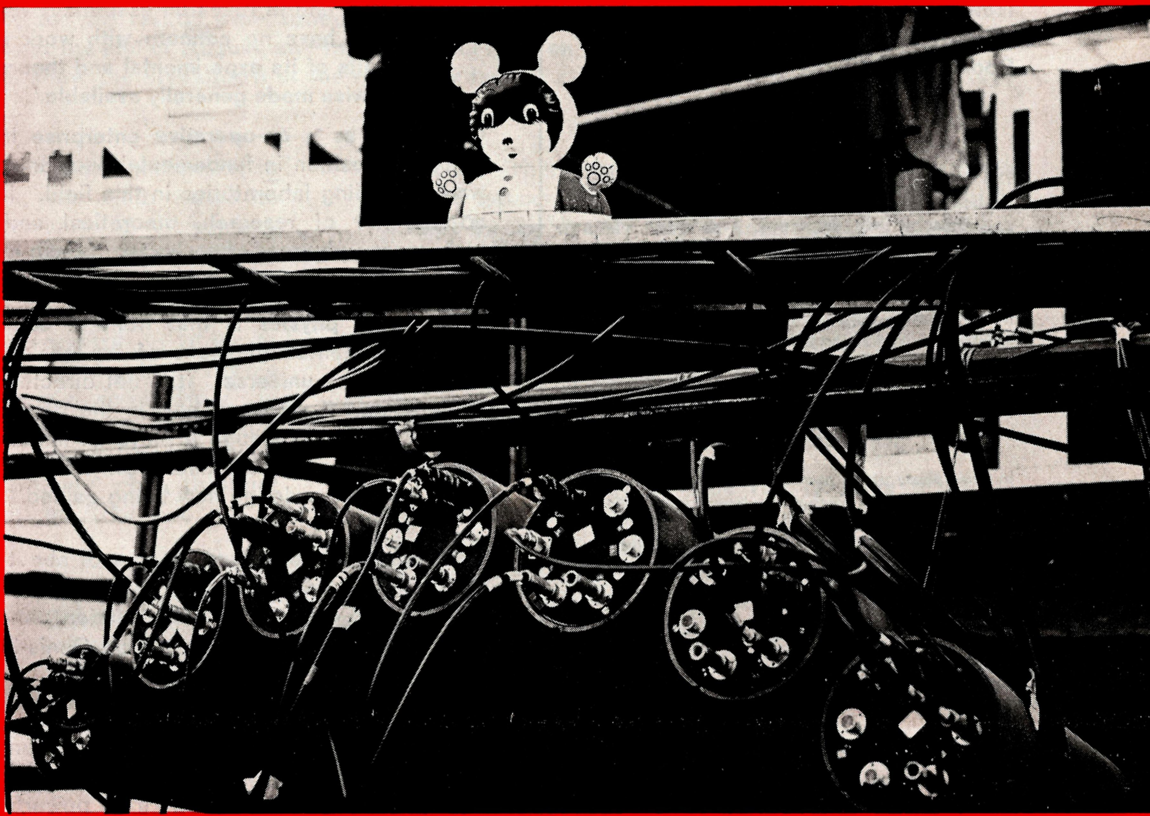
CERN COURIER



CERN/PI 325.12.65

No. 9 Vol. 6

September 1966

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN COURIER

NO. 9 VOL. 6 SEPTEMBER 1966

Contents

The cover photograph is a humorous introduction to the main article in this issue which describes a very important experiment concluded at CERN in August. The experiment concerns the investigation of a possible violation of charge symmetry. A recent result from America suggested that it is violated, which implies that the symmetry between matter and anti-matter is broken; that the particle and anti-particle worlds are not mirror images of one another as we believed. The CERN experiment did not confirm this result.

In the photograph can be seen an array of counters used to detect neutrons and sitting above them, Sumxixmuz, the mascot of the experiment oblivious to the particles being fired in his direction. Note that Sumxixmuz is a very symmetrical mascot.

The CERN COURIER is published monthly by CERN in English and in French editions. It is distributed free of charge to CERN employees, and others interested in the construction and use of particle accelerators or in the progress of sub-nuclear physics in general.

Editor: Brian Southworth
Public Information Office,
CERN, 1211 Geneva 23, Switzerland.
Tel. (022) 41 98 11 / Telex: 2 25 48

Printed by: Ed. Cherix et Filanosa S.A.
1260 Nyon, Switzerland.

The European Organization for Nuclear Research, more commonly known as **CERN** (from the initials of the French title of the original body, 'Le Conseil européen pour la Recherche nucléaire', formed by an Agreement dated 15 February 1952), was created when the Convention establishing the permanent Organization came into force on 29 September 1954.

In this Convention, the aims of the Organization are defined as follows:

> **'The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.'**

Conceived as a co-operative enterprise in order to regain for Europe a first-rank position in fundamental nuclear science, CERN is now one of the world's leading laboratories in this field. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of **high-energy physics,** often known as **sub-nuclear physics** or the **physics of fundamental particles.**

High-energy physics is that front of science which aims directly at the most fundamental questions of the basic laws governing the structure of matter and the universe. It is not directed towards specific applications — in particular, it plays no part in the development of the practical uses of nuclear energy — though it plays an important role in the education of the new generation of scientists. Only the future can show what use may be made of the knowledge now being gained.

The laboratory comprises an area of about 80 ha (200 acres), straddling an international frontier; 41 ha is on Swiss territory in Meyrin, Canton of Geneva (the seat of the Organization), and 39.5 ha on French territory, in the Communes of Prévessin and St.-Genis-Pouilly, Department of the Ain.

Two large particle accelerators form the basis of the experimental equipment:

— a 600 MeV synchro-cyclotron,
— a 28 GeV proton synchrotron,

the latter being one of the two most powerful in the world.

The CERN staff totals about 2300 people.

In addition to the scientists on the staff, there are over 360 Fellows and Visiting Scientists, who stay at CERN, either individually or as members of visiting teams, for periods ranging from two months to two years. Although these Fellows and Visitors come mainly from universities and research institutes in the CERN Member States, they also include scientists from other countries. Furthermore, much of the experimental data obtained with the accelerators is distributed among participating laboratories for evaluation.

Thirteen Member States contribute to the cost of the basic programme of CERN in proportion to their net national income:

Austria (1.90 %)	Italy (11.24 %)
Belgium (3.56 %)	Netherlands (3.88 %)
Denmark (2.05 %)	Norway (1.41 %)
Federal Republic of Germany (23.30 %)	Spain (3.43 %)
	Sweden (4.02 %)
France (19.34 %)	Switzerland (3.11 %)
Greece (0.60 %)	United Kingdom (22.16 %)

Poland, Turkey and Yugoslavia have the status of Observer.

The 1966 budget for the basic programme amounts to 149 670 000 Swiss francs, calling for contributions from Member States totalling 145 860 000 Swiss francs.

Supplementary programmes, financed by twelve states, cover construction of intersecting storage rings for the 28 GeV accelerator at Meyrin and studies for a proposed 300 GeV accelerator that would be built elsewhere.

Breaking the Law

A team of physicists from Columbia University and State University, Stony Brook in the USA, published in Physical Review Letters on 27 June the result of an experiment, carried out at the Brookhaven 33 GeV proton synchrotron, on the decay of the eta meson into three pions. The conclusion from their experiment was that one of the symmetry laws which are assumed to govern the behaviour of charged particles can be broken. An equivalent experiment has been carried out at CERN and the results were announced at the 13th International Conference on High Energy Physics at the end of August, and in Physics Letters on 1 September. The CERN investigation did not show the breakdown of the symmetry law.

The news from the USA caused great excitement in the world of sub-nuclear physics; once again one of the accepted laws about the behaviour of elementary particles appeared to have been broken. In this article we will try to explain what the excitement is about. It is not easy to communicate the problem in everyday language because it has been necessary, in order to describe the phenomena occurring under the extreme conditions created at our particle accelerators, to develop a new language which is essentially mathematical. Nevertheless, some of the basic ideas involved could almost be arrived at intuitively when thinking about how we would expect particles to behave.

Three symmetries

It is all concerned with symmetries and we need to define three of these. The first goes under the name of parity (P), and implies that if a particle interaction is possible then its mirror image is also possible. This is a statement of a symmetry which we might intuitively expect to apply, for it suggests that Nature does not distinguish between right and left. Surely it is only a matter of convention that we call this direction 'right' and the opposite direction 'left'? We could not communicate to the inhabitants of another galaxy whether our 'left' was their 'left'.

The second is charge (C) symmetry which implies that the detailed behaviour of an interaction should be the same whether it takes place between particles or their anti-particles. It was predicted almost forty years ago that for every particle we have an anti-particle which has all the properties of the particle, except that its charge and magnetic properties are reversed. Thus the anti-proton carries a negative charge whereas the proton is positively charged and their magnetic di-poles are opposite. (For the particles which have no charge: they may have magnetic properties, as is the case with the neutron, and these are reversed in the anti-particle; or they may have neither electrical nor magnetic properties and the particle and anti-particle are precisely the same, as is the case with the eta meson.)

This C symmetry makes it possible, for example, to postulate an anti-galaxy where all the nuclei would be negatively charged, surrounded by positively charged electrons, and where all the laws of physics would be precisely the same as in our galaxy. (The observation of the anti-deuteron — an anti-proton and an anti-neutron together — at Brookhaven and at CERN gave added weight to this postulate since it is an example of anti-particles coming together to build up an anti-nucleus.) There would be no way of telling whether a distant galaxy was made of matter or anti-matter, except by the drastic step of introducing a bit of our galaxy, such as a space ship, into the distant galaxy. If the space ship met anti-matter it would be annihilated in a flash of energy. Again we can bring this back to an intuitive idea that it is only a matter of convention that we call this charge positive and that negative, and that a world constructed in the opposite sense is equally possible.

The last symmetry is time (T). It says that if a sequence of events involving particles can occur then the exactly reverse sequence is possible. If a + b gives us c + d and we could reverse the dynamics of c + d we could get a + b again, just as if we recorded the progress of the interaction on film and then ran the film backwards.

Three forces

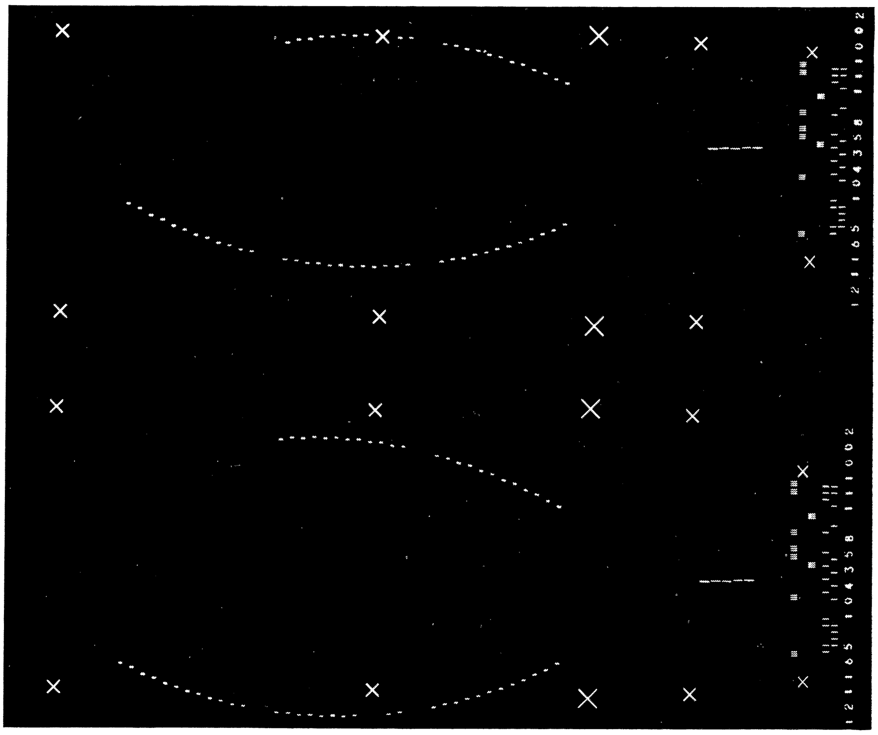
Before reviewing the present status of the three symmetries we need to recall that it has proved necessary to define four different types of force which control the behaviour of matter. When dealing with elementary particles, we can ignore one of them — gravitation — since its influence, as far as we know, is far too small to be significant and we are left with the following three:
the 'strong' force, which for example acts to hold the nucleus together,
the 'electromagnetic' force, which acts between charged particles, for example holding the negative electrons in orbits around the positive nucleus,
and the 'weak' force, which controls the slow decay of the heavier particles into lighter particles.

The strong force is a hundred times more powerful than the electromagnetic and a million million times more powerful than the weak.

Historical survey

It was ten years ago that the first suggestion that the symmetries might not hold in all elementary particle interactions was put forward. The iconoclasts were two American physicists, T. D. Lee and C. N. Yang, who later collected a Nobel prize for their efforts. They pointed out that parity appears to be violated in the two and three meson decays of the K meson and suggested that this breakdown of P symmetry was characteristic of interactions involving the weak force.

In December of 1956, this prediction was confirmed in the case of the radio-active decay of nuclei by C. S. Wu.



A typical photograph taken during the experiment on the eta meson. It consists of separate views taken by two cameras looking down on a sequence of spark chamber gaps. The two views make it possible to reconstruct the event in three dimensions when analysing the photograph. On the far right, the number of the photograph (104 358) and other experimental parameters are recorded. Coming from the right, the track of a negative pion from the proton synchrotron can be seen as it passes across five spark chamber gaps (the short, almost straight, track). It enters a hydrogen target where it can produce an eta meson. The eta decays rapidly into three pions. Two of these are charged (one positive and one negative) and their curved paths in a magnetic field are detected by further spark chambers. Measuring these curvatures (the crosses are reference points for measurement) which are dictated by the energies of the pions and the known strength of the magnetic field, makes it possible, with a large number of photographs, to assess the symmetry between the positive and negative pions.

CERN/PI 26.7.66

She looked at the electrons coming from the decay of cobalt 60 nuclei and found that the majority of them were emitted in a particular direction with respect to the spin of the nuclei. The mirror image of this, which P symmetry says is equally possible, is not observed in Nature. Thus parity is not conserved in weak interactions; there is a way of defining right and left in an absolute sense. We can contact a physicist somewhere else in the universe, ask him to observe radio-active decay, and thus tell him right from left.

Symmetry was reimposed on the weak interactions by combining P and C saying that CP was conserved in all weak interactions. In other words, if we consider not just a straight geometric reflection, right becoming left, but change all particles to anti-particles at the same time, we will arrive at possible interactions. For example, in radio-active decay where a neutron decays preferentially into an electron spinning left, CP reflection gives us an anti-neutron decaying preferentially into an anti-electron (or positron) spinning right. This combined symmetry was tested in the weak interactions and found to be good. Peace reigned again until 1964.

In that year, a team from Princeton University, led by V. L. Fitch and A. J. Cronin, in an experiment at the 33 GeV Brookhaven synchrotron looked at the decay of the long lived neutral K meson, K^0_L, which is again due to the weak force. If CP is conserved, this is allowed to decay into three pions. It was found that about once in five hundred decays it went to two pions in violation of the symmetry. Perhaps more surprising than the break-down of the symmetry itself was the fact that it occurred so rarely. If this symmetry is not good why is it broken on such a small scale ?

Experiments at CERN and at the Rutherford Laboratory in the UK confirmed the American result and further showed that the effect was not due to a special type of very weak 'fifth force' in Nature, which was one of the first ideas put forward to explain the violation.

Violation of C ?

One of the ideas which then emerged was that what we are seeing is not really a violation of CP in weak interactions but a violation of C symmetry in the strong or electromagnetic interactions between the K mesons and the pions, which is interfering with the weak force responsible for the decay. T. D. Lee pointed out that if it is charge symmetry that is violated in the electromagnetic interaction, then the effect would be of the right order of magnitude to explain the small scale of the observations on the K^0_L.

Experiments started at CERN (a collaboration between CERN, E.T.H. Zurich and one scientist from Saclay), at the Rutherford Laboratory (a Rutherford-Saclay collaboration) and then at Brookhaven (a team led by P. Franzini, Columbia University, and his wife J. Lee-Franzini, State University Stony Brook) to look for C violation in the electromagnetic interaction. They all concentrated on the same particle — the eta meson. This is a neutral particle for which particle and anti-particle are the same. It can decay into three pions, one positive, one negative and one neutral (which is also its own anti-particle). The lifetime of the eta meson is about 10^{-18} seconds. This means that the decay is an electromagnetic interaction since it occurs too fast to be weak (where lifetimes are about 10^{-10} seconds) and is not strong because it does not conserve a property known as isotopic spin which is characteristic of the strong interactions.

We have therefore the interaction $\eta^0 \rightarrow \pi^+ + \pi^- + \pi^0$ for which the C reflection is $\eta^0 \rightarrow \pi^- + \pi^+ + \pi^0$. Thus, if the C symmetry is good, the behaviour of the positive pion and the negative pion coming from the decay will be symmetrical. The experiments have looked at the energies of the positive and negative pions to see whether the number of pions of a given energy is equally divided between positive and negative types.

The result from Brookhaven emerged first. 435 000 photographs were taken at a bubble chamber filled with liquid deuterium and detailed measurements on 80 000 of these photographs led to 1441 of them being accepted as genuine cases of the production of the eta meson and its decay into three pions. It was found that in 724 events the positive pions were emitted from the decay with greater energy, compared with 627 events where the negative pions were more energetic. It is on the basis of this result that the Americans announced the violation of charge symmetry in the electromagnetic interactions.

The asymmetry measured in their experiment was 0.072 ± 0.028. When adding this to the results of previous observations on the eta meson the asymmetry is 0.068 ± 0.020. These figures, taking into account the number of eta decays which have been observed, imply that there is about one chance in a hundred that charge symmetry is not violated.

The CERN experiment

The experiment carried out in the Nuclear Physics Division at CERN used a negative pion beam of momentum 713 MeV/c from the 28 GeV proton synchrotron directed onto a hydrogen target. The eta was then produced in the interaction, pion plus proton gives neutron plus eta:

$$\pi^- + p \rightarrow n + \eta.$$

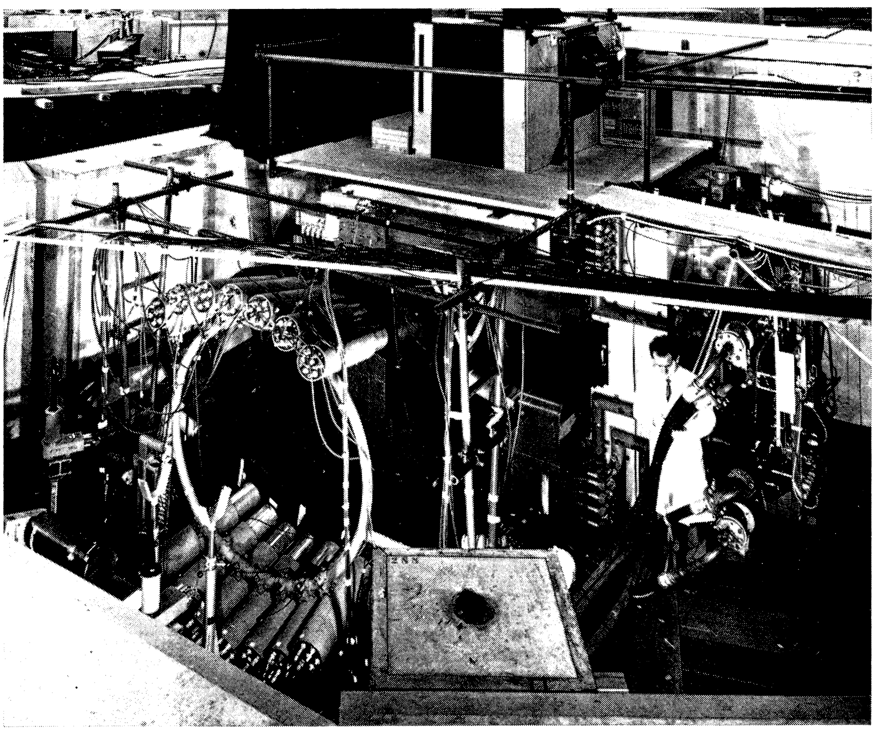
One of the checks to identify the eta was measurements (using a method known as the time-of-flight technique) on the neutron. Since the parameters of the incoming pion, the proton and the neutron are known, the production of the eta can be calculated though the eta itself is only observed through its decay.

The two charged pions from the decay of the eta were observed in spark chambers, placed in an accurately known magnetic field of 7180 gauss. The curvature of the pion tracks in the magnetic field enabled the energies of the positive and negative pion to be determined. To make sure that asymmetrical effects in the apparatus itself did not influence the result, the magnetic field was reversed for half the measurements thus reversing the curvature of the respective charged pions.

From 350 000 photographs about 45 000 events were measured and 10 600 of these were accepted as genuine eta events. The experiment took about six weeks to perform and the experimental team consisted of five scientists from CERN — A. M. Cnops (Belgium), G. Finocchiaro (Italy), J. C. Lassalle (France), P. Mittner (Italy) and P. Zanella (Italy); three from Eidgenössische Technische Hochschule, Zurich — J. P. Dufey, B. Gobbi and M. Pouchon; and A. Muller from Saclay. The result, which was extracted from three times as many events as in all the other published experiments combined, showed no evidence for C violation in the decay of the eta into three pions.

The same team is now looking at the possibility of investigating the same effect by observations on the X^0 meson which can be considered as a heavier version of the eta meson.

An identical experiment to the Franzini experiment (using deuterium in a bubble chamber) has been performed using the 7 GeV accelerator, Nimrod, at the Rutherford-Saclay team. They used an 81 cm chamber from Saclay. They obtained 800 accepted eta events, about half the statistics of the American experiment, and detected no asymmetry.



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An overall view of the experimental equipment. The circular array of neutron counters can be seen towards the left of the photograph; in the centre is the cube shape of the magnet, which contains the spark chamber assembly, topped by the photographic apparatus. The whole set-up is surrounded by concrete shielding blocks to reduce radiation levels in the rest of the experimental hall.

Where are we now ?

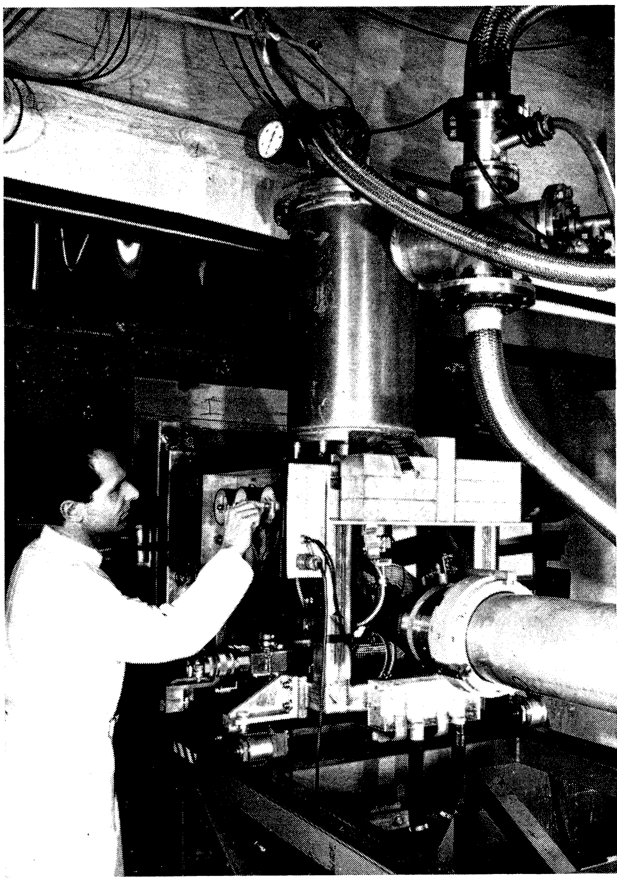
To conclude, let us summarize the present status of the different symmetries we have discussed, in the three interactions (see Table I). First, it is believed, and experimentally there has been nothing to throw doubt on this, that the reflection of all three — charge, parity and time — together (CPT) is a good symmetry. This emerges theoretically from the fundamental postulates of special relativity and quantum theory and if this combined symmetry is shaken it would undermine the foundations of modern theoretical physics.

In the weak interactions we know that P and C are violated and the combined CP seems to be experimentally violated in K^0_L decay but we do not know yet whether this is really a CP violation or whether is is due to an effect in the strong or electromagnetic interactions. If CP is violated, then T must be also, so that CPT will be safe; thus T also has a question mark under weak interactions.

The recent eta experiments have questioned whether C and thus CP is good for the electromagnetic interactions and, again to preserve CPT, it puts a question mark under T.

To complete the story we should mention the other ideas coming from the theoretical physicists — all aimed at resolving the observed CP violation in weak interactions. One idea breaks up the strong interaction into very strong and semi-strong and suggests that violations may occur in the semi-strong which are of the right order to produce the observed small scale violation with the K^0_L. Another breaks up the weak into semi-weak and very-weak and says that it is violation of the very-weak CP which gives the scale of the K^0_L observation.

The whole field of investigation is obviously in the melting pot but one can hope that the intensive research, at CERN and other Laboratories, on the various possibilities thrown up by the recent observations will soon clarify the present intriguing picture.



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Adjustments to the controls of a small magnet which is used (together with another in the beam line from the accelerator) to ensure, as far as possible, that the negative pions enter the hydrogen target along the axis of the experimental equipment. The path of the pion would otherwise be bent by the fringe field of the large magnet and elaborate arrangements would be needed to compensate for this effect. The straight pipe from the right brings the pion beam from the synchrotron and behind the small magnet assembly can be seen the large magnet containing the spark chambers which detect the pions produced in the decay of the etas.

Table I. The present status of the symmetries

INTERACTION	SYMMETRY				
	CPT	P	C	CP	T
Strong	✓	✓	✓	✓	✓
Electromagnetic	✓	✓	?	?	?
Weak	✓	X	X	?	?

News from Abroad

Base of the Pyramid Experiment

In 1965 a plan was put forward, by Dr. Luis Alvarez from the Berkeley Laboratory in the USA, to examine the Egyptian pyramids for hidden chambers, by means of a particle detection technique. It is reported in the July issue of 'The Magnet' that on 14 June the governments of the USA and the United Arab Republic entered into an agreement to proceed with the experiment.

The aim is to test one of the theories concerning the structure of the pyramids. These mighty monuments constructed some 4 500 years ago are still largely unexplored, which is not so surprising when one appreciates their colossal size. Some Egyptologists contend that the Egyptian monarchs ingeniously planned the pyramids, which were to be their tombs, to mislead predators in future generations into believing that the tombs had already been sacked.

If this deception theory is correct it could mean that the most exciting of the passageways and chambers remain to be discovered. Several of the now known upper chambers did in fact escape detection for thousands of years.

But how can one decide where to tunnel in the vast pyramids to have a good chance of finding a chamber? The idea of Alvarez, who is himself a keen Egyptologist as well as a celebrated physicist, is to 'X-ray' the pyramids by spark chamber analysis of cosmic ray muons. The muons will lose energy as they pass through matter in proportion to the density of the matter. If there are voids (which could possibly be chambers) in the structure they should show up, when the spark chamber telescope points in their direction, as peaks in the muon counts recorded by the spark chambers. If voids exist, Alvarez is confident that they can be detected and positioned to within a few metres. Tunnelers could then penetrate directly to the possible chamber.

Two wire spark chambers with magneto-strictive read out will be used and it is estimated that several months round-the-clock observation per pyramid will be needed. An iron absorber will be placed around the spark chamber assembly to stop muons scattered in the rock of the pyramid interfering with the readings.

The investigation will be carried out by an international team of scientists headed by Dr. F. L. Bedewi, a physicist from Ein Shams University at Cairo, Dr. A. Fakhry, an archeologist, and Alvarez himself. They will look first at the second pyramid of Chephren at Giza. This pyramid has a suspiciously solid structure, standing over 140 metres high with a base of side 216 metres, in which only one chamber has been found at the base. If the technique is successful the team may then move on to other pyramids such as the Great Pyramid of Cheops which is also at Giza.

The United Arab Republic, the US Atomic Energy Commission and the Smithsonian Institute are providing the finance, $ 250 000, for the research.

Desy

The seventh issue of the journal of the DESY Laboratory at Hamburg in the Federal Republic of Germany reports on the experiments and developments at the 6 GeV electron synchrotron.

One item of information concerns a major machine improvement. A contract was signed in July for a new linear accelerator for the synchrotron injector, which will raise the injection energy from 40 MeV to 300 MeV. The higher energy of the injector will increase the accelerated electron beam intensities from the synchrotron and the new linear accelerator will have the additional advantage of being able to inject beams of positrons as well as electrons. This will make possible a range of experiments with high energy positron beams at DESY for the first time.

Excavation work for the building to house the new injector has already started and it is hoped to commission the machine within three years. The existing 40 MeV injector will be kept in service and will be used whenever high intensities are not required. In this way, it will be possible to pursue development work on the new linear accelerator without interrupting the operation of the synchrotron.

CERN News

At the PS

Some information concerning operation and development at the proton synchrotron in the last few months.

For two weeks at the beginning of July, the machine operated at an energy of 19.2 GeV with a long flat top (200-300 ms) and achieved an average intensity of over 10^{12} protons/pulse. This is the first time such a high average intensity has been maintained for two weeks of operation. Only 3.2 % of the scheduled machine time in this period was lost due to breakdowns. Average intensities approaching 10^{12} protons/pulse have been reached in subsequent weeks but it is not known why beams of over 10^{12} cannot be regularly accelerated. Some of the operating time given to machine development is concentrating on 'beam loss measurements' in an attempt to determine why high losses are experienced in the first 20 ms after injection.

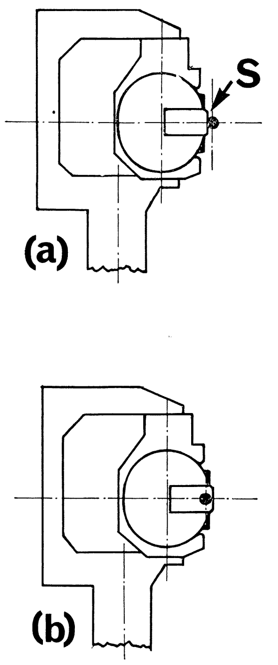
The new type of ion source, the duoplasmatron, which was installed during the long shutdown at the beginning of this year (see CERN COURIER vol. 6 no. 5 (May 1966) p. 88) has been working extremely well. The number of faults connected with the source has halted operation for only a few hours in 1700 hours of PS time. One very pleasing feature of the performance of the source has been the 'life' of the cathode. It was expected that it would be necessary to change the cathode filament fairly frequently but the present cathode has given 2050 hours of service so far, without any signs of deterioration. The 50 MeV linear accelerator reliably injects 80 to 100 milliamps into the synchrotron and with this high beam intensity available, multi-turn injection is not, for the present, being used.

The ways in which the accelerated protons can be used to provide beams for the experiments have become more and more versatile. The most significant new feature of the machine operation programme is that beam ejection is now almost always used. A standard programme takes, say, five of the twenty accelerated proton bunches for fast ejection from the ring, uses some of the remainder onto a target in the ring to provide a short burst of secondary particles for bubble chamber experiments, and then divides the remainder between two separate targets to give long bursts of secondary particles for counter experiments.

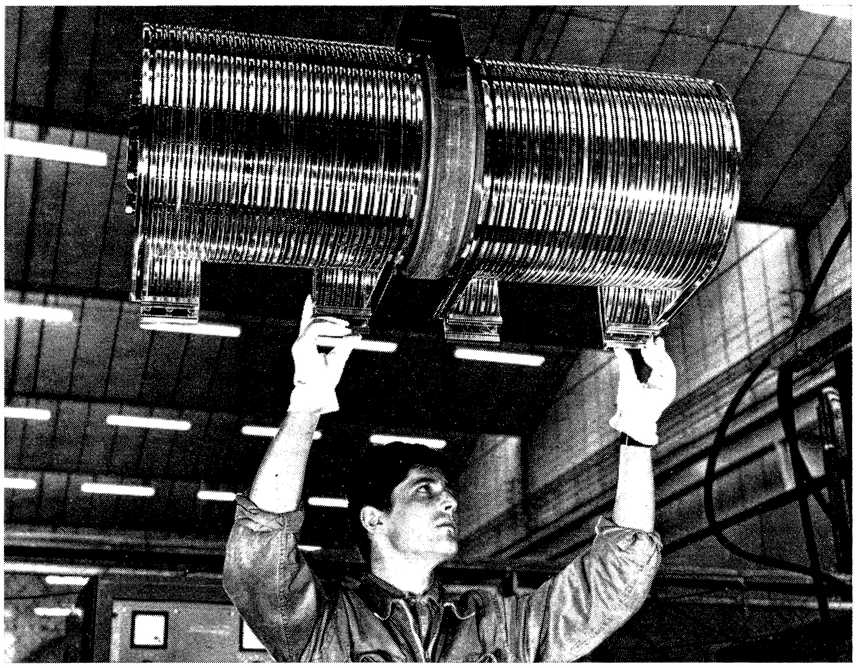
Within one machine cycle, consecutive short bursts have been obtained from two different targets by pulsing the same kicker magnet (R.B.D.-rapid beam deflector) twice. Moreover, beams of scattered protons at three different energies (13, 16 and 19 GeV) have been supplied to the 2 metre hydrogen bubble chamber.

Work continues on the development of an ejection magnet with a very thin septum. This type of magnet will be used in the slow beam extraction system of the proton synchrotron from straight section 62, which is otherwise similar to the system in straight section 58 described in detail in CERN COURIER, vol. 5, no. 10 (October 1965). The figure below indicates the role of the septum which is a thin current-carrying plate fixed across the aperture of the magnet to cut down the fringe field almost to zero outside the magnet aperture, so that it has no influence on the circulating beam.

The existing septum magnet has a septum 3 mm thick, which is sufficiently thin for fast ejection (where the beam jumps across the septum due to action of a fast kicker magnet).



Schematic diagram of the way in which a septum magnet is used. At (a), the beam passes just outside the septum S where the effect of the magnet is almost nil, at (b) the beam has been deflected by the kicker magnet so that it passes inside the septum, comes under the full influence of the magnetic field, and is ejected from the accelerator.



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An improved version of the kicker magnet (or rapid beam deflector) used in the fast extraction system of the proton synchrotron. Work on this improved version has been carried out in the NPA Division and the magnet is seen here being transported for voltage tests to a vacuum box which is identical to the box in straight section number 97, where it is eventually intended to place the new magnet. If all the preliminary tests go well, it may be installed in the synchrotron early in 1967.
The magnet has a bigger horizontal and vertical aperture than the version in use at present and will give a better pulse shape. This improved performance gives more margin for error in beam position and magnet setting. Also the magnet has been constructed using a minimum of organic materials to reduce the likelihood of deterioration due to radiation. The older version uses polyethylene and oil as dielectric in its capacitor arrangement and these show signs of deterioration. With the increase in beam intensity scheduled in the PS improvement programme, this could become a considerable problem.
The photograph shows a rear view of the magnet (the beam aperture being on the opposite side) and the condenser plates of the co-axial conductor can be seen along its length. The vacuum in the PS, as opposed to oil, will be the insulator. The magnet is constructed in two identical parts and it is being held by the mechanic at two of the positions where the power is fed in.

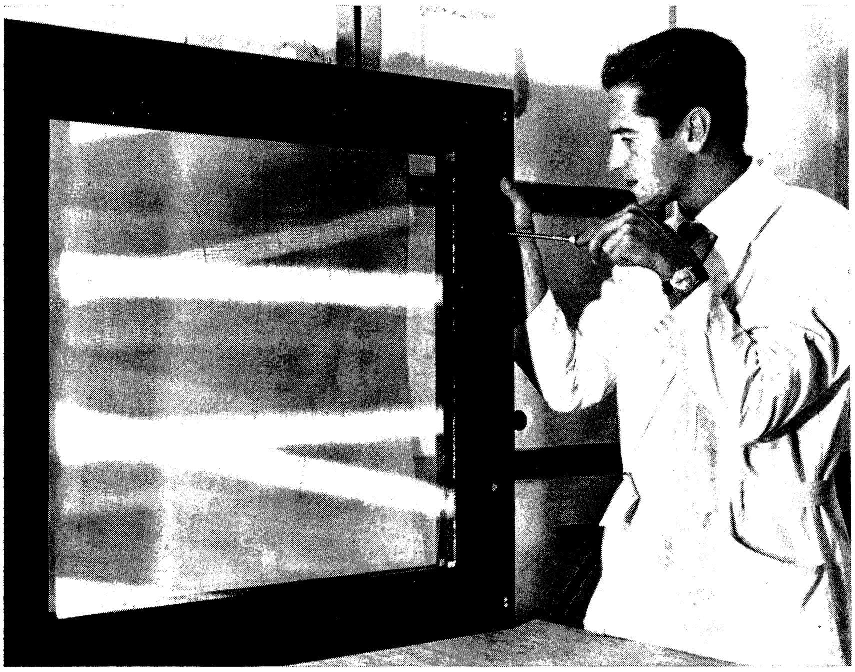
In contrast, this septum limits the efficiency of slow (multi-turn) ejection to about 70 %, a value considered too low because of the radio-activity induced by the high proportion of the beam which is lost. To improve this situation a new first stage of deflection will be added. The task of this new magnet is to deflect the particles just enough to miss the 3 mm septum. As this deflection is small, the septum can be as thin as about 0.2 mm, thereby increasing the theoretical slow ejection efficiency to above 95 %. To improve the beam optics, the magnetic field across the aperture varies from about +400 gauss (at the septum) to –620 gauss, the gradient being 600 gauss/cm. Therefore, this new magnet is being referred to as a septum lens.

The septum will inevitably get hot, because of the current which it carries and the bombardment by high energy protons, but, to keep the septum thin, it cannot be water-cooled directly. Thus the heat has to be dissipated by water-cooled conductors in good thermal contact with the septum at the top and bottom. The thermal contact must provide sufficient electrical insulation to hold off about 20 V. The insulation has also to have good mechanical resistance to abrasion since the septum dilates at each pulse as it heats up whereas the water-cooled conductors to which it is joined do not move.

Different insulating materials and manufacturing methods have been attempted and the best results were achieved using a thin layer of aluminium oxide (0.1 to 0.2 mm thick) sprayed onto the water-cooled conductors. This solution should withstand many millions of magnet pulses without appreciable wear. With the required current fed to the magnet, the mean septum temperature becomes as hot as can be allowed (95° C). There remain however some hot spots (145° C max.). It seems that at these spots only a small part of the septum surface, where the heat transfer should take place, is in contact with the water-cooled conductor. The manufacture of the septum is now being improved to ensure good contact everywhere.

Down to Earth

Near where the road crosses the proton synchrotron ring by the North Hall, it looks as if some mathematically minded moles have been at work. Along the circumference of the ring and going radially outwards an array of holes has appeared in the ground.



A two-gap wire spark chamber assembly. It is to be tested in an experiment, scheduled to run on the proton synchrotron in November, looking at the decay modes with a γ or π^0 of the η^0, ω^0, X^0 and $\varnothing^0$ mesons. The chamber will be placed in the field of the large magnet used in the charge symmetry experiment reported in the main article of this issue. Use in a magnetic field has had a great influence on the design of the chamber and, if the chamber proves successfull in operation, it will be a major factor in any decision concerning future large magnet spark chamber projects. Spark chamber techniques are developing rapidly. The chambers in use are still predominently of the optical type, where the sparks formed in the wake of charged particles are photographed, but these have the disadvantage of rather slow measurement and analysis. Sonic spark chambers, which use the sound of the spark to position the particle, gain by presenting the required information immediately as an electronic signal but have difficulty sorting out several sparks occurring at the same time. The new wire chambers can cope with several sparks and again present their information in electronic form. The chamber photographed here uses magnetostrictive read-out (see CERN COURIER vol. 6 no. 3 (March 1966) p. 43).
The bands of light, which can be seen in the photograph reflected from the planes of wires in the chamber, show the directions in which the wires are laid (the horizontal bands coming from wires set in the vertical plane, the other bands from wires at angles to the vertical). The chamber will be positioned in a magnetic field and the magnetostrictive read-out wire will not operate if it lies in the direction of the field – hence, the planes of wires cannot be laid simply horizontal and vertical.

The moles are in fact a team of scientists interested in doing a detailed, systematic experiment to learn more about the properties of the PS earth shielding as a protection against particle radiation. The experiment is a collaborative effort in which R. D. Fortune of the ISR-300 GeV Study Group is organizing the extensive CERN facilities required and coordinating the work of the different laboratories involved. Berkeley, USA, is providing the major share of the manpower and of the instrumentation with a strong team led by W. S. Gilbert. R. H. Thomas with a team from the Rutherford Laboratory and K. Goebel of the Health Physics Group are also participating. Earth is obviously cheap and plentiful and, especially when considering the large scale of the coming generation of particle accelerators, it is the shielding to use where possible. However, results from shielding measurements at Brookhaven, Saclay and CERN do not fit together very well and there is need for a carefully planned experiment to sort out the problem.

The following extract from the interim report of Working Group 2 of the European Committee for Future Accelerators indicates the importance of the present experiment for the 300 GeV accelerator project.

'The calculation of shielding for the accelerator and experimental areas, and the design of access tunnels depends, among other things, on knowledge of both transverse and longitudinal attenuation lengths, build-up factors, dose spectrum outside thick shields and radiation attenuation in the tunnels. Present information on these factors is generally unsatisfactory and inadequate. The Working Group felt very strongly that more reliable information would help to avoid the need for a high degree of conservatism in shielding design, and could certainly lead to significant cost reductions. Therefore, it recommended that experiments on an adequate scale be carried out in the near future, for example, at CERN, to improve present information. The Working Group wished to emphasize the vital importance and urgency of these experiments. They should have at least as high a priority as normal physics experiments, with opportunity for data interpretation between runs to guide the course of the work.

A concentrated effort on shielding studies could, and should, be obtained by a collaboration of experts from the various interested European laboratories.'

The same kind of information is needed for the American 200 GeV project and it was in fact W. S. Gilbert from Berkeley who suggested doing the present experiment at CERN. The necessary machine time was accepted for the PS experimental programme by the Nuclear Physics Research Committee and data taking began on 29 September. Ten twelve hour periods at the rate of about one per week are planned.

The full accelerated 25 GeV beam in the PS is fired at a target in straight section 32. The experiment is thus unusual in being the sole user of the machine when it is taking data. Around the target, mainly down-stream and radially outwards, holes have been drilled in the earth at regular intervals out to a distance of 15 m from the ring. Into the holes are lowered tubes containing samples of carbon, aluminium, sulphur and gold. In each tube in the holes directly above the ring, the samples are regularly spaced (separated by earth) so that information about radiation in the vertical as well as the horizontal plane will be obtained. Holes to the side have samples only at beam height.

The principle measurement technique to be employed is known as 'activation analysis'. When the samples are subjected to particle bombardment some of their nuclei will be changed to form radioisotopes. Subsequent examination will reveal, by the radiation the samples emit, the radioisotopes which have been formed, and this in turn will give some measure of the intensity and the energy spectrum of the initial radiation to which they were subjected at the accelerator. To catch the short lived radioisotopes the samples have to be withdrawn quickly from the holes and taken to a special low-level counting room set up in the basement of the Health Physics building.

The experiment should yield some information about the intensity of the radiation and how it falls off (or is 'attenuated') as it passes through progressive thicknesses of shielding; how it is distributed in space (in the horizontal and vertical direction); what range of energies are involved; and what particle production processes ('build-up factors') go on in the shielding itself.

At CERN, Health Physics and Nuclear Chemistry personnel are also assisting in the experiment and several theoreticians are involved, particularly in work on the particle production processes at the target and cascade phenomena in the shielding. It is hoped to feed the future accelerator projects with more detailed and reliable information on which to base their shielding calculations.

The Hunting of the Quark

'Quarks' are the hypothetical particles which may underlie the apparent order among the many sub-nuclear particles we have identified up to now. The observed particles can be assigned to groups in a way which is often compared to the positioning of the chemical elements in the Periodic Table in the last century. Since this order exists it is felt that there must be some underlying reasons, as yet unknown, why this is so (just as the behaviour of the atomic electrons was the underlying reason for the order in the Periodic Table). In 1964, M. Gell-Mann and G. Zweig (then at CERN) independently suggested the idea of massive particles bound together in different ways to build up the particles we observe. Gell-Mann baptized them 'quarks'.

The quarks would have a very distinctive property. They would carry a fraction (one third or two thirds) of the unit of electric charge (e) carried by the electron. Such a fraction of the unit charge has so far never been observed (1). But, whether or not the quarks really exist, they are serving as a useful model in current theoretical work.

Since the initial suggestions were put forward, quarks have been looked for at CERN (see CERN COURIER, vol. 4, no. 3 (March 1964) p. 26) and elsewhere without success. All the experimental evidence indicates that the frequency with which free quarks occur is very low.

There have recently been two further investigations. The first was carried out by W. A. Chupka, J. P. Schiffer and C. M. Stevens from Argonne National Laboratory, USA, and reported in Physical Review Letters (4 July 1966). They examined three materials — iron meteorites, air and sea water — for any sign of stable quarks carrying charge $\frac{1}{3}e$ or $\frac{2}{3}e$. If particles carrying these fractional charges exist they would not be 'neutralized' by an opposite charge (as the negative electron charge is neutralized by the positive proton charge). Atoms with quarks would never become electrically neutral and the experiment attempted to detect them by passing the sample under investigation through an electric field sufficiently strong to extract fractionally charged atoms. No such fractional charges were observed and the result of the experiment set the concentration of quarks as less than 10^{-17}, 5×10^{-27} and 3×10^{-29} per nucleon for iron meteorites, air and sea water respectively.

A further experiment was carried out at CERN by A. Buhler-Broglin, G. Fortunato, T. Massam, Th. Muller and A. Zichichi and reported at the Berkeley Conference at the beginning of this month and in Nuovo Cimento letters on 20 September 1966. They examined cosmic radiation using a vertical telescope, with a sensitive area of 900 cm^2, consisting of six plastic scintillator counters and two spark chambers to look for events involving particles with either $\frac{1}{3}e$ or $\frac{2}{3}e$. The electronics of the telescope were arranged to detect fractionally charged particles. 40 000 pictures were taken in a useful running time of 850 hours but no quarks were found and the experiment set new upper limits for the existence of quarks in cosmic radiation as less than $1.5 \times 10^{-9}/cm^2/$steradian/second for quarks carrying charge $\frac{1}{3}e$ and $1.4 \times 10^{-9}/cm^2/$steradian/second for quarks carrying charge $\frac{2}{3}e$.

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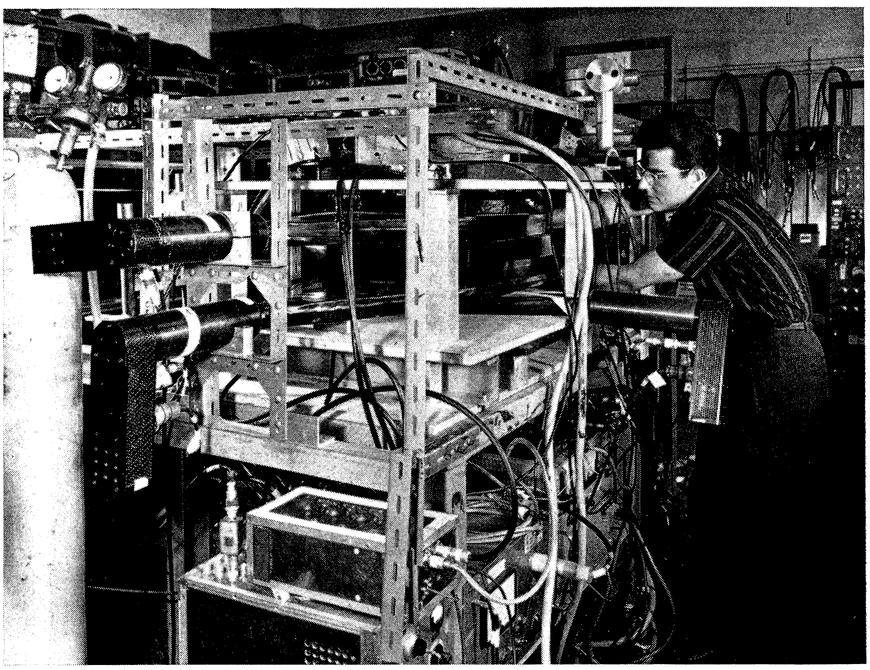
(1) The Argonne report quotes an interesting remark by Millikan when he made the first published measurement of the electron charge on water droplets in a cloud chamber — 'I have discovered one uncertain and unduplicated observation apparently upon a single charged drop, which gave a value of the charge on the drop some 30 % lower than the final value of e'.

The quark-hunting telescope. Adjustments are being made to the scintillation counters. The black shapes of six of these counters can be seen in the centre of the telescope and above and below them are spark chambers each with four gaps filled with a helium-neon mixture. The counters were arranged so that the plexiglass light guides which carry to the photomultipliers the light, which a charged particle makes in the scintillator, were not in line. This was because a particle of integral charge passing through the light guide gives a light signal of about the same intensity as could be expected from a quark passing through the scintillator. The two could be differentiated by looking at the spark chambers but to reduce the likelihood of unnecessary counts, the light guides were positioned as seen in the photograph.



CERN/PI 51.8.66

BOOKS

Introduction to space science, by the Staff of the Goddard Space Flight Center (NASA), USA, edited by W. N. Hess (New York, Gordon and Breach Science Publishers, 1965, 920 pages. No price indicated).

This book is one of eight already published in Gordon and Breach's professional editions which are for sale to individuals only. The series of hardback books is meant to enable individuals to purchase reference volumes for their own use at a price substantially lower than that of the books normally sold to institutions or libraries. The book starts, therefore, with a request from the publishers that it be retained solely for personal use and a warning that failure to comply may cause the publisher to exercise his legal rights.

The book is in three parts — the Earth and its environment; Space; the Solar system and beyond. The first part covers knowledge of the earth and the region of space near the earth extending roughly to 10 earth radii. The role played by satellites in the advancement of this knowledge is emphasized, for instance, by describing the studies of aurorae and of ion and atom distributions in altitude, latitude, type and time. It has been possible to gather information about the earth in ways and with a speed that could not be achieved from the ground; for example, world wide cloud patterns, the earth's magnetic field and the gravitational potential field.

The second part considers 'Space' roughly outwards from the edge of the pear-shaped magnetic field of the earth. The region between this magnetopause and the immediate solar environment shows interesting features: collisionless shocks, turbulance, particle acceleration processes, etc... Outside the magnetopause, the region is dominated by the sun and one finds the famous solar wind.

The chapter on cosmic rays should be read by anyone interested in high-energy particle production and acceleration or who desires an introduction to cosmology. An attempt is made to cover the properties and characteristics of the cosmic rays as known in spring 1965. Although extensive air showers and experimental detection problems, for instance, are not dealt with, the chapter gives a general idea of the state of knowledge and of some current areas of research. Active investigation, particularly of the production and propagation of low energy solar cosmic rays and the solar modulation of low energy galactic cosmic rays, is under way using sophisticated detectors carried on balloons and satellites. Interplanetary dust particles, cosmic chemistry, orbital mechanics and the advent of man in space to further the physical sciences, are other chapters in this section.

'The solar system and beyond' is the third and largest part. It deals with the planets in the solar system, the stars and galaxies. Much of the classical discipline of astronomy is covered here but the book reflects the fact that, although research has started in this field, the progress has been limited. Pictures of the moon have been taken from space and more data has been obtained on the atmospheres of Venus and Mars. However, much of the work is still referred to in the future tense: probes to study the atmosphere of the sun, large telescopes put into orbit above our atmosphere, etc. This part of the book is very well worth reading. There is an excellent chapter, with surprisingly little mathematics, on the origin of the solar system.

The chapter on space astronomy describes briefly the observational techniques and space flight instrumentation. But perhaps the most exciting part of the book is located in the last three chapters about stellar evolution, extragalactic radio sources and nucleosynthesis. The thought-provoking birth and death of a star, the mystery of radiogalaxies and quasars — tentatively explained as involving the explosion of supernovae or the gravitational collapse of superstars — and the mystery of the formation of the elements during the evolution of a star are all here, including, of course, a description of the ever present neutrino process looked upon as a kind of safety valve to carry away large amounts of energy from the interior of a high temperature star.

Materially, the book suffers from few printing errors although the quality of paper and offset reproduction is not always even. These are minor points, however, considering the immense amount of information supplied. Each chapter begins with a useful introduction and ends with a list of references extending to the end of 1964; existing knowledge of Soviet work in this field could have permitted reference to wider and more recent sources outside the 'western world'. Name and subject indexes conclude this excellent volume which should be a precious addition to the private library of any cultivated person. **R. A.**

Space Science and Engineering, a collection of lectures by seven scientists of the Marshall Flight Center, edited by E. Stuhlinger and G. Mesmer (New York, McGraw-Hill Book Company, 1965, 455 pages; $ 20).

This partial survey of space technology originated as a series of lectures at Washington University (St. Louis, Missouri) which constituted the first American course on space technology. The lectures presented the state of the art as it stood in 1961 and they have been brought up to date (early 1965) by the lecturers.

The topics discussed have been selected to cover the exploration of the universe beyond the dense layer of the Earth's atmosphere. The first 16 chapters — some of them, such as 'Cosmic Radiation' skeletaly short, — describe the physical features of outer space; they treat the physics of the lower atmosphere and then introduce the reader to the physics of the higher atmosphere and to the radiation phenomena in space. The reader will find in this 'science' half of the book a wealth of data as well as numerous references; most of the information would, however, have gained from a more thorough development even if this had meant expanding the volume by some 50 pages.

The second group of 16 chapters deals with the 'Engineering'. It comprises selected topics — orbits, instrumentation for physical measurements, propulsion and power problems are discussed in some detail. Altogether they offer a broad introduction to present space technology, though communication, guidance, materials and design have been omitted, presumably again in order to limit the size of the volume. The chapter on instruments for radiation measurements comprises a list of sub-nuclear particles — including the omega minus — and descriptions of detectors usable in space, i.e. excluding bubble chambers !

This book will be of interest to students and professional workers in science and engineeering, as well as to the layman who is already acquainted with some physics and mathematics. As such, it is perhaps less entertaining than the one reviewed above, but it remains quite informative to a mind open to one of the most striking scientific disciplines of our time. **R. A.**

High Energy Physics (Les Houches 1965), edited by C. DeWitt and M. Jacob (New York, Gordon and Breach Science Publishers Inc., 1965).

This book consists of the lectures delivered at Les Houches, France, during the 1965 session of the Summer School of Theoretical Physics of the University of Grenoble. The lectures contain material that will be of value to post-graduate experimental and theoretical physicists, although the school was intended primarily for advanced graduate students.

There has been a great proliferation of published lecture notes and reprints in the field of high energy physics in recent years; in fact, the growth rate of the literature often appears to outstrip that of new developments. This reviewer felt that the collection of lectures stands out both because the content is still, a year later, in the forefront of interest, and because a greater amount of pedagogical effort than usual went into the writing.

A broad range of subjects is covered. The first two chapters are concerned with symmetries and groups. G. C. Wick's contribution, entitled 'Group Theory, Invariance Principle, Symmetries', discusses space-time invariance principles, the Poincaré group and internal symmetries including isotopic spin and SU_3.

The second chapter, 'Groups combining internal symmetries and spin', treats recent developments in the search for still higher symmetry. In analogy with Wigner's SU_4 theory which combined spin and isotopic spin, the SU_6 theory combines spin and SU_3. As emphasized by Gursey, the SU_6 group cannot describe an exact symmetry of the S-matrix for arbitrary scattering processes.

The third chapter, 'Introduction to the Theory of Strong Interactions', contains lectures delivered by M. Froissart and R. Omnes. An enormous amount of material including potential scattering and analyticity properties, the Lorentz group, Mandelstam representation, and three particle interactions, is clearly and simply presented. These topics are not treated in isolation but are tied together in a manner that gives these lectures special value. 'The Analytic S-Matrix: a Theory for Strong Interactions' is the title of the fourth chapter which is written by G. F. Chew. With the previous chapter well understood, the reader should have little difficulty in following this presentation of the S-matrix theory. The emphasis in the treatment is on physical ideas rather than mathematical derivations.

Quarks are the subject of Chapter 6. These hypothetical particles could explain the 'periodic table' of the elementary particles if they exist. The lectures were delivered by R. H. Dalitz, who shows that some of the properties of many of the observed particles fit the assumption that they are composite states built up from quarks. The lectures should raise as many questions for the experimentalist as for the theorist.

The following chapter consists of two sets of lectures given by D. J. Jackson. The first set is entitled 'Particle and Polarization Angular Distribution for Two and Three-Body Decays' and its purpose is to show how a spin-parity analysis of two and three body resonances can be made from a knowledge of the distributions and polarizations of the decay products. This material should be of particular value to experimentalists. The second set is concerned with 'Peripheral Interactions' and is a short introduction to the peripheral model of high energy scattering, supplemented with a reprint of a review article by Prof. Jackson on the same subject. The 'Theory of Weak Interactions' is discussed by J. S. Bell in the final chapter. The material covered is reasonably up-to-date and includes results from current algebras, and a detailed discussion of CP violation and the K-meson complex, as well as a good review of historical developments.

While most physicists did not have the opportunity to absorb these lectures amidst the beauty of the French Alps, they now fortunately have the chance to read them in this worthwhile book. **J. H.**

Dynamical Theory of Groups and Fields, by Bryce S. DeWitt (New York, Gordon and Breach Science Publishers Inc., 1965; paper $ 2.95, cloth $ 5.95).

This book is based on lectures given by the author at the Les Houches Summer School in 1963. As compared to the lectures which have already been published in the proceedings of that school (Relativity, Groups and Topology; Gordon and Breach, 1964) the manuscript is enlarged by one short chapter. The form of this book is neither that of a textbook nor an introduction to current research, since only few references are given. Nevertheless, it seems to us to be very useful as it deals with subjects which are spread over many different journals and textbooks in the literature.

The different topics are discussed from one central point of view, that of invariance groups with an infinite number of parameters. These groups are called pseudo-groups by the mathematicians. Two examples of such groups are well known to physicists: the gauge groups of electrodynamics with a gauge function depending on space and time, and the general co-ordinate transformation group used in the general theory of relativity. Instead of the gauge group with scalar gauge function, the author makes use of the more general notion of Yang-Mills groups or non-abelian gauge groups. These transform particle fields at a fixed point according to an irreducible representation of a compact simple Lie group and let the group parameters vary as functions of space and time. All gauge groups necessitate the introduction of compensating fields. In the simplest example the electromagnetic potential is such a field, for non-abelian groups we obtain the so-called Yang-Mills fields. In the case of co-ordinate transformations the affinities serve as compensating fields.

The author develops a theory for the combined system of one particle field with abelian or non-abelian gauge invariance in a curved space interacting with its compensating fields, the Yang-Mills fields and the gravitational fields. His ultimate aim is the quantization of this system.

The book begins with the Lagrangian formalism of classical field theory. A review of the theory of measurement in the manner of Bohr and Rosenfeld prepares us for the transition to the later quantum treatment.

A conventional formulation of quantization of free fields, a discussion of Lie groups and their generalization to infinite parameter groups provides the language for the second half of the book. There the author studies the quantization of the field system and scattering matrix. The latter matrix is introduced by means of a LSZ formalism. Deviations from flat space-time are taken into account by perturbative methods. The main problems are connected with renormalizations when additional invariance under gauge groups is required. The problems involved are not completely solved, but interesting outlooks are given.

Finally, we remark that the book, particularly in the notations, profits much from Schwinger's work. The elegance of the notation should not, however, make the reader forget that the mathematical rigor is rather low throughout. **W. Rühl**

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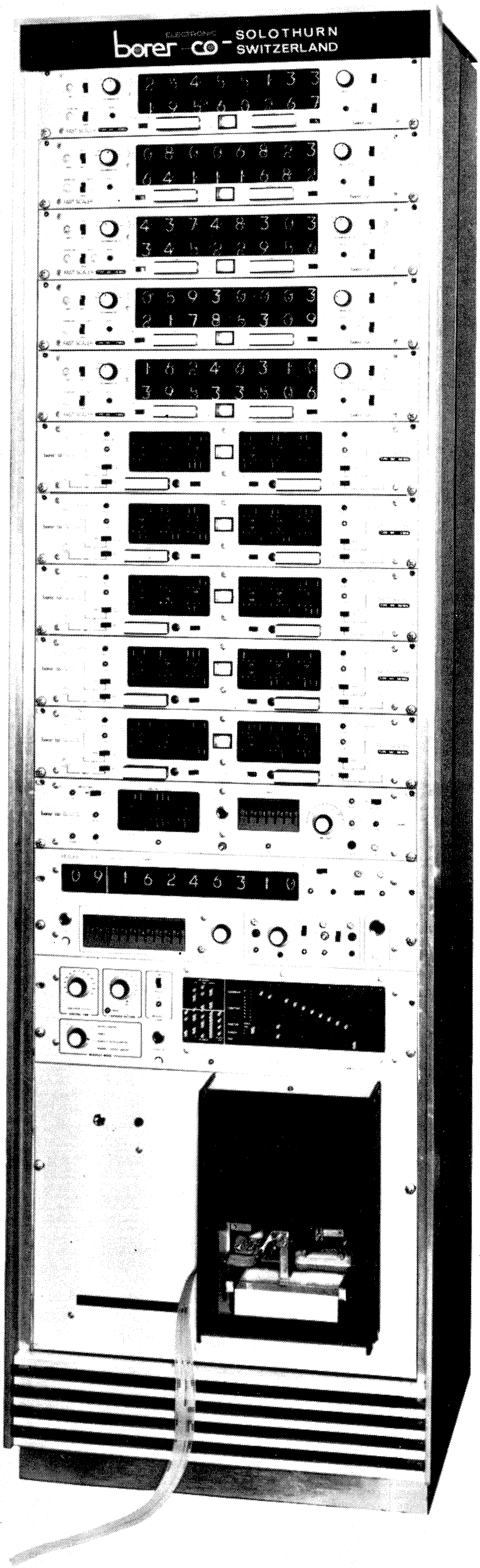

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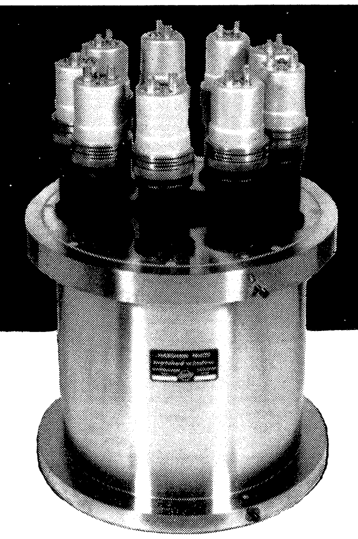

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THERMAL CONDUCTIVITY Cal/sec. cm² °C at 0°C	500×10^{-4}
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* P. Brinckmann, Physics Letters, Vol. 15, No. 4, 305, April, 1965.

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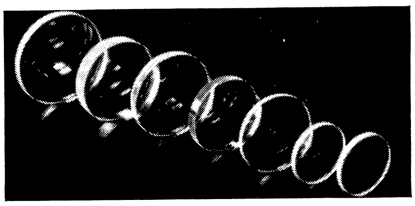

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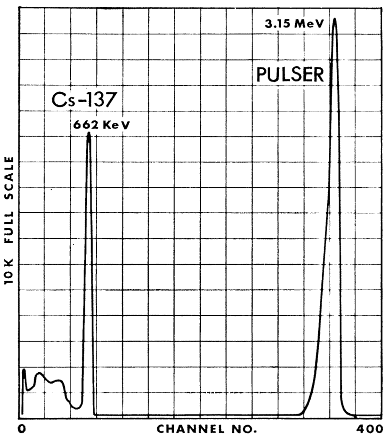

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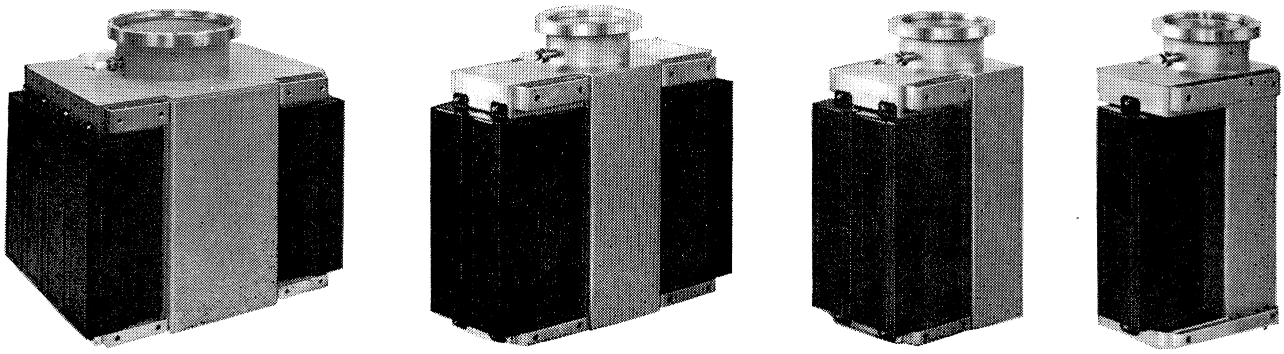

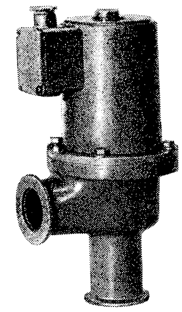

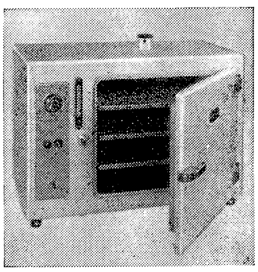

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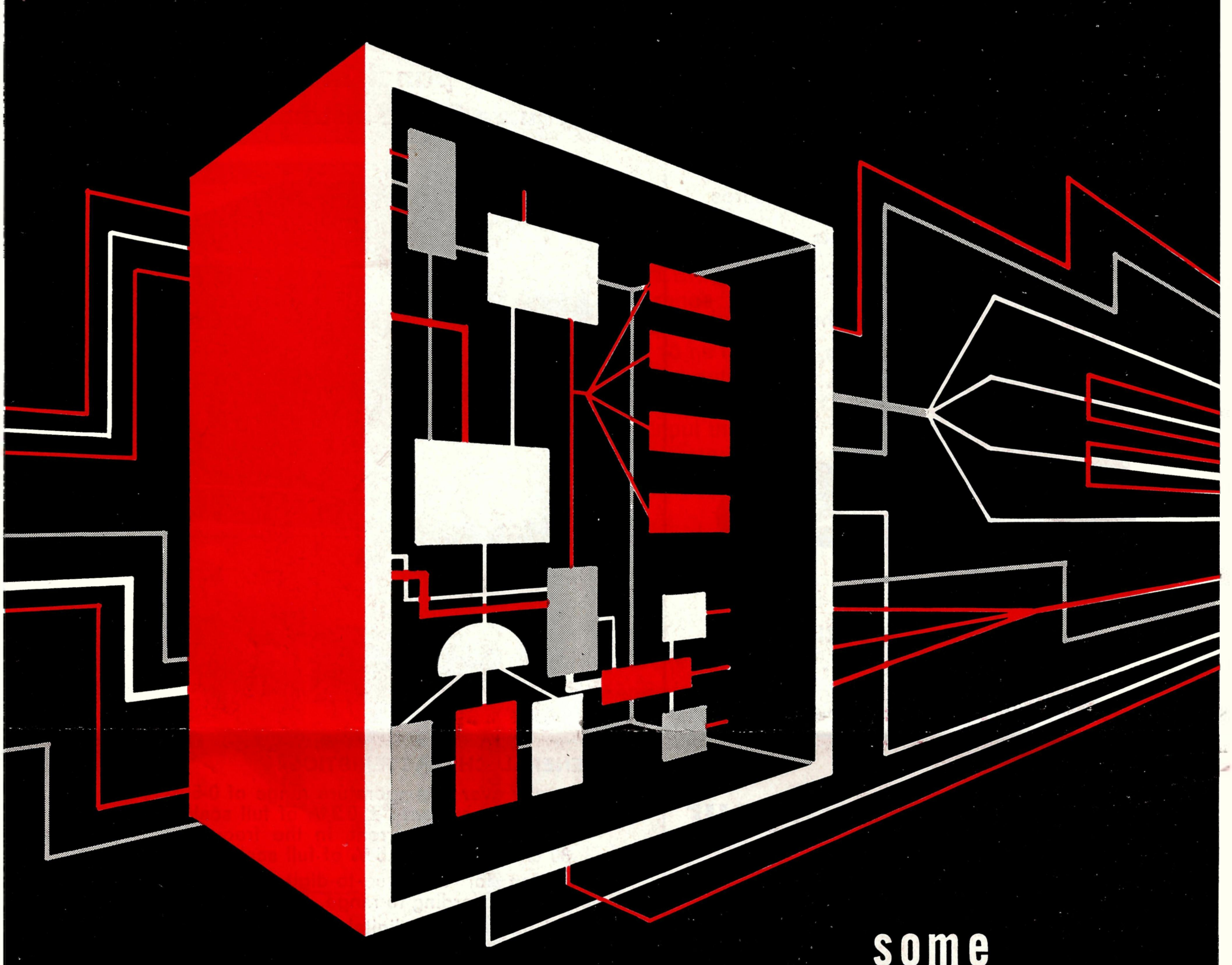

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Europe: 39 Rue Rothschild, Geneva, Switzerland (022) 31 81 80 TELEX 22266