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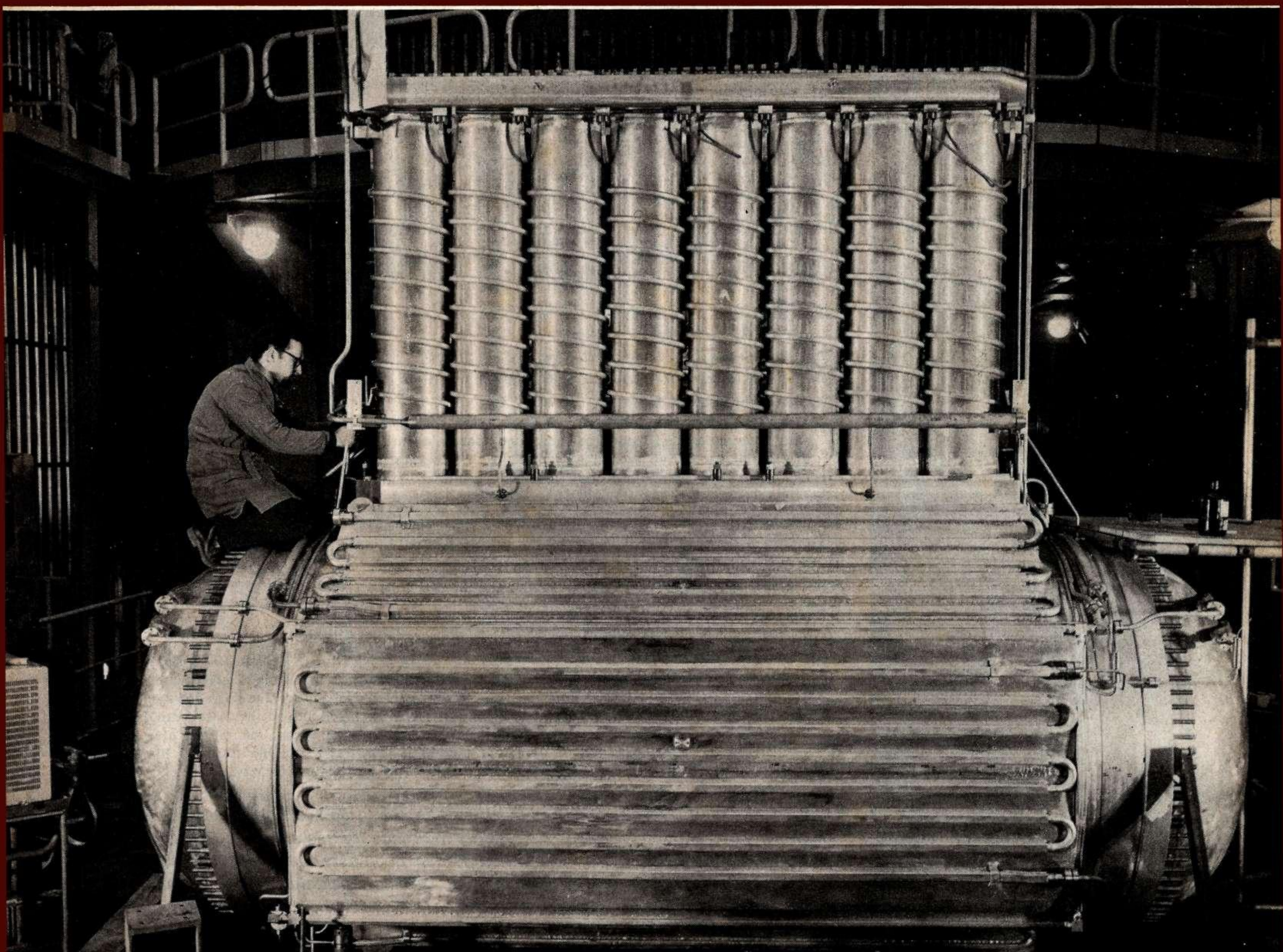
European Organization for Nuclear Research



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. 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 2850 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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Comment

The October Council Meeting, where decisions on the 300 GeV project were to be taken, was not held. The decisions will now be forthcoming in December.

Does another three months delay matter? Not in itself, particularly if absorbed in pushing through remaining administrative decisions. But it depends what three months are being added to, and, clearly, time is running out for the 300 GeV project.

It is vital for the 1980's that Europe achieves experimental facilities of the very highest quality, comparable to or better than those anywhere else in the world. This is needed to keep the field of particle physics vigorously alive, to retain the interest of the highest calibre of scientist and, ultimately, to make the investment of the Member States worthwhile. And with the 200-400 GeV project in the USA already several years in advance, Europe does not want to come along so late that it is left to dot the 'i's and cross the 't's of the creative work done elsewhere. The final design of the 300 GeV machine will already be taking account of the progress in the USA and will no doubt be able to achieve something different and better in one respect or another of the machine design. However the time is not far off when the European project will need to be radically different.

Why should this be worrying? The timescale for the development of radically new techniques, added to the timescale for political approval, added to the timescale for construction of a large new Laboratory could then mean as long as fifteen years before Europe is ready with its next generation accelerator. It would take a confident man to assert that particle physics in Europe could retain its present strength with existing facilities over this length of time.

Is it important that particle physics should continue prominently in Europe? In an ideal world probably not. It seems right that the fascinating penetration of the nature of matter should continue, but it could be done elsewhere. And it does not need much imagination to think of other activities which could usefully draw the resources of Europe.

Contents

Cover photograph: The chamber body of Mirabelle, the large hydrogen bubble chamber which has been built at the Saclay Laboratory in France for use on the 76 GeV proton synchrotron at Serpukhov, USSR. The chamber has been assembled and successfully operated at Saclay. Further tests with a particle beam are scheduled for the beginning of 1970 before the chamber is dismantled and sent to Serpukhov. More news on Mirabelle page 308. (Photo Saclay)

But to sacrifice particle physics certainly does not mean that the resources will go into something equivalent. CERN and related Laboratories are a successful venture in physics, and they themselves represent just the tip of the iceberg in terms of their total effect on physics. The existence of their excellent experimental facilities and the high calibre of scientist that they attract has an effect which gives extra vitality, both directly and indirectly, to physics departments in Universities throughout Europe.

Also CERN is a successful venture in terms of the organization of large scale science. It is perhaps the most successful of all the efforts at European collaboration. When there is much that has not succeeded, it would be a pity to jeopardize that which has.

Despite the serious problems which individual countries seem to be confronting one after another, Europe still has colossal resources both materially and intellectually. Particle physics is a comparatively small but significant field where, at present, they are being successfully applied.

Physics in the 20th Century

V. F. Weisskopf

Professor Weisskopf spent several summer months at CERN working in the Theory Division. During his stay he has given three talks to the Summer Vacation Students under the title 'Fundamental Questions of Physics'. Some of the themes in his talks also appeared in the talk which he gave at the Inaugural Conference of the European Physical Society in April. The Proceedings will be published as a special issue of 'La Rivista del Nuovo Cimento' and can be purchased from Messrs. Editrice Compositori, Viale XII Giugno 1, 40124 Bologna, at an estimated cost of $ 12.

Reviewing the development of physics in the 20th century is indeed a dazzling experience. Relativity, quantum theory, atomic physics, molecular physics, the physics of the solid state, nuclear physics, astrophysics, plasma physics, particle physics, all these new insights into nature are children of the 20th century.

There was a definite change in the character of physics at the turn of the century. The older physics was under the spell of two fundamental forces of nature: gravity and electromagnetism. The development of classical mechanics from Galileo and Newton to Lagrange and Hamilton had shown the validity of the same natural law, the law of gravity, on earth and in the universe. Electrodynamics, a child of the 19th century, reared by Faraday, Maxwell and Hertz, was the first extensive application of the field concept in physics; it revealed the importance of electric phenomena in matter. The discovery of the electromagnetic field as an independent entity in space, the spectrum of electromagnetic waves, the electromagnetic nature of light, are some of the greatest human insights into the natural world. But the properties of matter were not understood at that time, they were not deduced from more elementary concepts, they were measured and expressed in the form of specific constants of materials, such as elasticity, compressibility, specific heat, viscosity, conductivity of heat and electricity, dielectric and diamagnetic constants.

The physicists of the 19th century were not unaware of the importance of interatomic forces for the determination of material properties. But there was no way of telling what the origin of these interatomic forces was, and how to account for their strength or absence. The great variety among the properties of the different elements was not considered a topic for physicists; it was the task of the chemists to analyze and systematize them, as was done so successfully a hundred years ago by Mendeleyev in his periodic system of elements. The specific features of the different species of atoms, their characteristics optical spectra, their chemical bounds, were known and catalogued by the chemists, but they were not considered a suitable subject for physicists.

The electron was already discovered before 1900 and it became obvious that electrons must be essential parts of the atomic structure, but classical physics could not give any clue as to the kind of structure one should expect within the atoms. The discovery of a quantum of electric charge, dominating all electric and optical phenomena was the beginning of a long development, in which deep insights into the essence of matter were gained. It behoves us to say, however, that the significance of this unit of charge is still a major riddle today, a hundred years after its discovery.

In physics, the 20th century truly begins in the year 1900. This date is not an accident, it is the year of publication of Max Planck's famous paper on the quantum of action, the birth year of quantum theory. It is impressive to contemplate the rate of progress in the first quarter of this century: Planck's quantum of action in 1900, Einstein's special relativity theory in 1905, Rutherford's discovery of atomic structure in 1911, Bohr's quantum orbits and explanation of the hydrogen spectrum in 1913, Einstein's general relativity in 1916, Rutherford's first nuclear transformation in 1917, Bohr's explanation of the periodic table of elements (Aufbauprinzip) in 1922, the discovery of quantum mechanics by de Broglie, Heisenberg, Schrödinger and Bohr in 1924-26, the exclusion principle by Pauli in 1925, the electron spin by Uhlenbeck and Goudsmit in 1927, the relativistic quantum mechanics by Dirac in 1928, Heitler-London's theory of the chemical bond in 1927, the theory of metallic conductivity by Bloch and Sommerfeld in 1930. Let us stop there, although the rate of progress by no means stopped in 1930; it went on for at least another ten years, before slowing down to the relatively slow pace of today.

Among the great systems of ideas which

were created in that period, relativity theory, special and general, has a place somewhat different from the others. It was born in the 20th century as the brain child of one towering personality. It is a new conceptual framework for the unification of mechanics, electrodynamics and gravity, which brought with it a new perception of space and time. This framework of ideas, in some ways, is the crowning and synthesis of 19th century physics, rather than a break with the classic tradition. Quantum theory, however, was such a break; it was a step into the unknown, into a world of phenomena that did not fit into the web of ideas of 19th century physics. New ways of formulation, new ways of thinking had to be created in order to gain insight into the world of atoms and molecules, with its discrete energy states and characteristic patterns of spectra and bonds.

These new ways of thinking were formulated and codified in the midst of the third decade of this century. The wave particle duality was proposed by de Broglie in 1924, the equation for particle-waves was conceived by Schrödinger in 1925. In these years the concepts of quantum mechanics were expressed and critically analyzed in Copenhagen under the leadership of Niels Bohr, with the help of ideas of Heisenberg, Kramers, Pauli and Born. The ink of these papers was hardly dry when the new way of thinking was applied successfully to explanations for almost all atomic phenomena that puzzled physicists since they had been discovered. The rules of quantization of Bohr and Sommerfeld, which seemed arbitrary when they were invented, turned out to be logical consequences of quantum mechanics; atomic spectroscopy became a deductive science; the semi-empirical Aufbauprinzip of Niels Bohr emerged logically from quantum mechanics, with the help of Pauli's exclusion principle. Mendeleyev's periodic table was easily explained. A few years later, the chemical bond was understood as a quantum mechanical phenomenon, so was the structure of metals and of crystals. A variant of a famous Churchill statement can aptly be applied to this golden age of physics: *'Never before have so few done so much in such a short time'*.

Let me mention three characteristic features which quantum mechanics has brought to our view of the atomic world. First, it has introduced a characteristic length and energy which dominate the atomic phenomena, endowing them with a scale and a measure. The combination of electrostatic attraction between the nucleus and the electron on the one hand, the typical quantum kinetic energy of a confined electron on the other hand, define a length: the Bohr radius, and an energy: the Rydberg unit. The size of the atoms is determined by the length which is the combination h^2/me^2 of a few fundamental constants, the unit of charge e, the electron mass m, and the quantum of action h. The Rydberg unit is given by the combination me^4/h^2. Thus atomic sizes and energies are basically determined and explained.

Second, quantum mechanics introduces a 'morphic' trait, previously absent in physics. The electron wave functions represent special forms of patterns of simple symmetry, characteristic of the symmetry of the situation which the electron faces in the attractive field of the nucleus and of the other electrons. These patterns are the fundamental shapes of which all things in our environment are made. These shapes are directly determined from the fields of force which bind the electrons. Here quantum mechanics has created the concept of ideal identity. Two atoms are either in the same quantum state, then they are identical; or in different ones — then they are definitely non-identical. The continuous transition between identical, almost identical and different has disappeared.

The third feature is the use of quantum numbers for the characterization of quantum states. Quality is reduced to quantity: the number of electrons and the quantum numbers of a given state fully determine all properties of the atom in that state. Pythagorean ideas are reborn here: the spectrum of frequencies of an atom represents a characteristic series of values, the typical chord of that atom, as it were; the 'harmonies of the spheres' reappear in the world of atoms. Kepler's speculation of simple geometrical and numerical ratios between the sizes of planetary orbits in the solar system proved to be wrong, but it is reborn in the electron orbits of the atom, as a direct consequence of quantum mechanics.

A fundamental problem of natural philosophy was solved by the discovery of laws which give rise to specific shapes and well-defined entities. Clearly, Nature is basically made of such entities, as our experience tells us every day; materials have characteristic properties, iron remains the same iron after evaporation and recondensation. The specific properties of matter were the subject of chemistry before and not of physics. Quantum mechanics explains these properties and thus has eliminated chemistry as a separate science.

The infinitely varied, but well defined, ways in which atoms aggregate to larger units are now accessible to a rational interpretation in quantum mechanical terms. A theory of the molecular bond came into being in which electron wave patterns keep atomic nuclei together in the right arrangement. Since one again deals here with the interaction of nuclear charges and electrons, the same sizes and energies must appear as in atoms, giving rise to interatomic distances of a few Bohr radii and binding energies of the order of electronvolts. Atomic aggregates consist of two kinds of particles, heavy nuclei and light electrons, which are bound to each other by mutual attraction. The interatomic distances are fixed by the size of the electron cloud, a length which also can be regarded as the amplitude of the zero point oscillation of the electron. Because of the much heavier mass, the zero point oscillations of the nuclei in a molecule are much smaller (the ratio is the square root of the mass ratio); hence the nuclei form a rather well localized skeleton in molecules and solids, a fact which introduces a structural feature into chemistry, and material science, with all its architectonic consequences. The quantum mechanical description of atomic aggregates leads to an understanding of all these material properties and material constants of which classical physics collected empirical information. In principle, all these constants that we mentioned above can be predicted and expressed in terms of the fundamental constants e, m, h and the nuclear masses.

The well-defined structure of the nuclear

Professor Weisskopf speaking at the Inaugural Conference of the European Physical Society in Florence.

(Photo Torrini)

framework in molecules is of special significance in macromolecules, which are long linear arrays of molecular groups. The enormous number of different orderings of these groups, each order being well defined and reasonably stable, is reflected in the numerous species of living systems in our flora and fauna, due to an intricate copying and reproduction process which has been unravelled during the last decade. So chemistry, material science and molecular biology are direct descendants of the quantum mechanics of electrons in the Coulomb field of atomic nuclei. The basic structures have a limited stability measured in fractions of the characteristic energy unit, the Rydberg. Perturbations of a strength of a few electronvolts would disrupt them. This is the tender world of chemistry and biology which is destroyed at temperatures higher than a few electronvolts as is the case in most stars. Matter, in the form in which we are accustomed to see it, is a rare phenomenon in the universe. There is more between heaven and earth.

The faint glow of radium in Mme Curie's hand was the first indication of the existence of other phenomena in matter. It was soon apparent from radioactive processes that there must be much higher energies than the Rydberg unit relevant in the atom. Rutherford made use of these energies in order to penetrate into the structure of atoms, when he discovered the atomic nucleus by anomalous scattering of alpha-rays in atoms. Incredible as it may seem, he used the same tool only six years later (1917) in order to study the composition of the nucleus and found that some of its constituents are protons. A new world of phenomena was discovered. However, the composition of the nucleus was only disclosed fifteen years later in the great year of physics, 1932. In that year Chadwick discovered the neutron, Fermi published his theory of the radioactive beta-decay and Anderson and Neddermeyer discovered the positron. Each of these three discoveries had far-reaching significance.

The existence of the positron confirmed the validity and depth of Dirac's relativistic wave equation (1927), one of the most remarkable examples of the power of mathematical thinking. This equation — a marriage of quantum mechanics with relativity theory — demonstrated the necessity of the existence of an electron spin with its typical magnetic moment. In addition, it exhibits a fundamental symmetry corresponding to the existence of two types of matter, ordinary matter and antimatter with equal properties but opposite charges and other characteristic quantum numbers.

The discovery of the neutron as a constituent of the nucleus revealed the existence of a new force in Nature. It pointed towards a strong non-electric effect which keeps neutrons and protons tightly bound with the confines of the nucleus. Here a manifestation of something new was observed, a new force of nature without any analogue in macroscopic physics. The strong interactions were discovered.

Fermi's theory of the beta-decay demonstrated the existence of another interaction between elementary particles. A neutron can transform itself into a proton with the emission of a lepton pair — an electron and a neutrino. This is the so-called weak interaction which appears as a fourth interaction, besides the gravitational, electromagnetic and strong. It is so weak that the time scale of its nuclear processes is of the order of seconds, days or years. Thus the year 1932 was the beginning of a new type of physics dealing with the structure of the nucleus and its constituents, and working with hitherto unknown forces and interactions.

Let us return to the force between neutron and proton. Scattering experiments have revealed a rather complicated structure of this force. It is short-ranged and attractive, except for small distances of less than a Fermi when it becomes repulsive. It is also strongly dependent on the relative spin orientation of the two particles and on the symmetry of the wave function. In this respect, as well as in respect to the repulsive nature at small distance, it resembles the chemical force between two atoms, an analogy to which we will return later. As an estimate of the strength of attraction, let us compare it with the electrostatic attraction which would be present if the neutron and the proton had opposite electric charges g and -g. It turns out that the nuclear attraction is roughly equivalent to an electric attraction between two opposite charges of a size $g \sim 3e$. This information allows us to estimate the approximate size and energy of simple nuclear systems by applying the same quantum mechanical principles as was done for the atom. All we have to do is to take the expressions for the Bohr radius and Rydberg unit and change e into g, and the electron mass into the nuclear mass. We then obtain the nuclear Bohr radius (h^2/mg^2) of about 2×10^{-13} cm, and the nuclear Rydberg (mg^4/h^2) of about 3 MeV. Nuclear systems are 10^{-5} times smaller than atomic systems and the relevant energies are in the million electronvolt region.

Once the nuclear force was established, quantum mechanics could be applied to the nucleus as a system of neutrons and protons. We find in nuclear physics a repeat performance of atomic quantum mechanics, but with a different scale of units. Nuclear energy level spectra presented a similar structure to atomic spectra, with the same kind of quantum numbers. One significant addition appeared however, the isotopic spin quantum number. It originates from the fact that the nuclear force does not distinguish neutrons from protons so that one should consider the two particles as equivalent states of a single particle, the nucleon. Thus a formally similar situation arises as with the two ordinary spin states of a fermion, and this analogy led Heisenberg to the introduction of the important concept of isotopic spin and its quantum numbers.

The weak interactions provide a process of changing a neutron into a proton and vice versa, so that the spin analogy has also a dynamical sense. The nuclear system therefore is not an entity with fixed numbers of neutrons and protons; all that is fixed is the total number A of nucleons. All nuclei with equal A belong to the same quantum system and one finds approximate degeneracy and other typical relations between quantum states of nuclei with equal A, which differ only by the replacement of neutrons by protons.

There are many striking similarities between atomic and nuclear structure. One is the periodicity of properties as a function of the atomic number A, arising from a similar shell structure. The occupation numbers at which the shells are completed are slightly different because of the different nature of the average potential and because of the important role which spin orbit coupling plays in nuclei. The role of the noble gases, consisting of high stability and low reaction rates, is played in nuclear physics by those nuclei for which shells are completed.

The analogy between atoms and nuclei is perhaps not thoroughly justified. It is probably more correct to compare nuclei with molecules where the nucleons play the role of the atoms rather than the nuclei. Why ? The force between nucleons is complicated, both in its dependence on distance and on other properties. That force is much more like the chemical force between atoms, with its repulsive character at small distances, its minimum of potential in between and its dependence on the symmetry of the wave function. It is tempting to assume that, in analogy to the chemical force, the nuclear force is not a fundamental force such as the electrostatic attraction; it may be a derived effect of a more basic phenomenon residing within the nucleon, a residue of something much more powerful and simple, just as the chemical force is a residue of the Coulomb attraction between electrons and nuclei within the atom.

Modern particle physics has discovered much evidence for an internal structure of the nucleon but has not yet been able to interpret it. The most important evidence is the fact that the nucleon seemingly changes its state when bombarded with energetic particle beams. It can be excited to a large number of quantum states. These states form a level spectrum which represents a third spectroscopy in which excitation energies are measured in GeV and not in MeV as in nuclei, or eV as in atoms. This level spectrum shows similar regularities as the others, the same quantum numbers appear with addition of a new one introduced by Gell-Mann and Nishijima, the hypercharge or strangeness. Transitions between the states occur again with emission or absorption of light quanta and lepton pairs, but a new form of energy exchange was found: the absorption or emission of mesons. The search for the internal structure of the nucleon is one of the most challenging frontiers of modern physics.

The existence of excited states certainly points to some internal dynamics. The presently known spectrum of these states exhibits certain regularities which are vaguely related to those of a system consisting of three kinds of particles with half-integer spin, sometimes referred to as 'quarks' or 'stratons'. In addition, the regularities in the spectrum of mesons — they also have been observed in many quantum states forming a spectrum — point towards a structure of mesons being made up of a pair of a quark and its antiparticle. In this hypothetical picture, the mesons are the quantum states of a quark-antiquark system, in analogy to positronium, which is an electron-positron system.

The question of an internal structure of the electron has not yet been opened. The most puzzling aspect of this question is the existence of the heavy electron or muon, a particle which, seemingly, is in every respect identical with the electron, except that it is 200 times heavier. It may be that the four known leptons — electron, muon, two types of neutrinos — represent the beginning of a more complicated lepton spectrum. Although today the electromagnetic interactions of the electron are extremely well described by the almost perfect theory of quantum electrodynamics, there remain grave questions regarding the nature of the electron: the reason for the apparent uniqueness of the elementary charge, the existence of the heavy electron, the source of the electron mass and, last but not least, the nature of weak interactions with their puzzling violations of established symmetries, such as right- and left-handedness and matter-antimatter symmetry.

Modern particle physics presents many challenging problems for the understanding of the numerous unexpected phenomena which were discovered. Theoretical understanding does not yet go very far, although theoretical physicists here contributed many ideas, models and analogies in order to correlate and systematize the wealth of experimental material. There is no Rutherford of particle physics yet, but neither has its Niels Bohr appeared. The lack of success is not caused by any lack of intellectual effort. The great insight into what goes on within a so-called elementary particle is not yet at hand.

(There is another variation of Churchill's remark: *'Never have so many done so little in so long a time'*. The value of achievement, however, must be measured in terms of the greatness of the task. Let me quote a favourite story of Niels Bohr about a British Lord telling of his exploits in lion hunting. When a young lady in the audience asked him how many lions he caught, he replied *'None'*. Whereupon the lady retorted *'Isn't that rather few'*. The Lord's reply was: *'Not for lions'.)*

So far, we have sketched the development of our knowledge of the structure of matter in the 20th century, from atomic physics to modern particle physics. Science develops not only in this 'intensive' direction towards smaller sizes, higher energies and towards phenomena and laws which are hidden deeper within the units of matter. There is also an 'extensive' direction of development in which the knowledge of the basic laws and properties of matter are applied to the understanding of broader fields of enquiry.

Modern physics of the solid state can

give a detailed account of the behaviour of metals, semi-conductors and crystals of all kinds. In particular, the behaviour of solid matter at very low temperature revealed phenomena such as superconductivity, which, for a long time, defied all explanation. But also these phenomena together with the superfluidity of certain liquids at low temperature, turned out to be understandable and derivable from the same basic assumptions about the quantum nature of atomic dynamics. It took a long time until adequate concepts were found which made it possible to formulate the main features of the quantum behaviour of systems with many constituents. Once such concepts were formed, they helped not only to understand the strange behaviour of bulk matter at low temperatures, but also some features in the behaviour of heavy nuclei, and these concepts served even to elucidate some problems of quantum electrodynamics and other field theories. The applicability of new concepts in many fields of physics is one of the gratifying developments which emphasize the unity of physics.

New vacuum techniques, microwave devices and strong magnetic fields make it possible to study plasmas, a form of matter at high temperatures and low pressure where most electrons are no longer in their atomic quantum orbits. This state of matter is very common in the universe, in the interior of stars as well as in the expanses of space. The behaviour of the plasma state is dictated by very simple laws; the electromagnetic interaction between nuclei and electrons. Quantum effects are negligible because of the high excitation. Hence we are dealing with the classical physics of electrons and nuclei which, surprisingly, is more complicated than quantum physics because of non-linear effects and various instabilities.

An account of physics in the 20th century would be very incomplete without mentioning astrophysics. It is a science born in this century and is the frontier of physics at extremely large distances, in contrast to particle physics, which is the frontier of extremely small distances. There is good reason to believe that the two are intimately related. There were two major insights which have shaped this branch of science. First, the recognition of nuclear reactions as the source of stellar energy, and second, the discovery of the expanding universe. The first discovery has shown that nuclear reactions are infinitely more important for the production of energy than ordinary chemical reactions. However, nuclear processes do not occur on earth with the exception of those few radioactive elements which are the last embers left over from the great supernova explosion in which our terrestrial matter was produced. We had to reproduce nuclear processes in our laboratories in order to study them. The places in the universe where they occur at a large scale are the interiors of the stars and the big star explosions. It was no mean feat of man to recreate on earth processes which naturally are found only in the centre of stars and to make technical use of them, although some of these uses have been destructive ones.

The second discovery, the expansion of the universe, is mysterious and of fundamental significance. A new time and space scale appears. It is the time in which the universe has expanded to its present state, an interval of approximately 10^{10} years. We are very far from knowing what the universe was like at the beginning of this time, but one fact is sure: the matter of our present universe was in a very different state at that time. The time interval also defines a length (the distance that light travels during that interval); it is the radius of the present universe, from beyond which no message can ever reach us. It defines a maximum size — about 10^{10} light years — in which our world is embedded.

The 20th century is to the universe what the 16th was to the earth: Magellan sailed around the planet and showed that there is a finite surface to it. We have learnt in this century that there is a finite universe which we can be in contact with and we have almost fathomed its depth when stellar objects were seen with a red shift of the order unity.

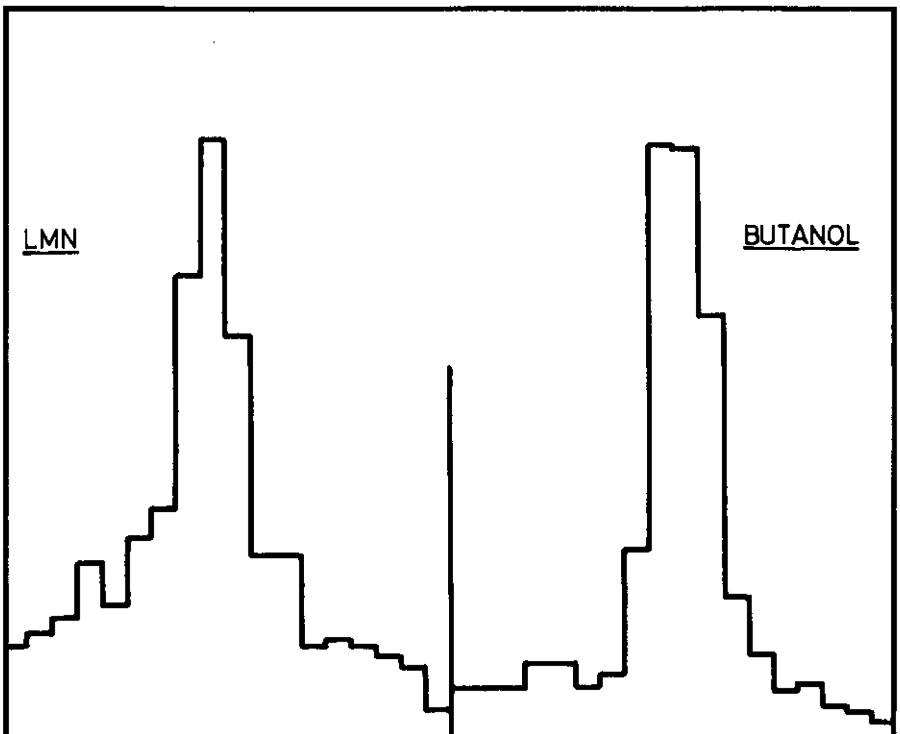
Modern astrophysics has brought a new aspect into physics: the historical perspective. Previously, physics was the science of things as they are; astrophysics deals with the development of stars, of galaxies, with the formation of the elements, with the expanding universe. There are many unsolved questions in this history, many phenomena such as quasars, which are unexplained, but part of this history is fairly well understood. It is the part in which stars are formed from a hydrogen cloud, elements are formed by synthesis from hydrogen, stars are developing through different states — some ending as cold chunks of solid matter, others ending in tremendous explosions which we observe as supernovas, sometimes leaving behind fast spinning neutron stars. One of these explosions occurred in the year 1054 AD and left the famous Crab Nebula behind in which we see the expanding remnants of the explosion with a pulsar in the centre.

The kinetic energies produced when larger stars contract after their nuclear fuel is exhausted, are such that individual protons reach energies of the order of a GeV, that is the energy of their rest mass. Therefore high energy physics will come into play at these stages of development and all the newly discovered phenomena of nucleon excitation and meson production will take place at a large scale, just as nuclear reactions take place at a large scale in the centre of ordinary stars. Perhaps it is significant that such energies are reached when the gravitational energy of a particle becomes of the order of its mass. This is the so-called Schwartzschild limit, at which the gravitational field becomes critically large and bends the local space such that light may not be able to leave, if our present ideas of gravity are still applicable to such unusual conditions. This may point to a connection between high energy physics and gravitational phenomena.

The cosmological aspects of matter reveal a certain insignificance of electronic quantum physics in the universe. Only rarely is matter in a state where the quantum properties of electrons around nuclei are of relevance. Mostly, matter is too hot or too dilute. But it is at those special spots where quantum orbits can be formed that nature developed its atoms, its aggregates, its macromolecules and its living objects. It is there where the greatest adventure of the universe takes place where Nature in the form of man begins to understand itself.

CERN News

Comparison of the performance of a LMN and a butanol target for elastic scattering of protons (pp → pp at 1.22 GeV/c). The number of events is plotted vertically against the scattering angle. The advantage of the butanol compared to the LMN target is the reduction of the background by a factor of 2.5, if only very lose co-planarity requirements for the interaction are applied.



Butanol targets

Since it became technically feasible from 1962 to build polarized proton targets, they have been used in about fifty experiments at CERN and in a number of other Laboratories. Up to now, these targets have been made of a complex substance (LMN) containing a certain proportion of 'free' protons (nuclei of hydrogen atoms) whose spins become polarized at very low temperature (around 1° K) under the combined influence of a high constant magnetic field of about 20 kG and a weaker magnetic field with a very high frequency, generally around 70 000 MHz. (The ideas and techniques involved were described in CERN COURIER, vol. 7, page 28.)

Thus polarized, these targets may be used in a wide variety of experiments — to determine the spin or parity of strange particles or resonances ; to study the role of spin in the dynamics of the interaction by measuring polarization parameters, spin rotation, spin-spin correlation, etc ; to check the invariance properties of strong or electromagnetic interactions ; to polarize intense neutron beams by transmission (this was done recently for example, with neutrons emitted by an underground atomic explosion, by a Los Alamos group in Nevada).

Until 1969, LMN (double nitrate of lanthanum and magnesium — $La_2Mg_3\,(NO)_{12}$ $24H_2O$) had been used exclusively. In spite of the high percentage polarizations obtained, varying from 50 % to 70 % according to Laboratory, this substance has the great drawback, as can be seen in the chemical formula above, that it contains many complex nuclei, which are not polarized. Moreover, the percentage polarization is very sensitive to radiation damage from the beams : for example, polarization is reduced to about half its initial value after the target has been exposed to 2×10^{12} minimum ionizing particles per square cm.

In recent years, several Laboratories have been carrying out research into substances which have a higher density of hydrogen nuclei and less heavy nuclei and which are more resistant to radiation than LMN. At CERN, this research began in 1966, carried out by M. Borghini, S. Mango and O. Runolfsson, and quickly showed good results with ethyl alcohol diluted with a little water. Unfortunately, these results were sometimes difficult to reproduce. (Nevertheless, these targets were used at the Cambridge Electron Accelerator in 1968 to check time reversal invariance of the electromagnetic interaction.)

A systematic study has been made of alcohol mixtures, alcohol and water mixtures and of the role of dissolved molecular oxygen, which led to the choice of a mixture of 95 % normal butanol (C_4H_9OH) and 5 % deoxygenated water containing approximately 1 % free radical porphyrexide (percentages by weight). Reproducible polarizations of the order of 40 % can be obtained in targets of volume 5 to 10 cm^3.

The first butanol polarized target was used at CERN in March 1969 for the study of positive kaon - proton and anti-proton - proton scattering at several GeV by the CERN-Holland group, and a second in May for the study of elastic scattering using proton, positive and negative pion, and positive and negative kaon beams at over 5 GeV by the CERN-Orsay-Pisa group. A third target of the same design constructed at Lawrence Radiation Laboratory, Berkeley, has been in use at the Stanford Linear Accelerator since April again checking, with greater precision, time reversal invariance in the electromagnetic interaction, and it is now being used to measure the polarization parameter in positive pion photo-production at high energies. For these latter experiments it has been necessary to have beams of very high intensity, for example 10^{11} electrons per second : alcohol targets are about 200 times more resistant to radiation damage than LMN and can tolerate these conditions.

The following table is a comparison of some of the characteristics of the two substances at a field of 25 kG and a temperature of 1° K.

	LMN	Butanol
Maximum polarization	70 %	40 %
Hydrogen density (g/cm^3)	0.06	0.12
Bound/Free protons	15	3.2
Acceptable number of minimum ionizing particles/cm^2	2×10^{12}	4×10^{14}

Filling the large container with frozen butanol spheres at 77° K. The cryostat was pre-cooled and covered with plastic to avoid water condensation. The photograph was taken in the polarized target laboratory at CERN where target materials are developed and tested before use in an experiment.

CERN/PI 104.10.69

As can be seen, the percentage of polarized hydrogen nuclei is higher in LMN than in butanol, which is an advantage of LMN for certain experiments, for example the polarization of neutron beams by transmission. However, butanol contains twice the amount of polarized hydrogen and 2.5 times less protons or neutrons bound in complex nuclei per unit volume. These two factors are important: they determine the number of useful events produced on polarized hydrogen and the number of background events produced on bound non-polarized protons or neutrons which must be eliminated from the experimental data when it is analysed. The advantage that butanol has over LMN is the ease with which it eliminates background though this depends on the nature of each experiment.

For experiments such as elastic scattering of protons, pions or kaons on polarized protons, which give rise to two charged particles of a relatively low energy, it is possible to distinguish between useful and background events using an LMN target and there is therefore no great call for butanol targets. This is not the case if the cross-sections are low and if the interactions under study are partly masked by other interactions produced simultaneously.

For other experiments, such as the study of charge exchange reactions $\pi^- p \rightarrow \pi^\circ n$ and $\pi^- p \rightarrow \eta^\circ n$ which have already been studied with LMN at CERN and $K^- p \rightarrow K^\circ n$ at Argonne, the number of useful events would be increased by a factor of the order of 5 to 10 if it was not necessary to observe the neutron. Polarized butanol targets are then a considerable improvement on LMN. Proposals for experiments of this type have recently been put forward at CERN.

One other advantage of butanol polarized targets which has already been mentioned is their resistance to radiation. This is only a minor advantage for the intensities of ordinary particle beams used for experiments at CERN. However, for the low cross-section interactions, such as high energy wide-angle proton - proton scattering, elastic or inelastic electron scattering and photo-production it would be impossible to use LMN. The development of butanol targets is therefore of crucial importance.

Polarized proton targets have aroused great interest at CERN and other Laboratories, and efforts are being made to improve them. Work is going on in three directions :

1) searching for new substances ;
2) lowering the operating temperature to 0.5° K for instance;
3) increasing the magnetic field to 50 kG and the frequency of the alternating field to 140 000 MHz.

The most recent progress made on substances is the production of strong polarizations (50 % at 1° K) with ethyl glycol $C_2H_4(OH)_2$ containing a chrome complex by H. Glattli et al. at Saclay. Although the glycol contains less hydrogen and more complex nuclei than butanol, it is interesting because of its higher polarization.

Concerning the influence of temperature on polarization ; measurements taken at 0.5° K by A. Masaiké et al. at Saclay and R. Hill et al. at Argonne have given polarizations of 82 % in ethyl glycol and 67 % in butanol respectively using small samples of 10 to 100 mm³.

Finally, superconducting coils, which enable fields of 50 kG to be obtained, have now been constructed or are under construction at Argonne, Saclay and CERN and new results may be expected soon.

PS Shutdown

The annual shutdown of the PS began on 13 October, to last until 26 November. It is being used for the usual overhaul and maintenance work and for a large number of modifications to a variety of components. Most of these modifications are relatively minor, and it would take up too much space to give a detailed list here. Only the more important ones will therefore be mentioned.

Linac

A lot of work will be done on the Linac in the context of the PS improvement programme. The pulse repetition frequency is to be doubled (from 1 to 2 per second) and the pulse length is to be increased fivefold (from 20 to 100 µs). Points worthy of special mention include:

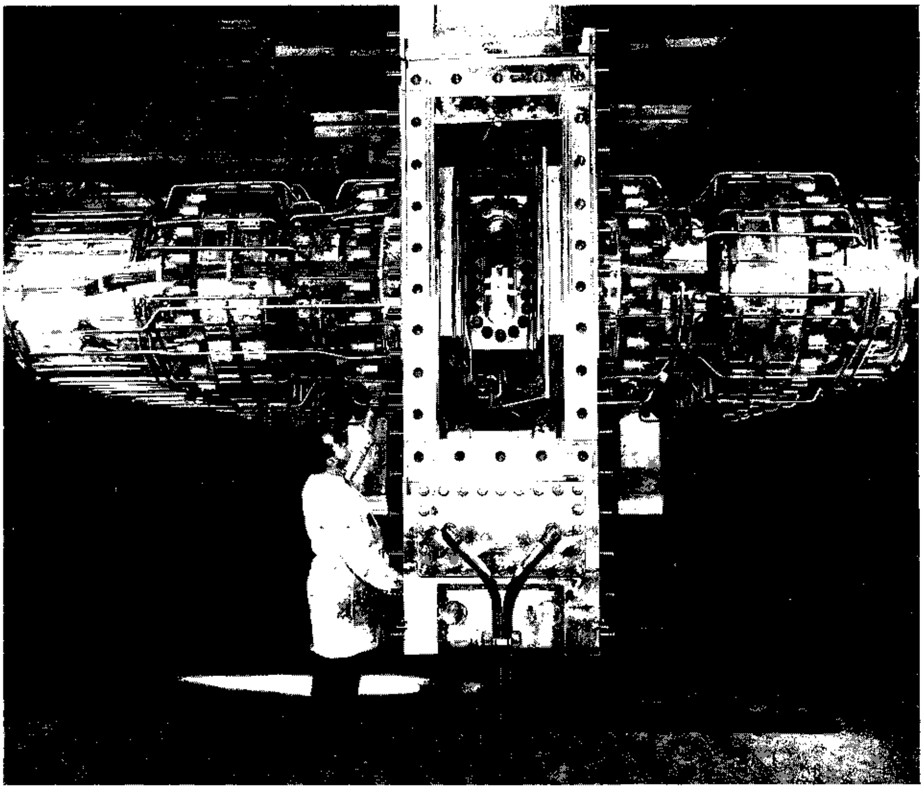
a) installation of optical links with the ion source control platform (five infra-red channels such as were described in CERN COURIER vol. 9, page 104);
b) installation of new digitized servo-controlled tuning systems based on the use of a stepping-motor (200 steps per revolution) which will allow certain changes in the accelerating field in the linac tanks to be computer-programmed;
c) modification of the power dividers and dephasers of the cavity amplifiers, which will be fitted at the inputs to the CFTH amplifiers;
d) modification of the two modulators in the r.f. circuit (Siemens and driving modulators) to allow power pulse lengths to be increased from 200 to 300 µs;
e) an increase in the cooling capacity of the pulsed quadrupoles of cavity No. 1.

The importance of this work on the Linac is explained by the fact that this PS shutdown is the last before connection is made between the Linac and the Booster at the end of 1970.

Synchrotron ring

The main work to be done on the PS includes the installation of the fast ejec-

The 2 metre hydrogen bubble chamber minus its magnet. The chamber is undergoing a series of modifications during the PS shutdown and for this the two halves of the magnet which normally hide the chamber, safety tanks, cooling pipes etc. are rolled back.
The chamber joined the select band of 10 million picture takers on 6 September. This figure has been reached in five years of operation.



CERN/PI 417.9.69

tion system for the Intersecting Storage Rings in straight section 16 and the setting up of the beam-line to the ISR for the first fifty metres from the PS. This represents a considerable volume of work and will involve almost all the PS groups, the ISR Division and the Technical Services and Buildings Division. The major part of the work will be done during the shutdown, but the rest will continue into February or March 1970. An enlarged vacuum chamber will be installed in four magnets, two downstream and two upstream of straight section 16.

It will also be necessary to turn two magnets around in this region to have the aperture opening towards the outside of the ring so that the ejected beam can emerge. In fact two magnets will be changed with two others in the ring which have the right configuration. Shims have to be fitted to correct stray fields; new vacuum tanks will be installed to take septum magnets; almost all straight sections have to be modified for the installation of dipoles for beam orbit deformation ; beam transport magnets, a beam dump and beam observation systems have to be installed.

Further modification involves the replacement of the vacuum chamber elastomer gaskets by metal ones over one-tenth of the circumference (sector No. II) where turbomolecular vacuum pumps and ion pumps will be installed to give a better vacuum than the oil-diffusion pumps previously in use. The supply lines to these ion pumps will be positioned in an extension to the central ring building.

Preparatory work will also be done for the fitting of a second kicker magnet in straight section 13 in the Spring of 1970. This magnet, which will be identical to the kicker magnet in straight section 97, will reinforce the perturbations induced in the orbit by the ejection magnet to provide greater flexibility in beam sharing.

Some work will be done in preparation for the Booster, especially:
a) enlarging the aperture through which the Linac-Booster injection line passes;
b) installing a heat dissipation system in that part of the Booster injection tunnel adjacent to the PS;
c) piercing an aperture for the connection of the Booster to the PS and building shielding around this aperture;
d) installing cabinets in the main control room for the Booster controls.

In readiness for the increase in intensity of the proton beam, the shielding of the PS ring will be reinforced. Almost half the ring (between the East and South Halls on the Salève side) will be covered with a further layer of earth a metre thick. This will provide the maximum thickness which the ring structure will safely carry. The other half will be covered when work on the Booster is completed.

External Beams

A large number of alterations are also being made in the experimental halls:

South Hall

— modification of the beam feeding the 81 cm hydrogen bubble chamber (beam k13 will replace k10);
— changing the separators of beam m7 from internal target 1;
— installation of a separator in beam q8 from internal target 8 (q8 becomes m8).

East Hall

— replacement of the pion beam p3 by a proton spectrometer (p3 becomes s5);
— fitting of a helium-cooled hydrogen target in the East target zone to feed s5.

Work on the bubble chambers

The PS shutdown also allows work to be carried out on the three bubble chambers in service at CERN, which have operated very satisfactorily over the past year. The 2 m hydrogen chamber has taken more than 3.8 million photographs during the operating period from November 1968 to October 1969. On 6 September it reached the total of ten million photographs, taken since it came into operation less than five years ago. The 81 cm hydrogen chamber took 1.9 million photographs in the same period (bringing its total close to 13 million since 1961). The 1.2 m propane chamber had taken 1.6 million (bringing its total to 7.5 million since 1960).

No major modifications are to be made to the propane and 81 cm chambers but some improvements will be made to the

A further stage in the assembly of the new heavy liquid bubble chamber, Gargamelle. The pipes which convey pressure changes to the diaphragms of the expansion system are manœuvred into place at the end of September. The large magnet of the chamber is on the right. The seven nitrogen tanks of the expansion system are also installed in the assembly hall and tests of the system will be carried out using two large tanks to simulate the chamber body itself which will not arrive until early 1970.

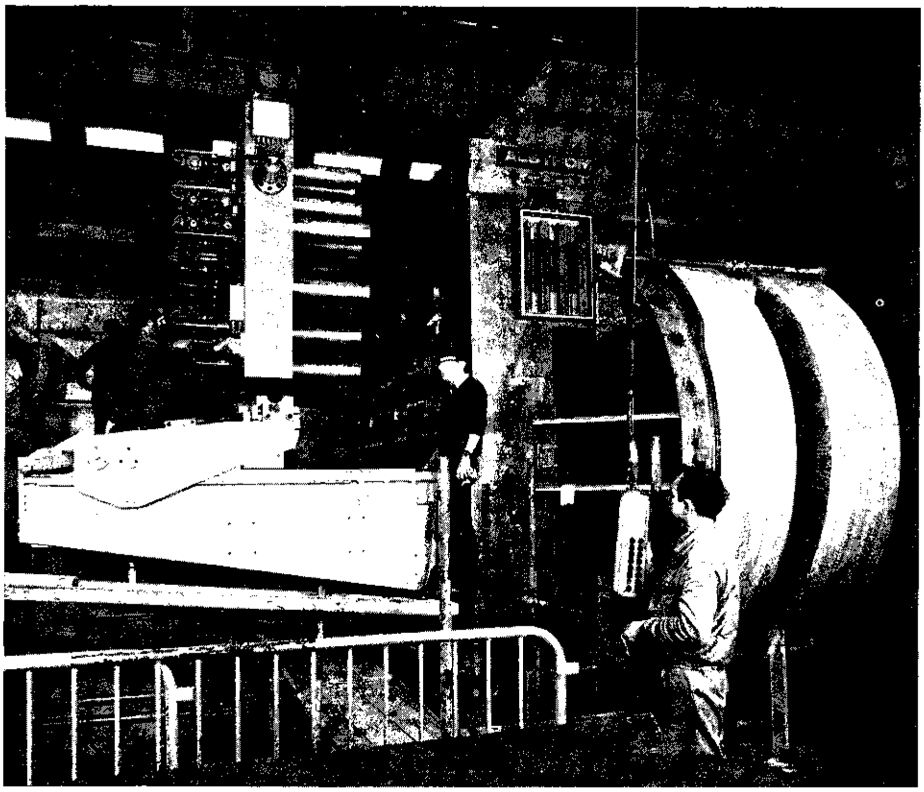
2 m chamber. The main one involves the replacement of the glass windows (17 cm thick) which form the two side walls of the chamber, by windows which have fiducial marks better suited for automatic measurement. The new windows are, in fact, the spares already in existence and the two windows which are being removed will, in turn, be re-engraved and put into store as spares.

A very careful check will be made on all the seals to reduce leakage to a minimum. It is intended to use deuterium rather than hydrogen for several months in 1970 and deuterium is about two hundred times more expensive than hydrogen. The storage capacity for deuterium will be increased.

Three of the four large motor generators which supply power to the 2 m chamber are being returned to the manufacturer for general overhaul (which is done every two or three years). The compressor control room will be integrated with the main bubble chamber control room.

Modifications will be made to a section of the outlet line connecting the vacuum tank of the chamber to the safety sphere to allow magnets to be fitted very close to the chamber for low energy beams. Finally, the expansion system, the vacuum and the cooling systems will be completely overhauled.

During the shutdown the magnetic field in the chamber will be mapped for a careful check with the previous map. Measurements will be made at about 1000 points in the chamber (three measurements at each point); the density of the points being greater in the areas where the field is least uniform. The results will be printed on tape. In addition, a computer will be used by way of experiment to make several measurements at each point and to calculate the mean value and the standard deviation.



CERN/PI 409.9.69

CAMAC Developments

To meet the ever increasing electronics needs of research centres and industry, 26 nuclear research organizations in Europe, members of the ESONE (European Standard for Nuclear Electronics) Committee began work in 1966 to establish standards for the construction of electronic plug-in modules and their crates. These modules had to be specially designed in view of the increasing use of computers, the aim being to make it easier to use automatic data acquisition and processing devices.

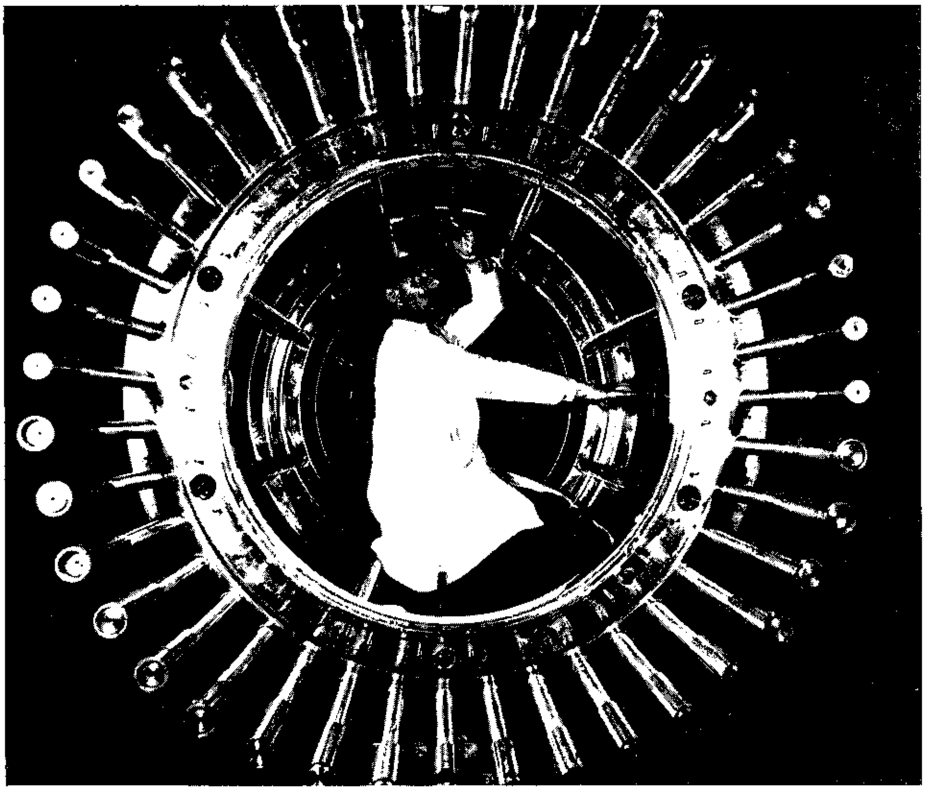
In May 1968 at the ESONE conference held in Rome, the principle of these standards was approved and was called CAMAC. At the same conference, the first part of the standards, covering the mechanics and logic of the interconnections of modules on the same crate, was adopted (CERN COURIER, vol. 8, page 314).

The second part of the standards, concerning the use and control of CAMAC crates (crate to crate links, crate to control system links, crate to adapters for computers, etc.) and of the nature and level of the various signals used for this purpose, had still to be defined.

This second set of standards, which has been studied by several Working Groups, was adopted at the ESONE Conference held at the end of September this year at Petten (Netherlands). It includes the following points :

1. the method of synchronizing external signals to the crates (this is the call-response-stimulus type) ;
2. the transfer system for these signals (this is the asymetrical-twisted-pairs type) ;
3. the method of processing requests from the modules. The system chosen uses data transmission lines and offers a range of possibilities of directing requests because of the (optional) use of a rear connector which permits a possible link with an additional request processing unit ;
4. crate controller : this is a link unit which is placed on each crate (taking the place of two or three modules) and interconnects with the main system. At the command of external signals, it addresses the required module or modules. It also generates the basic CAMAC cycle and varies the signals according to their destination ;
5. nature and level of the signals, synchronization of commands and data transmission. These signals are of the 'classic micrology' type. Loads are

An unusual view into the 1.2 m heavy liquid bubble chamber which is also having a wash and brush up while it is out of action during the PS shutdown.



CERN/ PI 176.9.69

designed for a maximum of 8 crates ;

6. the type of main (frontal) connector for the crate controller which is responsible for crate-to-exterior links.

Interest from Industry

Many European manufacturers of electronics equipment are interested in the CAMAC standards and several of them (five in France, two in Italy, four in the Federal Republic of Germany, eight in the United Kingdom, one in Sweden and two in Switzerland) have already put power supplies and CAMAC crates and modules on the market. It is interesting to note that this interest in CAMAC is not limited to the field of nuclear electronics, but extends to other sectors of data handling, such as electronics in medicine, servo-controls in industry, automatic units, etc.

All Laboratories belonging to ESONE are working on the manufacture of CAMAC systems. At CERN, three systems are being built, two of which will be used in nuclear physics experiments. All three conform to CAMAC standards in dimensions and inter-module connections and they are equipped with an external logic system which, although, it was designed before the second stage of the CAMAC standards was adopted, differs little from the CAMAC standards.

Information on the first part of the standards is already available (Euratom report EUR 4100). The second part will be published as a preprint at the end of the year and will be available from ESONE members.

CODD in action

The CODD (Closed Orbit Digital Display) system, which enables the trajectory of a single proton bunch to be measured as it goes round one turn of the machine, has been linked to the IBM 1800 computer in the control room since the end of August. The PS is the only accelerator with a system of closed orbit measurement of this type. CODD (described in CERN COURIER, vol. 8, page 177) uses 20 beam observation stations of a new design from which numerical signals are transmitted to the computer. It has three functions :

1. to present numerical results on a screen, before processing ;
2. to punch cards recording these signals for later processing;
3. to process signals giving the beam position of a single bunch at the 20 observation stations.

The results may be printed out or presented in analogue form on an oscilloscope screen. Since May 1969, the measurement system has been in operation and a series of tests were carried out in preparation for a direct link with the IBM 1800.

CODD makes it possible to measure the trajectory of a bunch to be ejected by the fast ejection system. A series of tests has therefore just been carried out to compare signals from CODD with the known oscillations produced by the fast kicker magnet. This served to check the functioning of the CODD system.

Until 13 October, the beginning of the annual PS shutdown, CODD was used for the automatic registering on punched cards of the characteristics of a large number of closed orbits at 10 GeV. This has given important statistics on the behaviour of the machine and information functioning of the CODD system.

At the moment only the 20 new observation stations are in use. These have the advantage over the old ones of being able to take measurements over a wide range of beam intensities. Nevertheless, because of the increased possibilities if there were double the number of measurement points, it is planned to link the 20 old stations, which are compatible with the new ones, to the system at the beginning of 1970.

Among the improvements to be carried out on CODD (in addition to bringing in the 20 additional stations) are modifications to the synchronization system and the installation of a semi-automatic calibration system. Artificial calibration signals which simulate a known beam position will be transmitted to a detection station. By observing the results at the end of the measuring sequence any error introduced by the electronics can be determined and the computer can automatically make any necessary corrections when receiving signals from the proton beam.

Professor de Shalit

Professor Amos de Shalit died on 2 September from acute pancreatitis. In his comparatively short life (he died at the age of 43) he had achieved prominence in the field of nuclear physics, had been a key figure in the development of science in Israel, and had contributed to the work of international organizations such as UNESCO, the European Physical Society, the International Centre for Theoretical Physics in Trieste, and CERN.

Amos de Shalit was born in 1926. He was educated at the Hebrew University of Jerusalem and at ETH Zurich. He did research in nuclear physics in the USA, at Princeton, Stanford and MIT, and spent a year at CERN as a Ford Foundation Fellow from October 1957 to October 1958. From 1956 he was Visiting Professor at the Hebrew University becoming Head of the Department of Physics from 1961 to 1963. He then moved to the Weizmann Institute of Science, Rehovoth, as Scientific Director and was Director General of the Institute from 1966 to 1968. In his last few years he devoted much thought and effort to the problems of science teaching. A few months before he died he took up the post of Head of a new Department of Science Teaching at the Weizmann Institute.

Professor de Shalit was a theoretical physicist whose work was mainly concerned with nuclear structure theory and nuclear spectroscopy, covering such topics as the application of group theoretical methods and diffraction theories of nuclear reactions. His most important contributions were on the nuclear shell model for which he received the Israel Prize, with I. Talmi in 1965. He had just completed a book, with H. Feshback, on nuclear structure. But as important as his directly creative work was his ability to absorb and assess what was happening in the whole field of nuclear physics. He was thus an outstanding review speaker able to draw out the essential developments and to initiate new lines of attack.

He was among the first to promote the use of high energy particle beams for the study of nuclear structure and took part in the discussions which led to this research playing an important part in the experimental programme of the CERN synchro-cyclotron. In May of this year he spoke at CERN evaluating the nuclear physics aspects of the research at the SC. Shortly before his death he had accepted to serve as a consultant to the CERN 'Physics III' Committee which concerns itself with the SC programme.

Together with Professor Weisskopf, he initiated a series of international conferences on High Energy Physics and Nuclear Structure which began at CERN in 1963. The latest conference in this series was held at Columbia USA a few days after his death. It was dedicated to Amos de Shalit.

One of the important formative influences on his life was his participation in Israel's war of independence in 1947 as a member of the Haganah. This left him with a very strong devotion to the cause of his country. He was one of the founders and the leaders of the brilliant school of physics in Israel, and one of his major concerns has been to ensure that science in his country should be closely integrated with that in leading centres elsewhere in the world. This was one of the motives which brought him into such close and fruitful contact with many international organizations.

Another legacy of the war years was a firm believe that things could be done given determination. This led him to devote seemingly endless energy to the things he believed in. He was always spilling over with things to be done and stimulated others by his enthusiasm. Coupled to this was a warmth of personality which carried others with him. He had exceptional skill in organization and successfully bore heavy administrative responsibilities from a very early age.

His concern with the social implications of science was always evident, particularly so in the last few years when he was in charge of the reform of science teaching in Israel and participated in work on science and education in developing countries. The thinking that he had already put into this important topic is likely to be influential for many years to come.

(Photo Weizmann Institute)

Cause and effect

In Physical Review vol. 180 p. 1266-81 P.L. Csonka develops, in an article pointedly entitled 'Advanced Effects in Particle Physics', ideas about 'full causality' according to which an effect may both precede and follow its cause. Csonka did some of his work on this revolutionary topic while at CERN in the Summer of 1968. This article is a brief general review of some of the ideas in his work and of the reasons for proposing them.

The generally accepted principle of causality is one which has been rarely questioned in the history of science. It says that no effect can precede its cause and is renamed by Csonka 'the principle of retarded causality'. This principle has become so embedded in thinking that the two phrases 'the state following the incoming state' and 'the state caused by the incoming state' are used synonymously to mean 'the outgoing or resultant state'. The two concepts of the time sequence of events and of the causal sequence of events have become merged. (Csonka calls attention to a similar merging of concepts in Ancient Egypt where the direction of the flow of the Nile made 'downstream' synonymous with 'travelling North'.)

By now, it is regarded as 'self evident' that a state caused by another state must follow it in time. There have, however, been some attempts to work out the implications of separating these two concepts and accepting what Csonka terms 'full causality' whereby an effect can also precede its cause in time.

About fifty years ago, K. Schwarzschild noticed that some problems in classical electromagnetic theory could be solved by dropping retarded causality (considering that the field 'produced by' an accelerated charge could both precede and follow the acceleration of the charge), but he ran into conflict with observation in other directions. H. Tetrode took up the idea without success, suggesting that the absorber is just as important as the emitter in determining the radiation even though absorption occurs after the radiation is propagated. Some twenty years later, R.P. Feynman and J.A. Wheeler went further in an attempt to explain the phenomenon of radiative damping using classical electrodynamics but they could not account for absorption. Cosmologists have also recently tried to bring the ideas into classical models of the Universe.

Csonka's new contribution is to attempt to build a particle theory (valid for particles with any quantum numbers) rather than a classical theory, on the basis of full causality where effect and cause are not tied to a time sequence. He was led to this by the consideration of several problems.

1. Most dynamical equations are symmetric with respect to time. It does not matter whether one feeds in +t (effect following cause) or —t (cause following effect) into these equations, the same laws of physics hold good for the system under consideration. Full causality leads naturally to such time symmetry.

2. It is not possible to construct finite causal chains if only retarded causality holds. A sequence of events is always open ended — the first state considered needs a cause which in turn needs a cause and so on. Full causality can close the loop, the past causing the future and vice-versa. This is an enormous conceptual simplification which could have a considerable impact on cosmological problems. Roughly speaking, it says for example that the Universe may 'create itself'.

3. Major difficulties are encountered in extending the basic equations of electromagnetic and weak interaction theories — the equations, developed using retarded causality, give infinity for such observably finite quantities as the difference in mass between the charged and neutral pion. Without some fundamental change these difficulties cannot be removed. T.D. Lee and G.C. Wick have since tackled this problem in detail (as reported in CERN COURIER vol. 9, page 35, and page 106) and their solution in fact involves the overthrow of retarded causality on a microscopic scale.

4. The impossibility of distinguishing between past and future (except by a definition). The full causality theory introduces a 'velocity of time matrix' from which a direction and 'velocity' of time can be determined at any point in the Universe as a function of the distribution of matter (in rough analogy to Newton's gravitation theory which determines the direction of acceleration as a function of the mass distribution).

5. The observation of CP violation which seems to be restricted to only very weak interactions. The full causality theory might explain this as a cosmological effect due to the transparency of the Universe to neutrinos.

Any such theory has of course to explain what is observed in the Universe — the predominant correlation between the time sequence and cause and effect. And, ideally, the theory should point to a situation where this usual correlation could break down, where effects could precede their cause, thus making it possible to test the theory. (The theory does not say that advanced (in time) effects *can* be observed but does say that nothing excludes the possibility). Such an experiment is proposed in the paper in Physical Review.

Due to the transparency of the Universe to neutrinos, these particles could show an advanced effect due to the lack of a cancelling signal from the surroundings which normally make it possible to see only retarded effects. It may then be possible to see neutrinos appearing before their cause (say pion decay) or with momenta directed towards the pion beam. If a detector is placed behind the pion beam produced at an accelerator, rather than in front of it where it normally catches the neutrino from pion decay, then using retarded causality, it would not be expected to record high energy neutrinos if retarded causality holds. But it could record neutrinos according to the theory of full causality. If such neutrinos were observed they could be a confirmation of the new theory.

Around the Laboratories

One of the photographs showing a 'quark candidate' observed in high energy cosmic ray showers by the University of Sydney team. The photograph was taken in a Wilson cloud chamber expanded after the arrival of the air shower and photographed a short interval later. The track (x-x) which could be that of a quark is the one composed of less droplets than its neighbours suggesting the passage of a particle producing lower ionization.

L.S. Peak, a member of the Sydney team, speaking at CERN on 8 September about their experiment.

Quark candidates

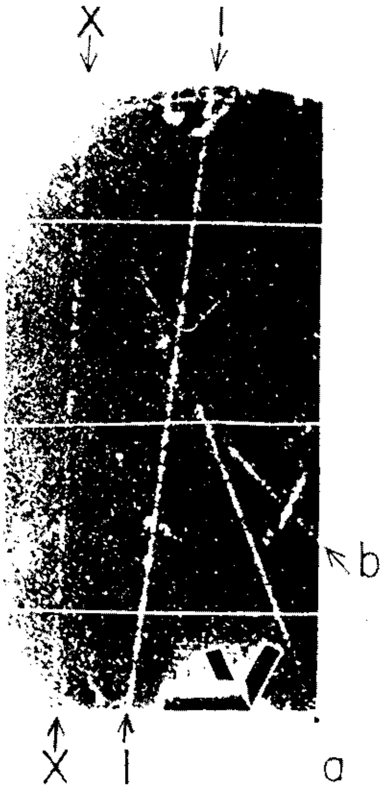
A report on a high energy cosmic ray search which seems to have evidence for quarks appeared in Physical Review Letters on 22 September. Prior to that date, there was a preliminary announcement at the 11th International Conference on Cosmic Ray Physics held at Budapest from 25 August to 4 September, and on 8 September, L.S. Peak, who participated in the experiment with I. Cairns, R.L.S. Woolcott and the team leader C.B.A. McCusker (from the Cornell-Sydney University Astronomy Centre in Australia) spoke at CERN about their intriguing findings.

Quarks are the particles proposed as the truly fundamental particles underlying the particles which are at present observed. The remarkable patterns of behaviour seen for the many strongly interacting particles certainly indicate that there is some more fundamental structure giving rise to these patterns (see the article by Professor Weisskopf at the beginning of this issue) and the postulate that the particles are built up from quarks, coming together in different ways, has been the most successful of the theoretical models which attempt to explain the observations. However, all previous searches both at particle accelerators and in low energy cosmic rays have failed to reveal a quark as a physical object. This does not necessarily mean that quarks do not exist — their mass may be too high for them to be produced at existing accelerator energies. They may, however, occur in the much higher energy world of cosmic rays.

One of their unusual properties would be that they would carry a charge of $1/3$ or $2/3$ the unit charge carried by the electron. Once above a certain energy, the ionization a particle produces as it passes through matter is proportional to the square of its charge and is independent of its mass. This provides a rather clean handle to get hold of the quark. It would produce ionization $1/9$ or $4/9$ that of a 'normal' particle. This is what the Sydney team looked for.

Beginning in July 1968, they looked at cosmic rays with a detector consisting of lead-shielded scintillation counters triggering four Wilson cloud chambers (three 30 cm diameter, 20 cm deep; one 20 cm diameter, 20 cm deep). The system was triggered at an energy over 10^{15} eV. In a little over a year, they took more than six thousand photographs of the high energy particle tracks produced in the chambers and, with an average of about ten tracks per picture, recorded about 60 000 particles looking for those which produced low ionization. By August of this year they had five quark candidates — five tracks were found with ionization about half that of a normal particle, possibly due to a quark carrying $2/3$ charge. Of these, the fifth one (event 66240) looks the most convincing.

The detector was arranged to look at cosmic ray air shower cores. The Wilson cloud chambers were expanded 100 ms after the arrival of the air shower and the photographs taken 200 ms after the expansion. Other possible sources of the low ionization — such as a statistical fluctuation in the number of ions produced, the Chudakoff effect, poor illumination,



CERN/PI 185.9.69

1) One of the first photographs taken during the tests on the large hydrogen bubble chamber, Mirabelle, in July. The tracks are of cosmic ray particles.

2) The piston of the chamber's expansion system - one of the most difficult components of the design. It is constructed from austenitic steel to give the strength to sustain accelerations of up to 200 G, and is hollow to make it as light as possible for rapid pulsing (moving 6 cm in 50 ms).

clearing field still present — have been eliminated, leaving the most likely source as the passage of a particle carrying less than unit charge.

The results have been greeted with guarded optimism, for obviously much more evidence is needed before people really believe in quarks as a physical reality, though they continue to be most fruitful in developing theory. The Sydney group are obviously keen to provide more evidence and are constructing a larger detection system with high pressure cloud chambers and streamer chambers both sensitive to particle charge.

SACLAY

Mirabelle marche

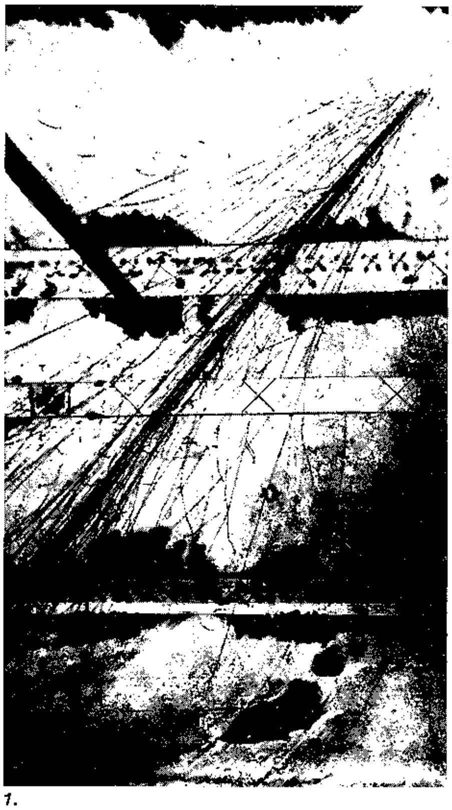
The large hydrogen bubble chamber Mirabelle came through its first tests in July with flying colours, fully meeting all the hopes of its designers. Over a period of two weeks the chamber was filled with liquid hydrogen. 13 000 expansion cycles were completed and more than 3000 photographs were taken, several of them being of cosmic-ray showers.

To recap some of the history of Mirabelle — In January 1965, when studies were being made on projects for chambers of several tens of cubic metres in the United States, at CERN and in the Soviet Union, the Elementary Particle Physics Department at Saclay decided to make a study of and to build a hydrogen chamber of intermediate size, with a volume of 11 m^3 and with a photographable volume of 6 m^3, which would nevertheless provide a 4.5 metre-long trajectory for the accelerated particles.

This project aroused a great deal of interest among Soviet physicists and the idea arose for Franco-Soviet collaboration, for which the experimental equipment was to consist of the large 70 GeV accelerator at Serpukhov and the Mirabelle bubble chamber. An official agreement was signed in Moscow on 11 October 1966, providing for the installation of Mirabelle with its team at Serpukhov for a minimum period of five years.

When the first internal proton beams had been obtained at Serpukhov in October 1967, the speed with which Mirabelle could be brought into operation became one of the prime factors determining the ultimate usefulness of the chamber. Partly because of this, and partly in the interests of safety, a special approach was used for the project resulting in the construction of a full-size prototype in less than two years. This prototype was christened 'Experimental Assembly No. 6' (ME 6). In fact, because of the reliability which had been achieved and the experience which had been gained in the construction of previous chambers, it was possible to begin immediately and to proceed rapidly with the construction of the essential components for the assembly, while the final solutions to other problems inherent in large bubble chambers, e.g. optics, cryogenics, expansion system, etc., were left open.

The solution of these problems was thus pursued in parallel with the construction of the prototype. In addition, the experience obtained during the work with



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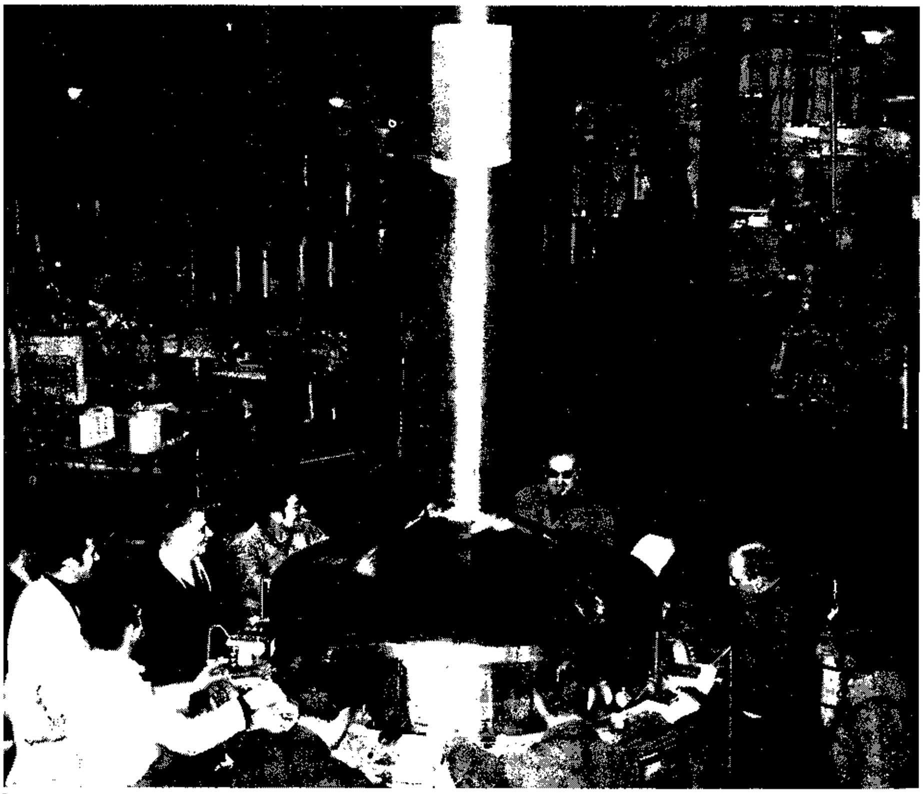


2.

3) The eight tubes of the optical system which pass through the magnet yoke. Each tube is 2.4 m long and weighs 160 kg. Fish-eye lenses are in contact with the liquid hydrogen at the chamber end of the tubes and the camera system is at the other end.

4) Mirabelle standing completely assembled in the hall where tests are being carried out prior to transport of the chamber to Serpukhov. It is 15 m high with a total weight of 2000 tons.

a full-scale prototype showed with certainty that the components for the final assembly would fully meet what was required of them, whereas, had their design not been completely checked experimentally, there would still be some doubt as to their performance until they were actually put into service.

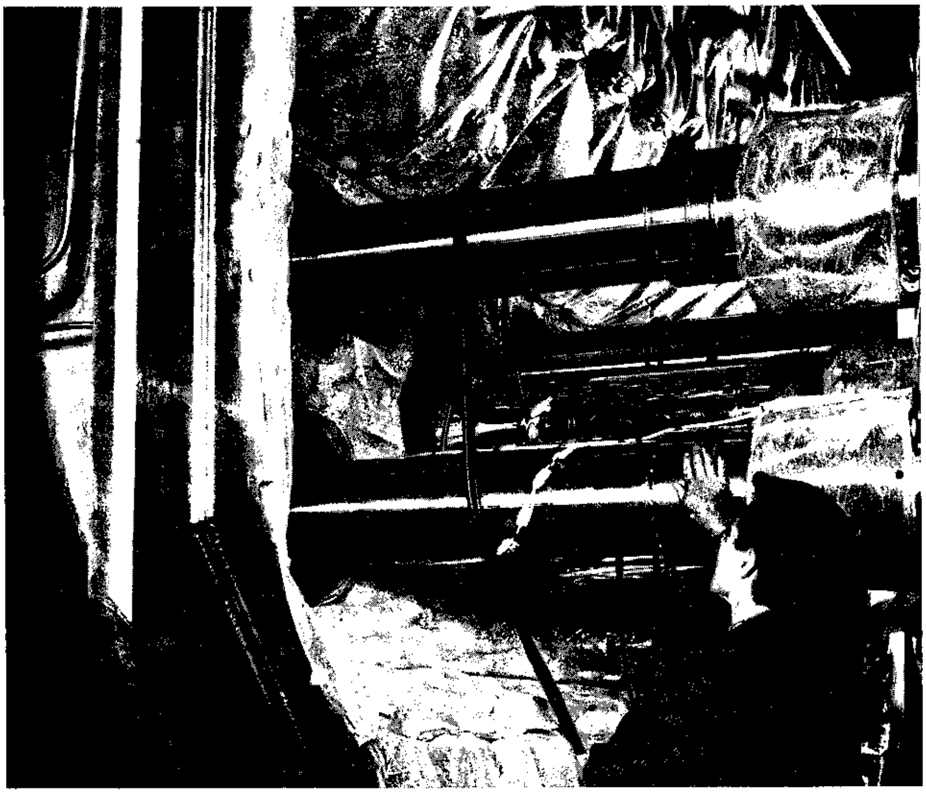
The first tests on ME 6 started at the beginning of 1967. There were, of course, several problems, both mechanical and cryogenic, but these were successfully overcome. During the July 1967 test, the prototype was filled with liquid hydrogen, and a number of expansions were achieved in fairly good conditions. Although this test lasted only a short time it was sufficient to prove that the photographable volume was sensitive to ionizing particles and that expansion was properly propagated from the piston to the furthest point in the chamber.

Mirabelle was quickly assembled two years after ME 6 and in July 1969, the first experiment was performed with very satisfying results. Three other experiments, with a beam are scheduled by the beginning of 1970 before it is transported to Serpukhov to be installed.

Mirabelle, when assembled, stands 15 m high weighing a total of about 2000 tons. The body of the chamber (a light alloy AG_4MC) is a horizontal cylinder 1.6 m in diameter and 4.5 m long. It is surmounted by a 'neck' composed of eight tubes of the same material, 1.8 m long and 0.3 m internal diameter, the upper part of which open into the base of a connecting member which culminates in a cylinder 1.6 m diameter containing the expansion piston.

The cold piston was a tricky component to design because it has to be robust (to sustain acceleration of 100 to 200 G) but light so that it can be moved easily (6 cm in 50 ms). It is made of austenitic steel, hollow, weighing 800 kg.

The optical system comprises eight objectives, the pictures being taken through optical tubes passing through the magnet yoke. Each tube is 2.4 m long and weighs 160 kg. Only the fish-eye lenses, which are in contact with the liquid hydrogen, are integral part of the chamber itself. The photographs are taken against a 'Scotchlite' background (bright-field illumination). The magnetic field is 20 kG.



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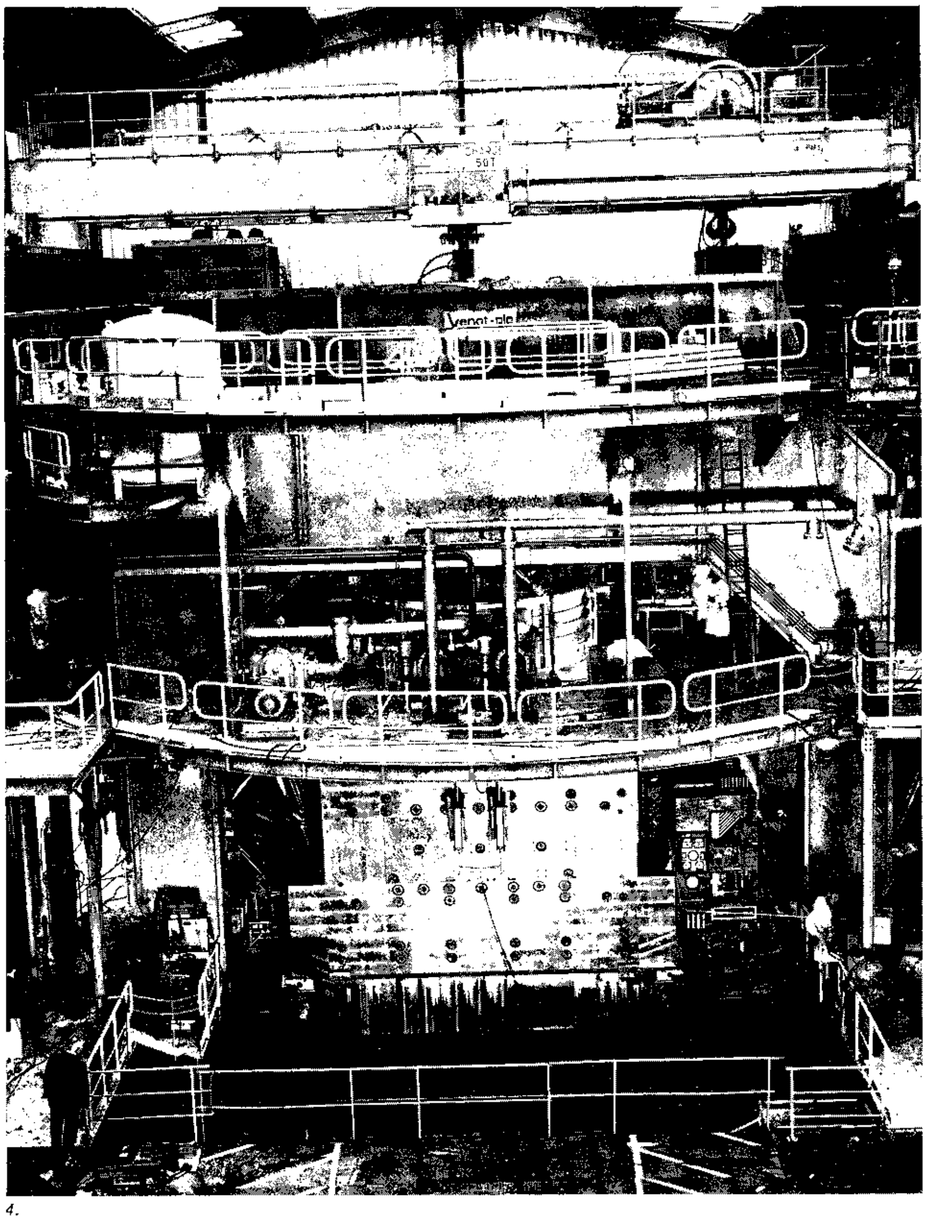

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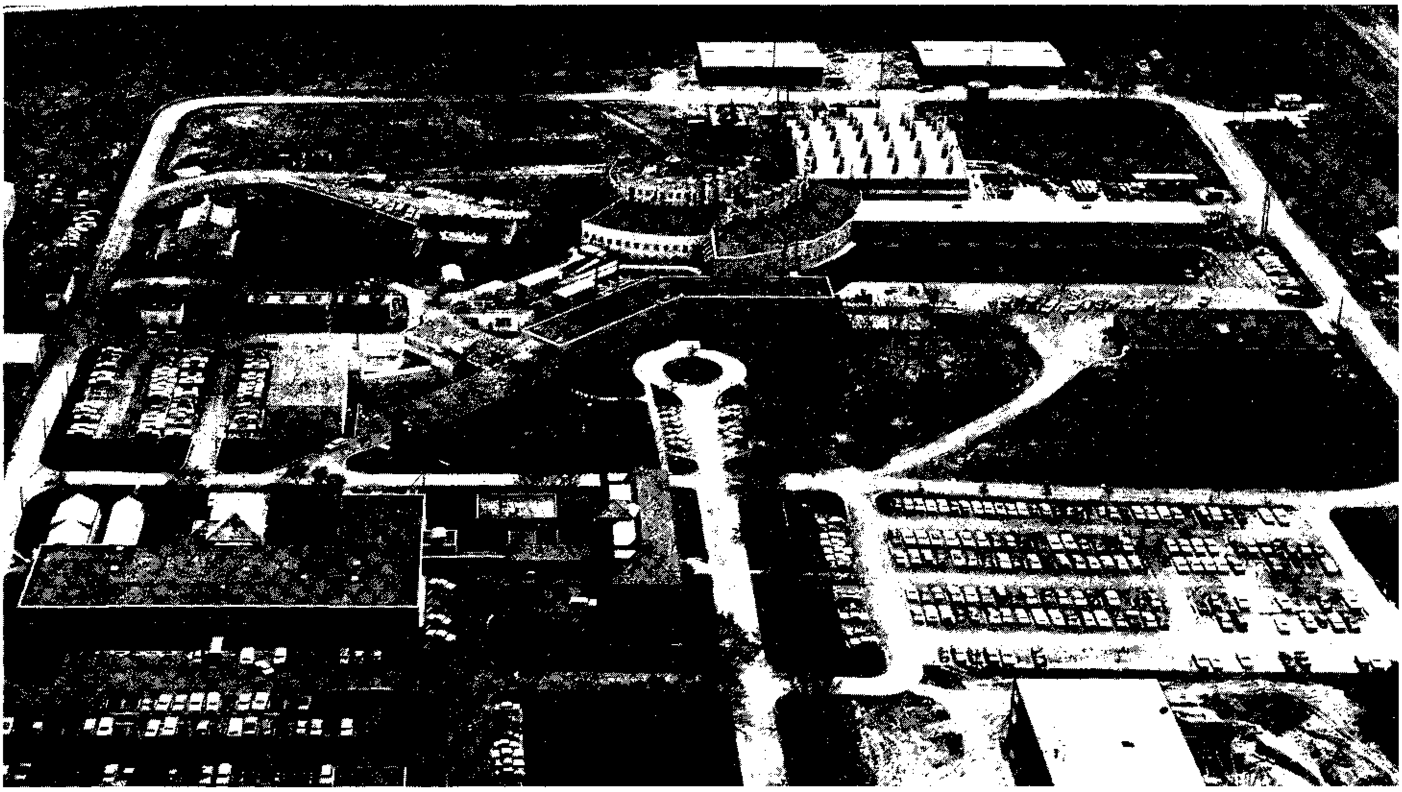


1.

Mirabelle is now the largest operational bubble chamber in the world. It marks an important step in the continuing development of bubble chambers, and is playing an important part in a new era of international scientific cooperation.

PRINCETON

PPA progress and plans

Recent improvements and future plans at the 3 GeV Princeton-Pennsylvania Accelerator were described by J.L. Kirchgessner in a paper at the Yerevan Conference at the beginning of September. The accelerator is a weak focusing proton synchrotron with the distinguishing feature that it is rapid cycling - accelerating about twenty pulses per second. It came into operation in April 1963 and has been active particularly in pion and kaon physics and in some of the most important experiments on CP violation. As many as fourteen experiments are set up at the accelerator at any one time and six to eight of them receive beam at the same time. Physicists from twenty Universities have been involved in the physics programme.

The main parameters of the machine are as follows. Injection is from a 3 MeV Van de Graaff providing 4 mA currents over 30 μs for 9 turn injection. The main ring, of diameter 25 m, is built up from 16 constant gradient magnet units 3.6 m long in which the field rises from 278 G at injection to a peak of 13.8 kG in 26.5 ms. There are 4 r.f. cavities covering the frequency range 2.5 to 30 MHz with a peak input power of 320 MW (80 MW average) giving an energy of 61 keV per turn to the protons.

For the past three years the synchrotron has been accelerating 5×10^{10} protons per pulse at 20 Hz with an 8 ms internal and external beam spill. In 1966 a slow ejected beam came into operation. It provides 3×10^{10} protons per pulse (an efficiency of 60%, which is a high figure for a weak focusing machine) in a spot size of 4×4 mm^2 at 30 m from the synchrotron. The ejected beam can be shared with internal targets during a single pulse or from pulse to pulse.

Another feature of the machine which has proved very useful is the one nanosecond bunch structure of the proton beam used on internal targets. This has made it possible to use time-of-flight techniques for neutral and charged particles.

Improvements under way

Before the end of this year a solid-state power supply for the main magnet will be brought into operation replacing the existing rotating machinery. It will make it possible to 'flat-top' for times up to 50 ms (when the repetition rate will go down to 10 Hz).

Also before the end of 1969 a new acceleration tube for the Van de Graaff will be delivered and the injection energy will then rise to 4 MeV. Together with some tricks in the r.f. system this may result in an increase of the accelerated beam intensity per pulse by a factor of three.

The improvements will also increase the maximum energy to which deuterons and alpha particles can be accelerated (up to 1.2 GeV/nucleon). Deuterons have already been accelerated to 600 MeV with a beam intensity of about 4×10^{10} particles per pulse and alpha particles have been accelerated to 50 MeV (which can easily be increased to 550 MeV) with 2×10^9 particles per pulse.

Improvements for the future

The proton beam intensity could be raised further by adding a small booster synchrotron to boost the injection energy into the main ring. A 75 MeV fast cycling booster has been designed to increase the intensity of the 3 GeV beam by a factor of twenty (giving 10^{12} protons per pulse). However a more important purpose of the proposed booster concerns the acceleration of heavy ions to high energy.

The acceleration of carbon and nitrogen nuclei should be feasible following the improvements at present under way. Heavier ions, up to xenon or uranium, could be accelerated following the installation (hopefully in 1970) of a new ceramic and metal vacuum chamber which is now being tested. With this chamber, pressures of 10^{-8} torr or better will be achieved. Ions could be accelerated to energies of around 10 MeV per nucleon. If the booster is built this could be taken much higher using some clever storage and re-injection routines. Energies could reach around 1 GeV per nucleon (for example, fully stripped uranium at 165 GeV) with ion currents of up to 10^9 particles per pulse.

Turning to higher proton energies, there are visions of using the PPA itself as the booster for a slow cycling high energy synchrotron. A 10 to 15 GeV ring of superconducting or cryogenic magnets (45 kG) could be built around the existing ring or a new larger ring tunnel could be built to climb up to 75 GeV.

1. Aerial view of the Laboratory housing the rapid cycling 3 GeV Princeton-Pennsylvania Accelerator (PPA). The accelerator and its experimental halls are top-centre of the photograph.

2. The layout of the PPA in relation to two proposed improvements — a booster to boost injection energy to 75 MeV (resulting in an increased beam intensity and in an ability to accelerate any ion to high energy) and a higher energy ring (for 10 to 15 GeV) of superconducting magnets built around the existing ring.

(Photo PPA)

BROOKHAVEN

Inside and outside at the same time

Successful tests have been carried out at the Brookhaven 33 GeV Alternating Gradient Synchrotron on the use of the slow ejected beam simultaneously with an internal target. In some ways this seems to be a more efficient way of operating the AGS. The tests were reported at the Yerevan Conference by L.N. Blumberg.

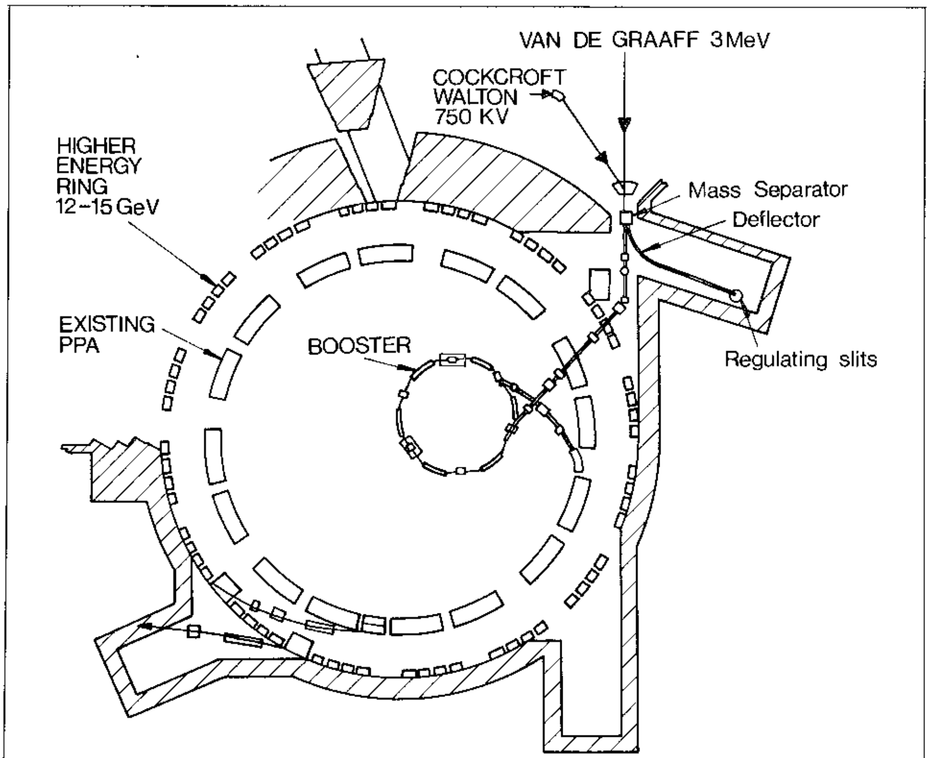
Since the slow ejected beam came into operation in July 1968 it has been used alone in extended runs (followed by an extended run using an internal target) or it has been used in sequence with the internal target (giving several pulses to the external target using the ejected beam followed by several pulses to the internal target). This separate operation of the two systems is more efficient in terms of making use of the maximum number of accelerated protons but it is wasteful in terms of making use of the experimental equipment and of the experimentalists time. There are also occasions when too many protons are available for the internal or the external target alone and the possibility of sharing the accelerated beam is then a great advantage.

The intensity of the AGS has reached 3×10^{12} protons per pulse during the past year and the machine can operate regularly at 2.3×10^{12} protons per pulse. But, because of the growing problem of radiation damage in the accelerator, the number of protons interacting in the internal target is being kept down to 1.5×10^{12} per pulse. Also, in the ejected beam it has sometimes been necessary to keep the intensity down to about 7×10^{11} to avoid excessive counting rates. These problems will get worse when the improvements programme pushes the beam intensity up to 10^{13}. It is then intended to operate the AGS with only external targets. In the meantime, it was considered worthwhile pursuing the possibility of sharing the beam between the slow ejection system and the internal target.'

However, it was by no means sure that this could be achieved with acceptable efficiency. It will be obvious from recent articles (see for example vol. 9, page 266) that slow ejected beams are very sensitive creatures and to disturb them by paying attention to something else at the same time could have resulted in an unacceptable deterioration in the beam quality and in the ejection efficiency. Simultaneous use could also have greatly reduced the internal targeting efficiency.

The results from the tests emerged as follows. The quality of the ejected beam was examined by measuring the vertical emittance. This was found to increase approximately quadratically as a function of the fraction of the beam given to the internal target. It reached a value about 1.8 times that of the emittance of the ejected beam used alone when 50% of the accelerated beam went to the internal target. The efficiency of the slow ejection (the number of protons we get out of the accelerator compared with the number of protons we try to get out of the accelerator) remained virtually constant for percentages of beam given to the internal target going from 0 to 80%. The efficiency of the internal targeting fell by 20% due to the way the beam path has to be distorted for slow ejection ($3\lambda/2$ orbit deformation) but this was reduced by introducing another distortion ($\lambda/2$ orbit deformation).

The conclusion from the tests is that the simultaneous use of the slow ejected beam and the internal target wins when the AGS intensity is over 2×10^{12} protons per pulse and when the beam on the internal target is restricted up to 1.5×10^{12} protons per pulse. Similar tests were carried out at the CERN proton synchrotron in 1967 and again this summer. However, because of the relative positions of the ejection area (East Hall) and the target area (South Hall) it is not possible to apply such a technique at present. A deeper analysis of the possibilities at the PS is under way.



2.

BERKELEY

Film analysis

In the fiscal year ending 30 June 1969, the bubble chamber groups at the Lawrence Radiation Laboratory measured almost two million events (including remeasures) and scanned about six million pictures (where each scan is counted separately). Three types of measuring system are in use at Berkeley and the 1.9 × 10⁶ measurements were divided among them as follows: 1.2 × 10⁶ were done on the two spiral readers, 0.45 ×10⁶ on the flying-spot digitizer, and 0.25 × 10⁶ on track-following Franckensteins (mostly computer controlled).

All together, the full-time equivalent of 120 persons were involved in this effort (this includes scanners, measurers, co-ordinators, keypunch operators and supervisors, but not physicists, programmers, computer operators, or maintenance technicians).

Film from the following hydrogen bubble chambers was used during this period:

Chamber	Location	Film format
25-inch	LRL	1 strip 46 mm
72-inch	LRL	1 strip 46 mm
82-inch	SLAC	1 strip 46 mm
30-inch	ANL	3 strip 35 mm
80-inch	BNL	1 strip 46 mm
81-cm	CERN	3 strip 35 mm
180-litre	SACLAY	3 strip 50 mm

More complete information for the fiscal year ending 30 June 1968 has been gathered by E.L. Fowler (Duke University), R.J. Plano (Rutgers University), and A.H. Rosenfeld (LRL, Berkeley), for LRL and for all other groups in the USA, and is obtainable from any of the above.

ARGONNE

Ten million pictures

On 24 August, the number of pictures taken with the 30-inch hydrogen bubble chamber at the ZGS passed 10 million. The chamber thus joined the 81 cm chamber at CERN and the 30 inch chamber at Brookhaven which have also taken more than 10 million pictures.

The CERN 2 m chamber, as reported earlier in this issue, joined the select band on 6 September.

The chamber at Argonne was designed and built by a group of physicists and engineers at MURA and installed at the ZGS in 1963. It has a magnetic field of 32.5 kG over the visible volume of 200 litres. Expansions are made by three pistons located above the chamber. Picture totals for each succeeding year have been: 80 000 (1964), 362 000 (1965), 1 878 000 (1966), 2 450 000 (1967), 3 323 000 (1968), 1 909 000 (to 25 August, 1969).

The chamber is located at the end of a beam that uses two stages of electrostatic separation to provide kaons and antiprotons up to a momentum of 5.5 GeV/c. This complicated beam together with the 44 different experiments completed in the chamber make the good picture taking rate noteworthy. In routine operation, several pictures per accelerator pulse are taken. For separated kaons and antiprotons, the requirements on the accelerator intensity limit this to two but for pion exposures three or five pictures per pulse are usually obtained.

The secret is in the fixing of the Brewster window —the angled glass plate at each end of the tube. In many tubes the seal is made with an epoxy resin which eventually cracks and ruins efficiency by letting in air. EEV, on the other hand, use fusion sealed windows where the seal is as strong as any other part of the tube. Fusion sealing allows the tube to be heated to a very high temperature during manufacture, driving out all the gases in the tube surface which would otherwise contaminate the helium-neon filling. EEV tubes have been life tested up to 6000 hours which is two or three times the life generally expected from tubes employing epoxy sealing techniques. There is a standard range of EEV laser tubes available, full details of which can be obtained by filling in the coupon. If your laser design calls for a special tube give us brief details of what you need as we can probably meet your requirements.

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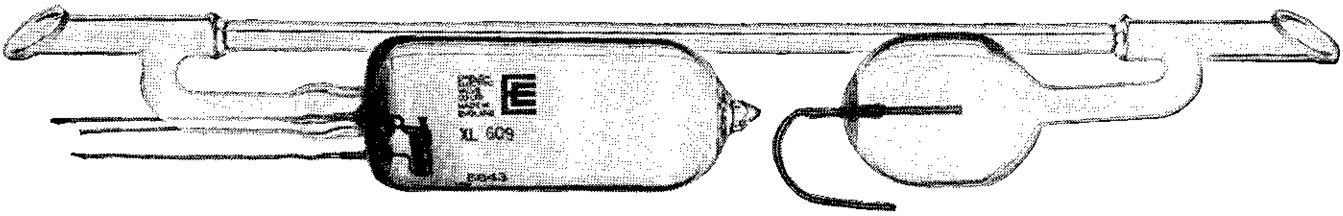

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Type	Excitation	Output power at 632.8nm (mW)	Bore diameter (mm)	Active length (mm)
XL607	R.F. (27MHz)	3.0	7.0	483
XL609	D.C.	2.5	3.0	229
XL612	D.C.	6.0	7.0	457
XL614	D.C.	8.0	7.0	584

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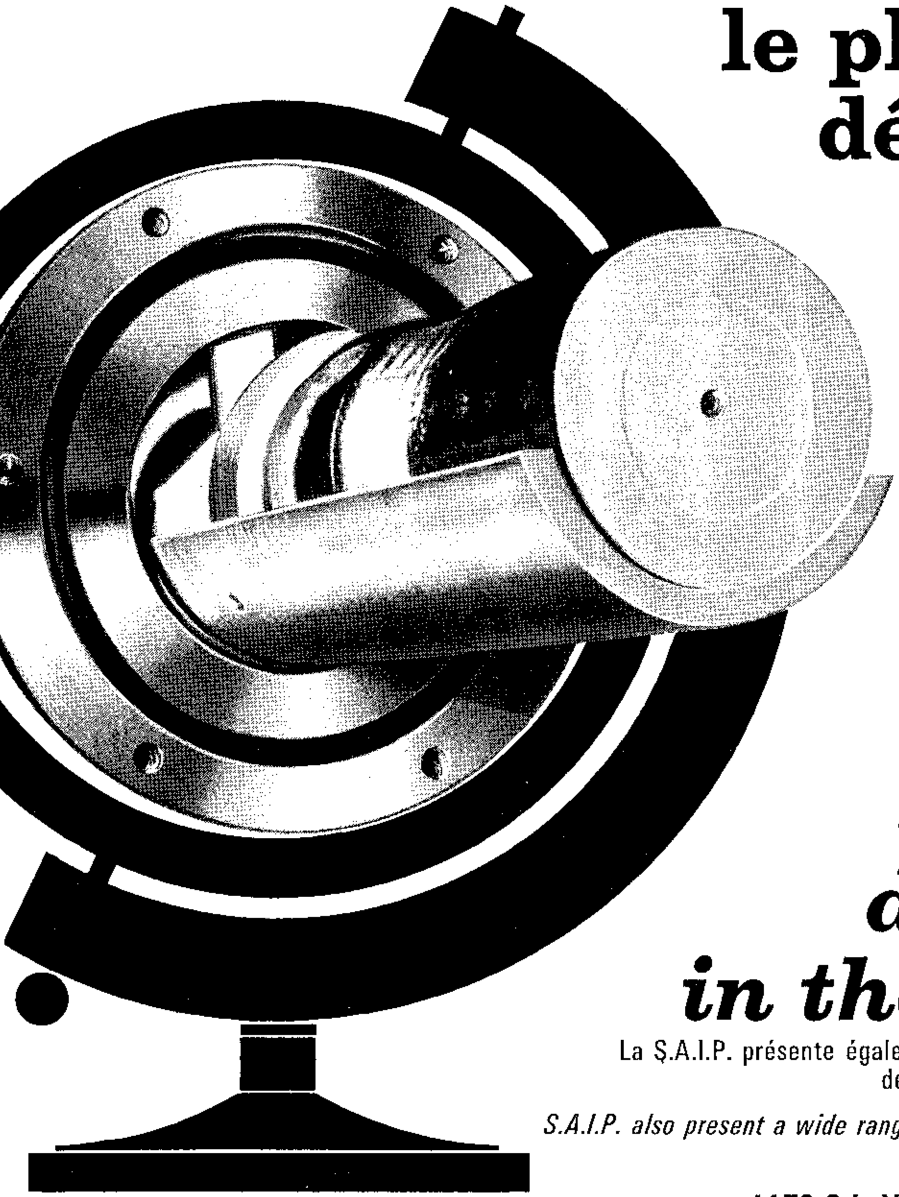

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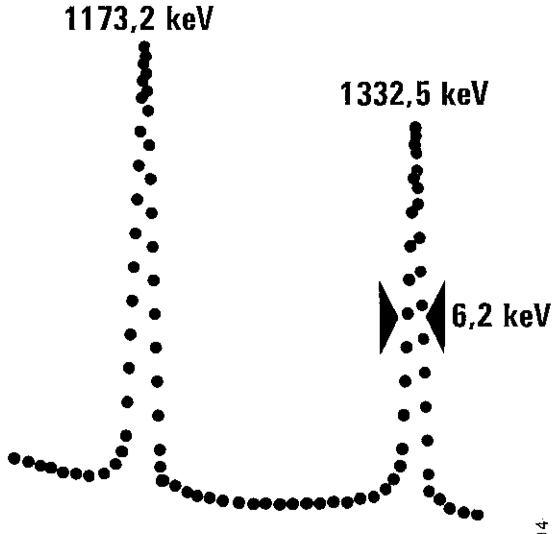

Structure coaxiale symétrique
Volume utile : 120 cm^3
Epaisseur compensée : 13 à 14,5 mm
Tension de polarisation : 1300 V
Capacité : 86 pF
Résolution en énergie L : 6,2 keV (^{60}Co 1332 keV)
Produit L x h : 68 (h = rapport pic/Compton)
Efficacité relative : 14,4 % (par rapport à un scintillateur I Na (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'' x 3'' 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.

S.P.I. 194

SAIP

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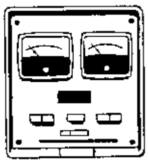
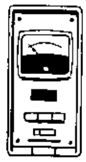


Pirani-Penning Gauge Model 4: replaces the Edwards Model 2A Pirani-Penning. A wide range instrument featuring multiple outputs for process control applications. No bridge voltage setting is required.
Range: 3 to 10^{-6} torr.



Penning Gauge Model 7: replaces the Edwards Model 5 Penning. Features robust, easily cleaned, series 6 gauge head. No bridge voltage setting is required.
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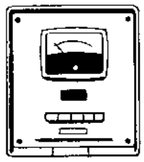

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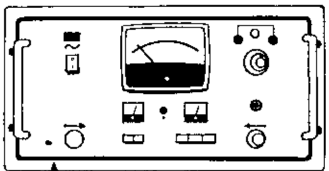

Ionization gauge model 5M: is an instrument which allows accurate measurement to the lowest pressures. X-ray limitations of the conventional gauge head eliminated by using the 5M and the modulated IG4 gauge head.
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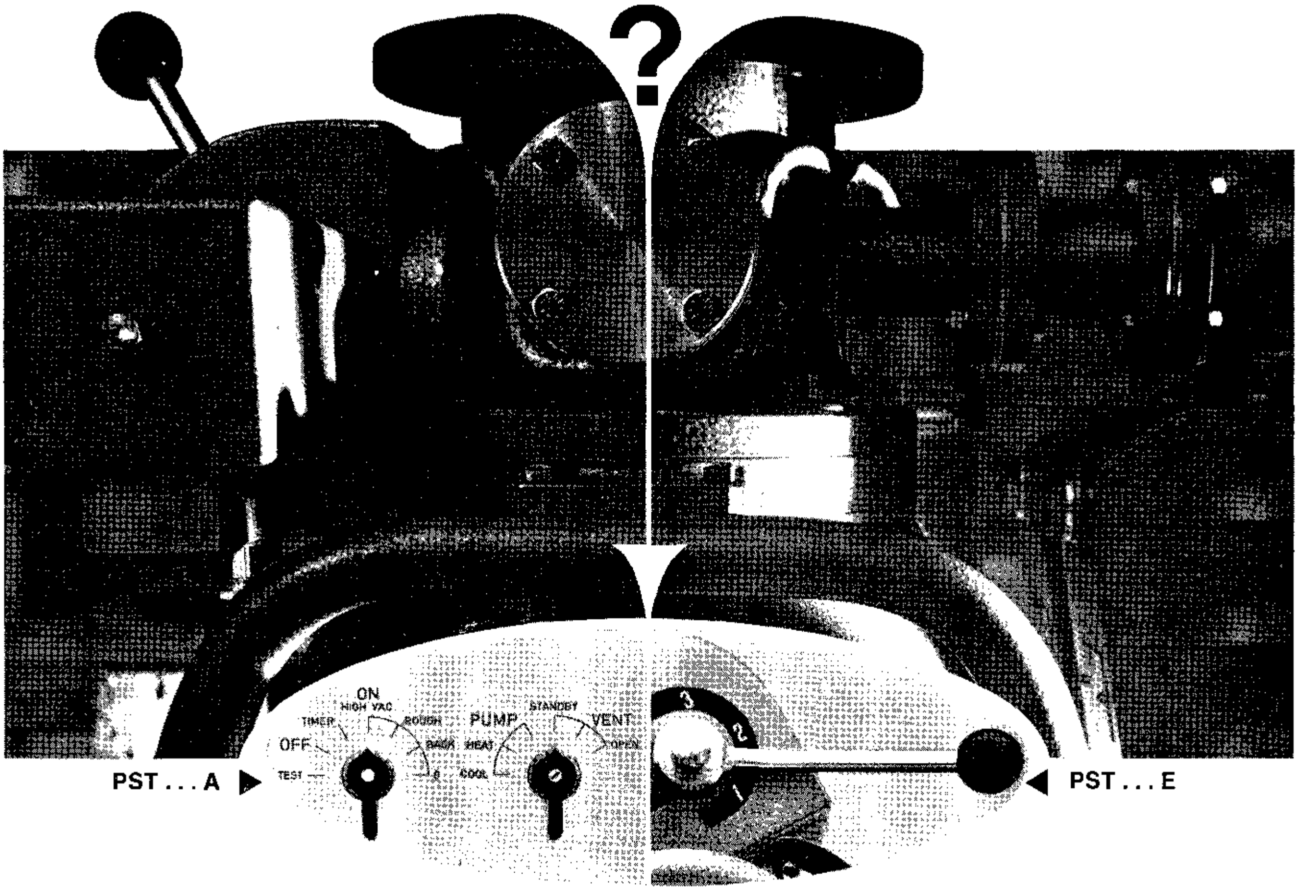

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PST 260 E	90	$< 5 \times 10^{-7}$
PST 900 E	315	$< 5 \times 10^{-7}$
PST 900 A	315	$< 5 \times 10^{-7}$
PST 1900 A	700	$< 5 \times 10^{-7}$
PST 5000 A	2150	$< 5 \times 10^{-7}$

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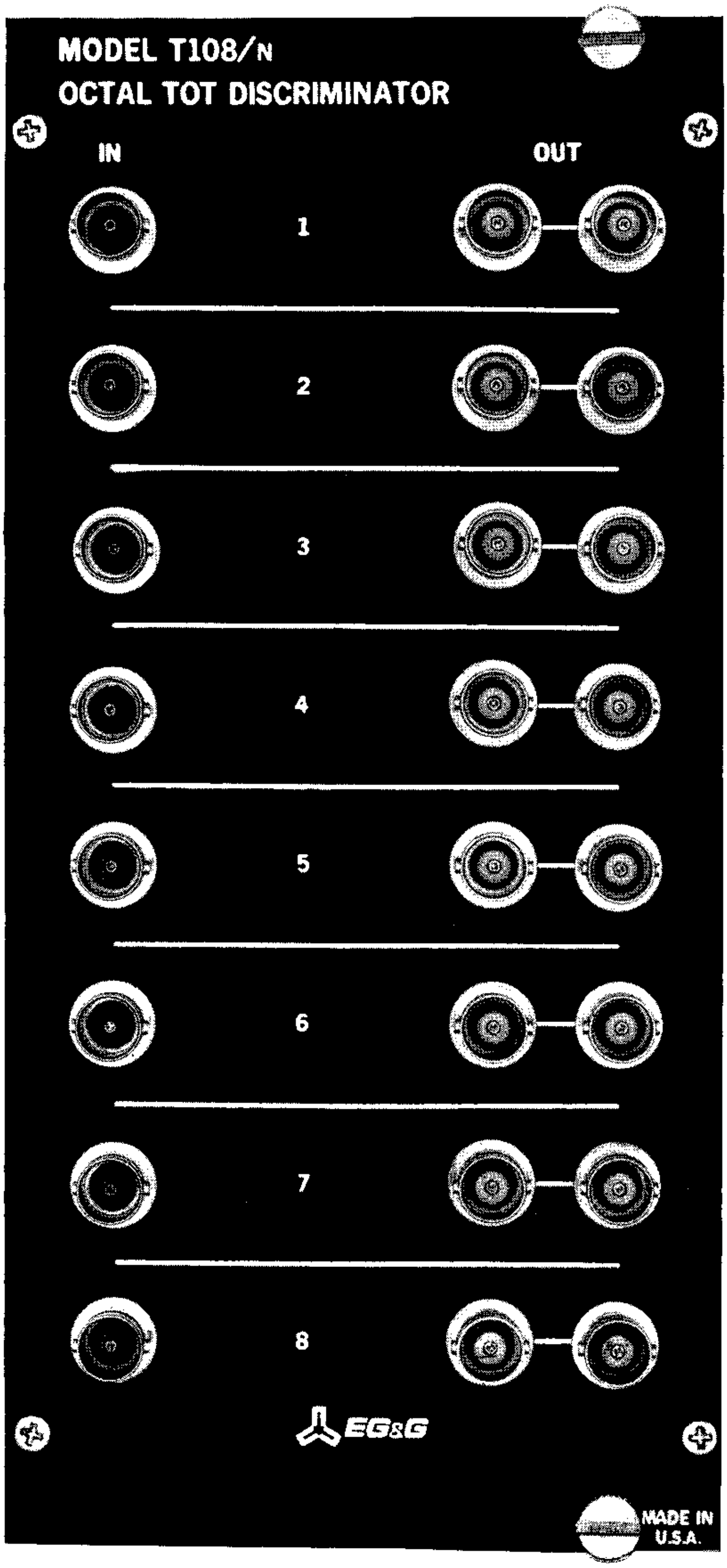

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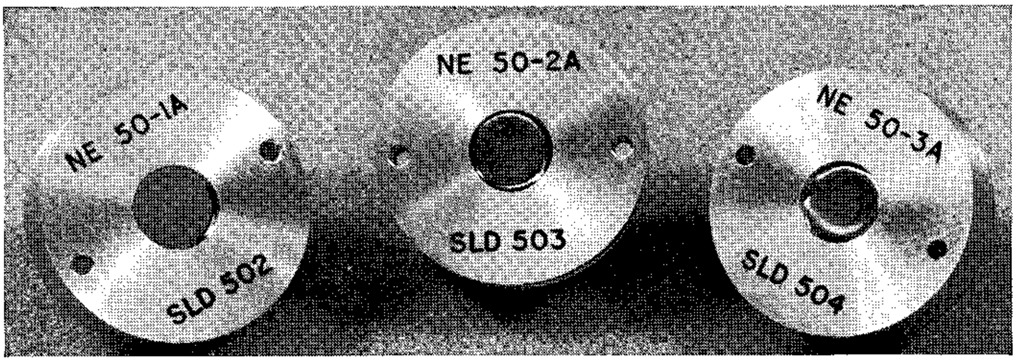

STANDARD GRADE

Type Number	Resolution—keV at 20°C Electron	Alpha	Thickness (mm)	Active Area (mm²)
NE50–½	18	30	½	
NE50–1	18	40	1	
NE50–2	18	50	2	50
NE50–3	25	60	3	
NE50–5	35	70	5	
NE100–½	23	35	½	
NE100–1	23	45	1	
NE100–2	23	55	2	100
NE100–3	30	65	3	
NE100–5	50	75	5	
NE200–½	25	50	½	
NE200–1	25	60	1	
NE200–2	26	70	2	200
NE200–3	40	80	3	
NE200–5	55	90	5	
NE300–½	35	55	½	
NE300–1	32	60	1	
NE300–2	30	70	2	300
NE300–3	50	80	3	
NE300–5	70	95	5	
NE500–½	43	80	½	
NE500–1	42	90	1	
NE500–2	40	100	2	500
NE500–3	60	110	3	
NE500–5	100	150	5	

RESOLUTION — Measurements are made with Nuclear Enterprises NE 5287 preamplifier and International Series units NE 4605 Detector Bias Supply and NE 4603 main Amplifier. System resolution is measured in keV full width half maximum at room temperature (20°C), and can be substantially improved by cooling.

SOURCES — Electron resolution is measured with conversion electrons from ^{137}Cs(624 keV). Alpha resolution is measured with alpha particles from ^{241}Am(5·477 MeV).

Full details of performance and prices available on request from:

SELECTED GRADE

Type Number	Resolution—keV at 20°C Electron	Alpha	Thickness (mm)	Active Area (mm²)
NE50–½A	12	24	½	
NE50–1A	11	27	1	
NE50–2A	12	30	2	50
NE50–3A	15	33	3	
NE50–5A	22	35	5	
NE100–½A	13	30	½	
NE100–1A	12	32	1	
NE100–2A	13	35	2	100
NE100–3A	18	37	3	
NE100–5A	25	40	5	
NE200–½A	15	35	½	
NE200–1A	17	37	1	
NE200–2A	18	42	2	200
NE200–3A	20	46	3	
NE200–5A	30	50	5	
NE300–½A	25	45	½	
NE300–1A	23	48	1	
NE300–2A	20	51	2	300
NE300–3A	25	54	3	
NE300–5A	32	60	5	
NE500–½A	32	60	½	
NE500–1A	30	64	1	
NE500–2A	28	68	2	500
NE500–3A	35	72	3	
NE400–5A	55	80	5	

CONNECTORS — All detectors are supplied with an Amphenol 27–9 connector. A Microdot 33–36 can be supplied at an additional cost. Other connectors are available on special order.

TRANSMISSION MOUNT — Available at an additional cost.

WARRANTY — Twelve months.

SPECIAL DETECTORS — Nuclear Enterprises welcomes enquiries for special detectors to meet customer requirements.

* *Details of Annular Detectors also available.*

NUCLEAR ENTERPRISES LIMITED

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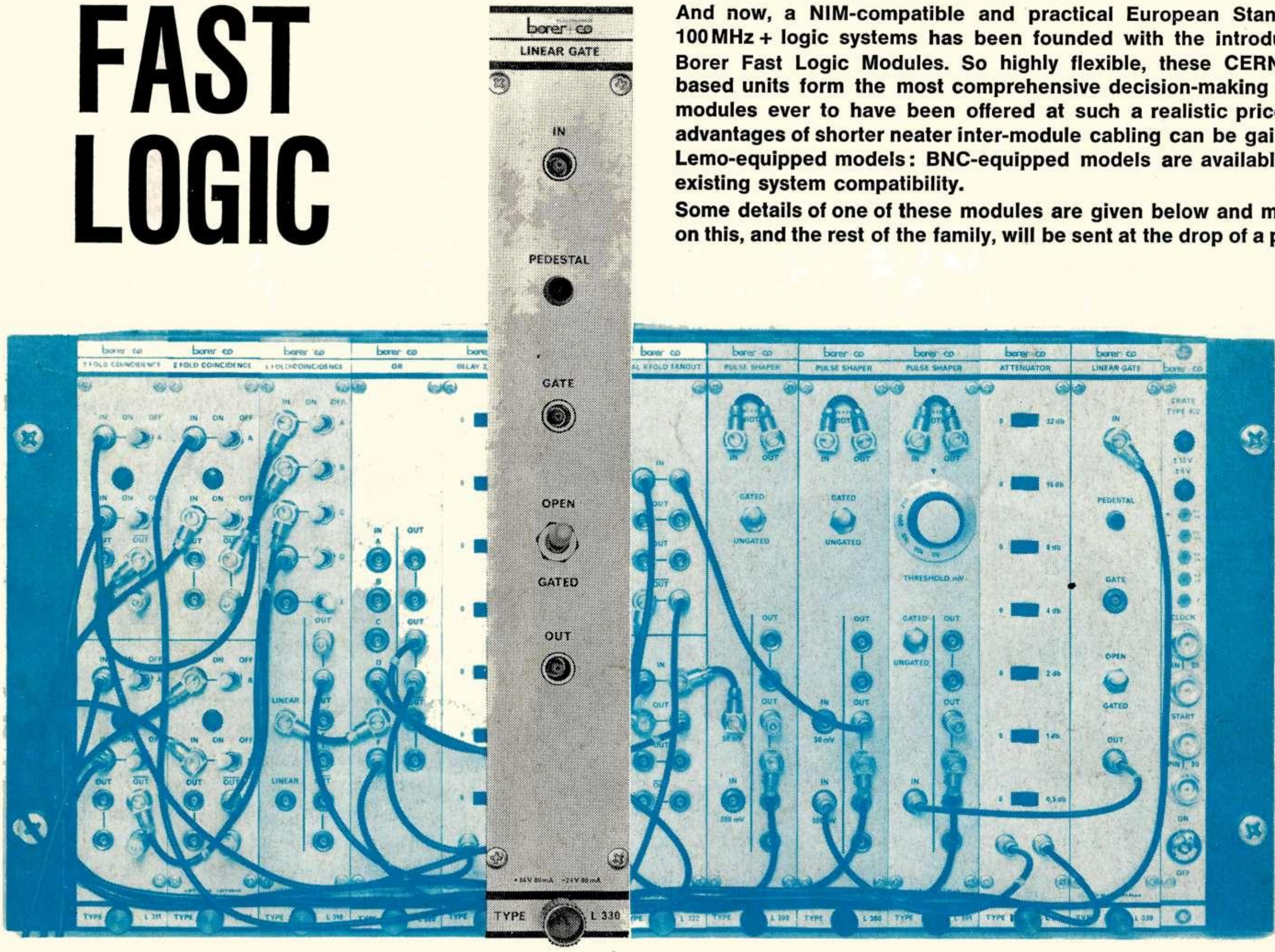
FAST LOGIC



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 design 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	5 % max. below ± 1 V 10 % max. below ± 10 V (tr = 1 ns)
	Current, max. cont.	75 mA
	Rate	Greater than 50 MHz
Output	Impedance	Current source, must be terminated, dc return path 125 ohms max.
	Rise time	2.5 ns max.
	Linearity	Better than 0.25 % (over range of ± 16 mA)
	Transmission attenuation	5 % approx. Output limited to ± 22 mA
	Pedestal	Adjustable to zero Stabilized to better than ± 0.5 mV over 50 ohms
	Signal feed-through	50 mV max., capacitively differentiated, for an input signal of 10 V and 1 ns rise time. Nett charge is zero
Gate	Input impedance	50 ohms ± 2 %
	Input level	—400 mV to —4 V to open gate
	Signal duration	10 ns min. Maximum duration unlimited
	Opening time	3 ns max. } to 90 % of max signal amplitude
	Closing time	4 ns max. } to 90 % of max signal amplitude
	Transients	30 mV max. from base line to worst peak, nett charge adjustable to zero

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