CERN COURIER

8

VOL. 2

August 1962

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

The European Organization for Nuclear Research (CERN) came into being in 1954 as a co-operative enterprise among European governments in order to regain a first-rank position in nuclear science. At present it is supported by 13 Member States, with contributions according to their national revenues: Austria (1.90%), Belgium (4.07), Denmark (1.95), Federal Republic of Germany (19.15), France (20.81), Greece (0.60), Italy (9.90), Netherlands (3.77), Norway (1.58), Spain (4.21), Sweden (4.15), Switzerland (3.23), United Kingdom (24.68).
The budget for 1962 is 78 million Swiss francs.

The character and aims of the Organization are defined in its Convention 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.'

Last month at CERN

July 1962 will certainly be recorded in the history of CERN as a momentous month. An auspicious start was made on Monday 2 July, when the **President of the Swiss Confederation,** Mr. P. Chaudet, visited the Laboratory, accompanied by several members of the Federal Council (see page 3).

Contents

The cover photograph is symbolic of the main topic of this month's issue. Prof. G. Puppi and Prof. W. Heisenberg stand before a table showing the properties of all the known particle 'resonances' which, while showing signs of late correction and still some question marks, nevertheless gives them grounds for satisfaction.

Photo credits : all photos by CERN/PIO.

CERN COURIER

is published monthly in English and in French. 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 nuclear physics in general.
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Published by the
European Organization for
Nuclear Research (CERN)
PUBLIC INFORMATION OFFICE
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CERN, Geneva 23, Switzerland
Tel. 34 20 50

Printed in Switzerland

Then, for over a fortnight CERN was the world's centre of research on sub-nuclear particles. From 4 July to 11 July, the leading scientists in this field from every continent gathered together for the **11th International conference on high-energy physics ;** many stayed on and were joined by others for the **International conference on instrumentation for high-energy physics,** held from 16 July to 18 July. The following day, the world's leading experts in **data-handling apparatus** had a full day's discussion on the latest developments in their field, the ways and means of examining and measuring the millions of photographs of particle tracks that are now being produced each year by the experimental physicists.

Less than a week later, in the hour before midnight on Monday 23 July, a few members of the PS Machine and Nuclear Physics Divisions represented the Organization in a historic experiment in another leading area of scientific and technological progress. This was the first 'live' television programme to be transmitted simultaneously to both Europe and the U.S.A., a programme made possible by the **'Telstar'** artificial satellite launched a fortnight previously from Cape Carnaveral in the U.S.A. CERN's participation was a particular honour, since the scenes of the ring and control room of the proton synchrotron had been selected as Switzerland's only contribution to the 'Eurovision' part of the two-way programme. It is true that the Laboratory was ideally equipped for such a broadcast — adequate lighting, suitable electricity supplies, good communications, by telephone with the control centre at Brussels and by 'line-of-sight' radio link with the Swiss transmitter at 'La Dôle' — but apart from this CERN was chosen as representing Switzerland's long tradition of hospitality to international organizations, as a symbol of its support for peaceful scientific research and international co-operation for the benefit of all. Although there is unfortunately no room in this issue of CERN COURIER for a complete report, one will be given next month.

Behind the extra activity of the Conferences the work of CERN went on more or less as usual, and a number of the physicists had to rush between Conference sessions and their experiments on one or other of the accelerators. During the period of the high-energy Conference, the **proton synchrotron** was operated again for a 'double' week, in order to give long uninterrupted runs for the Saclay 81-cm hydrogen bubble chamber and the École Polytechnique 1-m heavy-liquid chamber. Some trouble was experienced at the beginning, but the accelerator then ran more or less continuously from Wednesday 4 July to Saturday 14 July, except for a pause of 2 1/2 hours on Saturday 7 July when participants at the Conference visited the machine. The beam current remained at its new average level of between 4.5 and 5.0×10^{11} protons per pulse.

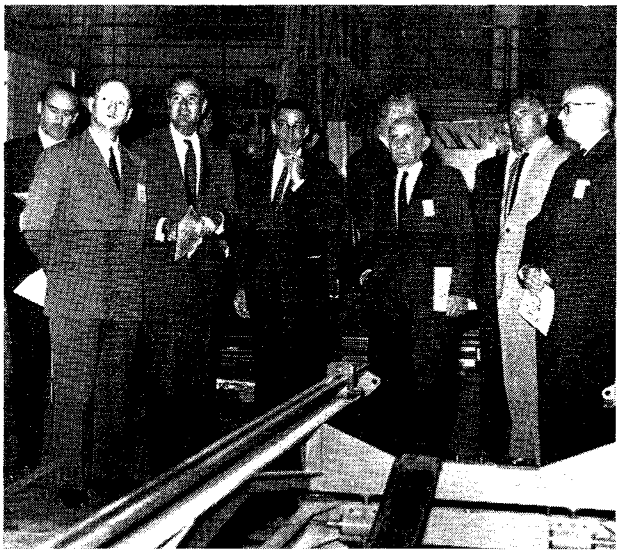
The experiment with the **École Polytechnique chamber** is of particular interest, since it is designed to give an unambigious answer to one of the uncertainties worrying physicists at the Conference — when one strongly interacting particle decays into another, together with two weakly interacting particles, must the change of 'strangeness' always be equal to the change of 'charge', or are other modes of decay possible ? ●

As a supplement to this month's issue of CERN COURIER we are including a leaflet (SIS/R/4487), now available at the Public Information Office, which shows the General Arrangement of the CERN 600-MeV synchro-cyclotron together with a plan of the accelerator itself and its experimental halls.

President of Swiss Confederation Visits CERN

On Monday 2 July a visit was paid to CERN by the President of the Swiss Confederation, Mr. P. Chaudet, together with four other members of the Federal Council, Messrs. F.T. Wahlen, L. von Moos, H. Schaffner, and W. Spühler. Also in the party were Mr. Ch. Oser, 'chancelier federal', and Mr. F. Weber, 'vice-chancelier', Mr. E. Dupont, President of the 'Conseil d'État' of the Canton, and Mr. P. Bouffard, representing the 'Conseil administratif' of the City of Geneva.

The visitors were received by the Director-general, Prof. V.F. Weisskopf, and were then conducted round the proton synchrotron and its experimental areas by S.A.ff. Dakin (Directorate Member for Administration) and R. Anthoine (Head of Public Information). At the entrance to the South hall extension, they were met by P.H. Standley, Deputy Leader of the PS Machine Division, and were taken to the main control room, where operation of the machine was explained. They were then given a general view of the South experimental hall from the 'visitors platform', where F. Grütter, Leader of the Engineering Division, and P. Preiswerk, Leader of the Nuclear Physics Division (who are both Swiss) helped to explain the experimental apparatus laid out around the accelerator. One of the pieces of equipment that was of particular interest was the 170-cm cloud chamber constructed jointly by CERN and the Eidgenössische Technische Hochschule at Zurich. W. Beusch, the senior physicist from Zurich, described its operation.

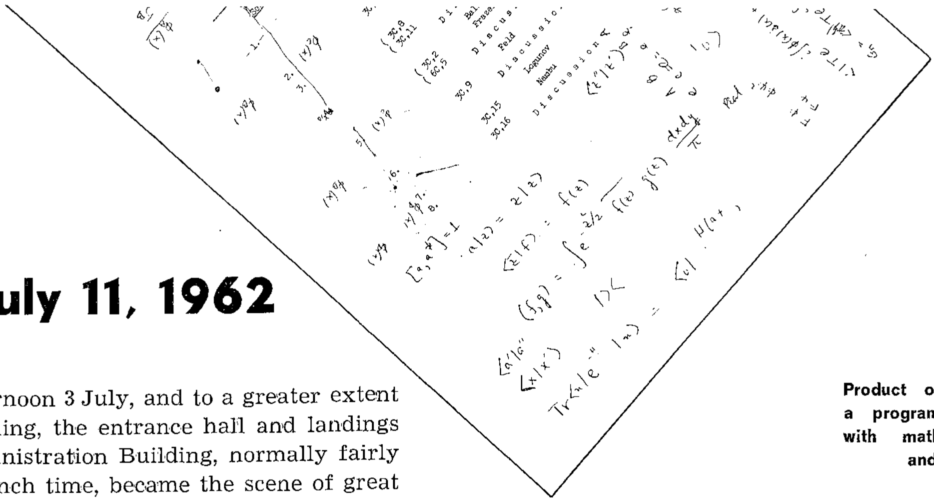


The party was then shown the Faraday cage containing the proton source and pre-injector for the linac, and the linac itself, before entering the machine tunnel to look at the PS ring. After passing through the radiofrequency control room at the centre of the ring, Mr. Chaudet and the other visitors were taken to the East experimental area, where Prof. Ch. Peyrou, Leader of the Track Chambers Division, explained the purpose and design of the two liquid-hydrogen bubble chambers being erected in the new building. Special interest was taken in the 2-m chamber designed at CERN, which is the only one of its size in Europe.

At the end of the tour, which lasted about two hours, the visitors were entertained to lunch in the CERN restaurant, where they were joined by Prof. J.R. Oppenheimer, Director of the Institute for Advanced Study, Princeton, U.S.A., Prof. E. Heer, of the University of Geneva, and the Director-general and Members of the Directorate of CERN ●

The photographs show, from top to bottom: (1) Mr. Chaudet (facing camera) next to the main control desk of the PS, discussing operation of the accelerator with Mr. Standley; (2) the party in the South experimental hall — Messrs. Bouffard, Chaudet, Preiswerk, Beusch, Wahlen, Grütter, and Spühler plainly visible; (3) Messrs. Spühler and Oser (left and centre) listening to an explanation by Mr. Grütter on the visitors' platform.

The 1962 International Conference



Product of the coffee-break: a programme well decorated with mathematical equations and calculations.

GENEVA

July 4 - July 11, 1962

On Tuesday afternoon 3 July, and to a greater extent the following morning, the entrance hall and landings of the CERN Administration Building, normally fairly empty except at lunch time, became the scene of great activity. Some 450 physicists, representing 158 laboratories in 39 countries were gathering for the 1962 International conference on high-energy physics, and for the next week they were to be joined by their colleagues already at CERN for what proved to be one of the most exciting conferences ever held in this field.

Now under the auspices of the International Union for Pure and Applied Physics, this was the 11th 'Rochester' Conference, the latest in the series started by Prof. R. E. Marshak in 1950. At the first, at the University of Rochester, U.S.A., there were only about 50 participants. This year there were eleven times that number, and there could have been many more if the number of invitations did not have to be so limited. Nowadays, too, the meetings are held once every two years, instead of every year, successively in the U.S.A., Western Europe, and the U.S.S.R. In 1960 the Conference was 'at home' in Rochester; two years from now it will be at the Joint Institute for Nuclear Research, in Dubna.

This rotation of the meeting place is only one reflection of the international nature of scientific research. There was little evidence of national delegations at CERN in the middle of July, and in general it was necessary to look at a person's badge to discover which country he or she came from. The name of the scientist or his laboratory was in any case of more interest. Certainly, one of the main values of such a meeting is the possibility of discovering the person behind the name appearing at the top of a scientific paper. People working on allied problems can get together and discuss them. Even if they come from opposite sides of the world, or opposite sides of political barriers, for a week at least they meet with a common aim. They even share a common language, for nearly all have at least a limited knowledge of some kind of English, which was the language of all the papers and discussion at this Conference.

Some of the activity in the entrance hall before the start of the first day's session.

Programme

As is becoming common nowadays, the conference was divided effectively into two parts. The first three days were more for the specialists, three parallel sessions being held at which the latest reports from the different laboratories were presented in papers lasting generally about 10 minutes each. Then, following two days at the week-end for which no lectures had been scheduled, came three days of 'plenary sessions', in which the results previously given were summarized and put into perspective by 'rapporteurs', one for each main subject division.

The need for parallel sessions and the large number of participants at the Conference meant that special lecture-room arrangements had to be made. For the parallel sessions the largest audience was accommodated in the main auditorium, with other meetings in the Council Chamber and in the 'proton room' (one of the two experimental rooms) of the synchro-cyclotron. This had been cleared of all experimental equipment and fitted out with chairs and desks, blackboards, projection equipment etc. For the plenary sessions the main auditorium was reserved for the 'delegates' to the Conference. The proceedings were then relayed to the two other rooms by means of television and loudspeakers for the benefit of the many participants, including members of CERN, who were classed as 'observers' and distinguished by their blue badges. A large-screen television projection system was used in the Council chamber, and small separate screens in

on High-Energy Physics at CERN

PROGRAMME OF THE CONFERENCE

SUBJECT and invited speakers	PARALLEL SESSIONS 4-6 July	PLENARY SESSION 9-11 July	RAPPORTEUR
Pion and nucleon physics, experimental	1A - Wednesday morning 4A - Thursday afternoon 5A - Friday morning	I - Monday morning	G. Puppi (Bologna, Italy)
Pion and nucleon physics, theoretical	3C - Thursday morning 6C - Friday afternoon	III - Monday afternoon	S. Mandelstam (Birmingham, England)
Electromagnetic properties of nucleons and pions, experimental R. HOFSTADTER (Stanford, U.S.A.)	2A - Wednesday afternoon	II - Monday morning	G. R. Bishop (Orsay, France)
Electromagnetic properties of nucleons and pions, theoretical	2A - Wednesday afternoon	IV - Monday afternoon	S. Fubini (CERN)
Strong interactions of strange particles, experimental	1B - Wednesday morning 3A - Thursday morning 6A - Friday afternoon	V - Tuesday morning	B. P. Gregory (École Polytechnique, France)
Strong interactions of strange particles, theoretical R. H. DALITZ (Chicago, U.S.A.)	1B - Wednesday morning	VI - Tuesday morning	G. A. Snow (Maryland, U.S.A.)
Weak interactions, experimental	2B - Wednesday afternoon 4B - Thursday afternoon	VII - Tuesday afternoon	F. S. Crawford (Berkeley, U.S.A.)
Weak interactions, theoretical	5B - Friday morning	VIII - Tuesday afternoon	L. B. Okun (Moscow, U.S.S.R.)
High-energy physics, experimental Cosmic-ray physics, experimental B. PETERS (Copenhagen, Denmark)	3B - Thursday morning 5C - Friday morning	X - Wednesday morning	G. Cocconi (Cornell, U.S.A.)
High-energy physics, theoretical M. GELL-MANN (California, U.S.A.), I. Ya. POMERANCHUK (Moscow, U.S.S.R.), D. AMATI (CERN)	4C - Thursday afternoon	X - Wednesday morning	S. Drell (Stanford, U.S.A.)
Electromagnetic properties of leptons, and quantum electrodynamics, experimental and theoretical	1C - Wednesday morning	IX - Wednesday afternoon	S. M. Berman (Stanford, U.S.A.)
Theory of elementary particles (group-theoretical methods)	5B - Friday morning	XI - Wednesday afternoon	B. d'Espagnat (CERN)
Theory of elementary particles (dynamical theories) W. HEISENBERG (Munich, Germany)	6B - Friday afternoon	–	–
Field theory T. REGGE (Turin, Italy), C.F. CHEW (Berkeley, U.S.A.)	2C - Wednesday afternoon 6B - Friday afternoon	–	–

the synchro-cyclotron room, the latter system proving in the end more practicable for the very warm weather, since it allowed the use of more light and fresh air.

The amount of information to be reported and discussed made the Conference particularly intensive. Each day, between 9.30 a.m. and 6 p.m., there were four sessions, each of one and a half hours, and individual conversations continued through coffee breaks, lunches, and into the evenings. To ensure that the latest results were reported, there were several changes to the detailed programme, and two completely new sessions. Dr. M. Schwartz's invited paper, scheduled for one of the Friday sessions, achieved particular importance with the publication just before the Conference of the results of the 'neutrino experiment' carried out in the U.S.A. As a result, the lecture was transferred to Monday evening and increased in length, to form an hour-long plenary session of its own. Many more people were thus able to hear the details of this masterpiece of particle detection carried out by the scientists from Columbia University and Brookhaven National Laboratory, in which they confirmed the theoretical possibility that there are two types of neutrino instead of only one. The theoretical physicists had a special session of their own on the Saturday morning, to be able to consider more fully the fundamental concepts underlying the new theoretical ideas that have been developed in recent years. Other participants in the Conference visited the CERN proton synchrotron on that day.

At the end of the first day's session, drinks and sandwiches were served in the restaurant, to allow the delegates to get to know each other and to meet old friends, and on the Monday evening there was a conference dinner, at which Prof. H. B. G. Casimir, Director of the Philips Research Laboratories at Eindhoven, gave an amusing, but nevertheless thought-provoking discourse. The following evening, Prof. V. F. Weisskopf, Director-General of CERN, and a dozen or so of the leading physicists present gave a Press Conference, at which they managed to convey at least some of the excitement and interest of the highly specialized subject matter.

Finally, at 6 p. m. on 11 July, the Conference was brought to a close by Prof. Weisskopf, at the end of an hour's talk into which he had compressed the major new facts, theories, and outstanding questions that had been made so much clearer during the previous eight days • • •

SOME BASIC CONCEPTS OF HIGH-ENERGY PHYSICS

— **HIGH-ENERGY PHYSICS** is the field of research concerned with the study of **sub-nuclear particles.** These particles are also called **'elementary'** or **'fundamental'**, but there are now so many of them that such a description should not be understood literally. They are either the constituents of atomic nuclei, or seem to be in some way connected with the formation of nuclei, and hence with the constitution of material substances. Each particle has a corresponding **antiparticle,** of identical mass but opposite electric charge. Antiparticles are included in the general scheme of 'particles' and do not need to be considered separately.

— **ELEMENTARY PARTICLES** behave in many ways like waves. There is a simple relation between the **momentum** of a single moving particle and the **wavelength** of the wave corresponding to it; the **amplitude** of the wave at any point in space or time measures the **probability** of finding the particle at that point. Ordinary (Newtonian) laws of motion of solid bodies are only an approximation that is not valid for the interaction of such particles. In fact, the behaviour of high-energy particles is often best understood in optical terms. Schrödinger first showed, in 1926, how a **wave equation** could describe the behaviour of an electron in the electric field of a proton. Later developments have led to **field theory,** which attemps to describe all interactions between particles (involving nuclear, electro-magnetic, or gravitational forces) in terms of the interactions of waves.

— **QUANTUM NUMBERS** are used to assign values to certain properties of particles known as **spin, isobaric spin** (or **isospin), strangeness,** etc. The numbers are integral in some cases, half-integral in others, and certain rules have been evolved from theory and experiment to govern their application both to single particles, and to systems of particles. For example, **spin** can be considered as a rotation of the particle about its own axis; the value 0 implies no rotation, the value $1/2$ implies two possibilities, $-1/2$, $+1/2$, rotation in opposite directions. **Isospin** is related indirectly to the **electric charge** of a particle; the value 0 allows only a neutral form (zero-charge), the value $1/2$ allows a positive charge of 1 unit or zero charge, the value 1 allows positive or negative charge of 1 unit, and zero charge. The concept of quantum numbers leads to certain **selection rules** for particle reactions, for example the total (net) spin of all the particles after the reaction must be the same as the total spin before, the total charge must not change, zero change of strangeness is more probable than a change of 1 unit, and so on.

— **FERMIONS** are particles with spin $1/2$, $3/2$, etc.
BOSONS have spin 0, 1, 2, etc. The two kinds are fundamentally different; in any system of particles, two bosons can occupy the same state (have identical sets of quantum numbers) at the same time, but two fermions cannot.

— **LEPTONS** are light particles in the fermion class.
BARYONS are heavy ones. The table below shows the situation before the newer particles were discovered.

FERMIONS			BOSONS	
leptons	**baryons**			**mesons**
neutrino(s)	nucleon	proton	photon	pion
electron		neutron		kaon
muon	lambda	hyperons		
	sigma			
	xi			

— **INTERACTIONS** between particles are of four kinds:
Strong; for most reactions between baryons and mesons, but not leptons, and responsible for the very short-range forces holding the nucleus together.
Electromagnetic; for interactions of charged particles with electromagnetic fields, involving photons.
Weak; for radioactive disintegration of nuclei, and other spontaneous transformations of one particle into another.
Gravitational; for keeping the atoms of the atmosphere near to the earth (and satellites in orbit).
The respective strengths of these interactions are in the ratios 10^{38}: 10^{36}: 10^{24}: 1 (approximately), and only the first three are of importance in experimental high-energy physics.

— **SCATTERING** is a general term given to interactions between particles, for example one involving two incident particles (often a moving one hitting a 'target') and two outgoing ones. **Elastic scattering** is when the outgoing particles are the same as the incoming ones and no kinetic energy (energy of motion) is lost. **Inelastic scattering** results in **excitation** of one or more of the particles or the formation of new ones.

— The **CROSS-SECTION** for a reaction is a measure of the probability that it will occur. It is the hypothetical area that a 'target' particle presents to an incoming one.

— The **GROUND STATE** of a particle is that state in which it has least energy and is therefore most stable. It usually has the lowest quantum numbers for its characteristic properties.

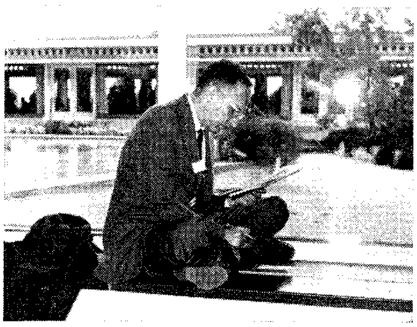
— An **EXCITED STATE** is one of higher energy, usually having one or more quantum numbers of higher value. According to the amount of excitation and the values of the quantum numbers, an excited particle either returns to its ground state by emitting one or more other particles or it splits up into new particles.

— **ISOBARS, RESONANCES** and **EXCITED STATES** are all names applied to the very short-lived 'particles' or particle states discovered in the last two years. Their different names arise largely from the different modes of formation, and the precise way in which they fit into the scheme of subnuclear particles is not yet clear.

What they talked about and the conclusions they came to

When he began his closing talk at 5 p.m. on the last day, Professor V. F. Weisskopf said: 'I am here to perform an impossible task. I am supposed to summarize this Conference that has been summarized by rapporteurs during the last three days, and I am supposed to do it in one hour'. To summarize the Conference adequately for the benefit of CERN COURIER readers is, unfortunately, a still more impossible task. Even Prof. Weisskopf's admirable report cannot be reproduced usefully, since it was addressed to specialists in their own language. So the attempt has to be made, taking that report as a guide, to describe in more common, if less precise terms, the purpose and achievements of the Conference.

The subject, high-energy physics, is the study of the behaviour and interactions of the basic constituents of matter. Many of the world's leading physicists, who are working to increase our knowledge of this fundamental aspect of the universe, were meeting to compare the fruits of some two years' work, to take stock of the present position, and to consider possible future trends.



The results of their discussions will not immediately be felt in the world at large — no momentous decisions were taken — because research of this kind is not directed towards any specific practical use. But for those who took part, and all those who take an interest in this problem of the constitution of matter, the facts were exciting and encouraging. The 1962 Conference could easily become a landmark in the history of the advancement of knowledge.

Although the steady flow of experimental results and theoretical ideas since the last Conference at Rochester in 1960 has added continually to our understanding, the meeting at CERN provided an opportunity to review it all as a whole, together with the latest results. Comparison with the picture of two years ago shows, in fact, how much progress has been made. As Professor Weisskopf remarked: a new world has emerged.

EXPERIMENTAL FACTS

Experimentally, many new facts have been found in this period, of which the most important ones can be divided into three groups, classified under the headings of 'high-energy scattering', 'isobars' and 'weak interactions'.

High-energy scattering

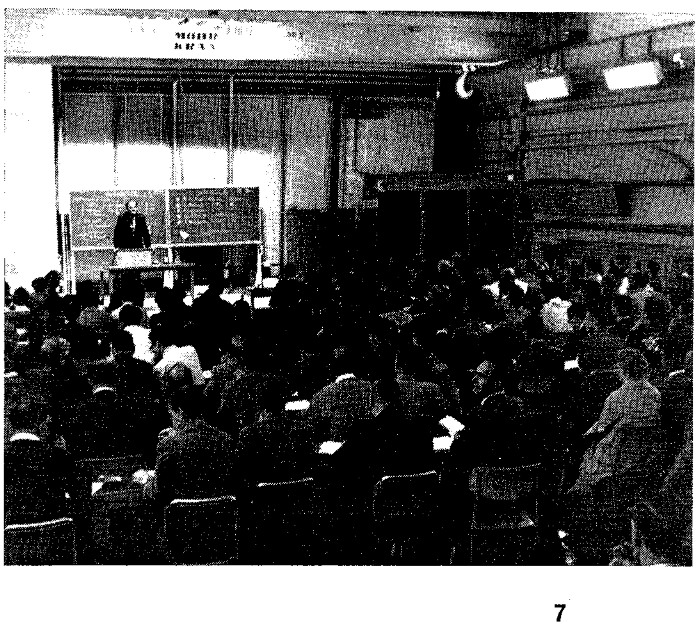
In the study of high-energy scattering, where particles are directed at great speed at a target and the distribution in space and various other properties of the scattered particles are examined, there have been two general sets of findings. The first is that as the total energy of the system gets higher so the scattering cross-section becomes constant and its value becomes the same for certain groups of particle pairs (for example for proton on neutron and proton on proton). This was not unexpected.

The second discovery is a completely new phenomenon, the 'shrinking diffraction peak'. When a beam of protons is directed at a hydrogen target (that is, other protons) with sufficiently high energy, most of them are absorbed by 'inelastic' processes. The distribution of the remaining 'elastically scattered' protons around the original direction is analogous to the bright ring that can be seen just inside the shadow of a disc held in front of a source of light, and the process is thus called 'diffraction scattering'. In the optical case, the ring gets more pronounced as the disc is made smaller, at any particular wavelength of light. In the case of proton-proton scattering, even after allowing for the change in energy, the distribution pattern gets narrower as the energy is raised.

This leads to the remarkable conclusion that as the energy of the incident particle is increased so the target nucleon appears steadily less dense, and larger in size. Previously it had seemed most likely that the nucleon consisted of a central core surrounded by a more diffuse 'cloud' (probably of pions), and that the

Prof. Weisskopf opens Session 1B of the Conference in the transformed 'proton room' of the synchro-cyclotron.

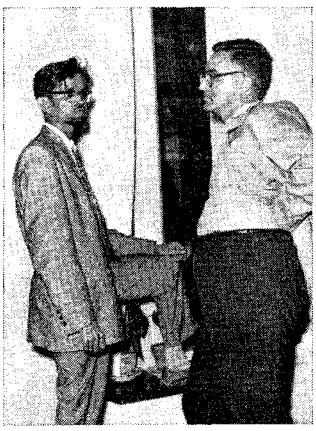
On p. 10 the two larger pictures show (top) one of the parallel sessions in the Council Chamber and (bottom) Prof. Gregory's plenary session in the main auditorium. The other pictures on pages 7-10 show some of the less formal meetings.



Group Photograph

higher the energy used for a bombarding particle the more information would be found about the core. However, the experiments now show that the optical analogy is not exact (confirming what was, in fact, already suspected on theoretical grounds), and point the way to a fuller understanding of nuclear structure.

Similar scattering experiments have been done with electrons as the incoming particles, and there the evidence for the core seemed stronger. The latest results seem to show a similar trend to those from the proton-scattering experiments, however, although it remains to be seen whether the two different methods will finally lead to the same conclusion.



New particles

The second group of phenomena, 'resonances', 'isobars', or 'excited states', produced some of the most impressive results of the meeting. A curiosity at the last Rochester Conference, they had already become a focus of interest at the Aix-en-Provence meeting of 1961, as described by Prof. Leprince-Ringuet in the CERN COURIER last February. Since then, many results have been reported from laboratories in different parts of the world, and a number of new ones were presented at this Conference. Many of the results have been in agreement with each other, although there have also been some contradictions. At this stage of the research, however, the contradictions are mainly a spur to further effort, and as Professor B. P. Gregory humourously remarked during his report: 'A result that is not valid in itself added to five other doubtful ones can give an interesting picture of new phenomena'.

Although they are of various different forms — a fact that largely accounts for the different names used to describe them — these new entities are all very short-lived particles that in a sense are compounded of the already well-known ones. Thus in pion-proton scattering a peak in the cross-section at a certain energy corresponded to the formation of an excited nucleon (or 'nucleon isobar'); in bubble-chamber photographs, where most of the results have now been obtained, two pions produced in the annihilation of an antiproton were found to have existed for some 10^{-22} second in a resonant state corresponding to a single particle, before going off separately; and so on. The more recent experiments have concentrated on measuring the quantum numbers that characterize each of these new 'particles', and a pattern is being built up showing how they arise and how they are related to each other.

One of the more recent discoveries, now fully confirmed, is that of the eta particle. It fits into a general pattern with the rho and omega particles, found earlier, and the well-known pions, to form a 'family' of eight bosons, with simple quantum numbers corresponding to all those that might be expected to arise from a system of a nucleon and its antiparticle in its lowest state. This is shown in the table below:

Spin	Isospin	Particles
0	0	η^0
0	1	π^- π^0 π^+
1	0	ω^0
1	1	ϱ^- ϱ^0 ϱ^+

Another boson family seems to be forming also, with the discovery of the K-star (K*) and anti-K-star to take their place with the kaon and antikaon, but information on this is less complete.

There was a lot of excitement about numerous baryons of different kinds, proved, suspected, or doubted. Starting with the previously established particles as 'ground states' — another 'family' of eight: nucleon (neutron and proton), lambda (zero), sigma (minus, zero, and plus), and xi (minus and zero) — there seems to be a superimposed system of excited states of the pion field. This results in a whole range of 'new particles' (or 'excited states' of existing ones,

according to how they are considered), each of very short lifetime. Careful and complicated measurements, often involving different experiments to enable systematic rejection of all but the correct assignment, have shown nearly all the simple quantum numbers to be represented in the list of excited states, although others remain to be established with certainty. On the analogy of excited states in atoms, an infinite number of states might be considered, but there are indications from other experiments that the number is much more limited in the nuclear case.

To resolve the discrepancies and achieve complete results as quickly as possible, Prof. Puppi thought the time had now come for a comprehensive attack on the problem, planned between the different laboratories interested.

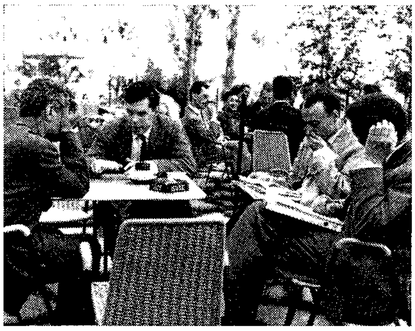
Weak interactions

In the field of weak interactions, there have been three important new advances, two of them very recent and just in time for the Conference. Most exciting, and most surprising except to some theorists, is the discovery of the existence of two types of neutrino. This particle, with apparently no charge and no mass, and extremely low probability of interaction with other particles, aroused little interest for many years after it had been postulated to explain nuclear beta-decay. A change was brought about by the experimental evidence for its existence in 1953, and now the latest discovery, that the neutrino emitted at the same time as an electron is not the same as the one emitted with a muon, has made it (or them) a centre of interest. A whole new field of research will be opened up by attempts to discover and explain the part these particles really play in the structure of matter.

The other new discovery, reported by several laboratories but so far not fully substantiated, is that a 'selection rule' known as $\Delta S = \Delta Q$ (delta S equals delta Q) may not be true. This rule is a consequence of the theory of particle 'currents', used to describe weak interactions. Applied to particles for which strong interactions are also possible, it states that if one decays (by weak interaction) into another the change of 'strangeness' quantum number must be the same as the change in electric charge. For example, when a neutral kaon (strangeness $+1$) changes into a negative pion (strangeness 0), emitting a positive electron and neutrino, the strangeness and the charge both decrease by one unit. However, if the kaon decayed into a positive pion (emitting a negative electron and an anti-neutrino), the change of charge would be from 0 to $+1$, and the process, although otherwise conceivable, was thought to be impossible. But now some examples of this and similar reactions appear to have been found.

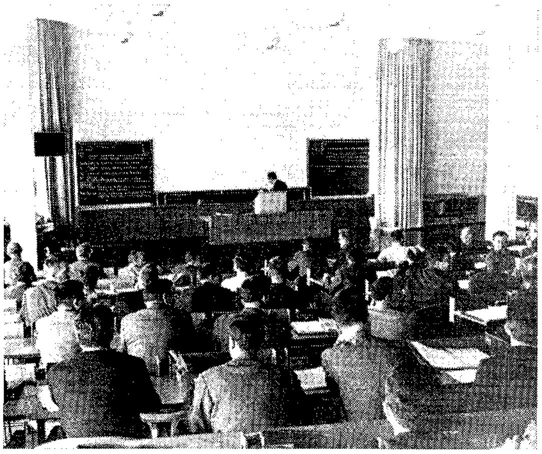
Perhaps related to the existence of two neutrinos is the strange fact that the relatively short-lived muon and the stable electron appear to be otherwise identical in all their properties except that of mass. Recent experimental evidence discussed at the Conference included results for the muon's anomalous magnetic moment (g-2), muon scattering from carbon nuclei, and the production of pairs of muons from high-energy gamma rays. All these processes are accurately described by the equations already developed for the same phenomena occurring with electrons.

Unfortunately, it is not possible to mention here all the other experimental results reported on or considered at the Conference, but the above examples give at least some idea of the progress being made along many different, but interconnected paths. All these new facts, with their accompanying changes of outlook, in only two years !



THEORETICAL STUDIES

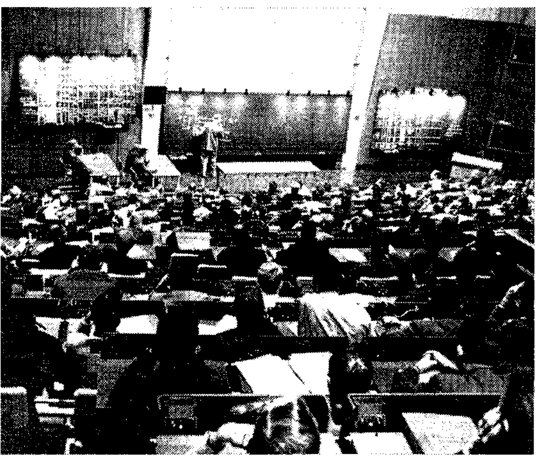
The main sense in conducting experiments is to suggest or to prove theories. Physicists don't just want to know what happens, they try to explain how. In recent years it has often been suggested that although there are many facts they cannot be understood, but Prof. Weisskopf dissented from this view, even while describing the Conference as an 'experimental' one, because of the many interesting and exciting results



presented. He reminded his audience that we understand how to talk about particles; we know what particles are and what quantum numbers mean; we ascribe to each particle certain properties, like charge, isotopic spin, strangeness, parity, statistics, etc., so that each one is distinguished from the others. These concepts, and that of antiparticles, have not been disturbed by any of the new discoveries. Moreover, we can describe a 'scattering event', in which particles *a* and *b* come in, and particles *c* and *d* go out, by introducing the mathematical idea of a 'scattering matrix', which must have certain properties. We can establish connexions between different parts of the matrix, so that from the above example we can also deduce the properties of a reaction in which *a* and *anti-c* come in and *anti-b* and *d* go out.

Scattering processes

Only when we come to describe the actual process causing the 'scattering' do we get into trouble. There, old concepts have to be used which are not really adequate. One of these is field theory, but the equations it produces have an infinite number of terms and have no solutions; even in approximation they are still often insoluble. All the time, theorists are trying to find new ways of approach, a new 'language' in which to describe these basic phenomena. Analogy still plays an important role in this search, and one of the most recent advances, much discussed at the Conference, is the idea of the 'Regge pole' or 'Regge trajectory' (named after the Italian physicist who first introduced it). It is an analogy taken from the much older Schrödinger theory of potentials (a non-relativistic one without antiparticles) and cannot give a complete answer, but it does seem to help in the field of strong interactions, where normal field theory is least useful. For example, it helps to explain the new results in diffraction scattering of protons. Prof. Weisskopf compared it with the theory of band structure in solid-state physics, which is very valuable for describing the electrical and thermal properties of metals, for example, though it is a bad approximation. In that case, however, the bad features are known and can be taken into account; in the case of Regge poles the comparable stage has not yet been reached. Perhaps it never will be, but on the other hand the concept may turn out to be a completely new principle. At the moment it is impossible to foretell what will happen.



Isobars

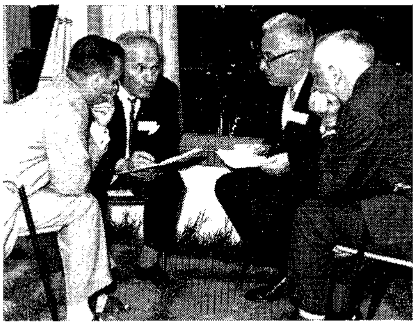
In a similar way the concept of 'supermultiplets', part of the application of so-called 'group' theory to atomic physics, has been applied to the phenomenon of isobars. Sometimes it has been successful, by predicting mass ratios correctly, sometimes not, when the relative probabilities for the occurence of different reactions proved to be wrong. Attempts are also being made to approach the isobar problem from the standpoint of field theory itself, to try to formulate a simple field equation and a certain type of interaction from which all the particles will be derived. Again it is not possible to tell whether these ideas will turn out to be useful analogies, false steps, or important new principles.

Weak interactions

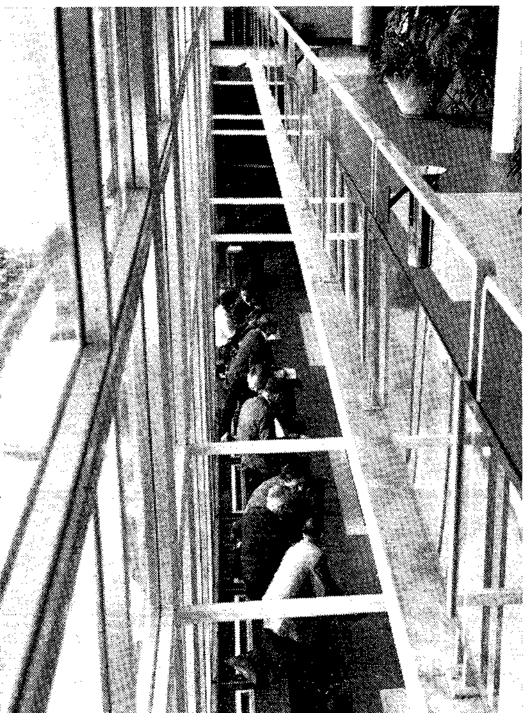
When it comes to considering weak interactions the situation has become very difficult. In the way that the pion was introduced to explain how the nucleus was held together, an 'intermediate boson' has been found useful to derive the equations describing weak interactions such as radioactive decay. Unlike the pion, though, this 'W particle' has not yet been found experimentally. Moreover if it exists, and the recent doubts over the rule $\Delta S = \Delta Q$ are confirmed, one implication will be that strangeness can change by two units in weak interactions, enabling, say, a neutral kaon to change into an antikaon. Such a reaction has already been shown to be impossible, according to the present theory, by the small difference found experimentally between the masses of the two related particles called K^0_1 and K^0_2. There is still the possibility that further experiments may show $\Delta S = \Delta Q$ to be correct, but otherwise the present theory will turn out to be inadequate, and the whole problem of the explanation of weak interactions will be thrown open again.

CONCLUSIONS

In some ways the general situation in elementary-particle physics is very similar to that of atomic physics in 1924, before the development of quantum mechanics. Then, as now, there was a large amount of undigested data, though it was then mostly in the form of exact measurement and now often consists only of a few isolated examples. Then analogies were being introduced from the more classical physics; today the analogies are mostly from atomic physics (for instance, Prof. Weisskopf compared the 'action integral' and Regge poles, both by chance using the same symbol, *J*). One big difference is that in those days there were a series of facts blatantly contradictory to established physics, whereas today there are really none. Although the completely new ideas on the interchangeability of particle and wave properties were needed then, there is always the possibility that all the phenomena we have now will follow from field theory, if only we can find out how.



To sum up, there is no better way than to reproduce Prof. Weisskopf's closing words: 'The theoretical situation is problematic but full of interesting ideas. The experimental situation is very much better — very much better than any one of us would have guessed two years ago. The world within the nucleon is much richer and much more interesting than we ever expected. Not in vain have we put so much effort into this field everywhere in the world, not in vain have we put so much effort and money into our aim, which is after all a basic aim of man on earth: to find out what it is, this common world of ours'. ● ● ●



COMMENTS ON THE CONFERENCE

Everyone agreed that this was a very good conference ; an exciting one because of the new results presented and discussed, and a significant one for CERN because of the many important contributions it could make to the sessions. The following comments given to CERN COURIER by some of the world's most well-known physicists are typical :

Prof. E. Segré (Lawrence Radiation Laboratory, Berkeley, U.S.A.) :

This has been an excellent Conference and a significant one because it has brought out several new things. I have enjoyed it very much. It is good to find CERN now so well equipped for a conference of this size, compared with the facilities it possessed the last time I was here, in 1958. For the first time, too, CERN has been able to contribute a really large part to the proceedings of the Conference.

Prof. C.F. Powell (University of Bristol ; Chairman of CERN's Scientific Policy Committee) :

I have found the Conference enormously impressive. When you consider that the work reported here represents the work of several thousand physicists throughout the world, and of thousands more supporting staff, you realize that this is something completely new in the field of pure academic research. Of course, it is an indication of the increasing role of science in the world today, and the rising tempo of discovery. These large conferences also have a part to play in promoting international understanding. It is a good thing for scientists of different countries to be able to meet once and discuss things of common interest; it is even better when they can do it again, several times, and greet each other as personal friends.

Prof. J. Robert Oppenheimer (Director, Institute for Advanced Study, Princeton, U.S.A.) :

This has been an excellent conference, full of interest. Moreover I am delighted that CERN has developed so well and can now play such a full part in the progress of high-energy physics.

Prof. W. Heisenberg (Director, Max Planck Institute, Munich) :

This has been one of the best conferences that I remember. It is particularly interesting for me because of the large amount of new data on particle 'states', and 'resonances', which are all needed to check the unified field theory which is my major interest. So far things are working out well and it seems possible that someone may discover the underlying law that will explain how all the many 'elementary' particles are formed. For me this is the most exciting time in physics since the early 1920s, when a similar situation existed. Then the many different lines in atomic spectra awaited the explanation given by quantum theory, whose development has brought us so far. Now in many ways we have 'lines' in a 'mass spectrum' awaiting a similar fundamental advance to explain all the empirical relationships so far discovered.

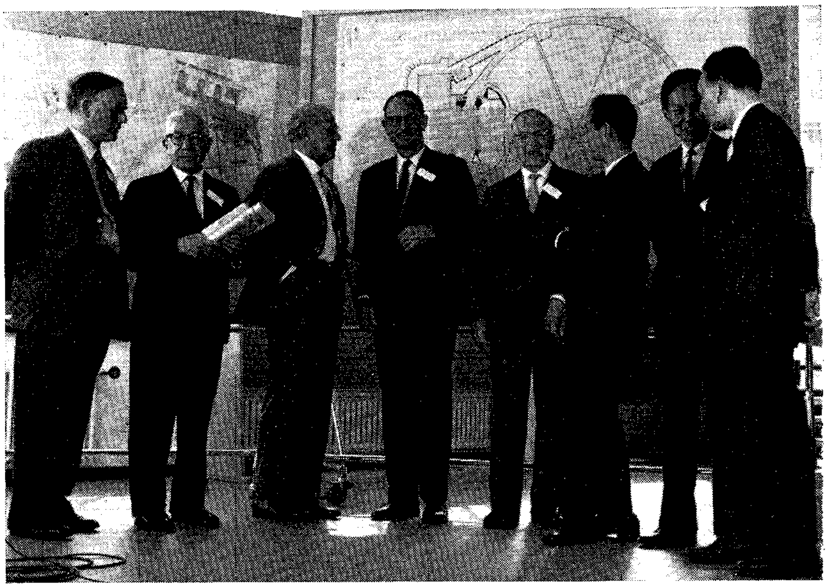
Prof. E.M. McMillan (Director, Lawrence Radiation Laboratory, Berkeley, U.S.A.) :

An important feature of the Conference has been the reporting and comparing of a great deal of detailed labour by many people. Much good work has been made known and much new knowledge gained, though there is also still much confusion. The most interesting thing for me is the number of new 'particles' or 'resonances', practically all of them discovered in the two years since the last Conference, and the amount of detailed knowledge we already have on their properties. The Conference as such has been very good, and very well organized.

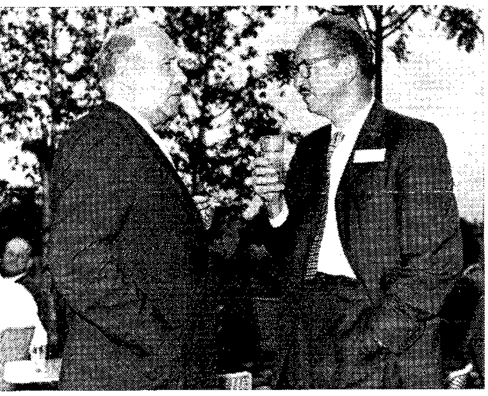
Prof. V.I. Veksler (Director, High Energy Laboratory, Joint Institute for Nuclear Research, Dubna, U.S.S.R) :

The Conference has been very interesting, and important steps forward have been made in our knowledge in three fields : strong interactions, 'resonances', and the proof that there are two types of neutrino.

Prof. V. F. Weisskopf and Prof. R. E. Peierls in a contemplative mood.

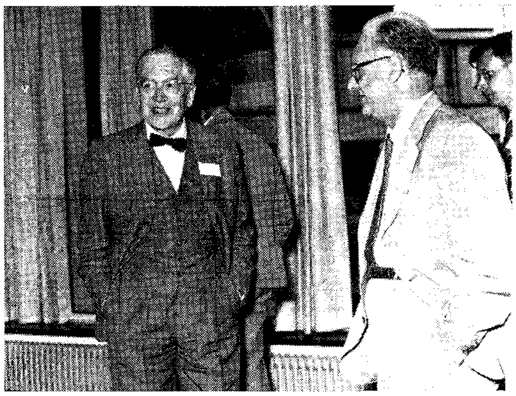


Among the most well-known 'names' at the Conference were these eight Nobel Prizewinners: (left to right) Profs. C.F. Powell, I.I. Rabi, W. Heisenberg, E.M. McMillan, E. Segré, T.D. Lee, C.N. Yang, and R. Hofstadter.



The Director of 'Dubna' (Prof. D.I. Blokhintsev) and the Director of 'Berkeley' (Prof. E.M. McMillan) chat together.

Prof. A.D.G. Källen and Prof. W. Heisenberg discuss a delicate point of theory.



Prof. E. Segré and Prof. E. Amaldi are distracted from their conversation on the first day of the meeting.

Prof. A.I. Alikhanov (left), with Prof. V.V. Wladimirsky and Prof. V.I. Veksler (on the right) form their own discussion group, with a fourth whose name is unfortunately not known.

In these two groups can be seen (left to right) Dr. D. Speiser and Profs. S. Kamefuchi, T.D. Lee, C.F. Powell (back to camera) and J.R. Oppenheimer.

CERN's scientific contribution to the Conference

Before the Conference began, abstracts of nearly 350 papers were submitted for consideration from many different laboratories. A few other papers, containing last-minute results of immediate interest, were brought out at the Conference itself. About one-tenth of the total were from CERN, either alone or in collaboration with one or more other laboratories. Particularly noteworthy among them were the experimental results showing the peculiar behaviour of the proton in scattering at high energies, the measurements that have confirmed the electron nature of the muon to high precision, contributions to the study of 'resonances', and a new theoretical model for high-energy interactions.

Unfortunately it is not possible to explain fully the meaning and importance of all the papers, which represented a considerable contribution by CERN to the subject matter of the Conference, but it is hoped that the list of titles below will give at least some idea of the type of work currently being carried out at CERN, the number of physicists involved, and the links with Member States and others. The papers listed are those that were actually read ; owing to the large number submitted from all the laboratories, in relation to the time available, it was not possible to accept all the proposed contributions.

— STUDY OF THE ω^0 MESON IN ANNIHILATIONS $\bar{p}+p \rightarrow K+\bar{K}+\omega^0$ AT REST.

R. Armenteros, R. Budde, L. Montanet, D.R.O. Morrison, A. Shapira, S. Nilsson, and J. Vandermeulen[1] (CERN) ; C. d'Andlau, A. Astier, C. Ghesquière, B. Gregory, D. Rahm, P. Rivet and F. Solmitz (Collège de France and École Polytechnique, Paris).

1. On leave from 'Institut interuniversitaire des Sciences Nucléaires', Belgium.

— ELASTIC SCATTERING AND SINGLE PION PRODUCTION BY 3.0-GeV/c ANTIPROTONS IN HYDROGEN.

Y. Goldschmidt-Clermont, M. Guinea[1], T. Hofmokl[2], R. Lewisch[3], D.R.O. Morrison, M. Schneeberger and S. de Unanumo[4].

1,4. On leave from University of Madrid, Spain.
2. On leave from University of Warsaw, Poland.
3. On leave from University of Technology, Vienna, Austria.

— THEORY OF LOW - ENERGY NUCLEON - NUCLEON SCATTERING.

D. Amati and E. Leader.

— EVIDENCE FOR A POSSIBLE π-N RESONANCE IN THE $P_{1/2}$, $t=1/2$ STATE AT 900 MeV.

B.T. Feld (M.I.T.) and W.M. Layson (CERN).

— POSSIBLE RESONANT ENHANCEMENT OF THE TWO-PHOTON EXCHANGE IN ELECTRON-PROTON SCATTERING.

D. Flamm and W. Kummer[1].

1. 'Institut für Theoretische Physik, Technische Hochschule', Vienna, Austria.

— A STUDY OF HYPERON-ANTIHYPERON PRODUCTION BY 3.0, 3.6 and 4.0 GeV/c ANTIPROTONS IN HYDROGEN.

Birmingham - C.E.N. (Saclay) - CERN - École Polytechnique (Paris) - Imperial College (London).

— STRANGE-PARTICLE PRODUCTION IN 10-GeV/c π^- INTERACTIONS IN HYDROGEN BUBBLE CHAMBERS.

A. Bigi[1], S. Brandt, R. Carrara[2], W.A. Cooper, A. de Marco, G.R. MacLeod, Ch. Peyrou, R. Sosnowski[3], and A. Wroblewski[4].

1,2. University of Pisa, Italy.
3. On leave from Institute for Nuclear Research, Warsaw, Poland.
4. On leave from Institute of Experimental Physics, University of Warsaw, Poland.

— STRANGE-PARTICLE CORRELATIONS IN HIGH-ENERGY PION-NUCLEON COLLISIONS.

H.H. Bingham, M. Block, D. Drijard (École Polytechnique); A. Minguzzi-Ranzi, M. Nikolic (CERN).

— ANTIPROTON-PROTON ANNIHILATION AT REST INTO TWO MESONS

and

STUDY OF THE K* RESONANCE IN $\bar{p}p$ ANNIHILATION AT REST.

R. Armenteros, L. Montanet, D.R.O. Morrison, A. Shapira, S. Nilsson, and J. Vendermeulen[1] (CERN) ; C. d'Andlau, A. Astier, C. Ghesquière, B. Gregory, D. Rahm, P. Rivet and F. Solmitz (Collège de France and École Polytechnique, Paris).

1. On leave from 'Institut interuniversitaire des Sciences Nucléaires', Belgium.

— INTERACTIONS OF 1.47-GeV/c NEGATIVE K-MESONS IN HYDROGEN.

W.A. Cooper, H. Courant[1], H. Filthuth, A. Minguzzi-Ranzi, H. Schneider[2], A.M. Segar[3], G.A. Snow[4], and W. Willis[5] (CERN) ;
E.S. Gelsema, J.C. Kluyver and A.G. Tenner (University of Amsterdam) ;
K. Browning, I.S. Hughes and R. Turnbull (University of Glasgow).

1. Ford Foundation Fellow.
2. On leave from University of Hamburg, Germany.
3. On leave from Rutherford Laboratory, England.
4. National Science Foundation Senior Postdoctoral Fellow, on leave from University of Maryland, U.S.A.
5. Ford Foundation Fellow, on leave from Brookhaven National Laboratory, U.S.A.

— K^+-PROTON INTERACTION AT LOW ENERGY.

G. Costa, R.L. Gluckstern and A.H. Zimerman.

— DETERMINATION OF THE μ^- TOTAL CAPTURE RATE IN LIQUID HYDROGEN.

E. Bertolini, A. Citron, G. Gialanella, S. Focardi, A. Mukhin[1], C. Rubbia, S. Saporetti.

1. On leave from Joint Institute for Nuclear Research, Dubna, U.S.S.R.

— DETERMINATION OF THE $\pi^+ \rightarrow \pi^0+e^++\nu$ DECAY RATE

and

EXPERIMENTAL EVIDENCE FOR STRUCTURE EFFECTS IN THE $\pi^+ \rightarrow e^++\nu+\gamma$ DECAY PROCESS.

P. Depommier[1], J. Heintze, A. Mukhin[2], C. Rubbia, V. Soergel and K. Winter.

1. On leave from the University of Grenoble, France.
2. On leave from Joint Institute for Nuclear Research, Dubna, U.S.S.R.

— A MEASUREMENT OF THE μ^+ LIFETIME.

F.J.M. Farley, T. Massam, T. Muller[1], and A. Zichichi.

1. 'Centre National de la Recherche Scientifique' and 'Institut de Recherches Nucléaires', Strasbourg, France.

— RESULTS ON PERIPHERAL PION-NUCLEON INTERACTIONS AT 12 AND 17 GeV/c.

D.O. Caldwell[1], E. Bleuler[2], B. Elsner[3], L.W. Jones[4], and B. Zacharov.

1. Now at Massachusetts Institute of Technology, U.S.A.
2. On leave from Purdue University, U.S.A.
3. On leave from the University of Hamburg, Germany.
4. On leave from the University of Michigan, U.S.A.

— EXPERIMENTS ON PROTON-PROTON SCATTERING BETWEEN 8 AND 26 GeV.

A.N. Diddens, E. Lillethun, G. Manning[1], A.E. Taylor[2], T.G. Walker[3] and A.M. Wetherell.

1,2. On leave from Atomic Energy Research Establishment, Harwell, England.
3. On leave from National Institute for Research in Nuclear Science, Harwell, England.

— A STATISTICAL INTERPRETATION OF LARGE-ANGLE ELASTIC SCATTERING.

L.W. Jones[1], G. Fast, and R. Hagedorn.

1. On leave from the University of Michigan, U.S.A.

— SOME RESULTS ON π^- INTERACTIONS AT 6, 11, AND 18 GeV/c.

École Polytechnique (Paris) - CERN - Milano.

— PERIPHERAL EFFECTS OF 16-GeV/c NEGATIVE PIONS AND THE π - π CROSS-SECTION.

D.R.O. Morrison.

— THEORY OF HIGH - ENERGY SCATTERING AND MULTIPLE PRODUCTION.

D. Amati, S. Fubini[1] and A. Stanghellini.

1. And 'Istituto di Fisica dell'Università', Turin, Italy.

— LIMITATIONS IMPOSED BY UNITARITY ON THE IMAGINARY PART OF A SCATTERING AMPLITUDE AND CONSEQUENCES ON ITS HIGH-ENERGY BEHAVIOUR.

André Martin.

— (g-2) OF THE MUON AND ITS CONSEQUENCES.

G. Charpak[1], F.J.M. Farley, R.L. Garwin[2], T. Muller[3], J.C. Sens and A. Zichichi.

1. On leave from 'Centre National de la Recherche Scientifique', Paris, France.
2. IBM Watson Laboratory, Columbia University, New York, U.S.A.
3. 'Centre National de la Recherche Scientifique' and 'Institut de Recherches Nucléaires', Strasbourg, France.

— SCATTERING OF μ^--MESONS BY CARBON.

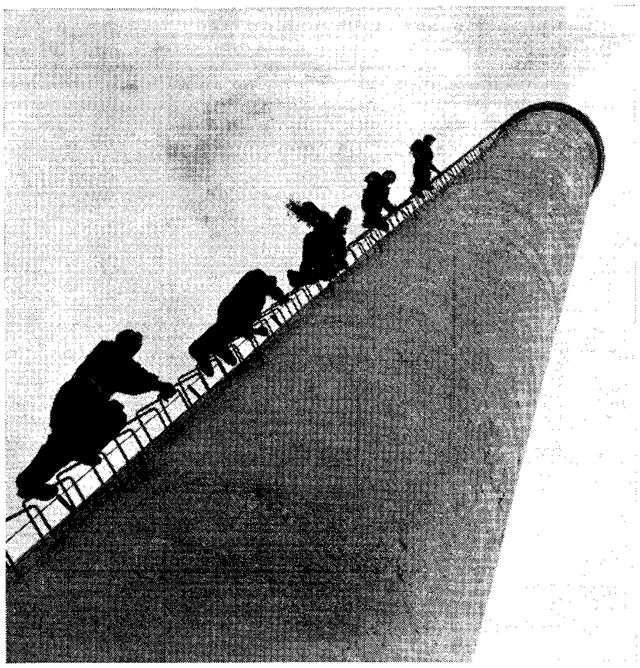
A. Citron, C. Delorme, D. Fries, L. Goldzahl[1], J. Heintze, D.E.G. Michaelis, C. Richard[2], and H. Øverås.

1. 'Laboratoire de Synthèse Atomique', Ivry, France.
2. 'Laboratoire de Physique Nucléaire', Grenoble, France.

— ANALYSIS OF REACTION CROSS-SECTIONS IN PARTIAL WAVES OF A CROSSED CHANNEL.

M. Gourdin and A. Martin.

A. G. H. ●



Once a year the Power House chimney, 30 m high and 2 m across on the inside, has to be cleared of its accumulated soot. This chimney sweeping on a grand scale, carried out during the short period in the summer when the boilers can be shut down for general servicing, was begun this year on Monday, 2 July, and finished some 195 ½ working hours later. Our picture shows the 5-man team from the contractors on their way up the outside of the chimney to begin their job.

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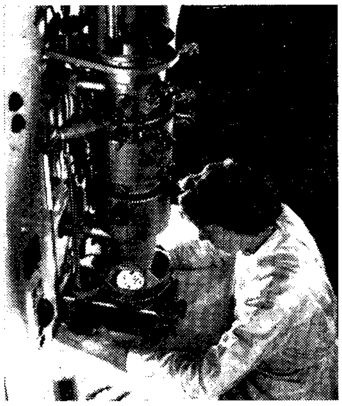

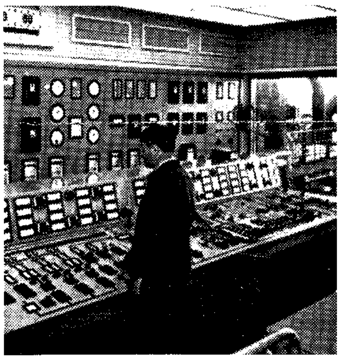

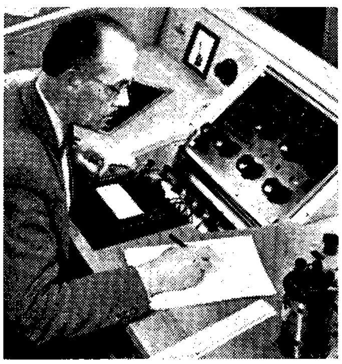

Measurement and control in thermal and processing techniques

Electrical metrology

Electronic microscopy

Non-destructive testing of materials

Measurement of mechanical quantities

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