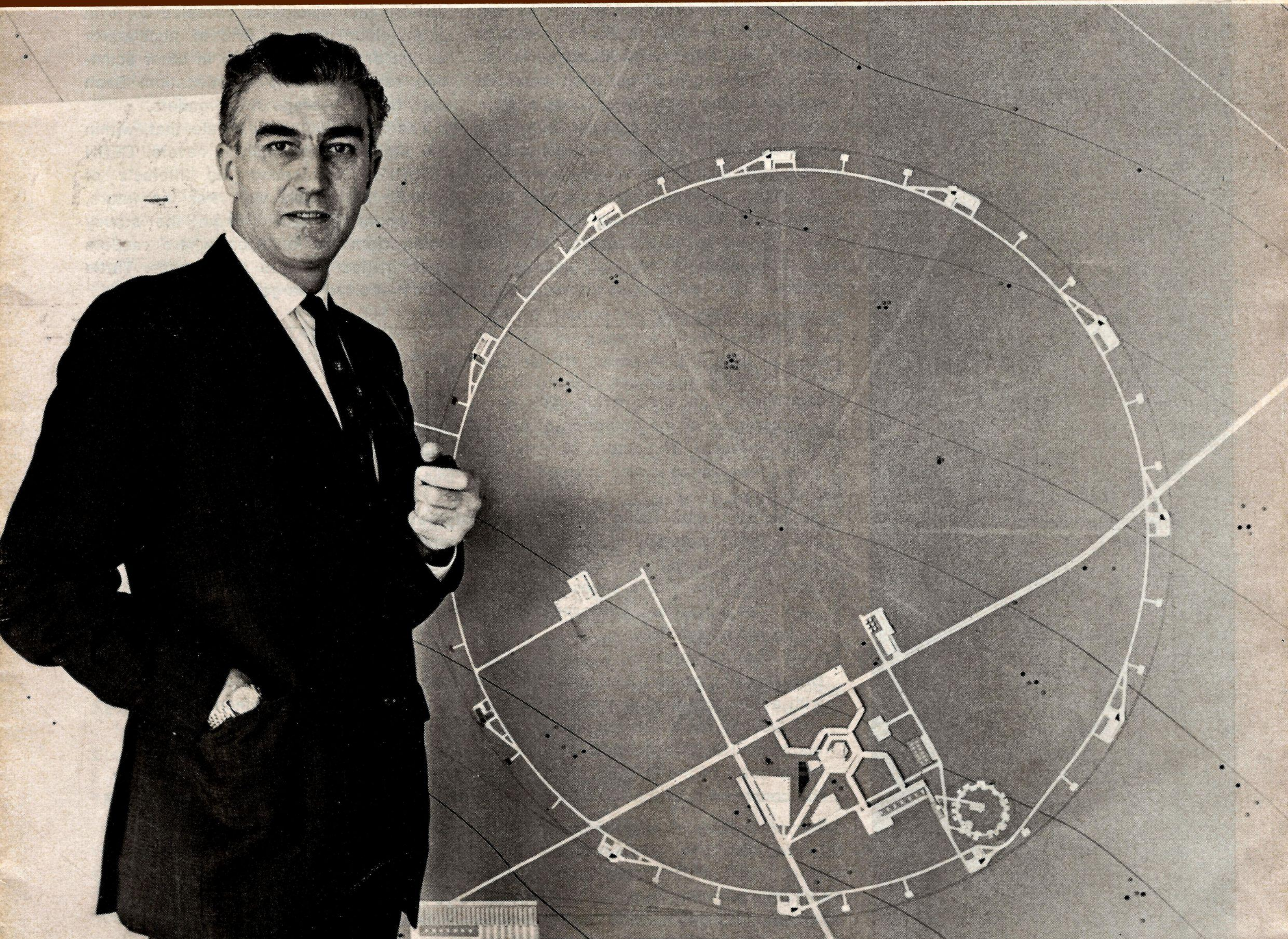
# CERN COURIER

No. 1 Vol. 9 January 1969

European Organization for Nuclear Research



CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientifice and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. Scientists from many European Universities, as well as from CERN itself, take part in the experiments and it is estimated that some 1200 physicists draw their research material from CERN.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2650 people and, in addition, there are over 400 Fellows and Visiting Scientists.

Thirteen European countries participate in the work of CERN, contributing to the cost of the basic programme, 235.2 million Swiss francs in 1969, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

CERN COURIER is published monthly in English and French editions. It is distributed free to CERN employees and others interested in sub-nuclear physics.



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# Comment

Ten years ago in August 1959, the first issue of CERN COURIER was published. It was intended as a 'house journal' for staff members and concerned itself mainly with conveying news about CERN inside CERN. A few years later the journal became also one of the main channels for informing people outside CERN about the work of CERN. More recently its character has evolved further to take in information on the work of related Laboratories.

During this time the number of copies distributed each month has grown steadily (the growth rate over the past three years has been 12 %/year). 8300 copies are now printed — 4700 in French, 3600 in English. This reflects the increase in the CERN population itself but even more the increase in the number of people from outside CERN who have asked to receive CERN COURIER. The external distribution is now greater than the internal distribution.

In 1968, a survey of the readership was carried out to check that the way in which the journal is developing is in line with the interests of the majority of readers. The survey confirmed many expectations but produced a few surprises.

Taking some of the results from the external readership: 50 % of the 2800 questionnaires which were sent out were completed and returned (surveys of this type might reasonably expect 15 % response) and 36 % of those who replied said that they are 'cover-to-cover' readers. In addition, 86 % find the level 'about right' — but then maybe they would not take CERN COURIER in the first place if it were not 'about right'.

The breakdown of the readership into activities showed that 75 % are graduate staff in science and engineering. The division into disciplines revealed 30 % in sub-nuclear physics, 9 % in accelerator design or operation, 24 % in other scientific research, 20 % in education. Each copy has an average of 3.5 readers.

The above figures indicate that, within the limited field which it covers, CERN COURIER is meeting the interests of readers reasonably well. For the future, the important results from the survey came from the question where readers were invited to state preferences. Three items received a large number of votes.

## Contents



*Cover photograph : It was learned in the middle of January that Dr. J.B. Adams has accepted the post of Director of the 300 GeV project offered to him at the December Council Meeting. Dr. Adams came to a Scientific Policy Committee Meeting and Committee of Council Meeting at CERN on 15-16 January and was photographed before the '300 GeV model'. The model shows one possible lay-out of the machine and its associate buildings. (CERN/PI 129.1.69)*

# Meanwhile...
# ...at the synchro-cyclotron

*A report on some features of operation, research and development at the CERN 600 MeV synchro-cyclotron.*

One was a request for a bigger issue. Over the past three years the number of pages produced has increased by 63 % and 1969 will see a further increase. But with a given editorial effort we must be careful that further quantity does not become inversely proportional to quality.

The second request was for more 'comment'. An effort will be made to increase the ratio of comment to factual reporting and we hope to introduce more comment, under various guises, from some of the senior figures in the field.

By far the highest vote was for 'more news from other Laboratories'. This section has been steadily increasing in importance but, up to now, it has depended largely on the Editor's personal awareness of events in other Laboratories. (It is appropriate to add here a word of appreciation for the full and immediate response that has come to every request for information.) Following the survey, it was decided to put the 'News from abroad' section (now called 'Around the Laboratories' which sounds less remote) on a more organized footing. Several Laboratories have been contacted in an attempt to find in each centre at least one person willing to be a source of information for CERN COURIER. The following people have already kindly agreed to help :

Argonne National Laboratory T.H. Groves
Batavia (National Accelerator Laboratory) C.W. Larsen
Brookhaven National Laboratory J. Spiro
Cambridge Electron Accelerator Wm. A. Shurcliff
Cornell (Wilson Synchrotron Laboratory) K. Berkelman
Dubna (Joint Institute for Nuclear Research) I. Birukov
Los Alamos Scientific Laboratory W. Regan
Rutherford Laboratory A.P. Banford
Saclay G. Neyret (with M. Beurtey and M. Thévenet)
Stanford Linear Accelerator Centre J. Sanders
TRIUMF Project (Canada) E. Auld

It is hoped to finalize arrangements with other centres in the near future — Berkeley, Bonn, Daresbury, DESY, Frascati, ICTP, ITEP, Karlsruhe, Novosibirsk, Orsay, Princeton, Serpukhov, Stanford (HEPL), Villigen and Yerevan.

The synchro-cyclotron has proved much richer in its research potential than was ever anticipated when it was first constructed. Although its usefulness in the field of intermediate energy physics (this is now legally defined in the USA as covering the range of energy from 100-1000 MeV) was obvious at the time it was completed in 1957, the growing demand for use of the machine and the growing variety of its research programme was never anticipated. One of the major reasons for the construction of the machine was to serve as a model prior to the more formidable task of constructing the 28 GeV proton synchrotron. As things have turned out, it has played as notable a role in its field as the PS has at higher energies.

In recent years, programmes of research in nuclear structure physics and in radiochemistry have been added to elementary particle physics and there has been a certain amount of work in solid-state physics and in radio-biology. As a bonus, the SC has also proved a useful, and economical, source of particles to test equipment intended for experiments at the PS. During the long 1968 shutdown of the PS, for example, there were as many as five PS teams at one time using the SC to prepare their equipment.

The number of scientists involved in experiments at the synchro-cyclotron has risen to 120. Of these, only 25 are CERN Staff, Fellows or CERN-paid visitors ; 95 are based on about 26 Universities and research centres from throughout Europe. In 1968 these included Aarhus, Bari, Braunschweig, Caen, Cambridge, Clermont-Ferrand, Copenhagen, Darmstadt, ETH Zurich, Gothenburg, Grenoble, Heidelberg, Karlsruhe, Lausanne, Louvain, Marburg, Modena, Orsay, Oslo, Oxford, Pisa, Rutherford, Saclay, Stockholm, Strasbourg, Studsvik, Toulouse, Trieste, Turin and Uppsala.

## *Present operation*

Operation of the machine has been developed to a high level of reliability. Out of the scheduled machine hours in 1968 less than 5% were lost due to breakdowns and in some months less than 1% were lost.

The machine is operated on a two week cycle - six days physics; one day technical development ; six days physics ; one day maintenance. The next long shutdown is planned for the Autumn of 1969.

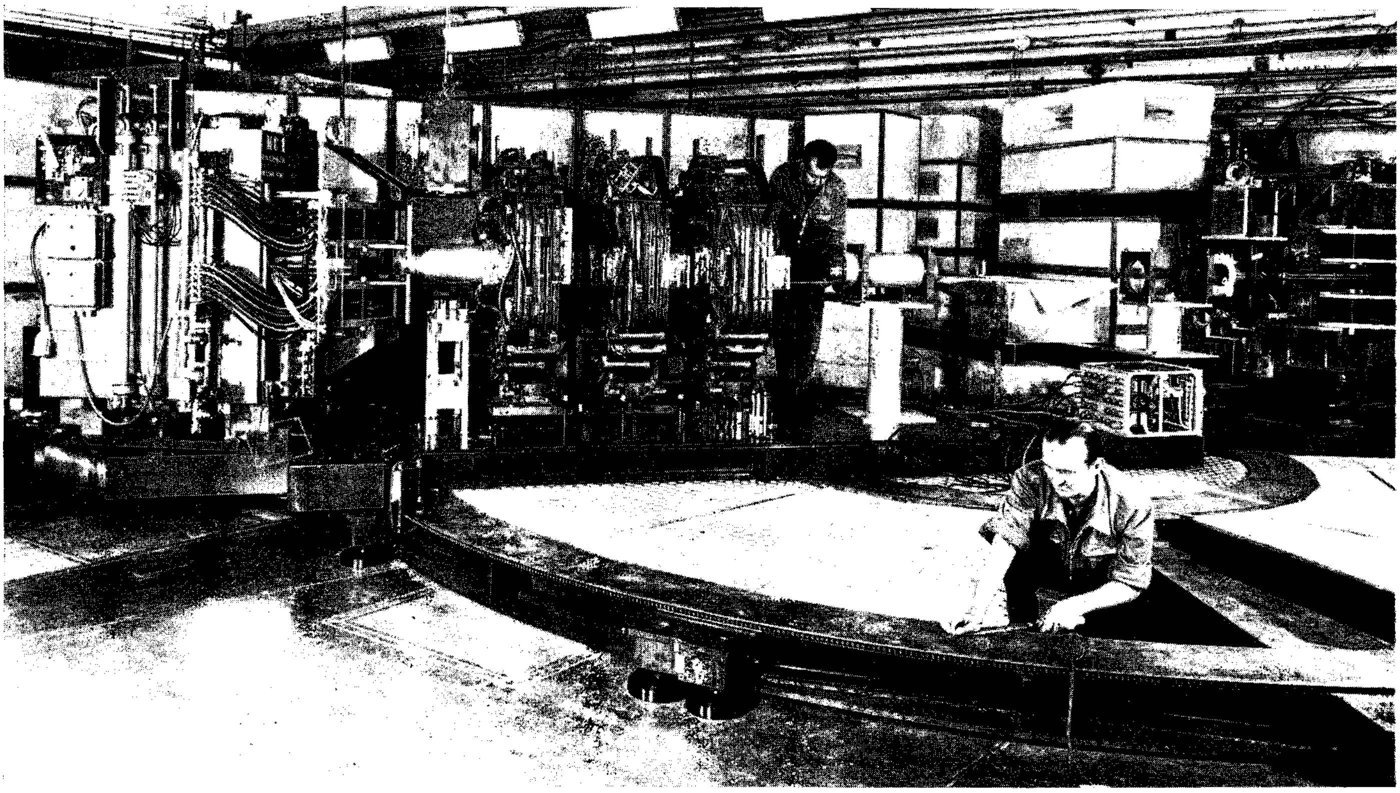
It is usually run to full energy and the average internal circulating beam is 1 μA ($6 \times 10^{12}$ protons/s). This is produced in 55 pulses per second which can be time-stretched to give an almost continuous beam from the machine if required, so that the duty-cycle can be more than 20%. The extraction efficiency is inherently poor (about 5%) nevertheless 3 to $5 \times 10^{11}$ protons/s can be used on external targets.

(To recall briefly the operating principle of a synchro-cyclotron with parameters of the CERN machine in brackets : Protons are produced at the centre of a circular magnet (5 m in diameter) which provides a constant magnetic field (19 kG). They are accelerated by r.f. fields applied across a gap across a diameter so that on each turn in the machine ($2 \times 10^5$ altogether) they receive two increments of energy (3 keV per turn). As the energy increases the protons spiral out onto larger orbits. To take account of the increase in mass of the protons as their velocity approaches that of light (80% of the velocity of light at 600 MeV) the frequency of the accelerating fields has to vary (from 30 to 16.5 MHz). The protons can be used on internal or external targets.)

The CERN machine yields —

1. Internally and externally produced pion beams in the energy range 80 to 300 MeV with maximum pion intensities of about $10^6$/s. Special pion beams can give $10^5$ pions per second over a range of energies with very narrow energy spread (the energy spread of the particles around the selected energy can be as low as 1%).
2. High purity muon beams down a 'muon channel'. Up to $10^5$ muons/s in the energy range 50 to 200 MeV can be achieved.
3. An external proton beam of 595 MeV and intensity from 3 to $5 \times 10^{11}$ protons/s which is taken through a tunnel to an underground laboratory for radiochemistry work.

*A double spectrometer used for pion-nucleon experiments at the SC. The spectrometer arm analyses the scattered particles.*



*CERN/PI 138.9.66*

## *Research programme*

In the history of research at the SC there have been many outstanding achievements including three important contributions to weak interaction physics :

- the discovery of the electron decay of the pion which proved experimentally an important prediction of the weak interaction theory
- the first exact measurement of the decay rate of the positive pion into a positron, neutrino and neutral pion
- the most accurate measurement of the capture rate of muons in liquid and gaseous hydrogen

The first precision measurement of the magnetic moment of the muon (recently carried further in an experiment on the PS) which extended the range over which electromagnetic theory is known to hold good, was also made at the SC.

The current programme can be considered under several headings and a few experiments are selected as examples.

### *1) Nuclear Structure*

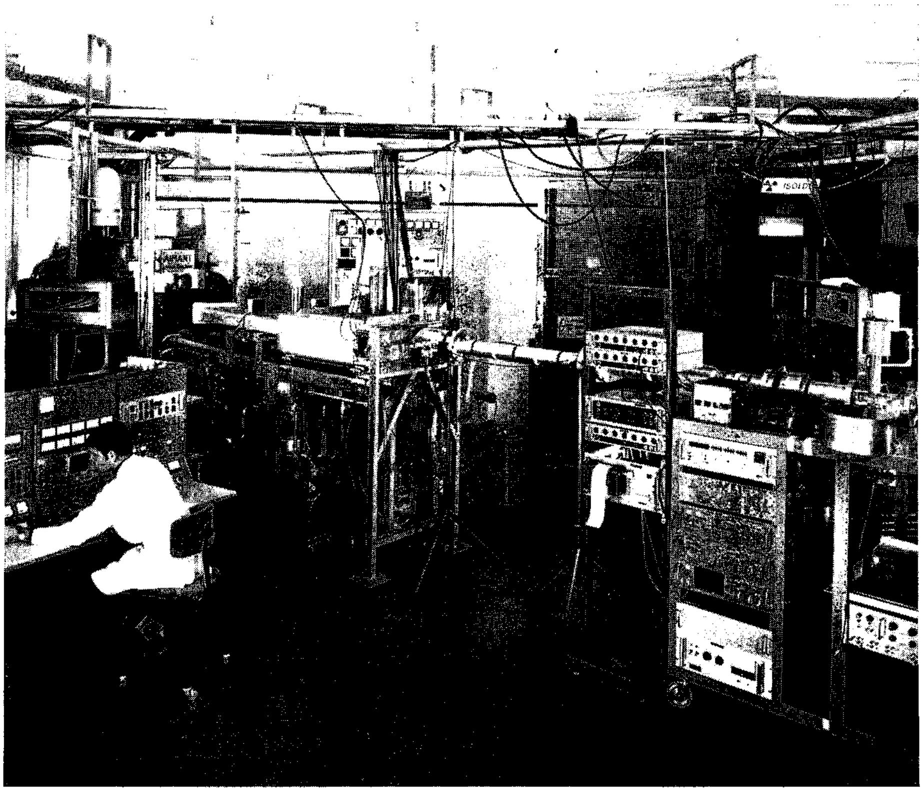
Several methods of investigating the structure of nuclei have been used in experiments on the SC — they include investigation of nuclear energy levels, of particle groupings in the nucleus and of nuclear shape.

Pion beams with precisely determined energy are used by an Orsay team headed by R. Meunier, M. Spighel and J.P. Stroot, for pion scattering measurements on a range of nuclei. Investigation of pion-nuclear scattering, as opposed to nucleon-nuclear scattering provides another view of nuclear matter. A related investigation with positive pion beams onto light nuclei is being carried out by an Oxford team headed by N. Tanner and J. Domingo. The beta and gamma rays emitted as the nuclei return to their normal state after being excited by the pions are another way of investigating energy levels.

Several experiments have investigated particle groupings in the nucleus using pion beams. The pion is effectively absorbed by the nucleus and can interact with an individual particle grouping such as a strongly bound proton and neutron leading to the ejection of two protons. Adding the energy of pairs of emerging protons gives information on the internal grouping. This particular experiment was done by a CERN team led by G. Charpak and C. Zupancic. An analogous experiment leading to two emerging neutrons was performed by a team from Trieste under C. Cernegoi.

Investigations of pi-mesic and mu-mesic X-rays have been a very fruitful source of information on nuclear radii and related topics. A CERN-Heidelberg-Karlsruhe team led by G. Backenstoss and H. Daniel have achieved important results using this method including some of the best available data on nuclear charge radii. Negative muons and pions can be captured by a nucleus in a similar way to electrons and can cascade through a series of orbits (energy levels) close to (and passing through) the nucleus emitting X-rays as they move to lower energy orbits, whose energies can be measured. (The new lithium-drifted germanium detectors make

*Part of ISOLDE — Isotope Separator On-Line. At the control desk the proton beam from the SC can be monitored and the performance of the target and separator controlled. The ion beam containing the isotopes enters through the wall and is analysed in the magnet. One of the analysed beams can then be transported to the detectors — the ions are transmitted with close to 100 % efficiency. At the end of the pipe, on the right, is a tape system for collecting the isotopes (the tape spool containers can be distinguished). The isotopes become embedded in the tape and detectors can be brought to the tape for measurements (an electron detector, above, and a gamma detector, below, can be brought into position). A system is being developed to make it possible to switch the ion beam to three users. This will increase the number of experiments which can be performed simultaneously with ISOLDE.*



CERN/PI 315.10.68

very precise measurements possible.) A variety of nuclei have been studied.

A related development is the study of the excitation of nuclear energy levels and of muon capture on excited nuclei. Experiments in this field have been performed by teams from Darmstadt and Louvain.

*2) Radio-chemistry*

This research received a great boost with the coming into operation of ISOLDE — Isotope Separator On-Line (described fully in CERN COURIER vol. 7, page 23). The ISOLDE collaboration involves scientists from Aarhus, Braunschweig, Copenhagen, CERN, Gothenburg, Heidelberg, Orsay, Oslo, Stockholm, Strasbourg and Studsvik.

An ejected proton beam from the SC is taken to an underground laboratory (which serves to shield the high radiation levels) and directed onto a target which can be one of a variety of elements. The isotopes of the element which are produced can be rapidly separated and measured using a sequence of techniques 'on-line'. This has enabled very short-lived isotopes to be identified and measured ; ISOLDE has made it possible to investigate isotopes with life-times measured in seconds rather than minutes.

Since ISOLDE came into operation towards the end of 1967 isotopes of radon, mercury, xenon, antimony, tin, cadmium, krypton and argon have been produced and measured and seventeen isotopes have been observed for the first time. These experiments are exploring new areas of the map of nuclides giving more information on nuclear decay properties.

*3) Elementary particle physics*

The beams available from the SC are suitable for the experiments on pion and muon interactions as can be seen from the examples of research at the SC cited at the beginning of this section.

Present work includes a remeasurement of pion-nucleon cross-sections in the energy range corresponding to the production of the N* (3/2) resonance. This investigation was started by a Modena-Bari team headed by P. Waloschek. A Cambridge-Rutherford team headed by D. Bugg is taking advantage of the high quality beams now available at the SC to make a very thorough survey of this region. Another facet of pion-nucleon interactions is radiative capture and charge exchange of negative pions on protons. This is being examined by a CERN-Lausanne team.

Studies of pion production with 600 MeV protons on various nuclei is relevant to elementary particle physics and to nuclear structure. CERN-Geneva and CERN-Grenoble teams have contributed to these studies which have also provided useful information for the design of beams from the SC.

## *The need for improvement*

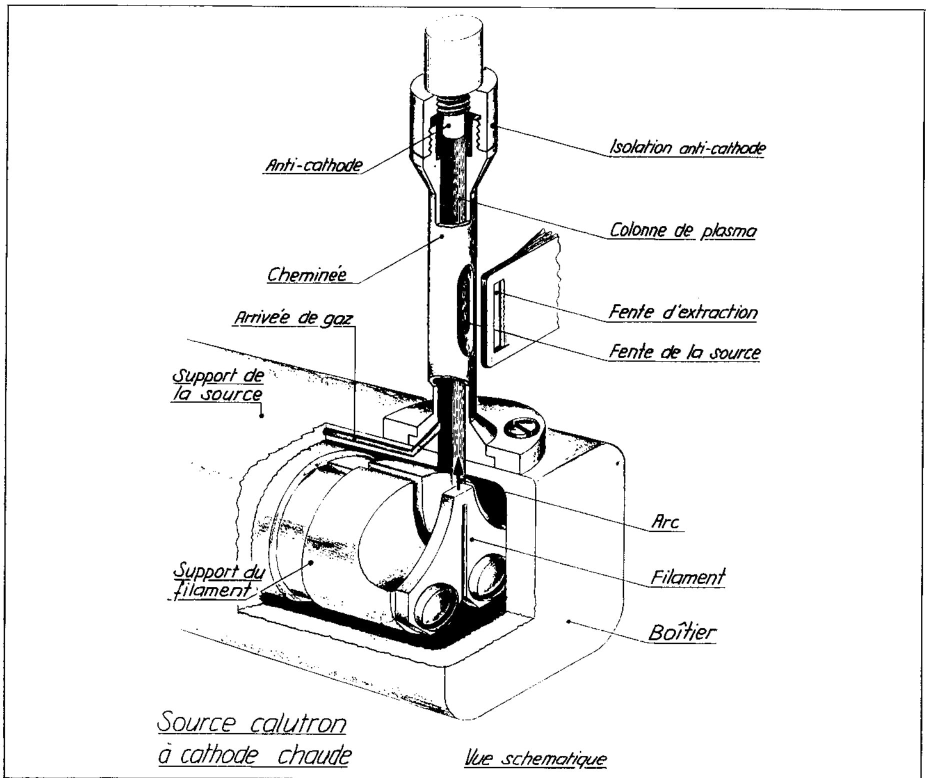
For several years (see, for example, CERN COURIER vol. 6, page 30) a lot of thought and practical investigation has been given to the possibility of improving the performance of the synchro-cyclotron by producing more intense beams. This has the double purpose of meeting the increasing demand for use of the machine and of extending the scope of its research.

A recent investigation has indicated that over the next two or three years, requests for machine time will rise by about 20 %. Higher beam intensity will make it possible to shorten the time involved in an experiment or to extend beam-sharing. It will also make possible a wide variety of experiments which are not feasible with the existing beam intensity (in a report entitled 'Physicists Comments on the SC Improvement Programme' some twenty team leaders have indicated research topics they could undertake given higher beam intensities). An improved SC will ensure that European physicists continue to have a first-rate machine available for physics at intermediate energy, particularly in the early 1970s.

This last point can be appreciated by looking at the facilities which will be available in the world in a few years time.

*In North America :*

The synchro-cyclotron at Columbia (CERN COURIER vol. 8, page 313) is being improved to have a 5 to 50 μA internal beam at 600 MeV coming into operation about 1970. Other synchro-cyclotrons at Berkeley and SREL will still be in operation and improvement programmes are




*A diagram of the new type of ion source (hot-cathode, hooded-arc) which will be installed on the SC. This source will result in the acceleration of a beam of much better quality with which much higher extraction efficiencies will be possible.*

being discussed. (The Carnegie and Chicago machines are likely to close down.) A sector-focused cyclotron at Indiana will have 10-100 μA internal current at 80-230 MeV. The novel sector-focused cyclotron TRIUMF in Canada (CERN COURIER vol. 8, page 136) accelerating negative hydrogen ions to yield pion intensities up to $10^8$/s is expected to be in operation in 1974. Linear machines for 220-440 MeV electrons at MIT and the mighty LAMPF at Los Alamos with 800 MeV proton beams will also contribute to physics at intermediate energy.

*In the Soviet Union :*

A 1000 MeV synchro-cyclotron at Gatchina, South of Leningrad, came into operation in November 1967 and the very successful 680 MeV synchro-cyclotron at Dubna is likely to have a series of improvements carried out by 1973.

*In Western Europe :*

Linear accelerators for electrons and positrons in operation at Saclay (140-600 MeV) and Frascati (450 MeV) will be used for pion and muon production. The 520 MeV sector-focused cyclotron at Zurich is scheduled to come into operation in 1973, rising to full intensity (100 μA) and utilization in 1975.

It can be seen that, especially through to the time when the Zurich machine is in operation, the European potential would be weak without development of the CERN SC to extend its productive life.

The aim of the SC improvement programme is to increase the internal beam intensity from 1 to 10 μA and to improve the efficiency of beam extraction. This efficiency is important not only to produce higher beam intensities for certain experiments but also to reduce the radiation problems in the machine which will be aggravated by the higher beam current. In fact, because of the radiation problem, it is not reasonable to plan for currents higher than 10 μA.

## *The Improvement Programme*

Item I is to replace the existing cold cathode Penning-type ion source by a hot-cathode hooded-arc source. The existing type feeds a plasma into the centre of the machine from which protons can be captured and accelerated. It suffers from the disadvantage of low efficiency and also results in a proton beam of poor quality which is the major cause of the low extraction efficiencies. The new type of source projects like a very thin pillar (about 6 mm in diameter) into the centre of the machine and protons emerge from a thin slit on the median plane. The beam quality from such a source is greatly improved and extraction efficiencies of up to 50 % may be possible.

Adoption of the new source involves modifications to the Dee structure at the centre of the machine (CERN COURIER vol. 6, page 32). The protons need to experience higher accelerating fields than at present at the centre of the machine so that their first orbit takes them away from the source. The voltage applied to the Dee at the beginning of the cycle will be increased from the present 5 kV to about 30 kV.

Considerable development work at CERN has gone into perfecting this new type of source including a lot of progress in filament design to produce filaments with sufficiently long life-times. At the same time a small (15 MeV) synchro-cyclotron, known as the 'central region model', has been built and operated. It has served to investigate the complex beam behaviour in the electric and magnetic fields at the centre of a synchro-cyclotron where it is known that most beam loss occurs.

In itself the new source will not result in much higher intensity per pulse, though, as mentioned above, it will produce a better beam and higher extraction efficiency. The increase in intensity per second will come from an increase in repetition rate of the machine from 55 Hz up to 600 Hz. This requires the installation of a new r.f. system.

The present r.f. system is based on the use of a mechanical vibrating capacitor — a huge tuning fork vibrates at 55 Hz (the repetition rate of the machine) and varying the distance between the prongs achieves the desired frequency modulation (from 30 MHz to 16.6 MHz) of the voltage applied to the Dee. Each 'prong' is 2m broad, 55 cm long, separated by a gap of 9 cm with a vibration amplitude of 2 to 5 cm. These figures are near to the limit of what is technologically possible with such a system. The tuning fork method cannot be used for repetition rates as high as 600 Hz.

A system based on the use of a mechanical rotating condenser has therefore been studied at CERN. The rotating condenser is not without its technological problems and several 1/5 scale models have been built to fix parameters and to test mechanical and electrical features of the design. Calculations on the expected frequency swing and field strength have been checked. A model is being constructed on a test bed at CERN to examine electrical and mechanical stresses.

The new r.f. system will be manufactured by AEG-Telefunken (Federal Republic of Germany) at a cost of just under 5 Million Swiss Francs.

It is intended to install the new equipment at the synchro-cyclotron early in 1971. The machine will then be able to continue to play a major part in physics at intermediate energy for many years to come.

# CERN News

## At the PS

### *Linac beam monitoring*

Since 1 November, the linac has been equipped with an on-line system to observe the energy spread in the 50 MeV beam fed to the proton synchrotron. The PS can accept particles within a spread of about ± 150 keV and it is obviously desirable to maximize the beam current lying within this energy spread.

The beam is measured first as it passes through a beam current transformer (BM 46), it then passes through a triplet, bending magnet and slit, which do momentum selection, and is remeasured by a beam current transformer (BM 48). The diagram shows the two measurements as they appear on an oscilloscope. The difference in the two signals shows the number of protons with energies outside the desired range. It is also easy to see from these traces, for example, at what time during the pulse the beam is poor. The linac controls can then be adjusted to bring the beam to an optimum.

The system has proved very useful. It enables the linac to be set up much more easily than previously and also gives the machine operators a rapid and easily assimilated picture of how the linac is performing.

### *A beam in minutes*

On 12 December, a fast ejected proton beam from the PS was 'set-up' through a complex beam transport system 140 m long and focused to a 1 mm spot on a target in a total time of seven minutes. The beam is usually operated at a momentum around 20 GeV/c feeding the south-east area (where the latest neutrino experiments took place) with a secondary beam (k11) produced from the target. The required beam intensity at the target is $10^{11}$ protons/pulse. From 23 January, the k11 beam has been supplying kaons to the 1.2 m heavy liquid chamber.

The beam transfer line from the PS contains twenty pulsed lenses and bending magnets (nine quadrupoles, five main bending magnets, three vertical and three horizontal correcting magnets). By pulsing the magnets there are savings in power, in cooling water and in magnet sizes. A glass vacuum tube with a minimum diameter of 34 mm runs through the magnets.

The very short setting up time was due mainly to good knowledge (from the previous neutrino run) of the initial parameters of the beam which emerges from the PS. This knowledge made it possible to calculate very precisely, in advance, the required fields for the transport magnets. The calculated settings proved so accurate that final manual adjustment when the beam was directed along the channel (the beam was monitored, for example, by nine scintillation screens observed by television cameras) could be made very easily in minutes.

The beam was designed and brought into operation by the pulsed beam transport group led by B. Langeseth. This group is currently engaged on the design of beams for the heavy liquid bubble chamber, Gargamelle, at CERN, and on an ejected proton beam-line for Serpukhov which will supply particles to the hydrogen bubble chamber, Mirabelle. Contracts have already been placed for the components of the Serpukhov beam-line. The beam-line for Gargamelle will be set up about the end of this year and will use many of the components currently in use to feed the 1.2 m heavy liquid chamber.

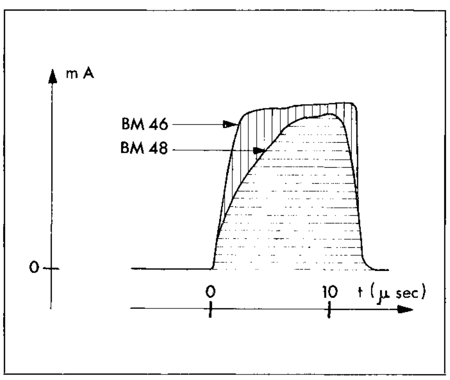
### *Highest momentum kaon beam*

In January the 2m hydrogen bubble chamber received the highest momentum positive kaon beam ever produced. The u5 beam in the East Hall was used in a clever way with two r.f. separators to achieve a kaon momentum of 16 GeV/c. (The previous record of 12.7 GeV/c was at the Brookhaven AGS.) Operation at this high momentum has been made feasible by the successful completion of the first stage of the PS improvement programme which enables the PS to be run at high energy and repetition rate.

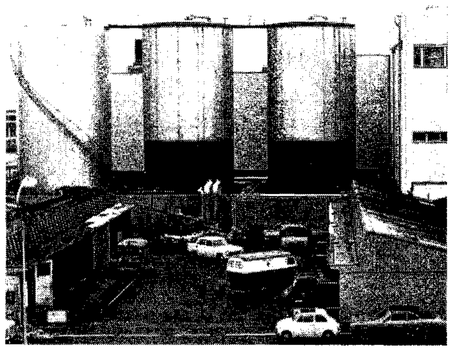
The work on the beam was led by P. Lazeyras, H. Lengeler and F. Grant. It has already served to take almost 200 000 pictures in a week for a Birmingham, Brussels, CERN, Institut de Physique Nucléaire (Paris), Saclay collaboration.

The collaboration is extending its study of resonance production in quasi two-body interactions to higher energies. The purpose is to discriminate between several theoretical predictions (including, for example predictions based on the Regge pole model). The cross-section of some interactions seems to be virtually independent of energy while others fall off with increasing energy. On the latest pictures it should therefore be easier to separate different kinds of interaction.

The principles of r.f. separation were explained in CERN COURIER vol. 7, page 125 and vol. 7, page 252. Using two cavities in the normal mode of operation one type of particles can be separated from two others only in certain small momentum ranges. Using three cavities the range can be wide and almost continuous, but, for momenta near 16 GeV/c, although protons and positive pions are well filtered out, a fairly high background of positive muons remains in a positive kaon beam. Going back to two cavities and slightly defocusing the pions and protons (using a larger beam stop to collect them) it was found that a clean kaon beam could be achieved, with a proton contamination of less than 4 %. There are about ten kaons per picture.

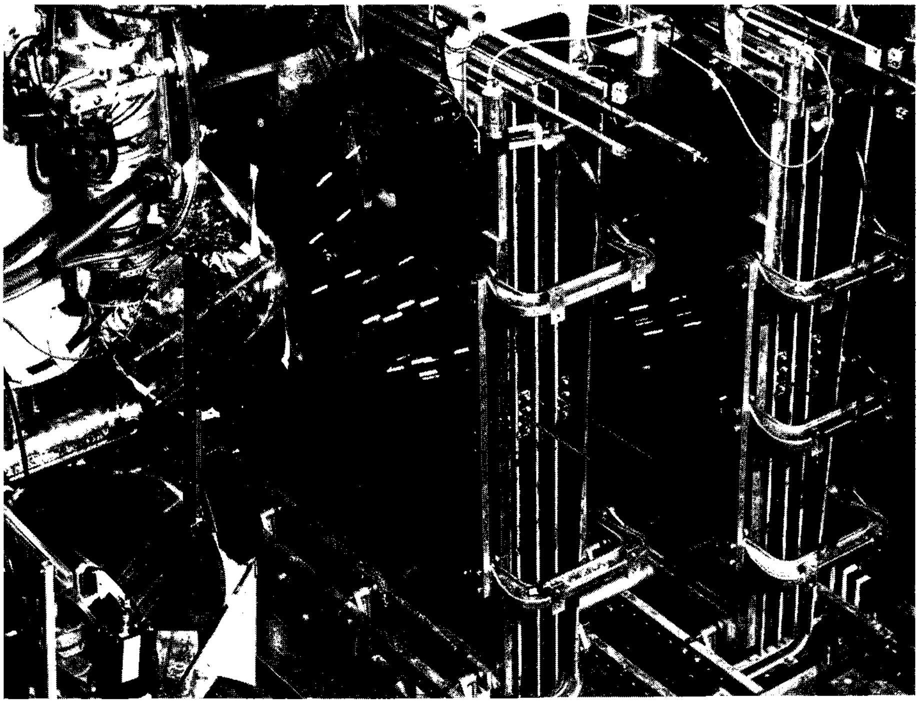



*A drawing of two typical traces received from the beam current transformers monitoring the energy of the linac.*



*Three-fold symmetry has been restored to the oil storage tanks supplying the power house. To cater for the increasing consumption, the two tanks on the left, (first installed in 1956) have been increased in capacity from 500 m³ to 750 m³ and they now match their partner on the right which was installed in 1963. The increase in capacity has been achieved by raising the tanks ten metres ; this has been done by jacking them up and welding on new, thicker sections at the base.*

CERN/PI 90.1.69

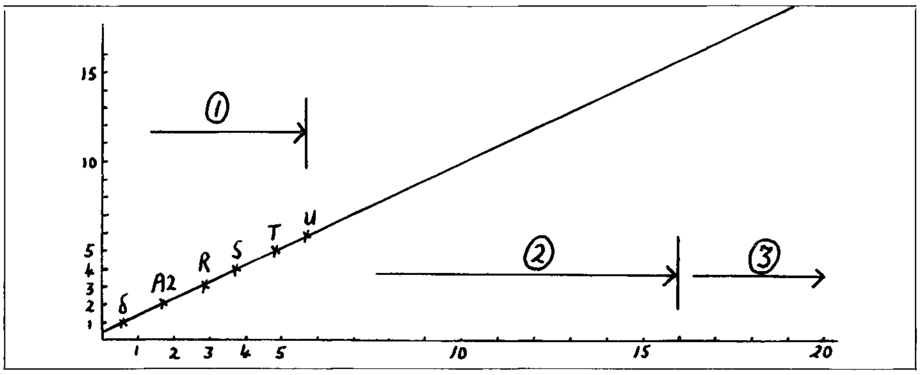


CERN/PI 211.1.69

*Part of the equipment for the boson missing-mass spectrometer experiment. On the left is the small horizontal cylinder, 30 cm long, which contains the target liquid hydrogen. It is cooled by liquid helium ; the refrigeration equipment is above the target. Two of the digitized wide-gap wire chambers are positioned close to the target. Note a few constructional details : The horizontal bars at the top of the chambers contain the magnetostrictive wires ; small isolating transformers make it possible to tap signals from the wire planes some of which are at 60 kV. Thin rods can be seen protruding horizontally at the centre of the chambers ; these carry air-filled mylar boxes (beam-killers) which receive direct beam particles so that these particles do not cause sparks.*

*Sparks can be seen in the chambers. Several are detected simultaneously and the detection efficiency is very high (in the photograph, each gap sees each particle trajectory — there is no case where a gap misses a particle). The sparks follow the particle trajectories, which is a feature of wide-gap chambers ; less wire planes are thus needed to give full information.*

*In the picture, two triggers are super-imposed and any interested reader may amuse himself tracing the sparks back to two vertices quite cleanly determined in the target, plus one beam track (parallel to the target cylinder).*




*The graph illustrates the regularity of the squares of the boson masses δ, A2,R,S,T,U, which were covered in the missing-mass spectrometer experiment (region ①). The mass squared is plotted along the x-axis and the peak number on the y-axis. Region ② is now being investigated by the boson spectrometer up to a mass squared value of about 16 GeV². Region ③ which extends to a mass-squared value of about 64 GeV² could be covered later at Serpukhov in collaboration with Soviet scientists.*

# Going up

The very successful missing mass spectrometer experiment is extending its search for negative bosons up to masses of 4.5 GeV with its detection equipment newly installed on a high momentum pion beam in the East experimental hall.

The story so far : In 1964 a team led by B. Maglic first applied the missing-mass spectrometer technique to look for non-strange, charged bosons. Within about two and a half years seven new particles were found. It was shown that the squares of boson masses seem to lie neatly on a straight line. (See CERN COURIER vol. 7, page 31.) In addition, the splitting of the A2 particle into two peaks which seem to have identical characteristics apart from a difference in mass — 1278 MeV and 1318 MeV — was demonstrated.

The missing-mass group (at that time a Bern, CERN, Geneva collaboration) decided to continue the experiment looking for particles of higher mass (the highest mass particle from the first experiment was the U particle with mass 2383 MeV). They changed the detection equipment and the experimental method and carried out a preliminary run in the South experimental hall last year. (CERN COURIER vol. 7, page 219.) This run served to test the equipment and method and also reproduced the A2 splitting.

The equipment and the method worked well and the experiment has now moved to a higher momentum pion beam available in the East hall. Bern has left the collaboration and Munich (Sektion Physik) has joined. The team leader is W. Kienzle.

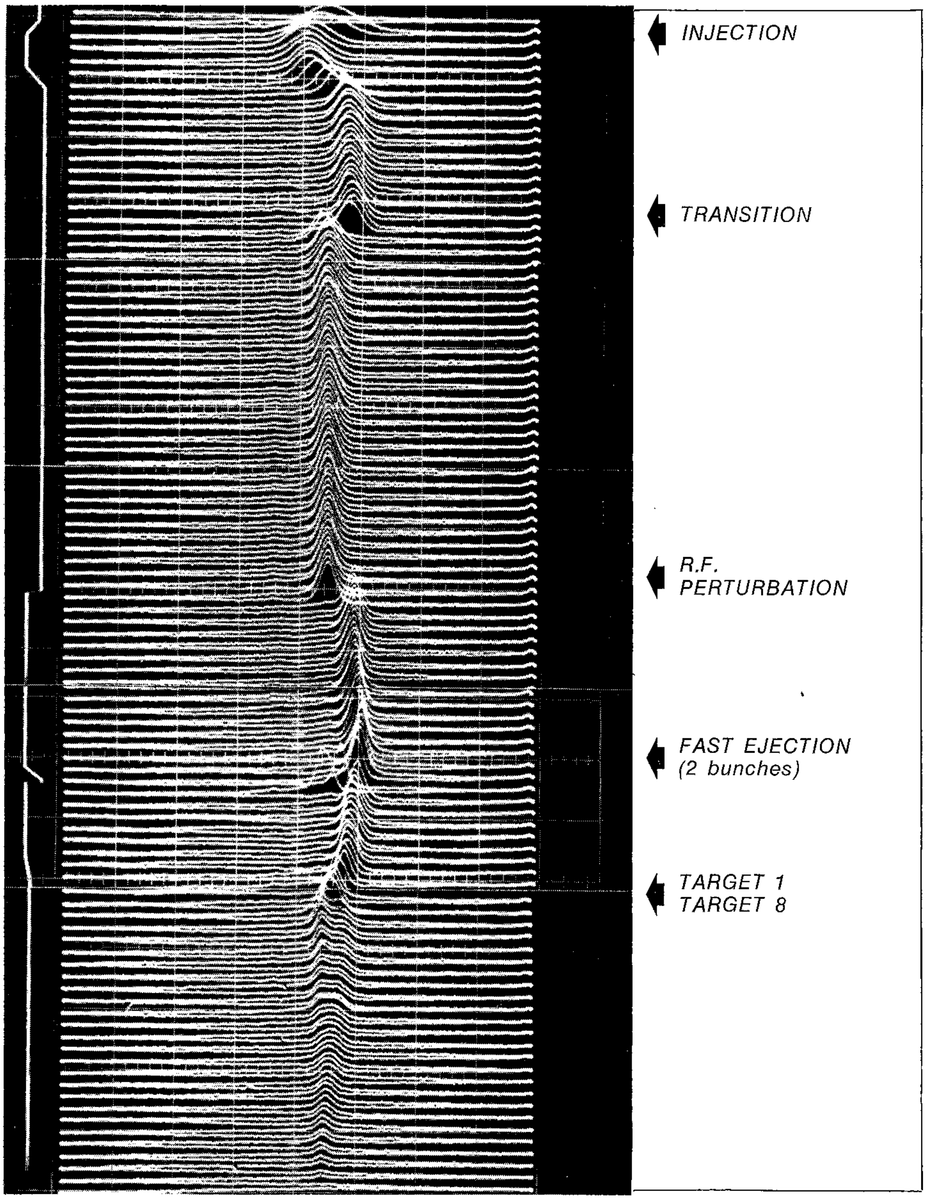
The interaction under investigation is

$$\pi^- + p \rightarrow p + X^-$$

where $X^-$ represents a heavy boson. Measuring the momentum of the incoming pion and identifying the recoil proton and measuring its momentum makes it possible to calculate the 'missing mass' of the recoil proton which is the mass of the boson. The missing-mass spectrum consists of a smooth background with peaks at those values corresponding to a boson mass.

A pion beam (p5) of precisely selected momentum, drawn from the slow ejected proton beam (e5), is directed onto a hydrogen target (a new type of helium cooled target developed in the group of L. Mazzone is being used and is working perfectly). The resulting recoil proton in the forward direction is detected and its momentum measured by an array of digitized wide-gap wire chambers and a large bending magnet. The chambers immediately following the target also detect the decay products of the boson. The resolution of the detection system is ± 10 MeV.

Setting the momentum of the incoming pion beam effectively enables the detection system to search a certain mass range. For example, the experiment is currently using a pion beam of momentum 9 GeV/c and this can yield any missing mass in the range 2.4 to 2.9 GeV. As the experiment proceeds the incoming pion momentum will be increased as high as 15 GeV/c so as to sweep the missing mass range up to 4.5 GeV boson mass. Higher values are not possible at the CERN proton synchrotron but the experiment may be continued later as a CERN-Serpukhov collaboration at the 76 GeV machine in the Soviet Union.




*Watching the proton beam, from injection through to targetting at high energy, with an 'ionization beam scanner' (IBS) in the CERN synchrotron. The scanner is believed to be the first working device to view the size and position of a proton beam in a strong focusing machine. (Similar devices, using different operating principles, have already operated on the Zero Gradient Synchrotron at Argonne where the spatial resolution requirements are less stringent.)*

*The beam is scanned every 5 ms (there is a 5 ms interval between each trace recorded on the oscilloscope) and the limits of the scan correspond to the sides of the vacuum chamber (beginning on the left at the outside wall of the chamber scanning about 15 cm across the chamber to the inside wall).*

*Notice the effects on the beam of the various machine operations indicated. The position of the hump indicates where the beam is travelling in the vacuum chamber, its area corresponds to the beam intensity, and its width to the width of the beam.*

*The ionization beam scanner operates by taking a signal from the electrons liberated when the proton beam ionizes the residual gas in the vacuum chamber. The number of electrons produced in this way is proportional to the intensity of the proton beam passing through the scanner and, of course, the position where the electrons are produced is the position at which the proton beam passes.*

*Using electric and magnetic fields these electrons are brought to a collector where they give a signal which is amplified and passed to recording devices. The collector is held at earth potential and the electric field is varied in such a way that the earth equipotential (around which the electrons spiral to reach the collector) moves across the vacuum chamber. In this way, electrons produced at different positions across the vacuum chamber can be picked out separately (to an accuracy of 1 to 2 mm).*

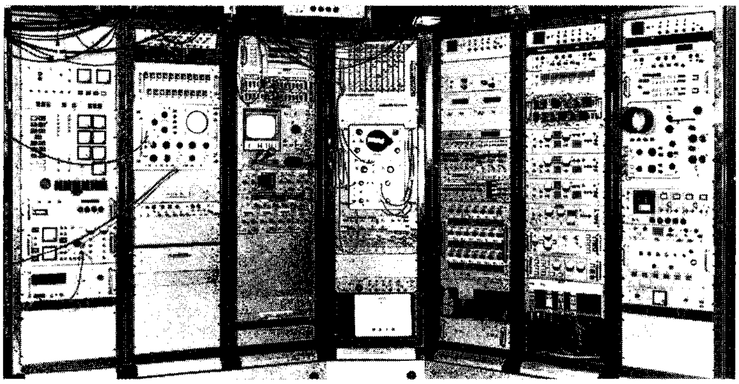
*The ionization beam scanner was developed at CERN particularly by C.D. Johnson and L. Thorndahl.*

## Conferences at CERN

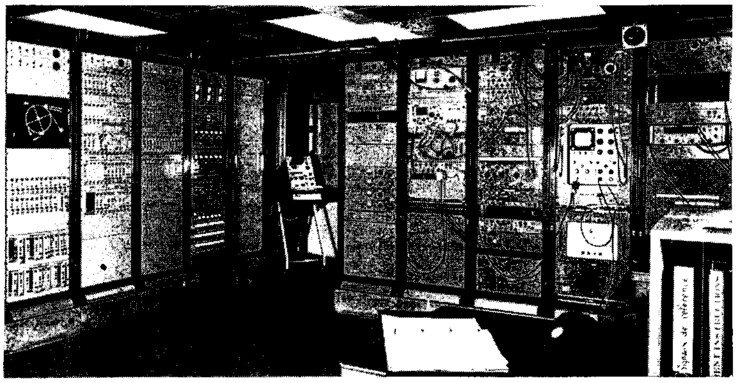
A major conference was held at CERN on 14-17 January. Entitled 'Topical Conference on Weak Interactions' it was attended by 150 scientists from other Laboratories in addition to CERN scientists. It is hoped to present a report on the conference in the next issue.

Just prior to the weak interaction conference on 13-14 January, a 'Neutrino Meeting' was held bringing together physicists involved in neutrino experiments, including over 40 physicists from outside CERN. Recent results from research at accelerators and on cosmic and solar neutrinos were discussed and the future plans of several Laboratories were described. Three topics from the meeting (the coming into operation of a 7 foot bubble chamber at Brookhaven and the plans of Serpukhov and Batavia) are covered on pages 12-14. A description of the large hydrogen chamber at Argonne, which will be used for neutrino experiments, will appear in the next issue.

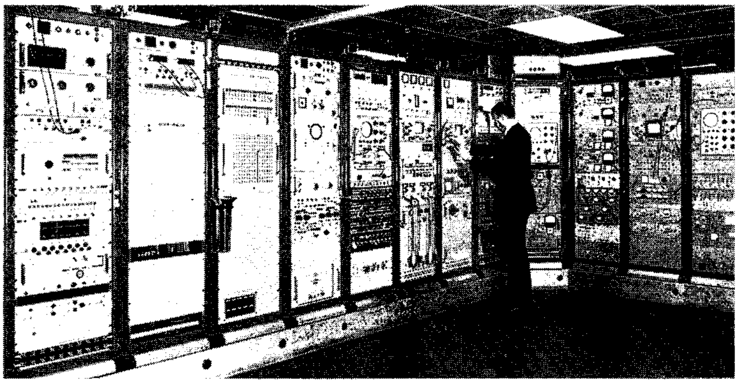
# Control Room



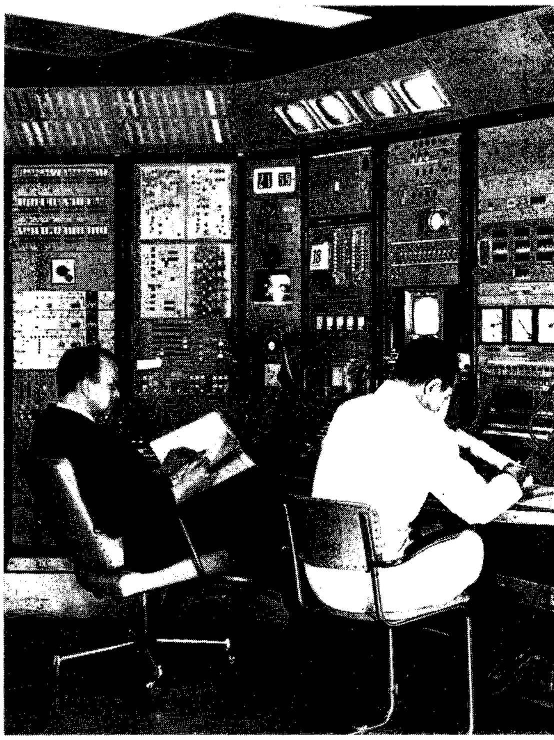
1. CERN/PI 208.1.69



2. CERN/PI 206.1.69



3. CERN/PI 205.1.69



4.

The nerve centre of the proton synchrotron is the Main Control Room (MCR) situated on the first floor in the South Experimental Hall. It is a low, dimly-lit room (so that oscilloscope traces can be easily observed) in which the atmosphere is often tense (especially when there is a machine breakdown !). Here the operators engage in a constant battle against beam blow-up, resonances and other phenomena which threaten the life of the beam.

The aims are to squeeze as many protons as possible from the machine and to make maximum use of them — an equally difficult task. The skill of the machine operators in achieving these aims contributes significantly to the quality of the experimental results.

What follows is a short guided tour of the MCR. Some of the control panels are shown in the photographs ; altogether there are nearly 30 oscilloscopes, 12 closed-circuit television screens, and more than a thousand pilot lamps. The units are grouped as follows :

*Main desk (photo 4)*

$P_3$ : radiation protection. Control of access-points to the ring. Safety circuits for controlling access to secondary and ejected beam areas.

S : concentration of essential operation information. The lower section carries the means of communication (telephones, intercom, loudspeaker) with the satellite control centres — linac control room, magnet power supply control room, experimenters, etc...
On the left are a group of thirty warning indicators — hydrogen alarms, five dials showing the linac beam intensity at various points. The next panel shows the number of protons per pulse, the radial position of the beam in the vacuum vessel. Below is a screen which can display one of many measurements made by the control computer (IBM 1800).
On the next panel there are monitors of the magnet cycle, three dials showing any fluctuation in the mains supply, and a general programming keyboard to control the sequence of operation according to the way in which the protons are to be used. The next panel records on tape the linac intensity, the number of protons accelerated per pulse and the mains voltage measured at various points.

T : display on a screen of machine data collected by the computer (these data are also printed out by the teletype below).

*Linac, Injection, Magnet Settings (photo 1)*

A : linac control — the panel in the corner presents information from beam observation stations and has an oscilloscope permanently displaying radial and vertical positions of the beam.

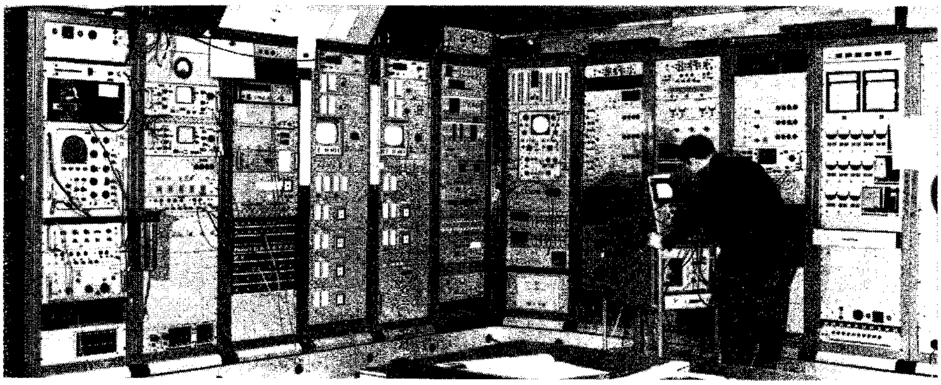
B : injection control — magnet correction and lens adjustment for injection, and measurements provided by beam current transformers. On the right, an oscilloscope shows a longitudinal cross-section of the proton bunches.

C : programming and measurement of the currents in the PS magnets ; dipoles, quadrupoles, sextupoles, correcting coils, etc...).

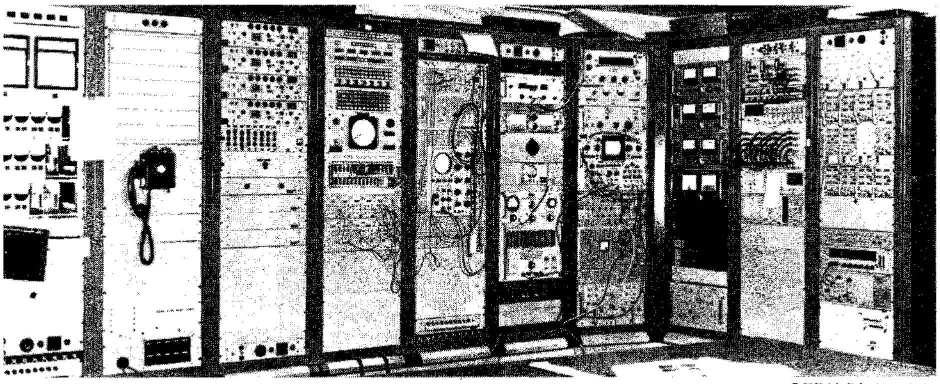
*Safety, Beam Measurement (photo 2)*

P2 : safety system for the access doors to the ring and emergency beam-off devices (small synoptic diagram).

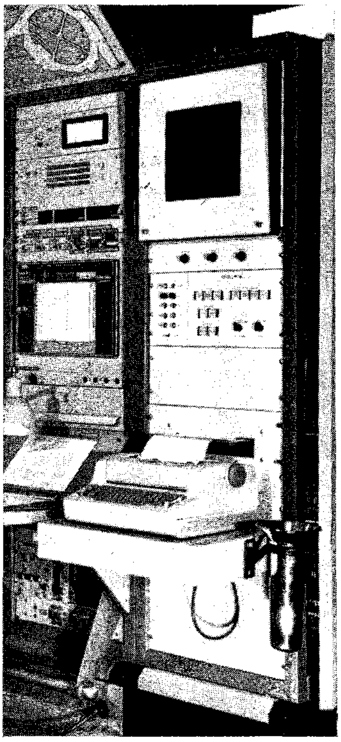
D : measurements on accelerated beam -



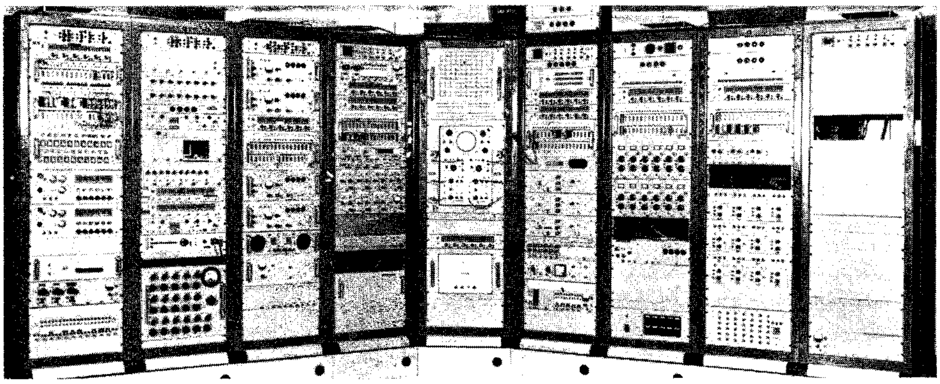
5. CERN/PI 209.1.69



6. CERN/PI 207.1.69



CERN/PI 203.1.69



7. CERN/PI 204.1.69

observation stations, mean radial position, timing related to the r.f. frequency.

*Ejection (photo 3)*

H : control and measurement of ejection (magnet supplies, timing, etc...). The position of the ejected beam can be observed on the screen in the third panel from the left.

*Beam Losses, Beam Transport (photo 5)*

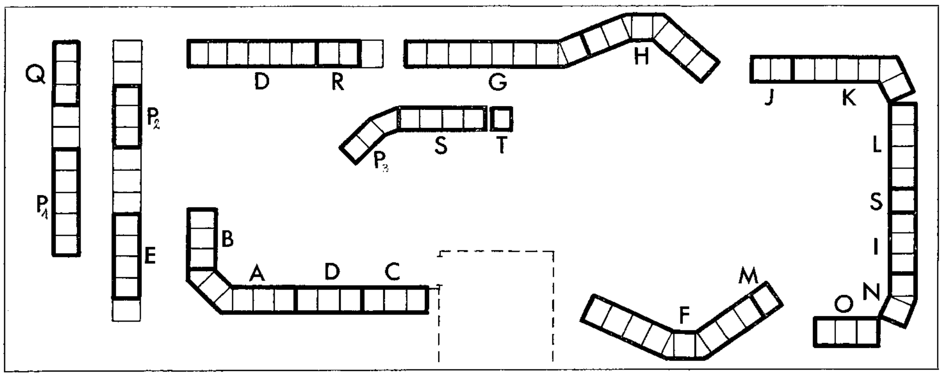
J : system for detecting beam losses in the ring.

K : ejected beam controls with facilities for closed circuit TV observation of the beam position on scintillation screens at various points along the beam-lines.

L : other ejected beam monitors ; measurement of ejection efficiency. On the right are radiation level indicators for the East Hall.

*Miscellaneous Equipment (photo 6)*

S : general operation monitors (above the telephone). At the top is a display of the number of protons accelerated per pulse.




I : controls for the full-aperture kicker.

N : signal from the beam scanner (IBS).

O : system for obtaining digital data (SEN). Some fifty parameters or their average over a certain number of cycles can be printed out.

*Internal Targets ; Beam Utilization (photo 7)*

F : monitoring beam utilization on internal targets (positioning of targets for each cycle, measurement of position, control of beam spill).

M : central programming system for all uses of the beam — targets, ejection, etc...

*Hidden Panels*

P1 : transistorized logic circuits for the PS and ejection safety systems.

Q : systems under development for measuring the beam intensity and for feeding this data to the IBM 1800.

G : controls for fast kicker 97.

E : timing system. Distribution of pulses related to the main magnetic field and the rotation speed in the main magnet power supply. Timing measurements.

# Around the Laboratories

*A cross-section drawing of the 7 foot hydrogen bubble chamber. Note that the superconducting magnet coils are not sketched in on this drawing. They sit in the helium dewar above and below the position of the beam windows. The common vacuum tank for the chamber and the helium dewar is 3.2 m in diameter and 5.5 m high, serving also as a protective enclosure in case of component failure.*

*Aerial photograph, taken in November 1968, of the equipment being installed for the neutrino experiment at the Brookhaven AGS using the 7 foot hydrogen bubble chamber. The small map indicates :*

## Brookhaven 7 foot model

The first operation of a hydrogen bubble chamber in a neutrino beam will take place soon at the Brookhaven Alternating Gradient Synchrotron. The bubble chamber is known as the 7 foot model and despite its imposing size earns the modest title of 'model' because it was initially intended to test various features of a proposed 14 foot chamber.

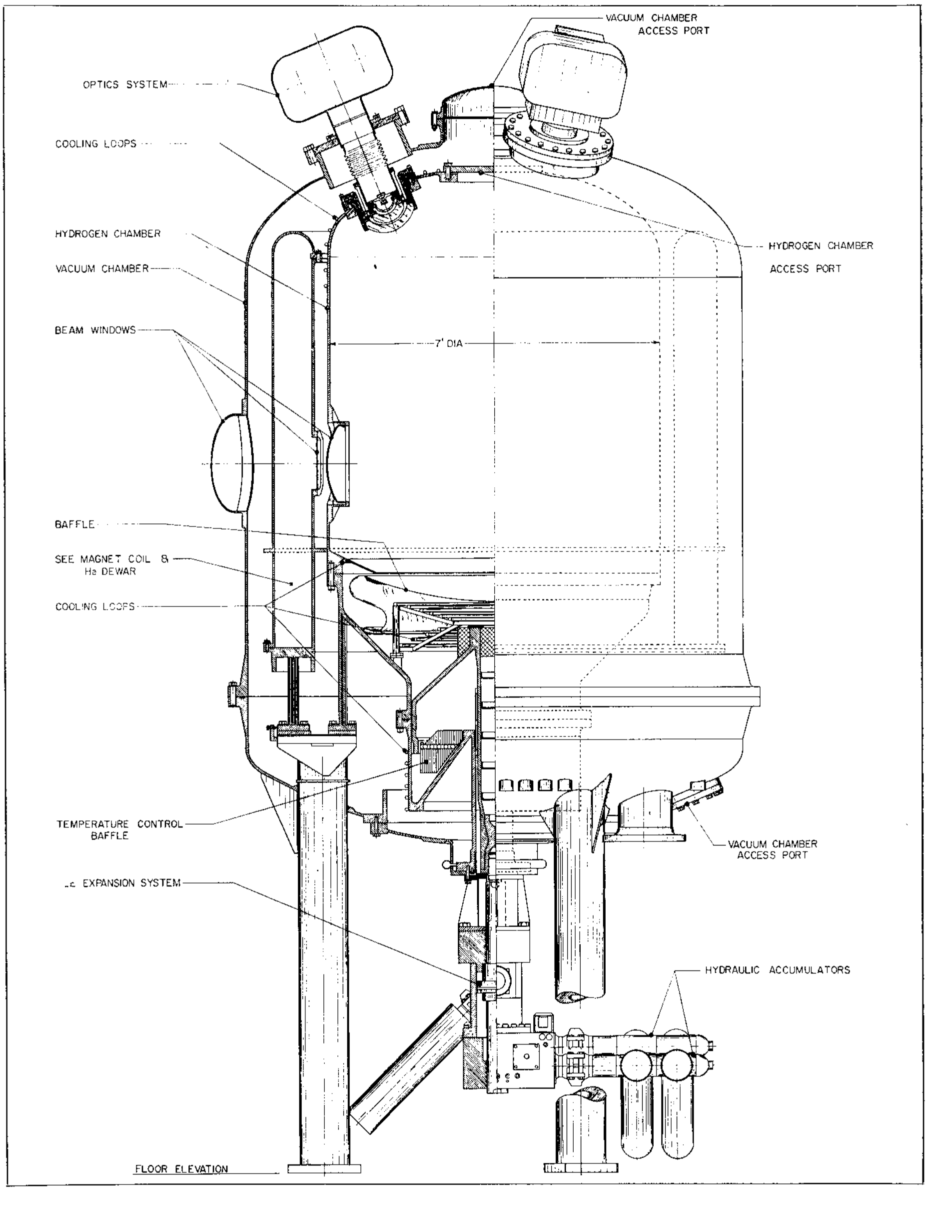
As far back at 1964, large volume hydrogen chambers were designed at Brookhaven but no funds were made available for construction of anything on the scale of the large European bubble chamber being built for CERN (see CERN COURIER vol. 7, page 143). It was decided in 1966 to start the 7 foot chamber for research and development testing of new concepts involved in the new generation of chambers such as the use of wide angle fish-eye window optics, superconducting magnets and plastic components in expansion systems. It was later decided, since finance for a larger chamber had still not appeared over the horizon, to use the model in a neutrino experiment while at the same time continuing the technical research.

A cross-section of the model can be seen in the figure the scale being set by the 7 foot (213.5 cm) internal diameter of the chamber vessel. The design has much in common with that of the large European chamber. The vessel has a total volume of 9400 litres and is constructed of stainless steel. The inner surface is covered with 'Scotchlite' retro-directive coating. Three camera ports are located on top of the chamber, each camera looking through three spherical windows which serve to contain the liquid hydrogen, to provide thermal radiation shielding and to seal the vacuum tank. The light sources to illuminate the bubbles are located close to the lenses so that the Scotchlite efficiently returns light to the cameras and the bubbles appear as dark spots on a bright background (bright-field illumination).

The expansion system is located at the bottom of the chamber and involves several novel ideas such as the use of a glass-fibre reinforced plastic for the 42 inch (107 cm) diameter expansion piston. The piston moves about 10 cm in 25 ms to give a 1 % expansion. It is driven by a fast response hydraulic unit which will allow multiple pulsing during a single accelerator pulse (see CERN COURIER vol. 8, page 312). For the neutrino experiment, the full beam intensity will be used to produce each burst of neutrinos to the chamber and multiple pulsing will therefore not be used.

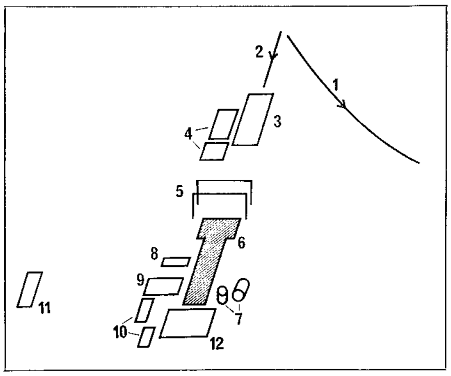
*Superconducting magnet*

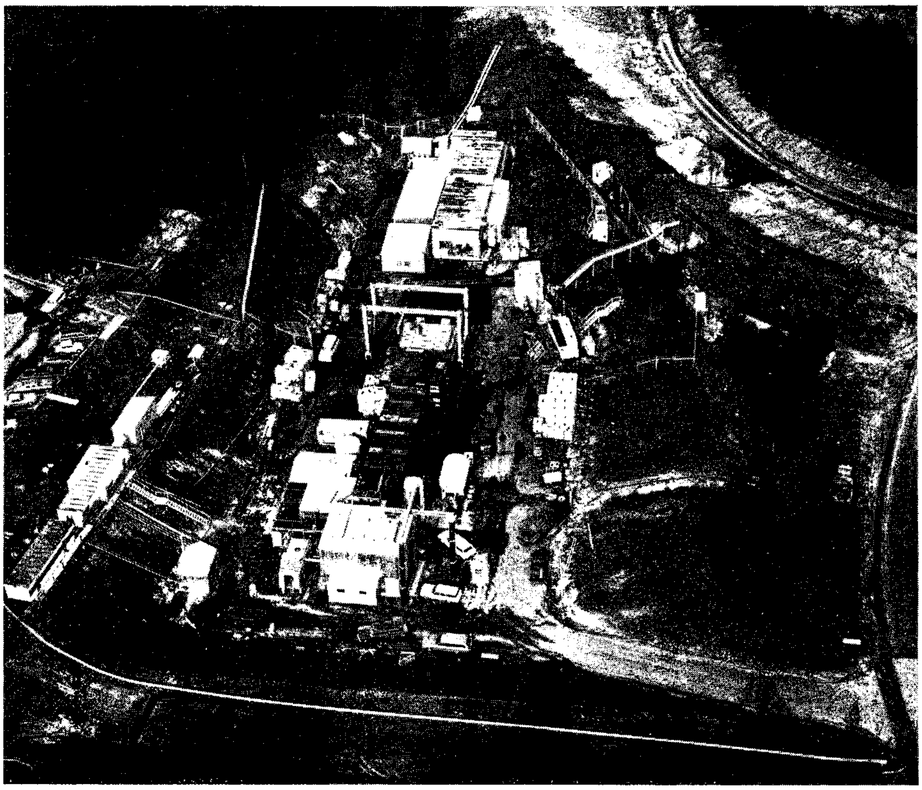
A vital feature of the new chambers is the use of superconducting magnets to produce the magnetic fields. In the model a composite superconductor is used, with six niobium-titanium filaments embedded in a ribbon of high conductivity copper, to give a field of 30 kG at the centre of the chamber. The ribbon is 5 cm wide and 2 mm thick and will carry a current of 6000 A. There is no iron yoke, which has given greater flexibility in the design and



1. *Direction of protons in the accelerator*
2. *Direction of the fast ejected proton beam*
3. *Concrete shielding house for magnetic finger focusing device and target*
4. *Power supply houses*
5. *Large gantry crane used for installing shielding*
6. *12 000 ton iron shielding 38 m long*
7. *Large hydrogen and deuterium dewars*
8. *Hydraulic power supply trailer for chamber expansion system*
9. *Building for helium equipment needed for superconducting magnet*
10. *Vacuum pump trailers*
11. *Control trailer*
12. *Building housing 7 foot bubble chamber.*

*(Photos Brookhaven)*



has reduced the cost. Liquid helium from a 240 W helium refrigerator-liquifier will maintain the superconductor at a temperature of about 4.8° K. Further parameters of the coils are as follows :

| | |
|---|---|
| Number of double pancakes in two coil halves | 16 |
| Total number of layers | 32 |
| Number of turns per layer | 45 |
| Ampere turns | $8.64 \times 10^6$ |
| Maximum central field | 30 kG |
| Maximum field at coil | 40 kG |
| Distance between top and bottom half | 34 cm |
| Coil inside diameter | 244 cm |
| Coil outside diameter | 280 cm |
| Total length of conductor | 12.2 km |
| Total weight of coils | 14 515 kg |

The coils were powered to 3500 A in May 1968 and following this first test several changes have been incorporated to ensure that full power can now be achieved.

The layout of the neutrino beam-line the bubble chamber and associated equipment is shown in the photograph. Cooldown of the chamber is scheduled to start this month (January) followed by operation of the magnet as soon as tracks have been photographed.

The neutrino experiment will use deuterium in the bubble chamber. It is intended to take one million pictures and about 2000 events are anticipated with the present AGS intensity of $2 \times 10^{12}$ protons per pulse and an improved three element magnetic 'finger' focusing device which will aim the neutrino parent particles at the chamber. It is hoped to take several hundred thousand pictures prior to a five month shutdown of the AGS which is scheduled to start in June.

In addition to their primary purpose of contributing important new information to the understanding of the weak interaction (see CERN COURIER vol. 6, page 211) these pictures will be of interest to the bubble chamber specialist since they will reveal what accuracy in the measurement of track positions can be achieved when photographing through long distances of liquid hydrogen. With the advent of higher energy machines measurement accuracy becomes still more important and the results from Brookhaven are therefore awaited with considerable interest.

## Batavia Neutrino plans

Plans for neutrino experiments at the National Accelerator Laboratory with the USA 200 GeV accelerator took shape at the 1968 Aspen Summer Study on the experimental programme for the new machine. The general consensus was that a neutrino programme should be based on a hydrogen bubble chamber of about 100 m³ volume. Toward this goal, in May 1968, the National Accelerator Laboratory and Brookhaven National Laboratory had agreed to collaborate in the construction of a 25 foot hydrogen bubble chamber. BNL will be responsible for the detailed design and construction of the chamber while the parameters which affect its research capabilities are to be agreed upon by both laboratories. The site plan, the design, construction and assembly of beams, buildings and on-site utilities necessary for operation of the chamber, will be the responsibility of NAL.

By the end of 1969 it is intended to produce a conceptual design of the bubble chamber (but not detailed design drawings). The present thinking envisages a chamber of 105 000 litres volume, 72 000 litres being seen by three cameras. Six cameras in all would be installed and two groups of three could for example be operated separately, one group for neutrino pictures and the other group for charged particle pictures if the chamber were operated in a double pulsed mode. A superconducting magnet would produce a field of 40 kG in the useful volume.

Money for the conceptual design of the chamber is presently being requested. If funds for construction are obtained in July 1970, detailed design could start with a view to completing construction by the end of 1973. By that time it is expected that the accelerator will reach its full design intensity of $5 \times 10^{13}$ protons per pulse. A tentative cost estimate for the chamber is $ 17 M, including $ 4 M for deuterium to fill the chamber.

Design concepts of the NAL neutrino beam facility are being studied ; it is not intended to freeze the design for the neutrino beam-line itself until September 1970. The beam-line as conceived at present is 2½ km long, including focusing elements for the neutrino parents ($\pi$ and K mesons) and a shield of 600 m of earth to filter the neutrinos. Such a long shield will cause a considerable drop in the intensity of the neutrino beam below about 4 GeV neutrino energy, but using earth may save several million dollars compared with a shorter (denser) iron shield.

The various elements of the neutrino facility are being designed with half an

*A simplified representation of the proposed heavy ion accelerator.*

1. *is the injection point*
2. *are the magnetic mirrors which send the ions repeatedly through the tandem accelerator*
3. *are the solids which strip the ions to carry high charge during their acceleration stage in the tandem (note that the precise position of the solids would not be as drawn)*
4. *is the gas at the high voltage terminal which results in lower charge for the deceleration stage in the tandem.*

eye to economical adjustment for operation with a 400-500 GeV beam later.

Physics experiments will begin at NAL in July 1972 when a 200 GeV proton beam will be available in the first experimental area. Soon after, neutrino physics could begin in the neutrino area with counter — spark chamber experiments, before the 25 foot hydrogen chamber comes into operation at the end of 1973.

Late news : President Johnson's budget for the fiscal year beginning 1 July 1969 includes a sum of $ 102 Million for the National Accelerator Laboratory — the full amount requested for the construction of the 200 GeV machine in the coming year.

## Serpukhov Neutrino plans

A series of neutrino experiments are also being prepared for the highest energy accelerator currently in operation — the 76 GeV proton synchrotron at Serpukhov, USSR. Both a large spark chamber array and a heavy liquid bubble chamber are planned.

A gallery 360 m long and 24 m wide is being constructed between the huge experimental hall which spans the machine and the position where two bubble chambers will sit, a hydrogen chamber 'Mirabelle' being constructed in France and a heavy liquid chamber 'SKAT' being constructed in the Soviet Union. For the neutrino experiments the gallery will accommodate the ejected proton beam, target, focusing horn, decay length for the neutrino parents and 50 m of iron shielding as the neutrino filter. A spark chamber array will preceed the heavy liquid bubble chamber which will be located 200 m from the target.

It is intended to use SKAT filled with freon for the neutrino experiments. The chamber dimensions are 4.5 x 1.5 x 1.1 $m^3$. It is intended to take a million pictures in the neutrino run, hoping for neutrino events at the rate of 6000 per day, with the intensity of the accelerator at $10^{13}$ protons per pulse.

The experiments will be concerned particulary with a search for the intermediate boson (up to 4 GeV in the SKAT, 6 GeV with the spark chambers), total cross-section measurements (up to 20 GeV in SKAT, 50 GeV with the spark chambers) and elastic cross-section measurements (up to 10 GeV in SKAT, 20 GeV with the spark chambers).

## Heidelberg New acceleration scheme

A new method for accelerating heavy ions has emerged from work (particularly at the Max Planck Institute Heidelberg, and Freiburg University, with valuable contributions from CISE, Karlsruhe and Dubna) led by G. Hortig. It uses the variation in the average charge carried by a heavy ion depending upon the density of the material it traverses, and involves passing the heavy ions backwards and forwards through the same system increasing their energy at each passage. The cost of such an accelerator could be comparatively cheap and it may be capable of accelerating, for example, uranium ions up to 3 GeV. A talk on the new method was given by Hortig at the 1st National USSR Accelerator Conference in Moscow on 8-17 October 1968.

The basic ideas of the proposed accelerator are quite simple and will be described here but the problems involved in retaining a focused ion beam while passing it repeatedly through solid and gas strippers are by no means simple. However, this problem has been investigated intensively and it has been found that effects such as multiple scattering can be countered by suitable design of the ion optics. Achromatic lens systems, involving magnetic mirrors and many quadrupole focusing doublets, have been worked out. As explained below, the whole process is statistical and Monte Carlo programmes are used to study scattering and charge exchange.

The principle of operation depends upon the following phenomenon : As ions pass through matter they lose and pick up electrons and it was found by N.O. Lassen in 1949 that the average charge carried by a heavy ion depends upon the density of the matter it traverses. For example, the average equilibrium charge on a uranium ion in solids is about twice as high as it is in gases. ('Equilibrium' here refers to the fact that it takes a certain thickness of matter to reach a stable average value - it is not necessary that these equilibrium values be reached for the accelerator to operate.) In addition, the average charge depends upon the ion velocity and the actual charges carried are distributed in a very narrow range around the average value.

These facts can be used to accelerate heavy ions from one end to the other of a tandem accelerator using solid and gas strippers as shown schematically in the

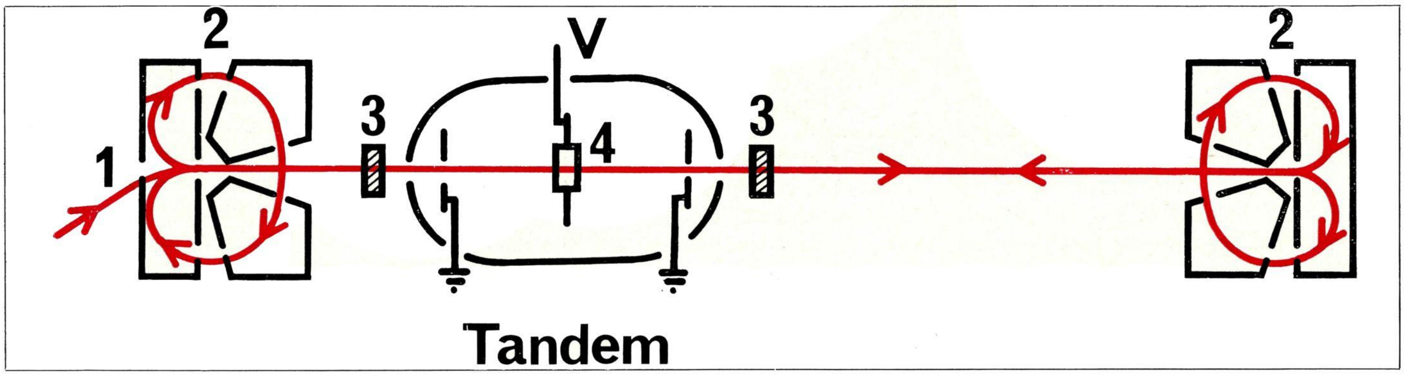


diagram. At earth potential the ion beam passes through a solid and emerges with a high average charge, $\bar{q}$ solid, and is accelerated to the central high negative voltage terminal, which has a voltage V, gaining energy eV($\bar{q}$ solid). The beam then passes through a gas and the average charge falls to ($\bar{q}$ gas). In the second stage of the tandem it is then decelerated losing energy eV($\bar{q}$ gas). The total gain in energy is then

$$eV(\bar{q} \text{ solid} - \bar{q} \text{ gas})$$

This gain in energy is limited to about 20 MeV and, to reach the energies of several GeV which are required for research, the cycle has obviously to be repeated many times. To construct a series of tandems in line is not practicable and therefore two magnetic mirrors, to send the beam back through the same tandem, are needed — one on each side as shown in the diagram.

These magnetic mirrors and the beam focusing system have to be 'achromatic' because they will be dealing with ions having a charge distribution, and therefore energy distribution, around an average value. They also have to cope with a range from injection to full energy — they will be d.c. operated. Just as an achromatic optical lens brings to the same point light which starts from the same point regardless of its wavelength, so achromatic magnetic lenses bring to the same point particles starting from the same point regardless of their energy. With achromatic ion optics it will be possible to retain the ion beam despite the charge and energy distribution. (A further focusing effect can be gained in the charge changing processes.)

The output of the accelerator would be continuous and operation involves no pulsed components. The high voltage system and all the magnets would be d.c. operated.

Work on this new idea has so far been rather scattered and the time is ripe for it to be concentrated in one place. It is estimated that about three years further development, involving an investment of less than 2 Million DM, would be needed before embarking on construction of an accelerator at a cost of around 20 Million DM.

## Minnesota Close down of PLA

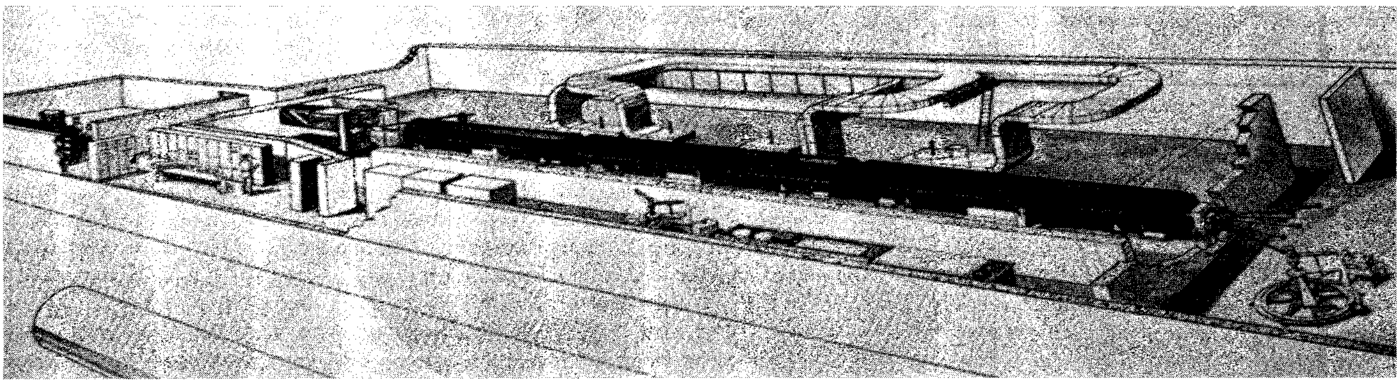
The 68 MeV proton linear accelerator of the John H. Williams Laboratory at the University of Minnesota, USA, has been closed down in January after fourteen years of operation. For many years it was an almost unique research accelerator (the only equivalent one being the 50 MeV PLA at the Rutherford Laboratory — which is also due to be closed down in six months time) but this type of machine has now been superseded by the sector-focused cyclotron which can do more efficiently the research for which the linear accelerator was designed.

### *Machine design and performance*

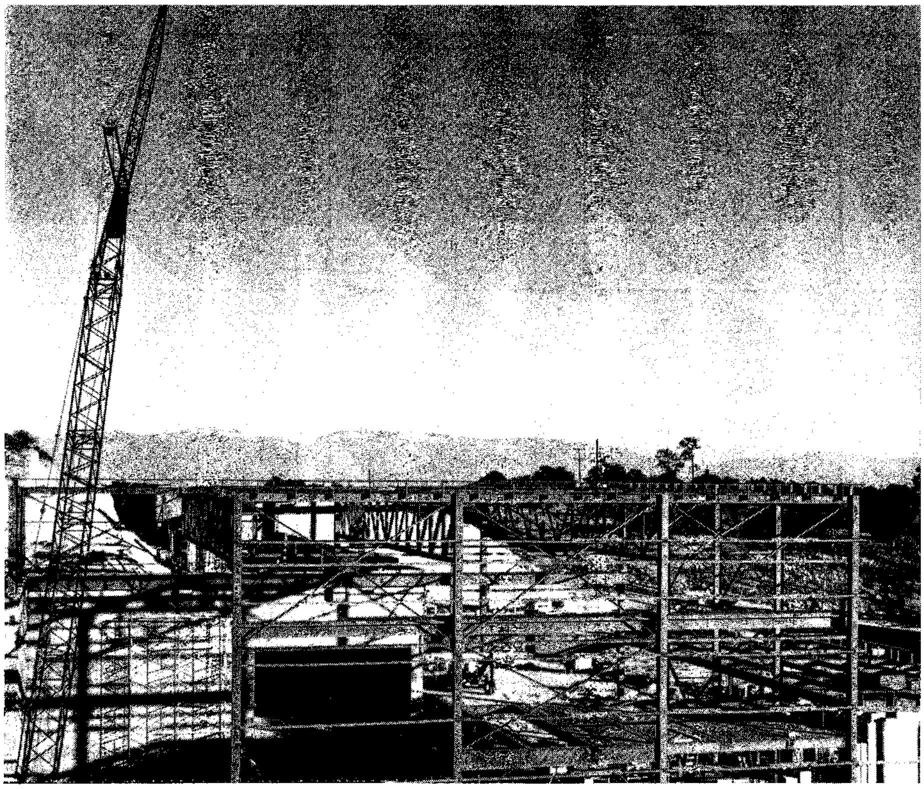
Following the successful operation of a 32 MeV proton linear accelerator at Berkeley in 1948, based on a new design by L. Alvarez, it seemed possible that much higher energies could be obtained from linear machines by using several of the Alvarez-type accelerator cavities in series. J.H. Williams at the University of Minnesota was then searching for much higher energies than he could obtain with his 4 MeV Van de Graaff to extend his nuclear physics research. He gained the support of the US Atomic Energy Commission and the State of Minnesota for the construction of a proton linear accelerator to reach an energy of around 60 MeV.

Design work began in July 1949 and actual construction in 1951. There were several design features, some of which are now standard practice on the linear injectors of large synchrotrons, which were confronted for the first time with the Minnesota machine. One was the choice of 'injection' energy — the energy at which protons are fed into the first resonant cavity. Alvarez had used a horizontal Van de Graaff giving 4 MeV, one reason for this high injection energy being that the particles had to pass through thin aluminium foils which would cause excessive scattering of lower energy particles. A foil covered the aperture in each drift tube to establish the required focusing fields along the accelerator.

By the time the Williams design was taking shape, tungsten grids were preferred to foils and lower injection energy was acceptable. (Note that the newer proton linear accelerators on the synchrotrons use neither foils nor grids. Their focusing function has been taken over by magnetic quadrupole lenses mounted inside the drift tubes. Quadrupole lenses were developed in 1952). 500 keV was chosen as the injection energy being high enough to avoid trouble with the design of the drift tubes at the low-energy end of the machine, and low enough to avoid a pressurized enclosure for the injector which had been a servicing problem on the Alvarez machine.



*An artist's impression of the 68 MeV proton linear accelerator of the John H. Williams Laboratory, University of Minnesota. The accelerator closed down this month after contributing to nuclear physics research for fourteen years.*
*(Photo Minnesota)*



*Construction work on the 800 MeV proton linear accelerator is in full swing at the Los Alamos Laboratory. In the photograph, the Injector and 201.25 MHz Sector Building is taking shape. The 850 m long accelerator will point towards the Sangre de Cristo mountain range in the background.*
*(Photo Los Alamos)*

Design of the 6 GeV Bevatron was under way at the same time and Williams settled for the 10 MeV Bevatron injector energy as the first stage of the Minnesota machine. (The Bevatron injection energy has since been raised to 20 MeV.) A joint design resulted and components were manufactured in duplicate for both machines. (The same drift-tube design was later adopted for the first stage of the CERN PS injector and at Rutherford. A more recent, human link with CERN was when R.P. Featherstone, who led machine operation at Minnesota, worked at the PS a year ago. He is now at Batavia.)

The cavity in the Alvarez machine was 12 m long and two more of them were obtained from the same manufacturer to act as stage two and three of the Minnesota machine. Thus the linear accelerator was a three cavity device with energies of 10 MeV, 40 MeV and 68 MeV at the end of successive stages.

The three cavity design required perfect synchronization between the accelerating fields in the separate cavities. It was decided to drive each one from a power amplifier and in turn to drive the three power amplifiers from a common source. Selection of the amplifier valves was very difficult at that time — the Alvarez machine had a high failure rate with 100 valves and the idea of multiplying this to perhaps 250 was not a happy one. The specification was peak output power 4 MW at 202.55 MHz with a pulse length of 300 μs and a repetition rate of 60 Hz. Collins Radio Corporation proposed a system based on their experience with 50 kW 'resnatrons' used for jamming radar during the war. After many modifications these proved very successful and one resnatron operated at about 600 kW for over 12 000 hours.

Proton beams were accelerated for the first time to 10 MeV in 1954 and to 40 and 68 MeV in 1955. Research using the machine began as soon as 10 MeV beams were available. Since then the accelerator has operated on a 160 hour schedule and in recent years the percentage of scheduled hours lost due to breakdown has been about 12%. Most of the experimental work has been carried out at 40 MeV with smaller amounts at 68 and 10 MeV.

It was not possible to make major improvements (such as replacing the grids by quadrupoles to greatly increase the intensity of the accelerated beam — as was done in the first cavity of the CERN injector) but a variety of smaller improvements were carried out. The most interesting was the addition of a polarized proton source in 1960 ; an improved version came into service in 1966 delivering about $10^7$ protons/s at 40 MeV with 55% polarization.

*Research programme*

The major research achievements were the series of precision proton-proton scattering experiments from 10 to 68 MeV led by L.H. Johnston ; the extensive elastic scattering cross-section and polarization studies principally by J.H. Williams, N.M. Hintz, R.M. Eisberg, G.W. Greenlees ; and the inelastic scattering and one- and two-particle transfer work led by N.M. Hintz.

Shortly after a 10 MeV beam was obtained, Williams and his students began a programme of elastic proton-nucleus scattering using a multi-plate camera originally built at Los Alamos by Williams and others. This led to extensive research on the optical model which continued to the last days of the machine.

Williams recognized in the mid 40's that nucleons in the energy range up to 68 MeV had a de Broglie wavelength such that elastic scattering angular distributions would be very sensitive to nuclear size and shape. The first major survey work on elastic scattering at 9.8 MeV was by Hintz. Its analysis by A.E. Glassgold and others showed clearly, for the first time, that elastic scattering data of moderate precision could not determine the radius and depth of the optical potential separately, but only fixed some product such as $VR^n$. Later, more accurate studies (one of the early surveys of elastic scattering on separated isotopic targets) and polarization studies, followed by an extensive series of scattering experiments and by the reformulated optical model analysis, established the Williams Laboratory as a major contributor to the study of nuclear matter and potential distributions.

Many of the most accurate elastic scattering and polarization studies yet done in the 10 - 40 MeV range have been completed in the last two years and are in press or are being analyzed. A major conclusion of the reformulated optical model is that the elastic and polarization data determine only the r.m.s. radius of the nuclear matter distribution, and not V, R and a (diffuseness), separately. The work shows unambiguous evidence for a neutron skin on the nucleon surface of approximately 0.7 f for heavy nuclei.

Also during the first years of machine operation, Johnston began a programme of precision p-p scattering measurements at 10, 40 and 68 MeV and at various energies in between. The objective was to obtain p-p data of an accuracy previously only attained at much lower Van de Graaff energies (approximately ± 1 % absolute) and far better than that usual for energies above 100 MeV (approximately 10 %). The work of Johnston and his collaborators remains the definitive work in this energy range and is included in every major new analysis of the nucleon-nucleon data.

The nuclear reaction and nuclear spectroscopy work of greatest importance were those on total proton reaction cross-sections where attenuation techniques were first developed and from which evidence emerged for imaginary potential radii larger than real radii, and those on inelastic scattering and two-neutron pickup reactions.

An important new line of work began in 1962 on (p, t) reactions. This was the first systematic work relating two-neutron pickup amplitudes to nuclear structure and illustrating the power of the reaction to determine two-neutron correlations (or configuration mixing) in nuclear wave functions.

J.H. Williams died in 1966 after more than thirty years of teaching and research at the University. He had been a source of inspiration throughout the construction of the machine and the development of the research programme. The Laboratory was renamed after him — the John H. Williams Laboratory of Nuclear Physics. Perhaps one of the finest tributes to the machine that he built and the nature of the Laboratory that grew around it, is to note that 29 research students gained their Ph.Ds on the basis of work performed on the accelerator in the years 1954 to 1968.

## Los Alamos LAMPF construction

With the release by the Bureau of the Budget, last October, of $26 Million for construction, the LAMPF project (Los Alamos Meson Physics Facility) has moved into top gear. (For detail of the design of the 800 MeV proton linear accelerator see CERN COURIER vol. 8, page 132.) $33 Million has been released so far which is more than half the cost estimate prepared in 1964 ($55 Million). Despite the many novel features of the project this cost estimate is still valid and the construction team still hold to the completion date of mid-1972.

The Equipment Test Laboratory has been completed, the building for the 750 keV injector is well under way and contracts for a Laboratory and Office building and for the 850 m long beam channel have been placed.

Construction of the waveguide section of the accelerator (using the new concept of side-coupled cavities) has started with the award of the contract for the copper forgings of the first fifth of the section.

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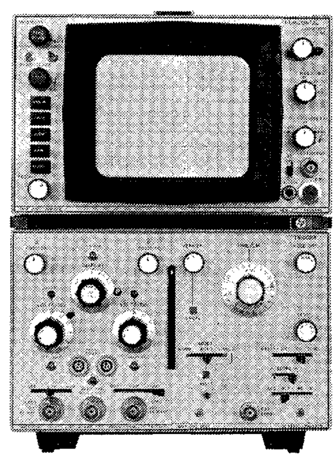

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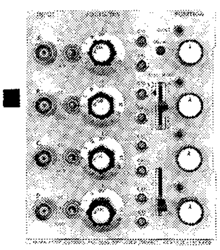

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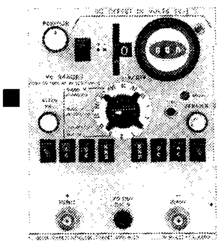

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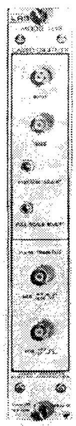

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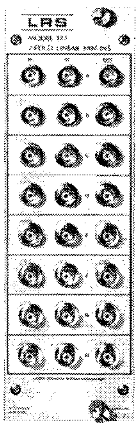

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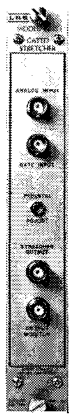

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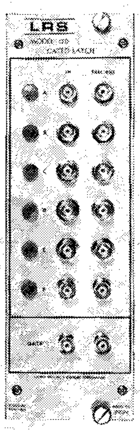

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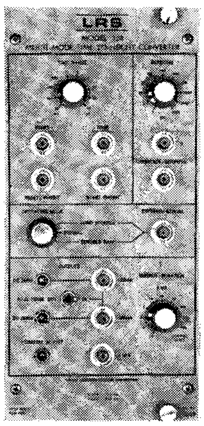
**6-CHANNEL GATED LATCH**

Six independent latch circuits store slow logic voltage level indicating coincidence events between channel input and common gate input. Separate fast logic outputs permit additional immediate use of coincidence information in logic system.

**Inputs:** 6 plus common gate; 2 paralleled BNC connectors permit reuse of gate signal. **Buffer Register Outputs:** 0 and +4 volts; duration same as readout strobe; via rear connector. **Fast Logic Outputs:** One per channel; −16 mA during output; duration internally adjustable from 10-1000 ns.



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Measures time intervals from 50 ns to 50 μs (50 ms optional). The **THREE** operating modes offer long-term data storage (Analog Storage Mode), sequential time measurements (Multiple Stop Mode), and a prompt readout (Normal Mode).

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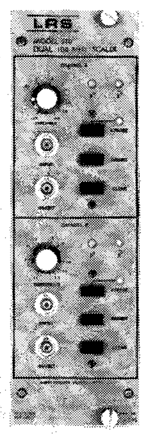

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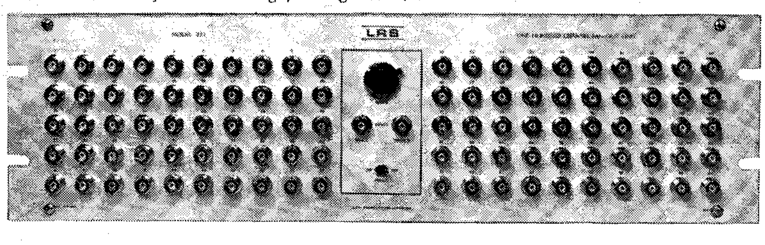

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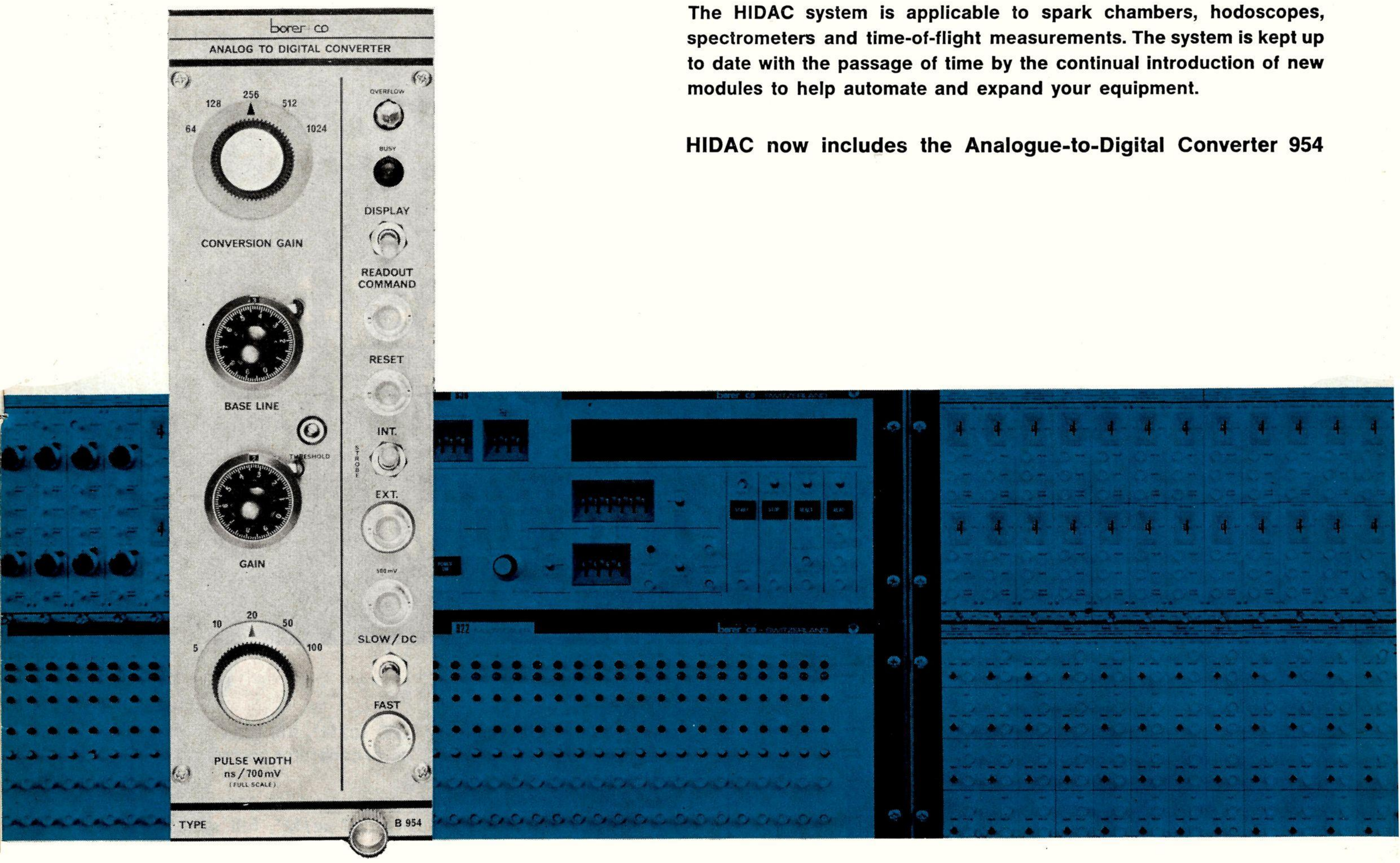


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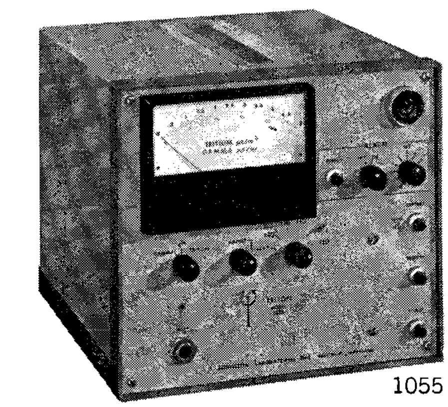

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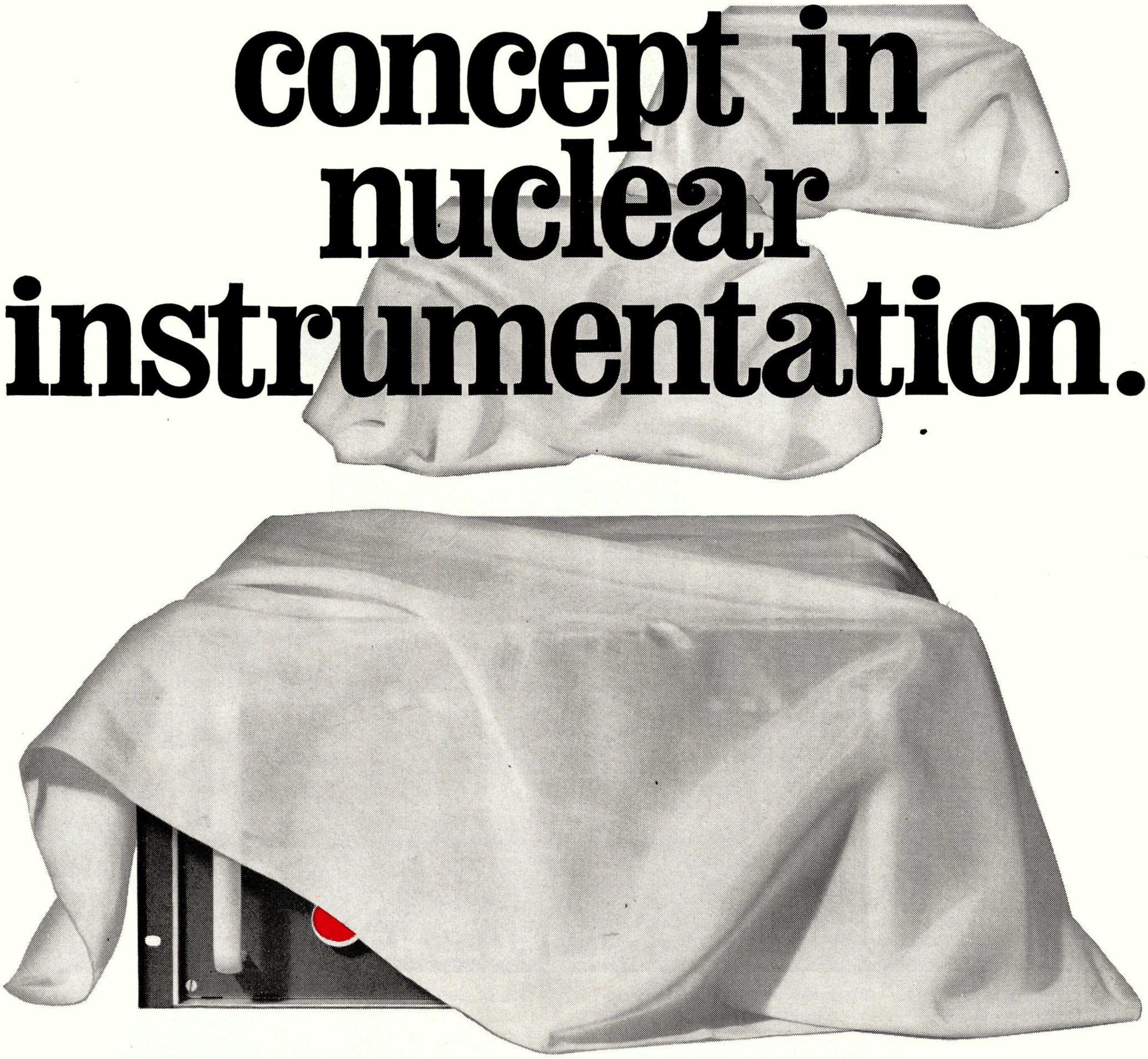

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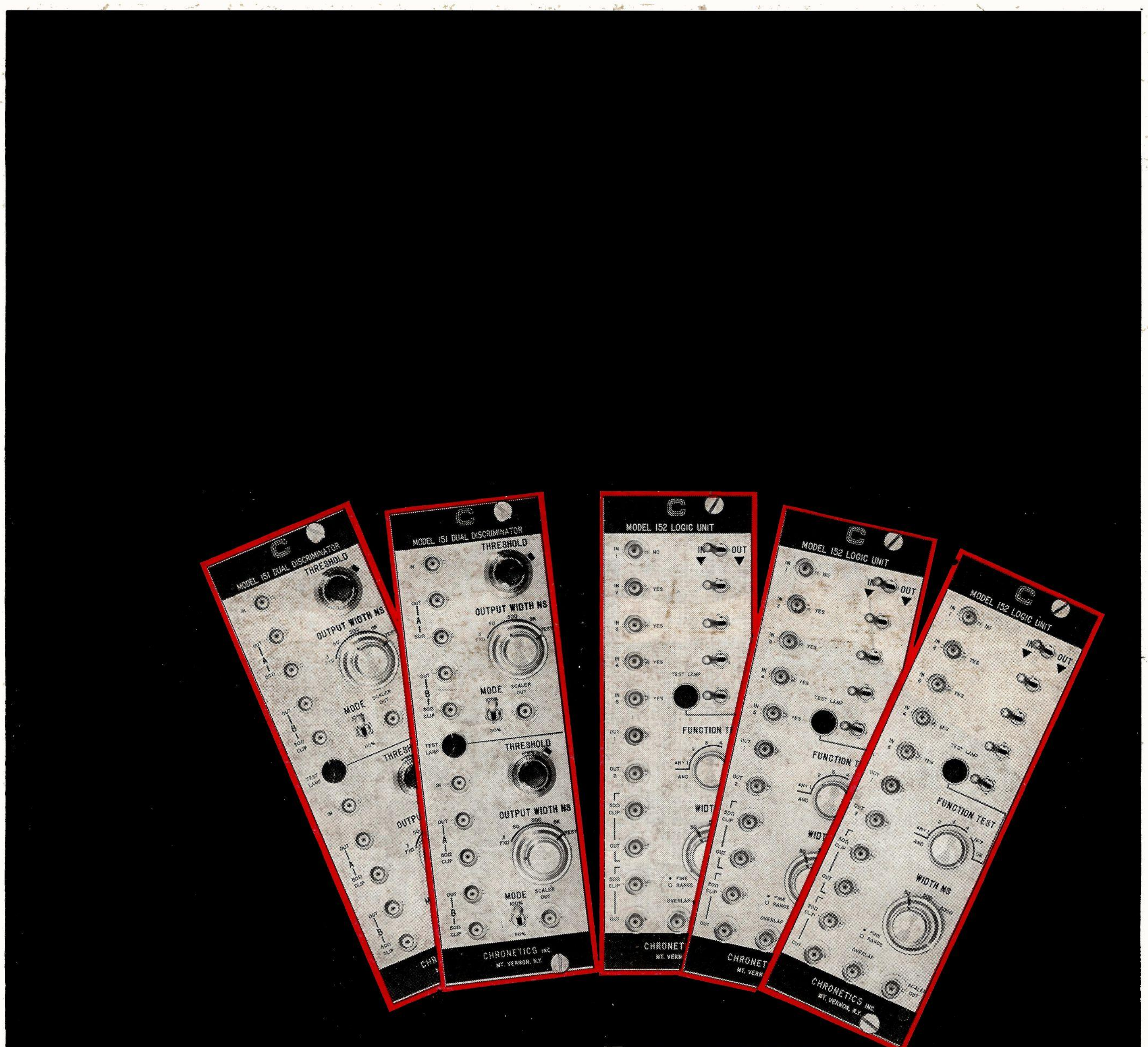


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