

CERN News

Linac current over 100mA

On 3 May, a 100 mA proton beam was accelerated to 50 MeV in the proton synchrotron injector. This achievement followed the installation of a duoplasmatron ion source and exceeded the highest beam current previously obtained from the linac.

To begin at the beginning. The protons to be accelerated in the synchrotron are obtained from hydrogen gas in an ion source. The proton sits alone at the centre of the hydrogen atom and to obtain a proton beam it is necessary to strip off the orbiting electron, creating a 'plasma' of free electrons and protons, and to apply appropriate voltages to draw off the protons. But this simple picture hides a multitude of complications and the ability to produce a good ion source involves a dexterity which could appropriately be named ion sorcery. Nevertheless, a good source is a key feature in the ultimate performance of the whole machine and a great deal of the success of the CERN PS could be attributed to the excellent quality of this first unit.

Up to now the sources have been of the r.f. type, where pulses of radio-frequency power set up fields in the source which tear the electrons from the hydrogen atoms. (Work on these

sources has been led by U. Tallgren.) Beam currents of 250 mA have been obtained from the r.f. sources giving, reliably, currents of around 70 mA accelerated in the linac. This was already a much better performance than is obtained on comparable linacs anywhere else in the world.

During the present PS shutdown the r.f. source has been replaced by a duoplasmatron type. With this source, the plasma is created by an arc discharge and concentrated by a special arrangement of electrodes. High proton currents can then be drawn off from the plasma. At the Dubna Conference in 1963, the Electrophysical Laboratory of Leningrad described their work on a duoplasmatron source incorporating a new feature, whereby the plasma is allowed to expand giving a larger plasma surface from which to extract the proton beam. This leads to a reduction of the space-charge effect inherent in an intense beam*. The effect can be further reduced by using a short accelerating gap immediately after the source.

Following the Conference, research on this type of source and accelerating gap was started at CERN. In recognition of its Soviet origins, the source was called the 'Vodkatron'**. (Work on the source was led by B. Vosicki and on the accelerating gap by J. Huguenin.)

After installation of the duoplasmatron source on the PS, proton beams of up to 125 mA have been accelerated to 50 MeV. A current of 900 mA is drawn from the source; the useful

pulse length is about 10 μ s; in the short accelerating gap, 540 kV is applied across 12.6 cm between titanium electrodes. The 540 keV beam emerging from the new pre-injector has a very high density in phase space*, approximately an order of magnitude greater than with the r.f. source system. One would, of course, like this to result in a corresponding increase in density at 50 MeV, and eventually in a significant increase in PS intensity, the ultimate aim of pre-injector development.

However, with the new beam, severe beam loading*** occurs in the linac tanks (the gross effects of which will be dealt with by the compensation system due for completion in a few months' time), there is also an aggravation of space charge effects, both in the linac and in the PS. It is unlikely that there will be a dramatic increase in the PS intensity, but it should be possible to study the space charge limitations in the synchrotron more easily.

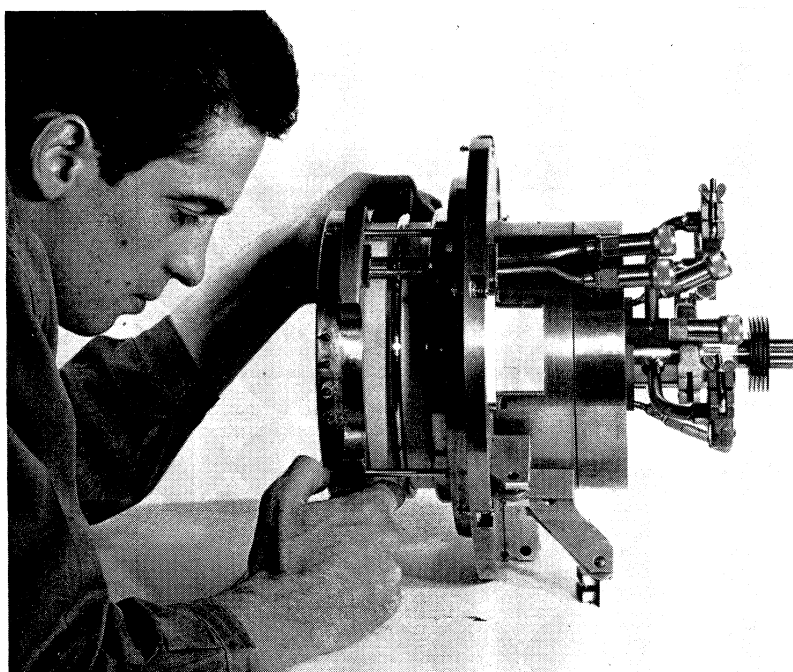
* CERN COURIER, vol. 6, no. 4 (April 1966) p. 63.

** It was found later that the plasma-expansion idea was in fact pre-dated by the Lamb and Lofgren source of 1956.

*** CERN COURIER, vol. 6, no. 2 (February 1966) p. 29.

Complex nuclei

On 18 and 19 April, an 'Informal seminar on the interaction of high energy protons with complex nuclei' was held at CERN. The seminar was arranged by the CERN Nuclear Chemistry Group. About 50 visitors



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A duoplasmatron source being assembled. On the right can be seen the connections to the electrodes and to the filament, and the hydrogen feed. The proton beam is extracted at the opposite end of the source.

from outside Laboratories, in addition to a considerable number from various CERN groups, participated.

The reactions discussed included fission, spallation and emission of fragments. The research is directed towards understanding these three processes which can be loosely defined as follows: fission — where a complex nucleus breaks up into two (or maybe more, see below) heavy fragments of approximately equal mass; spallation — where a number of light particles break off from the nucleus leaving one heavy fragment; emission of fragments — where one medium weight fragment breaks off from the nucleus. CERN has been active in this field of research ever since the Theoretical Study Division, which was then located at Copenhagen, sponsored some high energy fission studies using the Uppsala synchro-cyclotron. The Nuclear Chemistry Group at CERN, which has to a large extent been recruited from the Uppsala workers, continued and extended these studies using both the SC and the PS (see CERN COURIER, vol. 3, no. 3 (March 1963) p. 31). The CERN Emulsion Group has also participated in similar studies and at present other experimental techniques are proposed for use at CERN by outside Laboratories.

A considerable amount of experimental data has been gathered on these complex reactions but so far they have not been explained very well theoretically. However, systematics have been worked out and have

become an important tool in various applications. For example, astrophysicists use these results in their work on cosmological phenomena and they are also used when calculating the shielding requirements for high energy accelerators. Quite recently a possible use of the spallation process as an intense neutron generator has been proposed in Canada. This project, which they have called ING for intense neutron generator, would involve a new type of accelerator (a separated orbit cyclotron, or SOC, first proposed by F. M. Russell of the Rutherford Laboratory) with an energy of 1 GeV and a proton beam of 65 mA.

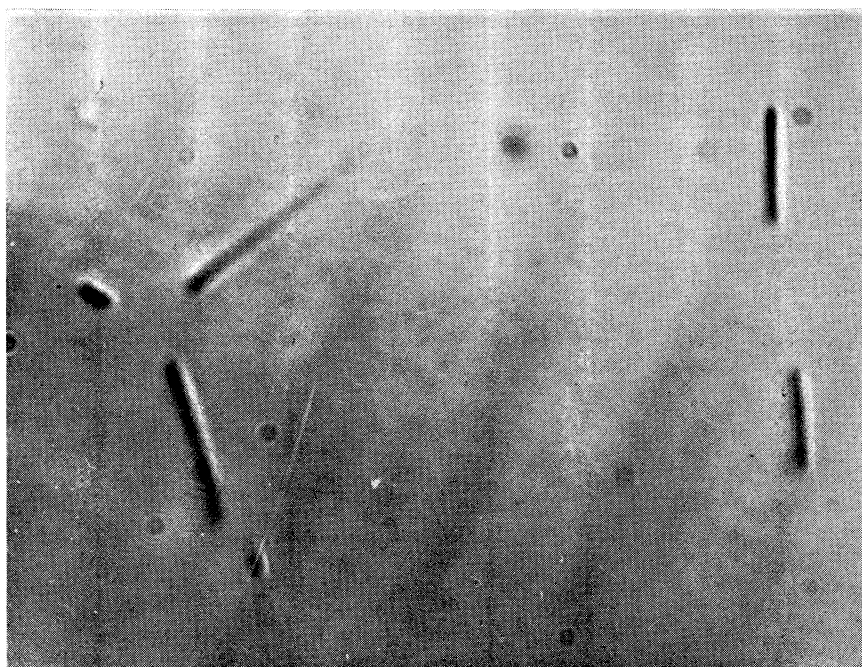
Among the many interesting contributions at the seminar, some concerning particularly promising new experimental developments might be mentioned. B. Hahn from the University of Fribourg/CERN reported on preliminary results from experiments using a freon bubble chamber to identify light fragments emitted by various heavy nuclides bombarded by 21 GeV protons, and to determine their energies and angular distributions.

R. Klapisch described some experiments at Orsay using a mass separator on-line to study the formation cross-sections for isotopes of lithium produced in carbon, and of rubidium and cesium produced in uranium by 150 MeV protons.

Over the past two years the use of a new type of detector, such as mica sandwiches, for the observation of heavy particles has received consider-

able attention. The method involves a rather similar process to the nuclear emulsion technique. When mica laminates are exposed to irradiation by heavy particles, tracks of damaged material are left in the wake of the particles as they pass through the mica and they can be made visible by an etching process. Hydrofluoric acid preferentially attacks the damaged parts of the mica lattice leaving fine hollow tubes in the material so that they become visible in an optical microscope. One great advantage of this method is that the mica is only sensitive to heavy particles (atomic mass number of about 30 and above) and therefore there is much less confusing background due to the particle beam from the accelerator. (For further information on this technique, see 'Science', vol. 149, no. 3682, 23 July 1965, p. 383).

Mrs. J. Piekarz, from the University of Warsaw, on behalf of a CERN/Heidelberg/Naples/Warsaw collaboration, reported on the use of mica detectors in irradiations at CERN. Mrs. M. Debeauvais from the Centre de Recherches nucléaires at Strasbourg spoke of similar work using foils of plastic polycarbonate which is sensitive to particles down to atomic mass number about 15. The technique makes it possible to look for fission cross-sections which are very small. Both the above experiments reported the observation of 'three prong events', the tracks apparently coming from a common centre. This may be due to fission reactions where the complex nucleus breaks into three large particles instead of the usual two.



A microphotograph of fission fragment tracks registered in a mica sandwich. This photograph shows a three prong (left) and a two prong event which were recorded during the CERN/Heidelberg/Naples/Warsaw experiment at the PS. In the experiment, a 20 GeV proton beam was incident on a uranium target. Typical track lengths in the mica are about $10\ \mu$ long.

A possible future use for the new detectors is to measure the intensity of high energy beams, though the method is a slow one. Using a material for which the fission cross-section is known, with an array of the detectors, it may be possible by counting the number of fissions recorded in the detectors to estimate the flux of the particle beam.

SC Shutdown

The 600 MeV synchro-cyclotron began a long shutdown on 8 May which will extend to mid-July. During this time major modifications will be carried out as part of a programme to improve the capacity of the machine and its associated facilities for research (see CERN COURIER, vol. 6, no. 2 (February 1966) p. 30).

The main items of work planned for the shutdown are —

- i) To reinforce the shielding on the roof of the SC building to keep radiation levels in neighbouring buildings and off the site down to acceptable limits, allowing a margin of safety for possible increases in beam intensity.
- ii) Construction of a new underground tunnel to take the external proton beam line to the ISOLDE (Isotope Separator On-line Development) project. This tunnel has to be constructed underground again to keep external radiation levels down. It also frees the existing proton room for experiments involving less intense beams.
- iii) Modification of the accelerating system of the synchro-cyclotron.

The modification is designed to increase the frequency sweep of the system permitting operation at higher magnetic fields.

- iv) Installation of new quadrupole lenses on the beam lines on the meson platform in the SC hall.

In addition new power supply and cooling installations will be brought into operation and many elements of the SC machine and its associated equipment will be overhauled.

Computer Programme

The long term planning of research facilities for high energy physics involves more than the provision of more efficient, or higher energy, accelerators. Application of the advances in particle detection techniques (such as bigger bubble chambers...) needs to keep in step with the foreseeable research requirements and, also, data processing facilities to analyse the information coming from the experiments must be planned to keep pace with the output of data. In particular, this involves the provision of extensive computing capacity.

A major study of CERN's computing needs was made by a European Committee in 1963 and the ensuing report recommended a considerable increase in computing capacity over the period 1965-69. The volume of 'data to be processed was expected to grow from that corresponding to the capacity of an IBM 7090 computer at the end of 1964, to between 10 and 15 '7090s' by the end of 1968. The actual growth to date has been very close to that

predicted and a more recent review (February 1966) was in general agreement with the analysis made in 1963. (The predictions for 1969 and beyond, considerably exceed the capabilities of any currently available computer but the next generation of computers can be expected to emerge about that time.)

The 1963 report recommended the purchase of the large CDC 6600 as the central computer together with a number of small peripheral computers (for special applications such as on-line counter experiments), and also the addition, at an appropriate time, of extra storage capacity to the main computer.

A 6600 was installed at CERN at the beginning of 1965. The problem of bringing the machine into reliable use has been much more difficult than was anticipated and the troubles came to a head towards the end of 1965 when the machine had to be taken out of use for four weeks to undergo engineering changes. The performance of the computer has in addition been restricted by the poor software delivered by CDC which necessitated CERN spending a considerable part of the computer's time on 'system development'. A CDC 3400 was installed at CERN while the 6600 was unavailable in order to provide some on-site capacity, and has been retained to help process the back-log of work.

For the past twelve months, CERN has been short of on-site computing



CERN/PI 56.5.66

Excavation of the hole for the underground laboratory of the ISOLDE (Isotope Separator On-line Development) project. The project will use extracted proton beams from the 600 MeV synchro-cyclotron and the underground beam line from the SC is to be constructed during the present machine shutdown. (The SC building can be seen on the right.)

capacity and has had to put considerable effort into system programming and into making provisional arrangements to get round the difficulties. The research programme has been badly affected. It seems possible that high energy physics Laboratories will have to live with this problem in one form or another from now on, since the demands on computer technology that the research makes, is pushing the technology to its limits. Computers capable of coping with the vast quantities of data and the large range of problems involved, may (for earlier models at least) not have reached a 'reliable' stage of production.

A major outcome of the experience of the past year has been a decision that the future CERN computing facilities should have a much better 'fail-safe' characteristic. This implies having a secondary computer permanently available on-site to take over the most urgent work in the event of the main computer being out of action. One requirement of this secondary computer, because of the nature of some of the CERN work, is that it should have a storage capacity of at least 64 K.

Thus, major items among CERN's computer needs involve the acquisition of an appropriate secondary computer and (in line with the 1963 report) the eventual purchase of more storage capacity for the 6600. Computer manufacturers were consulted about these requirements and, after replies had been received, discussion took place in the Scientific Policy Committee on 8 March and in the Finance Committee on 10 March and approval was given to continue negotiations on the proposals with CDC. Negotiations took place at the end of March and the financial aspects of the agreements which resulted were approved at the Finance Committee meeting on 17 May.

Among the agreements were the following:

The CDC 3400 will be replaced by a CDC 3800 (arriving in July of this year) on a rental contract. (There will be some overlap of the two machines at CERN.) This will enable production work now being done on a CDC 3600 in Paris to return to CERN and will provide a better standby machine on-site. It will have a storage capacity of 65 K and is very similar to the CDC 3600 which is regarded as a proven 'reliable' machine.

By September 1966, CERN will decide whether to replace the 3800 by a CDC 6400 which is being reserved for delivery in February 1967. This also has a 65 K memory but is faster than the 3800. It is compatible with the 6600 and would therefore make a most convenient standby machine and enable a computing service to be maintained round the clock, even though both machines require daily maintenance. Because of this close compatibility, the 6400 would also be suitable as part of a future computer complex in which the 6600, the 6400 and the extra storage capacity, mentioned above, could be linked together in a flexible, powerful time-sharing system. This could be organized so that either machine could operate independently to maintain the 'fail-safe' characteristic.

The hardware for the extra storage capacity will probably be a 512 K Extended Core Store also made by CDC, for which CERN has an option for delivery at the beginning of 1968.

Rencontres de midi

The aim of the 'Rencontres de Midi', organized jointly by the Staff Association and the Welfare Section is to provide information by direct contact. To this end, making use of the mid-day break once a month, the CERN Staff is invited to hear a prominent Swiss or French personality speaking on a subject of current and general interest.

The guest speaker at the last 'Rencontres de Midi' (on 25 April) was Mr. Herzig, Mayor of the Commune of Meyrin, conseiller municipal, conseiller administratif and a member of the Grand Conseil of Geneva, who spoke about the social problems of Meyrin. The Commune has grown from 1915 inhabitants in 1939 to 11 500 at present, which gives Meyrin the status of a town. This figure includes about 40 % foreigners and members of international organizations.

Mr. Herzig said that while he was happy to see this growth at Meyrin, which was the first example in Switzerland of a satellite town, he regretted that the federal law did not allow communes, at present, to increase their income. The public authorities and private enterprise, he said, have already done a great deal to solve the problems set by the large increase in population. There remain, however, problems which the Commune is ill-equipped, financially and technically to

solve quickly by itself: road maintenance, schools, theatre and concert hall, for example.

Beginning in the Autumn, the 'Rencontres de Midi' will invite in turn the leaders of the various political parties in Geneva.

Etc...

Professor Gregory, Director General of CERN, visited Spain from 25 to 29 April at the invitation of Professor Otero Navascues, President of the Junta de Energia Nuclear. The Director General spoke at the Institute of Civil Engineering, Madrid, on 'Engineering problems of large particle accelerators' and at the Science Faculty of the University of Valencia on 'Sub-nuclear physics'. He also visited the site near El Escorial, Madrid, put forward by Spain for the construction of the proposed 300 GeV accelerator.

The Society for Radiological Protection, U.K., held an international symposium in the third week of April. 240 delegates from 19 countries were present including some members of the Health Physics Group at CERN. The symposium was concerned with 'The radiological protection of the worker by the design and control of his environment' and A. Rindi, of the CERN Health Physics Group, spoke on the special problems connected with the use of high energy accelerators (see CERN COURIER, vol. 6, no. 3 (March 1966) p. 45).

A new proposal for the 300 GeV accelerator site has come from Greece. The site is near Athens. Germany has withdrawn its site at Reimsbach.

The Directorate has decided to set up a study group in the MPS Division to investigate the proposal to use slow-cycling synchrotrons in the injection system of the CERN PS as part of the machine improvement programme (see CERN COURIER, vol. 6, no. 4 (April 1966) p. 63).

At the time of writing (10 May) everything is going according to plan to bring the proton synchrotron back into operation. The repaired magnet power supply motor returned to CERN on 9 May. If the installation of the motor and initial tests are successful, operation of the PS will begin again on 25 May.