, the UK, Spain and Germany.

TCP/IP

TCP/IP services have been in use for several years by HEP on a local or regional basis in almost all countries. On the international front, Japan (KEK) and the USA (Berkeley) exploit an IP connection. In Europe, a first international TCP/IP link has been opened between the Netherlands (NIKHEF) and the Nordic countries (especially the Niels Bohr Institute, Denmark). Other international TCP/IP services are planned in the near future in Europe for France, Germany, Italy, Spain and Switzerland. Transatlantic HEP services are also being considered.

Gateways and converters

To improve connectivity, the HEP community has developed and installed a number of converter and gateway facilities: the GIFT system for file transfer, jointly developed

by several organizations including INFN in Italy, and in operation at CERN.

For electronic mail, a number of sites operate gateways, including INFN Bologna, CIEMAT Madrid, Niels Bohr Institute Copenhagen, and the MINT system at CERN. In addition, commercially available gateways and converters are in use. In several cases, the functionality of the HEP converters (e.g. the GIFT on-the-fly multiprotocol system) is unparalleled.

The GIFT service at CERN is in fact now near the end of its life, but has been further developed at the SARA computer centre in Amsterdam, and is now in use outside HEP.

HEPnet organization

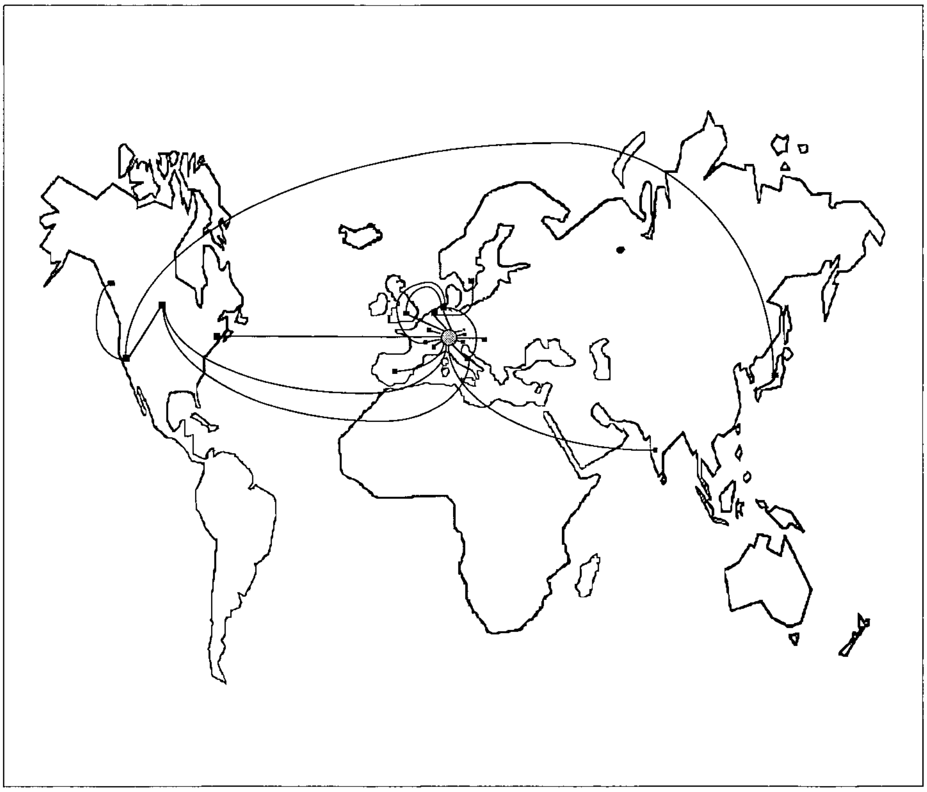
Despite an impressive list of achievements, serious problems remain and more work is needed to improve interfaces, reliabilities, response times, documentation, etc. Higher bandwidths allowing more demanding applications are urgently required.

In some countries physicists are still somewhat underprivileged and vast additional territories need to be covered. A line to India is on order.

The features described so far are mostly funded and operated by individual institutes. Thus, at least until the end of 1988, HEPnet was coordinated, but not designed: it just grew. In Europe, recent growth has been mainly driven by the requirements of the LEP experiments at CERN.

However it became clear that HEPnet's complexity warranted a clarification of its organization. Two committees were set up and have both become operational during the first half of this year.

HEPnet – worldwide links.



The HEPnet Requirements Committee (HRC) is constituted by ECFA (European Committee for Future Accelerators) to represent the networking needs of the European HEP community. Its members are mainly physicists designated by their national community and its role is to formulate needs and review how well they are being met. Current chairman is Rob Blokzijl of NIKHEF-H.

The HEPnet Technical Committee (HTC) is constituted by the HEP-CCC (HEP Computer Centre Coordinating committee) and its members are in general the managers responsible from each site or country operating HEPnet leased lines. Its purpose is to coordinate the planning and operation of HEPnet, wherever possible by reaching a consensus rather than by a vote.

All formal agreements remain bilateral. A number of subcommittees handle individual services such as DECnet or SNA/RSCS. The HTC chairman (currently François Flückiger of CERN) sits on the HRC, and vice versa.

For the future, there will be increasing emphasis on tools and procedures for operational network management. Optimistically, some of this work could be delegated to PTOs and the general-purpose networks, particularly for the lower level (data transport) services, but HEP will have to face the prospect of having to do more itself, especially for application services.

An example of ongoing effort is the establishment of the first high-speed link in the 2 Mbit/sec range, now coming into use between INFN (Bologna) and CERN (October, page 17). Others are expected to follow.

US developments

In the US, Fermilab has been chosen by the US Department of Energy to manage HEPnet. Manager Philip DeMar and staff at Fermilab will provide planning and coordination for operations and improvements and will be a focus for the development of network services.

Fermilab already supports over half the US HEPnet users and maintains the majority of HEPnet links to US universities. Fermilab's proposal to provide management was a direct response to a HEPnet Review Committee's report issued in June 1988 which recommended central management.

HEPnet encompasses a wide variety of networks and services including the large international DECnet network with Digital Equipment Corp. VAX and other computer systems in the US, Europe and Japan reaching in all over 17,000 outlets. HEPnet also uses the BITNET and INTERNET educational and research networks.

The HEPnet Manager will represent the technical needs of the high energy physics community to these networks, coordinate with other networks the implementation of new software and standards, and monitor traffic and reliability with a view to introducing new and/or additional features.

The management task is integrated with an overall reorganization of the Fermilab data communications group under Mark Kaletka, covering both on- and off-site networking. HEPnet management is part of the latter, and the HEPnet Manager will also act as the Laboratory's external network Manager.

Links at this speed are comparable in throughput to a Local Area Network (LAN) and will go on to have a dramatic effect on the ability to exploit computers over geographical distances, and will thus noticeably increase the productivity of distributed physics data processing.

The high-speed links must take account of HEPnet's multiple services (DECnet, TCP/IP, SNA, etc.). Several techniques for sharing such links between services have been studied: exclusive use of a single basic protocol such as X.25 or IP; transparent LAN bridging; and intelligent multiplexing. HEPnet has recommended the latter for international 2 Mbit/sec lines, since it is a robust, well-understood technique using off-the-shelf components. Modern intelligent multiplexers allow reallocation of bandwidth, and can be managed remotely, and combinations of protocols can share a line with zero risk of interference.

Hopefully, HEPnet soon will be able to use international links much faster than 2 Mbit/sec, keeping in step with LANs which will then routinely be 100 Mbit/sec. The best techniques for sharing the bandwidth of (say) 140 Mbit/sec international links, or even faster, are still under debate, although the Baden-Würtemberg network has already proven its own technology.

by Brian E.Carpenter and François Flückiger

Glossary

BITNET – American original of EARN

BSC – Proprietary protocol from IBM

CBS – Coloured Book Software, the JANET protocols Converter Device converting one network protocol to another

COSINE – Cooperation for Open Systems Interconnection in Europe

DECnet – Proprietary network architecture from DEC

DFN – Deutsches Forschungsnetz

DTE – Data Terminating Equipment (user of X.25 network)

EARN – European Academic Research Network

EUNET – European Unix Network

Eureka – A European intergovernmental research programme

Gateway – Device connecting two different networks

GIFT – General Internet File Transfer, a converter at CERN

JANET – Joint Academic Network (UK)

MINT – Mail Interchange, a set of converters at CERN

NORDUNET – Nordic University Network

OSI – Open Systems Interconnection, generic standards for networking

PTO – Public telecommunications operator (e.g. a PTT)

RSCS – Proprietary protocol from IBM

SNA – Proprietary network architecture from IBM

SPAN – Space Physics Analysis Network

TCP/IP – De facto standard protocols from America

USENET – American original of EUNET

X.25 – Standard for public data networks

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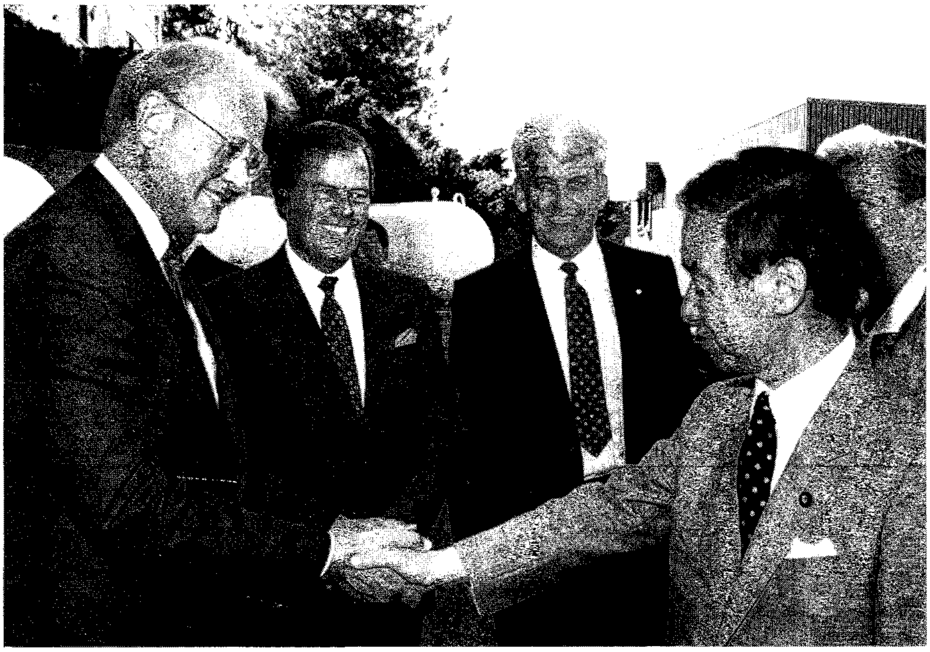
People and things

Japanese Prime Minister Toshiki Kaifu (right) greeted at the Canadian TRIUMF Laboratory in Vancouver by (left to right) Advanced Education Minister S. Hagen, British Columbia Premier W. Vander Zalm and TRIUMF Director E.W. Vogt. An article on physics groundwork for the proposed international KAON project at TRIUMF will appear in the December issue.



On people

Kenneth Stanfield becomes Deputy Director at Fermilab. Formerly Head of Fermilab's Research Division, he now takes on certain special assignments as well as deputizing for Director John Peoples.

Beat Hahn retired recently as Leader of the High Energy Physics Group at Berne, Switzerland. From 1968-71 he was a member of CERN's Scientific Policy Committee and from 1984-88 served enthusiastically on the Swiss delegation to CERN Council. With the revolutionary BIBC (Berne Infinitesimal Bubble Chamber) apparatus he made valuable contributions to the measurement of charm particle lifetimes. He is succeeded at Berne by Klaus Pretzl, who moves from Munich's Max Planck Institute, and on the Swiss delegation to CERN by Ernest Heer of Geneva.

After nine years at Brookhaven, where he took over as CERN Courier correspondent from Peter Wanderer and Philip Schewe, Neil Baggett moves to Texas to join Roy Schwitters' team preparing to build the big SSC Superconducting Supercollider. With Neil, CERN Courier readers can look forward to timely and informed progress reports on this key US project for the 90s. His place as Brookhaven correspondent is taken by Alan Stevens.

Phillip Pile, formerly of the Physics Department at Brookhaven, becomes Head of the Experimental Planning and Support Division of the Alternating Gradient Synchrotron (AGS). He replaces Don Lazarus, Division Head for the last five years and who will now take on some of the experimental area technical challenges which high intensity operation with the AGS Booster will present.

One of the six scientists speaking at a special top-level closed seminar organized at the instigation of UK Prime Minister Margaret Thatcher was John Hassard of London's Imperial College on 'Particle physics and the LEP accelerator'.

AdA at Orsay

The caption of the photograph of Frascati's AdA electron-positron collider which appeared on page 4 of the September issue was unfortunately incorrect. This revolutionary machine, when moved from Frascati to the French Orsay Laboratory in 1962, where increased injection energies were available, went on to make pioneer studies of electron-positron collisions.

Supercollider users

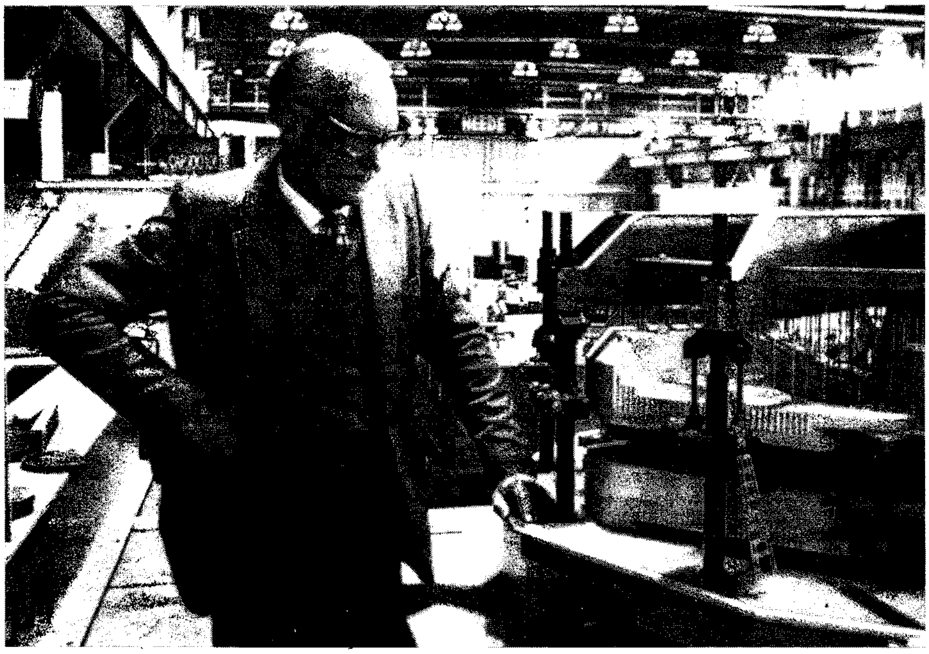
New Chairman of the Users Organization of the US Superconducting Supercollider – SSC, to be built in Ellis County, Texas – is David Cassel of Cornell, who succeeds Lee Pondrom of Wisconsin.

J.C. Kluyver

J.C. Kluyver died on 30 September, aged 69. After working at CERN from 1956-60, he left to become professor of physics at Amsterdam. The founding father of Netherlands experimental high energy physics, he played a major role in the creation of the Netherlands National Institute for Nuclear and High Energy Physics (NIKHEF). He continued to collaborate in experiments at CERN, and was Dutch

J.C. Kluyver

John Warren, 1915-1989, founder and first director of the Canadian TRIUMF Laboratory in Vancouver.



delegate to CERN Council from 1980-87, serving for the latter three years as one of Council's Vice-Presidents.

ohn Warren

John Warren, chief instigator and first Director (1968-71) of the Canadian TRIUMF Laboratory in Vancouver, died on 7 September at the age of 74. His physics debut in electron diffraction at London's Imperial College was followed by work on airborne radar during World War II (when he was John Adams' group leader at Malvern). Switching fields, from 1945-8 he built the first two accelerators in Canada at Chalk River and Vancouver (both Van de Graaffs) and another at Glasgow. The school of nuclear physics he founded at the University of British Columbia flourished under his liking for fundamental experiments and provided the manpower base from which heled the initial construction of the TRIUMF Meson Factory. Neither retirement in 1980, nor a stroke last year could put him out of action. He continued to contribute actively to muon and muonium experiments, recently provoking and participating in a check of the muon catalysis of cold fusion. His inspiring leadership will be remembered in a new John Warren Chair in Nuclear Physics at the University of British Columbia.

William Fairbank

William Fairbank died on 30 September, aged 72. He was best known for his work in superconductivity, where, with Bascom Deaver, he discovered flux quantization in 1961. His ingenious low temperature precision instrumentation profited a variety of fields, while his pioneer work and inspiration pushed the application of superconducting radiofrequency techniques, now such an integral of modern physics. He also developed ultralow magnetic field technology for use in searches for free quarks and magnetic monopoles.

Krypton from Saturne

In the report on the successes with krypton ion beams at the Saturne synchrotron at the French Saclay Laboratory (September, page 17), the maximum krypton energies unfortunately were given wrongly. The machine takes krypton-30+ to 700 MeV per nucleon.

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The Department of Physics at the University of California, Riverside expects to make a faculty appointment in the area of Experimental Relativistic Heavy Ion Collisions on or after July 1, 1990.

Individuals with a background in experimental nuclear/particle physics are invited to apply.

The level of appointment will be that of Assistant Professor (tenure-track) or, for an exceptionally qualified individual with an established record in research, an Associate Professor (tenure) appointment can be considered.

The individual appointed will be expected to join the ongoing Riverside research program in relativistic heavy ion collisions, and to be strongly committed to teaching at all levels of graduate and undergraduate studies.

Please send a resume and request that at least three letters of reference be sent to:

Chair, Search Committee
Experimental Relativistic Heavy Ion Collisions
Department of Physics
University of California
Riverside, CA 92521

The deadline for applications will be January 15, 1990. Any applications received after this date will be considered only if an appointment is not made from the original pool.

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Approximately nine appointments will be made over the next six years, at the average rate of one or two a year. The majority of these appointments will be at the junior level, but each appointment will be considered separately.

The Department pursues research in fundamental physics and maintains a strong teaching program at all levels.

Candidates will be expected to have demonstrated originality and the ability to carry out an independent research program, along with a commitment to teaching.

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(HIGH-ENERGY)

Applications are invited for a Chair (Professorship) in THEORETICAL HIGH-ENERGY PHYSICS at the Niels Bohr Institute, as from July 1, 1990.

The professor will be appointed as a Civil Servant under the Ministry of Education and Research. The annual salary amounts to approximately 360 000 Danish kroner.

The present research activities within the field of theoretical high-energy physics at the Niels Bohr Institute include in particular: lattice field theories, (super-) string theory, conformal field theory, cosmic strings, studies on the foundations of the standard model, aspects of electro-weak theory (baryon decay, large magnetic fields), numerical and analytical investigations of random surfaces, quantum gravity.

In the evaluation of the applicant, importance will be attached to the applicant's broad background within theoretical high-energy physics, and the chosen candidate will be expected to interact with the existing research group in theoretical high-energy physics at the Niels Bohr Institute. The professor will also participate in the university teaching at all levels. The language of instruction is Danish, but English will be accepted for the first two years of the appointment.

Further information about research planning, facilities, and staff at the Niels Bohr Institute may be obtained from the Director, Blegdamsvej 17, DK-2100 Copenhagen Ø, Denmark.

Applications should include a **curriculum vitae**, a complete list of publications, copies of scientific publications and further documentation which the applicant wishes to be considered, and a brief outline of proposed research. Information concerning the applicant's teaching experience, which will be evaluated by the Study Board, should also be submitted. The material should be submitted in triplicate together with a complete list of the material.

After evaluation of the applicants' qualifications by a specially appointed Evaluation Committee, the Committee's report will be sent to all applicants.

Applications are to be addressed to **Her Majesty the Queen of Denmark,** and sent to **the Faculty of Natural Sciences, Panum Instituttet, Blegdamsvej 3, DK-2200 Copenhagen N, Denmark.** The closing date for receipt of applications is January 15, 1990.

INDIANA UNIVERSITY

FACULTY POSITION ACCELERATOR PHYSICS

The Department of Physics at Indiana University-Bloomington invites applications for a tenure-track faculty position at the associate or full professor level in accelerator physics.

The department is establishing a new graduate program in accelerator physics and is inviting applications from Ph.D. physicists with extensive experience in the theory and practice of accelerator design who are interested in and capable of taking a leading role in building and guiding a strong academic and research program in accelerator physics.

Responsibilities include developing and teaching an appropriate curriculum in accelerator physics and supervising graduate student research in accelerator physics at the Indiana University Cyclotron Facility or other major accelerator facilities.

Indiana University is a major research institution with strong programs in accelerator-based nuclear and high energy particle physics and a 50-year history of forefront accelerator development and construction.

Present facilities include a 200 MeV separated-sector cyclotron and a 500 MeV storage ring/synchrotron with electron cooling. Several senior faculty members and IUCF staff members with experience in accelerator design will also be involved in the new accelerator physics program.

To apply please send a complete vita (including a description of research interests, accomplishments, and a list of publications), and arrange for a minimum of three letters of reference to be sent to

Professor J.M. Cameron
Department of Physics
Indiana University
Bloomington, IN 47408

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