CERN COURIER

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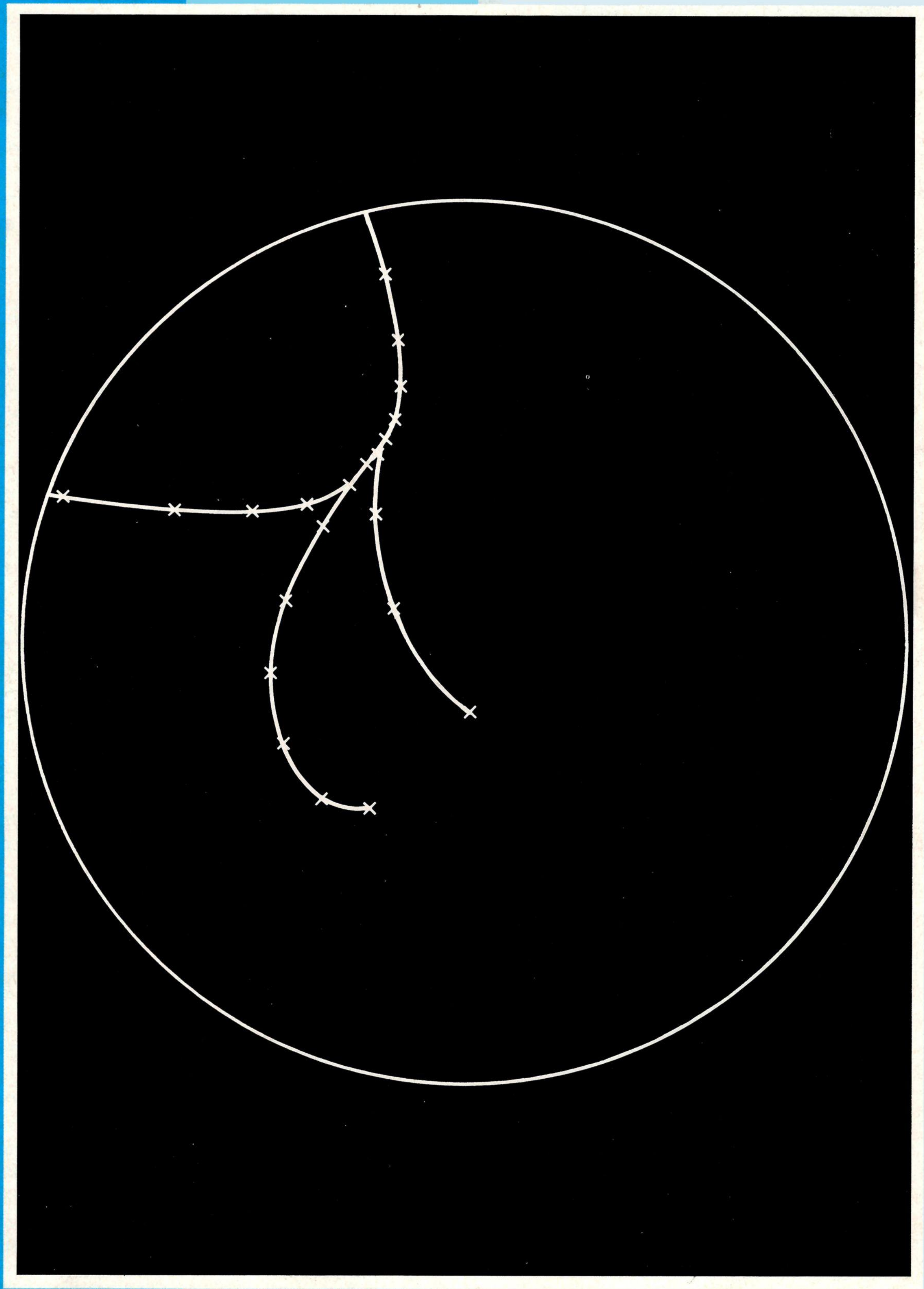

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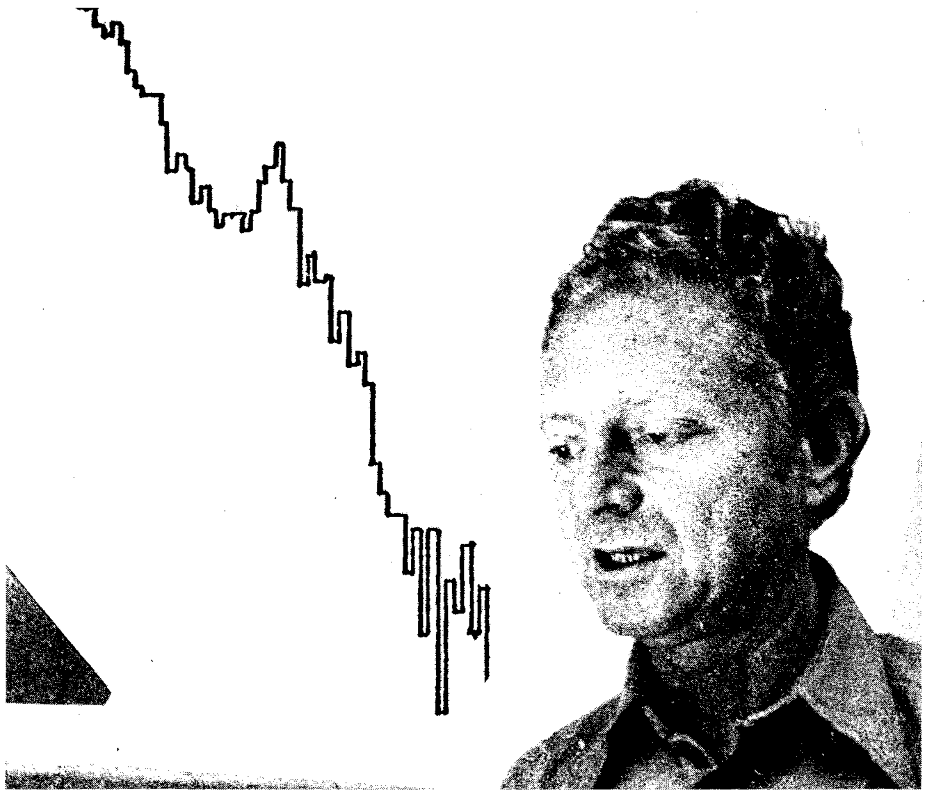
Cover photograph: A high energy neutrino interaction producing four muons. The event was seen by the CERN / Dortmund / Heidelberg / Saclay collaboration in their detector at the CERN SPS. The picture is a reconstruction of the tracks of the four muons as seen by drift chambers (the crosses correspond to the drift chamber signals) which are interspersed with disc-shaped magnet blocks in the detector. It is an end-on view looking from the direction of the incoming beam. This is the first ever observation of a neutrino interaction resulting in the production of four muons.

Where are we now?

A brief review of some of the progress in particle physics during 1977



The discovery of the year, the Upsilon particles of mass about 10 GeV, being announced by Leon Lederman at the Budapest Particle Physics Conference in July.

Perhaps the simplest and most honest answer to the question in the title is that we do not know. During the year several discoveries, or convincing confirmations of earlier discoveries, have opened a door that we thought we were closing. Just as theory was putting the produce of the experiments into order in a very promising way, there have been new findings that now need to be absorbed. However, we have certainly moved nearer to understanding the workings of Nature as a result of the research in 1977.

A simplified picture of where we were in our knowledge of hadrons at the end of 1976 would show us holding four types of quark (up, down, strange and charmed) as the constituents of all the hadrons — the particles sensitive to the strong force. We had absorbed the Brookhaven / Berkeley / Stanford discovery of the J/psi particle at the end of 1974 by introducing the charmed quark and all the known families of hadrons could be built up from combinations of these four quarks in a calculable way.

During 1977 some empty corners of this picture have been painted in with results from the electron-positron storage rings at DESY and at Stanford. The J/psi had already been interpreted as consisting of a charmed quark and charmed antiquark where the charm property was hidden. It was desirable, therefore, to identify particles with 'naked charm'. This has been thoroughly done in the study of D mesons, the first of which was found at Stanford in 1976, and in the discovery of F mesons at DESY announced in July. The Ds and Fs all exhibit naked charm in the ways that were predicted.

A question mark on the quark front was some data from a Fermilab experiment showing 'anomalous' behaviour of antineutrinos at high energy, for which one explanation was the existence of an additional type of quark. More neutrino data from CERN during 1977 has removed this anomaly but the possibility of a new quark has come back, again from Fermilab, though from a different direction and looking much more solid.

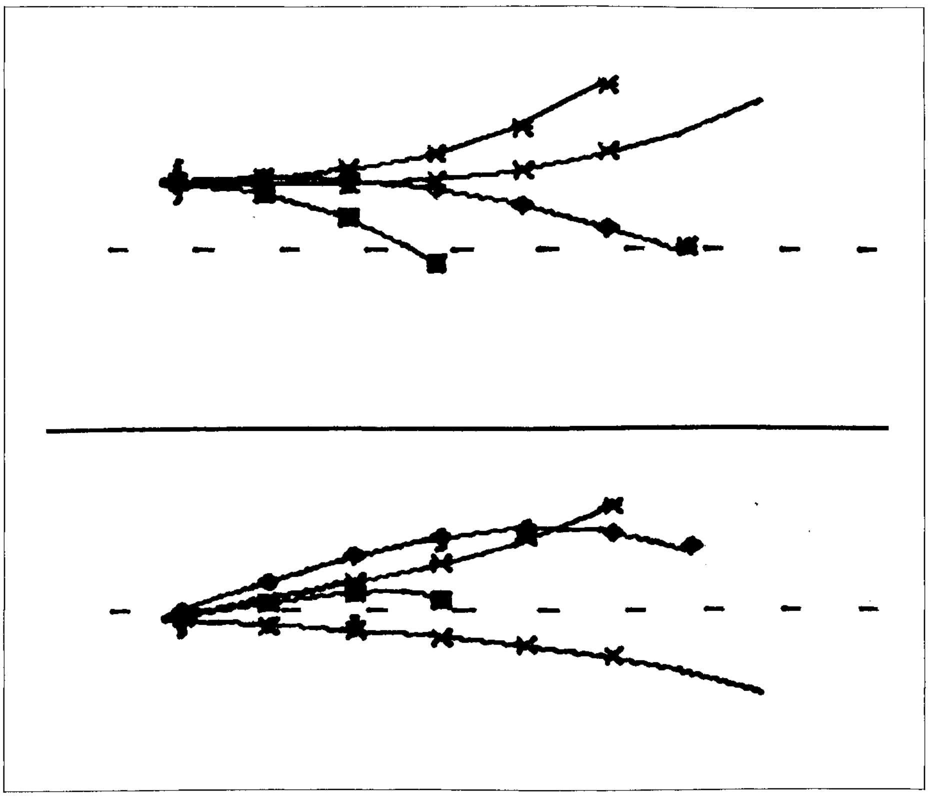
If a 1977 oscar is to be given to any particular particle for a starring role during the year, it must go to the muon. In July came the announcement that, in observing muon pairs emerging from high energy interactions at the Fermilab accelerator, new very heavy particles have been seen around a mass of 10 GeV. Known as the Upsilon particles, they are most frequently interpreted as consisting of a quark-antiquark pair of a new type.

The postulated new quark has been assigned names like 'beauty', 'top' or 'bottom'. Just as the J/psi provoked the search for naked charm, so the Upsilon now offers physicists the exciting prospect in 1978 of looking for naked bottom.

The study of muons coming from high energy neutrino interactions ran like a thread through the year. It began with 'dileptomania' — the attempt to learn more about the phenomenon of two muons coming directly from a neutrino interaction. Then in February Fermilab discovered three muons emerging. This result and the dimuon events were strongly reinforced by the start of high energy neutrino experiments at the CERN SPS, where much more data could be assembled. To round the year off, CERN discovered in November four muons emerging from a high energy neutrino interaction.

The origin (or origins) of this proliferation of muons is not clear. It may become so when we know more about new types of quark. Alternatively, it may be at least partly the result of the existence of new types of heavy lepton.

At the beginning of 1976 we could pretend that we had four leptons — the particles which do not feel the strong interaction. These are the



Other views of the four muon neutrino event shown on the cover, this time looking from the side. The CERN / Dortmund / Heidelberg / Saclay collaboration led by Jack Steinberger has amassed the enormous total of 5 million neutrino interactions (3.5 million of the charged current type, 1.5 million of the neutral current type). Among them are six thousand dimuon events, thirty-five trimuon events and this single four muon event.

electron, muon, electron-type neutrino and muon-type neutrino. This gave a pleasing symmetry with the four quarks which build up the hadrons and made the theoreticians happier in their attempts to develop a model which would incorporate all known particle behaviour.

However, a heavy lepton (tau) had already been discovered on the SPEAR storage ring at Stanford. Though people tried not to believe it and would really have liked to see it go away, this now seems a forelorn hope because during 1977 there has been still more evidence from Stanford and it is now also backed by data from DESY.

There were three highlights a little outside the main-stream of the development of particle physics. One was the annual discovery of an isolated quark, announced in April, this time in a Millikan-type experiment at Stanford University. It has not deviated theoreticians from their efforts to demonstrate why it is not possible to see an isolated quark (see Physics Monitor).

A second highlight came from several experiments during 1977 which clearly established 'baryonium' as a way of life. These well-defined states have been seen in a number of spectroscopy experiments and have the peculiar property that, while they look superficially like mesons, they prefer to decay into a baryon-antibaryon pair. Thus additional selection rules now have to be incorporated into the underlying quark model.

The third side highlight featured the muon again. Rumours circulated in February on the basis of very preliminary data from an experiment at SIN, that the muon had been seen to decay at a very low rate into an electron and a gamma ray. If such a decay were found, it would destroy the distinction between the electron and the muon which has always seemed absolute up to now. However, the decay has not been confirmed by later data from SIN or from TRIUMF.

Some theoreticians would have been pleased to see this muon decay into an electron plus gamma. It can be predicted as occurring at a low rate from some gauge theory calculations. Gauge theories are all the rage, and an article on them can be found in the September issue. They have had wide success in explaining our present knowledge of particle behaviour and they have the fundamental attraction of being applicable to any force field-gravitational, weak, electromagnetic or strong. They thus hold out the long searched for holy grail of unifying our interpretation of all types of behaviour in Nature.

To date, they have welded together weak and electromagnetic behaviour, an achievement rubbed home by the discovery of neutral currents at CERN in 1973. The only cloud on that horizon is the failure to see neutral current effects in some other physics experiments where they might have appeared. Fortunately, for the moment, we can hide behind the complexity of some of the necessary calculations and believe that these are wrong, or that the structure of the neutral currents is more complex, rather than that the neutral current effect is not there.

Now gauge theories are being extended to absorb the observation of the Upsilon and the tau. The tau is likely to have its own neutrino, in analogy to its electron and muon confreres, bringing the total number of leptons to six. The Upsilon type of quark (if that proves to be the correct origin of the particle) is also likely to have a companion, bringing the total number of hadron constituents to six. The gauge theory manoeuvers with the extended list of particles may well absorb more easily a few uncomfortable phenomena, like the violation of charge-parity symmetry in the decay of the neutral kaon, which have been largely swept under the carpet in the general progress of our understanding of particle behaviour.

Turning to the machines on which particle physics research is done, a major event in 1977 was the start, in January, of the physics programme on the CERN 400 GeV proton synchrotron (the SPS) with some of the most intense beams and most sophisticated detection systems available.

Among the machines under construction the star has been the PETRA 18 GeV electron-positron storage ring at DESY where a cracking pace has been set and maintained throughout the year. They must now, however, look over their shoulder because the twin machine, PEP at Stanford, has begun building in earnest with formal ground breaking in June. Work on the Tevatron, with the addition of a superconducting ring to take the energy to 1000 GeV, continues at Fermilab. A variety of possibilities for colliding beams as well as 1 TeV fixed target physics will be opened up.

The 400 GeV proton-proton storage ring (ISABELLE) at Brookhaven has received its first construction money. Authorization is also through for the 8 GeV electron-positron storage ring (CESR) at Cornell. The same energy range will be reached by VEPP-4 at Novosibirsk which is nearing completion.

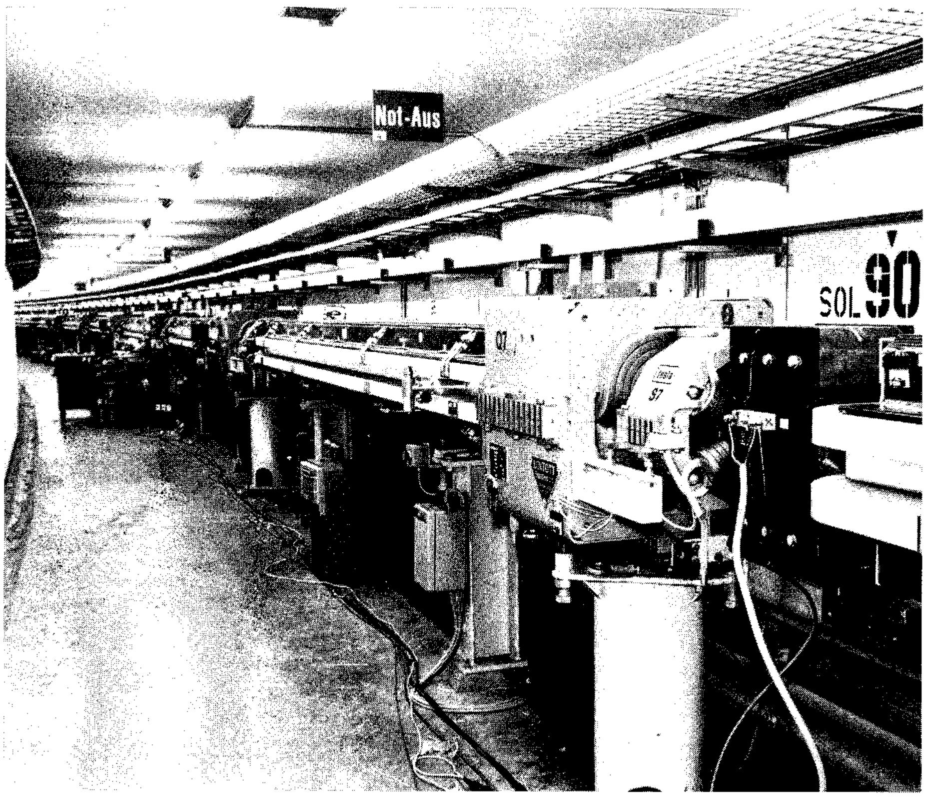
Europe, via the European Committee for Future Accelerators (ECFA), has decided that a very high energy electron-positron storage ring, to give about 200 GeV in the centre of mass, should have top priority as its future project. The Soviet Union continues its study of UNK, a several TeV fixed target proton synchrotron. And we welcome some new colleagues to the high energy physics community from China where a several hundred GeV proton synchrotron is planned.

It has been very satisfying to see that international use of new and planned facilities has been taken very much to heart (for example at PETRA and ISABELLE) in line with the recommendation which emerged from the inter-regional discussions held in 1976. These same discussions led to the setting up of the Inter-regional Committee for Future Accelerators (ICFA) to keep alive the possibility of a 'world machine' in the years to come.

In the field of accelerator technology, the idea of beam cooling has been taken up at CERN and Fermilab in addition to Novosibirsk and the realization of high intensity antiproton beams, for proton-antiproton colliding beams and for other experiments, is probable only a few years away.

Other applications of accelerators continue to mushroom. They are being developed more and more for use in medicine. The synchrotron radiation community using electron rings is growing rapidly and many new dedicated rings are being built. Accelerators are also to be the source of the intense neutron beams of the near future. The possibility of using accelerated heavy ion beams in fusion reactor systems is being keenly pursued in the USA.

All in all, it has been a very lively year in high energy physics holding out the promise of even livelier things to come.



One of the completed octants of the electron-positron storage ring, PETRA, which has maintained a very rapid construction pace during 1977. The machine is scheduled for operation in 1978.

(Photo DESY)

CERN COURIER's crystal ball

A new simulation computer program, OMEN (On-going Multiparticle Event Number-cruncher) is being developed to aid the long-term planning of particle physics experiments. Although the program is not yet available for general release, we were fortunate enough to obtain a prototype version, and used input data culled from the pages of the 1977 COURIER to obtain this unique glimpse of what could be in store in 1978.

JANUARY
Twenty new high mass particles discovered in lepton pair experiments. Theorists propose periodic table of quarks. Copies printed and distributed to schools. IBM announces a new computer to handle the world's neutrino data.

FEBRUARY
Fractional electronic charges detected on a television screen in Memphis, Tennessee. Five muons seen coming from a neutrino interaction. Weinberg-Salam angle remains unchanged. US Supreme Court rules that jets must no longer be produced in hadronic reactions.

MARCH
Leptons get heavier and heavier. Very high energy cosmic ray event recorded in South America. Government overthrown. The A_1 meson disappears from view. Medical applications of charmed quarks demonstrated. Six muons seen coming from neutrino interaction.

APRIL
Analysis of cosmic ray event reveals ten free quarks, a tachyon, four Higgs particles, two magnetic monopoles, three superheavy nuclei and an intermediate vector boson (the charged kind). Weinberg-Salam angle remains unchanged but accelerator building stops throughout the world.

MAY
Particle Data Group publishes special quark souvenir issue. Land prices in the Andes soar as USA physicists rush to install particle detectors. European physicists hold Workshops to decide which cosmic rays to observe. Muon production in neutrino interactions included as event in Olympic games.

JUNE
The Big Shut Down starts. Accelerator sites used as car parks. BEBC is resited for cosmic ray experiments on the summit of Mont-Blanc. g-2 experiment reconstructed to measure the Weinberg-Salam angle to one part per million. South American governments introduce import tariffs on multiwire proportional chambers.

JULY
Photograph of cosmic ray event hung in Louvre. IBM (South America) reanalyses world's neutrino data. World record of 256 muons seen coming from a neutrino interaction is not ratified because of following wind and physicists taking anabolic steroids. Weinberg-Salam angle unchanged. Physicists read 'Finnegan's Wake' to learn significance of quarks.

AUGUST
CERN COURIER reports naked bottom seen on Copacabana beach. International high energy physics conference hurriedly convened in Rio de Janeiro. High energy physics football team wins final of World Cup in Argentina.

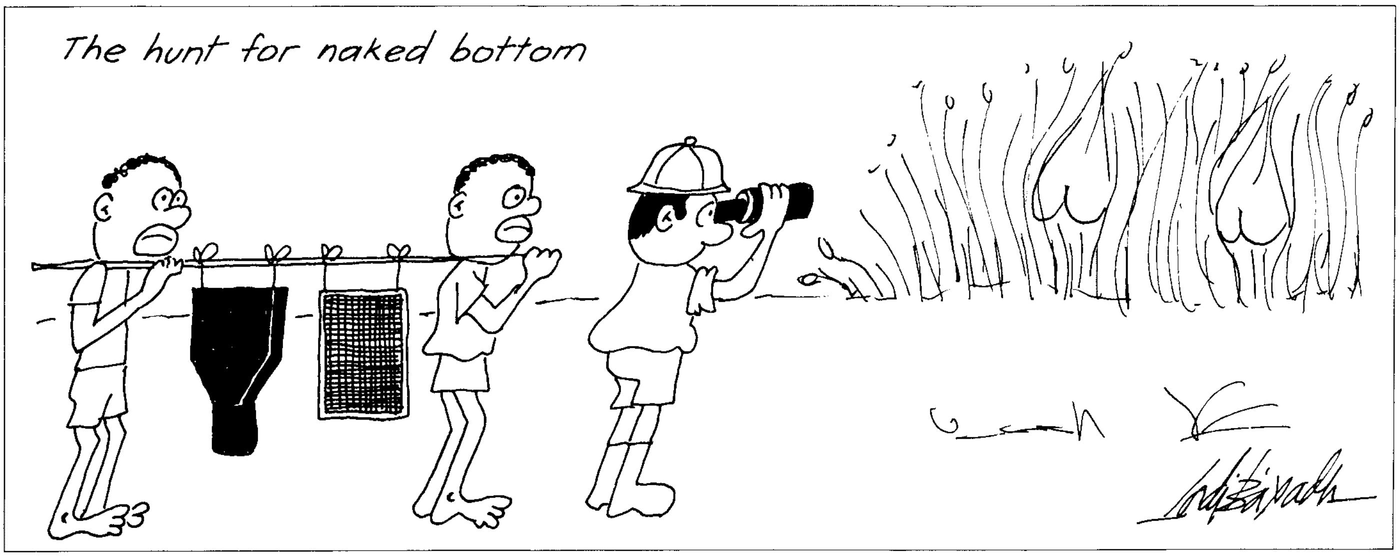
SEPTEMBER
South American cosmic ray event shown to be a hoax. Land prices in Andes plummet as physicists return to machines. Owners reluctant to remove their cars from accelerator sites. Parity experiment discovers violation of atomic physics. IBM analyses 'Finnegan's Wake'.

OCTOBER
IPCFA (Inter Planetary Committee for Future Accelerators) holds first meeting. Although next generation of machines envisaged to be built on a regional basis, plans to construct a Cosmic Ray Storage Ring in ten years' time as a World Machine are put forward. The A_1 reappears. Five million physicists now using synchrotron radiation facilities.

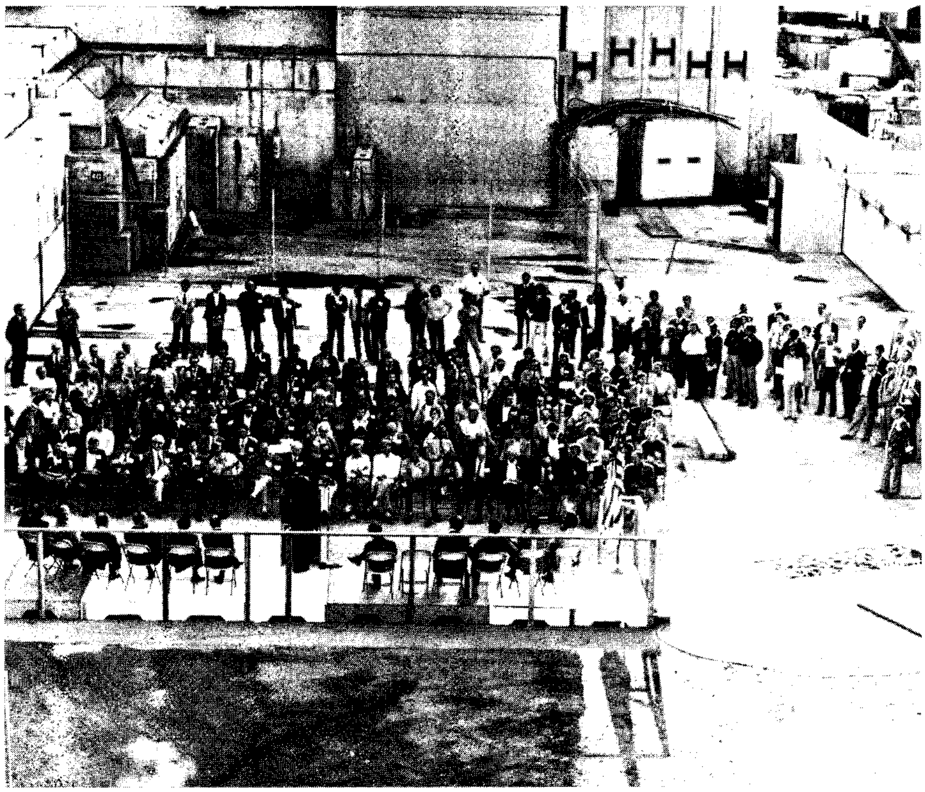
NOVEMBER
IBM computer wins Nobel prizes for physics and literature. IPCFA proposes Energy Doubler for the Cosmic Ray Storage Ring. Mohammed Ali says 'I can knock muons out of anything!' Accelerator building stops again.

DECEMBER
Bug found in OMEN.

Oh well.



Around the Laboratories



The scene at the dedication of the Stanford Synchrotron Radiation Laboratory, held on the site of the SSRL South Arc Expansion at the SPEAR storage ring on 27 October. On the right is the plot of ground used for the ceremonial ground breaking.

The line-up for the ground breaking ceremony at SSRL (left to right) — Seb Doniach, Ron Gould, Bill Spicer, Stig Hagström, Bill Oosterhuis, Artie Bienenstock, Andy Sessler, Bill Miller, Herm Winick, Pief Panofsky, Stan Stamp and George Pimentel.

(Photos SLAC)

STANFORD SSRL breaks new ground

A dedication ceremony for the Stanford Synchrotron Radiation Laboratory (SSRL) was held on 27 October with George Pimentel, the recently appointed Deputy Director of the National Science Foundation, as the principal speaker. Construction of the Laboratory, initially with the status of 'project', started in 1973 and it began operation in 1974 but the busy staff did not find time for a formal dedication ceremony until now.

The ceremony included ground-breaking for a new synchrotron radiation experimental hall being constructed on the south arc of the SPEAR electron-positron storage ring. Funds ($ 6.7 million) have been authorized over a three year period by the National Science Foundation for this new hall plus up to seven new synchrotron radiation beam-lines and up to nineteen experimental stations. Also included are funds for a wiggler magnet and much experimental equipment (monochromators, detectors, vacuum sample chambers, etc.).

The need for these new facilities can be appreciated from the exponential increase in proposals for experiments at SSRL — which have been approximately doubling in number each year for the past three years. The original beam-line provided for five simultaneously operating experimental stations. This has now been expanded to nine with the addition of a second beam-line in 1976 but the demand far exceeds the supply.

This has been particularly true recently because of the increased high energy physics interest in the 4 GeV centre of mass region which requires that the storage ring be operated at 2 GeV beam energy where the X-ray flux is minimal and many SSRL experiments cannot take useful data. They require stored beam energy of 2.5 GeV or higher to obtain high intensity at photon energies of 10 keV and higher.

SPEAR was run at a beam energy greater than 2.5 GeV for about 50% of the operations time during 1975, 76. During 1977 this took a precipitous drop to 16% and, coupled with the rising user interest, this has resulted in a serious lack of running time for X-ray experiments.

At present SSRL operates symbiotically on SPEAR and the beam energy is determined by the needs of the high energy programme. When PEP is operational, SPEAR will become available as a dedicated source of synchrotron radiation for 50% of its operation time. High current, multibunch, single beam high energy operation will then provide vastly increased synchrotron radiation flux, especially at X-ray wavelengths. During brief multibunch trials, 225 mA was stored in SPEAR and more should be possible.

In addition to the increased facilities now being constructed at SSRL, four new electron storage rings have been authorized in the USA, three as dedicated synchrotron radiation sources and one for colliding beams plus synchrotron radiation:

At Brookhaven the Department of Energy has authorized construction of 2.5 GeV and 0.7 GeV storage rings. The project is called the National Synchrotron Light Source (NSLS) and the Director is Arie Van Steenbergen.

At Wisconsin the National Science Foundation has authorized construction of a 0.75 to 1.0 GeV storage ring called Aladdin with Ed Rowe as Director.

At Cornell the National Science Foundation has authorized the construction of an 8 GeV electron-positron colliding beam storage ring called CESR and a synchrotron radiation laboratory is planned to operate symbiotically. The project is called the Cornell High Energy Synchrotron Source (CHESS) and is directed by B. Batterman and N. Ashcroft.

The increasing interest in synchrotron radiation research, leading to the construction of new facilities in the USA and elsewhere, is due primarily to the exciting research results from existing laboratories such as SSRL, DESY, Daresbury, Orsay, Novosibirsk, Wisconsin and more than ten other laboratories throughout the world. Programmes in X-ray absorption, diffraction, fluorescence and in UV photoemission among others, have been actively pursued for several years. New applications include Mössbauer studies, pumping of soft X-ray lasers, X-ray microscopy and X-ray micro-lithography (for replicating microstructures such as integrated circuits on a sub-micron scale).

The new storage rings in the USA should begin operation around 1980-81. Until then, the only US source of synchrotron radiation providing photons above 150 eV will be at SSRL where the first of the new beam-lines will be operational in 1978. Additional beam-lines, including a wiggler line, will come into action in 1979 and 1980.

CERN
SPS getting better all the time

Apart from one bad hiccup in July following the long shutdown, there has been a rather steady improvement in the performance of the 400 GeV proton synchrotron, the SPS, during 1977. Physics began at the accelerator in January with average intensities around 3×10^{12} protons per pulse. This figure has now moved to about 5.5×10^{12} and the general reliability of the machine has enabled some 10^{18} protons to be fed to the experimental targets during the three recent monthly operating periods. The reliability of the whole SPS complex is now over 80%.

The present peak operating intensity (sustained for 15 minutes) is 9.1×10^{12} and there is confidence that this will be increased to over 10^{13} when double pulse injection becomes part of the regular operating cycle next year. On 29 November, a pulse of 1.01×10^{13} was accelerated to 200 GeV with single pulse injection. A third r.f. cavity is to be installed, providing 167 GeV/s rather than 110 GeV/s, so as to reduce the acceleration time. With two flat-tops of 2 s duration, at 200 GeV and 400 GeV the cycle time will then move to 9.6 s compared to the present 8.4 s with only one long flat-top.

The long flat-top at 400 GeV will be needed to serve the counter experiments in the North Area which are nearly ready. Flexibility in extraction manoeuvres at the SPS will then be even more a feature of machine operation than it is at present when fast, fast-slow and slow extractions can all be used to feed the West Area experiments.

North Area gets ready

The SPS feeds two experimental areas — one to the West and another to the North of the site. Experiments in the West Area are in full swing and the first generation of experiments in the North Area are preparing to receive their first particles next year.

The initial experimental programme for the North Area splits into mainly hadronic physics in one experimental hall (EHN 1), using high energy electron of hadron beams, and muon physics in a second experimental hall (EHN 2), using a high intensity muon beam designed to provide bursts of 10^8 muons at energies up to 300 GeV.

Several hadronic experiments will run simultaneously in EHN1 and any of them using high intensity beams would produce unacceptable levels of background for their neighbours. Therefore, to allow the full force of the 400 GeV beam to be used directly, an underground experimental area EHN3 is being built, scheduled for completion in 1979. While hadron beams in EHN1 will provide up to 10^8 particles per pulse, the underground 'cave' EHN3 will permit secondary beams of up to 10^{10} particles per pulse to be used. Its experimental programme has yet to be decided but the proposed first generation of experiments should emerge next year. Probably two experiments could be installed alongside each other.

The initial experiments for EHN1 are as follows:

NA1. A Frascati / Milan / Pisa / Rome collaboration will use photons from a high energy electron beam to look for the production of heavy mesons.

NA3. A CERN / Collège de France /

The superconducting magnet system on the r.f. separated beam-line to the BEBC bubble chamber. The feed lines to the three magnets from the local liquid helium dewar are easily distinguished and part of the 60 m long helium transfer line, which is used about once a week, can be seen on the right.

(Photo CERN 154.8.77)

Ecole Polytechnique / Orsay / Saclay collaboration will investigate the hadronic production of high transverse momentum particles, including electron and muon pairs. This could provide more information on possible additional quark-antiquark bound states.

NA5. Originally designed as a study of inelastic hadron reactions by a Karlsruhe / Munich team, using a streamer chamber triggered by a single arm spectrometer to select particles of a particular type and momentum, the collaboration has been joined by physicists from Bari / Krakow / Liverpool / Munich. Additional triggers will be used to extend the study of hard hadron-hadron collisions. An electron-hadron calorimeter will assist in the study of jet production.

NA6. An investigation of high energy neutron proton elastic scattering at very small angles by a Freiburg / Karlsruhe / Moscow group. This could provide the first evidence of 'magnetic scattering' due to the magnetic moment of the neutron. These experiments for EHN1 have recently been joined by NA7 where the electromagnetic form factors of pions and kaons will be measured by a Frascati / Milan / Pisa / Rome / Southampton / Westfield group using the NA1 spectrometer.

Experimental Hall EHN2 will be the home of two large collaborations doing muon physics:

NA2. The European Muon Collaboration is confronting a programme of muon physics using a specially designed spectrometer to distinguish between muons and produced hadrons. The collaboration of CERN / Daresbury / DESY / Freiburg / Kiel / Lancaster / LAPP (Annecy) / Liverpool / Oxford / Rutherford / Sheffield / Shrivenham / Turin / Wuppertal, led by Erwin Gabathuler, will first concentrate on high energy inelastic scattering of muons to investigate the properties of photon exchange over a wide range of momentum transfer.

NA4. The other muon experiment involves a CERN / Dubna / Munich / Saclay collaboration, led by Carlo Rubbia, using high energy muons to study the deep inner structure of nucleons. The experiment uses a 50 m long target, surrounded by a specially designed magnet to trap the scattered muons in orbit and increase their chances of detection.

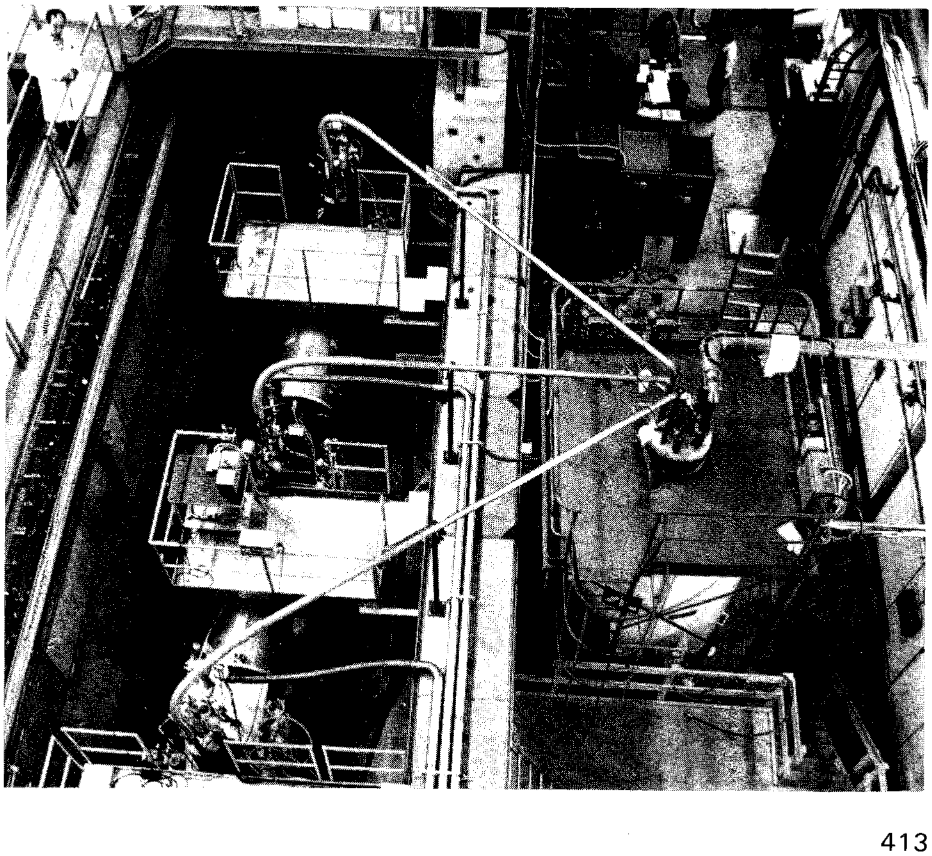
To cope with the increased demand for data handling when these and similar experiments get under way, a computer network (CERNET) is being developed. It will link experiments with the main computer centre and ensure rapid processing of trial data samples, etc. The new network is not specifically designed for work with the North Area experiments but they will most likely be the first to use it. The network applies the 'packet-switching' technique to make the most efficient use of the available communications links on the CERN site.

Superconducting magnet operation

In the May issue 1973, we described a superconducting bending magnet installed at the last deflection point in the hadron beam-line to the BEBC bubble chamber. Since then this magnet has been joined by two others to cope with the higher energy particles coming down the r.f. separated beam-line from the SPS. The three superconducting magnet system has been operating reliably for over a year.

The peak bending power of the group of magnets is 27 Tm which can handle beam momenta up to 150 GeV/c. Main parameters of the two new magnets are — central field 4.75 T at a current of 700 A, 74 mm bore and a cryostat length of about 3 m.

A problem in the use of superconducting magnets is that of the liquid helium supply. Big magnets, like those



Photographs of this style are becoming an almost regular feature of the COURIER — an indication of the blossoming collaboration with our Chinese colleagues, which has been one of the happiest features of the high energy physics scene in recent years. This time the photograph comes from the visit to China of Herwig Schopper, Director of DESY (front row, 4th from left) to help arrange collaboration between the Peking Institute for High Energy Physics and the DESY Laboratory. The photograph was taken at a reception given by Fang Yi (front row 5th from left), Vice-Chairman of the Academia Sinica.

on bubble chambers, justify the installation of their own liquefier and small magnets, with low liquid helium consumption, can be supplied from mobile dewars without too much inconvenience. But for a system of a scale described here, with a typical liquid helium consumption of 25 litres/hour, neither of these solutions is attractive. A liquefier would be rather uneconomic due to its small size, while the work involved in changing dewars at the necessary frequency would be unacceptable.

The adopted solution is a locally installed 6000 litre liquid helium storage dewar which is permanently connected to the three magnets. It is topped up once a week from the BEBC liquefier via a 60 m long transfer line. This method of operation has worked without problems and the overall losses are 7 to 8 W per magnet, averaged over a weekly cycle, including a transfer.

DESY Collaboration with China

Following an invitation of the Academia Sinica (the Chinese Academy of Sciences), Herwig Schopper, Director of DESY, spent two weeks in November visiting China where he was received with warm hospitality.

The main purpose of the visit was to discuss possible collaboration between the High Energy Physics Institute in Peking and DESY. The political basis for such a collaboration has been provided, on the one hand, by visits of several members of the German government to China and, on the other hand, by the new science policy laid down in a circular by the Central Committee of the Chinese Communist Party on 18 September.

After the modernisation of agriculture, industry and defence, the new policy puts emphasis on the development of science and technology. Within this programme basic research enjoys high priority with emphasis on high energy physics, molecular biology, astrophysics and fusion. However, the rapid development of science in China after several years of stagnation can only be achieved by collaborating with other countries.

This is not only the desire of the Chinese scientists concerned but is also supported in the highest political circles. This was demonstrated by a reception given by Fang Yi in the 'Great Hall of the People' for Professor Schopper in the presence of the German Ambassador, H. Wickert. Fang Yi is a member of the Polit Bureau of the Central Committee of the CPC and Vice-Chairman of the Academia Sinica.

As a first step in collaboration, it is planned that six Chinese physicists will

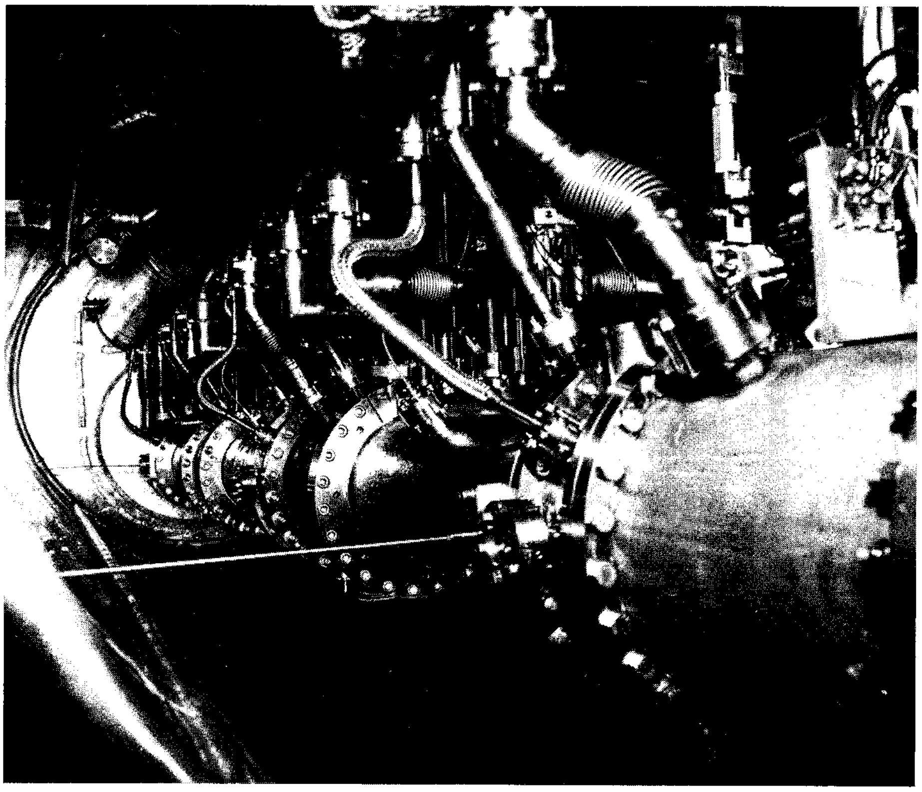
work at DESY at the beginning of 1978, joining the Mark J experiment at PETRA under the leadership of Sam Ting. Following the new policy declaration, this will be the first group of Chinese physicists sent to work in a foreign country since many years.

Professor Schopper spent several days at the High Energy Physics Institute lecturing on recent results obtained at DORIS and on the design, construction and experimental programme of PETRA. The administrative structure of DESY and in particular the decision taking procedures were also reviewed. In long and detailed discussions with leading representatives of the Academia Sinica (Li Chang, Tsien San-Tsiang and others) the plans for the Chinese High Energy Physics programme were covered and problems, like the choice of energy for a large proton accelerator, how to organize a big Laboratory, how to choose a site and how to arrive at a lively experimental programme, were considered.

The main aim of the Chinese high energy physics programme is now defined as the construction of a several hundred GeV proton synchrotron with a booster as an intermediate step. The idea of building a 1 GeV machine to begin seems to have been abandoned. A site near Peking for this accelerator has yet to be found. There exist also plans for an electron storage ring as a synchrotron radiation source to be located in southern China.

Herwig Schopper was also consulted in his role as Chairman of the Association of German National Laboratories (AGF) to describe the research programme of various German centres. Here again there was strong interest in learning from experience in organization and management. The hope was expressed that collaborations with other German Laboratories besides DESY could be established in the future.

Other centres visited were the Institute for Atomic Energy near Peking, which can be considered the cradle of Chinese nuclear physics, the Institute of Nuclear Research and the Fu Tang University (both in Shanghai). The future scientific programmes, the training of students and the relation between Universities and research centres were discussed.



Inside the first tank of the superconducting proton linac at Karlsruhe looking upstream towards the injector. The suspended units are three niobium containers around the superconducting niobium helices with liquid helium tanks of focusing quadrupole doublets in between them. To give an idea of scale, the outside diameter of the helium tanks is 40 cm.

(Photo Karlsruhe)

KARLSRUHE Progress in superconductivity

A high proportion of the research and development work at GfK, Karlsruhe, is now concentrated on superconductivity. It ranges from 'pure' research on the basic properties of superconducting materials through to applications in energy storage, in Tokamak fusion systems and in medicine. En route, it takes in many components for use in particle accelerators and high energy physics experiments.

Of great potential importance for future developments in high energy physics facilities is the work on superconducting radio-frequency cavities. For example, considerable savings in capital investment, space requirements and power consumption in the r.f. systems of large electron-positron storage rings might be possible if reliable superconducting systems are developed.

Karlsruhe have several years of experience in this work and have completed two sizable projects — a superconducting linac and superconducting r.f. separators. Both projects have proved very difficult to implement but a great deal of experience has been gathered in the process and they have helped to define what is practically possible, rather than theoretically possible, given the present state of the art.

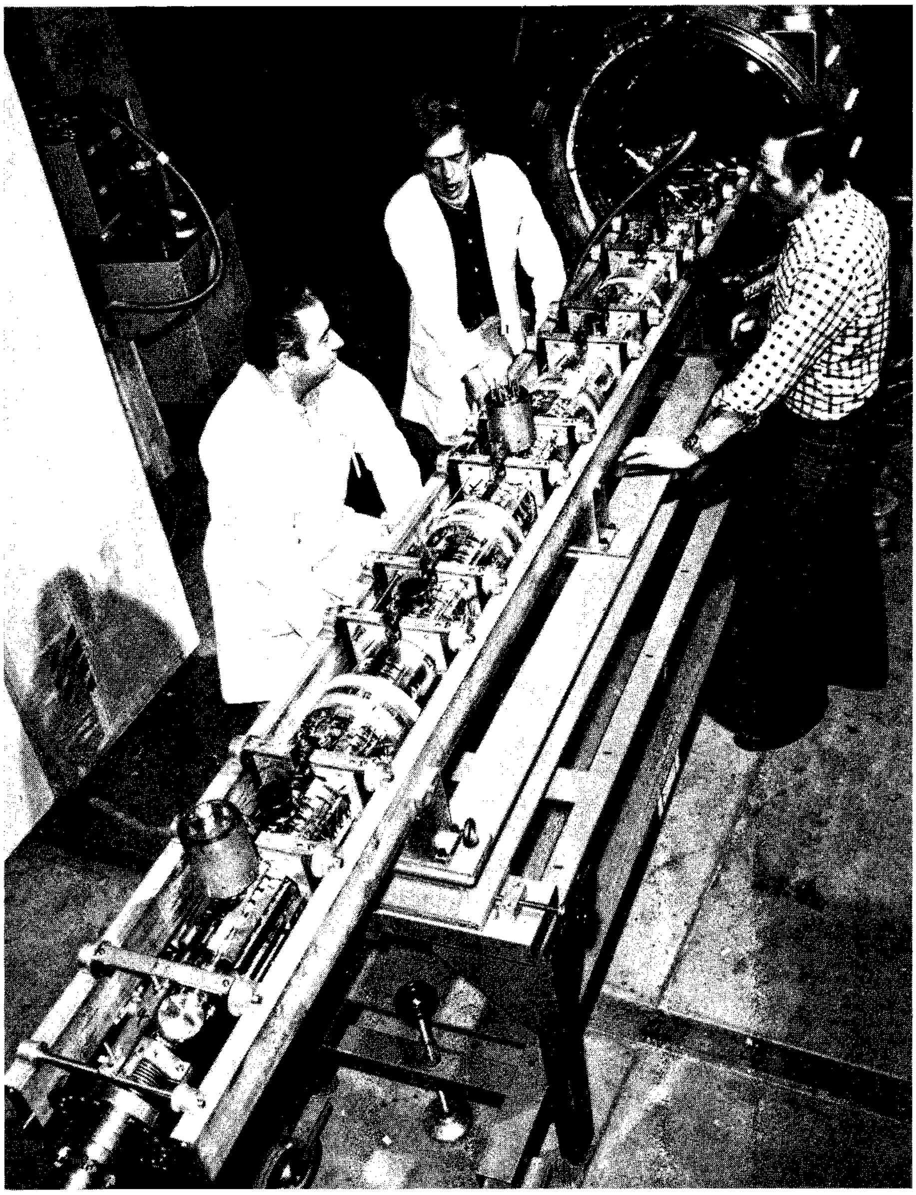
The linac has been built as a

A superconducting r.f. separator structure being assembled at CERN for installation in the SPS beam-line to the Omega spectrometer. The separator was built at Karlsruhe.

(Photo CERN 94.11.77)

prototype for accelerators with potential application in medicine. Karlsruhe has recently been involved, in collaboration with the Cancer Research Centre at Heidelberg, in a project study for the Ministry of Research and Technology concerning the use of ions and negative pions in radiation therapy and diagnosis. The construction of an accelerator was proposed in the project study.

The Karlsruhe prototype linac went for superconductivity in order to reduce size and operating cost. A helical structure was selected to avoid the large cryostats which would be required by a low frequency Alvarez structure. Taming the structure has not been easy, particularly from the point of view of stabilizing frequencies with several helices which have a tendency to vibrate like springs. This problem has been surmounted by adding a fast feedback system and protons have been accelerated to 2.35 MeV with three helices in the first tank.



The present aim is to bring three tanks into operation, the first two of which would have helical structure (five helices in the first and four in the second) and the third an Alvarez structure which would receive the protons at about 6 MeV. It is felt that, if the more difficult problems of the low energy end of the linac are solved, extension to the necessary energy for medical applications will be readily assured.

Small superconducting quadrupole doublets (25 cm long) are being built for installation in the linac. They will operate in the persistent current mode (10^4 hours time constant) so as to reduce the number of leads into the 1.8 K cryogenic system. The quads will be brought on and disconnected, with current circulating, during linac operating periods.

Other work relating to medical applications is the construction of a movable superconducting magnet which will help guide leads through veins, for example during the introduction of a 'pacemaker' into the body The operation time could then be reduced from an hour to minutes which is important when the patient is being exposed to X-rays in order to locate leads correctly.

Returning to r.f. superconductivity — two superconducting r.f. separators built at Karlsruhe have been delivered to CERN for installation in the beam-line to the Omega spectrometer at the SPS. They had achieved deflecting fields of 1.2 MV/m and 1.4 MV/m prior to dispatch from Karlsruhe and we will carry a fuller report on their performance when they are in action at CERN. In addition to the experience gathered in their construction, their operation in the beam-line will be a testbed for aspects of long-term reliability.

The most important superconducting r.f. work now being launched at Karlsruhe is the construction of a cavity to be installed on the DORIS electron-positron storage ring at DESY. It is a joint CERN / DESY / Karlsruhe project. CERN has interest because it is charged by the European high energy physics community to pursue, as top priority, the construction of a very high energy (about 200 GeV in the centre of mass) electron-positron storage ring (the LEP project) for which superconducting r.f. cavities could have significant impact in reducing costs. DESY has interest because superconducting r.f. cavities are likely to prove the only feasible way to go to higher energies (perhaps 30 GeV) in the PETRA electron-positron storage ring. The installation of the 500 MHz cavity in DORIS is scheduled for the end of 1979 and it will test performance in an actual storage ring environment.

Among other projects are the construction of the superconducting coils, together with Saclay, for the CELLO detection system at PETRA and participation in the large coil project (LCP) at Oak Ridge in which six big superconducting coils are being built by different Laboratories to test performance of large scale systems such as would be needed in a Tokamak fusion reactor. Six smaller superconducting toroidal coils (TESPE project) are to be built in advance.

BROOKHAVEN
At low energies

In the April issue, page 115, two experiments were described which required beam from the Alternating Gradient Synchrotron at very low energies — 5 GeV and 800 MeV kinetic energy. The AGS staff learned how to make the accelerator run at these energies and both experiments recently completed successful runs.

A BNL / Princeton group needed the 5 GeV proton beam in order to search for a six-quark bound state with mass near the two lambda threshold of 2230 MeV. A sensitive search required high flux, good duty cycle, and a beam containing no pions. This was achieved by diffractive scattering of the internal beam with 5% efficiency, lengthening of the flat-top to 3 s and careful tuning of the power supplies to eliminate ripple. A proton flux of 5×10^8 protons per second was achieved with a duty cycle up to 80%. The data are being analysed and the experimenters expect sensitivities of the order of a few tens of nanobarns.

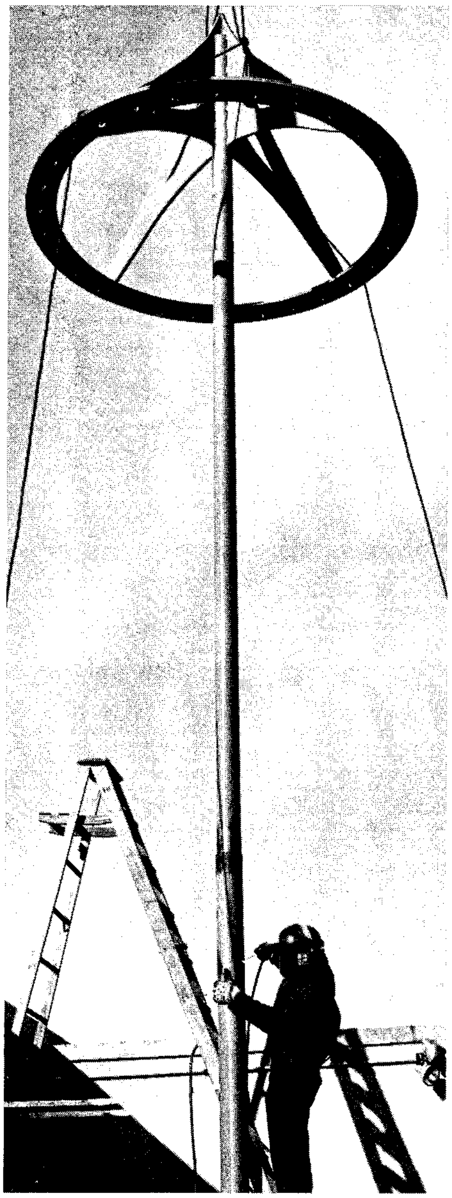
A Harvard / Pennsylvania / BNL group searched for neutrino oscillations by making neutrinos from the decay of pions which were produced with 1.5 GeV/c protons. Duty cycle was not a concern but it was necessary to obtain as high a flux as possible. The problem of transporting a beam with a much larger emittance was solved by vertical shaving, extracting over five turns and adding several quadrupoles to the beam-line. In order to obtain satisfactory regulation of the magnet currents, all power supplies to the existing magnets had to be replaced. A new neutrino horn was designed to optimize the flux still further.

The experiment has recently run for a week with a beam on target of 4.5×10^{12} protons per pulse and a 700 ms period for the AGS cycle. Several new records were set, including that of the total number of protons accelerated in a 24 hour period — 1.05×10^{18}. Data from the run are being analyzed.

FERMILAB
Negative ion injection

A negative ion beam has been accelerated by the Fermilab linac en route to a further increase in the accelerator intensity. The ions emerged from a second Cockcroft-Walton injector with a negative hydrogen ion source which has been installed in an extension to the linac gallery.

A negative ion beam was first injected into the linac on 12 October when 17 mA was accelerated to 200 MeV. Since that time one afternoon per week has been devoted to ion beam studies and, at the time of writing, the maximum current through the linac is 33 mA. During one exercise, a 15 mA beam was accelerated

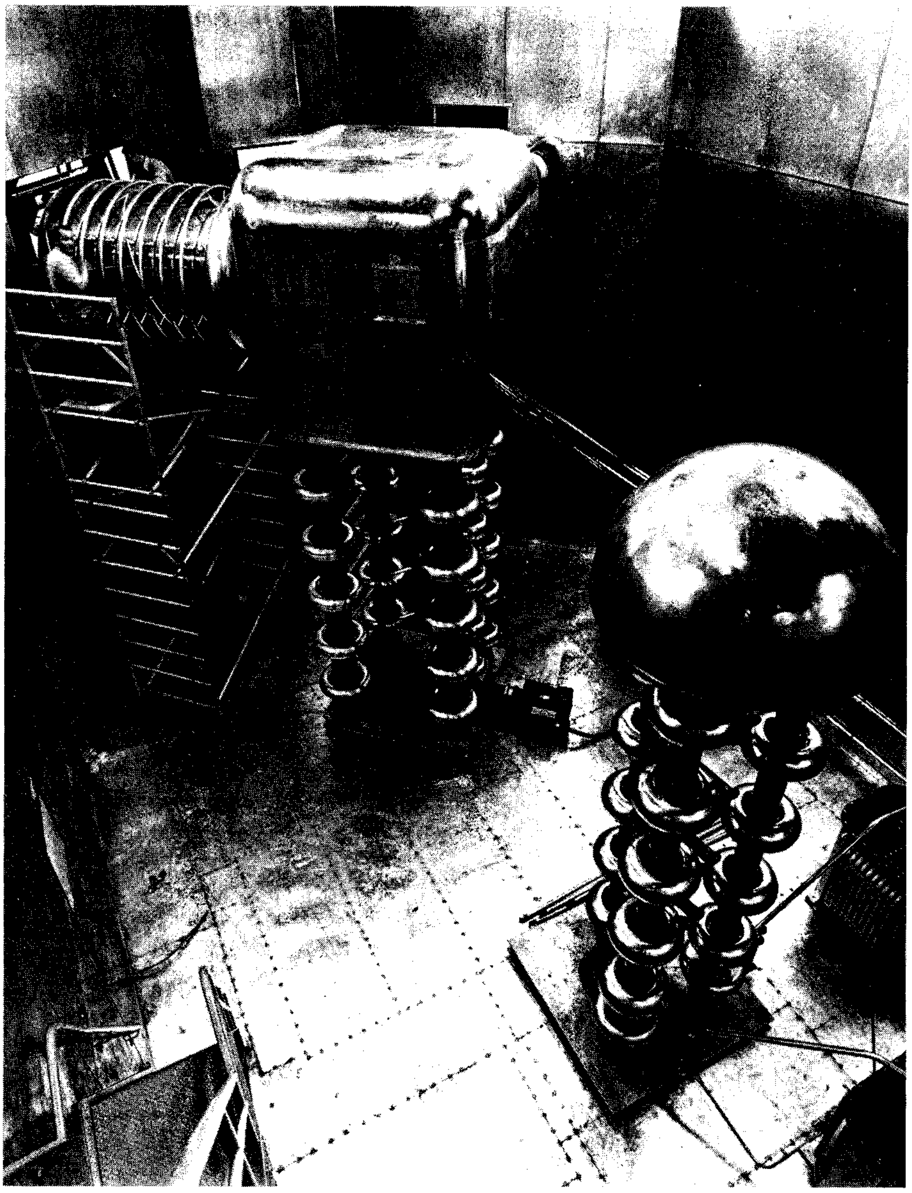


An 'energy fountain' installed at the Fermilab main ring as a power dump for the superconducting magnets of the Energy Doubler. This is the first of six such fountains which will take the magnet power in the event of an emergency. The fountains stand 10 metres high and are painted light orange. They continue the unique Fermilab tradition of bringing a certain aesthetic elegance to the most functional of equipment.

(Photo Fermilab)

The second Cockcroft-Walton injector built at Fermilab to provide negative hydrogen ions for acceleration through the linac so as to be able to increase the current injected into the booster. The linac accelerated its first ions in October.

(Photo Fermilab)



through the linac and delivered to the booster injection point.

Actual multiturn injection into the booster by stripping on a carbon foil is now awaiting completion of a new inflector and orbit-bump system. The stripping process takes two electrons off the negative hydrogen ion liberating protons. Multiturn injection into the booster is then possible without corresponding increase in beam emittance and the stripping thus provides a means of circumventing Liouville's theorem.

The goal is to deliver 25 mA of negative hydrogen ion beam to the booster for 20 turns (56 μs). This requires a 50 mA beam at 750 keV, using a magnetron ion source of the Dimov type, and this has already been achieved. Measurements indicate little change in beam properties during the pulse; the beam emittance in both planes is slightly less than that of the proton beam (when reduced to the same current level). Some distortions in the 750 keV beam emittance from the accelerating column occur at currents above 20 mA and are being studied.

A stripping efficiency of 90 % should give 10^{14} protons for 20 injected turns of 25 mA ion beam and 13 booster batches (required to fill the main ring). A 50% transmission of the booster plus main ring would then yield the accelerator design aim of 5×10^{13} protons per pulse. Because of space charge limits, however, the booster may not reach this level as operated at present.

This work has been led by Cy Curtis, Chuck Schmidt, and Wes Smart.

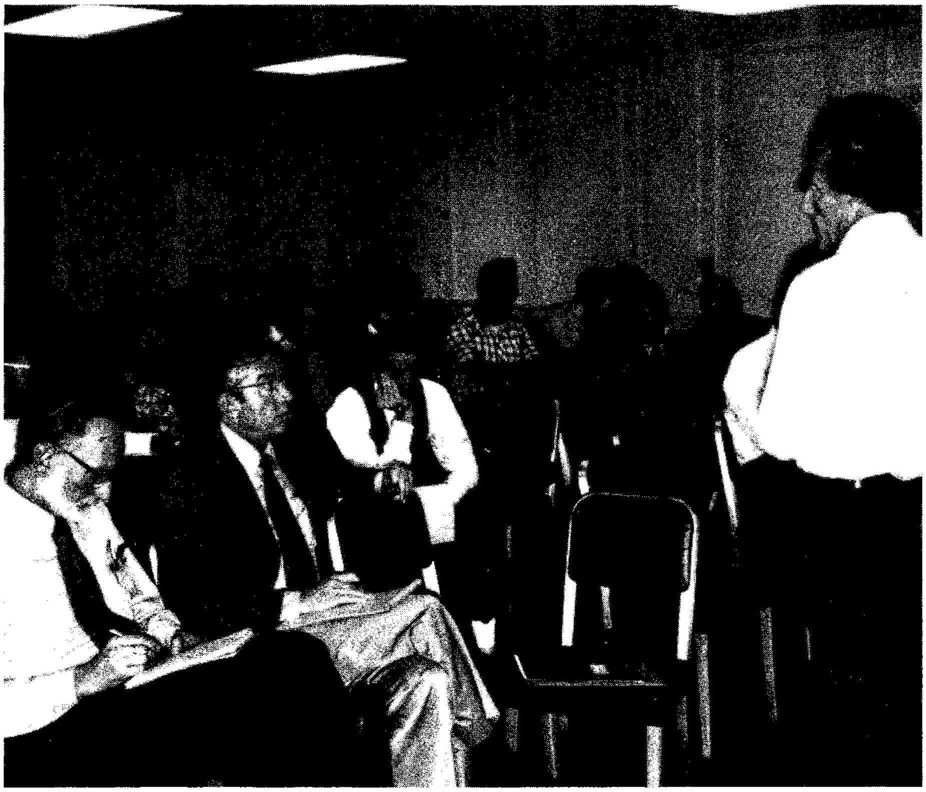
MICHIGAN Polarized Beam Workshop

A successful 'Workshop on Possibilities for Polarized Proton Beams at Higher Energy' was held at the University of Michigan from 18-27 October. Some 38 experimenters, theorists, accelerator physicists and administrators from 23 centres in Europe and North America gathered for ten days to seek a feasible way to study spin-spin forces in strong interactions at very high energy.

They were spurred on by the recent discovery of very large spin-spin forces in high transverse momentum proton-proton scattering by an Argonne / Michigan / Niels Bohr Institute / Oxford collaboration at the Argonne ZGS (see August issue, page 237) and the surprisingly large lambda polarization recently seen in inclusive lambda production at the CERN PS and at Fermilab.

The Workshop was devoted to planning for a type of high energy physics, rather than planning for a specific accelerator project at a specific

Participants at the Polarized Beam Workshop at Michigan listening to F.E. Low discussing the theory of spin at very high energy. In the front row are O. Chamberlain (left) and R. Cool.



Laboratory. Polarized proton and deuteron beam possibilities were studied in considerable detail for the AGS, PS, SPS, Fermilab, ISR and ISABELLE and in some detail for KEK and Serpukhov.

At the start of the Workshop, the organizer, A.D. Krisch (Michigan), proposed that the theorists should work on improving polarized ion sources. Instead, by the end of the Workshop, F.E. Low (MIT) and his theoretical colleagues were designing 200 GeV polarimeters using the Primakoff effect and Coulomb interference, while L. Michel (Bures-sur-Yvette) was vigorously discussing the 'Siberian Snake' scheme for eliminating depolarizing resonances. This surprising scheme, recently proposed by Y.S. Derbenev, I. Kondratenko and A.N. Skrinsky (Novosibirsk), has the protons polarized in the accelerator plane rather than vertically. If it works, it could totally eliminate depolarization, even up to the full energies of Fermilab, the SPS or ISABELLE.

The polarized ion source experts, H.F. Glavish (ANAC), E. Chamberlin (Los Alamos), W. Kubishta (CERN) and E.F. Parker (Argonne), came up with a simple new idea which they believe will increase the polarized source intensity by a factor of about thirty. It uses the ANAC atomic beam type source that already exists at Argonne and CERN, but bombards the polarized neutral hydrogen atoms in the ionizer stage with negative deuteron ions instead of electrons. The cross section for the production of polarized negative hydrogen ions is two orders of magnitude larger than that for the production of polarized protons using the present process.

The source experts expect the polarized ion source intensity to increase from its present 50 to 100 μA to perhaps 1 to 5 mA. This scheme was carefully studied and no one could find any flaw. The 'sourcerers' have rushed back to their laboratories to try it.

A second highlight was that the accelerator experts, led by E.D. Courant (Brookhaven), pointed out that while depolarizing resonances are certainly worse in strong focusing accelerators than in the weak focusing ZGS, they may not be as bad as was once feared. In fact, for polarized deuteron acceleration the resonances are almost trivial, and achieving polarized deuterons looks fairly easy at 30 GeV or indeed at 300 GeV. However O. Chamberlain (Berkeley) made it clear that the experimenters would much prefer polarized protons.

The accelerator experts found that polarized protons might somehow be possible. Courant calculated that, using ZGS-type resonance jumping schemes (pulsed quadrupoles for intrinsic resonances and pulsed orbit bumps for imperfection resonances), a polarized proton beam could probably be accelerated to almost 25 GeV at either the AGS or PS without very serious depolarization. Much of the new optimism comes from the ZGS success in repeatedly jumping 31 depolarization resonances with no significant depolarization up to 12 GeV.

Other studies included polarized proton beams produced by hyperon decay led by G. Fidecaro (CERN), and the use of polarized gas jets. J.B. Roberts (Rice) led a study of polarimeters for protons and deuterons, with the accelerator physicists stressing the need for an 'internal' polarimeter which could measure polarization during acceleration.

Hoping to reduce the confusion caused by different groups using different symbols for the same spin-parameter, the participants led by E. Leader (Westfield College) tried to agree on a uniform notation. This was the most violent part of the Workshop with hard fought battles, such as C_{nn} slowly but surely being beaten down

Construction details of the large drift chambers being built at Rutherford Laboratory.

by A_{nn}. To everyone's surprise, agreement was finally reached (by almost everyone) and the Workshop established the 'Ann Arbor convention' which will appear in the Workshop proceedings.

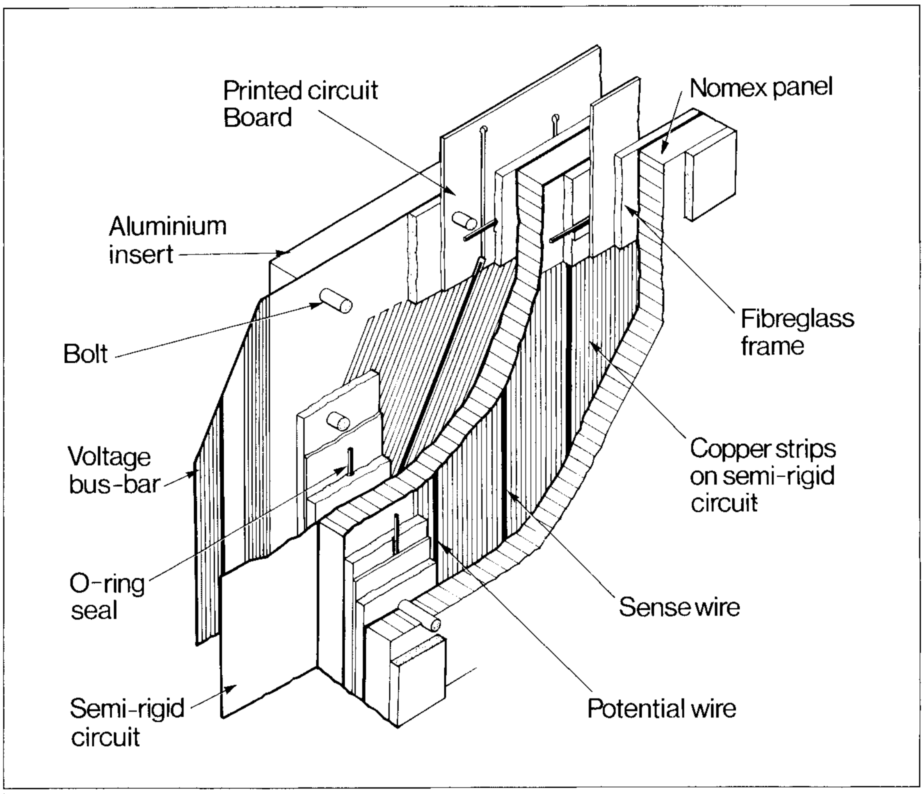
An international organizing committee was established to ensure the continuation of the 'Symposia on High Energy Physics with Polarized Beams and Polarized Targets'. These were held at Argonne in 1974 and 1976 under the sponsorship of the ZGS users group but the increased activity makes a broader sponsorship now seem appropriate. The 3rd Symposium will most likely be held at Argonne in 1978 and the 4th in Europe in 1980.

From the discussions in the Workshop there were two general conclusions:

1. Understanding some features of fundamental interactions needs precise spin experiments with both electron and proton accelerators — electron-proton scattering to give information about the quark wave function and proton-proton scattering to give information about the quark-quark interaction.

2. The spin-spin forces in very high energy large transverse momentum proton-proton interactions may be a key to understanding the quark-quark force. The spin-spin inclusive experiments may be even more important than the spin-spin elastic experiments.

The Workshop was coloured by the optimism of the source experts and accelerator experts. There was a strong feeling that we might be studying, in the 1980's, proton-proton inclusive cross sections in pure spin states in clean colliding beam experiments.



RUTHERFORD
Drift chambers for muon experiment

The first of twelve large drift chambers have arrived at CERN from the Rutherford Laboratory to be installed in the spectrometer of the European Muon Collaboration in the North Area of the SPS.

A 'production-line' approach has been adopted at Rutherford and the chambers are built under stringent quality control to ensure the necessary high standards. A novel design is used, suitable for building large chambers, and two sizes are being made with active areas of 3.5 m × 3.0 m and 4.5 m × 3.5 m.

Each chamber assembly has two, three or five planes with sense (readout) wires aligned horizontally, vertically or at 60° to the vertical. The planes are fabricated using panels of Nomex honeycomb with glass fibre skins. The panels are 25 mm thick, extremely flat, strong and lightweight. Datum alignment holes are drilled into them using a master jig and all subsequent positionings are relative to these holes.

The graded high voltage planes are made from copper strips (3 mm wide and 6 mm pitch) etched from a 0.4 mm flexible sheet of copper-clad glass fibre laminate. Special tools were developed to cut and trim the sheets since these 'circuits' are up to 5 m long and the etchings must be straight to within 0.5 mm.

The circuits are accurately aligned and held flat on a vacuum table for gluing to the panels. A spacer frame (7.5 mm glass fibre epoxy resin) is then glued to the graded voltage planes and the line voltages are brought to the planes using bus-bars and resistive decoupling.

The sense wires (20 µm diameter gold-plated tungsten) and potential

The production line at the Rutherford Laboratory for building the large drift chambers to be installed in the muon spectrometer of the European Muon Collaboration at the CERN SPS. In the foreground can be seen the stacking of the honeycomb panels. The subsequent production stages follow in the background.

(Photo Rutherford)

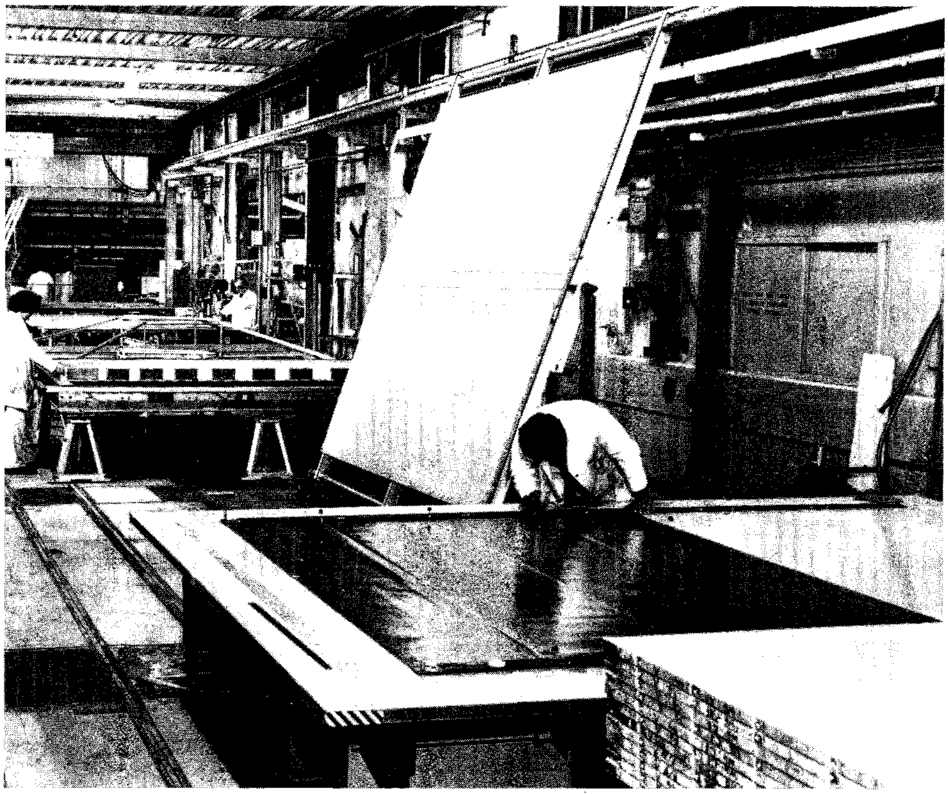
Physics monitor

wires (100 µm diameter beryllium-copper) are accurately tensioned (50 ± 5 g and 375 ± 25 g, respectively) and soldered to printed circuit boards. Using specially designed handling frames, the panels are assembled and held in a steel frame. They are finally fitted with gas connections and tested for leaks under high voltage conditions. A gas mixture of 75% argon and 25% isobutane is presently used and about ten inlet / outlet ports are fitted to each gap to guarantee adequate gas purity throughout the large volume.

There is a 60 mm drift space between a sense wire and potential wire. The output from the sense wire goes into readout electronics, developed in the CERN EP Division, which has a high capability for analysing multi-hits. The resolution time is ± 4 ns corresponding to ± 0.2 mm position accuracy.

A prototype chamber, designed and built at Daresbury, gives overall position accuracy of ± 0.3 mm for straight single tracks. For the SPS muon physics programme, an accuracy of ± 0.5 mm will be sufficient.

The success of this chamber construction is due to close collaboration between the physicists, several groups at Rutherford and industry. Delivery of the drift chambers will be completed early in 1978.



Gravitinos and photinos

Supersymmetry, according to Murray Gell-Mann, is 'amusing'. Although it has, as yet, no experimental support, it could help in the construction of a unified theory incorporating particle interactions and gravity.

The basic idea of supersymmetry is to extend the space-time symmetry of the Universe beyond that required by relativity. This is done by introducing new space-time transformations which behave like the square root of ordinary translations. The technique is the same as that in the Dirac equation where 'spinors' describing spin one-half particles are brought in as the 'square root' of the Klein-Gordon equation which describes ordinary relativistic behaviour. Supersymmetry also has its conserved quantities behaving as spinors.

The concept was first developed in the USSR but the work went almost unnoticed until it was reformulated by theorists at CERN. Subsequent work has extended the application of the ideas to include gravity and has attempted to forge that elusive link between particle physics and general relativity.

One immediate result of supersymmetry is that particles of different spin and statistics can occur in the same particle multiplet, which has interesting consequences. Spontaneous symmetry breaking in a supersymmetry picture brings in Goldstone fermions as well as bosons. The familiar photon and graviton (the massless boson communicators of electromagnetism and gravity) then acquire as fermion companions the photino (spin 1/2) and the gravitino spin (spin 3/2). It is very tempting to identify the photino with one of the known neutrinos but this encounters some difficulties.

The requirement for zero mass Goldstone particles, which emerges from the theory, can be eliminated by introducing a 'Super Higgs' mechanism (see September issue, page 272) which at the same time gives the gravitino some mass and leads to a mixing of gravitational and weak interactions.

One persistent problem with supersymmetric theories is that they can frequently indicate that the proton is unstable and further special mechanisms then have to be brought in to stop the proton from rotting away.

Is parity violated by neutral currents?

Parity violation in weak interactions was first observed some twenty years ago. The violations of right-left symmetry were associated with the charged current type of weak interaction in which the electrical charges are exchanged between the incoming and outgoing particles.

In 1973, experiments using the Gargamelle bubble chamber at CERN discovered that there is another type of weak interaction, the neutral current type, which does not involve the exchange of electrical charges of the participating particles. Conjecture mounted as to whether this current, like its charged counterpart, also violates the parity symmetry. This question has still not been resolved and, in his summing up of the Ben Lee Memorial Conference at Fermilab in October (see November issue, page 363), Steve Weinberg devoted a lot of time to describing the progress which has been made on this topic.

He emphasised that although we see different behaviour in neutrino-nucleon and antineutrino-nucleon interactions, this does not necessarily mean that parity is violated in neutral current interactions. What the results do show is that, if there is only one neutral intermediate vector boson mediating the neutral current interactions, then it cannot be of pure vector or pure axial vector type.

If only one intermediate vector boson exists then these results demonstrate parity violation in neutral current interactions. However, there is nothing (other than simplicity) which limits theory to only one such particle at the moment. If the theory describing the interactions is expanded, more such particles can be introduced and the experimental results could then be compatible with parity conservation.

But why consider expanding the gauge group in the theory beyond the standard Weinberg-Salam model, when neutral current interactions of neutrinos are already very well described by the model?

Some theorists have shown that a large class of bigger gauge groups can be formulated which mimic the standard Weinberg-Salam model. Their predictions for neutrino interactions stay the same but calculations for electron neutral current and nuclear neutral current interactions give new results.

It was the atomic physics experiments with bismuth which provoked interest in these questions. Results from Oxford and Washington showed an upper limit for parity violation in electron-nucleon interactions well below what would be expected from the Weinberg-Salam model (see May issue, page 155). However, these results hinge on some detailed atomic physics calculations, which are apparently not yet complete as additional contributions due to shielding, etc., are still being estimated. For this reason, most people seem to be reserving judgement on these electron neutral current effects until experiments have been carried out on atoms with more 'benign' structure where the calculations are simpler.

Experiments on hydrogen, the most benign atom of all, are lined up at Michigan, Washington and Yale but, due to some perversity, little or no effect might be seen if the Weinberg-Salam angle is near a particular value. This value corresponds to $\sin^2\Theta = 0.25$, which (in due accordance with Murphy's law) is compatible with the latest measurements. Parity violation in these neutral currents might therefore be difficult to pin down. Observations on deuterium would help and such experiments are also in the pipeline.

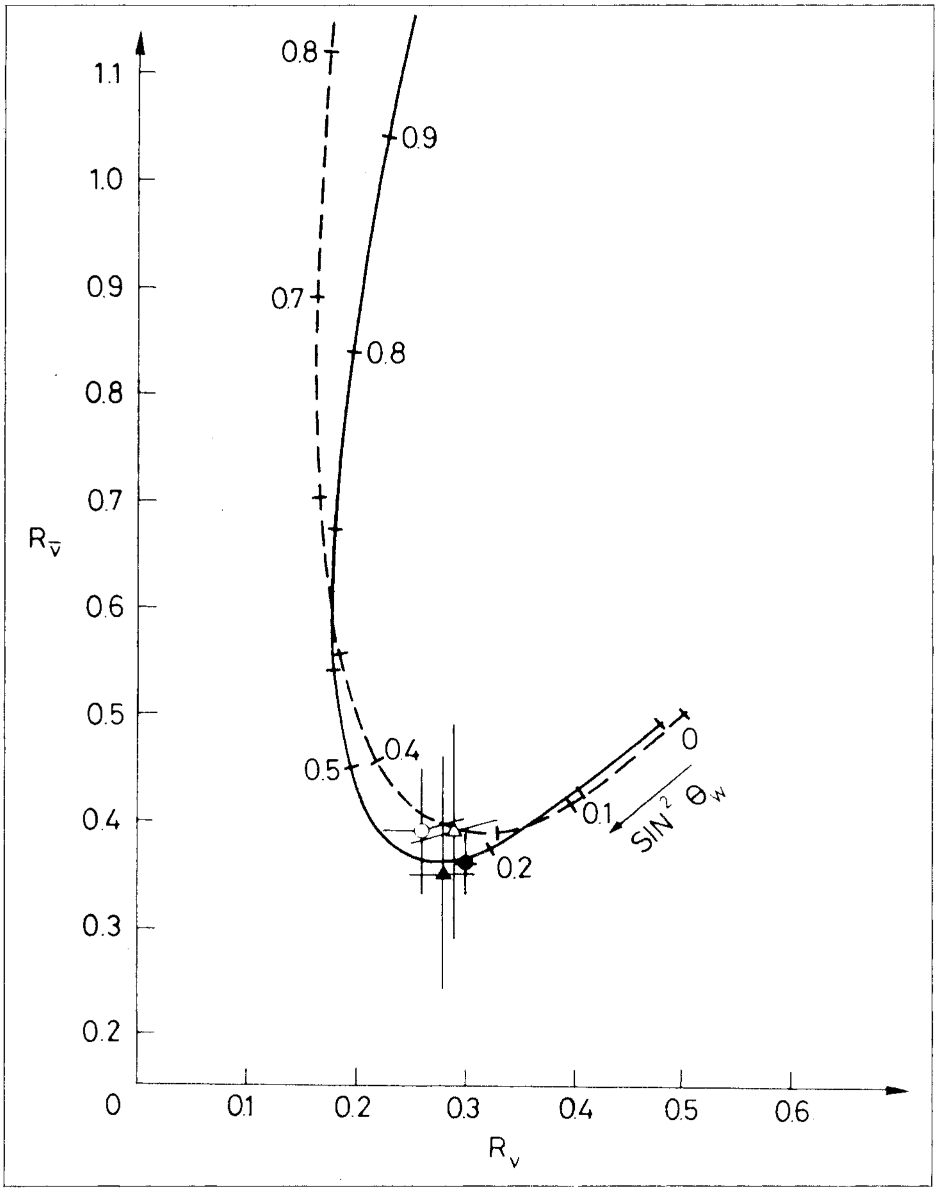
Another experiment, devoid of atomic physics complications, is the investigation of deep inelastic electron-nucleus scattering at SLAC, where parity violating electron neutral current effects would show up as asymmetries. The accuracy available with this experiment could soon reach a level at which these effects could be expected to be seen.

For neutral currents in nuclear interactions, experiments on oxygen 16 have detected effects on a level expected from charged current interactions alone. However, these are isospin-conserving reactions in which the neutral current would not be expected to have much to say anyway and any parity violating contribution would be correspondingly more difficult to observe. Preliminary results from experiments on other nuclei are not inconsistent with neutral current parity violation but further results and data from a wider range of nuclei should soon be available to help clarify this point.

One crucial question, mentioned by Weinberg, is whether the basic form of the global (charged plus neutral) weak interaction is itself parity violating, or whether the parity violating effects seen in weak interactions come about as a result of a spontaneous symmetry breaking mechanism. The status of parity conservation in neutral current interactions could be an important indicator to help reserve this issue.

However, if the neutrino mass is truly zero and not just a small value which is difficult to measure, then there is

The points show the measured ratio of neutral current to charged current cross sections for neutrinos (x-axis) and for antineutrinos (y-axis) from different neutrino experiments at CERN and Fermilab. All the results home in on roughly the same range of values for the 'Weinberg-Salam' angle, Θw. This angle, which comes in as sin² Θw, is the free parameter in the theory which dramatically unified weak and electromagnetic interactions and predicted the existence of the neutral current. The dotted line is the prediction of the theory assuming no antiquarks in the target nucleons, while the solid line takes account of the small antiquark effects due to the 'sea' of virtual quark-antiquark pairs which accompanies the nucleon.



strong reason for suspecting that parity is not conserved in the basic form of the global interaction. Another phenomenon which could shed light on this problem is the possibility of muon decay into an electron, the separate conservation of muons thus being only approximate. Weinberg has said that he would be 'amazed' if conservation of muon number were not violated at some low level — so experiments continue.

Quark confinement: 2. Bags

Experiments show that quark-like objects exist deep inside nuclear matter but they are reluctant to come out into the open. This problem of the 'permanent confinement' of quarks is proving difficult to describe quantitatively using field theory techniques (see November issue, page 380, which introduced concepts used more freely here).

The problem in field theory is to develop mathematical methods for extracting information while avoiding some diseases which afflict conventional perturbation theory. There are new field theory methods which show embryonic signs of having useful characteristics but, since the right mathematical tools have not yet been perfected, other physicists are taking a different approach.

Any successful theory of hadrons should incorporate three ingredients — quarks, colour and the existence of hadrons as extended objects in space-time. Quantum chromodynamics (see the previous article on quark confinement) has the first two ingredients and has the advantage of using quantum field theory which for many years has been the lifeblood of theoretical particle physics. However it comes unstuck when trying to explain quantitatively the existence of extended hadrons containing quarks.

The bag model

Instead of starting out with quarks interacting through the exchange of gluons and somehow trying to arrive at a picture of hadrons with quarks confined inside them, some physicists assume confinement as a basic feature of the theory, so that the colour interaction exists only inside a definite volume or 'bag'.

The first formulation of this bag model was at MIT and described the affinity of quarks inside hadrons in terms of an empirical 'pressure' term which kept the bag intact. The space inside a hadron in which the colour interactions take place is somehow different from the space outside, so that hadrons can be viewed as 'bubbles' in the rest of the geometry of space-time.

This bubble analogy has been extended by introducing 'surface tension' effects to further describe the properties of the hadronic bags. The existence of the bags is then due to the hadronic forces inside them. Other physicists take the view that hadron structure is a direct result of some granular geometry of space-time, and that the quarks come in as the hadronic co-ordinates which describe what goes on inside these small domains.

While a bag model may sidestep the difficulties of 'explaining' quark confinement and extended hadrons, it is not without its problems. For example, we cannot ignore possible additional bag states. What is the significance of an 'empty bag' — some kind of bubble in space-time containing no quarks? What is the significance of 'glueballs' — bags containing gluons but no quarks?

Apart from these peculiarities, the simplest kind of bags are those in which quarks and gluons just sit there with no angular momentum, looking very much like bags of free quarks. The success of asymptotically free field theory (i.e. free quarks) in explaining the observed behaviour in electron-nucleon and neutrino-nucleon scattering can be seen as a demonstration of the approximate validity of this simplest bag picture.

In the bag model, the effective masses of the 'up' and 'down' quarks are so small that they can be considered as massless inside their bags, while the strange quark is attributed a mass of 0.5 GeV. The effective masses of the hadrons are then composed of the constituent quark masses and kinetic energies, together with the energy of the bag.

The observed spectrum of mesons and baryons can be 'explained' by introducing spin-spin effects in the gluon exchange between quarks, similar in principle to the hyperfine structure effects seen in atomic physics. In this way the observed particle masses can be fitted using a minimal number of parameters, and the properties of new states can be predicted. However, the approach has conceptual problems due to the neglect of other effects like 'radiactive corrections' due to virtual gluons, which cannot be ignored without more justification.

Bigger bags

So long as the correct colour configurations are maintained, these bag ideas can be readily extended to meson states containing more than the normal quark-antiquark pair and to baryon states exceeding the standard quota of three quarks. For example, a bag can be proposed containing two quarks and two antiquarks to explain the 'baryonium' effects recently seen in a number of experiments (see June issue, page 197 and July/August issue, page 243).

Additional quarks in baryon bags could give rise to dibaryon states (see October issue, page 335). How these states are related to non-relativistic bound states like the deuteron is an interesting question and this point of contact between particle theory and established nuclear physics principles could well provide an additional lever to help uncover the secrets of quark confinement.

The bag model is an attempt to provide a framework for describing hadronic phenomena, including the ideas of quarks, exact colour symmetry and quark confinement, in a way which circumvents some of the current deficiencies in field theory techniques.

Its successes in describing the observed spectroscopy of hadrons are impressive but the model is totally deficient when it comes to any dynamic behaviour like resonance formation or particle production, where quark bags split apart or fuse together. The description of the bags themselves remains totally phenomenological, so that many things go unexplained, including quark confinement.

However, until some exact formulation of quark confinement turns up and enables more complete calculations to be made, the bag idea provides one way of handling the quark structure of hadrons.

(We would like to acknowledge the help given by Giuliano Preparata in putting together these two articles on quark confinement.)

People and things

On people

One of the leading practitioners of particle accelerator theory, J.D. Lawson from the Rutherford Laboratory, has written a book entitled 'The Physics of Charged Particle Beams'. Rather than concentrating on particular applications, John Lawson takes a broad view of his subject and emerges with a book which should be of interest to plasma physicists as well as his accelerator colleagues.

Changes in the leadership at the Stanford Synchrotron Radiation Laboratory — On 1 January Sebastian Doniach, who has led the Laboratory since its early days, hands over to Arthur Bienenstock as Director. Professor Doniach will then spend three months at Orsay before returning to SSRL as Consulting Director. Herman Winick, the Deputy Director, will serve as Acting Director until April when Professor Bienenstock completes a sabbatical leave. Ronald Gould has been appointed Associate Director for Administration.

Professor W.D. Allen has retired from the Rutherford Laboratory. Since 1966 he has held a joint appointment at Rutherford and at Reading University. During his career he made a speciality of building Van der Graaffs, leading several projects culminating in the 10 MV Oxford Electrostatic Generator.

Lee Teng, associate Head for advanced projects in the Accelerator Division at Fermilab has visited China, extending the contacts with the growing Chinese high energy physics community.

Maurice Jacob of the CERN Theory Division has been elected 'Correspondant de l'Académie des Sciences de l'Institut de France' for the physics section.

This tableau greeted John and Rene Adams and Michael Crowley-Milling during their September visit to Peking. It reads 'Warm welcome to Uncles and Aunties from the European Organization for Nuclear Research who have come to visit our kindergarten.'

Atom Smasher Exhibition

On 1 December an exhibition tracing the historical development of high energy particle accelerators and particle detectors was officially opened at the National Museum of History and Technology of the Smithsonian Institution in Washington. It has been prepared by the Smithsonian in collaboration with the DOE (ERDA as it then was), under Paul Forman, the Curator of Modern Physics. We hope to carry more information and some pictures from the exhibition in a coming issue.

New INFN President

Antonio Zichichi has been elected President of the Italian Istituto Nazionale di Fisica Nucleare (INFN). Zichichi is Professor of Advanced Physics at the University of Bologna (Italy) and has been for ten years Director of the Bologna INFN Section and Director of the Bologna Postdoctoral School of Physics. He is well known as founder and Director of the 'Ettore Majorana' Centre for Scientific Culture established in 1962 and now consisting of 70 National and International Schools. Since 1976 Antonio Zichichi has been a member of the Executive Committee of the European Physical Society, of which he is one of the founding members.

Zichichi's scientific work has covered the study of lepton pairs produced in hadronic interactions and the search for heavy leptons produced in electron-positron annihilations, where he made pioneering contributions. He has been active in many fields: high precision tests of quantum electrodynamics, the systematic study of the electromagnetic form factors of the proton and pseudoscalar mesons, the first measurement of the omega-phi mixing angle, the discovery of the antideuteron and of the two gamma

1. A. Zichichi
2. G. von Dardel
3. M. Vivargent


1.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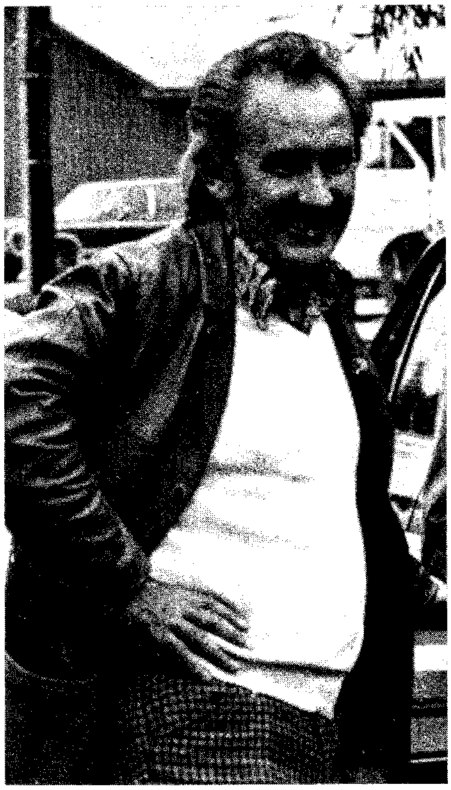
3.

decays of the X^0 meson, the high precision measurement of the weak coupling constant. His present activity is in a systematic study of the inner structure of the proton.

New ECFA Chairman

At a Plenary Meeting of ECFA (European Committee for Future Accelerators), Marcel Vivargent from LAPP Annecy, France, was elected Chairman to succeed Guy von Dardel from the University of Lund, Sweden, who has held this position during the past three years. At the Meeting Leon Van Hove, Research Director General of CERN, expressed the 'appreciation and gratitude' of the European high energy physics community to Guy von Dardel for his guidance of ECFA affairs. Among the many ECFA activities during his term of office, was the formulation of two important recommendations — one encouraged the rapid construction of an electron-positron storage ring with centre of mass energy above 20 GeV (which was realized in PETRA at the DESY Laboratory) and the international exploitation of such a machine, the other urged the construction of an electron-positron storage ring with centre of mass energy in the 100 to 300 GeV range (which now has top priority as Europe's main accelerator project for the future).

Upsilon at ISR

Further evidence for Upsilon resonances has been reported from an experiment at CERN. A Brookhaven / CERN / Syracuse / Yale collaboration have measured the production of electron pairs at intersection I-8 of the Intersecting Storage Rings and find an excess of events in the region from 8.7 to 10.3 GeV, ascribed to the new Upsilon particles first reported from Fermilab in July. Though only a few Upsilon-type events have been seen in the ISR experiment, the production rate at the higher ISR energy seems to be considerably greater than at Fermilab. This increase in production with energy is much greater than that of the well-known J/psi particle and suggests that more surprises may be in store.

Booster boosted

The peak energy of the Fermilab booster was nudged from 8 GeV to 10 GeV in November. With this it is hoped to be able to feed a better quality beam to the main ring and the higher energy would be useful in antiproton production for proton-antiproton colliding beam schemes. The energy increase followed r.f. improvements (voltage raised 25 %)

and magnet power circuit reorganization to increase the magnet currents (also by 25 %).

CERN enters ICE age

Protons from the CERN PS were injected into ICE (Initial Cooling Experiment) on 5 December. ICE is designed to study techniques for cooling particle beams and the experience gained in this study will be especially useful for possible future CERN proton-antiproton colliding beam projects. ICE will concentrate initially on the stochastic cooling method (invented at CERN and already demonstrated at the ISR) to reduce the cooling time down to a minimum. Subsequent investigations will look at electron cooling. ICE uses equipment from the famous g-2 experiment reassembled in the hall left vacant when the Gargamelle bubble chamber moved to the SPS.

Royal Medal

John Adams, Executive Director General of CERN, was among three recipients of Royal Medals for 1977. The awards were recommended to the Queen by the Council of the Royal Society of the UK and the medals were presented by the President of the Society, Lord Todd, on 30 November. Dr. Adams received his award for 'contributions to the design and operation of high energy particle accelerators.'

To close the 1977 Volume of CERN COURIER, we should like to record our thanks to all those who so readily provided us with the information from which we pulled together our articles. This thanks goes especially to the correspondents from the Laboratories listed inside our front cover who have been a major source of input. Our next issue covers the months of January and February 1978 and will appear towards the end of February.

La Chesnay Associés Communications 488

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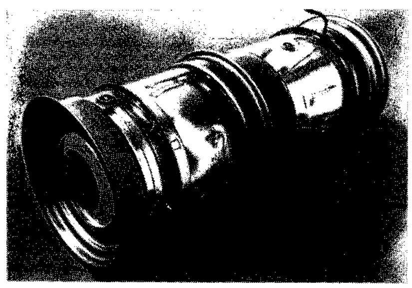
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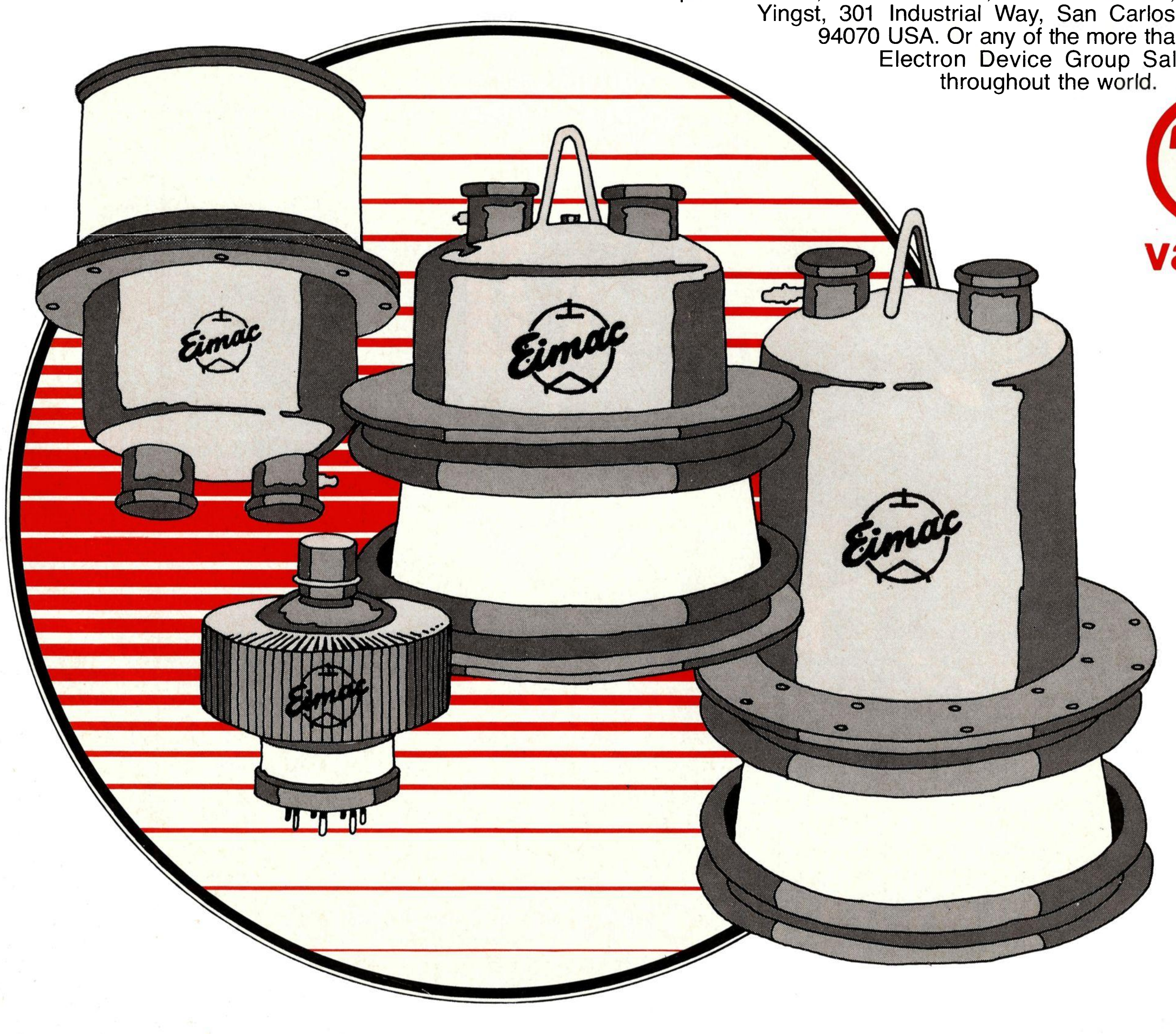

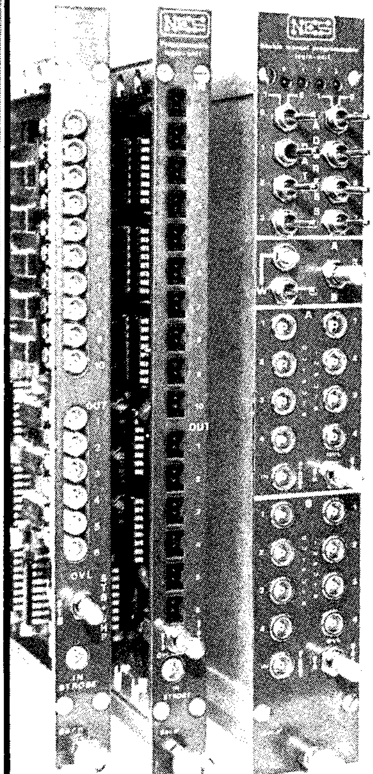

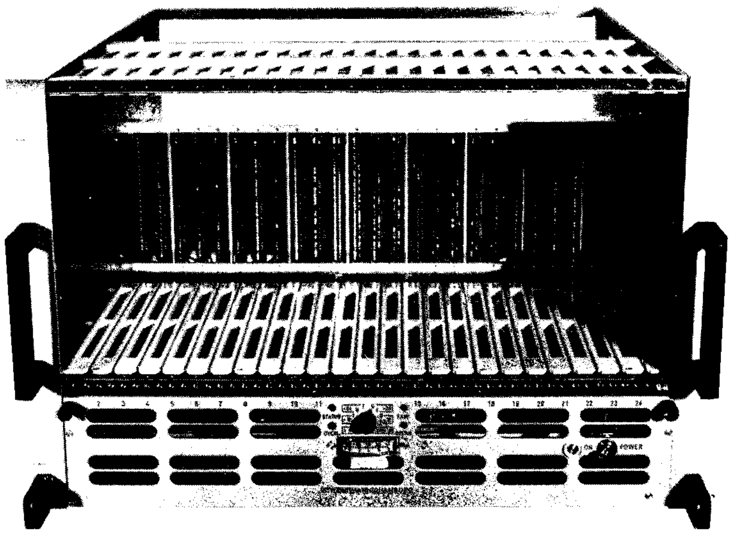

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This month, we introduce:

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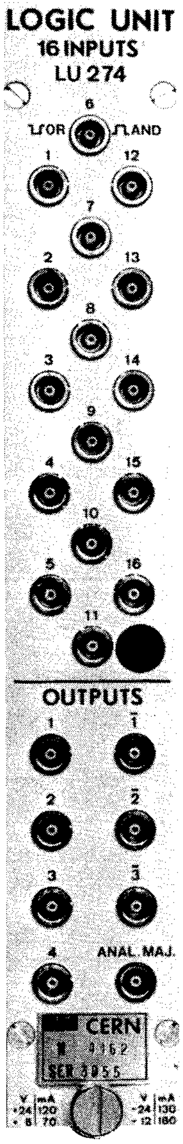
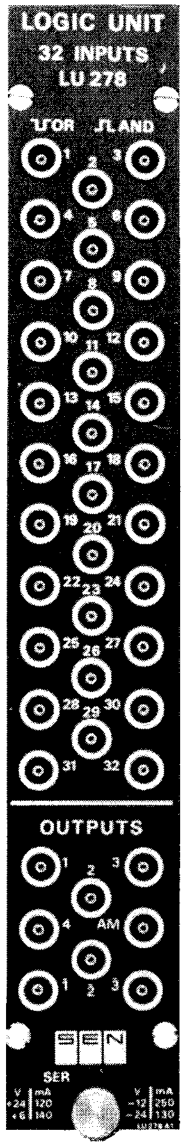
16 input logic unit



LU 278
32 input logic unit



— 16 — or 32 — OR/AND Logic unit
— more than 1, 2, 3, 4 logic majority outputs
— analog majority output

inputs	:	32 (LU 278) or 16 (LU 274) 50 Ω decoupled NIM level
width	:	minimum 5 ns for 4 majority output, minimum 3.5 ns for 1 majority output
logic outputs	:	4 outputs allowing to discriminate if more than 1, 2, 3 or 4 simultaneous inputs 3 complementary outputs
level	:	16 mA current sources
width	:	input width or overlap minus 2, 3 or 4 ns for outputs 1, 2 and 3
I/O delay	:	⩽ 11ns
analog output	:	1 output allowing to discriminate if 1, 2, 3, 4, 5 or 6 inputs
level	:	current source 2,66 mA/input
width	:	input width or overlap minus 2.5 ns
I/O delay	:	⩽ 6.5 ns

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• Carmig (Ar/CO_2 - $Ar/CO_2/O_2$)
• Carmox (Ar/O_2)
• Carbac (Ar/H_2 - Ar/He)
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