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Laboratory correspondents:
Argonne National Laboratory, USA
M. Derrick
Brookhaven National Laboratory, USA
N. V. Baggett
Cornell University, USA
D. G. Cassel
Daresbury Laboratory, UK
V. Suller
DESY Laboratory, Fed. Rep. of Germany
P. Waloschek
Fermi National Accelerator Laboratory, USA
R. A. Carrigan
KfK Karlsruhe, Fed. Rep. of Germany
M. Kuntze
GSI Darmstadt, Fed. Rep. of Germany
G. Siegert
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M. Gigliarelli Fiumi
Institute of High Energy Physics, Beijing, China
Tu Tung-sheng
JINR Dubna, USSR
V. Sandukovsky
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K. Kikuchi
Lawrence Berkeley Laboratory, USA
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Anne-Marie Lutz
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A. Zylberstejn
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J. F. Crawford
Stanford Linear Accelerator Center, USA
W. W. Ash
Superconducting Super Collider, USA
Rene Donaldson
TRIUMF Laboratory, Canada
M. K. Craddock

Copies are available on request from:
China —
Dr. Qian Ke-Qin
Institute of High Energy Physics
P.O. Box 918, Beijing,
People's Republic of China
Federal Republic of Germany —
Gabriela Martens
DESY, Notkestr. 85, 2000 Hamburg 52
Italy —
INFN, Casella Postale 56
00044 Frascati
Roma
United Kingdom —
Elizabeth Marsh
Rutherford Appleton Laboratory,
Chilton,
Didcot
Oxfordshire OX11 0QX
USA/Canada —
Margaret Pearson
Fermilab, P. O. Box 500, Batavia
Illinois 60510
General distribution —
Monika Wilson
CERN, 1211 Geneva 23, Switzerland

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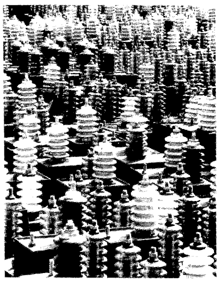
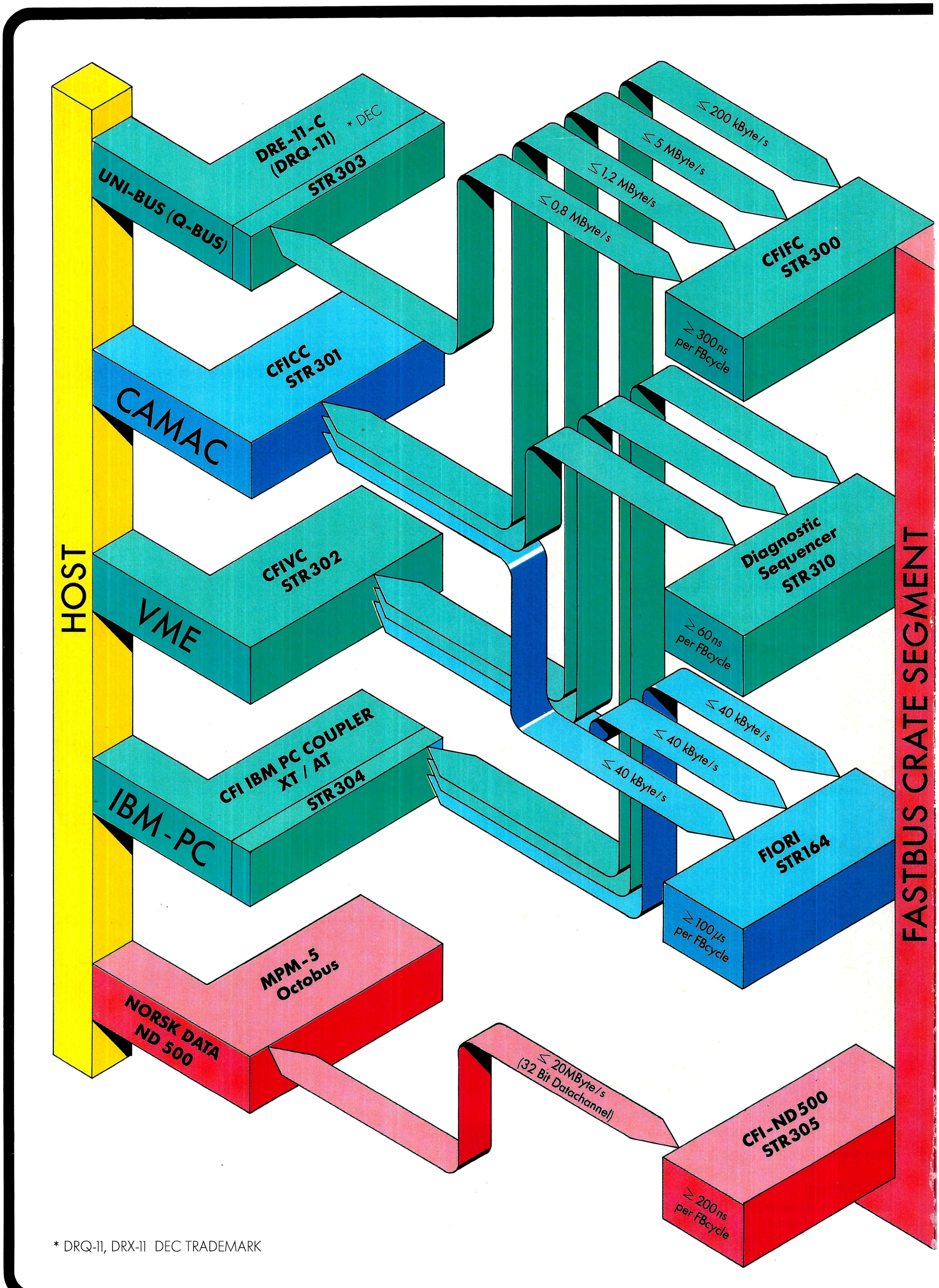
Around the Laboratories



Cover photograph:
'Spare capacity', a study by Joe Faust at the Stanford Linear Accelerator Center, California.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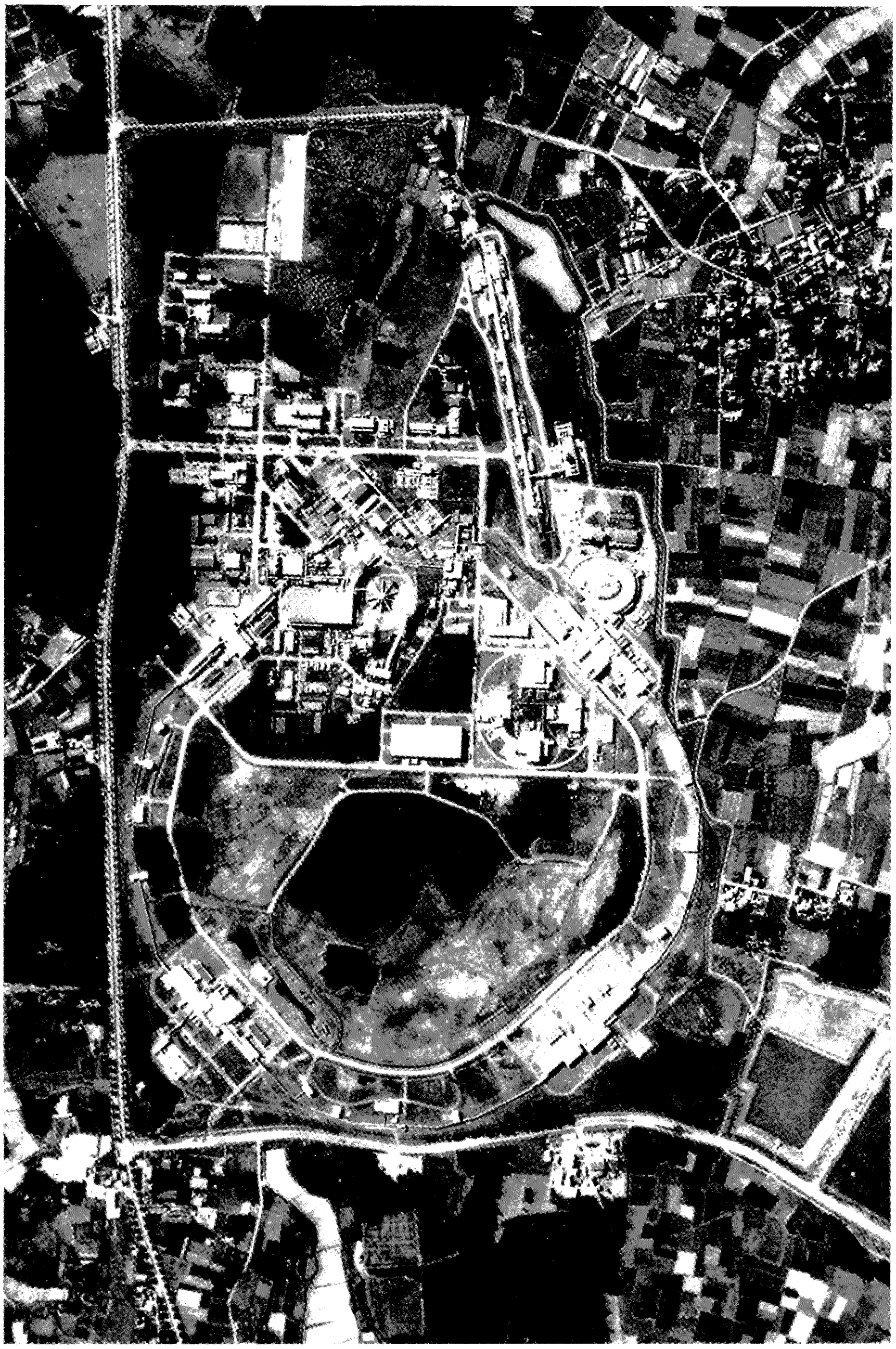
Japanese success

Aerial view of the Japanese KEK Laboratory showing the 3 kilometre TRISTAN ring with its four straight sections. At the top can be seen the building housing the injectors, including the 400 metre linac.



A few days before the fifth anniversary of its 19 November 1981 groundbreaking ceremony, the gleaming new TRISTAN colliding beam accelerator at the Japanese KEK Laboratory smashed together contrarotating 25 GeV beams of electrons and positrons, setting up a new world electron-positron collision energy record of 50 GeV, and with the promise of more energy to come.

Several days after the initial collisions in the ring on 14 November, the big VENUS detector surrounding the collision point in the 'Fuji' experimental hall saw its first electron-positron events. Maximum luminosity in the initial run was a modest 2.6×10^{29} cm^{-2} s^{-1}, but this will surely be coaxed much higher in the months to come.

TRISTAN's positrons (antielectrons), manufactured by a high current (around 10 A) 200 MeV electron beam from a linac hitting a tantalum target, are collected and accelerated to 250 MeV in a second linac. They are then fed into the appropriate point of the 400 m linac operational since 1982 as the injector for KEK's 'Photon Factory' for synchrotron radiation. This linac has been modified to provide short (less than 1 ns) pulses to enable electrons and positrons to be injected in a single radiofrequency accelerating 'bucket'.

Leaving the long linac at 2.5 GeV, the particles pass into a 377 m-circumference Accumulation Ring. When the current reaches a sufficient level (about 10 mA), they are accelerated to between 6.5 and 8 GeV ready for injection into the three kilometre Main Ring.

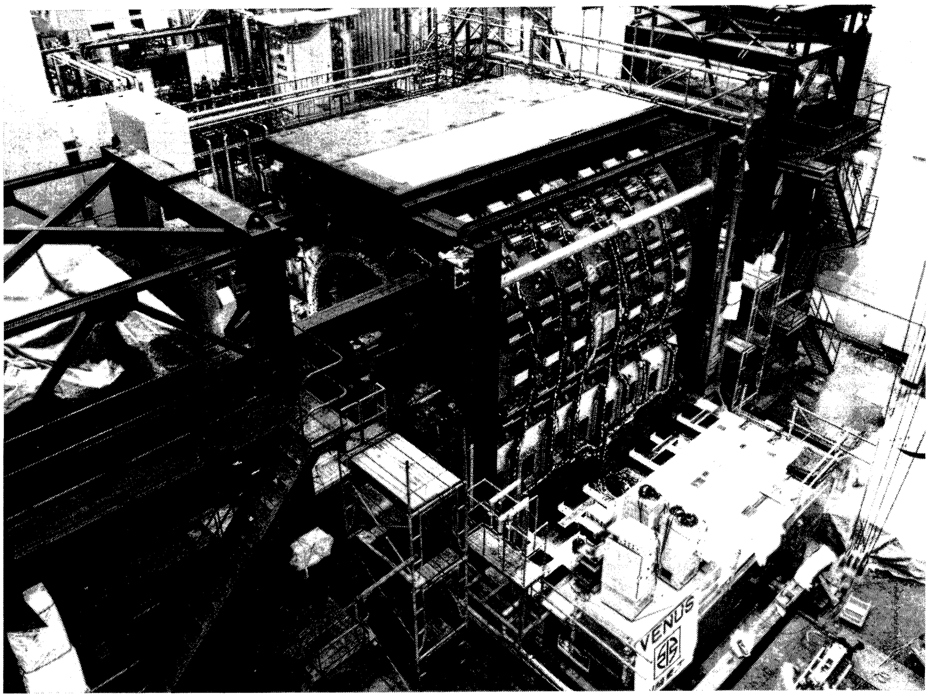
Acceleration in the Main Ring is currently handled by 64 units of nine-cell radiofrequency accelerating cavities of the Alternating Periodic Structure type (508 MHz) driven by 16 1 MW (cw) klystrons. This equipment is installed in two of the machine's four straight sections.

TRISTAN's curved sections use 272 5.86 m bending magnets, 280 0.8 m quadrupoles and 240 sextupoles. Additional quadrupoles are installed in the straight sections.

Main Ring tests got underway on 16 October with injection of 6.5 GeV electrons from the Accu-

The VENUS detector in position in the TRISTAN Main Ring, showing the casing of the electromagnetic shower counter barrel.

(Photos KEK)

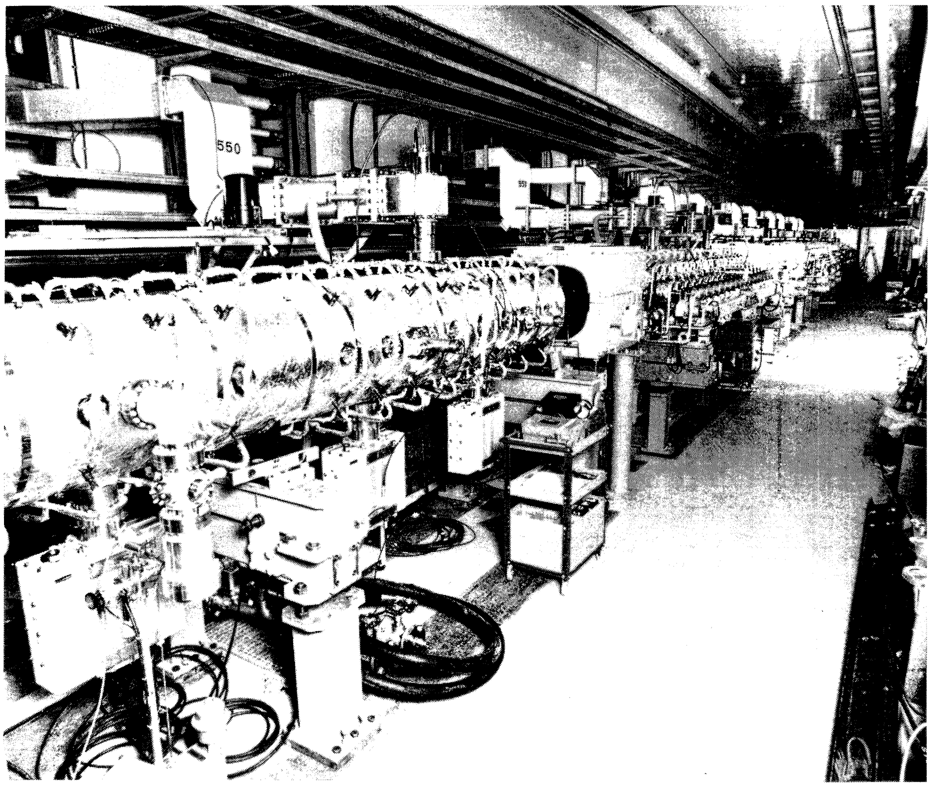


mulation Ring. On 22 October the control room reported a 1 ms spiralling beam, limited by synchrotron radiation losses, and just two days later efforts were rewarded as the obedient electrons went all the way to 25.5 GeV. This was soon followed by injection and acceleration of positrons.

The TRISTAN team is particularly proud of achieving acceleration of electrons and positrons to 25.5 GeV in the initial tests without deploying any steering correction magnets. A fully computerized control system and high speed optical fibre communications also contributed significantly to the fast commissioning.

Initial studies concentrate on improving Main Ring performance, with both VENUS (superconducting magnet, conventional tracking) and the smaller AMY detector profiting from beam tests. AMY is operated by a highly international team (US, Korea, China and Japan — see November 1985 issue, page 387). The big TOPAZ detector is complete but is undergoing further trials before being rolled into the ring.

▼ *One of the two strings of radiofrequency accelerating cavities. A third is being installed to take the beam energy towards 30 GeV.*



Next objective is to install 40 additional r.f. cavities of the same type into a third straight section, aiming for beam energies close to 30 GeV. With the TOPAZ detector scheduled to be in position by the spring, the full TRISTAN experimental programme should be underway early in May.

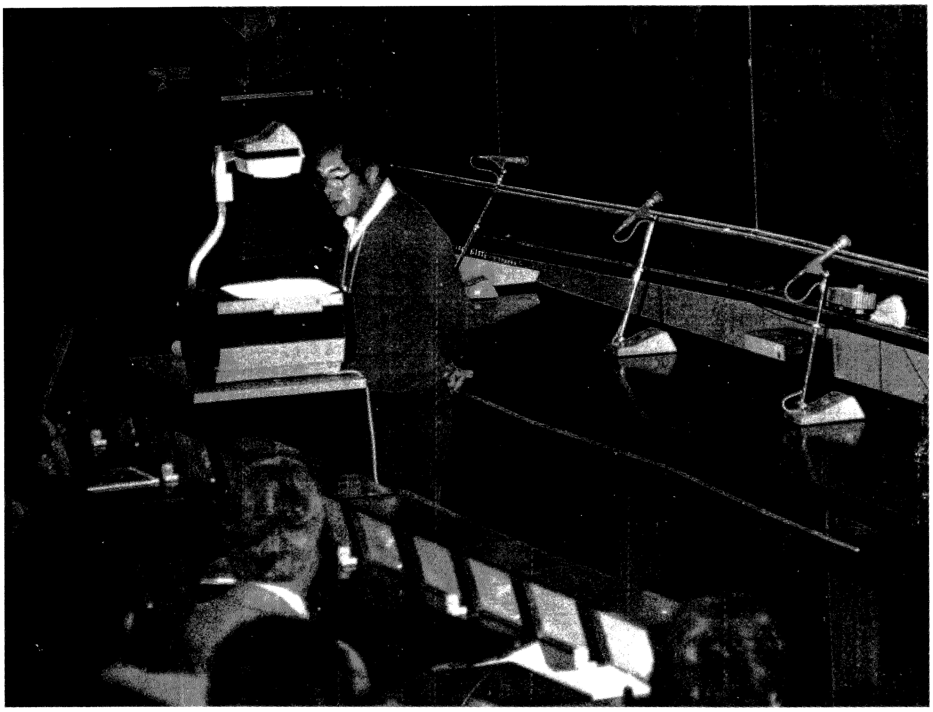
With TRISTAN, Japan joins Europe, the US and the Soviet Union in the centre stage of world particle physics.

Meanwhile at Stanford the new Linear Collider is being prepared to take electron-positron collisions to even higher energies.

Computational physics

Kenneth Wilson — comparing today's particle colliders with the microscopes of Galileo's time.

(Photo ICTP)



Computers have for many years played a vital role in the acquisition and treatment of experimental data, but they have more recently taken up a much more extended role in physics research. The numerical and algebraic calculations now performed on modern computers make it possible to explore consequences of basic theories in a way which goes beyond the limits of both analytic insight and experimental investigation.

This was brought out clearly at the Conference on Perspectives in Computational Physics, held at the International Centre for Theoretical Physics, Trieste, Italy, from 29-31 October. It was directed by Fred James (CERN), Alvise Nobile (Trieste), and Claudio Rebbi (Brookhaven and Boston).

The birth of computational physics can be traced back to the late 1960s with the first journals, conferences and schools on the subject. Although enormous progress has been made since then and whole new fields such as lattice gauge calculations have started up, it is clear that computational physics is still in its infancy. In fact Ken Wilson (Cornell) in his invited talk compared the current situation in computational physics with that of experimental physics at the time of Galileo when important discoveries were made using rudimentary microscopes, telescopes and leaning towers. Four hundred years later, experimental physics has developed techniques capable of penetrating many orders of magnitude deeper into matter and into the universe.

By analogy we expect that four hundred years from now it will be possible to perform calculations many of orders of magnitude more complex, and future computing engines compared with those of today will be like today's particle colliders compared with the microscopes of Galileo's time.

For Wilson, perhaps the greatest algorithmic challenge facing contemporary computational physics is demonstrated by the problem of electronic structure. Here is an area where the basic theory, quantum electrodynamics, is known to be valid to an extremely high accuracy, sufficient to predict the physical, chemical, and biological properties of all atomic and molecular states. However current calculation techniques are barely powerful enough to compute gross properties of systems involving a few hundred electrons, with computing time increasing typically as the square of the number of electrons, and interesting chemistry and biology taking place in the region up to millions of electrons at least.

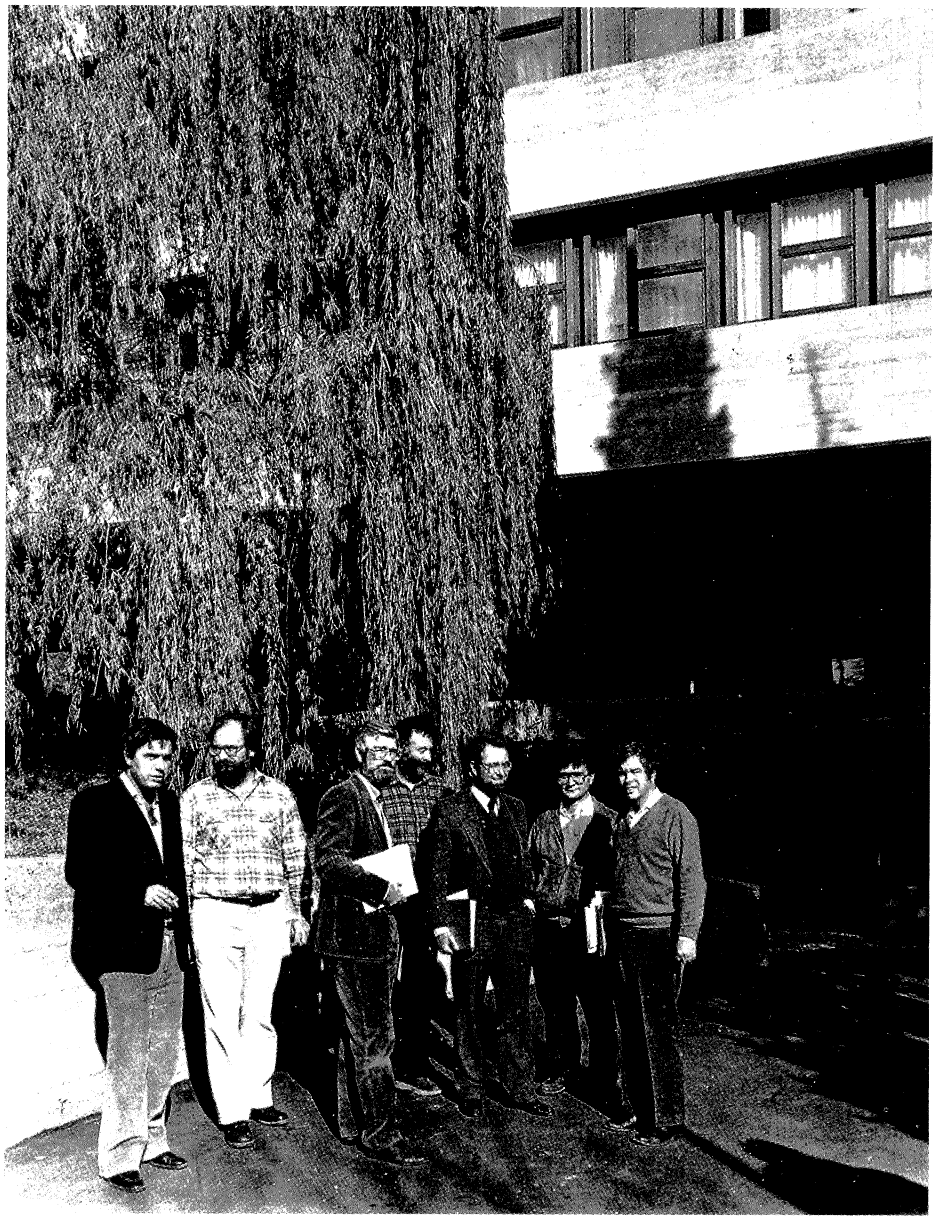
But the conference was not only devoted to dreaming about the future: world experts in many areas of computational physics reviewed the state of the art from all points of view: physics algorithms, software techniques, and hardware developments, as well as their interrelationships.

Supercomputer architecture was of course a topic of interest to all participants, and was covered in talks by several physicists and representatives of computer manufacturers. The physics areas covered in greatest detail, in addition to several aspects of electronic structure, were lattice gauge theory, stellar dynamics, and many-nucleon systems.

One of the highlights of the conference was the real-time demonstration of the possibilities of cellular automata by Tom Toffoli (MIT). In these discrete systems, each successive state is derived from the previous state by a relatively simple rule, which may be deterministic or partly random. By varying the replication rule, Tom

At the Conference on Perspectives in Computational Physics held at the International Centre for Theoretical Physics, Trieste, Italy, in October. Left to right: G. Parisi, A. Nobile, F. James, G. Jacucci, C. Rebbi, T. Toffoli and K. Wilson.

(Photo G. Montenero)



was able to model many mathematical and physical phenomena from shock waves to fractal growth and stellar dynamics. Using his own special hardware board under the control of an Olivetti M24 personal computer he was able to calculate successive states of the automata with sufficient speed that large-screen colour projection gave an uncanny feeling of observing the evolution of complex continuous systems obeying known 'physical' laws. This provides considerable insight into important phenomena like order and disorder, phase transitions, stability and reversibility in physical systems.

The conference took place immediately after the School on Advanced Techniques in Computing in Physics, held also at ICTP and with the same organizers. The three-week school offered in-depth courses on pure computing topics (programming languages, operating systems, networking, etc.), numerical and symbolic analysis techniques, and physics applications, to 150 students selected from over 400 applicants, and coming mostly from the developing countries.

These 'students' turned out to be highly qualified computational scientists, which made for an unexpectedly lively and stimulating school. One of the lecturers even remarked that it was his most responsive audience, despite having given similar talks as seminars in some of the world's most prestigious laboratories. One explanation was the school's highly selective acceptance procedure, but it is also a clear sign that competence in computing is increasing fast in many less developed countries. Only a few years ago, access to a reasonable computer meant the installation of an entire computer centre, with everything from a false floor to a team of systems analysts, all of which was beyond the possibilities of many countries. Nowadays the same computer power is available just by plugging in a PC. The effects of this quiet revolution have been spectacular.

Most of the 150 school participants stayed on for the conference, where they were joined by about 70 more people (nearly all from Western Europe and North America).

One evening was devoted to an open discussion of the future of Computational Physics. The presence of large delegations from developing countries made it a natural forum for computational physics research in the poorer regions of the globe. One western participant said he had never be-

fore been at a conference where so many developing countries had been represented, and it clearly came as a surprise to him and others that it was not only possible to carry on computational physics research in such places, but that it was being done actively. The obvious conclusion is that this enormous source of intellectual potential cannot be neglected.

Ken Wilson's summary talk covered the major outstanding issues for computational science as he saw them and as they were brought out at the conference. His first point was: what is quality research? Or, equivalently, what research will still be respected four centuries from now?

The great algorithmic challenges remain: electronic structure (solution of the Schrödinger equation), turbulence, function minimization (for protein folding, spin glasses, etc.), quantum field theory, and stellar evolution. The difference in the time-, length-, and energy-scales is impressive.

Communications issues are also very important. The usual language of Computational Physics, Fortran, has long been recognized as inadequate in many respects, especially as a vehicle for explaining what a program is expected to do. Yet none of the many other languages has had widespread acceptance.

There are other important aspects of the publication issue: Where should new papers be published, where and how should programs be published? The list of journals needed for a complete Computational Physics library is enormous. And there is networking, which both solves and introduces many problems, but does not obviate the need for centres of excellence.

The economic aspects of the research cannot be neglected. The future of Computational Physics will depend on how we interact with the larger scientific computing market, which has a huge industrial base representing about $ 10 billion per year, and is truly international. With the technology advancing rapidly on many fronts, the prospects for Computational Physics are apparently limited only by our own skill and imagination.

By Fred James

History of the weak interactions

by T. D. Lee

At the 'Jackfest' marking the 65th birthday of Jack Steinberger (see July/August 1986 issue, page 29), T. D. Lee gave an account of the history of the weak interactions. Lee was a graduate student with Steinberger under Enrico Fermi in Chicago from 1946, and went on to win the 1957 Nobel Physics Prize with C. N. Yang for their suggestion that the weak interaction does not conserve parity (mirror symmetry). This edited version omits some of Lee's tributes to Steinberger, but retains the impressive insight into the subtleties of a key area of modern physics by one who played a vital role in its development.*

* The full version is available as a 'Yellow Report' No. 86-07 from CERN Scientific Information Service.

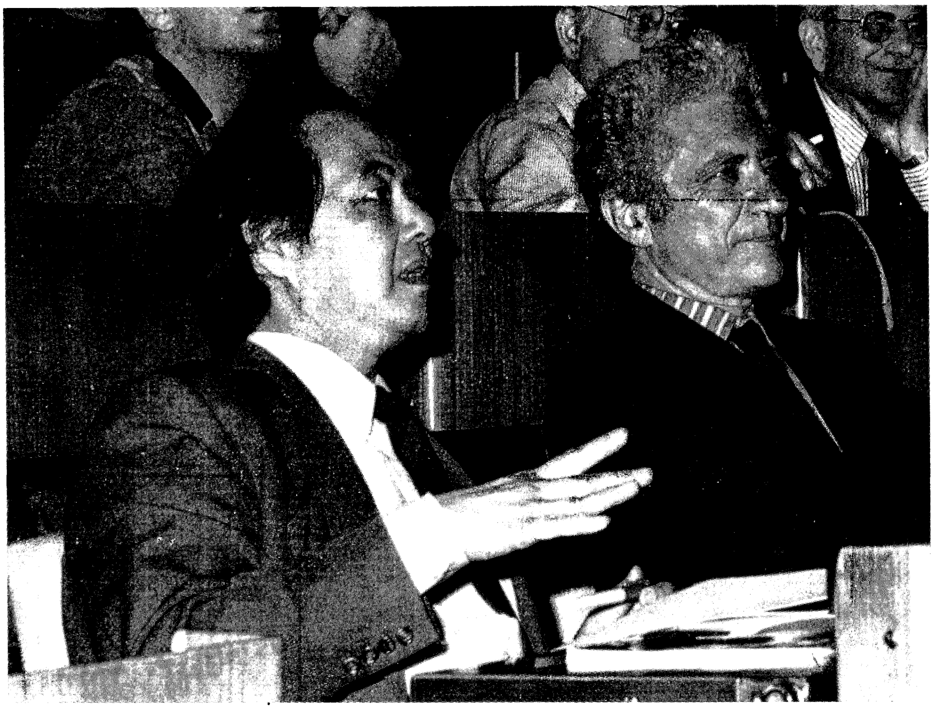
In 1898 Rutherford discovered that the so-called Becquerel ray actually consisted of two distinct types of radiation: one that is readily absorbed which he called alpha radiation, and another of a more penetrating character which he called beta radiation. Then, in 1900, the Curies measured the electric charge of the beta particle and found it to be negative. That, at the turn of the century, began the history of the weak nuclear interaction. From the very start the road of discovery was tortuous, and the competition intense.

A letter written by Rutherford to his mother expressed the spirit of research at that time: 'I have to keep going, as there are always people on my track. I have to publish my present work as rapidly as possible in order to keep in the race. The best sprinters in this road of investigation are Becquerel and the Curies...' Rutherford's predicament is very much shared by us to this day.

Soon even more runners appeared: Otto Hahn, Lise Meitner, William Wilson, von Baeyer, John Chadwick, Niels Bohr, Wolfgang Pauli, Enrico Fermi, Charles Ellis, George Uhlenbeck, and many others. We know that to reach where we are today took nearly a whole century and a large cast of illustrious physicists. Yet probably any modern physicist is only three handshakes away from these pio-

T. D. Lee (left) and Jack Steinberger — two lucky breaks.

(Photo CERN)



neers (for some perhaps only two) — you shake Jack Steinberger's hand, which shook Fermi's hand, which shook all those other hands.

In the mid-1960s, Lise Meitner came to New York and I had lunch with her at a restaurant near Columbia. When K. K. Darrow joined us, Meitner said 'It's wonderful to see young people.' To appreciate this comment, you must realize that Darrow was one of the earliest members of the American Physical Society and at that lunch he was over 70. But Lise Meitner was near 90. I was quite surprised when she told me how she started her first postdoctoral job in theory with Boltzmann, a contemporary of Maxwell. That shows us how recent even the classical period of our profession is.

After Boltzmann's unfortunate death in 1906, Meitner had to find another job. She said she was grateful that Planck invited her to Berlin. However, upon arrival, she found that because she was a woman she could only work at Planck's institute in the basement, and only go in and out through the servants' entrance. At that time, Otto Hahn had his laboratory in an old carpenter's shop. Lise Meitner decided to join him and to become an experimentalist. For the next thirty years, their joint work shaped the course of modern physics.

In 1908 they found that the absorption of beta particles through matter followed an exponential law. From that they concluded beta rays are of unique energy. It was Wilson, in 1909, who drew an opposite conclusion that the beta rays are heterogeneous in energy. But soon Hahn and von Baeyer found line spectra, which again confused the issue. This was cleared up by Chadwick in 1914, who established the continuous beta spectrum.

With the advent of quantum theory, Meitner, in 1922, raised the question concerning the origin of the continuous spectrum. She reasoned that a nucleus, presumably quantized, should not emit electrons of varying energy. Could it be that the observed inhomogeneity was introduced after the expulsion of the electron from the nucleus? A series of experiments by Ellis and others quickly established that this is not the case. This then led to Bohr's suggestion that perhaps energy was not conserved in beta decay. Pauli countered this by formulating the neutrino hypothesis. Fermi then followed with his celebrated theory of beta decay. This in turn stimulated further investigation on the spectrum shape, which did not agree with Fermi's theoretical prediction. This led to other ideas, and the confusion was only cleared up completely after World War II, in 1949, by C. S. Wu and R. D. Albert.

New horizons (1949-1953)

In 1946, the pion was not known. Fermi and Edward Teller had just completed their theoretical analysis of the important experiment of M. Conversi, E. Pancini and O. Piccioni. I attended a seminar by Fermi on this work. Where he arrived at the conclusion that the 'mesotron' (the observed particle) could not possibly be the carrier of strong forces hypothesized by Yukawa. Fermi's lectures were always superb, but that one to me, a young man not yet twenty and fresh from China, was absolutely electrifying.

One lucky break in my life was to have Jack Steinberger as a fellow student at Chicago, because he told us that the muon decays into an electron and two neutrinos. This made it look very much like any other beta decay, and stimulated M. Rosenbluth, C. N. Yang and myself to launch a systematic investigation. Are there other interactions, besides beta decay, that could be described by Fermi's theory?

We found that muon decay and capture resembled beta decay. This began the 'universal Fermi interaction'. We then went on to speculate that, in analogy with electromagnetic forces, the basic weak interaction could be carried by a universal coupling through an intermediate heavy boson which I later called $W^{\pm}$ for weak.

Naturally we went to Enrico Fermi and told him of our discoveries. He was extremely encouraging. With his usual deep insight, he immediately recognized the further implications beyond our results. He put forward the problem that if this is to be the universal interaction, then there must be reasons why some pairs of fermions should have such interactions, and some pairs should not. For example, why does the proton not decay into a positron and a photon, or into a positron and two neutrinos?

A few days later, he told us that he had found the answer; he then proceeded to assign various sets of numbers, + 1, − 1, and 0, to each of these particles. This was the first time to my knowledge that both the laws of baryon-number conservation and of lepton-number conservation were formulated together to give selection rules. However, at that time (1948), my own reaction to such a scheme was to be quite unimpressed: surely, I thought, it is not necessary to explain why the proton does not decay into a positron and a photon, since everyone knows that the identity of a particle is never changed through the emission and absorption of a photon; as for the weak interaction, why should one bother to introduce a long list of mysterious numbers, when all one needs is to say that only a few combinations can have interactions with the intermediate boson. (Little did I expect that soon there would be many others.)

C. N. Yang — violating mirror symmetry.

(Photo CERN)

Most discoveries in physics are made because the time is ripe. If one person does not make it, then surely another person will do it at about the same time. In looking back, what we did in establishing the universal Fermi interaction was a discovery of exactly this nature. This is clear, since the same universal Fermi coupling observations were made independently by at least three other groups, O. Klein, G. Puppi, and J. Tiomno and J. A. Wheeler, all at about the same time. Yet Fermi's thinking was of a more profound nature. Unfortunately for physics, his proposal was never published. The full significance of these conservation laws was not realized until years later. While this might be the first time that I failed to recognize a great idea in physics when it was presented to me, unfortunately it did not turn out to be the last.

In the early fifties, extensive efforts were made to determine the space-time transformation properties of beta decay and so give an insight into the underlying mechanisms. A 1953 experiment on helium-6 decay seemed to rule out the theoretical idea of the intermediate boson, and I became quite depressed.

The theta-tau puzzle (1953-1955)

During a recent physics graduate qualifying examination in a well-known American university, one of the questions was on the theta-tau problem. Most of the students

were puzzled over what theta was; of course they all knew that tau is the heavy lepton, the charged member of the third generation. So much for the history of physics.

In the early 1950s, theta referred to the meson which decays into two pions, whereas tau referred to the one decaying into three pions. Experiments showed that these mesons had different intrinsic parities (behaviour under mirror reflection), but on the other hand had the same lifetime and the same mass. This was the puzzle.

My first efforts were all on the wrong track. In the summer of 1955, Jay Orear and I proposed a scheme to explain the puzzle within the bounds of conventional theory. We suggested a cascade mechanism, which turned out to be incorrect.

The idea that parity (left/right symmetry) is perhaps not conserved in the decay of these particles flickered through my mind. After all, strange particles are by definition strange, so why should they respect parity? The problem was that, after you say parity is not conserved in these decays, then what do you do? Because if parity non-conservation exists only in theta/tau, then we already have all the observable facts, namely the same particle can decay into either two or three pions with different parity. I discussed this possibility with Yang, but we were not able to make any progress. So we instead wrote papers on parity doublets, which was another wrong try.

The breakthrough (1956)

In 1956, I had second lucky break, this time because Jack was my colleague at Columbia. Discussing with him the definitions of the decay angles in the disintegration of hyperons (heavy relatives of the nucleon, carrying strangeness) I realized how non-conservation of parity might be revealed if the data were analysed the right way.

Very soon, Jack and his collaborators (R. Budde, M. Chretien, J. Leitner, N. Samios and M. Schwartz) had their results, and the data were published even before Yang and I published our theoretical paper on parity non-conservation. There was a suggestion that mirror symmetry was being violated in hyperon decays, but because of the limited statistics, no conclusion could be drawn. Nevertheless, except for the high standard of Jack and his group, this might have been claimed as the first indication of parity non-conservation.

However, on the theoretical side there was still the question of parity conservation in ordinary beta decay. In this connection, about two weeks later, I had the further good fortune of having Yang join me. This led to our discovery that, in spite of the extensive use of parity in nuclear physics and beta decay, there existed no evidence at all of parity conservation in any weak interaction.

Several months later followed the decisive experiments by C. S. Wu, E. Ambler, R. Hayward, D. Hoppes and R. Hudson, at the end of 1956, on beta decay, and by R. Garwin, L. Lederman and M. Weinrich and by J. Friedman and V. Telegdi on other decays.

From then on we entered the modern period: theta and tau became the kaon, the transformation properties of beta decay were finally determined, and the weak interaction was unified with electromagnetism in the electroweak picture.

The modern period

At present, there seems to be a divergence in the viewpoints of theorists and experimentalists. The experimentalists are full of problems, looking for solutions — money problems, managerial problems, scheduling problems, etc. On the other hand, the theorists think they already have the ultimate solution and that there is no problem. Superstrings may well be the theory of everything (TOE), but how about calculating things like the Higgs mass, quark-lepton masses, etc? Therefore, instead, I would like to go over our experience and try to extract not the laws of physics, but the laws of physicists.

We all know that to do high energy physics requires accelerators. When each new accelerator is proposed, theorists are employed like high priests to justify and to bless such costly ventures. Therefore it pays to look at the track record of theorists in the past, to see how good their predictions were before experimental results. Looking at the important discoveries made in particle physics for more than three decades, it is of interest to note that, with the exception of the antinucleon and the intermediate bosons W and Z^0, none of these landmark discoveries was the original reason given for the construction of the relevant accelerator.

When Lawrence built his 184 inch cyclotron, the energy was thought to be below pion production. Therefore, after the cyclotron was turned on, even though pions were produced abundantly, for a long time nobody noticed them.

The progress of particle physics is closely tied to the discovery of

Galaxy of Physics Nobels at Columbia in March to mark the 60th birthday of T.D. Lee and the thirtieth anniversary of parity (mirror symmetry) nonconservation – left to right, S. Chandrasekhar (1983), J. Cronin (1980), I. Rabi (1944), T. D. Lee (1957) and S. Ting (1976).

(Photo Joe Pineiro, Columbia)

resonances, which started at the Chicago cyclotron. Yet even the great Enrico Fermi, when he proposed the machine, did not envisage this at all. After the unexpected discovery of the first nucleon resonance, for almost a year Fermi expressed doubts whether it was genuine.

A similar story can be told about the next landmark discovery. When the Cosmotron was constructed at Brookhaven, some of the leading theorists thought that the most important high energy problem was to understand the angular distribution of proton-proton collisions, which remains mysteriously flat even at a few hundred MeV, although at that energy the dynamics of the collision are quite complicated; many different levels are all involved. Why should they conspire to make a flat angular distribution? But as it turned out, when the energy increases the angular distribution of proton-proton collisions no longer remains flat and becomes quite uninteresting. Instead, it was production and decay dynamics of strange particles that put the Cosmotron on the map.

We could go on and on, and the same pattern would repeat itself. This leads to my first law of physicists: 'Without experimentalists, theorists tend to drift.' There is no reason for us to believe that it will change, nor should we expect too much from our present theorists for the prediction fo the future.

The density of great discoveries per unit time is quite uniform and averages out to about one in two years. Let us hope that this long-standing record of constant rate of discovery can be maintained. In order to achieve that, we must have good experiments.

We now come to my second law of physicists: 'Without theorists, experimentalists tend to falter.'

A good example is the history of the Michel parameter, which governs the shape of the spectrum ot the electrons produced in muon decay.

It is instructive to plot the experimental value of this parameter against the year when the measurement was made. Historically it began with zero and then slowly drifted upwards; only after the theoretical prediction in 1957 did it gradually become 0.75. Yet, it is remarkable that at no time did the 'new' experimental value lie outside the error bars of the preceding one!

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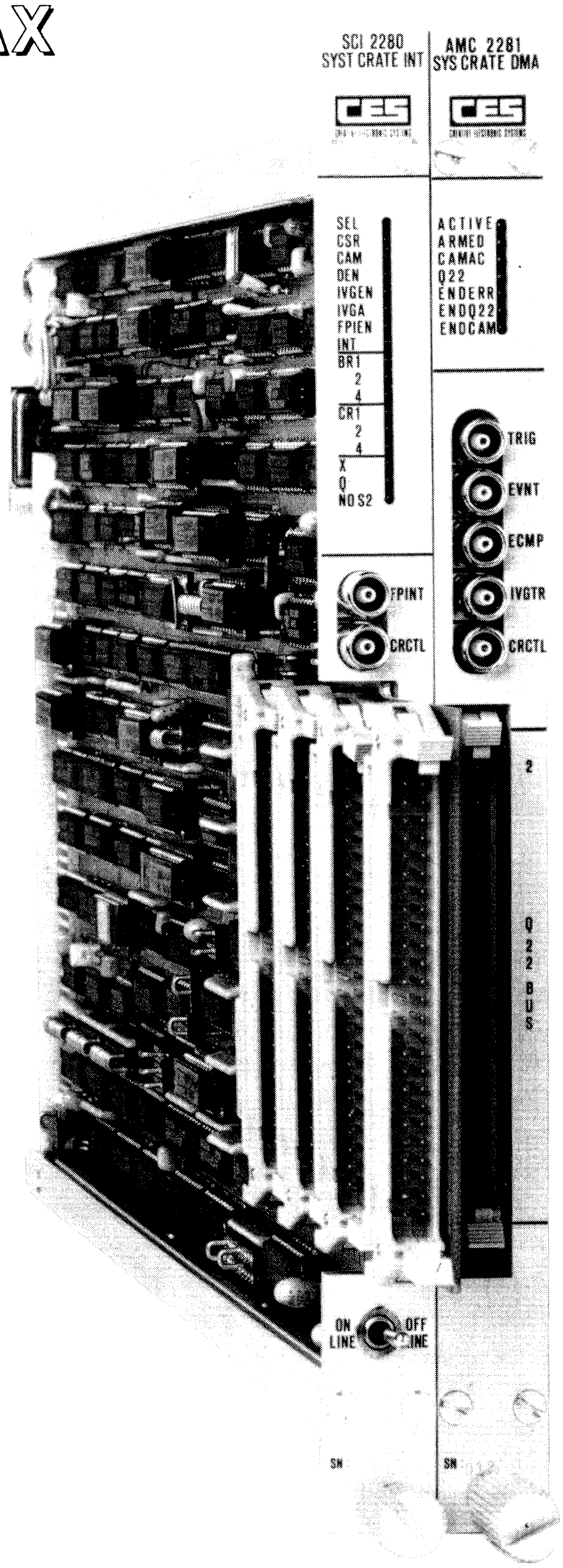

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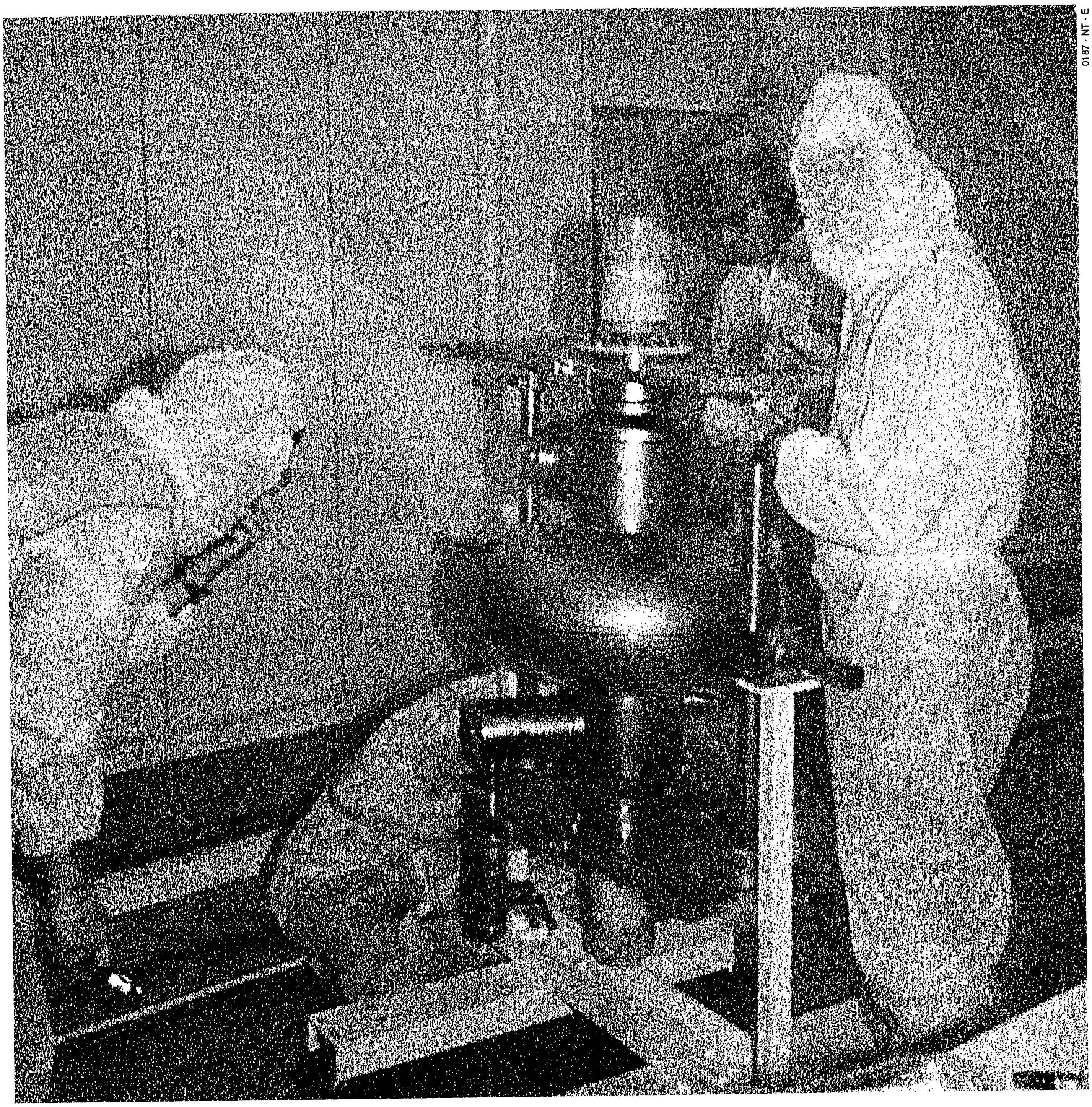


Around the Laboratories

CERN
Lightest glueball?

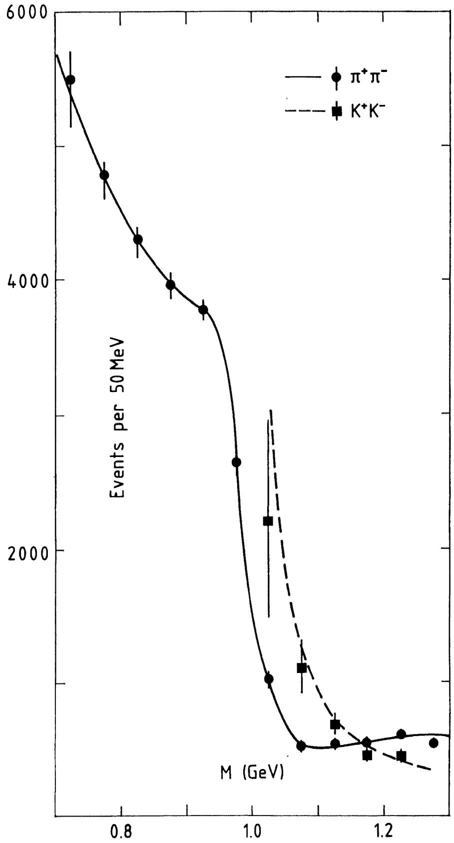
One of the key features of our present standard theory of strong interactions, Quantum Chromodynamics (QCD), is that the carriers of the strong force — the gluons — are themselves sources of the force.

As a result two or more gluons should bind together to form particles called 'gluonium' or 'glueballs'. Theorists expect a whole spectrum of electrically neutral glueballs with various values of spin, and with positive or negative parity. The masses are difficult to calculate precisely because of the complexity of QCD at low energies.

Three methods can be used for estimating glueball masses — so-called 'bag' models, lattice gauge theory calculations and potential models. Despite these rather different approaches, there is general agreement that the lighter glueballs should have masses between 0.7 and 2 GeV, and that the lightest of all should be a scalar state (no spin, positive parity).

Discovering these particles and measuring their spectrum is generally considered a key step in understanding how to apply QCD at low energies. One overriding problem is that in this mass region there are many conventional (quark-antiquark) mesons which can perhaps mix with each other and with purely gluonic states in a complicated way.

It may take many years and many different experiments — as well as many theorists — before we have a complete picture of this mass region. Though it has been studied for a quarter of a century, new states are still being found!



The Axial Field Spectrometer experiment at the CERN Intersecting Storage Rings (now closed) looked (among many other things) for examples of two forward protons leaving in their wake pairs of pions or kaons almost at rest. The mass (M) spectra have an interesting structure, and a detailed analysis by K. L. Au, D. Morgan and M. Pennington reveals a rich underlying structure of particle resonances, one of which could be the long-awaited lightest 'glueball' — a state made of gluons rather than quarks.

The prime candidates up to now have been the f_2 (mass 1720 GeV), previously called theta, and the eta (1440), previously called iota, both found in the radiative decays of J/psi particles, a favourite hunting ground for glueballs. The spin-parity of these particles make them unlikely candidates for the lightest member of the spectrum.

Other candidates include the f_0 (1590) which decays mainly to eta plus eta prime, and three states just above 2000 MeV seen in the production of pairs of phi mesons. If the mass scale of bag model calculations is set by accepting the f_2 (1720) and eta (1440) as glueballs, the mass of the lightest (spin zero) member of the spectrum can be estimated at about 1000 MeV.

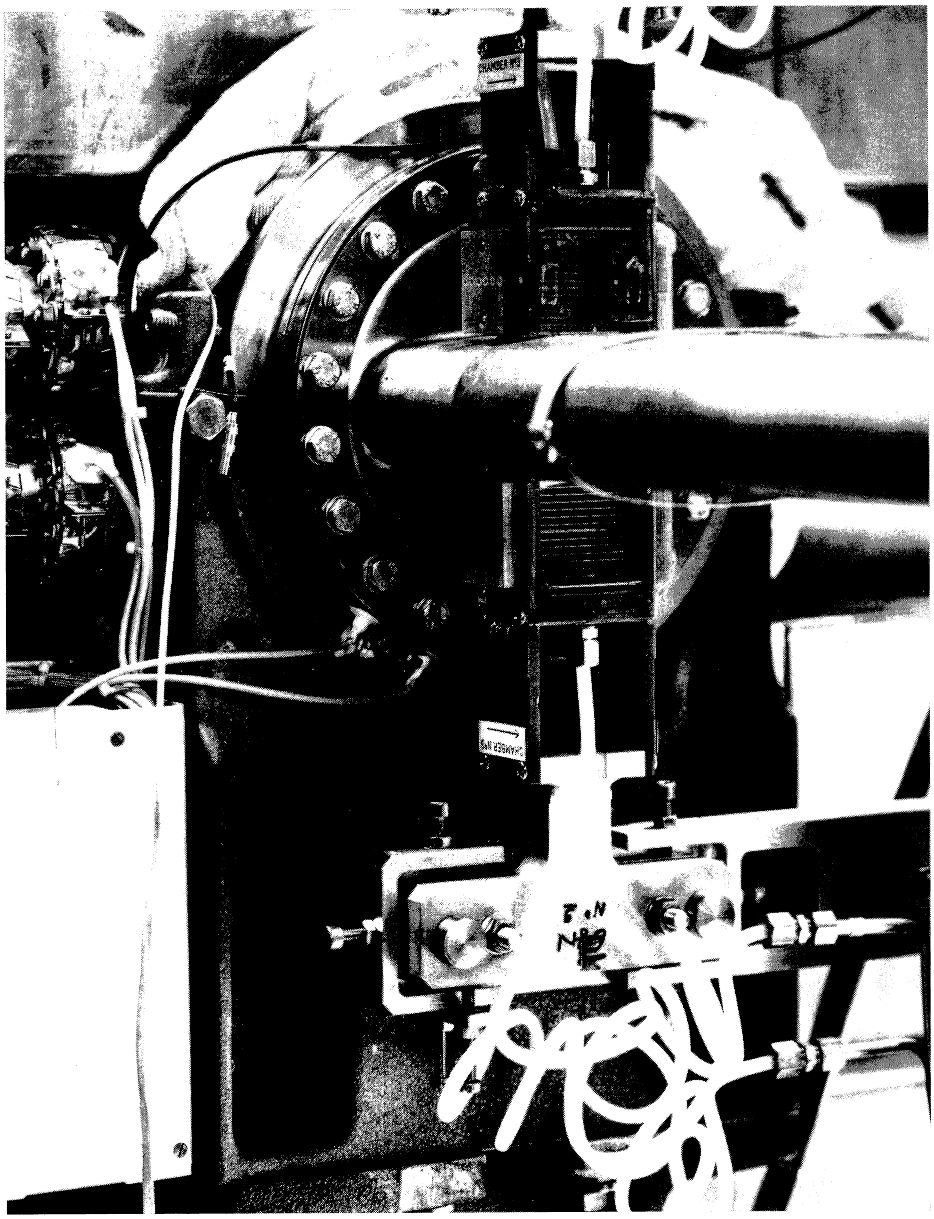
It is almost exactly here that a new candidate state has been found in a deep analysis of data taken by the Axial Field Spectrometer Collaboration (Experiment R807) during the last year of running at CERN's Intersecting Storage Rings. Using additional detectors placed close to the beam direction, the experiment selected a sample of some three million events with the unusual feature of having the two colliding protons emerging almost unchanged in energy and direction (quasi-elastic scattering).

Subsequently selecting events with just a pair of pions or kaons created almost at rest in the collision's centre-of-mass, the group studied the mass spectrum and angular distributions of the pion or kaon pair. This type of reaction can be thought of in terms of a (virtual) state potentially present in the vacuum being kicked into reality by the glancing passage of the two protons.

The positive plus negative pion spectra show a peculiar shoulder and drop at 1000 MeV, and there is more structure at higher masses. Analysis of the angular distributions shows that up to above 1000 MeV the pion pair carries zero spin and positive parity. The steep drop at 1000 MeV was initially interpreted as being caused by a known resonance called the S* (now f_0 (975)) considered to be essentially a bound state of two neutral kaons.

The chambers used by the Axial Field Spectrometer experiment to pick up forward protons close to the beam pipe of the CERN Intersecting Storage Rings.

(Photo CERN 239.2.82)



However a recent and more refined analysis of this data, together with information from the positive plus negative kaon spectrum just above the 987 MeV threshold (by K. L. Au, D. Morgan and M. R. Pennington) concludes that a single narrow resonance is not enough to fit the data, and suggests that the S* is in reality two close and narrow states.

One, the S_1 (988) prefers neutral kaons and is likely to be a bound state of these particles. The new feature is the S_2 (991), with a width of about 42 MeV and coupling equally to pion and kaon pairs, as expected for a glueball. This analysis also finds two broad scalar resonances, epsilon (900) and epsilon prime (1430), which can be relatively conventional light-quark mesons. The analysis takes into account and also fits many other experimental results. Unless it is particularly perverse, the lightest glueball should be heavier than about 900 MeV, according to this analysis. Hopefully more high statistics experiments, especially on the kaon pair channel thresholds, will provide additional insights.

From Mike Albrow

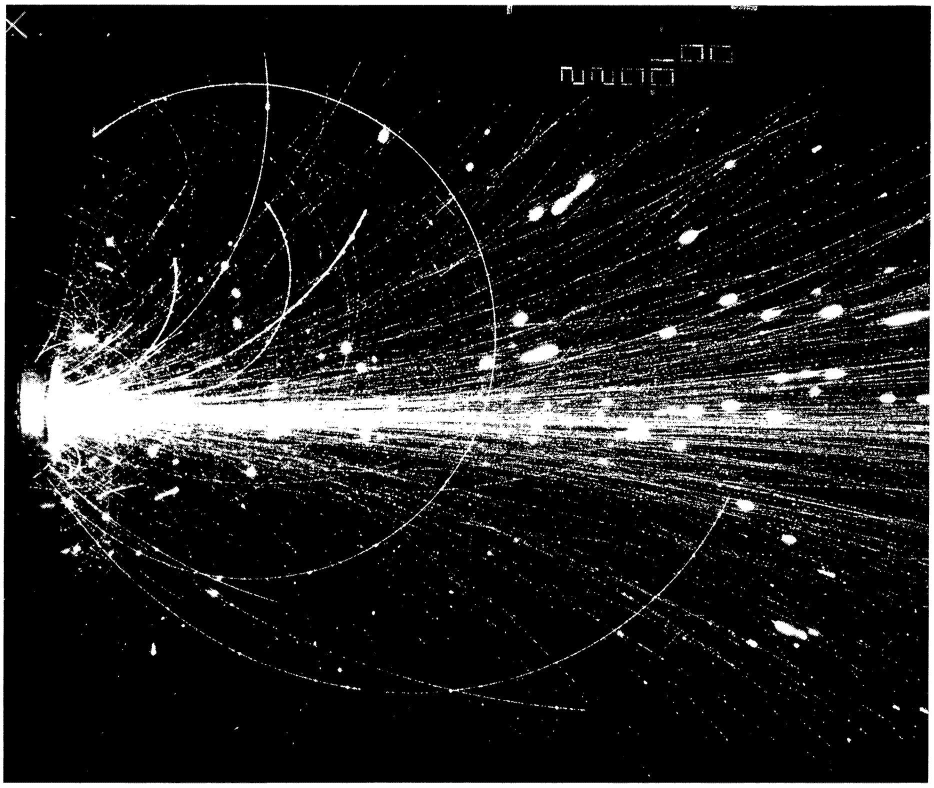
End of the film

For many years, physicists relied on photography to record the details of subnuclear interactions. Film in particular has a long tradition, dating back over thirty years to the demise of emulsion techniques and the advent of accelerators supplying regular beams. Film came from spark chambers, from generations of cloud and bubble chambers, and more recently from triggerable streamer chambers.

Having taken the pictures, the next task was to study and analyse them. Initial manual measurements of range and track curvature rapidly gave way to the computer. Also the increased picture output per experiment led to fully automatic devices like the HPD (Hough-Powell Device) and the Spiral Reader, and to on-line checking and reconstruction.

The arrival of giant bubble chambers such as Gargamelle and BEBC at CERN, the 15-foot at Fermilab and Mirabelle at Serpukhov brought complicated optics and large, intricate event patterns, especially when using heavy liquids. Fully automatic measurement was impossible for such complex events, but automatic track following with on-line quality checking, recording and reconstruction became indispensable.

The streamer chamber pictures from the NA35 experiment at CERN looking at the results of oxygen ion collisions are among the last customers for CERN's ERASME/Bessymatic film measurement and analysis system.



Hence the ERASME project was launched in 1970. Using a light ray, film scanning measurements reached a precision of several microns, while in parallel a whole area of film could be reproduced as a high precision TV picture. In this way a picture could be overlaid with measurements, considerably assisting the subsequent analysis.

The first ERASME measuring table came into operation in 1973, and was followed by five more. Tables based on the CERN design were also used in Bonn and Madrid. Digital Equipment Corp. (DEC) computers were the norm, both for table control (PDP 11) and for central data handling (PDP 10 and VAX 780).

Although ERASME could have been used for all aspects of film analysis, the workload became so large that some tasks had to be subcontracted to the simpler Bessymatic tables, and the two systems became highly complementary.

With the advent of the SPS in 1977 and its comprehensive programme of experiments with hadron and neutrino beams, ERASME really came into its own, uncovering many important physics results. Later came a series of major SPS experiments incorporating special bubble chambers to study the initial interaction vertex. Among other things, this effort helped to pin down the lifetime of charmed particles. With the recent arrival of higher energy beams from Fermilab's Tevatron, several experiments migrated, and the resulting pictures are among the final tasks for ERASME and Bessymatic machines.

In parallel, the streamer chamber technique was evolving fast. A milestone was the UA5 experiment at CERN's proton antiproton Collider: here were chambers six metres long, with six cameras (a total of twelve views) recording sometimes hundreds of tracks emerging in all directions from an out-of-sight interaction point. However the excellent pictures turned out to be relatively easy to analyse, and made vital contributions to the historic proton-antiproton Collider physics programme.

One of the experiments (NA35) studying the recently-arrived high energy ion collisions in the SPS synchrotron (see October issue, page 37) also uses a streamer chamber and is perhaps the last new ERASME/Bessymatic client.

Although no longer a front-line particle physics technique, photography continues to provide some of the most striking examples of particle physicists' work. Schoolchildren, students, VIPs, all have admired and profited from the immediacy that film pictures provide. Just as generations of physicists had their first insight into the subnuclear world through Patrick Blackett's cloud chamber pictures, so film records of particle physics will be assured of a captive audience for many years to come.

From Peter Schmid

Three of CERN's ERASME film handling tables are being dismantled, and the remaining three will soon follow the same fate. Bessymatic tables too are being phased out. Because of the age of the equipment, installation and commissioning elsewhere appear difficult. However requests for components as spares or replacements should be addressed to J. C. Gouache, EF Division, CERN, 1211 Geneva 23, Switzerland, as soon as possible.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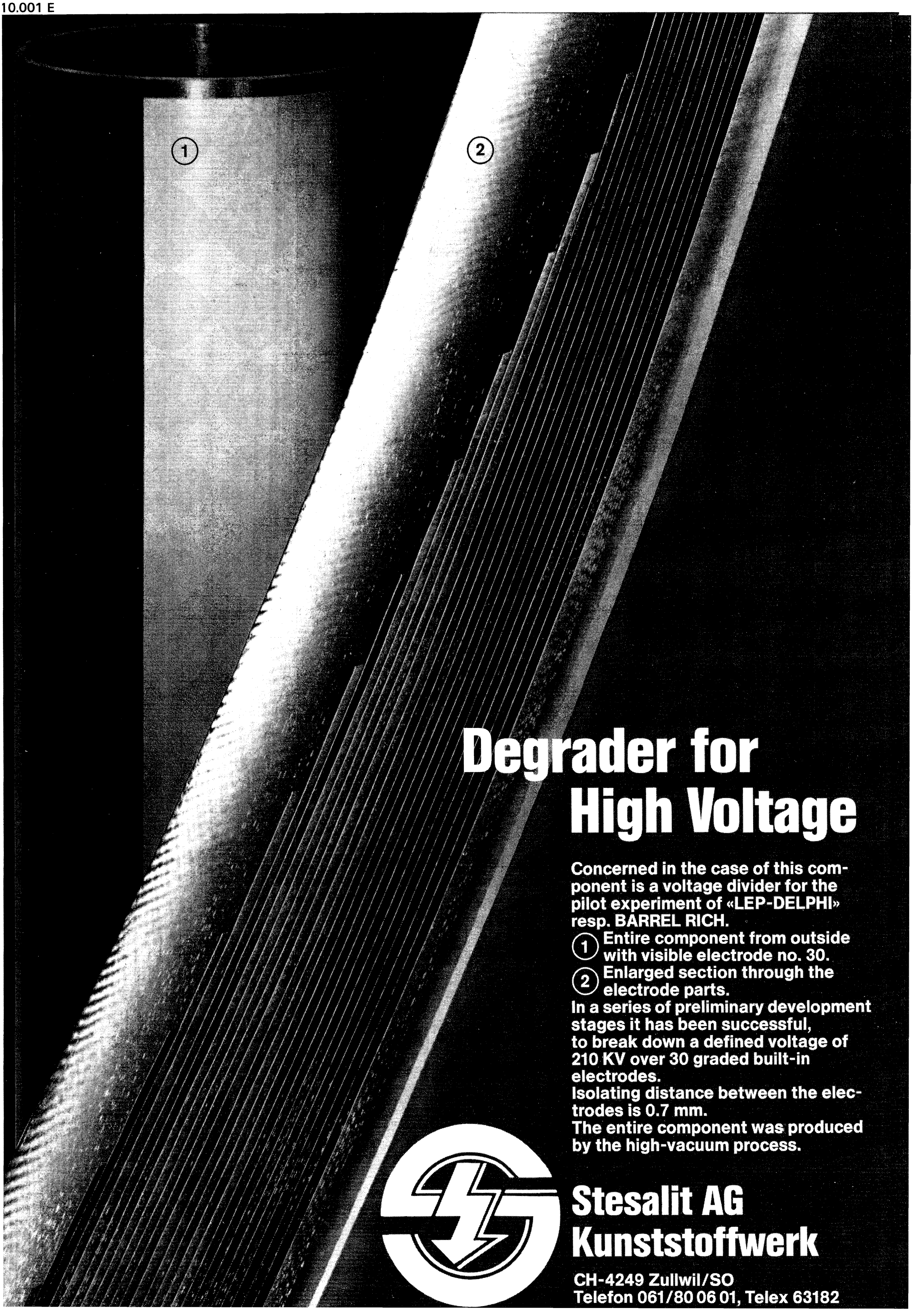
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DESY Theoryfest

The traditional annual Theory Workshop at the German DESY Laboratory in Hamburg concentrated this time on quantum chromodynamics (QCD) — the unchallenged but yet to be convincingly confirmed theory of quark and gluon forces in strong nuclear interactions.

In principle, QCD describes a broad range of phenomena, but it is a long way to get from the apparently simple basic equations of the theory to the observed experimental data. Tests of QCD are good only to within about 20 per cent, and in many cases a lot of work is required even to attain this goal.

However the workshop showed that theorists are far from discouraged by technical difficulties and try to make progress with refined perturbation methods and with numerical simulations.

A number of invited speakers discussed the production of 'jets' of hadrons in electron-positron and proton-antiproton annihilation. W. Scott of the UA1 experiment at the CERN proton-antiproton Collider summarized new data, reporting broad agreement with QCD. But there are large uncertainties, in particular when measuring the jet energy, making it difficult to give accurate production rates. The strength of the QCD coupling quoted by Scott was higher than that from previous electron-positron measurements at DESY's PETRA ring. It could be that higher orders of QCD perturbation theory are required or that the formation of hadrons from quarks and gluons ('fragmentation') does not follow the assumed pattern.

PETRA retires undefeated

On 3 November, the PETRA electron-positron storage ring at the DESY Laboratory in Hamburg ended its remarkable eight-year career as a machine for high energy physics experiments. By cunningly switching off ten days before the new TRISTAN ring at the Japanese KEK Laboratory collided 25 GeV beams (50 GeV total energy, see page 1), PETRA managed to retire with its record of 23.35 GeV colliding electron and positron beams still intact.

Built with a design goal of 19 GeV per beam, additional PETRA accelerating power was gradually wheeled in, eventually leading to the record figure early in 1984. As well as pushing up the energy of the collisions, PETRA supplied lots of them, with good luminosity being enjoyed by five experiments over the years — CELLO, MARK-J, JADE, PLUTO and TASSO, bringing together a total of about 400 physicists from 12 countries.

A milestone discovery in 1979 assured PETRA of a place in physics history. Clear two-jet structures, coming from quark pairs formed in the electron-positron annihilations, were seen almost as soon as PETRA was switched on. The sighting of a third jet showed that gluons were also being released. As well as providing the first direct evidence for the carriers of the inter-quark force, this new PETRA physics enabled the strength of the quark forces to be measured.

Although PETRA's energy was insufficient to isolate the W and Z boson carriers of the weak nuclear force, delicate effects due to these particles were nevertheless observed. This boosted confidence in the underlying theory and helped pave the way for the discovery of the W and Z at CERN in 1983.

PETRA experiments also made pioneer contributions in the field of two-photon physics — the scattering of light by light.

Despite the big push for higher energy, the sixth ('top') quark was not reached, but this provided important new limits.

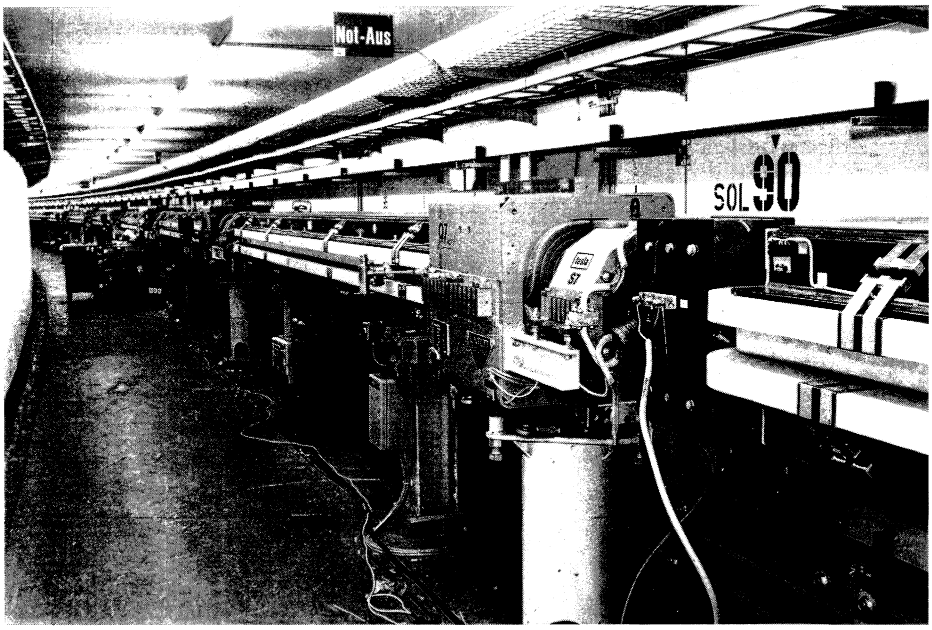
As well as physics successes, the groups working at PETRA also made notable contributions to instrumentation progress — the JADE jet chamber, precision vertex chambers, etc.

On the machine side, PETRA was to give the first example of the 'mini-beta' scheme in action. This technique had been proposed at DESY to squeeze the colliding beams even tighter together and improve the luminosity. Good polarization (spin alignment) levels were obtained thanks to careful machine tuning, while new materials, such as aluminium for vacuum chambers, were exploited. PETRA also served as a test-bed for prototype superconducting radiofrequency accelerating cavities, providing valuable experience in this new technology, now planned for several future machines.

Over the next twelve months, the PETRA ring will be modified for its new role as an electron, positron and proton injector for the HERA storage ring now being built at DESY.

PETRA at the DESY Laboratory in Hamburg, retired undefeated champion of the electron-positron ring.

(Photo DESY)



New calculations in quark dynamics have already begun (reported by R. K. Ellis of Fermilab). Results for jets are not yet available but a study of single hadron production shows large effects, particularly in the angular dependence.

A fundamental problem in all this work is the appearance of terms which increase rapidly with energy and must therefore be summed. D. Soper of Oregon explained how to deal with such soft gluons.

When using only a few orders of QCD perturbation, it is important to choose the coupling constant correctly to minimize contributions from higher orders. M. Fontannaz of Orsay gave a phenomenological justification for this optimization in the case of photoproduced hadrons.

During the fragmentation of high energy quarks into observable particles, cascades of gluons are radiated away. B. Webber of Cambridge showed that the coherence of this radiation has important implications.

A traditional test-bed for QCD is the quark structure (structure functions) of nucleons measured with penetrating lepton beams. C. Geweniger of Heidelberg concluded that the detailed kinematic dependence from QCD is applicable over a narrower range of exchanged momentum than had been thought (Q^2 above about 10 GeV^2).

For electron-positron physics in the upsilon region, D. Wegener of Dortmund had many results to report, including improved limits on certain tau lepton decays which, if seen, would upset conventional dogma.

The upsilon particles are understood as bound states of beauty quarks and antiquarks. Full QCD treatment is difficult and physicists habitually resort to non-relativistic potential models, covered by J. Kühn of MPI Munich. This approach describes the upsilons quite well, but there are still a few missing states. The emerging form of this potential is also suggested by numerical studies of lattice gauge theories (described by C. Michael of Liverpool), but the correlation of the two approaches is not straightforward.

No convincing evidence was presented for glueballs (particles composed of gluons rather than quarks) although there are candidates such as the eta 1440.

M. Pennington of Durham covered a careful analysis of pion and kaon pair production in proton-proton collisions (see page 17) which suggests several resonances, of which at least one could be a glueball.

QCD sum rules are one method for avoiding perturbation theory difficulties, and were described by L. J. Reinders of Bonn. However the most promising attempts to solve QCD at laboratory energies are coming from numerical calculations based on a theoretical lattice. While new predictions are beginning to emerge, the method is still in its infancy (A. Kronfeld of DESY — 'Solving QCD on a computer'). This is because realistic numerical QCD simulations using today's algorithms need 10^{20} arithmetical operations, not easily digestible by today's computers.

But the algorithms are being improved and computing time can be saved by improving the simulation procedures and overcoming the effects of the lattice, holding out new hope. More powerful computers would be an asset, and A. Terrano of Columbia related how some theoreticians have turned their attention to the design of special computers with highly parallel architectures.

Several completed or nearly completed machines attain speeds of between 0.1 and 10 Giga-operations per second, and are significantly cheaper than commercial machines with comparable performance. However the potential user

Roberto Peccei (left) and Martin Luscher at the traditional Theory Workshop organized by the DESY Laboratory in Hamburg.

(Photo DESY)

has to confront reduced flexibility and difficult software.

Even if a full QCD simulation on a lattice is still a dream, some interesting physics follows from bold approximations. G. Martinelli of CERN told of promising results for the weak decays of kaons into pions.

A crucial question underlying the whole lattice approach is whether the continuum limit of the (artificial) lattice really exists, and whether a perturbation approach is correct. Hints can come from numerical calculations, but a full analytic proof would be more acceptable. G. Mack of Hamburg spoke on the continuum limit of lattice field theories and showed how the 'phase space cell expansion' (essentially a variant of the Wilson-Kadanoff block spin transformation) gives reason to be optimistic.

There is growing interest in the link between QCD and nuclear physics as pictures of the strong nuclear force under different conditions. F. Lenz of SIN covered a simple non-relativistic model for the interaction between many quarks and antiquarks, opening up, for example, the role of quark exchange in pion scattering and the states of the helium-4 nucleus.

The long-awaited quark-gluon plasma, where the quarks and gluons break loose from their conventional nucleon confinement, may be transiently produced in the collision of high energy ions, as indicated by H. Satz of Bielefeld. With no detailed understanding of the underlying scattering process, thermodynamic approaches can pay dividends.

At low temperatures, H. Leutwyler of Bern showed how the situation is well understood in terms of a pion gas whose properties can be calculated elegantly and accurately. At higher temperatures lattice techniques have to be brought in, and the phase transition to a quark-gluon plasma comes at an energy density of some 2.5 GeV/fm^3. With 20-50 GeV/fm^3 expected from heavy ion collisions, the creation of the plasma looks on the cards. How could it be recognized? One possibility would be a dilepton spectrum without or with a reduced J/psi signal, as plasma quarks are not expected to form bound meson states.

The members of the DESY Theory Workshop Organizing Committee were R. Baier, H. Fritzsch, M. Lüscher, R. D. Peccei and K. Schilling.

From M. Lüscher

BROOKHAVEN
More from spin

For more than a decade it has been known that hyperons produced by protons are polarized to an unexpected degree. Most models try to relate these observations to polarization effects at the underlying quark level: polarization of the quark-antiquark pairs produced when colour-flux strings break, and/or the Thomas precession effect have been suggested as mechanisms responsible for the polarization. This type of model has had several successes and a few failures (see September 1986 issue, page 15).

It has long been realized that important information could come from measuring the influence of the proton polarization on that of the hyperon. Does the hyperon spin remember the proton spin direction? The simple quark picture implies that lambda particles should have no memory of the proton spin direction but that sigma particles should have their spin pointing in the same direction as the proton almost all the time.

The advent of the polarized proton beam at the Brookhaven Alternating Gradient Synchrotron allowed this measurement to be made. A team of physicists from Rice / Brookhaven / Johns Hopkins / Houston / Southeastern Massachusetts performed the first part of the experiment by measuring the lambda polarization using 13 and 18 GeV polarized proton beams. They report that, as predicted, the lambda polarization is uninfluenced by that of the proton. In addition the left-right asymmetry in lambda production arising from the proton spin direction is very small, in agreement with the prediction of the model. This group is planning to extend the measurements to the neutral sigma particle.

Ions in the fire

In the euphoria following the smooth addition of high energy ion beams to the physics armoury at CERN, the pioneering work in other Laboratories or the plans elsewhere to carry the ion energies still higher should not be overlooked.

Berkeley has held pride of place for some years with the Bevalac providing ions across the periodic table at energies from 20 MeV to 2 GeV per nucleon. Many of the beams have the highest available intensities, supporting a broad nuclear physics programme plus a biomedical programme. The latest proposal dates from 1986 and involves replacing the venerable Bevatron with a modern synchrotron to step up beam intensities by a factor of a hundred.

Alert readers spotted the inadvertent error in our September 1986 issue alleging that the SPS wrested the oxygen ion energy record from the Bevalac. The Berkeley machine can reach 32 GeV for oxygen but this is surpassed by the Synchrophasotron at Dubna (USSR) which takes the ions to 67 GeV. This work at Dubna began in 1971 and they can achieve 4.2 GeV per nucleon with fully stripped ions up to silicon. They have been working on the design of a superconducting synchrotron, called the Nuclotron, to accelerate the full range of elements up to 6 GeV per nucleon. Another machine that was revivified by conversion to ions, like the Synchrophasotron, is Saturne at Saclay.

A Laboratory with long experience with ions is GSI Darmstadt where the Unilac linear accelerator has been providing beams since 1976. They are now constructing a synchrotron and small storage ring to be fed from Unilac. They plan to have a wide range of ion beams with energies up to 2 GeV per nucleon.

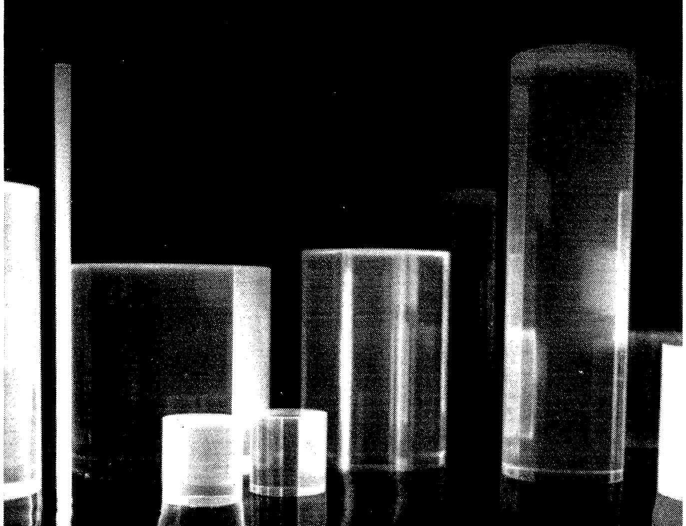
In Japan interest in ions has been alive since the mid-70s. A Test Accumulation Ring, TARN, at INS Tokyo is being upgraded as TARN II to provide 0.5 GeV per nucleon for the lighter ions. Dreams of GeV beams with ions up to uranium led to a design report for a 'Numatron' ten years ago, but it has not had financial support.

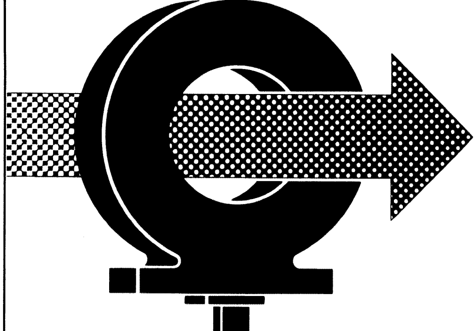
Another possibility is provided by the 12 GeV Proton Synchrotron at the nearby KEK Laboratory.

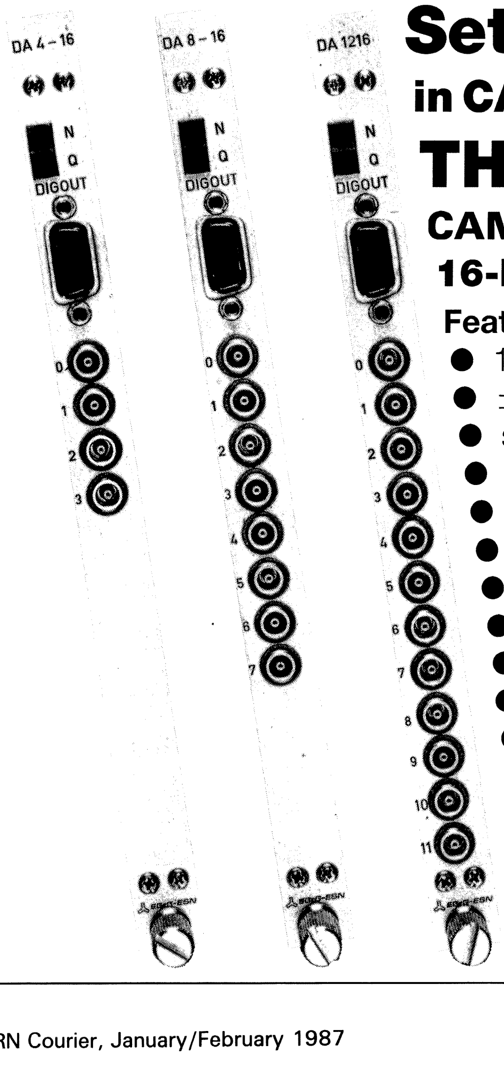
Another project awaiting dollars is one which could take over the torch from CERN — the RHIC, Relativistic Heavy Ion Collider, at Brookhaven. This would use the Isabelle ring tunnel to set up colliding ion beams at up to 100 GeV per nucleon. Preparations are well underway and ions went through Brookhaven's Alternating Gradient Synchrotron for the first time in 1986.

PARTICLE BEAMS
Frontier course

Driven by the quest for higher energies and optimal physics conditions, the behaviour of particle beams in accelerators and storage rings is the subject of increasing attention. Thus the second course organized jointly by the US and CERN Accelerator Schools looked towards the frontiers of particle beam knowledge. The programme,







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DIGOUT

At the US/CERN Joint Topical Course on the Frontiers of Particle Beams, held on South Padre Island, Texas, from 23-29 October, the US Particle Accelerator School's 1986 Prize for Achievement in Accelerator Physics and Technology was awarded to Tom Weiland of DESY, Helmut Piel of Wuppertal and Maury Tigner, Director of the Central Design Group of the proposed US Superconducting Supercollider. With the awards are (left to right) Piel, ceremony chairman and CEBAF project director Herman Grunder, Jorg Rossbach of DESY (receiving the award on behalf of Weiland), and Tigner.
(Photo S. Turner)

The US Particle Accelerator School's 1986 Prize for Achievement in Accelerator Physics and Technology was awarded to Tom Weiland, Helmut Piel and Maury Tigner (see October 1986 issue, page 39) after the School banquet.

The next major event for the CERN Accelerator School (CAS) is a Workshop on New Developments in Particle Acceleration Techniques to be held in Orsay, France, from 29 June-4 July. It will review current theoretical and experimental developments in the techniques for accelerating charged particles, including specific objectives related to higher energy machines for the future. After introductory talks, the programme will be split between plenary sessions and working/discussion groups. Further information from Mrs. N. Mathieu, LAL, Bat. 200, 91405 Orsay Cedex, France.

CAS will be having its Advanced Accelerator Physics Course in Berlin (West), in collaboration with the BESSY synchrotron radiation centre, from 14-25 September.

held at South Padre Island, Texas, from 23-29 October attracted 125 participants including some 35 from Europe. (The first joint course, held in Sardinia early in 1985, dealt with nonlinear dynamics.)

The first half of the course covered mainly mathematical topics - single and multiparticle dynamics, multiparticle correlations and beam noise, intra-beam scattering, coherent instabilities, and electromagnetic fields with emphasis on wake field calculations and space-charge dominated beams. Synchrotron radiation and coherent radiation in the free electron laser were described from a less mathematical viewpoint.

The second half of the course reflected the wide interest in linear colliders. The programme was supplemented by a series of topical seminars including the recent idea of 'crystal beams', where the transverse beam temperature becomes so low that in principle the beam particles should take up positions in a lattice.

CHALK RIVER Superconducting tandem

The Tandem Accelerator Superconducting Cyclotron (TASCC) at the Chalk River Nuclear Laboratories of Atomic Energy of Canada Limited, officially opened in October, provides world-class research facilities for intermediate energy heavy ion physics.

The Chalk River tandem which came into operation in 1967 was upgraded from 10 MV terminal voltage to 13 MV in 1972. At the same time, plans were made to use it as an injector for a booster accelerator to produce beams of up to 50 MeV/nucleon for light, fully stripped ions and up to 10 MeV/nucleon for uranium.The chosen accelerator was a superconducting cyclotron conceived at Chalk River by Bruce Bigham and Harvey Schneider: a four-sector isochronous machine with a maximum midplane field of 5 T.

For budgetary reasons the project was divided into two parts: the first covered building additions, modifications to the tandem (including reversing the beam direction, construction of the cyclotron and beamlines from the tandem). Interim target locations just beyond the cyclotron are available with beams from TASCC or from the tandem alone. The second phase covers construction of beamlines

The Chalk River Superconducting Cyclotron with most of the people who helped to bring it into operation.

(Photos Atomic Energy of Canada Ltd.)

to nine target locations. Phase 1 was approved in the autumn of 1978 and the tandem shut down in May 1982. The first beam of 1.3 GeV iodine-127 ions (10 MeV/nucleon), was successfully extracted in mid-November 1985.

Although accelerator commissioning is not complete, experiments are well underway at the interim target locations. The first was a measurement by the recoil-distance method of lifetimes of high-spin levels in osmium-174 produced from vanadium-51 using a 5.6 MeV/nucleon iodine-127 beam. In the second experiment, the little known isotopes tantalum-160 to 164 far from the stable 181 isotope, were produced by bombarding calcium-40 also with a 5.6 MeV/nucleon iodine-127 beam; their alpha and gamma decay properties will yield up to eight new nuclear masses in a remote region of the nuclear chart.

The TASCC experimental programme will centre on three major facilities. The first is ISOL, an on-line isotope separator for studying the properties of nuclei far from stability which came into operation in 1979 and has already produced impressive results. It combines high mass resolution with low cross-contamination, thus allowing direct mass determinations and exceptionally precise half-life and decay measurements.

The second major piece of equipment is a recently completed gamma ray spectrometer consisting of a hollow sphere (22 cm inner diameter) formed by 72 BGO crystals surrounding a target. Outside the BGO ball are twenty high resolution germanium detectors, each of which has BGO Compton suppression. The instrument is a national facility and was constructed as a joint Chalk River/Montreal/McMaster venture with half of the funding provided by Atomic Energy of Canada and half by the Natural Sciences and Engineering Research Council (NSERC) which provides research funding for Canadian universities.

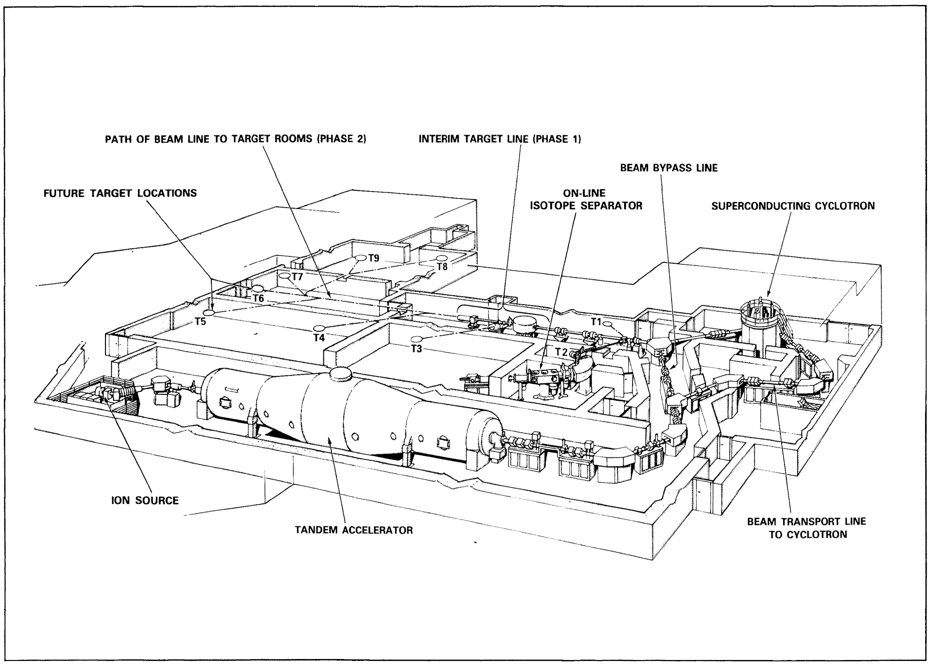
The third major facility will be a large (over 3 m diameter) particle scattering chamber now being designed. It will have a spherical array of 64 Bragg curve heavy-ion spectrometers backed by detectors for measuring light ion energy and angle and for particle identification, and a forward angle array for products emitted approximately along the beam trajectory.

At the TASCC opening ceremony, Allan Bromley of Yale gave the keynote address, reminiscing about his early days at Chalk River working on the world's first tandem accelerator, the EN. He traced the development of heavy ion experiments and machines to today's accelerators which are capable of producing beams energetic enough to exceed the Coulomb barrier for any projectile-target combination. He also pointed out the many practical applications resulting from basic scientific research and stressed the need for government funding if a country is to be technologically advanced.

The ceremonies concluded with the unveiling of an official plaque by the Atomic Energy of Canada Chairman R. Dépres. He called the opening 'a national achievement of international proportions. Nuclear physics research at Chalk River has, over four decades, consistently earned a worldwide reputation for innovation and excellence. This new accelerator complex will ensure that Canadian scientists remain at the forefront of their field.' He read a statement from Marcel Masse, Canada's Minister of Energy, Mines and Resources, which lauded the value of basic research. 'By providing a facility at which government and university scientists can do this basic research together, TASCC is helping to build this country's future.'

Following the official opening, a one-day symposium on heavy ion nuclear physics brought together experts on heavy ion accelerators and the physics of the TASCC experimental programme. Henry Blosser of Michigan State University and Director of the US National Superconducting Cyclotron Laboratory (NSCL) spoke about the technological breakthrough of superconducting cyclotrons (10-20 times lighter than normal magnet machines) and discussed some of the challenging design issues. The NSCL machine, the first of its type, had first extracted beam in August 1982 (see also December 1986 issue, page 22). Blosser felt that no large room-temperature cyclotron would ever be built again.

Peter Braun-Munzinger of the State University of New York, Stony Brook, presented recent results on pions and high energy photons as probes of heavy ion reaction dynamics. Dick Diamond of Berkeley gave an overview of the current state of high spin nuclear physics and Gregers Hansen of CERN and Aarhus spoke on nuclei far from stability.



▲ *Layout of the accelerators, beamlines and interim target locations for Phase 1 (completed) as well as the beamlines for Phase 2 (dot-dashed lines, under construction) at the Tandem Accelerator Superconducting Cyclotron at Chalk River, Canada.*

▼ *Guest speakers at the opening ceremonies and symposium for the new Canadian superconduction machine. Left to right, Gregers Hansen, CERN and Aarhus; Henry Blosser, Director of the US National Superconducting Cyclotron Laboratory, Michigan; Peter Braun-Munzinger, Stony Brook; Richard M. Diamond, Berkeley; and D. Allan Bromley, Yale. The after-dinner speaker at the banquet was R. E. Bell, professor emeritus and former principal of McGill University.*

Accent on the future at Novosibirsk Conference

Status reports on colliding beam facilities, superconductivity, new acceleration concepts for linear colliders, and plans for future big accelerators... these were the main topics at the XIIIth International Accelerator Conference in Novosibirsk last summer.

The luminosity goals for the high energy colliders were spelled out. This year the superconducting Tevatron at Fermilab hopes to reach 10^{29} per cm^2 per s with 800 GeV proton and antiproton beams, climbing eventually to 10^{30}. The lower energy CERN Collider, with its addition of the ACOL antiproton collector, is shooting for 10^{30} in 1987-88. For the electron-positron colliders, TRISTAN in Japan was on the brink of first operation at the time of the Conference and as reported on page 1 has come superbly into action with 25 GeV beams. The Stanford Linear Collider should not be far behind with 50 GeV beams and is hoping for progressively improving luminosity — 10^{29} this year, $5x10^{29}$ early next year, $2x10^{30}$ a year later and $6x10^{30}$ at the beginning of 1990. The luminosity goal of LEP at CERN with 60 GeV beams is the design figure of 10^{31} which should be reached fairly quickly. Finally HERA at DESY in Hamburg, with electron beams of 30 GeV and proton beams of 820 GeV, aims for a luminosity of $2x10^{31}$ when it turns on in 1990.

The superconductivity sessions covered the magnets which are now confidently incorporated in both projects for the next hadron collider — the SSC in the USA and the LHC at CERN — following the experience at the Fermilab Tevatron and HERA. This work was reviewed also at the ICFA Workshop on superconducting magnets held at Brookhaven in May of last year (see September 1986 issue, page 3).

Superconducting radiofrequency cavities are now being prepared for the 100 GeV stage of LEP at CERN, for HERA at DESY, for TRISTAN in Japan, and for the CEBAF linac in the USA. A superconducting linac is also an option under study for future linear lepton colliders in one of the two-beam schemes.

The various schemes for reaching high energies in linacs were reviewed and sets of parameters for linacs up to 1 TeV beam energy were presented less tongue-in-cheek than in the past. Experimental work, both on the linac schemes and on the plasma beat-wave concept are beginning to bear fruit.

The most ambitious of the future accelerator plans is, of course, the Superconducting Super Collider (SSC) in the USA which aims for 20 TeV proton beams. While this mighty project awaits a green light, CERN has pushed further its ideas on a 8.5 TeV Large Hadron Collider which could sit over the electron ring in the LEP tunnel. The LHC scheme would benefit from the existing high quality injectors at CERN and from the LEP infrastructure, and has the added attraction of rather easily having electron-proton collisions as an extra physics tool.

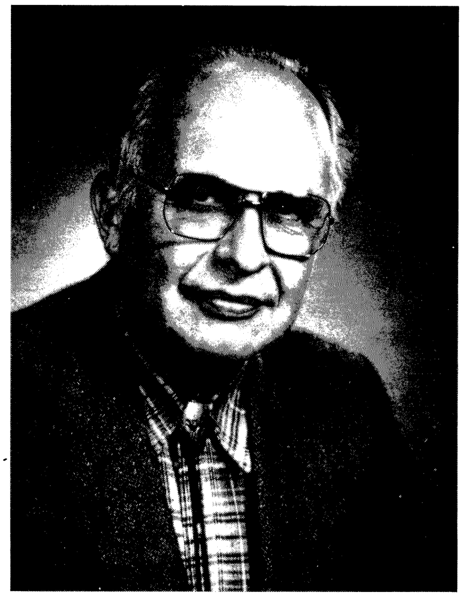
In the interim, the construction of UNK at Serpukhov in the Soviet Union is underway and they hope for 3 TeV beams for fixed target physics in 1993. On the electron front, people at Stanford are meditating about multi-hundred GeV machines to follow experience with SLC, and the Conference host Laboratory at Novosibirsk has similar ambitions.

People and things

On people

The prestigious Enrico Fermi Award, given by the US Department of Energy for exceptional and altogether outstanding achievement, was attributed in 1986 to Ernest Courant of Brookhaven and the late Stanley Livingston for their landmark contributions to the development of particle accelerators. It is unusual for the Fermi Award to be given posthumously, and a pity that after 'leadership contributions to the development of nuclear accelerators over a half-century' Livingston died last August before the announcement was made.

Robert K. Adair has been appointed Associate Director of Brookhaven National Laboratory for High Energy and Nuclear Physics. He is thus responsible for Brookhaven's AGS (Alternating Gradient Synchrotron) and Physics Departments, and Instrumentation Division.



Robert K. Adair — Brookhaven Associate Director

Taking advantage of its presence in England for the annual meeting of the British Association for the Advancement of Science, the CERN itinerant exhibition visited two other seats of learning before returning home. Pictured is the facade of Queen Mary College, London, where nearly 2000 schoolchildren saw the exhibition. Packed lectures on particle physics were held in parallel. At Royal Holloway and New Bedford Colleges, London, the exhibition was a key feature of a series of Open Days visited by fifty schools, the local population and some 300 industrialists.

(Photo Georges Claude)

Pulling in the crowds

Behind the trendy docklands developments along the north bank of the River Thames, London's sordid 'East End' hides from the public eye. Defying the drabness of Mile End Road, a main artery leading towards the glitter of the City financial district, is Queen Mary College, part of the University of London.

British physics, rather like London's East End, has not benefited from the most glamorous of images in recent years. Gone are the halcyon days of Rutherford, or so it seems. Yet, when QMC physicists invited schoolchildren along to their department recently, they discovered, almost to their surprise, that there are youngsters out there who are interested in finding out more about physics. And not just any physics, but the physics of elementary, subatomic particles — a topic that some have dismissed as irrelevant and impractical, and which has even come under special scrutiny.

The schoolchildren came along in droves — some 2000 during the course of four days, from all over the country — in response to the physicists' invitation.

Centrepiece of the visit was an exhibition from CERN. Earlier, this had been at Bristol University at the annual meeting of the British Association for the Advancement of Science. CERN had done a professional job, and it gave Peter Kalmus, professor in particle physics, the idea of housing the exhibition in his department at QMC for a week to make it accessible to more people. At the same time, he hoped to encourage potential students to visit the college. In addition to the exhibition, there were to be lectures on antimatter and the W and Z particles — areas of research in which QMC has played a key role.

The lecturers found themselves giving their talks each afternoon in lecture theatres that were filled to capacity. In addition, a cable TV company came to film the proceedings for a programme called Eureka, which goes out to 12 European countries in three languages.

The success of this venture shows to the doubtful that physics can pull in the crowds — if put over in the right way. And it shows again that fundamental research can captivate young minds. So what if it isn't going to lead to a new manufacturing industry next year; if it can encourage more students to regard physics as interesting, then basic research is performing an important task.

(From an article by Christine Sutton which originally appeared in the 'New Scientist'.)

Jean Sacton of Brussels has been reelected Chairman of the European Committee for Future Accelerators (ECFA). It was originally intended that Italo Mannelli would take over from Sacton, until Mannelli was elected as the next Chairman of CERN's Scientific Policy Committee, succeeding Don Perkins.

At CERN, Pierre Darriulat has been appointed Director of Research from 1 July, to succeed Robert Klapisch. Pierre Lehmann (France) has been elected Vice President of CERN Council.

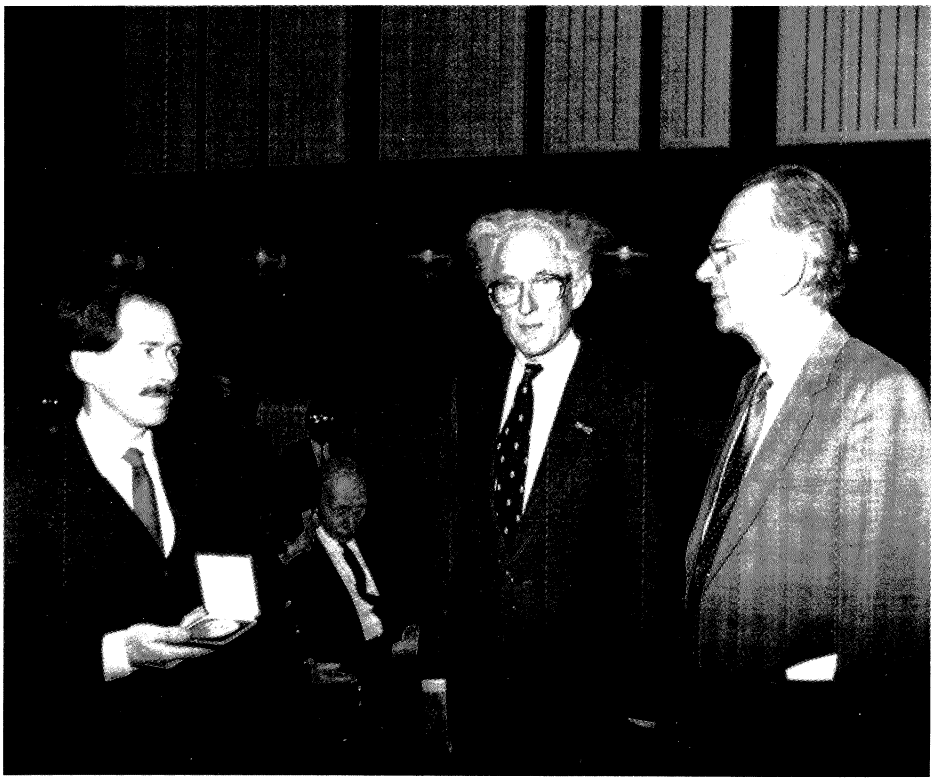
Geoff Manning has left the Directorship of the Rutherford Appleton Laboratory to become Chairman of Active Memory Technology Ltd, a new computer company specializing in array processors. Paul Williams becomes Acting Director of the Laboratory.

Retirements

Recently retired from CERN is Erhard Fischer, who made his mark in the 60s and 70s as Leader of the Vacuum Group for the Intersecting Storage Rings. Under his leadership, the ISR became the first large scale vacuum system bettering 10^{-11} torr, at a time when typical accelerators achieved 10^{-7} torr. This improved on the ISR design figure, very fortunately so as subsequent experience showed that the machine could not have worked at the specified 10^{-9} torr. A long term effort by his group also ensured that the ISR vacuum withstood the effects of large proton currents. His wide knowledge of accelerators has led to contributions on topics such as the motion of ions trapped in the ISR antiproton beams.

Another of the long-serving accelerator physicists now 'retiring' from CERN is Bryan Montague. He participated in the building of the Proton Synchrotron and first came into prominence as the prime mover of the work on radiofrequency particle separators which delivered much purer particle beams to the experimentalists at the PS.

He did much work on the electron ring accelerator concept after it first emerged in the Soviet Union and then joined the construction team of the Intersecting Storage Rings, with particular responsibility for the flags and scrapers for monitoring and tidying the beams. In recent years he has been an authority on polarization in electron-positron storage rings.

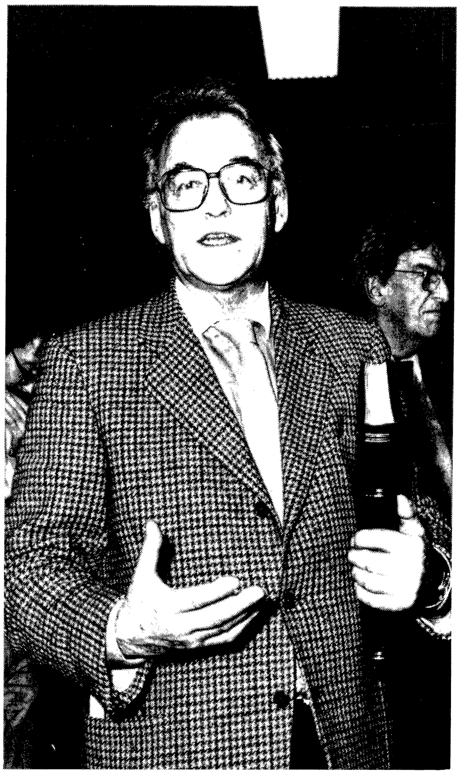


▲ *Theoretician Gerard 't Hooft (left) at the Amsterdam Trippenhuis on 24 November after having received the prestigious Lorentz Medal of the Royal Dutch Academy of Sciences from Leon Van Hove (right), who also gave the address. Centre is Academy President Johan van der Waals.*

(Photo Harry van Steenis)

▼ *Louis Dick, spin physics specialist and a pioneer of the gas jet target technique, was given an enthusiastic ovation by his colleagues to mark his 65th birthday*

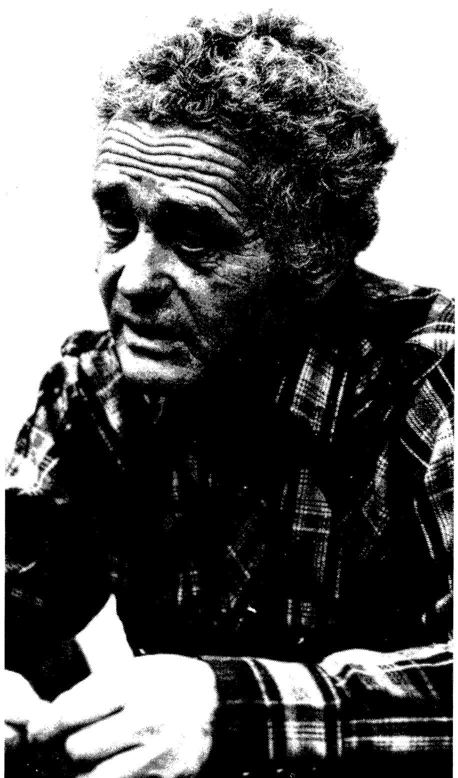
(Photo CERN 461.11.86)



Computing School

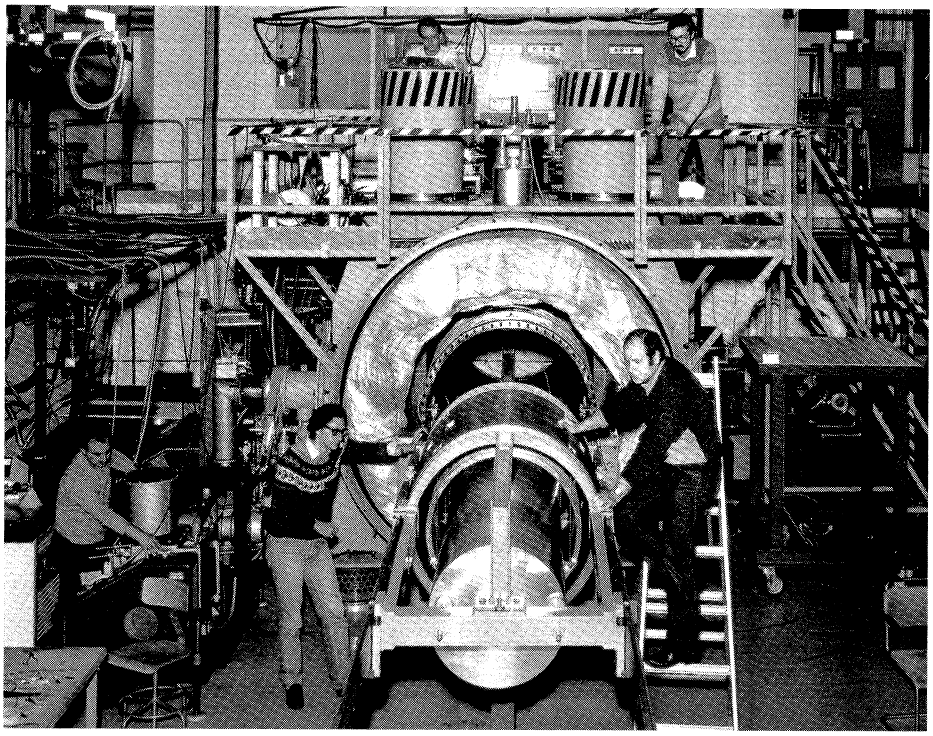
The CERN School of Computing, hitherto biennial, has become an annual event. The School is aimed at postgraduate students and research workers in physics or computing. This year it will cover a wide range of topics, and is being held in Troia, Portugal, from 13-26 September. Further information from Mrs. Ingrid Barnett, CERN, 1211 Geneva 23, Switzerland.

▶ *Yuri Orlov addressed a packed meeting of the Yuri Orlov Committee recently at CERN.*



At CERN recently was Heinrich Rohrer, who shared the 1986 Nobel Physics Prize with Gerd Binnig for their development of the scanning tunneling microscope, and with Ernst Ruska, pioneer of the electron microscope.

(Photo CERN 302.11.86)



Gravitational waves

The search goes on for gravitational radiation — the carrier of the large scale force between accumulations of matter. The existence of such waves was implied by the first formulations of general relativity some sixty years ago, but

Highly sensitive cryogenic antennae, such as this one at CERN operated by a Rome group, and two more in the US, are looking for signs of gravitational radiation. Although the individual detectors see some effects, no coincident signals are reported and the search goes on.

(Photo CERN 305.11.86)

Martin Wilson from Oxford Instruments (left) gave the second John Adams Memorial Lecture at CERN on 27 November, seen here with Phil Bryant who organizes the CERN Accelerator School. The theme of the lecture was 'Accelerators and superconductivity: a marriage of convenience' and Martin Wilson reviewed the long, hard road to the present applications of superconductivity, in which accelerator Laboratories played such an important part. While at the Rutherford Laboratory, Wilson helped develop the famous Rutherford cable. In addition to the big hadron machines, Martin Wilson cited widespread applications in nuclear magnetic resonance scanners and the promising development of tiny electron synchrotrons for silicon chip lithography.

(Photo CERN 440.11.86)

Stig Lundqvist (left), Chairman of the Scientific Council of the International Centre for Theoretical Physics (ICTP), Trieste, about to present one of the 1986 ICTP Dirac Medals to Alexander Polyakov of the Landau Institute of Theoretical Physics, Moscow, who admires his new ICTP tie. Looking on is ICTP Director Abdus Salam. Polyakov's award came in recognition of his important work in quantum field theory. The other 1986 ICTP Dirac Medal goes to Yoichiro Nambu of Chicago's Enrico Fermi Institute.

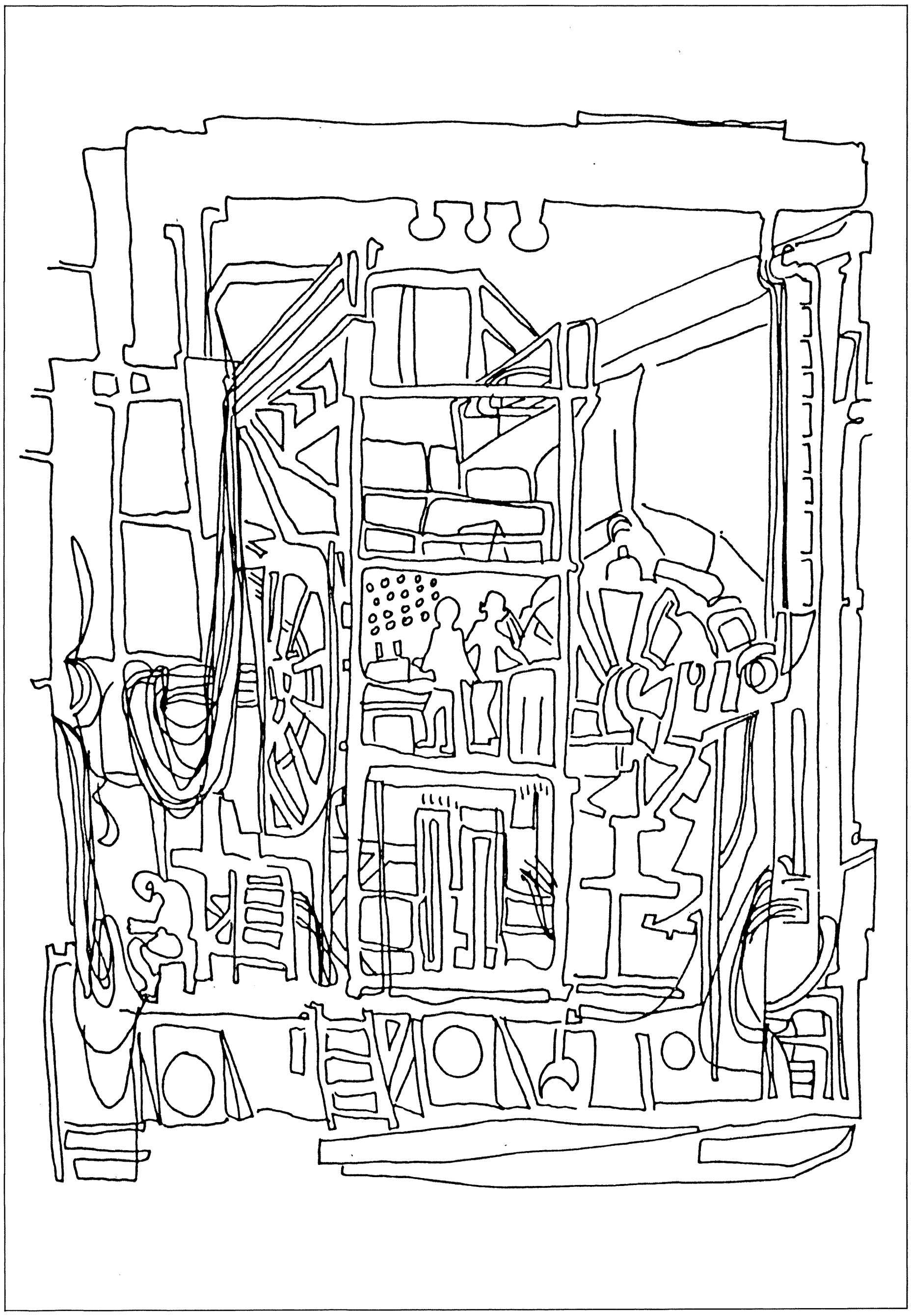
their detection has taxed the ingenuity of experimenters.

Any signals would be easily screened by seismic noise, etc. In an effort to eliminate this background, a network of three highly sensitive cryogenic detectors was set up — one at CERN, used by a Rome group, another at Stanford and a third at Louisiana State.

Preliminary results indicate no triple coincidences, despite individual detectors picking up some 60 'events' per day. However even the phenomenal sensitivity of these cryogenic detectors (about 1 part in 10^{18}) is insufficient to match the size of the signals expected from outside our Galaxy, where most of the gravitational activity should originate.

1987 JINR-CERN School of Physics

The 1987 JINR-CERN School of Physics is the tenth in a series organized by the Joint Institute for Nuclear Research (JINR, Dubna, USSR) and CERN. The aim is to teach various aspects of high energy physics, especially theoretical, to young experimentalists with at least one year's research experience, coming mainly from Member States of JINR and CERN. The 1987 School will take place at the Varna Department of the Academy of Social Sciences and Manage-



Artist's impression of a particle physics detector from 'Der Multimensch', the latest book from Pedro Waloschek, CERN Courier's regular correspondent at the German DESY Laboratory in Hamburg. Pedro's book (published by ECON Verlag of Düsseldorf) gives a fascinating glimpse into the inside world of particle physics.

(Illustration Jutta Waloschek)

Visiting CERN in November was Greece's Deputy Minister for Industry, Energy and Technology Mme Vasso Papandreou, seen here with CERN Director General Herwig Schopper.

(Photo CERN 288.11.86)

ment, Varna, Bulgaria, from 6-19 September.

Further information from Miss D. A. Caton, Organizing Secretary, 1987 JINR-CERN School of Physics, CERN, 1211 Geneva 23, Switzerland, or from Mrs. T. S. Donskova, USSR, 101 000 Moscow, Head Post Office, PO Box 79, JINR, as appropriate.

LEAR workshop

The fourth workshop to discuss physics at CERN's LEAR Low Energy Antiproton Ring will be held at Villars-sur-Ollon, Switzerland, from 6-13 September. As well as results from LEAR experiments to date and immediate plans, the meeting will also look to the longer-term future. Further information from C. Leluc, University of Geneva/-DPNC, 24 Quai E. Ansermet, 1211 Geneva 4, Switzerland.

Particle physicist John Rander practising a few tricks for a big climb. Such methods, described in his new book 'Assure sec' (in French), are the last resort in today's new wave of athletic rockclimbing.

(Photo Brigitte Rander)

Rock steady

An American experimental physicist leading the Saclay group participating in the construction of the electromagnetic calorimeter for the ALEPH experiment at CERN's LEP electron-positron Collider recently published a book in French on a subject rather far afield from particle physics: John Rander, in collaboration with his French wife, Brigitte, is the author-illustrator of 'Assure sec!' Techniques d'escalade en falaise, published by Edisud in Aix-en-Provence. The author drew from experience ranging from leading climbs on Yosemite walls, solitaires, frozen waterfalls, alpine north-faces... to sunny limestone cliffs in the south of France. John worked with René Turlay at Saclay on the WA 1 neutrino experiment at CERN before participating in ALEPH.

CERN Review Committee

The CERN Review Committee, under the Chairmanship of Professor A. Abraham, is soliciting the opinions of all CERN users on questions relating to the task entrusted to it by the Council.

For reasons of efficiency, a coordinator in each Member State has agreed to invite all CERN users to write down their views, to collect their contributions and to forward them to the Chairman of the Committee, with a brief summary of the main points, not later than 15 March.

The Committee is also prepared to consider any document addressed directly to it at CERN (c/o Simone Dubois).

The coordinators are:

Austria
Dr. W. Majerotto
Institut für Hochenergiephysik
Nikolsdorfergasse 18
A-1050 Vienna

Belgium
Prof. J. Lemonne
Institut Interuniversitaire
des Sciences Nucléaires
5, rue d'Egmont
B-1050 Brussels

Denmark
Prof. O. B. Nielsen
Niels Bohr Institutet
Blegdamsvej 17
DK-2100 Copenhagen Ø

France
Prof. M. Davier
Laboratoire de l'Accélérateur
Linéaire
Université de Paris-Sud
Bâtiment 200
F-91 405 Orsay Cedex

Dr. R. Turlay
Département de Physique
des Particules Elémentaires (DPhPE)
CEN, Saclay
B.P. N° 2
F-91 191 Gif-sur-Yvette Cedex

Germany
Prof. H.-E. Stier
Fakultät für Physik
Universität Freiburg
Hermann-Herder-Str. 3
D-7800 Freiburg

Greece
Prof. N. Antoniou
Democritos Nuclear
Research Centre
Aghia Paraskevi — Attiki
GR - Athens

Italy
Prof. L. Foa
INFN — Sezione di Pisa
Via Livornese
San Piero a Grado
I-56 010 Pisa

Netherlands
Prof. W. Hoogland
NIKHEF-H
P.O. Box 41 882
NL-1009 DB - Amsterdam

Norway
Prof. E. Lillestol
Department of Physics
University of Bergen
Allégatan 55
N-5014 Bergen

Portugal
Prof. J. Gago
Fisica Teorica et Met. Mat
Inst. Nac. de Invest. Cientifica
Av. Prof. Gama Pinto 2
P-1699 Lisbon Codex

Spain
Dr. J. A. Rubio
Junta de Energia Nuclear
Avenida Complutense 22
E-Madrid

Switzerland
Prof. R. Mermod
Ecole de Physique
Université de Genève
Quai Ernest-Ansermet 24
CH-1205 Geneva

Sweden
Prof. P. Carlson
Department of Physics
University of Stockholm
Vanadisvägen 9
S-11 346 Stockholm

United Kingdom
Prof. R. Devenish
Department of Nuclear Physics
University of Oxford
1 Keble Road
GB-Oxford OX1 3NP