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The cover photograph shows an interesting view of the enlarged CERN heavy-liquid bubble chamber, taken during its re-assembly in preparation for the latest experiment with antineutrinos at the proton synchrotron. Photographed through the aperture in the 27 000-gauss magnet that surrounds the chamber during operation, Henri Lenique is seen preparing to mount a beam window in the new chamber body. Details of the antineutrino run are given in 'Last month at CERN' in this issue of CERN COURIER.

The same photo, incidentally, has also been used to introduce the section on the NPA Division in the CERN Annual Report for 1964, which was published during June.

CERN COURIER

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

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

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

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

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

The laboratory occupies an area of 41 hA (100 acres) at Meyrin, Canton of Geneva, Switzerland, next to the frontier with France. A similar area on adjacent French territory is expected to be taken over shortly.

Its main experimental equipment consists of two large particle accelerators:

— a 600-MeV synchro-cyclotron,
— a 28 000-MeV (or 28-GeV) proton synchrotron,

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

The CERN staff totals some 2100 people.

In addition to the scientists on the staff, there are about 300 Fellows and Visiting Scientists, who stay at CERN, either individually or as members of visiting teams, for periods ranging from two months to two years. Although these Fellows and Visitors come mainly from universities and research institutes in the CERN Member States, they also include scientists from other countries.

Thirteen Member States contribute to the cost of the Organization, in proportion to their net national income:

Austria (1.95%)
Belgium (3.83%)
Denmark (2.07%)
Federal Republic
of Germany (22.74%)
France (18.57%)
Greece (0.60%)
Italy (10.78%)
Netherlands (3.92%)
Norway (1.47%)
Spain (2.18%)
Sweden (4.23%)
Switzerland (3.19%)
United Kingdom (24.47%)

Poland, Turkey and Yugoslavia have the status of Observer.

The budget for 1965 amounts to 128 760 000 Swiss francs (= $29 800 000), calling for contributions from Member States totalling 126 400 000 Swiss francs (= $29 300 000).

A supplementary programme, financed by twelve states, covers design work on two projects for the future of high-energy physics in Europe — intersecting storage rings for the 28-GeV accelerator at Meyrin and a possible 300-GeV accelerator that would be built elsewhere ●

Prof. Gregory to succeed Prof. Weisskopf next January

On 17 June, delegates to the 30th Session of the CERN Council unanimously agreed to the appointment, as from 1 January 1966, of Prof. Bernard P. Gregory as the next Director General of CERN, for a period of five years.

Prof. V. F. Weisskopf, Director since August 1961, will be returning at the end of this year to the Massachusetts Institute of Technology, U.S.A., from where he is on leave of absence. In a message circulated to the staff after the Council Session, he explained that the responsibilities of the job of Director General left little opportunity for other work and he wished now to devote more time to purely scientific questions.

Prof. Gregory is French, 46 years old and Professor at the Ecole Polytechnique, Paris. His whole career as a physicist has been devoted to the experimental study of the particles in high-energy interactions, working first with cosmic rays and afterwards with the CERN proton synchrotron. His close relationship with CERN began when he was made responsible for the scientific side of the 81-cm Saclay/Ecole Polytechnique hydrogen bubble chamber, which has provided over 5 million photographs for Europe's physicists since it began operation at CERN in 1961, and he was Chairman of the CERN Track Chambers Committee for the first three years of PS operation. Early in 1964, Prof. Gregory was appointed Directorate Member for Research at CERN.

A more complete account of his career will be found in *CERN COURIER*, vol. 4, p. 28, March 1964 ●

Approval of intersecting storage rings (ISR) for the PS

Early in the 30th Session of the Council, unanimous approval was given in principle to the construction of intersecting storage rings (ISR) for the proton synchrotron, as a supplementary programme of the Organization. This project is one of the three parts of the programme for the development of European high-energy physics facilities put to the Council by the Amaldi Committee in 1963; the other parts are the improvement programme for the present CERN facilities and a new proton synchrotron of 300 GeV. The actual start of construction of the ISR will be decided in December, when the budget will be voted by the Member States who will take part in this supplementary programme. Almost all the thirteen Member States of CERN have indicated that they are prepared to participate.

The intersecting storage rings will provide a unique means for carrying out certain experiments in sub-nuclear physics research at energies much higher than those currently available, or even planned. Indeed, to do these experiments in the conventional way, with accelerated protons striking, say, a liquid-hydrogen target, would require an accelerator some 60 times more powerful than the 28-GeV proton synchrotron at CERN.

The equipment will consist essentially of a vacuum chamber formed by two concentric distorted rings, each about 300 metres in diameter, intersecting each other in eight places. Electromagnets spaced round the rings will serve to keep high-energy protons circulating in them, clockwise in one, anticlockwise in the other. The protons will be injected from the proton synchrotron and successive bursts stored until a sufficiently high intensity is reached, at which time the two beams will be made to collide in one or more of the crossing regions. Detection apparatus placed in these areas will enable the resulting interactions between protons to be studied.

The project is estimated to cost 330 million Swiss francs, at current prices, spread over a six-year construction and commissioning period. More information concerning the storage rings will be found on pp. 103 to 107 of this issue ●

Last month at CERN

30th Session of Council

On the afternoon of 16 June and the morning of 17 June, delegates from the 13 Member States of CERN met for the 30th Session of the CERN Council, under their President, Mr. J. H. Bannier (Netherlands). Two of the most eagerly awaited decisions are reported on the previous page, further details of the Council Session will be given in next month's issue of *CERN COURIER*.

PS operation, 19 April—31 May

The first two weeks after the short Easter shut-down at the proton synchrotron were devoted mainly to counter experiments, the accelerator parameters during most of the time being the typical ones of maximum proton momentum 19.2 GeV/c, one pulse every 2.3 seconds and flat-top duration (when protons circulate in the accelerator at constant momentum) 300 milliseconds. For three days over the second week-end, however, the primary beam energy was lowered to 9.97 GeV/c, with a repetition rate of one pulse every 1.2 second and a flat-top of 200 milliseconds, in order to carry out some important measurements on proton-proton scattering.

Among the experiments previously mentioned in these columns of *CERN COURIER*, the group aiming to measure the parity of the xi-hyperon successfully collected more data, the missing-mass-spectrometer group investigated three overlapping regions of the mass spectrum in their systematic search for possible new meson resonances, and 50 000 more photographs were taken by the physicists investigating the decay of the rho meson. The 'CERN/Ivry group' took some 200 000 photographs of kaons and pions scattered directly backwards from hydrogen. Several hundred thousand photographs of particle tracks in the six conventional spark chambers that have provided the main data for this experiment will be analysed automatically with the aid of the cathode-ray-tube flying-spot digitizer, Luciole, at CERN. Apart from the measurement of proton-proton scattering at low energy mentioned above, measurements of proton-nucleus scattering were made, with a proton momentum of 19 GeV/c, about 110 000 events being recorded by the sonic-spark-chamber and computer combination.

Also during this time, new equipment for future experiments was tested by various groups, among them one from Frascati, which measured the background of a neutron telescope (apparatus for detecting neutrons travelling along a specific path) and tried out time-of-flight equipment to be used in a forthcoming investigation of the decay of the eta meson into a neutral pion and a gamma ray. Tests were carried out on the CERN heavy-liquid bubble chamber in preparation for the antineutrino run that began in the following week.

Antineutrino run

The three weeks 7—31 May were used mainly for an experiment with the 'neutrino beam' and the enlarged CERN heavy-liquid bubble chamber, to complete the present phase of the neutrino experiments begun at CERN in July 1963. During the first part of this last run, the fast beam-ejection equipment was used to eject 17 proton bunches on to the external target in the throat of the magnetic horn at each accelerator pulse. The remaining 3 bunches circulated during the 'flat-top' and were then directed on to target no. 60, by means of the rapid beam deflector, to give a 200 μs burst for the British bubble chamber at the end of the o_2 beam line. For the last few days, the whole of the circulating beam was ejected on to the neutrino target.

Altogether 2.3×10^{17} (230 thousand million million) protons struck this target during actual operation of the bubble chamber. Of these, 91 % were used to give pictures for analysis; the rest were accounted for by the study of the neutrino-parent spectrum (that is, of the energy distribution of the pions and kaons produced in the target and decaying to give neutrinos) and adjustment of the chamber. Although this was largely an experiment with antineutrinos, produced in the decay of negatively charged pions and kaons, the magnetic horn was set to focus positive particles during part of the time (during which 14.2% of the total number of protons were utilized), the particle flux in the bubble chamber then being predominently of neutrinos. The data so obtained will be used for a comparison of the antineutrino and neutrino event rates.

The first scanning of the 367 000 bubble-chamber photographs was made during the run, resulting in about 100 candidates of each type of interaction, of which about half are suitable for detailed analysis. As an indication of how techniques have been improved, this may be compared with the first run of 6 days in 1963 using the smaller version of the bubble chamber, when only a dozen events were obtained in spite of a higher proton intensity on the target. Part of the increase in event rate is, of course, due to the enlargement of the visible volume (that viewed by at least two cameras) of the bubble chamber from about 440 litres to 1090 litres. The final analysis of the events and comparison with previous observations will continue into next year.

A valuable technical by-product of the run has been the development and installation of a freely suspended rigid plate in front of the plastic membrane that expands the chamber. This plate changes the pattern of the pressure distribution in the chamber during the operating cycle, so that the hydrodynamic behaviour of the bulk of the liquid is much closer to that obtainable with a large piston than to that around a gas bubble, as was the case previously. The presence of such a plate has been found to improve the optical quality of the pictures, and its success opens up the possibility of further developments for the chamber, such as the installation of Scotchlite reflector* or the mounting of a mirror on the plate. If a mirror were installed in this way, a proposed bubble-chamber experiment on the decay of the K^0_2 meson into two neutral pions would become feasible, since it would then be possible to photograph and measure phenomena that occurred on the other side of the

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* Scotchlite is the Trade name of a highly reflecting plastic film, used for example on many road signs; its use in a bubble chamber results in tracks that are seen as trails of dark spots on a light background, instead of the other way round.

vacuum chamber that would have to be inserted in the bubble chamber for the traversal of the kaons.

Last experiment at CERN of the British bubble chamber

During week 18 of the synchrotron schedule (beginning 27 April) the 152-cm British national hydrogen bubble chamber took 110 000 photographs of 6-GeV/c proton interactions in hydrogen. Then, in weeks 20 and 21, 135 000 photographs were obtained of negative pions incident at 11 GeV/c, as part of an experiment in which the interactions of both negative and positive pions are being studied at this momentum. This last run ended the operation of the chamber at CERN for physics experiments. It has been in full operation since June 1964, since when more than 1½ million photographs have been obtained. The chamber will not be returning to England until September of this year and in the meantime a 'technical' run will be carried out in which various new ideas, for example the use of a Scotchlite optical system, will be tried.

Purdue conference on instrumentation for high-energy physics

Seven members of CERN — R. Böck, G. von Dardel, A. N. Diddens, G. R. Macleod, A. Michelini, W. G. Moorhead and D. Wiskott — attended the International conference on instrumentation for high-energy physics, held at Purdue University, Indiana, during 12—14 May, 1965. This was the largest instrumentation conference since the one held at CERN in 1962, not excepting the one following the 'Rochester' Conference at Dubna last year, and was organized largely on the initiative of Prof. L. Kowarski, who has been on leave from CERN as Visiting Professor of Nuclear Engineering at Purdue.

A series of invited survey talks and contributed papers covered the field of spark chambers and bubble chambers and the measuring devices and methods of analysis used with them. The main impression gained from the conference was that, at nearly all the laboratories represented, the last year or two has been spent in consolidation and obtaining physics

Continued on p. 102

'Humanisme Scientifique'

In last month's CERN COURIER, *two aspects of the relationship between 'CERN' and 'Geneva' were treated at some length (pp. 85-89), with emphasis on the more practical and personal viewpoints. Unknown to us when those contributions were being prepared, a further example was to appear in the form of an editorial in the April/May issue of the publication* Industries Atomiques *(vol. 3/4, 1965, p. 51). This editorial, inspired by one of the periodic evening lecture meetings arranged by the CERN Staff Association, throws an interesting light on an aspect of CERN that is not often discussed, and we are therefore pleased to be able to reproduce it (in translation) here. Extra interest is given by the fact that its author, Mr. André Chavanne, is one of the seven members of the Executive body of the State of Geneva (the 'Conseil d'Etat') with responsibility for the Department of Education. As a physicist, he taught at one time in the 'Ecole supérieure technique' in Geneva and he is a former editor of* Industries Atomiques. *On the Federal level, he is a member of the recently formed Science Council and also represents Switzerland in the Council of CERN.*

Though it would pass unnoticed in a capital city, the presence of a large scientific research centre in a medium-sized town has a considerable effect on the local cultural life, which is enriched in a very special way: scientific humanism is, by its very nature, a mixture of curiosity, generosity and enterprise, even to the point of aggressiveness.

Not long ago I was present at one of the gatherings (concerts, discussions, lectures and the like) organized by CERN — or rather its staff — and open to the Geneva public. It was a discussion between Dr. Garaudy, a member of the policy committee of the French Communist party, and a member of the Dominican Order, a physicist, Father Dubarle; they were pursuing their dialogue concerning materialism and spiritualism, entered into previously in France and Belgium. Seldom have I encountered such an audience, following closely and intelligently this exchange of subtle arguments on matters very far removed from its everyday concerns.

One could see there the humanism of the future, founded on the sciences, expressed in mathematical terms, restrained, precise. This is not to deny the value of our classical humanism, based on a knowledge of languages — particularly the dead ones but also the living — and with a long tradition behind it ('are you for or against Latin ?' is a typically inane question); but we must recognize how the experimental sciences, as well as the humanities of the Greek and Latin tradition, can be the basis of a truly general education. Will the most important fundamental questions of knowledge continue to be regarded solely in a historical context when they can be illumined in incomparable fashion by the up-to-date, lively considerations of mathematicians and biologists on their respective subjects ? Can our only interest in psychology be through literature, when for the last century the behaviour of the human mind has been studied in the laboratory ? We must get right away from the sterile opposition of science and philosophy, which is in any case a recent invention of mediocre thinkers of the last century and obviously unknown to Plato and Aristotle, Descartes and Leibnitz; was not the initial work of Kant prompted by Newton's theories ?

But humanism is not just intellectualism, it is also aesthetic and ethical in nature. It would not be difficult to put forward to youthful minds, trained in the disciplines of science, a course of instruction largely devoted to the development of a liking for art through its rational study. It should also be possible to give them that extra spiritual development necessary for the command of today's infinitely powerful technical resources, by showing them how science extends the responsibilities of everyone, beyond the confines of family or nation, to embrace the whole of humanity here on our tiny planet.

A. C.

Colliding - beam error

The dangers of editorial tampering with carefully worded press releases, as well as the suspicion — often voiced — that so much is published in the scientific literature nowadays that nobody has a chance to read it all, have both been highlighted by a note that appeared in the April issue of CERN COURIER *(p. 57) under the sub-heading 'World's first experiment with colliding beams'. In preparing that note, we were taken in by one of those press releases that so often hide the actual state of affairs in their enthusiasm for a particular event. As a result, when copies of the French edition of the April issue reached the Linear Accelerator Laboratory of the University of Paris, at Orsay, and the CNEN National Laboratory at Frascati near Rome, they were read with some astonishment, since the physicists clearly remembered their own experiments, carried out a year earlier at Orsay, with the storage ring known as AdA (Anello di Accumulazione), designed and built at Frascati. To help put the record straight,* CERN COURIER *has now been supplied with the following information:*

The first measurements on interactions produced by colliding beams were carried out at Orsay, using the positron-electron storage ring, AdA, from Frascati, in April 1964. The results were published in December of the same year*.

Previously the storage of weak-intensity electron and positron beams had been successfully achieved at Frascati and AdA was then moved to Orsay in order to take advantage of the higher photon fluxes available there (gamma rays from the linear accelerator are used to produce positrons and electrons for storage in the ring). The ring was operated by a mixed Italian and French team from 1962 until early 1965.

In the course of this work, beam intensities of up to 0.5 milliampère (electrons and positrons) were stored, with lifetimes of several hours. A new fundamental limitation on the lifetimes of intense beams was then discovered and analysed (the so-called 'Touschek effect').

Interactions between the two beams were observed for the first time by detecting the single bremsstrahlung gamma ray arising from the process $e^+ + e^- \rightarrow e^+ + e^- + \gamma$. From the observed rate of interaction the cross-sectional area of the beams could be computed and this allowed a complete understanding to be obtained of the beam structures in weak-focusing positron-electron storage rings at intermediate intensities.

AdA was taken back to Frascati in March 1965.

It is true that the Press Release from which our original story was derived claimed only 'the first high-energy collisions between electrons ever achieved', leaving open the question of collisions between electrons and positrons. The Release also mentioned the operation of the Italian storage ring at Orsay. At the same time, however, announcement of the Stanford/Princeton results at a particle-accelerator conference in Washington, with its associated press publicity, seems to have produced a greater impact than the earlier publication of the Italian/French results in a normal scientific journal. It is true that the Stanford rings are bigger than the one at Frascati (there are two at Stanford, instead of one, because both beams are of electrons), the energy used is rather higher and the beams have greater intensity. Nevertheless, we deeply regret having overlooked one of the great pioneering efforts of European physicists in the field of storage rings, particularly as the Italian/French collaboration that made possible its success is yet another indication of the unity of Europe's high-energy physicists, characterized by CERN itself. Neglect of the European results would, in fact, now be doubly regrettable, in view of the recent Council decision to support the construction of proton storage rings at CERN and thus to give European scientists a great opportunity to continue leadership in this field in the coming years ●

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* C. Bernardini, G. F. Corazza; G. di Guigno; J. Haissinski, P. Marin; R. Querzoli; B. Touschek: Measurement of the rate of interaction between stored electrons and positrons, **Nuovo Cimento**, vol. 34 (1964), pp. 1473-1493.

Last month at CERN (cont.)

results from some of the many devices announced at previous conferences, rather than in inventing new instruments.

Thus, to deal only with contributions involving CERN, G. R. Macleod gave an invited paper on spark-chamber picture analysis with raster scan in which he described two experiments already completed at CERN (one measured on the Hough-Powell device (HPD) and the other on Luciole), as well as mentioning several others under way here. Some preliminary results of a bubble-chamber experiment that is being analysed at CERN with the HPD were presented, by P. V. C. Hough of Brookhaven, in a joint survey paper with B. W. Powell of CERN, on flying-spot digitizer systems for bubble-chamber films. A paper by W. G. Moorhead described the CERN computer programme used for this analysis. The operation of the sonic spark-chamber system with on-line computer that is used at CERN for proton-scattering experiments was described by A. N. Diddens.

The practice of attaching film-measuring instruments such as IEP and Frankenstein directly on-line to a small computer, so that instant checking can take place, is very widespread, and there are many different approaches to this, both in the U.S.A. and in Europe (including CERN). This idea is interesting as being one of the few that were not already mentioned at the 1962 CERN Conference ●

Physics with storage rings

At a meeting of the European Committee for Future Accelerators[1] held at CERN on 19 October 1964, one of the speakers was Prof. G. COCCONI, a senior member of CERN's Nuclear Physics Division and one of the leaders of the group that has obtained so many interesting and important results in the last few years on the scattering of protons from protons. After giving some indications on how these and other experiments could be extended enormously in scope by the construction of the proposed intersecting storage rings for the CERN proton synchrotron, he posed the more general question of why, in fact, we want to carry out such experiments at all. In view of the recent approval by the CERN Council of the storage-ring project (see p. 99), the answers Prof. Cocconi gave to this question, together with the rest of his speech, have taken on a new topicality and we are pleased to be able to reproduce here what he said on that occasion.

I have been asked to give reasons why the construction of a system of intersecting storage rings (ISR), to be coupled to the existing proton synchrotron (PS) of CERN, is considered important for the future of physics.

Obviously, the principal reason is that the ISR would make it possible, in the near future, to experiment at effective energies, that is at centre-of-mass energies[2], nearly ten times higher than those available with the existing accelerators and about two times higher than those that will be available in the more remote future when a 300-GeV accelerator is built.

The following table illustrates the situation:

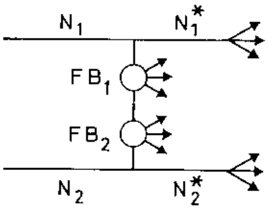
	Lab. kinetic energy	C.M. total energy[4]
Present PS	25 + 0.12 GeV[3]	7.1 + 1.9 GeV
ISR	27 + 27 GeV	54 + 1.9 GeV
300 GeV PS	300 + 0.12 GeV	30 + 1.9 GeV

However, why do we value so much centre-of-mass energy? Because we have learned from nature that thresholds exist, and that classes of phenomena exist that cannot be studied if one operates below or too near their threshold energy. The threshold that separates the 'nuclear world' from the 'chemical world' is a classical example.

Mesonic matter

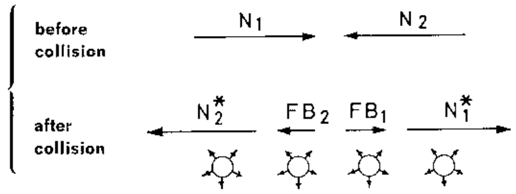
During the last ten years, man has just crossed another threshold, the threshold that separates the nuclear world from the mesonic world. The richness in particles, antiparticles, excited states and resonances that mesonic matter (as we shall call this new state of matter) presents as soon as the threshold of about 1 GeV is crossed is a sure sign of unexpected complexities, hence of unpredictable consequences. In these conditions the quest for higher energies is both obvious and imperative.

How does mesonic matter present itself? The most general picture that can be given today of what happens when two energetic nucleons collide, as deduced from machine and cosmic-ray experiments, is summarized by the following figures which describe the phenomena (a), diagrammatically and (b), in a time sequence as seen in the c.m. system.



(a)

N_1, N_2, original nucleons
N_1^*, N_2^*, excited isobars
FB_1, FB_2, fireballs



(b)
time sequence in c.m.

After the collision, two excited nucleons are produced, each one keeping a good fraction (about 50%) of its original energy, while two fireballs, that is, two massive centres that rapidly decay emitting a certain number of secondaries, are left behind, moving essentially in the direction of the original nucleons, but with smaller velocity. Both the excited nucleons, each with baryon number one, and the fireballs, with baryon number zero, are mesonic matter which, in our laboratories, lasts only 10^{-22}- 10^{-23} second, but exhibits the peculiar properties that completely new ideas such as strangeness, SU_3, and other schemes attempt to describe.

How accurate is this picture? What determines the properties of the excited nucleons and of the fireballs? What are their dimensions, their spins, their magnetic properties?

Are these the only entities formed by mesonic matter, or do others exist, more stable and of larger mass than so far observed?

Is it conceivable that, in appropriate conditions, even larger bodies, all composed of mesonic matter, can be formed? Is there any limit imposed on their size, analogous to the limit imposed on nuclei by the Coulomb electrostatic repulsion?

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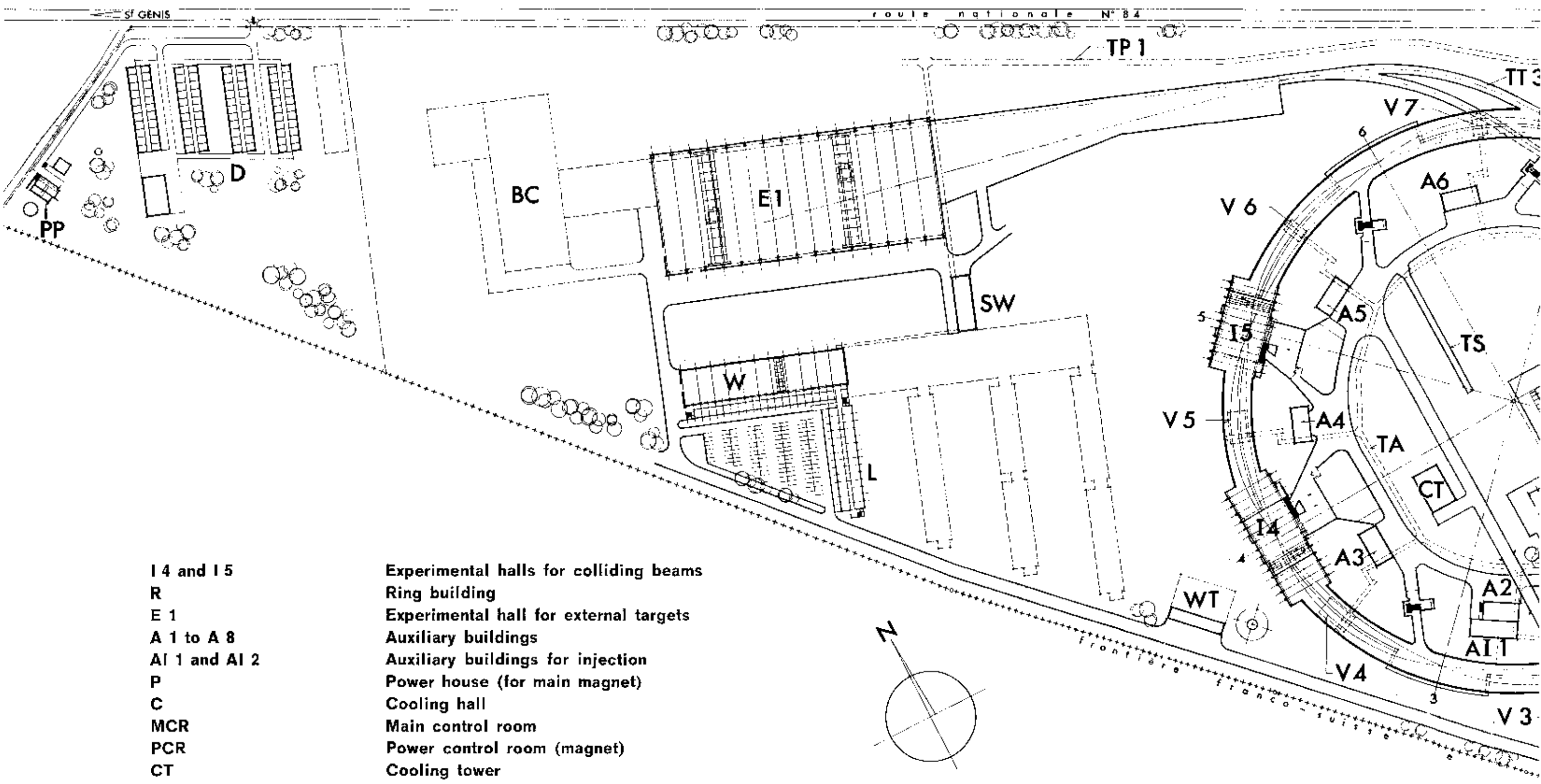
[1] A committee composed of senior physicists from European high-energy physics laboratories, which was responsible for drawing up the European programme of new accelerators published originally as the Amaldi Report, CERN FA/WP/23.

[2] Measured in the 'centre-of-mass system', a frame of reference in which the centre of mass of the colliding particles appears to be stationary and the algebraic sum of all the momenta, both before and after the collision, is zero.

[3] 0.12 GeV is a characteristic Fermi energy for the nucleons of a target made of complex nuclei.

[4] The c.m. energy is divided into two parts: the first can be used in producing additional particles or excited states, the second (1.9 GeV) is the combined rest mass of the two original nucleons.



I 4 and I 5	Experimental halls for colliding beams
R	Ring building
E 1	Experimental hall for external targets
A 1 to A 8	Auxiliary buildings
AI 1 and AI 2	Auxiliary buildings for injection
P	Power house (for main magnet)
C	Cooling hall
MCR	Main control room
PCR	Power control room (magnet)
CT	Cooling tower
L	Laboratories
W	Workshop
Y	Rectifier building for beam-transfer equipment
SW	Electrical sub-station
WT	Water tower and reservoir
TT 1 to TT 3	Beam-transfer tunnels
TA	Tunnel linking auxiliary buildings
TP 1	Main service tunnel (connecting to sub-station on present site)
TP 2 and TP 3	Tunnels between C and TA and between P and TA
TS	Calibration tunnel (for survey instruments)
PP	Sewage purification plant
BC	Reserved for possible construction of bubble-chamber buildings
CPS	Present proton synchrotron
D	Barracks
V 1 to V 8	Air-conditioning rooms for the ISR

General layout of the ISR buildings – a number of changes have been made since the previous plan was issued with the CERN COURIER of July 1964.

The variety and the naïvety of the questions show how little we know about mesonic matter. Experimenting with storage rings will certainly not give definite answers to all of the questions, but it will give information of the above kind, and hence will be of fundamental importance.

Experimental arrangements

The main objection that one usually raises against the construction of storage rings is the difficulty of experimenting around them. I personally feel that at least part of this difficulty can be attributed to our mental flabbiness. From lack of imagination we are led to extrapolate from experience with present accelerators. We should not forget instead that, so far, nearly every time new experimental problems have arisen, technology has provided fresh solutions.

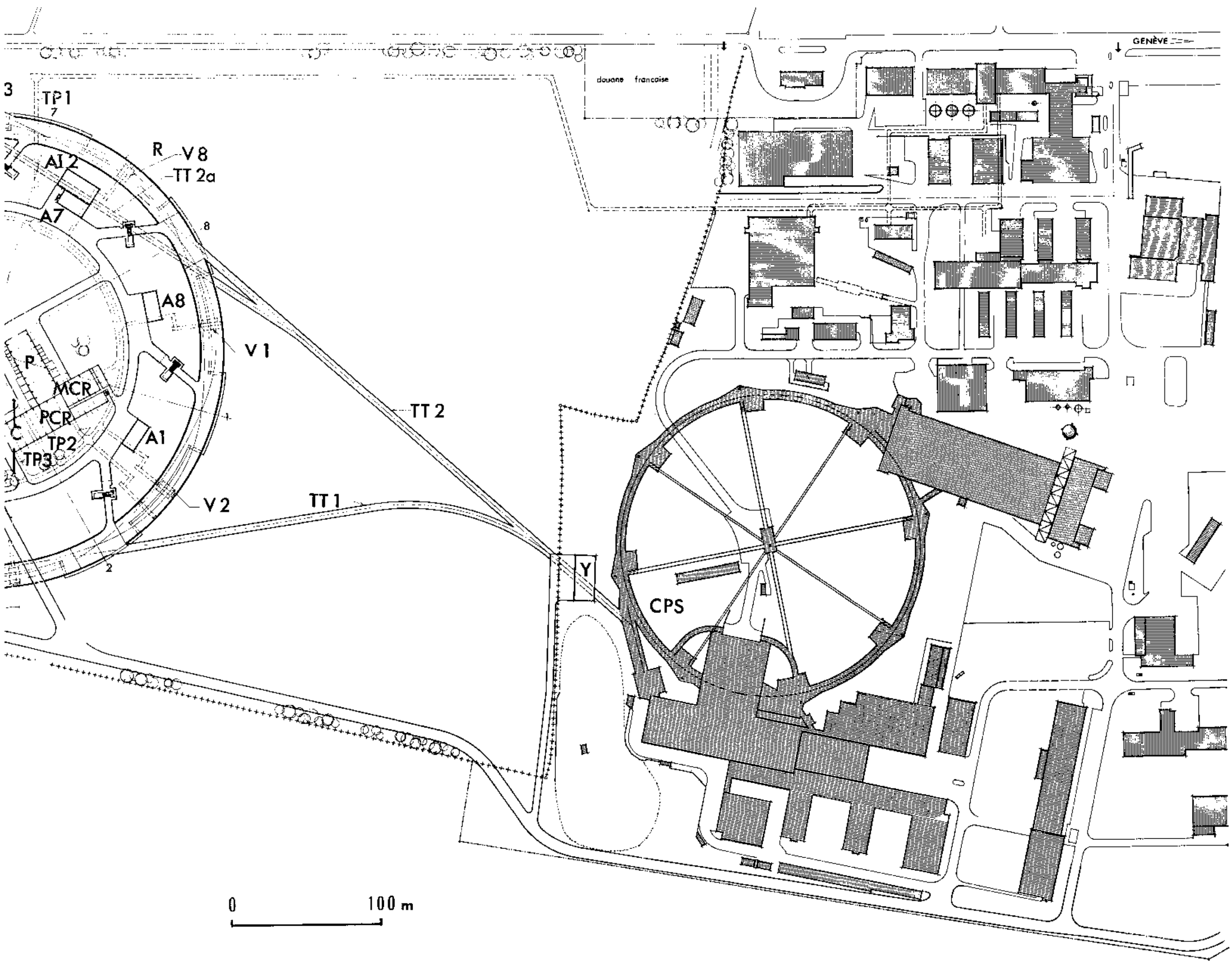
Apart from this, the extrapolations from present technologies do not look discouraging.

Let us consider the general characteristics of the rings proposed for CERN. The rate of proton-proton collisions will be about $10^4 - 10^5$ interactions per second and will take place within a volume of $45 \times 1 \times 6 = 140$ cm^3. Most of the solid angle around that region will be free. The interactions with the residual gas (at a pressure of 10^{-10} torr) will create a signal-to-background ratio of the order of one.

Experiments on p-p cross-section and scattering will be 'easy' and will not be discussed.

I shall instead mention the possibilities of what is now our 'maid of all work', the spark chamber. The fact that it can be triggered and that it can ignore a random background counting rate of 10^5/second or more will allow the use of this instrument at small distances from the collision region in the ISR. Definite experiments utilizing spark chambers have already been designed, for example by Dayton. With them one can identify and study isobar production in the forward and in the backward directions by measuring the momenta and the direction of emission of the secondaries.

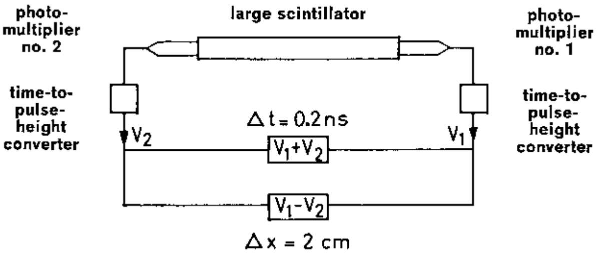
But I want to point out that with the storage rings other, less 'ad hoc', instruments could also be successfully used. For instance, let us consider the bubble chamber, an instrument that generally is not thought of as useful for colliding-beam experiments because it cannot be triggered. However, a hydrogen bubble chamber can be operated with a 1-cm pipe going



M. Bron (CERN-SB G. 52-117-R)

through it. In this pipe, two intersecting beams of protons could produce 10^2 interactions per second. When the chamber is expanded at random, in 10% of the cases one interaction takes place within the one millisecond during which the chamber is at its optimum sensitivity. The illumination and the picture taking can then be triggered by counters sensing the secondaries. A 15-kilogauss vertical field can be present, compensated by equal and opposite fields outside the colliding region but still in the long free section. The bubble chamber will give a detailed description of what happens near the origin. The story can be completed by spark chambers placed further out.

Promising possibilities are offered by the recent advance in counter technique realized at CERN by Charpak and Dick*. Previously, the signal produced in a large scintillator, say 1 metre long, could not be used with resolving times shorter than about 2 nanoseconds, because of differences in the path followed by the light reaching the photomultipliers, depending on where the particle crossed the counter. Now the limit has been reduced to 0.2 ns by *summing* the times measured by two photomultipliers, placed at the two extremes of the counter. The following figure is self-explanatory.



On the other hand, the time *difference* between the two photomultiplier signals gives the position of the ionizing particle that caused the flash of light. A system of these counters can thus measure times of flight with a precision of a few 10^{-10} s and identify the path of the particle to within a few centimetres (the 'velocity' of light in a Perspex light pipe is about 10 cm per nanosecond).

What does this mean for storage-ring experiments? It means that time-of-flight measurements over distances of a few metres can determine Lorentz factors (= total energy/mc^2) up to a value of about ten, and this with large counters, that is with large apertures, since the actual path will be known too. A

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* See, for example, G. Charpak, L. Dick and L. Feuvrais: Location of the position of a particle trajectory in a scintillator; **Nuclear Instruments and Methods**, vol. 15 (1962), pp. 323-326.

simultaneous momentum measurement will then give the mass of the particle, and this is what we need for discovering heavy, stable or semi-stable particles produced at large angles by colliding beams.

At this point one may ask what is the probability of production, per interaction, of a pair of such heavy, strongly interacting particles, say a quark 15 times heavier than a proton ? The rule of thumb is:

probability per interaction $\approx (m_\pi/M)^2$,
giving $\sim 10^{-4}$ with $M = 15$ GeV,
(m_π = mass of π meson).

Since a system of large and fast scintillators can cover a solid angle of about 0.1 sterad, the rate of measurable events could be about 100 per hour — a comfortable one — if these particles exist.

Why go on ?

I cannot finish without asking the general question that involves us all. Why do we want to know these things, and *urgently* ? Could it not be that we are a cast of maniacs, who try to solve problems created only by our machines, problems not at all important for the equilibrium of nature, the nature we live in ?

If that were the case, if our pure science were so pure as to be of no foreseeable utility, then I fear that in the long run Society would stop us from progressing so fast. We begin to be a burden to Society when we go on asking for larger and costlier accelerators.

My answer to these disturbing questions is that, practical applications apart, we are not so queer and that our problems are not Byzantine. My faith comes from the fact that there are places in the universe where matter consists uniquely of particles having an energy of 10^{12}–10^{13} eV each, and these places are light years in dimensions and contain a number of particles equivalent to millions of suns. I have in mind, of course, the centre of the radio galaxies.

Mesonic matter is thus not only produced in the odd situations present in our accelerators (or in the even more odd one that will be created by colliding beams), but it is also the basic matter at the centre of not-so-rare galaxies. Possibly even the apparent rarity of these objects is due to the fact that galaxies remain in those conditions only for a small fraction of their evolution. Perhaps all galaxies, all of us, went or will go through that stage. Thus the GeV, the TeV world* cannot be an abstraction, since it is deeply connected with the nature that surrounds us. It is even imaginable that in time we will be able to exploit it to our advantage.

The parallel with stellar evolution is too banal for us to dare to think that, mutatis mutandis, it will be applicable in this case. But I cannot help recalling that what, forty years ago, looked like the impossible problem of understanding how the centre of the sun kept on burning is nowadays reduced to the still difficult but not so impossible problem of making nuclear energy economically competitive with coal burning.

Can we afford to be ignorant about these problems; can we avoid asking what is the equation of state of matter at these excitations, what are the properties of a mass collapsing towards the relativistic limit ? Can we afford to wait ? According to the rules of the human game, we must go ahead, and as fast as we can ●

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* TeV: 1 Tera-electronvolt = 10^{12} eV = 1000 GeV.

BOOKS

Nuclear radiation detection, by William J. Price (New York, McGraw-Hill Book Co., 2nd ed. 1964; $12.75).

This volume is the second edition of a text-book developed for use by students of the Nucleonics Instrumentation Course at the U.S. Air Force Institute of Technology. In the book, according to the author, 'an attempt is made to collect the basic information on all the important nuclear-radiation detectors in use today ... including sufficient specific information to enable the reader to select his own detection equipment and, in many cases, to apply it'. Although not explicitly stated, the main emphasis is on those problems and techniques most frequently met in reactor physics, low-energy nuclear physics and dosimetry.

The first chapter covers many of the essential aspects of the interaction of radiation with matter, treating particularly proton, neutron, electron, gamma-ray and fission-fragment interactions. This, together with the next two chapters, surveying detection methods and the statistics of detection systems generally, provides a foundation for the more detailed study of detectors in the following sections.

Succeeding chapters are devoted to ionization chambers, Geiger-Müller counters, proportional counters, scintillation detectors, and semiconductor radiation detectors. The chapter entitled 'Photographic emulsions and other detection methods', which briefly mentions cloud chambers, bubble chambers and spark chambers, includes a section on chemical and calorimetric techniques. A separate chapter is devoted to methods of neutron detection, because of the special problems involved and because of the importance of neutron measurements. In the concluding chapter a more detailed treatment of the electronics used for nuclear-radiation detection is given.

The scope of this single volume is large; consequently, the treatment is mainly descriptive and little attempt is made to derive most of the equations used. Nevertheless, much quantitative data are given and a useful guide to students is provided by means of frequent numerical examples interspersed throughout the text. A good balance is obtained between practical and theoretical considerations and, on the whole, the aims of the author can be considered to have been largely fulfilled.

Although the treatment is generally concise and the presentation logical there are, occasionally, passages which are either misleading or not altogether clear. For example,

Continued on p. 108

the variation of photomultiplier single-electron pulse amplitude is due to the statistical nature of the multiplication process rather than to any 'variation in secondary-emission ratio', as stated on p. 181. In discussing noise in pulse amplifiers on p. 381, it is not 'the low resistance associated with a short clipping-time constant ...' that would make '... thermal noise intolerable', but rather the correspondingly increased bandwidth; indeed, the noise generated by the resistor decreases with its resistance. The fact that the d.c. feedback amplifier on p. 406 is phase-inverting is not mentioned, and there is confusion in the application of the appropriate sign, which appears correctly in some equations and wrongly in others. No explanation is given here of the virtual-earth principle and it is by no means clear that 'the amplifier (of gain G) is seen to act as a current amplifier ...' with the feedback acting such that '... the input capacitance C is reduced to $C/(1+G)$'. The time constant of the input circuit is indeed reduced to $RC/(1+G)$, but because the feedback reduces the input resistance R to $R/(1+G)$ rather than affecting C.

Many additions have been made since the first edition, and the extensive set of references has been largely brought up to date. Newcomers to the field of nuclear radiation detection should find the book useful, and the chapter devoted to semiconductor detectors should prove valuable as an introduction to the subject. Notable omissions in the range of topics covered are time-of-flight techniques, and only very little space is devoted to multichannel analysers. On the other hand, it is difficult to see why any space was devoted, for example, to bubble chambers in a volume which otherwise almost completely ignores high-energy radiation.

B. Z.

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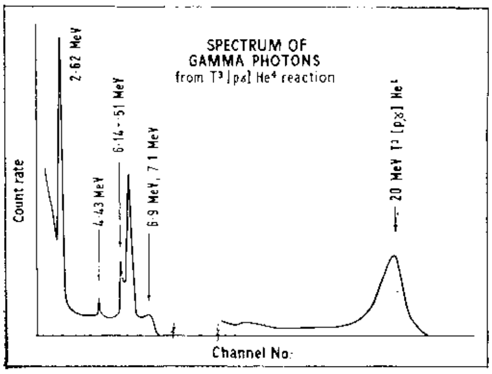
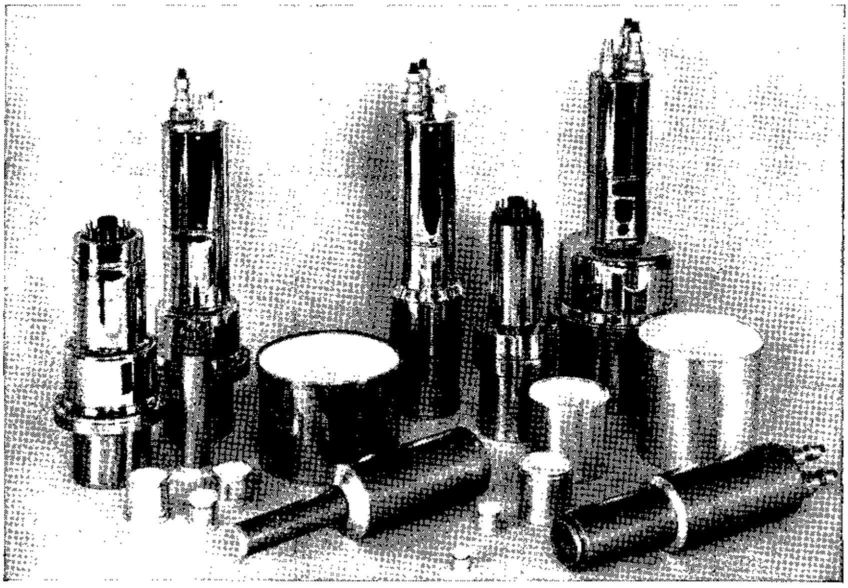
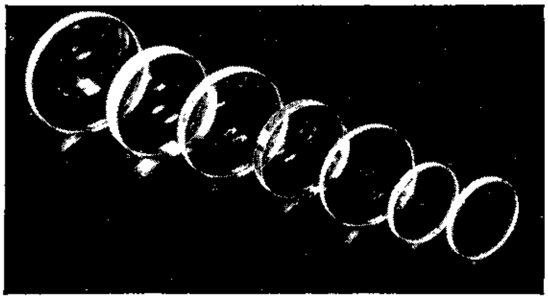
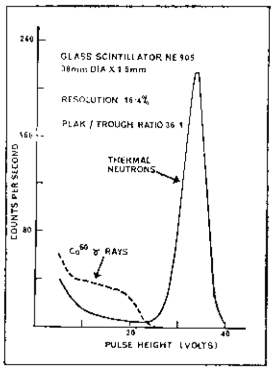
ThC″ (2.62 MeV)	5.7%
F^{19} (p, α γ) 6.14 MeV	5.2%
T (p, γ) 20.5 MeV	6.9%







Lithium Glass Scintillators



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NEUTRON DETECTION EFFICIENCY: For $\frac{1}{8}$ in. thick glass with 7.5% Li^6 (NE 905) detection efficiency for thermal neutrons is 99%.
For 1 in. thick glass detection efficiency for 1 keV neutrons is approximately 20%.
DISCRIMINATION AGAINST GAMMA RADIATION: Excellent especially with thin glass (see graph).
LIGHT OUTPUT: 30% anthracene.
STABILITY: Chemically inert and stable up to 600°C.
DECAY CONSTANT: 75 x 10^{-9} seconds.
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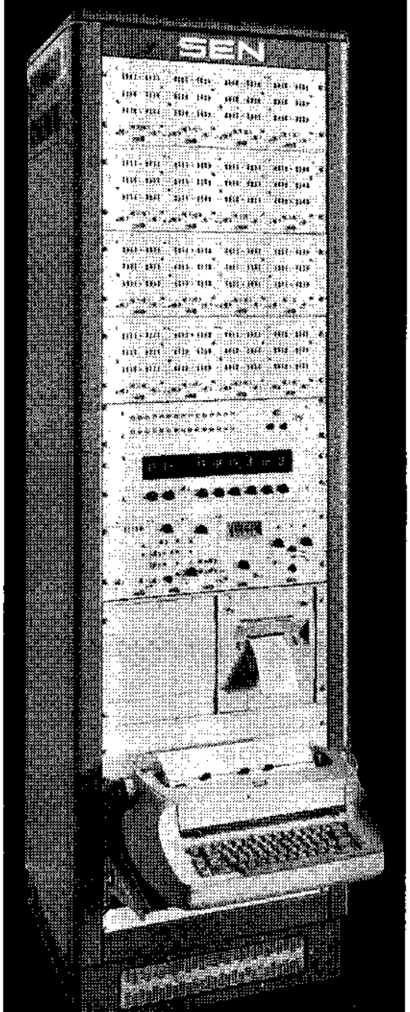

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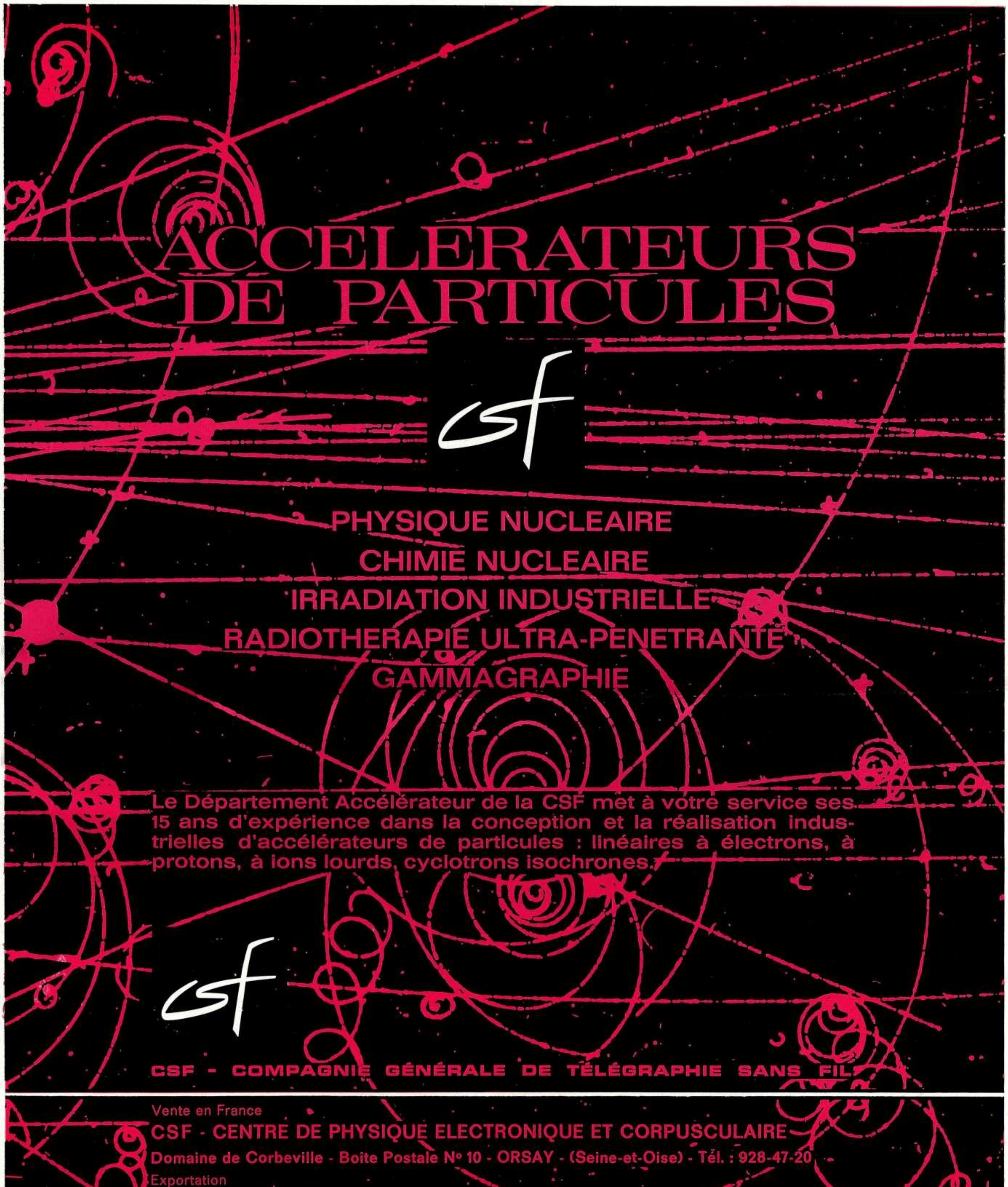

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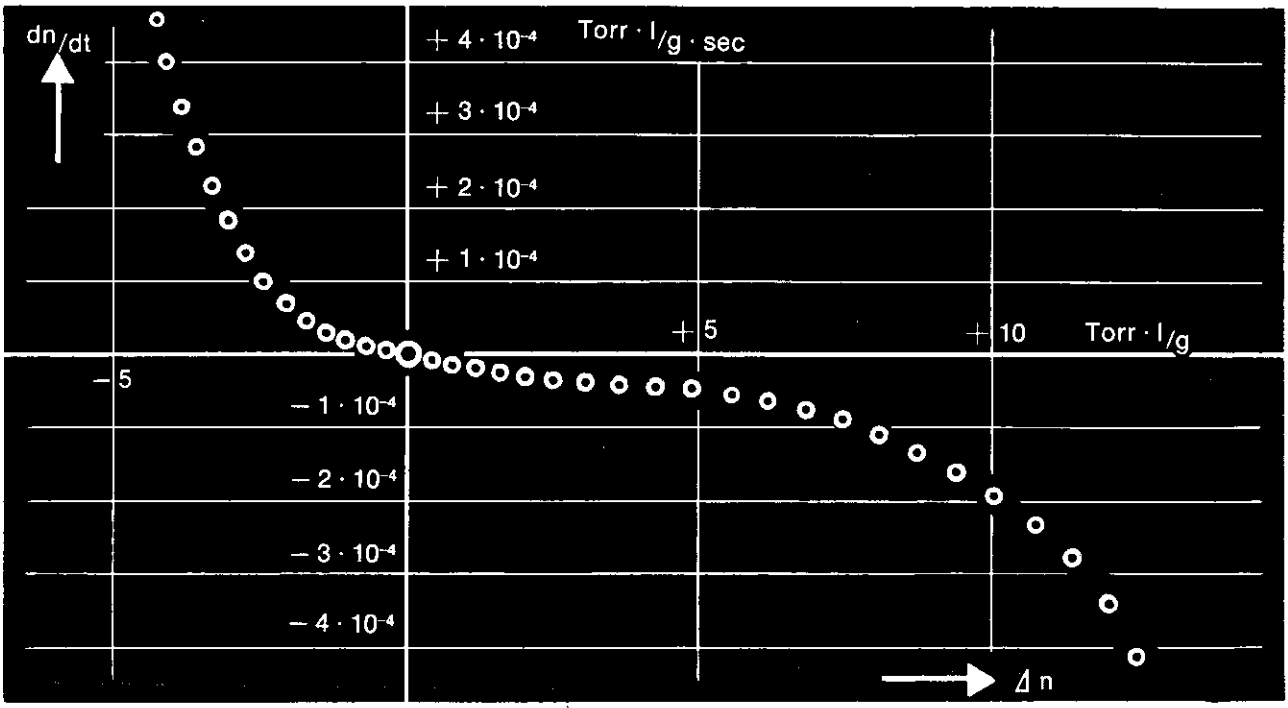

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