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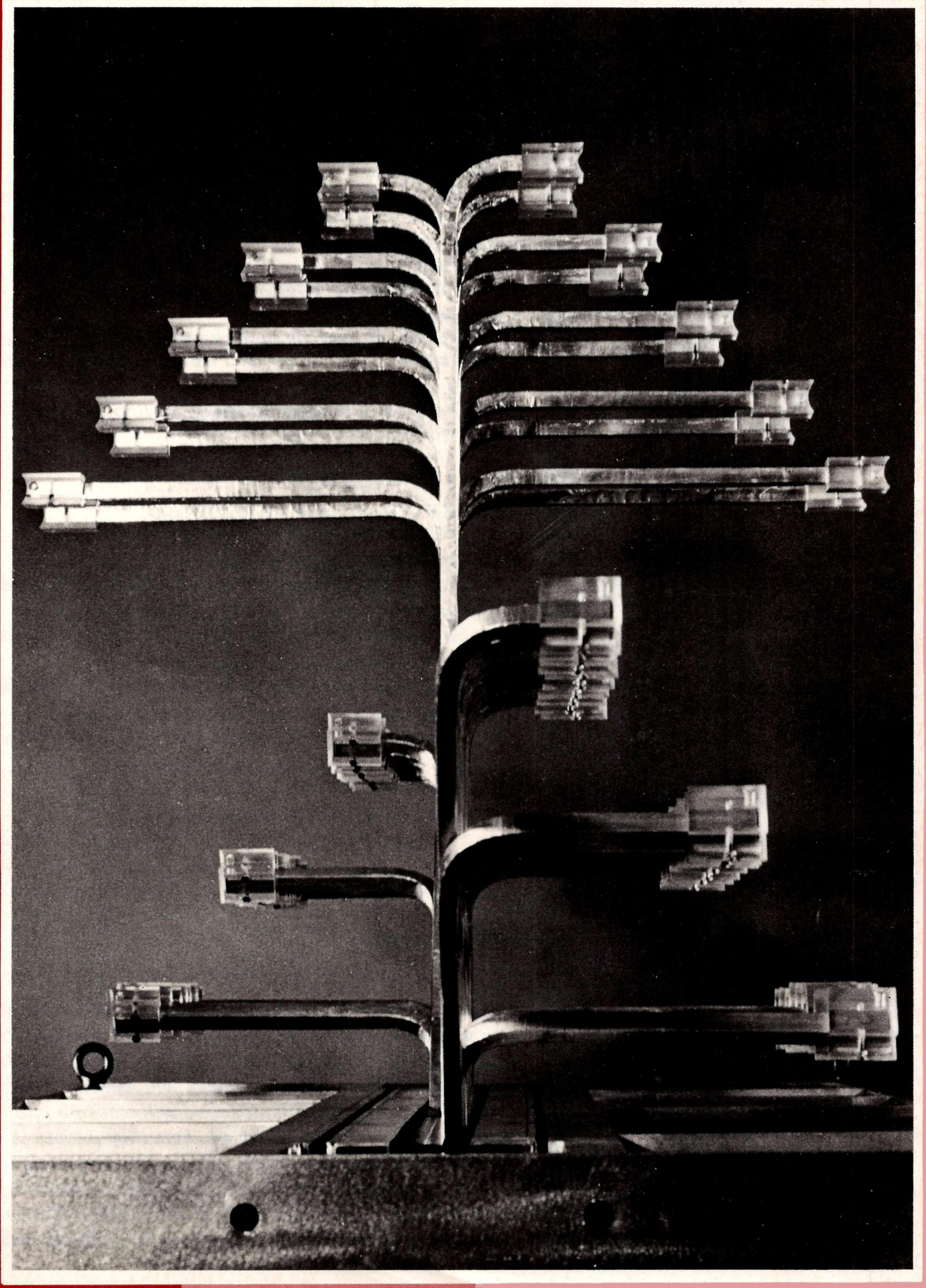

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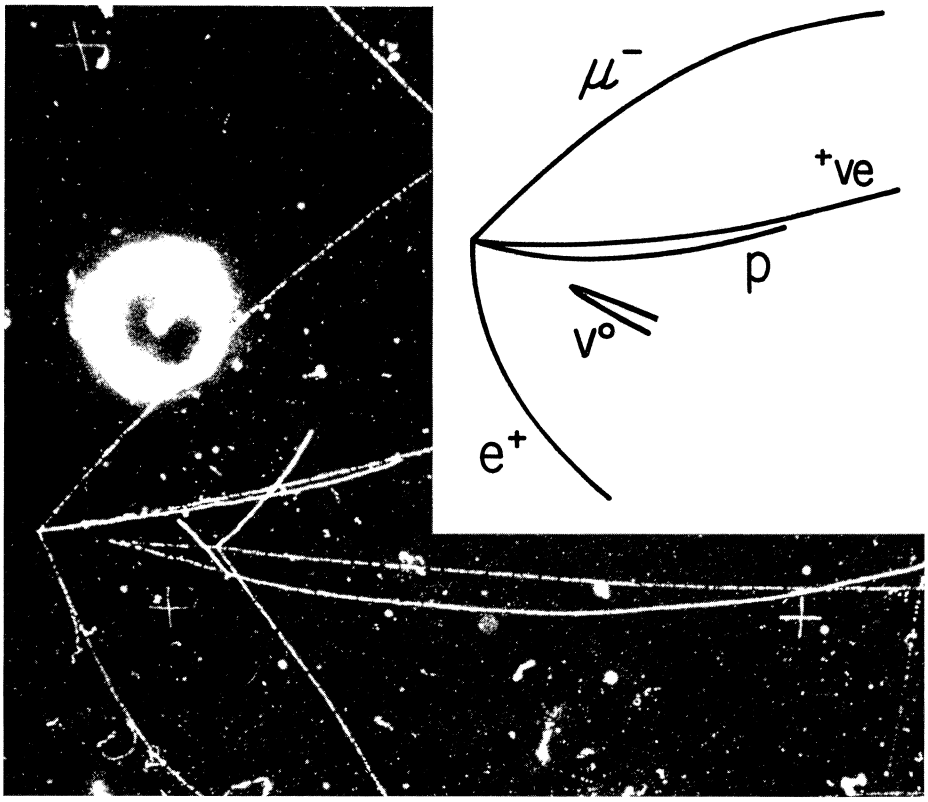
# Contents

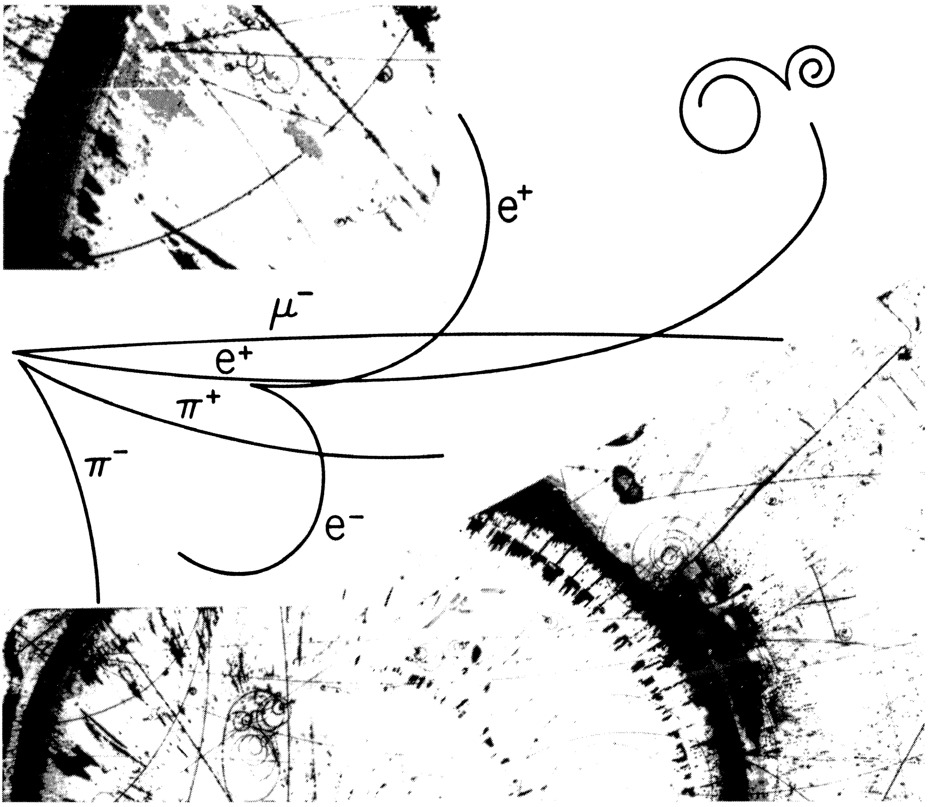
Around the Laboratories

*Cover photograph: Staying with futuristic Christmas trees, of which we had one version on the cover of the December issue, this is a side view of a scintillator hodoscope built at Padua in Italy and known as the Forward Gamma Detector (FGD). Lead glass blocks will measure photon (gamma) energies by total absorption; the hodoscope will measure photon positions by determining the profile of the showers they initiate. A picture of the FDG seems a suitable one to introduce our first international issue. After tests at CERN, it has been taken to the Fermilab by Italian and French physicists for a calibration run this month. It will be used this year in a hybrid experiment at the 30 inch bubble chamber. An enlarged version is scheduled later for the CERN SPS.*

# Charming start to the New Year



*1. One of the three events photographed in the CERN Gargamelle bubble chamber. The positron and the neutral strange particle (detected by the characteristic V track formation) are assumed to come from the decay of a charmed particle.*



*2. One of the four events photographed in the Fermilab 15 foot chamber. Again a positron and a strange particle (the neutral kaon decaying into two pions) indicate a charmed particle.*

High energy physics was given a splendid start to 1976 with two announcements that hot candidates for charmed particles have been seen in neutrino experiments in bubble chambers.

The favoured explanation of the heavy stable particles discovered a year ago at Brookhaven and Stanford is that they are made of a new type of quark carrying a property given the name 'charm'. If this is so, we should be able to build many new particles using the charmed quark together with some of the other three quarks which have been our building bricks for many years. There has been an intense search for such particles at many Laboratories yielding several tantalising indications of the presence of a charmed particle (an event in the 7 foot bubble chamber at Brookhaven, an event in the Gargamelle bubble chamber at CERN, a narrow resonance in an electronics experiment at Fermilab, a few events not significantly above background in the 15 foot bubble chamber at the Fermilab).

The recent findings look much cleaner and move convincing. They come from the Gargamelle heavy liquid bubble chamber at CERN, which has added two more charmed particle candidates to its earlier one, and from the 15 foot chamber at Fermilab (made semi-heavy liquid by being filled with a hydrogen-neon mixture) which has seen four charmed particle candidates.

The experiment with Gargamelle involved seven European Laboratories (Physikalisches Institut der Technischen Hochschule, Aachen / Inter-University Institute for High Energies, Brussels/CERN/Laboratoire de Physique nucléaire des Hautes Energies, Ecole Polytechnique Palaiseau/Istituto di Fisica dell'Università, Milan and INFN, Milan/Laboratoire de l'Accélérateur linéaire, Orsay/University College London). Their first candidate came from scanning about 400 000 pictures taken with a neutrino beam generated by the proton sychrotron, operating without the booster at an intensity around $10^{12}$ protons per pulse. The other two came from a subsequent run with the booster in action and a beam intensity around $5 \times 10^{12}$. From a total of about 250 000 pictures nearly 200 000 have been scanned so far.

The experiment with the 15 foot chamber involved four Laboratories (University of Wisconsin/Berkeley/CERN/University of Hawaii). Their four candidates come from scanning about 1000 neutrino interactions. They had higher energy, higher intensity neutrino beams than at CERN since they were generated by the 400 GeV synchrotron operating around $10^{13}$ protons per pulse. The higher event rate means that they might see as many as 50 candidates in analysing all their pictures. *

All the events have the same basic features. An incoming neutrino interacts with a nucleon in the bubble chamber liquid and produces a muon, a positron and a 'strange' particle (plus other hadrons which are not important for the argument). The muon is easily explicable — it results from the usual 'charged current' form of the weak interaction where the uncharged muon-type neutrino converts to the negatively charged muon. But the positron and the single particle carrying the property of strangeness cannot be explained under the traditional rules governing particle interactions.

The positron could come from the decay of a particle produced in the interaction. Also, the decays of charmed particles are expected to produce, predominantly, strange particles. The bubble chamber pictures can thus be interpreted as neutrino plus nucleon giving muon plus charmed particle (C) with the charmed particle decay giving the strange particle (S) the positron and a neutrino (which is not seen).

$$\nu_\mu + N \rightarrow \mu^- + C + \ldots$$
$$C \rightarrow S + e^+ + \nu_e$$

A few rough estimates of the charmed particle properties are possible. Calculating mass gives figures around 2 GeV which is what is anticipated (see April issue 1975, page 106) and the lifetimes before decay (since they have no track length in the chamber) appears to be less than $2 \times 10^{-11}$ s.

The high energy physics world wants so much for charm to exist that we have to be careful not to read too much into the present evidence. No other interpretation, however, seems to fit the observations and, if charm is not at work, some other new process must have been recorded. When analysis of the two experiments is complete, the situation should be clearer. It looks as if 1976 is to be a charming year.

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*They now (19 January) have four more.*

# The State of High Energy Physics

## W.K. Jentschke

Having solved the secrets of the atom, we have turned in the second half of this Century to probe the structure of the particles from which the atoms are constructed — the electron, proton and neutron. Along the path of discovery, other particles have been found which do not themselves have a place in atoms.

Their behaviour appears to be dictated by three types of force. The strong force is responsible for binding nucleons together to form nuclei. It is about 100 times stronger than the electromagnetic force, responsible for the existence of atoms and molecules, which, in turn, is many orders of magnitude more powerful than the weak force responsible for radioactive decay. The force of gravity plays an insignificant role in this world of particles.

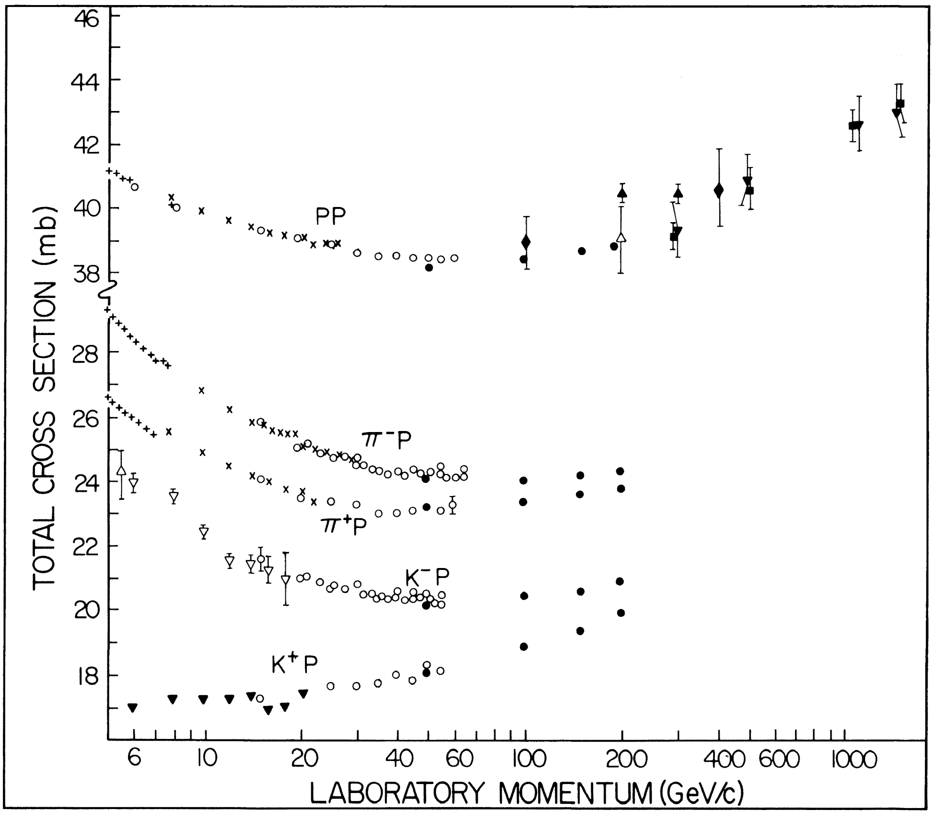
The representation of the characteristics of the three forces in mathematical form has been achieved with complete success for the electromagnetic force, only partial success for the weak force and not at all for the strong force. Tests of quantum electrodynamics (the quantized form of Maxwell's equations) have so far always demonstrated the validity of our electromagnetic theory over a range from about a million kilometers down to $10^{-15}$ cm. Moreover, experiments on the electromagnetic properties of electrons and muons (leptons which do not feel the strong force) indicate no effects due to size or structure; they behave as points.

The situation is quite different for the hadrons, (baryons, like the proton, and mesons, like the pion) which can interact through the strong force. They do have finite size and, probably, a complex internal structure.

### *Proton size*

First I will report our information on the overall size of the proton as re-

*At the CERN Council Meeting on 18 December, Professor Willie Jentschke reviewed developments in high energy physics particularly during the five years for which he had been Director General of CERN. This is a condensed version of his talk.*



*A strongly interacting particle, or hadron, increases in effective size as its energy is increased. This was seen first in the positive kaon-proton ($K^+ p$) collision at Serpukhov, was extended to the highest presently available energies for the proton-proton (pp) collision at the CERN ISR, and was seen for positive and negative pions, kaons and protons at Fermilab.*

vealed in high energy collisions where the protons interact as a whole, rather than in ways reflecting their internal structure.

One of the early discoveries at the CERN Intersecting Storage Rings was that the total cross section (giving the probability that two protons will interact), which had reached a plateau at the highest energies previously accessible at the Serpukhov Laboratory, rises again at higher energies. This demonstrates that the overall effects of the strong interaction are still changing, albeit slowly, at energies up to 60 times greater than that associated with the proton mass. This rise of cross section at high energy had already been observed for the positive kaon interaction with protons at Serpukhov and has since been shown, at Fermilab, to be a common feature of hadron collisions with the nucleon.

Another characteristic of the proton-proton interaction which has been measured at the CERN ISR is the probability of deflection at a given angle when two protons collide without the production of new particle states (elastic scattering). The probability depends on angle in a way which is typical of the process of optical diffraction, showing a sharp fall to a low dip followed by a second maximum as the scattering angle increases. The position of the dip moves to smaller angles as the collision energy is increased.

From these results we can deduce that the proton, as seen through the strong interaction, is like a disc with a radius less than about $10^{-13}$ cm which increases slowly in size as its energy increases. Moreover, it does not behave as an opaque disc, two protons may sometimes pass through each other (like ghosts) without interacting. The overall size is similar to that inferred for the average charge distribution in the proton from electron scattering experiments at the Stanford Linear Accelerator Center (SLAC).

This finite size of the nucleon implies some form of internal structure. Important clues as to the nature of this structure have been obtained from studies of the rich variety of possible hadron states (much as an inspection of a particular set of geometrical patterns might reveal that they had been made up from a subset of three-sided shapes rather than ones of four-sides or more).

## *Hadron spectroscopy and quarks*

The search for order within the apparent chaos of hadronic states was crowned with success in the work of Murray Gell-Mann and Yuval Ne'eman in 1961. They found that the observed hadrons can be grouped into families each containing particles with the same spin and parity (parity is related to properties equivalent to reflection in a mirror). The mesons form families containing one or eight particles; the baryons occur in families containing one, eight or ten particles. Within each family there is a precise relationship between the properties of electric charge and strangeness of the particles and a well satisfied relationship also between the masses of the particles. A large programme of systematic studies has established that all the observed particle states belong to such families (although not all members of the known families have yet been found).

The origin of the families can be readily understood (following the idea of Gell-Mann and George Zweig in 1964) by a simple picture in which all hadrons are built up from three types of 'brick' which have been given the name 'quarks'. The elegant success of the quark model in accounting for the hadrons only needs the detection of free quarks to become one of the great break-throughs in the quest for the ultimate components of matter. This last step, Nature has so far refused to yield, even at the highest energies so far available. The reason may be that the mass of free quarks is too great (say over 10 GeV). Alternatively, theories of quark confinement have been developped which deny the possibility of ever releasing individual quarks from their very strong bondage within the hadrons.

## *Leptons as probes of the nucleons*

Different types of experiments have proved to be powerful methods of examining the internal structure of the nucleon. The point-like nature of leptons make them very suitable probes but high energy is also required to resolve fine details of the structure.

The nucleon is bombarded with electrons at SLAC. These experiments probe the small scale features of the electric charge distribution within the nucleon through the electromagnetic interaction. The nucleon is bombarded with neutrinos at Argonne, Brookhaven, CERN and Fermilab. These experiments probe the spatial characteristics through the weak interaction.

The observations made in these two totally different approaches, taken together, provide an astonishingly detailed picture of the constitution of the nucleon. They can be interpreted in terms of a model in which the nucleon's response to both the weak and electromagnetic interactions is located on point-like grains within the nucleon, of size less than 3/100 of the nucleon diameter, which have the properties expected of quarks (spin 1/2 and fractional electric charge).

One unexpected result, however, is the observation that only about half the nucleon energy is carried by the quark constituents. This has led to the speculation that the other half is carried by other components which participate in neither the weak nor the electromagnetic interactions. These have been termed gluons and it is supposed that they are carriers of the very strong force which binds the quarks so tightly within the nucleon that they cannot be freed.

## *Structure revealed by proton-proton collisions at high energies*

At high energies, collisions between protons should also reveal some aspects of this granular structure. However, the complexity of the strong interaction, which dominates the behaviour of the two nucleon collision, and the finite range over which it extends (comparable with the nucleon size) do not allow as clean interpretations of these processes as are possible with lepton scattering. We must be content, so far, with a more crude and limited view.

The rare violent encounters in which high momentum transfers occur may reveal the secrets of internal structure. Such encounters have been observed at the ISR at a rate 10 000 times more frequent than was expected. In these events, particles are emitted sideways with high momentum, that is at a large angle to the line of flight of the colliding protons, in a manner reminiscent of the large angle scattering observed by Rutherford early this Century when he bombarded atoms with alpha particles. Just as Rutherford's observations led him to deduce that the mass of the atom is concentrated in a very small nucleus about 10 000 times smaller than the whole atom, so the presently favoured interpretation of the ISR results is that we are seeing small scale structure within the proton, this time via the strong interaction. In this picture the high transverse momentum particles are emitted on the rare occasions when a point-like constituent (called a 'parton' which is possibly synonymous with quark) of one proton encounters one in the other proton.

The study of such processes has been vigorously pursued at the ISR and at Fermilab. The parton-parton collision process is expected to give rise to two rather well defined clusters of particles, or jets; in particular, if we call the particle of highest transverse momentum A, then:

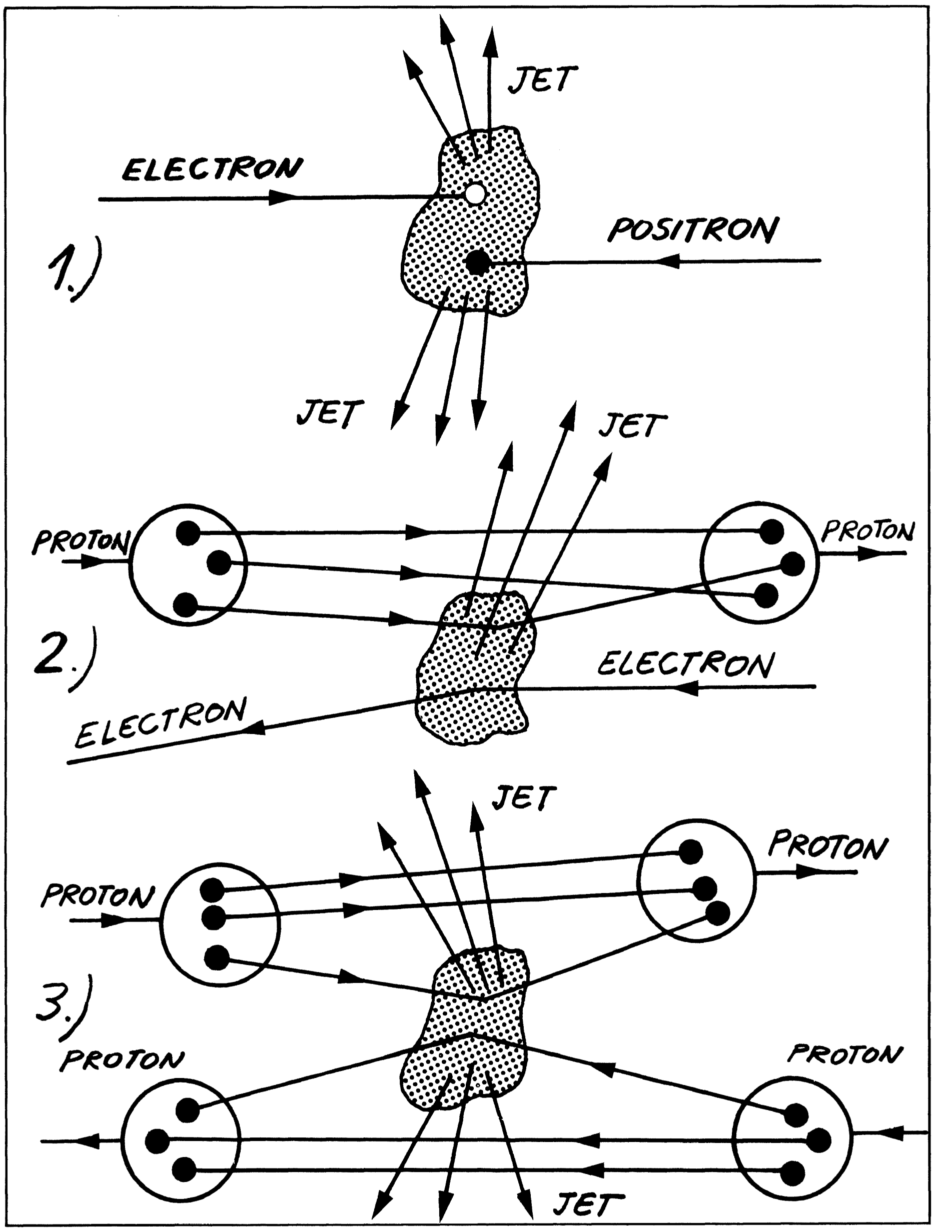
– all other particles of large transverse momentum should have directions lying close to the plane defined by the incident protons and A;

– a large transverse momentum particle emitted into the same hemisphere as A should lie close to A in direction;

– several large transverse momentum particles occurring in the hemisphere opposite A should be closely clusted in direction.

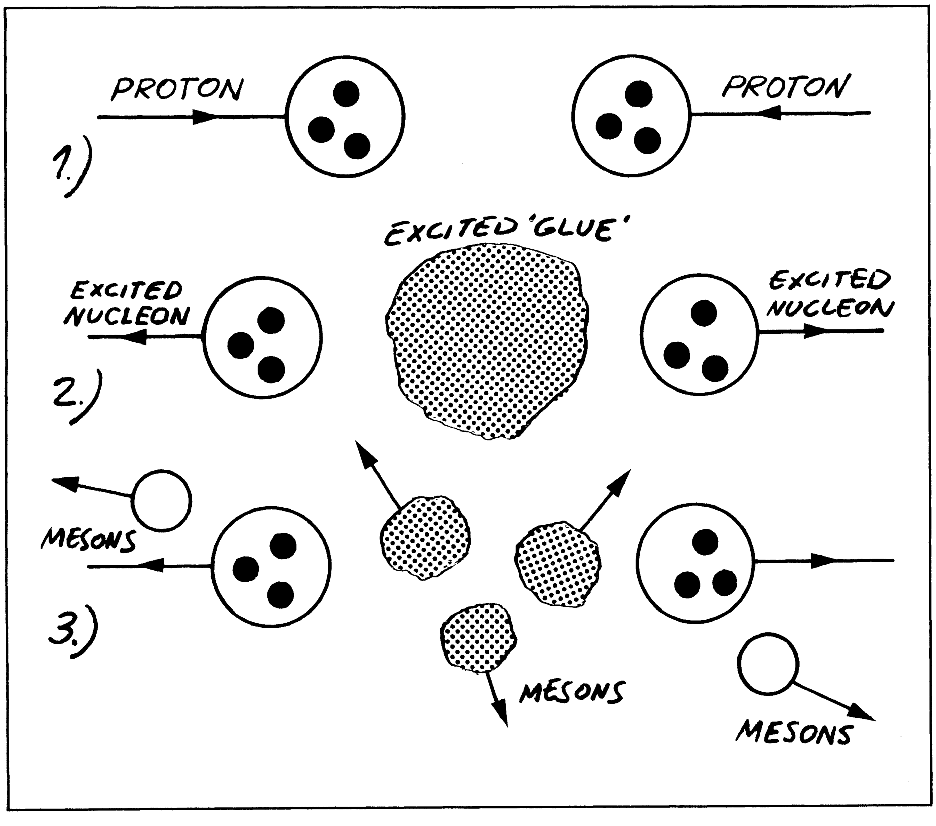
An experiment yielding results which appear to confirm these expectations has recently been performed at the ISR using the Split Field Magnet detection system.

The studies made so far of the jet structure are unable to convey much information on the actual nature of the partons; future experiments, especially those which study correlations between the identity of the emitted particles, will surely give some clues. However, it seems reasonable to identify them with the quarks revealed by the high momentum transfer lepton scattering experiments. A comparison of the characteristics of hadron emission at high transverse momentum in the three different processes proton-proton (CERN/ISR, Fermilab), electron-proton (SLAC) and electron-positron (SLAC/SPEAR storage ring) supports this conjecture. Jet structure has been established at SPEAR in the annihilation of electron and positron to hadrons when the total hadron momentum has values comparable to that for the particles observed in high transverse momentum processes at the ISR.



*The 'jet' phenomenon:*

1. *As seen in electron-positron collisions at the SPEAR storage ring at SLAC.*
2. *As seen in electron-proton collisions at Stanford.*
3. *As seen in proton-proton collisions at the CERN ISR.*



*A general feature of proton-proton collisions (1) at the CERN ISR. Protons emerge in an excited state (2) emitting pions and carry with them about half the total energy which went into the interaction. Pions then emerge from the central region of the collision (3) where some 'excited glue' seems to be left behind.*

## *Multiple production of particles in high energy collisions*

Some of these ideas could explain more typical events observed at the ISR. In a typical collision, there seem to be two mechanisms contributing to the creation of an average of about eighteen particles which are mainly pions. These are — fragmentation of the protons (resulting in the emission of a cluster of pions accompanying one or both of the emerging nucleons) and the emission of other clusters of pions (more or less randomly in direction) from the central region of the collision.

We can imagine that the quarks of each incident proton fly through the interaction volume carrying (as indicated by the lepton scattering experiments) about half the initial nucleon energy. They then heal, coming together to form the outgoing nucleons (usually in an excited state) which then de-exite or fragment, giving off one or more pion clusters. Left behind, in the central region of the collision, is a cloud of gluons which has been scrapped off the passing nucleons; this breaks up into clusters decaying into the pions detected as emerging from the central region. This picture plausibly explains two characteristic features of such collisions — the outgoing nucleons have typically about half the initial proton energy, the total charge of the pion clusters which are centrally emitted is usually zero (as one would expect if their source was the cloud of gluons having no electromagnetic interaction and hence no electric charge).

## *The neutral current form of the weak interaction and charm*

The weak interaction was believed to have only the charged current form, where a neutrino would always change into a charged muon when interacting with matter, until an experiment in the Gargamelle heavy liquid bubble chamber at CERN found neutrino interactions where no muon is created and the neutrino is presumed to leave the interaction unchanged. This is called a neutral current interaction. Two different processes due to neutral currents have been observed. In the first, a neutrino is scattered by an electron; in the second, a neutrino creates hadrons in its interaction with a nucleon without the production of a muon. Neutral current interactions with neutrinos have been investigated by experiments at Argonne, Brookhaven, CERN and Fermilab.

The discovery is of profound significance since it opens the door to theories which offer the prospect of a unification of the weak and the electromagnetic interactions and which awaited evidence for just such a form of the weak interaction. However, the existence of neutral currents introduces another puzzle because neutral kaons have not been observed to decay into two leptons via the neutral current form of the weak interaction.

An explanation was found by reviving an earlier version of the quark model. In 1964, Bjorken and Glashow argued on symmetry grounds for the existence of a fourth quark and distinguished it from the other three by the label 'charm'. Until the discovery of neutral currents there was no obvious need for charmed quarks, but it can now play a role in partnership with the strange quark to cancel out neutral kaon decays into two leptons.

### *Recent discoveries*

The introduction of a fourth quark, an additional building block for hadrons, should lead to new families of hadrons. At the beginning of November 1974, news came from Brookhaven and SLAC (SPEAR) of the discovery of a new particle of mass 3.1 GeV. Within a short time the particle was also observed at the electron-positron storage rings Adone at Frascati and DORIS at DESY. Further particles in the same mass region have been found at SPEAR and DORIS.

One of the outstanding properties of some of these new particles is their lifetime (about $10^{-20}$ s) which is about a thousand times longer than is typical for hadrons of 3 GeV mass. A number of explanations have been proposed and one of them incorporates the existence of a charmed quark such as was discussed in relation to neutral current interactions. The particles are interpreted as bound states of a charmed quark and an anticharmed quark. If the charmed quark is relatively heavy, the long lifetime of the particles finds a possible explanation.

The quark-antiquark state of a meson is similar to the electron-proton system in the hydrogen atom. In this analogy, a large number of possible energy levels is expected and transitions are possible between the various levels when the proper quantum mechanical selection rules are observed. By now seven states have been seen in the 3 GeV mass region and they fit very well into the predicted energy level scheme.

The predictions of the charm model are being verified one after the other with the exception of definite proof of the most direct type, namely the identification of a particle carrying charm (that is composed of normal quarks plus a single charmed quark). There is, however, growing evidence with charmed particle 'candidates' from bubble chamber experiments at Brookhaven, CERN and Fermilab.

The search is intensive and other new and unexpected effects have been observed but it is not yet proved that they are related to charm or to the new particles. Some of these new effects concern direct production of leptons.

### *New lepton production processes*

Four discoveries concerning the production of leptons have recently been made at CERN, Fermilab and SLAC. Explanations of these processes are not yet established but they are surely of great importance; they may be related to charm, or to the existence of a new form of lepton, heavier than the muon.

The first concerns the direct production of electrons and muons in proton-proton collisions. This is seen at the ISR and at the Fermilab with the remarkable feature that, over most of the range of transverse momentum and up to quite high values, the ratio of electron to pion production appears to be constant at about $10^{-4}$. As yet little is known about other characteristics of the interactions in which these electrons are emitted.

The second concerns di-muon events. Two neutrino experiments at the Fermilab have detected two muons emerging from interactions rather than one. It is believed that one of the muons may be a decay product of a new, short lived particle — perhaps a charmed hadron or heavy lepton. Again little is known beyond the fact of the existence of such events.

The third is di-lepton events in bubble chambers. Events in the Gargamelle chamber at CERN and the 15 foot chamber at the Fermilab show a positron accompanied by a strange particle and a negative muon. These characteristics are expected in charmed hadron production by neutrinos.

The fourth is di-lepton events seen at the SPEAR storage ring at SLAC. The direct production of electron-muon pairs has been observed which seems to have a threshold just below 4 GeV. They might result from the production of pairs of charmed and anti-charmed particles with masses around 2 GeV or they might come from the decay of new heavy leptons.

Great strides have been made in recent years in this fundamental question of the nature of matter. Perhaps the ultimate elementary particles of Nature are now coming into view — the four leptons and the four quarks — for there is an attractive symmetry in the pairing of leptons and quarks. I hope I have been able to convey some appreciation of the great excitement which exists in particle physics today. Great discoveries and surprises are in store for those who pursue this quest for knowledge further.

*Professor Willie Jentschke (second from left) in happy mood at the end of his last Council Session as Director General in December. The President of the Council, Paul Levaux, is on his left and the two present Directors General of CERN, Léon Van Hove and John Adams, are on the left and right of the photograph respectively.*

*CERN 327.12.75*

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## Tribute to Professor Jentschke

At the end of the December Council Session the President, Paul Levaux, paid tribute to the contribution of Professor Jentschke to the work of CERN during his five years as Director General of CERN Laboratory I.

He recalled that Professor Jentschke's term of office had begun with the commissioning of the Intersecting Storage Rings for which he had already prepared the way in the preceding years as Chairman of the ISR experiments committee. Such preparatory work has continued in recent years, this time making ready for the experiments of the 400 GeV proton synchrotron, where Professor Jentschke has been involved in the selection of the first experiments and the allocation of resources for the detection systems.

He steered CERN through an exciting time in physics with the fascinating results pouring out from the ISR and the great discovery of neutral current interactions in Gargamelle. At the same time, he sustained the close relationships with the CERN Member States despite the difficulties of retaining a viable programme in a troubled European economic situation.

Relationships with non-Member States have been further cultivated. Many scientists from the USA participate in the CERN programme, especially at the ISR. The collaboration with scientists in the Soviet Union, particularly at Serpukhov, has been extended and Soviet scientists will join in SPS experiments. New contacts have been made with scientists in China and Professor Jentschke led the CERN delegation to Peking in 1975.

Professor Jentschke now returns to his research at the University of Hamburg, though he will remain involved in CERN affairs as a member of the Scientific Policy Committee. M. Levaux bade him farewell with gratitude and respect.

As from 1 January, the two CERN Laboratories have been unified with J.B. Adams as Executive Director General and L. Van Hove as Research Director General.

# SLAC is healthy

*Below: A prototype bending magnet for the proposed 14 GeV electron-positron storage ring, PEP, of the Berkeley and Stanford Laboratories. It is a C magnet with a 60 mm gap, an 8.5 ton laminated core and aluminium coils epoxy resin impregnated.*

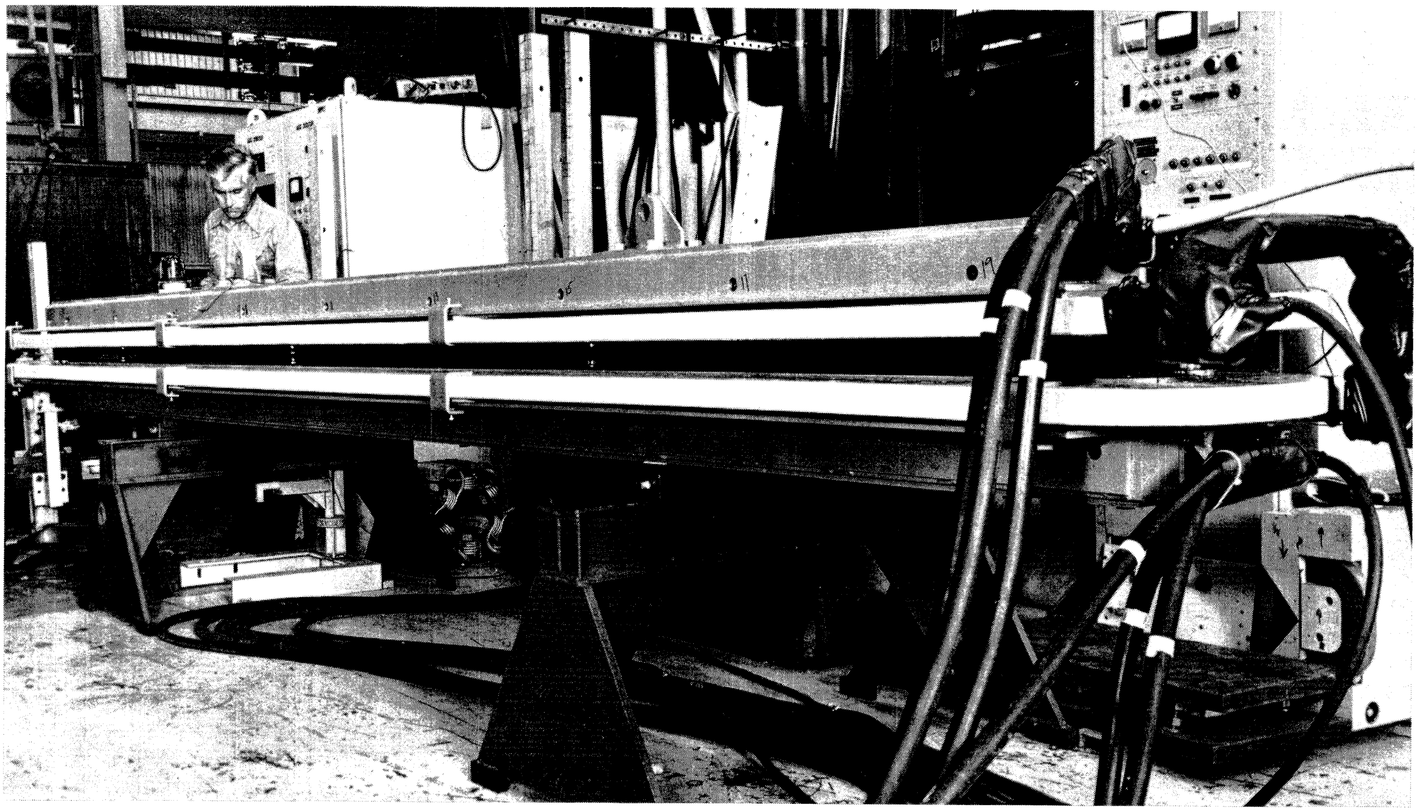
It was with these words 'SLAC is healthy' that Professor Panofsky, Director of the Stanford Linear Accelerator Center, opened a review talk to the SLAC Users' Conference on 21 November.

At the linear accelerator, electrons with energies over 20 GeV are feeding a very full programme of experiments. At 'end station A' electrons, positrons and photons are available for experiments with the 20, 8 and 1.6 GeV spectrometers. Experiments include a measurement of the photoproduction of psis and photons are used to look at lepton production with high momentum transfer. Polarized beams are also available and in great demand. Scattering of polarized electrons on a polarized target has been investigated and asymmetries on unpolarized targets will be studied to see if there are any parity violating effects. For this an improved version (PEGGY II) of the polarised electron source will be a great help.

At 'end station B' the large aperture superconducting solenoid spectrometer (LASS) is coming into action. It has had a hard time with cryogenic problems (helium boiling off at a rate which strains the refrigeration capacity) but the tests with the detector are now going well and part of the spectrometer has already been used in experiments. The 40 inch bubble chamber in a hybrid set-up (described in the July issue 1975) is at this end station. There is also a 15 inch rapid cycling bubble chamber capable of operating at 36 pulses per second with a hydrogen filling and 20 pulses per second with deuterium (these figures may be pushed higher when improved optics become available).

At 'end station C' a 2 m streamer chamber is a general facility. It has been used in muon scattering experiments, a charm search and a search for exotic mesons. The detection system has a downstream spectrometer magnet, arrays of wire chambers and a Cherenkov counter. It is hoped to move to filmless readout from the chamber, using charge coupled device (CCD) arrays, and to add detectors of neutral particles.

The research at the electron-positron storage ring, SPEAR, has been so productive that it has been regularly reported in the COURIER pages. Also drawing beams from SPEAR is the Stanford Synchrotron Radiation Project (SSRP) and since it has received much less attention we will give it some limelight here. A major expansion of facilities, including a second tangential beam line, is underway to extend the research in physics, chemistry, structural biology and other disciplines using the intense X-rays and ultraviolet radiation from SPEAR. SSRP has been the first to exploit synchrotron radiation from a multi-GeV storage ring and many exciting results have been obtained in the



*Right: The electron-positron ring SPEAR at Stanford which has contributed so much to the new particle excitement. The ring is under the concrete block tunnel, the two colliding beam experimental areas are diametrically opposite one another, the control room is inside the ring and the synchrotron radiation experimental area is on the right.*

*(Photos SLAC)*

fields of Extended X-ray Absorption Fine Structure (EXAFS — a new probe of local atomic environment), biological X-ray diffraction, protein crystallography, and soft X-ray photoemission.

The new beam line at SSRP will accommodate five or more additional X-ray experiments and will be located near the first beam line in an extension of the laboratory building. Additional equipment (X-ray monochromators, detectors, data collection system, etc.) is planned along with support facilities (biochemistry laboratory, animal storage and dissecting room, darkroom, etc.).

At present, SSRP operates mostly as a secondary programme using radiation produced during single bunch colliding beam runs of SPEAR. Considerably more synchrotron radiation is produced in the single beam, multibunch mode because more current is stored and the transverse beam dimensions are smaller. Several shifts of such operation took place at the end of December and discussions are in progress to arrange regular use of 5 % of SPEAR time for such synchrotron radiation research runs.

Looking further ahead, the use of SPEAR exclusively for synchrotron radiation research once PEP takes over the colliding beam particle physics programme is being considered. As a dedicated synchrotron radiation facility, SPEAR could serve a much larger community of research workers with several additional beam lines and high field wiggler magnets installed in 3 m straight sections and the low beta interaction regions where the transverse beam dimensions are exceedingly small.

PEP, the 15 GeV electron-positron storage ring proposed by SLAC and the Lawrence Berkeley Laboratory, has $ 2.9 million appropriated for construction by the Senate Appropriations Committee for the present Fiscal Year. (Note that a change in Fiscal Year arrangements extends the year to the end of September rather than the end of June.) It is likely to be used particularly for the detailed work on the storage ring buildings so that when more money becomes available their construction can go ahead immediately.

Polishing of the machine design continues. For example, following the experience on SPEAR where the synchrotron radiation from the last magnet bend before the interaction straight section sprayed the collision region, the pre-straight section magnet configuration for PEP has been redesigned. A PEP Summer Study at Berkeley, attended by sixty physicists from 27 July to 20 August last year, did much to clarify thinking on experimental possibilities, detection systems, experimental area requirements... The potential users of PEP are beginning to organize themselves so as to establish the procedures for arriving at the experimental programme.

Not all the SLAC eggs are going into the PEP basket since it is considered important to sustain the research programme with beams onto stationary targets. This will both broaden the range of physics which can be confronted at the Laboratory and make it possible to continue to support the community of high energy physicists of whom only a limited number could be involved in research at PEP at any one time.

Plans for extending research with stationary targets centre on the SLAC Energy Doubler (SLED) project which was described in the July issue 1974. It involves the use of microwave networks between the klystrons and the accelerator. They hang on to the power during most of the pulse and then pass the crowded power through in a shorter pulse. The electron energy gain is thus increased at the expense of pulse length. It is intended to fund SLED to the tune of about $5 million from non-operating money over four years.

The energy will increase in steps as the networks are installed and also as the klystrons are progressively changed to higher power versions (20 MW to 30 MW to 40 MW). The present schedule aims to achieve 30 GeV electrons in 1978 assuming the present klystron mix, the present peak current of 50 mA, a repetition rate of 360 pulses per second and 230 ns pulse length. If the klystron mix is changed, moving eventually to all 40 MW versions, the SLED scheme could take the peak energy as high as 50 GeV.

If the research possibilities do extend in these ways, SLAC is likely to remain healthy well into the 1980s.

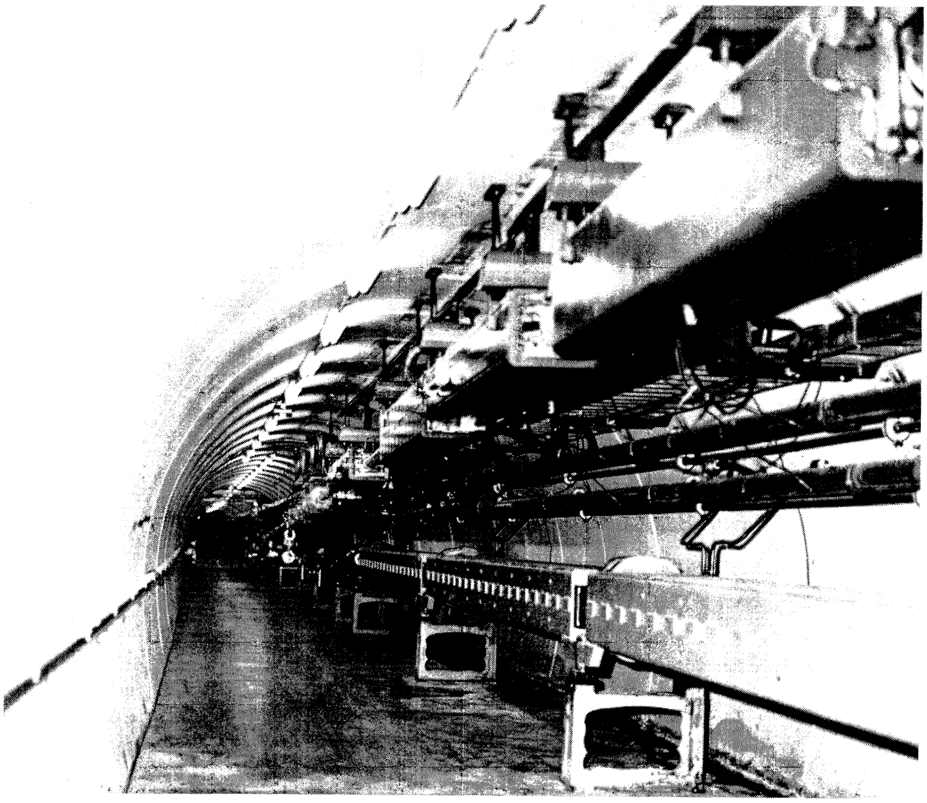
# 1000 GeV next stop

(*) See page 27.

The preoccupations of the Fermilab accelerator specialists at present are to push the proton beam intensity higher towards the goal of $5 \times 10^{13}$ (*) per pulse and to tame the accelerator components to operate at 500 GeV. Looking beyond these tasks, there is the vision of doubling the peak energy by adding a ring of superconducting magnets — a project known as the Energy Doubler/Saver. This project is now playing a bigger part in the life of the Laboratory and the Director, Professor Wilson is spending a considerable part of his time working on it. Bob Wilson heads the Doubler project with Bill Fowler as assistant.

A move to higher energy has never yet failed to uncover new features of particle behaviour. The latest advances have perhaps been the most fruitful of all — 400 GeV protons at Fermilab, colliding proton beams in the CERN ISR and colliding electron-positron beams at SLAC and DESY have been the source of such radical discoveries that we seem to have crossed a threshold into a new era of understanding Nature. Extending to 1000 GeV could confront some of the questions raised in this new era.

One of the most important is to look for the intermediate boson, the particle which is postulated as the carrier of the weak force. The discovery of neutral currents has strengthened those theories which seek to unify our descriptions of the weak and electromagnetic forces and those theories predict boson masses to be greater than 37 GeV. Certainly, the intermediate boson has not been seen with neutrino beams up to energies around 150 GeV at Fermilab and its mass must therefore be above 10 GeV. Protons of 1000 GeV yielding neutrinos of 750 GeV could look for bosons up to a mass of 60 GeV and to find this particle would be a crucial contribution to our understanding of the weak force.



1.

Other particle searches are obviously suggested by the new charm picture of the hadrons. Higher energy neutrino beams would be able to produce charmed particles, if they exist, and the way in which the neutrino interaction cross section increases with energy will also depend on the existence of such particles.

Several other topical areas of research would benefit from higher energies. They include the production of dimuons, which was discovered at Fermilab, about which little is known and even less understood, the jet phenomena, high momentum transfer events, J/psi production with higher energy photons, ... And then higher energies, as in the past, could initiate phenomena which cannot be conjectured at present.

To hold 500 GeV protons, the magnets in the existing Fermilab Main Ring have to reach a peak field of 2.25 T. To hold 1000 GeV protons it is proposed to install above the existing ring an equivalent series of superconducting magnets capable of reaching a peak field of 4.5 T. This is where the name 'Energy Doubler' comes in.

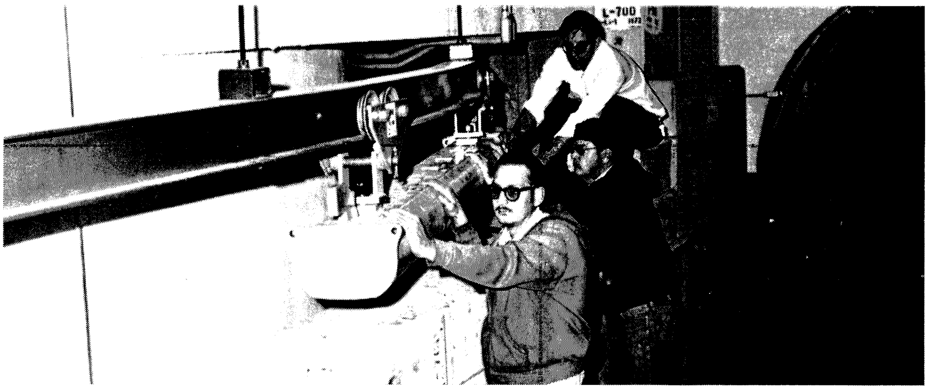
The power consumption involved in operating the Doubler, with very low losses in the superconducting magnets plus the costs of refrigeration, is much less than for conventional magnet rings. There are a variety of possible combinations for operation of the existing ring in tandem with the Doubler so as to benefit from power savings. For example, at present a 7 s pulse to 400 GeV with a 2 s flat top soaks up about 90 MW of power. If the Doubler were run to 400 GeV field levels fed by the conventional ring at 275 GeV, the same cycle and flat top times could be maintained but with a power consumption of only 30 MW (23 MW conventional ring, 7 MW Doubler). This is where

*1. The Main Ring tunnel of the Fermilab accelerator where prototype magnets of the Energy Doubler/Saver can be seen suspended from the roof. It is hoped to have a length of twenty 6 m magnets installed in the tunnel by the middle of this year.*

*2. In building the Doubler, it will be important to interfere very little with the experimental programme which is under way on the existing machine. Techniques such as wheeling in the magnets on rails (Tony Rader, Ron Norton, Jerry Czop, left to right) at six points distributed around the Main Ring should enable most of the installation to take place during normal shutdown periods.*

*3. The transfer lines, which will take helium to the magnets to hold them at superconducting temperatures, are one of the trickiest Doubler components. Don Richied is photographed with two transfer line cross sections. The selected version is on the left.*

*(Photos Fermilab)*


2.


3.

the name 'Energy Saver' comes in.

Another possibility is to feed protons from the conventional ring into the Doubler with its magnets held at constant field, so that protons could be drawn off with 100 % duty cycle. This gives the name 'Beam Stretcher' if any enthusiast wants three names for the same project.

The Doubler requires an injection system (preceded by an ejection system from the conventional ring), an r.f. accelerating system, vacuum system, power supplies, beam diagnostics, ejection system... but the components presenting the greatest technological challenge are the superconducting magnets and their associated refrigeration system. The Doubler needs about 800 dipole bending magnets, each 6 m long, and 200 quadrupole focusing magnets. They have to be retained at a temperature of about 4 K all around the 6 km ring circumference.

The magnet design has a cold bore, 7.5 cm in diameter, and warm iron which adds to the peak field. The coil is wound in two concentric shells sitting around the bore tube on ceramic rings. The two-phase helium coolant return path passes around the bore tube. The single phase helium channel, insulation and an outer vacuum tube are outside the coils and surrounded by iron laminations. The superconducting cable is of the type developed at the Rutherford Laboratory with 2300 niobium-titanium filaments, 7 $\mu$m diameter, in 25 strand cable compacted to $1.25 \times 7.5$ mm$^2$. It is designed to carry almost 5 kA. For the full project, a length of over 1500 km of such cable would be needed.

To provide the large amount of liquid helium there would be a central helium liquifier (2500 l per hour) from which coolant would be distributed by tanker to twelve satellite units spaced around the ring. From there it would be pumped along a length of Doubler through the magnets. A Joule-Thomson valve at the turn-around point gives boiling liquid helium which returns to the satellite unit, again through the magnet.

Both magnets and refrigeration are under attack at present. Development of the magnets has reached a fifth series. The first of this 'E-series' had 4 kA in the cable before its first quench, reached 3.8 T after a small amount of training and the 4.4 T when iron was added. Large amounts of cable are being purchased with Fermilab itself assembling the billets of superconductor and copper which are then extruded by the manufacturers. In 1975 Fermilab was possibly the largest single purchaser of superconducting materials in the USA. Wire costs have already dipped by a third and it is hoped to push them lower.

Plans for the coming months involve a fast programme of superconducting magnet construction. By July it is intended to have twenty of the 6 m bending magnets installed in the Main Ring tunnel and to add another twenty by the end of September. Even if these magnets are not all of adequate quality for the Doubler, this exercise checks the installation procedures. If the project goes ahead, magnet construction may subsequently escalate to 60 per month.

For the central liquifier, an oxygen-nitrogen plant, previously involved in missile work near Los Angeles, has been purchased and will be converted to supply helium. It is being moved to Fermilab. The first components are scheduled to arrive in April and the plant should be ready for operation in October 1977. Meanwhile a small version of a satellite unit has been built and successfully tested linked to a helium transfer line and two magnets.

The optimist approach to construction schedules and cost gives Fiscal Year 1977 as the start of the project, June 1978 as the completion date and $35 million as the cost. Costing for a less rapid schedule sets this figure at $50 million.

# Christmas Workshop at Erice SPS and the new particles

From 20 to 29 December, forty physicists deserted their home firesides to spend Christmas at Erice in Sicily discussing 'How the new particles affect the SPS experimental programme?'. This was the first of a series of 'Workshops on Experimental High Energy Physics', of which the 'Theoretical' counterparts have been running for some time. They were initiated by Nino Zichichi whose benevolent dictatorship of the Erice centre has made it among the world's greatest science meeting places.

No regular reader of the COURIER can be unaware that the discovery of the new particles a year ago has thrown the high energy physics world into a ferment. The existence of stable objects in the 3 to 4 GeV mass region has opened a new era to such an extent that pre-1974 is referred to as 'the physics of yesteryear'. Experimental programmes are revitalised and theoretical interpretations are sketching new visions of how Nature operates. The favourite interpretation involves the additional property of particles, given the name 'charm', which features in our opening story. (It should not be forgotten, however, that charm is not the only interpretation. One involving another property, given the name 'colour', still has its advocates and was given a spirited defence by Paul Mathews at a discussion at CERN on 19 December.)

The CERN 400 GeV proton synchrotron, the SPS, hopes to have particles into the West experimental area by the end of this year. The Erice Workshop was an intense investigation of how its experiments could contribute to the 'new physics'. It was directed by Jim Allaby who has played a leading role in recent years in bringing the SPS experimental programme into shape.

There were a series of scene setting talks. Roy Billinge reported on SPS construction progress. J.J. Aubert (Orsay, a member of the new particle discovery team at Brookhaven) and Burt Richter (at present at CERN, a leader of the new particle discovery team at Stanford) covered their accumulated experimental evidence on the particles. Don Cundy (CERN, who has recently spent six months at the Fermilab) covered the relevant information coming from Fermilab experiments with neutrino beams, plus their fascinating discoveries of dimuon events (see December issue, page 396) which may or may not be relevant to the new particle picture, charm, etc... Alan Astbury (Rutherford, who is Chairman of the CERN Electronics Experiments Committee) described charm searches in experiments at the 28 GeV proton synchrotron at CERN. Peter Schubelin (Strasbourg, who played a major part in the difficult task of mastering MASS — Multiparticle Argo Spectrometer System — at Brookhaven) projected his ideas on how electronic systems in the new physics era could do the job that bubble chambers did for the physics of yesteryear.

The theoretical background was confronted in a review by Leon Van Hove (now one of the Directors General of CERN). G. Preparata talked about quark confinement schemes and their implications for experiments. He invented the term 'fire sausage', (missing 'hot dog' by a hair's breadth), to describe excited particle states (similar to the 'fireball' description of the instant of collision between two particles) visualized as bags containing quarks. It was typical of the atmosphere at the Workshop that he was presented with a flambéed salami in the restaurant on the evening of his talk. D.W. Sivers endeared himself to the experimental heart by carrying theory to the point where it emerged with figures which can be experimentally tested. He took the existing information on the new particles (such as the hadron versus muon production rates in electron-positron collisions, photoproduction cross-section,...) and by several routes came out with a way of estimating production rates for charmed particles in various types of interaction.

These figures could be so important in planning charm experiments that it is worth pulling some of them out here. In electron-positron collisions with an energy of over 4 GeV, judging by the Stanford, SPEAR and DESY, DORIS results, it looks as if the production of particles involving charm goes on in half the interactions. (If heavy leptons exist they could throw this estimate out.) In neutrino-nucleon collisions the estimate is that the production is about one tenth of all the interactions. In muon-nucleon collisions a similar figure of one tenth emerges for high $Q^2$ (over 20) interactions. In photon-nucleon collisions the figure is one hundredth. In hadron-nucleon collisions there is a fairly complicated scaling factor.

The meat of the Workshop came in presentations by spokesmen (or spokespersons) from almost all the experimental teams which have experiments approved for the SPS programme. Given the timescales involved in preparing for experiments at 400 GeV energies and the fact that the new particles have not been with us long, the approved aims of the experiments are not directly relevant to the 'new physics'. This means that the approved experimental set-ups have to be re-geared in some way in order to answer new physics questions. Fortunately, the scale and cost is such that they tend to be made in a flexible way so that they can easily be adapted to attack a variety of questions. Approval is likely to be readily given for changes in the aims of experiments where they can obviously make a real contribution.

We concentrate here on those ex-

*To encourage the Workshop participants that their Christmas efforts were not wasted, here is a photograph of the throng in the tunnel of the CERN 400 GeV proton synchrotron tunnel on 18 December when the last of the main magnets was rolled into position comfortably on schedule.*

*CERN 236.12.75*

periments where it looks as if something important can be done with equipment well adapted to doing it. First of all there are interesting possibilities with the bubble chambers — BEBC (3.7 m European bubble chamber) and Gargamelle (heavy liquid). Gargamelle has already been successful beyond the dreams of its most optimistic advocate, contributing what is arguably CERN's most important discovery (the existence of neutral current weak interactions) and recently clocking up the charmed particle candidates. Its scope with neutrino beams from the SPS were covered by S. Natali. It is likely to continue the general search work for which bubble chambers are so well suited adding further information on neutral currents (with neutrino-nucleon and neutrino electron events) and on charm particle production.

BEBC (discussed by J. Lemonne) will also receive neutrino beams and, equipped with a track sensitive target (TST), could provide cleaner information on neutral currents than is possible in heavy liquid chambers. In addition, with hadron beams into BEBC, the TST in action and the external muon identifier (EMI), it could provide excellent data on the phenomenon of direct lepton production which may be tied up with the new particles. Several events could be expected in every thousand pictures.

For electronics experiments we discuss only what seem to be the most interesting possibilities in the West Area; those in the North Area will only have beam in a couple of years' time and the whole emphasis could have changed by then.

Experiment WA 5 of the Indiana/Saclay collaboration involves the use of a large aperture magnet (known as Goliath) containing a dozen multiwire proportional chambers surrounding a target, followed by spectrometer magnets and a Cherenkov. G. Laurens described how, by turning the MWPCs at right angles to follow the target they could trigger on two muons coming from the decay of the J/psi particle produced in the target and, with their spectrometer, look for charmed particles produced in association with the J/psi.

Experiment WA 7 of the CERN/Genova/Orsay/Oslo/University College London collaboration involves a big system of Cherenkovs. R. Mollerud explained how by introducing some steel, so that muons (which readily traverse the steel) can be distinguished from pions, they can do some thorough work on the J/psi, looking in detail at such things as the kaon to pion ratio in the particle decays.

Experiment WA 10 of the Geneva/Lausanne collaboration has an array of scintillation counters and multiwire proportional chambers which, with little modification, can be used for spotting charmed particles. M. Martin described the detection system and brought out how the mass range of the new particles can be covered with very good resolution and high data taking rates. Narrow peaks in mass distributions of particles emerging from the decay of charmed particles could be found.

There are also possibilities with the Omega spectrometer covered by John Dowell. It should be able to fasten onto direct leptons, as mentioned for BEBC above, and it will receive a photon beam which, if the production rate of 1 % calculated by Sivers is correct, is a promising route to charmed particles in rather clean conditions.

There was no lack of sharp discussion at the Workshop which helped to hone, or to stifle, many of the ideas on modifying experiments at the SPS. It is now clear that, in several cases, experiments at the CERN 400 GeV proton synchrotron can be contributing to the new physics very quickly.

# GESSS work broadens

The activities of the Group for European Superconducting Systems Study (GESSS) have been given added impetus by the decision of Euratom to sponsor a working group to look into the application of superconductor techniques to fusion technology. In this working group, the original GESSS members — Institut für Experimentelle Kernphysik of Karlsruhe, the Rutherford Laboratory and Centre d'Etudes Nucléaires de Saclay — have been joined by Culham in the UK, Fontenay-aux-Roses in France, Frascati in Italy, Garching in Germany and Petten in the Netherlands.

The working group's immediate objective is to formulate a research and development programme for the superconducting magnets for a post-JET (European Tokamak) experiment before going on to consider the problems of the ultimate fusion reactor. The reactor would have to use some form of superconducting magnets, otherwise the energy needed to power the magnets might well exceed the output of the station.

GESSS met in December at the Rutherford Laboratory to review progress and to examine the theoretical and experimental problems involved in designing superconducting magnets for use in thermonuclear fusion experiments. Such magnets at the post-JET stage are likely to be enormous by present standards — possibly a toroidal ring 20 m diameter containing 20 D-shaped magnets each 14 m high and 8 m wide. Such a structure would encounter problems of high stress levels, protection, stability and the effect on the conductor of the pulsed magnetic fields, which are required to heat the plasma in a Tokamak-type reactor.

A new type of a.c. loss mechanism comes into play here because, unlike a synchrotron for example, most of the pulsed magnetic field is parallel to the conductor rather than perpendicular to it. In such a longitudinal field, the twisted filaments of the usual superconducting composite may together exhibit a greatly increased a.c. loss and the hysteretic loss in the individual filaments may also be much greater than is the case with transverse fields because of anisotropic effects in the superconducting material. Saclay is carrying out a theoretical analysis of losses due to longitudinal fields.

## *Other topics being tackled by GESSS*

Although originally set up specifically to look into the possible applications of superconducting magnets in high energy physics, the work of GESSS has now expanded to cover superconducting a.c. generators and power supply cables, magnetic levitation and applications in medicine and mineral separation as well as in thermonuclear fusion.

At the December meeting, workers from Karlsruhe outlined plans to have a pilot scheme for the separation of ores using superconducting magnets in operation by 1977 and to investigate the possible uses for magnets for controlling the direction of catheters for introducing heart pacemakers. The use of superconducting detectors to measure the amount of ferromagnetic dust in lung tissue is thought by Karlsruhe to be an effective way of monitoring atmospheric pollution. If patients are first made to inhale a known amount of ferromagnetic dust, it may also be possible to detect cancer and other lung abnormalities.

A new 'mixed' system for magnetic levitation has been investigated at Rutherford, following an original idea from the Culham Laboratory. The Rutherford experiments have achieved stable levitation of a superconducting magnet near a passive piece of iron. The lifting force has been shown to be very large and, unlike many other MAGLEV systems, does not depend on any relative motion between the two components. In a transport application this system could, therefore, provide lift from rest to maximum speed with no magnetic drag and with a large clearance gap between the vehicle magnets and the iron track. Although the Rutherford experiments are promising and could well form the basis for a practical levitation system, a lot more theoretical and experimental work has to be done to investigate other possible solutions before an optimum high speed ground transport system can be designed.

Progress continues to be made to bring the technology of filamentary niobium-tin — potentially a higher performance superconductor — to a level where it can be used in place of the more conventional niobium-titanium alloy in the construction of high field magnets. Recent results at Rutherford have indicated that the critical current density at high fields depends on the stoichiometry of the compound. But regions of pure copper are still required even in a filamentary niobium-tin composite with a bronze matrix. In the past there have been difficulties with the diffusion barrier surrounding the copper but the technology has now advanced to the point where a composite may be heat treated for many hundreds of hours to react the niobium-tin without contaminating the copper. Small coils have been successfully operated at fields up to 12 T and work is in progress on a sextupole magnet to work at high current density and produce a 7 T field.

'Training' continues to be a problem in high field work. Superconductors and many magnets still can only achieve a field substantially below that of the 'short sample' field of the same superconductor or require many quenches before full performance is reached. A small computer program has been developed at Rutherford which simulates this training process and demonstrates how it might be affected by such factors as differential contraction, stress level in the magnet and the strength of the material used to impregnate the windings.

### *Work for the high energy physics programme*

Superconducting magnets are being developed at Karlsruhe, Rutherford and Saclay for use in beam line and detection apparatus at CERN both for the Intersecting Storage Rings (ISR) and for the 400 GeV proton synchrotron (SPS). Status reports were given at the Rutherford Laboratory meeting on the CERN magnet development work being carried out by each GESSS member Laboratory. Parameters have now been finalised for Cesar, a dipole project at Saclay for the SPS beam lines, and tests are scheduled to start at CERN in November 1977. The production schedules for the SPS hyperon beam high gradient superconducting quadrupoles at Karlsruhe should allow the magnets to be shipped to CERN in the second half of this year.

CERN, Rutherford and Saclay are collaborating in a design study of a superconducting magnet for a rapid cycling bubble chamber vertex detector to be used in SPS experiments in the North Area, but no decision has yet been taken as to where the magnet will be designed and built.

A proposal to develop a large-aperture superconducting magnet hadron spectrometer for the ISR has not been accepted by CERN but the idea continues to stimulate a lot of interest. Design work is continuing in a collaboration between Rutherford and the Lawrence Berkeley Laboratory. Karlsruhe is also designing a similar device which would be required by late 1978 for use at the PETRA electron-positron colliding beam facility at DESY.

A study is being carried out by Saclay on power consumption for the heavy ion cyclotrons, GANIL, which are to be built at Caen. Using conventional main field coils requires 600 kW whereas superconducting coils using 30 litres per hour of liquid helium might require only 8.5 kW.

With this wide variety of projects, the GESSS collaboration has a lot of interesting work to get its teeth into. It continues to play a very important role in mastering the techniques which are needed to bring the great potential of superconductivity into practical use.

## BERKELEY
## Superconducting solenoid

A large superconducting solenoid, using a new technique for controlling quenches, has been successfully operated by a group from the Lawrence Berkeley Laboratory consisting of P.H. Eberhard, M.A. Green and J. Taylor. On 24 November, a prototype module 1 m in diameter and 50 cm long was eased up to the full design current of 700 A. At this current, the module produced a peak field of 1.1 T. With a full complement of four modules and an iron yoke, a uniform field of 1.5 T would result.

The design incorporated a novel method for dissipating the stored energy in a quench from the superconducting to normal state. An aluminium bore tube is tightly coupled inductively to the superconducting coil and thus acts like a shorted one-turn secondary of a transformer. During a quench, currents are induced in the tube and measurements indicate that more than 70 % of the stored energy is dissipated harmlessly in this way.

The full design current was achieved by a systematic progression of controlled quenches moving to larger and larger currents, the quenches being induced locally by pulsing a small coil near the superconducting coil. By studying the results, the onset of the next quench could be predicted and the current would then be increased to a safe level, climbing progressively to the design current.

The design is particularly appropriate for detector magnets surrounding interaction regions in colliding beam machines since the coils can be made very thin. The prototype assembly is only 0.25 radiation lengths thick, excluding the external vacuum tank. Work is continuing at Berkeley to arrive at a practical detector magnet such as could be used at the proposed PEP electron-positron storage ring which is a joint project of Berkeley and Stanford.

*The Berkeley superconducting solenoid which incorporates a new quench control technique. Its designers/operators, Eberhard, Green and Taylor (left to right) stand alongside it.*

*(Photo LBL)*

## RUTHERFORD
## Counting bubbles

The measurement of bubble densities along charged particle tracks has been a standard way of identifying 'slow' hadrons in bubble chamber photographs but the identification of very fast hadrons, such as are/will be emerging from interactions at the 400 GeV synchrotrons of the Fermilab and CERN presents a major problem. However, observation of the behaviour of particle tracks in a neon-hydrogen mixture has led bubble chamber physicists at the Rutherford Laboratory to believe that bubble density measurements could still be used to help distinguish between relativistic pions, kaons and protons without the need for external particle identifiers.

An increase of about 50% in the rate of energy loss of charged particles for Lorentz Factors ($\gamma = E/m$) from about 4 to 200 is seen in a variety of gases. If the momentum of a relativistic particle is known and if its rate of energy loss, and hence its Lorentz factor, can be measured precisely enough, then its mass can be calculated and the particle identified. This effect is the basis of the external particle identifier (EPI), which is being built for use with the 3.7 m European bubble chamber, BEBC.

In 'visual' detectors, like bubble chambers, any increase in ionisation density along a track is highly dependent on the mechanism of track formation. Relativistic rises in track density are seen in heavy liquid bubble chambers and nuclear emulsions but are notably absent, in hydrogen bubble chambers so that, with hydrogen chambers, relativistic particles cannot be directly identified.

In track-sensitive target (TST) experiments, a hydrogen target is surrounded by a heavy liquid (usually a neon-hydrogen mixture) with the aim of detecting neutral secondaries, especially gamma rays. In the course of such an experiment in the Rutherford Laboratory cryogenic bubble chamber, Colin Fisher, John Guy and Wilbur Venus studied film of 4 GeV/c positive pions. They found that a neon-hydrogen mixture shows an appreciable rise in bubble density. The comparisons of electron tracks (having Lorentz factors of over 200) with slow pion tracks (having Lorentz factors of 4) in a mixture of 73 mole per cent of neon in hydrogen show a total rise in bubble density of some 30 per cent. Since BEBC will be fitted with a TST this observation is of wide importance.

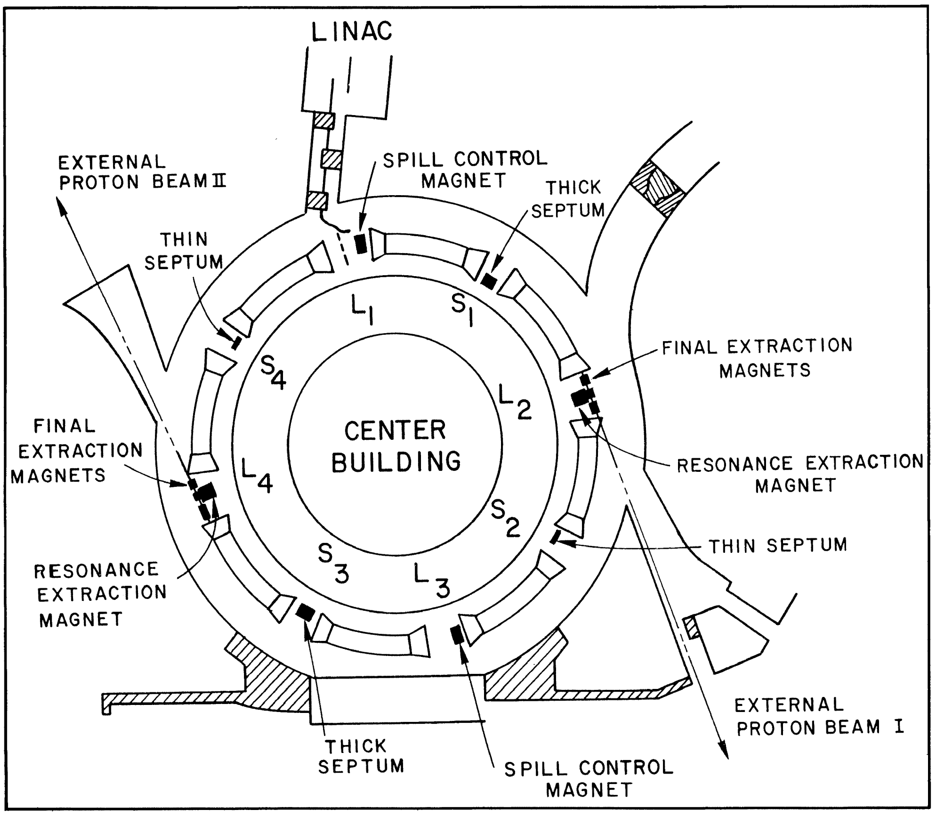
The detailed behaviour of this relativistic rise in bubble density in neon/hydrogen has yet to be determined but, if systematic errors from automatic measuring techniques can be reduced to a level where they are comparable to the accuracy with which bubble densities can be measured and provided that stable operating conditions can be maintained, relativistic particle identification inside BEBC is a real possibility. Its most important application would be in neutrino experiments for which the external particle identifier which is under construction is not suitable.

## ARGONNE
## Slow resonant extraction at the ZGS

During October, slow resonant extraction of the proton beam in the 12 GeV Zero Gradient Synchrotron was perfected. This new technique permits

*Components distributed around the 12 GeV Zero Gradient Synchrotron, ZGS, at Argonne, which are used in achieving simultaneous slow extraction down two diametrically opposed external proton beam lines. With the achievement of high extraction efficiencies the way is now open to push for higher accelerated beam intensities.*

*(Photo Argonne)*



the beam to be extracted, using the 2/3 resonance with minimal spill structure, simultaneously to two experimental areas 180° apart around the circumference of the machine with a combined efficiency of about 50 %. (The actual efficiency may in fact be somewhat higher than 50 %, since it is suspected that the present calibration of circulating beam intensity in the ZGS may be too high.)

This represents an increase of beam available to experiments by a factor of two. The duty cycle of the extracted beam was measured to be at least as good as with the older targeted extraction method and resonant extraction will now become the standard mode of ZGS operation with both polarized and unpolarized beams.

The technique involves a pair of resonance extraction magnets with large sextupole field components which bring the tune of the machine near to the 2/3 resonance point. Protons are deflected by the extraction magnets and pass through two septum magnets on the inside of the ring. The septum magnets then bend the beams into the two extraction channels.

Problems of beam intensity and position stability and, particularly, time structure, have prevented implementation of the technique as a standard operating mode of the ZGS for some time. The initial scheme for extraction was to control the position of the debunched, coasting beam by ramping the ZGS magnetic field during extraction. A feedback using two dipole spill control magnets was used to reduce low frequency ripple. However, despite all efforts, the resulting beam spill had only a 20 % duty cycle with 80 % modulation in the 2 to 6 kHz range, which was unacceptable for experimental use. This was because the resonance was developing very slowly and producing unstable feedback conditions.

The next attempt was to use 'tune jitter', introduced by driving the radial damper at frequencies corresponding to tunes between 0.661 and 0.655, to excite the 2/3 resonance. This had the desired effect of producing high efficiency extraction without large low-frequency structure but introduced structure at the excitation frequency (around 500 kHz) which upset certain high-rate experiments.

Finally it was decided to drive the beam resonance by operating the r.f. system in a non-synchronous mode. The r.f. amplifier was shut off for 10 ms and then turned back on at a non-synchronous frequency. With the synchronous frequency of 13.921 MHz, high efficiency extraction with improved structure was found at 13.840 ± 0.010 MHz and at 14.025 ± 0.010 MHz. This 'r.f. jitter' gave a spill with a large duty cycle and very little low frequency modulation.

High efficiency beam extraction from the ZGS has been a goal for some time and its successful implementation means that the way is now clear to bring the ZGS intensity from the present 2.5 × $10^{12}$ protons per pulse to over $10^{13}$ through use of the 500 MeV Booster II injector, currently under construction. The new intensity level is expected around January of 1977 when its initial application will be for second generation neutrino experiments in the 12 foot bubble chamber.

## CORNELL Experimental programme

A new round of experiments is under way on the 12 GeV electron synchrotron at the Wilson Synchrotron Laboratory, Cornell. Two experiments using large-aperture magnets to study deep inelastic electron scattering are in the data taking stage. The LAME experiment (Large Aperture Magnet Experiment) and the DECO experiment (DESY/Cornell streamer chamber collaboration) are both in the final 'shakedown' stage before starting long data taking runs. A Harvard/Cornell collaboration is setting up a double arm spectrometer system to study the electroproduction of phi mesons. The spectrometers have been tuned and test runs started in January.

A group from the University of Rochester will be taking data in February to study the radiative decays of vector mesons (i.e., rho, phi and omega decays into eta and gamma). They use a tagged photon beam to produce the vector mesons coherently from a copper target. An experiment on photon shadowing is being set up to measure the total photoproduction cross sections on hydrogen, deuterium and complex nuclei. The same group has recently completed a measurement of total electroproduction cross sections and the results show little shadowing even at low momentum transfers, approaching those which are involved in photoproduction ($Q^2$ of 0.1 $GeV^2$).

A group from the department of Applied and Engineering Physics at Cornell is busy with experiments using synchrotron radiation. They are studying K- and L- edge absorption spectra (in the energy range from 3 to 120 keV), forbidden reflections in silicon and germanium, chemical shifts using high resolution fluorescence spectroscopy and other interesting subjects that can take advantage of the high energies and intensities and the low angular divergence of the beams of x-rays emerging from the orbiting electrons. In future issues some of the experiments mentioned above will be described in more detail.

Most members of the Laboratory are also involved in designing an electron-positron storage ring. The project aims to achieve colliding beams with a luminosity of $10^{32}$ per $cm^2$ per s at beam energies of 8 GeV. The scheduled turn-on date is early 1979 if funds become available for the coming fiscal year. More details will be presented as the project gets under way.

## ECFA helps prepare for electron-positron physics

At its June Meeting of last year (see June issue, page 198) the European Committee for Future Accelerators adopted a resolution urging the construction of a higher energy electron-positron storage ring in Europe. One of the recommendations was that the exploitation of the machine should be open to the European scientific community. Now that authorization has been granted for the building, at the DESY Laboratory in the Federal Republic of Germany, of the 2 × 19 GeV electron-positron storage ring known as PETRA, ECFA is helping to implement its recommendation. This is entirely in keeping with ECFA's function as the forum for all the components of the European high energy physics community — the Universities, the National Laboratories and CERN itself.

ECFA has set up an Informal Advisory Committee which will examine ways in which PETRA could be exploited by international collaborations. The Committee will consist of A. Messiah, G. Salvini, H. Schopper (Director of DESY), G.H. Stafford (Director of the Rutherford Laboratory), G. Von Dardel (Chairman of ECFA) and a member to be appointed from CERN.

As a first task this Committee will advise the organizers of a meeting which ECFA is sponsoring in March of this year which will look at the experimental possibilities opened up by PETRA. The meeting will be held at Frascati and will be organized jointly by DESY and Frascati. It will be attended by about 120 physicists from all over the world. This follows the style of the ECFA meetings at Tirrenia (see October issue 1972) which helped so much in preparing the experimental programme for the CERN 400 GeV proton synchrotron.

ECFA remains very much involved, of course, in the developments at CERN and reacted strongly to the budget problems, reported on page 23. A recommendation was submitted to the Directors General and transmitted to the CERN Council and its Committees expressing deep concern about the implications of additional budget cuts at a time when research at the 400 GeV proton synchrotron is about to begin. ECFA maintained that the research programme and the participation of the scientists from the Member States are the two most important aspects of CERN's activities and recommended the re-establishment of a long range budget procedure to allow optimum planning for achieving these important aims within the budget limitations.

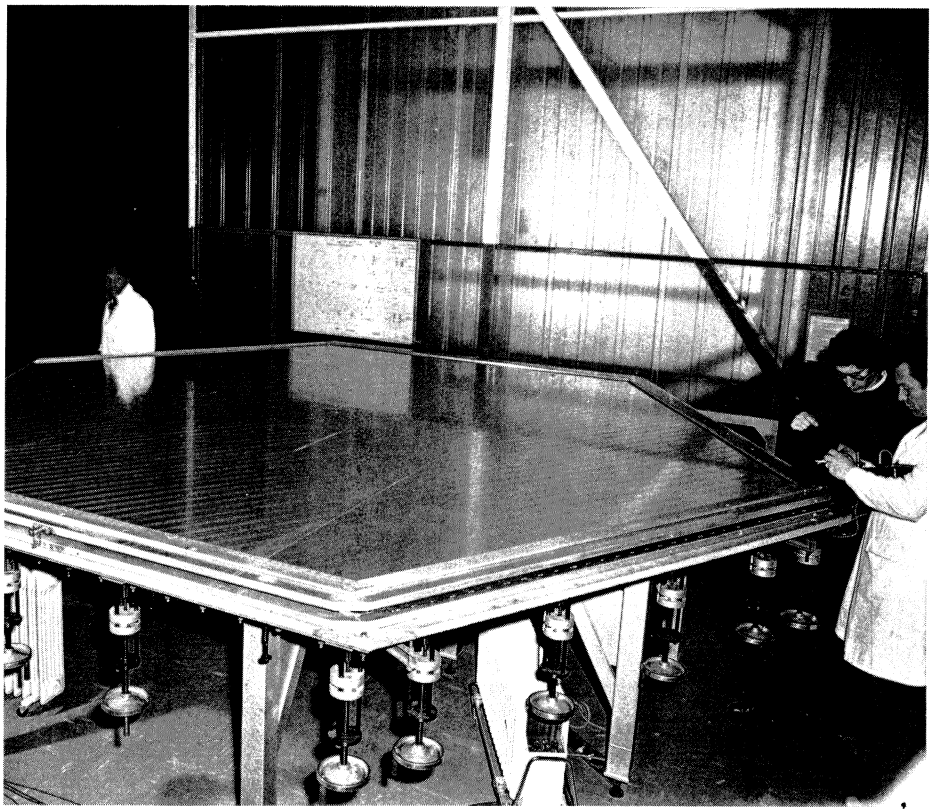
Other work at the moment is a follow-up of the report on the relationships between the different parts of the European high energy physics community. As one aspect of this problem, the conditions encountered by short and long term visitors to CERN are being examined, in collaboration with the Services involved at CERN, to see whether it is appropriate to do anything to improve them.

ECFA will turn again to its original purpose, implied in its name, and initiate a study of the long term situation with regard to possible future accelerators.

*1. The first of the drift chambers intended for a neutrino experiment with the CERN 400 GeV proton synchrotron being tested at the Centre d'Etudes nucléaires, Saclay. Excellent operation was observed with cosmic rays. The chamber is hexagonal in shape, stands 4 m high and has a useful area of 11 m².*

*2. A drift chamber leaving Saclay at the beginning of December. The arrival of the chamber at CERN marked the culmination of eighteen months of design work on a large number of prototypes.*

*(Photos Saclay)*



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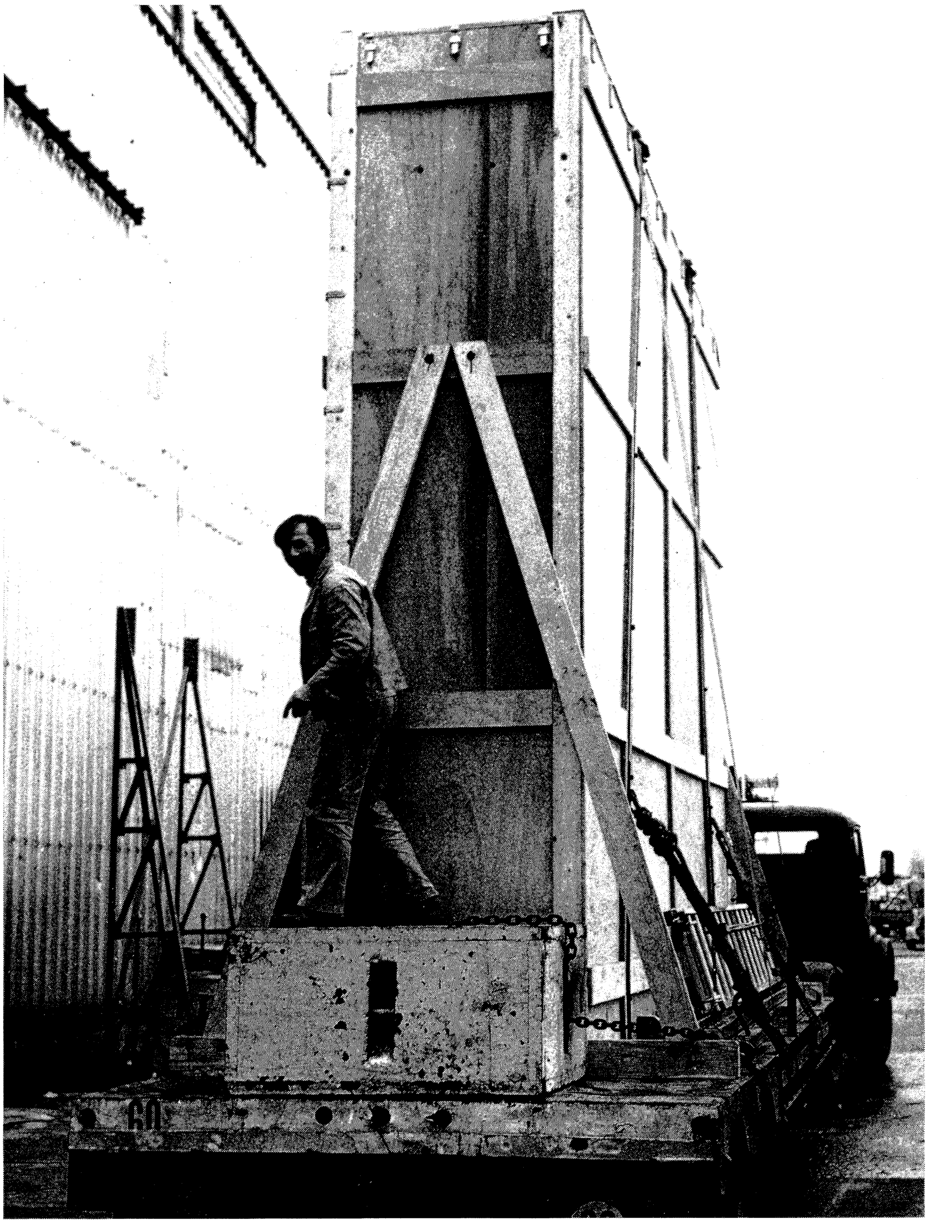

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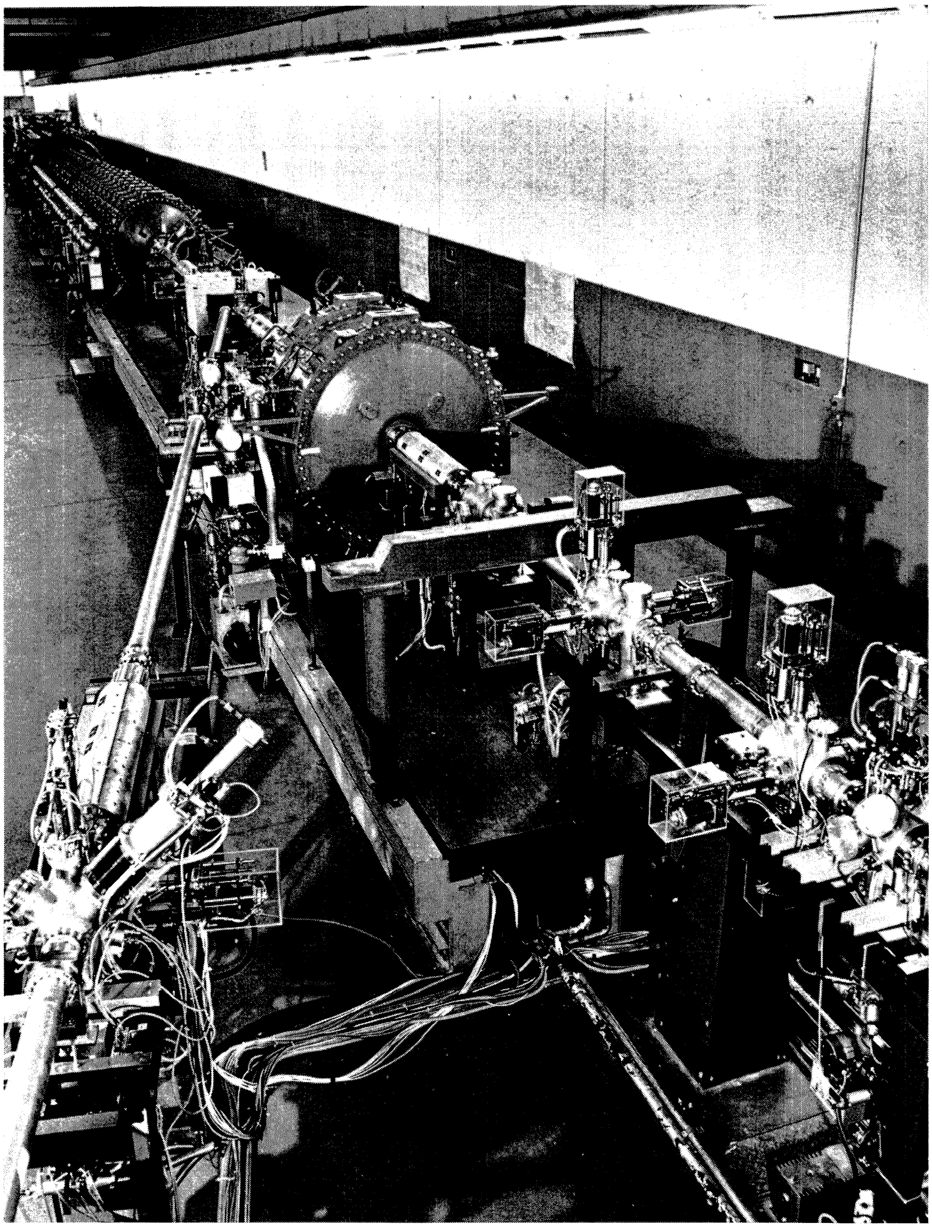
## SACLAY
## Drift chambers for SPS experiment

At the beginning of December, the first of nineteen drift chambers arrived at CERN from the Saclay Laboratory to be installed in the large spectrometer of a CERN/Dortmund/Heidelberg/Saclay collaboration for neutrino experiments at the 400 GeV proton synchrotron.

The chambers have a useful area of 11 m² and stand 4 m high. They consist of a drift space in which there is a uniform electric field with a wire at its centre which acts as the anode of a conventional proportional counter. Using a special gas mixture, the drift speed of the electrons is independent of the field provided it is over 800 V/cm. This alleviates the need to achieve a very uniform field and simplifies construction by limiting the number of potential wires defining the drift space. Drift distances of a few centimetres can be found to an accuracy of some tenths of a millimetre by measuring the time elapsed between the passage of a particle (clocked by scintillators) and the appearance of the signal on the read-out wire. Juxtaposing many cells (each with a read-out-wire) makes it possible to extend the position measuring system to large areas with a small number of sense wires and associated electronics.

For the SPS experiment, each assembly consists of three identical chambers in sequence with their read-out wires aligned at respective angles of 120°, thus providing the three co-ordinate measurements. The chambers consist of rigid aluminium honeycomb structured panels with 62 cells each 6 cm wide. They make it possible to separate two particles more than 1 cm apart in the same cell.

The electronic system is designed to give an accuracy of ± 0.5 mm using



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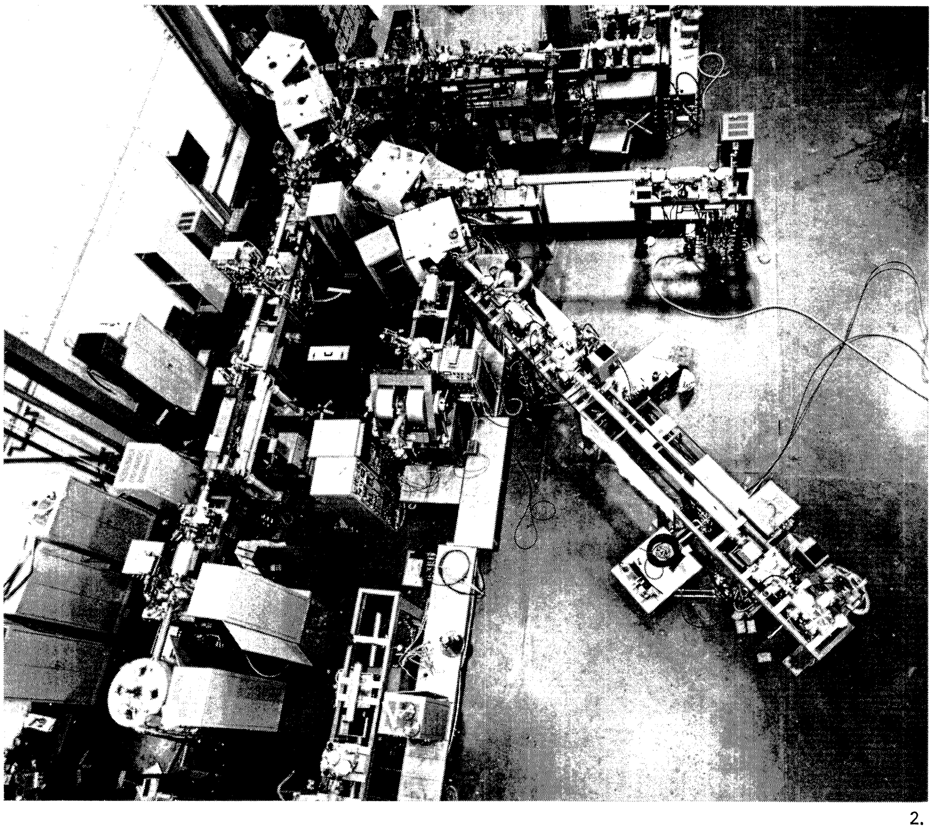

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*1. The output end of UNILAC where the beam line on the right leads from the last single resonator group of the accelerator (in the background) and the experimental hall (off to the right). By a 13° bending magnet it is possible to deflect the beam to the area for irradiation experiments (off to the left). A single-gap cavity on the right serves as a debuncher.*

*2. The UNILAC low energy experimental area that is fed by an ion beam of 1.4 MeV/amu. Charge states higher than those selected for injection into the poststripper accelerator can be deflected out by a septum magnet. A further bending magnet directs this 'parasitic' beam to the hall for atomic and solid state experiments.*

*(Photos GSI)*

one high performance screened preamplifier per read-out wire. The arrival time signals from the 3700 wires are coded and memorised in groups of sixteen on a single coder which can cope with four such signals provided they are at least 20 ns apart.

## GSI DARMSTADT Heavy ions emerging

Since October, the mechanical installation of virtually all components of UNILAC, the heavy ion linear accelerator at the Gesellschaft für Schwerionenforschung, has been completed. The accelerator consists of a Wideroe section and an Alvarez section, followed by single gap cavities.

The second group of the single gap cavities and the emerging beam transport system in the accelerator tunnel have been assembled and a series of sub-systems have been completed or provisional arrangements have been replaced. These include automatic control of the vacuum, beam diagnostics, magnet power supplies (acceptance tests), control units for magnet power supplies that are necessary for the computer control of magnets (installation and tests), feedback control for the 27 MHz 'phase axis', injection beam line (installation of a macropulse chopper to protect beam diagnostic elements from destruction at high currents), installation of a buncher (to increase the current in the Wideroe by a factor of 3 to 4) and the interlock system.

With the prestripper accelerator (Wideroe section) a first short operating period has taken place. It was used for accelerator experiments as well as for physics experiments in the low energy experimental hall. For the four Wideroe tanks, the set values — amplitudes, phases, phase acceptances and particle energies — were systematically determined. Experiments have been done with argon and xenon ions at energies of 0.2, 0.6, 1.0 and 1.4 MeV/amu in nuclear spectroscopy by Coulomb excitation and by neutron pick up, in x-ray spectroscopy of quasimolecules, in Auger spectroscopy and in measuring sputter rates of thin targets.

Altogether, a beam could be delivered to four different target positions for 120 h. Particle currents were $10^9$ to $10^{12}$ per s. The separation of charge states by the charge separator, after the ions have passed through the stripper, works without difficulties. This makes it possible to feed the Alvarez section and, at the same time, the low energy experimental hall with a 'parasitic' beam. The measured currents are those of isotopes separated in the injection beam line. The beams seem to be very pure; Coulomb excitation experiments revealed that the $^{132}$Xe beam contained no more than 1 % $^{129}$Xe (27.0 and 26.4 % are the natural isotopic abundances).

Component reliability has been improved considerably during this time and routine operation does not seem to be far away. The longest running time was 36 h which was terminated when the machine was deliberately switched off.

The first accelerating tests in the Alvarez section were performed successfully, $^{132}$Xe being accelerated to 5.9 MeV/amu. The energy was determined by a time of flight measurement. Because the 108 MHz r.f. supply system is not complete, this was only possible with a second stripper between the two Alvarez tanks. Successful operation was also obtained with the helix serving as rebuncher between the stripper and the first Alvarez tank. There are still some problems to be solved in feeding full r.f. power into the Alvarez cavities (1.6 MW peak power is necessary for accelerating uranium using the gas stripper).

The single gap cavities are still at the debugging stage. It is hoped to try accelerating ions through them during the next two months but, for use in experiments, the energy of any beam into the main experimental hall will be restricted to 5.9 MeV/amu maximum for the near future. Installation of the beam transport system in the experimental hall has progressed to the stage where beam can be brought to targets along the undeflected beam line. A first test of components was carried out with a 3.6 MeV/amu krypton beam ($2\times10^{11}$ pps).

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## CERN

## Decisions at the December Council Session

The 56th Session of CERN Council was held at CERN on 17, 18 December under the Presidency of M. Paul Levaux. It received reports on the work of the two CERN Laboratories from the Directors General J.B. Adams and W.K. Jentschke (whose physics review is reported on page 4).

The major discussions prior to the Council Session concerned the CERN budgets in the coming years. In June, Council had asked CERN to gear its programme to annual budgets diminishing by 3 % per year through to 1979. In the intervening months, the detail of how to apply this directive while sustaining the best possible research programme has occupied the CERN management and the delegates of the Member States.

For 1976, a budget of 663 million Swiss Francs (1976 prices) was accorded of which the Member States will find 642 MSF. It did not prove possible to agree the forward budgets for 1977, 78, 79, as is the custom under the 'Bannier procedure'. On the one hand, some Member States are concerned that the CERN budgets do not make sufficient concession to the overall European economic situation. On the other hand, other Member States are concerned that too severe cuts could seriously damage the quality of the CERN scientific programme. A range of figures for the coming years was considered and will be debated further before the June 1976 Session.

The Council re-elected Paul Levaux as its President for 1976 with Professor Bernard Gregory and Professor A.C. Pappas as Vice-Presidents. Dr. M. Lemne was reelected Chairman of the Finance Committee while Professor W. Paul remains Chairman of the Scientific Policy Committee. Professor J. Prentki was appointed Head of the Theoretical Physics Division at CERN.

## Annual shutdown

On 21 December, the CERN machines were switched off for their long annual shutdown. During the Christmas holidays the radiation level was allowed to fall and maintenance and modifications started at the beginning of January. The PS is due to be switched on again on 25 February.

The linac's main concern is reliability since its operation is crucial to the PS, ISR and SPS. The mercury diffusion pumps of the vacuum tanks will be replaced by turbomolecular pumps and more powerful fans will be installed for cooling the tube contacts of the final stages of the r.f. amplifiers.

The system of multipole correction magnets in the booster will be completed to provide better beam control. A new magnet is being installed to distribute the linac beam to the four booster rings which operates faster than the previous one and will ensure a cleaner cut of the four beams removing the head and tail of the linac beam.

The PS itself is preparing for high intensity, $10^{13}$ protons per pulse, and 'supercycle' operation (see page 26). A new reference system (function generation) for the r.f. cavities and a new high-dynamics beam control system, enabling intensity modulation during the supercycle without change in level, are being installed. To improve the control of the operating point and chromaticity, a figure-8 loop system will be introduced in the 100 magnets making it possible to feed the poleface windings from three separate power supplies.

At the beginning of the beam line leading from the PS to the ISR or SPS, two magnets will be installed in order to direct the unused beam to a static beam dump located outside the PS ring in order to reduce radiation damage in the PS. The final extraction septum magnet will be installed for continuous transfer of the beam to the SPS and a wide-aperture septum magnet for fast ejection to the 2 m bubble chamber, which will thus be able to operate with higher intensity beams.

At the Intersecting Storage Rings a CERN/Columbia/Oxford/Rockefeller collaboration is installing an experiment to study high transverse momentum phenomena at intersection I-1. In the outer hall at this intersection work has begun on assembling the magnet of a Frascati/Gênes/Harvard/MIT / Naples / Pisa collaboration to study high mass muon pairs and associated hadrons. This will be installed about the middle of the year. At intersection I-6 a CERN/Harvard/Munich/Riverside/Northwestern collaboration is installing a detection system to search for charmed particles. It involves an additional trench to take a magnet and the installation of a new vacuum chamber.

On the machine itself, nearly half the vacuum chamber will be opened. New beam diagnostic equipment will be installed as well as a static titanium screen on the kicker magnet. This replaces the moving screen to help improve the beam stacking conditions.

The programme of replacing sector valves and fast acting valves will be completed. Power supplies for the auxiliary magnets and compensating poleface windings will be modified and tested. A cooling plant extension will be linked up to increase cooling capacity by 4.3 MW. All this work is scheduled for completion on 27 February.

## OMICRON spectrometer for the synchro-cyclotron

Interest has recently been focused on certain rare events or weak effects at nuclear energies. They can only be studied by looking at interactions with a detection system giving a large solid angle for observations combined with accurate measurement of momenta and angles. To achieve these experimental conditions, an Amsterdam/Birmingham / CERN / Lubljana / Oxford/Turin/Zagreb collaboration is designing a spectrometer which can be used for a wide range of experiments with the proton beam from the CERN 600 MeV synchro-cyclotron.

In building this spectrometer, use will be made of a 190 ton magnet which was previously used in a bubble chamber at the Rutherford Laboratory. It is roughly cube shaped with a side of 3 m. The poles have to be modified and the magnet gap will be 1 m wide, 85 cm high and 2 m long. The alterations to the magnet are now being made at the Rutherford Laboratory and it is hoped to carry out acceptance tests at CERN in the middle of the year.

In the SC, the beam is located 1.25 m above ground level and to bring the centre of the magnet aperture to the same height, the magnet will be sunk in a pit 4.8 m in diameter. It will sit on a ring so that it can be rotated around a vertical axis.

The detection system consists mainly of wire chambers and drift chambers installed in a closed vessel which will be filled with helium in order to reduce multiple scattering. This vessel will be located in the magnet gap and its precise positioning is being studied to ensure that the counters can be arranged with the precision needed to satisfy the particular types of experiment which will be carried out.

Data acquisition will involve an HP21M computer, and it is hoped to be able to reduce the volume of data taken on-line. This means eliminating a large part of the many unwanted events in order to single out the rare or weak-effect events for study by this spectrometer.

The list of experiments envisaged is already long: back-scattering of pions and muons on light nuclei; reactions with double charge exchange; branching ratio of the rare decay of the neutral pion into an electron and positron; decay into a positron and electron from a pionic atom and the form factor of beta decay; production of low energy pions.

Hopefully the experiments will start before next autumn beginning what could be a long career for this very versatile spectrometer which has been given the name OMICRON.

# Bits and pieces


1 CERN 317.12.75

1. George Hampton


2 CERN 201.6.72

2. Kees Zilverschoon


3.

3. Vikki Weisskopf as active as ever in projecting physics. He is photographed here at the Stanford Linear Accelerator Center in December where he gave a series of lectures on 'Qualitative Physics' and one on the 'MIT-Bag' — one of the models which attempts to explain why we do not see quarks in isolation.

(Photo SLAC)

## *Two CERN Directors leave office*

*At the end of 1975, George Hampton, who had headed the Administration since 1963, returned to England.*

*As Director of CERN Administration, he certainly had one of the hottest seats in high energy physics. He worked with three Directors General, coped with an empire of Personnel, Finance, Site and Buildings and Directorate staff, and steered much of the Council business. The range of problems which he had to confront were legion. To mention just one, his work on vital documents, like the revised CERN Convention, revealed many of his abilities. No-one was quicker to see the ramifications of any proposed changes.*

*In one of his farewell speeches, George Hampton told a splendid administration story concerning a cat, repeatedly pursued by dogs, who was advised by an owl to change into a wolf. After futile attempts at such a transformation, the cat complained to the owl and was told 'My dear fellow, I am here to establish policy. It is for you to see to the implementation'.*

*Kees Zilverschoon left for a year's sabbatical leave at the end of 1975. He was one of the CERN pioneers having looked after installation and coordination during the building of the proton synchrotron in the 1950s. He later moved to another big success story as Kjell Johnsen's right hand man during the building of the Intersecting Storage Rings. In recent years, he has been Director of the Proton Synchrotron Department and has taken responsibility for the long-term planning of CERN budgets. In the prevailing financial climate, this has been a hard task and Kees Zilverschoon brought all the necessary qualities of foresight, thoroughness and patience to bear. He has always believed intensely in CERN and has never hesitated to make his opinions known. His abilities and his devotion have contributed a great deal to CERN's success.*

## Gravity at Rutherford

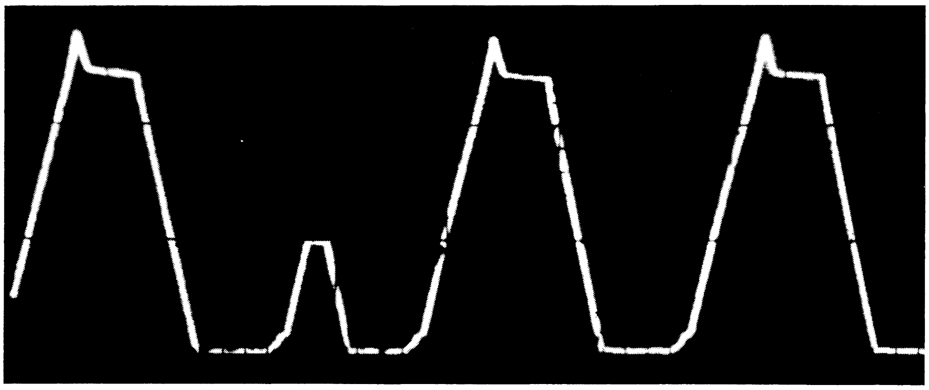
C. Christodoulides and Doug Allen of Reading University and the Rutherford Laboratory have looked for the gravity waves that Joe Weber believes he has seen at Maryland. Two detectors (1.5 m long cylinders sliced in two along the axis with piezo-electric transducers between the two halves) were located one at Reading and the other at Rutherford. Gravitational waves reaching the earth would be expected to cause both of them to resonate simultaneously. However the rate at which such events were observed was not higher than chance coincidences occurring because of random thermal movements triggering the resonances. Shifting the delay time between the two signals gave the same coincidence rate as when their clocks were synchronized. (Journal of Physics A, vol. 8 page 1726.)

## *Superconducting magnet for MHD generator*

*The magnet group at Argonne, which has considerable experience in the technology of superconductivity, is building a large superconducting magnet (5 T peak field, 12 Tm field integral) for installation in a magnet hydrodynamic generator in the Soviet Union. The project is in the context of the USA-USSR Agreement on cooperation in science and technology. The work is being carried out within the High Energy Physics Division with John Purcell as project manager. Coil winding is now in progress and it is hoped to ship the magnet for use in the U-25 generator in Moscow by the end of the year.*

## Ions on pellets for thermonuclear power

Al Maschke at Brookhaven has looked at the idea of bombarding pellets of fusionable material with heavy ions (report BNL 20297).



*Trace representing the variation of the field in the magnets of the proton synchrotron while trying out the 'supercycle' designed to feed the SPS and the PS/ISR users in an interleaved fashion. The large pulses correspond to acceleration of the proton beam to 25 GeV with slow ejection for experiments and the small pulse corresponds to acceleration to 10 GeV for injection in the SPS. The total cycle time for two 25 GeV pulses and one 10 GeV pulse was six seconds.*

*On 13 January, the UK Secretary of State for Education and Science Mr. Fred Mulley, visited CERN together with Sir Sam Edwards, Chairman of the Science Research Council. He is pictured here (left) confronting the SPS control system with the help of Michael Crowley-Milling.*

*CERN 54.1.76*

Typical aims to achieve fusion would be to deposit about $10^{15}$ watts of power on a 1 mm radius pellet within a depth of about 200 μm. Doing the sums for singly charged uranium ions these figures seem realizable. The method proposed is to accelerate $U^+$ in a conventional synchrotron to an energy of around 25 GeV and to store the ions in a storage ring. Extrapolating from existing designs the figures of $50 million for the storage ring, $100 to 200 million for the accelerator and a power consumption of 30 MW are calculated. On paper, the power gains from igniting the thermonuclear pellet are about a factor of a hundred.

### *Proton radiography at a standstill*

*Radiography using proton absorption (see September 1974, page 303) was investigated at Argonne on the prototype 200 MeV booster accelerator. Development of this technique is now in abeyance since the booster was dismantled six months ago to prepare for construction of 'Booster II'. Funds for design and construction of a Proton Diagnostic Accelerator were not forthcoming from the National Cancer Institute on the grounds that the technique is not a proven 'radiological modality' (i.e. applicable for use with human beings and superior to X-ray techniques). Funds have been requested from ERDA under the New Technology Initiatives programme but without response so far.*

### *Super test of 'supercycle'*

*During the night of 18-19 December, the CERN PS machine specialists tried out the operation sequence which will be needed in the course of this year so as to feed the 400 GeV synchrotron and the PS/ISR experimental programmes in an interleaved fashion. This 'supercycle' calls for the pulses at around 25 GeV, possibly with a flat-top for slow ejection at peak energy, to be followed by a pulse at around 10 GeV for injection into the SPS, with a short flat top while beam is ejected over ten turns. The linac, booster and PS ring were all in action and a sizable team of accelerator people was available to help synchronize all the systems involved. These included the components for fast ejection, slow ejection and continuous transfer. Satisfactory operation was achieved and it now remains to tame the 'supercycle' to the point where it can be switched on as routine.*

### *CERN Schools*

*6-19 June: The 1976 CERN School of Physics will be held at Wépion, near Namur in Belgium. The aim of the school is to teach some aspects of theoretical high energy physics to young experimental physicists. Lectures will be given on gauge theories, new particles, neutrino physics and quarks and partons. There will be additional lectures on special topics and reviews of the experimental programmes at some of the major Laboratories. The School is being organized by the CERN Scientific Conference Secretariat together with a Committee of Belgian physicists.*

*12-25 September: The 1976 CERN School of Computing will be held at La Colle-sur-Loup near Nice in France. It is intended for post-graduate students and young research workers in physics or computer science. Special emphasis is to be given to operating systems, distributed* *computing (data communications and micro-processors) numerical and non-numerical techniques appropriate to modern computing environments. The School is being organized by the CERN Scientific Conference Secretariat together with IN2P3, Paris.*

### *ESO's future home*

Since 1970 a Division of the European Southern Observatory has been based at CERN and there has been collaboration between the two organizations in the construction of a 3.6 m telescope which is to be installed at the La Silla Observatory in Chile. The Federal Republic of Germany has offered a site at Munich (near the Max Planck Institutes at Garching) to ESO. This will make it possible to bring together the ESO Administrative Department (now at Hamburg), the Scientific Department which is being created to promote collaboration in European astronomy and, eventually, the staff currently working at CERN. The move from CERN is scheduled for late 1978 comfortably after commissioning of the telescope. The only 'external' ESO centre will then be at La Silla — a rather necessary state of affairs since the purpose of ESO is to study the southern skies.

### *Fermilab tops $2\times10^{13}$*

*On 20 January, $2\times10^{13}$ protons per pulse were squeezed through the Fermilab synchrotron at 400 GeV. The main contribution to this new record came from a very healthy Linac beam (150 mA) with two turn injection into the Booster. The new intensity levels are being held consistently at the time of writing with average intensities not short of $2\times10^{13}$.*

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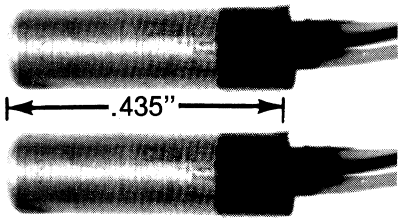
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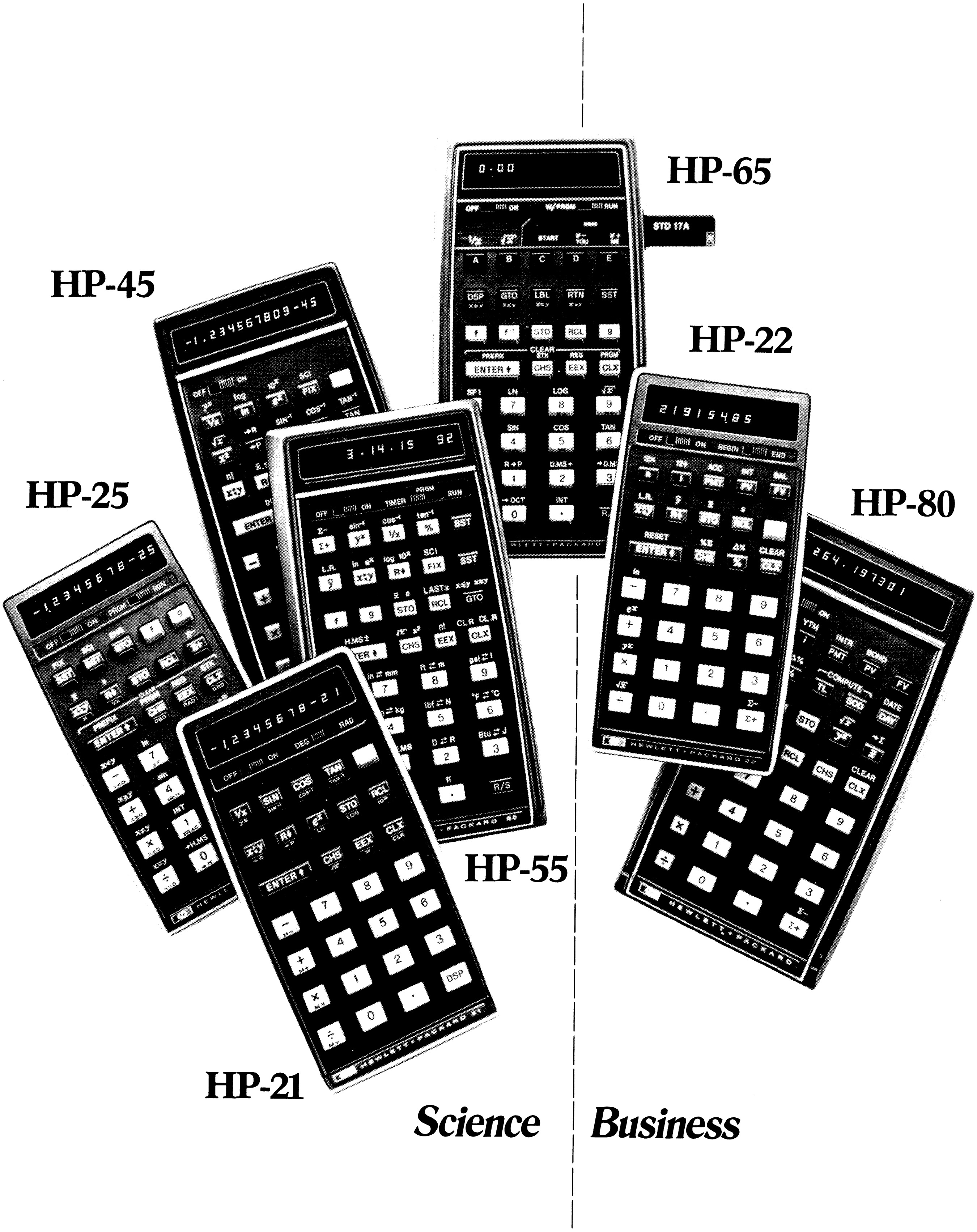

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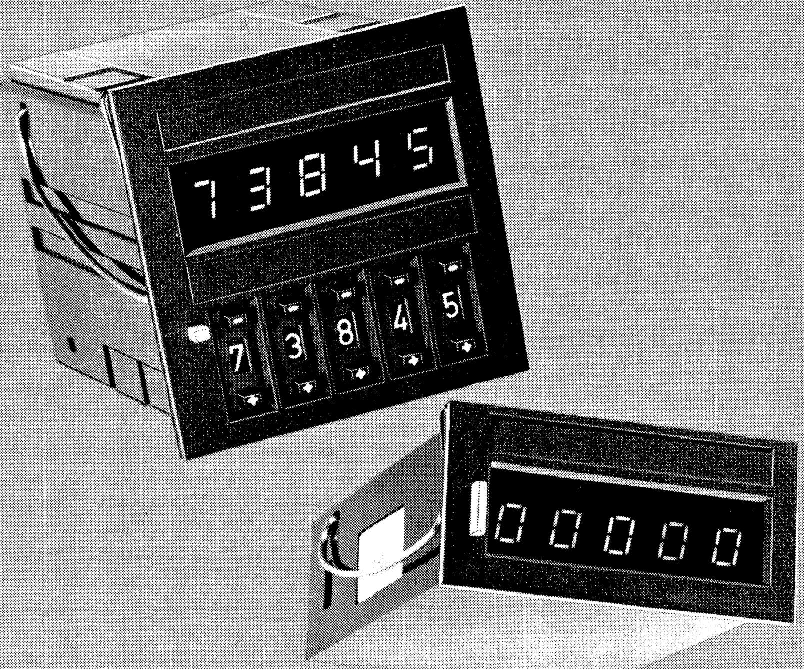
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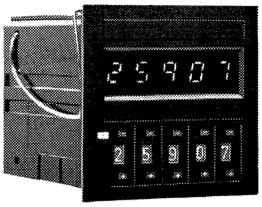
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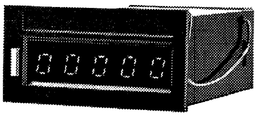
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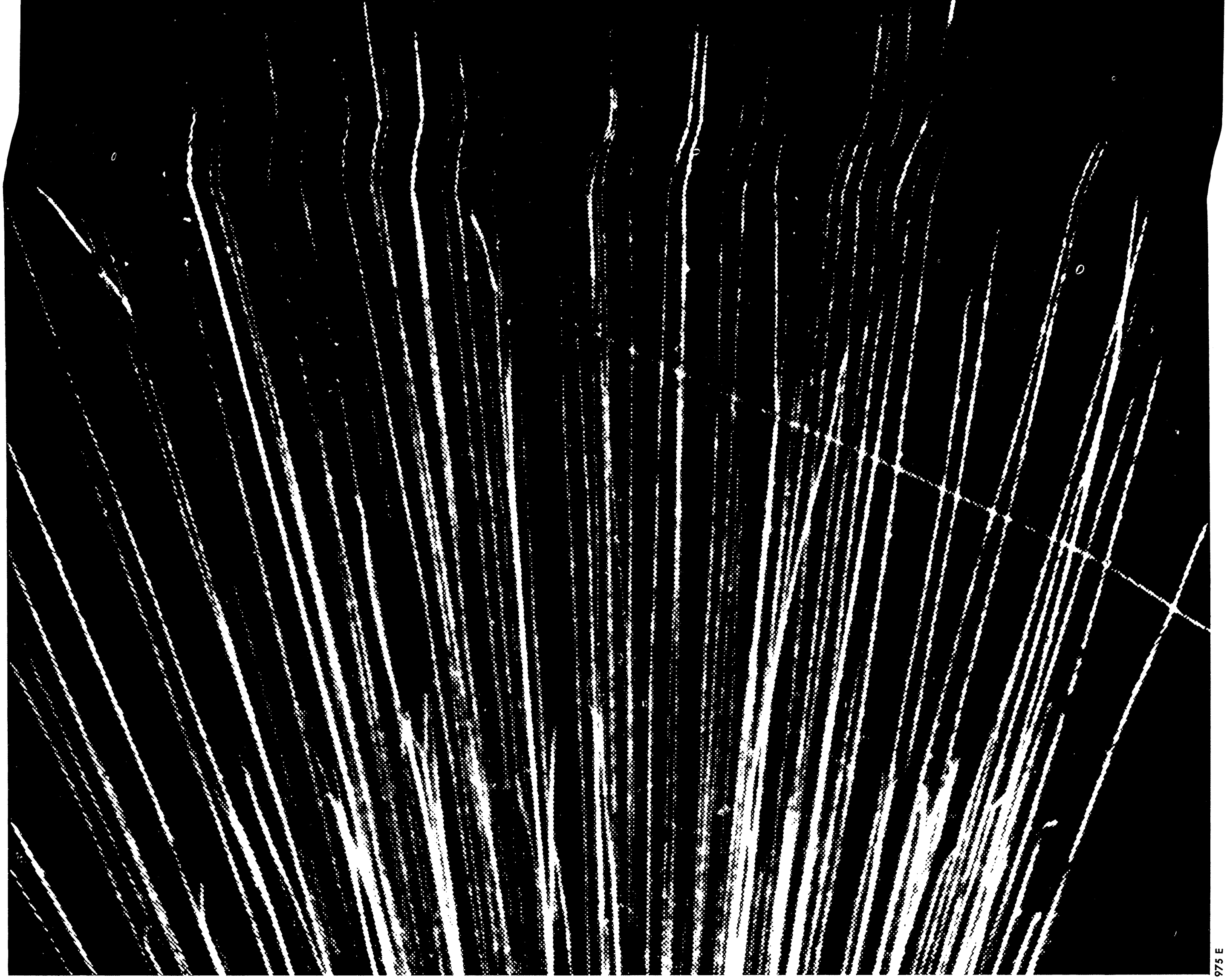

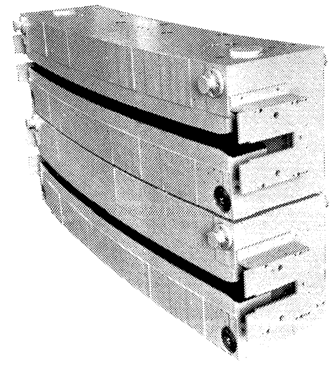

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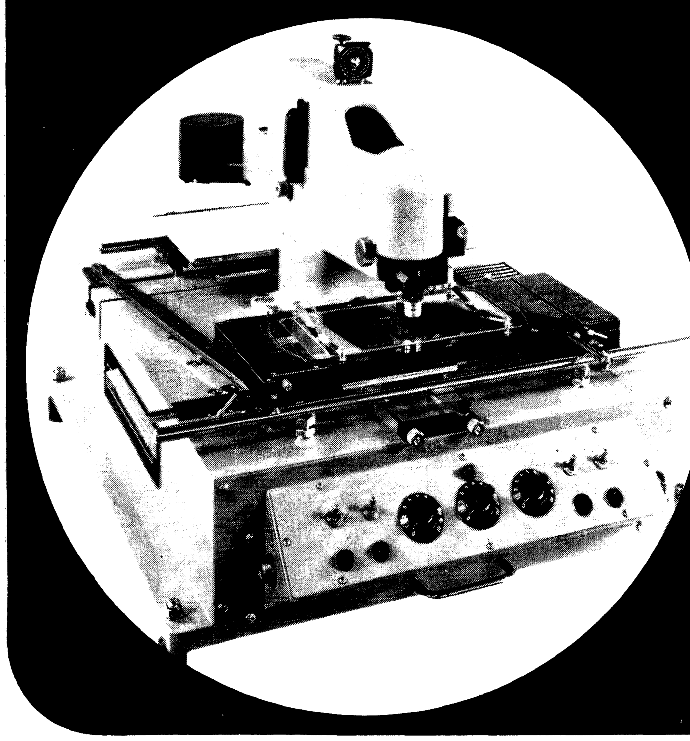

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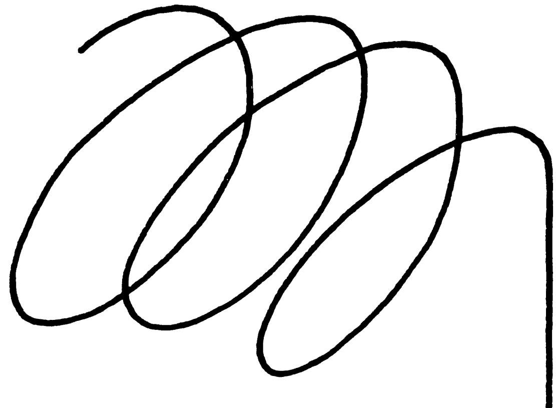

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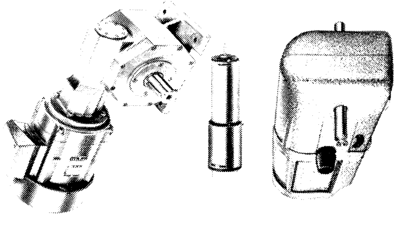

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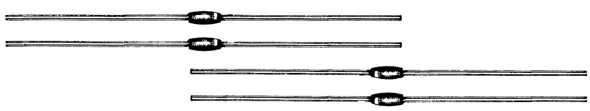

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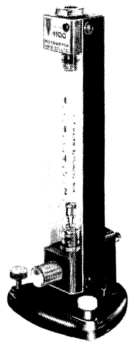

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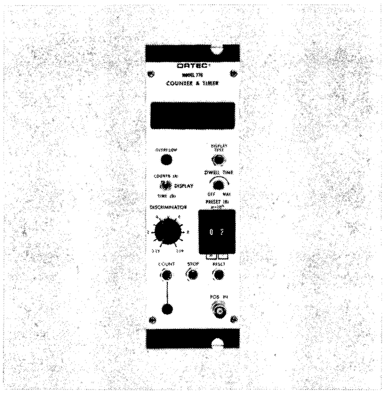
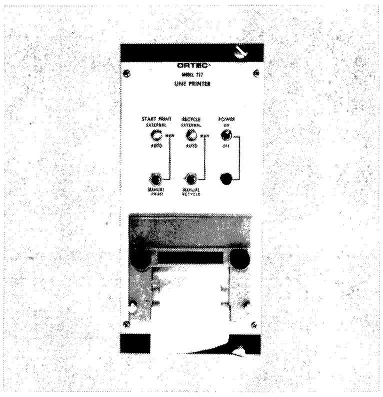
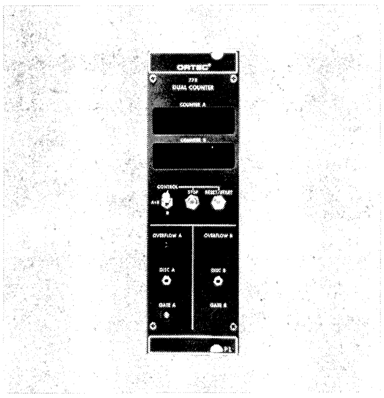

Simultaneous Timer & Counter operation, or as 2 counters.


Parallel Line Printer & printout controller. Prints 3 Lines/sec.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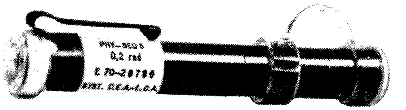

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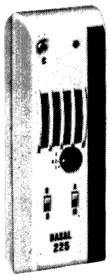

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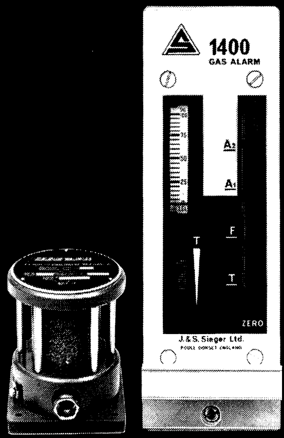

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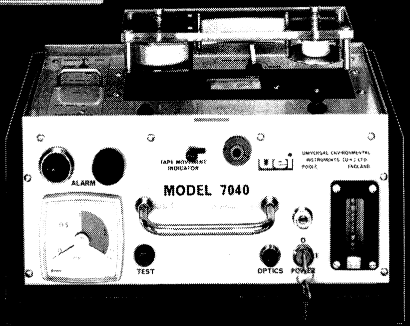
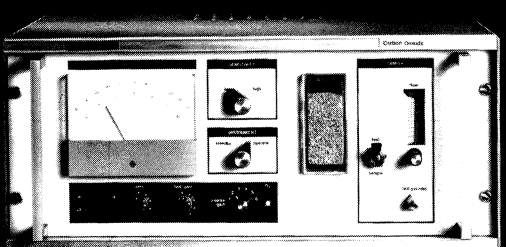


**UEI**

For TDI, for instance. Hydrogen sulphide, phosgene, nitrogen dioxide, chlorine, vinyl chloride.



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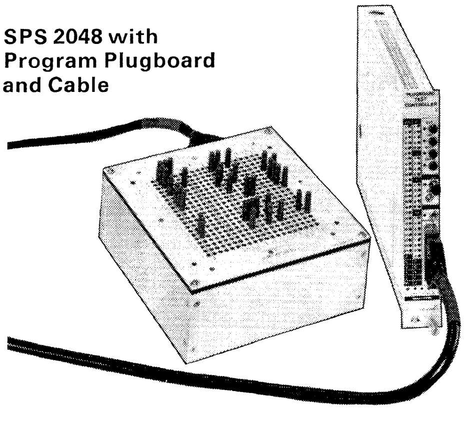
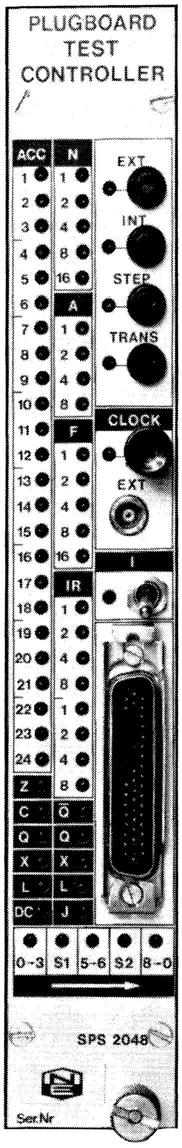
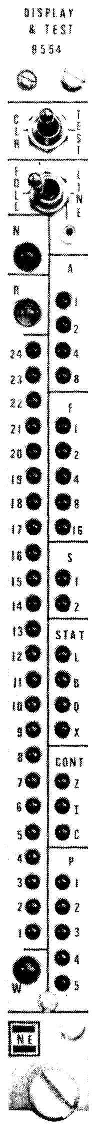


**SPS 2048 with Program Plugboard and Cable**





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The 9554 module can be used to diagnose basic dataway faults, to indicate errors presented on the dataway by faulty modules, and to display immediately the state of the dataway when a control program halts.

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