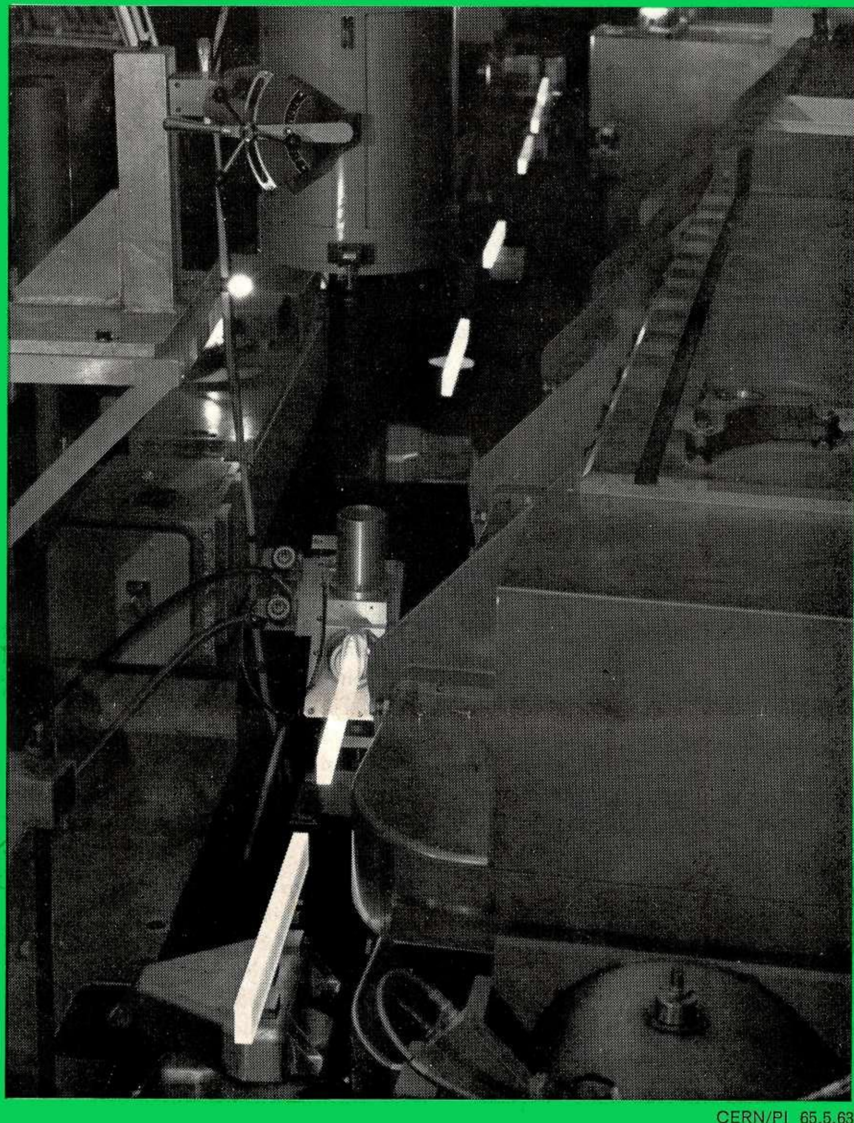
CERN COURIER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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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 (1.92 %), Belgium (3.78), Denmark (2.05), Federal Republic of Germany (22.47), France (18.34), Greece (0.60), Italy (10.65), Netherlands (3.87), Norway (1.46), Spain (3.36), Sweden (4.18), Switzerland (3.15), United Kingdom (24.17).
Contributions for 1963 total 92.5 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.'

Contents

The cover photograph shows the world's first 25-GeV proton beam to be extracted from an accelerator and travel in free air. On 13 May, the day after the beam was obtained for the first time, blocks of plastic scintillator were placed along its path and G. Bertin and F. Julliard, of the Public Information Office, set up their camera to record the effect. As expected, the scintillators glowed brilliantly as the beam passed through them. To the right can be seen magnet units nos. 3 and 4 of the synchrotron ; to the left of the beam is the pulsed beam-transport system, temporarily moved out of the way. The cylinder is the TV camera viewing screen no. 3 in the extracted beam, as mentioned in the story which begins on p. 63.

CERN COURIER

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Last month at CERN

After being shut down for a period of eight weeks, the **proton synchrotron** was put into operation again on the planned date, 24 April. To allow continued installation work and testing on the fast ejection system, a modified schedule was used, involving start-up of the accelerator every evening for nuclear-physics experiments during the night, work on the ejection system being confined to the period 8 a.m. to 5 p.m. each day. To hold the induced radioactivity in the ring within reasonable limits, beam currents were kept low.

There is no doubt that they could have been much higher, as another milestone was passed by the **Linac** group during the month. Less than a year ago we reported their celebration upon reaching an output current of 20 mA. On 4 April, this figure was raised above 50 mA, a justified reason for more champagne but, even before the party had taken place, further increases to around 65 mA were obtained.

Apart from the fact that the linac was not designed to accelerate anything like this value of proton current, there have been two main problems in providing ever larger input currents to the synchrotron. The first of these was to get as much as possible of the current produced by the ion source into the linac, and up to now most attention has been paid to this. The ion source itself has also been improved.

An encouraging feature of the improvements so far is that the 'emittance' of the beam (its diameter and angle of divergence) at the exit of the linac has hardly changed, in spite of the greatly increased number of protons. The second problem is to get as much as possible of the linac current accelerated by the synchrotron. So far, increases in the final accelerated beam intensity have not been proportional to the increases in the linac current, and the reasons for this are now being investigated, by other sections of the PS Division as well as by the Linac group.

Incidentally, the current in the linac has now become so much higher than the design figure (a few milliampères) that operation is visibly effected. The power supplies are just not capable of giving energy to any more protons. Special tricks have already had to be applied to enable the present current to be handled successfully, but any further increase of the loading would require new radiofrequency power supplies.

One result of all these considerations is that the Linac group's new target is no longer a value of linac current but one of accelerated beam intensity. The next champagne party will probably have to wait until 10^{12} protons per pulse are obtained at 25 GeV.

As reported in the February issue of *CERN COURIER* (p. 18), a group known as the **Working party on a European high-energy-accelerator programme** was set up at the beginning of the year, following the convening of a **European committee on future accelerators.** As part of its activities, the Working party held five meetings in the first three months of the year, the fifth being on 1 April, and on 2 April its conclusions were considered at the second meeting of the full Committee.

At this meeting the text was approved of an interim report, which was afterwards submitted for consideration to CERN's Scientific Policy Committee, meeting on the afternoon of 2 April.

The accelerator committee is continuing its work by studying national programmes of high-energy physics in Europe, to complement its considerations of large international projects. It hopes to produce a final report to the Scientific Policy Committee in June this year, in time for the next meeting of CERN Council.

A particularly interesting development at the Committee's meeting on 2 April was the presence as observers of Profs. Panofsky and Ramsey, from the U.S.A., and Profs. Kolomenskij and Yablokov, from the U.S.S.R. It seems that there is a possibility of reaching an informal agreement with American and

Continued on p. 70

Knocking out the PS beam

On 12 May, at thirty-five minutes past four in the afternoon, history was made again at the CERN proton synchrotron. The first accelerating machine in the world to produce 25-GeV protons then became the source of the world's first beam of 25-GeV protons to travel freely in air.

The story of events in the accelerator's main control room on that day is here told by Berend Kuiper, *one of those chiefly responsible. For once, no apology is made for the retention of a certain amount of 'jargon' and specialist language, but it is hoped that the notes on p. 64 will assist those to whom the fast-ejection system is unfamiliar. A fuller account of the system itself will appear in the June issue of* CERN COURIER.

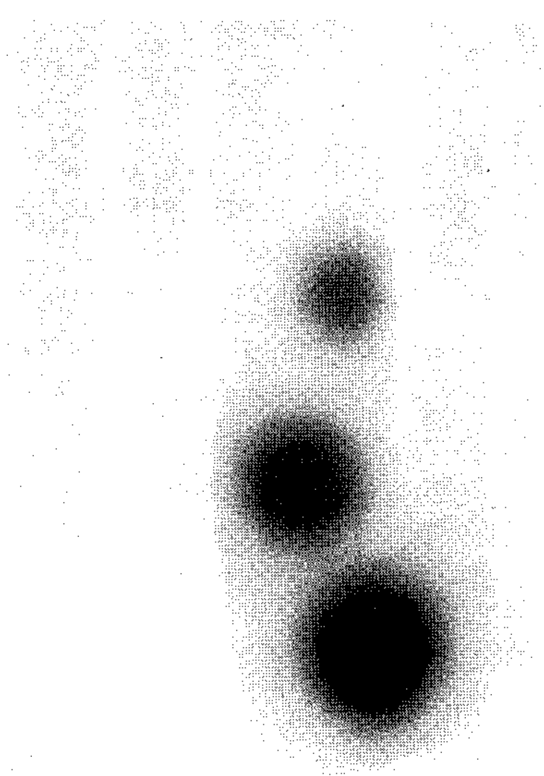


Photo : CERN NPA Division

Blackening produced by the beam on passing through a sheet of photographic paper. Spots, top to bottom, are from one pulse, five pulses, and ten pulses respectively (paper was moved between each set of exposures). Circularity for higher exposures shows that beam travelled always along the same path, different spot sizes being only a photographic effect.

The mood of the ejection team in the PS main control room on Sunday morning, 12 May, was one of moderate confidence, since several operations of the ejection magnets together with the proton beam had already been rehearsed before and results had proved reasonably close to the predictions.

After patching up the high-voltage feeds, which had recently led to some trouble, the kicker magnet had been reinstalled in its vacuum box in straight-section 97 the previous Friday night. On Saturday morning the box had been reopened for a final check and the electrical connexions verified by pulsing the magnet in air for an hour. The lid had just been replaced on the tank, when suddenly the NPA mechanics, Albert Bertuol, Yves Favereau, Anton King and Pierre Pugin produced a baby pine tree with a beautiful yellow lace, which they solemnly mounted on top of a hydraulic accumulator by means of that indispensable tool of the physicists, 'Scotch' tape. Saturday afternoon had been spent on rehearsing some gymnastics of the magnet movement and the beam displacement, so as to study the correct positioning of one to the other. Also, the two magnets were for the first time electrically pulsed in the presence of a proton beam. The leakage field of the bending magnet proved not to disturb the unkicked beam appreciably, and the kicker magnet produced the expected deflection of the protons. All these preliminary results were the basis for the good hopes on that Sunday morning when, between 8 and 9 a.m., Hugh Hereward with his MPS operating team were setting up the 3-second 25-GeV synchrotron cycle and the NPA ejection men warmed up their equipment.

For some months now, the actual publication date of CERN COURIER has been considerably later than the nominal one shown on its cover. Unfortunately, since each issue of normal size tends to require rather more than one month to prepare, it is easier for this time interval to increase rather than to decrease. Nevertheless, it is hoped to make the publication dates gradually more realistic again. Meanwhile, as will be seen from this issue, an attempt will be made to relate important news items to the actual date of publication rather than the nominal one, even though this may seem like prediction to someone referring back at a later date.

After Sten Milner had made his final round and was satisfied that his hydraulic actuators moved the ejection magnets smoothly in and out in their vacuum boxes, the PS magnet ring was closed and the green sign 'beam on' appeared on its panel in the main control room. Sten Milner then slowly adjusted the kicker magnet towards its working position, observing on the oscilloscope its periodic plunging forward and drawing back. Advancing it beyond its working position until it intercepted some protons he 'felt' for the beam position, then went back about one centimetre. Subsequently Hugh Hereward twiddled the PS controls and moved the proton beam up and down until interception, thus feeling for the two magnet poles of the kicker magnet. He then placed the beam in the middle. This now meant that at the end of each PS acceleration cycle, at the instant chosen for ejection, the beam was for a very short moment exactly in the centre of the kicker-magnet's aperture. At this stage Laurens Caris turned on the kicker-magnet pulsers while Herman van Breugel and Javier Goñi watched the steadily increasing electrical and magnetic field impulses on the scope. Everything was still like the day before. The voltage was kept moderate and the morning was spent on things like synchronization of the kicker movement and its magnetizing pulse, checking proportionality between voltage and beam deflection, etc. This all went well, so that some time after 1 p.m. there didn't seem to be any good reason left not to make a serious attempt to eject the beam.

The kicker-magnet voltage was cut and Sten Milner gently increased the bending-magnet movement until it started popping up on the TV screen. The upstream end of the BM, which has the window into which the

THE FAST EJECTION SYSTEM

● Two electromagnets, energized by powerful pulses of electric current, are used in the fast ejection system. The first of these is the fast kicker magnet, here referred to as the KM. It is moved mechanically in time with the acceleration cycle in such a way that when the protons have low energy they move clear of it while as they reach full energy they find themselves passing between its poles. The second magnet is the fast ejection magnet, here referred to as the bending magnet or BM. This also moves in synchronism with the acceleration cycle in such a way that as the protons reach full energy the magnet approaches very close to their trajectory. The magnet is so constructed that even at full strength it has little effect on the beam in this position, but if the beam passes inside the so-called 'septum' of the magnet it is sharply deflected.

● The bending magnet is switched on first, its rise to full strength being comparatively slow (though still measured in millionths of a second). As the field of the magnet nears its peak, the kicker magnet is pulsed. The proton beam is thus kicked inside the septum of the bending magnet and hence out of the accelerator.

● For the tests, a television camera was arranged to view the fluorescent screen surrounding the aperture of the bending magnet, while others viewed screens placed at various positions along the expected path of the beam.

KM must shoot the beam, had been equipped with a fluorescent frame following the contours of the window and the septum, the latter being the barrier to be jumped by the beam. This is a spectacular sight actually, as the fluorescent frame is very clearly visible on the TV and the presence of the proton beam manifests itself as a small light flash from the outside of the septum every time the magnet is in its highest position. This arises from stray protons around the actual beam which hit the fluorescent paint on the frame. In order to try the trick first with a low voltage on the KM, the beam had to be moved as close to the septum as possible, so that the jump from the outside of the septum to the inside would be a minimum. Hugh Hereward turned a knob until some beam loss on the septum was apparent, then went back slightly. Now Günther Plass switched on the bending-magnet pulser and slowly increased the current until a green lamp signalled that the theoretical ejection current had been reached. Laurens Caris started the one-minute timer of the KM pulsers which were still preadjusted on the previous, moderate voltage.

By now a small crowd had gathered before the TV screen of the ejection controls. Apart from the ejection men, the machine operators and engineers, and some passers-by, Colin Ramm and Guy von Dardel followed the proceedings. On a table nearby, praying, sat the builder of the actual kicker magnet, Stephan Pichler; close to him, Berend Kuiper was going over his already eaten finger nails once more. Herman van Breugel, sensing the suspense of the moment, started counting back the seconds, while everyone waited for the kicker magnet to give its first pulse. At zero, an intense light flash from the middle of the septum indicated that the KM had kicked the beam in the right direction. The voltage would now only have to be increased to make ejection a fact. Laurens Caris was already pressing the button and slowly, shot after shot, the light spot moved sideways over the septum until it disappeared within the window of the BM. Immediately, Horst Wachsmuth dashed forward and switched the TV receiver to camera 2, viewing a fluorescent screen in straight-section 2 outside the PS vacuum chamber. A light spot here would mean that the beam was outside. The screen, however, was blank.

General disappointment... Generous suggestions and lots of useful indications from the crowd... Meanwhile Hendrik Dijkhuizen and Javier Goñi climbed into their electronics and after a while found that the delay between the bending magnet and the kicker was inactive. The pulse for the latter, which should be 75 microseconds later than the pulse for the bending magnet, was in fact being triggered at the same time, so that the kicked beam arrived in the aperture of the bending magnet when the field there was still very nearly zero.

By this time the functioning of the proton synchrotron had become very irregular and defective, apparently because of some trouble with its power supply. The beam was available for only a very small fraction of the time, and then only for a few pulses. Progress in this way was very slow as Javier Goñi and Hendrik Dijkhuizen still hunted for the spurious signal that prematurely triggered the kicker magnet. 'Hash' coming back from the BM ignitrons over their trigger cable was the apparent cause.

Meanwhile the clock had reached 4 p.m. and time was quickly running out, as the machine shifts allocated to ejection studies were due to end an hour later. To make a final attempt before closing time, Hendrik and Javier then locked the KM and the BM over entirely separate timing units on to the PS cycle. This permitted their proper phasing without mutual interference. The magnets were now pulsed again, but the PS still didn't function any better than before. Each time the PS accelerated a few pulses the mob dashed to the TV screen, but over and over again the PS fell out before anything could be seen. Then, finally, at 4.35 p.m. the 'beam on' signal stayed alight rather longer than usual and the TV reproduced the picture of the beam being kicked into the BM window. As Horst Wachsmuth then again switched the receiver to camera 2, a piercing light flash near the cross mark on the fluorescent screen proved that the world's first 25-GeV proton beam had been successfully ejected — very close to the theoretical trajectory ●

Berend Kuiper

Colin RAMM

Leader, Nuclear Physics Apparatus Division


CERN/PI 56.6.63

Colin Ramm, Leader of the Division responsible for the realization of the fast ejection system on the synchrotron, was born in Perth, Western Australia, in 1921. After completing his early studies at Guildford Grammar School, he obtained an exhibition to the University of Melbourne, but was unable to accept it. Instead, he joined the Commonwealth Meteorological Bureau, and began to study part time with a free place at the University of Western Australia. At school his passion had been chemistry, but later he concentrated on physics, gaining a first-class Honours degree in 1942.

Owing to the war, the Meteorological Bureau became part of the Royal Australian Air Force, from which he was seconded to the University for optical munitions work. Skilful at experimental techniques, he spent much time in the final polishing of lens test plates, which have to be accurately figured to around a ten thousandth of a millimetre and which had always before been obtained overseas. He thus became acquainted with optical techniques and metrology, and learned the connexion between patience and precision.

After the war, he stayed on at the University, becoming interested in cosmic rays, klystrons, and teaching. In 1947 he accepted an invitation from Prof. M.L.E. (now Sir Marcus) Oliphant to be a lecturer at Birmingham University (England), where Europe's first proton synchrotron, to give an energy of 1 GeV, was being built.

The h.t. set destined for the synchrotron injector was about to be delivered, so Prof. Oliphant proposed that he build an accelerator tube and spend a few years measuring the energy released in a number of nuclear reactions. As a by-product, he and his colleagues remeasured some of the energies of natural alpha particles, with improved absolute precision. For this work he obtained his doctorate in 1951. By that time the synchrotron had progressed sufficiently to require its high-voltage set; he then designed and built the injection equipment and stayed with the synchrotron team until completion of the machine.

At about this time plans were being made for the 28-GeV CERN proton synchrotron. Like many others, Colin Ramm was stirred by the deep significance of an international collaboration to build a much larger accelerator, of great promise for experimental physics. In 1954 he joined the PS Division, as leader of the magnet group, which became responsible for the whole of the synchrotron's magnet system, apart from the main power supply. Exceptional uniformity had to be obtained in the magnetic properties of the individual components, so it was essential to find physical principles by which the processes of construction would in themselves produce the necessary precision. In fact, when the synchrotron was built, the protons circulated at the first trial, to the satisfaction and relief of all concerned.

With work on the magnet system finished, the magnet group — which became the Nuclear Physics Apparatus Division in 1961 — turned towards helping to make the PS usable as an experimental device, and in the course of time a number of projects took shape: the heavy-liquid bubble chamber, magnets and lenses for guiding secondary beams, electrostatic separators, a high-energy antiproton beam, scanning apparatus for the bubble-chamber photographs, the fast beam-ejection system, and finally the enhanced neutrino beam. The Division views its task as primarily one of helping the advancement of physics, and is convinced that the best ideas can only come from a very close contact with experiments. For this reason there is also a small experimental-physics group which analyses a proportion of the pictures from the bubble chamber.

The *bubble chamber*, with a volume of 500 litres, is still the largest heavy-liquid chamber in the world operating in a magnetic field. The maximum field of 26 700 gauss is also somewhat of a record for a large chamber. Built by a project group led by Renzo Resegotti (now in the Accelerator Research Division), it was completed towards the end of 1960 and used in CERN's first attempts to detect neutrino interactions. It has since been used for experiments with negative kaons, and is now again installed for neutrino physics. The chamber is at present run by a team under Pier-Giorgio Innocenti, while Robert Voss is in charge of the physics programme.

The *electrostatic separators* have already given CERN's experimenters some of the world's highest-energy beams of separated particles. Claude Germain, with Roger Tinguely, François Rohrbach and others, have also produced smaller separators for specialized applications and are now carrying out research on the more basic principles of high-voltage breakdown in vacuum.

It is the *enhanced neutrino beam* that has currently grown to be the Division's main preoccupation. When interest in neutrino physics was first aroused, the group under Berend Kuiper and Günther Plass was already working on a proposal they had made for extracting protons from the synchrotron. The idea had been conceived without a particular experiment in view, but it became obvious that with the ejected beam a greater pion flux could be obtained in the experimental areas. Then Simon Van der Meer produced the idea of a magnetic horn, to concentrate the pions so that an even larger number of neutrinos from their decay would be directed towards the detectors. A project with Manfred Geisch, Gerrit Pluym and others was formed for its continuation. To guide the proton beam to the target in the horn, compact, pulsed, beam-transport components were developed by Bas de Raad (now in Accelerator Research Division), Dick Neet (now with the Stanford 2-mile-linac project), and Bjarne Langeseth, who now has responsibility for the components. This time they had behind them the experience of some 500 tons of beam-transport equipment, already produced by the Division for use with the synchrotron.

The enhanced neutrino beam is now installed, and those responsible for it will be well occupied for some time to come. Eventually, no doubt, it will be regarded as another normal feature of the accelerator, but there may still be more novel problems to be solved before its designers and constructors work on their next projects. And who knows how the present neutrino experiment will stimulate ideas for the future ? ●

THE 'PARTICLES' OF SUB-NUCLEAR PHYSICS

From the early days of just the proton and the electron, the list of so-called 'fundamental particles' grew until a year or two ago some 30 particles and antiparticles were known or predicted. Then came the discovery of the first 'resonances' or 'excited states', and the list began rapidly to lengthen again. It now seems clear, however, that neither these new particles nor, perhaps, many of those in the earlier list are truly 'fundamental' or 'elementary'. As Prof. Weisskopf has remarked[1], it is rather like calling every atomic excited state by a different name, producing ten thousand different atoms instead of the hundred or so that are in fact recognized. New ideas abound, and a more rational classification will undoubtedly arise in time, but for the moment, for those not closely involved, a certain amount of confusion appears inevitable.

The known 'particles' have here been placed into two groups, arbitrarily defined to separate the older particles from the newer ones. It happens that these groups also correspond more or less to those of the 'long-lived' and 'short-lived' particles, by comparison with a 'nuclear year', which is the time taken for a nucleon to revolve about the centre of a nucleus, or about 10^{-22} second. In each group, the particles fall into classes, within which they have been ordered according to their masses.

TABLE 1 : The 'elementary particles' — lifetime long compared with nuclear year

			Particle name	Particle symbol and charge states	Mass (MeV)	Mean life (second)	Antiparticle symbol and charge states[4]	Antiparticle name
FERMIONS (spin 1/2) Only one fermion can exist in a particular state at any given time	LEPTONS (light particles)		neutrino[2]	ν_e	0	stable	$\bar{\nu}_e$	antineutrino
			neutretto[2]	ν_μ	< 3.5	stable	$\bar{\nu}_\mu$	antineutretto
			electron	e^-	0.51	stable	e^+	positron
			muon (mu minus)	μ^-	105.66	2.2×10^{-6}	μ^+	muon (mu plus)
	BARYONS (heavy particles)	nucleons[3]	proton	$p\ (=N^+)$	938.2	stable	$\bar{p}\ (-)$	antiproton
			neutron	$n\ (=N^0)$	939.5	1×10^{3}	$\bar{n}\ (0)$	antineutron
		hyperons	lambda	$\Lambda\ (0)$	1115.4	2.5×10^{-10}	$\bar{\Lambda}\ (0)$	antilambda
			sigma plus	Σ^+	1189.4	8×10^{-11}	$\bar{\Sigma}^-$	antisigma
			sigma zero	Σ^0	1191.5	$\ll 1 \times 10^{-11}$	$\bar{\Sigma}^0$	
			sigma minus	Σ^-	1196.0	1.6×10^{-10}	$\bar{\Sigma}^+$	
			xi zero	Ξ^0	1315	3.9×10^{-10}	$\bar{\Xi}^0$	antixi
			xi minus	Ξ^-	1321	1.7×10^{-10}	$\bar{\Xi}^+$	
BOSONS (spin 0 or 1) Two or more bosons can exist in the same state at the same time			photon	γ	0	stable	γ	photon[5]
	MESONS (intermediate particles)		pion pi zero	π^0	135.0	1.0×10^{-16}	π^0	pion[5]
			pion plus or minus	π^+ or π^-	139.6	2.6×10^{-8}	π^- or π^+	
			kaon K plus	K^+	493.9	1.2×10^{-8}	K^-	antikaon
			kaon K zero[6]	K^0 K^0_1 K^0_2	497.8	1.0×10^{-10} 6.0×10^{-8}	$\bar{K}^0$	

TABLE 2 : resonances, isobars and excited states

	'Particle' name	Mass[7] (MeV)	Charge states[7]	Principal decay products[8]	'Regge' assignment[9]
MESONS	η (eta)	548	0	neutrals $\pi^+\pi^-\pi^0$	χ_β 0^-
	ϱ (rho)	750	$-0+$	$\pi\pi$	π_γ 1^-
	ω (omega)	785	0	$\pi^+\pi^-\pi^0$ neutrals	χ_γ 1^-
	χ (khi)	1020	0	$K_1 K_1$	χ_α 0^-
	ϕ (phi)	1019	0	$K_1 K_2 (K^0 \bar{K}^0)$	χ_γ 1^-
	f	1250	0	$\pi\pi$	f_α 2^+
	K^*	888	$0+$	$K\pi$	K_γ 1^-
BARYONS	N^*	1238	$-0+2+$	$N\pi$	Δ_δ $^3/_2{}^+$
	N^{**}	1512	$0+$	$N\pi$	N_γ $^3/_2{}^-$
	N^{***}	1688	$0+$	$N\pi$	N_α $^5/_2{}^+$
	N^{****}	1920	$-0+2+$	$N\pi$	Δ_δ $^7/_2{}^+$
	Y_0^* (1405)	1405	0	$\Sigma\pi$ $\Lambda\pi\pi$	Λ_β $^1/_2{}^-$
	Y_0^* (1520)	1520	0	$\Sigma\pi$ $\bar{K}N$ $\Lambda\pi\pi$	Λ_γ $^3/_2{}^-$
	Y_0^* (1815)	1815	0	$\bar{K}N$	Λ_α ? $^5/_2{}^+$
	Y_1^* (1385)	1385	$-0+$	$\Lambda\pi$ $\Sigma\pi$	Σ_δ $^3/_2{}^+$
	Y_1^* (1660)	1660	$-0+$	$\bar{K}N$ $\Lambda\pi$ $\Sigma\pi$	Σ_γ ? $^3/_2{}^-$
	Ξ^*	1530	-0	$\Xi\pi$	Ξ_δ ? $^3/_2{}^+$
	Ξ^* (predicted)	1600	-0		Ξ_γ ? $^3/_2{}^-$
	Ω (predicted)	1676	-		Ω_δ ? $^3/_2{}^+$

1. For those interested in the newer, more fundamental classifications, Prof. Weisskopf's lecture at the Royal Society earlier this year (see CERN COURIER vol. 3, no. 3, p. 36) has been published also as a CERN report, CERN 63-8, entitled 'The place of elementary-particle research in the development of modern physics'.
2. The terms 'electron neutrino' and 'muon neutrino' are probably more common at the present time. Separate symbols without the suffixes e and μ have not yet been adopted.
3. The symbols N and $\bar{N}$ are used for nucleons and antinucleons when the charge does not have to be considered specifically.
4. For mostly historical reasons, the notation for the symbols of antiparticles appears somewhat inconsistent to those not familiar with it. In cases where no confusion is possible, sometimes the 'bar' is omitted, sometimes the charge sign. When both are included, two conventions are in use, exemplified by the fact that the charged antixi, which is positive, can be written $\bar{\Xi}^+$, as here, or $\bar{\Xi}^-$, as previously used in CERN COURIER.
5. For photons and neutral pions (π^0), particle and antiparticle are identical. For charged pions there is no way of telling which charge corresponds to the particle and which to the antiparticle.
6. Experimentally, in observations of their decay by weak interaction, the neutral kaon and antikaon always appear as particular combinations of the two, which are called K^0_1, and K^0_2.
7. Table 2 is more condensed than table 1, so that, for example, the states ϱ^-, ϱ^0 and ϱ^+ are listed together, with an approximate mass relating to all three.
8. $\pi\pi$ means that the state decays into two pions, the charge of each pion depending on the charge of the excited state. Where more than one kind of decay is possible, these are listed in order of importance.
9. The first symbol represents the 'trajectory'; the second gives the total angular momentum and the parity of the 'particle'.

CERN Easter School for Emulsion Physicists

by **W. O. LOCK** Nuclear Physics Division

From 20-27 March, 1963, the second Easter School for Emulsion Physicists was held at St. Cergue, in the Swiss Jura, under the auspices of the CERN Emulsion Experiments Committee. Some 58 students were present (compared with 51 last year), 43 of them from Member states. The largest numbers came from France, Germany and the U.K. (10, 9 and 9 respectively) and the average age, as last year, was 27.

The first school concentrated on experimental methods ; this year the main emphasis was placed on physics, and particularly on some of the topics which are at the centre of attention at the present time. Accordingly, the school began with four lectures by Dr. R. Hagedorn (CERN) on high-energy scattering and Regge poles.

Starting with elementary diffraction theory, he discussed the present theoretical ideas used for the description of current results on the elastic scattering of high-energy particles from hydrogen. If one extrapolates to high energies the classical description of the elastic scattering process for small momentum transfer (that is, for scattering through small angles), on the assumption that this gives a measurement of the size of the colliding bodies, the present experimental results suggest two things, which are complementary. In the range of energies available at CERN, Brookhaven and Dubna, the proton radius, as seen by another proton, appears to increase as its energy gets bigger, and at the same time the proton becomes more transparent. The experimental evidence for this phenomenon was described at the school by D. A. M. Wetherell (CERN). Dr. Hagedorn developed the elementary theory of elastic scattering to show how the experimental behaviour could be consistent with current theoretical ideas on the existence of 'Regge trajectories', pointing out, however, that there is already some experimental evidence from pion-proton scattering that such a description cannot be entirely (if at all) valid.

Prof. L. Van Hove (CERN) discussed two different approaches to a more general classification of the elementary particles in terms of a small number of families, where the particles in each family have the values of certain quantum numbers, or certain other properties, in common. One approach discussed classification in families where the only variation lay in angular momentum (that is, along Regge trajectories) while the other approach suggested classification in groups of fermions, bosons, etc.

At the end of the course of lectures by Dr. Hagedorn and Prof. Van Hove, one complete session was devoted to questions from the students to the lecturers. The clear way in which the theoretical concepts had been explained is demonstrated by the fact that questions flowed in for more than an hour, and only lunch (and hunger) terminated the discussion.

Another topic of particular interest to CERN this year is neutrino physics. Prof. G. Bernardini of Rome (until recently Director of Research at CERN) gave two lectures on weak-interaction physics, with particular reference to the interest which now surrounds neutrino interactions and the possible existence of an intermediate vector boson (meson) of very short lifetime (perhaps around 10^{-17} second). Dr. G. von Dardel (CERN) outlined the results obtained from the neutrino experiment carried out at Brookhaven last year and explained the experimental arrangement which has been set up at CERN to extend this kind of work. The CERN experiment should start to run this summer.

A field in which many emulsion physicists are now occupied is the study of the so-called 'hyperfragments', and work has recently been stimulated by the discovery of a 'hypernucleus' containing two lambda particles (lambda hyperons). The occurrence of a conference on hyperfragments, also at St. Cergue, immediately after the Easter School, made it possible for two of the leading experts in this field to attend the closing day of the school and to summarize for the students the present state of knowledge. Prof. R. H. Dalitz dealt with the theoretical situation and Prof. R. Levi-Setti the experimental position. Both speakers are from the University of Chicago.

Two other lectures were given during the school. One by Prof. G. Ekspong (Stockholm University) surveyed our present knowledge of resonant states ; the other, by Prof. G. Zhdanov (Lebedev Institute, Moscow), reporded on recent work in high-energy nuclear physics in the Soviet Union, both in cosmic rays and in accelerator physics.

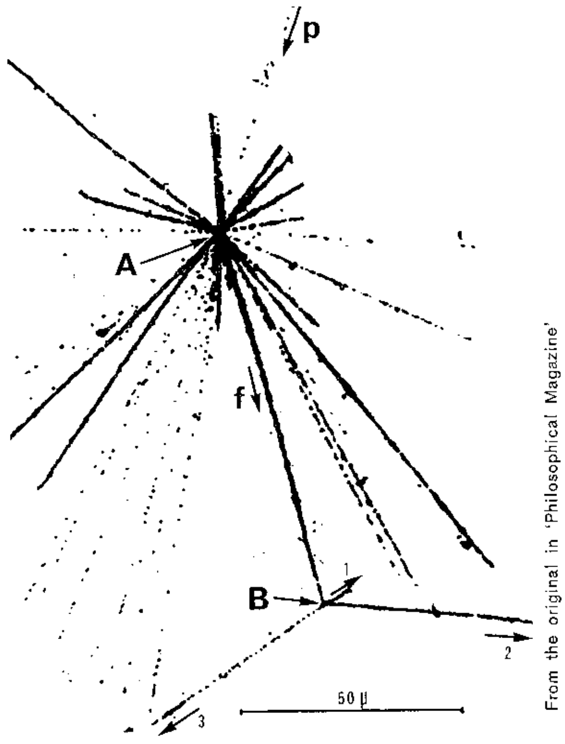
As last year, all the participants were housed in the same hotel. Two lectures were given each morning, and the afternoons were free until five o'clock, when a third session began and continued until dinner time. Unfortunately the sun did not shine as much as had been hoped; nevertheless many people were able to enjoy some skiing and the only injury was a bruised hand. Several of the students from Pakistan and India attempted winter sports for the first time in their lives. On the last evening a banquet was held, at which Prof. Bernardini was the guest of honour.

The third Easter School for Emulsion Physicists will be held in April or May 1964, at Hercigi Novi, by kind invitation of the Yugoslav Nuclear Energy Commission. The programme is now under active discussion ●

Saint-Cergue, 28-30 March, 1963

International Conference on Hyperfragments

by **E. H. S. BURHOP** and **W. O. LOCK**



The first hyperfragment, discovered by Danysz and Pniewski in 1953. A cosmic-ray particle (p) causes a nuclear disintegration at A; one of the particles (f) emitted in the 'star' comes to rest at B and disintegrates with the emission of three charged particles. This particle (f) is the hyperfragment.

Recent exposures of emulsions to beams of 1.5-GeV/c negative kaons at CERN have already produced several possible examples of 'stars' in which two hyperfragments are produced.

Background to the Conference

In the early fifties, soon after the discovery of the so-called 'strange particles', two Polish physicists, M. Danysz and J. Pniewski, observed that nuclei could be formed in which a lambda hyperon was trapped. These **'hypernuclei'** were unstable and, of course, broke up when the trapped hyperon decayed into a pi meson and a nucleon after a time of the order 10^{-10} second. Such hypernuclei may be produced as a result of the break-up of a nucleus after an interaction, and their life-time is still long enough to enable them to produce a track of length from a few microns (thousandths of a millimetre) up to several millimetres in a nuclear photographic emulsion. Because they are usually produced as a result of the breaking up or 'fragmentation' of a larger nucleus, hypernuclei produced in this way are commonly referred to as **'hyperfragments'**.

The fact that hyperfragments can be formed at all shows that the interaction between a lambda hyperon and a nucleus must be one of attraction, at least under some conditions. From an estimate of the binding energy of the hyperon (that is, the amount of energy needed just to remove the lambda hyperon from the rest of the nucleus), some information about the force between the lambda and a nucleon can be obtained. This is very important information for elementary-particle physics and very hard to obtain in other ways. For example, the most direct way of obtaining such data is to study the scattering of lambda hyperons by nucleons. These studies are very difficult, however, because of the short life of the hyperon, which means that there is usually a path length of only a few millimetres before the decay, and an enormous number of hyperons need to be studied in order to obtain just a few examples of scattering.

From time to time in CERN COURIER, reference has been made to 'hypernuclei' and 'hyperfragments' and, although some kind of explanation was usually appended, many readers no doubt remained with only a vague idea of their real significance. In the present article, the authors have first described in general terms the nature and properties of these special kinds of nuclei, and then reviewed the major topics discussed at the recent international conference on this subject.

Prof. E.H.S. Burhop, of University College, London University, has been particularly interested in this field for some time, and for the last two years has been responsible for the 'European K⁻ Collaboration' which co-ordinated the efforts of eight different laboratories for the analysis of nuclear emulsions exposed at the CERN proton synchrotron to beams of K^- mesons. He is at present at CERN for a year, as a CERN Visiting Scientist, concerned chiefly with the study group on new accelerators. W.O. Lock has worked with nuclear emulsions for many years, and is joint Leader of the Nuclear Emulsion Group in the Nuclear Physics Division at CERN. He is also at present secretary of the Nuclear Physics Research Committee.

On the other hand, many hundreds of examples of hyperfragments have now been identified and their binding energies measured. This is possible if all the products resulting from the break-up of the hyperfragment are charged, so that their individual kinetic energies can be measured. From the sum of these, the energy available from the break-up of the hypernucleus is obtained, and this is equal to the energy released in the decay of the trapped hyperon (the Q-value, known quite accurately as 37.57 MeV) less the binding energy of the hyperon in the hypernucleus. In practice, accurate values of the binding energy can be estimated only if the pi meson resulting from the lambda decay escapes from the fragment (mesonic decay). In many cases the pi meson is absorbed before leaving the fragment (non-mesonic decay).

A whole new branch of nuclear physics is in process of being built up around the properties of hypernuclei. A start has been made in the determination of the spins and isospins of their ground states, and methods are being considered for the study of their excited states.

In these circumstances it seemed timely to organize a conference to review the present state of knowledge in this field. Further, since most hyperfragments have short ranges, the technique that is best suited to study them is usually that of nuclear emulsions. It was therefore very appropriate that the conference should have been organized on behalf of the CERN Emulsion Experiments Committee. Other techniques are beginning to show their value in the field, however, and some of the most interesting results described at the conference had in fact been obtained using Prof. Martin Block's helium bubble chamber in the U.S.A., although the number of different varieties of hyperfragment that can be produced in such a chamber is limited.

The Conference itself

The conference was held at St. Cergue, in the Swiss Jura, during 28-30 March, 1963. There were 70 participants (excluding CERN staff and visitors) from 43 laboratories in 14 countries. Since everyone was staying in the same hotel, it was possible to arrange the programme so as to give the maximum possible time for people to talk to each other, if they so desired. Thus, two conference sessions were held in the morning, the afternoon was free, and a third session started at five o'clock and continued until dinner time. Another device to increase the time available for discussion was to circulate the contributed 5-minute papers in advance and to read them in title only at the Conference. Fifteen invited papers were given, spead over eight sessions.

The most exciting new development reported at the conference was undoubtedly the discussion of a new type of event interpreted as a **double hypernucleus,** that is, a nucleus in which two lambda hyperons are trapped. This event came as a result of a systematic search by the 'European K^- Collaboration' for events of double strangeness in nuclear emulsion exposed to the 1.5-GeV/c K^- beam at CERN in March 1962. It was most fitting that this beautiful example of a double hyperfragment should be discovered and identified by the Warsaw group, led by Professors Danysz and Pniewski, the discoverers of the original hyperfragment in 1953.

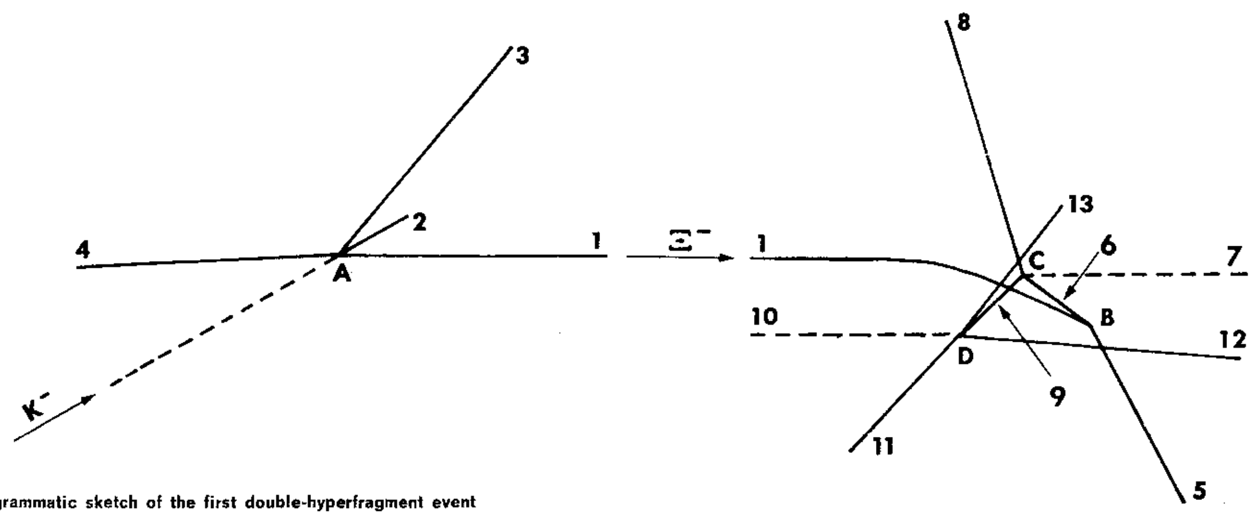
A diagrammatic sketch of the event is shown at the bottom of the page. A K^- meson of momentum 1.5 GeV/c interacts at A with a nucleus present in the emulsion. One of the particles emitted from the interaction is interpreted as a negative xi hyperon that comes to rest in the emulsion, after travelling through 357 microns. This hyperon interacts at B with a light nucleus (possibly carbon) in the emulsion and two tracks are observed, of which one (labelled 6), a short track of length only 3 microns, produces a star at C with the emission of a pi meson (track 7) and two other particles. The track 6 is interpreted as being due to the new type of fragment, containing two bound lambda hyperons. The short track 9, emitted from its decay at C, is only 2.5 microns long and is seen to be due to a hyperfragment whose track ends in the emulsion, undergoing mesonic decay at D. Although the interpretation of the actual hypernuclei involved is not unambiguous, the most likely interpretation is that the track 6 is due to a hypernucleus in which two lambda hyperons are bound to a beryllium nucleus. Also, it appears most likely that the interaction between two lambda hyperons is attractive and has a mean value of about 4 MeV inside the hypernucleus.

The availability of the fast K^- beams at CERN has also made possible the study of new heavy hypernuclei in which the lambda hyperon, instead of being emitted in a nuclear fragment, remains behind in the heavy residual nucleus. Such **heavy hypernuclei** are provided with sufficient energy to produce a visible track only when they are formed in the interaction of fast K^- mesons. When they decay mesonically it is possible to determine an upper limit to the binding energy of a lambda hyperon in a heavy nucleus, a parameter of considerable theoretical interest.

Interesting measurements were described, both from the helium bubble chamber and from emulsions, of the **lifetimes of light hyperfragments** that decay in flight. It was reported that the lambda hyperon trapped in a hydrogen hyperfragment lives for less than half as long as a free lambda. The presence of the other nucleons near the hyperon was expected to produce a change of this kind in the life-time, but the observed effect is unexpectedly large.

The helium-bubble-chamber observations have also enabled some interesting information to be obtained about the spins of the hyperfragments ${}_{\Lambda}^{3}H$, ${}_{\Lambda}^{4}H$, and ${}_{\Lambda}^{4}He$ (that is nuclides analogous to hydrogen-3, hydrogen-4 and helium-4, but in which one of the neutrons is replaced by a lambda).

The final talk by Prof. R.H. Dalitz, which reviewed **outstanding problems** and made suggestions for future work, was one of the most interesting and challenging of the whole conference. It is clear that in the hyperfragment field not only does much interesting work remain for emulsion physicists but one can expect bubble-chamber and counter techniques to play an increasingly important role in the future ●



Diagrammatic sketch of the first double-hyperfragment event

A POWERFUL SOURCE OF NEUTRONS FOR SOLID-STATE PHYSICS

At CERN, our two accelerators both produce high-energy protons for use as projectiles and probes in the search for increased knowledge of the constitution of matter. High-energy electrons are also used in some laboratories. Another possible tool, though it is of more interest to those studying the normal physical states of matter (notably solid and liquid) rather than its ultimate constitution, is the neutron.

Nuclear-physics research carried out with feeble sources of neutrons in the 1930s led to the discovery of fission and eventually to the construction of nuclear reactors in all their many forms, some with a fantastically great production of neutrons. A great deal of work has been done on the gross effects of neutron irradiation on materials, but this is essentially applied research. For more fundamental research in this field and for studies in which the neutron is used more specifically as a probe, well-defined beams of neutrons of accurately known energy are required, as is the case when using protons. High intensity is also necessary. To achieve all this with neutrons emitted from a reactor, particularly while keeping to a minimum the heat produced at the same time, is no easy task. As yet, no such specialized 'very-high-flux' reactor exists, though one approaching this description is now under construction at Brookhaven National Laboratory in the U.S.A.

Following an initial recommendation from L. Kowarski who, besides being Leader of the Data Handling Division at CERN is also Scientific Adviser to the European Nuclear Energy Agency, the Agency has recently launched a study project for a reactor of this kind in Europe. If built, it could become the heart of another centre for fundamental research, like CERN. It is, however, more likely that the internationally built and owned reactor, together with its supporting laboratories, would form an annex to one of the existing reactor research centres.

Last month at CERN (cont.)

Soviet scientists to avoid duplication in accelerator programmes.

The Working party met again on 27 April, many of its members having been present at the Conference on sector-focused cyclotrons and meson factories held at CERN that week.

The 1963 international conference on sector-focused cyclotrons and meson factories was held at CERN from 23-26 April, organized by the Synchro-cyclotron Division with, as usual, the indispensable help of the CERN Scientific Conference Secretariat — namely Miss E.W.D. Steel and Miss Y. Henry. About 160 participants from all parts of Europe (including the U.S.S.R.) and the U.S.A. joined scientists at CERN in discussion on the new types of cyclotron now coming into widespread use to produce particle beams of much higher intensity than previously possible. Included in their talks were considerations of 'meson factories' — 'nuclear x-ray machines', as Prof. Weisskopf called them — which are accelerators specially designed to produce very intense beams of pi mesons.

We expect to publish a report on this conference in a forthcoming issue of *CERN COURIER.*

Not all the experiments at the CERN **synchro-cyclotron** are concerned only with fundamental research; some of them come much more easily under the heading of applied science. Thus on 25-26 April, instead of the usual inanimate matter, large numbers of mice and rats were exposed to the 600-MeV external proton beam from the accelerator. These irradiations follow earlier ones last October and form part of a large programme of biophysics research on the biological action of high-energy radiation which is being carried out by the 'Istituto di Farmocologica' of the University of Milan, under the direction of Prof. A. Pasinetti, the 'Institut du Radium', University of Paris, under Prof. Bonet-Maury, and the 'Laboratoire de Radiobiologie', Saclay, under Prof. Jamsuet. The experiments at CERN were planned and carried out in conjunction with the CERN Health Physics Group under J. Baarli.

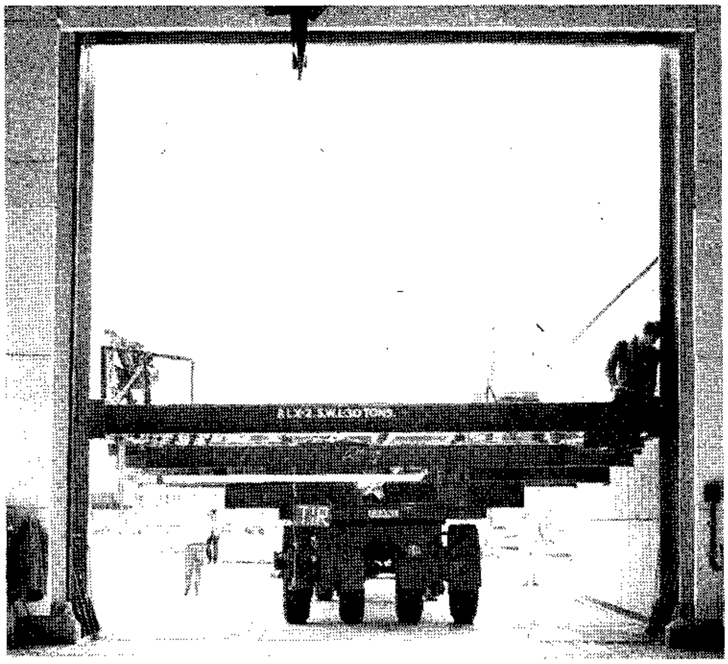
It is of interest to note in this connexion that the **Langley Research Centre of NASA,** the National Aeronautics and Space Administration (U.S.A.), is to be equipped with a synchro-cyclotron especially for the simulation of the kinds of ionizing radiations encountered in space flights. This cyclotron will be an almost exact copy of the CERN accelerator. It will form the nucleus of the 'Space Radiation Effects Laboratory' which will probably be operated for NASA jointly by the College of William and Mary, the University of Virginia and the Virginia Polytechnic Institute.

The **hydrogen refrigeration** plant for the CERN 2-m hydrogen bubble chamber was put into operation for the first time at the beginning of April. After a surprisingly short running-in period of about 30 hours, the plant worked at full power for several days until the scheduled Easter shut-down.

This first run was merely a general trial of the overall performance of the entire installation. Nevertheless, preliminary efficiency measurements could already be made and they indicate that the refrigeration power produced at the desired temperature of 23°K (= -250°C) is certainly well up to specification (4000 watts). Furthermore the cool-down period, (that is, the time elapsing between the start at ambient temperature and the beginning of hydrogen liquefaction) is about two hours, which is substantially shorter than expected.

Layout and design of this plant were carried out by the contractors at Winterthur, in close co-operation with CERN. The plant is distinguished from conventional installations of this type by the use of a low gas pressure throughout the system, a 'dry' (oil-free) gas circuit, and high-speed low-temperature expansion turbines as the only source of refrigeration.

After successful completion of the acceptance tests, which are scheduled for May/June 1963, CERN will dispose of a very unique and most modern refrigeration plant for its 2-m bubble chamber. We hope later on to give a more detailed description of it in *CERN COURIER.*



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On Saturday 13 April, after a journey of 1000 km spread over 17 days, the bridge for the 1.5-m British national hydrogen bubble chamber arrived safely at CERN. After the Easter holiday it was brought into the East bubble-chamber building and lifted temporarily into position on top of the magnet. Fortunately the entrance to the East building was wide enough – but only just, as this picture shows.

Among the more important **visitors** to the Laboratories during April were delegations from the Scientific Policy Committee, the British Scientific Instrument Manufacturers' Association and the Japanese Council for Science and Technology.

After their meeting on 2 April, the chairman, Prof. C.F. Powell, and a number of other delegates to CERN's **Scientific Policy Committee** stayed on in Geneva and paid a special visit to the Laboratory the following morning. Their main interests were the fast ejection system for the synchrotron beam and the experimental equipment and layout for neutrino experiments.

On 23 and 24 April, several members of the **Scientific Instrument Manufacturers' Association**, including the Vice-president, Mr. A.W. Jones, and the Director, Mr. R.A. Villiers, paid a visit to acquaint themselves with the Organization and the type of instrumentation that is used. They were accompanied by Mr. G. Hubbard, of the Department of Scientific and Industrial Research and frequent 'Adviser' to the British Delegation to CERN Council.

At the same time, on 23 April, CERN received the six delegates of a **Survey Mission** under the auspices of the **Council for Science and Technology** of Japan. The mission, led by Dr. Kiyoharn Utsuni, was particularly interested in the organization and cost of the various aspects of CERN's work, seeking information that would be of use to them in the development of high-energy research in Japan.

New records were set up on 11 May when over **800 visitors were received in one day.**

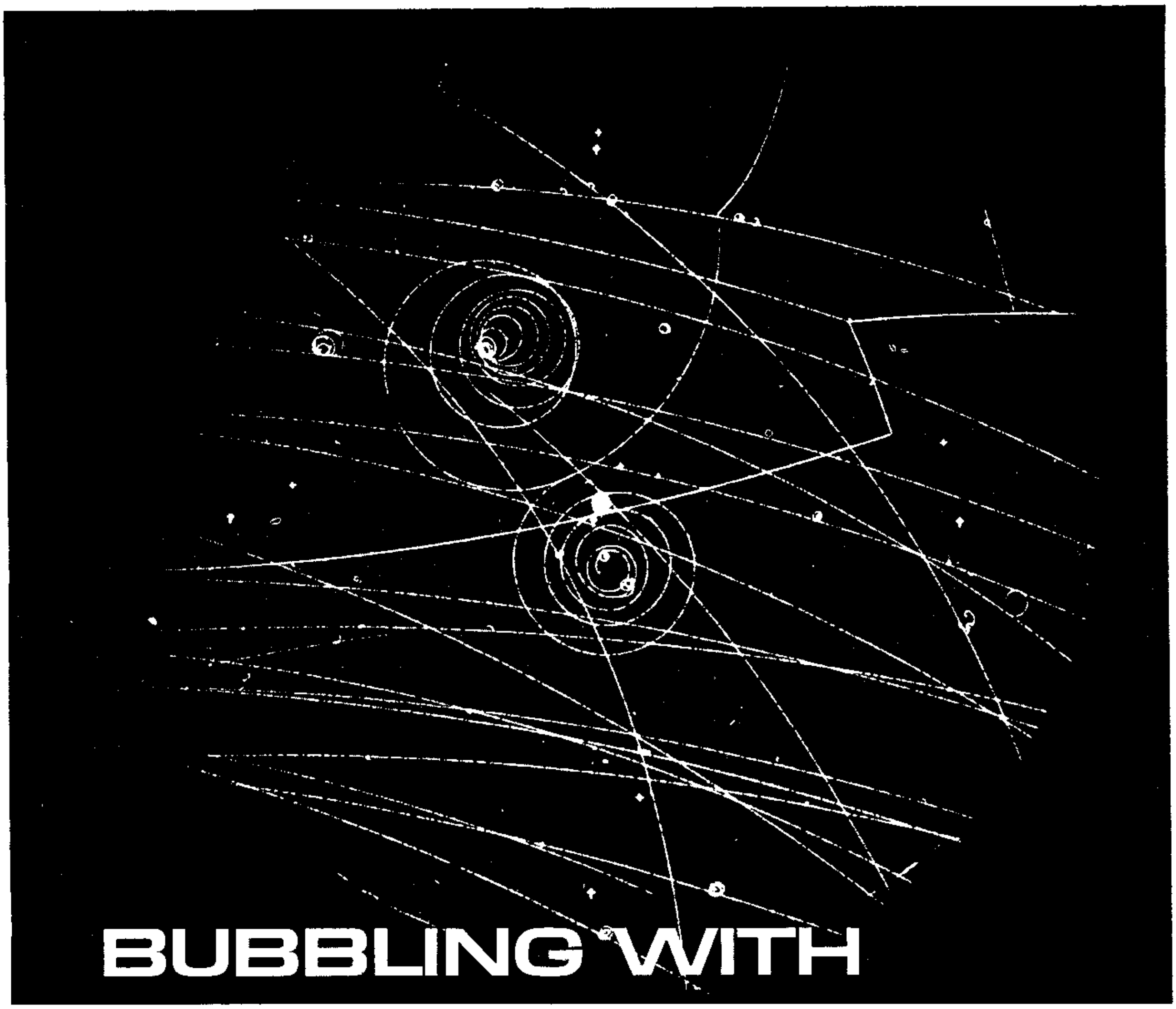
In the morning, 600 members of the 'Société suisse de Chronométrie' came as part of the programme of their annual Congress. At the same time, 130 members of the Swiss Society for Wool Industry visited the Organization. With the aid of 25 guides, drawn from various Divisions, they were all taken on a 2-hour tour of the site, as well as hearing a general talk on CERN (in French or in German) and seeing the CERN film, 'Étoiles nucléaires' or 'Ins Innere der Natur'.

The afternoon was more normal, with only 100 visitors made up of various groups from the German-speaking parts of Switzerland.

Nuclear electronic instruments

The latest catalogue containing specifications of transistorized electronic instruments developed by the Electronics Group of the Nuclear Physics Division has recently been published. Details are included of fast scalers, with print-out and punch-out, and of a range of compatible 'nuclear boxes', such as coincidence circuits and discriminators. Copies of the catalogue can be obtained from Dr. I. Pizer, Electronics Group, NP Division, CERN, Geneva 23.

Although it is not included in the catalogue, a new item of compact, electronic equipment, for use with a measuring table for spark-chamber pictures, has also been completed. Full details of all the instruments are available on request to universities and other institutes and to interested commercial firms. No exclusive manufacturing rights can be given, but it is CERN policy to encourage the marketing of such instruments ●



Tracks of high energy particles in a bubble chamber.

NEW IDEAS AT -270°C

The National Institute for Research in Nuclear Science has asked British Oxygen to design and build a refrigerator for use with a liquid helium bubble chamber. With this the institute will be investigating the paths and interactions of high energy particles.

The refrigerator, believed to be the largest of its kind in the world, will operate continuously at —269° to —270°C for periods of 30 days with an accuracy of ±0·05°. It will provide 80 watts refrigerating capacity at these temperatures, plus another 500 watts at —193°C.

To meet this exacting and unique specification, the refrigerator is being specially designed by British Oxygen's Scientific Division. Many new techniques are being employed such as expansion turbines running on helium gas lubricated bearings at up to 350,000 r.p.m., and pipe-work lagged with reflecting layers of aluminium interleaved with glass fibre.

The plant will be constructed by British Oxygen's Engineering Division at Edmonton and will be installed and operating in 1964.

BRITISH OXYGEN

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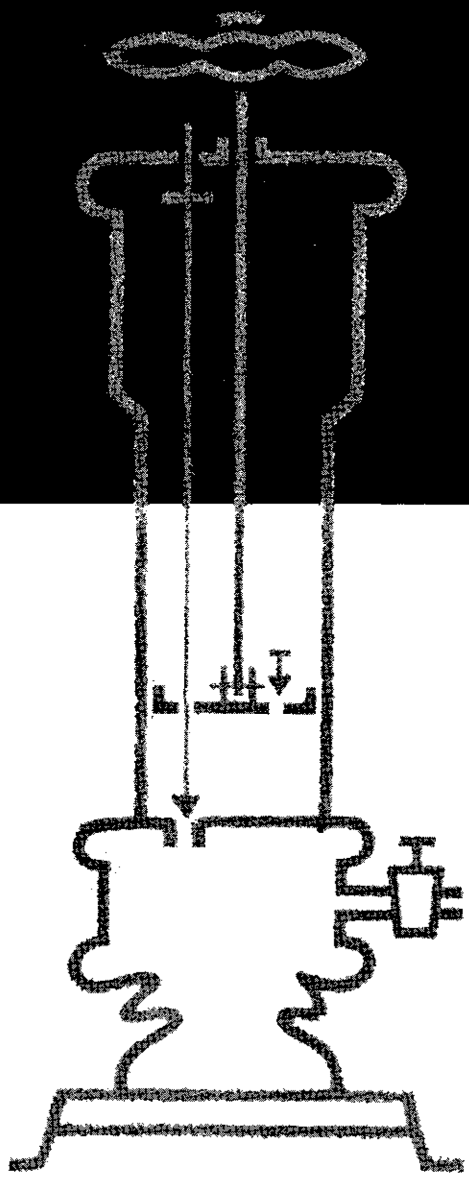

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