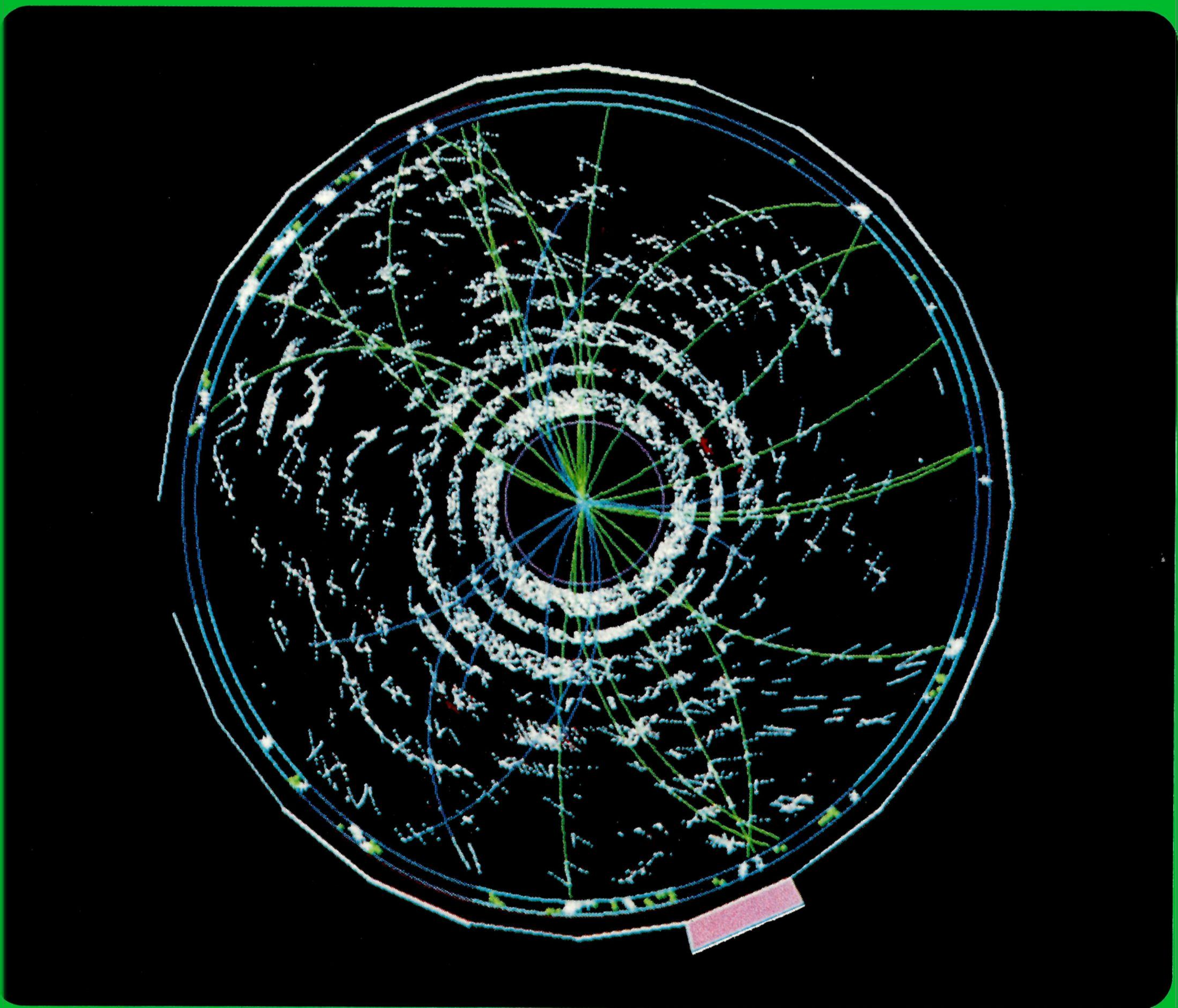
CERN COURIER

International Journal of High Energy Physics



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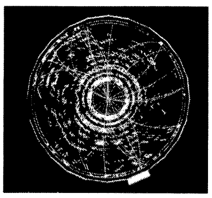
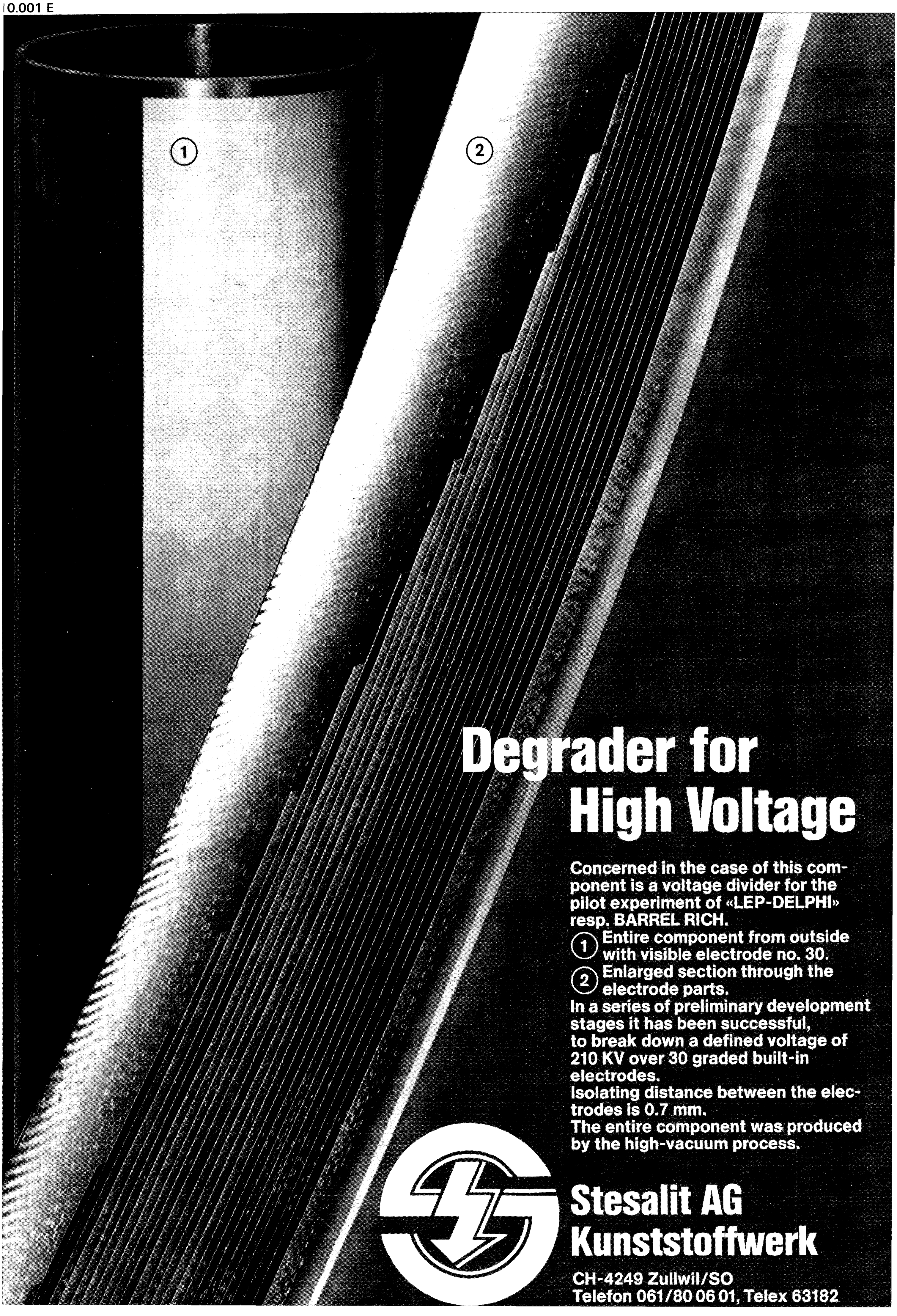


Cover photograph:
A beam's-eye view of the inner regions of the CDF detector at the Fermilab (US) Tevatron, showing particle tracks resulting from proton and antiproton beams smashing into each other at the world's highest laboratory particle collision energies (900 GeV/beam). The emerging tracks are bent by a magnetic field — the higher the momentum, the straighter the track. Bottom right is a very straight electron track, going on to deposit energy (pink) in the calorimeter beyond. Energy has to balance, and the apparent lack of a signal in the opposite direction suggests that energy is carried off by an invisible neutrino — the detector is 'seeing' the telltale energetic electron and neutrino from the decay of a W particle, the electrically charged carrier of the weak nuclear force, discovered in 1983 from a similar experiment at CERN.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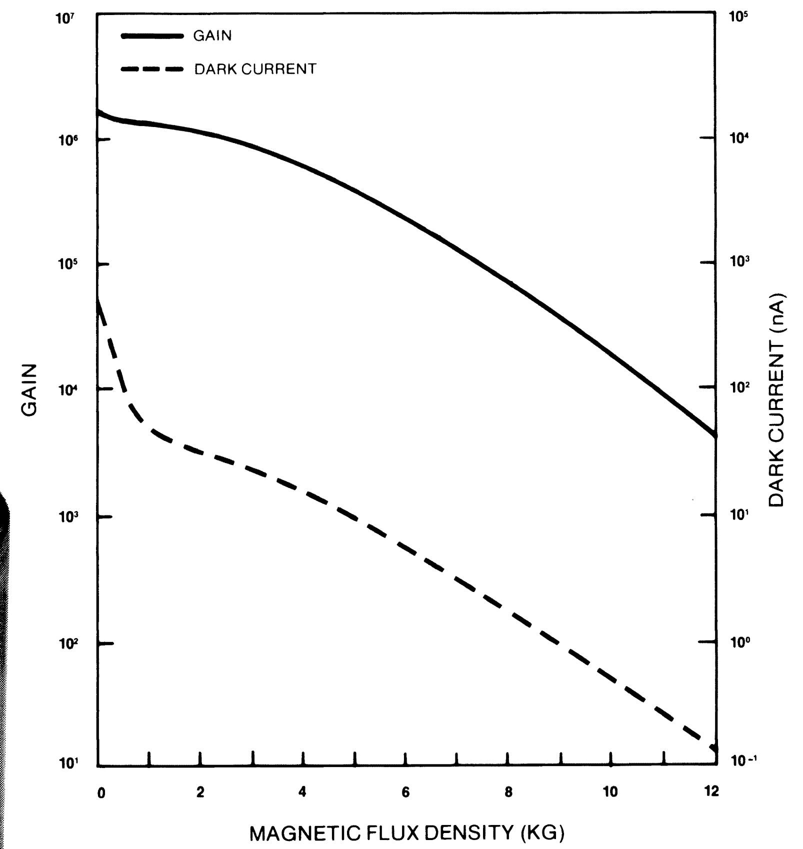

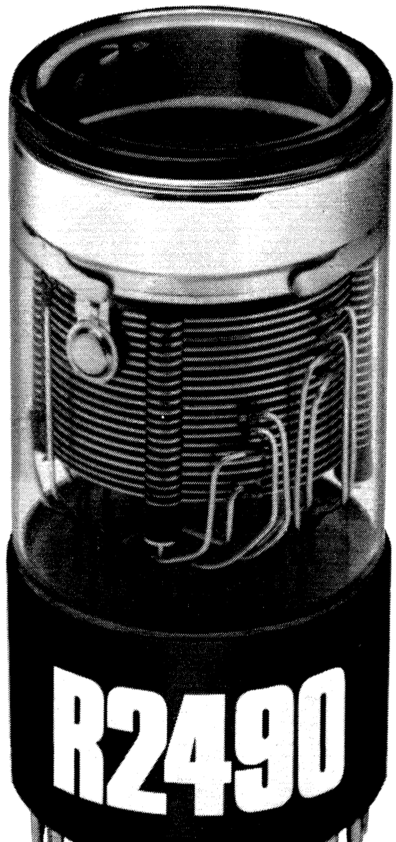

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Magnet attraction

CERN Director General Herwig Schopper (right) shows the distinguished visitor's book to Swiss President Pierre Aubert (centre) and French Prime Minister Jacques Chirac.

(Photo CERN 038.6.87)

On 4 June, CERN hit the headlines and prime time TV slots again when French Premier Jacques Chirac and Swiss President Pierre Aubert ceremonially installed the first magnet in the 27 kilometre tunnel for the LEP electron-positron collider, less than four years after French President François Mitterrand, with President Aubert, came to CERN for LEP's official groundbreaking.

Away from the hoopla, LEP tunnel piercing is nearing completion, and the remaining civil engineering work is progressing well. A vast programme for the installation of the thousands of LEP magnets will soon get underway to continue where Chirac and Aubert left off.

Multiton elements for 744 straight sections and 1640 pairs of dipole magnets to bend the beams are being put together on the surface, and will be taken by monorail to pithead PM18 for their descent to the tunnel 80 metres below. Here the LEP monorail will take the elements round the ring to their final destination.

The tricky business of placing the heavy magnets to a fraction of a millimetre in the tight confines of the tunnel (3.8 m diameter) will be handled by specially-developed 'Lobster' and 'Crayfish' manipulators.

With the room to manœuvre underground necessarily limited, certain components are nevertheless being built as long as possible (up to 12 metres) to speed up installation. The crunch comes when 60 000 tons of equipment have

Flanked by LEP Installation Group Leader Gérard Bachy and LEP Project Leader Emilio Picasso on the left and by CERN Director General Herwig Schopper and French Research Minister Jacques Valade on the right, Jacques Chirac and Pierre Aubert manipulate LEP's first magnet into position.

(Photo CERN 068.6.87)

to be lowered into the tunnel and installed. Rotating beams on the gantry cranes at five shafts will upend long units so that they can be eased down the narrow (6.7 x 2 m) shafts.

As the four large areas to house LEP experiments also near completion, work on the four complex detectors pushes forward, with thousands of components from all over the world arriving at CERN for final assembly and installation.

On 2 June, two days before the magnet installation ceremony, the big superconducting coil for the ALEPH experiment arrived at CERN from the French Saclay Laboratory, where it had left three weeks earlier (see page 14).

The superconducting coil for the DELPHI experiment will soon be tested at the Rutherford Appleton Laboratory in the UK.

Preparations for the big machine's electron and positron beams also gather momentum as CERN's 28 GeV 'Proton' Synchrotron, the hub of CERN's unique subnuclear particle supply system, restarted operations after a six-month shutdown and a major face-lift.

LEP's particles, supplied by the LEP Injector Linacs (LIL) via the EPA Electron-Positron Accumulator, will be pre-accelerated in the PS and the 450 GeV SPS Super 'Proton' Synchrotron before being injected into LEP. The PS had its first taste of electrons last year. Work on the positron supply continued during the six-month shutdown of the big machines, and the first positron beam was stored in EPA in April. The next step is to feed positrons into the PS and from there to the SPS (see April issue, page 13).

LEP's next major public exposure should be in spring 1989, when its colliding beams will open up a new domain of physics. Meanwhile, plans to install a second ring in the LEP tunnel, for colliding proton beams, are being pushed forward.

Jacques Chirac — synergies are possible between European and US projects.

(Photo CERN 101.6.87)

Caring about LEP

The ceremonial installation of the first magnet for CERN's LEP electron-positron collider by French Prime Minister Jacques Chirac and Swiss President Pierre Aubert on 4 June reflected their pride in Europe's achievements in particle physics, and the strong motivation to maintain its position.

CERN Director General Herwig Schopper underlined that the electron-positron collider was not the end of the road. 'This is why the new investment agreed by the CERN Member States, which is beginning to take shape as LEP, is worthy of all our care and attention and is of paramount importance for the future of European research. This is also why it is absolutely vital that this investment be exploited in the long term for all it is worth... Knowing that the LEP tunnel will probably be the last large ring to be excavated in Europe, at least for some considerable time to come, we contrived to optimize LEP's dimensions so as to be able to install a new machine in the same tunnel at some future date.'

After referring to LEP and to the US Superconducting Collider project, Jacques Chirac declared 'synergies are without doubt possible between the two projects'.

TRISTAN inauguration

Tetsuji Nishikawa, Director General of the Japanese KEK Laboratory, addresses the official inauguration ceremony for the new TRISTAN electron-positron collider on 7 April.

On 7 April, the floor of the Tsukuba experimental hall at the Japanese KEK Laboratory was filled with proud KEK staff and with official representatives from Japan and overseas for the formal dedication of the TRISTAN electron-positron collider.

In November last year, just five years after groundbreaking for the 3 kilometre ring, first electron-positron collisions were observed with 24 GeV beams, at the time the world's highest electron-positron collision energy. This heroic achievement propelled Japan and the KEK Laboratory into the front rank of world high energy physics, and the speeches at the dedication ceremony reflected the pride of the machine's instigators, builders and users, and the admiration of the world high energy community.

KEK Director General Tetsuji Nishikawa described the long road leading to TRISTAN: 'Cyclotrons built in this country by the late Professors Yoshio Nishina and Seishi Kikuchi and their coworkers were unfortunately destroyed and sunk in Tokyo and Osaka Bay respectively right after the war, consequently keeping Japanese experimental physics with high energy accelerators behind the world frontier of the field for a long time. In 1952, the Peace Treaty was ratified, and in 1955, thanks to the zeal and efforts of our seniors, the Institute for Nuclear Study attached to the University of Tokyo was founded and construction of a 1 GeV electron synchrotron followed. This, I would say, initiated Japanese high energy physics.

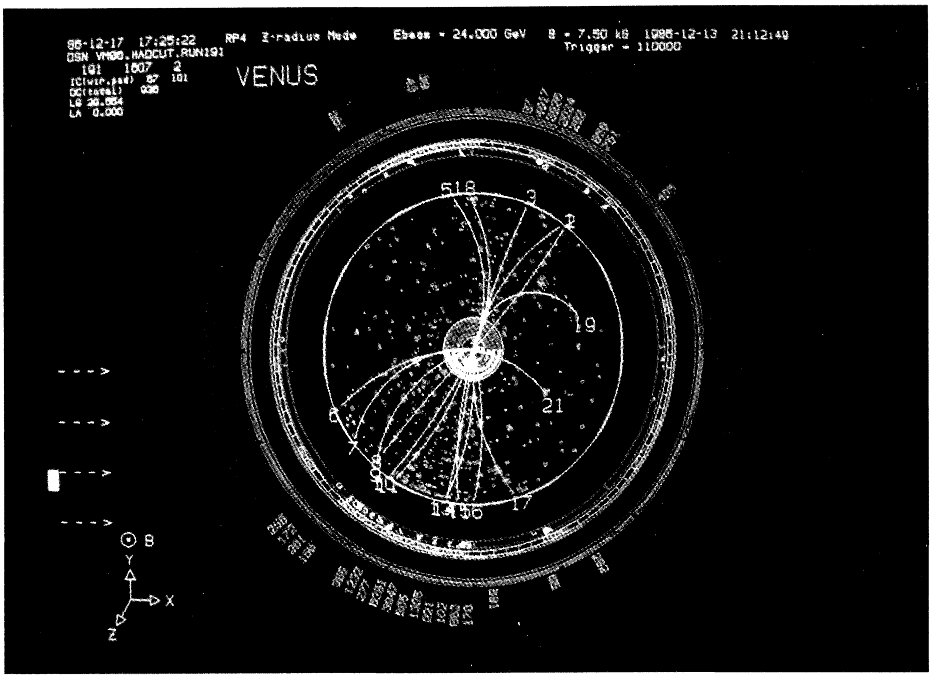
Since then, after much discussion and effort, a totally new type of research organization was introduced, the National Inter-University Research Institute, and our Laboratory is its first example. It also is one of the first research institutes in the newly founded Science City of Tsukuba. A proposal for TRISTAN was presented in 1973, three years before the laboratory's 12 GeV proton synchrotron was completed. As interdisciplinary collaborative research facilities arrived, enthusiasm mounted for an accelerator capable of reaching the very frontier of elementary particle physics. In 1981, on the tenth anniversary of KEK, we were able to start construction of a 3 km circumference electron-positron collider, a truly national project.

Construction of TRISTAN was completed in just five years. We thank deeply the members of the parliament and the government, the administrative officers who did not spare their support for pure fundamental science, despite national financial difficulties. Construction was driven not only by a united research, engineering and administrative effort, but also by the support and cooperation of many universities and research institutes both in our country and further afield.

TRISTAN required a lot of ultra-large equipment built with ultra-high precision. To meet this requirement, Japanese industry contributed its best, and this effort was behind the completion of the machine on schedule.'

After congratulating the machine's builders, Minister of Education, Science and Culture Masajura Shiokawa underlined his support for basic research: 'Today, when society is becoming more and more sophisticated and complex, it has become an urgent and important task to build a firm basis for every academic discipline with the advancement of basic research. The Ministry of Education, Science and Culture has been actively striving to promote scientific research. Above all, as one of the major directions for the promotion of important basic research, the ministry has given a strong support to accelerator science whose purpose is the elucidation of the ulti-

Good track-fitting fast. The first example of electron-positron annihilation into hadrons seen at TRISTAN by the VENUS detector last November.



Chief director of the TRISTAN project Satoshi Ozaki — 'the commissioning went smoothly with lots of difficulties!'

mate structure of the matter.

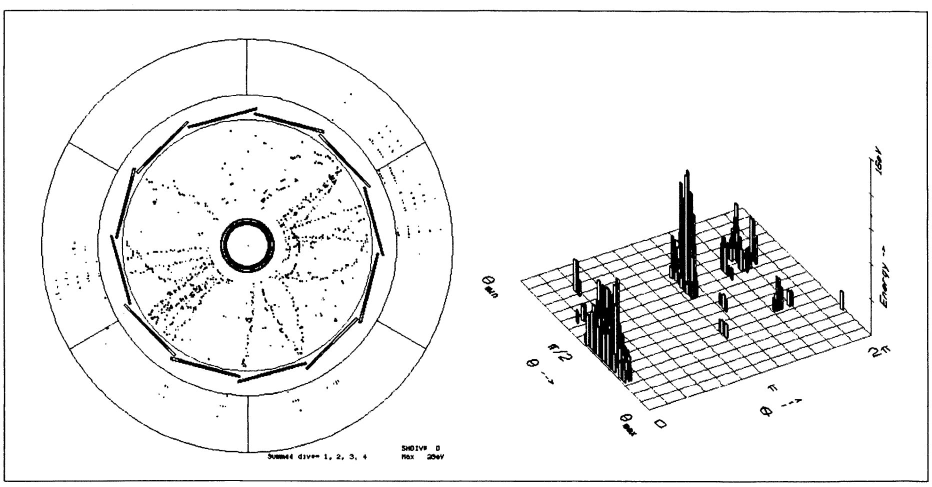
When one considers the prospect of Japan, approaching the 21st century, a further promotion of advanced and basic scientific research is, needless to say, the most vital task which the entire country has to tackle for achieving a more prosperous society and national life.'

For the international community, Karl Strauch, Secretary of the Commission on Particles and Fields of the International Union of Pure and Applied Physics (IUPAP), read a message from Italo Mannelli, the Chairman of both the IUPAP Commission and CERN's Scientific Policy Committee. After recalling earlier such inaugurations, Strauch emphasized the international aspect of this research: 'As high energy physicists, we are most fortunate to be able to be involved in one of the most exciting fields of human endeavour and are deeply grateful to our governments and leaders who have the vision to support this basic research. Our fantastic progress has come through the genuine collaboration of scientists from many countries with different social and political backgrounds — and surely our success must inspire all of us to also push for similar successes on broader, more social and political questions.'

Machine progress

In initial runs with 25 GeV beams, TRISTAN's average collision luminosity figure was $3 \times 10^{29}\ cm^{-2}\ s^{-1}$, with a maximum of 2×10^{30}. The machine's vacuum system has been improved to reduce beam-gas background and extend the beam lifetime. Titanium wire is now used instead of aluminium on the distributed ion pump. Some heating problems in the electrostatic beam separators have also been ironed out.

The plan is to continue at 25 GeV per beam using radiofre-



A three-jet hadronic event seen by the multinational AMY group (Japan / US / Korea / China).

quency accelerating equipment in two of the machine's four straight sections, although some additional equipment has been installed to underpin 25 GeV working. Subsequently, r.f equipment will be installed in a third straight section to boost beam energy by several GeV.

For the future, superconducting r.f. equipment is foreseen for the fourth straight section, taking to beam energy to 33 GeV. Any further increase in beam energy would require the replacement of conventional r.f. by superconducting equipment.

The four TRISTAN detectors are in good shape for the ongoing physics programme. The big TOPAZ detector is in the ring for the first time, while the VENUS detector which recorded the first TRISTAN collisions is now almost complete. From the initial runs, VENUS recorded 1.4 million triggers, including 16 events where the electron-positron collisions produced hadronic (strongly interacting) particles.

Examples of hadronic events have also been recorded by the AMY detector operated by a multinational Japan / US / China / Korea group. AMY instrumentation was pratically complete earlier this year, and the plan is now to use the full 3 T field of the superconducting magnet.

The fourth experimental area contains a small detector for a particle search (the SHIP experiment), but could eventually accommodate a new detector as and when future research requirements become clear.

Other new physics opportunities could come from an as yet unused experimental area in the 377 m-circumference Accumulation Ring which takes particles to between 6.5 and 8 GeV prior to injection into TRISTAN's main ring.

New Japanese project

Participants at a recent International Workshop in Santa Fe, New Mexico, heard plans for a new Japanese Hadron Facility project to be sited at the national KEK Laboratory (see April issue, page 24). The plan envisages a 1 GeV proton linac, a separate linac to handle heavy ions, a 2 GeV rapid cycling high intensity proton synchrotron, and a slow cycling stretcher/synchrotron hybrid ring capable of taking ions to 1 GeV per nucleon or protons to 3 GeV.

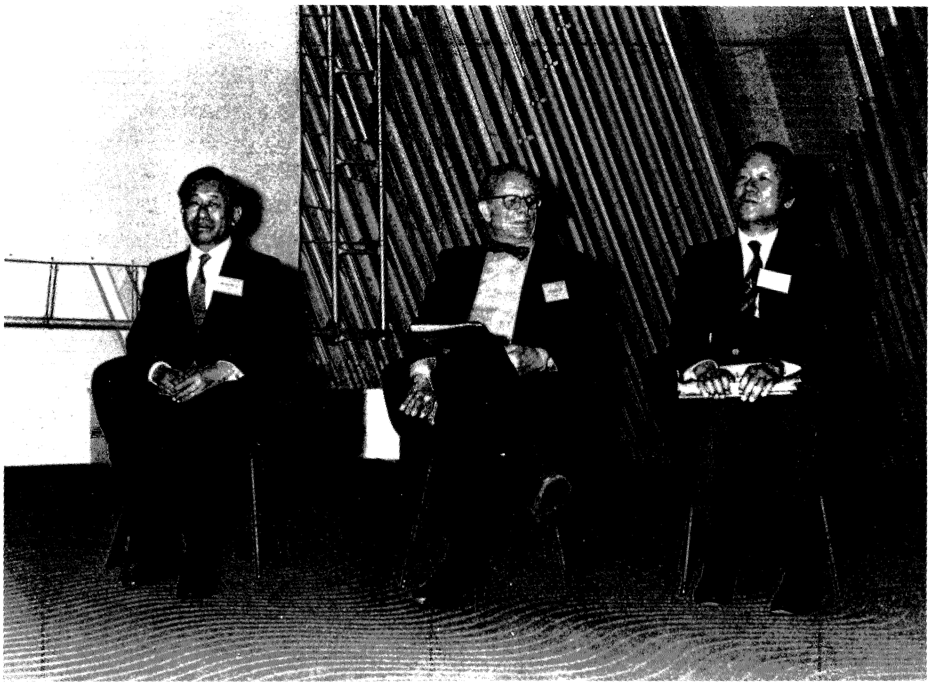
After the demise of the Numatron heavy ion project in the face of the buildup for the TRISTAN electron-positron collider at KEK, Japanese nuclear physicists carefully prepared a new project for intermediate energy physics and for interdisciplinary science. It aims to capitalize on the pioneer work at KEK using pulsed meson and neutron beams as matter probes, and to continue the Japanese involvement in radioactive beam physics initiated at the Berkeley Bevalac.

The new scheme is also seen as a joint venture for KEK and Tokyo's Institute for Nuclear Study, the birthplace of Japanese high energy physics, but which has been lacking a new project for some time.

Although the JHF scheme is still a proposal, Japanese physicists are confident that an initial configuration, not necessarily the full project as proposed, could emerge and get underway fairly quickly, continuing the rapid rate of development in Japanese fundamental physics.

Particles and nuclei in PANIC

The opening addresses at the International Conference on Particles and Nuclei (PANIC) held in Kyoto from 20-24 April were given by (left to right) Y. Yamaguchi (Tokai, President of the Physical Society of Japan), H. Feshbach (MIT, Chairman of the Nuclear Physics Commission of the International Union of Pure and Applied Physics), and T. Yamazaki (INS Tokyo, the Conference Chairman).



PANIC is the triennal International Conference on Particles and Nuclei, and judging from the latest PANIC, held in Kyoto from 20-24 April, there is no need for panic yet.

Faced with two pictures — one of nuclei described in nucleon and meson terms, and another of nucleons containing quarks and gluons — physicists are intrigued to know what new insights from the quark level can tell us about nuclear physics, or vice versa.

Summing up at Kyoto, Sir Denys Wilkinson of Sussex suspected it was too early to reconcile the two pictures. Explanations for nuclear effects do not yet demand quarks and gluons, he maintained. As long as traditional approaches work, we do not need to resort to quarks, which 'mind their own business inside hadrons.' Accounting for the apparent resilience of nucleons in nuclei is a more pressing problem.

Earlier in the conference there had been much debate about possible nuclear effects in nucleon structure, but Wilkinson submitted that while the nucleon should respond to its environment there was 'no compelling evidence for change', with some properties varying by only a few per cent across a wide range of nuclei.

Covering the common ground between nuclear and particle physics and its possible extension, PANIC plenary sessions were intended to be widely comprehensible, and generally succeeded. All subjects were awarded a question mark to underline that here was physics in evolution, and plenty of time was allowed for discussion. The intensity of the resulting debate frequently depended on the skill of the session chairmen as well as the physics content.

The question of the impact of quantum chromodynamics (QCD — the field theory of quarks and gluons) on nuclear physics was taken up by R. Jaffe of MIT. He suspected that the bridge between the quark/gluon picture and the meson/baryon approach might be a difficult one to cross. Quark physics seems to be deeply embedded — 'even to flip a quark spin costs 300 MeV', he remarked — so that the meson/baryon approach can look very self-contained. 'Now is not the moment to calculate the magnetic moment of lead from first principles,' he warned.

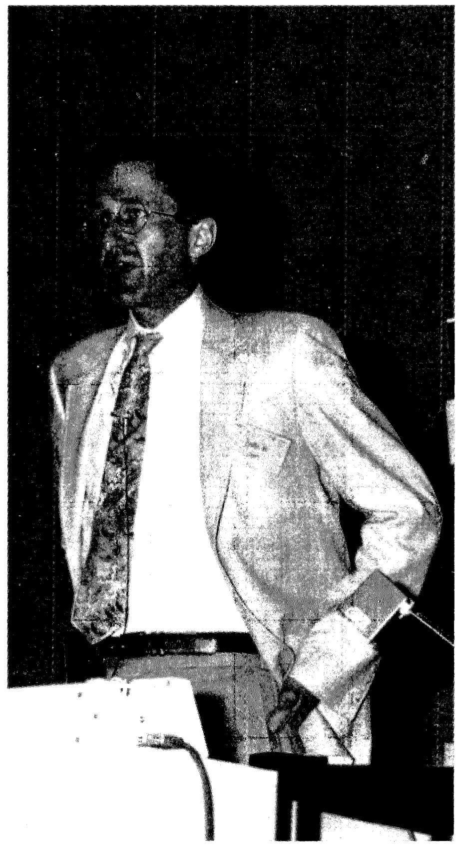
Jaffe also took up the topical question of possible strange quark contributions in the nucleon. 'The fact that we are asking these questions in 1987 shows how far off a complete theory is,' he commented. This was also taken up by Wilkinson in his summary, pointing out that we don't even know yet which quarks have to be included in a description of hadrons.

Jaffe was the first to confront the 'EMC Effect' — a variation of nucleon quark structure with the surrounding nuclear environment. 'Quark properties do vary,' claimed Jaffe, but suspected that some or most of the observed effect could be explained by nuclear binding.

D. von Harrach of Heidelberg, in reply to the question 'Do hadrons keep their free identity in nuclei?', maintained that a better knowledge of the contributions from principal (valence) and their accompanying ('sea') quarks as well as gluons is required. Models are also needed as the data are 'already richer than any single picture'. In response to the same question, P. Mulders of NIKHEF outlined how nuclear measurements using electron beams provide another probe of nucleon inside nuclei.

The controversy around the EMC Effect and its interpretation was also highlighted in a parallel session. Frank Close warned of the dangers of trying to rewrite nuclear physics from these measurements, but pointed out that an underlying

R. Jaffe of MIT — 'not the moment to calculate the magnetic moment of lead'.



change of scale does seem to be required.

In response to 'What is a realistic picture of hadrons?', G. Brown of the State University of New York proposed an 'engineering approach' rather than recourse to first principles, while A. Migdal of Moscow examined some of the implications of gluon dynamics. Session chairman A. Thomas of Adelaide advocated the development of models to guide the transition from QCD to traditional nuclear physics, 'an urgent task', according to Wilkinson.

Strangeness provides an additional lever on quark properties in nuclei. R. Hayano of Tokyo recalled the progress made since the first 'hypernucleus (synthetic nucleus containing a strange particle) was manufactured 35 years ago. While interesting effects have been noted, much more information is needed before the exact quark properties become clear. This could come from the 'kaon factories' now being proposed for several Laboratories. P. Barnes of Pittsburgh showed how hypernuclei could provide additional information on selection rules to supplement what has been learned from weak decays but is not yet completely understood.

Of universal interest is the possible phase change from conventional nuclear matter to a quark/gluon plasma, when quarks and gluons succeed in breaking loose from their nucleon confinement. W. Willis of CERN looked at how such a phase change could be recognized, and went on to the suggest that initial photoproduction signals from the experiments using CERN's high energy nuclear beams hint at production of a 'mixed phase'. A. Ukawa of Tsukuba covered computer simulations of such phase changes resulting from hundreds of supercomputer hours. Interesting possibilities emerge for the properties of free quarks.

A session on possible interplays between astrophysics and cosmology on one hand and particle/nuclear physics on the other gave the opportunity for a review of the supernova neutrino data recorded by the big underground Kamiokande (Japan — Y. Totsuka) and Irvine/Brookhaven/Michigan (US — J. Learned) detectors (see May issue, page 1). As well as catching supernova neutrinos, the upgraded Kamiokande detector should soon start to provide useful information on neutrinos from the sun.

An electron-positron session gave the opportunity for news of Japan's TRISTAN collider (Y. Nagashima — see also page 3), while H. Schulz of DESY described the particle mixing observed by the ARGUS detector at the German DESY Laboratory (see June issue, page 16). P. Kienle of Darmstadt (GSI) gave the latest results on the monoenergetic electron-positron signals seen in experiments at Darmstadt using heavy ion beams (see April 1986 issue, page 22). With increased sensitivity, several lines are now seen, and new apparatus will soon be ready to extend these investigations. Summary speaker Wilkinson admitted to being 'baffled' by these sharp lines. He is not alone.

The high precision measurements needed to test the validity of discrete symmetries and conservation laws (such as the combined CP charge conjugation/space reflection operation) were outlined by B. Holstein (Massachusetts) and V. Lobashev (Moscow). While experiments push the limits of observation back, both speakers suspected that large effects might show up in as yet untested areas.

In addition to the plenary discussion sessions, there was a wide range of parallels, where detailed results and ideas flew thick and fast. Especially interesting were the 'circus' sessions on controversial topics. In addition to the EMC Effect, these included neutrino physics and hyperons in nuclei.

Before Wilkinson's conclusion, summary talks on the final afternoon looked at possible future directions in attempts to link the particle and nuclear spheres. H. Lipkin of the Weizmann Institute illustrated this in terms of multiquark physics, while J. Walecka described the potential of the US CEBAF electron machine soon to be built at Newport News, and G. Garvey of Los Alamos pointed out the need for new intense sources of hadrons.

From the success of the Japanese Kamiokande project, M. Koshiba of Tokyo believed that big new underground detectors are required to push forward the frontiers of particle physics. Useful neutrino signals would be obtained from larger such detectors, he claimed, and advocated setting up a worldwide network of them.

B. Povh of Heidelberg looked for 'missing links' in the 'hadronic trinity' encompassing nuclear structure, soft hadronic physics (such as diffraction scattering), and hard hadronic physics (violent collisions when a probe particle penetrates deep inside a target nucleon, reaching the quark level). With question marks still hanging over each of the three sectors, Povh claimed it was premature to look for the missing links.

'The Conference has reminded us of how much we do not know,' confessed Wilkinson as he embarked on his summary. Thus a shortlist of hopeful breakthroughs tabled at the previous PANIC (Heidelberg, 1984) has to be carried over to MIT in 1990.

The Conference was sponsored by the International Union of Pure and Applied Physics and the Physical Society of Japan, and supported by the Science Council of Japan and the Ministry of Science, Education and Culture. Conference Chairman was T. Yamazaki of INS Tokyo, and the Secretaries were M. Morita of Osaka and K. Nakai of KEK. There were some 600 participants.

Report by Gordon Fraser

More useful overlap

The overlap between nuclear and particle physics was also highlighted in a UK Institute of Physics conference held in Birmingham from 6-8 April.

The conference was held under a lucky star, in the shape of the first nearby supernova for over 200 years, which exploded about a month beforehand (see May issue, page 1). The forethought of the organizers in inviting as a review speaker Tegid Jones, freshly back from the IMB underground experiment in the US which observed bursts of neutrinos from the supernova, did not extend to the choice of room. A last-minute move was needed to accommodate the large and excited audience intent on the latest news!

Cosmology and its relation to nuclear and particle physics was the subject of a lively and lucid presentation by Martin Rees of Cambridge. The rotation properties of galaxies and galactic clusters imply far more matter than is directly visible. Possible candidates for such 'dark matter' range from massive black holes via Jupiter-like planets to neutrinos, supersymmetric particles, or other still undiscovered weakly interacting massive particles ('wimps'). If dark matter is present in sufficient quantity outside galactic clusters, it could eventually halt the present expansion of the universe. Particle physics measurements restrict these possibilities; on the other hand, measurements of the cosmic helium abundance yield limits on the rate of expansion of the early universe and hence on the number of light neutrino species.

W. Geist of Berkeley presented preliminary results from the studies at CERN with nuclear beams at the end of 1986. The events were often spectacular, with hundreds of particles produced, but with no

A. Thomas (left) of Adelaide — asking the question 'What is a realistic picture of hadrons?' — with Frank Close of Rutherford/Appleton — 'rescaling is a fact'.

A feature of the recent UK Institute of Physics Joint Conference on Nuclear and Particle Physics held at Birmingham from 6-8 April was the opportunity given to young researchers to present their work, much appreciated by Birmingham physicists (left to right) Mary Trainor, Andrew Kirk and Stephen ('Desperately seeking SUSY') Haywood.

clear sign yet of the hoped-for phase transition from nuclear matter to a quark-gluon plasma. Still on extremes, in a talk emphasizing the importance of angular momentum in high energy collisions, C. N. Yang pointed out that collider experiments had reached a regime where the typical angular momentum per collision was 2000 units.

The high quality data now coming from CERN's LEAR Low Energy Antiproton Ring were reviewed by Chris Batty of Rutherford. These have led to the demise of 'baryonium', but are yielding precision measurements in other fields such as antiproton-nucleus elastic scattering and the effect of the strong interaction on the energy level structure in antiprotonic atoms.

On the machine side, Simon van der Meer of CERN gave a comprehensive but realistic overview of present and future developments, and came down clearly in favour of a changeover to linear accelerators. He pointed out that the recent exciting developments in high temperature superconductors might find applications in superconducting radiofrequency cavities well before the technology for winding large dipole magnets could be mastered. Samples of the new superconducting materials were on display in the poster session, along with recent measurements by a Birmingham group of flux quantization demonstrating the pairing of electrons.

The continuing physics from CERN's proton-antiproton collider were reviewed by Ian Kenyon of Birmingham. This includes new evidence from the UA1 experiment for the production of the 'beauty' quantum number in the production of J/psi particles in confined 'jets' of hadrons.

Production of the W (the electrically charged carrier of the weak force) is now so well understood that it has become a testing ground for quantum chromodynamics (QCD), the candidate field theory of quarks and gluons, according to James Stirling of Durham. The first W candidates from the Fermilab Tevatron collider were presented by Chris Quigg (see May issue, page 18).

Progress in the understanding of heavy quark-antiquark bound states (such as the upsilon particles) pleased Max Irvine of Manchester who in his closing talk stressed the relationship between bound states of quarks and bound states of nucleons in nuclei.

The latest theoretical developments were given a cool appraisal by Mike Duff in 'Not the standard superstring review'. He warned that the undoubted attractions of superstrings might prevent us from looking critically at some of their claimed properties, particulary uniqueness. And after superstrings in 10 dimensions, supermembranes in 11 are on their way!

A large part of the nuclear physics programme concentrated on the exciting new developments on superdeformed nuclei following the first results from Daresbury last year (see March 1986 issue, page 14). Some nuclei are shaped like rugby balls with correspondingly large moments of inertia, giving spins of up to 60 units. The identification of these states is leading to a rapid reassessment of the interplay between single particle and collective phenomena in nuclei.

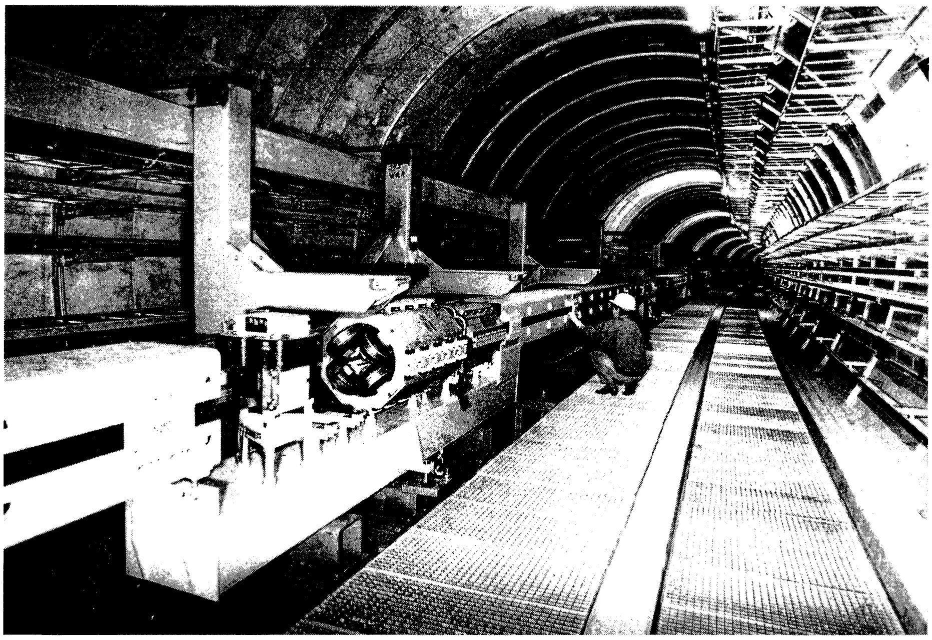
A second strong theme was the push to produce and study exotic nuclei with large proton or neutron excesses. These reveal new nuclear phenomena, providing in turn stringent checks on nuclear models based on conventional nuclei. One talking point was the discovery by a Manchester group at Daresbury of zirconium-80, the heaviest 'doubly magic' nucleus yet studied, showing anything but the behaviour expected.

The outlooks for nuclear and particle physics were reviewed by the chairmen of the respective committees of the UK Science and Engineering Research Council, Max Irvine and Erwin Gabathuler. The financial outlook is uncertain, the scientific outlook is bright and exciting, as judged from a successful and invigorating conference.

From Martyn Corden

Around the Laboratories

Installation of the magnets is getting underway for the electron ring of the 6.3 km HERA eletron-proton collider at the German DESY Laboratory in Hamburg.



DESY HERA progress

At the end of April, the first magnets for the 30 GeV electron storage ring were installed in the underground tunnel being excavated for the HERA electron-proton collider at the German DESY Laboratory in Hamburg. These magnets are mounted in 12 metre modules, and a hundred modules are needed to fill the curved part of each quadrant of the ring. Meanwhile the superconducting magnets (dipoles, quadrupoles and correction coils) for the 820 GeV proton ring have been ordered.

The electron injection tunnel from the PETRA pre-accelerator to HERA is being completed and first beam tests are imminent. The proton line from PETRA to HERA has already been tested (with positrons – see May issue, page 18) with particles being ramped from 7 to more than 12 GeV in PETRA.

After progress with the new linac to provide HERA's protons, work is getting underway for the 40 GeV proton acceleration system for the PETRA pre-accelerator. The Canadian TRIUMF and Chalk River Laboratories are collaborating closely with DESY in this work.

HERA's cryogenic plant has now been installed. As well as being the biggest in Europe, its constructors claim it to be the most efficient cooling system of its type ever made. It comprises three independent compressor and cooling lines each of 6.4 kW at 4.3 K. The first was tested in April and produced 1500 litres of liquid helium. Two lines will be sufficient to run HERA, leaving one in reserve.

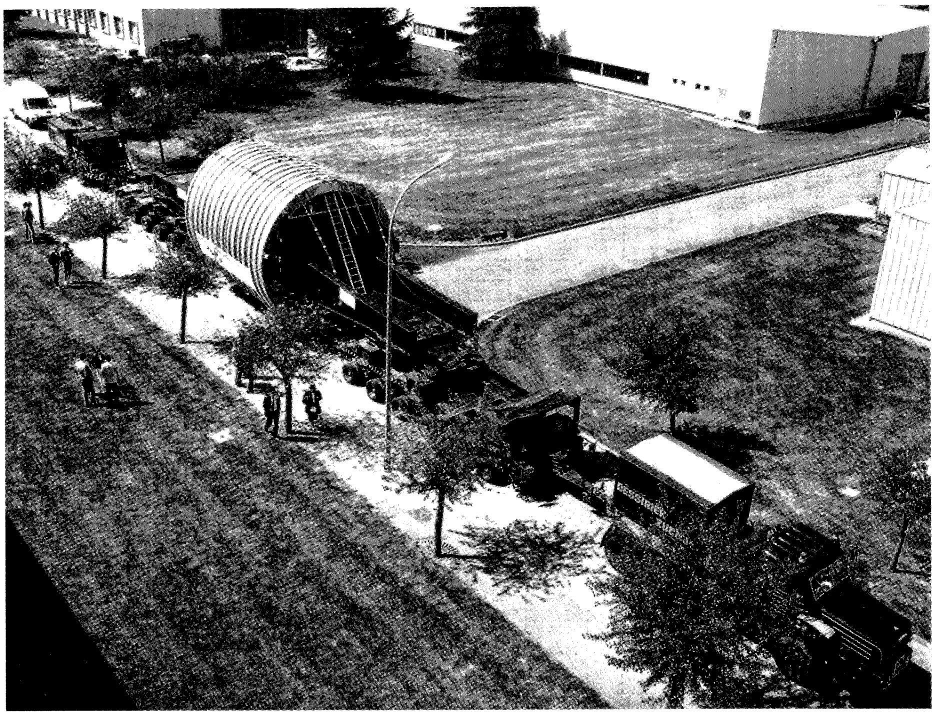
This cryogenic plant also provides the cooling power for the big magnet test hall, now ready for series tests of all industrial magnets arriving. In a separate hall provided with an independent 900 W cooling plant, systematic tests of a chain of three dipole and two quadrupole magnets began in April.

▼ *The electron ring for the HERA electron-proton collider being built at the German DESY Laboratory envisages 30 GeV beams, requiring superconducting radiofrequency accelerating cavities in addition to conventional equipment. 500 MHz four-cell niobium units such as this built by industry have performed well in tests at DESY. Beam tests (in the PETRA ring) should begin soon.*

(Photos DESY)

An impressive convoy (over 50 metres long and weighing 182 tons) left the French Centre d'études nucléaires at Saclay on 11 May bound for CERN, carrying the superconducting magnet for the ALEPH experiment at CERN's LEP electron-positron collider. It arrived on 2 June.

(Photo CEN Saclay)



SACLAY ALEPH coil hits the road

The size and precision of components for the four big experiments being prepared for CERN's new LEP electron-positron collider make special demands on designers and manufacturers.

An example is the superconducting solenoid for the ALEPH experiment at CERN's LEP electron-positron collider, contracted to the Institut de recherche fondamentale of the French Atomic Energy Commission (CEA) in 1983.

It was designed and built by engineers and technicians of the Department of Elementary Particle Physics of the CEN's Saclay Laboratory. Recent tests at Saclay were highly successful, with current attaining 60 per cent of its design value, the (temporary) absence of shielding not permitting it to go any higher.

Weighing 60 tons, 5 metres across and 7 metres long, the ALEPH solenoid produces a magnetic field of 15 kilogauss (1.5 tesla) in a volume of 130 m^3. The use of a superconducting coil reduces electric power requirements by a factor of 40 and overall weight by a factor of four. Producing the required field involves 9 million ampere-turns and a stored magnetic energy of 130 million joules.

Special technology had to be developed for its manufacture in view of the dimensions of the coil and the constraints imposed by the detector design — minimum weight and a minimum of material to be traversed by the particles produced by LEP.

Applying this technology on the required scale called for special tooling for winding, impregnation, fitting and transport. Tests at Saclay checked that the adopted solutions could reach the required performance levels.

Special features of the coil also include: almost exclusive use of aluminium; superconducting niobium-titanium cable coextruded in a pure aluminium sheath (30 kilometres to handle a current of 5 000 amperes); the collar constraining the magnetic forces being used as the winding mandrel — the conductor being wound inside the collar; vacuum impregnation of the coil; and indirect coil cooling through tubes welded on the collar.

Meanwhile the barrel yoke for the ALEPH magnet has been reassembled at CERN after initial assembly by Ferriere-Cattaneo and INNSE in Milan.

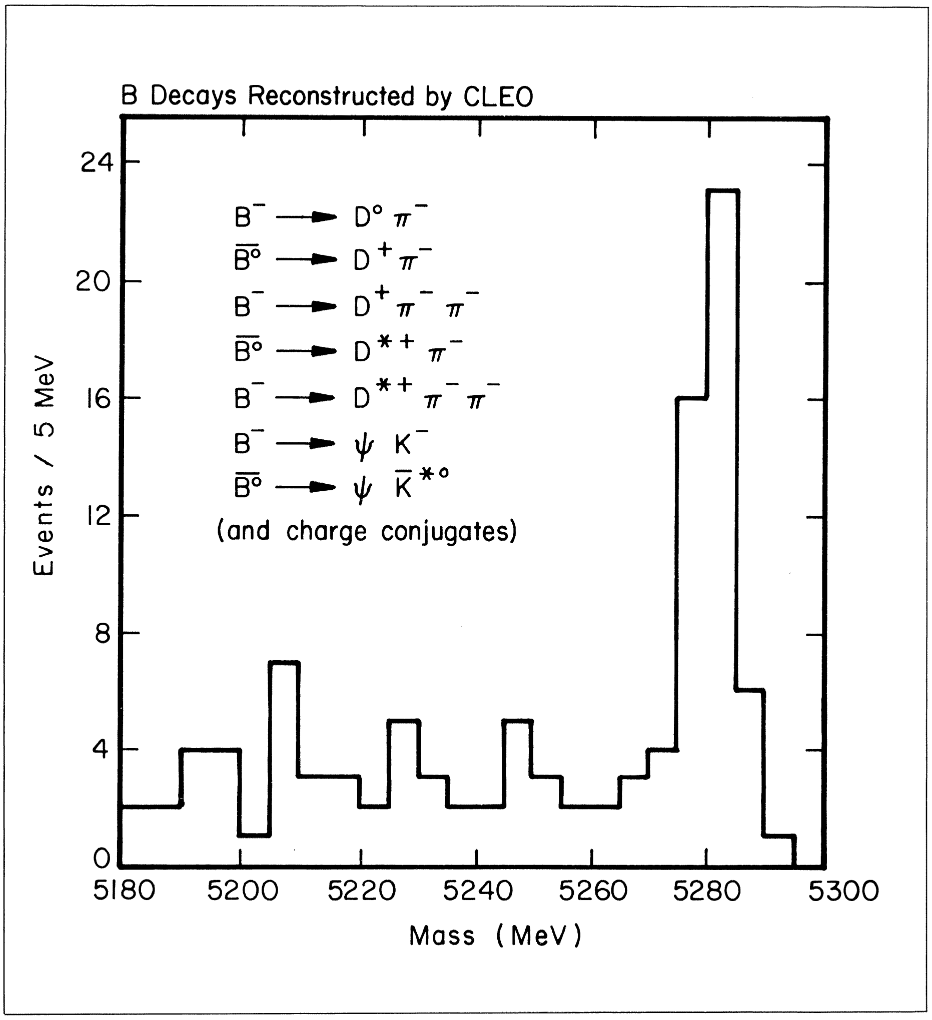
The coil for the other superconducting coil for a LEP experiment, that for DELPHI, is undergoing tests at Rutherford Appleton Laboratory, UK, while the barrel yoke using Soviet steel is being assembled at CERN.

CORNELL B meson masses

The CLEO experiment at the Cornell Electron Storage Ring CESR has recently measured more accurately the masses of the electrically charged and neutral B mesons. These particles, consisting of a 'beauty' (b) quark (antiquark) paired with an 'up' (u) or 'down' (d) antiquark (quark) were discovered in 1983, also by the CLEO group.

The analysis is based on a sample of some 260 000 decays of B mesons formed in electron-positron annihilations at the fourth upsilon (4S) resonance at 10.58 GeV. The masses were determined from the analysis of decays giving a small number of particles — a B giving a charmed D or D* meson

Disintegration of B mesons into two or three particles, although rare, allow the decays to be fully reconstructed. This sample from the CLEO detector at the Cornell CESR electron-positron ring gave precision values for the masses of the B.



plus one or two charged pions, or giving a J/psi meson and a kaon.

The measured masses are 5281.3 MeV for the neutral B and 5279.3 MeV for the charged B, with the statistical and systematic errors in both cases being ± 0.8 and ± 2.0 respectively.

Thus the neutral B is only 2.0 MeV ($\pm 1.1 \pm 0.3$) MeV heavier than its charged counterpart, closer than the neutral and charged kaons, for instance. This suggests that the B mesons are compact quark systems where electromagnetic effects are more marked.

The few-particle decay modes allow the B decays to be fully reconstructed, but are measured to be less than one per cent of all the possible decay modes, underlining the difficulty of obtaining such a sample. These decays also involve the decay of a b quark into a charm quark, expected to be the dominant decay transition. However there could also be decays with the b quark switching into a u quark, such as the neutral B giving a charged pion pair.

The CLEO group searched for such decays and was able to establish that they are less than a few ten thousandths of all the possible decays, thus confirming theoretical expectations that the b to u transition is much less likely than b to c.

RUTHERFORD APPLETON
Improving ISIS

Although it has yet to reach its design level, the ISIS spallation neutron source at the UK Rutherford Appleton Laboratory can already claim to be the most powerful accelerator-based pulsed neutron source in the world. The high flux of neutrons, combined with the use of advanced neutron scattering spectrometers, has also revealed the structure of a number of the new high temperature superconducting materials.

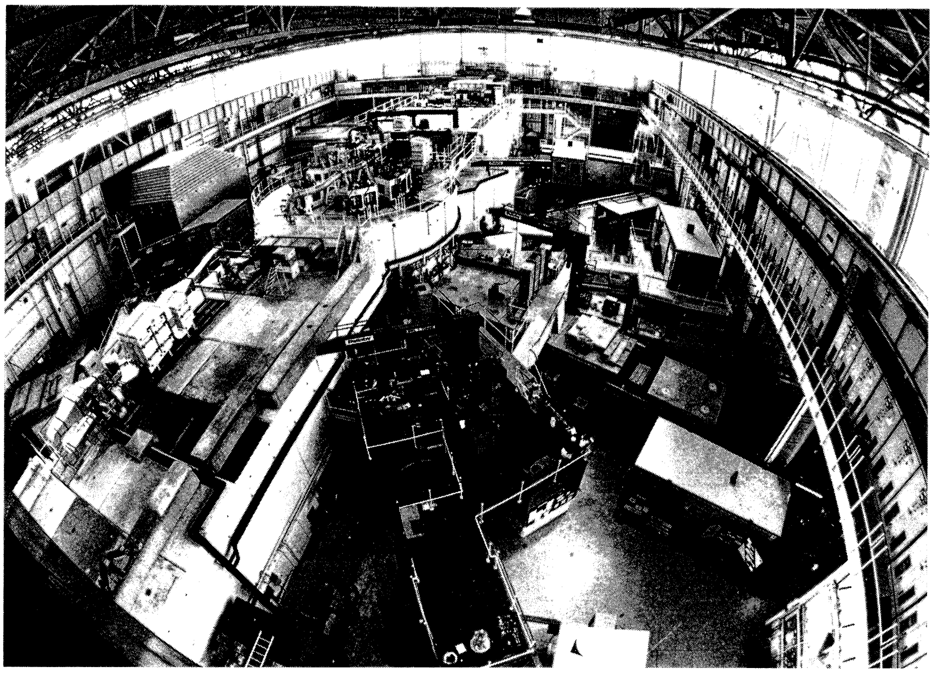
During March the ISIS accelerator reached a peak current of 50 microamps (6.25×10^{12} protons per pulse at 50 Hz) at a proton energy of 550 MeV. A four-week research run was given over to neutron scattering studies. During the last two weeks of this run an average of 30 microamps was achieved and during the last four days the average current attained 42 microamps.*

The successful run resulted firstly from an improvement in the reliability of the accelerator system, notably the injector. Secondly, the increase in current came after limitations were overcome due to the voltage induced in the four radio-frequency cavities by the beam. Uncorrected, this voltage is about the same as the r.f. voltage used for trapping the protons. A previous feed-forward system was running at the limit of performance at about 4×10^{12} ppp. The cavity impedance and hence the induced voltage has been reduced by loading the cavities by a resistance. A ring main of copper sulphate solution is used to provide the resistive load capable of dissipating the

** Last year the Proton Storage Ring at Los Alamos reached 3.4×10^{13} protons per pulse, but this was not used for physics research. The ring will soon be back in action.*

'Fish-eye' view of the experimental hall of the ISIS spallation neutron source at the UK Rutherford Appleton Laboratory. As long as funds permit, the proton beam comes in from the bottom left towards the neutron target (centre). Beamlines for experiments fan out on either side. The stepped block on the left of the target is the Karlsruhe (KfK) neutrino experiment.

(Photo RAL)



power, so that the r.f. system is now much more docile.

Ease of routine operation has been improved by the use of beam-loss monitors along the linac, around the synchrotron and along the transfer line to the target station. These enable the operators to detect the potential onset of beam loss which could damage or irradiate the machine. No more than one per cent beam loss is permitted after the trapping process — a very tight specification, but regularly, achieved.

More than 90 per cent, on average, of beam from the 70 MeV injector is injected, trapped, accelerated, extracted and transported to the neutron-producing target. The target station, containing the 35 kg depleted uranium target, four moderators to slow down the 1 MeV produced neutrons, and a reflector system has worked well at 25 per cent of design level.

The day following the successful neutron run, the internationally-funded beam for muon spin resonance and rotation applications in materials and other science was successfully commissioned with positive muons. Even with a very thin muon production target and 20 per cent of ISIS design current, the highest muon stopping rates in the world for a pulsed surface channel were achieved, and these rates could yet increase a hundredfold!

The beamline was also successfully tuned for negative muons (60 MeV) to run some initial tests for potential experiments in catalyzed muon fusion and other science.

The next day the accelerator was run at 750 MeV at low repetition rate (mindful of electricity costs!). This was the first time that all six r.f. cavities had been run simultaneously with beam. All went well and 5 x 10^{12} ppp were accelerated and extracted from the synchrotron to a beam dump.

Plans are to run at 750 MeV with four weeks for users and two weeks for development until the end of September when, as things stand, the available funds run out! It is expected that 100 microamps of proton current will be obtained by September.

At present there are 13 neutron scattering instruments in operation, commissioning, development or construction. Of those in construction, one is being provided by Italy and another by Japan under international collaboration agreements.

The big recent highlight has been the investigations of the new high temperature superconductors — a number have been studied with transition temperatures up to 100 K. The temperature dependence of their crystal structures has been determined using the High Resolution Powder Diffractometer, a uniquely powerful instrument in terms of resolution and intensity. Subtle structural effects have been found which may well be correlated with superconductivity. In addition the density of states has been determined using an inelastic scattering spectrometer, and shows marked changes at a few tens of MeV, again thought to be important.

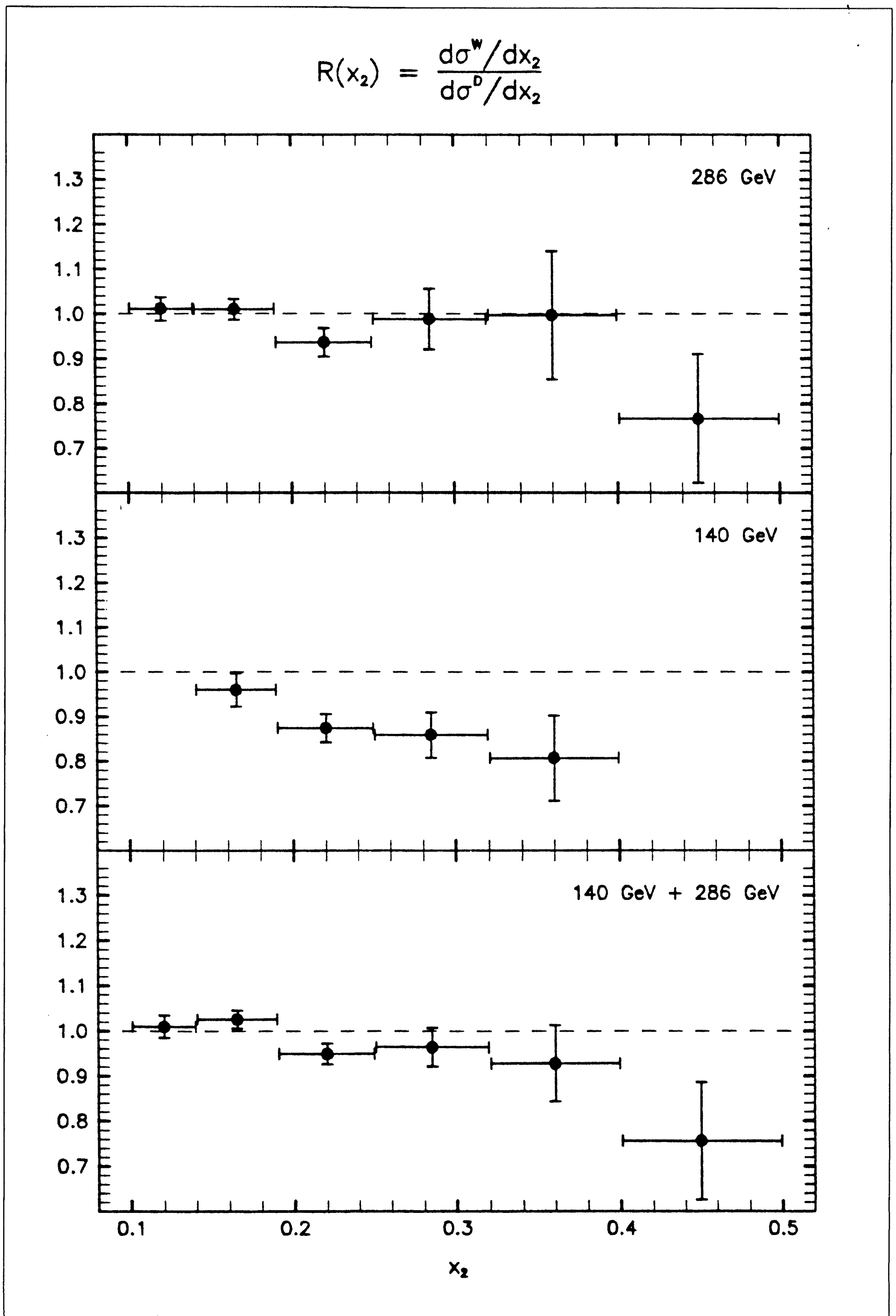
Among the other unique instruments at ISIS is a critical reflection spectrometer designed for surface and interface studies by measuring the wave vector dependence of specular reflection. Structural information can be obtained, for example, on structures comprising layers of different composition and thickness (in the range 10-1000 angstroms), on Langmuir-Blodgett films, and on absorption at liquid-vapour interfaces. The instrument has recently been extended to include a polarized neutron option for the investigation of magnetic films and surface magnetism and a recent success has been the determination of the magnetic moment of cobalt atoms in films only a few atoms thick.

As the performance of the machine increases towards its design level, as the number of operational instruments grows, and as the muon facility comes into operation a lot of interesting research is expected over the next few months.

CERN
More nuclear effects

In 1983, the European Muon Collaboration (EMC) using CERN's high energy muon beams discovered that the internal quark structure of nucleons depends on the surrounding nuclear environment.

This has since been corroborated by other experiments using muon and electron beams, and more data has enabled the effect to be better measured (see March issue, page 10).



Different production rates of muon pairs from tungsten (W) and deuterium (D) targets using 140 and 286 GeV pion beams as observed at CERN by the NA 10 collaboration (CERN / Naples / Ecole Polytechnique / Strasbourg / ETH Zurich). This reflects the different quark structure of nucleons in the two targets (EMC Effect).

Indications of the 'EMC Effect' have now been seen for the first time in the related process of dimuon production using hadron beams (negative pions) by the NA10 experiment at CERN (CERN / Ecole Polytechnique / Naples / Strasbourg / Zurich collaboration). Muons and electrons are (supposedly) pointlike particles, but hadrons are composed of quarks, so that the NA10 results reflect the quark content of the projectile particles as well as that of the target nucleons.

The experiment is housed in a special underground area so as to be able to exploit the highest intensity beams available from the 450 GeV Super Proton Synchrotron. Using 140 and 286 GeV pions at up to 2 x 10^9 particles per pulse, secondary particles other than muons are stopped by a five metre beam dump behind the target zone. The muons are measured using a pulsed toroidal magnet and an array of multiwire chambers and scintillators.

Away from sharp resonances in the J/psi and upsilon regions, the production of muon pairs reflects interactions of the constituent quarks (quark-antiquark annihilations via an energetic photon).

Two targets were used, one of deuterium, the other of tungsten, and simultaneous exposure of both minimized systematic errors. The corresponding dimuon signals were separated by changing the trigger conditions. Muon pairs from sources other than direct quark interactions between the incoming beam and the target were carefully eliminated.

The kinematic dependence of the relative production rate of muon pairs from different targets reflects the underlying quark behaviour. As expected, the quark content (structure function) of the incoming pions is not affected by nuclear composition.

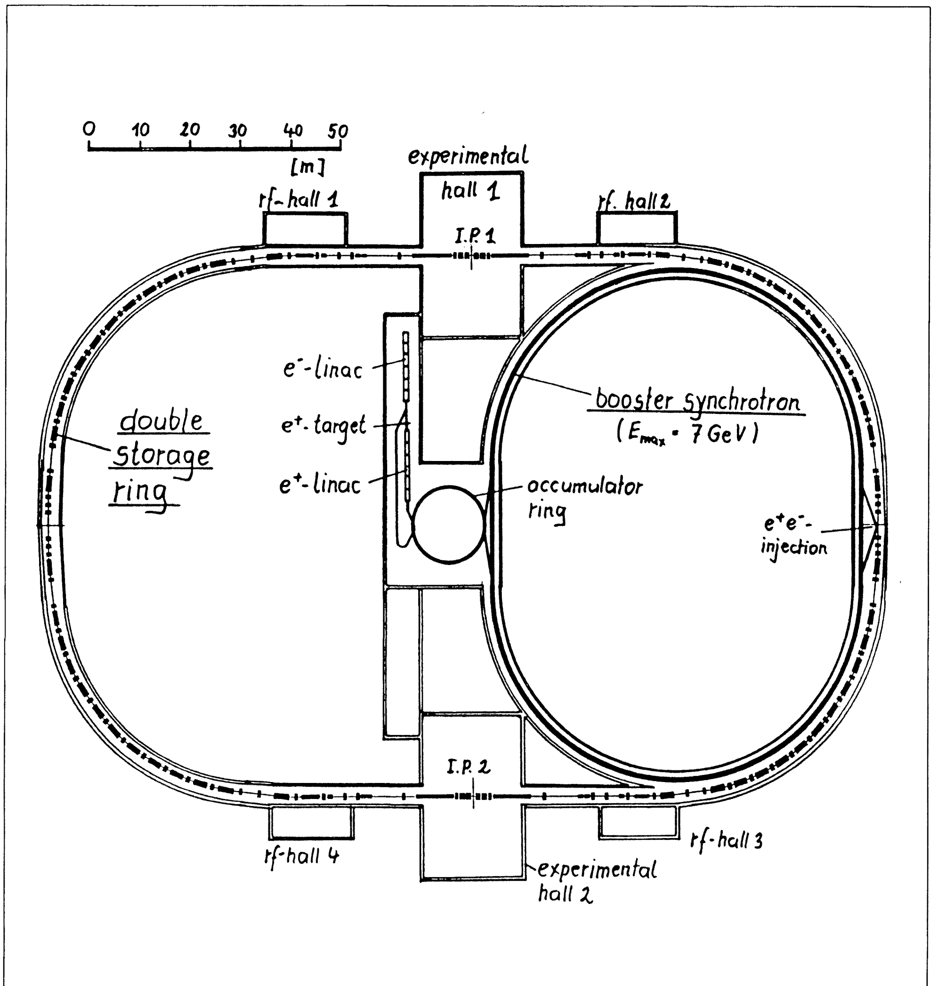
However the nucleon quark content is seen to vary from target to target, tying in with what is seen using muon and electron probes.

As well as a target dependence of the nucleon quark structure, the transverse momentum distributions of the muon pairs also change, underlining what has been seen in experiments at Fermilab looking at hadron production.

This is the first time that such a dependence has been seen for muon pairs. Data taken with two different lengths of tungsten target show no significant difference, implying that the effect is more likely to be due to effects in the target nucleus where the quark-antiquark interaction takes place, rather than pion scattering. The experimenters suggest that it is probably due to the scattering of the incident quark as it burrows into the target nucleus.

Physics monitor

Sketch of the B particle 'factory' idea prepared by a Swiss/German group. Electron and positron beams would be taken up to 7 GeV.



WORKSHOP B factories

The physics potential of B particles (containing the heavy 'beauty' quark) has been highlighted by the work on B particle mixing by the UA1 experiment at CERN (see October 1986 issue, page 17) and more recently by the ARGUS group at the German DESY Laboratory (see June issue, page 16).

In principle the decays of B mesons provide an additional window on the violations of the combined CP symmetry (charge conjugation plus mirror reflection). CP violation has been studied for almost a quarter of a century in the decays of the neutral kaons, but is still not understood.

However the relevant B meson decays are rare, so that physics would need a copious supply of particles. Both circular and linear colliding beam machines have been proposed, and a workshop at UCLA in January looked in particular at the linear collider approach.

With circular colliders nearing their maximum yield (luminosity), linear colliders hold out the hope of attaining higher levels, although there are serious technical problems to be overcome. Target luminosities of the order of 10^{34} cm^{-2} s^{-1} are stated, compared with present levels of 5 x 10^{31} in circular electron-positron machines (see June issue, page 6).

High current linear machines would need novel positron sources, ten or even a hundred times more intense than the new SLC Stanford Linear Collider. In addition, new accelerating techniques using superconducting cavities or high gradient/frequency r.f. sources are being proposed. As well as surveying these requirements, the workshop looked at the underlying physics and the types of detectors needed.

At the end of the meeting, working groups reported their findings, underlining the need for and feasibility of such a B factory, provided extensive R and D groundwork was carried out.

A Swiss/German group has prepared a design for a B factory based on a 7 GeV storage ring for electron and positron beams. Calculated luminosity is well into the 10^{32} cm^{-2} s^{-1} range, but falls off with increasing beam energy.

From D. Cline

Quantum cosmology

Physicists and astrophysicists from throughout the world came to Fermilab for the weekend of 1-3 May for an informal workshop on quantum cosmology which led to a free-wheeling exchange of ideas and views. Carrying some important names, the attendance list included about 55 physicists from the US, Europe, the Soviet Union and Japan, in addition to the Fermilab participants. The principal organizer was Chris Hill from the Theory group, with co-organizers Rocky Kolb and Mike Turner from the Astrophysics group.

Murray Gell-Mann — attacking deep issues.

(Photo Fermilab)

The success of any workshop or conference depends upon the planning and thought that goes into the organization, and on the participation. The Quantum Cosmology Workshop was fortunate to attract a large number of extremely talented people. After all, the aim was to try to find out why and how the Universe was created — not a subject for the faint of heart.

Part of the success of the meeting was the participation and contribution of Murray Gell-Mann. Recently, with Jim Hartle of the University of California at Santa Barbara, he has been attacking deep issues at the foundation of quantum mechanics which must be addressed in the context of cosmology. He opened the conference with the observation that 'crackpots do double damage to the fields they populate by spreading misinformation and by preventing serious people from doing honest research.'

Quantum mechanics contains subtleties which are amplified as one delves into the very earliest instants of the Big Bang. In ordinary textbook quantum mechanics the state of a system is influenced by the observer; in the early Universe who plays the role of observer?

Gell-Mann and Hartle propose that this dichotomy between observer and system arises only when one restricts attention to a few of the infinite degrees of freedom of the world; indeed it is more than a practical necessity that one does so. Thus in any analysis of the early Universe as a quantum mechanical system in which one tracks a subset of the full infinite degrees of freedom there will be effective observers, termed IGUs (Information Gathering and Utilization Systems) by Gell-Mann, acting to disturb the state of the system, but arising self-consistently within the larger framework of the infinite number of physical degrees of freedom.

Another notable contributor was Yakov Zel'dovich, one of the best-known and most respected of Soviet physicists. During his long and distinguished career in physics and chemistry he has made important contributions to the idea of a 'quantum birth' of the Universe. Along with Alexei Starobinsky (also attending), he presented a historical perspective of the important contributions of Soviet physicists to quantum cosmology.

One of the most original and talented minds in physics belongs to Stephen Hawking. Fermilab was lucky that Hawking's second visit to the Lab was during the Workshop. In addition to his talk, the workshop benefited from Stephen's deep and profound questions and observations. Hawking recounted that his discovery of the evaporation of black holes followed conversations with Zel'dovich. Hawking and Zel'dovich had much time together at Fermilab; perhaps something equally profound will result.

Neutron riches

One latter-day physics innovation at the venerable Berkeley Bevalac (which in its original Bevatron form came into action in 1954) has been the production of high energy beams of exotic isotopes. Produced when nuclear beams hit a target, the isotopes are filtered magnetically and further identified by velocity and electric charge measurements.

Japanese teams play a prominent role in this work, part of the fruitful Japan-US Joint Programme for High Energy Physics.

From measurements of the interaction rates of a range of these isotopes, physicists were able to deduce the effective nuclear radii.

While the properties of relatively stable isotopes agree with measurements made using electron beams, the very neutron-rich nucleus lithium-11 (three protons and eight neutrons) appears to be much larger than neighbouring isotopes, suggesting that something new is happening.

On the nuclear 'drip line', lithium-11 is saturated with neutrons and is the heaviest drip line nucleus yet studied in detail. In addition to the information from the Bevalac studies, lithium-11 properties (mass, decay modes, spin, magnetic moment) have been measured in experiments at CERN.

Back in 1972, A. Migdal of Moscow suggested that a pair of neutrons, although incapable of binding together unaided, could perhaps stick together when a nucleus is around. The small binding energy (190 $\pm$ 110 keV) of the final lithium-11 neutron pair, and the fact that lithium-10 cannot stick together, suggested to Gregers Hansen of Aarhus (presently at CERN) and Bjorn Jonson of Chalmers University of Technology, Goteborg, that lithium-11 could be looked at as a 'quasi-deuteron' with a lithium-9 core loosely coupled to a dineutron. (The deuteron, consisting of a proton and a neutron, is the textbook example of a loosely bound nucleus.)

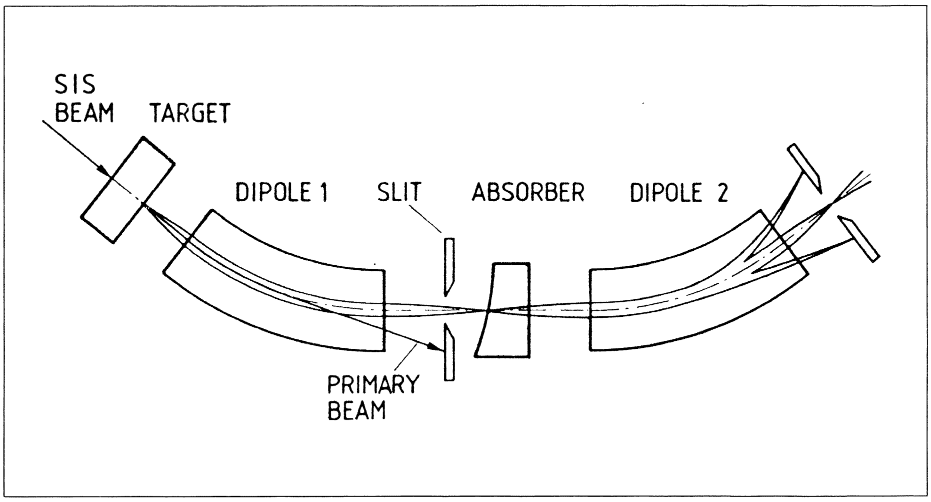
According to this model, the weak binding brings about a 'neutronization' of the nuclear surface, with the lithium-9 core surrounded by a neutron halo. It is this halo which pushes out the nuclear radius, and an estimate agrees with the value measured at Berkeley.

This suggests that other nuclei at or near the neutron drip line should show interesting behaviour. The nuclei are so loosely bound that even a very soft interaction would remove the neutron pairs.

Additional experimental information comes from the French GANIL heavy ion accelerator looking at the reaction rates of neutron-rich nuclei from carbon to magnesium. The GANIL work shows that the absorption radius increases rapidly with neutron excess rather than with atomic (proton) number.

This should also provide added research value for the SIS heavy ion synchrotron now under construction at the Darmstadt heavy ion Laboratory (GSI), scheduled to become operational in 1989, where a spectrometer for work with fast beams of radioactive ions is foreseen.

The projectile fragmentation mass separator planned with the SIS/ESR heavy ion complex now being built at the GSI Darmstadt Laboratory. It follows a scheme used first at the French GANIL heavy ion machine, with an initial magnetic field removing the primary beam, and an absorber introducing an additional nuclear dependence, so that the second dipole can select specific nuclei.

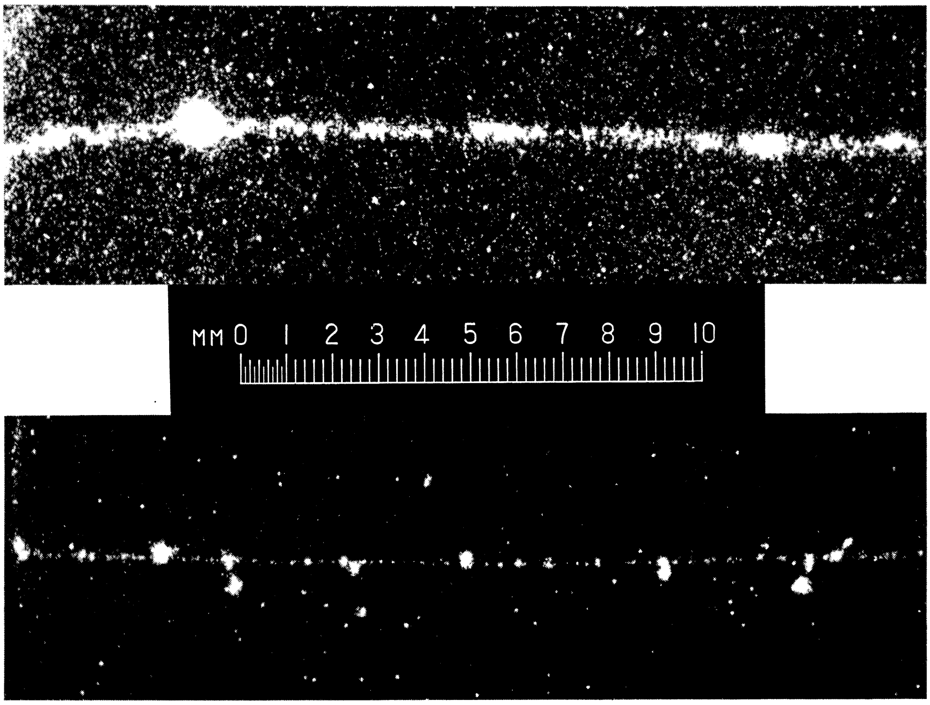


DETECTORS
High resolution streamer chamber

The production of particles containing heavy quarks using hadron beams presents severe challenges because of the low production rates and the topological complexity of the events. These problems are especially severe in the hadroproduction of 'beauty' (b) quark systems where production rates are about one part per million of the total interaction rate and a typical event has five separate interaction vertices.

A promising approach is the use of a a streamer chamber with a setting error (per streamer) of some ten microns and a two-track resolution in the 30-50 micron range. Such a chamber would serve as triggerable high resolution vertex detector with excellent pattern recognition and high rate capability. Even with conservative assumptions about the production rate, samples of 500 B meson pair events per experiment appear reasonable. The topological reconstruction capabilities of the streamer chamber would mean that nearly

Example of diffusion suppression of electron tracks in a high resolution streamer chamber. The top track is not diffusion suppressed and was taken at 33 atm in a neon/helium mixture with 1.2 microsecond trigger delay. The bottom track was taken with the same trigger delay but with diffusion suppression. Oxygen (4 psi) leading to 50 ns capture time was used as explained in the text. The scale applies to both tracks.



all the events will be useful for physics analysis.

For some time it has been known that small streamers (less than about 50 microns) can be obtained using a high pressure chamber, but the resolution has been severely limited by the diffusion of the ionization electrons during the trigger delay time, typically a few microseconds. For example, an earlier version of the Yale-Fermilab chamber operating at 40 atmospheres and a 1.4 ns high voltage pulse gave tracks of 120 microns, leading to two-track resolutions of 225 microns, about four times the statistical spread of track widths.

A Yale-Fermilab group has now developed a technique for suppressing this diffusion. It involves rapid capture of the ionization electrons on oxygen molecules leading to the formation of (O_4^-) ions. The time for an average electron to be captured depends on the oxygen partial pressure and on the strength of the electric clearing field used. Capture times of some 50 ns have been achieved with 4 psi of oxygen in a neon/helium mixture at 30 atmospheres. There is no problem in reducing the capture time to 20 ns if desired, the diffusion width of the tracks decreasing roughly as the square root of the capture time.

The track ionization is thus stored in the form of (O_4^-) ions during the trigger delay time. Because they are heavy, these ions diffuse less than one micron during a 3 microsecond trigger delay. To make the track visible, a pulse of ultra-violet light from an excimer laser (wavelength 351 nm) is passed through the chamber just before the high voltage pulse is applied. The time delay between the laser pulse and the high voltage pulse is about 30 ns. Thus many of the photo-liberated electrons will escape recapture and grow into streamers. Work is progressing on improving the timing so that capture times of 20 ns can be used. Very pure gas must be employed since trace amounts of organic compounds can lead to multiphoton ionization in the residual gas and a subsequent general background. A continously circulating gas system is used in which the gas passes through a catalytic converter operated at 500°C.

This scheme would have a very long (many milliseconds) memory time, unacceptable for triggered operation in an intense beam. This arises because of small amounts of CO_2 which introduce other ions. By controlling the CO_2 content, memory times from 1 to 100 microseconds have been obtained. The CO_2 level is controlled by a cryogenic system with a cold trap in the gas loop at an appropriate temperature.

Measurements on a sample of diffusion-suppressed tracks showed that the statistical spread of streamer centres was less than 18 microns and the average streamer diameter was 45 microns. This diameter may still be limited by the resolution of the image intensifier used to take the pictures. The number of streamers per mm can be varied at will up to about 15 by varying the laser intensity. In a high energy experiment, where the full pressure of 60 atmospheres can be used, with 20 ns capture time the diffusion spread should be less than 10 microns.

The tests have so far been carried out at Yale but the chamber and its associated equipment is being moved to a Fermilab test beam for a complete set of measurements with high energy tracks. Plans for using the chamber in a subsequent heavy particle production experiment are being prepared.

At the Conference at London's Imperial College in April marking the centenary of the birth of Erwin Schrödinger — Schrödinger's daughter Ruth Braunizer with Austrian theorist Walter Thirring, who celebrated his 60th birthday this year (see page 29).

Schrödinger centenary

The centenary of the birth of polymath Erwin Schrödinger was marked by a suitably multidisciplinary conference in April at London's Imperial College, reflecting the impact of the man's work on physics, chemistry, molecular biology and the history and philosophy of science.

Born in Vienna, Schrödinger had positions at Zurich, Berlin, Graz and Vienna but stayed longest in Dublin. E. T. S. Walton, from Dublin, and the senior of the many Nobel laureates at the meeting (he shared the 1951 award with John Cockcroft) delightedly maintained that the grandfather of particle physics, J. J. Thomson, would have scorned modern theoretical ideas.

Undeterred, Abdus Salam summarized today's viewpoint while Steven Weinberg and Alexander Polyakov sketched the possibilities of unified 'string' theories.

C. N. Yang drew attention to a 1922 Schrödinger paper (predating the famous ones by several years) containing an embryo form of the path dependent phase factors so useful in modern gauge theory.

In a grand finale, Linus Pauling illustrated the impact of the celebrated equation on molecular biology. Although Schrödinger's fame rests on his equation, he was more an ideas man, claimed Pauling, who like Max Perutz, was nevertheless sceptical of the role of

At the Schrödinger centenary meeting, Alexander Polyakov (left) covered ideas in string theory while cosmology benefited from Stephen Hawking. In the background is Tom Kibble, who spoke on topological defects in gauge theory.

(Photos Imperial College)

People and things

Schrödinger's widely-read book 'What is life?' in advancing modern molecular biology.

A 1948 BBC recording 'Do electron's think?' testified to the quality of Schrödinger's English, attributed by him to his maternal grandmother. Another vivid reminder came from his daughter Ruth Braunizer, who was delighted by the cat adorning the logo on the conference rostrum.

The Conference was supported by the Austrian government, the Dublin Institute for Advanced Studies and by many generous donations.

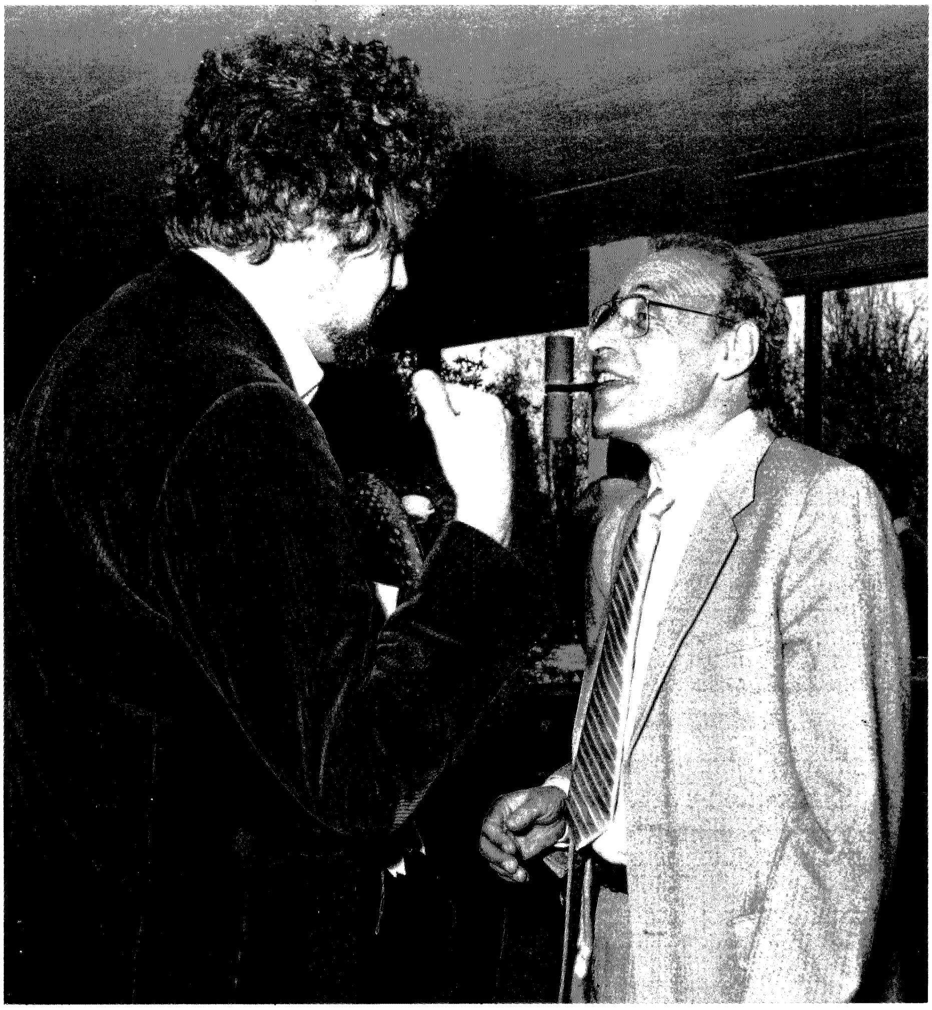
From D. Olive

On people

After 25 years, distinguished Soviet physicist V. N. Gribov recently revisited CERN. After recalling then having seen Murray Gell-Mann making his historic prediction of the omega-minus particle, Gribov presented his somewhat unorthodox views on the role of light quarks in the quark confinement mechanism. He also claimed that gluonium — matter made of gluons rather than quarks — should not exist. Despite vigorous efforts, no conclusive evidence for the existence of gluonium has yet been found.

Earlier this year, the sixtieth birthday of Austrian theoretician and former CERN director and Scientific Policy Committee member Walter Thirring was marked by dedicating the 1987 sessions of the annual Universitätswochen für Kernphysik in the Austrian town of Schladming, with lectures given by his friends and collaborators.

Alan Jeavons, Peter Frey, David Townsend and Alfred Donath have been awarded this year's Prix de Jubilae from the Swiss Society of Radiology and Nuclear Medicine for their work on the development of a positron camera for diagnostic



V. N. Gribov (right), seen here with Tord Ekelof of Uppsala.

HEAD OF ENGINEERING GROUP

Sincrotrone Trieste spa, an Italian limited company invites, applications for the position of Head of the Engineering Group in the Synchrotron Radiation Source Project. The Project, planned for construction in Trieste, Italy, consists of a 2 GeV electron storage ring and its injection system. The storage ring will produce beams of VUV and soft X-ray synchrotron radiation from wiggler and ondulators with extremely high flux and brillance. When completed, it will provide outstanding research opportunities to a multi-disciplinary scientific community.

The successfull candidate will report directly to the Project Head, and will be responsible for the coordination of design, construction and operation of the magnets and power supplies, the survey system and the coordination of the electrical and mechanical installation. This is a senior position which requires advanced degree in electrical or mechanical engineering and at least ten years' experience in the management, design and construction of large particle accelerators.

To apply please send a complete curriculum vitae, a list of publications and the names of the referees to the attention of:

Max Cornacchia
Sincrotrone Trieste
Area di Ricerca
Padriciano 99
34 012 Trieste, Italy

Ref. M/001 (to be indicate in the envelope)

High Energy Physics Research Associates

There are vacancies for Research Associates to work with groups in high energy physics. Groups from the Rutherford Appleton Laboratory are working on experiments at CERN, DESY, ILL, and SLAC. There is in addition a vacancy in the HEP Theory Group.

Candidates should normally be not more than 28 years old. Appointments are made for 3 years, with possible extensions of up to 2 years. RAs are based at the accelerator laboratory where their experiment is conducted, and at RAL, depending on the requirements of the work. Most experiments include UK university personnel with whom particularly close collaborations are maintained.

Please write for an application form quoting VN 567 to: **Recruitment Office, R20, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX ENGLAND.**

serc Rutherford Appleton Laboratory

SIN

Experimental Physicist

A position is available for an experimental physicist at the Swiss Institute for Nuclear Research.

SIN operates a 600 MeV isochronous cyclotron which is used to produce a number of meson beams. The position is initially available for three years.

The successful candidate will be expected to work primarily in medium energy nuclear physics experiments at SIN, but the opportunity to also take part in an experiment at CERN may be available.

Additional information can be obtained from:

Dr. Q. Ingram (Tel. 056/99 32 58)

or Dr. J. Domingo (Tel. 056/99 32 51).

Applications, containing curriculum vitae, list of publications and references should be sent as soon as possible, but not later than July 31, 1987 to

SIN
Personnel Division
CH-5234 Villigen
Switzerland
Code 588

UNIVERSITY OF CAPE TOWN

SPES BONA

Chair of Theoretical Physics

Applications are invited for the above tenured Chair in the Department of Physics, for appointment on 1 October 1987 or as soon as possible thereafter. The appointee will be expected to participate in teaching at undergraduate and graduate levels and to strengthen existing research interests.

The University is seeking a theoretical physicist with an established research reputation at international level. Current research interests in theoretical physics involve quantum chromodynamics, chiral symmetry breaking and the confinement problem, superstrings, statistical mechanics of strongly interacting matter, nuclear structure and reactions, and approximation methods in quantum mechanics. The main thrust of research in experimental physics lies in the fields of nuclear and laser physics.

Appointment, according to qualifications and experience will be made in the salary range R37 482-R45 069 per annum, with an annual bonus and attractive staff benefits. The University anticipates that salary ranges may be increased in the foreseeable future.

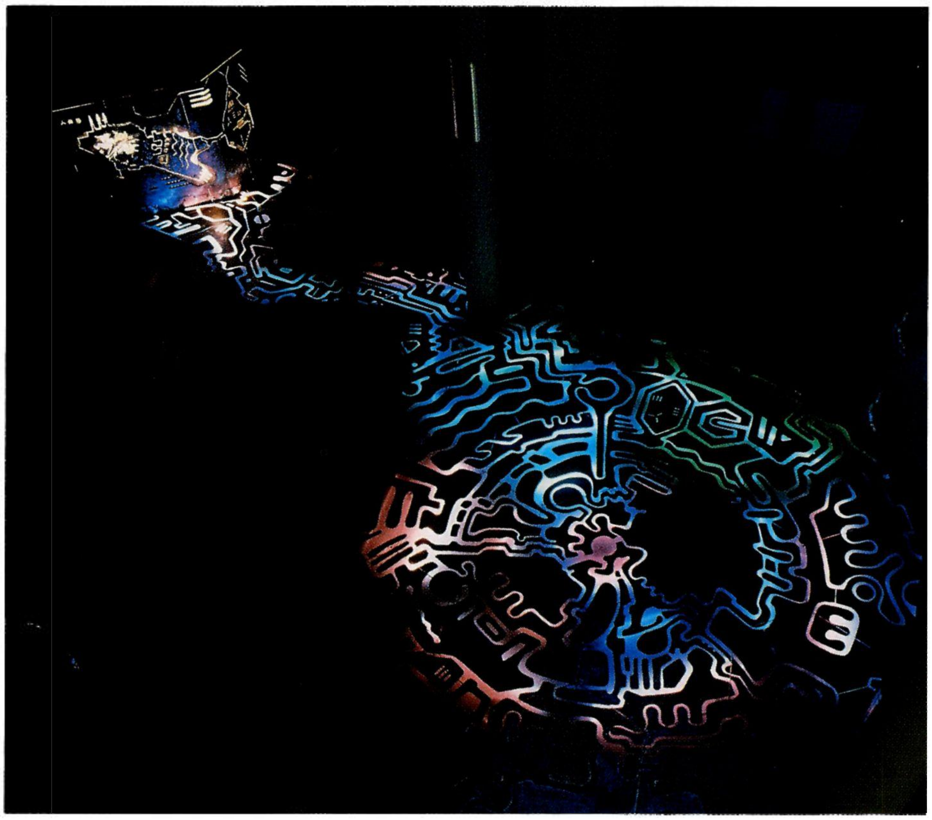
Applicants should submit a full curriculum vitae and the names and addresses of three referees, not later than 11 September 1987 to the Registrar (Attention: Appointments Office FH1687) University of Cape Town, Rondebosch, 7700, Republic of South Africa. Further information may be obtained from the above or from the Secretary, SA Universities Office, Chichester House, 278 High Holborn, London WC1V 7HE.

The University's stand against apartheid and all racially discriminating legislation is on record. Information on this as well as on the University's policy not to discriminate in the appointment of staff or the selection of students on the grounds of sex, race or religion is obtainable on request.

Bates Wells Recruitment CT 181R

Karl Lanius, Director of the Institute for High Energy Physics of the German Democratic Republic.

'Cosmic Song' — visitors arriving at CERN can now admire Serge Moro's dynamic sculpture illuminated by fluorescent tubes responding to cosmic ray signals. The display was caught at its best by CERN photographers Gilbert Cachin and François Julliard.



imaging. Development began at CERN in the late 1970s and continued in the Division of Nuclear Medicine of Geneva Cantonal Hospital.

On 3 May, the Institute for High Energy Physics of the East German Academy of Sciences celebrated the 60th birthday of Director Karl Lanius. Besides playing a major role in the development of high energy physics research in the German Democratic Republic, Lanius has been also a member of several major international committees, and a vice-director of the Joint Institute for Nuclear Research, Dubna.

The Institute for High Energy Physics, Zeuthen, German Democratic Republic, has been in existence for 25 years. Its researchers are presently collaborating in the neutrino physics programme at Serpukhov (USSR), in the L3 experiment for CERN's LEP electron-positron collider and the H1 experiment for the HERA electron-proton collider at the German DESY Laboratory. The statue is of Max Planck.

INTRODUCING OUR LATEST DETECTOR DEVELOPMENT TOOL

Model 2262 Multi-Input, 10-Bit, 40/80 Megasample/sec Waveform Digitizer

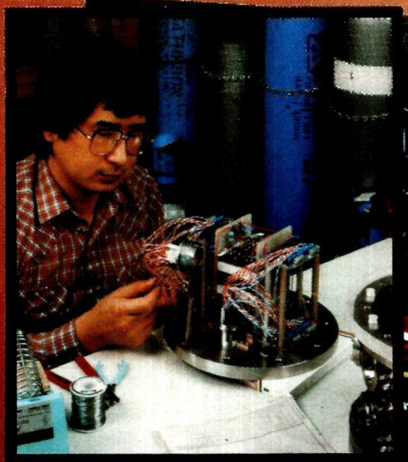
Developed for Jet, Image and Time Projection Chamber (TPC) Systems in High Energy Physics and Heavy Ion experiments, LeCroy's Model 2262 Waveform Digitizer offers precision analysis of both chamber performance and readout electronics.

Bi-polar inputs permit simultaneous sampling from sense wires or pads. The DC-coupled 40 MHz analog bandwidth and 10-bit resolution means that the details of the chamber signals will not be lost. Up to four signals at 40 megasamples/sec or two signals at 80 megasamples/sec are captured by a single-width CAMAC (IEEE-583) module. External timebases may also be used.

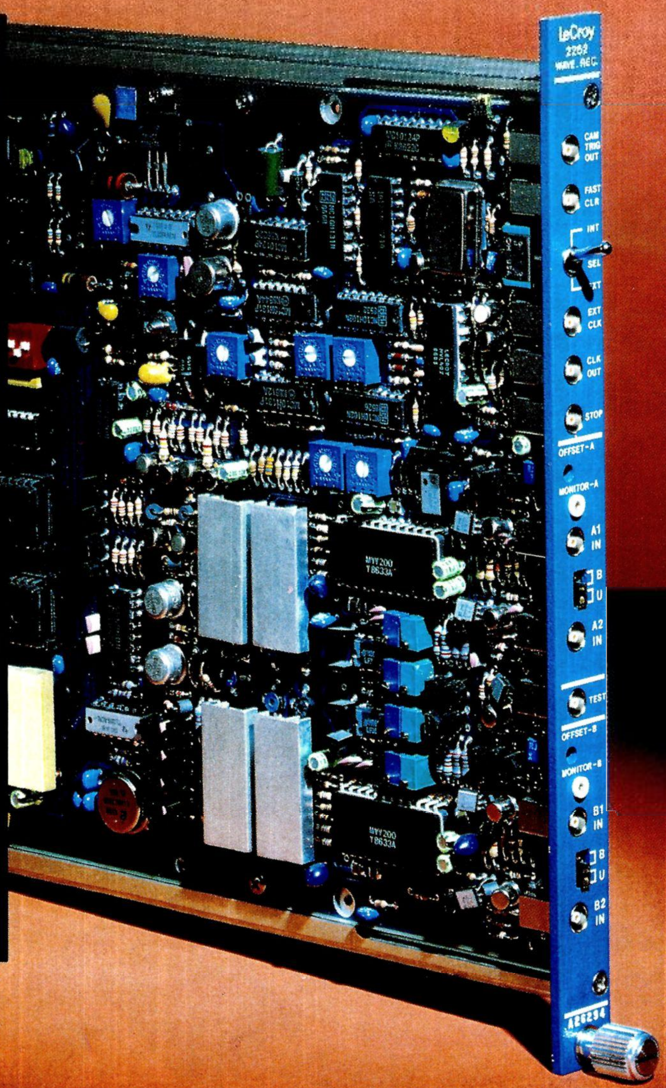
The Model 2262 is compatible with GPIB (IEEE-488) operation and works with IBM PC™-based software for easy, user-oriented, waveform display and control. Support and accessory modules are available. Contact LeCroy worldwide for more information and detailed specifications.

LeCROY—for the performance, service and support you can count on today and in the future.

™IBM PC is a registered trademark of International Business Machines Corporation.
™CATALYST is a registered trademark of LeCroy Corporation



LeCroy digitizers are being used for detector development in Lawrence Berkeley Laboratory's radial drift detector.



Detector Development Station with HV supply, digitizer, amplifier and time base in bench top mainframe. GPIB connection to an IBM PC AT running CATALYST™ Software.

LeCroy

700 Chestnut Ridge Road, Chestnut Ridge, NY 10977-6499, USA. Tel: (914) 578-6013
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CATALOG

KOBOLD
MESSRING GMBH

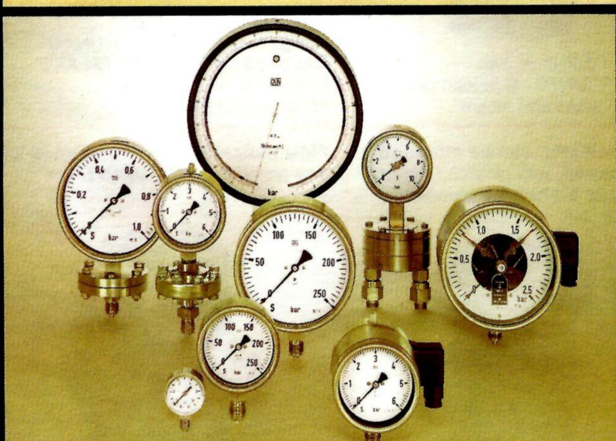
Instrumentati
and control f
FLOW RATE
PRESSURE
FLUID LEVE
TEMPERATU

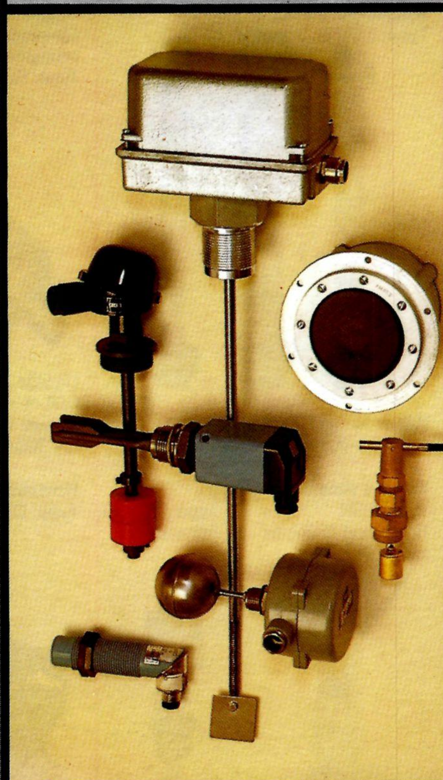
Flow measurement
Indicating instruments, controllers and recorders

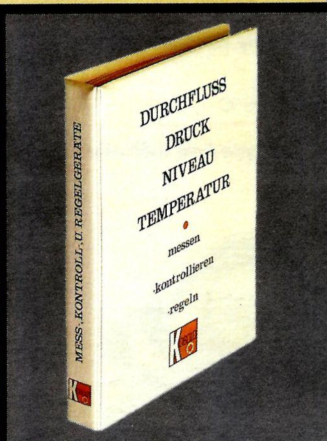
Pressure measurement
Liquid column devices and switches

Level measurement
Indicating instruments, controllers and recorders

Temperature measurement
Thermometers, controllers and monitors





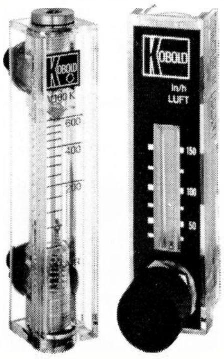


The Kobold Handbook will be sent to you, free of charge, on request.

Sodener Straße 120
D-6233 Kelkheim
Postfach 2052
☏ (0 61 95) 69 11/69 72
Tx 4 072 326 komr d
Telefax (0 61 95) 6 50 00

Flow measurement

Microvolume flowmeters
with or without needle valve
in **polycarbonate, polysulfone and acrylic glass**

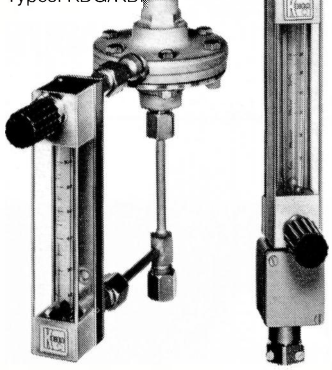


Water: 0.1 - 1.5 l/h to 5 - 80 l/h
Air: 0.5 - 5 L_n/h to 0.2 - 2.6 Nm^3/h

Microvolume flow controllers
Explosion-proof iG 5
Types: KSR and SVN

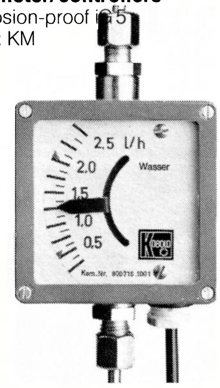
Water: 0.1 - 120 l/h
Air: 2 l_n/h - 2 Nm^3/h

Microvolume flowmeter/controllers
Explosion-proof iG 5
Types: KDG/KDF



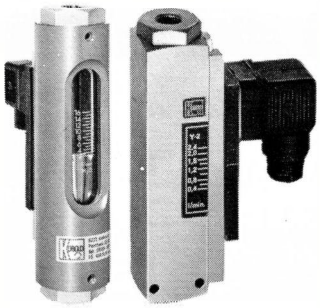
Water: 0.002 - 0.02 to 16 - 160 l/h
Air: 0.03 - 0.3 l_n/h to 430 - 4300 l_n/h

All-metal microvolume flowmeter/controllers
Explosion-proof iG 5
Type: KM



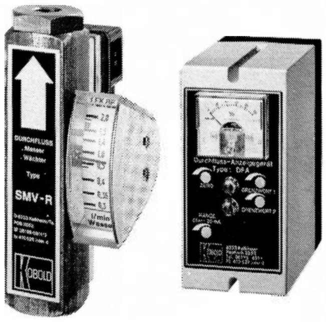
PN 40 - PN 100/–20 … +150 °C
Water: 0.1 - 1 l/h to 25 - 250 l/h
Air: 4.5 - 45 l_n/h to 0.8 - 8 Nm^3/h

Flowmeter/controllers
Explosion-proof iG 5
Type: SV-R/S-R



Water: 6 - 60 l/h to 0.5 - 9 m^3/h
Air: 0.2 - 2 Nm^3/h to 20 - 250 Nm^3/h

All-metal flowmeter/controllers with analog output
Explosion-proof iG 5
Type: SMV-R/VKM-G

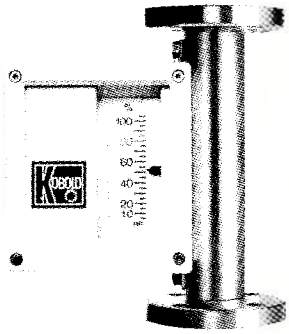


PN 350/–50 °C … +160 °C
Water: 3 - 60 l/h to 0.5 - 15 m^3/h
Air: 3 - 35 l/h to 20 - 400 Nm^3/h

Flowmeters and controllers with analog output independent of viscosity and location
Types: VKG and VKM

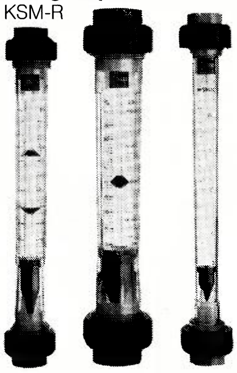
Viscosity range: 1 - 5000 mm^2/s
e. g.: 0.01 - 0.07 to 8 - 80 l/min of oil

All-metal flowmeters and controllers with analog output
Type: MC



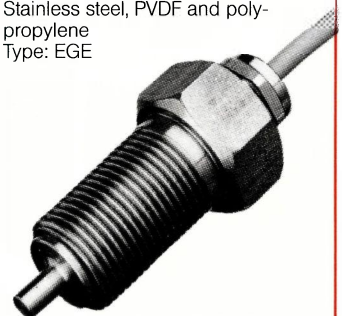
PN 40 - PN 600 /–50 … +300 °C
Water: 2.5 - 25 l/h to 10 - 100 m^3/h
Air: 75 - 750 l_n/h to 180 -1800 Nm^3/h

Trogamid and polysulfone flowmeter/controllers with analog output
Type: KSM-R



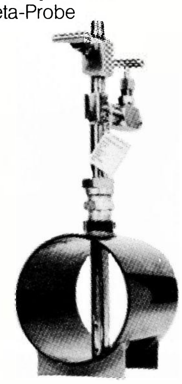
Water: 16 - 160 l/h to 2 - 20 m^3/h
Air: 0.25 - 2.5 Nm^3/h to 58 - 580 Nm^3/h

Electronic flow controllers
for gases, liquids and powders
Media: $\triangle$p=O
Stainless steel, PVDF and polypropylene
Type: EGE



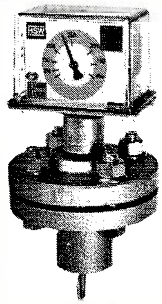
Liquids (incl. **highly viscous):**
0.01 - 4 m/s.
Gases: 0.1 - 15 m/s
PN 300/–40 … + 90 °C

Flow sensors proportional to differential pressure
Type: Beta-Probe



Error: ± 0.5% or ± 2%
R ½" - R 2"/DN 50 - 9 m lead dia
Liquids, gases and steam

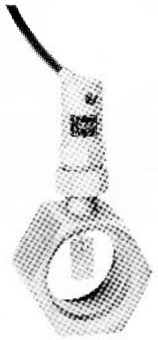
Paddle-bellows flowmeters and controllers for heavily contaminated media
Types: HSW - DWU/-DWP/-DWS



Pipe connection ³/₈" - 2"
Flange connection DN 10 - DN 50
Slip-on flange for DN 40 - DN 1000
1 - 4 l/min to 10 000 m^3/h
PN 6 - PN 10 / 100 °C

Paddle flow controllers

Type: PSR
Brass and stainless steel



3 - 5 l/min
to 20 - 28 m^3/h
PN 16 - PN 25/100 °C

Type: PPS-3S
Polysulfone

10 - 110 l/min
PN 10/110 °C

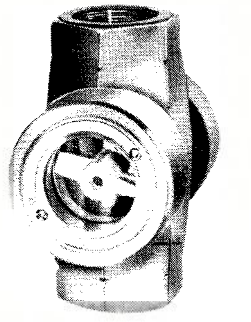
Horizontal ball-type flow indicator
Type: DA - KU

Range
Water: 0.3 l/min - 90 l/min
Air: 0.015 Nm^3/min - 200 Nm^3/h

Flow indicator, can be mounted in any position, with plastics rotor and **automatic sight-tube cleaner**
Type: DA - RA

R ¼" - R 1½"
PN 16/100 °C

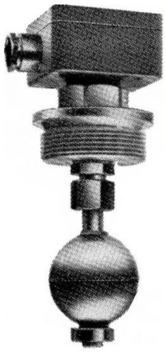
Flow indicator, can be mounted in any position, with Teflon rotor
Type: DA - R



R ¼" - R 1½" / flange DN 25/40/50
suitable for both dark opaque liquids and for gases

Measurement of level

Magnetic float switches
Type: N
180 different types in high-grade steel, titanium, brass, PPH, PVC, PVDF and PTFE

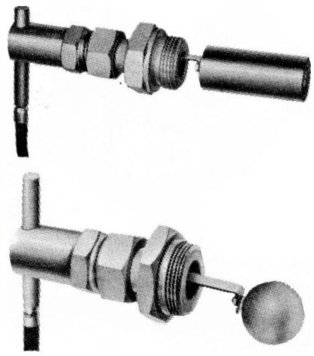


PN 100/180 °C
Den.$_{liq.}$ min ≥ 0.25 kp/dm^3

Magnetic float switches
Type: NS
for side-fitting

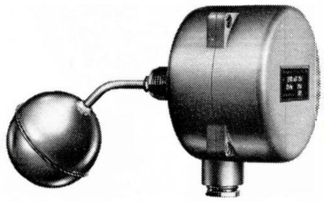
PN 100/180 °C
Den.$_{liq.}$ min ≥0.25 kp/dm^3

Magnetic float switches
Type: NV 1/2" und NV 3/4"
for side-fitting



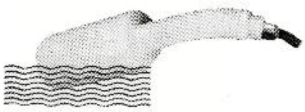
PN 18/110 °C
Den.$_{liq.}$ min ≥0.8 kp/dm^3

Float switches with spring contact
Type: FNS
for side-fitting



PN 16/350 °C
Den.$_{liq.}$ min ≥0.8 kp/dm^3
I_{max} = **10 A** bei 220 V ~

PTFE float switches
Type: NST
for side-fitting with **mercury contact**

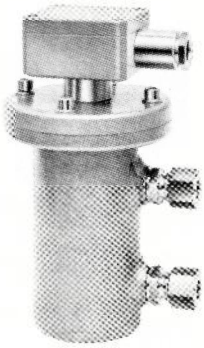


1 bar/160 °C
Den.$_{liq.}$ min ≥0.7 kp/dm^3
I_{max} = **4 A** bei 220 V ~

Bypass float switches
with spring contact
Type: FNS

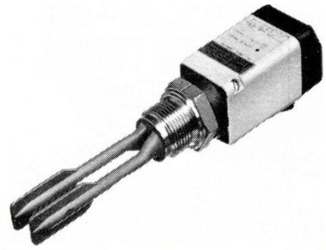
PN 16/350 °C
Den.$_{liq.}$ min ≥0.7 kp/dm^3
I_{max} = **10 A** bei 220 V ~

Bypass magnetic float switches
Type: NB-10



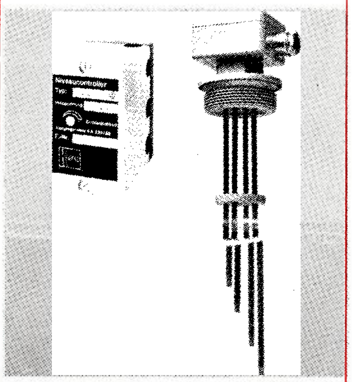
PN 10/150 °C
Den.$_{liq.}$ min ≥0.7 kp/dm^3

All-purpose limit switches
for liquids
Type: FTL 160



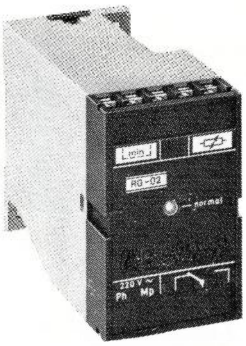
Den.$_{liq.}$ min: independent
max. viscosity: 2000 mm^2/s
PN 16/−40…+150° C
G x 5 Cr Ni Mo Nb 1810 austenitic steel

Limit switches for conductive fluids



PN 100/150 °C
single to quintuple electrodes

Thermal resistor switches for **nonconductive** liquids

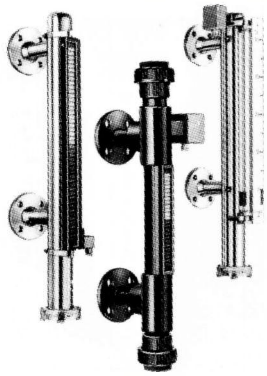


t_{max} = −25 °C… +55 °C
max. viscosity 10 °E

Level indicators
Level pick-ups
Type: NM

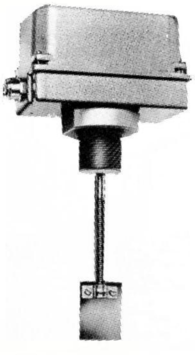
PN 25/−50 °C…+130 °C

Bypass level indicators
with magnetic transmitters
Type: BMG



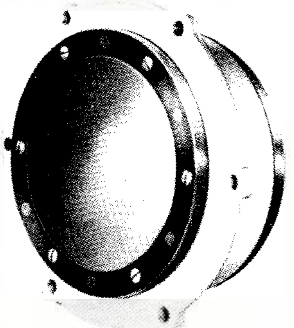
PN 350/300 °C

Vibratory level signalling devices for heavy and viscous media with **flexible** vibratory sensor
Type: NBV



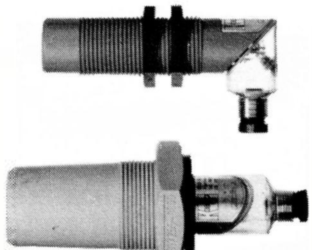
PN 6/80 °C/IP 55
R1 1/2" or flange DN 50 - DN 150

Diaphragm-type level signalling devices for installation in silos, bunkers, etc. for coarse and fine **bulk goods**
Type: NMF



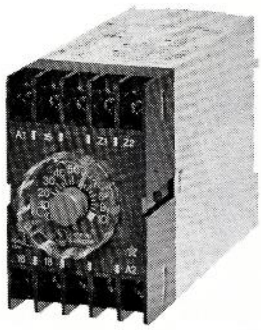
−30 °C…+200 °C
for Zone 11 explosion-proof rooms without ancillary equipment

Capacitive level switch
for fine and powder bulk goods
Type FTC 960



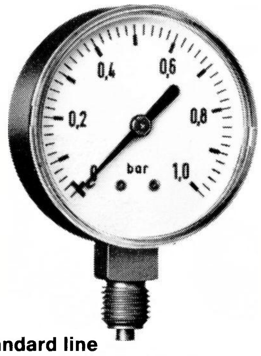
PN 6/−20…+80 °C
R1"/adapter R 1 1/2"

Time-delay starting relays
Contact protector relays

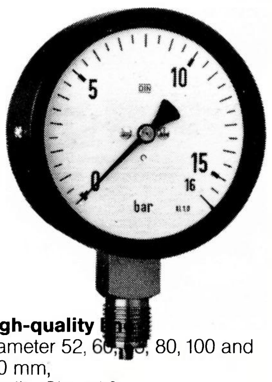


Explosion-proof relays - Zone 0
Control systems

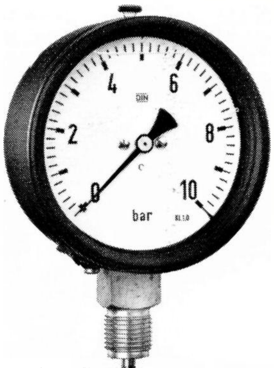
Pressure



Standard line
Diameter 40, 50, 63, 80, 100 and 160 mm,
Quality Class 2.5
Measuring range 0 - 1 bar to 0 - 400 bar

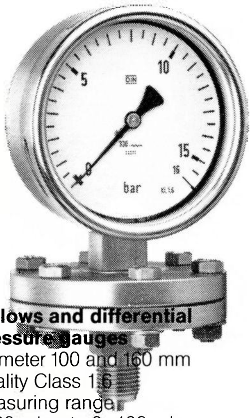


High-quality line
Diameter 52, 60, 63, 80, 100 and 160 mm,
Quality Class 1.0
Measuring range
0 - 60 mbar to 0 - 400 mbar
0 - 0.6 bar to 0 - 1600 bar

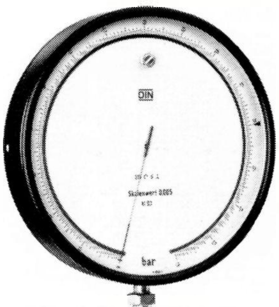


Glycerine-filled pressure gauges
Diameter 63, 100 and 160 mm
Quality Class 1.0 to 2.5
Measuring range
0 - 0.6 bar to 0 - 1000 bar

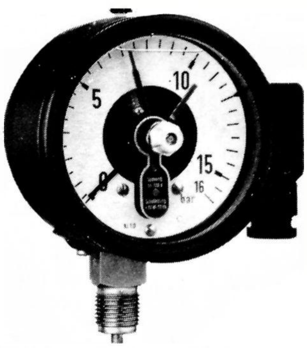
Chemical line
Diameter 40, 50, 63, 100 and 160 mm,
Quality Class 1.0
Measuring range
0 - 0.6 bar to 0 - 1000 bar



Bellows and differential pressure gauges
Diameter 100 and 160 mm
Quality Class 1.6
Measuring range
0 - 60 mbar to 0 - 400 mbar
0 - 0.6 to 0 - 25 bar

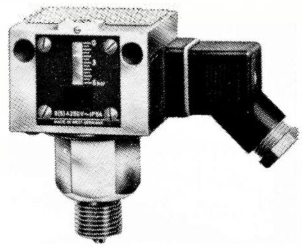


Precision pressure gauges
Diameter 160 mm, Quality Class 0.6 and 0.3
Diameter 250 mm, Quality Class 0.3, 0.2, 0.1
Measuring range
0 - 0.6 bar to 0 - 1600 bar



Contact pressure gauges
- Magnetic snap-action contacts
- Crawl contacts
- Inductive contacts
- Pneumatic contacts

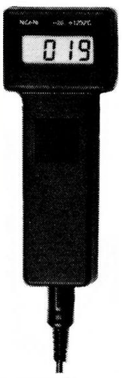
Pressure and differential pressure switches
Adjustable differential setting
Liquids, steam and gases
Type: KD / KV



–250 mbar to 100 mbar
15 bar to 63 bar
250 V AC, 10 A

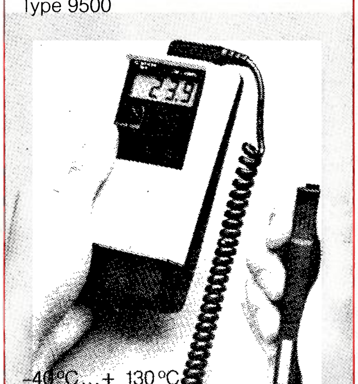
Temperature

Digital hand thermometers
Type: 7300 / 9300



–200 °C … + 600 °C
– 40 °C … +1200 °C

Digital hand thermometers
For **Zone 0** explosion-proof rooms
Type 9500

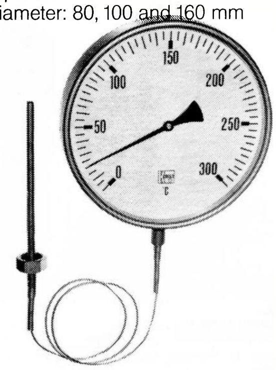


–40 °C … + 130 °C
–70 °C … +1200 °C
–50 °C … +1750 °C

Precision dial thermometers
Nitrogen-filled
For food industry, etc.
Error: ±0.6 and ±1.0% of full-scale reading
Diameter: 80, 100, 160 and 250 mm

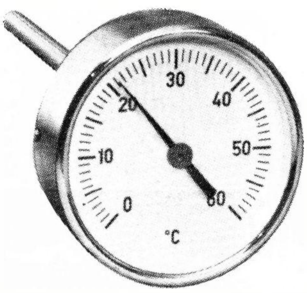
–250 °C … +650 °C

Precision dial thermometers
Mercury-filled,
error ±1.0% of full-scale reading
Type: 610
Diameter: 80, 100 and 160 mm



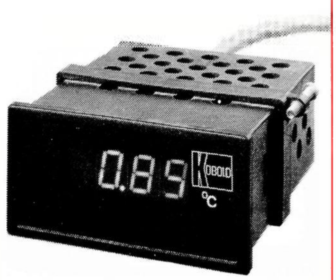
–30 °C … +500 °C

Machine thermometers
Bimetal
50, 63, 80, 100, 160, 250 mm



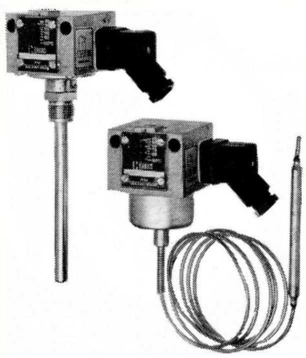
–35 °C … + 50 °C
0 °C … +300 °C

Digital 48x24 thermometers for panel mounting
Type: TT 4600



0 °C … + 99.9 °C
–20 °C … +600 °C

Temperature controllers
with adjustable set point
Type: KTAM/KTXM



–30 °C … + 10 °C
+80 °C … +130 °C

Temperature controllers and monitors with fixed set point
Type: TWR

+30 °C … +120 °C
PN 16 / IP 65