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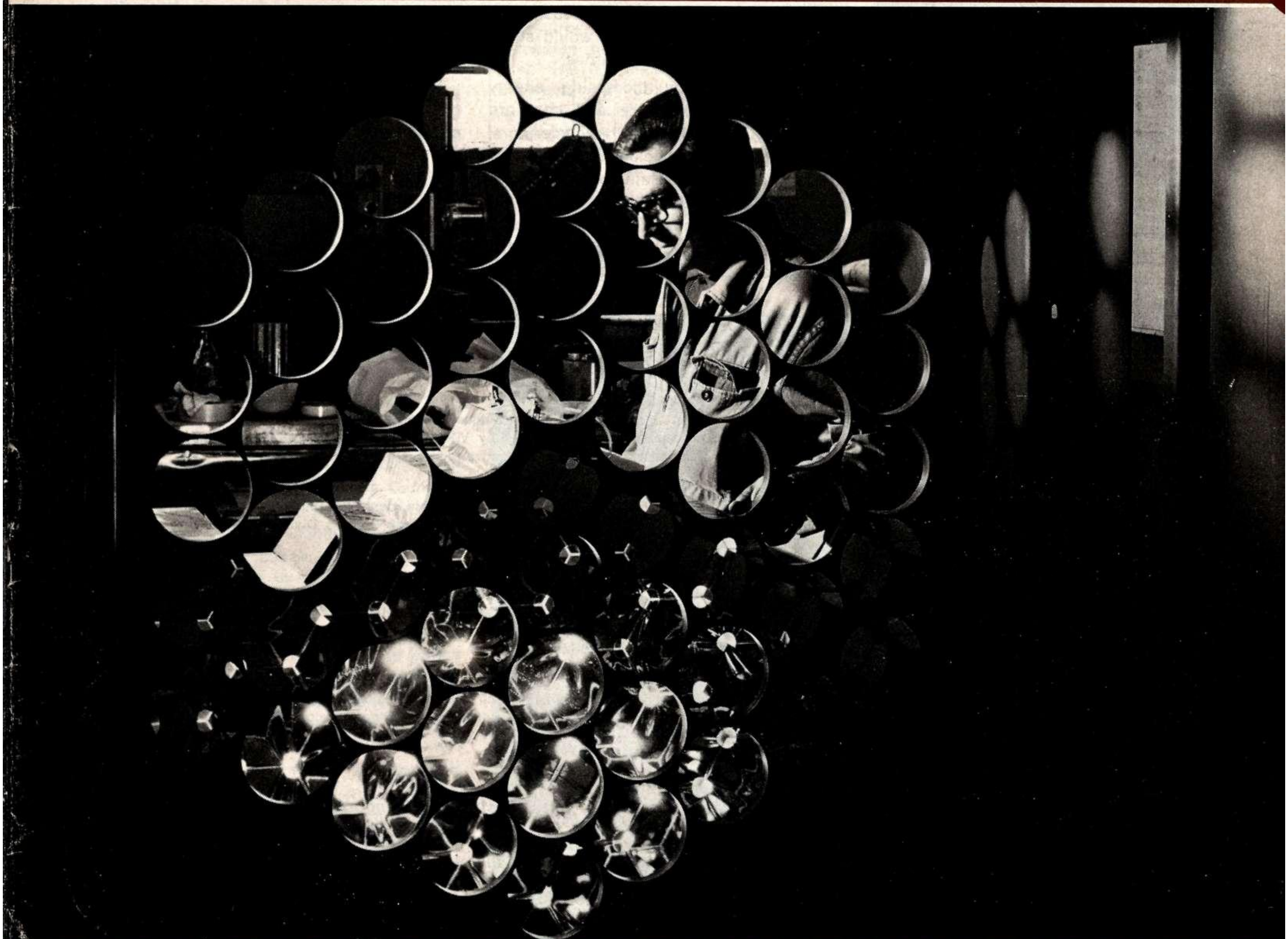

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, 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. 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.

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Collective Ion Acceleratio

The author is the leader of the Dubna team in the USSR which did the pioneering work on electron ring accelerators in 1966-67.

V. P. Sarantsev

The rapid development that has taken place in sub-nuclear physics has yielded a number of discoveries of fundamental importance. However, it will probably be impossible to understand the really basic laws relating to elementary particles and the structure of matter until accelerators have been built which can provide particles with an energy of tens or hundreds of thousands of GeV.

The task of designing accelerators with energies of hundreds of GeV has shown that accelerators designed for even higher energies would require an enormous effort. The sheer size and cost of such installations would go beyond what is reasonable and attain proportions which would strain the resources of entire countries.

The reasons why increasing energy results in increasing size and cost are generally these : In linear accelerators, the strength of the accelerating field acting on the particles is relatively low ; above an energy of 10 GeV, the length of the accelerator becomes colossal. In cyclic accelerators, which currently provide the highest energies (strong-focusing proton synchrotrons), higher and higher energies can be obtained only by increasing the radius of the particle trajectories because the maximum strength of the magnetic field used to keep the particles in orbit does not at present much exceed 15 kG. The size of the electromagnet, its weight, the demand on the power supply and the cost of the whole installation rise in proportion. «

This is why it is clear that the construction of ultra-high-energy accelerators (of the order of 1000 GeV) requires methods of acceleration based on a new principle in which the fields acting on the particles would be much stronger than in the current accelerators.

V.I. Veksler and others pointed to the possibility of acceleration making use of collective and coherent effects.The fundamental idea behind such methods is that the field which causes the particles to be accelerated is not produced directly by external sources but by the interaction of the particles we wish to accelerate with another group of charges, such as a jet

Contents

Cover photograph: A large lead-glass spectrometer being assembled at CERN for an experiment on the CP violating decay of the long-lived neutral kaon into two neutral pions being carried out by the Aachen, CERN, Torino group. Nearly half of the lead-glass crystals can be seen in the lower part of the photograph already installed. Incident electrons and gamma rays will dissipate their energy in the crystals and the resulting light will be captured by photomultipliers (not installed at the time the photograph was taken). The important feature of the assembly is its excellent energy resolution of 1.5 %. (CERN/PI 174.7.69) of electrons, plasma flux or electromagnetic radiation.

The principles of collective acceleration were presented at the 6th International Conference on Accelerators held at Cambridge, USA, in 1967. (See CERN COURIER vol.7, page 201 and vol. 8, page 28). It will, however, be worthwhile recalling the general principles.

Imagine a compact cluster or bunch of electrons containing a relatively small number of ions — protons, for example. If we force the bunch to move in an external electrical field which accelerates electrons, the ions will stay in the bunch in certain circumstances, because they are held by the Coulomb field, and will be accelerated with the electrons. If the effective mass of the electron is m, after allowance has been made for its movement within the bunch itself, and that of the ion is M, the energy possessed by the ion, at the same velocity as the electron brunch, will be M/m times greater than the energy of the electron.

The strength of the external field cannot be arbitrarily large, otherwise the ions will become detached from the bunch of electrons, and lag behind. Obviously, the external fields that can be applied, and thus the ion energy that can be obtained for a given accelerator length, can be increased if the strength of the Coulomb forces retaining the ions is increased. If we consider a bunch of electrons produced in the form of a ring, the Coulomb field at its boundary will be of the order of 1 to 10 MV/cm for reasonable numbers of electrons in the bunch. Then we could use accelerating fields of upto this strength without pulling the bunch apart.

During acceleration, the bunch becomes polarized, the centre of the bunch of ions lagging slightly behind the centre of the bunch of electrons (though still within the bunch of electrons) and the force acting on the ions due to the accelerating fields is balanced by the Coulomb force acting on the ions as they have moved to the rear of the bunch. It is clear that the bunch must have the following properties : the number of electrons must be considerably greater than that of the ions, and the electron density must be as high as possible.

At Berkeley

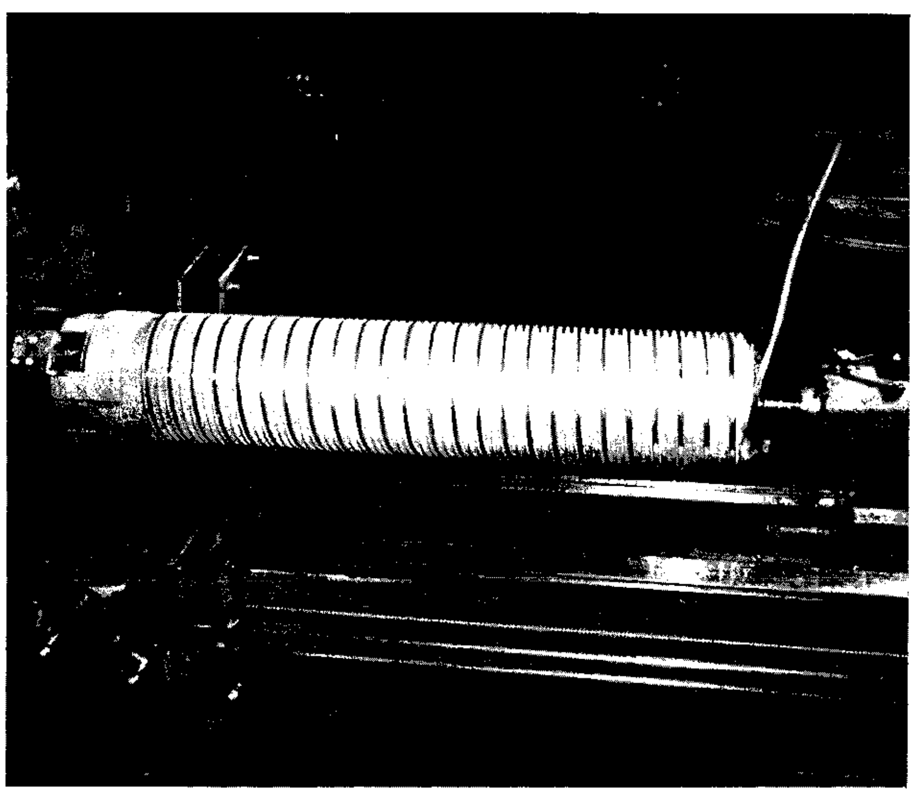
Since last October, when the successful ring-forming experiments were carried out with 'Compressor 2', the Berkeley ERA group have been busy analyzing those experimental results and designing and constructing apparatus for the next round of experiments. This apparatus, called 'Compressor 3', is a pulsed compressor to form rings with a high holding power. It has additional features that will allow the ring to be extracted from the compressor and accelerated axially in a long solenoid with a tapered field.

After compression and loading with ions, the symmetry of the magnetic field in the compressor is deliberately disturbed to move the ring out of the median plane for several centimeters so that it comes into the field of the solenoid. By adjusting the parameters of the electrical circuits which power all the magnet coils, the ring should reach a point of 'spill-out' where the magnetic field gradient vanishes and the ring accelerates because of a small constant radial component of magnetic field in the solenoid. When the magnetic field gradient vanishes, the focusing forces needed for the ring to retain its integrity should be supplied by the trapped ions. The main difficulties are expected to arise from the serious integral resonance (QR=1).

The Berkeley design includes the possibility of either remaining below this resonance (QR < 1), or of jumping across it (QR > 1) by means of a very fast magnetic perturbation. Experiments using the former approach will begin at the end of July.

Plans are well advanced for the construction of a high-current source of relativistic electrons specifically for ERA research. Acceleration to a few MeV will be accomplished by linear induction in a sequence of pulsed ferrite-loaded, accelerating cavities. The pulse length will be 35 nanoseconds, the repetition rate 1 to 10 pulses per second, and the current in the range 500-1000 Amps. The source should be available early in 1970,

Fabrication at Berkeley of the solenoid in which electron rings will be accelerated. One layer of the trifilar winding can be seen. To achieve the required field, the tolerance on the positioning of the conductors is 0.2b mm. (Photo Berkeley)



At Karlsruhe

It is hoped to reach the stage of inductively compressed electron rings very quickly so as to direct efforts onto the really interesting problems of acceleration.

For the future it is planned to have a high repetition, bright beam electron source (static compressor) but initially, Karlsruhe has bought a field emission apparatus (a Febetron 705 manufactured by the Field Emission Co., Oregon) and are testing it as an injector. The measurements indicate that it should be possible to obtain 10^{13} electrons of 2 MeV within an energy spread of ± 2 % into an emittance of 0.1 cm rad during 9 ns. Attempts are being made to improve the field emission tube lifetime and electron beam brightness by running the tube without a window. The main obstacle is the ultra high vacuum of around 10^{-9} which must then be maintained in the whole beam transport system.

A three stage compressor is scheduled to be constructed by the end of August. Inflection studies and compression will then be carried out using a provisional vacuum chamber made of epoxy. The final vacuum chamber is being fabricated of alumina ceramics. Electrons will then be injected onto a radius of 22 cm and compressed to 3 cm while the electrons reach an energy of 19 MeV. During the compression time of 250 μs, the field index will vary between 0.6 and 0.15, the dangerous half integer resonance being crossed only once at a small radius. Forced oscillations of the loaded electron ring in the medium plane will be studied as a means for ion diagnostics. By careful matching of the admittances it is hoped that a high holding power can be achieved.

The application of smooth wave guides (e.g. helix, dielectric tube) for the acceleration of the electron rings is being investigated theoretically.

At Munich

The main aims of the Munich group are: the production of an electron ring with high aspect ratio; fast compression of the electron ring (with a compression time an order of magnitude smaller than at Berkeley and Dubna); development of electron sources with high current and small emittance; production of an ion ring, which can be combined with the electron ring; and, later on, the axial acceleration of this ring.

A Febetron is used giving a current of 4 kA of electrons with an energy of 1.9 to 2.4 MeV. The current which can be used to form electron rings, that is the current entering the snout (13 mm 0) of the compressor after passing through a beam transport system, is only 40 A at present but it is hoped to increase it. The emittance of the beam is about 70 mrad cm. Measurements of the energy distribution of the electrons are now being made with the aid of the compression field.

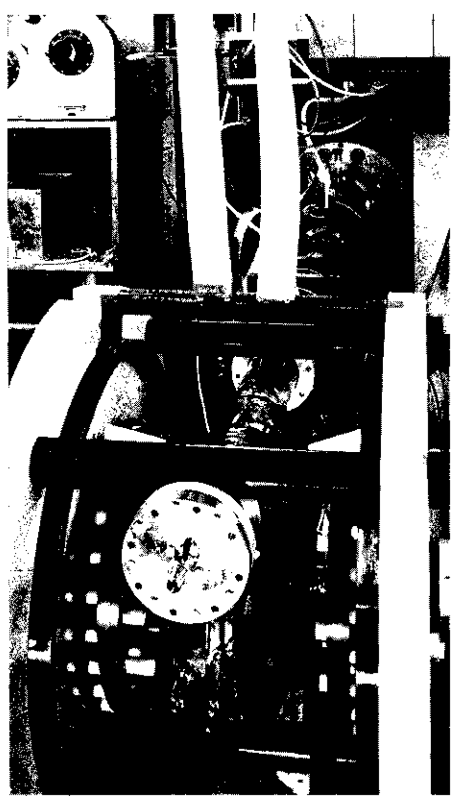
A different type of electron gun is being investigated. A laser pulse of 17 ns is focused on a metal target and the emitted electrons are accelerated in an electric field. With a laser power of 2 J at a voltage of 30 kV, an electron current of 930 A has been reached. By increasing the laser power and the voltage, higher electron currents might be expected.

The ion gun consists of aduoplasmatron, which produces protons with an energy of 3.7 keV and a current of 10 mA. The ion beam emittance has been measured to be smaller than 100 mrad cm.

The compressor is designed for 3-stage compression. It is now being operated using 2-stage compression having maximum currents of 68 kA and 210 kA in the two coils with the currents rising to maximum values in 8 μs and 10 μs respectively.

Theoretical work is being done on injection mechanisms of the electrons, on the properties and stability problems of electron rings, and on radiation losses of accelerated rings in cavities.

A photograph of the Munich compressor. The electron beam-line can be seen coming in from the rear to the compressor which has coils arranged symmetrically on each side. (Photo Munich)



Formation of the electron-ion bunch

The bunch is produced in an adhesion unit, also known as a 'compressor' for the method of bunch production we will discuss first. A ring of electrons is formed and compressed in the adhesion unit and a small amount of neutral gas (hydrogen, if the aim is to accelerate protons) is introduced by megns of a pulsed gas valve. The relativistic electrons collide with the hydrogen molecules and molecular ions are first formed which, during subsequent collisions with electrons, separate into hydrogen atoms and protons. The protons will then be captured in the ring.

Other gases than hydrogen may be used, and different ions trapped in the ring. The possibility of obtaining multiply charged ions of heavy elements in the electron ring has been examined. Successive collisions between the ions and electrons lead to an accumulation of ions with different degrees of ionization. To take a concrete example — for mercury ion accumulation in the ring, we find that the ionization time of an Hg atom ionized five times is 30 μs. With the adhesion unit in operation at Dubna it is already possible to obtain mercury atoms ionized 10 times. The time during which the ring is in its compressed state (i.e. the time during which it can be used to ionize atoms) could probably be increased by an order of magnitude.

This method of bunch production is not the only one, but an analysis of certain other variants has shown that, at present, the radial compression of an electron ring makes it possible to obtain greater particle densities. Among the other methods, mention should be made of two methods which are similar from the physics standpoint. One is based on the use of a tubular beam of electrons moving at relativistic speeds. When this type of beam hits a hump in a magnetic field, a bunching process takes place and a ring is formed. By varying the electron energy, the length of the beam and the magnetic field gradients, high contraction coefficients can be obtained and this method holds out the possibility of producing a bunch containing a very high number of particles (10^{15} and above) if there are no strict requirements on the dimensions of the cross-section of the resulting bunch. A bunch of this type could be used during the production of the so-called 'shock acceleration'. However, the practicability of accelerating a tubular beam is not clear.

A further possible way of obtaining annular bunches is by using a magnetic 'bottle' with a field which increases adiabatically. This possibility was examined at Dubna as an alternative to the adhesion unit, and experiments have been carried out elsewhere in which this alternative solution has been used. The method has several drawbacks, the most important being that when many turns are injected into the magnetic bottle it is difficult to obtain, in the final state, a ring cross-section of small dimensions, and when a single turn is injected it is unlikely that a sufficiently large number of particles can be stored in the ring. The question of how the ring could be extracted has also to be settled — it is certainly not a trivial matter in such a system.

I would especially like to mention certain considerations about ways of obtaining a relativistic stabilized Budker-type beam.

Estimates show that it is not possible to obtain this sort of ring in an adhesion-type installation because of the need for extremely high vacuum (10~^{12} torr) and difficulties relating to the compensation of electron energy losses (since the time taken for the ring to reach a stationary state is long — about a second). The difficulties can, it seems, be overcome if the ring is extracted from the adhesion unit with a special trap. The ring stabilization process in such a system occurs when the ring is constantly moving between 'stoppers' and the above-mentioned difficulties are fully overcome. In a system of this type, the energy losses may be offset by simple methods and the vacuum requirements are less exacting (10^{-7} torr). The question of the stability in such a system must be studied separately.

A few words about the part which such a stabilized ring could play in collective ion acceleration. The accelerating field limit values undergo, as a result of the small cross-sectional dimensions (10~^{3} and 1CT^{4} cm^{2}) of the ring, an increase of 1000 times, which means that such a bunch can be used in shock acceleration. If this is combined with the possibility of obtaining an intense bunch from a tubular beam, it will increase acceleration efficiency and reduce still further the cost of the accelerator, by one or two orders of magnitude compared with the method which has so far been practically studied.

Extraction of the electron-ion ring

The magnetic field of the adhesion unit is produced by a system of coils symmetrically arranged around the plane in which compression of the electron ring takes place. Then for the electron ring to be extracted, it is necessary to overcome the barrier created by an increasing magnetic field, along its axis.

Studies of particle movement in fields which are spatially non-uniform, show that an annular bunch will move in the direction in which the field decreases. The velocity of the bunch as it travels along the axis will increase while the velocity of the electrons orbiting around the ring itself will decrease, so that the ring expands radially (so-called 'expansion acceleration'). Consequently, to extract the electron ring, a magnetic field must be created which decreases along the axis in one direction. It must be remembered however that the gradients of this field must not exceed the limit at which ion detachment begins.

In the Dubna equipment, to remove the potential barrier and extract the electron ring, we have three additional coils which are powered at a specified time. This time is chosen so that, though the field from the main coils continues to rise, the effect of the additional coils removes the potential barrier on one side. Calculations have been done for the entire system of coils and the results have shown that the particles should move a distance of 10 cm along the axis at low velocity.

Experiment has revealed some disagreement with these calculations, particularly as regards the precise time at which to power the additional coils. This is probably due to the fact that, in the calculations, no account was taken of the resistance of the switching component which turned out to be considerable. The subsequent movement of the ring occurs in the direction of decreasing field and the preliminary experiments have shown that the velocity of the extracted ring reaches 0.3 times the speed of light. This has given us the idea of using the adhesion unit as an autonomous accelerator.

We have already shown that it is possible to obtain multiply-charged ions in the electro/i ring. A large part of the research using such ions calls for energies of the order of 5 to 10 MeV/nucleon and calculations have been made of the possibility of obtaining such energies from the adhesion unit. The movement of the electron ring with multiply-charged ions is influenced by the fact that the mass of the ring is essentially contained in the ion component.

Let us take a concrete example — the acceleration of atoms with atomic number say 200. As shown above, with the existing adhesion unit, we could achieve ions ionized ten times. Let us choose the ratio of the number of ions to the number of electrons as 10~^{3} and the number of electrons as 10^{14}. The tolerable fields could be 40 kV/cm, which corresponds to a magnetic field decreasing at the rate of about 50 G/cm and the total acceleration length will then be equal to 50 cm to achieve an energy of 10 MeV/nucleon. The intensity of the accelerated ion beam will depend on the number of ions per ring (10^{11}) and the operating frequency of the equipment used to produce the rings. Judging from the equipment currently in use, this frequency, at the present development stage of the technique, is about 10^{3} per second, giving an ion intensity of about 10^{14} per second.

The same system of expansion acceleration may be used for the construction of intermediate energy proton accelerators and the intensity obtained will be higher, by an order of magnitude than that of the multiply charged ions since, for protons, 10~^{2} is selected for the ratio of ions to electrons. Proton energies up to 1 or 2 GeV should be attainable.

All of the estimates mentioned above are based on the assumption that the Coulomb field of the ring acting on the ion remains constant. This is so providing the dimensions of the cross-section of the electron rings can be retained effectively.

We have examined several devices for confining the dimensions, such as self-phasing on a travelling wave, r.f. focusing, and focusing on opposed waves. AH of these methods have their limitations ; for example, self-phasing can only be used at low ring velocities because the required focusing field gradients become too severe at high velocities. On the other hand, focusing on opposed waves is effective only for high velocities. R.f. focusing also has its limits for high velocities and calls for very powerful r.f. power supplies or for complex r.f. cavity structures.

We have discovered that the forces due to the image charges in screens along the accelerator can be used for focusing ; the result is that there is a focusing force along the axis. For practical purposes, however, this effect must be increased. Calculations for a slotted screen indicate that it should be possible to keep the ring cross-section dimensions constant, which is essential for effective acceleration of the bunch.

Acceleration of the ion-electron bunch

Very high ion energies cannot be obtained with an expansion acceleration system alone. We need to make use of the properties of alternating magnetic field gradients, combined with a system of accelerating cavities.

In the spaces between the cavities, the magnetic field is arranged to decrease linearly along the axis and the ring is there accelerated as described above. Inside a cavity the magnetic field increases so that energy is transmitted to the ring, basically into rotational movement of the particles, and only part of the energy (that which corresponds to the tolerable acceleration) contributes directly to movement along the axis.

The system of acceleration by cavities is not the only one ; the pulsed-line system proposed at Berkeley may prove highly advantageous. In such a system, the main energy accumulator is a condenser and it is a well-known fact that the cost of a single joule of energy may vary by as much as 100 to 1, depending on whether it is stored in a condenser or a cavity. Complexity of construction, particularly in the electrical switching system, means that in practice this price ratio does not exceed 10 to 1 and in this case, it is assumed that the coefficient of accumulated energy utilization is high. To do this in a pulsed-line system it is necessary to produce switching elements with an operating accuracy of 10^{-10} s.

It might seem that this drawback offsets all of the advantages of the system but the requirements for such high accuracy can be substantially reduced if such a system is used in combination with magnetic field variation, as in the cavity system. Studies will be carried out along these lines.

Ring stability

The problem of stability of the bunch can be split into two parts : stability of the electron ring during the contraction process in the adhesion unit and stability of the electron-ion ring during extraction and acceleration. The first problem has now been fully resolved. Specific criteria have been obtained for the density, number and energy dispersion etc... of particles, in which certain instabilities arise.

Confidence in these criteria is further supported by certain factors which are by no means insignificant : those of experimental checks. To understand fully all of the processes which take place during contraction, we should probably make a detailed examination of the influence of the resonances which occur during contraction and ion absorption.

As regards the second problem, there •are two aspects which are of interest. The first is the influence of the so-called 'radiative instability' on the movement of the ring. This problem should be solved in using the slotted screen and a modified magnetic field. The second concerns the energy emission by radiation as the charged bunch travels through the cavity system. This remains to be investigated in practice but does not seem as serious as was first thought.

The work on collective ion accelerators has become of major importance. I think that from now onwards the efforts of many physicists will eventually result in the construction of the first accelerator to operate on the principle of collective acceleration.

CERN News

Appointments

The following appointments were made at the meeting of the CERN Council on 19-20 June.

H. Schopper will succeed P. Preiswerk as head of the Nuclear Physics Division. Professor Schopper has been appointed for a period of three years, beginning 1 February 1970. •

Four Directors of Departments were reappointed for a period of three years beginning 1 June 1969. P. Germain (Proton Synchrotron), G.H. Hampton (Administration), K. Johnsen (ISR Construction) and Ch. Peyrou (Physics II).

As from 1 September 1969, the Nuclear Physics Apparatus Division will be disbanded.

The Scientific Policy Committee has lost the services of two of its members in recent months — J.B. Adams (on becoming Director of the 300 GeV project) and G. Bernardini (on becoming President of the European Physical Society). G. Puppi has succeeded J.B. Adams as Vice-Chairman of the SPC and four new members have joined — M. Conversi, G. Ekspong, B. Hahn and A.W. Merrison.

Robots enjoy radiation

Nearly a year ago, 100 dosimeters of the air ionization chamber type were installed in the PS ring (one per magnet) to monitor the particle losses at various positions around the machine.

The ionization chamber is a small container of non-conducting material, filled with gas, inside which pairs of electrodes, held at a high potential difference, are arranged. The ionization produced by radiation makes the gas conducting in proportion to the radiation dose received. The ionization itself is proportional to a characteristic constant of each gas, and, for example, argon offers a high degree of sensitivity. Air chambers are however cheaper and far less complex, since they require no special gas supply.

It has been possible to observe particle losses, as expected, but to evaluate their intensity and precise origin has proved difficult because the probes become saturated in the case of very high losses (such as near the ejection zones) and give no reading in the case of very slight losses. A way around this problem in an important region of the machine has recently been found using the remotely controlled manipulator (described in CERN COURIER vol. 8, page 246). The manipulator can move around sections 57 to 63 covering the slow ejection region and fast ejection 58. A small ionization chamber with two sensitivity scales (argon and helium) was designed to be carried at the end of the main arm of the manipulator. This probe can then be moved while the PS is in operation, to take measurements around the vacuum chamber and even inside the magnet poles.

The unprecedented flexibility of this monitoring method allows losses to be traced rapidly and accurately. Also, since the probe can travel from one magnet to another, direct comparisons can be made, avoiding the calibration problem which is present when data from several different probes have to be compared.

The assembly is very simple, as can be seen from the photograph; the probe is placed at the end of the arm and argon reservoirs are carried on the main part of the arm together with a glass tube reservoir of coloured liquid through which the argon passes producing bubbles to check the gas circulation.

Mobile television cameras follow the movements of the probe using known reference marks. Up to now, reference marks such as certain magnet connections or a few reference points marked on the magnets have been used, but to chart the losses systematically, a grid coordinate system will be introduced around the magnets.

The manipulator control console is not in the main control room but the communications problem has been reduced by using two-way radio and by transferring the manipulator TV camera picture to the main control room.

The manipulator soon provided some very useful information. For example, it has been possible to determine whether losses are produced by the internal beam or by the ejected beam in the ejection region where the two beams are very close. It is also possible to follow how losses vary as machine performance parameters are changed.

These, however, are early days in the use of remotely controlled manipulators. They are rapidly becoming important tools to help accelerator operators and are certain to grow in number and in versatility in the years to come. This will be especially true in future accelerators where higher intensities and corresponding radiation levels will make some remote handling essential. Future accelerators will include manipulators as an integral part of the machine design, specifically adapted to particular requirements, so that their effectiveness will be greater.

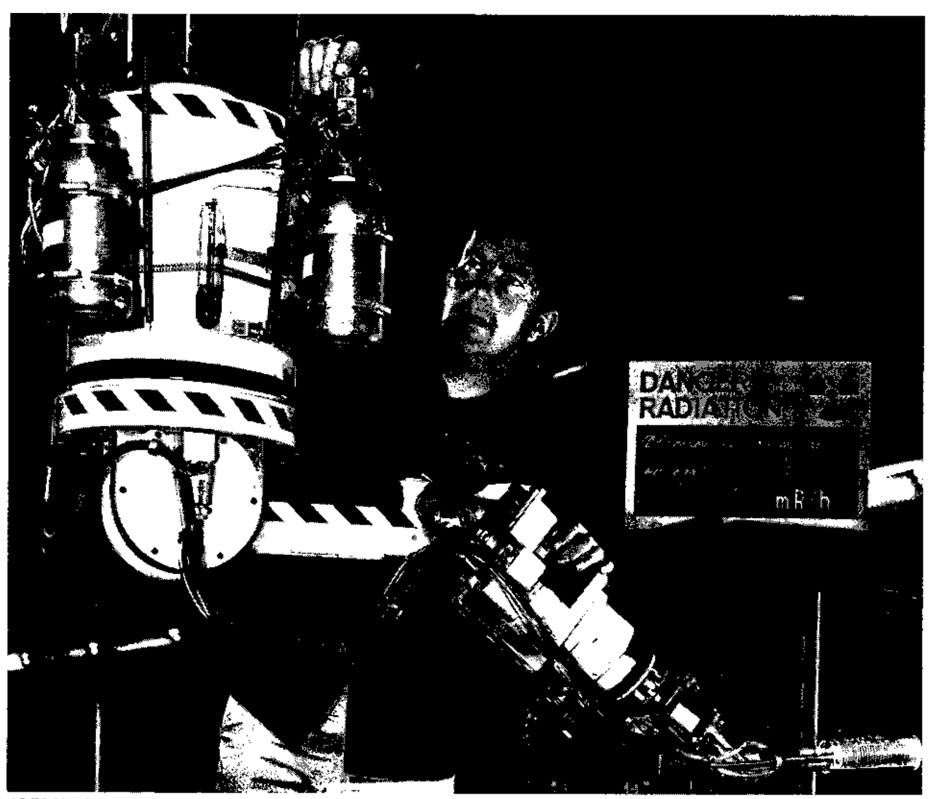
To each his computer

The Nuclear Physics Division has acquired two small Hewlett Packard computers to plug a gap in the computing facilities available to experimenters in the Division. Some experiments in NP that presently do not have an on-line computer would be happy with a computer much smaller than the IBM 1800 and their needs are met by the new Hewlett Packards.

The associated computer hardware is modular so that it can be expanded to the power of an IBM 1800 should the need arise. This means that the computers can be tailored to the needs of a particular experiment. They are thus well adapted to a variety of tasks, and all the more so since they are easily transportable. One is a 2115 A and the other a 2116 B — both having a memory of up to 8 k words of 16 bits without magnetic tape or disk. Their peripheral equipment is limited to a teleprinter and a rapid punched-tape reader.

The first computer, delivered at the end of December 1968, has initially two tasks — one being to check, on reception, the proper functioning of new equipment (for example, new electronic equipment conforming to Camac standards) and the other being to help in the installation and tuning of beam-lines.

The second computer delivered on 23 June is used to monitor a spark chamber experiment that records its data on magnetic tape (and on film). The computer reads the data transferred to the magnetic tape calculates certain functions and produces histograms.



The main arm of the remotely controlled manipulator carrying an argon ionization chamber near the straight section 58 (fast ejection region). The two bottles on the arm contain the argon gas supplied to the chamber and the return flow of gas passes through the 'bubbler' mounted between the bottles. The cables are for the high tension (1 kV) and the output signal.

(CERN/PI 35.7.69)

Computers in use in the Nuclear Physics Division

Type	User group	Computer provided by	Memory (thousand words)		Magnetic tape	Disk
SDS 920	Deutsch Welsdale	Nuclear Physics Division	8	(24b)	2	0
IBM 1800	Kienzle	»	16	(16b)	2	1
IBM 1800	Rubbia	»	16	(16b)	2	1
IBM 360/44	Dick	»	32	(32b)	3	2
HP 2115 A	Electronics and beams groups	»	8	(16b)	0	0
HP2116B	Zichichi	»	8	(16b)	0	0
DDP516	Thresher	Rutherford Lab.	8	(16b)	2	0
DATA 620/1	Winter/Vivargent	Inst, du Radium	4	(16b)	1	1
CDC 1700	Runge/Schopper	Univ. G.F.K. (Karlsruhe)	24	(16b)	2	1
CII 90-10	Van Rossum	Saclay	16	(12b)	2	0
IBM 1800	Mermod	Université de Genève	16	(16b)	2	0
IBM 1800	Sens	F.O.M. (Netherlands)	16	(16b)	2	1
DDP516	Darmstadt	Inst. Tech. Kern Phys (Darmstadt)	16	(16b)	2	0
PDP-8	Charpak	I.P.N. (Orsay)	4	(12b)	1	0
PDP-8	Oxford-Gôteborg	Oxford University	4	(12b)	1 DEC tape	0
PDP-9	Isolde	Isolde Collaboration	8	(18b)	1 + 2 DEC tapes	0
IBM 1130	MSS	Orsay	8	(16b)	0	1

Several experimental groups would also like to have small computers of this type to monitor their experiments or ensure the correct setting of magnets (in the case of a spectrometer, for example)...

At the present time, including these two recent acquisitions, 17 computers of 12 different types are used for the experiments of the Division. Six of them belong to CERN while the remaining 11 belong to visiting outside groups. This explains the disparity which leads to duplications in programming. The ideal would be to have all the computers compatible from the programming point of view. The purchase of the two Hewlett Packards is a step in that direction.

Reliable for a million hours

A constant watch has to be kept on the vacuum conditions in an accelerator and several types of vacuum gauge have been developed for this purpose. For pressures in the region of 10^{-2} torr, thermocouples are generally used because of their simplicity and reliability. However, the signal that they send out is weak and sensitive amplifiers are needed to boost it to a level appropriate for display on control room instruments and for the operation of relays.

Around 1960, a large number of such amplifiers were needed in connection with the vacuum system of the PS linac and it was decided to tackle their design at CERN itself since the commercially available units at that time were not suitable, were of high price and operated from the mains at 220 V. (The CERN units are built to operate from 48 V batteries.)

The weak signal from the thermocouple is converted to 100Hz (which is easy to amplify using semiconductors) by means of a transductor-type second harmonic converter. This makes it possible to pass the signal through the amplifier without having direct wire connections between the input and output and the power supply. This protects the signals from disturbance, particularly via earth loops, by the powerful sources in the linac region such as the 200 MHz r.f. system which generates megawatts of power.

The price of the amplifier unit, which also supplies the heater current to the thermocouple, is less than one quarter of the commercially available units.

A first batch of twenty were installed on the linac at the beginning of 1962, and they have been working virtually non-stop since then. In a total of one million working hours only one failure (a faulty condenser) has occurred. A further 60 units have been produced and are in use in vacuum systems throughout CERN. (Some are also being sent to Lyon this summer to be used in the studies on a high energy pre-injector.) They too have totalled a million hours operation, and no failures have been reported.

Hydrogen targets

At the present time, there are six liquid hydrogen targets in use in secondary beams at the proton synchrotron and two in the secondary beams of the synchrocyclotron. These targets consist of reservoirs of liquid hydrogen placed in vacuum tanks which ensure thermal insulation.

They are of three types differing in the procedure used to maintain the hydrogen reservoir at the required temperature (in the region of 20°K).

The most usual targets, and also the simplest, have two hydrogen reservoirs placed one above the other. The smaller (lower) one is supplied with liquid hydrogen by gravity from the larger one which is under atmospheric pressure. A pipe takes away the hydrogen which evaporates due to heating. A system of valves ensures that the upper reservoir is filled from an external dewar when the level drops below a certain limit.

The hydrogen consumption, which is of the order of **V4** litre per hour, depends mainly on the effects of heat radiation, which are now considerably reduced by the use of aluminized mylar screens and cooled copper screens; the losses by conduction across the support and the residual gas are negligible in comparison.

Not long ago, the installation of a liquid hydrogen target inside the PS ring, although it had been considered for some time, had never been seriously studied because of the safety problems. The rules applicable to the use of liquid hydrogen — involving excellent ventilation, easy accessibility, continuous surveillance, etc... — posed difficult technical problems which would be very costly to solve with the first type of target.

In 1967, to meet the needs of a proton scattering experiment (Allaby et al.), the problem was raised again and a solution, which eliminated all safety problems, was found by using liquid helium. The target, of the second type, constructed by this method, has only a small volume of liquid hydrogen. Furthermore, in order to avoid switching off the PS, which could have

The amplifier of the thermocouple vacuum gauge, which has given a million hours of service without failure. The unit is about 12 X 7 x 28 cm^3. The thermocouple heater current can be adjusted on the front panel. The amplifier will read pressure or heater current and a lamp lights up when the pressure falls below the preset value.

A diagram of the hydrogen target system which is to be installed inside the proton synchrotron ring at the end of 1969. The target itself, K, where the particle beam is directed, receives its liquid hydrogen via the heat exchanger, J, where helium is circulated.

To evacuate the liquid hydrogen from the target the valve F is closed by remote control and the hydrogen gas which can no longer escape from the target forces the liquid up into the heat exchanger.

A — input of gaseous hydrogen, B — level gauge, C — transfer line, D — helium gas outlet, E — liquid helium reservoir, F — valve, G — helium gas outlet, H — copper screens cooled by helium, I — aluminized mylar screens, J — heat exchanger, K — target (stainless steel vessel), L — stainless steel windows. The hatched area shows the hydrogen volume.

been necessary to operate the target, all the controls and the monitoring system were designed to be used remotely and the auxiliary equipment was installed outside the ring. The system consists of a 'hot' hydrogen reservoir (300°K) linked to a small reservoir — the target proper — by a system of pipes. The circulation of helium gas in the exchanger of the target causes the hydrogen to liquefy and its temperature is kept stable by regulating the helium flow.

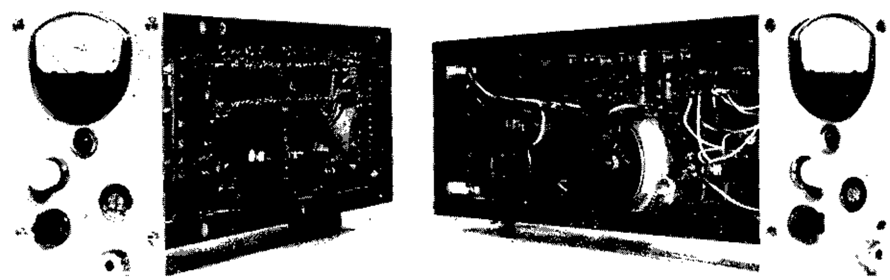
Finally, the third type of target is a small, independent hydrogen liquifier, which has the advantage of not needing to be supplied with cryogenic liquid.

The target vessel and windows set in the vacuum tank are generally made of mylar (12 to 19 hundreds of a millimetre thick) or, in the case of very high beam intensities, of metal (stainless stee! 3/100 mm thick for example).

At the moment, five targets of the first type (four on the PS and one on the SC) are in use. There are three targets of the second type (two on the PS and one on the SC) — the SC target and one of the two on the PS are based on the target developed for the scattering experiment. The second PS target, which works on a slightly different principle, was constructed by a group of physicists from Orsay. A fourth target of the same type (see diagram), which is to be used in a new experiment of the Allaby et al. group, which is also to be installed inside the ring, is undergoing trials and should be ready at the end of 1969.

The third type of target with the liquifier incorporated, is to be tested soon in the East Hall before leaving for Serpukhov, where it will be used in a joint CERN-Serpukhov experiment.

The group led by L. Mazzone has constructed most of the targets used atCERN.



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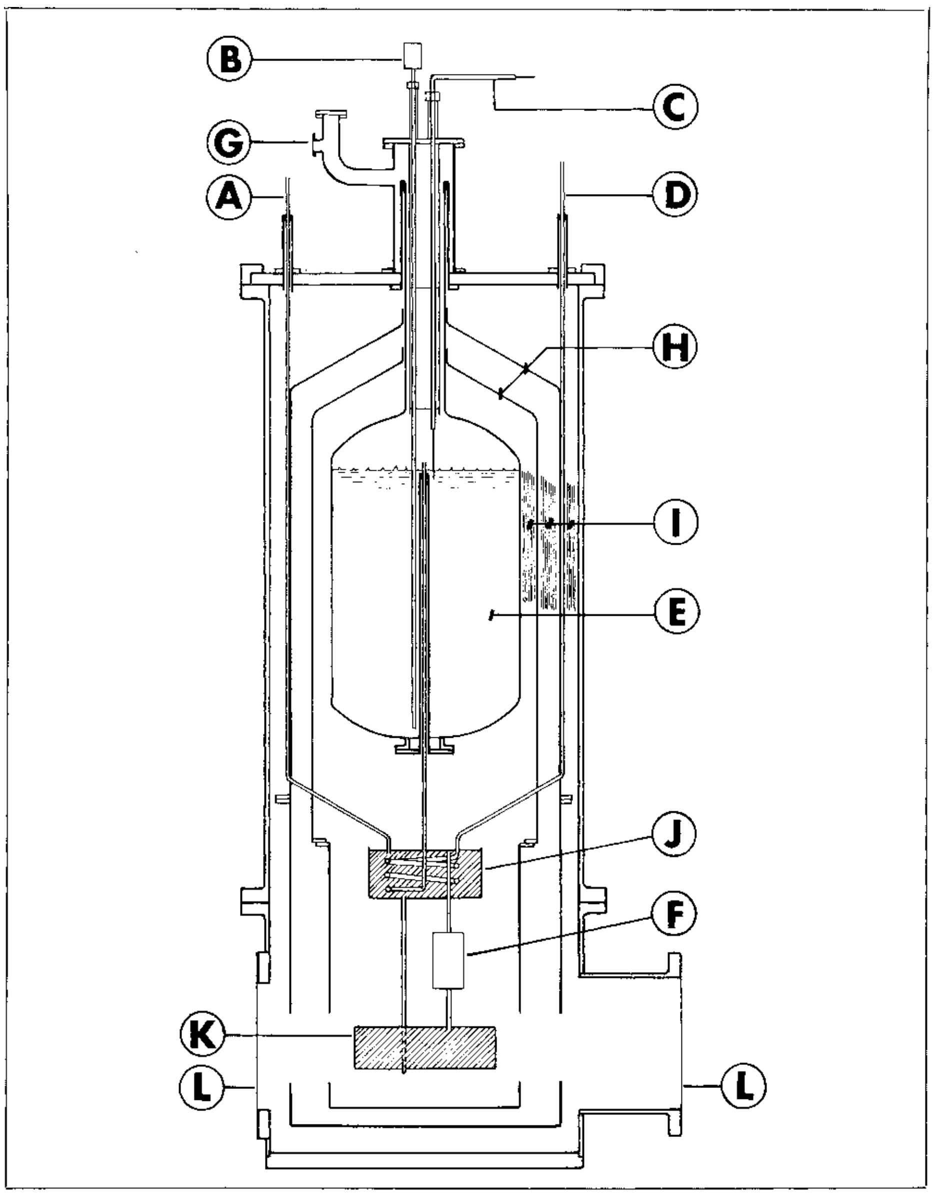


Around the Laboratories

1. A plan view of the ring of the Zero Gradient Synchrotron showing the positions of the two ejected proton beam-lines and of the beam-lines drawn from internal targets.

2. Scope traces showing on a scale of 100 ms per division :
Top - the signal from EPB I
Centre - the signal from EPB II
Bottom - the signal from the neutron beam

(Photos Argonne)

GATCHINA
1 GeV Synchro-cyclotron

The highest energy synchro-cyclotron in the world is in operation at the Joffe Physico-technical Institute at Gatchina, a 'science town' 50 km south of Leningrad, USSR. The machine is designed for a peak energy of 1 GeV for protons. It also has the ability to operate with deuterons and alpha-particles. The first high energy beams were obtained in November 1967 when protons were taken to 750 MeV.

Major parameters of the machine are as follows: the magnet is 7 m in diameter and weighs 8500 tons (in 100 ton stacks of 30 steel sheets 1 mm thick — a special railway had to be built to bring them to the site). It takes a current of 5 kA and a power of 1 MW in achieving of field of 19 kG. The vacuum chamber between the poles of the magnet has an aperture 50 cm high in which a DEE electrode is installed to establish the accelerating field. The pressure is below 10^{-5} torr. A variable capacitor (two parallel rotary capacitors) controls the frequency change of the field as acceleration proceeds. The beam makes about 40 000 revolutions the particles travelling about 400 km in the machine.

The design and construction of the accelerator was carried out by the Scientific Reseach Institute for Electro-physical Apparatus at Leningrad, under the leadership of E.G. Komar and I.F. Malyskev, in conjunction with the specialists from Gatchina itself, D.M. Kaminker, D.G. Alkhasov and A.P. Komar.

Many experiments are under way in the main experimental hall which has an area of 2500 m^2, shielded from the accelerator by a wall of ferro-concrete 5 to 8 m thick. The experimental programme is very similar to that at the CERN synchro-cyclotron with three major fields of research — meson physics using secondary beams of pions and muons; nuclear structure physics using meson beams for the study of various nuclei; short-lived radio-isotope research. There is considerable interest in using particle beams for medical diagnosis and therapy.

Experimental equipment includes a magnetic time-of-flight spectrometer (construction led by A.A. Vorobiev), a pion spectrometer (W.G. Vovchenko) and a propane chamber (M.-W. Stabnikov). It is planned to use holography in photographing particle events in this propane chamber.

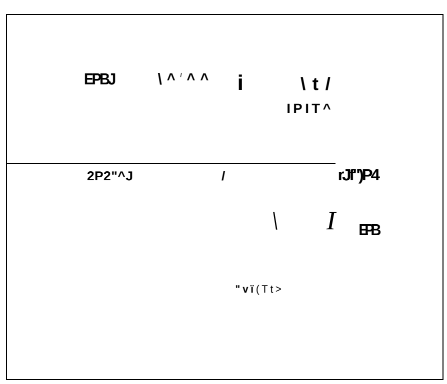
ARGONNE
Simultaneous operation of two extracted beams

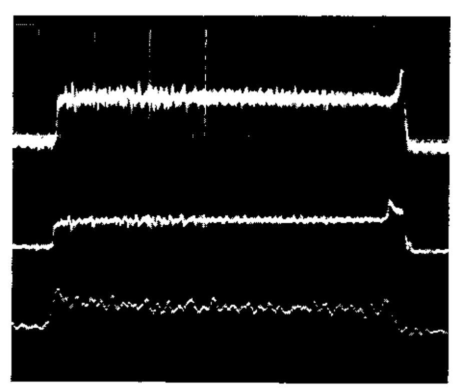
During the first quarter of 1969, a second extracted proton beam was brought into operation at the Zero Gradient Synchrotron. It is feeding a new experimental area, which has space for several experiments as well as the 12 foot hydrogen bubble chamber. At the present time there are three experiments using the new beam and two more are being installed.

It is now possible to use the entire length of the ZGS flat-top to give slow beam spills to both extracted proton beam-lines simultaneously. The two extracted proton beams are located 180° apart around the ring (as shown in the Figure) with their Piccioni targets located at Ti and T2. By adjusting the relative radial position of these targets, the circulating beam can be divided to give any desired percentage down each beam-line. At the same time, a negative pion beam, which uses Ti as a pion production target, can be operated, and a neutron beam is drawn from target B. This target came into operation on 29 May and gives a neutron beam at 1° production angle into the Meson Hall.

Two feedback loops are sufficient to maintain uniform spill rates in the four beam lines. A feedback signal from an ion chamber (which monitors the spill in the first extracted proton beam EPB I) is used to control the radio-frequency program which brings beam onto target Ti. A feedback signal from the neutron beam spill is used to program the vertical position of the neutron production target B. The result of this feedback control are shown in the photograph of the oscilloscope traces.

Recently seven experiments were taking data simultaneously with the ZGS producing beam spill for *J00* ms on each pulse at a repetition rate of 17 pulses per minute.



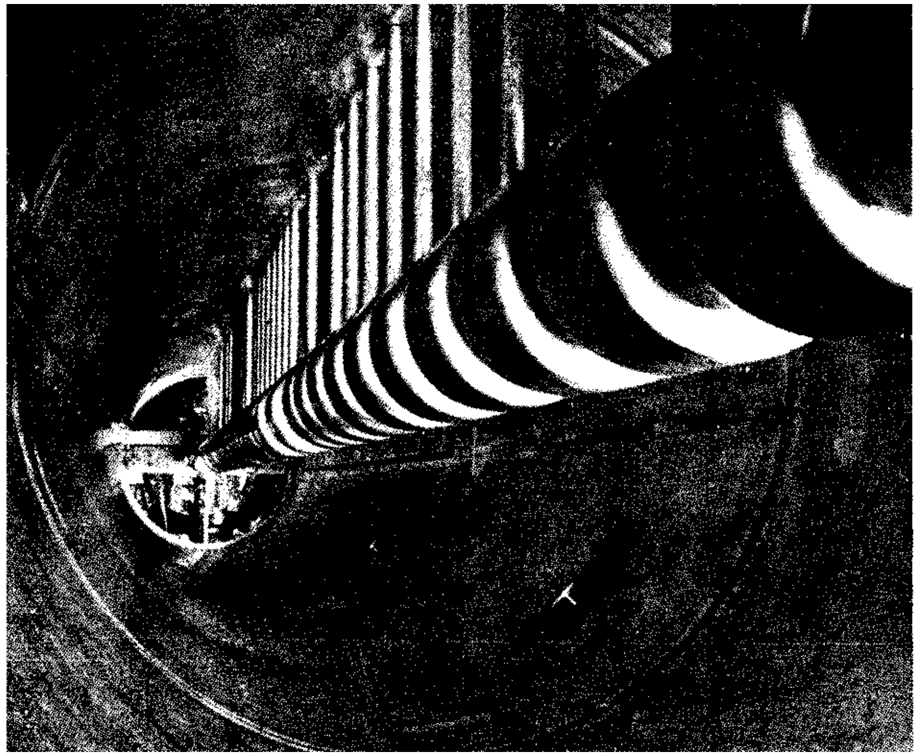


CAMBRIDGE University
Sweepnik supported

Another way of attacking the daunting task of measuring the millions of bubble chamber pictures pouring out from accelerator Laboratories has received financial support for development work. (Just how daunting this task is may be realized from the fact that CERN is currently placing an order for five million metres of 50 mm film for the 2 m bubble chamber.) The new automatic measuring machine is known as Sweepnik.

Sweepnik, in prototype form, has been built at the Cavendish Laboratory, Cambridge University from ideas of Professor O.R. Frisch working with G.S.B. Street. It uses a laser beam spread out by an astigmatic lens to give a thin line one millimetre long which is made to rotate over small areas of the film by means of a spinning prism. A photomultiplier behind the film picks up a peak signal when the line of laser light is precisely aligned with the direction of a particle track. (Thus the machine SWEEPS up information while the light circles like a sputNIK.)

The protoype linac tank at Batavia, with the drift tubes installed, in which protons were accelerated to 10 MeV for the first time on 26 June.



Taking up new posts in high energy physics in the UK:
1. *Dr. T.G. Pickavance becomes Director of Nuclear Physics at the Science Research Council.*
2. *Dr. G.H. Stafford becomes Director of the Rutherford Laboratory.*
3. *Professor A. Ashmore becomes Director of the Daresbury Laboratory.*

The width and angle of the track is registered and a small computer (PDP 7) guides the light to examine the next likely area of film in 1 mm steps using a system of steering mirrors. The mirrors have to be manoeuvred with an accuracy of 0.1 second of arc, which is done using the Michaelson interferometer method.

A particular advantage of this new type of machine is that, thanks to the coherent laser light, it is possible to follow feeble tracks which would not be accessible using other types of automatic measuring machine. It should also be capable of a high measuring rate and requires only modest on-line computing facilities.

The Science Research Council has given a grant of £ 40 473 towards the development of the new machine which will be led by S.G. Rushbrooke. It is hoped eventually to reach the stage of commercial production of Sweepniks at a cost less than £ 100 000 each (including the on-line computer).

UK Appointments

Changes at the top of high energy physics Laboratories in the UK were announced on 30 June. Dr. T.G. Pickavance who has been Director of the Rutherford Laboratory since 1957, throughout the design, construction and first years of operation of the 7 GeV proton synchrotron Nimrod, has been appointed Director of Nuclear Physics at the Science Research Council. In this position he will oversee all the Council's work in high energy physics involving the two national Laboratories and the participation in CERN Meyrin. Dr. Pickavance will be based in the Council's London office as from 1 September.

His successor as Director of the Rutherford Laboratory will be Dr. G.H. Stafford, present Deputy Director. Dr. Stafford has also been with the Laboratory from its early days, first as head of the 50 MeV Proton Linear Accelerator Division and, with the coming into operation of Nimrod, as head of the High Energy Physics Division, becoming Deputy Head of the Laboratory in 1966. Dr. Stafford is well known at CERN as a regular member of the Nuclear Physics Research Committee which selects the experiments for the CERN machines.

We have already announced that Professor A.W. Merrison, Director of the Daresbury Laboratory, is leaving to take up an appointment as Vice-Chancellor of the University of Bristol on 1 September. His successor has been named as Professor A. Ashmore who is at present Head of the Physics Department and Professor of Nuclear Physics at Queen Mary College, London. Professor Ashmore will take up his new appointment about the middle of 1970 and, until then, Dr. R.G.P. Voss, Head of the Experimental Physics Group at Daresbury will be acting Head of the Laboratory.

BATAVIA
10 MeV beam

On 26 June, right on schedule, protons were accelerated in the prototype first tank of the linac. A lot of trouble arose with sparking in the 750 kV preaccelerator but was overcome by installing an air conditioning unit to lower the humidity, by moving the high voltage supply to increase the distance between the two electrodes, by rebuilding the limiting and measuring resistors, by replacing the sulphur-hexafluoride in the pressure vessel insulating the accelerating column, and by shorting out the last gap in the column which then operated at 705 kV. It is obvious that the people involved didn't get much sleep in the weeks leading to the scheduled beam date but they achieved their beam on time.

Measurements of the accelerating fields in the linac tank are in excellent agreement with the computed fields and the r.f. system powering the tank is operating very well.

1.

2.

3.

High voltage in vacuum

This article, written by the leader of the group 'EMSA' (Electromagnetism Studies and Applications), covers the research carried out at CERN and elsewhere on the subject of very high voltage (whether pulsed or d.c.) in vacuum, and mentions some of the future possibilities.
The group is one of those in the Nuclear Physics Apparatus Division led by C.A. Ramm, which have carried out some notable research into the fundamental physics connected with the apparatus needed for high energy physics experiments. In a reorganization within CERN, the NPA Division will cease to exist as such from the end of August.

F. Rohrbach

Wheter it be in accelerators (accelerating columns, electrostatic inflectors, r.f. cavities or fast ejection units), secondary beams (separators and deflectors) or detectors (all types of spark chamber), the technological problems to be solved often centre around the insulation or switching of high voltages. In the case of insulation, attempts are made to minimize leakage currents, to eliminate flashover, to increase electric field gradients, or to lengthen the useful life and operational reliability. In the case of electrical breakdown, the salient factors are certain features of the arc such as jitter, rise time, lifetime, etc. for spark gaps; and brilliance, plasma size, memory, etc. for spark chambers and especially streamer chambers.

Over the past ten years, a great deal of work has been done, particularly in the USA and the USSR, on the insulation of high voltage in vacuum and on the physics of arcs, because of the rapid development of novel applications for high voltages — including X-ray flash tubes (operating at several MeV), circuit breakers, very high voltage electron microscopy (MV range), and equipment used in plasma physics and in high energy physics. Vacua, and even ultra high vacua, are involved in most of these new applications.

In 1964, the Massachusetts Institute of Technology, together with the University of Illinois and industry (the Ion Physics Corporation and the High Voltage Engineering Company), organized the first International Symposium on High Voltage Insulation in Vacuo. Currently these symposia take place every two years and are attended by delegates from all over the world. An international committee, on which CERN is represented, has been set up.

Since 1961, CERN has devoted special attention to this subject by stimulating applied research in connection with the development of electrostatic separators (see for example CERN COURIER vol. 9, page 132) and accelerating columns.

Technical developments with d.c. voltages

In spite of some spectacular fundamental discoveries concerning the physics involved, and some notable technological advances, the theory of breakdown in vacuum at very high voltage has still to be formulated. The most important technological advances, in which CERN has often played a pioneering role, include:

— Considerable improvements in voltage holding by abandonning stainless steel for the cathode in favour of heated glass (Berkeley), aluminium oxide (CERN) or titanium (CERN).
— Discovery of the marked effect of pressure and of the nature of the residual gas between 10^{-5} and 10^{-3} torr on behaviour under voltage and on operating life (many Laboratories including CERN).
— Discovery of the importance of the cleanliness of the surfaces subjected to powerful electric fields leading to the use of ultra high vacuum techniques (CERN).

The progress in the last ten years with homogeneous fields using large electrodes of the order of a square metre has made it possible to pass from
55-60 kV/cm over 5 cm and 40-50 kV/cm over 10 cm in 1960, to
150-160 kV/cm over 5 cm and 100-110 kV/cm over 10 cm in 1969.
Nevertheless this is still far from the theoretical limit set by the field emission — 100 000 kV/cm!

The state of the theory

The large difference between the values obtained and the theoretical limit can now be explained. Though no new results have been published for some years on technical aspects, there have been some fundamental discoveries throwing new light on the mechanisms at the origin of an electric arc in vacuum. It has been found that there is high local amplification of the electric field at microscopic points which appear on metal surfaces under the action of intense fields. The heights of these points vary between a few tenths and several hundreds of microns. They can occur at either the anode or the cathode, but exactly how they are produced is still completely unknown.

It is now believed that there are several mechanisms which give rise to breakdown, the predominant one depending on parameters such as distance, voltage, residual pressure and the surface state of the electrodes. There are essentially two major regimes:
1. Short gaps between electrodes (less than a few millimetres) in a uniform field, or strong electric fields which are non-uniform (point-plane geometry);
2. Large gaps (more than a few millimetres) and very high voltages (more than a few hundred kV).^

1. In the first regime, breakdown follows local heating either at the cathode due to field emission at the points which mysteriously develop, or at the anode by electron bombardment. The heating causes serious vaporization when current densities reach critical values between 10^7 and 10^8 A/cm^2. The metal vapour thus produced is then rapidly ionized by cold emission electrons, leading to the final breakdown within a period varying from a few nanoseconds to a few hundred nanoseconds.

As the breakdown threshold is closely related to a critical current, and thus to a field, the characteristic breakdown voltage V_s as a function of the gap d between the electrodes should be linear. Also, the law of the variation of current with field should follow the predictions of field emission theory. These results have been confirmed over the past few years up to distances of a few millimetres between electrodes in a uniform, d.c, pulsed or high frequency field. The improvements in behaviour under pulsed voltage that can possibly be gained in this case are very small, when the time for which the voltage is applied is longer than a few tens of nanoseconds.

2. At CERN, with only a few exceptions, most of the applications of high voltage in vacuum are in the second regime which it had been difficult to study in University research laboratories because of the cost involved. Theoretical studies, in conjunction with experiments, were undertaken at CERN and have led to several new experimental observations and the elaboration of a model of the discharge phenomena.

When voltages are increased beyond a few hundred kV, the behaviour of the breakdown voltage threshold as a function of the different parameters changes completely. The characteristic V_s as a function of d is no longer linear but proportional to the square root of d. The residual pressure is of considerable importance (which is not so with short distances) and the threshold V_s is no longer determined by a critical current — the current before breakdown varies by several orders of magnitude when the distance varies only by a factor of two or three. Finally, and this is a fundamental point, the average time-lag to breakdown lengthens considerably — in the range of microseconds to several milliseconds.

These characteristics can be explained by the 'micro-particle' hypothesis. The mechanism leading to breakdown could then be described as the following: a collection of atoms is torn away from the anode as a result of the application of the field and electron bombardment. This micro-particle, electrically charged, is accelerated by the field between the electrodes and strikes the cathode with a velocity v and an energy W. If v and W are higher than critical values v_c and W_c, the energy dissipated at the moment of striking is high enough, and remains within the interaction volume for long enough, to give rise to intense vaporization. Breakdown can then take place inside the bubble of gas thus formed. It can be shown by the double condition W greater than W_c and v greater than v_c that the characteristic V_s as a function of d is then indeed of the square root form and that the minimum time lag T min is such that ln T min is linear with V^2.

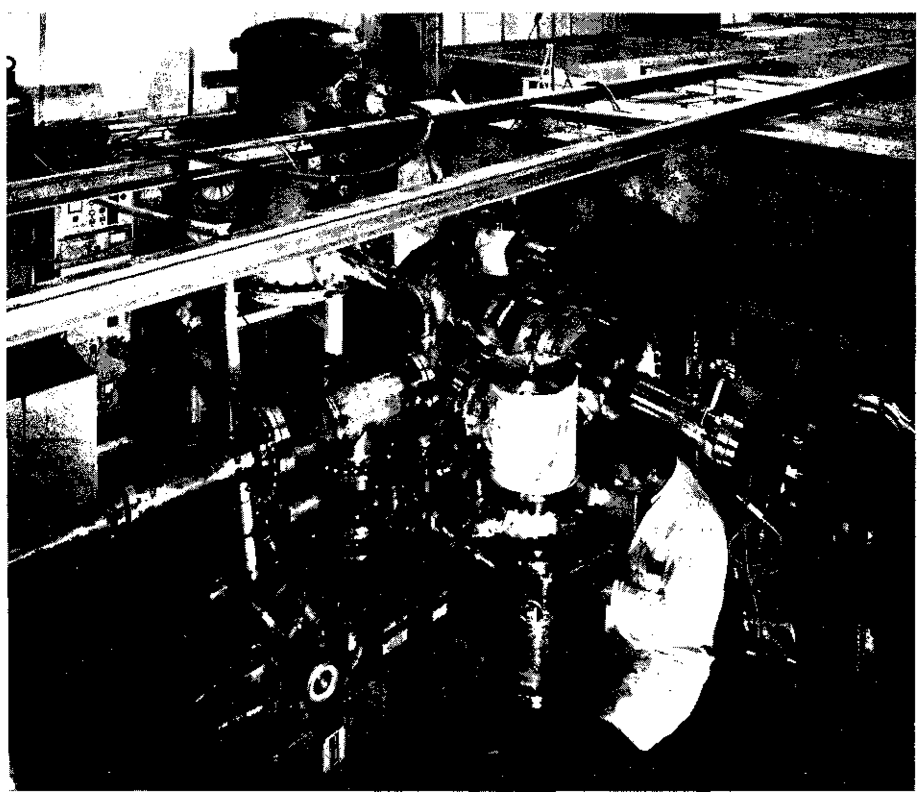
Application of the theory to pulsed voltages

For high voltages (MV) and large distances (cm) in ultra high vacua (10^{-9} to 10^{-8} torr), present investigations at CERN show that, in fact, the mechanism involved in initiating a breakdown takes a considerable time (μs to ms) to develop and that these times are statistically distributed in such a way that T min is proportional to V^2. Because of these results, obtained with stainless steel and titanium electrodes, it would be possible to increase the strength of electric fields in vacuum very appreciably for all applications where the field is needed for only a short time (a maximum of several microseconds), which is often the case around large particle accelerators. The advantages obtained would allow the present values of d.c. fields to be doubled for times of the order of a few microseconds and distances between electrodes greater than a centimetre.

Future possibilities

Such an increase in the intensity of electric fields would allow further steps forward in the use of high energy particle separators and fast deflectors. Other conceivable applications include strong field accelerating lines in electron ring accelerators, coaxial beam guides, electromagnetic lenses, etc.

In all these applications, the new technical problem which arises is that of generating voltage pulses of several MV with very steep leading edges (less than 10 ns). The duration of the pulse depends on the application in view (from 10 ns to a few μs). A Marx generator in conjunction with a Blumlein line can be used for very short pulses as is already done for the Stan-



Vacuum cavity constructed at CERN as part of a programme to study high voltage in vacuum. This cavity has, among other things, shown the importance of cleanliness in high voltage phenomena, and made it possible to measure the breakdown delay time during pulsing, and to attempt to detect the micro-particles which could cause the sparking.

The high voltage electrodes are placed in the central cylinder; the distance between them may be adjusted. The anode is supplied with a high voltage pulse by the discharge of a line (maximum 600 kV) initiated by a CO_2 pressurized spark gap (bottom left of the photograph) which is triggered either by over-voltage or by a laser-beam. The cathode is supplied with continuous voltage by a 300 kV generator.

The pumping is carried out by a Pfeiffer turbomolecular pump (bottom centre) and a cryogenic titanium pump, constructed by the group, which gives pressures of 1 to 2 10^{-10} torr.

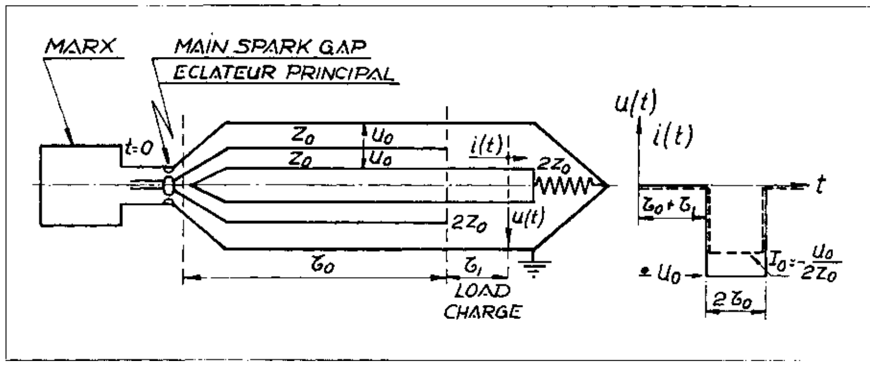
The tube perpendicular to the high voltage line permits the passage of a very high-powered ruby laser beam which is used to try to detect the passage of micro-particles which would cause sparking. The laser beam illuminates the intermediate plate and ensures the simultaneous triggering of the high voltage pulse. The light, which is diffused by the micro-particles which may be present, is detected by a photomultiplier tube.

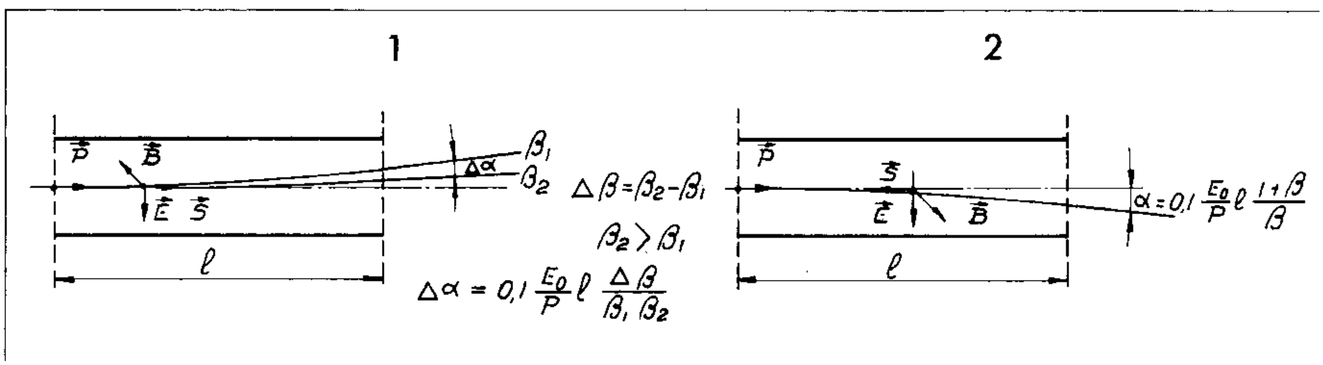
CERN/PI 506.6.69

1. Production of a very high voltage pulse with a steep leading edge.
A Marx generator charges the intermediate cylinder to a positive voltage. It is then completely discharged (in a few ns) through the intermediary of the main spark gap which, by successive reflections of the discharge wave, induces on the load a square wave with a steep leading edge in which current and voltage are in phase (see right).

2. Left: the electromagnetic separator principle. The deviations due to the electric and magnetic fields are opposed to one another. A a *is the angle of separation between two types of particle of the same momentum but different velocities.* *E_0 is the intensity of the electric component of the electromagnetic wave.*

Right: the electromagnetic deflector principle. In this case an angle of deflection is obtained under the joint influence of the magnetic and electric fields.





ford 600 kV streamer chamber (see CERN COURIER vol. 7, page 219). The most delicate problems are those involved in striking the main spark-gap in the Blumlein line with a very low jitter (ns), since this spark-gap must operate at 2 MV with an impedance of 30 ohms. There are thoughts of using a ruby laser, a multiple-electrode spark-gap or perhaps a liquid dielectric spark-gap. A rise time of 50 to 100 ns would be adequate for pulses lasting several mircroseconds, in which case the Blumlein line would not be needed.

In an application of the deflector or separator type, the beam element can be included in the load on the Blumlein line. Profit could then be drawn from having the magnetic field in phase with the electric field, and a TEM (transverse electromagnetic) wave is then set up. There are two advantages:

1. If the particles are sent into the equipment in the same direction as that of the propagation of the wave, the unit is an electromagnetic separator — a velocity selector with automatic magnetic compensation (with chromatic aberrations reduced to a minimum).

2. If the particles are sent in the opposite direction to the TEM wave, then the electric and magnetic deflections are added together and an electromagnetic deflector is formed. The same power of deflection is obtained for a conventional magnetic deflector and an electro-magnetic deflector of the same length if Eo (kV/cm) = 150 Bo (kG) with **(3** = 1. In view of the present technical results, deflectors can be made with 450 to 500 kV/cm (1 MV over 2 cm), or the equivalent of 3 kG.

Thus the same piece of equipment can serve either as a deflector or as a separator.

The main potential of high electric field electromagnetic separators lies in the field of the separation of low-energy (a few hundred MeV) kaon beams for bubble chambers. It is possible in these cases to reduce the length of the separator considerably while retaining the same angle of separation, and thus to have particle beams with a short decay length (0.75 m for 100 MeV charged kaons).

The refined technology which has been developed to obtain very high voltage pulses and to overcome the complex problems in striking a spark-gap operating at several MV, allow one to think of building streamer chambers with very high gaps (of the order of a metre) using such high voltages. It is probably in this direction that interest in pulsed high voltages will be concentrated, because the advantages offered by such chambers are so attractive that physicists will almost certainly want them built. Finally, it is interesting to note that many other laboratories and commercial firms are particularly interested in the work currently being done at CERN in the field of high voltages. These laboratories and firms include those working in such varied fields as emitters, the transmission of electric power, circuit breakers, rectifiers, colour television, etc...

Do-it-yourself CERN COURIER Writing kit

At certain times of the year, such as the times when everyone is on holiday, the volume of material which is covered in CERN COURIER is likely to fall. However, to compensate our more eager readers for the sparser issue this month, we present a 'writing kit' from which the reader himself may construct a large variety of penetrating statements, such as he is accustomed to draw from our pages. It is based on the SIMP (Simplified Modular Prose) system developed in the Honeywell computer's jargon kit.

Take any four digit number — try 1969 for example — and compose your statement by selecting the corresponding phrases from the following tables (1 from TABLE A, 9 from TABLE B, etc..)

TABLE A

1 It has to be admitted that
2 As a consequence of inter-related factors,
3 Despite appearances to the contrary,
4 Until such time as fresh insight reverses the present trend,
5 Using the principle of cause and effect,
6 Presuming the validity of the present extrapolation,
7 Without wishing to open Pandora's box,
8 It is now proven beyond a shadow of a doubt that,
9 Worrying though the present situation may be,

TABLE B

1 willy-nilly determination to achieve success
2 construction of a high-energy accelerator
3 access to greater financial resources
4 pursuit of a Nobel prize
5 bubble chamber physics
6 a recent computation involving non semi-simple algebra
7 over-concern with the problems of administration
8 new measurements of eta zero zero
9 information presented in CERN COURIER

TABLE C

1 should only serve to add weight to
2 will inevitably lead to a refutation of
3 can yield conclusive information on
4 might usefully take issue with
5 must take into consideration
6 will sadly mean the end of
7 ought to stir up enthusiasm for
8 could result in a confirmation of
9 deflates the current thinking regarding

TABLE D

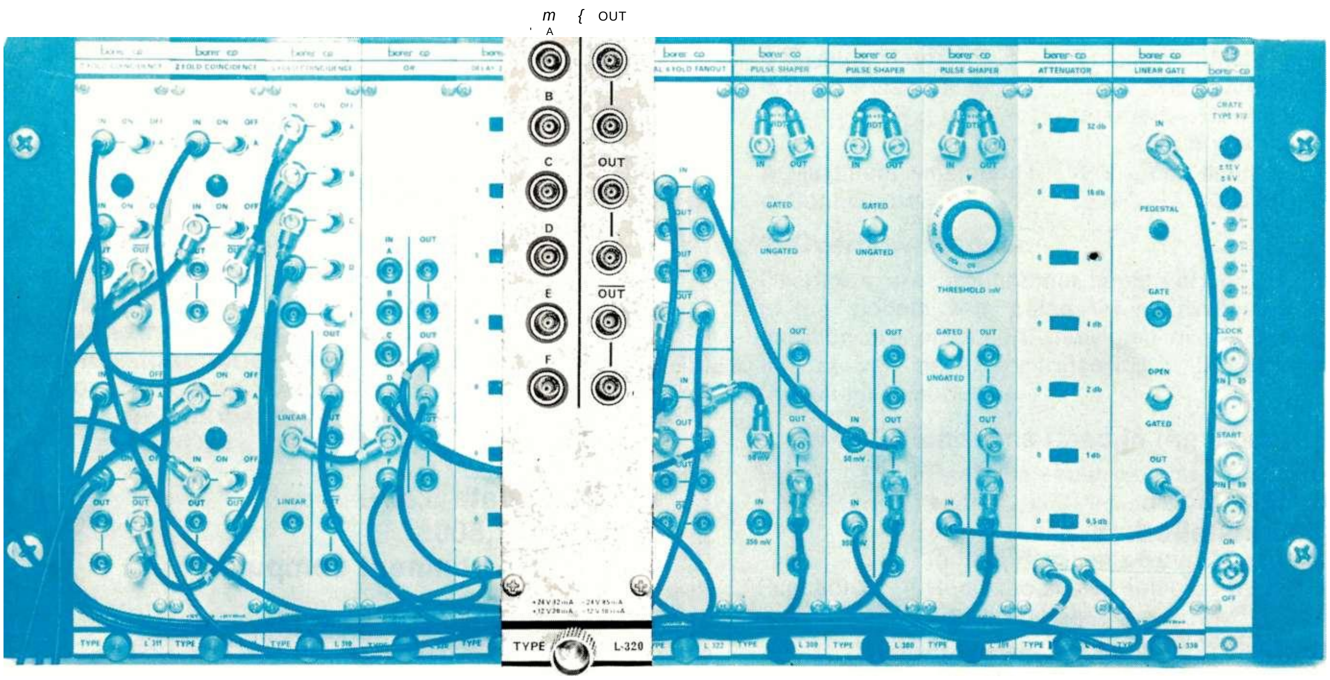
1 the need to acquire further computing capacity.
2 humanitarian concern with the personnel ceiling.
3 the Veneziano model.
4 a design which produces collisions at a later stage.
5 Macbeth's instruction Throw physic to the dogs'.
6 divergencies in weak interaction theory.
7 the desire to ensure that certain scientists go far.
8 bootstraps, conspiracies, poles and dips.
9 the future of physics in Europe.

FAST LOGIC

borer

And now, a NIM-compatible and practical European Standard for 100 MHz + logic systems has been founded with the introduction of Borer Fast Logic Modules. So highly flexible, these CERN specification based units form the most comprehensive decision-making family of modules ever to have been offered at such a realistic price. Bonus advantages of shorter neater inter-module cabling can be gained from Lemo-equipped models: BNC-equipped models are available too for existing system compatibility.

Some details of one of these modules are given below and more data on this, and the rest of the family, will be sent at the drop of a postcard.



Specifications

Input	Impedance	50 ohms ± 2%
	Reflections	10% max. for tr = 1.5 ns
	Voltage	— 700 mV, typically (logical 1)
		— 200 mV, — 4 mA max for output = 0
		— 600 mV, —12 mA min for output = 1
	Overload	+ 5V absolute maximum dc
		± 50 V for 100 ns maximum
	Width	2.5 ns min. (measured at 600 mV level on 800 mV pulse) to dc
	Rate, max.	150 MHz
Output	Impedance	High, current source, 16 mA per output. Unused outputs must be terminated.
	Rise time	2.0 ns, max.
	Fall time	2.2 ns, max.
	Width	Equal to inputs + 1 ns
	Propagation delay	5.5 ns + 0.5 ns

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ELECTRONICS
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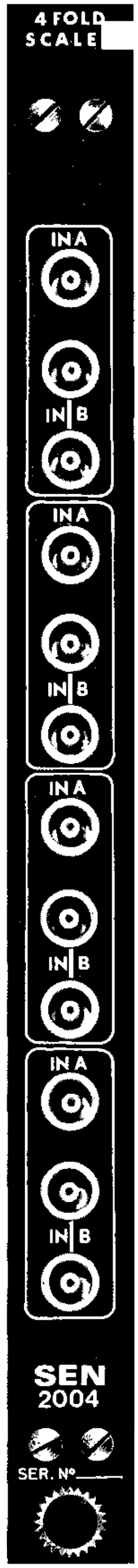
Switzerland: P. O. Box, 4500 Solothurn 2
Tel: (065) 4 88 21 Telex 34228

Type 2004 FOUR-FOLD CAMAC SCALER

The type 2004 four-fold scaler is a simple, general purpose CAMAC scaler with 16 bit capacity. Low price was the main design objective. Thus, useful functions only have been incorporated and the input specifications are those readily obtainable with current TTL technology.



DESCRIPTION AND SPECIFICATIONS.

1. Input

Each scaler has a 50 ohm input (IN A) and an unterminated dual connector input (IN B). Both inputs accept fast NIM pulses or levels and enter an AND gate. Thus, either input A or B can be used as count input or as gate input. While using A cas count input, B may be left open. Input B allows bridging connection of a gate line for reduced fan-out requirements.

® Scaling Rate:	typically 40 MHz
• Input Pulses, A or B:	12 ns pulses are typically required, -200 mV is max. "O",-600 mV is min. "L",
• Maximum Amplitude:	-2 V, diode limited
• Connectors:	LEMO RA 00 C 50

2. Overflow outputs

Overflows are brought out separately on the back of the module. Nim pulses of approximately 1 ***/LIS*** duration are produced. Individual overflow outputs may be very useful for triggering a "Direct Memory Increment"- module.

3. CAMAC Functions Used in the Module

Function 0:	Read the scaler selected by the subaddress, Clear the corresponding overflow flag, Produce a Q-response for the duration of the Camac cycle.
Function 2:	Read the scaler selected by the subaddress, Reset the scaler, Clear its overflow flag, Produce a Q-response for the duration of the Camac cycle.
Function 25:	Increment all 4 scalers, Produce a Q-response.
Function 8:	Test L. This function produces a Q-response if the scaler selected by the subaddress has its overflowset **and** its L enabled.
Function 17:	Write a 4 bit mask. This 4 bit mask -written from the W1 to W4 lines-enables the individual sources of L request.
Clear and initialize:	Reset all scalers, Clear all overflow flags and set the L-mask at 0000.
Inhibit:	Close the input gate of all 4 scalers.

The L-mask register is a particulary powerful device when the L signal is used as a computer interrupt request. Managing nested interrupt service routines is much easier because priority assignment is under program control.

4. Physical

Single unit CAMAC module, fully shielded construction.

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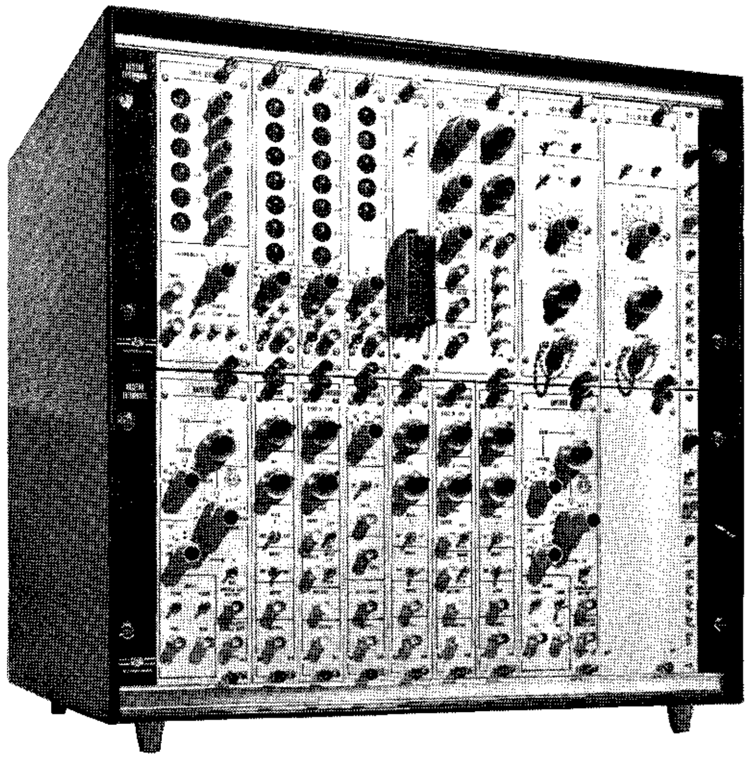
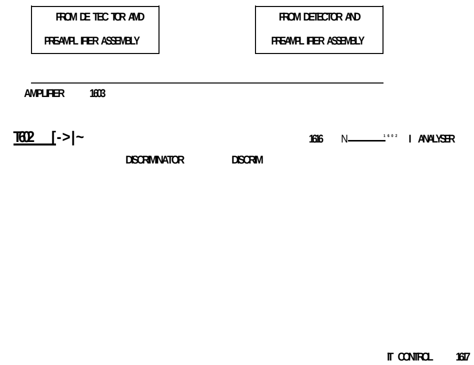


Coincidence spectrometer for measurement
of Ge(Li) detector rise time



This International Series system is designed to allow a measure of the distribution of rise times of a germanium lithium drifted detector to be obtained. Coincidence gamma events from a ^{22}Na source are used to operate two timing channels.

NOT INTERESTED? Well, perhaps you wish to do spectral analysis, time-of-flight measurements, anti-coincidence counting, alpha, beta or gamma spectrometry, muon decay measurements. X-ray fluorescence analyses using isotope sources and cooled Ge(Li) detectors, *or* **neutron activation analysis neutron spectrometry,** *or* **in the medical field, renography** *or* **whole body monitoring etc., etc.**

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Brochure No.40A gives full details on the International Series and No.44 covers CAMAC. Both are available on request from our Sales Departments at Edinburgh or Beenham.

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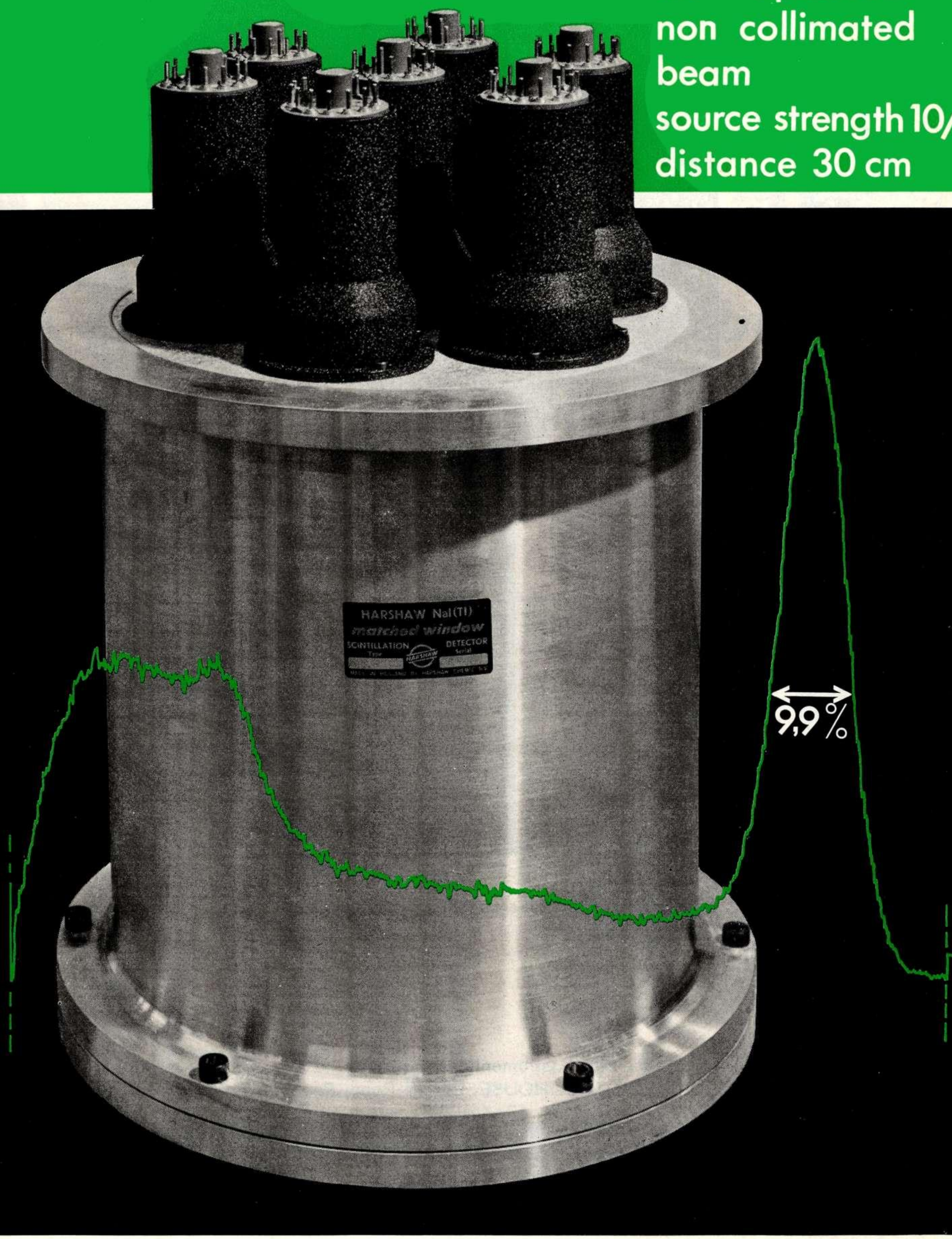
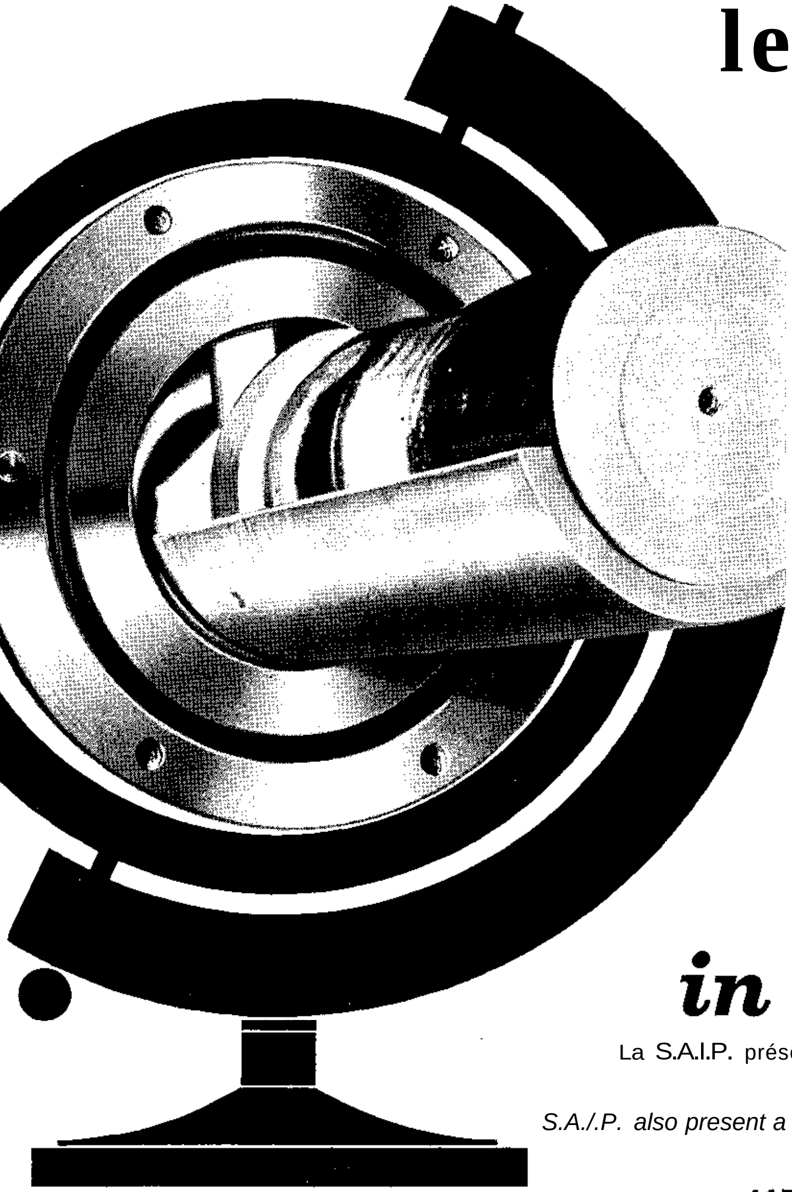
Cs^{137} spectrum
non collimated beam
source strength 10 μc
distance 30 cm





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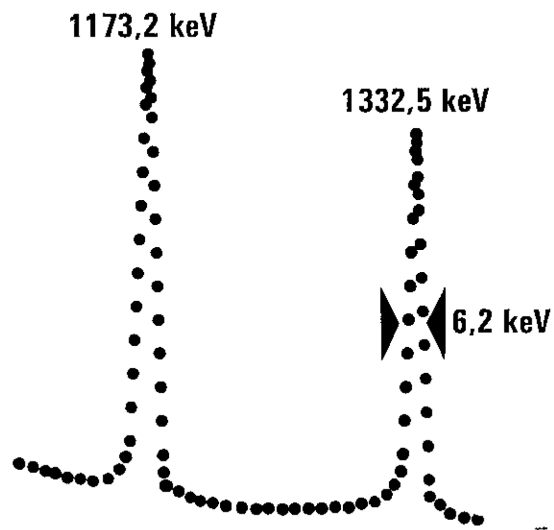
S.A./.P. also present a wide range of semi-conductor detectors.



Structure coaxiale symétrique
Volume utile : 120 cm^3
Epaisseur compensée : 13 à 14,5 mm
Tension de polarisation : 1300 V
Capacité : 86 pF
Résolution en énergie L : 6,2 keV (^{60}Co 1332 keV)
Produit Lxh : 68 (h = rapport pic/Compton)
Efficacité relative : 14,4% (par rapport à un scintillateur I Na (T1) 3" x 3", placé à 25 cm d'une source de ^{60}Co)
Temps de collection de charges : 80 à 155 ns
Résolution en temps : 8 ns à 511 keV et 5,4 ns à 1332 keV

Symmetrical coaxial structure
Active volume: 120 cm^3
Drifted depth: 13 to 14.5 mm
Bias voltage: 1300 V
Capacitance: 86 pF
Energy resolution L: 6.2 keV (for ^{60}Co 1332 keV)
Product L x h: 68 (h = peak to Compton ratio)
Relative efficiency: 14.4% (compared with a 3"x3" I Na (T1) scintillator set 25 cm far from a ^{60}Co source)
Collection time of charges: 80 to 155 ns
Time resolution: 8 ns on 511 keV and 5.4 ns on 1332 keV.

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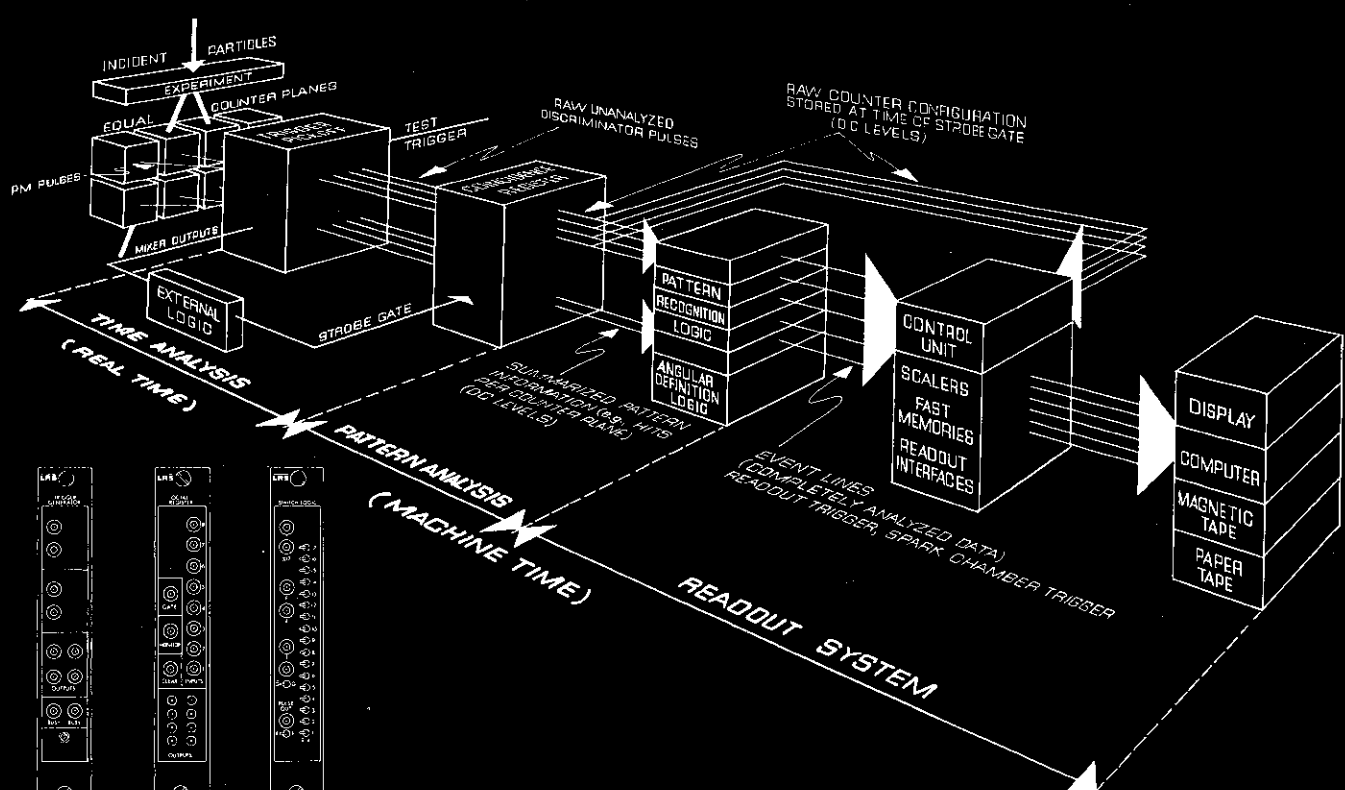


Model 901 TRIGGER GENERATOR | **Model 902 OCTAL REGISTER** | **Model 903 SWITCH LOGIC**

INNOVATORS IN INSTRUMENTATION

Happiness is...two new discriminators

The T105/N:
New general purpose dual discriminator with low threshold.

Variable threshold:
10-turn calibrated potentiometer for −50mV to −500mV threshold settings. One and only one output per threshold crossing.

Output width:
Typically 4 nsec plus delay of WIDTH cable; 3 nsec FWHM in MIN WIDTH position with cable removed.

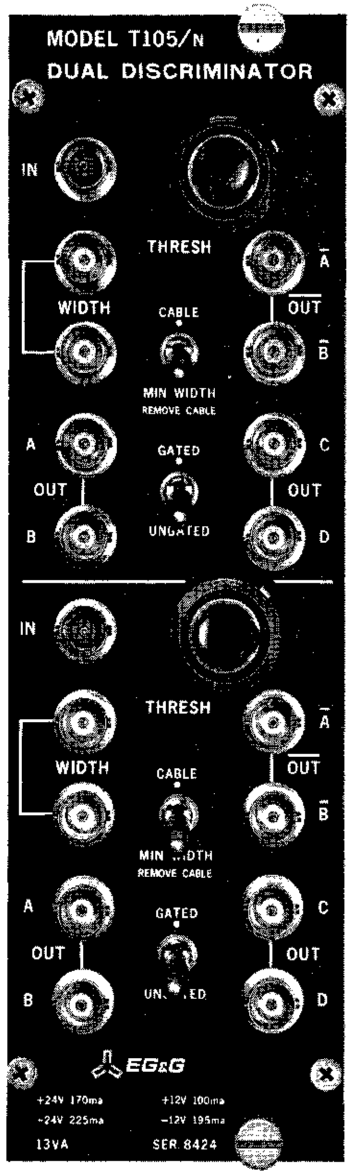
Stability:
WIDTH cable assures invariant output width and deadtime. Sophisticated circuitry guarantees threshold stability.

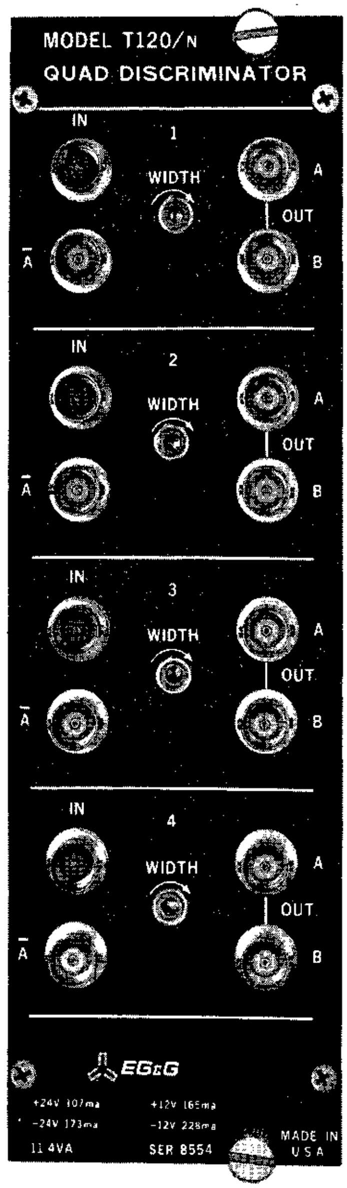
Inputs:
50-ohm termination with dc or transient reflections less than 5%; fully protected.

Slewing:
Less than 1 nsec from threshold to 10X threshold.

Rate:
Greater than 150 MHz CW or pulse burst for full NIM logic output signals.

Fanout:
3 Dual Outputs.





The T120/N:
New quad updating discriminator, designed for low-cost-per-channel.

Threshold:
−100mV, internally adjustable from −80 to −200mV.

Updating Timer:
Guarantees pre-selected output pulse width after most recent threshold crossing, independent of previous operating history.

Inputs:
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Output width:
Continuously adjustable from 5 to 150 nsec.

Bin gating:
All sections controlled by single rear panel toggle switch.

Slewing:
Typically 1.0 nsec from threshold to 10X threshold.

Rate:
100 MHz CW. Pulse pair resolution typically 8 nsec.

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For detailed data on the T105/N or T120/N - or information on the complete line of system-engineered EG&G instruments - contact EG&G, Inc., Nuclear Instrumentation Division, 40 Congress Street, Salem, Massachusetts 01970. Phone : (617) 745-3200. Cables : EGGINC-Salem. TWX : 710-347-6741. TELEX : 949469.

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Nanologic® NIM: Model 166 Fast Linear Gate and Hold; Model 169 Dual Fast Linear Gate.

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Model 166 gate circuits are followed by a stretcher amplifier and will accept any input waveshape from 2 ns wide to DC. Gate can be internally generated with 5 ns to 500 μs range. The "hold" output is a rectangularly shaped pulse whose amplitude contains the input pulse amplitude information. Hold outputs are directly compatible with computer ADC's for information storage applications not utilizing PHA's.

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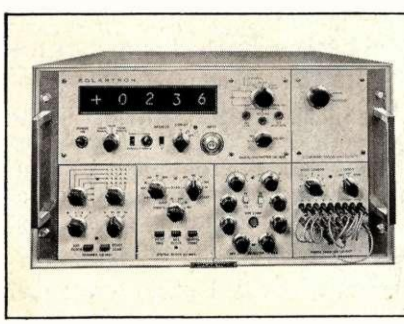

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