CERN COURIER

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CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1500 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3200 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 410 million Swiss francs in 1975.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of 400 GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1975 is 237.9 million Swiss francs and the staff totals about 450.

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Contents

Around the Laboratories

CERN News

Cover photograph: Posing for the traditional group photograph at the National Peoples Congress Palace in Peking are Chinese physicists and the CERN group, whom they invited to visit China. The occasion at the Palace was an interview with Wu Lein-Fu (centre of front row) where further contacts between the scientific communities were discussed. (Photo Hsinhua News Agency)

Further contacts with China

In the Summer of 1973 a delegation of physicists from the Peoples Republic of China, headed by Professor Chang Wen-Yu, made an extensive tour of high energy physics Laboratories in the USA concluding with a week's visit to CERN. In September there was a return visit from CERN by W.K. Jentschke (Director General of Laboratory I), G. Charpak, L. Van Hove and V.F. Weisskopf. The invitation for this visit proved to be much more than an act of reciprocal hospitality. The discussions in China were wide-ranging and thorough and carried the contacts between the scientific communities a stage further.

Since the 1973 tour, the Academia Sinica (the Chinese Academy of Sciences) has decided to establish an Institute of High Energy Physics headed by Chang Wen-Yu. This is now being set up in Peking with a sizable staff. The Institute is to work on theoretical high energy physics, particle detector instrumentation and high energy accelerator studies. Obviously, in order to participate in experimental high energy physics from within China, the choice of an appropriate accelerator at this stage of the research is not easy.

The tour of the CERN group centred on Peking and Shanghai; it took in several Universities, Institutes and factories. The visitors saw, for example the work on controlled thermonuclear fusion (involving laser technology and a mini-Tokomak) at the Institute of Physics at Peking, on computers (1 μs per operation) at the University of Peking where there is a theoretical group in high energy physics, on lasers, thin films and integrated circuits at Tsing Hua University, on reactor technology at the Institute of Atomic Energy in Peking, on nuclear physics involving the use of a cyclotron (including isotope production) at the Institute of Atomic Energy Shanghai...

Some very fine work, often emerging from modest means, was seen in the field of instrumentation. This included integrated circuits, many other electronic instruments and multiwire chambers (a follow-up from a chamber passed by Charpak to the Chinese delegation in 1973). It was also obvious that part of the role of the Universities is seen as that of research centres to feed knowledge into industry.

Despite their achievements, the hosts insisted that China is a 'developing' country in need of scientific and technical input from the 'developed' countries. Together with this, however, there was strong emphasis on self-reliance. Though avid to learn from experience elsewhere, they insist that it must be the Chinese people themselves that do the work and apply the knowledge.

At Peking and Shanghai, the CERN visitors gave lectures on the present status of high energy physics and its organization in Western Europe. These talks, particularly in Peking, were followed by long, animated discussions which revealed that the Chinese physicists are well up-to-date with recent developments and able to partake in informed debate on current theories.

On 13 September in Peking, there were two important discussions concerning the future development of the relationships between the scientific communities. In the morning, the interest of the Chinese physicists in continuing the contact was expressed by Professor Chien Shan-Tsiang, Vice-Chairman of the Institute of Atomic Energy during a tour of the Institute. This was reiterated by Professor Wu Yiu-Hsun, Vice-President of the Academia Sinica, at a dinner offered to the CERN visitors in the evening.

These exchanges led to a highlight of the tour — a meeting with Wu Lein-Fu, Vice-Chairman of the Standing Committee of the National Peoples Congress. The Vice-Chairman said that China wishes to see the contacts and exchanges with high energy physicists, particularly of CERN, extended and again stressed the readiness of China to learn from scientific and technical experience elsewhere.

In concluding discussions with Chang Wen-Yu, Tsu Hong-Yan and Tu Tung-Sheng of the Institute of High Energy Physics, future exchanges of information and of people were discussed. Concerning the exchange of people, we can finish with a typical Chinese proverb quoted by Wu Lein-fu — 'One eye is better than a hundred ears'!

In conversation at the National Peoples Congress Palace, left to right, Mme Charpak, Mrs Weisskopf, G. Charpak, Mrs Jentschke, V.F. Weisskopf, W.K. Jentschke, Wu Lein-Fu, two Chinese interpreters, L. Van Hove, Mme Van Hove.

(Photo Hsinhua News Agency)

Around the Laboratories

DESY
PETRA construction to begin

As part of the measures taken to stimulate the economy in the Federal Republic of Germany, the Ministry for Research and Technology has allocated money for the buildings of the proposed 19 GeV electron-positron storage ring, PETRA. Additional funds totalling 14.85 million DM have being granted for 1975/76 to the DESY Laboratory for this purpose.

The funds include money specifically assigned to the building of extra experimental halls. In the PETRA proposal, money is requested for the construction of four experimental halls. The machine design, however, has eight beam intersection regions and the possibility of four other halls, being built in the context of international collaboration in the use of the machine, was left open. The money that has been allocated is to cover the construction of six halls, two of them to ensure accommodation for experimental teams from other countries.

The additional budgetary allocation has passed through all the relevant Committees. Since construction plans are already complete, building will go ahead immediately when the formal notification is received from the Ministry.

Improvements at the synchrotron

In the midst of the excitement concerning the PETRA decision, the Laboratory continues to tackle its immediate tasks. A shutdown of the 7.5 GeV electron synchrotron and the DORIS electron-positron storage rings extended from 18 August to 30 September while a series of improvements were implemented. Normal operation has now resumed.

The ejection system from the synchrotron for DORIS was rebuilt and the transfer channels between the machines were modified to raise the DORIS injection energy from 2 to 4.3 GeV. It is now possible to fill DORIS at all operation energies, eliminating the necessity of 'energy ramping' in the storage ring itself. This will improve operation at high energies.

The 400 MeV linac II injector has been modified to yield higher positron currents. The linac used to have 12 accelerator sections with the electron-positron converter positioned behind section 5. The converter has now been moved downstream by two sections leading to a 40 % increase in the energy of the bombarding electrons and to a higher positron yield. At the same time, two accelerator sections were added at the end of the linac to keep the emerging positron energy unchanged.

The linac I injector was also modified for higher energy. In the usual DORIS injection scheme, positrons and electrons can be fed in on a pulse-to-pulse basis. This necessitates simultaneous operation of linac II as a positron injector and linac I as an electron injector into the synchrotron, the energy of linac I was raised from 40 to 60 MeV by doubling the klystron power.

In readiness for proton injection into the synchrotron (to take a first look at electron-proton colliding beam problems), a Van de Graaff proton injector was received in August after successful testing at the manufacturers. Its installation in the inner experimental area of the synchrotron begun in September and the proton injection channel was installed. The r.f. accelerating unit for proton acceleration in the synchrotron has been operated during the summer, but technical difficulties in the control systems have caused some delay. The accelerating unit was not, therefore, installed during the shutdown and will probably be moved in in November.

The storage rings, DORIS, are looking in progressively better shape. During recent months, they have mainly operated at energies of 1.5 and 1.84 GeV at currents of about 2 × 250 mA and a beam lifetime greater than 10 hours. The average luminosity, over a period of several weeks, was about 4×10^{29} per cm^2 per s.

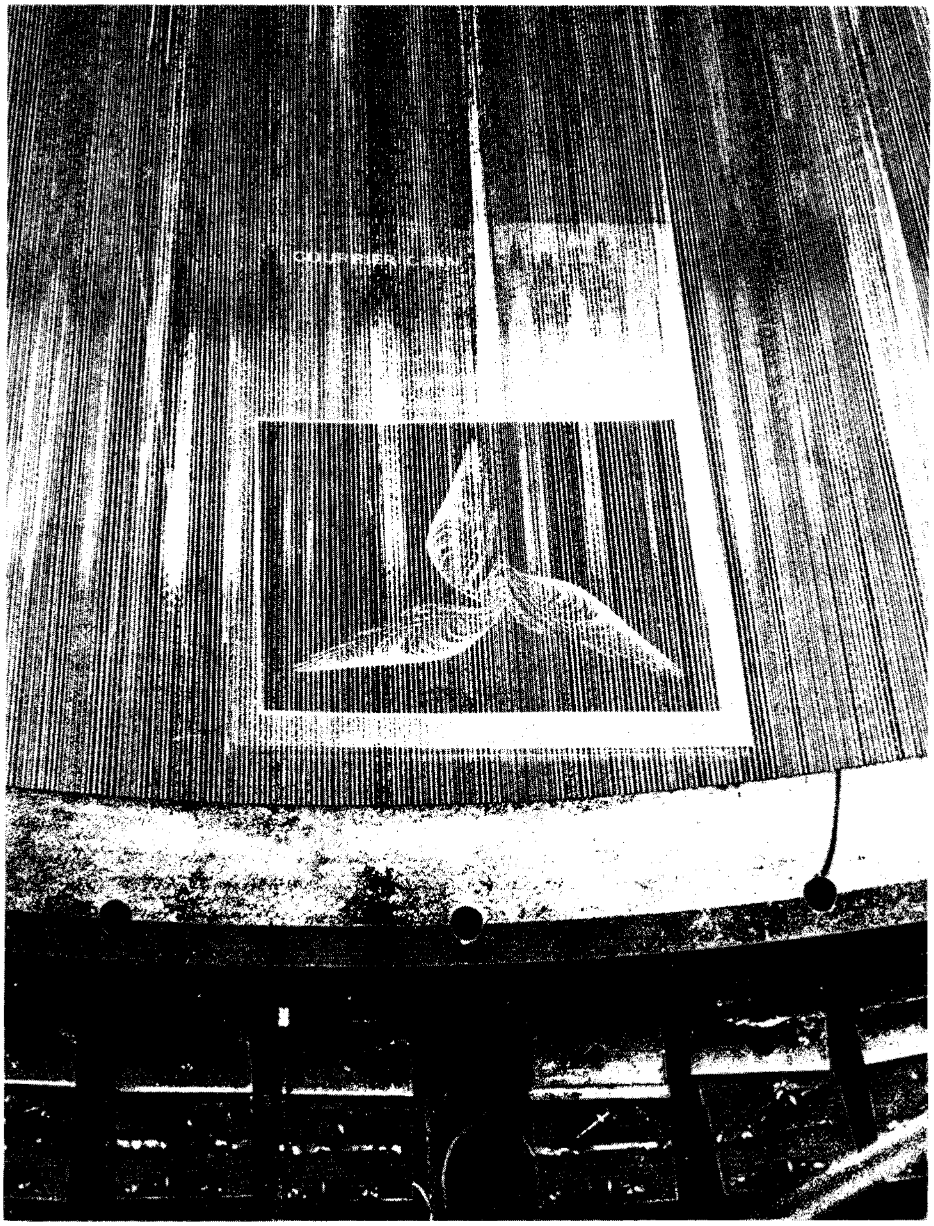
IN2P3
Establishing centre at Annecy

Construction of a Nuclear Physics Institute is now in progress at Annecy in France (45 km from CERN). It is to be a research centre specifically for the French National Institute of Nuclear Physics and Particle Physics, known abbreviatedly as IN2P3. The aim is to have a laboratory close to CERN which can serve as a base for the physicists who are using the major CERN facilities and preparing for the future SPS experiments. Most of the physicists will come from the High Energy Division of the IPN at Orsay.

The construction is on a 45-hectare site specially set aside for the development of the University of Annecy as part of the University of Savoie. Building is scheduled for completion in July 1976 when Professor M. Vivargent, who is in charge of the project, will be appointed the Director. It is intended that personnel will include thirty-five physicists and about fifty technicians and administrative staff, whose task will be to prepare and carry out experiments at CERN. A programme has already been drawn up, comprising experiments at present under way at the PS — the systematic investigation of heavy mass particles, such as the J/ψ, with the symmetrical

The curtains of wires of a cylindrical multiwire proportional chamber built at Orsay to look at the events produced by colliding electron-positron beams in the new storage rings, DCI. Behind the wires can be seen a not unfamiliar journal. One could say that the appearance of CERN COURIER is always an event...

(Photo Orsay)



bispectrometer (in collaboration with a team from IISN Brussels) and the study of spin-dependent effects in proton-proton interactions (in collaboration with CERN and Oxford teams). It also includes current ISR experiments — the study of isobaric production in the I-4 interaction region (in collaboration with teams from CERN, Hamburg and Vienna) and the study of large-angle correlations (in collaboration with Scandinavian and MIT teams). Finally the programme covers experiments in preparation for the SPS — study of large-momentum transfer hadronic elastic interactions (in collaboration with teams from CERN, Genoa, Oslo and University College London) and a study of muon inelastic scattering using a large spectrometer, as part of a European collaboration.

ORSAY
Cylindrical detector accurate and transparent

A solenoid magnetic detector, which will be installed on the new DCI electron-positron colliding beam machine at Orsay (see July issue, page 229), is being used at present on the smaller storage ring ACO. It has been in operation for nine months.

The detector was designed during the very first few months following the development of multiwire proportional chambers at CERN, and has incorporated the most sophisticated features of this type of chamber. The solenoid sets up a field of 0.9 T and encloses four concentric cylindrical proportional chambers 0.26 to 1.60 m in diameter and 0.5 to 1.06 m long. This particular geometry gives an acceptance of 2π in the azimuthal plane. Multiple scattering is minimised by the extreme transparency of the chambers (6×10^{-4} radiation length).

A problem with these techniques is to measure both co-ordinates with a single chamber. A novel method involving detection in the cathode plane in conjunction with the traditional method of detection in the anode plane has been developed and has been in use at the Laboratory for four years. The chamber has anode wires parallel to the axis and two sets of cathode wires inclined at ± 45° to the anode wire direction supported by coated glass fibres. This array makes it possible to locate the track of a charged particle to within 0.6 mm. The accuracy of the cathode measurement is very nearly as good as that of the anode measurement, which is difficult to achieve in this type of detector.

A charged particle describes a helical trajectory in the solenoid and is picked out by four readings, making it possible to measure the momentum to within 0.5 %. The data is read-out by an on-line computer from amplifiers associated with each of the 11 520 anode or cathode wires. The events may be monitored during the experiment on a display screen. A new measurement of the form factor of the pion at low energy has already been made using this detector.

DUBNA
News on relativistic nuclear physics

'Relativistic nuclear physics' is a new trend, on the boundary between high energy nuclear physics and elementary particle physics. It embraces the field of multi-baryon phenomena, corresponding to the condition where a particle has momentum (p) very much greater than its mass (m).

One of the characteristic phenomena is the cumulative effect when a particle, such as a pion, receives energy from a group of nucleons in a relativistic nucleus. In 1971, it was announced that Dubna had seen such an effect in the production of pions by relativistic deuterons. These experiments also proved the scale invariance of the interaction of relativistic nuclei with hadrons, as A.M. Baldin, Director of the Laboratory of High Energy, predicted.

The ratio of the differential cross-sections of pion production by deuterons and by protons at zero degrees for the same p/p_{max} ratio was found to be independent of the energy of the incident particles and of the pions produced. The experiments were carried with 11 GeV deuterons, from the synchro-phasotron.

Since these first results, research in the field of relativistic nuclear physics has progressed in various directions using a variety of techniques.

The group led by V.S. Stavinskij has investigated meson production on various nuclei looking at the backward pions produced in the collision of a nucleus at rest bombarded by a proton. Investigations were made with the nuclei of ^{6}Li, ^{7}Li, C, Al, Cu, ^{144}Sm, ^{154}Sm, ^{182}W, ^{186}W, and Pb and it was shown that the invariant cross-section of cumulative pion production increases practically linearly with atomic weight.

With higher cumulative orders (increasing the number of nucleons of the fragmenting nucleus) and with secondary particles other than pions, the exponent in the dependence of the cross-section on the atomic number, A, becomes greater than unity. The dependences of the cross-section on the atomic number were determined up to A^2 (when the secondary particle is a deuteron). These dependences confirm the existence of group and collective dependences of nucleons in nuclei. Scale invariance of the particle production cross-section was also shown to apply in the region of cumulative orders higher than 2.

Studies have been made of proton emission in the backward direction during high energy pion interactions with carbon nuclei. These experiments were carried out in a 2 m propane bubble chamber exposed to a 40 GeV meson beam at Serpukhov. It was found that in processes where the proton is emitted backward with a momentum of over 300 MeV/c, (i.e. when the cumulative effect takes place) scale invariance is observed in the 5 to 40 GeV energy range. Research into the cumulative effect is continuing.

Other experiments at Dubna involve a 17 GeV alpha particle beam directed onto the SKM-200 installation, the main part of which is a 2 m streamer chamber in a magnetic field. The main aim is to study the characteristics of the interaction of relativistic nuclei with other nuclei. At present studies are being carried out on the interaction of alphas with lithium nuclei in a target inserted in the streamer chamber.

Emulsions have been irradiated in beams of relativistic deuterons and alpha-particles and the initial results on the interactions with the emulsion nuclei give information on total inelastic cross-sections.

Preparatory work is being carried out in order to direct beams of relativistic nuclei from the synchro-phasotron to the bubble chambers — 2 m propane, 1 m hydrogen and 26 litre xenon chambers.

A big programme of research is under way at the synchro-phasotron bombarding a thin internal target. Slow recoil protons are recorded by telescopes of semiconductor detectors. This original technique was successfully used in experiments at Serpukhov and at the FermiLab. The current programme concerns studies of elastic scattering of nuclei on nuclei and the fragmentation of a fast primary nucleus and the target nucleus.

Similar to the experiments carried out with a thin internal target at Dubna are the collaborative experiments which are part of a Soviet-American Agreement for scientific and technical co-operation. The forthcoming work includes a study of elastic and inelastic proton-helium scattering at the 400 GeV FermiLab accelerator

For research in relativistic nuclear physics, it is desirable to accelerate heavy nuclei also. To obtain such beams it is preferable first to strip the atoms of all orbiting electrons in an ion source. Preliminary acceleration can then be carried out with the usual injectors and they can subsequently be accelerated in a synchrotron. Development work is being carried out at Dubna on a cryogenic variant of the electron-beam source of multi-charged ions (KRION) which is already able to produce beams of nuclei of elements with Z from 6 to 10 with an intensity of 10^{10} particles per pulse and also highly-charged ions such as A^{+15}, Xe^{+29}.

Ionization in this source is produced by a magnetically focused electron beam which has a current density which increases during the pulse. To fully ionize nitrogen atoms in the KRION electron beam, it is necessary to hold the ions in the electron beam region for 40 to 50 ms while the beam density rises to 30 A/cm². A vacuum of 2×10^{11} torr in this region is produced by cryosorption. A superconducting solenoid (1.5 T) focuses the beam. The length of the source is 1 m, the quantity of liquid helium stored is 20 l and the consumption of liquid helium 0.2 l/hour. To obtain beams of nuclei of heavier elements, the current density of the electron beam in the source needs to be increased.

The prospects offered by research in the field of relativistic nuclear physics depend on being able to make a detailed study of the asymptotic region of the interaction of relativistic nuclei. The need for investigations in this field is dictated primarily by the development of the physics of strong interactions requiring the investigation of complex systems. Important features of collisions of relativistic nuclei compared with collisions of particles are — the internal structure of the colliding objects is known (at least in the non-relativistic region) and the quantum numbers of the colliding objects can be varied over a wide range; investigations can be made into multiple processes when many particles are present and not only into the final state (cumulative effects); it is possible to make more justified use of statistical and hydro-dynamical approaches since averaging is over at greater number of configurations. The nuclei may serve as a realistic quark model of the relativistic object.

To investigate this asymptotic region, the energy level in the Dubna synchro-phasotron (up to 5.5 GeV/c per nucleon) is not high enough. It seems essential to have an energy of at least 10 to 15 GeV per nucleon. ubna has therefore prepared a proposal for constructing a cryogenic accelerator for relativistic nuclei — a nucleotron with an energy of about 15 to 20 GeV per nucleon, able to accelerate the nuclei of light and medium elements. An analysis of the list of problems that can be tackled by experiments on a nucleotron, covering an extremely wide range of questions, shows that the nucleotron could become a very useful adjunct to the family of existing and planned high energy accelerators.

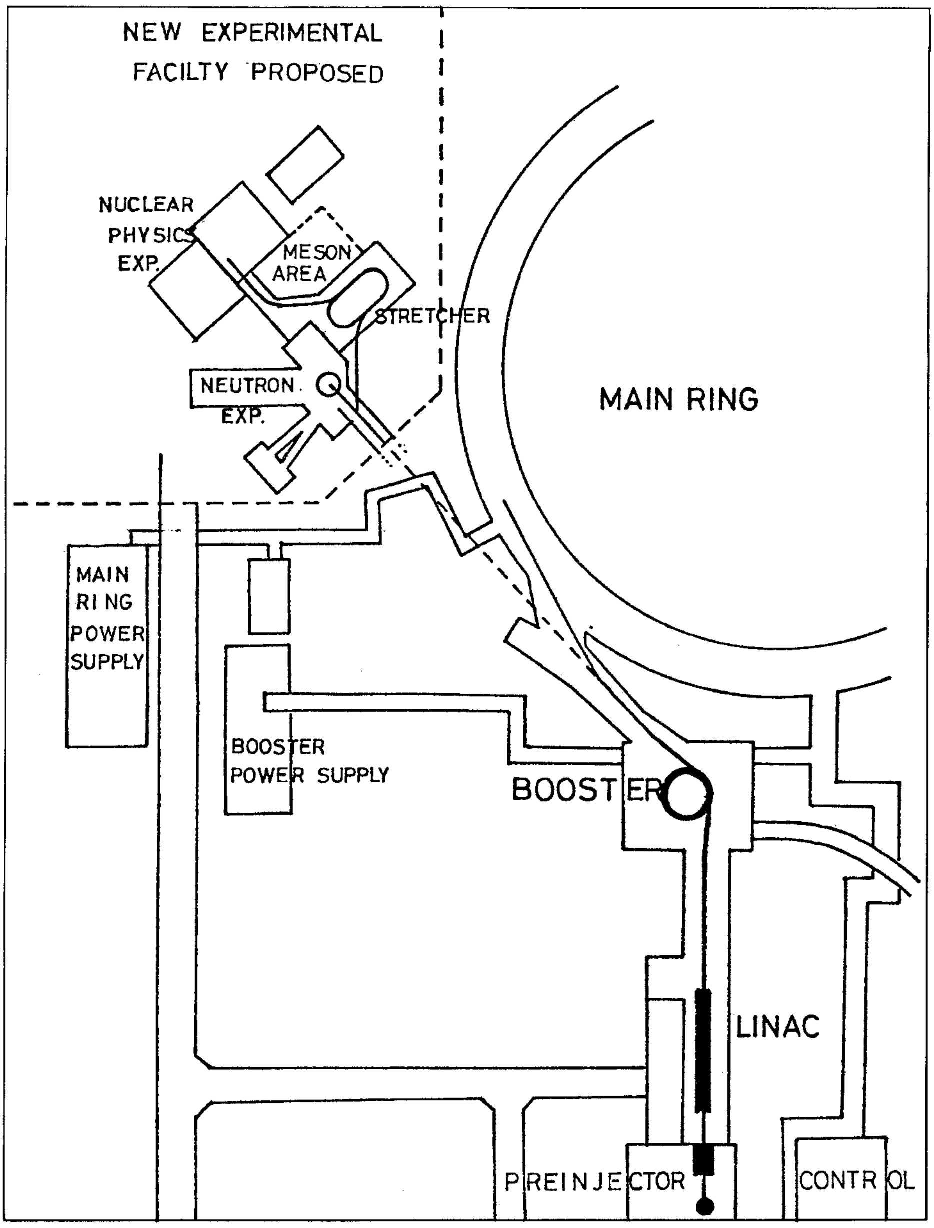
KEK
Boosting the booster

Construction of the 12 GeV proton synchrotron at the National Laboratory for High Energy Physics, KEK, in Japan proceeds on schedule. During the summer, tests on the 500 MeV booster continued and some important decisions were taken.

The 20 MeV linac has virtually reached its design intensity of 100 mA. A 95 mA beam at 20 MeV was achieved during a test run from an input of 200 mA at 750 keV provided by the preinjector. The ion source is in fact providing a 260 mA pulse, 60 mA being lost at present during transfer to the linac tank.

It has proved difficult to accelerate these high intensities through the booster. The r.f. voltage pulse appears to be too short and the resulting 'bucket' where the protons are captured and accelerated is too small. It has therefore been decided to add another r.f. cavity to spread the bucket.

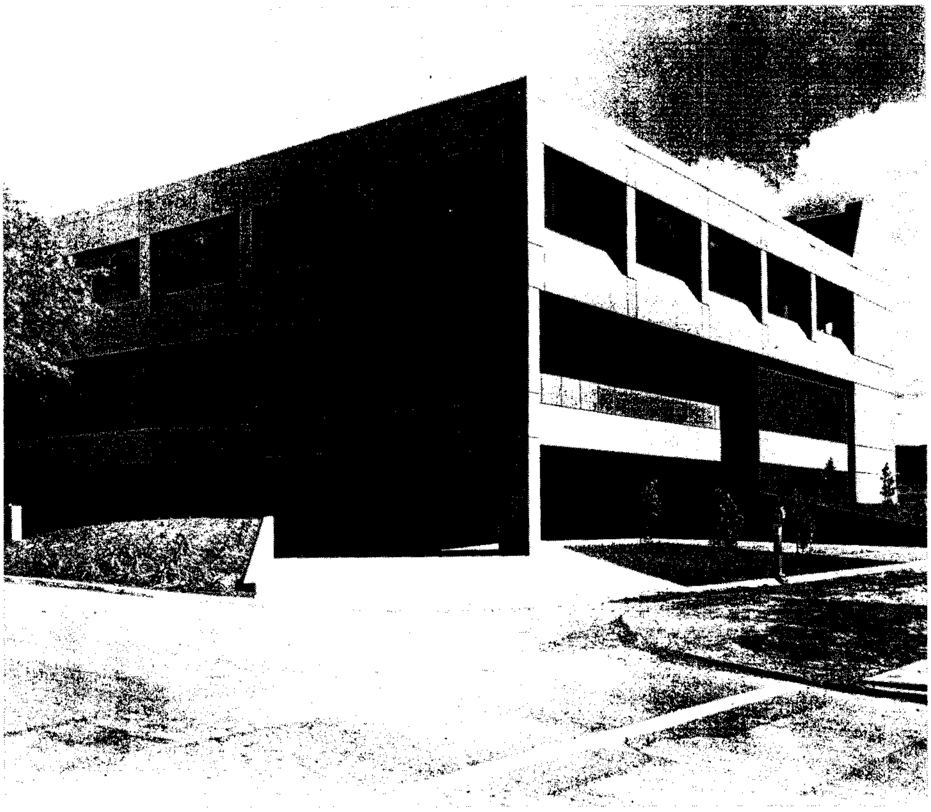
A new facility is being proposed to make use of the abilities of the linac



Layout of the injection units of the 12 GeV proton synchrotron nearing completion in Japan. It shows the location of the proposed new experimental facility for nuclear and medical experiments which would make use of the 'spare' 500 MeV protons which will be available from the booster.

The new computer building, which has recently been completed and occupied at Stanford, looking serene in its Californian setting. It houses the Laboratory's IBM computers which are extensively used in 'real time' data processing on-line to experiments. The computer system is also used by IBM for 'field tests' in developing advanced software.

(Photo SLAC)



and booster to provide more 500 MeV proton pulses than the main 12 GeV ring can swallow (only nine pulses out of twenty). It emerged as a joint proposal from a nuclear physics experimental group and a neutron diffraction research group. Doctors in a cancer therapy group have also started to study the application of the proton beam for medical treatment.

A proposal is being put together ready for a budget request for 1976. It involves a pulsed magnet, along the transfer line between the booster and the main ring, deflecting some of the 500 MeV beam pulses to a new experimental facility.

RUTHERFORD Laser facility

On 3 October, the UK Science Research Council announced that it is establishing central laser facilities at the Rutherford Laboratory for the use of University scientists. The initial investment of £1 million will cover the purchase of a versatile high power neodymium glass laser plus diagnostic and experimental equipment. The total cost of providing and operating the facilities over the next six years is foreseen as £ 5.7 million and there will be a development programme on laser and optical technology which may lead to the use of higher power lasers in the future.

This decision follows a study by a Committee chaired by D.J. Bradley. It aims to sustain the high quality of the UK research programmes involving high power laser pulses, in the light (no pun intended) of progress in other countries, particularly the USA, USSR, Japan, France and Germany.

The research programme will tackle subjects such as — very dense plasmas produced by laser compression; nonlinear interactions of laser radiation with matter; laser development... The possible use of laser beams to induce controlled fusion reactions (which has been promoted perhaps rather prematurely) is not a direct part of the programme but if such a possibility is to be investigated in the UK at a later stage, the information coming from the research at the Rutherford Laboratory would be an important input.

The main high power laser system will be capable of power densities of over 10^9 MW per cm^2, the laser delivering 10 J in 100 ps (rod amplifier) or over 200 J in 300 ps (disc amplifier). Extension to higher powers could readily be made. It will be possible to split the disc amplifier output into two beams to give symmetrical irradiations.

The complete system is expected to be in operation, initially in temporary accommodation, fifteen months from the time it is ordered. The broad support for the University scientists, which can be provided by the experienced Rutherford Laboratory, should further strengthen the UK research effort in this field.

BROOKHAVEN ISABELLE magnet outdoes design requirement

On 6 October, a prototype superconducting magnet for the proposed 200 GeV proton storage rings, ISABELLE, topped the design field of 4 T the first time it was powered. The magnet is a full size prototype 4.25 m long. A preliminary look at the field quality in the dipole (not at the ends) indicates that the field harmonics are also at the levels which would be appropriate for the operation of ISABELLE.

At the time of writing, no detailed measurements of field quality have been made. The magnet has been powered once more and quenched at the same field level though the operating temperature was slightly higher (4.7 K compared to 4.3 K). This may indicate that the magnet will train to higher fields.

This is the second full size superconducting dipole to be built. The first, whose performance was reported in the September issue, page 273, was hardly a fair test of the design since it was built in a considerable hurry. To have hit the jackpot with the second without any training of the magnet is making the ISABELLE project people very happy.

ARGONNE
Record energy for polarized protons

On 30 September, polarized protons were accelerated in the Argonne Zero Gradient Synchrotron to a new peak momentum of 12 GeV/c. The climb to this new high energy was accomplished in only 30 hours of machine development time despite the fact that five new depolarizing resonances (two strong and three weak) had to be crossed in going beyond the previous peak.

In July 1973, the ZGS became the first accelerator to give polarized proton beams of GeV energy. Since then, operation with polarized protons has been limited to energies of 6 GeV for lack of funds and because of limitations in the beam-lines used to convey the polarized protons to experiments. There has, however, been plenty of original work to do with polarised beams up to 6 GeV. Now things are ready for higher energies. A new beam-line with superconducting magnets is being installed to take 12 GeV polarized protons to the Effective Mass Spectrometer (see October issue 1974) and they can also be taken to the 12 foot bubble chamber.

The speed with which the beam energy could be taken higher is a consequence of several improvements since the 1973 tests when two weeks work was needed to achieve 6 GeV. The higher beam intensity and the use of a fast polarimeter made it much easier to locate and cross the depolarized resonances by means of rapid tune shifts using a pulsed quadrupole system.

Improvements in the polarized ion source and in acceleration efficiency give a beam over an order of magnitude more intense than was available two years ago. The fast polarimeter was developed by the group of C. Johnson at CERN and taken to the ZGS for testing. It consists of two telescopes each with three counters looking at the recoil particles from a small polyethylene target mounted in the extracted beam just outside the accelerator ring. Absolute measurement of the polarization was performed, as before, with a polarimeter consisting of a pair of double arm spectrometers.

At 9.5 GeV/c, when the last strong resonance was crossed, the proton beam polarization was measured as 67 ± 12 % and no change was seen up to 12 GeV/c using the CERN polarimeter. (At the time of writing the absolute value at the highest energies has not been checked.)

A month of ZGS operation with 12 GeV polarized protons has now been scheduled for February of next year and further time is anticipated later in the year. On the basis of the September tests the experimenters can expect an intensity of around 5×10^9 polarized protons per pulse in the extracted beam.

The availability of high energy polarized protons makes possible a series of measurements on proton-proton elastic scattering for the first time in the GeV energy range. This will determine experimentally the amplitudes that govern the process. Because each particle in the initial and final states has spin 1/2, a minimum of nine independent measurements are required to make a unique determination of the amplitudes (assuming parity conservation and time reversal invariance). These measurements are being made by an Argonne-Northwestern group mainly at a beam momentum of 6 GeV/c. An array of proportional wire chambers is used to detect both scattered and recoil protons emerging from a polarized proton target.

The first measurements have used the polarized beam in conjunction with an ethylene glycol polarized target in which the proton spins are aligned vertically, approximately normal to the scattering plane. The polarization of the proton beam, as it comes from the ZGS, is also in the vertical direction. However, the number of independent measurements that can be made with the spin directions normal to the scattering plane is limited and measurements with the polarization oriented in the scattering plane are also required.

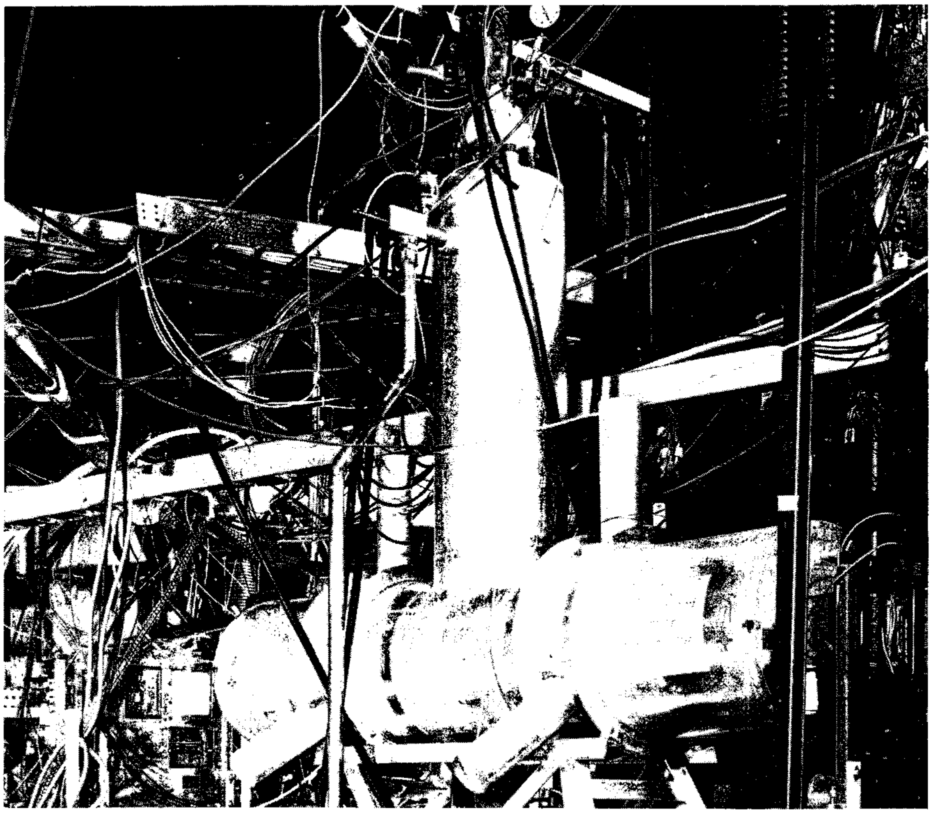
For this purpose, a new superconducting spin-tipping magnet has been put into service. The solenoid rotates the spins of the beam protons by 90° about the beam direction as they pass through it. It is a cold bore magnet designed and fabricated by American Magnetics Inc., in collaboration with Argonne, and the cryostat was built by Cryogenic Associates. The coil winding is 12.25 cm inner diameter and 178 cm long. The operational current is 420 A, producing an integral field of 11.3 T.m for 6 GeV/c operation. The magnet has been in operation at the ZGS for several months without any problems.

A polarimeter has recently been

added to measure the polarization of the recoil protons. It consists of a block of carbon with two proportional wire chambers on either side. The spin of the recoil proton is analyzed by a second scattering in the carbon, detected by the multiwire proportional chambers. The polarimeter can be used to analyze polarization components transverse to the recoil particles direction of motion, both normal to the scattering plane and in the scattering plane.

The combination of all these elements has allowed the first measurement at high energies of a triple spin-correlation parameter, denoted as (S, N; 0, S). In this notation the spin orientation of all four particles is given in the order: beam, target; scattered particle, recoil. Polarization normal to the production plane is denoted by N, along the particle direction by L, and transverse to these two by S. A zero denotes that the particle spin is not observed. In this notation, a conventional polarized target scattering experiment measures (0, N; 0, 0) which is the polarization parameter. Earlier experiments at the ZGS have measured such quantities as (N, N; 0, 0) or (0, N; 0, N). In addition to the triple-spin correlation measurement, the present experiment can measure (S, 0; 0, S), by averaging over the target polarization, and (0, N; 0, N), by averaging over the beam polarization and detecting a recoil particle in the polarimeter in the plane of the first scattering.

The next step will be to use a target which can be polarized in the scattering plane, providing L- and S-type target polarizations. For this, the present polarized target magnet will be replaced by a pair of superconducting Helmholtz coils with the field direction in the horizontal plane. This magnet has been built and successfully tested and will soon be installed for operation in the experiment next year.



The spin-tipping solenoid installed on the extracted polarized proton beam at Argonne which rotates proton spins in the incoming beam by 90° as they pass along its bore. It has been in operation for several months without problems. The tangle of wires is also associated with the polarized proton target and proportional wire chamber detectors of the experiment which are barely distinguishable on the left of the photograph.

(Photo Argonne)

FERMILAB
On computing

Computing for the experimental programme at the 400 GeV proton synchrotron of the Fermi National Accelerator Laboratory covers three basic tasks — on-line computing at the experiments themselves, 'fast turnaround' computing to back up experiments taking data and batch processing of the bulk of the experimental data.

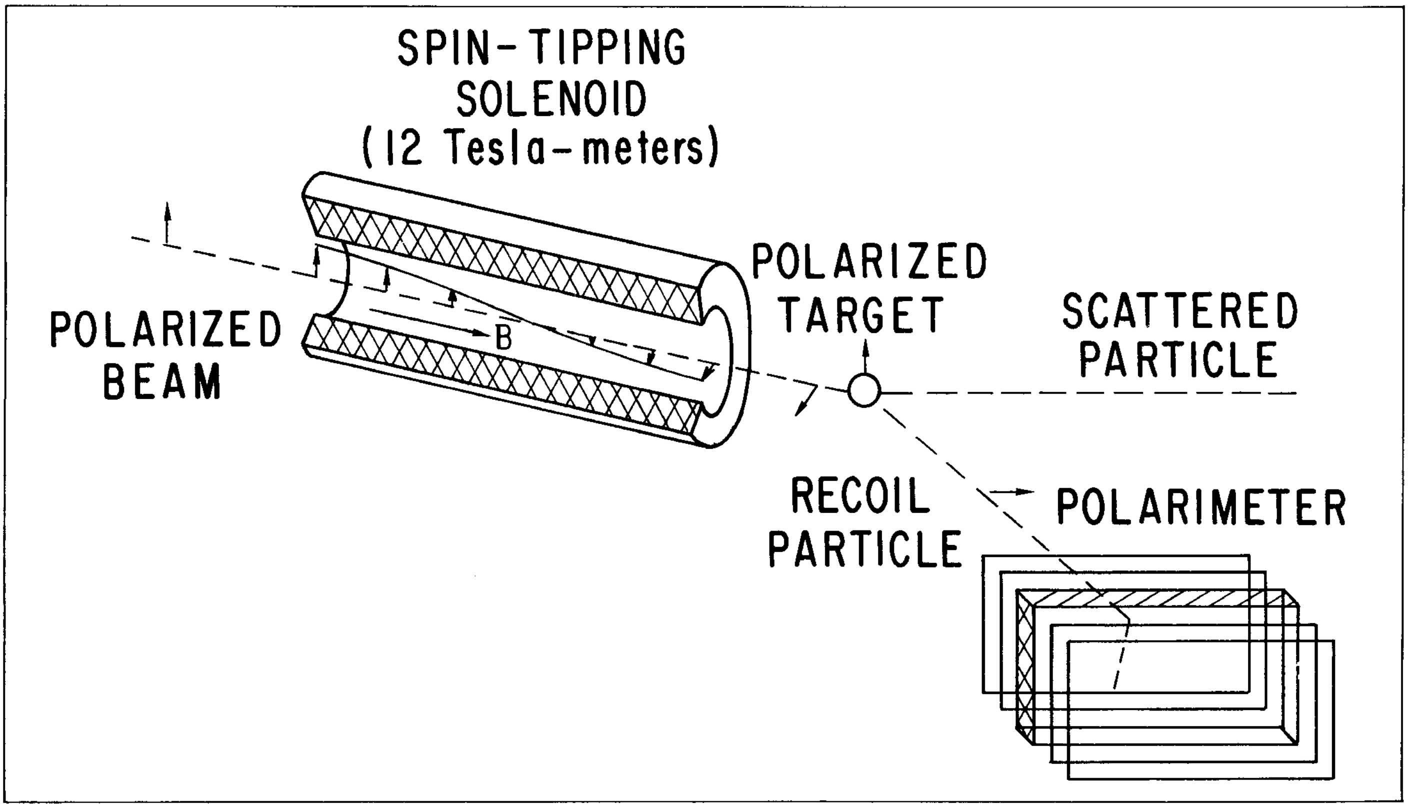
About 35 small computers are involved in on-line computing (mainly PDP-11s used in a Fermilab configuration called BISON — Basic Instrument for the Support of On-line Needs). Fast turn-around computing is implemented in the computer centre in a room on the 7th floor of the Hi-rise building. A CDC 6600 (131 kwords of memory) has been installed there since 1973. Its capacity became saturated this year and a second CDC (65 kwords of memory) was installed in the summer of this year. The two computers will be linked together in November and are expected to cater for the computing needs through to the middle of next year.

A broad band data communications network (BISON-NET) links the central computers to the small on-line computers enabling sample checks on data to be made in 'real time'. The production prototype modules for BISON-NET are installed.

Remote job entry terminals are also being developed. They will be able to talk to either the Fermilab computer centre or the IBM 370/195 at the Argonne National Laboratory.

The installed computing facilities at the Laboratory are limited, mainly due to the restricted financial resources, and there are long range plans for major new equipment to cater for the needs into the 1980s. Nevertheless, the Fermilab expects to be able to

Schematic diagram of the experiment measuring the 'triple spin correlation parameter' in proton-proton elastic scattering. It requires the high energy polarized proton beam from the Argonne Zero Gradient Synchrotron, a spin-tipping superconducting solenoid to rotate the proton spins, a polarized target and a polarimeter to analyze the spin of the recoil proton.



maintain a 'lean but adequate and responsive computer capability'. (A report by A.E. Brenner on the computing service appears in the September issue of NALREP.)

TRIUMF
Cyclotron performance

The cyclotron at the TRIUMF Laboratory in Canada is now in regular operation and experiments are well under way. Proton beams with energies between 180 to 520 MeV have been extracted and a 48 μA average current was accelerated in a pulsed mode (100 μs/10 ms). (In normal operation currents are kept lower to keep radioactivity problems manageable.)

The machine is operated on a 4 days/week schedule, 24 hours per day, over periods of eight weeks followed by a few weeks shutdown to take a look inside the cyclotron and to implement improvements. Three 8 hour shifts per week go to machine development, the rest of the time going to feeding two beams simultaneously to experiments. There are two experimental halls on opposite sides of the machine. Extracted beam currents are held down to 300 nA in the 'Meson Hall' and 50 nA in the 'Proton Hall'.

The cyclotron has a unique ability to send beams of independently variable energy and intensity to the two experimental halls which can thus have their schedules fixed independent of one another. This is possible because of the acceleration of negative hydrogen ions. The ions are stripped by introducing targets into the magnet gap yielding protons which are then bent out of the machine by the field which was holding in the negative ions. The radial location of the targets dictates the energy of the emerging protons and the extent to which the targets protrude into the beam sets the relative intensities of the emerging beams (the absolute intensities being set by controlling the intensity at injection). The successful performance of these systems has been one of the most gratifying features of the cyclotron operation. In general, conditions are so reproducible that it may soon be possible to let a computer set up the operating parameters.

Machine development is concentrating on slowly increasing the intensity towards 100 μA, improving beam quality (reducing the emittance), achieving better vacuum conditions (10^{-8} Torr rather than 2×10^{-7} Torr), accelerating polarized ions (300 nA with 80% polarization have been obtained from a Lamb shift type ion source), and installing a third harmonic r.f. amplifier to give separated turn acceleration which will reduce energy spread to 100 keV at 500 MeV.

CERN News

The SPS control room. In the foreground is the console which is now integrated into the control system. The top left and top right consoles are used for simulation runs and safety monitoring respectively. ▶

PS comes on again

As we reported in the September issue (page 269), on 29 August a fire broke out near the South Hall of the proton synchrotron. Besides damage due to the fire itself, there has been considerable secondary damage caused by hydrochloric acid from the interaction of burning PVC insulation and humidity. The PS power station, the power supplies for the auxiliary magnets, poleface windings and the injection correction components, timing circuits, the hydraulics of fast kicker magnet 97 and many other pieces of equipment in the South Hall extension were all damaged to some extent, depending on how close they were to the fire.

Thanks to the advice of J. Birabeau from the Surface Treatment workshop, a lot of electronic equipment was saved by fast cleaning action during the week-end following the fire. Later, two specialist firms (Reichenberger and Allianz) helped by providing the materials and the technical instructions for cleaning up the corroding electrical and electronic equipment.

Rebuilding of the damaged equipment started in parallel with the cleaning operations and on 10 September the Linac started up again with a provisional power line. On 15 September the Booster was able to take up the running with some machine experiments and the target date of 24 September for the start-up of the whole machine was achieved. This was thanks to great efforts, from both inside the PS Division and outside (mainly the Site and Buildings Divisions), helping those responsible for the damaged material.

The physics programme is being operated at a reduced level for a few weeks having started as planned on 25 September with internal targets 1 and 8 sharing beam at 19 GeV/c. The beam energy was not higher because of the non-availability of the poleface winding power supply but the spill length was increased (600 ms) and the repetition time was faster (1.8 s) than usual. Filling of the Intersecting Storage Rings was done at 15 GeV/c. It proved possible to adjust the machine intensity to the level needed by the users (1.5×10^{12} protons per pulse for the internal targets and 2×10^{12} ppp for the ISR), despite the fact that the low energy corrections were not usable, thanks to the use of the Booster in injection. The next step, on 10 October, was to increase the energy to the usual levels of 26-24 GeV/c using a power supply provided and adjusted to the characteristics of the poleface windings supply by ISR staff. Slow ejection 62 could also start at that date. For the following run, after an eight day stop (instead of 10 days initially foreseen), it will almost be possible to carry out the normal experimental programme, though with many provisional solutions. The effects of the fire are likely to be around till Christmas.

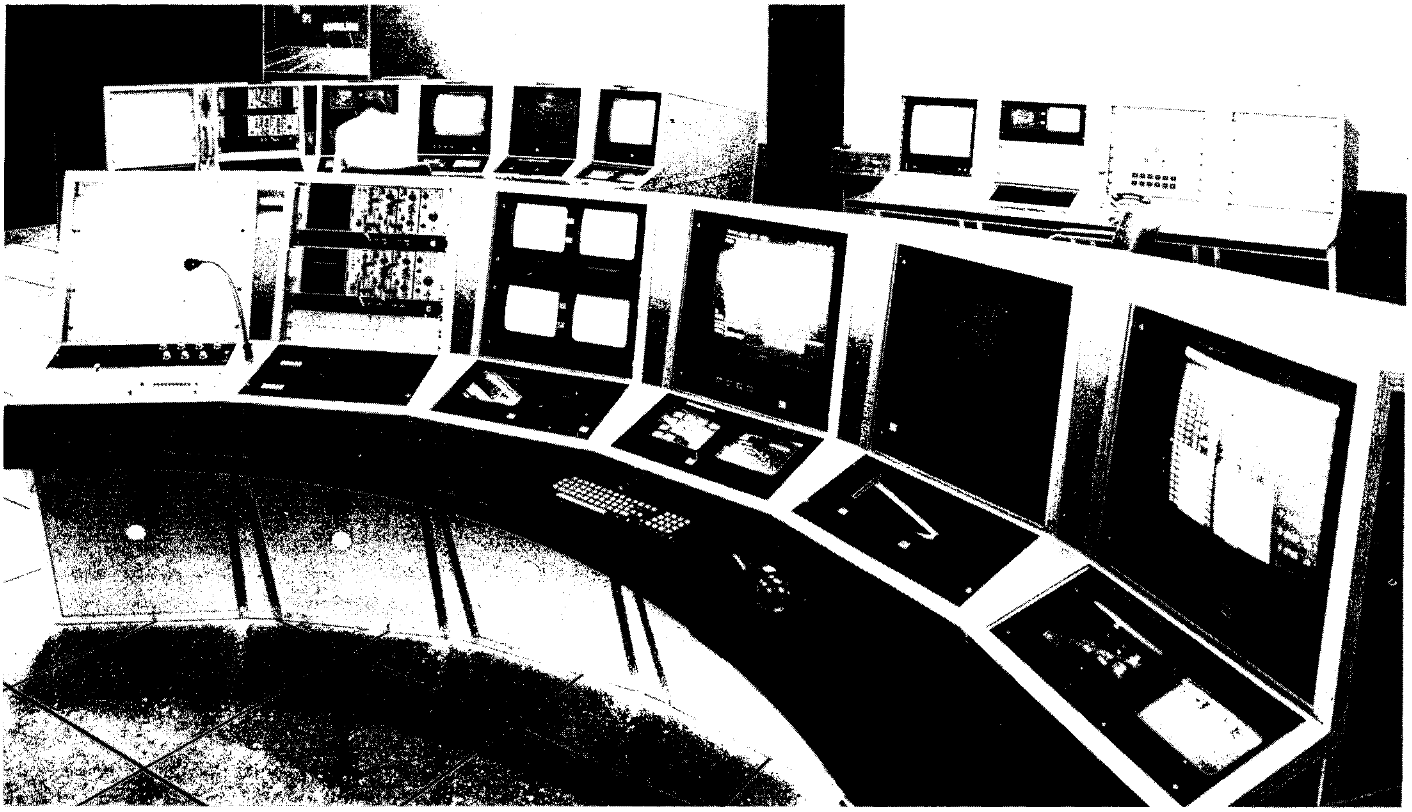
SPS control system taking shape

One of the control consoles of the 400 GeV proton synchrotron is now connected via its computer and the message transfer system to the satellite computers which directly monitor and control the machine components. Dialogue tests with the computers have been under way since the beginning of August and the entire system seems to be operating well.

All twenty-four NORD-10 computers initially ordered have been on site for some time and seventeen of them are now installed in their destined positions. The others are in action in the laboratories and the assembly hall,

On 23 September Academician P.L. Kapitza visited the CERN Laboratories. He is pictured here (right) down the tunnel of the 400 GeV proton synchrotron listening to the explanations of R. Levy-Mandel.

CERN 310.9.75



CERN 152.9.75

where they are used for adjusting and testing SPS equipment. This use has made it possible to check the reliability of the computers, which has proved well up to specification, and to perfect the NODAL language which will be used in controlling the machine. NODAL is a very simple interpretative language which can be learned quickly by unspecialised personnel, thus allowing those directly responsible for machine components to compose their own monitoring programs.

The seven computers for the main control building are all now in place. The message transfer system, installed by TITN, has been used to transmit several million messages between computers and it has achieved the specified reliability. The control room has three man-machine dialogue consoles and a fourth, simpler one, for monitoring and safety. Console No. 1 has been operating in the simulation mode since Easter and is being used to develop programs and to test the man-machine dialogue. Console No. 2 is already linked to the message transfer system and, since the beginning of August, it is this console which has been involved in the tests of the chain — console / message transfer system / satellite computer.

The three consoles will be almost identical and the accelerator will normally be controlled from a single one of them. The others will be used for the separate control of particular components during machine study periods and to control beam-lines and experimental areas during periods of physics operation.

With the black-and-white and colour television display screens and the simple NODAL language, machine control should become child's play, once the system is properly run-in — given reasonably bright children.

SC going up

The 600 MeV synchro-cyclotron is gradually climbing towards the high level of performance which is the aim of the machine improvement programme. An internal beam intensity of 2.8 μA was achieved in September.

The repetition rate of the machine, which is controlled by the rotary condenser, will have to be raised in order to obtain the rated intensity of 10 μA. Only one in every two of the sixteen acceleration cycles in each turn of the rotor in the stator was used in attaining 2.8 μA. When all the cycles are in use, the repetition rate will be doubled, but before this is done a large number of precautions need to be taken. The equipment is highly sophisticated and has to be nursed very gradually to its maximum performance. Since there are two rotary condensers, changes can be made when necessary and weak points can be corrected as they are identified.

The voltages applied to the Dee electrode in the synchro-cyclotron will also have to be increased to raise the intensity further. The range so far used has been restricted to between 14 and 18 kV (varying during the cycle) while the electrode is designed to withstand a voltage of 30 kV. The effect of increasing the voltage is to capture and accelerate more particles. It is now possible to say that to attain 10 μA there will be no need to go much beyond 20 kV. This should ensure greater machine reliability, since it will be running well within its limits.

Measurements on the beam itself have shown that the amplitude of the radial and vertical oscillations is lower than 1 cm, a very good figure for this type of machine. Paradoxically, this excellent quality is a drawback when attempting to share the beam between an internal target and an extraction channel. It is much more difficult to split the present small beam precisely than it was with the old machine's larger one! Extraction efficiency is now at 70 % compared with the previous figure of 7 % (not 1 % as mentioned in the July issue).

Radiation problems, such as those associated with the useful life of the units of the internal targets, are also beginning to raise their heads. This will become more important as the intensity increases further. One solution, involving the eventual elimination of internal targets, is being considered but it requires new fitting out of experimental areas. The optimum solutions are seldom the cheapest.

A new machine trick which is now being used is to reverse the SC magnetic field and invert the central region so that the protons circulate in the opposite direction. This makes it possible to extract a wider variety of secondary particles from the internal targets. This operation is made easier by the central region arrangement, which allows it to be removed and inverted very quickly.

The efficiency of the beam transfer line to the ISOLDE isotope separator on-line, which comprises a 60 m beam-line, has now risen to 88 %, giving ISOLDE beams of high intensity.

Iron in the neutrino line

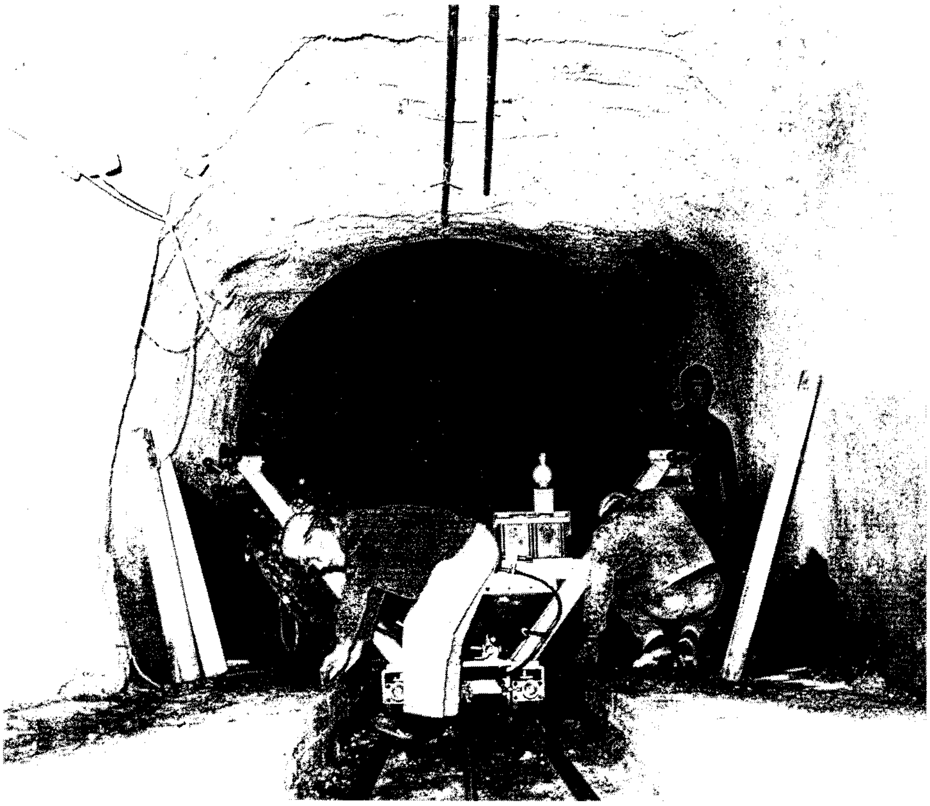
Work has started on the installation of the shielding which is designed to filter out all particles other than neutrinos en route from the 400 GeV proton synchrotron to the 3.7 m European Bubble Chamber, BEBC, ready for the neutrino experiments which will be an important part of the SPS programme.

To produce the neutrinos, protons from the SPS are directed onto a target near the accelerator ring giving rise to the production of pions and kaons with an average energy of around 40 GeV/c. A magnet will concentrate these particles into a 13 mrad cone and a second magnet, 90 m downstream, will further focus the beam. The pions and kaons will then enter a vacuum tube measuring 1.20 m in diameter and 300 m long, in which most of them will decay, giving rise to muons and neutrinos.

Once the neutrinos have been produced, all other particles, in particular the muons, have to be eliminated from the beam. This will be the task of the shielding, which is now being installed, comprising 170 m of iron (followed by 180 m of earth). Calculations show that this shielding (equivalent to 230 m of iron with a density of 7.2) will reduce the muon flux from 10^{13} to 10 in each machine pulse, under standard operating conditions.

The iron shielding is being erected in an underground tunnel with a 4 % slope, since the neutrino beam is climbing up from the underground SPS to BEBC at ground level. It consists of 425 iron discs, from which an arc is cut so that they can stand on the floor of the tunnel. Each disc, is 2.50 m in diameter, 40 cm thick, and weighs about 14 tons. They are lowered down a shaft, and run on a rail-mounted trolley to their desired location at a rate of ten per day. Gaps between the discs and the tunnel walls are then filled with concrete to stop particles which might otherwise sneak through. The concrete is of a type which does not adhere to the iron which can thus be readily salvaged at a later date if necessary. This is quite a substantial long-term investment.

A gap has been left in the shielding after the first ten metres for the installation of muon detectors and similar spaces will be left every 20 m so that detectors can monitor the muon flux progressively through the shielding. Positioning of the shielding will be complete by the end of the year.



Inside the tunnel which will house the iron shielding for the neutrino beam-line. The photograph shows a 14 ton disc which has been carried by a trolley on rails to the position in the tunnel where it is to be unloaded. 425 of these discs, each 2.50 m in diameter and 40 cm thick, will be installed to stop all particles other than neutrinos.

Recent discoveries in high energy physics

H. Schopper

At the 14th International Cosmic Ray Conference at Munich in August, Professor Schopper, Director of the DESY Laboratory, reviewed the recent findings. This is an abridged version of his talk. It is a little more specialised than we normally include but, for those who recall some of their physics education, it adds background to the arguments that we have been sketching in recent articles.

Why are physicists so excited about the new particle discoveries — the J or ψ family of particles found at Brookhaven, DESY and Stanford? First of all it had not been expected that bosons (spin = 1 particles) more than twenty times heavier than the lightest boson, the pion, would exist. In particular, the newly discovered bosons, J or ψ at 3.1 GeV, and ψ' at 3.7 GeV, do not fit in the well established quark classification scheme. Secondly, bosons with masses larger than 3 GeV have many possibilities to decay into lighter particles, yet the lifetimes of the J/ψ and ψ' are about 1000 times longer than expected. Finally, a new law of nature is necessary to understand these extremely long lifetimes and some of the particle decay properties.

Pointlike constituents of particles

Before discussing possible explanations of the new particles, there are other interesting results which were known before the discovery of the J and ψ particles and which have some bearing on their interpretation.

In 1973 there were already indications at the Cambridge Electron Accelerator that the cross-section for electron-positron annihilation had an anomalous behaviour above centre of mass energies of 2 GeV. If the annihilation into hadrons, particles feeling the strong force, is compared to the annihilation into pointlike particles, such as muons, we expect that the ratio of the cross-sections $R = \sigma\,(e^+ + e^- \rightarrow \text{hadrons})/\sigma\,(e^+ + e^- \rightarrow \text{muons})$ will be less than 1. This is because the coupling of the photon, produced in the electron-positron interaction to hadrons is reduced by destructive interference from the different parts of the hadron. Indeed for hadrons with a finite radius R should approach 0 if the energy gets very large.

If, however, the hadrons contain pointlike constituents (partons or quarks) R should approach a constant limit asymptotically. For example, it can be assumed that the photon converts into a quark-antiquark pair and the quarks subsequently decay into normal particles. The photon-quark coupling strength is given by the electric charges of the quarks and R should approach the value of the sum of all the charges squared. For the three well-known quarks with their charges of $(-1/3, -1/3, 2/3)$ we expected R to settle at 2/3. The experimental results demonstrate that R neither goes to zero nor approaches 2/3 but tends to rise even at the highest energies accessible at present. The full interpretation is still lacking but the behaviour of R indicates that the hadrons contain pointlike constituents and that there must be more such constituents than the three known quarks.

Possible explanations of the new particles

The possibility was considered that the new particles are leptons, feeling the weak interaction, which would explain their long lifetimes. However, several experiments showed that they are subject to the strong interaction and hence are hadrons of the boson type because of their spin 1. Knowing the coupling strength of the nuclear forces and the number of decay channels into lighter particles which are open, the decay width (which gives the lifetime via the uncertainty principle) of a hadron with a mass above 3 GeV should be 40 to 200 MeV whereas the measured widths are a thousand times smaller.

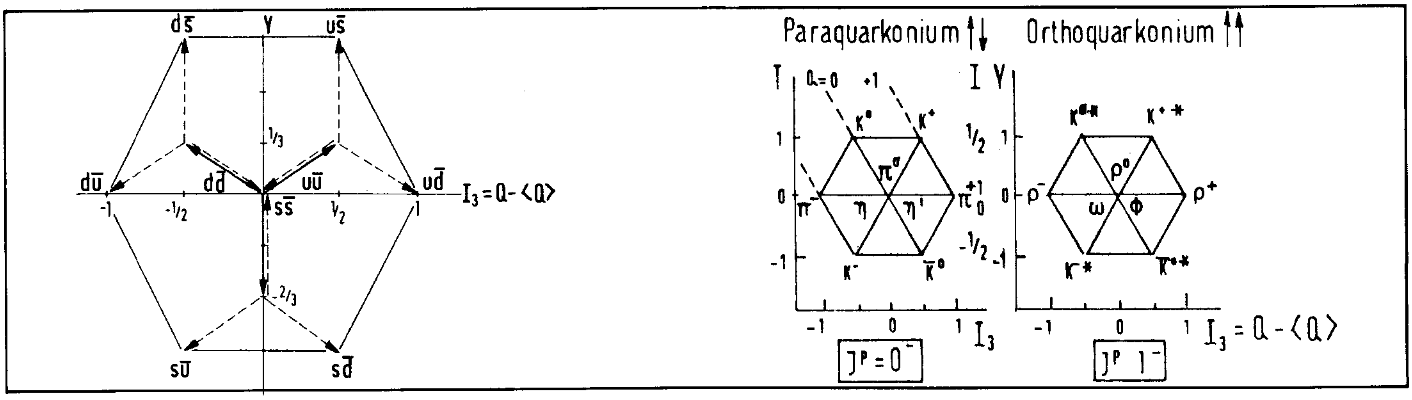
The explanations that have survived so far are theoretical models in which a new quantum number is introduced giving a new selection rule or symmetry principle which inhibits the decay. In terms of quarks, a new quantum number implies that the number of quarks has to be increased. I will describe the charm model based on four quarks; it is the simplest and, for my personal taste, the most attractive model. It is by no means clear which of the models will turn out to be correct, if any, but the most important qualitative features of the following description are likely to be incorporated in a future theory.

The usual quark model has three units, the u, d and s quarks, which are the building bricks of all the hadrons. The three quarks have spin 1/2 and baryon number 1/3. They are distinguished by their electric charges represented by the third component of isospin I_3 (u is isospin up and d is isospin down) and their hypercharge, Y, which is closely related to the strangeness quantum number (s is the 'strange' quark). Mesons can be obtained by combining a quark with an antiquark and baryons by combining three quarks (for example the proton is uud and the neutron is udd). The great success of the quark model is based on the fact that it accommodates all of the several hundred known hadrons into this classification scheme and, indeed, some previously unknown particles could be predicted.

The new particles, however, do not fit into the three quark model. To incorporate them, the existence of a fourth quark with a new quantum number, charm C = +1, has been proposed.

If we then construct the possible combinations of quark and antiquark given four of each, we arrive at a

The quark model of the mesons. All possible combinations of a quark (u, d, s) and antiquark ($\bar{u}$, $\bar{d}$, $\bar{s}$) to form a meson can be obtained by superimposing the triangle representing the antiquarks on the three edges of the quark triangle as shown on the left. It gives a group of nine particles, a nonet, and the three particles in the centre are combinations of a quark and its own antiquark.
Since the spins of the quark and antiquark can be parallel (ortho-quarkonium) or antiparallel (para-quarkonium) there should be two such nonets. In fact all the vector ($J^P = \bar{1}$) and pseudoscalar ($J^P = \bar{0}$) mesons found in Nature exactly fit the quark model predictions as indicated on the right.



three dimensional structure and there are three new particles D^+, D° and F^+, which are composed of a charmed and an ordinary quark, which should exist. They have the charm number $C = +1$ and their antiparticles have $C = -1$. In addition, there is one more particle composed of the charm quark and its antiquark (charmonium) having $C = +1 + -1 = 0$ (hidden charm). This state with parallel spins (orthocharmonium) is identified with the new particle J/ψ. The second new particle ψ′ is interpreted as the first radially excited state of orthocharmonium. This explains, among other things, why the ψ′ decays preferentially into the ground state J/ψ.

This interpretation opens a new field of charmonium spectroscopy. One of the results is that the binding energy in charmonium is small so that the mass of the charmed quark is roughly half of the J/ψ mass, i.e. about 1.6 GeV. From the 'ordinary' quarkonium system one can infer masses for the 'ordinary' quarks of the order 0.3 to 0.5 GeV and hence the charmed quark is much heavier. Using this knowledge one can estimate the masses of the charmed D and F particles — since they are composed of a charmed and an ordinary quark, we expect masses of about (1.6 + 0.4) = 2 GeV. Many searches for these particles have been performed but so far their existence has not been definitely established.

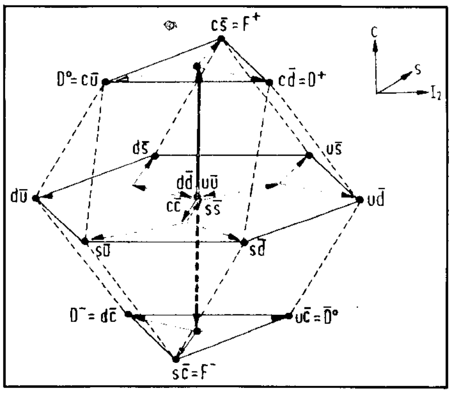
The reason for introducing a new quantum number was not only to fit the new particles into the quark scheme, but also to explain their narrow decay widths. This can be achieved by applying 'Zweig's rule' as described in the diagram below. It should be mentioned that Zweig's rule, which applies to all hadrons and not just to the new particles, is an empirical rule which is not yet understood.

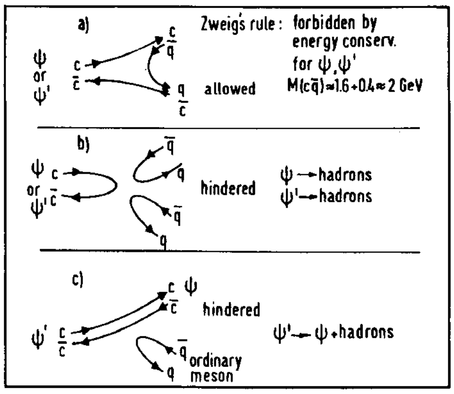
Charmonium spectroscopy and the P_c and X particles

The quark-antiquark state of a meson is a system similar to the proton-electron system in the hydrogen atom and one might hope to get a wealth of information from its possible energy levels, just as was achieved from the hydrogen atom earlier this century. For ordinary mesons, the quantitative treatment is difficult since ordinary quarks have a low mass and relativistic effects are important. For charmonium on the other hand the classical non-relativistic procedure should be quite adequate since the mass of the charmed quark is rather large. The good old Schroedinger equation becomes honourable again, except that the force binding the two quarks is not known. From field theoretical arguments, the force between two quarks should be rather weak at small distances becoming stronger at larger

Left: If we build mesons with four quarks (u, d, s, c) and four antiquarks ($\bar{u}$, $\bar{d}$, $\bar{s}$, $\bar{c}$) we get the structure shown. Compared to our three quark structure above, note the appearance of charmonium (c $\bar{c}$) at the centre which is believed to be the newly discovered J/ψ particle, and of the D and F particles containing a charm quark or antiquark.

Right: Possible decays of charmonium which are inhibited a) by energy conservation, b) and c) by 'Zweig's rule'. This empirical rule says that interactions which can be drawn with initial and final particles as throughgoing lines (representing the participating quarks and antiquarks) are allowed. Interactions involving unconnected loops are hindered.





Charmonium, consisting of a charm quark, c, and a charm antiquark, c̄. This is the most popular interpretation of the new particles. As with the proton-electron system of the hydrogen atom, there are several possible energy states of charmonium. Some of them are indicated, together with their angular momentum and spin designations. The particles which have so far been discovered (ψ, ψ', Pc, X) fit well into such an interpretation.

distances. (This might be a reason why quarks have not been separated.) Phenomenological fits to the energy level scheme of quarkonium use potentials with a distance, r, dependence which is in between a Coulomb potential (varying as 1/r) and a harmonic oscillator potential (varying as r^2). For these reasons, investigating charmonium could play a key role in understanding strong interactions by giving clearer information on the force acting between quarks.

As with the hydrogen atom, one expects different sequences of energy levels for charmonium according to the orbital angular momenta (the s, p, d, . . . levels) due to one quark moving around the other. The levels above the lowest level correspond to radial excitations. For a Coulomb potential the 1p and 2s energy levels are identical. Since the quark potential is supposed to be stronger than the Coulomb, the 1p should be lower than the 2s energy level in charmonium and hence the position of the 1p level could give valuable information on the quark potential.

Again analogously to the hydrogen atom, one has to introduce hyperfine splitting (HFS) and spin orbit splitting (LS) of the levels since the quarks have spin 1/2. The levels with opposite spin orientation (S = 0) are expected to be lower than those with parallel spin (S = 1). The LS coupling splits the p states with S = 1 into 3 states with $J = 0^+, 1^+, 2^+$.

Between the various levels, transitions are possible (again in complete analogy with the hydrogen atom) when the proper selection rules are observed. The transition $\psi' \rightarrow \psi + \pi\pi$ induced by the strong interaction is the strongest of all since the suppression, by Zweig's rule, does not reduce this transition probability to the magnitude of electromagnetic transitions. For electromagnetic transitions, parity conservation has the consequence that the orbital angular momentum must change by one unit.

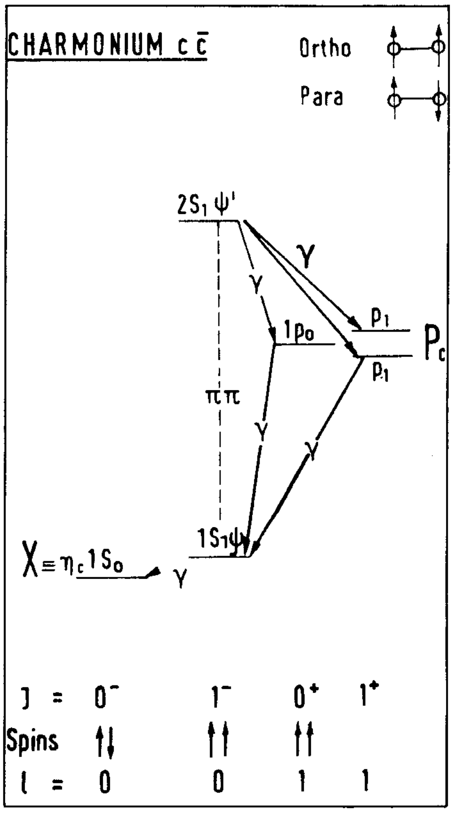
The transition ψ' (3.7) → ψ (3.1) + γ + γ was detected at DESY, proving the existence of an intermediate state which was named P_c. The energies of the gammas were found to be 160 and 420 MeV corresponding to a P_c mass of 3.52 or 3.26 GeV depending on the sequence in which the photons are emitted. Two states at 3.53 and 3.41 GeV have been identified also at Stanford by their decays into hadrons; the first could be identical with P_c. If these states are identified with the predicted states, we can draw the conclusion that the quark potential has indeed a stronger r dependence than the Coulomb potential and, secondly, the LS splitting is of the order of 100 MeV which is surprisingly large. (Maybe history is repeating itself since a large LS splitting in nuclei was originally met with scepticism.)

Also, at DESY, there is evidence for the decay ψ (3.1) → X (→ $\gamma\gamma$) + γ with the mass of X about 2.8 GeV. This could be the expected decay of paracharmonium (J = 1) into orthocharmonium by flipping the spins. If this interpretation is right, it implies a rather large (about 300 MeV) hyperfine splitting.

It seems that the predictions of the charm model are being verified one after the other with the exception of the detection of the charmed mesons, D and F. It must be mentioned, however, that some different theoretical approaches, particularly the colour model, can be made compatible with the data and much more experimental information is required before the whole question is settled.

The neutral current of the weak interaction

A different subject has a very interesting relationship with the new particle discoveries.



The electromagnetic interaction between two electrons can be described by the exchange of a photon. In a similar way, the weak interaction can be described by the exchange of an intermediate boson, W. There are two differences. The range of the interaction is (by the uncertainty principle) determined by the mass M_B of the boson as h/M_Bc. The infinite range of the electromagnetic force is associated with the vanishing mass of the photon whereas the very short range (less than 10^{-17} cm) of the weak force implies a high mass for the boson (over 30 GeV). This high mass is probably the reason why it has not been found so far. The second essential difference is that the photon does not carry electric charge whereas the W does. In the familiar weak interaction the incoming lepton changes its charge due to the fact that a charged boson is exchanged.

In spite of these differences, theorists have tried for 20 years to find a unified field theory for the electromagnetic and weak interaction based on the principle of 'gauge invariance' in which an additional symmetry is assumed to exist between the two interactions. A number of theories were proposed and almost all required that the intermediate boson could be neutral as well as charged. The neutral boson, Z°, is in a way a brother of the photon.

If the Z° exists, some processes should be observed which are not possible by an exchange of the charged W. The most straightforward is the elastic scattering of an electron and a neutrino. Another process is the inelastic neutrino scattering from protons with the proton breaking up in several hadrons and the neutrino not changing. The incoming lepton in these interactions does not change sign and they are known as neutral current interactions. In 1973 such processes were observed in the heavy liquid bubble chamber Gargamelle at CERN and then in other experiments at the FermiLab and elsewhere.

This discovery opens the possibility for a unified theory. However, immediately, a difficulty arose. Weak interactions in which a strange particle is converted into a non-strange hadron should be allowed, thanks to the participation of Z°, but experiments showed that these processes are about 10^5 times less likely to take place than expected.

To remedy this difficulty it had been proposed that, instead of describing the hadrons by three quarks, a fourth quark with a new property called charm should be introduced. This hypothesis was brought forward in 1970 (long before the new particles were found!) but did not meet with great enthusiasm. Nevertheless, besides explaining the suppression of neutral current events with a change of strangeness, the hypothesis of a charmed quark has an additional virtue.

The weak interaction is formulated in terms of interacting pairs of particles. It is evident that three quarks cannot be grouped easily in pairs. Since it had been found that the d and s quarks, participate in the weak interaction only as a mixture, it is the mixture, denoted by d', that is treated as a single entity as regards the weak interaction. The pair (u, d') is then used to describe the weak interaction of hadrons. The way in which d and s mix are expressed by a mixing angle θ and $d' = d \cos \theta + s \sin \theta$. θ was determined from experimental decay rates as $\theta = 0.26$ which implies that the strange quark is involved only weakly because $\sin \theta$ is small.

The picture is appreciably changed with four quarks. Now a second quark pair (c, s') with $s' = s \cos \theta - d \sin \theta$ can interact with lepton pairs. There is then full symmetry between lepton and quark pairs. Strong and weak interactions differ in that leptons have integer charges while quarks have third integer charges and the d and s quarks participate in the weak interactions as a mixture. Though these ideas met with great scepticism initially, they appear in a completely different light after the discovery of the new particles.

The detection of the new particles has opened the door to a new branch of hadron physics and a better understanding of the symmetries governing the structure of elementary particles might ensue. The discovery of neutral currents in weak interactions might provide a basis for unifying the electromagnetic and weak forces.

The concept of a charmed quark or any other extension of the three classical quarks will give new insights about the basic units of matter and perhaps yield links between the weak and strong interactions.

Of course, many detailed, but also fundamental, problems remain. Are quarks real particles or mathematical symbols for certain symmetries? Such philosophical questions are certainly very interesting but, for me as an experimental physicist, it is already very exciting and gratifying that unpredicted new facts have been found and that relations between phenomena which had seemed completely disconnected before have been established.

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6006, 6011	Discriminators	6219, 6220, 6225	Coincidences
6703	Time to Amp. Conventer	7015	Pulse Encoder

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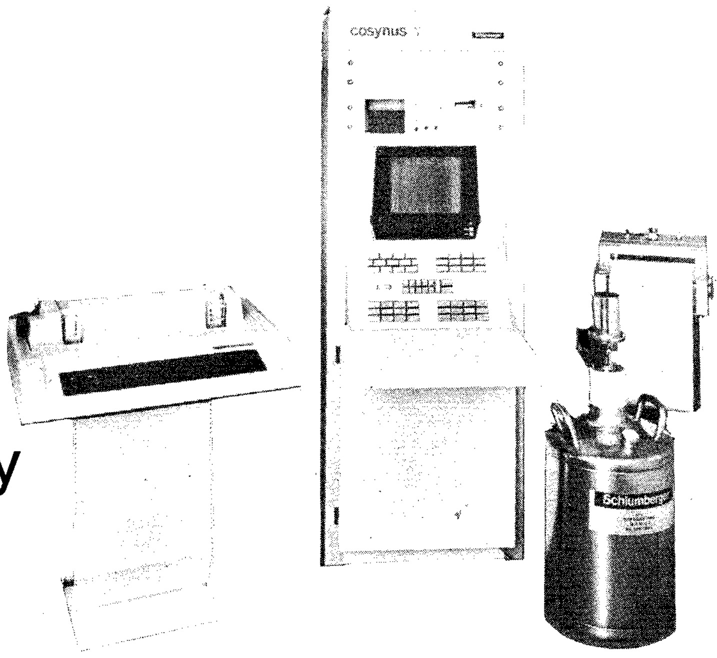

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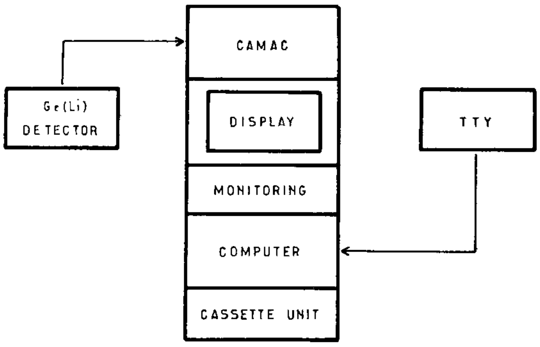

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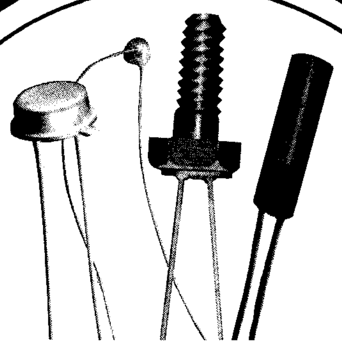

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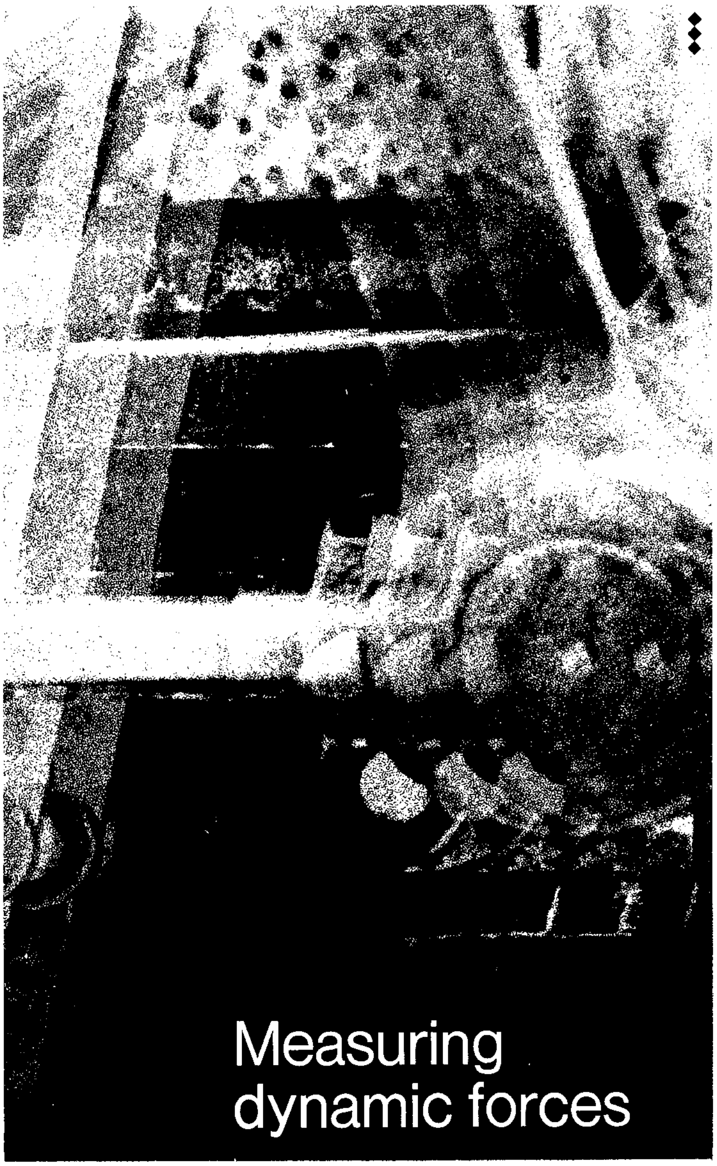

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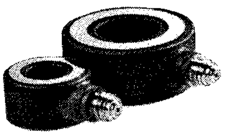

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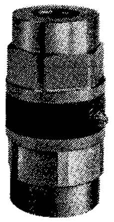

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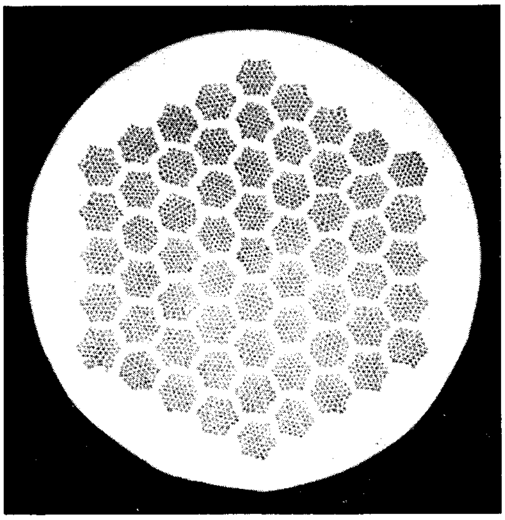

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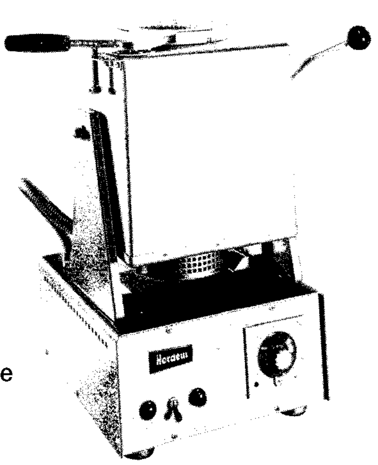

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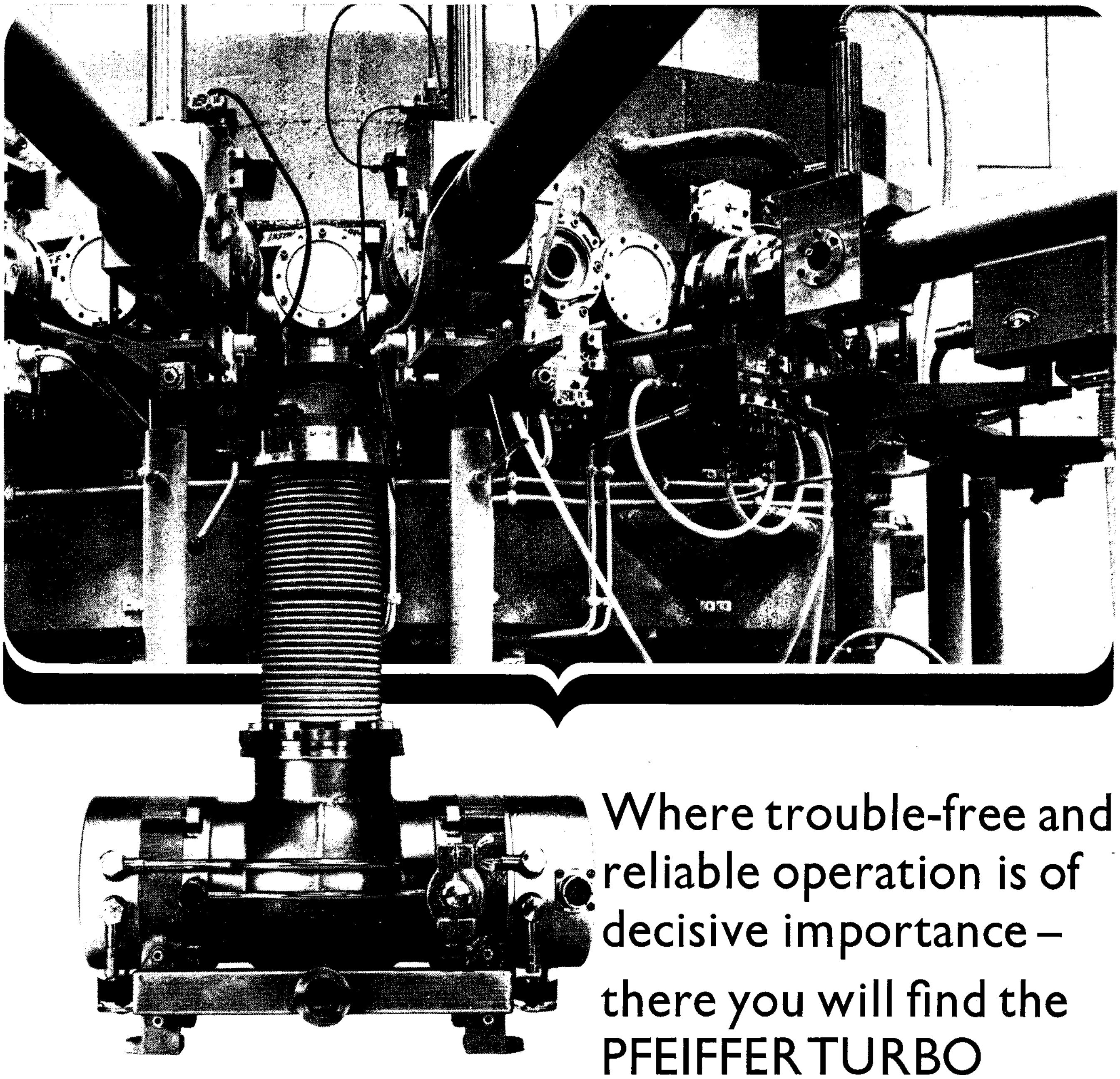

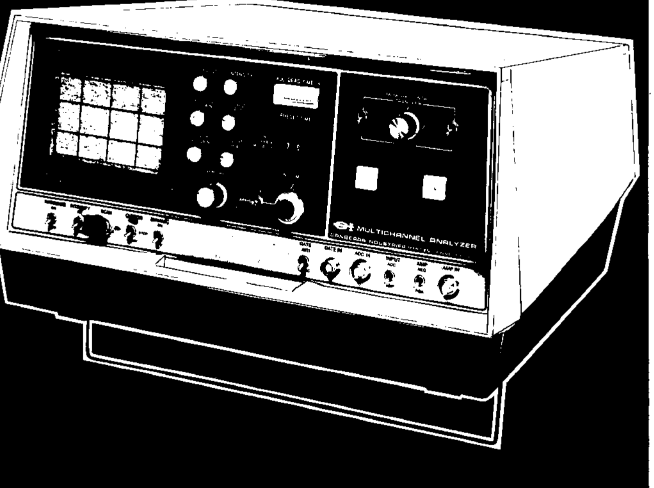
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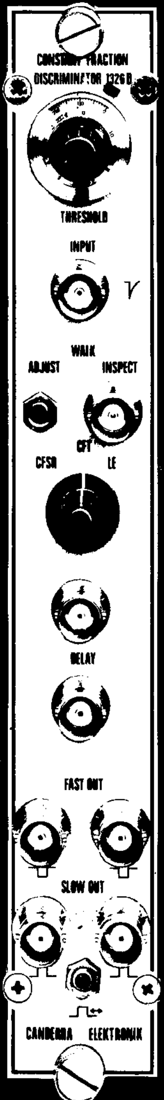
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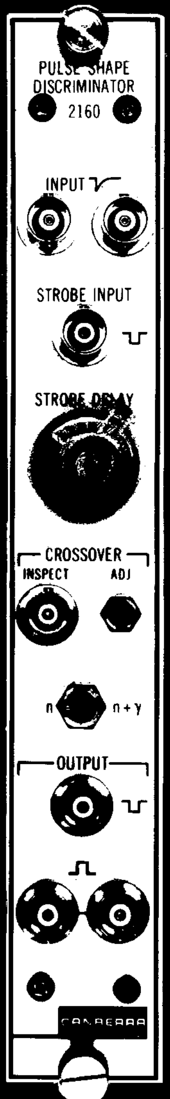
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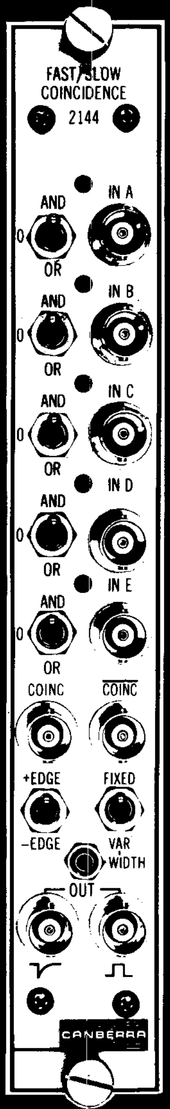
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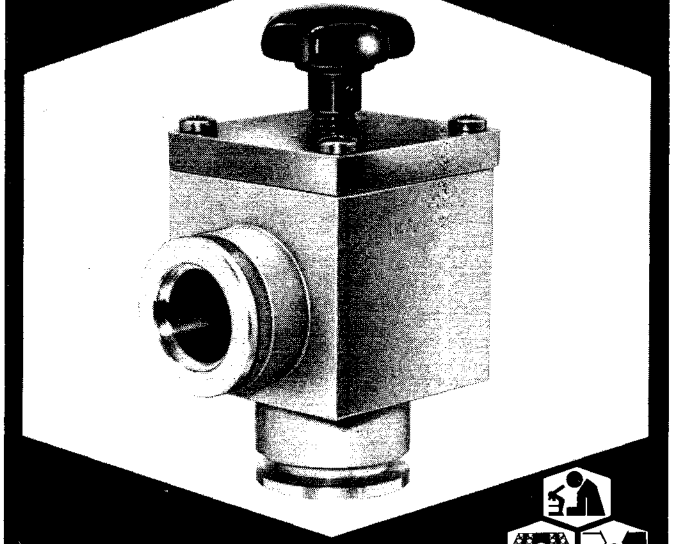

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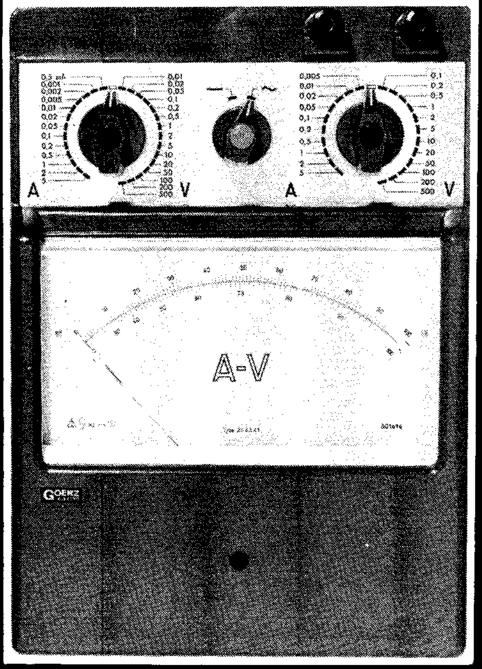

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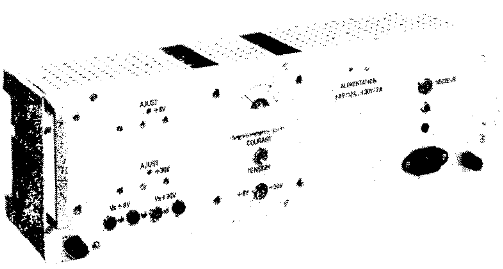

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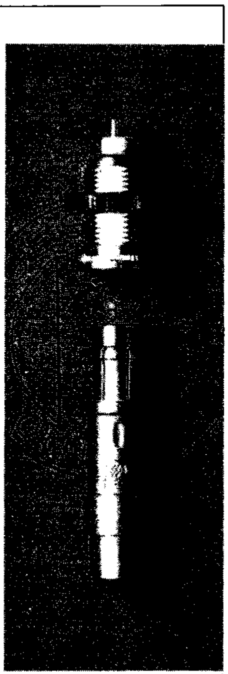

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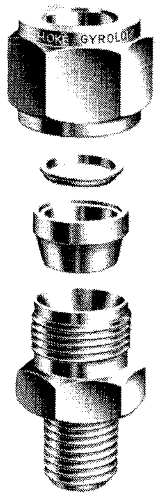

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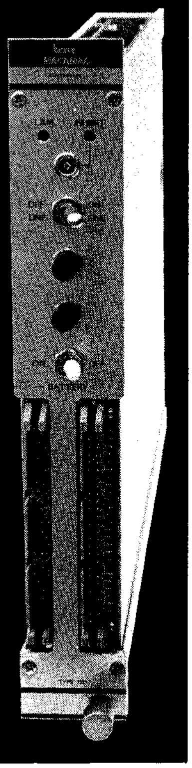
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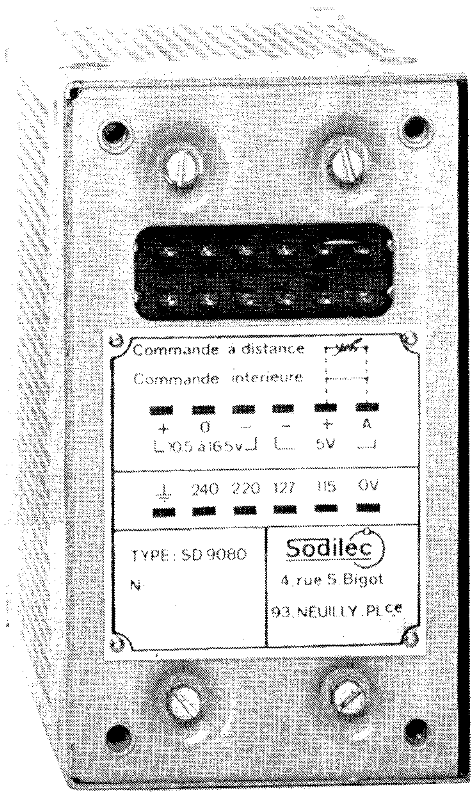
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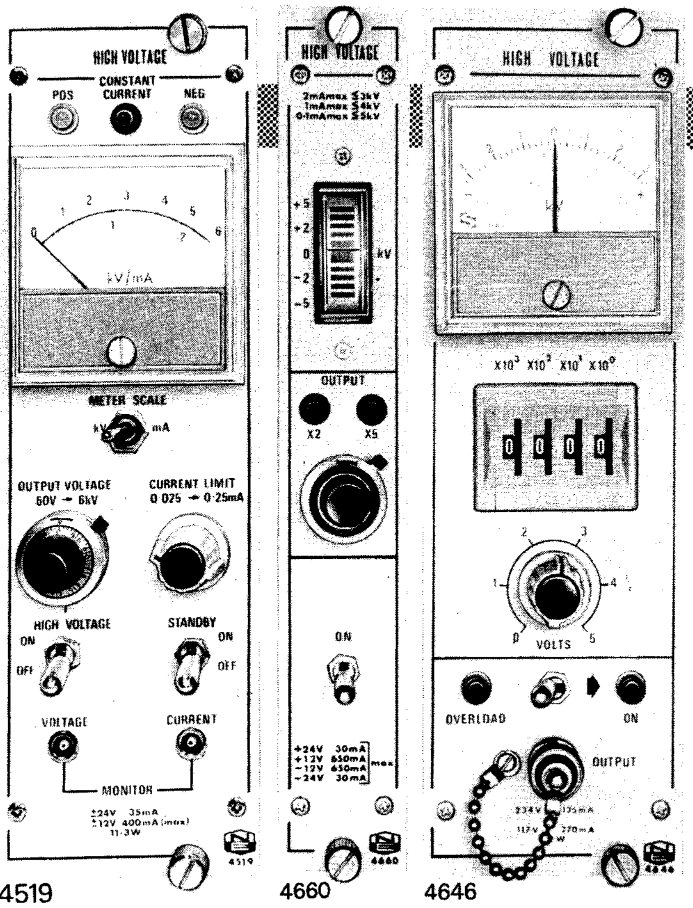

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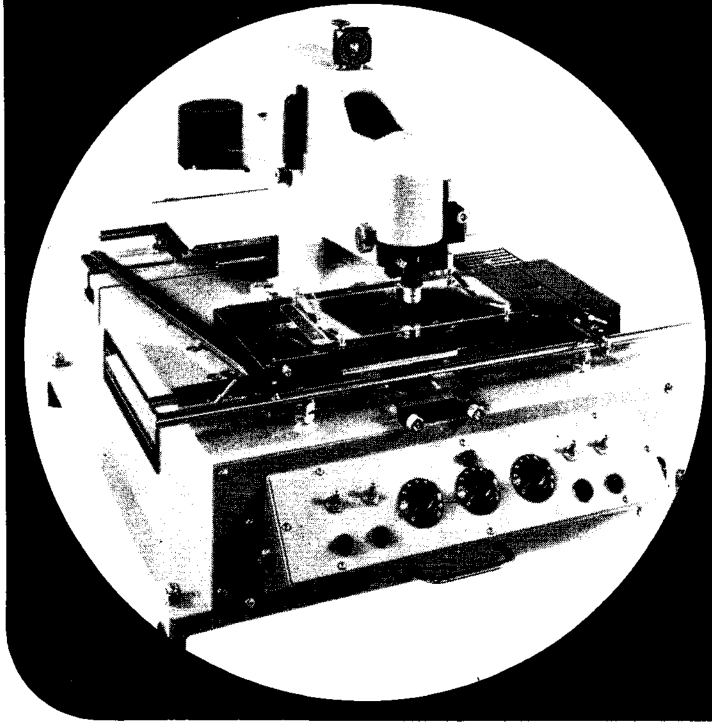

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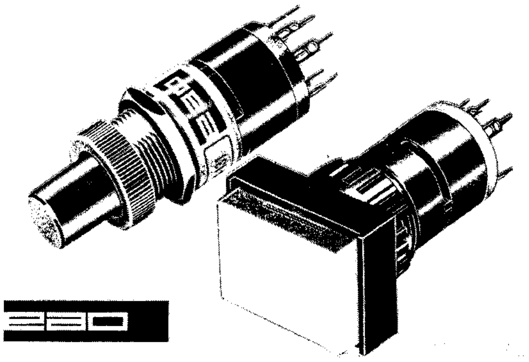

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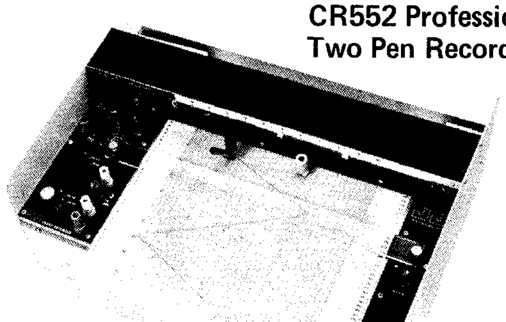

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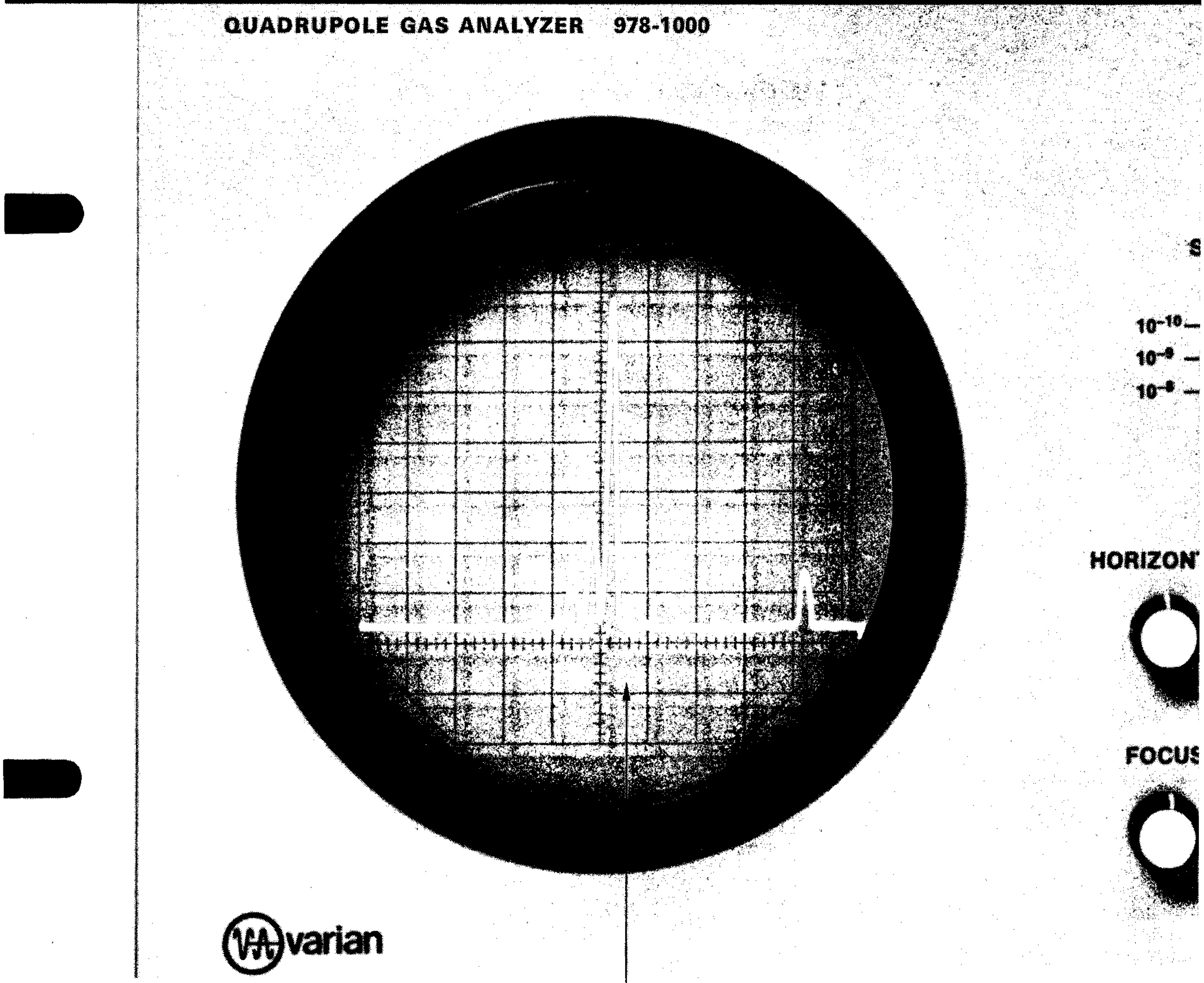
* Rectilinear Traces - servo operated self balancing potentiometers.
* Sprocket Driven chart paper by stepper motor.
* Fully Overlapping and independent pen systems.
* Vertical or Horizontal Mounting.
* Accuracy - 0.5% class.
* Event Marker.
* Electric Pen Lift.
* Writing Speed < ½ second FSD.

J.J. Lloyd Instruments Ltd

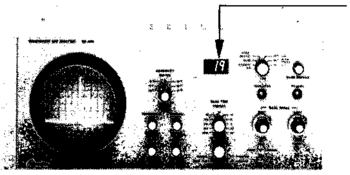
JJ INSTRUMENTS

Brook Avenue, Warsash,
Southampton SO3 6HP. Tel: Locks Heath 4221
Telex 477042 JAY JAY - SOTON

Plus d'incertitude dans vos mesures d'analyses de gaz



Un marqueur de masse indique un «pic» gazeux sur l'oscilloscope incorporé et sa masse s'inscrit sur l'affichage digital.



... La réponse à vos problèmes d'analyse de gaz en production et en laboratoire

L'analyseur de gaz quadrupole Varian, compact, résistant, d'utilisation simple et de haute précision, vous offre tous ces avantages, à un prix extraordinairement bas. Programmation interne asservie sur un spèctre présélectionné. Programmation externe pour sélection des «pics». Mesure de la pression partielle dans la gamme de 1 x 10^{-4} à 2 x 10^{-11} Torr. Lecture digitale de la pression totale. Fonctionne également en détecteur de fuites.

Si vous souhaitez éliminer l'incertitude de vos problèmes de mesure retournez-nous ce coupon pour documentation détaillée.

varian

Varian S. p. A.
Via Fratelli Varian/I-10040 Leinì (Torino)
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Veuillez me faire parvenir votre documentation sur l'analyseur de gaz «sans incertitude».

Nom: __________

Compagnie: __________

Adresse: __________

VEO-VAC 0176F

MODEL 5175

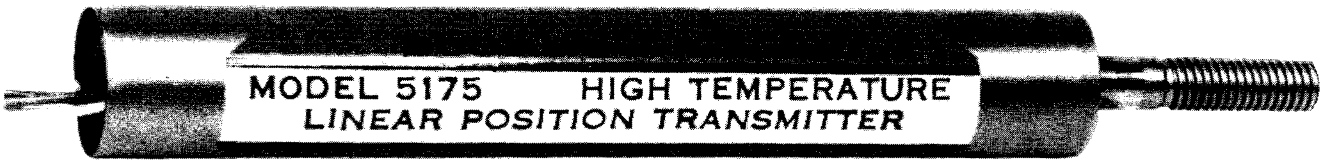
HIGH TEMPERATURE LINEAR POSITION TRANSDUCER

PRODUCT DESCRIPTION

Measures linear position up to **6"** and will provide an equivalent output signal proportional to change in position. Transducer wiper is positioned along a precision electrical element thus allowing the input voltage to be divided as a function of the mechanical input.

FEATURES

- High Level Output Signal
- +260°C Operating Capability
- Stainless Steel Construction
- Continuous Shaft Rotation
- Sand, Dust and Fungus Protection
- Radiation resistant on request



PRINCIPLE OF OPERATION

The transducer contacts are positioned along a precision electrical element which varies the resistance. Excited by either an AC or DC input voltage, mechanical backlash is eliminated by a positive connection between the shaft and contact assembly.

BOURNS (Schweiz) AG Baarerstrasse 8 6301 Zug
Tel. 042 23 22 42 Telex 78 722

qVt® *the revolutionary*

MULTICHANNEL ANALYZER

Conventional MCA's are big, expensive, full of little-used features, and require a wealth of ancillary electronics to make basic measurements. The LRS *Model 3001 qVt® Multichannel Analyzer* is different. It's packaged in standard research hardware, costs a realistic **$1,995***, provides uncompromising performance, and measures physics parameters directly. Truly a revolution in analyzer design.

Consider these outstanding characteristics . . .

COMPACT PACKAGING Hybrid/LSI technology now permits a complete 1024-channel high-performance analyzer to be housed in a NIM module. It's more portable, it's less costly, and it joins the rest of your research instruments in a standard NIM bin. Perfect for multiparameter, multiple-detector applications.

3 DIRECT ANALYSIS MODES Actually 3 analyzers in 1:

q: In the *q (charge) mode*, the 3001 directly integrates photomultiplier anode pulses *without the need for a charge-sensitive preamp* or pulse stretcher. Less electronics and less noise. ADC sensitivity is 0.25 pC/channel. The integration interval is adjustable from 10-500 nsec for compatibility with a wide range of scintillators including fast plastic, NaI, and lead glass. A fast linear gate and direct coupling eliminate pileup and subsequent baseline shift.

V: In the *V (voltage) mode*, the 3001 operates as a conventional pulse height analyzer accepting 0 to 1 volt inputs from amplifiers or other voltage sources. Built-in lower level discriminator can be adjusted to < channel 1 or fired externally. Useful for low-gain detectors with preamps.

t: In the *t (time) mode*, the *qVt*® replaces the standard TAC-MCA combination with a built-in time-to-digital converter. It accepts start/stop inputs directly to accumulate time duration spectra with switch-selectable resolution of 100 psec/channel or 1 nsec/channel.

FLEXIBLE OPERATION Memory contents (16 bits) can be displayed in linear/log fashion on any oscilloscope, even during data accumulation. Intensified channel markers simplify visual analysis. . . . Segmentable memory allows analysis over all 1024 channels or in 256-channel quadrants (for spectra comparisons) without gain changes. . . . Built-in linear gate and inhibit circuitry permit logic decisions right at the analyzer. . . . And the rear-panel digital interface connector permits data from external devices to be loaded into memory for histogramming or display as well as providing conventional data readout to hard copy devices or the CAMAC dataway.

For further information on the new 3001 *qVt*® -MCA, please call or write: LeCROY RESEARCH SYSTEMS CORP., in West Nyack, New York, or your local Sales Office.

*Within U.S.A. Slightly higher abroad

LRS

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Innovators in Instrumentation

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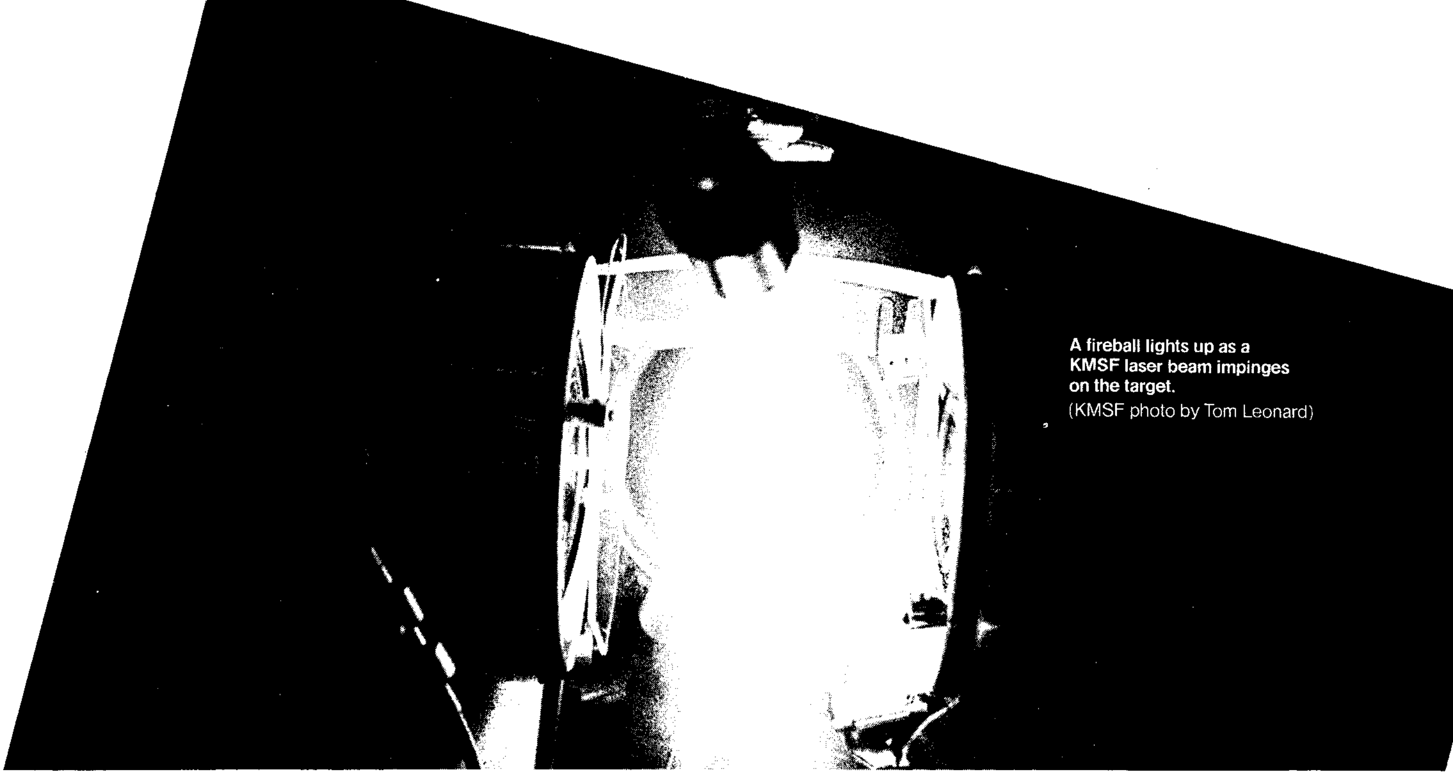
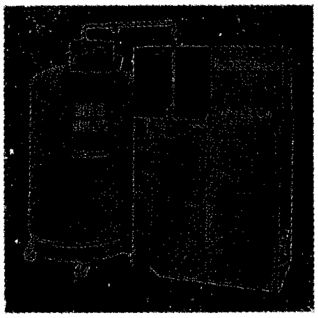


A fireball lights up as a KMSF laser beam impinges on the target.
(KMSF photo by Tom Leonard)

is helping things happen at KMSF

Our Model 1400 provides vital cooling for their laser-fusion program



The search for new energy sources is being pursued in a number of promising areas, including the utilization of controlled thermonuclear reactions.

KMS Fusion of Ann Arbor is in the development phase of a system to produce useful energy from laser-induced thermonuclear activity. In the KMSF system, energy pulses from a mode-locked YAG laser are amplified and focused on microscopic targets—glass spheres filled with deuterium or deuterium and tritium. KMSF reports having formed plasmas with temperatures of 20,000,000°C and densities of 10^{24} nuclei per cubic centimeter (20 times the density of solid deuterium) by compression of the targets.

CTi's model 1400 Helium Liquefier/Refrigerator supplies liquid helium to cool five 40-kilogauss superconducting magnets that activate five Faraday rotators. These rotators serve as optical gates to protect the upstream amplifiers and optics from damaging reflected energy and make possible the unique KMSF double-pass arrangement that in effect doubles the gain of the amplifiers.

The Model 1400 is the standard by which all other low-temperature systems are judged. Laboratories and research centers worldwide depend upon the reliable Model 1400 for liquid helium supply or for closed-cycle cooling of superconducting magnets, cryopumps, and gas recondensers.

Write or call CTi-Cryogenics today for complete technical and price information on the versatile and reliable Model 1400.

CTi-Cryogenics
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Kelvin Park, Waltham, Massachusetts 02154
(617) 890-9400