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Contents

The cover photograph was taken during a visit to CERN by the Minister of Scientific Research from the Federal Republic of Germany, Dr. Gerhard Stoltenberg (right). The Minister is seen here with Professor Paul, co-Leader of Nuclear Physics Division, (left) at the 600 MeV synchro-cyclotron. Professor Weisskopf, former Director General of CERN and now a member of the Scientific Policy Committee can be seen in the background.

Dr. Stoltenberg spent a full day touring the installations at the Laboratory and discussing various aspects of present and future European collaboration in sub-nuclear physics. Germany now makes the largest financial contribution to this collaboration and 220 people (including 65 physicists and engineers) fo German nationality are on the CERN staff. The Minister saw several of the experiments on the CERN accelerators in which physicists from universities and sub-nuclear physics Laboratories in Germany are taking part.

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The European Organization for Nuclear Research, more commonly known as **CERN** (from the initials of the French title of 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 comprises an area of about 80 ha (200 acres), straddling an international frontier; 41 ha is on Swiss territory in Meyrin, Canton of Geneva (the seat of the Organization), and 39.5 ha on French territory, in the Communes of Prévessin and St.-Genis-Pouilly, Department of the Ain.

Two large particle accelerators form the basis of the experimental equipment:

- a 600 MeV synchro-cyclotron,
- a 28 GeV proton synchrotron,

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

The CERN staff totals about 2200 people.

In addition to the scientists on the staff, there are over 350 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. Furthermore, much of the experimental data obtained with the accelerators is distributed among participating laboratories for evaluation.

Thirteen Member States contribute to the cost of the basic programme of CERN in proportion to their net national income:

Austria (1.90 %)	Italy (11.24 %)
Belgium (3.56 %)	Netherlands (3.88 %)
Denmark (2.05 %)	Norway (1.41 %)
Federal Republic of Germany (23.30 %)	Spain (3.43 %)
France (19.34 %)	Sweden (4.02 %)
Greece (0.60 %)	Switzerland (3.11 %)
	United Kingdom (22.16 %)

Poland, Turkey and Yugoslavia have the status of Observer.

The 1966 budget for the basic programme amounts to 149 670 000 Swiss francs, calling for contributions from Member States totalling 145 860 000 Swiss francs.

Supplementary programmes, financed by twelve states, cover construction of intersecting storage rings for the 28 GeV accelerator at Meyrin and studies for a proposed 300 GeV accelerator that would be built elsewhere ●

The use of Slow-cycling Synchrotrons in Injection Systems

An aerial view of the CERN site may look more and more like the inside of a Swiss watch following a proposal which could lead to another wheel being added to those of the proton synchrotron and the intersecting storage rings. The new wheel would be for the interlaced magnet rings of slow-cycling synchrotrons in the injection system of the PS. Discussions are now in progress at CERN to decide whether to set up a study group to pursue the project further.

The idea originated with W. Hardt of the Accelerator Research Division about a year ago and is one of the most interesting developments in accelerator technology for some time. The aim of this article is to present this new idea and to indicate its role in injection systems with some particular reference to its possible use in the improvement programme of the CERN PS.

The Editor acknowledges helpful discussions with O. Barbalat, A. Carne and W. Hardt during the preparation of this article.

The PS improvement programme is concerned with increasing the potential of the PS for high energy physics. It involves developing the performance of the proton synchrotron itself and providing major items of experimental equipment to be used on the machine. The latter category includes particularly, the provision of two new, very large, bubble chambers. Work on one of these, 'Gargamelle' — a heavy liquid bubble chamber with a useful volume of 10 m^3 — is already under way at the Saclay Laboratory in France. It is hoped to have this chamber in operation, initially for neutrino experiments, at the beginning of 1969. The second is a proposed very large hydrogen bubble chamber, which would be constructed for the early 1970s.

For the synchrotron itself the aim is to increase the intensity, the number of protons accelerated per second, which is one of the main parameters dictating the efficiency with which experiments can be done on the machine. It will enable more experiments to be completed in a given time and possibly allow experiments to be done which are not feasible with the present machine performance. Compared with about 10^{12} protons per pulse with a pulse repetition rate of about 1 per 2 to 5 seconds, intensities of up to 10^{13} protons per pulse with a repetition rate of 1 per 1 to 2 seconds may be possible.

Repetition rate

The increase in intensity is planned in two stages. The first stage, which is now being implemented, concerns an increase in the repetition rate (the number of pulses per second) by a factor of 2 to 3 (depending upon the particular mode of operation of the machine). An additional magnet power supply has been ordered, the magnet cooling system is to be extended, three additional r.f. accelerating cavities will be added in the PS ring and extra shielding will be constructed over part of the ring. This phase of the programme is scheduled for completion in 1968.

Protons per pulse

The second stage is concerned with increasing the number of protons accelerated in each pulse and the factors which have the greatest effect on this, are the quality and the energy of the proton beam fed into the synchrotron ring from the injector.

The beam quality is represented in the language of machine physics by the term 'emittance' which takes into account the physical cross-section of the beam (how wide and how high it is) and the movements of the particles within the beam. The beam from the injector should have an emittance which lies within the 'acceptance' of the synchrotron — it should be able to pass into the finite aperture of the synchrotron and around the ring without particles being lost to the walls of the vacuum vessel — and be trapped and accelerated by the r.f. fields in the ring.

The energy of the beam is important because of the 'space charge' effect. The intense concentration of protons, each carrying a positive charge, tends to make the beam blow up in size because of the coulomb repulsive force between like charges. Thus the space charge acts to weaken the effect of the focusing forces applied in the magnet ring. The space charge phenomenon is the principle limitation on the ultimate intensity it is possible to achieve in a synchrotron. In the PS itself, for example, when lower beam intensities were available, 60 to 70 % of the injected beam could be trapped and accelerated. With increasing intensities this figure has now fallen to about 40 % and it is believed that space charge is the biggest contributor to this fall.

If however the injected protons have higher energies the effect of the space charge force is not as acute. The particles experience, in addition to the coulomb force, a magnetic attraction which increases with the energy of the particles and tends to cancel out the repulsive force. This is why, when thinking about intense beams, a high energy injector is one of the first considerations. At the Bevatron (Berkeley, USA) a higher energy injecto[illegible] incorporated in their improvement progr[illegible]was completed at the beginning of 1963. [illegible]S (Brookhaven, USA) a 200 MeV injector will probably be authorized, with provision for increasing to 500 MeV in the future. At the ZGS (Argonne, USA) at Saturne (Saclay, France) and at Nimrod (Rutherford Laboratory, UK) higher energy injectors are being considered.

Thus, unless optimisation of the existing machine components brings a considerable gain in intensity (and this is not thought to be likely, though new theoretical ideas on synchrotron operation have emerged recently) a high energy injector would be the major machine component of the second stage of the PS improvement programme. Some preliminary studies to this end have already been done and it is hoped that, if a new injector is agreed, it will be built and commissioned by 1971.

200 MeV linac

Thoughts were originally concentrated on the use of a 200 MeV linear accelerator. Some preliminary work had been done on an injector of this type in the design study for the proposed 300 GeV accelerator. Such a linac would probably be an extension of the technology of the existing type of linear accelerator. This employs the 'Alvarez structure'. Resonant cavities are excited by r.f. power and the beam is accelerated through a system of 'drift-tubes' being exposed to the accelerating forces in the gaps between the drift-tubes and being shielded in the drift-tubes from decelerating forces when the r.f. field swings in the opposite direction.

This technique is by now well tried and well understood. It has not been extended to such high energies as 200 MeV but it is thought that such an extension would not involve serious problems. (Still higher injection energy would be better if this were reasonably possible.) The advantage of such an injector lies in the experience that exists in construction and operation. It would involve a single, simple beam transfer between the injector and the PS magnet ring but would require multi-turn injection (see CERN COURIER vol. 6, no. 2 (February 1966) p. 29) which could be quite complicated. The theoretical increase in intensity which could be obtained with the 200 MeV linear injector is a factor of 5.

A disadvantage of linacs is that they are costly in terms of r.f. power and there is therefore great incentive to seek structures of higher efficiency. Other desirable properties for a linac are the ability to accelerate intense beams, without elaborate methods to cope with beam loading problems, and mechanical simplicity. Some work has been going on concerning a new structure for very high energy linacs, called the 'cross-bar structure'. Over the past two years, this has been studied first at the Rutherford Laboratory and now at CERN. It has these desirable features and is superior to the Alvarez structure for energies above 100 MeV.

The name comes from the use of two sets of bars — alternate bars being crossed at right angles — to carry the drift-tubes. As opposed to the much thinner bars of the Alvarez structure, one set would be so thick that they would dictate the shape of the fields in the linac cavity. In the mode of operation envisaged (π mode), they behave like a series of coupled co-axial resonators giving a more efficient use of r.f. power at high energies than the Alvarez type.

Slow-cycling synchrotrons

One preliminary proposal should be mentioned before discussing the new ideas. This arose at Brookhaven and became known as the 'bootstrap' method of injection. The idea was to inject protons into the AGS from the existing injector, use the synchrotron to accelerate the beam up to an energy of several hundreds of MeV, extract it from the AGS and stack it in an adjoining magnet ring. Repeating this process for several pulses would then allow the injection of an intense, high energy beam into the AGS. It is however, expensive in terms of machine time requiring several injector and magnet ring (albeit not to full energy) cycles before reinjection of the intense proton beam to be accelerated to full energy.

The new scheme was given the name TART — Twin Accelerator Ring Transfer, and involves several original ideas which remove the objection to the bootstrap method and offer other advantages as well. The scheme consists of two slow-cycling synchrotrons, which accelerate the proton beam to an energy of 600 MeV before transferring the beam into the PS ring. The word 'transfer' as opposed to 'injection' is used to describe the process of introducing the TART beams into the PS for reasons which will be brought out below.

The two TART rings would be constructed in the same tunnel and in fact the beam paths in

Some parameters of the TART scheme

Proton energy at injection into TART	50 MeV
Proton energy at transfer to the PS	600 MeV
Number of interlaced beams	2
Diameter of the magnet rings	100 m
Number of superperiods	18
Number of focusing magnets	36
Aperture of focusing magnets	92 x 32 mm
Length of focusing magnets	2.094 m
Number of focusing lenses	36
Aperture of focusing lenses	110 x 24 mm
Number of defocusing lenses	36
Aperture of defocusing lenses	(33 + 13 for crossing) x 78 mm
Length of lenses	0.3 m
Magnetic field at injection	0.172 T
Magnetic field at transfer	0.677 T
R.F. peak voltage	23 kV

the rings are interlaced in the manner shown in Figure 1. It is calculated that the interference between the two beams will produce no serious effects. The sequence of magnets through which a beam passes is also illustrated in the figure; it consists of a focusing magnet (which is also a bending magnet) a defocusing lens, a focusing lens, a defocusing lens, a focusing (bending) magnet again, and so on. The defocusing lenses are common to both rings. One simplification compared with the conventional alternating gradient synchrotron is that all the bending magnets have the same (focusing) gradient.

A 50 MeV beam from the present injector would fill up the two rings one after the other and acceleration to 600 MeV would then proceed in parallel for 0.7 s. This preliminary injection and acceleration can be under way ready for the next cycle, while the PS itself completes its full energy cycle.

To fill the PS ring with 600 MeV protons for one turn requires that the combined 'length' of the beam in the two TART rings equals the circumference of the PS ring. Thus the two rings would each be half the diameter of the PS. If three interlaced beams were used their ring diameter would be one third and so on. The possibility of using three interlaced beams as opposed to the two of the initially proposed TART scheme is in fact under consideration. The ideas involved are the same as for TART. In the USA, members of the team at Berkeley which put together the design study for the proposed American 200 GeV accelerator, have taken over the TART principle and are working on a system of four interlaced beams in connection with the large machine. They have called this system QUART.

The advantages

It might seem at first sight, since the process of injection from a 50 MeV linac into a synchrotron is still involved with injection into TART, that the same problems we are trying to overcome with respect to the PS still exist. To explain how these problems are made less acute we will consider injection into TART in two aspects (which are to some extent inter-related) — the injection capability and the space charge effect.

It is first necessary to appreciate the way in which particles are trapped in a synchrotron. The 'length' of the beam in the TART rings was referred to above but in fact the beam in a synchrotron is not a continuous, homogeneous stream of particles but is broken up into bunches (20 in the beam orbiting the PS for example). This arises from the r.f. acceleration process. We can think that only protons travelling with a particular speed (more precisely having the right momentum) will be trapped and accelerated, getting the right kick in energy each time they pass through a cavity, retaining the right momentum to stay in the ring as the magnetic field rises, and reaching the next cavity at the right time (having the right phase) for the next kick. In fact, a spread around this 'right' momentum and phase can be trapped and accelerated. The extent of this spread of the trapping is called the 'bucket' and the protons trapped form a 'bunch'.

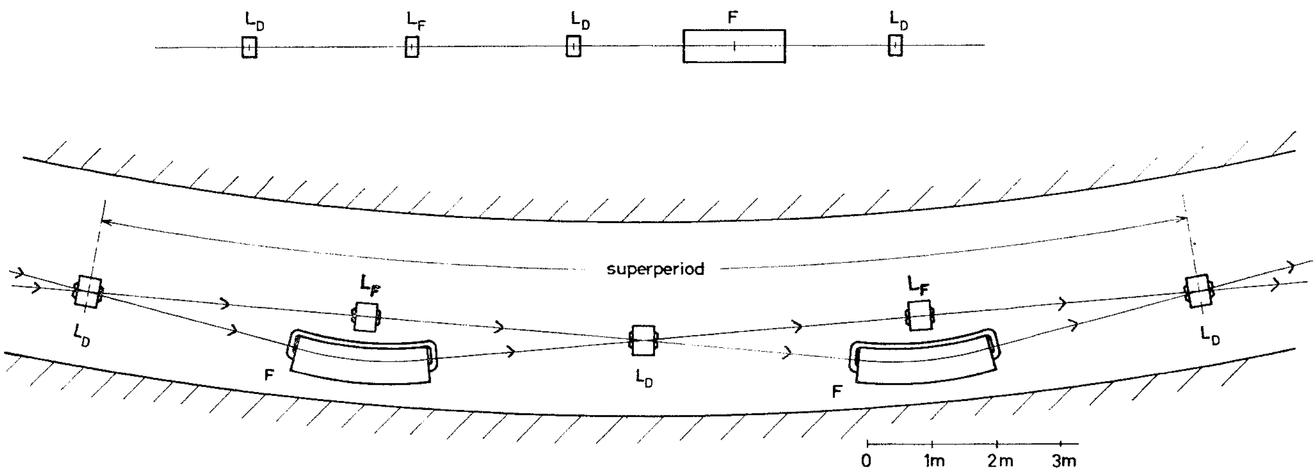
At injection into TART, the buckets are larger than those of the PS. The magnetic structure in TART and the relatively small maximum fields required (see the table of parameters) enable a vacuum chamber with a larger effective aperture to be used giving more physical room for the beams. Also the TART rings are 'slow cycling' (taking almost three quarters of a second to accelerate particles from 50 to 600 MeV). The fields in the rings do not pack the protons together as powerfully. Because of these features we can get more beam into TART at 50 MeV than we can get into the PS and the gains can be seen under the two aspects as follows:

Injection capability

a) The larger horizontal aperture for the beams gives a larger horizontal acceptance. This is particularly important for multi-turn injection into TART, which would still be necessary. More 50 MeV beam can be fed in to be accelerated.

b) The 'bunching factor' (the ratio of the average density

Figure 1. A section of the TART rings showing the two interlaced beams and (above) the sequence of lenses and magnets that they pass through. (L_D — defocusing lens; L_F — focusing lens; F — focusing/bending magnet.)



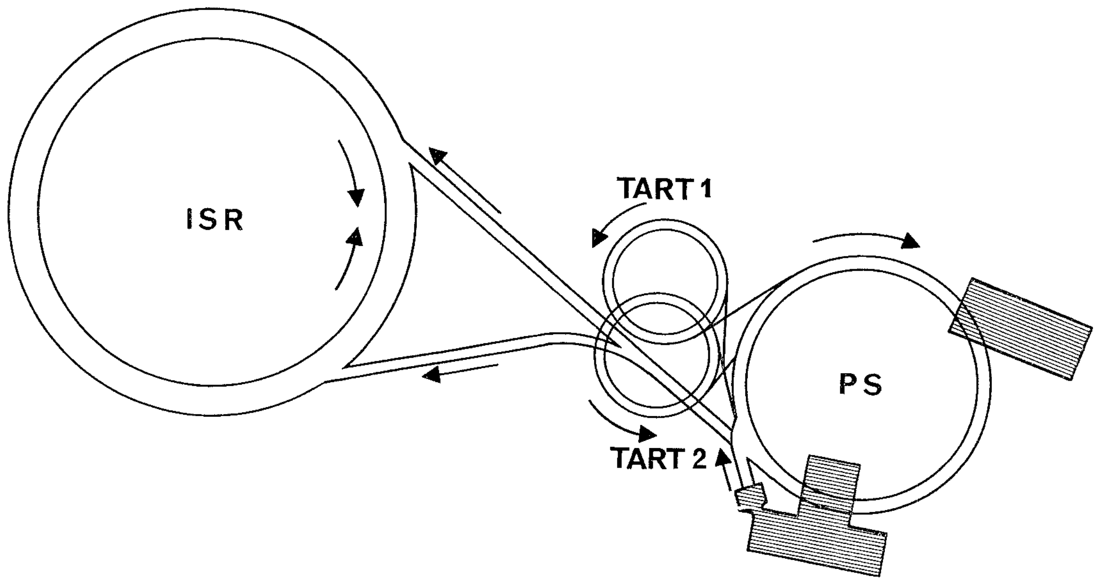


Figure 2. Two possible positions (TART 1 and TART 2) for the twin accelerator rings in relation to the 28 GeV proton synchrotron (PS) and the intersecting storage rings (ISR). Note that TART 1 and TART 2 are not the two rings of the twin accelerator ring transfer scheme: either position TART 1 or position TART 2 could be the location of the interlaced rings.

of the beam spread around the machine to the local density at the bunches) is larger. This allows more of the injected beam to be trapped.

Space charge effect
a) From the point of view of the space charge forces, the number of particles which can be fed into a synchrotron ring is independent of the diameter of the ring. Thus by using two rings a factor of two in intensity is gained; by using three rings a factor of three and so on.

b) The higher bunching factor again contributes to overcoming space charge effects because the protons are not packed so powerfully together and the repulsive forces between them are less strong.

c) The problem of the space charge effect is more acute in the vertical plane than in the horizontal and here it is the increase in vertical aperture in the TART rings which is the predominent factor in increasing the limit of the beam intensity set by space charge forces.

Transfer

We have just considered how it is possible to increase the beam intensity injected into TART as compared with the PS. When we consider taking the beams from TART to the PS the bunches in TART can be formed, using the r.f. fields in the TART rings, so that they are matched to the buckets of the PS. And the higher momentum, 600 MeV compared with 50 MeV, reduces the space charge effect as discussed above.

By synchronizing TART and the PS, using the same r.f., the bunches which have been accelerated to 600 MeV in the two TART rings can be made to fall into the buckets of the PS, discharging one ring after the other to fill up the 20 PS buckets. It is for this reason that the word transfer rather than injection is used to describe the way TART feeds the PS. The transfer process is very efficient, involving practically no loss of particles, which is an important consideration in comparison with injection from a 200 MeV linac.

The total theoretical gain in PS intensity, using a two ring system, is a factor of 12, (2 from using two rings; 1.5 from the bunching factor; 4 from the higher momentum at transfer). Whether so high a gain would be used in practice depends upon such problems as increased induced radio-activity, radiation damage, shielding requirements and on the quality of the very intense accelerated beam for use in the physics experiments and for the storage rings. If the upper limit of practical operation is about 10^{13} protons per pulse, the TART scheme would be working below its full capability which should result in higher reliability.

Construction and Siting

The construction of such slow cycling synchrotrons offers no major technological problems. The magnets and the r.f. system are much simpler that for the PS itself. The scheme also justifies improvements to the existing injector. Two beam exchanges are necessary — from the 50 MeV injector to TART, from TART to the PS — but these are not difficult. It is worth remarking, however, that had the TART scheme arisen a few years ago it might not have seemed so feasible a proposition. It is only recently that the technology of fast pulsed magnets has been developed to the point where a project requiring the extraction of beams with very high efficiency from a circular machine can be accepted. A preliminary cost estimate has been made and it suggests that the cost of a 200 MeV linac and of TART would be comparable, with, if anything, TART being slightly cheaper.

The possible siting of the TART rings has also been considered. A ring tunnel of 50 m radius, with a cross-section about 3 m wide by 4 m high, is required. Since the existing 50 MeV linac would be used to inject into TART, the rings need to be positioned close to the injector to the west of the PS. Two positions, shown on Figure 2, are being studied. Position 2 crosses the beam transfer lines to ISR and the TART rings would need to be lowered by over 6 m to give 1 m of concrete shielding below the ISR tunnels. Position 1 would require an extra 40 m of transfer tunnel.

The project was brought to the attention of the Scientific Policy Committee at its meeting at the beginning of March. If it is decided that this scheme (or a similar one, for example using three rings) is worth pursuing for the second stage of the PS improvement programme it is probable that a study group will be set up in the near future to work out the precise details of the scheme.

For those who would like more detailed technical information, see :

'A circular injector for the CPS (TART-scheme)' W. Hardt, 1965, AR/Int. SG 65-10.

'A slow cycling injection method for intensity improvement of the CERN-PS (Twin Accelerator Ring Transfer Scheme)' W. Hardt, to appear in the proceedings of the Vth International Conference on High Energy Accelerators, Frascati 1965.

'On interlaced injector synchrotrons' W. Hardt, 1966, ISR-300/GS/66-7.

CERN News

Bubble Chambers

The bubble chamber experiments with the 2 m hydrogen chamber are expected to be under way again in June and are now scheduled to continue right through to December. It had previously been planned to have a shut-down in the Autumn to convert the chamber for some experiments using deuterium instead of hydrogen. The changeover to deuterium has now been postponed, because of the PS breakdown, until the beginning of 1967.

Some preparatory work for this changeover is being done during the present extended shut-down. In particular, four new gaskets are being installed to improve the sealing of the safety cold tanks around the chamber itself.

When the system is being cooled down, heat conduction to the glass windows and condenser lenses in the chamber and the cold tanks is via gaseous hydrogen or deuterium. With deuterium, which is much more expensive than hydrogen and in limited supply, care has to be taken to reduce leakage from the cold tanks to a lower level than can be tolerated with hydrogen. Flexible gaskets are needed to cope with the stresses introduced during the cool-down (when temperature gradients as high at 40° C can appear across adjoining surfaces). This is a problem in itself because few materials remain flexible at temperatures of the order of —200° C. Inflatible gaskets are used, filled with helium. The new gaskets have been specially developed at CERN and are different to those employed on other bubble chambers. Two have been installed and it is hoped to have the other two in position before the chamber is cooled down in June.

The chamber has been moved a few metres to a new beam line (called u3) incorporating r.f. separators. This is an improved version of the existing r.f. separated beam (u2). Probably, about 1 million pictures will be taken in the u3 beam before starting to run in the new beam line (m6) in October. A further million pictures are planned in the m6 beam in 1966.

The Saclay 81 cm hydrogen chamber may take about 900 000 to 1 000 000 pictures before the end of the year. The 120 cm heavy liquid chamber will be involved in one experiment (looking at K^0_2 decays) before starting the new series of neutrino experiments.

Quotes

'The primary function of technology is to make things which are socially useful, but the essential end of science is quite different. It is the broadening of knowledge and the deepening of understanding. The processes and goals of technology are more visible to society than are those of science, but because its products are devised with the aid of knowledge that science provides, they are likely to be attributed to science itself.'

C. P. Haskins
President of Carnegie Institution of Washington, Annual Report for 1964-65.

'The second Heisenberg uncertainty principle: For theories of the structure of matter, mathematical precision and physical relevance cannot be simultaneously achieved.'

E. C. G. Sudarshan
Syracuse University
(Concluding remarks at the International Seminar on Unified Field Theories, July 1965).

'Particle physics is admittedly remote, as the exploration of the far frontier has always been. It does not pretend to yield daily bits to input to other sciences or to technology. Basic research never has and it never will. What high energy physics may do at any time, if it is allowed to continue in a forward looking way, is to create new sciences, to revolutionize old ones, and perhaps to revolutionize our lives. These things are more likely in this field where we are dealing with the elemental and the primordial, than in other fields of science.'

E. McMillan
Director of the Lawrence Radiation Laboratory
Congressional Hearings on the USA High Energy Physics programme, March 1965.

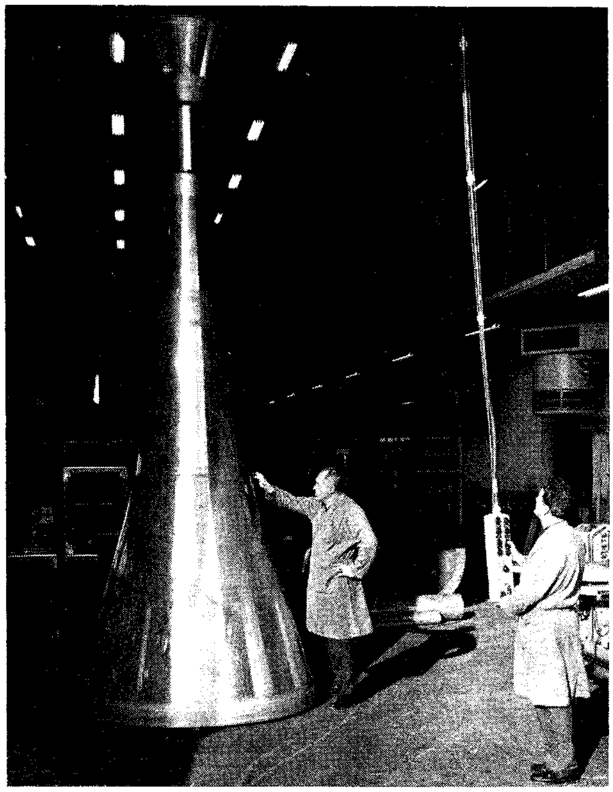
'We do not discover the laws of physics, we invent them: when something is so ridiculous that we cannot possibly understand it, we invent a law of physics which says it must be so.'

D. H. Wilkinson
Oxford University
('The Elementary Particles' Science Journal, March 1966).

Craftsmen in the Main Workshop putting the final touches to the first of the three new r.f. test cavities for the PS (see CERN COURIER, vol. 6, no. 3 (March 1966) p. 43) before it went to the manufacturers of the amplifier and power supply systems on 14 April. As can be seen in the photograph, the new cavities are very much bigger than the existing units on the PS. They are 2.4 m in diameter, the maximum that can be accommodated between the height of the beam path and the floor of the PS tunnel. Since only 1 m of axial length is available in a short straight-section (as compared to the 2.5 m for the existing cavities), the maximum possible diameter was chosen in order to dispense with water-cooling and thus to reduce maintenance work in the ring.

Three such cavities are required in order to add 50 % to the accelerating voltage of the 15 cavities now in the PS ring. This will make it possible to accelerate twice as fast during most of the rise-time of the magnet field. Power will be fed to the cavities at frequencies from 17 to 19 MHz. The cavity is tuned at 19 MHz.

The large port at the bottom of the cavity gives access for internal adjustments of electrodes etc., and the cavity can also be opened along the diameter which is diagonal across the photograph.



The inner conductor of one of the 'reflectors', to be incorporated in the new neutrino beam line, being checked for dimensional accuracy after welding in the West workshop. The conductor is 5 m long, with an inner diameter of 20 cm minimum and 2 m maximum, and will take peak pulsed currents up to 500 kA. This is the most difficult component of the reflector to construct, and it has been made on site (other components are being manufactured outside). It is constructed from cones of aluminium alloy 2 to 3 mm thick – horizontal bands on the completed conductor indicate where the separate sections are welded together.

The reflector is part of the focusing system designed to increase the flux of neutrinos in the new beam line to a value four times higher than in the previous experiments. It will be placed 15 m from the target located in a modified magnetic horn (as used in the previous experiments, see CERN COURIER vol. 2, no. 9 (September 1962) p. 4) and followed by a second reflector, 4 m long, positioned 50 m from the target. These three devices will serve to focus the 'neutrino parents', π and K mesons which decay to produce the neutrino beam.

It is hoped that assembly of the reflector, when this inner conductor will be placed inside its large cylindrical outer conductor will begin at the end of May and that tests will be completed in July and August. The reflector will then be installed with the many other components in this complex beam line.

Chassis goes West

High energy physics is 'big science' and the days of string and sealing wax in experimental equipment are virtually over. Because of the cost of the equipment and the pressure for time on the accelerators it is necessary to ensure that all the units used in the operation of the machines themselves and in the experimental set-ups, achieve a high standard of reliability. It should be possible to replace faulty units easily and to move units from laboratory to accelerator, from experiment to experiment, from country to country. This has brought about an increasing degree of standardization in instrumentation.

In the early 1960's, work was carried out at CERN on chassis systems. This was to standardize the construction of the boxes carrying electronic equipment to be fixed in 19 inch racks (the standard rack size) so as to achieve, as far as possible both physical and electrical interchangeability.

In 1962, a meeting of the International Electrotechnical Commission was held on this topic in Geneva. The American representative, from Oak Ridge, was then introduced to the CERN system and subsequent development in the USA incorporated many features of the CERN design. In July 1964 the AEC Committee on Nuclear Instrument Modules made its recommendations (TID-20893) which have by now been accepted by the majority of American laboratories and manufacturers (see 'Nucleonics', March 1966, p. 20).

It is possible that the CERN system will soon be updated to incorporate some of the ideas which have emerged over the past few years, including some of the refinements introduced in the American standard. This will be especially necessary because of the great quantity of new instrumentation required for the ISR project.

Visit to Serpukhov

by **Y. Goldschmidt-Clermont**

Track Chambers Division

At its Meeting in December 1965, the Council approved the initiative of Professor Weisskopf in pursuing the possibility of collaboration with the Russian accelerator Laboratory at Serpukhov. This article conveys more information about the new Laboratory, together with some of the impressions received during a recent visit by a group of physicists from CERN.

At the end of last year, five physicists from CERN visited the Institute for High Energy Physics at Serpukhov, where the Soviet 70 GeV proton accelerator is under construction. Soon afterwards, the Director of the Laboratory, A. A. Logunov, and several of his colleagues spent a week in CERN*. Thus contacts with the new Laboratory have been renewed opening up possibilities of future collaboration.

Leaving Moscow early on a November morning, our small bus shared the main road to Kharkov with the usual heavy commercial traffic. The countryside is now flat, now gently undulating with small hills. A grey sky covered large pastures and fields, forests of birch and spruce, and occasional groups of traditional houses decorated in bright colours. Leaving the main road at the entrance of the industrial city of Serpukhov, a smaller road first follows the wide valley of the Oka river, then enters a forest of high spruce.

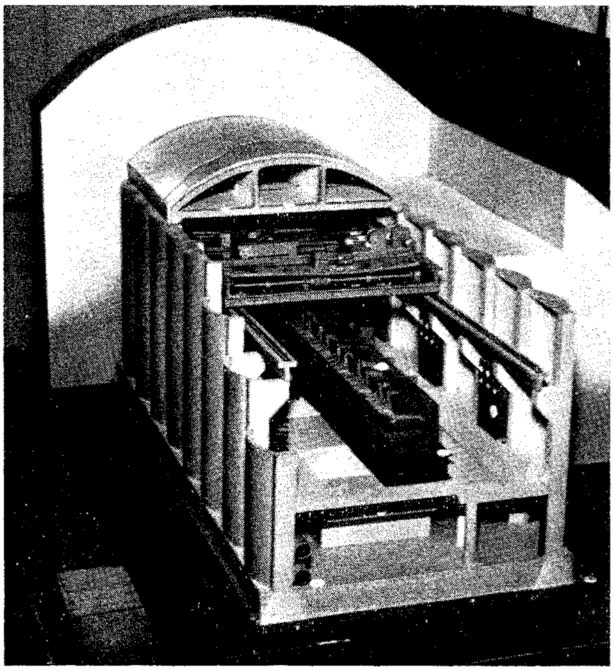
After a total of two and a half hours driving, the headquarters of the Laboratory appeared in a clearing. This functional building, recently taken over from the builder, houses the directorate offices and a number of laboratories. We were welcomed by the Director and his staff and were first reminded of the general characteristics of the accelerator (see Table) and briefed on the present and future activities.

The Serpukhov project started several years ago, under the guidance of physicists from the Moscow Institute of Experimental and Theoretical Physics. Preliminary work on the site began in 1960. The project recently became more autonomous under the name 'Serpukhov Institute for High Energy Physics'. Construction work received new impetus and a programme for the preparation of beams and experiments was launched. Part of the work takes place on the site itself and part is done by teams temporarily stationed at Dubna. The experimental physics staff now numbers about 70, and is expected to grow to a size comparable to CERN's in about two years. The accelerator design is done at the Research Institute for Electro-Physical Equipment in Leningrad, which centralizes this type of work for the entire Soviet Union. The parts are built by industry.

On site, some limited workshops facilities are available to help with the minor modifications and repair always connected with the assembly work. A large engineering firm is responsible for the construction of the machine. Their representatives asked us not to take photographs on the spot but we were given, later, a picture of magnet units in the accelerator ring*. We attempted to capture some of the atmosphere by photographing, under the amused eyes of our hosts, a model of a section of the accelerator (figure 1), the hosts and guests themselves (figure 2), and an artist's view of the experimental hall (figure 3).

The artist, indeed, gives a good impression of this huge and elegant hall. Its symmetrical external shape fits nicely with the rounded mounds of the shielding banks, where bulldozers seemed to be giving the finishing touches while we were there. Inside the hall, the huge arch is constructed from a light aluminium frame and a large overhead crane is installed. Also sheltering in the hall, are a few birds taking refuge from the forest, begging the warden for crumbs. The vast floor, 150 x 90 m^2, is at present used to store and test the magnet units and coils. The magnetic properties of the magnet blocks and units are measured on an automated test bench with the help of a small on-line computer. We saw some of the final stages of this work and carried

Figure 1. A model of a section of the magnet ring tunnel of the 70 GeV accelerator. Most of the magnets are now in position and installation of the magnet coils is underway.



CERN/PI 299.3.66

* See CERN COURIER, vol. 6, no. 1 (January 1966) p. 14.

Figure 2. The CERN visitors and their hosts photographed in front of the Laboratory headquarters at Serpukhov. From left to right: B. Montague (CERN), A.A. Filippov (Dubna), A. Rousset (Ecole Polytechnique and CERN), A. A. Logunov (Serpukhov), M. Ferro-Luzzi (CERN), J. M. Perreau (CERN), Y. D. Prokoshkin (Serpukhov) and R. M. Sulaiev (Serpukhov).

away as souvenirs, a few punched cards, exactly the same as our familiar western counterparts, except for a few printed cyrillic characters. The coils are tested hydraulically and electrically, and most of the repairs are done on the spot. On both sides of the hall, inside and outside the ring, laboratory buildings are planned. Slightly further out are the generator buildings, workshops and other facilities. It is planned to extend the hall by a long gallery, containing particle separator equipment, leading to a bubble chamber building to be situated several hundred meters away.

We passed over the scar of mud and dust that the construction work has made in the forest, to visit the building housing the injector, a three-stage linear accelerator (40 - 70 - 100 MeV) with a Cockcroft-Walton generator as input and with quadrupole focusing. The generator is already there, together with a spare, and so are two of the linear accelerator vacuum tanks. The copper resonators are ready to be mounted in the first tank. We were told that the titanium pump and r.f. generators were ready at a Moscow factory. Some of the electrical installation was under way, but it was obvious that first priority was being given to completion of the building. Concrete dust was still flying around and we met many men and women workers — carpenters and masons.

The accelerator ring tunnel is relatively spacious. On both sides, room is available for the installation of equipment and for storage (see figure 1). Most of the magnet units were in position in the ring and the job on hand was the installation of the magnet coils. We noticed the use of aluminium conductors, both to feed the coils and for the coils themselves, and a systematic use of aluminium welding.

The straight sections in the magnet ring are relatively short, creating some problems for beam injection and ejection. Designs are in progress for a fast ejected beam for protons up to 40 GeV/c, and for slow extraction up to 60 or 65 GeV/c, with target dates of 18 months to a year after the first accelerated beam has been obtained (see below). To our eyes, more familiar with the CERN and Brookhaven machines, the Serpukhov magnets and their supports appeared large and massive, the tunnel endless. Alice in Wonderland's mushroom that makes everything bigger is in this case partly the Russian engineering tradition and partly the factor of almost three in accelerator energy.

The question on all our lips was, of course, 'When do you expect the first accelerated beam?' The best estimate our hosts gave us was two years (end of 1967), with a margin of error of minus two months, plus one year. They asked us, in turn, to make an estimate on the basis of what we had seen. But we saw only a point on a curve, and not its slope. Instead of a wild guess, we wished our friends the best of luck in reaching this date which must be dear to all their hearts.

The first ray of sunshine of the day accompanied our return to the laboratory buildings. The barks of the birches were shining and the Serpukhov spruces, which are also three times larger than their Brookhaven counterparts, stood out prominently. We broke into smaller groups to talk shop about our respective fields. Everywhere we found a high level of competence, and the fire of questions and answers showed the keen knowledge and understanding that our hosts had of all the works published by other Laboratories. From these conversations we learned the proposals for beams and the experimental programme.

Design is in progress on the following:

- a high energy unseparated negative beam (30 to 60 GeV/c) from an internal target for π^- (and $\bar{p}$) to go diagonally across the experimental hall;
- a high energy unseparated positive beam, from an internal target, with momenta up to 40 or 50 GeV/c;
- two electrostatically separated beams, going towards the inside of the ring: one fully separated (up to 7 or 8 GeV/c), the other with one-stage partial separation and high flux, reaching 15 GeV/c;

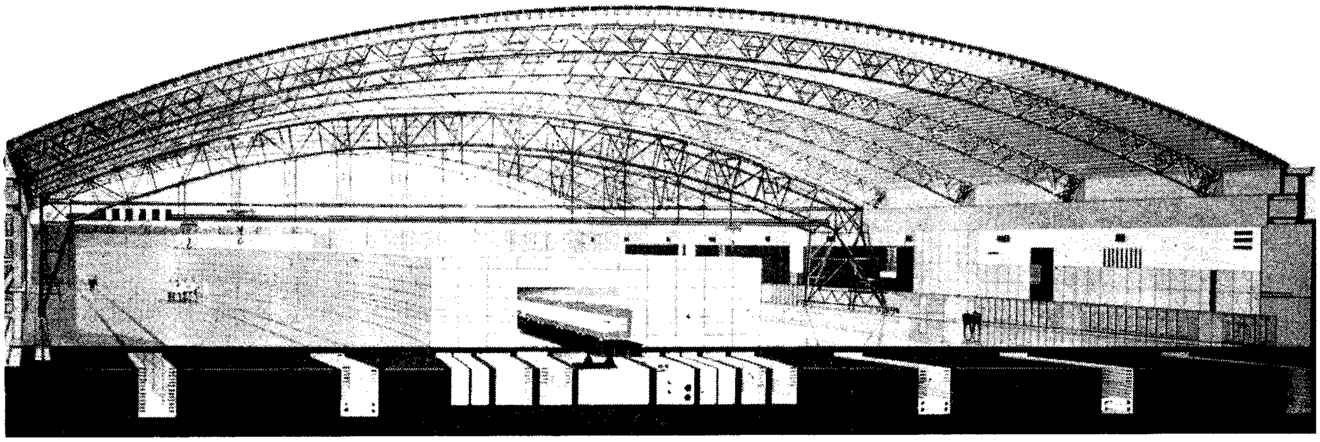


Figure 3. An artist's impression of the large experimental hall. As can be seen, the building has no internal supports to interfere with the positioning of beam lines. The accelerator itself and its surrounding shielding are in the centre of the picture. The tunnels for the various ancillary supplies can be seen under the floor level of the hall.

TABLE : Design parameters of the Serpukhov accelerator*

Type — strong focusing, alternating gradient	
Orbit length	1483.64 m
Effective radius of the orbit inside the magnet blocks	194.12 m
Length of normal block measured along its iron core	10.42 m
Length of shortened block	9.3 m
Number of blocks	120
Number of superperiods	12
Number of normal blocks in a superperiod	3 F + 3 D = 6
Number of shortened blocks in a superperiod	2 F' + 2 D' = 4
Length of short straight section	1.27 m
Length of medium straight section	2.62 m
Length of long straight section	4.86 m
Maximum field at equilibrium orbit	1.0 to 1.2 T
Number of betatron oscillations per turn	9.7
Kinetic energy at injection	100 MeV
Transition energy (total)	8.9 GeV
Maximum proton energy	58 to 70 GeV
Field at injection	0.0076 T
Chamber half-height	57.5 mm
Chamber half-width (effective)	85.0 mm
Maximum orbit displacement at a unit momentum deflection $\Delta p/p = 1$	3.53 m
Maximum amplitude of forced oscillations	34 mm
Maximum amplitude of free oscillations	22.8 mm
Total weight of silicon steel in magnet	20 000 t
Total weight of aluminium in the windings	700 t
Energy stored in magnetic field	120 MJ
Peak supply power	100 MW
Number of cycles per minute	5—10
Rectified voltage at the beginning of the cycle	9230 V
Maximum rectified current	2 x 5750 A
Current rise time	3.5 s
Duration of pulse flat top	1.5 s
Expected intensity for first beam	10^{11} protons/pulse
Maximum intensity	2 to 3 10^{12} protons/pulse

* Vladimirski V. V., Goldin L. L., Koshkarev D. G., Tarasov E. K., Yakovlev B. M., Komar E. G., Monoszon N. A., Strelzov N. S., Stolov A. M., Titov V. A., Malyshev I. F., Popkovitch A. V., Gustov G. K., Kulikov V. V., Minz A. L., Rubchinski S. M., Vodopjanov F. A., Kuzmin A. A., Uvarov V. A., Kuzmin V. F., Shirjajev F. Z., Filaretov S. G., Zhadanov V. M.:
Proceedings of the International Conference on High Energy Accelerators, Dubna, August 21—27, 1963

Atomizdat, Moscow 1964 pp. 197—201

Transl. AEC, Conf. 114, TID-4500, 43rd Ed., pp. 233—239

Small changes and additions after visit to Serpukhov.

— a r.f. separated beam not yet fully defined, to operate probably with an external target, leading through the outside gallery to the bubble chamber building.

The bubble chamber programme includes a project for a 4 to 5 m heavy liquid chamber, to be constructed at Serpukhov, a 5 m x 1.5 m hydrogen bubble chamber, under study by a group in Dubna, and a 2 m hydrogen bubble chamber with horizontal window, which will be initially assembled and operated in Dubna, where parts have already arrived. Active work is under way to prepare analysis programmes, designed for the future large digital computer, BECM 6 a (10^6 operations per second, 16 magnetic drums, 54 magnetic tapes, Algol, Fortran).

Several experiments are being prepared using electronic and spark chamber techniques: for instance, hodoscope type experiments with computer on-line to measure total cross-sections and elastic scattering; a large 6 m magnetic spark chamber. Development work is in progress on total absorption spectrometer sandwiches for gamma ray detection, and on digitized spark chambers.

A neutrino experiment will not be attempted before obtaining the extracted proton beam. A 100 m decay path and the necessary shielding will probably be placed next to the r.f. gallery. Multi-ton spark chambers and the heavy liquid chamber will be used for detection.

As dusk settled on the forest, we walked to the new, elegant cafeteria, where our hunger, aroused by a long and exciting day, was soon appeased by delicacies matching the refinement of the setting. Toasts were exchanged to the future of a commencing collaboration.

Serpukhov is in the heart of a countryside which attracted many artists, painters and poets, and thus belongs to the Russian cultural tradition. Nearby, many kinds of sport can be practised, from fishing to aviation. Within easy reach also are other scientific Institutes, for instance in the field of astrophysics. On our walk back to the laboratory buildings, we had noticed between the trees the small laboratory town, with its school and apartment houses, lit up by the windows of its shops. The people in the few streets seem young, alert and confident, and the atmosphere is homely. Serpukhov will soon be contributing to the cultural tradition as one of the outposts of scientific thought and achievement. In the words of the Serpukhov Scientific Director, Y. D. Prokoshkin, it will be a place where physicists from all over the world will, also, feel at home.

BOOKS

Nuclear techniques in analytical chemistry, by Alfred J. Moses (Oxford, Pergamon Press Ltd., 1964; 45 s.), is intended to guide the analytical chemist in the use of nuclear methods. As an introduction it contains general information about the handling of radioactivity and the measurement of radioactive nuclides. Then follow a number of chapters describing the application of nuclear techniques to various fields of analytical chemistry, including activation analysis, tracer methods, dating methods, etc.

The general impression of this little book is that the introductory part is rather weak. The author has tried to lighten the text with a large number of illustrations, but many of these are quite uninteresting (the first two chapters contain, for instance, six photographs of counters and spectrometers). He would have been better advised to give more space to textual matter instead.

The chapters concerning the applications of the techniques are of greater value, however. The larger number of examples giving procedures for the analysis of specific elements will give the reader, not already familiar with the use of these methods, a feeling for the amount of work involved, the instrumentation needed, and the sensitivity and accuracy of the analytical methods. He will then be in a better position to make comparisons with more conventional methods. He might even make direct use of the procedures described.

There are a few typographical errors, such as the interchange of figure captions. More confusing, however, is a statement that cobalt can be extracted in 2-nitroso-1-naphthol. This would certainly be quite difficult, as the latter compound is a solid (it forms a complex with cobalt which can be extracted with a solvent such as chloroform).

In spite of its shortcomings the monograph gives a fair survey of the place of nuclear techniques in analytical chemistry. It can certainly serve as an introduction to this field and can therefore be said to answer to its purpose.

G. R.

Quantum optics and electronics, edited by C. DeWitt, A. Blandin and C. Cohen-Tannoudji (New York, Gordon and Breach Science Publishers Inc., 1965; paper $ 8.50, cloth $ 10.50) is a record of the lectures on these subjects at the Les Houches Summer School in 1964. Although the title could be taken to cover a wide range of subjects, the emphasis is clearly on those fields which are most affected by the recent spectacular development of maser and laser technology.

The introductory lectures by N. M. Kroll on 'Quantum theory of radiation' and R. J. Glauber on 'Optical coherence and photon statistics' presuppose no special knowledge beyond, say, what may be found in Messiah's *Quantum mechanics*. These lectures, especially the ones by Glauber, are of a high pedagogical standard and their contents should form part of the basic knowledge of every physicist. Subsequent lecturers include those who have been most directly responsible for the great progress in the field of masers and lasers. Lectures by W. E. Lamb (with an introduction which reminds physicists that they are citizens in addition to being scientists) on the 'Theory of optical masers' and N. Bloembergen on 'Non-linear optics' are authoritative accounts of the most recent work. There are shorter contributions by A. Javan on 'Gaseous optical masers' and P. Aigrain (in French) on 'Les lasers à solides'.

Whereas most of the lectures give adequate references, the last mentioned contribution has the doubtful distinction of containing only one. It will not fill the lacuna to mention the fact, but it may be of interest to readers that the n-p junction laser, which has been achieved only very recently, was described in the forties by J. von Neumann in an unpublished memorandum (which is included in his posthumous 'Collected works') giving what is probably the first discussion of maser action. The 'Théorie de la largeur de la raie' is discussed by J. M. Winter, and a long chapter on 'Pompage optique', by J. Brossel, deals with a subject that is a little removed from those treated by the other lecturers, but which nonetheless belongs under the title of the book. To this reviewer, who is not a specialist in the field, the treatment appears to be competent and careful. Lectures by A. Abragam on 'Le modèle du champ cristallin en résonance paramagnétique' appear in title only, since they are to be published elsewhere.

This series of lectures, which maintains the high standard one has come to expect from the Les Houches Summer Schools and the distinguished lecturers who teach there, can be unhesitatingly recommended to anyone wishing to learn of the recent work on masers and lasers. Next to actually attending the lectures, the published texts offer the best and easiest way to acquire a clear picture of the present situation and also indicate where one may seek further details.

P. K. Kabir

Handbook of radiochemical exercises, by A. N. Nesmeyanov, V. I. Baranov, K. B. Zaborenko, N. P. Rudenko and Y. A. Priselkov, translated from the Russian by E. Kloczko (Oxford, Pergamon Press Ltd., 1965; 84 s.).

As indicated by the title, this book is mainly intended as a handbook for students in radiochemistry courses. The contents are divided into five chapters, of which the first three are of a basic character, dealing with the manipulation of radioactive substances, the measurement of nuclear radiation and the decay and growth of radioisotopes. The remaining chapters cover the production and properties of radioactive nuclides and the use of radioisotopes as labelled atoms. Each chapter, except the first, consists of a section with detailed descriptions of a large number of practical exercises — the book contains extensive descriptions of 89 laboratory experiments — preceded by a thorough treatment of the theoretical and experimental background for the exercises. These analyses are well written, quite complete, and contain a lot of useful information on radiochemical problems.

The scope of the book is limited to the practical use of nuclear techniques in chemistry. A large amount of material included in ordinary textbooks on radiochemistry is thus omitted. Therefore the book cannot replace such a textbook, but it will serve as an excellent complement, and it is recommended not only for the student attending a laboratory course in radiochemistry (and for the instructor preparing the course) but for all workers in the field.

An important disadvantage is that most of the references given refer to work published in Russian and therefore inaccessible to most readers of this translated version.

G. R.

Condensation and evaporation of solids, Proceedings of the international symposium on condensation and evaporation of solids, Dayton, Ohio, September 12-14, 1962, edited by E. Rutner, P. Goldfinger, and J. P. Hirth (New York, Gordon and Breach Science Publishers, 1964; professional edition $ 19.50, regular edition $ 38.00).

This volume contains all the contributions (with discussions) to the symposium. The mere fact that such a symposium was arranged, completely devoted to the subject of the condensation and evaporation of solids, reflects the increasing interest in solid-state physics during recent years. The field is experimentally rather difficult. Vapour pressures are in most cases extremely low and the temperatures required for the experiments very high. Nevertheless, these proceedings show that a large amount of reliable experimental data has been accumulated. In addition, the field is very well covered theoretically.

This book is directed, in the first place, to solid-state physicists of all kinds. The wealth of information it contains will make it very useful also for many other branches of research where condensation and evaporation phenomena are important, for instance physical and analytical chemistry, radiochemistry, and reactor technology.

G. R.

Rare-earth research II, Proceedings of the third conference on rare-earth research, April 21-24, 1963, edited by K. S. Vorres (New York, Gordon and Breach Science Publishers Inc., 1964; professional edition $ 12.50, standard edition $ 29.50).

This book gives a rather detailed picture of the present status of research on the rare-earth elements. It includes sections concerned with classical inorganic chemistry and the application of chemical methods to the preparation of many possible rare-earth compounds. Such compounds can be studied with respect to their structure and to their magnetic and optical properties. In addition one can study the thermal equilibrium and phase equilibrium of rare-earth compounds and metals.

The important field of nuclear properties of rare-earth elements is not included. However, the last report in this volume covers the interesting aspect of the behaviour of different rare-earth elements in meteoroids. It also reveals what rare-earth elements can tell us about the nucleon synthesis of elements in stars.

R. Brandt

Coulomb Excitation, by L. C. Biedenharn and P. J. Brussaard (Oxford, Clarendon Press, 1965; 40 s.).

This book by Biedenharn and Brussaard is one of the reference books published in the series *Oxford Library of the Physical Sciences.*

A very specialized subject is treated in the style to which we have become accustomed in the articles already published by these two authors. The point of departure is semi-classical; a first theoretical result, in good agreement with experiment, suggests that the point of view is valid and the authors devote themselves to explaining the success of this classical approach by taking up the quantum point of view, from which they draw the maximum amount of information by very skillful handling of the main symmetry principles of modern physics.

The book certainly takes in a wider field than is suggested by its title. An elegant use of quantum mechanics makes it a useful handbook for the topics it covers. It is also — and this should not be overlooked — a good description of a subject within nuclear physics which, after 12 years of investigation, has had considerable impact on the development of the latter. The authors have, moreover, drawn attention to this, concluding the book with a chapter on models of the nucleus. However the scale on which this is done is perhaps regrettable, even though they use an original technique, for the section on models takes up 70 pages out of the 334 in the book. It would have been better to include a chapter on the electromagnetic interaction of muons, pions and other particles with the atomic nucleus.

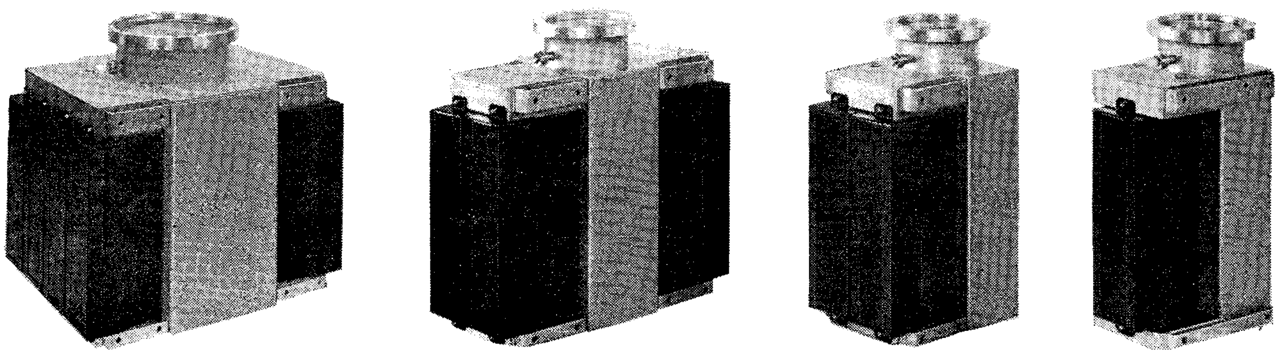
The titles of the chapters are as follows:
1. Introduction
2. The semi-classical treatment
3. Quantum calculation of non-relativistic coulomb excitation
4. More involved coulomb excitation processes
5. Multiple coulomb excitation
6. Excitation by energetic electrons
7. Coulomb excitation and nuclear structure.

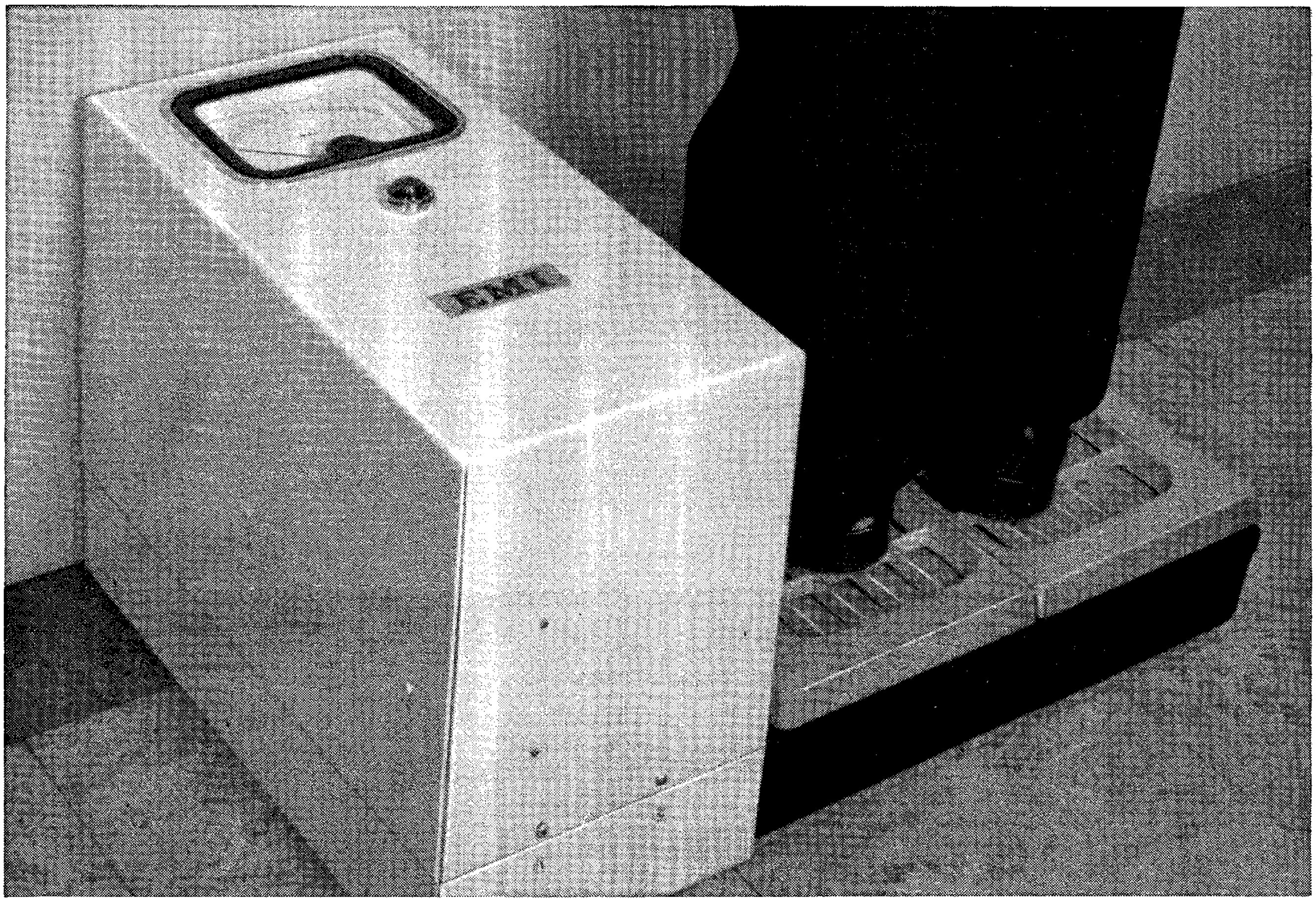
With more than 500 references dating up to mid-1964, the book is extremely useful for nuclear physics experimenters and theoreticians.

The print is clear but the small size of the pages sometimes makes the presentation rather difficult, since a mathematical equation can hardly ever be fitted onto one line. Also, in a book as long as this we could reasonably expect each chapter to start on a new page. This would at least give the reader some breathing space at the end of each chapter. **P. C. M.**

Also received:

Radiation damage in graphite, by J. H. W. Simmons (Oxford, Pergamon Press Ltd., 1965; £ 4).
Energetics in metallurgical phenomena, vol. 2, edited by William M. Mueller (New York, Gordon and Breach Science Publishers Inc., 1965; cloth $ 11, paper $ 5.50).
Thermal stress techniques, by Zenons Zudans, Tsi Chu Yen and William H. Streigelmann (New York, American Elsevier Publishing Company Inc., 1965; £ 8).
Dielectrics — Intermolecular forces — Optical rotation, by John G. Kirkwood, edited by R. H. Cole (New York, Gordon and Breach Science Publishers Inc., 1965; cloth $ 8.50, paper $ 4.95).
Eléments des échanges thermiques, by Louis Weil (Paris, Gauthier-Villars, 1965).
The entomology of radiation disinfestation of grain, edited by P. B. Cornwell (Oxford, Pergamon Press Ltd., 1966; 63 s.).
Data for plasmas in local thermodynamic equilibirium, by Hans-Werner Drawin and Paul Felenbok (Paris, Gauthier-Villars, 1965; 62 F.).
Importance of the adjoint function, by Jeffery Lewins (Oxford, Pergamon Press, 1965; £ 3).





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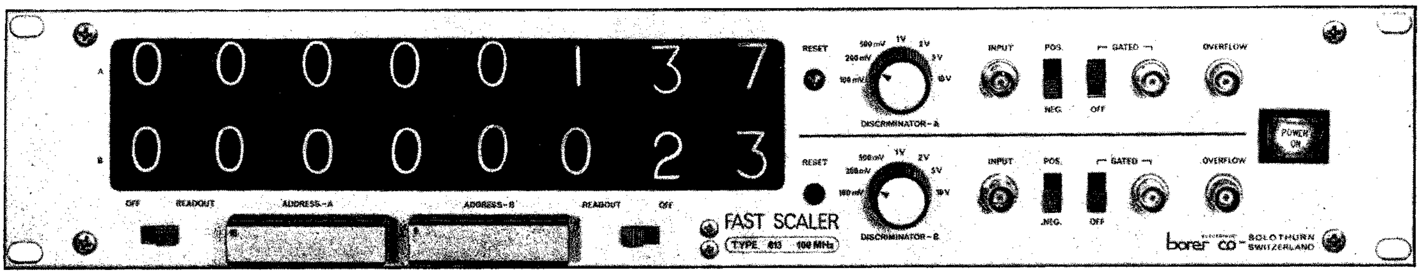

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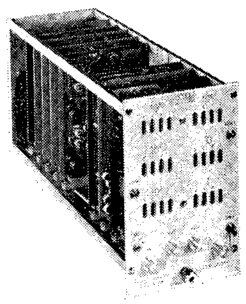

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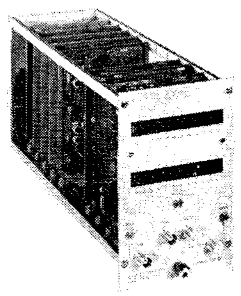

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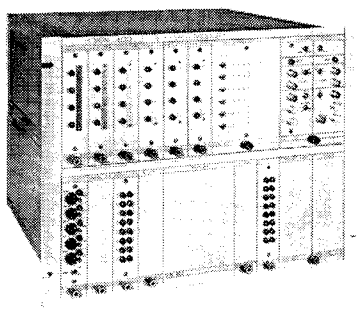

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