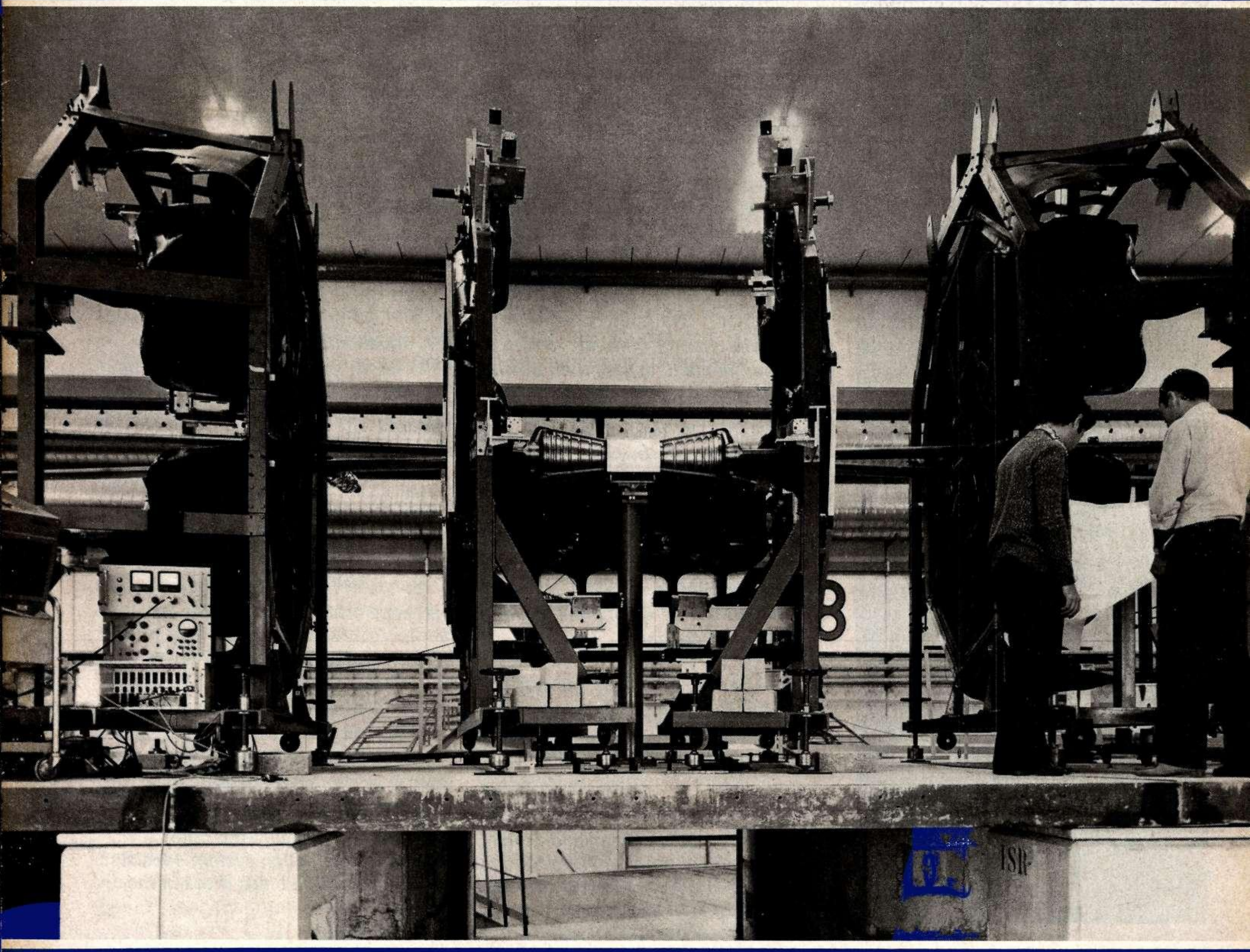
CERN COURIER

No. 9 Vol. 11
September 1971

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 scientific 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. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. 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 research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3000 people and, in addition, there are about 650 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 353.4 million Swiss francs in 1971.

The CERN Laboratory II was authorized by ten European countries in February 1971; it will house a proton synchrotron capable of a peak energy of hundreds of GeV. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1971 is 29.3 million Swiss francs.

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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Photographs: PIO photographic section

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Printed by: Ed. Cherix et Filanosa S.A.
1260 Nyon, Switzerland

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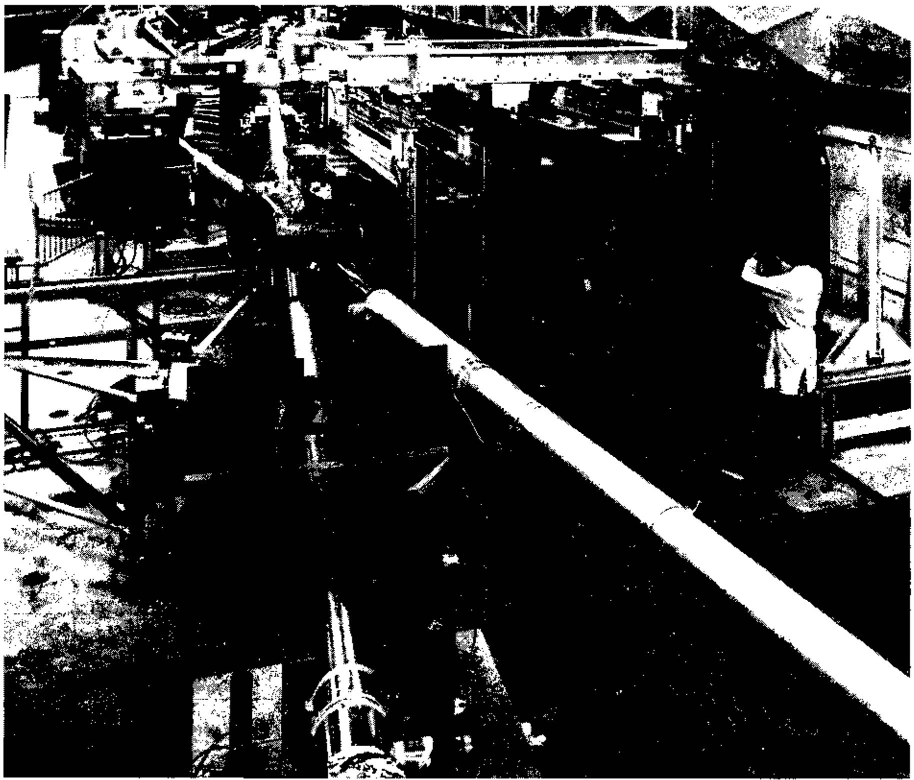
Around the Laboratories

Cover photograph : Intersection region I-8 of the ISR where a collaboration of scientists from Pisa (Italy) and Stony Brook (USA) will measure the total cross-section of the proton-proton interaction. Their detection system consists principally of a large array of counters (appearing as large black discs in the photograph) around the beam-pipes. (CERN 306.8.71)

Experiments at the ISR

A run-through of the present and near future experimental programme at the Intersecting Storage Rings.

Intersection region I-1 where, to the right, can be seen the detection system of the Saclay, Strasbourg collaboration which records gammas and electrons produced in the decay of particles which emerge from the collisions.



CERN 300.8.71

The chance to see what happens at the new range of energies available when proton beams are fired at one another in the ISR has given a new lease of life to the high energy physics programme in Europe. With energies in excess of what could be achieved at a 1000 GeV conventional synchrotron now at our fingertips there has been feverish activity to mount experiments, which are likely to tell us not only something new (practically all experiments aim to tell us something new) but something different. This ' something different ' might provide us with clues to help sort out the morass of information about particle behaviour that we have gathered over the past ten years.

Twelve experiments have been ' approved ' for the ISR programme involving some 200 physicists (not counting the manpower required for data handling). Seven are installed at the machine and taking data and four have already given results. We will move around the ISR tunnel looking at the intersection regions in sequence and saying a little about each experiment before coming back to give some more detail on the information already gathered.

Intersection I-1

Experiment R 101 : A Bombay, Bucharest, CERN, Cracow collaboration used nuclear emulsions to measure the angular and momentum distribution of particles flying out from the proton-proton interactions. Emulsions have been exposed over the angular range 35 to 90° and some results are being published. The study is continuing looking for such things as gammas from neutral pions, slow antiprotons, etc. The investigations are of a type particularly suited to emulsions or where emulsions can give a quicker look than other techniques.

Experiment R 102 : A Saclay, Strasbourg collaboration are catching gammas and electrons which emerge from the interactions with large transverse momenta. They have a large aperture magnet, a gas counter and wire chambers to help distinguish between particles followed by a shower chamber (optical spark chambers interspersed with lead plates) which ' sees ' the gammas and electrons. These could come from the decays of pions and kaons but also from the decay of the postulated intermediate vector boson (W) for example :

$$W^{\pm} \rightarrow e^{\pm} + \nu .$$

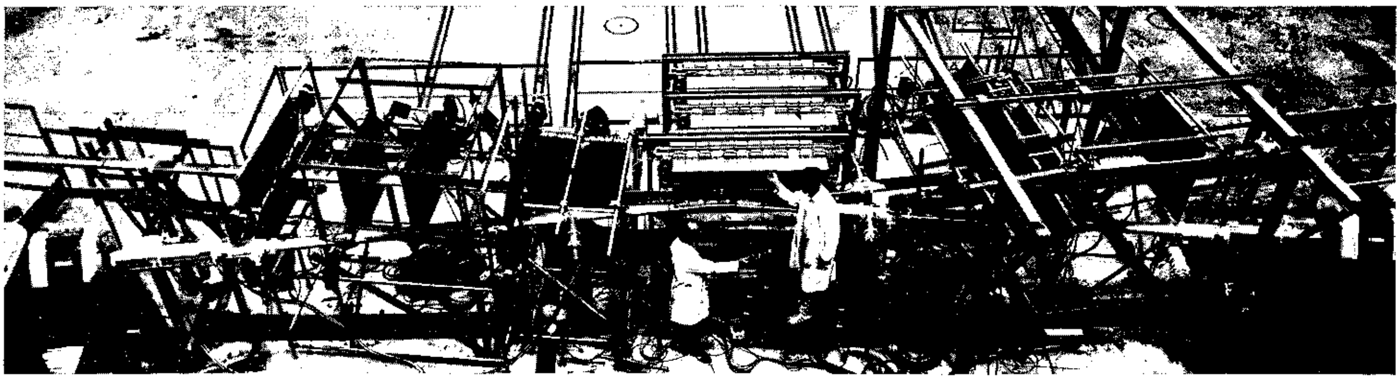
They are also looking for another type of postulated particle, the quark, via their tell-tale fractional charges. A CII 9010 computer is on-line.

Experiment R 103 : A CERN, Columbia, Rockefeller collaboration are having their equipment installed as R 101 is completed and will take data alternating with R 102. They will use wire chambers and lead glass Cherenkov counters in a search for massive particles which divide into electron pairs of high momentum. An HP 2116 B computer will be on-line.

Intersection I-2

Experiment R 201 : A CERN, FOM, Lancaster, Manchester collaboration is at an advanced stage of installation of equipment for an experiment to study particles produced at small angles (between about 15 and 150 mrad) and with momenta between about 0.5 and 25 GeV/c. The particles will be monitored in a spectrometer about 30 m long (beginning with two septum magnets and ending in a large Cherenkov counter) which climbs vertically over the top of the ISR magnets. An IBM 1800 computer will be on-line and linked to the central CDC computers.

Experiment R 202 : An Argonne, Bologna, Michigan collaboration has already some results on particle pro-



CERN 302.8.71

duction at medium angles (about 80 to 200 mrad) and momenta from 1.5 to 10 GeV/c. Their detector is a spectrometer extending over 45 m beginning with a septum magnet followed by two large bending magnets with scintillation and Cherenkov counters interspersed. They first looked at the emerging positive particles and have now moved to the negatives.

Experiment R 203 : A collaboration involving British and Scandinavian Universities have a double barrelled experiment involving a search for quarks and an extensive study of particle (pions, kaons, protons, etc.) production at large angles (30 to 90°). The detection system is a large mobile spectrometer arm (weighing about 30 tons) carrying two magnets, spark chambers and counters. A DDP 516 computer is in use on line. The experiment has started taking data on low momentum (below 2 GeV/c) particles. It will later be adapted to catch high momentum particles and search for quarks.

Experiment R 204: A U.K. collaboration have an experiment installed on the opposite side of the intersection region to R 203. They are concerned with a careful search for the intermediate vector boson through its potential decays into muons

$$W \rightarrow \mu^- + \bar{\nu}\ ;\ \mu^+ + \nu$$

With ISR interaction energies a W with a mass of several GeV could be produced and detected via its highly energetic decay muons. They will also study muon pairs from the decay of massive virtual photons. The detector is an optical spark chamber, iron plate sandwich weighing about 250 tons. It is surrounded by about 100 mirrors to allow the chambers to be photographed by a single camera. The whole is encased in a light-tight igloo which reaches to the roof of the ISR tunnel. Data handling is via a PDP 8 computer and the film will be measured at the Rutherford Laboratory.

Intersection I-4

This intersection region will eventually be occupied by the split field magnet (see, for example, vol. 10, page 148) which will be a ' universal ' detection system adaptible to a variety of experiments. Since its installation is a year away, the region is being used currently for test purposes. Two experiments have been ' accepted ' for the region.

Experiment R 401 : A CERN, Hamburg, Orsay, Vienna collaboration will study the energy dependence of the production of nuclear resonances.

$$p + p \rightarrow p + N^*$$

using multiwire proportional chambers and a neutron detection system in the split field magnet. The SFM computer system (EMR 6130 eventually linked to a CII 10070) will be used.

Experiment R 402 : A CERN, Munich collaboration is slipping in before the arrival of the SFM to carry out a quark search using a large assembly of scintillators and multiwire proportional chambers. They already have some estimates of cross-sections using the scintillator telescopes alone.

Intersection I-6

Experiment R 601 : A CERN, Rome collaboration was among the first to report results from the ISR. They are looking at elastic scattering of the protons down to very small angles. The published data covers 7 to 16 mrad ; the data to be gathered now goes down to 1.7 mrad or 1.4 mrad using special ' Roman pots ' which accommodate counters actually inside the machine vacuum chamber. Counters are thus arrayed downstream on each beam. They are coupled to an HP 2116 B computer.

Experiment R 602 : An Aachen CERN, Genoa, Harvard, Turin collaboration was another of the first teams with results from the ISR. They nicely complement the experiment above by extending the elastic scattering observations to wider angles (15 to 27 mrad). Sets of spark chambers around each downstream arm give added precision in the measurements. A PDP 11, an IBM 1800 and a link to the CDC computers covers data handling.

Intersection I-8

Experiment R 801 : A Pisa, Stony Brook collaboration has its equipment at an advanced stage of assembly. It aims to measure the total cross-section of the proton-proton interactions. The interaction region is surrounded with a vast array of counters to catch the particles flying out and, in order to have also the very small angle data, the results of Experiment 601 will be fed in.

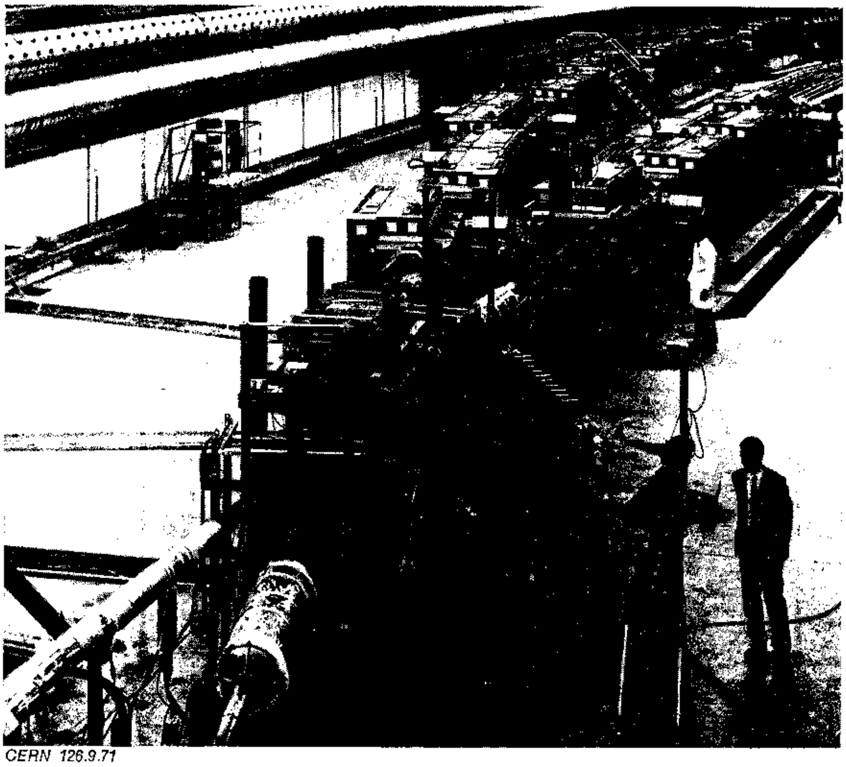
Experimental results

We now return to the four experiments which already have results. Three of them were covered in the account of the Amsterdam Conference on Elementary Particles in the July issue (page 185) and graphs illustrating their first data can be seen in that issue ; a graph illustrating data from the fourth experiment appears on page 242.

Most attention has been concentrated on the two experiments which have studied the elastic scattering of the colliding protons carried out by the CERN, Rome group (small angle data) and the Aachen, CERN, Genoa, Harvard, Turin group (wider angle data). Their results immediately modified the predictions based on measurements at lower energies. As a change from presenting results as a series of numbers and describing how they have been obtained, let us try to

Left : Intersection region I-4 where a CERN, Munich collaboration has slipped in (prior to the arrival of the split field magnet) to carry out a search for quarks.

Intersection region I-6 where elastic scattering measurements are being carried out. The small angle measurements are carried out by a CERN, Rome team and a ' Roman pot ', which has counters within the machine vacuum, can be seen at the bottom of the photograph on the beam pipe on the right. Detectors for the wider angle measuremens of the Aachen, CERN, Genoa, Harvard, Turin collaboration branch off to the right.



CERN 126.9.71

understand, very simply, why these two experiments are interesting and what they are telling us.

One of the ways to get to know the particles is to observe them under extreme conditions when hitherto unsuspected aspects of their nature can emerge. (However, it is worth remembering that the conditions we artificially set up at particle accelerators are only extreme on planet Earth. Research in astronomy and cosmology has shown that, on the scale of the Universe, a high proportion of particles live in just such conditions.)

The ISR enable us to throw protons together at energies far above what was possible before. To watch how they bounce off one another (elastic scattering) can tell us a lot about what form the proton has. This technique is far from new — we are, in fact, doing in a much more sophisticated way the sort of experiment that Rutherford did in 1911 when he fired alpha particles at a thin gold foil and, from the way they bounced off the atoms in the foil, deduced that the atom had a nucleus.

When we say ' what form the proton has ' we should not imagine a rigid geometrical structure. It is better to say ' what region of influence the proton has '. The information which had been previously gathered at accelerators (up to a peak energy of 70 GeV at Serpukhov) showed that as the energy of the protons increased, so the effective radius of the proton increased. When a proton rushed past another with higher energy then it felt, and was affected by, the other proton at a greater distance. (An analogy is that of a satellite travelling through the earth's atmosphere. If it is travelling slowly, i.e. with low energy, it will hardly feel the presence of the earth via its atmosphere. If it is travelling with high speed it can feel the earth via its atmosphere and can burn up. The higher its speed, the further out will this effect take place. The earth's region of influence grows with increasing energy.) By what mechanism one proton feels the influence of another we still do not fully understand and yet it is obviously fundamental to understanding particle behaviour. Thus more knowledge of this phenomenon is important.

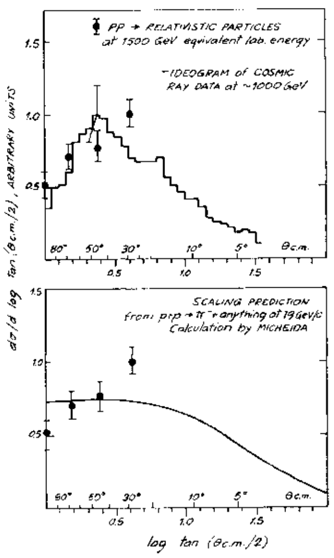
When protons are fired at one another in the ISR at energies equivalent to 1500 GeV, for example, the size of the region of influence can be predicted from the previous lower energy measurements. The prediction was wrong. Although the region is still growing as the energy is increased its rate of growth has slowed down a lot. This was immediately obvious from both experiments.

It was also obvious that looking at the protons bouncing off at very small angles and looking at larger angles gave different values for the extent of the region. (That this is a genuine effect and not due to one of the experiments being wrong was checked by overlapping the measurements so that they were each looking at the same angles — their results were then in agreement.) It looks therefore as if for a proton to be influenced considerably (bent off at wider angles, the region of influence is smaller. This again looks reasonable, thinking intuitively about what is going on, but it is going to need careful theoretical work for a complete explanation.

The Argonne, Bologna, Michigan experiment aims to study the total production cross-section for pions, kaons and for protons at angles from 80 to 200 mrad. This study is a reflection of a new trend to look at the numbers of particles of a particular type flying out rather than worrying about their modes of production. Experiments of this sort are comparatively easy and are a very useful indication of the way things are going at these newly accessible energies.

The particles are detected by a 45 m spectrometer. A septum magnet close to the interaction region is positioned so as to pick out particles emerging at a particular angle and aim them back into the spectrometer. A compensating magnet downstream then aligns the particles along the central axis (thus the whole spectrometer does not have to be manoeuvred to check different angles).

An analysing magnet is the next major unit and it deflects particles vertically gaining accuracy from the fact that the height of the interaction region is only about 6 mm compared with a width of 400 mm. To be sure that events are from true colliding beam interactions rather than from collisions with particles in the residual gas, a single beam is passed through the interaction region and the



The four points obtained from the Bombay, CERN, Cracow experiment using nuclear emulsions illustrating the angular distributions of relativistic particles emerging from the ISR collisions. They are plotted against cosmic ray data (above) and against a scaling prediction (below).

'background' then seen by the spectrometer is subtracted from the beam-beam data. Thanks to the outstanding machine vacuum, the background is limited to about 20 %, with this particular spectrometer. The particles are identified by scintillation and Cherenkov counters.

The first measurements were on positive pions emerging from the interaction

$$p + p \rightarrow \pi^+ + \text{(anything)}$$

this is an 'inelastic' process — the protons do not simply bounce off one another but produce other particles. At very high energies inelastic collisions completely dominate in strong interactions and therefore it is very important to get a hold on the inelastic events in order to understand the strong interactions. However this is easier said than done because of the complexity of the inelastic events — for example, a proton hurtling into another proton at an energy equivalent to 1500 GeV can throw off a dozen pions, a proton and neutron, sometimes a couple of kaons and occasionally a proton-antiproton pair.

Recently, theoretical physicists have been gnawing at this problem and have suggested ignoring the detail of what is happening and looking at only one kind of behaviour such as studied in this experiment

$$p + p \rightarrow \pi^+ + \text{(anything)}$$

R.P. Feynman coined the word 'inclusive' for this sort of cross-section and Feynman and C.N. Yang each suggested that inclusive cross-sections should approach a simple limit at very high energy.

Knowing that ISR energies were just around the corner, Feynman sat down and worked out what he expected to happen at the ISR. He predicted that the pion production cross-section expressed in a particular way would depend on only two variables (on the familiar transverse momentum of the pion and on the 'scaled' longitudinal momentum, P(longitudinal) divided by P(maximum), and that it wolud be independent of the energy of the colliding protons.

The prediction proved true with remarkable precision when the ISR data was plotted along with lower energy data from Argonne and CERN. The significance of this is not completely understood. It probably supports the Lorentz-contracted geometrical model for the proton suggested by A.D. Krisch and K. Huang. This model sees the proton as a sphere, with some sort of internal Gaussian distribution, which is squashed down by the Lorentz contraction at high energies. Huang noted that the distribution of pions would then depend on the two variables used by Feynman.

The ISR elastic scattering results show 'shrinkage' of the diffraction peak which is proportional to the Lorentz contraction factor. This would explain why the apparent 'shrinkage', which was so rapid at lower energies, has now almost stopped. This also seems to support a geometrical interpretation in which the proton is a sphere of about 10^{-13} cm radius which is squashed down at high energies. The great jump in energy given by the ISR gives a lever arm in testing this picture which is not available from the conventional accelerators. But the ISR still gives the precision laboratory conditions which make accelerator experiments so much easier than those with cosmic rays.

The Bombay, Bucharest, CERN, Cracow collaboration which did emulsion experiments I-1, are publishing measurements of the angular distribution of relativistic charged particles (ignoring lower energy particles) emerging from very high energy proton-proton collisions. The emulsions (600 μm films deposited on glass plates) were exposed for nine hours and took data at four positions from 35° to 90° when the beam conditions were — an energy of 26.5 GeV (i.e. a centre of mass energy of 53 GeV, equivalent to about 1500 GeV laboratory energy) and an intensity of about 1 A per beam. In order that the emulsions would not be collecting particles during other times, such as when the beams were being set up, they were normally hidden behind the shielding wall and then run out into position on a rail.

The results can be compared with the data on very high energy interactions obtained from observations on cosmic rays and can also be compared with what has been observed at much lower energies at synchrotrons. The first results seem in reasonable agreement with information gleaned from cosmic rays and out of line with the scaling prediction drawn from lower energy data.

The angular distribution is strongly anisotropic. At an angle of 90°, for example, the number of observed particles is well down compared with that recorded at 35°. The angular distribution in log tan $\Theta_{c.m.}/2$ coordinates has a pronounced dip in the neighbourhood of 90° (as in the data from cosmic ray jets but as opposed to the flat distribution predicted by scaling). The collaboration is continuing with studies of lower energy particles recorded in the emulsions.

Performance of the ISR

Since the first operation of the two rings of the ISR at the end of January this year, we have intermittently reported progress in working the rings towards the design performance. This article takes a fuller look at what has been achieved in recent months.

E. Keil

Improvements in hardware and operation

R. f. stacking

A general description of r. f. stacking appeared in vol. 8, page 270 explaining how successive pulses from the proton synchrotron can be built up into intense beams in the ISR. There are two schemes available — stacking 'at the top' and stacking 'at the bottom'. When stacking at the top, an injected pulse is always accelerated to the same radial position in the vacuum chamber. Since the stack (the protons previously accumulated) is moved towards the injection orbit, the injected pulse must be accelerated through the stack and will disturb it. However, the scheme is relatively simple because the r. f. program is exactly the same for all pulses. This is why this method was used during the initial running-in of the ISR.

When stacking at the bottom, the r. f. acceleration is stopped closer to the injection orbit on successive pulses thus avoiding the traversal of the stack and the perturbations caused by it. However, the r. f. program has then to take account of the appropriate stepping back in the radial position as successive pulses are injected. This process, which is usually more efficient, has now become the standard procedure.

Control computer

By now the ISR control computer is asked to do a wide range of jobs for the operators. In a typical running-in session which lasts six hours, it executes about 600 programs, many of them several times in succession.

Setting up the beam transfer channels is done via computer, as is the setting up of all the auxiliary power supplies for the ISR proper. Injection errors are automatically reduced to the minimum (involving changes in both angle and position of the injected beam from the PS arriving in the ISR vacuum chamber, both horizontally and vertically). The settings of the various power supplies are stored in the computer and previous settings can be restored automatically. Also a number of programs exists which allow the operator to change magnetic working conditions, for example the Q values. One simple command adjusts a large number of power supply settings which are required to make the requested change in working conditions.

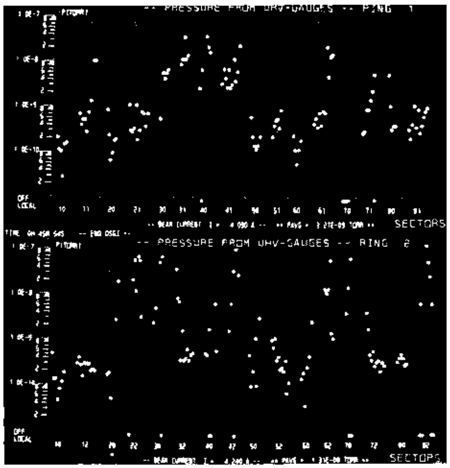
Another field of applications is closed orbit correction, which the computer performs in a dialogue with the operator. It reads closed orbit positions from pick-up stations and allows the operator to eliminate suspect readings and to specify the closed orbit harmonics which he wants corrected (usually a few in the neightbourhood of the Q value are sufficient). The computer then calculates the corrections required, either excitations of correcting magnets or displacements of the magnet units, and asks the operator whether they should be applied.

More recently, with new knowledge about the behaviour of the vacuum pressure as a function of beam current, a large number of vacuum programs have come into extensive use. Figure 1 is an example of the display of all the vacuum gauges in the ISR at high current.

Another important function of the computer is to keep a watch on many parameters. It periodically compares the actual values to a list of set values and tells the operating crew whenever a parameter is outside a specified tolerance.

Closed orbit correction

It is worth returning to the subject of closed orbit correction, the ISR being one of the first machines for which



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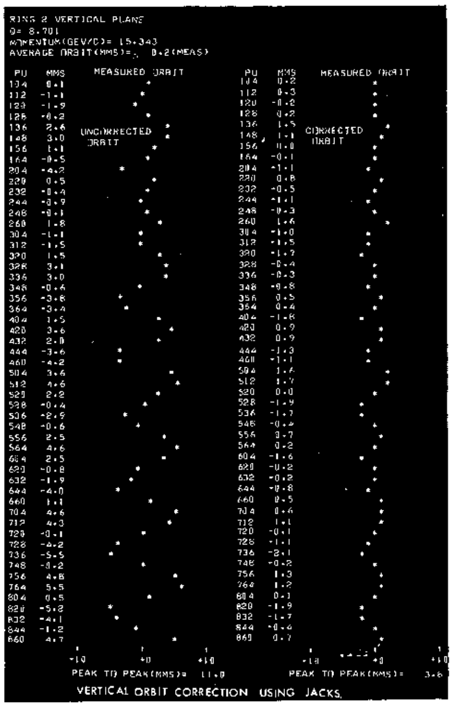


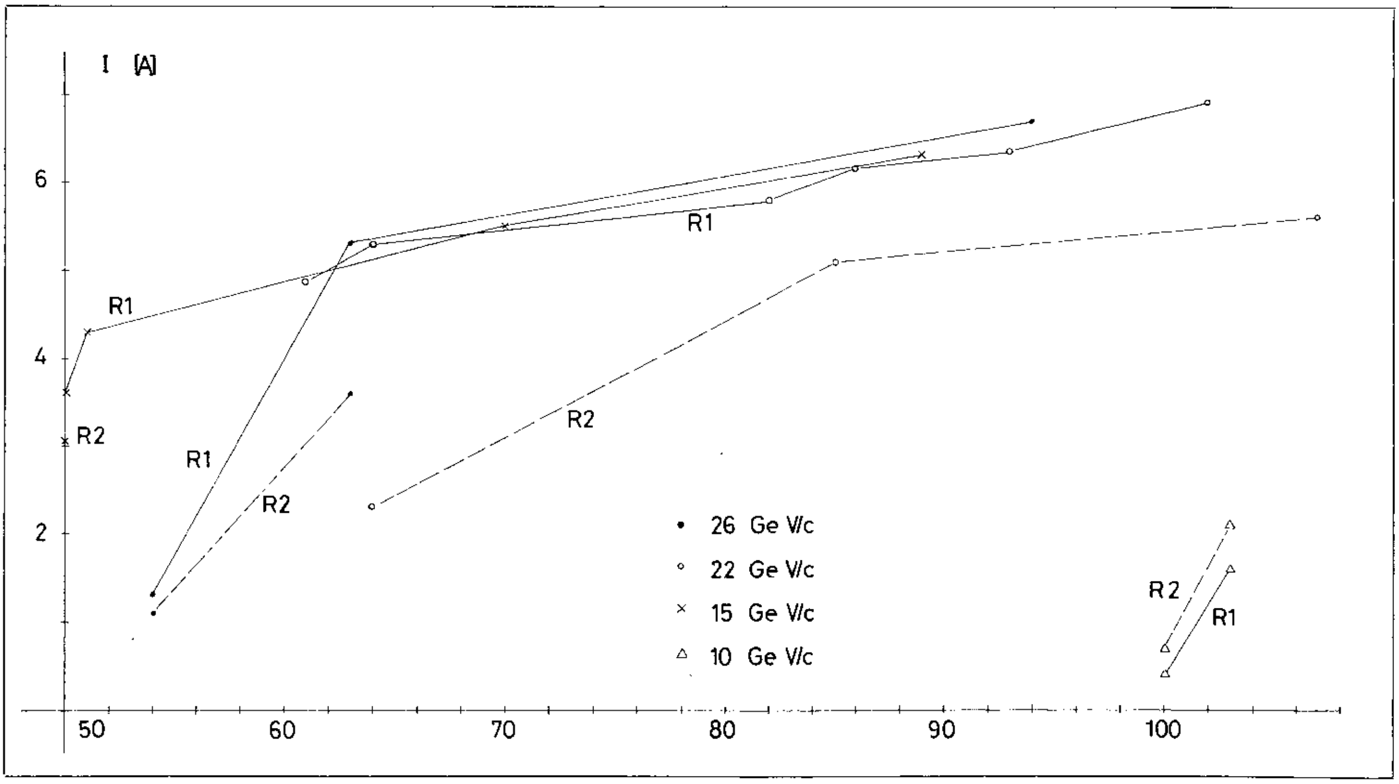
```
RING 2 VERTICAL PLANE
Q= 8.701
MOMENTUM(GEV/C)= 15.343
AVERAGE ORBIT(MMS)=  0.2(MEAS)

PU   MMS   MEASURED ORBIT          PU   MMS   MEASURED ORBIT
104   0.1                          104   0.2
112  -1.1                          112   0.3
120  -1.9                          120  -0.2
128  -0.2                          128   0.2
136   2.6  UNCORRECTED             136   1.5  CORRECTED
148   3.0   ORBIT                  148   1.1   ORBIT
156   1.1                          156   0.0
164  -0.5                          164  -0.1
204  -4.2                          204  -1.1
220   0.5                          220   0.8
232  -0.4                          232  -0.5
244  -0.9                          244  -1.1
248  -0.1                          248  -0.3
260   1.8                          260   1.6
304  -1.1                          304  -1.0
312  -1.5                          312  -1.5
320   1.5                          320  -1.7
328   3.1                          328  -0.4
336   3.0                          336  -0.3
348  -0.6                          348  -0.8
356  -3.8                          356   0.5
364  -3.4                          364   0.4
404   1.5                          404  -1.6
420   3.6                          420   0.9
432   2.0                          432   0.9
444  -3.6                          444  -1.3
460  -4.2                          460  -1.1
504   3.6                          504   1.6
512   4.6                          512   1.7
520   2.2                          520   0.0
528  -0.4                          528  -1.9
536  -2.9                          536  -1.7
548  -0.6                          546  -0.4
556   2.5                          556   0.7
564   4.6                          564   0.2
604   2.5                          604  -1.6
620  -0.8                          620  -0.2
632  -1.9                          632  -0.2
644  -4.0                          644  -0.8
660   1.1                          660   0.5
704   4.6                          704   0.6
712   4.3                          712   1.1
720  -0.1                          720  -0.1
728  -4.2                          728  -1.1
736  -5.5                          736  -2.1
748  -0.2                          748  -0.2
756   4.8                          756   1.3
764   5.5                          764   1.2
804   0.5                          804   0.1
820  -5.2                          820  -1.9
832  -4.1                          832  -1.7
844  -1.2                          844  -0.4
860   4.7                          860   0.7
          -10     +0     +10                 -10     +0     +10
     PEAK TO PEAK(MMS)=  11.0           PEAK TO PEAK(MMS)=   3.6
          VERTICAL ORBIT CORRECTION USING JACKS.
```

2.

1\. *Map of vacuum pressure in the ISR collected from gauges distributed around both rings and presented on a display screen via the control computer. This map was taken with high currents (4.09 and 4.24 A) in the rings and some of the 'pressure bumps' can be seen.*

2\. *Closed orbit data collected from 53 electrostatic pick-up stations distributed around a ring. Correction is carried out in a dialogue between the operator and control computer and has proved very efficient. The two presentations in the figure illustrate the reduction of orbit distortion when corrections are applied.*

3. Record currents stacked in the ISR at different momenta. The y-axis gives the circulating current in amperes ; the x-axis records the ' Run Number ' extending until the beginning of September. Up to the present, it has proved more difficult to stack beams of ' low ' momenta such as 10 GeV/c. (R1 and R2 stands, of course, for Ring 1 and Ring 2.)



3.

closed orbit correction was foreseen in the construction.

The correcting elements are correction coils on about 36 magnet units, 16 radial field magnets (mainly serving to correct the closed orbit in the intersection regions in order to have the two beams collide fully), and 36 motorized jacks which move pairs of F and D magnet units, one up and the other one down. The closed orbit position is measured with 53 electrostatic pick-up stations in each ring. Programs had been prepared and tested in advance making it possible to calculate the necessary currents in the correction windings or the vertical displacements of the magnet units, to correct closed orbit distortions. These programs were used with actual ISR data soon after the machine was put into operation and they corrected the closed orbit as expected. An example of closed orbit data is shown in Figure 2.

Closed orbit corrections can never be perfect because there are errors in the readings from the pick-up stations and there are not enough measuring and correcting elements.

The present system of pick-up stations correcting elements and programs correct the vertical closed orbit down to a peak-to-peak distortion of a few millimetres and the horizontal closed orbit to about 5 mm. Because closed orbit correction is available, it has been possible to run the ISR without re-alignment since October 1970 for Ring 1 and January 1971 for Ring 2 although the magnets moved 0.9 mm downwards on the average, and the rms spread of their vertical positions is now 0.6 mm.

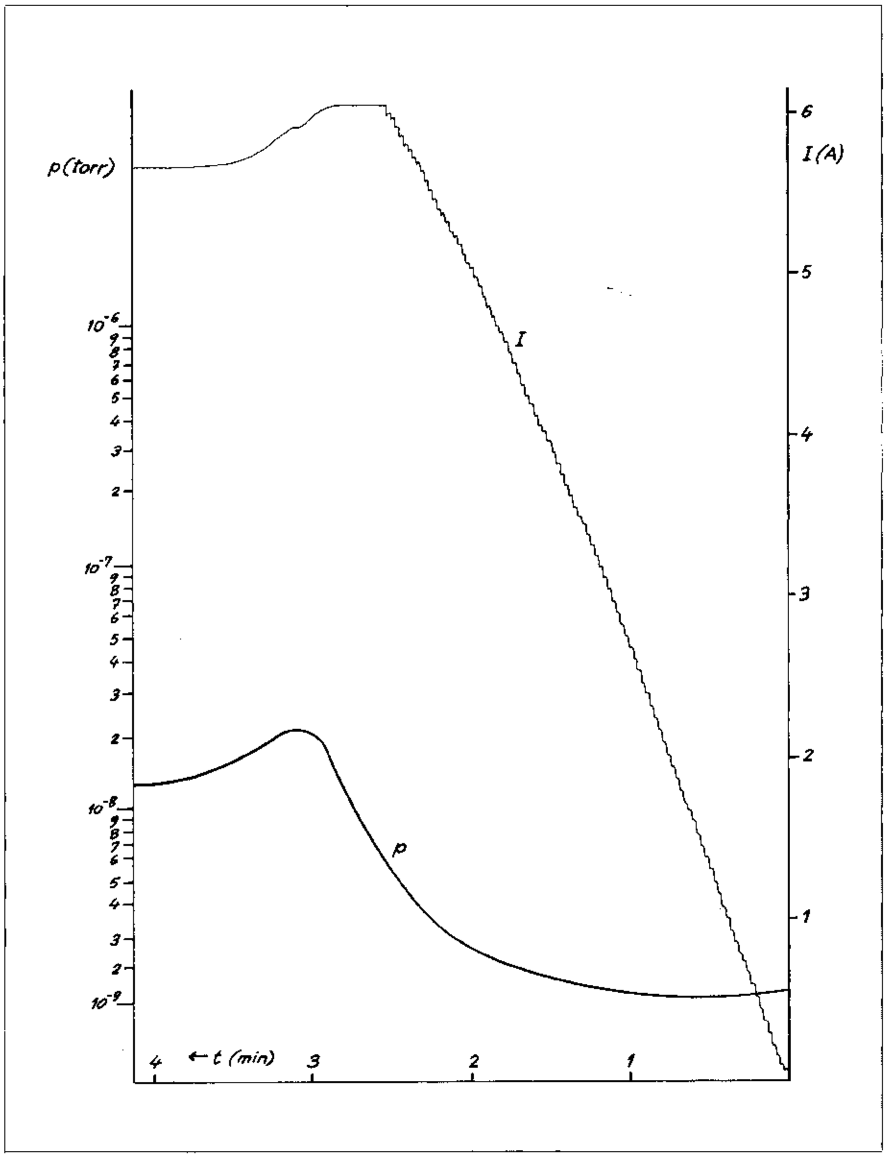
New achievements

Transverse instability

The transverse instability, which earned the name 'Brickwall', has been cured by applying a sextupole component to the magnetic field (see vol. 11 page 94). Now that this is being done on a regular basis the transverse instability is hardly seen. However, it has been artificially provoked in order to study it. The frequency of coherent signals induced in pick-up stations and the fact that the instability can be influenced by sextupole fields show that it is a low frequency instability driven by the resistivity of the vacuum chamber walls and by the inductivity due to the cross-section variations of the chamber. The sextupole component which is required to cure it, agrees within a factor of two or so with that calculated earlier on.

Maximum currents and lifetimes

Figure 3 shows the history of peak currents at different beam momenta through to the beginning of September. A good method for making stacks



4.

4. Graph illustrating how pressure follows the stored current. A possible explanation it that ions created by the beams in the residual gas liberate molecules from the vacuum chamber walls. (Time reversal is practised on this graph — the x-axis records time in minutes counting towards the left.)

with a long lifetime was discovered more or less by accident: the stack is not built up in one go but in several steps - stopping injection at intervals of about one ampere and waiting about ten minutes before stacking the next ampere. Stacking in this slow fashion gave a good lifetime on several occasions. The present best relations between stored beam current and decay rate are:

1 A	5.10^{-6}	per minute
3 A	10^{-5}	per minute
4 A	3.10^{-5}	per minute
4.5 A	10^{-4}	per minute
5 A	3.10^{-4}	per minute

The decay rates observed during the colliding beam runs are usually not as good and there is quite a fluctuation from run to run, even at the same current (the rates at about 2.5 A range from a few times 10^{-5} to a few times 10^{-4}). The lifetime is expected to worsen after a certain time since the beam is continuously blown up by scattering on the residual gas, and losses become significant when the beam fills the available aperture. The observed loss rates are in rough agreement with those expected for a beam which fills the available aperture. However, they appear too soon — from multiple scattering alone one could hardly expect to see them within the duration of a normal physics run. It seems that even at the usual currents for colliding beam physics runs there is a mechanism, other than multiple scattering, which causes a growth of the beam size.

New problems

Vacuum pressure bumps

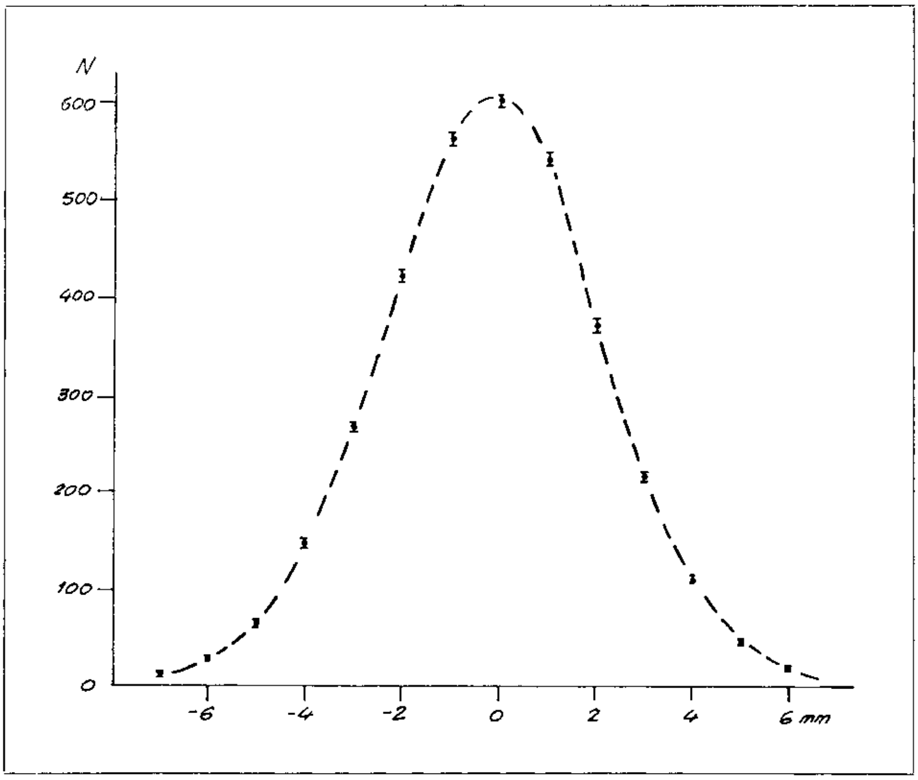
One of the most striking observations made during the past few months is that of the dependence of the pressure on the circulating current. Before the beginning of a run, the pressure is usually a few times 10^{-10} torr, well below the pressure originally specified. This remains true as stacking begins and the circulating current rises. However, there are certain regions in the chamber where the pressure rises rapidly once the current exceeds a certain limit. A typical recording of the circulating current and of the pressure in a long straight section is shown in Figure 4. The pressure keeps rising even after stacking has finished. After a pause of about half a minute the current starts to go down, and so does the pressure.

The places where these pressure bumps occur are more or less fixed, although their relative height may change from run to run. They can be removed by baking the vacuum chamber at about 300° C instead of the usual 200° C. However, for the moment, one region with a pressure bump is not being baked so that this phenomenon can be studied at the present current levels.

A number of explanations have been put forward: the circulating beam ionizes the residual gas — the electrons produced are collected by clearing electrodes installed at the end of the magnet units but the ions may get lost everywhere along the circumference. When they hit the vacuum chamber wall they may liberate molecules providing more gas which can be ionized by the beam in a process which sustains itself if the number of molecules liberated from the walls is a little bigger than the number of ions which hit the vacuum chamber wall. This ratio can be measured experimentally by observing the pressure drop which occurs when the beam is dumped. It turned out, that the experimental figure is quite close to unity, which supports this explanation.

Saturation and antistacking

When stacking it is found that from a certain current onwards there is no



5.

5. A luminosity calibration at intersection I-2. The two beams (1.38 A in Ring 1 and 1.13 A in Ring 2) each with momentum 22.5 GeV/c were moved relative to one another vertically (the x-axis records the beam separation in millimetres). The y-axis gives the number of counts recorded during 10 s intervals as the beams collided. The effective height of the beams was 5.7 mm.

longer any accumulation of particles. When injection is stopped the stored current decays rather slowly for up to about half a minute and then a much faster decay of current sets in which reduces the circulating current to about 4 A within a very short time (less than one minute). At this level, the current stabilizes again, but never reaches the low decay rates obtainable when stacking is stopped at 4 or 5 A. If stacking is not stopped at the saturation current there can be even a reduction in circulating current while stacking. This is called 'stacking downwards' or 'antistacking'. The explanation may be that the same phenomenon which causes beam loss after half a minute, already starts during stacking and is well under way when 'stacking downwards' begins.

Soon after the pressure bumps were observed for the first time, it was thought that saturation could be explained by them in the following way : since the beam does not fill the aperture at the beginning, there is a short time interval where the betatron amplitudes can grow by scattering of the circulating beam protons on the residual gas molecules without causing beam loss. But after a while, when the beam size has grown to fill the vacuum chamber aperture, beam losses set in, and they explain the rapid decay. This explanation could be made to fit the observations within less than an order of magnitude of the required average pressure. In the meantime, the vacuum pressure has improved, in particular at higher currents, but the maximum currrent which can be achieved has not improved in proportion. This simple explanation therefore does not seem to hold.

Betatron oscillations

A more recent explanation of saturation assumes that, for one reason or another, the amplitude of the betatron oscillations of the protons grows. It has indeed been observed, that above a certain current (of the order of 4.5 A) the betatron oscillation amplitude grows. This has been found by slowly running the beam scrapers into the beam and by observing the beam loss as a function of the scraper position. One can do this both from the inside and from the outside, and a comparison of the curves obtained gives quantitative measurements of the distribution of betatron amplitudes inside the beam. It is found that for currents below the 4.5 A limit, the beam size is small (less than anticipated) but above the limit, the beam size is bigger than anticipated. The growth is limited in the horizontal direction by the beam scraper which protects the injection kicker magnet, and indeed large losses are observed on this scraper. These losses are sometimes bigger than the current injected during the last PS pulse, thus causing 'stacking downwards'. So far, there are only speculations about the source of this growth and much more work on it is required. One of the crucial questions is whether the pressure rises form an essential part of this phenomenon or not.

Beams for experiments

The operation schedule for the ISR follows that of the proton synchrotron (three week periods). In each period one week is free of ISR running in order to allow for machine modifications and the installation of experiments. The ISR are in operation for four days in each of the other two weeks and the running time is divided as follows :

60 hours — machine development
12 hours — Setting up experiments
94 hours — physics.

There is one extended physics run during which the beams are kept circulating for 34 hours.

The procedure during setting up for physics is to make stacks at the intensity agreed upon beforehand with the experimental teams and the ISR coordinator. The beams are then displaced vertically in steps in all the active intersection regions by exciting horizontal field magnets in pairs such that the displacement in one intersection region does not affect the beam position in any other intersection region. This operation has three purposes — first, the vertical position of the two beams in an intersection region should be equal so as to obtain the highest counting rate ; second, their common vertical position should be such that the background is at a minimum ; — third, the effective beam height needs to be measured to calculate luminosity.

An example of the variation of the counting rate when the two beams are moved relative to each other is shown in Figure 5 where the effective height was 5.7 mm. This is about half the figure assumed during the construction of the ISR. Since the luminosity of the ISR — which is a quantity describing the rate at which events take place — is inversely proportional to the beam height it is higher than the figure one obtains by just scaling from the product of the two currents.

Most of the background seems to come from protons being lost on the vacuum chamber walls in the vicinity of the intersection regions. It therefore can vary considerably from run to run, and can be modified by choosing a good vertical beam position in the intersection region and nearby. The stacked current for colliding beam physics is mainly decided on the basis of the observed background rates, rather than luminosity, a typical figure is about 2.5 A in each ring. This is at least partly due to the fact that most experiments have ample data-taking rates (the ISR provide data continuously in contrast to the pulsed operation of a synchrotron). An example of the data-taking rate is the 2 million events collected by the Aachen-CERN-Genoa-Harvard-Turin team in the first 34 hour run.

The highest currents used in a run for physics were about 4 A in Ring 1 and 3.4 A in Ring 2, the luminosity achieved in this run was $1.8 \times 10^{29}\,\text{cm}^{-2}\,\text{s}^{-1}$ which is only a factor 20 below design luminosity.

It was never expected that so early in its life the ISR would be providing beams of the quality and reliability which are already feeding a very healthy programme of experiments. Nevertheless there remains much difficult, but fascinating, work for the machine physicists to do in order to push performance of the storage rings towards still higher levels.

CERN News

On 7 September the Minister for Education and Science of the Federal Republic of Germany, Professor Dr. Hans Leussink, visited CERN. He is photographed (top centre) hearing about the CERN-Karlsruhe experiment on charge exchange scattering which is located in the South Experimental Hall of the 28 GeV proton synchrotron. This experiment will, next year, be carried to higher energies by the same team in collaboration with Soviet scientists at the 76 GeV machine at Serpukhov.

BEBC

The hall of the 3.7 m hydrogen chamber, BEBC, was the scene of vigorous activity before the holidays — final assembly work was taking place at an accelerated rate. The main components were in position, the magnet had been assembled, and the first vacuum tests in the large tanks had been successfully completed. The first cooling tests seemed assured to take place according to schedule before the end of this year. However, CERN's present financial situation has to be taken into consideration.

In order to sustain this pace of assembly and testing, a great deal of outside labour would have to be used, and the CERN teams would have to do a considerable amount of overtime work. In the context of CERN's present economy drive, such action could seriously prejudice the scale of operation of the chamber next year, since the only method of paying the costs involved would be to draw on the 1972 budget.

In view of this situation, the BEBC Steering Committee has prefered to slow the programme down. The first tests on the large chamber and the magnet will not, therefore, take place until the Spring of 1972. There is still, however, the hope that the first experiment with beams to be installed in the West Hall will begin before the end of next year.

Tests of the refrigeration plant associated with the chamber have begun and are going encouragingly well. The body of the chamber is now fitted with all the heat exchangers which are needed to control the temperature of the hydrogen, and has been tested under vacuum. When the ' fish-eyes ' of the optical system are in place the body will be installed in its permanent position inside its large vacuum tank in the magnetic shield.

Around the Laboratories

BERKELEY
Seeing particles

It has become a standard part of the introductory patter in introducing newcomers to the mysteries of particle detectors to say that particles are so very tiny that we cannot see them with the human eye. Some research carried out at Berkeley and elsewhere over the past year seems to demonstrate quite conclusively that this is not strictly true. Astronauts on Apollo flights and people exposed to beams in the Laboratory have seen individual particles appearing as light flashes as they passed through the retina of the eye.

Light flash phenomena (or 'phosphenes' from the Greek 'phos' meaning light and ' phainen ' meaning to show) from sources other than normal light entering the eye have been known for a long time. As long ago as 1755 it was recorded that small electric currents can produce phosphenes (any enthusiastic reader might try leads from a 3 V torch battery to the forehead and back of the head, preferably in a darkened room). They can also be induced by dipping the head in a magnetic field (of about 0.1 T for example) or by pressure on the closed eye or by exposure to X-rays in the dark. The study of a new type of phosphene was stimulated by the experience of the astronauts on the space flight Apollo 11 and on all subsequent Apollo missions. When it was dark in the spacecraft they reported seeing light flashes (pinpoints and streaks) at a frequency of about one or two per minute.

The postulate was that the light flashes were caused by heavy cosmic ray particles (in the carbon, nitrogen, oxygen region) entering the eye. Laboratory experiments therefore simulated such cosmic rays by producing recoil carbon, nitrogen and oxygen nuclear fragments in the eye, initially exposing ' dark adapted ' people to a low intensity neutron beam at energies going up to 640 MeV at the Berkeley cyclotron. Light flashes were observed. Subsidiary tests cleared X-rays as the possible source (the levels were too low) and also cleared, as a major source, Cherenkov light produced by fast recoil protons or pions (exposure to 1.5 GeV/c pions at the Bevatron, where there would certainly be Cherenkov phenomena, produced no phosphenes).

Lower energy experiments at the University of Washington, Seattle, cyclotron revealed a further source — slow recoil protons and alpha particles (with an energy deposition of greater than about 100 MeV per gram per cm^2). The frequency of the light flashes with regard to the orientation of the head in the beam, indicated that the eye (rather than something triggered directly in the brain itself) is the site of the phenomena.

The investigation moved back to the Berkeley cyclotron ad attempted to obtain rather more quantitive data using a carefully controlled beam of 240 MeV helium ions. It was definitely established that the phenomena originated in the retina and also an idea was obtained of the efficiency of the eye in detecting the particles (about 40 % efficient if the particles were coming at a rate of around 10 per second — efficiency fell off at lower and higher rates). This gives a very rough calibration on man as a detector of certain classes of cosmic rays.

The astronauts on the recent Apollo flights were seeing light flashes at a rate of about 1 or 2 per minute. Some calculations on the expected concentration of heavy cosmic rays (from carbon atoms up) give values of 2 to 4 per minute passing through an area equivalent to the retina of the human eye. Slow protons and helium ions could also be contributing, so that, within the very tentative estimates that can be made, the postulate of cosmic rays as the source of the astronauts light flashes looks good.

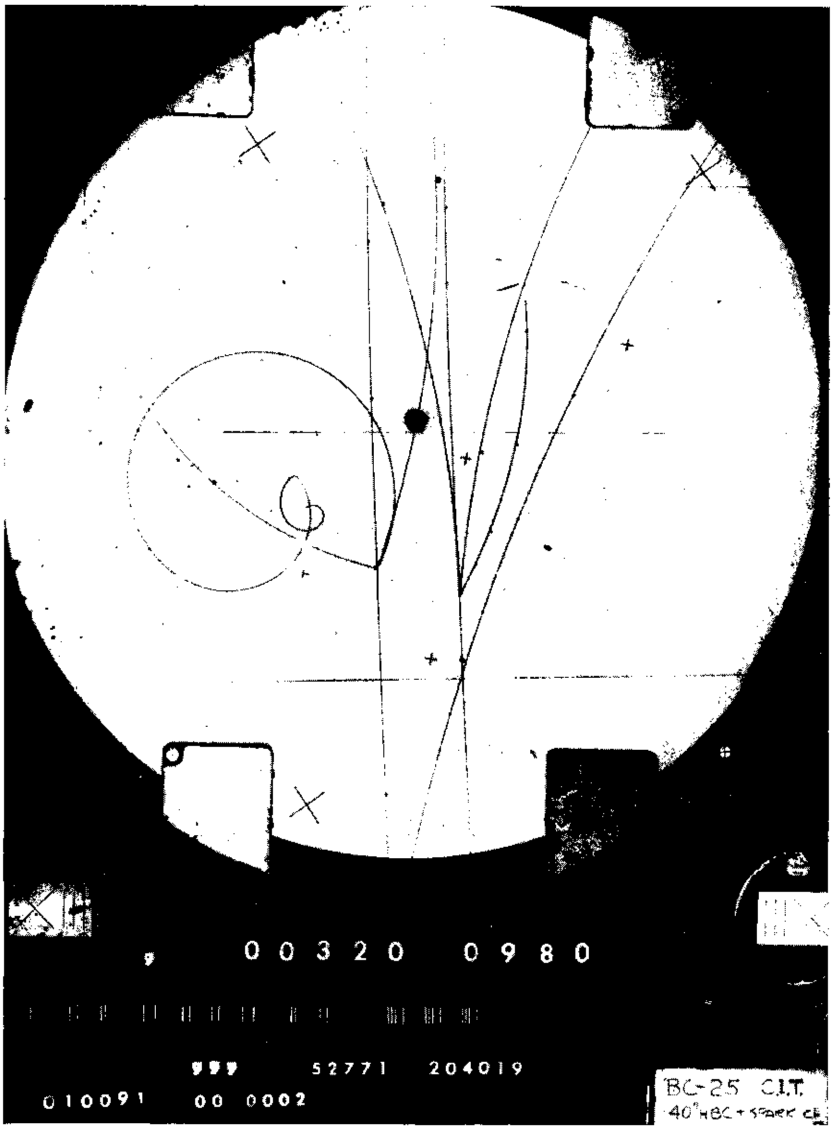
The full story of this intriguing work can be found in a Berkeley report LBL-31. The authors are T. F. Budinger, C. A. Tobias, J. T. Lyman (Donner Laboratory and Lawrence Berkeley Laboratory)*, P. K. Chapman, L. S. Pinsky (Manned Spacecraft Centre, Houston), H. Bichsel, J. D. Denney, W. B. Nelp (University of Washington).

On 24 August, a nitrogen ion beam (250 MeV per nucleon) was used to stimulate visual phenomena in the scientifically sceptical eye of the Laboratory Director, E. M. McMillan. With only 30 particles through the retina, McMillan had to confess to ' a whole constellation '. More quantitative work with nitrogen ions is in progress.

** The Lawrence Radiation Laboratory has been formally split into its Berkeley and Livermore components. They are now, organizationally, two separate Laboratories and have been renamed Lawrence Berkeley Laboratory and Lawrence Livermore Laboratory. Hence the high energy physics research centred at the Bevatron etc. is now done at LBL not LRL.*

STANFORD
Hybrid experiment

A group from Cal. Tech. (led by C. Peck) and the Lawrence Berkeley Laboratory has completed an experiment at Stanford using a fast cycling 1 metre hydrogen bubble chamber in conjunction with a spark chamber spectrometer. This type of hybrid arrangement is likely to become more common as bubble chamber pulsing rates are increased and as beam

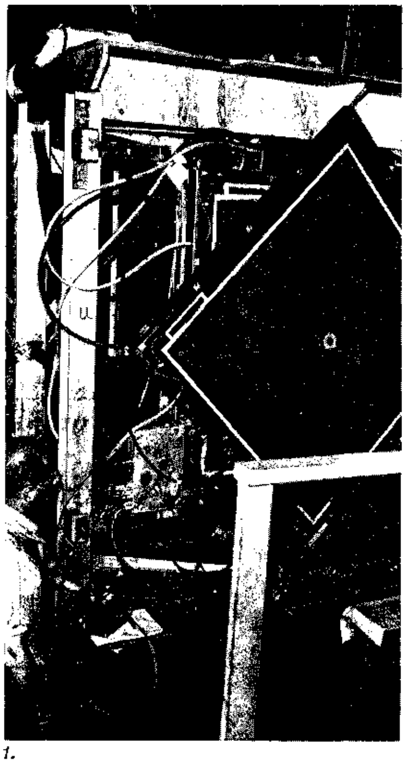


A photograph taken in the fast cycling 1 m hydrogen bubble chamber at Stanford. It shows some typical events which triggered the hybrid bubble chamber and spark chamber spectrometer system in a study of diffractive production of resonances. Pions, entering from below in the photograph, interact with protons and give up a little energy continuing almost straight on. The excited protons decay and emit low energy particles.
1. The first of the twelve 1 m square wire spark chambers which spot emerging pions which have lost some of their energy.
2. The 1 m diameter bubble chamber dismantled for modifications.

energies climb higher. At higher energy machines particles will be thrown forward more and it will be possible to catch a greater number of interesting events by setting up a spectrometer system behind the bubble chamber. Also hybrid arrangements make it reasonable to study rare events in bubble chambers since their selective properties can greatly reduce the number of photographs which need to be studied.

The experiment at the 20 GeV electron linear accelerator used this last advantage to study diffractive production of N* resonances. Building up adequate statistics of this process using a conventionally operated 2 m bubble chamber would require as many as 10 million pictures to be taken ; at SLAC with the hybrid experiment the data was collected within two months. During this time the 1 m chamber pulsed about 8 million times but the spectrometer asked for only about 300 000 pictures to be taken (on a first examination well over half of them seem to have caught the required events). Initially the bubble chamber was operated four times per second but later in the run this was stepped up to five and six times per second. (For brief periods, not during this experiment, the chamber has run as high as ten pulses per second.) Since the 20 GeV accelerator supplies 360 pulses per second, the experiment was an almost negligible burden for the machine.

The experiment proceeded as follows : pulses of electrons from the linear accelerator were fired onto a target and from the resulting particles a few 14 GeV pions were selected and guided into the 1 m chamber. The chamber expansion system was pulsed on their arrival and the charged particles (the pions and any charged produce of their interactions in the hydrogen) left growing bubbles in their wake. Fortunately, bubbles in



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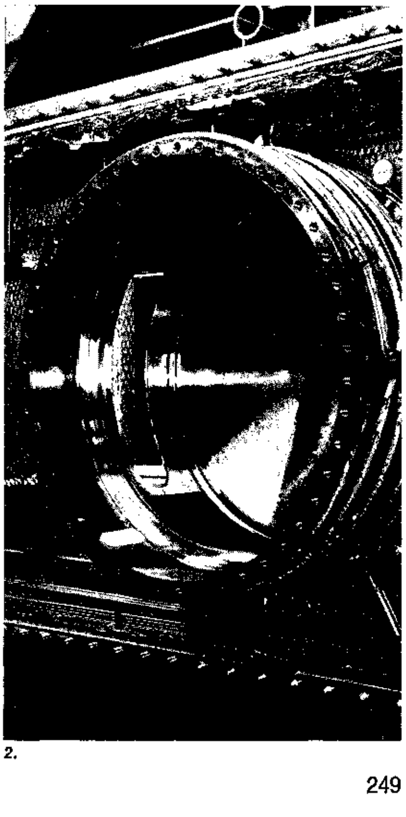


2.

The first sector of the TRIUMF cyclotron magnet assembled at the manufacturer's (Davie Shipbuilding Limited, Quebec) prior to dispatch to the site at the University of British Columbia at the end of July. Two of the six sectors have now reached the site and all are scheduled to be delivered by December. The magnet will be completely assembled by June 1972.

Layout of the experimental areas on either side of the TRIUMF cyclotron. They will be fed, initially, by two beams as shown (dimensions are given in feet).

hydrogen take about 3 ms to grow to a size suitable for photographing. This is ample time for electronic detectors to look at what is emerging from a chamber and to decide whether that particular pattern of bubbles is worth recording.

In the SLAC experiment the electronic detection system consisted of twelve 1 m square wire spark chambers, positioned around a magnet, and a XDS Sigma 2 computer which did the sums as to whether an event of interest was likely to have happened. The system fastened onto pions emerging in the direction of the beam fired into the bubble chamber and the amount by which these pions were bent in the magnet revealed whether they had lost a significant amount of energy. If this proved to be the case, the computer told the bubble chamber flash tubes to fire and the charged particle tracks in the chamber were recorded.

The process that the experimenters wished to study was that where a pion meets a proton and passes essentially straight through it although giving up some energy to the proton in the process. The proton is then left in an excited state (transformed into a short-lived resonance) and will decay back into its normal tranquillity emitting low energy particles which can usually be readily identified in the bubble chamber. The information one then has covers the incoming pion, the outgoing pion (momentum known to 0.5 % and position in the chamber known to within 1 mm) and the decay products of the resonance. This is enough to study the ways in which the pion can pass energy to the proton (to study the selection rules in the production of the N* resonances).

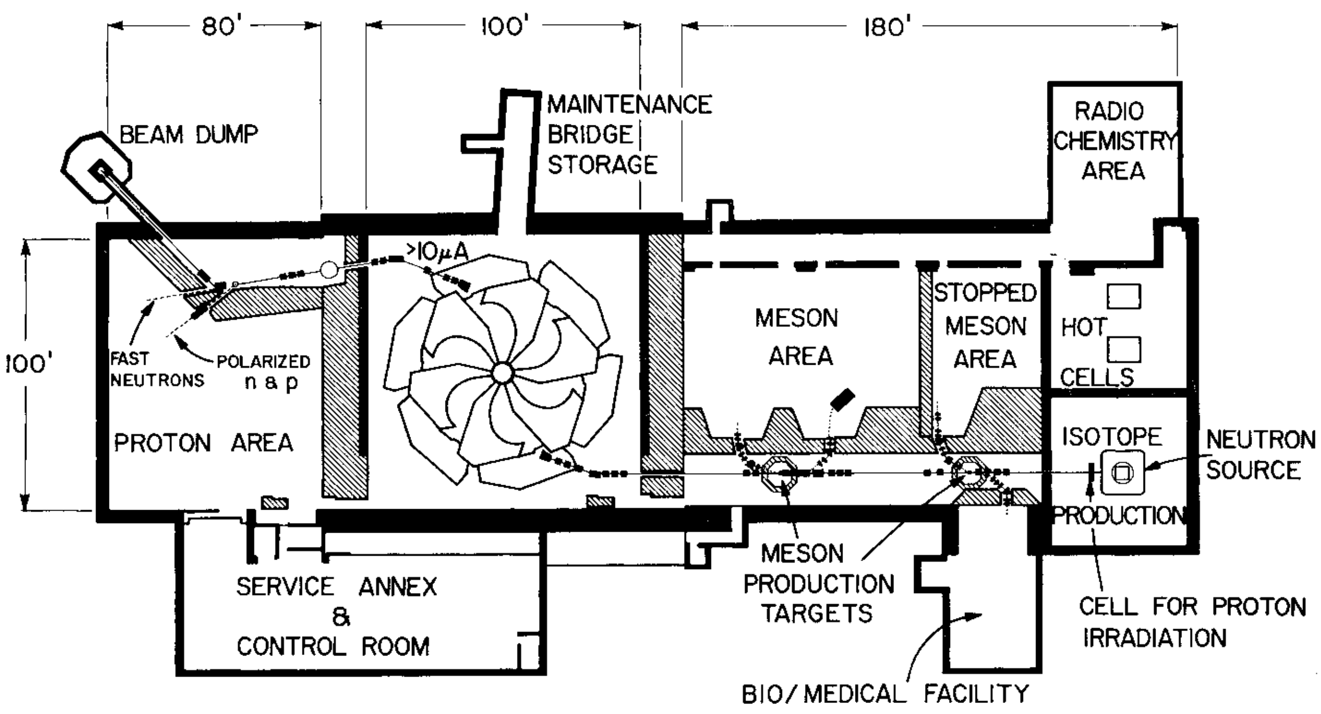
The hybrid technique seems to have been very successful. It has been used before at Princeton and Argonne (see vol. 10 page 190) but the experiment at SLAC has brought it to a new level of sophistication. There is little doubt that this will be carried still further at SLAC and elsewhere. The 30 inch chamber used in the hybrid set up at Argonne for example has now been moved to Batavia and will be ready from November to be used in a hybrid experiment with very high energy incoming particles.

Information on some most important results emerging from the experimental programme at the 20 GeV machine can be found in recent issues of 'Scientific American'. The June issue carries a story (by H. W. Kendall and W. K. H. Panofsky) of the deep inelastic scattering experiments revealing structure inside the proton and the neutron which could possibly be the point-like objects known as partons. The July issue carries a story on 'Photons as Hadrons' by F. V. Murphy and D. E. Yount and discusses particularly an experiment at SLAC which demonstrates that high energy photons can have properties once thought exclusive to hadrons.

TRIUMF
Coming together

On 5 August, the first component (the centre support on which the magnet will rest) of the TRIUMF cyclotron was lowered into place. At the same time, on either side of the machine vault, other machine components were in evidence — the first magnet sector was being stored in the 'Proton Area' and the huge vacuum chamber was being welded together in the 'Meson Area'.

The TRIUMF project, involving four Canadian Universities — Alberta, Simon Fraser, Victoria and British Columbia, is one of the three 'meson



factories' currently under construction (the other two being the linear accelerator, LAMPF, at Los Alamos and the two-cyclotron system of SIN at Villigen). Its particular feature is that it will accelerate negative hydrogen ion beams (of intensity up to 100 μA) and will have high extraction efficiency when the ions are stripped to protons since the cyclotron magnet itself will bend the particles of opposite charge out into the experimental areas. The magnet is a six sector structure weighing 4000 tons. With a peak field of almost 0.6 T it will hold ions up to an energy of 500 MeV. It may be possible to push the peak energy a little higher (about 550 MeV where the focusing properties of the magnet fade) and the r.f. system has been designed to achieve this. However the 'high energy' mode of operation will involve high internal beam loss and hence, lower extracted currents.

The machine was described in some detail in vol. 8, page 163. Since then the major design change has been the decision to have two experimental halls, one on each side of the machine. Inserting two stripper foils into the cyclotron, it will be possible to have two extracted beams completely independent and variable in both energy and intensity. The addition of a high resolution beam (about 100 kV energy spread) at a later stage has also been considered.

The general layout of the experimental areas, as it is envisaged at present, is shown in the diagram. More detail is now being fed into the layout following a symposium on the experimental programme in August which involved people from each of the disciplines which will be represented in the research programme (radiochemistry, nuclear physics, radiotherapy, etc.). The first proposals for experiments were considered by the Experimental Evaluation Committee this month. It is hoped that money to build up the experiments will become available as from the start of the next financial year (April 1972).

The cyclotron is scheduled to come into operation in 1973 and construction progress on almost all components of the machine is in line with the programme. Since December 1970 the ion source has been reliably providing good quality negative hydrogen ion beams in excess of 2 mA which is ample for initial operation. For studies of beam behaviour in the crucial first turns in the cyclotron, the 300 keV injector will be used to feed a 3 MeV central region model in a few months' time.

Two of the large magnet sectors have arrived at the site, having been previously assembled at the manufacturers, and installation of the first of them in the machine vault has started. All six sectors should be delivered by the end of the year and in place by June 1972 ready for the field mapping and what may prove to be a lengthy process of magnet trimming. There is considerable confidence that the required magnet performance will be readily attained following measurements on a tenth scale model which reproduced excellently the previous satisfactory results from a twentieth scale model.

The huge vacuum vessel (about 18 m in diameter) is being welded, to the accompaniment of many decibels, alongside the machine vault since it is too big to have been manoeuvred through the streets of Vancouver as a complete unit. It will be completed in December. The pumping system is a cryo array maintained at 20 K with a heat shield at 80 K. The r.f. system is the last machine component to take definitive shape but the contracts are now being placed. Assembly of the r.f. units should start towards the end of next year. Controls and instrumentation are being finalized. Small 'dedicated' computers in conjunction with CAMAC modules will be used.

PRINCETON

Nitrogen beams

As has been reported several times before (see, for example vol. 11, page 16), tests on the acceleration of nitrogen ions are being carried out at the fast cycling 3 GeV proton synchrotron at the Princeton Pennsylvania Accelerator Laboratory in an attempt to keep the machine in operation as a centre for heavy ion research. On 15 July a beam of nitrogen ions (N^{5+}) was accelerated to an energy of 3.9 GeV with an estimated beam intensity of 10^4 ions per second. This is the first time heavy ions of such high energy have been produced artificially and it opens the door to experiments in a variety of disciplines.

For three weeks from 4 August the accelerator was in operation with 3.9 GeV nitrogen ions feeding several experiments. For most of the time the beam was ejected, though there was a 12 hour irradiation of an internal platinum target in an experiment to study pion production. The ejected beam intensity has been averaging about 5×10^4 ions per second with a peak intensity of 3×10^5. The beam purity was better than 99 %. It has served experiments on the physical properties of heavy ions, inactivation cross-sections for mammalian cells, excitation energy of nuclides, and depth dose studies.

Proposals for experiments demanding well over 1000 hours of running time have been received and a Science Advisory Committee has been formed to review the proposals. A committee from the National Cancer Institute visited the PPA on 5 August concerning the request for long-term funding of the machine research programme. They heard talks on the advantages of using heavy ion beams for cancer therapy, for radiation dosimetry, for cosmic ray and solid state studies related to biological problems, and on the possibility of treating 1000 patients per year from a Radiation Therapy Centre. The Committee is now evaluating its findings.

Meanwhile work is going ahead on the machine with the aim of increasing the available beam intensity towards 10^6 ions per second. In the previous runs, the average pressure in the accelerator vacuum chamber was about 2×10^{-7} torr. This is being improved by a factor of two, which will allow more intense beams to be accelerated and, in addition, the ejected beam system is being improved.

BERKELEY

Nitrogen beams again

At the end of August, news came from the Lawrence Berkeley Laboratory that ion beams of excellent quality have been accelerated in the Bevatron, which normally provides 6 GeV protons for high energy physics research. Berkeley have been thinking about high energy heavy ion research for some time and have plans for the development of a major research facility, known as Bevlac, using the combined forces of the Bevatron and the Super-Hilac.

The recent work began with the acceleration of deuterons (10^{11} particles per pulse ejected) and alphas (5×10^9 particles per pulse ejected) up to energies of 2.1 GeV per nucleon. This corresponds to 4.2 GeV deuterons and 8.4 GeV alphas. Neutron beams of 2.1 GeV energy could be obtained with about 120 MeV energy spread by stripping the deuterons. These beams were achieved using the usual injection system operated in a different mode. Sufficient intensities of each type of particle could be pulled from the normal duoplasmatron ion source (with a slightly larger anode aperture for alphas) and about 5 % could be accelerated through the 20 MeV proton linac, with field settings almost the same as usual, to an energy of 5 MeV per nucleon.

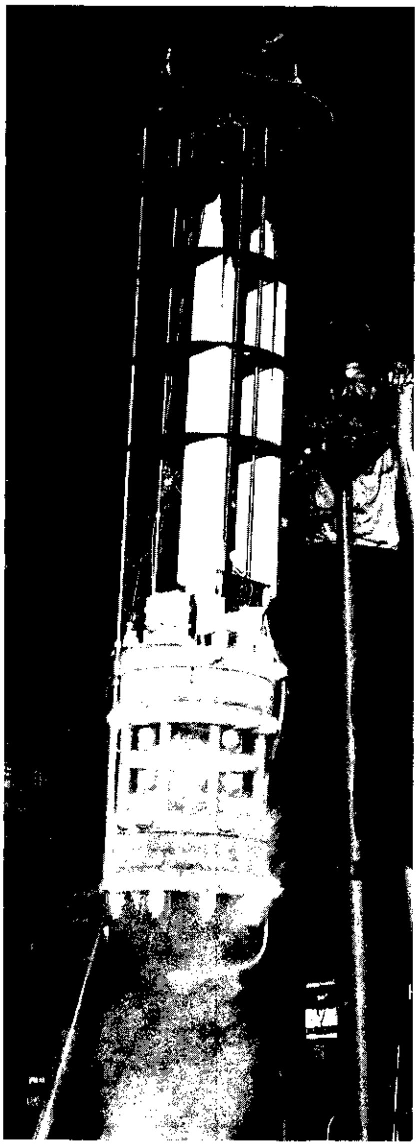
Things get stickier for the acceleration of nitrogen ions. Adequate intensities (20 to 30 μA) from a P.I.G. source can only be obtained for N^{5+} ions. The charge to mass ratio (5/14) then required accelerating and focusing field gradients 40 % higher than usual in the linac. After acceleration to 5 MeV per nucleon the ions loose their remaining two electrons when they are passed through a stripper yielding a beam of about 0.5 μA of N^{7+} ions for injection into the Bevatron.

The Bevatron, an ejection system and an external beam transport system are previously carefully set up with an alpha beam, where the beam signal is strong enough to operate the phase loop control, and the settings are stored on computer tape. Injection then switches to nitrogen and the computer, from its alpha settings does the sums and controls the adjustments for the nitrogen ions. With about 10 % capture efficiency, about 10 % of the ions held during acceleration and 50 % to 70 % ejection efficiency, beams of about 2×10^5 particles per pulse were available for experiments at 2.1 GeV per nucleon (29.4 GeV N^{7+} ions). The purity of the ejected beams was about 90 to 95 %. The highest energy achieved (at which beams were not ejected) was 2.57 GeV per nucleon (36 GeV). This, incidentally, fulfills a prophecy of the late E. O. Lawrence. In his Nobel Prize acceptance speech, given in 1951, he referred to the acceleration of heavy nuclei, 'Since in cosmic radiation such heavy particles play an important role, they will surely be produced in the Bevatron some day'. He suggested the energy of the heavy particles would be 36 GeV !

Perhaps the most encouraging feature of the tests was that almost immediately after achieving the first ejected high energy nitrogen ions it was possible to supply beams of sufficient intensity and reliability for a start to be made on experiments. The first experiment was to look along the beam at the 'fragmentation' products as the beam passed through a target which come predominantly from the breaking down of the nitrogen nucleus. The surprising result appeared that all fragments heavier than alpha particles had virtually identical velocity to the nitrogen ions. The separation of as intense as possible a beam of any nuclide (say a beryllium ion with seven nucleons) is then a simple matter, knowing the charge and mass of the desired nuclide, of selecting appropriate magnet settings in a spectrometer arrangement. This is an unexpected additional experimental possibility which will add to the interest of the research programme.

The results from Princeton and Berkeley have sent a wave of interest washing through a wide variety of Laboratories. There is new potential, for example for cancer therapy, for heavy ion cosmic ray research, for studies on radiation initiated genetic effects, for nuclear physics, for 'super-heavy' element production, etc...

Berkeley have (following the suggestion of the heavy ion linac, HILAC, team led by A. Ghiorso) been studying the possibility of connecting, via a long beam-line, the souped up version of the linac (Super-Hilac described in vol. 11, page 75) to the Bevatron to serve as a first class heavy ion injector. The combined machines, Bevlac, will have a much higher intensity capability with the heavy ions than has been achieved so far and will extend the available range of accelerated ions (e. g. argon, element 18, and possibly krypton, element 36). As plans take detailed shape we will no doubt be returning to the Bevlac project.



The pulsed superconducting magnet, AC3, which is operating successfully at the Rutherford Laboratory. For convenience it was mounted in a vertical cryostat. The magnet has parameters close to those which would be appropriate for a high energy superconducting synchrotron.

(Photo Rutherford)

RUTHERFORD

Superconducting pulsed magnet

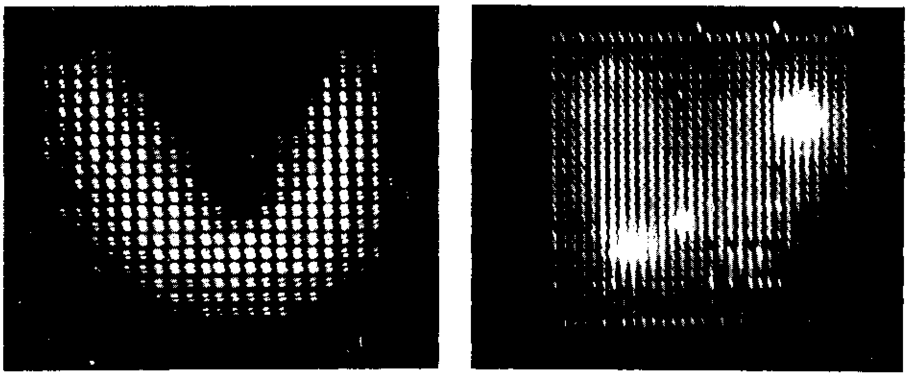
One of the vital questions for the future of high energy physics concerns the development of pulsed superconducting magnets (and all the associated technologies that they bring in their wake) to the state where they could confidently and economically be used in the construction of large synchrotrons. It is only by taking advantage of their potentially higher fields and lower running costs that we can, at present, envisage pushing synchrotrons to higher energies. In particular it has been left as an option in CERN Laboratory II that the construction of Europe's new machine could incorporate, in one of several possible ways, pulsed superconducting magnets. It is important for this project to know in the fairly near future whether such magnets are feasible and economic. A very encouraging demonstration of their feasibility has come with recent tests at the Rutherford Laboratory of a superconducting dipole model known as AC3.

The magnet is 50 cm long (effective length 40 cm) with an aperture of 10 cm diameter. It is designed to give a peak field of about 4 T and an additional insert is now being built which will take the field to 4.5 T in an 8 cm bore. It is capable of cycling continuously with rise times as short as 1 to 2 s.

In the recent tests it was pulsed at 90 % of its critical current (5400 A) with rise times down to 1 s. The measured a.c. loss was about 10 W with a 4 s cycle time, which is close to the expected value with the particular conductor used. This was a composite from IMI with 1045 filaments of 0.4 mm diameter, formed into a 90 strand transposed cable and then compacted to have a square cross-section of 5 mm side. The coil was built up of this conductor so as to give the appropriate field geometry. It was wound in six concentric layers and fully impregnated with epoxy resin. Mats of copper wire were sandwiched between the coil layers to carry the heat, produced when the coil is pulsed, to the liquid helium.

The magnet was quenched many times without any deterioration of its performance. Some 'training' (progressive approach to critical values) was observed. In the first cooldown the maximum central field was 3.8 T. This sort of figure could be taken 20 to 40 % higher in a synchrotron by adding an iron shield.

Work is continuing with AC3 and improved variants (known as AC4 and AC5), using better types of cable, iron shielding and higher precision in the winding of the coils, are on their way for 1972. The successful tests with



The two photographs on the left show the mapping of a thyroid gland by means of a system of MPCs associated with a collimator with parallel holes : on the left — normal thyroid gland, on the right — artificial 'phantom' thyroid gland in which γ-active radio-isotopes have been fixed.

The photo on the right is an X-ray photograph of the leaf of a tree taken by means of proportional chambers. The 1 mm space between the wires gives very good definition.

AC3 are believed to be the first demonstration of the operation of a pulsed superconducting magnet with parameters (such as aperture, peak field and operating current) comparable to those which would be needed in a high energy superconducting synchrotron.

Medical applications

High energy physics has multiple repercussions in the field of advanced modern industry, including superconductivity, high voltage and vacuum techniques, electronics, metallurgy, etc. Now multiwire proportional chambers, which owe a great deal to the work done at CERN, are in their turn being used for an interesting purpose in the field of medical diagnosis.

Mapping the thyroid

The 'Centre d'Etudes nucléaires' in Grenoble a few months ago under the guidance of M. Allemand began to study systems for mapping organs by means of X or α ray emitting radio-isotopes which are detected by high-efficiency multiwire proportional chambers.

They work on the following principle. The patient absorbs products containing radio-isotopes with a short lifetime which are fixed in the tissues to be examined. These tissues emit radiation which is collimated by a block pierced by a series of parallel holes and a multiwire proportional chamber show the distribution of the radiation which passes through.

A system of this kind has been developed by the CENG for the Faculty of Medicine at Tours (France) and is at present in clinical use for mapping the thyroid (after absorption of I 125) and the eye (after absorption of Cs 131). The proportional chamber is filled with a mixture of Xe - 5 % CH_4. The collimator has 31 × 31 3 mm diameter holes which define its spatial resolution.

The device has the advantage over scintillation cameras of a much simpler design and of being adaptable in dimensions, shape and efficiency to the different types of organ. Furthermore, direct coding of the information in binary form greatly facilitates data acquisition for the study of dynamic functions. On the other hand, these detectors have low detection efficiency when the energy of the radio-isotopes is greater than about 100 keV. Studies are being carried out at the CENG on the use of liquefied gases (argon or xenon) to overcome this drawback. In addition better spatial resolution, might then be possible which is now of interest to various high energy physics groups. (Recent work on liquid proportional chambers at Berkeley will be reported in a coming issue).

Radiography by MPCs

At the Lawrence Berkeley Laboratory great interest is also being shown in the medical applications of multiwire proportional chambers. The aim there is also to develop apparatus for studying the spatial distribution of γ and X radiation.

A 20 cm × 20 cm chamber with 3 planes of wires (x, y and oblique) 1 mm apart has just been constructed for this purpose. It is filled with a mixture of 94.5 % Xe, 5 % CO_2 and 0.5 % freon 13 B-1.

Excellent X-ray photographs with very good definition (as can be seen in the figure) have already been taken. However, in this case the method is not based on the ingestion of radioactive substances as in the previous one, but on the use of an X-ray source placed behind the object to be observed. The detection efficiency of the chamber is 97 % at 5 keV and 2.5 % at 100 keV. It is also intended to use the energy discrimination power of MPCs in order to obtain the best possible contrast for the particular object observed.

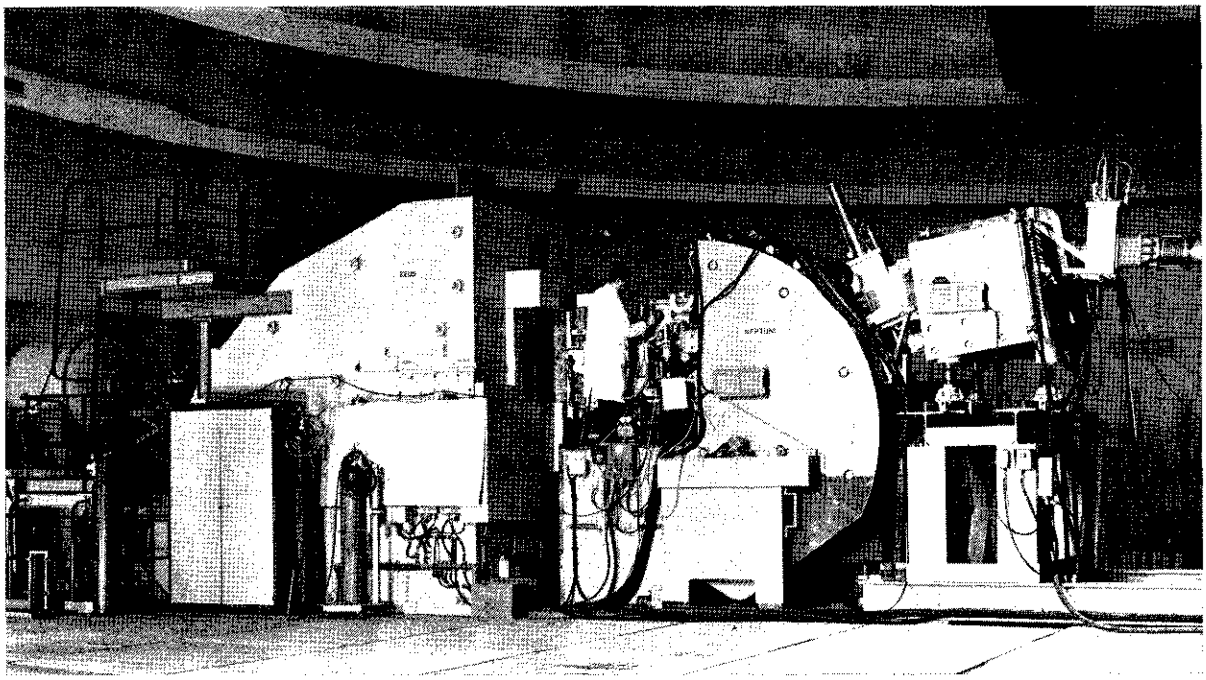
(See report : Multiwire proportional chamber for low X-radiography, L. Kaufmann, V. Perez-Mendez, J. Sperinde, G. Stoker).

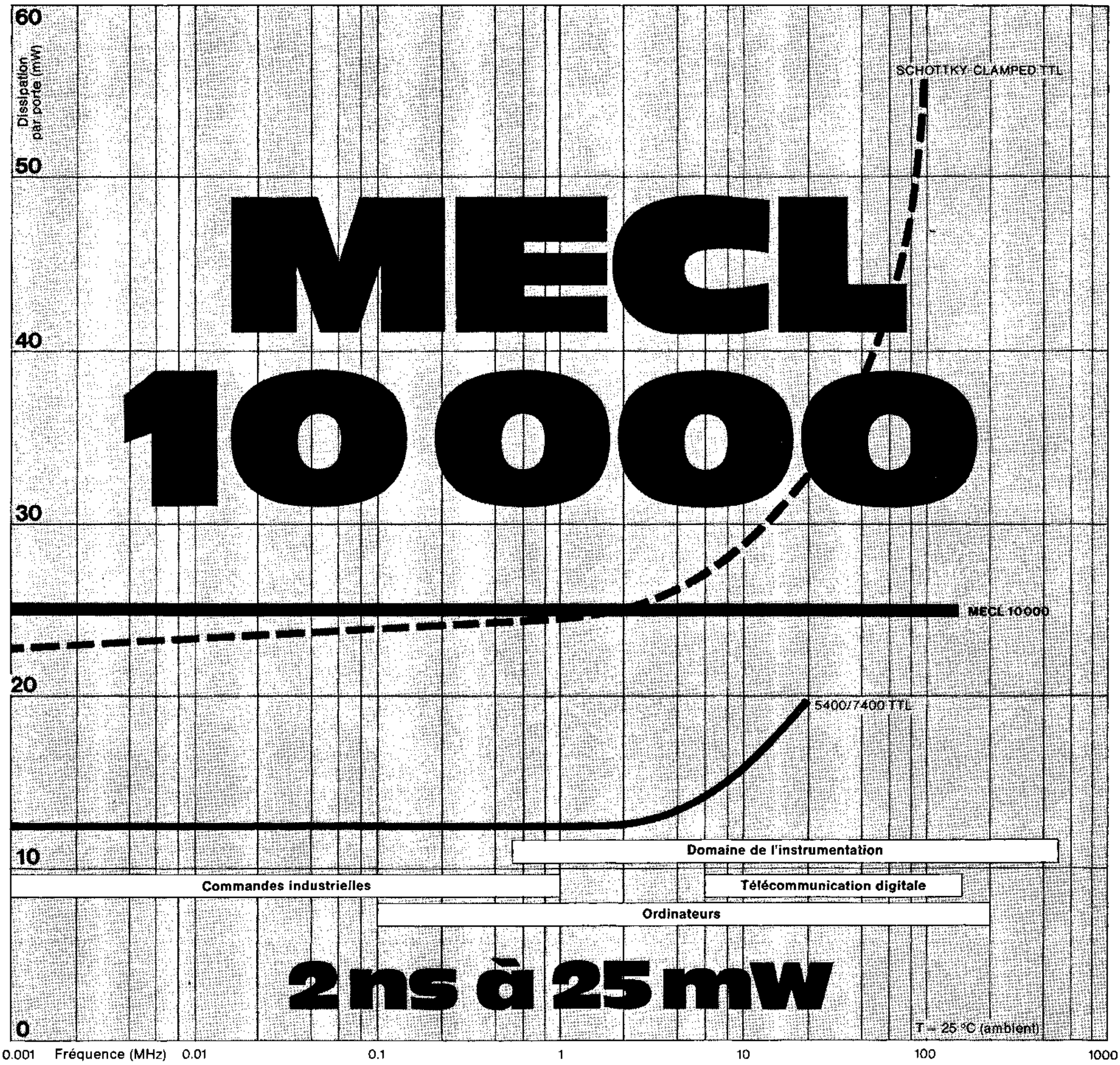
And a note on tracers

A team at Brookhaven (D.E. Lebowitz, M. Greene, P. Richards and M. Kinsley) has just completed a study on the possible uses for medical tagging of two radioisotopes, dysprosium 157 and bismuth 204, produced with the sixty-inch cyclotron at the Laboratory.

The first one, with a half-life of 8 ½ hours, lodges readily in the marrow and the skeleton, thus allowing the associated diseases to be studied. It can be produced in large quantities and with a high degree of purity at 33 MeV. It has the advantage that it can also be produced by small, lower-energy cyclotrons.

The second element has a particular affinity for cervical tumours (almost 100 times greater than that for the neighbouring tissues, whereas other competitive tracers have only a twenty times greater affinity for the tumour). The irradiation energy, at least a few tens of MeV, and the thickness of the target must be selected with great care to prevent the production of parasitic isotopes like bismuth 203 and 205.





La logique des circuits intégrés (ECL), dans laquelle la Motorola fait œuvre des pionniers depuis 1962, a été enrichie d'une nouvelle unité, la logique MECL 10000. La MECL 10000 se distingue par un excellent produit vitesse-dissipation par 50 pJoules. Partant, elle convient particulièrement aux circuits digitaux haute vitesse, tels que compteurs haute vitesse, convertisseurs A/D de haute vitesse, transmission de données (par ligne torsadée), synthétiseurs de fréquences, mémoires haute vitesse.

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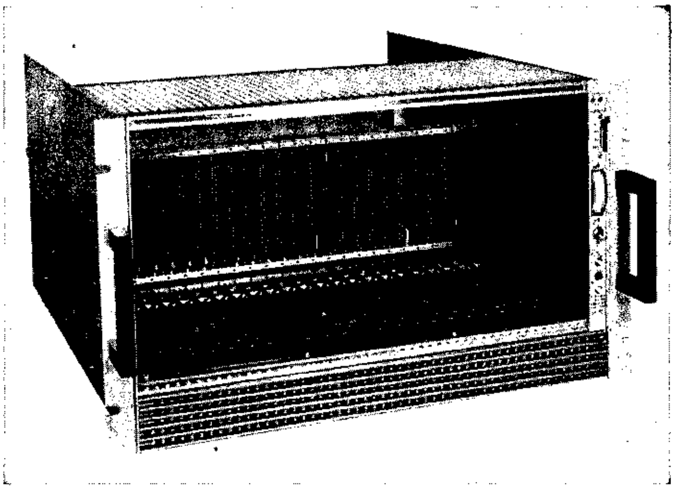

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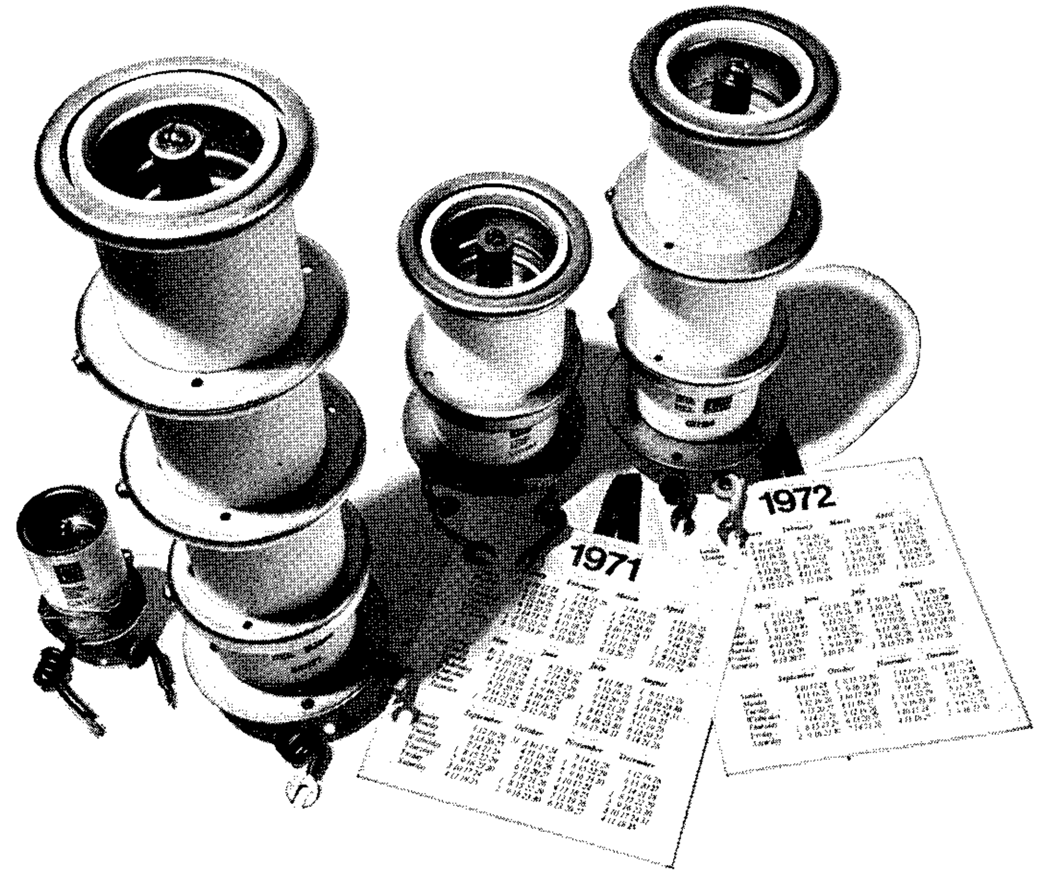
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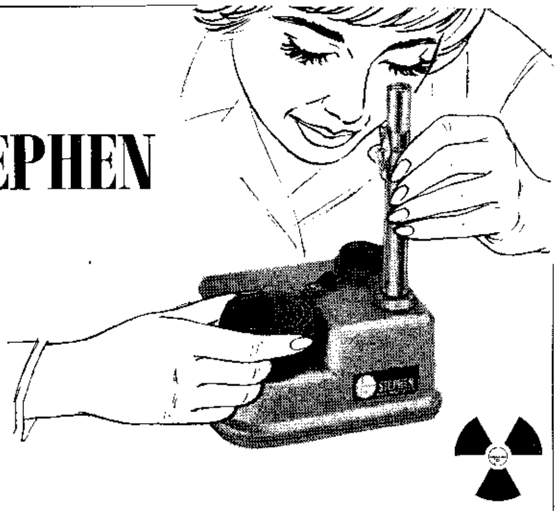

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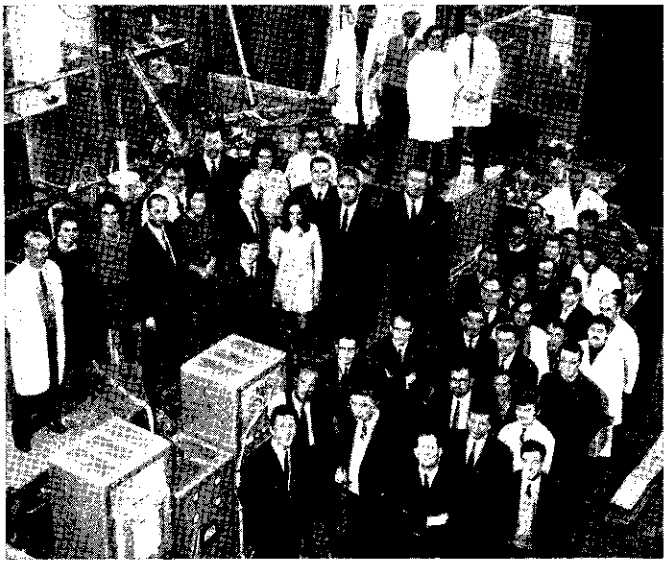

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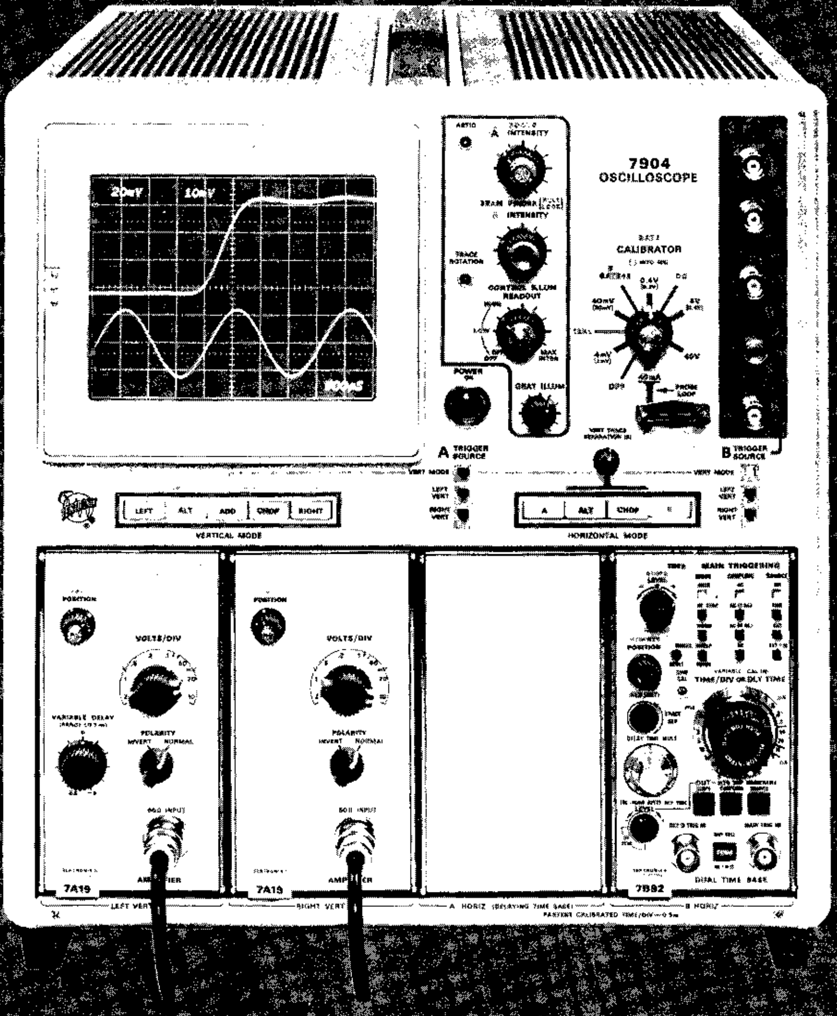

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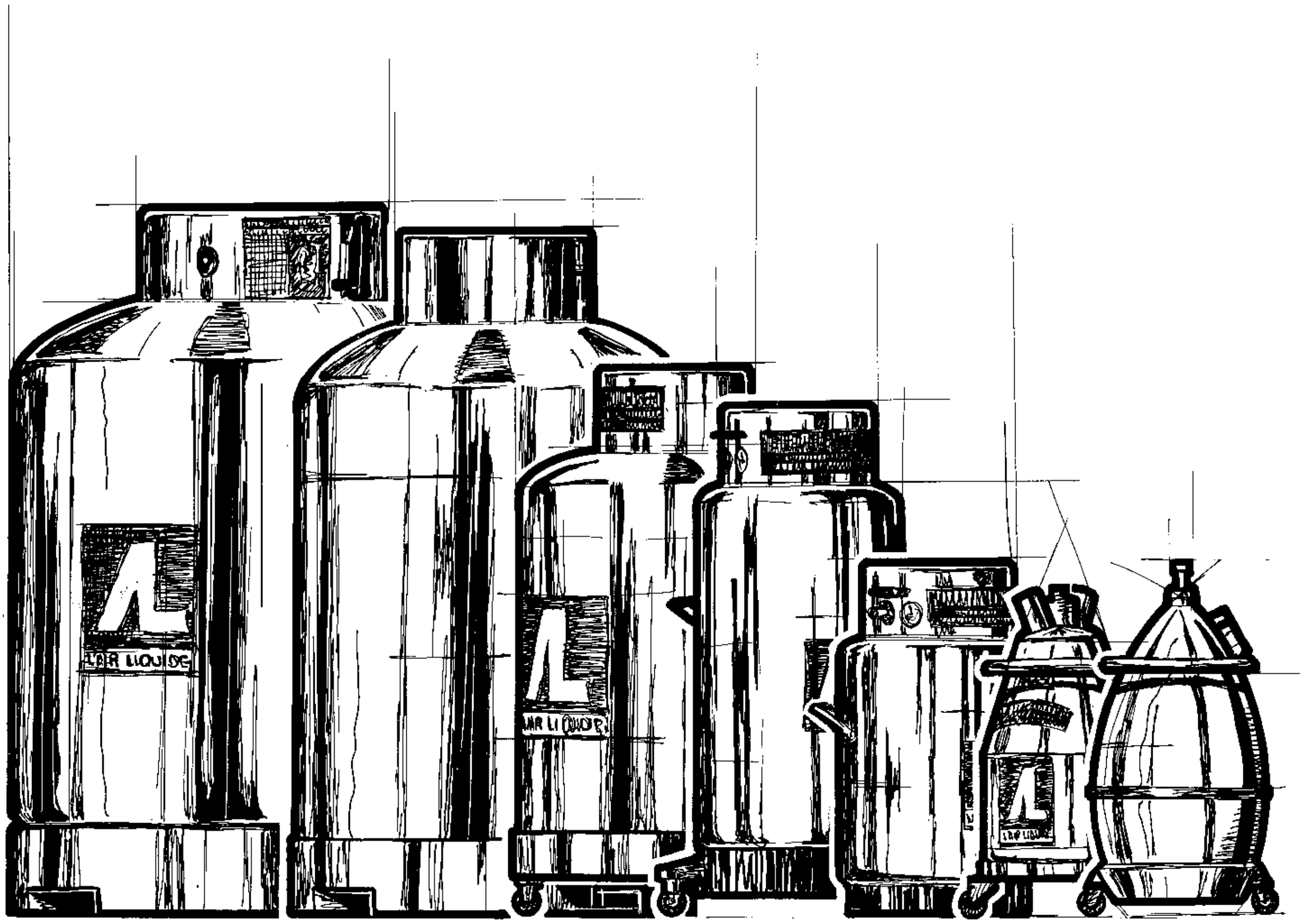
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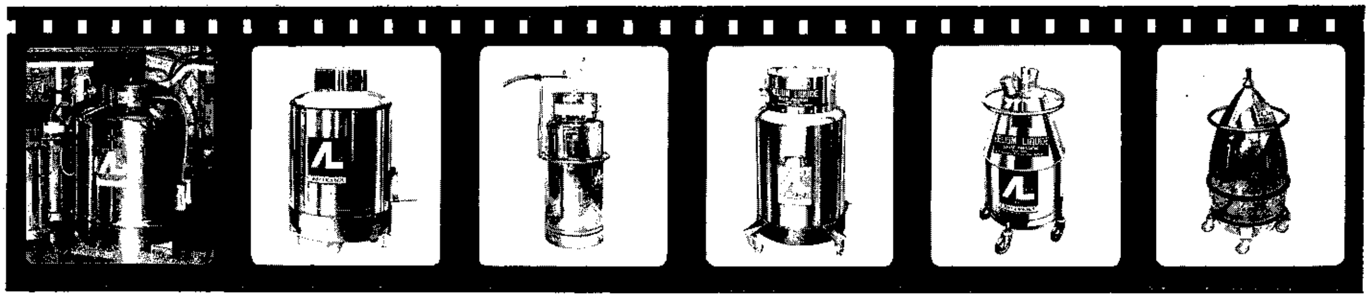
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Here the CRT DISPLAY modules
In the last month's we showed the SCALERS
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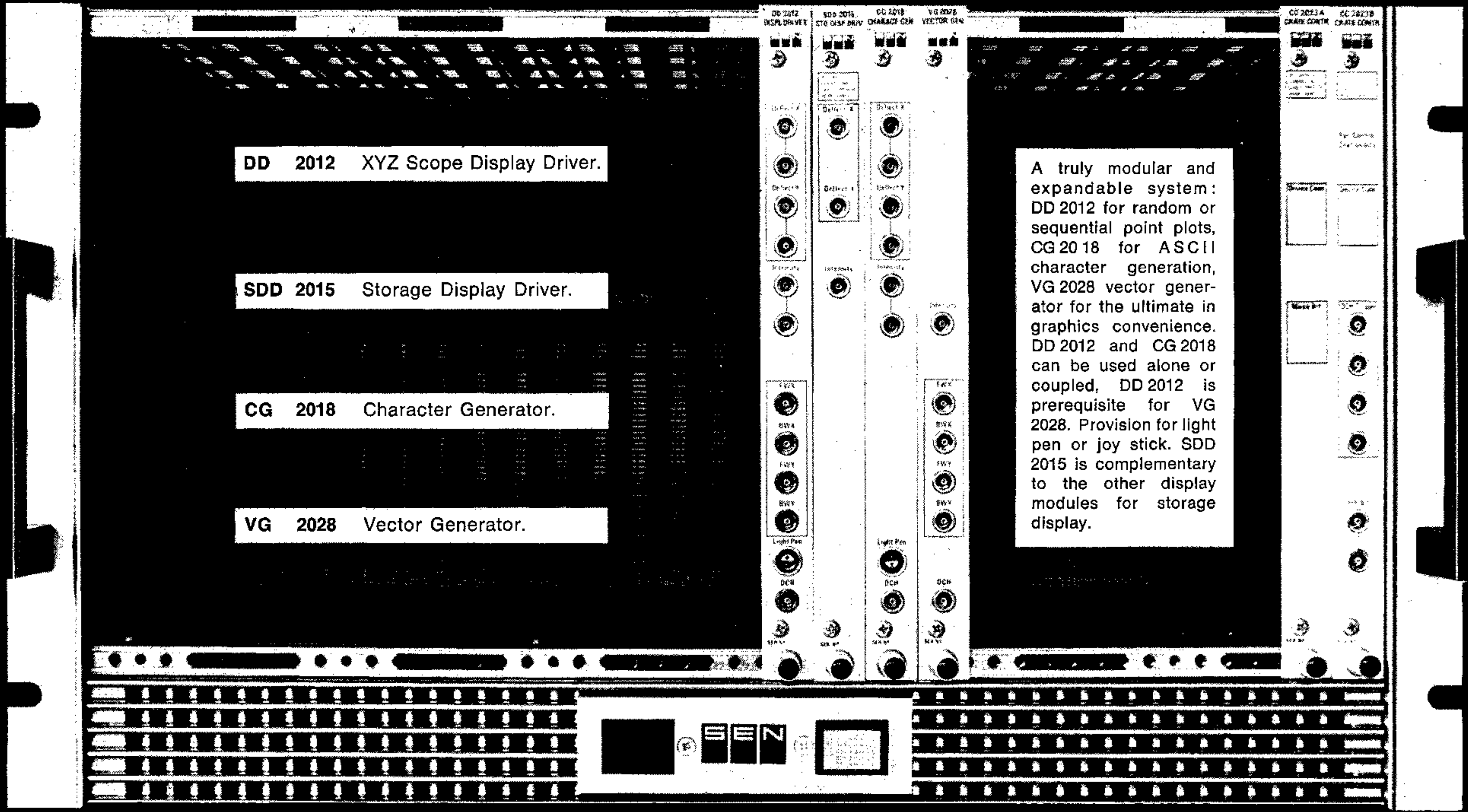

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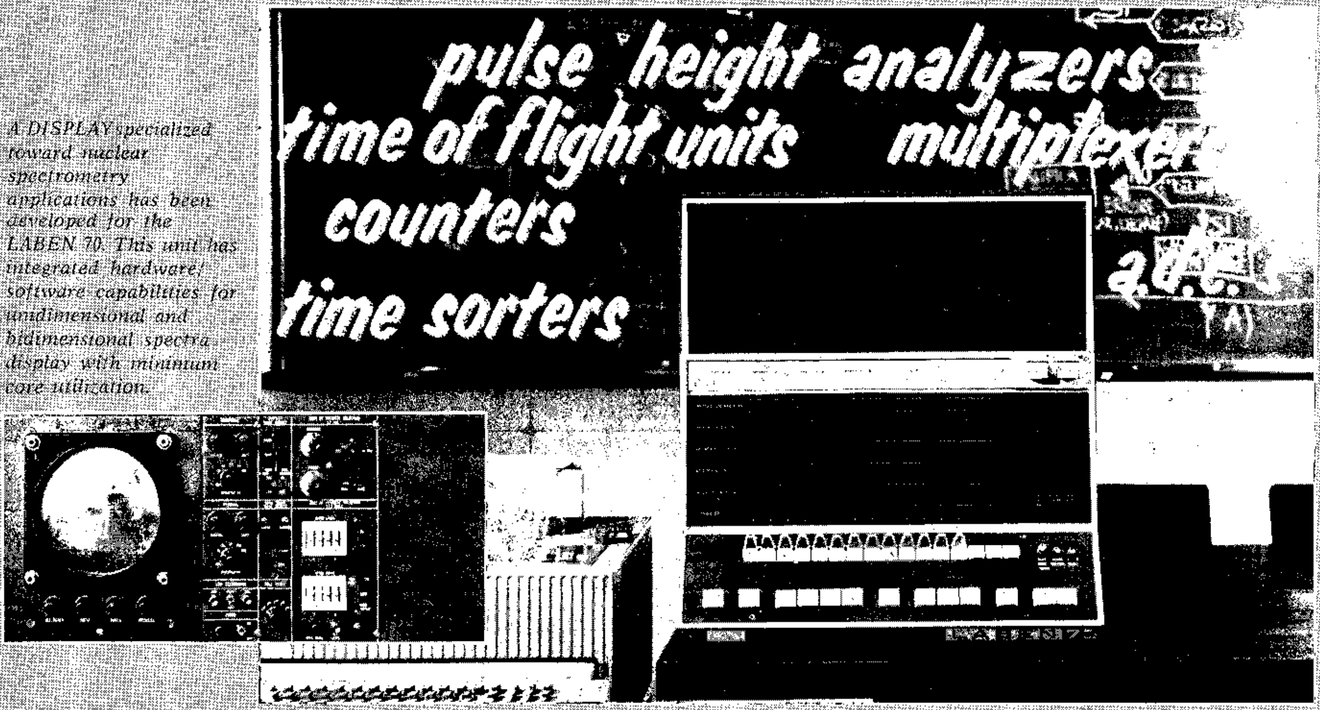

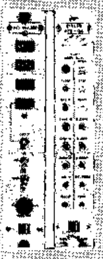

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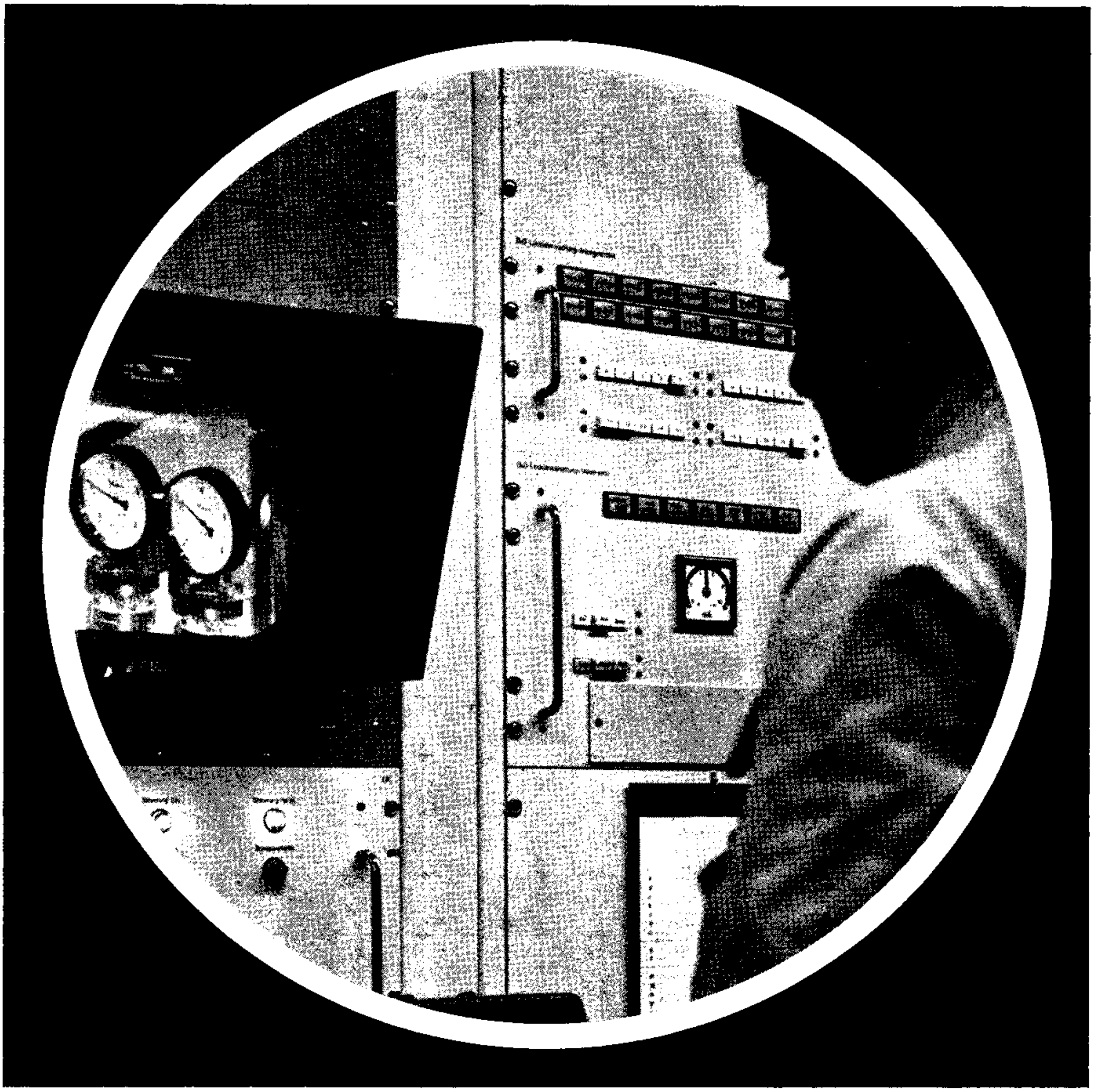

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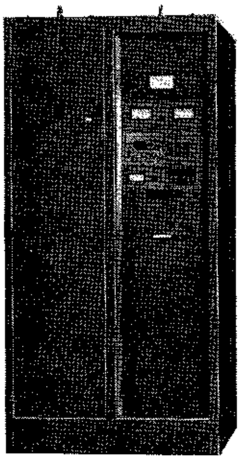

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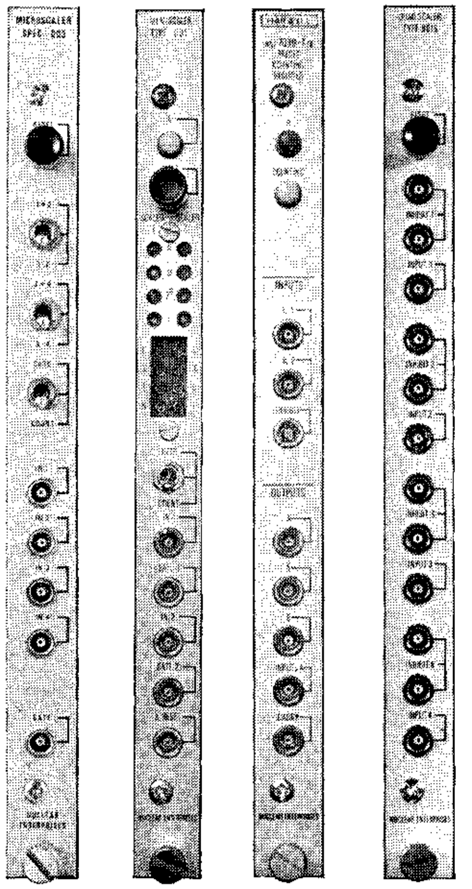

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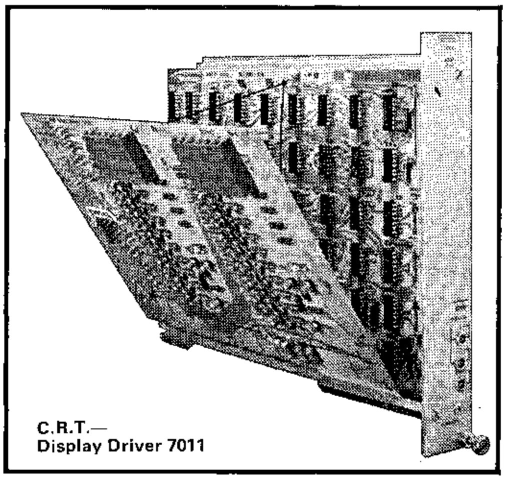

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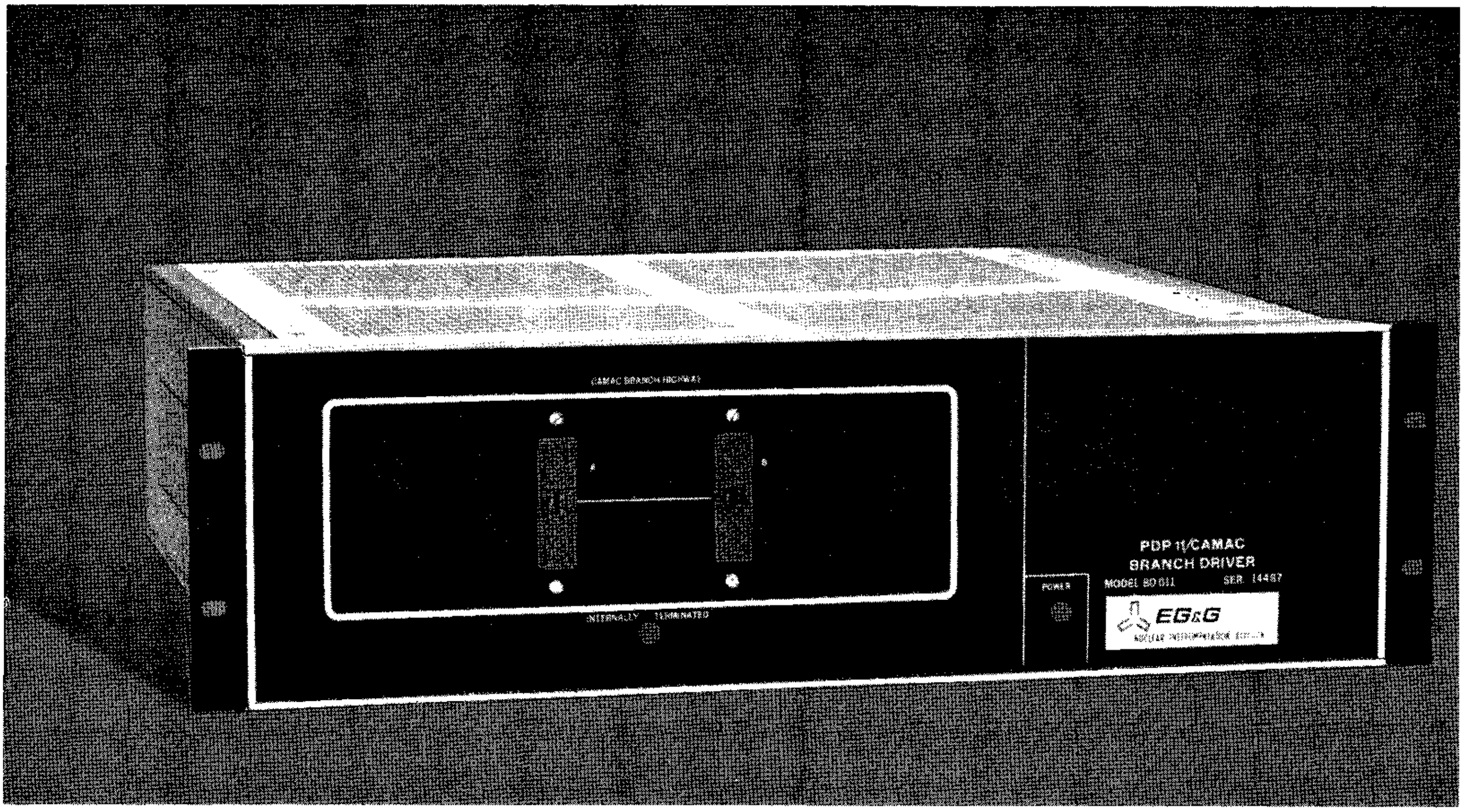
Display Driver 7011

CAMAC can operate with all computers and is compatible with NIMS modules such as the Nuclear Enterprises International Series. Full details of the units above and complete range are available on request from:-

NUCLEAR ENTERPRISES LIMITED
Bath Road, Beenham, Reading RG7 5PR, England. Tel: 07-3521 2121.
Cables: Devisotope, Woolhampton. Telex 84475.
Sighthill, Edinburgh, EH11 4EY, Scotland. Tel: 031-443 4060. Cables: Nuclear, Edinburgh. Telex 72333.
Germany: Nuclear Enterprises GmbH, Munich 2, Karlstrasse 45. West Germany. Telex: 529938.

Swiss Agents: **High Energy and Nuclear Equipment S.A.,**
— 2, chemin de Tavernay, Grand-Saconnex, 1218 Geneva, tel. (022) 98 25 82 - 98 25 83



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- Functions as an integral part of the system diagnostic software and allows CAMAC arrays to be debugged to the module level.
- Double-width CAMAC module.
- Diagnostic and data-handler software provided.

Contact EG&G or your nearest EG&G Sales Office for complete details of the BD011, TM024, and our other CAMAC system products.

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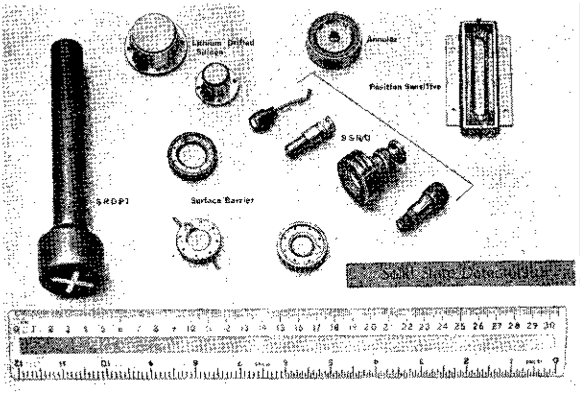
CENTRONIC SHOWCASE



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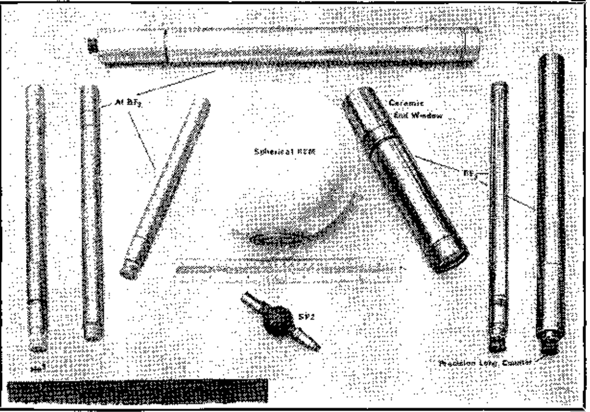

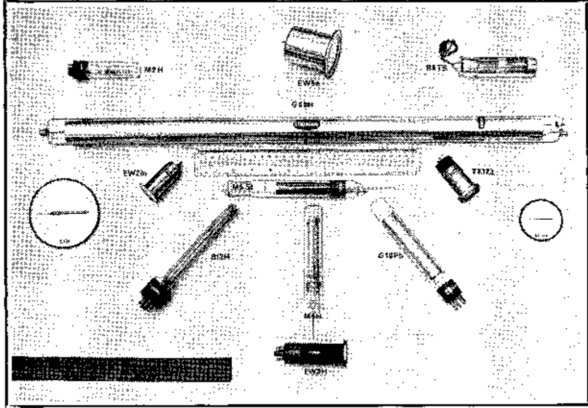

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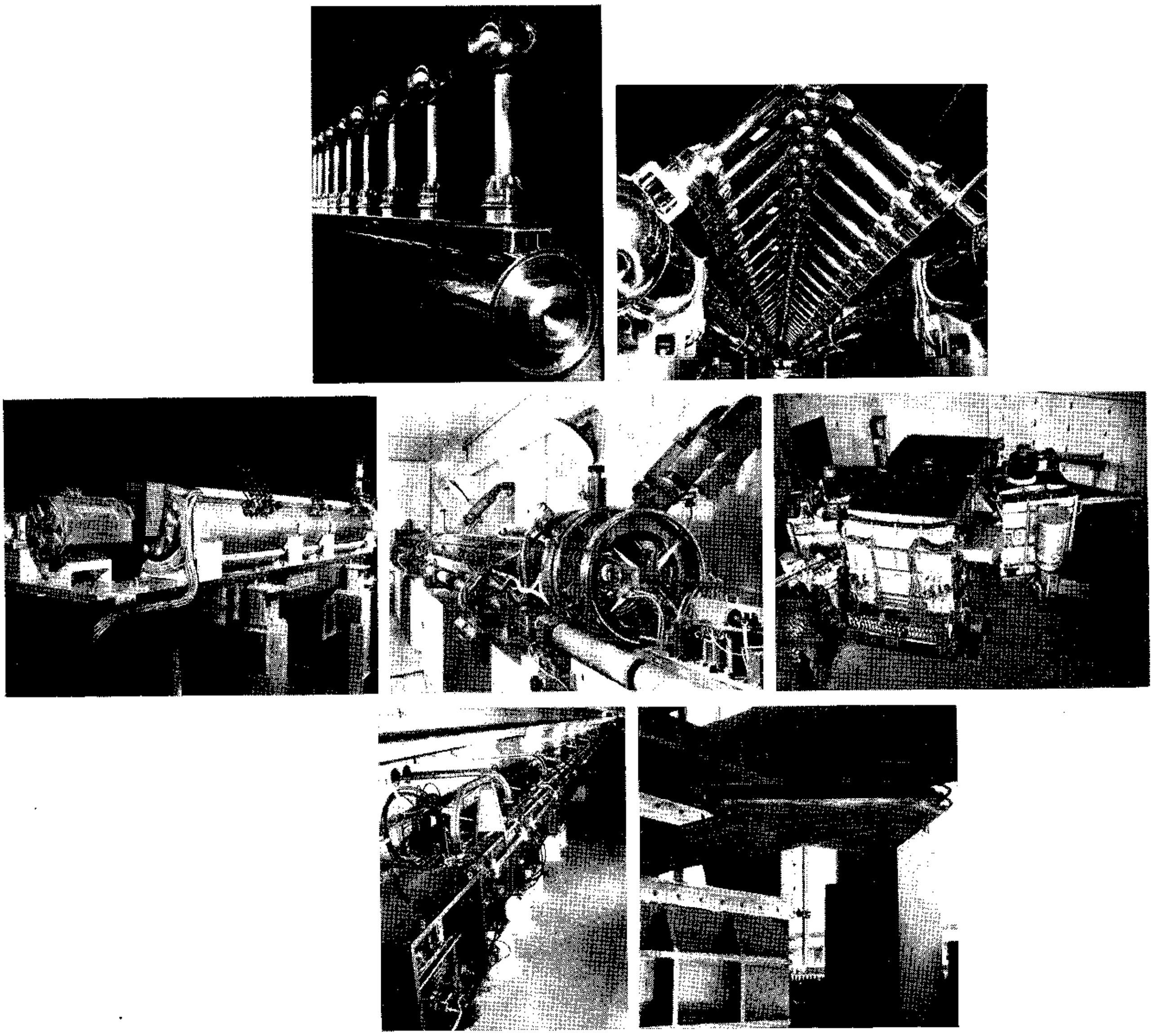

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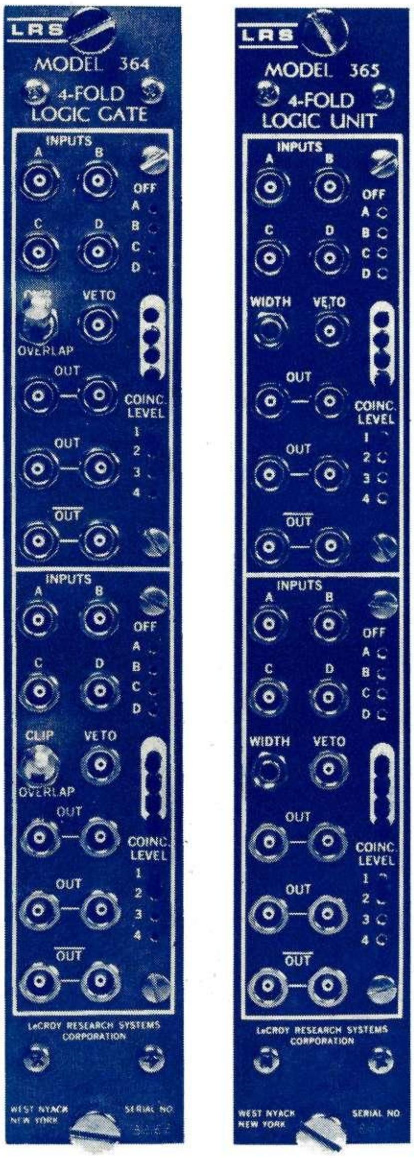

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