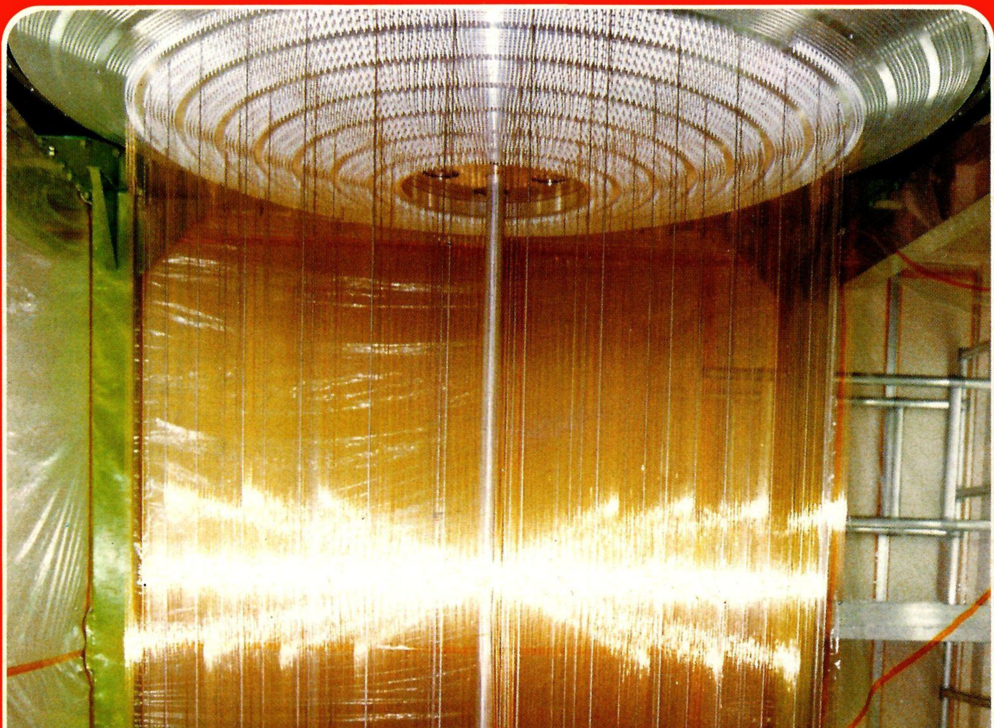
CERN COURIER

International Journal of High Energy Physics



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Cover photograph: Assembly of the central drift chamber for the VENUS experiment at the TRISTAN electron-positron collider now under construction at the Japanese KEK Laboratory (Photo KEK).

Nobel 1984

1984 Nobel laureates Carlo Rubbia (left) and Simon van der Meer acknowledge the cheers.

(Photo CERN 523.10.84)

There was general jubilation at CERN following the announcement from Stockholm on 17 October that Carlo Rubbia and Simon van der Meer had been nominated for the 1984 Nobel Prize for physics by the Royal Swedish Academy of Sciences 'for their decisive contributions to the large project which led to the discovery of the field particles W and Z, communicators of the weak interaction'.

These discoveries, made last year at CERN, rank among the greatest achievements in the history of science. They confirmed a new picture of Nature which unifies electromagnetism with the weak nuclear force. This quest began exactly 50 years ago with the first formulation of the theory of the weak force by Enrico Fermi, and ultimately led to the elegant 'electroweak' picture which earned the Nobel award for Sheldon Glashow, Abdus Salam and Steven Weinberg in 1979.

At CERN, the story began in 1968 when Simon van der Meer, inventor of the 'magnetic horn' used in producing neutrino beams, had another brainwave. It was not until four years later that the idea (which van der Meer himself described as 'far-fetched') was demonstrated at the Intersecting Storage Rings. Tests continued at the ISR, but the idea — 'stochastic beam cooling' — remained a curiosity of machine physics.

In the United States, Carlo Rubbia, together with David Cline of Wisconsin and Peter McIntyre, then at Harvard, put forward a bold idea to collide beams of matter and antimatter in existing large machines. At first, the proposal found disfavour, and it was only when Rubbia brought the idea to CERN that he found sympathetic ears.

Stochastic cooling was the key, and experiments soon showed that antimatter beams could be made sufficiently intense for the scheme to work. With unprecedented boldness, CERN, led at the time by Leon Van Hove as Research Director General and the late Sir John Adams as Executive Director General, gave the green light.

At breathtaking speed, the ambitious project became a magnificantly executed scheme for colliding beams of protons and antiprotons in the SPS Super Proton Synchrotron, with the collisions monitored by sophisticated large detectors.

The saga — for this is what the story is — was chronicled in the special November 1983 issue of the CERN Courier, with articles describing the development of the electroweak theory, the accelerator physics which made the project possible, and the big experiments which made the discoveries*.

While it is Rubbia and van der Meer who go to Stockholm to receive the most prestigious scientific accolade of all, the CERN discoveries were only made possible by technological excellence and teamwork unparalleled in the domain of pure research.

This was underlined at a celebration at CERN on 19 October, when the two latest arrivals to the physics hall of fame paid ample tribute to their colleagues and co-workers. There was special mention of the crucial roles played by Leon Van Hove and John Adams during their joint 1976-80 term of office.

Recalling those days, Van Hove described the growing realization that something 'significant' had to be done for CERN. He reviewed the list of options open back in 1978 — perhaps a superconducting ISR, or an electron-proton collider in the SPS, and then the Antiproton Project. Van Hove admitted that he had never dreamt the choice of the Antiproton Project would turn out to be so successful.

Van Hove paid tribute to the efforts of John Adams in pushing the beam cooling experiments and facing up to the problems of machine building and transformation. At first, some Americans were confident that they could beat CERN, but the European Laboratory had the 'Adams factor' working in its favour, the technical perfection which ensured the SPS performed so well that, as Carlo Rubbia once put it, 'it became apparent that a storage ring was right there ready to be used'.

Summing up, Director General Herwig Schopper ventured that CERN has now learnt how to make big discoveries and win Nobel Prizes, and it is important that this new skill be passed on to younger generations of physicists.

The physics students of the future will surely read avidly of the deeds of Rubbia and van der Meer at CERN in the same way that previous generations were stimulated by retracing the brilliant insights of Einstein and the subtle craft of Rutherford.

* 'Achievements with Antimatter', available from Publications, CERN, 1211 Geneva 23, Switzerland.

Leon Van Hove, Research Director General at CERN when the decision to go ahead with the Antiproton Project was taken, explains how to pick winners in physics.

(Photo CERN 596.10.84)

25 years... and still going strong

In the evening of 24 November 1959, a jubilant crowd in the control room of the sparkling new CERN Proton Synchrotron witnessed a proton beam accelerated to 24 GeV, at the time a new world record. The pride of Europe, the machine was the first to use the then new principle of alternating gradient focusing, and came into operation a full year ahead of its US counterpart, the Brookhaven Alternating Gradient Synchrotron.

The availability of the world's most powerful accelerator was a good start for high energy physics at the world's first international Laboratory. The PS has long since ceased to hold the world particle beam energy record, but thanks to the vision of its designers and a series of ingenious improvements which have provided increased performance and reliability, it remains the kingpin of CERN's installations, the largest and most versatile complex of high energy particle accelerators in the world.

After exploiting the original configuration to the full, the second decade of the machine's operation saw the arrival of the 800 MeV Booster synchrotron which increased the injection energy and hence the available beam intensity, and a new radiofrequency accelerating system. Later improvements included a new 50 MeV linac alongside the old one, new pole face windings for the magnets, the replacement of the original mercury arc rectifiers by solid-state ones, a new modular control system to take care of the complicated new modes of operation of the machine, and a radiofrequency quadrupole to replace the classic Cockcroft-Walton electrostatic pre-injector at the 'old' linac.

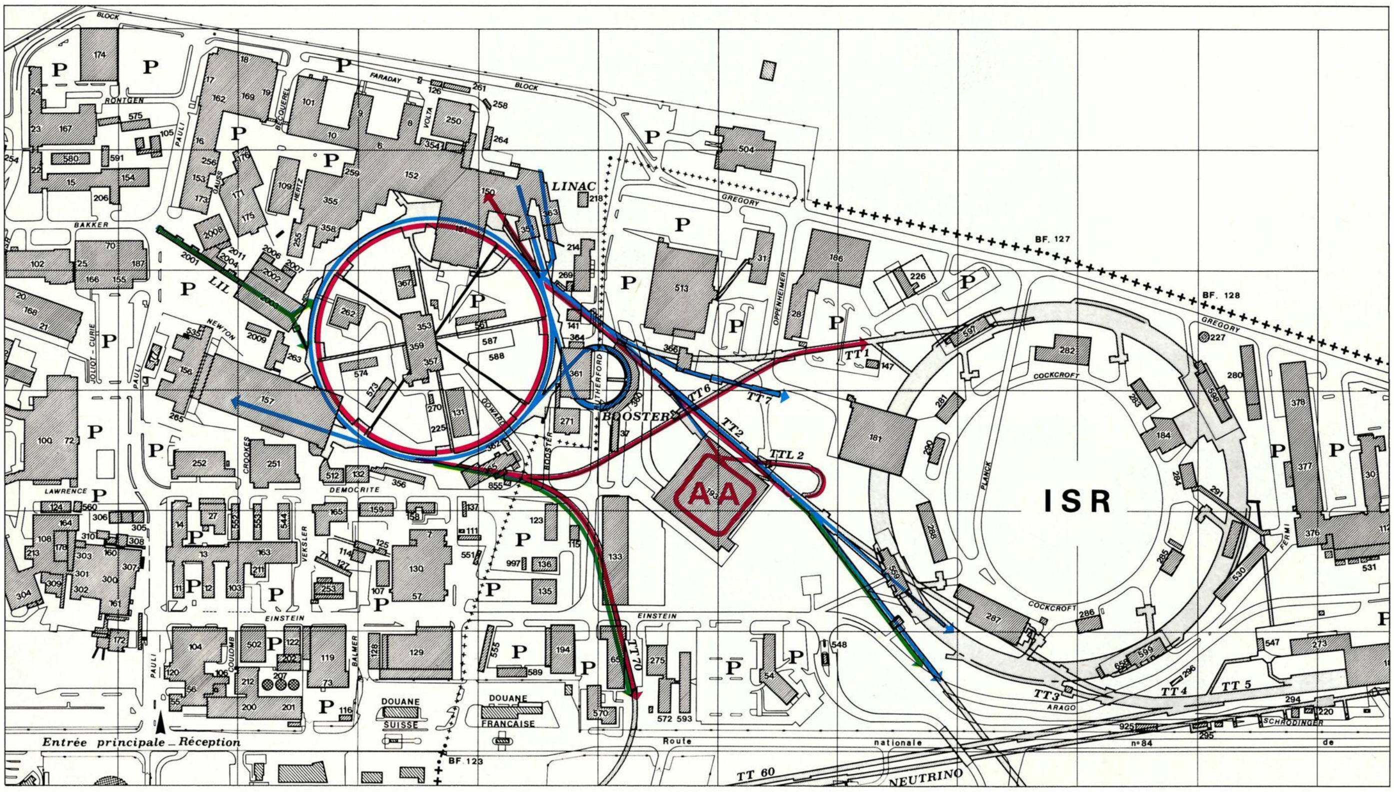
However the biggest change came in the role of the machine itself. Originally, the PS provided particle beams directly to the adjacent exper-

Beam exercises

The evolution of the CERN PS. In blue, the proton circuit, including the two linac injectors (top) and the adjoining Booster. The principal extracted beams fan out to the right, serving, from the top, the low energy neutrino beam, the Intersecting Storage Rings (ISR — now closed) and the 450 GeV Super Proton Synchrotron (below, not visible on plan), and the antiproton target.

In red, the antiproton circuit. The secondary antiprotons are stored in the Antiproton Accumulator (AA) and loop back to the PS. At the bottom, the extracted beam branches in two to serve the ISR and the SPS. At the top, the low energy antiprotons emerge for the LEAR ring.

In green, the future. Top left, electrons and positrons arrive from the new LEP injector. Before reaching LEP, the electrons pass to the SPS along the same path as the antiprotons, while positrons follow the proton path, along which the PS will also feed oxygen ions to the SPS.



On 5 February 1960, Niels Bohr presses the button at the formal inauguration ceremony of the CERN Proton Synchrotron. The machine attained its 24 GeV design energy on 24 November 1959.

(Photo CERN 2129A)

imental areas. But over the years it was increasingly called on to supply particles to other machines, first the Intersecting Storage Rings in 1971 and then in 1976 the SPS 400 GeV Super Proton Synchrotron.

With the advent of the CERN antiproton project, the PS became in 1981 the world's first antiproton synchrotron. Working in this mode, the PS takes 3.5 GeV antiprotons from the Antiproton Accumulator (AA), accelerating them to 26 GeV ready for injection into the SPS.

As if this were not enough, another antiproton requirement emerged. For the LEAR Low Energy Antiproton Ring, the PS has to take on yet another very different role, that of a particle decelerator rather than an accelerator. The precious antiprotons from the AA are slowed down from 3.5 GeV to a kinetic energy near 200 MeV.

In addition, there were alpha particles for the ISR, new beams for low energy neutrino experiments, new test beams... The valiant PS never failed to rise to the occasion.

The machine's big moment for physics came in 1973 with the discovery of the neutral current in neutrino interactions using the Gargamelle bubble chamber. With the arrival on the scene of the SPS, many of the big detectors migrated to the bigger machine. The PS retained a faithful band of experimenters, and in the last few years the novel LEAR programme has attracted a flock of several hundred physicists to the PS, many of them new to CERN.

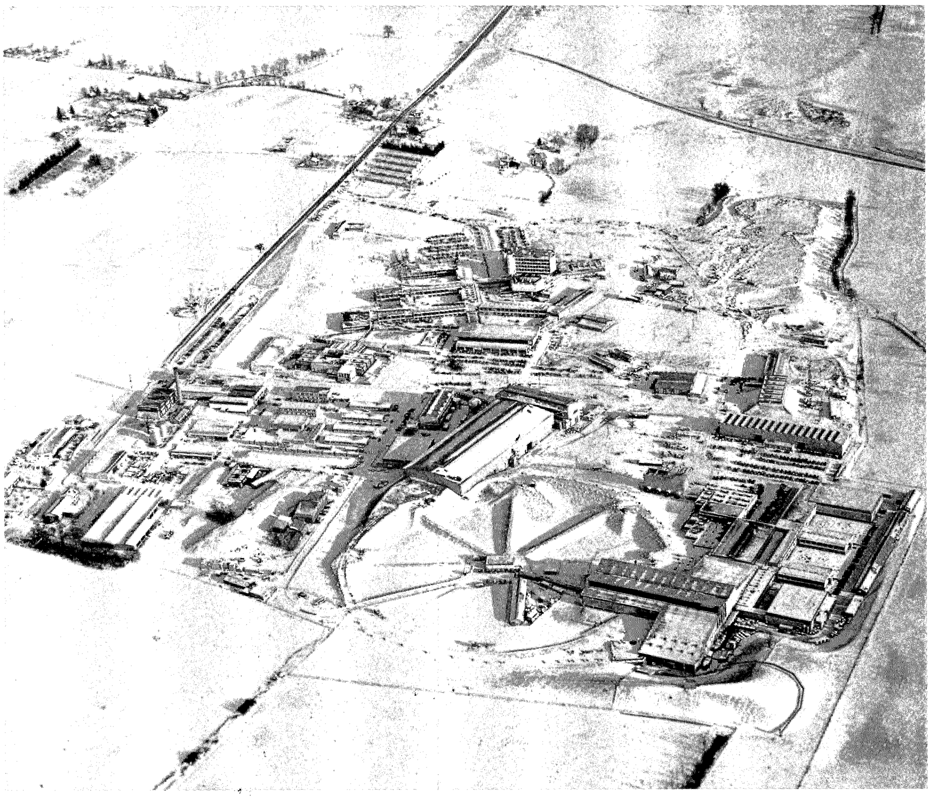
The PS provides per pulse over a thousand times the intensity delivered back in 1959 and works in complicated 'supercycles' to cater for its

Another shot from the inauguration, showing left to right, John Adams, Niels Bohr, Ed McMillan, and J. Robert Oppenheimer.

(Photo CERN 2065)

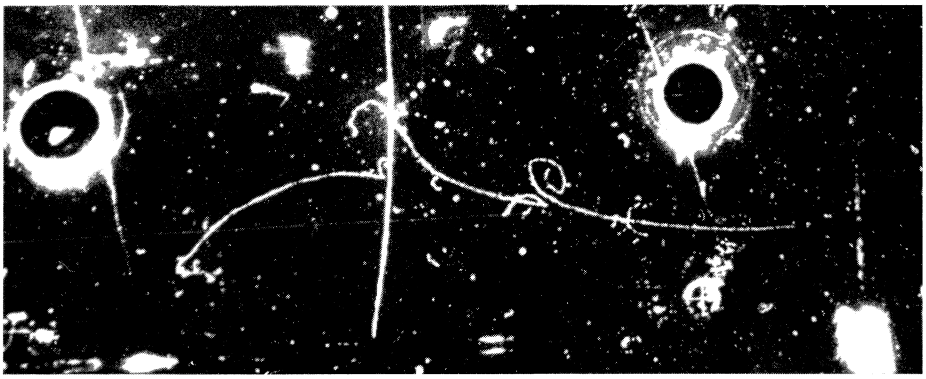
Evolution of CERN Proton Synchrotron parameters

	1959	1984 (* under development)
Intensity	design 10^{10} p/p achieved 3×10^{10} p/p	2.2×10^{13} p/p
Pulse rate	1 per 3 to 5 s	1 per 1.2 to 2.4 s
Energy	design 25 GeV achieved 28 GeV	0.2 to 25 GeV (kinetic)
Injector	50 MeV Linac	Injector 1 — 800 MeV four-ring Booster (PSB) fed by new 50 MeV Linac Injector 2 — Antiproton Accumulator Injector 3* — Electron Positron Accumulator
Accelerated particles	Protons	Protons, deuterons, alphas, antiprotons, electrons*, positrons*, oxygen*
Magnet Power Supply	Motor generator set with one mercury arc rectifier	Motor generator set with two thyristor rectifiers
Voltage	5400 V	9000 V
Current	6000 A	6000 A
Cycle type	single cycle with 20 ms peak	Supercycle adapted to the user: 14 GeV for SPS, 26 for SPS Collider and AA, 24 for experimental physics, and decelerating cycles for LEAR antiprotons
Accelerating systems		
Accelerating cavities	16 units of 10 kV each tunable from 2.5 to 9.5 MHz	10 units of 20 kV each tunable from 2.5 to 9.5 MHz 8 units of 50 kV each tuned at 200 MHz, 2 units of 500 kV each at 114 MHz
RF power	16 x 6 kW	10 x 100 kW (at 9.5 MHz) 8 x 20 kW (at 200 MHz) 2 x 160 kW (at 114 MHz)
Vacuum System		
Pumps	60 oil diffusion	139 ion and 14 turbomolecular (New vacuum chamber*)
Average pressure	4.10^{-6} torr	2.10^{-8} torr
Volume under vacuum	9 m³	16 m³
Injection system		
50 MeV	single turn with 1 electrostatic inflector and 3 pulsed inflectors	
800 MeV protons 3.5 GeV antiprotons 600 MeV electrons*		single turn with septas, fast deflectors and orbit deformation
Beam utilization systems	2 internal targets for South Hall (target 1) and North Hall (target 6)	Slow Extraction for East Hall Fast extraction for SPS/AA and with decelerated particles for LEAR Continuous extraction for SPS
Experiments	1 main user plus parasite tests, emulsion exposures and irradiation chemistry Exploratory counter experiments, 32 cm hydrogen bubble chamber	Test beams in East Area.



An early aerial view (1962) of the CERN site showing the PS ring with its experimental halls to the south (right) and to the east.

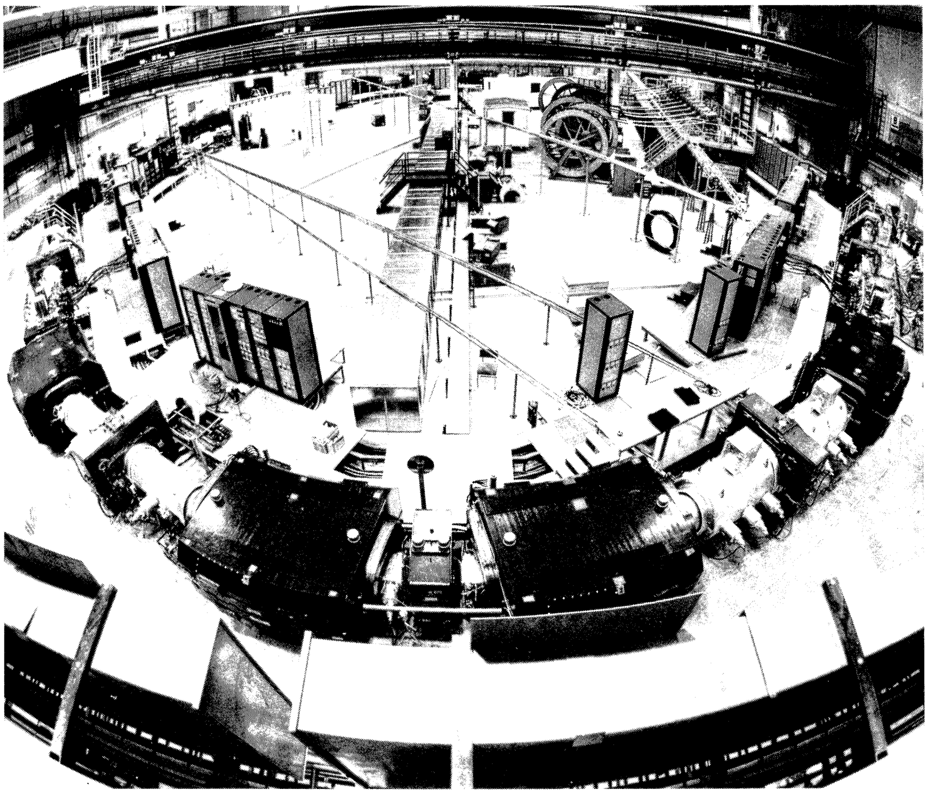
(Photo CERN 256.1.63)



Left, in 1973 came the big physics discovery at the PS — the neutral current of the weak interaction, seen in neutrino interactions in the Gargamelle heavy liquid bubble chamber.

wide variety of users. While one customer, the ISR, has disappeared, for the future the PS will have to handle beams of 'heavy' ions (oxygen 16) for a new generation of experiments, and the electron and positron bunches for the LEP collider, now under construction. For this, the PS will receive particles from the new EPA electron-positron accumulator taking shape in the south-east sector of the machine.

No proposal for a successor to the PS has yet appeared on the horizon, so that the machine, now at the hub of a complex particle factory of ten interconnected accelerators, seems likely to be still providing CERN's particles when the 21st century arrives. The flexibility and astounding reliability of this faithful CERN workhorse bear tribute to the sound engineering work of the team which designed and built it in those far-off days, and to the imagination and resourcefulness of those who have developed it into the unique facility it is today.



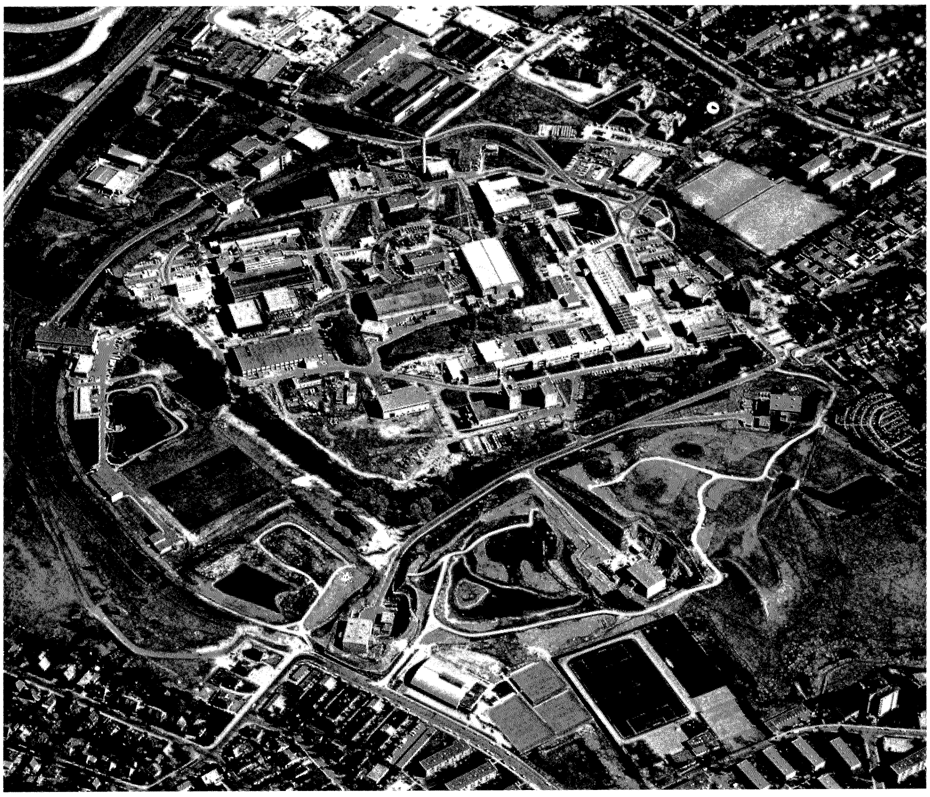
The Antiproton Accumulator, the heart of the CERN antiproton scheme, which provides the PS with antiprotons at 3.5 GeV.

(Photo CERN 582.10.80)

A quarter century of DESY

The German DESY Laboratory at Hamburg as it looks today, grouped around the faithful electron synchrotron ring (centre) with the outlying buildings marking the path of the 2.3 km circumference PETRA electron-positron collider. For the future, the aeroplane will have to fly higher. The HERA electron-proton collider now under construction requires a 6.5 km ring. Below, the DESY site in 1930.

(Photos DESY)



Although the official birthday falls in December, the Deutsches Elektronen Synchrotron (DESY) Laboratory at Hamburg celebrated its 25th anniversary in September to take advantage of (hopefully) the more clement weather. It is an anniversary of which DESY can be justly proud. While several national European high energy physics Laboratories have slipped into lower gear or redeployed their resources, the Hamburg Laboratory remains in the world front rank of high energy physics, and with the HERA electron-proton collider now under construction and scheduled to begin operations at the end of the decade, it looks likely to remain there for a long time to come.

As Europe struggled to get back on its feet after the nightmare of World War II, West Germany was among the founder Member States which signed the CERN Convention in 1954. But for a country with such a distinguished heritage in nuclear physics, this commitment to an international Laboratory was far from enough.

In 1954, Wolfgang Paul in Bonn embarked on a project to build a small electron synchrotron, and thinking soon turned to the construction of a larger machine. While electron accelerators are naturally cheaper to build than their proton counterparts, a new electron synchrotron was seen as providing complementary physics facilities to the major proton accelerator project already underway at CERN.

At the Geneva accelerator conference in 1956, a group of physicists met at the home of Wolfgang Gentner, then working at CERN, and looked at the idea of building a German 6 GeV electron synchrotron. Austrian Willibald Jentschke, who had recently returned from the US to become the director of the Hamburg Institute of Physics, was nominated to lead the project.

Discussions with the Hamburg City authorities and with the Federal Ministry for Research and Technology (then under a different name) began soon afterwards, and on the 18 December 1959 the official agreement between the federal and local Hamburg governments was signed. While the Laboratory has grown in stature over the years, the link between the local and federal governments remains a characteristic feature of DESY's charter.

In the meantime a working group drew up a detailed specification for the new machine, and in a selfless way the American machine builders from Cambridge, Massachusetts, helped their Hamburg counterparts. On 25 February 1964 the DESY synchrotron began operation, providing for a time the highest energy electron beams in the world.

18 December 1959. Federal German Atomic Energy Minister Siegfried Balke (left) and Hamburg Mayor Max Brauer sign the official agreement setting up the German DESY Laboratory. These close links between local and federal governments remain a characteristic feature of DESY's charter.

The experimental programme with the new machine began at an opportune time as Robert Hofstadter's group, working with electron beams at Stanford, had shown that the proton is not pointlike, but has dimensions. The next step was to investigate what was inside this extended proton, and experiments at DESY did valuable work. Unfortunately these initial clues were insufficient to provide the full picture, and it needed the 20 GeV energies of the new two-mile Stanford linac to uncover the granular structure of the proton.

As well as experiments with electrons, beautiful results were obtained using 'bremsstrahlung' — secondary photon beams — to study pion production.

With the electron energy record wrested by the new Stanford linac, DESY proposed in 1967 to build a new research tool, the DORIS (Doppel-Ring-Speicheranlage) electron-positron collider to provide an effective collision energy of 9 GeV (4.5 GeV per beam), compared to the 5.3 GeV effective collision energy provided by the 20 GeV Stanford beam hitting a fixed target.

DORIS began operation just too late to make a spectacular discovery which could have been easily in its grasp. In November 1974, an experiment led by Sam Ting at Brookhaven and another by Burt Richter at the SPEAR electron-positron collider at Stanford discovered the J/psi particle — opening the door to the 'new physics' of charm and heavier quarks.

While just missing the initial discovery, the DASP experiment at DORIS was soon adding its contributions to this new spectroscopy by spotting the gamma rays coming from decays of heavy quark-antiquark bound states.

Several years later, the SPEAR ring at Stanford scored again with the tau lepton. Once again the DORIS experimenters were soon on the scene, adding vital information on this new particle, showing that the tau has identical properties to the electron, although 3487 times heavier.

The next big breakthrough in particle physics was the discovery of the upsilon particle at Fermilab in 1977, the first sign of the fifth 'bottom' quark. The collision energy of the DORIS ring was quickly boosted to make an initial survey of this upsilon region, and the experiments began to unravel the spectroscopy of these new particles.

To probe further into the upsilon region, the bold decision was taken to rebuild DORIS as a single ring machine, and a new detector, ARGUS, was constructed. In the new DORIS, collision energies exceeded 11 GeV, collision rates went up by a factor of twenty, and with electron and positron beams circulating in the same vacuum vessel, power consumption was halved.

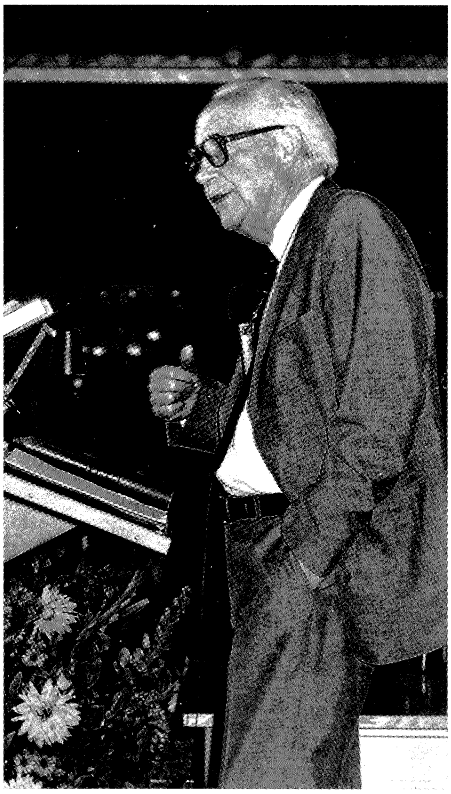
The increased performance of the new DORIS ring enticed a one-time competitor, the Crystal Ball detector which had participated in many of the major SPEAR discoveries, to quit Stanford and charm physics in 1982 and come to DORIS for upsilon physics instead.

The decision to revamp DORIS has paid off handsomely, as the experiments (along with the teams working at the CESR ring at Cornell) have creamed off the best results in upsilon spectroscopy and the study of heavy quark-antiquark bound states.

But DESY had another card up its sleeve. Back in 1974, a bigger electron-positron collider was proposed. In 1978, the 2.3 km circumference PETRA (Positron-Elektron-Tandem-Ring-Anlage) storage ring began operations, providing collision ener-

Willibald Jentschke, leader of the initial DESY project and the Laboratory's first Director.

(Photos DESY)



Guests of honour at the DESY 25th anniversary celebrations were Federal German President Richard von Weizsäcker (left) and Hamburg Bürgermeister Klaus von Dohnanyi.

(Photo F. Becker)

gies initially around 38 GeV. Though the cost of this machine at first seemed large, it was really no more expensive than the original DESY synchrotron, once inflation had been taken into account. After DORIS had been beaten several times to the post by SPEAR, the lesson had been learned. PETRA came on-line a whole nine months before the initially scheduled date, and two years before the comparable PEP machine at Stanford.

With PETRA, a new concept for exploiting such machines was introduced. While the machine itself was basically built by West Germany, experiments are financed by many countries. When experiments in PETRA began in July 1978, the PLUTO detector had been transferred from DORIS (later PLUTO was replaced in PETRA by CELLO). The remaining three intersection regions were occupied by the JADE, Mark-J and TASSO experiments. About half of the cost of these PETRA experiments is contributed from abroad.

In 1979 came the pay-off. The TASSO and Mark-J detectors saw electron-positron annihilations producing three sprays ('jets') of particles, two coming from a produced quark-antiquark pair and the third from an additional particle — the long-sought carrier of the inter-quark force. The gluon had at last come out into the open.

With its record energies, PETRA embarked on a detailed analysis of muon production, finding convincing evidence for the new 'electroweak' theory, which received explicit confirmation from CERN last year with the discovery of the W and Z particles. Analysis of the strongly interacting particles produced in PETRA's annihilations gave vital information on the parameters of the inter-quark force.

In a heroic effort, the collision energy of the PETRA beams was cranked up to 47 GeV in a search (unfortunately unsuccessful) for the sixth ('top') quark. PETRA will remain the world's highest energy electron-positron ring until the completion of the TRISTAN project at KEK in Japan and the LEP machine at CERN.

As well as continuing to provide sterling physics with colliding beams, for a third of the time the DORIS ring is filled with single high current beams to exploit the electromagnetic synchrotron radiation which emanates from the circulating particles. A special Laboratory, HASYLAB, has been set up at DESY where each year about 500 scientists come to make use of this radiation. A substation of the European Laboratory for Molecular Biology (based in Heidelberg) has also been set up at DESY.

Over its impressive history, the

DESY Director Volker Soergel addresses the assembled guests at the official celebrations to mark the 25th anniversary of the signing of DESY's charter.

DESY machine group has made many important contributions to the art of building storage rings. The resourcefulness of these specialists is also reflected in the way the DESY machines have gone on to surpass their initial design aims.

On its twenty-fifth birthday, DESY can review with pride and satisfaction the accomplishment of an ambitious programme of machine construction and physics experiment. But the Laboratory looks to the future as well as the past. Earlier this year, formal approval was received and construction began for the giant new HERA electron-proton collider.

In the 6.3 km HERA tunnel, extending far beyond the boundaries of the present DESY site, protons will be accelerated to 820 GeV and collided with 30 GeV electrons. While the earthmoving for HERA gets underway in earnest, the technology for the proton ring's superconducting magnets looks well under control. For these cryogenic magnets, the biggest refrigeration plant in Europe will be constructed. Plans for the experiments for this new ring are now being drawn up, attracting physicists from all over the world. DESY looks set to remain a focus of major high energy physics research at least until the end of the century.

Basic research — curse or blessing

Wolfgang 'Pief' Panofsky, former director of the Stanford Linear Accelerator Center, was a guest at the recent celebrations of the 25th anniversary of the German DESY Laboratory. We publish here some extracts from his stimulating keynote address.

'We are gathered here in order to celebrate the 25th Anniversary of DESY. I am particularly pleased to participate in this celebration for several reasons. First, DESY is a sister institute to the Stanford Linear Accelerator Center — SLAC for short, which is a part of Stanford University in California, my place of work for the last 34 years. SLAC and DESY work on similar topics — we both operate electron accelerators and electron-positron storage rings. Our institutes are of similar size and we have about the same number of staff members. We both are now starting to build colliding beam machines using new principles.

Secondly, I am pleased to be here in order to congratulate DESY for the great progress in science which has been set in motion from here. But in addition this visit is for me a sentimental occasion. I lived in Hamburg as a child from 1919 until 1934. I was educated at the Gelehrtenschule des Johanneums and my father taught at the University of Hamburg.

Particle physics is a great unifier of different topics of science. However, particle physics is also a unifier of people. Physicists and other scientists who throughout the world work on this subject know one another and share a mutual respect. There are no secrets in particle physics. All new results are published promptly. It is particularly important that the role of particle physics is not only recognized by specialists but that all citizens who share the required interest have the opportunity to understand this subject. After all, we are all paying the bill for the work on this topic.

Keynote speaker at DESY's 25th anniversary was former Stanford Director Wolfgang 'Pief' Panofsky who spoke on 'fundamental research — curse or blessing'. Panofsky spent his boyhood in Hamburg before emigrating to the US.

Laboratories which are active in this field exist in almost all countries of the world. There is not such a thing as "the best machine in the world" for particle physics. Laboratories operate installations of many kinds: accelerators or storage rings, electron or proton machines, weak beams or intensive beams. Each machine is particularly effective in exploring a special topic; the ideal machine for all purposes has not been invented and is not inventable. International collaboration in this field does not only serve international culture and international peace and understanding but is also necessary for purely scientific reasons.

Are the results of nuclear physics a curse or a blessing? Are the future results of particle physics generated by DESY or other fundamental research institutes a curse or a blessing? There are few questions which are more important for the future of the world than these. The laws of nature exist irrespective of whether man discovers them today, tomorrow, or the day after tomorrow. For example, we know today that the first nuclear reactor was not produced by Fermi and his collaborators in Chicago during the war in 1943, but that a nuclear fission explosion was released by nature in Gabon on the west coast of Africa 2 billion years ago! This fact was discovered 12 years ago by analyzing the ore produced in a uranium mine at that location. To deny knowledge to humanity is no answer to difficult questions.

The future of civilization is to a large extent dependent on progress in technology. In turn, the progress of technology depends on progress in basic research. Therefore throughout the world in which we live there is no alternative to the duty of human society to carry out scientific research intensively — the only question is how intensively.

Basic research requires money and work. When the economy or industry are in difficulty one often hears the question, 'Yes, but can we afford basic research?' The answer is that without basic research or technology the economy cannot be healthy. This would be a tree without roots which cannot thrive for any length of time. If money is short it often appears to be the simplest solution to defer everything which only serves the long-range future. However whoever chooses such a course mortgages the future.

Basic research is absolutely necessary for the future of civilization. With science it is at least possible that we can live in harmony with the natural world. However this can only become reality when our citizens listen critically to scientific advice. In a fundamental sense science is not a curse but it can only become a blessing if it is treated and explored carefully. The truth is inseparable: Man cannot pick out those laws of nature with which he feels comfortable and ignore those which he considers uncomfortable.

In conclusion, research including basic research is a necessity of modern society and makes possible the improvement of the quality of life within the whole world but it does not assure such improvement. DESY can be proud to have played a very important role in this undertaking. This statement applies not only to the past but also to the future. The new machine HERA will provide a unique opportunity to DESY to find new fundamental results in particle physics.

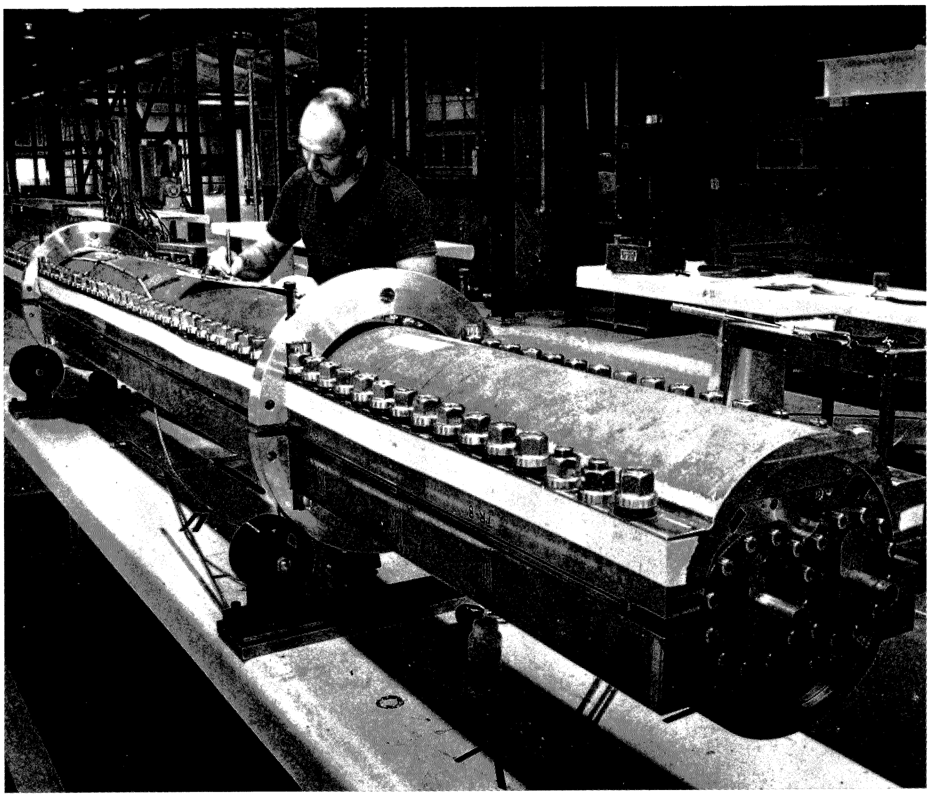
The future of laboratories like DESY and my own institution SLAC depends on continuing renewal. When DESY was founded 25 years ago no one could imagine the future with DORIS, PETRA and HERA. The progress of high energy physics is paced by inventions of new means of acceleration. Each new method of acceleration of elementary particles makes it possible to raise the attainable energy limit. Yet each one method can only lead to a certain progress until it becomes too expensive; then a new technology has to be invented and introduced. DESY has contributed to many of these jumps; I believe that DESY will also contribute to the subsequent advances.

I conclude with congratulations to DESY, a Laboratory which has played such a large role through a quarter century in this great adventure of our time.'

Around the Laboratories

One of the 'two-in-one' superconducting magnets designed and built at Brookhaven for the proposed US Superconducting Super Collider (SSC). In tests, the magnets performed successfully, promising that the SSC's exacting requirements can be met.

(Photo Brookhaven)



Supercollider

The Superconducting Super Collider (SSC) — a proposal for a 20 TeV (20 000 GeV) colliding beam accelerator — has been recommended for construction in the US and design studies are well underway. The University of California's Lawrence Berkeley Laboratory has been chosen as the home of the SSC Central Design Group (see November issue, page 391) but work is being carried out at a number of existing US Laboratories.

To reflect the growing impetus of the SSC proposal in the US, the CERN Courier is introducing the 'Supercollider' heading in its 'Around the Laboratories' section. The project has yet to be formally approved and funded, and even the site remains to be chosen. Meanwhile by bringing developments under a single heading we hope to provide a more coherent coverage of this ambitious and exciting new idea.

SUPERCOLLIDER
Super-magnets

The first items of hardware designed for the proposed US Superconducting Super Collider (SSC) have emerged from the Brookhaven SSC magnet programme, underway for the past year. Two 4.5 m superconducting dipoles have been successfully tested, demonstrating key concepts developed to meet the SSC requirements for economy and for strength and uniformity of magnetic field.

Each of the 'two-in-one' magnets reached a field of 6 tesla, the limit of the superconductor at 4.5 K, with little or no training. At reduced temperature (2.5 K), the magnets trained to the 7 T limit of the conductor in 5 to 7 quenches. The shape of the magnetic field in the four bores was the same to within a few parts in 10 000, the general level of reproducibility required by the SSC, and agreed well with the calculated shape. The construction of the magnets was expedited by the use of superconductor and modified tooling from the Brookhaven Colliding Beam Accelerator (CBA, ex-ISABELLE) design, now in cold storage.

The magnet coils were made with the same type of niobium-titanium superconducting cable used in the CBA and Fermilab Tevatron magnets, and a similar two-layer coil design was used. However the inner diameters were 3.2 cm, much smaller than previous magnets. This required that the cable shape be modified to achieve the tighter fit. The good reproducibility of the field shape attests to the very uniform spacing of the individual turns in the coil (within 0.05 mm), especially impressive in view of the small coil diameters.

In the two-in-one design, the coils needed for the two magnet rings of a proton-proton collider are clamped in a single iron yoke and cryostat. As well as economy of manufacture, the closeness of the iron to the coil also enhances the field in the bore. Performance of the conductor at its limit at 4.5 K with minimal training indicates that the required compression of the coil was obtained in both bores of the yoke. The small number of additional training quenches required to attain 7 T indicates a margin at 4.5 K and the potential to accommodate a higher current conductor such as niobium-tin. Tests with niobium-tin are scheduled for the coming few months.

With the ideas necessary for the construction of small bore two-in-one magnets seemingly in good shape, attention has turned to magnets for SSC Reference Design A, worked out in collaboration with the Berkeley Magnet Group. These two-in-one magnets will use the higher current niobium-titanium now becoming available and will have an inner coil diameter of 4 cm. The design will be produced in both 4.5 m and 17.7 m lengths, the latter being the full-scale SSC dimension.

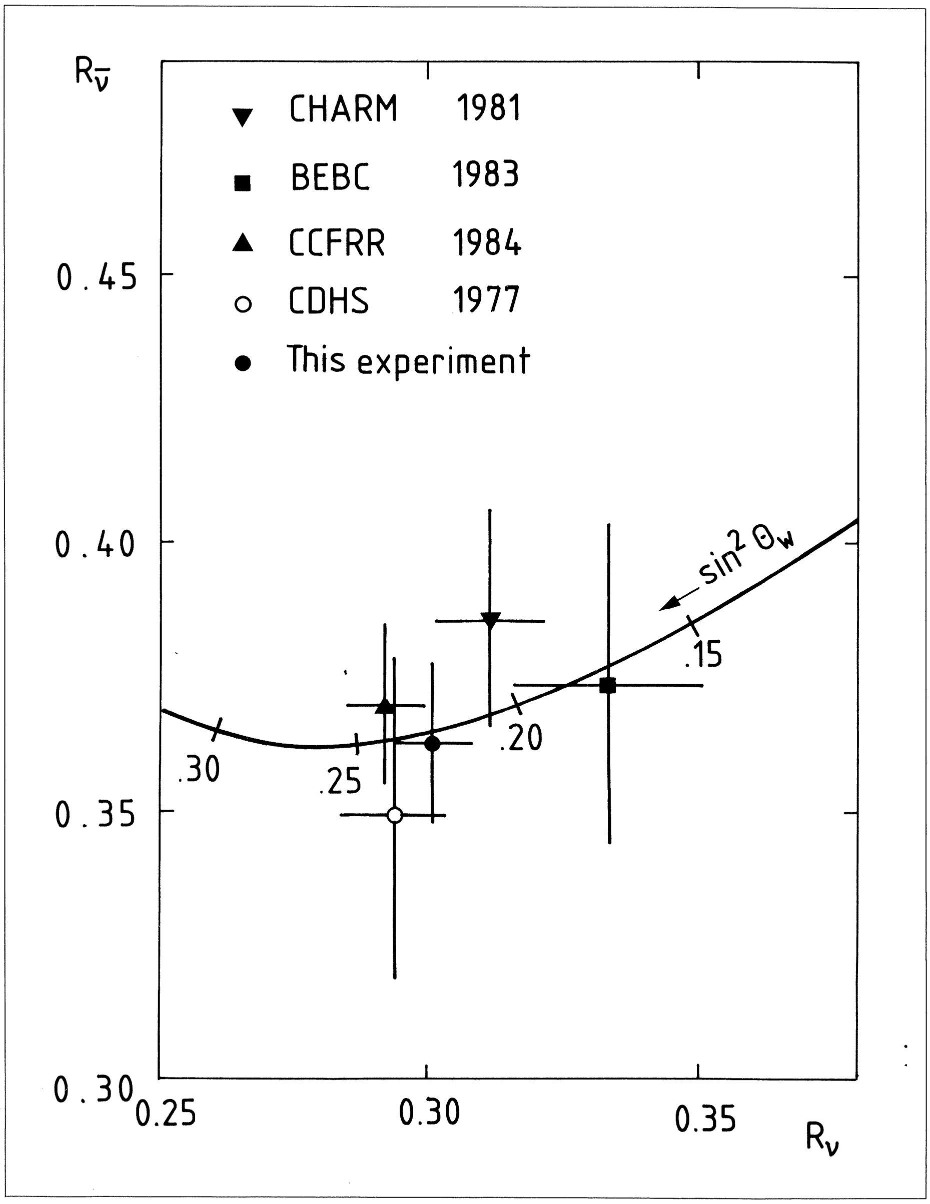
CERN
Last of the first

It is perhaps a sign of the coming of age of the CERN 450 GeV Super Proton Synchrotron when after eight years of painstaking work its first approved experiment — the WA1 study by a CERN/Dortmund/Heidelberg/Saclay/Warsaw ('CDHS') collaboration, led by Jack Steinberger, bows out.

Proposed back in 1973, WA1, with its 1500 ton detector consisting of 20 magnetized iron modules instrumented with scintillator sheets and interspersed with drift chambers, set a new scale for neutrino experiments.

At the time, the high energy behaviour of the weak interaction was under lively debate, and the immediate object of the experiment, which measured the energy deposited by the interacting neutrinos and studied the resulting muon tracks, was to see if the neutrinos from the SPS followed the same rules as their lower energy counterparts.

WA 1 results for the neutral-to-charged-current ratio of neutrino and antineutrino scattering on heavy nuclei. The curve gives the expectation of the electroweak theory for different values of the electroweak mixing parameter. With this parameter known, the masses of the W and Z bosons could be accurately predicted.



As the experiment got underway, other experiments looking at high energy neutrino interactions had reported strange happenings. Perhaps the high energy neutrinos did not follow the rules. Exploiting the unparalleled quality of the SPS neutrino beams and after amassing more data than all the rest of the world put together, the WA1 experiment put the record straight. High energy neutrinos were well behaved. The neutrino and antineutrino reaction rates (cross-sections) were consistent with a linear rise with energy, the gross features of the differential cross-sections showed scaling behaviour, and if a second muon with opposite charge emerged from the neutrino interaction, its properties were consistent with the excitation and semileptonic decay of single charmed quarks.

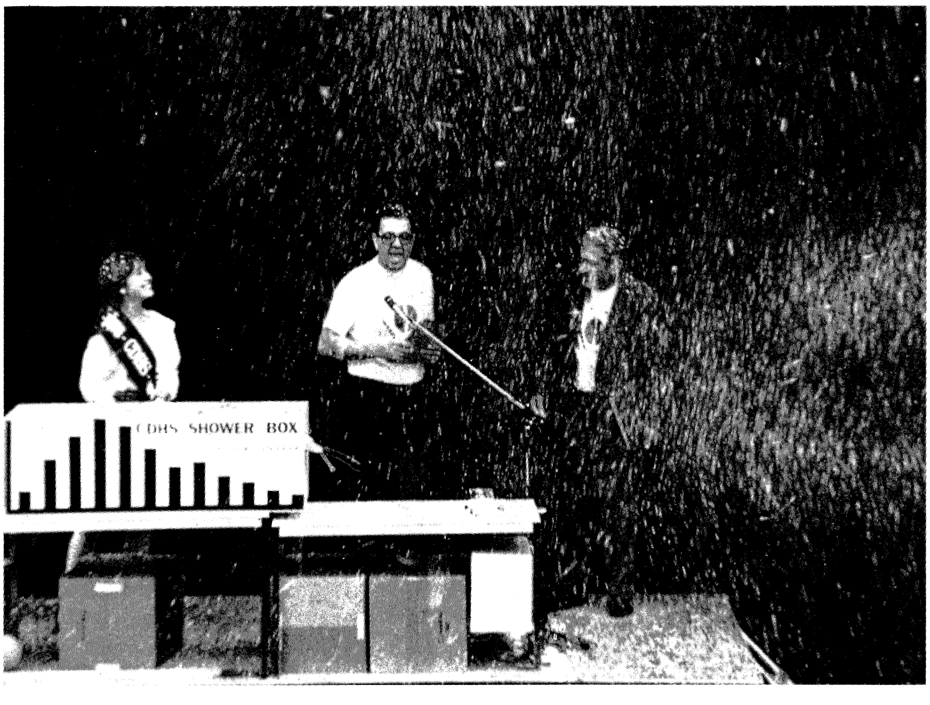
Once there were four...

When the neutrino physics programme at the CERN SPS Super Proton Synchrotron got underway in earnest, there were four major detectors at work — the BEBC and Gargamelle bubble chambers, the WA 1/CDHS counter experiment and the WA 18/CHARM counter experiment. (There are other, more specialized detectors, such as the WA 44 quark search by a Bologna/ CERN/Frascati/Rome collaboration.) Between them, these big detectors made impressive contributions to physics progress.

For one reason or another, each of the four major detectors have retired from the scene, and for the moment only the new CHARM II experiment (see May issue, page 153) is scheduled for a full programme of neutrino physics at the SPS.

The first detector to be retired was the five metre-long Gargamelle heavy liquid bubble chamber, victim of a crack which curtailed its operations at the SPS in 1979. Gargamelle was originally installed at the 28 GeV Proton Synchrotron where in 1973 it was the scene of the famous discovery of the neutral current of the weak interaction.

Also first built for operation at the PS was the 3.7 m diameter Big European Bubble Chamber, BEBC, which ceased operation earlier this year after taking 6.3 million photographs of particle interactions from 13 million expansions. As well as being used with neutrino beams, BEBC carried out valuable work in hadron physics. During its working life, BEBC was exposed to PS and SPS beams with fillings of hydrogen, deuterium and mixtures of neon and hydrogen. BEBC also became a hybrid detector by adding an external muon identifier (EMI), internal picket fence (IPF), external particle identifier (EPI) and a track sensitive target (TST). BEBC was equipped with the largest superconducting magnet in the world. Its twin coils produced a magnetic field of 35 kilogauss over a volume of 55 cubic metres, representing a stored energy of 730 Megajoules.



A scene from the WA 1 end-of-experiment party at CERN with Jack Steinberger (right), Paolo Palazzi (centre) and a welcome interloper.

Another early achievement was the first precision measurement of the electroweak mixing parameter (the 'Weinberg angle'). It was only as a result of such measurements that confidence in the electroweak theory began to grow and firm predictions could be made for the masses of the W and Z bosons, thus paving the way for the spectacular results from the CERN proton-antiproton Collider in 1983.

With high energy weak interactions in good shape, the emphasis changed to using the neutrino beams as a probe of hadron structure. WA 1 went on to make classic experiments of the inner structure of nucleons, measuring for the first time their content in terms of gluons as well as quarks and antiquarks, and comparing results from iron and hydrogen targets. This work also provided values for vital parameters in the quantum chromodynamics theory describing the forces between quarks and gluons.

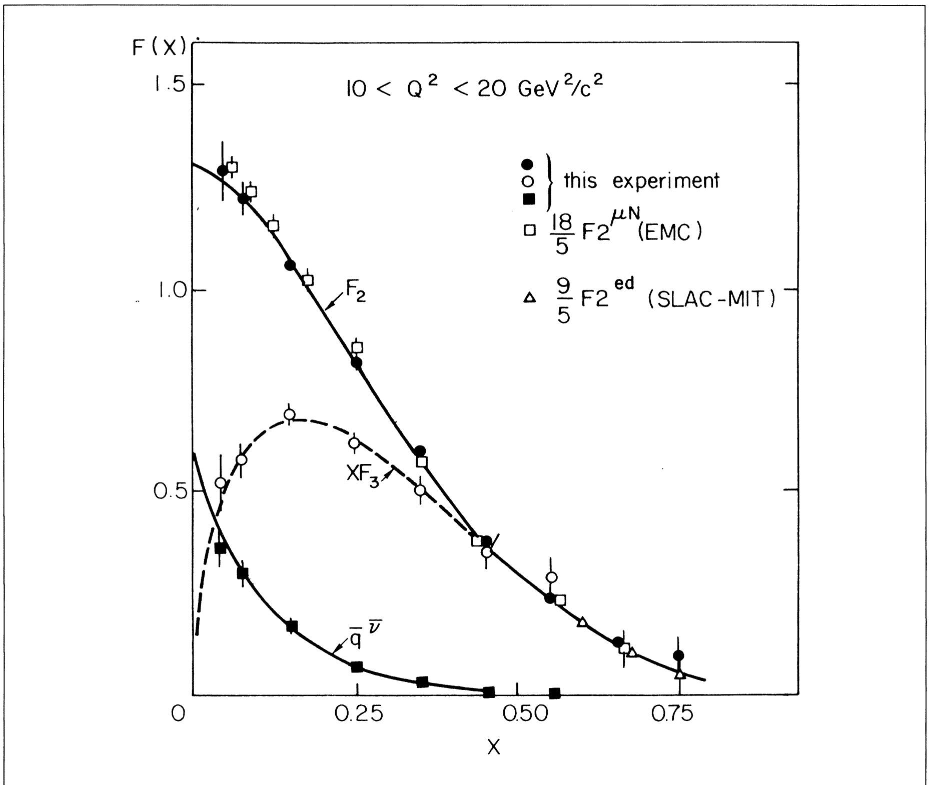
WA 1, along with the BEBC bubble chamber and the WA 18 'CHARM' (CERN / Hamburg / Amsterdam / Rome / Moscow) electronic counter experiment, was one of the pillars of CERN's unique SPS neutrino physics programme. As well as conventional studies using the high energy beams from the SPS, a series of 'beam dump' experiments were mounted, with the beam striking a thick metal target to attenuate common sources of neutrinos and isolate any additional component.

In 1983, the new low energy neutrino beam from the 28 GeV Proton Synchrotron came into action, with WA 1 and WA 18 modules mounted upstream of the main detectors in order to compare the neutrino signals at two points in an attempt to track down neutrino 'oscillations'.

As WA1 retires from the SPS scene, neutrino physics is altogether better understood. However there are still a few corners still to be tidied up — the oscillation question has yet to be settled, the beam dump studies have perhaps not been quite as enlightening as had been hoped, and the sighting of pairs of muons carrying the same electric charge deserves some further work.

The WA1 experiment is now switched off, but its milestone physics results and its mass of accumulated neutrino data remain as a monument to what will surely go down as one of the classic physics experiments of our time.

The fractional momentum of the nucleon carried by all quarks (F_2), by valence quarks only (xF_3), and by antiquarks ($\bar{q}$). The WA1 measurements with neutrinos compare well with measurements using muon (EMC) and electron (SLAC-MIT) beams.



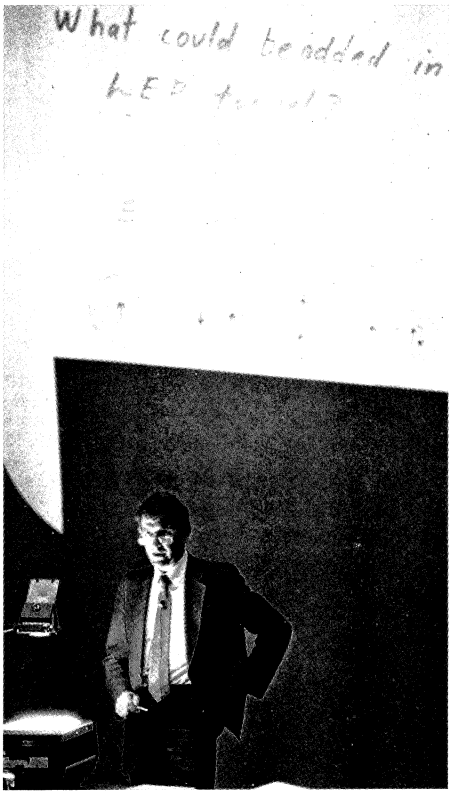
Groundbreaking for the new Brookhaven Heavy Ion Project. Wielding shovels are, left to right, Brookhaven Director Nick Samios, US Congressman William Carney, and Director of the US Department of Energy's Office of Energy Research Alvin Trivelpiece. Awaiting their turn are Herman Feshbach (left) and Robert Hughes, Chairman and President respectively of the Board of Trustees of Brookhaven's parent organization, Associated Universities Inc.

(Photo Brookhaven).

BROOKHAVEN
Heavy ion project underway

Ground was broken for Brookhaven's new Heavy Ion Project on 16 October. The first phase of this project is the construction of a 600 metre beamline to transfer heavy ions from the 16 MV tandem Van de Graaff to the Alternating Gradient Synchrotron. There they will be accelerated to a kinetic energy of 14.6 GeV/n and extracted for fixed target experiments. Ion beams with masses from 12 to 35 are expected to be available beginning in October 1986. Five proposals for experiments using such beams had been received as of October, and some 320 physicists from the US and abroad had joined the new Heavy Ion Users Group (HUG).

At the recent US Summer School on High Energy Particle Accelerators, held at Fermilab, Roy Billinge of CERN described what else could be put into the tunnel now being constructed at CERN for the LEP electron-positron collider.



Speakers at the brief groundbreaking ceremony were US Congressman William Carney, Herman Feshbach, Chairman of the Board of Trustees of Associated Universities Inc. (Brookhaven's parent organization), Brookhaven Director Nick Samios, and Alvin Trivelpiece, Director of the US Department of Energy's Office of Energy Research. They emphasized the strong enthusiasm for starting a new direction in physics research and the opportunities for discoveries, in particular 'an unmatched ability to examine nuclear matter under conditions only previously present at the creation of the universe.'

With the 1 GeV booster planned for construction in 1986-88, ions up to mass 200 will be available at the AGS. These could then be injected into the Relativistic Heavy Ion Collider (RHIC) proposed to be built in the CBA tunnel for collisions at energies of 100 GeV/n per beam. The October groundbreaking ceremony may be the beginning of a major new programme of investigations into the nature of matter at extremely high densities and temperatures, where quarks and gluons are expected to be deconfined from their usual hadronic states.

FERMILAB Accelerator School

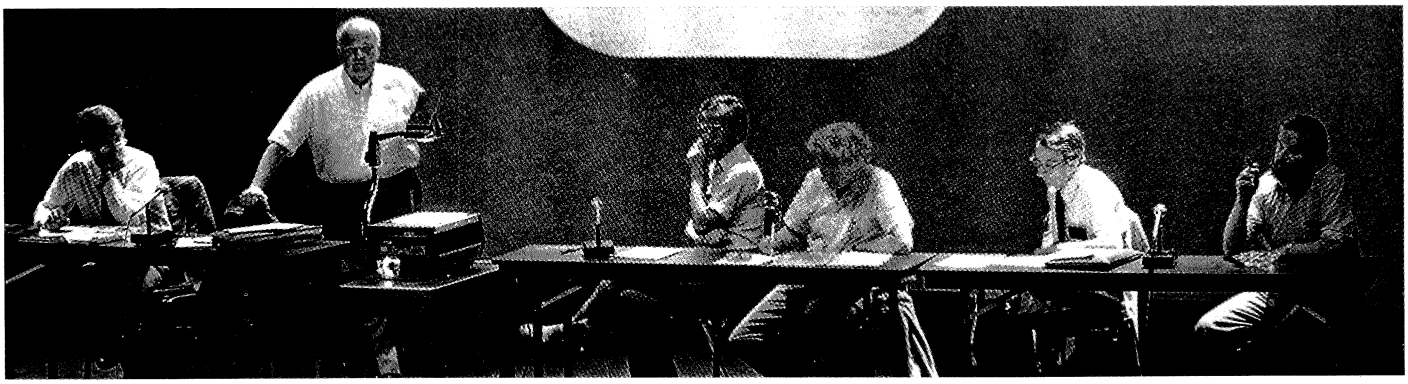
Fermilab once again hosted the US Summer School on High Energy Particle Accelerators. Held between 13-24 August, it was the fourth in an annual series of Schools on accelerator science that was initiated at Fermilab in 1981. Mel Month of Brookhaven and Frank Turkot of Fermilab organized this year's School. Stimulated in part by the recent discussions of the Superconducting Super Collider (SSC), school attendance numbered about 225, a 50 per cent increase over 1981.

The central theme of this year's school was the conceptual design of large accelerators utilizing colliding beams to achieve particle collision energies 1000 times larger than that available with current fixed-target experiments using the Tevatron beam. Nearly two-thirds of the lectures were devoted to collider accelerators and related topics.

In a special symposium entitled 'Accelerators for the 1990s', three proposals to achieve these ultra-high energies were presented. Boyce McDaniel from Cornell reviewed the SSC, the US proposal for a 20-mile diameter circular accelerator colliding protons on protons, and Roy Billinge from CERN presented a design study of a similar machine which could be placed in the 6-mile diameter LEP tunnel now under construction at CERN. Burt Richter from Stanford outlined an alternative proposal to achieve the same result with electron-positron collisions using a 30-mile long linear accelerator.

The School featured a round-table discussion 'The world-wide growth of high energy physics — competition or collaboration' with (left to right) Roy Billinge of CERN, Burt Richter of Stanford, Stan Wojcicki of Stanford University, Leon Lederman of Fermilab, Boyce McDaniel of Cornell and Martinus Veltman of Michigan.

(Photos Fermilab)



Physics monitor

The 1990s Symposium was followed by an evening round-table discussion 'The World-Wide Growth of High Energy Physics– Competition or Collaboration?' The above speakers were joined by Martinus Veltman of Michigan, Stan Wojcicki of Stanford and Fermilab Director Leon Lederman. In the lively exchange that ensued, it was argued that (a) the costs of the new machines rule out duplication of accelerator facilities; (b) the construction of the SSC and the CERN option could be a duplication of facilities; (c) the interested governments are encouraging an international collaboration as a means to reduce the financial burden to any individual country; (d) at present there is no mechanism to build a world-wide consensus; (e) there do exist many examples of international collaboration on R&D for accelerator components and detectors.

A second symposium on 'Accelerators of the 1980s' reviewed the status and time schedules for the five new high energy accelerators under construction in the western world. All five are colliders; the Tevatron (TeV I) at Fermilab (completion in 1986), SLC at Stanford (1986), TRISTAN at the KEK Laboratory in Japan (1986), LEP at CERN (1988), and HERA at DESY in Germany (1990). Recent experimental discoveries and advances in particle theory lead to great expectations from these new facilities.

By Frank Turkot

PANIC at Heidelberg

Earlier this year in Heidelberg there was PANIC — short for Particle and Nuclei International Conference. This is the new name which has been adopted for a series which in fact began in 1963, the aim being to cover the common ground between the physics of nuclei and of elementary particles.

Many years ago, it was believed that the pion had some privileged role to play in nuclear physics, but as experiments and understanding have progressed, this has become less evident.

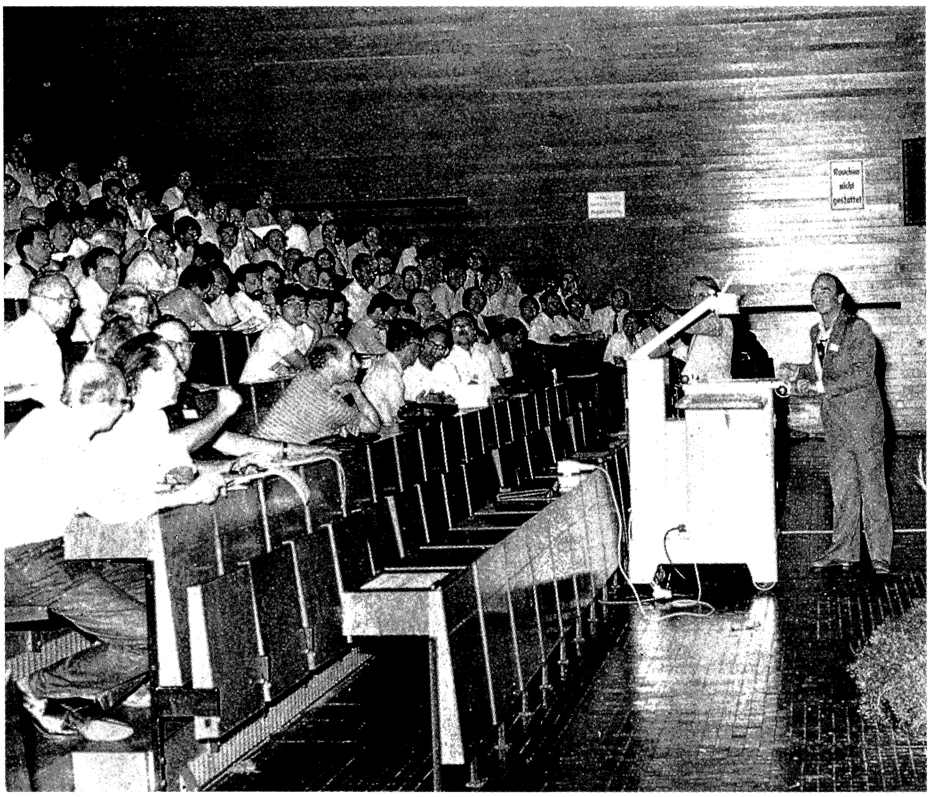
Now it is known that the so-called 'elementary' particles (at least those found in atomic nuclei) are composite, made up of smaller 'grains, quarks, with the inter-quark forces being brought about by the exchange of gluons.

Recent experiments have demonstrated that this deeper level of structure also has a role to play on the nuclear level. Studies, notably those of the European Muon Collaboration at CERN (see April 1983 issue, page 90), have revealed that the quark properties of individual nucleons can depend on their surrounding nuclear environment. At PANIC, there was a great deal of discussion on the so-called 'EMC effect'. Chris Llewellyn Smith reviewed some of the many models which have been proposed. The undecided question is whether an explanation with pions in nuclei is sufficient or whether explanations based on quantum chromodynamics (QCD) have to be considered.

Just as an understanding of molecular spectroscopy requires insight into the structure of the atom, it is now clear that the description of the nucleus will depend on the behaviour

PANIC scene from the recent Particle and Nuclei International Conference at Heidelberg. Sir Denys Wilkinson (left), Chris Llewellyn-Smith and Gordon Baym (back to camera) presumably discuss the role of quarks in nuclei.

More PANIC. CERN Research Director Robert Klapisch describes the new results emerging from CERN's Low Energy Antiproton Ring, LEAR.



at a deeper, quark level. At PANIC, Sir Denys Wilkinson organized a round-table discussion on quarks and nuclei. A quantitative description of nucleons in a quark picture is difficult, and the role of the pion, once revered as the carrier of nuclear forces, now seems to be obscure. Why is it so light compared to other mesons?

While our everyday world is composed of nucleons containing only the lightest two quarks ('up' and 'down'), heavier quarks were once thought to be irrelevant to nuclear physics. Now it appears that the next heavier (strange) quark will help to trace the role of the quark degree of freedom in nuclei. One possibility comes through the exciting discovery at CERN of long-lived sigma hypernuclei, reported at PANIC by Thomas Walcher.

Even further-reaching speculations on the role of the heavier quarks in nature were presented by Alvaro de Rujula. In a typically entertaining talk, he predicted the existence of massive, electrically neutral entities made of strange and light quarks, as yet unobserved but which could carry some of the 'missing mass' of the Universe.

Now beginning to filter out are the first results from the LEAR Low Energy Antiproton Ring at CERN, covered at PANIC by CERN Research Director Robert Klapisch. The first LEAR runs have provided interesting glimpses into this new area of physics, which will have surely developed considerably by the time the next PANIC occurs.

In his closing speech, Gisbert zu Putlitz of Heidelberg looked to the future. New sources of antiprotons, strange particles and leptons could provide much more information in this meeting ground of nuclear and particle physics. In particular, he advocated the construction of a new high intensity proton machine providing energies of around 30 GeV in Europe (see July/August issue, page 243).

PANIC at Heidelberg was attended by some 600 scientists from 35 countries. The next meeting is scheduled for Japan in 1987.

High Field Workshop

A Workshop was held in Frascati at the end of September under the title 'Generation of High Fields for Particle Acceleration to Very High Energies'. It was organized by the CERN Accelerator School, the European Committee for Future Accelerators (ECFA) and the Italian INFN and was a further stage in the exploratory moves towards new techniques of acceleration. Such techniques might become necessary to respond to the needs of high energy physics some decades from now when the application of conventional techniques will probably have reached their limits.

The Workshop was a follow-up to the ECFA Conference at Oxford (see December issue 1982) where it became clear that the most promising new ideas involved expertise in technologies, such as plasma physics and laser physics, which have not been common up to now in the accelerator world. The reason for the rather cumbersome title of the Frascati meeting was to provide an umbrella which would cover these additional disciplines also. This purpose was achieved and there was a good mix of accelerator, laser and plasma experts amongst the ninety or so participants at the Workshop.

It is possible to focus rather confidently on what 'the Machine' several decades from now could be. It must be a colliding beam machine, because of the high required centre-of-mass energy (TeV range), but one providing luminosity around 10^{32} per cm^2 per s. It must be a linear machine to avoid the burden of energy loss by synchrotron radiation. The Workshop therefore concentrated on new technologies which might open up the possibility of much higher energy electron-positron colliders at significantly reduced cost. To get the high luminosity, beam focusing will need to be stronger than used up to now and ability to handle sub-micron size beams has not yet been demonstrated. However Stanford will be confronting a comparable challenge in a few years' time at the SLAC Linear Collider.

The interrelation between the various parameters that can be specified for such a machine is quite well understood and a list of needs, in order to achieve much higher energies with good luminosities, can therefore be written down. They include better quality particle sources, ways to sustain beam quality, much better efficiencies in converting power 'from the wall plug' to power in the beam, higher accelerating fields... The last of these requirements has been receiving most attention so far in the search for new techniques but, somewhere along the line, the others will need serious attention also.

At the Workshop, the techniques were considered under several headings. 'Near field' devices include improvements to the conventional linac where work is underway for example at Stanford and Novosibirsk. There is particular interest (to push up the accelerating fields beyond the 100 MeV per m already achieved) in greatly improved power sources. An interesting development has emerged in a project for 1 TeV colliding linacs which has wide participation from institutes in Japan. They are working on a new type of r. f. power source called a lasertron aiming for 10 GW.

Other near field schemes are two-beam accelerators (under study at Berkeley) and wake field accelerators (DESY). They both act as transformers taking energy from a comparatively low energy, high current beam and passing it to what becomes a low current, high energy beam. Several structures for two-beam schemes are being developed and a wake field structure should be ready for tests next year. A new idea in this category comes from Bob Palmer at Brookhaven who has imagined beam passing through a structure made of spray droplets 'plasmafied' by laser radiation. Tests with arrays of synchronized jets showed remarkable droplet positional regularity but, as one participant elegantly put it, 'the technique is fraught with potential difficulties'.

'Far field' devices, such as the inverse free electron laser, do not seem to have gone far. It looks as if synchrotron radiation effects kill these ideas.

'Media' devices were the ones that stirred up most excitement at the Oxford meeting and that excitement is still alive. The essence of the scheme is to beat two laser waves together, creating very high accelerating fields in a plasma. The production of such beat waves has been demonstrated as has the feasibility of some particle acceleration. Many centres are involved in theoretical and experimental work and, though there are clearly many problems ahead, nothing has been encountered so far to damp the high enthusiasm.

It was impressive at the Workshop to see the rate at which interest in new acceleration techniques has taken hold. In the two years since the realization became strong that conventional accelerators are hitting up against the stops, a lot of thinking has gone into the subject. At Frascati it was even more impressive to see that experimental checks on this thinking are also underway.

Local equilibrium

From 3-6 September the First International Workshop on Local Equilibrium in Strong Interaction Physics took place in Bad-Honnef at the Physics Centre of the German Physical Society.

There are common phenomena and methods in different energy regimes of strong interaction physics (nuclear and particle physics) which are intimately linked with local equilibrium, a concept familiar in macroscopic physics, but less popular in microscopic physics. The simplest example from everyday life is a system in which the temperature is non-uniform. Such a situation is however also met in nuclear and particle physics in the phenomenon of 'hot spots' (see March 1979 issue, page 24). But local equilibrium has a much wider range of applications. Thus such topics of high current interest as phase transitions and quark-gluon plasma, as well as the applicability of hydrodynamical and statistical methods in general, which are so useful when the number of particles and degrees of freedom are large, as is the case in strong interaction physics, are difficult to conceive without the existence of local equilibrium.

That is probably the reason that this workshop, convened by D. K. Scott (Michigan) and R. M. Weiner (Marburg) could attract so many leading experts from all over the world.

A number of talks covered the experimental and theoretical investigation of the 'hot spots' effect, both in high energy particle physics and in

Some of the participants at the First International Workshop on Local Equilibrium in Strong Interaction Physics, which took place in September at Bad-Honnef, West Germany.

intermediate energy nuclear physics. In this last domain this effect has become one of the main tools of investigation, being used by some researchers even for 'applications', like the study of phase transitions. As a possible mechanism for the formation of hot spots in nuclear matter, solitons were suggested.

Great interest centred on the large fluctuations observed by the CERN UA5 experiment studying proton-antiproton collisions at 540 GeV collision energy in the number of produced secondaries in narrow (rapidity) intervals, which were reported by K. Böckmann (Bonn). The question whether these fluctuations are only of statistical nature or whether they are due to hot spots in quark-gluon plasma, as suggested by L. Van Hove (CERN), has yet to be answered. Similar fluctuations in proton-nucleus reactions at 300 GeV laboratory energy were reported for the first time at this meeting by E. M. Friedlander (Berkeley).

The determination of sizes and lifetimes of sources (hot spots?) both in nuclear and particle physics was another topic of discussion. The method used for this determination is again inspired from macroscopic physics, being essentially equivalent to the interference method used for the measurement of radii of stars; the role of photons (light) is played in microscopic physics by mesons, nucleons or light nuclei. An important piece of evidence for 'hot spots' in nuclei at intermediate energies reported by Gelbke (Michigan) referred to the fact that the interference (two-body correlations) effect is observed only for the high energy protons, confirming thus that the emitting source is indeed 'hot'. Similar observations were reported earlier at higher energies in heavy ion collisions; the same interference method was used to determine the freeze-out density of nuclear matter.

The analogy between astronomy and particle physics goes however much further. Light beams can be both coherent (laser-like) and chaotic (incoherent) and the same duality is expected to hold for mesonic fields, too. This may have important implications for our understanding of strong interaction dynamics, being possibly connected with the existence for example of gluon or quark-antiquark condensates in hadronic and pion condensates in nuclear matter.

The recent measurements in electron-positron reactions from DESY reported by P. Mättig and from SLAC reported by G. Goldhaber show strong evidence that a very large amount of coherence (over 90 per cent) characterizes the pion fields in these reactions. This evidence is now based on two independent experimental facts: the Bose-Einstein two-body correlations and the multiplicity distributions of secondaries.

As a point of historical interest it should be mentioned that the Bose-Einstein correlation effect discovered by G. Goldhaber, S. Goldhaber, Lee and Pais and known as the GGLP effect had its 25th anniversary at this workshop. G. Goldhaber's review talk (presented by P. Mättig) summarized the subject both in particle and heavy-ion physics.

The relationship between hadron production in electron-positron and hadron-hadron reactions in general was the subject of several talks. While Barshay (Aachen) treated this relationship from the point of view of the impact parameter, Plümer et al. (Marburg) introduced the inelasticity distribution as an alternative, which has the advantage that it is not dependent on geometric considerations and is directly accessible to measurements. This physical quantity has important implications in the interpretation of many-particle production processes, since it appears that these processes depend on the actual energy deposited into the system rather than the total available energy. This inelasticity, which is also related to the leading particle effect in hadronic interactions, can be determined event by event in hadronic interactions and related to the behaviour in electron-positron reactions at the appropriate energy.

One interesting application of the inelasticity distribution discussed at Bad-Honnef is a possible explanation of the correlation between the average transverse momentum of secondaries and the multiplicity within Landau's hydrodynamical model. This is a subject of high current interest since it may be connected with a phase transition to quark-gluon plasma. While so far this correlation was known only in proton-proton (ISR) and proton-antiproton (CERN Collider) reactions, at Bad-Honnef, Mättig presented for the first time experimental results on this effect in electron-positron reactions.

The meeting, sponsored by the Deutsche Forschungsgemeinschaft, was a success. It certainly clarified several important problems connected with local equilibrium in strong interaction physics and brought up new results and viewpoints. The proceedings are being published by World Scientific.

(From Richard Weiner)

Muon-catalyzed fusion revisited

A negative muon can induce nuclear fusion in the reaction of deuteron and triton nuclei giving a helium nucleus, a neutron and an emerging negative muon. The muon forms a tightly-bound deuteron-triton-muon molecule and fusion follows in about 10^{-12} s. Then the muon is free again to induce further reactions. Thus the muon can serve as a catalyst for nuclear fusion, which can proceed without the need for the high temperatures which are needed in the confinement and inertial fusion schemes. At room temperature, up to 80 fusions per muon have recently been observed at the LAMPF machine at Los Alamos, and it is clear that this number can be exceeded. These and other results were presented at a summer Workshop on Muon-Catalyzed Fusion held in Jackson, Wyoming. Approximately fifty scientists attended from Austria, Canada, India, Italy, Japan, South Africa, West Germany, and the United States. The Workshop itself is symbolic of the revival of interest in this subject.

Muon-catalyzed (proton-deuteron) fusion was first observed in 1956 by Luis Alvarez and colleagues in hydrogen bubble chamber experiments at Berkeley, but the effect had been predicted as early as 1948 by F. C. Frank and A. D. Sakharov. Following a brief flurry of interest in the mid-50s, interest waned following predictions of, at most, only a few fusion cycles during the muon lifetime.

Muon catalysis has received renewed attention during the past six years or so primarily because of the work of the Soviet theorist L. I. Ponomarev and his colleagues, who have developed a model of resonant formation of the muon molecules. In this model, a small neutral triton-muon atom can penetrate a D_2 or DT molecule and then link with a deuteron to form a deuteron-triton-muon molecular ion without breaking up the electronic host molecule. The ion serves as one of the nuclear centres of the electronic molecule. The energy released as the ion forms must be absorbed by the vibration and rotation of the electronic molecular complex. This muon-molecular formation process depends on the existence of a very loosely bound excited state of the molecule. Observations of very rapid molecular formation rates (about 10^9 per s) and pronounced dependence of that rate on the temperature of the deuteron-triton mixture lend strong support to this exotic model.

The field is now burgeoning with experiments at Dubna, Gatchina, Los Alamos, Vancouver, and Zurich. Efficient means of producing muons in a dedicated facility are being discussed (for example, using radio-frequency quadrupole pre-accelerators and neutron-rich projectiles and targets). Based on recent developments, several participants of the Workshop broached the subject of power production by means of muon-catalyzed fusion. Evidently, this long-standing dream of high energy physicists will be re-examined.

Further information on the Workshop can be obtained from the organizer, Steven Jones, Idaho National Engineering Lab., P.O. Box 1625, Idaho Falls, ID 83415.

Shower Simulation

A three-day meeting on the Simulation of Hadronic and Electromagnetic Showers will be held in the CERN Council Chamber beginning on Tuesday 29 January 1985.

People and things

Paul Dirac

Paul Dirac

On 20 October, one of the few remaining links with the birth of quantum mechanics was broken when Paul Dirac died at the age of 82. In 1923, the young Dirac arrived in Cambridge after initial training as an engineer. Over the next few years, along with Heisenberg, Schrödinger and others, he helped mould the new quantum mechanics from the old quantum theory. He recast the formalism in his own inimitable way, work which was included in his PhD thesis and which was later to stimulate many generations of theoretical physicists through his monumental book 'The Principles of Quantum Mechanics', a work which has been compared in its stature with Newton's 'Principia'. Among these early results, he discovered how to handle systems containing many identical electrons — 'Fermi-Dirac' statistics.

After visits to Copenhagen and Göttingen, Dirac returned to Cambridge where his attention turned to the unification of the new quantum mechanics with special relativity. His theory, including the famous equation which bears his name, soon appeared, explaining in an elegant way the newly-discovered 'spin' property of electrons, but it required the existence of puzzling negative energy solutions. He first assumed that the theory naturally encompassed both electrons and protons. This error was quickly rectified, and he predicted the existence of 'anti-electrons'. In 1932, the positron was discovered.

In 1933, he shared the Nobel prize with Erwin Schrödinger. With the antimatter companion of the electron known, he alluded in his Nobel lecture to the possibility of 'negative protons'. In further investigations of quantum electromagnetism, he proposed the existence of magnetic monopoles, a subject which remains controversial to this day. His later researches grappled with the creation and annihilation of particles, paving the way for the modern formulation of quantum electrodynamics.

Also in 1933, he succeeded to the prestigious Lucasian Chair of Mathematics at Cambridge, and in 1937 he married Margit Wigner, sister of the famous physicist. After his retirement from Cambridge, Dirac moved to the warmer climes of Florida State University, Tallahassee, but was frequently seen at international meetings and conferences.

His work will surely be remembered for ever.

On people

Martin Blume has been named Deputy Director of Brookhaven National Laboratory.

As Brookhaven's Associate Director for Low Energy Physics and Chemistry since 1981, he has been responsible for the Laboratory's programmes in solid state, materials, chemical and nuclear sciences. In addition, he has served as Acting Chairman of the US National Synchrotron Light Source Department since November 1983.

In his new capacity, Martin Blume will work closely with Brookhaven's Director in the general administration of the Laboratory. He will continue to have primary responsibility for Brookhaven's research in the basic energy sciences, including work in such fields as chemistry, materials, engineering, mathematics, and geosciences. He will also continue as Acting Chairman of the NSLS until a permanent chairman is designated.

Eminent theorist and former CERN Research Director General Leon Van Hove has been named as Brookhaven National Laboratory's first Leland J. Haworth Distinguished Scientist. The nomination is in memory of Leland J. Haworth, Brookhaven Director from 1948-61.

At a simple ceremony on 2 October at the University of Milan, the title of Professore Emirito was conferred on the Italian physicist Giuseppe Occhialini, well known as one of the leading researchers from the era of cosmic rays. He participated in several historic experiments, including the co-discov-

ery of the positron with P. M. S. Blackett in 1933 and the 1947 study with C. M. Lattes and C F. Powell which revealed that both pions and muons exist in Nature.

Reorganization at Fermilab

With the primary goal of exploiting the new Tevatron facilities for physics, Fermilab Director Leon Lederman has announced a management reshuffle, effective from 1 October.

Three new Associate Directors have been named — James Bjorken for Physics, Bruce Chrisman for Administration, and Dick Lundy for Technology. Phil Livdahl will continue to serve as Acting Deputy Director but will devote much of his time to technical problems in the Accelerator Division.

Peter Koehler, formerly head of the Research Division, will join the Accelerator Division as Associate Division Head, responsible for providing support for the D0 project (see May issue, page 147) and Main Ring tunnel experiments other than the main Collider Detector. Ken Stanfield, formerly Head of the Business Office, will take Peter's place as Head of the Research Division. Jim Finks has been appointed Business Manager.

Tom Kirk will succeed Drasko Jovanovic as Head of the Physics Department, in addition to continuing as Manager of the Tevatron II project. Tom's Deputy Head will be Dan Green.

Paul Mantsch will replace Dick Lundy as the head of the Technical Support section. Paul has been concentrating recently on the design of prototype magnets for the Superconducting Super Collider (SSC). In his new role, Paul will have responsibility for all conventional magnet work, drafting service, the machine shop, and magnetic measurements as well. Gene Fisk will head the continuing SSC magnet work.

Proton beam at Rutherford Appleton machine

The first 550 MeV proton bunches have been successfully extracted from the new Spallation Neutron Source at the Rutherford Appleton Laboratory, UK, at the first attempt. The extracted proton beam will soon be guided onto the uranium target to produce the first neutrons.

Synchrotron radiation in Taiwan

Lee Teng of Fermilab has been appointed Director of Taiwan's recently founded $30 million Synchrotron Radiation Research Centre, the island's first major large scale research project. Teng will be assisted by Thomas K. C. Liu as Deputy Director.

The 96 m circumference electron storage ring will have an energy of about 1.5 GeV, with beam injected at 250 MeV from a 40 m linac, and is scheduled for completion in five years.

Chinese protocol

A Protocol on cooperation between CERN and the Chinese Academy of Sciences was signed at CERN on 18 October by Zhao Guangzhao, a Vice-President of the Academy, and CERN Director General Herwig Schopper. The new protocol continues the existing collaboration with the Institute of High Energy Physics in Beijing and extends it to other Institutions, in particular those involved in the LEP experiments at CERN. It comes into force on 1 January 1985, for a period of three years.

Symposium proceedings

The Proceedings of the first ESO-CERN Symposium on 'Large Scale Structure of the Universe, Cosmology and Fundamental Physics', held at CERN in November 1983 (see January/February issue, page 3) are now available. The Proceedings were edited by G. Setti and L. Van Hove and copies can be obtained from K. Kjär, Publication Service, European Southern Observatory, Karl-Schwartzschild-Strasse 2, D-8046 Garching bei München, Federal Republic of Germany, at DM 35 per copy including postage and packing.

1985 Particle Accelerator Conference

The next Particle Accelerator Conference will be held in Vancouver, Canada, from 13-16 May 1985, organized by the TRIUMF Laboratory. Following the 1983 Santa Fe Conference, it will be the 11th in this biennial series devoted to all aspects of accelerator science, engineering and technology. Regular attendees should note that the meeting has been extended to four days and is being held two months later than usual. Detailed information from the Arrangements Chairman, J. J. Bugerjon, TRIUMF, 4004 Wesbrook Mall, Vancouver, BC V6T 2A3, Canada.

A lighter moment during the CERN Accelerator School at Gif-sur-Yvette.

Meetings

The 1985 International Symposium on Lepton and Photon Interactions at High Energies will be held in the Kyoto International Conference Hall, Kyoto, Japan, from 19-24 August 1985. It will be sponsored by IUPAP, the Science Council of Japan and the Physical Society of Japan. The host institutions are the Research Institute for Fundamental Physics and Department of Physics, Kyoto University. Chairman of the Organizing Committee is Yoshio Yamaguchi of INS, University of Tokyo, and further information is available from the Conference Secretariat, Research Institute for Fundamental Physics, Kyoto University, Kyoto 606, Japan, telephone 075-711-1381, telegram RIFPKYOTOU, telex 542 3179 RIFPK, facsimile 075-701-4247.

Looking further ahead, the XXIII International ('Rochester') Conference on High Energy Physics will be held at Berkeley (California) from 16-23 July 1986. Following the style of the most recent such meeting to be held in the US, at Madison, Wisconsin, in 1980, this will be an 'open' conference, with a minimum of official invitations being issued. Organizer will be S. C. Loken, 50-137 Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, USA.

The CERN Accelerator School will organize a course on advanced accelerator physics, to be held at Oxford from 16-27 September 1985. This will build on the General Accelerator Physics course held at Gif-sur-Yvette, France, in September (see following story), but will be open to all suitably qualified people. Attendance, however, will be limited to about 130. Further information from Mrs. S. Von Wartburg, Secretary of the CERN Accelerator School, CERN, 1211 Geneva 23, Switzerland.

1984 CERN Accelerator School
A participant's view

From 3-14 September, the CERN Accelerator School organized (jointly with the Laboratoire de l'Accélérateur Linéaire, Orsay and the Laboratoire National Saturne, Saclay) a course on General Accelerator Physics at the Ecole Supérieure d'Electricité, Gif-sur-Yvette.

Under the leadership of Kjell Johnsen, a two-week intensive course of excellent quality was given by more than twenty specialists from nine European Laboratories. The 148 participants came from a wide background — 21 from CERN and the rest came from 17 countries in Europe, North and South America, Africa and Asia. It must have been difficult to set the level to suit the varying needs but we were given an interesting course covering the essentials of accelerators.

The course dealt with theory, starting with an introduction to weak and strong focusing and continuing with transverse and longitudinal beam dynamics. Some special topics were resonances, coupling, transition, injection, extraction, coherent instabilities, dynamics of radiating particles and space-charge image forces. These were complemented by seminars on the advanced technology used in accelerators for magnets (conventional and superconducting), radio-frequency, vacuum and control.

To widen our appreciation of the accelerator field, seminars were also given on accelerator projects, synchrotron light sources, and medical and industrial applications. The sessions ended with lively discussions, where the participants could glean all the information they needed about regular applications.

Part of the success of this course was due to the organizing committee led by P. J. Bryant (CERN), J. Buon (Orsay), J. R. Le Duff (Orsay) and J. C. Laclare (Saclay). The social program included an excellent talk by G. Conforto on discoveries and on what remains to be discovered in high energy physics. Visits to Saclay, Orsay and GANIL laboratories as well as a tour of the old town of Rouen completed two very full weeks.

Manfred Schmitt

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from whom further particulars may be obtained. The appointment will be dated from 1st October 1985 or by agreement at an earlier date. Salary will be according to age and experience on the lecturer scale currently £ 8376 to £ 15 311 per annum.

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personnel division,
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For further information please contact Dr. R. D. Peccei, theory group.

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Send resume and names of three persons as reference to:

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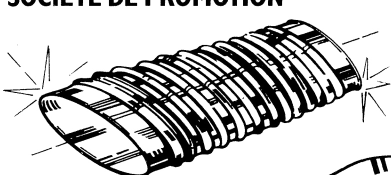

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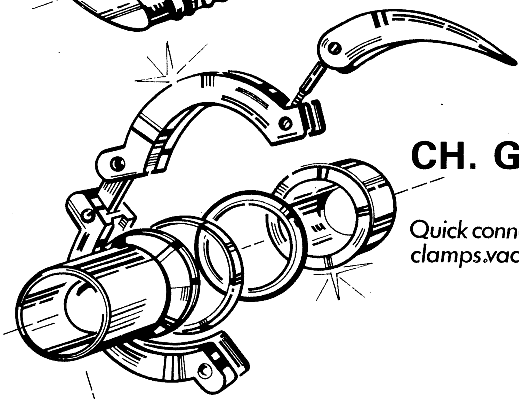

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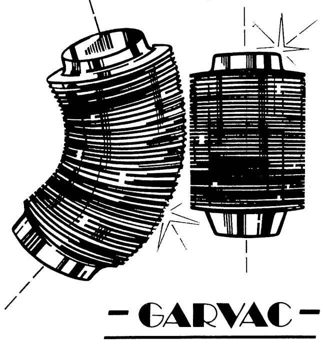

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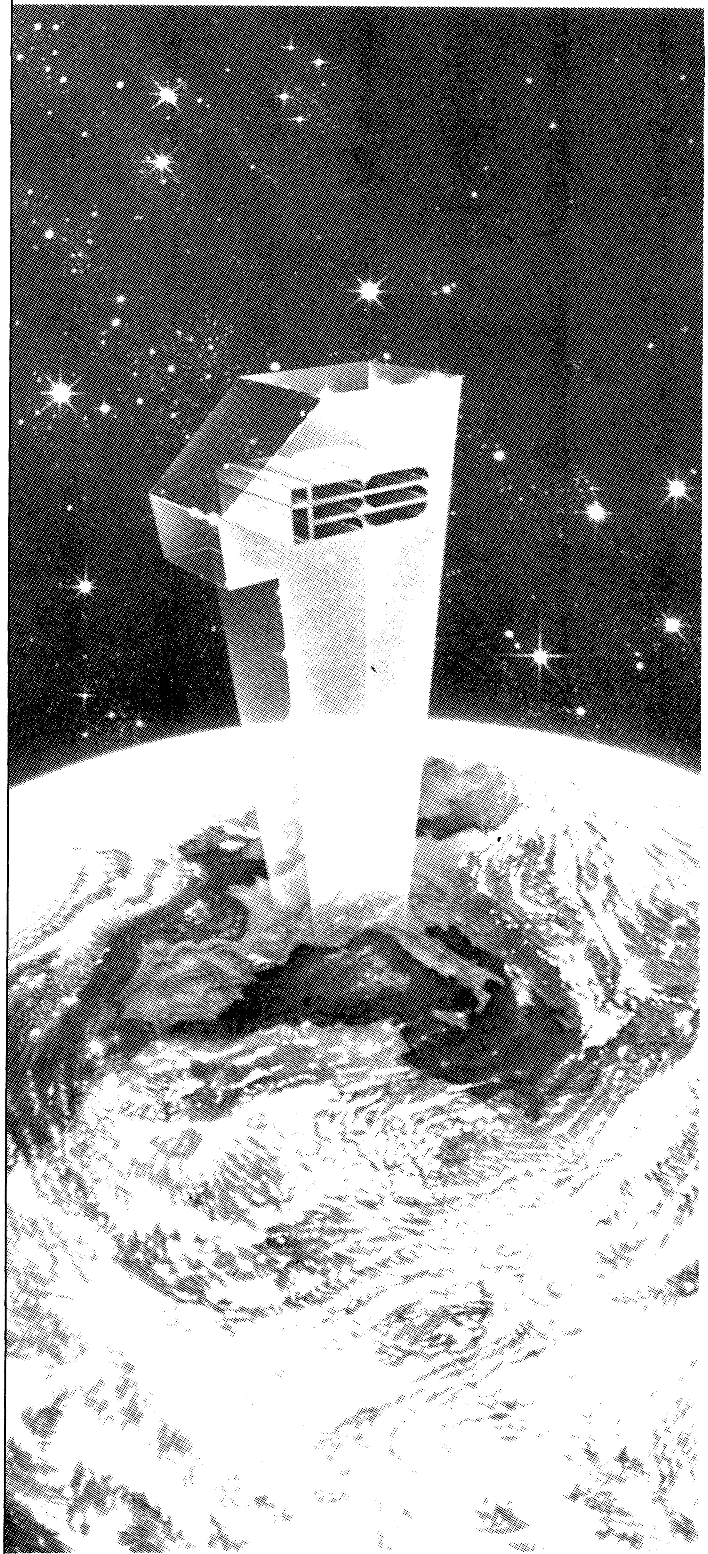

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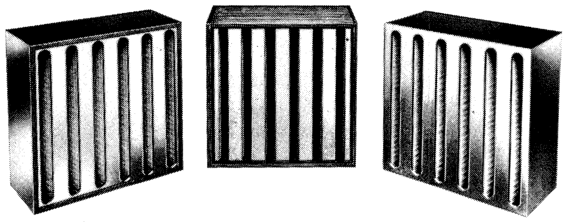

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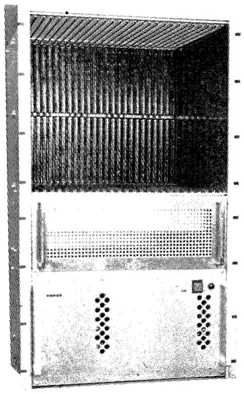

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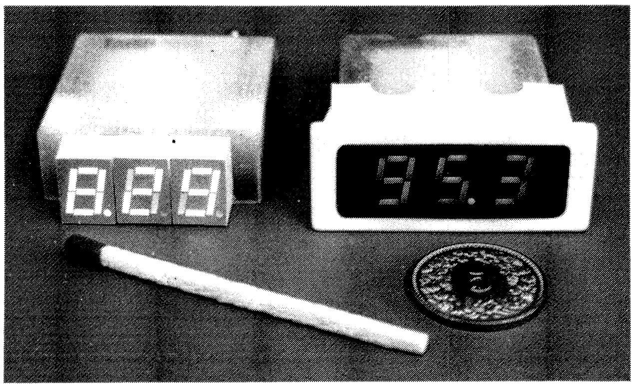

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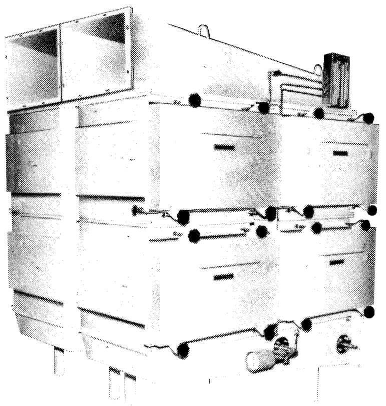

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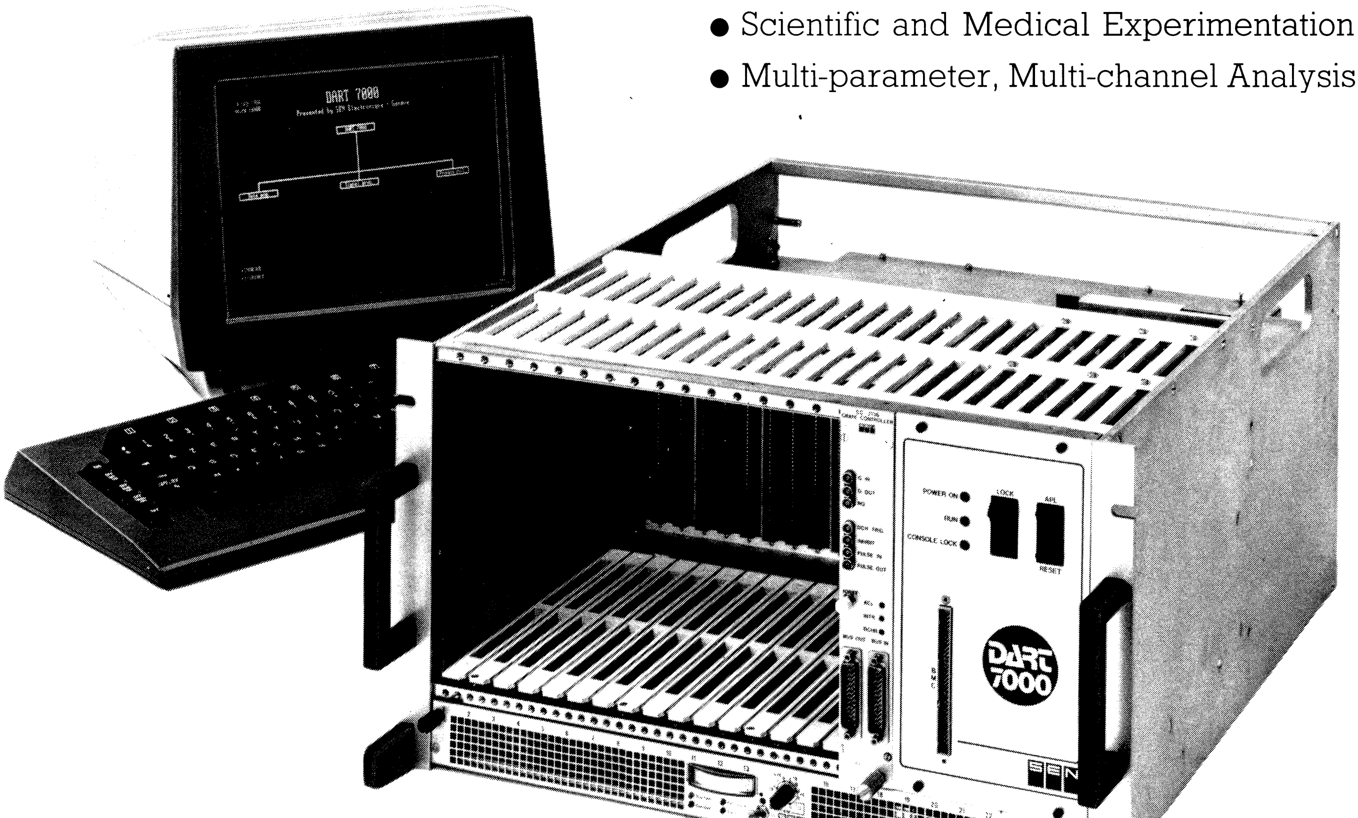

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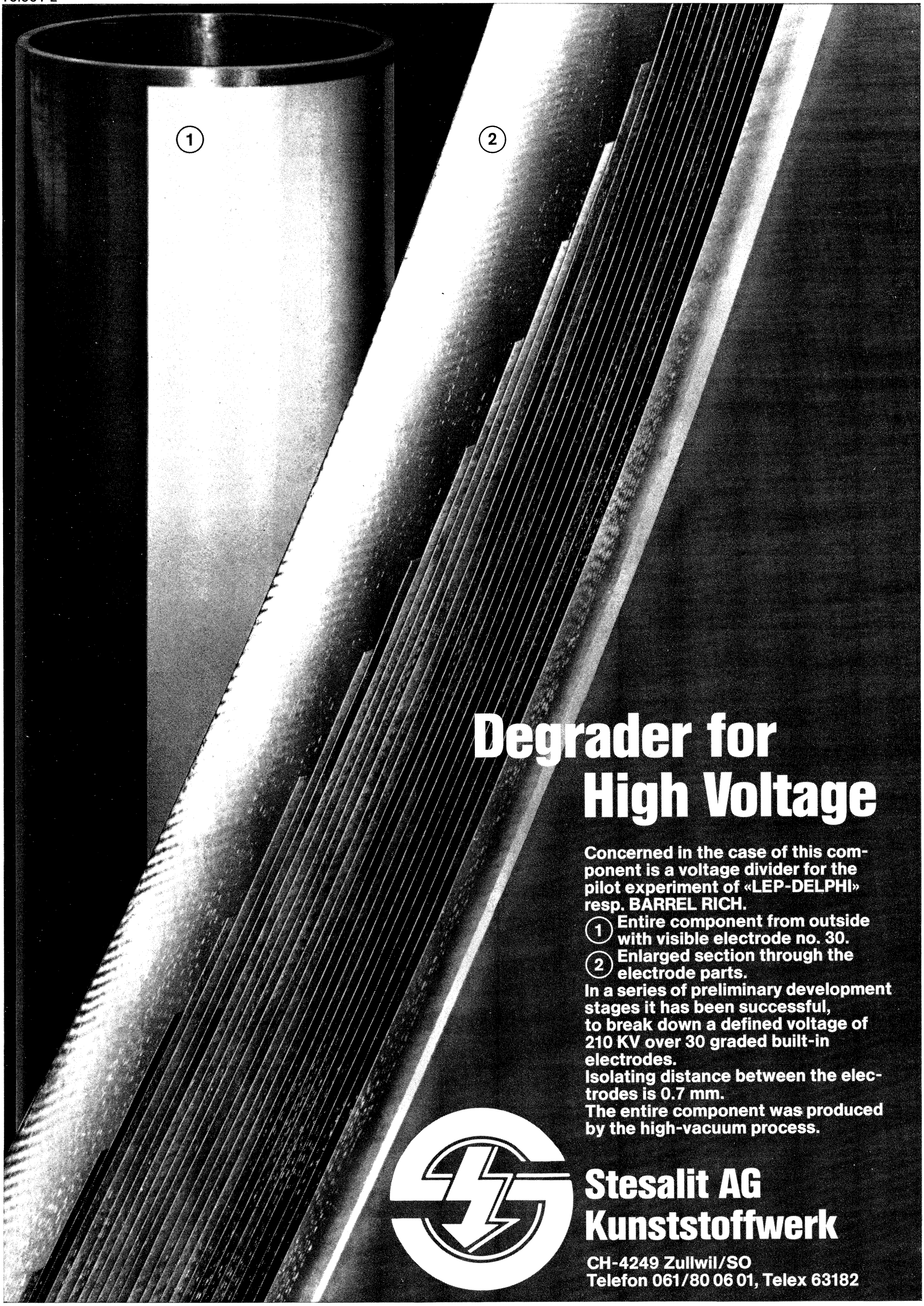
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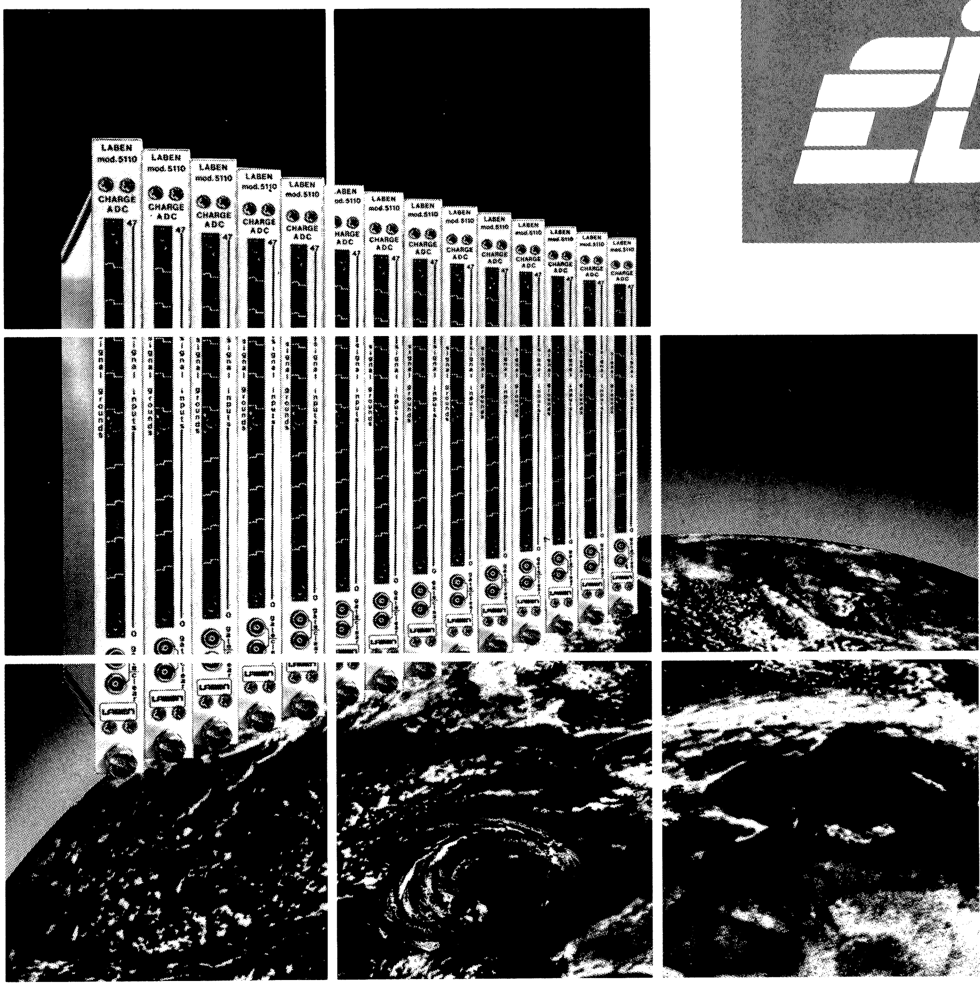

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