

Dubna — 1963

21-27 August

International conference on high-energy accelerators

Last year CERN was host when the International conference on high-energy physics *, was held here, under the auspices of the International Union of Pure and Applied Physics. This year it was the turn of Dubna, the Joint Institute for Nuclear Research, where the companion International conference on high-energy accelerators took place from 21-27 August.

The accelerator conference was founded by CERN in 1956, and held here again in 1959. In 1961 it took place in the U.S.A., at the Brookhaven National Laboratory. Like the conference on high-energy physics, with which it alternates, it is now held every other year, successively in the U.S.A., U.S.S.R. and Western Europe (CERN).

Twenty-one physicists and engineers, including the Director-general, went to Dubna from CERN. This article has been compiled from the accounts they gave afterwards of the conference and the visits that were made to other laboratories.

The conference brought together some 300 participants, of whom about a quarter were from the U.S.A. and a quarter from Western Europe. Its purpose was to review the developments in the design, construction and operation of high-energy particle accelerators (generally those giving energies of about 1 GeV and above) during the two years since the last conference, at Brookhaven, and to survey the future possibilities.

No doubt because there are so few secrets among the scientists and engineers working in this field, much of the material presented at the conference was already known. In addition, the large number of papers submitted (169 distributed among 11 sessions) produced a heavily loaded programme that unfortunately allowed little time for discussion. However, in a developing field it is always worth while to survey progress occasionally and the 'proceedings' of the conference will certainly become a highly useful source of reference. Moreover, valuable personal contacts were possible between experts from many laboratories, which is, in any case, one of the chief reasons for holding any conference. For the Americans and Western Europeans in particular, there was the added interest of being able to hear of the Soviet work at first hand and to visit their major laboratories afterwards.

Development of existing accelerators

From the status reports presented on the principal accelerators already in operation, it could be seen that beam intensity, always an important feature from the experimenter's point of view, had in most cases been improved. For instance, the 6-GeV Bevatron at the Lawrence Radiation Laboratory, Berkeley, U.S.A., had reached 2.3×10^{12} protons per pulse, following the extensive modifications carried out the previous year. The Cambridge Electron Accelerator, also in the U.S.A., had an intensity of 5×10^{10} electrons per pulse, but with a repetition rate of 60 per second this represented 3×10^{12} electrons per second. As previously mentioned in *CERN COURIER*, the achievement by the CERN PS of an intensity of 0.9×10^{12} protons per pulse was announced to the conference shortly after the event. For the first time, it seems that fundamental intensity limitations are being encountered, so that in the two American machines mentioned it is now mainly interactions in the beam itself, or between the beam and the accelerating system, that hinder further increases in

intensity. Formerly of lesser importance practically, these interactions will now require closer study if further gains are to be made.

Since the beam can be used more efficiently outside the accelerator, a complementary approach to higher intensities is given by the development of good extraction systems. Here the most noteworthy results were presented by speakers from CERN, who gave details of the 'fast' system, an invaluable component of the neutrino experiment then in progress, and of the 'slow', resonant extraction system, operated for the first time a fortnight before the conference.

Accelerators recently completed

Information was presented on three new accelerators, all completed this year, two of them just in time for the conference. These are the Princeton-Pennsylvania Accelerator, at the Forrestal Research Centre, Princeton, U.S.A., 'Nimrod', at the Rutherford High Energy Laboratory, Chilton, England, and the 'ZGS', or Zero Gradient Synchrotron, at the Argonne National Laboratory, Chicago, U.S.A. The first two of these are conventional weak-focusing synchrotrons, accelerating protons to 3 GeV and 8 GeV respectively; the third is a unique form of the same general type giving protons of up to 12.5 GeV. All three have been discussed briefly in recent issues of the *CERN COURIER*.

Accelerators under construction

Of the accelerators now under construction the one that attracted most attention, certainly among the visitors, was the 70-GeV proton synchrotron being built at Serpukhov, about 100 km South of Moscow (in other words, some 230 km South of Dubna). The design has evolved to some extent since it was first discussed in 1956, and this accelerator is now essentially a conventional strong-focusing synchrotron, that is, a larger version of the CERN PS or the Brookhaven AGS. As injector it will have a 100-MeV strong-focusing linear accelerator, fed in turn by a 700-keV pre-accelerator equipped with a 'duoplasmatron' ion source of remarkably improved design. This pre-accelerator is already in existence and was reported to give quite well defined beams of up to 400 mA of protons. The site itself, in pleasant wooded surroundings, was visited by a number of the conference participants. Civil engineering work is well under way and two thirds of the tunnel, the

linac zone, and a vast experimental hall 160 m $\times$ 90 m in area have been covered. The accelerator is expected to come into operation in about three years' time.

The other machines under construction are all for accelerating electrons. The largest is the Stanford Linear Accelerator (sometimes known as 'the monster'), in the U.S.A., which will initially give electrons of energy 20 GeV. Another linear accelerator, for 2 GeV is being built at Kharkov, in the U.S.S.R. At Hamburg, Federal Republic of Germany, 'DESY', an electron synchrotron designed for 6 GeV, is now nearing completion, and a very similar machine is well under way at Erevan, in Armenia. Finally, there is the new British machine, 'Nina', for 4 GeV, to be built at Daresbury, Cheshire. At the time of the conference, building of this had not actually begun, but an announcement in November from the National Institute for Research in Nuclear Science stated that construction of the laboratory, had been started. It will be known as 'The Daresbury Nuclear Physics Laboratory'.

Accelerator projects

The demand by the experimental physicists for higher-energy projectiles has resulted in a number of new design studies for larger proton synchrotrons, and although these are all far from complete their presentation formed one of the focal points of the conference.

In the U.S.A., two projects have been proposed. One of these, by a group at the Lawrence Radiation Laboratory, Berkeley, is for a machine giving an energy of 200 GeV. The magnet ring would be about 1.6 km in diameter and the injector a synchrotron of 5 GeV, not much less than the energy of the Bevatron. A group at the Brookhaven National Laboratory is working on the design of an even larger machine, in the range of 600 to 1000 GeV.

Western European work in this field is centred at CERN, where the outline of a 300-GeV synchrotron has been produced. This would be about 2.4 km in diameter, contain some 27 000 tons of steel plate in the magnets and consume about 20 MW of power. The accelerator would be located entirely underground and

the site, including space for the experimental areas and supporting services, would have to be over 20 km² in area.

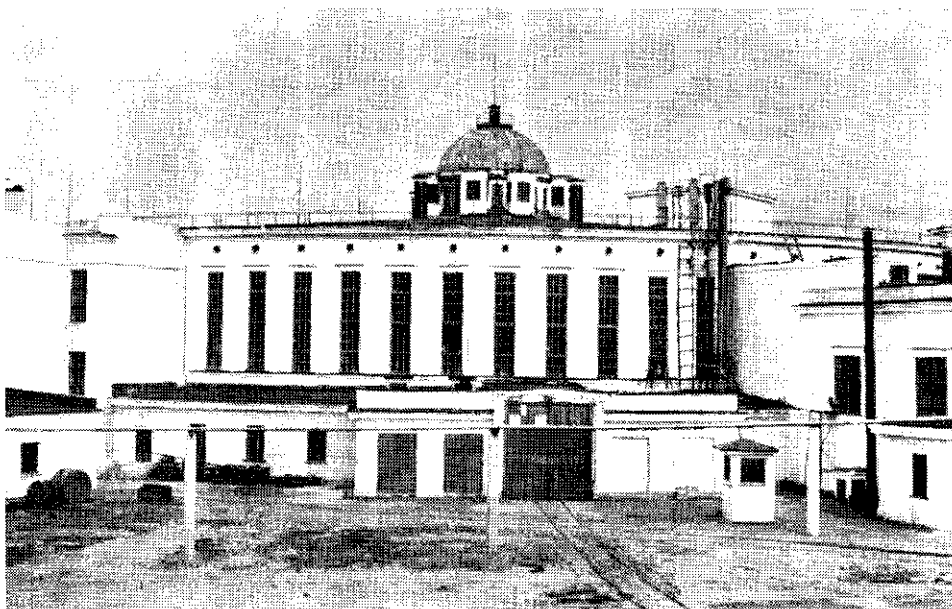
All three of the above machines represent fairly straightforward extrapolations of the present PS and AGS designs. Also in this category is a 500-GeV synchrotron under consideration at the Institute of Theoretical and Experimental Physics in Moscow. A second Russian group, however, is working on plans for a machine operating on so-called 'cybernetic' principles, to give 1000 GeV. The aim is to take better advantage of the alternating-gradient principle by considerably reducing the beam fluctuations that are normally set up by the slightest misalignment of the magnetic field, and thereby to reduce the size of the vacuum chamber and hence that of the magnets required. Not just the radiofrequency supply but also the magnet currents would be continuously adjusted automatically by measurements on the beam itself. The forces that accelerate the particles and also those that keep them on their approximately circular path would thus be continuously related to the beam position, and the otherwise severe effects of slight misalignment of the magnets and other small irregularities in the magnet field would be reduced. Whether the extra complexity in the control equipment would be worth the saving in magnet steel seems rather problematical to many, but the Russians are planning a 1-GeV 'model' to test the system.

In the more conventional energy range, an unconventional design for a 10-GeV electron synchrotron is being worked on at Cornell University, U.S.A. This would have the magnet, complete with its coils, inside the vacuum tank instead of outside. It should still be possible to maintain a sufficiently good vacuum with such an arrangement and it is claimed that the overall cost would be considerably reduced.

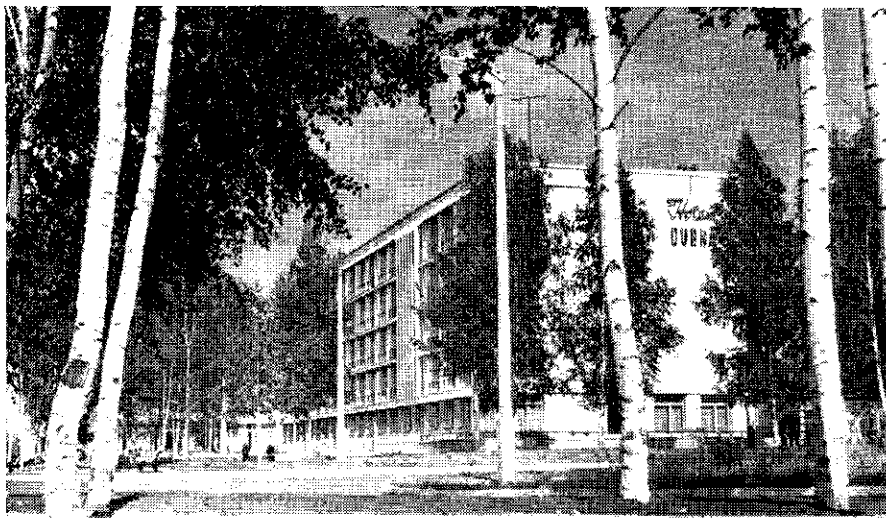
Storage rings and colliding beams

By arranging for two beams of particles to collide more or less head-on, certain reactions can be investigated at energies much higher than would otherwise be practicable. To obtain a useful collision rate however, means have first to be found to create beam intensities

Photo : JINR



The building housing the 10-GeV proton synchrotron (synchrophasotron) of the Joint Institute for Nuclear Research at Dubna, U.S.S.R.



Arriving foreign delegates found the brand-new 'Hotel Dubna', built specially for the conference, as a symbol of hospitality to come. Among evening entertainments were performances by the Moscow Symphony Orchestra and prize winning soloists, the head of the Moscow Puppet theatre, and variety artists. On the Sunday there was a boat trip up the Volga to the Moscow Sea. Visits were arranged to the accelerator laboratories at Dubna itself, and to other laboratories in Erevan, Kharkov, Leningrad, Moscow, Novosibirsk and Serpukhov.

many times higher than are possible with present accelerators, and one way of doing this is to inject successive pulses of particles into two intersecting 'storage rings' in which each beam is accumulated until the required intensity is reached. A number of papers on the CERN design for a pair of rings to be fed by the 28-GeV proton synchrotron were read at the conference.

Several storage rings have already been built for electrons, although the energies involved are much lower and the rings are still being used to study the problems involved in the use of this technique rather than for physics experiments.

At Stanford, U.S.A., in conjunction with Princeton University, a pair of rings has been constructed for 500-MeV electrons. Early operation revealed that a limit of 15-20 mA was being imposed on the intensity of the stored beams by vertical oscillations of the electrons, but a number of studies have revealed the probable causes and it is hoped that the instability can be overcome. Trouble has also been experienced with a pair of rings designed by the Frascati Laboratory, Italy, and being tested with the aid of the linear accelerator at Saclay, France. These rings are meant for storing a beam of electrons and a beam of positrons. An increasing loss of electrons with increasing beam intensity has been traced to mutual interactions between electrons in the beam.

In the U.S.S.R., the Institute of Nuclear Physics at Novosibirsk has a pair of storage rings in which 50-100 mA of electrons can be stored for up to about 1 hour at 100 MeV. The injector is a rather interesting air-cored synchrotron, of 40 MeV, capable of accelerating enough electrons to give a current of this order in a single pulse. Also at Novosibirsk is a pair of electron-positron rings, for 700 MeV, fed by another air-cored synchrotron of 350 MeV, in an advanced state of construction. A pair of rather more conventional rings for 100 MeV, is being built at Kharkov.

An interesting experiment is in progress at the Lebedev Institute in Leningrad, using their 280-MeV electron synchrotron, constructed with the aid of the magnet from the former model of the Dubna 10-GeV accelerator. It has been found possible to keep the beam in the machine after it has been accelerated, during the decelerating half of the cycle, and to

accumulate several successive pulses in this way. The aim is to inject positrons and electrons simultaneously and to build up the two beams, circulating in opposite directions, before allowing them to collide.

New ideas

Apart from the innovations inherent in some of the designs already mentioned, such as the 'cybernetic' accelerator and the placing of guiding magnets inside the vacuum chamber, various new ideas were presented to the conference as possible bases for future developments.

The most interesting of these was the 'non-linear' accelerator proposed by the Soviet physicist Orlov. This would be a circular machine with a fixed magnetic field (not varying with time), the strength of which increases and then decreases with distance from the axis of the vacuum tube through which the particles are accelerated. In this particular form of guiding field the particles execute complicated ('non-linear') betatron oscillations inside the tube, of large amplitude, which take them alternately into areas of positive and negative gradient of the magnetic field. A kind of alternating-gradient focusing in the vertical direction is thus induced automatically. Such a machine is said to be capable of accelerating protons to any energy between 1 GeV and 1000 GeV, with enormous beam intensities. The vacuum tank would need to be about 2 metres wide, however, which would entail very large magnets, and the tolerances allowed in construction are extremely small. Also, long straight sections would not be possible, a great disadvantage from the operational point of view. It remains to be seen whether such difficulties will prove to outweigh the undoubted advantages shown by this design.

Other devices reported indicate a growing link between the fields of high-energy accelerators and the plasma devices normally associated with experiments on nuclear fusion. Finally, it is worth noting that the advent of high intensity monochromatic and non-divergent light beams from so-called 'lasers' has led to the suggestion that the protons in such a beam might be considerably increased in energy as a result of Compton scattering during collision with a very high-energy electron beam, to produce a beam of high-energy gamma rays of well-defined energy and polarized with respect to a particular direction ●