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Advertisements: Micheline Falciola

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Tel. (312) 840 3000, Telex 910 230 3233

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Cover photograph: The scene in the huge experimental hall EHN1 when the CERN 400 GeV proton synchrotron was inaugurated on 7 May. About 2000 people attended this ceremony to mark the start up of Europe's new facility for particle physics. (Photo CERN 4.5.77)

Inauguration of the SPS

On 7 May about 2000 people gathered at CERN for the formal inauguration of the 400 GeV proton synchrotron, the SPS. They included high ranking officials of the twelve CERN Member States, the CERN Council, local government officials, representatives of Laboratories and Universities closely connected with CERN, representatives of European industries which participated in the machine construction, the press, and CERN staff.

After a morning which included a Press Conference and tours of the accelerator followed by a dinner offered by the Swiss and French authorities, the ceremony of inauguration was held under the Presidency of M. Paul Levaux (President of the CERN Council) in the huge experimental hall of the SPS North Area, EHN1.

The opening talk was by Professor Edoardo Amaldi from the University of Rome — one of CERN's founder members, a leading proponent of the building of the SPS during the 1960s, President of Council when the project was authorized in 1971. He spoke about the years leading up to the decision to build the machine.

He was followed by Professor Wolfgang Paul from the University of Bonn — President of the CERN Scientific Policy Committee. Professor Paul spoke about the years of construction of the accelerator and of its experimental facilities.

The final speaker was Professor Christopher Llewellyn Smith from the University of Oxford who spoke as a representative of the younger generation of physicists who will exploit the new accelerator. He spoke about the physics which can be confronted with the SPS and (since the topics of the previous speakers have already been covered in detail in the COURIER) we will concentrate on an abridged version of his talk.

'The aim of particle physics is to investigate the constituents of matter and the forces which control their behaviour at the most fundamental level. The subject is a very old one which can be traced back to Democritus whose idea that matter is composed of tiny indivisible atoms is near 2500 years old. However, the atomic theory was not generally accepted until the late nineteenth century.

Soon after, in 1911, the experiments of Rutherford showed that atoms are not indivisible but consist of electrons orbiting a very small nucleus. During the 1930s it was found that the nuclei of atoms are themselves composed of even smaller particles called protons and neutrons, which are about one tenth of a millionth of a millionth of a centimetre in size.

Attention then switched to the structure of the neutrons and protons about which we now know a great deal. Experiments at the old CERN accelerator have made major contributions to this knowledge and, because it accelerates particles to much higher energy, the SPS will allow us to study the constituents of matter at an even deeper level.

One of the most surprising discoveries is that not only are many particles produced in high energy collisions but the variety of particles which can be created in this way is enormous. More than a hundred different particles are known today and more will undoubtedly be discovered at the SPS.

At first this proliferation of particles was very bewildering but some simplicity was restored by the realization that they can be grouped into families whose members have properties in common. Knowing the behaviour of one particle, we can predict the behaviour of its relatives. This classification into different species brought order into the subnuclear world and is similar to the classification of the chemical elements into the few families of the periodic table which brought order into

chemistry during the nineteenth century.

The family structure strongly suggests the existence of a small number of more fundamental constituents which can be grouped together in many different ways to make the known nuclear particles. These more basic constituents are known as quarks — a meaningless word made up by the Irish writer, James Joyce. The hundreds of different nuclear particles which are known today can all be interpreted as different composite structures of just four different sorts of quarks. Nowadays we are concerned with the quark structure of the proton and neutron and their relatives and the properties of the quarks themselves.

One of the most interesting experiments at the SPS, which will tell us about the properties of quarks, is similar to the experiments of Rutherford which led to the discovery of the atomic nucleus. He bombarded a thin metal foil with alpha particles; generally, they passed straight through the foil or were deflected by small amounts but very occasionally they bounced backwards. Rutherford realized that this occurred because they had encountered a very small nucleus in the atom.

Ten years ago the surprising discovery was made that when a beam of very high energy electrons is directed at a proton or neutron, some of them also bounce backwards as if they had struck some small, hard, indivisible object — presumably a quark. This was confirmed by experiments at the CERN PS using particles called neutrinos and the new SPS will make it possible to carry out similar experiments at very much higher energies using neutrinos and also 'heavy electrons' called muons.

Large detectors are under construction which will tell us how the muons are scattered when they strike a target. Will they sometimes bounce backwards when they encounter quarks as the electrons of lower energy did or will they behave differently, revealing structure inside the quarks? Perhaps their behaviour will not change and the quarks will turn out to be elementary objects without deeper structure.

If quarks are structureless, they might even turn out to be related to non-nuclear particles such as electrons, muons and neutrinos, which seem to be structureless, although they differ from quarks in almost every other respect. The properties of quarks are mysterious and are not fully understood. Many experimental attempts to isolate an individual quark have failed and some people believe that it may be completely impossible to free quarks from their nuclear prison. It would be exciting if this conjecture were proved because it might then make sense to think that we had at last reached the end of the road in the search for smaller and smaller constituents and that quarks are the ultimate layer of nuclear matter.

I have said something about our knowledge of the constituents of matter but what do we know about the forces which control their behaviour? Four forces are known today. Gravity is the most familiar but it is negligible on the scale of particle physics. It is electromagnetism which holds electrons in their atomic orbits and is therefore responsible for all of chemistry and much of physics.

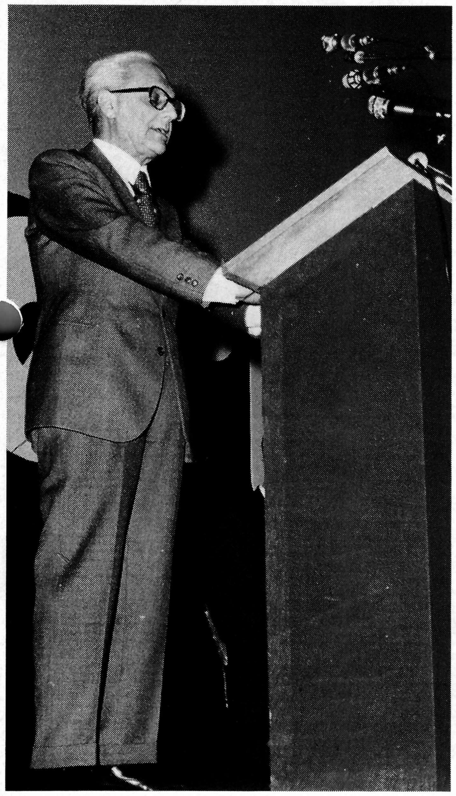
In addition, there is a strong force which acts very powerfully, but only over short distances, and holds together the atomic nucleus and the quarks in protons and neutrons. Finally, there is the so-called weak force. It does not seem to be powerful enough to bind particles together, but is responsible for the break-up of some particles which would otherwise be stable. The weak force is also responsible for other forms of transmutation which, although relatively rare, are vital for our very existence since they control part of the cycle by which the sun produces energy.

Perhaps the greatest triumph in particle physics during the past decade has been the discovery that, out of these four forces, two — the electromagnetic and the weak force — are almost certainly different manifestations of a single underlying interaction. What this means is that knowing electromagnetic phenomena we can, in principle, predict some weak phenomena and vice versa. It is similar to the nineteenth century discovery that electric and magnetic forces are different aspects of a single force. That discovery was particularly pleasing because electric and magnetic phenomena don't seem very similar.

The discovery that the weak force is another aspect of electromagnetism is perhaps even more surprising and gratifying since the phenomena it produces are totally different. For example, as anyone who has used a compass is aware, electromagnetism can act over large distances. The weak force, on the other hand, is negligible beyond nuclear distances. The theoretical discovery that a single force can give rise to phenomena which differ so radically is extremely important. It raises the hope that there may be just one fundamental force which is responsible for gravity, as well as for the strong, weak and electromagnetic interactions.

The first experimental evidence that the weak and electromagnetic forces may be connected was the observation at CERN in 1973 of so-called 'neutral current' interactions, which fit easily into the framework of models which unify these forces. Further and much stronger evidence for unification was provided by the discovery of particles with an attribute called 'charm' last year, since unified models require and had unambiguously predicted their existence. The discovery that weak and electromagnetic forces are probably

The three speakers at the Inauguration ceremony:
1. Edoardo Amaldi who spoke of the years prior to the authorization of the project. (Photo CERN 226.5.77)
2. Wolfgang Paul who spoke of the years of construction of the machine and its experimental equipment. (Photo CERN) 225.5.77)
3. Chris Llewellyn-Smith who spoke of the contributions that the SPS can make to particle physics. (Photo CERN 222.5.77)



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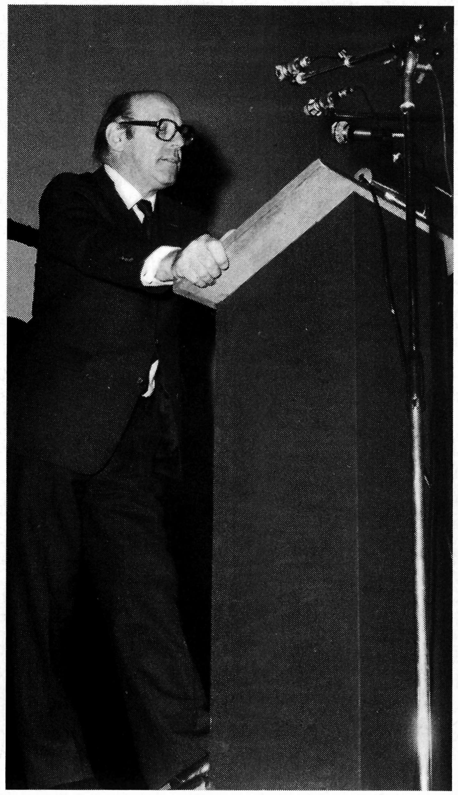

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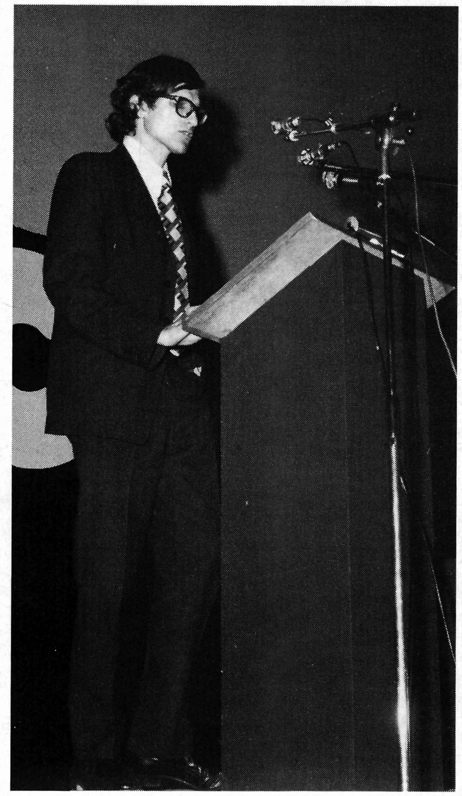


3.

the same is a fundamental advance.

Experiments at the SPS will provide tests of the ideas about the constituents of matter and the forces of nature which I have described. However, as in the past, new experiments will not only allow us to test and consolidate our present theories but they are also likely to produce quite new and unexpected phenomena. In fact, given the variety and quality of the beams of particles which the SPS produces, this seems almost inevitable.

For example, more high energy neutrinos are available for experiments at the SPS than everywhere else in the world. They will help us to study the connection between the weak and electromagnetic forces in detail. Furthermore, since neutrinos can penetrate right to the heart of neutrons and protons, their interactions are sensitive to whether quarks have structure and to the nature of the forces which hold quarks together.

In addition, neutrino experiments seem the most likely to produce surprises. If there are more than four quarks, and hence nuclear particles with new attributes beyond charm, neutrinos are likely to produce them. In fact, there are already hints of a fifth quark. What is its role? Could there be yet more? There is also some evidence for further non-nuclear particles, like electrons, which can be created in neutrino collisions. Again their properties and their role are not known. These are things we hope to learn from neutrino experiments.

The many spectacular discoveries which have been made can now be seen to fit into a simple framework in which nuclear particles are made of quarks which are governed by gravity, the strong force and a single weak-electromagnetic force. However, recent experiments have reminded us that there are many outstanding problems: How many quarks are there? What determines their number? How many non-nuclear particles, like the electron, are there? What determines their number?

The fundamental discovery that the weak and electromagnetic forces may be the same encourages even bolder questions: Can we comprehend all the forces of nature simultaneously? Could quarks, electrons, neutrinos and all the other particles be relatives belonging to a single family, subject to a single fundamental force? We are far from knowing the answers to such questions but the fact that they can now seriously be posed is extremely exciting.

The study of the constituents of matter and the forces which shape the Universe in which we live is an intellectual activity of the first rank to which the SPS will make major contributions. Experiments at the SPS will enable us to consolidate what we have learned

and test some of our new and more ambitious theories. However, as in the past, new experiments will undoubtedly reveal a richer and more elegant reality than is dreamt of in our present philosophy.'

Dr. John Adams concluded the ceremony with a brief introduction to a film, directed by Georges Pessis, about the SPS and its builders. He expressed his admiration for the team which built the SPS and congratulated them on their achievement.

Dr. Adams also thanked the Member States for sustaining their financial support and for their confidence during the project saying, 'We at CERN are fortunate to have been given the chance to achieve great technological projects, not once, but several times during the past 20 years or more. The quality of the massive equipment at CERN, of which the SPS is the latest and largest example, clearly demonstrates that European scientists and technicians can design and build the most advanced and sophisticated technical equipment in the world. It also shows that European industry can manufacture this equipment and deliver it on time.

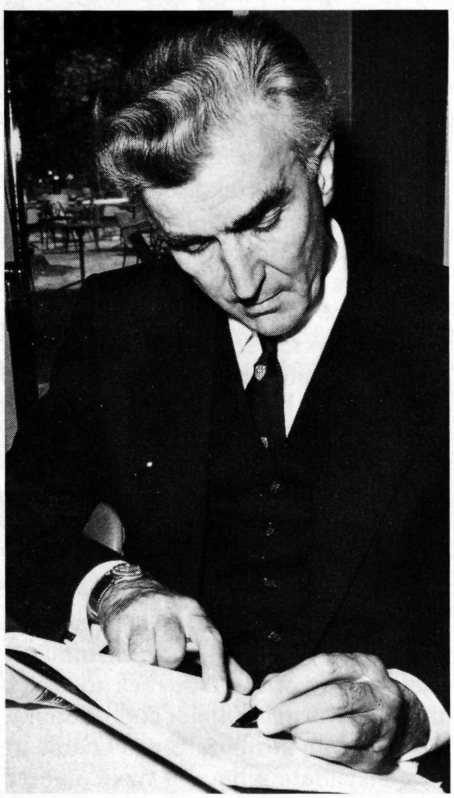
But it takes more than technical competence and industrial efficiency to produce a machine like the SPS. It needs also an Organization whose Member States have a common purpose and the confidence to trust the Management to carry it out successfully. This common purpose and confidence we enjoy at CERN and the result is the machine we are inaugurating today.'

There was much activity on the sidelines in connection with the Inauguration. Good coverage was obtained on television and in the Press. A historical exhibition of photographs was set up. The CERN exhibition returned from Hanover was reassembled. Special documentation — a technical notebook and an inauguration brochure — was prepared.

A particular activity which may interest COURIER readers involved the CERN Amateur Radio Club. For two days, 7/8 May, they were accorded a 'special event' call sign by the French authorities, HW6SPS (a call sign which will now never be heard again) and about ten of the Club's licensed operators worked two shortwave a VHF and a UHF station in six languages with news of the Inauguration.

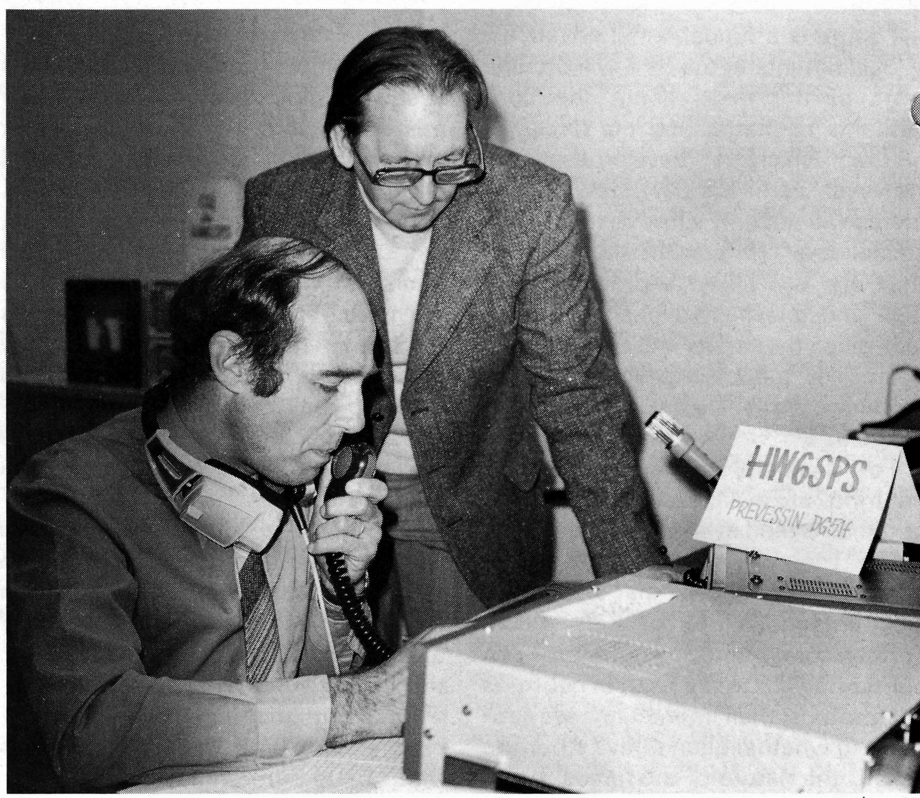
They had contacts with the local networks in Geneva and the Département de l'Ain and, via the OSCAR 7 satellite, with operators in many Western European Countries, the Soviet Union and the Middle East.

Altogether an impressive day, marking, with dignity, a fine European achievement and another important step in Europe's scientific potential.



One memento of Inauguration Days is the accumulation, in the 'Golden Book', of the signatures of many of the personalities who attended the ceremony. Here John Adams who led the SPS construction team, adds his signature.

(Photo CERN 107.5.77)



Michael Crowley-Milling, Head of the SPS Division, watches Jaap den Herder, President of the CERN Amateur Radio Club working the special radio call signal HW6SPS on Inauguration Day. The Radio Club contacts were one of many activities on the fringes of the formal ceremony.

(Photo B. Sagnell)

Around the Laboratories

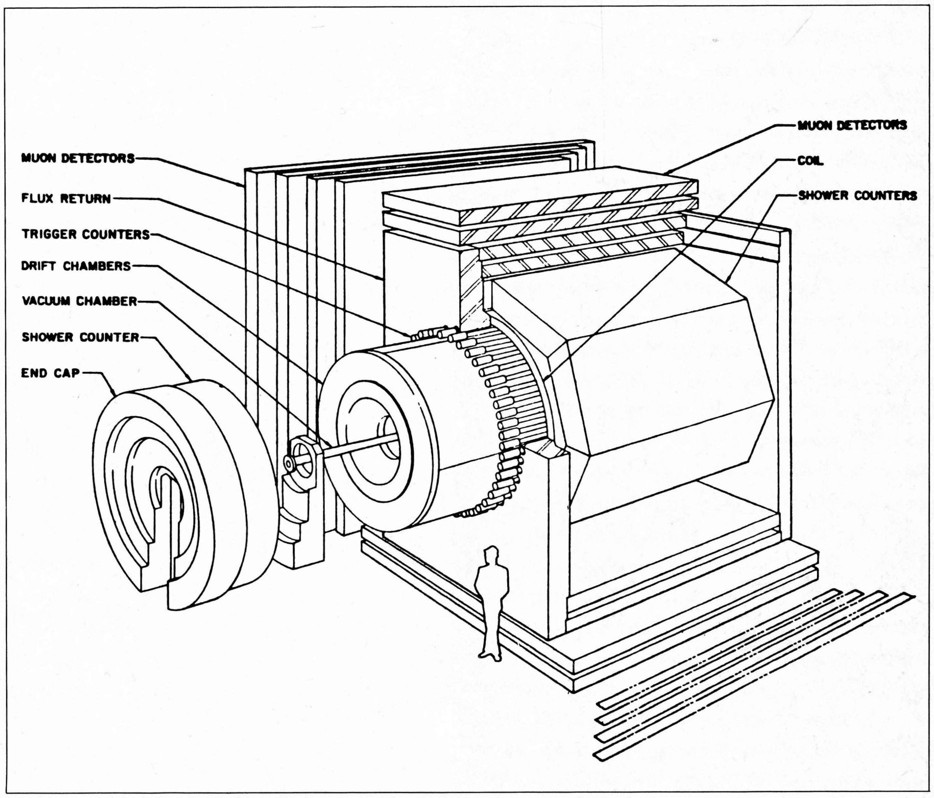


Diagram of the Mark II detector of the SLAC/LBL collaboration, which is to be installed for one of the first round of experiments at the PEP electron-positron storage ring at Stanford. This year, this detector will operate on SPEAR, replacing the Mark I version, which has been arguably the most fruitful piece of experimental apparatus in the history of physics. Mark II will thus be broken in well before PEP experiments start.

STANFORD
First experiments for PEP

Four proposals have been accepted by the Directors of Berkeley and Stanford for the initial experimental programme at the electron-positron storage ring, PEP, now under construction at SLAC.

The experiments involve some 100 physicists from thirteen research centres and have been selected to achieve a balanced programme both in relation to one another and in relation to the programme selected for the PETRA storage ring at DESY (see November issue 1976). They will occupy three of the PEP interaction regions leaving two free for later decisions (possibly early in 1978) in the light of the development of physics during the next year. The detection systems for the approved experiments are as follows:

A SLAC / LBL collaboration will move their Mark II detector from SPEAR where it is to be installed this year. It is the son of Mark I, the famous detector which found the psis, etc..., incorporating new detection techniques. For the move to the higher energies of PEP, more iron and muon detectors will be added and the detector will have a flying start as a proved, tested system which will carry out a general survey of electron-positron interactions.

Mark II has a 0.5 T solenoid magnet, 4 m long and 3 m in diameter, enclosing a cylindrical system of drift chambers. Lead-liquid argon calorimeters surround the magnet coil to provide electron and gamma identification. The two ends of the solenoid are capped with chambers and calorimeters so that there is nearly 4π solid angle coverage of the interaction region.

A John Hopkins / LBL / UCLA / UCR / Yale collaboration will use a 'time projection chamber (TPC)' for another general survey of electron-positron interactions. If the potential of this new detection technique, which promises to track and to identify particles in the same volume, can be fully realised, the TPC will be the most versatile detector on PEP. It is receiving heavy investment of resources for its development which will not be an easy task.

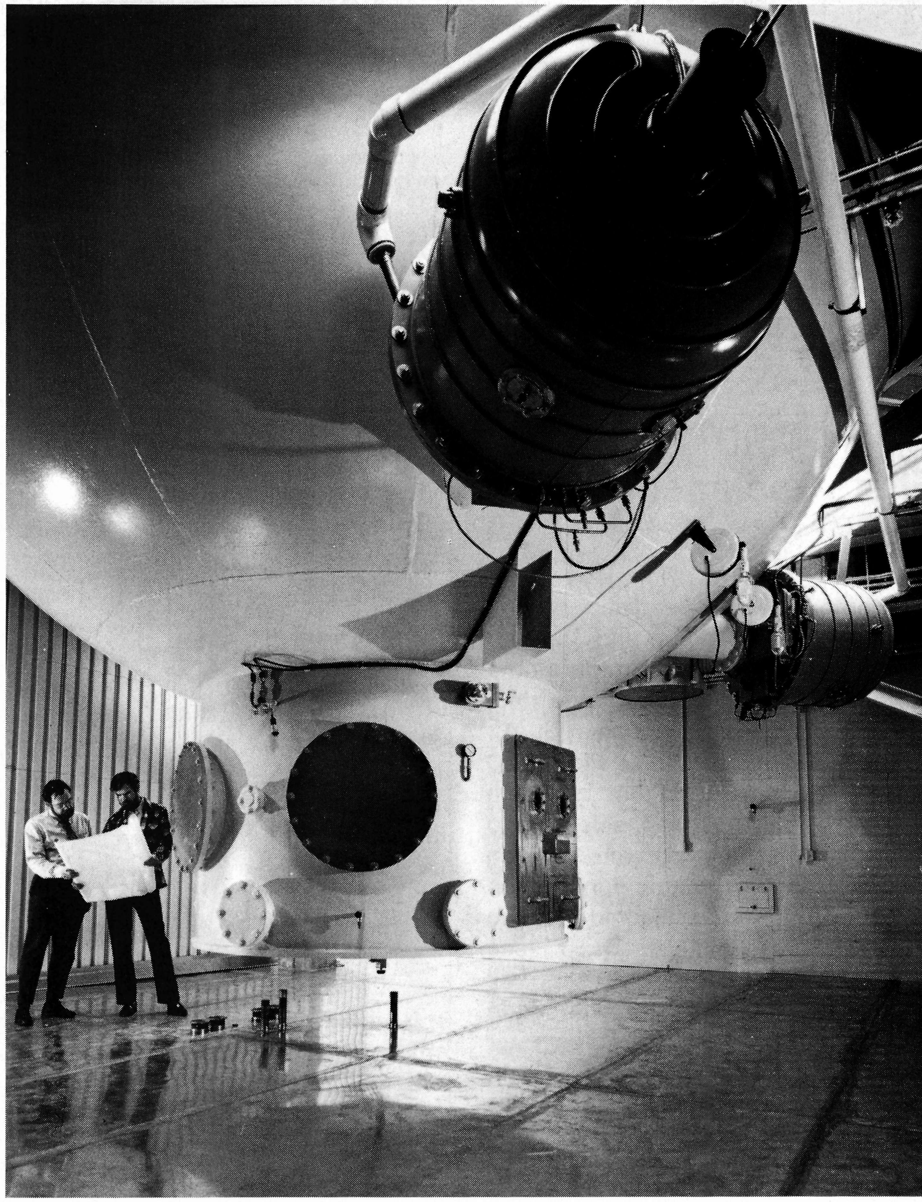
The TPC involves an inner cylindrical tank containing an argon-methane mixture at ten atmospheres pressure. Ionized particles left in the wake of a high energy charged particle passing through the gas mixture are collected after drifting to detectors in the end caps. A thin superconducting coil provides a field in the drift direction, limiting diffusion, and the time taken to reach the end cap could position the original track with an accuracy of about 150 µm. Measuring the ionization from almost 200 segments of the track should make it possible to identify particles of a very wide range of momentum. A calorimeter, iron filter and muon detector surround the magnet coil.

A Colorado / Northwestern / SLAC / Stanford / Utah / Wisconsin collaboration will use a magnetic calorimeter (MAC) which is the only hadronic calorimeter in the PEP (or PETRA) programme and could therefore have access to different information on the interactions. Excellent muon identification and homogeneous detection at almost all angles should give very accurate total cross-section measurements.

MAC will allow the measurement of total energies in an iron-gas calorimeter. Multiwire proportional chambers with a total of 100 000 wires (read into 6400 channels) will sample the energy. The core of the detector is a small solenoid, 0.5 m radius, containing drift chambers. This is surrounded by a finely segmented

Neutral beam injection system developed at Lawrence Berkeley Laboratory for the TFTR (Tokamak Fusion Test Reactor) at Princeton. It is designed to add fuel and energy to the Tokamak plasma by feeding in pulses of deuterium 0.5 s long and with an intensity equivalent to 65 A at 120 kV.

(Photo LBL)



lead calorimeter for electron and photon detection followed in turn by the hadron calorimeter.

The fourth experiment will be carried out by a UCD / UCSB / UCSD collaboration and will be located at the same interaction region as the Time Projection Chamber. They will look at the two photon process which is expected to be the most copious source of events from the electron-positron interactions and needs to be studied also to define the background to the less frequent one-photon annihilation. This area of physics has received comparatively little attention up to now.

The detector consists of a septum magnet on each side of the TPC followed by an array of sodium-iodide crystals to identify electrons and to measure energies. It adds to the abilities of the TPC by being able to look at very small angles relative to the beam directions where it can perform electron tagging and hadron and muon identification.

Wiggler Workshop

A Workshop on wiggler magnets was held at SLAC on March 21-23 attracting about sixty scientists from seventeen Laboratories throughout the world. The aim was to discuss wigglers and their use for synchrotron radiation research and other applications. Herman Winick of the Stanford Synchrotron Radiation Project (SSRP) was Chairman of an organizing committee, including John Blewett, Albert Hofmann, Phil Morton, Claudio Pelligrini, Ed Rowe and Andy Sessler.

Wigglers are devices which produce particularly intense synchrotron radiation from high energy electrons. They are planned for existing storage rings and for the new machines now being constructed or designed. Also the designers of high energy colliding beam storage rings for electrons and positrons plan to use the effects of the extra synchrotron radiation produced by wigglers to control the damping rates and cross section of stored beams so as to achieve higher luminosity.

Simple wigglers consist of a few sections (three or more) of alternating polarity magnets with relatively high transverse field (1.6 to 5 T) installed in a storage ring straight section to produce no net deflection or displacement of the orbiting beam. Because their field is considerably higher than that in the normal ring magnets, they cause the electron trajectories to bend more abruptly thus producing intense synchrotron radiation extending to higher photon energies. Wigglers with a large number of poles of alternating polarity transverse fields or of rotating helical fields are also being considered to produce interference effects resulting in very high intensity radiation at certain particular wavelengths.

Andy Sessler, Director of the Lawrence Berkeley Laboratory, opened the Workshop with an introductory survey on wigglers and their applications, setting the stage for the more detailed talks that followed. Part of the Workshop was devoted to a presentation of magnet designs and analyses of their effects on the behaviour of stored beams.

Wigglers for SPEAR were discussed by Bill Brunk, Dick Helm, and Klaus Halbach and for PEP by Helmut Wiedemann. John Blewett and Bill Sampson described superconducting wigglers that are being considered for the synchrotron radiation rings proposed for Brookhaven. Sergio Tazzari presented the plans for ADONE and Vic Suller and Elwyn Baynham described the wiggler planned for the Daresbury 2 GeV synchrotron radiation source now under construction. Jim Spencer of Los Alamos discussed alternative designs which also produce some focusing; Terry Martin of SLAC and

Sam Krinsky of Brookhaven outlined the severe problems of handling the high power densities that can be produced by wigglers.

Another part of the Workshop was devoted to the exciting possibilities of interference and coherence effects. Albert Hofmann of CERN discussed the intense peaks that are expected at certain wavelengths from structures with many periods. Coherent radiation by very short electron bunches and the production of coherent X-rays were discussed by Hans Motz of Oxford and Paul Csonka of Oregon. Motz was the first to produce radiation with wigglers observing interference peaks in the millimeter wavelength range, in the early 1950's at Stanford, from a 100 MeV electron beam and an array of alternating polarity permanent magnets.

In related talks, the Free Electron Laser was described by John Madey, Dave Deacon and Bill Colson. Lasing action was recently demonstrated using a 43 MeV beam from the superconducting linac at HEPL. The device could possibly be included in a small (100 to 200 MeV) high current storage ring to produce a very powerful tunable laser extending into the ultra-violet.

The Workshop closed with considerable optimism that wigglers could be made to work in storage rings with little or no adverse effect on the ring performance. Part of this optimism is based on the successful use of a pair of damping wigglers at the late Cambridge Electron Accelerator to achieve storage in the alternating gradient structure of the ring.

However, some problems remain to be solved (particularly handling the high power densities) and detailed analysis is needed to optimize the design in particular machines. Much exciting research, using the extraordinary properties of radiation produced by high energy electrons in storage rings equipped with wiggler structures, will then become possible.

FERMILAB Investigating the neutral kaon

A Chicago/Wisconsin collaboration with participants from ETH Zurich has just completed a series of experiments in the Meson Area at Fermilab studying the interactions and properties of neutral kaons. Among other things, their results provide more evidence that elementary particles are able to pass through nuclear matter more easily than we first thought.

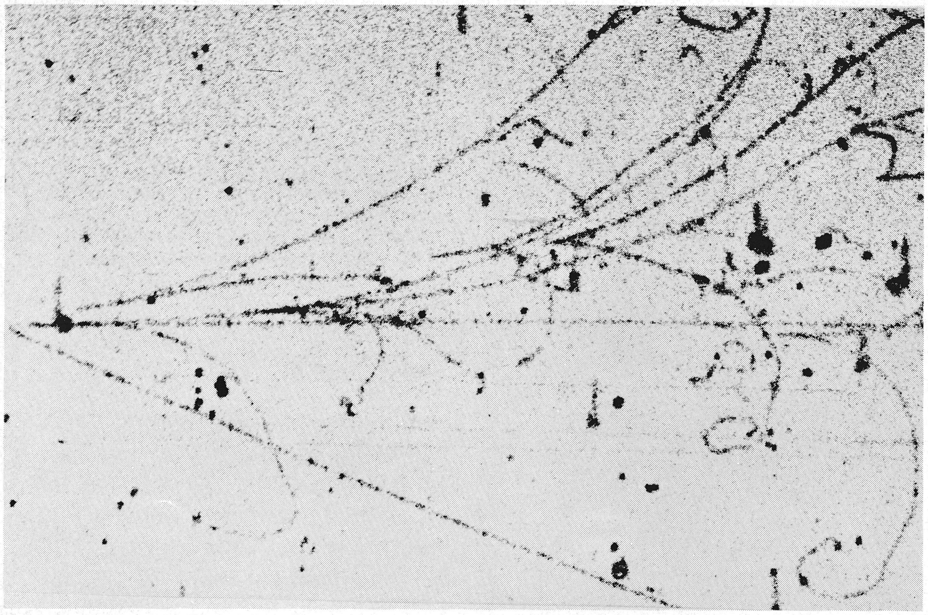
They used the M4 neutral beam line which carries a large fraction of long-lived neutral kaons, K_L. The K_L is peculiar in that it has almost equal content of matter and anti-matter at the same time. The experimenters have exploited this natural bounty to study, among other things, the very small differences in the way that matter and anti-matter interact.

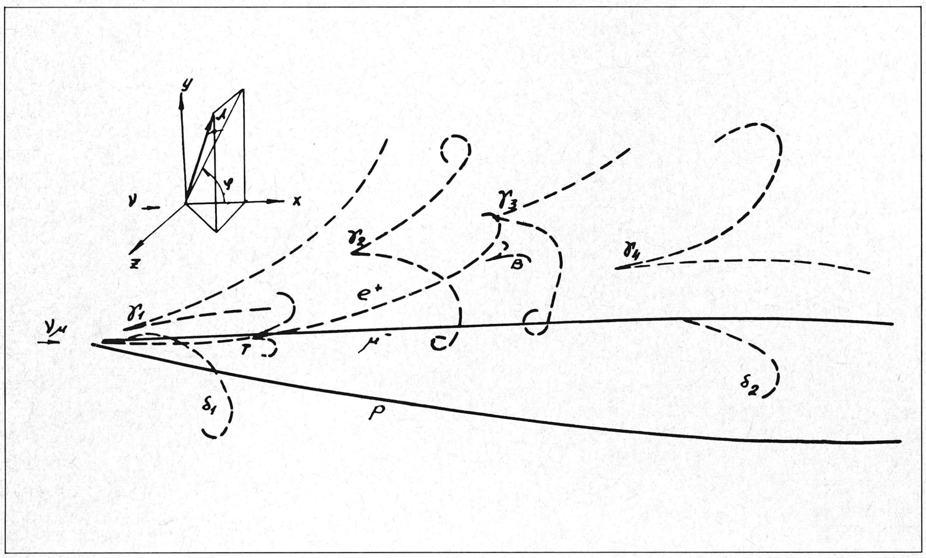
The signature of any difference in interaction is called 'regeneration'. That is, when a beam of K_L mesons passes through matter, short-lived kaons, K_S, are observed to exist just behind the target. This phenomena can be thought of as follows: the K_L is a delicate mixture of particle and antiparticle. If in the passage through matter, the particles interact in any way differently from the antiparticles, then that mixture will be slightly altered. The altered mixture makes itself known by the presence of K_S mesons which are easily observed by their decay into two pions (typically a few metres after their creation).

One of the Chicago/Wisconsin/ETH experiments has been a systematic study of the energy dependence of the interaction of K_L with different nuclei. Two particular results are already available. First, the total probability of interaction of a K_L with a heavy nucleus

On the right is the concrete pad for the electron cooling ring which is being constructed during the April-May shutdown at Fermilab. The oval shaped ring is located to the right of the booster galleries. The widened portion is the location of the electron cooling region. Also visible beyond the booster pond is the installation of a penetration into the booster tunnel. This will allow the 8 GeV protons to enter the main ring in the reverse direction. Also, 80 GeV protons can be extracted from the main ring and targeted to provide 5 GeV antiprotons to the booster for deceleration to 200 MeV.

(Photo Fermilab)





The event seen in the SKAT heavy liquid bubble chamber exposed to a neutrino beam at Serpukhov. A muon-positron pair is seen and the favoured explanation is the production of a heavy neutral lepton.

was expected to increase as the energy increased, paralleling the other rising cross-sections at high energy. Here it was actually found to decrease! Secondly, the experimenters have found that the 'regeneration' power of heavy nuclei is significantly larger than expected. These results, taken together, lend strong support to the idea that elementary particles travel much more freely in the interior of nuclei than previously expected.

A second challenge taken up by this collaboration has been an experiment to observe the internal charge structure of the neutral kaon. In this experiment, a K_L is scattered off an electron to get regeneration in the atomic cloud around a lead nucleus. The scattering is very small indeed as the net charge of the kaon is zero. As a result, a very large sample of data (50 million events) was required. The experimenters are now reducing this data to isolate the part that comes from the electrons.

This experiment, especially when coupled with the Meson Laboratory experiment by a Dubna/Fermilab/Notre Dame/Pittsburgh/UCLA collaboration studying the scattering of charged kaons on electrons, will provide unique information on the substructure of the kaon. The latter collaboration has already measured the size and shape or, more precisely, the form factor of the pion at 100 GeV/c. They find a pion radius of 0.56 ± 0.04 fermi or roughly two-thirds the size of the proton. They have just completed a run at 250 GeV obtaining four thousand kaon-electron scattering events to provide a similar accurate picture of the charged kaon.

It is interesting to note that the neutral kaon form factor experiment actually makes use of four of the fundamental forces in nature: the strong force, which is what holds the atomic nucleus together, causes regeneration when the K_L passes near the lead nucleus; the electromagnetic force, the one that holds atoms and molecules together, regenerates when the K_L is in contact with an atomic electron; the weak force is the cause of the K_S decay and of the formation of the K_L mesons in the beam; and, finally, the super-weak or CP-violation force, which has so far only shown itself in the decay of the K_L meson, has also to be taken into account.

SERPUKHOV
Possible observation of heavy lepton

The SKAT heavy liquid bubble chamber, with a filling of CF_3Br, has been operated in the neutrino beam of the IHEP accelerator at Serpukhov. During the first runs about 25 000 pictures were taken with a total proton flux on the target of 4×10^{16} and scanning half of this data has revealed 500 neutrino interactions.

Among them was an event which has the following peculiarities:

a) A pair of charged particles is observed which can be interpreted as a muon and a positron; both have a common vertex at a distance of 4.8 mm from the neutrino interaction.

b) The pair produces a 'vee' with an opening angle of 11°.

c) The direction of the total momentum of the pair does not coincide with the one that connects the pair vertex and neutrino interaction vertex.

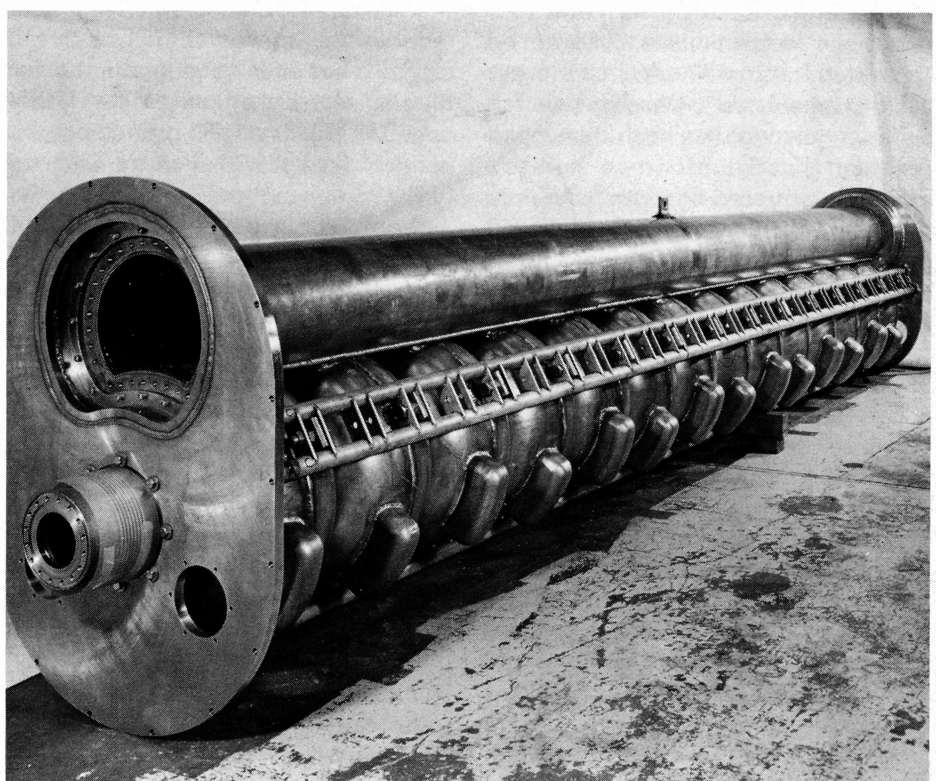
The observed event may be interpreted, for example, as an interaction of the type $\nu + N \rightarrow M^\circ + p + 2\pi^\circ$ followed by the decay of the M° (a heavy neutral lepton) $M^\circ \rightarrow \mu^- + e^+ + \nu$. Theoretical possibilities for the existence of such a heavy lepton with muonic quantum number have already been discussed.

In analysing the event seen in SKAT it was assumed that all the products of

A view inside the tunnel of the Cornell 12 GeV electron synchrotron (the magnet ring on the left) with prototype dipole magnets for the CESR storage ring project in place on the right. An extruded aluminium vacuum chamber 8 m long is shown insered in the dipoles.

The 14-cell, 500 MHz r.f. accelerating cavity structure for CESR. At the top is the lune-shaped coaxial transmission line which feeds power into all the cells in parallel. The cells are made of deep drawn copper cups. The wart-like protrusions on the outside of the cavities are to ensure symmetrical fields in the fundamental mode and to fix the polarization for other modes. The entire structure will be immersed in a water-jacket which is not shown.

(Photos Cornell)



the interactions are observed in the chamber. This assumption is based on the fact that the measured total transverse momentum of the reaction is only 100 ± 50 MeV while the potential length for the detection of neutral particles is 260 cm.

On the basis of four-momentum conservation and taking account of the Fermi motion of the nucleons in the liquid the effective mass of the heavy neutral particle is calculated as between 1.4 and 2.1 GeV/c^2. The life time is about 6 x 10^{-12} s. The mass of the neutral system with gammas is between 1.6 and 2.5 GeV/c^2. It is also possible to interpret the event as the production, via a neutral current, of the charmed meson D° within the same mass limits (1.4 to 2.5 GeV/c^2). The probability of any other explanation is considered very low.

CORNELL
CESR progress report

The general design of the Cornell Electron Storage Ring, CESR, was described in the April 1976 issue. Within the past year, prototypes have been developed for most major systems and intense effort is going into the completion of a 'protosector', consisting of six lattice cells of the storage ring, to be installed in the existing tunnel and tested by October. The sector includes the positron injection line which will be used for injection studies before the 'long' shut-down of the synchrotron in October.

This date brings to an end the scheduled round of fixed target experiments at the 12 GeV electron synchrotron since modifications must be made near the main (South) experimental hall, requiring the removal of several synchrotron magnets and generally disrupting operations. When the storage ring is installed, there are no explicit plans for continuing fixed

target experiments in the near future. However, a high energy photon line will be maintained for testing apparatus for colliding beam experiments.

Prototype dipole magnets have been built and are installed in the synchrotron tunnel. Each half-cell will have two 3.3 m dipole cores at an angle of 2.1°, energized by chevron-shaped coils linking both the cores. The dipole pair will have four pancake coils, about 7 m long, and laminated cores assembled at Cornell. Production of magnet coils for the protosector is well under way in the experimental hall of the old 2.2 GeV synchrotron. All day long, a warning trolley car bell rings out as a coil-winding jig pulls aluminium conductor from big reels and, at night, two vacuum-potting molds produce the coil pancakes. A pair is completed every two days.

A prototype quadrupole is undergoing field measurements. It has four separate quadrants but most of the normal lattice quads will be made from two-piece laminations which can be separated horizontally. A circuit (duty-cycle modulated transistor-switch series regulating) has been developed so that each of the hundred quadrupoles can be independently powered, allowing great flexibility in adjusting the tune of the ring.

The 500 MHz r.f. cavity consists of fourteen copper cavities coupled in parallel through a resonant coaxial line. The cells are made from deep-drawn copper cups, with a variety of welding and brazing techniques used for the various joints, and the entire assembly will be immersed in a water tank. The first cavity is now undergoing low power tests after being successfully tuned to within 10 kHz of the design frequency. High power tests are scheduled for May and June, using a 500 MHz, 250 kW klystron provided by DESY.

Aluminium extrusions, 11 m long, for the vacuum chamber of the protosector, have been received and pumping slots are being punched in the wall separating the beam and pump chambers, using an ingenious punching machine developed by a local firm. The next step is to bend the chambers to the correct radius. An 8 m chamber is installed in the prototype dipole. It has been slotted and bent but is not yet fitted with its ion pumps, end-flanges, etc. A gate valve has been developed to provide a smooth beam-chamber profile when it is in the open position. This will avoid large beam induced r.f. fields which can be produced with even slight changes in profile.

A fast kicker magnet has been developed for the extraction of single positron bunches from the storage ring. This is used during 'vernier compression' of the sixty circulating bunches into one final bunch (April issue 1976, page 131). The kicker is a C-shaped, ferrite loaded transmission line, placed around a ceramic vacuum chamber. A thin metallic coating on the inside of the ceramic chamber reduces the leakage of beam-induced r.f. fields but does not degrade the rise time of the kicker pulse. The kicker operates successfully producing the required field of 300 G with a rise time of 30 ns.

From 29 November last year synchrotron operations were interrupted for three months, while the entire Linac and its power system were torn out and a new improved 250 MeV Linac installed, including several sections of the late Cambridge Electron Accelerator Linac and positron converter. It is entirely computer controlled as a prototype for the computer control system of the storage ring. Synchrotron operation for high energy physics was resumed on schedule on 1 March. High intensity operation, 60 bunch modulation, positron production, and injection studies are scheduled together with regular operation for high energy physics in the coming months.

Detailed design of the one large magnetic detector for the main South interaction region is proceeding. Prototype drift chambers, argon shower counters, proportional chamber shower counters, etc., have been made and are being tested. Design studies are well advanced on a superconducting coil 1 m radius, 3 m long.

Mechanical design of the magnet iron and various assembly schemes are under discussion and superconducting compensating solenoids are being designed.

The list of participants in 'The Experiment' shows a collaboration of forty physicists from Cornell, Harvard, Rochester, Rutgers, Syracuse, and Vanderbilt Universities who meet every three weeks. Their detector will be described in a later issue.

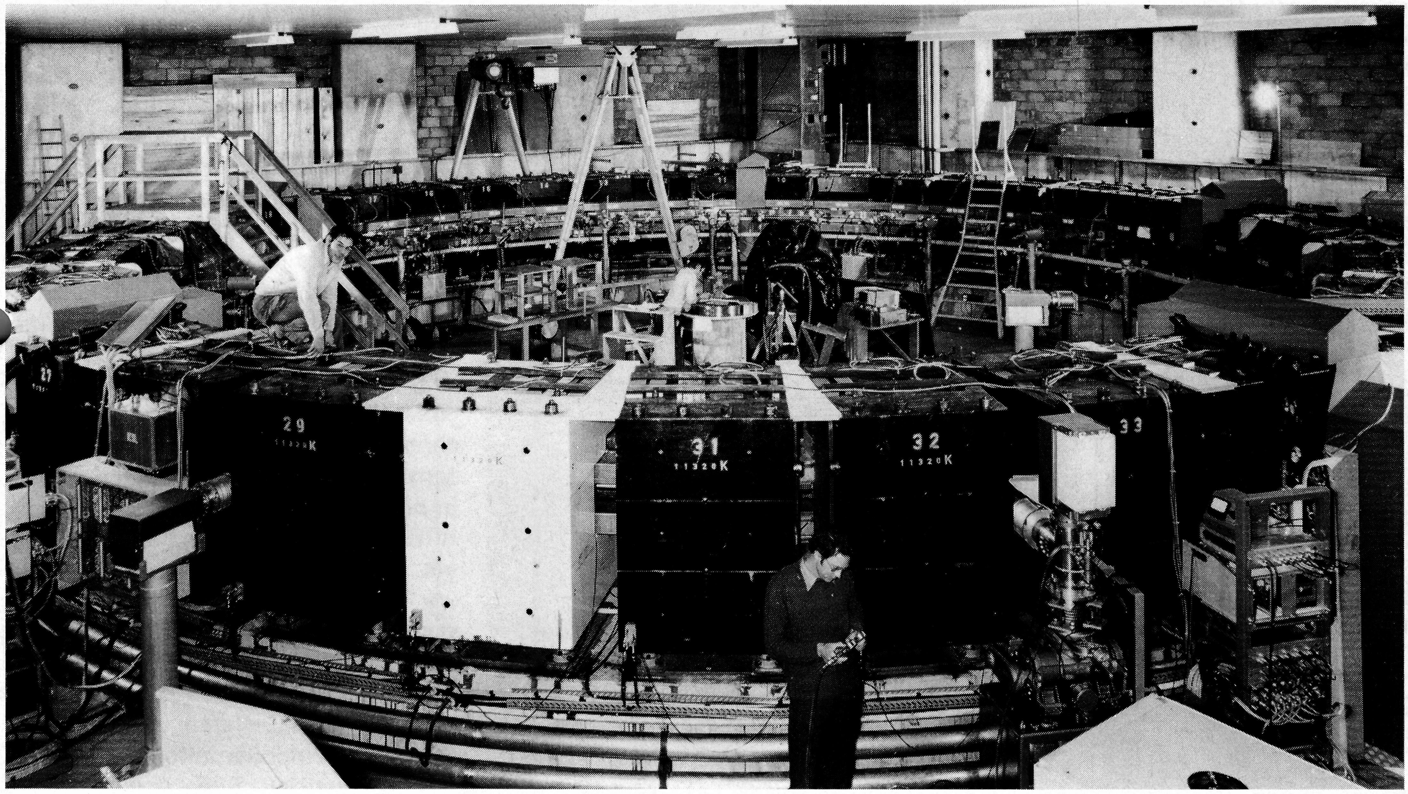
The North interaction region is underground in a room of dimensions 12 m x 9 m. This area has limitations of power, cooling, space, crane capacity and access. It may, however, be possible to use it for compact, simple (and, hopefully, elegant) experiments. No assignment of this region has been made yet and any interested groups should submit a detailed proposal by 1 October. Professor B.D. McDaniel, Laboratory of Nuclear Studies, Cornell University, Ithaca, N.Y. 14853, can provide further details.

CERN
The well behaved muon

Results from the latest g-2 experiment at CERN, to measure the anomalous magnetic moment of the muon with very great accuracy, are once again in total agreement with the calculated value. With a factor of 38 improvement in precision over earlier experiments, results have now reached a level of accuracy where effects due to the strong interaction must be taken into account.

The muon storage ring used for the third generation g-2 experiment. This series of increasingly accurate measurements is among the most important physics to emerge from CERN. They are a sensitive touchstone against which theoretical calculations can be tested.

(Photo CERN 55.9.74)



This latest experiment, carried out in the specially built muon storage ring at the 28 GeV proton synchrotron gives a value for the anomalous g-factor a = (g-2)/2 of 1165922 ± 9 × 10^{-9}, which could hardly be closer to the predicted value of 1165921 ± 10 × 10^{-9}. Comparisons of the magnetic moments of positive and negative muons in the same experiment show that their g-factors are equal to within 0.026 ± 0.017 parts per million, showing that the CPT theorem also looks good.

The third in a series of experiments of increasing accuracy at CERN, this measurement improves earlier results obtained first at the 600 MeV synchro-cyclotron in 1960 and then at the PS in 1966-67. It represents the culmination of two years of data taking and the collaborative efforts of physicists from CERN, Daresbury and Mainz.

Owing mainly to the effect of electromagnetic radiative corrections, the gyromagnetic ratio of any charged lepton is slightly larger than the value 2 predicted by Dirac theory. These radiative corrections can be calculated using quantum electrodynamics, and the comparison of calculated and observed values for charged lepton magnetic moments provides an acid test for the accuracy of modern quantum physics calculations.

The CERN g-2 experiments are among the most accurate measurements ever made, and as well as demonstrating physicists' abilities to devise more and more sophisticated experimental techniques, also show that the calculational techniques now available can be assumed almost perfectly reliable.

Most of the anomalous portion of the magnetic moment (a=1165851.8 × 10^{-9}) is due to electromagnetic radiative effects, but at this level of accuracy, allowance also has to be made for the effect on the vacuum due to the existence of virtual hadron states.

This latter effect can be calculated using data from the annihilation of electrons and positrons into hadrons, and gives an additional contribution to a of 66.7 × 10^{-9}. A third contribution to the anomalous magnetic moment comes from weak interactions and now that the necessary calculational rules have been developed to handle these cases, this effect can be quantified. This contribution is however only of the order of 2 × 10^{-9}.

In the latest CERN experiment, pions were injected into a storage ring 14 metres in diameter. The muons, produced by decay of the pions, were then constrained in a 1.47 T magnetic field produced in a ring of forty bending magnets. The vertical motion of the muons was controlled by an electric quadrupole field.

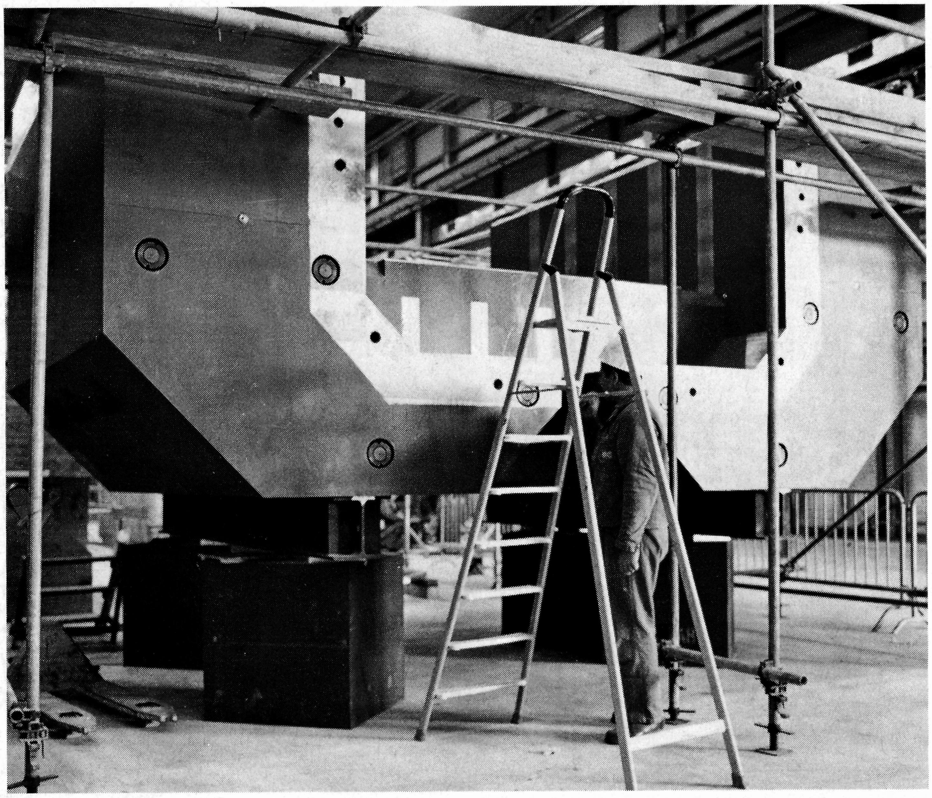
The muons subsequently decay into electrons and neutrinos, and variations

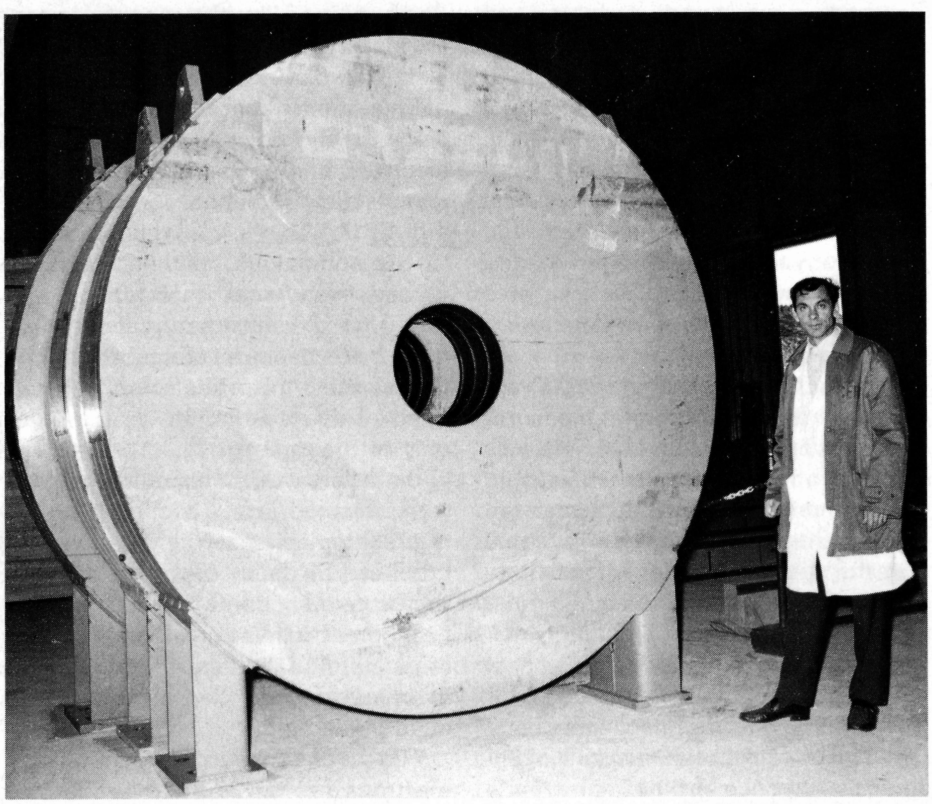
The first magnet units have arrived for the large spectrometer which will be used in the general study of electromagnetic interactions of muons by a CERN / Daresbury / Freiburg / Kiel / Lancaster /Liverpool / Orsay / Oxford / Rutherford /Sheffield / Turin / Wuppertal collaboration. A wide programme of physics will be carried out with this detector in the muon beam of the North Area of the SPS.

(Photo CERN 224.4.77)

The first sections of toroidal magnet, made in the USSR and assembled at the Joint Institute for Nuclear Research (Dubna), have arrived at CERN for a muon scattering experiment to be carried out by a CERN / Dubna / Munich / Rome /Saclay collaboration in the North Area at the SPS. 1640 tons of steel is to take the route from Dubna to CERN (changing trains at the Russia-Hungary frontier because of different rail gauges) for this experiment.

(Photo CERN 340.3.77)





in the electron count rate were observed with the help of twenty lead-glass scintillation counters. It is these variations which indicate how the spin axis of the muon is precessing in the magnetic field from which the anomalous magnetic moment can be deduced.

Meanwhile at the University of Washington, a new set of measurements on the anomalous magnetic moment of the electron have come up with results accurate to two parts in 10^7, while calculations are accurate to three parts in 10^7. However, the quantum electrodynamics predictions could improve by a factor of 10 when more of the sixth-order Feynman diagrams are worked out.

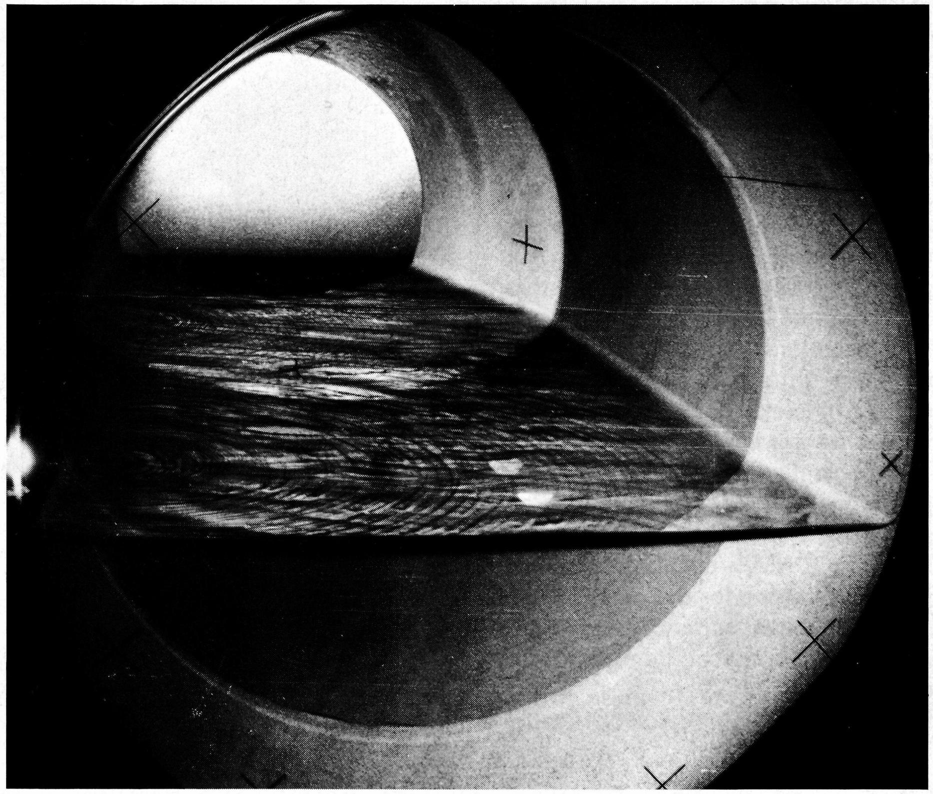
First results from the SPS

Just three months after the formal start of the SPS experimental programme, the first results are available and already show some new physics. This initial experiment, using the Omega spectrometer, measures the production of J/psi particles by pions, kaons, protons and antiprotons, and extends the data already collected at Fermilab and Serpukhov which was restricted to just pions and protons.

The SPS results show that, while the cross-sections for J/psi production by pions, kaons and antiprotons on a thick copper target at 39.5 GeV/c beam momentum are roughly equal, the proton cross-section is about six times smaller.

The thick copper target also acted as an absorber, making sure that only muons passed through to the detecting apparatus. About a thousand examples of 'hidden charm' were seen in the detected muon pairs, with all six types of incident particle showing examples of J/psi production. The ratio of production cross-sections by positive and negative pions (0.87 ± 0.14) and

These photographs are probably a unique demonstration of the diamagnetic property of hydrogen. They were taken in the HYBUC bubble chamber at CERN. The top one shows the chamber about half full with hydrogen and the surface of the liquid appears as a fairly tranquil plane. The bottom one shows the effect when the very high field (11.5 T) of the chamber magnet is switched on. The very small induced magnetic moment in the hydrogen atoms in the opposite direction to the applied field (diamagnetism) causes the hydrogen to rear away from the field and climb up the HYBUC window. When time permits, a simple atomic physics measurement of the diamagnetic property of hydrogen can be carried out with HYBUC.



positive and negative kaons (0.85 ± 0.50) is about the same, while production by protons at this energy is found to be only 0.15 ± 0.08 that by antiprotons.

For the theoreticians, this number seems to be very model-dependent, and these first results from the SPS should provide a useful foundation for further model building.

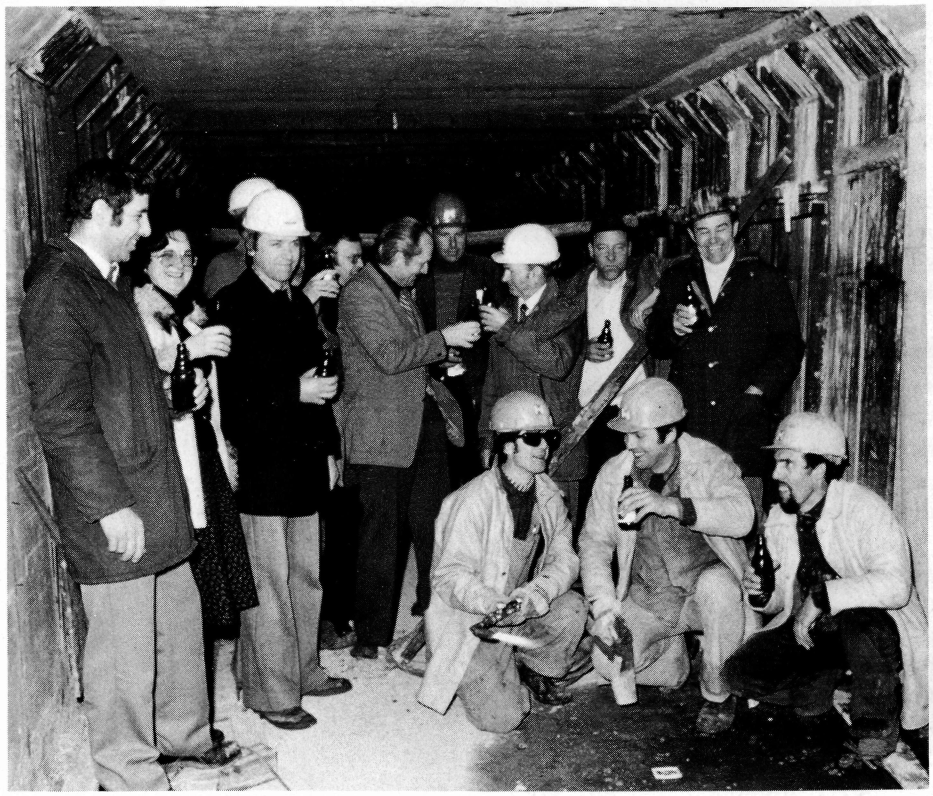
Data-taking for this experiment stopped earlier this year, and the Birmingham / CERN / Ecole Polytechnique / Munich / Neuchâtel collaboration is now turning its attention to the main part of the experiment — a charm search using emulsion techniques.

News is also coming from the WA3 experiment in the West Hall. It expected to be one of the first SPS experiments to take data but these hopes were dashed when a fire earlier this year destroyed part of the equipment already installed, including a big 120 ton spectrometer magnet.

After a tremendous team effort, the Amsterdam / CERN / Cracow / Munich / Oxford / Rutherford collaboration, is very much back in business. First runs have concentrated on hadron interactions using pion beams of up to 92 GeV, and analysis of the interaction $\pi^- p \rightarrow \pi^+\pi^- n$ gives a foretaste of things to come. Above the resonance region, where S, f, g, and h mesons are all observable, the $\pi^+\pi^-$ spectrum shows a significant number of events with effective masses greater than 3 GeV. This should allow a detailed analysis of the high mass two-pion region for the first time.

Another interesting preliminary result comes from the study of the angular distribution of the negative pion for different $\pi\pi$ effective masses. This shows a definite asymmetry, the negative pion coming off exclusively in the forward direction for $\pi\pi$ masses greater than 2.5 GeV.

Many other experiments are also in full flood at the SPS, both in the West Hall and on the neutrino beams.



PETRA tunnel builders celebrate completion of the last stretch of the ring. Beam is scheduled to be injected into the first completed octant of the machine mid-May.

(Photo DESY)

Companion for the deuteron

Despite new meson and baryon resonances being discovered all the time, there has been up to now only one stable two-baryon bound state — the deuteron — known to man. Occasional evidence for two-baryon bound states has been seen, often to be subsequently discounted, but there has been little reliable data to point firmly to the existence of a companion for the deuteron.

Now statistics on low energy interactions of negative kaons and deuterons from the CERN/Heidelberg/Munich (CHM) collaboration give reliable evidence for the existence of a narrow s-wave enhancement in the peripherally-produced lambda-proton dibaryon system, very close to the threshold for sigma-nucleon scattering.

Analysis of 10000 $\Lambda p\pi^-$ final states by the CHM collaboration shows a pronounced peak in the Λp effective mass at 2129 MeV, with a width of about 6 MeV and a cross-section of about 25 microbarns. The signal is not affected by the removal of 'spectator' events, where one or other of the target nucleons is essentially free, and underlines preliminary evidence for such a dibaryon state from previous experiments.

In a model calculation, H.-G. Dosch and V. Hepp have disentangled the kaon-nucleon and deuteron dynamics from the part of the transition amplitude responsible for the hyperon-nucleon scattering. These calculations show clearly that the observed Λp enhancement cannot be explained from deuteron dynamics alone.

The new dibaryon, codenamed 'H', could be the first companion for the deuteron in a decuplet SU_3 representation in which the deuteron forms the ispin singlet and H is one half of an ispin doublet. An experiment recently proposed by Princeton to study the reaction pp goes to K^+K^- plus anything might come up with some indications of other dibaryon states.

At CERN itself, a CERN / Heidelberg / Munich / Madrid / Saclay / Vanderbilt collaboration have proposed a further experiment to extend statistics by an order of magnitude. The proposal may involve the use of the small HYBUC chamber in a hybrid system. HYBUC, which operated in the early 1970s for a sigma magnetic moment measurement, has an appropriate geometry for spotting forward particles.

The chamber worked very well for the sigma experiment and clocked up several technological firsts. It was described in the November issue 1970. The magnet is a superconducting three coil system giving 11.5 T in the chamber volume — the largest high field (over 10 T) superconducting magnet in the world. It has sustained this field level for over 5000 hours in spite of magnetic forces in excess of 10^6 N. The expansion system can operate at 50 Hz.

Because of its potential new application, HYBUC has been taken out of mothballs and, on 6 April, peak field was reached again after charging at the maximum design rate of 2.5 T/hour. This brought some relief because it was feared that 'tin pest' (a long-term transition from metallic white tin to semiconducting grey tin powder) might have damaged the soft solder used for superconducting joints.

The vacuum systems and associated electronics have also been reactivated. The hydraulic pumps were already tested since they have been used in rapid cycling tests which are part of the European Hybrid Spectrometer programme.

(Late news: The experiment will probably begin as a purely counter experiment following discussions in the PS Committee.)

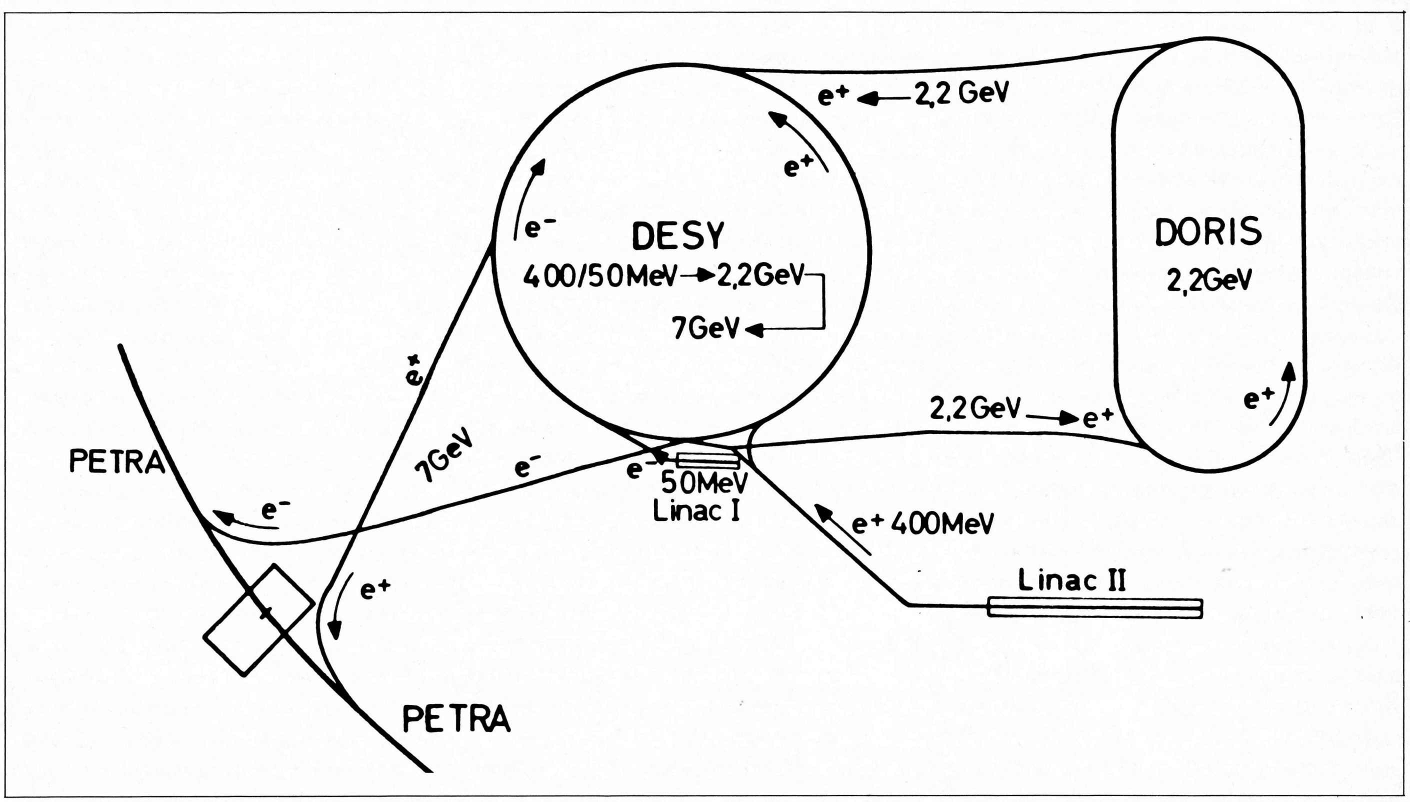
DESY
Positrons for PETRA

At the time of writing, preparations are well advanced for the first injection of a positron beam into an octant of the 19 GeV electron-positron storage ring, PETRA. An important step has already been taken — the complex interplay between Linac II, the synchrotron and the storage rings DORIS, worked very successfully in the acceleration, storage, accumulation and further acceleration of positron bunches as is required for PETRA injection.

This was the first time that this method of positron acceleration with intermediate storage had been tried. The tests were awaited with some apprehension since DORIS had not been built with this purpose in mind and a number of changes were also needed in the synchrotron. In DORIS a fast kicker and two beam bump magnets were installed for ejection but the drastic change was the conversion of the double storage ring into single ring operation to give the most economical way to accumulate and eject the positron bunches. The two upper half rings were linked to each other by some changes in vertical bending. The tests showed that neither the single ring operation nor the ejection of accumulated positron bunches cause basic difficulties.

The pulse ejected from DORIS was reinjected into the synchrotron and further accelerated to 7 GeV, the PETRA injection energy. Following the intermediate storage, the intensity (number of particles per bunch) increased by a factor of hundred giving a higher positron density than is available from any other injector at present. At 7 GeV, the positrons were extracted into the PETRA injection channel, where they traversed a 100 m drift distance without loss.

DESY is now looking forward to the injection tests that are scheduled for mid-May. The pre-accelerated positron bunches will then be fed into the arc of the injection channel and injected into the first PETRA octant that will be assembled at that time.



The intricate linking of the DESY synchrotron and the DORIS storage rings in the positron injection system for the 19 GeV electron-positron storage ring, PETRA. The system worked very well during tests in April.

Physics monitor

This is a new pocket for the presentation of information in CERN COURIER. It will be used for particle physics news which does not come naturally under one of the Laboratory headings in our 'Around the Laboratories' section. It will not replace the review articles which appear from time to time, giving rather thorough coverage of a particular topic, but over some months we hope it will reflect a fairly balanced picture of activity in particle physics.

Quark sighting?

In a paper submitted at the last minute to the Spring Meeting of the American Physical Society in Washington DC, George LaRue, William Fairbank and Arthur Hebard of Stanford University presented (on 26 April) their 'Evidence for the existence of fractional charge on matter'. They have evidence for electric charges of about a third that of the electron — the charge which graces the elusive quark.

Their experiment, which in one form or another has been in progress for about seven years, magnetically records the vertical oscillations of superconducting spheres driven at resonance by an alternating electric field. Fractional charges have been detected on tiny niobium spheres treated with tungsten, while no fractional charges are apparent with pure niobium spheres. More data is being taken, and even if the fractional charges continue to show up, they would still have to be explained as quarks.

In the Stanford experiment, the oscillation of the spheres between capacitor plates depends on the charge of the spheres, which can be changed with the help of a radioactive source. This charge is some multiple of the electronic charge, together with a residual effect, which could be due to electric and magnetic dipole forces together with any non-integer residual charge.

Applying a small fixed field along with the alternating field enables the experimenters to rule out residual measured charges due to permanent electric dipole effects, while extensive calculations show that higher order electric moments cannot produce such appreciable effects.

However, in the niobium spheres treated with tungsten, an electric dipole could be set up because of a contact potential difference between the inner layer of pure niobium and the outer region containing the diffused tungsten. When put in an alternating electric field, such a dipole would create a magnetic moment and produce observable effects. The experimenters say that the very largest residual charge effect which could be produced in this way is about 0.17e and even this looks unlikely.

Despite its sophistication, the Stanford experiment has a strong resemblance to the technique originally used by R.A. Millikan in 1911 to measure the charge on the electron. Both experiments observe the behaviour of electrically charged spheres between capacitor plates. While Millikan used d.c. fields and oil droplets from an atomiser, the Stanford group use a.c. fields and superconducting spheres.

Residual non-integer charges have shown up in many experiments to measure the charge on the electron. It is sobering to remember that in his very first published measurement of the electron charge Millikan remarked 'I have discovered one uncertain and unduplicated observation, apparently upon a single charged drop which gave a value of the charge on the drop some 30% lower than the final value of e'. Obviously the $u^{2/3}$ quark. Also, Ehrenhaft in 1910 reported the observation of 'subelectrons' with fractional charges but these results were ascribed to experimental errors in the experiments.

These early experiments aimed at measuring the charge difference between numbers of oil drops rather than the residual charges on any one drop. In 1968, motivated by the quark proposal, D. Rank at Michigan did a series of oil drop experiments to measure such residual charges. After the oil samples had been subjected to strong electric fields to try to separate out any net charges, in a number of cases the experiments did show residual fractional charges. However these results were not enhanced by further efforts at concentration and it was concluded that none of those fractional charge results could be substantiated.

Also, Giacomo Morpurgo with G. Gallinaro and M. Marinelli in Genova have been carrying out experiments to try to detect residual charges in matter since 1965. His latest improvements increase the sensitivity of his technique by 10^3 so that the overall sensitivity is some 10^7 times that of the original Millikan experiment. He has no sign of fractional charges and sets the free quark/nucleon ratio in iron below 3×10^{-21}.

World's biggest neutrino detector

Plans are being put together to build the world's largest particle detector — not in a laboratory but in the ocean! The idea being put forward by the DUMAND — Deep Underwater Muon And Neutrino Detector — group is to use the ocean itself as the detection medium for cosmic ray neutrinos and muons. Only by using a detector of this size, says John Learned of the University of California Irvine campus, will it be possible to make a detector big enough to give results with high energy but low-flux cosmic rays.

As well as extending the available data on neutrino interactions by covering energies up to 10 TeV, the project could well uncover sharply defined extraterrestrial neutrino sources. This could give birth to a whole new science of neutrino astronomy and would complement the work being done by astronomers with X-ray and radio telescopes.

The loose knit but enthusiastic DUMAND organisation involves a diverse group of scientists including oceanographers and geophysicists as

well as astronomers and particle physicists. The idea is to try to detect neutrino-produced cascades, for instance by acoustic means using hydrophones, and a proposal has been submitted for experimental work at Fermilab in which hydrophones will monitor a tank placed in front of the big Fermilab neutrino counter. As well as enabling experimenters to better understand acoustic detection techniques, the tank could itself be used as a possible neutrino detector in its own right.

At the same time, a group mainly made up of University of Hawaii oceanographers has been busy doing underwater tests using hydrophones at a Pacific test site. Although preliminary work revealed noise pick-up problems, the group insists that these difficulties are 'surmountable'. In site studies for this work, a cable parted in an underwater camera run, leaving $20000 worth of camera equipment somewhere on the ocean bed, giving perhaps some indication of the sort of problems which will have to be overcome with this kind of work.

It looks as if detection of high energy cascades is feasible with hydrophones from distances of about 100 m, while enough photons would be emitted to make the cone of Cherenkov radiation detectable at similar distances. This means that one optical or acoustic detection unit could monitor an effective detector volume of about a million tons of water!

One plan for a detector array involves sinking several hundred 1 km long strings of detector modules in 3000 fathoms of water in a deep basin not far from the island of Maui, Hawaii. Each detector module would have its own signal processing electronics package, and the whole detector configuration would be connected to shore by a cable to feed power and signal commands in and to send data and responses out. Data analysis could in principle be carried out anywhere.

Billions of tons of water would be required for an effective oceanographic neutrino detector, but a 'small' detector of just a million tons might be sufficient for muon studies, while giving a taste of the sort of problems which could arise in this kind of work. For a detector just an order of magnitude larger, new possibilities open up. Searches for intermediate vector bosons, Higgs bosons, gravitationally-collapsing stars and new flavours could proceed at the same time as new measurements on the distribution and homogeneity of cosmic rays. In addition, the parallel disciplines of high energy physics and astronomy would be brought a little closer together.

Meanwhile, back in the Soviet Union, a large neutrino detector is to be built using the gallium to germanium transformation caused by low energy neutrinos. The ideas is similar to the chlorine to argon detection technique used by R. Davies and his colleagues from Brookhaven in a South Dakota mine (see March issue 1968, page 54). They spotted no solar neutrinos and caused theoretical headaches to reexplain the burning cycle of the sun.

V. Ginzburg, M. Markov and I. Zatsepin are leading the Soviet team building a solar neutrino telescope in the North Caucasus. The technical problems are being tackled by the Laboratory of Neutrino Astrophysics and other centres. They call for about five tons of gallium a year for the next few years and they will also have a smaller chlorine to argon system.

The gallium system is preferred because it should have a reasonable cross section for the interaction of the low energy neutrinos (below half an MeV) which emerge from the primary interaction in the burning of the sun — fusion of two protons to give deuterium. A nucleus of the isotope gallium-71 can interact with such a neutrino to produce a nucleus of germanium-71. Filtering out the number of germanium atoms from the bulk of the gallium will give a measure of the low energy neutrino flux.

In search of violation

When the weak force is in action, Nature is concerned about the direction in which things happen. This 'parity violation' has been known for twenty years since the investigation in 1956 of the beta decay of nuclei revealed that the electrons emerge preferentially in the direction of the axis of the nuclear spin.

Since the discovery at CERN in 1973 of the neutral current form of the weak interaction, other manifestations of parity violation can be expected. It should be possible, at least in principle, to see the effects of weak interactions in stable nuclei and, if neutral currents behave like charged ones, to detect some sort of parity violation apart from that seen in beta-decay.

Neutral current interactions in atoms must be very small, and an order of magnitude calculation shows them to be down by a factor of 10^{-14} on electromagnetic ones, so it would be no use looking for them directly. One hope would be to pick up the effects through parity violations, which would not be masked by electromagnetic effects. This is the motivation behind a number of 'bench-top' experiments at the Universities of Oxford UK, Washington (Seattle) USA and elsewhere, but preliminary results show that the parity violating effect is nowhere near as big as that expected from the 'naive' Salam-Weinberg theory.

However comparisons of neutrino and antineutrino scattering at CERN, Fermilab and Brookhaven all show that the structure of the weak neutral current is almost certainly of a form which does produce parity violation. The conclusion is that either the bench-top ex-

periments are wrong, which now looks unlikely, or some other explanation is required.

The idea behind the bench-top experiments is that in a heavy atom (bismuth is being used at both Oxford and Washington), the atomic electrons spend enough of their time in or near the nucleus to be affected by the weak neutral force. Any parity-violating component in the interaction could rotate polarised light when passed through the atomic vapour, and sophisticated laser-based systems have been developed to detect any resulting rotation.

Calculations on the bismuth atomic structure based on the Salam-Weinberg theory suggest a rotation of the plane of polarisation by about 1.5×10^{-7} radians — an angle roughly equivalent to the width of a needle seen from five miles! Nevertheless with the help of laser equipment the Oxford group has established a sensitivity of 5×10^{-8} radians and the Washington group has reached 2×10^{-8}. No optical rotation by the bismuth atoms has yet been seen.

The apparatus is indeed so sensitive that even fingerprints, which contain large numbers of optically-active molecules, have a greater effect on the results of the experiment than any effect attributable to neutral current weak interactions!

One immediate objection to this negative result is that it hinges on a complicated atomic physics calculation to estimate the effect on atomic electrons due to nuclear interactions. Patrick Sandars of the Oxford group says that strenuous efforts are being made to improve the reliability of this calculation, but any larger discrepancy in the final result now seems 'unlikely'. Groups at both Oxford and Michigan are now proposing similar experiments using hydrogen where the atomic implications are much simpler.

Meanwhile high energy experiments at CERN, Fermilab and Brookhaven have come up with some guideline statistics on neutrino and antineutrino scattering, and although the events are still pretty thin on the ground, it looks as though the cross-sections for neutral current interactions by neutrinos and antineutrinos are very different.

Although the isotopic spin structure of the neutral currents is still far from clear, this simple inequality shows that the neutral current cannot be of a simple vector or axial-vector form and, like its charged counterpart, must be a mixture of vector and axial-vector currents. The required vector and axial-vector mixture is as would be expected in a Salam-Weinberg picture. Mixtures of vector and axial-vector currents normally lead to non-conservation of parity, so why don't the atomic physics experiments see any violation?

One answer put forward by theoreticians is that the Salam-Weinberg model could be an oversimplification of what is going on. For instance the vector and axial-vector parts of the neutral current could couple to different bosons. This would preserve the vector and axial-vector structure of the current and the neutrino/antineutrino cross-section inequalities but could make the observation of any parity violation more difficult.

So far, neutral current interactions have only been seen in neutrino interactions and the negative result obtained by the Oxford and Washington groups underlines this. Any positive result by a bench-top experiment would not only measure the extent of parity violation attributable to the weak neutral current, but would also be the first sign of neutral current phenomena outside the neutrino arena.

Come Together

Whenever an experiment comes out with an unexpected result, the fertile minds of theoreticians are further stimulated to revamp their existing ideas or come out with completely new ones. For example, when a few trimuon events were reported from Fermilab and CERN (April issue, page 95), it wasn't long before new mechanisms were put forward to explain the new phenomenon.

But now something else seems to be happening as well. Instead of picking on just one new observation, some of the biggest guns in theoretical physics are concentrating on producing a unified picture which accounts for a number of, at first sight, seemingly unrelated observations.

It has long been thought that the original Weinberg-Salam model of weak and electromagnetic interactions is an oversimplification of what is really going on, but opinions differ as to just where it is deficient. Each new embellishment would bring its own consequences — some wanted, some unwanted.

Rather than trickling in one by one, there now seems to be a bottleneck of new results in lepton physics. As well as the new, but still sparse, trimuon data, there are the details of dimuon events still to be explained. There is the evidence for new heavy leptons at SLAC and DESY. New experimental techniques still fail to detect any level of parity violation in atomic physics experiments. Details of neutrino scattering defy explanation by a simple quark model.

As a result, some authors are saying that the theory of weak and electromagnetic interactions needs a radical rethink to explain all these new observations in one go. Although the approaches taken differ widely, there seem to be two underlying common denominators — a proliferation of the number of quarks and leptons taking part in the interactions, and the introduction of 'right-handed' particles.

The proliferation of quarks and leptons is not necessarily a bad thing.

Besides the new leptons reported at SLAC and DESY which have to be introduced into the theory anyway, some of the anomalous new results can be attributed more or less directly to the existence of still more as yet unobserved particles.

Trimuon production, for example, is attributed by some people to a cascade decay process involving two new leptons which are incorporated into the formalism of the theory. However, others take a more conservative approach to trimuon production, saying that it is a hadronic phenomenon, resulting from the production and decay of a pair of charmed hadrons.

In the first formulations of the gauge theory model of weak and electromagnetic interactions, the sets of quarks and leptons were assumed to be only 'left-handed'. This assumption was a natural extension from the standard theory of beta decay, in which neutrinos always rotate anti-clockwise (i.e. left-handedly), when viewed from behind.

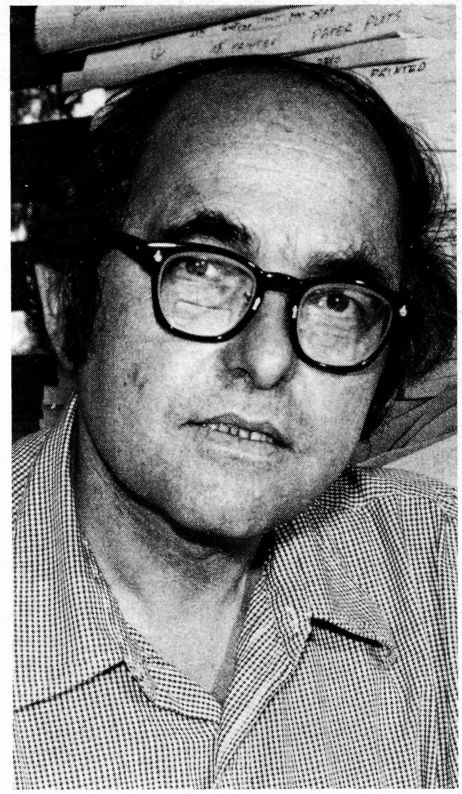
The non-observation of parity in atomic physics experiments in particular is making people think that additional 'right-handed' currents may be at work. Their extended theories of weak and electromagnetic interactions then include left- and right-handed particles on a more or less equal footing. Once these right-handed particles are brought in, cunning mechanisms have to be invented to make sure that the new phenomena are adequately explained without spoiling old-established notions of beta and muon decay.

Meanwhile the claims and counterclaims of the different new formulations go on, and the situation is not made any clearer by the scarcity of 'anomalous' data which is the motivation for many of the new models. But with all the interest which has been stirred up in these new phenomena, the scarcity of data may not last long.

People and things

On People

Gerson Goldhaber, Physics Group Leader at the Lawrence Berkeley Laboratory, received two honours in quick succession at the end of April. He was elected to the National Academy of Sciences and named Californian Scientist of the Year by the California Museum Foundation. Gerson Goldhaber has many fine achievements in experimental physics behind him and is a leading member of the LBL / SLAC team which has charmed high energy physics during the past few years.



Gerson Goldhaber

Bob Diebold has been appointed Associate Director of the High Energy Physics Division at Argonne. Also at Argonne, Ed. Berger of the theory group has been promoted to Senior Physicist in recognition of 'outstanding professional achievement'.

John White from the University of Oxford, UK, has been appointed to succeed R.L. Mössbauer as Director of the Institut Laue Langevin at Grenoble. The Institut is supported by the Federal Republic of Germany, France and UK for neutron research using a high flux reactor.

Robert Walgate, Science News Editor of 'New Scientist', had personal experience of three quark flavours following a talk on particle physics to a branch of the UK Institute of Physics. He was presented with varieties of German mild cream cheese — quark strawberry dessert, quark peach dessert and pure quark. After consuming them he was up and down, feeling strange but rather charmed by it all.

Doubler string operated

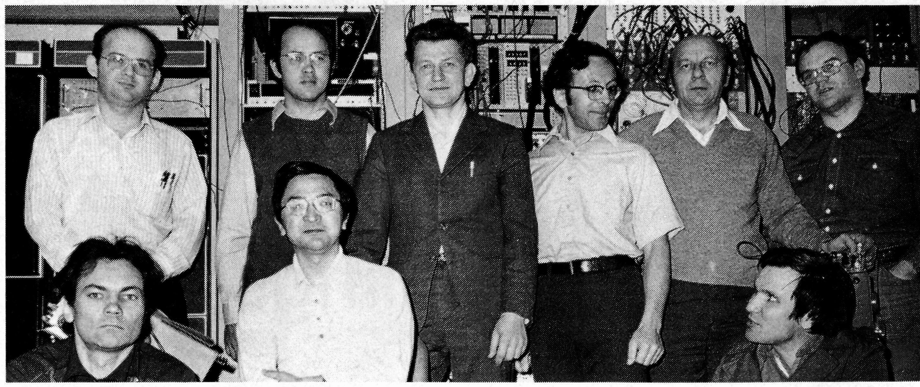
In April, a string of four 22 foot superconducting magnets was operated at Fermilab. They are prototypes for the 1000 GeV Energy Doubler. Currents of 4.3 kA were achieved, equivalent to 4.5 T magnetic fields, and no problems were encountered with quench protection or with the cryogenic system. The next step is to test these magnets in continuous operation for a month and then to extend the string, first to eight and then to sixteen magnets. At the end of April, the superconducting magnet assembly line achieved, for the first time, its goal of building one magnet per day.

Events

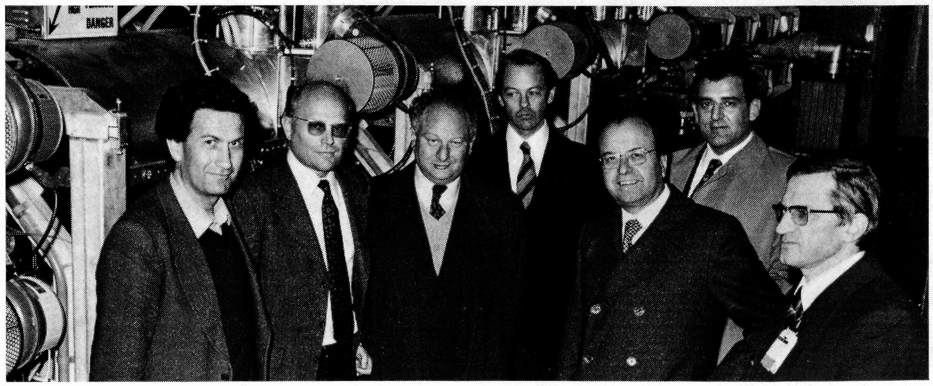
On 17 June, Shirley Williams, UK Secretary of State for Education and Science, will inaugurate the Central Laser Facility at the Rutherford Laboratory where research is carried out using a high power neodymium glass laser. At the Facility on 29 April, laser compression of a target (85 μm diameter glass balloon) was achieved for the first time in Western Europe.

From 26-30 September a Workshop on the 'Role of CERN Accelerators in European Intermediate Energy Physics' will be held at CERN under the Chairmanship of R. Klapisch. The subjects covered will be — Far-unstable

Fifth anniversary photograph of the USA-USSR collaboration involved in the gas jet experiment in the internal target area at Fermilab. Top left to right — Dan Gross (Rochester), Peter Nomokonov (Dubna), Yuri Pilipenko (Dubna), Ernest Malamud (Fermilab), Anatole Kuznetsov (Dubna), Vitaly Smirnov (Dubna). Below — Vladimir Nikitin (Dubna), Ryuji Yamada (Fermilab) and Boris Morozov (Dubna).



On 4 April, the Italian Ambassador to the Office of the United Nations and other Organizations in Geneva, His Excellency Rinaldo Petrignani, visited CERN. He is photographed here (third from the right) with senior CERN staff from Italy at the ISR. (Photo CERN 370.3.77)



nuclei and radioactive beams (convener P.G. Hansen), Atomic physics (G. Backenstoss), Nuclear physics (J.P. Deutsch / C. Wilkin), Solid state physics and chemistry (E. Karlsson/to be confirmed), Particle physics (J. Duclos) and Unconventional ideas (B. Povh). Suggestions on any of these subjects should be addressed to the appropriate convener. The Workshop will have about 40 invited participants with an Open Session on the last day.

SNS past another approval stage

At its meeting on 20 April, the UK Science Research Council formally approved the construction of the Spallation Neutron Source (SNS) at the Rutherford Laboratory. It was also agreed that authorization of the project should be immediately requested from the Department of Education and Science. Construction of the SNS, based on a high intensity 800 MeV proton synchrotron, would follow closedown of the 7 GeV Nimrod proton accelerator and would use facilities from both Nimrod and the 5 GeV electron accelerator, Nina (which was closed down in April).

Inertial fusion in Europe

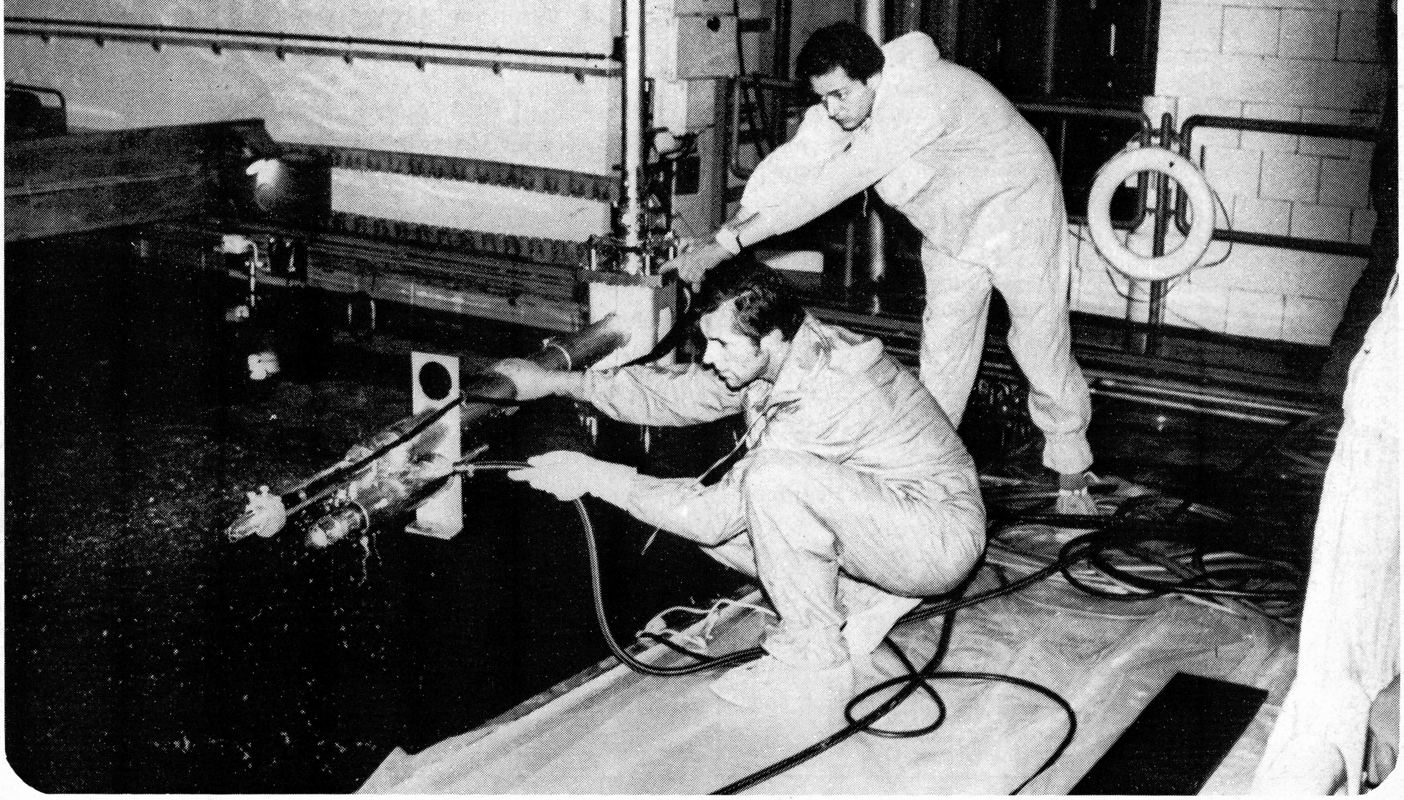
The Euratom Liaison Group has set up a study group on 'Inertial Confinement Techniques' which attempt to use lasers, electron beams or heavy ion beams to achieve thermonuclear fusion. The study group is under the Chairmanship of R. Balescu from the University of Brussels. The group will review present activities in Europe, study and possibly initiate further developments (with awareness of the programmes in the USA and USSR), promote coordination and collaboration in Europe and propose a programme to the European governments. The aim is to emerge with some recommendations in 1978. The Group had its first meeting on 1 April in Brussels; Kjell Johnsen and Kees Zilverschoon from CERN were among the participants. Anyone interested in these problems is invited to contact R. Balescu, Faculté des Sciences, CP 231, Campus Plaine, Université Libre de Bruxelles.

Things historical

Maurice Goldsmith and Edwin Shaw have written a book on the building of the CERN 400 GeV proton synchrotron, the SPS. The book, entitled 'Europe's Giant Accelerator' is published by Taylor and Francis Ltd., 10-14 Macklin Street, London WC2B 5NF, at a price of £ 13. It covers the physics background, the difficulties experienced in getting the project off the ground, the design and construction of the major systems and the start of the experimental programme. There are many shrewd observations on the course of events during the pre-project and construction years and on the personalities involved. It is rare to have such a comprehensive story of a project written so soon after its completion and anyone in the high energy physics field (and hopefully many outside it as well) will find the book a fascinating read. Maurice Goldsmith initiated the book and benefited greatly from the help of Ted Shaw who was Head of Public Information at CERN during most of the period covered by the book.

A Fermilab History Committee has been set up as the Laboratory approaches the tenth anniversary of its foundation. Under the Chairmanship of Lab. Director, Bob Wilson, members are Drasco Jovanovic, Frank Cole, Dick Carrigan, Lee Teng and Roger Thompson. They are collecting material on the life of the Laboratory from its early days — papers, tapes, books, photos — and will house the collection in the Library.

The Office for History of Science and Technology (470 Stephens Hall, University of California, Berkeley 94720) is issuing a series of bibliographies of non-technical writings of modern physicists. The first to appear is that of Max Planck which picks out six hundred items in six languages. These bibliographies are unique and are intended to aid students of the relations of physics with other sciences, arts and politics and anyone who needs to know the history of particular speeches or essays. The Planck bibliography is available from the Office at a price of $ 2. Cheques should be made payable to the 'Regents of the University of California'.



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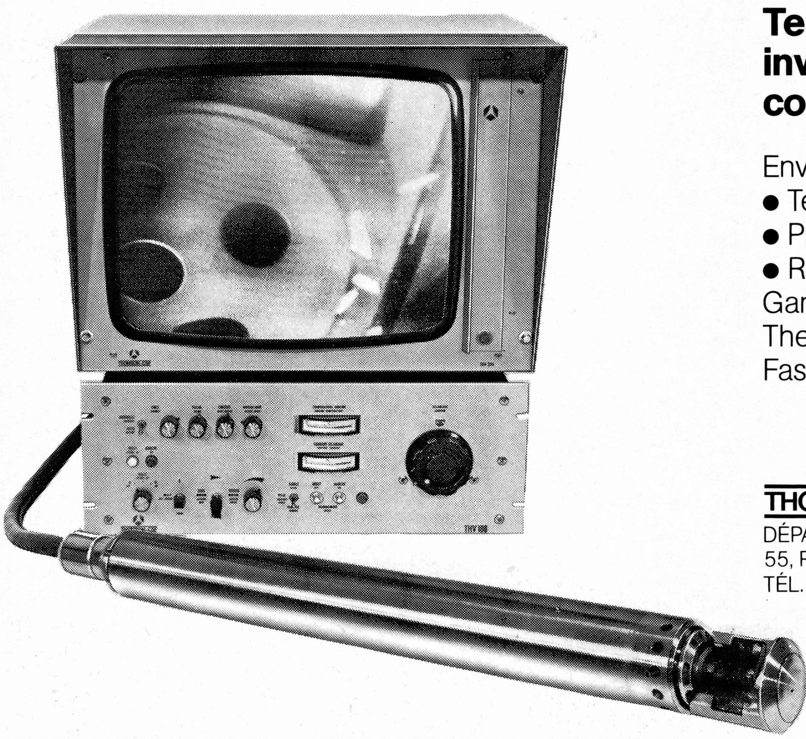

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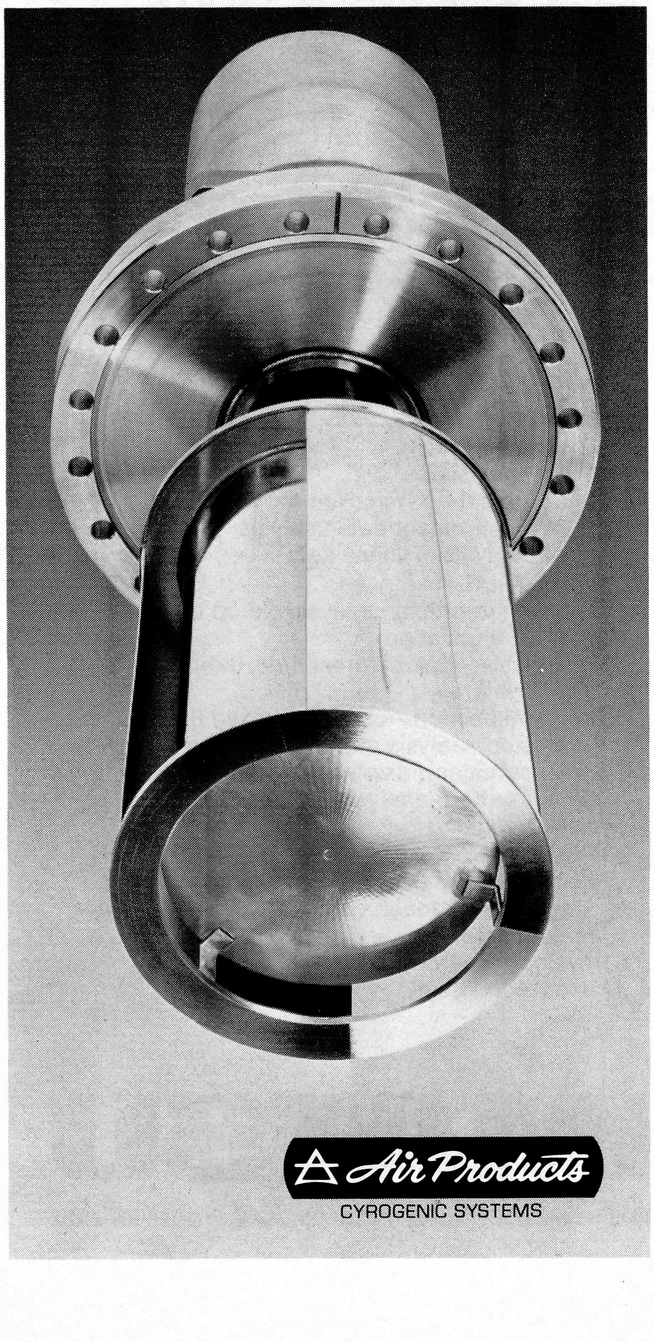

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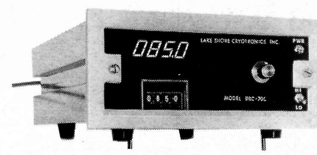

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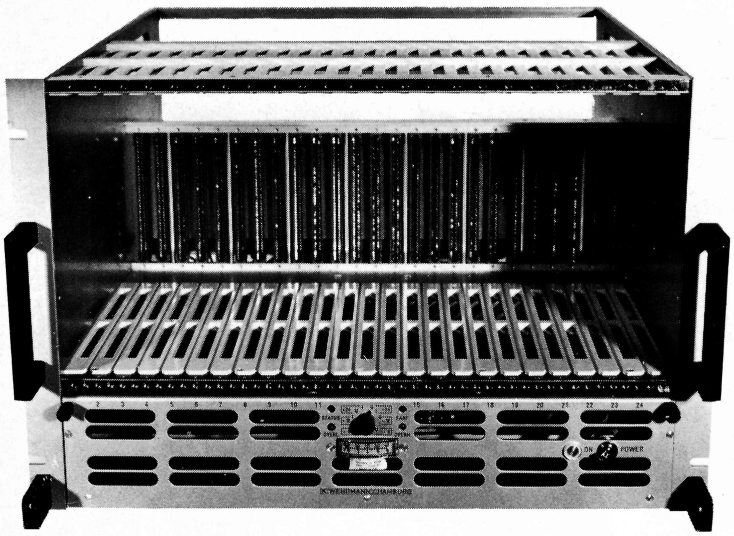

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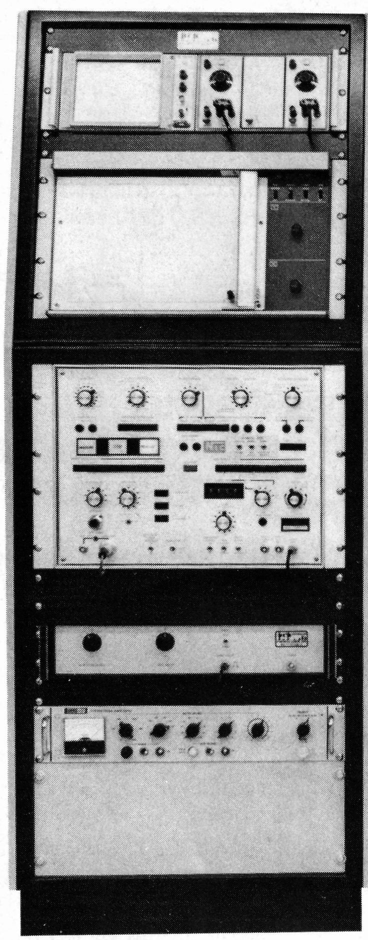

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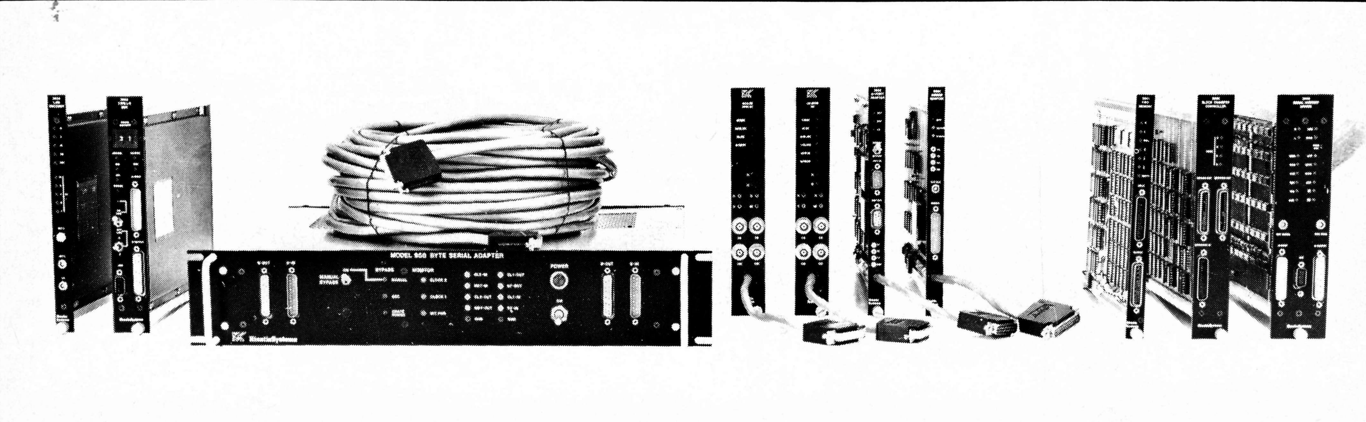

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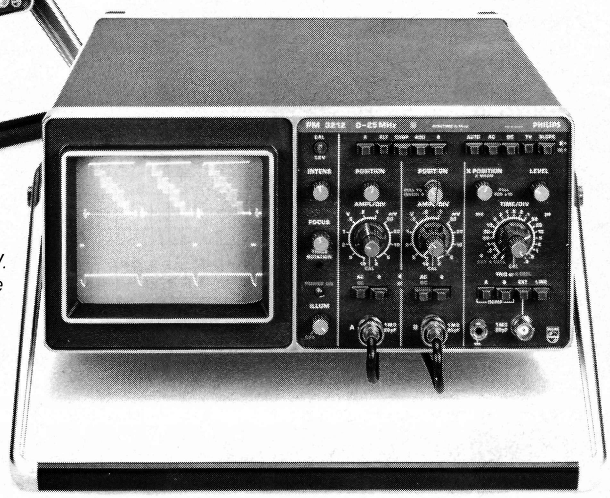

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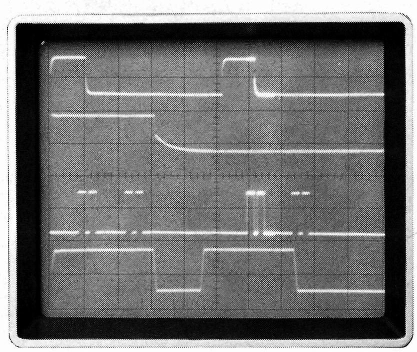

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If you attach importance to optimum shielding- we can help you.

Shield for a miniature radiation system. It weighs over half a ton for a height of 0.52 m and a diameter of 0.33 m.

Depleted uranium metal is being widely accepted as a shielding material in radioactive environments. Depleted uranium metal shields are used, for example, in medical cobalt radiation systems, in fixed and portable isotope units.

Because of its high density (18,7 g/cm³) and thus resulting minimum volume, it is used not only in the nuclear field, but also in aircraft manufacture and shipbuilding, as a trimming ballast and counterweight. Other applications are in contents gauges, inertia masses and eccentric weights.

NUKEM has many years of experience in working depleted uranium metal. This material can be fused, cast, extruded, rolled, forged and machined in our own workshops.

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