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'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.'

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The cover photograph, taken in the North experimental hall of the CERN proton synchrotron, shows part of the counter experiment in search of a possible 'resonance' in the reaction between a pion and a deuteron to produce two protons. Inside the blockhouse in the centre of the area, a beam of pions with momentum between 0.6 and 2.0 GeV/c strikes a target of liquid deuterium (heavy hydrogen). Unseen and unheard, the products of the interaction emerge through two long slits in the sides of the blockhouse; no-one is allowed inside the outer wall of concrete blocks. Six pairs of detectors, large slabs of plastic scintillator mounted on photomultipliers, stand guard around the target. Four of them can be clearly seen. They relay information, to the physicists outside, on the angular distribution of the particles emitted from the target, and on the time (measured in thousand-millionths of a second) taken for each one to travel from the target to the detector.

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Last month at CERN

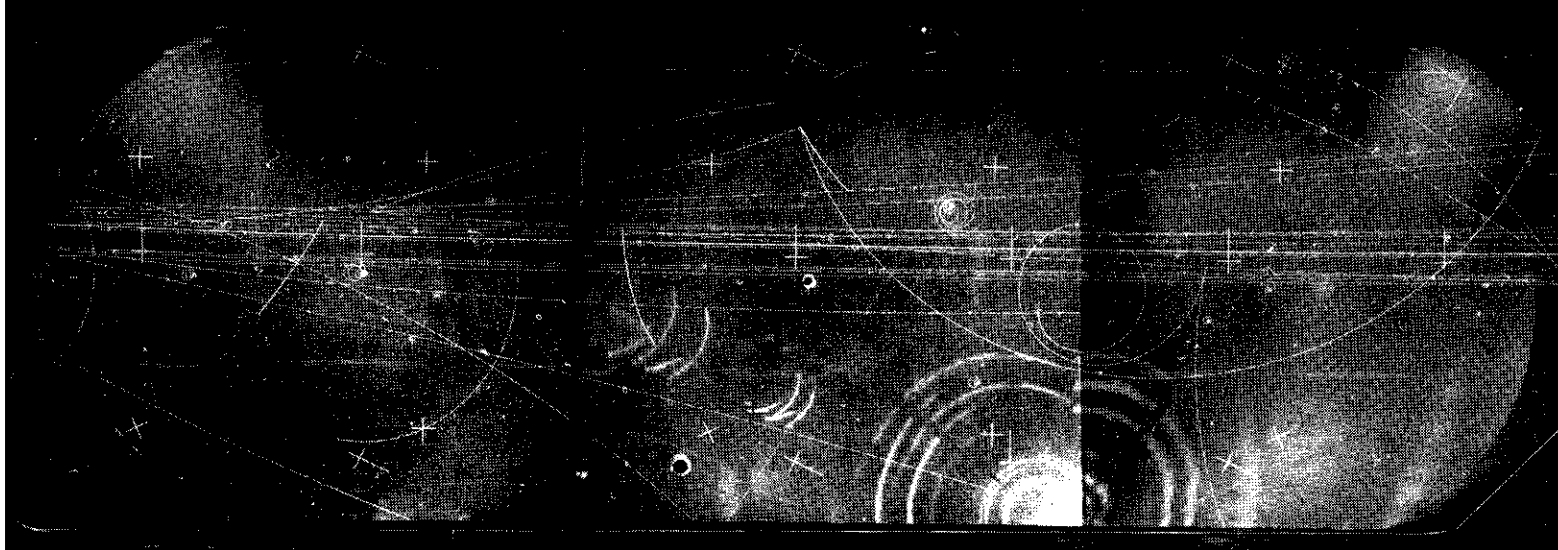
For most of the year at CERN, work goes on normally and, because few people are directly concerned, the fact that one or other of the experimental groups is at that moment discovering something new goes relatively unnoticed. In February, however, a number of events combined to provide the kind of excitement for the physicists that more than makes up for the long periods of monotony and to make the rest of the staff somewhat more aware than usual that interesting things were happening.

The clues to part of the excitement had, in fact, been available in the library for a week or two, in the form of 'pre-prints' of two theoretical papers, one by **M. Gell-Mann**, of the California Institute of Technology, U.S.A., and the other by **G. Zweig**, of the same Institute but at present a Visiting Scientist at CERN. Gell-Mann's paper was published in *Physics Letters* on 1 February; Zweig's, the more detailed of the two, is expected to appear later in *Physical Review*. Produced independently, both papers put forward a possible new way of looking at the theory of 'unitary symmetry' known as SU_3 .

The application of this theory, notably in the particular form known as the 'eightfold way', has enabled a considerable amount of order to be brought into the chaos created by the discovery of so many new, supposedly 'fundamental', particles during the past few years. SU_3 itself is a particular branch of a whole set of related systems of algebra developed by the Norwegian mathematician Sophus Lie nearly a hundred years ago. The symmetry properties of fundamental particles and the rules developed for quantum-mechanical calculations have been found to be closely related to some of the Lie algebras and to SU_3 in particular. Specific properties of particles can be represented by certain quantum numbers which can take only certain values, and application of the algebraic rules to these numbers then groups all the strongly interacting particles in a definite way.

Unfortunately, the parallel between physically observed particles and mathematical theory is not exact; in particular, although in SU_3 all positions in the groups arise from a set of three fundamental entities, in physics even such old-established particles as the proton and the neutron can only belong to a set of altogether eight particles, forming one of the Lie groups. There seem to be eight basic particles instead of three. The suggestion of both Gell-Mann and Zweig was that fewer outside restrictions should be imposed on the algebra. They assumed that all known strongly interacting particles could in fact be made up from just three basic units, combined in different ways. They then worked out the properties that such units would have, and found that they would be similar to the proton, neutron and lambda particle, except that their baryon number would be $1/3$ instead of 1 and their electric charge would be $2/3$, $-1/3$ and $-1/3$ respectively, instead of 1, 0 and 0 (in units of the electron charge).

It was this last property that caused the stir. From the time of Millikan's classic experiments in 1911 (repeated by generations of students since) it has been accepted that the charge of the electron is the smallest one possible and that all others are integral multiples of this unit (positive or negative). The new ideas had a basic simplicity that was very appealing, and difficulties that had had to be explained away in the former versions of the theory did not seem to arise this time, yet the idea of fractionally charged particles seemed quite preposterous. Even those who had suggested it seemed to share the doubts; Gell-Mann called his new particles 'quarks', bringing together literature and science with a reference to *Finnegan's Wake*! Zweig turned to the field of card games for inspiration, and called his particles 'aces', with their combinations 'deuces' and 'treys'. At least one person found the whole situation too much, and the following contribution to the discussion appeared on the notice board of the Theory Division:



One of the early photographs taken with the British 150-cm hydrogen bubble-chamber at CERN. Protons with a momentum of 15 GeV/c enter from the left of the picture and some of them interact with protons in the chamber. The fineness of the tracks and the advantage of a chamber of this size for seeing all the stages of a complex series of

events can be gauged from this example, though it shows nothing spectacular. One of the problems remaining is to reduce the general background of light and the unwanted reflexions that might make measurements difficult in some circumstances.

CERN/TC (PI 14/364)

OH, HORRIBLE THOUGHT

Think of the words that our subject is fraught with,
Words that old Webster would never be caught with,
Ladders and tadpoles and majorization,
Bootstraps and buddahs and peratization,
Hafnians, pfaffians, some think it's drollish,
Why, half of the world speaks Regge Polish!
Things are so bad that I must protest it,
From Joycean footnotes, please give us some respite!
Oh, horrible thought if in nature 'tis observed,
That the quarks and the aces,
Keep changing their places,
And charge seems never conserved!

Anon

From the **experimentalist's** point of view, the excitement lay in the prediction that at least one of the new particles would be stable. This quark, or ace, if produced in a reaction between high-energy particles, would behave like the known charged particles, but if its charge was only one-third that of a proton its ionizing power (and therefore the number of bubbles per centimetre along its track in a bubble chamber, for instance) would be only one-ninth, for the same apparent momentum. Of course aces might still be very rare, or their mass (which could not be predicted theoretically) might be too high for them to be produced with present-day accelerators. Nonetheless, the Electronics Experiments Committee, meeting on 11 February, decided that aces should be taken seriously, and that same afternoon the particles provided an unexpected subject for the weekly 'Experimental Physics Discussion'. Here G. Zweig explained his theory, and two proposals for experiments, from groups led by G. Cocconi and A. Zichichi, were described.

Some people felt that if aces existed then they ought to have been seen in at least one of the millions of bubble-chamber pictures already scanned for other experiments, though it was also

reasoned that they could have been missed if the scanners were not looking specifically for them. In any case it quickly became clear that the combination of a bubble chamber and the O_2 beam in the PS East hall provided the quickest way of looking for the particles. Some time in March the PS will be run at almost its full energy and the O_2 beam (without the electrostatic separators) will be set to accept high-energy negative particles (mostly pions) from the internal target and direct them into the 81-cm Saclay/École Polytechnique bubble chamber. The pions will provide the calibration tracks against which that of a quark, ace, or any other fractionally charged particle could be compared.

While working on this proposal, D.R.O. Morrison realized that the same kind of bubble-chamber exposure had in fact been carried out with the CERN 32-cm chamber in 1960. The photographs were got out and a team of physicists and scanners looked through 10 000 of them in one night. No aces were found. Inspired by this search, the group working with the École Polytechnique heavy-liquid bubble chamber then scanned a set of 100 000 photographs. Again the result was negative, leading to the conclusion that particles with charge $1/3$ are produced at least a million times less frequently than antiprotons at the higher PS energies. The possibility was also raised that the aces might be formed in weak interactions rather than in the strong ones investigated in these two searches, in which case the arrangement of the CERN neutrino experiment would be ideal for their detection. Accordingly, the photographs of about 300 neutrino events in the CERN heavy-liquid bubble chamber were looked at again, but still no tracks with too few bubbles could be found.

The **theorists**, meanwhile, had not been idle, and by the end of the month H. Bacry, J. Nuyts and L. Van Hove had produced a paper showing that if two sets of three particles were taken as fundamental building blocks, instead of only one set, then fractional charges were no longer a requirement. Zweig's aces and Gell-Mann's quarks may or may not be found, but obviously their ideas have triggered off a new series of moves in this search for an explanation of the occurrence of the so-called fundamental particles.

Adding point to the discussion was the news from Brookhaven in the middle of the month that two examples of the **omega-minus particle** had been discovered in photographs taken with their new 80-inch (200-cm) bubble-chamber. This particle, which has rather unusual properties, had been predicted by the 'eightfold-way' theory and was the last one needed to complete a group of ten particles. Its discovery showed that the use of unitary symmetry to gain insight into the relationships between particles was indeed justified, and that further investigations would be well worth while. Of course, at CERN, the satisfaction of knowing that the omega really existed was tempered with a certain amount of disappointment, not to say envy, as two bubble-chamber runs last year and another one in January had been carried out here to look for the particle, but several hundred thousand pictures had so far provided no trace of it.

During all the excitement over aces and SU_3 , other groups of physicists and engineers working at the **proton synchrotron** also had more immediate things to concern them. For the first time since last September the **fast ejection system** was to be used again for the proton

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BOOKS

Sonnenenergie, by H. Rau, (Mainz, Krauskopf-Verlag, 1962; DM. 12.80).*

In its airy manner this delightful little book possesses certain attributes of a soufflé. While consuming it, one has that sense of well-being which only a tasty morsel can convey, and on finishing it, one is pleasantly replete. But one very soon develops a craving for more. So with this book: it acts as an *apéritif* without really answering all the questions.

The author is obviously endowed with the gift of being able to convey to the reader a relatively large amount of information, requiring the minimum of effort on his part to understand and to absorb. This is no idle compliment: we note that the book is written in German, a language more fitted for semantic acrobatics than for an exercise in simple expression. Mr. Rau had rightly decided to tackle his subject from the 'Ur-beginning' and to leave no fact

* We understand that Dutch, English, and Italian editions are also available, or will be shortly, and that editions in Croat and Arabic are in preparation.

untouched, however insignificant. The result is not only a formidable table of contents but also a tidily written book which it is a pleasure to read.

The opening chapter, not unexpectedly, discusses the need for new sources of energy. The next deals with existing 'stocks' of energy and on we go, relentlessly. A quick look at the mythology and what our ancestors thought of the whole affair, then a little physics of the sun, followed by the first pioneers who attempted to harness solar energy for other purposes but human sacrifice. (Curiously, the author does not mention the Mayas or the Aztecs, who, after all, were the experts in this field. But that is unimportant). The technology and economics of solar energy, with all their ramifications, form the backbone of the book. Photobiology and the rocket strato-probe experiments are mentioned, and the book ends, inevitably, with an outlook on the future. All this information is carefully packed into some 170 pages, including some very fine illustrations, both photographs and line drawings, and a truly magnificent bibliography. Is one permitted to wonder whether the author has indeed read all the material he lists?

Strangely enough it is just this extensive bibliography which is the main weakness of the book. The author had evidently decided that the reader for whom the book is intended would rarely if ever bother to look up one or the

Last month at CERN (cont.)

beam. A new central conductor, designed to increase the number of neutrinos produced at higher energy, had been put into the magnetic horn, and a completely new arrangement of spark chambers had been installed for further measurements on **neutrino interactions**. In the event, everything worked well, and very soon the scanners were busy again, picking out photographs of neutrino interactions obtained both in the spark-chamber array and in the CERN heavy-liquid bubble chamber. The spark-chamber set-up now includes one section of chambers interspersed with magnetized iron plates, intended to provide a good distinction between positive and negative particles arising in the interactions. Altogether, the arrangement contains more than 100 tons of material.

In the East bubble-chamber building, another centre of activity was formed by the **150-cm British bubble-chamber**, filled with liquid hydrogen again, cooled to -246°C , and producing high hopes of a good run. The decompression and recompression cycle was successfully put into operation, and the cycle time afterwards reduced to once every two seconds. After about 24 hours testing like this, particles from the o_2 beam were introduced into the chamber and conditions adjusted to give the best tracks. Later the magnetic field was turned on, and finally the automatic cameras tested. On 22 February several

thousand photographs were taken with incident protons. But a number of small troubles made it less clear that the chamber would be able to run continuously for several days at a time and, rather reluctantly, the beam was switched to the 81-cm Saclay/École Polytechnique chamber for the physics experiments scheduled.

This period was also of particular interest since, for the first time, a bubble-chamber experiment at the PS was being carried out simultaneously with the neutrino experiment. By using the '**rapid beam deflector**', a small part of the circulating beam was directed at the target serving the o_2 beam shortly before full energy was reached; this was then followed by ejection of the full-energy beam in the usual way.

Missing from last month's issue of *CERN COURIER* was the news that electrons had been successfully 'stacked' in the **electron storage-ring model, CESAR**. Towards the middle of January the circulating current from a single pulse of the Van de Graaff injector was accelerated slightly by means of the betatron core, so that it circulated on an orbit of larger diameter, but oscillations of the beam were building up to large values and soon causing it to be lost. With a shut-down for maintenance and alterations scheduled for 31 January, there was little incentive for a full investigation of the reasons; instead, by manipulation of some two dozen

different magnetic corrections around the ring, it proved possible to accelerate the beam to the full energy determined by the 7-cm width of vacuum chamber available. Whereas the betatron core accelerates all the particles circulating in the ring, the radiofrequency system accelerates only those electrons which have about the right energy. This system was then tried out, and 20 successive pulses were injected into the ring and 'stacked' into adjacent orbits. After this, measurements were made on the lifetime of the circulating current, for single turns in different positions and for multiple turns, and the second radiofrequency system, intended for phase-space analysis of the stacked beam, was successfully tested.

These preliminary experiments completed the 'running-in' phase of the storage-ring, and their success provides grounds for believing that CESAR will prove an extremely useful experimental device. During the subsequent shut-down, the 2-MeV Van de Graaff was completely dismantled and rebuilt, with many new components. Among many other jobs, the whole of the vacuum chamber also had to be dismantled, for modifications to the clearing-field electrodes, and several new targets for measurement of the beam position were added. Insertion of a new inflector tank should enable the pressure to be reduced for the first time to 10^{-9} torr or better, giving much longer beam lifetimes when experiments are resumed ●