

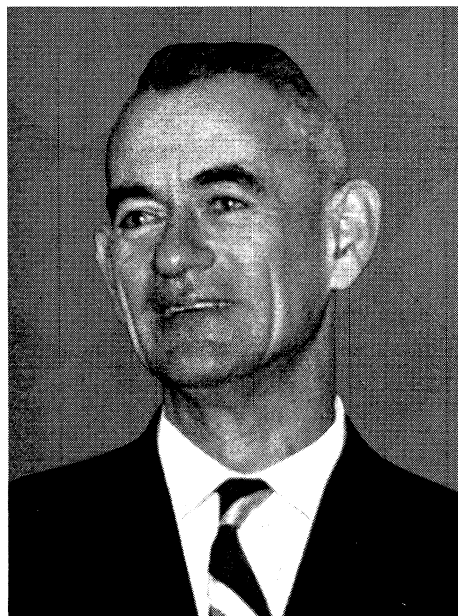
'Resonant States' at the Aix-en-Provence Conference

New outlook in
elementary-particle physics

by Louis LEPRINCE-RINGUET

Prof. Leprince-Ringuet, who is a Professor of Physics at the Ecole Polytechnique, Paris, has been vice-chairman of CERN's Scientific Policy Committee since its formation in 1954. He is a member of the Académie des Sciences.

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The memory of the splendid Physics Conference that was held last September at Aix-en-Provence will take a long time to fade. Everything was in its favour : the gathering of five hundred nuclear physicists, nearly all of them very young, engaged on elementary-particle research in all the universities of Europe ; the interest of the working meetings, and of the impressive plenary sessions which ended the Conference like a firework display in the hands of some of the great stars of the world of physics ; the most friendly welcome of the University of Aix-Marseilles, of the Municipality of Aix, of the Navy, who arranged the sea cruise on Sunday ; and of course the charm of this region of Provence in mid-September.

This was the first time that all the young nuclear physicists of Europe had met together ; those whose work is concerned with the great European Organization for Nuclear Research and its giant accelerator at Geneva, those from the important national centres, which certainly have their place, and also those from the less-endowed laboratories of the provincial universities. For the problem is this : a great new movement has sprung to life in European scientific research, developed during the last few years solely through the notable achievements of CERN, which has succeeded in raising the level of science in Europe to that of the two great blocs. CERN is not alone in Europe, however ; in several large institutes important work may well give results of international standing from time to time. Then we have the main bulk of European universities, which are in a difficult situation. It is not easy for them to participate in the big experiments, which need so much experience and equipment and require the collaboration of large and strong teams. Sometimes they are not even aware of what is going on in the larger centres ; they do not know which methods are used or even the subjects of research. On the whole they ignore the spirited nature of present-day research and the way the

principal items on the programme change so rapidly. Whilst the physicists who work at the frontiers of scientific progress see the centre of interest in elementary-particle physics shifting from year to year, and beset it constantly with significant experiments, the physicists who are somewhat isolated in their universities, and often more attached to their teaching duties than to the possibilities of research, see science flowing along with a slower and a quieter rhythm.

To animate these universities, who not only wish to bring themselves up to date in the marvellous developments of modern physics, but would also like to take some part in them, it is necessary above all to lay the foundations for a lively relationship between them and the other groups. That was the basic idea of the Conference at Aix.

It is well known that for more than ten years a large international gathering has been held each year in the United States, at Rochester, on the shores of Lake Ontario, bringing together the most famous physicists in the world. Very few young people have been there ; it was felt that the meeting should not be allowed to grow too large, becoming a kind of fair on the model of some of the large assemblies of the American Physical or Chemical Societies. Hence only a few representatives of the biggest centres were present. Between 1945 and 1957, never more than three to five Frenchmen were invited each year. In these limited conferences, which might almost be called summit conferences, the latest events were discussed by the leading specialists. In this way the Rochester Conferences have marked the stages in the principal developments of physics since the war. There the classification of heavy mesons and hyperons was considered ; there the difficult notion of strangeness * took shape before the audience

* In order to explain the properties of strange particles, that is the newly discovered heavy mesons and hyperons, it was necessary to give them an additional quantum number, which was called **strangeness**.

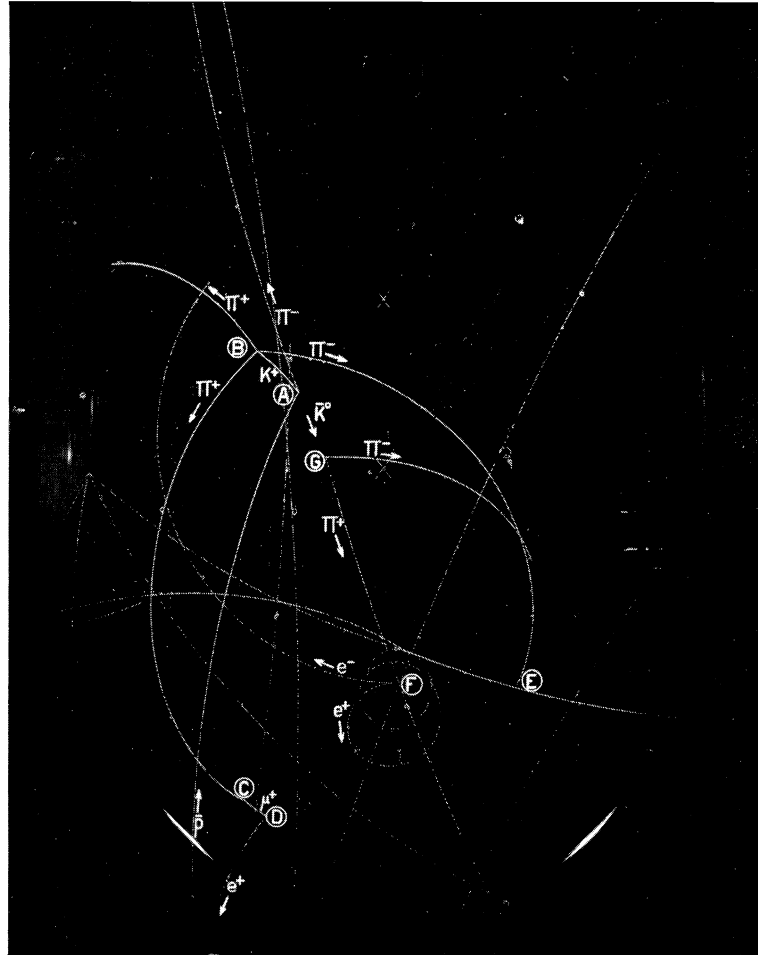
of physicists ; there the problems of parity were discussed. Rochester certainly marked the turning points of physics.

In the last few years, the icy, inhospitable banks of Lake Ontario in winter have sometimes been replaced by others — those of Lake Geneva or of the Dnieper. It is becoming customary to meet successively at Rochester, at CERN, and in Russia, the symbols of the three great scientific entities of our time. But the younger generation can have only a small part in such gatherings. They can of course read the enormous volumes of proceedings that appear three months later, but these are heavy, and sometimes indigestible for those who are not already very familiar with the subject. Now, this year, everything favoured a meeting of the young scientists : the organizers themselves were newly appointed French professors at the Ecole Polytechnique, Saclay, Orsay, Marseilles, and CERN (which was also able to supply the necessary secretariat). Where should the meeting be held, though ? Geneva was a possibility : the facilities at CERN are admirable and many physicists work there already. But no, one feels a little uneasy in Geneva, everything is almost too well organized, one enters automatically into a sort of mould ; the charm of Provence is missing, the pleasantness of a small university town, not too big, but more human. Geneva should be left to the big formal meetings, to the interminable political discussions on nuclear disarmament. For young physicists, who are so informal, who worry so little about their ties, who are so scornful of ceremony, the wonderful opportunities of Aix and of Provence are so much better.

Everybody came, all these young scientists ; many of them by car, so that between the sessions and during the 'break' on Sunday they could amble through the countryside, around the mountain of Saint-Victoire in the light of Cezanne, dear to many of us, in the home of the liqueurs of Cassis and Bandol. A few older scientists, carefully chosen from among the small group at the head of international physics, had agreed to come to discuss their work and also, in the form of reviews, to put it into focus in a very dignified, exact, and instructive way. Thus Heisenberg and Lee, both Nobel Prizewinners, came most readily. Thus Feynman, the famous theoretician from California, closed the Conference with a scintillating talk on theoretical physics.

A great deal of work was done at Aix. The sessions covered four hours in the morning, and at least as many in the afternoon, and you may well imagine the considerable effort represented by eight hours of difficult physics. For this reason the Conference was opened on the Thursday, to allow for a day and a half of welcome relaxation in the middle of the programme. During the first two days there were specialized sessions in which each group reviewed its recent work. A hundred and fifty papers were presented in this way, but for this it was necessary to split the meeting into parallel sessions. Simultaneously, in four different rooms, questions of low energy, very high energy, form factors, theory, experimental methods, interactions of classical particles, and interactions of strange particles, were successively developed, hardly any communication lasting longer than fifteen minutes. In this way, by Saturday, 16th September, two days after the start of the Conference, all the specialized contributions had been presented, and everything was ready for the plenary sessions. None of the young speakers had to worry still about a contribution to come. All the discussions that inevitably accompany an incomplete presentation were over. A feeling of relaxation was now able to spread among the members of the conference, and they could look forward to listening to the dozen great addresses which were to succeed each other until the following Wednesday, to put the current problems into better perspective.

I do not think many of the physicists in the audience, in spite of their ability, understood very much of some of the theoretical expositions, but there is no doubt that they sensed



Hundreds of photographs like this one, taken with the Ecole-Polytechnique/Saclay 81-cm hydrogen bubble chamber at CERN, are needed to provide data from which the existence of resonant states may be deduced. Here, an antiproton stops in the hydrogen at A and 'annihilates' with a proton to give a positive kaon, a negative pion, and a neutral antikaon. Two of these particles may possibly start life together in a resonant state. The kaon then disintegrates at B into three pions, of which one decays at C into a muon which decays to a positron at D, and another reacts with a proton at E to give a neutron and a neutral pion (neither of which give tracks). This pion is converted into two gamma rays, one of which gives an electron pair at F. The antikaon (also leaving no track disintegrates into a pair of pions at G. The tracks are curved because the chamber is placed within a magnetic field.

the distinction and power of the developments considered, and they will have the chance in the course of the year, re-reading the texts of the papers, discussing them among themselves, studying them in the course of later colloquia, to arrive little by little at a slightly better understanding of this difficult science.

Each year sees the adoption of a new point of view in physics. A main problem arises each year, and it is during a big conference that rapid or spectacular developments are sometimes made, where before there was stagnation because of the multitude of possibilities.

This year was the year of *resonant states* or *isobars*. The Aix Conference was the conference of super-unstable particles : they were discovered everywhere — a pi-meson and a proton, a pi-meson and a neutron, a hyperon and a pi-meson, and even three pi-mesons, can unite to form a true particle during a very short time. They choose for this combination a certain *state*, which has well-defined properties of nuclear force, relative motion, and orientation of the spin of each particle. Thus a *state* of two particles can be defined, in much the same way as a slate can be defined corresponding to the two stars of a double star, where each star has a mass and a definite motion with respect to the other, as well as a self-rotation similar to the spin of a nuclear particle. Transferring this to the domain of elementary particles, however rough

the comparison may be, it is conceivable that two particles can exist in an ephemeral manner in a certain state characterized by well-defined quantum numbers.

It is very striking that such complexes are formed in so many reactions. They are called *resonant states* (between pions and proton, for example, or between hyperon and pion). What is most extraordinary is the frightfully unstable nature of these complex particles. The discovery of this instability seems in itself miraculous. It is quite amazing that one can be so certain that the particles disintegrate after a time of the order of 10^{-22} second. I do not know if the reader is able to comprehend the meaning of such a short time: he must consider the fact that a thousand-millionth of a second, already a very short time, is at the limit of production possible with the most refined electronics, and then 10^{-22} second is still less than a millionth of a millionth of this limit.

How then can we know that a particle lives for a time of this order? For no direct measurement of time is capable of showing such a short interval.

We know well, by direct measurements, that the average life of mesons is of the order of a hundred-millionth of a second. We know equally well that the mean life of hyperons is a little shorter, but we do not go any further with direct measurements. There is, therefore, an enormous jump to be made; an extraordinary interval has to be spanned. The answer is simple, however. It lies in the celebrated uncertainty relations, which link every variation of energy to a variation of time. There is a measurable uncertainty in the energy of the resonant state formed during certain interactions, and it is this which gives the mean life of the resonant state.

I would like to enlarge upon this somewhat obscure statement. Suppose that an event, for instance the annihilation of an antiproton and a proton, gives birth to two particles. I assume that everything happens at rest, that is to say, the disintegration arises from an antiproton and a proton at rest, with no velocity. The nuclear reaction (annihilation in the case we are considering) will produce energy. If then one of the particles created goes off in one direction, the other will always go in the opposite direction. The energies of the two particles will be completely determined, with no uncertainty.

But if one of the particles is very unstable and disintegrates very soon after its production, the other one will be aware of this, and its energy will no longer be completely determined. The change of energy will be linked to the lifetime of the unstable particle.

As an example, consider a reaction giving a hyperon, a positive pi-meson and a negative pi-meson. If one looks at the energy spectrum of the positive pi-mesons, one finds, instead of a classical continuous spectrum corresponding to a three-body disintegration, a spectrum with a very pronounced hump at a particular energy, the hump itself having a certain width. From these data one can say that the hyperon and the negative pi-meson have gone in the opposite direction not as a stable element but with an extra-short life, defined by the uncertainty in energy of the measured band.

These are the problems of today: this is wonderful physics. On the experimental level, it brings into play the great accelerators with all their power, since distributions of all sorts of particles in all possible reactions need to be studied, to see if the same complexes can be found using different methods. It is equally wonderful physics because the theoretical interpretation of all these investigations gives rise to a considerable number of questions, in particular on the connexion between the nuclear forces that may link mesons, nucléons, hyperons, heavy mesons, etc. Finally, the discovery of states in which these ultra-unstable particles are formed, the defining of these states as functions of the observed properties, all this brings into play the most wonderful and complicated machinery of experiment and theory in modern physics©

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Last month at CERN (cont.)

Peter T. Kirstein, of Accelerator Research Division, and Karl-Martin Yahlbruch, Nuclear Physics Apparatus Division, left towards the end of January for the Joint Institute for Nuclear Research at Dubna, U.S.S.R. They expect to be there for about six months, under the exchange scheme which brought Vladimir Nikitin (Track Chambers), Adolf Mukhin (Nuclear Physics), and Walter Zöllner (Theory) to CERN a short while ago.

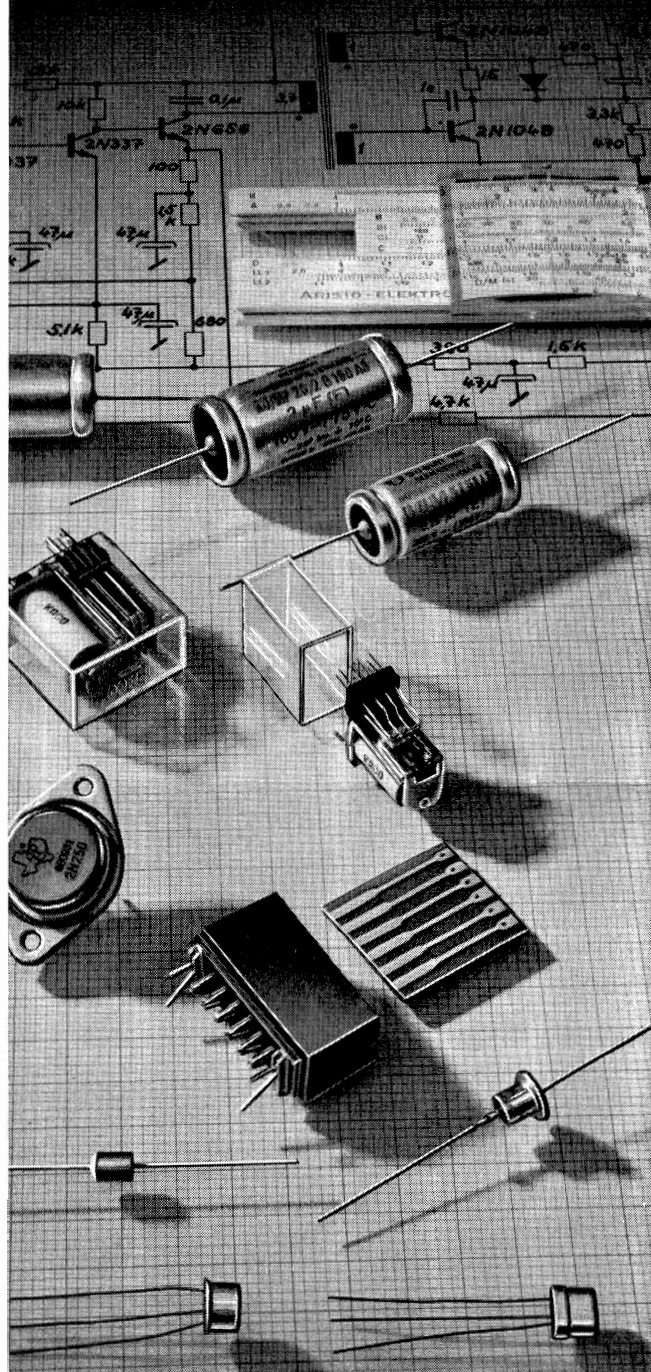
Among the visitors to CERN during January were the Hon. Graham A. Martin, U. S. Ambassador to the European Office of the United Nations.

'Matter in Question' the 35-minute colour film of the Organization, has been awarded First Prize in its Class at the 2nd International Festival of Technical and Scientific Films held in Budapest last November.

* * *

Lastly, a correction to the report in last month's issue: owing to a cumulation of errors the figure for the consumption of liquid hydrogen at CERN last year was given as 15 000 litres, whereas it should have been 83 000 litres. Our apologies to the Track Chambers Division for appearing to underestimate their efforts*

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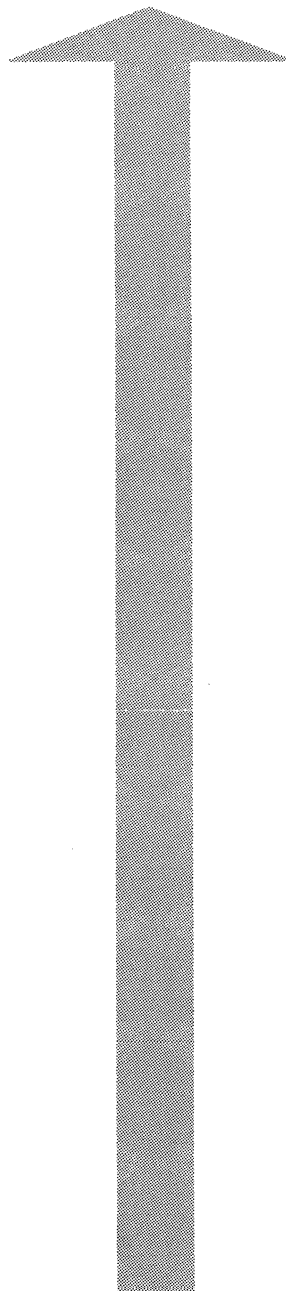
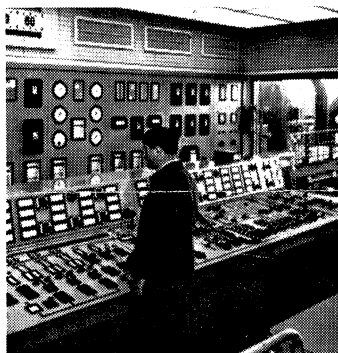
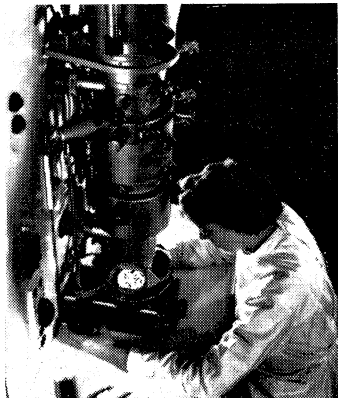
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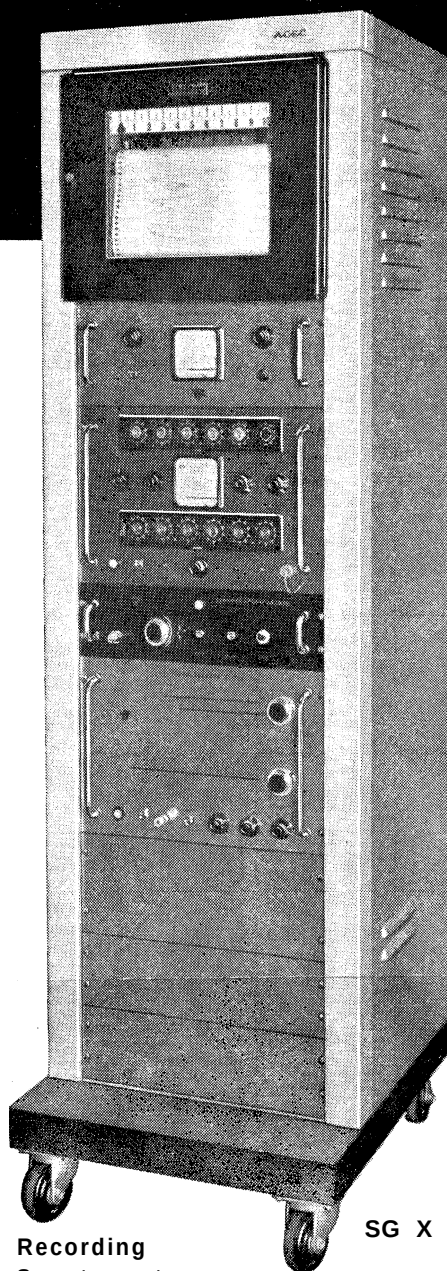
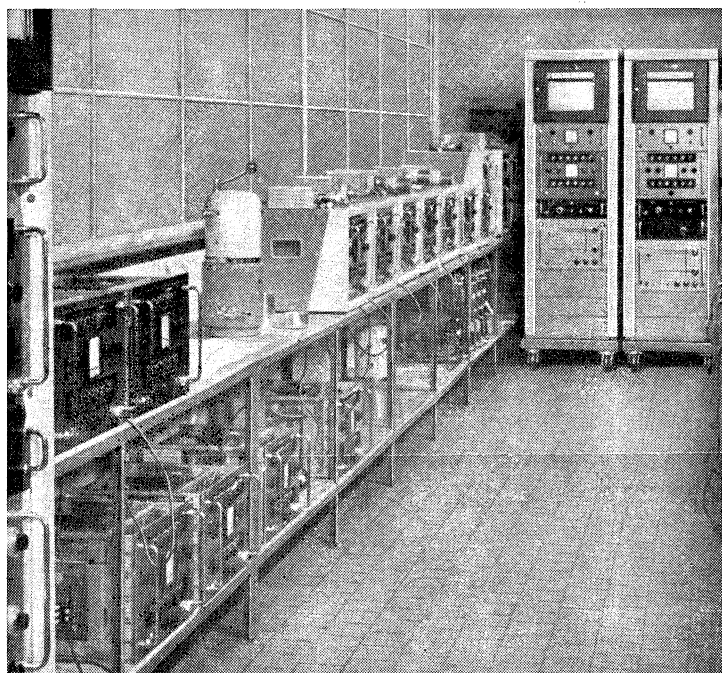
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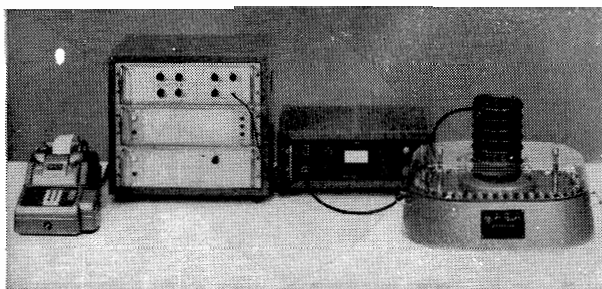
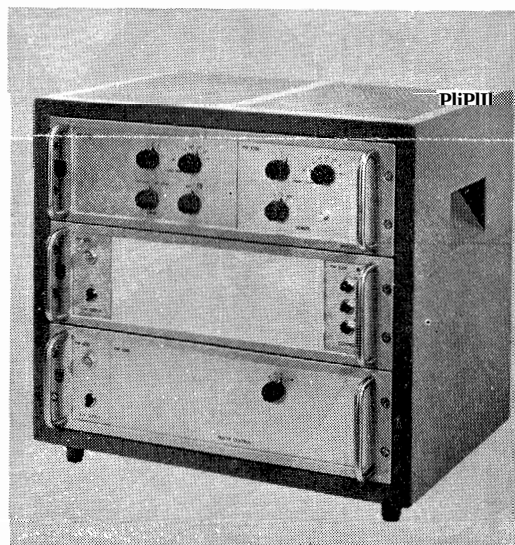
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