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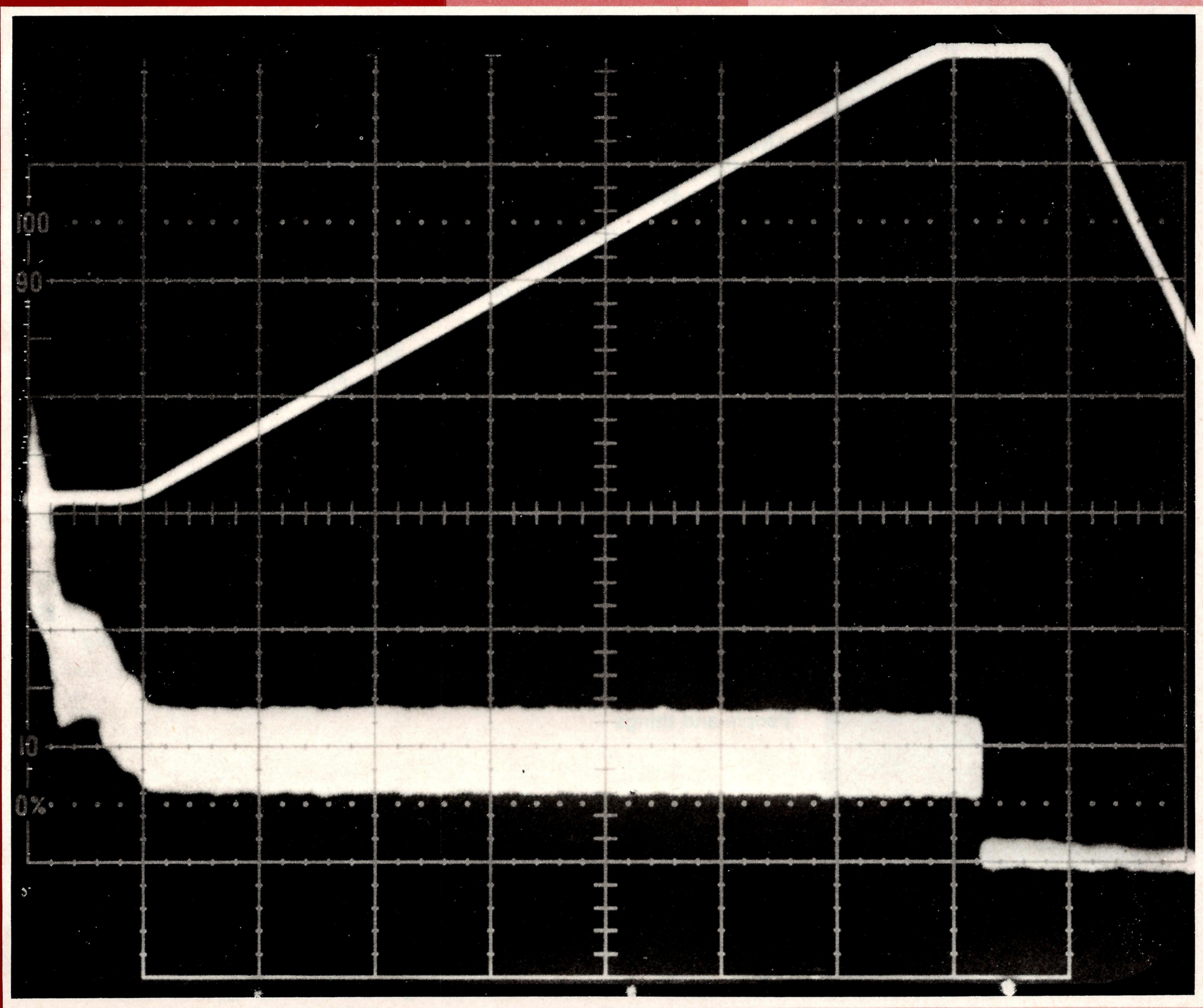

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Contents

Cover photograph: The very first pulse at 400 GeV recorded in the Main Control Room of the CERN SPS at 15.35 h on 17 June. The upper trace records the current to the accelerator bending magnets raising their fields to the level necessary to hold 400 GeV protons. The lower trace was from a beam detector in the ring and records protons surviving out the full energy.

SPS reaches design energy

Happy faces in the Main Control Room on 17 June watch the display screens flashing 400 GeV pulses regular as clockwork.

On Thursday 17 June John Adams, Executive Director General of CERN, addressed the Summer Session of the CERN Council. He described the operation of the accelerators and concluded with the announcement that, at mid-day, the SPS had reached an energy of 300 GeV — the design energy specified in the programme approved by the Member States. He then consulted Council about going to 400 GeV, in accordance with Council discussions three years earlier in June 1973, and the higher energy was approved. The time was 15.30 h. At 15.35 h the SPS accelerated protons to 400 GeV.

The story of the machine commissioning

This was the climax of the commissioning programme that we have been reporting since the April issue and we will recall the major events. It began on 5 April when 10 GeV protons from the PS were guided 1 km along the transfer tunnels to the underground SPS. With the first touch of the buttons, a healthy beam hit the beam stop at the entrance to the SPS, only millimetres off target. The transfer system was obviously in great shape. A similar success came on 3 May when the first injected pulse toured the 7 km ring circumference for a single turn without difficulty and, later the same evening, did 12 000 turns demonstrating beam stability in a perfect magnet system.

On 6 May, the radio-frequency accelerating system was brought into action and several evenings' work achieved a trapping efficiency of about 60 % and an acceleration for a few GeV. At 15 GeV, however, the beam was lost.

On 12 and 14 May a thorough study of the Q diagram was made. The Q values are the number of oscillations that a proton makes either side of its ideal 'closed orbit' during a single turn of the machine in both horizontal and vertical planes. Specific values of Q have to be avoided, otherwise during successive turns a proton will feel minute imperfections in a cumulative fashion. If for example the Q has integer or half integer values the beam blows up and is lost. The machine is tuned by adjustment of the quadrupole focusing fields, to stay clear of such values.

The examination of the Q diagram at injection energy revealed that the width of the troublesome resonance regions is very narrow indeed — another indication of the perfection of the machine. Someone remarked that it looked more like a storage ring than an accelerator. It didn't seem, at that time, as if Q value problems were behind the beam loss.

The next investigation was of the chromaticity — the way that the momentum spread of the protons varies with Q. As expected, a large chromaticity was found and was corrected by powering sextupole magnets appropriately. Removing the chromaticity let loose the resistive-wall instability and this in turn was corrected by octupole fields. In all these manoeuvres, the machine was behaving exactly as expected. But the beam could still not be coaxed past 15 GeV and frustration was setting in. Thoughts were turning to such exotic explanations as a screwdriver left in the vacuum vessel lifting up into the beam as the magnet field increased.

The breakthrough came on 26 May when it was found that Q was hitting a half integer resonance at 15 GeV. Although the machine tune was fine at injection energy, it moved away from the desired values as the magnetic fields rose. The fault was that the bending fields and the focusing fields were not tracking together correctly

CERN 313.6.76

A big day in the construction of the machine — on 31 July 1974 the tunnel boring machine completed its journey around the ring. It had cut out 7 km of tunnel emerging within millimetres of its scheduled position.

* *First tests of extraction system on 9 July achieved fast extraction of almost all the circulating beam onto an external dump in one turn. Difficulties with tracking between main dipoles and quadrupoles were overcome and on 15 July over 4×10^{12} protons per pulse were accelerated to 200 GeV.*

CERN 268.7.74

(not keeping in step as their fields increased). Although the cause of this was not then known, provision had been made to apply corrections to the tracking at any point in the magnet cycle.

At 17.00 h, after the adjustments were made, protons sailed out to 50 GeV passing through transition energy without problem. The two power supplies that were then hooked up could give currents in the dipoles sufficient to reach 80 GeV, and 80 GeV protons were achieved later in the evening. The SPS had become the highest energy accelerator outside the USA passing the 76 GeV of Serpukhov.

In all this work on individual components of the machine and on beam characteristics, the excellence of the computer control system was the most striking feature of all. It is so versatile, so easy to use, so efficient at presenting the required information that, time and time again, measurements and corrections which in older accelerators would have taken weeks of work, were possible within hours.

For the run of 3, 4 June six power supplies had been connected allowing a 200 GeV peak energy. The first pulse of protons injected with this magnet cycle resulted in acceleration right up to 200 GeV. Adiabatic trapping was then tried, showing at times efficiencies approaching 100 % by 10, 11 June and the r.f. system was looking very good. This was a relief because it is of novel type for synchrotron rings and there is always a residual touch of magic in the most thoroughly designed r.f. systems.

A few more nail-biting days followed while the power supply system received attention. It was found that with ten supplies hooked up (sufficient for 400 GeV) instabilities occurred in the supply circuits at power levels equivalent to 240 GeV. Thorough work was needed to tame the supplies one by one and they were ready for the big event on 17 June.

At 12.10 h on that day, with the magnet field ramp set for 300 GeV, the initial design energy was achieved and the promised intensity of 10^{12} protons per pulse was accelerated. In careful steps, watching the power supplies for any sign of trouble, the magnet field ramp was taken progressively higher during the afternoon yielding 400 GeV protons at 15.35 h.

There are still some heavy losses during the early part of the acceleration cycle to be cured, component reliability has to be assured, and the ejection system has to be brought into action. But the experimenters seem certain to have their higher energy particles in the West experimental area by the end of 1976 as promised and it looks as if CERN has provided them with another magnificent machine. *

The design of the accelerator

On 19 February 1971 eleven of the CERN Member States — Austria, Belgium, Denmark, Federal Republic of Germany, France, Italy, Netherlands, Norway, Sweden, Switzerland and United Kingdom — approved 'The 300 GeV Programme' at an estimated cost of 1150 million Swiss francs (1970 costs) spread over an eight year construction programme. The accelerator was to be built on a newly allocated site across the Franco-Swiss border adjoining the existing CERN Laboratory. It acquired the name of Super Proton Synchrotron — SPS.

Several of the major features of the accelerator design are set by the decision to locate the machine alongside the existing Laboratory. The land in this area is not flat and since the SPS had to be built in the bedrock for stability reasons, it was not possible to use the cut and fill method for

Plan of the SPS showing the link with the PS, which serves as injector, and the two experimental areas. The six service buildings and access shafts, which are located at the six long straight sections of the machine, are indicated together with a seventh located over the beam line to the West Experimental Area.

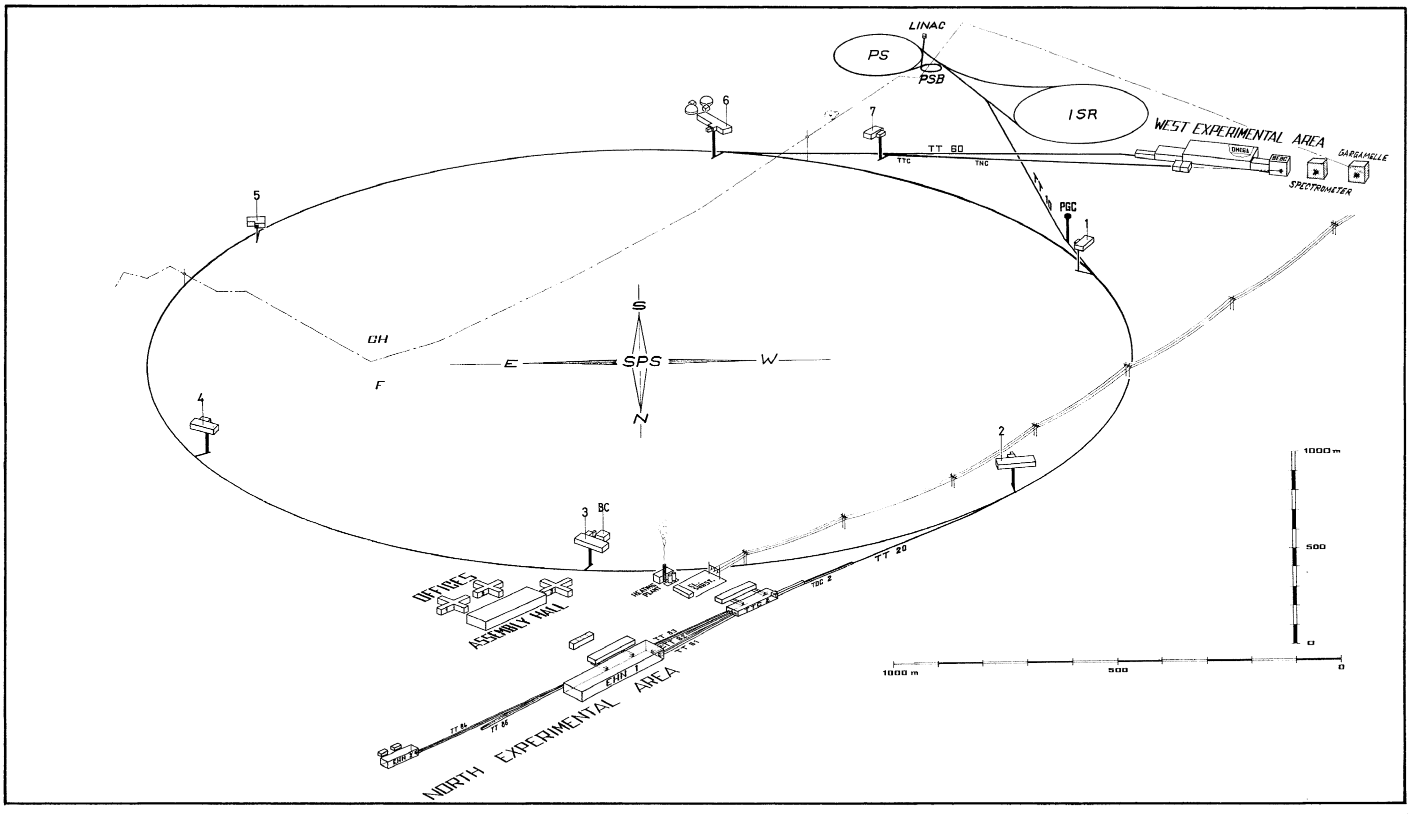
making the tunnel to house the machine. It was decided to bore the tunnel using a full-face boring machine. The rock ridge has a width which permits a ring diameter of 2.2 km. (The maximum possible diameter is desirable since it is one of the parameters which determines the peak energy of the synchrotron.) The depth at which the tunnel lies below the surface on the circumference of this ring varies between a minimum of 18 m and a maximum of 64 m.

The precise location of the ring is also dictated by the fact that the proton synchrotron (PS) provides the particles for injection and that the accelerated particles are to be sent to the already existing West experimental area. This fixes the positions of two long straight sections, one for injection and one for ejection to the West area. The ring is divided into six arcs and six long straight sections, the other straights being taken up for ejection to the North experimental area, for the radio-frequency accelerating system, for the beam dump, and one left free.

Six access shafts, located at the long straight sections, are sunk to the ring, and six service buildings are constructed on the surface to house the power supplies and other equipment feeding the machine components installed in the ring tunnel underground. The disturbance to the existing environment has been kept to a minimum, and farming and forestry continues on most of the area of the SPS site as it had done previously.

Protons are to be injected into the SPS from the PS with a beam intensity which will enable the SPS to reach an intensity of 10^{13} protons per pulse. In order to spread the protons around the SPS circumference, which is eleven times longer than that of the PS (the PS diameter being 200 m), a novel method of ejection from the PS is used. It is known as 'continuous transfer' and consists of debunching the PS beam and peeling it off during ten turns so that a ribbon of even intensity is ejected towards the SPS. The ejection/injection is done at a momentum which can be varied between 10 and 14 GeV/c. This is high enough to avoid problems of quality of the injection field in the SPS magnets and to limit the necessary frequency swing in the SPS radio-frequency accelerating system. It also keeps the time for which the PS is occupied with injection into the SPS to a minimum so that it can continue to supply protons for its own experimental programme at lower energy and for filling the Intersecting Storage Rings.

The beam from the PS first travels along a section of tunnel, TT2, which is part of the beam transfer system of the Intersecting Storage Rings. Two



Inside the completed tunnel with an arc of bending and focusing magnets installed. The ring contains about a thousand magnets all aligned to better than a millimetre and providing fields accurate to a few parts in ten thousand.

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hundred metres along TT2 a switching magnet is powered to direct the beam along a new tunnel, TT10, towards the SPS (a distance of 800 m). A septum magnet and kicker magnet bend the protons onto their orbits in the ring. The ten-turn ejection from the PS gives a ribbon of protons filling 10/11 of the SPS circumference. The magnetic field in the kicker magnet can thus drop to zero before the first injected protons pass it on completing their initial turn so that their trajectories will not be disturbed by the injection field.

The magnet system into which the beam is injected has two purposes — it has to curve the trajectories of the protons, so that they complete a near circle around the ring, and it has to maintain the beam well focused, so that the protons do not hit the wall of the vacuum vessel in which they travel. While being accelerated to 400 GeV, the protons orbit the ring about 150 000 times covering a distance of over a million kilometres. To ensure that they follow the desired trajectories throughout this journey, it is necessary that the magnetic fields be accurate to better than a few parts in ten thousand over the entire region in which the protons travel.

The magnet system is of the 'separated function' type in which the tasks of bending and of focusing the beam are carried out in separate units — dipole magnets and quadrupole magnets, respectively. There are eight dipoles and two quadrupoles in each normal 'period' of the magnet lattice and the pattern of this period is repeated 108 times around the ring. The quadrupoles are arranged so that their fields are successively focusing and then defocusing giving a net focusing effect in both horizontal and vertical planes. Their peak field gradient is 21 T/m. The bending magnets are of the H-type in a compact design which keeps cost and power requirements to a minimum. It is this design which enables 400 GeV fields to be achieved within the cost estimate foreseen for 300 GeV. The dipoles are 6.26 m long, and each normal period has four magnets with an aperture of 145 mm × 35 mm and four magnets with an aperture of 120 mm × 48 mm. These dipoles are positioned so as to match the undulations in the beam profile determined by the focusing magnets. The dipoles are pulsed to give a peak field of 1.8 T (corresponding to 400 GeV) with a peak current of 4.9 kA.

In addition to 744 dipoles and 216 quadrupoles, there are correction magnets — dipoles, sextupoles, and octupoles to compensate for any remaining defects in the magnet lattice and to allow refined control of the orbiting beam.

The magnets are powered using a 'static power supply' rather than a motor-alternator set common in older synchrotrons. This is possible because the power storage capacity of the public electricity network is much greater than the peak pulse power required by the SPS, so that the load is distributed over a number of generating stations. The static supply allows the pulses of power to flow between the network and the SPS and back again without significant fluctuation of the network voltage. It is necessary to connect at an electrically strong point of the network and this is done at Génissiat in France. A 380 kV line brings the power from Génissiat to CERN.

The peak power for the bending magnets and quadrupoles is 135 MW and there is a mean power consumption of about 34 MW. This allows an SPS cycle time of about 6 s, including 0.2 s for injection, 3.7 s for magnet field rise (acceleration time), 0.7 s for a 'flat-top' (during which protons can be ejected to feed the experiments), and 1.2 s for the magnet field to fall again. The power dissipated in the magnets is absorbed by a water-cooling system. Water is pumped from the Lake of Geneva (Lac Léman) and stored in two reservoirs, with a total capacity of 10 000 m^3, on the SPS site. When the machine is in operation the necessary flow of cooling water is 1000 l/s.

The vacuum system is maintained at a pressure of better than 10^{-7} torr by about 650 sputter ion pumps and 80 turbomolecular pumps. The vacuum tube, of low permeability stainless steel, changes in profile as it threads through the magnets and other machine components.

Acceleration of the protons is assured by two radio-frequency cavities, 20 m long, each with a waveguide structure of 56 drift tubes. This form of r.f. structure is novel in the acceleration system of a synchrotron ring and is the most economic way of transferring power to the beam.

John Adams addressing the SPS construction team who were joined by delegates of the Member States on the night of 17 June to rejoice with a glass of champagne.

(Photo Jean Collombet)

Since the proton velocity varies very little (0.4 %) during the acceleration cycle, it is possible to use an almost constant frequency of 200 MHz for the r.f. This frequency divides the orbiting beam into 4620 bunches. The r.f. system accelerates the protons by about 2.5 MeV per turn, corresponding to an acceleration rate of over 100 GeV/s.

Separate equipment is provided to extract the accelerated beam towards the West area and towards the North area. Three methods of extraction can be operated to meet the different needs of the experimental programme. Fast extraction involves bending the protons out during a few microseconds (all, or a fraction, of the bunches extracted during one turn) and will be used particularly to provide a neutrino beam and a r.f. separated beam to the BEBC bubble chamber. Slow extraction involves bending the protons out during times up to a second or more, providing beams best adapted to the needs of electronic experiments. Medium extraction which will require some extra development, involves bending the protons out during several milliseconds, the maximum duration of beam that BEBC can cope with while still being acceptable to some electronic experiments.

Each extraction system comprises four electrostatic septa 3 m long with septa made of tungsten-rhenium wires 0.1 mm thick spaced 1.5 mm apart. Outside the wire septa are electrodes at a potential of up to –200 kV. The field deflects the protons sufficiently so that they enter the aperture of septum magnets, of which there are four, 2.2 m long with septa 4 mm thick, followed by another five, 2.2 m long with septa 16 mm thick.

From the extraction point for the West area, proton beams can be taken up to the West experimental hall and split between three targets to yield secondary beams. The dimensions of the hall can accommodate secondary beams produced by protons with energies up to 200 GeV. Alternatively, protons from the same extraction point can be used on underground targets to yield either secondary beams of a type and energy which can be selected by r.f. separators, or neutrino beams which are aimed at the BEBC and Gargamelle bubble chambers and counter experiments. For the neutrino beams, the incident protons can have energies up to 400 GeV.

From the extraction point for the North area, proton beams can be taken almost 600 m to the surface and split between three targets to yield hadron beams in North experimental hall 1, and hadron and muon beams into North experimental hall 2. These secondary beams can be produced by protons with incident energies up to 400 GeV.

Monitoring and control of the multitude of machine components and of the proton beams themselves are carried out by a computer control system which has advanced the techniques of accelerator control in several ways. The system has 24 small computers — 13 distributed around the ring, 8 at the Main Control Room, and 3 in the experimental areas. They are mostly capable of independent operation and in some cases are 'dedicated' to the monitoring and control of specific components (for example, one computer looks after all aspects of the radio-frequency system). The computers communicate with one another and with three consoles in the Main Control Room by means of a high-speed message transfer system.

Much attention has been given to the control philosophy so that data can be called up easily and presented in a way which is easily assimilated by the machine operators. The operator views a number of colour TV screens which present the status of components of the machine which can be selected with a 'touch screen'. The screen has 16 transparent buttons backed by a TV upon which different labels can be written by a computer. Almost all the hundreds of knobs and switches of a conventional control room are channelled into three elements, a knob, a rolling ball and a touch screen. A specially developed computer language is used which allows changes to any computer program to be made rapidly and easily.

A great European achievement

We cannot let the coming into operation of the 400 GeV proton synchrotron go by unsung. The SPS is among the greatest technological achievements in the history of Europe. It involves fraction of a millimetre precision over distances of kilometres, a 7 km magnet system perfect to better than a few parts in 10 000, an accelerator control system which is the most sophisticated ever built, engineering and electrical expertise of the highest order, all backed by a very efficient administration which has respected cost estimates and timescales.

It is the product of a wide range of talents. The project was led by John Adams from the UK, who has the rare combination of outstanding engineering ability and shrewd political judgement, with, as deputy, Hans-Otto Wüster from Germany, who brought detailed knowledge of accelerator theory and construction to his handling of many managerial problems. The group leaders were — Roy Billinge from England who mass-produced a thousand perfect magnets, Clemens Zettler from Germany who tamed the novel r.f. system, Bas de Raad from Holland who has made a habit of transporting beams with minute precision, Simon Van der Meer from Holland whose meticulous work on the power supplies in June was the key to reaching 400 GeV, Michael Crowley-Milling from England who thought out and executed the brilliant control system, Jean Gervaise from France whose immaculate survey and alignment work underlies the perfection of the whole construction, Klaus Goebel from Germany who ensured radiation safety, Giorgio Brianti from Italy who supervised the planning and construction of the vast experimental areas, Hans Horisberger from Switzerland who bore the brunt of the mechanical design, Robert Lévy-Mandel from France who oversaw the civil engineering aspects from tunnelling to electricity supply to water cooling to building construction, and André Klein from France who looked after administration and smoothed, particularly, the negotiations with the host countries France and Switzerland.

The design specification of the accelerator has already been exceeded. The time schedule has been bettered. It also looks as if the project will be completed for a cost comfortably within the estimate. This is a great and rare achievement in which everyone at CERN can take pride.

The experimental programme will be under way by the end of the year and Europe's physicists will have at their service beams of higher energy particle, in many cases of a better quality and intensity than are available anywhere in the world.

Tbilisi under the spell of Charm

This review is based on notes kindly provided by Yves Goldschmidt-Clermont, but thanks for additional material are also due to other Tbilisi participants too numerous to name.

The 18th International Conference on High Energy Physics, one of the biennial series known as Rochester Conferences, took place from 15 to 21 July 1976 in Tbilisi, the capital of the Georgian Soviet Socialist Republic. About 800 physicists from many parts of the world had gathered there so that a good thousand people were to be seen in and around the buildings of the State University where the lectures were held. The authorities and organizers had spared no effort to make the event a success, even without the science, and the full and solid lecture programme was lightened by cultural and social events and excursions. The weather may not have come up to the expectations of West Europeans only lately acclimatized to much heat and drought, but the atmosphere was bright in the light of recent discoveries if not overheated by the new arguments they had engendered.

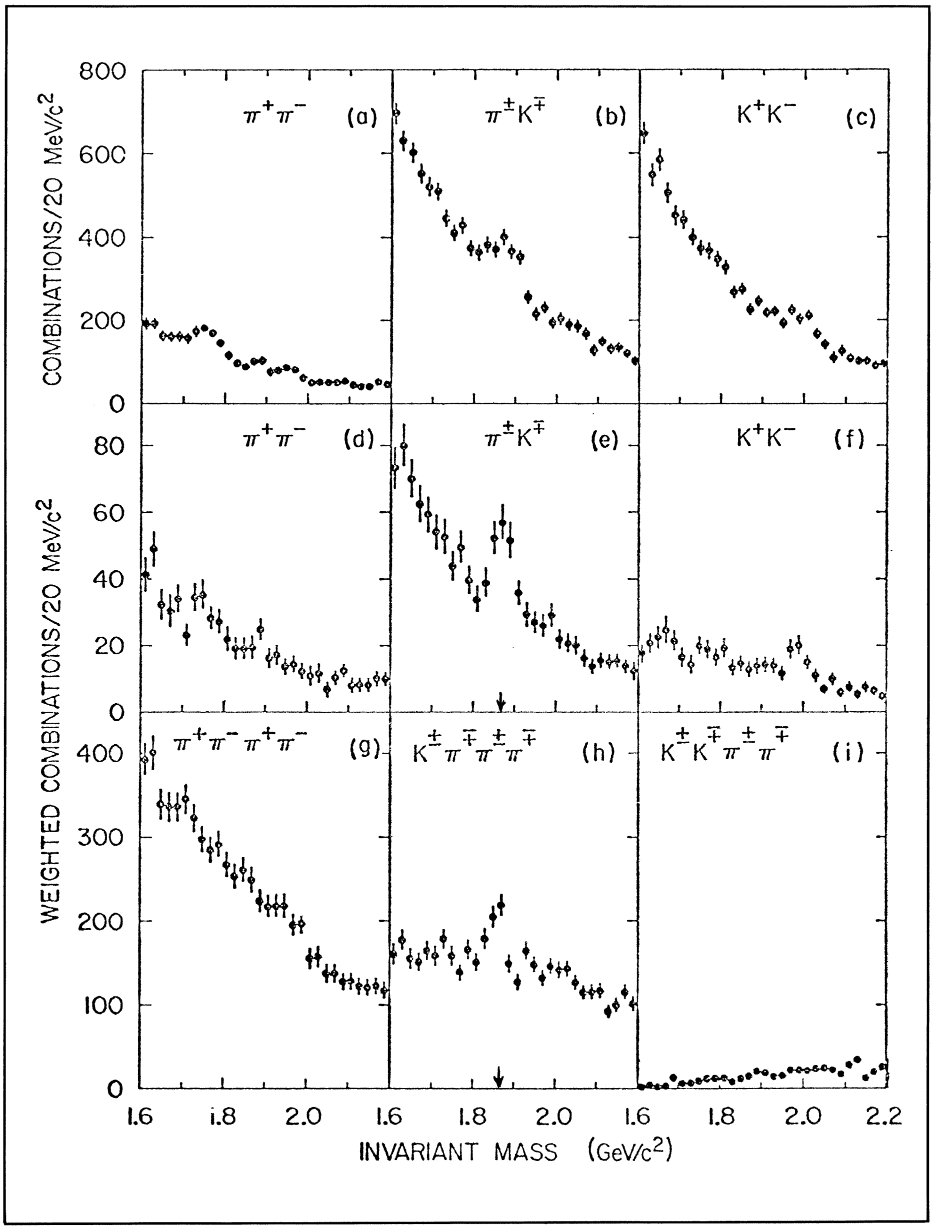
The year of the Charm

Events found in Gargamelle at CERN involving fast muons, slow electrons and strange particles, similar findings in the 15 foot chamber at Fermilab, prompt electrons associated with a K meson detected at DESY (see also this issue), a multiplet of charged and neutral mesons all at the same mass of 1.87 GeV discovered at SPEAR in Stanford. These are, as A. de Rújula, the rapporteur on new particle theory put it: '. . . if not charm itself, then the best possible counterfeits!' Experimental results in the field of e^+e^- interactions were discussed by R. Schwitters, and the search for new particles in such colliding beam machines was the subject of B. Wiik's rapporteur talk. The consensus of the physicists in face of the latest evidence from numerous experiments variously related to this burning topic clearly was that particles bearing the new quantum number of charm have in fact been found. And the charm was not merely 'hidden' as in the case of the J/ψ and ψ' particles but also unashamedly 'naked' producing characteristic decays involving leptons and strange particles and exhibiting 'exotic' relationships between electric charge and strangeness. The spectroscopy of the new particles, also covered by B. Wiik, showed that much work had gone into studying the properties of the J/ψ and ψ' particles, their modes of production and of decay, their branching ratios, etc. The related states of opposite charge conjugation are now well established with an almost definite attribution of quantum numbers. The states follow closely the pattern, predicted by the interaction of a fermion — antifermion pair (e.g. $e^- e^+$ yielding positronium) and have become known as 'charmonium'.

A theory of weak and electromagnetic processes

The discovery of charm confirms one of the more striking aspects of a theory developed over several years by many authors. One of its several versions, sometimes called the 'standard model' is based on the work of Weinberg and Salam and of Glashow, Iliopoulos and Maiani. Besides predicting the new quantum number 'charm' the theory is proving powerful in explaining and predicting phenomena such as neutral currents, as shown below. It is very satisfactorily based on fundamental ideas of field theory as well as on gauge invariance, renormalization and other concepts renowned as powerful tools in quantum electrodynamics. The advance in understanding brought about by its unification of electric and weak forces has been compared to that achieved by Maxwell in the last century in unifying electricity and magnetism. The theory also indicates similarities between the

SPEAR: Most direct evidence for charmed meson decay. Figs. (e) and (h) show a neutral meson (D^o) decaying into $\pi^\pm K^\mp$, $K^\pm 3\pi$.



symmetries of weak and strong interactions that could lead to further progress. In the opinion of de Rújula, it has the sociological advantages of offering to physicists an 'orthodoxy' with its eloquent partisans and violent detractors.

Neutrino physics

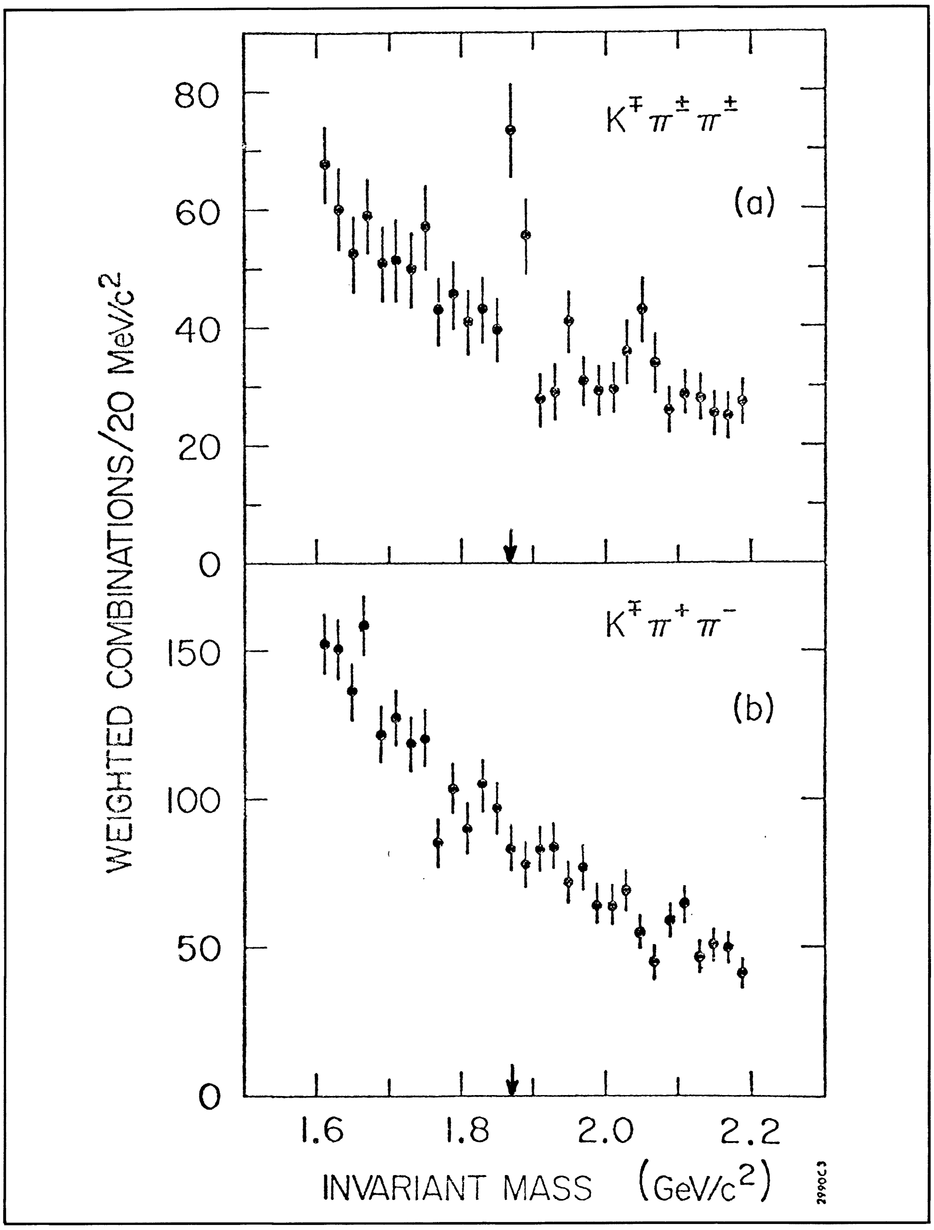
Here the situation as reviewed by S.S. Gershtein appears to be one of consolidation. The neutral currents discovered at CERN have been further studied at several laboratories. Three types of experiment, neutrino collisions with electrons (Gargamelle, and NUE of the Aachen-Padua collaboration) with protons (Brookhaven) and with nuclei (Gargamelle), concur in the determination of their space-time structure. They appear to follow the pattern predicted by the Weinberg-Salam model with a value of the characteristic Weinberg angle θ_W such that $\sin^2 \theta_W = 0.3$ to 0.4. This further support of the 'standard model' provides a definite prediction for the masses of the so far elusive vector bosons.

Experiments at Fermilab at incident neutrino energies above 50 GeV have indicated an anomaly, with respect to the 'standard model', in the distribution of events relative to the parameter describing the inelasticity of the collision (Y anomaly). Is this evidence of some basic limitation of the model and of an entirely new type of interaction or is it the result of the excitation of the 'ocean' of quark-antiquark pairs? To quote just one other fascinating aspect of neutrino experimental physics: recent measurements at ITEP have set a new (and lower) upper limit of the electron neutrino mass at 35 eV. On the theoretical side the hypothesis of neutrino oscillations in analogy with the K^o oscillations was discussed in a paper by B. Pontecorvo and S. Bilenky, which also suggested ways of observing such phenomena at accelerators and on solar neutrinos.

Direct production of electrons and muons

The great experimental effort concentrated at the major accelerators and the ISR on the direct production of electrons and muons in high energy collisions has yielded many new results, but to determine the source of these particles more evidence will have to be collected on their rate of production, their energy dependence, their angular distribution, etc. It remains to be seen whether all results obtained so far can be interpreted in terms of the 'standard model'. Do the direct leptons arise from quark-quark interactions (the Drell-Yan model) or from the decay of vector bosons (ρ, ω, φ, ψ, ψ') together with the decay of charmed particles? One puzzling result from Serpukhov indi-

SPEAR: Observation of a charmed charged meson decaying into the exotic channel $K^{\mp}\pi^{\pm}\pi^{\pm}$ (exactly as expected for a charmed meson, i.e. no signal in the non-exotic $K^{\mp}\pi^{+}\pi^{-}$ channel).



cates that directly produced muons may be polarized but with opposite polarization to that expected from these models. The effect is scarcely more than two standard deviations from zero and needs confirmation. At Fermilab in another kinematic region no polarization was found.

The 'right faith' available to experimentalists in the form of the 'standard model' will provide them at least for a while with a nice yardstick for their results. Do they follow the model or indicate violations — do they point towards the existence of other particles or other types of interaction? First on the list of possible further extensions are perhaps the heavy leptons. The observations at SPEAR have not so far been confirmed at DESY. The question remains, if heavy leptons exist, whether they also contribute to the direct production of muons and electrons.

Deep inelastic collisions

Quarks and antiquarks of the 'ocean' are sometimes referred to by the more general name of partons (quarks are partons with specified quantum numbers). The parton model which successfully described the scaling behaviour of deep inelastic electron, muon and neutrino scattering appears in need of some drastic extension. The Fermilab experiments on deep inelastic muon scattering confirm and extend previous observations at Stanford: in the deepest inelastic region there are striking departures from scaling.

Hadronic collisions

Two-body collisions and, above all, the proton-proton elastic scattering studied at high energy at the ISR, have been investigated at even higher energies and larger angles so that a comprehensive description can gradually be discerned. The growing realization of the importance of spin effects contrasts sharply with what was anticipated perhaps ten years ago.

Many-body processes, covered in particular by the inclusive reactions as reviewed by P.V. Chliapnikov, also produced a wealth of new results, interpreted in terms of the concepts of Feynman scaling, limiting fragmentation, factorization, Regge exchanges, etc. Such concepts, so far often limited to a merely semi-qualitative description, are slowly becoming more precise in their meaning as the experimental findings define their areas of validity and their limitations. The emission of 'clusters' of particles as revealed by the study of the correlations between the emitted particles, appears to be closely related if not identical to the production and subsequent decay of known resonances.

Particularly striking (and related to the deep inelastic electron and muon scattering) is the phenomenon of particle emission at large transverse momentum p_T. First discovered at the ISR this has been clarified by many new results reviewed by P. Darriulat. The behaviour of the particles accompanying that of large p_T (the 'towards movers') and of those going in the opposite direction (the 'away movers') is now known in some detail.

Meson and baryon spectroscopy

The Conference offered the usual opportunity of reviewing progress in the field of meson and baryon spectroscopy. In both cases the quantum numbers of known states are established; decay modes and coupling have become better understood and some new states are found. The rapporteur, K. Lanius, chose to present the results in the framework of the classical quark model where the agreement is particularly striking. Practically all known states fall in predicted slots and, at least in the lower parts of the spectra, no empty place remains for the mesons, if one accepts as genuine states the very wide scalar objects known as ε and $\varkappa$, and particularly so for the baryons where the predictions of the model appear to retain their validity up to high quantum numbers.

New particles

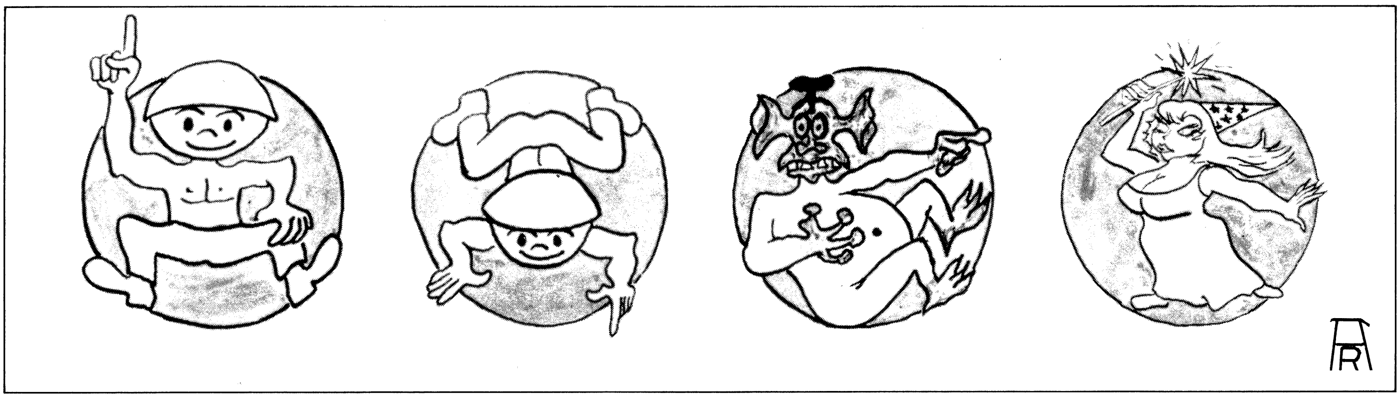
The four quarks, including the one with charm, constitute the basis of the spectroscopy of all known particles and also of the 'standard model' covering the new theory of weak and electromagnetic interactions. Quark believers can no longer be considered a 'bunch of religious fanatics'. However, the search for free quarks has remained unsuccessful, and theoretical models postulating or explaining the unbreakable confinement of quarks attract much interest. Other searches, so far in vain, were continued for such hypothetical particles as monopoles, tachyons, metastable particles of long (millisecond) lifetime, metastable nuclei, etc.

This line of research into entirely new phenomena predicted by far-out speculations or by analogy with known processes will certainly continue, but the main stream of research in the next few years will be directed towards testing experimentally the properties of charm and of other predictions of the 'standard model', to establish its range of validity, to fill in missing details and, by defining its limitations, to advance a little further in our understanding of Nature.

New accelerator techniques

Many of the recent experimental discoveries have been made with the aid of $e^- e^+$ and other particle storage devices: such machines and their more powerful successors should thus prove a fruitful source of important results for years to come. It was therefore appropriate that some developments in new accelerator techniques should be mentioned. A. Skrinsky reported on continued investigations of electron cooling carried out on a 100 MeV proton ring at Novosibirsk, work which was originally started in 1960 by G.I. Budker (see March COURIER 1975, page 73). Today's achievement is a cooling time of 80 ms and the process may well find application at UNK, the big Serpukhov machine where $p\bar{p}$ collisions with an estimated luminosity of 10^{30} — 10^{31} cm^{-2} s^{-1} are aimed for. The method of stochastic cooling already tried experimentally at the ISR (see September COURIER 1975, p. 264) could also prove useful for the cooling of $\bar{p}$ beams.

So it was, to all accounts, a very successful conference at an exciting stage in the history of high energy physics. There were no reports of excessive inebriation, which confirms that charmed particles had been found because a London rapporteur in 1974 (Iliopoulos) bet a crate of wine on that. In Tbilisi de Rújula went further, backing quantity rather than quality and betting a whole wine store that the next such conference would be dominated by charm particles and their pals. With so much wine (and a 'Weinberg') is the 'orthodoxy' perhaps becoming a cult of Bacchus?



The four quarks — Up, Down, Strange (sideways), Charm — as imagined and sketched by A. de Rújula. Only colour reproduction could do them full justice, however.

Nuclei at Cargèse

During the Cargèse Conference another 'Physique dans la rue' exercise was held in nearby Ajaccio (some 30 000 inhabitants). It was organized by Corsican physicists with experienced help from Orsay colleagues and M.-C. Detoeuf from IN2P3. Some 2000 people were attracted to this event and it received good coverage in the Press and on French TV. For one afternoon Conference participants, backed

From 19-26 May the 3rd International Conference on Nuclei far from Stability was held at Cargèse on the island of Corsica. It drew some 160 physicists from twenty countries to the attractive setting of the Institut d'Etudes Scientifiques. The location was selected particularly by R. Klapisch who animated the Conference with his enthusiasm which brings people as well as nuclei into an excited state.

It is six years since the previous Conference in this series held at Leysin and the study of highly unstable nuclei has advanced considerably since then, both in terms of the physics and of the experimental techniques which it employs. The field has become mature in the sense that experiments can now be planned with insight into the nature of the phenomena under investigation. We have space for just a few of the results presented at the Conference.

The experimental techniques are giving better results by orders of magnitude in some cases. A particularly fine example of this was reported from Los Alamos by G. Butler. They are using telescopes in combination with time of flight techniques which lock onto the r.f. structure of the 800 MeV linear accelerator LAMPF. The telescope gives a first stab at the mass, and the time of flight timing, using the 805 MHz signal from the linac, is then used to sharpen the value giving about 1 % mass resolution.

On-line isotope separators, such as ISOLDE at CERN, are now a prolific source of experimental results and the experimental techniques seem thoroughly mastered. It was amusing to hear O. Kofoed-Hansen recalling crudities of the very first such experiment at Copenhagen 25 years ago.

A new method for measuring extremely short lifetimes of nuclei was presented by J. Hardy of Chalk River. It uses the phenomenon of delayed proton emission (see January issue 1970) combined with electron capture to pin down nuclear lifetimes to 10^{-16} s. For example, a selenium nucleus can capture an orbiting electron from its K shell converting to an excited state of an arsenic nucleus which can then decay to a germanium nucleus via delayed proton emission. The proton can actually be emitted before the K shell is refilled by an electron and the X ray corresponding to this refilling is then modified in energy because the K shell has become that of germanium rather than arsenic. Ratios of X-ray intensities make it possible to measure lifetimes by relating the unknown nuclear lifetime to the known atomic lifetime.

Another technique, not discussed at the Conference, which can give such accuracy in lifetime measurement is under development at CERN using the channelling effect and drift chambers (see June issue 1975). The recoil of nuclei into the gaps between crystal planes and their subsequent decay while able to emit along the direction of crystal axes could allow lifetime measurements down to 10^{-18} s. It is interesting that both techniques come from outside the nuclear domain: atomic physics and solid state physics.

D. Hoffman from Los Alamos described an intriguing result on fermium (element 100) nuclei. In a technically very clever experiment they bombarded fermium 257 in a tritium beam from a tandem Van de Graaff and measured the masses of the fission products from the decay of fermium 259 which was thus formed. This revealed that the nucleus seems to split predominantly into two nearly identical pieces. It may be that the high stability of the tin 50 nucleus with 82 neutrons (doubly magic numbered) is already having its influence even though the parent nucleus is 5 neutrons away from being able to give two such tin nuclei.

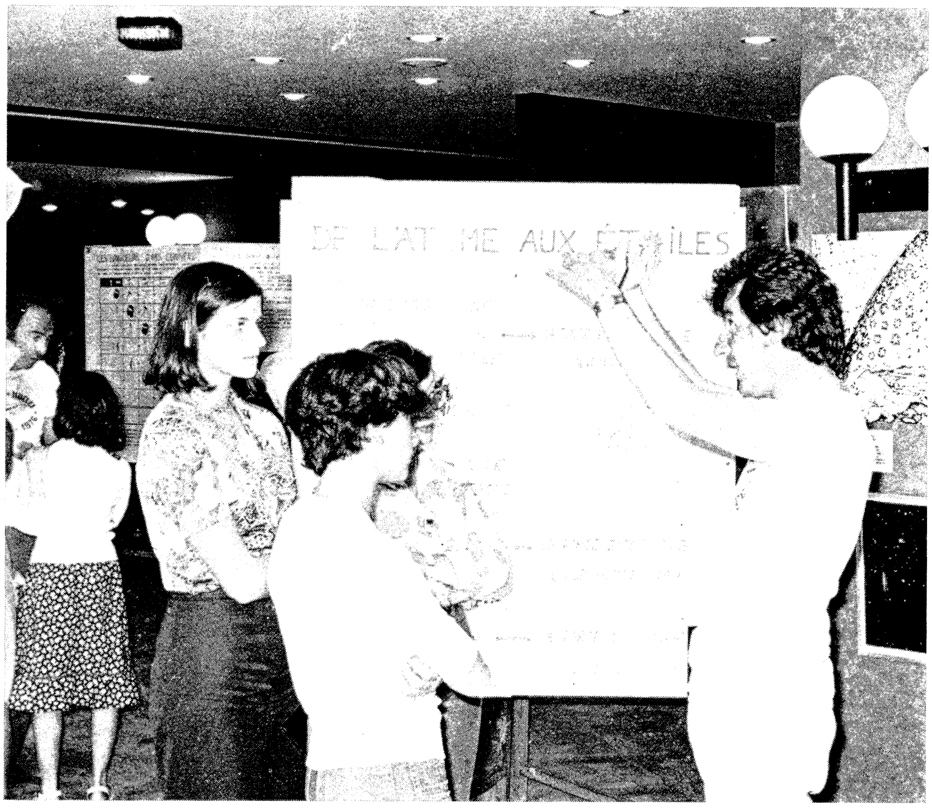
C. Thibault covered the latest measurements of the Orsay spectroscopy group at CERN. Using the PS they have covered a range of sodium isotopes and found two heavy isotopes much more tightly bound than expected. The group has moved to ISOLDE since the beginning of this year with a spectrometer which improves their mass resolution by one to two orders of magnitude. They take nuclei already separated by ISOLDE and after a second acceleration the atoms are analysed through magnetic and electrostatic elements. The group has already covered the rubidium isotopes as the first of a long series of high precision measurements which the spectrometer can tackle.

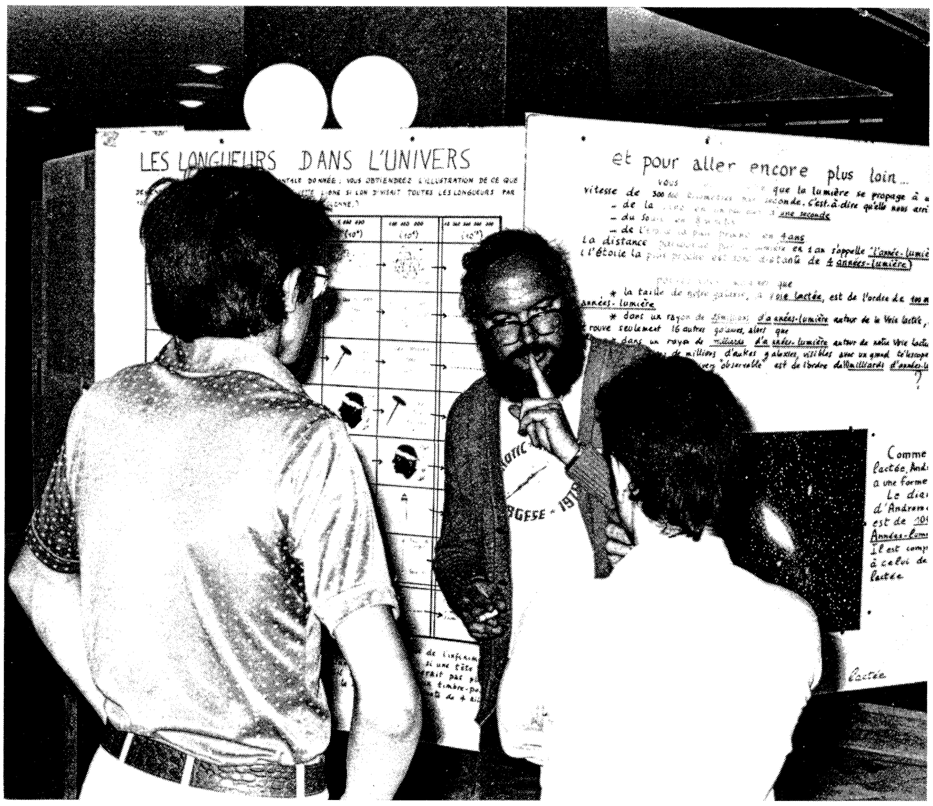
Another series of measurements in its early days at ISOLDE has been started by a CERN/Jülich group using a bent-crystal spectrometer. They now have sufficient intensities to look at X rays from electron capture and to see the effect of excited nuclei. They thus have a tool for measuring how the nuclear radius changes in the various excited states — as if they were measuring the nuclear thermal expansion coefficient.

There was, of course, the traditional discussion on heavy elements between Berkeley and Dubna concerning who found what, where and when. It is a pity that the claim from the group of R.V. Gentry at Oak Ridge that they have seen superheavies came after the Conference where they could really have been submitted to specialist scrutiny. The claim is that nuclei of elements 116 and 126 have been spotted via stimulated X-ray emission in crystals of monazite. It will be interesting to see whether these elements have gone away or have been well established by the time the far from stability physicists get together for their next Conference.

by exhibits, operating spark chambers, films, solar cooking of the local sausage etc., confronted the public ready to discuss any topic that arose: C. Détraz, explaining the forces binding the atom and all around us, raises his arms towards the stars, while silence seems to be called for (by P. Quentin) in contemplation of the immensity of our universe.

Around the Laboratories





ARGONNE
Future of the ZGS

ERDA has announced its intention to close down the 12 GeV Zero Gradient Synchrotron at the Argonne National Laboratory at the end of calendar year 1978. This is another stage of the retrenchment in the USA high energy physics programme in the light of limited funds and of the priority given to the new facilities at Fermilab and at Stanford.

A study of the ZGS programme was carried out in 1974 and, at that time, the recommendation from the study was that the ZGS should be kept in operation until 1979 at the earliest. 'Earliest' has rapidly become 'latest' and the Argonne management is developing plans for the coming years to extract the maximum physics from the facility before the close down takes place.

The ZGS has been a very productive machine in its twelve years of life supporting some 200 experiments by 500 experimenters from 70 institutions. The major areas of research have been hadron spectroscopy, neutrino physics with the 12 foot bubble chamber (which is currently being rejuvenated by the installation of a track sensitive target) and polarized beam experiments.

The study of spin effects in high energy interactions using polarized beams and polarized targets is the most lively feature of the present experimental programme. The ZGS is unique in accelerating polarized protons to GeV energies: 6 GeV polarized beams were achieved in July 1973 and 12 GeV polarized beams in 1976. Polarizations are 70 % at 6 GeV and 60 % at 12 GeV. Intensities have been raised from about 10^8 protons per pulse to 2×10^{10} ppp and further improvements to the ion source (adding a second sextupole in the atomic beam stage and using a microwave dissociator) will probably allow 5×10^{10} ppp to be achieved soon. There are six beam lines capable of transporting polarized beams and some have spin rotating magnets and polarized targets. To complete a thorough programme of experiments on spin dependences using these beams requires several more years of ZGS operation and this has prompted the following reaction to the projected close down.

To finish the present series of experiments in hadron and neutrino physics, Argonne is requesting more extensive exploitation of the accelerator during 1977 and 1978 (additional finance of about $1 million per year to allow about nine months of operation rather than the present seven months). For 1979, 80 and 81 Argonne proposes that the ZGS continues to run six months per year with polarized beams only. This would require an expenditure of about $5.5 million per year on machine operation compared to $10.5 million at present. After that date it is hoped that a strong base for high energy physics research and development will be sustained at Argonne involving an investment of about $4.8 million per year which is the level at which this work runs at the moment.

The ZGS performance with unpolarized beams has been raised to the level of 5.4×10^{12} protons per pulse peak intensity with an average intensity of about 4.6 ppp. Further increase in intensity will be achieved with the commissioning of a 500 MeV booster (known as Booster II) early next year. It is a 30 Hz, 5×10^{12} ppp machine designed to take the ZGS to 10^{13} ppp. It uses negative hydrogen ion injection — a technique pioneered at Argonne. Direct injection of H^- into the ZGS has been successfully tested (see May issue 1976, p. 176).

Construction of the Booster is well under way and is scheduled for completion by the end of the year. Insulation problems with the first magnets to be delivered have caused some delay and magnet assembly is now being done within the Laboratory. One r.f. accelerating station is installed and the other is almost ready. The 50 MeV injection line, the magnet power supplies, the injection and ejection magnets are well advanced.

The ZGS will not need all the Booster pulses. Even for maximum intensity neutrino runs only about 10 % will be needed which leaves protons available for other uses. One possible application is in proton radiography where very encouraging results were obtained two years ago (see September issue, 1974, p. 303) but this is not being pursued at the moment.

Another application is to plough the proton into a target to serve as an intense source of neutrons. This was promoted under the name ZING (ZGS Intense Neutron Generator) following work on Booster I, and further tests will be carried out with Booster II. A variety of schemes culminating in a proposal to build an Intense Pulsed Neutron Source (IPNS) at a cost of about $50 million have been developed. This proposal has strong indigenous backing from research workers in materials science at Argonne who are probably the strongest group in their field in the country. The neutron source would be used for materials science, solid state physics and life science research.

There is a strong belief that this project will be supported — it seems the only practical way to increase neutron fluxes beyond those presently obtained at reactors — the research programme that it could support is very broad and the user community is very large. A very similar scheme is being promoted by the Rutherford Laboratory in the UK and there is another proposal to use the LAMPF proton linear accelerator at Los Alamos. How rapidly such a project would receive support depends on the priority given to neutron research in the USA science budgets and on the close down programme of the ZGS, since IPNS would use some of the ZGS buildings and equipment.

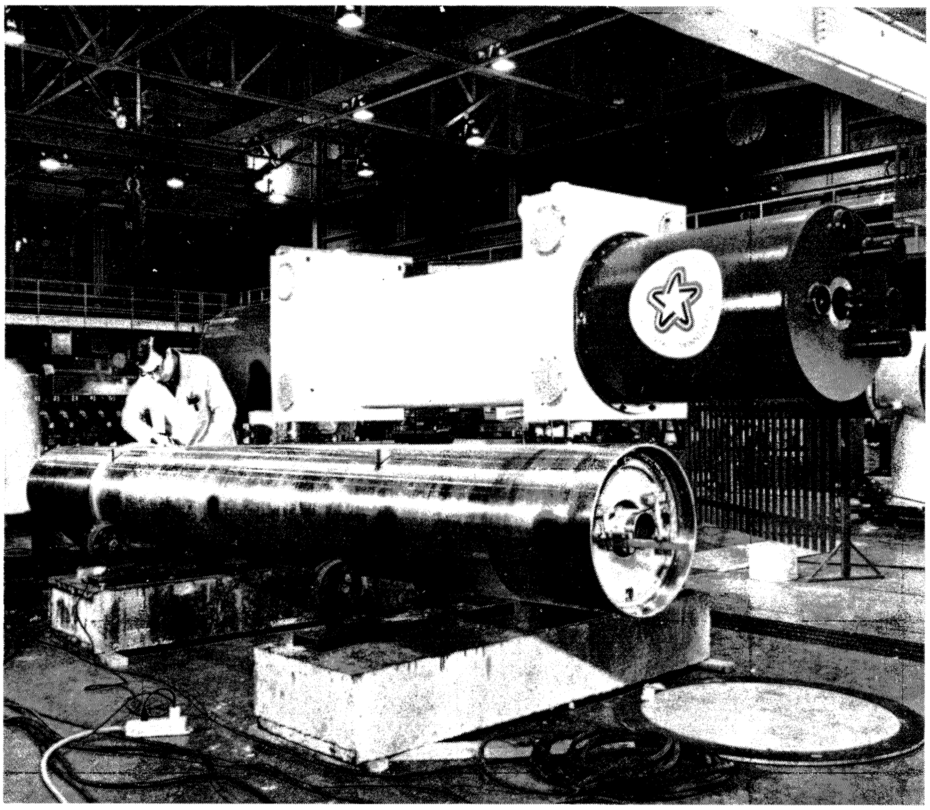
Another major project which would call on accelerator expertise is a scheme to use high energy heavy ions to achieve fusion in deuterium-tritium pellets. The Argonne project is known as HEATHFIRE (High Energy Accelerator for THermonuclear Fusion with Ion beams of Relativistic Energies) and involves stored beams of singly charged hydrogen-iodide ions at 40 GeV. Iodine ions would be released by photon bombardment (xenon flash doppler shifted by a ruby laser) in a bypass of the storage ring. The iodine ions are focused on a pellet 1 mm in diameter in a few nanoseconds to initiate fusion. There are some fundamental questions to be answered (such as the ability to hold the ions in a singly charged state and the accuracy of the pellet calculations) but essentially the scheme is based on proven accelerator technology. A research and development programme spanning two or three years and costing several million dollars a year has been proposed prior to launching HEATHFIRE itself.

BROOKHAVEN Work on ISABELLE

The 200 GeV proton-proton colliding beam machine, ISABELLE, proposed for construction at the Brookhaven National Laboratory has received CP and D (Construction, Planning and Design) money to the tune of almost a million dollars (as reported in our March issue). The money is to be used to tighten the cost estimate for the project and is allocated when a project is likely to receive full support.

The MkII 4.25 m superconducting dipole, which is a full-scale model bending magnet for the ISABELLE storage ring project at Brookhaven, in front of its cryostat decorated to celebrate the bicentennial. This magnet has been modified so that forced cooling can be used. The first tests with the new cooling technique have been extremely encouraging.

(Photo Brookhaven)



(The money is, in effect, a loan which would be deducted from the budget when construction began.)

ISABELLE is an 'intersecting storage accelerator' scheme taking 30 GeV protons from the Alternating Gradient Synchrotron, accelerating them in opposite directions in two rings and colliding them at energies up to 200 GeV per beam. There are eight intersection regions where luminosities up to 10^{33} per cm^2 per s could be achieved. The revised cost estimate is $166 million and the hoped for starting date for construction is in Fiscal Year 1978 (from October 1977).

All aspects of the machine design are under study but attention tends to focus on the development programme for the superconducting magnets. We have already reported the performance of MkI and MkII full size (4.25 m long, 8 cm warm bore) dipoles. Their coils are constructed of braid, 1.7 cm wide, made of 97 niobium-titanium composite wires each 0.3 mm in diameter. The coils are supported in cores built up of 15 cm thick unsplit laminations which are also held at liquid helium temperature.

MkII reached design field of 4 T on its first quench and peaked at 4.5 T after twenty quenches. MkIII was tested in June and ran into some heating problems probably due to a change of filler which was introduced to help quench propagation through the magnet (quench front stalling in MkI had burned out a turn). Replacing with tin based filler should clear these problems. MkIV is ready for assembly. MkIII and IV are prototypes for the ISABELLE ring magnets with some changes compared to I and II mainly in the coil end configurations to improve the total field integral.

The most important recent news on magnet performance concerns the conversion of MkII from a 'pool boiling' cooling technique to a 'forced cooling' technique after inserting the coils in an unsplit core. During tests on the converted magnet, there was a higher heat load than anticipated (not related to the magnet itself) and the temperature could only be taken down to 4.4 K. On the second test, training started at a field of a little above 4 T and the field ultimately reached over 4.75 T at 4.6 K. The system performed very well and the time necessary to climb back to a high field after a quench was reduced to about 15 minutes compared to many hours with pool boiling.

The ISABELLE magnets are to be cooled by forced circulation of high pressure gaseous helium. Such a cryogenic system is much more efficient than a 'pool boiling' system where the magnets are immersed in liquid helium. In MkII the helium was fed to the magnet at about 15 atmospheres pressure and circulated through spiral and axial channels in the fibreglass bands of the coils.

The focusing quadrupoles for ISABELLE incorporate many of the design features of the dipoles using the same braid with the coils clamped in cold iron and with the same 8 cm beam aperture. Tests of the first full-scale model, 1.5 m long, began in Spring and the first quench occurred at a field gradient of 51 T/m which is about the required operating gradient. After 14 quenches the quadrupole had trained to 71 T/m (equivalent to a dipole field of 4.8 T).

The immediate aim of the ISABELLE magnet development programme is to operate a 'half-cell' of the ring lattice — two dipoles and a quadrupole — in a few months' time. The half-cell will be fully instrumented and computer controlled and should give valuable experience on bringing all the necessary systems together. Meanwhile the magnet experts are also busy bringing together four large aperture beam line magnets for the high energy unseparated beam line (HEUB) which will feed particles to the multiparticle spectrometer (MPS). These magnets are close relatives of the ISABELLE dipoles but are 2.5 m long with a 20 cm beam aperture. Two are being installed having met their design parameters and the other two are likely to be ready by the end of this year.

Other ISABELLE systems such as cryogenics, vacuum, r.f., etc. are also under development. A series of workshops has been initiated, with the participation of experts from both inside and outside Brookhaven, to look at aspects of the machine design and of the experimental exploitation of the storage rings. Options for longer term development are also receiving attention — the possibility of proton-antiproton experiments building up antiproton beam intensities using the 'cooling' techniques pioneered at Novosibirsk and CERN, the possibility of an additional ring of conventional magnets for stacking current prior to injection into ISABELLE, the possibility of higher energies using higher field superconducting magnets.

The considerable effort being devoted to the ISABELLE project has necessarily weakened the support of the 33 GeV AGS and its experimental programme. Nevertheless the AGS has been performing better than ever reaching a peak intensity of 1.1×10^{13} protons per pulse and sustaining an average of 0.9×10^{13} for whole operating periods.

Neutrino physics is a major feature of the experimental programme since the AGS is able to supply high neutrino fluxes (it has given 9×10^{12} protons on to the neutrino target at a repetition rate of one pulse per second) at energies high enough to produce interesting physics without the high multiplicities in particle production which can occur at higher energies. A new series of counter neutrino experiments has been proposed and the 7 foot bubble chamber will be back in action in the neutrino beam in October. (The chamber had a support structure failure when being used with neon.) Experiments have started in the MPS multiparticle spectrometer and the first results are coming out. Finally, a fascinating experiment looking at short lived neutral kaon decays has seen the emerging pion and muon in orbit around one another and the Lamb shift in this mini-atom can be observed.

Other studies using Brookhaven accelerator expertise include the acceleration of heavy ions to produce fusion reactions in deuterium pellets, the production of neutron beams for fusion reactor materials testing, the production of neutral beams for plasma heating in a fusion reactor, and electron storage rings as intense sources of synchrotron radiation. We shall be coming back to some of these topics in future issues.

FERMILAB 500 and doubling

Fermilab is still basking in the achievement of 500 GeV peak energy in May. More than the intensity records, this has been a major goal of the Laboratory and has brought great satisfaction. Experiments at the new energy are likely to be scheduled within a year. 400 GeV has been the standard operating energy since July 1975 with average intensities around 1.8×10^{13} protons per pulse fairly reliably and a peak intensity of just over 2×10^{13} ppp. About 100 hours per week go to the high energy physics programme, up to 15 hours to accelerator physics with the rest scheduled and unscheduled downtime.

The 200 MeV linac has accelerated a beam of 235 mA, more than double the design intensity, since the installation of a larger aperture 750 keV pre-injector column. If this current could be transmitted through the rest of the machine it would give intensities of over 5×10^{13} ppp. Another large aperture column was installed at the end of July with better focusing properties which should give improved beam quality and, possibly, still higher currents.

With such a high linac current, single turn injection into the 8 GeV booster is acceptable, rather than the multiturn injection initially intended, and losses at injection are reduced. A peak output beam of 2.7×10^{13} has been sent to the main ring. Two new booster r.f. accelerating stations have been added, which has improved the ability to accelerate more intense beams and the overall reliability. 'Dampers' in the booster and in the main ring have helped to suppress parasitic modes in the r.f. cavities.

More dampers will be installed as part of the continuing refinement process towards extracting more protons from the machine. Two turn injection into the main ring will be attempted soon (it adds about 1 s to the machine cycle time) and it is expected that over 2.5×10^{13} at 400 GeV will be reached before the end of the year. The next major improvement may follow the introduction of negative hydrogen ion injection into the booster; this project is going slower than initially intended but it is hoped to begin H^- operation in about a year's time.

Meanwhile there is more to be done to increase reliability. Magnet failures are now less than one per month, more feeder cables conveying power to the main ring need to be added and others replaced, the main ring magnet power supplies are being improved . . . The capacitor tree in the Laboratory substation, which matches the magnet system to the electricity network, is now in action reliably and was crucial to the achievement of 500 GeV and to operation with flat-tops of 2 s duration at 400 GeV.

The physics programme

The experimental programme at the accelerator is locked into the exciting developments in particle physics in the past three years. A particular forte is the ability to produce the world's highest energy neutrino beams and the neutrino experiments have thrown up a lot of surprising new information. The latest eye-brow raiser has been evidence for a 'high Y anomaly'. Counter experiment data indicate that the ratio of antineutrino to neutrino interaction cross sections, which is constant at a value around 1/3 at low energies is rising at energies above 50 GeV. (The bubble chamber experimental data are not convincingly pro high Y and will be gathering more statistics.) From the three-quark model of the nucleon, the value of 1/3 for the probability of an antineutrino

On 12 July 'citations of appreciation on the occasion of the achievement of 500 billion electronvolt energy' were presented to Fermilab staff 'in recognition of many valuable contributions to the successful construction and operation of the Fermi National Accelerator Laboratory'. The photograph shows Bob Wilson making the presentations to the operations support group during a lunchtime barbecue.

(Photo Fermilab)

interaction compared to the probability of a neutrino interaction emerges logically. If the ratio rises at high energies it implies that there is something else (perhaps more quarks and antiquarks) around.

Is the three-quark nucleon picture, for which we now have so much evidence, hiding some quark-antiquark core — the three quarks being valence quarks acting like electrons orbiting the nucleus of the atom and causing all its more obvious behaviour? Another hint in this provocative direction comes from the 15 foot bubble chamber pictures in the neutrino experiments which are candidates for interactions involving charmed particles (see January issue, page 3). The interactions produce a surprising number of kaons and, unless there are some extra quarks around in the nucleon, it is not easy to work out where all the kaons are coming from.

These are highly speculative ideas at the moment but some new phenomena seem to be at work. To try to pin them down in more detail, the counter experiment is having its detection system improved and the 15 foot bubble chamber has more neutrino runs scheduled. Also the advent of the SPS neutrino programme at CERN will add greatly to the information input.

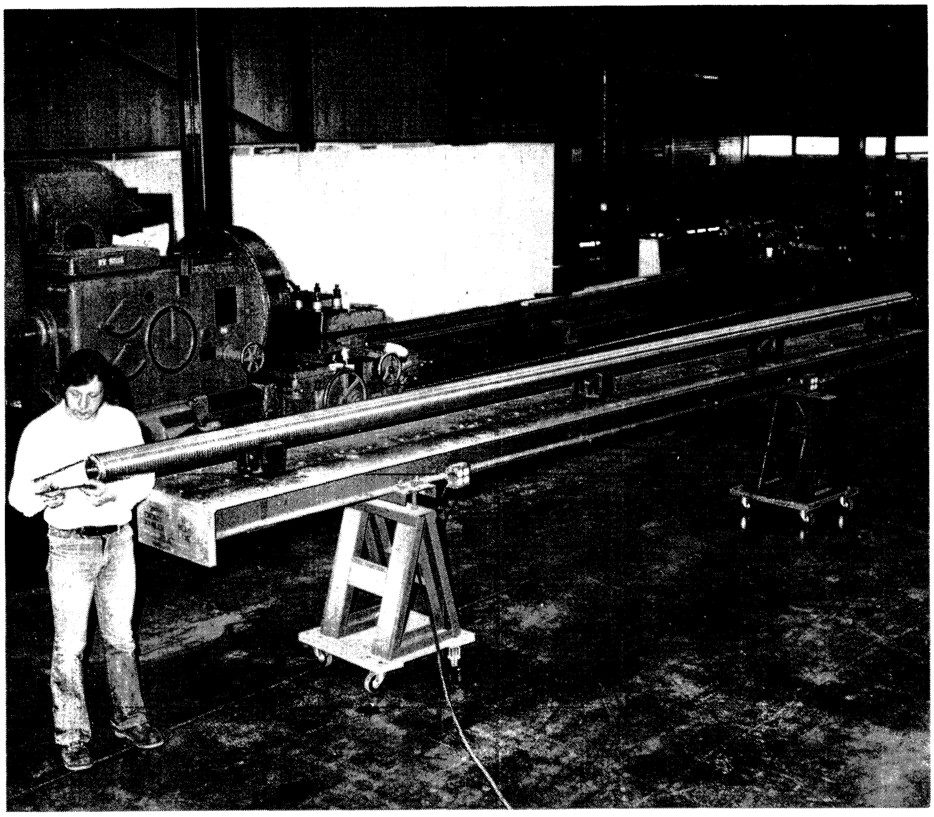
The first run with a heavy hydrogen/neon mix in the 15 foot chamber gave pictures of excellent quality and it seems to be reasonably straightforward to sort out the interactions. The data taking rate goes up considerably with the more dense target liquid and as many as four neutrino interactions have been recorded on a single photograph. Following discussions with the Program Advisory Committee (PAC), which met in Aspen at the end of June, the bubble chamber schedule for the next year will probably begin with a hydrogen fill in late autumn followed by a heavy hydrogen/neon fill. A deuterium fill, to take a cleaner look at the interaction with the neutron, will take place next summer. By this time it is hoped that the accelerator intensity will be considerably higher and that double pulsing of the 15 foot chamber for neutrino experiments using the focusing horns will be feasible.

Other searches for charmed particles in hadronic interactions, such as proton-proton collisions, have not unearthed any clear evidence for them. There are so many ways in which such high energy interactions can go that sorting out the wanted event from the background is extremely difficult. Leon Lederman stimulated discussions on this problem at the PAC meeting by graphically describing high energy hadron-hadron collisions as 'like throwing two garbage cans at one another'. There is so much garbage flying around that spotting any gems is almost impossible. Fermilab is taking another look at the emphasis given to experiments using tagged photon and broad-band photon beams where sorting out the interactions produced is easier.

The experiments with the muon beams, drawn parasitically from the neutrino beams, have provided some useful information. They have shown that scaling breaks down at high energies (as predicted by field theories) and they have evidence for new phenomena such as the di-muon events seen in the counter neutrino experiment. These events where two muons emerge from an interaction could originate in the production of a pair of charmed particles. When they are recorded in reasonable numbers in bubble chamber experiments too, it should be possible to work out what is happening to the hadrons when di-muon production occurs. The improved counter detection systems should also add more information.

It has been decided, following the PAC meeting, to launch a facility for hyperon experiments at Fermilab. It will be located in the Center pit of the Proton Laboratory which will thus house proton experiments, as at present, and the first half of the hyperon beam. It is hoped that the first charged hyperon experiment will start by the summer of 1978.

A major discussion at the PAC meeting covered the 'modest storage ring proposals' which have emerged at Fermilab during the past year. They included schemes for building a small storage ring (SSR) of around 30 GeV to collide protons with protons in the main ring, for colliding protons with protons using the Energy Doubler and the main ring, and for colliding antiprotons with protons using the main ring and the Doubler. PAC recommended rejection of all the proposals so that in the immediate future the resources of the Laboratory would not be diverted from the challenging task of building the Doubler.



The coils of a 22 foot superconducting magnet, such as are being developed for the Energy Doubler at Fermilab, prior to being introduced into their cryostat and iron yoke. This is one of the recent types where the coils are held in stainless steel collars which eliminate deformations encountered with the previous banding technique. At the time of writing the coils of six 22 foot magnets had been wound.

(Photo Fermilab)

The recommendation was in no way a rejection of the ideas behind the colliding beam schemes or of their physics potential. On the contrary the PAC urged a detailed look at the various possibilities, suggesting a 'workshop' to define optimal configurations of the Doubler, experimental halls and detectors prior to calling for colliding beam proposals. They also urged the study of methods to produce stored antiproton beams so that this option would also be kept open. In July, there were also meetings at Fermilab to discuss the possibilities with electron beams, which adds still more options to the list. Before the end of the year some selection is likely to be made so as not to dissipate effort over too many possible colliding beam projects.

The Energy Doubler/Saver

Work on the Energy Doubler is going ahead as the Laboratory's major project for the next few years. It is being built as a research and development project, which seems appropriate to an exercise involving the first large-scale use of pulsed superconducting magnets, and no special authorization for the construction is necessary. The present funding includes $8.6 million from the Laboratory's resources plus $3.9 million from ERDA specifically assigned to the Doubler. At the latest Congressional hearings on high energy physics money it was stated that the government expects to fund the project next year (fiscal year 1978, beginning October 1977). The cost estimate (depending on such things as the rate of funding) is $50 million.

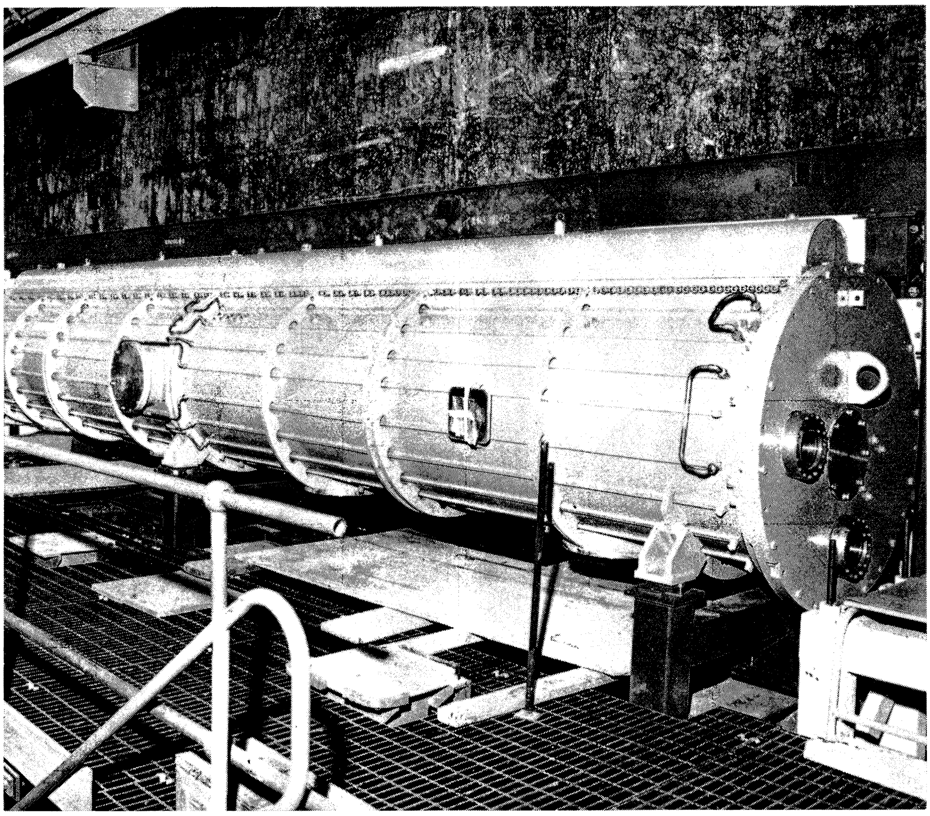
The Doubler is a ring of superconducting magnets to be installed underneath the existing main ring magnets with a field capability of 4.5 T compared to the main ring 2.25 T, enabling the peak energy to be taken from 500 GeV to 1000 GeV (1 TeV). Since the use of superconducting magnets rather than conventional magnets would absorb less power for an equivalent energy performance the project carries the additional title of Energy Saver.

Since the Doubler programme began in September 1972 a multitude of superconducting magnets have been built and gradually the goal of magnets of appropriate quality for a synchrotron at reasonable cost has been coming more and more into view. A full scale (22 foot) prototype achieved the desired field in March of this year and superconductor cost is near the original estimate of $1.5 per foot. The latest 23 strand cable (Rutherford style) is $1.52/foot growing to $1.83 with insulation. Since close on 5 million feet are required (800 dipoles with about 6000 ft each plus about a million feet in the focusing quadrupoles) superconductor cost is a vital parameter.

Coils for six 22 foot magnets have been wound and the winding rate is now about one set of coils every two weeks. An inner shell half coil has 34 turns and an outer shell 21 turns. The conductor is keystoned (made approximately trapezoidal in cross section) so that it packs together better. Coil banding has been abandoned in favour of close fitting collars (half ring laminations of stainless steel). Both these changes — keystoning and collaring — hold the conductor better and improve magnet training characteristics. Assembly with a central mandril in place has improved the mechanical alignment.

Testing of construction techniques, field measurements etc. continue on a series of smaller scale magnets. It is accepted that some tens of full size magnets may need to be built before the production schedule can settle down giving quality magnets. The experimental area beam lines will also need converting to handle 1 TeV beams and many of the early 22 foot magnets could be used there where the quality requirements are not so stringent. There have been trial installations in the main ring which did not uncover any great problems. The next milestone, before the end of the year, will be to power a string of magnets in series (perhaps four of them initially, though the strings in the Doubler will be seventeen magnets long) to test the ability to quench the magnets without causing any damage.

The refrigeration system for the Doubler will be the most powerful in the world. The building for the central plant is under construction; it will produce 4000 litres of liquid helium per hour, which will be conveyed to satellite stations around the ring. The first of the satellites is under test. There is a tremendous amount of work still to be done but the Doubler looks firmly on its way.



Tank 1 of the new 70 MeV linac at the Rutherford Laboratory in its raw state after delivery from Morfax Ltd. Water cooling, electrical connections, vacuum pumps, r.f. feeds have since been added and the tank has done its bit in achieving design energy in May.

(Photo Rutherford)

RUTHERFORD Commissioning of new linac

Construction of a 70 MeV proton linear accelerator at the Rutherford Laboratory, originally designed as a new injector to increase the intensity of the 8 GeV Nimrod proton synchrotron, is now complete and a 70 MeV beam has been obtained. The injector, sited alongside the existing 15 MeV linac, figures prominently in the Laboratory's plans to adapt the Nimrod complex into a high intensity neutron source (see May COURIER).

The design specification for the new linac calls for an output beam intensity of 75 mA with a pulse duration of 500 μs and a maximum repetition rate of 1 pulse per second. It has four tanks, the second and third being from the 50 MeV proton linear accelerator (PLA) closed down at the Rutherford Laboratory in 1969. The first and fourth tanks are new and are based on the design of the Brookhaven and Fermilab 200 MeV injectors.

The pre-injector is designed for a 200 mA beam intensity of 500 μs pulse length. Protons from a small duoplasmatron source (outer dimensions 130 mm long by 100 mm diameter) are focused into a medium gradient column (16 kV/cm) and accelerated to an energy of 665 keV. The effect of beam loading on the output voltage of the Haefeley Cockcroft-Walton EHT generator is reduced by means of a 0.01 μF reservoir capacitor. A drop of about 10 kV would still occur, but is stabilised by means of an electronic stabiliser (the 'bouncer') which applies a compensating signal to the earthy plate of the reservoir capacitor. In October, the pre-injector was working to specification with stable, repeatable characteristics. The bouncer worked at almost the first attempt and held the accelerating potential steady to within 200 V.

In parallel with the commissioning of the pre-injector, installation of the four radio-frequency power systems was proceeding. A common low power drive chain, from the old Rutherford Laboratory PLA, supplies a 202.5 MHz drive signal at a power level of 20 kW, which is divided between the four r.f. power amplifiers. Each of these has a peak power output capability of 4.25 MW and produces a 700 μs pulse which is loop-coupled to the tank. The first system to be completed was that of tank 2, which was operated at its design field in the autumn of 1975.

Installation of the remainder of the machine was completed early in 1976 and a beam was accelerated through the first tank to 10 MeV in February. Tuning runs gave 28 mA of 10 MeV beam within the first week without the buncher. Subsequently, with the buncher powered and with improved tuning, more than 80 mA of 10 MeV beam was measured at tank 1 output. By the end of April beam was allowed through the machine to an external beam-stop. Working with short pulses, tanks 2, 3 and 4 have been progressively commissioned and 70 MeV protons were first seen on 19 May. Efforts now turn to minimising beam losses and achieving high reliability. Commissioning will probably be completed by the end of 1976.

DESY On-line

One of the VIT's (very important things) at a high energy physics Laboratory is the computer centre — frequently used but comparatively rarely mentioned. It is well known that today it would be impossible to do high energy physics without big and fast computers, handling the large quantity of data produced by the experiments. In most Laboratories the normal way of doing physics is to take data at the experiment, assisted by a small computer and to go afterwards to a big computer to sort out the results. At DESY (and a few other Laboratories such as Daresbury) the concept is different — the big computer is part of the experiment from the beginning.

24 'assistant' computers at the experiments, including an HPD automatic film measuring machine, are connected on-line with two IBM 370/168s at the computer centre. The small computers are checking the experimental set-up and collecting data, but the data go directly to one of the 168s. The primary data will be written on a tape and also used to calculate some first physical results. DASP and PLUTO for example — the two big detection systems situated at the interaction regions of the DORIS storage rings — are sending ten kilo-

bytes per second to the IBM filling a magnetic tape with 36 megabytes per hour. Performing this job and doing calculations on this on-line data absorbs about 10% of the IBM's capacity.

The argument of the not-on-line specialist that he would never dare to be dependent with his experiment on a computer centre is countered by the DASP group's experience — only four days within the last 17 months lost because of the on-line connection.

Each on-line computer is supported by a separate on-line job in the central computer. To avoid overloading the store and unnecessary scans of supervisory programs through mainly inactive queues, every job which is idle for more than an hour is automatically thrown out but can be reinvoked through an interrupt within 20 s. Thus the number of on-line jobs living in the computer at any one time has been reduced to about 5 to 6.

Another important facility is the data-set migration scheme. Every user's request for allocation of a permanent data-set on disc is satisfied out of a pool of discs which now extends to 500 megabytes. Whenever a certain upper threshold is reached, this disc pool is emptied, to a certain amount on a least-recently-used basis, by copying data-sets to tape. This can be done because the user identifies his data by a unique name only, not specifying the name of the volume his data resides on. Once this data is emigrated, the user is free to process his data off tape or to immigrate it first. By this method it was possible to extend the effective disc space to 3 gigabytes at the cost of some data movement which is mainly done during night shifts.

The following figures show that most of the users are wanting their data-sets frequently: More than 1000 jobs are calculated each weekday. Each week in recent months 5.2 to 6.7 kilojobs were passing through the computers. During 325 days in 1975 263 kilojobs were calculated. Within these 7800 hours for each '168', 7005 hours CPU-time was used — an average CPU time per job of about 1.6 min. At the end of this year the capacity of the DESY computer centre will be saturated.

Starting a job on the machine is possible by feeding cards into the reader or by using one of 16 terminals of the TSO time sharing system located at different places on the DESY site. An interactive plotting system, IPS, enables users to look at their data in a graphic form or even to produce a graph of their experimental setup. Most of these special services are programmed and handled by the DESY computer staff. The centre is run by 6 system programmers, 4 programmers and 18 operators.

New particles

Reports about new particles continue coming in. Those people who favoured charm theory already at the end of 1974, when the J/ψ and ψ' were found, seem now to be the final winners over their colleagues who preferred other models. At the same time when SPEAR announced a spectrum of particles near 2 GeV as good candidates for charmed mesons (see June COURIER 1976, p. 211) DORIS, the electron positron storage ring at Hamburg, presented results on the semi-leptonic decay of those particles.

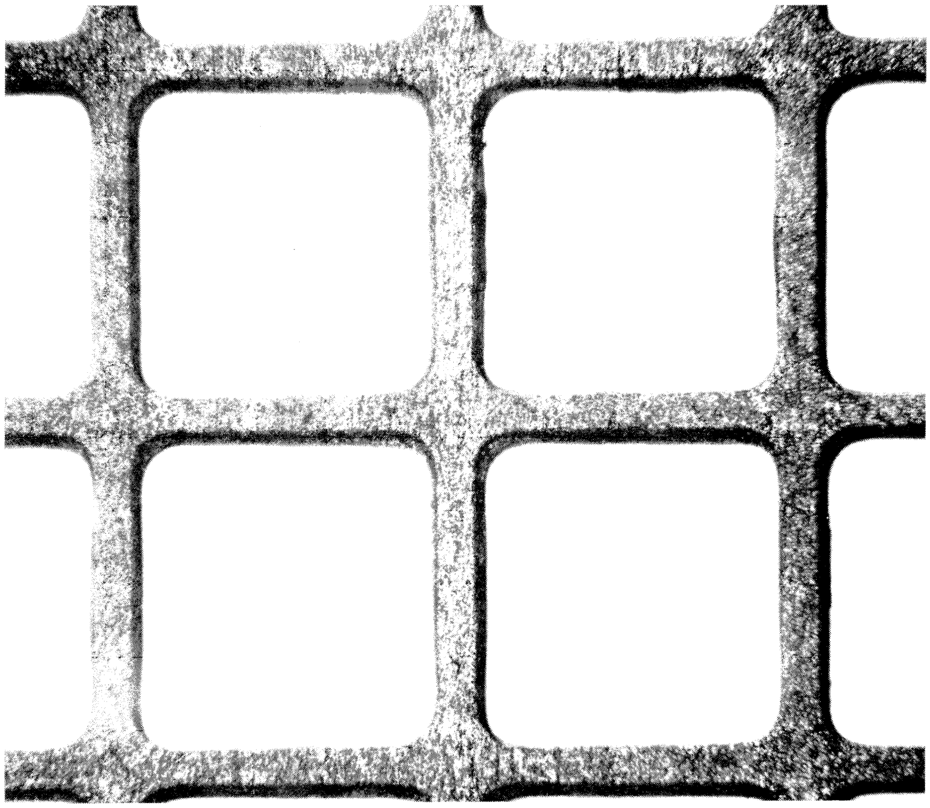
As the members of the J/ψ family are bound states of a charmed quark and an anticharm quark they have no visible charm. Charmed mesons are however combinations between a charmed quark and one of the three old quarks. As charm is not violated in strong and electromagnetic interactions a charmed meson can only decay by weak interaction. The charm theory predicts that charm quarks couple preferentially to strange quarks, which means that the decay into a K and a lepton must be visible besides the decay into a kaon and one or more pions seen at SPEAR.

Since the beginning of 1976 DORIS experiments have concentrated on these channels and found an extraordinary electron production starting at energies above 4.0 GeV. The spectrometer PLUTO (run by a collaboration of DESY, University of Hamburg, Siegen and Wuppertal) and the DASP collaboration (Aachen, DESY, Hamburg University, Max-Planck-Institute Munich, and Tokyo) are able to see electrons and positrons down to an energy of only 300 resp. 200 MeV/c. DASP people, for example, used a Cherenkov counter in front of the magnet to identify electrons. Asking for at least three other particles in the inner detector led to 22 events which can only be due to a weakly decaying particle. A high multiplicity of pions, which peaked at 5 to 6, excluded heavy lepton decay for these events.

Since the charm theory predicts a strong relation between charm quarks and strange quarks both experiments looked for events with the appearance of a kaon and a single lepton. Both spectrometers were successful: at PLUTO a sample of simultaneous production of K^0_s and electrons was found and DASP people are sure that they have observed events with charged kaons and electrons, both together with a high multiplicity of pions. It is interesting to know that PLUTO saw this correlation at a centre of mass energy of 4.1 GeV but not at 4.4 GeV though a good K-signal there has also been observed. Measuring at 3.6 GeV showed that there is no eK correlation below the threshold. All these events cannot be interpreted without the existence of new hadrons with a new quantum number and all properties of these new particles are consistent with charm.

A tungsten grid (about 25× magnification) obtained by a method of electrolytic etching developed in CERN's Central Workshops: foil thickness 0.1 mm, etching time 30 minutes.

CERN
New etching techniques



CERN's Central Workshops have just successfully used an interesting method for the production of special grids made of high density metal and insulating material. These grids are intended for the manufacture of converters associated with proportional chambers. They make it possible to obtain highly efficient gamma ray detectors with great spatial precision, either for medical purposes in nuclear image displays or for high energy physics. These detectors normally consist of a stack of alternately insulating and conducting grids which are frequently expensive and difficult to produce using normal machining techniques.

The method developed at CERN makes use of chemical or electrochemical photogravure techniques. The main problems encountered are the preparation of a suitable etching solution for each material, and the choice of an appropriate mask. Various tests carried out over the past few months have shown that the results lie within the required tolerances, while the cost remains competitive.

As the solutions used to etch insulating materials are extremely corrosive, it is necessary to employ metal masks in place of the usual photoresists. The following materials, available as thin foils, have been successfully machined:

Mylar (Du Pont de Nemours Trade Mark): Excellent resolution and good etching uniformity has been obtained with chemical machining in a sulphuric and nitric acid solution (0.1 mm etched in 2 minutes).

Kapton (Du Pont de Nemours Trade Mark): The alcaline solution of hydrazine hydrate normally used is both expensive and dangerous, but comparable results can be obtained faster with a solution of sodium hydrosulphite (75 microns etched in 5 minutes).

Epoxy resin-glass fibre composite: In spite of the non-uniformity of this material, good results have been obtained with a hydrofluoric and sulphuric acid solution (0.15 mm etched in 12 minutes).

Other materials, like metals and metal alloys, which are difficult to machine by conventional methods, have also been successfully photoetched.

Among the soft materials, satisfactory results have been obtained with the machining of lead by chemical etching in propionic acid (0.2 mm etched in 15 minutes), while the rate achieved on lead-bismuth alloy foil with a mixture of nitric and an organic acid was 0.2 mm in 40 seconds.

With the hard materials, the electrochemical machining of tungsten with a solution of caustic soda containing a suitable additive was highly successful (0.2 mm etched in 1 hour). The same method may be used to machine molybdenum electrochemically, but comparable and more rapid results can be obtained by chemical etching in a nitric acid solution followed by electrochemical etching by a similar process to that used for tungsten (0.1 mm etched in 20 minutes). Tests with titanium and niobium are now in progress.

These methods of machining are likely to be of great interest to industry. An internal report on this technique may be obtained from CERN on request quoting reference SB/AC/ST/3180/gp.

People and things

Godfrey Stafford, Director of the Rutherford Laboratory and Vice-President of the CERN Council, was awarded a C.B.E. in the Queen's Birthday Honours List on 12 June. The award of 'Commander of the British Empire' is one of the highest tributes for public service in the UK.

Awards

The Antonio Feltrinelli Prize, attributed to physicists once every five years, has been awarded by Italy's Accademia dei Lincei to Prof. Massimilla Baldo-Ceolin and to Prof. Ferdinando Amman.

Massimilla Baldo-Ceolin, Director of the Physics Institute of Padua University and an accomplished experimentalist, was responsible for the successful search for the antilambda. After investigations into the $K^0\bar{K}^0$ system her interests turned to the selection rules in weak interactions (mainly for K^+ and K^0) and invariance principles. Following the NUE experiment at the CERN PS (see July/August COURIER 1974, p. 252) she is now looking into leptonic neutral currents.

Ferdinando Amman, professor of physics at the Engineering Faculty of Pavia University, started research on particle accelerators in 1953 at the Frascati National Laboratory where he collaborated in the design and realization of the electron synchrotron. Subsequently he directed the project of ADONE, the 2 × 1.5 GeV electron-positron storage ring at Frascati. His theoretical and experimental studies on the physics of colliding beams proved fruitful in the design of storage accelerators all over the world. He was also Chairman of the 300 GeV Advisory Machine Committee at CERN.

Nuclear physicists in Italian Senate

Following the June general elections in Italy two nuclear physicists have entered Italy's Upper House, the Senate. They are Prof. Carlo Bernardini, Dean of the Faculty of Sciences of Rome University and Prof. Claudio Villi, formerly President and now Vice-President of INFN, the National Institute of Nuclear Physics. Another nuclear physicist, Prof. Protogene Veronesi has been re-elected as Senator.

Soviet representatives visit CERN

A party of Soviet scientists visited CERN during the second half of June. Composed of representatives from the IHEP in Serpukhov, the ITEP in Moscow and the State Committee for the Use of Atomic Energy, the party was particularly interested in the technology and construction of large particle accelerators. Much of their time was spent, therefore, in talking to specialists working on the Super Proton Synchrotron, which reached an energy of 400 GeV on 17 June during their stay. The visit came only a short time after the Serpukhov meeting where the major topic was a project for a very big accelerator by a world-wide collaboration. The Russians are proposing a 2 TeV machine, whereas other physicists, in the United States, have in mind a more ambitious project for a 10 TeV machine (see May COURIER 1976, page 167).

Appointments at CERN Council

At its Session on 17 June, the CERN Council appointed E. Lohrmann (now at DESY) as Member of the CERN Directorate in succession to John Mulvey who returns to Oxford University at the end of September. Robert Lévy-Mandel, who has supervised the civil engineering work at the SPS project, was also appointed to the Directorate for a period of three years from the beginning of July. The appointment of S. Fubini as Directorate Member was extended for two years as were the appointments of C. Tièche and G. Ullmann as Division Leaders of the Finance and Personnel Divisions respectively.

The Council also approved the nomination of new members of the CERN Scientific Policy Committee — M. Veltman and I. Mannelli in succession to M. Conversi and A.G. Ekspong. A. Bohr and G.H. Stafford have their appointments renewed for a further three years.

Italian Exhibition in Teheran

During the first half of June an exhibition under the title 'Italy, Science and Technology' was held in Teheran. Promoted by the Italian Ministry of Foreign Affairs in collaboration with the main research institutions and industry it aimed to give an up-to-date picture of Italian accomplishments in science and technology tracing the development back to historical roots. One sector of the exhibition was devoted to fundamental research illustrated by three topics: nuclear and elementary particle physics, astrophysics and biology. The material for the first topic was chosen and arranged by the National Institute of Nuclear Research (INFN) with the aim of describing the trends and problems of high energy physics research as faced by Italian groups in worldwide collaborations. A few detectors shown included a large multiwire proportional chamber used by a Turin group in a PS experiment on the production of hypernuclei, and slides gave information on the most important facilities and on research being carried out by Italian groups at Frascati and at CERN, covering the description of an electronic experiment (Pisa-Stony Brook at ISR) from its inception to the final results. In the field of nuclear physics, projects of new accelerators for installation at Legnaro, Frascati and Catania and the model of a superconducting cyclotron under study at Milan were shown. The possibility of presenting this exhibition in other countries is being considered.

Scientific Inauguration of TRIUMF

Following the dedication of TRIUMF by the Canadian Prime Minister in February, a scientific inauguration was held on 4 June coupled to a two-day meeting of TRIUMF Experiments Evaluation Committee where experimental results were reported and new proposals puffed. Visiting speakers included H.A. Bethe (Chairman of the 1964 US report on meson factories), B. Dropesky, E.M. Henley, H. Primakoff and Sir Denys Wilkinson.

TRIUMF retiring Director J.R. Richardson reported that the cyclotron had operated at 85% reliability over the past four months. Two simultaneous proton beams of independently variable energy from 180-520 MeV were available with 1 MeV energy spread, small emittance (about 10 mm mrad) and ± 75% polarization when required. In addition, three secondary beams of stopped pions and muons were in operation. Plans were well under way for raising the primary beam intensity to 10 μA later this year and to the full design value of 100 μA by the end of 1977. Experimental results of interest had already been obtained in pp scattering, pion production, polarized (p,2p) reactions, pi-radiative capture of hydrogen and deuterium, and in muon spin resonance studies of single metal crystals at low temperatures.

The incoming Director, J.T. Sample, thanked his predecessors for their efforts and commented on his good fortune saying, 'John Warren started it up, Reg Richardson got it off the ground, now I get to fly it'.

Changing hands at TRIUMF...

On 1 July, J.T. Sample succeeded J.R. Richardson as Director of TRIUMF, the Canadian cyclotron laboratory at the University of British Columbia. Jack Sample is a nuclear physicist from the University at Alberta who combines a distinguished research career with experience in science management and science policy making in Canada. He has been Chairman of the Physics Department of Alberta since 1967 and played a major role in Alberta's joining the TRIUMF project. Reg Richardson, following John Warren, has seen the 500 MeV cyclotron through its construction and commissioning. Karl Erdman, who has been on the staff of the University of British Columbia for 15 years, was appointed Associate Director for 1976-1977 in succession to Brian Pate of Simon Fraser University. Karl Erdman has been associated with the building of the cyclotron since its inception and led the group responsible for the r.f. system.

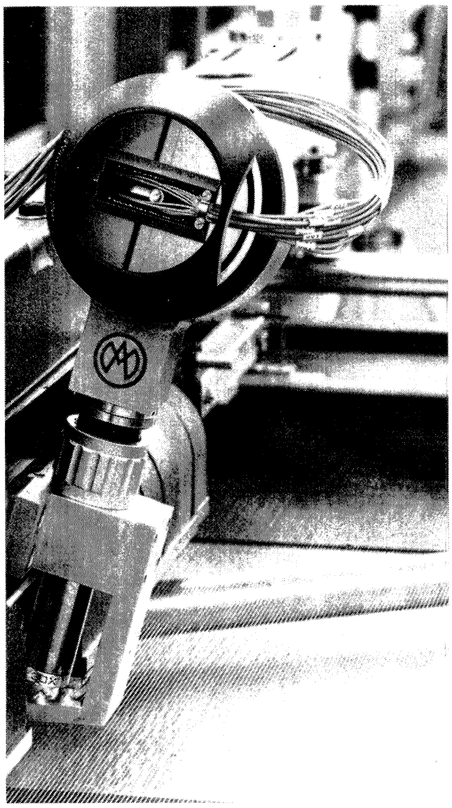
...and at FERMILAB

The Accelerator Division at Fermilab changed hands mid-July when Russ Huson succeeded Phil Livdahl as Division Head. Since the departure of Paul Reardon to lead the TFTR fusion project at Princeton, Phil has steered the Division with Russ as second in command through the heady days of achieving 500 GeV. He will now give most of his time to working on the Energy Doubler/Saver (see this issue, page 262).

Dr. Jack Sample, new Director of TRIUMF.

(Photo John Morris UBC Information Services)

Clever gadget developed at CERN for rapid checking of the vital wire tension in wire chambers. It emerged from work for the Omega spectrometer where it has enabled a plane of 1600 wires to be checked in an hour and a half. The gadget sweeps across the plane with magnets plucking at the wires. The wire displacement, measured via a microscope and photocells, in a known field gives the tension directly.



CERN 305.5.76

Second synchrotron radiation beam at SPEAR

At the Stanford Synchrotron Radiation Project (SSRP) a second tangential beam line for synchrotron radiation from the SPEAR ring came into operation on 30 June. The new beam line, funded by the National Science Foundation, will accommodate four or more X-ray experiments simultaneously and relieve the users' pressure on the first beam line that started up in May 1974 (see February COURIER 1975, p. 41). One rapidly tunable channel-cut crystal monochromator is in operation and two similar systems with provision for additional focusing are under construction. The programme of SSRP, which is carried out parasitically during colliding beam runs of SPEAR has grown rapidly in the past two years and now involves about 150 researchers and 35 institutes with 64 active proposals, so that demand continues to exceed the time available on existing facilities. An expansion of research towards the vacuum ultraviolet part of the spectrum is under discussion and proposals have been submitted for extending the experimental facilities during 1978-1980. Plans are being considered for using SPEAR as a dedicated synchrotron radiation source at 50 % when PEP, the LBL/SLAC 18 GeV electron-positron storage ring is operating for half its time on high energy physics research. The success of SSRP in research over a wide variety of fields such as surface physics, catalytic chemistry, structural biology, etc., has stimulated interest in the USA to provide additional research facilities using synchrotron radiation.

Accelerator Meetings

A 1st Course (under the title 'Theoretical Aspects of the Behaviour of Beams in Accelerators and Storage Rings') of an International School of Particle Accelerators is being organized for Erice, Sicily on 10-22 November 1976. The School will be directed by Professor Kjell Johnsen of CERN.

The 1977 Particle Accelerator Conference 'Accelerator Engineering and Technology' (the USA Accelerator Conference) will be held at Chicago, Illinois on 16-18 March 1977. Further information may be obtained from L.C. Teng at the Fermi National Accelerator Laboratory.

LASS ready for action

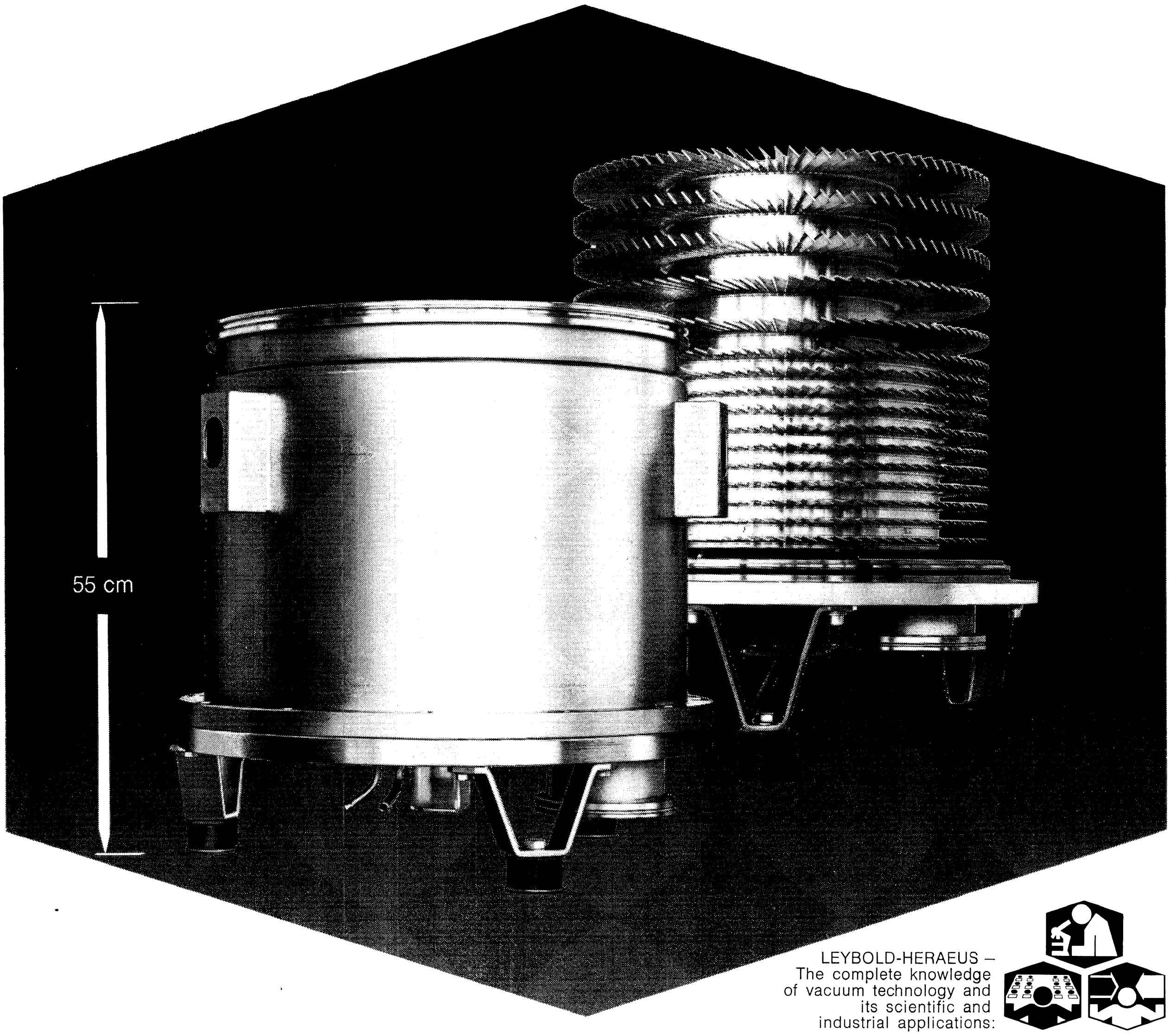
The Large Aperture Solenoid Spectrometer (LASS) at the Stanford linear accelerator has been built to study multiparticle interactions. The magnet has been performing well over the past six months and detectors and software are also in good shape. Proposals for hadron beam experiments are now being gathered at Stanford. Further information is available from David Hutchinson.

Superconductor testing facility at Rutherford

The Superconducting Magnet Research Group at the Rutherford Laboratory is providing superconductor testing facilities for users in industry, universities and other research establishments. This function is being assumed following the closure of 'High Field House' at Malvern. The Rutherford facility will have two superconducting magnets to provide background fields — one 9 T, 85 mm bore and the other 10.5 T, 50 mm bore. Further magnets for 12 and 15 T are being prepared. Further information is available from Gordon Fraser at Rutherford.

Using the sun at Los Alamos

The solar energy group led by Doug Balcomb at the Los Alamos Scientific Laboratory has brought a 'first phase' solar heated modular home into action. 80 to 85 % of the heating requirements of a 1056 square foot structure is provided via flat plate, air heating solar collector panels oriented at 60°. Four solar heated homes are on the drawing board and will benefit from lessons learned with this first phase exercise. The aim, of course, is to achieve costs which are competitive with other forms of energy and to produce a design which proves to be aesthetically acceptable.



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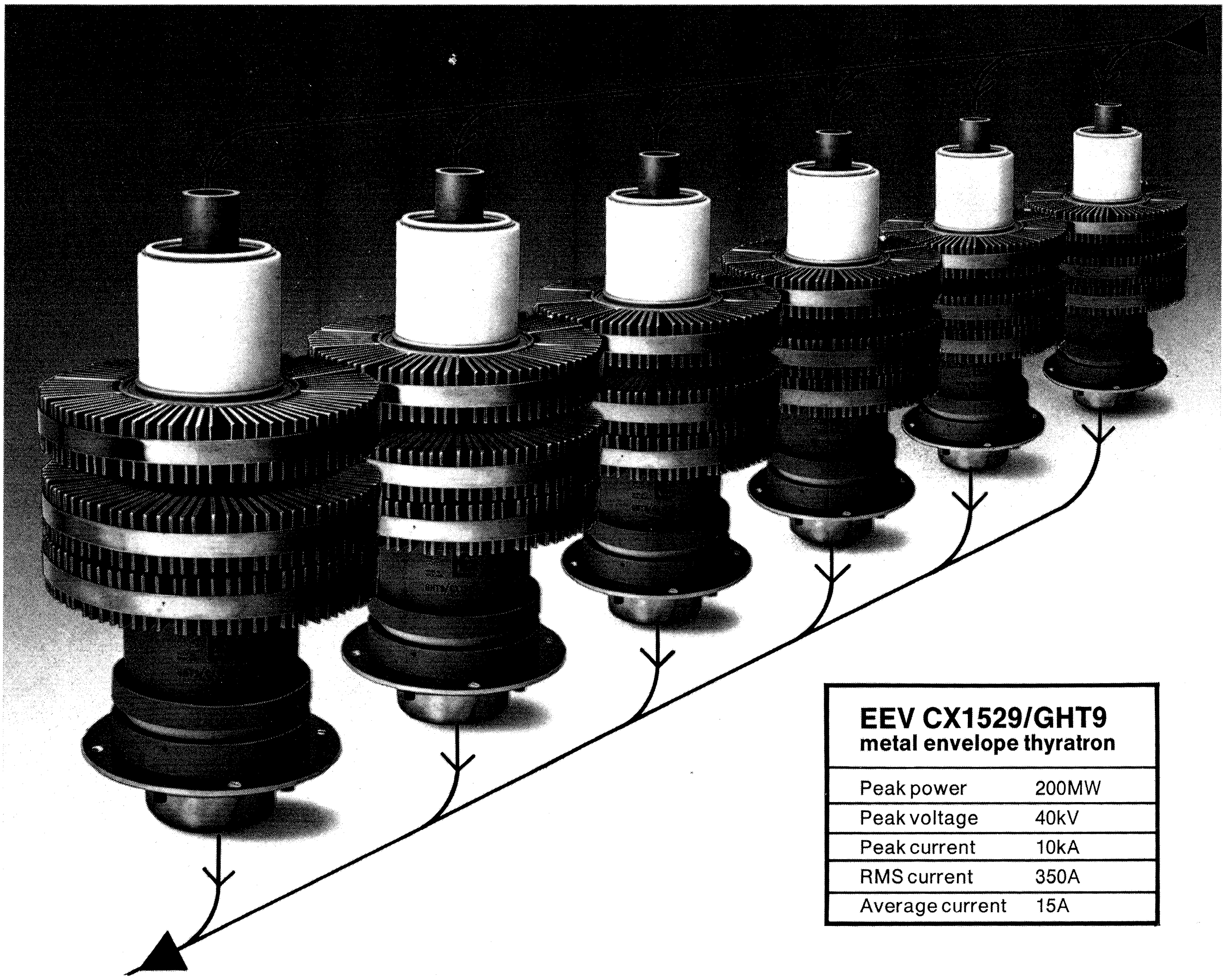

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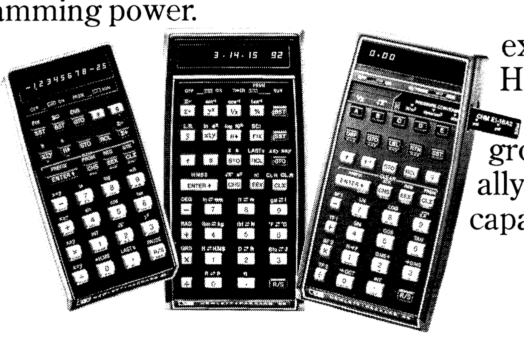

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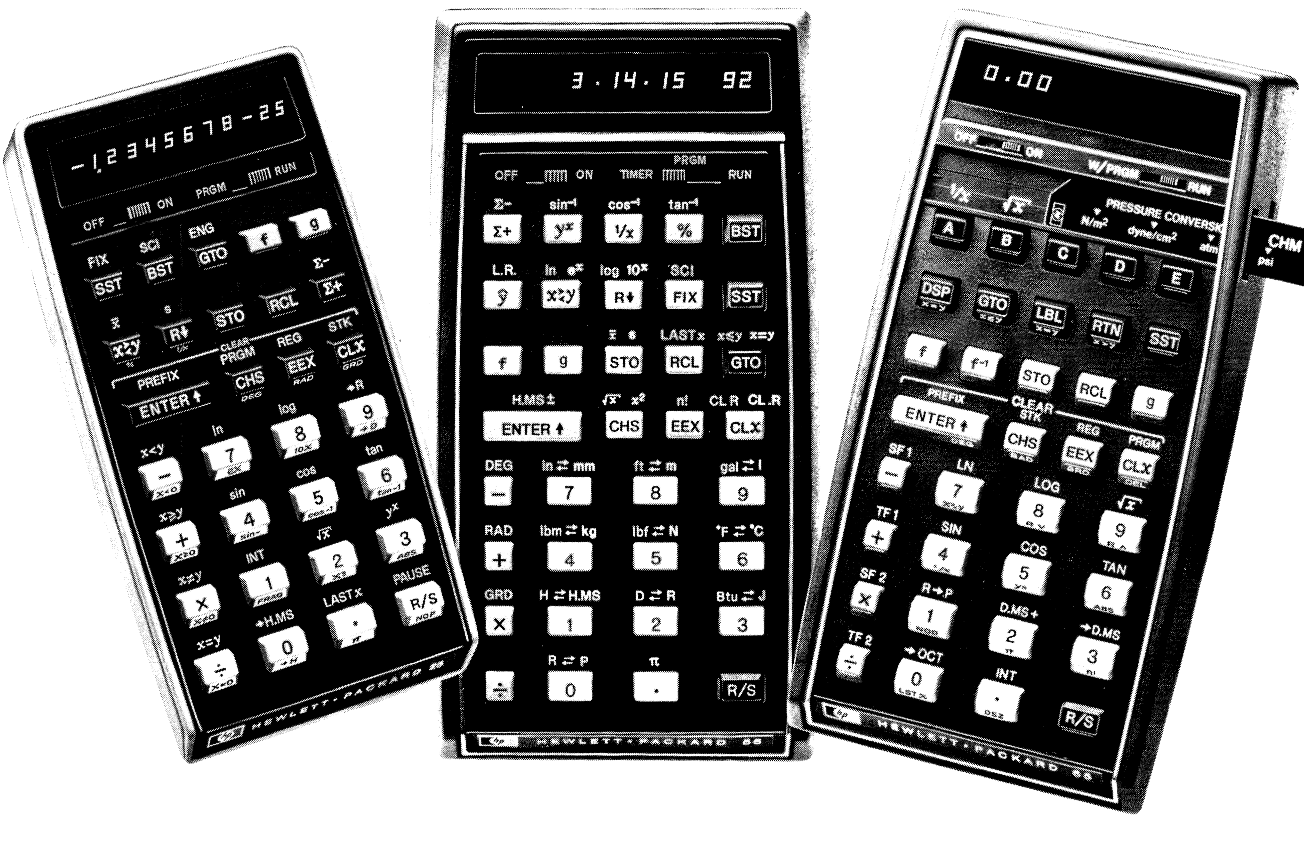

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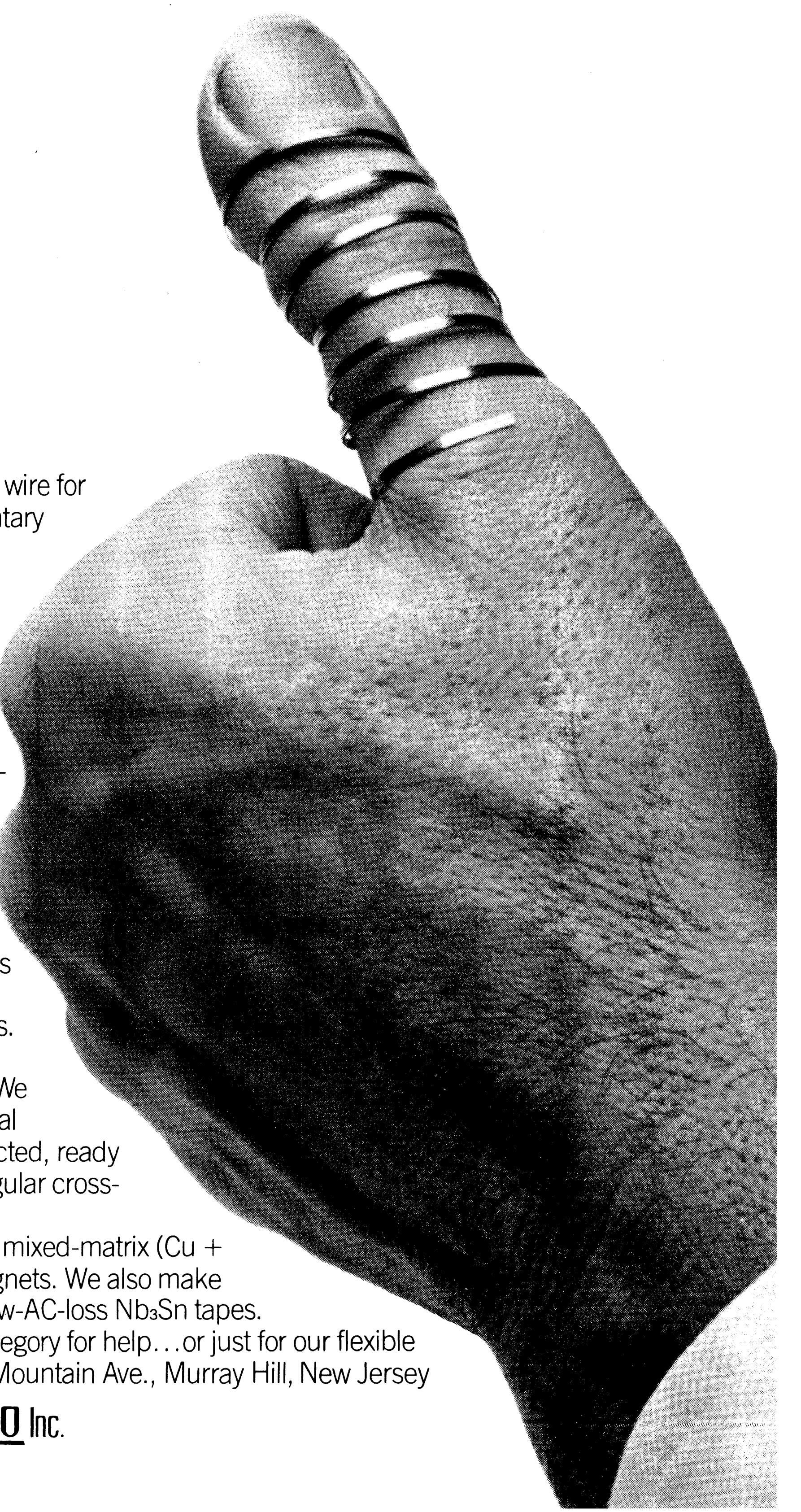

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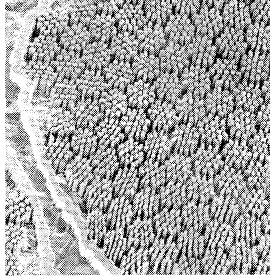
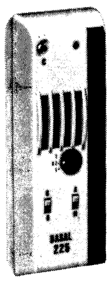


We can provide copper-stabilized wires, cables and braids, all with high-packing densities. From 300 to 500,000 filaments per strand. We can supply the material unreacted, or pre-reacted, ready to wrap and use. In round, square, or rectangular cross-sections to wind bores as small as 25 mm.

We also stock NbTi copper-stabilized or mixed-matrix (Cu + CuNi) superconductors for pulsed or DC magnets. We also make custom-designed shapes, composites and low-AC-loss Nb_3Sn tapes.

Call or write Dr. Erik Adam or Dr. Eric Gregory for help...or just for our flexible brochure. (201) 464-2400. Airco, Inc., 100 Mountain Ave., Murray Hill, New Jersey 07974, U.S.A. TWX 710-984-7985.

AIRCO Inc.



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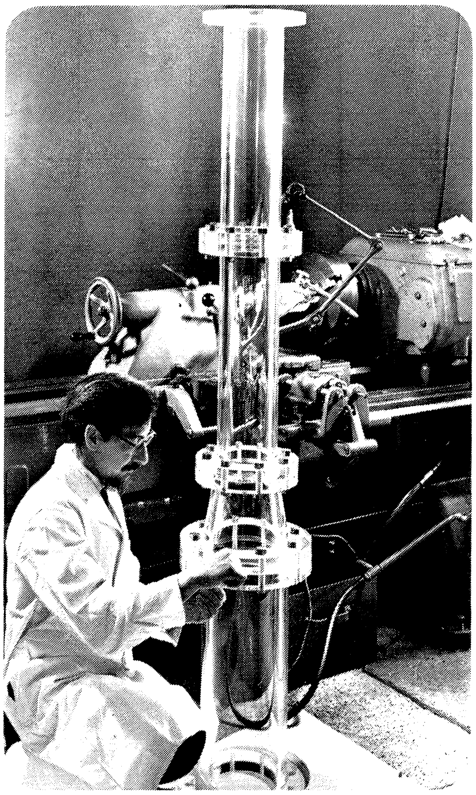
advanced technology in acrylics

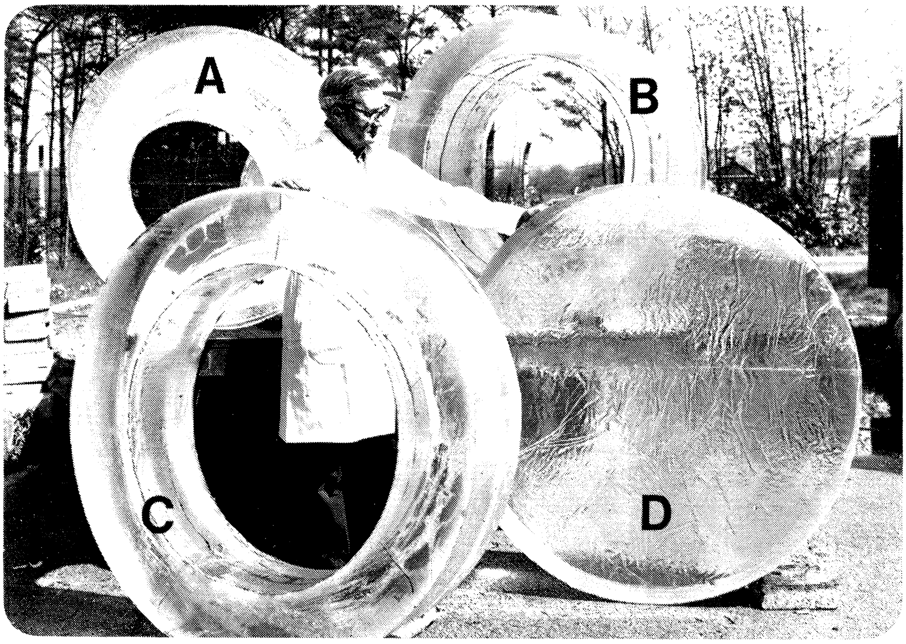
Precision castings in 'Transpalite' can offer the perfect solution to many problems in nuclear research and processing.

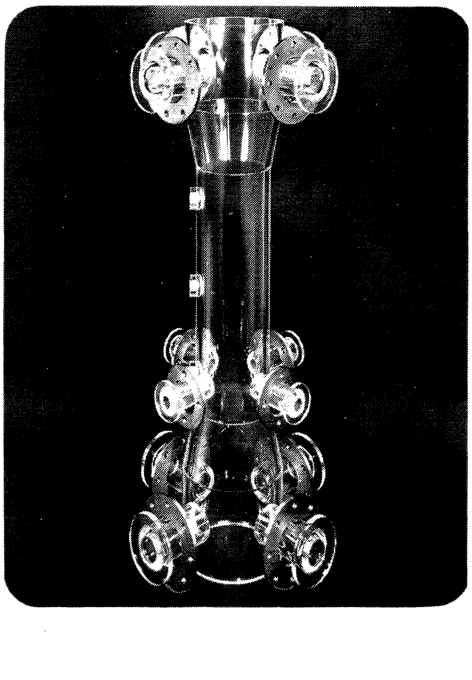
'Transpalite' seamless castings combine strength with extreme clarity. There are virtually no limits to size, shape of complexity. Custom made castings can be produced in any quantity from singles upwards. They are ideal for prototypes or experimental models.

'Transpalite' can be turned, milled, drilled, tapped and polished. The manufacturers, Stanley Plastics Limited, have supplied castings to atomic energy establishments and university research centres throughout the world.



Seamless flanged tubes up to 609mm dia. wall thickness up to 100mm or more, for high pressure visibility working. Blocks and castings up to 3253mm X 1524mm X 609mm (2268 kg).





Above: Massive castings prior to machining. A – 914mm OD X 508mm ID X 762mm thick. Weight 453 kg. B – 1016mm OD X 762mm ID X 660mm thick. Weight 317 kg. C – 1270mm OD X 914mm ID X 381mm thick. Weight 317 kg. D – 1371mm dia. X 508mm thick. Weight 1134 kg.

Top left: Seamless flanged pipe assembly 304mm OD X 254mm ID with tapering section leading to 203mm OD X 152mm ID. For use as visibility section in pipe line. Working pressure 800 kg/sq.m.

Left: 2133mm high manifold manufactured from 355mm dia. X 25mm wall seamless tube with 152mm OD X 25mm thick exit ports. Tolerance ± .50mm.

Stanley Plastics Limited

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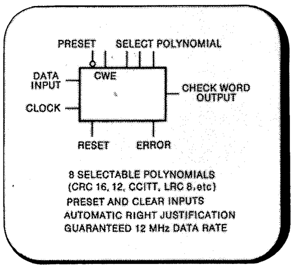
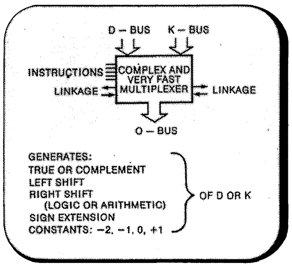
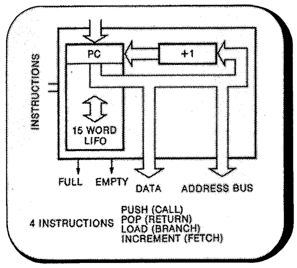
FUNCTIONAL BUILDING BLOCKS



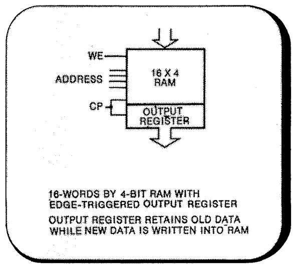
The 9401 Cyclic Redundancy Check Generator/ Checker is an advanced tool for implementing the most widely used error-detection scheme in serial digital data handling systems. A 3-bit control input selects eight different generator polynomials, including CRC-16 and CRC-CCITT, as well as their reciprocals (reverse polynomials). Separate Clear and Preset inputs are provided.



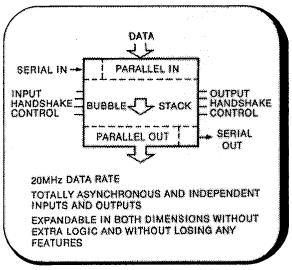
The 9404 Data Path Switch (DPS) is a very fast combinatorial array for closing data path loops around arithmetic logic networks (like the 9405 ALRS). A 5-bit instruction word selects one of the 32 instructions operating on two sets of 4-bit data inputs. Four linkage lines are available for expansion in 4-bit increments. The delay is less than 30ns over 16 bits. Samples available August.



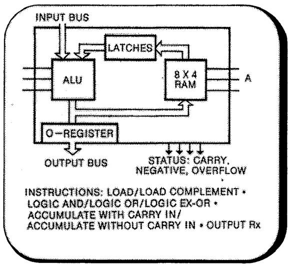
The 9406 16-word by 4-bit "Push Down-Pop Up" Program Stack stores program counter and return addresses for nested subroutines in programmable digital systems. It executes four instructions – Return, Branch, Call, and Fetch as specified by a 2-bit instruction. The 9406 may be expanded to any word length without additional logic and operates at a 10 MHz Microinstruction rate over 16 bits.



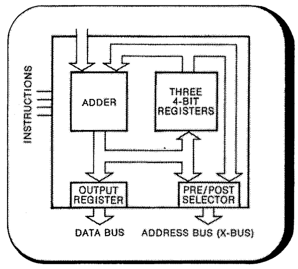
The 9410 64-bit Read/Write Memory is a register-oriented high-speed device organized as 16 words by four bits. An edge-triggered 4-bit output register allows new input data to be written while previous data is held. Three-state outputs are provided for maximum versatility. The 9410 operates at a 10 MHz Microinstruction rate.



The 9403 FIFO Buffer Memory is a high-speed expandable fall-through type with totally independent and asynchronous inputs and outputs. Organized as a 4-bit wide by 16-word deep "bubble stack," it has four bits parallel and bit-serial data inputs and outputs. Complete "handshake" control signals are provided for unambiguous operation in asynchronous systems. It is intended for disk and high-speed communications applications with data rates of up to 20 MHz.



The 9405 Arithmetic Logic Register Stack contains a 4-bit arithmetic logic unit (ALU), an 8-word by 4-bit RAM, an edge-triggered output register, and associated control logic. The ALU implements eight different arithmetic or logic functions where one of the two 4-bit operands is supplied from the input data bus and the other is supplied from one of the eight registers selected by the Address inputs. The result of the operation is loaded back into the same register and is also loaded into the edge-triggered output register and becomes available on the 3-state output data bus. The 9405 operates at a 10 MHz microinstruction rate over 16 bits.



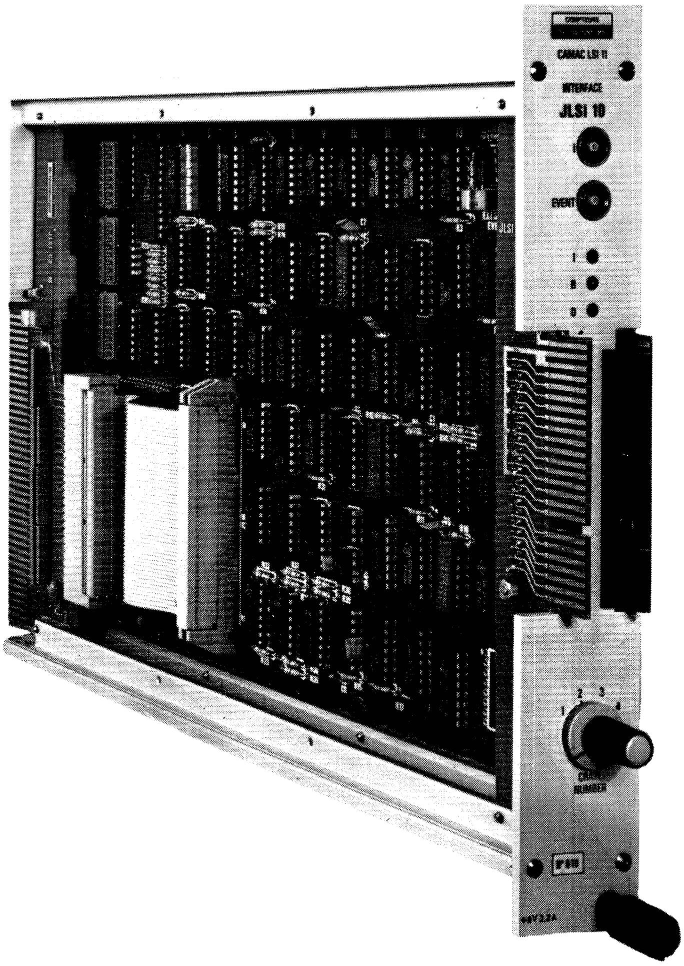
The 9407 Data Access Register (DAR) performs memory address arithmetic for RAM resident stack applications. It contains three 4-bit registers – program counter, stack pointer and operand address – a 4-bit adder, a 3-state address output buffer and a separate output register with 3-state buffers. The DAR performs 16 instructions, and operates at a 10 MHz Microinstruction rate. Samples available August.

Information here.

Most devices are available for sampling immediately.

For more detailed information on Macrologic devices, write or call your Fairchild Sales Office.

camac



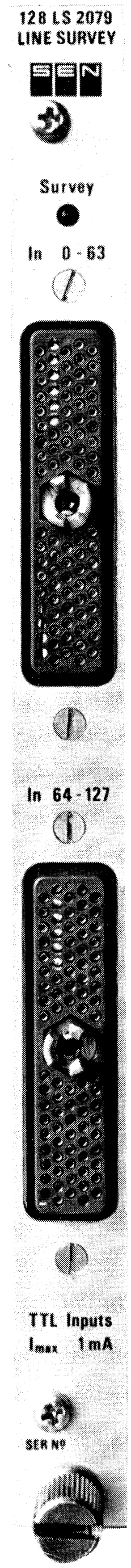
CAMAC - LSI 11 INTERFACE

- Dedicated crate controller
- from the user's point of view equivalent to the interface type JCC 11
- CASIC language valid for JLSI 10
- two most powerful features of UNIBUS extended to the CAMAC modules :
  - DIRECT CAMAC REGISTER ADDRESSING : 371 addresses per crate
  - FAST INTERRUPT HANDLING : 8 interrupt vectors can be individually masked
- UP TO 4 CRATES in a CAMAC system
- FAST Q AND X TEST in the case of block transfers or CAMAC data less instructions.

COMPTEURS
Schlumberger

FOR MORE INFORMATION PLEASE CONTACT :

Département Nucléaire COMPTEURS SCHLUMBERGER
BP 47 - 92222 Bagneux (France)
Tél. : (1) 655.22.11 - Télex : SAIPEX 25075 F



128 Line Surveyor

128 LS 2079

Surveys and memorises the states of the 128 lines

Will survey continuously or in individual cycles

All updating is done in the unit - no computer memory space needed for table comparisons

All data immediately available as the LAM is sent - address, status, etc ...

F(0) A(0)	Reads the address of the line which has given an alarm onto the R1-R14 bus-lines. The state of R16 corresponds to the state of the line. Generates Q if the alarm is valid. Generates X.
F(2) A(0)	Same action as F(0) A(0), but also resets the L source to zero, and continues the survey. Generates Q if the alarm is valid. Generates X.
F(8) A(0)	Tests the state of the L source. Q=1 if L=1. Generates X.
F(9) A(0)	Initialization. This instruction sets the 64 cells of the line state memory to '0' or '1', according to the chosen survey mode. The line mask is also cancelled. Generates X.
F(10) A(0)	Same action as F(8) A(0), but resets the L source to zero and continues the survey. Generates X.
F(16) A(0)	Selects one of the inputs, the address being sent on the W1-W6 bus-lines. This instruction stops the survey ; after its transmission, the functions F(0) or F(2) permit the actual state of the selected line to be tested. Generates Q and X.
Z:	Same as F(9) A(0).
I:	Blocks the acquisition.
F(16) A(1)	Selection of the survey mode. The choice of modes, depending on W1 and W2, are as follows:- $\overline{W1}$ $\overline{W2}$: Generates L when any input is '0'. The input states are memorised by the register. W1 $\overline{W2}$: Generates L when any input is '1'. The input states are memorised by the register. $\overline{W1}$ W2: Generates L when any input changes state with reference to that which is stored in the register. Once the alarm has been acknowledged, the new value is loaded into the register. W1 W2: Each input authorised by the enable register generates an L. The contents of both registers remain unmodified by this instruction. Generates Q and X.
F(24) A(0)	Cancels the line survey. Generates X.
F(24) A(1)	Masks the request at the selected address. Generates X.
F(25) A(0)	Instructs a single survey cycle. Generates X.
F(26) A(0)	Starts a continuous survey of the inputs. Generates X.
F(26) A(1)	Authorises the request at the selected address. Generates X.
F(27) A(0)	Tests the functioning of the module. During a survey when there are no L requests, or during the initialization, this command generates Q. Generates X.

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Programm zur Lösung Ihres Registrier- -Problemes

Kompensationsschreiber
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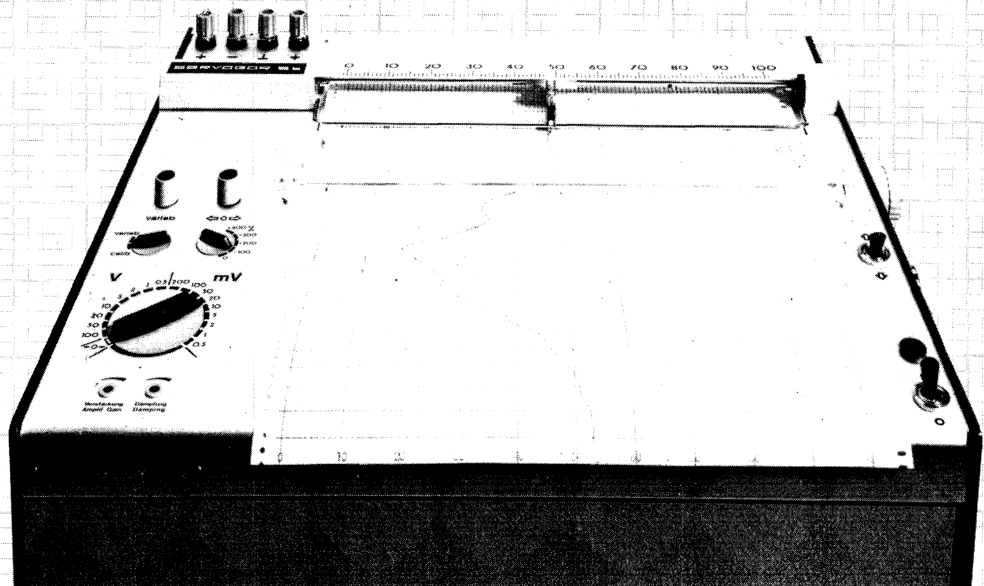

250 mm Schreibbreite
0,3 sek. Einstellzeit
0,25% Genauigkeit
Bitte verlangen Sie Liste B-8·13

Das Servogor S-Programm bietet 40 verschiedene Typen mit umfangreichen Zusätzen und Zubehör.

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CAMAC Digital Voltmeter 9068

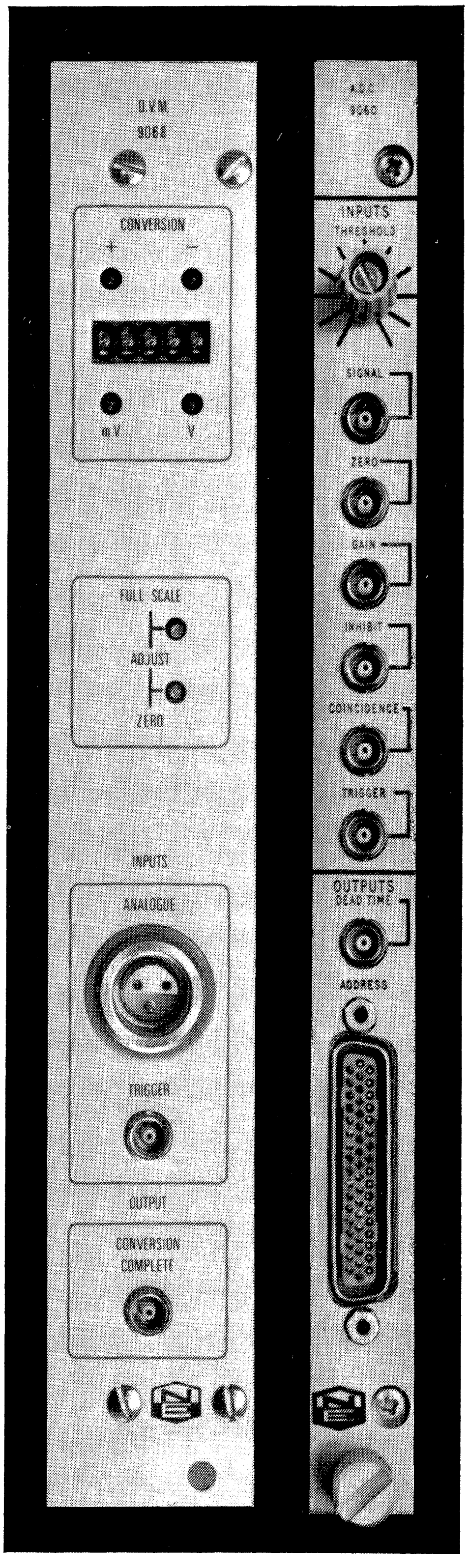
CAMAC Nuclear ADC 9060

- 5 character visual display
- 2000 volt input isolation
- 6 bipolar programmable ranges
- Selectable ramp intervals
- Free run or Command Mode operation
- Front panel trigger in Command Mode

The 9068 has been cleverly engineered into a double width Camac compatible module.

Positive or negative input voltages, in six programmable ranges from 20mV to 2kV, are converted to a digital number for access by the dataway and visually via a 5 digit LED display on the front panel.

Dataway selectable ramp intervals allow user optimisation of conversion speed and resolution parameters.



- 4096 channels
- 80MHz digitising rate
- 8 conversion buffers
- Voltage Sampling Gate
- Stabilisation Inputs

The Nuclear Enterprises 9060 is a single width Camac compatible, high resolution Wilkinson type convertor, provided with all those functions found desirable in a Nuclear ADC.

A control register stores the commands necessary to set digital range, offset and conversion gains, together with the coincidence and conversion mode features.

Eight conversion addresses are stored in the module before service is requested, giving a fast maximum rate of accumulation.

Full details of the 9068 and 9060 and copies of the new 8-page NE CAMAC Selection Guide available on request.

NUCLEAR ENTERPRISES S.A.

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1218 Grand Saconnex/
Genève. Tel (022) 98 16 61/62
Telex 289 066

Also at
Nuclear Enterprises Limited, Bath Road, Beenham, Reading RG7 5PR, England. Tel 073-521 2121. Telex 848475. Cables Devisotope, Woolhampton.

Nuclear Enterprises GmbH, Schwanthalerstrasse 74, 8 München 2, Germany. Telephone 53-62-23. Telex: 529938

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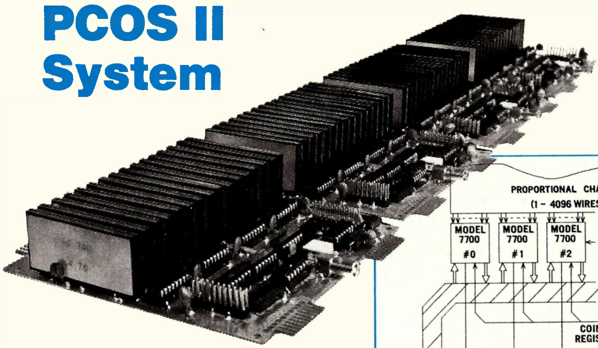
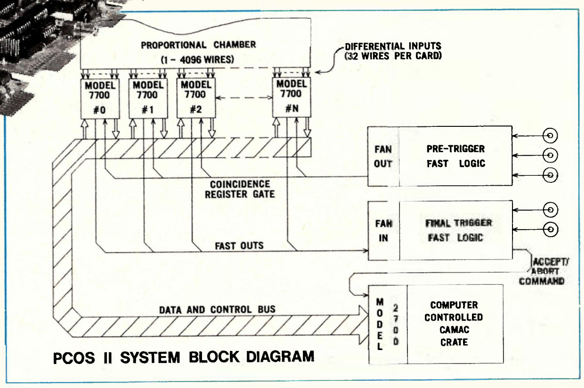
As a research physicist, you are undoubtedly aware of the significant proportion of time typically devoted to *instrumenting* multiwire proportional chambers. Different chamber sizes, different wire spacing, different gas mixture requirements . . . All the time and effort spent on building appropriate readout electronics detract from the time one could spend on actual experimental research. — Well, *you* can be different! Now, two systems available *off-the-shelf* from LeCroy provide you with the flexibility and cost effectiveness you need — save you the time and drudgery — in setting up your own particular wire chamber system. Look . . .

PCOS II System



Designed to fulfill substantial requirements at CERN, this system consists of a series of 32-channel chamber-mounted amplifier/discriminator/delay/register cards and a special CAMAC controller linked to the front ends by a serial transfer data highway. A single controller handles up to 4096 wires, storing the center address and the size of hit clusters in FIFO memories for CAMAC transfer to the computer. The PCOS II System features:

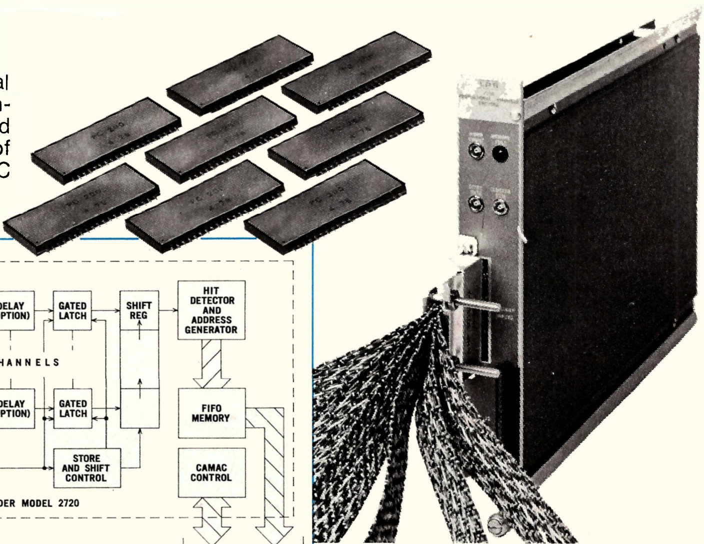


PCOS II SYSTEM BLOCK DIAGRAM

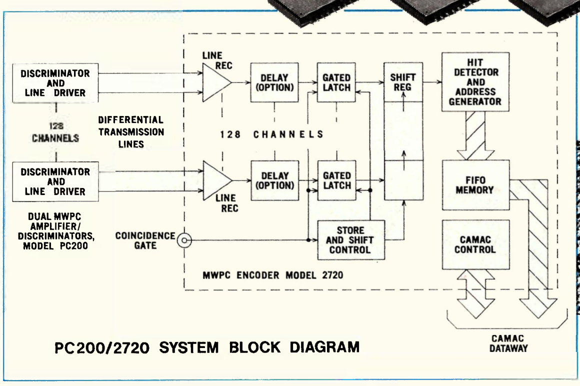
- —1 μA minimum threshold
- 200 Ω input impedance
- Differential inputs
- 10 nsec slewing, 2X to 20X
- Dual monostable to permit 30 nsec double-pulse resolution
- Fast open collector latch outputs
- Model 7700 32-channel chamber card, ready for chamber mounting
- Low, low cost

PC200/2720 System

This system consists of individual front ends (Model PC200 Dual Discriminators) and the Model 2720 CAMAC 128-Channel Encoder, which receives the differentially transmitted standardized wire signals from the PC200's and stores up to 80 addresses of hit wires in a built-in FIFO memory for readout onto the CAMAC Dataway. The PC200/2720 System features:



- Differential signal transmission
- 5 kΩ input impedance
- —200 μV minimum threshold
- Fast analog outputs
- 10 μsec average encoding time
- Compact hybrid size, permitting user-determined layout to match chamber characteristics
- Individual front and back ends
- Cable delays to eliminate excessive deadtime
- Event accumulation for high rate situations
- Fast cluster sum for additional trigger logic



PC200/2720 SYSTEM BLOCK DIAGRAM

Call or write for details. Note our new address and telephone number.

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RF power tubes with up to 1250 kW anode dissipation and cavities at 50 to 110 MHz are also available at reasonable prices from EIMAC. For example:

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