

Equipment from CERN installed in the experimental hall at the Serpukhov 76 GeV accelerator. On the left, the large horizontal cylinder of a DISC Cherenkov counter can be distinguished; in the centre are racks of associated electronics. The secondary particle beam comes in from the right.

(Photo Serpukhov)

Particle yields at Serpukhov

Results from the first collaborative experiment to be carried out at the Serpukhov 76 GeV proton synchrotron by a joint team of CERN and Soviet scientists were reported in *Physics Letters*, 31 March*. The experiment aimed to measure particle 'yields' (the numbers of secondary particles of different types yielded when the accelerated beam bombards a target) at the higher energies available from the Serpukhov machine.

These measurements are important for several reasons. They provide more data on particle production processes at high energy, extending the extensive measurements carried out up to the energies (about 30 GeV) of the Brookhaven and CERN machines; they are essential for the planning of the future experimental programme at Serpukhov to enable the intensities of secondary particle beams at the machine to be predicted with good accuracy; and they also serve as a useful

intermediate step, between 30 GeV and several hundred GeV, to estimate the particle yields which will be available at the Batavia 200 GeV and the European 300 GeV accelerators. At the same time, the measurements served to test detection techniques for identifying particles of higher energy.

The experiment was carried out in the last few months of 1968. For most of the time, the synchrotron was operated at 70 GeV with an average beam intensity of 3×10^{11} protons per pulse and a pulse rate of 1 per 7 s. Cylindrical aluminium targets (21 mm long and 2 mm diameter) were used in three positions inside the magnet ring so that the beam-line, where the detectors were installed, could take the negative secondary particles coming off in the forward direction or at very small angles (particles emitted at a tangent to the ring) at three momenta 40, 50 and 60 GeV/c depending on the target position. Some data was also collected with the synchrotron running at lower energy (at 20 GeV and then at 43 GeV) to tie up with the information from existing machines

and to provide Serpukhov with knowledge of beam intensities for experiments below full energy.

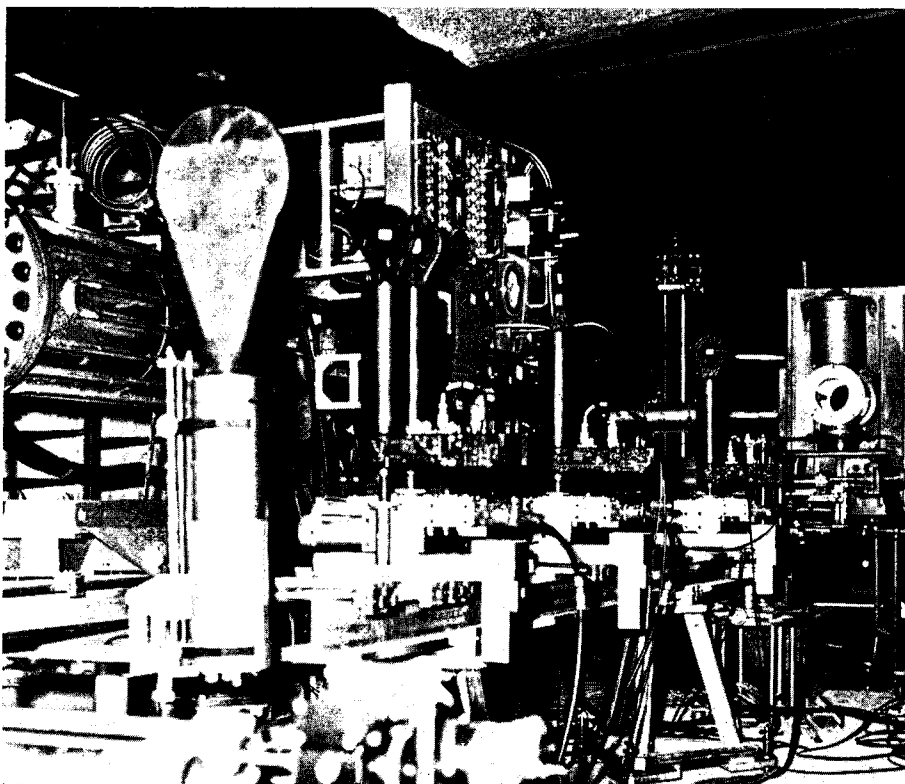
The composition of the beam was measured by various combinations of Cherenkov counters of different design (as many as four independent detection techniques could be used which provided a useful cross-check of the measurements). There were two differential Cherenkov counters ('DISCs'), which record particles in a narrow velocity range (detecting the Cherenkov light emitted within a small angular spread), and three threshold Cherenkov counters which record all charged particles with velocities above a selected value (the Serpukhov team have developed excellent threshold counters). It was demonstrated in the course of the experiment that Cherenkov counter techniques provide a clear identification of particles up to the top momentum investigated (60 GeV/c) and they can confidently be incorporated in experiments planned for the 200 and 300 GeV machines.

The yields of negative pions, negative kaons and antiprotons were measured, and the main results can be expressed briefly as follows:

The yield of pions was as expected, but the kaons and antiprotons were less abundant than expected. (Approximate figures for a 70 GeV incident beam of 10^{12} protons and secondary particles at 50 GeV are — 10^5 negative pions, just over 10^3 negative kaons and just under 10^2 antiprotons.

The yields decrease as the secondary particle beam energy increases, the decrease being at about the expected rate for pions but faster than expected for kaons and antiprotons. This means that the ratio of kaons and antiprotons to pions falls off rapidly with increasing energy which has important implications when it is necessary to sift out one type of particle from the others.

By 'expected' is meant the prediction of a particular model (called the statistical model) of the process of secondary particle production. This is one of several models, but the one which has been most thoroughly worked out so that it gives figures for Serpukhov energies. It con-



Two beam-lines coming from the Serpukhov accelerator (the synchrotron itself curves round top left). The beam-lines diverge from a bending magnet, the one on the left leading to the joint CERN/Serpukhov yields experiment and the one on the right to the Serpukhov quark experiment. The first collimators on each line can be seen at the bottom of the photograph.

(Photo Serpukhov)

siders all the possible interactions (many hundreds of them) which can take place when a high energy proton collides with a nucleon in the target and the probability of each of the interactions. A statistical calculation then gives figures for what can be expected to come out of the target on average. The results of the experiment imply that further refinement of the model is needed.

The joint team is now doing total cross-section measurements — taking a second-

ary beam and firing it at a hydrogen target to find the probability of a beam particle interacting with a proton (a hydrogen nucleus).

The collaboration of scientists from Serpukhov and CERN has been working smoothly and rapidly and has provided an excellent start to the new venture of co-operation between the two Laboratories.

* 'Negative particle production at the 70 GeV IHEP accelerator'

Yu.B. Bushnin, S.P. Denisov, S.V. Donskov, A.F. Dunaitsev, Yu.P. Gorin, V.A. Kachanov, Yu.S. Khodirev, V.I. Kotov, V.M. Kutyin, A.I. Petrukhin, Yu.D. Prokoshkin, E.A. Razuvaev, R.S. Shuvaev and D.A. Stoyanova (Institute for High Energy Physics, Serpukhov).
J.V. Allaby, F. Binon, A.N. Diddens, P. Duteil, G. Giacomelli, R. Meunier, J.-P. Peigneux, K. Schlupmann, M. Spighel, C.A. Stahlbrandt, J.-P. Stroot and A.M. Wetherell (CERN).

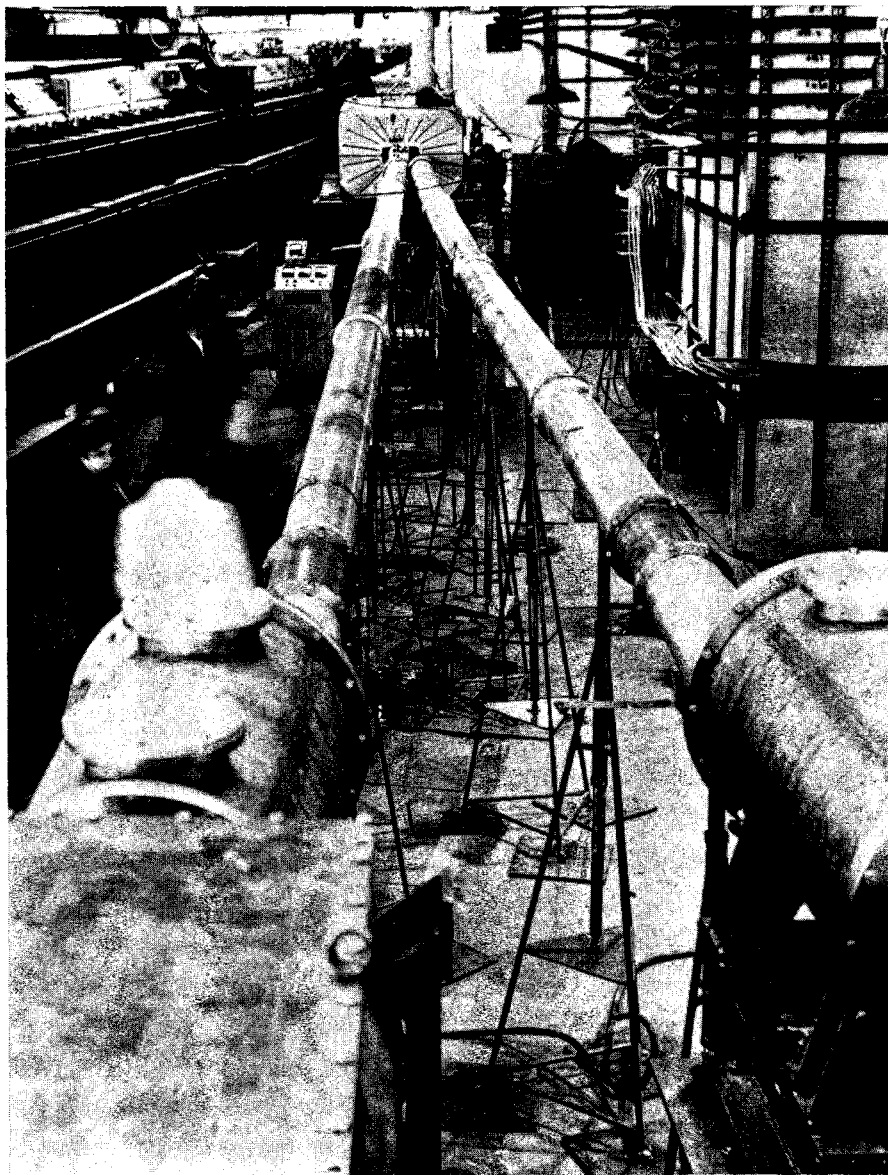
Towards the 300 GeV Laboratory

Dr. J.B. Adams arrived at CERN at the beginning of April to take over the Direction of the 300 GeV Laboratory programme.

The immediate task is to finalize the documentation on which the Council will base its decisions. The documents include, in particular, the exact definition of the construction programme for the new laboratory and further information on the proposed sites.

Several of the detailed design aspects of the 300 GeV accelerator have been studied during the past year in Working Groups set up by the 300 GeV Steering Committee, chaired by Professor E. Amaldi. The membership of these Groups includes CERN staff and is mainly composed of staff belonging to the various national accelerator groups in Europe. The Convenors of the Working Groups met at CERN towards the end of April to present the results of their studies and to consider further work for the remainder of this year. One Working Group has been reviewing the research on the Electron Ring Accelerator technique which is under investigation in various laboratories in the Soviet Union, USA and in Europe.

Assuming that the Council decisions on the new Laboratory, its programme and its location, are taken before the end of the year, the team to be responsible for the construction phase will be built up first at CERN, Meyrin. They will transfer to the new site probably about a year after the Council decision to launch the programme. The final design of the Laboratory and the accelerator, which depends to some extent on the characteristics of the chosen site, will be determined during that year, using the facilities which exist at the CERN Meyrin Laboratory.



A group of Members of Parliament from Austria visited CERN on 21 March to tour the site and discuss the future of high energy physics in Europe. They are here having a demonstration of the new 'display' system connected to a CDC 3100 computer.

Quarks still elusive

An experiment at the CERN proton synchrotron has searched, unsuccessfully, for the elusive quarks. The experiment pushed detection techniques as hard as possible so as to be able to see these particles even if they are produced only very rarely (down to a production cross-section of about 10^{-39} cm², a hundred times lower than previously investigated) and it can be concluded that the likelihood of observing quarks at existing accelerator energies is now very remote.

The synchrotron was operated at an energy of 27 GeV and the proton beam was directed onto a target positioned in the magnet ring (straight-section 1). A special beam-line (d28) was built in the south experimental hall to catch quarks, making use of their distinctive property of carrying a fraction of the normal electron charge.

Quarks are the particles which have been postulated to explain the orderly grouping of particles. The orderly grouping could be the result of the observed particles being different combinations of more fundamental objects called quarks. This demands however that an individual quark carries a charge $1/3$ or $2/3$ of the charge on the electron. The fractional charges provide an excellent handle to get hold of the quarks if they exist.

The beam-line was tuned to a 'super-momentum' of over 30 GeV/c. This meant that particles carrying normal charge, which, because of conservation laws, cannot come from the target with a momentum higher than the moment of the incident proton (i.e. they would all be below 30 GeV/c), would not be able to find their way through the beam-line magnets to the detectors. On the other hand, a particle of about 10 GeV/c carrying $1/3$ charge would be guided to the detectors.

Advantage was taken of the fact that particles carrying $1/3$ charge will produce only $1/9$ of the ionization of a normal particle. Scintillation counters were set to record only particles giving such low ionization and, in addition, a streamer chamber was installed (the first use of a streamer chamber — see CERN COURIER vol. 7, page 219 — at the CERN proton



CERN/PI 292.3.69

synchrotron) which gives tracks of a density depending upon the ionization.

Particles with charge of $\pm 1/3$ and $\pm 2/3$ were looked for but none was found.

A quark search has also been carried out by Soviet scientists at the higher energies available from the Serpukhov 76 GeV machine, but again without success.

Extension to central computers

At its meeting on 11 March, the Finance Committee approved the extension of the central computing system by the conversion of the CDC 6400 computer into a 6500, together with the purchase of more peripheral equipment. This extension will serve as an interim solution of CERN's computing needs for the next few years.

The use of computers is by now an integral part of practically all the scientific and technical work of the Laboratory. In reaching this situation, the demand for

computing capacity has for ten years been doubling every year (see CERN COURIER vol. 7, page 166). The existing central computing system, consisting of a CDC 6600 and a CDC 6400 computer, can cope with the present demand — it handles about 1000 jobs per day catering for about 700 computer users — but to prepare for the years to come further extensions are necessary.

In 1967, a thorough study of the future needs began. It revealed that, although the growth rate in demand is expected to fall to a doubling every two years, a new, much larger, system will be required to give an increase in computing capacity by a factor of four in 1972 ideally with the possibility of extension to a factor of ten in later years.

The two major uses of the central computing system are for the analysis of bubble chamber experiments (about a third of the total load) and of electronics experiments (also about a third). The growing appetite for computers in both these fields is a combination of increased facilities for experiments as the various elements of

Computers at CERN

A list of the computers in use on the site in April 1969 (including those brought by visiting teams for use in experiments)

Type	Quantity
CDC 6600	1
CDC 6400	1
CDC 3100	3
CDC 1700	1
IBM/360 - 44	1
IBM/360 - 30	1
IBM 1800	5
IBM 1130	2
IBM 1401	1
Honeywell DDP 516	2
SDS 920	1
PDP 9	4
PDP 8	3
Varian 620 I	1
Hewlett Packard P 2115	2

the improvements programme are completed, the trend towards 'high statistics' experiments collecting more data to push the accuracy of the results much further, and the technological developments in detectors which make it possible to collect data much more quickly. Among the main contributors to the future demand will be the 3.7 m hydrogen bubble chamber (for completion in 1971), the Omega project (for completion in 1971), the 2 m hydrogen bubble chamber, now capable of taking pictures at twice its former rate, and wire spark chambers coming into increasing use capable of very high data-taking rates.

When computer firms in Europe and USA were contacted in search of new computers considerably larger than the existing CDC 6600, it emerged that none was likely to be available as a standard, proven machine before 1972. To cover the CERN needs until then, the firms were invited to propose an 'interim system'.

The most economical and convenient offer was that of CDC to enlarge the present 6400 computer by the addition of 65 536 words of central memory and of a

second central processor, which comes close to doubling the capacity of the machine. This upgrades the 6400 to a 6500 at a cost of 4.52 million Swiss francs. Various items of peripheral equipment are needed to keep pace with these extensions, the main items being an additional disk and drum, and more printing capacity (totalling about 2 million Swiss francs).

This solution has also the advantages that no new buildings are needed to accommodate the computer extension and that, from the point of view of the users preparing programmes for the machines, there is no change.

Power supply overhaul

An overhaul of the new magnet power supply of the proton synchrotron (see CERN COURIER vol. 7, page 87), manufactured by Siemens was carried out in March. The accelerator continued in operation at lower repetition rate during the overhaul using the old power supply.

The new supply had been in operation since the 1968 shutdown. Operation has been very satisfactory and has increased the repetition rates at different energies to the intended values. Some problems have arisen with the mercury arc rectifiers. The system to switch off the current has failed many times and at the peak voltage of 10 800 V (which will not actually be used for machine operation until 1972 when the r.f. system in the synchrotron ring has been modified to increase the rate of acceleration) arc-back became troublesome. These problems are now being investigated by the manufacturer.

It was scheduled in advance to take a good look at the power supply after about six months of operation to see how well it was standing up to its arduous pulsed regime. The investigation revealed that practically everything is in good shape. There was no sign of metal fatigue or of uneven wearing. Bearings were repolished and the damping system of the large, floating, concrete platform on which the power supply is mounted was modified to increase the damping of the induced movements.

The next overhaul is scheduled to be carried out in 1 1/2 to 2 years time.

Magnet for ISR interaction region

A decision has been taken on the large, general-purpose, magnet system to be installed at one of the interaction regions (I4) of the intersecting storage rings. The system is 'general-purpose' because it is intended to serve for a wide variety of experiments.

To achieve all the desirable properties of such a system is very difficult. Ideally, the magnet should make it possible to measure accurately the momenta of all the charged particles coming from the interactions, should permit reasonably straightforward event reconstruction (tracing particles back to the positions where they were produced), should have space and access for efficient configurations of detectors, and should not disturb the stored beams circulating in the rings. (The beam paths will be bent in the magnet system but the beams should emerge from the interaction region as if there were no magnet there, all deviations being compensated.) In addition to the physics criteria, there are practical considerations such as physical size to be accommodated in the interaction region, cost for construction and operation, and time-scale for construction (since the magnet should be available early in the experimental programme).

Several systems were proposed which met these different requirements to different degrees but no system was ideal in all respects. After long discussions, it has been decided to build a simplified version of one of the proposals known as the split-field magnet.

From the centre of the interaction region, the split-field magnet system will have two arms, one on either side, each 5 m long, 2 m wide (increasing to 3 m towards the centre) with a gap height of about 1 m. The field goes in opposite directions in the two arms. The total weight of magnet will be in the region of 1000 tons. Compensating magnets are needed downstream on each beam to restore the circulating beams to their correct trajectories.

Design and construction of the system has been assigned to the Magnet Group

A model of a split-field magnet system. A simplified version of such a system has been chosen for installation in one of the interaction regions of the ISR. The split-field magnet is symmetric about its centre, the magnetic field being in opposite directions in each half. The actual ISR magnets are positioned to the right and left.

An assembly of 40 foils for a secondary emission chamber (SEC). The foils are separated by glass insulators and the connections on alternate foils which are taken to positive voltage can be seen on the left. The top twenty foils have a central aperture and serve to help beam control by giving signals only when the beam is not well collimated. The lower foils cover the whole aperture and give signals proportional to beam intensity.

The lower photograph illustrates typical signals of beam intensity and cross-sectional distribution from a SEC made of eight foil strips — each strip giving one of the signals shown. The burst of protons lasted 100 ms and the striated appearance of the signals shows that the protons received by each strip were not constant in number during the full time of the burst. The SEC can pick out the microscopic structure of the burst.

of the ISR Department and the aim is to have the magnet in operation in the second half of 1972.

Secondary emission chambers (SEC)

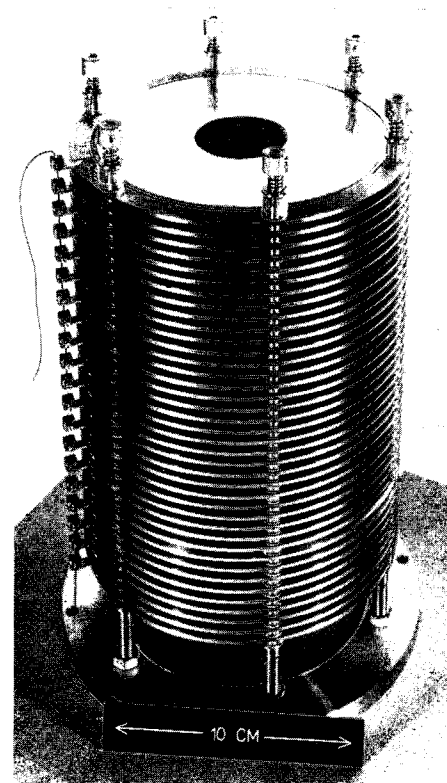
Yet another method (in use at CERN since 1965) of carrying out intensity and position measurements on a high energy proton beam is the use of secondary emission chambers; earlier this year information has appeared in CERN COURIER on the ionization beam scanner (page 9) and on beam current transformers (page 67). All these methods, and others, are being developed because each has its virtues and limitations. In the case of the secondary emission chamber, it is the only device which can give intensity and distribution measurements for 'long-spill' beams when the burst of charged particles may last for a few hundred ms. It is therefore used particularly in the monitoring of slow ejected proton beams.

The SEC method is based on the phenomenon of emission of electrons from the surface of a foil when a high energy charged particle is incident on it. The high energy particle can give sufficient energy to the electrons of the atoms near the surface for them to escape from the foil. The phenomenon is independent of the foil thickness but in practice very thin foils (a few microns of aluminium) are used so that the SEC is almost invisible to the high energy beam which passes through it, causing negligible deterioration, due to scattering, in beam quality. To give an idea of the scale of the phenomenon, 100 protons with an energy of say 20 GeV will

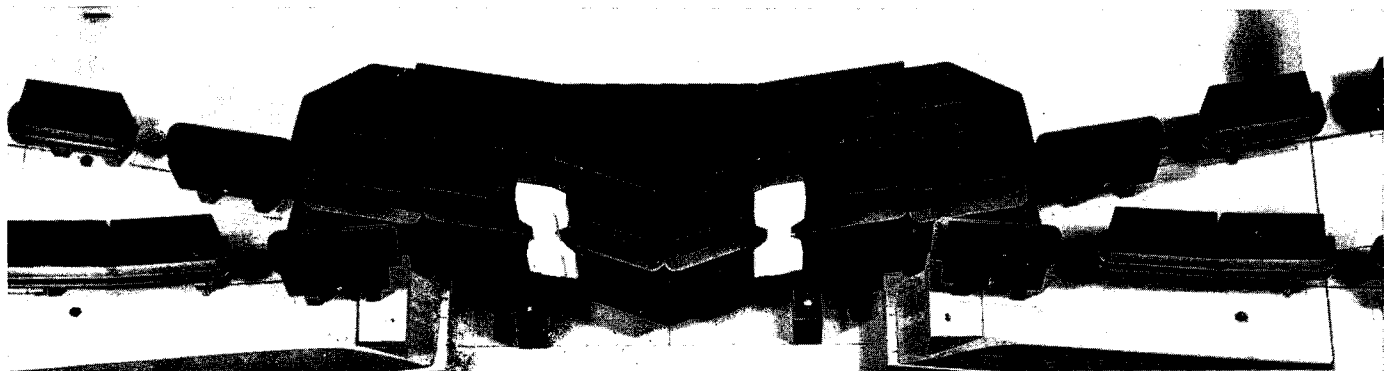
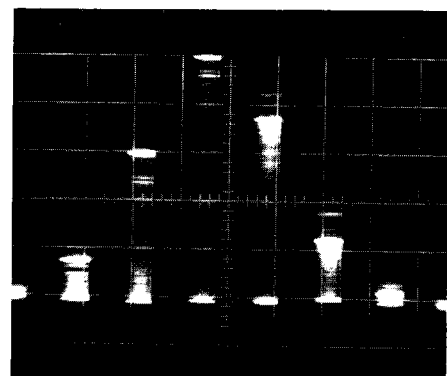
cause about five electrons to be emitted from a foil (2.5 from each surface on average).

A secondary emission chamber is built up as follows. A series of foils are assembled parallel to one another separated by a distance of a few mm. Alternate foils are connected to a voltage line (which gives them a positive potential of 50 V or above). The other alternate foils are connected to a charge measuring device. This assembly is inserted into the path of a particle beam with the foils perpendicular to the beam direction. Electrons emitted from the foil surfaces are drawn to the positively biased foils and thus a flow of charge takes place. The recorded signal is proportional to the intensity of the incident beam to very good accuracy; effects such as interactions with nuclei in the foils being responsible for only a few percent of the signal. The foils have to be enclosed in a good clean vacuum (better than 10^{-6} torr) since the emitted electrons are of low energy (around 10 eV) and the SEC could not operate at high pressure.

Various changes can be rung on this simple system. The foils can be divided each into several separate strips and the signals recorded from the separate strips will give the beam position and the way in which the beam intensity varies over the cross-section of the beam. (Such a device has been given the name 'toposcope' since it reveals the topology of the beam.) Another application is in the alignment of beams when a SEC is built of foils with a central circular aperture. If the beam is correctly aligned it passes through the central aperture and there is



CERN/PI 63.1.67



CERN/PI 234.10.68

to reading from the SEC; if the beam hits the foils, the beam-line components need adjustment. Used in these ways, SECs could be used in automatic control systems for beam-lines sending signals to computers which then control power supply settings.

There are now five SECs constructed for use at the proton synchrotron, three of them are installed in the slow ejected beam e3 in the East Hall. They cover all the functions mentioned above and have proved very satisfactory and reliable instruments.

The problem of the calibration of such instruments is a complex one which will not be covered here. Anyone who wishes to dig deeper on this and on the whole subject of beam monitoring is referred to the Proceedings of the Symposium on Beam Intensity Measurement held at the Daresbury Laboratory in April 1968.

Infra-red link

The first stage of acceleration in the synchrotron is the 'pre-injector' which accelerates protons to an energy of 500 keV before they are fed into the first tank of the linear accelerator. It is the only stage of the machine where acceleration takes place under the influence of a d.c. voltage — throughout the rest of the accelerator radio-frequency fields are used. Since many components in the pre-injector are taken to a potential of half a million volts it poses a few problems not met with elsewhere in the machine.

The proton source end of the pre-injector is at a potential of +500 kV and this involves having all the source supplies and controls installed on a platform mounted on insulating legs 2 m high. It is then necessary to send signals to this insulated equipment and to receive information back. A cable, carrying information electrically, cannot be used because of the voltage difference and mechanical communication via long insulating rods is not appropriate to the type of information transmission that is required.

Up to now two systems have been in use:

- 1) A cathode ray tube sends a light signal to the platform where a photomultiplier

converts it into an electronic signal. This system has a fast response time and is used to trigger equipment where precise timing of the source pulses is required. It involves, however, complex and bulky units (particularly a 1 kV power supply for the photo-multiplier on the platform).

- 2) A system involving light signals sent via a light-guide. It involves the use of LAS light-sensitive control rectifiers which switch on motors to set potentiometers and thus set the parameters of the different source components. A television camera observes the equipment which is being controlled.

As part of the PS improvements programme more effort is going into achieving the best possible beam from the proton source. This seems to have a marked influence on the ultimate accelerated beam intensity — see the note on page 105 — and it is important to be able to study the influence on beam quality of variations in the many parameters controlling the source operation. To transmit this information a new system is being installed which uses infra-red.

This has the advantages of rapid response rate (data can be transmitted at a frequency of 500 kHz), of high efficiency (by precise superposition of emission and receiving spectra), and of not being sensitive to surrounding light. The units are also inexpensive, small and light (fully-transistorized). The emitter uses a gallium-arsenide semi-conductor which produces a very clean line in the infra-red ($\lambda=0.9\mu$), and the receiver uses a 'fotofet' field effect, light-sensitive transistor.

A single infra-red link operated in multi-

The units of the infra-red link for sending trigger signals to the synchrotron ion source platform. On the left is the emitter (gallium-arsenide semi-conductor) and, on the right is the receiver ('fotofet' — field effect transistor). The associated electronics are in the two small rectangular boxes.

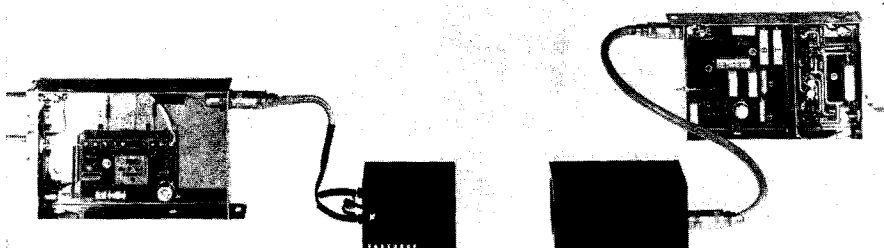
plex fashion can be used to transmit information on the operating parameters of the source. (The source is a duoplasmatron type and important parameters are — source current and voltage, voltage on the intermediate electrode, current settings in two source magnets, filament current, pulse length, and hydrogen pressure.)

In May, two infra-red links will be brought into operation — one to trigger the source and the other to pass information initially on a single source parameter. Later the final assembly will incorporate the multiplex system which is still being developed. In the meantime, the light-guide system will remain in use but the cathode ray tube and photomultiplier will be removed.

One further point on the infra-red link. Information is transmitted in digital form and this is ideal for coupling directly into the IBM 1800 control computer of the accelerator. At some future time the studies of source behaviour and its monitoring and control are likely to take place by the intermediary of the control computer.

Gargamelle magnet measurements

The pulsed beam transport group in the Nuclear Physics Apparatus Division is carrying out detailed measurements of the magnetic field in the large magnet of the new heavy liquid bubble chamber, Gargamelle. These measurements are checking that the field configuration agrees with the design calculations and are proving the equipment which will carry out a field



The measuring equipment used in the Gargamelle magnet. This view taken inside the magnet complements the photograph on the cover of this issue which shows the exterior view of the equipment. The probe can be positioned at different points along the arm and can move around the magnetic field describing co-axial cylinders.

The new extraction grid fitted to the ion source of the proton synchrotron. Since it has been fitted on the machine a beam of better quality has been achieved. It was machined in the CERN workshops from tantalum by the electro-erosion technique.

plot inside the chamber body when it is installed in the magnet later this year.

Measurements are taken at positions 100 mm apart (the actual positions being read-off in practice in cylindrical co-ordinates) giving a total of 10 000 readings in the magnet aperture (10 m^2). The probe can be positioned to an accuracy of 0.5 mm and the value of the magnetic field (obtained using the Hall effect) is measured to an accuracy of one part in a thousand.

All the readings are recorded on punched tape and are later transferred to magnetic tape which is fed to an IBM 1401 computer to give the field plot.

PS intensity up

On 17 April, the 28 GeV proton synchrotron produced an average intensity of 1.54×10^{12} protons per pulse over a hundred consecutive pulses reaching a peak intensity of 1.59×10^{12} . This is the highest intensity ever achieved at the PS and it has followed a fairly steady improvement over the years of operation of the machine.

When the PS was designed, estimating intensity was a hazardous exercise since the accelerator incorporated the newly evolved strong focusing principle and a few unknowns had to be confronted. A figure of 10^{10} protons per pulse was predicted but this was exceeded early in the machine's life. Maximum intensity figures over the years have been 3.8×10^{11} in 1961, 8.9×10^{11} in 1963, 1.09×10^{12} in 1965, 1.15×10^{12} in 1967 and 1.31×10^{12} in 1968.

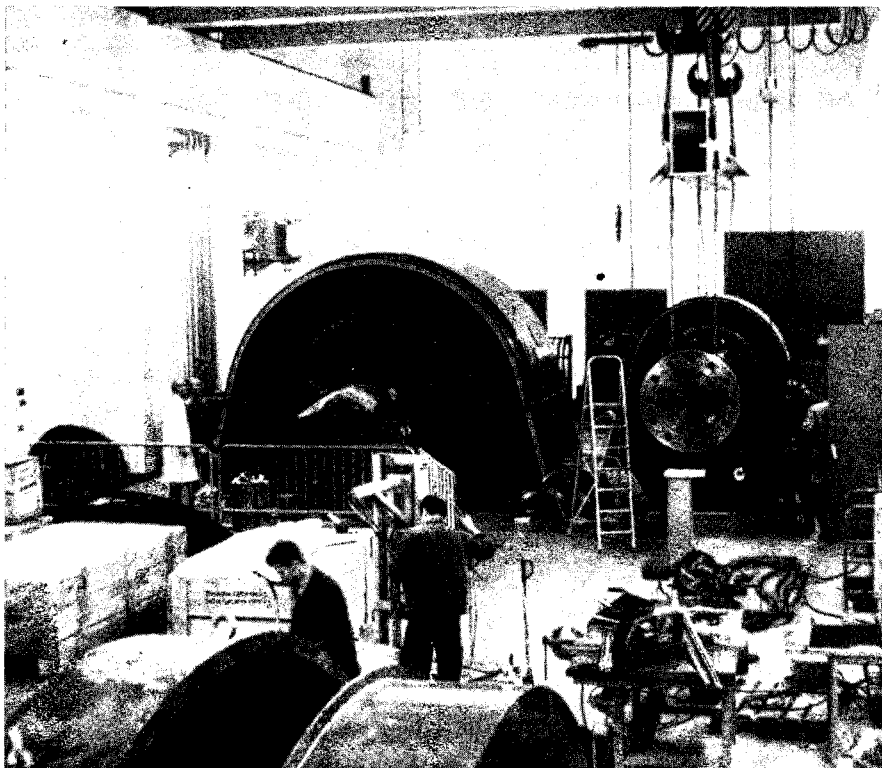
The steady improvement has been a consequence of many inter-related modifi-

cations to the accelerator (such as better tuning of the radio-frequency accelerating cavities, better correction of the magnet field configuration, ...). But the improvement seems to have been particularly related to the quality of the beam fed into the synchrotron ring. The latest advance has followed modifications to the proton source itself.

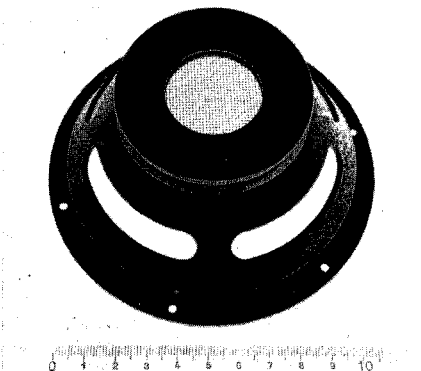
One of these modifications has involved the replacement of the grid on the extraction electrode which carries a negative voltage of 65 kV to pull the protons from

the source. The old version had separate planes of tantalum wires at right angles. Although these planes lay side by side, the slight difference in distance to the plasma seemed to produce asymmetry in the beam. Also if a wire fused, the machine had to be stopped to put it right. The new grid (see photo) is machined by electro-erosion from a tantalum plate 0.013 mm thick (made in the West Workshop with equipment on loan from 'Ateliers des Charmilles', Geneva). It has given a more symmetric beam and continues to work if a filament is fused.

A second improvement on the source has been the use of high purity hydrogen. Bottles of hydrogen from 'Air Liquide' are being used which are filled by a special process (dry membrane) to give 99.998 % pure hydrogen. Linac beam instability encountered in February and March seemed to be related to hydrogen purity.



CERN/PI 374.3.69



The new magnet power supply being taken apart after six months of operation for an overhaul (see the note on page 102).