CERN COURIER

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

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

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3100 people and, in addition, there are about 1000 Fellows and Scientific Associates. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 391.1 million Swiss francs in 1974.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. A 'super proton synchrotron' (SPS), capable of a peak energy of 400 GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1974 is 227.1 million Swiss francs and the staff totals about 350 plus 10 Scientific Associates.

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Cover photograph: Rural scene at Meyrin near Geneva on 17 May 1954. Site work was beginning for the Laboratory of the European Organization for Nuclear Research. That day, CERN began its transformation from ideas and hopes in the minds of European scientists and politicians into the hardware of a modern scientific research centre.

Comment

On 17 May 1954 the first shovelful of earth was dug out of the ground at Meyrin, Geneva and construction of the Laboratory of the European Organization for Nuclear Research was under way. CERN has come a long way in the subsequent twenty years. It is unlikely that anyone watching the start of work on the site had any vision of the future as full as it has proved to be — both in terms of installations, with Laboratories housing a mighty complex of accelerators and storage rings spanning the frontier of France and Switzerland, and in terms of CERN's stature and influence on the European physics scene.

The Convention of the European Organization for Nuclear Research, which came into force in 1954, foresaw the construction of a synchro-cyclotron capable of energies of up to 600 MeV and of a proton synchrotron for energies above 10 GeV. These accelerators came into action in 1957 and 1959 respectively. They have since been joined by the Intersecting Storage Rings, authorized as a supplementary programme at the end of 1965 and brought into operation in 1971, and by the 300 GeV accelerator under construction in CERN Laboratory II, which was approved under the terms of a revised Convention. This latest machine will provide its first beams in a few years' time.

Backing the armoury of accelerators is a mass of experimental and data analysis equipment (bubble chambers, electronic detection systems, computers, film measuring devices. . .). To carry out the research, to sustain this equipment and to ensure the smooth running of the Laboratories there is a staff of scientists, engineers, technicians and administrators now totalling about 3500 people. The site of the Laboratories has grown from an initial 40 hectares to an area of 560 hectares. Their annual budgets top 600 million Swiss francs.

The number of physicists from over a hundred Universities and research centres throughout Europe who use the installations at CERN to carry out their research is about 1500. Papers on the research results flood into the scientific journals each year in their hundreds.

The above paragraphs give a few facts and figures to illustrate the development of CERN in the past twenty years, but we prefer to celebrate the anniversary by concentrating on the evolution of the physics to which CERN has contributed during this time. Our understanding of the behaviour of elementary particles, though there have been some spectacular advances, has tended to grow in small steps as piece after piece of information has been slotted into the jig-saw puzzle. It is in taking a look back at the picture, which had been composed when the CERN Laboratory did not exist, that we see how dramatically our knowledge has evolved.

CERN has contributed much to this changing picture but it is presented here without distinction as to the origin of each new piece of information. American and Soviet Laboratories have been partners in all the research and it is the accumulated knowledge from the world's high energy research centres that we are describing. The Editor wishes to acknowledge the helpful talks with many physicists, particularly F. Farley, L. Van Hove and L. Wolfenstein, in pulling the story together.

Among the visitors who came to the Meyrin site to see the start of the CERN Laboratory was Albert Picot (third from the right). Albert Picot, who died in October 1966, was then in charge of the educational and cultural department of the Canton and was the prominent advocate of CERN's coming to Geneva.

Our changing view of the nature of matter 1954-1974

We carry out research into the nature of matter because we do not know enough about the particles of which matter is composed to be able to understand why they behave as they do. As more knowledge of their behaviour has accumulated during the past twenty years, so our picture of matter has changed.

We are still in the unsatisfying situation where we distinguish between four different types of behaviour which we say is caused by four different types of force. It may be our present ignorance that prevents us seeing that these forces are different manifestations of the same force and very recent observations are giving clues that might dispel this ignorance. But for the moment just as twenty years ago, we describe what particles are doing under the headings of four types of force:

The strong force acts, for example, between the particles in the nucleus of the atom so that they stay together. It can be felt over only a very short range — about the distance across a nucleus, a millionth of a millionth of a centimetre.

The electromagnetic force acts between all particles carrying an electric charge — pulling oppositely charged ones together, pushing similarly charged ones apart. It is about a hundred times less powerful than the strong force but can be felt over an infinite range (though its strength falls off inversely as the square of the distance between the charged particles).

The weak force acts, for example, when particles break up spontaneously into lighter ones. By comparison with the forces above, it really is weak — a thousand million times less powerful than the strong force. The range over which it can be felt, to the best of our present knowledge, is limited to within the particle itself.

The gravitational force acts to pull together all particles which have mass. We can see it in impressive action when particles assemble in bulk — like the pull between the sun and its planets or the earth and its inhabitants — but on the individual particle scale it is extremely feeble. The strong force acts between two particles over .a million million million million million million times more powerfully than the gravitational force. Like the electromagnetic force it is felt over an infinite distance with its strength falling off inversely as the square of the distance.

Because it is so feeble, the gravitational force is generally ignored in interpreting the behaviour of matter at the level of individual particles. We always have to keep our minds open — perhaps gravitational effects do come into play, in ways we have not yet appreciated, when particles interact. But in the following pages we look at what we have learned about how the first three forces are involved in particle interactions.

The particles themselves can also be slotted into categories. All of those that feel the strong force are called hadrons. They are of two types — baryons (whose spins are always half integer units and whose most famous member is the proton) and mesons (whose spins are always integer units and whose most famous member is the pion). All those particles (with the exception of the photon) which do not feel the strong force are called leptons. They all feel the weak force, and those which are electrically charged also feel the electromagnetic force.

Now let us see how we interpretated particle behaviour under each of the three forces in 1954 and how our interpretation has since evolved.

The electromagnetic force

The surprising thing about the electromagnetic force in the past twenty years is that there have been no surprises. Compared to the upheavals relating to the strong and the weak forces, our understanding of the interaction between two charged particles remains essentially unchanged and has rather been refined and reinforced by the experimental data which has been amassed in the meantime.

The successful ideas are those of quantum electrodynamics (QED).They say that the electromagnetic force is transmitted by the intermediary of particles called photons — packets of electrical energy which are transmitted from one charged particle to another. According to their energy they are the particles of radio waves, of visible light, of X radiation.. . Each charged particle has associated with it a cloud of 'virtual' photons constantly emitted and absorbed by the particle and extending out to infinity. An interaction occurs when one of these photons passes to another charged particle conveying its packet of energy from one to the other.

The virtual photon cloud can exist under the provisions of the 'uncertainty principle'. This tells us that depending on the energy of the photon a definite time is needed to detect it. If the photon energy is high, it can hop out of the charged particle for only a very short time, otherwise it becomes real, or detectable, and the electron can then be observed as having lost that amount of energy. If the photon energy is low, it can hop out of the electron for a longer time.

These virtual photons carry the information which sets up the attraction of oppositely charged particles and the repulsion of similarly charged particles. The way the cloud 'thins out' as the distance from the particle increases gives rise to the inverse square law of the interaction between two charged particles.

The QED ideas are philosophically satisfying in that they dispose of the enigma of 'action at a distance'. In classical theory the concept of electromagnetic fields did not really remove the difficulty of understanding how a charged particle knew of the existence of another and thus interacted with it. The intermediary action of the photons removes this difficulty.

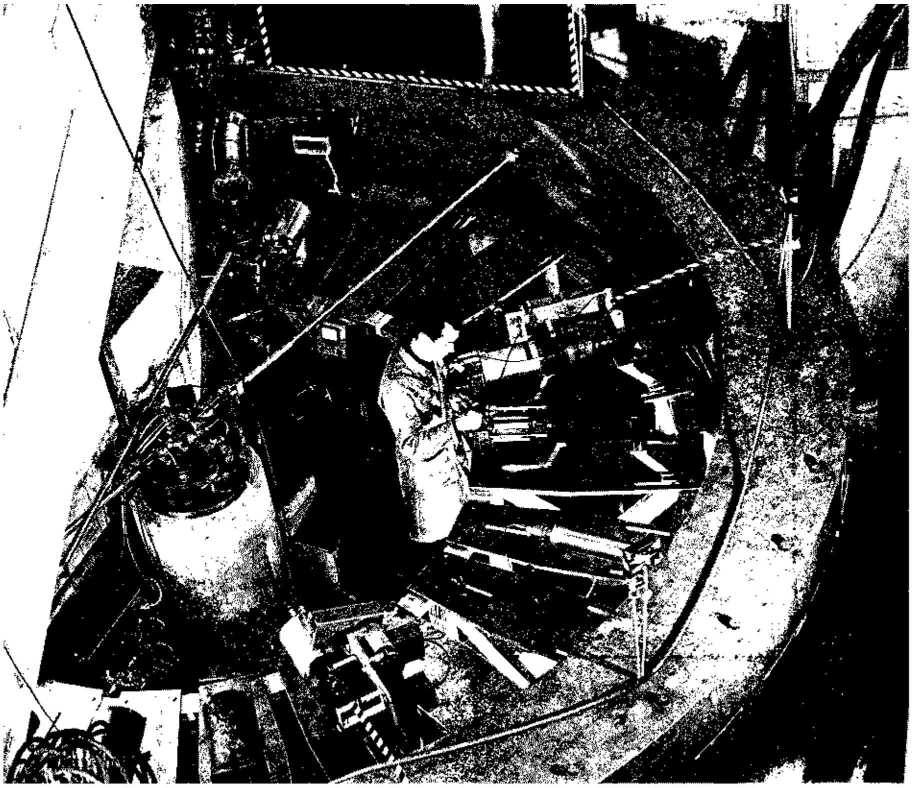
The theory took initial shape in the late 1920's. At that stage however there was a weakness in that when trying to calculate physical quantities, we finished up with infinite values. How this is so can be glimpsed from realizing that the charged particle sets up its photon cloud which changes the properties of the charged particle which changes the properties of the cloud and so on. In the late 1940s, R.P. Feynman, J. Schwinger and S. Tomonaga got around this problem by noticing that behind all the infinities lie apparent infinities of the particle mass and charge. They 'rénormalized' the theory by feeding in the physically observed values for the mass and charge and when the sums are done now, finite values emerge for all the phenomena involving the electromagnetic force and they can be compared with the experimentally observed values. One particular calculation, which gave the rénormalized QED theory all the strength that it had in 1954, was that of the Lamb shift. The existence of the photon cloud does modify the charged particle properties to a small extent and, because of this, a tiny modification occurs in the energy levels of the electrons around the nucleus. Such a modification was first detected by W.E. Lamb and R.C. Retherford in 1947 for the electron in the hydrogen atom and this 'Lamb shift' agreed well with the QED theory.

In 1954, all this was comparatively fresh. A measurement of the Lamb shift in 1953 had brought agreement with QED theory to the level of 1 part in a thousand but the theory was still felt to be an approximation to the truth. The question was more 'how far will the theory extend in its validity?' rather than the 'eureka' which QED theory can claim in 1974. Generally it was expected that QED would break down when the energies involved reached that of the nucléon mass (about 1 GeV). Furthermore, with the sea of virtual photons around, it was feasible on paper that many complex exchanges of photons could take place as well as the straightforward exchange of a single photon. But it was not known whether these 'higher order terms' should be fed into the calculations since there was no experimental evidence for their existence.

When we talk of the electromagnetic interaction, we talk mostly about the electron. In 1954, it was not at all certain that the electron was 'point-like' since this is not tested in a Lamb-shift type of experiment. (The expression 'point-like' is applied to a particle when it has no discernible internal structure — it acts as if from a single point.)

The results of the electron-proton scattering experiment of R. Hofstadter in 1954 revealed that structure was involved somewhere in the interaction (it was not point-like) and the electron was initially as suspect as the proton. It gradually became accepted however that the proton is the particle with the structure though the rigorous proof of this came later. The experiments at the electron-positron storage rings, beginning with the Frascati-Orsayand Princeton-Stanford

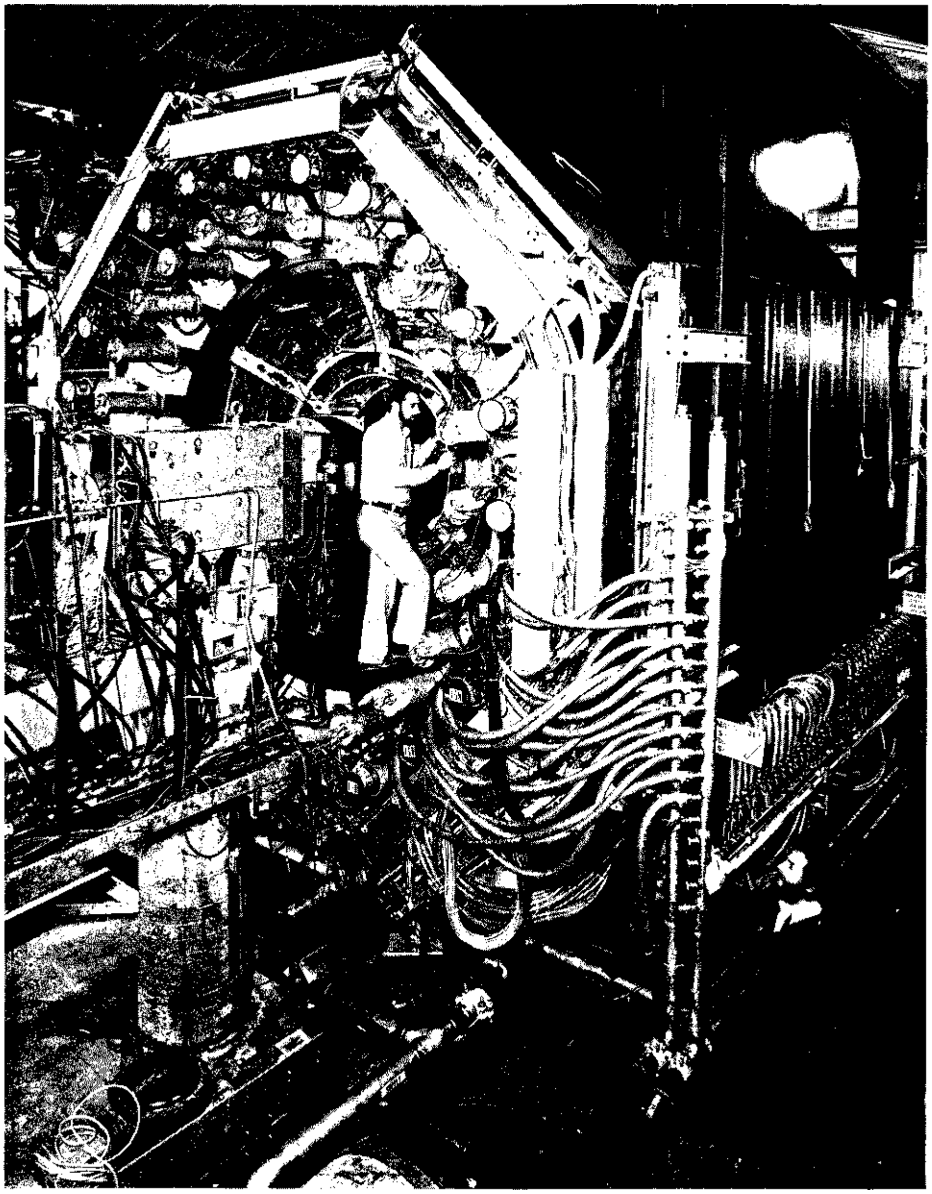
Part of the muon storage ring which was used in the second experiment to measure g-2 of the muon. This measurement is a direct insight into the way in which we believe the electromagnetic force manifests itself and it agrees with the calculations of quantum electrodynamics to high accuracy.
Inside the ring is a fan of counters to detect the electrons produced as the muons decay and it is via these electrons that the orientation of the magnetic moment of the muon in the field of the ring is determined.



CERN 17.1.66

The detection system surrounding a collision region in the electron-positron storage ring, SPEAR, at the Stanford Laboratory. A large solenoid magnet surrounds cylindrical wire chambers and scintillation counters. The system has recently gathered astonishing results (reported in the February issue page 39) on the production of hadrons in the collisions. The results bring a worry to our calculations of the influence of the strong force on electromagnetic interactions and also disrupt our view of the strong interaction.

(Photo S LAC)



machines in the early 1960s confirmed that to the best of our present knowledge, the electron is point-like with no internal structure.

Another uncertainty was the relationship between the muon and the electron — the muon was not well enough studied to reveal just how close a relative to the electron it is. In the following years, when the muon parameters were pinned down with more certainty (for example, the mesic X ray work proving that it has spin 1/2 and the famous Brookhaven experiment showing that there is an electron-type neutrino and a muon-type neutrino), the muon emerged convincingly as a heavy variant of the electron.

The studies of quantum electrodynamics where CERN has been particularly active have concerned the measurement of the g-2 of the muon. The g-2 value arises directly from the ideas of how the electromagnetic force is transmitted and the concept of virtual photons. The spinning charge of the muon (or the electron) gives the particle a magnetic moment as if a tiny bar magnet lay along the spin axis. The value of the magnetic moment is proportional to the angular momentum and the classical value has to be multiplied by the gyro-magnetic ratio or g-factor. For particles with spin 1/2, the Dirac theory predicts a g-factor of 2 whilst the new theory predicts a very small change in the g-factor and thus in the magnetic moment (known as the anomalous part of the magnetic moment). It is the existence of the virtual photon cloud which produces the change and, thus, measuring the g-factor (or more usually g-2) gives a direct look at the accuracy of quantum electrodynamics.

Measurements for the electron were going on in 1954 and had reached accuracies of 1 part in a thousand. The observation of muon polarization in pion decay towards the end of the 1950s and of the asymmetric decay of the muon to give an electron opened the door to g-2 experiments on the muon also. In 1960, a first experiment at CERN measured g-2 to 2%, later improved to 0.4%, accuracy. The QED value was confirmed which was in a way surprising because, at the 0.4 % accuracy, breakdown would have been observed if it had occurred at the 1 GeV level anticipated in 1954. This experiment also underlined the electron-muon relationship — no new force was observed to distinguish the muon from the electron.

A second series of CERN experiments carried the g-2 accuracy even further using a muon storage ring and now experiment and theory agree to (240 ± 270) parts per million. A third experiment of still higher accuracy is being prepared. Meanwhile the g-2 of the electron has been pushed to a precision of a few parts in a million.

At the accuracy now expected for the muon, the experimental value is confirming the validity of the theory of quantum electrodynamics down to distances of 1CH^{5} cm and energies equivalent to over 20 GeV. It is confirming the calculations which the theorists have extended to include higher order terms (many photon exchanges as discussed above) and is beginning to reach levels where the existence of the strong interaction is expected to influence the observed values. It is also confirming the view of the muon as simply a heavy electron. One comment aroused by the precision of the measurements is that 'the g-2 value acts as a great restraint on the fantasy of theorists'.

One cloud did appear on the QED horizon when the Lamb shift measurements moved out of line with theory but this was dispelled about 1970 when S. Brodsky spotted an error in the calculations. Since then, theory and experiment have lined up with a perfection which would have staggered the physicist of 1954.

So, is everything rosy in our understanding of the electromagnetic force? No, because there are two long-standing mysteries and a new worry which has raised its head only in recent months.

The first mystery concerns the existence of the muon. To quote I. Rabi 'Consider the muon. Whoever ordered that?'. It is believed that the mass of a particle is a consequence of the interactions it undergoes. If so, how can two particles be so identical as the electron and the muon which seemingly differ only in their mass? Where is the force felt by the muon and not by the electron? Are there other heavier particles, so far unidentified, resulting from whatever it is that turns the muon on?

The new worry comes from the high energy electron-positron storage ring results reported in the February issue. If the production of hadrons in electron-positron interactions continues constant as the measurements are taken to ever higher energies, then the strong interaction influence on electromagnetic interactions would no longer be calculable. The present closed nature of the QED calculations would be spoiled and new, at present unknown, factors would have to be fed into the sums.

The second mystery is in the very roots of the theory. Why do we have to plug in the observed mass and charge of the electron or muon (the process of renormalizing the theory) in order that the calculations work with such perfection? The theory, left to itself, gives infinite values for both of these quantities. It would obviously be philosophically more satisfying if the observed mass and charge emerged naturally from the theory itself.

Perhaps the electron is a black hole! One can plausibly argue that its Schwarzchild radius of about 10^{-55} cm would give it enough size to get rid of the infinities in quantum electrodynamics and give the correct electron mass. So perhaps gravitation is deeply involved with the electric properties of matter but so far no firm framework has been found for these ideas.

Altogether, from 1954 to 1974 our understanding of the electromagnetic force has remained in surprisingly good health. It has been shown that it can predict, with accuracy, the effect of the electromagnetic force over a vast range of distances from 10^{-15} to 10^{10} cm.

The strong force

Compared with the order which has reigned in the observations of particle behaviour under the influence of the electromagnetic force, the observations of behaviour under the strong force have opened up a completely new world. *

In 1954, the interpretation of the strong force was still dominated by the insights of Yukawa many years previously in 1935. He interpreted the interaction between two hadrons in terms of the exchange of mesons (later called pi mesons or pions). This can be seen as the proton having a virtual pion cloud associated with it, just as the electron has a virtual photon cloud associated with it. There is a considerable difference between the two pictures however.

It is clear, first of all, that the meson cloud produces a much more powerful effect than the photon cloud — the strong force between protons in the nucleus holds them together despite the electromagnetic force due to their positive charges trying to push them apart. Secondly, the range of the force is very short (about 10^{-13} cm) — the protons stick together only if brought within nuclear distances of one another. This second clue led Yukawa to the pion. Using the uncertainty principle, as discussed in the article above, and knowing the time to travel 10^{-13} cm at the speed of light (10^{-23} s), he could calculate the minimum energy which a particle could have to traverse this distance while remaining as a virtual particle. It came out at around 100 MeV. The pion, when first identified in 1947, proved to have a mass of 140 MeV.

The predominant picture in 1954 was therefore of protons and neutrons bound in the nucleus through the intermediary action of pions (positive, negative and neutral charged forms accounting for the equal strengths of the interactions proton-proton, neutron- neutron and proton-neutron).

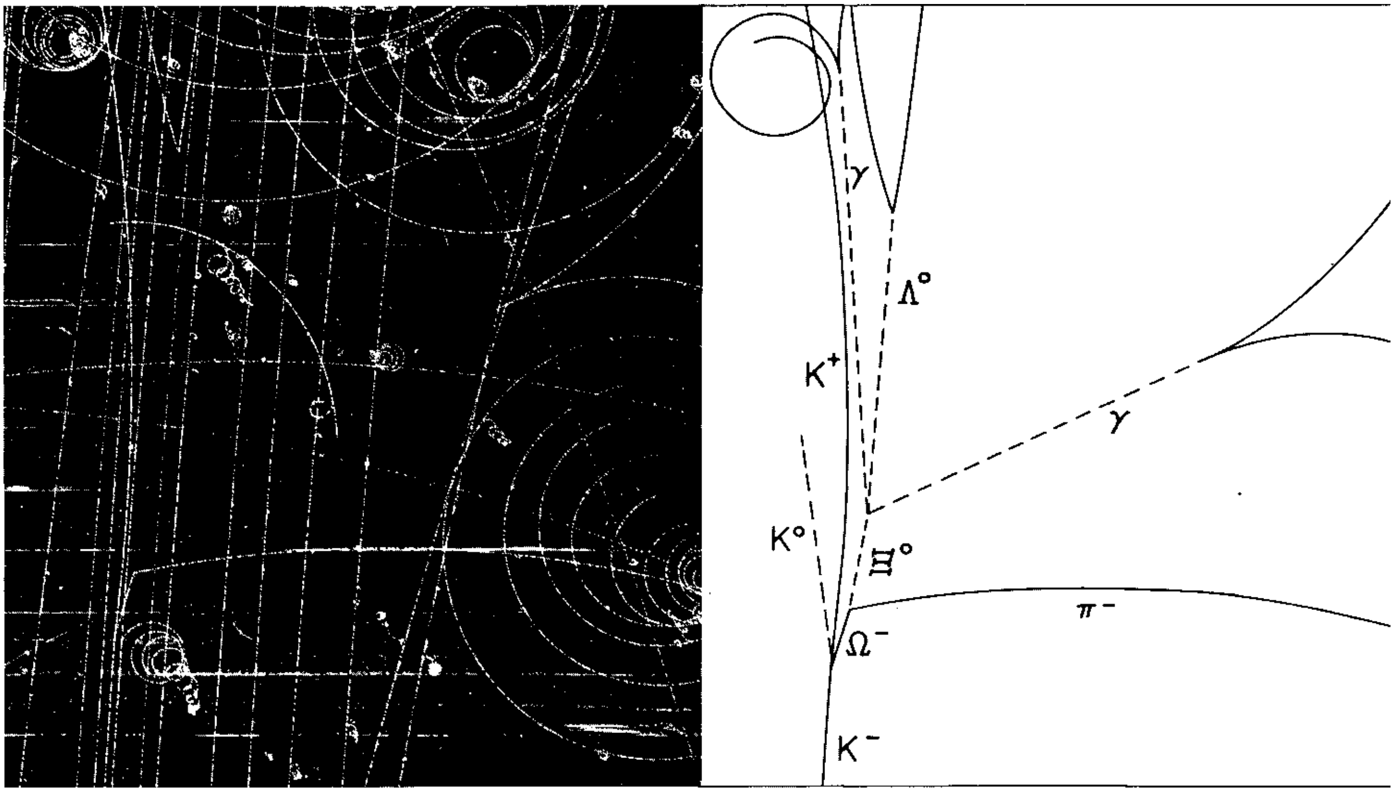
Trouble was already brewing at that time. A heavier meson, the kaon, had been spotted in nuclear emulsion photographs of cosmic rays and heavier baryons (heavier variants of the proton and neutron such as the lambda and sigma) had been seen. But they were initially thought of as rather exotic entities and did not rock the Yukawa boat immediately. They needed something new, however, to explain their behaviour. The kaons were the intermediary of the strong force between the proton and the new baryons (but not between the protons themselves) and a property called 'strangeness' was conjured up for the new particles by M. Gell-Mann and K. Nishijima to explain why this limitation applied.

Doubts really began to multiply when the Hofstadter experiment, mentioned above, indicated that the proton charge radius was smaller than the Compton wavelength of the pion. Y. Nambu analysed this problem theoretically and suggested in 1957 that another virtual meson, a heavier mediator of the strong force, be called into play. Pions could themselves be produced in the decay of the heavier meson, which was called the rho meson. This new particle was detected in 1961.

The floodgates really opened when the large bubble chambers of L. Alvarez came into operation at the Berkeley 6 GeV Bevatron. Through to the early 1960's, a whole host of new mesons and baryons were identified and many of their properties measured. The list has grown to include over 200 distinct particles. High energy physicists became like botanists recording the features of plant after plant as they walked through pastures new.

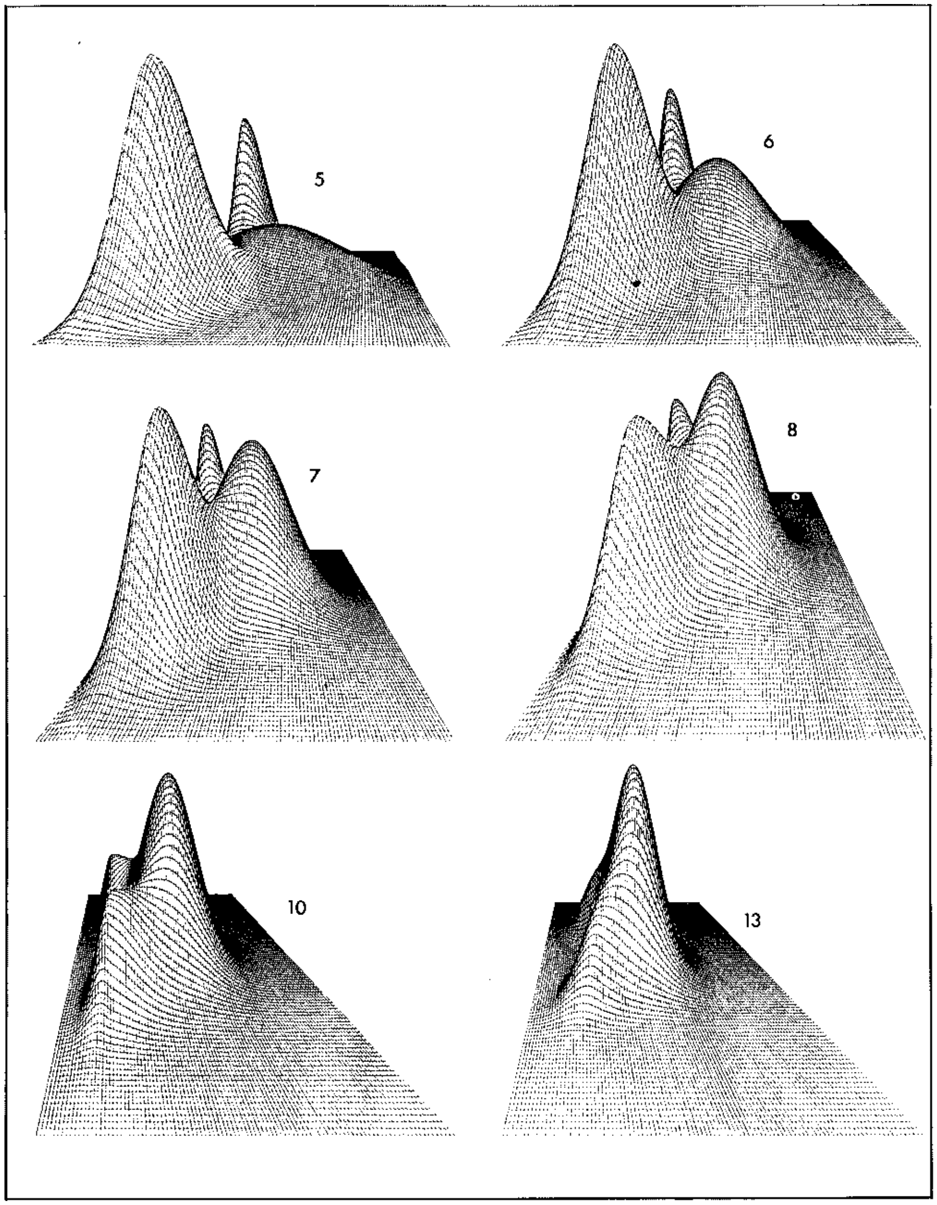
This was the first big change and a change from which we have still not recovered. The simple picture of Yukawa was obviously inadequate to absorb the behaviour of this multitude of particles, yet, even now, no convincing picture has been put in its place. There has, however, been a lot of tidying up — a lot of elegant work which has demonstrated remarkable relationships within the large family of particles and it must surely be true that some deep reasons exist for the similarities in behaviour that we observe.

The most important advance in classifying the particles came in 1961 from Y. Ne'eman and M. Gell-Mann. They used a mathematical technique from 19th Century group theory, called SU(3) — simple unitary group of transformations in three complex dimensions — which is a technique for studying sets of three basic objects. Applying this to particle pro-



Perhaps the most famous bubble chamber picture in history — the detection of the omega minus particle predicted by the classification scheme of unitary symmetry. It was taken in the 80 inch chamber at Brookhaven and crowned the efforts to put some order into the plethora of particles, which were found at the high energy accelerators in the late 50s/early 60s, being produced under the influence of the strong force.

To illustrate the new flood of information coming with the opening up of higher energy ranges at Batavia and the CERN ISR, is this presentation of strong interactions resulting in the emergence of many particles from an experiment at the ISR. Each diagram corresponds to a number of emerging particles (5 to 13). When only five particles emerge, most of the events involve the 'fragmentation' of one or other proton (the two high peaks) and only a few involve the 'centralregion'. But the higher the number of particles, the more the central region events dominate until, with thirteen emerging particles, they are almost entirely from central region events.



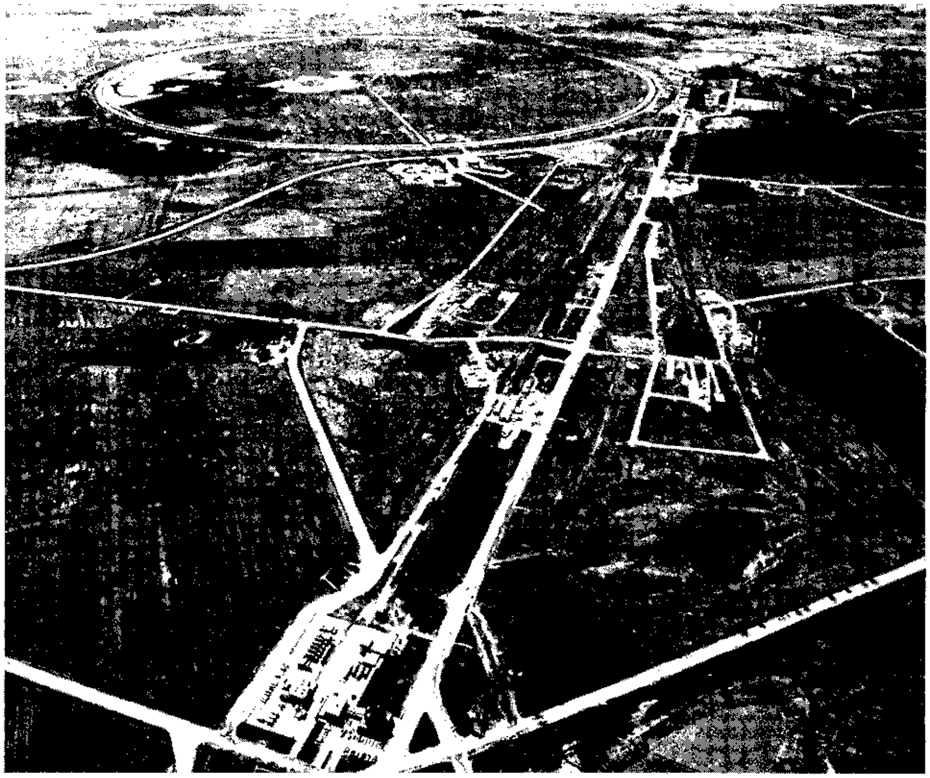
perties, they classified the particles in groups, usually called multiplets. What Ne'eman and Gell-Mann were doing mathematically was to treat the known particles as if in reality they were built up of three more basic 'building blocks'.

The scheme predicted how the particles should group together. For example, it said that all mesons of the same spin should exist in groups of eight. An eighth companion for the three zero spin pions plus the four zero spin kaons was found in 1961; eight spin one mesons like the rho were also found that year; eight spin two mesons were found by 1964. The most spectacular prediction was of the existence of the particle now known as the omega minus. Playing with their three mathematical blocks, they grouped the baryons of spin 3/2 in a group of ten and by 1961 nine of these had been identified. During the CERN conference of 1962, Gell-Mann wrote on the blackboard the mass (1680 MeV), charge (minus one) and strangeness (minus three) of the then missing tenth member. At the beginning of 1964, the omega minus, with precisely these properties was seen for the first time at Brookhaven.

This really rubbed home the validity of the classification scheme and (following work by G. Zweig and Gell-Mann) opened the hunt for physical objects, usually referred to as quarks, inside the hadrons which would correspond to the mathematical objects of SU(3). There is still no sign of an individual quark but SU(3) has worked magnificently in classifying the known hadrons and its implication of something deeper within the hadrons looks ever more valid as more and more experimental data is accumulated.

Had this sketch of the role of the strong interaction in the behaviour of particles been written a few years ago, we could stop here with a tantalising theoretical indication of another layer of the onion of matter, but very little experimental indication except for the success of the classification scheme. Many frustrating years followed the advent of SU(3). Experimental data poured in. Theoretical schemes showed up further remarkable relationships — the Regge trajectories and their exchange mechanism, the duality concept, the multiperipheral model — but no deeper insight really emerged.

They were all useful concepts for categorizing what was being seen. They had considerable predictive power — they could predict new particles of higher spin; they gave the energy dependence of interaction cross-sections; they could bring out the rate of increase of particle production as the energy goes higher. But none of them really passed from



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The two sources of completely new information on the strong force:

1) *The 400 GeV accelerator at the Fermi National Accelerator Laboratory, Batavia, is seen in the background in this aerial view. The ejected protons travel to the experimental areas towards the bottom of the picture.*
2) *The CERN Intersecting Storage Rings of which one intersection is pictured here showing the two crossing beam pipes surrounded by detectors.*

the stage of being a useful concept for describing what we saw into the stage of giving a true understanding of what we saw. Also, when pushed to describe detailed features of particle interactions due to the strong force, the concepts fell over.

In the 1970s two new features have been fed into the strong force picture. The first is the result of access to higher energies at the CERN Intersecting Storage Rings and at the 400 GeV synchrotron of the Fermi National Accelerator Laboratory in the USA. Prior to their operation, particle behaviour had been studied almost entirely in terms of 'two-body' interactions — when a hadron meets a hadron giving two other particles emerging. To tackle the situation when more than two particles emerged looked a daunting task — after all we could not even make real sense of the seemingly moresimple'two-body'case.

The higher energy collisions make it more difficult to leave aside the 'multi-body' events because particles pour out in profusion from the higher energy strong interactions. The big surprise has been that analysing these multibody events at very high energy is very much simpler than could be anticipated from what was seen before. Particles may pour out in profusion but the underlying phenomena can be distinguished with greater ease.

Let us look at the information coming from the proton-proton collisions in the ISR. Leaving aside the purely elastic events, where the protons effectively bounce off one another, we can see two types of interaction. In one type, one proton remains itself but the other one is severely disturbed and sheds pions. This type has collected the name 'diffraction dissociation' collisions. The other type (often called 'pionization' collisions) sees both protons disturbed and the production of pions in large numbers. Even with the large number of partides there seems to be something fairly simple going on because strong correlations are seen (for example, if a positive pion of a certain energy flies off, we are likely to find a negative pion around with very similar energy).

This surprising simplicity has swung our thinking about the strong force onto new paths. The pouring out of pions in pionization collisions while protons emerge perhaps excited but essentially intact, is likely to be a profound clue to the nature of the strong force.

Before saying more about this, let us return to the second piece of information of the 1970s. The success of the SU(3) scheme seems to be telling us that a baryon, e.g. a proton, contains three 'building blocks' or 'quarks', each carrying a fraction of the proton electron charge ($^2/_3$, ^{2}A and -$^1/_3$).

The 22 GeV linear accelerator at SLAC (Stanford) has looked at the proton with electron beams to see where the electromagnetic force is effective, i.e.. how the electric charge is distributed inside the protons. The result agrees with a picture where it is concentrated on three 'grains' of diameter at least ten times smaller than the proton, the grain charges being again $^2/_3$,^{2}A, - Vs. It is therefore natural to identify these point-like grains with quarks. The Stanford experiments show in addition that in a high energy proton, about half the energy is carried by the grains, the other half being carried by hadronic matter which is essentially uncharged and is often speculated to be a kind of 'glue' holding the grains together. The neutrino experiments, especially the CERN experiment with the bubble chamber Gargamelle, have looked at the hadron to see where the weak force is effective (the neutrino, being a lepton and carrying no charge, only feels the tiny weak force). Again the three grain picture emerges.

Returning now to our high energy strong interactions at the ISR, in particular the pionization collisions: We see that our protons emerge essentially intact (in other words, still as a bound three-grained object), albeit with about half their original energy, while a clutch of pions are left in their wake. It is as if the grains go through with about their share of the proton energy, while the glue produces the many pions emerging from the collision, each with rather low energy.

When a hadron gets involved with the weak or electromagnetic force, the glue seems quiescent but when it gets involved with the strong force the glue becomes highly activated and results in an outpouring of pions. The glues of two hadrons stick together as the grains rush on. The^correlations which are seen in the outpouring, tie up with this sort of picture.

So perhaps we are evolving a new picture of the hadrons and thus of the strong force. But the experimental information is new and will no doubt be augmented considerably in the next few years, so any interpretation at this stage is a first shot at a deeper understanding. There are obvious problems such as our inability to extract the grains themselves. And also there is this very recent information on hadron production in electron-positron annihilation collisions, mentioned when discussing the electromagnetic force above. This fits no picture that we can draw at the moment.

Compared with twenty years ago, the behaviour of particles under the influence of the strong force has proved rich beyond belief. We have seen the force in action in a myriad different ways. Our view of the hadron is completely transformed. But we still cannot claim that we really understand what we are seeing.

The weak force

Experiments with high energy accelerators have revolutionized our knowledge of particle behaviour under the influence of the weak force every bit as much as they have of the strong force. With the weak force it is perhaps less surprising since the probability of weak interactions taking place rises in proportion to the energy and it is only at high energies that we begin to see the force at work in a variety of ways.

Prior to 1954, practically all the information on the weak force came from observations of beta decay — the emission of an electron from a nucleus due to the breakup of a neutron to give a proton, an electron and a neutrino. The mysterious neutrino had been seen for the first time a year previously in a reactor experiment by F. Reines and C.L. Cowan. This cost W. Pauli a case of champagne. When he postulated the existence of the neutrino in 1931 in order to make sense of the energy and spin balance in beta decay, he thought that the likelihood of a particle which only feels the weak interaction ever being observed made a champagne wager a safe financial proposition. Cowan and Reines, however, used the flood of neutrinos from beta decays in a nuclear reactor to spot their interaction with a proton to produce a neutron and an electron.

The theory of how the weak force worked dated back to E. Fermi in 1934. He modelled it on the theory of the electromagnetic interaction — hence come the terms 'charged current' and 'vector force' in analogy to the electric current and electric and magnetic vectors. Since the force seems to be effective only over an extremely short range, he treated the interaction as 'point-like' with no need for an intermediary particle such as we call for in explaining the electromagnetic and strong forces.

The idea of an interaction which is really point-like did not make everyone happy but with comparatively little disturbance to the main aspects of Fermi's theory, the concept of an intermediary particle can be brought in. Following what we have said above about the uncertainty principle, the intermediary of the weak force since its acts only over short distances can bë a particle of high mass. It has been given the name 'intermediate boson' or 'W-particle'. Despite many searches, up to possible W masses of many GeV, it has never been seen. This may simply mean that the interaction is effective only over extremely short distances and that the boson is a very massive particle indeed.

Another feature of the observations on the weak force through to 1954 (in fact through to 1973), and on the theory that emerged from these observations, is that the charged currents involved always changed sign when the interaction took place. For example, in the reactor experiment when the neutrino meets the proton and gives a neutron and an electron, the hadron changes its charge (the positive proton becomes the neutral neutron) and the lepton changes its charge (the neutral neutrino becomes the negative electron). Fermi therefore said that charge changing currents were always in action in the weak force and the intermediate boson picture said that the exchanged W particle was always either positive or negative.

The first big change in our view of the weak force came in 1956. It was triggered by observations on high energy accelerators but was in fact something which could have been seen years before in beta decay. T.D. Lee and C.N. Yang in attempting to explain some puzzling observations on the decay of the kaon into two and three mesons made the revolutionary suggestion that parity might be violated by the weak force — that when a weak interaction takes place, Nature might be particular about the direction in which things happen. Immediately after, C.S. Wu looked at the electrons emerging from the beta decay of cobalt 60. They were spinning clockwise and, to preserve the angular momentum balance, the emerging neutrinos which could not be detected must always be spinning anticlockwise. By now we know that there are only left-hand spinning neutrinos in Nature; right-hand spinning neutrinos do not exist.

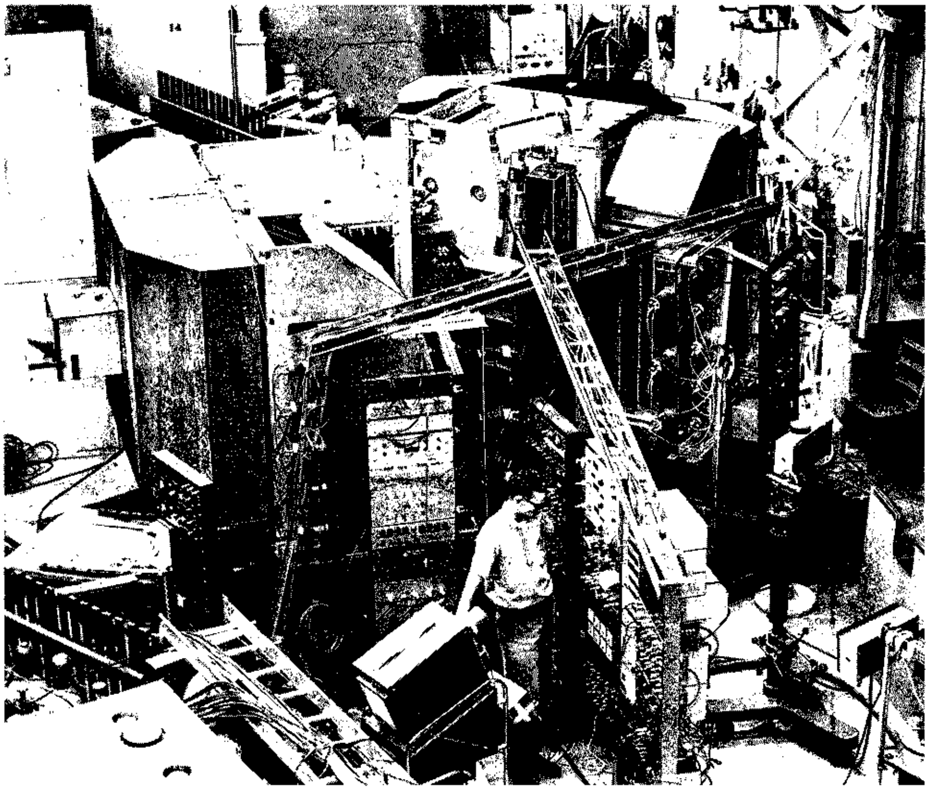
This was a profound philosophical change in our view of Nature. We had believed that 'right' and 'left' were human conventions to help us find our way around traffic islands and that Nature did not distinguish between right and left — that Nature was symmetric and did not insist on things happening in a particular direction. The violation of parity in the weak interaction has overthrown this belief and in its place has left the suspicion that Nature *always* cares about the direction that things happen but that in the strong and electromagnetic interactions this is hidden by more powerful effects. Now we could contact intelligent beings in a remote corner of the Universe and communicate to them in which direction we turn around traffic islands.

The Fermi theory required a major revision to absorb parity violation. It was converted from a vector theory to add an 'axial-vector' part (bringing in the need for distinguishing direction). The revised theory worked very well when applied to the data on beta decay though not all the data from experiments fitted well. One hole was plugged by the first important result to come from CERN. The theory predicted that a small percentage of pions could decay directly into an electron and neutrino instead of the usual decay into muon and neutrino. This was seen in 1958 at the 600 MeV synchro-cyclotron.

We could say that to understand the electromagnetic force is to understand the electron and that to understand the strong force is to understand the proton. Then to understand the weak force is to understand the neutrino. It is a lepton not feeling the strong force and carries no charge not feeling the electromagnetic force. But the very fact that it only feels the weak force makes it extremely difficult to detect. We believe that neutrinos are produced in the energy cycles of the stars and that they pour in abundance through the Universe but with only the weak force to disturb them they can pass happily through the earth with very very little chance of interaction.

A new window opened on the weak interaction when it was realized in the early 1960's that it was just about feasible to do experiments on neutrinos with the detectors and neutrino fluxes available at the new Brookhaven and CERN accelerators. Their probability of interaction increases a million-fold as their energy goes from a few MeV to a few GeV. About 1962-63, experiments started at both Laboratories with event rates of around one per day. With present detectors and fluxes, this has increased to about one per minute.

The first important discovery, in 1962, was that there are two distinct types of neutrino. One type is always involved in interactions in association with an electron, the other always in association with a muon. Thus the type which is produced at accelerators in the decay of pions and kaons into muons and neutrinos does not take part in further interactions to give electrons but always to give muons. The discovery, as mentioned above in discussing the electromagnetic inter-



The detection system at Brookhaven which first saw the decay of the long-lived neutral kaon into two pions and thus the violation of charge-parity in the weak interaction. The origin of this violation is still not really identified and the disruption to the theory of the weak force is nicely side-stepped by postulating a 'super-weak' force which, to the best of our present knowledge, only produces a discernible effect with the sensitive neutral kaon system.

(Photo Brookhaven)

action, emphasized again the relationship between-the muon and the electron but otherwise has neither disturbed nor illuminated our interpretation of the weak force.

The first neutrino experiments confirmed such things as the rising probability of the weak interaction taking place as the energy increased. They did not however see any sign of the intermediate boson. Up to possible W masses of over 5 GeV such particles have still not been observed.

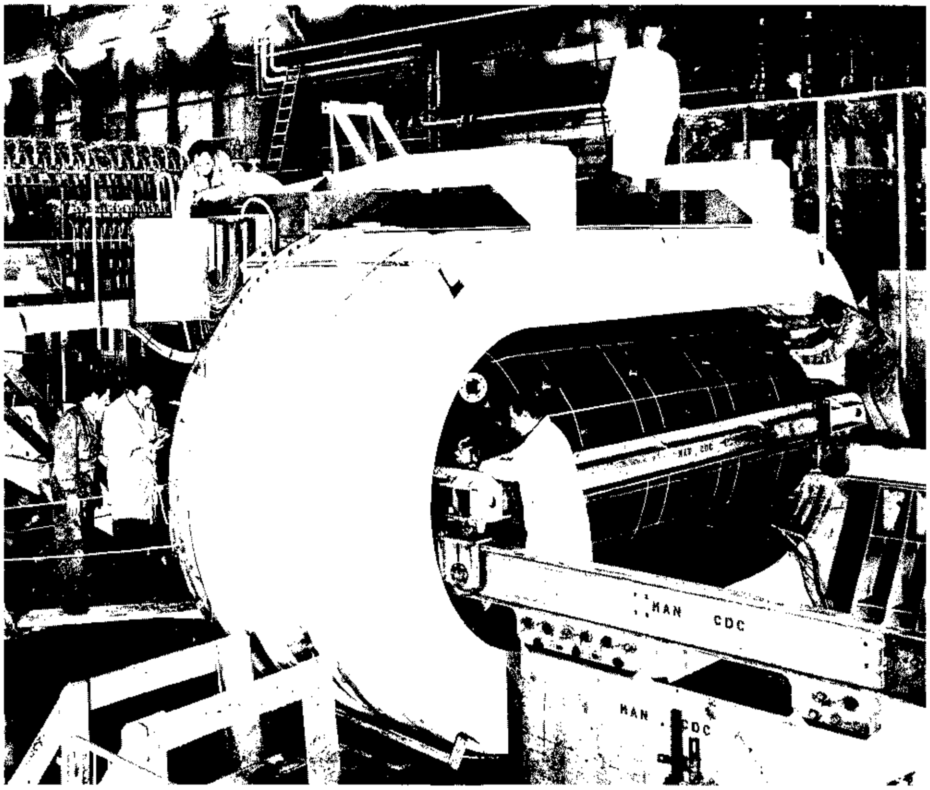
The two neutrino discovery may not have affected any theoretical interpretation but when Brookhaven struck again with the experiment of V.L. Fitch and A.J. Cronin in 1964, it looked likely to overturn the revised Fermi theory completely. The experiment showed that, in the decay of the long-lived kaon, the product of charge conjugation and parity (CP) is violated. Symmetry had been reimposed on the weak interactions in saying that though Nature may limit itself for example to a particular particle always spinning right handedly then its antiparticle spinning left handedly is equally feasible. If a neutron decays giving a right spinning electron, an antineutron can decay giving a left spinning positron.

It was found that the neutral kaon decayed at a very low rate (about one decay in 500) into two pions and CP symmetry says that this decay can not occur. The breakdown of the symmetry can be appreciated more easily from the results of later experiments looking at the decay of the long-lived neutral kaon into pion, electron and neutrino. If CP symmetry were preserved, the production of a positive pion, an electron and an antineutrino should balance the production of a negative pion, a positron and a neutrino. It does not quite balance — CP symmetry is broken on a small scale. In addition it can be shown that time symmetry is also violated in the kaon decay. This is a real philosophical shaker for it uproots the idea that if it were possible to run backwards in time, we could precisely reverse Nature's behaviour.

A great deal of information on the long-lived neutral kaon has been amassed at the high energy accelerators but no clue emerged to enable the observation of the violation of charge-parity symmetry to be slotted into the theory of the weak interaction. The only way in which this problem can be removed is to postulate a 'super-weak' force (an idea which came first from L. Wolfenstein) whose effect can only be noticed in the highly sensitive neutral kaon system. The experimental evidence is in line with such an idea but this is only sweeping the difficulty under the carpet because there is no understanding of why such a super-weak force should exist and not much possibility of studying it further experimentally.

It was 1973 before the next piece of information came along which is not in line with the revised Fermi picture of the weak force. In a neutrino experiment with the large heavy liquid bubble chamber, Gargamelle, at CERN, weak interactions were detected which did not involve the charge changing currents of the Fermi theory that we mentioned above. Neutral current interactions have been seen in considerable numbers. (If we retain the intermediate boson picture, this means that interactions can take place via the intermediary of a neutral W particle.)

This observation is not so disruptive because some new work on the theory of the weak force said that neutral current interactions should be possible. The work attempted to remove the big defect of the weak interaction theory, namely that it could only calculate the simplest effects of the weak force and all 'higher order'



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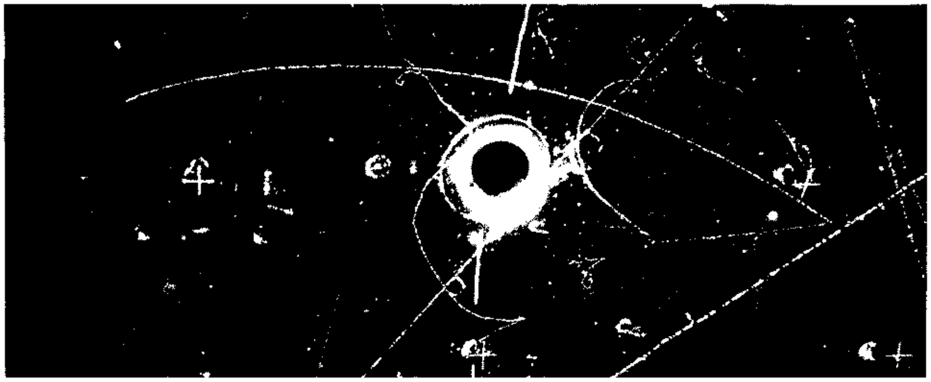


Above : the Gargamelle chamber photographed when it was being assembled. Its large volume enabled the products of neutrino interactions to be identified with confidence which was crucial in isolating those which are believed to involve neutral currents.

The track photograph shows an interaction of the neutral current type involving the weak force. It was taken in the CERN heavy liquid bubble chamber, Gargamelle. A neutrino (entering on the right) interacts with a neutron but no muon is seen emerging. This, in contrast to all previously observed weak interactions, implies that no charge current has been at work.

effects, such as are so well mastered In electromagnetic theory, are impossible to calculate. By building on the revised Fermi theory in a more detailed way and extending the analogy with the electromagnetic theory, 'rénormalized' forms of the weak theory can be produced. They preserve the successful features of the old theory and extend it so as to be able to tackle higher order effects. They link the weak and electromagnetic interactions and they predict the existence of neutral currents.

In 1974, therefore, the picture of the behaviour of matter under the influence of the weak force is painted on a much bigger canvas than that of 1954. It absorbs the existence of parity violation and of neutral currents and makes it possible to calculate higher order effects. It remains to be seen which of the many new forms of the theory will be the most successful in interpreting the experimental results. We have still, almost certainly, much to learn about the neutrino and we have still the doubt that we have not heard the last of the violation of charge-parity symmetry.

CERN News

Start-up of the Booster

After the long shut-down of the machines at the beginning of the year, the Booster has been brought back into action. Advantage was taken of the shut-down to carry out a number of modifications, the most important of which was the realignment of all the magnets and the main lenses. This had been made necessary by distortions of 5 to 6 mm in the closed orbit caused by earth movements during 1973.

Another operation was to modify the observation system to facilitate beam measurements on the first turn in the Booster. Originally this observation depended on chopping the Linac beam at 3 MHz, but the method had to be dropped in favour of a half-turn injection into the Booster, which modulates the intensity as required for position measurement by electrostatic 'pick-up'. In addition, the injection septum magnet, hitherto a prototype only, was replaced by the final version.

Tests have shown that the Booster performs splendidly at intensities around 5×10^{12} protons per pulse. Transverse and longitudinal instabilities are now well under control at this level.

Beam quality is still limited by the imperfections of the Linac beam. The 50 mA pulses provided by the Linac are not regular, and variations appear along the pulse which cause differences in the Booster from ring to ring and from cycle to cycle.

Since the shut-down there have been ten machine experiment runs during which subjects such as emittance development during the cycle, measurement of closed orbit distortion, stop bands, and coherent transverse and longitudinal instabilities were studied. Although these last can be corrected at the intensities at which the Booster is now working, they remain a preoccupation for the higher intensity levels the machine has to reach in future, and methods for their elimination must be found now.

In addition, the 800 MeV measurement line of the ejected beam is being taken into operation. This will be a valuable tool for measuring the quality of the beam ejected by the Booster.

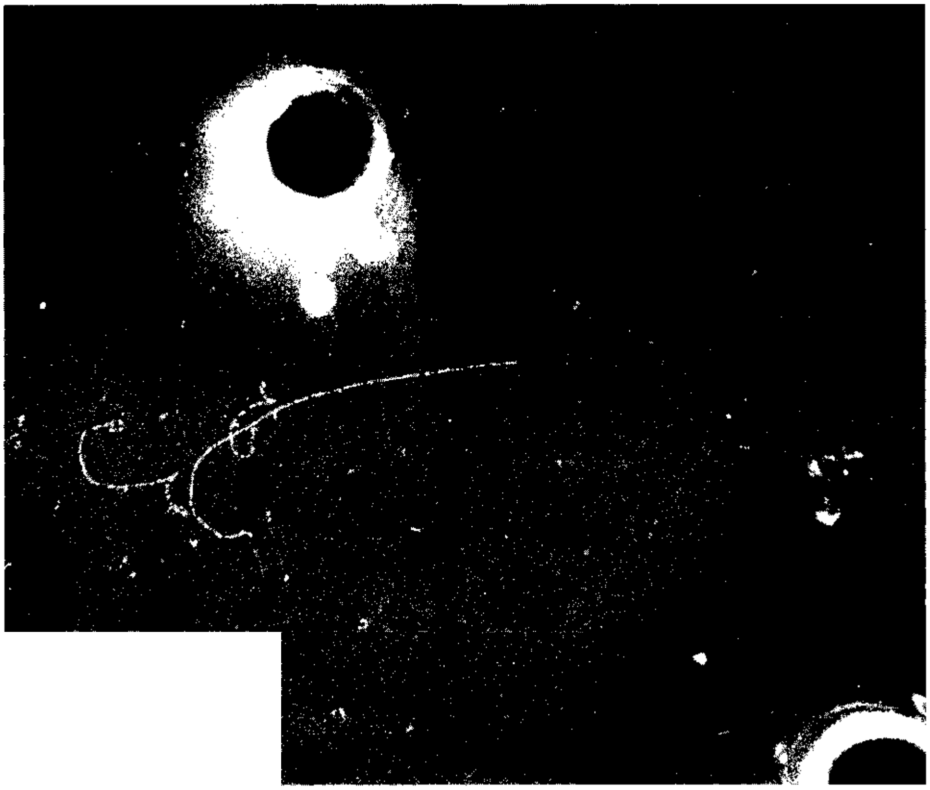
During these runs a start was also made on how best to produce intensity modulation from one pulse to another. When Booster and PS function attheirdesign intensity (10^{13} ppp), there will be a requirement, the users say, for successive pulses of varying intensity.

An experiment was scheduled with the Booster for 10 April during which the ISR rings would be filled. Unfortunately, on 30 March an accident to the vacuum chamber in the I-2 area of the ISR intervened. While a 100-ton spectrometer was being rotated, a small piece of scaffolding, left by oversight near the machine, was thrust against the fragile vacuum chamber. This was ruptured, and air penetrated into six sectors of the ISR before the sector valves could be closed.

Two weeks were lost to physics experiments by the accident, the sectors having to be baked out to re-establish the ultra high vacuum. It is hoped however to reorganize the ISR time-table so as to make up during the summer for the time lost.

The tests for filling the ISR with the Booster have been deferred. They are of great importance, for the beam has to be adapted to the very particular requirements of the ISR.

After the first two experimental periods in late 1973, an operational team was formed, which is presently undergoing a training programme to familiarize itself with the highly automated control of the machine. The teams value was demonstrated during the Booster's first operational run which began on 22 April, with the main object of supplying neutrinos to the Gargamelle bubble chamber. The average intensity was 5 x 10^{12} ppp at a breakdown rate of less than 2 %.



A second candidate tor the leptonic neutral current obtained with the Booster in action, seen in the Gar gamelle heavy liquid bubble chamber. The ant/neutrino beam is entering at right. An isolated trace can be seen on the photograph, perfectly identified as an electron and practically following the direction of the beam. The simplest interpretation of this event is an antineutrino-electron scattering: vu + e~~ —> vn+ e~. This is the second event of this type recorded in Gargamelle. A very weak background is expected for this type of reaction.

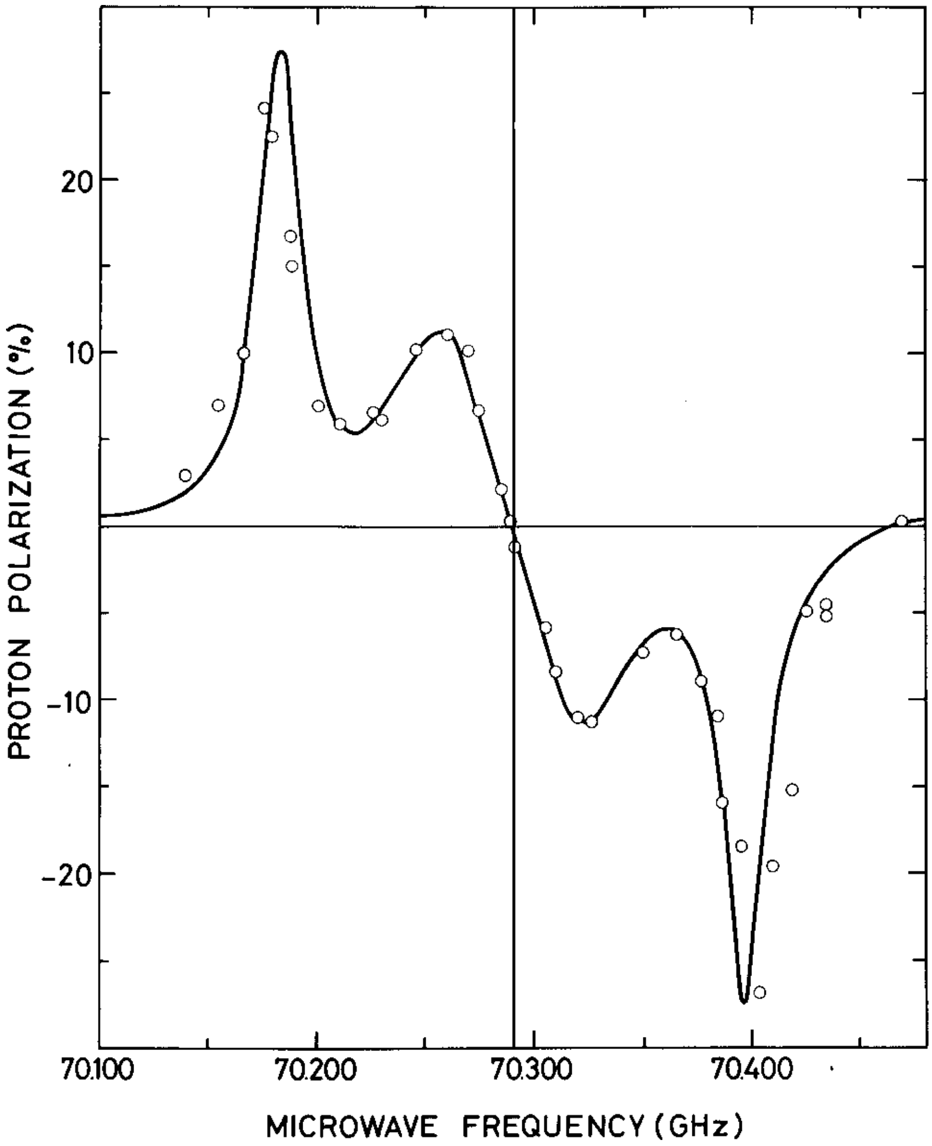
The use of the Booster for the neutrino experiment is of prime importance, given the rarity of the events sought for. The intensity of 5 x 10^{12} ppp is distributed between the Omega spectrometer, the 2 m bubble chamber and the Gargamelle bubble chamber, the last named receiving an intensity of 3 x 10^{12} ppp as against 10^{12} without the Booster. That is, Gargamelle is getting three times as many neutrinos as before.

The result is especially important for current research on neutral current reactions of the type *vy.* + e^- -> v^. + *e~*, as only about 3 to 8 events of this type are expected during the whole experimental period lasting a year.

One such event had been detected before the start-up of the Booster (see vol. 13, page 212), and the photograph shows another which was revealed during the first experimental runs with the Booster.

In a forthcoming experiment, in which Gargamelle will be filled with propane, an attempt will be made to separate the free proton and neutron cross-sections, which is impossible with the freon currently in use. The Booster will be essential for this experimental period, since the free proton reaction rates are lower than those for bound nucléons.

The increase in efficiency provided by the Booster in these experiments, carried out by the Aachen-Brussels-CERN-Ecole Polytechnique de Paris-Milan-Orsay-University College London collaboration, is proving of great value, and will without doubt contribute to a better understanding of the weak interaction and its role in the behaviour of matter.



Measurement of the polarization of the protons in relation to the microwave frequency. The two high peaks on the outside may be attributed to the solid effect, while the two inside ones are due to dynamic polarization by the cooling of the electron spin-spin interaction reservoir. The theoretical curve was calculated taking both mechanisms into account. The points correspond to the experimental values.

Polarized targets

An account was given on pages 183-184 in the June, 1973, issue of the interesting results obtained with polarized proton and deuteron targets by the use of a different method of dynamic polarization based on cooling what is referred to as 'the electron spin-spin interaction reservoir'.

Since then, the mechanism of this polarization has been more thoroughly investigated, and we now know a lot more about the process.

If nuclei having a magnetic moment are placed in a uniform magnetic field, they become distributed over energy levels corresponding to the various orientations of their angular moments or spins.

In the simple case of the electron or proton, which behaves in a similar way to a small magnetized rod, there are two possible energy levels depending on the upward or downward direction of the spin.

The spins tend to assume the direction corresponding to the lowest energy state but, because of thermal agitation which, at high temperatures, is enough to cause them to break ranks, the various energy levels will all more or less be occupied to the same extent.

If, now, a sample is cooled and the thermal agitation is reduced, one can expect that the degree of polarization reached will be the higher, the more intense is the magnetic field and the lower the temperature.

With magnetic fields of 2.5 T and temperatures lower than 1 K, the free electrons of a sample are nearly all polarized. The same cannot be said of the protons, the magnetic moment of which is about three orders of magnitude lower than that of the electron; it applies still less to the deuteron, the magnetic moment of which is six times lower than that of the proton.

The solid effect method of dynamic polarization used since 1958 consists in reversing the direction of the powerful magnet formed by the electron, hoping that this magnet, which is a thousand times stronger than that of the proton, may take with it the little magnet represented by one of the protons in its vicinity.

In order to induce these 'flip-flop' transitions, the material containing the protons to be polarized is subjected to microwave irradiation, the frequency of which is selected according to the energy state to which the protons are to be taken; i.e. to have either a positive or a negative polarization.

After a flip-flop transition, the proton remains oriented in the same direction for several seconds, whereas the electron, which has been taken to its highest energy state, returns to its state of equilibrium within a period of the order of a millisecond, and is once more ready to induce fresh transitions. The free protons of a sample can, by this mechanism, be taken to high degree of polarization.

This simple explanation, taking into account only the coupling between an electron and a proton, has been found inadequate to account for the behaviour of all the very many electrons and free protons in a sample.

It has therefore been necessary to provide a quantum statistical interpretation of the polarization mechanism. This interpretation, which was studied especially by groups of the Moscow Radio-electronics Institute, the University of Leyden, Netherlands, and the CERN polarized target group, has been confirmed by a large number of experimental results.

Not all the magnets constituted by the electrons of a sample can be regarded as mutually independent, and all are capable of interacting among themselves. They have therefore come to be regarded as forming a group dubbed the electron spin-spin interaction reservoir, with a single parameter typifying it: the spin temperature.

The various other kinds of magnets present in the sample then form as many other energy reservoirs as there are different kinds (proton, deuteron, etc., reservoirs).

As the electron reservoir is made up of very powerful magnets in comparison with the other groups, a strong thermal coupling may be expected between the electron reservoir and each of the others. The tendency will therefore be for this thermal coupling to bring the various nuclei to the same spin temperature as the electron reservoir.

This thermal coupling provides a new dynamic polarization mechanism. If the electron spin-spin interaction reservoir can be cooled, i.e. if its spin temperature can be lowered, the spin temperature of the other reservoirs will be lowered at the same time. The direct effect of this will be to raise the polarization .of the free nuclei in the sample.

The cooling is produced by irradiating the sample with microwaves at a frequency close to the magnetic resonant frequency of the electron.

It has been possible very accurately to check this latter method experimentally, especially with partially deuterized 1.2 ethanediol (see vol. 13, page 184), in which the protons and deuterons assume the same spin temperature as the electrons, giving high polarization.

However, the two polarization mechanisms described above are closely related and difficult to distinguish. Nevertheless, the results obtained with a sample of partially deuterized m-xylene (2.2-D6) doped with BDPA (6×10^{18} spins/cm^3) proved the existence of these two mechanisms.

The results of measuring the proton polarization in relation to the microwave wavelength exhibit four peaks (see illustration), the two highest of which are caused by the solid-effect dynamic polarization mechanism, while the two lowest are due to the cooling of the electron spin-spin interaction reservoir.

The latter mechanism becomes dominant in certain substances like butanol and propanediol, for example.

Just as it is possible to produce dynamic polarization by cooling the electron spin-spin interaction reservoir, the proton interaction reservoir can be cooled by irradiation with an r.f. field. There seems to be a thermal coupling between this reservoir and the quadrupole energy reservoir of the deuterons due to the interaction with the electric field gradient in the target.

The deuterons can be purely aligned by cooling this reservoir. The alignment, like the polarization, defines a certain degree of orientation of the spins of the deuterons, which can assume three different orientations in a magnetic field. The degree of alignment may become as high as 60 % for the deuterons having a favourable orientation in the external magnetic field, and this corresponds to a spin temperature of 7 *[iK.* The average alignment of all the deuterons is unfortunately only about 10%.

Better results could probably be obtained in monocrystals, in which it is possible to select the orientation of the molecules.

BEBC dismembered

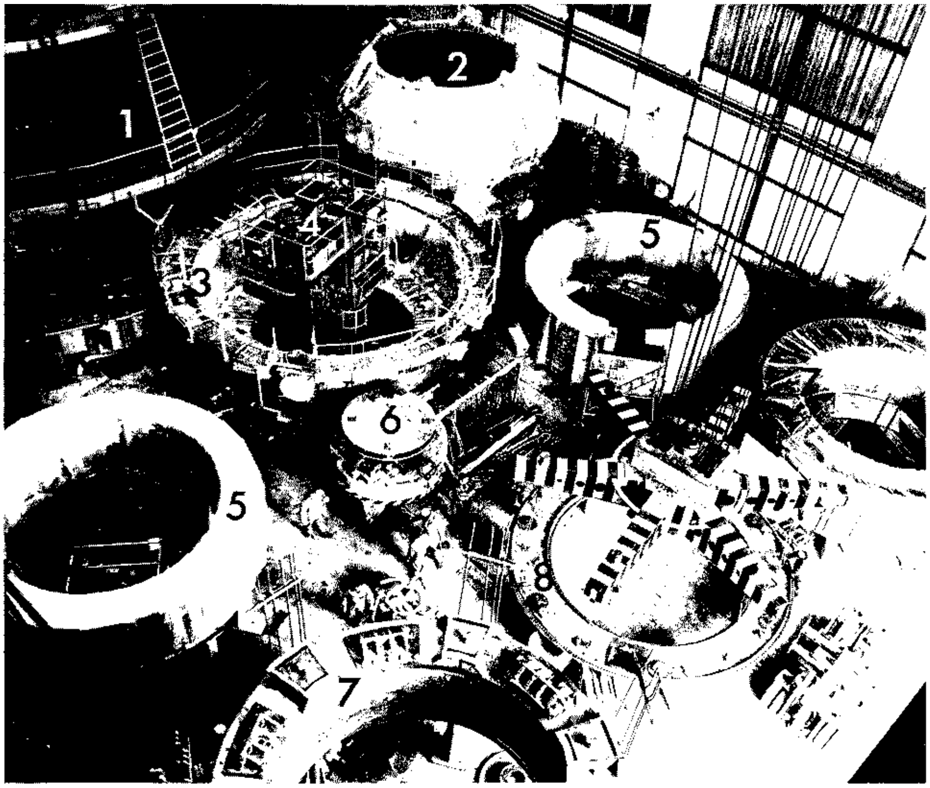
Since the beginning of March, somewhat drastic surgery has been performed on BEBC, the 3.7 m European bubble chamber.

It will be remembered that BEBC had been from time to time behaving rather oddly during the charging and discharging of the magnet. While the

As is covered in our main article, the CERN site is 20 years old this month. When the first people moved in, they were housed in 'temporary' barracks. How temporary can you get? The picture shows one of these barracks being dismantled a few weeks ago after twenty years of continuous use.

CERN 169.4.74

Photo taken at the beginning of May, showing a view of the dismantling of the magnet of BEBC, the 3.7 m European bubble chamber: iron magnetic shielding (1); lower (2) and upper (3) parts of the vacuum enclosure of the magnet; turbo-molecular vacuum pumps for the 'fish-eye' windows (4); the two superconducting coils (5); a handling platform (6); the two cryostats (7); the cover of the upper cryostat (8) suspended from the bar of the travelling crane which has a 170 ton carrying capacity. The chamber proper, not dismantled, is inside the shielding (1).



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magnet was being reheated last January, the same transitory phenomena re-occurred and measurements soon confirmed that there was a short-circuit not in the coil itself, but between the non-superconducting auxiliary wires. It was therefore decided to make repairs rather than run the risk of operating under these conditions bearing in mind there is a huge amount of energy stored in the magnet (730 MJ at 3.5 T). In order to make the repair, the magnet has had to be systematically dismantled starting with the upper plug of the magnetic shielding down to the coil and its defective wires inside the vacuum tank and the cryostats.

By the beginning of May, the diagnosis that had been made in February was shown to be right. While the whole of the superconducting section of the coil is in good order, the effects of a short-circuit have been detected (burnt insulation, fused copper wires, etc.) between the ordinary wires passing vertically along one of the stays. The double pancake stacks are at present being taken apart so that the pancakes can be cleaned and the whole of the coil carefully inspected.

It is hoped that an explanation for this incident will be found, and various theories are now being examined. We shall be returning to this question in a subsequent issue.

Technology Meeting

From 24-26 April, CERN was the scene of the 'Meeting on Technology arising from High Energy Physics' which was the main subject of our April issue. Over 220 participants arrived from throughout Europe and heard review talks on the major fields of technology involved in doing our research. Half the time of the Meeting was available for touring the CERN site where almost 300 exhibits were on display.

On Saturday, 27 April, the gates were opened for visitors from the technological and industrial community close to CERN. For example, technical colleges and chambers of commerce from Lyon, Bourg, Annecy, Grenoble, etc... in France and from Geneva, Lausanne, etc.* in Switzerland were invited to visit the exhibition.

Reactions to the Meeting were generally very favourable and most people appear to have drawn something useful from their visit. Many people seemed interested in sustaining the flow of information on the technological front. An attempt is being made to learn with some precision just what interested the industrial community before discussing whether CERN could do anything useful to respond to these interests.

In addition to the visitors from outside the laboratory, CERN staff also had the opportunity to learn in more detail of the work of their colleagues and even as a purely internal exercise in technological communication the Meeting and exhibition served a very useful purpose.

CERN COURIER Readership survey

In this issue of CERN COURIER is a readership survey for our 'external readers.' We should be grateful if you would give a few minutes to filling this in and returning it to CERN as soon as possible.

The aim of the survey is two-fold. First of all we should like to spring-clean our distribution list. Inevitably over many years, people's interests change and there may be a considerable number of names on our list, of people who at one time had reason to receive the journal but who are now no longer interested. *In order to continue to receive CERN COURIER, please return the insert at the beginning of this issue with at least your name, address, and reply to the first question filled in.*

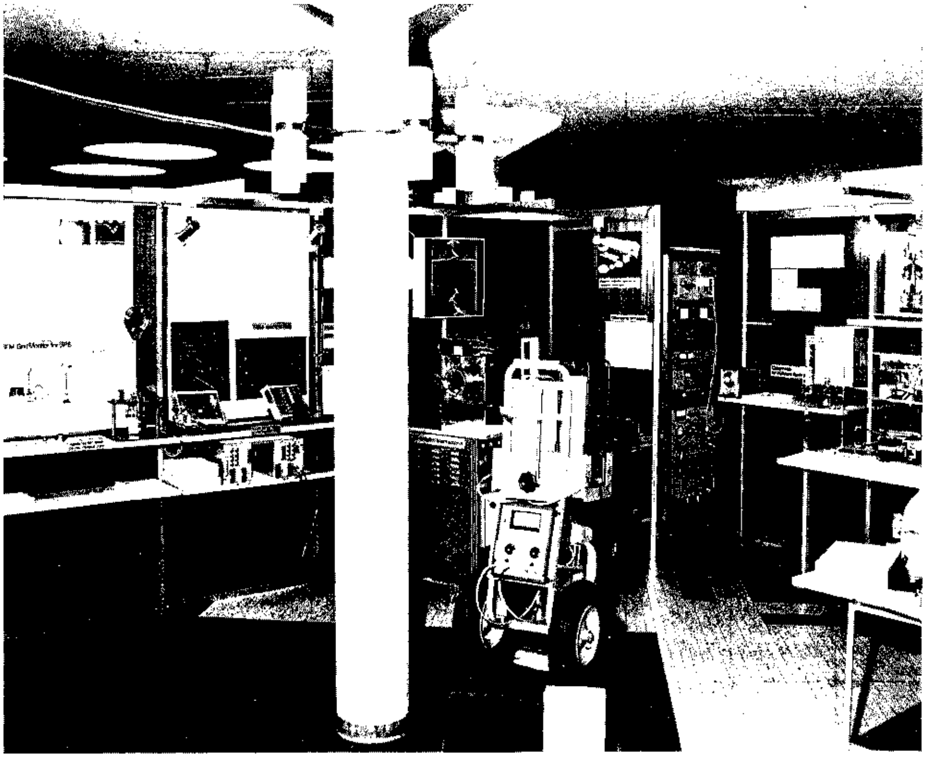
The second aim is to see whether the readership continues to have about the same composition and about the same interest in CERN COURIER as in 1968 when a similar survey was carried out. This is useful to us in judging whether we are providing the kind of information that the majority of readers wish to receive and whether we are providing it at about the right level to be accessible to the maximum number of readers. This information is also useful to the advertisers who use our pages.

Replies to the survey will up-date some of the basic information on CERN COURIER readership. However, if any readers are feeling very enthusiastic (or antagonistic) we shall be happy to receive fuller comments by accompanying letter. We try to cater for a broad range of interests and to present the information in such a way that it is accessible to people of widely differing professional expertise. Individual reactions, suggestions, and constructive criticisms concerning the journal are welcome.

On the opening day of the Meeting on Technology arising from High Energy Physics, held at CERN from 24 to 26 April, Professor W. Jentschke, Director General of Laboratory I, made a speech of welcome to an audience which included a large number of specialists from the various Member States.

CERN 174.4.74

Part of one section of the exhibition organized at CERN from 24 to 26 April for the Meeting on Technology arising from High Energy Physics. The exhibition, which was highly successful, was distributed over a number of the CERN buildings in eight areas and comprised almost 300 items. It presented equipment, very often still at the prototype stage, devised and brought into use to meet the advanced technical requirements of the European sub-nuclear research programme.



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Around the Laboratories

BATAVIA
Dedication ceremony

On 11 May, the National Accelerator Laboratory was officially dedicated and named the Fermi National Accelerator Laboratory in honour of the Italian physicist who did some of his most famous work at the nearby University of Chicago. Mrs. Laura Fermi, the widow of Enrico Fermi, spoke at the dedication together with representatives of scientific and political authorities of the USA including the Chairman of the US Atomic Energy Commission, Dr. Dixy Lee Ray.

The ceremony took place in a stimulating gale outside the Central Laboratory building which is a symbolic work of outstanding architecture. NAL has rapidly developed into a very impressive research centre and L. Lederman, on behalf of the experimental physicists, spoke of the excellence of the Laboratory's 400 GeV accelerator.

We shall be returning to the performance of the machine in the June issue when reporting the recent International Accelerator Conference. In the July-August issue we will have news of the experiments and in the September issue a full report on progress at the Fermi National Accelerator Laboratory.

STANFORD
Getting the most out of bubble chambers

The Stanford Linear Accelerator Centre has led the development of the techniques to operate bubble chambers at a rhythm much faster than was standard a few years ago. Their 22 GeV electron machine emits its particles at the rate of 360 pulses per second and, since bubble chambers like their incoming particles in short bursts, the Stanford machine is ideally suited to the use of rapid cycling bubble chambers. The proton synchrotrons with their longer pulse lengths at intervals of several seconds are not so naturally geared to sending a rapid series of short bursts.

Even a large 82 inch bubble chamber (previously 72 inch at Berkeley) was modified at Stanford to pulse at a rate of 2 to 3 per second. It has now been retired from active service after accumulating 24 million pictures in its six years at SLAC. Two other chambers remain in action — the 40 inch and the 15 inch which are both rapid cycling chambers.

The 40 inch has been modified to take 12 pulses per second and is being used in association with electronic detectors in 'hybrid' experimental set ups. The electronic detectors record whether an event of interest has taken place and only then is a picture taken in the bubble chamber. Used in this way, comparatively rare events can be studied without the pain of examining millions of photographs (for example, a recent experiment took just 540 000 pictures from 14 million chamber expansions).

The chamber has already been modified to fit better in such hybrid set ups and further improvements are now being implemented. Its magnet yoke was cut away at the exit window to enable particles to escape easier to the electronic detectors. A subsequent field map showed little change from the original configuration with near uniform field of 2.6 T. Multiwire proportional chambers (of similar design to those used in the Split Field Magnet at the CERN ISR) are being built for installation at the chamber exit window where the fringe field will give some momentum measurement. A Cherenkov will follow immediately downstream to distinguish between pions, kaons and protons over a broad momentum range.

The electronics will pass signals of events to a NOVA 840 computer. Two events can be collected within the 1.5 s beam pulse from the accelerator and the computer can then decide whether to take a photograph in the chamber. To handle large numbers of emerging partiels the use of hardware processors (see April issue page 117) to help the computer is being considered.

A new series of hybrid experiments was discussed at the April meeting of the SLAC Program Advisory Committee and it is hoped that the 40 inch chamber will be back in action with its revamped associated detection systems by October of this year.

At 12 pulses per second, the 40 inch is close to its peak pulse repetition rate. The 15 inch chamber however is capable of faster speeds. It has completed its first physics experiment (see vol. 13, page 114). Operating at 20 cycles per second it gave 43.3 million expansions while only 120 000 pictures were taken. This year it is hoped to increase the rate to 30 or even 40 cycles per second.

Rencontre de Moriond

The 9th Rencontre de Moriond was held at Meribel les Allues from 3-15 March organized by Orsay (Laboratoire de Physique Théorique et Particules Elémentaires) and especially J. Tran Than Van. It involved about fifty theoretical and experimental physicists from Europe and the USA for each of the two weeks. Having this reasonably small number helped create a very stimulating atmosphere for discussion.

The theme of the meeting was interactions at high energies. The first week tackled the hadronic interactions with such topics as the large

Mrs. Laura Fermi speaking at the dedication of the National Accelerator Laboratory named the Fermi National Accelerator Laboratory in honour of her late husband.

(Photo NAL)

transverse momentum processes, diffraction dissociation, multiparticle features and two-body scattering and resonance production. Recent results from the 400 GeV machine at NAL and from the ISR at CERN were at the hub of many discussions.

There were particular themes such as the origin of the rise in total cross-section in proton-proton interactions as observed at the ISR and the phenomena of particle cluster formation and particle correlations. Following on naturally from this was a forward look at the new experimental possibilities which will open up when the SPS comes into action.

The second week swung over to electromagnetic and weak interactions. The startling results from the electron-positron storage ring SPEAR (reported in the February issue) were obviously the burning topic. The breakdown of scaling and the simultaneous undermining of so many theoretical models of particle behaviour could have absorbed the whole time of the Conference. The neutral current data from the heavy liquid bubble chamber, Gargamelle, and from NAL was another main theme and again the possibilities to push such investigations further with high energy muon and neutrino beams at the SPS were discussed.

The proceedings of the Rencontre are excepted to be available in a month's time from R.M.I.E.M., Lab. de Physique Théorique et Particules Elémentaires, Bâtiment 211, Université Paris-Sud, F-91 405 Orsay.

RUTHERFORD BASQUE solenoid for TRIUMF

A large superconducting solenoid has been operated at the Rutherford Laboratory. It is a 6 Tesla metre magnet built for use by the BASQUE collaboration (an experimental team with physicists from Bedford College, AERE Harwell, Surrey, Queen Mary College and University College London) who will join Canadian colleagues in an experiment scheduled for the TRIUMF cyclotron at Vancouver. The magnet will be used to precess the spin axis of polarized protons in the energy range 200-500 MeV in a scattering experiment.

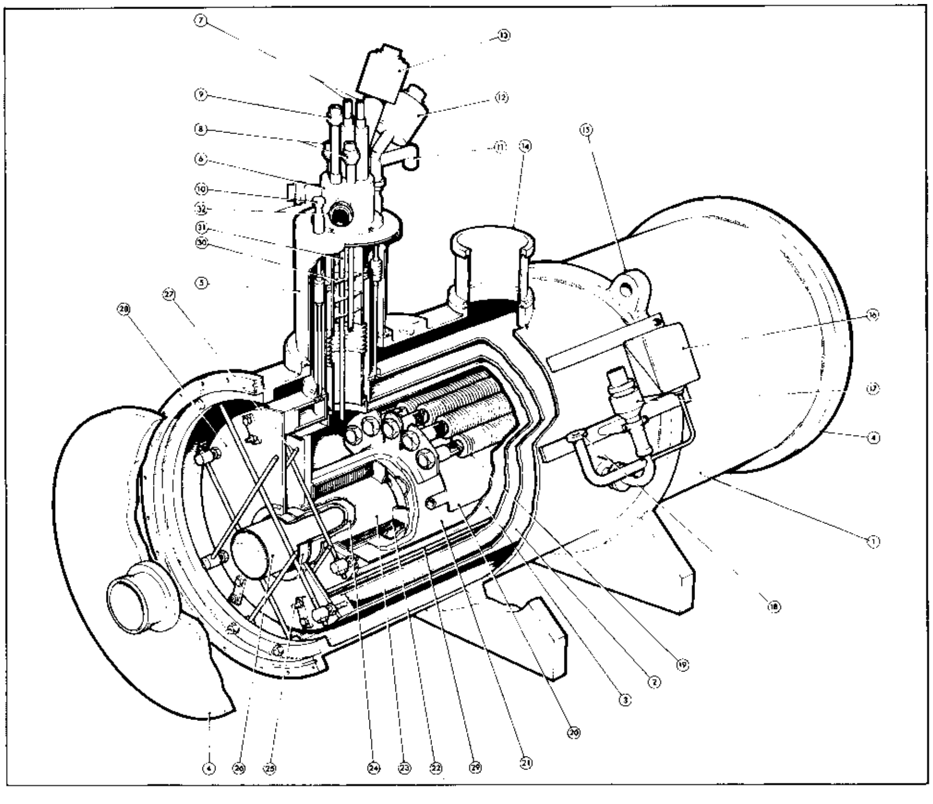
The solenoid is divided into five sections each with a protection resistor to take a large fraction of the stored energy (290 kJ) in the event of the magnet going normal. This could occur if the liquid helium supply failed or the critical current of 230 A were exceeded and precautions are taken to prevent or warn of these happenings. The cryostat has a 10 cm warm bore where the polarized protons travel and within which a field of 6 T is maintained. The cold bore within the cryostat is 14 cm in diameter and 1 m long.

Special attention was paid to the operational requirements when constructing the magnet. It will operate for 30 hours without needing a helium refill (liquid nitrogen for the radiation shield is transferred automatically). It is easy to align using conventional triangulation techniques. All its associated components (protection resistors, current lends, pressure protection devices, etc.) have been designed to give simple, reliable operation so that the magnet should be no more difficult to use then a conventional magnet. In addition, its capital cost was less than for a conventional solenoid using copper conductor and the operating costs are a few percent of a conventional magnet to give the same performance.

The magnet and associated power supplies and instrumentation have operated successfully for 500 hours of which for 300 hours it **was** u.,o^_. vised. It is now ready to be transported to the TRIUMF Laboratory and could be ready for the experiment before the end of the year.

The conductor in the solenoid is IMI type 361/100 niobium-titanium multifilamentary conductor with filament diameter of 31 ^m. Work on the use of multifilamentary conductor is continuing at Rutherford. New composites using niobium-titanium are being examined and, more recently, the possibilities of filamentary niobium-tin have been taken up again. Although it has higher potential than niobium-titanium, niobium-tin is a more difficult material metallurgical^ speaking. More attention is also going into using the expertise on superconductivity which has built up. Large magnets of the BASQUE solenoid type are likely to be seen around particle physics Laboratories much more from now on whenever they can provide better performance, greater ease in operation or lower costs than their conventional counterparts.

Cut away diagram of the 6 Testa metre BASQUE solenoid on which can be picked out (1) the cryostat vacuum vessel, (19) the protection resistors (22) the superconducting windings.



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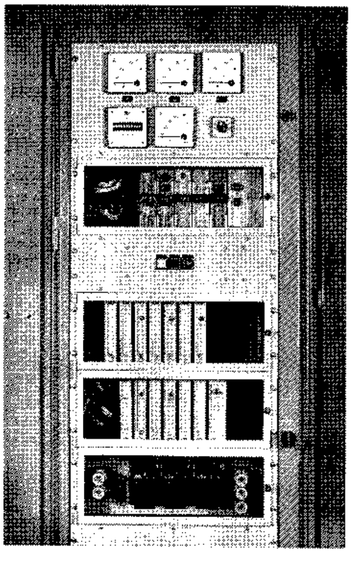

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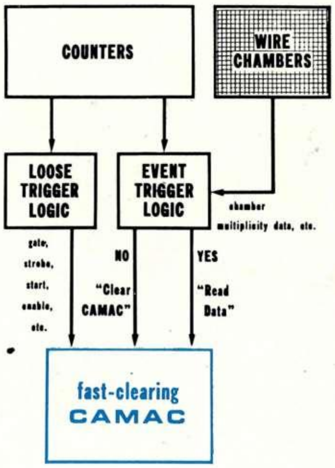

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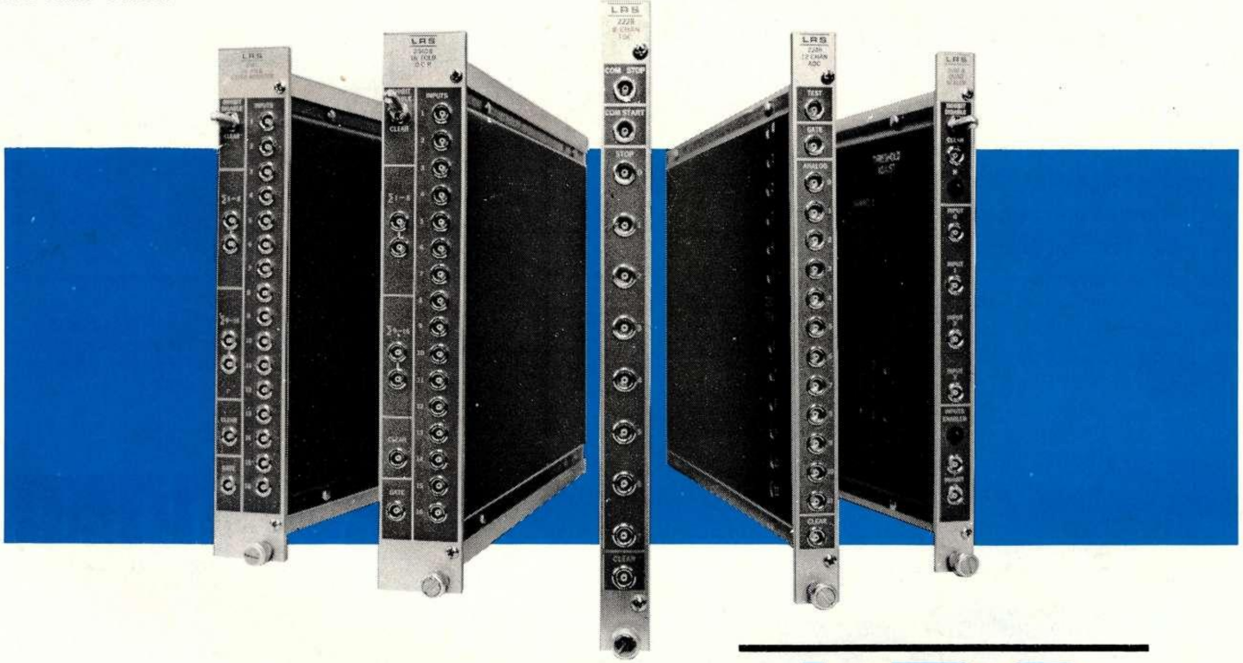

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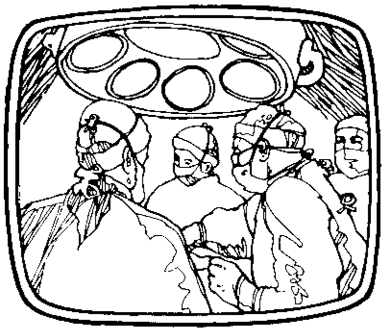

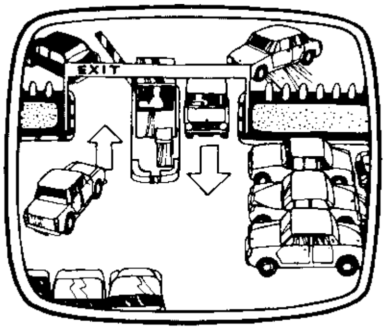

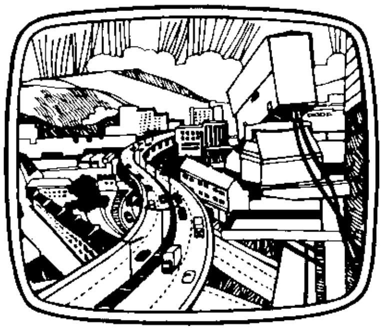

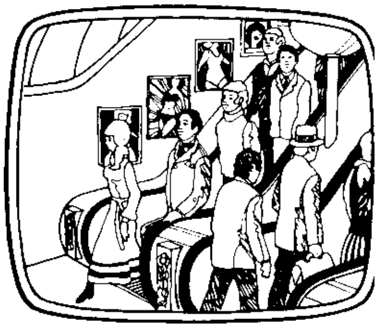
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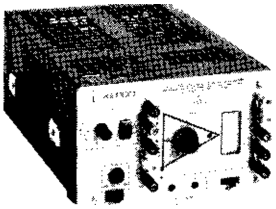
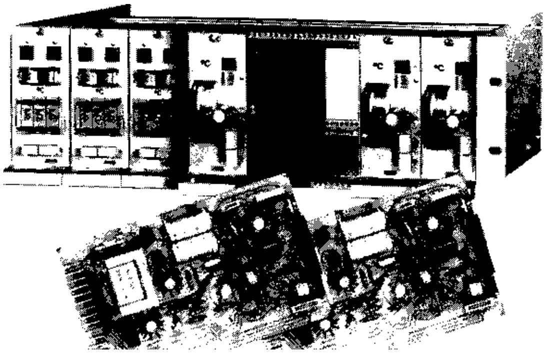
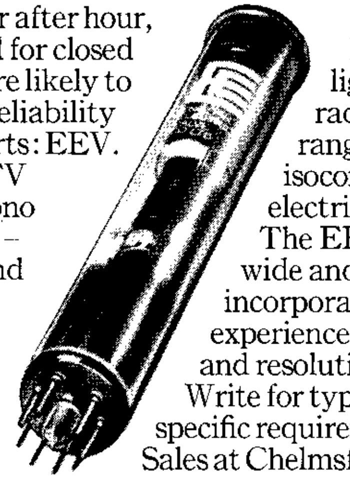




And on EEV vidicons, isocons, intensifiers and pyro-electric tubes.

LAP 71



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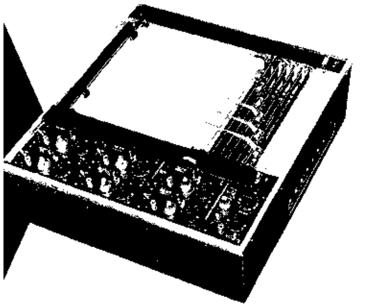

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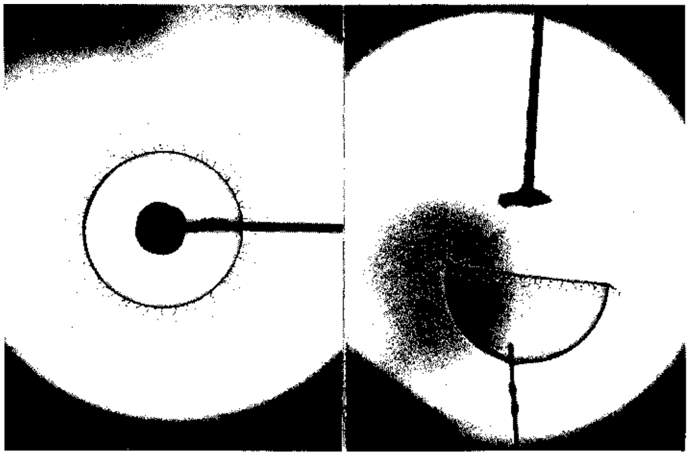

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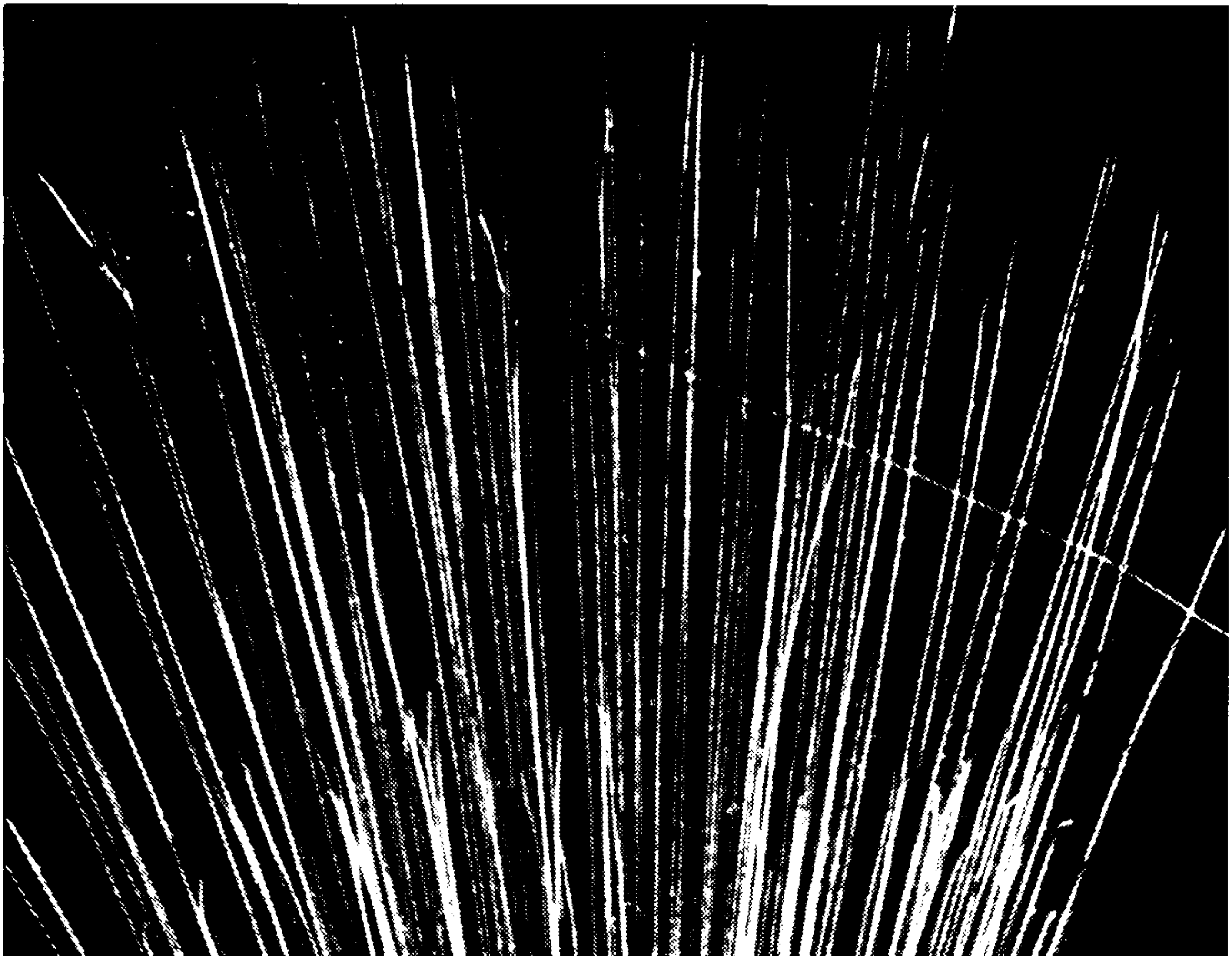

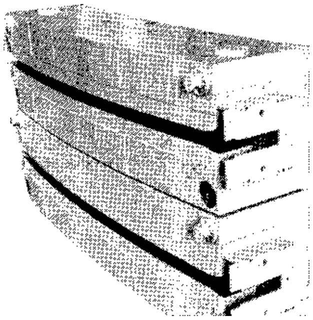

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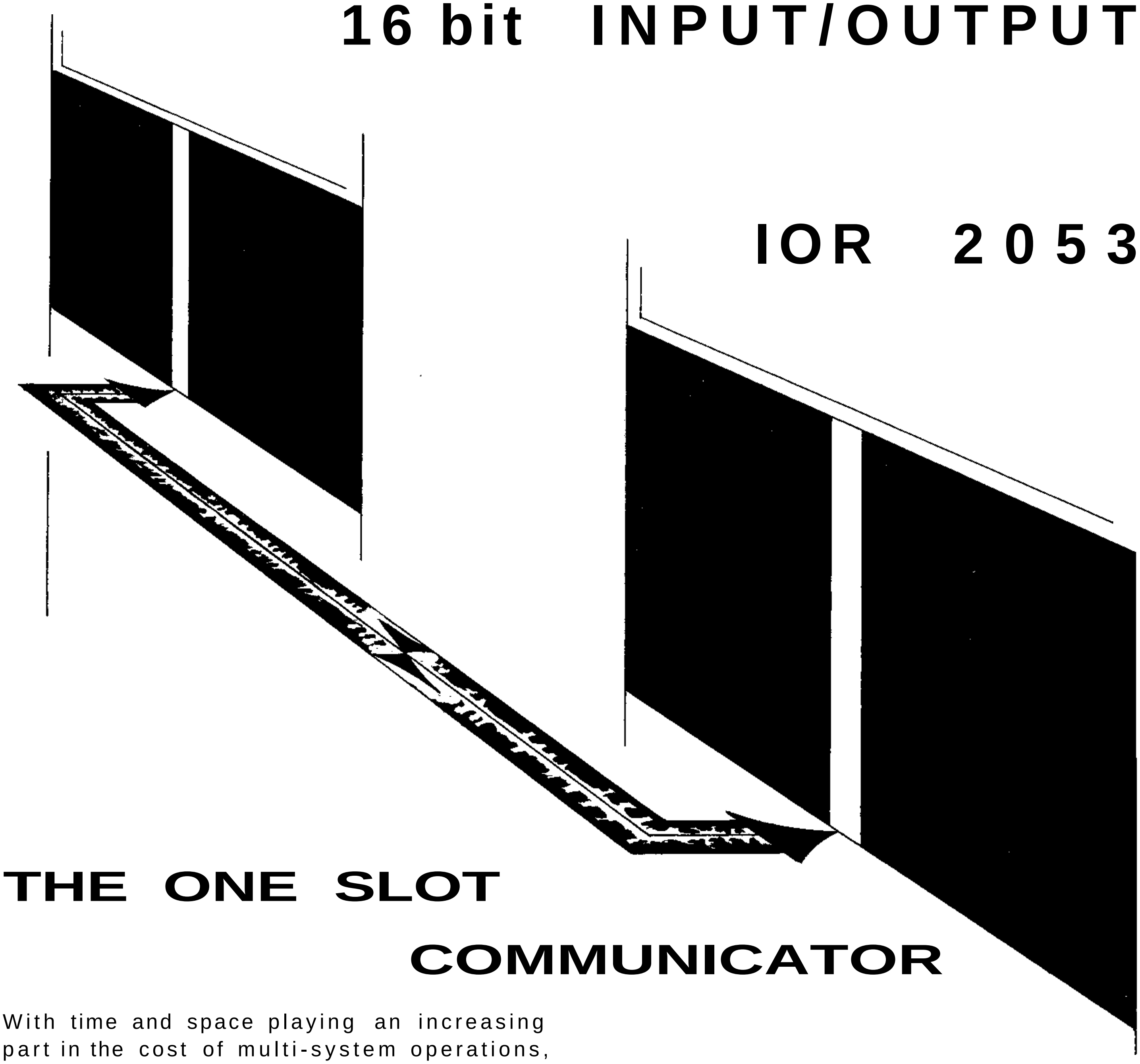

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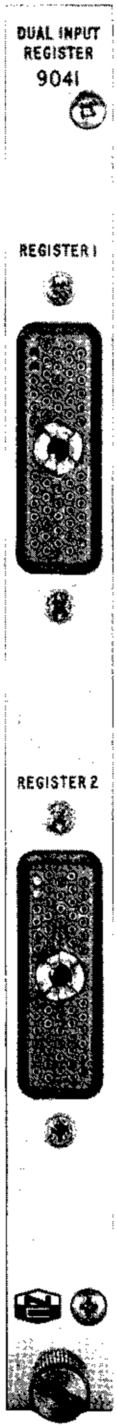

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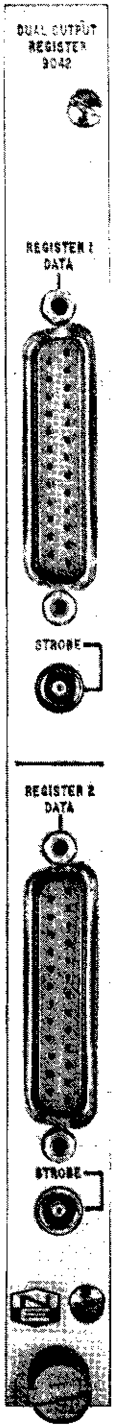

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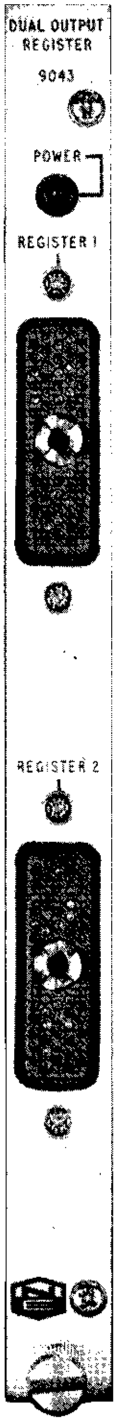

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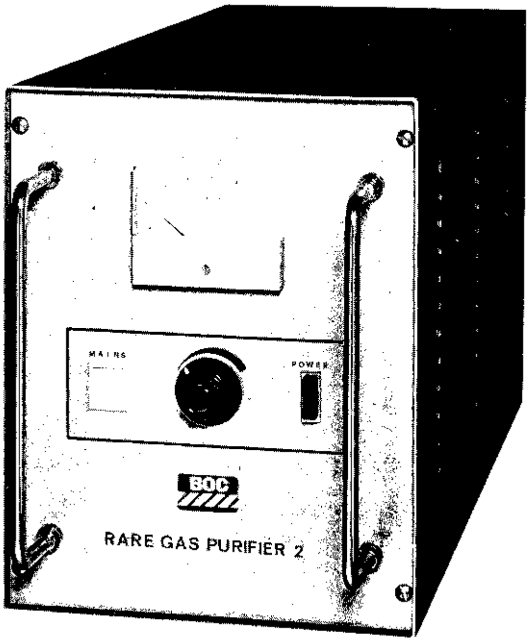
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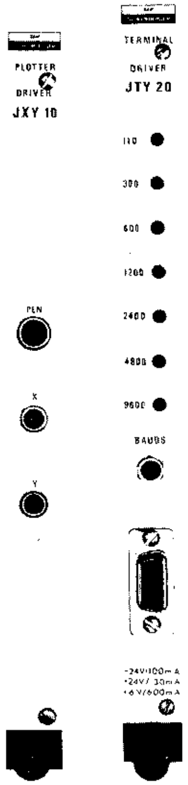

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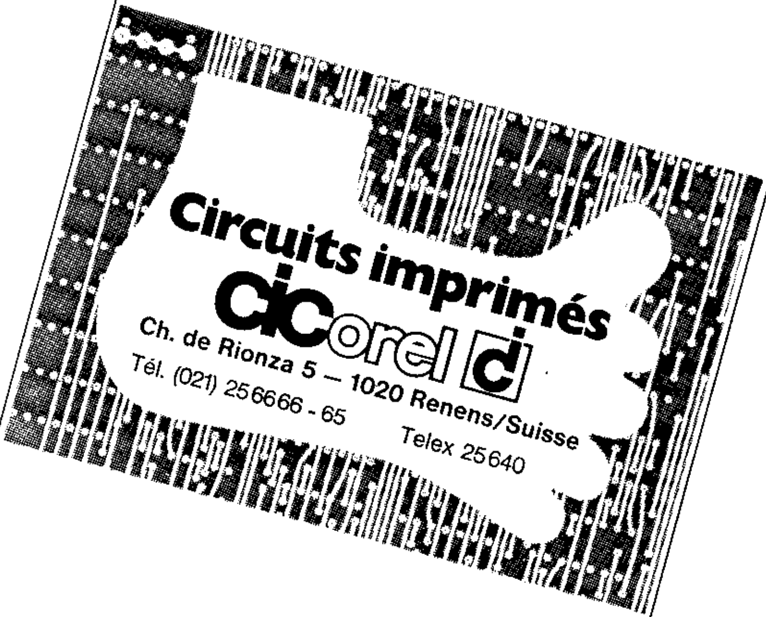

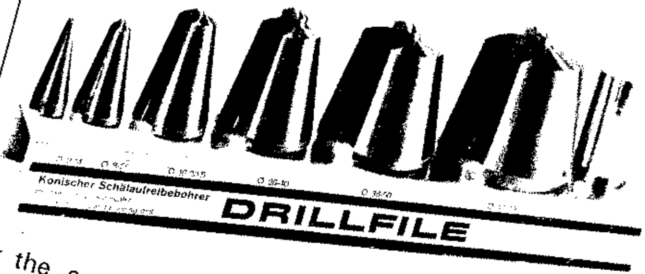
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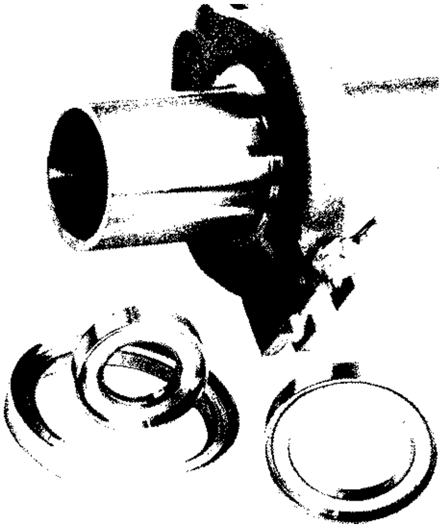

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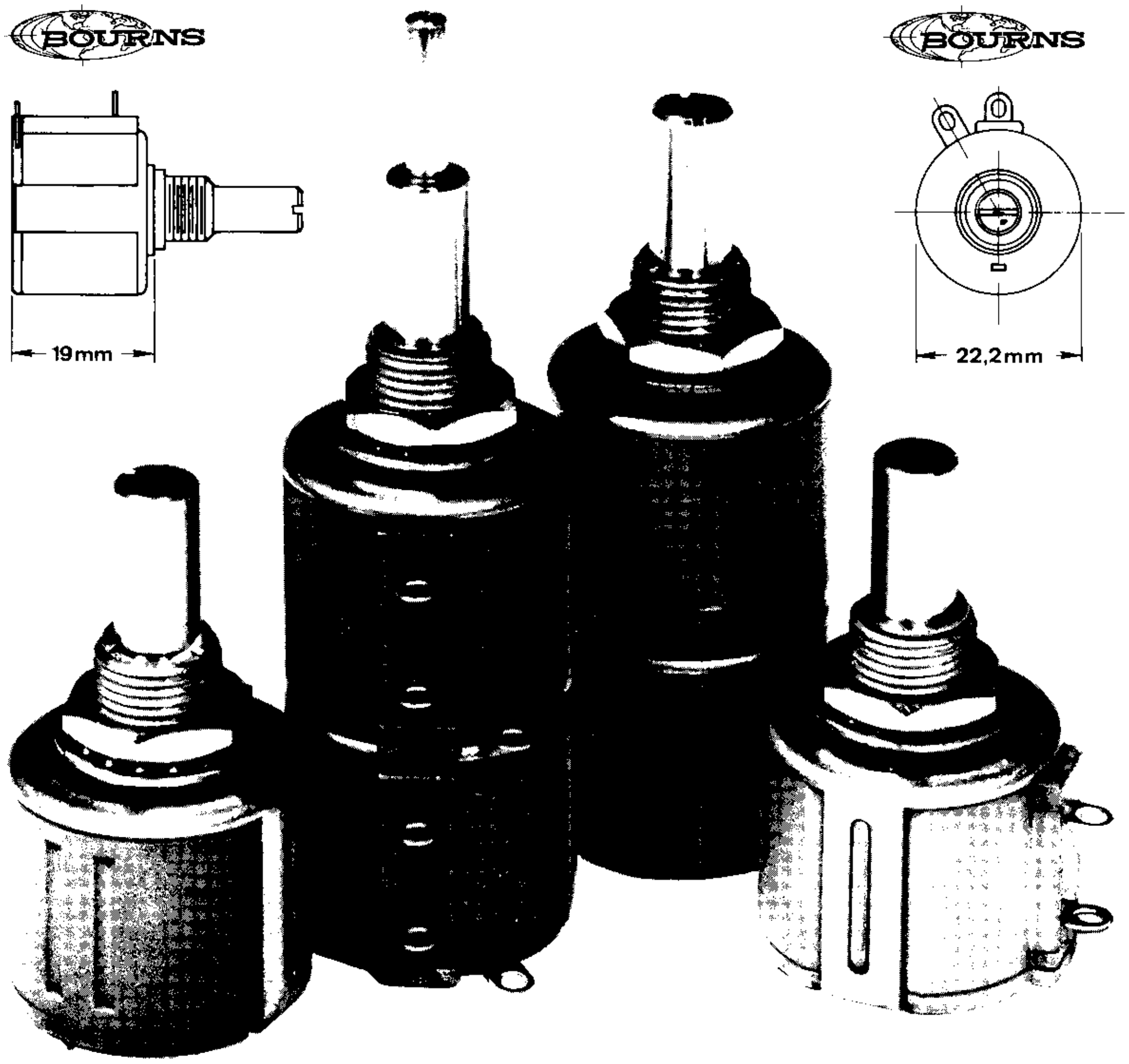

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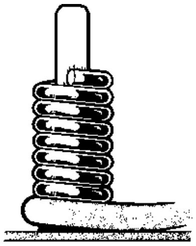

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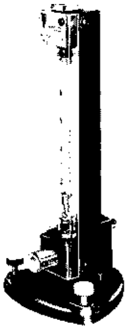

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Si vous désirez éviter quelques pièges, retournez-nous le bon ci-joint.

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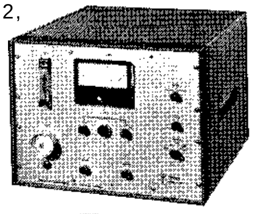
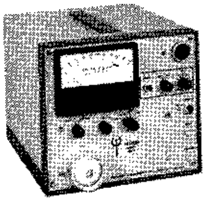
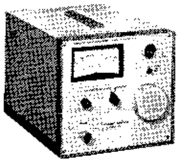


TRITON 955B — Highest sensitivity system: 10/uCi/M^3 full scale for tritium. Highest sensitivity as a gamma area monitor: 0.05 mR/HR full scale. Particularly useful for industrial and reactor monitoring, as an analytical tool, and for H^3 and C^{14} tracer work generally.



TRITON 1055B for portability — A lightweight (less than 20 lbs.) battery-operated monitor whose size belies its sensitivity (50AtCi/M^3, full scale). Features rechargeable nickel-cadmium batteries. The 1055 can be operated (and its batteries recharged) on standard line current. Has recorder output.



TRITON 1125 — Mil-spec quality. Portable, rugged, rainproof. lOO/^Ci/M^3 full scale for H^3.

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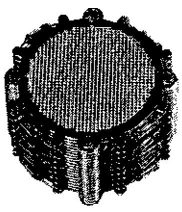

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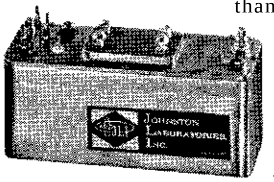
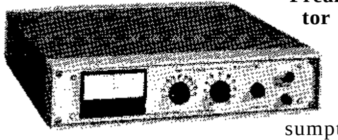


Model MM-2 Similar characteristics as MM-1 but only half the diameter (1").



Preamplifier-Amplifier-Discriminator (Model PAD) Rugged. Miniature. Charge sensitive input. Risetime: 3 nsec. Adjustable discriminator: 20:1 range. PAD-1: lowest power consumption. Pulse count rates to 10^5/second. PAD-2: for pulse count rates to lOVsecond.

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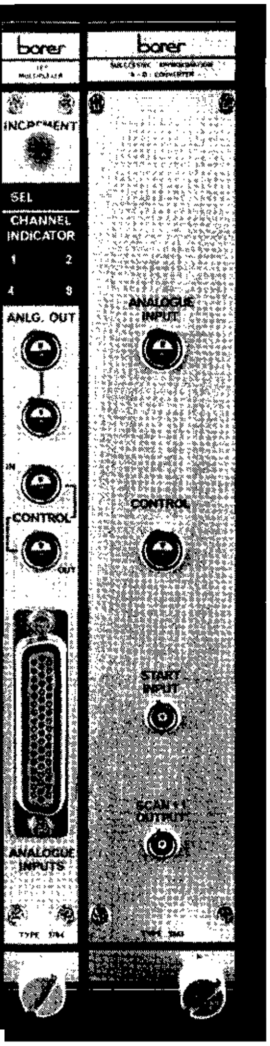

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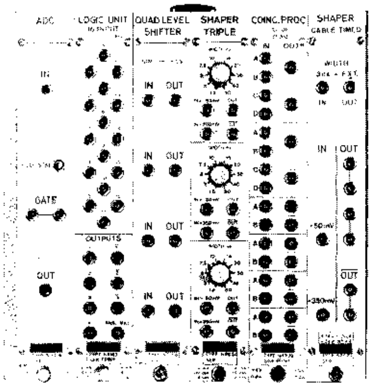

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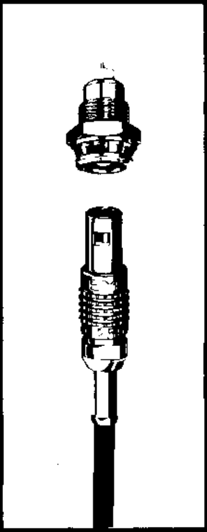

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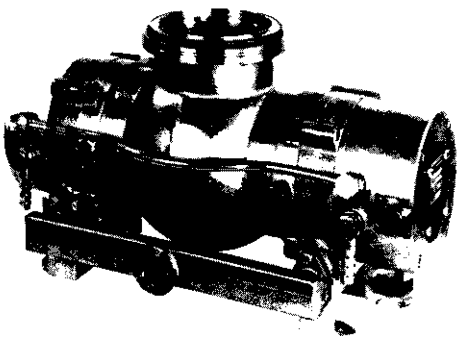

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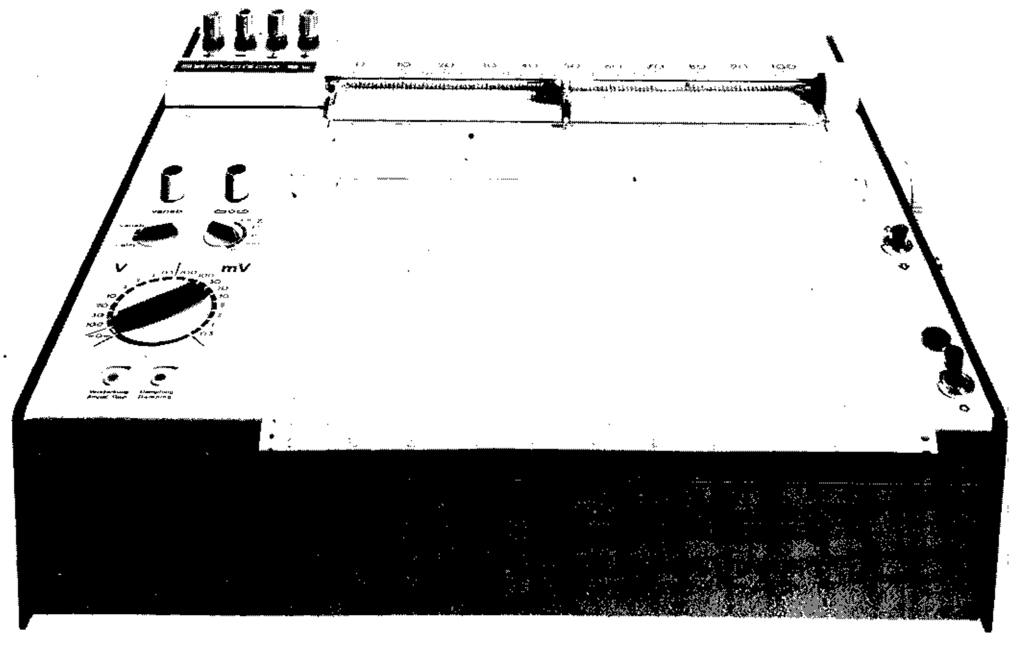

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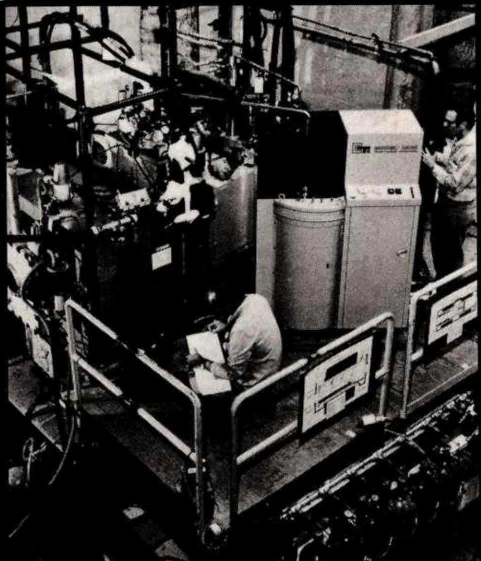

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